WRF Data and Utilities

Kelly Werner
July 2016
## Supported Post-processing Packages

http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V3.8/contents.html

<table>
<thead>
<tr>
<th>Package</th>
<th>Users’ Guide Page #</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCL</td>
<td>9-2</td>
<td>Graphical package Supported by NCAR/CISL (<a href="mailto:wrfhelp@ucar.edu">wrfhelp@ucar.edu</a> and <a href="mailto:ncl-talk@ucar.edu">ncl-talk@ucar.edu</a>)</td>
</tr>
<tr>
<td>ARWpost</td>
<td>9-29</td>
<td>Converter (GrADS) (<a href="mailto:wrfhelp@ucar.edu">wrfhelp@ucar.edu</a>)</td>
</tr>
<tr>
<td>RIP4</td>
<td>9-20</td>
<td>Converter and interface to graphical Package, NCAR graphics (<a href="mailto:wrfhelp@ucar.edu">wrfhelp@ucar.edu</a>)</td>
</tr>
<tr>
<td>UPP</td>
<td>9-36</td>
<td>Converter (GrADS &amp; GEMPAK) (<a href="mailto:upp-help@ucar.edu">upp-help@ucar.edu</a>)</td>
</tr>
<tr>
<td>VAPOR</td>
<td>9-38</td>
<td>Converter and graphical package Supported by VAPOR (<a href="mailto:vapor@ucar.edu">vapor@ucar.edu</a>)</td>
</tr>
<tr>
<td>IDV</td>
<td>None – see unidata.ucar.edu</td>
<td>GRIB (from UPP) GEMPAK (from wrf2gem) Vis5d CF compliant data (from wrf_to_cf) Supported by unidata (<a href="mailto:support@unidata.ucar.edu">support@unidata.ucar.edu</a>)</td>
</tr>
<tr>
<td>GEMPAK</td>
<td>None - see: unidata.ucar.edu/software/gempak</td>
<td>Data from wrf2gem or UPP Supported by unidata (<a href="mailto:support@unidata.ucar.edu">support@unidata.ucar.edu</a>)</td>
</tr>
</tbody>
</table>
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 are data below the ground handled?
- Vertical grids?
- How are model time stamps handled?
- Easy to use?
- Cost of package?
- How well supported is it?
<table>
<thead>
<tr>
<th></th>
<th>NCL</th>
<th>RIP4</th>
<th>GrADS</th>
<th>UPP</th>
<th>VAPOR</th>
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<tbody>
<tr>
<td>netCDF</td>
<td></td>
<td>ripdp</td>
<td>ARWpost</td>
<td>converter</td>
<td>converter</td>
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<td>GRIB</td>
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<td>geogrid &amp; metgrid output</td>
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<tr>
<td>intermediate file format</td>
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<td>V6.3.0</td>
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<tr>
<td>wrfinput data</td>
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<tr>
<td>Idealized data</td>
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<tr>
<td>Post-processing</td>
<td>NCL</td>
<td>RIP4</td>
<td>GrADS</td>
<td>UPP</td>
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<td>IDV</td>
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<tr>
<td>Post-processing</td>
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<td>Data output</td>
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<tr>
<td>3D</td>
<td></td>
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</tr>
<tr>
<td>diagnostics</td>
<td>some</td>
<td>a lot</td>
<td>some</td>
<td>some</td>
<td>limited</td>
<td>limited</td>
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<tr>
<td>Add diagnostics</td>
<td>Very easy</td>
<td>easy</td>
<td>easy</td>
<td>Relatively easy</td>
<td>Not as easy</td>
<td>Not as easy</td>
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<tr>
<td>Vertical output</td>
<td>Model pressure height</td>
<td>Model pressure height</td>
<td>Model pressure height</td>
<td>pressure</td>
<td>model</td>
<td>model</td>
</tr>
<tr>
<td>Extrapolate Below ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
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
  – Horizontal
  – 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

<table>
<thead>
<tr>
<th>Script Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cbar.gs</td>
<td>Plots a color bar on shaded plots</td>
</tr>
<tr>
<td>rgbset.gs</td>
<td>Allows you to add/change colors from color # 20 – 99</td>
</tr>
<tr>
<td>skew.gs</td>
<td>Program to plot a skewT</td>
</tr>
<tr>
<td>plot_all.gs</td>
<td>Automatically finds all .ctl files in the directory and lists them so the user can pick when to use, will plot all fields chosen</td>
</tr>
<tr>
<td>rain.gs (real data only)</td>
<td>Plots total rainfall (must have data that contain fields RAINC and RAINNC)</td>
</tr>
<tr>
<td>cross_z.gs (real data only)</td>
<td>Plots a NS and EW cross section of RH and T (C)</td>
</tr>
</tbody>
</table>
RIP4
RIP4: Example Plots

- Landuse Category
- Potential Temp
- Circulation Vectors
- Skew-T Diagram
- Potential Vorticity
RIP4: Example Plots

**Cyclone Tracking**
- Trajectories
- Zooming Capability
RIP4: Program Flow

INPUT DATA

RIPDP

RIPDP formats one file per TIME & VARIABLE

RIP

[Map Image]
RIP4: General Information

• Requires NCAR Graphics Libraries
  – [http://www.ncl.ucar.edu](http://www.ncl.ucar.edu)

• Source Code
  – [http://www2.mmm.ucar.edu/wrf/users/download/get_source.html](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](http://www2.mmm.ucar.edu/wrf/users/docs/ripug.htm)

• Online Tutorial
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
  
  ```sh
  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

• Maintains high resolution – great for publishing!

• Cannot deal with .ncgm files
Model Domain Design

- plotgrids.ncl
  - \textit{WPS/util/plotgrids.ncl}
  - Reads namelist information to generate plot
  - X11, png, pdf
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
OBSSGRID: How to Run

- Get the source code
  http://www2.mmm.ucar.edu/wrf/users/downloads.html
- Compile
- 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_V3/users_guide_chap7.htm
OBSGRID: How to Use to Run WRF

• Link the ‘metoa_em*’ files to WRF running directory
  
  `ln -sf ../../../OBSGRID/metoa_em.d01.*`

• Add the following to the &time_control section of the namelist
  
  `auxinput1_inname = “metoa_em.d<domain>.<date>”`

• Run real.exe

• Run wrf.exe
• If you are interested in doing surface analysis nudging

• OBSGRID creates a file called wrfsfdda_d0*

• How to use this:
  – In &fdda, set grid_fdda = 1 and grid_sfdda = 1
  – Run real.exe and get a file called wrffdda_d01, and use with wrfsfdda_d01, wrfinput_d01, and wrfbdy_d01
  – Run wrf.exe

• For more information, refer to Jimy Dudhia’s ARW Nudging talk
OBSGRID – Observation Nudging

• Allows for input observation data & quality control

• Used if you have a large number of extra observations, and a single case study (not recommended for climate studies)

• Can get obs data from CISL (little R format)

• How to use this
  – OBSGRID creates a files called OBSDOMAIN_XXX (can concatenate files into 1: OBSDOMAIN_101)
  – In &fdda, add obs_nudge_opt = 1
  – In &time_control, add auxinput11_interval_s = 180, auxinput11_end_h = 24
  – Will need OBSDOMAIN_101, wrfinput_d01 and wrfbdy_d01 files
  – Run real.exe and wrf.exe as usual

• For more information, see http://www2.mmm.ucar.edu/wrf/users/wrfv3.1/How_to_run_obs_fdda.html and Jimy Dudhia’s ARW Nudging talk
NCO Tools

http://nco.sourceforge.net

- netCDF Operators are command-line programs that take netCDF (HDF and/or DAP) files as input, then operate (e.g., derive new data, compute stats, print, manipulate metadata) and output to the screen or files in various formats (text, binary, netCDF, etc.)

- ncdiff
  - Shows the differences between 2 files
  ncdiff input1.nc input2.nc output.nc

- ncrcat (nc cat)
  - Writes specified variables/times to a new file
  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, ncssubtract, ncmultiply, ncdivide)
- **ncea**: ensemble averager
- **ncecat**: ensemble conCATenator
- **ncflint**: FiLe INTerpolator
- **ncpq**: permute dimensions quickly, pack data quietly
- **ncrename**: RENAME-er
- **ncwa**: weighted averager
ncview

- Beginning V3.7

- Works with all WRF .nc output files (geo_em*, met_em*, wrfinput*, etc.)

- Must have 1 time period per file
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
Input Data: Mandatory Fields

• **3D Data (data on pressure levels, for example)**
  - Temperature
  - U and V components of wind
  - Geopotential Height
  - Relative Humidity/Specific Humidity

• **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
## External Data Sources: Global

<table>
<thead>
<tr>
<th>Name</th>
<th>Resolution</th>
<th>Coverage</th>
<th>Temporal Availability</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP/NCAR Reanalysis (R1)</td>
<td>2.5°</td>
<td>Global</td>
<td>Jan 1948 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds090.0">http://rda.ucar.edu/datasets/ds090.0</a></td>
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<tr>
<td>NCEP/DOE Reanalysis (R2)</td>
<td>2.5°</td>
<td>Global</td>
<td>Jan 1979 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds091.0">http://rda.ucar.edu/datasets/ds091.0</a></td>
</tr>
<tr>
<td>ERA Interim Data</td>
<td>0.7°</td>
<td>Global</td>
<td>Jan 1979 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds627.0">http://rda.ucar.edu/datasets/ds627.0</a></td>
</tr>
<tr>
<td>ECMWF’s Operational Model Analysis</td>
<td>Highest Resolution of the DA and forecast system</td>
<td></td>
<td>Jan 2011 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds113.0">http://rda.ucar.edu/datasets/ds113.0</a></td>
</tr>
<tr>
<td>NCEP GDAS/FNL Reanalysis</td>
<td>0.25°</td>
<td>Global</td>
<td>July 2015 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds083.3">http://rda.ucar.edu/datasets/ds083.3</a></td>
</tr>
<tr>
<td>GFS Real-time</td>
<td>1°</td>
<td>Global</td>
<td></td>
<td>ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/gfs</td>
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<tr>
<td>NCEP GFS/FNL Reanalysis</td>
<td>1°</td>
<td>Global</td>
<td>Aug 1999 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds083.2">http://rda.ucar.edu/datasets/ds083.2</a></td>
</tr>
<tr>
<td>GFS Gridded Model Data</td>
<td>0.5°</td>
<td>Global</td>
<td>Dec 2002 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds335.0">http://rda.ucar.edu/datasets/ds335.0</a></td>
</tr>
<tr>
<td>NCEP GFS 0.25°</td>
<td>0.25°</td>
<td>Global</td>
<td>Jan 2015 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds084.1">http://rda.ucar.edu/datasets/ds084.1</a></td>
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## External Data Sources: North America

<table>
<thead>
<tr>
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<th>Resolution</th>
<th>Coverage</th>
<th>Temporal Availability</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAM Real-time</td>
<td>32/12 km</td>
<td>North America</td>
<td></td>
<td>[ftp://ftpprrd.ncep.noaa.gov/pub/data/nccf/com/nam]</td>
</tr>
<tr>
<td>NAM Analysis</td>
<td>12 km</td>
<td>North America</td>
<td>Jan 2012 – present</td>
<td>[<a href="http://rda.ucar.edu/datasets/ds609.0">http://rda.ucar.edu/datasets/ds609.0</a>]</td>
</tr>
<tr>
<td>GCIP NCEP Eta</td>
<td>40 km</td>
<td>North America</td>
<td>April 1995 – present</td>
<td>[<a href="http://rda.ucar.edu/datasets/ds609.2">http://rda.ucar.edu/datasets/ds609.2</a>]</td>
</tr>
<tr>
<td>NCEP NARR</td>
<td>32 km</td>
<td>North America</td>
<td>Nov 1979 – present</td>
<td>[<a href="http://rda.ucar.edu/datasets/ds608.0">http://rda.ucar.edu/datasets/ds608.0</a>]</td>
</tr>
</tbody>
</table>
## External Data Sources: Climate

<table>
<thead>
<tr>
<th>Name</th>
<th>Resolution</th>
<th>Coverage</th>
<th>Temporal Availability</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP Climate Forecast System Reanalysis (CFSR)</td>
<td>38 km</td>
<td>Global</td>
<td>Jan 1979 – Dec 2010</td>
<td><a href="http://rda.ucar.edu/datasets/ds093.0">http://rda.ucar.edu/datasets/ds093.0</a></td>
</tr>
<tr>
<td>NCEP Climate Forecast System Reanalysis II (CFSR2)</td>
<td>0.2°</td>
<td>Global</td>
<td>Jan 2011 – present</td>
<td><a href="http://rda.ucar.edu/datasets/ds094.0">http://rda.ucar.edu/datasets/ds094.0</a></td>
</tr>
<tr>
<td>NCAR CESM CMIP5 data (netCDF format)</td>
<td></td>
<td>Global</td>
<td>Jan 1950 – 2100</td>
<td><a href="http://rda.ucar.edu/datasets/ds316.0">http://rda.ucar.edu/datasets/ds316.0</a></td>
</tr>
<tr>
<td>NCAR CESM CMIP5 data (IM – Bias Corrected)</td>
<td></td>
<td>Global</td>
<td>Jan 1951 – 2100</td>
<td><a href="http://rda.ucar.edu/datasets/ds316.1">http://rda.ucar.edu/datasets/ds316.1</a></td>
</tr>
</tbody>
</table>

### SST DATA

<table>
<thead>
<tr>
<th>Name</th>
<th>Resolution</th>
<th>Coverage</th>
<th>Temporal Availability</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP SST Analysis</td>
<td>1° - 1/12°</td>
<td>Global</td>
<td></td>
<td><a href="http://polar.ncep.noaa.gov/sst">http://polar.ncep.noaa.gov/sst</a></td>
</tr>
<tr>
<td>NOMAD3 SST</td>
<td>1° - 0.25°</td>
<td>Global</td>
<td>Jan 1854 – present (depending which product)</td>
<td><a href="http://nomads.ncdc.noaa.gov/data.php">http://nomads.ncdc.noaa.gov/data.php</a></td>
</tr>
<tr>
<td>NCEP &amp; NCDC Reconstructed SST</td>
<td>1°</td>
<td>Global</td>
<td>Jan 1854 – Dec 2015</td>
<td><a href="http://rda.ucar.edu/datasets/ds277.0">http://rda.ucar.edu/datasets/ds277.0</a></td>
</tr>
</tbody>
</table>
GRIB Data Handling

• Documents and decoders
  – GRIB1 and GRIB2
    wgrib, wgrib2, unpackgrib2.c, grib2to1.c
    [http://rda.ucar.edu/#!GRIB](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

• **nc_convert2nc**
Writing Intermediate File Format

- [http://www2.ucar.edu/wrf/users/docs/user_guide_V3/users_guide_chap3.htm#_Writing_Meteorological_Data](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_write_int(IM_name,FIELD,UNITS,DESC,VAR(:,:,),opt)`
• `wrf_wps_read_int`

`!
opens file
istatus = wrf_wps_open_int(filename)`

`!
reads header
wrf_wps_rdhead_int(istatus,head_real,field,head_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 ungridded 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`
• Additional utilities
  – `read_wrf_nc`: reads WRF netCDF file, outputs various data
  – `iowrf`: thins or extracts a box from WRF netCDF files
  – `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 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
  – 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
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:

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

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?