



# The WRF Preprocessing System

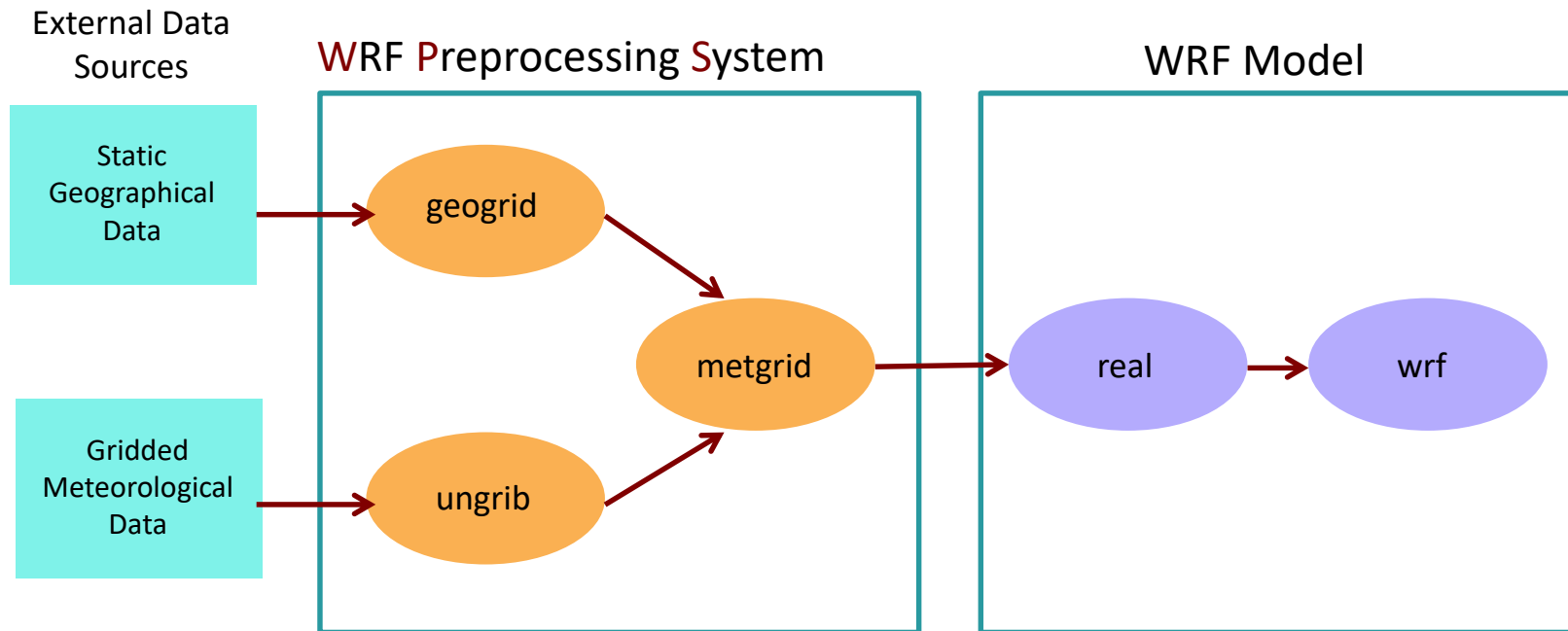
Kelly Werner – February 2019



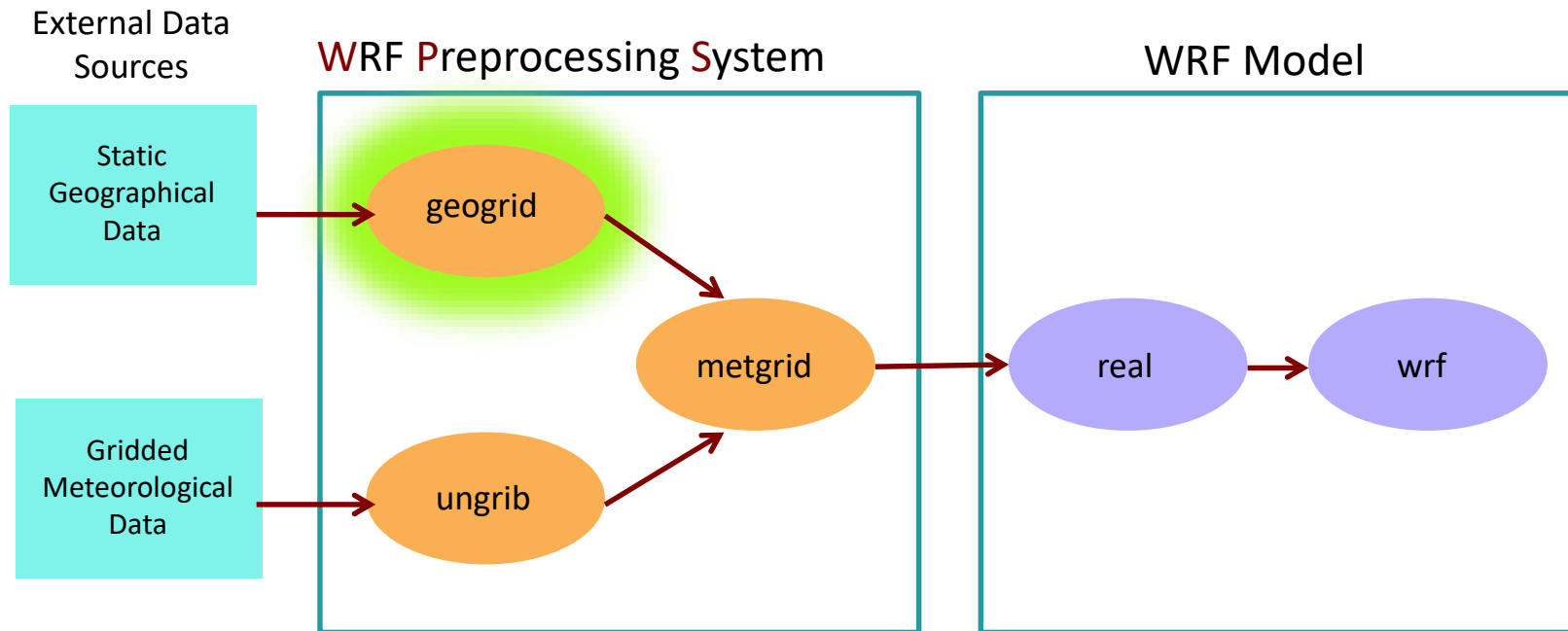
# Purpose of the WPS

- Prepares input to WRF for real-data simulations
  - Defines simulation coarse domain and nested domains
  - Computes latitude, longitude, map scale factors, and Coriolis parameters at every grid point
  - Interpolates time-invariant terrestrial data to simulation grid (e.g., terrain height and soil type)
  - Interpolates time-varying meteorological fields from another model onto simulation domains

# WRF/WPS Flowchart



# The *geogrid* Program



geogrid: think geographical

# The *geogrid* Program

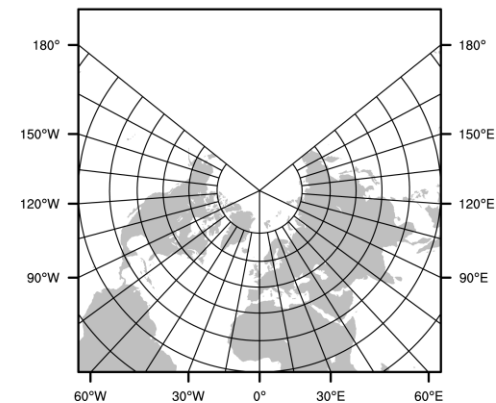
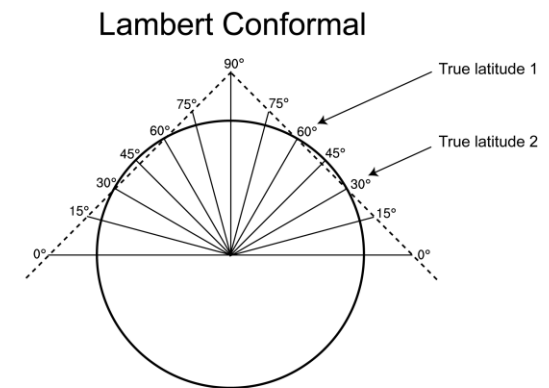
- For WRF model domains, geogrid defines:
  - Map projection (all domains must use the same projection)
  - Geographic location of domains
  - Dimension of domains
  - Horizontal resolution of domains
- Geogrid provides values for static (time-invariant) fields at each model grid point
  - Computes latitude, longitude, map scale factor, and Coriolis parameters at each grid point
  - Horizontally interpolates static terrestrial data from global datasets
    - E.g., topography height, land use category, soil type, vegetation fraction, monthly surface albedo

# *geogrid*: Defining Model Domains

- Choose a map projection to use for your domains
  - The real earth is (roughly) an ellipsoid
  - But WRF computational domains are defined by rectangles in the plane
  
- Can use any of the following projections:
  - Lambert conformal
  - Mercator
  - Polar stereographic
  - Latitude-longitude (must be chosen for a global domain!)

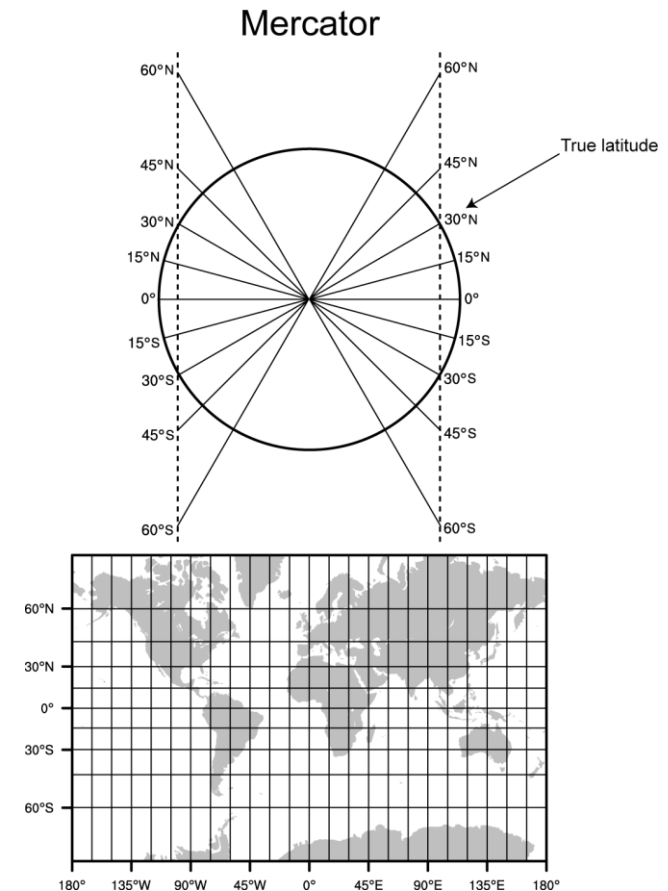
# *geogrid* Projections: Lambert Conformal

- Well-suited for mid-latitudes
- Domain cannot contain either pole
- Domain cannot be periodic in west-east direction
- Either one or two 'true latitudes' may be specified
  - If 2 are given, the order does not matter



# *geogrid* Projections: Mercator

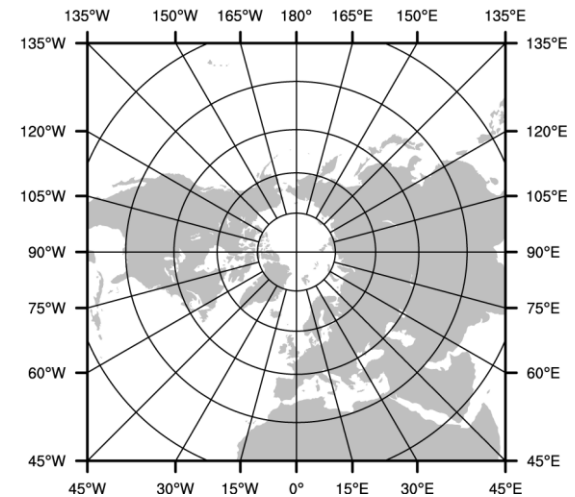
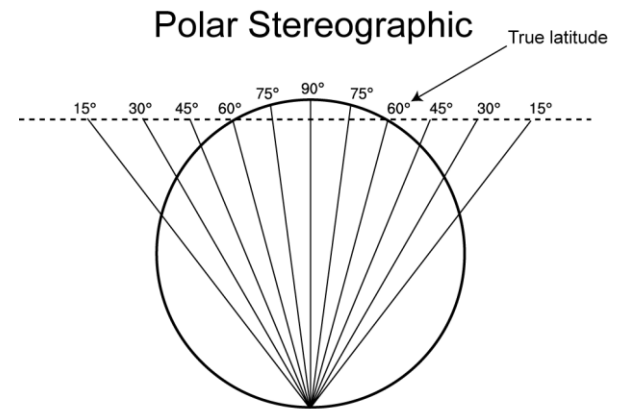
- Well-suited for low-latitudes (near equator)
- May be used for periodic domains in the west-east direction
- A single “true latitude” is specified
  - Cylinder intersects the Earth’s surface at +/- truelat





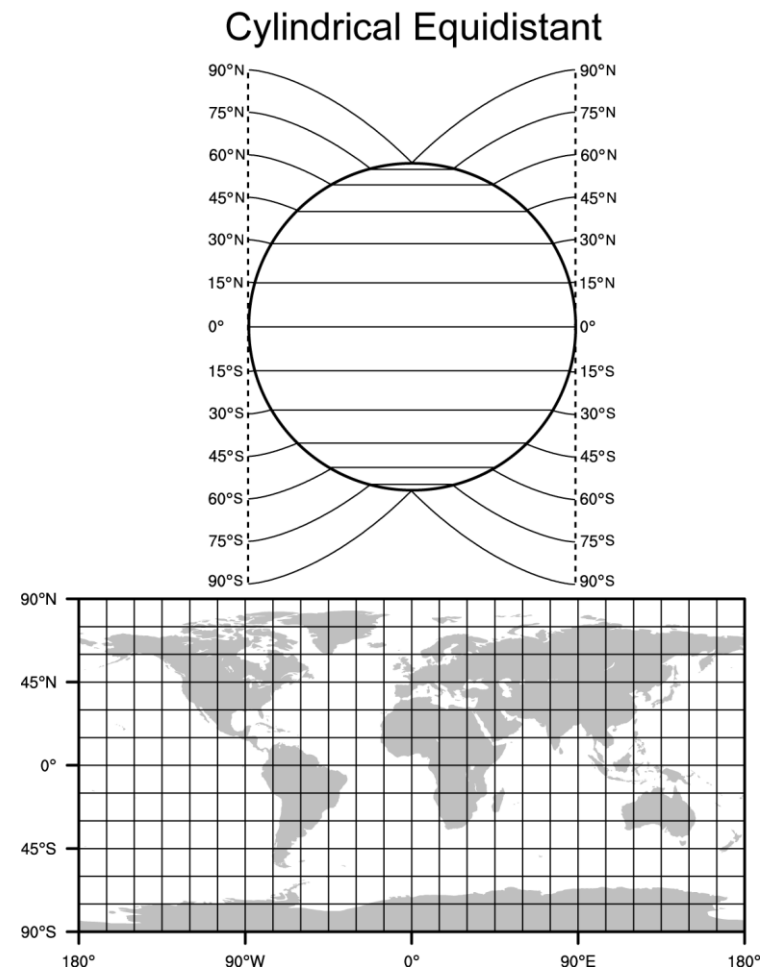
# *geogrid* Projections: Polar Stereographic

- ➔ Good for high-latitude domains, especially if the domain must contain a pole
- ➔ A single “true latitude” is specified



# *geogrid* Projections: Latitude-longitude

- Required for global domains
- May be used for regional domains
- Can be used in its normal or rotated aspect



# *geogrid*: Defining Model Domains

All parameters reside in the &geogrid section of the namelist.wps file

## ➤ Parameters for defining map projection

- **MAP\_PROJ**: 'lambert', 'mercator', 'polar', or 'lat-lon'
- **TRUELAT1**: First true latitude
- **TRUELAT2**: Second true latitude (only for Lambert conformal)
- **POLE\_LAT, POLE\_LON**: Location of North pole in WRF computational grid (only for lat-lon)
- **STAND\_LON**: The meridian parallel to the y-axis

[http://www2.mmm.ucar.edu/wrf/users/namelist\\_best\\_prac\\_wps.html](http://www2.mmm.ucar.edu/wrf/users/namelist_best_prac_wps.html)

# *geogrid*: Defining Model Domains

All parameters reside in the &geogrid section of the namelist.wps file

## ➤ Parameters for location and size of domain

- **REF\_LAT, REF\_LON**: The (lat/lon) location of a known location in the domain (by default, the center point of the domain)
- **DX/DY**: Grid distance (resolution)
  - For Lambert, Mercator, and Polar: **meters**
  - For (rotated) lat-lon: **degrees**
- **E\_WE**: Number of velocity points in the west-east direction
- **E\_SN**: Number of velocity points in the south-north direction

[http://www2.mmm.ucar.edu/wrf/users/namelist\\_best\\_prac\\_wps.html](http://www2.mmm.ucar.edu/wrf/users/namelist_best_prac_wps.html)

# geogrid: Why Map Projections Matter

- Each choice of map projection and associated parameters distorts distances at a given point on the globe differently

- Geographic grid distance in WRF at a point is given by

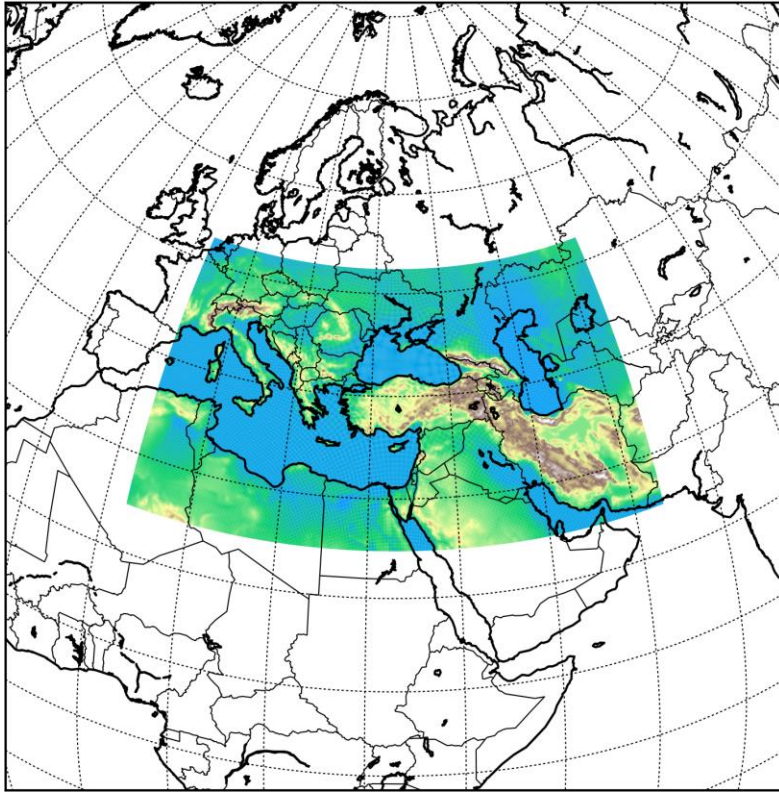
$$\Delta x_{\text{geographical}} = \Delta x_{\text{nominal}} / m$$

where  $m$  is a *map scale factor*.

- *Maximum stable timestep in WRF is determined by geographic grid distance, not nominal (i.e., namelist) grid distance!*
- Map scale factor is a 2D field available in the geogrid output files
  - Can easily check min/max map scale factor using, e.g., ncview

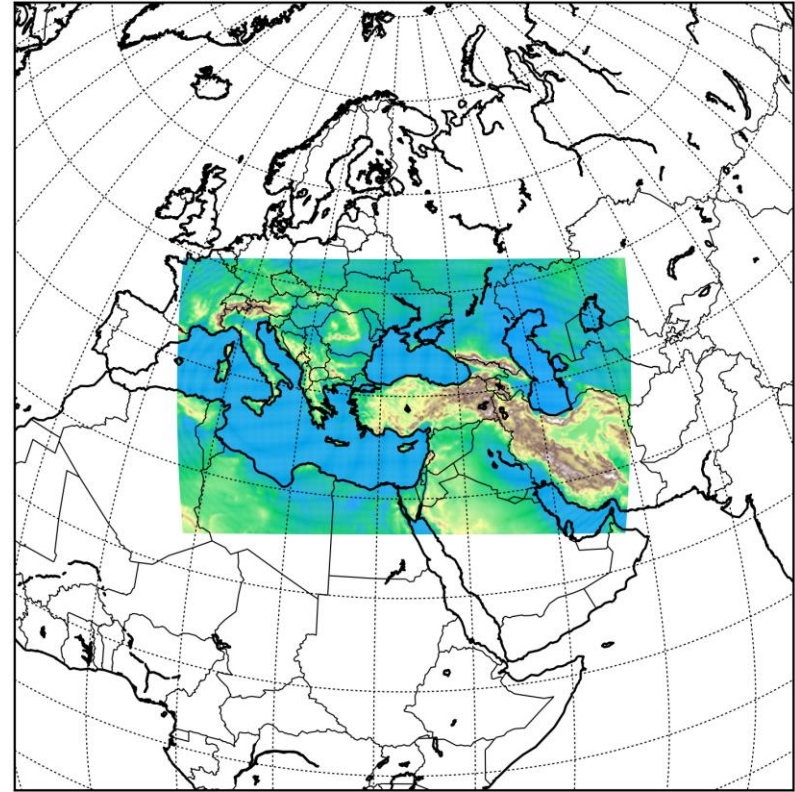
# geogrid: Why Map Projections Matter

Mercator projection,  $\phi_1 = 42.0$ ,  $0.819 \leq m \leq 1.218$



*For a nominal 12-km grid, the above projection yields grid distances from **9.9 km to 14.6 km**.*

Lambert conformal projection,  $\phi_1, \phi_2 = 30.0, 47.5$ ,  $0.988 \leq m \leq 1.023$



*For a nominal 12-km grid, the above projection yields grid distances from **11.7 to 12.1 km**.*

# Running *geogrid*: Namelist Set-up

- ➔ Edit **namelist.wps** file
  - ➔ For *geogrid*, only the ***&share*** and ***&geogrid*** namelists need to be edited

## ***&share***

```
wrf_core = 'ARW',  
max_dom = 2,  
io_form_geogrid = 2,
```

/

## ***&geogrid***

```
parent_id      = 1,      1,  
parent_grid_ratio = 1,      3,  
i_parent_start = 1,      20,  
j_parent_start = 1,      17,  
e_we          = 220,    181,  
e_sn          = 175,    181,  
geog_data_res = '5m',  '2m',  
dx            = 15000,  
dy            = 15000,  
map_proj      = 'lambert',  
ref_lat       = 37.0,  
ref_lon       = -97.0,  
truelat1     = 45.0,  
truelat2     = 30.0,  
stand_lon    = -97.0,  
geog_data_path = '/data/static/WPS_GEOG/'
```

/

# Running *geogrid*: Namelist Set-up

```
&share
```

```
wrf_core = 'ARW',  
max_dom = 2,  
io_form_geogrid = 2,  
/
```

Which WRF core?

- for ARW, set to 'ARW'

Total number of model domains,  
including nests

Format for geogrid output files  
2 = netCDF is recommended



# Running *geogrid*: Namelist Set-up

## &geogrid

```
parent_id      = 1,      1,
parent_grid_ratio = 1,      3,
i_parent_start = 1,      20,
j_parent_start = 1,      17,

e_we           = 220,  181,
e_sn           = 175,  181,
dx             = 15000,
dy            = 15000,

geog_data_res  = '5m',  '2m',
geog_data_path = '/data/static/geog/'
```

Used for nesting purposes

- What is the grid ratio for each nest?
- Where is it located inside its parent?

Domain sizes: How many grid points does the domain have? What is the grid spacing?

Static data:

- What resolution of source data to interpolate from for each domain
  - default is 30s USGS
  - other options: 2m, 5m, 10m
- path to static data

# Running *geogrid*: Namelist Set-up

## &geogrid

```
map_proj    = 'lambert',  
ref_lat     = 37.0,  
ref_lon     = -97.0,  
truelat1    = 45.0,  
truelat2    = 30.0,  
stand_lon   = -97.0,
```

/

Map projection:

- What projection to use
- What are the parameters of the projection?



# Running *geogrid*: Check for Success

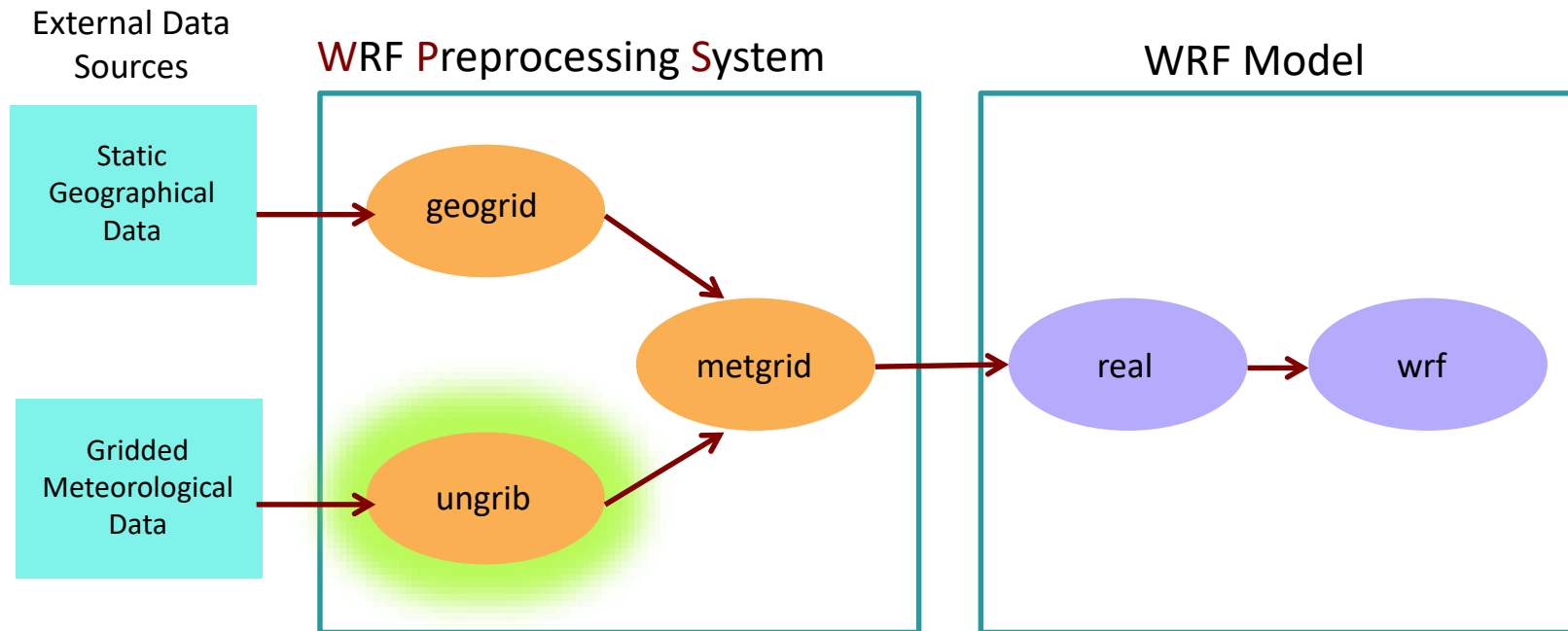
- Check that *geogrid* ran successfully. If so, this message should be printed:

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!   Successful completion of geogrid.           !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

- And you should have a *geo\_em.d0X* file for each domain

**If there was an error, check for an ERROR message in the *geogrid.log* file, or for a system error, like “Segmentation fault”.**

# The *ungrib* Program



ungrib: think un + grib

# The *ungrib* Program

## ➤ What is a GRIB file?

- Files that contain meteorological/atmospheric data (3D and surface)
- GRIB is a WMO standard file format for storing regularly-distributed (e.g., gridded) fields
- Fields in a file are identified only by coded numbers
  - These numbers must be referenced against an external table to determine the corresponding field

# The ungrib Program

- Reads GRIB Edition 1 and GRIB Edition 2 files
- Extract meteorological fields
- If necessary, derive required fields from related ones
  - E.g., compute RH from T, P, and Q
- Write requested fields to an intermediate file format
  - Expected by the metgrid program

# *ungrib*: Vtables

- How does *ungrib* know which fields to extract?
- Using Vtable (Variable Tables)
  - Files that provide the GRIB codes for fields extracted from GRIB input files
  - One Vtable for each source of data
  - Vtables are provided for many sources of data (e.g., NAM, GFS, Reanalysis 2, CFSR, ECMWF, etc.)



# ungrib: Vtables

## Vtable for GRIB1 Data

| GRIB1<br>Param | Level<br>Type | From<br>Level1 | To<br>Level2 | UNGRIB<br>Name | UNGRIB<br>Units | UNGRIB<br>Description                    |
|----------------|---------------|----------------|--------------|----------------|-----------------|--|
| 11             | 100           | *              |              | T              | K               | Temperature                              |
| 33             | 100           | *              |              | U              | m s-1           | U  |
| 34             | 100           | *              |              | V              | m s-1           | V  |
| 52             | 100           | *              |              | RH             | %               | Relative Humidity                        |
| 7              | 100           | *              |              | HGT            | m               | Height                                   |
| 11             | 105           | 2              |              | T              | K               | Temperature at 2 m                       |
| 52             | 105           | 2              |              | RH             | %               | Relative Humidity at 2 m                 |
| 33             | 105           | 10             |              | U              | m s-1           | U at 10 m                                |
| 34             | 105           | 10             |              | V              | m s-1           | V at 10 m                                |
| 1              | 1             | 0              |              | PSFC           | Pa              | Surface Pressure                         |
| 130            | 102           | 0              |              | PMSL           | Pa              | Sea-level Pressure                       |
| 144            | 112           | 0              | 10           | SM000010       | kg m-3          | Soil Moist 0-10 cm below grn layer (Up)  |
| 144            | 112           | 10             | 40           | SM010040       | kg m-3          | Soil Moist 10-40 cm below grn layer      |
| 144            | 112           | 40             | 100          | SM040100       | kg m-3          | Soil Moist 40-100 cm below grn layer     |
| 144            | 112           | 100            | 200          | SM100200       | kg m-3          | Soil Moist 100-200 cm below gr layer     |
| 85             | 112           | 0              | 10           | ST000010       | K               | T 0-10 cm below ground layer (Upper)     |
| 85             | 112           | 10             | 40           | ST010040       | K               | T 10-40 cm below ground layer (Upper)    |
| 85             | 112           | 40             | 100          | ST040100       | K               | T 40-100 cm below ground layer (Upper)   |
| 85             | 112           | 100            | 200          | ST100200       | K               | T 100-200 cm below ground layer (Bottom) |
| 91             | 1             | 0              |              | SEAICE         | proprtn         | Ice flag                                 |
| 81             | 1             | 0              |              | LANDSEA        | proprtn         | Land/Sea flag (1=land,2=sea in GRIB2)    |
| 7              | 1             | 0              |              | HGT            | m               | Terrain field of source analysis         |
| 11             | 1             | 0              |              | SKINTEMP       | K               | Skin temperature (can use for SST also)  |
| 65             | 1             | 0              |              | SNOW           | kg m-2          | Water equivalent snow depth              |
| 223            | 1             | 0              |              | CANWAT         | kg m-2          | Plant Canopy Surface Water               |
| 224            | 1             | 0              |              | SOILCAT        | Tab4.213        | Dominant soil type category              |
| 225            | 1             | 0              |              | VEGCAT         | Tab4.212        | Dominant land use category               |

# *ungrib*: Vtables

## Vtable for GRIB2 Data

| metgrid                                  | GRIB2 | GRIB2 | GRIB2 | GRIB2 |
|--|-------|-------|-------|-------|
| Description                              | Discp | Catgy | Param | Level |
| Temperature                              | 0     | 0     | 0     | 100   |
| U  | 0     | 2     | 2     | 100   |
| V  | 0     | 2     | 3     | 100   |
| Relative Humidity                        | 0     | 1     | 1     | 100   |
| Height                                   | 0     | 3     | 5     | 100   |
| Temperature at 2 m                       | 0     | 0     | 0     | 103   |
| Relative Humidity at 2 m                 | 0     | 1     | 1     | 103   |
| U at 10 m                                | 0     | 2     | 2     | 103   |
| V at 10 m                                | 0     | 2     | 3     | 103   |
| Surface Pressure                         | 0     | 3     | 0     | 1     |
| Sea-level Pressure                       | 0     | 3     | 1     | 101   |
| Soil Moist 0-10 cm below grn layer (Up)  | 2     | 0     | 192   | 106   |
| Soil Moist 10-40 cm below grn layer      | 2     | 0     | 192   | 106   |
| Soil Moist 40-100 cm below grn layer     | 2     | 0     | 192   | 106   |
| Soil Moist 100-200 cm below gr layer     | 2     | 0     | 192   | 106   |
| Soil Moist 10-200 cm below gr layer      | 2     | 0     | 192   | 106   |
| T 0-10 cm below ground layer (Upper)     | 0     | 0     | 0     | 106   |
| T 10-40 cm below ground layer (Upper)    | 0     | 0     | 0     | 106   |
| T 40-100 cm below ground layer (Upper)   | 0     | 0     | 0     | 106   |
| T 100-200 cm below ground layer (Bottom) | 0     | 0     | 0     | 106   |
| T 10-200 cm below ground layer (Bottom)  | 0     | 0     | 0     | 106   |
| Ice flag                                 | 0     | 2     | 0     | 1     |
| Land/Sea flag (1=land, 0 or 2=sea)       | 2     | 0     | 0     | 1     |
| Terrain field of source analysis         | 2     | 0     | 7     | 1     |
| Skin temperature (can use for SST also)  | 0     | 0     | 0     | 1     |
| Water equivalent snow depth              | 0     | 1     | 13    | 1     |
| Dominant soil type cat.(not in GFS file) | 2     | 3     | 0     | 1     |
| Dominant land use cat. (not in GFS file) | 2     | 0     | 198   | 1     |

# *ungrib*: Vtables

- What if a data source has no existing Vtable included in the WPS code?
- Create a Vtable
  - Obtain a listing of GRIB codes for fields from the source
    - Check documentation from originating center, or
    - Use utility such as g1print/g2print (found in WPS/util/), or wgrib
  - Use existing Vtable as template
  - Check documentation in Chapter 3 of the WRF Users' Guide for more information about Vtables
    - [http://www2.mmm.ucar.edu/wrf/users/docs/user\\_guide\\_V4/users\\_guide\\_chap3.html](http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V4/users_guide_chap3.html)

# *ungrib*: Intermediate File Format

- After extracting fields listed in the Vtable, *ungrib* writes those fields to intermediate format
- For meteorological data sets not in GRIB format, the user may write to intermediate format directly
  - Detailed information in Chapter 3 of the WRF Users' Guide:  
[http://www2.mmm.ucar.edu/wrf/users/docs/user\\_guide\\_V4/users\\_guide\\_chap3.html](http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V4/users_guide_chap3.html)

# Running *ungrib*: Namelist Set-up

- ➔ For *ungrib*, only the **&share** and **&ungrib** sections of the namelist will need to be edited

## **&share**

```
wrf_core = 'ARW',  
max_dom = 2,  
start_date = '2006-04-01_00:00:00',  
end_date = '2006-04-01_12:00:00',  
interval_seconds = 21600  
io_form_geogrid = 2,
```

/

## **&ungrib**

```
out_format = 'WPS',  
prefix = 'GFS',
```

/

# Running *ungrib*: Namelist Set-up

**&share**

```
wrf_core = 'ARW',  
max_dom = 2,
```

```
start_date = '2006-04-01_00:00:00',  
end_date   = '2006-04-01_12:00:00',
```

```
interval_seconds = 21600
```

```
io_form_geogrid = 2,
```

/

**Data time range:** between which times should ungrib process GRIB data?

**Data frequency:** How many seconds between output files for ungrib?  
- E.g., 10800 s = 3 hrs

# Running *ungrib*: Namelist Set-up

```
&ungrib
```

```
  out_format = 'WPS',
```

```
  prefix = 'GFS',
```

```
 /
```

**Intermediate file format:** which  
Format to use for intermediate files?

- Use 'WPS' here

**Intermediate file names:** Gives prefix for  
Intermediate files.

- prefix can include a path
- E.g., 'GFS' would give intermediate files  
named GFS:YYYY-MM-DD\_hh

# Running *ungrib*

- Link the GRIB files to the running directory
  - Use the *link\_grib.csh* that is provided in the WPS/ directory
    - `./link_grib.csh path_to_your_grib_files/gribfile_prefix`
  - The ungrib program looks for files named *GRIBFILE.AAA*, *GRIBFILE.AAB*, *GRIBFILE.AAC*, etc. in the run directory
    - `GRIBFILE.AAA -> /data/GRIB/GFS/gfs_060401_00_00`
  
- Link to the correct Vtable
  - In `-sf ungrib/Variable_Tables/Vtable.xxx` Vtable



# Running *ungrib*

➔ Run ungrib: `./ungrib.exe`

```
*** Starting program ungrib.exe ***
Start_date = 2006-08-16_12:00:00 ,      End_date = 2006-08-16_12:00:00
output format is WPS
Path to intermediate files is ./
  ungrib - grib edition num          2

#####
Inventory for date = 2006-08-16 12:00:00

PRES    TT      UU      VV      RH      HGT
-----
2013.0  O       O       O       O       O       O
2001.0  X       X       X       X       O       X
1000.0  X       X       X       X       X
  975.0  X       X       X       X       X
  950.0  X       X       X       X       X
  925.0  X       X       X       X       X
  900.0  X       X       X       X       X
```

# Running *ungrib*: Check for Success

- Check that *ungrib* ran successfully. If so, this message should be printed

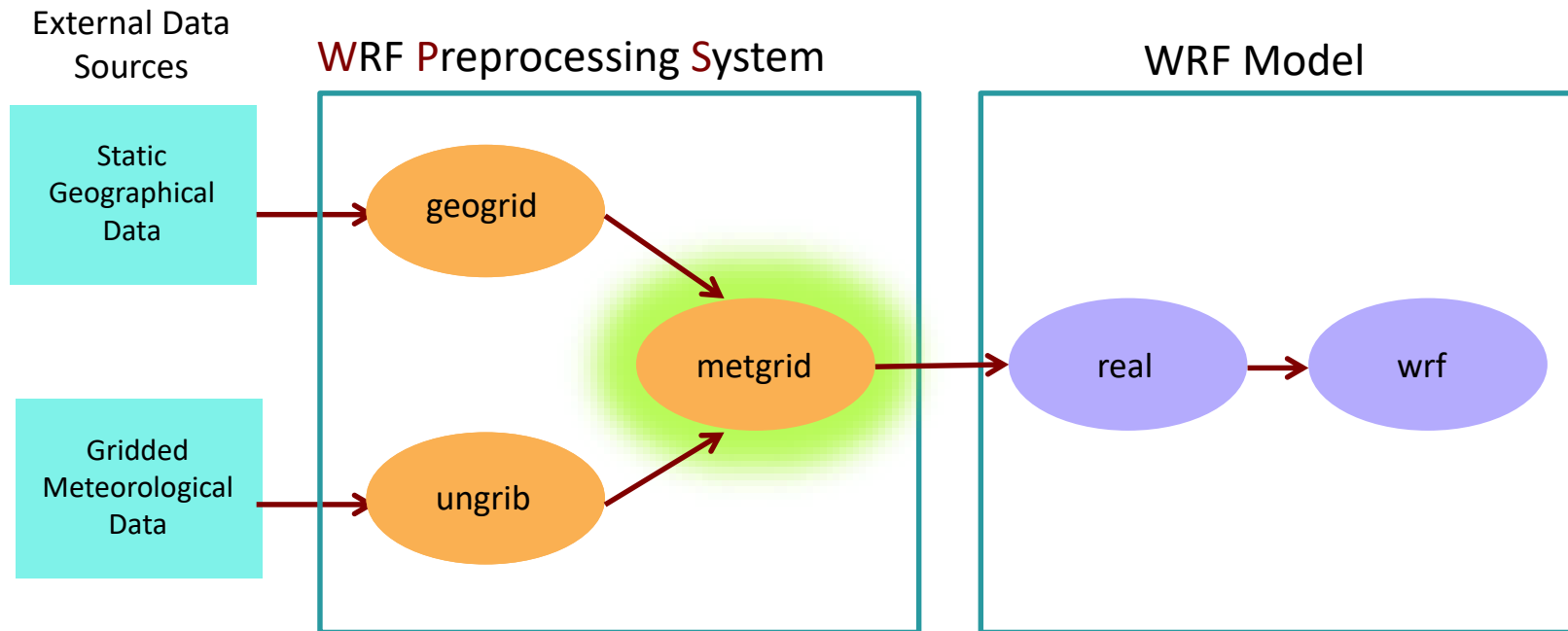
```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!   Successful completion of ungrib.                               !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

- And you should have files with a format similar to  
`FILE:YYYY-MM-DD_hh` for each data file you used

If there was an error, check for error message in *ungrib*'s printout or in the *ungrib.log* file.

Common errors are related to incorrect date specifications in the *&share* namelist, or because GRIB2 data was used with a version of WPS compiled without GRIB2 libraries.

# The *metgrid* Program



metgrid: think meteorological

# The *metgrid* Program

- Horizontally interpolates meteorological data (extracted by ungrib) to simulation domains (defined by geogrid)
- Rotates winds to WRF grid
  - i.e., rotates so that the U-component is parallel to the x-axis, and the V-component is parallel to the y-axis

# Running *metgrid*: Namelist Set-up

- ➔ For *metgrid*, only the **&share** and **&metgrid** sections of the namelist will be edited

## **&share**

```
wrf_core = 'ARW',  
max_dom = 2,  
start_date = '2006-04-01_00:00:00', '2006-04-01_00:00:00',  
end_date = '2006-04-01_12:00:00', '2006-04-01_00:00:00',  
interval_seconds = 21600  
io_form_geogrid = 2,  
/
```

## **&metgrid**

```
fg_name = 'GFS',  
io_form_metgrid = 2,  
/
```

# Running *metgrid*: Namelist Set-up

**&share**

```
wrf_core = 'ARW',  
max_dom = 2,
```

```
start_date = '2006-04-01_00:00:00', '2006-04-01_00:00:00',  
end_date   = '2006-04-01_12:00:00', '2006-04-01_00:00:00',
```

```
interval_seconds = 21600  
io_form_geogrid = 2,
```

/



**Data time range:** Time range to process *for each domain*.

# Running *metgrid*: Namelist Set-up

```
&metgrid  
  fg_name = 'GFS',  
  io_form_metgrid = 2,  
/
```

**Intermediate file prefixes:** Prefix(es) of Intermediate files to interpolate to model Domain.

- This should match the prefix given in ungrib

**Metgrid I/O format:** Which I/O format to use For metgrid output?

- 2= netCDF is recommended

# Running *metgrid*

➔ Run metgrid: `./metgrid.exe`

```
Processing domain 1 of 1
Processing 2012-01-27_00
    FILE
Processing 2012-01-27_06
    FILE
Processing 2012-01-27_12
    FILE
Processing 2012-01-27_18
    FILE
Processing 2012-01-28_00
    FILE
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!   Successful completion of metgrid.   !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Metgrid output files:

```
met_em.d01.2012-01-27_00:00:00.nc
met_em.d01.2012-01-27_06:00:00.nc
met_em.d01.2012-01-27_12:00:00.nc
met_em.d01.2012-01-27_18:00:00.nc
met_em.d01.2012-01-28_00:00:00.nc
```

The metgrid output files will be used to run `real.exe`!



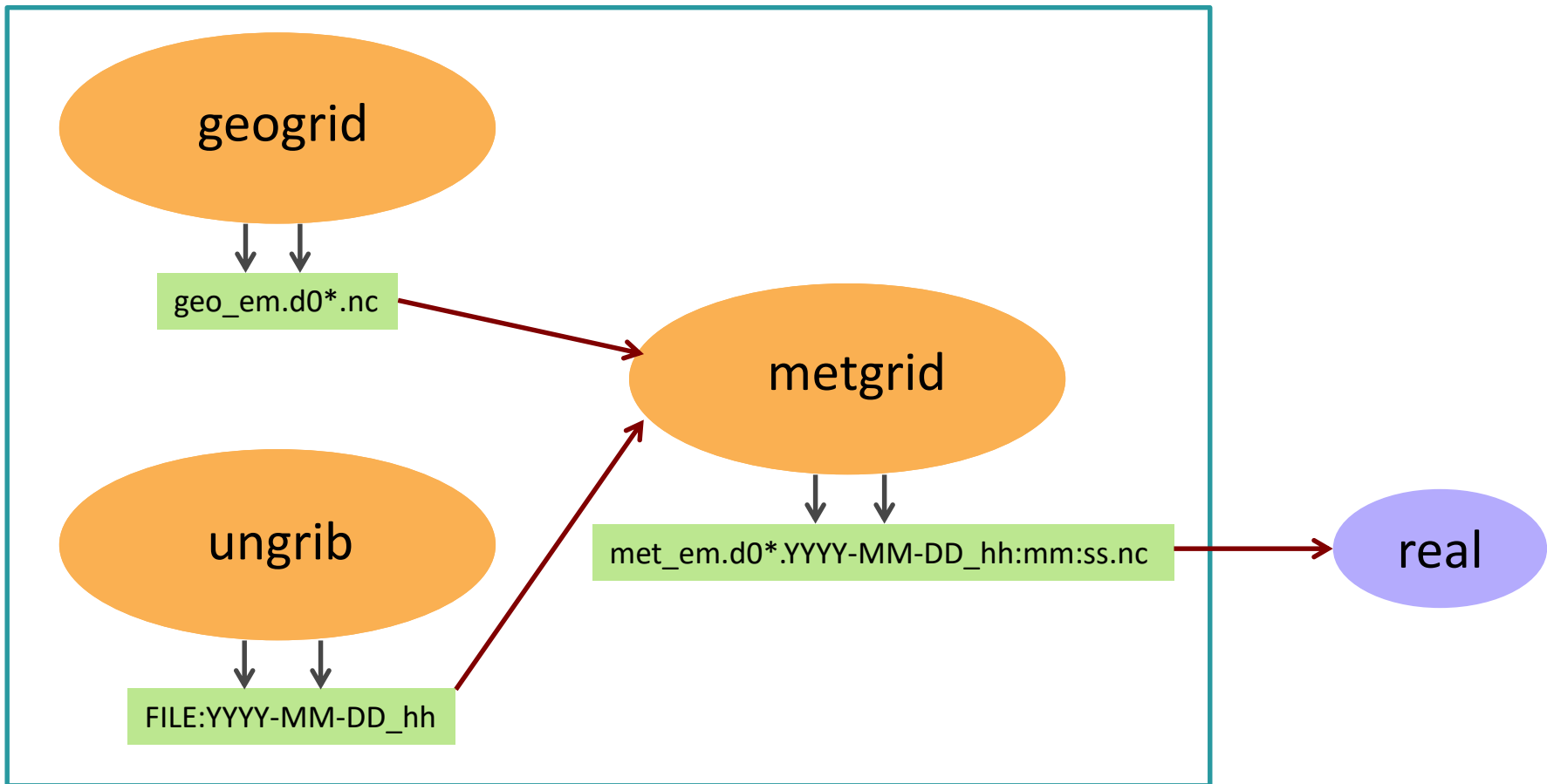
# Running *metgrid*

- Check that *metgrid* ran successfully. If so, this message should be printed:

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!   Successful completion of metgrid.           !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

**If there was an error, check for an ERROR or WARNING message in the *metgrid.log* file, or for a system error, like “Segmentation fault”.**

# The WPS Process





Questions?