

WRF Data, Utilities & Post-processing

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Input Data

Input Data: Mandatory Fields

- **3D Data (for data on constant pressure levels)**

- Temperature

- U and V components of wind

- Geopotential height

- Relative Humidity (or Specific Humidity)

- **3D Data (for data on native model levels)**

- Temperature

- U and V components of wind

- Geopotential height

- Relative Humidity (or Specific Humidity)

- Pressure

- **2D Data**

- Surface pressure

- Mean sea-level pressure

- Skin temperature/SST

- 2 meter temperature and relative humidity

- 10 meter U and V components of wind

- Soil data (temperature and moisture) and soil height

- * Recommended Fields**

- LANDSEA mask field for input data

- Water equivalent snow depth

- SEAICE

- Additional SST data

External Data Sources: Global

Name	Resolution	Coverage	Temporal Availability	Website
NCEP/NCAR Reanalysis (R1/NNRP)	209 km 6-hourly	Global	Jan 1948 - present	http://rda.ucar.edu/datasets/ds090.0
NCEP/DOE Reanalysis (R2)	209 km 6-hourly	Global	Jan 1979 - present	http://rda.ucar.edu/datasets/ds091.0
ERA Interim Data	1.125° - 0.703° 6-hourly	Global	Jan 1979 - present	http://rda.ucar.edu/datasets/ds627.0
ECMWF's Operational Model Analysis	Varying		Jan 2011 - present	http://rda.ucar.edu/datasets/ds113.0
NCEP GDAS/FNL Reanalysis	0.25° 6-hourly	Global	July 2015 - present	http://rda.ucar.edu/datasets/ds083.3
GFS Real-time	1°	Global		ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/gfs
NCEP GFS/FNL Reanalysis	1° 6-hourly	Global	Aug 1999 - present	http://rda.ucar.edu/datasets/ds083.2
GFS Gridded Model Data	0.5° 24-hourly	Global	Dec 2002 - present	http://rda.ucar.edu/datasets/ds335.0
NCEP GFS 0.25°	0.25° 3-hourly & 12-hourly	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 6-hourly	North America		ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/nam
NAM Analysis	12 km 6-hourly	North America	Jan 2012 - present	http://rda.ucar.edu/datasets/ds609.0
GCIP NCEP Eta	40 km 3-hourly & 6-hourly	North America	April 1995 - present	http://rda.ucar.edu/datasets/ds609.2
NCEP NARR	32 km 3-hourly	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)	0.3° to 2.5° 6-hourly	Global	Jan 1979 - Dec 2010	http://rda.ucar.edu/datasets/ds093.0
NCEP Climate Forecast System Reanalysis II (CFSv2)	0.2° to 2.5° 6-hourly	Global	Jan 2011 - present	http://rda.ucar.edu/datasets/ds094.0
NCAR CESM CMIP5 data (netCDF format)	6-hourly	Global	Jan 1950 - 2100	http://rda.ucar.edu/datasets/ds316.0
NCAR CESM CMIP5 data (IM - Bias Corrected)	6-hourly	Global	Jan 1951 - 2100	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° - 2°	Global	Jan 1854 - Dec 2015	http://rda.ucar.edu/datasets/ds277.0

External Data Sources: RDA

http://www2.mmm.ucar.edu/wrf/users/download/free_data.html

Available GRIB Datasets from NCAR

Dataset	Spatial Resolution	Temporal Resolution	Temporal Availability	Vtable
NCEP Final Analysis (GFS-FNL) <i>ds083.0</i>	2.5 degree	12-hourly	1997-04-01 to 2007-06-30	Vtable.GFS
NCEP Final Analysis (GFS-FNL) <i>ds083.2</i>	1 degree	6-hourly	1999-07-30 to current	
NCEP GDAS Final Analysis <i>ds083.3</i>	0.25 degree	6-hourly	2015-07-08 to current	
NCEP GFS <i>ds084.1</i>	0.25 degree	3-hourly (for first 240 hrs) 12-hourly (hrs 240-384)	2015-01-15 to current	
NCEP/NCAR Reanalysis (NNRP) <i>ds090.0</i>	209 km	6-hourly	1948-01-01 to current	Vtable.NNRP
NCEP Climate Forecast System Reanalysis (CFSR) <i>ds093.0</i>	0.3, 0.5, 1.0, 1.9, & 2.5 degree	6-hourly	1979-01-01 to 2011-01-01	Vtable.CFSR_press_pgbh06 & Vtable.CFSR_sfc_flux06
NCEP Climate Forecast System Version 2 (CFSv2) <i>ds094.0</i>	0.2, 0.5, 1.0, and 2.5 degree	6-hourly	2011-01-01 to current	
ECMWF Operational Model Analysis <i>ds113.0</i>	varying		2011-01-01 to current	Vtable.ECMWF
NCEP North American Mesoscale (NAM) <i>ds609.0</i>	12 km	6-hourly	2012-01-01 to current	Vtable.NAM

External Data Sources: RDA

<http://rda.ucar.edu>

Dataset	
NCEP Final Analysis (GFS-FNL) <i>ds083.0</i>	
NCEP Final Analysis (GFS-FNL) <i>ds083.2</i>	
NCEP GDAS Final Analysis <i>ds083.3</i>	
NCEP GFS <i>ds084.1</i>	
NCEP/NCAR Reanalysis (NNRP) <i>ds090.0</i>	
NCEP Climate Forecast System Reanalysis (CFSR) <i>ds093.0</i>	0.
NCEP Climate Forecast System Version 2 (CFSv2) <i>ds094.0</i>	0.
ECMWF Operational Model Analysis <i>ds113.0</i>	
NCEP North American Mesoscale (NAM) <i>ds609.0</i>	

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NCAR UCAR

 **Research Data Archive**
Computational & Information Systems Lab

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 **NCEP GDAS/FNL 0.25 Degree Global Tropospheric Analyses and Forecast Grids**
ds083.3 | DOI: 10.5065/D65Q4T4Z

For assistance, contact [Riley Conroy](#) (303 497-2467).

[Description](#) [Data Access](#) [Documentation](#) [Software](#) [Metrics](#)

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Data Citations: [?](#) This dataset has been cited **13** times.
[▶ Published works that cited this dataset](#)

Abstract: These NCEP FNL (Final) operational global analysis and forecast data are on 0.25-degree by 0.25-degree grids prepared operationally every six hours. This product is from the Global Data Assimilation System (GDAS), which continuously collects observational data from the Global Telecommunications System (GTS), and other sources, for many analyses. The FNLs are made with the same model which NCEP uses in the Global Forecast System (GFS), but the FNLs are prepared

Temporal Range: 2015-07-08 00:00 +0000 to 2019-09-26 03:00 +0000 (Entire dataset)
[▶ Period details by dataset product](#)

Updates: Daily

Variables:

Air Temperature	Albedo	Cloud Frequency	Cloud Liquid Water/Ice
Dew Point Temperature	Evaporation	Geopotential Height	Gravity Wave
Heat Flux	Humidity	Hydrostatic Pressure	Ice Extent



External Data Sources: NOMADS

<http://nomads.ncdc.noaa.gov>

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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The NOAA National Operational Model Archive and Distribution System (NOMADS) is a Web-services based project providing both real-time and retrospective format independent access to climate and weather model data.

Update: 11.10.15
Website appearance changes.
We are upgrading our web appearance. [Click here](#) to view our new pages.

Important Notice: 12.17.15
Plot|FTP4U and offline ordering change.
Our offline ordering interface has transitioned from the Plot|FTP4U system to the [HAS website](#). Links to the HAS website for each product have been added to the NOMADS Data Access page. The Plot|FTP4U system is still available for online data.

DOC > NOAA > NESDIS > NCEI > NOMADS

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NAM
GFS
RUC
CFS
NARR
R1/R2
SST



Utilities

- Grib and Intermediate Data
- Designing a model domain
- netCDF tools
- Other Utilities
- ImageMagick
- Special WRF Output Variables
- OBSGRID
- MET

GRIB Data Handling

■ Documents

- <https://rda.ucar.edu/index.html#gribdoc> (GRIB1 data)
- <https://rda.ucar.edu/index.html#grib2doc> (GRIB2 data)

■ Decoders

- *wgrib, wgrib2, unpackgrib2.c, grib2to1.c*
<http://rda.ucar.edu/#!/GRIB>
<http://www.cpc.ncep.noaa.gov/products/wesley/wgrib.html>
<http://www.cpc.ncep.noaa.gov/products/wesley/wgrib2>
- *g1print.exe and g2print.exe*
 - Show data available in GRIB1 and GRIB2 files
 - Available from util/ directory in WPS

GRIB Data Handling (cont'd)

- **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**

- Converts from grib format to netcdf format
- http://www.ncl.ucar.edu/Document/Tools/ncl_convert2nc.shtml

Writing Intermediate File Format

- http://www2.ucar.edu/wrf/users/docs/user_guide_V4/v4.0/users_guide_chap3.html#_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)

Fortran script to convert netCDF to Intermediate format:

http://www2.mmm.ucar.edu/wrf/users/special_code.html



Reading Intermediate Format Files

NCL Code

▪ wrf_wps_read_int

! opens file

```
istatus = wrf_wps_open_int(filename)
```

! reads header

```
wrf_wps_rdhead_int(istatus, head_real, field, hdate, \
```

```
units, map_source, desc)
```

! reads slab

```
Slab = wrf_wps_rddata_int(istatus, nx, ny)
```

! Loop until reaching the end of the file

Found in WPS/util/

▪ rd_intermediate

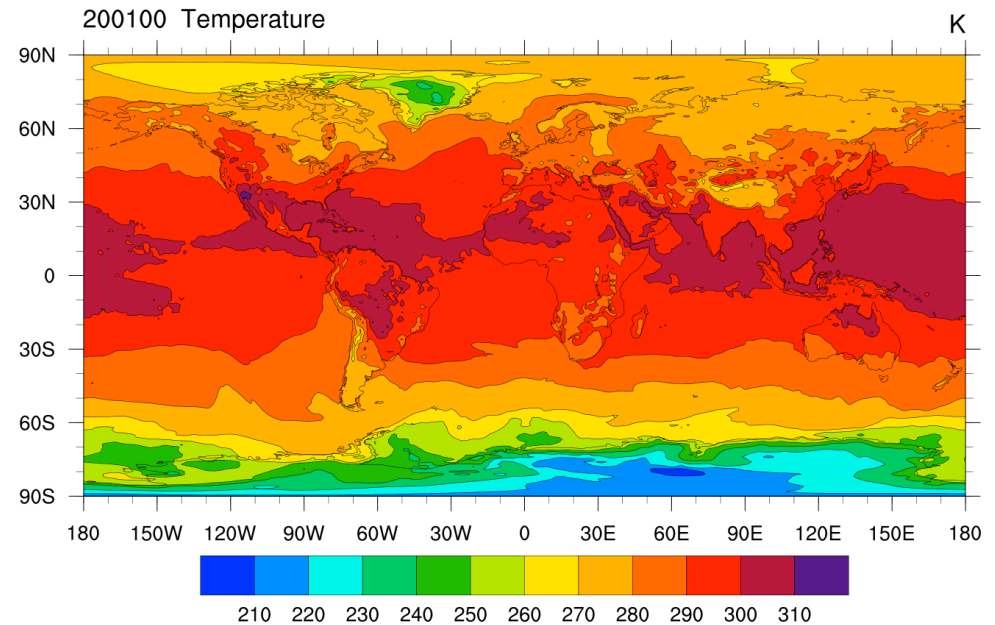
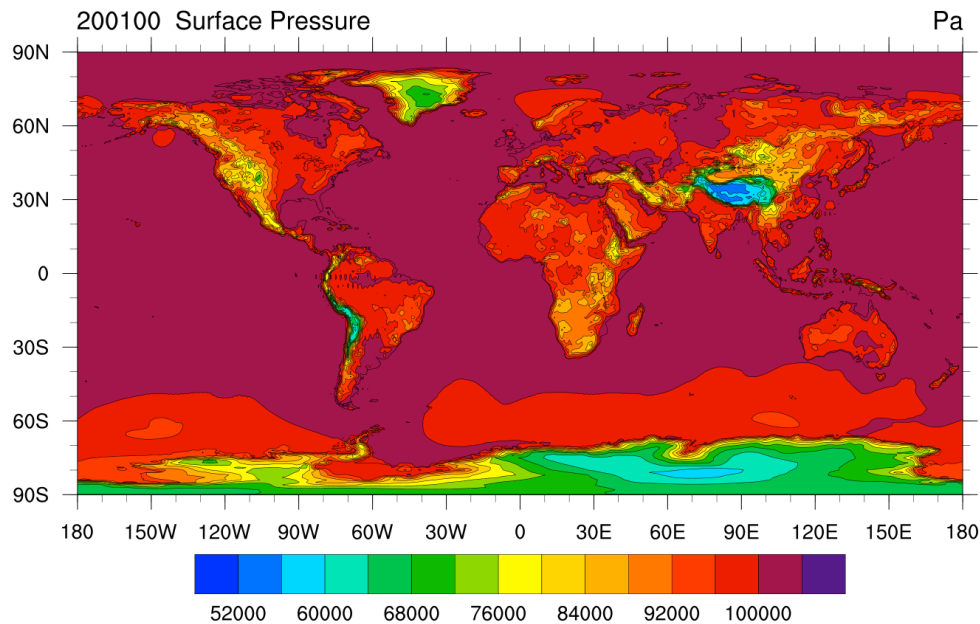
```
=====
FIELD = TT
UNITS = K DESCRIPTION = TEMPERATURE
DATE = 2000-01-24_12:00:00 FCST = 0.000000
SOURCE = unknown model from NCEP GRID 212
LEVEL = 200100.000000
I,J DIMS = 185, 129
IPROJ = 1

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 ungribbed intermediate files

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



Found in WPS/util/

Plot Intermediate Files in netCDF Format

- Use the utility **int2nc.exe**

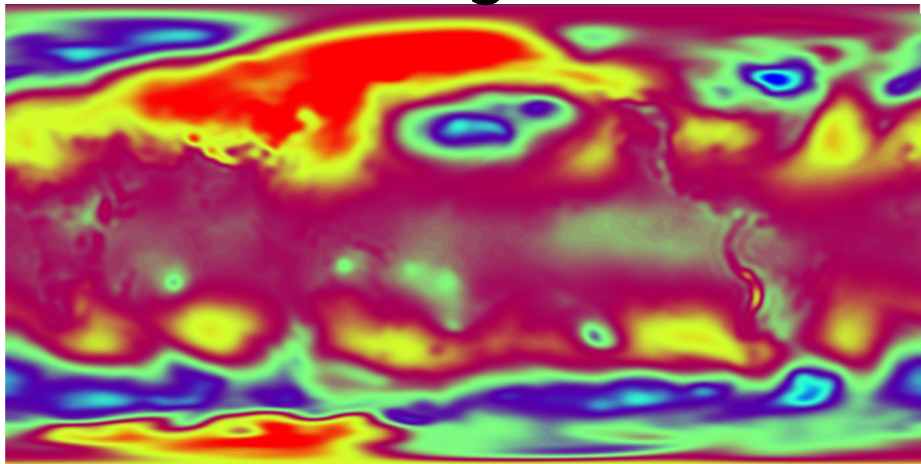
- Converts intermediate files created by `ungrib.exe` to netcdf format

- `./int2nc.exe FILE:yyyy-mm-dd_hh`

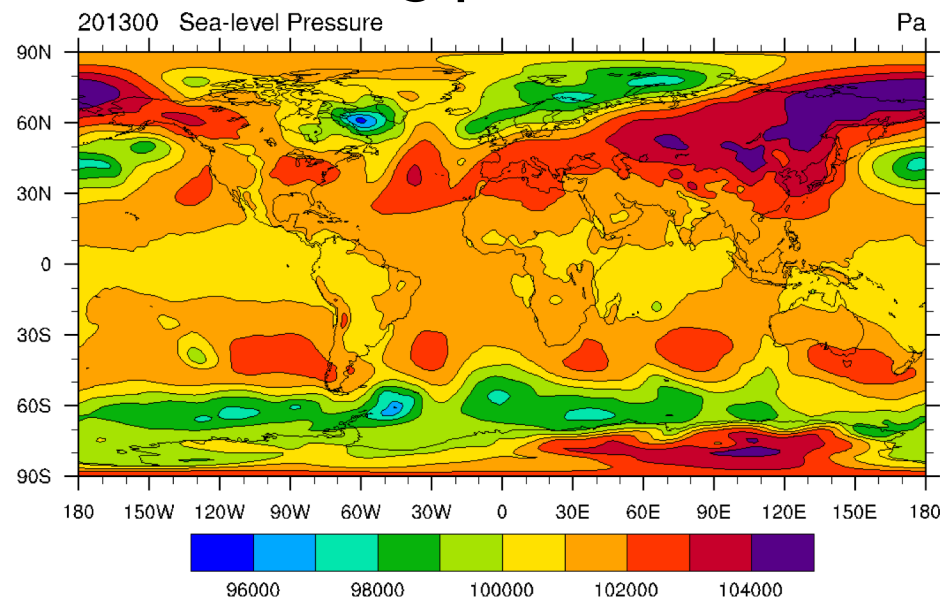
- To plot: **plotfmt_nc.ncl**

```
ncl plotfmt_nc.ncl `inputFILE="FNL:YYYY-MM-DD_HH.nc"``
```

Plot Using ncview



Plot Using plotfmt_nc.ncl



***Both are found in WPS/util/**

Model Domain Design

```
mpres@mpFillColor =  
  (/ "background", "DeepSkyBlue",  
    "ForestGreen", "DeepSkyBlue",  
    "transparent" / )  
  
mpres@mpGridSpacingF = 45  
  
lnres@domLineColors = (/  
  "white", "Red", "Red", "Blue" / )
```

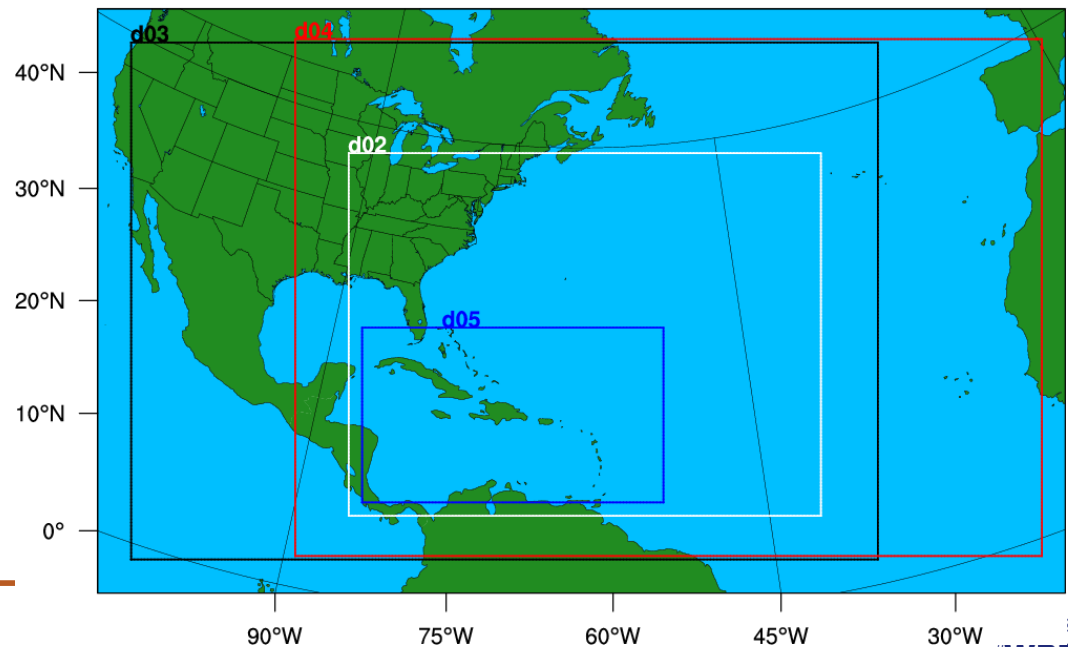
```
mpres@mpOutlineBoundarySets  
  "NoBoundaries" ; "Geophysical"  
  "National" ; "USStates"  
  "GeophysicalAndUSStates"  
  "AllBoundaries"
```

```
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



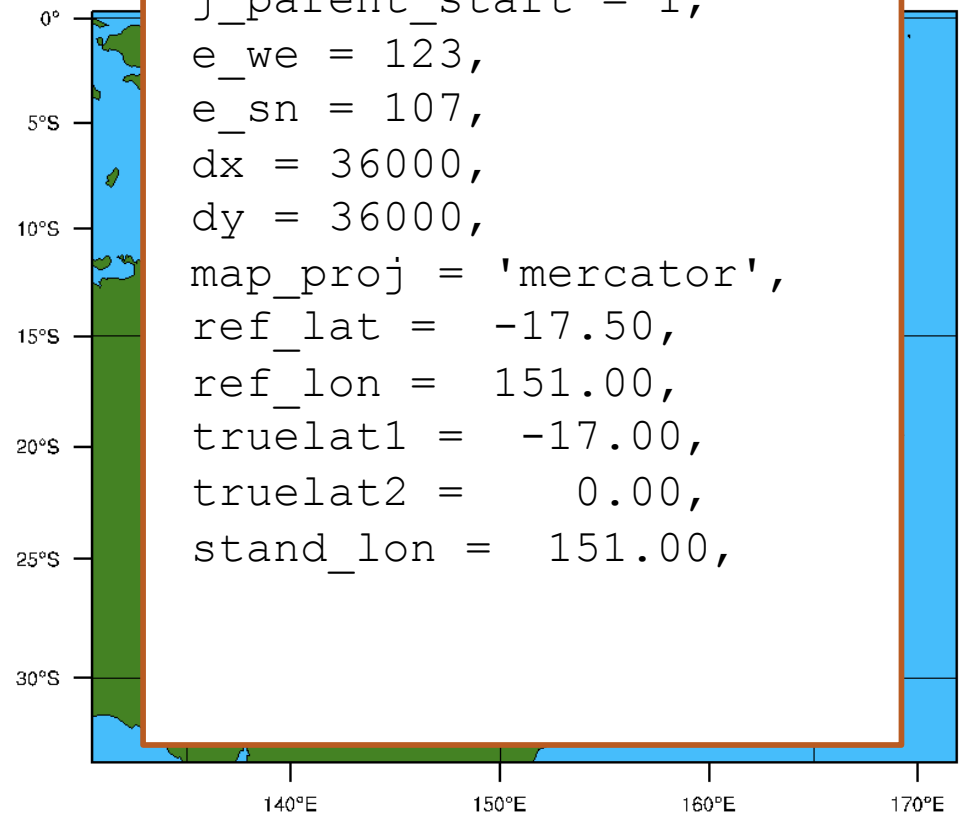
Model Domain Design

```
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,
```



http://www2.mmm.ucar.edu/wrf/users/special_code.html

netCDF Tools

NCO Tools

<http://nco.sourceforge.net>

netCDF Operators:

- command-line programs
- take netCDF input -> perform operation -> output in various formats (text, binary, netCDF, etc.)

Examples:

- **ncdiff**
 - Shows the differences between 2 files
`ncdiff input1.nc input2.nc diff.nc`
- **ncrcat** (nc cat)
 - Writes specified variables/times to a new file, or concatenates files
`ncrcat file1.nc file2.nc combined.nc`
`ncrcat -d Time,0,231 -v RAINNC wrfout* RAINNC.nc`
- **ncra** (nc average)
 - Averages variables in files and writes to a new file
`ncra -v T2 file1.nc file2.nc -o T2.nc`
`ncra -v T2 wrfout* -o T2.nc`

NCO Tools (continued)

<http://nco.sourceforge.net>

- **ncrename**

- Renames variables, dimensions, attributes

```
ncrename -v LANDUSE, LAND -a missing_value, _FillValue  
file.nc
```

- **ncks** (nc kitchen sink)

- Combination of several NCO tools to allow cutting/pasting subsets of data into a new file

- Extracting a specific variable

```
ncks -v RAINNC wrfout_d01_2015-06-01_00:00:00 RAINNC.nc
```

- Splitting files

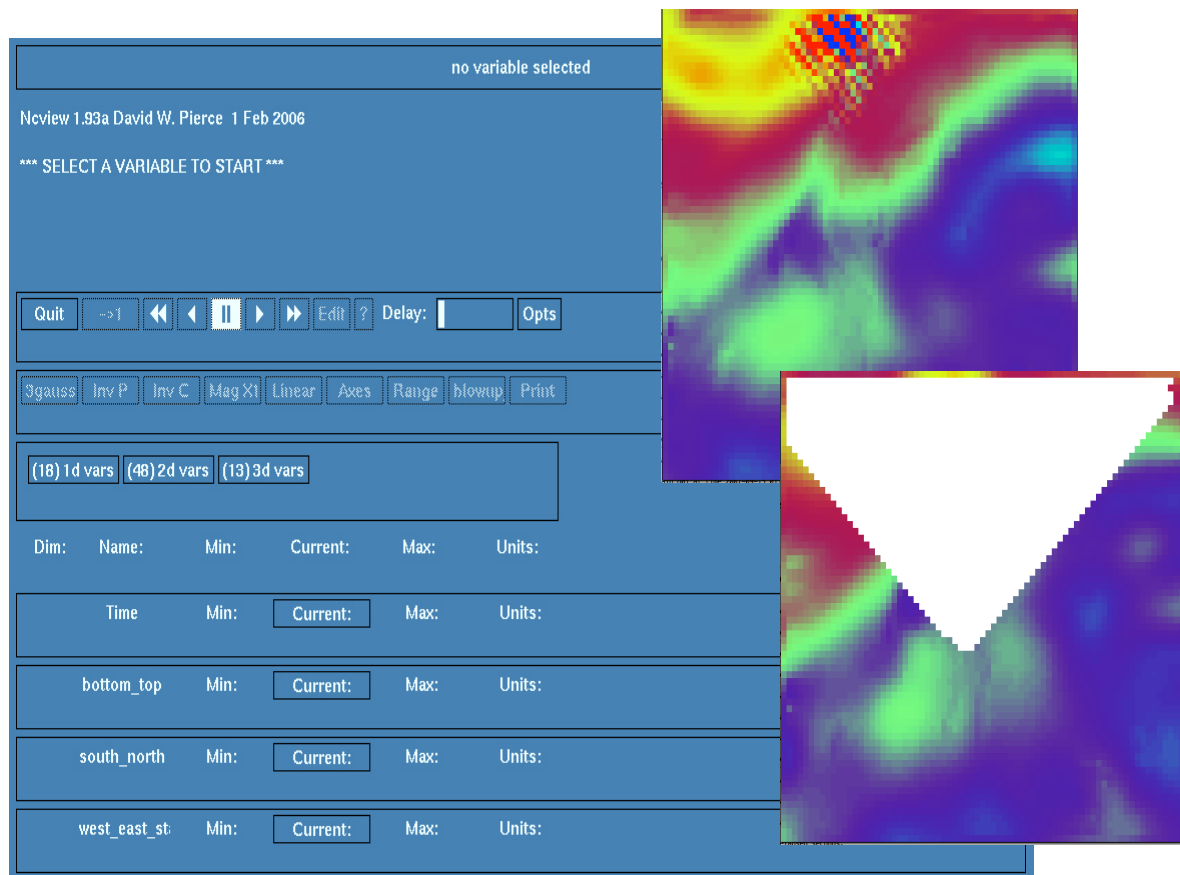
```
ncks -d Time, 1, 1 wrfout -o wrfout1.nc
```

NC0 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
- **ncwa:** weighted averager

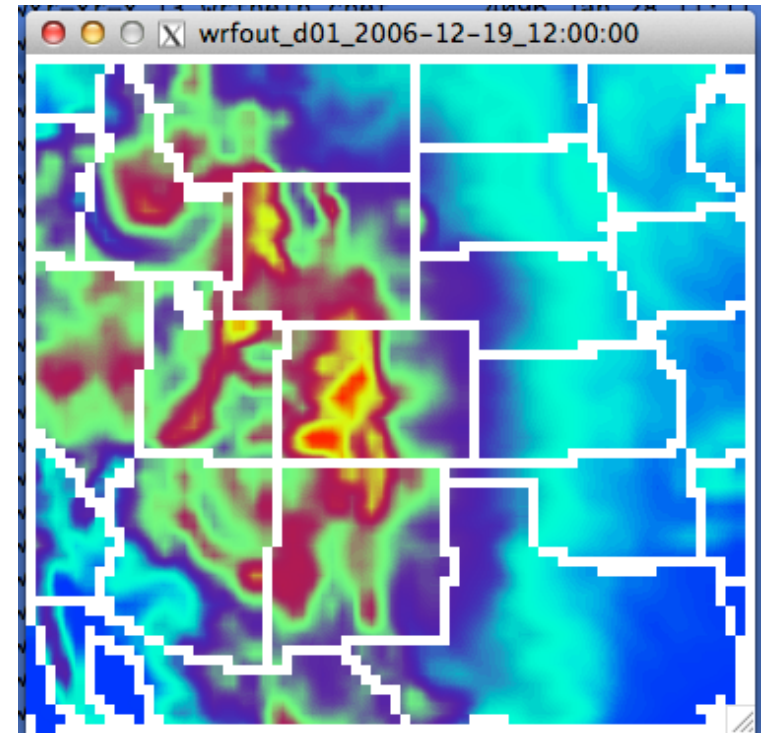
ncview

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



- Graphical interface that allows quick viewing of netCDF files
 - All variables found in file
 - Detect where things go wrong
- Other options
 - Time series
 - Vertical Cross Section
- Any netCDF format file:
 - geo_em.d0*
 - met_em.d0*
 - wrfinput_d0*
 - wrfout.d0*
 - wrfst.d0*

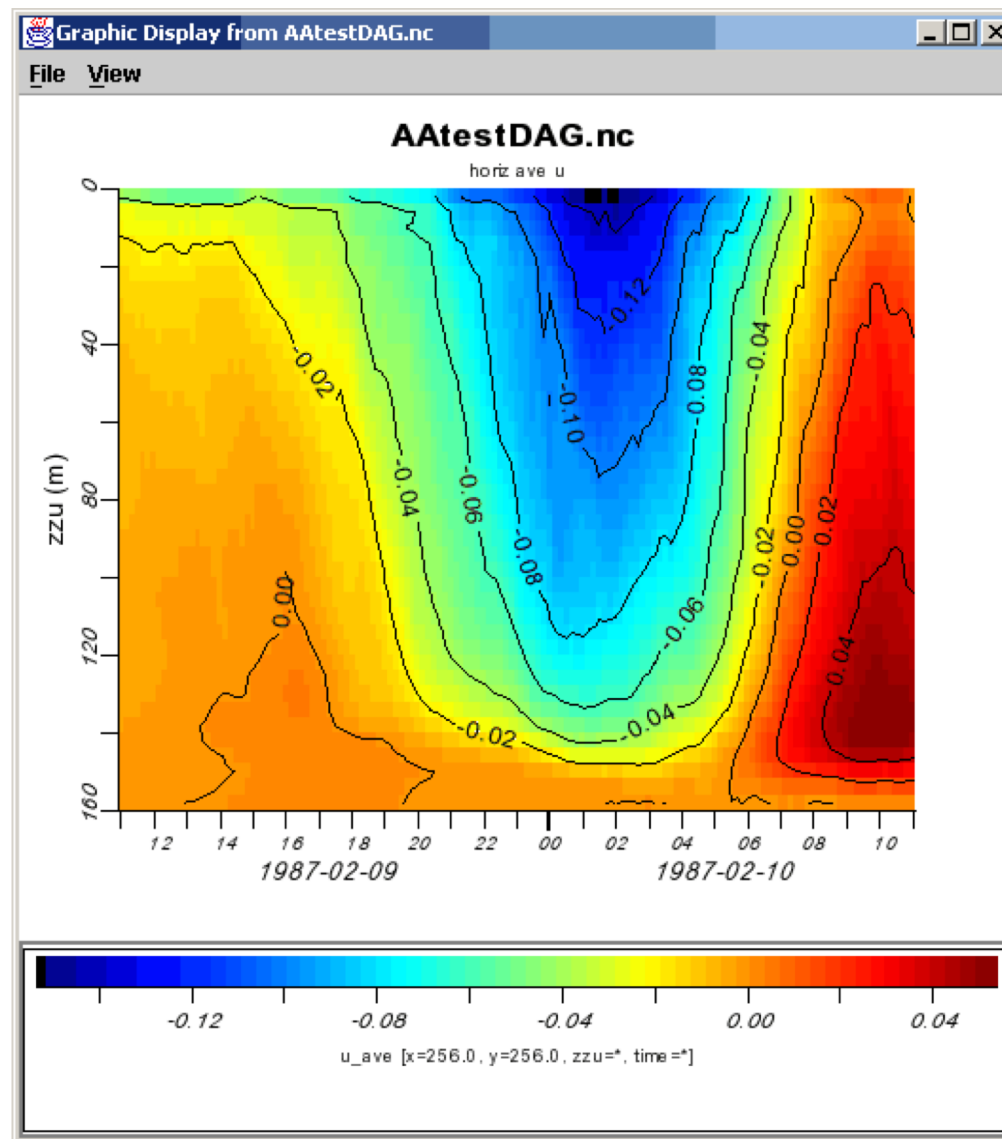
ncview



- Beginning WRFV3.7
- Works with wrfinput* and wrfout* files
- Must have 1 time period per file
i.e, frames_per_outfile = 1

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 specific data for the variable 'VAR'
- **ncdump -v *Times file***
 - Prints the times that are included in the file

ncdump -v Times *file*

```
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"
```

Other Utilities

- Additional utilities

- **read_wrf_nc**: reads WRF netCDF file, outputs various data
- **iowrf**: extracts a box from WRF netCDF files, thin or destagger data
- **wrf_interp**: interpolates WRF output files to pressure, height-agl, height-msl, potential temp, and equivalent potential temp, and can perform underground extrapolation
- **p_interp**: converts wrfout data (from sigma levels) to pressure levels
- **v_interp**: adds vertical levels in WRF input and boundary files
- **diffwrf**: performs several functions, including making comparisons of two WRF files (available in WRF/external/io_netcdf/)
- For more details on the above utilities, see:
<http://www2.mmm.ucar.edu/wrf/users/utilities/util.htm>

- To download utilities:

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

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.
 - 2 ways to use
 - 1) *display plot.png*
 - 2) *Convert -trim +repage -background white -flatten plot.pdf plot.png*
- Can make movies
 - Can create individual frames for each image
- Maintains high resolution - great for publishing!
- Cannot deal with .ncgm files

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

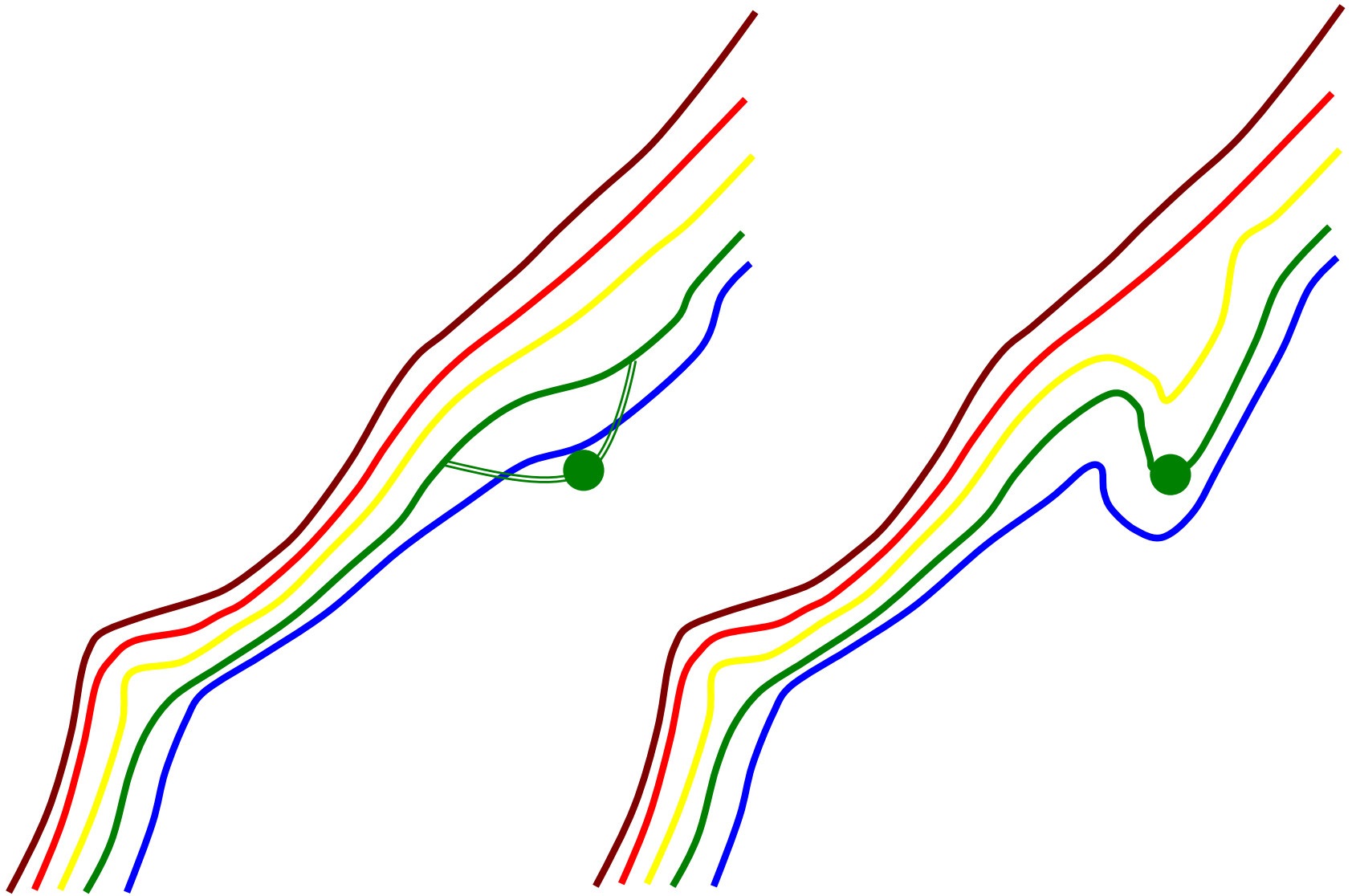
See [WRF/Registry/Registry.EM_COMMON](#) for description of variables

OBSGRID

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/downloads.html>

- Compile (serially)
- Prepare observation files
- Edit the namelist.oa
- Link in met_em* files from WPS
- Run the program
 - ./obsgrid.exe
- Check your output

See the WRF Users' Guide for detailed information:

http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V4/v4.0/users_guide_chap7.htm

OBSGRID: Output

- **metoa_em***

- Final analysis files at sfc and pressure levels
- Can be used to replace met_em* files during real.exe

- **wrfsfdda_d0***

- Contains sfc analyses for T, TH, U, V, RH, QV, PSFC, PMSL, and a count of obs within 250 km of each grid point
- Use as input for surface analysis nudging (in &fdda section of namelist, set grid_fdda = 1 and **grid_sfdda = 1**)

- **OBS_DOMAIN*01** (e.g., OBS_DOMAIN101, OBS_DOMAIN103)

- Contain list of all observations available to OBSGRID program
- User has option to set values > a specified value to “missing”
- Used during WRF for observational nudging
- Must all be concatenated into a single file (OBS_DOMAIN101)
 - Use ‘run_cat_obs_files.csh’ to do this

OBSGRID: Output (continued)

- **qc_obs_raw.d01.YYYY-MM-DD_HH:mm:ss.tttt(.nc)**
 - Similar to OBS_DOMAINXXX, but raw data, and output is in either ASCII or netCDF format
 - ASCII file can be used as input to plotting utility “plot_sounding.exe”
 - NetCDF file can be used to plot both station & sounding data
- **qc_obs_used.d01.YYYY-MM-DD_HH:mm:ss.tttt(.nc)**
 - Same as above (can be used in the same way), but identical data to OBS_DOMAIN*01 files
- **qc_obs_used_earth_relative.d01.YYYY-MM-DD_HH:mm:ss.tttt(.nc)**
 - Identical to above, but winds are in an earth-relative framework, rather than model-relative
 - The non-netCDF version can be used as input to MET verification software
- **plotobs_out.d01.YYYY-MM-DD_HH:mm:ss.tttt**
 - Lists data by variable and by level
 - Each observation used for objective analysis is grouped with all associated observations for plotting or other diagnostic purposes

OBSGRID: Plot Utilities

- **sounding.ncl (found in util/)**
 - Generates & plots soundings from qc_obs_raw* and qc_obs_used*
- **station.ncl (found in util/)**
 - creates station plots for each analysis level

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?