WRF Modeling System Overview

- WRF: Weather Research and Forecasting Model
  - Used for both research and operational forecasting
- It is a supported “community model”, i.e. a free and shared resource with distributed development and centralized support
- Its development is led by NCAR, NOAA/GSD and NOAA/NCEP/EMC with partnerships at AFWA, FAA, NRL, and collaborations with universities and other government agencies in the US and overseas.

WRF Dynamical Cores

- Currently, WRF software infrastructure supports two dynamical cores:

1) the Advanced Research WRF (ARW): developed by the leader of NCAR

2) the Non-hydrostatic Mesoscale Model (NMM): by NCEP/NOAA

WRF Application Cores

- ARW base:

  WRF/CHEM, CWRF

- NMM base:

  HWRF

What are ARW and NMM

- The Advanced Research WRF (ARW) and Nonhydrostatic Mesoscale Model (NMM) are dynamical cores
  - Dynamical core includes mostly advection, pressure-gradients, Coriolis, buoyancy, filters, diffusion, and time-stepping.
- Both are Eulerian mass dynamical cores with terrain-following vertical coordinates.
- ARW support and development are centered at NCAR/MMM
- NMM development is centered at NCEP/EMC and support is provided by NCAR/DTC.
- Both are downloadable in the same WRF tar file.
- Physics, the software framework, and parts of data pre- and post-processing are shared between the dynamical cores.

WRF as a Community Model

- Version 1.0 WRF was released December 2000.
- Version 2.0 May 2004 (NMM added, EM nesting released).
- Version 2.1 August 2005 (EM becomes ARW).
  - Version 2.1.1 Nov 2005 (NMM released).
  - Version 2.1.2 Jan 2006.
- Version 2.2 December 2006 (WPS released).
  - NMM nesting released in 2007.
  - 2.2.1 released in Nov 2007.
- Version 3.0 released in April 2008.
- WRF Model Version 3.1 (Released April 9, 2009)

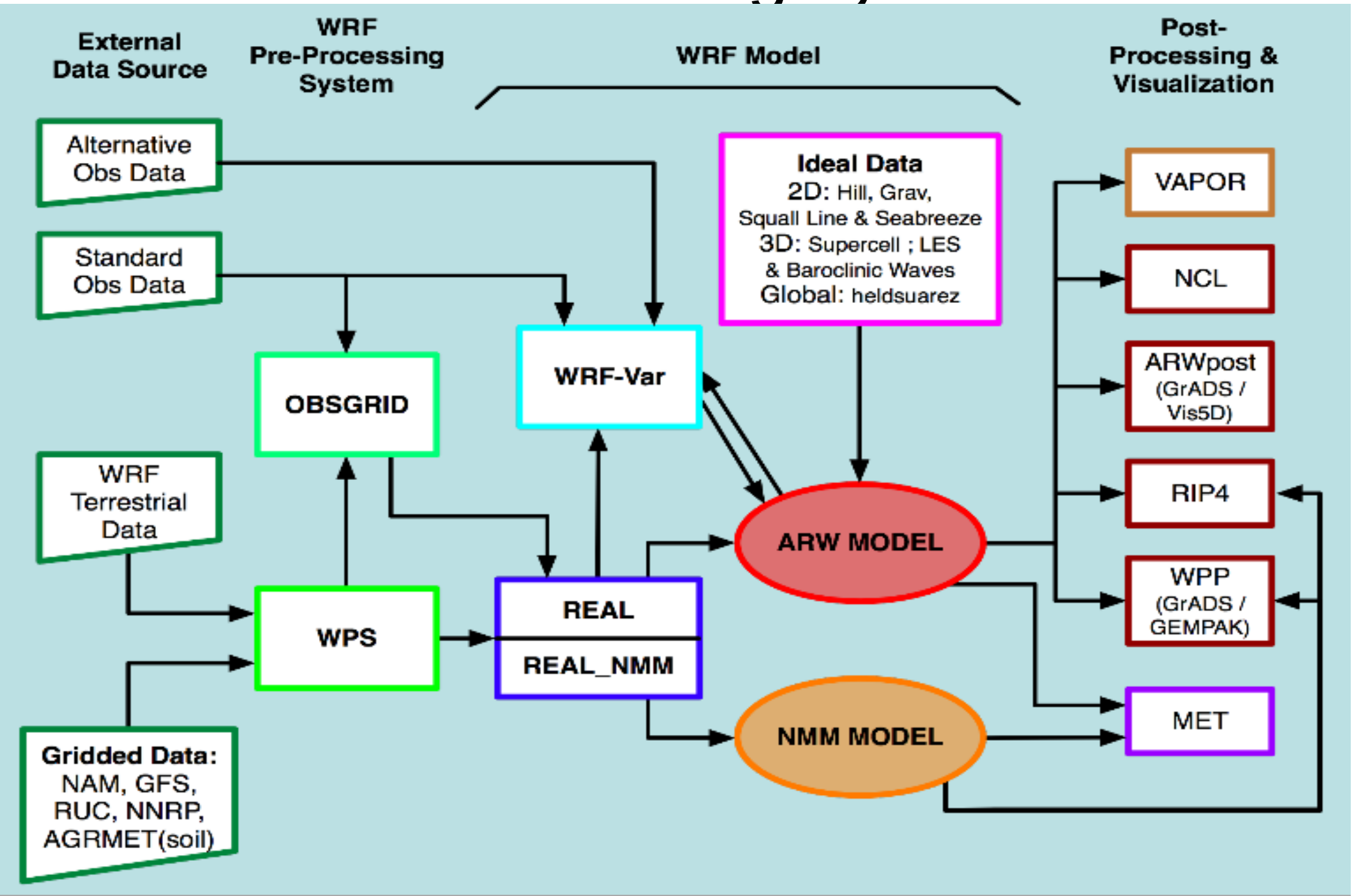
What can WRF be used for

- ARW and NMM
  - Atmospheric physics/parameterization research.
  - Case-study research.
  - Real-time NWP and forecast system research.
  - Teaching dynamics and NWP.
- ARW only
  - Regional climate and seasonal time-scale research.
  - Coupled-chemistry applications.
  - Global simulations.
  - Idealized simulations at many scales (e.g. convection, baroclinic waves, large eddy simulations)
  - Data assimilation research.

Who uses WRF

- Academic atmospheric scientists (dynamics, physics, weather, climate research).
- Forecast teams at operational centers.
- Applications scientists (e.g. Air Quality, Hydrology, Utilities).

WRF modeling system



Modeling System Components

- WRF Pre-processing System (WPS)
  - Real-data interpolation for NWP runs.
  - New obsgrid program for adding more obs to analysis.
- WRF Model (ARW and NMM dynamical cores)
  - Initialization programs for real and (for ARW) idealized data(real.exe/ideal.exe).
  - Numerical integration program (wrf.exe).
- Graphics and verification tools.
- WRF-Var.
- WRF-Chem.

Basic Software Requirement

- Fortran 90/95 compiler
- C compiler
- Perl
- netCDF library
- Public domain mpich for MPI.

Portability

- Runs on Unix single, OpenMP and MPI platforms:
  - IBM SP AIX (xlf).
  - Linux (PGI, Intel, g95, gfortran, Pathscale compilers).
  - SGI Altix (Intel).
  - Cray XT (PGI, Pathscale).
  - Mac Darwin (xlf, PGI, Intel, g95 compilers).
  - Others (HP, Sun, SGI Origin, Compaq).

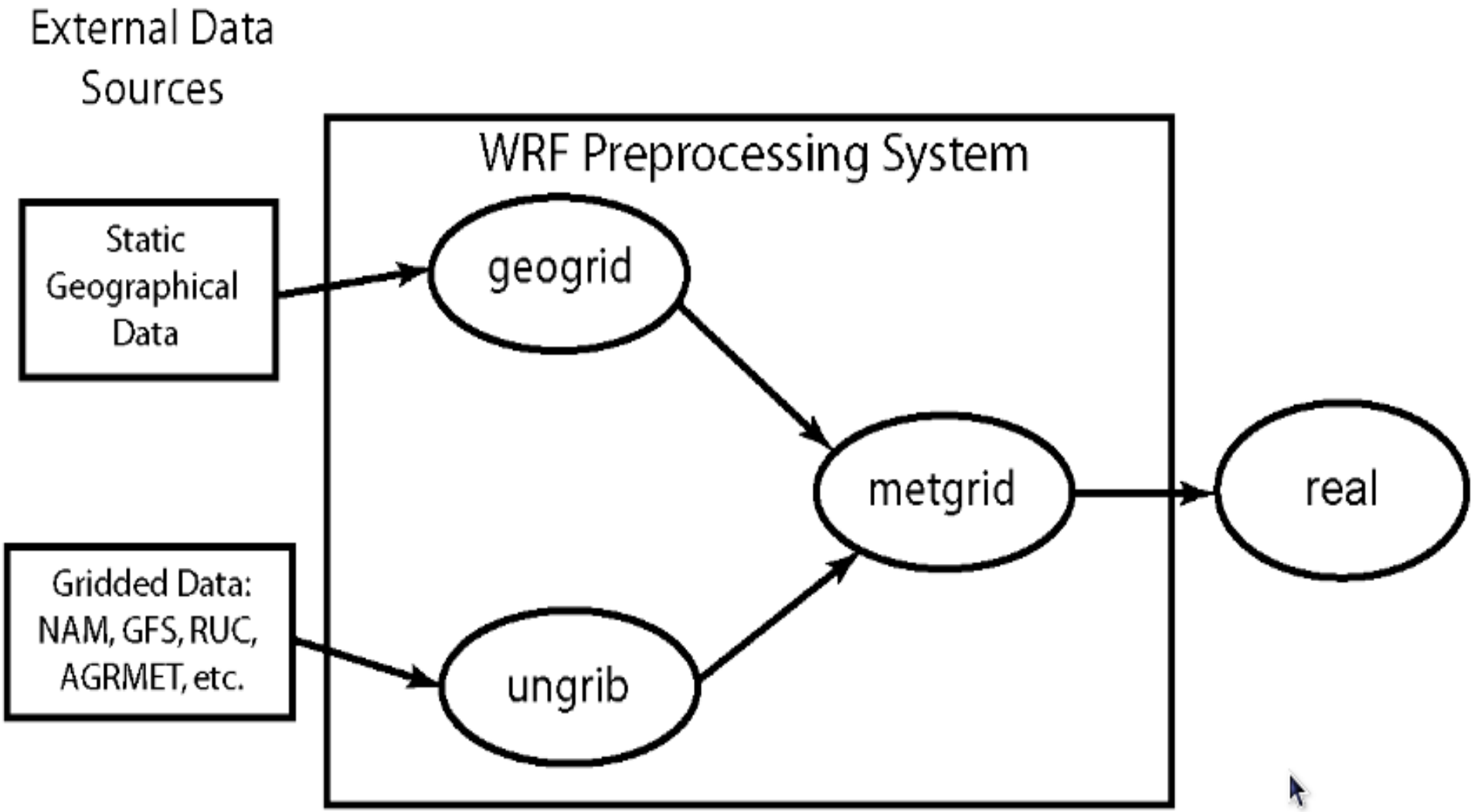
User Support

- Email: wrfhelp@ucar.edu
- User Web pages:
  ARW:http://www.mmm.ucar.edu/wrf/users/
  NMM:http://www.dtcenter.org/wrf-nmm/users/
  – Latest update for the modeling system
  – WRF software download
  – Various documentation
    - Users' Guide
    - Technical Note (ARW Description)

WPS

- Define simulation domain area (and nests).
- Produce terrain, landuse, soil type etc. on the simulation domain (“static” fields).
- Degrib GRIB files for meteorological data (u, v,T, q, surface pressure, soil data, snow data, sea-surface temperature, etc).
- Interpolate meteorological data to WRF model grid (horizontally).
- Optionally add more observations to analysis (separate obsgrid program).

WPS Program Flowchart



The geogrid program

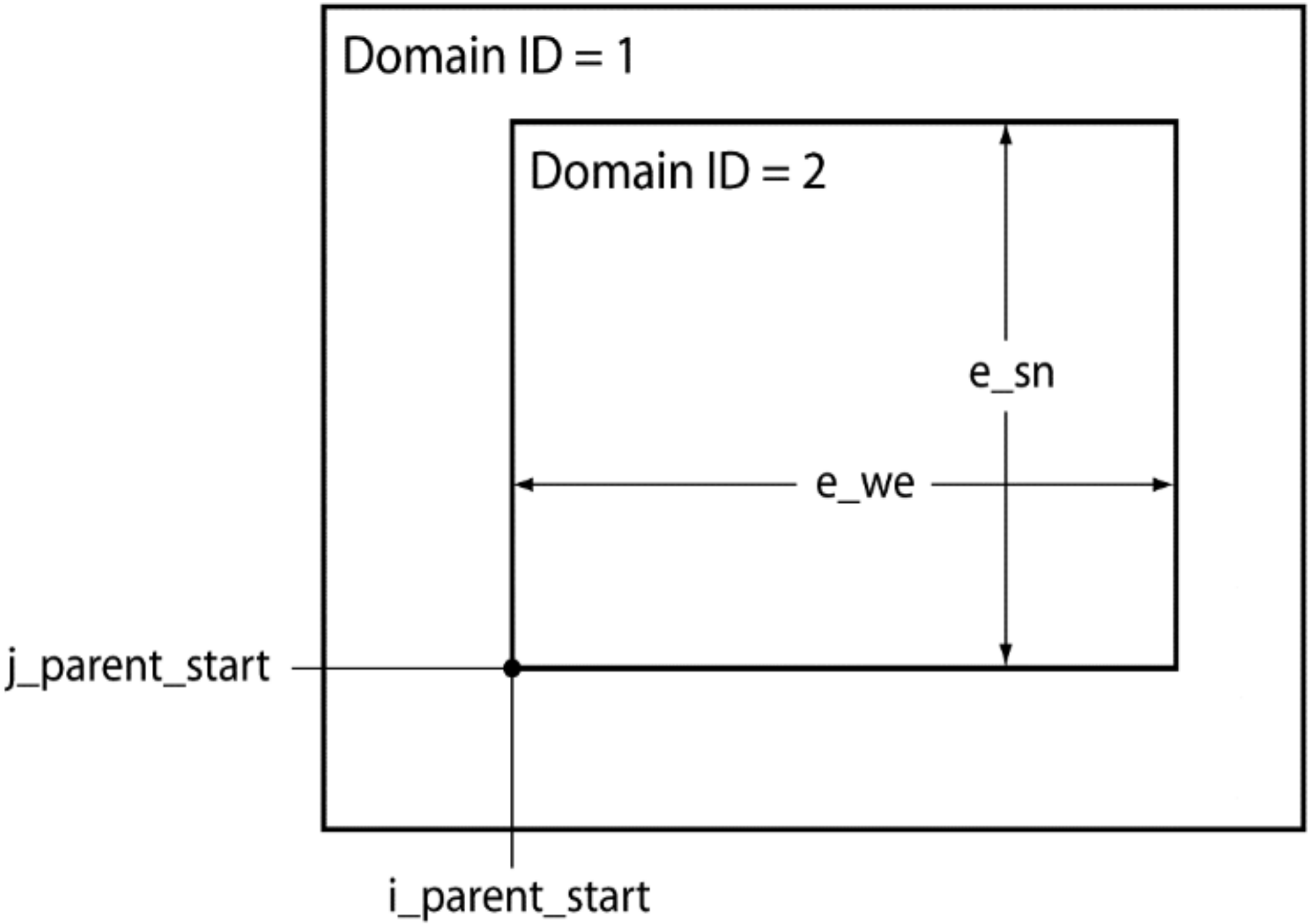
- For WRF model domains, geogrid defines:
  - Map projection (all domains must use the same)
  - Location of domains
  - Dimensions of domains
- Geogrid provides values for static (time-invariant) fields at each model grid point
  - Compute latitude, longitude, map scale factor, and Coriolis parameters at each grid point.
  - Horizontally interpolate static terrestrial data (e.g., topography height, land use category, soil type, vegetation fraction, monthly surface albedo).

Geogrid: Defining Model Domains

- Define projection of domains using subset of the following parameters (All parameters reside in the file namelist.wps)
  - MAP_PROJ: ‘lambert’, ‘mercator’, ‘polar’, ‘lat-lon’, or ‘rotated_ll’
  - TRUELAT1: First true latitude
  - TRUELAT2: Second true latitude
  - STAND_LON: The meridian parallel to y-axis
  - 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 where map factor = 1
    For Lambert, Mercator, and polar stereographic: meters; For (rotated) latitude-longitude: degrees
  - E_WE: Number of velocity points in west-east direction for ARW; number of mass points in odd rows for NMM
  - E_SN: Number of velocity points in south-north direction for ARW; number of rows for NMM

Defining Nested ARW 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 velocity points in west-east direction
  - E_SN: Number of velocity points in south-north direction


Domain ID = 1
Domain ID = 2
e_sn
e_we
j_parent_start
i_parent_start

Geogrid: Defining Model Domains

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

- Output file: geo_em.d0n.nc

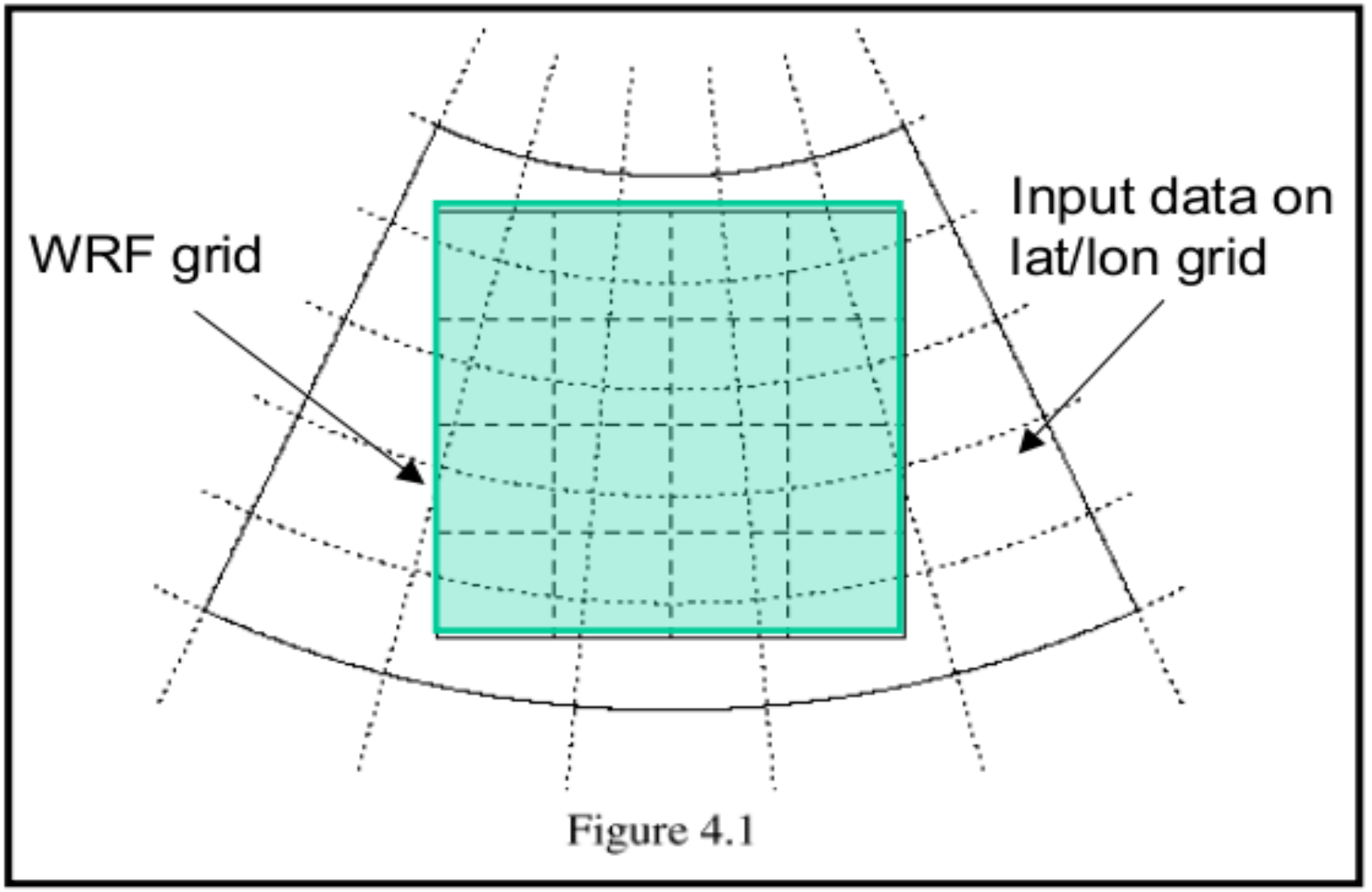


Figure 4.1

In general, source data are given on a different projection from the model grid

The ungrib program

- Read 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
- 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.

Ungrib: Obtaining GRIB Data

- Where does one get GRIB data?
  Some free data are available from NCAR and NCEP.
  See
  http://www.mmm.ucar.edu/wrf/users, under the
  "Downloads" tab: Some NCEP data in the past year.
  NCEP operational data available daily.

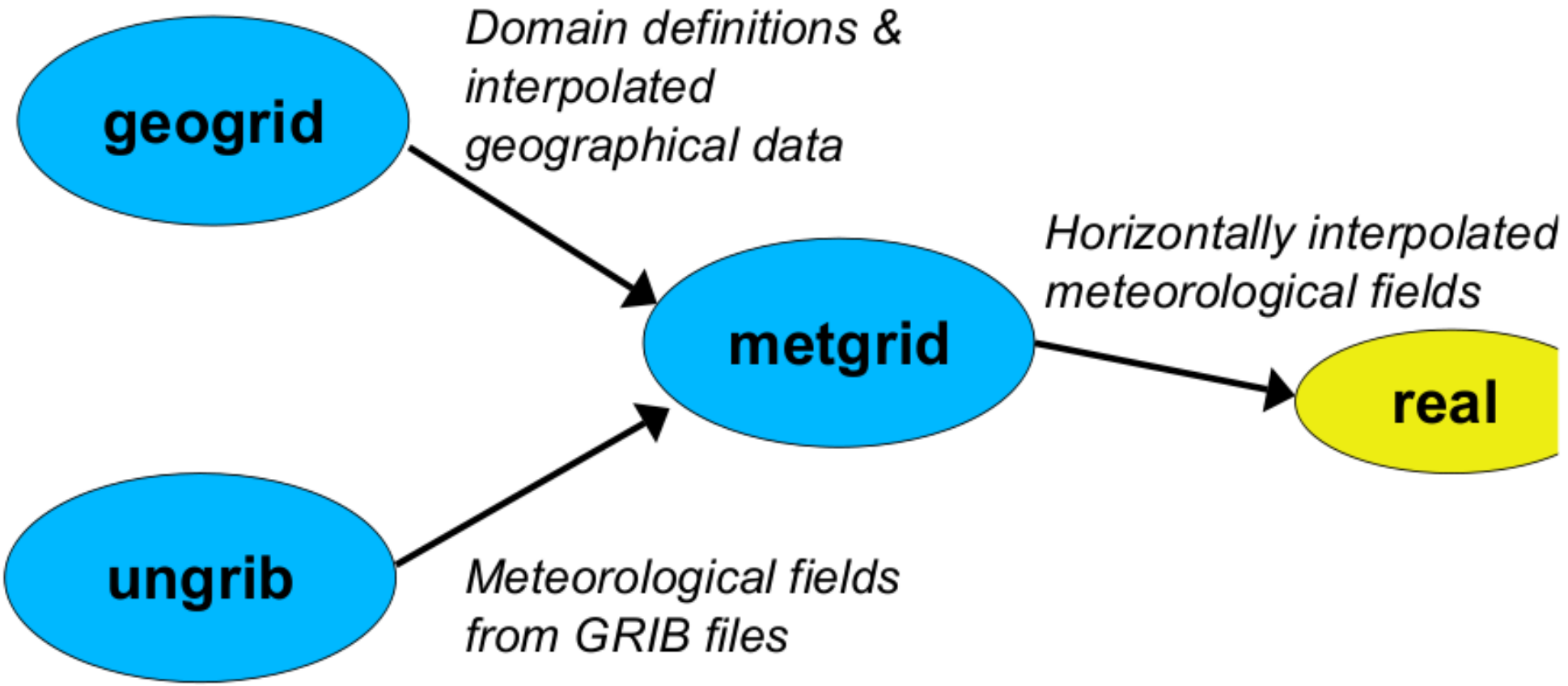
The metgrid program

- Horizontally interpolate meteorological data (extracted by ungrib) to simulation domains (defined by geogrid)
  Masked interpolation for masked fields
  - Rotate winds to WRF grid. i.e., rotate so that U-component is parallel to x-axis,
  - V-component is parallel to y-axis
- For ARW, wind U-component interpolated to “u” staggering;
  Wind V-component interpolated to “v” staggering;
  Other meteorological fields interpolated to “θ” staggering by default.
- Input wind fields (U-component + V-component) are either:
  * Earth-relative: U-component = westerly component; V-component = southerly 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: Program Output

- For coarse domain, one file per time period
  In ARW, we also get the first time period for all nested grids.
  Files contain static fields from geogrid plus interpolated meteorological fields
  Filenames:
  ARW: met_em.d0n.YYYY-MM-DD_HH:mm:ss.nc
  (where n is the domain ID #)

WPS Summary


geogrid
Domain definitions &
interpolated
geographical data
Horizontally interpolated
meteorological fields
metgrid
real
ungrib
Meteorological fields
from GRIB files