The WRF Preprocessing System

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Purpose of this Lecture

In this lecture, our goals are to:

1) Understand the purpose of the WPS

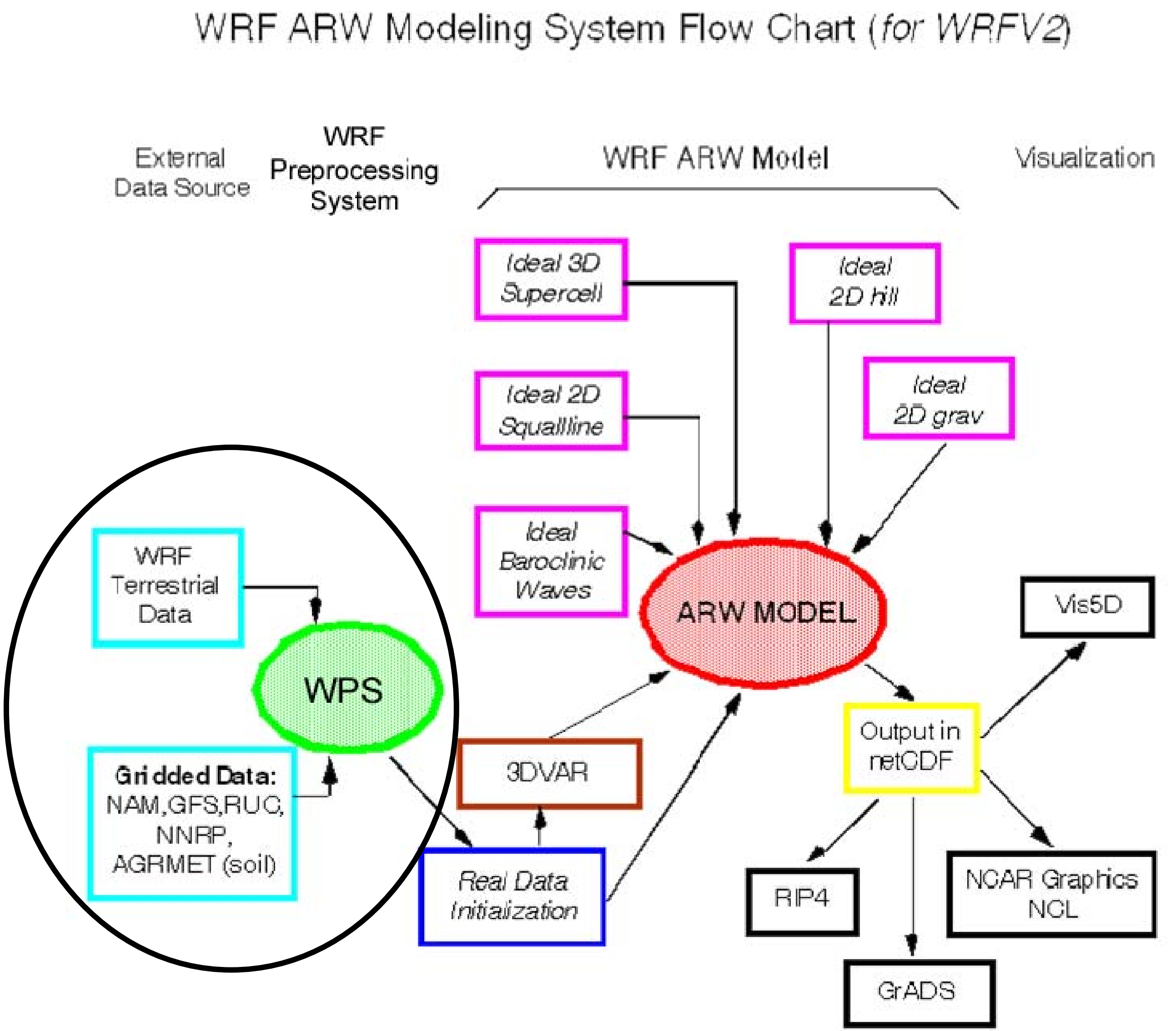
2) Learn what each component of the WPS does

The details of *actually running* the WPS will be covered in a later lecture!

Outline of Topics

- Overview of the WRF Preprocessing System
- Purpose and functionality of WPS components
- Checking WPS output files

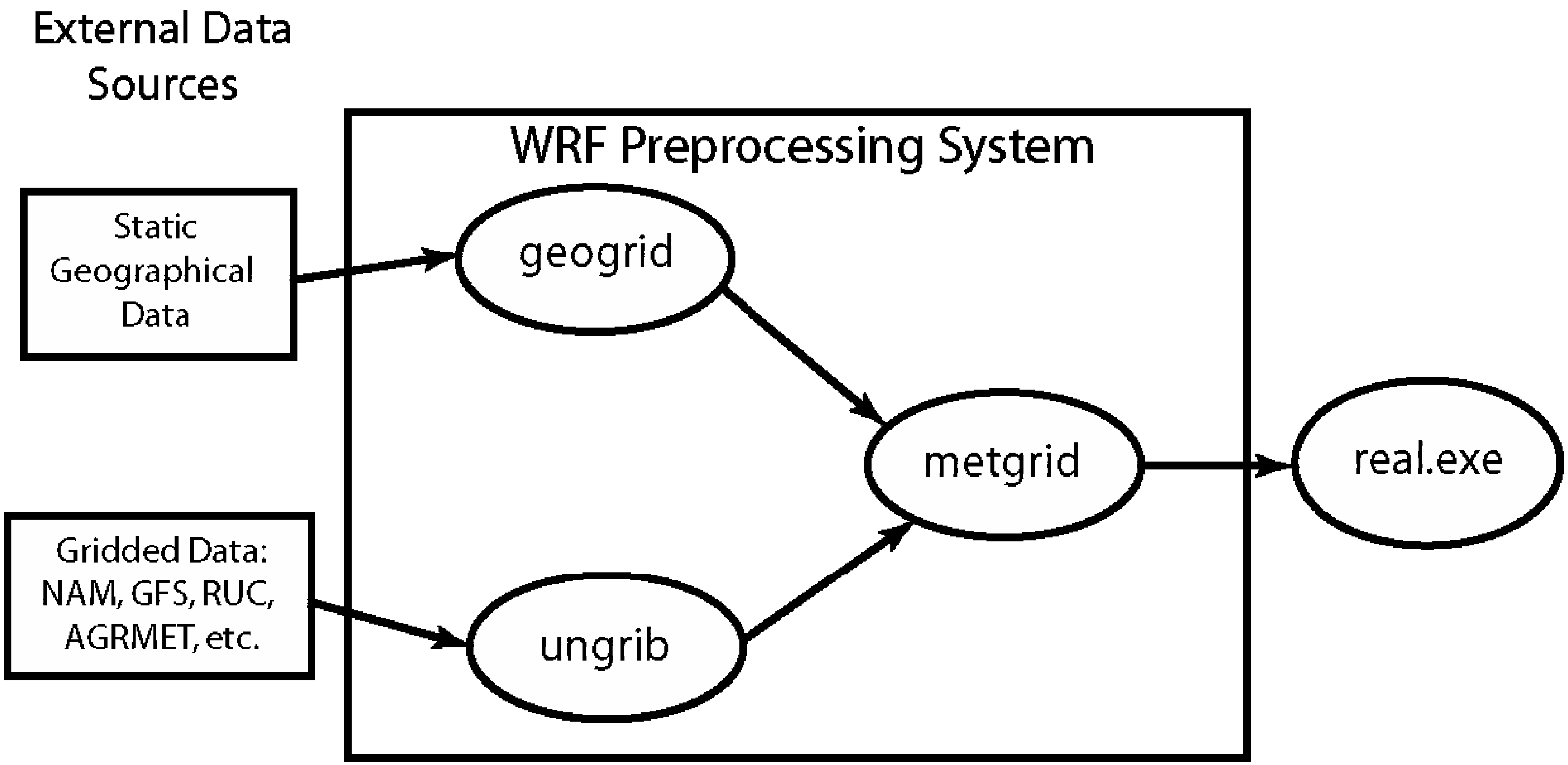
ARW Modeling System Flowchart



Purpose of the WPS

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

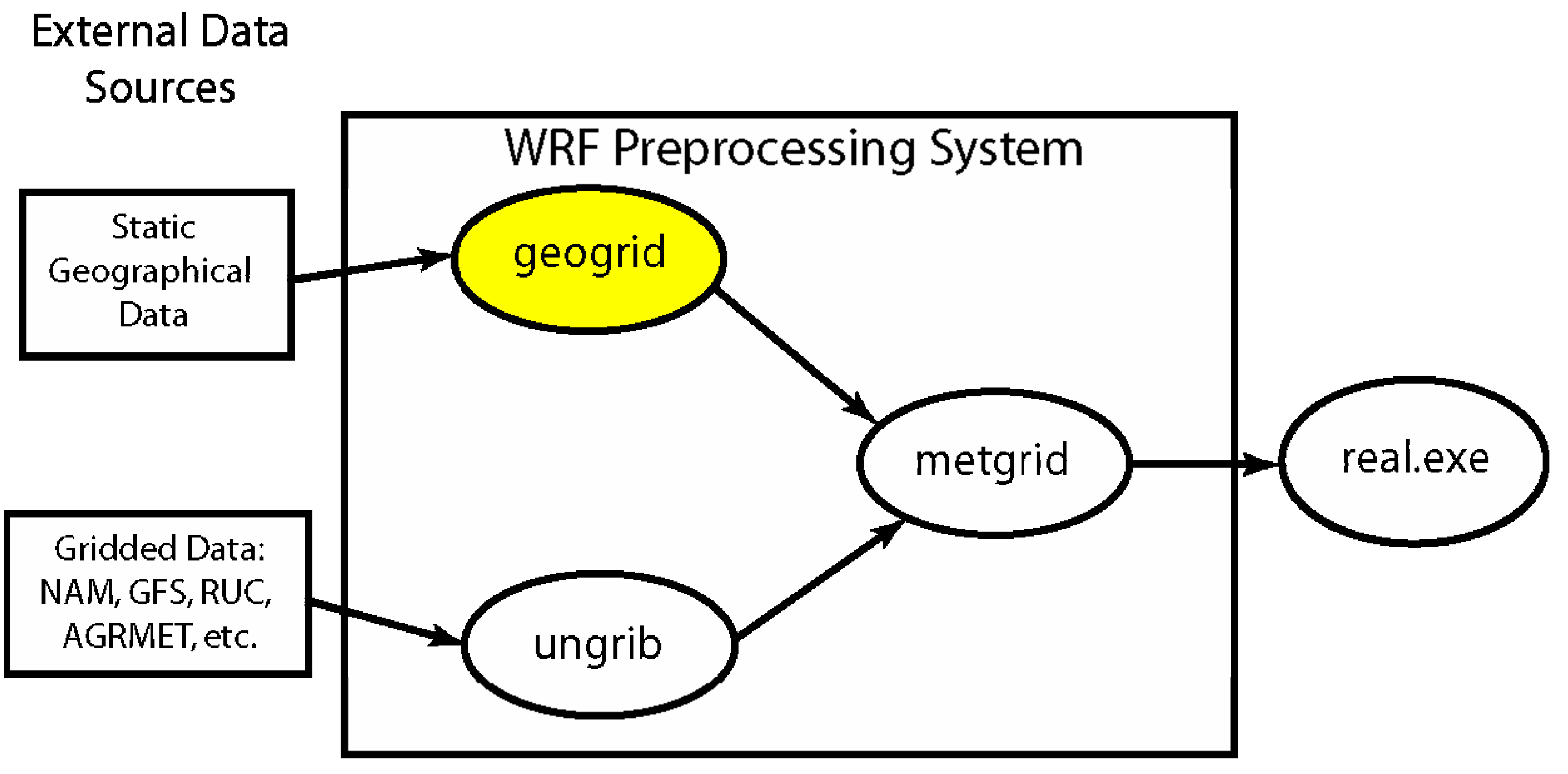
WPS Program Flowchart



Function of WPS Components

- geogrid
  - Define model domains and interpolate static terrestrial fields to simulation grids
- ungrib
  - Extract meteorological fields from GRIB files
- metgrid
  - Horizontally interpolate meteorological fields to simulation grids

The *geogrid* program



The *geogrid* program

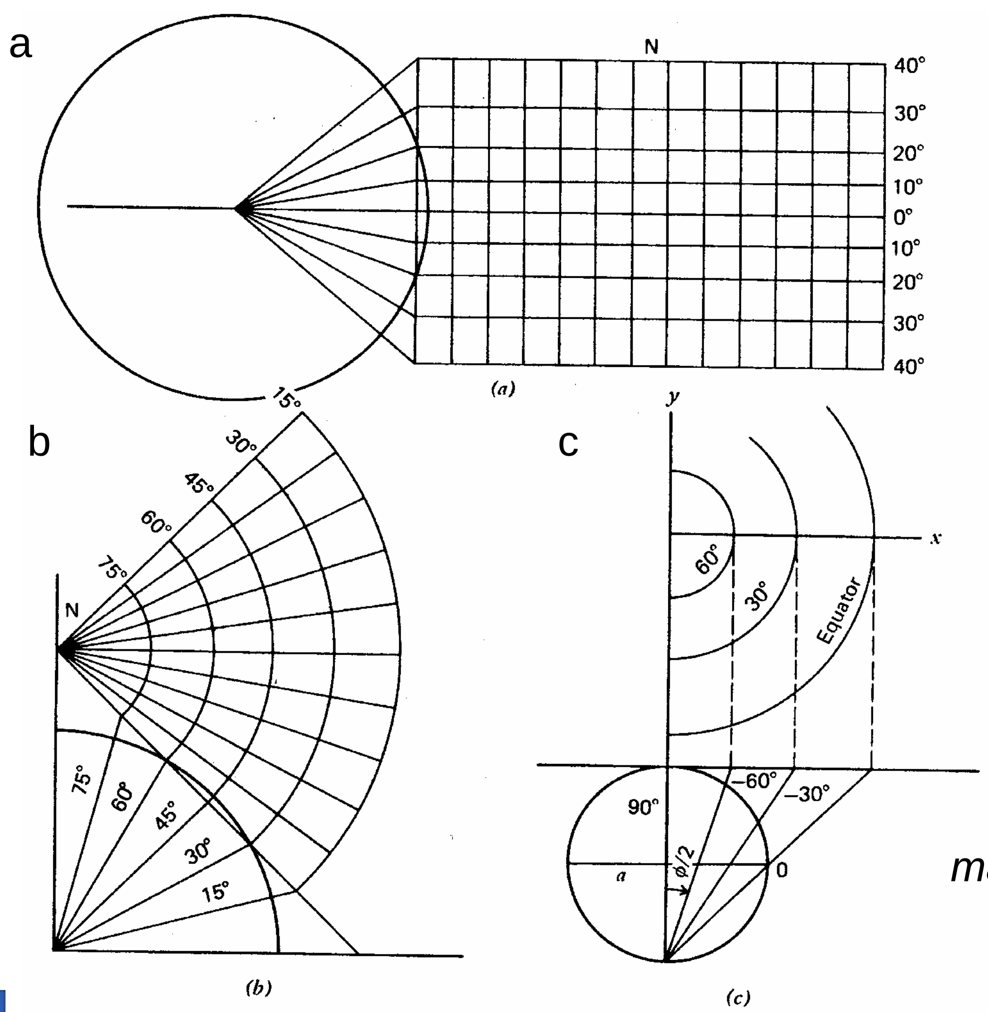
- Define projection, location, and dimensions of simulation domains, including nested domains
- Compute latitude, longitude, map scale factor, and Coriolis parameters at each grid point
- Horizontally interpolate static terrestrial data to each grid point
  - Topography height, land use category, soil type, vegetation fraction, monthly surface albedo, etc.

Geogrid: Defining model domains

- First, we must choose a map projection to use for the domains
  - Earth is (roughly) an ellipsoid
  - But computational domains are defined by rectangles in the plane – maps

- Map projections supported by ARW:
  1. Lambert conformal
  2. Mercator
  3. Polar stereographic

Aside: Map Projection Review



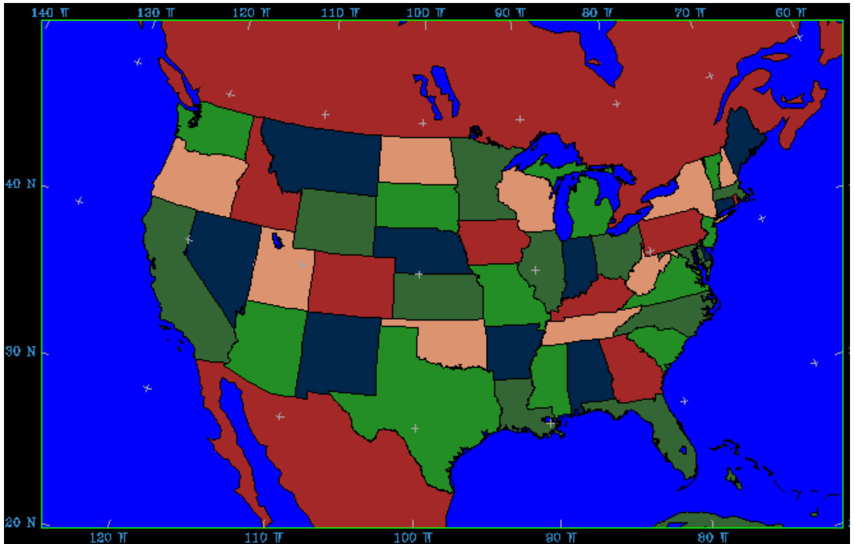
a. Mercator true at 20 N.
b. Lambert-Conformal true at 30 and 60 N.
c. Polar stereographic true at 90 N

$$\textit{map scale factor} = \frac{\textit{distance on grid}}{\textit{distance on earth}}$$

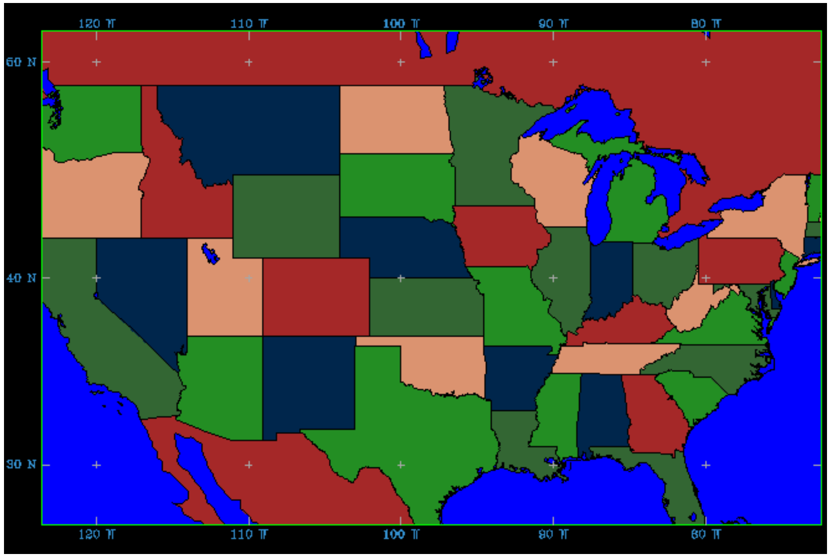
From *Numerical Prediction and Dynamic Meteorology* by Haltiner and Williams

Aside: Map Projection Examples

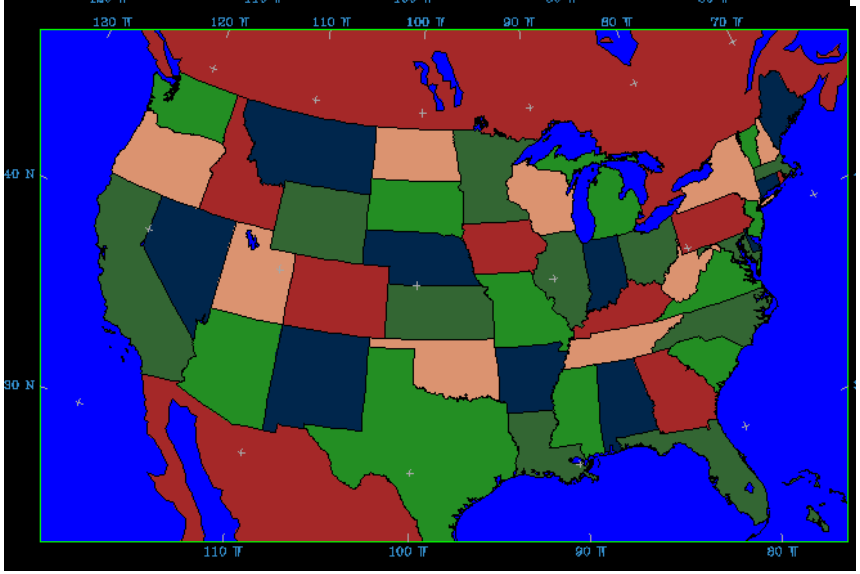
Lambert-Conformal



Mercator



Polar stereographic



Geogrid: Defining Model Domains

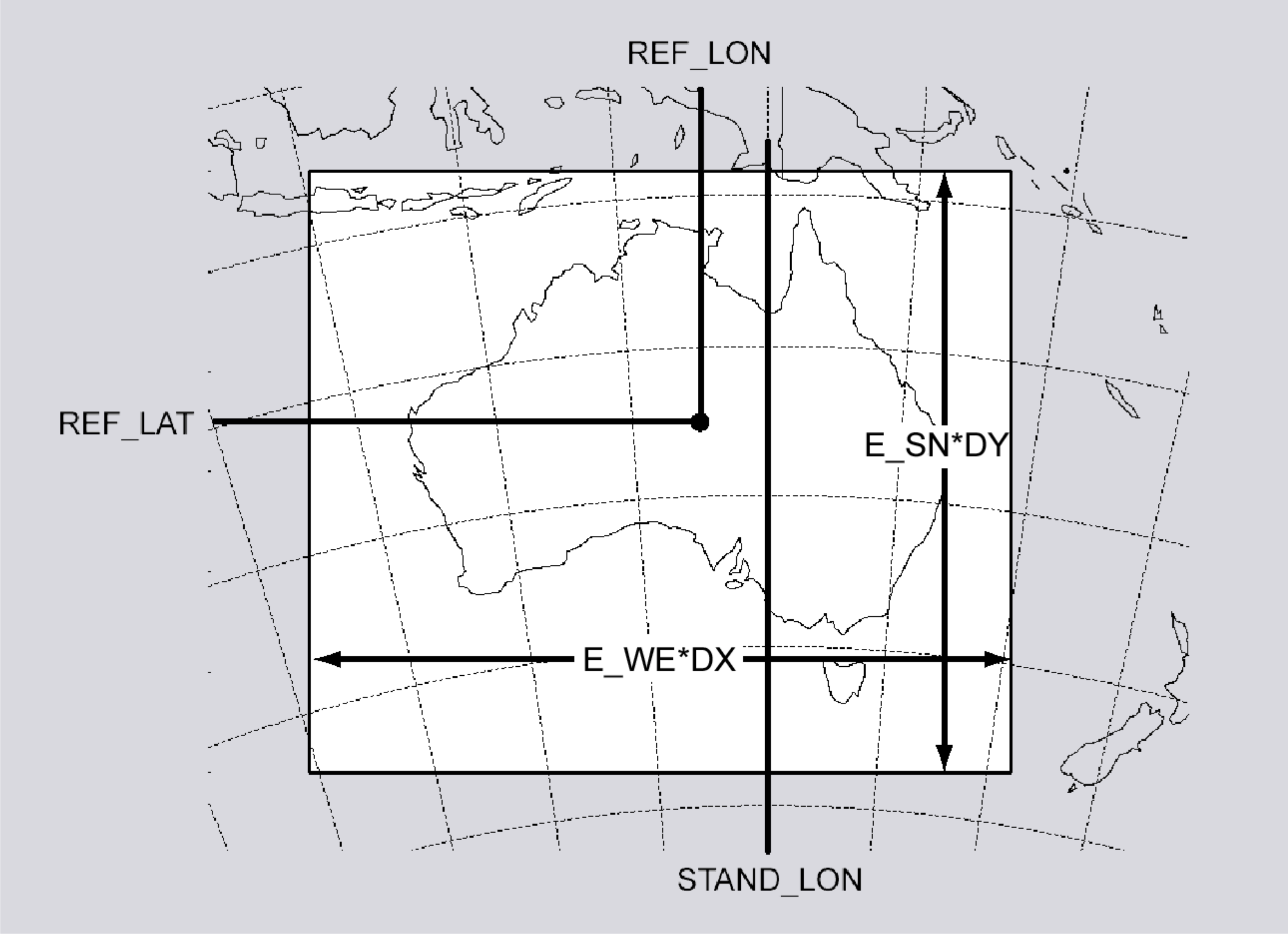
- Define projection of domains with (at most) the following parameters
  - **MAP_PROJ**: ‘Lambert’, ‘Mercator’, or ‘Polar’
  - **TRUELAT1**: First true latitude
  - **TRUELAT2**: Second true latitude (only for Lambert conformal)
  - **STAND_LON**: The meridian parallel to y-axis

- All parameters reside in a *namelist*

Geogrid: Defining Model Domains

- Define the area covered (dimensions and location) of domain using the following:
  - **REF_LAT, REF_LON**: Which point (lat,lon) is at the center of the domain
  - **DX, DY**: Grid distance where map factor = 1
  - **E_WE**: Number of grid points in west-east direction
  - **E_SN**: Number of grid points in south-north direction

Geogrid: Defining Model Domains

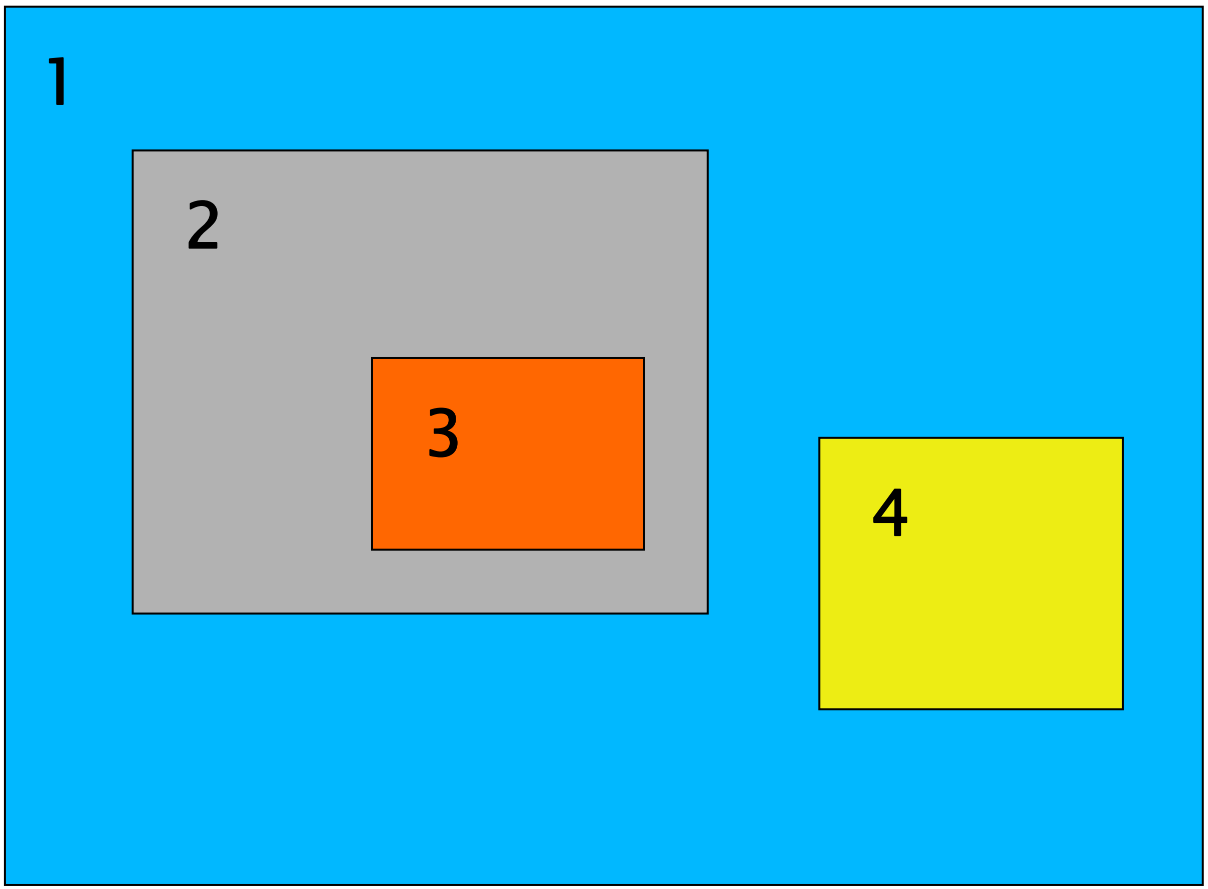


Geogrid: Nesting Basics

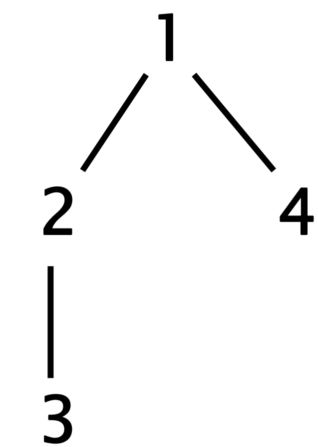
- A *nested domain* is a domain that is wholly contained within its *parent domain*, and may feed information back to its parent
  - A nested domain has exactly one parent
  - A domain (mother or nested) may have one or more children
- In ARW, nests must not overlap in coverage!

Geogrid: Nesting Example

Example configuration – 4 domains



Each domain is assigned a *domain ID #*

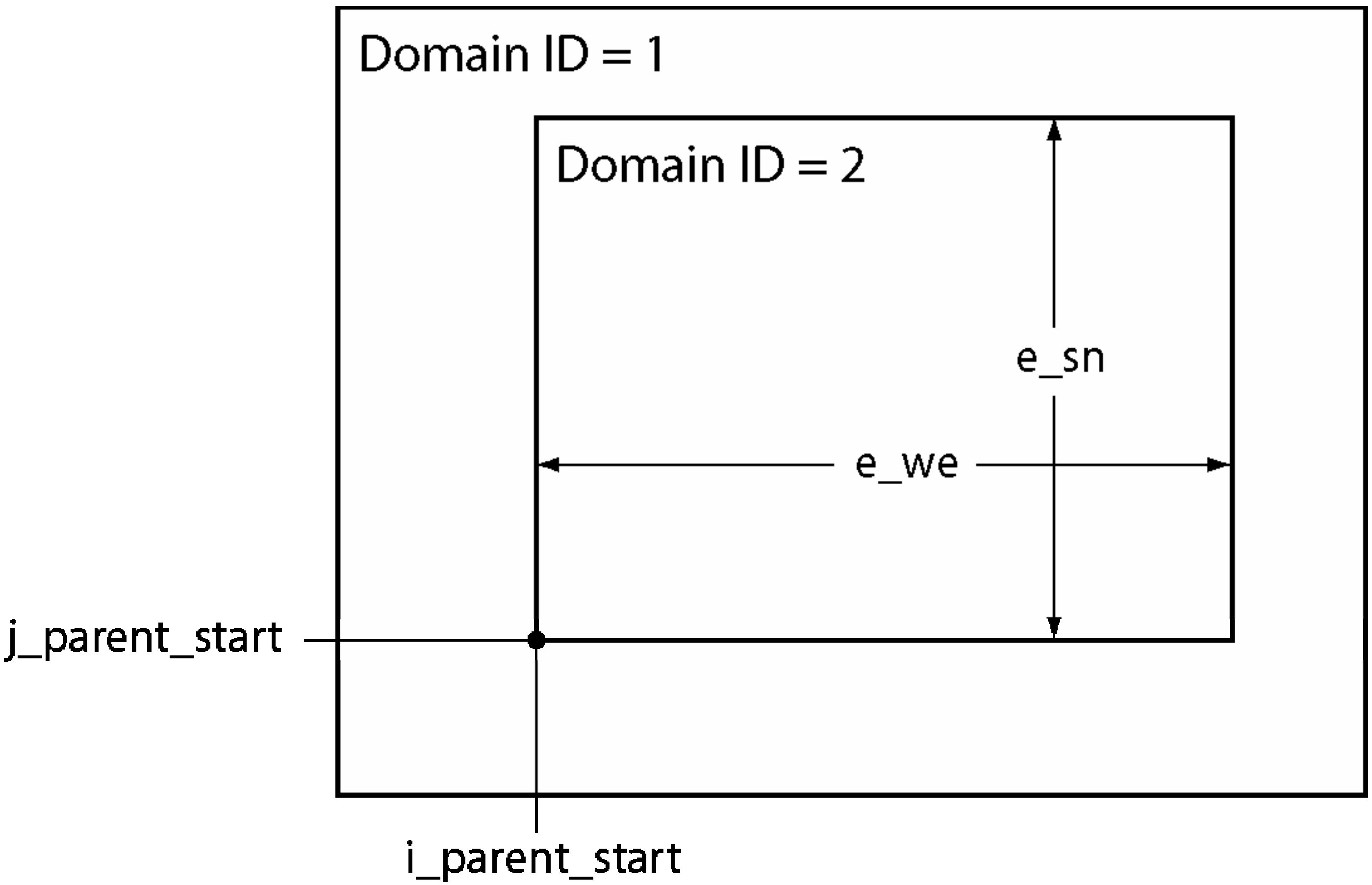


Nesting structure shown as a tree for the domains at left

Geogrid: Defining Nested Domains

- Define the dimensions and location of nested domains using:
  - **PARENT_ID**: Which domain is the parent?
  - **PARENT_GRID_RATIO**: What is the ratio between grid spacing in parent to grid spacing in this nest?
  - **I_PARENT_START**: *i*–coordinate in parent of this nest's lower–left corner
  - **J_PARENT_START**: *j*–coordinate in parent of this nest's lower–left corner
  - **E_WE**: Number of grid points in west–east direction
  - **E_SN**: Number of grid points in south–north direction

Geogrid: Defining Nested Domains



The grid spacing (*dx*) of domain 2 is determined by grid spacing of domain 1 and the *parent_grid_ratio*

e_we and e_*sn* must equal (*k**PARENT_GRID_RATIO)+1 for some positive integer *k*

Geogrid: Interpolating Static Fields

- Given definitions of all computational grids, interpolate terrestrial, time-invariant fields
  - Terrain height
  - Land use categories
  - Soil type (top & bottom layer)
  - Annual mean soil temperature
  - Monthly vegetation fraction
  - Monthly surface albedo

Geogrid: Interpolating Static Fields

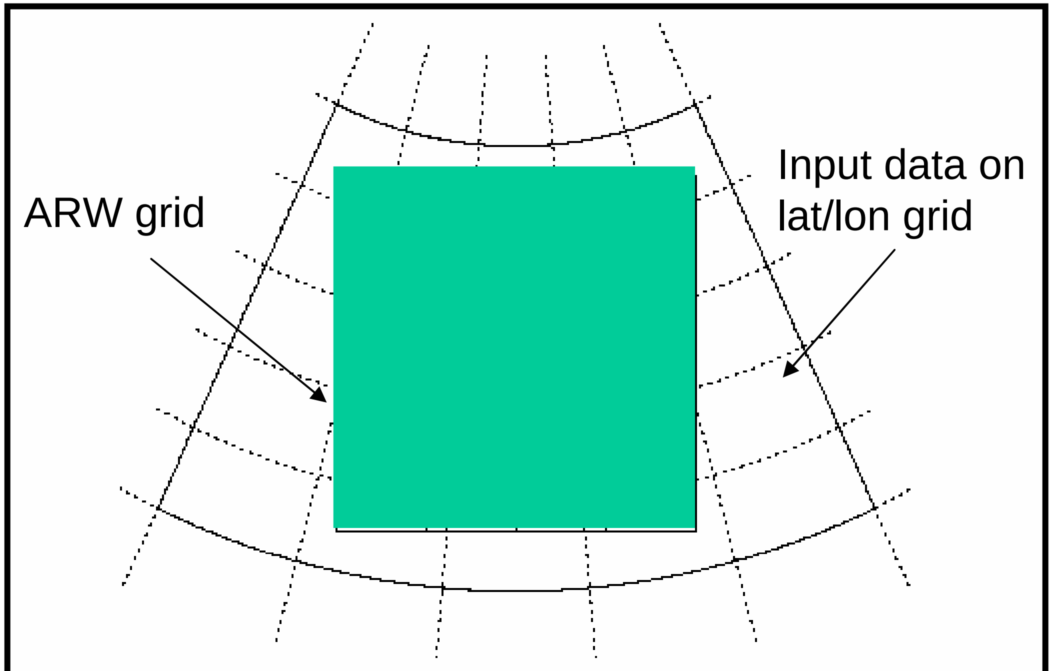


Figure 4.1

In general, source data are projected differently from the simulation grid.

Geogrid: Interpolation Options

- Nearest neighbor
- 4-point bilinear
- 16-point overlapping parabolic
- 4-point average
- 16-point average
- Grid cell average

Geogrid: Program Flexibility

- *geogrid* is flexible enough to ingest and interpolate new static fields
  - handles either continuous or categorical fields
- New data sets must be written to simple binary format
- User needs to add an entry to the file `GEOGRID.TBL`

Geogrid: Program Flexibility

- Format of `GEOGRID.TBL` file is simple text, with specifications of the form <keyword>=<value>
- Example entry for new landuse data set:

```
===============================
name=LANDUSEF
        priority=2
        dest_type=categorical
        z_dim_name=land_cat
        interp_option=30s:nearest_neighbor
        abs_path=30s:/users/duda/Houston/
===============================
```

Geogrid: Program Flexibility

- The GEOGRID.TBL file also allows user to change interpolation methods used for default terrestrial data sets
- Example:

```
interp_option=sixteen_pt
```

or

```
interp_option=four_pt+average_4pt
```

Geogrid: Program Flexibility

- Other options in the GEOGRID.TBL include smoothing options and slope calculation
- Example:

```
smooth_option=smth-desmth

smooth_passes=2
```

- Complete documentation will be made available when WPS is officially released (September 2006)

Geogrid: Program Output

- The parameters defining each domain, plus interpolated terrestrial fields, are written using WRF I/O API
  - One file per domain
- Filenames: geo_em.d0*n*.nc

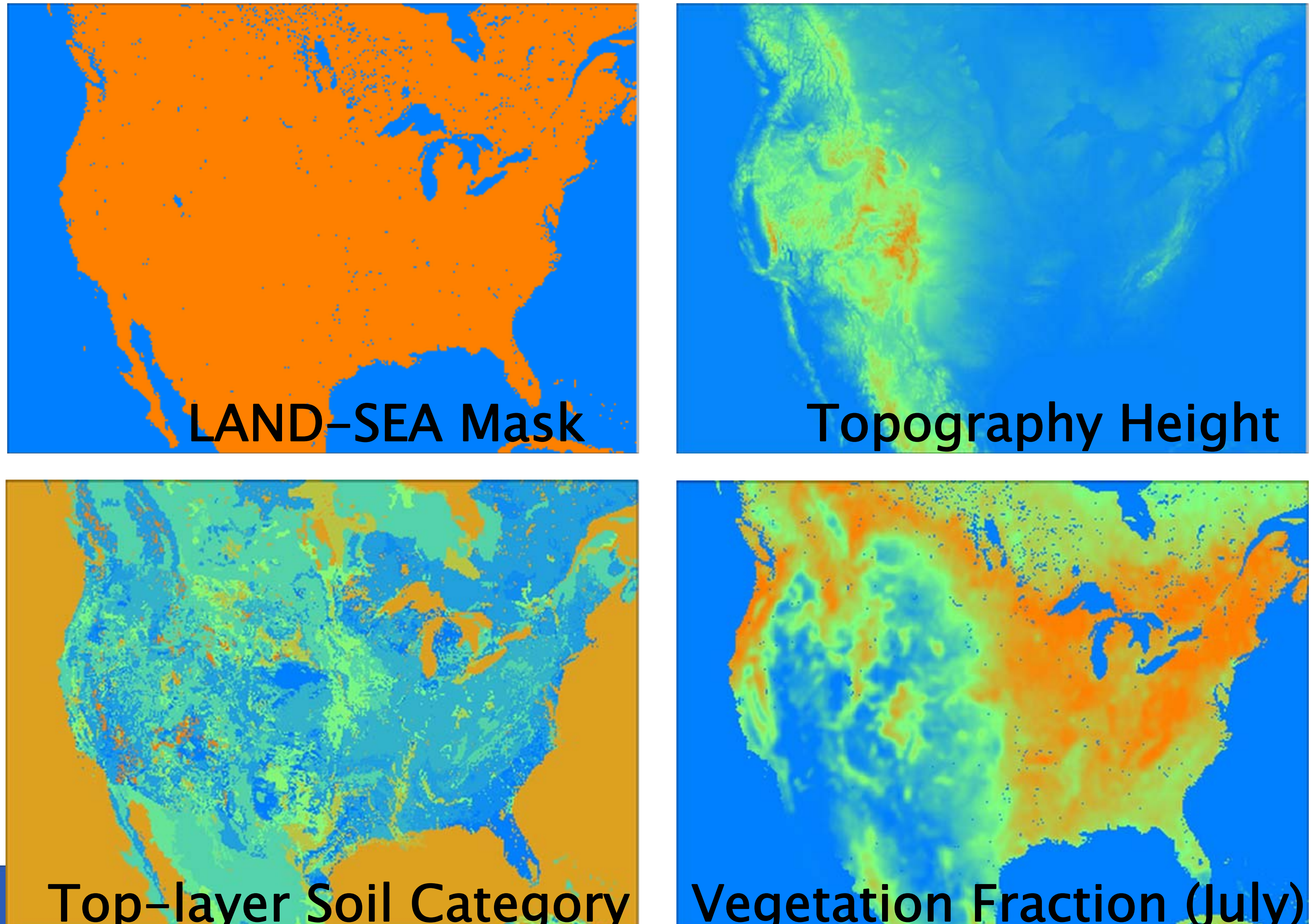
  (where *n* is the domain ID #)
- Example:

  geo_em.d01.nc

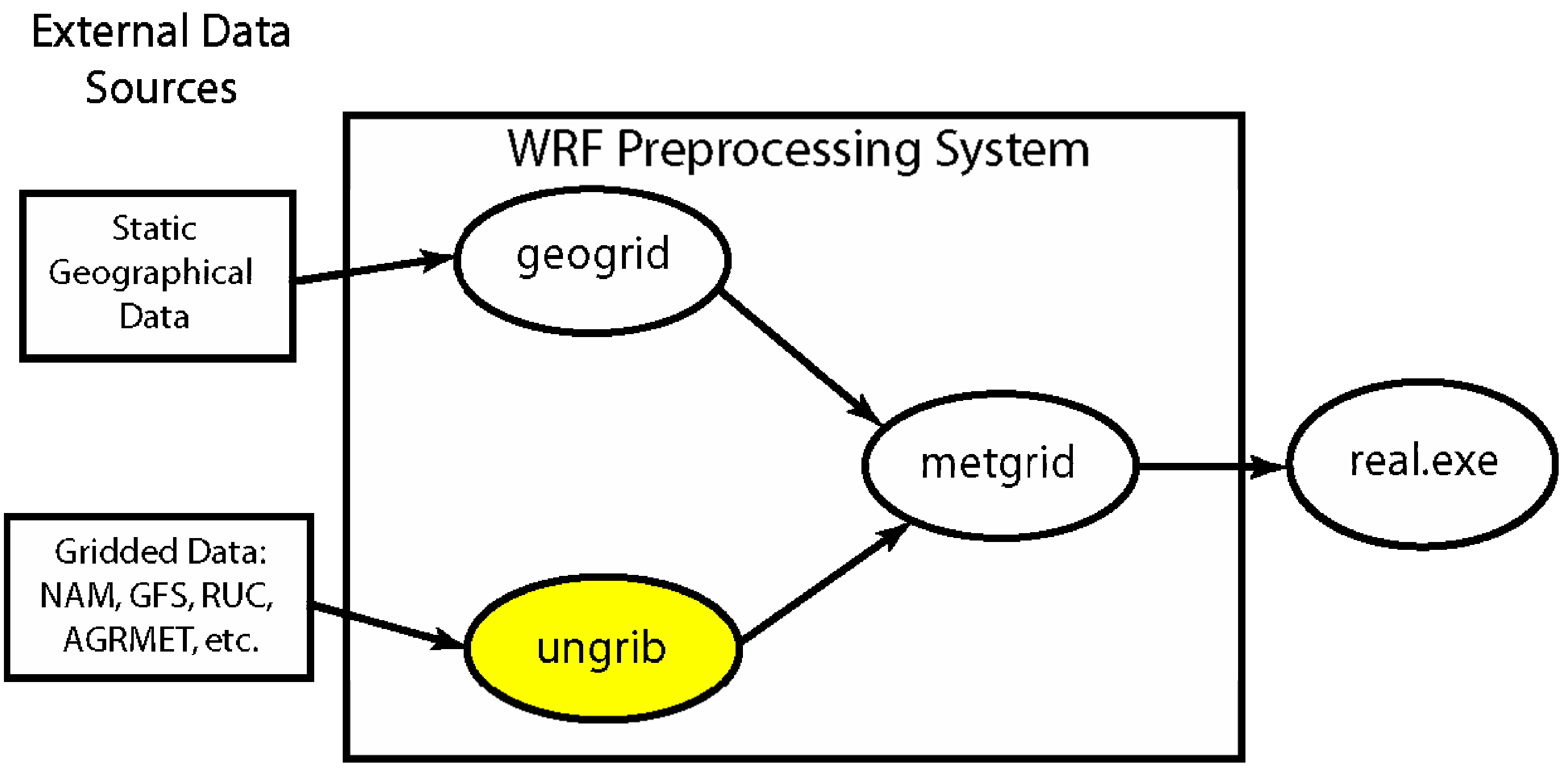
  geo_em.d02.nc (nest)

  geo_em.d03.nc (nest)

Geogrid: Example Output



The *ungrib* program



The *ungrib* program

- Read GRIB Edition 1 and GRIB Edition 2 files
- Extract meteorological fields
- If necessary, derive required fields from related ones
  - Ex: Compute RH from specific humidity
- Write requested fields to an intermediate file format

Ungrib: Vtables

How does ungrib know which fields to extract?

Using Vtables

- Vtables are files that give the GRIB codes for fields to be extracted from GRIB input files
- One Vtable for each source of data
- Vtables are provided for: NAM 104, NAM 212, GFS, AGRMET, and others

Ungrib: Example Vtable

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

What if a data source has no existing Vtable?

Create a Vtable

- Get a listing of GRIB codes for fields in the source
  - Check documentation from originating center or use utility such as *wgrib*
- Use existing Vtable as a template

Ungrib: Intermediate File Format

- After extracting fields listed in Vtable, ungrib writes those fields to intermediate format
- For meteorological data sets not in GRIB format, can write to intermediate format directly
  - Allows WPS to ingest new data sources; basic programming required of user
  - Simple intermediate file format is easily read/written

Ungrib: Program Output

- Output files named *FILE:YYYY-MM-DD_HH*
  - *YYYY* is year of data in the file; *MM* is month; *DD* is day; *HH* is hour
  - All times are UTC
- Example:

  FILE:2006-07-24_00

  FILE:2006-07-24_12

  FILE:2006-07-25_00

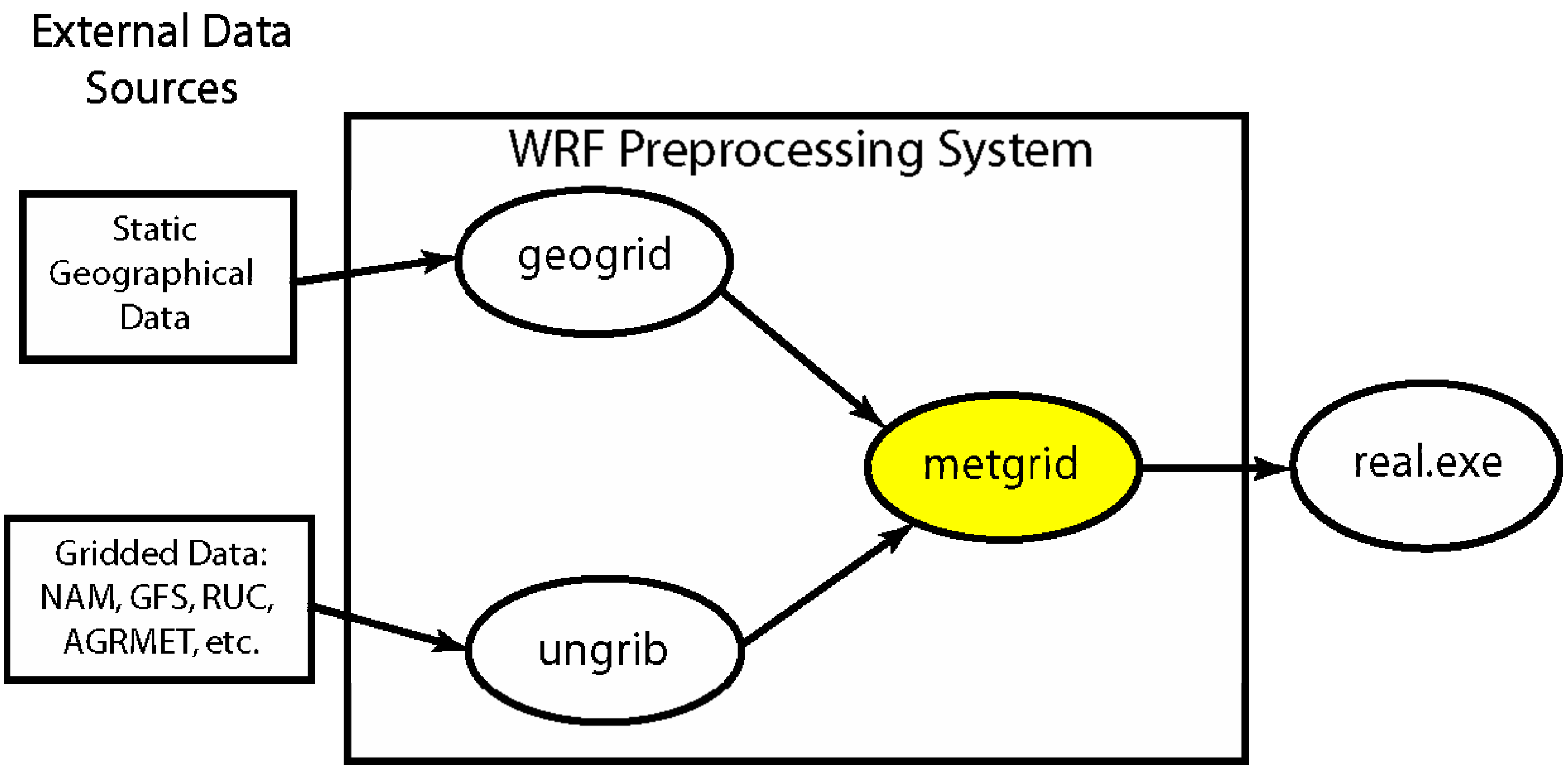
Ungrib: Obtaining GRIB Data

- Where does one get GriB data?
  - User's responsibility
  - Some free data are available from NCAR and NCEP. See
  - *http://www.mmm.ucar.edu/wrf/users/*

    > *Download*

    - Some NCEP data in the past year
    - NCEP operational data available daily

The *metgrid* program

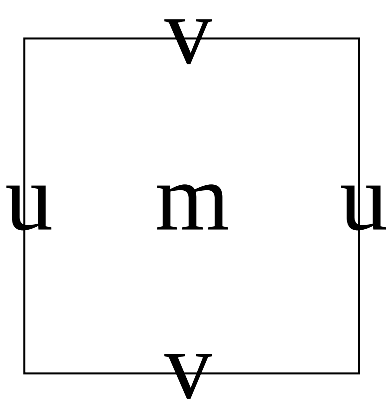


The *metgrid* program

- Horizontally interpolate meteorological data (extracted by ungrib) to simulation domains (defined by geogrid)
  - Masked interpolation for masked fields
- Rotate winds to ARW grid
  - i.e., rotate so that U–component is parallel to *x*–axis, V–component is parallel to *y*–axis

Metgrid: Grid Staggering

- For ARW, wind U-component interpolated to "u" staggering
- Wind V-component interpolated to "v" staggering
- Other meteorological fields interpolated to "m" staggering



A single ARW grid cell, with "u", "v", and "m" points labeled.

Metgrid: Interpolation Methods

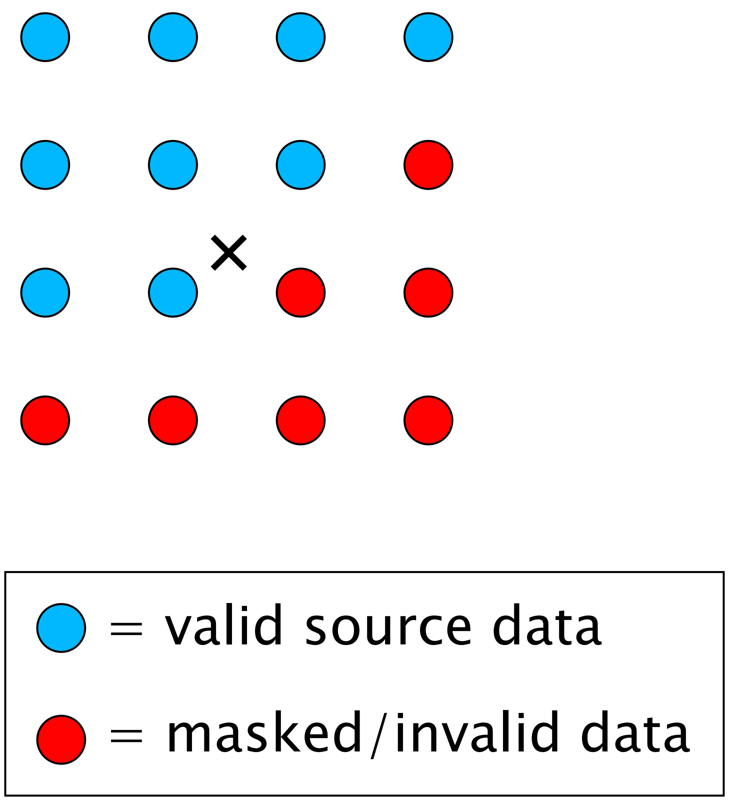
- Nearest neighbor
- 4-point bilinear
- 16-point overlapping parabolic
- 4-point average
- 16-point average
- Grid-cell-average

Metgrid: Masked Interpolation

- *Masked fields* may only have valid data at a subset of grid points
  - Ex: SST field only valid on water points

- When metgrid interpolates masked fields, it must know which points are invalid (masked)
  - Can use separate mask field (ex: LANDSEA)
  - Can rely on special values (ex: 1×10^{30}) in field itself to identify masked grid points

Metgrid: Masked Interpolation



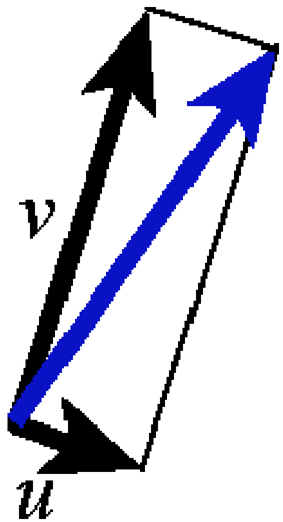
Suppose we need to interpolate to point X

- Using red points as valid data can give a bad interpolated value!
- Masked interpolation only uses valid blue points to interpolate to X

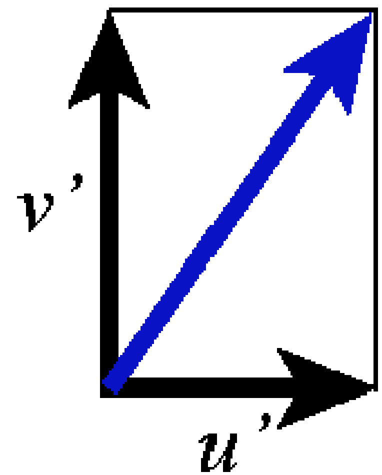
Metgrid: Wind Rotation

- Input wind fields (U-component + V-component) are either:
  - **Earth-relative**: U-component = southerly component; V-component = westerly component
  - **Relative to source grid**: U-component (V-component) parallel to source model x-axis (y-axis)
- WRF expects wind components to be relative to the simulation grid

Metgrid: Wind Rotation Example



A wind vector, shown in terms of its U and V components with respect to the source grid.



The same vector, in terms of its U and V components with respect to the ARW simulation grid.

Metgrid: Constant Fields

- For short simulations, some fields may be constant
  - Ex: SST, sea-ice fraction
- Constant fields typically only available at one time
- Use namelist option `CONSTANTS_NAME` option to specify such fields:
  - `CONSTANTS_NAME = 'SST_FILE:2006-07-24_00'`

Metgrid: Program Flexibility

- *metgrid* is capable of interpolating both isobaric and native vertical coordinate data sets
- User may specify interpolation methods and related options in the `METGRID.TBL` file
- `METGRID.TBL` file similar in format to the file `GEOGRID.TBL`

Metgrid: Program Flexibility

- Example METGRID.TBL entry (for “soil moisture 0-10cm”)

```
========================================
name=SM000010
interp_option=sixteen_pt+four_pt+average_4pt
masked=water
interp_mask=LANDSEA(0)
fill_missing=1.
flag_in_output=FLAG_SM000010
========================================
```

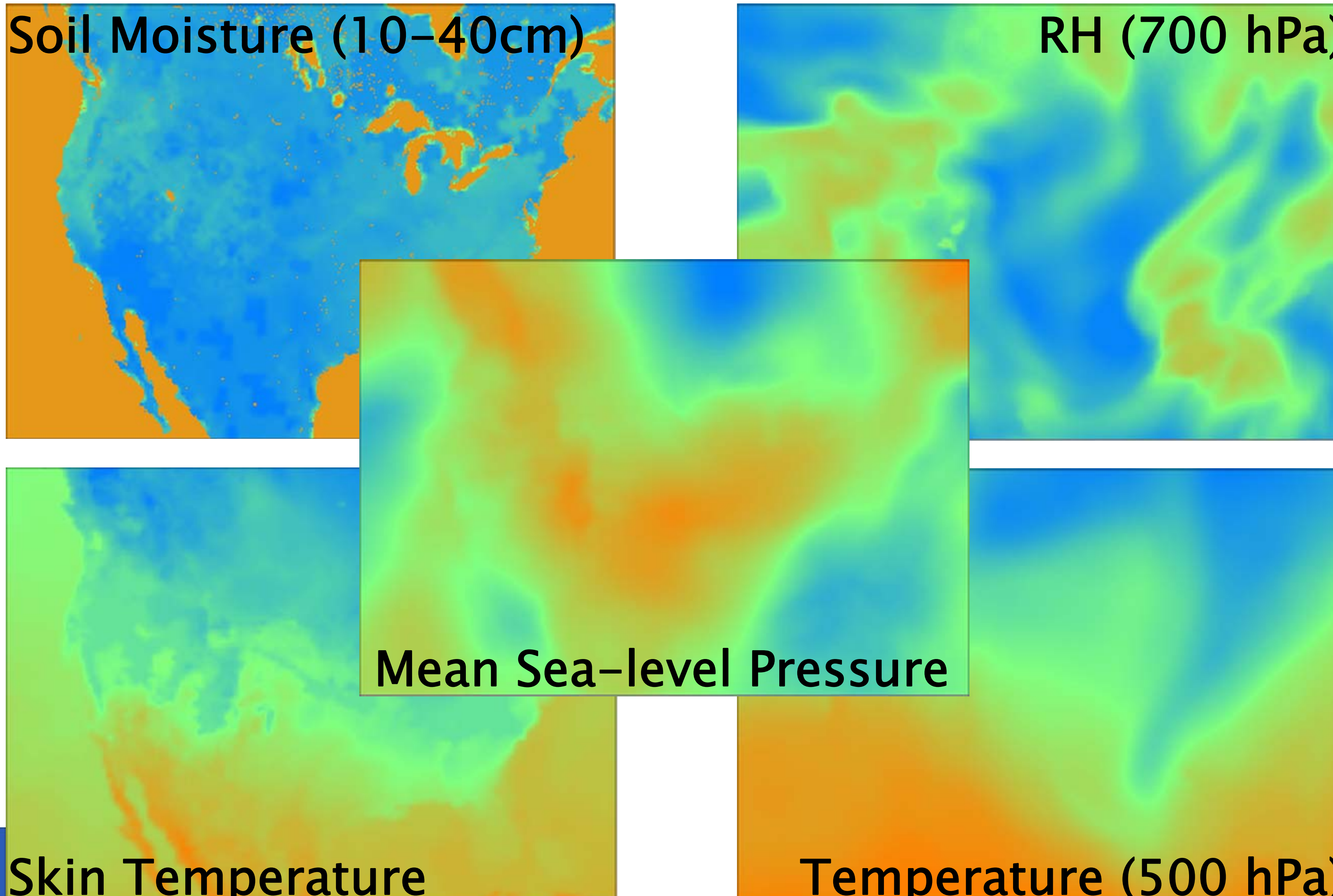
Metgrid: Program Output

- One output file per domain per time
  - Except nests, which only have initial time!
- Files contain static fields from geogrid plus interpolated meteorological fields
- Filenames:

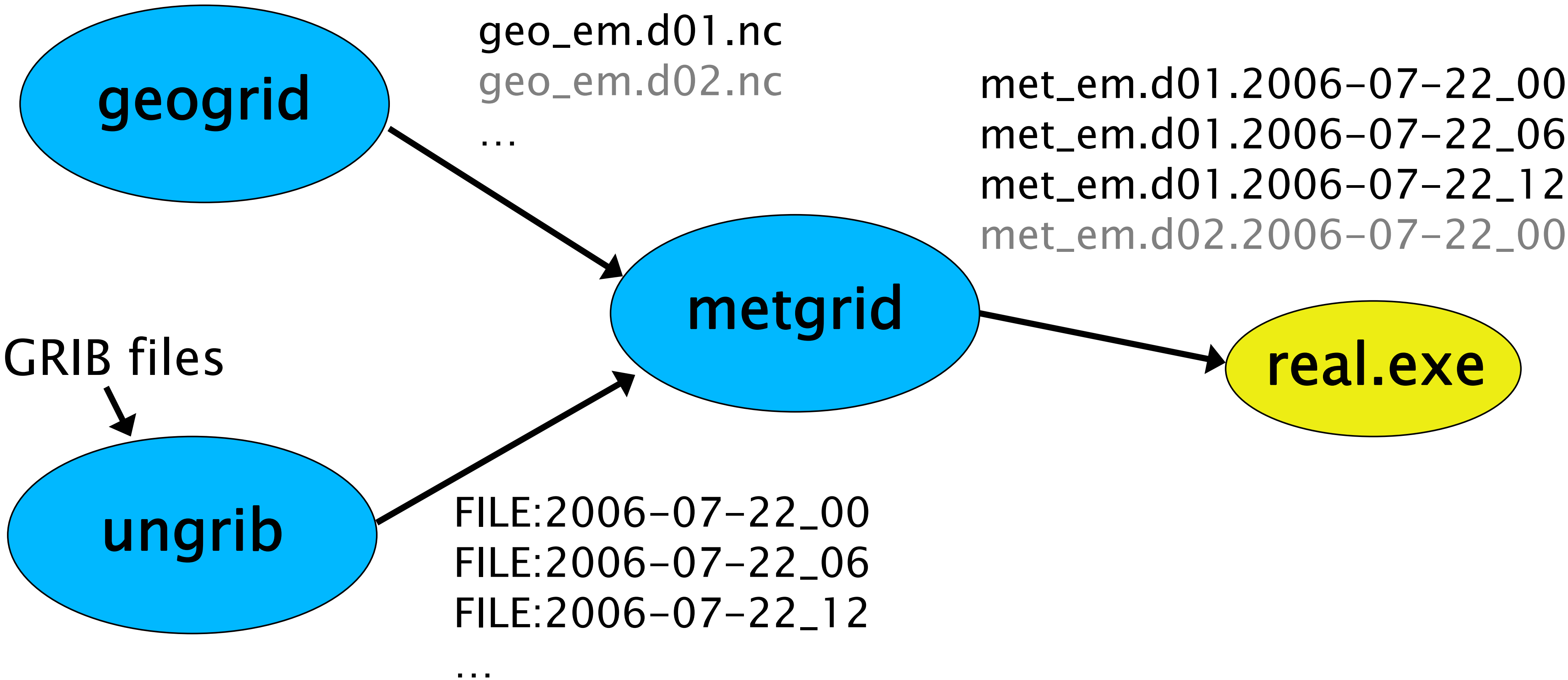
  `met_em.d0`*`n`*`.`*`YYYY-MM-DD_HH`*`.nc`

  (where *n* is the domain ID #)

Metgrid: Example Output



WPS Summary


geogrid
geo_em.d01.nc
geo_em.d02.nc
...
met_em.d01.2006-07-22_00
met_em.d01.2006-07-22_06
met_em.d01.2006-07-22_12
met_em.d02.2006-07-22_00
metgrid
GRIB files
real.exe
ungrib
FILE:2006-07-22_00
FILE:2006-07-22_06
FILE:2006-07-22_12
...

Checking WPS Output

- For NetCDF output from *geogrid* and *metgrid*:
  - ncdump, ncview, RIP4 (next release)

- For intermediate-format output from *ungrib*:
  - plotfmt (MM5 program; for pregrid format)
  - plotfmt (SI program; for grib_prep format)

Checking WPS Output

- For more about graphical tools for checking output, see the talk this afternoon:

"WRF ARW Graphical Tools"

Cindy Bruyère