The WRF Preprocessing System
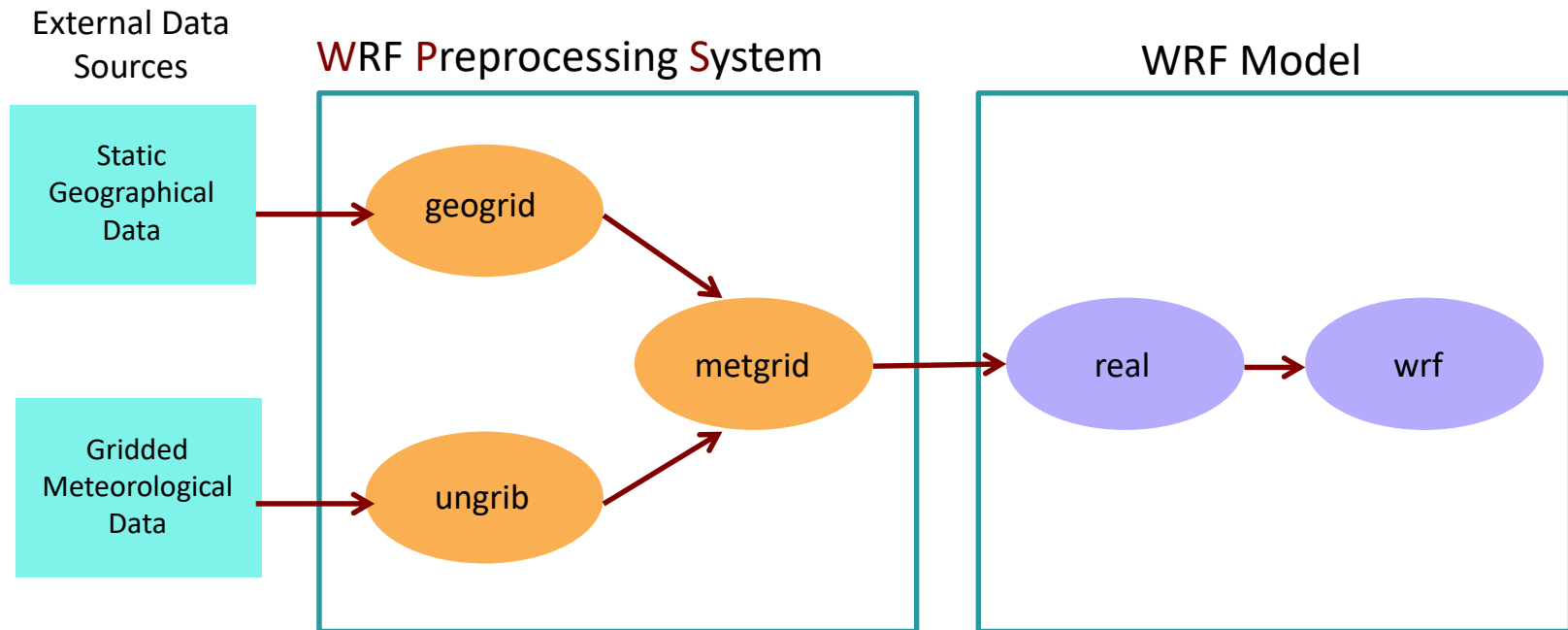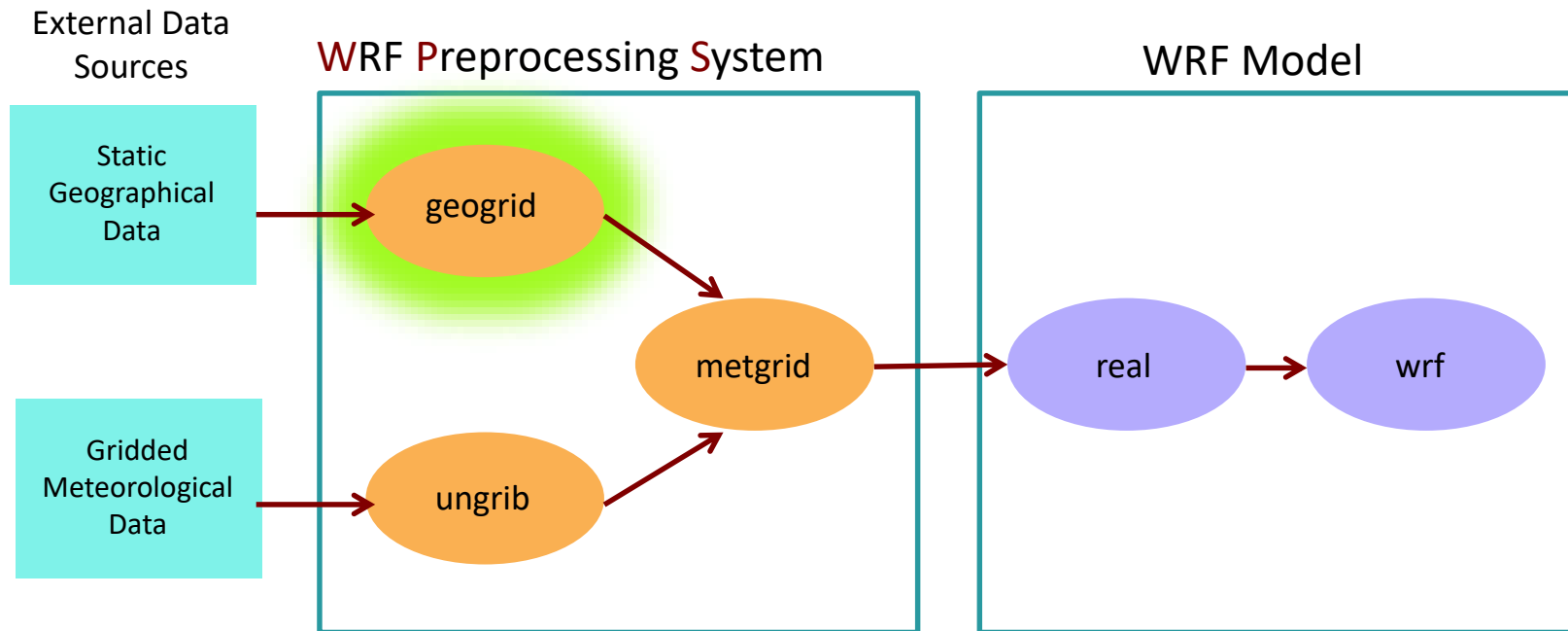
Kelly Werner – February 2019

ビデオ (A) 1:11:00

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

External Data Sources

WRF Preprocessing System

WRF Model

Static Geographical Data

geogrid

Gridded Meteorological Data

ungrib

metgrid

real

wrf

geogrid: think <u>geo</u>graphical

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!)
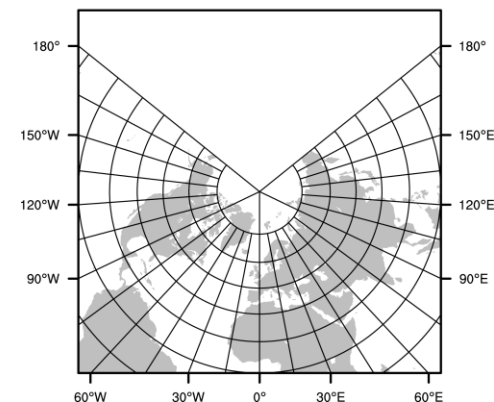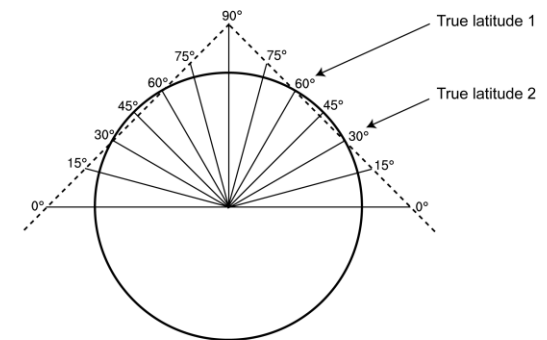
geogrid Projections: Lambert Conformal

↗ 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

Lambert Conformal

True latitude がいつのみなら
その点の接平面を
採用するのだろう.
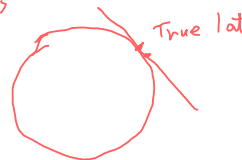
True lat

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

   ↗ Cyclinder intersects the Earth's surface at +/- truelat

Mercator
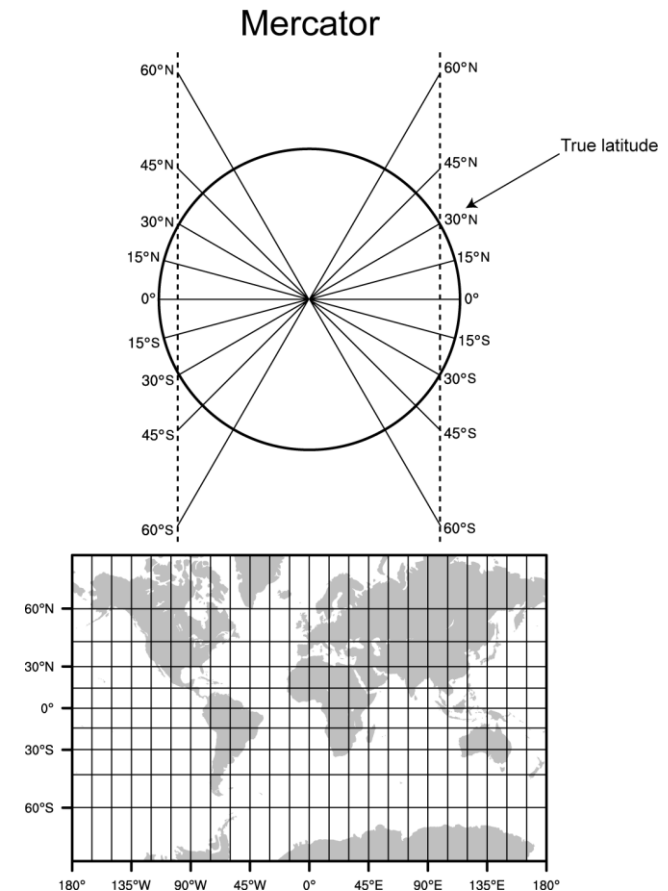
geogrid Projections: Polar Stereographic

Polar Stereographic

↗ Good for high-latitude domains, especially if the domain must contain a pole

↗ A single "true latutide" is specified
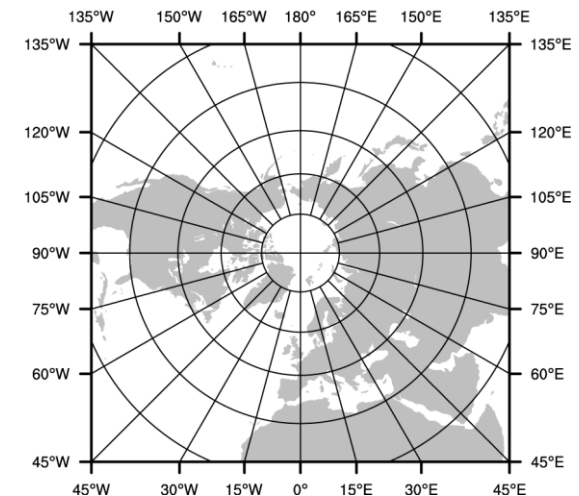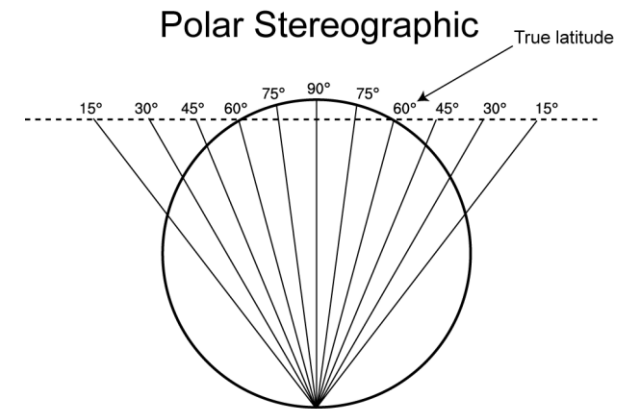
geogrid Projections: Latitude-longitude

↗ Required for global domains

↗ May be used for regional domains

↗ Can be used in its normal or rotated aspect
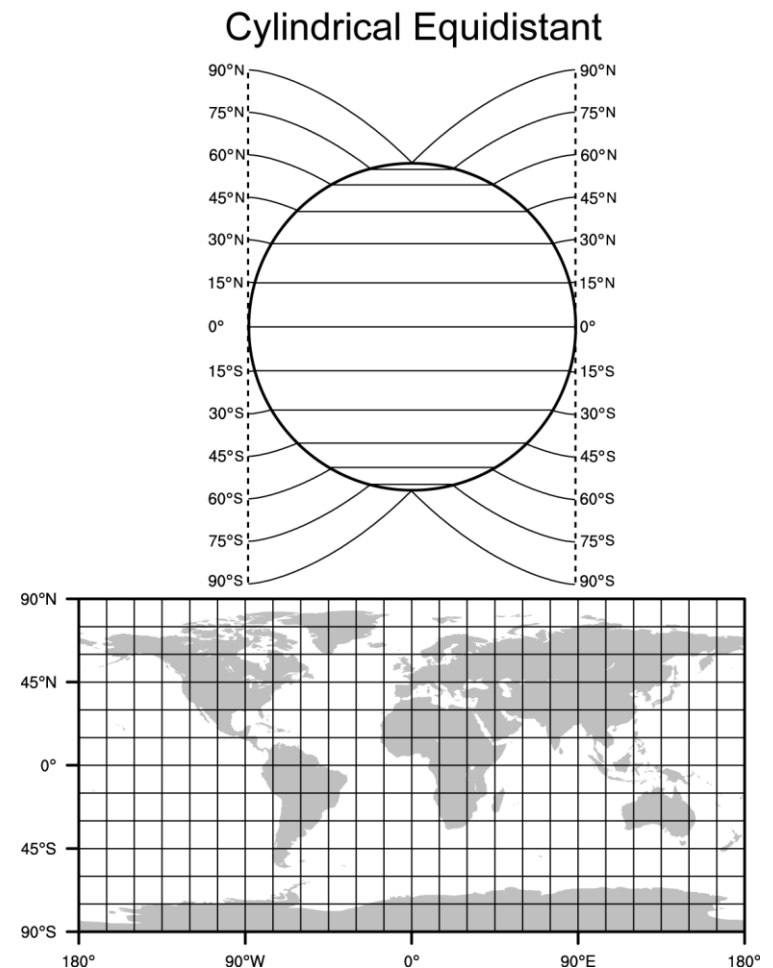
Cylindrical Equidistant

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軸に平行な経線

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

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

   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, $\phi_1 = 42.0$, $0.819 \le m \le 1.218$

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

Lambert は格子線が lat, lon に平行ではない
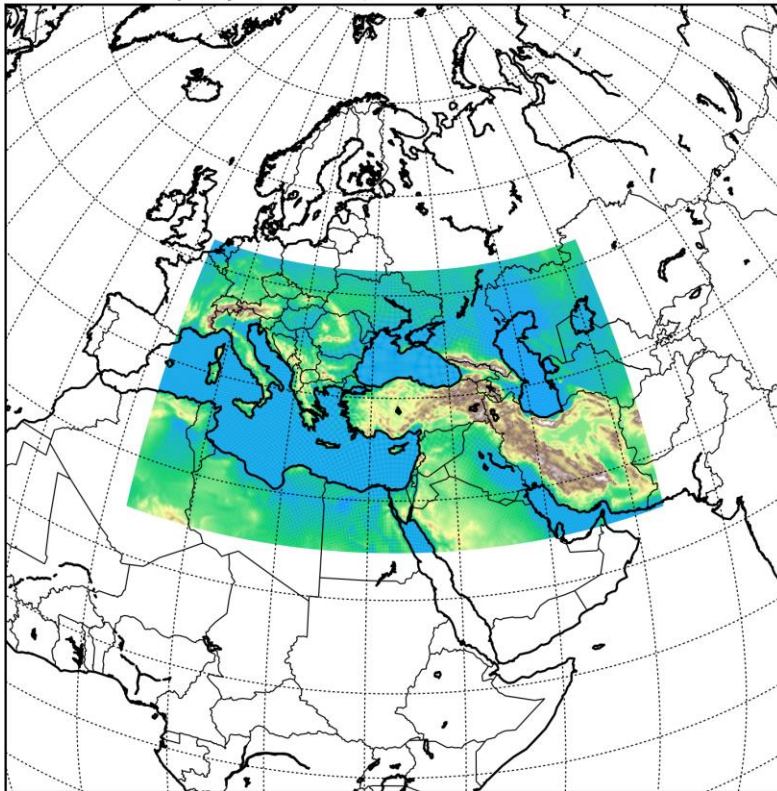
For a nominal 12-km grid, the above projection yields grid distances from **9.9 km to 14.6 km**.
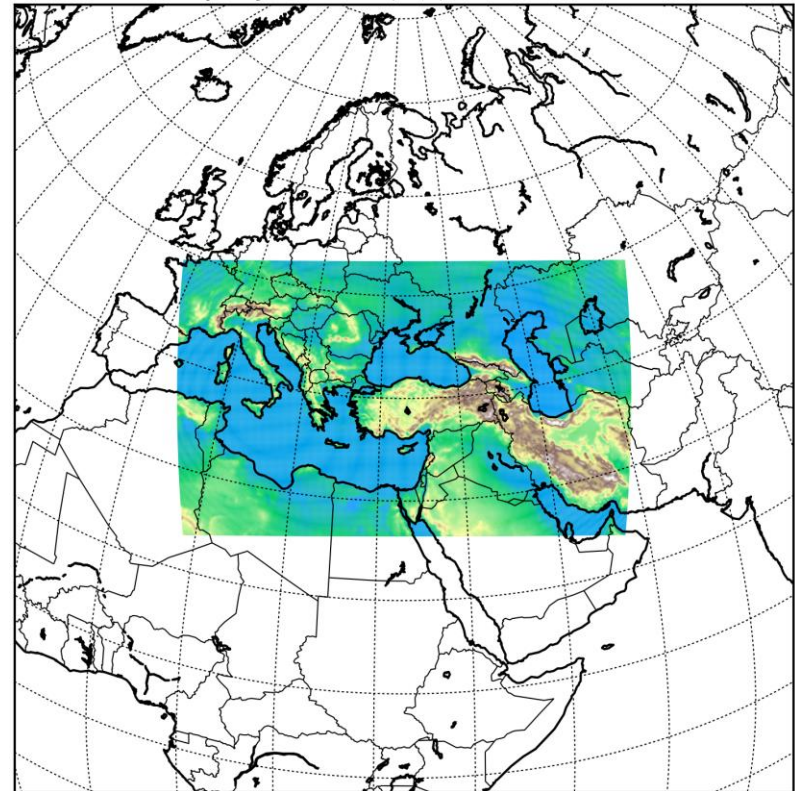
For a nominal 12-km grid, the above projection yields grid distances from **11.7 to 12.1 km**.

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

Which WRF core?
- for ARW, set to 'ARW'

&share
    wrf_core = 'ARW',
    max_dom = 2,
    io_form_geogrid = 2,
/

Total number of model domains, including nests

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    西東方向      =  220,       181,
   e_sn    南北方向      =  175,       181,
   dx      Domain 1 の   = 15000,
           格子サイズ'
   dy      Domain 2 は 1/3 の = 15000,
           5000

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

格子数

分

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

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

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
領計の中心点を通るので、
ref_lon と同一

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

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

↗ 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.       !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

↗ 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

External Data Sources

WRF Preprocessing System

WRF Model

Static Geographical Data → geogrid

Gridded Meteorological Data → ungrib

geogrid → metgrid

ungrib → metgrid

metgrid → real → wrf
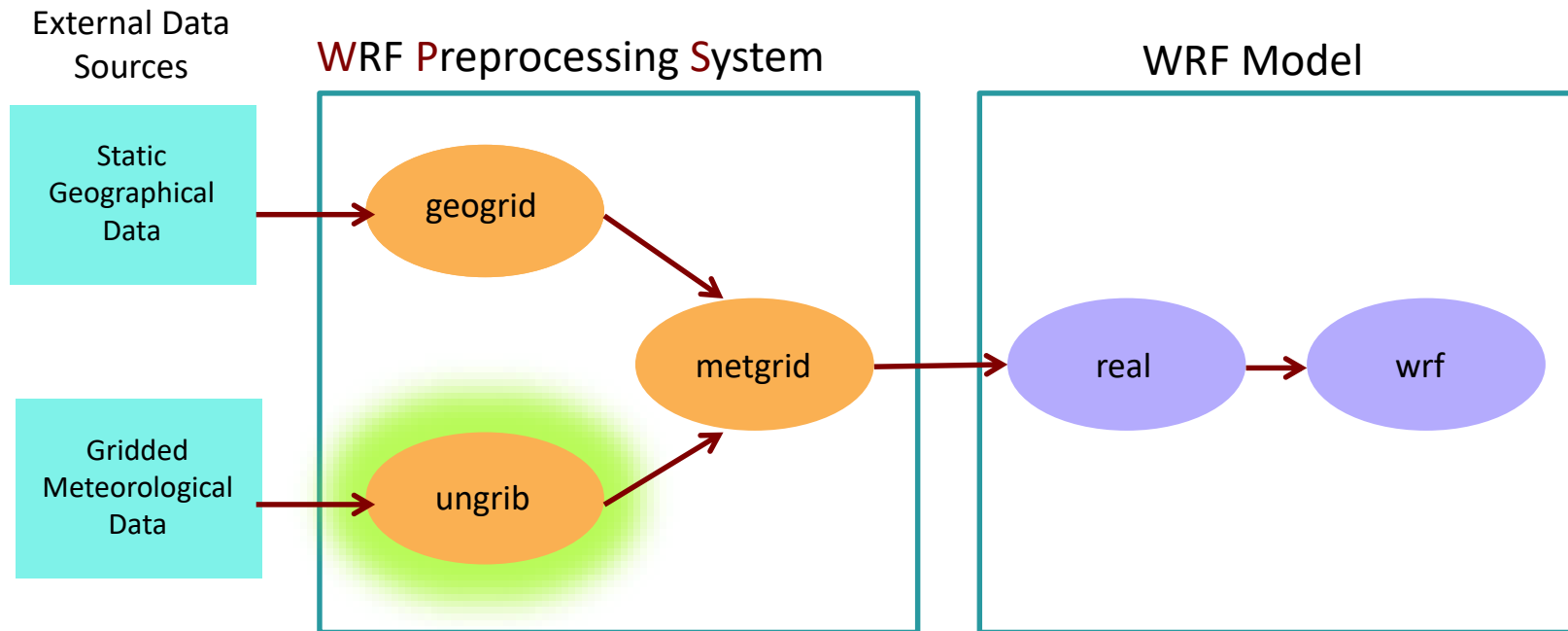
ungrib: think <u>un</u> + <u>grib</u>

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| Level| From |  To  | UNGRIB    | UNGRIB   | UNGRIB
Param| Type |Level1|Level2| Name      | Units    | 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 Description	GRIB2 Discp	GRIB2 Catgy	GRIB2 Param	GRIB2 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

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

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

Intermediate file format: which
Format to use for intermediate files?
 - Use 'WPS' here

```
&ungrib
    out_format = 'WPS',

    prefix = 'GFS',
/
```

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
    - ↗ ln –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

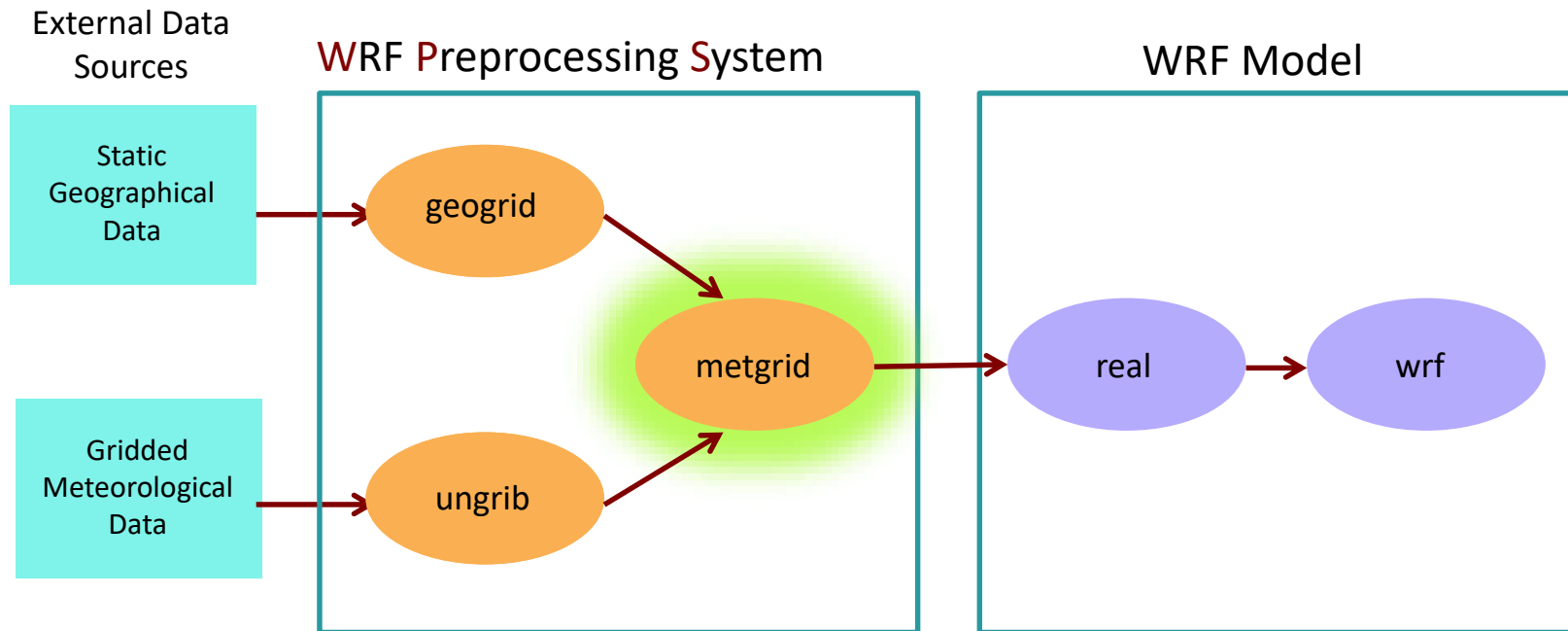↗ Check that ungrib ran successfully. If so, this message should be printed

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!   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

External Data Sources

WRF Preprocessing System

WRF Model

Static Geographical Data → geogrid → metgrid

Gridded Meteorological Data → ungrib → metgrid

metgrid → real → wrf

metgrid: think **met**eorological

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

↗ 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
```

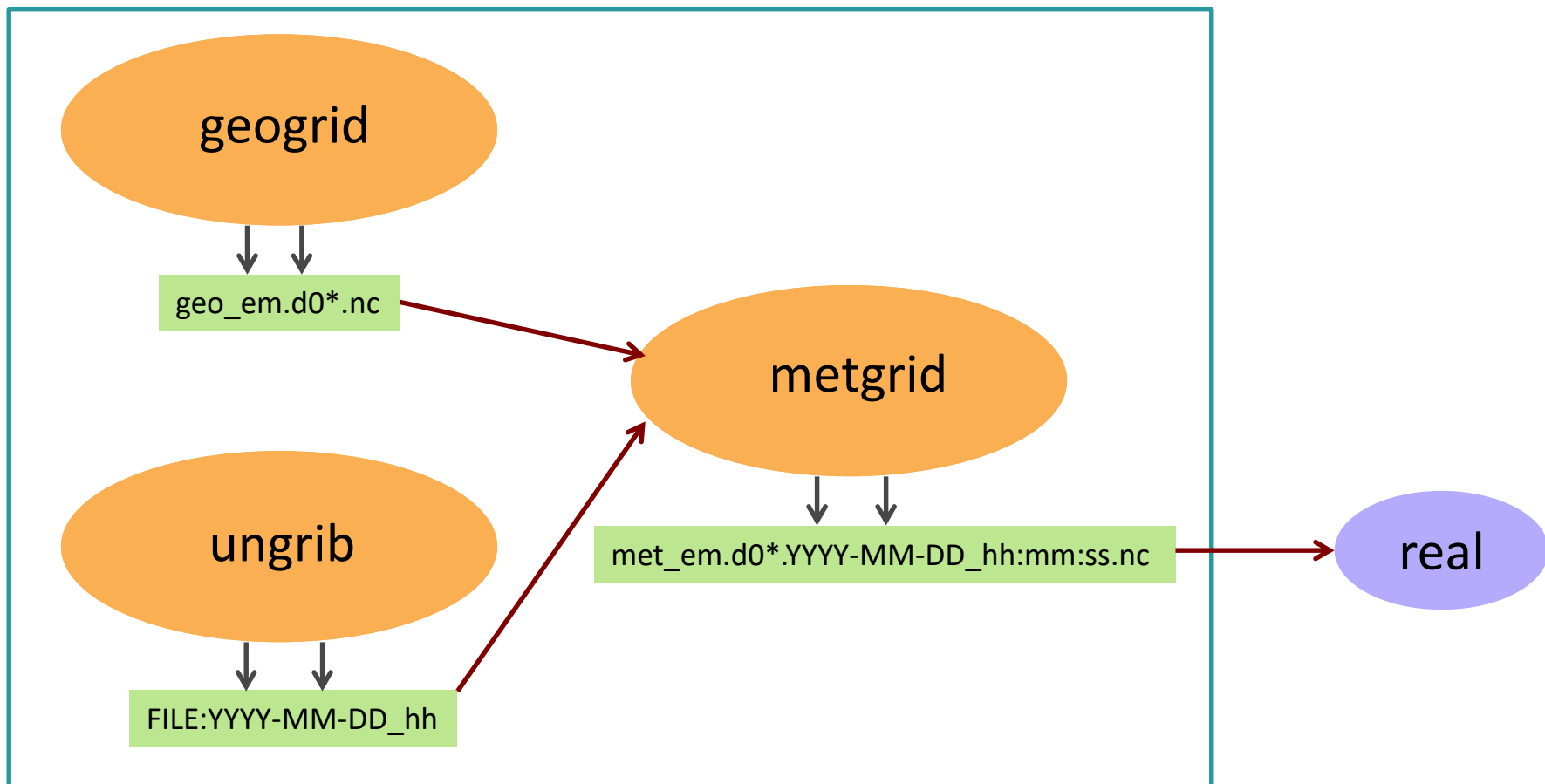The metgrid output files will be used to run real.exe!

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".**

Questions?