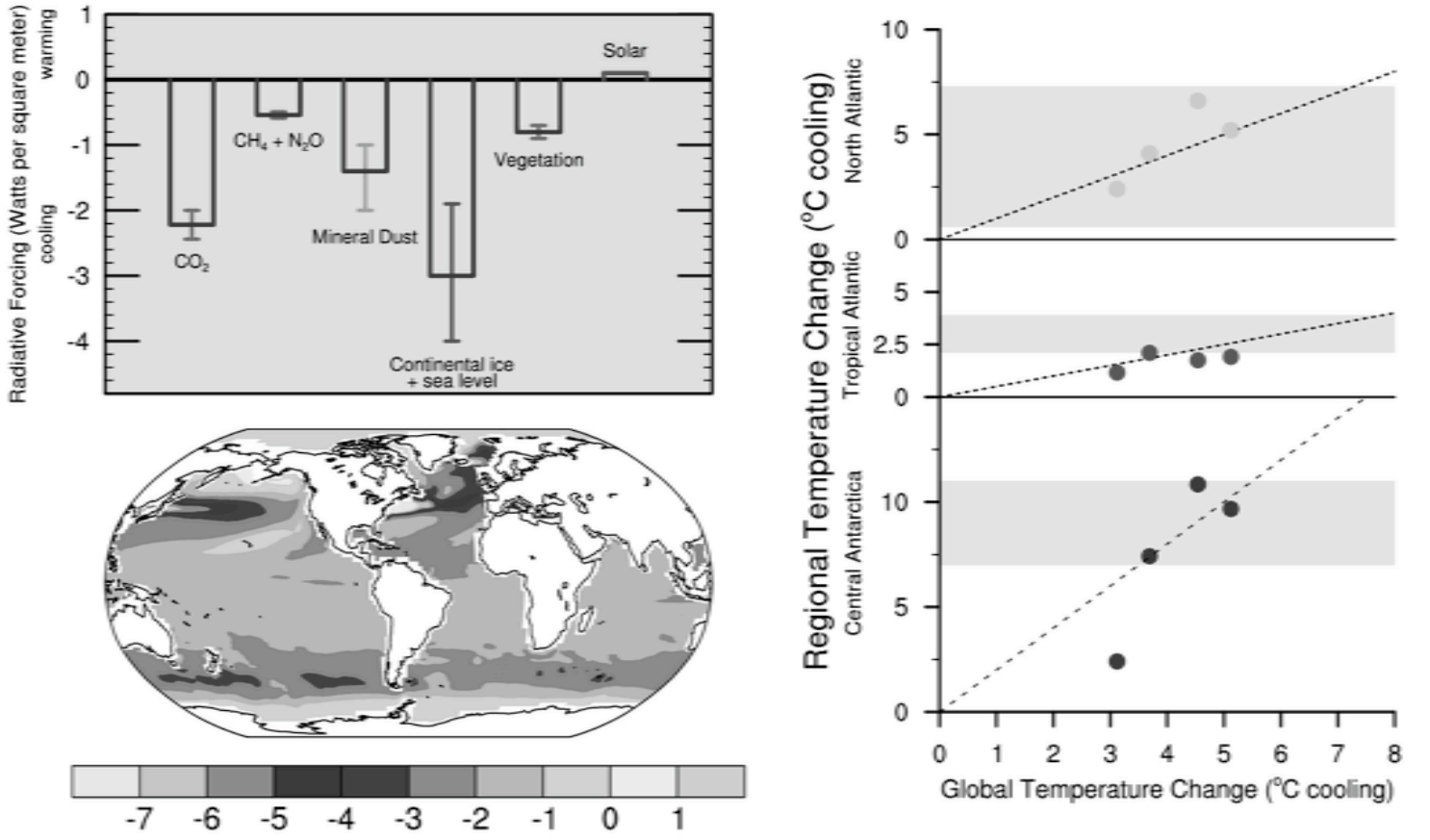
Introduction to NCL Graphics



Mark Branson steals from Mary Haley and Dennis Shea

CISL NCAR NSF

My goals for this FAPCRD

- ✓ Familiarize you with the structure of an NCL graphics script
- ✓ Get you started with understanding resources
- ✓ Show you the most common things users need to do with NCL graphics
- ✓ Show you debugging tips and common user mistakes
- ✓ Provide you with useful documentation links

Overview

- ✓ NCL is a product of Computational and Information Systems Laboratory (CISL) at NCAR, sponsored by NSF
- ✓ free interpreted language designed specifically for scientific data processing and visualization
- ✓ robust file input and output: it can read and write netCDF-3, netCDF-4 classic, HDF4, binary and ASCII data. It can read HDF-EOS, GRIB1, GRIB2, etc.

- ✓ intended to be an objected-oriented language, but GSN libraries provide a simpler interface (GSN = getting started using NCL).
- ✓ can be run in interactive mode or batch mode
- ✓ over 600 built-in functions
- ✓ can call C and Fortran external routines
- ✓ fantastic examples on their website, great support

Topics

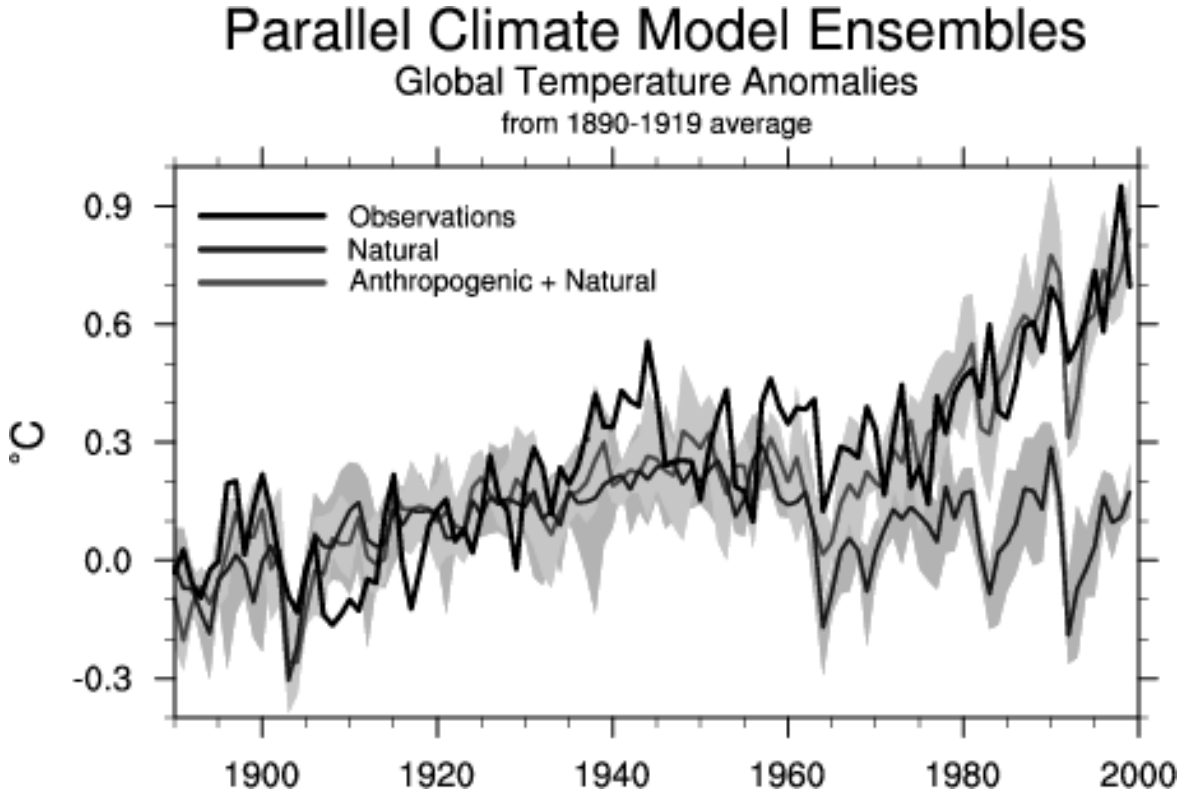
- Quick tour of high-level graphics interfaces
- How to get it working on your Mac
- Basic code structure for NCL graphics
- **Step-by-step NCL visualization examples**
- Customizing your NCL graphics environment
- Debugging tips and common mistakes

Quick tour of graphics interfaces

- Over 40 plotting interfaces
- Some highly specialized (bar charts, skew-T, wind roses, histograms, taylor diagrams)
- Hundreds of examples:

  http://www.ncl.ucar.edu/Applications/
- Graphical interface documentation**:**

  http://www.ncl.ucar.edu/Document/Graphics/Interfaces/



XY Plots

gsn_csm_xy

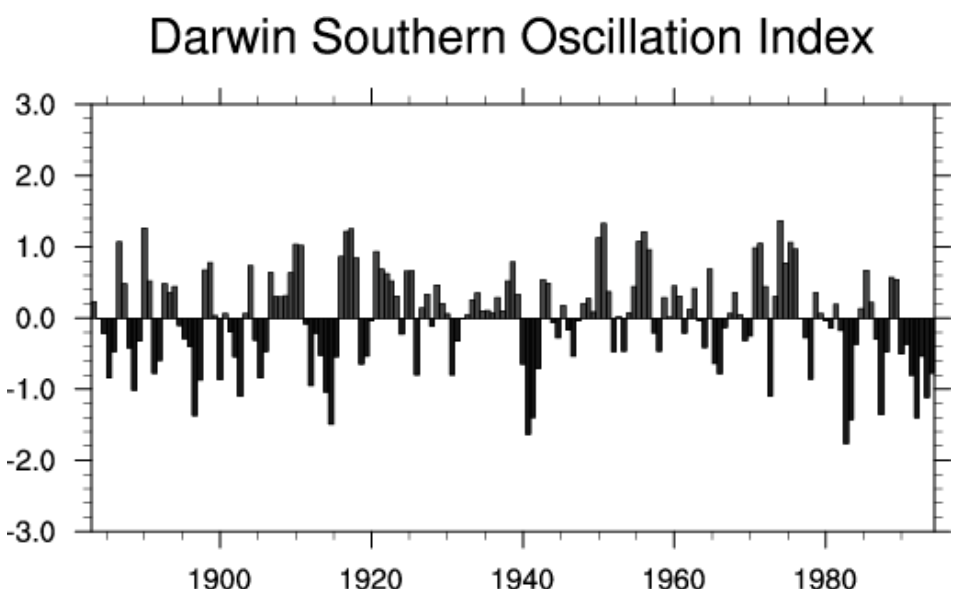
gsn_csm_y

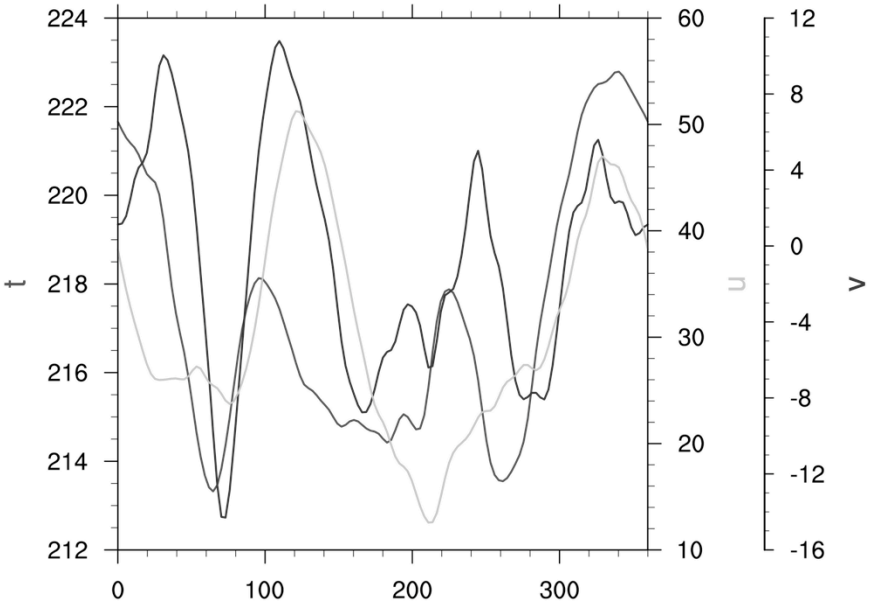
gsn_csm_xy2

gsn_csm_x2y

gsn_csm_x2y2

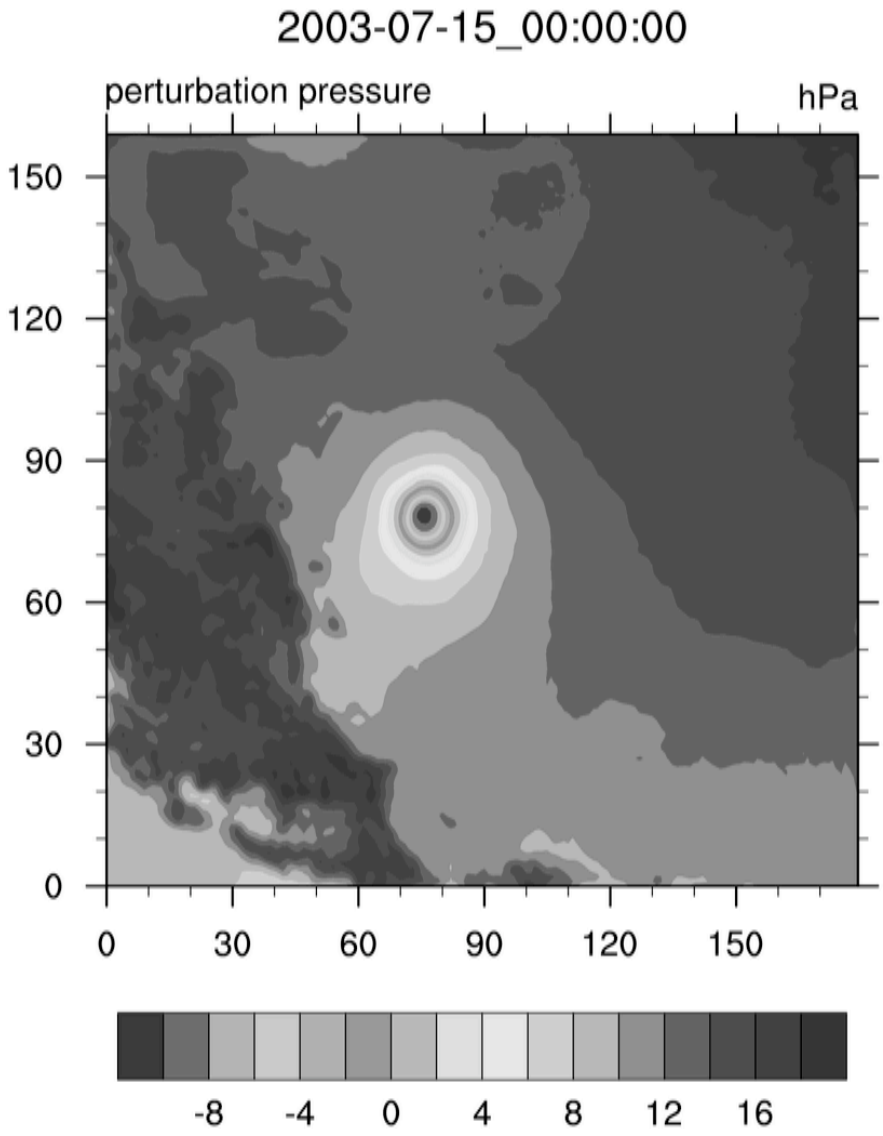
gsn_csm_xy3

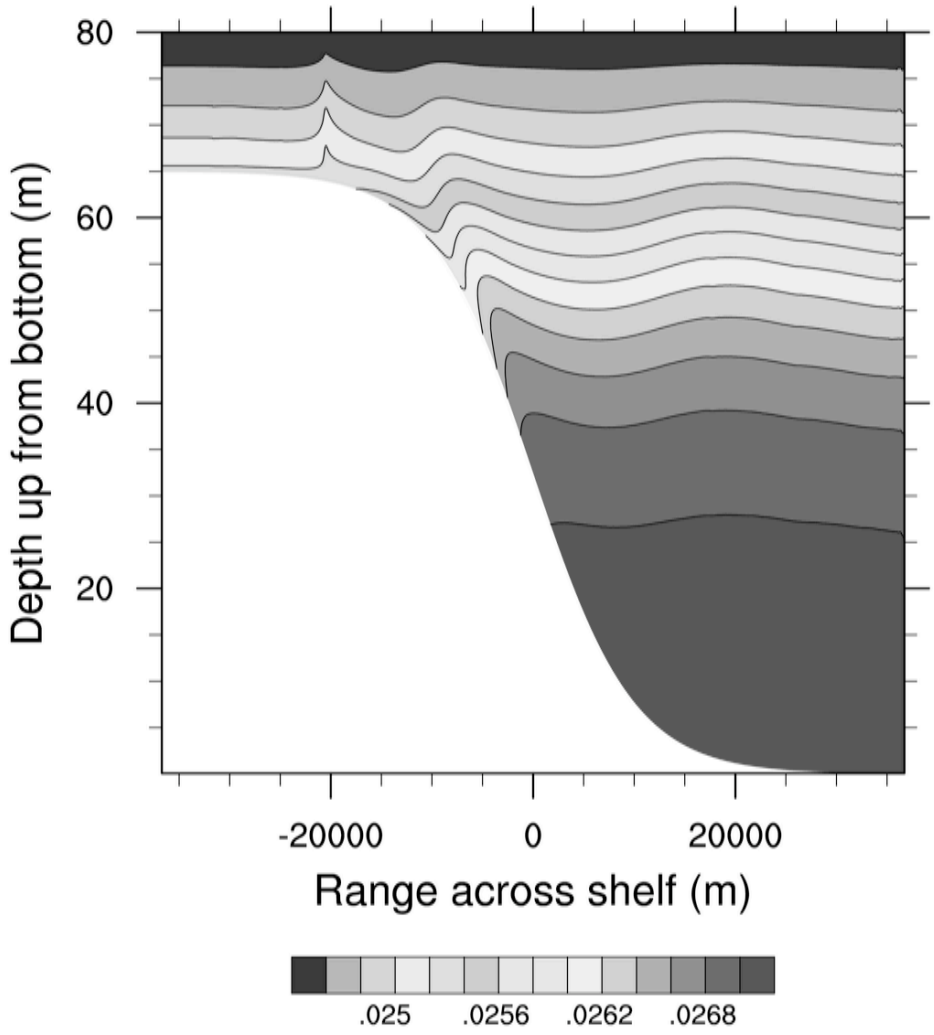




Contour plots

gsn_csm_contour

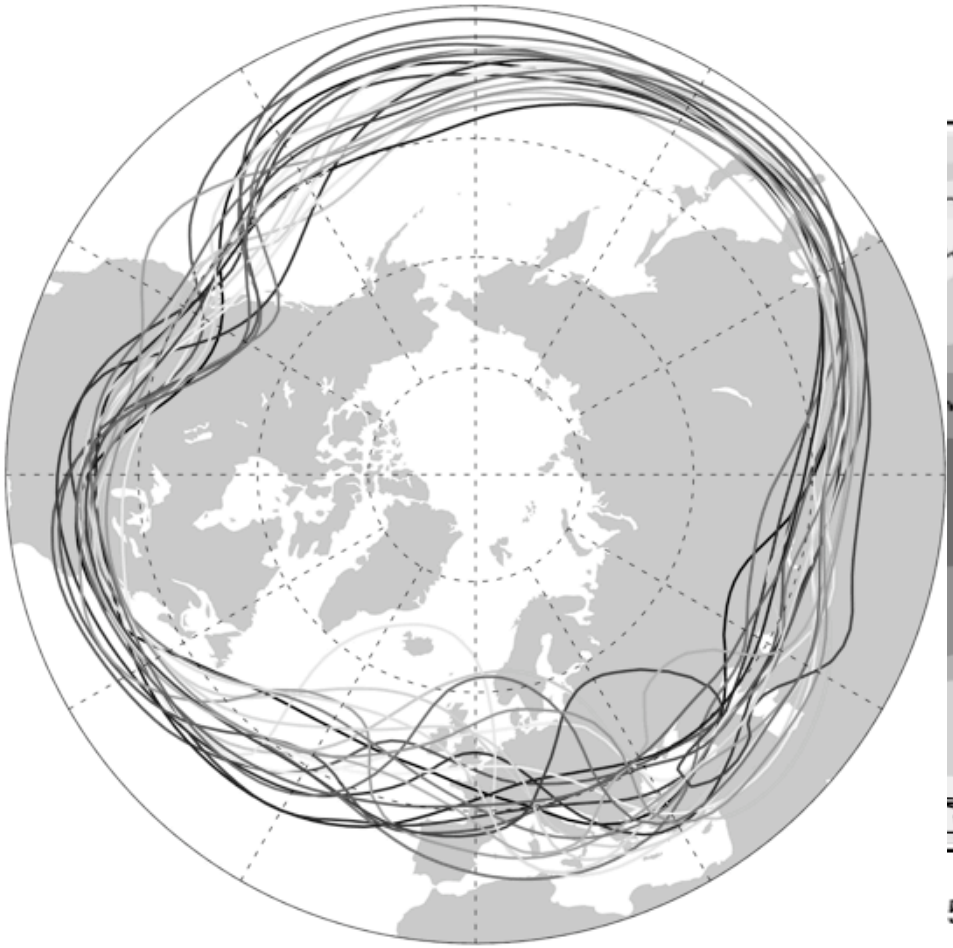


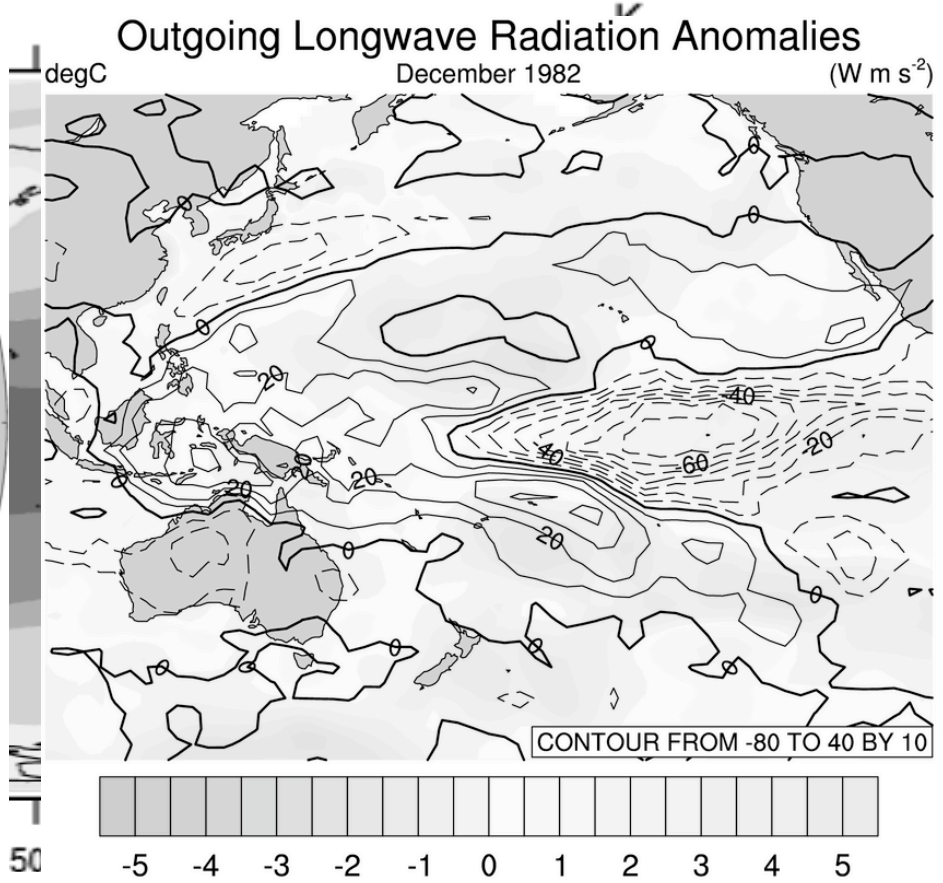


Contour over maps

gsn_csm_contour_map • gsn_csm_contour_map_ce

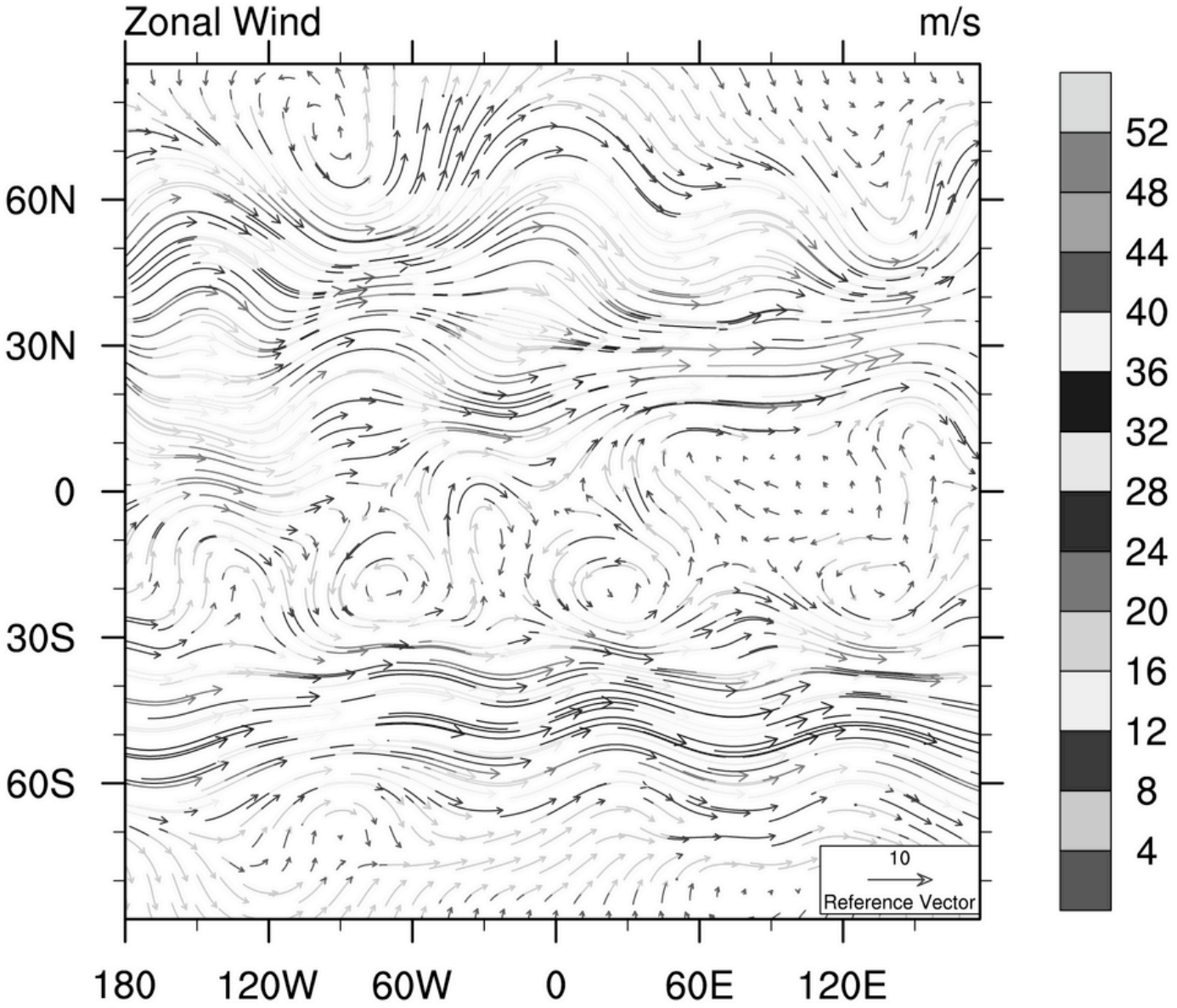
•gsn_csm_contour_map_polar • gsn_csm_contour_map_overlay





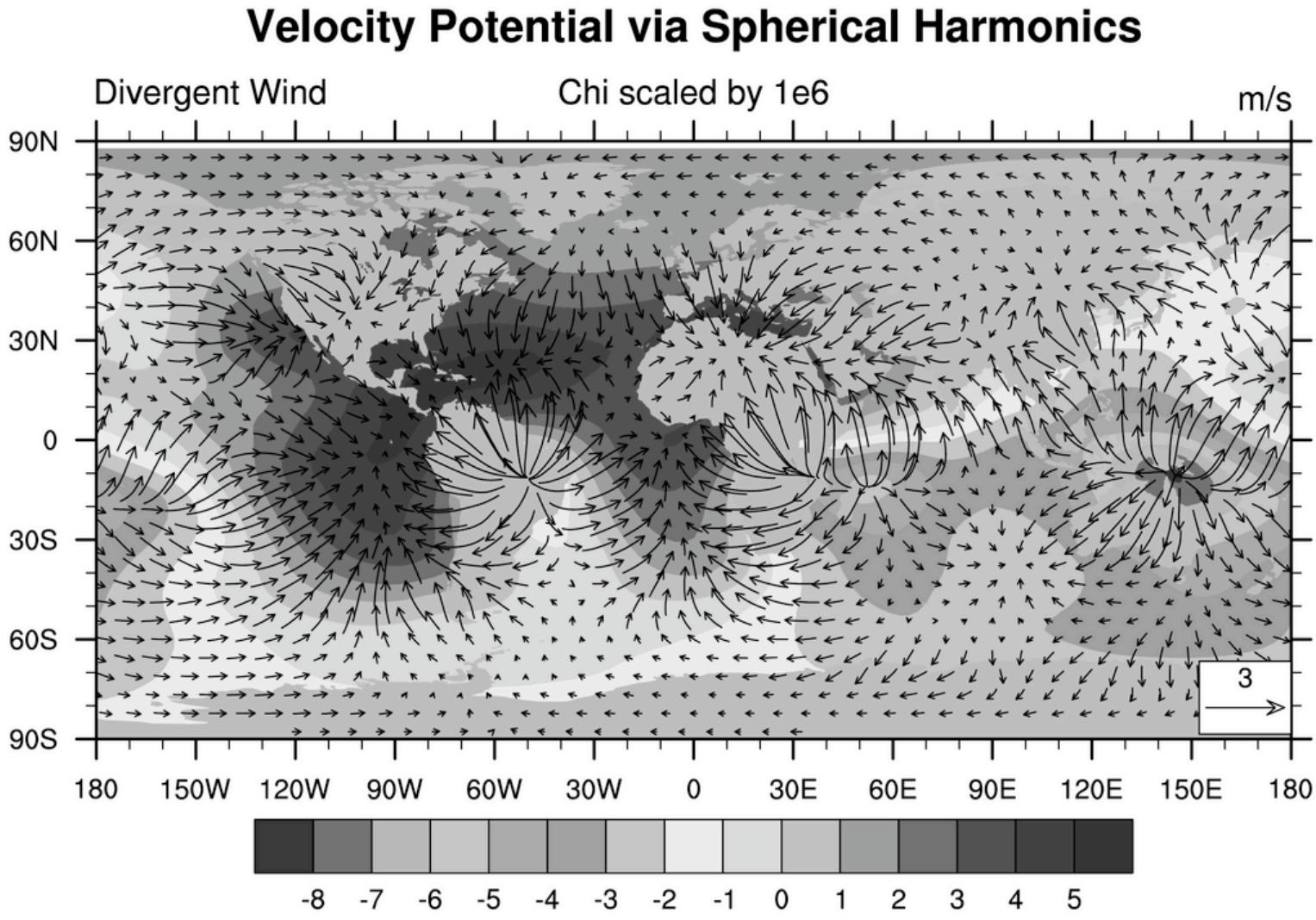
Vector plots

gsn_csm_vector • gsn_csm_pres_hgt_vector • gsn_csm_vector_scalar



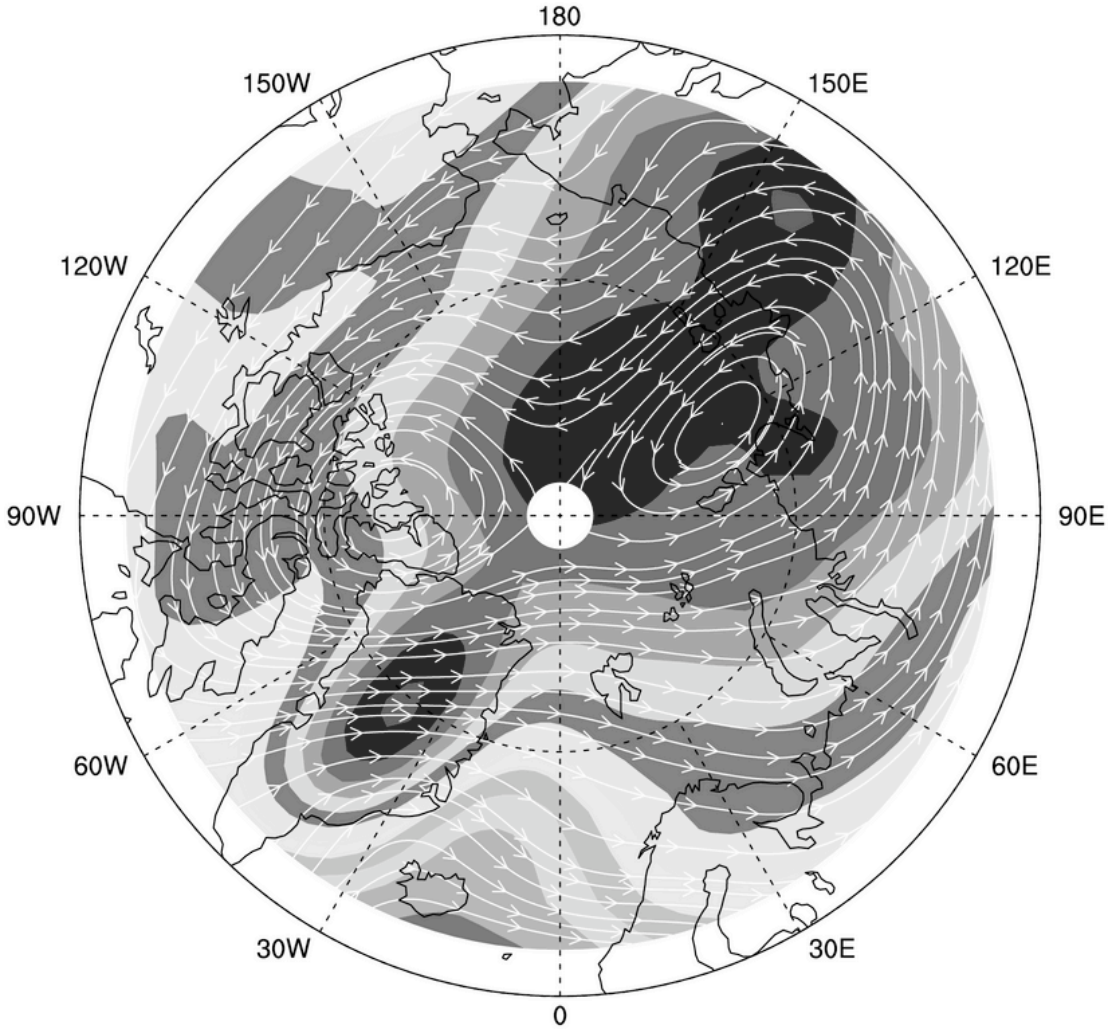
Vectors over maps

gsn_csm_vector_map • gsn_csm_vector_map_polar • gsn_csm_vector_scalar_map • gsn_csm_vector_scalar_map_ce • gsn_csm_vector_scalar_map_polar • gsn_csm_vector_map_ce

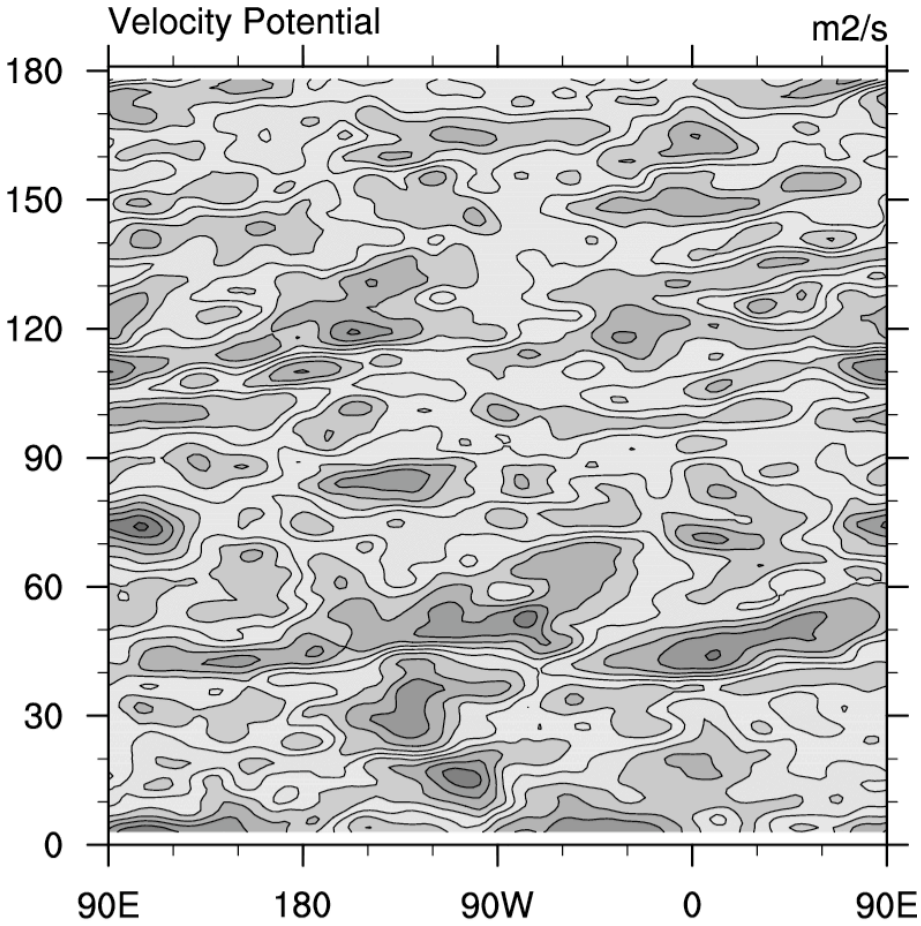


Streamline Plots

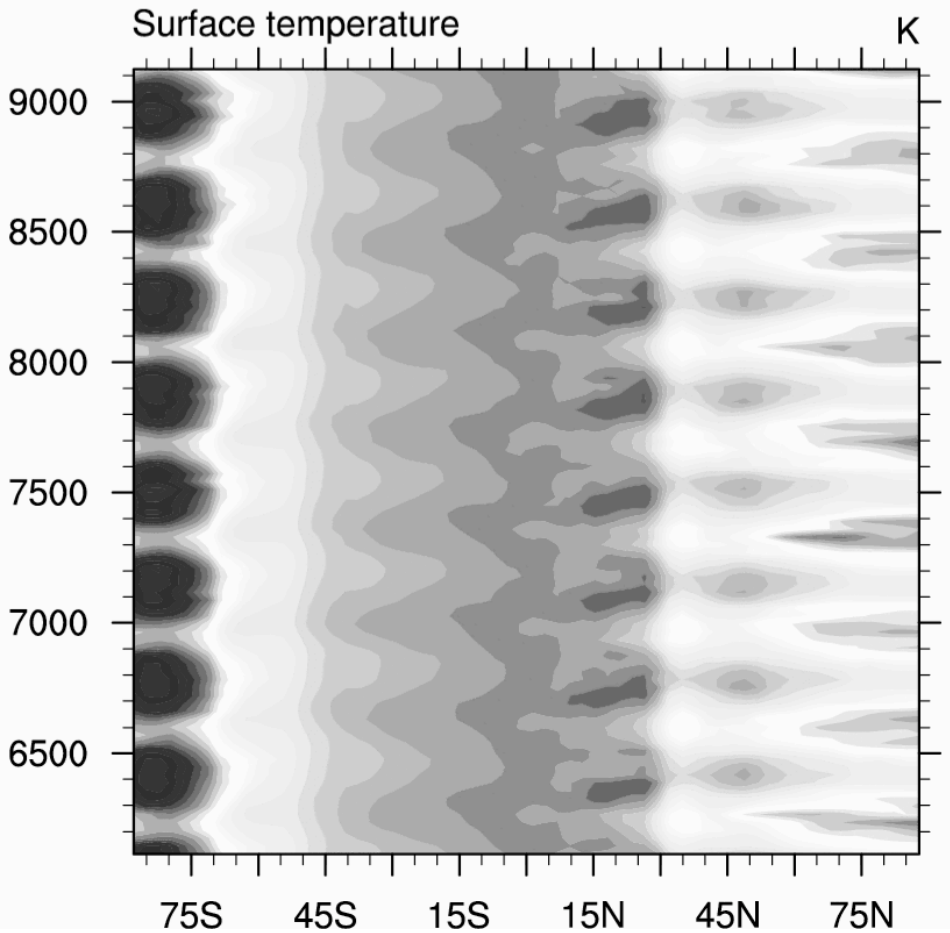
gsn_csm_streamline • gsn_csm_streamline_map •
gsn_csm_streamline_map_polar • gsn_csm_streamline_contour_map •
gsn_csm_streamline_contour_map_polar • gsn_csm_pres_hgt_streamline



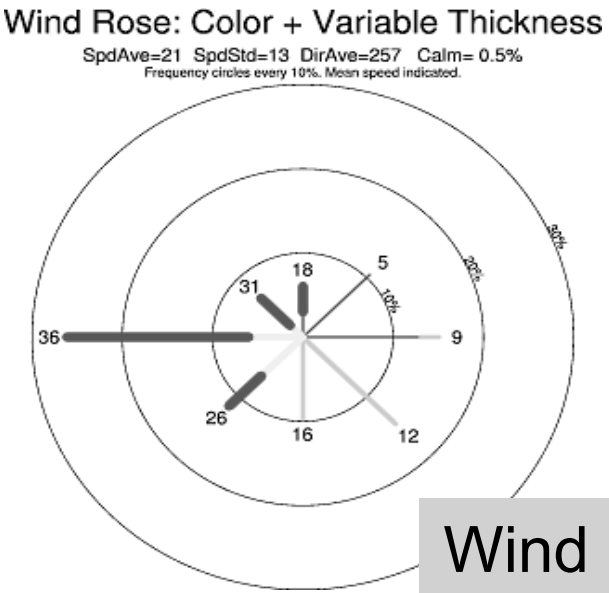
gsn_csm_hov



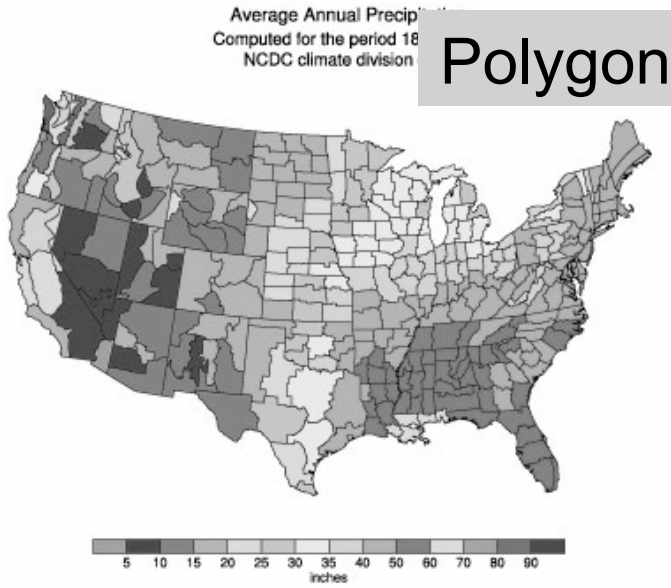
gsn_csm_time_lat



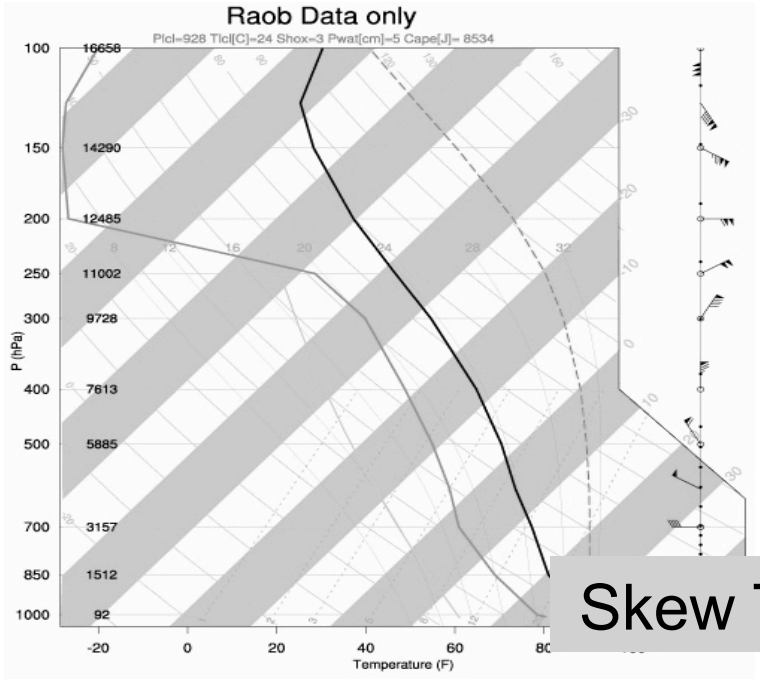
Special Templates and Scripts



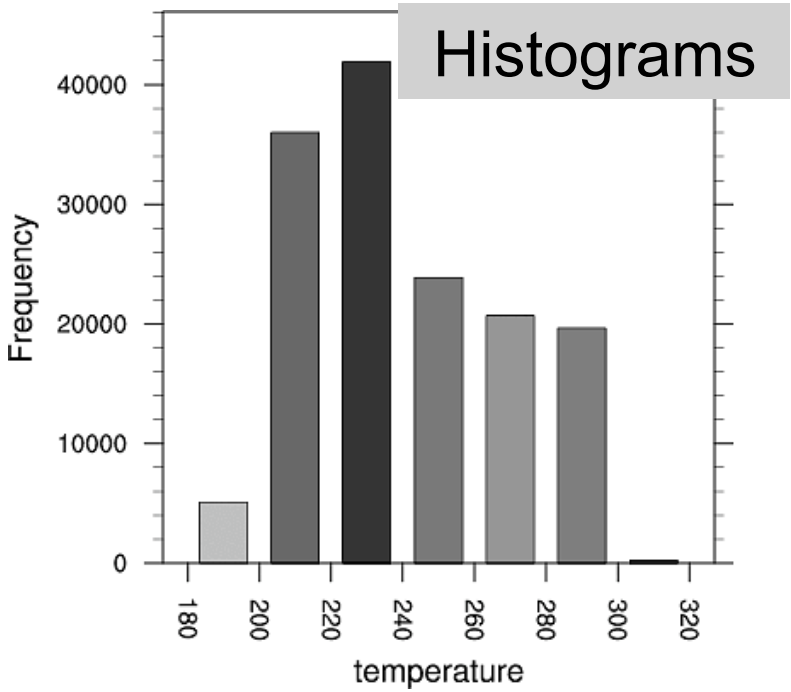
Wind Rose



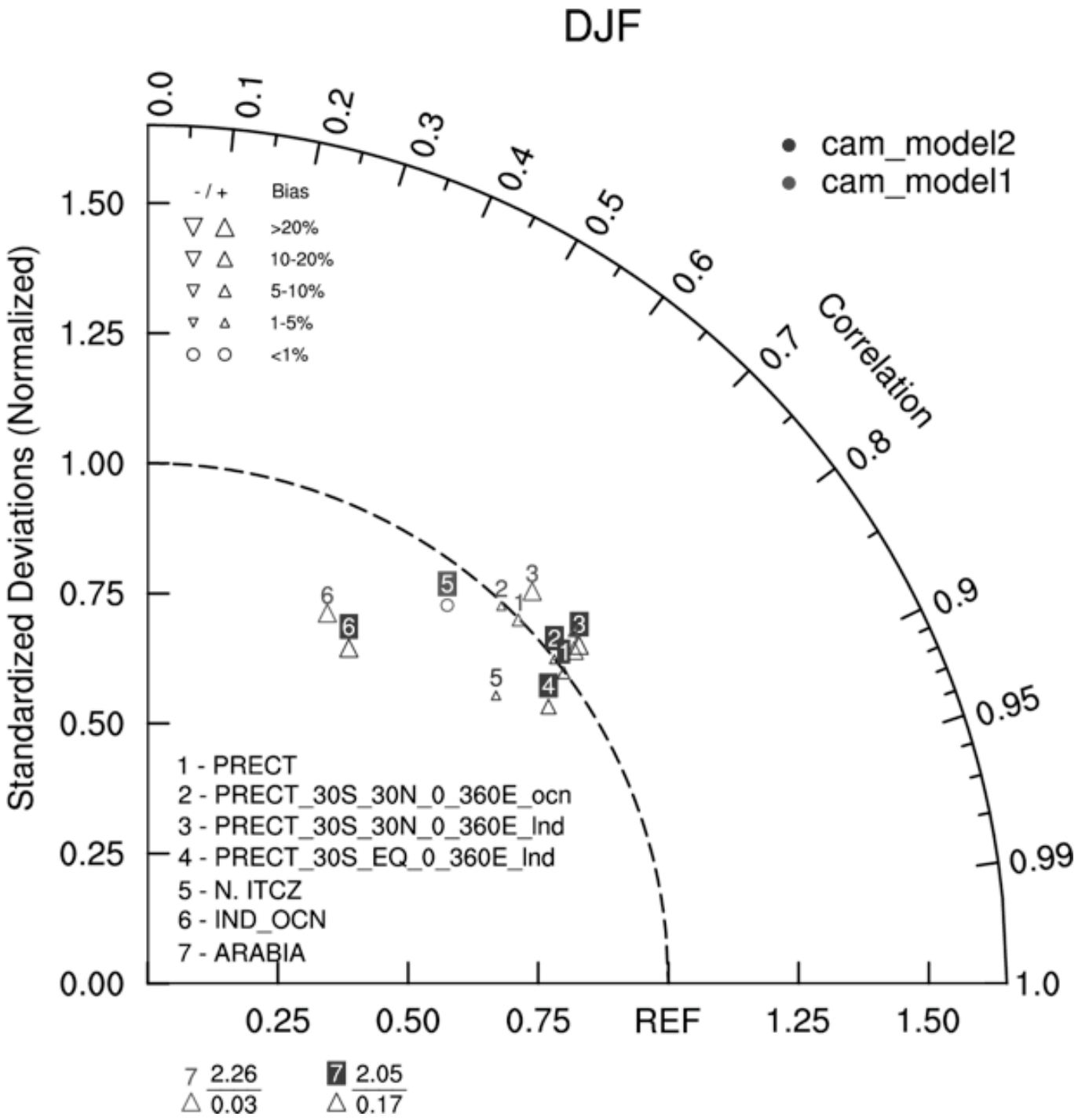
Polygons



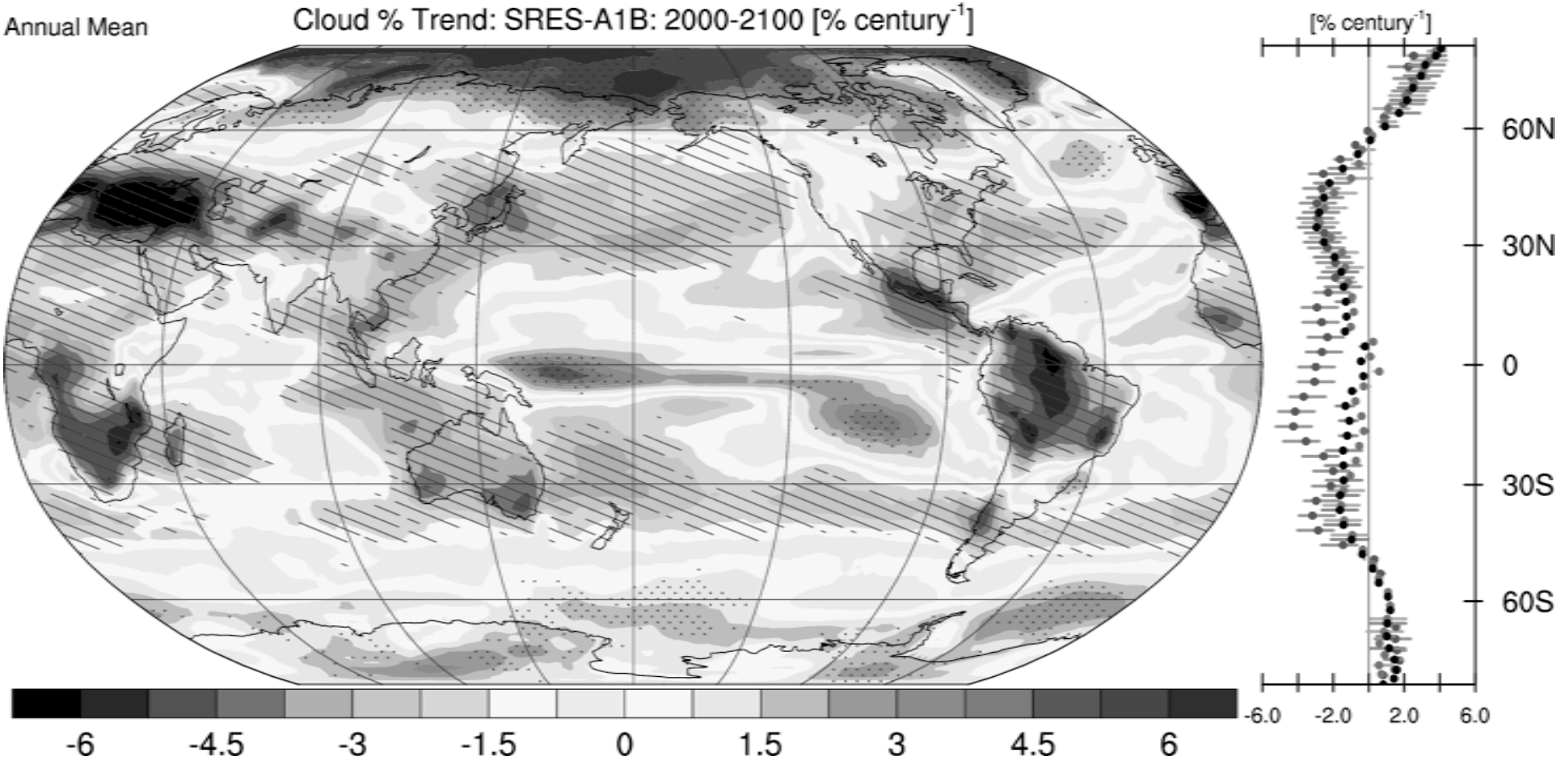
Skew T



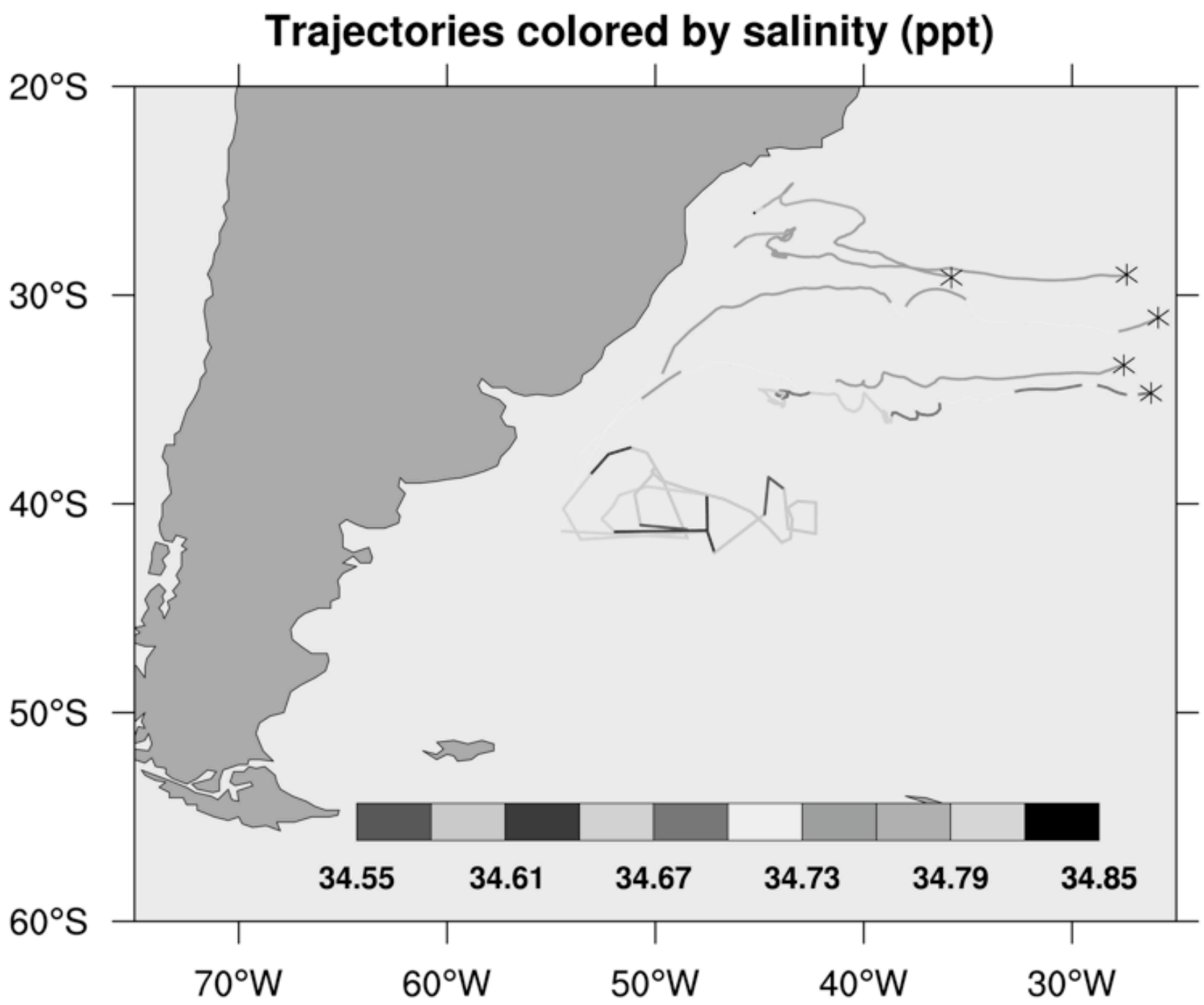
Histograms

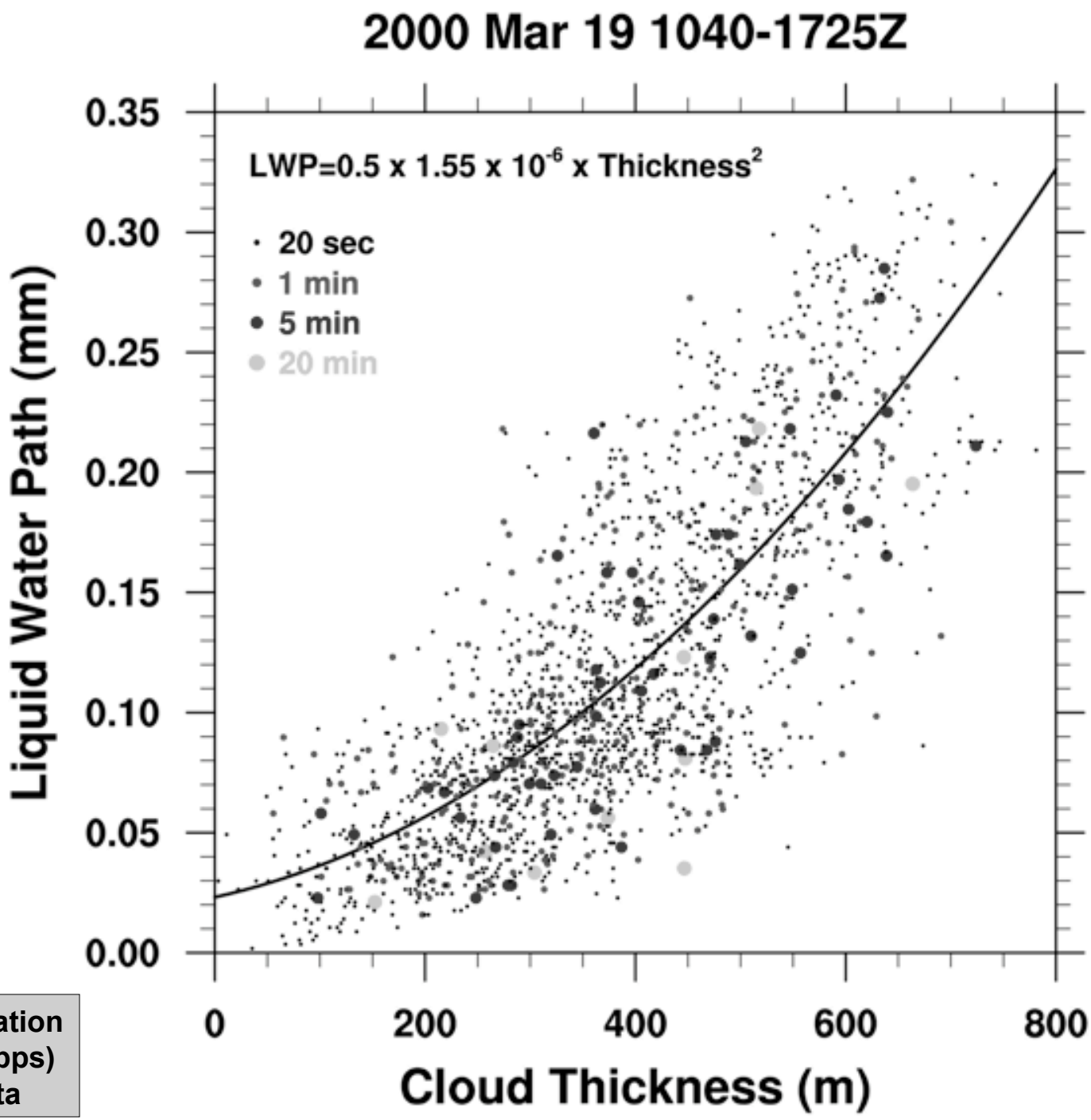


Taylor diagram Courtesy of Dennis Shea and Adam Phillips, CGD



John Fasullo, NCAR/CGD

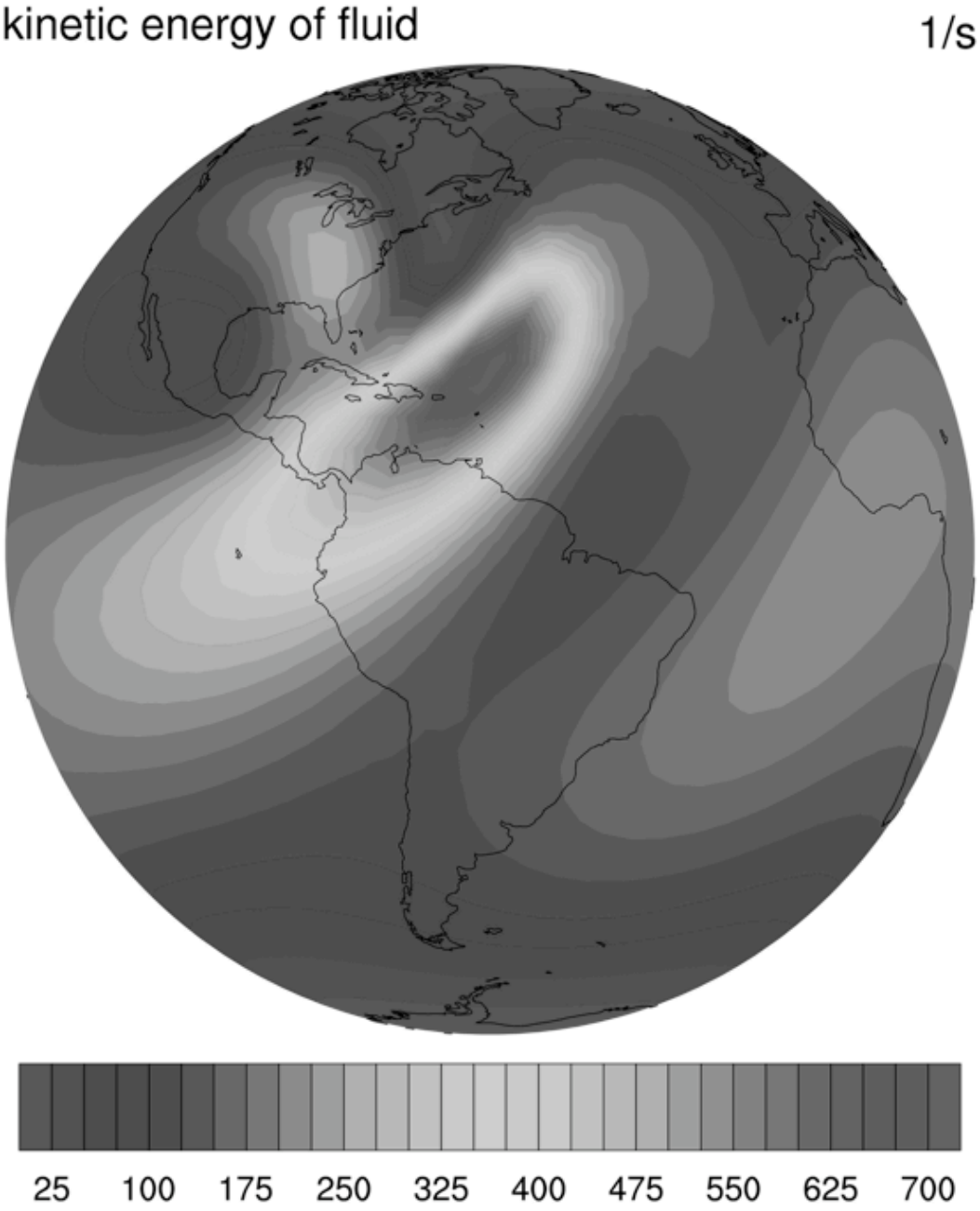

Trajectories colored by salinity (ppt)
20°S
30°S
40°S
50°S
60°S
70°W
60°W
50°W
40°W
30°W
34.55
34.61
34.67
34.73
34.79
34.85



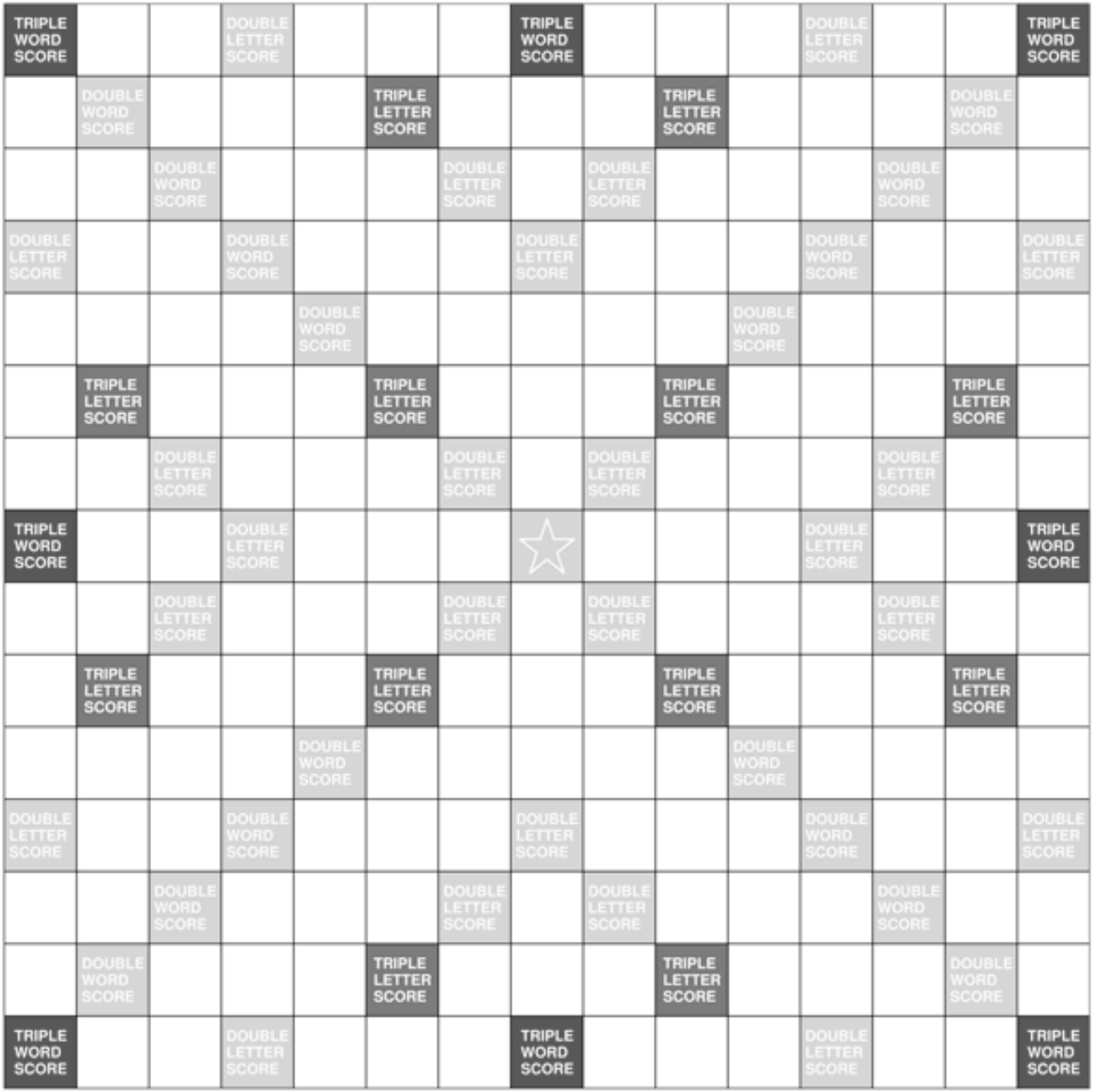
Based on a visualization of Joel Norris (Scripps) using dummy data

Contouring 1-dimensional x,y,z data

Data from Dave Randall, Todd Ringler, Ross Heikes of CSU



Most geodesic grids appear to be formed by elaborating an icosahedron; each of the 20 faces of the icosahedron is subdivided into smaller triangles in a more or less obvious way.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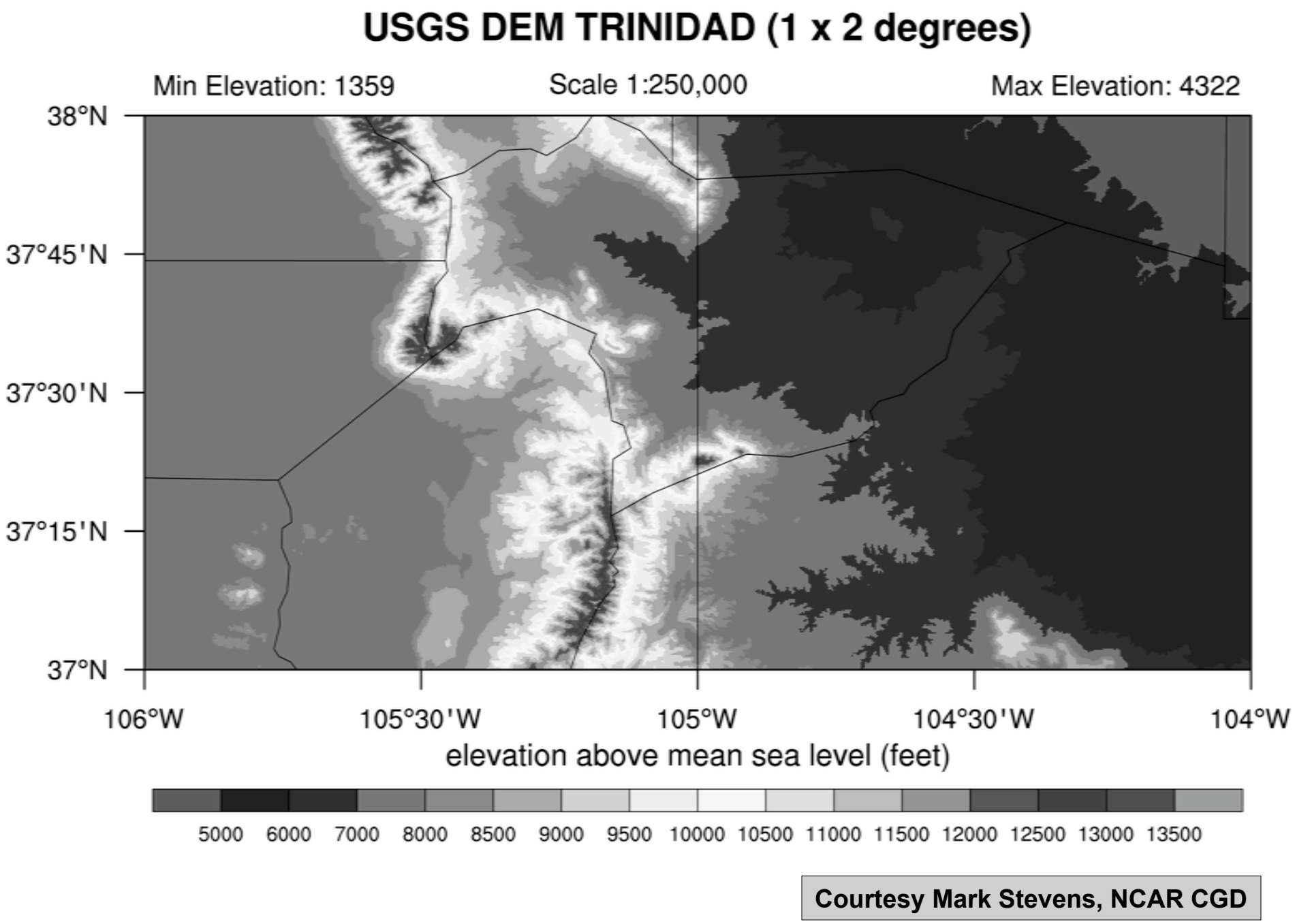
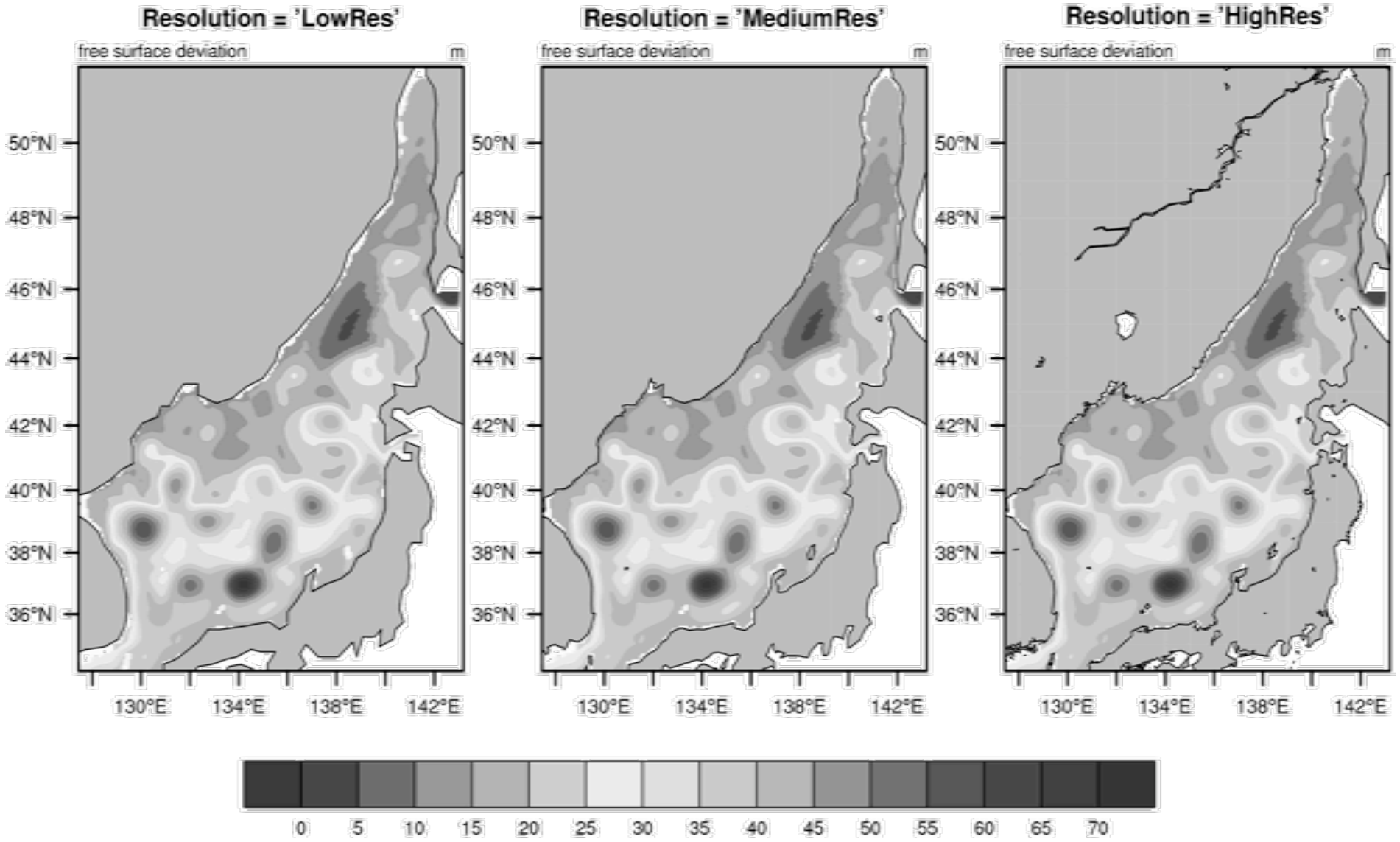
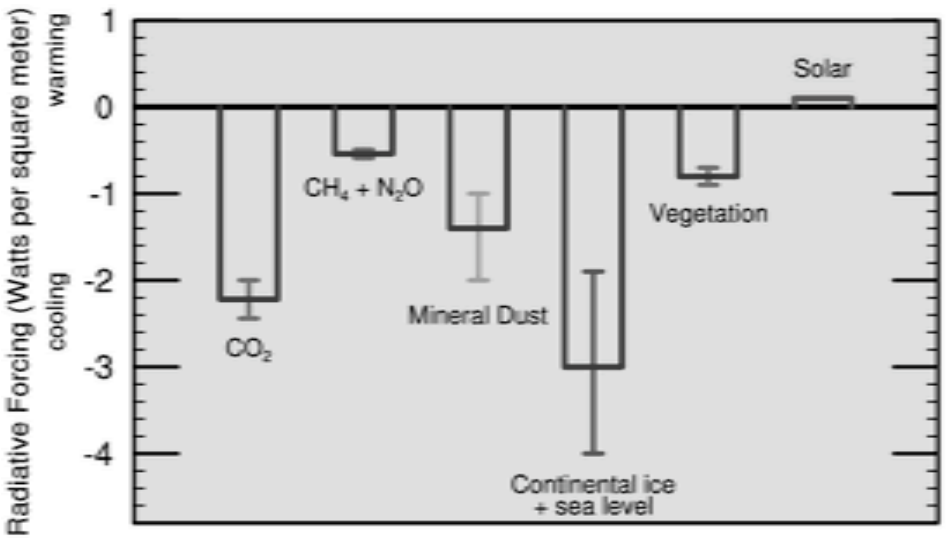


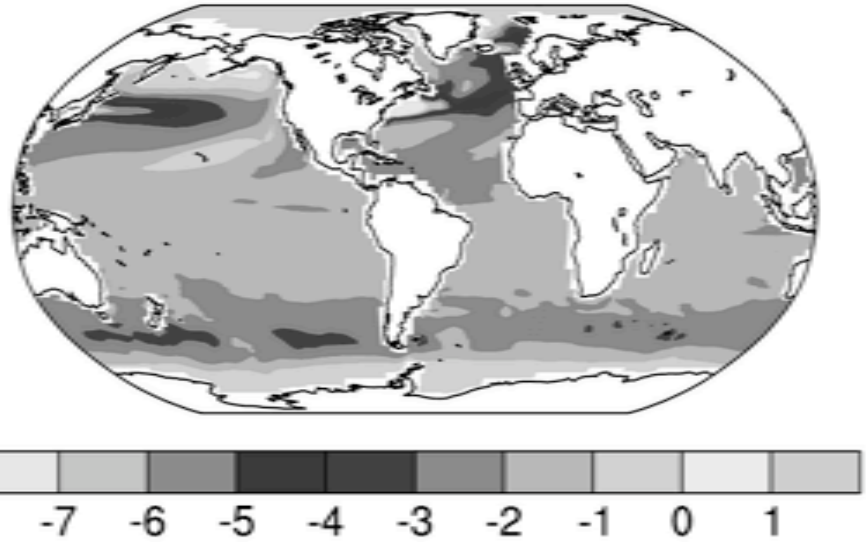
Courtesy Mark Stevens, NCAR CGD

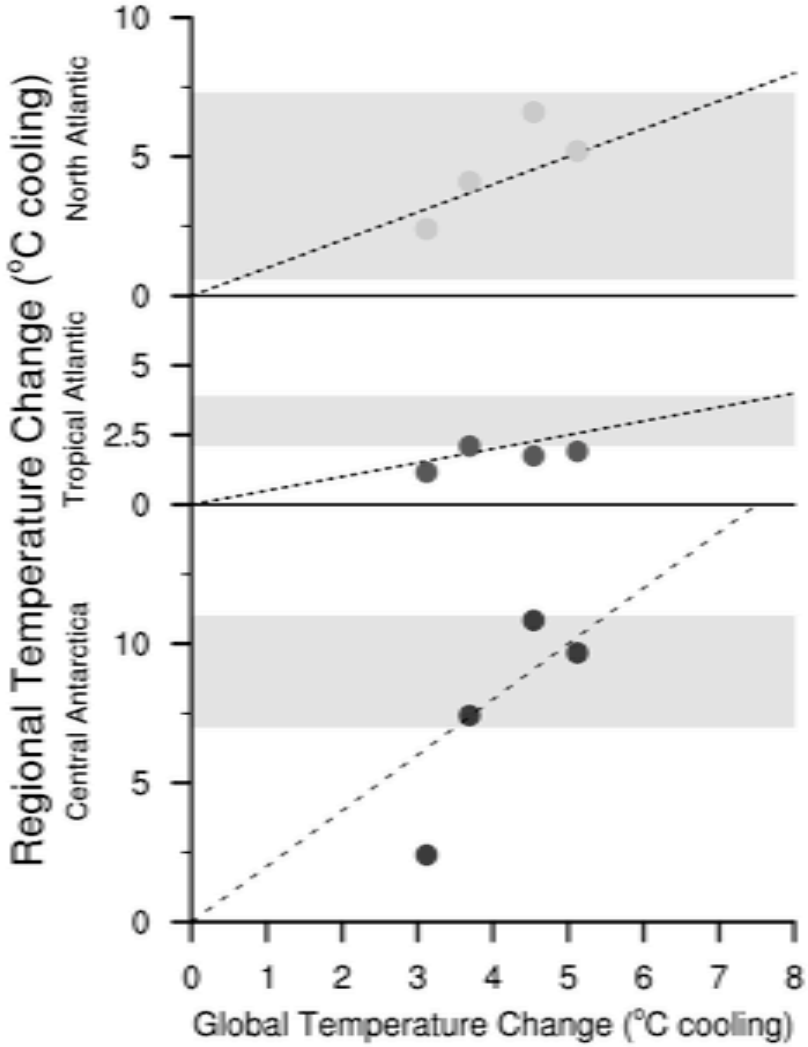
Comparison of coastline resolutions



First two map databases built-in; high-resolution available as simple download

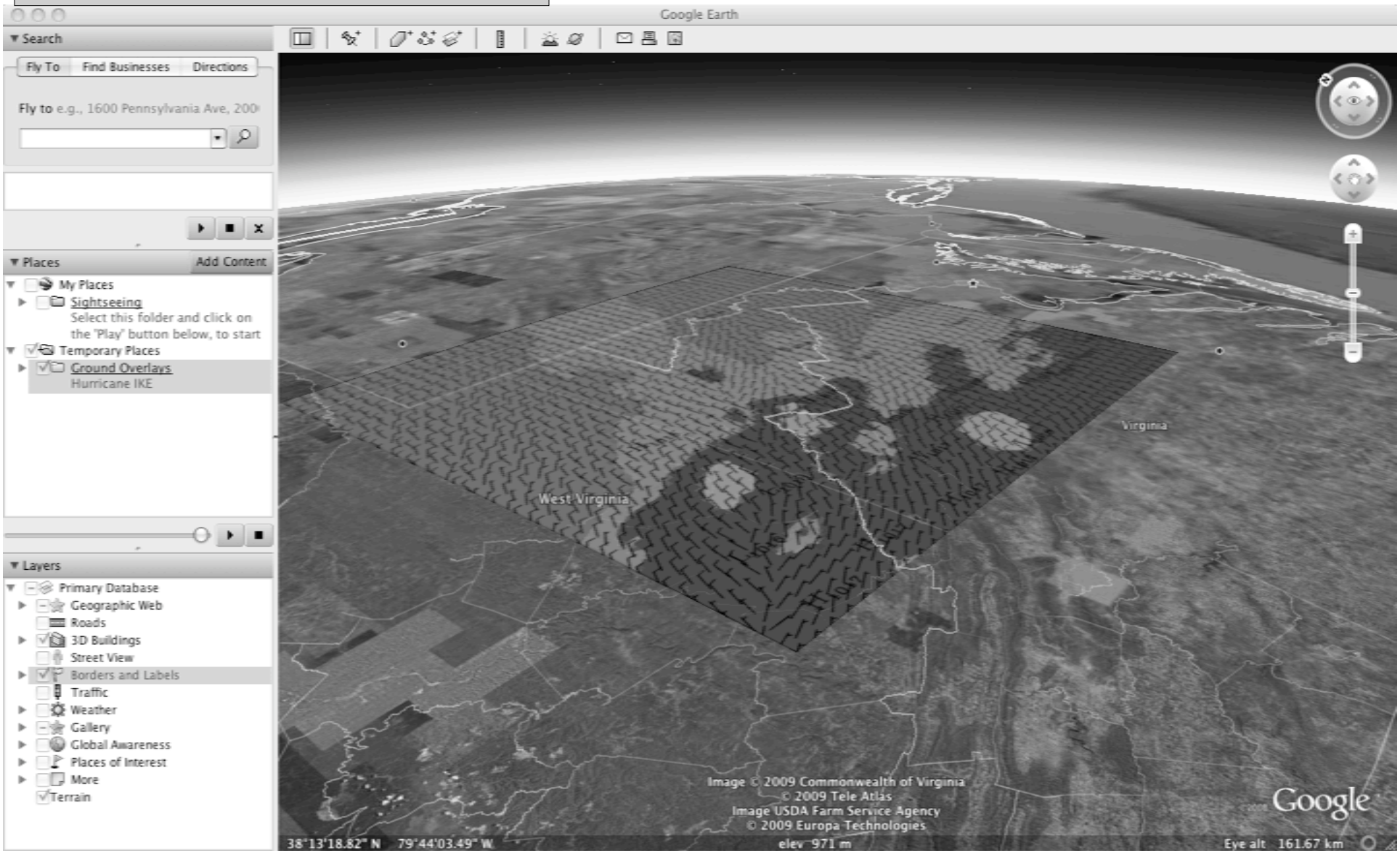


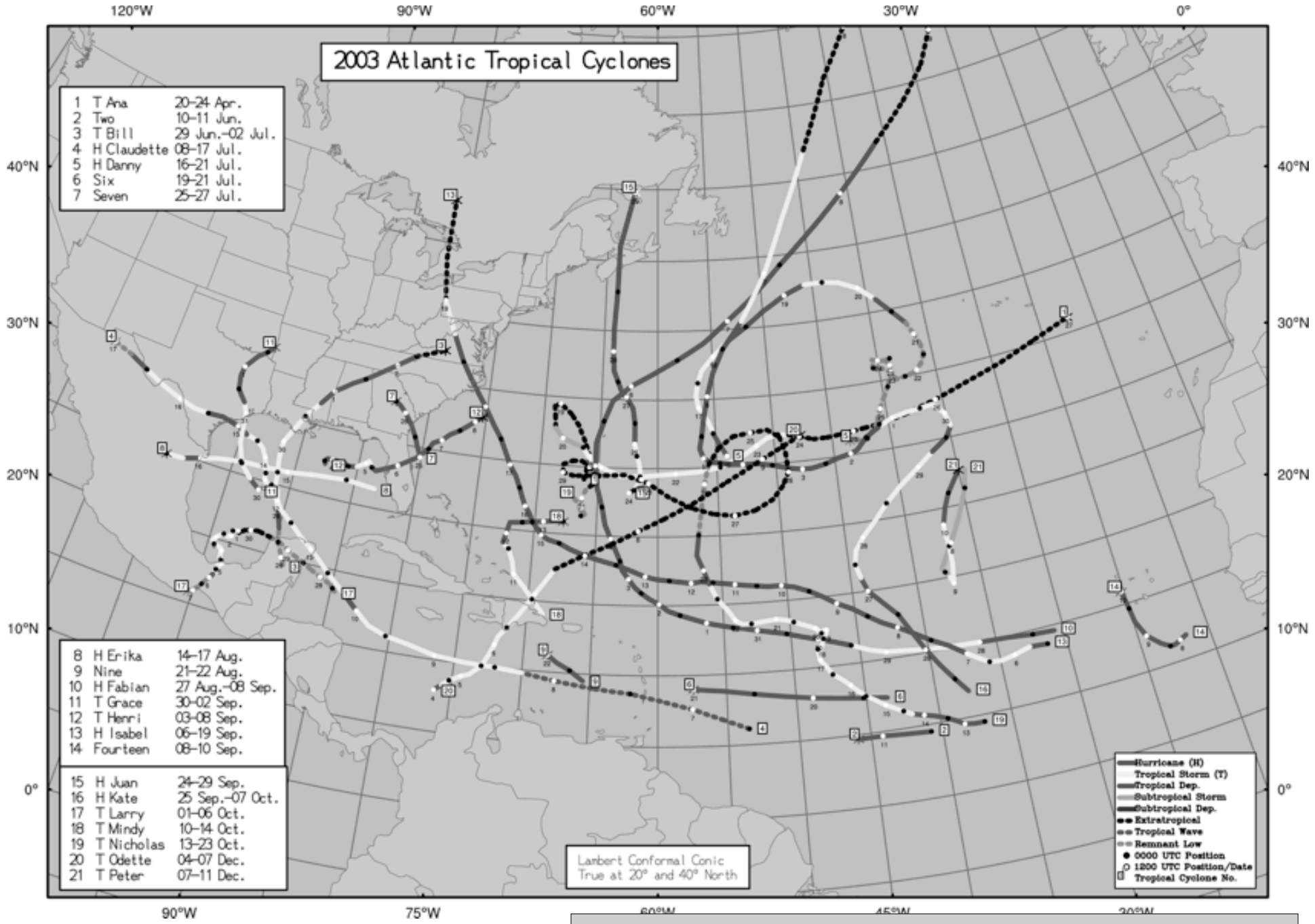




Courtesy Adam Phillips, NCAR CGD

Image courtesy Rick Brownigg
WRF/VAPOR/NCL





Graphic by Jonathan Vigh, Colorado State University

Running NCL

- **Interactive Mode (Command line)**
  - **ncl** *[options][command-line-arguments]* <return>
    ncl> enter commands
    ncl> **quit** <return>
  - can save interactive commands
    ncl> **record** "file_name"
    ncl> **stop record**

- **Batch Mode** [**.ncl** suffix is optional]
  - **ncl** *[options][arguments]* script.ncl
    - **ncl <** script.ncl [also acceptable]
  - **ncl** *[options][arguments]* script.ncl **>&!** out
  - **ncl** *[options][arguments]* script.ncl **>&!** out **&**

NCL Graphics - the basics

- The minimum steps needed to create a plot
- How resources (plot options) work
- NCL variable overview
- Where to try some exercises or download example scripts and data
- Useful documentation links

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

begin
  y = sin(0.0628*ispan(0,100,1))   ; 101 points

  wks = gsn_open_wks("ps","test")  ; 'test.ps'
  gsn_define_colormap(wks,"rainbow")

  res                   = True           ; plot options
  res@xyLineColor = "HotPink"    ; line color

  plot = gsn_csm_y(wks,y,res)    ; no X values
end
```

1. Load the necessary libraries

1.5 Get some data!

2. Open a workstation

3. Change color map

4. Set plot options

5. Call the graphical function

Step 1: Load necessary libraries

- Two ways of doing graphics in NCL:
  1) Using object-oriented method
  2) Using high-level graphical interfaces
- I will be discussing 2), which requires libraries to be loaded.
- There are two of these libraries (also called “scripts”): one is more “metadata aware” and contains functions that set more plot options on behalf of user.

The two libraries

`$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl`

`$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl`

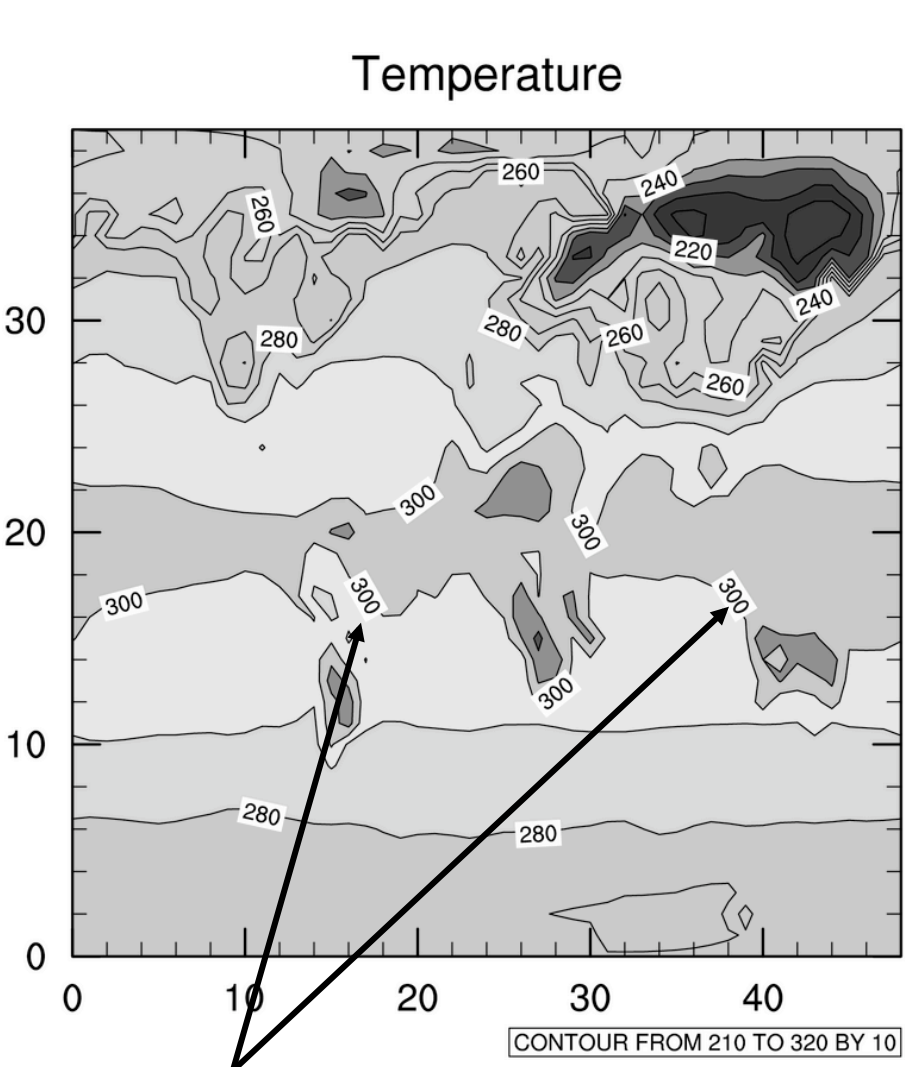
- First library contains “generic” interfaces and supplemental routines
- Second library contains **gsn_csm** interfaces that use CCSM conventions.
- Second library uses functions in first library---order is important!

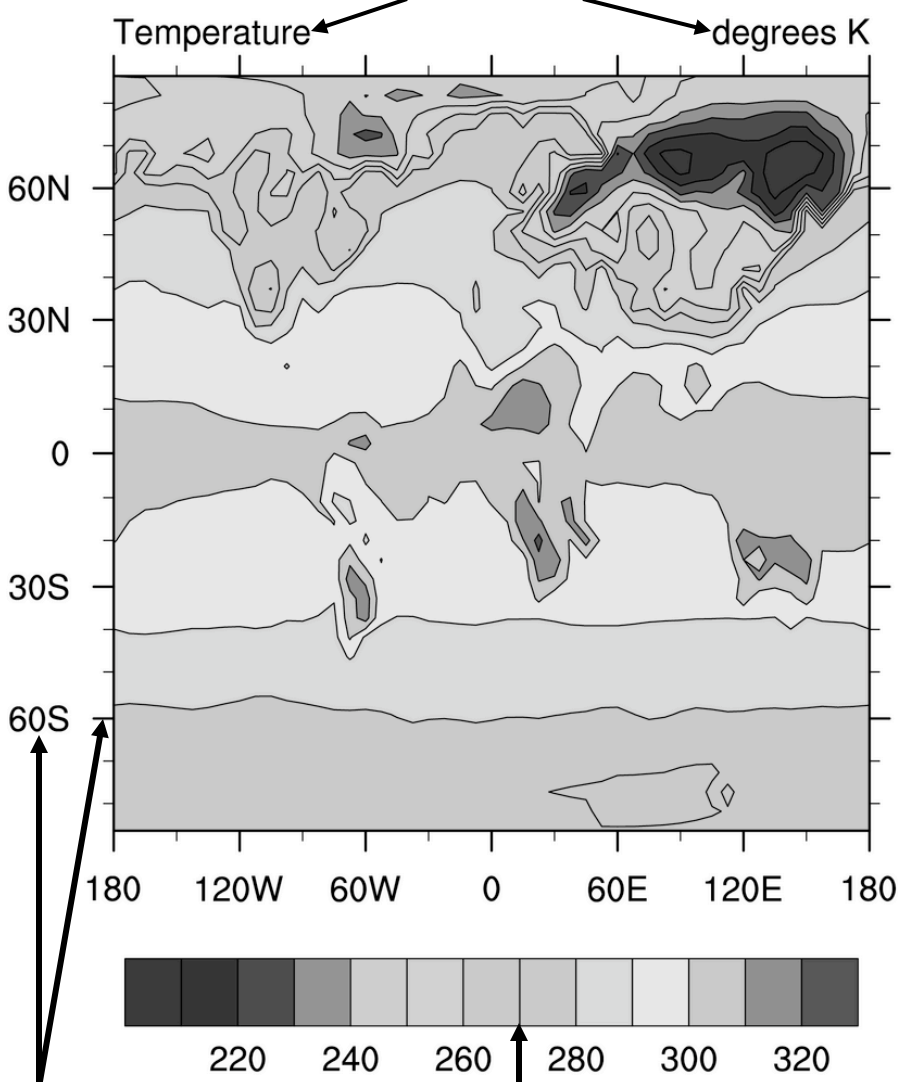
What are CCSM conventions?

- _FillValue attribute recognized as missing value
- Data attributes such as “long_name” and “units” used for plot titles
- Coordinate arrays used for axes values
- If geo-referenced coordinate arrays, then “units” attribute of “degrees_east” or “degrees_north” expected

“basic” interface: gsn_*xxxx*

“metadata aware” interface: gsn_csm_*xxxx*





contour line labels

information label

tickmarks out & lat/lon labels

automatic labelbar

Step 2:
Open graphics "workstation"

- Can be PostScript (PS or EPS), PDF, X11 window, or NCAR CGM (NCGM)
- Has a default color map associated with it.

```
wks = gsn_open_wks("x11","test")   ; X11 window

wks = gsn_open_wks("ps","test")    ; "test.ps"

wks = gsn_open_wks("eps","wrf")    ; "wrf.eps"

wks = gsn_open_wks("pdf","slp")    ; "slp.pdf"

wks = gsn_open_wks("ncgm","cn")    ; "cn.ncgm"
```

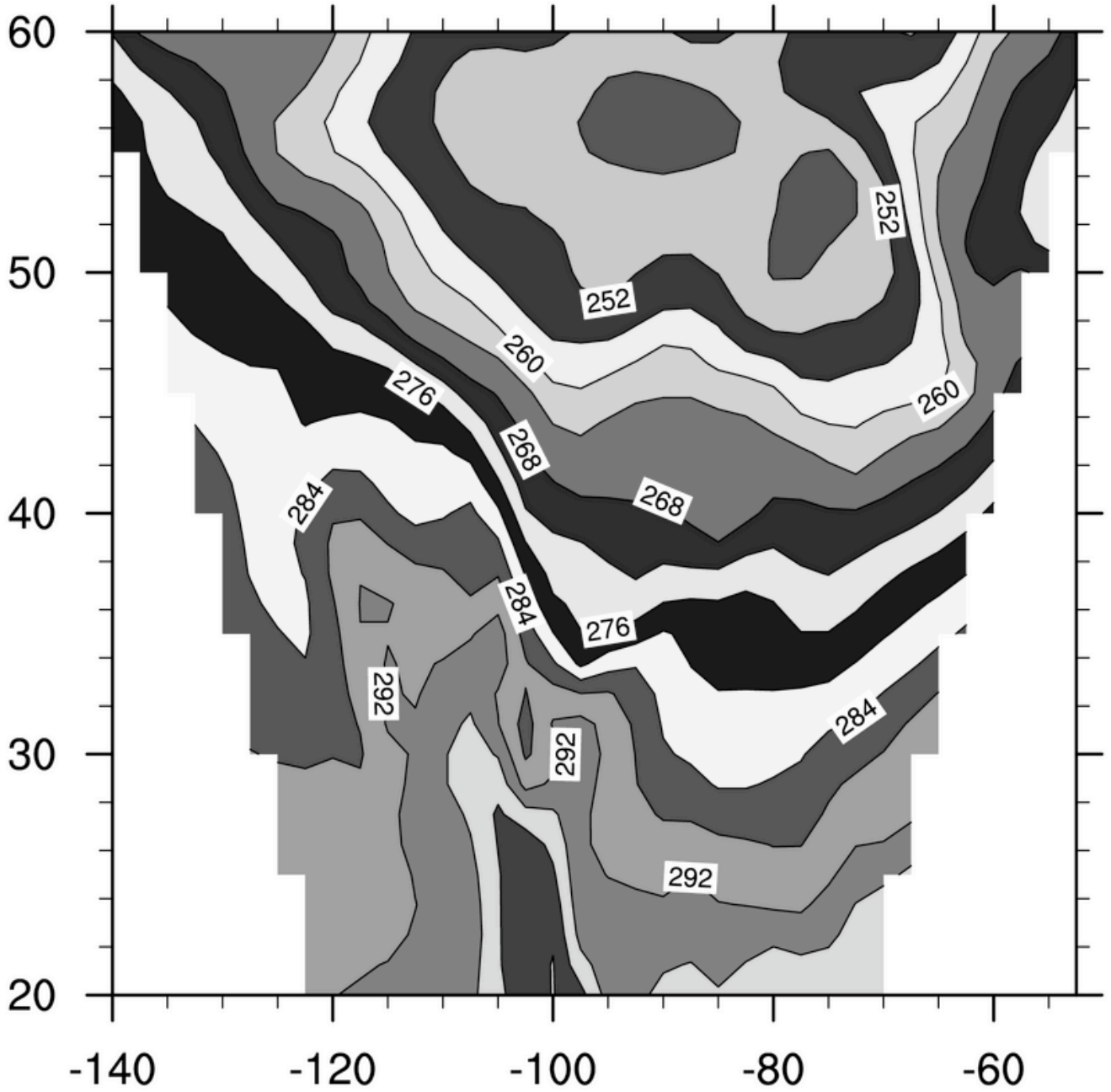
Step 3:
Change the color map (opt'l)

- Do this before drawing to the frame.

```
gsn_define_colormap(wks,"rainbow")
```

- If you use the same color map a lot, can put in ".hluresfile" (more later)
- Can use one of the other 40+ color maps, or create your own.
- If you don't change the color map, here's what you'll get…

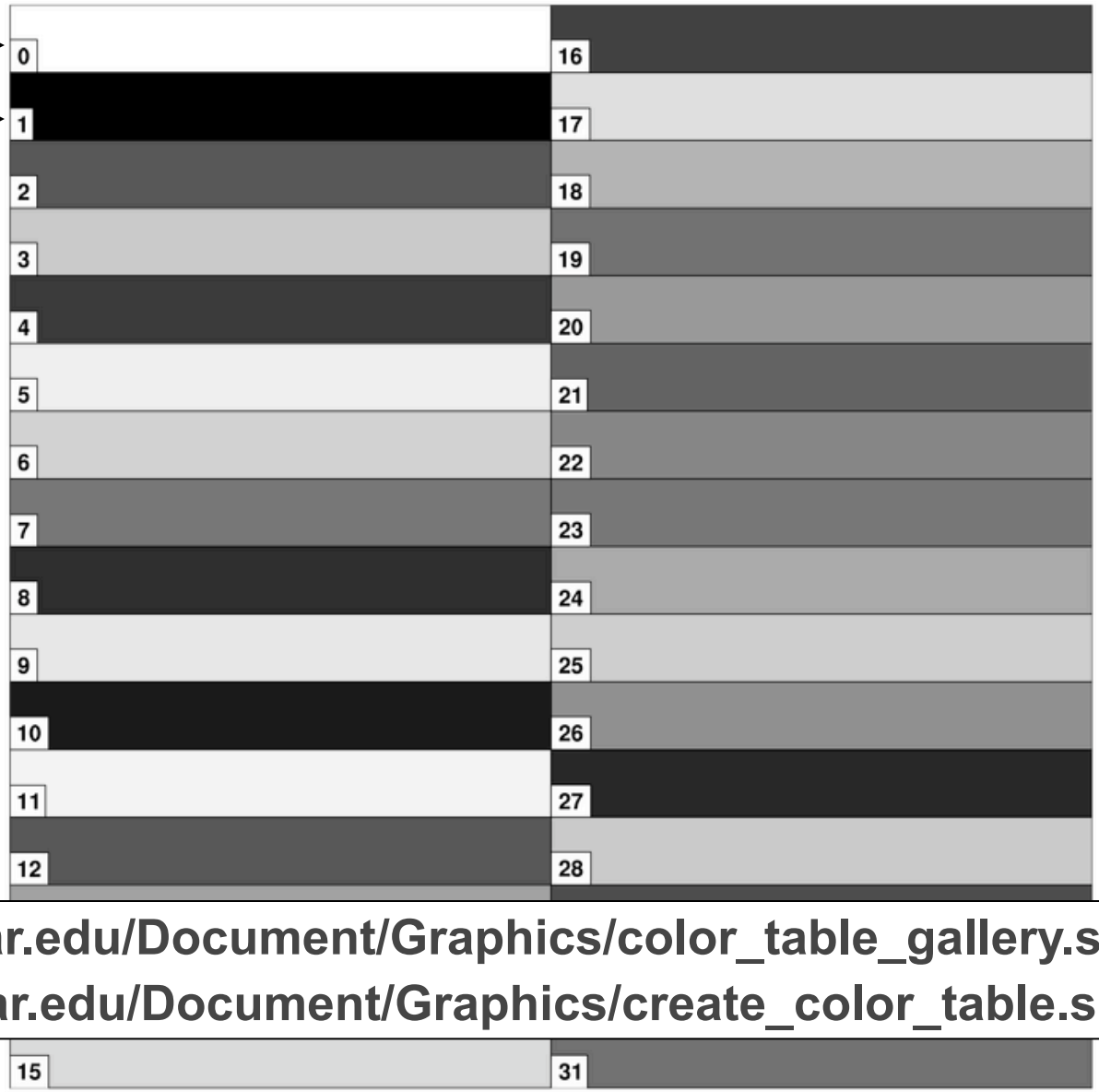
Default color table (yuck)



Default color table (yuck)

Index 0 is the background color

Index 1 is the foreground color

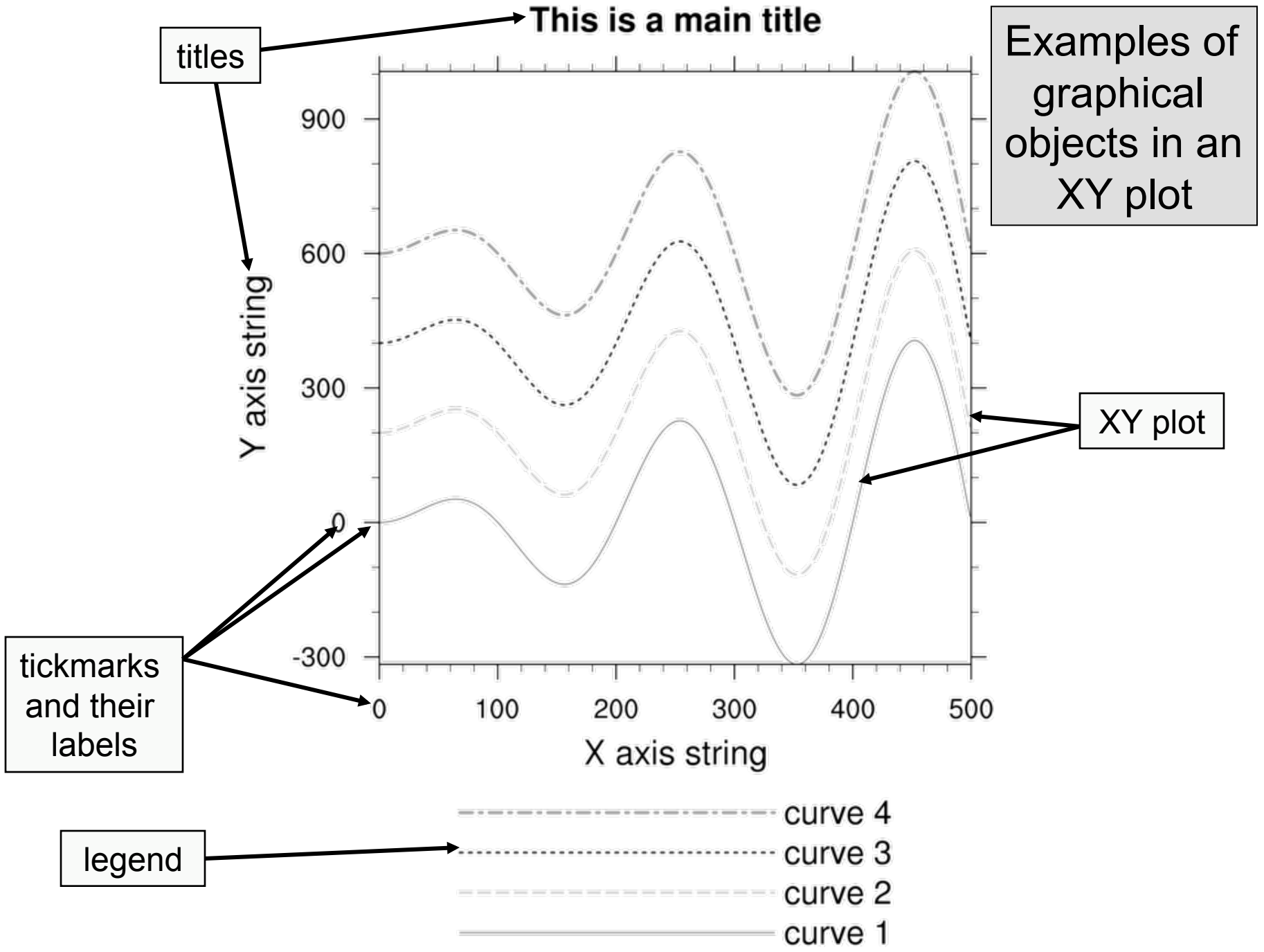


Pick a better color table… or create your own

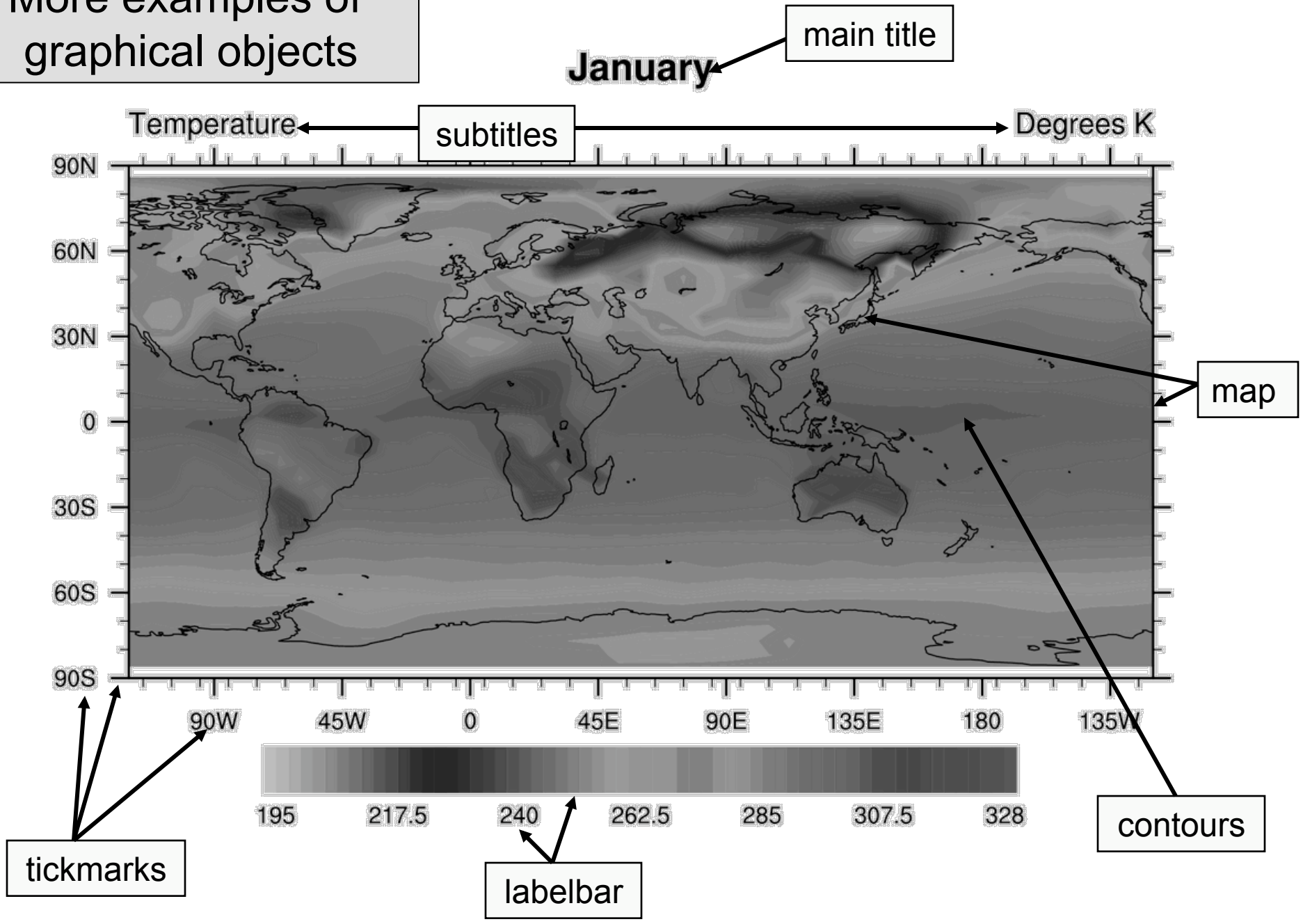
http://www.ncl.ucar.edu/Document/Graphics/color_table_gallery.shtml
http://www.ncl.ucar.edu/Document/Graphics/create_color_table.shtml

Step 4:
Set optional resources

- Resources are the heart of your NCL graphics code.
- There are over 1,400 resources!
- Resources are grouped by object type.
- There are 11 “graphical” objects: contours, labelbars, legends, maps, primitives, streamlines, text strings, tickmarks, titles, vectors, XY plots


Examples of graphical objects in an XY plot
titles
This is a main title
Y axis string
900
600
300
0
-300
0
100
200
300
400
500
X axis string
XY plot
tickmarks and their labels
legend
curve 4
curve 3
curve 2
curve 1

More examples of graphical objects



Detour: anatomy of a resource

- Starts with 2 or 3 lower-case letters based on object it is associated with. Some examples:

“xy” - XY Plots	“cn” - Contour plots
“vc” - Vector plots	“ti” - Titles
“tm” - Tickmarks	“gsn” - special resources not associated with any object

- Made up of full words with first letter of word capitalized:
  - “xyLineColor”, “cnFillOn”, “tiMainString”, “vcRefMagnitudeF”, “gsnMaximize”
- Some have an “F” on the end to indicate a floating point resource: “xyLineThicknessF”

Anatomy of a resource (cont'd)

- Resources are set by attaching them as attributes to an NCL *logical* variable:

  res = True ; can name it whatever you want

  res@mpMinLatF = 30 ; decimal not necessary

- Most have default values.
- There are many types:
  - res@tiMainString = "This is a title"
  - res@tmXBLabelFontHeightF = 0.01
  - res@cnLineLabelsOn = True
  - res@xyLineColors = (/5,7,11/)
  - res@xyLineColors = (/"red", "green", "blue"/)

http://www.ncl.ucar.edu/Document/Graphics/Resources/

Anatomy of a resource (cont'd)

- Resources across objects are similarly named for easier recollection:
  - xyLineColor, cnLineColor, gsLineColor, mpGridLineColor, tmBorderLineColor
  - tiMainFontHeightF, tmXBLabelFontHeightF, lbLabelFontHeightF, cnLineLabelFontHeightF
  - xyDashPattern, mpPerimLineDashPattern, lbBoxLineDashPattern, cnLineDashPattern

and so on…

Step 5:
Draw the graphics

- Call one of the gsn_csm_*xxxxx* functions from the second library we loaded.
- Some examples:

```
xy   = gsn_csm_xy(wks,x,y,res)
plot = gsn_csm_contour(wks,data,res)
plot = gsn_csm_vector(wks,u,v,res)
map  = gsn_csm_vector_map(wks,u,v,res)
phgt = gsn_csm_pres_hgt(wks,data,res)
```

http://www.ncl.ucar.edu/Document/Graphics/Interfaces/

Now for some actual NCL graphics code samples…

Scripts and sample datasets may also be available on your machine.

In review…

- Five steps to create a plot
- Use X11 window while debugging script; move to PS/PDF later
- Hardest part are the resources: start simple
- Organize resources for easier debugging
- Start with an existing script if possible

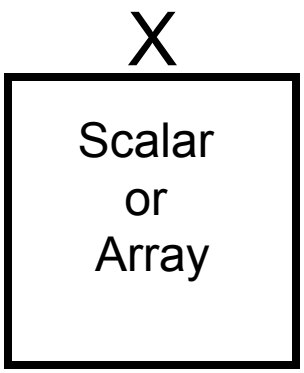
NCL Variables

- ✓ Must begin with an alphabetic character
- ✓ May contain any mix of numeric and alphabetic characters
- ✓ One exception: the underscore _ is allowed
- ✓ Variable names ARE case-sensitive
- ✓ Max name length is 256 characters
- ✓ Examples: a A forecast_time __t__

NCL Syntax Characters

- **;** - comment [can appear anywhere]
- **@** - reference/create attributes
- **!** - reference/create named dimension
- **&** - reference/create coordinate variable
- **{…}** - coordinate subscripting
- **$** - enclose strings when (im/ex)port variables via addfile
- **(/../)** - array construct characters
- **:** - array syntax
- **|** - separator for named dimensions
- **** - continue character [statement to span multiple lines]
- **::** - syntax for external shared objects (eg, fortran/C)
- **->** - use to (im/ex)port variables via **addfile** function

netCDF [NCL] Variable model



attributes

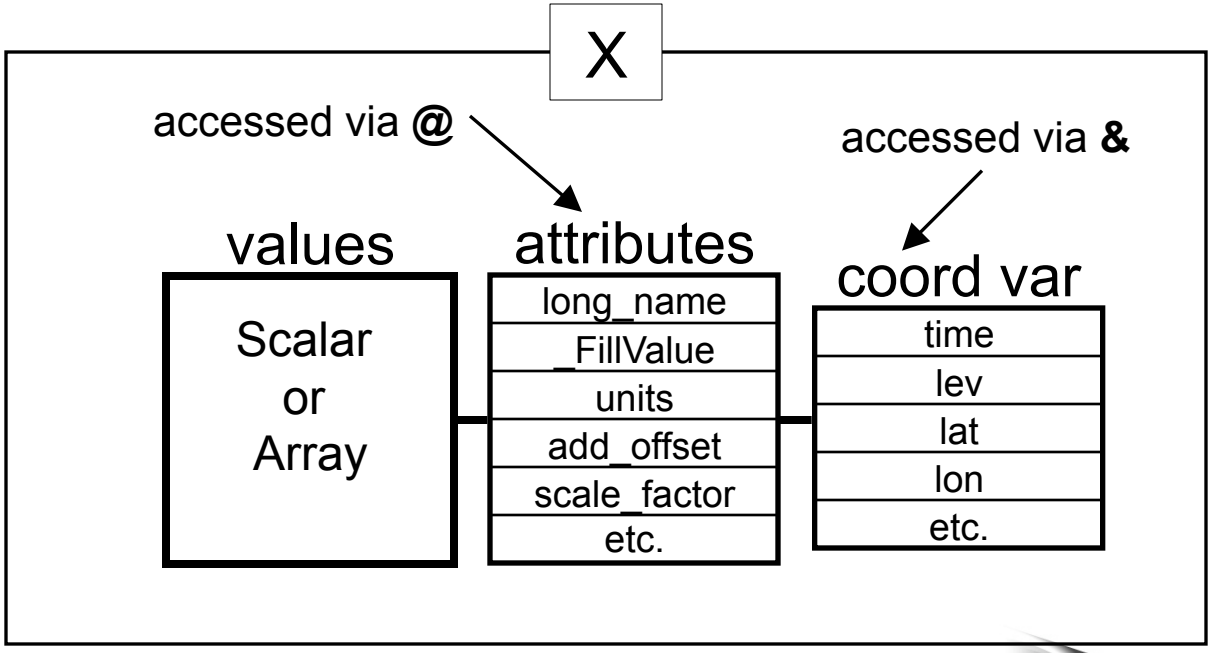
long_name
_FillValue
units
add_offset
scale_factor
etc.

coordinates

time
lev
lat
lon
etc.

```
f = addfile("foo.nc", "r")    ; grb/hdf
x = f->X
```

NCL reads the scalar/array, attributes, and coordinate variables as an object



Customize your graphics environment

Optional, but most highly recommended.

(Come to think of it, not really that optional!)

- Download ".hluresfile" file, put in home directory
  - Changes your default background, foreground colors from black/white to white/black
  - Changes font from **times-roman** to **helvetica**
  - Changes "function code" (default is a colon)
  - Can be used to change default color map
- Available on your lab machines:

```
cat ~/.hluresfile
```

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

Sample ".hluresfile"

```
! White background/black foreground
*wkForegroundColor      : (/0.,0.,0./)
*wkBackgroundColor      : (/1.,1.,1./)

! Color map
*wkColorMap             : rainbow+gray

*Font                   : helvetica

! Function code [Default is a colon]
*TextFuncCode           : ~

! Set size of x11 window
*wkWidth                : 700
*wkHeight               : 700
```

Common mistakes or problems

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

- Forgot .hluresfile (fonts will look wrong)
- "*xyLineColour" is not a resource in XyPlot at this time*"
  - Misspelling a resource, "xyLineColour"
  - Using the wrong resource with the wrong plot (i.e. using "vcRefMagnitudeF" in a contour plot).
- "*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*."
  - Lack of (or wrong) "units" attribute attached to your data's coordinate arrays

More common mistakes or problems

- Data values in plot look off-scale
  - Maybe “_FillValue” attribute not set or not correct.
- Not getting gray-filled lands in map plots.
  - You are using a color map that doesn’t have gray in it (use “NhlNewColor” to add gray or change color maps to one that has gray).
- “_NhlCreateSplineCoordApprox: Attempt to create spline approximation for Y axis failed: consider adjusting trYTensionF value”
  - Data is too irregularly spaced in the X or Y direction. May need to subset it.

Debugging tips

1. Start small, don't set 50 resources all at once
2. Start with an existing script, if possible
3. Group resources by type
4. Don't share resource lists
5. Comment out resources and add back slowly to see where problem is
6. Use "printVarSummary" to examine variables
   - Missing coordinate arrays
   - No "_FillValue" or wrong "_FillValue"
7. Use
   - print(min(x)) and print(max(x)) ; Minimum/maximum of data
   - print(num(ismissing(x))) ; Count number of msg vals

   to further examine data
8. Read errors and warnings carefully

Creating images for web or PowerPoint

- Start with PS or PDF file
- Download “convert”, part of free ImageMagick package

  http://www.imagemagick.org/script/index.php

  Mac users can try “fink install imagemagick”
- Use:

```
convert -geometry 1000x1000 -density 300 -trim xy.ps xy.png
```

- The “-density 300” option is what gives you higher-quality images. You can play with this number. Use a larger value for posters.

Converting images inside NCL script

- Send output to “ps” file
- Use “delete(wks)” to force the close of the PS file
- Use NCL’s “system” to call “convert”

```
. . .
filename = “test”
psf      = filename + “.ps”    ; PS file name
pngf     = filename + “.png”   ; PNG file name
wks = gsn_open_wks(“ps”,filename)
res = True
. . .
plot = gsn_csm_xxxx(wks,data,res)
delete(wks)

options = “ -geometry 1000x1000 -density 300 -trim ”
system(“convert“ + options + psf + “ “ + pngf)
```