USER GUIDE

High Quality Graphics with NCL 6.4.0

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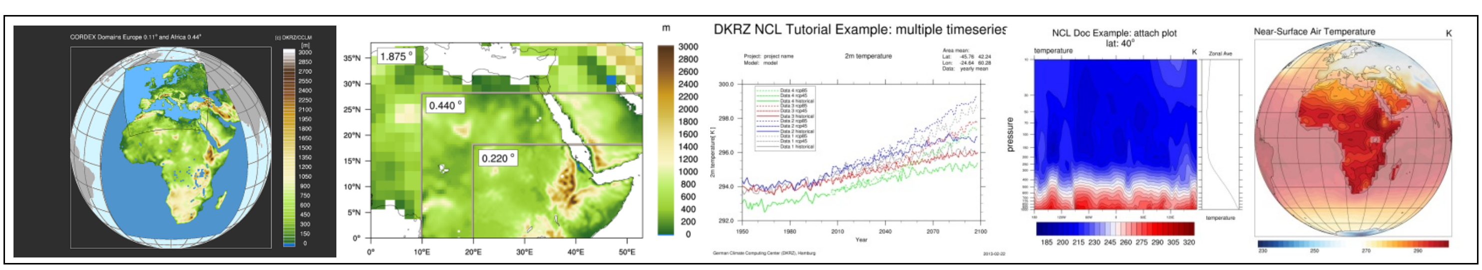
Version: 1.1 2017/02/28



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The NCAR Command Language (Version 6.4.0) [Software]. (2017).
Boulder, Colorado: UCAR/NCAR/CISL/VETS. http://dx.doi.org/10.5065/D6WD3XH5

http://www.ncl.ucar.edu

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1 Introduction

NCL (**N**CAR **C**ommand **L**anguage) is an open source interpreted language, designed specifically for scientific data processing and visualization. It is a powerful language for reading, writing, manipulating, and visualizing scientific data. It uses an internal netCDF variable model. Further, it supports a variety of input file formats: netCDF3, netCDF4, GRIB1, GRIB2, HDF-SDS, HDF-EOS, HDF5, Fortran/C binary, shapefiles and ASCII.

This tutorial will give an introduction on the use of interactive NCL for testing purposes, or in batch mode with NCL scripts to process and visualize data.

NCL Home page: http://www.ncl.ucar.edu/

The NCAR Command Language (Version 6.4.0) [Software]. (2017). Boulder, Colorado: UCAR/NCAR/CISL/VETS. http://dx.doi.org/10.5065/D6WD3XH5

1.1 Documents from NCAR

Two printable NCL PDF manuals, the so-called called "mini" documents are available:

Graphics: http://www.ncl.ucar.edu/Document/Manuals/graphics_man.pdf
Language: http://www.ncl.ucar.edu/Document/Manuals/language_man.pdf

Manuals web page: http://www.ncl.ucar.edu/Document/Manuals/

Getting Started: http://www.ncl.ucar.edu/Document/Manuals/Getting_Started/
Reference Manual: http://www.ncl.ucar.edu/Document/Manuals/Ref_Manual/

Examples: http://www.ncl.ucar.edu/Document/Manuals/Getting_Started/examples.shtml

Further information can be found online on the documentation page:

Online Documentation: http://www.ncl.ucar.edu/Document/

NCL Frequently Asked Questions (FAQ): http://www.ncl.ucar.edu/FAQ/

1.2 Example Scripts and Data

All example scripts used in the NCL User Guide are distributed within the NCL software since version 6.4.0. That applies to many example data sets used in the NCL User Guide and the bigger data sets are provided on the NCL web page only.

Example scripts: **$NCARG_ROOT/lib/ncarg/nclex/nug/**
or
http://www.ncl.ucar.edu/Document/Manuals/NCL_User_Guide/Scripts/

Example data sets: **$NCARG_ROOT/lib/ncarg/data/nug/**
or
http://www.ncl.ucar.edu/Document/Manuals/NCL_User_Guide/Data/

1.3 Support for NCL

The NCL group at NCAR offers two email lists: one for installation issues and the second for general questions, information exchange and bug reports.
Email support information:

http://www.ncl.ucar.edu/Support/email_lists.shtml

Before you send a request to the email lists, you have to subscribe to them. Please read the posting guidelines first:

http://www.ncl.ucar.edu/Support/posting_guidelines.shtml

1.4 Installation

All information on how to download and install NCL on a UNIX-based operating system (Linux, MacOSX and Cygwin/X) can be found on the NCL installation web page:

http://www.ncl.ucar.edu/Download/

1.5 NCARG_ROOT and PATH

If you have installed NCL on your local computer, you will have to do the following steps:

Set the NCARG_ROOT environment variable to the root directory of where the NCL software is installed, e.g. */opt/local/ncl-6.2.1.* Then add the bin directory of the NCARG_ROOT path to your PATH environment variable.

For sh:

```
NCARG_ROOT="/opt/local/ncl-6.2.1"
export NCARG_ROOT
PATH=$NCARG_ROOT/bin:$PATH
```

For bash or ksh:

```
export NCARG_ROOT="/opt/local/ncl-6.2.1"
export PATH=$NCARG_ROOT/bin:$PATH
```

For csh and tcsh:

```
setenv NCARG_ROOT "/opt/local/ncl-6.2.1"
setenv PATH "$NCARG_ROOT/bin:$PATH"
```

1.6 .hluresfile

NCL has a default graphical environment that most users prefer to alter. This is accomplished through the .hluresfile. Upon execution, NCL looks for this file in the user's home directory.

The following lists the most common usage of this file:

```
! White background/black foreground (the default)
*wkForegroundColor       : (/0.,0.,0./)
*wkBackgroundColor       : (/1.,1.,1./)
! Color map (default is ncl_default)
*wkColorMap              : rainbow
```

```
! Font stuff (default is helvetica)
*Font                        : helvetica
! Function code [Default is a tilde]
*FuncCode                    : :
! X11 window size
*windowWorkstationClass*wkWidth  : 1200
*windowWorkstationClass*wkHeight : 1200
! PNG pixel size (default is 1024x1024)
*imageWorkstationClass*wkWidth  : 1500
*imageWorkstationClass*wkHeight : 1500
```

Placing this file in your home directory would result in a large X11 window size, larger PNG images, a common font, different default color map, and plots that have white as the background color and black as the foreground color.

You can download a sample .hluresfile at:
http://www.ncl.ucar.edu/Document/Graphics/hlures.shtml

1.7 UNIX Editor Settings

It is very helpful when editors can do syntax specific highlighting, which means that language specific names, resource names, built-in functions, and procedures of your NCL script are colored (highlighted) in your editor window. Then e.g. you can easily see if a resource or function name you typed is misspelled or correct (colored) and it is more convenient reading the script text whenscript parts are colored, too.

Many different editor plugins or settings are available to support syntax specific highlighting for NCL scripts, like Emacs, NEdit, VIM, JED, TextMatekate, gedit, Aquamacs, NetBeans, TextWrangler, Kate, Sublime Text, and Notepad++.

The page http://www.ncl.ucar.edu/Applications/editor.shtml contains the installation instructions of the editor enhancements and some handy scripts for customizing various editors to do special highlighting of NCL syntax. They were documented and contributed by other users.

2 Overview

NCL was designed for the analysis and visualization of scientific data, specifically in the area of atmospheric modelling. It combines many features of modern programming languages with a huge number of analysis and visualization functions and examples. For testing purposes, NCL can be run in an interactive mode, meaning that each command is interpreted as it is entered in your workstation. For more complex and repeated work, it is recommended to first write the NCL commands into script files. These files can later be used in batch mode where NCL works as an interpreter of the complete script.

2.1 Interactive Mode

For a short example on how to use NCL in interactive mode, enter the following at a UNIX prompt and hit <return>:

```
ncl
```

NCL will prompt:

```
ncl 0>
```

Next, enter:

```
val=102
a=val/4.
print(a)
```

You should get the following lines on the standard output:

```
Variable: a
Type: float
Total Size: 4 bytes
                  1 values
Number of Dimensions: 1
Dimensions and sizes:   [1]
Coordinates:
(0)     25.5
```

To exit NCL, enter:

```
quit
```

There are several command line options you can include when running NCL. For example, to get the NCL version:

```
ncl -V
```

To get information on all the NCL command line options, type:

```
ncl -h
```

```
Usage: ncl -fhnpxV <args> <file.ncl>

              -f:       Use New File Structure, and NetCDF4 features
              -n:       don't enumerate values in print()
              -p:       don't page output from the system() command
              -o:       retain former behavior for certain
      backwards-incompatible changes
              -x:       echo NCL commands
              -V:       print NCL version and exit
              -h:       print this message and exit
```

To prevent printing the NCL copyright information on stdout at the beginning you can use the undocumented option '-Q':

```
ncl -Q
```

To record an interactive session:

```
ncl 0> record "my_script.ncl"
ncl 1> statements
…
ncl 8> stop record
ncl 9> quit
```

2.2 Batch Mode

NCL can be used interactively by entering the commands and settings directly in the command line. This might be useful for testing purposes or development work. However, especially for repeated actions, it is suggested that NCL scripts be used in order to save time. Due to the fact that NCL offers a variety of graphical resources, you won't want to enter lengthy commands again and again. Instead, open a UNIX editor and create an NCL script which can be easily changed and executed.

The commands from the interactive section can be written into a file using the ***record*** command in NCL:

```
ncl <return>

ncl 0>  record "my_script.ncl"
ncl 1>  val=102
ncl 2>  a=val/4.
ncl 3>  print(a)
ncl 4>  stop record
ncl 5>  quit
```

The 'my_script.ncl' file will contain all commands after the **record** statement and before the **stop record** statement. The saved script will include any errors you have made so you may have to edit 'my_script.ncl' prior to execution. Now you are able to run your first NCL script file 'my_script.ncl' in batch mode:

```
ncl my_script.ncl
```

You should get the following text returned:

```
 Copyright (C) 1995-2014 - All Rights Reserved
 University Corporation for Atmospheric Research
 NCAR Command Language Version 6.4.0
 The use of this software is governed by a License Agreement.
 See http://www.ncl.ucar.edu/ for more details.

Variable: a
Type: float
Total Size: 4 bytes
                        1 values
Number of Dimensions: 1
Dimensions and sizes:   [1]
Coordinates:
(0)   25.5
```

The '-n' option prevents the enumeration of the **print**() command. To prevent the long output of the variable description, use a Unix-pipe and the "tail" command to only print the last line of the output:

```
ncl -n my_script.ncl | tail -1
```

Will return:

```
25.5
```

2.3 Input, Export and Graphics Output File Formats

NCL can import the following data file formats:

- ✓ netCDF3, netCDF4
- ✓ HDF4-SDS, HDF2-EOS HDF5, HDF5-EOS
- ✓ GRIB 1, GRIB 2
- ✓ CCM History Tape
- ✓ shapefiles
- ✓ binary
- ✓ ASCII

NCL can export (write) the following data file formats:

- ✓ netCDF3, netCDF4
- ✓ HDF4, HDF5
- ✓ Binary (flat or fortran sequential; big or little endian)
- ✓ ASCII

NCL can write the following graphics output file formats:

- ✓ PS, EPS, EPSI
- ✓ PDF
- ✓ PNG
- ✓ SVG (good for web usage)
- ✓ NCGM (an older format that is generally not recommended)
- ✓ X11 (graphics output only to a X11 window)

2.3.1 NetCDF

NetCDF (Network Common Data Form) is a self-describing and machine independent data format from UNIDATA:

http://www.unidata.ucar.edu/software/netcdf/

NetCDF is a "container format"; different data structures and different types of content are supported. Along with the data itself, metadata needed for the interpretation of the data can be stored in the files.

2.3.2 NetCDF Metadata

The netCDF metadata section allows you to store a description that should enable users to correctly interpret or use the data: the underlying grid, its dimensions and coordinates (lat, lon, depth, time, ..), the variable names, the units used for the variables, global information and so forth.

One of the most commonly used conventions in climate modelling is the *NetCDF Climate and Forecast* (CF) Metadata Convention (*NetCDF-CF*):

http://cf-pcmdi.llnl.gov/

CF-Metadata: "The conventions define metadata and provide a definitive description of what the data in each variable represents and the spatial and temporal properties of the data".

2.4 Data Operators: CDOs and NCOs

Within the atmospheric, oceanographic and land model communities, general purpose tools which can be executed from the command line are commonly used to process data sets. These tools are very efficient and simple to use. No 'programming' is involved. Each operator typically performs one task. The output from the tools are files (typically, netCDF) containing the computational results. For example, it might be advantageous to extract one or more selected variables and/or time steps from a large data set spanning multiple files. Subsequently, the derived file may be used as input to a tool such as NCL, Matlab or Python This and many other tasks can be done using the Climate Data Operators (CDO) developed by the Max-Planck-Institute for Meteorology. The CDO is a collection of command line operators that manipulate and facilitate analysis of climate data sets in netCDF and GRIB formats:

https://code.zmaw.de/projects/cdo/embedded/1.6.4/cdo.pdf

A feature is that the output of each CDO operator can be used as input to the next operator. This operation is called pipe lining.

```
cdo [options] operator_1 [operator_2 [operator_n]]
```

Manipulation and some calculations on data within netCDF and some HDF files can be done with the NetCDF Operators (NCO):

http://nco.sourceforge.net/

2.5 User Guide Data Sets

The datasets used in this document are available for download:

http://www.ncl.ucar.edu/Document/Manuals/NCL_User_Guide/Data/

or in the directory

$NCARG_ROOT/lib/ncarg/data/nug/

The most important rule in data processing is:

Look At Your Data

You can avoid many errors and warnings if you are familiar with your data.
To get an overview of a file's contents, type either of the following at the command line:

For a netCDF-3/4, GRIB-1/2 or HDF-4/5 enter:

ncl_filedump ***<the_filename>***

or for netCDF-3/4

ncdump -h ***<the_filename>***

3 Language Basics

Similar to fortran, C, Matlab, IDL, etc, NCL has many features of modern programming languages like variables, data types, constants, functions, procedures, operators (arithmetic, relational and logical), expressions, conditional statements, loops, functions and procedures. To get more comfortable with the work in this document, simple example scripts which may readily be executed, can be found in subsequent chapters.

3.1 Syntax Characters

Commonly used syntax characters include:

=	assignment syntax
:=	reassignment operator
;	starts a comment
/;…;/	starts a block comment
@	create or reference an attribute
!	create or reference a named dimension
&	create or reference a coordinate variable
$...$	enclose strings when importing or exporting variables via *addfile*
{…}	subscript arraya using coordinate values
[…]	subscript variables of type *list*
(/…/)	array constructor
[/…/]	list constructor
:	array syntax delimiter
|	separator for named dimensions
****	continuation character for wrapping long lines
::	separator when calling external codes
→	used for inputting/outputting supported data formats

3.2 Expressions

After the execution of an expression, a value will be returned. There are three different kinds of expressions:

- Algebraic expressions
- Logical expressions
- Array expressions
- Functions

3.2.1 Algebraic Operators

+	Addition, string concatenation
-	Subtraction / Negation
*****	Multiplication
/	Division
%	Modulus (integers only)
>	Greater than
<	Less than
^	Exponentiation
#	Matrix multiplication

Note:

- Use parentheses to circumvent precedence rules:

```
➢ x = (2 + 3) * 3                       → 15
➢ print(-(3+2)^2)                       → 25
➢ print(-((3+2)^2))                     → -25
```

- The + sign is an overloaded operator, which means that it has two different applications:

```
➢ Addition:  x = 2.3 + 5.8              → x = 8.1
➢ String concatenation:  "Value: "+12.7 → "Value: 12.7"
```

- The – sign can also be used in two different ways:

  - negation has the highest precedence:

```
➢ x = - 3^2  is equal to  x = (-3)^2    → 9
```

  - treated as a minus:

```
➢ x = 8 – 3^2                           → -1
```

3.2.2 Logical Operators

.lt.	Less than
.le.	Less than or equal
.eq.	Equal
.ne.	Not equal
.ge.	Greater than or equal
.gt.	Greater than
.and.	AND
.or.	OR
.xor.	Exclusive OR
.not.	NOT

Logical expressions are guaranteed to be evaluated left to right. Hence, for efficiency, put the logical expression which will most likely fail on the left side:

```
if ( x .gt. 3 .and. x .lt. 7) then
   [statement(s)]
end if
```

3.2.3 Array Expressions

NCL's arithmetic operators (add, multiply, divide, compare and so forth) can be applied for both scalars and arryays. *See Arrays in chapter 3.5.*

3.2.4 Functions

A function is an expression, too, because it returns a value. Functions include statements and are called by their name and an argument list. *See Functions in chapter 7.5.*

3.3 Data Types

Numeric data types:

- double (64 bit)
- float (32 bit)
- long (32 bit or 64 bit; signed +/-)
- integer (32 bit; signed +/-)
- short (16 bit; signed +/-)
- byte (8 bit; signed +/-)
- complex NOT supported

Enumeric data types:

- int64 (64 bit; signed +/-)
- uint64 (64 bit; unsigned)
- uint (32 bit; unsigned)
- ulong (32 bit or 64 bit; unsigned)
- ushort (16 bit; unsigned)
- ubyte (8 bit; unsigned)

Non-numeric data types:

- string
- character
- graphic
- file
- logical
- list

3.4 Variables

Variable names are case sensitive, which means "T2M" is different from "t2m".

To assign a variable:

```
x      = 1                               ; integer
y      = 2.6                             ; float
z      = 20.d                            ; double
title  = "This is the title string"      ; string
a      = True                            ; logical

a     = (/1, 3, 2, 4/)                   ; integer array
b     = (/1, 2.0, 3.0, 4./)              ; float array
c     = (/1., 2, 3., 4.0/) * 1d5         ; double array
d     = (/"green", "red"/)               ; string array
e     = (/True, False, False, True/)     ; logical array
f     = (/ (/1,2/), (/3,6/), (/4,2/) /)  ; 2 dimensional array
```

NCL variables may have associated information called metadata (like netCDF metadata). There are three types of variable metadata: attributes, named dimensions, and coordinate variables.

3.4.1 Metadata and Attributes

Metadata is textual or numeric information associated with a variable or file. Typical variable attributes include *units, long_name, standard_name, coordinates, scale_factor, add_offset,* *valid_min, valid_max and axis*. However, there may be many other attributes, especially associated with satellite data. Here are some examples:

```
var@units              = "degK"
lon@units              = "degrees_east"
t@long_name            = "Near-Surface Air Temperature"
time@units             = "days since 1949-12-01 00:00:00"
temp@_FillValue        =  1e20
temp@missing_value     =  1e20
title                  =  varlong_name
```

To get all attributes of a variable "slp" from a file named "file.nc" you can use the built-in function ***getfilevaratts***:

```
fin         = addfile("file.nc", "r")
file_atts   = getfilevaratts(fin, "slp")
```

To verify whether a a specific attribute of a variable exists, use the function ***isatt***:

```
if(isatt(slp,"units")) then
   print(slp@units)
end if
```

If missing_value is set, the attribute _FillValue must be the same type and value.

3.4.2 Named Dimensions

The number of dimensions (shape) and the number of elements for each dimension (size) are integer values, and a single-dimension variable with one value is called a scalar variable.

By convention, the dimensions are numbered from 0 to n-1 (like in C), where n is the number of dimensions of the referenced variable, and the leftmost dimension is numbered 0. This also applies to arrays.

If a variable has four dimensions, the following statements will attach the names to the dimensions using the ! syntax character:

```
tas!0 = "time"
tas!1 = "height"
tas!2 = "latitude"
tas!3 = "longitude"
```

3.4.3 Coordinate Variables

By netCDF definition, “a ***coordinate variable*** is a one-dimensional variable with the same name as a dimension, which names the coordinate values of the dimension. It must not have any missing data (for example, no `_FillValue` or `missing_value` attributes) and must be strictly monotonic (values increasing or decreasing).

This is best illustrated via an example. Consider the two-dimensional variable ‘temp(4,5)’, The following two statements name the dimensions "lat" and "lon":

```
temp!0      = "lat"      ; left dimension
temp!1      = "lon"      ; right dimension
```

Now, the coordinate values can be defined, here, "lon_pts" and "lat_pts":

```
lon_pts     = (/ 0., 15., 30., 45., 60. /)   ; size 5
lat_pts     = (/ 30., 40., 50., 60. /)       ; size 4
```

Also, it is suggested that a units attributes be assigned using the @ syntax:

```
lon_pts@units   = "degrees_east"
lat_pts@units   = "degrees_north"
```

Lastly, assign the "lon_pts" and "lat_pts" arrays to the named dimensions "lon" and "lat" of the variable temp using the **&** character. The **coordinate variable** is now the construct “temp&lon” or “temp&lat”, respectively, which points to the arrays with the coordinate values.

```
temp&lon    = lon_pts
temp&lat    = lat_pts
```

Rules:

- coordinate arrays associated with a coordinate variable must have the same size as the named dimension with which the coordinate variable is associated
- a coordinate variable must have the same name as its corresponding named dimension: eg, lat(lat), p(p), time(time)
- the elements in a coordinate array must be monotonically increasing or decreasing
- any of the numeric data types may be used for values in the coordinate arrays associated with a coordinate variable

3.4.4 String References

Sometimes it is impossible to know the names of the attributes and coordinates before writing a script, or these names may vary from variable to variable. To solve this problem, string variables can be used to reference attributes and coordinates by enclosing the variable reference within dollar signs '$'. The following are examples of this:

```
dimnames = (/"frtime","lat","lon"/)
attnames = (/"_FillValue", "long_name"/)
```

Direct access to the attribute

```
att0 = temperature@$attnames(0)$
```

Example of referencing a coordinate variable without knowing the dimension name using the built-in function ***iscoord***:

```
if(iscoord(dimnames(0))
      coord0 = temperature&$temperature!0$
end if
```

3.4.5 List Variables (Container Variables)

Variables of type list may be used to contain a heterogeneous suite of NCL variables. Specifically, the variables within a list may be different types, sizes and shapes. An additional feature is that list variables can be treated like stacks or queues.

There are two ways to create a list variable. The first is use the '[/.../]' syntax as shown in the following example:

```
i = (/ (/1,2,3/), (/4,5,6/), (/7,8,9/) /) ; 2-dimensioal integer array
x = 5.0                                   ; scalar of type float
d = (/100000.d, 283457.23d/)              ; 1-dimensional double array
s = "abcde"                               ; string
c  = stringtochar("abcde")                ; character
```

```
vl = [/i, x, d, c, s/]                    ; construct list via [/.../]
```

The second is to treat the list variable as a stack. This feature allows variables to be dynamically added to an existing list variable. The following example illustrates the basic approach. The NewList function creates a list and ListPush can be used to dynamically add variables to the list.

```
x       = (/1,2,3,4/)
x@attr  = "integer array"
y       = (/6.,7.,8.,9./)
y@attr  = "float array"
s       = (/"one","two","three"/)
s@attr  = "string array"

my_list = NewList("lifo")

ListPush(my_list,x)
ListPush(my_list,y)
ListPush(my_list,s)
```

Note: When using ListPush to add elements to the list, the newly added elements are always at the the head (top) of the list.

The ListCount counts the total elements in a list, and a function named ListIndex can be used to check if an element is in the list.

```
cnt = ListCount(my_list)
print(cnt)

idx = ListIndex(my_list, x)
print(idx)
```

There are two ways to access elements in a list. The first way is to access an element at a certain position via numeric indexing using square brackets. This does not change the element (number) in the list.

One can use ListIndex to get the index of of a variable, and then use this index to access the desired element.

```
e = my_list[1]
print(e)

idx = ListIndex(my_list, x)
print(idx)

nx = my_list[idx]

print("ori x = " + x)
print("new x = " + nx)
```

The second is to access the element with the ListPop function. For those familiar with stacks and queues, there is an alias ListDequeue).

```
a = ListPop(my_list)
```

Note: When using ListPop to access an element in the list, the element itself is removed from the list. Also, there is a choice to Pop/Dequeue from head/tail of the list depending on the type of the list. There are two types of list: 1. FIFO (First-In, First-Out, which functions like a queue in computer science); and, 2. LIFO (Last-In, First-Out, which is like a stack).

The list type can be checked using ListGetType, and changed with ListSetType.

```
lt = ListGetType(my_list)
ListSetType(my_list, "lifo")
ListSetType(my_list, "fifo")
```

3.4.6 Variable Assignment

It is important to understand what happens when a variable is used in an assignment statement in NCL. The assignment statement functions differently depending on whether the variable being assigned to is currently undefined or defined. The assignment statement also functions differently depending on whether a variable or a value occupies the right side of the assignment.

When a variable appearing on the left side of an assignment has not be defined or was previously deleted, the assignment statement causes the variable to become defined and the data type and dimensionality of the variable is determined by the right side.

When a variable appearing on the left side is already defined, then the right side must have the same type, or be coercible to the type on the left, and the right side must have the same dimensionality.

3.4.6.1 Value-only assignment

Value-only assignments to variables are fairly straightforward. In essence, value-only assignments mean that the right side of the assignment is not a variable, it is the result of an expression, a value. In this case, if the left side variable reference was not defined prior to the assignment statement, the variable on the left side becomes defined and references the value of the right side. No dimension names, coordinate variables or attributes other than _FillValue are assigned. If the right side of the expression does not contain any missing values, then _FillValue is not assigned either.

If the left side variable was defined prior to the assignment statement, then the value on the left side is assigned the value of the right side. If the left side is a subscripted reference to a variable, then the right side elements are mapped to the appropriate location in the left side variable. If the left side has meta data, they are left unchanged since only a value is being assigned to the left side variable. When the left side is defined, then the type of the right side and the dimensionality must match. However, there is one exception to the requirement that the dimension sizes of the left side and the right side match, a single scalar value can be assigned to more than one location. Consider the following example:

```
a = (/1,2,3,4,5,6,7,8,9,10/)
a(0:3) = -1
print(a)

Variable: a
Type: integer
Total Size: 40 bytes
            10 values
Number of Dimensions: 1
Dimensions and sizes:   [10]
Coordinates:
(0)     -1
(1)     -1
(2)     -1
(3)     -1
```

```
(4)     5
(5)     6
(6)     7
(7)     8
(8)     9
(9)     10
```

This example demonstrates the value of -1 being assigned to the first four elements of the variable ‘a’.

3.4.6.2 Variable-to-variable assignments

During variable-to-variable assignment attributes, coordinate variables and dimension names, in addition to actual multi-dimensional values, are assigned. Before discussing this type of assignment, it is important to note that the array designator characters '(/' and '/)' can be used when assigning one variable to another to force only the right side's value to be assigned to the left side and the right side's attributes, dimensions, and coordinates are ignored. Essentially using the array designator characters forces value-to-variables assignment. The following shows how the array designator characters can be used to do this:

Example of array designator use to force "Value Only" assignment

```
variable1 = (/ variable2 /)
```

Variable-to-variable assignment occurs when both the left side and the right side are variables. In this situation, the assignment statement also tries to assign attributes, dimension names, and coordinates of the right side to the left side.

The two simplest cases are:

- The left side is undefined prior to the assignment
- The variable on the left side is not subscripted, meaning the entire variable is being referenced

In both these situations, all of the right side's attributes, coordinates, and dimension names are assigned to the left side. If the left side has the same dimension and coordinate names, then only the coordinate variable is overwritten with the value and attributes of the right side's coordinate variables. However, if the names of the dimension names do not match, a warning message is generated and the names and coordinate variables of the left side are overwritten. As far as attributes go, if the left side has attributes, then the left side's attribute list is merged with that of the right side. If the same attribute name appears on both the left and right sides, the right side's attribute overwrites the left side's. If the types of the attribute values do not match, you could have a type mismatch error.

The following are examples of some variable-to-variable assignment situations:

This first example shows assignment to an undefined variable and then shows the use of the array designator characters '(/' and '/)' to perform a value-only assignment.

Create variable be with values, dimension names, coordinate variables and attributes

```
b = (/ (/1.0,2.0,3.0/), (/4.0,5.0,6.0/), (/7.0,8.0,9.0/) /)
b!0 = "dim0"
b!1 = "dim1"
b@units = "none"
```

```
b&dim0 = (/.1,.2,.3/)
b&dim1 = (/10,100,1000/)
```

Variable-to-variable assignment with left side undefined

```
a = b
```

Use of array designator characters to assign "Value Only" to undefined left side

```
c = (/b/)
```

This print shows that all of the dimension names, attributes, and coordinate variables have been assigned to a.

```
print(a)

Variable: a
Type: float
Total Size: 36 bytes
           9 values
Number of Dimensions: 2
Dimensions and sizes:   [dim0 | 3] x [dim1 | 3]
Coordinates:
          dim0: [0.1..0.3]
          dim1: [10..1000]
Number Of Attributes: 1
  units :       none
(0,0)   1
(0,1)   2
(0,2)   3
(1,0)   4
(1,1)   5
(1,2)   6
(2,0)   7
(2,1)   8
(2,2)   9
```

This print shows that only the values of b were assigned to c.

```
print(c)

Variable: c
Type: float
Total Size: 36 bytes
                   9 values
Number of Dimensions: 2
Dimensions and sizes:   [3] x [3]
Coordinates:
(0,0)   1
(0,1)   2
(0,2)   3
(1,0)   4
(1,1)   5
(1,2)   6
(2,0)   7
(2,1)   8
(2,2)   9
```

This second example demonstrates a defined variable being assigned to a defined variable. Note the changes resulting from assignment to the dimension names, attribute values, and coordinate variables in variable a. These assignments that change the left side's coordinates and dimension names generate errors. When left and right dimension names are different, NCL considers this an error that the user should be warned about. To avoid these errors you can either make sure before assignment that the left and right sides have the same dimension names, or if you only want to assign a value and don't care about attributes, dimensions, and coordinate variables, you can enclose the right side using '(/' and '/)', which forces NCL to use only the value of the right side.

Define variable a with value, dimension names and attributes. No coordinate variables assigned.

```
a = (/ (/1.1,1.2,1.3/), (/2.1,2.2,2.3/), (/3.1,3.2,3.3/) /)
a!0 = "test0"
a!1 = "test1"
a@units = "Degrees"
a@long_name = "A"
```

Define variable b with value, dimension names, attributes, and coordinate variables.

```
b = (/ (/1.0,2.0,3.0/), (/4.0,5.0,6.0/), (/7.0,8.0,9.0/) /)
b!0 = "dim0"
b!1 = "dim1"
b@units = "none"
b&dim0 = (/.1,.2,.3/)
b&dim1 = (/10,100,1000/)
```

Here is the "Variable-to-variable" assignment. The dimension names of a change, and the coordinate variables of b are assigned to a. In addition, the attribute lists are merged.

```
a = b
print(a)

Variable: a
Type: float
Total Size: 36 bytes
                   9 values
Number of Dimensions: 2
Dimensions and sizes:   [dim0 | 3] x [dim1 | 3]
Coordinates:
          dim0: [0.1..0.3]
          dim1: [10..1000]
Number Of Attributes: 2
  units :       none
  long_name :   A
(0,0)    1
(0,1)    2
(0,2)    3
(1,0)    4
(1,1)    5
(1,2)    6
(2,0)    7
(2,1)    8
(2,2)    9
```

The remaining case is that when the left side is subscripted, only a portion of the target variable is being assigned to. The simplest case here is when the left-side dimension names are the same and both the left side and right side have coordinate variables for the same dimensions. In this case, assignment occurs for each coordinate variable. The subscripted left-side coordinate variable is assigned the subscripted right side coordinate. The attributes lists for the right side is merged with that of the left side and assigned to the left side variable. The following demonstrates this kind of variable-to-variable assignment.

Define variable a with values, dimension names, attributes and coordinate variables.

```
a = (/ (/1.1,1.2,1.3/), (/2.1,2.2,2.3/), (/3.1,3.2,3.3/) /)
a!0 = "dim0"
a!1 = "dim1"
a&dim0 = (/.1,.2,.3/)
a&dim1 = (/.1,.01,.001/)
a@units = "Degrees"
a@long_name = "A"
```

Define b with same dimension names, and assign different coordinate variables for dim1.

```
b = (/ (/1.0,2.0,3.0/), (/4.0,5.0,6.0/), (/7.0,8.0,9.0/) /)
b!0 = "dim0"
b!1 = "dim1"
b@units = "none"
b&dim0 = (/.1,.2,.3/)
b&dim1 = (/10.0,100.0,1000.0/)
```

Here is the example of "Variable to Variable" assignment where the left side is already defined. The coordinate variable for "dim1" is overwritten.

```
b(0,:) = a(0,:)
print(b)

Variable: b
Type: float
Total Size: 36 bytes
                   9 values
Number of Dimensions: 2
Dimensions and sizes:   [dim0 | 3] x [dim1 | 3]
Coordinates:
          dim0: [0.1..0.3]
          dim1: [0.1..0.001]
Number Of Attributes: 2
  units :       Degrees
  long_name :   A
(0,0)   1.1
(0,1)   1.2
(0,2)   1.3
(1,0)   4
(1,1)   5
(1,2)   6
(2,0)   7
(2,1)   8
(2,2)   9
```

If the left side variable does not have a coordinate variable and the right side does, a coordinate variable is created and assigned. If the left side is subscripted, then the created coordinate variable only has values assigned for the subscripted range, and the rest of the coordinate variable is filled with missing values. The following example illustrates this feature:

Define b with no coordinate variables.

```
b = (/ 1.0,2.0,3.0,4.0,5.0,6.0,7.0,8.0,9.0/)
b!0 = "dim0"
```

Define a with coordinate variables.

```
a = (/ 1.1,1.2,1.3,2.1,2.2/)
a!0 = "dim0"
a&dim0 = (/.1,.2,.3,.4,.5/)
```

Assignment of a to b. Selection of dim0 selects only every other element.

```
b(::2) = a(:)
```

Print of the coordinate variable "dim0" demonstrates filling of missing value for non-selected element.

```
print(b&dim0)

Variable: dim0 (coordinate)
Type: float
Total Size: 36 bytes
            9 values
Number of Dimensions: 1
Dimensions and sizes:   [dim0 | 9]
Coordinates:
Number Of Attributes: 1
  _FillValue :  -999
(0)     0.1
(1)     -999
(2)     0.2
(3)     -999
(4)     0.3
(5)     -999
(6)     0.4
(7)     -999
(8)     0.5
```

The final situation that must be considered when assigning one variable to another is when the dimension names of the left side and the right side do not match. In this case, the assignment overrides the left side's dimension names and coordinate variables, and a warning message is generated. If this is not the desired effect, then the array designator characters '(/' and '/)' can be used to make the assignment a "value-only" assignment.

3.4.6.3 Variable reassignment

Reassignment is reusing a variable that has been previously defined (if it is not defined, the the reassignement will be simple assignment). With reassignment, a variable appearing on the left side of a reassignment can be defined or not defined, the reassignment statement causes the variable to become defined (or redefined) and the data type and dimensionality of the variable is determined by the right side.

When a variable appearing on the left side is already defined, then it is actually deleted first, and then redefined to the data type and dimensionality of the variable is determined by the right side. The reassignment operator is commonly used in loops where array sizes may change with each iteration.

The reassignment is available in version 6.1.1 or later.

3.4.6.3.1 Value-only reassignment

Value-only reassignments to variables are similar to value-only assignment, except that the left hand side variable could have been in different type and shape.

Consider the following example:

```
 a = (/1,2,3,4,5,6,7,8,9,10/)
 ; use a for something
 a := (/(/"I", "am"/), (/"string", "now"/)/)
 print(a)

Variable: a
Type: string
Total Size: 32 bytes
            4 values
Number of Dimensions: 2
Dimensions and sizes:   [2] x [2]
Coordinates:
(0,0)    I
(0,1)    am
(1,0)    string
(1,1)    now
```

This example demonstrates the type of a changed from integer to string, and the dimensionality changed as well.

3.4.6.3.2 Variable-to-variable reassignments

During variable-to-variable reassignment the left hand side variable is deleted (if it is defined) and then variable-to-variable assignment is performed. The following shows how it works in NCl:

```
 a = new((/20, 20/), string)
;
; Create variable be with values, dimension names,
; coordinate variables and attributes
;
  b = (/ (/1.0,2.0,3.0/), (/4.0,5.0,6.0/), (/7.0,8.0,9.0/) /)
  b!0 = "dim0"
  b!1 = "dim1"
  b@units = "none"
  b&dim0 = (/.1,.2,.3/)
  b&dim1 = (/10,100,1000/)

; Variable-to-variable reassignment with left side defined

 a := b

; Variable-to-variable reassignment with left side undefined

 c := b

 print(a)
 print(c)

Variable: a
Type: float
Total Size: 36 bytes
            9 values
Number of Dimensions: 2
Dimensions and sizes:   [dim0 | 3] x [dim1 | 3]
```

```
Coordinates:
             dim0: [0.1..0.3]
             dim1: [10..1000]
Number Of Attributes: 1
  units :       none
(0,0)    1
(0,1)    2
(0,2)    3
(1,0)    4
(1,1)    5
(1,2)    6
(2,0)    7
(2,1)    8
(2,2)    9

Variable: c
Type: float
Total Size: 36 bytes
            9 values
Number of Dimensions: 2
Dimensions and sizes:   [dim0 | 3] x [dim1 | 3]
Coordinates:
             dim0: [0.1..0.3]
             dim1: [10..1000]
Number Of Attributes: 1
  units :       none
(0,0)    1
(0,1)    2
(0,2)    3
(1,0)    4
(1,1)    5
(1,2)    6
(2,0)    7
(2,1)    8
(2,2)    9
```

3.5 Arrays

The array processing capabilities of NCL are similar to those of Fortran 90, Matlab, IDL, etc. The arithmetic operators (add, multiply, divide, compare, etc.) apply to arrays as well as scalars. Array operations require that all arrays conform to each other. This means that the arrays must have the same size and shape!

But remember, the subscription of an array or dimension starts, like in C, with the index 0.

```
a = (/ 4, 2, 1, 3 /)          4 elements; index 0-3
b = (/ 0, 1, 1, 0 /)          4 elements; index 0-3

c = a + b           →     c = (/ 4, 3, 2 , 3 /)
c = a - b           →     c = (/ 4, 1, 0 , 3 /)
c = a * b           →     c = (/ 0, 2, 1 , 0 /)
c = a /(b+0.1)      →     c = (/40,1.818182,0.909090,30 /)
```

The leftmost dimension of a multi-dimensional array varies slowest and the rightmost dimension varies fastest (row major). Similar to C, the arrays are stored in the "row x column" format.

`T(12, 5,4)` left dimension index 0 with 12 elements (varying slowest)
middle dimension index 1 with 5 elements

right   dimension index 2 with 4 elements (varying fastest)

To assign a new array you can use the NCL statement '***new'***:

```
new (array_size, type, [_FillValue])

n = new(4,integer)                  → integer array of size 4
m = new(12, float)                  → float array of size 12
q = new((/2,3,5/), float)           → float array of size 2 x 3 x 5
k = new(100,float,1e20)             → float array of size 100 with
                                       _FillValue=1e20
l = new(100,float,"No_FillValue")   → same as k but no _FillValue
p = new(dimsizes(pr), double)       → new array of shape of pr, type
                                       double
cities = new(20,string)             → string array of size 20
```

The '***new'*** statement will automatically fill all values of the array with the default missing value for that type, unless a missing value is specified, or if the special "No_FillValue" option is set.

3.5.1 Standard Subscripts

The indices used in standard subscripting are integers and the general form of a standard subscript is:

m:n:i   range **m** to **n** in strides of **i**

The following NCL statements illustrate the possibilities for standard subscripts:

Example array   `a = (/ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, /)`

```
a1 = a             →   new_1 contains 0,1,2,3,4,5,6,7,8,9
a2 = a(3)          →   new_2 contains 3
a3 = a(1:4)        →   new_3 contains 1,2,3,4
a4 = a(0:9:3)      →   new_4 contains 0,3,6,9
a5 = a(:5)         →   new_5 contains 0,1,2,3,4,5
a6 = a(:7)         →   new_6 contains 7,8,9
a7 = a(1:6:-1)     →   new_7 contains 6,5,4,3,2,1
a8 = a(8:4)        →   new_8 contains 8,7,6,5,4
                             note: no need to set the stride to -1
a9 = a(::-1)       →   new_9 contains 9,8,7,6,5,4,3,2,1,0
                             this is equal to new_9 = a(9:0)
```

Example 3-dimensional array   `T = (12, 100, 120)`

```
T1 = T(0:11:3, :19, :)  →   defines a 4 x 20 x 120 array
```

3.5.2 Named Subscripts

Named subscripting allows you to reorder arrays, but is only allowed when all dimensions of the array are named dimensions.

Let us use a variable pressure that has two dimensions named "lon" and "lat". The dimension "lat" is of size 21 and the dimension "lon" is of size 40:

```
pres(21,40)                 → pres(lat,lon)
```

Re-order the dimensions:

```
p_reord1 = pres(lon|:, lat|:)        → p_reord1(40,21) ~ p_reord1(lon,lat)

p_reord2 = pres(lon|19:39, lat|0:9) → define an array 20x10
                                      p_reord2(20,10)
```

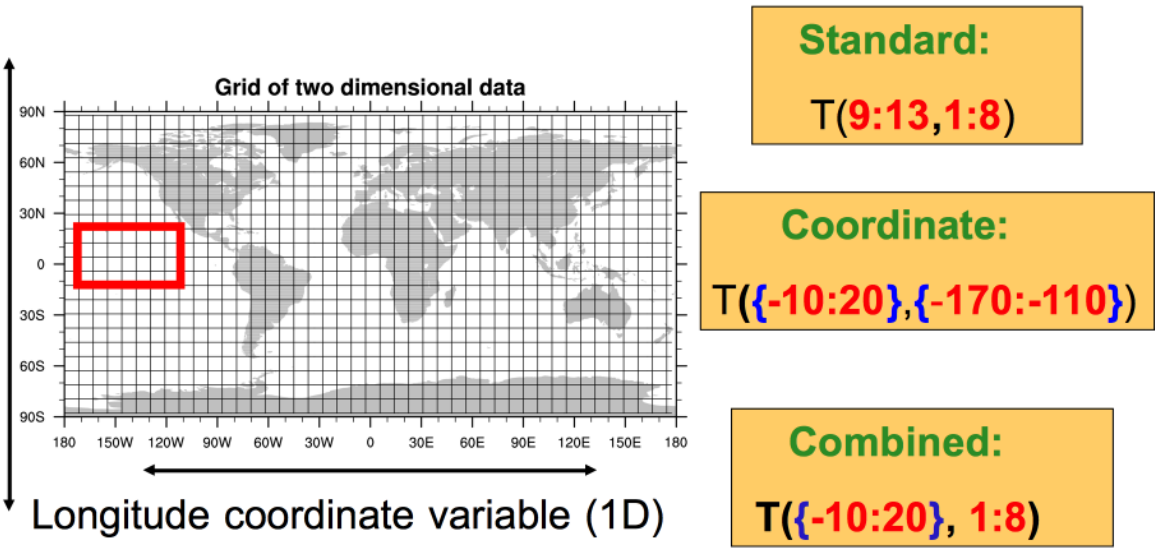
The vertical bar | after the dimension name and before the subscript range is required.

3.5.3 Coordinate Subscripts

For coordinate subscripting, all of the rules for the standard subscripting apply except for curly brackets { }, which are used to distinguish coordinate subscripts from standard subscripts.

Example array

```
m = (/ -5.0, 10.0, 15.0, 20.0, 25.0, 30.0 /)

m!0   = "lat"                  →     name the dimension
m&lat = m                      →     associate the array
mw    = m({ -5.0 : 25.0 : 2})  →     contains the values -
                                     5.0,15.0,25.0
```



3.6 Statements

The fundamental elements of NCL are statements, just like in other scripting or programming languages. Statements are blocks (a group of statements), conditional expressions (if-then, if-then-else), loops (do, do-while), assignments, reassignments, procedures, functions, or graphic statements.

3.6.1 Block

Blocks can be used to bundle many statements into a group of statements as used in functions and procedures. The statements between the ***begin*** and ***end*** statement will be executed.

```
begin
      statement 1
      statement 2
      ……
end
```

The begin and the end statement in the main part of a script are not necessary but sometimes a good practice.

3.6.2 If - Statement

```
if (scalar_logical_expression) then
      [statement(s)]
else
      [statement(s)]
end if
```

There is no "else if", but you can use a trick to get the same effect. Combine the "if" and "else" on one line, as long as you end with an "end if" for each one:

```
if (scalar_logical_expression_A) then
      [statement(s)]
else if (scalar_logical_expression_B) then
      [statement(s)]
else if (scalar_logical_expression_C) then
      [statement(s)]
else
      [statement(s)]
end if                   ; C (includes the "else")
end if                   ; B
end if                   ; A
```

For example:

```
x = 7

if ( x .eq. -5 ) then
   print("if-statement 1")
else if ( x .gt. 0  .and. x .lt. 5 ) then
   print("if-statement 2")
else if ( x .lt. 0 ) then
   print("if-statement 3")
else
   print("if-statement 1 else")
end if
end if
end if
```

```
(0)     if-statement 1 else
```

3.6.3 Loops

Loops are useful but may not be efficient and should be minimally used in any interpreted language. To be more efficient, use array arithmetic and/or built-in functions if available. It may be better to write a Fortran or C function and use a wrapper to load it into your NCL script (see chapter 0).

Loop over n-times:

```
do n=start,end[,stride]
     [statement(s)]
end do
```

The stride value is not optional if the end value is less than the start value.

Loop while a logical expression is True:

```
do while (scalar_logical_expression)
          [statement(s)]
end do
```

Special statements:	**break**	exit a loop
	continue	skip to next loop iteration

3.6.4 Assignment / Reassignment

To assign values to variables, arrays, or attributes, or to assign string values to a variable of type character or named dimensions, the assignment statement, already introduced in chapter 3.4 and 3.5, is used.

Once a variable or array has already been defined and values assigned by using the '**=**' syntax, it can only be overwritten with the values of the same type and shape. In order to reuse a variable with values of a different data type, size or shape, the variable can be deleted before re-defining it:

```
var = "This is a string"           ;-- var of type string
…
delete(var)
var = (/1.0,10.0,15.0/)            ;-- var of type float
```

Or since version 6.1.1, NCL provides the new reassignment syntax '**:=**' which can change the size and/or shape of a variable. The ':=' operator eliminates the need to delete a variable before reassigning and makes the code a little bit cleaner. Now, the example above can be written as

```
var = "This is a string"           ;-- var of type string
var := (/1.0,10.0,15.0/)           ;-- var of type float
```

The reassignment operator is particularly useful in loops when the size and shape of arrays may change with each iteration.

3.7 Print Data and Variable Information

NCL provides print procedures to return information to the standard output (stdout).

print(*variable_or_expression*)
            prints the value of a variable or an expression

printVarSummary(*data_variable*)
            prints summary of a variable's information

print_table(*list*)

```
                formatted print of all elements from a list

printMinMax(data_variable,0)
                prints the minimum and maximum value of a variable

printFileVarSummary(file,varname)
                prints a summary of a file variable's information
```

The printVarSummary procedure should be used frequently when debugging code. If questions are sent to ncl-talk@ucar.edu, providing the output from printVarSummary is very useful.

3.8 Reserved Keywords

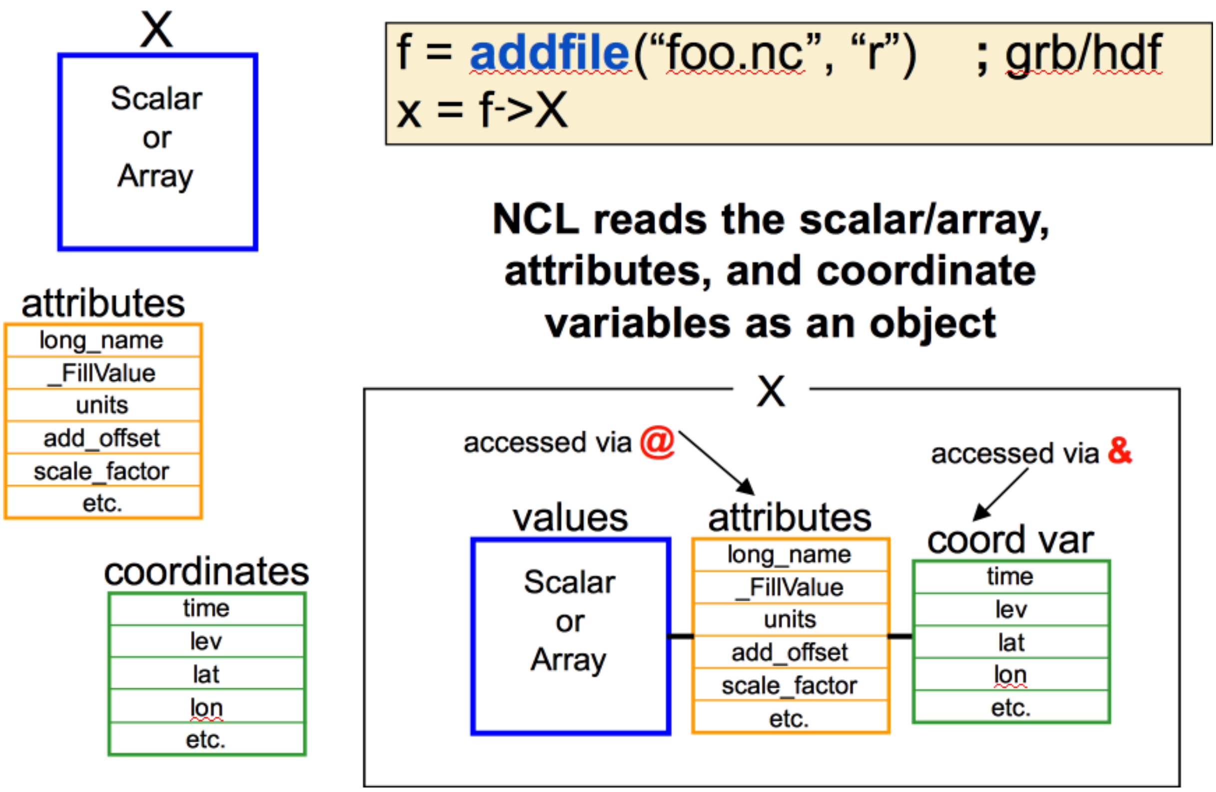
The following keywords can not be used for user defined variables, arrays, lists, functions, or procedures:

begin	break	byte	character
continue	create	defaultapp	do
double	else	end	external
False	file	float	function
getvalues	graphic	if	integer
load	local	logical	long
new	noparent	numeric	procedure
quit	quit	QUIT	record
return	setvalues	short	string
then	True	undef	while

All built-in function and procedure names are also reserved keywords.

4 File I/O

NCL provides two functions **addfile** and **addfiles** to open and access files for reading, writing, and creating. An important feature of these functions is that when variables are imported, they are placed into a consistent variable model regardless of the original source file format (netCDF-3/4, HDF-4/5, GRIB-1/2). This common structure facilitates data processing and the creation of generic functions. Specifically, the variable model is based on the netCDF variable model. It is a data structure containing the array values and all associated meta data Many NCL functions are 'meta data aware'.



4.1 addfile

The function **addfile** can open existing data files written in supported file formats or create new data files in one of the supported data file formats.

```
f = addfile(filename, status)

f                   reference to the data file (type 'file')
filename            file name with full or relative path
status              r = read-only
                    w = read-write (overwrite)
                    c = create
```

If you use the status "c" to open a file, it will be created if it doesn't already exist. If the file already exists, an error message is returned to stdout. Previously created files should be removed before using **addfile** to create new data files with the same name, e.g. `system("rm –f new_data.nc")`

```
f = addfile("data.nc", "r")
      opens the file data.nc in the current directory for reading
```

```
g = addfile("dataT.nc", "w")
      opens the file dataT.nc in the current directory for reading
      and writing

filename = "/tmp/dataT_new.nc"
system("rm -f " + filename)
g = addfile(filename, "c")
      creates a new file dataT_new.nc in the /tmp directory
```

Once a file is opened, you can get more information about it using the following functions:

```
getvaratts              return a list of global attributes on the file
getfiledimsizes         return a list of dimension sizes
getfilevaratts          return a list of attributes associated with a
                        given variable on the file
getfilevardims          return a list of dimension names associated
                        with a given variable on the file
getfilevardimsizes      return a list of dimension sizes associated
                        with a given variable on the file
getfilevarnames         return a list of variable names on the file
getfilevartypes         return a list of variable types for the given
                        variable(s) on the file
```

To read a variable from any supported file format with all metadata information included:

```
fin = addfile("data.nc", "r")  ; .grb, .hdf, .h5, .hdfeos, .shp
t   = fin->T
```

To strip off the metadata, enclose the file variable reference with '*(/…/)*'. Only, the special _FillValue attribute will be carried over.

```
fin = addfile("data.nc", "r")
t   = (/ fin->T /)
```

Keep in mind that every calculation made on the data will strip of the meta data because NCL is not able to know which meta data is still correct.

4.2 addfiles

For the comparison of different simulations or the joint analysis of ensemble simulations, it is very useful to access multiple files at once. The function **addfiles** can open multiple existing data files or create multiple new data files using one of the supported file formats.

```
file_list = addfiles(list_of_files, status)

file_list        list of references to the multiple data files
list_of_files    a 1D array of strings containing the full or
                 relative path of the data files
status           r = read-only
                 w = read-write
                 c = create
```

However, there are some differences from the function **addfile**:

1. **addfiles returns a variable of type list. The returned variable contains references pointing to each file.** This yields a special type of list: the **file list** type:

   ```
   files = systemfunc("ls *.nc")       ; NetCDF file names
   ```

```
f = addfiles(files, "r")            ; data type 'list'
```

2. To import a variable into memory, two options are provided via the **ListSetType** procedure: "*cat*" and "*join*". The "cat" option is the default. It will concatenate a file variable which spans multiple files. Accessing elements of a list variable requires use of the [..] syntax. Consider three files containing the variable 'TEMP' with sizes TEMP(1,10,20,30), TEMP(22,10,20,30) and TEMP(4,10,20,30), respectively. Then the following will import the variable with all meta data:

   ```
   t = f[:]->TEMP                      ; default is 'cat'
   printVarSummary(t)                  ; t(27,10,20,30)
   ```

   Use of the "join" option requires that the leftmost dimension be the same across all files. Consider X(12,72,144) on each of three files, then

   ```
   ListSetType(f, "join")
   x = f[:]->X                         ; x(3,12,72,144)
   ```

   The "*join*". option results in an additional dimension being added.

3. Access to the opened files can be done more specific. For example, you can read data from every second file of an input file list. First, you have to specify from which files the variable should be read. For example, to access the variable T (first time step, first level) in all files opened, T must exist in all files of the **file list** `f` and have the same shape:

   ```
   T_all = f[:]->T(0,0,:,:)
   ```

   To get every second file of a list of 12 files:

   ```
   T_sec = f[0:12:2]->T(0,0,:,:)
   ```

   To get the variable names off the list of files, use first file in list:

   ```
   varnames = getfilevarnames(f[0])
   ```

4. It is only possible to write to an individual file of the *file list* `f`:

   ```
   f = addfiles(files,"w")
   ```

4.3 Assign a Variable from a File Variable

```
f = addfile("dataT.nc", "r")
T = f->T                      → set T to file variable T
```

or

```
T = f->T(0,:,:)               → set T to file variable T, only
                                first time step
```

If the name of a file variable, attribute, or coordinate variable includes hyphens or blanks, NCL will exit with a fatal error. To avoid this, the name can first be stored in a string variable. If this is enclosed by '$' characters, it can then be referenced.

```
tnam = "RCP85 MPI-ESM tas"
var  = f->$tnam$
lon  = x&"lon-1"
```

4.4 Read ASCII File

An ASCII file contains integers or floating point data values in ASCII format.Sometimes it can also contain a header of type string. NCL provide the function asciiread to do this for the user. More examples can be found at http://ncl.ucar.edu/Applications/read_ascii.shtml

Here is a short example how to read an ASCII file containing 14 lines with a single value each line.

Example data asc1.txt:

```
1965
1970
1971
1973
1978
1980
1982
1985
1990
2000
2001
2002
2005
2008
```

The NCL script NUG_read_ASCII_1.ncl reads the data in a 1D array:

```
begin
; Read data into a one-dimensional int array of length 14:

  data = asciiread("asc1.txt",14,"integer")

  npts = dimsizes(data)    ; should be 14
  print("Number of values: "+npts)
  print(data)              ; print the values

end
```

If you don't know how many data values you have, you can use the special "-1" value for the dimension size. When you use -1, data values will be read from left-to-right, top-to-bottom, into a 1D array, until there are no values left.

```
begin
; Read data into a one-dimensional array of unknown length:

  data = asciiread("asc1.txt",-1,"integer")

  npts = dimsizes(data)    ; should be 14
  print("Number of values: "+npts)
  print(data)              ; print the values

end
```

Both versions will return the following lines:

```
(0)   Number of values: 14

Variable: data
Type: integer
Total Size: 56 bytes
```

```
              14 values
Number of Dimensions: 1
Dimensions and sizes:   [14]
Coordinates:
Number Of Attributes: 1
   _FillValue :    -2147483647
(0)    1965
(1)    1970
(2)    1971
(3)    1973
(4)    1978
(5)    1980
(6)    1982
(7)    1985
(8)    1990
(9)    2000
(10)   2001
(11)   2002
(12)   2005
(13)   2008
```

ASCII files containing a header line followed by multiple columns of integer and floating point data are more common and the next example will show how to handle it.

Example data asc2.txt:

```
Estimated world population (in millions) taken from Wikipedia
1000    310
1750    791
1800    978
1850    1262
1900    1650
1950    2518.6
1955    2755.8
……
```

In this case, the header line will be ignored because it doesn't contain any numerical data.

NUG_read_ASCII_2.ncl:

```
begin

; To read this data into a 2D array dimensioned 17 x 2
; (17 rows by 2 columns), use:

  data = asciiread("asc2.txt",(/17,2/),"float")
  print(data)      ; Print the values

end
```

Output to the terminal:

```
Variable: data
Type: float
Total Size: 136 bytes
            34 values
Number of Dimensions: 2
Dimensions and sizes:   [17] x [2]
Coordinates:
Number Of Attributes: 1
   _FillValue :    9.96921e+36
(0,0) 1000
```

```
(0,1) 310
(1,0) 1750
(1,1) 791
(2,0) 1800
(2,1) 978
(3,0) 1850
(3,1) 1262
(4,0) 1900
(4,1) 1650
(5,0) 1950
(5,1) 2518.6
(6,0) 1955
(6,1) 2755.8
…..
```

Another case is a file containg with several columns of integer, float and string data. See example data file asc3.txt:

```
200306130209   0.38   25.28 10088 233.95   6  92  9.99  9.99 99999.0   0.0 -9.99 167.9 p p p 1782  BOS  ATL 3
200306130209   0.38   25.28 10088 233.95   6  92  9.99  9.99 99999.0   0.0 -9.99 167.9 p p p 1782  ORD  ATL 3
200306122341 -45.10  168.70   914 279.35   4 272  9.99  9.99     1.1   0.0  0.01 -99.9 p p p 4552  DTW  MSP 3
200306122341 -45.10  168.70   914 279.35   4 272  9.99  9.99     1.1   0.0  0.01 -99.9 p p p 4552  SDF  MHR 3
```

The first column contains date values, which we want to parse into separate year, month, day, hour, and minute arrays. We also want to read the third-from-the-last-column, which are the station names.

NUG_read_ASCII_3.ncl:

```
begin

  fname  = "asc3.txt"
  data   =  asciiread(fname,-1,"string")
  year   =  tofloat(str_get_cols(data, 1,4))
  month  =  tofloat(str_get_cols(data,5,6))
  day    =  tofloat(str_get_cols(data,7,8))
  hour   =  tofloat(str_get_cols(data,9,10))
  minute =  tofloat(str_get_cols(data,11,12))

;-- read the station name (field 18)

; sta = str_get_cols(data,99,101);-- you must know the digit column numbers
  sta = str_get_field(data,18," ")   ;-- you must know the field number

  print("Year: "+year+"  month: "+month+"  day: "+day+"  hour: "+hour+\
  "  minute: "+minute)
  print("Data:")
  print(""+sta)

end
```

Output to the terminal:

```
(0)   Year: 30  month: 61  day: 30  hour: 20  minute: 9
(1)   Year: 30  month: 61  day: 30  hour: 20  minute: 9
(2)   Year: 30  month: 61  day: 22  hour: 34  minute: 1
(3)   Year: 30  month: 61  day: 22  hour: 34  minute: 1
(0)   Data:
(0)   BOS
(1)   ORD
(2)   DTW
(3)   SDF
```

4.5 Read Excel CSV Data Files

An Excel sheet can be exported as a CSV text file with delimiters. These CSV files can be read and plotted with NCL using the built-in functions asciiread, str_fields_count and str_get_field.

Given example data file Test_6h.csv contains a value for 0h,6h,12h,18h per line:

```
2.00;3.50;5.10;8.20
2.40;3.10;4.80;8.90
2.60;3.70;5.30;10.10
2.75;3.90;5.55;10.25
3.00;4.10;6.05;10.50
```

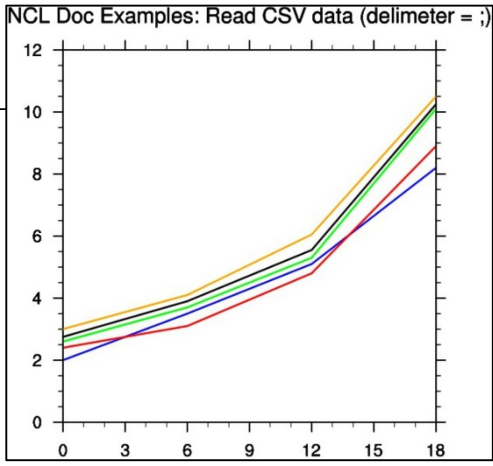
The NCL script to read and plot the data from each line with different colors on a XY-plot: NUG_read_CSV_1.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclex/gsun/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclex/gsun/gsn_csm.ncl"

begin
  diri = "./"
  fili = "Test_6h.csv"

;-- read in file as array of strings so we can parse each line
  delim  = ";"

  data   = asciiread(diri+fili, -1, "string")
  scount = str_fields_count(data(0),delim)

;-- read 6h values
  nl     = dimsizes(data)
  lines  = new(nl, "string")
  cols   = new(scount, "string")
  val    = new((/nl,scount/), float)

  do i=0,nl-1
    do j=1,scount
       value = tofloat(str_get_field(data(i),j,delim))
       val(i,j-1) = value
    end do
  end do
  print("Val: " + val)

;-- 4 timesteps, interval 6h
  x = ispan(0,18,6)

  wks = gsn_open_wks("png","plot_read_CSV_1")

  res                         =  True
  res@gsnDraw                 =  False
  res@gsnFrame                =  False
  res@tiMainString       = "NCL Doc Examples: Read CSV data (delimiter = ;)"
  res@xyLineThicknessF        =   5
  res@trYMinF                 =   0.0
  res@trYMaxF                 =  12.0
  res@trXMinF                 =   0
  res@trXMaxF                 =  18

  res@xyDashPattern           =  0               ;-- make lines all solid
  res@xyLineColor =  (/"blue", "red", "green", "black", "orange"/)
```

All of this code can be replaced with a single call:

`val = str_split_csv(data,delim,0)`

```
  plot = gsn_csm_xy(wks, x, val, res)

  draw(plot)
  frame(wks)
end
```



The next example will show you how to read a more complex CSV data file.

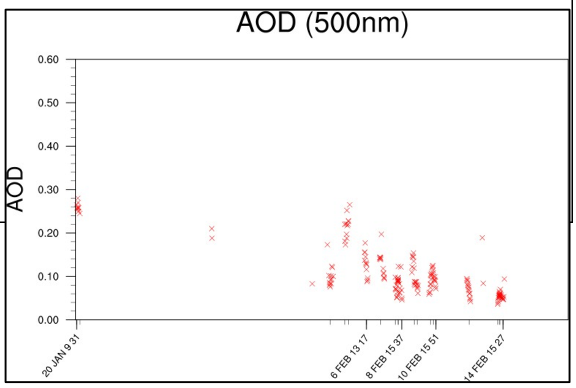
Example data file: multiple_columns.csv

1.line
```
19747,01/20/2014, 9:31:38, 43.194,  27.971,   75, 1011,64.23,2.291,0.969, 22.0,
0, 395.20, 369.01, 361.25, 734.49,1209.62,NaN   ,NaN   ,NaN   ,NaN   ,NaN
,1.0710,1.0215,0.4918,0.6072,0.308,0.278,0.265,0.208,0.144,NaN
```
2.line
```
19747,01/20/2014,10:18:05, 43.188,  28.062,   75, 1008,63.28,2.216,0.969, 21.2,
0, 414.54, 389.68, 377.82, 770.75,1216.23,NaN   ,NaN   ,NaN   ,NaN   ,NaN
,1.0638,1.0314,0.4902,0.6337,0.313,0.272,0.259,0.195,0.147,NaN
```
3.line
```
19747,01/20/2014,10:32:54, 43.208,   7.012,   75, 1008,65.32,2.384,0.969, 19.8,
0, 388.66, 364.70, 355.26, 731.68,1171.65,NaN   ,NaN   ,NaN   ,NaN   ,NaN
,1.0657,1.0266,0.4855,0.6245,0.287,0.263,0.257,0.200,0.152,NaN
```
4.line
```
19747,01/20/2014,10:52:49, 43.236,  28.219,   75, 1007,63.83,2.258,0.969, 19.0,
0, 413.64, 385.64, 375.76, 751.42,1184.56,NaN   ,NaN   ,NaN   ,NaN   ,NaN
,1.0726,1.0263,0.5001,0.6343,0.300,0.267,0.254,0.201,0.156,NaN
……
```

Example script to read the CSV file and plot it: NUG_read_CSV_2.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/contrib/time_axis_labels.ncl"

begin
;-- input file name
  fname = "multiple_columns.csv"

;-- used delimiter in file for columns or strings (date)
  delim1 = ","
  delim2 = "/"
  delim3 = ":"

;-- read in file as array of strings so we can parse each line
  data   = asciiread(fname, -1, "string")
  scount = str_fields_count(data(0),delim1)      ;-- get number of columns

;-- read variable AOD (500)
  var    = tofloat(str_get_field(data,29,delim1))

;-- read date and split it to year, month and day
  dat    = str_get_field(data,2,delim1)
  year   = toint(str_get_field(dat,3,delim2))
  month  = toint(str_get_field(dat,1,delim2))
```

```
  day     = toint(str_get_field(dat,2,delim2))

;-- read time and split it to hour, minutes and seconds
  tim     = str_get_field(data,3,delim1)
  hour    = toint(str_get_field(tim,1,delim3))
  minute  = toint(str_get_field(tim,2,delim3))
  second  = toint(str_get_field(tim,3,delim3))

;-- convert the UT-referenced time to a mixed Julian/Gregorian time
  units   = "hours since 2000-01-01 00:00:00"
  time2   =  cd_inv_calendar(year,month,day,hour,minute,second,units, 0)
  time2!0= "time"

;-- define the workstation (plot type and name)
  wks   = gsn_open_wks("png","plot_NUG_read_CSV_2")

;-- set resources
  res                          =  True
  res@gsnMaximize              =  True       ;-- maximize the plot

  res@xyMarkLineModes          = "Markers"   ;-- use markers instead of lines
  res@xyMarkers                =  5          ;-- type of marker (cross)
  res@xyMarkerColor            = "red"       ;-- marker color
  res@xyMarkerSizeF            =  0.007      ;-- marker size

  res@vpXF                     =  0.25       ;-- viewport x-position
  res@vpYF                     =  0.6        ;-- viewport y-position
  res@vpWidthF                 =  0.7        ;-- viewport width
  res@vpHeightF                =  0.37       ;-- viewport height

  res@tiMainString             = "AOD (500nm)" ;-- title string
  res@tiYAxisString            = "AOD"       ;-- y-axis string

  res@trYMinF                  =  0.0        ;-- y-axis minimum value
  res@trYMaxF                  =  0.6        ;-- y-axis maximum value

  res@tmXBLabelFontHeightF     =  0.01       ;-- x-axis label font size
  res@tmXBLabelJust            = "CenterRight" ;-- x-axis label justification
  res@tmXBLabelDeltaF          =  1.0        ;-- moves x-axis labels downward
  res@tmXBLabelAngleF          =  50.        ;-- rotate x-axis labels
  res@tmYROn                   =  False     ;-- no tick marks on right y-axis
  res@tmXTOn                   =  False      ;-- no tick marks on top x-axis

;-- set the time format for res
  restime            =  True
  restime@ttmFormat = "%d %C %h %m"
  time_axis_labels(time2,res,restime)

;-- create the plot
  plot = gsn_csm_xy(wks, time2, var, res)
end
```



4.6 Read Binary File

A binary file is a file whose contents are to be interpreted as a sequence of bits, rather than characters. There are different flavours of binary files. A 'flat' binary file is a sequence of bits with no ancillary information about the file contents. All records are the same size. This type is created and read by C programs. Fortran creates and reads flat binary files only when in direct-access mode. By default, Fortran creates another type of binary file which can contain variable-length records. This is called a sequential-access binary file. In a sequential-access binary file, record length is embedded prior to each record.

Each type of binary data has its own read function. You must know how your data was written.

Direct Access:	`data = fbindirread (path,rec,dim,type)`
Sequential Access:	`data = fbinrecread (path,rec,dim,type)`
Cray (C block IO write):	`data = cbinread (path,dim,type)`
Cray sequential:	`data = craybinrecread (path,rec,dim,type)`

Binary files created on one machine may not be directly portable to another machine. The terms used to describe the way numbers are stored are big-endian and little-endian. A big-endian representation means the most significant byte is on the left while a little-endian representation means the most significant byte is on the right.
NCL allows users to read files created using, say, big-endian machines on little-endian machines and vice versa via the `setfileoption` procedure. This procedure also allows the data to be written according to a specific byte order.

```
setfileoption("bin","ReadByteOrder","LittleEndian")
v = cbinread("data.littleEndian.bin",-1,"float")

setfileoption("bin","WriteByteOrder","BigEndian")
cbinwrite("data.bigEndian.bin",v)
```

To read the example big-endian binary file topo.bin: NUG_read_Binary_1.ncl

```
begin

;-- path and file name
  diri  = "./"
  fname = "topo.bin"

;-- set byte order
  setfileoption("bin","ReadByteOrder","BigEndian")

;-- read binary file
  topo =  fbindirread(diri+fname,0,(/293,343/),"float")

;-- set some attributes
  topo@units     = "m"
  topo@long_name = "topography"

;-- print information
  printVarSummary(topo)

  print("Minimum value: "+min(topo))
  print("Maximum value: "+max(topo))

end
```

To read a GrADS binary data file you need the information from the descriptor file (.ctl), like the dimensions of time (TDEF), latitude (YDEF) and longitude(XDEF).

ps_grads_model.ctl:

```
DSET   ^ps_grads_model.dat
```

```
OPTIONS little_endian
UNDEF  -2.56E33
TITLE 5 Days of Sample Model Output
XDEF 73 LINEAR  0.0 5.0
YDEF 46 LINEAR  -90.0 4.0
ZDEF  1 linear 1 1
TDEF  5 LINEAR 02JAN1987 1DY
VARS  1
PS     0    99   Surface Pressure
ENDVARS
```

Example script to read the ps_grads_model.dat binary file: NUG_read_Binary_GrADS.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"

begin

  diri = "./"
  fili = "ps_grads_model.dat"

;-- read data
  setfileoption("bin", "ReadByteOrder", "LittleEndian")
  ps = fbindirread (diri+fili, 0, (/ 5, 46, 73 /), "float")

  print ("-- read GrADS binary data -- done")

  ps@long_name = "Surface Pressure"
  ps@units     = "Pa"

  printVarSummary(ps)
  print ("min(ps)="+min(ps))
  print ("max(ps)="+max(ps))

end
```

4.7 Write ASCII File

NCL has five main functions for writing data to an ASCII file:

`write_table`	writes formatted, mixed-type data with a single format statement.
`write_matrix`	writes nicely-formatted 2D arrays of integer, float, or double precision data.
`asciiwrite`	an older and rather limited function that writes one value per line. This is useful for outputting a one-dimensional time series.
`sprintf`	converts floats or doubles into formatted strings.
`sprinti`	converts integers into formatted strings.

The first example shows how to write the data values one value per line to the output file.

NUG_write_ASCII_1.ncl:

```
begin

;-- Generate a dummy 2x3x4 array

  data = random_uniform(-5,5,(/2,3,4/))

;-- Write it to a file

  asciiwrite("file1.txt",data)

end
```

The first lines of `file1.txt` should look like this:

```
-1.762895
-1.75608
-0.06612359
-2.112701
-1.469934
-3.460391
0.6621115
```

The second example shows how to write a mix of data (string, float, and integer) using write_table.

NUG_write_ASCII_2.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"

begin
;---Generate some dummy integer and float data.
   npts = 100
   i    = ispan(1,npts,1)
   j    = generate_unique_indices(npts)
   k    = generate_unique_indices(npts)
   x    = random_uniform(-10,10,npts)
   y    = random_uniform(0,1000.,npts)

  write_table("file2.txt","w",[/j,x,i,y,k/], \
              "string_%03i %8.2f %4.0i %8.1f     string_%03i")

end
```

The first lines of `file2.txt` should look like:

```
string_031    -0.11    1    269.1     string_040
string_074     5.17    2    798.3     string_018
string_015     8.73    3    408.6     string_082
string_037     2.14    4    546.1     string_054
string_016    -1.39    5    653.1     string_017
```

The third example writes the same ASCII file as the previous example, except it uses a combination of sprintf and sprinti to format the data, and then asciiwrite to write the strings to a file.

This method can be *very* slow if you have a lot of data to format.

NUG_write_ASCII_3.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"

begin
;-- Generate some dummy integer and float data.
   npts = 100
   i    = ispan(1,npts,1)
   j    = generate_unique_indices(npts)
   k    = generate_unique_indices(npts)
   x    = random_uniform(-10,10,npts)
   y    = random_uniform(0,1000.,npts)

   lines = "string_" + sprinti("%03i", j) + " " + \
           sprintf("%8.2f",x) +  " " + \
           sprinti("%4.0i", i) + " " + \
           sprintf("%8.1f",y) +  " " + \
           "    string_" + sprinti("%03i", k)

;---Write to a file
  asciiwrite("file3.txt",lines)

end
```

The first lines of `file3.txt` should look like:

```
string_031    -0.11    1    269.1     string_040
string_074     5.17    2    798.3     string_018
string_015     8.73    3    408.6     string_082
string_037     2.14    4    546.1     string_054
string_016    -1.39    5    653.1     string_017
```

The fourth example shows how to write a 3D array to a file, by writing 2D blocks of data at a time. In general, we do not recommend writing large arrays to an ASCII file as this is very inefficient.

We have to use write_table because it is the only NCL function that allows you to append data to an existing ASCII file. This function requires the data be in a list object, so we push each column of a 2D subsection of data to the list object, and then write out that 2D list of data to the file using the "append" option.

This method gets a little kludgy because you have to use a unique variable for every "push" onto the list object. We do this by using unique_string to generate a unique string, and attributes.

NUG_write_ASCII_4.ncl:

```
begin
;-- Generate a dummy 3D array
  nx   = 200    ; # of blocks
  ny   = 100    ; # of rows
  nz   = 10     ; # of columns
  data = random_uniform(-5,5,(/nx,ny,nz/))
;
; Use this to create "nice" numbers for debug purposes.
; This makes it easier to see how the data file is being written.
;
;  data = reshape(conform_dims((/200,ny*nz/),ispan(1,ny*nz,1),1),\
;          (/nx,ny,nz/)) + conform_dims((/nx,ny,nz/),ispan(1,nx,1),0)\
;           /1000.
```

```
;-- Remove file just in case
  filename = "file4.txt"
  system("rm -f " + filename)

;-- Write a header to the file
  header = "This ASCII file contains " + nx + " blocks of " + ny + \
           " x " + nz + " arrays"
  write_table(filename, "w", [/header/], "%s") ; Use "w" to create file

;-- Create row format string. It will have "%7.3f" repeated nz times
  fmt_str = "%s" + str_concat(conform_dims(nz,"%8.3f",-1))
;
; Loop through each column of each block and write the
; column of data to a List object.  We can then use
; write_table to append a whole block of formatted data
; to an ASCII file.
;
  row_labels = "Row " + sprinti("%3i",ispan(1,ny,1))

  dtmp = True   ; Variable to hold temporary attributes
  do i=0,nx-1

;-- Write out the block number. Use "a" to append to existing file.
    slist = [/"Block " + (i+1) + " of " + nx/]
    write_table(filename, "a", slist, "%s")

;-- Create a new List object for this block of data
    dlist = NewList("lifo")

;-- Loop in reverse order so items are written in correct order
    do j=nz-1,0,1
      ListPush(dlist,(/data(i,:,j)/))
    end do

;-- Push array of row headers onto list object
    str = unique_string("test")
    dtmp@$str$ = row_labels
    ListPush(dlist,dtmp@$str$)

;-- Append this List of data to file.
    write_table(filename, "a", dlist, fmt_str)
  end do

end
```

The first lines of file4.txt should look like:

```
This ASCII file contains 200 blocks of 100 x 10 arrays
Block 1 of 200
Row   1   -1.763   -1.756   -0.066   -2.113   -1.470   -3.460    0.662    3.207   -1.745   -1.599
Row   2    3.952   -1.634   -2.150    0.034    2.735   -4.788   -4.630   -2.094   -4.139    2.476
Row   3   -1.406   -2.919   -4.202   -3.521    2.082   -1.046    2.644    1.459   -0.269    3.595
Row   4   -0.025   -4.976    4.233    2.525   -1.127   -0.600    3.011   -4.735   -3.468   -4.152
```

The fifth example shows how to write nicely-formatted two-dimensional arrays of numeric data to an ASCII file using write_matrix. This script creates three ASCII files, one with float data, one with integer data, and one with double data.

NUG_write_ASCII_5.ncl:

```
begin
```

```
;-- create random data
  nrows = 5
  ncols = 7
  ave   = 0.0
  std   = 5.0
  xf    = random_normal (ave, std, (/nrows,ncols/)) ; float
  xi    = round (xf, 3)                             ; integer
  xd    = todouble(xf)

;-- set 2 missing values
  xf@_FillValue = 1e36
  xf(1,1) = xf@_FillValue
  xf(3,3) = xf@_FillValue

;-- set resources for write_matrix
  option        = True
  option@row    = False
  option@tspace = 0

;-- output type float
  option@fout   = "file5.f.txt"
  option@title  = "floating point data with two missing values"
  write_matrix (xf, "7f7.2", option)

;-- output type integer
  option@fout   = "file5.i.txt"
  option@title  = "integer data with no missing values"
  write_matrix (xi, "7i7", option)

;-- output type double precision
  option@fout   = "file5.d.txt"
  option@title  = "double precision data with no missing values"
  write_matrix (xd, "7f7.2", option)

end
```

The file5.f.txt should look like (containing 2 missing values):

```
floating point data with two missing values
   4.35   4.36   9.73   4.91   1.77  -0.63  -4.29
   4.39*******  -5.84   4.59   3.68 -14.12   0.07
   0.27   3.77   0.89  -3.09   5.08  -2.51   5.85
  -3.35  -1.66   8.46*******   0.14   1.76   0.87
  -6.90   4.06  10.39   4.56  -5.63  -1.43   8.65
```

The file5.i.txt should look like (no missing values):

```
integer data with no missing values
      4      4     10      5      2     -1     -4
      4      5     -6      5      4    -14      0
      0      4      1     -3      5     -3      6
     -3     -2      8      8      0      2      1
     -7      4     10      5     -6     -1      9
```

The file5.d.txt should look like (no missing values):

```
double precision data with no missing values
   4.35   4.36   9.73   4.91   1.77  -0.63  -4.29
   4.39   4.66  -5.84   4.59   3.68 -14.12   0.07
   0.27   3.77   0.89  -3.09   5.08  -2.51   5.85
  -3.35  -1.66   8.46   7.55   0.14   1.76   0.87
```

```
  -6.90    4.06  10.39    4.56   -5.63   -1.43    8.65
```

4.8 Write CSV File

The next example will show you how to write a 2-dimensional array printed as comma-separated-values (CSV) to an ASCII output file.

The example 2 of the write_table function manual page on http://ncl.ucar.edu/Document/Functions/Built-in/write_table.shtml is one approach. Another approach is to do your own line formatting.

```
outfile = "out.txt"
x = (/ (/ 4.35,    4.36,    9.73,    4.91 /), \
       (/ 4.39,    4.66,   -5.84,    4.59 /), \
       (/ 0.27,    3.77,    0.89,   -3.09 /)    /)

dimx  = dimsizes (x)
nrows = dimx(0)                           ;-- ncols = dimx(1)
lines = new (nrows, string)

do i = 0, nrows-1
   lines(i) = str_concat (sprintf ("%7.2f,", x(i,:)))
end do

asciiwrite (outfile, lines)
```

To conserve space, you can remove all spaces between numbers by changing the format string to "%0.2f,". This is standard CSV format as used by spread sheet software. For single spaces between numbers, use " %0.2f,".

4.9 Write Binary File

NCL has four main functions for writing data to binary files:

fbinrecwrite	multiple unformatted sequential records
fbindirwrite	specified direct record
fbinwrite	single unformatted sequential record
cbinwrite	mimics a C block IO write

This example shows how to read data from a NetCDF file and write it to a Fortran unformatted binary file using fbinrecwrite.

NUG_write_Binary_1.ncl:

```
begin

;-- set path and file name
  diri     = "./"
  fili     = "rectilinear_grid_2D.nc"
  file_out = "example.bin"

;-- read netCDF file and variable
  fi = addfile(diri+fili,"r")
  t  = fi->tsurf

  if (isfilepresent(file_out)) then
```

```
    system("rm -rf "+fileout)      ;-- make sure that file does not exist
  end if

;***********************************************************
; note the -1 indicates to just add on to the end of the file
; the (/.../) syntax means output the values only with no meta
; data
;***********************************************************

;-- output latitudes
   fbinrecwrite (file_out, -1, (/ fi->lat /))

;-- output longitude
   fbinrecwrite (file_out, -1, (/ fi->lon /))

;-- output data subsection: 1st time step, 2nd latitude
   fbinrecwrite (file_out, -1, (/ t(0,1,:) /))

end
```

The next example shows how to use fbindirwrite to write three variables to the same file, and then fbindirread to read them back in. NUG_write_Binary_2.ncl:

```
begin
;-- Create some dummy arrays.
  nlev = 10
  nlat = 64
  nlon = 128

  t1 = random_uniform(0,100,(/nlev,nlat,nlon/))
  t2 = random_uniform(0,100,(/nlev,nlat,nlon/))
  t3 = random_uniform(0,100,(/nlev,nlat,nlon/))

;-- Remove file just in case
  filename = "dummy_file.bin"
  system("rm -f " + filename)

;-- Write first variable to file
  fbindirwrite(filename,t1)
  system("ls -l " + filename)

;-- Append second variable to file
  fbindirwrite(filename,t2)
  system("ls -l " + filename)

;-- Append third variable to file
  fbindirwrite(filename,t3)
  system("ls -l " + filename)

;-- Read data back in and compare the diffs. Should be equal to 0.
  t1r = fbindirread(filename,0,(/nlev,nlat,nlon/),"float")
  t2r = fbindirread(filename,1,(/nlev,nlat,nlon/),"float")
  t3r = fbindirread(filename,2,(/nlev,nlat,nlon/),"float")

  print("")
  print("If the result below is 0/0 then everything is fine!")
  print(min(t1r-t1) + "/" + max(t1r-t1))
  print(min(t2r-t2) + "/" + max(t2r-t2))
  print(min(t3r-t3) + "/" + max(t3r-t3))

end
```

Output to terminal:

```
-rw-r--r--  1 k204045  staff  327680  9 Jan 18:23 dummy_file.bin
-rw-r--r--  1 k204045  staff  655360  9 Jan 18:23 dummy_file.bin
-rw-r--r--  1 k204045  staff  983040  9 Jan 18:23 dummy_file.bin
(0)
(0)    If the result below is 0/0 then everything is fine!
(0)    0/0
(0)    0/0
(0)    0/0
```

4.10 Write NetCDF File

NetCDF is a self-describing, machine-independent data format which is very common in climate science. There are four types of NetCDF files currently supported by NCL: classic, 64-bit offset, netCDF-4 classic, and netCDF-4.

If you have a newer version of NetCDF installed on your system, you can use "ncdump -k" to determine the type of NetCDF file you have. It will output either "classic", "64-bit offset", or "netCDF-4" for the various types of NetCDF files.

Some of the examples below make use of the setfileoption procedure for setting options before you write to a file. The first example shows the simple but inefficient way and the second is the more efficient and faster way.

1st Method – NUG_write_netCDF_1.ncl:

```
begin
  diri    = "./"
  fili    = "rectilinear_grid_2D.nc"
  outfile = "t_in_Celsius_1.nc"

  if (isfilepresent(outfile)) then
    system("rm -rf "+outfile)      ;-- make sure that file does not exist
  end if

  fin  = addfile(diri+fili,"r")    ;-- open data file
  fout = addfile(outfile,"c")      ;-- create new file (netcdf 3)

  filedimdef(fout,"time",-1,True)  ;-- make time and UNLIMITED dimension

  tK          =  fin->tsurf        ;-- get variable
  tC          =  tK                ;-- copy variable and its related
                                      ;dimensions and attributes
  tC          =  tK - 273.15       ;-- convert from Kelvin to Celsius
  tC@units    = "degC"             ;-- define new units

  fout->tC    =  tC                ;-- write variable to new netCDF file

end
```

Terminal output of `'ncdump -h t_in_Celsius_1.nc'`:

```
netcdf t_in_Celsius_1 {
dimensions:
      time = UNLIMITED ; // (40 currently)
      lat = 96 ;
      lon = 192 ;
```

```
variables:
      float tC(time, lat, lon) ;
            tC:grid_type = "gaussian" ;
            tC:table = 128 ;
            tC:code = 169 ;
            tC:units = "degC" ;
            tC:long_name = "surface temperature" ;
      double time(time) ;
            time:calendar = "standard" ;
            time:units = "hours since 2001-01-01 00:00:00" ;
            time:standard_name = "time" ;
      double lat(lat) ;
            lat:axis = "Y" ;
            lat:units = "degrees_north" ;
            lat:long_name = "latitude" ;
            lat:standard_name = "latitude" ;
      double lon(lon) ;
            lon:axis = "X" ;
            lon:units = "degrees_east" ;
            lon:long_name = "longitude" ;
            lon:standard_name = "longitude" ;
}
```

2nd Method – NUG_write_netCDF_2.ncl:

```
begin

  diri    = "./"
  fili    = "rectilinear_grid_2D.nc"
  outfile = "t_in_Celsius_2.nc"

  if (isfilepresent(outfile)) then
    system("rm -rf "+outfile)      ;-- make sure that file does not exist
  end if

;-- open data file
  fin  = addfile(diri+fili,"r")    ;-- open data file

;-- get variable t and its dimensions and dimension sizes
  tK    =  fin->tsurf              ;-- get variable

  time  =  fin->time               ;-- get dimension time
  lat   =  fin->lat                ;-- get dimension lat
  lon   =  fin->lon                ;-- get dimension lon

  ntim  =  dimsizes(time)          ;-- get dimension sizes of time
  nlat  =  dimsizes(lat)           ;-- get dimension sizes of lat
  nlon  =  dimsizes(lon)           ;-- get dimension sizes of lon

  printVarSummary (tK)             ;-- print variable information

;-- convert variable t: Kelvin to Celsius
  tC           =  tK               ;-- copy variable and its dimensions
                                      ;and attributes
  tC           =  tK - 273.15      ;-- convert from Kelvin to Celsius
  tC@units     = "degC"            ;-- define new units

;-- create new netCDF file
  fout = addfile(outfile,"c")

;-- begin output file settings
  setfileoption(fout,"DefineMode",True) ;-- explicitly declare file
```

```
                                            ;definition mode
;-- create global attributes of the file
  fAtt               =  True       ;-- assign file attributes
  fAtt@title         = "NCL Efficient Approach to netCDF Creation"
  fAtt@source_file   =  fili
  fAtt@Conventions   = "CF"
  fAtt@creation_date =  systemfunc ("date")
  fAtt@history       = "NCL script: NUG_write_netCDF_2.ncl"
  fAtt@comment = "Convert variable tsurf from degrees Kelvin to degrees
Celsius"
  fileattdef(fout,fAtt)            ;-- copy file attributes

;-- predefine the coordinate variables and their dimensionality
  dimNames = (/"time", "lat", "lon"/)
  dimSizes = (/ -1   ,  nlat,  nlon/)
  dimUnlim = (/ True , False, False/)
  filedimdef(fout,dimNames,dimSizes,dimUnlim)

;-- predefine the the dimensionality of the variables to be written out
  filevardef(fout, "time" ,typeof(time),getvardims(time))
  filevardef(fout, "lat"  ,typeof(lat), getvardims(lat))
  filevardef(fout, "lon"  ,typeof(lon), getvardims(lon))
  filevardef(fout, "tC"   ,typeof(tK),  getvardims(tK))

;-- copy attributes associated with each variable to the file
  filevarattdef(fout,"time" ,time)   ;-- copy time attributes
  filevarattdef(fout,"lat"  ,lat)    ;-- copy lat attributes
  filevarattdef(fout,"lon"  ,lon)    ;-- copy lon attributes
  filevarattdef(fout,"tC",   tC)     ;-- copy tC attributes

;-- explicitly exit file definition mode (not required)
  setfileoption(fout,"DefineMode",False)

;-- output only the data values since the dimensionality and such
;-- have been predefined. The "(/…/)" syntax tells NCL to only
;-- output the data values to the predefined locations on the file.
  fout->time   =  (/time/)           ;-- write time to new netCDF file
  fout->lat    =  (/lat/)            ;-- write lat to new netCDF file
  fout->lon    =  (/lon/)            ;-- write lon to new netCDF file
  fout->tC     =  (/tC/)             ;-- write variable to new netCDF file

end
```

Terminal output of `'ncdump -h t_in_Celsius_2.nc'`:

```
netcdf t_in_Celsius_2 {
dimensions:
      time = UNLIMITED ; // (40 currently)
      lat = 96 ;
      lon = 192 ;
variables:
      double time(time) ;
            time:standard_name = "time" ;
            time:units = "hours since 2001-01-01 00:00:00" ;
            time:calendar = "standard" ;
      double lat(lat) ;
            lat:standard_name = "latitude" ;
            lat:long_name = "latitude" ;
            lat:units = "degrees_north" ;
            lat:axis = "Y" ;
      double lon(lon) ;
            lon:standard_name = "longitude" ;
```

```
            lon:long_name = "longitude" ;
            lon:units = "degrees_east" ;
            lon:axis = "X" ;
      float tC(time, lat, lon) ;
            tC:grid_type = "gaussian" ;
            tC:table = 128 ;
            tC:code = 169 ;
            tC:units = "degC" ;
            tC:long_name = "surface temperature" ;

// global attributes:
            :comment = "Convert variable tsurf from degrees Kelvin to
degrees Celsius" ;
            :history = "NCL script: NUG_write_netCDF_2.ncl" ;
            :creation_date = "Fr  9 Jan 2015 17:38:36 CET" ;
            :Conventions = "CF" ;
            :source_file = "rectilinear_grid_2D.nc" ;
            :title = "NCL Efficient Approach to netCDF Creation" ;
}
```

5 Tools

The following shell commands are included in the NCL software distribution:

- **`ncl_filedump`** generates an ASCII representation of supported files (netCDF, HDF, GRIB1, GRIB2, shapefile) on the standard output. It is similar to the netCDF program called ‘`ncdump -h`’.

```
Copyright (C) 1995-2017 - All Rights Reserved
 University Corporation for Atmospheric Research
 NCAR Command Language Version 6.4.0
 The use of this software is governed by a License Agreement.
 See http://www.ncl.ucar.edu/ for more details.

Variable: f
Type: file
filename:       ECHAM5_OM_A1B_2001_2D
path:    ECHAM5_OM_A1B_2001_2D.nc
   file global attributes:
      CDI : Climate Data Interface version 1.0.8
      Conventions : CF-1.0
      history : Wed Feb 27 10:05:05 2008: cdo merge .........
      CDO : Climate Data Operators version 1.0.9 available from http://www.mpimet.mpg.de/cdo
      source : ECHAM5.2
      institution : Max-Planck-Institute for Meteorology
   dimensions:
      lon = 192
      lat = 96
      time = 1460  // unlimited
   variables:
      double lon ( lon )
         long_name :          longitude
         units :       degrees_east
         standard_name :      longitude

      double lat ( lat )
         long_name :          latitude
         units :       degrees_north
         standard_name :      latitude

      double time ( time )
         units :       hours since 2001-01-01 00:00

      float tsurf ( time, lat, lon )
         long_name :          surface temperature
         units :       K
         code :        169
         table :       128
         grid_type :  gaussian
……
      float slp ( time, lat, lon )
         long_name :          mean sea level pressure
         units :       Pa
         code :        151
         table :       128
         grid_type :  gaussian
```

- **`ncl_convert2nc`** Converts GRIB1, GRIB2, shapefile, HDF, or HDF-EOS files to NetCDF files

- **`ng4ex`** a script for generating hundreds of available C, Fortran, and NCL object-oriented examples

- **`WRAPIT`** wraps Fortran 77 or 90 code so you can call it directly from NCL

6 Data Processing

Prior to visualization, it is quite often necessary to apply additional processing steps to the original data. For processing NetCDF data, you can use separate tools such as CDO or NCO. These tools are designed to efficiently perform specific tasks and, depending on the task, can be more efficient than NCL. Another approach is to use NCL's internal processing capabilities directly.

Here, we will only show a few examples of data processing with NCL and CDO:

1) Compute yearly means from monthly data
2) Compute the time average at each grid point
3) Compute the standard deviation of a dimension
4) Compute the area average
5) Compute Linear regression
6) Compute Running mean

The most important rule in data processing is to

look at your data!

You can avoid many errors and warnings if you are familiar with your data. Keep that in mind.

To get an overview of the contents of your file, type the following on the shell command line:

```
ncl_filedump <your_filename>
```

or

```
ncdump -h <your_filename>
```

Assume an input file is of format netCDF and contains the variable 'tas' on a lat/lon grid with 120 timesteps (10 years monthly data):

```
tas(120,194,201)
```

6.1 NCL - Compute yearly means from monthly data

To calculate the yearly (annual) mean, use the function `month_to_annual` which can be found in the contributed.ncl library:

```
ret_array = month_to_annual(array_mon, option)
```

`array_mon`:	an array containing monthly data	
`option`:	option=0	compute the unweighted sum of 12 values
	option=1	divide the unweighted sum by 12 to get the annual mean value(s)
`ret_array`:	returned array with "time" dimension is decimated by a factor of 12	

Example code:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"
```

```
…
tas_ym = month_to_annual(tas,1)     ;-- tas_ym(10,194,201)
```

6.2 NCL - Compute the time average at each grid point

To compute the area mean without weights of the variable tas, use the functions *dim_avg_n* or *dim_avg_n_Wrap*:

Example code: assume tas(time,lat,lon)

Without transferring the metadata -

```
tasAvg = dim_avg_n(dim_avg_n(tas,2),1)
```

- ➔ Results 1D array of area mean values
- ➔ First average over lon (= index 2) and then lat (= index 1)

To preserve the metadata of tas, use the _Wrap version of this function

```
tasAvg = dim_avg_n_Wrap(dim_avg_n_Wrap(tas,2),1)
;-- 1D array of area mean values with the attributes
;   and coordinate arrays of tas
```

6.3 NCL - Compute the standard deviation of a dimension using *dim_stddev_n*

```
ret_var = dim_stddev_n(var)
```

`var:`	variable of numerical type and any dimension
`ret_var:`	variable of same type as var, dimension rank is reduced by one

If you want to retain the metadata, use *dim_stddev_Wrap*. Use the function *dim_stddev_n_Wrap* if no reordering is needed and the wanted dimension can be specified directly.

To calculate the temporal standard deviation at each grid point:

Example code:

```
tasStdT = dim_stddev_n(tas,0)       ;--  tasStdLon(194,201),
                                    ;--  no metadata
tasStdT = dim_stddev_Wrap(tas(lat|:,lon|:,time|:)
                                    ;--  tasStdLon(194,201),
                                    ;--  with metadata
tasStdT = dim_stddev_n_Wrap(tas,0)  ;--  tasStdLon(194,201),
                                    ;--  with metadata
```

6.4 NCL - Compute the weighted area average

```
rad  = get_d2r(lat)                 ;-- float if "lat" is float,
                                    ;-- double otherwise
```

```
weights   = cos(lat*rad)              ;-- cosine weights
area_avg = wgt_areaave(var,weights,1.0,1)
```

6.5 NCL – Compute Linear Regression

Linear regression is an approach for modeling the relationship between a dependent variable y and one or more explanatory or independent variables denoted x.

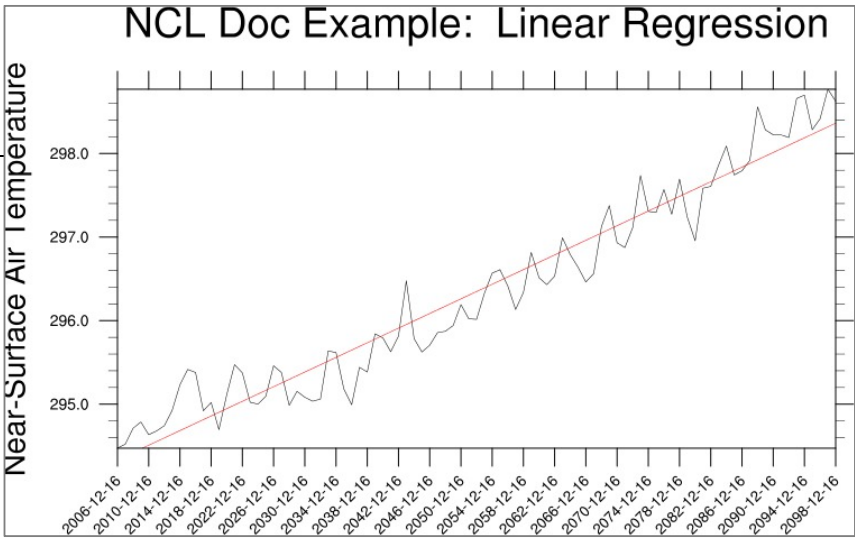
The NCL built-in function ***regline*** computes the information needed to construct a regression line: regression coefficient (trend, slope,...) and the average of the x and y values. regline is designed to work with one-dimensional x and y arrays. Missing data are allowed. If the regression coefficients for multi-dimensional arrays are needed, use ***regCoef***.

Note: Version 6.2.0 has an improved version named ***regline_stats*** that also returns an ANOVA table.

Example script: NUG_statistics_linear_regression.ncl

```
begin

  diri = ./"
  fili = "tas_mod1_rcp85_rectilin_grid_2D.nc"

  f     =  addfile(diri+fili,"r")
  var   =  f->tas(:,0,:,:)
  time =  f->time                              ;-- get time values

;-- convert a mixed Julian/Gregorian date to a UT-referenced date
  utc_date =  cd_calendar(time, 0)
  year     =  tointeger(utc_date(:,0))
  month    =  tointeger(utc_date(:,1))
  day      =  tointeger(utc_date(:,2))
  date_str =  sprinti("%0.4i-", year)+sprinti("%0.2i-", month) + \
              sprinti("%0.2i", day)
;----------------------------------------------------------------------
;-- y = mx+b
;-- m is the slope:       rc         returned from regline
;-- b is the y intercept: rc@yave    attribute of rc returned from regline
;----------------------------------------------------------------------
  x   = time                          ;-- get time values
  y   = dim_avg_n_Wrap(dim_avg_n_Wrap(var,1),1) ;-- timeserie

  rc = regline(x, y)                  ;-- calculate the linear regression
  y_stat2 = rc*(x-rc@xave) + rc@yave  ;-- rc@yave = y intercept; rc = slope

;-- open workstation
  wks = gsn_open_wks("png","plot_stat_linear_regression")

;-- set resources
  res                     =  True
  res@gsnDraw             =  False      ;-- don't draw plot yet
  res@gsnFrame            =  False      ;-- don't advance frame

  res@tiMainString        = "NCL Doc Example:  Linear Regression"

  res@vpHeightF           =  0.4        ;-- viewport height
  res@vpWidthF            =  0.8        ;-- viewport width
  res@vpXF                =  0.125      ;-- viewport x start pos
```

```
  res@trXMinF              =  min(x)     ;-- x-axis min value
  res@trXMaxF              =  max(x)     ;-- x-axis max value
  res@trYMinF              =  min(y)     ;-- y-axis min value
  res@trYMaxF              =  max(y)     ;-- y-axis max value

  res@tmXBMode             = "Explicit"  ;-- use explicit x-axis values
  res@tmXBValues           =  time(::4)  ;-- x-axis values (every 4th)
  res@tmXBLabels           =  date_str(::4)  ;-- x-axis labels (every 4th)
  res@tmXBLabelJust        = "CenterRight"   ;-- x-axis label justification
  res@tmXBLabelDeltaF      =  0.15       ;-- move x-axis labels down
  res@tmXBLabelAngleF      =  45.        ;-- rotate x-axis labels
  res@tmXBLabelFontHeightF =  0.012      ;-- decrease x-axis label font size

  res@xyMarkLineModes      = "Lines"     ;-- line mode

;-- create timeserie plot
  res@xyLineColor          = "black"     ;-- line color black
  plot1 = gsn_csm_xy(wks, x, y, res)

;-- create linear regression plot
  res@xyLineColor          = "red"       ;-- line color red
  plot2 = gsn_csm_xy(wks, x, y_stat2, res)

  overlay(plot1,plot2)                   ;-- overlay plot2 on plot1

;-- draw the plot
  draw(plot1)
  frame(wks)

end
```



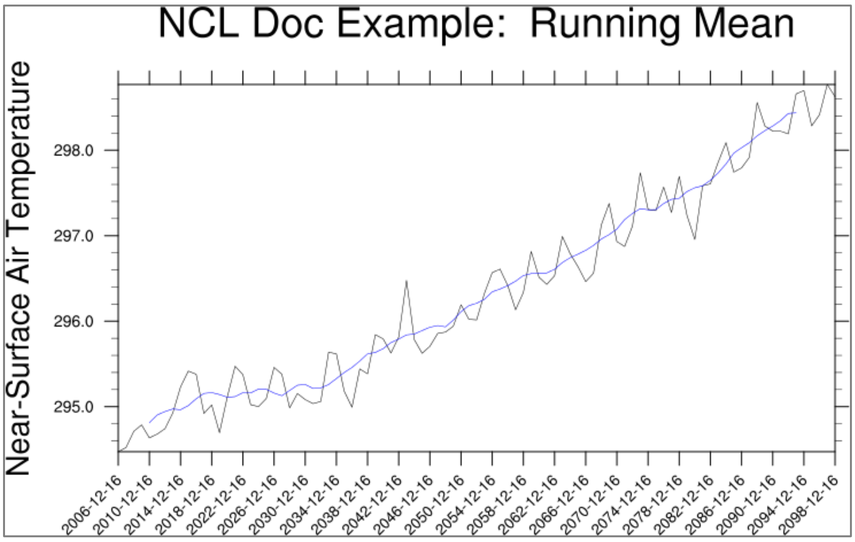
6.6 NCL – Compute Running Mean

In statistics, a running mean (moving average) is a series of calculated averages of different subsets of the full data set to analyse data points.

Example script: NUG_statistics_running_mean.ncl

```
begin

  diri = "./"
  fili = "tas_mod1_rcp85_rectilin_grid_2D.nc"

  f    =  addfile(diri+fili,"r")
  var  =  f->tas(:,0,:,:)
  time =  f->time                       ;-- get time values
```

```
;-- convert a mixed Julian/Gregorian date to a UT-referenced date
  utc_date =  cd_calendar(time, 0)
  year     =  tointeger(utc_date(:,0))
  month    =  tointeger(utc_date(:,1))
  day      =  tointeger(utc_date(:,2))
  date_str =  sprinti("%0.4i-", year)+sprinti("%0.2i-", month)+ \
              sprinti("%0.2i", day)

  x          =  time                      ;-- get time values
  y          =  dim_avg_n_Wrap(dim_avg_n_Wrap(var,1),1) ;-- timeserie

;-- calculate the running mean
  y_rave     = runave_n_Wrap(y,10,0,0)    ;-- 10 time steps are included in
                                          ;-- running average

;-- open workstation
  wks = gsn_open_wks("png","plot_stat_running_mean")

;-- set resources
  res                    =  True
  res@gsnDraw            =  False          ;-- don't draw plot yet
  res@gsnFrame           =  False          ;-- don't advance frame

  res@tiMainString       = "NCL Doc Example:  Running Mean"

  res@vpHeightF          =  0.4            ;-- viewport height
  res@vpWidthF           =  0.78           ;-- viewport width
  res@vpXF               =  0.14           ;-- viewport x start pos

  res@trXMinF            =  min(x)         ;-- x-axis min value
  res@trXMaxF            =  max(x)         ;-- x-axis max value
  res@trYMinF            =  min(y)         ;-- y-axis min value
  res@trYMaxF            =  max(y)         ;-- y-axis max value

  res@tmXBMode           = "Explicit"      ;-- use explicit x-axis values
  res@tmXBValues         =  time(::4)      ;-- x-axis values (every 4th)
  res@tmXBLabels         =  date_str(::4)  ;-- x-axis labels (every 4th)
  res@tmXBLabelJust      = "CenterRight"   ;-- x-axis label justification
  res@tmXBLabelDeltaF    =  0.15           ;-- move x-axis labels down
  res@tmXBLabelAngleF    =  45.            ;-- rotate x-axis labels
  res@tmXBLabelFontHeightF =  0.012        ;-- decrease font size

;-- create timeserie plot
  res@xyLineColor        = "black"         ;-- line color black
  plot1 = gsn_csm_xy(wks, x, y, res)

;-- create linear regression plot
  res@xyLineColor        = "blue"          ;-- line color blue
  plot2 = gsn_csm_xy(wks, x, y_rave, res)

  overlay(plot1,plot2)                     ;-- overlay plot2 on plot1

;-- draw the plot
  draw(plot1)
  frame(wks)

end
```



6.7 CDO - Compute annual means from monthly data

The CDOs must be run on the command line or within a shell and in most cases need an input file (stream) and output file (stream). In the next few cases we will write out a netCDF file ('-f nc') with a relative time axis ('-r').

To calculate the yearly mean use the operator *yearmean*:

```
cdo -r -f nc yearmean <input file> <output file>
```

6.8 CDO - Compute the time average at each grid point

To compute the time average of all time steps included in the NetCDF file use the operator *timmean*:

```
cdo -r timmean <input file> <output file>
```

6.9 CDO - Compute the temporal standard deviation at each grid point using *timstd*

```
cdo -r timstd <input file> <output file>
```

6.10 CDO - Compute the area average

To calculate the area average for each time step use *fldmean:*

```
cdo fldmean <input file> <output file>
```

6.11 CDO - Compute Linear Regression

To calculate a timeserie use the fldmean operator and compute the linear regression by piping the output stream to the detrend operator. The output file contains the values, which have to be subtracted from the original timeseries values to be plotted:

```
cdo -sub <input file> -detrend -fldmean <input file> \
         <output file>
```

6.12 CDO - Compute Running Mean

To calculate the running mean (moving average) values over 10 timesteps, use the *runmean* operator:

```
cdo runmean,10 <input file> <output file>
```

6.13 CDO – Select Variables

For large data sets it would be more efficient to do the computations first, e.g. selecting the wanted variable, do the computation, and save the file in the appropriate file format.

To select a variable use the selvar parameter with a single variable name or list of variables separated by a colon:

select 1 variable

```
cdo -r -f nc selvar,temp <input file> <output file>
```

select 3 variables

```
cdo -r -f nc selvar,temp,u10,v10 <input file> <output file>
```

6.14 CDO – Piping commands

The operations can be piped within cdo, e.g. select variable temp, only the first 10 time steps and do an area average:

```
cdo -r fldmean -seltimestep,1/10 -selvar,temp <input file> \
       <output file>
```

Note that the second and third option starts with a dash!

The computations will be done right to left. At first, select the variable *temp* and pipe the output stream to *seltimestep* operator which selects the first *10 time steps*, and then further pipe the output stream to the *fldmean* operator to compute the field mean, which will be stored in the output file *outfile*.

See also: https://code.zmaw.de/projects/cdo/embedded/1.6.4/cdo.pdf

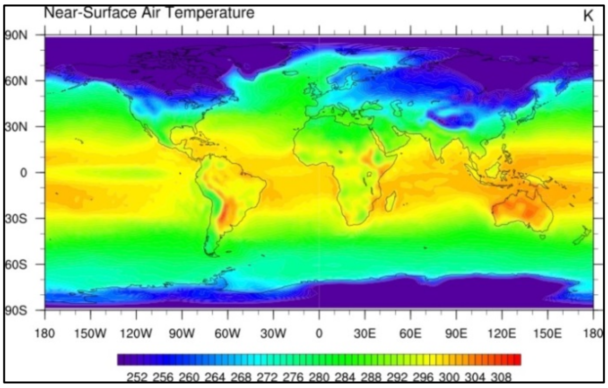
7 Advanced NCL features

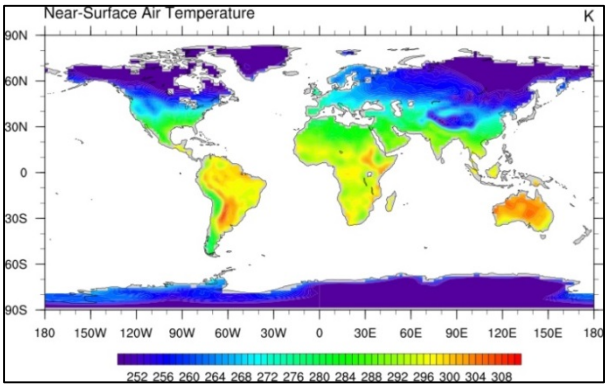
Now, let us start going deeper into some features of NCL.

7.1 Masking

To mask data elements means that you mark parts of the data, i.e. specific grid points, which should not be drawn. With NCL's `mask` function you can mark data elements with `_FillValue` (out-dated: `missing_value`) in order to exclude them from being plotted. Furthermore, you can use so-called "graphical resources" to control the masking or change the order of the plotting elements.

See also the applications "mask" page, http://www.ncl.ucar.edu/Application/mask.shtml





Assume *var* is a two dimensional data array and ***lsm*** is a two dimensional array which contains the land sea mask array; the value 1 represents land and the value 0 represents water.

- Using the ***mask*** function (see also NCL example mask_1.ncl)

```
xLand  = var                → xLand has the same metadata as var
xOcean = var                → xOcean has same metadata as var
xLand  = mask(var, lsm, 1)→ equal to var where lsm=1
xOcean = mask(var, lsm, 0)→ equal to var where lsm=0
```

- Using the ***where*** function and the ***_FillValue*** (old netCDF notation is missing_value) from the data

```
xLand = where(lsm .eq. 1, T, T@_FillValue)
                              → if lsm equal 1 then plot T else
                                set to _FillValue
xOcean = where(lsm .eq. 0, T, T@_FillValue)
                              → if lsm equal 0 then plot T else
                                set to _FillValue
```

- Graphical resources (see also NCL example mask_4.ncl)

```
res@mpAreaMaskingOn        =  1
res@mpMaskAreaSpecifiers   = "France"
res@mpFillAreaSpecifiers   = (/ "water", "land" /)
res@mpSpecifiedFillColors  = (/7,2/)
```

- `change the order of the plotting elements`

→ `see NCL example mask_2.ncl`

7.2 Date Conversion

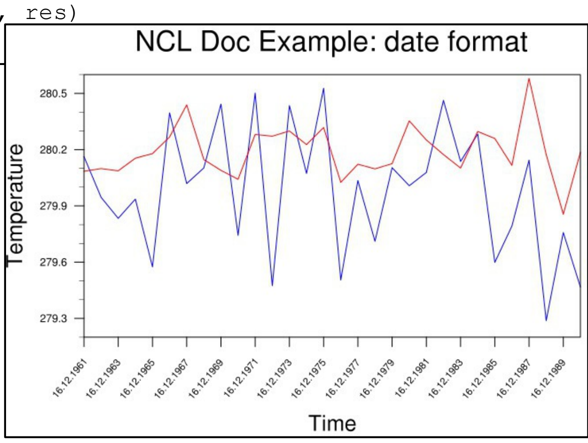
The dimension data of time can be stored in different ways: relative and absolute values. To convert the time values, NCL provides a set of calendar functions, e.g. cd_calendar, cd_convert, cd_inv_calendar and cd_string.

More ‘Date Routines’ : http://www.ncl.ucar.edu/Document/Functions/date.shtml

`cd_calendar`	converts a mixed Julian/Gregorian date to a UT-referenced date
`cd_string`	converts time values into nicely formatted strings
`cd_convert`	converts a variable from one set of units to another
`cd_inv_calendar`	converts a mixed Julian/Gregorian date to a UT-referenced date

NUG_date_format.ncl:

```
….
  time            = var&time
  timax           = dimsizes(time) - 1
….
;-- convert the time proleptic_gregorian calendar to UTC date
   utc_date      = cd_calendar(time, 0)

;-- set date variable names
   year          = toint(utc_date(:,0))
   month         = toint(utc_date(:,1))
   day           = toint(utc_date(:,2))
   hour          = toint(utc_date(:,3))
   minute        = toint(utc_date(:,4))
   second        = utc_date(:,5)

;-- write date as string (DD.MM.YYYY)
   date_str_i    = sprinti("%0.2i",day) + "." + \
            sprinti("%0.2i",month) + "."  + sprinti("%0.4i",year)
….
;-- create the time strings, plot every second axis annotation
  incr                         =  2
  labels                       =  (/ date_str_i(0::incr) /)
….
;-- set the resources
  res@trXMinF                  =  time(0)           ;- time minimum on axis
  res@trXMaxF                  =  time(timax)      ;- time maximum on axis
  res@tmXBMode                 = "Explicit"         ;- explicit time setting
  res@tmXBValues               =  var&time(::incr) ;- axis ticks position
  res@tmXBLabels               =  labels            ;- labels on axis ticks
….
  plot = gsn_csm_xy(wks, var&time, var, res)
….
```



7.3 String Operations

Sometimes you may need to manipulate a string in order to get rid of leading blanks, convert from lower case to upper case, or just select parts of a text line. NCL offers a variety of string manipulation functions.

http://www.ncl.ucar.edu/Document/Functions/string.shtml

- Convert upper to lower case, lower to upper case and capitalize a text string using the functions **str_lower**, **str_upper** and **str_capitalize**

```
str = "HELLO WORLD"
strlower = str_lower(string)        → "hello world"

str = "good morning"
strupper = str_upper(string)        → "GOOD MORNING"

str = "good morning to everybody"
strcapital = str_capital(string)    → "Good Morning To Everybody"
```

- Strip off blanks: leading, ending, all, or replace multiple blanks or TABs with a single blank using the functions: **str_left_strip**, **str_right_strip**, **str_strip**, **str_squeeze**

```
str = "  This is   the title   "

strnew = str_left_strip(str)        → "This is the   title  "
strnew = str_right_strip(str)       → "  This is the   title"
strnew = str_strip(str)             → "This is the   title"
strnew = str_squeeze(str)           → "This is the title"
```

- Count and select fields of a text string: **str_fields_count** and **str_get_field**

```
str = "This is a string"
nf = str_fields_count(str, " ")     → nf = 4

str = "tas_domain_model_ensemble_version_starttime-endtime.nc"
delim = "_-."

nf = str_fields_count(str, delim)   → nf = 8

str = "20130101000000 53.33 10.0 278.32 t2m"
field_1 = str_get_field(str,1," ")
                                    → field_1 = "20130101000000"
field_5 = str_get_field(str,5," ")
                                    → field_1 = "t2m"
```

- Split strings with a given delimiter or split a CSV string using **str_split** or **str_split_csv**

```
str = "Using NCL makes a lot of fun"
strlist = str_split(str, " ")
qc = str_get_dq()                   ; the quote character
print(qc + strlist + qc)

(0)    "Using"
(1)    "NCL"
(2)    "makes"
```

```
(3)    "a"
(4)    "lot"
(5)    "of"
(6)    "fun"
```

CSV (Comma-separated values) is an output format, e.g. used by EXCEL to export the data of a table to an ASCII file. It can contain consecutive delimiters, because there are no values available, the missing value will be inserted.

```
str = "20130101,000000,53.33,10.0,278.32,t2m,,,\
       Near-Surface Air Temperature"

str_new = str_split_csv(str, ",", 0)
print(str_new)
→
Variable: str_new
Type: string
Total Size: 72 bytes
                           9 values
Number of Dimensions: 2
Dimensions and sizes:   [1] x [9]
Coordinates:
Number Of Attributes: 1
  _FillValue :  missing
(0,0)   20130101
(0,1)   000000
(0,2)   53.33
(0,3)   10.0
(0,4)   278.32
(0,5)   t2m
(0,6)   missing
(0,7)   missing
(0,8)   Near-Surface Air Temperature
```

Note that the returned values of the str_* functions are of type string. To use the string content as a numeric value, it must be converted using **tofloat**, **todouble**, **toint**, **toshort** or **tolong**:

```
str = "20130101000000 53.33 10.0 278.32 t2m"

val = tofloat(str_get_field(str,4," "))
                        → val = 278.32  of type float

idate = toint(str_get_field(str,1," "))
                        → idate = 20130101000000 of type integer
```

7.4 System Calls

The **system** procedure and **systemfunc** function are used to interact with the underlying operating system. The difference is that **system** is used to pass a command to the system to perform an action while **systemfunc** returns information to the NCL environment. Other system calls include: **status_exit**, **getenv**, **sleep** and **get_cpu_time**. More details are at:

http://www.ncl.ucar.edu/Document/Functions/system.shtml

- To execute a shell command:

```
system("rm -f tmp.asc")
system("export NCARG_COLORMAPS=$HOME/NCL/Colors")
```

- To execute a shell command and return the output of the call:

```
file_list = systemfunc("ls t2m_*.nc")
date_string = systemfunc("date")
```

- Exit the NCL script returning an integer value as status code:

```
fin = addfile("tas.nc", "r")
if(ismissing(fin)) then
   status_exit(99)
end if
```

- Get the content of a shell environment variable:

```
ret = getenv("SHELL")
→
Variable: ret
Type: string
Total Size: 8 bytes
            1 values
Number of Dimensions: 1
Dimensions and sizes:   [1]
Coordinates:
(0)     /usr/bin/tcsh
```

7.5 User-defined Functions and Procedures

Generally, functions return values and procedures perform tasks. The structure of a procedure or function in NCL is similar to Fortran and C. Procedures and functions can be written directly as the uppermost part of your script code, or they can separately be saved in an external file, which can be loaded by the “load” or "loadscript" command. It might even be useful to collect multiple functions and procedures often needed and save them as your personal external library files, which can be made available within other NCL scripts with the "load" command.

For example:

`;-- load pre-defined functions and procedures`	
`load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"`	*GSN code lib*
`load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"`	*GSN csm lib*
`load "$HOME/NCL/mylib/funs_and_procs.ncl"`	*User defined lib*

7.5.1 Procedures

Generally, procedures are used to perform a task (eg: draw a plot).

General structure:

```
undef ("procedure_name")                          ;-- optional
procedure procedure_name(declaration_list)
local local_variables                             ;-- optional
begin
  statements
end
```

You can, for example, save the user-defined procedure to a new file *my_library.ncl* in the directory */your_home/NCL/lib* and load it into your NCL scripts.

/your_home/NCL/lib/my_library.ncl:

```
undef("wallClockElapseTime_german")
procedure wallClockElapseTime_german(tstart:string, title:string)
begin
   tend         = systemfunc("date +%s")
   tend_i       = toint(tend)
   tstart_i     = toint(tstart)
   elapsed_time = tend_i - tstart_i
   NL           = str_get_nl()
   print (NL + "------>  Wall clock elapsed time - "+ title + \
                          ":   "+ elapsed_time +" s" + NL)
end
```

To use this new procedure, load the file to your NCL script:

```
load  "$HOME/NCL/lib/my_library.ncl"
```

Other example procedures:

```
;-- convK2C: convert data from Kelvin to Celsius
undef("convK2C")
procedure convK2C(var)
begin
   var       = var - 273.15
   var@units = "C"
end

;-- convK2F: convert data from Kelvin to Fahrenheit
undef("convK2F")
procedure convK2F(var)
begin
   var       = ((var-273.15)*9/5)+32
   var@units = "F"
 end
```

7.5.2 Functions

Functions are used to perform one or more tasks and return values to the parent NCL script.

General structure:

```
undef ("function_name")                         ;-- optional
procedure function_name(declaration_list)
local local_variables                           ;-- optional
begin
  statements
  return(return_value)
end
```

To compute the value of ***pi***, you can write a short function:

```
undef("my_pi")
function my_pi()
local lpi
```

```
begin
  lpi = 4*atan(1)   ;-- 4d*atan(1) for double precision
  return(lpi)
end
…
…
x=my_pi()           ;-- Note: NCL has a "get_pi" function
print(x)
```

→

```
      Variable: x
      Type: float
      Total Size: 4 bytes
                  1 values
      Number of Dimensions: 1
      Dimensions and sizes:   [1]
      Coordinates:
      (0)   3.141593
```

NCL can return multiple variables contained within a variable of type list.

If a function is to return multiple variables (eg: ni,nj and nk) they can be returned as a variable of type list. The can be created using the [/ …/] syntax For example:

```
undef ret_mulvar(val1,val2)
function ret_mulvar(val1,val2)
local ni,nj,nk
begin
   ni = val1 + val2
   nj = val1 - val2
   nk = val1 * val2
   return([/ni,nj,nk/]) ;-- return values as list variable
end
```

Use the function as customary. For example:

```
comp = ret_mulvar(5,2)
vadd = comp(0)          ;-- store first list element to vadd
vsub = comp(1)          ;-- store second list element to vsub
vmul = comp(2)          ;-- store third list element to vmul
delete(comp)            ;-- not needed any longer
```

7.6 Handling Metadata

Metadata is defined as “data describing data”. When a data file is opened with addfile, variables and the corresponding metadata included in the file are accessed. As an example, information on the variables such as their dimensions, the grid used, the variable names, the units, the file history, etc. are typical metadata for the files we work with.

Some processing steps can cause the loss of metadata or invalidate it, so it is important that the user take care of it. Some NCL functions have a corresponding “_Wrap” function, like “dim_avg_n_Wrap”, which means that the metadata will be copied (retained) to the new computed variable.

Sometimes it will be necessary to set, overwrite, or delete variable attributes.

- Set an attribute

```
m = sqrt(u^2 + v^2)                this will strip of metadata
→
      Variable: m
      Type: float
      Total Size: 155976 bytes
                        38994 values
      Number of Dimensions: 2
      Dimensions and sizes:   [201] x [194]
      Coordinates:
```

To add new metadata information to the variable:

```
m@standard_name = "magnitude_of_wind_velocity"
m@long_name      = "magnitude of wind velocity"
m@units          = "m s-1"

→
      Variable: m
      Type: float
      Total Size: 155976 bytes
                  38994 values
      Number of Dimensions: 2
      Dimensions and sizes:   [201] x [194]
      Coordinates:
      Number Of Attributes: 3
        units :              m s-1
        long_name :          magnitude of wind velocity
        standard_name : magnitude_of_wind_velocity
```

- Overwrite an attribute

```
m@long_name = "magnitude (sqrt(u^2+v^2)"
→
      Variable: mm
      Type: float
      Total Size: 155976 bytes
                  38994 values
      Number of Dimensions: 2
      Dimensions and sizes:   [201] x [194]
      Coordinates:
      Number Of Attributes: 3
        units :              m s-1
        long_name :     magnitude (sqrt(u^2+v^2)
        standard_name : magnitude_of_wind_velocity
```

- Delete an attribute

```
delete(m@long_name)
delete(m@units)

→
      Variable: mm
      Type: float
      Total Size: 155976 bytes
                  38994 values
      Number of Dimensions: 2
      Dimensions and sizes:   [201] x [194]
      Coordinates:
      Number Of Attributes: 3
              standard_name : magnitude_of_wind_velocity
```

Example:

```
if(isatt(var,"original_name")) then
   delete(var@original_name)
end if
```

A newly-assigned variable has no named dimensions or attributes unless the user defines them manually:

```
latitudes       = u&lat             ; allocate latitudes array
longitudes      = u&lon             ; allocate longitudes array

m               = sqrt(u^2+v^2)     ; assign and compute m
m!0             = "lat"             ; define named dimension lat
m!1             = "lon"             ; define named dimension lon
m&lat           = latitudes         ; allocate latitude values
m&lon           = longitudes        ; allocate longitude values
m&lat@units     = "degrees_north"   ; set lat units
m&lon@units     = "degrees_east"    ; set lon units

m@standard_name = "magnitude_of_wind_velocity"
m@long_name     = "magnitude (sqrt(u^2+v^2)"
m@units         = "m s-1"
```

A shortcut is assigning the new variable by copying a variable u with the same dimensions first. The new variable m has the same dimensions and attributes as u:

```
m               = u                 ; assign: copy u to m
m               = sqrt(u^2+v^2)     ; compute m

m@standard_name = "magnitude_of_wind_velocity"
m@long_name     = "magnitude (sqrt(u^2+v^2)"
```

8 Introduction to NCL Graphics

In this chapter we will present an overview of the NCL's graphics capabilities. An introduction of the following plot types is given: simple XY-Plots, multiple time series, contour plots, displaying lines or colored fields, paneled plots, overlays, map projections, and the use of shapefiles. The complete variety of NCL's plotting features can hardly be described here, but we've highlighted some of the most common and interesting ones.

An NCL script for plotting data commonly can be sectioned into different parts:

0) Load and/or define functions and procedures
1) Open data file/files
2) Define the variable/variables
3) Open the plot output
4) Define the plot resources
5) Plot

NCL provides a huge number of plot resources to control and manage the layout of the plot, such as annotations, projection, plot type, colors, labelbars, multiple plots on one page, plot output format and name, and further more. For most of the settings reasonable defaults are set, such as a default colortable.

CAUTION: starting with NCL 6.1.0 the default color table had been changed. This may cause differently colored results for the examples compared with older versions of NCL.

See also: http://www.ncl.ucar.edu/Document/Graphics/Resources/list_alpha_res.shtml

Example scripts and data are available on the NCL examples page:

http://www.ncl.ucar.edu/Applications/

If you don't know how to write the plotting script, but know exactly what it should look like, it would be very useful to visit the following NCL web pages:

http://www.ncl.ucar.edu/Training/Workshops/Scripts/
http://www.ncl.ucar.edu/Applications/Templates/

On these pages there are many plot examples supplied with their appropriate scripts for downloading.

We recommend writing and saving the scripts to a file, rather than typing commands and resources again and again.

8.1 NCL Graphics – in 5 steps

To create a very simple plot with default settings, only 5 steps are necessary. Here is a contour plot example to show how easy NCL scripting can be.

A short template file is provided in the directory NCL_Doc/scripts: NUG_template.ncl.

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin

end
```

The first two lines tell NCL to load the graphic libraries *gsn_code.ncl* and *gsn_csm.ncl*. These library files contain high level procedures and functions for contours, vectors, legends, labelbars and so on, which are not yet included directly in NCL. Additional library files like *contributed.ncl* or *shea_util.ncl* which are also used in the examples, contain procedures and functions for averaging, converting and other helpful tasks. You may take a look into these files to copy and modify procedures and functions for your own purpose, but we strongly recommend using your own function or procedure names.

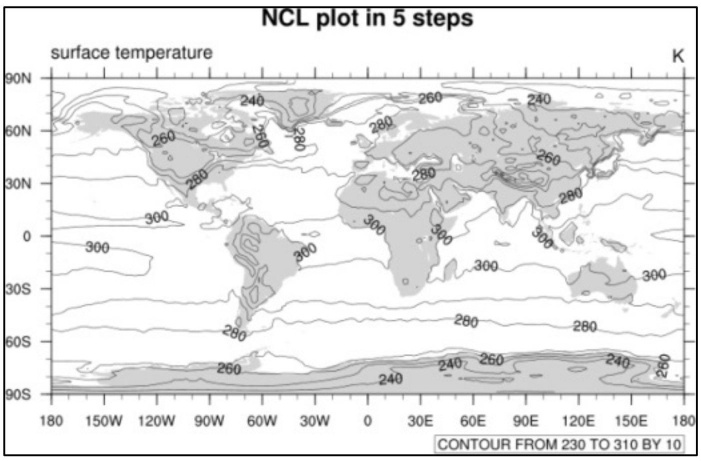
Since NCL release (6.2.0) these libraries (gsn_code.ncl, gsn_csm.ncl and contributed.ncl) are not longer required because they will be loaded automatically. But for backward compatibility it is a good idea to load the libraries in your scripts.

To get your own simple plot, copy the template file and edit it as shown in the box below. Don't forget to save it in a directory where you have write permission, e.g. $HOME/my_simple_plot.ncl.

1. Open a data file
2. Set variable references (e.g. first time step)
3. Open the plot output (X11 → output to screen)
4. Set plot resources (Detailed list of all available resources: http://www.ncl.ucar.edu/Document/Graphics/Resources/list_alpha_res.shtml)
5. Plot

NUG_plot_in_5_steps.ncl:

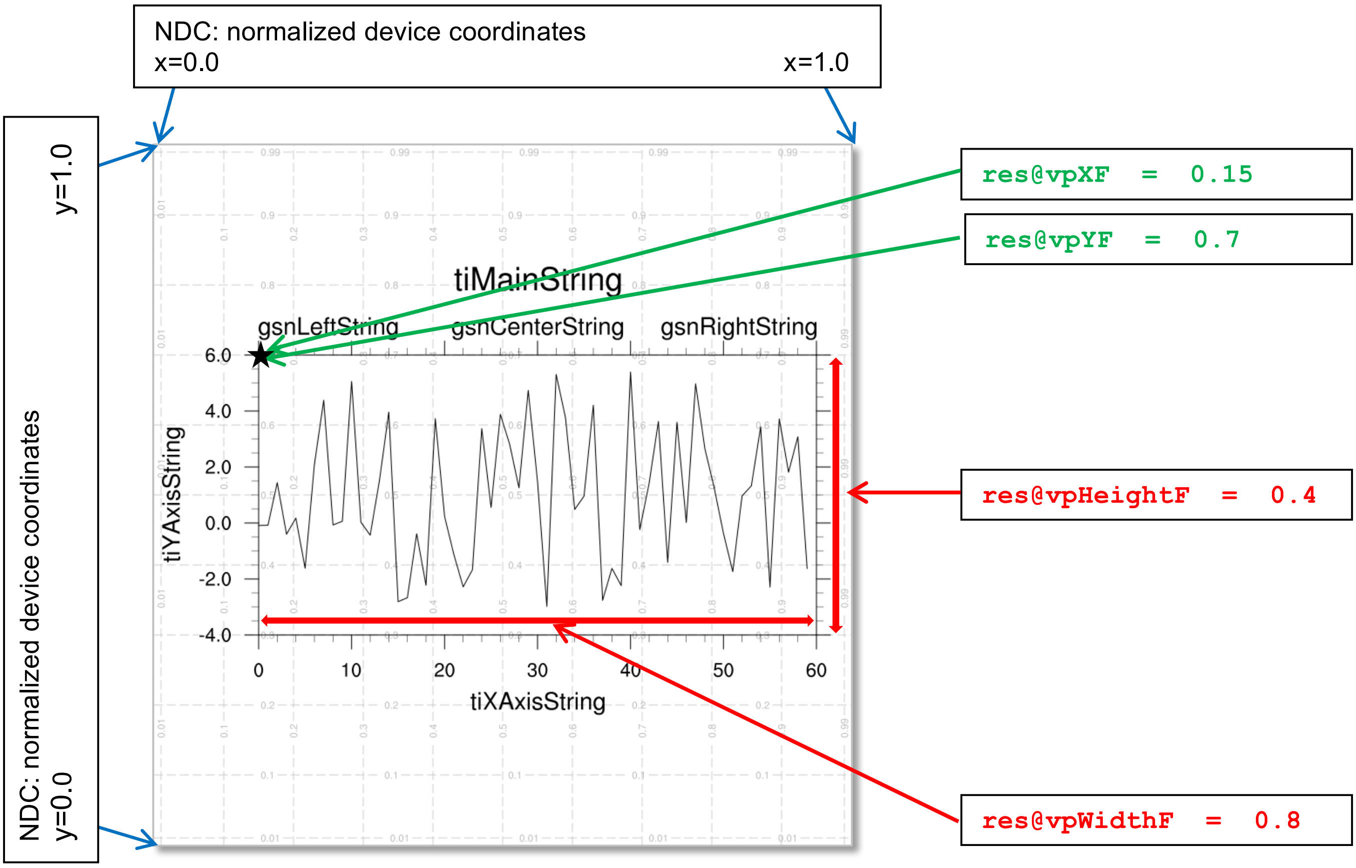
```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   f= addfile("$NCL_TUT/data/ECHAM5_OM_A1B_2001_0101-1001_2D.nc", "r")

   var = f->tsurf(0,:,:)

   wks = gsn_open_wks("x11","plot_in_5_steps")

   res               =  True
   res@tiMainString = "NCL plot in 5 steps"

   plot = gsn_csm_contour_map(wks, var, res)
end
```



8.2 The Viewport

The viewport of NCL in which the plot appears uses the NDC (Normalized Device Coordinates) with its values range from 0.0 to 1.0. The plots will be placed in the viewport automatically with the best aspect ratio. You can resize, move, overwrite text and many things more by using the appropriate resources.

The graphic below shows the NDC grid and the vp-resources (Viewport) used to define the start x- and y-position for plotting the plot size in NDC coordinates.



8.3 Maps

NCL supports many different map types and projections. By default, the continents are color filled using light grey; this behaviour can easily be changed by setting the *mpLandFillColor* resource to the desired color. You can also turn off the color fill by setting *mpFillOn* to False.

The default tickmark settings for a map can be changed by some **@gsn** and **@tm** resources, Not every resource can be used for map projections other than 'Cylindrical Equidistant', but on the NCL examples web page there are some examples for work arounds.

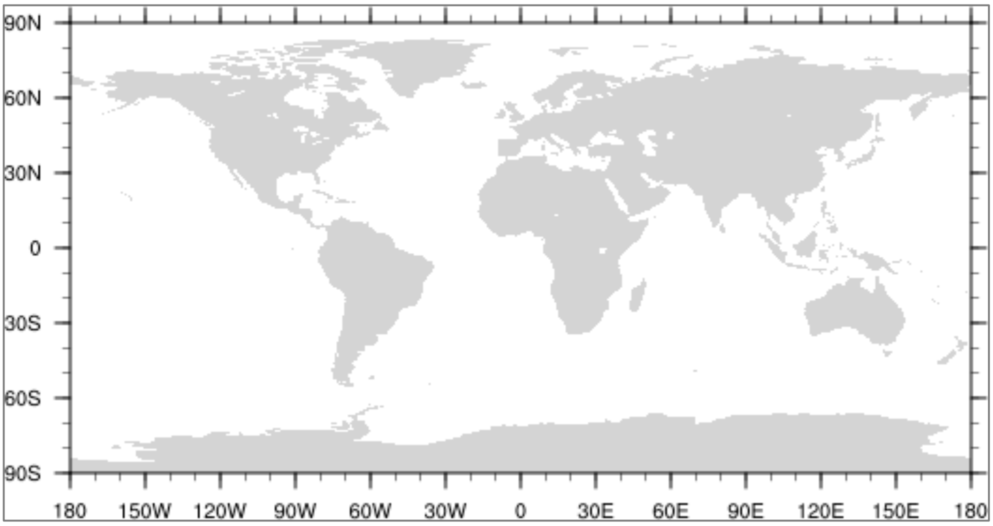
See also http://ncl.ucar.edu/Applications/mptick.shtml

8.3.1 Default Map

To create a simple map of the Earth open a workstation and call the function *gsn_csm_map*.

NUG_map_default.ncl:

```
begin

  wks = gsn_open_wks("png","plot_map_default")    ;-- define the workstation

  map = gsn_csm_map(wks, False)                   ;-- draw the map

end
```



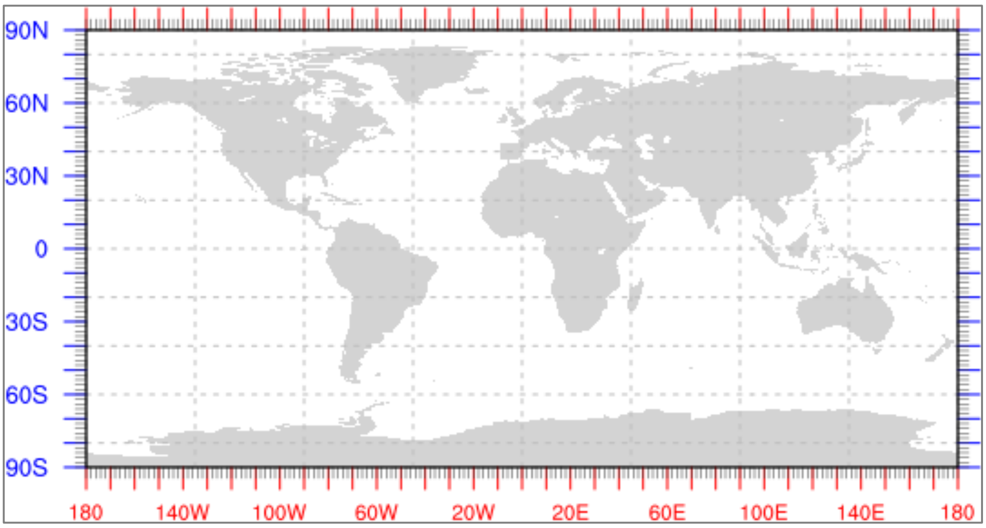
8.3.2 Map Grid and Tickmark Settings

To control the grid lines of the latitude and longitude axis as well as their major and minor tickmarks you have to use different resource groups like ***@gsn***, ***@tm***, and ***@mp***.

NUG_map_grid_and_tickmark_settings.ncl:

```
begin
;-- define the workstation (plot type and name)
  wks = gsn_open_wks("png","plot_map_grid_and_tickmark_settings")

;-- set resources
  res                          =  True
;-- grid line settings
  res@mpGridAndLimbOn         =  True     ;-- draw grid lines on the plot
  res@mpGridLatSpacingF       =  20       ;-- grid line latitude spacing
  res@mpGridLonSpacingF       =  45       ;-- grid line longitude spacing
  res@mpGridLineColor         = "gray"    ;-- grid line color
  res@mpGridLineThicknessF    =  2        ;-- grid line thickness
  res@mpGridLineDashPattern   =  2        ;-- grid line dash pattern
                                          ;-- (2: dotted)
;-- latitude settings
  res@gsnMajorLatSpacing      =  10      ;-- change major lat tickmark spacing
  res@gsnMinorLatSpacing      =  2.5     ;-- change major lat tickmark spacing

  res@tmYLLabelStride         =  3       ;-- write only every 3rd label
  res@tmYLLabelFontHeightF    =  0.016   ;-- change major lat tickmark spacing
  res@tmYLMajorLengthF        =  0.02    ;-- change the tickmark length
  res@tmYLMinorLengthF        =  0.01    ;-- change the tickmark length
  res@tmYLMajorLineColor      = "blue"   ;-- change major tickmarks color
  res@tmYLMinorLineColor      = "grey20" ;-- change major tickmarks color
```

```
  res@tmYLLabelFontColor     = "blue"  ;-- change label color

;-- longitude settings
  res@gsnMajorLonSpacing     =  10     ;-- change major lon tickmark spacing
  res@gsnMinorLonSpacing     =  2.5    ;-- change major lon tickmark spacing

  res@tmXBLabelStride        =  4      ;-- write only every 4th label
  res@tmXBLabelFontHeightF   =  0.014  ;-- change major lat tickmark spacing
  res@tmXBMajorLengthF       =  0.02   ;-- change the tickmark length
  res@tmXBMinorLengthF       =  0.01   ;-- change the tickmark length
  res@tmXBMajorLineColor     = "red"   ;-- change major tickmarks color
  res@tmXBMinorLineColor     = "grey20";-- change major tickmarks color
  res@tmXBLabelFontColor     = "red"   ;-- change label color

;-- draw the map
  map = gsn_csm_map(wks, res)

end
```



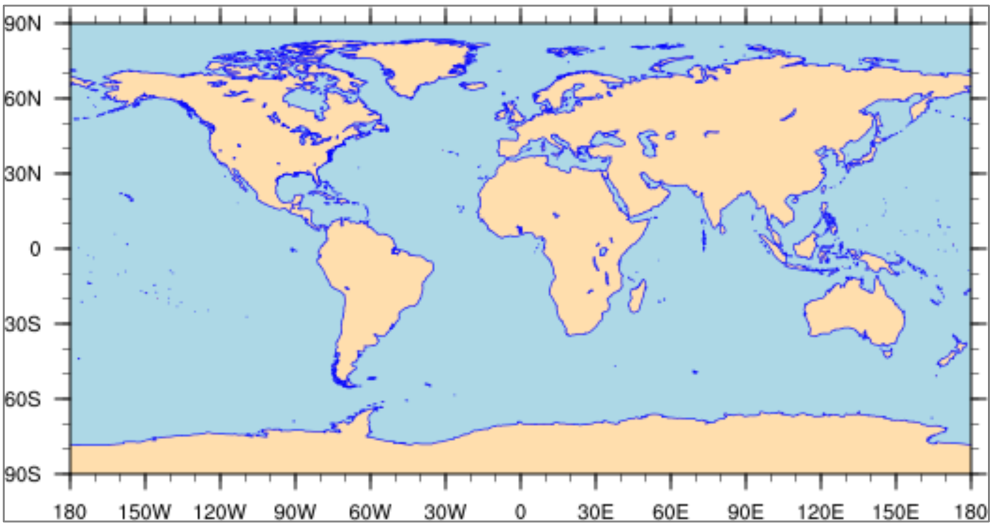
8.3.3 Map Content Settings

To change the color of land, inland water and ocean areas NCL provides the resources *mpOceanFillColor*, *mpInlandWaterFillColor*, and *mpLandFillColor.* Also, the line color and thickness of the continents can be controlled by resources.

NUG_map_land_ocean_settings.ncl:

```
begin
;-- define the workstation (plot type and name)
  wks = gsn_open_wks("png","plot_map_land_ocean_settings")

;-- set resources
  res                        =  True
  res@mpFillOn               =  True       ;-- use land fill (default: True)
  res@mpOutlineOn            =  True       ;-- outline land  (default: False)

  res@mpOceanFillColor       = "lightblue" ;-- color to fill ocean
  res@mpInlandWaterFillColor = "lightblue"    ;-- color to fill inland water
  res@mpLandFillColor        = "navajowhite1"  ;-- color to fill land

  res@mpGeophysicalLineColor = "blue"          ;-- outline color
  res@mpGeophysicalLineThicknessF = 1.2        ;-- thickness of continental
```

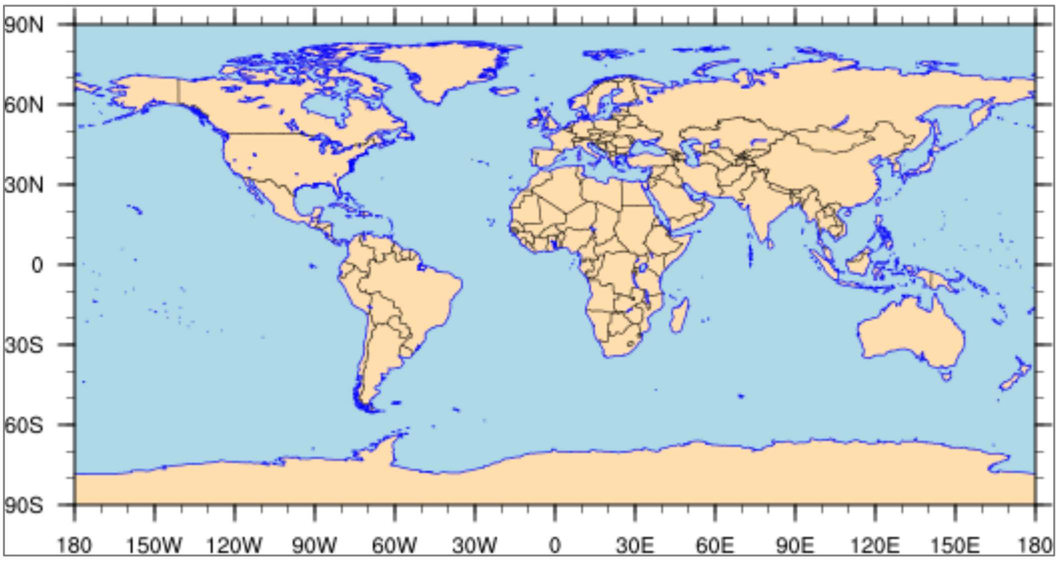
```
                                                    ;-- outlines
  res@mpDataBaseVersion     = "MediumRes"      ;-- map resolution

;-- draw the map
  map = gsn_csm_map(wks, res)

end
```



Using the MediumRes map database allows you to add country outlines in addition to the default map outlines. (Note:http:/www.gadm.org/ provides shapefiles containing better outlines. See also chapter 8.12)

NUG_map_countries.ncl:

```
begin

;-- define the workstation (plot type and name)
  wks = gsn_open_wks("png","plot_map_countries")

;-- set resources
  res                        =  True
  res@mpFillOn               =  True        ;-- use land fill (default: True)
  res@mpOutlineOn            =  True        ;-- outline land  (default: False)

  res@mpOutlineBoundarySets = "National" ;-- turn on country boundaries

  res@mpOceanFillColor      = "lightblue" ;-- color to fill ocean
  res@mpInlandWaterFillColor = "lightblue"  ;-- color to fill inland water
  res@mpLandFillColor       = "navajowhite1" ;-- color to fill land

  res@mpGeophysicalLineColor = "blue"     ;-- outline color
  res@mpGeophysicalLineThicknessF = 1.2   ;-- thickness of continental
                                          ;-- outlines
  res@mpDataBaseVersion     = "MediumRes" ;-- map resolution

;-- draw the map
  map = gsn_csm_map(wks, res)

end
```



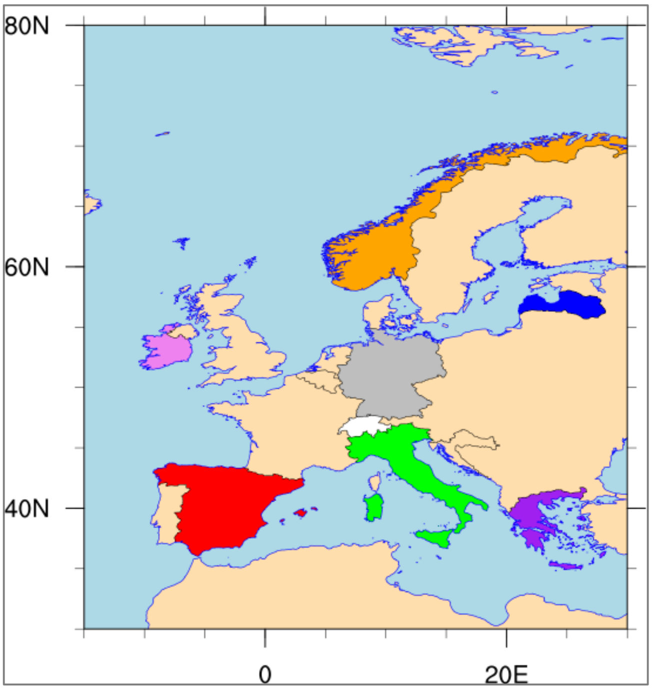
The map dataset "Earth..4" provides the provinces of Canada, the states of Mexico, and the states and counties of the conterminus United States, it also provides the state/province outlines of Australia, Brazil, China, and India. The ice shelves of Antarctica are included as separate entities, that can be made to appear or not, as desired.

The next example will show how to use this map dataset to plot Europe and color and/or outline some named countries.

NUG_map_selected_countries.ncl:

```
begin
  fill_colors = (/"red", "green", "white", "gray", "blue", \
                  "violet", "orange", "purple"/)           ;-- fill colors
  fill_areas = (/"Spain", "Italy", "Switzerland","Germany", "Latvia", \
                 "Ireland", "Norway", "Greece"/);-- countries to be colored
  outline_areas = (/"Belgium", "Croatia"/)         ;-- only outline countries
  outline_areas := array_append_record (outline_areas, fill_areas, 0)
                                                   ;-- concatenate arrays
  outline_colors = (/"red","green","white","gray","blue","hotpink", \
                     "orange","purple"/)
;-- define the workstation (plot type and name)
  wks = gsn_open_wks("png","plot_map_select_countries")

;-- set resources
  res                         =  True
  res@gsnMaximize             =  True

  res@mpOutlineOn             =  True          ;-- outline land  (default: False)
  res@mpOutlineSpecifiers     =  outline_areas  ;-- which country to be
                                                ;-- outlined
  res@mpFillOn                =  True          ;-- use land fill (default: True)
  res@mpFillAreaSpecifiers =  fill_areas   ;-- which country to be colored
  res@mpSpecifiedFillColors =  outline_colors ;-- set colors to be used

  res@mpOceanFillColor      = "lightblue"      ;-- color to fill ocean
  res@mpInlandWaterFillColor = "lightblue"     ;-- color to fill inland water
  res@mpLandFillColor       = "navajowhite1"   ;-- color to fill land

  res@mpGeophysicalLineColor = "blue"          ;-- outline color
  res@mpGeophysicalLineThicknessF = 1.2        ;-- thickness of continental
                                                ;-- outlines
```

```
  res@mpDataBaseVersion     = "MediumRes"      ;-- map resolution
  res@mpDataSetName         = "Earth..4"

  res@mpMinLatF             =  30.0            ;-- min latitude
  res@mpMaxLatF             =  80.0            ;-- max latitude
  res@mpMinLonF             = -15.0            ;-- min longitude
  res@mpMaxLonF             =  30.0            ;-- max longitude

;-- draw the map
  map = gsn_csm_map(wks, res)

end
```



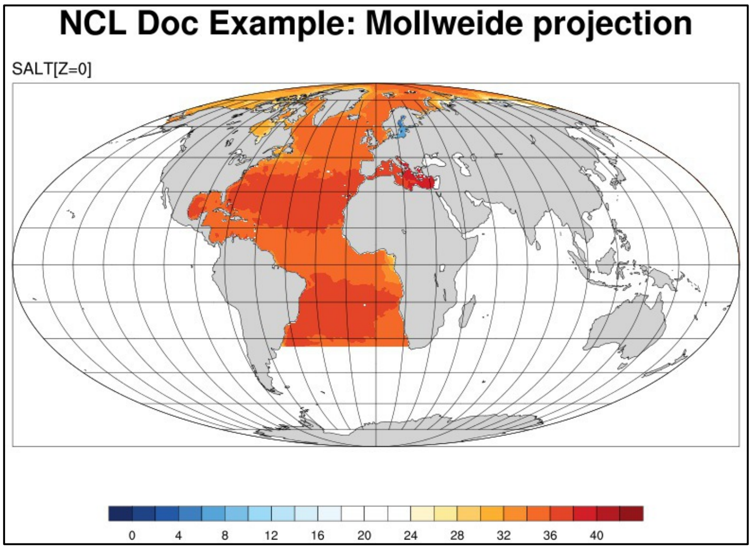
8.3.4 Change Map Projection

How to create a simple filled contour plot using the Mollweide projection can be seen in the next example.

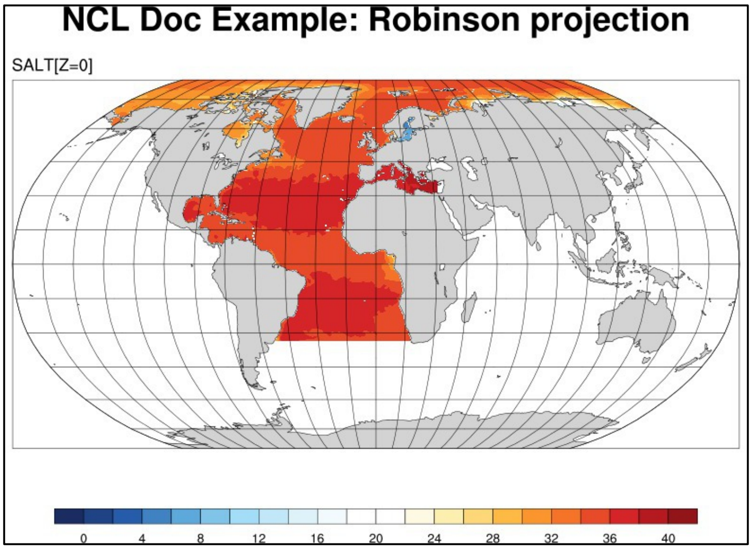
NUG_projections_mollweide.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- read the data and define
  diri = "./"
  fili = "MITgcm_rectilinear_grid_3D.nc"
  file1 =  addfile(diri+fili,"r")
  var   =  file1->SSS(0,0,:,:)

;-- define the workstation (plot type and name)
  wks = gsn_open_wks("png","NUG_mollweide")

;-- set resources
  res                        =  True
  res@gsnMaximize            =  True
  res@lbLabelStride          =  2
```

```
  res@lbBoxMinorExtentF      =  0.15 ;-- decrease the height of the labelbar
  res@cnFillOn               =  True          ;-- turn ofncontour fill
  res@cnLinesOn              =  False         ;-- turn off contour lines
  res@cnLineLabelsOn         =  False         ;-- turn off line labels
  res@cnLevelSelectionMode   = "ManualLevels";-- set contour levels manually
  res@cnMinLevelValF         =   0.           ;-- minimum contour level
  res@cnMaxLevelValF         =  42.           ;-- maximum contour level
  res@cnLevelSpacingF        =   2            ;-- contour level spacing
  res@mpProjection           = "Mollweide"    ;-- change projection
  res@mpGridAndLimbOn        =  True          ;-- plot grid lines

  res@tiMainString   = "NCL Doc Example: Mollweide projection" ;-- title
  res@tiMainFontHeightF      =  0.02

;-- draw the contour map
  plot = gsn_csm_contour_map(wks, var, res)

end
```



To change the map projection from "Mollweide" to "Robinson", just change the *res@mpProjection* setting to "Robinson".



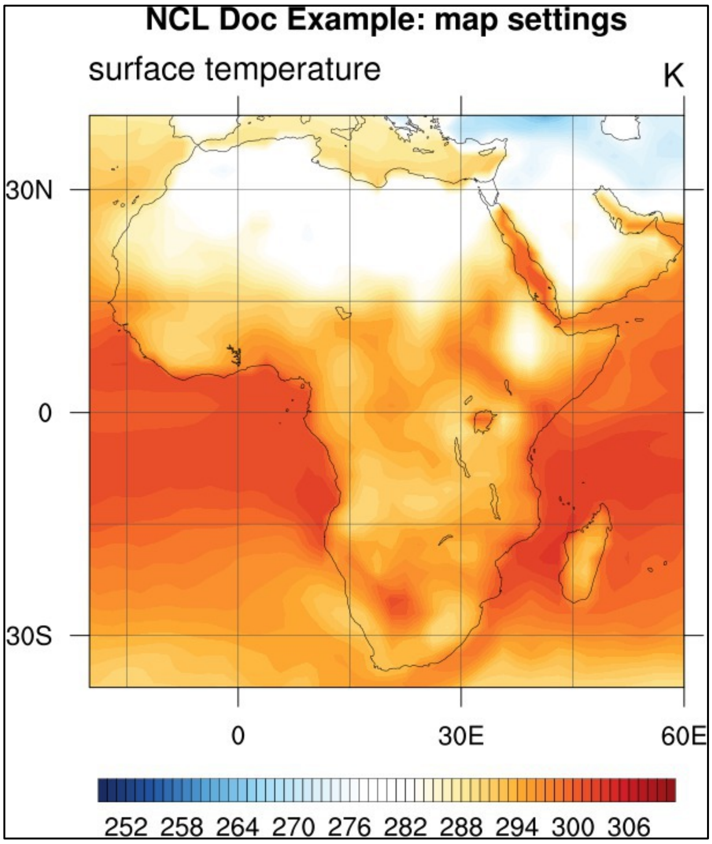
The default projection is "CylindricalEquidistant". To change back to the default projection, uncomment the *res@mpProjection* line or set it to "CylindricalEquidistant".

8.3.5 Regional Map

Sometimes just a specific region of the data is of interest. To define the extent of a map region, insert the following resource settings in the script NUG_map_settings.ncl:

```
res@mpMinLonF       = -20.0          ;-- min longitude
res@mpMaxLonF       =  60.0          ;-- max longitude
res@mpMinLatF       = -37.0          ;-- min latitude
res@mpMaxLatF       =  40.0          ;-- max latitude
res@mpDataBaseVersion = "MediumRes" ;-- better map resolution
```

NUG_map_settings.ncl:



8.3.6 Polar Plot

To create a polar plot of the Northern Hemisphere, the **gsn_csm_contour_map_polar** function of NCL can easily be used. In this example, some additional settings are made to show the capabilities of polar plot resources.

Plot Northern Hemisphere:	`res@gsnPolar`	`= "NH"`
Label distance to the map:	`res@gsnPolarLabelDistance`	`= 1.1`
Label font size:	`res@gsnPolarLabelFontHeightF`	`= 0.015`
Label font:	`res@gsnPolarLabelFont`	`= "helvetica-bold"`

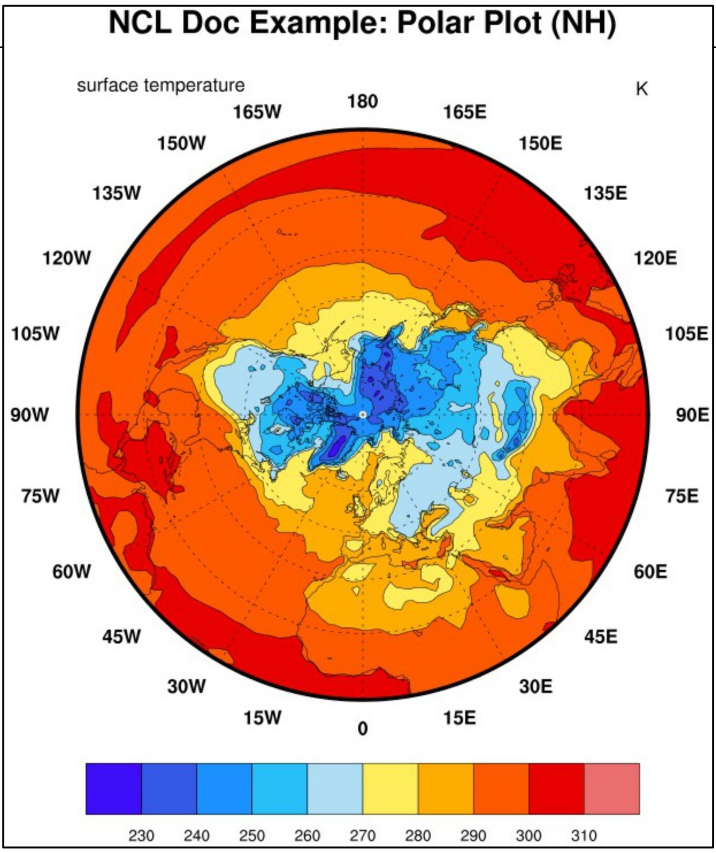
A procedure *polar_map_circle* is included to draw a thicker line around the map.

Use the acronym "SH" to plot the Southern Hemisphere instead of "NH" for the Northern Hemisphere in the resource *res@gsnPolar*.

Simple polar plot for the Northern Hemisphere : NUG_polar_NH.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"

;----------------------------------------------------------------------
;-- procedure : polar_map_circle
;-- plot a circle around the polar map using width wsize and color col
;----------------------------------------------------------------------
undef("polar_map_circle")
procedure
polar_map_circle(wks,plot:graphic,wsize:integer,col:string,offset:numeric)
local degrad,degrees,xcos,xsin,xcenter,ycenter,radius,xc,yc
begin
  getvalues plot     ;-- get viewport coordinates
    "vpXF"      : x
    "vpYF"      : y
    "vpWidthF"  : w
    "vpHeightF" : h
  end getvalues

  degrad  = 0.017453292519943
  degrees = ispan(0,360,1)
  xcos    = cos(degrad * degrees)
  xsin    = sin(degrad * degrees)
  xcenter = w/2 + x
  ycenter = h/2 + (y-h)
  radius  = w/2 + offset
  xc      = xcenter + (radius * xcos)
  yc      = ycenter + (radius * xsin)

;-- set resources for circle and plot
  lnres                     =  True
  lnres@gsLineColor         =  col
  lnres@gsLineThicknessF =  wsize
  gsn_polyline_ndc(wks,xc,yc,lnres)
end
;------------------------------------------------------------
;-- main program
;------------------------------------------------------------
begin
;-- read the data and define var

  diri = "./"
```

```
  fili = "rectilinear_grid_2D.nc"
  f    =  addfile(diri+fili, "r")
  u    =  f->tsurf(0,:,:)

;-- define the workstation (plot type and name)
  wks = gsn_open_wks("png" ,"plot_polar_settings")
  gsn_define_colormap(wks,"ncl_default")

  res                            =  True
  res@gsnDraw                    =  False           ;-- don't draw the plot
  res@gsnFrame                   =  False        ;-- don't advance the frame
  res@gsnPolar                   = "NH"          ;-- show Northern Hemisphere
  res@gsnPolarLabelSpacing       =  15              ;-- grid spacing
  res@gsnPolarLabelDistance      =  1.1             ;-- default is 1.04
  res@gsnPolarLabelFontHeightF =  0.015
  res@gsnPolarLabelFont          = "helvetica-bold"
  res@gsnSpreadColorStart        =  14              ;-- color index start
  res@gsnSpreadColorEnd          =  -8              ;-- color index end

  res@cnFillOn                   =  True

  res@tiMainString               = "NCL Doc Example: Polar Plot (NH)"

;-- draw the plot
  plot = gsn_csm_contour_map_polar(wks,u,res);-- from contributed.ncl lib
  draw(plot)                                       ;-- draw plot

;-- draw a circle around the map of plot: wsize=10, col="black", offset=0
;-- use function polar_map_circle from above
  polar_map_circle(wks, plot, 7, "black", 0)

;-- advance the frame
  frame(wks)

end
```



8.3.7 Map Resolutions

Maps can be drawn by NCL using one of the three different map resolution databases. The “LowRes“ and “MediumRes“ databases come with the NCL distribution, and the “HighRes” database has to be installed separately (a very simple installation). At DKRZ the high resolution database is already installed.

http://www.ncl.ucar.edu/Document/Graphics/rangs.shtml

Low resolution: `res@mpDataBaseVersion = "LowRes"    ;-- the default`

Medium resolution: `res@mpDataBaseVersion = "MediumRes"`

Using the HighRes database differs from the other settings, because you can specify a resolution, too.

High resolution:

```
res@mpDataBaseVersion = "HighRes"
res@mpDataResolution  = "<resolution>"
```

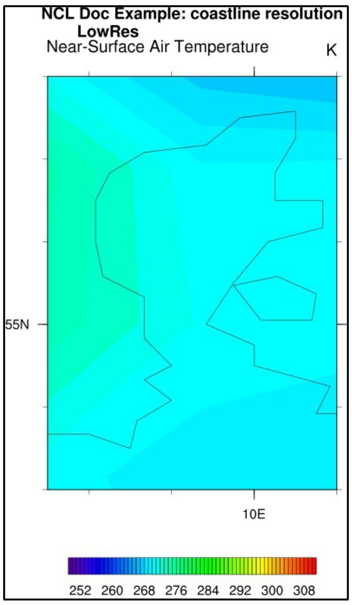
resolution =

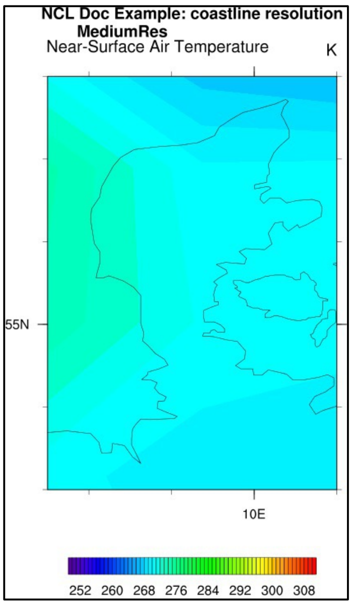
```
Unspecified          (default)
Coarsest
Coarse
Medium
Fine
Finest
```

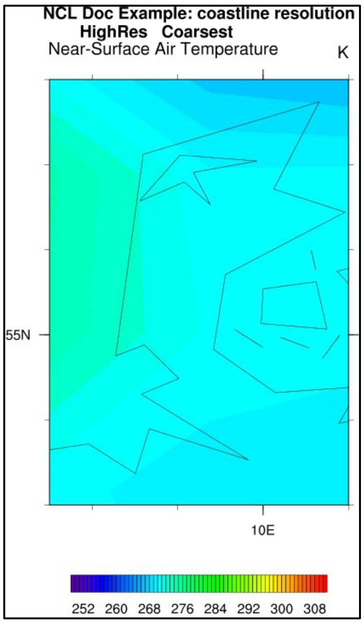
If “Unspecified” (default), the resolution is automatically set depending on the scale and size of the chosen region. A coarse resolution would be chosen for a map with a smaller scale, and a fine resolution for a map with a large scale. It is not recommended to use the "HighRes" database when plotting data over the whole globe, as it will take a long time and likely will not produce the correct plot.

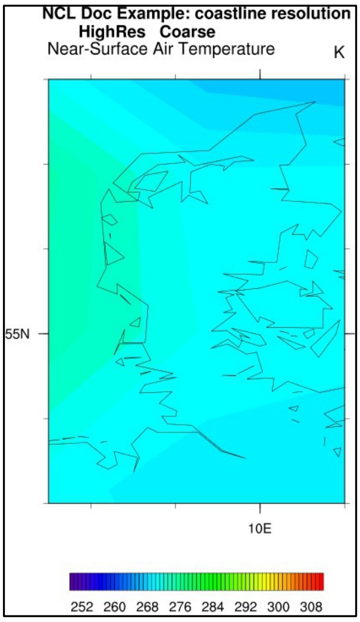
You can also turn off the NCL map outlines and draw your own map outlines read in from a shapefile. Shapefiles can be downloaded for free, and are provided in many different resolutions. See section 9.13.

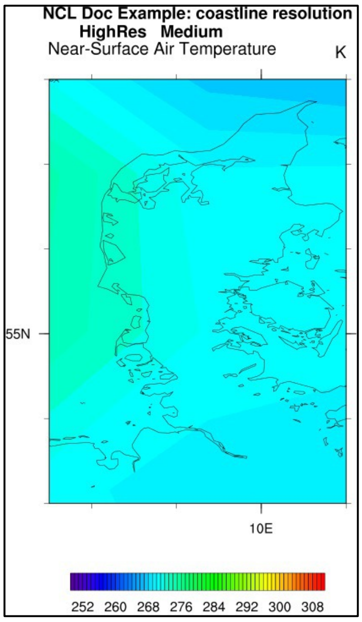
Map resolution example: NUG_map_resolutions.ncl

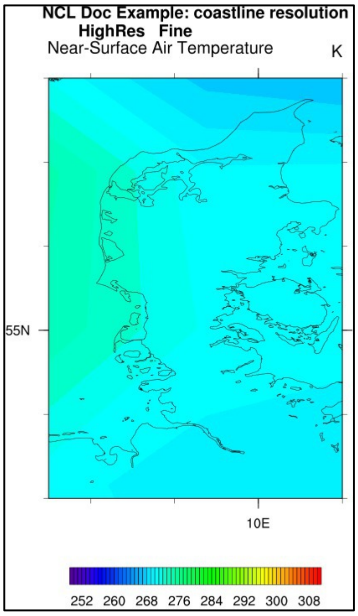


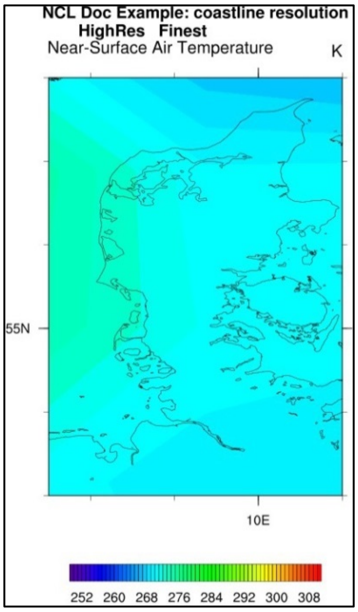



NCL Doc Example: coastline resolution
HighRes Coarsest
Near-Surface Air Temperature
K
55N
10E
252 260 268 276 284 292 300 308


NCL Doc Example: coastline resolution
HighRes Coarse
Near-Surface Air Temperature
K
55N
10E
252 260 268 276 284 292 300 308


NCL Doc Example: coastline resolution
HighRes Medium
Near-Surface Air Temperature
K
55N
10E
252 260 268 276 284 292 300 308


NCL Doc Example: coastline resolution
HighRes Fine
Near-Surface Air Temperature
K
55N
10E
252 260 268 276 284 292 300 308

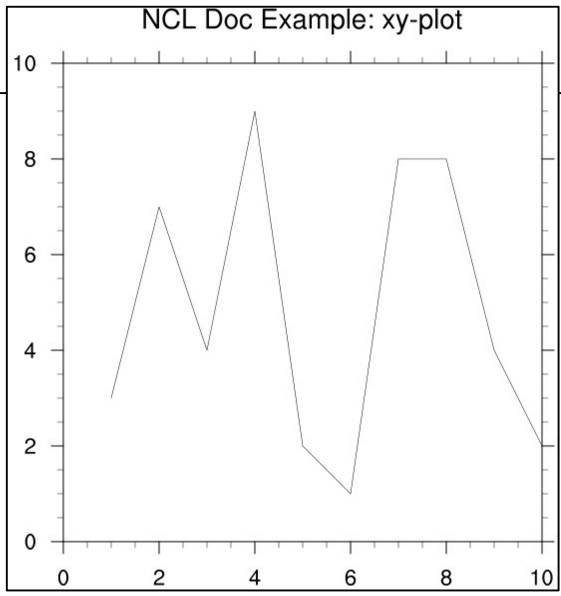

NCL Doc Example: coastline resolution
HighRes Finest
Near-Surface Air Temperature
K
55N
10E
252 260 268 276 284 292 300 308

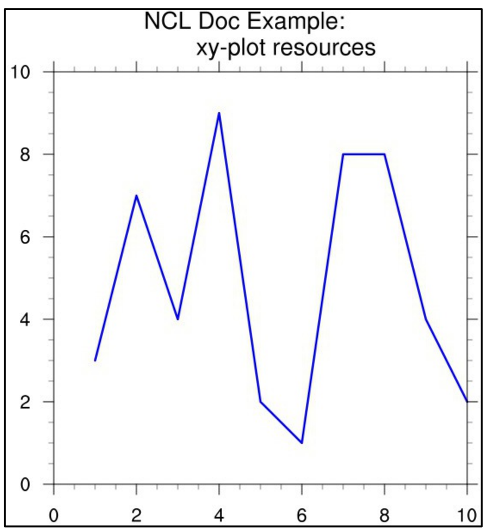
8.4 XY-Plots

An XY-plot is a plot containing curves made up of X/Y coordinate pairs. It also may contain tick marks, titles and/or a legend, and the look of the curves can be changed to different patterns or colors.

Simple xy-plot example: NUG_xy_plot.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin

   x = (/1,2,3,4,5,6,7,8,9,10/)
   y = (/3,7,4,9,2,1,8,8,4,2/)

   wks = gsn_open_wks("png","xy_plot")

   res                        =  True
   res@tiMainString           = "NCL Doc Example: xy-plot"

   plot = gsn_csm_xy(wks, x, y, res)

 end
```

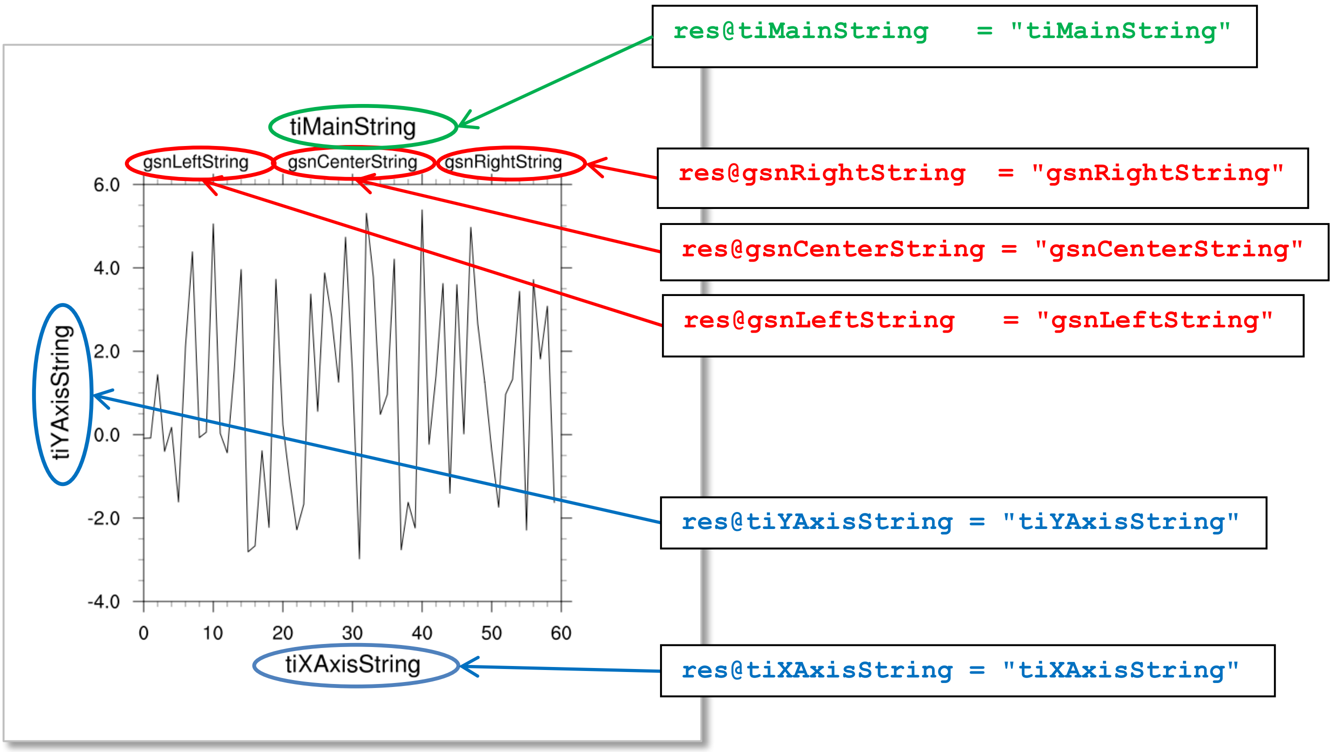




Insert the following lines below ‘res = True’ and see what happens:

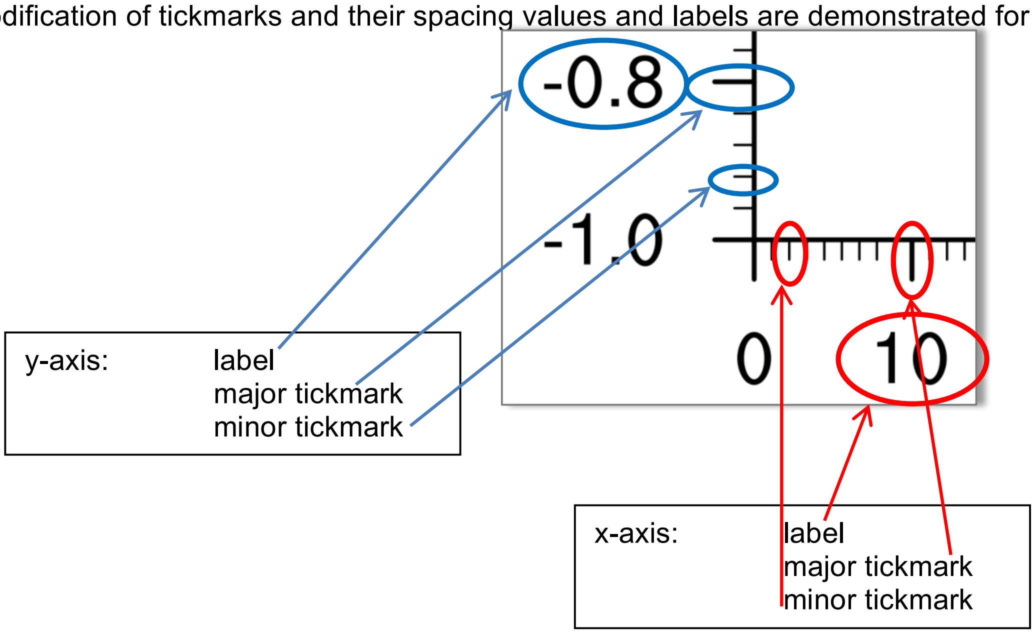
```
res@xyLineColor          =   "blue"
res@xyLineThicknessF     =   5
```

To change the x-axis and y-axis strings some resource settings can be changed. The @ti in the resource name indicates that the 'Title' resources are used. Some title strings are set by default by NCL but if you want to change them you are able to overwrite them. Good examples are the sub-title strings on top of the plot which are set to the long_name of the variable (gsnLeftString) and units of the variable (gsnRightString). The gsnCenterString in the middle has no default setting.

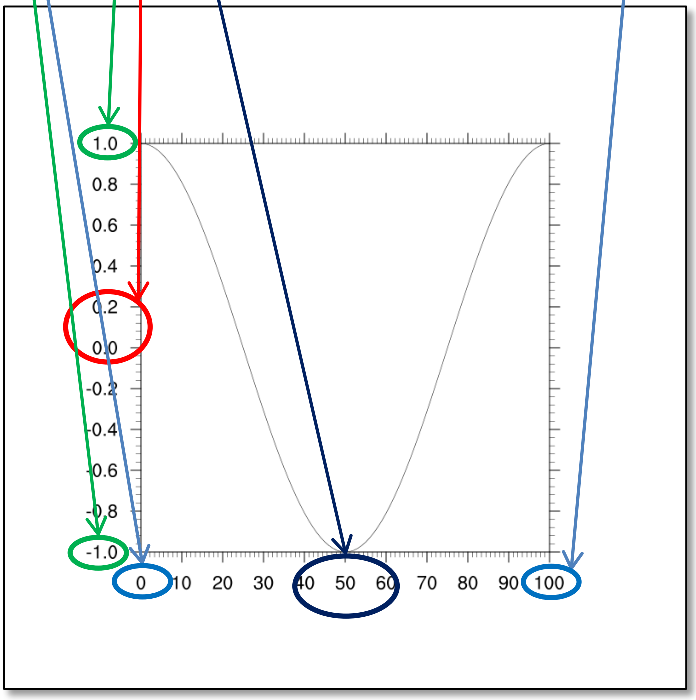


8.4.1 Tickmark Settings

NCL draws major and minor tickmarks on the x- and y-axis by default. In the next part the modification of tickmarks and their spacing values and labels are demonstrated for xy-plots.



```
;-- set minimum and maximum values of the axis
  res@trYMinF              =  -1.0         ;-- y-axis minimum value
  res@trYMaxF              =   1.0         ;-- y-axis maximum value
  res@trXMinF              =  min(x)       ;-- x-axis minimum value
  res@trXMaxF              =  max(x)       ;-- x-axis maximum value

;-- set y-axis major and minor tickmarks and tickmarks values
  res@tmYLMode             = "Manual"      ;-- set tickmarks resources manually
  res@tmYLTickSpacingF     =   0.2         ;-- label every 0.2th tickmark
  res@tmYLMinorPerMajor    =   4           ;-- draw 4 minor tickmarks between
                                           ;-- the labeled major tickmarks

;-- set x-axis major and minor tickmarks and tickmarks values
  res@tmXBMode             = "Manual"      ;-- set tickmarks resources manually
  res@tmXBTickSpacingF     =  10.0         ;-- label every 10th tickmark
  res@tmXBMinorPerMajor    =   8           ;-- draw 8 minor tickmarks between
                                           ;-- the labeled major tickmarks
```



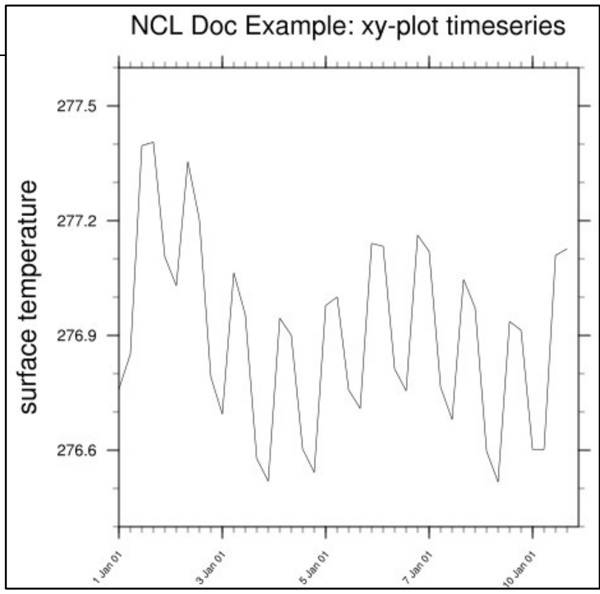
8.4.2 Time-series

A time-series plot is a little bit tricky because the time data type is commonly an integer or floating point value representing the values of "seconds since…" or "days since …" for instance. To convert these numeric values to a normal date format, NCL provides a bunch of "calendar" functions. See also section 7.2 and the special procedure "time_axis_labels".

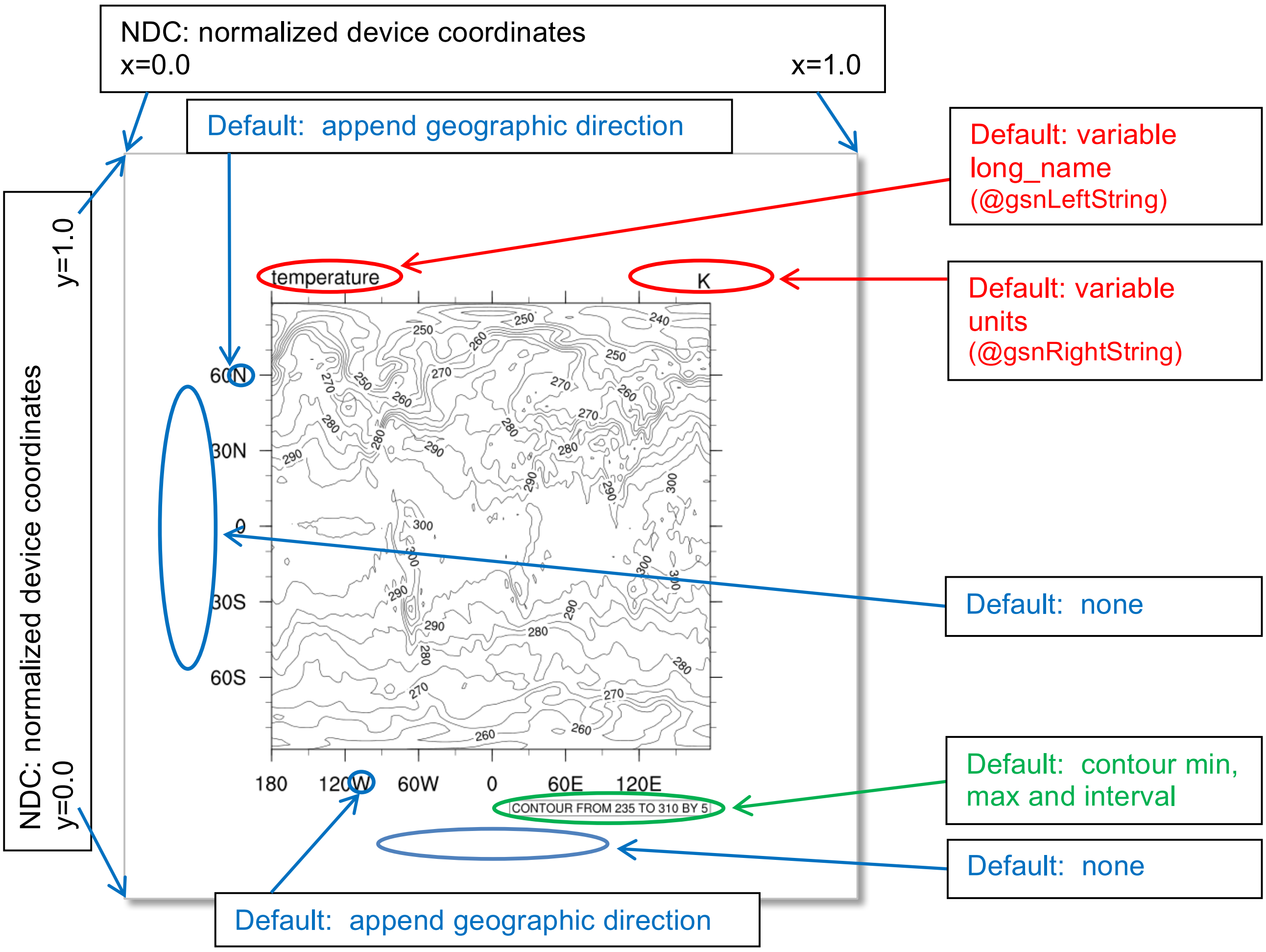
Simple contour example: NUG_xy_plot_timeseries.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/contrib/time_axis_labels.ncl"

begin
```

```
   diri = "./"
   fili = "rectilinear_grid_2D.nc"
   f    =  addfile(diri+fili, "r")
   var  = f->tsurf
   time = var&time

;-- compute the area mean without weighting
   fldmean = wgt_areaave_Wrap(var,1.0,1.0,1)

   wks = gsn_open_wks("png","xy_plot_timeseries")

;-- set resources
   res                       =  True
   res@tiMainString          = "NCL Doc Example: xy-plot timeseries"

   restime                   = True           ;-- set time tickmark resources
   restime@ttmFormat         = "%d %c %y"     ;-- time tickmark format

   time_axis_labels(time,res,restime) ; sets the correct time labels

   res@tmXBLabelFontHeightF =  0.01
   res@tmXBLabelJust         = "CenterRight"
   res@tmXBLabelDeltaF       =  1.0
   res@tmXBLabelAngleF       =  50.
   res@tmLabelAutoStride     =  True

   plot = gsn_csm_xy(wks, time, fldmean, res)

 end
```



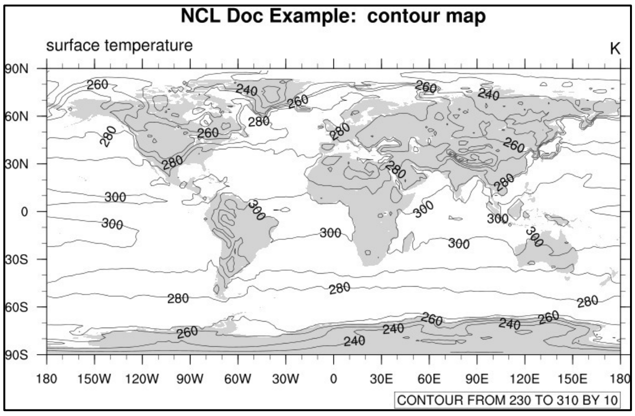
8.5 Contours



Simple contour example: NUG_contour_map.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;---- read the data and define variable reference var

  diri = "./"
  fili = "rectilinear_grid_2D.nc"

  f    =  addfile(diri+fili, "r")
  var  =  f->tsurf(0,:,:)

;---- define the workstation (plot output type and name)
  wks = gsn_open_wks("png","plot_contour_map")

;---- set resources
  res                        =  True
  res@gsnMaximize            =  True
  res@tiMainString        = "NCL Doc Example:  contour map"   ;-- title string
  res@tiMainFontHeightF      =  0.02

;---- draw the contour map
```

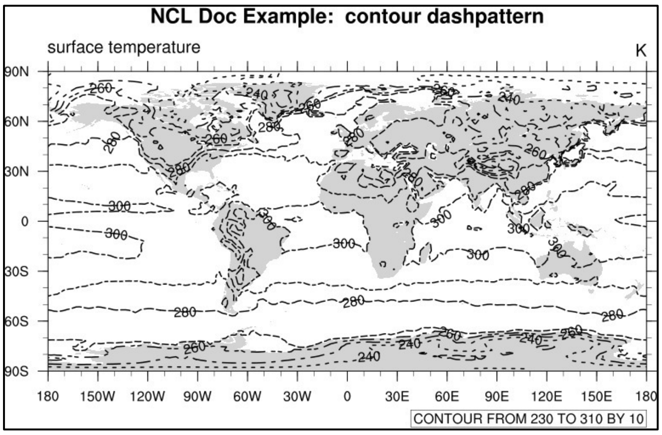
```
  plot = gsn_csm_contour_map(wks, var, res)

end
```



The default type of contours lines are solid black lines. To change to a different color or dash pattern, use the cn resources:

Insert
```
        res@cnLineDashPattern     =  1     ; use dash pattern 1
    or
        res@cnMonoLineDashPattern =  False ; use different dash pattern
                                                  for each contour
        res@cnLineColor           = "NavyBlue"
```

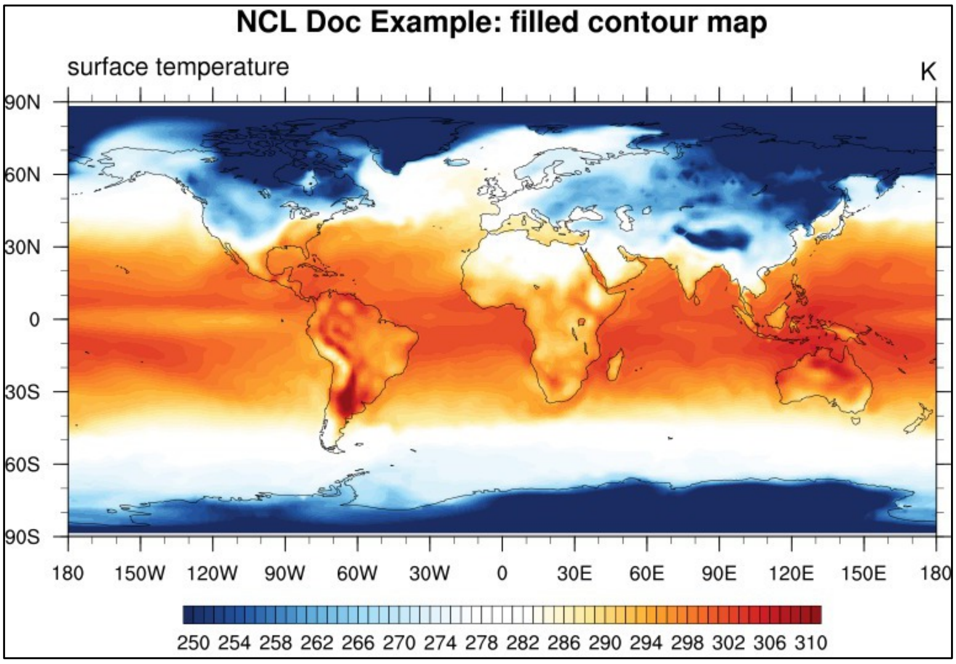
A table of all available dash Patterns can be found in the *Appendix C - Dash Pattern*.



8.5.1 Filled Contours

Simple filled contour example: NUG_contour_filled_map.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- read the data and define

  diri = "./"
  fili = "rectilinear_grid_2D.nc"
  f    =  addfile(diri+fili, "r")
  var  =  f->tsurf(0,:,:)

;-- define the workstation (plot type and name)
  wks = gsn_open_wks("png","plot_contour_filled_map")

;-- set resources
  res                         =  True
  res@gsnMaximize             =  True

  res@cnFillOn                =  True            ;-- turn on contour fill
  res@cnFillPalette           = "BlueWhiteOrangeRed" ;-- choose color map
  res@cnLinesOn               =  False           ;-- turn off contour lines
  res@cnLineLabelsOn          =  False           ;-- turn off line labels
  res@cnLevelSelectionMode    = "ManualLevels"   ;-- set contour levels manually
  res@cnMinLevelValF          =  250.            ;-- minimum contour level
  res@cnMaxLevelValF          =  310.            ;-- maximum contour level
  res@cnLevelSpacingF         =  4.              ;-- contour level spacing

  res@lbBoxMinorExtentF       =  0.15     ;-- decrease the height of the labelbar
  res@tiMainString     = "NCL Doc Example: filled contour map"   ;-- title string
  res@tiMainFontHeightF       =  0.02

;-- draw the contour map
  plot = gsn_csm_contour_map(wks, var, res)

end
```



By default, NCL will calculate an equally-spaced array of 10 to 16 “nice” contour levels based on the minimum and maximum of your data values. You can change the level spacing that NCL chooses by simply setting `res@cnLevelSpacingF` to the desired spacing. To further control the contour levels as the above example does, you can set:

```
res@cnLevelSelectionMode  = "ManualLevels"
res@cnMinLevelValF        =  250.            ;-- minimum contour level
res@cnMaxLevelValF        =  310.            ;-- maximum contour level
res@cnLevelSpacingF       =  1               ;-- contour level spacing
```

To set an array of unequally-spaced contour levels, set:

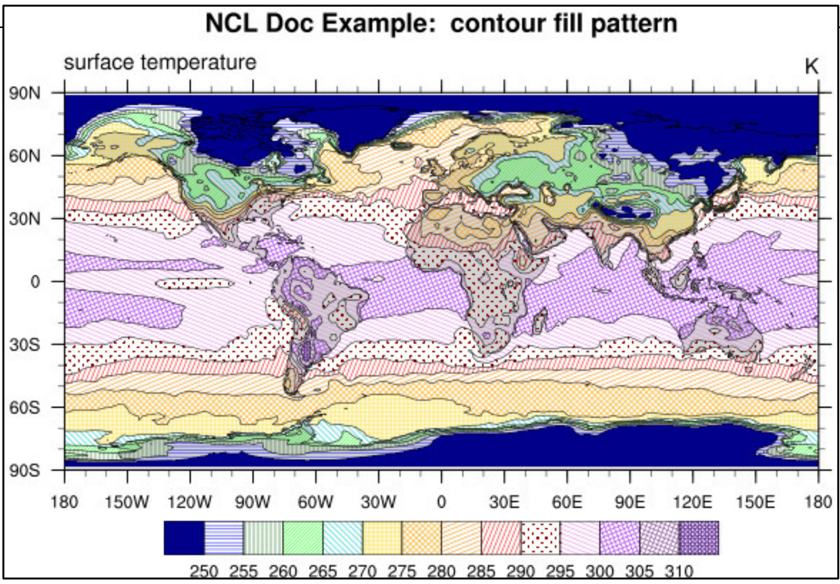
```
res@cnLevelSelectionMode  = "ExplicitLevels"
res@cnLevels              =  (/250,255,270,275,280,300,310/)
```

8.5.2 Filled and Dash Pattern Contour

A table of all available fill patterns can be found in the *Appendix D - Fill Pattern*.

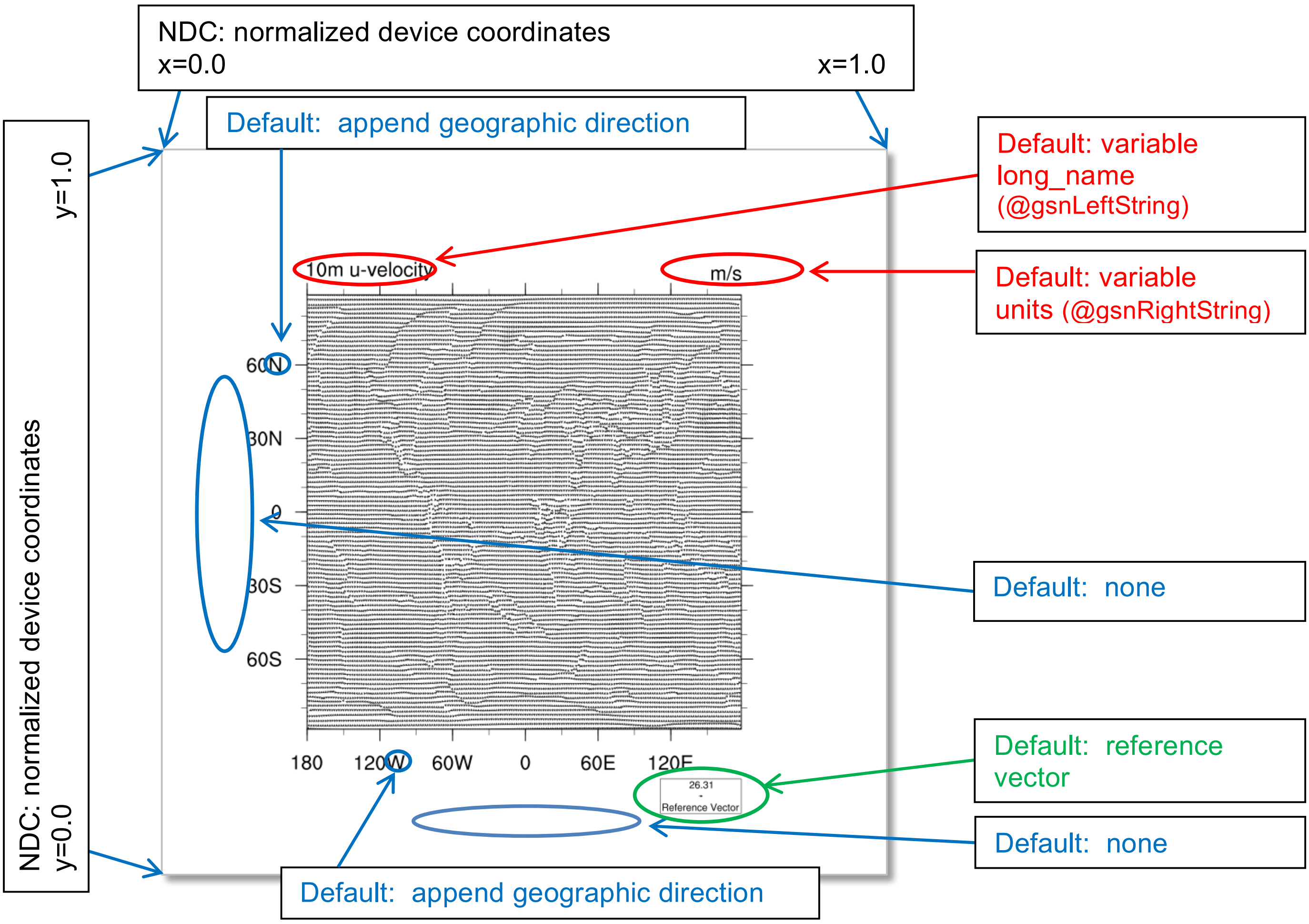
Simple fill pattern contour example: NUG_contour_fillpattern.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;---- read the data and define variable reference var
  diri = "./"
  fili = "rectilinear_grid_2D.nc"
  file1 =  addfile(diri+fili,"r")
  var   =  file1->tsurf(0,:,:)

;---- define the workstation (plot output type and name)
  wks = gsn_open_wks("png","plot_contour_fillpattern")

;---- set resources
  res                        =  True
  res@gsnMaximize            =  True
  res@tiMainString           = "NCL Doc Example:  contour fill pattern"
  res@tiMainFontHeightF      =  0.02

  res@cnLevelSelectionMode = "ManualLevels"
  res@cnMinLevelValF         =  250.
  res@cnMaxLevelValF         =  310.
  res@cnLevelSpacingF        =    5.
  res@cnMonoFillPattern      =  False
  res@cnMonoFillScale        =  False
  res@cnFillOn               =  True
  res@cnFillColors           = (/"blue4","blue","darkgreen","green","cyan3",\
                               "gold","orange","darkorange","red","red4",\
                               "violet","purple","mediumorchid4","purple4"/)
  res@cnFillPatterns         =  (/0,1,2,3,4,5,6,7,8,17,10,11,12,16/)
  res@cnFillDotSizeF         =  0.003
  res@cnFillScales           =  (/1.,.4,.5,.3,.5,.5,.5,.5,.5,1.,.5,.5,.5,.4/)

;---- draw the contour map
  plot = gsn_csm_contour_map(wks, var, res)

end
```



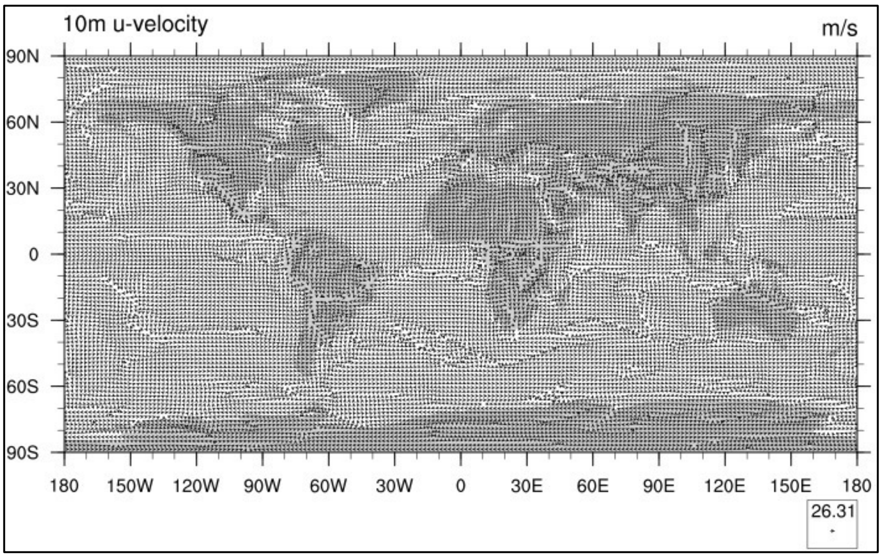
8.6 Vector Plots

Plotting vector data as arrows is as simple as was seen earlier for contour lines. NCL provides a function that does all the work for the user. The next example uses only the NCL default settings for vector plotting.



Vector field example: NUG_vector_default.ncl

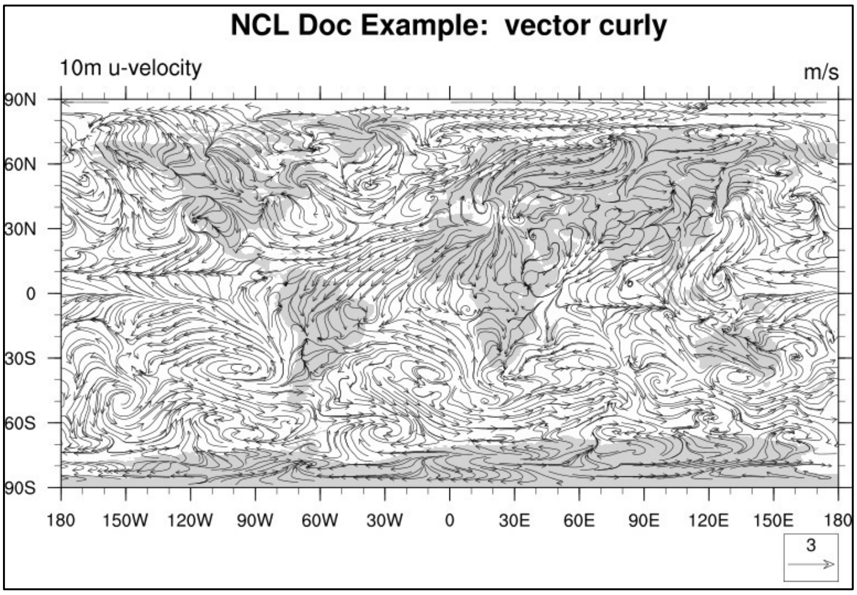
```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin

  diri = "./"
  fili = "rectilinear_grid_2D.nc"

  f    =  addfile(diri+fili, "r")
  u    =  f->u10(0,:,:)                    ;-- first time step
  v    =  f->v10(0,:,:)                    ;-- first time step

;-- define the workstation (graphic will be written to a file)

  wks =  gsn_open_wks("png","plot_vector_default")

;-- draw the vectors

  plot = gsn_csm_vector_map(wks,u,v,False)

end
```



A very nice way of displaying a vector field is *CurlyVector*, which plots short streamline segments with curved arrows instead of straight arrows. This example also sets some useful resources to control the length and density of the vectors.

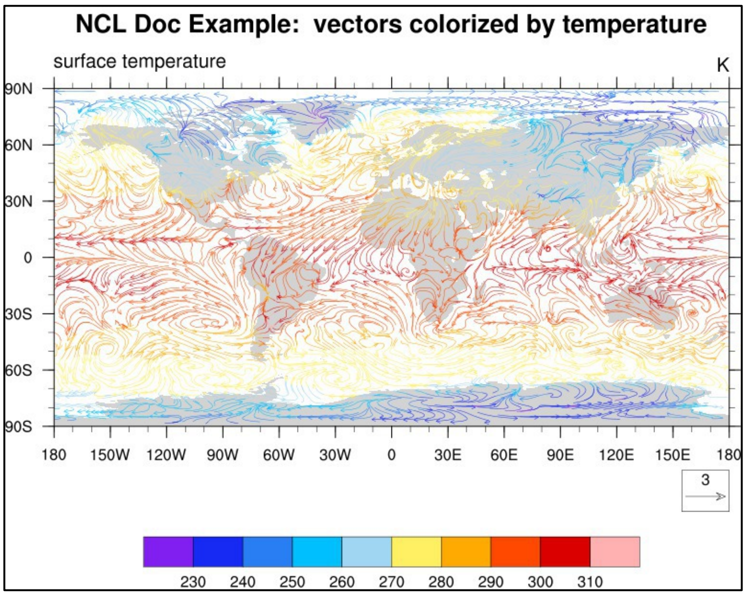
Vector field example: NUG_vector_curly.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri = "./"
  fili = "rectilinear_grid_2D.nc"
  f    =  addfile(diri+fili, "r")
  u    =  f->u10(0,:,:)                      ;-- first time step
  v    =  f->v10(0,:,:)                      ;-- first time step

;-- define the workstation (graphic will be written to a file)

  wks =  gsn_open_wks("png","plot_vector_curly")

;-- set plot resources

  vres =  True
  vres@gsnMaximize          =  True
  vres@tiMainString         = "NCL Doc Example:  vector curly"
  vres@vcMinFracLengthF     =  1.0  ;-- length of min vector as
                                    ;-- fraction of reference vector
  vres@vcRefMagnitudeF      =  3.0     ;-- make vectors larger
  vres@vcRefLengthF         =  0.045   ;-- ref vec length
  vres@vcGlyphStyle         = "CurlyVector" ;-- turn on curly vectors
  vres@vcMinDistanceF       =  0.01    ;-- thin out vectors

;-- draw the vectors

  plot = gsn_csm_vector_map(wks,u,v,vres)

end
```



Vector field colorized by surface temperature: NUG_vector_plot_colorized.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri  = "./"
  fili  = "rectilinear_grid_2D.nc"
  uname = "u10"
  vname = "v10"
  tname = "tsurf"

;-- read the data
  f   =  addfile(diri+fili,"r")          ;-- open file with read
access
  u   =  f->$uname$(0,:,:)               ;-- first time step
  v   =  f->$vname$(0,:,:)               ;-- first time step
  t   =  f->$tname$(0,:,:)               ;-- first time step

;-- define the workstation (graphic will be written to a file)
  wks =  gsn_open_wks("png","plot_vector_colorized")

;-- set plot resources
  res                     = True
  res@gsnMaximize         =  True       ;-- maxmize plot in frame
  res@vcMinFracLengthF =  1.0        ;-- length of min vector as
                                     ;-- fraction of reference vector
  res@vcRefMagnitudeF  =  3.0        ;-- make vectors larger
  res@vcRefLengthF     =  0.045      ;-- ref vec length
  res@vcGlyphStyle     = "CurlyVector"  ;-- turn on curly vectors
  res@vcMinDistanceF   =  0.01       ;-- thin out vectors
  res@vcLevelPalette   = "ncl_default"  ;-- choose color map

  res@tiMainString =\
       "NCL Doc Example: vectors colorized by temperature" ;-- title

;-- draw the vectors
  plot = gsn_csm_vector_scalar_map(wks,u,v,t,res)

end
```

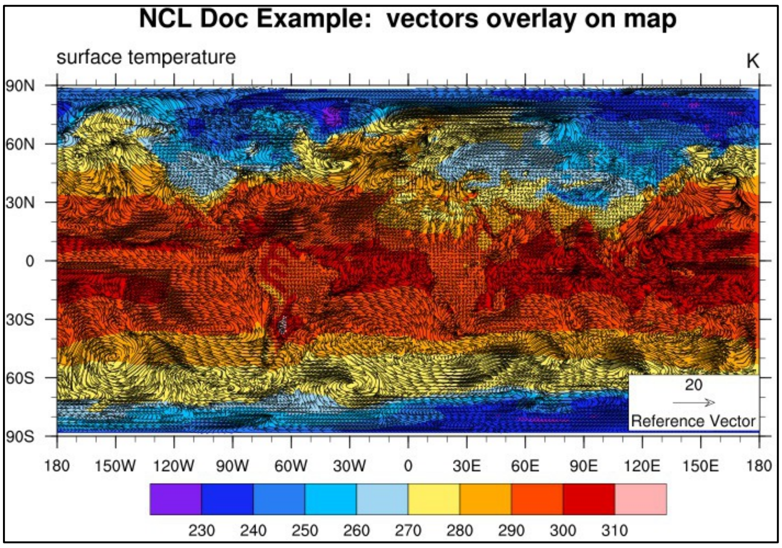


This example uses the “overlay” procedure to overlay vectors on a contour/map plot. See Section 9.10 for more information about overlays.

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri  = "./"
  fili  = "rectilinear_grid_2D.nc"
  uname = "u10"
  vname = "v10"
  tname = "tsurf"

;-- read the data
   f    =  addfile(diri+fili,"r")            ;-- open file with read access
   u    =  f->u10(0,:,:)                      ;-- first time step
   v    =  f->v10(0,:,:)                      ;-- first time step
   t    =  f->tsurf(0,:,:)                    ;-- first time step

;-- define the workstation (graphic will be written to a file)
   wks =  gsn_open_wks("png","plot_vector_overlay")

;-- set plot resources
   cnres                       = True
   cnres@gsnDraw               = False        ;-- don't draw
   cnres@gsnFrame              = False        ;-- don't advance frame
   cnres@cnFillOn              = True         ;-- turn on color
   cnres@cnLinesOn             = False        ;-- no contour lines
   cnres@ncFillPalette         = "ncl_default"   ;-- chosose color map
   cnres@mpFillOn              = False        ;-- no map fill
   cnres@gsnLeftString         = "surface temperature" ; change left string
   cnres@gsnRightString        = t@units      ;-- assign right string
   cnres@tiMainString          = "NCL Doc Example:  vectors overlay on map"

   vcres                       = True         ;-- vector only resources
   vcres@gsnDraw               = False        ;-- don't draw
   vcres@gsnFrame              = False        ;-- don't advance frame
   vcres@vcGlyphStyle          = "CurlyVector" ;-- curly vectors
   vcres@vcRefMagnitudeF       = 20           ;-- define vector ref mag
   vcres@vcRefLengthF          = 0.045        ;-- define length of vec ref
   vcres@vcRefAnnoOrthogonalPosF = -.535      ;-- move ref vector into plot
   vcres@gsnRightString        = " "          ;-- turn off right string
```

```
   vcres@gsnLeftString        = " "          ;-- turn off left string
   vcres@tiXAxisString        = " "          ;-- turn off axis label

   cplot  = gsn_csm_contour_map(wks,t,cnres)
   vplot  = gsn_csm_vector(wks,u,v,vcres)
   overlay(cplot,vplot)

   draw(cplot)
   frame(wks)
end
```

Vector field on filled contour map example: NUG_vector_plot_overlay.ncl

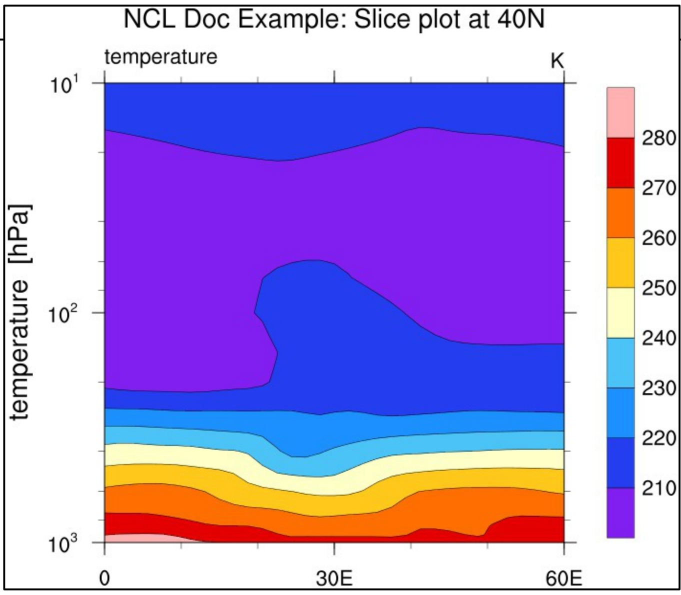


8.7 Slice Plots

3-dimensional structures in the data can be examined by means of 2D visualization methods if different slices through the data are jointly analyzed. The example here shows a vertical slice through a 3D data volume at latitude 40N, longitudes ranging from 0 to 60E across all levels in hPa units.

Slice plot example: NUG_slice_plot.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri  = "./"
  fili  = "rectilinear_grid_3D.nc"
  f     =  addfile(diri+fili, "r")
  var   = f->t(0,:,{40},{0:60}) ;-- first time step,latitude=40N,longitude=0-60E.
  lon_t = f->lon({0:60})        ;-- longitude=0-60E
  lev_t = f->lev                ;-- currently 17 levels

;-- define workstation
  wks = gsn_open_wks("png","plot_slices")

;-- set resources
  res                          =  True
  res@tiMainString        = "NCL Doc Example: Slice plot at 40N"   ;-- title string

  res@cnFillOn                 =  True       ;-- turn on color fill
  res@cnLineLabelsOn           =  False      ;-- turns off contour line labels
  res@cnInfoLabelOn            =  False      ;-- turns off contour info label
  res@cnFillPalette            = "ncl_default"  ;-- choose color map

  res@lbOrientation            = "vertical"  ;-- vertical label bar
  res@tiYAxisString            =  var@long_name+"  [hPa]"

  res@sfXArray                 =  lon_t      ;-- uses lon_t as plot x-axis
  res@sfYArray                 =  lev_t/100  ;-- uses lev_t in hPa as plot y-axis

  res@trYReverse               =  True       ;-- reverses y-axis
  res@gsnYAxisIrregular2Log  =  True  ;-- converts y-axis irregular to linear depth

;-- generate the plot
  plot = gsn_csm_contour(wks,var,res)

end
```

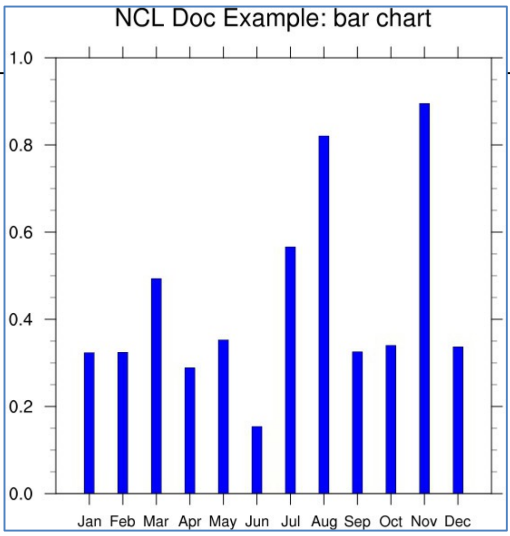


8.8 Bar Charts

Bar chart plots are more or less simple XY-plots with bars for the xy-points. Graphically, there is only a small difference between histograms and bar charts, but histograms are for binning data and have their own resources, which are described in the last example of the bar chart section.

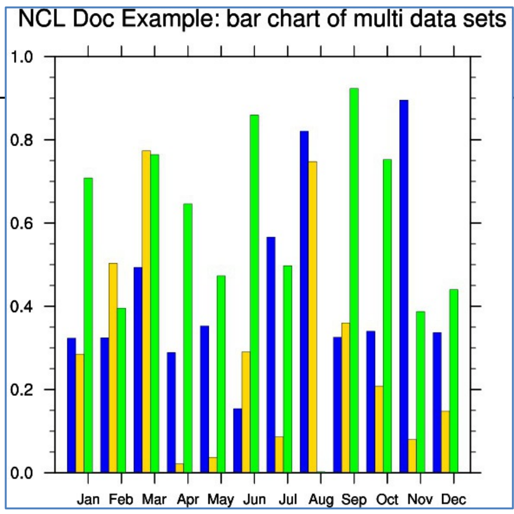
Bar chart example: NUG_bar_chart.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin

   low  =  0.0
   high =  1.0

   n = 12

   x = fspan(1.0, 12.0, n)
   y = random_uniform(low, high, n)

   wks = gsn_open_wks("png","plot_bar_chart")

   res                          =  True
   res@gsnXYBarChart            =  True
   res@gsnXYBarChartBarWidth =  0.3
   res@gsnXYBarChartColors      = "blue"

   res@trXMinF                  =  0.0              ;-- x-axis min value
   res@trXMaxF                  = 13.0              ;-- x-axis max value
   res@trYMinF                  =  0.0              ;-- y-axis min value
   res@trYMaxF                  =  1.0              ;-- y-axis max value

   res@tmXBMode                 = "Explicit"        ;-- explicit labels
   res@tmXBValues               =  ispan(1,12,1)
   res@tmXBLabels               =
(/"Jan","Feb","Mar","Apr","May","Jun","Jul","Aug","Sep", \
                                  "Oct","Nov","Dec"/)
   res@tmXBLabelFontHeightF   =  0.015

   res@tiMainString             = "NCL Doc Example: bar chart"

   plot = gsn_csm_xy(wks, x, y, res)

end
```



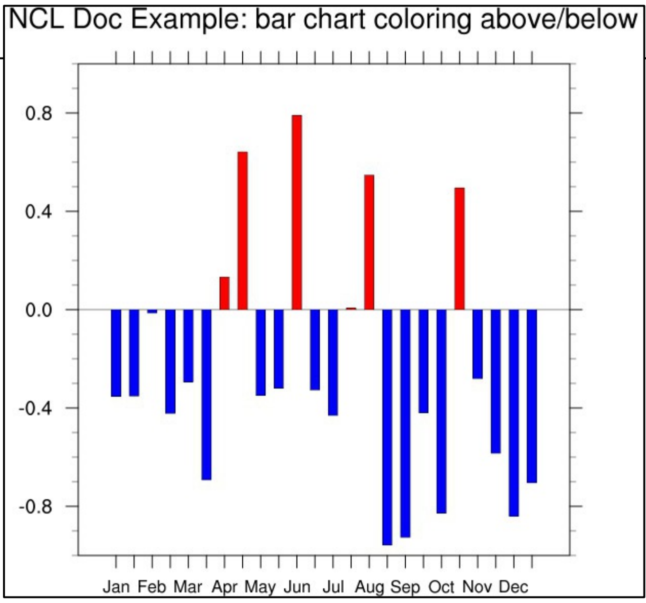
Bar chart example displaying 3 different data sets - a method which can be used to visualize 3 different realizations of an ensemble simulation: NUG_bar_chart_multi.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   low  =  0.0
   high =  1.0
   n    = 12

   x  = fspan(0.5,  11.5,  n)
   y1 = random_uniform(low, high, n)
   y2 = random_uniform(low, high, n)
   y3 = random_uniform(low, high, n)

   wks = gsn_open_wks("png","plot_bar_chart_multi")

   res                          =  True
   res@gsnDraw                  =  True
   res@gsnFrame                 =  False
   res@gsnXYBarChart            =  True
   res@gsnXYBarChartBarWidth =  0.25

   res@trXMinF                  =  0.0              ;-- x-axis min value
   res@trXMaxF                  = 12.5              ;-- x-axis max value
   res@trYMinF                  =  0.0              ;-- y-axis min value
   res@trYMaxF                  =  1.0              ;-- y-axis max value

   res@tmXBMode                 = "Explicit"        ;-- explicit labels
   res@tmXBValues               =  ispan(1,12,1)- 0.25 ;-- center labels
   res@tmXBLabels               = (/"Jan","Feb","Mar","Apr","May", "Jun", \
                                    "Jul","Aug","Sep",
                                    "Oct","Nov","Dec"/)
   res@tmXBLabelFontHeightF  =  0.015
   res@tiMainString     = "NCL Doc Example: bar chart of multi data sets"

   res@gsnXYBarChartColors    = "blue"
   plots1 = gsn_csm_xy(wks, x, y1, res)

   res@gsnXYBarChartColors    = "gold"
   plots2 = gsn_csm_xy(wks, x+0.25, y2, res)

   res@gsnXYBarChartColors    = "green"
   plots3 = gsn_csm_xy(wks, x+0.5, y3, res)

   frame(wks)
end
```



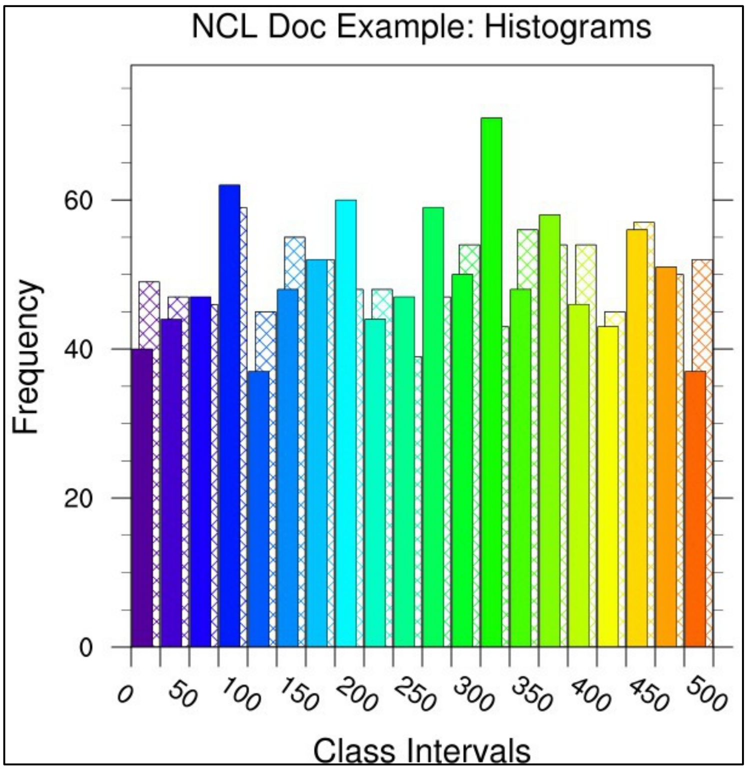
Bar chart example displaying values above or below a reference value with different colors: NUG_bar_chart_col_above_below.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   low  = -1.0
   high =  1.0
   n    = 24

   x = fspan(1.0,  12.0,  n)
   y = random_uniform(low, high, n)

   wks = gsn_open_wks("png","plot_bar_chart_col_above_below")

   res                         =  True
   res@gsnDraw                 =  True
   res@gsnFrame                =  False
   res@gsnXYBarChart           =  True
   res@gsnXYBarChartBarWidth   =  0.25

   res@trXMinF                 =  0.0              ;-- x-axis min value
   res@trXMaxF                 = 13.0              ;-- x-axis max value
   res@trYMinF                 = -1.0              ;-- y-axis min value
   res@trYMaxF                 =  1.0              ;-- y-axis max value

   res@tmXBMode                = "Explicit"        ;-- explicit labels
   res@tmXBValues              =  fspan(1,12,n)
   res@tmXBLabels              =  (/"Jan","","Feb","","Mar","","Apr","",\
                                    "May","","Jun","","Jul","","Aug","",\
                                    "Sep","","Oct","","Nov","","Dec",""/)
   res@tmXBLabelFontHeightF    =  0.015
   res@tiMainString   = "NCL Doc Example: bar chart coloring above/below"

   res@gsnYRefLine             =  0.             ; reference line
   res@gsnXYBarChart           =  True           ; create bar chart
   res@gsnAboveYRefLineColor = "red"             ; above ref line fill red
   res@gsnBelowYRefLineColor = "blue"            ; below ref line fill blue

   plot = gsn_csm_xy(wks, x, y, res)

   frame(wks)
end
```



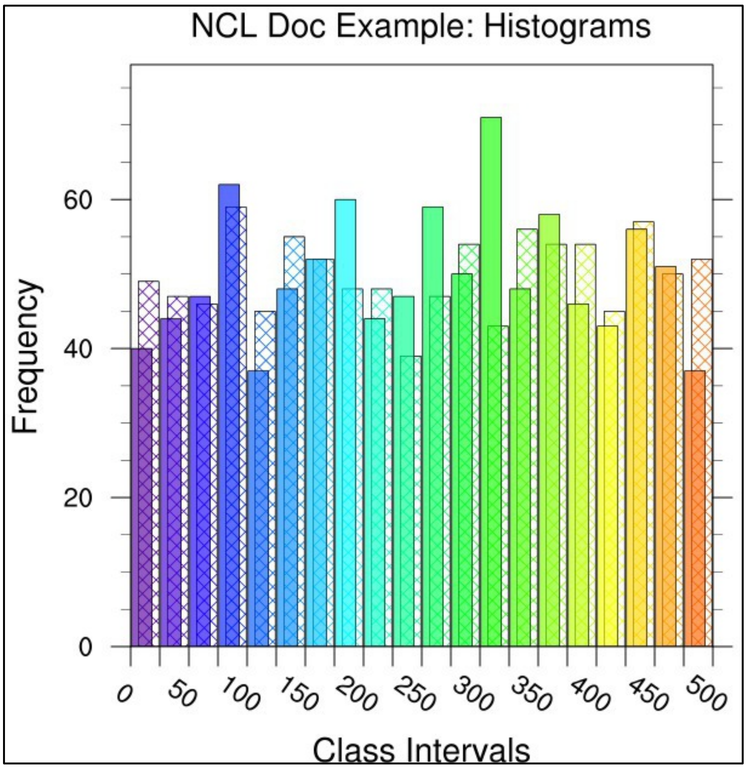
Histogram example : NUG_histograms.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin

;-- generate a 2D data set (gsn_histogram will go into compare mode)
  data = new((/2,1000/),float)
  data(0,:) = random_uniform(0,500.,1000)
  data(1,:) = random_uniform(0,500.,1000)

  xint = ispan(0,500,25)

;-- open workstation
  wks = gsn_open_wks("png","plot_histograms")       ;-- open workstation
  gsn_define_colormap(wks,"rainbow")                ;-- choose color map

  res                                    =  True
  res@gsnHistogramBarWidthPercent        =  70.
  res@gsnHistogramClassIntervals         =  xint
  res@tmXBLabelAngleF                    =  325.    ;-- change label angle
  res@tmLabelAutoStride                  =  True    ;-- prevent label overlap

  res@tiMainString                       = "NCL Doc Example: Histograms"

  plot = gsn_histogram(wks,data,res)                ;-- create histogram

end
```



To change the filled histogram bars to a more transparent mode, the gsFillOpacityF resource can be used:

```
res@gsFillOpacityF       =  0.4
```



8.9 Overlay Plots

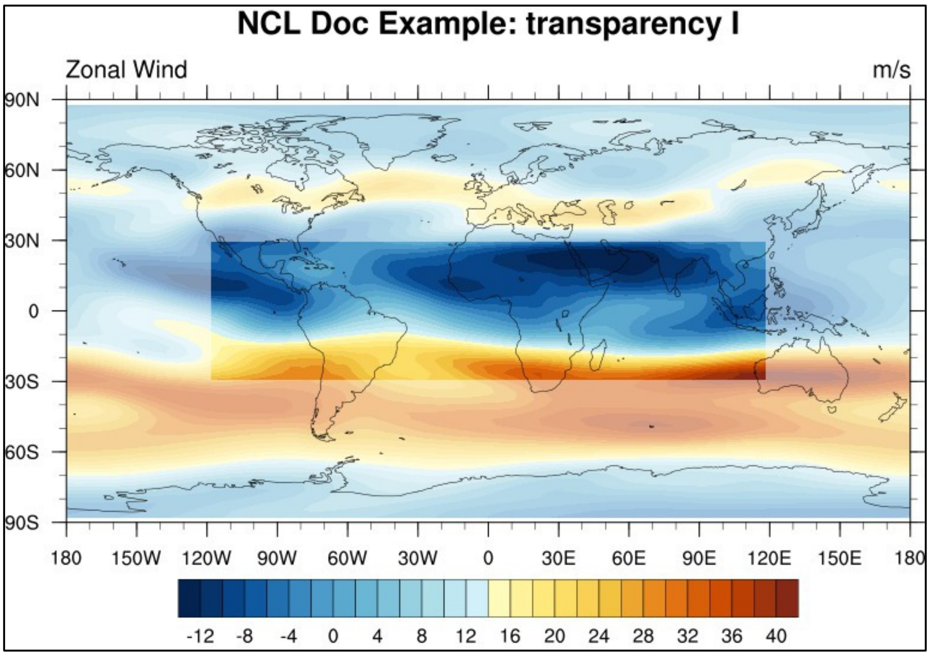
One great feature of NCL is its support for overlaying graphical elements on top of other elements. Take a look at the NUG_vector_plot_colorized.ncl example in section 8.6, where a filled contour plot is overlaid by a vector plot. The powerful “overlay” procedure overlays one plot on a base plot, such that the base plot now contains both plots. NCL examines the data space of both plots to correctly transform the overlay plot to the base plot. If both plots you want to overlay are maps, then only the base plot can be a map, and the overlay plot must just be a contour, vector, or other type of plot.

Furthermore, NCL supports transparency in combination with overlays. This is, as an example, quite useful for highlighting a region of interest while the area outside of this region is still visible. The transparency/opaque example script shows how to emphasize a region of interest:
NUG_transparent_filled_contour.ncl

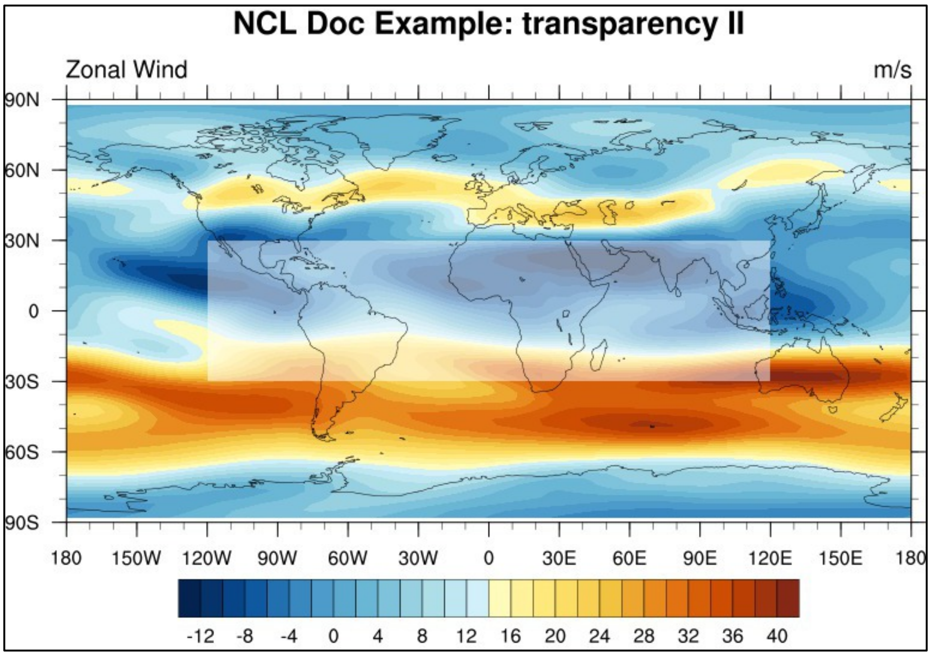
```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- read data
  diri = "./"
  fili = "uv300.nc"

  a    = addfile(diri+fili,"r")
  u    = a->U(1,:,:)

;-- open a workstation
  wks  = gsn_open_wks("png","plot_transparency")

;-- set resources
  res                          =  True
  res@gsnFrame                 =  False
  res@gsnDraw                  =  False
  res@cnFillOn                 =  True
  res@cnFillPalette            = "BlueYellowRed"
  res@cnLinesOn                =  False
  res@cnLineLabelsOn           =  False
  res@cnInfoLabelOn            =  False
  res@cnLevelSelectionMode     = "ExplicitLevels"
  res@cnLevels                 =  ispan(-12,40,2)

;-- set resources only for main plot displaying the contours
  bres                         =  res
  bres@gsnMaximize             =  True        ;-- maximize main plot
  bres@mpFillOn                =  False
  bres@tiMainString            = "NCL Doc Example: transparency I"
  bres@cnFillOpacityF          =  0.5         ;-- 50% opaque

  main_plot = gsn_csm_contour_map(wks,u,bres)

;-- set resources for the overlayed plot
  ores                         =  res
  ores@cnFillOpacityF          =  1.0         ;-- 100% opaque
  ores@gsnRightString          = ""
  ores@gsnLeftString           = ""
  ores@lbLabelBarOn            =  False

  overlay_plot = gsn_csm_contour(wks,u({-30:30},{-120:120}),ores)
```

```
  overlay(main_plot,overlay_plot)

  draw(main_plot)
  frame(wks)

;-- create a new plot with 100% opacity
  bres@tiMainString          = "NCL Doc Example: transparency II"
  bres@cnFillOpacityF        =  1.0        ;-- 100% opaque
  plot = gsn_csm_contour_map(wks,u,bres)

;---Set resources for a partially transparent polygon.
  gnres                      =  True
  gnres@gsFillOpacityF       =  0.5        ;-- 50% opaque
  gnres@gsFillColor          = "white"

  lat_box = (/ -30,-30, 30,  30, -30/)
  lon_box = (/-120,120,120,-120,-120/)

  gsid = gsn_add_polygon(wks,plot,lon_box,lat_box,gnres)

;-- draw the second plot to a new page
  draw(plot)
  frame(wks)
end
```

The first image shows a more 'highlighted' section:



The second image of this example, a semi transparent white rectangle is displayed on top of the opaque contours plot.



Another good application of the overlay technique is drawing multiple time series on one plot to compare different model data or variables. The lines of the data/variable are plotted with different colors, dash pattern, and a user-defined legend which will be replaced inside the plot frame.

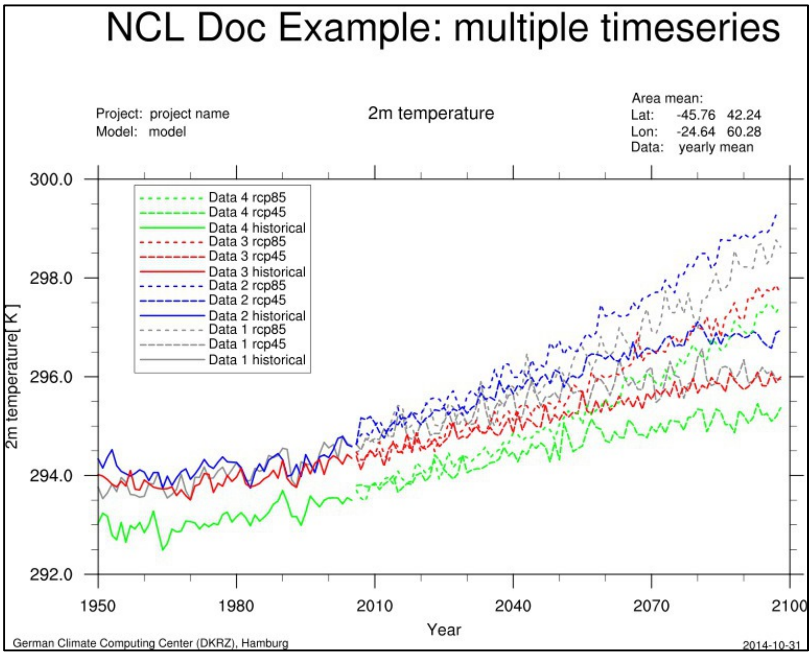
This example is saved in NUG_multi_timeseries.ncl.

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/shea_util.ncl"

begin
  diri   = "./"
  fil1   = "tas_mod1_hist_rectilin_grid_2D.nc"
  fil2   = "tas_mod1_rcp45_rectilin_grid_2D.nc"
  fil3   = "tas_mod1_rcp85_rectilin_grid_2D.nc"
  fil4   = "tas_mod2_hist_rectilin_grid_2D.nc"
  fil5   = "tas_mod2_rcp45_rectilin_grid_2D.nc"
  fil6   = "tas_mod2_rcp85_rectilin_grid_2D.nc"
  fil7   = "tas_mod3_hist_rectilin_grid_2D.nc"
  fil8   = "tas_mod3_rcp45_rectilin_grid_2D.nc"
  fil9   = "tas_mod3_rcp85_rectilin_grid_2D.nc"
  fil10  = "tas_mod4_hist_rectilin_grid_2D.nc"
  fil11  = "tas_mod4_rcp45_rectilin_grid_2D.nc"
  fil12  = "tas_mod4_rcp85_rectilin_grid_2D.nc"

  f1     = addfile(diri+fil1,   "r")
  f2     = addfile(diri+fil2,   "r")
  f3     = addfile(diri+fil3,   "r")
  f4     = addfile(diri+fil4,   "r")
  f5     = addfile(diri+fil5,   "r")
  f6     = addfile(diri+fil6,   "r")
```

```
  f7    = addfile(diri+fil7,  "r")
  f8    = addfile(diri+fil8,  "r")
  f9    = addfile(diri+fil9,  "r")
  f10   = addfile(diri+fil10, "r")
  f11   = addfile(diri+fil11, "r")
  f12   = addfile(diri+fil12, "r")
;-----------------------------------------------------
  temp1           =  f1->tas(:,0,0,0)
  temp1@long_name = "2m temperature"
  temp2           =  f2->tas(:,0,0,0)
  temp2@long_name = "2m temperature"
  temp3           =  f3->tas(:,0,0,0)
  temp3@long_name = "2m temperature"
;-----------------------------------------------------
  temp4           =  f4->tas(:,0,0,0)
  temp4@long_name = "2m temperature"
  temp5           =  f5->tas(:,0,0,0)
  temp5@long_name = "2m temperature"
  temp6           =  f6->tas(:,0,0,0)
  temp6@long_name = "2m temperature"
;-----------------------------------------------------
  temp7           =  f7->tas(:,0,0,0)
  temp7@long_name = "2m temperature"
  temp8           =  f8->tas(:,0,0,0)
  temp8@long_name = "2m temperature"
  temp9           =  f9->tas(:,0,0,0)
  temp9@long_name = "2m temperature"
;-----------------------------------------------------
  temp10           =  f10->tas(:,0,0,0)
  temp10@long_name = "2m temperature"
  temp11           =  f11->tas(:,0,0,0)
  temp11@long_name = "2m temperature"
  temp12           =  f12->tas(:,0,0,0)
  temp12@long_name = "2m temperature"
;-----------------------------------------------------
  time = ispan(1950,2098,1)
  time@long_name = "Time"
;------------------------------------------------------
; to plot multiple lines, you must put them into a
; mulidimensional array
;------------------------------------------------------
  data            = new((/12,149/),float)

  data(0,0:55)    = temp1
  data(1,56:148)  = temp2
  data(2,56:148)  = temp3

  data(3,0:55)    = temp4
  data(4,56:148)  = temp5
  data(5,56:148)  = temp6

  data(6,0:55)    = temp7
  data(7,56:148)  = temp8
  data(8,56:148)  = temp9

  data(9,0:55)    = temp10
  data(10,56:148) = temp11
  data(11,56:148) = temp12

;-- open a workstation
  wks =  gsn_open_wks("png", "plot_multi_timeseries")
```

```
;-- set resources
  res = True
  res@xyExplicitLegendLabels = (/" Data 1 historical",\
                                " Data 1 rcp45"," Data 1 rcp85", \
                                " Data 2 historical",\
                                " Data 2 rcp45", " Data 2 rcp85", \
                                " Data 3 historical",\
                                " Data 3 rcp45", " Data 3 rcp85",\
                                " Data 4 historical",\
                                " Data 4 rcp45",  " Data 4 rcp85"/)
  res@xyLineColors           =  (/ "gray55", "gray55", "gray55", \
                                  "blue", "blue", "blue", \
                                  "red", "red", "red", "green", \
                                  "green", "green"/)
  res@xyDashPatterns       =  (/0, 5, 2, 0, 5, 2, 0, 5, 2, 0, 5, 2/)
  res@xyLineThicknessF       =  3
  res@tiYAxisString          =  temp1@long_name+"[ K ]"
  res@tiYAxisFont            =  21
  res@tiYAxisFontAspectF     =  1.3
  res@tiYAxisFontHeightF     =  0.012
  res@tiXAxisString          = "Year"
  res@tiXAxisFont            =  21
  res@tiXAxisFontAspectF     =  1.3
  res@tiXAxisFontHeightF     =  0.012
  res@tiXAxisOffsetYF        =  0.0
  res@tiMainOffsetYF         =  0.11
  res@tiMainString         = "NCL Doc Example: multiple timeseries"
  res@tmXBLabelFontAspectF   =  1.3
  res@tmXBLabelFontHeightF   =  0.012
  res@trYMinF                =  292.0
  res@trYMaxF                =  300.0
  res@gsnMaximize            =  True
  res@gsnDraw                =  False
  res@gsnFrame               =  False
  res@vpXF                   =  0.25      ;-- set viewport resources
  res@vpYF                   =  0.6
  res@vpWidthF               =  0.7
  res@vpHeightF              =  0.4
  res@pmLegendDisplayMode    = "Always"
  res@lgLabelFontHeightF     =  0.01
  res@pmLegendWidthF         =  0.12           ;-- set legend width
  res@pmLegendHeightF        =  0.19           ;-- set legend height
  res@pmLegendOrthogonalPosF = -1.14           ;-- move legend up
  res@pmLegendParallelPosF   =  0.18           ;-- move legend right

;-- create plot
  plot = gsn_csm_xy(wks,time,data,res)

;-- set text resources
  txres                 = True
  txres@txFontHeightF = 0.010

;-- text bottom
  TimeStamp            = systemfunc( "date +%F" )
  txres@txJust         = "BottomLeft"
  gsn_text_ndc(wks,"German Climate Computing Center (DKRZ),
Hamburg",0.03,0.1, txres)
  txres@txJust         = "BottomRight"
  gsn_text_ndc(wks,TimeStamp,0.97, 0.1, txres)

;-- text top middle
  txres@txFontHeightF = 0.012
```

```
  txres@txJust         = "CenterCenter"
  gsn_text_ndc(wks,"~Z130~2m temperature~N~",  0.53, 0.74, txres)

;-- text top left side
  txres@txFontHeightF = 0.012
  txres@txJust         = "CenterLeft"
  gsn_text_ndc(wks,"Project:  project name",   0.13, 0.74, txres)
  gsn_text_ndc(wks,"Model:   model",          0.13, 0.72, txres)

;-- text top right side
  txres@txFontHeightF = 0.012
  txres@txJust         = "CenterLeft"
  gsn_text_ndc(wks,"Area mean:",               0.77, 0.76, txres)
  gsn_text_ndc(wks,"Lat:      -45.76   42.24", 0.77, 0.74, txres)
  gsn_text_ndc(wks,"Lon:     -24.64   60.28",  0.77, 0.72, txres)
  gsn_text_ndc(wks,"Data:    yearly mean",     0.77, 0.70, txres)

;-- draw the plot
  draw(plot)
  frame(wks)

end
```



A very pretty example demonstrating the benefit of overlays is plotting three data sets with different grid resolutions on one map.

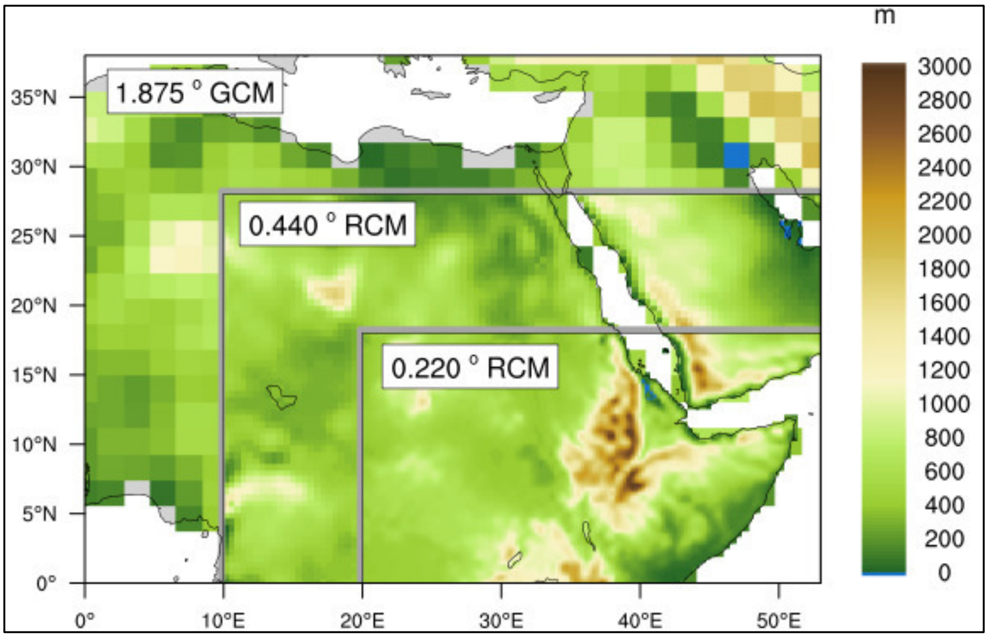
Compare grid resolution example script: NUG_grid_resolution_comparison.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  lon0    =   0.0
  lon1    =  53.0
  lat0    =   0.0
  lat1    =  38.0
  border1 =  10.0
  border2 =  20.0
```

```
  diri = "./"
  fil1 = "orog_mod1_rectilinear_grid_2D.nc"
  fil2 = "orog_mod2_rectilinear_grid_2D.nc"
  fil3 = "orog_mod3_rectilinear_grid_2D.nc"

  msk1 = "sftlf_mod1_rectilinear_grid_2D.nc"
  msk2 = "sftlf_mod2_rectilinear_grid_2D.nc"
  msk3 = "sftlf_mod3_rectilinear_grid_2D.nc"

  file_1    =  addfile(diri+fil1, "r")
  variable1  = file_1->orog(:,:)

  mask_1 = addfile(diri+msk1,"r")
  lsm1   = mask_1->sftlf(:,:)
  lsm1   = lsm1/100                 ;-- do this cause data in percent
  lsm1   = where(lsm1.gt.0.5,-9999,lsm1)

;-- mask data over ocean
  land_only1  = variable1
  land_only1  = mask(variable1,lsm1,-9999)

;-- second file
  file_2    =  addfile(diri+fil2, "r")
  variable2  = file_2->orog(0,{lat0:lat1-border1},{lon0+border1:lon1})
  variable2&rlat@units = "degrees_north"
  variable2&rlon@units = "degrees_east"

  mask_2 = addfile(diri+msk2,"r")
  lsm2   = mask_2->sftlf(0,{lat0:lat1-border1},{lon0+border1:lon1})
  lsm2   = where(lsm2.gt.0.5,-9999,lsm2)

;-- mask data over ocean
  land_only2  = variable2
  land_only2  = mask(variable2,lsm2,-9999)

;-- third file
  file_3    =  addfile(diri+fil3, "r")
  variable3  = file_3->orog(0,{lat0:lat1-border2},{lon0+border2:lon1})
  variable3&rlat@units = "degrees_north"
  variable3&rlon@units = "degrees_east"

  mask_3 = addfile(diri+msk3,"r")
  lsm3   = mask_3->sftlf(0,{lat0:lat1-border2},{lon0+border2:lon1})
  lsm3   = where(lsm3.gt.0.5,-9999,lsm3)

;-- mask data over ocean
  land_only3  = variable3
  land_only3  = mask(variable3,lsm3,-9999)

;-- open workstation
  wks                    = gsn_open_wks("png","plot_grid_resolution_comparison")
  gsn_define_colormap(wks,"OceanLakeLandSnow")

;-- define the global resources for all plots
  cnres                         =  True     ; plot mods desired
  cnres@gsnDraw                 =  False
  cnres@gsnFrame                =  False
  cnres@gsnMaximize             =  True     ; Maximize plot in frame
  cnres@gsnAddCyclic            =  False    ; Don't add a cyclic point
  cnres@gsnLeftString           = ""
  cnres@gsnCenterString         = ""
  cnres@gsnRightStringFontHeightF  = -0.02
  cnres@gsnRightStringParallelPosF = 1.1    ; move the RightString slightly right

  cnres@cnInfoLabelOn           =  False
  cnres@cnLinesOn               =  False
  cnres@cnLineLabelsOn          =  False
  cnres@cnLevelSelectionMode    = "ManualLevels"  ; Set contour levels manually
  cnres@cnMinLevelValF          =  0.             ; Minimum contour level
```

```
  cnres@cnMaxLevelValF        =  3000.          ; Maximum contour level
  cnres@cnLevelSpacingF       =  20             ; Contour level spacing
  cnres@cnFillOn              =  True           ; Turn on contour fill
  cnres@cnFillMode            = "RasterFill"
  cnres@gsnSpreadColors       =  True
  cnres@gsnSpreadColorStart   =   2
  cnres@gsnSpreadColorEnd     = -26

  cnres@lbLabelBarOn          =  True
  cnres@lbLabelStride         =  10
  cnres@lbOrientation         = "Vertical"
  cnres@tiMainOn              =  False

;-- resources first plot (map)
  res = cnres
  res@mpProjection            = "CylindricalEquidistant"
  res@mpLimitMode             = "Corners"
  res@mpLeftCornerLonF        =  lon0
  res@mpRightCornerLonF       =  lon1
  res@mpLeftCornerLatF        =  lat0
  res@mpRightCornerLatF       =  lat1
  res@mpGridAndLimbOn         =  False         ; turn on grid lines
  res@mpDataBaseVersion       = "MediumRes"
  res@pmTickMarkDisplayMode   = "Always"       ; turn on tickmarks
  res@lbLabelBarOn            =  True
  res@lbBoxLinesOn            =  False         ; turn off labelbar box lines
  res@gsnAddCyclic            =  True

  map = gsn_csm_contour_map(wks, land_only1, res)

;-- second plot
  res2 = cnres
  res2@lbLabelBarOn           =  False
  res2@gsnMaximize            =  False
  res2@cnLinesOn              =  False
  res2@cnInfoLabelOn          =  False
  res2@gsnRightString         = ""

  plot2 = gsn_csm_contour(wks, land_only2, res2)

;-- third plot
  res3 = cnres
  res3@lbLabelBarOn           =  False
  res3@gsnMaximize            =  False
  res3@cnLinesOn              =  False
  res3@cnInfoLabelOn          =  False
  res3@gsnRightString         = ""

  plot3 = gsn_csm_contour(wks, land_only3, res3)

;-- overlay the two data sets
  overlay(map,plot2)

;-- draw a shaded box around plot2 (means draw two boxes with different line width)
  shres2                      =  True
  shres2@gsLineThicknessF     =  7.0
  shres2@gsLineColor          = "gray65"

  dx = 0.15
  dy = 0.25

  shypts2=(/lat0+dy,lat1-border1+dy, lat1-border1+dy,  lat1-border1+dy,  lat0+dy/)
 shxpts2=(/lon0+border1-dx,lon0+border1-dx,lon1-dx,lon0+border1-dx,lon0+border1-dx/)

  shdum2 = new(4,graphic)
  do i = 0 , 3
    shdum2(i)=gsn_add_polyline(wks,map,shxpts2(i:i+1),shypts2(i:i+1),shres2)
  end do
```

```
;-- draw a box around plot2
  lnres2                        =  True
  lnres2@gsLineThicknessF       =  1.0
  lnres2@gsLineColor            = "Black"

  ypts2=(/ lat0,           lat0,  lat1-border1,  lat1-border1,  lat0/)
  xpts2=(/ lon0+border1,   lon1,  lon1,          lon0+border1,  lon0+border1/)

  dum2 = new(4,graphic)
  do i = 0 , 3
    dum2(i)=gsn_add_polyline(wks,map,xpts2(i:i+1),ypts2(i:i+1),lnres2)
  end do

;-- overlay plot3
  overlay(map,plot3)

;-- draw a shaded box around plot3 ( means draw two boxes with different line width
  shres3                        =  True
  shres3@gsLineThicknessF       =  7.0
  shres3@gsLineColor            = "gray65"

  dx = 0.15
  dy = 0.25

  shypts3=(/lat0+dy, lat1-border2+dy, lat1-border2+dy,  lat1-border2+dy,  lat0+dy/)
 shxpts3=(/lon0+border2-dx,lon0+border2-dx,lon1-dx,lon0+border2-dx,lon0+border2-dx/)

  shdum3 = new(4,graphic)
  do i = 0 , 3
    shdum3(i)=gsn_add_polyline(wks,map,shxpts3(i:i+1),shypts3(i:i+1),shres3)
  end do

;-- draw a box around plot3
  lnres3                        =  True
  lnres3@gsLineThicknessF       =  1.0
  lnres3@gsLineColor            = "Black"

  ypts3 = (/ lat0,           lat0,  lat1-border2,  lat1-border2,  lat0/)
  xpts3 = (/ lon0+border2,   lon1,  lon1,          lon0+border2,  lon0+border2/)

  dum3 = new(4,graphic)
  do i = 0 , 3
    dum3(i)=gsn_add_polyline(wks,map,xpts3(i:i+1),ypts3(i:i+1),lnres3)
  end do

;--drawing the map will draw contours and vectors too.
  draw(map)

;-- draw text on plot (map)
  txres                         =  True
  txres@txFontHeightF           =  0.02
  txres@txFontColor             = "Black"
  txres@txBackgroundFillColor   = "White"
  txres@txPerimOn               =  True

  gsn_text_ndc(wks,"1.875 ~S~o~N~ GCM", 0.200, 0.730, txres)
  gsn_text_ndc(wks,"0.440 ~S~o~N~ RCM", 0.330, 0.600, txres)
  gsn_text_ndc(wks,"0.220 ~S~o~N~ RCM", 0.470, 0.460, txres)

  frame(wks)
end
```



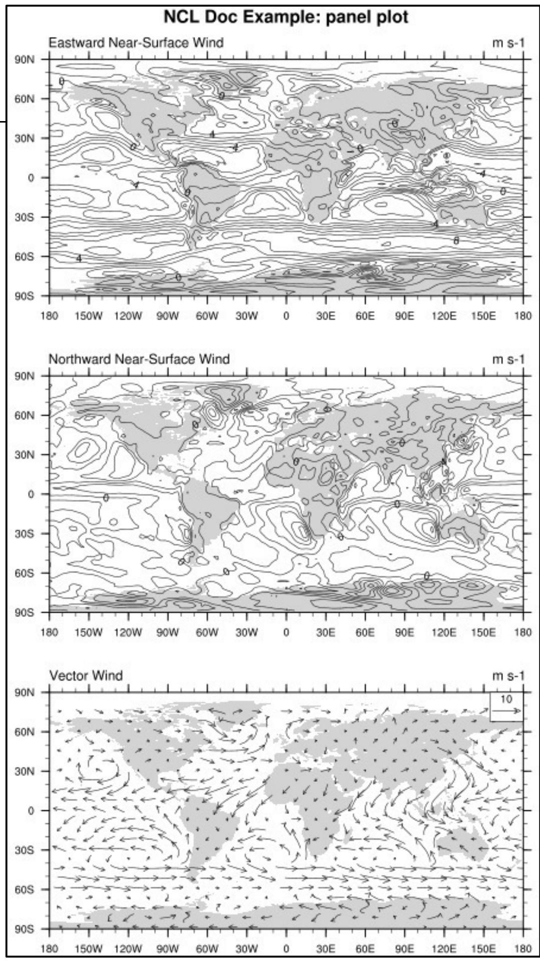
8.10 Panel Plots

NCL allows the drawing of multiple plots on a single page (frame) using the procedure **gsn_panel**. The plots will be drawn from the left to right side of the page and from the top down to the bottom. A common labelbar or title for all plots can be included.

Panel plot example: NUG_panel_plot.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- read data and set variable references

  diri = "./"
  fil1 = "orog_mod1_rectilinear_grid_2D.nc"
  fil2 = "sftlf_mod1_rectilinear_grid_2D.nc"
  fil3 = "tas_rectilinear_grid_2D.nc"
  fil4 = "uas_rectilinear_grid_2D.nc"
  fil5 = "vas_rectilinear_grid_2D.nc"

  f1   =  addfile(diri+fil1, "r")
  f2   =  addfile(diri+fil2, "r")
  f3   =  addfile(diri+fil3, "r")
  f4   =  addfile(diri+fil4, "r")
  f5   =  addfile(diri+fil5, "r")

  orog  = f1->orog
  sftlf = f2->sftlf
  t     = f3->tas
  u     = f4->uas
  v     = f5->vas

;-- open a PNG file
  wks = gsn_open_wks("png","plot_panel_plot")

;-- create plot array
  plot = new(3,graphic)

;-- set resources for contour plots
```

```
  res                                = True
  res@gsnDraw                        = False
  res@gsnFrame                       = False
  res@gsnAddCyclic                   = True
  res@gsnMaximize                    = True
  res@tiMainString                   = "NCL Doc Example: panel plot"
  res@cnInfoLabelOn                  = False

  plot(0) = gsn_csm_contour_map(wks,u(0,:,:),res)

  res@tiMainString                   = ""
  plot(1) = gsn_csm_contour_map(wks,v(0,:,:),res)

;-- set resources for vector plot
  vres                               = True
  vres@gsnDraw                       = False
  vres@gsnFrame                      = False
  vres@gsnAddCyclic                  = True
  vres@gsnMaximize                   = True
  vres@gsnLeftString                 = "Vector Wind"
  vres@vcRefAnnoOrthogonalPosF       = -1.0
  vres@vcRefMagnitudeF               = 10.0
  vres@vcRefLengthF                  = 0.045
  vres@vcGlyphStyle                  = "CurlyVector"
  vres@vcMinDistanceF                = 0.017

  plot(2) = gsn_csm_vector_map(wks,u(0,::4,::4),v(0,::4,::4),vres)

;-- create panel plot
  gsn_panel(wks,plot,(/3,1/),False)

end
```

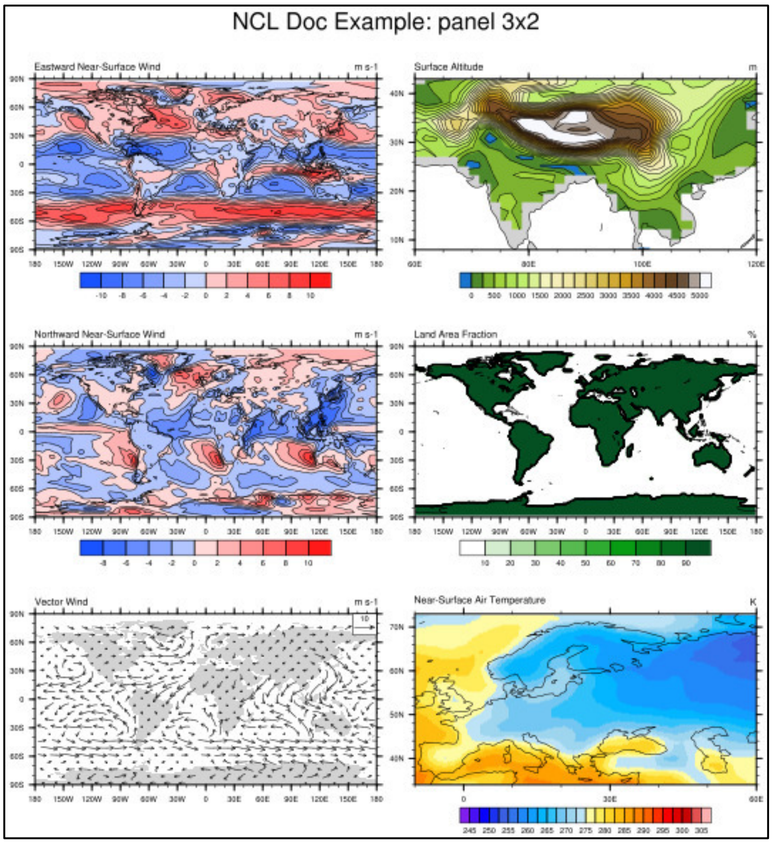


Panel plot example 3 rows x 2 columns: NUG_panel_plot_3x2.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri = "./"
  fil1 = "orog_mod1_rectilinear_grid_2D.nc"
  fil2 = "sftlf_mod1_rectilinear_grid_2D.nc"
  fil3 = "tas_rectilinear_grid_2D.nc"
  fil4 = "uas_rectilinear_grid_2D.nc"
  fil5 = "vas_rectilinear_grid_2D.nc"

  f1   =  addfile(diri+fil1, "r")
  f2   =  addfile(diri+fil2, "r")
  f3   =  addfile(diri+fil3, "r")
  f4   =  addfile(diri+fil4, "r")
  f5   =  addfile(diri+fil5, "r")

  orog  = f1->orog
  sftlf = f2->sftlf
  t     = f3->tas
  u     = f4->uas
  v     = f5->vas

  land_only = orog
  land_only = where(sftlf .ge.10, orog, orog@_FillValue)

;-- open a PNG file
  wks = gsn_open_wks("png","plot_panel_3x2_plot")

;-- create plot array (3 rows and 2 columns  3*2=6)
  plot = new(6,graphic)

;-- set resources for contour plots
  res                                  =  True
  res@gsnDraw                          =  False
  res@gsnFrame                         =  False
  res@gsnAddCyclic                     =  True
  res@tiMainString                     = ""
  res@cnInfoLabelOn                    =  False
  res@cnFillOn                         =  True
  res@cnFillMode                       = "RasterFill"
  res@cnRasterSmoothingOn              =  True
  res@cnFillPalette                    = "BlueRed"

;-- upper left plot
  plot(0) = gsn_csm_contour_map(wks,u(0,:,:),res)

;-- upper right plot
;-- set the viewport to the same size as plot(0)
  getvalues plot(0)
    "vpWidthF"  : vpw
    "vpHeightF" : vph
  end getvalues

  res@mpShapeMode            = "FreeAspect"
  res@vpWidthF               =  vpw
  res@vpHeightF              =  vph
  res@mpLimitMode            = "Corners"
  res@mpLeftCornerLonF       =  60.0
  res@mpRightCornerLonF      = 120.0
  res@mpLeftCornerLatF       =   8.0
```

```
  res@mpRightCornerLatF     =  43.0
  res@cnFillPalette         = "OceanLakeLandSnow"
  res@cnLevelSelectionMode  = "ManualLevels"  ;-- manually levels
  res@cnMinLevelValF        =  0.             ;-- minimum level
  res@cnMaxLevelValF        =  5000.          ;-- maximum level
  res@cnLevelSpacingF       =  250            ;-- level spacing

  plot(1) = gsn_csm_contour_map(wks,land_only,res)

;-- delete some resources
  delete([/res@mpLimitMode,res@mpLeftCornerLonF,res@mpRightCornerLonF, \
           res@mpLeftCornerLatF,res@mpRightCornerLatF,  \
           res@cnLevelSelectionMode,res@cnMinLevelValF, \
           res@cnMaxLevelValF,res@cnLevelSpacingF/])

;-- middle left plot
  res@tiMainString          = ""
  res@cnFillPalette         = "BlueRed"
  res@cnLevelSelectionMode  = "AutomaticLevels" ;-- automat. levels

  plot(2) = gsn_csm_contour_map(wks,v(0,:,:),res)

;-- middle right plot
  res@cnFillPalette         = "WhiteGreen"

  plot(3) = gsn_csm_contour_map(wks,sftlf,res)

;-- set resources for vector plot
  vres                      =  True
  vres@gsnDraw              =  False
  vres@gsnFrame             =  False
  vres@gsnAddCyclic         =  True

  vres@gsnLeftString        = "Vector Wind"
  vres@vcRefAnnoOrthogonalPosF  =  -1.0
  vres@vcRefMagnitudeF      =  10.0
  vres@vcRefLengthF         =  0.045
  vres@vcGlyphStyle         = "CurlyVector"
  vres@vcMinDistanceF      =  0.017
;-- lower left plot
  plot(4) =gsn_csm_vector_map(wks,u(0,::4,::4),v(0,::4,::4),vres)

;-- lower right plot
;-- set the viewport to the same size as plot(4)
  getvalues plot(4)
    "vpWidthF"  : vpw
    "vpHeightF" : vph
  end getvalues

  res@mpShapeMode          = "FreeAspect"
  res@vpWidthF             =  vpw
  res@vpHeightF            =  vph
  res@cnFillPalette        = "ncl_default"
  res@cnLinesOn            =  False
  res@cnLevelSelectionMode = "ManualLevels"  ;-- manually levels
  res@cnMinLevelValF       =  245.           ;-- minimum level
  res@cnMaxLevelValF       =  305.           ;-- maximum level
  res@cnLevelSpacingF      =  2.5            ;-- level spacing
  res@mpLimitMode          = "Corners"
  res@mpLeftCornerLonF     = -10.0
  res@mpRightCornerLonF    =  60.0
  res@mpLeftCornerLatF     =  34.0
```

```
  res@mpRightCornerLatF     =  73.0

  plot(5) = gsn_csm_contour_map(wks,t(0,:,:),res)

;-- plot one title on top of the plot
  pnlres                      = True
  pnlres@txString             = "NCL Doc Example: panel 3x2"
   ;-- FYI: from version 6.4.0 gsnPanelMainString replace the txString here

;-- create panel plot
  gsn_panel(wks,plot(/3,2/),pnlres)

end
```



8.10.1 Control Panel Plots

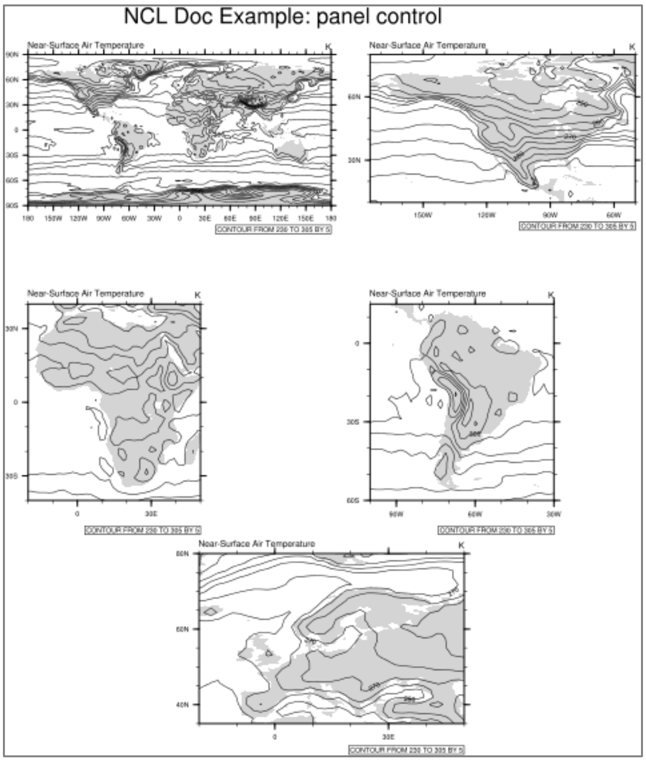
There are just a few resouces that can be used to control a panel plot. The next example shows a panel plot containing plots of different sizes.The "gsnPanelScalePlotIndex" allows you to indicate the index number of which plot to base the scaling on. If your plots are different sizes, then you want to use the index of the plot that has the largest width or height.

NUG_panel_control.ncl:

```
begin
;-- read data and set variable references
  diri = "./"
  fili = "tas_rectilinear_grid_2D.nc"

  f    =  addfile(diri+fili, "r")
  t    =  f->tas
```

```
;-- open a PNG file
  wks = gsn_open_wks("png","plot_panel_control")

;-- set resources for contour plots
  res                                   =  True
  res@gsnDraw                           =  False
  res@gsnFrame                          =  False
  res@gsnAddCyclic                      =  True
  res@gsnLeftStringOrthogonalPosF       =  0.03
  res@gsnRightStringOrthogonalPosF      =  0.03

  res1 = res
  res2 = res
  res3 = res
  res4 = res
  res5 = res

;-- global
  plot_1 = gsn_csm_contour_map(wks,t(0,:,:),res1)

;-- North America
  res2@mpMinLatF                        =   10.0
  res2@mpMaxLatF                        =   80.0
  res2@mpMinLonF                        = -175.0
  res2@mpMaxLonF                        =  -50.0
  plot_2 = gsn_csm_contour_map(wks,t(0,:,:),res2)

;-- Africa
  res3@mpMinLatF                        =   -40.0
  res3@mpMaxLatF                        =    40.0
  res3@mpMinLonF                        =   -20.0
  res3@mpMaxLonF                        =    50.0
  plot_3 = gsn_csm_contour_map(wks,t(0,:,:),res3)

;-- South America
  res4@mpMinLatF                        =   -60.0
  res4@mpMaxLatF                        =    15.0
  res4@mpMinLonF                        =  -100.0
  res4@mpMaxLonF                        =   -30.0
  plot_4 = gsn_csm_contour_map(wks,t(0,:,:),res4)

;-- Europe
  res5@mpMinLatF                        =    35.0
  res5@mpMaxLatF                        =    80.0
  res5@mpMinLonF                        =   -20.0
  res5@mpMaxLonF                        =    50.0
  plot_5 = gsn_csm_contour_map(wks,t(0,:,:),res5)

;-- create the panel plot
  pnlres                              =  True
  pnlres@gsnMaximize                  =  True
  pnlres@gsnPanelScalePlotIndex       =  3
  pnlres@gsnPanelTop                  =  0.94
  pnlres@gsnPanelBottom               =  0.001
  pnlres@gsnPanelXWhiteSpacePercent   =  0
  pnlres@gsnPanelXWhiteSpacePercent   =  30

  pnlres@txFontHeightF                =  0.020    ;-- text font size
  pnlres@txString                     = "NCL Doc Example: panel control"
   ;-- FYI: from version 6.4.0 gsnPanelMainString replace the txString here
```

```
;-- create panel plot
  gsn_panel(wks,(/plot_1,plot_2,plot_3,plot_4,plot_5/),(/3,2/),pnlres)

end
```

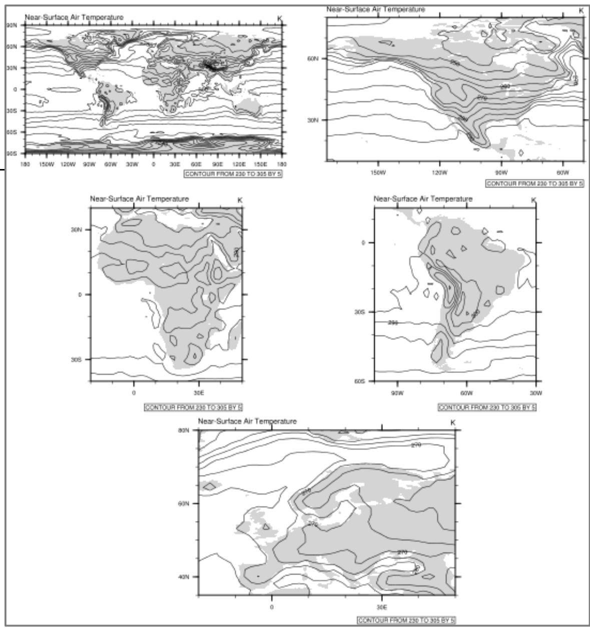


Sometimes you will get unexpected results trying to plot plots of different size using gsn_panel. An alternative way to place the plots is the use of @vp resources.

NUG_panel_vp.ncl:

```
begin
;-- read data and set variable references
  diri = "./"
  fili = "tas_rectilinear_grid_2D.nc"

  f    =  addfile(diri+fili, "r")
  t    =  f->tas

;-- open a PNG file
  wks = gsn_open_wks("png","plot_panel_vp")

;-- set resources for contour plots
  res                               =  True
  res@gsnDraw                       =  False
  res@gsnFrame                      =  False
  res@gsnAddCyclic                  =  True
  res@gsnLeftStringOrthogonalPosF   =  0.03
  res@gsnRightStringOrthogonalPosF  =  0.03
  res@vpWidthF                      =  0.4
  res@vpHeightF                     =  0.27
;-- global
  res@vpXF                          =  0.08
  res@vpYF                          =  0.99

  plot_1 = gsn_csm_contour_map(wks,t(0,:,:),res)
  draw(plot_1)
```

```
;-- North America
  res@vpXF                              =  0.55
  res@vpYF                              =  0.99
  res@mpMinLatF                         =   10.0
  res@mpMaxLatF                         =   80.0
  res@mpMinLonF                         = -175.0
  res@mpMaxLonF                         =  -50.0

  plot_2 = gsn_csm_contour_map(wks,t(0,:,:),res)
  draw(plot_2)

;-- Africa
  res@vpXF                              =  0.1
  res@vpYF                              =  0.67
  res@mpMinLatF                         =  -40.0
  res@mpMaxLatF                         =   40.0
  res@mpMinLonF                         =  -20.0
  res@mpMaxLonF                         =   50.0

  plot_3 = gsn_csm_contour_map(wks,t(0,:,:),res)
  draw(plot_3)

;-- South America
  res@vpXF                              =  0.55
  res@vpYF                              =  0.67
  res@mpMinLatF                         =  -60.0
  res@mpMaxLatF                         =   15.0
  res@mpMinLonF                         = -100.0
  res@mpMaxLonF                         =  -30.0

  plot_4 = gsn_csm_contour_map(wks,t(0,:,:),res)
  draw(plot_4)

;-- Europe
  res@vpXF                              =  0.35
  res@vpYF                              =  0.33
  res@mpMinLatF                         =   35.0
  res@mpMaxLatF                         =   80.0
  res@mpMinLonF                         =  -20.0
  res@mpMaxLonF                         =   50.0

  plot_5 = gsn_csm_contour_map(wks,t(0,:,:),res)
  draw(plot_5)

;-- advance the frame
  frame(wks)

end
```



8.11 Polylines, Polygons, Polymarkers, Text (primitives)

To draw lines, polygons, markers, or text strings on a plot or the NCL frame, NCL provides the **gsn** functions:

- **gsn_polyline**(wks, plot, x, y, resource)
- **gsn_polyline_ndc**(wks, x, y, resource)
- **gsn_add_polyline**(wks, plot, x, y, resource)
- **gsn_polygon**(wks, plot, x, y, resource)
- **gsn_polygon_ndc**(wks, x, y, resource)
- **gsn_add_polygon**(wks, plot, x, y, resource)
- **gsn_polymarker**(wks, plot, x, y, resource)
- **gsn_polymarker_ndc**(wks, x, y, resource)
- **gsn_add_polymarker**(wks, plot, x, y, resource)
- **gsn_add_text**(wks, plot, text_string, x, y, resource)
- **gsn_text**(wks, plot, text_string, x, y, resource)
- **gsn_text_ndc**(wks, text_string, x, y, resource)

The “ndc” functions draw primitives on the NCL canvas using NDC coordinates (values that go from 0 to 1). All the other functions draw primitives on the given plot, using that plot’s data space. The gsn_add_xxx functions are identical to the gsn_xxx procedures, except the “add” functions actually attach the primitives to the given plot. The “add” functions are especially useful if you plan to resize the plot later, say in a call to gsn_panel, because the primitives will also be automatically resized.

See also: http://www.ncl.ucar.edu/Applications/polyg.shtml

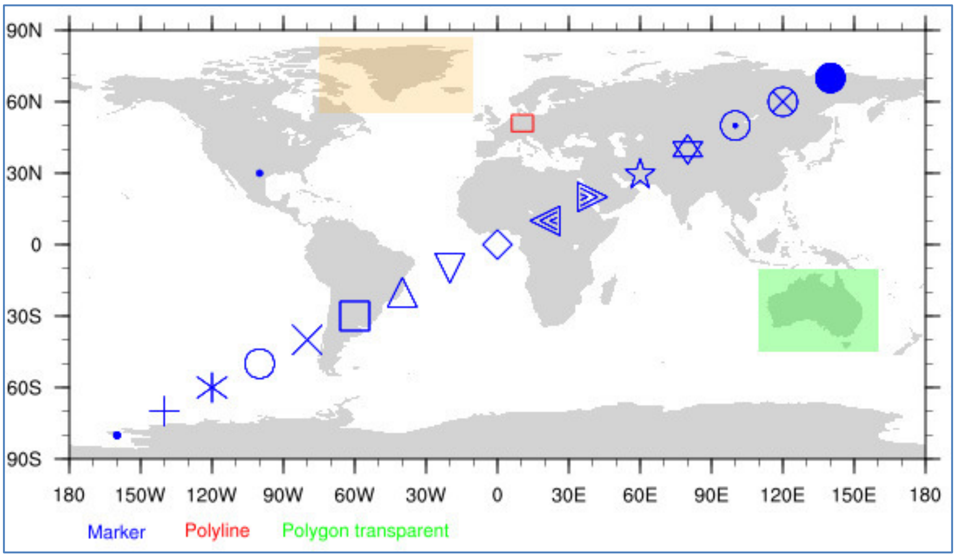
The next example shows how to plot polylines, polygons and polymarkers on a map plot and add a polygons via a procedure.

NUG_polyline_polygon_polymarker.ncl:

```
undef("add_poly")
procedure add_poly(wks,map)
local xx, yy, pres
begin
  xx = (/-75., -10., -10., -75., -75./) ;-- define polygon x-array
  yy = (/ 55.,  55.,  87.,  87.,  57./) ;-- define polygon y-array

  pres                      =  True
  pres@gsFillColor          = "orange"             ;-- fill color
  pres@gsFillOpacityF       =  0.2                 ;-- set opacity

;-- add polygon to map
  map@polygon = gsn_add_polygon(wks, map, xx, yy, pres)
end

;----------
;  MAIN
;----------
begin
;-- open a workstation and define color map
```

```
  wks = gsn_open_wks("png","plot_polystuff")

;-- set resources
  res                          =  True
  res@gsnDraw                  =  False        ;-- don't draw the plot yet
  res@gsnFrame                 =  False        ;-- don't advance the frame yet

  res@vpXF                     =  0.08         ;-- x-position
  res@vpYF                     =  0.92         ;-- y-position
  res@vpWidthF                 =  0.88         ;-- width
  res@vpHeightF                =  0.65         ;-- height

  res@mpFillOn                 =  True

  map = gsn_csm_map(wks,res)      ;-- create the map, but don't draw it yet

;-- write strings at the bottom of the plot
  txres                       =  True
  txres@txFontHeightF         =  0.014         ;-- default size is HUGE!
  txres@txFontColor           = "blue"
  txres@txJust                = "CenterLeft"   ;-- puts text on top of bars
  dty = 0.3
  gsn_text_ndc(wks,"Marker", 0.1, dty, txres)
  txres@txFontColor           = "red"
  gsn_text_ndc(wks,"Polyline", 0.2, dty, txres)
  txres@txFontColor           = "green"
  gsn_text_ndc(wks,"Polygon transparent", 0.3, dty, txres)

;-- polyline
  x = (/ 6.,  15.,  15.,   6.,   6./)
  y = (/47.5, 47.5, 54.5, 54.5, 47.5/)

;-- trace: polyline resources
  plres                            =  True
  plres@gsLineThicknessF           =  2.0        ;-- set line thickness
  plres@gsLineColor                = "red"       ;-- set line color
  box_1 = gsn_add_polyline(wks, map, x, y, plres)  ;-- add polyline to map

;-- define polygon x- and y-arrays
  x = (/110., 160., 160., 110., 110./)
  y = (/-45., -45., -10., -10., -45./)

;-- trace: polygon resources
  pgres                            =  True
  pgres@gsFillColor                = "green"      ;-- fill color
  pgres@gsFillOpacityF             =  0.3         ;-- set opacity of polygon
  gon_1 = gsn_add_polygon(wks, map, x, y, pgres)
                                                  ;-- add filled polygon to map

;-- polymarker
  pmres                            =  True
  pmres@gsMarkerColor              = "blue"       ;-- marker color
  pmres@gsMarkerIndex              =  1           ;-- use marker 1
  pmres@gsMarkerSizeF              =  0.03        ;-- set size of marker
  pmres@gsLineThicknessF           =  3.          ;-- marker line thickness

;-- unique identifier name for polymarker drawing, here marker_1
  marker_1 = gsn_add_polymarker(wks, map, -100., 30., pmres)

;-- draw all 16 marker on plot using unique identifier name and
;-- additional map attribute settings
  x = -160.                                    ;-- x-position of first marker
```

```
  y =  -80.                                  ;-- y-position of first marker
  do i = 0,15                                       ;-- 16 different marker
     pmres@gsMarkerIndex  =  i+1
     str = unique_string("poly")             ;-- result is poly0-poly15
     map@$str$ = gsn_add_polymarker(wks, map, x+(i*20.), y+(i*10.), pmres)
                                             ;-- add marker to map
  end do

;-- add polygon calling the procedure add_poly()
  add_poly(wks,map)

;-- print map contents to see how unique_string works with map@$str$
  print(map)

;-- create the plot and advance the frame
  draw(map)
  frame(wks)

end
```



Tip: Using polylines, polygons or polymarkers within a user defined function or procedure can cause problems. If plotting information of the poly*** routines are getting lost you can save them by assigning an additional attribute to the graphics plot object.

Example user defined function 'add_poly':

```
undef("add_poly")
procedure add_poly(wks,plot)
local xx, yy, pres
begin
  xx = (/-75., -10., -10., -75., -75./)
  yy = (/ 55.,  55.,  87.,  87.,  57./)

  pres                          =  True
  pres@gsFillColor              = "orange"
  pres@gsFillOpacityF           =  0.2

  plot@polygon = gsn_add_polygon(wks, plot, xx, yy, pres)

end
```

8.12 Shapefile Plots

Shapefiles are a popular geospatial vector data format for GIS software. They contain points, lines and polygons representing entities like rivers, lakes, countries, counties, population of cities, locations of popular landmarks, and so on.

Some useful data sets can be found at:
http://www.gadm.org/
http://www.nws.noaa.gov/geodata/
http://www.geodatenzentrum.de/geodaten/gdz_rahmen.gdz_div

To attach shapefile points, lines, or polygons to a plot, NCL provides the **gsn** functions

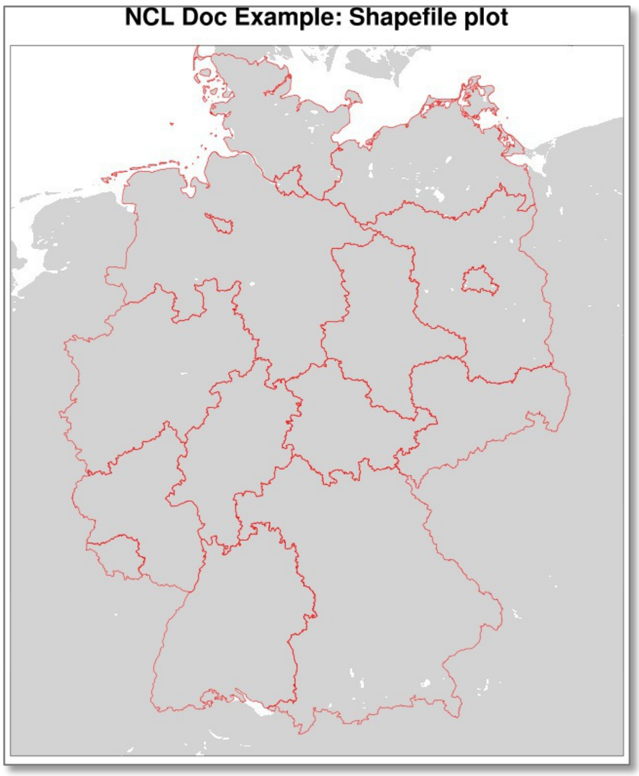
- **gsn_add_shapefile_polymarkers**(wks, plot, filename, resource)
- **gsn_add_shapefile_polylines**(wks, plot, filename, resource)
- **gsn_add_shapefile_polygons**(wks, plot, filename, resource)

The next example plots outlines from a Germany shapefile downloaded from gadm.org. This example also uses the "HighRes" map database to get high resolution coastal outlines for other areas. See the "Map Resolutions" section for information on how to download this database.

Simple shapefile example: NUG_shapefile_plot.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri = "./"
  fili = "DEU_adm/DEU_adm1.shp"
  f    =  addfile(diri+fili, "r")

;-- read data from shapefile
   segments = f->segments
   geometry = f->geometry
   segsDims = dimsizes(segments)
   geomDims = dimsizes(geometry)

;-- get global attributes
   geom_segIndex = f@geom_segIndex
   geom_numSegs  = f@geom_numSegs
   segs_xyzIndex = f@segs_xyzIndex
   segs_numPnts  = f@segs_numPnts
   numFeatures   = geomDims(0)

;-- open workstation
   wks = gsn_open_wks("png","plot_shapefile_plot")

;-- set resources for the map
   res                       =  True
   res@gsnDraw               =  False         ;-- don't draw the plot
   res@gsnFrame              =  False         ;-- don't advance frame yet
   res@gsnMaximize           =  True          ;-- maximize plot in frame
   res@mpDataBaseVersion     = "HighRes"
   res@mpDataResolution      = "Medium"
   res@mpProjection          = "Mercator"     ;-- change projection

;-- select coordinates for Germany
```

```
   res@mpLimitMode          = "Corners"
   res@mpLeftCornerLatF     =  47.
   res@mpRightCornerLatF    =  55.
   res@mpLeftCornerLonF     =  5.
   res@mpRightCornerLonF    =  16.

   res@tiMainString         = "NCL Doc Example: Shapefile plot"
   res@tiMainFontHeightF    =  0.015

;-- generate map, but don't draw it
   plot = gsn_csm_map(wks,res)         ;-- draw map, but don't advance frame

;-- add polylines from the shape files to the plot
   lines = new(segsDims(0),graphic)    ;-- array to hold shapefile polylines

;-- set resources for the polylines
   plres                    =  True
   plres@gsLineColor        = "red"

;-- generate polylines, but don't draw it
   lon    = f->x
   lat    = f->y
   segNum = 0
   do i=0, numFeatures-1
      startSegment = geometry(i, geom_segIndex)
      numSegments  = geometry(i, geom_numSegs)
      do seg=startSegment, startSegment+numSegments-1
         startPT = segments(seg, segs_xyzIndex)
         endPT   = startPT + segments(seg, segs_numPnts) - 1
         lines(segNum) = gsn_add_polyline(wks, plot, lon(startPT:endPT),
lat(startPT:endPT), plres)
         segNum = segNum + 1
      end do
   end do

;-- draw the plot
   draw(plot)
   frame(wks)

end
```

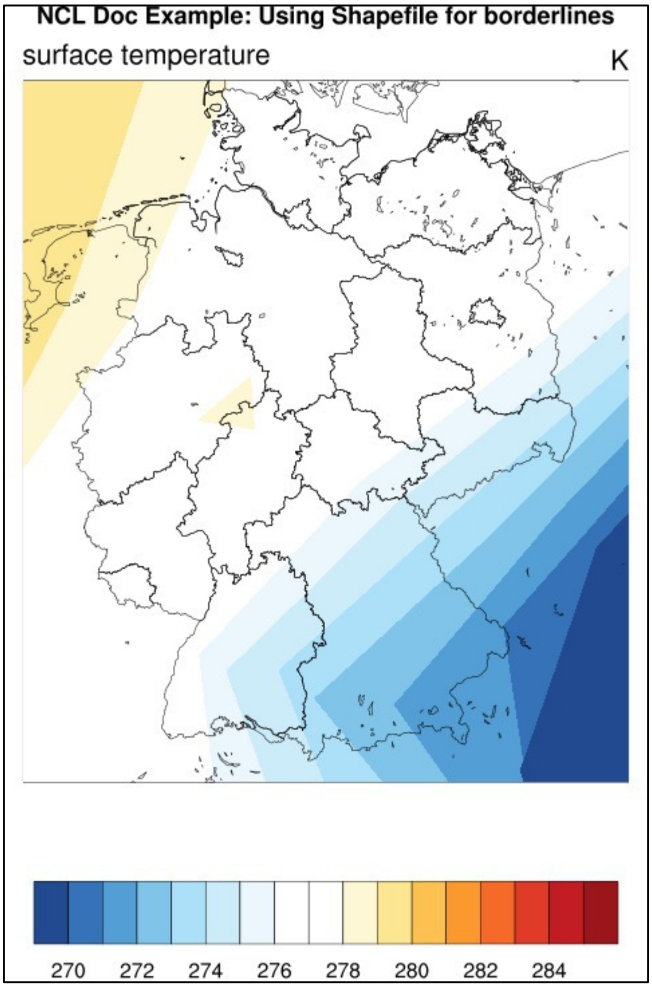


The next example will show how to combine a contour fill plot of your data and the content of a shapefile related to the latitudes and longitudes.

Simple shapefile example: NUG_shapefile_plot_data.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   diri    = "./"
   shpname = "DEU_adm/DEU_adm1.shp"

;-- read data to display
   fili = "rectilinear_grid_2D.nc"
   g    =  addfile(diri+fili,"r")
   var  =  g->tsurf(0,:,:)

;-- open workstation
   wks = gsn_open_wks("png","plot_shapefile_plus_data")

;-- set resources for the map
   res                     =  True
   res@gsnDraw             =  False      ;-- don't draw the plot
   res@gsnFrame            =  False      ;-- don't advance frame yet
   res@gsnMaximize         =  True       ;-- maximize plot in frame
   res@gsnSpreadColors     =  True       ;-- full color map
   res@gsnSpreadColorStart =  18         ;-- start at color 14
   res@gsnSpreadColorEnd   =  -3


   res@cnFillOn            =  True
   res@cnLinesOn           =  False
   res@cnSmoothingOn       =  True
   res@cnLevelSelectionMode = "ManualLevels"
   res@cnMinLevelValF      =  270.0
   res@cnMaxLevelValF      =  285.0
   res@cnLevelSpacingF     =    1.0

;-- select coordinates for Germany
   res@mpFillOn            =  False
   res@mpLimitMode         = "Corners"
   res@mpLeftCornerLatF    =  47.
   res@mpRightCornerLatF   =  55.
   res@mpLeftCornerLonF    =  5.
   res@mpRightCornerLonF   =  16.
   res@mpDataBaseVersion   = "HighRes"
   res@mpDataResolution    = "Medium"
   res@mpProjection        = "Mercator"

   res@tiMainString = "NCL Doc Example: Using Shapefile for borderlines"
   res@tiMainFontHeightF   =  0.015

;-- generate map, but don't draw it
   plot = gsn_csm_contour_map(wks,var,res)

;-- set resources for the polylines
   plres                   =  True
   plres@gsLineColor       = "black"

   poly = gsn_add_shapefile_polylines(wks,plot,shpname,plres)

;-- draw the plot
```

```
   draw(plot)
   frame(wks)

end
```



8.13 Color Maps

Many different color tables, also called color maps, are available. Alternatively, you can define your own color maps or convert color tables from other graphic packages, such as GrADS, into your own **RGB** (= Red Green Blue) or **RGBA** (= Red Green Blue and Alpha, the transparency channel) color map in order to use it within NCL.

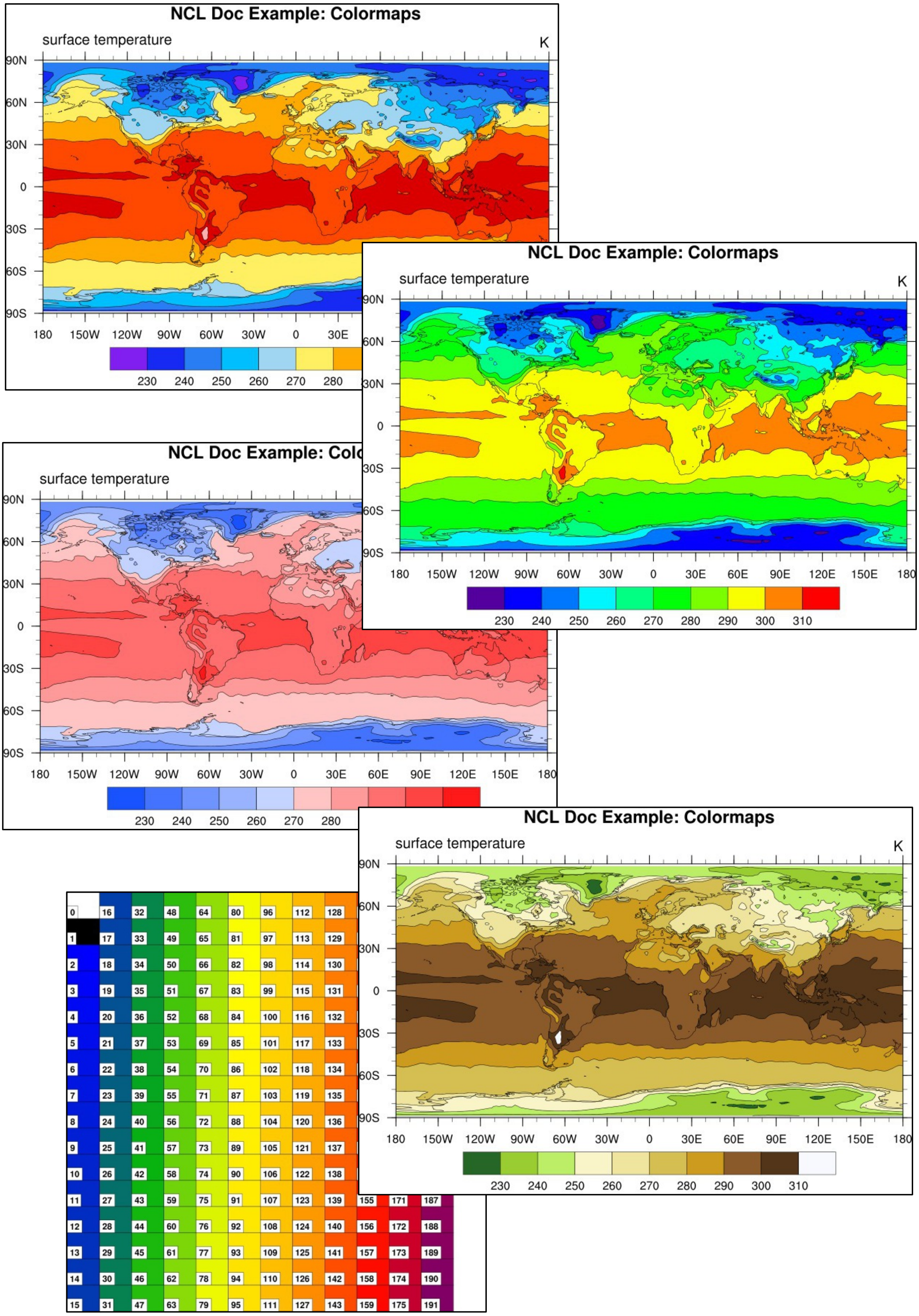
At this point, only a short description of how to handle different color maps in NCL is given. A more detailed description can be found on the web page

Color Table Gallery: http://www.ncl.ucar.edu/Document/Graphics/color_table_gallery.shtml

The next example uses both gsn_define_colormap and cnFillPalette to set the color map for the filled contours. Using cnFillPalette is the preferred method.

Simple color map example: NUG_colormaps.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   diri  = "./"
   fili  = "rectilinear_grid_2D.nc"
   file1 =  addfile(diri+fili, "r")
   var   =  file1->tsurf(0,:,:)

;-- define the workstation (plot type and name)
   wks = gsn_open_wks("png","plot_colormaps")

;-- set resources
   res                        =  True
   res@gsnMaximize            =  True
   res@cnFillOn               =  True        ;-- turn on contour fill
   res@tiMainString   = "NCL Doc Example: Color maps"  ;-- title
   res@tiMainFontHeightF      =  0.02

;-- 1: set color map to "ncl_default" and draw the contour map
   gsn_define_colormap(wks,"ncl_default")
   plot = gsn_csm_contour_map(wks, var, res)

;-- 2: change the color map to "rainbow" and draw the contour map
   gsn_define_colormap(wks,"rainbow")
   plot = gsn_csm_contour_map(wks, var, res)

;-- 3: change the color map to "BlueRed" and draw the contour map
   gsn_define_colormap(wks,"BlueRed")
   plot = gsn_csm_contour_map(wks, var, res)

;-- 4: color map set by resource cnFillPalette instead of
;--    gsn_define_colormap
   res@cnFillPalette          = "OceanLakeLandSnow"
   plot = gsn_csm_contour_map(wks, var, res)

;-- 5: draw just the color map - no data. !! Uses the last
;--    gsn_define_colormap setting to wks
   gsn_define_colormap(wks,"BlGrYeOrReVi200")
   gsn_draw_colormap(wks)

end
```


NCL Doc Example: Colormaps
surface temperature
K
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
230
240
250
260
270
280
290
300
310
NCL Doc Example: Colormaps
surface temperature
K
NCL Doc Example: Colormaps
surface temperature
K
NCL Doc Example: Colo
surface temperature
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95
96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111
112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143
155 156 157 158 159
171 172 173 174 175
187 188 189 190 191

If you don't want to use the complete color map it can be read into an array and a subset of the array can be set as color map.

Old fashioned way:

```
gsn_define_colormap(wks,"ncl_default")
res@gsnSpreadColorStart      =  14        ;-- color index start
res@gsnSpreadColorEnd        =  -8        ;-- color index end
```

Recommended way:

```
cmap = read_colormap_file("ncl_default")
res@cnFillPalette = cmap(14,247,:)
```

8.13.1 Converting a GrADS color table

This shell script converts a GrADS color table to an NCL color map:
grads2ncl_coltab.ksh

```
#!/bin/ksh
#----------------------------------------------------
#-- convert GrADS color table to NCL color map (RGB)
#--
#-- Usage:  grads2ncl_coltab.ksh <GrADS color table file>
#----------------------------------------------------
in=$1

grads_coltab=${in##*/}
coltab=NCL_${grads_coltab%.*}.rgb

ncols=$(cat ${in} | grep -v "\*" | grep -v "\#" | wc -l)
ncols=$(expr ${ncols} + 2)

#-- insert background (1) and foreground (0) colors; NCL starts with color index 2
cat << EOF > ${coltab}
ncolors=${ncols}
# r   g   b
0 0 0
1 1 1
EOF

cat ${in} | grep -v "\*" | grep -v "\#" | sed -e "s/'//g" | \
    awk '{print $4" "$5" "$6}' >> ${coltab}

exit
```

8.13.2 Converting a GMT color table

Since NCL release (6.2.0) many GMT color tables are imported to NCL.

This shell script can be used to convert a private GMT color table to an NCL color map:
gmt2coltab.ksh

```
#!/usr/bin/ksh
#----------------------------------------------------------------------
#-- KSH  - NCL Doc Example script:
#--
```

```
#-- convert GMT color tables to NCL color tables
#-- used by   gsn_define_colormap(wks,"NCL_GMT-BYR-03")
#--         or cnFillPalette
#-- Example GMT color table file:   GMT-BYR-03.cpt
#--
#-- Usage:  gmt2coltab.ksh GMT-BYR-03.cpt
#--          ---> creates new file NCL_GMT-BYR-03.rgb
#--
#-- KMF 03.05.13
#-----------------------------------------------------------------------
in=$1
gmt_coltab=${in##*/}
coltab=NCL_${gmt_coltab%.*}.rgb

#-- count number of colors plus foreground and background color.
#-- BUT, delete the last 3 color entries from the GMT color table
#-- they're not needed --> number of colors + 2 - 3  =  number of colors -1

ncols=$(cat ${in} | grep -v "\#" | wc -l)
ncols=$(expr ${ncols} - 1)

#-- insert background (1) and foreground (0) colors
#-- NCL starts with color index 2
cat << EOF > tmp_col.rgb
ncolors=${ncols}
# r   g   b
0 0 0
1 1 1
EOF

#-- read and write the color values
cat ${in} | grep -v "\#" | sed -e "s/'//g" | awk '{print $2" "$3" "$4}' >>
tmp_col.rgb
head -n -3 tmp_col.rgb > ${coltab}

\rm -rf tmp_col.rgb

exit
```

8.14 Curvilinear Grids

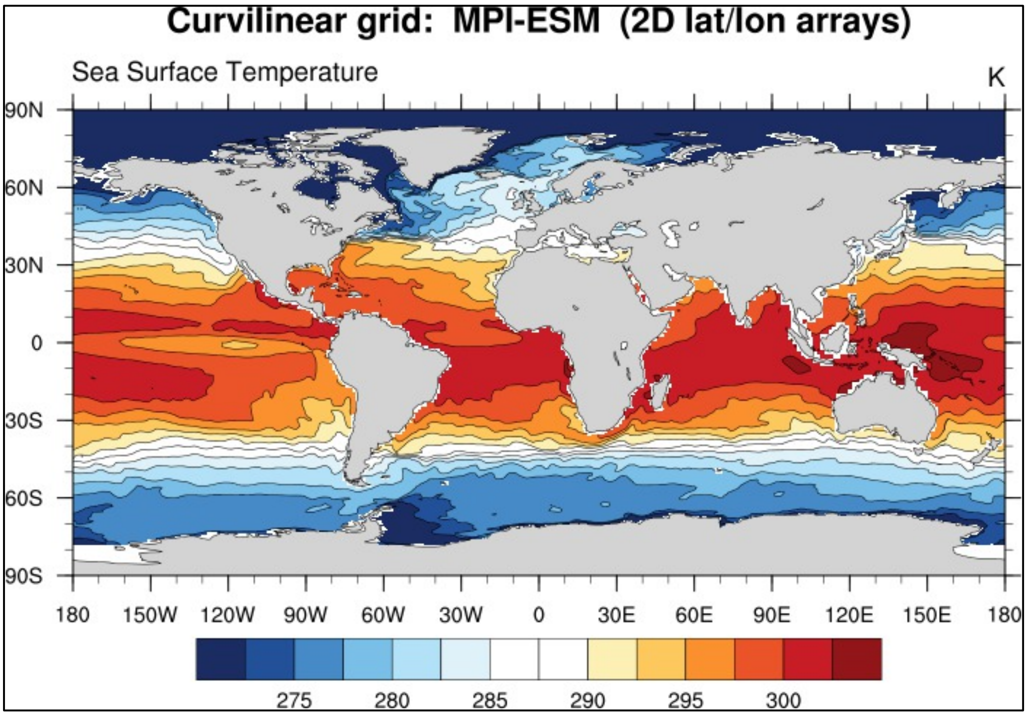
Curvilinear grids are those represented by two-dimensional latitude/longitude arrays. There are two methods plotting curvilinear grids. One method is to set the special sfXArray and sfYArray resources to the two-dimensional longitude and latitude arrays, respectively. A second method is to add attributes “lat2d” and “lon2d” to your data variable, and set them to the two-dimensional latitude and longitude arrays. If your data is regional, then you will also need to set gsnAddCyclic to False. Generally, the second method is preferred, because the first method doesn’t recognize the gsnAddCyclic resource.

The example script below will show you how to get a quick view of your curvilinear data file.

NUG_curvilinear_basic.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   diri = "./"
```

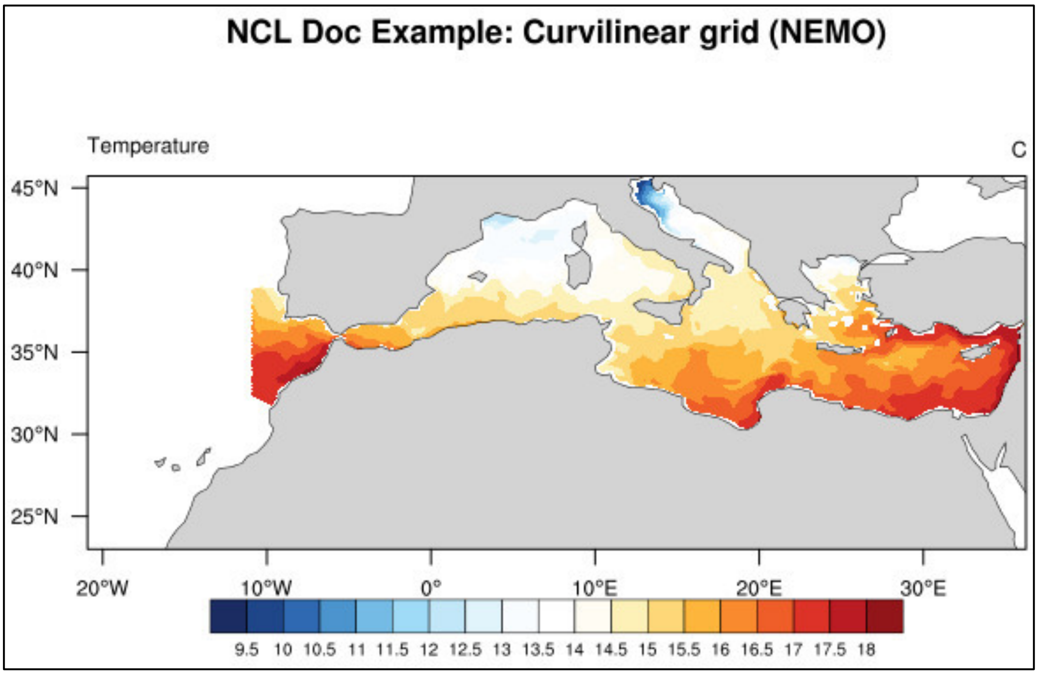
```
   fili = "tos_ocean_bipolar_grid.nc"

   f            =  addfile(diri+fili, "r")
   var          =  f->tos(0,:,:)
   var@lat2d    =  f->lat
   var@lon2d    =  f->lon

   wks = gsn_open_wks("png","plot_curvilinear_basic")

   res                          =  True        ;-- set resources
   res@gsnAddCyclic             =  False       ;-- lon < 360 degrees
   res@cnFillOn                 =  True        ;-- turn on contour fill
   res@cnFillPalette = "BlueWhiteOrangeRed" ;-- change color map

   res@tiMainString = "Curvilinear grid:  MPI-ESM  (2D lat/lon arrays)"

   plot = gsn_csm_contour_map(wks,var,res)           ;-- create the plot

end
```



Curvilinear grid example: NUG_curvilinear_grid.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   diri       = "./"
   fili       = "CNTASN_1m_200103_grid_T_curvilinear_grid.nc"
   f          =  addfile(diri+fili,"r")
   var        =  f->votemper(0,0,:,:)
   var@lat2d =  f->nav_lat                      ;-- 2D latitudes
   var@lon2d =  f->nav_lon                      ;-- 2D longitudes

;-- define the workstation (plot type and name)
```

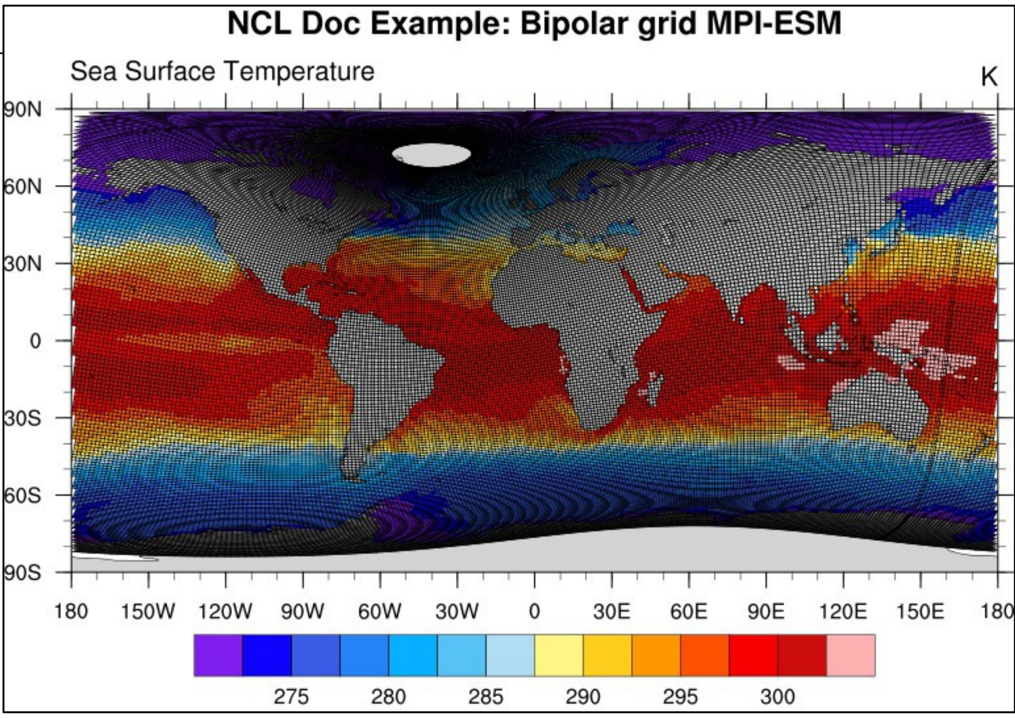
```
   wks = gsn_open_wks("png","plot_curvilinear_grid")

;-- set resources
   res                          =  True
   res@gsnAddCyclic             =  False          ;-- don't add lon cyclic point
   res@gsnMaximize              =  True

   res@cnFillOn                 =  True           ;-- turn on contour fill
   res@cnMinLevelValF           =   5.
   res@cnMinLevelValF           =  25.
   res@cnLevelSpacingF          =   0.5
   res@cnLinesOn                =  False
   res@tiMainString       = "NCL Doc Example: Curvilinear grid (NEMO)" ;-- title
   res@tiMainFontHeightF        =  0.02

;---Zoom in on map
   res@mpMinLatF                =  min(var@lat2d)
   res@mpMaxLatF                =  max(var@lat2d)
   res@mpMinLonF                =  min(var@lon2d)
   res@mpMaxLonF                =  max(var@lon2d)

   res@pmTickMarkDisplayMode = "Always"          ;-- nicer tickmarks

;-- draw the contour map
   plot = gsn_csm_contour_map(wks,var,res)

end
```



8.14.1 MPI-ESM-LR

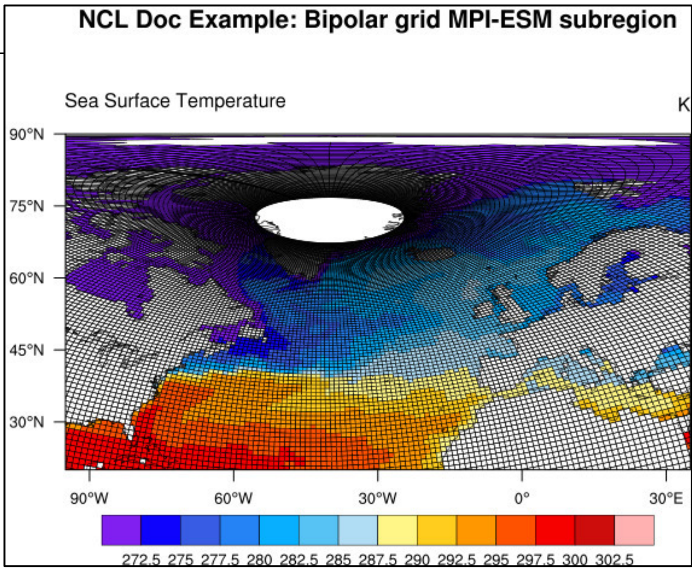
MPI-ESM bipolar grid example (MPI-OM TP04): NUG_bipolar_grid_MPI-ESM.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   diri = "./"
   fili = "tos_ocean_bipolar_grid.nc"

   f            =  addfile(diri+fili, "r")
   tos          =  f->tos
   tos@lat2d    =  f->lat
   tos@lon2d    =  f->lon
   var          =  tos(0,:,:)

;-- define the workstation (plot type and name)
   wks = gsn_open_wks("png","plot_bipolar_grid_MPI-ESM")

;-- set resources
   res                          =  True
   res@gsnMaximize              =  True
   res@gsnAddCyclic             =  True

   res@cnFillOn                 =  True             ;-- turn on contour fill
   res@cnFillPalette            = "ncl_default"
   res@cnFillMode               = "CellFill"
   res@cnLinesOn                =  False            ;-- Turn lines off
   res@cnLineLabelsOn           =  False            ;-- Turn labels off
   res@cnCellFillEdgeColor      = 1
   res@cnCellFillMissingValEdgeColor = "black"

   res@tiMainString      = "NCL Doc Example: Bipolar grid MPI-ESM"  ;-- title
   res@tiMainFontHeightF        =  0.02

;-- draw the contour map
   plot = gsn_csm_contour_map(wks,var,res)

end
```



Plot a sub-region of the MPI-ESM bipolar grid example (MPI-OM TP04):
NUG_bipolar_grid_MPI-ESM_subregion.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- read the data and define
   diri = "./"
   fili = "tos_ocean_bipolar_grid.nc"
   f = addfile(diri+fili,"r")

   tos        =  f->tos
   tos@lat2d  =  f->lat
   tos@lon2d  =  f->lon
   var        =  tos(0,:,:)                   ;-- select first time step

;-- define the workstation (plot type and name)
   wks = gsn_open_wks("png","bipolar_grid_MPI-ESM_subregion")

;-- set resources
   res                           =  True
   res@gsnMaximize               =  True      ;-- maximize plot output
   res@gsnAddCyclic              =  True      ;-- add cyclic point
   res@cnFillOn                  =  True      ;-- turn on contour fill
   res@cnFillMode                = "CellFill" ;-- fill mode
   res@cnFillPalette             = "ncl_default" ;-- choose a color map
   res@cnLinesOn                 =  False     ;-- turn lines off
   res@cnLineLabelsOn            =  False     ;-- turn labels off
   res@cnCellFillEdgeColor       = 1
   res@cnCellFillMissingValEdgeColor = "black" ;-- _FillValue color
   res@mpLimitMode               = "Corners"
   res@mpLeftCornerLonF          = -95.       ;-- min longitude
   res@mpRightCornerLonF         =  35.       ;-- max longitude
   res@mpLeftCornerLatF          =  20.       ;-- min latitude
   res@mpRightCornerLatF         =  90.       ;-- max latitude
   res@mpDataBaseVersion         = "MediumRes" ;-- map data base
   res@mpFillOn                  =  False     ;-- turn off map fill

   res@tiMainString              = "NCL Doc Example: Bipolar grid MPI-ESM"
   res@tiMainFontHeightF         =  0.02

;-- draw the contour map
   plot = gsn_csm_contour_map(wks,var,res)

end
```

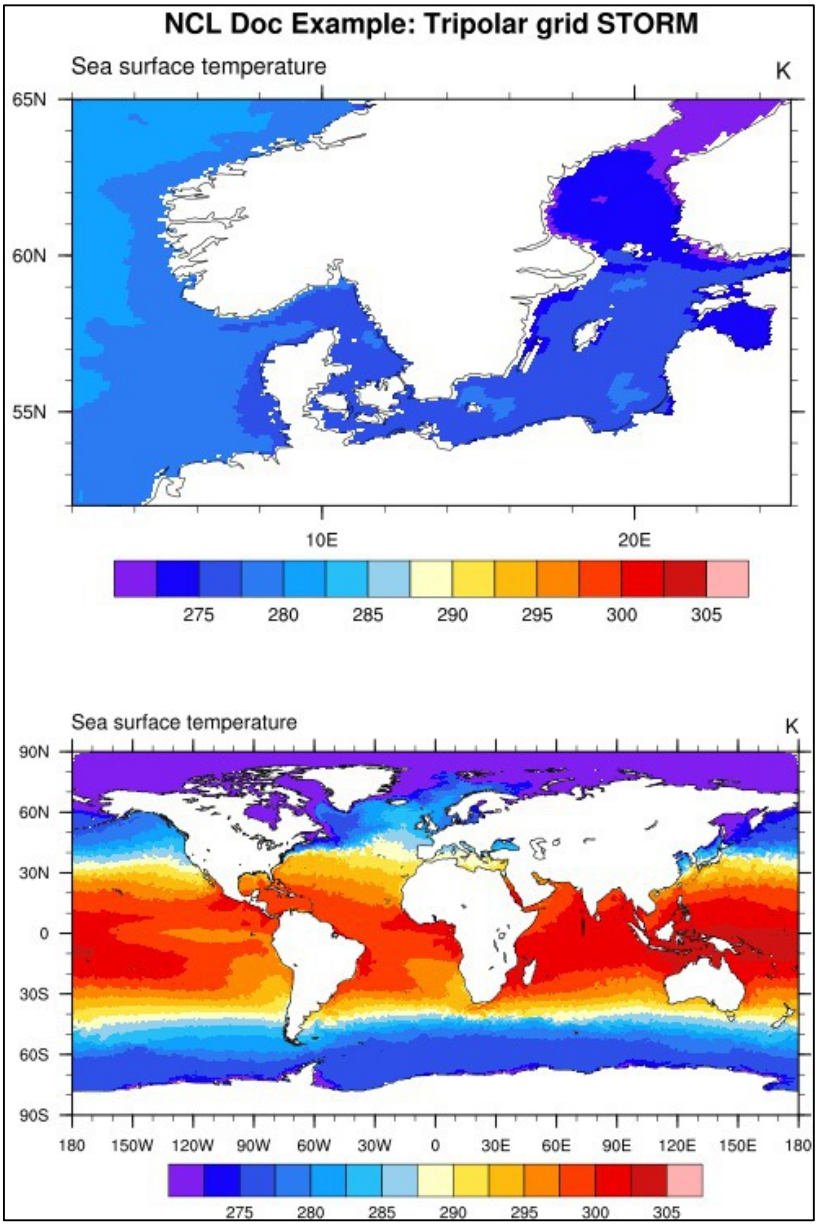


8.14.2 STORM

STORM: MPI-OM TP6M tripolar grid example: NUG_tripolar_grid_STORM.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   diri = "./"
   fili = "tripolar_grid_STORM.nc"

   f               = addfile(diri+fili, "r")
   var             =  f->sst(0,0,:,:)
   var@lat2d       =  f->lat
   var@lon2d       =  f->lon

;-- define the workstation (plot type and name)
   wks = gsn_open_wks("png","plot_tripolar_grid_STORM")

   plot = new(2,graphic)

;-- set resources
   res                          =  True
   res@gsnDraw                  =  False
   res@gsnFrame                 =  False
   res@gsnMaximize              =  True

   res@mpProjection             = "CylindricalEquidistant"   ;-- choose
                                                             ;-- projection
   res@mpDataBaseVersion        = "MediumRes"
   res@mpPerimOn                =  False           ;-- turn off box around plot
   res@mpFillOn                 =  False
   res@mpMinLonF                =   2.0
   res@mpMaxLonF                =  25.0
   res@mpMinLatF                =  52.0
   res@mpMaxLatF                =  65.0

   res@cnFillOn                 =  True            ;-- turn on contour fill
   res@cnFillMode               = "CellFill"
   res@cnLinesOn                =  False           ;-- Turn lines off
   res@cnLineLabelsOn           =  False           ;-- Turn labels off
   res@cnCellFillEdgeColor      =  -1
   res@cnCellFillMissingValEdgeColor = -1

   res@tiMainString       = "NCL Doc Example: Tripolar grid STORM"   ;-- title
   res@tiMainFontHeightF        =  0.02

;-- plot sub-region
   plot(0) = gsn_csm_contour_map(wks,var,res)

;-- plot all -180-180 deg.
   res@mpMinLonF                = -180.0
   res@mpMaxLonF                =  180.
   res@mpMinLatF                =  -90.
   res@mpMaxLatF                =   90.

   delete(res@cnCellFillEdgeColor)
   delete(res@cnCellFillMissingValEdgeColor)
   delete(res@tiMainString)

   res@cnCellFillEdgeColor      =  -1
   res@cnCellFillMissingValEdgeColor = -1
```

```
   plot(1) = gsn_csm_contour_map(wks,var,res)

;-- create panel plot
   gsn_panel(wks,plot,(/2,1/),False)
end
```

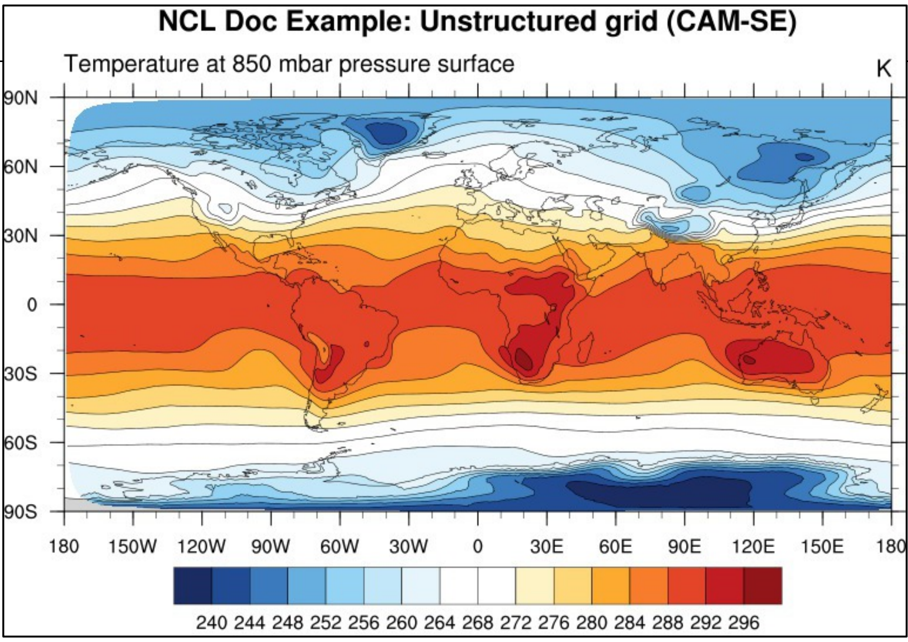


8.15 Unstructured Grids

Unstructured grids are typically defined as points or cells, and consist of one-dimensional arrays of values, latitude points, and longitude points. To plot this data correctly you need to set the special sfXArray and sfYArray resources to the one-dimensional longitude and latitude arrays, respectively.

Unstructured grid example: NUG_unstructured_grid.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   diri  = "./"
   fili  = "camse_unstructured_grid.nc"

   f      =  addfile(diri+fili, "r")
   var    =  f->T850
   lat1d =  f->lat
   lon1d =  f->lon


;-- define the workstation (plot type and name)
   wks = gsn_open_wks("png","plot_unstructured_grid_camse")

;-- set resources
   res                         =  True
   res@gsnMaximize             =  True

   res@cnFillOn                =  True              ;-- turn on contour fill
   res@cnFillPalette          = "BlueWhiteOrangeRed"  ;-- choose color map

   res@tiMainString = "NCL Doc Example: Unstructured grid (CAM-SE)" ;-- title
   res@tiMainFontHeightF      =  0.02

;---Lat/lon arrays of curvilinear grid for overlaying on map
   res@sfXArray                =  lon1d
   res@sfYArray                =  lat1d

;-- draw the contour map
   plot = gsn_csm_contour_map(wks,var,res)

end
```



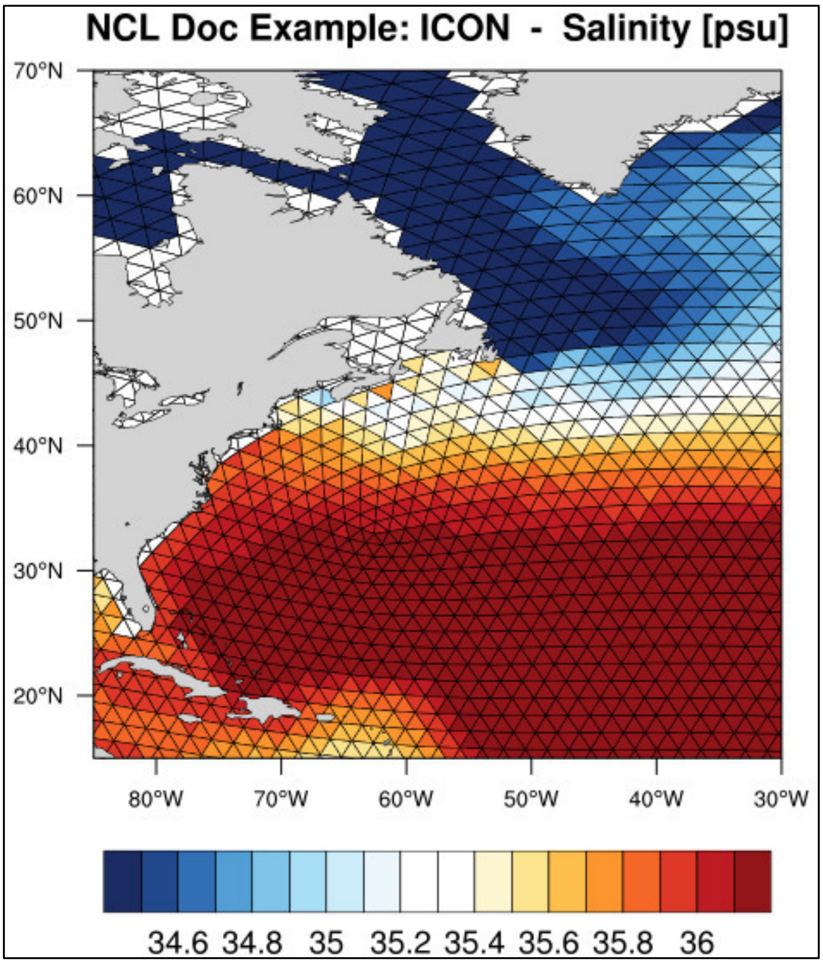
8.15.1 ICON

ICON icosahedral grid example: NUG_triangular_grid_ICON.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/shea_util.ncl"

begin
  start_code_time = get_cpu_time()

  diri = "./"
  fili = "triangular_grid_ICON.nc"
  f    = addfile(diri+fili, "r")
  var  = f->S(0,2,:)

  var@_FillValue = getVarFillValue(var)   ;-- retrieve missing value of var
  var_min  =  34.5                        ;-- minimum value to be displayed
  var_max  =  36.1                        ;-- maximum value to be displayed
  var_inc  =   0.1                        ;-- increment

  lon_min  = -85.0                        ;-- minimum longitude
  lon_max  = -30.0                        ;-- maximum longitude
  lat_min  =  15.0                        ;-- minimum latitude
  lat_max  =  70.0                        ;-- maximum latitude

  rad2deg = get_r2d("float")              ;-- radians to degrees
  x = f->clon * rad2deg                   ;-- cell center, lon
  y = f->clat * rad2deg                   ;-- cell center, lat

;-- if variable wet_c exist: create missing values with it:
  if (isfilevar(f,"wet_c")) then
     wet = f->wet_c(2,:)                          ;--  time=0, depth=0; cells
     var = where ( wet .ge. 0.01, var, -999.)
     var@_FillValue = -999.                       ;--  missing value
  else
     print("WARNING: variable wet_c doesn't exist  -->  no masking")
  end if

;-- calculate the latitude and longitude values
  vlon = f->clon_vertices * rad2deg
  vlon = where(vlon.lt.0, vlon + 360, vlon)       ;-- lon: 0 - 360
  vlat = f->clat_vertices * rad2deg

  wks = gsn_open_wks("png", "plot_ICON_data")     ;-- open a workstation

  res                        =  True
  res@gsnDraw                =  False      ;-- don't draw the plot yet
  res@gsnFrame               =  False      ;-- don't advance the frame
  res@gsnLeftString          = ""          ;-- don't add variable name to plot
  res@gsnRightString         = ""          ;-- don't add units to plot
  res@gsnMaximize            =  True       ;-- maximize plot output

  res@tiMainString     = "NCL Doc Example: ICON  -  Salinity [psu]" ;-- title
  res@tiMainFontHeightF      =  0.02
  res@pmTitleZone            =  2

  res@mpFillOn               =  True       ;-- fill map grey
  res@mpFillDrawOrder        = "PostDraw" ;-- draw map outline at last
  res@mpDataBaseVersion      = "MediumRes" ;-- map resolution
  res@mpMinLonF              =  lon_min    ;-- sub-region minimum longitude
  res@mpMaxLonF              =  lon_max    ;-- sub-region maximum longitude
  res@mpMinLatF              =  lat_min    ;-- sub-region minimum latitude
  res@mpMaxLatF              =  lat_max    ;-- sub-region maximum latitude
```

```
  res@mpGreatCircleLinesOn   =  True        ;-- important

  res@sfXArray               =  x           ;-- longitude grid cell center
  res@sfYArray               =  y           ;-- latitude grid cell center

  res@cnFillOn               =  True        ;-- contour fill
  res@cnFillPalette          = "BlueWhiteOrangeRed" ;-- choose color map
  res@cnLinesOn              =  False       ;-- don't draw contour lines
  res@cnFillMode             = "RasterFill" ;-- contour fill mode
  res@cnLevelSelectionMode   = "ManualLevels" ;-- set manual contour levels
  res@cnMinLevelValF         =  var_min     ;-- set min contour level
  res@cnMaxLevelValF         =  var_max     ;-- set max contour level
  res@cnLevelSpacingF        =  var_inc     ;-- set increment

  res@pmTickMarkDisplayMode = "Always"      ;-- nicer tickmarks

  plot = gsn_csm_contour_map(wks,var,res)   ;-- create the plot, but don't
                                            ;-- draw it

;-- retrieve contour level and color informations
  getvalues plot@contour
     "cnLevels"     : levels                ;-- # 26 (n)
     "cnFillColors" : colors                ;-- # 27 (n+1)
  end getvalues

  plot = setColorContourClear(plot,min(var),max(var)) ;-- clear plot, but
                                            ;-- keep all the information

;-- create color array for triangles
  ntri     = dimsizes(y)                    ;-- Number of triangles
  gscolors = new(ntri,integer)
  gscolors = -1                             ;-- Initialize to transparent

;-- set resources for the triangles (polygons)
  pres                       =  True
  pres@gsEdgesOn             =  True        ;-- turn on edges
  pres@gsFillIndex           =  0           ;-- solid fill

;-- set color for data less than given minimum value var_min
  vlow = ind(var .lt. levels(0)) ;-- get the indices of values less levels(0)
  gscolors(vlow) = colors(0)                ;-- choose color
  ntri_calc = dimsizes(vlow)                ;-- number of triangles

;-- set colors for all cells in between var_min and var_max
  do i = 1, dimsizes(levels) - 1
     vind := ind(var .ge. levels(i-1) .and. var .lt. levels(i)) ;-- get the
                                            ;-- indices of 'middle' values
     gscolors(vind) = colors(i)             ;-- choose the colors
     ntri_calc = ntri_calc + dimsizes(vind) ;-- number of triangles
  end do

;-- set color for data greater than given maximum var_max
  nc=dimsizes(colors)-1               ;-- get the number of colors minus one
  nl=dimsizes(levels)-1               ;-- get the number of levels minues one
  vhgh := ind(var .gt. levels(nl))    ;-- get indices of values greater
                                      ;-- levels(nl)
  gscolors(vhgh) = colors(nc)         ;-- choose color
  ntri_calc = ntri_calc + dimsizes(vhgh)    ;-- number of triangles

  print("--> triangles calculated:  "+ ntri_calc)

;-- Attach all the triangles using the list of colors
```

```
  pres@gsColors    = gscolors
  pres@gsSegments = ispan(0,dimsizes(var) * 3,3)  ;-- assign segments array
  polygon = gsn_add_polygon(wks,plot,ndtooned(vlon),ndtooned(vlat),pres)
                                                  ;-- draw all triangles

  draw(plot)            ;-- draw plot and attached filled triangles
  frame(wks)            ;-- advance the frame

  end_code_time = get_cpu_time()
  print("--> Elapsed time in CPU seconds: " + (end_code_time-
start_code_time))
end
```



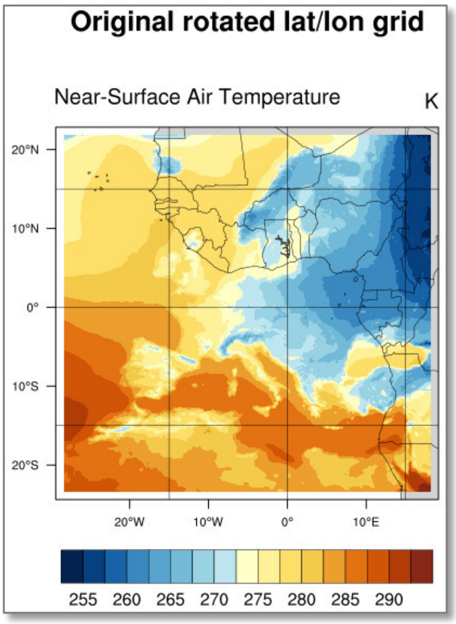
8.16 Rotated Grids

Some models compute their data on a rotated latitude-longitude grid, which means that the poles of the grid are shifted. The information about the rotation is sometimes stored in the netCDF or GRIB file, for example, as attributes called "Longitude_of_southern_pole" and "Latitude_of_southern_pole" or "grid_north_pole_longitude" and "grid_north_pole_latitude".

The output of the 'ncdump –h' command of a rotated grid file, here CORDEX EUR-11:

```
> ncdump -h tas_rotated_grid_EUR11.nc
netcdf tas_rotated_grid_EUR11 {
dimensions:
      rlon = 424 ;
      rlat = 412 ;
      height = 1 ;
      time = UNLIMITED ; // (60 currently)
      tbnds = 2 ;
variables:
      double rlon(rlon) ;
            rlon:standard_name = "grid_longitude" ;
            rlon:long_name = "rotated longitude" ;
            rlon:units = "degrees" ;
            rlon:axis = "X" ;
      double rlat(rlat) ;
            rlat:standard_name = "grid_latitude" ;
            rlat:long_name = "rotated latitude" ;
            rlat:units = "degrees" ;
            rlat:axis = "Y" ;
      char rotated_pole ;
            rotated_pole:grid_mapping_name = "rotated_latitude_longitude" ;
            rotated_pole:grid_north_pole_latitude = 39.25 ;
            rotated_pole:grid_north_pole_longitude = -162. ;
      double height(height) ;
            height:standard_name = "height" ;
            height:long_name = "height" ;
            height:units = "m" ;
            height:positive = "up" ;
            height:axis = "Z" ;
      double time(time) ;
            time:standard_name = "time" ;
            time:bounds = "time_bnds" ;
            time:units = "days since 1949-12-01 00:00:00" ;
            time:calendar = "proleptic_gregorian" ;
            time:long_name = "time" ;
      double time_bnds(time, tbnds) ;
            time_bnds:units = "days since 1949-12-01 00:00:00" ;
            time_bnds:long_name = "time bounds" ;
      float tas(time, height, rlat, rlon) ;
            tas:standard_name = "air_temperature" ;
            tas:long_name = "Near-Surface Air Temperature" ;
            tas:units = "K" ;
            tas:grid_mapping = "rotated_pole" ;
            tas:original_name = "T_2M" ;
            tas:cell_methods = "time: mean" ;
            tas:_FillValue = 1.e+20f ;
            tas:missing_value = 1.e+20f ;
```

If you try to plot this data using the given rlat/rlon grid it will incorrectly show you that the map sub-region is west of Africa and not in the correct part of Europe.



8.16.1 Plotting on the native grid

One of the keys to plotting rotated grids correctly on their native map projection is that you must know the correct center longitude and latitude of the data. This information may appear as metadata in your NetCDF or GRIB file, for example, as attributes "grid_north_pole_latitude" and "grid_north_pole_longitude" attached to a variable called "rotated_pole". To get the center lat/lon rotation correct in NCL, the formula for this grid is:

```
  res@mpCenterLatF =  90 - rotated_pole@grid_north_pole_latitude
  res@mpCenterLonF = 180 + rotated_pole@grid_north_pole_longitude
```

The first frame of the example below sets the *tfDoNDCOverlay* resource to True to tell NCL we are plotting the data natively. No data transformation will take place.

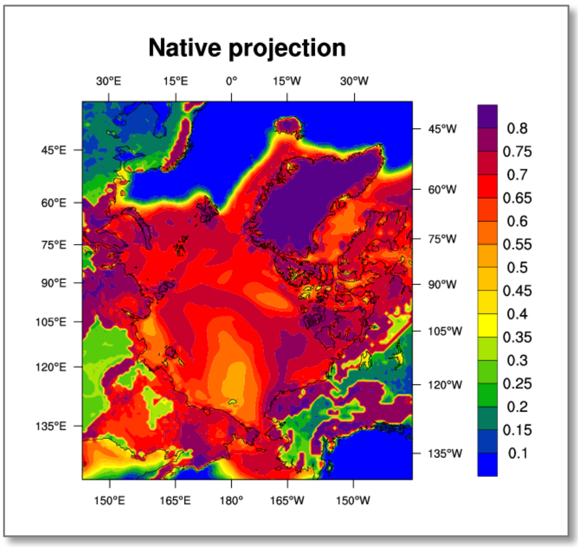
The second frame shows how to plot the data using the 2D lat/lon coordinates provided on the file. This data is plotted over a polar stereographic projection over the North Pole.

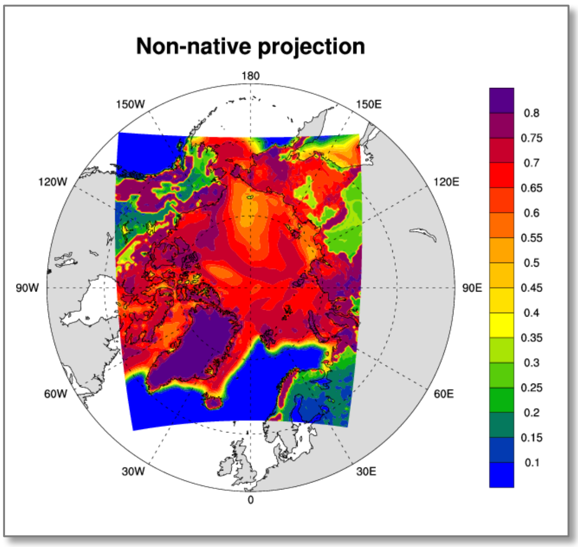
rotatedltln_2.ncl (from the NCL Examples web page http://ncl.ucar.edu/Applications/rotatedltln.shtml):

```
;*****************************************************
; rotatedltln_2.ncl
;
; Concepts illustrated:
;   - Drawing filled contours over a rotated lat-lon grid
;   - Drawing a map using the medium resolution map outlines
;   - Overlaying contours on a map without having lat,lon coordinates
;   - Overlaying contours on a map using lat,lon coordinates
;*****************************************************
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  albedo_filename      = "albedo_a.nc"
  albedo_grid_filename = "albedo_a_curvilinear.nc"

  f1 = addfile(albedo_filename,"r")
  f2 = addfile(albedo_grid_filename,"r")
```

```
;---Variable to plot
  sbt = f1->var242

;---Needed for getting the projection parameters in plot.
  lat2d          = f2->lat
  lon2d          = f2->lon
  north_pole_lat = f1->rotated_pole@grid_north_pole_latitude   ; 6.55
  north_pole_lon = f1->rotated_pole@grid_north_pole_longitude  ; 0.0

  nlat  = dimsizes(lat2d(:,0))
  nlon  = dimsizes(lon2d(0,:))

;----------------------------------------------------------------------
; Start the graphics section
;----------------------------------------------------------------------
  wks  = gsn_open_wks("png", "rotatedltln")

;---Set resources common to both types of plots we plan to create

  res                          = True             ; plot mods desired

  res@gsnMaximize              = True             ; maxmize plot in frame

  res@cnFillOn                 = True             ; turn on color
  res@cnLinesOn                = False            ; no contour lines
  res@cnLineLabelsOn           = False            ; no contour labels
  res@cnFillPalette            = "BlGrYeOrReVi200"
  res@lbOrientation            = "Vertical"       ; vertical labelbar
  res@pmLabelBarOrthogonalPosF = 0.18             ; move lbar away from plot

  res@mpDataBaseVersion        = "MediumRes"      ; use finer database

  res@gsnAddCyclic             = False

;------------------------------------------------------------
; First frame: use native projection information to plot
; the data.
;------------------------------------------------------------
  res_native = res      ; Copy over common resources.
;
; Setting tfDoNDCOverlay to True means you have specified the
; exact projection that your data is on, and thus no data
; transformation takes place when the contours are overlaid
; on the map.
;
  res_native@tfDoNDCOverlay         = True
  res_native@mpLimitMode            = "Corners"
  res_native@mpLeftCornerLatF       = lat2d(0,nlon-1)
  res_native@mpLeftCornerLonF       = lon2d(0,nlon-1)
  res_native@mpRightCornerLatF      = lat2d(nlat-1,0)
  res_native@mpRightCornerLonF      = lon2d(nlat-1,0)

  res_native@tiMainString           = "Native projection"
  res_native@pmTickMarkDisplayMode  = "always"

  res_native@mpCenterLatF        =  90 - north_pole_lat
                                                     ; north_pole_lat=6.55
  res_native@mpCenterLonF        = 180 + north_pole_lon  ; north_pole_lon=0

  plot_native = gsn_csm_contour_map (wks,sbt(0,0,:,:),res_native)
```

```
;---------------------------------------------------------------
; Second frame: use lat2d/lon2d coordinates to plot
; the data.
;---------------------------------------------------------------
  res_nonnative = res   ; Copy over common resources
  res_nonnative@sfXArray                = lon2d    ; needed for non-native
  res_nonnative@sfYArray                = lat2d    ; contouring
  res_nonnative@gsnPolar                = "NH"
  res_nonnative@mpMinLatF               = min(lat2d)
  res_nonnative@pmLabelBarOrthogonalPosF = 0.05
  res_nonnative@tiMainString            = "Non-native projection"

  plot_nonnative = gsn_csm_contour_map (wks,sbt(0,0,:,:),res_nonnative)

end
```





8.16.2 Transform rotated to unrotated lat-lon grid

Another way to plot the data on an unrotated grid is to compute the transformation of the rotated to the unrotated grid. In the next example the input data file contains one-dimensional latitude and longitude arrays, which will be used to create the two-dimensional arrays for the unrotated latitudes and longitudes using the rotated pole information.

The upper figure zooms into the map using a Cylindrical Equidistant projection and the lower figure shows the data with an Orthographic projection.

NUG_plot_rotated_grid.ncl:

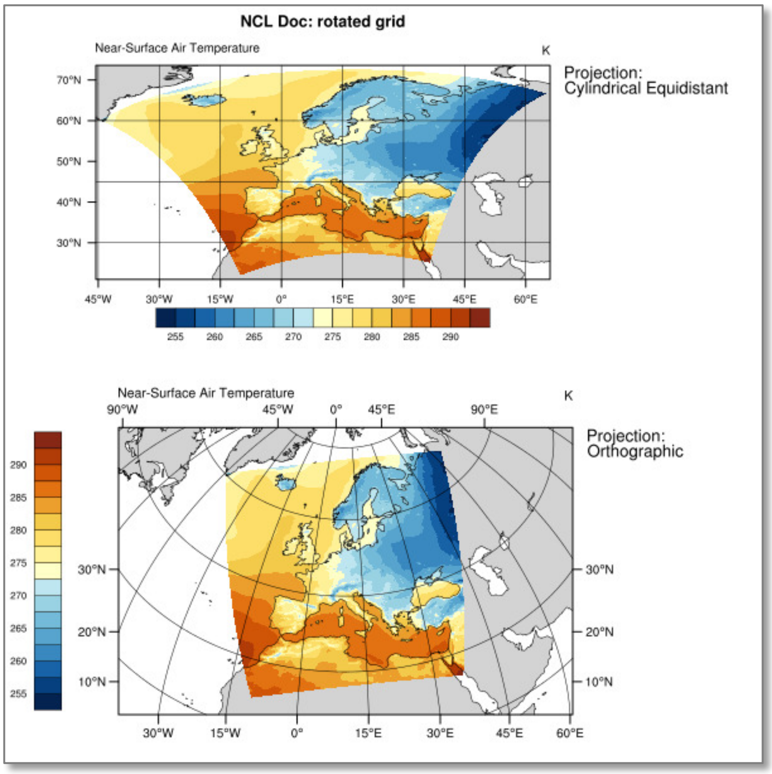
```
;---------------------------------------------------------------
;-- set global constants
;---------------------------------------------------------------
deg2rad  =  get_d2r("float")
rad2deg  =  get_r2d("float")
fillval  = -99999.9

;---------------------------------------------------------------
;-- Function:      unrot_lon(rotlat,rotlon,pollat,pollon)
;-- Description:   transform rotated longitude to longitude
;---------------------------------------------------------------
undef("unrot_lon")
function unrot_lon( rotlat:numeric, rotlon:numeric, pollat[1]:numeric,
```

```
pollon[1]:numeric )
local rotlat,rotlon,nrlat,nrlon,nrlat_rank,nrlon_rank,pollon,pollat, \
      lon, s1, c1, s2, c2, rlo, rla, i, tmp1, tmp2
begin
  lon = fillval
  lon@_FillValue = fillval

  nrlat      = dimsizes(rotlat)
  nrlon      = dimsizes(rotlon)
  nrlat_rank = dimsizes(nrlat)
  nrlon_rank = dimsizes(nrlon)

  if (any(nrlat.ne.nrlon).and.(nrlat_rank.ne.1.or.nrlon_rank.ne.1)) then
      print("Function unrot_lon: unrot_lon:  rotlat and rotlon dimensions
do not match")
    return(lon)
  end if

  if (nrlat_rank.eq.1 .and. nrlon_rank.eq.1) then
    rla = conform_dims((/nrlat,nrlon/),rotlat,0) ;-- create 2D lat array
    rlo = conform_dims((/nrlat,nrlon/),rotlon,1) ;-- create 2D lonarray
  else
    rla = rotlat
    rlo = rotlon
  end if

  rla = rla*deg2rad                      ;-- convert from degree to radians
  rlo = rlo*deg2rad                      ;-- convert from degree to radians

  lon := (/rlo/)                         ;-- reassign lon
  lon@_FillValue=fillval

  s1   = sin(pollat*deg2rad)
  c1   = cos(pollat*deg2rad)
  s2   = sin(pollon*deg2rad)
  c2   = cos(pollon*deg2rad)

  tmp1 = s2*(-s1*cos(rlo)*cos(rla)+c1*sin(rla))-c2*sin(rlo)*cos(rla)
  tmp2 = c2*(-s1*cos(rlo)*cos(rla)+c1*sin(rla))+s2*sin(rlo)*cos(rla)

  lon  = atan(tmp1/tmp2)*rad2deg
  lon@units = "degrees_east"
  print("Function unrot_lon: min/max     "+sprintf("%8.4f",
min(lon(0,:)))+\
        "  "+sprintf("%8.4f", max(lon(0,:))))

  delete([/rlo,rlo,c1,s1,c2,s2,tmp1,tmp2/])

  return(lon)
end

;-------------------------------------------------------------
;-- Function:      unrot_lat(rotlat,rotlon,pollat,pollon)
;-- Description:   transform rotated latitude to latitude
;-------------------------------------------------------------
undef("unrot_lat")
function unrot_lat( rotlat:numeric, rotlon:numeric, pollat[1]:numeric,
pollon[1]:numeric )
local rotlat,rotlon,nrlat,nrlon,nrlat_rank,nrlon_rank,pollon,pollat, \
      lat, s1, c1, rlo, rla, i
begin
  lat = fillval
```

```
  lat@_FillValue = fillval

  nrlat      = dimsizes(rotlat)
  nrlon      = dimsizes(rotlon)
  nrlat_rank = dimsizes(nrlat)
  nrlon_rank = dimsizes(nrlon)

  if (any(nrlat.ne.nrlon).and.(nrlat_rank.ne.1 .or. nrlon_rank.ne.1)) then
    print("Function unrot_lat:  rotlat and rotlon dimensions do not match")
    return(lat)
  end if

  if (nrlat_rank.eq.1 .and. nrlon_rank.eq.1) then
    rla = conform_dims((/nrlat,nrlon/),rotlat,0)    ;-- create 2D lat array
    rlo = conform_dims((/nrlat,nrlon/),rotlon,1)    ;-- create 2D lon array
  else
    rla = rotlat
    rlo = rotlon
  end if

  rla = rla*deg2rad                           ;-- convert from degree to radians
  rlo = rlo*deg2rad                           ;-- convert from degree to radians

  lat := (/rla/)                              ;-- reassign lat
  lat@_FillValue=fillval

  s1  = sin(pollat*deg2rad)
  c1  = cos(pollat*deg2rad)

  lat = s1*sin(rla)+c1*cos(rla)*cos(rlo)
  lat = asin(lat)*rad2deg

  lat@units = "degrees_north"
  print("Function unrot_lat: min/max     "+sprintf("%8.4f",
min(lat(:,0)))+\
        "  "+sprintf("%8.4f", max(lat(:,0))))

  delete([/rlo,rla,c1,s1/])

  return(lat)
end


;----------------
;--  MAIN
;----------------
begin
;-- open file and read variables
  diri    = "../data/"
  fili    = "tas_rotated_grid_EUR11.nc"
  f       =  addfile(diri+fili,"r")
  var     =  f->tas
  rlat    =  f->rlat
  rlon    =  f->rlon
  rotpole =  f->rotated_pole
  pollat  =  rotpole@grid_north_pole_latitude
  pollon  =  rotpole@grid_north_pole_longitude

;-- unrotate the grid and set 2D lat/lons
  var@lon2d      =  unrot_lon(rlat, rlon, pollat, pollon)
  var@lat2d      =  unrot_lat(rlat, rlon, pollat, pollon)
```

```
;-- calculate the min and max lat/lons for the map plot
  minlat  =  min(var@lat2d)            ;-- retrieve minimum latitude value
  minlon  =  min(var@lon2d)            ;-- retrieve maximum latitude value
  maxlat  =  max(var@lat2d)            ;-- retrieve minimum longitude value
  maxlon  =  max(var@lon2d)            ;-- retrieve maximum longitude value

;-- open a workstation
  wks_type           = "png"
  wks_type@wkWidth   =  1024
  wks_type@wkHeight  =  1024
  wks = gsn_open_wks(wks_type,"plot_rotated_grid")

;-- set resources
  res                        =  True
  res@gsnFrame               =  False         ;-- don't advance frame
  res@gsnAddCyclic           =  False         ;-- don't add lon cyclic point

  res@pmTickMarkDisplayMode = "Always"        ;-- draw nicer tickmarks

  res@mpDataBaseVersion      = "MediumRes"    ;-- choose map database
  res@mpMinLatF              =  minlat - 1.   ;-- set min lat
  res@mpMaxLatF              =  maxlat + 1.   ;-- set max lat
  res@mpMinLonF              =  minlon - 1.   ;-- set min lon
  res@mpMaxLonF              =  maxlon + 1.   ;-- set max lon
  res@mpGridAndLimbOn        =  True          ;-- turn on grid lines

  res@cnFillOn               =  True          ;-- turn on contour fill
  res@cnLinesOn              =  False         ;-- don't draw contour lines
  res@cnFillPalette          = "BlueYellowRed" ;-- choose color map

  res@lbLabelBarOn           =  True          ;-- turn on labelbar

  res@tiMainString           = "NCL Doc: rotated grid"  ;-- title
  res@tiMainOffsetYF         = -0.025         ;-- move title downward

  res@vpWidthF               =  0.6           ;-- width of viewport
  res@vpHeightF              =  0.48          ;-- height of viewport

;-- create the first plot
  res@vpXF                   =  0.12          ;-- start x-position
  res@vpYF                   =  1.02          ;-- start y-Position

  plot1 = gsn_csm_contour_map(wks,var(0,0,:,:),res)
                                          ;-- use default projection (CE)

;-- create the second plot
  delete(res@tiMainString)                ;-- we don't need the title twice

  res@vpXF                   =  0.15          ;-- start x-position
  res@vpYF                   =  0.493         ;-- start y-position

  res@mpProjection           = "Orthographic" ;-- change projection
  res@mpCenterLatF           =  minlat+(maxlat-minlat)/2
                                     ;-- center point of view latitude
  res@mpCenterLonF           =  minlon+(maxlon-minlon)/2
                                     ;-- center point of view longitude
  res@mpLimitMode            = "LatLon"       ;-- map limits mode
  res@mpMinLatF              =  minlat - 1.   ;-- set min lat
  res@mpMaxLatF              =  maxlat + 1.   ;-- set max lat
  res@mpMinLonF              =  minlon - 1.   ;-- set min lon
  res@mpMaxLonF              =  maxlon + 1.   ;-- set max lon
  res@mpPerimOn              =  False ;-- don't draw the box around the plot
```

```
  res@lbOrientation          = "vertical"    ;-- vertical label bar
  res@lbLabelStride          =  2
  res@lbLabelPosition        = "Left"        ;-- labelbar labels on left side
  res@pmLabelBarOrthogonalPosF = -1.37       ;-- labelbar on the left side

  res@tmXTLabelDeltaF        = -0.5          ;-- decrease space between ticks
                                             ;   and labels
  res@tmXBLabelDeltaF        = -0.5          ;-- decrease space between ticks
                                             ; and labels
  res@tmYLLabelDeltaF        = -0.5          ;-- decrease space between ticks
                                             ; and labels
  res@tmYRLabelDeltaF        = -0.5          ;-- decrease space between ticks
                                             ; and labels

  plot2 = gsn_csm_contour_map(wks,var(0,0,:,:),res)     ;-- draw second plot

;-- draw text
  txres                 =  True
  txres@txFontHeightF   =  0.016
  txres@txJust          = "CenterLeft"

  gsn_text_ndc(wks,"Projection:",              0.74, 0.91, txres)
                                              ;-- next to first plot
  gsn_text_ndc(wks,"Cylindrical Equidistant", 0.74, 0.89, txres)

  gsn_text_ndc(wks,"Projection:",  0.77, 0.43, txres)
                                              ;-- next to second plot
  gsn_text_ndc(wks,"Orthographic", 0.77, 0.41, txres)

;-- advance the frame
  frame(wks)

end
```



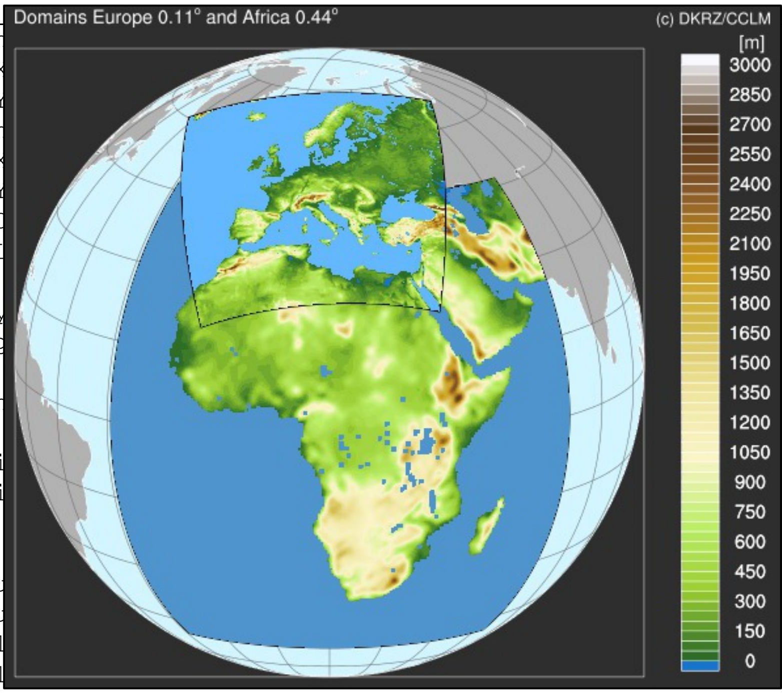
8.17 Globe with different grid resolutions

A very special kind of plot is the following example, which shows two regional model domains with different grid resolutions mapped onto one globe. The background color of the plotting frame is changed to dark grey and the foreground color to white. One single color map is used to visualize the orography in both model domains, while two different shades of blue are used for the water areas of the two data sets in order to make the grids more distinguishuable. This is a good demonstration of the capabilities of NCL graphics.

Globe with different grid resolutions example: NUG_globe_orography_grid_resolution.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri = "./"
  fil1 = "HSURF_regional_model_0.11deg.nc"
  fil2 = "FR-LAND_regional_model_0.11deg.nc"
  fil3 = "HSURF_regional_model_0.44deg.nc"
  fil4 = "FR-LAND_regional_model_0.44deg.nc"

  f1           = addfile(diri+fil1,"r")
  var1         = f1->HSURF(0,:,:)
  mask1        = addfile(diri+fil2,"r")
  lsm1         = mask1->FR_LAND(0,:,:)
  lsm1         = where(lsm1.gt.0.5,-9999,lsm1)
  land_only1   = var1
  land_only1   = mask(var1,lsm1,-9999)

  f2           = addfile(diri+fil3,"r")
  var2         = f2->HSURF(0,:,:)
  mask2        = addfile(diri+fil4,"r")
  lsm2         = mask2->FR_LAND(0,:,:)
  lsm2         = where(lsm2.gt.0.5,-9999,lsm2)
  land_only2   = var2
  land_only2   = mask(var2,lsm2,-9999)

  lat2d        = f1->lat
  lon2d        = f1->lon
  nlat         = dimsizes(lat2d(:,0))
  nlon         = dimsizes(lon2d(0,:))

;-- open workstation
  wks_type                         = "png"
  wks_type@wkBackgroundColor       = "grey18"
  wks_type@wkForegroundColor       = "white"
  wks = gsn_open_wks(wks_type, "plot_globe_orography_grid_resolution")

;-- global resources
  res                              = True
  res@gsnDraw                      = False
  res@gsnFrame                     = False

;-- map resources
  mpres                            = res
  mpres@mpProjection               = "Orthographic"
  mpres@mpLabelsOn                 = False
  mpres@mpPerimOn                  = True
  mpres@mpGridLineColor            = "grey40"
  mpres@mpGridAndLimbOn            = True
  mpres@mpFillOn                   = True
```

```
  mpres@mpOutlineOn             = True
  mpres@mpOutlineDrawOrder      = "PostDraw"
  mpres@mpFillDrawOrder         = "PreDraw"
  mpres@mpOceanFillColor        = (/ 0.824, 0.961, 1.0 /)
  mpres@mpLandFillColor         = (/ 0.7, 0.7, 0.7 /)
  mpres@mpCenterLatF            = 15.
  mpres@mpCenterLonF            = 15.

  map   = gsn_csm_map(wks,mpres)

;-- AFR-44
  cnres2                        =  res
  cnres2@cnFillOn               =  True
  cnres2@cnMissingValFillColor  = "steelblue3"
  cnres2@cnLinesOn              =  False
  cnres2@cnLineLabelsOn         =  False
  cnres2@cnLevelSelectionMode   = "ManualLevels"
  cnres2@cnMinLevelValF         =  0.0
  cnres2@cnMaxLevelValF         =  3000.
  cnres2@cnLevelSpacingF        =  50.
  cnres2@cnFillPalette          = "OceanLakeLandSnow"
  cnres2@cnFillDrawOrder        = "PostDraw"
  cnres2@gsnRightString         = ""
  cnres2@gsnLeftString          = ""
  cnres2@lbOrientation          = "vertical"
  cnres2@lbLabelFontHeightF     =  0.013
  cnres2@tiXAxisString          = ""
  cnres2@tiYAxisString          = ""

  plot2 = gsn_csm_contour(wks,land_only2,cnres2)

;-- overlay Africa
  overlay(map,plot2)

;-- polyline resources
  resl                          =  True
  resl@gsLineThicknessF         =  2.0
  resl@gsLineColor              = "black"

;-- plot the box around the data field
  xbox = (/-29.04, 64.68, 64.68, -29.04, -29.04/)
  ybox = (/-50.16, -50.16, 46.64, 46.64, -50.16/)
  dum1 = gsn_add_polyline(wks, plot2, xbox, ybox, resl)

;-- delete unnecessary things
  delete([/resl,cnres2,var2,mask2,lsm2,land_only2/])

;-- EUR-11
  cnres                         =  res
  cnres@cnFillOn                =  True              ; turn on color
  cnres@cnMissingValFillColor   = "steelblue1"
  cnres@cnLinesOn               =  False             ; no contour lines
  cnres@cnLineLabelsOn          =  False             ; no contour labels
  cnres@cnLevelSelectionMode    = "ManualLevels"     ; set manually levels
  cnres@cnMinLevelValF          =  0.0               ; minimum contour level
  cnres@cnMaxLevelValF          =  3000.             ; maximum contour level
  cnres@cnLevelSpacingF         =  50.               ; contour level spacing
  cnres@cnFillPalette           = "OceanLakeLandSnow"
  cnres@cnFillDrawOrder         = "PostDraw"
  cnres@gsnRightString          = "["+var1@units+"]"
  cnres@gsnRightStringFontHeightF    =  0.013
  cnres@gsnRightStringParallelPosF   =  1.19
```




```
  cnres@gsr
  cnres@tiX
  cnres@tiY
  cnres@gsr
  cnres@sfX
  cnres@sfY
  cnres@lbC
  cnres@lbI

;-- overlay
  plot1 = g

;-- polylir
  resl
  resl@gsLi
  resl@gsLi

;-- define
  lon_val_u
  lat_val_u
  lon_val_l
  lat_val_l
  lon_val_left  = lon2d(:,0)
  lat_val_left  = lat2d(:,0)
  lon_val_right = lon2d(:,nlon-1)
  lat_val_right = lat2d(:,nlon-1)

;-- draw edges
  upper = gsn_add_polyline(wks, plot1, lon_val_upper, lat_val_upper, resl)
  lower = gsn_add_polyline(wks, plot1, lon_val_lower, lat_val_lower, resl)
  left  = gsn_add_polyline(wks, plot1, lon_val_left,  lat_val_left,  resl)
  right = gsn_add_polyline(wks, plot1, lon_val_right, lat_val_right, resl)

  overlay(map,plot1)

;-- draw title strings
  str = "Domains Europe 0.11~S~o~N~ and Africa 0.44~S~o~N~"
  txres                         =  True
  txres@txFontHeightF           =  0.013
  txres@txJust                  = "BottomLeft"
  gsn_text_ndc(wks, str, 0.20, 0.82, txres)

  txres@txJust                  = "BottomRight"
  txres@txFontHeightF           =  0.011
  str = "(c) DKRZ/CCLM"
  gsn_text_ndc(wks,str, 0.92, 0.82, txres)

;-- draw the frame
  draw(map)
  frame(wks)

end
```

8.18 Helpful Resources

Many NCL resources were used to modify the NCL graphics to get the desired result for the plot layout.

For example:

```
res                        =  True  ; create a resource object list
res@cnFillOn               =  True
res@tiMainFontHeightF =  0.02
res@mpProjection        = "Mollweide"
```

The first two lowercase letters are the abbreviation of the resource type.

Resource types:

am	Annotation Manager (AnnoManager)
app	App (App)
ca	Coordinate Array (CoordArrays)
cn	Contour (ContourPlot)
ct	Coordinate Array Table (CoordArrTable)
dc	Data Comm (DataComm)
err	Error
gs	Graphic Style (GraphicStyle)
gsn	GSN High-level Interfaces (GSN)

lb	Label Bar (LabelBar)
lg	Legends (Legend)
mp	Maps (MapPlot and MapTransformation)
pm	Plot Manager (PlotManager)
pr	Primitives (Primitive)
sf	Scalar Field (ScalarField and MeshScalarField)
st	Streamline (StreamlinePlot)
tf	Transform
ti	Title
tm	Tickmark (TickMark)
tr	Transformation (Transformation, IrregularTransformation, LogLinTransformation)
tx	Text (TextItem)
vc	Vectors (VectorPLot)
vf	Vector Field (VectorField)
vp	View Port (View)
wk	Workstation (Workstation, DokumentWorkstation, ImageWorkstation, NcgmWorkstation, PDFWorkstation, PSWorkstation, XWorkstation)
ws	Workspace
xy	XY-Plots (XyPlot)

8.18.1 Title Strings and Function Codes

The "~" character in NCL has a special meaning for all text-based resources. It's a "function code" that tells NCL you want to do something special to the string, like create a super/subscript, insert a carriage return, or change the font:

Text/title examples:	http://www.ncl.ucar.edu/Applications/text.shtml	
Function code examples:	http://www.ncl.ucar.edu/Applications/fcodes.shtml	
Insert a carriage return:	~C~	
Change font size:	~Z80~	decrease font size to 80%
	~Z50~	decrease font size to 50%
Superscript:	~S~o~N~	degrees sign ^{o}
Subscript:	~B~2~N~	subscript 2 like $_{2}$

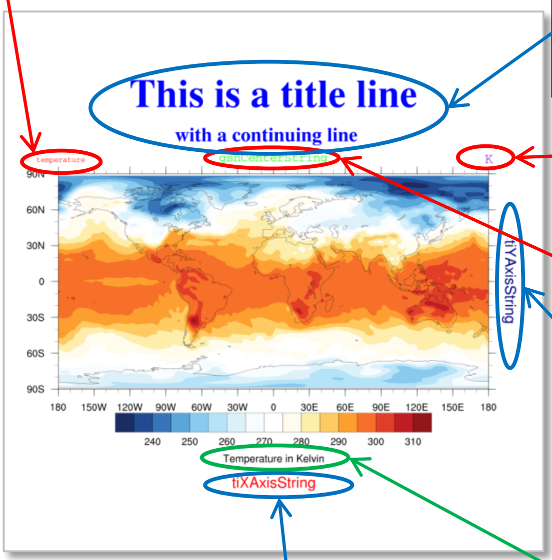
Select font: ~F33~ select greek font

Reset to default: ~N~

If you want a different character to be the function code, then you can either set a resource, i.e. restiMainFuncCode = ":", or you can change the default for all resources by setting the special TextFuncCode value in your ".hluresfile". See section 1.6.

```
res@gsnLeftStringFontHeightF   =  0.008
res@gsnLeftStringParallelPosF  = -0.05
res@gsnLeftStringFontColor     = "red"
```

```
res@tiMainString = "This is a title line~C~~Z50~
with a continuing line"
res@tiMainFontHeightF =  0.05
res@tiMainFontColor   = "blue"
```




```
res@gsnRightStringFontHeightF  =  0.015
res@gsnRightStringFontColor    = "darkorchid"
res@gsnRightStringParallelPosF =  1.01
```

```
res@gsnCenterString  = "gsnCenterString"
res@gsnCenterStringFontHeightF =  0.013
res@gsnCenterStringFontColor   = "green"
```

```
res@tiYAxisString = "tiYAxisString"
res@tiYAxisFontHeightF =  0.02
res@tiYAxisFontColor   = "navy"
res@tiYAxisSide        = "right"
res@tiYAxisAngleF      =  270
```

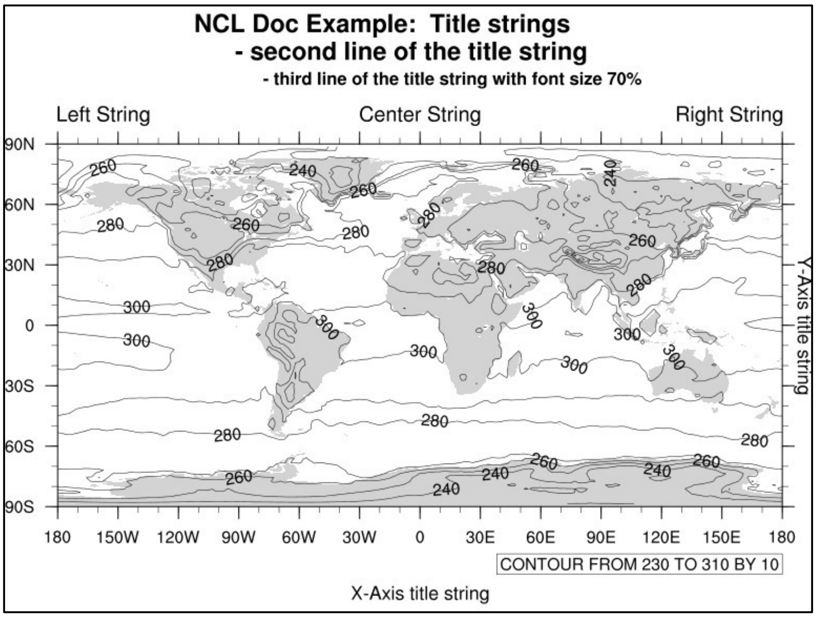
```
res@lbTitleOn          = True
res@lbTitleFontHeightF =  0.014
res@lbTitlePosition   = "Bottom"
res@lbTitleString      = "Temperature in Kelvin"
```

```
res@tiXAxisString      = "tiXAxisString"
res@tiXAxisFontHeightF =  0.02
res@tiXAxisFontColor   = "red"
```

More than one title string on top of the plot: NUG_title_strings.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri  = "./"
  fili  = "rectilinear_grid_2D.nc"

  file1 =  addfile(diri+fili, "r")
  var   =  file1->tsurf(0,:,:)

;---- define the workstation (plot output type and name)
  wks = gsn_open_wks("png","plot_title_strings")

;---- set resources
  res                        =  True
  res@gsnMaximize            =  True

;-- set the gsn title strings
  res@gsnLeftString          = "Left String"
  res@gsnCenterString        = "Center String"
  res@gsnRightString         = "Right String"
```

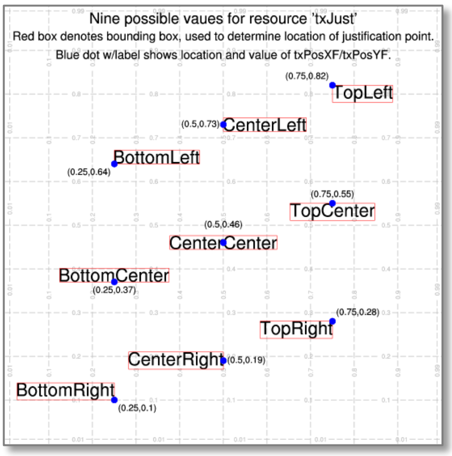
```
;-- set the title string. ~C~ insert a carriage return (no \ allowed).
  res@tiMainString           = "NCL Doc Example:  Title strings ~C~      -
second line of the title string ~C~ ~Z70~             - third line of the
title string with font size 70% ~C~  "
  res@tiMainFontHeightF      =  0.02

  res@tiXAxisString          = "X-Axis title string"
  res@tiYAxisString          = "Y-Axis title string"

  res@tiXAxisSide            = "Bottom"    ;-- X-Axis title on bottom
  res@tiYAxisSide            = "Right"     ;-- Y-axis title on right side
  res@tiYAxisAngleF          = 270         ;-- Y-axis title rotate 270 degrees

  res@tiXAxisFontHeightF     = 0.015       ;-- X-Axis title font size
  res@tiYAxisFontHeightF     = 0.015       ;-- Y-Axis title font size

;---- draw the contour map
  plot = gsn_csm_contour_map(wks, var, res)

end
```



8.18.2 Adding Text To The Plot

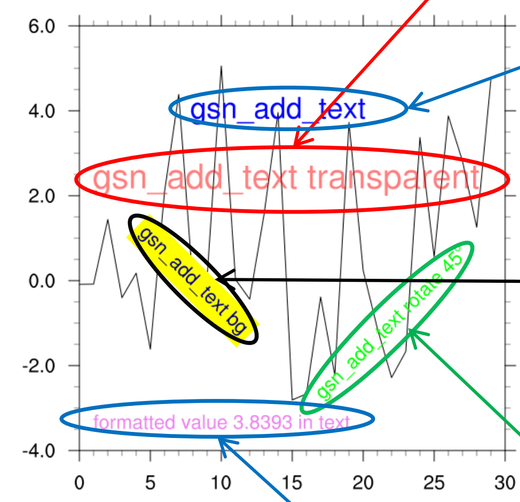
Sometimes the settings described before do not fit your requirements and it is necessary to add more text to the plot. This can be done by the text function **gsn_add_text** which adds text to an existing plot (only in the plot area) or **gsn_text_ndc** which writes text at any place on the frame using NDC coordinates to position the text.

The right figure shows the location of the justification point for a string which is defined by resources that end in the word **"Just"** .




```
txres@txFontColor              = "red"
txres@txFontHeightF            =  0.035
txres@txFontOpacityF           =  0.5
txres@txJust                   = "BottomLeft"
txres@txBackgroundFillColor    = -1

id = gsn_add_text(wks,plot,"gsn_add_text transparent",1,2,txres)
```

```
txres@txFontColor       = "blue"
txres@txFontHeightF     =  0.03
txres@txJust            = "CenterCenter"

id =
gsn add text(wks,plot,"gsn add text",14,4,txres)
```




```
txres@txFontColor                = "navy"
txres@txFontHeightF              =  0.02
txres@txAngleF                   = -45
txres@txBackgroundFillColor      = "yellow"

str = "gsn_add_text bg"

id = gsn_add_text(wks, plot, str, 8, 0, txres
```

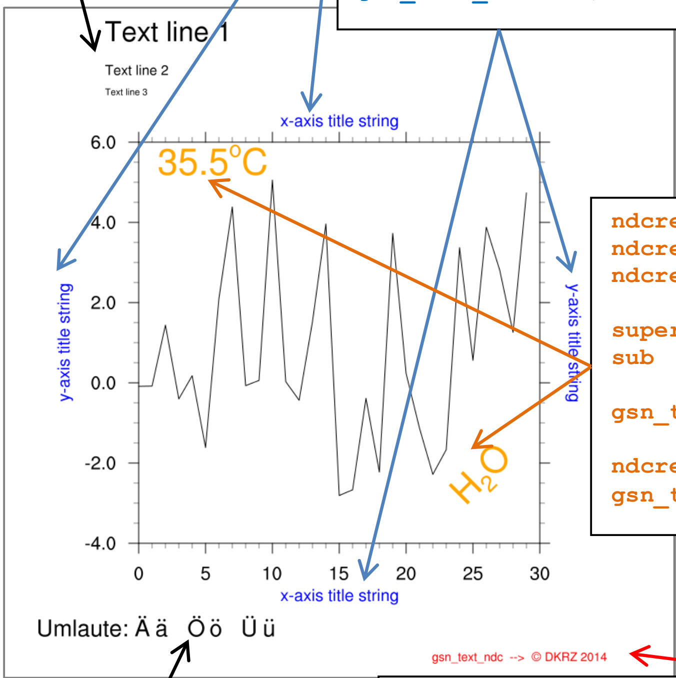
```
txres@txFontColor       = "green"
txres@txFontHeightF     =  0.02
txres@txAngleF          = 45

str = "gsn_add_text rotate 45~S~o~N~"

id = gsn_add_text(wks,plot,str,22,-1,txres)
```

```
value = 3.83927489235
str = "formatted value "+sprintf("%3.4f", value)+" in text"

txres@txFontColor        = "violet"
txres@txFontOpacityF     =  1.0

id = gsn_add_text(wks, plot, str, 1, -3.5, txres)
```

Just to show you more about NCLs capabilities to add text to a plot.

```
ndcres@txFontHeightF     =  0.03
ndcres@txJust            = "BottomLeft"
gsn_text_ndc(wks, "Text line 1", 0.15, 0.95, ndcres)
ndcres@txFontHeightF     =  0.015
gsn_text_ndc(wks, "Text line 2", 0.15, 0.90, ndcres)
ndcres@txFontHeightF     =  0.01
gsn_text_ndc(wks, "Text line 3", 0.15, 0.87, ndcres)
```

```
ndcres@txFontHeightF     =  0.018
ndcres@txFontColor       = "blue"
ndcres@txAngleF          =  90
ndcres@txJust            = "CenterCenter"
gsn_text_ndc(wks, "y-axis title string", 0.09, 0.5, ndcres)

ndcres@txAngleF          = -90
gsn_text_ndc(wks, "y-axis title string", 0.85, 0.5, ndcres)

ndcres@txAngleF          =  0
gsn_text_ndc(wks, "x-axis title string", 0.5, 0.83, ndcres)
gsn_text_ndc(wks, "x-axis title string", 0.5, 0.12, ndcres)
```




```
ndcres@txFontHeightF     =  0.04
ndcres@txFontColor       = "orange"
ndcres@txJust            = "BottomLeft"

super = "35.5~S~o~N~"
sub   = "H~B~2~N~O"

gsn_text_ndc(wks,super,0.23,0.75,ndcres)

ndcres@txAngleF          = 45
gsn_text_ndc(wks, sub,0.7,0.25 ndcres)
```

```
ndcres@txFontColor       = "red"
ndcres@txFontHeightF     =  0.013
ndcres@txJust            = "BottomRight"
string = "gsn_text_ndc  -->  ~F35~c ~F21~~N~DKRZ 2014"
gsn_text_ndc(wks, string, 0.9, 0.02, ndcres)
```

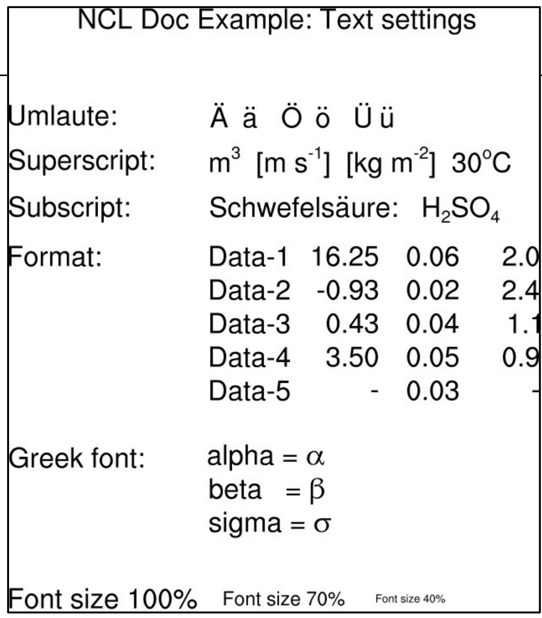
```
Auml    = "A~H-15V6F35~H~FV-6H3~"
auml    = "a~H-13V2F35~H~FV-2H3~"
Ouml    = "O~H-16V6F35~H~FV-6H3~"
ouml    = "o~H-14V2F35~H~FV-2H3~"
Uuml    = "U~H-15V6F35~H~FV-6H3~"
uuml    = "u~H-13V2F35~H~FV-2H3~"
string = "Umlaute: "+Auml+" "+auml+"   "+Ouml+" "+ouml+"   "+Uuml+" "+uuml
ndcres@txFontColor       = "black"
ndcres@txFontHeightF     =  0.025
gsn_text_ndc(wks, string, 0.05, 0.06, ndcres)
```

8.18.3 Function Codes for Creating Special Characters

Different text settings such as Umlaut, superscript and subscript: NUG_text_settings.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"

begin
;-- define german "Umlaute"
  Auml     = "A~H-15V6F35~H~FV-6H3~"
  auml     = "a~H-13V2F35~H~FV-2H3~"
  Ouml     = "O~H-16V6F35~H~FV-6H3~"
  ouml     = "o~H-14V2F35~H~FV-2H3~"
  Uuml     = "U~H-15V6F35~H~FV-6H3~"
  uuml     = "u~H-13V2F35~H~FV-2H3~"

;-- define super- and subscript variable
  super    = "m~S~3~N~  [m s~S~-1~N~]  [kg m~S~-2~N~]  30~S~o~N~C"
  sub      = "Schwefels"+auml+"ure:   H~B~2~N~SO~B~4~N~"

  data  = (/ "Data-1",   "Data-2", "Data-3",  "Data-4", "Data-5"/)
  diff  = (/ 16.25,    -0.93,     0.43,      3.5,    0.0/)
  var   = (/  0.06,      0.02,     0.04,      0.05,   0.03/)
  ratio = (/     2,       2.4,      1.1,      0.9,    0.0/)

  ntext = dimsizes(data)

;-- open workstation
  wks = gsn_open_wks("png","plot_text_settings")

;-- x, y start point for writing
  x    = 0.1
  y    = 0.95
  inc = 0.07

;-- text resources
  txres                     = True
  txres@txFontHeightF       = 0.03
  txres@txJust              = "CenterCenter"
  str                       = "NCL Doc Example: Text settings"
  gsn_text_ndc(wks,str,0.5,y,txres)

  txres@txJust              = "CenterLeft"
  str1                      = "Umlaute:"
  gsn_text_ndc(wks,str1,x,y-2*inc,txres)

  str2                      = Auml+"  "+auml+"   "+Ouml+"  "+ouml+"   "+Uuml+" "+uuml
  gsn_text_ndc(wks,str2,x+0.3,y-2*inc,txres)

  str1                      = "Superscript:"
  gsn_text_ndc(wks,str1,x,y-3*inc,txres)
  str2                      = super
  gsn_text_ndc(wks,str2,x+0.3,y-3*inc,txres)

  str1                      = "Subscript:"
  gsn_text_ndc(wks,str1,x,y-4*inc,txres)
  str2                      = sub
  gsn_text_ndc(wks,str2,x+0.3,y-4*inc,txres)

;-- nice formated text output using sprintf
  str = "Format:"
  gsn_text_ndc(wks,str,x,y-5*inc,txres)

  xpos = 0.4
  do i=0,ntext-1
    ypos = y-5*inc-i*0.05
    gsn_text_ndc(wks,data(i),xpos,ypos,txres)
  end do
```

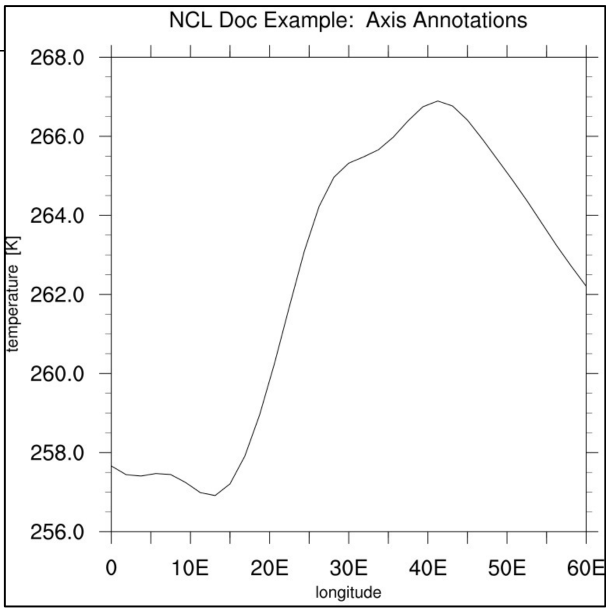
```
  txres@txJust = "CenterRight"
  do i=0,ntext-1
    xpos = 0.65
    ypos = y-5*inc-i*0.05
    if(diff(i).ne.0.0) then
      str     = sprintf("%6.2f",diff(i))
      gsn_text_ndc(wks,str,xpos,ypos,txres)
    else
      str     = "-"
      gsn_text_ndc(wks,str,xpos,ypos,txres)
    end if
    xpos = xpos + 0.12
    if(var(i).ne.0.0) then
      str     = sprintf("%5.2f",var(i))
      gsn_text_ndc(wks,str,xpos,ypos,txres)
    end if
    xpos = xpos + 0.12
    if(ratio(i).ne.0.0) then
      str     = sprintf("%3.1f",ratio(i))
      gsn_text_ndc(wks,str,xpos,ypos,txres)
    else
      str     = "-"
      gsn_text_ndc(wks,str,xpos,ypos,txres)
    end if
  end do

;-- greek characters
  xpos = 0.3
  ypos = 0.3
  str1                    = "Greek font:"
  gsn_text_ndc(wks,str1,xpos,ypos,txres)
  str2                    = "alpha = ~F33~a~N~"
  gsn_text_ndc(wks,str2,xpos+0.27,ypos,txres)
  str2                    = "beta   = ~F33~b~N~"
  gsn_text_ndc(wks,str2,xpos+0.27,ypos-0.05,txres)
  str2                    = "sigma = ~F33~s~N~"
  gsn_text_ndc(wks,str2,xpos+0.28,ypos-0.10,txres)

;-- decrease the font
  str1                    = "Font size 100%"
  gsn_text_ndc(wks,str1,xpos+0.08,ypos-3*inc,txres)
  str2                    = "~Z70~Font size 70%~N~"
  gsn_text_ndc(wks,str2,xpos+0.3,ypos-3*inc,txres)
  str3                    = "~Z40~Font size 40%~N~"
  gsn_text_ndc(wks,str3,xpos+0.45,ypos-3*inc,txres)

  frame(wks)
end
```



8.18.4 Axis Annotations

Adding units and axis labels to the plot: NUG_axis_annotations.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;---- read the data and define variable reference var

   diri  = "./"
   fili  = "rectilinear_grid_3D.nc"

   f     =  addfile(diri+fili, "r")
   var   = f->t(0,{70000},{55},{0:60})
   lon_t = f->lon({0:60})                      ;-- longitude=0-60E

;---- define the workstation (plot output type and name)
   wks = gsn_open_wks("png","plot_axis_annotations")

;---- set resources
   res                         =  True
   res@gsnMaximize             =  True

;-- set the title string. ~C~ insert a carriage return (no \ allowed).
   res@tiMainString            = "NCL Doc Example:  Axis Annotations"
   res@tiMainFontHeightF       =  0.02

   res@tiXAxisSide             = "Bottom"         ;-- X-Axis title on bottom
   res@tiXAxisFontHeightF      =  0.015           ;-- X-Axis title font size
   res@tiYAxisFontHeightF      =  0.015           ;-- Y-Axis title font size

   res@tiXAxisString           =  lon_t@long_name
   res@tiYAxisString           =  var@long_name + "  [" + var@units + "]"

   res@tmLabelAutoStride       =  True
   res@tmXBTickSpacingF        =  5             ;-- label X-Axis every 10 deg

   res@xyLineThicknessF        =  2.0

   plot = gsn_csm_xy(wks,lon_t,var,res)

end
```

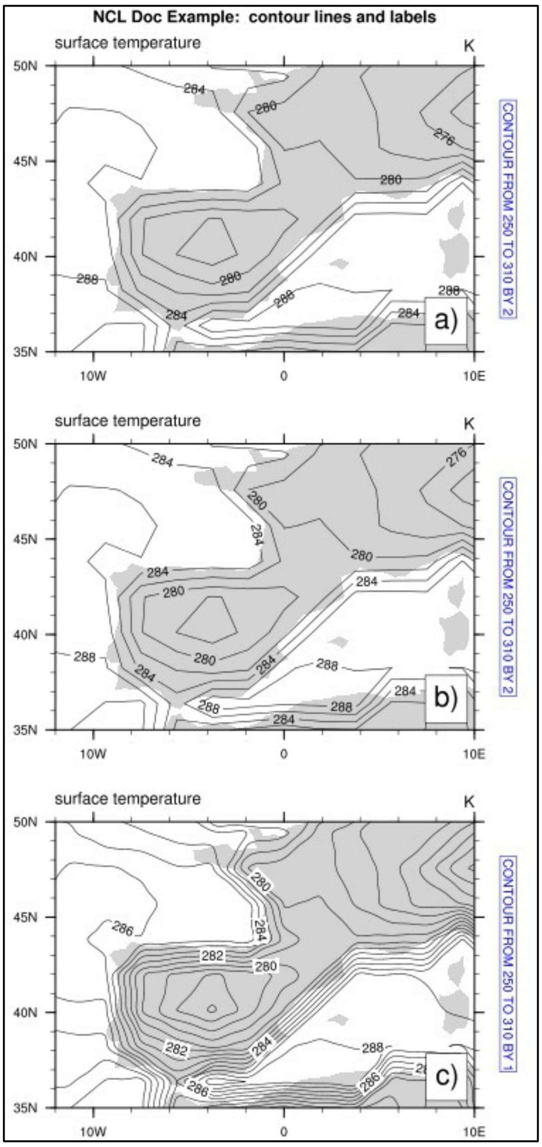


8.18.5 Contour Lines and Label Settings

The next example shows how to change the strings for the contour lines and their labels: NUG_contour_labels.ncl

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
  diri  = "./"
  fili  = "rectilinear_grid_2D.nc"
  file1 =  addfile(diri+fili,"r")
  var   =  file1->tsurf(0,:,:)

;---- define the workstation (plot output type and name)
  wks = gsn_open_wks("png","plot_contour_lines_labels")

;---- set resources
  res                          =  True
  res@gsnDraw                  =  False
  res@gsnFrame                 =  False
  res@gsnMaximize              =  True
  res@tiMainFontHeightF        =  0.02
  res@cnLevelSelectionMode     = "ManualLevels"
  res@cnMinLevelValF           =  250.
  res@cnMaxLevelValF           =  310.
  res@cnLevelSpacingF          =    2.
  res@mpLimitMode              = "Corners"
  res@mpLeftCornerLatF         =  35.
  res@mpRightCornerLatF        =  50.
  res@mpLeftCornerLonF         = -12.
  res@mpRightCornerLonF        =  10.

;-- create plots
  plot = new(3,graphic)

  res@cnInfoLabelOrthogonalPosF  = -0.88
  res@cnInfoLabelParallelPosF    = 1.1
  res@cnInfoLabelAngleF          = -90.
  res@cnInfoLabelFontColor       = "blue"
  res@cnInfoLabelPerimColor      = "blue"
  res@tiMainString             = "NCL Doc Example:  contour lines and labels"
  res@cnLineLabelPlacementMode   = "computed"
  plot(0) = gsn_csm_contour_map(wks, var, res)

  res@tiMainString               = ""
  res@cnLineLabelPlacementMode   = "constant"
  plot(1) = gsn_csm_contour_map(wks, var, res)

  res@tiMainString               = ""
  delete(res@cnLineLabelPlacementMode)      ;-- set to default: randomized
  res@cnLineLabelBackgroundColor = "white"
  res@cnSmoothingOn              =  True
  res@cnSmoothingTensionF        =  1.
  res@cnSmoothingDistanceF       =  0.005
  res@cnLevelSpacingF            =  1.
  plot(2) = gsn_csm_contour_map(wks, var, res)

;-- draw the panel plot
  pres = True
  pres@gsnPanelFigureStrings = (/"a)","b)","c)"/)
```

```
  gsn_panel(wks,plot,(/3,1/), pres)

end
```

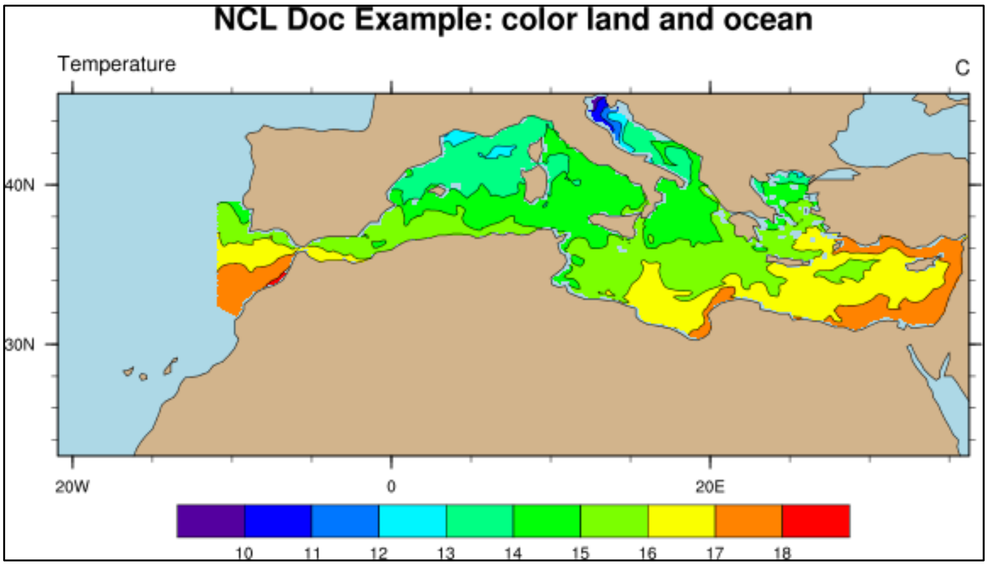


8.18.6 Colorizing Land, Ocean and Lakes

Colorize land and ocean areas differently: NUG_color_Land_Ocean.ncl

```
begin
   diri     = "./"
   fili     = "CNTASN_1m_200103_grid_T_curvilinear_grid.nc"
   f        =  addfile(diri+fili,"r")
   var      =  f->votemper(0,0,:,:)
   lat2d    =  f->nav_lat
   lon2d    =  f->nav_lon

;-- define the workstation (plot type and name)
   wks = gsn_open_wks("png","plot_color_Land_Ocean")

;-- set resources
   res                         =  True
   res@gsnAddCyclic            =  False         ;-- don't add lon cyclic point
```

```
   res@gsnMaximize            =  True
   res@cnFillOn               =  True           ;-- turn on contour fill
   res@cnFillPalette          = "rainbow"       ;-- choose color map
   res@tiMainString       = "NCL Doc Example: color land and ocean"  ;-- title
   res@tiMainFontHeightF      =  0.02

;-- color land and ocean (looks nicer)
   res@mpOceanFillColor       = "lightblue"
   res@mpInlandWaterFillColor= "lightblue"
   res@mpLandFillColor        = "tan"

;---Zoom in on map
   res@mpMinLatF              =  min(lat2d)
   res@mpMaxLatF              =  max(lat2d)
   res@mpMinLonF              =  min(lon2d)
   res@mpMaxLonF              =  max(lon2d)

;---Lat/lon arrays of curvilinear frid for overlaying on map
   res@sfXArray               =  lon2d
   res@sfYArray               =  lat2d

;-- draw the contour map
   plot = gsn_csm_contour_map(wks,var,res)

end
```



8.18.7 Colorize Countries by Values

NCL allows the user to colorize the countries by given values. Let us say you have an ASCII file containing the country name and the number of users for something, separated by a delimiter. You can store the names of the countries into an array (e.g. "states") after reading and generate an array containing the desired colors (e.g. "icols") depending on the values of the countries. With the *@mp* resources

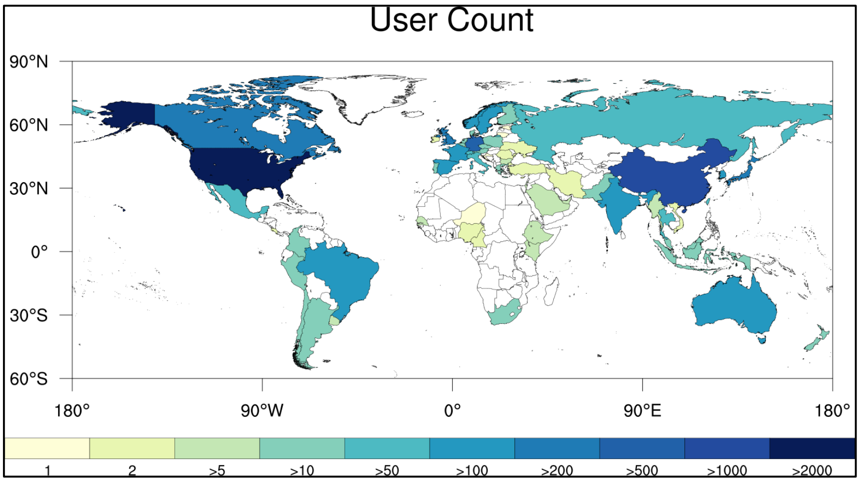
```
res@mpFillAreaSpecifiers  =  states     ;-- fill listed states
res@mpSpecifiedFillColors =  icols      ;-- use generated color array
```

NCL will plot the country states(i) colored by the color icol(i).

NUG_color_country_user.ncl:

```
begin

  diri = "./data/"
  fili = "data_country_user.txt"

  data    =  asciiread(diri+fili, -1,"string" );-- read all lines
  delim   = ";"                                ;-- set delimiter
  nfields =  str_fields_count(data(0),delim)   ;-- count number of columns

  states  =  str_get_field(data,1,delim)       ;-- get 1st column
  ivalues =  toint(str_get_field(data,2,delim));-- get 2nd column
  nvalues =  dimsizes(ivalues)

  levels  =  (/1,2,5,10,50,100,200,500,1000,2000/) ;-- value levels
  labels  =  (/"1","2",">5",">10",">50",">100",">200", \
               ">500",">1000",">2000"/)            ;-- labelbar labels

  rgb_colors = (/ (/0.997785, 0.999139, 0.846059/), \
                  (/0.910127, 0.964937, 0.695640/), \
                  (/0.769320, 0.909419, 0.706959/), \
                  (/0.521292, 0.812964, 0.731073/), \
                  (/0.304483, 0.732118, 0.761430/), \
                  (/0.141961, 0.597647, 0.756078/), \
                  (/0.122107, 0.483137, 0.712711/), \
                  (/0.131949, 0.382745, 0.665467/), \
                  (/0.138408, 0.297578, 0.624990/), \
                  (/0.031373, 0.113725, 0.345098/)/)
  nlevels =  dimsizes(levels)                      ;-- number of levels
  colors  =  new((/nvalues+1,3/),typeof(rgb_colors))

;-- compute the data color array
  do i = 0,dimsizes(ivalues)-1
     if(ivalues(i).eq.levels(0)) then
        colors(i,:) = (/1.,1.,1./)                 ;-- white
     end if
     if(ivalues(i).gt.levels(nlevels-1)) then
        colors(i,:) = rgb_colors(nlevels-1,:)
     end if
     do j = 0,nlevels-2
        if(ivalues(i).gt.levels(j).and.ivalues(i).le.levels(j+1)) then
           colors(i,:) = rgb_colors(j,:)
        end if
     end do
     print("State: "+sprinti("%2.2i",i)+"   Count:  "+ \
           sprinti("%4.2i",ivalues(i))+"  "+states(i))
  end do
```

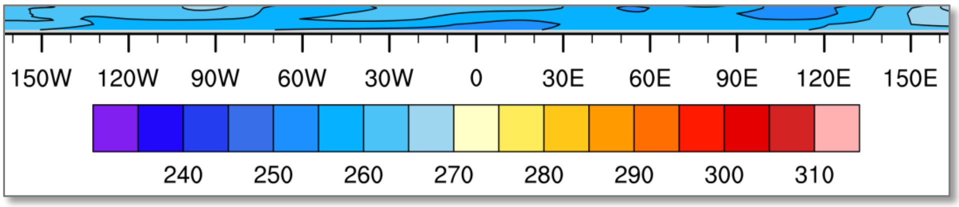
```
;-- open a workstation
;-- set workstation resources
  wks_type                  = "png"         ;-- plot output type
  wks_type@wkWidth          =  1600         ;-- wk width
  wks_type@wkHeight         =  1600         ;-- wk height
  wks = gsn_open_wks(wks_type,"plot_color_country_user")

;-- set resources
  res                        =  True
  res@gsnMaximize            =  True        ;-- maximize plot
  res@gsnFrame               =  False       ;-- don't advance the frame yet

  res@pmTickMarkDisplayMode = "Always"      ;-- turn on map tickmarks

  res@mpDataSetName          = "Earth..4"   ;-- new database
  res@mpDataBaseVersion      = "MediumRes"  ;-- Medium resolution database
  res@mpOutlineOn            =  True        ;-- turn on map outlines
  res@mpFillOn               =  True        ;-- turn on map fill
  res@mpOutlineBoundarySets = "National"    ;-- draw only national bounds
  res@mpLandFillColor        = "white"      ;-- set map land fill to white
  res@mpMinLatF              = -60          ;-- don't plot Antarctica

;-- set colors and states
  res@mpFillAreaSpecifiers   =  states      ;-- fill listed states
  res@mpSpecifiedFillColors =  colors       ;-- use generated color array

  res@tiMainString           = "User Count" ;-- title string
  res@tiMainFont             = "helvetica"  ;-- title string font
  res@tiMainFontHeightF      =  0.025       ;-- set title string font size

  map = gsn_csm_map(wks,res)    ;-- create the map

;-- add custom label bar to the plot
  lbres                      =  True
  lbres@lbPerimOn            =  False       ;-- no label bar box outline
  lbres@lbOrientation        = "Horizontal" ;-- labelbar orientation
  lbres@vpXF                 =  0.01        ;-- labelbar x-position
  lbres@vpYF                 =  0.26        ;-- labelbar y-position
  lbres@vpWidthF             =  0.98        ;-- labelbar width
  lbres@vpHeightF            =  0.08        ;-- labelbar height
  lbres@lbLabelFontHeightF   =  0.012       ;-- label font height
  lbres@lbMonoFillPattern    =  True        ;-- fill sold
  lbres@lbAutoManage         =  False       ;-- make settings by yourself
  lbres@lbLabelAlignment     = "BoxCenters" ;-- where to draw the labelbar
                                            ; labels
  lbres@lbFillColors         =  rgb_colors  ;-- use colors

  gsn_labelbar_ndc(wks,nlevels,labels,0.13,0.28,lbres) ;-- draw labelbar

  frame(wks)                                ;-- advance the frame

end
```



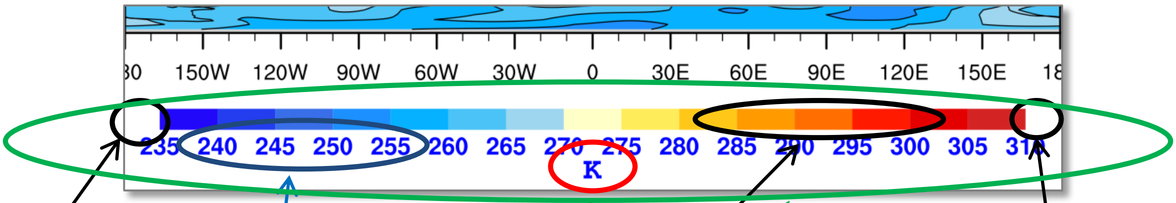
8.18.8 Labelbar Settings

Labelbars are often needed to show the mapping between physical values and colors. If a contour plot with fill mode turned on is chosen NCL will add a labelbar to the plot. The labelbar is centered below the plot, having nice values below the color boxes. By default no title string is included with the labelbar.

The user can change the labelbar width, height, position, color and font of the labels, exclude outer color boxes, add minimum and maximum labels to the outer boxes, add a title to the labelbar, etc.



Default labelbar

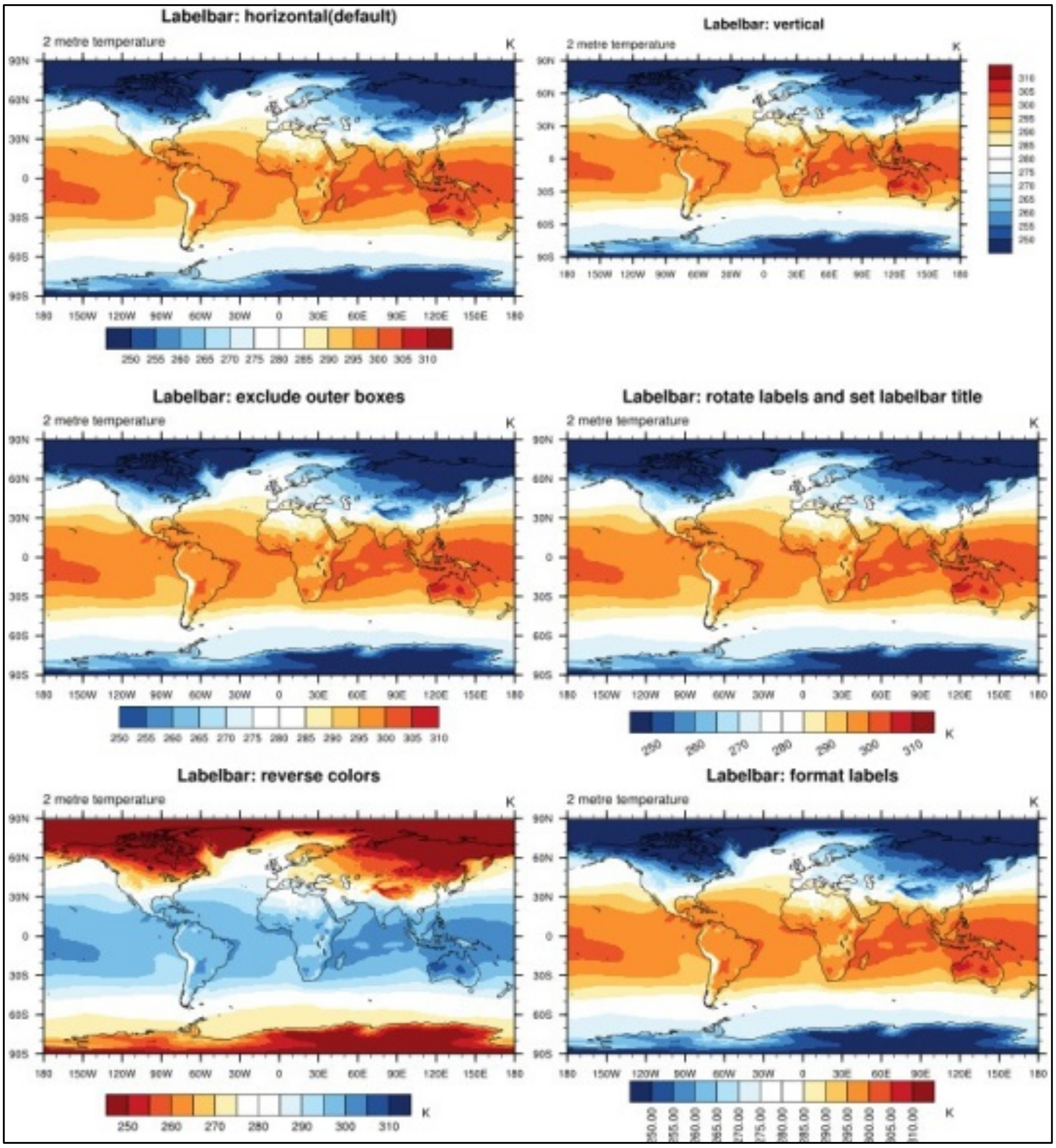



```
res@cnLabelBarEndStyle     = "ExcludeOuterBoxes";-- exclude the outer color boxes

res@lbTitleOn              =  True           ;-- write title (default: "labelbar")
res@lbTitleFont            = "courier-bold"  ;-- set title font
res@lbTitleFontColor       = "blue"          ;-- set title font
res@lbTitleFontHeightF     =  0.015          ;-- decrease the font size (default: 0.025)
res@lbTitlePosition        = "Bottom"        ;-- labelbar title postion (default: "Top")
res@lbTitleString          =  t@units        ;-- define labelbar title string
res@lbTitleOffsetF         = -0.3            ;-- move the labelbar title upwards

res@lbBoxMinorExtentF      =  0.2            ;-- decrease height of labelbar boxes and vp
res@lbBoxLinesOn           =  False          ;-- don't draw lines around labelbar boxes

res@lbLabelFontColor       = "blue"          ;-- label color
res@lbLabelFontHeightF     =  0.015          ;-- label font height
res@lbLabelFont            = "helvetica-bold";-- label font
res@lbLabelOffsetF         =  0.07           ;-- move the labelbar labels downwards

res@pmLabelBarWidthF       =  0.8            ;-- labelbar width; default is shorter
res@pmLabelBarHeightF      =  0.1            ;-- labelbar height; default is taller
res@pmLabelBarOrthogonalPosF =  0.07         ;-- y-position (positive: downward; def: 0.02)
res@pmLabelBarParallelPosF =  0.5            ;-- x-position (CenterCenter); default: 0.5
```

The next example shows how to achieve different labelbar styles and annotation formats: NUG_labelbars.ncl

```
begin
   diri  = "./"
   fili  = "T2M_ERAINT_rectilinear_grid_2D.nc"
   f     =  addfile(diri+fili, "r")
   var   =  f->T2M(0,:,:)

;-- define the workstation (graphic will be written to a file)
   wks      =  gsn_open_wks("png","plot_labelbars")

;-- set plot resources
   res                     = True
   res@gsnDraw             = False
   res@gsnFrame            = False
   res@gsnMaximize         = True

   res@cnFillOn            = True
   res@cnLinesOn           = False
   res@cnLineLabelsOn      = False
   res@cnInfoLabelOn       = False
   res@cnLevelSelectionMode = "ManualLevels"
   res@cnMinLevelValF      =  250.
   res@cnMaxLevelValF      =  310.
   res@cnLevelSpacingF     =    5.

   plot = new(6,graphic)
```

```
;-- upper left
   res@tiMainString       = "Labelbar: horizontal(default)"
   plot(0) = gsn_csm_contour_map(wks,var,res)

;-- upper right
   res@tiMainString       = "Labelbar: vertical"
   res@lbOrientation      = "vertical"
   plot(1) = gsn_csm_contour_map(wks,var,res)

;-- middle left
   res@tiMainString       = "Labelbar: exclude outer boxes"
   res@lbOrientation      = "horizontal"
   res@cnLabelBarEndStyle = "ExcludeOuterBoxes"
   plot(2) = gsn_csm_contour_map(wks,var,res)

;-- middle right
   res@tiMainString       = "Labelbar: rotate labels and set labelbar title"
   res@lbTitleOn          =  True
   res@lbTitleString      = "degK"
   res@lbTitlePosition    = "Right"
   res@lbTitleOffsetF     =  -0.03
   res@lbTitleFontHeightF =  0.015
   res@lbLabelFontHeightF =  0.015
   res@lbLabelAngleF      =  30
   res@pmLabelBarOrthogonalPosF = 0.10
   delete(res@cnLabelBarEndStyle)

   plot(3) = gsn_csm_contour_map(wks,var,res)

;-- lower left
   res@tiMainString        = "Labelbar: reverse colors"
   res@gsnSpreadColorStart =  -1
   res@gsnSpreadColorEnd   =  2
   delete(res@lbLabelAngleF)
   plot(4) = gsn_csm_contour_map(wks,var,res)

;-- lower right
   getvalues plot@contour
     "cnLevels" : levels
   end getvalues

   res@lbLabelStrings      =  sprintf("%3.2f",levels)
   res@lbLabelAngleF       =  90
   delete([/res@gsnSpreadColorStart, res@gsnSpreadColorEnd/])
   res@tiMainString        = "Labelbar: format labels"
   plot(5) = gsn_csm_contour_map(wks,var,res)

;-- draw the panel plot
   gsn_panel(wks,plot,(/3,2/),False)

end
```



8.18.9 Legend Settings

For line plots with different line types or colors, legends are recommended to annotate the respective meanings of the different lines.

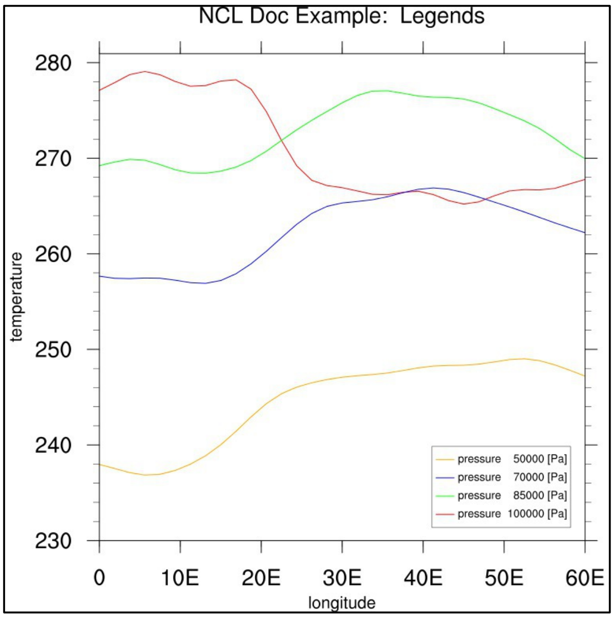
To add a legend to a XY-plot, set:

```
res@pmLegendDisplayMode = "Always"
```

This will add a legend below the plot with a size scaled to the plot width. The default legend will likely need to be customized, which you can do with pmLegendXXX and lgXXX resources.

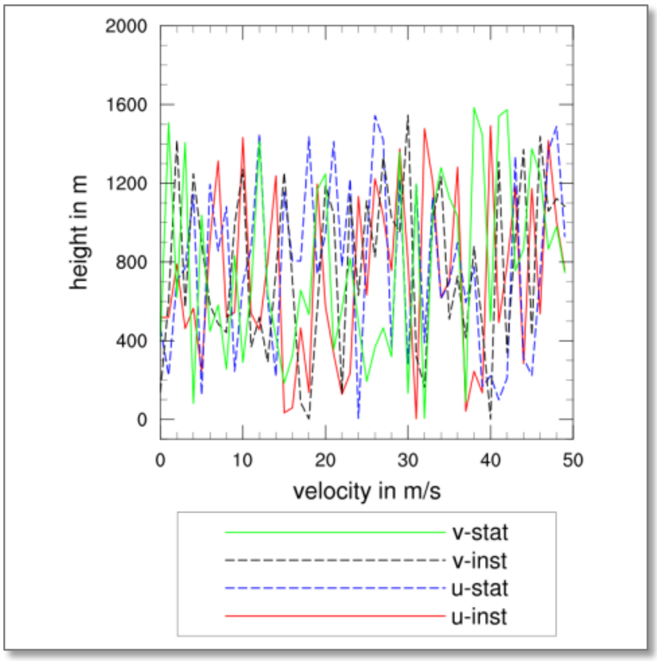
Legends example: NUG_legends.ncl

```
;-----------------------------------------------------------------
;  NCL Tutorial Example:   NUG_legends.ncl
;
;  KMF 30.10.14
;-----------------------------------------------------------------

begin
;---- read the data to be plotted
   diri  = "../data/"
   fili  = "rectilinear_grid_3D.nc"
   f     =  addfile(diri+fili, "r")
   temp  =  f->t(0,:,{55},{0:60})

;-- set the desired levels to extract
   levels = (/100000,85000,70000,50000/)

;-- define the colors of the lines and their labels
   colors = (/"red", "green", "blue", "orange"/)
   labels = " " + temp&lev@long_name + sprinti("%9i",levels) + \
            " [" + temp&lev@units + "]"

;---- define the workstation (plot output type and name)
   wks = gsn_open_wks("png","plot_legends")

;---- set resources
   res                          =  True
   res@gsnMaximize              =  True

   res@trYMinF                  =  230
   res@trYMaxF                  =  max(temp)

;-- set the title string
   res@tiMainString             = "NCL Doc Example:  Legends"
   res@tiMainFontHeightF        =  0.02
   res@tiXAxisString            =  temp&lon@long_name
   res@tiYAxisString            =  temp@long_name
   res@tiXAxisSide              = "Bottom"     ;-- X-Axis title on bottom
   res@tiXAxisFontHeightF       =  0.015       ;-- X-Axis title font size
   res@tiYAxisFontHeightF       =  0.015       ;-- Y-Axis title font size

   res@tmXBTickSpacingF         =  10          ;-- label X-Axis every 10 deg
   res@xyLineColors             =  colors
   res@xyExplicitLabels         =  labels
   res@xyDashPatterns           =  (/0,0,0,0/) ;-- all dash pattern are solid
   res@xyLineThicknessF         =  2.0

   res@lgJustification          = "TopRight"
   res@lgLabelJust              = "CenterRight"
   res@lgLabelFontHeightF       =  0.01
   res@lgBoxMinorExtentF        =  0.16       ;-- make the legend lines shorter
   res@pmLegendDisplayMode      = "Always"
   res@pmLegendWidthF           =  0.15         ;-- set legend width
   res@pmLegendHeightF          =  0.1          ;-- set legend height
   res@pmLegendOrthogonalPosF = -0.34           ;-- move legend up
   res@pmLegendParallelPosF     =  0.97         ;-- move legend right

   plot = gsn_csm_xy(wks,temp&lon,temp({levels},:),res)

end
```



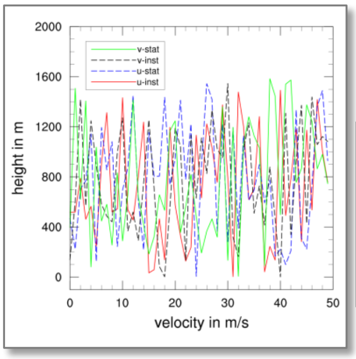
To change the legend size, its position, label font, the background color or reverse the order of the legend lables and lines the following resources are needed.

Lets assume the following default legend of a plot:

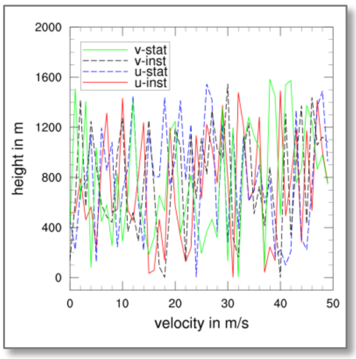


Default legend

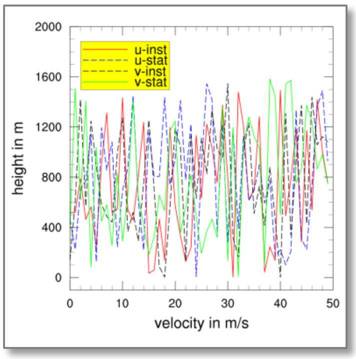
And here are some variations with their resource settings:




```
res@pmLegendDisplayModce     = "Always";-- display legend
res@pmLegendWidthF          =  0.18     ;-- define legend width
res@pmLegendHeightF         =  0.11     ;-- define legend height
res@pmLegendOrthogonalPosF = -1.10     ;-- move the legend upward
res@pmLegendParallelPosF    =  0.21     ;-- move the legend to the
                                        ;-- right
```



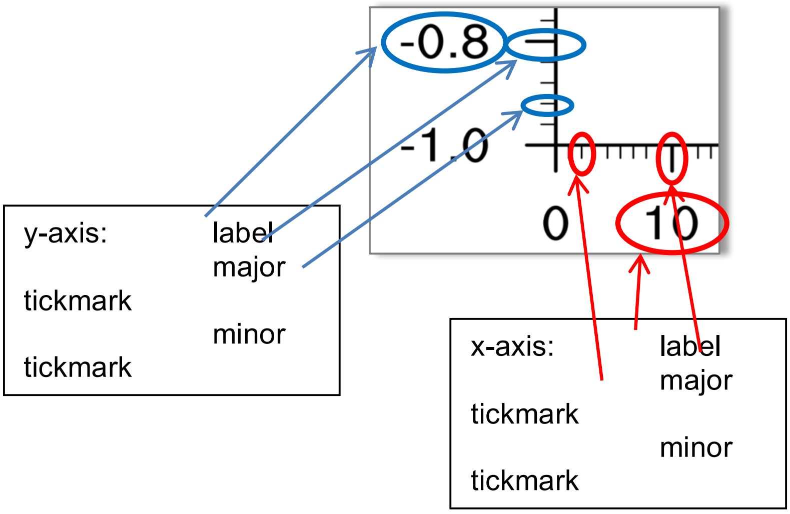

```
res@lgAutoManage          =  False   ;-- switch auto manage off
res@lgLabelFontHeightF    =  0.022   ;-- increase label font size
```




```
res@lgPerimFill       = "SolidFill"  ;-- fill mode for legend box
res@lgPerimFillColor = "yellow"      ;-- fill color for legend box
res@lgItemOrder       =  (/3,2,1,0/) ;-- reverse legend
```

8.18.10 Tickmark Settings

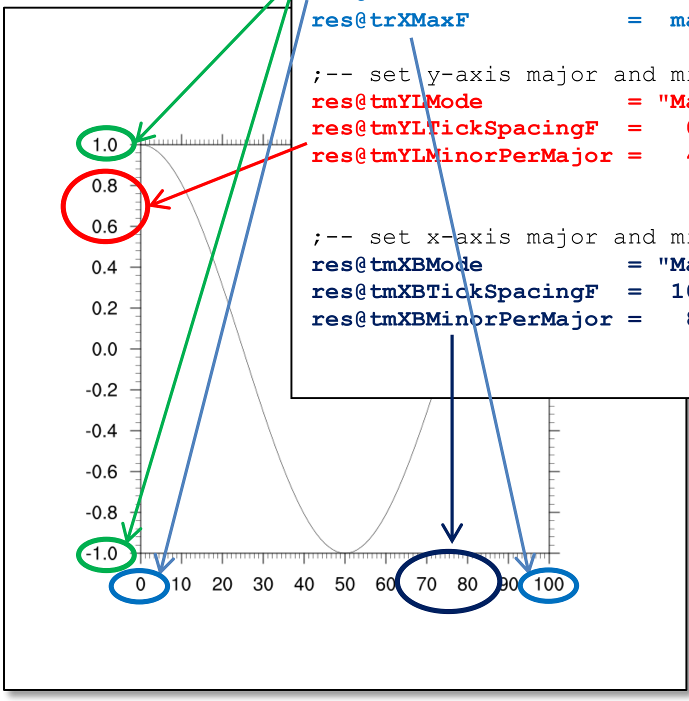
NCL draws major tickmarks at the x- and y-axis by default. In the next part the modifications of tickmarks, their spacing, and their labels are demonstrated for xy- and map plots.



8.18.10.1 XY-plot

See also http://ncl.ucar.edu/Applications/tickmarks.shtml

```
;-- set minimum and maximum values of the axis
res@trYMinF             =  -1.0      ;-- y-axis minimum value
res@trYMaxF             =   1.0      ;-- y-axis maximum value
res@trXMinF             =  min(x)    ;-- x-axis minimum value
res@trXMaxF             =  max(x)    ;-- x-axis maximum value

;-- set y-axis major and minor tickmarks and tickmarks values
res@tmYLMode            = "Manual"   ;-- set tickmarks resources manually
res@tmYLTickSpacingF    =   0.2      ;-- label tickmarks at 0.2 intervals
res@tmYLMinorPerMajor =     4        ;-- draw 4 minor tickmarks between
                                     ;-- the labeled major tickmarks

;-- set x-axis major and minor tickmarks and tickmarks values
res@tmXBMode            = "Manual"   ;-- set tickmarks resources manually
res@tmXBTickSpacingF    =  10.0      ;-- label tickmarks at 10. intervals
res@tmXBMinorPerMajor =     8        ;-- draw 8 minor tickmarks between
                                     ;-- the labeled major tickmarks
```

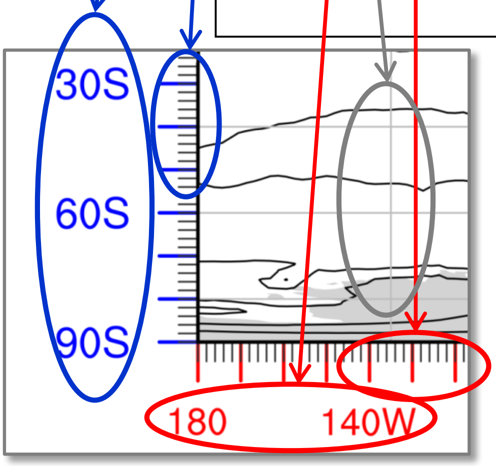


8.18.10.2 Map-plot

The default tickmark setting for a map can be changed by some **@gsn** and **@tm** resources. Not every resource can be used for other map projections than 'Cylindical Equidistant' but on the NCL examples web page there are some examples for work arounds.

See also http://ncl.ucar.edu/Applications/mptick.shtml

```
;-- latitude settings

mpres@gsnMajorLatSpacing    =  10      ;-- change major lat tickmark spacing
mpres@gsnMinorLatSpacing    =  2.5     ;-- change major lat tickmark spacing

mpres@tmYLLabelStride       =  3       ;-- write only every 3rd label
mpres@tmYLLabelFontHeightF  =  0.016   ;-- change major lat tickmark spacing
mpres@tmYLMajorLengthF      =  0.02    ;-- change the tickmark length
mpres@tmYLMinorLengthF      =  0.01    ;-- change the tickmark length
mpres@tmYLMajorLineColor    = "blue"   ;-- change major tickmarks color
mpres@tmYLMinorLineColor    = "grey20";-- change major tickmarks color
mpres@tmYLLabelFontColor    = "blue"   ;-- change label color

;-- longitude settings

mpres@gsnMajorLonSpacing    =  10      ;-- change major lon tickmark spacing
mpres@gsnMinorLonSpacing    =  2.5     ;-- change major lon tickmark spacing

mpres@tmXBLabelStride       =  4       ;-- write only every 4th label
mpres@tmXBLabelFontHeightF  =  0.014   ;-- change major lat tickmark spacing
mpres@tmXBMajorLengthF      =  0.02    ;-- change the tickmark length
mpres@tmXBMinorLengthF      =  0.01    ;-- change the tickmark length
mpres@tmYLMajorLineColor    = "red"    ;-- change major tickmarks color
mpres@tmYLMinorLineColor    = "grey20";-- change major tickmarks color
mpres@tmXBLabelFontColor    = "red"    ;-- change label color

;-- grid line settings

mpres@mpGridAndLimbOn       =  True    ;-- draw grid lines on the plot
mpres@mpGridLatSpacingF     =  20      ;-- grid line lat spacing
mpres@mpGridLonSpacingF     =  45      ;-- grid line lon spacing
mpres@mpGridLineColor       = "gray"   ;-- grid line color
```



8.18.11 Date Format

The time steps of data in a netCDF file are commonly stored like

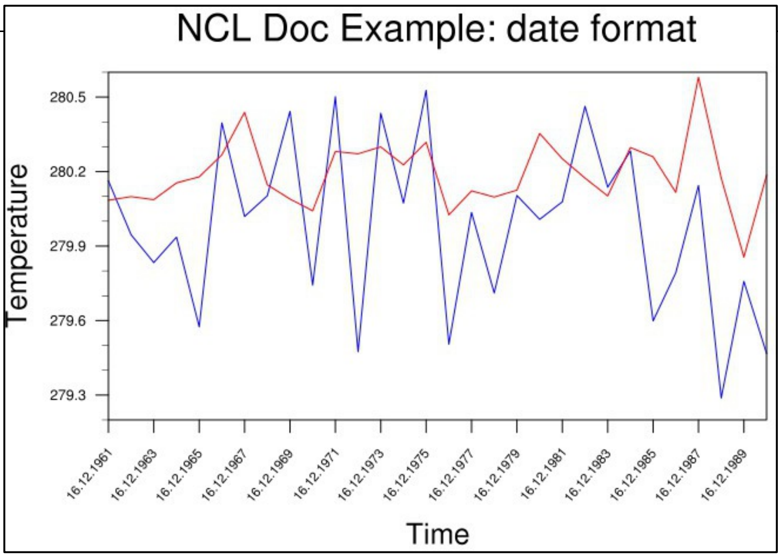
```
double time(time) ;
        time:standard_name = "time" ;
        time:units = "hours since 2001-01-01 00:00:00" ;
        time:calendar = "standard" ;
```

Here in the example it is saved as “hours since the reference date” in the netCDF file, but we want to annotate something like day.month.year (e.g. 15.01.2000). We don’t want to use the numeric time for annotations directly, so we have to convert it into a more readable format. The function **cd_calendar** will do most of the work for us.

Date Format example: NUG_date_format.ncl
This example requires “cdo”, which can be downloaded from
https://code.zmaw.de/projects/cdo/files

```
undef ("getDate")
function getDate(time)
;----------------------
begin
   ;-- convert the time proleptic_gregorian calendar in UTC date
   utc_date = cd_calendar(time, 0)
   ;-- set date variable names (just helpful)
   year   = toint(utc_date(:,0))
   month  = toint(utc_date(:,1))
   day    = toint(utc_date(:,2))
   hour   = toint(utc_date(:,3))
   minute = toint(utc_date(:,4))
   second = utc_date(:,5)
  ;-- write date as string (DD.MM.YYYY)
   date_str_i = sprinti("%0.2i",day) + "." + sprinti("%0.2i",month) + \
                "."  + sprinti("%0.4i",year)
   return(date_str_i)
end

;----------------------------------------------------
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"

begin
  diri = "./"
  fil1 = "tas_mon_1961-1990_rectilinear_grid_2D.nc"

  system("cdo -s -r -f nc yearmean "+diri+fil1+" tser_tmp.nc")

  f1                         = addfile("tser_tmp.nc","r")
  var                        = f1->tas(:,0,0,0)
  time                       = var&time
  timax                      = dimsizes(time) - 1

  f2                         = addfile(diri+fil1,"r")
  var2                       = f2->tas(:,0,:,:)
  var2_avg                   = dim_avg_n_Wrap(month_to_annual(var2,1),2)
  tas_avg = var2_avg(:,0)

;-- create the time strings, plot every second axis annotation
  incr                       = 2
  date_str_i                 = getDate(time)
  labels                     = (/ date_str_i(0::incr) /)
;-- define the workstation (plot type and name)
  wks  = gsn_open_wks("png", "plot_date_format")

;-- set resources
  res                        =  True
  res@gsnDraw                =  False
  res@gsnFrame               =  False

  res@xyLineColor            = "blue"
  res@xyLineThicknessF       =  2
  res@xyDashPattern          =  0
  res@vpWidthF               =  0.7
  res@vpHeightF              =  0.37
```

```
  res@tiMainString            = "NCL Doc Example: date format"
  res@tiXAxisString           = "Time"
  res@tiYAxisString           = "Temperature"
  res@trYMinF                 =  279.2
  res@trYMaxF                 =  280.6
  res@trXMinF                 =  time(0)
  res@trXMaxF                 =  time(timax)
  res@tmXBMode                = "Explicit"
  res@tmXBValues              =  var&time(::incr)
  res@tmXBLabels              =  labels
  res@tmXBLabelFontHeightF    =  0.01
  res@tmXBLabelJust           = "CenterRight"
  res@tmXBLabelDeltaF         =  1.0
  res@tmXBLabelAngleF         =  50.
  res@tmYROn                  =  False
  res@tmXTOn                  =  False

;-- draw the contour map
  plot = gsn_csm_xy(wks, var&time, var, res)

  res@xyLineColor        = "red"
  plot2 = gsn_csm_xy(wks, var&time, tas_avg, res)

;-- merge contents from plot2 to plot
  overlay(plot,plot2)

;-- draw the merged plot
  draw(plot)
  frame(wks)

;-- delete temporary file
  system("rm -f tser_tmp.nc")

end
```



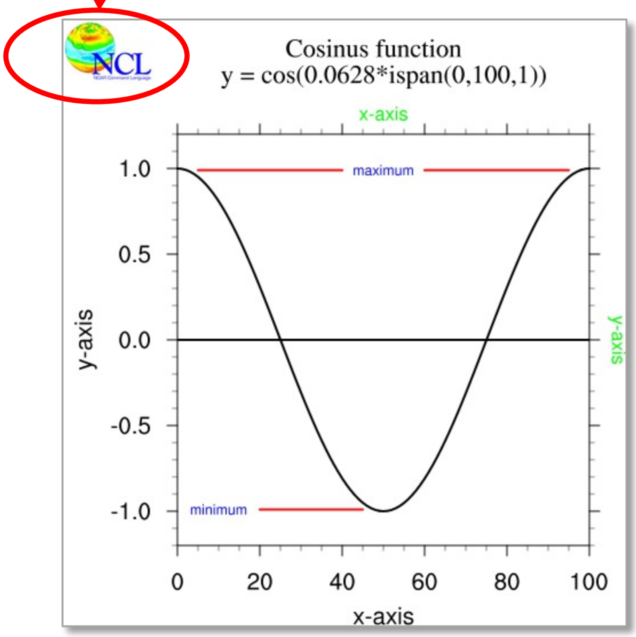
8.18.12 Insert a Logo

It is not possible to overlay a file containing a picture of your logo onto the NCL plot, but we can use ImageMagick's 'composite' program to overlay a PNG or JPEG file. The NCL output file type (workstation type) can be PNG, PS or PDF. The call of 'composite' can be done interactive as a command line call or in a NCL script file. The system call in the NCL script must be done after finishing the plot using the NCL procedure 'system'.

NUG_insert_logo.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- generate dummy data
  x  = ispan(0,100,1)
  y  = cos(0.0628*ispan(0,100,1))     ;-- generate a curve with 101 points.

;-- output file
  dummy  = "dum_tmp.png"
  output = "plot_with_logo.png"

;-- open a workstation
  wks  = gsn_open_wks("png", dummy)

;-- set plot resources
  res                              =  True
  res@gsnDraw                      =  False       ;-- don't draw plot yet
  res@gsnFrame                     =  False       ;-- don't advance frame
  res@gsnYRefLine                  =  0.0         ;-- create a reference line
  res@gsnYRefLineThicknessF        =  4.0         ;-- create a reference line

  res@xyLineThicknessF             =  4.0         ;-- line thickness

  res@tiMainString = "          Cosinus function~C~y = cos(0.0628 *
ispan(0,100,1))"    ;-- main title string
  res@tiXAxisString                = "x-axis"     ;-- set x-axis title string
  res@tiYAxisString                = "y-axis"     ;-- set x-axis title string
  res@tiMainOffsetYF               =  0.05        ;-- move title string
  res@tiMainFont                   = "times-roman” ;-- title string font size

  res@tmXBLabelFontHeightF         =  0.025       ;--larger x-label font size
  res@tmYLLabelFontHeightF         =  0.025       ;--larger y-label font size

;-----------------------------------------------------------
;-- create the plot
;-----------------------------------------------------------
  plot = gsn_csm_xy(wks, x, y, res)             ;-- create the default plot

;-----------------------------------------------------------
;-- additional text on plot using plot coordinate
;-----------------------------------------------------------
  txres                  =  True           ;-- text resources additional text
  txres@txFontColor      = "blue"          ;-- change to white
  txres@txFontHeightF    =  0.015          ;-- decrease font size
  txres@txJust           = "CenterCenter"  ;-- text justification

  id = gsn_add_text(wks, plot, "maximum", 50, 0.99, txres)
                                           ;-- center position x=50, y=0.99
  id = gsn_add_text(wks, plot, "minimum", 10, -0.99, txres)
                                           ;-- center position x=10, y=-0.99
;-----------------------------------------------------------
;-- draw red lines
;-----------------------------------------------------------
  plres  =  True
  plres@gsLineColor      = "red"
  plres@gsLineThicknessF =  4.0
```

```
  plid1 = gsn_add_polyline(wks, plot, (/ 5,40/), (/0.99,0.99/), plres)
  plid2 = gsn_add_polyline(wks, plot, (/60,95/), (/0.99,0.99/), plres)
  plid3 = gsn_add_polyline(wks, plot, (/20,45/), (/-0.99,-0.99/), plres)

;------------------------------------------------------------
;-- additional text on plot using page coordinate (NDC)
;------------------------------------------------------------
  ndcres                 =  True          ;-- text resources copyright string
  ndcres@txFontColor     = "green"             ;-- change to white
  ndcres@txFontHeightF   =  0.02               ;-- make font size smaller
  ndcres@txJust          = "CenterCenter"      ;-- text justification

  gsn_text_ndc(wks,"x-axis", 0.5, 0.83, ndcres) ;-- draw right axis label

  ndcres@txAngleF                = -90.         ;-- rotate the text

  gsn_text_ndc(wks,"y-axis", 0.84, 0.5, ndcres) ;-- draw right axis label

;------------------------------------------------------------
;-- draw the plot
;------------------------------------------------------------
  draw(plot)
  frame(wks)
  delete(wks)

;------------------------------------------------------------
;-- add a logo to the finished plot (upper left corner)
;-- (this could be done only for PNG plot output)
;------------------------------------------------------------
  logo = "./NCLLogoWeb.jpg"

  cmd  = "composite -geometry 80x80+20+20 "+logo+" "+dummy+" "+output
  system(cmd)
  system("rm -rf "+dummy)

end
```



9 Regridding

For data analysis and visualization in climate modeling, data sets from different sources have to regularly be compared or jointly analysed on the same grid. NCL supports displaying visualizations of different data sets on different grids within one single plot or by using a panel plot. But beyond that, it is often necessary to apply mathematical operations on the data before visualizing it. As an example, a model's bias is typically visualized as the difference between a model data set and reference data such as observational data. The difference between two fields is built gridpoint by gridpoint, and therefore, as a prerequisite for this type of processing step, all data concerned need to be defined on one single common grid.

To regrid a model data set from one grid to another, the **CDOs** or the **ESMF regridding functions** can be used. The CDOs are command line based and can be called from within NCL with the **systemfunc** function in order to generate new, regiridded data files (see also 2.4). The **ESMF** functions can be directly called within your NCL script to generate a new data file or keep the data in the memory. The user has to load the *contributed.ncl* and *ESMF_regridding.ncl* library files first:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/contributed.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/esmf/ESMF_regridding.ncl"
```

There are different methods for regridding the data:

- bilinear (CDOs, ESMF)
- patch (ESMF)
- conservative (CDOs, ESMF)
- bicubic (CDOs)
- distance weighted (CDOs)
- nearest neighbor (CDOs, ESMF)
- largest area fraction (CDOs)

These examples will only demonstrate the bilinear interpolation with a short NCL script and for CDOs with a short Korn-Shell script.

More information can be found on the following web pages:

ESMF: http://www.ncl.ucar.edu/Applications/ESMF.shtml

CDOs: http://www.mpimet.mpg.de/fileadmin/software/cdo/cdo.pdf

9.1 ESMF Regridding

The Earth System Modeling Framework (ESMF) is "software for building and coupling weather, climate, and related models". The ESMF "ESMF_RegridWeightGen" tool has been incorporated into NCL for generating weights for interpolating (regridding) data from a one grid to another.

The basic steps of NCL/ESMF regridding involve:

1. Reading or generating the "source" grid.
2. Reading or generating the "destination" grid.
3. Creating special NetCDF files that describe these two grids.

4. *Generating a NetCDF file that contains the weights.
5. Applying the weights to data on the source grid, to interpolate the data to the destination grid.
6. Copying over additional metadata to the newly regridded data.

*This is the most important step. Once you have a weights file, you can skip steps #1-4 if you are interpolating data on the same grids.

9.1.1 Curvilinear Grid to Rectilinear Grid

Regrid source data on a curvilinear grid to a destination rectilinear grid with grid distance 1° for latitude and longitude. Interpolation method is bilinear.

NUG_regrid_curvilinear_to_rectilinear_bilinear_weights_ESMF.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/esmf/ESMF_regridding.ncl"

begin
  start_time = get_cpu_time()                    ;-- get cpu time

  diri = "./"
  fili = "thetao_curvilinear_ocean.nc"

;-- read data
  sfile               =  addfile(diri+fili,"r")
  thetao              =  sfile->thetao(0,0,:,:)
  thetao@lat2d        =  sfile->lat
  thetao@lon2d        =  sfile->lon
  printVarSummary(thetao)

;-- set resources
  Opt                 =  True
  Opt@InterpMethod    = "bilinear"                ;-- interpolation method
  Opt@SrcFileName     = "CMIP5_SCRIP_bilinear.nc" ;-- source file name
  Opt@DstFileName     = "World1deg_SCRIP_bilinear.nc"
                                                  ;-- destination file name
  Opt@WgtFileName     = "CMIP5toWORLD_1x1_bilinear.nc"
                        ;-- name of weights file, which will be generated
  Opt@ForceOverwrite  =  True                     ;-- force overwrite
  Opt@SrcMask2D       =  where(.not.ismissing(thetao),1,0)
                                                  ;-- what to mask
  Opt@DstGridType     = "1x1"                     ;-- Destination grid
  Opt@DstTitle        = "World Grid 1x1-degree Resolution bilinear"
                                                  ;-- destination title
  Opt@DstLLCorner     = (/-89.75d,   0.00d /)
                                         ;-- destination lower left corner
  Opt@DstURCorner     = (/ 89.75d, 359.75d /)
                                         ;-- destination upper right corner
  print("---------------------------------------------------")
  print("Generating interpolation weights from CMIP5 to")
  print("World 1x1 degree grid.")
  print("")
  print("Method: bilinear")
  print("---------------------------------------------------")

;-- call ESMF_regrid
  thetao_regrid = ESMF_regrid(thetao,Opt)
  printVarSummary(thetao_regrid)
  nlon = dimsizes(thetao_regrid&lon)
```

```
  nlat = dimsizes(thetao_regrid&lat)

;-- assign a output netcdf file for the new regridded data
;-- (npoints = 180x360)
  system("rm -rf regridded_bilinear_CMIP5_thetao_ESMF.nc")
  fout = addfile("regridded_rectilinear_bilinear_ocean_thetao_ESMF.nc","c")

;-- start to define output file settings
  setfileoption(fout,"DefineMode",True)
                               ;-- explicitly declare file definition mode
;-- create global attributes of the file
  fAtt             =  True         ;-- assign file attributes
  fAtt@Conventions = "CF-1.4"
  fAtt@comment    = "Regrid curvilinear to 1x1 rectilinear grid using ESMF"
  fAtt@title       = "Regrid to 1x1 deg rectilinear grid"
  fAtt@project_id  = "NCL User Guide"
  fAtt@source_file =  fili
  fAtt@creation_date =  systemfunc ("date")
  fAtt@history = "NUG_regrid_CMIP5_bilinear_with_weights.ncl: "+fili+" to
1x1 deg rectilinear grid"
  fileattdef(fout,fAtt)                          ;-- copy file attributes

;-- predefine the coordinate variables and their dimensionality
  dimNames = (/"lat", "lon"/)
  dimSizes = (/nlat,  nlon/)
  dimUnlim = (/False, False/)
  filedimdef(fout,dimNames,dimSizes,dimUnlim)

;-- predefine the the dimensionality of the variables to be written out
  filevardef(fout,"lat",typeof(thetao_regrid&lat), \
                                     getvardims(thetao_regrid&lat))
  filevardef(fout,"lon",typeof(thetao_regrid&lon), \
                                     getvardims(thetao_regrid&lon))
  filevardef(fout,"thetao",typeof(thetao_regrid), \
                                     getvardims(thetao_regrid))

;-- copy attributes associated with each variable to the file
  filevarattdef(fout,"lat",thetao_regrid&lat)     ;-- copy lat attributes
  filevarattdef(fout,"lon",thetao_regrid&lon)     ;-- copy lon attributes
  filevarattdef(fout,"thetao",thetao_regrid)
                                      ;-- copy thetao_regrid attributes

;-- explicitly exit file definition mode (not required)
  setfileoption(fout,"DefineMode",False)

;-- output only the data values since the dimensionality and such
;-- have been predefined; the "(/", "/)" syntax tells NCL to only
;-- output the data values to the predefined locations on the file
  fout->lat    =  (/thetao_regrid&lat/)    ;-- write lat to new netCDF file
  fout->lon    =  (/thetao_regrid&lon/)    ;-- write lon to new netCDF file
  fout->thetao =  (/thetao_regrid/)   ;-- write variable to new netCDF file

;-- get the resulting CPU time
  end_time   =  get_cpu_time()
  cpu_time   =  end_time - start_time
  print("Elapsed time:  "+ cpu_time + "s")

end
```

9.1.2 Curvilinear Grid to Rectilinear Grid from a given File

Comparing datasets from different models that are on different grids, ESMF can also be used to regrid the data onto a given destination grid. In this example a curvilinear dataset (MPIOM) will be regridded to a 192x96 rectilinear grid (ECHAM5).

NUG_regrid_curvilinear_to_rectilinear_bilinear_wgts_destgrid_ESMF.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/esmf/ESMF_regridding.ncl"

begin
  start_time = get_cpu_time()                    ;-- get cpu time

  diri = "./"
  fili = "thetao_curvilinear_ocean.nc"
  grid = "tas_rectilinear_grid_2D.nc"

;-- read destination grid data
  g       =  addfile(diri+grid,"r")
  dst_lat =  g->lat
  dst_lon =  g->lon

;-- read data
  sfile                    =  addfile(diri+fili,"r")
  thetao                   =  sfile->thetao(0,0,:,:)
  thetao@lat2d             =  sfile->lat
  thetao@lon2d             =  sfile->lon
  printVarSummary(thetao)

;-- set resources
  Opt                      =  True
  Opt@InterpMethod         = "bilinear"           ;-- interpolation method
  Opt@SrcFileName          = "CMIP5_SCRIP_bilinear.nc"  ;-- source file name
  Opt@DstFileName          = "World1deg_SCRIP_bilinear.nc"   ;-- destination
                                                             ;-- file name
  Opt@WgtFileName          = "CMIP5toWORLD_192x96_bilinear.nc"   ;-- name of
                                   ;-- weights file, which will be generated
  Opt@ForceOverwrite       =  True                     ;-- force overwrite
  Opt@SrcMask2D            =  where(.not.ismissing(thetao),1,0) ;-- what to
                                                                ;-- mask
  Opt@DstGridType          = "rectilinear"            ;-- Destination grid
  Opt@DstTitle             = "World Grid 192x96 Resolution bilinear"
                                                      ;-- destination title
  Opt@DstGridLon           =  dst_lon
  Opt@DstGridLat           =  dst_lat

  print("---------------------------------------------------")
  print("Generating interpolation weights from CMIP5 to")
  print("World destination 192x96 grid.")
  print("")
  print("Method: bilinear")
  print("---------------------------------------------------")

;-- call ESMF_regrid
  thetao_regrid = ESMF_regrid(thetao,Opt)
  printVarSummary(thetao_regrid)
  nlon = dimsizes(thetao_regrid&lon)
  nlat = dimsizes(thetao_regrid&lat)

;-- assign a output netcdf file for the new regridded data
;--  (npoints = 192x96)
```

```
  system("rm -rf regridded_rectilinear_bilinear_ocean_thetao_destgrid_ESMF.nc")
  fout =  addfile("regridded_rectilinear_bilinear_ocean_thetao_destgrid_ESMF.nc",
"c")

;-- start to define output file settings
  setfileoption(fout,"DefineMode",True)          ;-- explicitly declare file
                                                 ;-- definition mode
;-- create global attributes of the file
  fAtt                    =  True                ;-- assign file attributes
  fAtt@Conventions        = "CF-1.4"
  fAtt@comment         = "Regrid curvilinear grid to 192x96 rectilinear grid"
  fAtt@title              = "Regrid to 192x96 deg rectilinear grid"
  fAtt@project_id         = "NCL User Guide"
  fAtt@source_file        =  fili
  fAtt@creation_date      =  systemfunc ("date")
  fAtt@history            = "NUG_regrid_CMIP5_bilinear_with_weights.ncl:
"+fili+" to 1x1 deg rectilinear grid"
  fileattdef(fout,fAtt)                             ;-- copy file attributes

;-- predefine the coordinate variables and their dimensionality
  dimNames = (/"lat", "lon"/)
  dimSizes = (/nlat,  nlon/)
  dimUnlim = (/False, False/)
  filedimdef(fout,dimNames,dimSizes,dimUnlim)

;-- predefine the the dimensionality of the variables to be written out
  filevardef(fout, "lat",   typeof(thetao_regrid&lat), \
                                        getvardims(thetao_regrid&lat))
  filevardef(fout, "lon",   typeof(thetao_regrid&lon), \
                                        getvardims(thetao_regrid&lon))
  filevardef(fout, "thetao",typeof(thetao_regrid), \
                                            getvardims(thetao_regrid))
;-- copy attributes associated with each variable to the file
  filevarattdef(fout,"lat",   thetao_regrid&lat)    ;-- copy lat attributes
  filevarattdef(fout,"lon",   thetao_regrid&lon)    ;-- copy lon attributes
  filevarattdef(fout,"thetao",thetao_regrid)        ;-- copy thetao_regrid
                                                    ;-- attributes
;-- explicitly exit file definition mode (not required)
  setfileoption(fout,"DefineMode",False)

;-- output only the data values since the dimensionality and such
;-- have been predefined. The "(/", "/)" syntax tells NCL to only output
;-- the data values to the predefined locations on the file.
  fout->lat    =  (/thetao_regrid&lat/)    ;-- write lat to new netCDF file
  fout->lon    =  (/thetao_regrid&lon/)    ;-- write lon to new netCDF file
  fout->thetao =  (/thetao_regrid/)   ;-- write variable to new netCDF file

;-- get the resulting CPU time
  end_time   =  get_cpu_time()
  cpu_time   =  end_time - start_time
  print("Elapsed time:  "+ cpu_time + "s")

end
```

9.1.3 Unstructured Grid to Rectilinear Grid

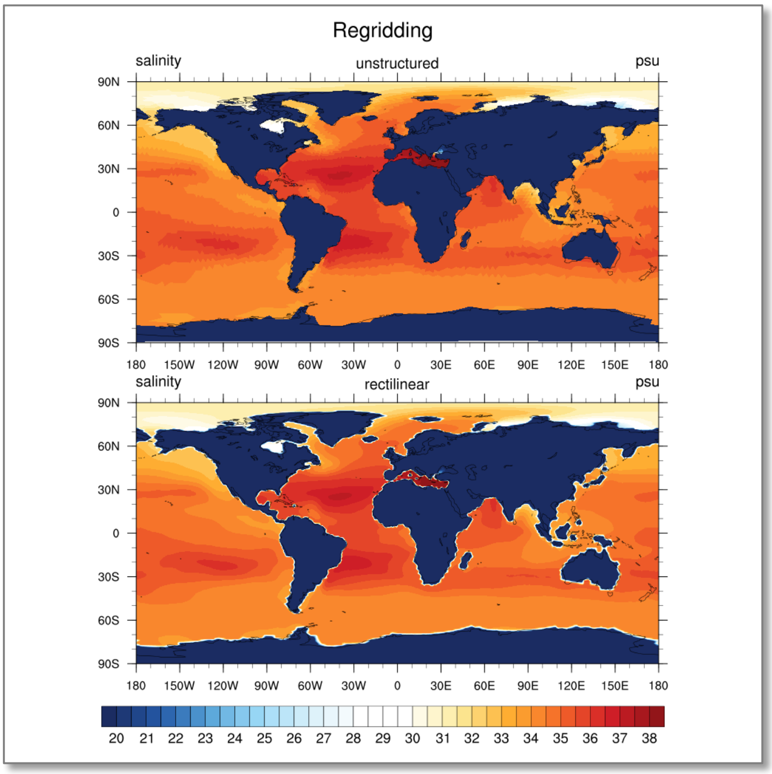
In this section we will show you how to regrid the data from an unstructured triangular mesh with 20480 cells to a 1-degree rectilinear grid, write the regridded data to a new netCDF file, and plot the original and regridded data in a panel.

NUG_regrid_unstructured_to_rectilinear_bilinear_wgts_ESMF.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/esmf/ESMF_regridding.ncl"

begin
  start_time = get_cpu_time()              ;-- get cpu time

  rad2deg = get_r2d("float")               ;-- radians to degrees

  diri = "$HOME/NCL/general/scripts/new/NCL_Doc_Example_scripts_and_data/"
  fili = "triangular_grid_ICON.nc"

;-- read data
  f       =  addfile(diri+fili,"r")
  var     =  f->S(time|0,depth|0,ncells|:)  ;-- set variable with dims:
                                            ;-- (time,depth,ncells)
  printVarSummary(var)

  x       =  f->clon * rad2deg              ;-- cell center, lon
  y       =  f->clat * rad2deg              ;-- cell center, lat
  x!0     = "lon"                           ;-- set named dimension lon
  y!0     = "lat"                           ;-- set named dimension lat
  x@units = "degrees_east"                  ;-- set lon units
  y@units = "degrees_north"                 ;-- set lat units

  vlon    =  f->clon_vertices * rad2deg     ;-- cell longitude vertices
  vlon    =  where(vlon.lt.0, vlon + 360, vlon) ;-- longitude: 0-360
  vlat    =  f->clat_vertices * rad2deg     ;-- cell lattitude vertices
  nv      =  dimsizes(vlon(0,:))            ;-- number of points in polygon

;-- set resources
  Opt                  =  True
  Opt@InterpMethod     = "bilinear"      ;-- interpolation method
  Opt@ForceOverwrite   =  True           ;-- force overwrite
;  Opt@Debug           =  True            ;-- print debug information
;  Opt@PrintTimings    =  True

  Opt@SrcFileName      = "CMIP5_SCRIP_bilinear.nc" ;-- source file name
  Opt@SrcInputFileName =  diri+fili      ;-- optional, but good idea
  Opt@SrcRegional      =  False
  Opt@SrcGridLat       =  y
  Opt@SrcGridLon       =  x
  Opt@WgtFileName      = "ICONtoWORLD_1x1_bilinear.nc" ;-- name of
                                  ;-- weights file, which will be generated
  Opt@DstFileName      = "World1deg_SCRIP_bilinear.nc" ;-- dest. file name
  Opt@DstGridType      = "rectilinear"                 ;-- destination grid
  Opt@DstTitle         = "World Grid 1x1-degree Resolution bilinear"
                                                       ;-- destination title
  Opt@DstRegional      =  False
  Opt@DstGridLon       =  fspan(-180.,180.,360)
  Opt@DstGridLat       =  fspan(-90.,90.,180)

  print("---------------------------------------------------")
  print("Generating interpolation weights from ICON to")
  print("World 1x1 degree grid.")
  print("")
  print("Method: bilinear")
  print("---------------------------------------------------")

;-- call ESMF_regrid
  var_regrid = ESMF_regrid(var,Opt)          ;-- do the regridding
  printVarSummary(var_regrid)
```

```
  nlon = dimsizes(var_regrid&lon)             ;-- dim size new lon
  nlat = dimsizes(var_regrid&lat)             ;-- dim size new lat

;-- assign a output netcdf file for the new regridded data
;-- (npoints = 180x360)
  system("rm -rf regridded_rectilinear_bilinear_ICON_S_ESMF.nc")
  fout =  addfile("regridded_rectilinear_bilinear_ICON_S_ESMF.nc", "c")

;-- start to define output file settings
  setfileoption(fout,"DefineMode",True)       ;-- explicitly declare file
                                              ;-- definition mode

;-- create global attributes of the file
  fAtt               =  True              ;-- assign file attributes
  fAtt@Conventions   = "CF-1.4"
  fAtt@comment = "Regrid unstructured grid to 1x1 rectilinear grid - ESMF"
  fAtt@title         = "Regrid to 1x1 deg rectilinear grid"
  fAtt@project_id    = "NCL User Guide"
  fAtt@source_file   =  fili
  fAtt@creation_date =  systemfunc ("date")
  fAtt@history = "NUG_regrid_ICON_bilinear_with_weights.ncl: "+fili+\
                 " to 1x1 deg rectilinear grid"
  fileattdef(fout,fAtt)                      ;-- copy file attributes

;-- predefine the coordinate variables and their dimensionality
  dimNames = (/"lat", "lon"/)
  dimSizes = (/nlat,  nlon/)
  dimUnlim = (/False, False/)
  filedimdef(fout,dimNames,dimSizes,dimUnlim)

;-- predefine the the dimensionality of the variables to be written out
  filevardef(fout, "lat",typeof(var_regrid&lat),getvardims(var_regrid&lat))
  filevardef(fout, "lon",typeof(var_regrid&lon),getvardims(var_regrid&lon))
  filevardef(fout, "S",  typeof(var_regrid),    getvardims(var_regrid))

;-- copy attributes associated with each variable to the file
  filevarattdef(fout,"lat", var_regrid&lat)  ;-- copy lat attributes
  filevarattdef(fout,"lon", var_regrid&lon)  ;-- copy lon attributes
  filevarattdef(fout,"S",   var_regrid)      ;-- copy var_regrid attributes

;-- explicitly exit file definition mode (not required)
  setfileoption(fout,"DefineMode",False)

;-- output only the data values since the dimensionality and such
;-- have been predefined. The "(/", "/)" syntax tells NCL to only
;-- output the data values to the predefined locations on the file.
  fout->lat =  (/var_regrid&lat/)     ;-- write lat to new netCDF file
  fout->lon =  (/var_regrid&lon/)     ;-- write lon to new netCDF file
  fout->S   =  (/var_regrid/)         ;-- write variable to new netCDF file

;-- get the resulting CPU time
  end_time =  get_cpu_time()
  cpu_time =  end_time - start_time
  print("Elapsed time:  "+ cpu_time + "s")

;-- open a PNG file
  wks_type          = "png"
  wks_type@wkWidth  =  1024
  wks_type@wkHeight =  1024
  wks = gsn_open_wks(wks_type,"plot_regrid_unstructured_to_rectilinear")

;-- set resources for contour plots
```

```
  res                      =  True
  res@gsnDraw              =  False                 ;-- don't draw plot yet
  res@gsnFrame             =  False                 ;-- don't advance the frame
  res@gsnCenterString     = "unstructured"
  res@gsnAddCyclic         =  False
  res@lbLabelBarOn         =  False                 ;-- no single label bar

  res@cnFillOn             =  True                  ;-- turn color fill on
  res@cnFillPalette        = "BlueWhiteOrangeRed" ;-- choose color map
  res@cnLinesOn            =  False                 ;-- turn lines off
  res@cnLineLabelsOn       =  False                 ;-- turn labels off
  res@cnLevelSelectionMode = "ManualLevels"   ;-- use manual contour levels
  res@cnMinLevelValF       =  20.                   ;-- contour min. value
  res@cnMaxLevelValF       =  38.                   ;-- contour max. value
  res@cnLevelSpacingF      =   0.5                  ;-- contour interval

  res2                     =  res
  res2@gsnCenterString     = "rectilinear"

  res@cnFillMode           = "CellFill"             ;-- set fill mode
  res@sfXArray             =  x          ;-- transform x to mesh scalar field
  res@sfYArray             =  y          ;-- transform y to mesh scalar field
  res@sfXCellBounds        =  vlon                ;-- needed if set "CellFill"
  res@sfYCellBounds        =  vlat                ;-- needed if set "CellFill"

;-- create the plots
  plot0 = gsn_csm_contour_map(wks, var, res)   ;-- original data

  plot1 = gsn_csm_contour_map(wks, var_regrid, res2) ;-- regridded data

;-- create the panel plot
  pres                     =  True
  pres@txString            = "Regridding"         ;-- panel title string
  pres@gsnPanelLabelBar    =  True                ;-- turn on a common
                                        ;-- labelbar for the entire panel plot

  gsn_panel(wks,(/plot0,plot1/),(/2,1/),pres)

end
```



9.1.4 Unstructured Grid to Rectilinear Grid from a Given File

Regridding data on an unstructured grid onto a given destination grid read off a netCDF file is shown in the next example. The script does the regridding, writes the regridded data to a new netCDF file and plot the original and the regridded data on a panel.

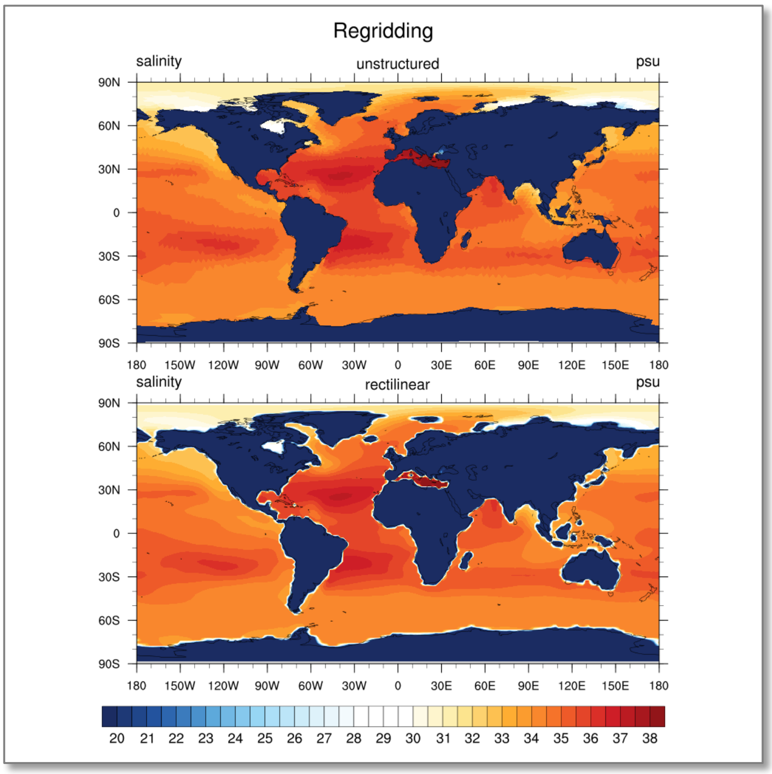
NUG_regrid_unstructured_to_rectilinear_bilinear_wgts_destgrid_ESMF.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/esmf/ESMF_regridding.ncl"

begin
  start_time = get_cpu_time()                   ;-- get cpu time

  outputfile = "regridded_rectilinear_bilinear_ICON_S_ESMF_destgrid.nc"

  rad2deg =  get_r2d("float")                   ;-- radians to degrees

  diri  = "$HOME/NCL/general/scripts/new/NCL_Doc_Example_scripts_and_data/"
  fili  = "triangular_grid_ICON.nc"
  grid  = "tas_rectilinear_grid_2D.nc"          ;-- use grid from file

;-- read destination grid data
  g       =  addfile(diri+grid,"r")
  dst_lat =  g->lat
  dst_lon =  g->lon

;-- read data
  f       =  addfile(diri+fili,"r")
  var     =  f->S(time|0,depth|0,ncells|:)  ;-- set variable with dims
  printVarSummary(var)

  x       =  f->clon * rad2deg                  ;-- cell center, lon
  y       =  f->clat * rad2deg                  ;-- cell center, lat
```

```
  x!0     = "lon"                           ;-- set named dimension lon
  y!0     = "lat"                           ;-- set named dimension lat
  x@units = "degrees_east"                  ;-- set lon units
  y@units = "degrees_north"                 ;-- set lat units

  vlon    =  f->clon_vertices * rad2deg     ;-- cell longitude vertices
  vlon    =  where(vlon.lt.0, vlon + 360, vlon) ;-- longitude: 0-360
  vlat    =  f->clat_vertices * rad2deg     ;-- cell lattitude vertices
  nv      =  dimsizes(vlon(0,:))            ;-- number of points in polygon

;-- set resources
  Opt                     =  True
  Opt@InterpMethod        = "bilinear"      ;-- interpolation method
  Opt@ForceOverwrite      =  True           ;-- force overwrite
;  Opt@Debug               =  True
;  Opt@PrintTimings        =  True

  Opt@SrcFileName         = "CMIP5_SCRIP_bilinear.nc" ;-- source file name
  Opt@SrcInputFileName    =  diri+fili      ;-- optional, but good idea
  Opt@SrcRegional         =  False
  Opt@SrcGridLat          =  y
  Opt@SrcGridLon          =  x
  Opt@WgtFileName         = "ICONtoWORLD_bilinear_192x96.nc"
                          ;-- name of weights file, which will be generated
  Opt@DstFileName         = "World1deg_SCRIP_bilinear.nc"  ;-- destination
                                                           ;-- file name
  Opt@DstGridType         = "rectilinear"   ;-- destination grid
  Opt@DstTitle            = "World Grid 1x1-degree Resolution bilinear"
                                                      ;-- destination title
  Opt@DstRegional         =  False
  Opt@DstGridLon          =  dst_lon
  Opt@DstGridLat          =  dst_lat

  print("---------------------------------------------------")
  print("Generating interpolation weights from ICON to")
  print("World destination 192x96 degree grid.")
  print("")
  print("Method: bilinear")
  print("---------------------------------------------------")

;-- call ESMF_regrid
  var_regrid = ESMF_regrid(var,Opt)         ;-- do the regridding
  printVarSummary(var_regrid)
  nlon = dimsizes(var_regrid&lon)           ;-- dims new lon
  nlat = dimsizes(var_regrid&lat)           ;-- dims new lat

;-- assign a output netcdf file for the new regridded data
;--(npoints = 180x360)
  system("rm -rf "+outputfile)
  fout =  addfile(outputfile, "c")

;-- start to define output file settings
  setfileoption(fout,"DefineMode",True)     ;-- explicitly declare file
                                            ;-- definition mode

;-- create global attributes of the file
  fAtt               =  True            ;-- assign file attributes
  fAtt@Conventions   = "CF-1.4"
  fAtt@comment = "Regrid unstructured grid to 192x96 rectilin. grid - ESMF"
  fAtt@title         = "Regrid to 192x96 rectilinear grid"
  fAtt@project_id    = "NCL User Guide"
  fAtt@source_file   =  fili
```

```
  fAtt@creation_date =  systemfunc ("date")
  fAtt@history       = "NUG_regrid_ICON_bilinear_with_weights.ncl: "+fili+\
                        " to 1x1 deg rectilinear grid"
  fileattdef(fout,fAtt)                     ;-- copy file attributes

;-- predefine the coordinate variables and their dimensionality
  dimNames = (/"lat", "lon"/)
  dimSizes = (/nlat,  nlon/)
  dimUnlim = (/False, False/)
  filedimdef(fout,dimNames,dimSizes,dimUnlim)

;-- predefine the the dimensionality of the variables to be written out
  filevardef(fout, "lat",typeof(var_regrid&lat),getvardims(var_regrid&lat))
  filevardef(fout, "lon",typeof(var_regrid&lon),getvardims(var_regrid&lon))
  filevardef(fout, "S",  typeof(var_regrid),    getvardims(var_regrid))

;-- copy attributes associated with each variable to the file
  filevarattdef(fout,"lat", var_regrid&lat) ;-- copy lat attributes
  filevarattdef(fout,"lon", var_regrid&lon) ;-- copy lon attributes
  filevarattdef(fout,"S",   var_regrid)     ;-- copy var_regrid attributes

;-- explicitly exit file definition mode (not required)
  setfileoption(fout,"DefineMode",False)

;-- output only the data values since the dimensionality and such
;-- have been predefined. The "(/", "/)" syntax tells NCL to only output
;-- the data values to the predefined locations on the file.
  fout->lat =  (/var_regrid&lat/)    ;-- write lat to new netCDF file
  fout->lon =  (/var_regrid&lon/)    ;-- write lon to new netCDF file
  fout->S   =  (/var_regrid/)        ;-- write variable to new netCDF file

;-- get the resulting CPU time
  end_time =  get_cpu_time()
  cpu_time =  end_time - start_time
  print("Elapsed time:  "+ cpu_time + "s")

;-----------------------------------------------------------
;-- control the netCDF output file; open file and read variable
;-----------------------------------------------------------
  p = addfile(outputfile,"r")
  new_var = p->S

;-- open a PNG file
  wks_type          = "png"
  wks_type@wkWidth  =  1024
  wks_type@wkHeight =  1024
  wks = gsn_open_wks(wks_type,"plot_regrid_unstruc_to_recti_destgrid")

;-- set resources for contour plots
  res                     =  True
  res@gsnDraw             =  False
  res@gsnFrame            =  False
  res@gsnCenterString     = "unstructured"
  res@gsnAddCyclic        =  False
  res@lbLabelBarOn        =  False           ;-- no single label bar

  res@cnFillOn            =  True
  res@cnFillPalette       = "BlueWhiteOrangeRed" ;-- choose a color map
  res@cnLinesOn           =  False           ;-- turn lines off
  res@cnLineLabelsOn      =  False           ;-- turn labels off
  res@cnLevelSelectionMode = "ManualLevels" ;-- manual contour levels
  res@cnMinLevelValF      =  20.             ;-- minimum level
```

```
  res@cnMaxLevelValF      =  38.            ;-- maximum level
  res@cnLevelSpacingF     =   0.5           ;-- contour spacing

  res2                    =  res

  res@cnFillMode          = "CellFill"      ;-- set fill mode

  res@sfXArray            =  x         ;-- transform x to mesh scalar field
  res@sfYArray            =  y         ;-- transform y to mesh scalar field
  res@sfXCellBounds       =  vlon      ;-- needed if set "CellFill"
  res@sfYCellBounds       =  vlat      ;-- needed if set "CellFill"

;-- create the plot of the original data
  plot0 = gsn_csm_contour_map(wks, var, res)

;-- create the plot of the regridded data
  res2@gsnCenterString    = "rectilinear"
  res2@gsnAddCyclic       =  True

  plot1 = gsn_csm_contour_map(wks, new_var, res2)

;-- create the panel plot
  pres = True
  pres@txString           = "Regridding"    ;-- panel title string
  pres@gsnPanelLabelBar   =  True           ;-- turn on a common labelbar
                                            ;-- for the entire panel plot
  gsn_panel(wks,(/plot0,plot1/),(/2,1/),pres)

end
```



9.1.5 Rectilinear Grid to Curvilinear Grid from a Given File

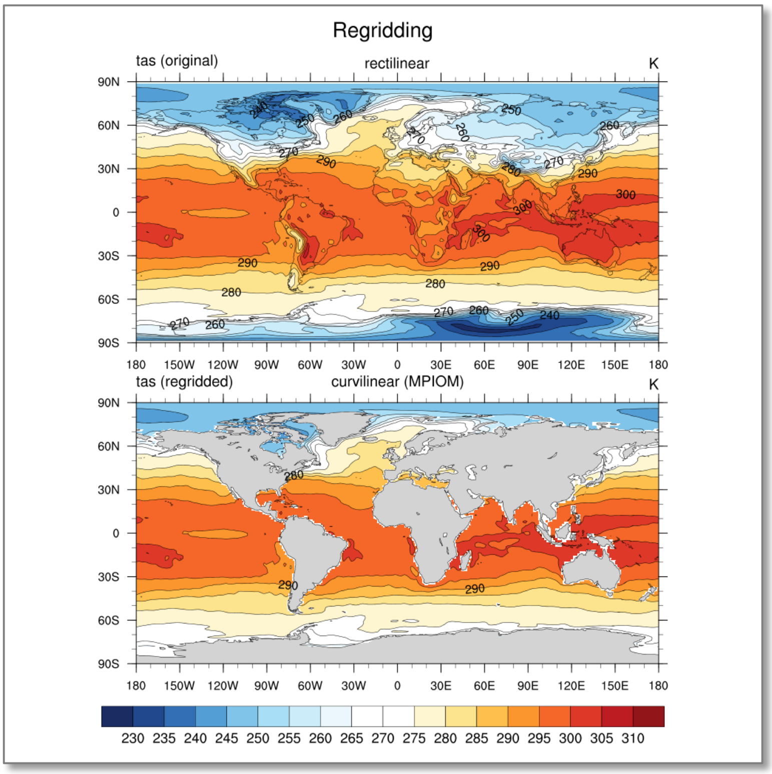
Sometimes you need to regrid a rectilinear grid to a curvilinear grid, both read from given netCDF files. The declaration of the netCDF output file is now a little bit different, because the output latitude and longitude arrays are 2-dimensional.

NUG_regrid_rectilinear_to_curvilinear_bilinear_wgts_destgrid_ESMF.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/esmf/ESMF_regridding.ncl"

begin
  start_time = get_cpu_time()               ;-- get cpu time

;-- read data
  diri    = "../data/"
  fili    = "tas_rectilinear_grid_2D.nc"
  f       =  addfile(diri+fili,"r")
  var     =  f->tas(0,:,:)

;-- name of output file
  outputfile = "regridded_rectilin_to_curvilin_bilin_wgts_destgrid_ESMF.nc"

;-- read the destination grid lat/lon arrays
  dstfili = "thetao_curvilinear_ocean.nc"   ;-- get dest. grid from file
  d       =  addfile(diri+dstfili,"r")
  dst_lat =  d->lat
  dst_lon =  d->lon
  dvar    =  d->thetao(0,0,:,:)
  dims    =  dimsizes(dst_lat)
  nlat    =  dims(0)
  nlon    =  dims(1)

  printVarSummary(dvar)
  print("")
  print("----> Destination dims:  lat "+nlat+"  lon "+nlon)
  print("")

;-- set resources
  Opt                 =  True
  Opt@InterpMethod  = "bilinear"              ;-- interpolation method
  Opt@SrcFileName   = "ECHAM5_SCRIP_bilinear.nc"  ;-- source file name
  Opt@DstFileName   = "WorldCurvilinear_SCRIP_bilinear.nc" ;-- dest. file
  Opt@WgtFileName   = "ECHAM5toWorldCurvilinear_bilinear.nc" ;-- name of
                              ;-- weights file, which will be generated
  Opt@ForceOverwrite =  True                       ;-- force overwrite
  Opt@DstMask2D    =  where(ismissing(dvar),0,1) ;-- create mask from dest.
  Opt@DstGridType   = "curvilinear"              ;-- Destination grid
  Opt@DstTitle      = "World Grid Curvilinear Resolution bilinear"
                                            ;-- destination title
  Opt@DstGridLon    =  dst_lon
  Opt@DstGridLat    =  dst_lat

  print("---------------------------------------------------")
  print("Generating interpolation weights from ECHAM5 to")
  print("World destination curvilinear grid.")
  print("")
  print("Method: bilinear")
  print("---------------------------------------------------")

;-- call ESMF_regrid
  var_regrid   =  ESMF_regrid(var,Opt)
  var_regrid!0 = "y"                        ;-- named coordinate
  var_regrid!1 = "x"                        ;-- named coordinate
  printVarSummary(var_regrid)
```

```
  delete(var_regrid@lat2d)                  ;-- delete attribute array lat2d
  delete(var_regrid@lon2d)                  ;-- delete attribute array lon2d

;-- assign a output netcdf file for the new regridded data
  system("rm -rf "+outputfile)
  fout =  addfile(outputfile, "c")

;-- start to define output file settings
  setfileoption(fout,"DefineMode",True)     ;-- explicitly declare file
                                            ;-- definition mode
;-- create global attributes of output file
  fAtt               =  True             ;-- assign file attributes
  fAtt@Conventions   = "CF-1.4"
  fAtt@comment       = "Regrid rectilinear grid to curvilinear grid - ESMF"
  fAtt@title         = "Regrid to curvilinear grid"
  fAtt@project_id    = "NCL User Guide"
  fAtt@source_file   =  fili
  fAtt@creation_date=  systemfunc ("date")
  fAtt@history       = \
"NUG_regrid_rectilinear_to_curvilinear_bilinear_wgts_destgrid_ESMF.ncl: "+\
                      fili+" to curvilinear grid"
  fileattdef(fout,fAtt)                      ;-- copy file attributes

;-- predefine the coordinate variables and their dimensionality
  dimNames = (/"y", "x"/)      ;-- curvilinear grid: dimensions not lat/lon
  dimSizes = (/nlat,  nlon/)   ;-- dimension size of destination y/x
  dimUnlim = (/False, False/)
  filedimdef(fout,dimNames,dimSizes,dimUnlim)

;-- predefine the the dimensionality of the variables to be written out
  filevardef(fout,"lat",typeof(dst_lat),getvardims(dst_lat)) ;-- variable
                                                             ;-- lat not dimension
  filevardef(fout,"lon",typeof(dst_lon),getvardims(dst_lon)) ;-- variable
                                                             ;-- lon not dimension
  filevardef(fout,"var",typeof(var_regrid),getvardims(var_regrid))

;-- copy attributes associated with each variable to output file
  filevarattdef(fout,"lat",dst_lat)    ;-- copy attributes from dest. lat
  filevarattdef(fout,"lon",dst_lon)    ;-- copy attributes from dest. lon
  filevarattdef(fout,"var",var_regrid) ;-- copy var_regrid attributes

;-- explicitly exit file definition mode (not required)
  setfileoption(fout,"DefineMode",False)

;-- output only the data values since the dimensionality and such
;-- have been predefined; the "(/", "/)" syntax tells NCL to only output
;-- the data values to the predefined locations on the file.
  fout->lat =  (/dst_lat/)          ;-- write lat to new netCDF file
  fout->lon =  (/dst_lon/)          ;-- write lon to new netCDF file
  fout->var =  (/var_regrid/)       ;-- write variable to new netCDF file

;-- get the resulting CPU time
  end_time =  get_cpu_time()
  cpu_time =  end_time - start_time
  print("Elapsed time:  "+ cpu_time + "s")

;----------------------------------------------------------
;-- control the netCDF output file; open file and read variable
;----------------------------------------------------------
  p = addfile(outputfile,"r")
  new_var = p->var
```

```
  new_var@lat2d   =  p->lat
  new_var@lon2d   =  p->lon

;-- open a workstation
  wks_type          = "png"
  wks_type@wkWidth  =  1024
  wks_type@wkHeight =  1024
  wks = gsn_open_wks(wks_type,"plot_regrid_rectilin_to_curvilin_destgrid")

;-- set resources for contour plots
  res                       =  True
  res@gsnDraw               =  False
  res@gsnFrame              =  False
  res@gsnLeftString         = "tas (original)"
  res@gsnCenterString       = "rectilinear"
  res@gsnAddCyclic          =  True

  res@cnFillOn              =  True
  res@cnLevelSelectionMode = "ManualLevels" ;-- manual contour levels
  res@cnMinLevelValF        =  230.          ;-- minimum level
  res@cnMaxLevelValF        =  310.          ;-- maximum level
  res@cnLevelSpacingF       =    5.          ;-- contour spacing

  res@lbLabelBarOn          =  False         ;-- no single label bar

;-- create the plot with original data on rectilinear grid
  plot0 = gsn_csm_contour_map(wks, var, res)

;-- create the plot with regridded data on curvilinear grid
  res2                      =  res
  res2@gsnLeftString        = "tas (regridded)"
  res2@gsnCenterString      = "curvilinear (MPIOM)"
  res2@gsnAddCyclic         =  True

  plot1 = gsn_csm_contour_map(wks,new_var,res2);-- from output netCDF file

;-- create the panel plot
  pres = True
  pres@txString           = "Regridding"     ;-- panel title string
  pres@gsnPanelLabelBar  =  True             ;-- turn on a common labelbar
                                             ;-- for the entire panel plot

  gsn_panel(wks,(/plot0,plot1/),(/2,1/),pres)

end
```



9.1.6 CMIP5 Grid to 1x1 degrees Grid

This example demonstrates the use of the ESMF regridding function to interpolate a global CMIP5 grid into a regular global 1x1° grid.

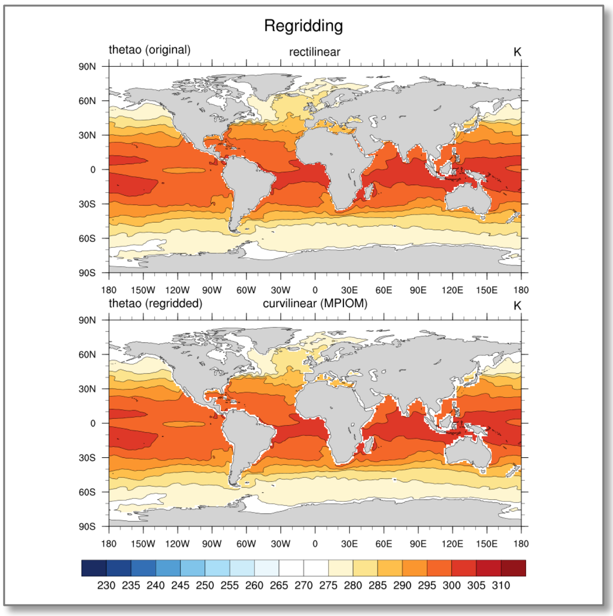
NUG_regrid_bilinear_CMIP5_grid_to_1x1deg_grid.ncl:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/esmf/ESMF_regridding.ncl"

begin
  start_time = get_cpu_time()                    ;-- get cpu time

;-- name of output file
  outfile = "regridded_CMIP5_to_rectilinear_bilinear_wgts_ESMF.nc"

;-- read data
  diri   = "../data/"
  fili   = "thetao_curvilinear_ocean.nc"

  sfile          =  addfile(diri+fili,"r")
  thetao         =  sfile->thetao(0,0,:,:)
  thetao@lat2d =  sfile->lat
  thetao@lon2d =  sfile->lon

;-- set resources to generate the weights and grid files
  Opt                 =  True
  Opt@InterpMethod =  "bilinear"
  Opt@SrcFileName   =  "CMIP5_SCRIP_bilinear.nc"      ;-- source grid file name
  Opt@DstFileName   =  "World1deg_SCRIP_bilinear.nc" ;-- dest. grid file name
  Opt@WgtFileName   =  "CMIP5toWORLD_1x1_bilinear.nc";-- name of weights file,
                                                    ;-- which will be generated
  Opt@ForceOverwrite   =  True
```

```
  Opt@SrcMask2D       =  where(.not.ismissing(thetao),1,0)
  Opt@DstGridType     = "1x1"                        ;-- dest. grid type
  Opt@DstTitle        = "World Grid 1x1-degree Resolution bilinear"
  Opt@DstLLCorner     =  (/ -89.75d,   0.00d /)
  Opt@DstURCorner     =  (/  89.75d, 359.75d /)

;-- interpolate data from CMIP5 to Worl 1x1 degree grid using ESMF
  print("---------------------------------------------------------------")
  print("Generating interpolation weights from CMIP5 to World 1x1deg. grid")
  print("   Method:  bilinear")
  print("---------------------------------------------------------------")

  thetao_regrid = ESMF_regrid(thetao,Opt)
  printVarSummary(thetao_regrid)

;-- write regridded data to file
  system("rm -rf "+outfile)
  fout = addfile(outfile, "c")
  fout->thetao = thetao_regrid

;-- get the resulting CPU time
  end_time =  get_cpu_time()
  cpu_time =  end_time - start_time
  print("Elapsed time:  "+ cpu_time + "s")

;-- open a workstation
  wks_type          = "png"
  wks_type@wkWidth  =  1024
  wks_type@wkHeight =  1024
  wks = gsn_open_wks(wks_type,"plot_regrid_CMIP5_to_rectilinear_ESMF")

;-- set resources for contour plots
  res                      =  True
  res@gsnDraw              =  False
  res@gsnFrame             =  False
  res@gsnLeftString        = "thetao (original)"
  res@gsnCenterString      = "rectilinear"
  res@gsnAddCyclic         =  True

  res@cnFillOn             =  True
  res@cnFillPalette        = "BlueWhiteOrangeRed" ;-- choose color map
  res@cnLineLabelsOn       =  False
  res@cnLevelSelectionMode = "ManualLevels" ;-- manual contour levels
  res@cnMinLevelValF       =  230.          ;-- minimum level
  res@cnMaxLevelValF       =  310.          ;-- maximum level
  res@cnLevelSpacingF      =    5.          ;-- contour spacing

  res@lbLabelBarOn         =  False         ;-- no single label bar

;-- create the plot with original data on rectilinear grid
  plot0 = gsn_csm_contour_map(wks, thetao, res)

;-- create the plot with regridded data on curvilinear grid
  res2                     =  res
  res2@gsnLeftString       = "thetao (regridded)"
  res2@gsnCenterString     = "curvilinear (MPIOM)"
  res2@gsnAddCyclic        =  True

  plot1 = gsn_csm_contour_map(wks, thetao_regrid, res2) ;-- from output
                                                        ;-- netCDF file

;-- create the panel plot
```

```
  pres = True
  pres@txString           = "Regridding"     ;-- panel title string
  pres@gsnPanelLabelBar  =  True             ;-- turn on a common labelbar
for the entire panel plot

  gsn_panel(wks,(/plot0,plot1/),(/2,1/),pres)

end
```

The script create a new data file named **plot_regrid_CMIP5_to_rectilinear_ESMF.**
Elapsed time: 6s



9.2 CDO Regridding

CDO (Climate Data Operators) is a collection of **Command Line Operators** to manipulate and analyse Climate and NWP model Data. Supported data formats are GRIB 1/2, netCDF 3/4, SERVICE, EXTRA and IEG. There are more than 600 operators available.

The buil-in operator module REMAPGRID contains operators to remap (=regrid) all input fields to a new horizontal grid.

Remapping operators:

remapbil	Bilinear interpolation
remapbic	Bicubic interpolation
remapdis	Distance-weighted remapping
remapnn	Nearest neighbor remapping
remapcon	First order conservative remapping
remapbil	Second order conservative remapping
remapbil	Largest area fraction remapping

See also https://code.zmaw.de/projects/cdo section REMAPGRID in the documentation.

9.2.1 Curvilinear Grid to Gaussian N32 Grid

Let us assume that the data file ***ifile*** contains fields on a quadrilateral curvilinear grid. To remap all fields bilinear to a Gaussian N32 grid, type in a terminal window:

```
cdo remapbil,n32 ifile ofile
```

To remap the input data to a 1x1° rectilinear grid:

```
cdo remapbil,r360x180 ifile ofile
```

To remap all fields bilinear to a Gaussian N32 grid using generated interpolation weights type type in a terminal window:

```
cdo genbil,n32 ifile remapweights.nc
cdo remap,n32,remapweights.nc ifile ofile
```

9.2.2 Curvilinear Grid to Rectilinear Grid (Korn-Shell Script)

This example demonstrates the use of the CDO remapping function to interpolate a global CMIP5 grid into a regular world grid 1x1° equivalent to the ESMF regridding. The commands

```
cdo genbil,r360x180 data.nc weights_bil.nc
cdo remap,r360x180,weights_bil.nc data.nc regridded_data.nc
```

will generate a bilinear weight file *weights_bil.nc*, which will be used to interpolate the data.

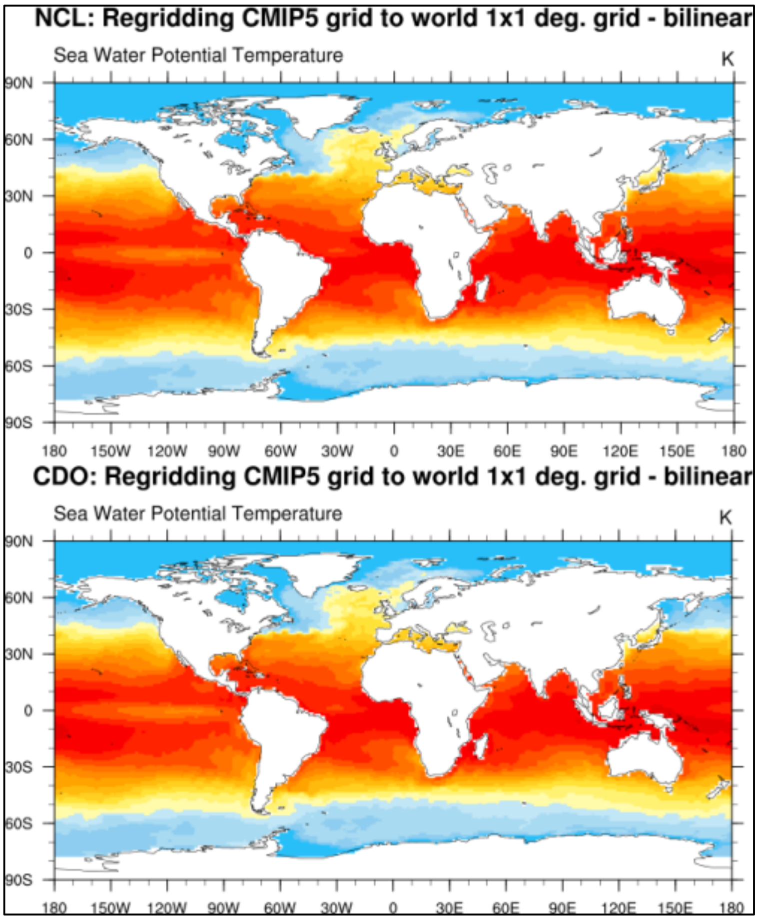
The next command line will generate a bilinear weight file, but only in memory, not saved on the disk:

```
cdo remapbil,r360x180 ${fin} ${fout}
```

NUG_cdo_remap_bilinear_CMIP5_grid_to_1x1deg_grid.ksh:

```
#!/usr/bin/ksh

t1=$(date +%s)

dir="./"
fin="$dir/thetao_curvilinear_ocean.nc"
fout="remap_bilinear_CMIP5_thetao.nc"
wgts="weights_bilinear.nc"          #-- generated by 'cdo genbil'

#-- generate bilinear interpolation weights
cdo genbil,r360x180 ${fin} ${wgts}

#-- remap to 1x1 degree grid using the weights file
cdo remap,r360x180,${wgts} ${fin} ${fout}

#-- following call will give the same result and elapsed time
#-- as 'cdo genbil' and 'cdo remap', but won't save the weights file
#cdo remapbil,r360x180 ${fin} ${fout}

t2=$(date +%s)
td=$(expr $t2 - $t1)
echo "Elapsed time:  ${td}s"

exit
```

The script creates a new netCDF file named ***remap_bilinear_CMIP5_thetao.nc .***
Elapsed time: 48s


NCL: Regridding CMIP5 grid to world 1x1 deg. grid - bilinear
Sea Water Potential Temperature
K
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
CDO: Regridding CMIP5 grid to world 1x1 deg. grid - bilinear
Sea Water Potential Temperature
K
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180

10 Using External Fortran or C Code

NCL supports calling subroutines in external code (e.g. Fortran or C). In this section we will show how to call external Fortran routines using the NCL WRAPIT tool. See also:

http://www.ncl.ucar.edu/Document/Tools/WRAPIT.shtml

To use WRAPIT, you must follow the next four steps:

1. Write special wrapper text file
2. Run WRAPIT
3. Load the generated shared object file
4. Call the subroutine/function

10.1 Fortran

In this example, the korn shell script *NUG_use_Fortran_subroutines.ksh* does it all: it first creates a Fortran code and pass it to WRAPIT in order to generate a shared object file. The script also creates the ncl script *ncl_script*, which finally is executed and invokes the wrapped Fortran executable.

Fortran Wrapper example: NUG_use_Fortran_subroutines.ksh

```
#!/usr/bin/ksh
#-----------------------------------------------------------
#-- NCL Doc Example script:  NUG_use_Fortran_subroutines.ksh
#--
#--     Write a short Fortran subroutine --> ex01.f
#--     Run the wrapper                  --> ex01.so
#--     Write NCL script                 --> NUG_use_Fortran_subroutines.ncl
#--     Run NCL script                   --> write results to stdout
#-----------------------------------------------------------
example=${0%.*}
ncl_script=${example}.ncl
#-----------------------------------------------------------
#-- write the NCL script
#-----------------------------------------------------------
cat << EOF > ${ncl_script}
external EX01 "./ex01.so"

begin
   print("")
;-- Calculate three values of a quadratic equation
   nump = 3
   x    = (/ -1., 0.0, 1.0 /)
   qval = new(nump,float)
;-- Call the NCL version of your Fortran subroutine.
   EX01::cquad(-1., 2., 3., nump, x, qval)
   print("Polynomial value = " + qval)     ;-- should be (/0,3,4/)
;-- Calculate an arc length.
   xc = (/ 0., 1., 2. /)
   yc = (/ 0., 1., 0. /)
;-- Call the NCL version of your Fortran function.
   arclen = EX01::arcln(nump,xc,yc)
   print("Arc length = " + arclen)         ;-- should be 2.82843
   print("")
end
```

```
EOF
#-----------------------------------------------------------
#-- fortran77 code
#-----------------------------------------------------------
cat<<EOF> ex01.f
C NCLFORTSTART
      subroutine cquad (a, b, c, nq, x, quad)
      real x(nq), quad(nq)
C NCLEND
C
C  Calculate quadratic polynomial values.
C
      do 10 i=1,nq
        quad(i) = a*x(i)**2 + b*x(i) + c
   10 continue

      return
      end

C NCLFORTSTART
      function arcln (numpnt, pointx, pointy)
      dimension pointx(numpnt),pointy(numpnt)
C NCLEND

C
C  Calculate arc lengths.
C
      if (numpnt .lt. 2) then
        print *, 'arcln: number of points must be at least 2'
        stop
      endif
      arcln = 0.
      do 10 i=2,numpnt
        pdist = sqrt((pointx(i)-pointx(i-1))**2 +
     +                        (pointy(i)-pointy(i-1))**2)
        arcln = arcln + pdist
   10 continue

      return
      end
EOF

#-----------------------------------------------------------
#-- run the NCL wrapper. Generates the ex01.so shared object file.
#-----------------------------------------------------------
WRAPIT ex01.f

#-----------------------------------------------------------
#-- run ncl
#-----------------------------------------------------------
ncl -n ${ncl_script}

exit
```

Result on stdout:

```
WRAPIT Version: 120209
COMPILING ex01.f
LINKING
END WRAPIT

Copyright (C) 1995-2017 - All Rights Reserved
```

```
University Corporation for Atmospheric Research
NCAR Command Language Version 6.4.0
The use of this software is governed by a License Agreement.
See http://www.ncl.ucar.edu/ for more details.

Polynomial value = 0
Polynomial value = 3
Polynomial value = 4
Arc length = 2.82843
```

10.2 C Code

The same example can also be set up for C code, but since NCLs WRAPIT is not able to work directly with C, a little more effort is necessary and we need to apply some tricks.

1. Write the C code
2. Create a Fortran stub file with the calling sequences and types
3. Run "wrapit77" on the Fortran stub file to create the C wrapper
4. Make some changes in the C wrapper file
5. Run "WRAPIT" with the '-d' option to get compiling informations
6. Create a Makefile to compile the C code and create the shared library
7. Use the external subroutine and functions within NCL

All steps are done by the following Korn-Shell script.

C Wrapper example: NUG_use_C_subroutines.ksh

```
#!/bin/ksh
#-----------------------------------------------------------
#-- NCL Doc Example script:  NUG_use_C_subroutines.ksh
#--
#-- original: http://www.ncl.ucar.edu/Document/Tools/WRAPIT.shtml#Example_6
#--
#--   Write a short C subroutine        --> ex01C.c
#--   Write a Fortran stub file         --> ex01C.stub
#--   Run the wrapper for ex01.stub     --> ex01CW.c
#--   Modify ex01W.c                    --> ex01CW.c
#--   Run the wrapper with option '-d' --> returns compilation information
#--   Compile the files                 --> ex01C.so
#--   Write NCL script                  --> NUG_use_C_subroutines.ncl
#--   Run NCL script                    --> write results to stdout
#--
#-- 23.07.13
#-----------------------------------------------------------
example=${0%.*}
ncl_script=${example}.ncl

#-- clean up
rm -rf ex01C.c ex01C.o ex01C.c~ ex01C.stub ex01CW.c ex01CW.o WRAPIT.stub
rm -rf WRAPIT.c WRAPIT.o ex01C.so NUG_use_C_subroutines.ncl objects
rm -rf WRAPIT_debug_output Makefile

#-----------------------------------------------------------
#-- create the C code. It is the same code as in the Fortran
#-- example for the functions cquad and arcln but implemented
#-- in C.
#-----------------------------------------------------------
cat << EOF > ex01C.c
```

```
/* http://www.ncl.ucar.edu/Document/Tools/WRAPIT.shtml#Example_6 */
#include <stdio.h>
#include <stdlib.h>
#include <math.h>

void *cquad(float a, float b, float c,int nq, float *x, float *quad)
{
  int i;
/* Calculate quadratic polynomial values. */
  for(i = 0; i < nq; i++ ) quad[i] = a*pow(x[i],2) + b*x[i] + c;
}

float arcln(int numpnt, float *pointx, float *pointy)
{
  int i;
  float pdist, a;
/* Calculate arc lengths. */
  if(numpnt < 2) {
    printf("arcln: number of points must be at least 2\n");
    return;
  }
  a = 0.;
  for( i=1; i < numpnt; i++ ) {
    pdist = sqrt(pow(pointx[i]-pointx[i-1],2) + pow(pointy[i]-pointy[i-
1],2));
    a += pdist;
  }
  return(a);
}
EOF

echo "--------------------------------"
echo "-- write C code            - done"

#----------------------------------------------------------
#-- create a Fortran stub file containing the same calling
#-- sequence and types for the C subroutines and functions
#----------------------------------------------------------
cat << EOF > ex01C.stub
C NCLFORTSTART
      subroutine cquad (a, b, c, nq, x, quad)
      real a, b, c
      real x(nq), quad(nq)
C NCLEND
C NCLFORTSTART
      function arcln (numpnt, pointx, pointy)
      integer numpnt
      real pointx(numpnt),pointy(numpnt)
C NCLEND
EOF

echo "-- write Fortran stub file - done"

#----------------------------------------------------------
#-- run the NCL wrapper on the Fortran stub to create the
#-- C wrapper
#----------------------------------------------------------
wrapit77 < ex01C.stub > ex01CW.c

echo "-- create the C wrapper    - done"

#----------------------------------------------------------
```

```
#-- modify ex01CW.c to make a few changes. The lines with
#-- NGCALLF should be changed:
#------------------------------------------------------------
cat ex01CW.c | sed -e
's/NGCALLF(cquad,CQUAD)(a,b,c,nq,x,quad)/(void)cquad(*a,*b,*c,*nq,x,quad)/g' >
tmp.c
cat tmp.c | sed -e 's/extern float NGCALLF(arcln,ARCLN)()/extern float arcln(int
numpnt, float *pointx, float *pointy)/g' > tmp1.c
cat tmp1.c | sed -e 's/arcln_ret =
NGCALLF(arcln,ARCLN)(numpnt,pointx,pointy)/arcln_ret =
arcln(*numpnt,pointx,pointy)/g' > tmp2.c
cat tmp2.c | sed -e 's/NhlErrorTypes cquad_W( void ) {/extern NhlErrorTypes
cquad_W( void ) {/g' > tmp3.c

rm -rf tmp.c tmp1.c tmp2.c
mv tmp3.c ex01CW.c

echo "-- modify ex01CW.c         - done"

#------------------------------------------------------------
#-- run the NCL wrapper
#------------------------------------------------------------
WRAPIT -d ex01C.stub > WRAPIT_debug_output

#------------------------------------------------------------
#-- create a Makefile and run it
#------------------------------------------------------------
compline=$(cat WRAPIT_debug_output | grep gcc | grep WRAPIT.c)
compline1=$(echo ${compline} | sed -e 's/WRAPIT.c/ex01C.c/g')
compline2=$(echo ${compline} | sed -e 's/WRAPIT.c/ex01CW.c/g')
linkline=$(cat WRAPIT_debug_output | grep gcc | grep WRAPIT.o)
linkline1=$(echo ${linkline} | sed -e 's/WRAPIT.o/ex01CW.o ex01C.o/g')

cat << EOF > Makefile
ex01C.so: ex01CW.o ex01C.o
      ${linkline1}

ex01C.o: ex01C.c
      ${compline1}

ex01CW.o: ex01CW.c
      ${compline2}
EOF

echo "-- write Makefile          - done"

make > /dev/null

echo "-- make                    - done"

#------------------------------------------------------------
#-- write the NCL script.
#-- Use the external functions cquad and arcln
#------------------------------------------------------------
cat << EOF > ${ncl_script}
external EX01C "./ex01C.so"

begin
   print("")
;-- Calculate three values of a quadratic equation
   nump = 3
   x    = (/ -1., 0.0, 1.0 /)
   qval = new(nump,float)
 ;-- Call the NCL version of your Fortran subroutine.
```

```
   EX01C::cquad(-1., 2., 3., nump, x, qval)
   print("Polynomial value = " + qval)     ;-- should be (/0,3,4/)
;-- Calculate an arc length.
   xc = (/ 0., 1., 2. /)
   yc = (/ 0., 1., 0. /)
;-- Call the NCL version of your Fortran function.
   arclen = EX01C::arcln(nump,xc,yc)
   print("Arc length = " + arclen)         ;-- should be 2.82843
   print("")
end
EOF

echo "-- write NCL script        - done"

#-----------------------------------------------------------
#-- run ncl
#-----------------------------------------------------------
echo "---------------------------------"
ncl -n ${ncl_script}

exit
```

Result on stdout:

```
---------------------------------
-- write C code            - done
-- write Fortran stub file - done
-- create the C wrapper    - done
-- modify ex01CW.c         - done
-- write Makefile          - done
-- make                    - done
-- write NCL script        - done
---------------------------------
 Copyright (C) 1995-2017 - All Rights Reserved
 University Corporation for Atmospheric Research
 NCAR Command Language Version 6.4.0
 The use of this software is governed by a License Agreement.
 See http://www.ncl.ucar.edu/ for more details.

Polynomial value = 0
Polynomial value = 3
Polynomial value = 4
Arc length = 2.82843
```

11 Creating Images for PowerPoint, Keynote, Web

For importing NCL visualizations to PowerPoint, Keynote or web pages, it is recommended to use the output format 'png'. For printable documents you should select larger width and height values to get a better resolution:

```
wkstype           =  "png"
wkstype@wkWidth   =  2500
wkstype@wkHeight  =  2500
wks = gsn_open_wks(wkstype, "plot_file_name")
```

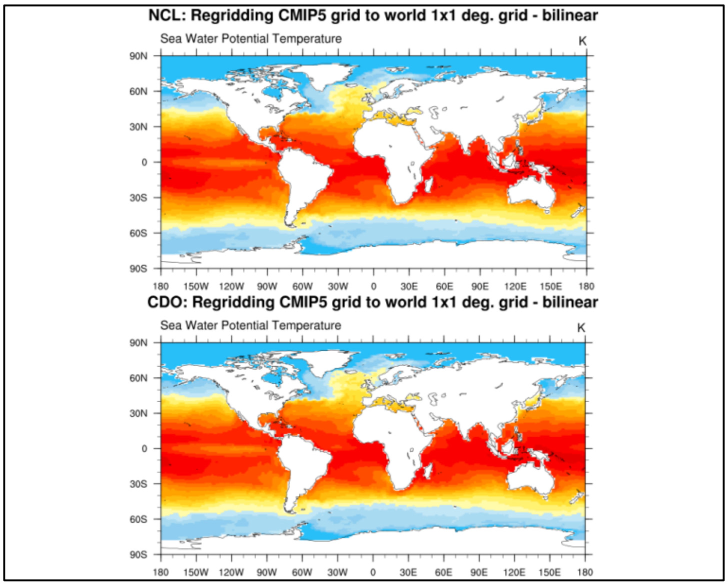
If the output format "png" doesn't produce good results, it may be better to use "ps" or "pdf" output format. The PS or PDF file can be converted using the free ImageMagick software package, which is installed on most machines.

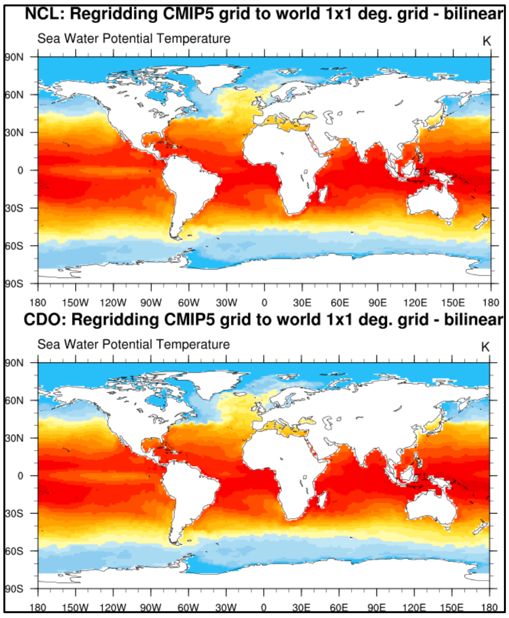
```
convert -geometry 2500x2500 -density 300 -trim plot.ps plot.png
```

For posters you have to increase the values for geometry and density.

To crop white space from the plot:

```
convert -alpha off -background white -geometry 1000x1000 \
        -density 300 -trim plot.ps plot.png
```





12 Customizing the NCL Graphics Environment

NCL requires only one environment variable, which is NCARG_ROOT, which should be set to the parent directory of the NCL installation.

Here some of the important NCL environment variables which can be changed in order to customize your NCL environment:

NCARG_ROOT	parent directory of NCL installation default: */usr/local*
NCARG_NCARG	location of supplemental directories, like databases, examples, resource files, etc. default: *$NCARG_ROOT/lib/ncarg*
NCARG_USRRESFILE	NCL HLU resource file default: *~/.hluresfile*
NCARG_COLORMAP_PATH	list of paths of color map files default: *$NCARG_NCARG/colormaps*
NCARG_RANGS	point to the RANGS/GSHHS database, if installed default: $NCARG_NCARG/rangs
NCARG_EXAMPLES	point to the low-level examples Default: *$NCARG_NCARG/examples*
NCL_GRIB_PTABLE_PATH	point to GRIB parameter table file default: *none*
NIO_GRIB2_CODETABLES	location of the GRIB2 code tables default: *$NCARG_ROOT/lib/ncarg/grib2_codetables*

All NCL environment variables are listed on the web page:

http://www.ncl.ucar.edu/Document/Language/env.shtml

13 Tips

13.1 Reverse Latitudes in Data File

Some functions require that the order of the latitudes has to be **South** to **North**. If needed, it is very easy to reverse the latitudes array by re-ordering it with the following command:

```
latitudes = var&lat(::-1)
```

Pre-conditions: variable ***var*** has a named dimension called ***lat***

13.2 Convert NaNs (not a number) to _FillValue

Some datasets contain non-numeric values called **NaNs,** which can cause problems when trying to use a function or graphically display the data. NCL provides two built-in functions for dealing with NaNs: ***isnan_ieee*** for checking for the existence of NaNs, and ***replace_ieeenan*** for converting all NaNs to a desired value.

If the variable var is of type float:

```
if (any(isnan_ieee(var))) then
   value = -99999.9
   replace_ieeenan (var, value, 0)
   var@_FillValue    = value
   var@missing_value = value
end if
```

Here is an example to convert variables from an input netCDF file which contain NaNs and write the converted variables to a new netCDF file.

NUG_change_NaNs_to_FillValue.ncl

```
begin
  infile  = "data_with_NaNs.nc"
  outfile = "nan_to_FillValue.nc"

;-------------------------------------------------
;-- read data
;-------------------------------------------------
  f     =  addfile(infile,"r")
  time  =  f->time                 ;-- get dimension time
  lat   =  f->lat                  ;-- get dimension lat
  lon   =  f->lon                  ;-- get dimension lon
  ntim  =  dimsizes(time)          ;-- get dimension sizes of time
  nlat  =  dimsizes(lat)           ;-- get dimension sizes of lat
  nlon  =  dimsizes(lon)           ;-- get dimension sizes of lon

;-------------------------------------------------
;-- set correct units
;-------------------------------------------------
  lat@units = "degrees_north"
  lon@units = "degrees_east"

;-------------------------------------------------
;-- get variables
;-------------------------------------------------
  var1 = f->COR_SST_FC
```

```
  var2 = f->COR_SST_FC_SIGN

;-------------------------------------------------
;-- copy variables
;-------------------------------------------------
  var1_miss      =  tofloat(var1)
  var2_miss      =  tofloat(var2)

;-------------------------------------------------
;-- set named coordinates for var1_miss and var2_miss
;-------------------------------------------------
  var1_miss!0    = "time"
  var1_miss!1    = "lat"
  var1_miss!2    = "lon"
  var1_miss&time =  time
  var1_miss&lat  =  lat
  var1_miss&lon  =  lon

  var2_miss!0    = "time"
  var2_miss!1    = "lat"
  var2_miss!2    = "lon"
  var2_miss&time =  time
  var2_miss&lat  =  lat
  var2_miss&lon  =  lon

;-------------------------------------------------
;-- convert NaNs to _FillValue/missing_value
;-------------------------------------------------
  if (any(isnan_ieee(var1_miss))) then
    value = -99999.9
    replace_ieeenan (var1_miss, value, 0)
    var1_miss@_FillValue    = value
    var1_miss@missing_value = value
  end if
  if (any(isnan_ieee(var2_miss))) then
    value = -99999.9
    replace_ieeenan (var2_miss, value, 0)
    var2_miss@_FillValue    = value
    var2_miss@missing_value = value
  end if

  printVarSummary(var1_miss)
  printVarSummary(var2_miss)

;-------------------------------------------------
;-- write var1_miss and var2_miss to new file
;-------------------------------------------------
;-- create new netCDF file
  system("rm -rf "+outfile)
  fout = addfile(outfile,"c")

;-- begin output file settings
  setfileoption(fout,"DefineMode",True)  ;-- explicitly declare file
                                         ;-- definition mode
;-- create global attributes of the file
  fAtt                  =  True          ;-- assign file attributes
  fAtt@title            = "NCL convert NaNs to _FillValue"
  fAtt@source_file      =  infile
  fAtt@Conventions      = "CF"
  fAtt@creation_date    =  systemfunc ("date")
  fAtt@history          = "NCL script: change_NaN_to_FillValue.ncl"
  fAtt@comment          = "convert NaNs to _FillValue"
```

```
  fileattdef(fout,fAtt)        ;-- copy file attributes to new file

;-- predefine the coordinate variables and their dimensionality
  dimNames = (/"time", "lat", "lon"/)    ;-- define dimension names
  dimSizes = (/ -1   ,  nlat,  nlon/)    ;-- time unlimited (-1)
  dimUnlim = (/ True , False, False/)    ;-- True: unlimited
  filedimdef(fout,dimNames,dimSizes,dimUnlim) ;-- copy to new file

;-- predefine the the dimensionality of the variables to be
;-- written out
  filevardef(fout, "time" ,typeof(time),getvardims(time))
  filevardef(fout, "lat"  ,typeof(lat), getvardims(lat))
  filevardef(fout, "lon"  ,typeof(lon), getvardims(lon))
  filevardef(fout, "COR_SST_FC", typeof(var1_miss), getvardims(var1_miss))
  filevardef(fout, "COR_SST_FC_SIGN", typeof(var2_miss), \
                                                  getvardims(var2_miss))

;-- copy attributes associated with each variable to the file
  filevarattdef(fout,"time" ,time)       ;-- copy time attributes
  filevarattdef(fout,"lat"  ,lat)        ;-- copy lat attributes
  filevarattdef(fout,"lon"  ,lon)        ;-- copy lon attributes
  filevarattdef(fout,"COR_SST_FC", var1_miss) ;-- copy var1_miss
                                              ;-- attributes to new file
  filevarattdef(fout,"COR_SST_FC_SIGN", var2_miss) ;-- copy
                                      ;-- var2_miss attributes to new file

;-- explicitly exit file definition mode (not required)
  setfileoption(fout,"DefineMode",False)

;-- output only the data values since the dimensionality and
;-- such have been predefined. The "(/ /)" syntax tells NCL to only
;-- output the data values to the predefinedlocations on the file
  fout->time      =  (/time/)         ;-- write time to new netCDF file
  fout->lat       =  (/lat/)          ;-- write lat to new netCDF file
  fout->lon       =  (/lon/)          ;-- write lon to new netCDF file
  fout->COR_SST_FC = (/var1_miss/)    ;-- write variable to new netCDF file
  fout->COR_SST_FC_SIGN = (/var2_miss/) ;-- write variable to new netCDF
                                        ;-- file

;===================================================
;-- open new netcdf file and plot the two variables
;===================================================
  g  = addfile(outfile,"r")
  v1 = g->COR_SST_FC
  v2 = g->COR_SST_FC_SIGN
;-------------------------------------------------
;-- open workstation
;-------------------------------------------------
  wks_type = "png"                    ;-- plot output type
  wks = gsn_open_wks(wks_type,"plot_change_NaNs_to_FillValue")
                                      ;-- open a workstation
;-------------------------------------------------
;-- set resources
;-------------------------------------------------
  res               =  True
  res@cnFillOn      =  True
  res@gsnDraw       =  False
  res@gsnFrame      =  False
;-------------------------------------------------
;-- create the plot, don't draw yet
;-------------------------------------------------
  plot1 = gsn_csm_contour_map(wks,v1(0,:,:),res)
```

```
  plot2 = gsn_csm_contour_map(wks,v2(0,:,:),res)
;-----------------------------------------------
;-- create the panel plot
;-----------------------------------------------
  pres                  =  True
  pres@gsnMaximize  =  True
  gsn_panel(wks,(/plot1,plot2/),(/2,1/),pres)

end
```

14 PyNGL and PyNIO

PyNGL (pronounced 'pingle') is a Python module used to visualize scientific data, with an emphasis on high quality 2D visualizations. PyNGL is based on NCL graphics. A working knowledge of Python is assumed.

PyNIO is a Python module that allows read and/or write access to the same variety of data formats using an interface modeled on netCDF.

See also: http://www.pyngl.ucar.edu/

The example scripts in this chapter will show you how to work with the PyNGL/PyNIO modules similar to some NCL examples in this User Guide.

PyNGL and PyNIO can be installed using "conda":

```
conda install -c dbrown -c khallock pyngl pynio
```

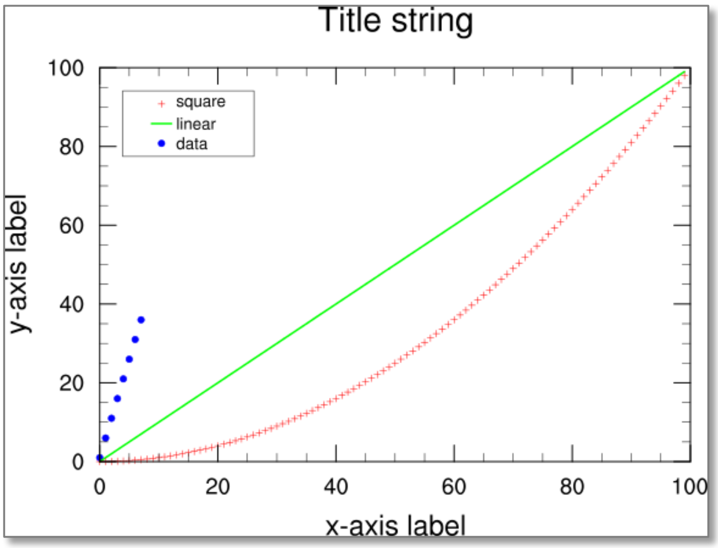
14.1 XY-Plot

The first PyNGL example creates aan xy-plot.

NUG_xy_plot_simple_PyNGL.py:

```
import numpy as np
import Ngl, Nio

#-- create x-values
x2 = np.arange(100)

#-- create y-values
data    = np.arange(1,40,5)
linear = np.arange(100)
square = [v * v for v in np.arange(0,10,0.1)]

#-- retrieve maximum size of plotting data
maxdim = max(len(data),len(linear),len(square))

#-- create 2D arrays to hold 1D arrays above
y = -999.*np.ones((3,maxdim),'f')               #-- assign y array containing
                                                #-- missing values
y[0,0:(len(data))]    = data
y[1,0:(len(linear))] = linear
y[2,0:(len(square))] = square

#-- open a workstation
wks                         =  Ngl.open_wks("png","plot_xy_simple_ngl")

#-- set resources
res                         =  Ngl.Resources() #-- generate an res object
                                                #-- for plot
res.tiMainString            = "Title string"   #-- set x-axis label
res.tiXAxisString           = "x-axis label"   #-- set x-axis label
res.tiYAxisString           = "y-axis label"   #-- set y-axis label

res.vpWidthF                =  0.9             #-- viewport width
res.vpHeightF               =  0.6             #-- viewport height
```

```
res.caXMissingV              =  -999.          #-- indicate missing value
res.caYMissingV              =  -999.          #-- indicate missing value

#-- marker and line settings
res.xyLineColors             =  ["blue","green","red"] #-- set line colors
res.xyLineThicknessF         =  3.0            #-- define line thickness
res.xyDashPatterns           =  [0,0,2]        #-- ( none, solid, cross )
res.xyMarkLineModes          =  ["Markers","Lines","Markers"] #-- marker mode
                                               #-- for each line
res.xyMarkers                =  [16,0,2]       #-- marker type of each line
res.xyMarkerSizeF            =  0.01           #-- default is 0.01
res.xyMarkerColors           =  ["blue","green","red"] #-- set marker colors

#-- legend settings
res.xyExplicitLegendLabels = [" data"," linear"," square"] #-- set explicit
                                               #-- legend labels
res.pmLegendDisplayMode    = "Always"          #-- turn on the drawing
res.pmLegendOrthogonalPosF = -1.13             #-- move the legend upwards
res.pmLegendParallelPosF   =  0.15             #-- move the legend to the
                                               #-- right
res.pmLegendWidthF           =  0.2            #-- change width
res.pmLegendHeightF          =  0.10           #-- change height
res.lgBoxMinorExtentF        =  0.16           #-- legend lines shorter

#-- draw the plot
plot = Ngl.xy(wks,x2,y,res)

#-- the end
Ngl.end()
```



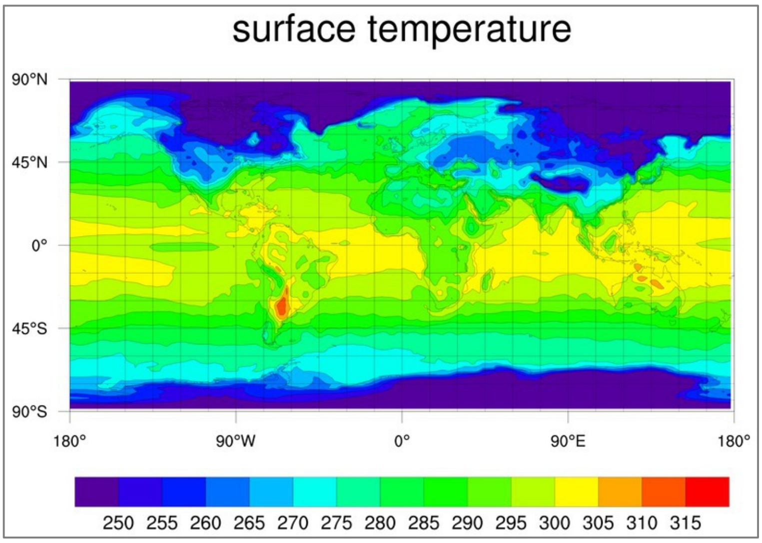
14.2 Contour Plot – Rectilinear Gridded Data

The first PyNGL example creates a filled contour plot of rectilinear gridded data.

PyNGL _rectilinear_contour.py:

```
import Ngl,Nio

#-- define variables
diri    = "./"                                 #-- data directory
fname   = "rectilinear_grid_2D.nc"             #-- data file name
```

```
minval =  250.                                 #-- minimum contour level
maxval =  315                                  #-- maximum contour level
inc    =    5.                                 #-- contour level spacing

#-- open file and read variables
f      =  Nio.open_file(diri + fname,"r")      #-- open data file
temp   =  f.variables["tsurf"][0,:,:]          #-- first time step
lat    =  f.variables["lat"][:]                #-- all latitudes
lon    =  f.variables["lon"][:]                #-- all longitudes

tempac,lon =  Ngl.add_cyclic(temp,lon)

#-- open a workstation
wks_type               = "png"                 #-- graphics output type
wkres                  =  Ngl.Resources()      #-- generate an res object
                                               #-- for workstation
wkres.wkWidth          =  2500                 #-- plot res 2500 pixel width
wkres.wkHeight         =  2500                 #-- plot resolution 2500
wks                    =  Ngl.open_wks(wks_type,"plot_contour_ngl",wkres)
                                               #-- open workstation
#-- set resources
res                    =  Ngl.Resources()      #-- generate an resource
                                               #-- object for plot
if hasattr(f.variables["tsurf"],"long_name"):
   res.tiMainString = f.variables["tsurf"].long_name  #-- set main title

res.cnFillOn              =  True              #-- turn on contour fill.
res.cnLinesOn             =  False             #-- turn off contour lines
res.cnLineLabelsOn        =  False             #-- turn off line labels.
res.cnInfoLabelOn         =  False             #-- turn off info label.
res.cnLevelSelectionMode  = "ManualLevels"     #-- select manual level
                                               #-- selection mode
res.cnMinLevelValF        =  minval            #-- minimum contour value
res.cnMaxLevelValF        =  maxval            #-- maximum contour value
res.cnLevelSpacingF       =  inc               #-- contour increment
res.cnFillPalette         = "rainbow"          #-- choose color map

res.mpGridSpacingF        =  30                #-- map grid spacing

res.sfXArray              =  lon             #-- longitude locations of data
res.sfYArray              =  lat             #-- latitude locations of data

res.lbOrientation         = "Horizontal"       #-- labelbar orientation

map = Ngl.contour_map(wks,tempac,res)          #-- draw contours over a map.

#-- end
Ngl.end()
```



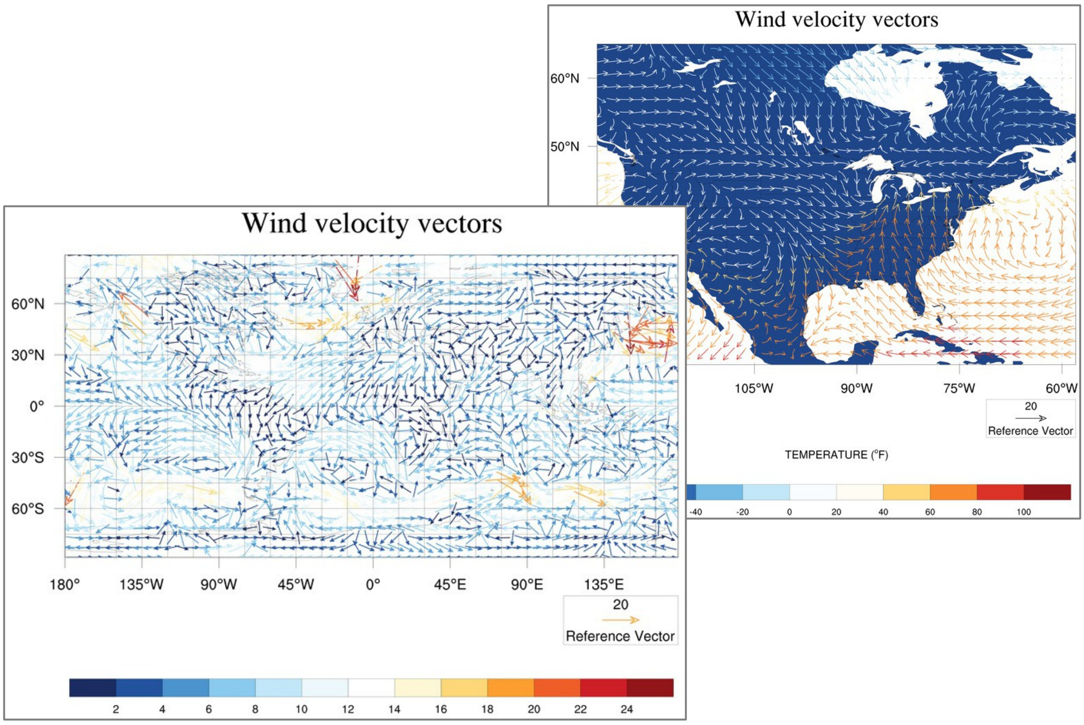
14.3 Vector Plot – Rectilinear Gridded Data

The next example script shows how to create a colored vector plot and a curly vector plot using some well known NCL resources.

NUG_rectilinear_vector_PyNGL.py:

```
import numpy, os
import Nio
import Ngl

#--  define variables
diri    = "./"                                  #-- data directory
fname   = "rectilinear_grid_2D.nc"              #-- data file name

#--  open file and read variables
f     = Nio.open_file(diri + fname,"r")         #-- open data file
temp = f.variables["tsurf"][0,:,:]              #-- first time step, reverse lat
u     = f.variables["u10"][0,:,:]               #-- first time step, reverse lat
v     = f.variables["v10"][0,:,:]               #-- first time step, reverse lat
lat   = f.variables["lat"][:]                   #-- reverse latitudes
lon   = f.variables["lon"][:]                   #-- all longitudes

nlon    = len(lon)                              #-- number of longitudes
nlat    = len(lat)                              #-- number of latitudes

#-- open a workstation
wkres            =  Ngl.Resources()             #-- generate an resources object
                                                #-- for workstation
wkres.wkWidth    =  2500                        #-- plot res 2500 pixel width
wkres.wkHeight   =  2500                        #-- plot res 2500 pixel height
wks_type         = "png"                        #-- graphics output type
wks              =  Ngl.open_wks(wks_type,"rectilinear_vector_PyNGL",wkres)

#-- create 1st plot: vectors on global map
res                       =  Ngl.Resources()

res.tiMainString          = "~F25~Wind velocity vectors"  #-- title string
res.tiMainFontHeightF     =  0.024              #-- decrease title font size

res.mpLimitMode           = "Corners"           #-- select a sub-region
```

```
res.mpLeftCornerLonF   =  float(lon[0])    #-- left longitude value
res.mpRightCornerLonF  =  float(lon[nlon-1]) #-- right lon value
res.mpLeftCornerLatF   =  float(lat[0])    #-- left latitude value
res.mpRightCornerLatF  =  float(lat[nlat-1]) #-- right lat value

res.mpPerimOn          =  True             #-- turn on map perimeter

res.vcMonoLineArrowColor =  False          #-- draw vectors in color
res.vcMinFracLengthF   =   0.33            #-- increase length of vectors
res.vcMinMagnitudeF    =   0.001           #-- increase length of vectors
res.vcRefLengthF       =   0.045           #-- set reference vector length
res.vcRefMagnitudeF    =  20.0             #-- set reference magnitude value
res.vcLineArrowThicknessF =6.0      #-- thicker vector lines (default: 1.0)

res.pmLabelBarDisplayMode = "Always"       #-- turn on a labelbar
res.lbOrientation      = "Horizontal"      #-- labelbar orientation
res.lbLabelFontHeightF =  0.008            #-- labelbar label font size
res.lbBoxMinorExtentF  =  0.22        #-- decrease height of labelbar boxes

res.vfXArray           =  lon[::3]         #-- longitude
res.vfYArray           =  lat[::3]         #-- latitudes

map1 = Ngl.vector_map(wks,u[::3,::3],v[::3,::3],res) #-- draw a vector plot

#-- create 2nd plot: sub-region colored by temperature variable
tempa = (temp-273.15)*9.0/5.0+32.0         #-- convert from Kelvin to
                                           #-- Fahrenheit
res.mpLimitMode        = "LatLon"          #-- change the area of the map
res.mpMinLatF          =  18.0             #-- minimum latitude
res.mpMaxLatF          =  65.0             #-- maximum latitude
res.mpMinLonF          = -128.             #-- minimum longitude
res.mpMaxLonF          = -58.              #-- minimum longitude

res.mpFillOn           =  True             #-- turn on map fill
res.mpLandFillColor    = "navyblue"        #-- change land color to navy
res.mpOceanFillColor   = "transparent"     #-- change color for oceans and
                                           #   inlandwater
res.mpInlandWaterFillColor = "transparent" #-- set ocean/inlandwater color
                                           #   to transparent
res.mpGridMaskMode = "MaskNotOcean"      #-- draw grid over ocean, not land
res.mpGridLineDashPattern =   2            #-- grid dash pattern
res.mpOutlineBoundarySets = "GeophysicalAndUSStates" #-- outline US States

res.vcFillArrowsOn     =  True             #-- fill the vector arrows
res.vcMonoFillArrowFillColor =  False      #-- draw vectors with colors
res.vcFillArrowEdgeColor =  "black"        #-- draw the edges in black
res.vcGlyphStyle       = "CurlyVector"     #-- draw nice curly vectors
res.vcLineArrowThicknessF = 5.0 #-- make vector lines thicker (default:1.0)

res.tiMainString       = "~F25~Wind velocity vectors"  #-- title string

res.lbTitleString      = "TEMPERATURE (~S~o~N~F)" #-- labelbar title string
res.lbTitleFontHeightF =  0.010            #-- labelbar title font size
res.lbBoxMinorExtentF  =  0.18        #-- decrease height of labelbar boxes

res.vfXArray           =  lon[::3]         #-- longitude
res.vfYArray           =  lat[::3]         #-- latitudes

map2 = Ngl.vector_scalar_map(wks,u,v,tempa,res)

#-- the end
Ngl.end()
```



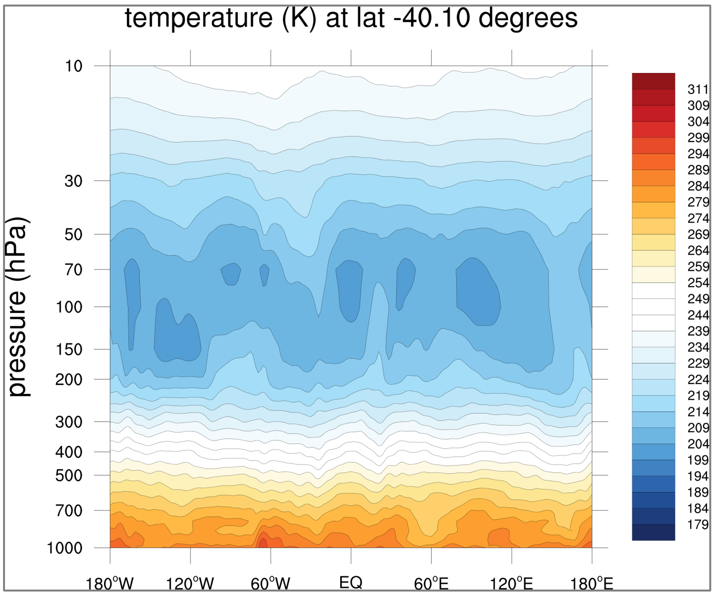
14.4 Slice Plot – Rectilinear Gridded Data

Creating a slice plot at a specified latitude index over all levels can be done in the same way as the index slicing in NCL.

NUG_rectilinear_slice_PyNGL.py:

```
import numpy as np
import sys,os
import Nio
import Ngl

def nice_lon_labels(lons):
  lonstrs = []
  for l in lons:
    if l < 0:
      lonstrs.append("%i~S~o~N~W" % np.fabs(l))
    elif l > 0:
      lonstrs.append("%i~S~o~N~E" % l)
    else:
      lonstrs.append("EQ" % l)
  return lonstrs

#--  define variables
diri    = "./"                          #-- data directory
fname   = "rectilinear_grid_3D.nc"      #-- data file name

#--  open file and read variables
f       =  Nio.open_file(diri + fname,"r") #-- open data file
t       =  f.variables["t"]             #-- get whole "t" variable
t26     =  t[0,:,26,:]                  #-- variable at lat index 26
lev     =  f.variables["lev"][:]*0.01   #-- all levels, convert to hPa
lat     =  f.variables["lat"][:]        #-- reverse latitudes
lon     =  f.variables["lon"][:]        #-- all longitudes

t26,lon = Ngl.add_cyclic(t26,lon)

strlat26 = lat[26]                      #-- retrieve data of lat index 26

#-- get the minimum and maximum of the data
minval =  int(np.amin(t[:]))         #-- minimum value
```

```
maxval =  int(np.amax(t[:]))            #-- maximum value
inc    =  5                             #-- contour level spacing

#-- values on which to place tickmarks on X and Y axis
lons = np.arange(-180,240,60)
levs = [1000,700,500,400,300,200,150,100,70,50,30,10]

#-- open a workstation
wkres                     =  Ngl.Resources()
                                #-- generate an res object for workstation
wkres.wkWidth             =  2500         #-- plot res 2500 pixel width
wkres.wkHeight            =  2500         #-- plot res 2500 pixel height
wks_type                  = "png"         #-- output type

wks =  Ngl.open_wks(wks_type,"plot_rectilinear_slice",wkres)
                                          #-- open workstation
#-- set resources
res                       =  Ngl.Resources

res.tiMainString          =  "%s (%s) at lat %.2f degrees" % \
                              (t.long_name,t.units,strlat26)
res.cnLevelSelectionMode  = "ManualLevels" #-- select manual levels
res.cnMinLevelValF        =  minval       #-- minimum contour value
res.cnMaxLevelValF        =  maxval       #-- maximum contour value
res.cnLevelSpacingF       =  inc          #-- contour increment
res.cnFillOn              =  True         #-- turn on contour fill
res.cnLineLabelsOn        =  False        #-- turn off line labels
res.cnInfoLabelOn         =  False        #-- turn off info label
res.cnFillPalette         = "BlueWhiteOrangeRed" #-- set color map
res.pmLabelBarOrthogonalPosF = -0.03      #-- move labelbar close to plot

res.sfXArray              =  lon          #-- scalar field x
res.sfYArray              =  lev          #-- scalar field y

res.trYReverse            = True          #-- reverse the Y axis
res.nglYAxisType          = "LogAxis"     #-- y axis log

res.tiYAxisString         = "%s (hPa)" % f.variables["lev"].long_name

res.nglPointTickmarksOutward = True       #-- point tickmarks out

res.tmYLMode              = "Explicit"    #-- set y axis tickmark labels
res.tmXBMode              = "Explicit"    #-- set x axis tickmark labels
res.tmYLValues            = levs
res.tmXBValues            = lons
res.tmYLLabels            = map(str,levs)
res.tmXBLabels            = nice_lon_labels(lons)
res.tmXBLabelFontHeightF  = 0.015        # - make font smaller
res.tmYLLabelFontHeightF  = 0.015

map = Ngl.contour(wks,t26,res)            #-- draw contours

#-- end
Ngl.end()
```



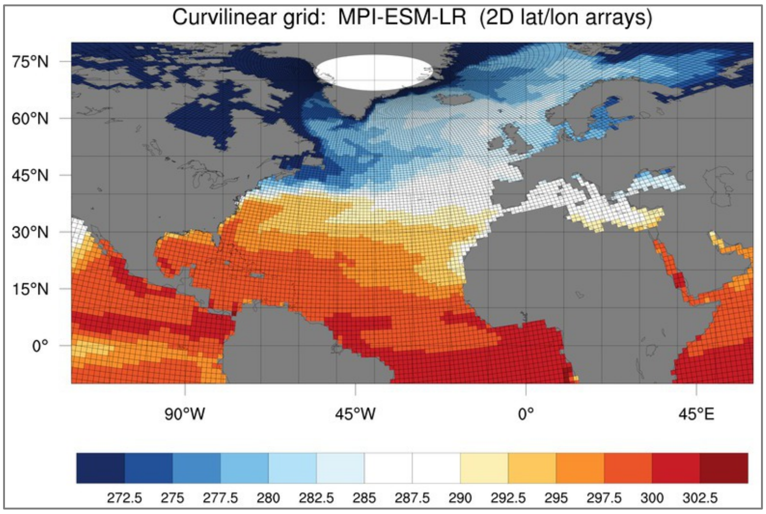
14.5 Contour Plot – Curvilinear Gridded Data

PyNGL is also able to plot curvilinear gridded data which is shown in the following example.

NUG_curvilinear_contour_PyNGL.py:

```
import numpy
import sys,os
import Nio
import Ngl

#--  define variables
diri    = "./"                              #-- data directory
fname   = "tos_ocean_bipolar_grid.nc"       #-- curvilinear data

#--  open file and read variables
f       = Nio.open_file(diri + fname,"r")
var     = f.variables["tos"][0,:,:]         #-- first time step, reverse lat
lat2d   = f.variables["lat"][:,:]           #-- 2D latitudes
lon2d   = f.variables["lon"][:,:]           #-- 2D longitudes

#-- open a workstation
wkres                    =  Ngl.Resources()
                           #-- generate an resources object for workstation
wkres.wkWidth            =  2500            #-- width of workstation
wkres.wkHeight           =  2500            #-- height of workstation
wks_type                 = "png"            #-- output type
wks =  Ngl.open_wks(wks_type,"Py_curvilinear_contour",wkres)
                                            #-- open workstation
#-- set resources
res                      =  Ngl.Resources()
                                  #-- generate an resources object for plot
res.cnFillOn             =  True            #-- turn on contour fill
res.cnLinesOn            =  False           #-- don't draw contour lines
res.cnLineLabelsOn       =  False           #-- don't draw line labels
res.cnFillPalette        = "BlueWhiteOrangeRed" #-- set color map

res.cnFillMode           = "CellFill"       #-- change contour fill mode
res.cnCellFillEdgeColor =  "black"          #-- edges color
res.cnCellFillMissingValEdgeColor = "gray50"   #-- missing value edges color
res.cnMissingValFillColor = "gray50"      #-- missing value fill color
```

```
res.lbOrientation      = "Horizontal"      #-- labelbar orientation

res.tiMainString     = "Curvilinear grid:  MPI-ESM-LR  (2D lat/lon arrays)"
                                           #-- title string
res.tiMainFontHeightF =  0.022             #-- main title font size

res.sfXArray           =  lon2d            #-- longitude grid cell center
res.sfYArray           =  lat2d            #-- latitude grid cell center

res.mpFillOn           =  False            #-- don't draw filled map
res.mpGridLatSpacingF =  10.               #-- grid lat spacing
res.mpGridLonSpacingF =  10.               #-- grid lon spacing

res.mpDataBaseVersion = "MediumRes"        #-- map database
res.mpLimitMode        = "LatLon"          #-- must be set using minLatF /
                                           #-- maxLatF / minLonF / maxLonF
res.mpMinLatF          = -10.              #-- sub-region minimum latitude
res.mpMaxLatF          =  80.              #-- sub-region maximum latitude
res.mpMinLonF          = -120.             #-- sub-region minimum longitude
res.mpMaxLonF          =  60.              #-- sub-region maximum longitude

#-- create the plot
plot = Ngl.contour_map(wks,var,res)        #-- create the contour plot

#-- end
Ngl.end()
```



14.6 Contour Plot – Unstructured Data

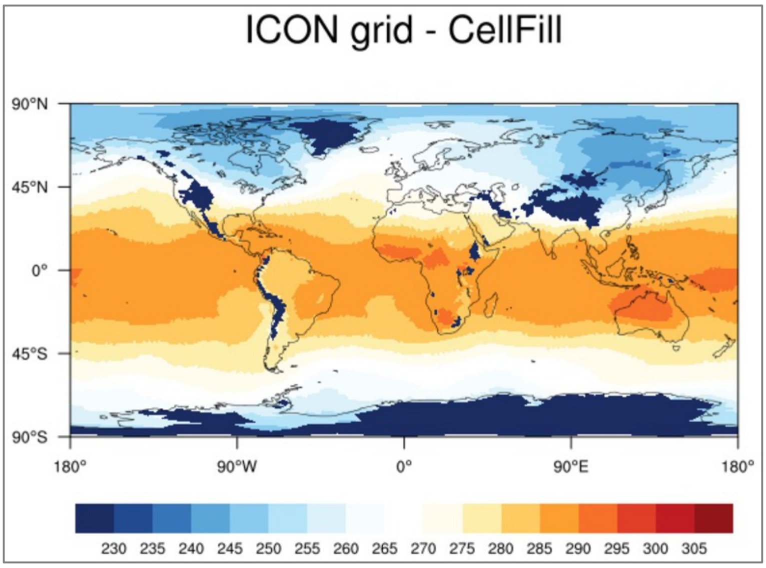
Unstructured data sets like ICON, MPAS, station data and others can contoured directly without having to regrid the data first. The example below reads the ICON data set from one file and the grid data from a second file.

NUG_unstructured_contour_cellfill_PyNGL.py:

```
import numpy as np
import math, time
import sys,os
import Nio
import Ngl
```

```
#----------------------
#-- MAIN
#----------------------
t1 = time.time()                          #-- retrieve start time
print ""

#--  define variables
diri  = "./"                              #-- data path
fname = "ta_ps_850.nc"                    #-- data file
gname = "grids/r2b4_amip.nc"              #-- grid info file

#--  open file and read variables
f = Nio.open_file(diri + fname,"r")       #-- add data file
g = Nio.open_file(diri + gname,"r")       #-- add grid file

#-- read a timestep of "ta"
var =  f.variables["ta"][0,0,:]           #-- first time step, lev, ncells

print "-----------------------"
print f.variables["ta"]                   #-- output like printVarSummary
print "-----------------------"

title    = "ICON:  Surface temperature"  #-- title string
varMin   =  230                           #-- data minimum
varMax   =  310                           #-- data maximum
varInt   =    2                           #-- data increment
levels   =  range(varMin,varMax,varInt)  #-- set levels array

#-------------------------------------------------------------------
#-- define the x-, y-values and the polygon points
#-------------------------------------------------------------------
rad2deg = 45./np.arctan(1.)               #-- radians to degrees

x      =  g.variables["clon"][:]          #-- read clon
y      =  g.variables["clat"][:]          #-- read clat
vlon   =  g.variables["clon_vertices"][:] #-- read clon_vertices
vlat   =  g.variables["clat_vertices"][:] #-- read clat_vertices

ncells =  vlon.shape[0]                   #-- number of cells
nv     =  vlon.shape[1]                   #-- number of edges

x      =  x    * rad2deg                  #-- cell center, lon
y      =  y    * rad2deg                  #-- cell center, lat
vlat   =  vlat * rad2deg                  #-- cell latitude vertices
vlon   =  vlon * rad2deg                  #-- cell longitude vertices

#-- longitude values -180. - 180.
for j in range(1,ncells):
    for i in range(1,nv):
        if vlon[j,i] < -180. :
           vlon[j,i] = vlon[j,i] + 360.
        if vlon[j,i] > 180. :
           vlon[j,i] = vlon[j,i] - 360.

#-- information
print ""
print "Cell points:           ", nv
print "Cells:                 ", str(ncells)
print "Variable ta   min/max:  %.2f " % np.min(var) + "/" + " %.2f" %
np.max(var)
print ""
```

```
#-- open a workstation
wks_type = "png"                         #-- graphics output type
wks      =  Ngl.open_wks(wks_type,"plot_contour_unstructured")
                                         #-- open a workstation
#-- set resources
res                         =  Ngl.Resources()  #-- plot mods desired
res.nglDraw                 =  False         #-- turn off plot draw
res.nglFrame                =  False         #-- don't advance frame

res.cnFillOn                =  True          #-- color plot desired
res.cnFillMode              = "CellFill"     #-- set fill mode
res.cnFillPalette           = "BlueWhiteOrangeRed" #-- set color map
res.cnLinesOn               =  False         #-- turn off contour lines
res.cnLineLabelsOn          =  False         #-- turn off contour labels
res.cnLevelSelectionMode = "ExplicitLevels" #-- use explicit levels
res.cnLevels                =  levels        #-- set levels

res.lbOrientation           = "Horizontal"   #-- vertical by default
res.lbBoxLinesOn            =  False         #-- turn off labelbar boxes
res.lbLabelFontHeightF      =  0.01          #-- labelbar label font size

res.mpFillOn                =  False         #-- don't use filled map
res.mpGridAndLimbOn         =  False         #-- don't draw grid lines

res.sfXArray                =  x           #-- transform x to mesh scalar field
res.sfYArray                =  y           #-- transform y to mesh scalar field
res.sfXCellBounds           =  vlon        #-- needed if set "CellFill"
res.sfYCellBounds           =  vlat        #-- needed if set "CellFill"

res.tiMainString            = "ICON grid - CellFill" #-- title string
res.tiMainOffsetYF          =  0.03        #-- move main title towards plot

#-- create the plot
plot = Ngl.contour_map(wks,var,res)

#-- draw the plot and advance the frame
Ngl.draw(plot)
Ngl.frame(wks)

#-- get wallclock time
t2 = time.time()
print "Wallclock time:  %0.3f seconds" % (t2-t1)
print ""

Ngl.end()
```



14.7 Triangles Plot – ICON Data

For some model data we want to see the cells colored by the data values. The next example first creates a contour plot to get the levels and colors which are used to create the second plot drawing triangles using Ngl.add_polygon function.

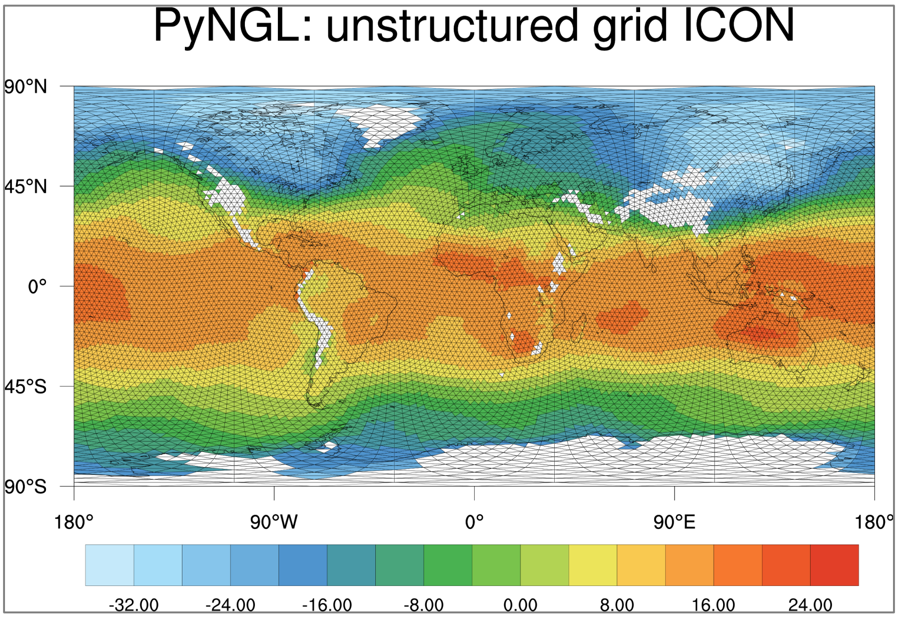
NUG_unstructured_ICON_triangles_PyNGL.py:

```
import numpy as np
import math, time, sys, os
import Nio, Ngl

t1 = time.time()                               #-- retrieve start time

#--  define variables
diri         = './'
fname        = 'ta_ps_850.nc'                  #-- data path and file name
gname        = 'r2b4_amip.nc'                  #-- grid info file
VarName      = 'ta'                            #-- variable name

#--  open file and read variables
f = Nio.open_file(diri + fname,'r')            #-- add data file
g = Nio.open_file(diri + gname,'r')            #-- add grid file (not contained
in data file!!!)

#-- read a timestep of 'ta'
variable =  f.variables['ta']                  #-- first time step, lev, ncells
data     =  variable[0,0,:]                    #-- ta [time,lev,ncells]; miss
_FillValue
var      =  data - 273.15                      #-- convert to degrees Celsius;
                                               #-- miss _FillValue
#-- define _FillValue and missing_value if not existing
missing = -1e20

if not hasattr(var,'_FillValue'):
   var._FillValue  =  missing                  #-- set _FillValue
if not hasattr(var,'missing_value'):
   var.missing_value =  missing                #-- set missing_value

varM = np.ma.array(var, mask=np.equal(var,missing)) #-- mask array with
                                               #-- missing values
nummissing = np.count_nonzero(varM.mask)       #-- number of missing values

#-- set data intervals, levels, labels, color indices
varMin, varMax, varInt = -32, 28, 4            #-- set data minimum, maximum,
                                               #-- interval

levels    =  range(varMin,varMax,varInt)       #-- set levels array
nlevs     =  len(levels)                       #-- number of levels
labels    =  ['{:.2f}'.format(x) for x in levels] #-- convert list of floats
                                               #-- to list of strings
#-- print info to stdout
print ''
print 'min/max:          %.2f' %np.min(varM) + ' /' + ' %.2f' %np.max(varM)
print ''
print 'varMin:           %3d' %varMin
print 'varMax:           %3d' %varMax
print 'varInt:           %3d' %varInt
print ''
print 'missing_value:    ', missing
print 'missing values:   ', nummissing
```

```
#-----------------------------------------------------------------------
#-- define the x-, y-values and the polygon points
#-----------------------------------------------------------------------
rad2deg = 45./np.arctan(1.)                 #-- radians to degrees

x, y       =  g.variables['clon'][:], g.variables['clat'][:]
vlon, vlat =  g.variables['clon_vertices'][:],
g.variables['clat_vertices'][:]

x, y       =  x*rad2deg,  y*rad2deg         #-- cell center, lon, lat
vlat, vlon =  vlat*rad2deg, vlon * rad2deg #-- cell latitude/longitude
                                            #-- vertices
ncells, nv =  vlon.shape                    #-- ncells: number of cells; nv:
                                            #-- number of edges
#-- print information to stdout
print ''
print 'cell points:      ', nv
print 'cells:            ', str(ncells)
print ''

#-- rearrange the longitude values to -180.-180.
def rearrange(vlon):
    less_than    = vlon < -180.
    greater_than = vlon >  180.
    vlon[less_than]    = vlon[less_than] + 360.
    vlon[greater_than] = vlon[greater_than] - 360.
    return vlon

vlon = rearrange(vlon)                      #-- set longitude values to
                                            #-- -180. to 180. degrees
print 'min/max vlon:     ', np.min(vlon), np.max(vlon)
print 'min/max vlat:     ', np.min(vlat), np.max(vlat)
print ''

#-- open a workstation for second plot:  triangles plot
wkres =  Ngl.Resources()
wkres.wkWidth, wkres.wkHeight  =  2500, 2500
wks_type = 'png'
wks =  Ngl.open_wks(wks_type,'unstructured_ICON_triangles_ngl',wkres)

#-- define colormap
colormap =  Ngl.read_colormap_file('WhiteBlueGreenYellowRed')[22::12,:]
#-- RGB ! [256,4] -> [20,4]
                                            #-- select every 12th color
colormap[19,:] = [1.,1.,1.,0.]              #-- white for missing values
print ''
print 'levels:           ',levels
print 'labels:           ',labels
print ''
print 'nlevs:            %3d' %nlevs
print ''

#-- set map resources
mpres                             =  Ngl.Resources()
mpres.nglDraw                     =  False  #-- turn off plot draw and
                                            #-- frame advance. We will
mpres.nglFrame                    =  False  #-- do it later after adding
                                            #-- subtitles.
mpres.mpGridAndLimbOn             =  False
mpres.mpGeophysicalLineThicknessF =  2.
mpres.pmTitleDisplayMode          = 'Always'
```

```
mpres.tiMainString                = 'PyNGL: unstructured grid ICON'

#-- create only a map
map = Ngl.map(wks,mpres)
Ngl.draw(map)

#-- assign and initialize array which will hold the color indices of the
cells
gscolors = -1*(np.ones((ncells,),dtype=np.int)) #-- assign array containing
                                         #-- zeros; init to transparent: -1
#-- set color index of all cells in between levels
for m in xrange(0,nlevs):
    vind = []                               #-- empty list for color
indices
    for i in xrange(0,ncells-1):
        if (varM[i] >= levels[m] and varM[i] < levels[m+1]):
           gscolors[i] = m+1    # 1 to nlevs
           vind.append(i)
    print 'finished level %3d' % m , ' -- %5d ' % len(vind) , ' polygons
considered - gscolors %3d' % (m+1)
    del vind
gscolors[varM < varMin]         =  0       #-- set color index for cells
                                           #-- less than level[0]
gscolors[varM >= varMax]        = nlevs+1  #-- set color index for cells
                                           #-- greater than levels[nlevs-1]
gscolors[np.nonzero(varM.mask)] = -1       #-- set color index for missing
                                           #-- locations
#-- set polygon resources
pgres                    =  Ngl.Resources()
pgres.gsEdgesOn          =  True             #-- draw the edges
pgres.gsFillIndex        =  0                #-- solid fill
pgres.gsLineColor        = 'black'           #-- edge line color
pgres.gsLineThicknessF   =  0.7              #-- line thickness
pgres.gsColors           =  colormap[gscolors,:] #-- use color array
pgres.gsSegments         =  range(0,len(vlon[:,0])*3,3) #-- define segments
                                           #-- array for fast draw
lon1d, lat1d = np.ravel(vlon), np.ravel(vlat) #-- convert to 1D-arrays

#-- add polygons to map
polyg  = Ngl.add_polygon(wks,map,lon1d,lat1d,pgres)

#-- add a labelbar
lbres                    =  Ngl.Resources()
lbres.vpWidthF           =  0.85
lbres.vpHeightF          =  0.15
lbres.lbOrientation      = 'Horizontal'
lbres.lbFillPattern      = 'SolidFill'
lbres.lbMonoFillPattern =  21           #-- must be 21 for color solid fill
lbres.lbMonoFillColor    =  False        #-- use multiple colors
lbres.lbFillColors       =  colormap
lbres.lbLabelFontHeightF=  0.014
lbres.lbLabelAlignment   = 'InteriorEdges'
lbres.lbLabelStrings     =  labels

lb = Ngl.labelbar_ndc(wks,nlevs+1,labels,0.1,0.24,lbres)

#-- maximize and draw the plot and advance the frame
Ngl.draw(map)
Ngl.frame(wks)

#-- get wallclock time
t2 = time.time()
```

```
print ''
print 'Wallclock time:  %0.3f seconds' % (t2-t1)
print ''

Ngl.end()
```



15 Common Error Messages

The first rule of NCL in avoiding errors and warnings is (as Dennis Shea would say):

Look at your data! You can avoid many errors and warnings if you are familiar with your data. Keep that in mind.

To see what's in your file, you can type the following on the shell command line:

```
ncl_filedump  <your_filename>
```
or
```
ncdump -h <your_filename>
```
or
```
cdo infov <your_filename>
```

In comparison to ncdump and ncl_filedump, CDO provides somewhat different information such as the date, time as well as minimum, maximum and mean value of each 2D data field in your file.

Use printVarSummary within your NCL script to get the information about variables and dimensions:

```
printVarSummary(tsurf)
```

Common language error messages:

Error message:
fatal:Subscript out of range, error in subscript #0

Cause:
Subscripting an array using an index that is out-of-bounds. Remember the first element index is 0.

Example:
```
x = (/1,2,3,4,5/)
print(x(5))                ; print 6th element, but the array contains only 5
```

Fix:
Check your subscripts to make sure they are in-range of your array size. Use "print" and "printVarSummary" to get more information about a variable.

Error message:
The following error message points to the subscript #1:
fatal: Subscript out of range, error in subscript #1

Sample code that causes the error:

```
x = random_uniform(-100,100,(/10,20,30/))
print(x(5,20,5))                ; index '20' is invalid
```

Cause:
Subscripting an array using an index that is out-of-bounds. Subscript numbers start at 0 and go from left to right, so **subscript "#1" refers to the second dimension** from the left.

Fix:
Check your subscript indexes to make sure they are in the range of your array size. Use print and printVarSummary.

Error message:
fatal:Number of subscripts on right-hand-side do not match number of dimensions of variable: (4), Subscripts used: (3)

Cause:
Subscripting an array using the wrong dimensionality

Example
```
x = random_uniform(-50,50,(/5,32,64/))
y = x(0,:,:,:)
```

Fix:
Check your subscript syntax.

Error message:
fatal:Assignment type mismatch, right hand side can't be coerced to type of left hand side

Cause:
Reassigning a variable using a different type or dimensionality

Example:
```
x = 5
x = "Now I'm a string"
```

Fix:
Use reassignment operator, or delete variable first.

Error message:
fatal:syntax error: possibly an undefined procedure

Cause:
Referencing a function or procedure that doesn't exist

Example:
```
i = 5
prnt(i)
```

Fix:
Check the spelling of function/procedure and whether you need load another NCL script that defines it.

Error message:
fatal:syntax error: function fspan expects 3 arguments, got 2

Cause:
Calling a function or procedure with the wrong number of arguments

Example:
```
x = fspan(0,10)
```

Fix:
Check your function or procedure arguments. Read the documentation.

Error message:
fatal:syntax error: line -1

Cause:
You have an unclosed code block, like a "begin" without an end" or an "if" without an "end if"

Example:
```
if (x.lt.0) then
   x = 5
```

Fix:
Check for unclosed code blocks and close them.

Error message:
fatal:Dimension sizes of left hand side and right hand side of assignment do not match

Cause:
Assigning a set of array elements to another array with a different number of elements

Example:
```
x = (/1,2,3,4/)
y = (/1,2,3,4,5/)
x = y
```

Fix:
Check the array sizes on the left and right side of the "=".

Error message:
fatal:The result of the conditional expression yields a missing value. NCL can not determine branch, see ismissing function

Cause:
Using a missing value in an "if" statement or some other conditional statement.

Example:
```
x = new(1,float)
if(x.eq.5) then
  print("x is 5")
end if
```

Fix:
Use "ismissing" to test for missing values.

```
x = new(1,float)
if(.not.ismissing(x).and.x.eq.5) then
  print("x is 5")
end if
```

Error message:
fatal:Variable (x1) is undefined

Cause:
Referencing a variable that doesn't exist

Example:

x = 5
print(x1)

Fix:
Check the spelling.

Error message:
warning:Attempt to reference attribute (FillValue) which is undefined

Cause:
Referencing an attribute variable that doesn't exist

Example:
```
x = new(1,float)
print(x@FillValue)
```

Fix:
Check the spelling.

Error message:
Argument 0 of the current function or procedure was coerced to the appropriate type and thus will not change if the function or procedure modifies its value

Cause:
Calling a function or procedure with the wrong argument type. This commonly happens if the function is expecting a string and you give it a numerical value.

Example:
```
x   = 12.34
str = str_split(x,".")
```

Fix:
Use one of the toxxxx functions to coerce the argument

```
x   = tostr(12.34)
str = str_split(x,".")
```

Common graphics error messages:

Error message:
gsn_csm_contour_map: Fatal: the input data array must be 1D or 2D
fatal:Illegal right-hand side type for assignment

Cause:
Calling the function gsn_csm_dontour_map to plot variable with the wrong dimension (> 2D).

Example:
```
plot = gsn_csm_contour_map(wks, tsurf,res)
```

Fix:
Look at your data! How many dimensions does your variable have? If you don't know it make a printVarSummary to see the number of dimensions of you variable.

assumed: float tsurf (time, lev, lat, lon)

You can choose one timestep and one level to use the gsn_csm_contour_map function to create the plot

plot = gsn_csm_contour_map(wks,tsurf(0,0,:,:), res)

Error message:
gsn_add_cyclic: Warning: The range of your longitude data is not 360. You may want to set gsnAddCyclic to False to avoid a warning message from the Spline function.

Cause:
Your longitude value range is less than 360 degrees

Fix:
res@gsnAddCyclic = False

Error message:
is_valid_lat_ycoord: Warning: The units attribute of the Y coordinate array is not set to one of the allowable units values (i.e. 'degrees_north'). Your latitude labels may not be correct.
is_valid_lat_xcoord: Warning: The units attribute of the X coordinate array is not set to one of the allowable units values (i.e. 'degrees_east'). Your longitude labels may not be correct.

Cause:
The dimensions of latitude and longitude don't have the correct units.

Fix:
Do a printVarSummary of your variable to be plotted or of your lat, lon arrays to see if the units of the dimensions lat and lon are correct. If not add the **units** attribute to the **lat** and **lon** coordinate arrays

```
lat@units  = "degrees_north"
lon@units = "degrees_east"
```

Error message:
warning:ScalarFieldSetValues: 2d coordinate array sfXArray has an incorrect dimension size: defaulting sfXArray
warning:ScalarFieldSetValues: 2d coordinate array sfYArray has an incorrect dimension size: defaulting sfYArray

Cause:
If you do not have a global grid, the problem is that, by default, the gsn_csm_xxxx routines set the resource gsnAddCyclic to True.

Example:

```
res@sfXArray = lon        ;-- range of lon values < 360
res@sfYArray = lat
```

Fix:
res@gsnAddCyclic = False

Error message:
warning:tmXBStride is not a valid resource in ex07-1_xy at this time

Cause:
The name of a resource is misspelled or it makes no sense to use the resources with the choosen plot function.

Example 1:
res@tmXBStride = 2

Fix 1:
Take a look at the name of the resource, in this case it is misspelled and it should be
tres@tmXBLabelStride = 2

Example 2:
res@xyLineColor = "grey"
plot = gsn_csm_contour_map(wks, t, res)

Fix 2:
The setting of the resource xyLineColor makes no sense when plotting contours. If you want the contour lines in black use cnLineColor for contours.
res@cnLineColor = "grey"

16 List of Example Scripts

The example scripts can be found in $NCARG_ROOT/lib/ncarg/nclex/nug/.

#	Example	Script File Name
4.4	Read ASCII File 1	NUG_read_ASCII_1.ncl
4.4	Read ASCII File 2	NUG_read_ASCII_2.ncl
4.4	Read ASCII File 3	NUG_read_ASCII_3.ncl
4.5	Read CSV File 1	NUG_readCSV.ncl
4.5	Read CSV File 2	NUG_read_CSV_2.ncl
4.6	Read Binary File 1	NUG_read_Binary_1.ncl
4.6	Read Binary GrADS file	NUG_read_Binary_GrADS.ncl
4.7	Write ASCII File 1	NUG_write_ASCII_1.ncl
4.7	Write ASCII File 2	NUG_write_ASCII_2.ncl
4.7	Write ASCII File 3	NUG_write_ASCII_3.ncl
4.7	Write ASCII File 4	NUG_write_ASCII_4.ncl
4.7	Write ASCII File 5	NUG_write_ASCII_5.ncl
4.9	Write Binary File 1	NUG_write_Binary_1.ncl
4.9	Write Binary File 2	NUG_write_Binary_2.ncl
4.10	Write netCDF	NUG_write_NetCDF_1.ncl
4.10	Write netCDF detailed version	NUG_write_NetCDF_2.ncl
6.5	Statistics Linear Regression	NUG_statistics_linear_regression.ncl
6.6	Statistics Running Mean	NUG_statistics_running_mean.ncl
7.1	Mask Land or Ocean	NUG_example_mask_1.ncl NUG_example_mask_2.ncl NUG_example_mask_4.ncl
8.1	NCL Template Script	NUG_template.ncl NUG_plot_in_5_steps.ncl
8.3.1	Map Default	NUG_map_default.ncl
8.3.2	Map Grids and Tickmarks	NUG_map_grid_and_tickmark_settings.ncl
8.3.3	Map Settings for Land, Ocean, and Countries	NUG_map_land_ocean_settings.ncl NUG_map_countries.ncl NUG_map_selected_countries.ncl
8.3.4	Map Projection Mollweide	NUG_projections_mollweide.ncl

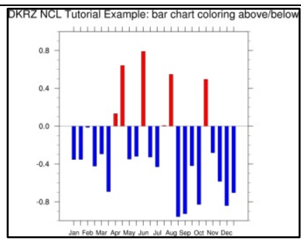
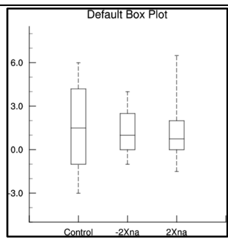
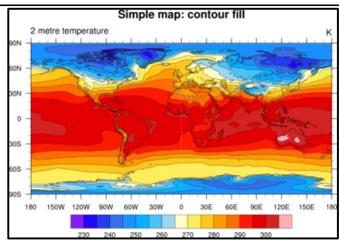
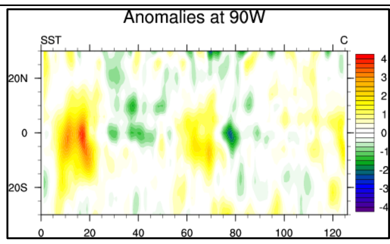
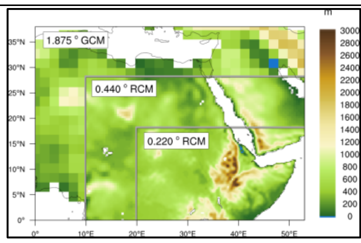
8.3.5	Regional Map	NUG_map_settings.ncl
8.4	XY-plot	NUG_xy_plot.ncl
8.4.2	XY-plot time series	NUG_xy_plot_timeseries.ncl
8.5	Contour map	NUG_contour_map.ncl
8.5.1	Contour filled map	NUG_contour_filled_map.ncl
8.5.2	Contour fill pattern	NUG_contour_fillpattern.ncl
8.3	Simple map with Mollweide projection	NUG_projections_mollweide.ncl
8.3.6	Polar plot Northern Hemisphere	NUG_polar_NH.ncl
8.3.7	Map resolutions	NUG_maps_resolution.ncl
8.6	Vector using defaults	NUG_vector_default.ncl
8.6	Vectors curly look	NUG_vector_curly.ncl
8.6	Vectors colorized	NUG_vector_plot_colorized.ncl
8.6	Vectors overlay on contour map	NUG_vector_plot_overlay.ncl
8.7	Slice plot	NUG_slice_plot.ncl
8.8	Bar Charts	NUG_bar_chart.ncl
8.8	Bar Charts of multi data sets	NUG_bar_chart_multi.ncl
8.8	Bar Charts using a reference line	NUG_bar_chart_col_above_below.ncl
8.8	Histogram	NUG_histograms.ncl
8.9	Overlays	NUG_transparency_filled_contour.ncl
8.9	Time series of multi data sets	NUG_multi_timeseries.ncl
8.9	Grid resolutions comparison	NUG_grid_resolution_comparison.ncl
8.10	Panel plot	NUG_panel_plot.ncl
8.10	Panel plot 3 rows and 2 cols	NUG_panel_3x2_plot.ncl
8.10.1	Panel Plot Settings	NUG_panel_control.ncl
8.10.1	Panel of Plots with Different Sizes	NUG_panel_vp.ncl
8.11	Polyline, polygon and polymarker	NUG_polyline_polgons_polymarker.ncl
8.12	Shapefile plot	NUG_shapefile_plot.ncl
8.12	Shapefile plot + data	NUG_shapefile_plot_data.ncl
8.13	Color map definition	NUG_colormaps.ncl

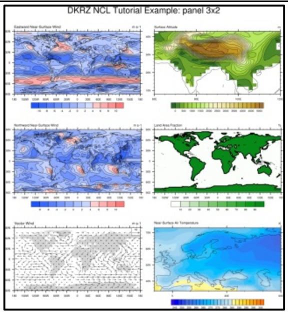
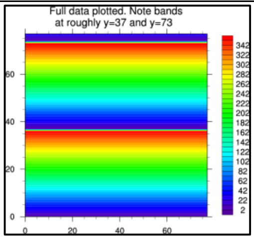
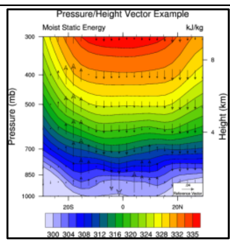
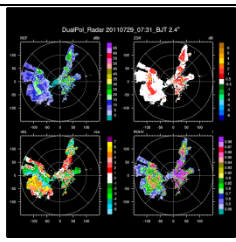
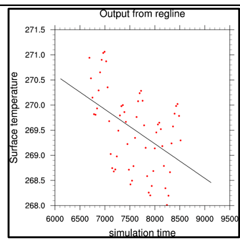
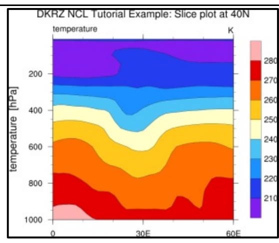
8.13.1	Convert GrADS coltab to NCL colmap	grads2ncl_coltab.ksh
8.13.2	Convert GMT coltab to NCL colmap	gmt2ncl_coltab.ksh
8.14	Curvilinear grid, quick look	NUG_curvilinear_basic.ncl
8.14	Curvilinear grid	NUG_curvilinear_grid.ncl
8.14.1	Bipolar grid – MPI-ESM	NUG_bipolar_grid_MPI-ESM.ncl
8.14.1	Bipolar grid – MPI-ESM – sub-region	NUG_bipolar_grid_MPI-ESM_subregion.ncl
8.14.2	Tripolar grid STORM	NUG_tripolar_grid_STORM.ncl
8.15	Unstructured grid	NUG_unstructured_grid.ncl
8.15.1	Tripolar grid ICON	NUG_tripolar_grid_ICON.ncl
8.16.1	Rotated grid on native projection	rotatedltln_2.ncl
8.16.2	Rotated grid transform rotated to unrotated grid	NUG_plot_rotated_grid.ncl
8.17	Globe with different grid resolutions	NUG_globe_orography_grid_resolution.ncl
8.18.1	Title string settings	NUG_title_strings.ncl
8.18.2	Text settings	NUG_text_settings.ncl
8.18.4	Axis annotations	NUG_axis_annotations.ncl
8.18.5	Contour lables	NUG_contour_labels.ncl
8.18.6	Colorize land and ocean	NUG_color_Land_Ocean.ncl
8.18.7	Colorize Countries	NUG_color_country_user.ncl
8.18.8	Labelbar settings	NUG_labelbars.ncl
8.18.9	Legend settings	NUG_legends.ncl
8.18.11	Date formats	NUG_date_format.ncl
9.1.1	ESMF regrid curvilinear to rectilinear grid with weights	NUG_regrid_curvilinear_to_rectilinear_bilinear_weights_ESMF.ncl
9.1.2	ESMF regrid curvilinear to rectilinear grid with weights using given destination grid	NUG_regrid_curvilinear_to_rectilinear_bilinear_wgts_destgrid_ESMF.ncl
9.1.3	ESMF regrid unstructured to rectilinear grid with weights	NUG_regrid_unstructured_to_rectilinear_bilinear_wgts_ESMF.ncl
9.1.4	ESMF regrid unstructured to rectilinear grid with weights using given destination grid	NUG_regrid_unstructured_to_rectilinear_bilinear_wgts_destgrid_ESMF.ncl
9.1.5	ESMF regrid rectilinear to curvilinear grid with weights using given destination grid	NUG_regrid_rectilinear_to_curvilinear_bilinear_wgts_destgrid_ESMF.ncl
9.1.6	NCL regrid bilinear	NUG_regrid_bilinear_CMIP5_grid_to_1x1deg_grid.ncl
9.2	CDO remap bilinear	NUG_remap_bilinear_CMIP5_grid_to_1x1deg_grid.ksh

10.1	Use external Fortran code	NUG_use_Fortran_subroutines.ksh
10.2	Use external C code	NUG_use_C_subroutines.ksh
13.2	Convert NaNs to _FillValue	NUG_change_NaNs_to_FillValue.ncl
14.1	PyNGL: Simple xy-Plot	NUG_xy_plot_simple_PyNGL.py
14.2	PyNGL: contour plot rectilinear data	NUG_rectilinear_contour_PyNGL.py
14.3	PyNGL: vector plot rectilinear data	NUG_rectilinear_vector_PyNGL.py
14.4	PyNGL: slice plot rectilinear data	NUG_rectilinear_slice_PyNGL.py
14.5	PyNGL: contour plot curvilinear data	NUG_curvilinear_contour_PyNGL.py
14.6	PyNGL: contour plot unstructured data	NUG_unstructured_contour_cellfill_PyNGL.py
14.7	PyNGL: polygon plot unstructured data	NUG_unstructured_ICON_triangles_PyNGL.py

17 Appendix A - Plot Types

In this tutorial we have not covered the full variety of different plot types possible with ncl. However, here we give a more comprehensive listing which might inspire you to dig deeper into NCL’s capabilities.

Bar charts	
Box plots	 *
Contours	
Latitude vs. Time	 *
Overlay plots	

Panel plot	
Phase plots	 *
Press/height vs. latitude/longitude/time	 *
Radar (r,theta) plots	 *
Scatter plots	 *
Slices	

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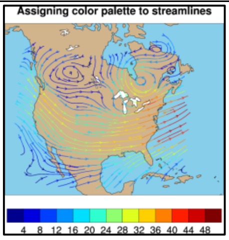
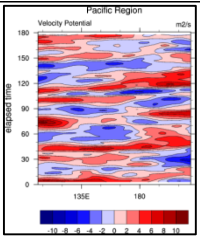
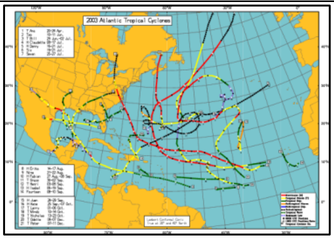
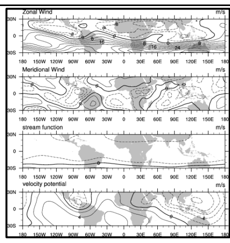
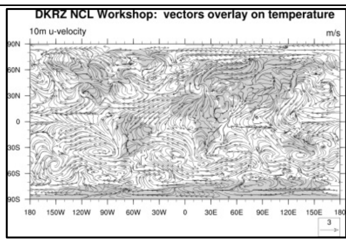
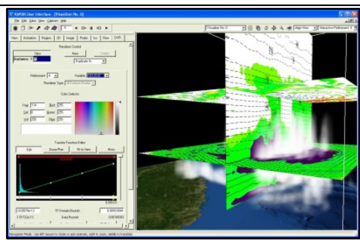
<tr><td>Streamlines</td><td>
 *</td></tr>
<tr><td>Time vs. longitude/latitude</td><td>
 *</td></tr>
<tr><td>Trajectories</td><td> *</td></tr>
<tr><td>Tropical strip plots</td><td> *</td></tr>
<tr><td>Vectors</td><td>
</td></tr>
<tr><td>WRF-VAPOR (3D) using Vapor</td><td> *</td></tr>
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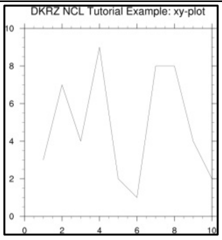
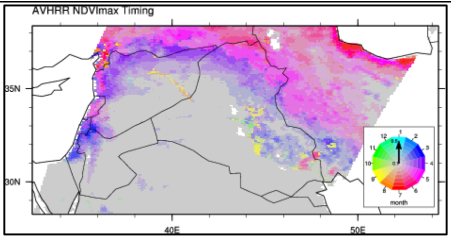
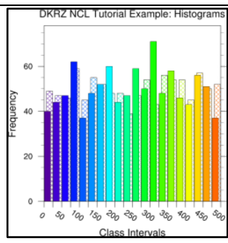
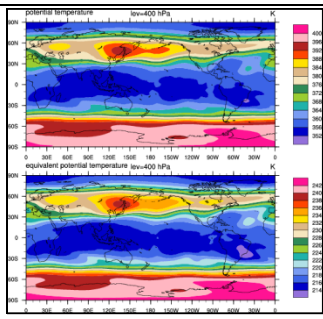
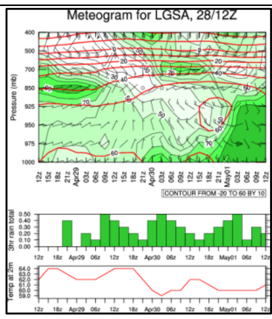
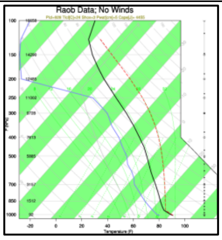
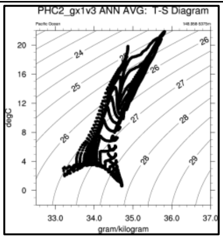
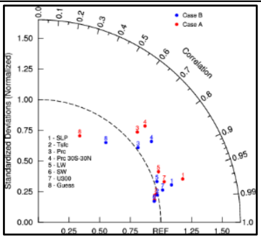
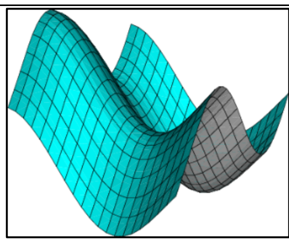
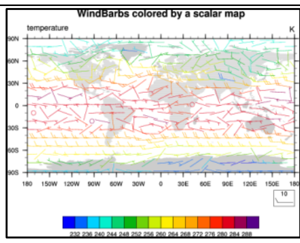
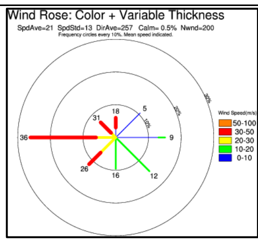
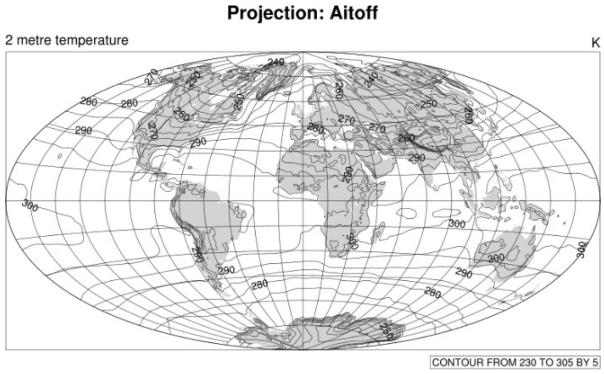
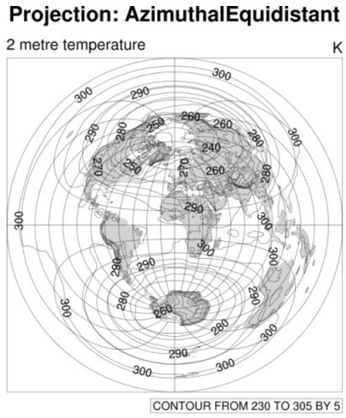
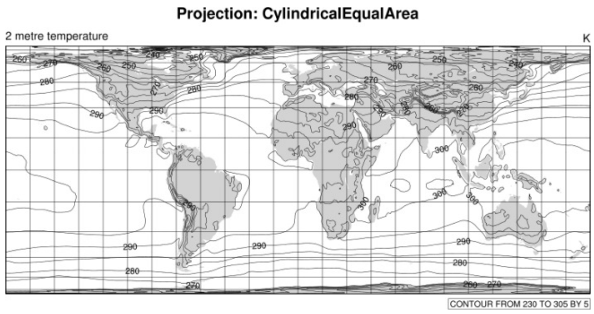
XY plots	
Evans plots	 *
Histograms	
Iso levels	 *
Meteograms	 *
Pie charts	 *

Skew-T	 *
T-S diagram	 *
Taylor diagram	 *
3D plots (TDPACK)	 *
Wind barbs	 *
Wind rose	 *

(* plots from the NCL web page - all examples - http://www.ncl.ucar.edu/Applications/)

18 Appendix B - Projections

<table>
<tr><td>Aitoff</td><td></td></tr>
<tr><td>AzimuthalEquidistant</td><td></td></tr>
<tr><td>CylindricalEqualArea</td><td></td></tr>
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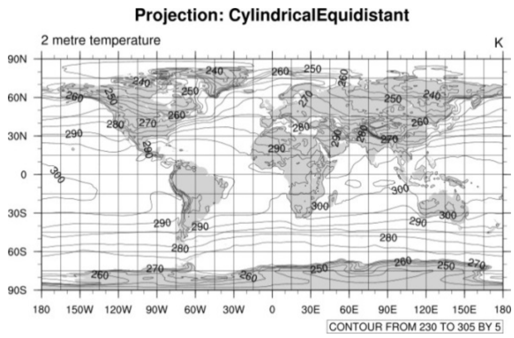
(default)</td><td></td></tr>
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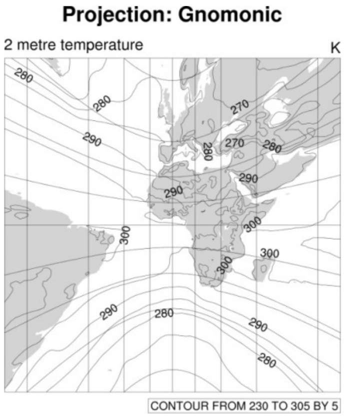
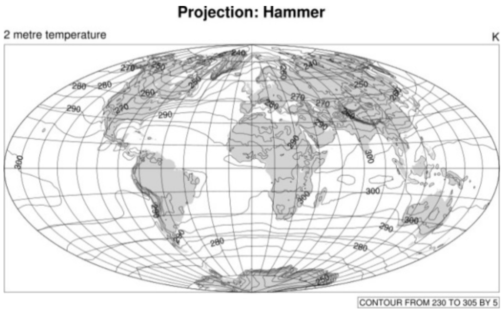
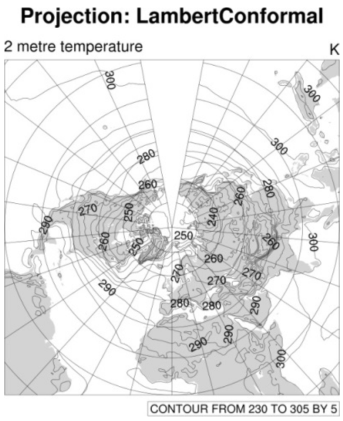
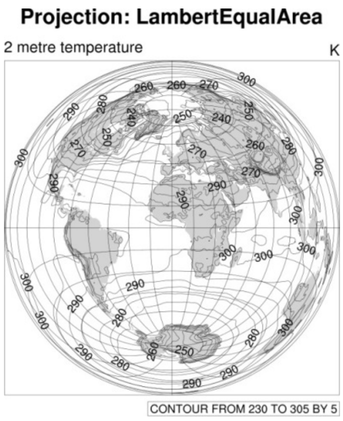
Gnomonic	
Hammer	
LambertConformal	
LambertEqualArea	

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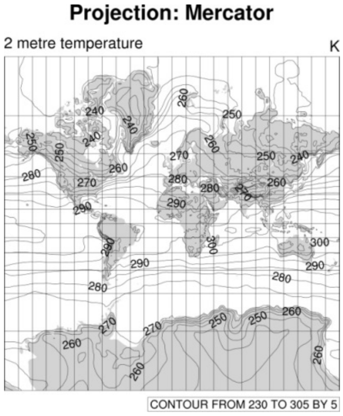
<tr><td>Mercator</td><td>
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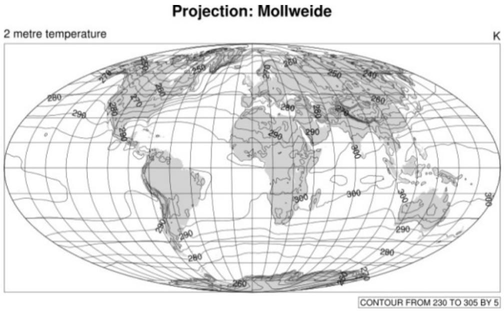
<tr><td>Mollweide</td><td>
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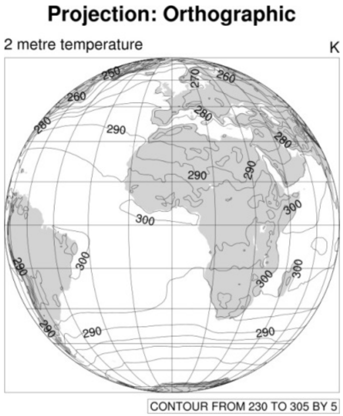
<tr><td>Orthographic</td><td>
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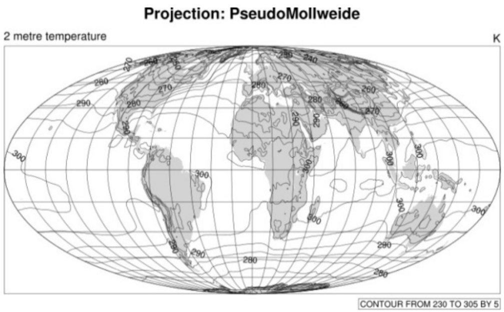
<tr><td>PseudoMollweide</td><td>
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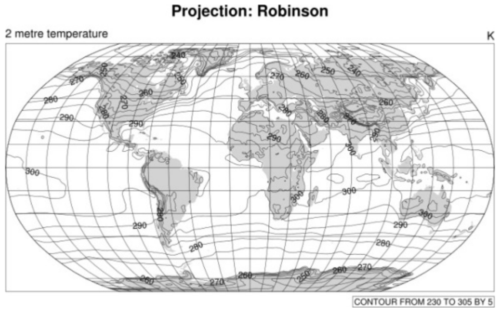
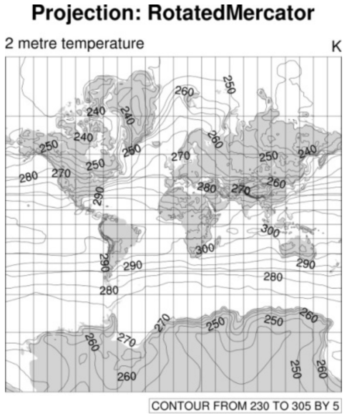
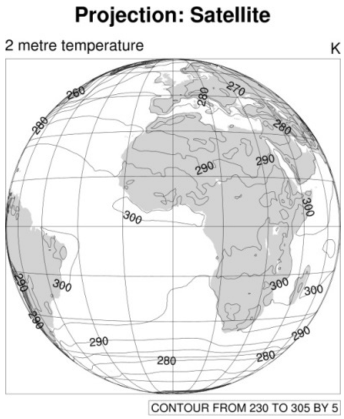
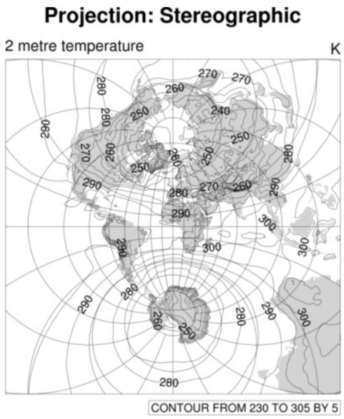
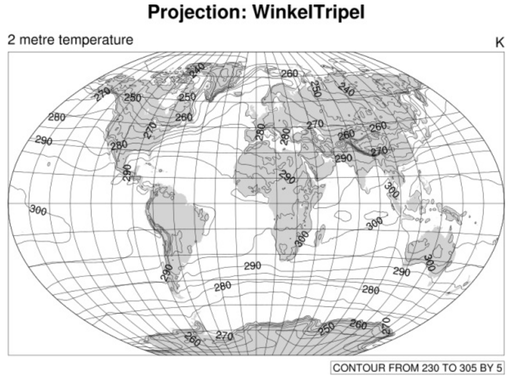
Robinson	
RotatedMercator	
Satellite	
Stereographic	

WinkelTripel	

To see how to generate all of these map projection plots take a look at the example script NUG_projections.ncl.

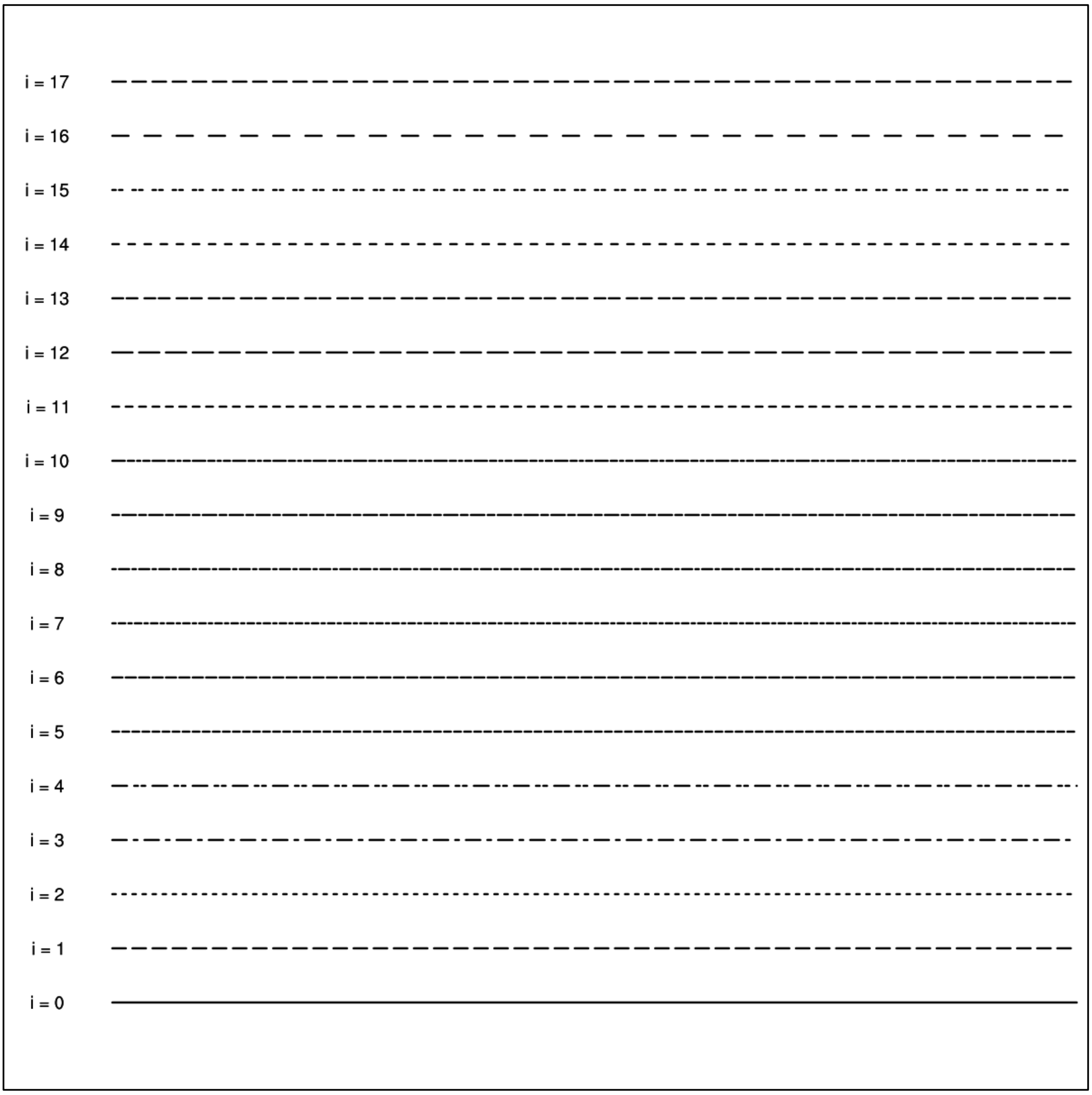
To change the map projection, set the "mpProjection" resource, e.g. to use Mollweide projection:

```
res                  =  True
res@mpProjection     = "Mollweide"
```

19 Appendix C - Dash Pattern Table

Seventeen dash patterns are available to use with the contour and polyline functions and their resources: cnLineDashPattern, cnLineDashPatterns, *xyDashPattern*, *xyDashPatterns and gsLineDashPattern*. You can create your own dash pattern using the NhlNewDashPattern function.

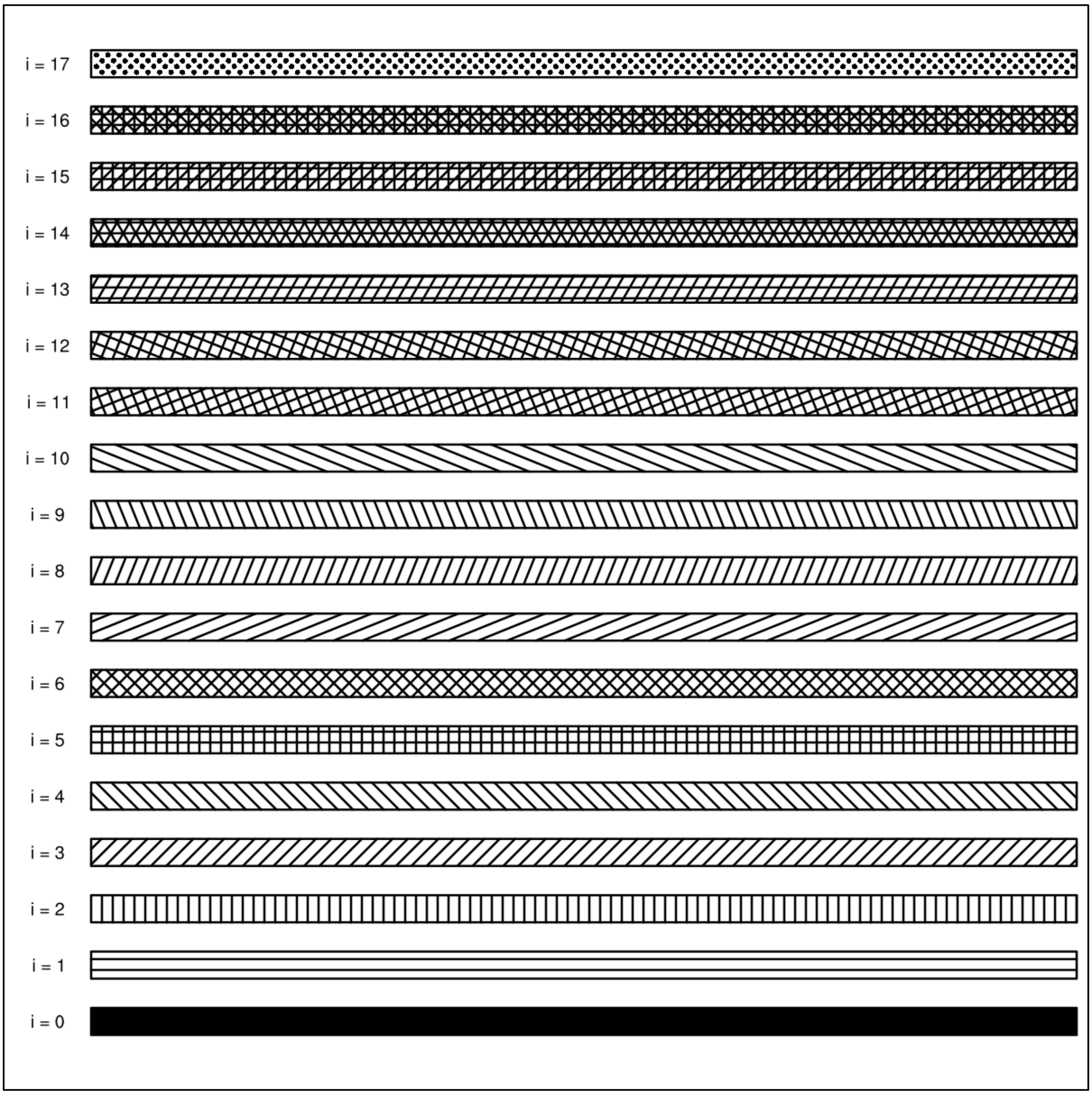
Dash pattern:



20 Appendix D - Fill Pattern Table

Eighteen fill patterns are available to use with the contour and polygon functions and their resources: *gsFillIndex*, *cnFillPattern* and *cnFillPatterns*.

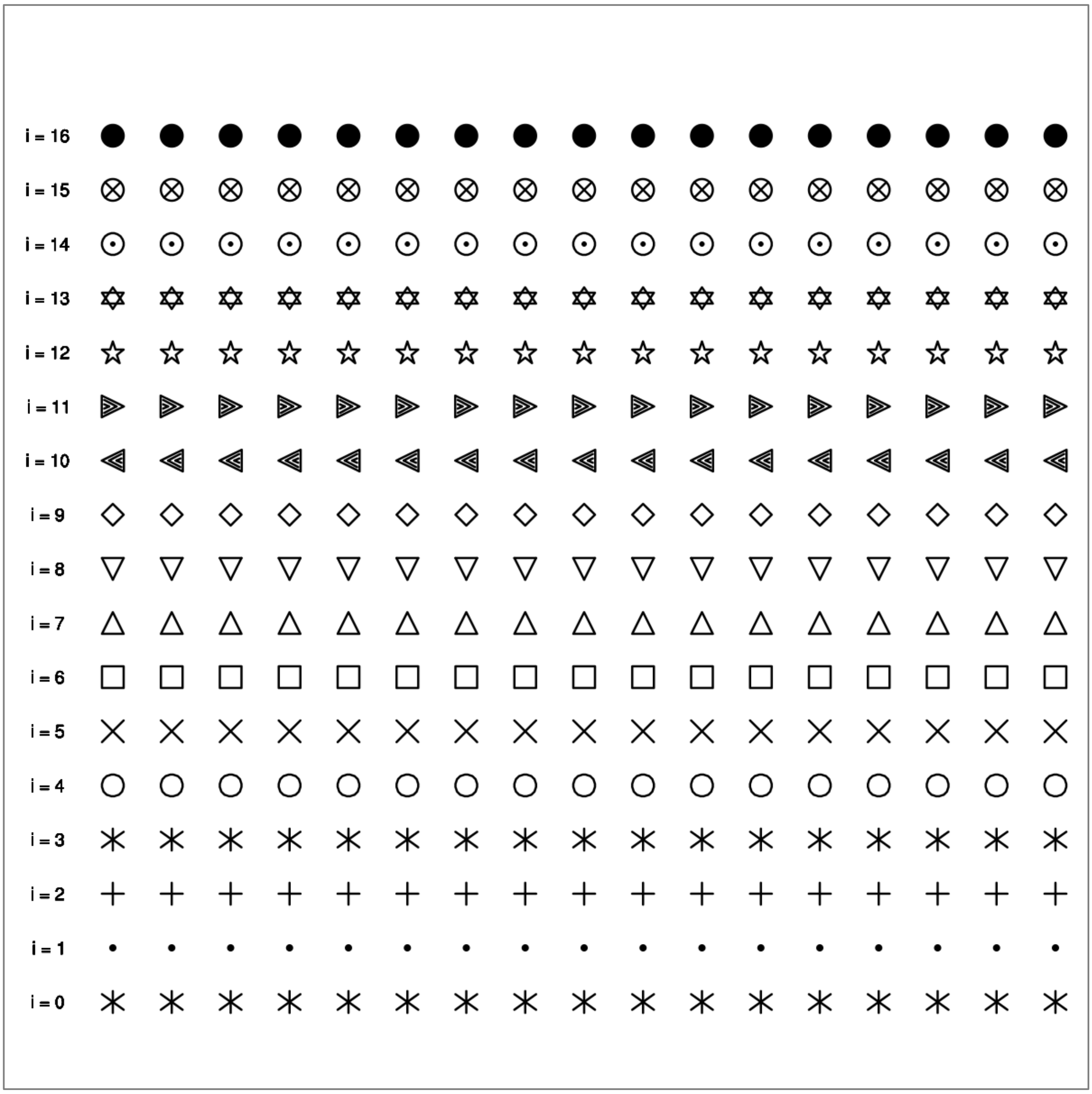
Fill pattern:



21 Appendix E – Marker Table

NCL provides 16 marker styles which can be set with the *gsMarkerIndex* resource. The default is an asterisk. You can also define your own marker style using the NhlNewMarker function.

Marker styles:



22 Appendix F - Important Built-in Functions and Procedures

NCL provide a huge bunch of built-in functions and procedures which are explained in detail with examples

alphabetically: http://ncl.ucar.edu/Document/Functions/list_alpha.shtml

by category: http://ncl.ucar.edu/Document/Functions/

The table below contains an overview of the important built-in functions and procedures.

addfile	Opens a data file that is (or is to be) written in a supported file format
addfiles	Creates a reference that spans multiple data files
all / any	Returns True if all/any of the values of its input evaluates as True
cd_calendar	Converts a mixed Julian/Gregorian date to a UT-referenced date
conform	Conforms an array to the shape of another array
delete	Deletes variables, attributes, and coordinate variables
dimsizes	Returns dimension sizes of input variable
exit	Forces an NCL script to exit immediately
fileexists	Checks for existence of any UNIX file
fspan	Creates an array of evenly-spaced floating point numbers
ind	Returns indices where the input is True
ismissing	Returns True for every element of the input that contains a missing value
ispan	Creates an array of equally-spaced integer, long, or int64 values
new	Creates a NCL variable
num	Counts the number of True values in input
print	Prints the value of a variable or expression
printVarSummary	Prints a summary of a file variable's information
sprinf	Converts floats or doubles into formatted strings
sprinti	Converts integers into formatted strings
system	Executes a shell command

systemfunc	Executes a shell command and returns output
typeof	Returns type of input variable
unique_string	Returns a unique string given the input string as a prefix
where	Performs array assignment based on a conditional array

23 Appendix G - Important Resources

These are a list of some common resources by topic. They are by no means exhaustive. The term dynamic means that the value is determined by NCL.

For an exhaustive list of resources, see:
http://www.ncl.ucar.edu/Document/Graphics/Resources/

Axis - http://www.ncl.ucar.edu/Document/Graphics/Resources/tr.shtml

Name	Function	Default	Example
trYReverse **trXReverse**	Reverse x or y axis	False	True
trYMinF **trXMinF**	Set minimum of x or y axis	0.0	3
trYMaxF **trXMaxF**	Set maximum of x or y axis	1.0	900
trYLog **trXLog**	Turn on/off log axis	False	True

Contours – http://www.ncl.ucar.edu/Document/Graphics/Resources/cn.shtml

Name	Function	Default	Example
cnFillOn	Turn on/off filled contours	False	True
cnFillPalette	Set color map	None	"rainbow"
cnFillOpacityF	Specifies fill opacity	1.0	0.5
cnLinesOn	Turn on/off contour lines	True	False
cnFillMode	Set type of contour fill	“AreaFill”	“RasterFill”
cnLevelSelectionMode	Control contour levels	“AutomaticLevels”	“ExplicitLevels” “ManualLevels”
cnMinLevelValF **cnMaxLevelValF**	Set minimum/maximum contour level	Dynamic	5 55
cnLevelSpacingF	Set contour spacing	Dynamic	2
cnLevels	Set contour levels when cnLevelSelectionMode is “ExplicitLevels”	Dynamic	(/3,5,7,10,13/)
cnLineThicknessF	Set thickness of contour lines	1.0	2.0
cnFillPatterns	Set pattern fills	“SolidFill”	(/1,3,-1/) -1 is transparent
cnInfoLabelOn	Turn on/off the contour info label	True	False

Labelbars – http://www.ncl.ucar.edu/Document/Graphics/Resources/lb.shtml

Name	Function	Default	Example
cnFillOn	Turn on/off filled contours	False	True
cnFillMode	Set type of contour fill	“AreaFill”	“RasterFill”
cnLabelBarEndStyle	Set style for end labels	“IncludeOuterBoxes”	“ExcludeOuterBoxes”
lbLabelBarOn	Turn on/off the labelbar	True for gsn_csm interfaces	False
lbOrientation	Set orientation of labelbar	“horizontal” for gsn_csm interfaces	“vertical”
lbLabelAutoStride	Automatically pick nice labelbar label stride	False	True
lbTitleOn	Turn on/off a labelbar title	False	True
lbTitleString	Set labelbar title	Null	“m/s”

lbLabelAlignment	St where the labelbar label is oriented wrt to the color boxes	"ExternalEdges"	"BoxCenters"
pmLabelBarOrthogonalPosF	Moves the labelbar orthogonally to its position. For a horizontal labelbar, this is up and down.	N/A	-0.03
pmLabelBarParallelPosF	Moves the labelbar perpendicularly to its position. For a vertical labelbar, this is left and right.	N/A	-0.01
pmLabelBarWidthF	Set the width of the labelbar	Set for the user in the gsn_csm interfaces	
pmLabelBarHeightF	Set the height of the labelbar	Set for the user in the gsn_csm interface	

GSN – http://www.ncl.ucar.edu/Document/Graphics/Resources/gsn.shtml

Name	Function	Default	Example
gsnAddCyclic	Turn on/off the addition of a cyclic point to the longitude coordinate values	True for data that has 1D coordinate variables	False
gsnDraw	Draw the plot	True	False
gsnFrame	Advance the frame (page)	True	False
gsnCenterString	Set center string above the plot	N/A	"string here"
gsnLeftString	Set left string above the plot	long_name (if exists) in gsn_csm interfaces	"Salinity"
gsnRightString	Set right string above the plot	units (if exists) in gsn_csm interfaces	"ppm"
gsnMaximize	Maximize the plot and rotate to landscape if necessary	False	True
gsnSpreadColors	Span full range of color map	False	True
gsnSpreadColorStart	Begin color map at particular index	2	46
gsnSpreadColorEnd	End color map at particular index	ncolors-1	89
gsnScalarContour	Force vector/scalar gsn_csm interfaces to draw vectors over the scalar field	False	True
gsnXYBarChart	Changes an xy-line into a bar chart	False	True
gsnXRefLine	Add a vertical reference line to a plot	None	1.0
gsnXRefLineColor	Change color of X reference line	Foreground color	"green"
gsnYRefLine	Add a horizontal reference line to a plot	None	0.0
gsnYRefLineColor	Change color of Y reference line	Foreground color	"blue"
gsnPanelLabelBar	Turn on/off a common labelbar in a panel plot	False	True
gsnPanelFigureStrings	Add a series of strings to the upper left corner of each plot in a panel plot	N/A	(/"a","b","c"/)

Legends - http://ncl.ucar.edu/Document/Graphics/Resources/lg.shtml

Name	Function	Default	Example
pmLegendWidthF	Set width of a legend	Dynamic	0.6
pmLegendHeightF	Set height of a legend	dynamic	0.3
lgTitleOn	Turn on a legend title	False	True
lgTitleString	Set title string	N/A	"Profiles"
lgOrientation	Set orientation of the legend	"horizontal"	"vertical"
lgPerimOn	Turn on/off the legend	True	False
xyExplicitLegendLabels	Change default legend labels	N/A	(/"line1","line2","line3"/)
pmLegendOrthogonalPosF	Adjust the legend orthogonally	N/A	-0.03
pmLegendParallelPosF	Adjust the legend perpendicularly	N/A	0.2

XY curves – http://www.ncl.ucar.edu/Document/Graphics/Resources/xy.shtml

Name	Function	Default	Example
xyDashPatterns	Set line pattern	Solid	(/0,2/) (/"solid","dash"/)
xyLineThicknesses	Set the line thicknesses	1.0	(/2.0,3.0,4.0/)
xyLineColors	Set line color	Foreground color	(/"red","green"/)
xyMarkLineModes	Set wheter lines contain markers, lines, or both markers and lines	"Lines"	"Markers" "MarkLines"
xyMarkers	Set marker styles	Asterisk	5
xyMarkerColor	Set marker color	Foreground color	"green"
xyMarkerSizeF	Set marker size	0.01	0.03

Maps – http://www.ncl.ucar.edu/Document/Graphics/Resources/mp.shtml

The second through fifth resources are to be used when zooming in on a cylindrical equidistant or polar stereographic projection. They are the limits set when using mpLimitMode = "LatLon". This resource is set for the user by the high-level plot interfaces. Other projections, such as lambert conformal, require a different limit mode (mpLimitMode = "Corners").

Name	Function	Default	Example
mpLimitMode	Determine how a map is zoomed in	Depends on the projection	"LatLon" "Corners"
mpMinLatF **mpMaxLatF**	Set the minimum/maximum latitude for map zoom	Dynamic	30. 60.
mpMinLonF **mpMaxLonF**	Set the minimum/maximum longitude for map zoom	Dynamic	-70. 89.
mpFillOn	Turn on/off map fill	True for gsn_csm	False
mpCenterLonF	Set center longitude of projection	0	120.
mpDataBaseVersion	Set map database resolution	"LowRes"	"MediumRes" "HighRes" (must be downloaded extra)
mpLandFillColor	Set color of land areas	"gray"for gsn_csm interfaces	"brown"
mpOceanFillColor	Set color of ocean areas	"transparent"	"SkyBlue"
mpInlandWaterFillColor	Set color of inland water areas	"transparent"	"blue"
mpOutlineOn	Turn on/off the map outlines	True	False

mpOutlineBoundarySets	Set various continental outlines on and off	"Geophysical"	"GeophysicalAndUSStates"
mpGeophysicalLineThicknessesF	Set line thickness of map outlines	1.0	2.0
mpGeophysicalLineColor	Set color of map outlines	Foreground color	"red"
mpUSStateLineColor	Set color of US state boundaries	foreground	"blue"

Polylines, polyfons, polymarkers – http://www.ncl.ucar.edu/Document/Graphics/Resources/gs.shtml

Name	Function	Default	Example
gsFillColor	Set fill color for inside of polygon	Transparent	"red"
gsEdgeColor	Set color of the outline oa a polygon	None	"black"
gsEdgesOn	Turn on/off polygon edge	False	True
gsLineColor	Set polyline color	Foreground color	"orange"
gsLineThicknessF	Set polyline thickness	1.0	2.0
gsMarkerIndex	Set marker style	Asterisk (*)	5
gsMarkerColor	Set marker color	Foreground color	"purple"
gsMarkerSizeF	Set marker size	0.007	0.014

24 Appendix H - Named Colors

255	250	250	snow
248	248	255	ghost white
248	248	255	GhostWhite
245	245	245	white smoke
245	245	245	WhiteSmoke
220	220	220	gainsboro
255	250	240	floral white
255	250	240	FloralWhite
253	245	230	old lace
253	245	230	OldLace
250	240	230	linen
250	235	215	antique white
250	235	215	AntiqueWhite
255	239	213	papaya whip
255	239	213	PapayaWhip
255	235	205	blanched almond
255	235	205	BlanchedAlmond
255	228	196	bisque
255	218	185	peach puff
255	218	185	PeachPuff
255	222	173	navajo white
255	222	173	NavajoWhite
255	228	181	moccasin
255	248	220	cornsilk
255	255	240	ivory
255	250	205	lemon chiffon
255	250	205	LemonChiffon
255	245	238	seashell
240	255	240	honeydew
245	255	250	mint cream
245	255	250	MintCream
240	255	255	azure
240	248	255	alice blue
240	248	255	AliceBlue
230	230	250	lavender
255	240	245	lavender blush
255	240	245	LavenderBlush
255	228	225	misty rose
255	228	225	MistyRose
255	255	255	white
0	0	0	black
47	79	79	dark slate gray
47	79	79	DarkSlateGray
47	79	79	dark slate grey
47	79	79	DarkSlateGrey
105	105	105	dim gray
105	105	105	DimGray
105	105	105	dim grey
105	105	105	DimGrey
112	128	144	slate gray
112	128	144	SlateGray
112	128	144	slate grey
112	128	144	SlateGrey
119	136	153	light slate gray
119	136	153	LightSlateGray
119	136	153	light slate grey
119	136	153	LightSlateGrey
190	190	190	gray
190	190	190	grey
211	211	211	light grey
211	211	211	LightGrey
211	211	211	light gray

211	211	211	LightGray
25	25	112	midnight blue
25	25	112	MidnightBlue
0	0	128	navy
0	0	128	navy blue
0	0	128	NavyBlue
100	149	237	cornflower blue
100	149	237	CornflowerBlue
72	61	139	dark slate blue
72	61	139	DarkSlateBlue
106	90	205	slate blue
106	90	205	SlateBlue
123	104	238	medium slate blue
123	104	238	MediumSlateBlue
132	112	255	light slate blue
132	112	255	LightSlateBlue
0	0	205	medium blue
0	0	205	MediumBlue
65	105	225	royal blue
65	105	225	RoyalBlue
0	0	255	blue
30	144	255	dodger blue
30	144	255	DodgerBlue
0	191	255	deep sky blue
0	191	255	DeepSkyBlue
135	206	235	sky blue
135	206	235	SkyBlue
135	206	250	light sky blue
135	206	250	LightSkyBlue
70	130	180	steel blue
70	130	180	SteelBlue
176	196	222	light steel blue
176	196	222	LightSteelBlue
173	216	230	light blue
173	216	230	LightBlue
176	224	230	powder blue
176	224	230	PowderBlue
175	238	238	pale turquoise
175	238	238	PaleTurquoise
0	206	209	dark turquoise
0	206	209	DarkTurquoise
72	209	204	medium turquoise
72	209	204	MediumTurquoise
64	224	208	turquoise
0	255	255	cyan
224	255	255	light cyan
224	255	255	LightCyan
95	158	160	cadet blue
95	158	160	CadetBlue
102	205	170	medium aquamarine
102	205	170	MediumAquamarine
127	255	212	aquamarine
0	100	0	dark green
0	100	0	DarkGreen
85	107	47	dark olive green
85	107	47	DarkOliveGreen
143	188	143	dark sea green
143	188	143	DarkSeaGreen
46	139	87	sea green
46	139	87	SeaGreen
60	179	113	medium sea green
60	179	113	MediumSeaGreen
32	178	170	light sea green
32	178	170	LightSeaGreen
152	251	152	pale green

152	251	152	PaleGreen
0	255	127	spring green
0	255	127	SpringGreen
124	252	0	lawn green
124	252	0	LawnGreen
0	255	0	green
127	255	0	chartreuse
0	250	154	medium spring green
0	250	154	MediumSpringGreen
173	255	47	green yellow
173	255	47	GreenYellow
50	205	50	lime green
50	205	50	LimeGreen
154	205	50	yellow green
154	205	50	YellowGreen
34	139	34	forest green
34	139	34	ForestGreen
107	142	35	olive drab
107	142	35	OliveDrab
189	183	107	dark khaki
189	183	107	DarkKhaki
240	230	140	khaki
238	232	170	pale goldenrod
238	232	170	PaleGoldenrod
250	250	210	light goldenrod yellow
250	250	210	LightGoldenrodYellow
255	255	224	light yellow
255	255	224	LightYellow
255	255	0	yellow
255	215	0	gold
238	221	130	light goldenrod
238	221	130	LightGoldenrod
218	165	32	goldenrod
184	134	11	dark goldenrod
184	134	11	DarkGoldenrod
188	143	143	rosy brown
188	143	143	RosyBrown
205	92	92	indian red
205	92	92	IndianRed
139	69	19	saddle brown
139	69	19	SaddleBrown
160	82	45	sienna
205	133	63	peru
222	184	135	burlywood
245	245	220	beige
245	222	179	wheat
244	164	96	sandy brown
244	164	96	SandyBrown
210	180	140	tan
210	105	30	chocolate
178	34	34	firebrick
165	42	42	brown
233	150	122	dark salmon
233	150	122	DarkSalmon
250	128	114	salmon
255	160	122	light salmon
255	160	122	LightSalmon
255	165	0	orange
255	140	0	dark orange
255	140	0	DarkOrange
255	127	80	coral
240	128	128	light coral
240	128	128	LightCoral
255	99	71	tomato
255	69	0	orange red

255	69	0	OrangeRed
255	0	0	red
255	105	180	hot pink
255	105	180	HotPink
255	20	147	deep pink
255	20	147	DeepPink
255	192	203	pink
255	182	193	light pink
255	182	193	LightPink
219	112	147	pale violet red
219	112	147	PaleVioletRed
176	48	96	maroon
199	21	133	medium violet red
199	21	133	MediumVioletRed
208	32	144	violet red
208	32	144	VioletRed
255	0	255	magenta
238	130	238	violet
221	160	221	plum
218	112	214	orchid
186	85	211	medium orchid
186	85	211	MediumOrchid
153	50	204	dark orchid
153	50	204	DarkOrchid
148	0	211	dark violet
148	0	211	DarkViolet
138	43	226	blue violet
138	43	226	BlueViolet
160	32	240	purple
147	112	219	medium purple
147	112	219	MediumPurple
216	191	216	thistle
255	250	250	snow1
238	233	233	snow2
205	201	201	snow3
139	137	137	snow4
255	245	238	seashell1
238	229	222	seashell2
205	197	191	seashell3
139	134	130	seashell4
255	239	219	AntiqueWhite1
238	223	204	AntiqueWhite2
205	192	176	AntiqueWhite3
139	131	120	AntiqueWhite4
255	228	196	bisque1
238	213	183	bisque2
205	183	158	bisque3
139	125	107	bisque4
255	218	185	PeachPuff1
238	203	173	PeachPuff2
205	175	149	PeachPuff3
139	119	101	PeachPuff4
255	222	173	NavajoWhite1
238	207	161	NavajoWhite2
205	179	139	NavajoWhite3
139	121	94	NavajoWhite4
255	250	205	LemonChiffon1
238	233	191	LemonChiffon2
205	201	165	LemonChiffon3
139	137	112	LemonChiffon4
255	248	220	cornsilk1
238	232	205	cornsilk2
205	200	177	cornsilk3
139	136	120	cornsilk4
255	255	240	ivory1

238	238	224	ivory2
205	205	193	ivory3
139	139	131	ivory4
240	255	240	honeydew1
224	238	224	honeydew2
193	205	193	honeydew3
131	139	131	honeydew4
255	240	245	LavenderBlush1
238	224	229	LavenderBlush2
205	193	197	LavenderBlush3
139	131	134	LavenderBlush4
255	228	225	MistyRose1
238	213	210	MistyRose2
205	183	181	MistyRose3
139	125	123	MistyRose4
240	255	255	azure1
224	238	238	azure2
193	205	205	azure3
131	139	139	azure4
131	111	255	SlateBlue1
122	103	238	SlateBlue2
105	89	205	SlateBlue3
71	60	139	SlateBlue4
72	118	255	RoyalBlue1
67	110	238	RoyalBlue2
58	95	205	RoyalBlue3
39	64	139	RoyalBlue4
0	0	255	blue1
0	0	238	blue2
0	0	205	blue3
0	0	139	blue4
30	144	255	DodgerBlue1
28	134	238	DodgerBlue2
24	116	205	DodgerBlue3
16	78	139	DodgerBlue4
99	184	255	SteelBlue1
92	172	238	SteelBlue2
79	148	205	SteelBlue3
54	100	139	SteelBlue4
0	191	255	DeepSkyBlue1
0	178	238	DeepSkyBlue2
0	154	205	DeepSkyBlue3
0	104	139	DeepSkyBlue4
135	206	255	SkyBlue1
126	192	238	SkyBlue2
108	166	205	SkyBlue3
74	112	139	SkyBlue4
176	226	255	LightSkyBlue1
164	211	238	LightSkyBlue2
141	182	205	LightSkyBlue3
96	123	139	LightSkyBlue4
198	226	255	SlateGray1
185	211	238	SlateGray2
159	182	205	SlateGray3
108	123	139	SlateGray4
202	225	255	LightSteelBlue1
188	210	238	LightSteelBlue2
162	181	205	LightSteelBlue3
110	123	139	LightSteelBlue4
191	239	255	LightBlue1
178	223	238	LightBlue2
154	192	205	LightBlue3
104	131	139	LightBlue4
224	255	255	LightCyan1
209	238	238	LightCyan2

180	205	205	LightCyan3
122	139	139	LightCyan4
187	255	255	PaleTurquoise1
174	238	238	PaleTurquoise2
150	205	205	PaleTurquoise3
102	139	139	PaleTurquoise4
152	245	255	CadetBlue1
142	229	238	CadetBlue2
122	197	205	CadetBlue3
83	134	139	CadetBlue4
0	245	255	turquoise1
0	229	238	turquoise2
0	197	205	turquoise3
0	134	139	turquoise4
0	255	255	cyan1
0	238	238	cyan2
0	205	205	cyan3
0	139	139	cyan4
151	255	255	DarkSlateGray1
141	238	238	DarkSlateGray2
121	205	205	DarkSlateGray3
82	139	139	DarkSlateGray4
127	255	212	aquamarine1
118	238	198	aquamarine2
102	205	170	aquamarine3
69	139	116	aquamarine4
193	255	193	DarkSeaGreen1
180	238	180	DarkSeaGreen2
155	205	155	DarkSeaGreen3
105	139	105	DarkSeaGreen4
84	255	159	SeaGreen1
78	238	148	SeaGreen2
67	205	128	SeaGreen3
46	139	87	SeaGreen4
154	255	154	PaleGreen1
144	238	144	PaleGreen2
124	205	124	PaleGreen3
84	139	84	PaleGreen4
0	255	127	SpringGreen1
0	238	118	SpringGreen2
0	205	102	SpringGreen3
0	139	69	SpringGreen4
0	255	0	green1
0	238	0	green2
0	205	0	green3
0	139	0	green4
127	255	0	chartreuse1
118	238	0	chartreuse2
102	205	0	chartreuse3
69	139	0	chartreuse4
192	255	62	OliveDrab1
179	238	58	OliveDrab2
154	205	50	OliveDrab3
105	139	34	OliveDrab4
202	255	112	DarkOliveGreen1
188	238	104	DarkOliveGreen2
162	205	90	DarkOliveGreen3
110	139	61	DarkOliveGreen4
255	246	143	khaki1
238	230	133	khaki2
205	198	115	khaki3
139	134	78	khaki4
255	236	139	LightGoldenrod1
238	220	130	LightGoldenrod2
205	190	112	LightGoldenrod3

139	129	76	LightGoldenrod4
255	255	224	LightYellow1
238	238	209	LightYellow2
205	205	180	LightYellow3
139	139	122	LightYellow4
255	255	0	yellow1
238	238	0	yellow2
205	205	0	yellow3
139	139	0	yellow4
255	215	0	gold1
238	201	0	gold2
205	173	0	gold3
139	117	0	gold4
255	193	37	goldenrod1
238	180	34	goldenrod2
205	155	29	goldenrod3
139	105	20	goldenrod4
255	185	15	DarkGoldenrod1
238	173	14	DarkGoldenrod2
205	149	12	DarkGoldenrod3
139	101	8	DarkGoldenrod4
255	193	193	RosyBrown1
238	180	180	RosyBrown2
205	155	155	RosyBrown3
139	105	105	RosyBrown4
255	106	106	IndianRed1
238	99	99	IndianRed2
205	85	85	IndianRed3
139	58	58	IndianRed4
255	130	71	sienna1
238	121	66	sienna2
205	104	57	sienna3
139	71	38	sienna4
255	211	155	burlywood1
238	197	145	burlywood2
205	170	125	burlywood3
139	115	85	burlywood4
255	231	186	wheat1
238	216	174	wheat2
205	186	150	wheat3
139	126	102	wheat4
255	165	79	tan1
238	154	73	tan2
205	133	63	tan3
139	90	43	tan4
255	127	36	chocolate1
238	118	33	chocolate2
205	102	29	chocolate3
139	69	19	chocolate4
255	48	48	firebrick1
238	44	44	firebrick2
205	38	38	firebrick3
139	26	26	firebrick4
255	64	64	brown1
238	59	59	brown2
205	51	51	brown3
139	35	35	brown4
255	140	105	salmon1
238	130	98	salmon2
205	112	84	salmon3
139	76	57	salmon4
255	160	122	LightSalmon1
238	149	114	LightSalmon2
205	129	98	LightSalmon3
139	87	66	LightSalmon4

255	165	0	orange1
238	154	0	orange2
205	133	0	orange3
139	90	0	orange4
255	127	0	DarkOrange1
238	118	0	DarkOrange2
205	102	0	DarkOrange3
139	69	0	DarkOrange4
255	114	86	coral1
238	106	80	coral2
205	91	69	coral3
139	62	47	coral4
255	99	71	tomato1
238	92	66	tomato2
205	79	57	tomato3
139	54	38	tomato4
255	69	0	OrangeRed1
238	64	0	OrangeRed2
205	55	0	OrangeRed3
139	37	0	OrangeRed4
255	0	0	red1
238	0	0	red2
205	0	0	red3
139	0	0	red4
255	20	147	DeepPink1
238	18	137	DeepPink2
205	16	118	DeepPink3
139	10	80	DeepPink4
255	110	180	HotPink1
238	106	167	HotPink2
205	96	144	HotPink3
139	58	98	HotPink4
255	181	197	pink1
238	169	184	pink2
205	145	158	pink3
139	99	108	pink4
255	174	185	LightPink1
238	162	173	LightPink2
205	140	149	LightPink3
139	95	101	LightPink4
255	130	171	PaleVioletRed1
238	121	159	PaleVioletRed2
205	104	137	PaleVioletRed3
139	71	93	PaleVioletRed4
255	52	179	maroon1
238	48	167	maroon2
205	41	144	maroon3
139	28	98	maroon4
255	62	150	VioletRed1
238	58	140	VioletRed2
205	50	120	VioletRed3
139	34	82	VioletRed4
255	0	255	magenta1
238	0	238	magenta2
205	0	205	magenta3
139	0	139	magenta4
255	131	250	orchid1
238	122	233	orchid2
205	105	201	orchid3
139	71	137	orchid4
255	187	255	plum1
238	174	238	plum2
205	150	205	plum3
139	102	139	plum4
224	102	255	MediumOrchid1

209	95	238	MediumOrchid2
180	82	205	MediumOrchid3
122	55	139	MediumOrchid4
191	62	255	DarkOrchid1
178	58	238	DarkOrchid2
154	50	205	DarkOrchid3
104	34	139	DarkOrchid4
155	48	255	purple1
145	44	238	purple2
125	38	205	purple3
85	26	139	purple4
171	130	255	MediumPurple1
159	121	238	MediumPurple2
137	104	205	MediumPurple3
93	71	139	MediumPurple4
255	225	255	thistle1
238	210	238	thistle2
205	181	205	thistle3
139	123	139	thistle4
0	0	0	gray0
0	0	0	grey0
3	3	3	gray1
3	3	3	grey1
5	5	5	gray2
5	5	5	grey2
8	8	8	gray3
8	8	8	grey3
10	10	10	gray4
10	10	10	grey4
13	13	13	gray5
13	13	13	grey5
15	15	15	gray6
15	15	15	grey6
18	18	18	gray7
18	18	18	grey7
20	20	20	gray8
20	20	20	grey8
23	23	23	gray9
23	23	23	grey9
26	26	26	gray10
26	26	26	grey10
28	28	28	gray11
28	28	28	grey11
31	31	31	gray12
31	31	31	grey12
33	33	33	gray13
33	33	33	grey13
36	36	36	gray14
36	36	36	grey14
38	38	38	gray15
38	38	38	grey15
41	41	41	gray16
41	41	41	grey16
43	43	43	gray17
43	43	43	grey17
46	46	46	gray18
46	46	46	grey18
48	48	48	gray19
48	48	48	grey19
51	51	51	gray20
51	51	51	grey20
54	54	54	gray21
54	54	54	grey21
56	56	56	gray22
56	56	56	grey22

59	59	59	gray23
59	59	59	grey23
61	61	61	gray24
61	61	61	grey24
64	64	64	gray25
64	64	64	grey25
66	66	66	gray26
66	66	66	grey26
69	69	69	gray27
69	69	69	grey27
71	71	71	gray28
71	71	71	grey28
74	74	74	gray29
74	74	74	grey29
77	77	77	gray30
77	77	77	grey30
79	79	79	gray31
79	79	79	grey31
82	82	82	gray32
82	82	82	grey32
84	84	84	gray33
84	84	84	grey33
87	87	87	gray34
87	87	87	grey34
89	89	89	gray35
89	89	89	grey35
92	92	92	gray36
92	92	92	grey36
94	94	94	gray37
94	94	94	grey37
97	97	97	gray38
97	97	97	grey38
99	99	99	gray39
99	99	99	grey39
102	102	102	gray40
102	102	102	grey40
105	105	105	gray41
105	105	105	grey41
107	107	107	gray42
107	107	107	grey42
110	110	110	gray43
110	110	110	grey43
112	112	112	gray44
112	112	112	grey44
115	115	115	gray45
115	115	115	grey45
117	117	117	gray46
117	117	117	grey46
120	120	120	gray47
120	120	120	grey47
122	122	122	gray48
122	122	122	grey48
125	125	125	gray49
125	125	125	grey49
127	127	127	gray50
127	127	127	grey50
130	130	130	gray51
130	130	130	grey51
133	133	133	gray52
133	133	133	grey52
135	135	135	gray53
135	135	135	grey53
138	138	138	gray54
138	138	138	grey54
140	140	140	gray55

140	140	140	grey55
143	143	143	gray56
143	143	143	grey56
145	145	145	gray57
145	145	145	grey57
148	148	148	gray58
148	148	148	grey58
150	150	150	gray59
150	150	150	grey59
153	153	153	gray60
153	153	153	grey60
156	156	156	gray61
156	156	156	grey61
158	158	158	gray62
158	158	158	grey62
161	161	161	gray63
161	161	161	grey63
163	163	163	gray64
163	163	163	grey64
166	166	166	gray65
166	166	166	grey65
168	168	168	gray66
168	168	168	grey66
171	171	171	gray67
171	171	171	grey67
173	173	173	gray68
173	173	173	grey68
176	176	176	gray69
176	176	176	grey69
179	179	179	gray70
179	179	179	grey70
181	181	181	gray71
181	181	181	grey71
184	184	184	gray72
184	184	184	grey72
186	186	186	gray73
186	186	186	grey73
189	189	189	gray74
189	189	189	grey74
191	191	191	gray75
191	191	191	grey75
194	194	194	gray76
194	194	194	grey76
196	196	196	gray77
196	196	196	grey77
199	199	199	gray78
199	199	199	grey78
201	201	201	gray79
201	201	201	grey79
204	204	204	gray80
204	204	204	grey80
207	207	207	gray81
207	207	207	grey81
209	209	209	gray82
209	209	209	grey82
212	212	212	gray83
212	212	212	grey83
214	214	214	gray84
214	214	214	grey84
217	217	217	gray85
217	217	217	grey85
219	219	219	gray86
219	219	219	grey86
222	222	222	gray87
222	222	222	grey87

224	224	224	gray88
224	224	224	grey88
227	227	227	gray89
227	227	227	grey89
229	229	229	gray90
229	229	229	grey90
232	232	232	gray91
232	232	232	grey91
235	235	235	gray92
235	235	235	grey92
237	237	237	gray93
237	237	237	grey93
240	240	240	gray94
240	240	240	grey94
242	242	242	gray95
242	242	242	grey95
245	245	245	gray96
245	245	245	grey96
247	247	247	gray97
247	247	247	grey97
250	250	250	gray98
250	250	250	grey98
252	252	252	gray99
252	252	252	grey99
255	255	255	gray100
255	255	255	grey100
169	169	169	dark grey
169	169	169	DarkGrey
169	169	169	dark gray
169	169	169	DarkGray
0	0	139	dark blue
0	0	139	DarkBlue
0	139	139	dark cyan
0	139	139	DarkCyan
139	0	139	dark magenta
139	0	139	DarkMagenta
139	0	0	dark red
139	0	0	DarkRed
144	238	144	light green
144	238	144	LightGreen

25 Glossary

A

adjustable array
An array that is a dummy argument in a Fortran subroutine or function whose dimensionality is determined at runtime. The dimensionality of an adjustable array is supplied in the argument list in which the dummy array name appears, or by values in a COMMON block.

animation
A sequence of two or more images that, when displayed in a rapid sequence, provide the illusion of continuous motion.

annotation
A viewable object whose location and usually size are set relative to the viewport or data coordinate space of a base plot. There are three kinds of annotations: intrinsic annotations, embedded annotations, and external annotations.

annotation functions
The functions used to add and remove annotations to and from plot objects. Specifically, these functions are NhlAddAnnotation and NhlRemoveAnnotation for the C and Fortran interfaces.

annotation plot
An annotation that is a plot object and not simply a viewable object. An annotation plot is a subordinate base plot.

ANSI
The American National Standards Institute, an independent non-profit organization that creates and publishes U.S. national standards (such as Fortran, C, CGM, and so forth) taking input from all sectors of the technical community and the public at large. ANSI also works in collaboration with other standards organizations such as ISO (the International Standards Organization) and IEEE (the Institute of Electrical and Electronics Engineers).

API
Application Programming Interface.

application
A program written in C, Fortran, or NCL that utilizes any of the functionality of NCAR Graphics.

application class
Refers specifically to the class App. Objects that are instances of this class are used to keep track of resource databases. Every application must create at least one App object (this will be done automatically for you if you use NhlOpen).

Application Programming Interface
The programming interfaces (C, Fortran, and NCL) to the NCAR Graphics package. These interfaces provide access to the support functions defined in the classes as well as provide additional useful functionality.

application resource file
A resource file that is specific to a particular application. There are two application-specific resource files: a system application-specific resource file and a user application-specific resource file. The user can specify what directories the application-specific resource files are in. By default, the user application-specific resource file is in the local current directory and the system application-specific resource file is in the directory specified by the setting of the environment variable NCARG_SYSAPPRES. Resources defined in the user application-specific resource file will override resources defined in the system application resource file.

area fill pattern
A pattern to use for filling a polygonal area. The patterns are selected by using an integer fill index into a table of patterns.

arithmetic operator
An operator that applies to variables having a numeric data type. Examples are "+" (addition) and "*" (multiplication).

ASCII
Stands for "American Standard Code for Information Interchange." This is an ANSI Standard specifying a set of 128 characters with their associated coded integer representations.

ASCII file
NCL: A data file that contains integers or floating point data values in ASCII format.

aspect ratio
Specifies the height-to-width ratio of a plot. This term is also applied to characters. For example, characters with an aspect ratio of 2.0 are twice as tall as they are wide.

associative operator
A binary operator that obeys the law of associativity: i.e. a binary operator "R" such that (aRb)Rc = aR(bRc) for all legal operands a, b, and c.

attribute
NCL: A singly-dimensioned datum of any type that is assigned to a variable using the ' @ ' operator. An attribute of a variable contains descriptive information about the variable.

B

background color
The color that will be used as a background color for the entire viewable surface of a physical workstation when plots are drawn on it.

base plot
A plot object responsible for setting the viewport of zero or more plot members relative to its own viewport. There are two kinds of base plot: primary base plots and subordinate base plots. At creation, any plot object is a primary base plot. A plot object ceases to be a base plot when added to another plot object as an overlay. When added as an annotation a plot object becomes a subordinate base plot. A plot object must be a primary base plot for users to draw it or change its workstation.

binary file
A file whose contents are to be interpreted as a sequence of bits, rather than characters. There are different flavors of binary files. A "flat" binary file is a sequence of bits with no ancillary information about the file contents. This type of file is created and read by C programs. Fortran creates and reads flat binary files only when in direct-access mode. All records are the same size in a flat binary file. By default, Fortran creates another type of binary file which can contain variable-length records. This is called a sequential-access binary file. In a sequential-access binary file, record length information is embedded prior to each record.

block statement
A statement that requires one or more individual statements bracketed by delimiters indicating the beginning and end of the block. Examples of block statements are: do-end do, if-then-end if, setvalues-end setvalues.

bounding box
For View class objects, the bounding box for such objects is the smallest rectangle in NDC space that contains all of the marks that would appear on an output workstation if the object were drawn.

built-in function or procedure
A built-in function or procedure in NCL is one that is built into the code for NCL, and hence you don't need to load any NCL scripts to use it. Examples of built-in functions include fspan and addfile. Examples of procedures include system and delete. An example of a function that is not considered a built-in function is gsn_open_wks.

cairo
From the wikipedia entry: a software library used to provide a vector-based graphics, device independent API for software developers. In NCL V5.2.0, new cairo workstations were added to provide PNG, TIFF, and alternate PS and PDF output.

cartesian grid
A cartesian grid is the simplest form of a structured grid. It simply consists of square cells arranged uniformly in a matrix. The grid cells are evenly spaced in all directions, and for every column there is the same number of rows and vice versa.

See also rectilinear and curvilinear grids.

CCM history tape format
A proprietary data format used by atmospheric climate simulation models developed at NCAR. (CCM stands for Community Climate Model.)

C function prototype
A C function declaration that declares a function's return type, how many arguments the function takes, and the types of the arguments.

CGM
Computer Graphics Metafile.

child
A relationship that holds between objects. If "A" and "B" are objects, then B is a child of A provided that when B was created, A was specified as being its parent (either in the fourth argument of an NhlCreate call, or in a NCL create expression), or B was made a child of A by using the NhlChangeWorkstation function. If B is a child of A, then the following conditions apply:

1. B inherits the resource database of A. If viewable, B will display to the same workstation as A; if A is a workstation, then B will draw to A.
2. Destroying A will destroy B.
3. Resources can be specified in resource files as: {App obj name} . {parent of A} . {Name of A} . {Name of B} . {resource of B} : {value}.

child/parent hierarchy
The tree structure determined by the child/parent relationship existing among all current objects in an application. A child can have only a single parent, but a parent may have many children. The child/parent hierarchy should not be confused with the class hierarchy. See also class hierarchy.

class
A template for defining objects that specifies variables, and procedures that operate on those variables. In the context of the NCAR HLU library, the class variables are called resources and the class procedures are called support functions. Objects are members, or instances, of a class formed by assigning specific values to the variables in the class.

class hierarchy
Each class, except the base class, is derived from some other class. The tree structure determined by the derived-class/superclass relationships among all of the classes is called the class hierarchy. The class hierarchy should not be confused with the child/parent hierarchy.

color index
An integer value that represents an index into the current color table. Index 0 represents the background color and 1 the foreground color. See also named color and gsn_draw_colormap.

color map
Same as color table.

color table
A table that associates integer values (called color indices) with RGB color values. In NCL, color tables contain up to a maximum of 256 colors (including the background and foreground colors). There are several predefined color tables, or you can define your own. See also gsn_draw_colormap.

command
NCL: Same as an NCL statement.

comment line
A line in an NCL code beginning with a semi-colon (;). A line in an NCL resource file beginning with an exclamation point (!). Comment lines contain descriptive information about the code.

composite class
A class that combines the resources of other classes with its own. A composite class inherits resources and functions from its superclass and it shares the resources from its composite members by the process of resource forwarding. If the composite class members have support functions, these functions do not apply to the composite class.

composite class member
A class used as part of the functionality of a composite class.

composite class resource
A resource available to a composite class by way of resource forwarding from a member class of the composite class.

Computer Graphics Metafile
A graphics metafile is a file that contains encoded vector graphics elements such as lines, colors, dash patterns, markers, and so forth. The Computer Graphics Metafile (CGM) is a precisely-defined formatting for a graphics metafile as defined and standardized by ANSI. NCL produces a version of the CGM that is called a conforming private encoding that can easily be converted to and from standard CGM by using the filters ncgm2cgm and cgm2ncgm. The NCAR private encoding is also called NCAR CGM, or NCGM.

contour plot
A plot of 2D data containing contour lines (lines marking points of equal elevation) to indicate surface shape. Contour plots may have color fill between contour lines and may have label bars and annotations.

coordinate addressing
A way of indexing array elements by specifying coordinate values rather than the normal integer array indices. Coordinate addressing is effected by using coordinate variables.

coordinate subscripts
Coordinate subscripts use the coordinate variables associated with a variable to determine which indexes are used in the selection. When specifying a coordinate subscript, braces '{' and '}' indicate the start and end values of the coordinate variable that will be used to select the indexes.

coordinate variable
Another word for coordinate variable.

coordinate variable
NCL: A value associated with a named dimension of a variable or file variable that contains numerical coordinate information for each index of the dimension. Coordinate variables must be singly-dimensioned values. Warnings are produced if the array of values assigned is not monotonically increasing or decreasing.

ctrans
The NCGM interpreter distributed with NCL.

curvilinear grid
A curvilinear grid is one which cannot be uniquely accessed by a pair of one-dimensional coordinate arrays. These grids require a pair of two-dimensional arrays to describe grid point locations.

See also cartesian and rectilinear grids.

D

dash pattern
A pattern (such as "solid", "dotted", and so forth) to use as a line style when lines are plotted using the NhlDraw function. Dash patterns are selected by using an integer index into a table of dash patterns.

data classes
Any of the classes that are used to provide user input data to any of the objects that utilize such data. These classes are the CoordArrays class, the CoordArrTable class, and the ScalarField class.

data conversion
The process of converting data stored in one format to another format, such as converting data stored as integers to data stored as floating point numbers. Some objects, such as ScalarField, perform automatic data conversions.

data coordinate space
The coordinate space that is appropriate to input data. Transformations can be effected between data coordinate space and NDC (see Normalized Device Coordinates).

data specific resource
A resource of a particular class, such as the XyPlot class, that can be used to modify the attributes of data supplied via a DataSpec object. Data specific resources can be used to control attributes such as curve colors, dash patterns, marker sizes, marker colors, and so forth.

data transformation
A process that transforms data from one coordinate space to another, such as transforming data in logarithmic space to data in linear space.

data type
A data type is a representation of data that defines a size and valid range for numerical data or provides a reference to a file or HLU graphical object.

decision statement
A language construct allowing for conditional program execution based on the truth or falsity of an expression. The basic decision statement in NCL is if.

derived class
See subclass.

DODs
Distributed Ocean Data. Now referred to as OPeNDAP.

drawable object
See viewable object.

draw function
Specifically, either the NhlDraw function of the C or Fortran interfaces, or the draw function of NCL, that is invoked to plot a View object.

E

embedded annotation
An annotation that may be incorporated as part of the functionality of subclasses of the Transform class. It is managed internally by the controlling PlotManager.

Encapsulated PostScript

Encapsulated PostScript (EPS) is a subset of regular PostScript. The restrictions placed on EPS files are for making it an appropriate format for importing into applications that import PostScript.

Encapsulated PostScript Interchange Format
Encapsulated PostScript Interchange Format (EPSI) files are Encapsulated PostScript files that have a "preview bitmap" that represents the PostScript image contained in the file. The bitmap (and it is a bitmap and not a color map) can be used by an importing application to quickly display a picture of the imported file.

endian
[Note: this definition was taken straight from Wikipedia]
Endianness generally refers to sequencing methods used in a one-dimensional system (such as writing or computer memory). The two main types of endianness are known as big-endian and little-endian. Systems which exhibit aspects of both conventions are often described as middle-endian. When specifically talking about bytes in computing, endianness is also referred to as byte order.

enumeric
NCL: Starting from 5.2.0, NCL has added int64 (aka long long), uint64 (unsigned long long), ulong (unsigned long), uint (unsigned int), and ushort (unsigned short). These newly added data types are named as enumeric.

EPS
see Encapsulated PostScript

EPSI
see Encapsulated PostScript Interchange Format

error class
A class that is used to configure the error reporting module of the HLU library. For any application, there is precisely one error object created, and it is created automatically for you. The error class defines several resources for controlling error reporting.

expression
NCL: Any sequence of NCL operators and operands that results in the computation of a value. In particular, any literal value is an expression and any variable is an expression. Also, arrays are expressions as well as functions. Operators applied to expressions are expressions.

external annotation
An annotation consisting of an arbitrary user-created viewable object added to a plot object. The user controls the location and size relative to the base plot by manipulating the resources of a user-accessible AnnoManager object.

F

file
NCL: A data file residing external to NCL in one of NCL's supported data formats.

file name suffix
A suffix appended to a file name to indicate its type. NCL recognizes the following supported suffixes: ".nc" for netCDF, ".hdf" for HDF, ".h5" for HDF5, ".he" ".he2" for HDFEOS, ".he5" for HDFEOS5, ".grb" ".grib" ".grb2" ".grib2" for GRIB, and ".ccm" for CCM History Tape. The obsolete suffix ".cdf" for a netCDF file is also recognized.

file variable
NCL: A variable, created by the NCL addfile function, that contains a reference to a file.

fill value
NCL: Same as missing value.

fixed grid

A fixed grid is a type of a rectilinear grid where each grid point can be uniquely accessed by one-dimensional, monotonically increasing or decreasing arrays (i.e. the coordinates are orthogonal). In cartesian coordinates, these may refer to the "x" and "y" coordinates, while on the globe these are longitude and latitude arrays. The grid spacing may be different in the latitude (y) and longitude (x) coordinates, but it is constant.

The special case where the grid spacing is the same in the latitude/longitude directions is called an "equally spaced" grid. Pole points may or may not be present. Some examples include: 1x1, 2x5, and 2.5x2.5 degree grids.

fixed offset grid
A fixed-offset grid is analogous to the fixed grid, but refers to the special case where the latitude/longitude grids are offset for the traditional Greenwich Meridian or poles.

fontcap
A file that contains detailed information used to plot characters. Fontcaps have a human-readable ASCII form and a binary form that is readable by ctrans.

foreground color
The color associated with color index 1. This is used as the default color in drawing viewable objects.

Fortran 90 interface block
A sequence of Fortran 90 statements (bracketed by special delimiting statements) used to describe a procedure interface. The statements in the interface block contain a declaration for the procedure and declarations for the dummy arguments and no executable statements.

function
HLU: Any member of the NCL functions or the HLU API.
NCL: An identifier with a list of parameters separated by commas and enclosed in parentheses. Functions return values when called. A function is defined by NCL source unlike the NCL intrinsic function.

G

Gaussian grid
A Gaussian grid is a type of a rectilinear grid one where each grid point can be uniquely accessed by one-dimensional latitude and longitude arrays (i.e. the coordinates are orthogonal). The longitudes are equally spaced while the latitudes are unequally spaced according to the Gaussian quadrature. There are no grid points at the poles. See also rectilinear and curvilinear grids.

GIF
A file format used for the storage and on-line retrieval of bitmapped graphical data. GIF stands for "Graphical Interchange Format"; it was created by the CompuServe Corporation in 1987.

graphcap
A file that contains detailed information used to define the capabilities of a specific plotting device. Graphcaps have a human-readable ASCII form or a binary form that is readable by ctrans.

graphical object
NCL: An NCL value of type graphic. A graphical object is an identifier for an HLU object.

Graphical User Interface
A non-programmatic, graphical, interface to the functionality of NCAR Graphics. Such an interface is sometimes referred to as a "point-and-click" interface, since that is how the interaction is accomplished.

GRIB
GRIB (GRIdded Binary) is a data format used for the storage of historical and forecasted weather data. The format is standardized by the World Meteorological Organization (WMO). There are two versions: GRIB1 and GRIB2. NCL supports both versions.

GSUN
Acronym for "Getting Started Using NCL."

GSUN scripts
NCL scripts that provide an "easy" interface to the graphics capabilities of NCL. Some examples are gsn_xy and gsn_csm_contour_map.

GUI
Graphical User Interface.

H

HDF
HDF (Hierarchical Data Format) is a multi-object file format, developed at NCSA, that facilitates the transfer of various types of data between machines and operating systems.

High Level Utilities
Objects, like XyPlot objects, Contour objects, TextItem objects, and so forth, that can be created and manipulated by a set of library functions, callable from either a C program, a Fortran program, the NCAR Command Language, or a GUI. High Level Utilities are also referred to as HLUs and are to be distinguished from the Low Level Utilities, or LLUs.

HLU resource string
A character string identifying a particular resource of a class. These are the resources listed in the descriptions of the classes.

HLUs
High Level Utilities.

HSV
Acronym for Hue/Saturation/Value. An additive color system based on the attributes of color (hue), percentage of white (saturation), and value (brightness or intensity).

I

identifier
NCL: The name of a variable, function, or procedure.

immediate mode
A mode used by certain API functions that produces immediate drawing without invoking a draw function.

instance
When specific values are assigned to all the resources defined in a class, the result is an instance of that class. Any instance of any class is called an object. Default values exist for all resources; before creating an object, users may override any default value.

instance hierarchy
Same as child/parent hierarchy.

inheritance
A class is said to inherit resources or support functions from its superclasses, since those functions and resources are available to the subclass. See superclass, and composite class.

interpreter
A program that transforms statements into machine code a statement at a time. The ncl executable is an interpreter of the NCL language.

intrinsic annotation

An annotation available as composite class member of the PlotManager class. Intrinsic annotations are available to any class of plot object and include TickMark, Title, LabelBar, and Legend annotations. The PlotManager manages these annotations internally.

intrinsic function
NCL: An identifier with a list of parameters, the parameters being separated by commas enclosed and in parentheses. Intrinsic functions return values when called. An intrinsic function is not defined by NCL source; it is a C or Fortran routine that has been added to the NCL function set. Intrinsic functions often perform operations that NCL source does not support.

irregular rectangular coordinate space
A 2-dimensional rectangular grid that has unequal spacing along the X and/or Y axes.

ISO
The International Standards Organization that publishes international standards. (see ANSI).

intrinsic procedure
NCL: An identifier with a list of parameters, the parameters being separated by commas enclosed in parentheses. An intrinsic procedure is not defined by NCL source; it is a C or Fortran routine that has been added to the NCL procedure set. Intrinsic procedures often perform operations that NCL source does not support.

J

K

keyword
NCL: A word reserved by NCL that not allowed to be used as a variable or function name.

L

label bar
A specialized label consisting of a bar of filled rectangular areas that are labeled to correspond with areas from an adjoining plot. Label bars can be filled with black-and-white patterns, with color, or with both. Label bars are commonly used with contour plots and with other types of plots where area pattern fills or color are used to differentiate values in the plot.

landscape
See portrait

lazy evaluation
NCL: The process whereby relational expressions are assigned a value as soon as it is possible to do so, without necessarily evaluating all of the components in the expression. For example, the expression (1 .lt. 3) .or. (2 .lt. 1) can be assigned the value True immediately after evaluating (1 .lt. 3) without having to evaluate (2 .lt. 1).

legend
A specialized annotation that formats a series of lines or markers of varying styles along with adjoining explanatory labels. Legends are designed to serve as "keys" for an associated plot.

literal array
NCL: An array of values specified using literal values, these values being separated by commas and enclosed in ' (/ ' and ' /) ' .

literal value
NCL: A single scalar value expressed by its actual string value (i.e. not referenced by a variable). For example, 1, 1.414 and "string" are literal values.

LLUs
Low Level Utilities.

local resources,
Resources defined in a particular class that are not inherited from another class.

logical operator
A operator that returns a true value or a false value depending on the truth or falsity of its operands. The logical operators in NCL are: .and., .or., .xor., .not..

loop statement
A language construct that allows for code repetition with incremental values set for a variable or variables. The looping statements in NCL are: do and do while.

Low Level Utilities
Traditional NCAR Graphics as it existed before the HLUs or NCL were developed. It is a package of about 500 graphics routines. User entries have both C and Fortran interfaces.

M

machine-independent data format
Same as Network-transparent data format.

marker
See polymarker.

member class
One of the class components of a composite class.

metadata
NCL: Information used to describe data, such as dimension names, variable attributes, valid ranges, and so forth.

metafile
A file containing encoded graphical elements. Metafiles are used for storing and transporting graphics images. In the context of NCL and NCAR Graphics "metafile" is generally synonymous with NCGM.

missing value
NCL: A special value for a variable or array element indicating that no legal data has been specified for that quantity. See the section on missing data in the evaluation of expressions in the NCL Language documentation details on how these missing values are handled.

monotone
A sequence of numeric values is monotone (or monotonic) if either: each element in the sequence is larger than (or equal to) its predecessor, or each element in the sequence is smaller than (or equal to) its predecessor. A sequence is monotonically increasing if each element in the sequence is larger than its predecessor; a sequence is monotonically decreasing if each element in the sequence is smaller than its predecessor. A sequence is monotonically non-decreasing if each element in the sequence is larger than, or equal to, its predecessor. A sequence is monotonically non-increasing if each element in the sequence is smaller than, or equal to, its predecessor.

N

named color
A string representing a predefined color. Named colors can be used with just about any graphical resource that defines the color of a plot attribute (like a line color or a polygon fill color). In order to use a named color, that color must be part of your current color table. See also color index.

named dimension
NCL: A dimension of a variable or file variable that has been assigned a name using the '!' operator.

NCAR Command Language

A language written for the purpose of interactive data manipulation and display. NCL has a command line interface and will accept netCDF, HDF, HDFEOS, HDF5, HDFEOS5, GRIB1, GRIB2, or ASCII input files. NCL also provides an easy interface to the HLUs.

NCAR Computer Graphics Metafile
The NCAR private binary encoding of a Computer Graphics Metafile.

NCGM
NCAR Computer Graphics Metafile.

NCL
NCAR Command Language.

NCL resource list
NCL: An NCL resource list is a list of HLU resource strings followed by a " : " followed by a valid NCL expression.

NDC
Normalized Device Coordinates. A coordinate system that describes positions on a virtual plotting device. The lower left corner corresponds to (0,0), and the upper right corner corresponds to (1,1). NDC space will be mapped onto the largest square which will fit on an actual plotting device. PostScript output is centered on the page by default, but options exist for positioning PostScript output anywhere on the page. See the PSWorkstation for details.

ncl
Refers to the interpreter that interprets NCL statements.

netCDF
NetCDF (network Common Data Form) is an interface for scientific data access and a library that provides an implementation of the interface. There are different kinds of NetCDF files: classic, 64-bit offset, netCDF-4 classic, and netCDF-4. See the NetCDF FAQ for more information.

netCDF 64-bit offset
In 2004, the 64-bit offset format variant was added. Nearly identical to the netCDF classic format, it allows users to create and access far larger datasets than were possible with the original format. (A 64-bit platform is not required to write or read 64-bit offset netCDF files.)

netCDF classic
The classic format was the only format for netCDF data created between 1989 and 2004. As of NetCDF version 4.2.x, it is still the default format for new netCDF data files, and the form in which most netCDF data is stored. Some users think of this as "NetCDF-3".

netCDF-4 classic
At the same time that the netCDF-4 format was as introduced, the "netCDF-4 classic" format was added for users who needed the performance benefits of the new format (such as compression) without the complexity of a new programming interface or enhanced data model.

netCDF-4
In 2008, the netCDF-4 format was added to support per-variable compression, multiple unlimited dimensions, more complex data types, and better performance, by layering an enhanced netCDF access interface on top of the HDF5 format.

network-transparent data format
A format for encoding data that removes any machine dependencies that might be involved in encoding the data. Typical examples of such data formats are netCDF and HDF.

numeric
NCL: Any data type that represents a numerical value. The numeric data types are: double, float, int64 (aka long long), uint64 (unsigned long long), long, ulong (unsigned long), integer, uint (unsigned int), short, ushort (unsigned short), and byte.

Starting from 5.2.0, NCL has added int64 (aka long long), uint64 (unsigned long long), ulong (unsigned long), uint (unsigned int), and ushort (unsigned short). these newly added data types are named as enumeric, means extra-numeric.

In order to make NCL backward compatible, we keep the name numeric refers to data types: double, float, long, integer, short, and byte, but create a new name snumeric, means super-numeric, which includes both numeric and enumeric.

numeric data type
A data type for numeric quantities. In NCL the numeric data types are: double, float, int64, uint64, long, ulong, integer, uint, short, ushort, and byte.

non-numeric data type
A data type for non-numeric quantities. In NCL the non-numeric data types are: string, character, graphic, file, and logical.

O

object
An object is created from a class by assigning specific values for the class resources. See class and instance.

OPenDAP
OPeNDAP, an acronym for "Open-source Project for a Network Data Access Protocol", is a data transport architecture and protocol widely used by earth scientists that simplifies all aspects of scientific data networking, allowing simple access to remote data. Visit www.opendap.org for more information.

output primitive
Procedures and functions for producing graphics output at the lowest level. GSUN procedures/functions exist for drawing lines (gsn_polyline, gsn_polyline_ndc, gsn_add_polyline), text (gsn_text, gsn_text_ndc, gsn_add_text), filled areas (gsn_polygon, gsn_polygon_ndc, gsn_add_polygon), and markers (gsn_polymarker, gsn_polymarker_ndc, gsn_add_polymarker).

overlay
A transform overlaid on a base plot using the add overlay function. The base plot sets the viewport of the overlay to match its own and transforms the coordinate data of the overlay into its own coordinate space. Only that portion of the overlay's coordinate space that intersects the coordinate space of the managing plot will be visible in the plot output. If the overlay is a plot object, it gives up its base plot status. The base plot to which the overlay is added assumes responsibility for managing the overlay's plot members.

overlay functions
The functions used to add and remove overlays to and from plot objects. Specifically, these functions are NhlAddOverlay and NhlRemoveOverlay for the C and Fortran interfaces.

overlay plot
An overlay created from a plot object rather than from a simple transform.

overlay sequence
The ordering of the transforms in a plot or subplot that contains overlays. The base plot is always first, followed by each overlay in an order that may be manipulated through the overlay functions. The overlay sequence determines the basic drawing order of the plot. The base plot is drawn first; each succeeding overlay is drawn on top of the preceding transforms. Annotations are not affected by the overlay sequence; they always drawn after all the transforms.

P

parent
A relationship that exists between objects. If A and B are objects, then A is a parent of B if and only if B is a child of A. See child for more information.

PDF
An acronym for Portable Document Format, a file format created by Adobe Systems, Inc. It uses the PostScript printer description language and is highly portable across computer platforms. PDF documents are created with Adobe Acrobat or other programs and can be viewed with Adobe Acrobat Reader and other PDF reader programs.

plot
Depending on context, the word plot may be used to mean:

A plot object.
A primary base plot and all its plot members.
The output resulting from drawing a primary base plot and all its plot members.
The output resulting from drawing any arbitrary collection of viewable objects.

plot_class
NCL: The plot_class in NCL is the same as the HLU class pointer used in the HLU API to specify what type of object to create. The NCL plot_class identifier is spelled the same as the HLU class pointer.

plot member
A viewable object managed by a base plot. If the base plot is a subordinate base plot then the object is indirectly a plot member of the complete plot managed by the primary base plot. Drawing the primary base plot causes all its plot members to be drawn. A plot member is either an overlay or an annotation. Although an annotation can be any arbitrary view , an overlay must be a view belonging to the Transform class. A plot member must belong to the same Workstation as its base plot and cannot be drawn independently. A view cannot belong as a plot member to more than one base plot at a time.

plot object
A Transform object instantiated with an active PlotManager. In general, unless otherwise restricted by their specific class, plot objects have the ability both to manage other viewable objects as plot members and to be managed as plot members themselves. A plot object that manages plot members is called a base plot. If the managing plot object is itself managed as a plot member, it is a subordinate base plot. If it manages itself (i.e. is not a plot member) it is a primary base plot. At creation, all plot objects are primary base plots.

polymarker
An array of coordinates specifying positions where certain specified symmetric symbols (markers) such as circles, dots, and so forth will be plotted.

portrait mode
(Definition taken from Wikipedia) Portrait mode and landscape mode refer to the orientation of text (and pictures) on a printed page. (The paper must be a rectangle, however in practice square sheets are hardly ever used.) In portrait mode the text is printed on the paper such that the reader will turn the long side of the paper vertical and the short side horizontal. In landscape mode on the other hand, the long side is horizontal, and the short side vertical (like most landscape paintings).

PostScript
A general-purpose programming language that contains a rich set of graphics operators. PostScript is produced by many popular word processing and graphics packages and can be displayed on a wide variety of printers, plotters, and workstation screens.

primary base plot
A self-managing plot object. A base plot that directly manages any number of plot members, consisting of overlays and annotations, but is not itself a plot member. At creation all plot objects are primary base plots. A plot object must be a primary base plot for the user to draw it or change its workstation.

primitive
see output primitive

procedure

NCL: An identifier with a list of parameters, these parameters being separated by commas and enclosed in parentheses. Procedures do not return values when called.

PS
see PostScript

Q

R

rectilinear grid
A rectilinear grid is very similar to a cartesian grid in that it is a basic rectangular matrix arrangement of data. The one difference is that the uniform spacing restriction is lifted. Rectilinear grids are usually represented by one-dimensional coordinate variables.

See also cartesian, gaussian, and curvilinear grids.

relational operator
A operator that returns a true value or false value depending on a relation between its operands. The relational operators in NCL are: .le., .lt., .ge., .gt., .ne., .eq..

resource
A variable defined as part of the definition of a class. Resource values in objects can be set by using a NhlCreate function or a NhlSetValues function. Resource values can be retrieved using a NhlGetValues function.

resource file
A file that can be used to set values for resources. There are four different resource files. See system resource file and user resource file.

resource forwarding
A technique that makes the resources of member classes available to a composite class.

RGB
Stands for the red, green, blue color space where colors are specified as triplets of floating point numbers between 0.0 and 1.0 inclusive. The triplet gives the percentage intensities for the red, green, and blue components of a color. The triplet <1,.0.,0.> would indicate a full percentage of red, and no green or blue percentage, for example.

RGBA
Stands for the red, green, blue, alpha color space where colors are specified as quadruplets of floating point numbers between 0.0 and 1.0 inclusive. The first three values of the quadruplet gives the percentage intensities for the red, green, and blue components of a color. The fourth value gives the percentage of opaqueness of that color. An opacity value of 1.0 means the color is fully opaque, and a value of 0.0 means it is fully transparent. The quaddruplet <1,.0.,0.,0.5> would indicate the color red at half opacity. The usage of RGBA colors was introduced in NCL V6.1.0.

S

scalar
NCL: A single element of data of any type is referred to as a scalar value.

scalar_logical_expression
NCL: A single element value of the logical data type with no missing values.

scope
NCL: The range or area within a program in which an identifier is meaningful.

script
A file containing a sequence of program statements that can be submitted to an interpreter for execution.

self-describing data format
A format for encoding data that can contain information that describes the data being encoded. Typical examples of such data formats are netCDF, HDF, and HDF5.

shape
The number of dimensions of an array. The statement a = new((/ 2, 3, 5 /), float) would create an array a of shape 3 (i.e. a has three dimensions).

simple overlay
An overlay created from a simple transform.

simple transform
A transform object created without an active PlotManager. Unlike a plot object, a simple transform cannot manage any plot members, either as annotations or as overlays. Therefore, the only elements that appear when a simple transform is drawn are those implemented within the object itself. However, unless restricted by its particular class, a simple transform may itself become an annotation or an overlay of a base plot. Since a plot object has all the capabilities of a simple transform and none of the limitations, the main reason for creating a simple transform would be to conserve system resources when PlotManager capabilities are not required.

size
The number of elements in array dimensions. The statement a = new((/ 2, 3, 5 /), float) would create an array a that has a first dimension of size 2, a second dimension of size 3, and a third dimension of size 5.

statement
A non-comment line of code (or a line of code prior to any commenting). A line of NCL code contains all continuations resulting from use of the "\" symbol.

stipple
To cover an area with small dots.

streamline
The path an idealized particle would follow if introduced into a wind or fluid flow. For example (as an approximation to the ideal), the path a speck of dust would take in a wind.

Streamline plot
A plot representing a vector field using streamlines, based upon 2-dimensional data. It may also contain tick marks and titles.

stride
The increment indicator in a subscript specifier. Using m:n:i as a subscript means to take the individual subscript values starting with m and ending with n in strides of i. The stride must always be an integer and should be thought of as a skip indicator rather than an additive increment value, since coordinate subscripts may not always be integers. A stride of 2 means to take every second value after the first, a stride of 3 means take every third value, and so forth.

snumeric
NCL: Starting from 5.2.0, NCL has a new name snumeric, means super-numerica, which includes both numeric and enumeric. snumeric includes: double, float, int64 (aka long long), uint64 (unsigned long long), long, ulong (unsigned long), integer, uint (unsigned int), short, ushort (unsigned short), and byte.

statement
NCL: A single language construct within NCL that performs a specific task.

statement list
NCL: A sequence of statements separated by a carriage returns (\n).

structured grid

Structured grids are the exact opposite of unstructured grids. A structured grid gets its name from the nature of having a structure implicitly defined by the arrangement of the data. A structured grid has a basic rectangular matrix structure that makes storage and use easy as integer offsets (Typically named i, j, and k) can be used to access individual data points. Data points are arranged into rectangular or cubic structures by simply connecting them to their neighboring i, j, and k cells. Three types of structured grids include cartesian, rectilinear, and curvilinear grids.

subclass
A class B is a subclass of A if B has in it all of the resources and support functions of A (B may have additional resources and support functions as well). If B is a class derived from A, then B is said to inherit its resources and support functions from A. If B is derived from A, then it is also said that B is a subclass of A.

subordinate base plot
A plot member that is an annotation plot. A subordinate base plot sets the viewport of the plot members it controls, while its own viewport is set by the base plot that controls it. Unlike a primary base plot, the user cannot directly draw or change the workstation of a subordinate base plot. A subordinate base plot and the plot members it manages are known collectively as a subplot.

subplot
The portion of a plot that is managed by a subordinate base plot.

superclass
A class A is a superclass of class B if A is on the same branch of the class hierarchy tree and A is higher on that branch.

superclass resource
A resource that one class inherits from a superclass.

supported data format
Any of the formats that can be read by the NCL addfile function. The supported formats are: netCDF, HDF, HDFEOS, HDF5, HDFEOS5, GRIB (1 and 2), and CCM History Tape. You do not have to know the details of these formats in order to use them with NCL.

support function
A function defined as part of a class definition.

system resource file
There are four files where resources can be set - two of these files are system resource files and the other two are user resource files. The name of one of the system resource files is specified by the setting of the environment variable NCARG_SYSRESFILE; the other system resource file is specified in an application-specific manner. See application resource file.

T

text function codes
Special characters embedded in a text string, usually starting and ending with the colon (":") character. Text function codes provide the capability for selecting various fonts, doing superscripts and subscripts, taking complete control of the positioning of characters relative to one another, and last but not least, "zooming" characters in either width or height, or both.

tick marks
Marks along an axis of a plot that are perpendicular to the axis and serve to divide the axis (or parts of the axis) into equal or logarithmetically spaced parts.

transform
A Transform object.

Transform class
The Transform class is a subclass of the View class that supports transformations from data coordinate space into the NDC space occupied by the Transform class instance's viewport. Transform

subclasses may include the PlotManager class as a composite class member. The Transform class provides a resource for activating or deactivating the PlotManager when a Transform instance is created. In addition, the Transform class provides support functions for converting between data coordinate space and NDC space, for drawing immediate mode graphics primitives, and for adding and removing overlays and annotations from plot objects.

Transform object
An object that is an instance of the Transform class. Transform objects become plot objects when created with an active PlotManager instance. A Transform object created without an active PlotManager is called a simple transform.

U

unstructured mesh or grid
Unstructured meshes are the exact opposite of structured grids, where the connectivity between points must be explicitly defined for every set of points. This makes them significantly more difficult and complex, and the nice relationships between neighboring cells or edges is no longer automatic and must be constructed manually. However, they are much more flexible in their ability to define complex shapes because they have no constraints on their arrangement.

Unstructured meshes are typically defined as points and cells. Cells are collections of points to define basic 2D or 3D primitives such as triangles, cubes, and tetrahedra.

user resource file
There are four files where resources can be set - two of these files are user resource files and the other two are system resource files. The name of one of the user resource files is specified by the setting of the environment variable NCARG_USRRESFILE; the other user resource file is specified in an application-specific manner. See application resource file.

V

variable
NCL: A name that can contain a singly-dimensioned or multi-dimensioned data array, dimension names, coordinate variables, attributes, and so forth.

Vector plot
A plot representing a vector field by drawing glyphs that represent magnitude and direction at grid points based on 2-dimensional data. It may also contain tick marks, titles, and/or a label bar. Three glyph styles are available: a basic line-drawn arrow, a filled arrow with an option edge, and a standard wind barb.

view
A viewable object.

viewable object
An object that is an instance of the View class.

View class
An object can be drawn only if it is an instance of the View class. The View class provides resources for sizing and positioning objects on an output device (workstation). The View class also provides a support function for determining the bounding box of a given object in the class. A View class object must have a Workstation class parent.

View object
A viewable object.

viewport
For View objects, the viewport is a rectangular subregion of NDC space that specifies where the View object will be placed when drawn. The precise meaning of the viewport depends on the View object. For example, for XyPlot objects, the viewport specifies where the grid containing the curves will

be placed, and the labeling (if any) will be drawn outside of the viewport. On the other hand, for TextItem objects, the viewport will be a rectangle surrounding the text string.

visualization block
NCL: A group of NCL resources specified in either an NCL create, setvalues, or getvalues statement. Visualization blocks are used to create, modify, or inquire about the values of resources of objects.

W

---

workstation
Used in NCL and HLU terminology to mean a valid output device such as an X Window System display, a PostScript file, a PDF files, or an NCGM.

workstation class
A class that provides interfaces to specific output devices.

wrapit interface block
A sequence of Fortran 77 statements that specify a procedure and its arguments, similar to C function prototypes and Fortran 90 interface blocks. Wrapit interface blocks are used by wrapit77, a program for generating wrappers.

wrapper function
A C function that provides an interface between NCL and an existing Fortran or C subroutine or function. The wrapper intercepts an NCL function or procedure, does the appropriate argument checks and conversions, then calls the existing code.

X

XY plot
A plot containing curves made up of X/Y coordinate pairs. It may also contain tick marks, titles, and/or a legend.

Y

Z

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