



The WRF Preprocessing System

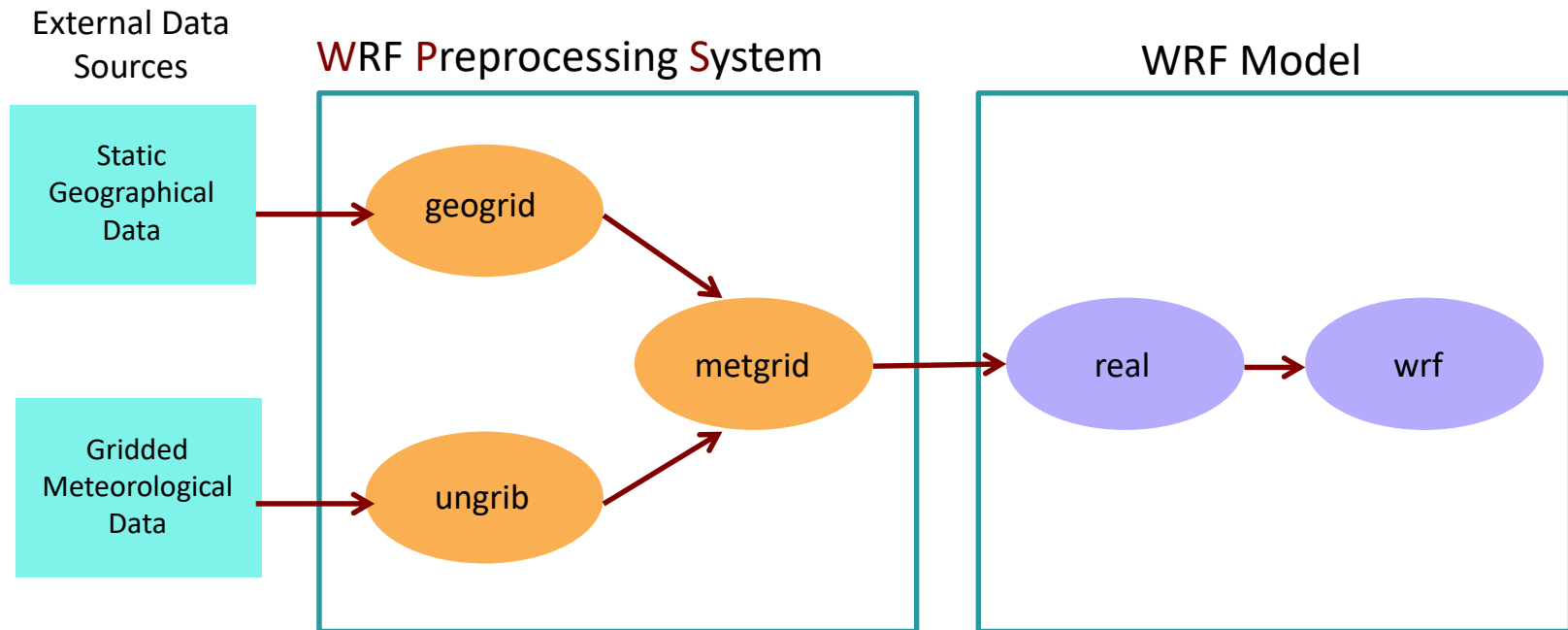
Kelly Werner – February 2019

1:11:00 (A)

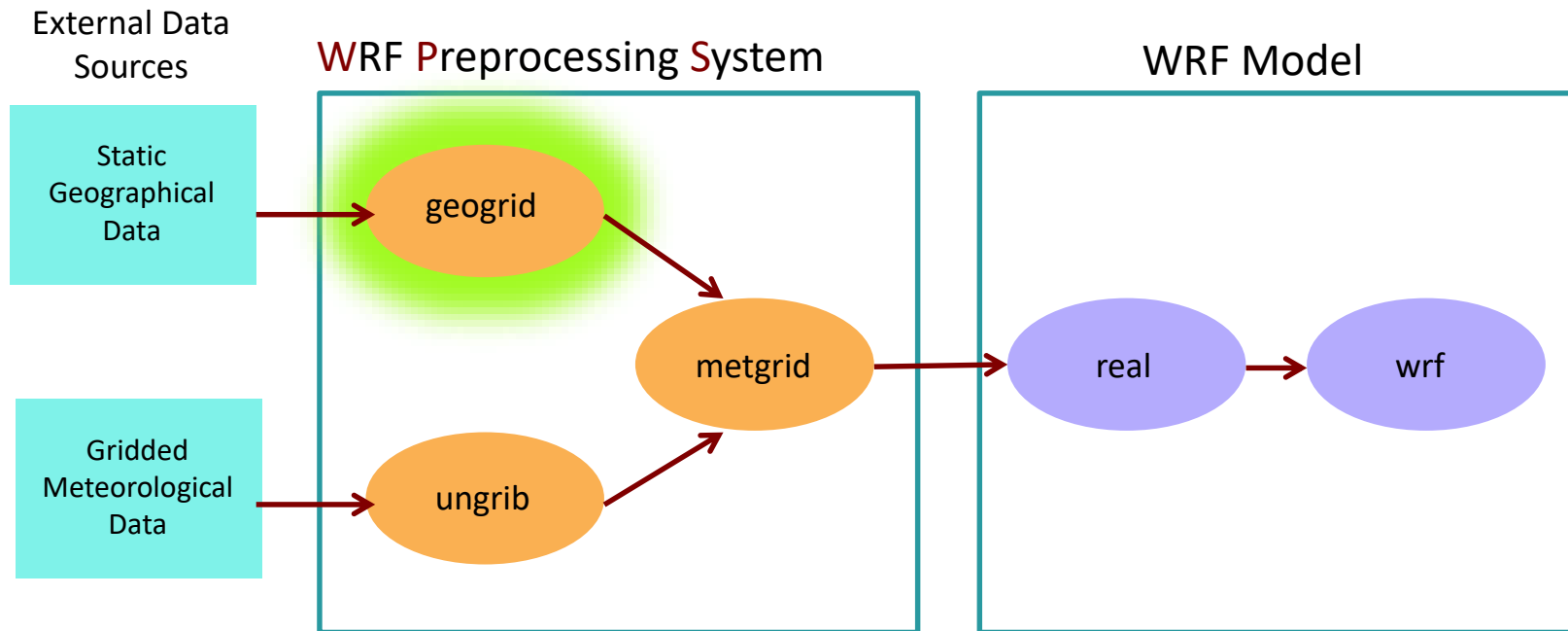
Purpose of the WPS

- 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

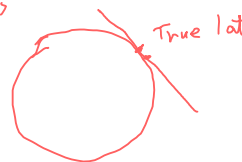
geogrid: Defining Model Domains

- 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!)

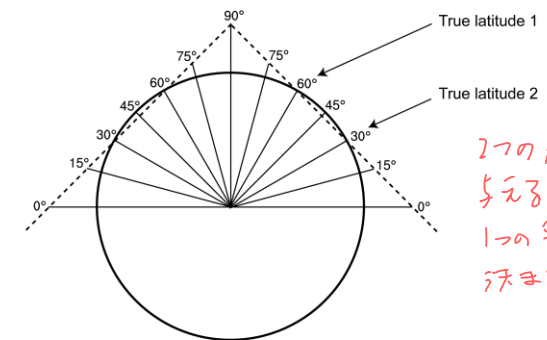
geogrid Projections: Lambert Conformal

- 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

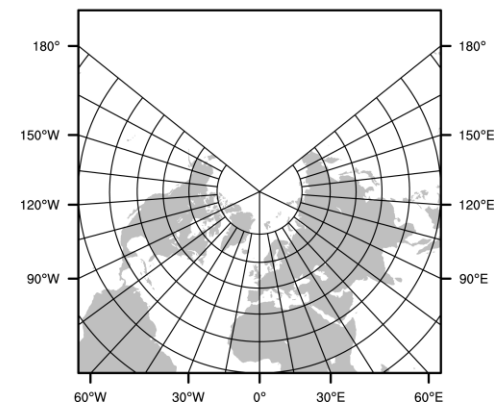
True latitude が 1 つのみなら
その点の接平面を
採用するのだから。



Lambert Conformal



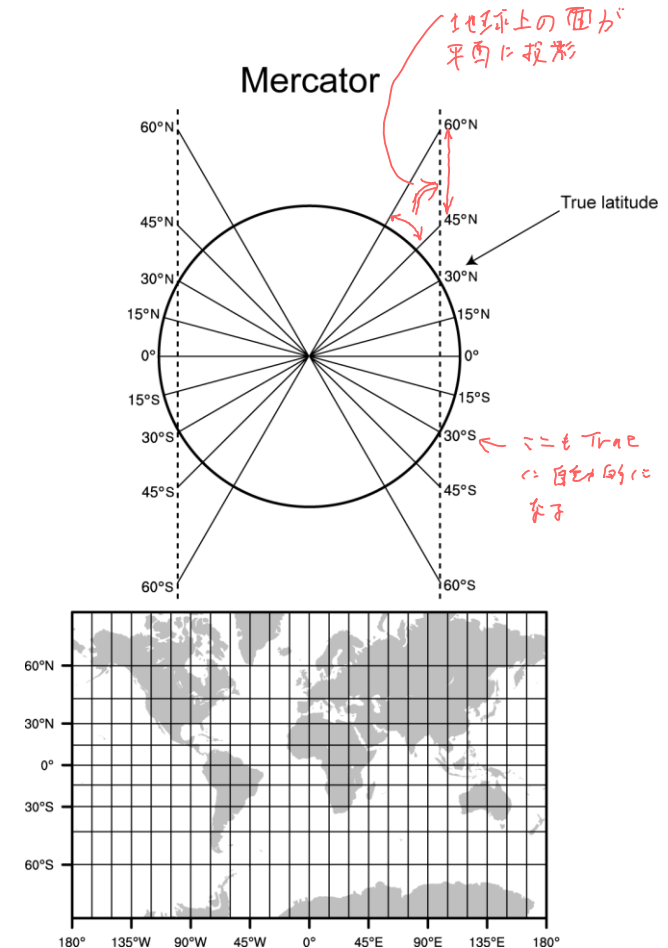
2つの赤緯度を与えると
1つの平面が
決まる



2.11 STANDARD LON は 0° の経線に
なると 7 平行に 30° の経度で指定する。
計算領域の北緯の

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 \pm true lat

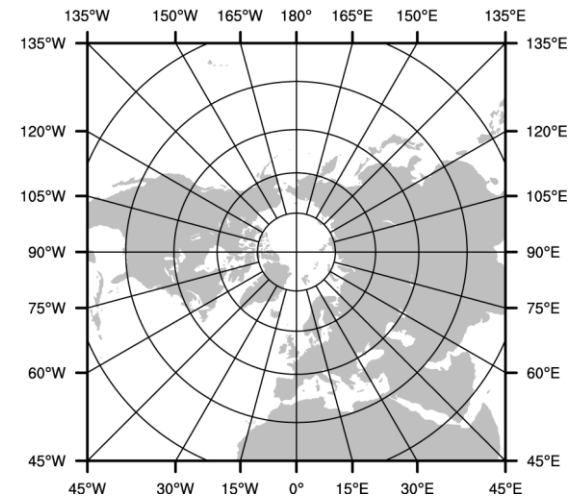
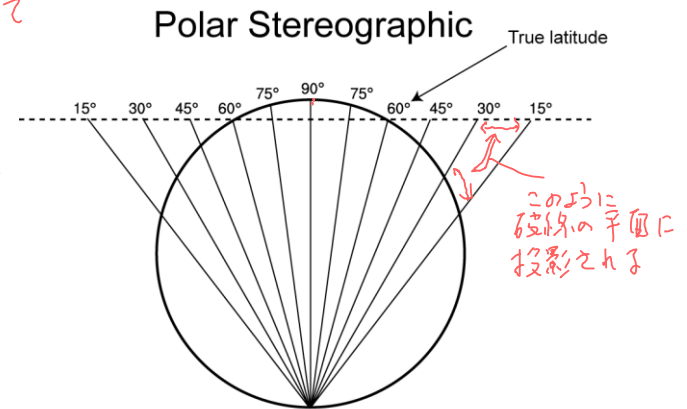


geogrid Projections: Polar Stereographic

北極点(海)を含めることが出来る。例では60°の経緯度線に沿って
南極点は大陸上であり、南極大陸を True となる
固定境界として全球を考慮できるとが、
True latitude から離れた緯度では歪みが大さくなりすぎ、全球は

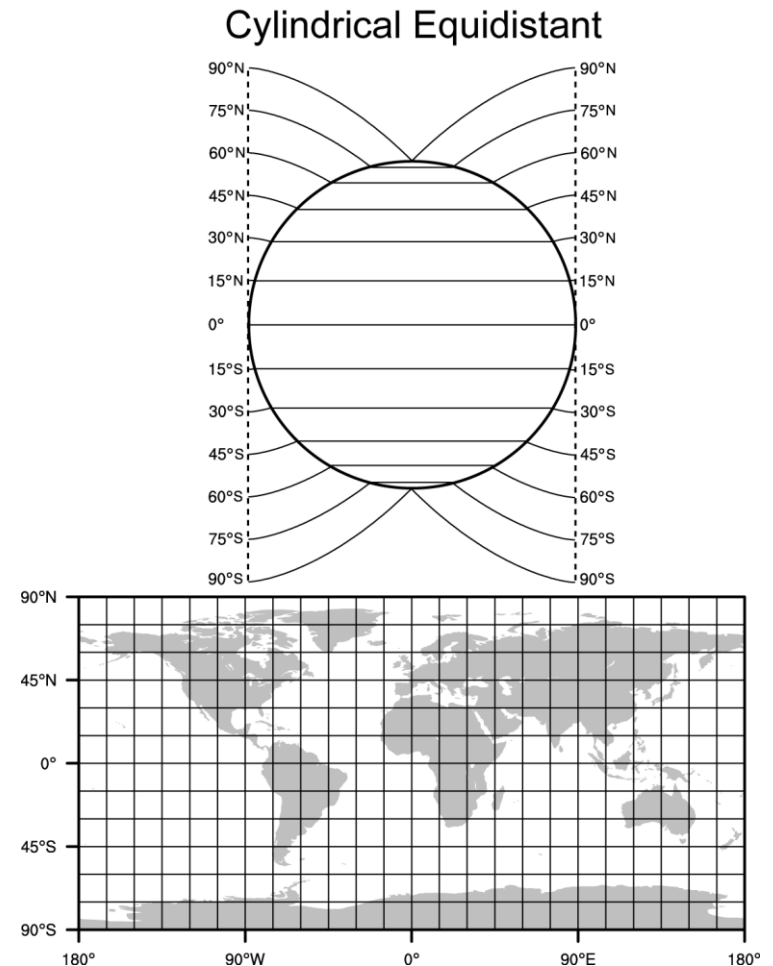
⇒現実的

- 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

y轴平行的經線 → Lambert 參照

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) 領域の中心点 (デフォルト)
- **DX/DY**: Grid distance (resolution) 格子サイズ
 - For Lambert, Mercator, and Polar: **meters**
 - For (rotated) lat-lon: **degrees**
- **E_WE**: Number of velocity points in the west-east direction 格子数
- **E_SN**: Number of velocity points in the south-north direction

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

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

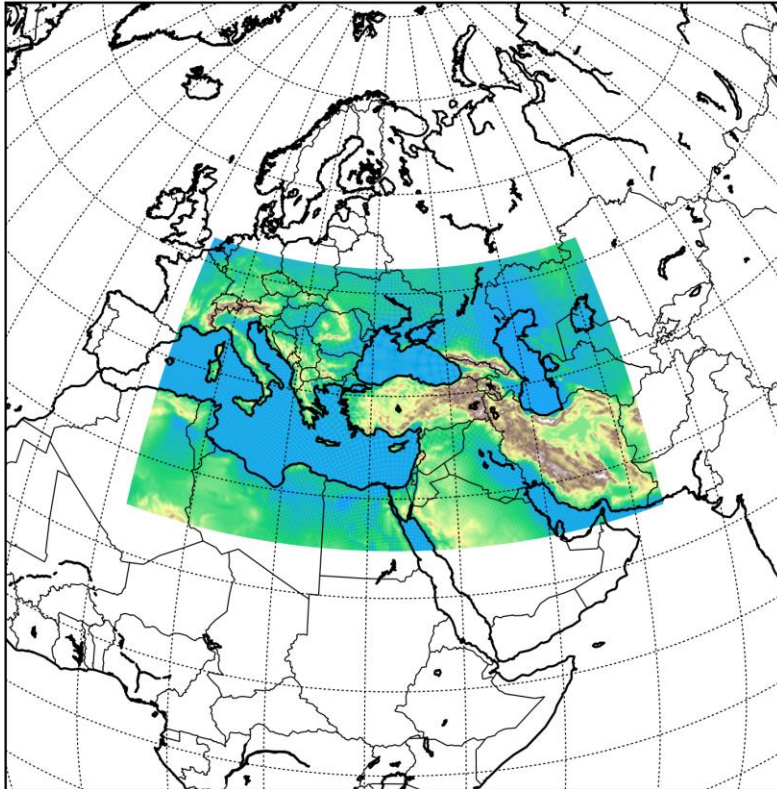
where m is a *map scale factor*.

- *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

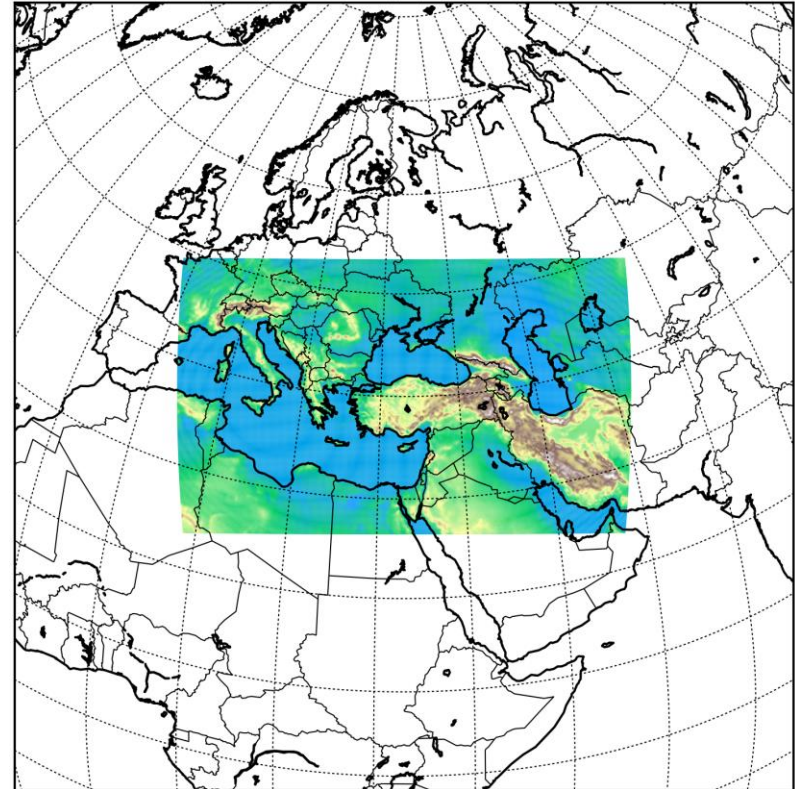
Lambert は格子線が lat, lon に平行ではない

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

01:25:00

&share

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

Which WRF core?

- for ARW, set to 'ARW'

ネスティングを含む領域の数
Total number of model domains,
including nests

ネスティングなしなら 1 とする。これを 2 以上にすることはすべての nesting 領域で以降の設定が必要。適切に設定されていないとエラーになる。

Format for geogrid output files
2 = netCDF is recommended

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

Running *geogrid*: Namelist Set-up

Domain 1の原点の
格子番号は (1, 1)

Domain 1の格子点 (20, 17)
が Domain 2の
原点

格子幅が 1/3

&geogrid

	Domain 1	Domain 2
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,
```

/

デフォルトは長方形領域
の中心の (lat, lon)
y軸に平行な経線
領域の中心点を通るため、
ref_lon と同一

Map projection:

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

Running *geogrid*

➤ Run geogrid.exe: `./geogrid.exe`

Geogrid processes each domain individually. There will be one section of messages for each domain.

As each field is processed, a message will be written to the screen and to the *geogrid.log* file

```

Parsed 11 entries in GEOGRID.TBL
Processing domain 1 of 2
  Processing XLAT and XLONG
  Processing MAPFAC
  Processing F and E
  Processing ROTANG
  Processing LANDUSEF
Calculating landmask from LANDUSEF
Processing HGT M

```

• •

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

Running *geogrid*: Check for Success

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

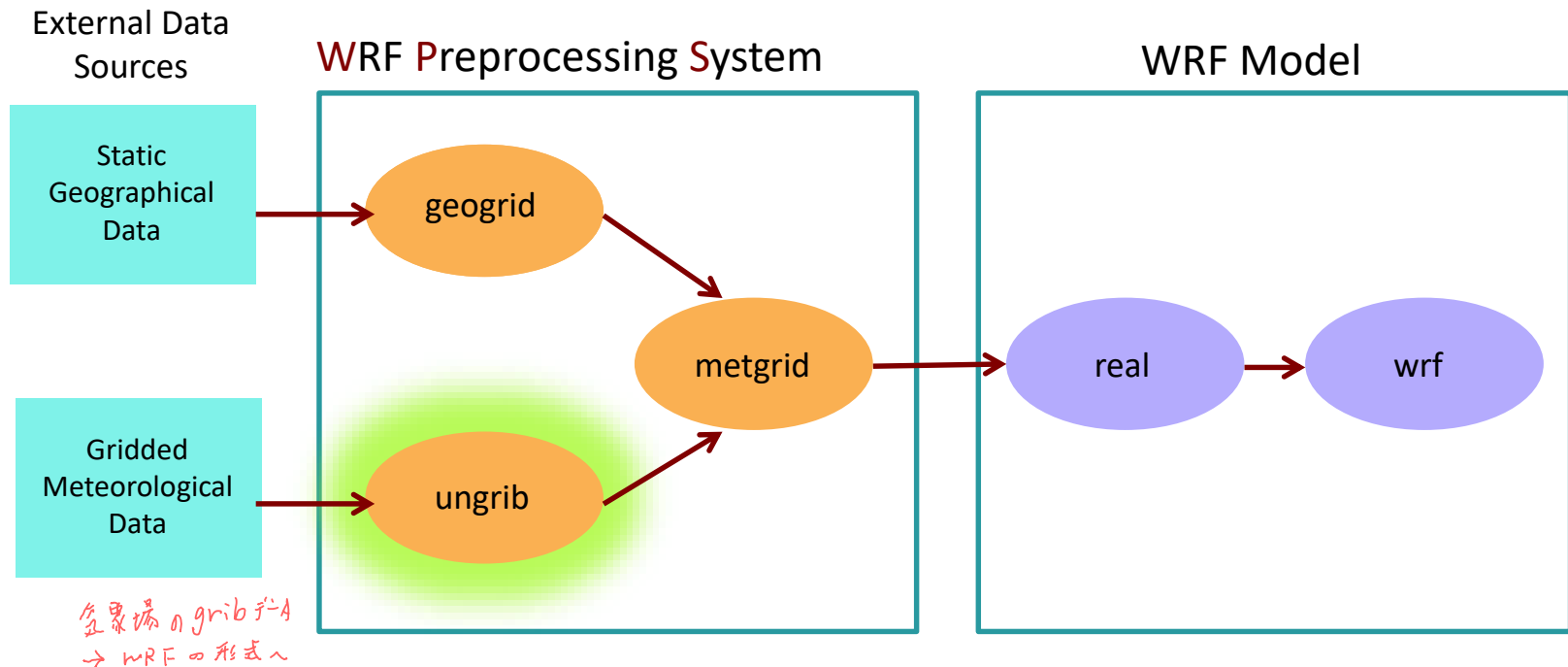
```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!  
!   Successful completion of geogrid.                        !  
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

各ネスティング領域毎にこのファイルが作成される。

- 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 Param	Level Type	From Level1	To Level2	UNGRIB Name	UNGRIB Units	UNGRIB 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** *Vtable が存在しない場合は自身で作る*
 - 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

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
 - GRIB フォーマットで提供されていないデータセット → 自身で中間形式に変換する
- 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

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

元データと同じ必要があるか？

Running *ungrib*: Namelist Set-up

&ungrib

out_format = 'WPS',

prefix = 'GFS',

/

常 = WPS

↓

↑
自身决定的

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*

GRIB ファイルが'存在'するディレクトリにリンクを張る

- 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

Vtable にモジュールを張る

 - 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.                        !  
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

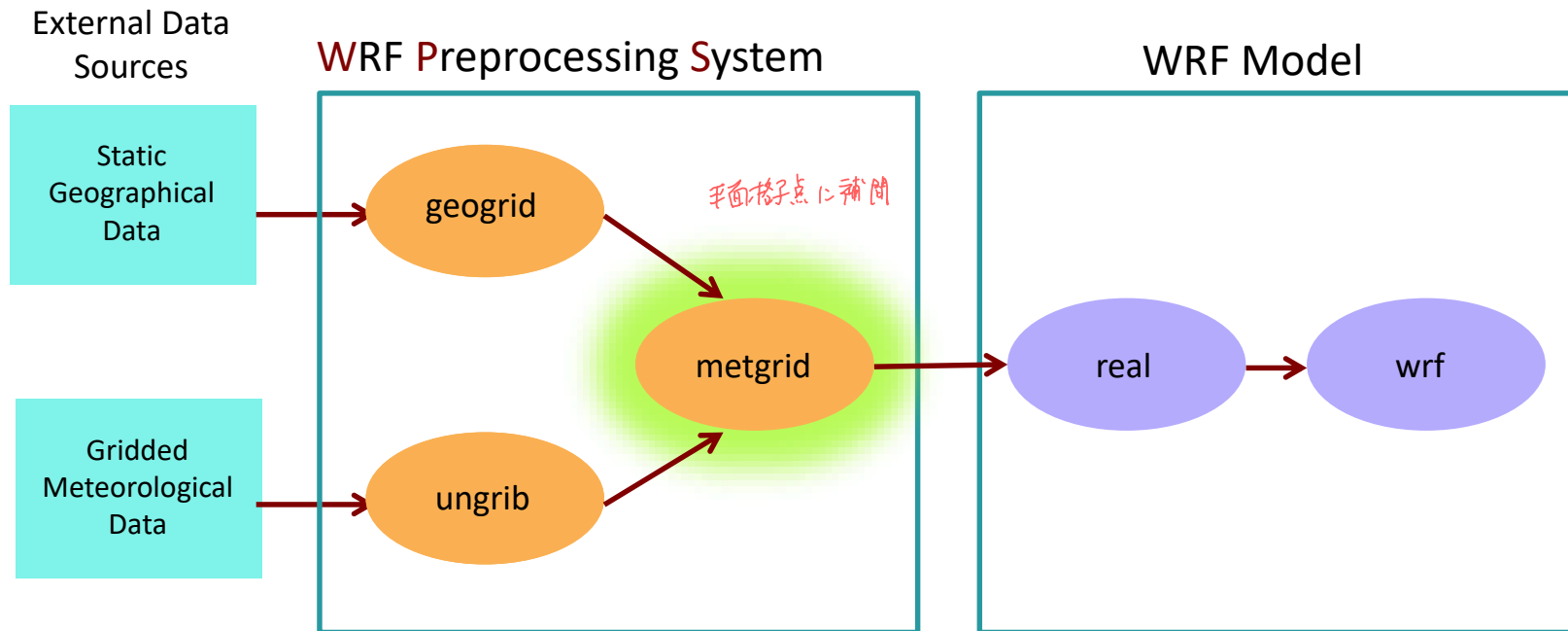
- And you should have files with a format similar to
FILE:YYYY-MM-DD_hh *for each data file you used*

ungrib.exe の 出力ファイル

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

計算の座標軸は一般に東西、南北方向とは限らない

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,
```

おての計算領域の数。

← unghib で設定したのと同じにする必要か？

↑ 常に2 (netcdf)

&metgrid

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

↑ 常に2 (netcdf)

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, 常に2 (netcdf)

/

ungrib で指定した prefix
と同一のもの

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
```

これらのファイルが生成された

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

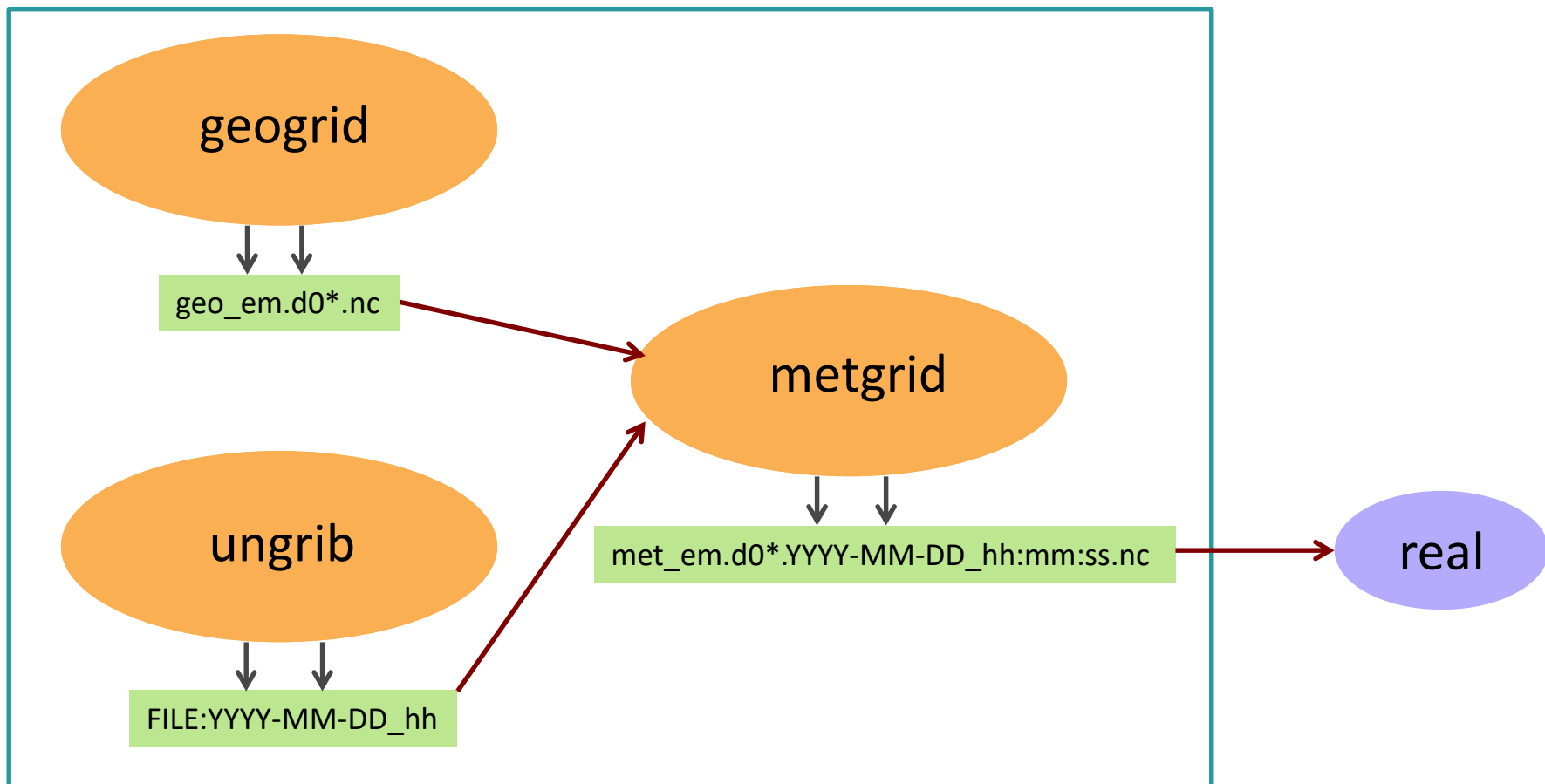
Running *metgrid*

- 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?