WRF Data and Utilities

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Supported Post-processing Packages

http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V3/contents.html

Package	Users' Guide Page #	Information
NCL	9-2	Graphical package Supported by NCAR/CISL (wrfhelp@ucar.edu and ncl-talk@ucar.edu)
ARWpost	9-29	Converter (GrADS) (wrfhelp@ucar.edu)
RIP4	9-20	Converter and interface to graphical Package, NCAR graphics (wrfhelp@ucar.edu)
UPP	9-36	Converter (GrADS & GEMPAK) (upp-help@ucar.edu)
VAPOR	9-38	Converter and graphical package Supported by VAPOR (vapor@ucar.edu)
IDV	None – see unidata.ucar.edu	GRIB (from UPP) GEMPAK (from wrf2gem) Vis5d CF compliant data (from wrf_to_cf) Supported by unidata (support@unidata.ucar.edu)
GEMPAK	None - see: unidata.ucar.edu/software/gempak	Data from wrf2gem or UPP Supported by unidata (support@unidata.ucar.edu)

Choosing the Right Tool

- Can it read your data?
- Will you need to pre-process the data first?
- Is it purely a visualization tool, or does it include post-processing?
- Can it handle big datasets?
- Which diagnostic/statistical functions does it have?
- How easy is it to add diagnostics?
- 3D or 2D visualization?
- Can it handle staggered grids?
- How is data below the ground handled?
- Vertical grids?
- How are model time stamps handled?
- Easy to use?
- Cost of package?
- How well supported is it?

Data Handling

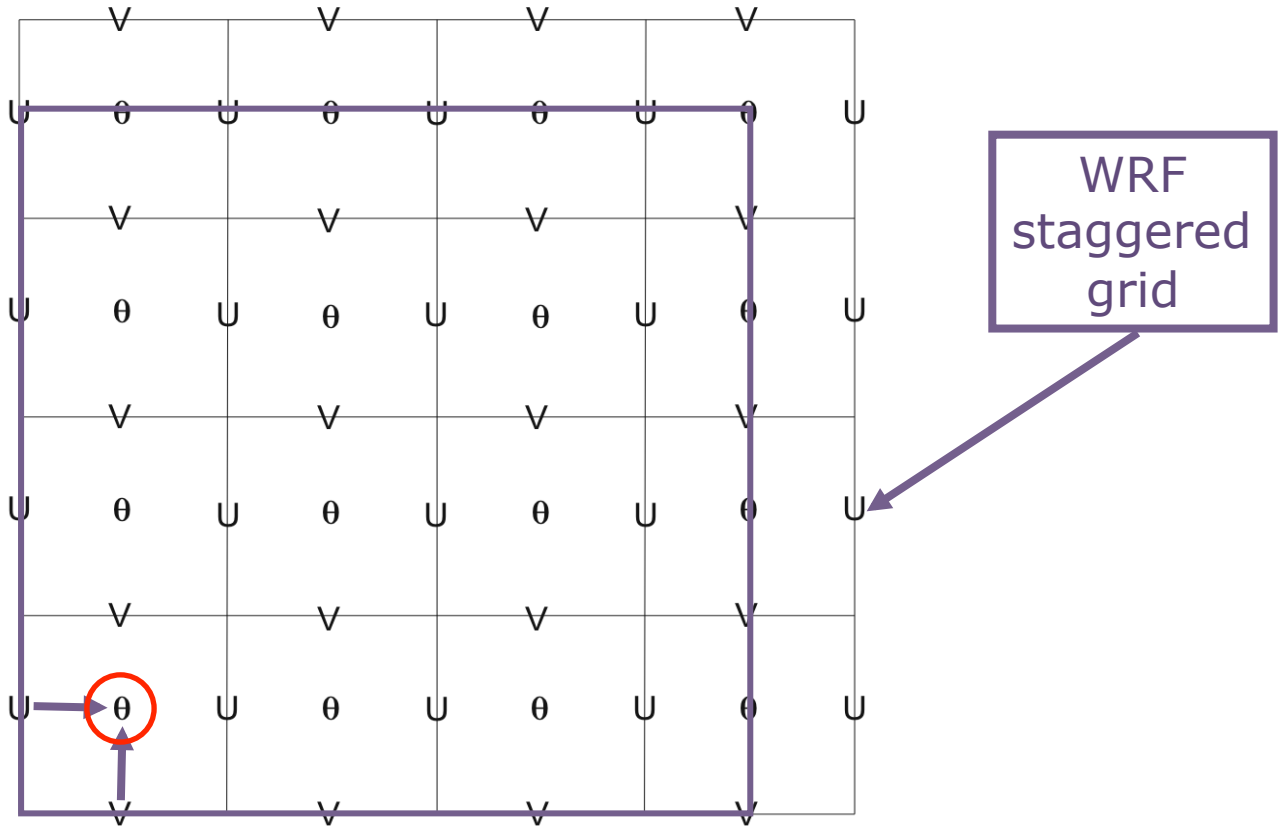
	NCL	RIP4	GrADS	UPP	VAPOR	IDV
netCDF		ripdp	ARWpost	converter	converter	converter
GRIB						
ASCII						
shapefiles						
geogrid & metgrid output						
intermediate file format	***V6.2.0*** ***V6.3.0***					
wrfinput data						
Idealized data						
wrfoutput						
big data						

Post-processing

	NCL	RIP4	GrADS	UPP	VAPOR	IDV
Post-processing						
Data output						
3D						
diagnostics	some	a lot	some	some	limited	limited
Add diagnostics	Very easy	easy	easy	Relatively easy	Not as easy	Not as easy
Vertical output Coordinate	Model pressure height	Model pressure height	Model pressure height	pressure	model	model
Extrapolate Below ground						

Model Staggering

Why is a converter necessary if a package can display netCDF files?



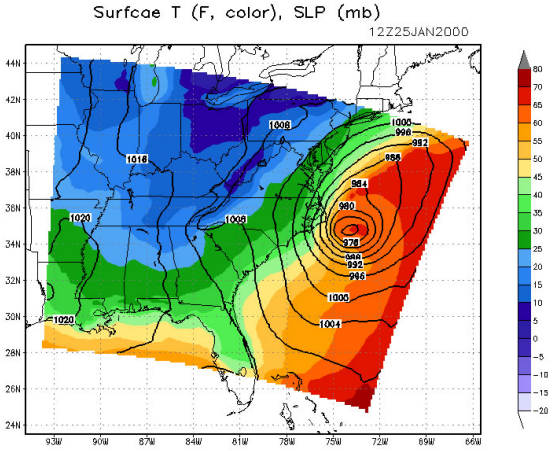
Converter co-locates data to mass points

ARWpost: General Information

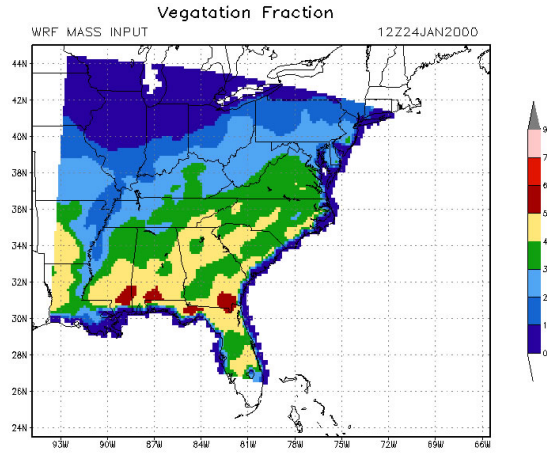
- Converter
  - Reads in wrf-arw model data, creates GrADS output files
  - Requires GrADS to display
- GrADS software is only needed to display data, not needed to compile the code
  - http://www.iges.org/grads/grads.html
- Generate a number of graphical plots
  - Horizonal
  - Cross-section
  - skewT
  - Meteogram
  - Panel
- Download Code
  - http://www2.mmm.ucar.edu/wrf/users/download/get_sources.html
- Online Tutorial
  - http://www2.mmm.ucar.edu/wrf/users/graphics/ARWpost/ARWpost.htm

ARWpost: Example Plots

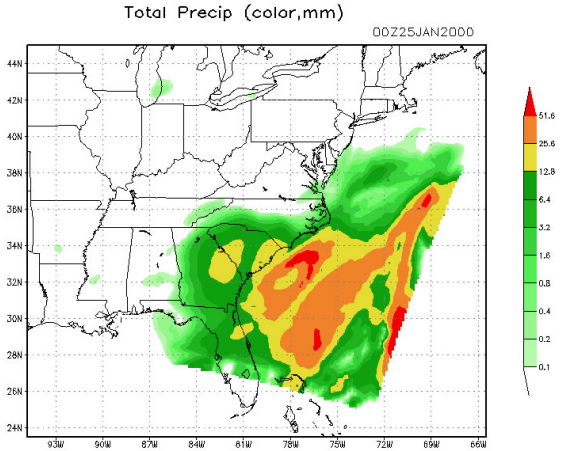
Surface Temp



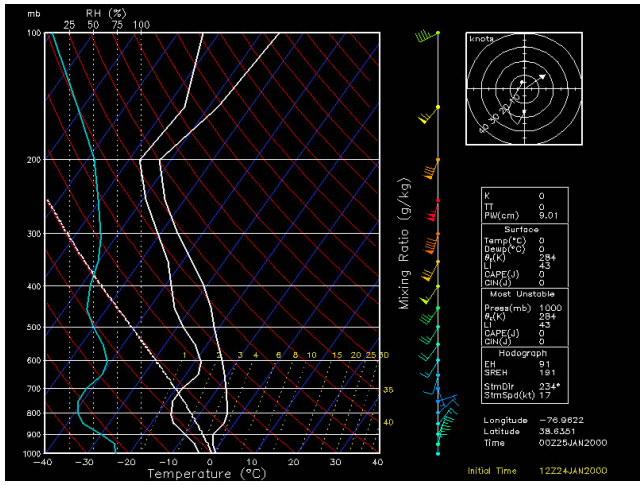
Vegetation Fraction



Total Precipitation

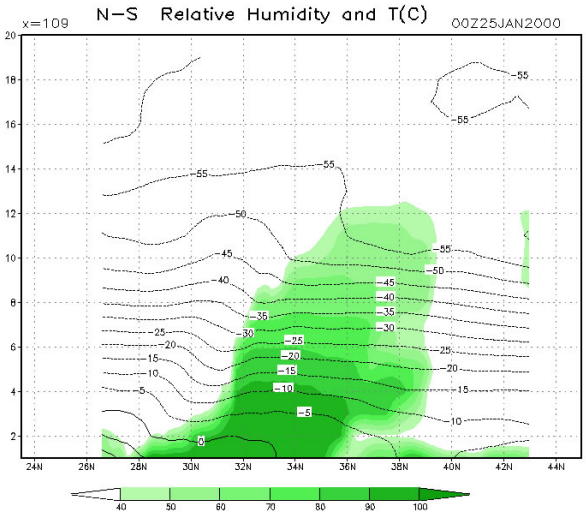


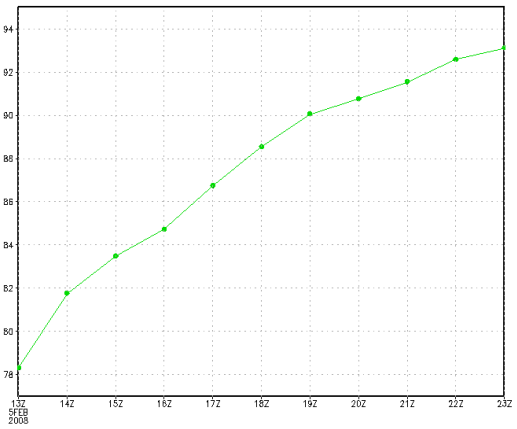
Skew-T Diagram



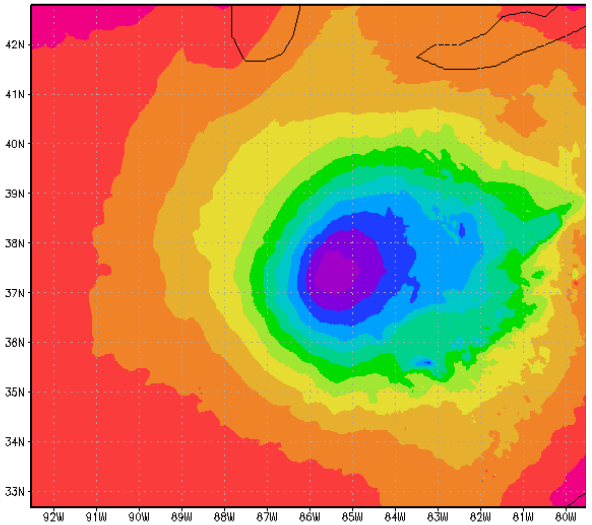
ARWpost: Example Functions

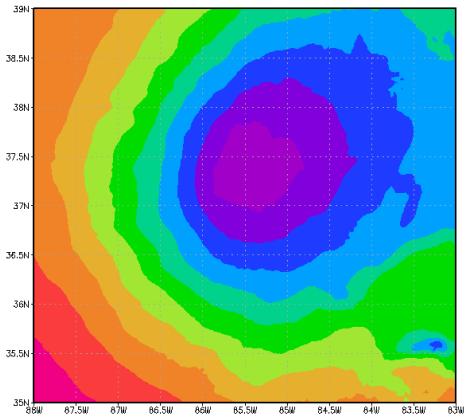
Cross-Sections





Zooming





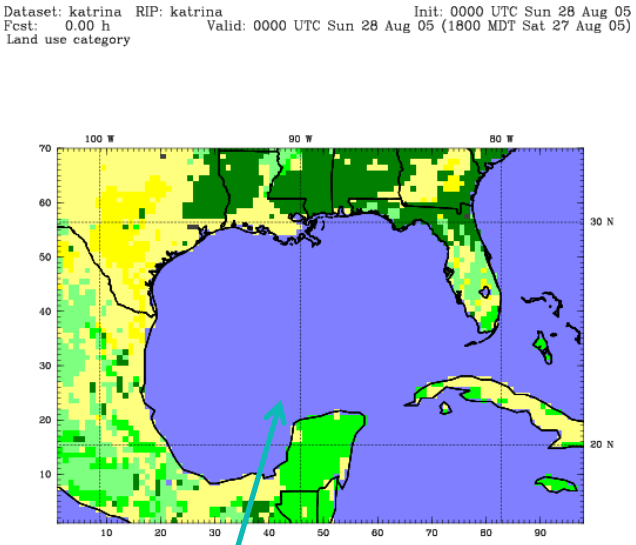
ARWpost: Diagnostics

- cape – 3d cape
- cin – 3d cin
- mcape – maximum cape
- mcin – minimum cin
- clfr – low/middle/high cloud fraction
- dbz – 3d reflectivity
- max_dbz – maximum reflectivity
- geopt – geopotential
- height – model height in km
- lcl – lifting condensation level
- lfc – level of free convection
- pressure – full model pressure in hPa
- rh – relative humididy
- rh2 – 2 m relative humidity
- theta – potential temperature
- tc – temperature in degrees C
- tk – temperature in degrees K
- td – dew point temperature in degrees C
- td2 – 2m dew point temperature in degrees C
- slp – sea level pressure
- umet & vmet – winds rotated to Earth coordinates
- u10m & v10m – 10 m winds rotated to Earth coordinates
- wdir – wind direction
- wspd – wind speed coordinates
- wd10 – 10 m wind direction
- ws10 – 10 m wind speed

ARWpost: Scripts

Script Name	Description
cbar.gs	Plots a color bar on shaded plots
rgbset.gs	Allows you to add/change colors from color # 20 – 99
skew.gs	Program to plot a skewT
plot_all.gs	Automatically finds all .ctl files in the directory and lists them so the user can pick when to use, will plot all fields chosen
rain.gs (real data only)	Plots total rainfall (must have data that contain fields RAINC and RAINNC)
cross_z.gs (real data only)	Plots a NS and EW cross section of RH and T (C)

RIP4: Example Plots

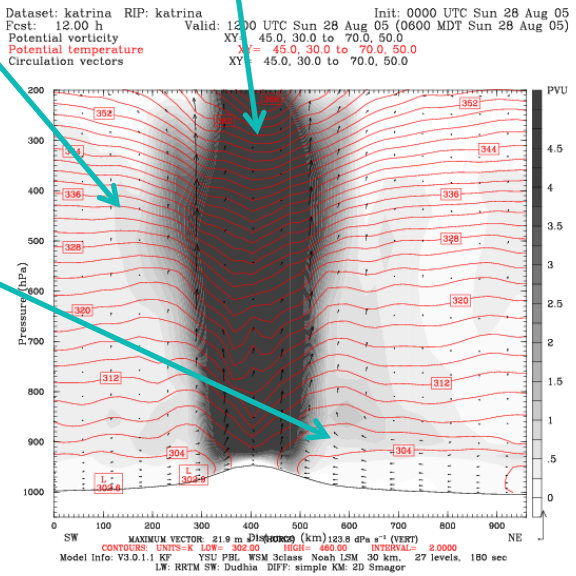


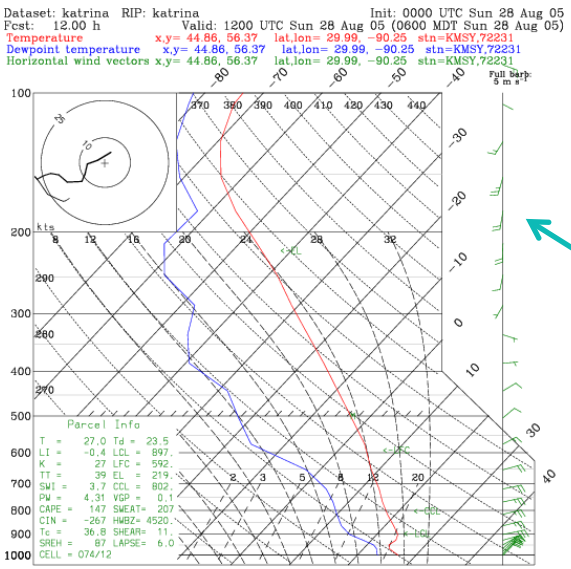
Landuse Category

Potential Vorticity

Potential Temp

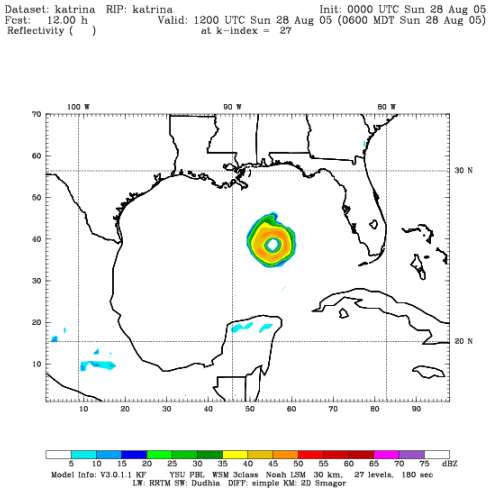
Circulation Vectors



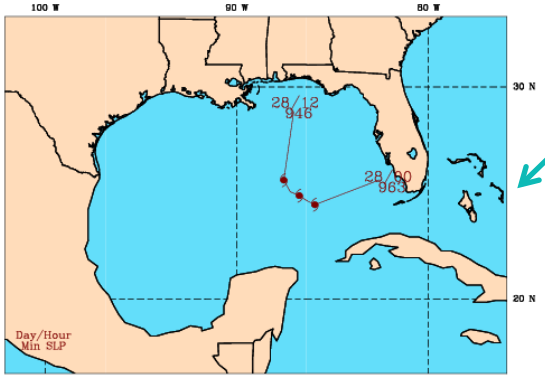


Skew-T Diagram

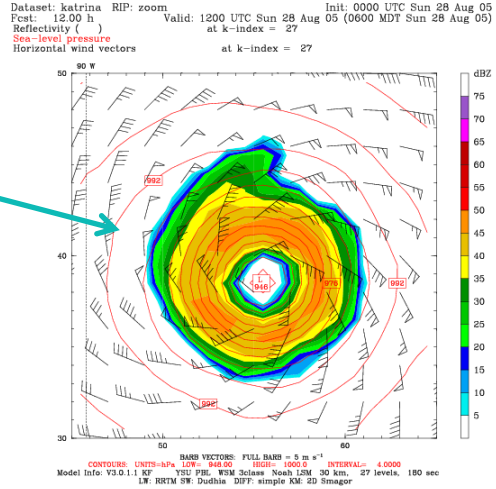
RIP4: Example Plots



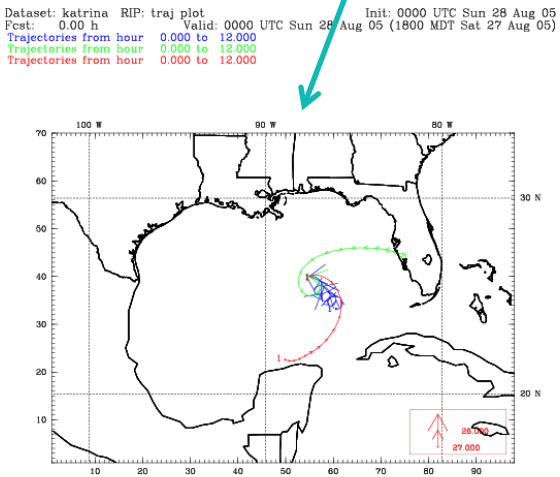
Cyclone Tracking



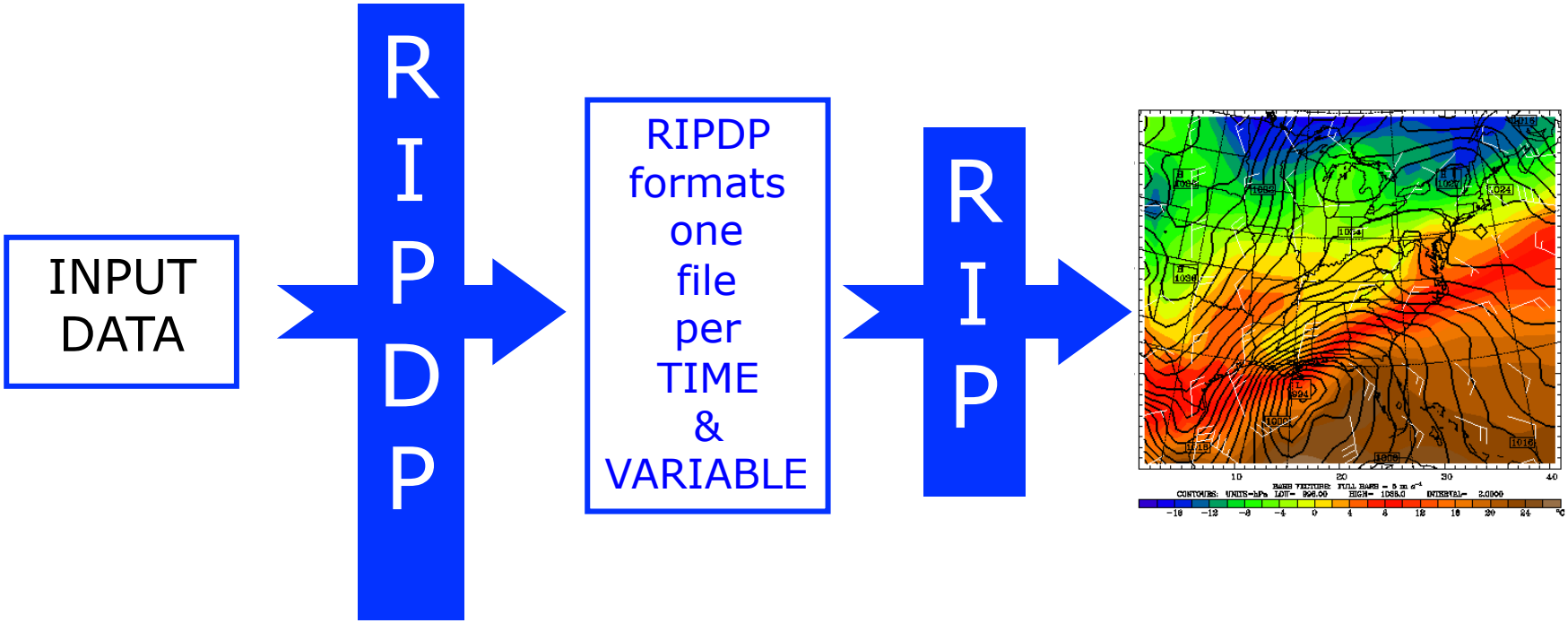
Zooming Capability



Trajectories



RIP4: Program Flow



RIP4: General Information

- Requires NCAR Graphics Libraries
  - http://www.ncl.ucar.edu
- Source Code
  - http://www2.mmm.ucar.edu/wrf/users/download/get_source.html
- Documentation
  - Included in program's tar file (in Doc/ directory)
  - http://www2.mmm.ucar.edu/wrf/users/docs/ripug.htm
- Online Tutorial
  - http://www2.mmm.ucar.edu/wrf/users/graphics/RIP4/RIP4.htm

Utilities

- Graphics
- Designing a model domain
- OBSGRID
- netCDF tools
- Data
- MET

Graphics: ImageMagick

http://www.imagemagick.org

- Converts graphical files from one format to another

  convert *file.*pdf *file.*png

  convert *file.*png *file.*bmp

- Many options available
  - Rotate frames, trim white space, etc.

- Can make movies
  - Can create individual frames for each image

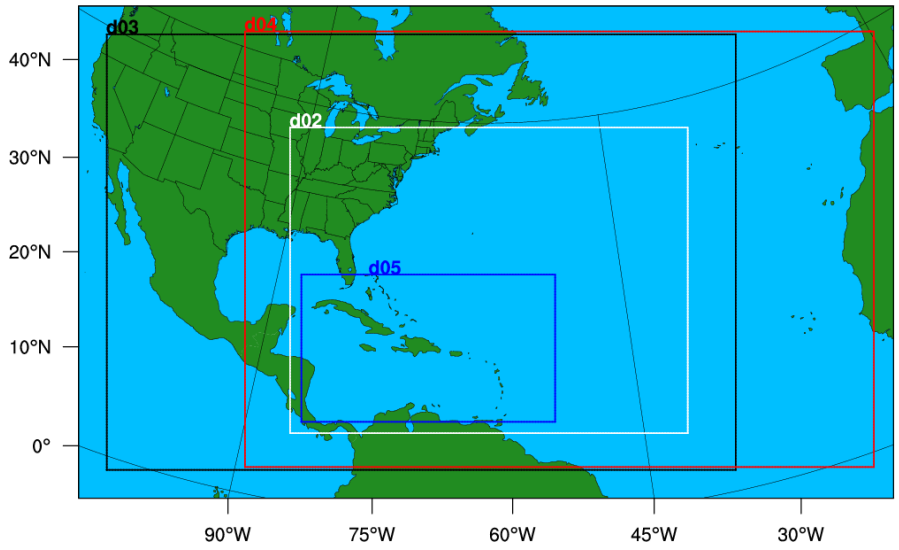
- Cannot deal with .ncgm files

Model Domain Design

```
mpres@mpFillColors  =
 (/"background","DeepSkyBlue",
 "ForestGreen","DeepSkyBlue",
 "transparent"/)


mpres@mpGridSpacingF    = 45


lnres@domLineColors     = (/
 "white", "Red" , "Red" , "Blue" /)


mpres@mpOutlineBoundarySets
 "NoBoundaries"   ; "Geophysical"
 "National"       ; "USStates"
 "GeophysicalAndUSStates"
 "AllBoundaries"
pares = True
 pmres@gsMarkerColor = "White"
 pmres@gsMarkerIndex = 16
 pmres@gsMarkerSizeF = 0.01
 gsn_polymarker(wks,mp,-77.26,38.56
 ,
                  pmres)
```

- plotgrids.ncl
  - *WPS/util/plotgrids.ncl*
  - Reads namelist information to generate plot
  - X11, png, pdf

Test Domain

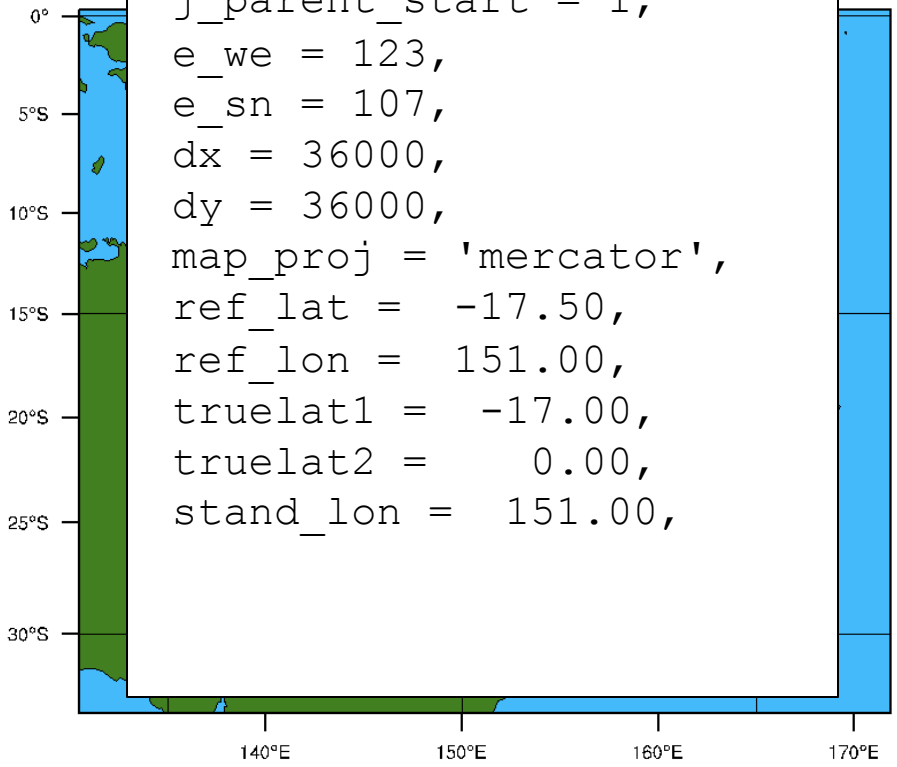


Model Domain Design

```
DOMS = 1
DX = 36.
MAP = "mercator"
LAT1 = (/ -35.0, -45., -27. /)
LAT2 = (/   0., -20., -23. /)
LON1 = (/ 131., 121., 125./)
LON2 = (/ 171., 159., 131./)
parent_id = (/ 0, 1, 2 /)
parent_grid_ratio = (/ 1, 3, 3 /)
```

design_grids.ncl

```
Suggested namelist options
 parent_id = 0,
 parent_grid_ratio = 1,
 i_parent_start = 1,
 j_parent_start = 1,
 e_we = 123,
 e_sn = 107,
 dx = 36000,
 dy = 36000,
 map_proj = 'mercator',
 ref_lat =  -17.50,
 ref_lon =  151.00,
 truelat1 =  -17.00,
 truelat2 =    0.00,
 stand_lon =  151.00,
```

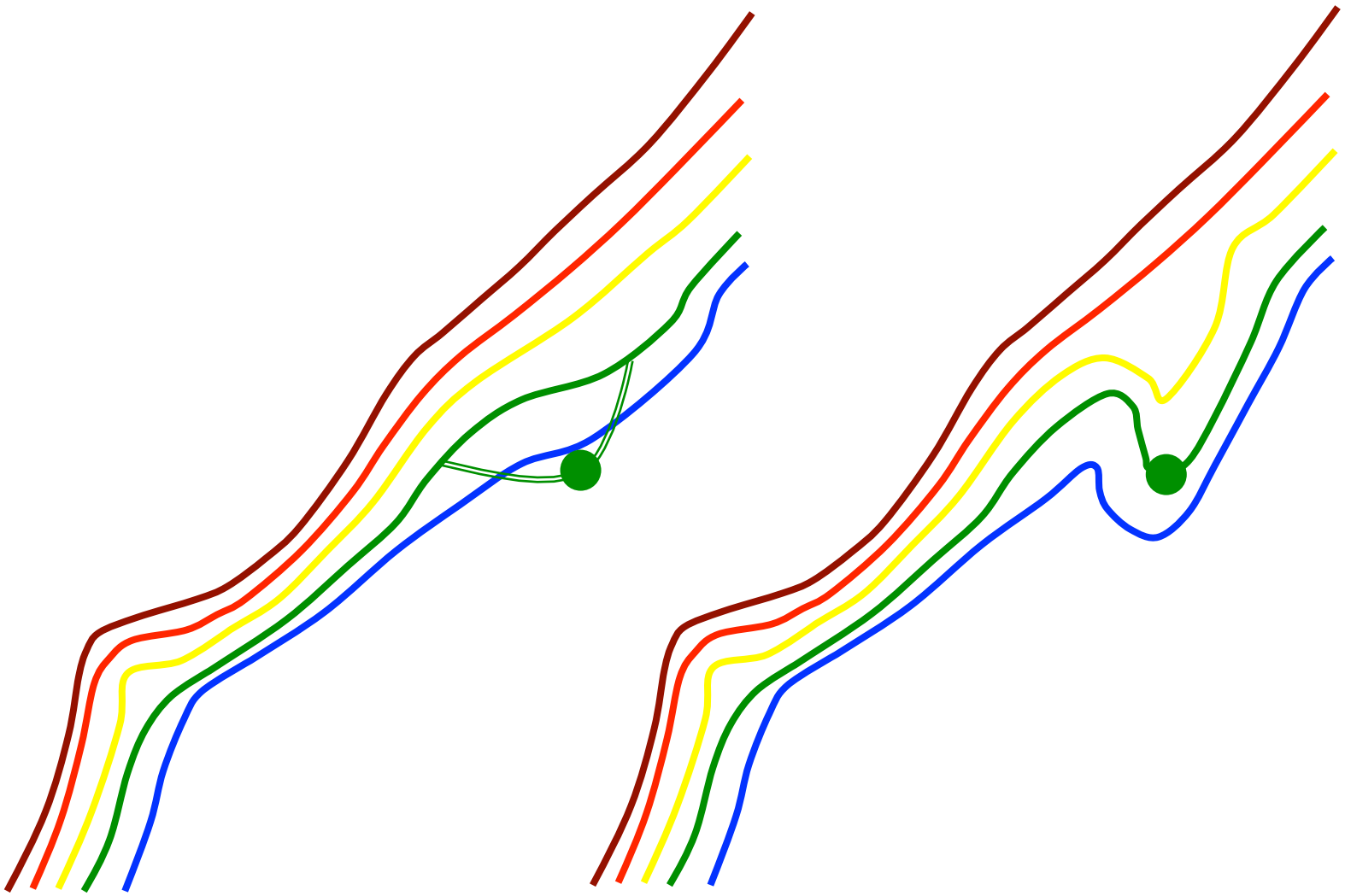


OBSGRID

- To improve a first-guess gridded analysis by incorporating additional observational information
  - Traditionally first-guess analysis came from low-resolution global analysis and forecast grids
  - These days, higher-resolution, regional scale analyses are more readily available

- When is this method useful?
  - When using very coarse resolution first-guess input data
  - If you conducted a field campaign and have acquired very high-resolution station data (for example)

OBSGRID: Basic Concept



OBSGRID: How to Run

- Get the source code

  http://www2.mmm.ucar.edu/wrf/users/download/get_sources.html#utilities

- Compile
- Prepare observation files
- Edit the namelist
- Run the program
- Check your output

See the WRF Users' Guide for detailed information
http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V3/users_guide_chap7.htm

NCO Tools

http://nco.sourceforge.net

- ncdiff
  - Shows the differences between 2 files

```
ncdiff input2.nc input2.nc output.nc
```

- ncrcat (nc cat)
  - Writes specified variables/times to a new file

```
ncrcat -v RAINNC wrfout* RAINNC.nc
ncrcat -d Time,0,231 -v RAINNC wrfout* RAINNC.nc
```

- ncra (nc average)
  - Averages variables and writes to a new file

```
ncra -v OLR wrfout* -o OLR.nc
```

- ncks (nc kitchen sink)
  - Combination of all NCO tools in 1
  - Specifically nice for splitting files

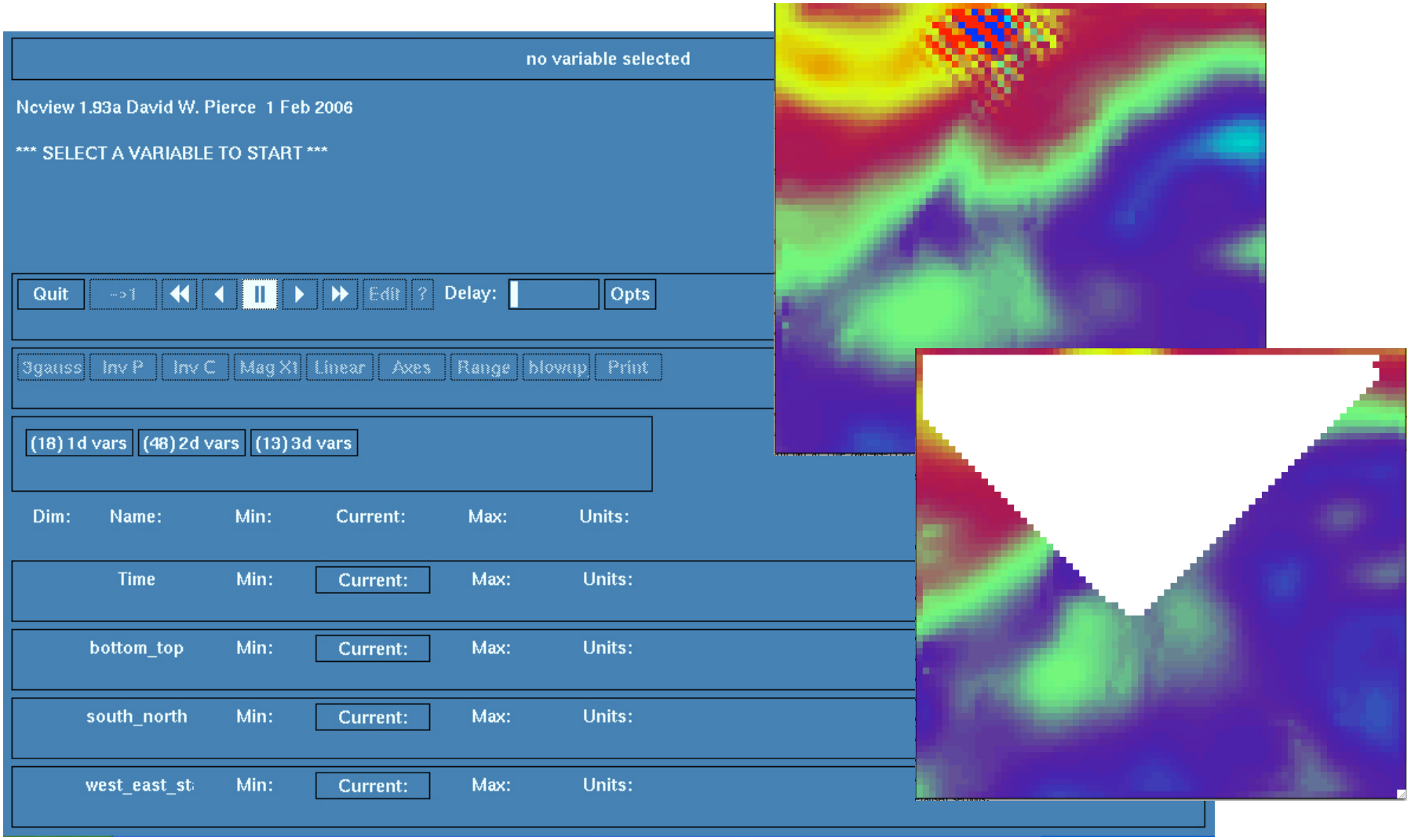
```
ncks -d Time,1,1 wrfout -o wrfout1.nc
```

NCO Tools: Other Available Operators

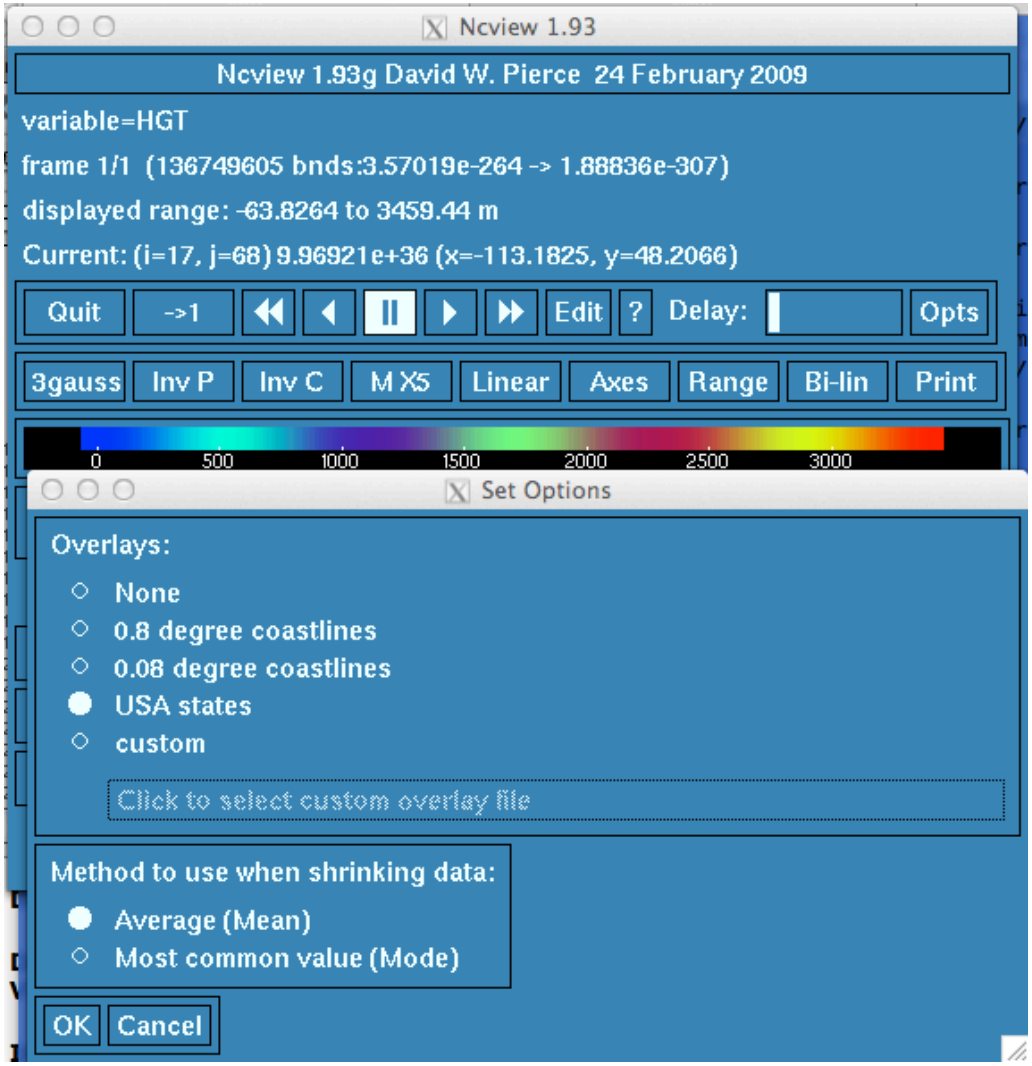
- **ncap2:** arithmetic processor
- **ncatted:** ATTribute editor
- **ncbo:** binary operator (includes ncadd, ncsubtract, ncmultiply, ncdivide)
- **ncea:** ensemble averager
- **ncecat:** ensemble conCATenator
- **ncflint:** FiLe INTerpolator
- **ncpdq:** permute dimensions quickly, pack data quietly
- **ncrename:** RENAME-er
- **ncwa:** weighter averager

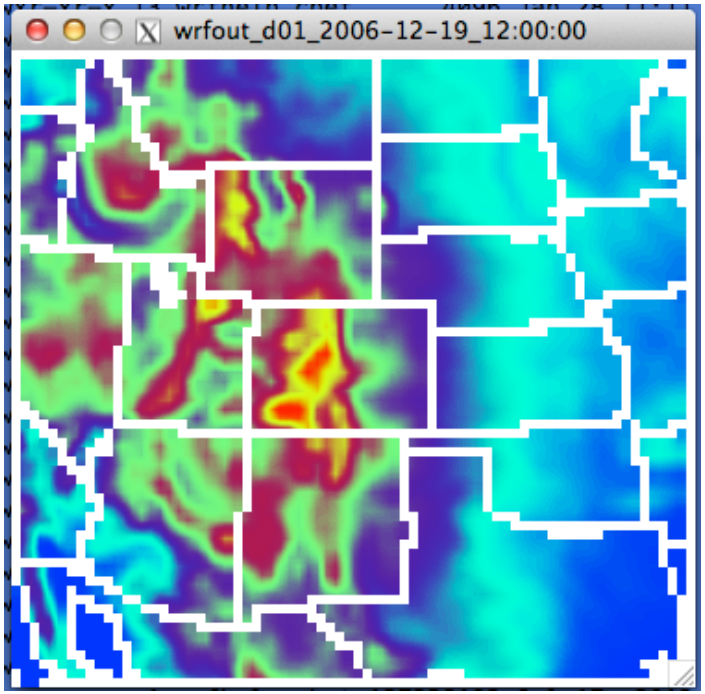
ncview

http://meteora.ucsd.edu/~pierce/ncview_home_page.html



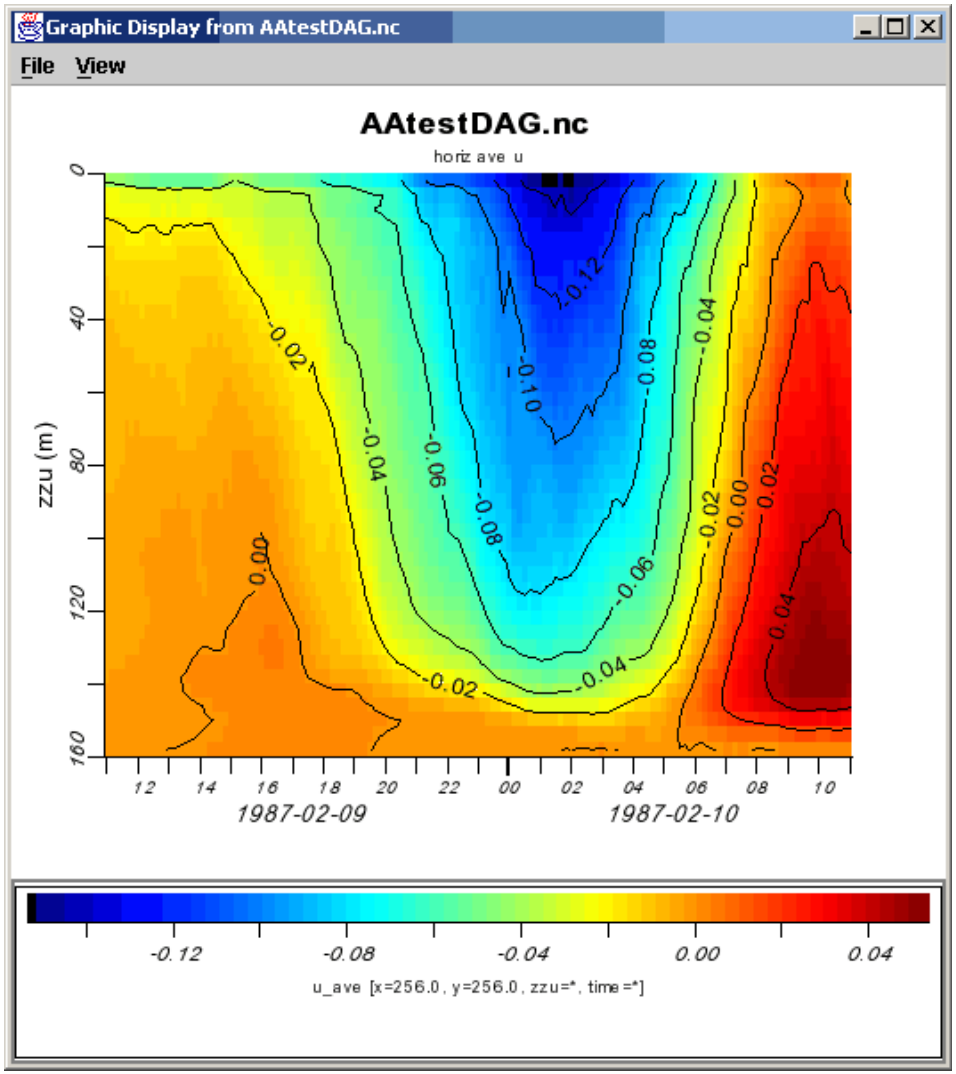
ncview


Ncview 1.93
Ncview 1.93g David W. Pierce 24 February 2009
variable=HGT
frame 1/1 (136749605 bnds:3.57019e-264 -> 1.88836e-307)
displayed range: -63.8264 to 3459.44 m
Current: (i=17, j=68) 9.96921e+36 (x=-113.1825, y=48.2066)
Quit
->1
Edit
?
Delay:
Opts
3gauss
Inv P
Inv C
M X5
Linear
Axes
Range
Bi-lin
Print
0
500
1000
1500
2000
2500
3000
Set Options
Overlays:
None
0.8 degree coastlines
0.08 degree coastlines
USA states
custom
Click to select custom overlay file
Method to use when shrinking data:
Average (Mean)
Most common value (Mode)
OK
Cancel


wrfout_d01_2006-12-19_12:00:00

ncBrowse

http://www.epic.noaa.gov/java/ncBrowse/



ncdump

- Reads a netCDF dataset and prints information from that dataset

- `ncdump -h` *`file`*
  - Prints header (inclusive list of variables in the file)

- `ncdump -v VAR` *`file`*
  - Prints data for the variable 'VAR'

- `ncdump -v Times` *`file`*
  - Prints the times that are included in the file

ncdump –v Times

```
netcdf wrfout_d01_2000-01-24_12:00:00 {
dimensions:
        Time = UNLIMITED ; // (3 currently)
        DateStrLen = 19 ;
        west_east = 73 ;
        south_north = 60 ;
        west_east_stag = 74 ;
        bottom_top = 27 ;
        south_north_stag = 61 ;
        bottom_top_stag = 28 ;
variables:
        char Times(Time, DateStrLen) ;
        float LU_INDEX(Time, south_north, west_east) ;
                LU_INDEX:FieldType = 104 ;
                LU_INDEX:MemoryOrder = "XY " ;
         LU_INDEX:description = "LAND USE CATEGORY" ;
                LU_INDEX:units = "" ;
                LU_INDEX:stagger = "" ;
.....
.....

global attributes:

                :TITLE = " OUTPUT FROM WRF V3.4.1 MODEL";
                :START_DATE = "2000-01-24_12:00:00" ;
                :WEST-EAST_GRID_DIMENSION = 74 ;
                :SOUTH-NORTH_GRID_DIMENSION = 61 ;
                :BOTTOM-TOP_GRID_DIMENSION = 28 ;
                :DX = 30000.f ;
                :DY = 30000.f ;
.....
.....

data:
 Times =
  "2000-01-24_12:00:00",
  "2000-01-24_18:00:00",
  "2000-01-25_00:00:00"
```

Input Data: Mandatory Fields

- **3D Data (data on pressure levels, for example)**
  - Temperature
  - U and V components of wind
  - Geopotential Height
  - Relative Humidity
- **2D Data**
  - Surface pressure
  - Mean sea-level pressure
  - Skin temperature
  - 2 meter temperature and relative humidity
  - 10 meter U and V components of wind
- **Recommended Fields**
  - LANDSEA
  - Soil data (temperature and moisture) and soil height
  - SST (required for climate runs)
  - Water equivalent snow depth
  - SEAICE

External Data Sources: Global

Name	Resolution	Coverage	Temporal Availability	Website
NCEP/NCAR Reanalysis	2.5°	Global	Jan 1948 – present	http://rda.ucar.edu/datasets/ds090.0
NCEP/DOE Reanalysis	2.5°	Global	Jan 1979 – present	http://rda.ucar.edu/datasets/ds091.0
ERA Interim Data	0.7°	Global	Jan 1979 – present	http://rda.ucar.edu/datasets/ds627.0
ECMWF's Operational Model Analysis	Highest Resolution of the DA and forecast system		Jan 2011 – present	http://rda.ucar.edu/datasets/ds113.0
NCEP GDAS/FNL Reanalysis	0.25°	Global	July 2015 – present	http://rda.ucar.edu/datasets/ds083.3
GFS Real-time	1°	Global		http://www.emc.ncep.noaa.gov
NCEP GFS/FNL Reanalysis	1°	Global	Aug 1999 – present	http://rda.ucar.edu/datasets/ds083.2
GFS Gridded Model Data	0.5°	Global	Dec 2002 – present	http://rda.ucar.edu/datasets/ds335.0
NCEP GFS 0.25°	0.25°	Global	Jan 2015 – present	http://rda.ucar.edu/datasets/ds084.1

External Data Sources: North America

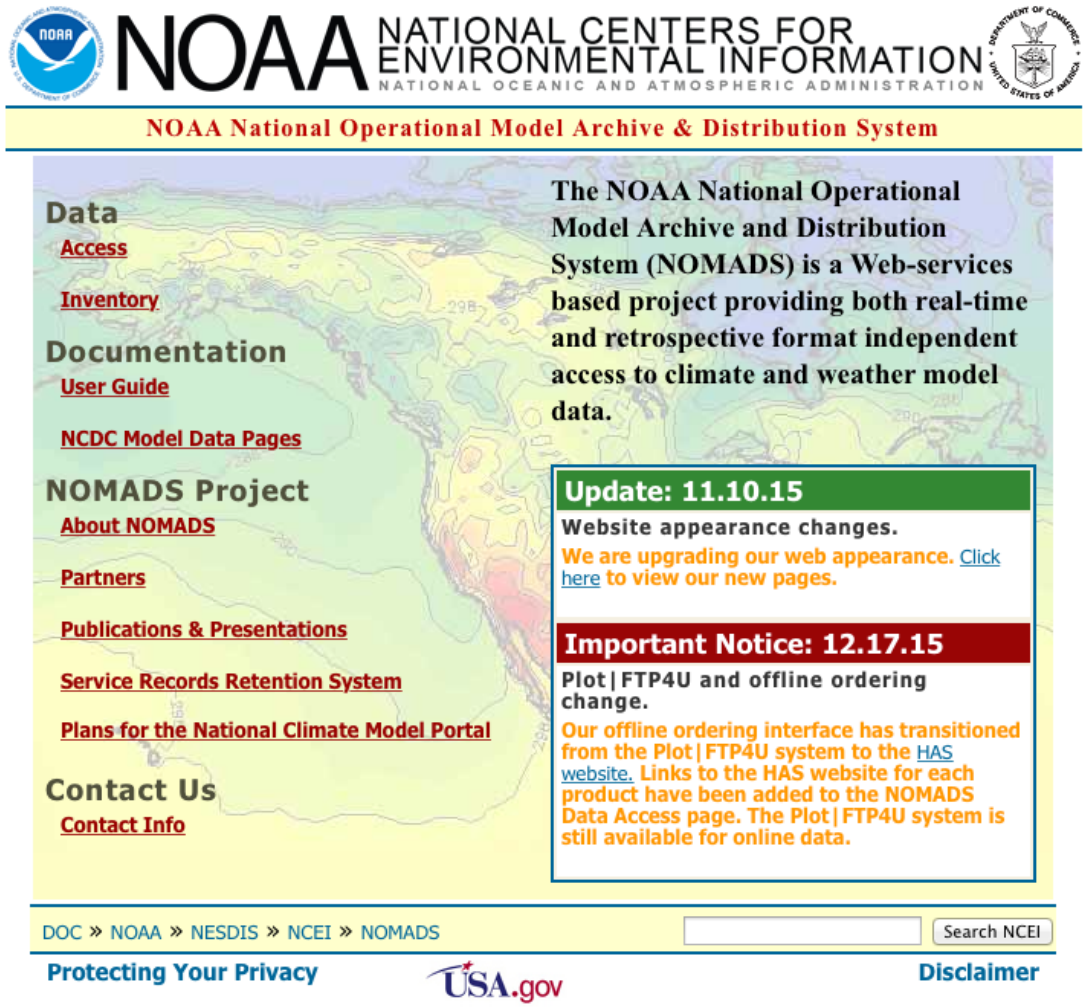
Name	Resolution	Coverage	Temporal Availability	Website
NAM Real-time	32/12 km	North America		http://www.emc.ncep.noaa.gov
NAM Analysis	12 km	North America	Jan 2012 – present	http://rda.ucar.edu/datasets/ds609.0
GCIP NCEP Eta	40 km	North America	April 1995 – present	http://rda.ucar.edu/datasets/ds609.2
NCEP NARR	32 km	North America	Nov 1979 – present	http://rda.ucar.edu/datasets/ds608.0

External Data Sources: Climate

Name	Resolution	Coverage	Temporal Availability	Website
NCEP Climate Forecast System Reanalysis (CFSR)	38 km	Global	Jan 1979 – Dec 2010	http://rda.ucar.edu/datasets/ds093.0
NCEP Climate Forecast System Reanalysis II (CFSR2)	0.2°	Global	Jan 2011 – present	http://rda.ucar.edu/datasets/ds094.0
NCAR CESM CMIP5 data (netCDF format)		Global	Jan 1950 – present	http://rda.ucar.edu/datasets/ds316.0
NCAR CESM CMIP5 data (IM – Bias Corrected)		Global	Jan 1951 – present	http://rda.ucar.edu/datasets/ds316.1
SST DATA				
NCEP SST Analysis	1° - 1/12°	Global		http://polar.ncep.noaa.gov/sst
NOMAD3 SST	1° - 0.25°	Global	Jan 1854 – present (depending which product)	http://nomads.ncdc.noaa.gov/data.php
NCEP & NCDC Reconstructed SST	1°	Global	Jan 1854 - present	http://rda.ucar.edu/datasets/ds277.0

External Data Sources: NOMADS

http://nomads.ncdc.noaa.gov



NAM
GFS
RUC
CFS
NARR
R1/R2
SST

GRIB Data Handling

- Documents and decoders
  - GRIB1 and GRIB2
    wgrib, wgrib2, unpackgrib2.c, grib2to1.c
    http://rda.ucar.edu/#!GRIB

- **g1print.exe** and **g2print.exe**
  - Show data available in GRIB1 and GRIB2 files
  - Available from util/ directory in WPS

- **grib2ctl.pl**
  - Create .ctl and .idx files, so that you can plot GRIB files with GrADS
  - http://www.cpc.ncep.noaa.gov/products/wesley/grib2ctl.html

- **ncl_convert2nc**
  http://www.ncl.ucar.edu/Document/Tools/ncl_convert2nc.shtml

Writing Intermediate File Format

- http://www2.ucar.edu/wrf/users/docs/user_guide_V3/users_guide_chap3.htm#_Writing_Meteorological_Data

- **wrf_wps_write_int**

```
FIELD = "SST"
UNITS = "K"
DESC = "Sea Surface Temperature"

opt = True
opt@map_source                = "ERA-I Data"
opt@projection                = 0
opt@startloc                  = "SWCORNER"
opt@startlon                  = 0.0
opt@startlat                  = -90.0
opt@deltalon                  = 1.25
opt@deltalat                  = 0.942408
opt@is_wind_earth_relative    = False
opt@date                      = "2015-07-26_00:00:00"
opt@level                     = 200100.

wrf_wps_wrtie_int(IM_name,FIELD,UNITS,DESC,VAR(:,:),opt)
```

Reading Intermediate Format Files

- **wrf_wps_read_int**

! opens file

istatus = wrf_wps_open_int(*filename)*

! reads header

wrf_wps_rdhead_int(istatus,head_real,field,h
date, \
units,map_source,desc)

! reads slab

Slab = wrf_wps_rddata_int(istatus,nx,ny)

! Loop until reaching the end of the file

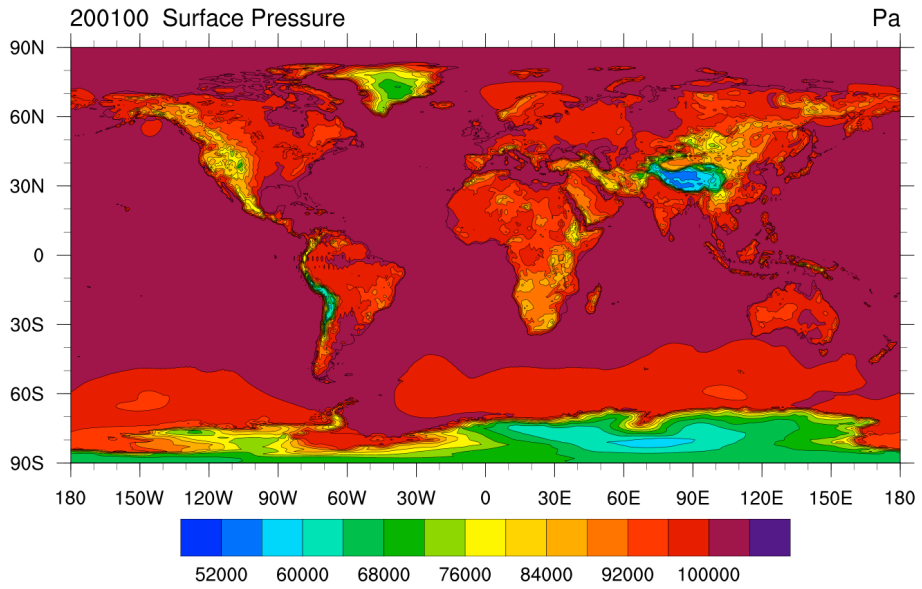
- **rd_intermediate**

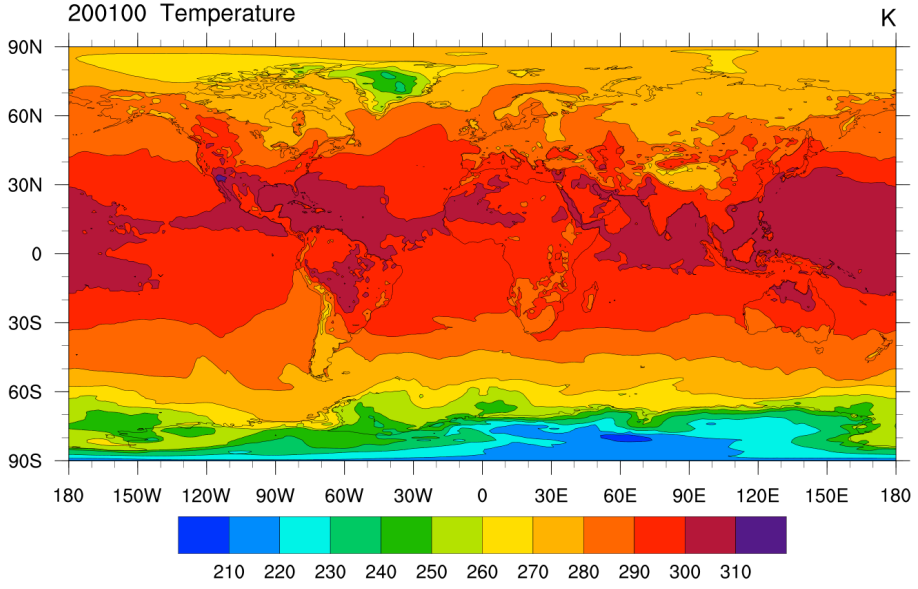
```
========================================
FIELD = TT
UNITS = K DESCRIPTION = TEMPERATURE
DATE = 2000-01-24_12:00:00 FCST = 0.000000
SOURCE = unknown model from NCEP GRID 212
LEVEL = 200100.000000
I,J DIMS = 185, 129
IPROJ = 1
   REF_X, REF_Y = 1.000000, 1.000000
   REF_LAT, REF_LON = 12.190000, -133.459000
   DX, DY = 40.635250, 40.635250
   TRUELAT1 = 25.000002
DATA(1,1) = 295.910950
========================================
```

Utility: plotfmt

- The plotfmt program plots the fields in the ungrib intermediate files

```
ncl plotfmt.ncl 'filename= FNL:2007-09-15_00"
```



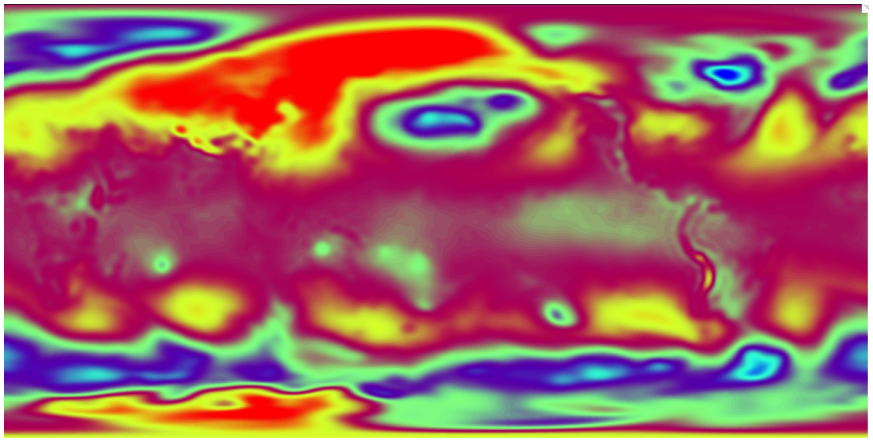


Plotting Intermediate Files in netCDF Format

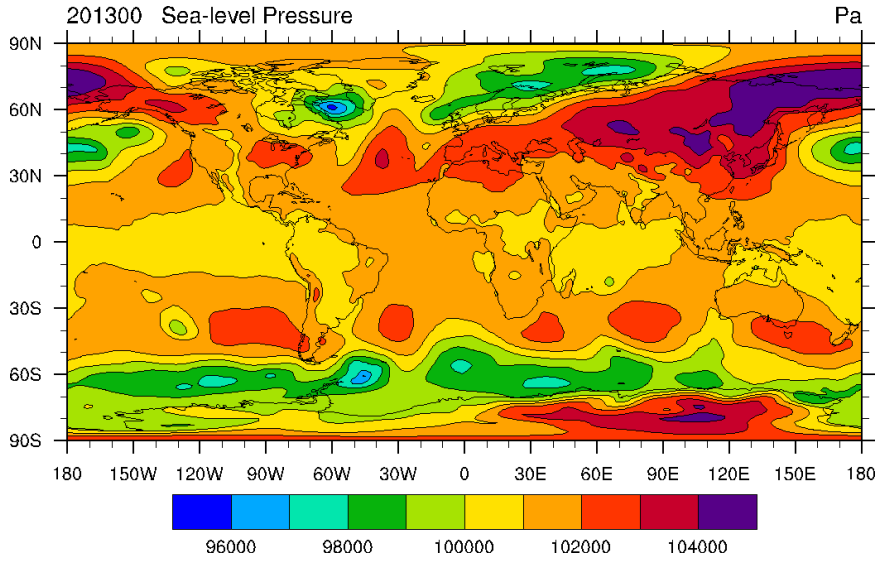
- Use the utility **int2nc.exe**
  - Converts intermediate files created by ungrib.exe to netcdf format
  - `./int2nc.exe`
- To plot: **plotfmt_nc.ncl**

```
ncl plotfmt_nc.ncl 'filename= FNL:2007-09-15_00"
```

Plot Using ncview



Plot Using plotfmt_nc.ncl



Special WRF Output Variables

- The WRF model outputs the state variables defined in the Registry file, and these state variables are used in the model's prognostic equations. Some of these variables are perturbation fields and therefore, the following definitions for reconstructing meteorological variables are necessary:

Total geopotential	PH + PHB
Total geopotential height in m	(PH + PHB) / 9.81
Total potential temp in K	T + 300
Total pressure in mb	(P + PB) * 0.01
Wind components, grid relative	U, V
Surface pressure in Pa	Psfc
Surface winds, grid relative	U10, V10 (valid at mass points)
Surface temp and mixing ratio	T2, Q2

See WRFV3/Registry/Registry.EM_COMMON for description of variables

MET Verification Software

- Model Evaluation Tools (MET)
- Provides all the basics (e.g., RMSE, bias, skill scores)
- Provides
  - Advanced spatial methods (wavelets, objects)
  - Confidence intervals
- Download it
  http://www.dtcenter.org/met/users/downloads/
- Support
  met_help@ucar.edu
- Documentation
  http://www.dtcenter.org/met/users/docs/overview.php

Questions?