WRF & WRF-Hydro model coupling
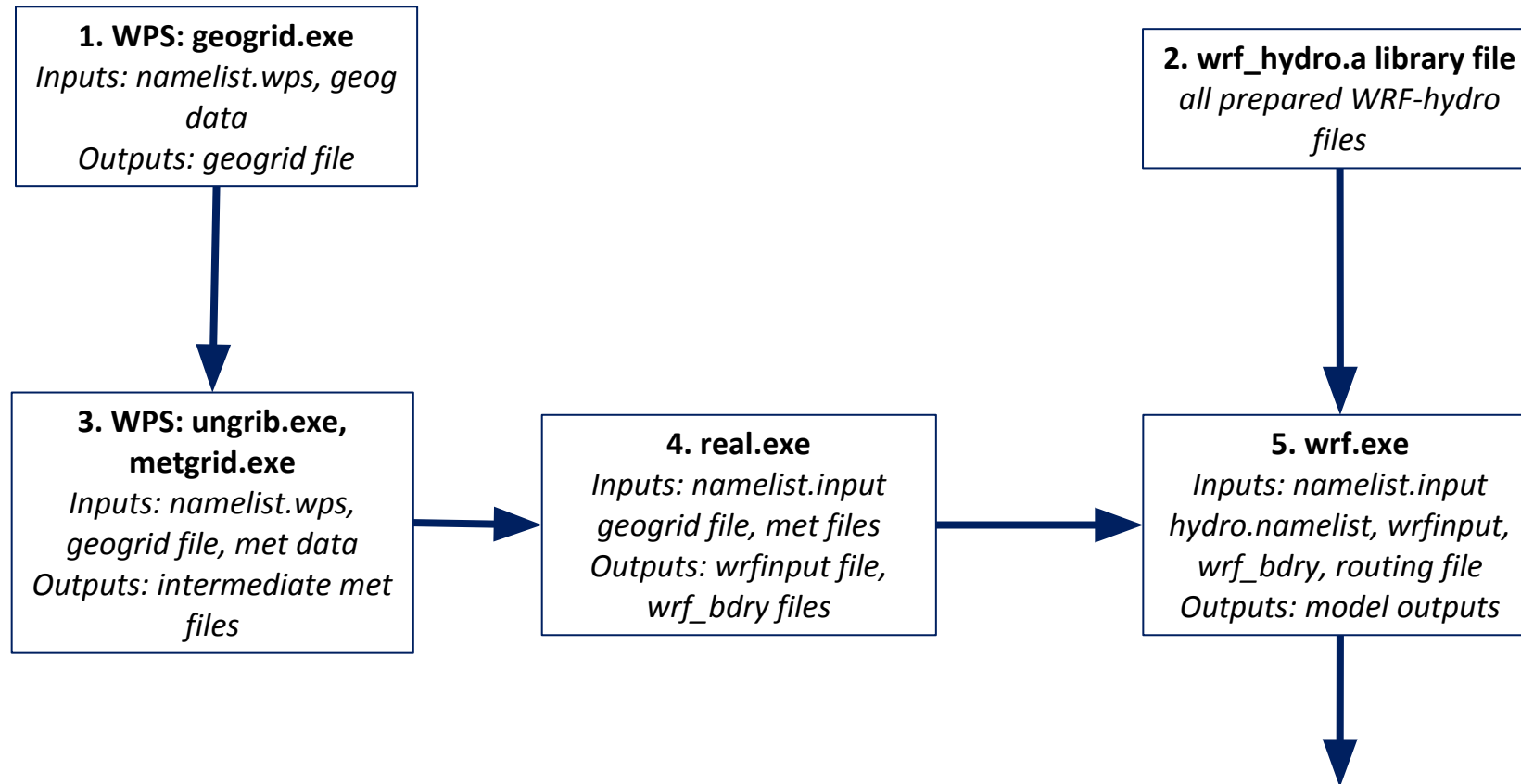

National Center for Atmospheric Research

Uncoupled WRF-Hydro Workflow
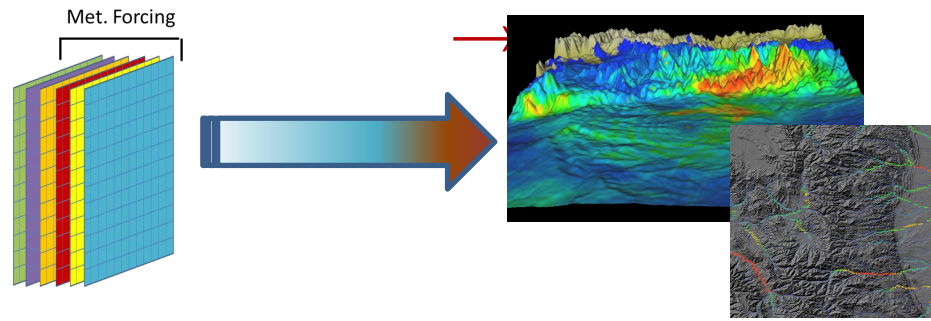
1. Define the Domain:

WRF-ARW/WPS: geogrid.exe

Inputs: namelist.wps, geographic data

Outputs: GEOGRID file
(defines the domain and grid)

2. Define Initial Conditions:

create_Wrfinput.R script
Inputs: GEOGRID file
Outputs: wrfinput file
(initial conditions for a 'cold' start and other default model parameters)

3. Create Hydrologic Routing Inputs:

WRF-Hydro GIS Pre-Processsing Tool
Inputs: GEOGRID file, station points, lakes
Outputs: Full domain file, geospatial metadata file, Optional routing files

4. Prepare Meteorological Forcing Data:
ESMF regridding scripts
Inputs: raw met. data, GEOGRID file,
(regridded to match the GEOGRID domain from step 1.)
Outputs: LDASIN (and optional PRECIP) files

5. Run Model Simulations:
wrf_hydro.exe
Inputs: GEOGRID file, fulldom_hires.nc, namelist.hrldas hydro.namelist, wrfinput file, Optional routing files, LDASIN & optional PRECIP files,
Outputs: model outputs

6. Evlauate Model Output:
Rwrfhydro
Inputs: model outputs, observations
Outputs: analyses, verifications, visualizations, etc.

Coupled WRF-Hydro & WRF Workflow

1. WPS: geogrid.exe
Inputs: namelist.wps, geog data
Outputs: geogrid file

2. wrf_hydro.a library file
all prepared WRF-hydro files

3. WPS: ungrib.exe, metgrid.exe
Inputs: namelist.wps, geogrid file, met data
Outputs: intermediate met files

4. real.exe
Inputs: namelist.input geogrid file, met files
Outputs: wrfinput file, wrf_bdry files

5. wrf.exe
Inputs: namelist.input hydro.namelist, wrfinput, wrf_bdry, routing file
Outputs: model outputs

Two Modes of WRF-Hydro

One-way ('uncoupled')

Two-way ('coupled') ↔

- Uncoupled mode critical for spinup, data assimilation and model calibration

- Coupled mode critical for land-atmosphere coupling research and long-term predictions
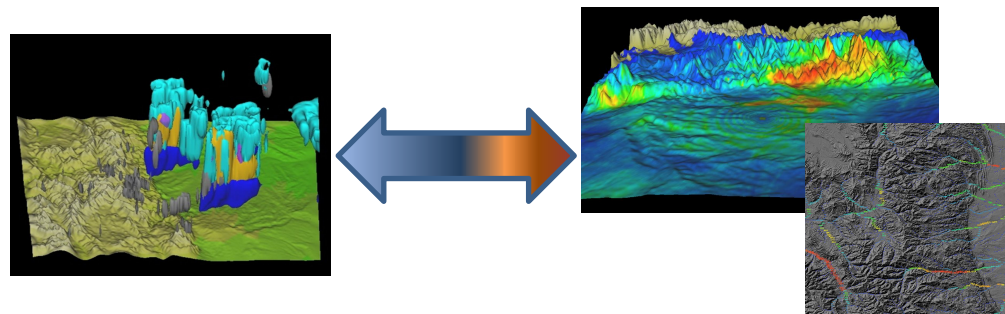
- Model forcing and feedback components mediated by WRF-Hydro:
  - Forcings: T, Press, Precip., wind, radiation, humidity, BGC-scalars
  - Feedbacks: Sensible, latent, momentum, radiation, BGC-scalars

Conceptualization of WRF-Hydro

- Multi-scale/Multi-physics modeling…
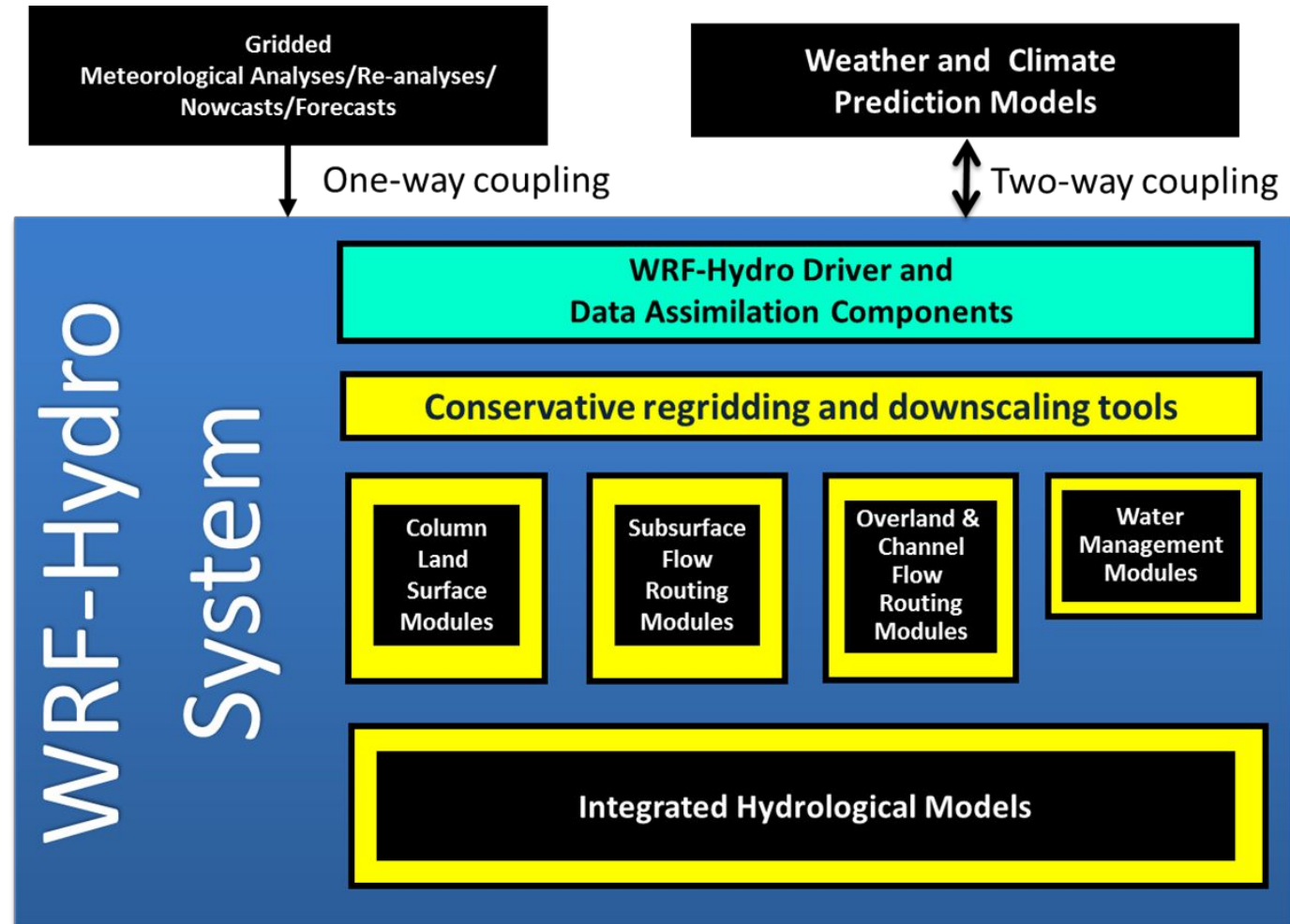
Intro to the Weather Research & Forecasting Model (WRF)

Weather Research and Forecasting Model (WRF)

- Modeling system for atmospheric research and operational prediction

- Provide many core functionalities:
  - Data pre-processing (model initialization and boundary conditions)
  - 3-d non-hydrostatic, multi-physics, multi-scale atmospheric model
  - Fully-parallelized for high performance computing applications
  - Data assimilation frameworks (EnKF, grid nudging, 3d/4d variational analysis)
  - Post-processing to produce standardized datasets for ingest into many analysis and visualization software

- Directly ingestible into the Model Evaluation Tools (MET) software for verification
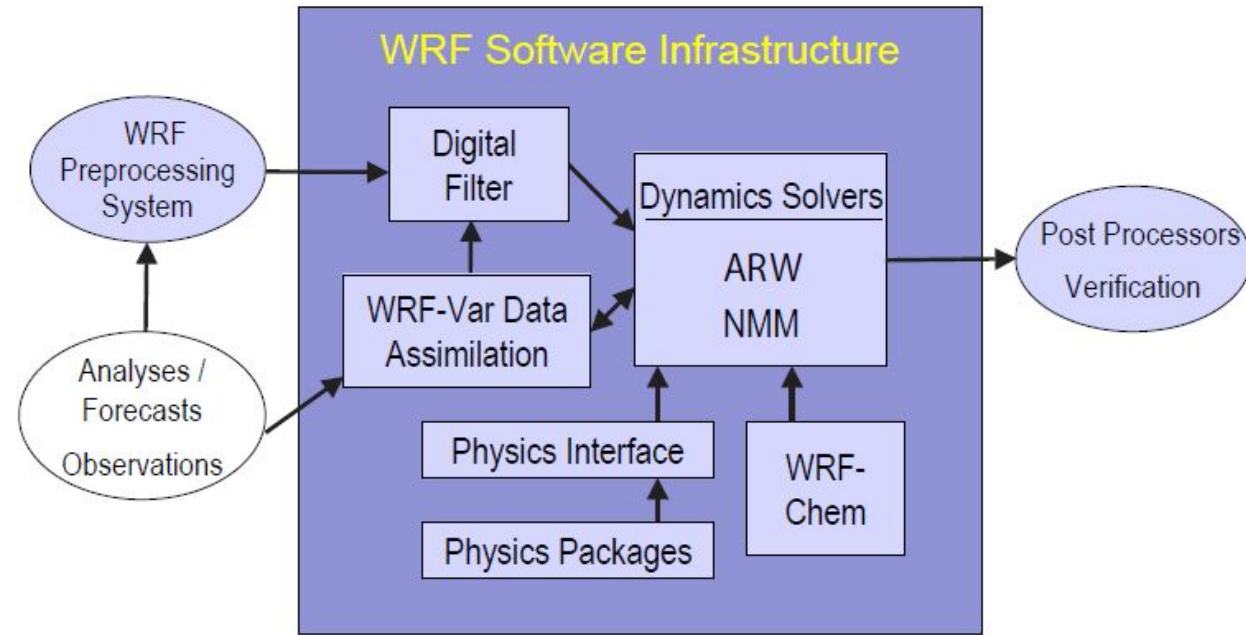
Figure 1.1: WRF system components.

WRF Model Physics

- <u>Microphysics:</u> Schemes ranging from simplified physics suitable for idealized studies to sophisticated mixed-phase physics suitable for process studies and NWP.

- <u>Cumulus parameterizations:</u> Adjustment and mass-flux schemes for mesoscale modeling. (dx > ~5km)

- <u>Surface physics:</u> Multi-layer land surface models ranging from a simple thermal model to full vegetation and soil moisture models, including snow cover and sea ice.

- <u>Planetary boundary layer physics:</u> Turbulent kinetic energy prediction or non-local K schemes.

- <u>Atmospheric radiation physics:</u> Longwave and shortwave schemes with multiple spectral bands and a simple shortwave scheme suitable for climate and weather applications. Cloud effects and surface fluxes are included.
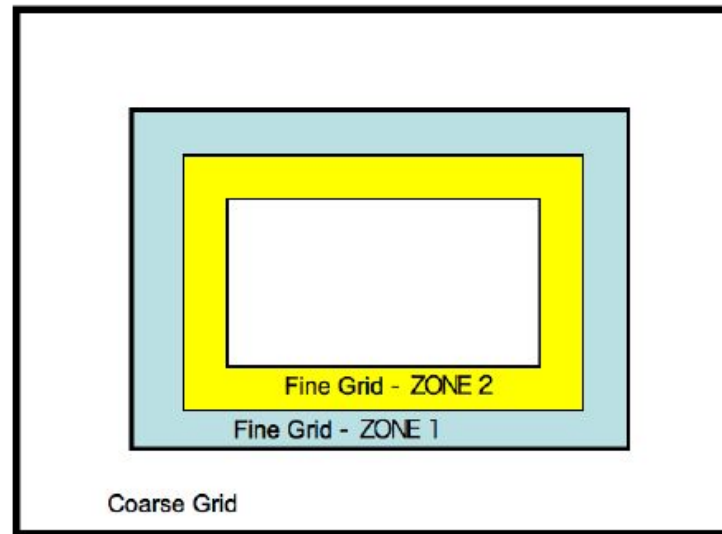
Figure 7.6: Zones of topographic blending for a fine grid. In the fine grid, the first zone is entirely interpolated from the coarse grid topography. In the second zone, the topography is linearly weighted between the coarse grid and the fine grid.

WRF Model Structure: Domain
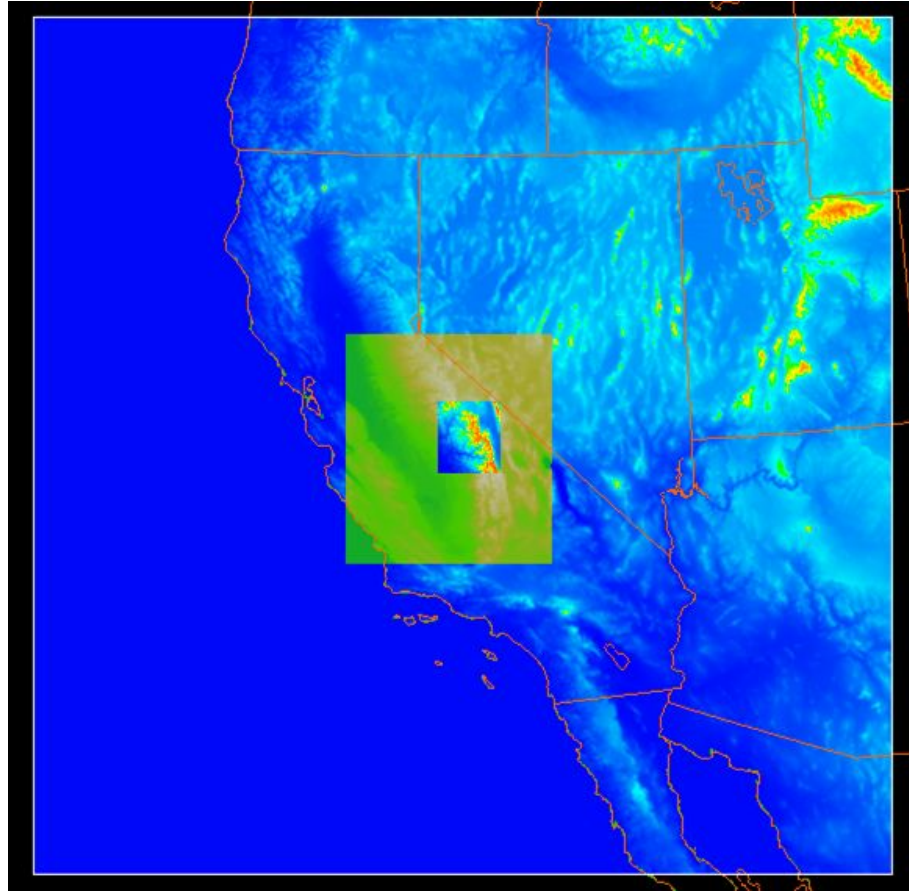
WRF Model Structure: Domain

Real-Data Lateral Boundary Condition: Location of Specified and Relaxation Zones
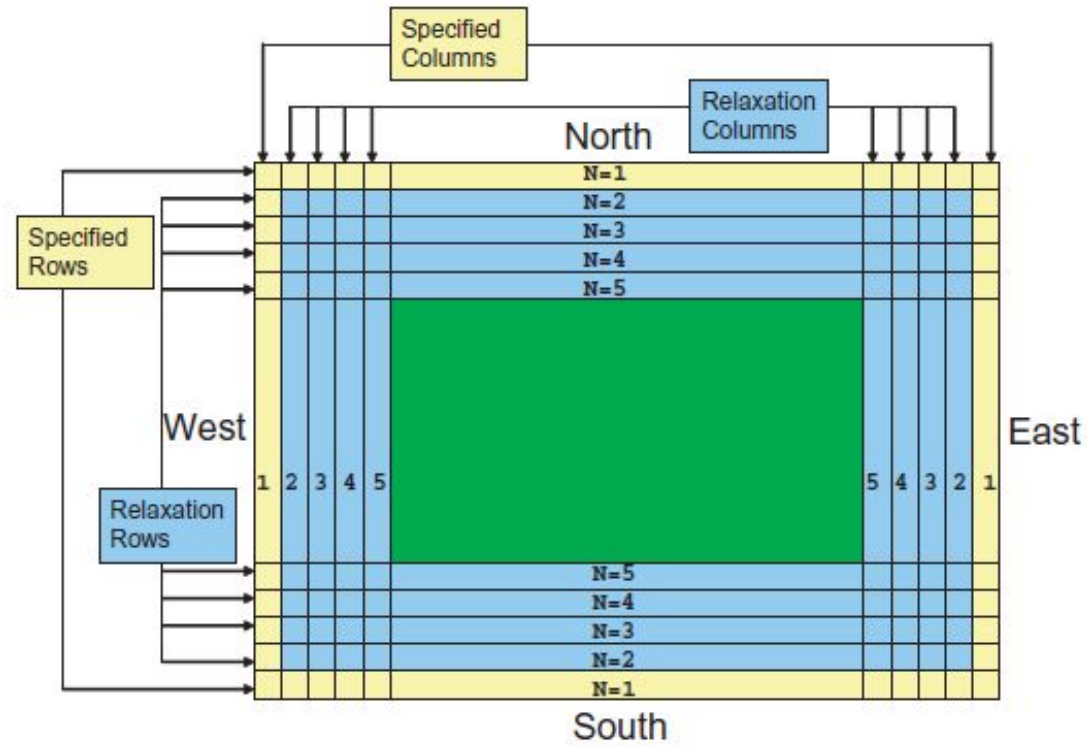
WRF Model Structure: Domain
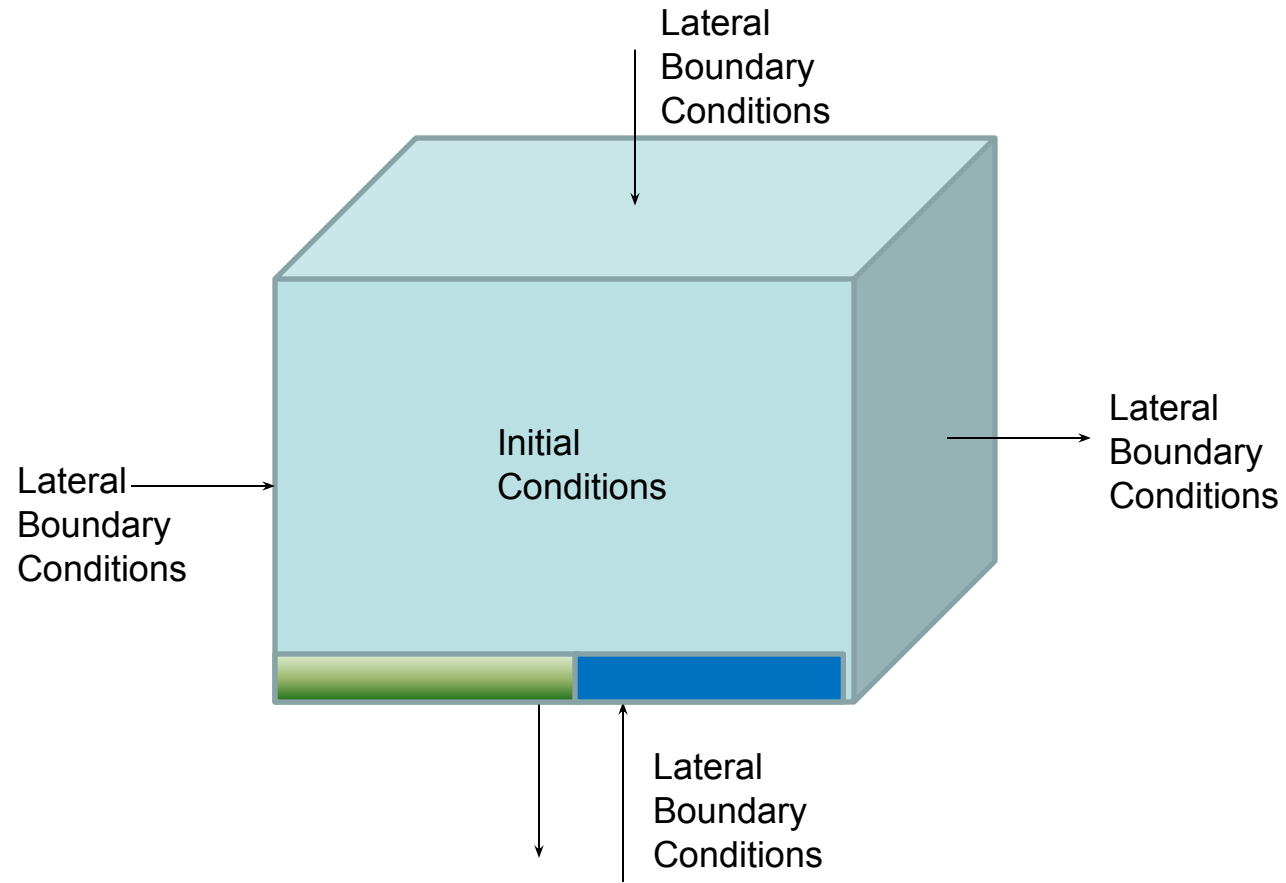
WRF Model Structure: Initial & Boundary Conditions

- Initial conditions: Provides the initial 'state' of the atmosphere and land surface at time = 0.

- Lateral boundary conditions: Provides 'forcing' to the regional domain from the 'sides' of the model, necessary condition for any forward-integrating numerical modeling problem

- The impacts of initial conditions can be very important or not very important depending on the problem and the variable of interest.
  - NWP – 'initial value problem', meaning the impact of initial conditions plays a 'dominant' role in the model solution along with model physics
  - 'Climate modeling' – 'boundary value problem', meaning the final solution is not as sensitive to initial conditions but, instead, more sensitive to boundary forcing and the model physics

WRF Model Workflow

1. Compile wrf-hydro as a library function for WRF
2. Compile WRF
3. Pull/point to data for 'geogrid.exe' execution: this is the WRF-WPS database
4. Dynamically edit the 'namelist.wps' file
5. Execute 'geogrid.exe' to create surface data
6. Get meteorological boundary condition data from a global server
7. Pull/point to data for 'metgrid.exe'

6. Run 'ungrib.exe' from the WPS directory to prepare data for metgrid.
7. Execute 'metgrid.exe' to prepare atmospheric boundary conditions
8. Edit principle WRF model namelist for model setup (namelist.input)
9. Run executables: 'real.exe; and 'wrf.exe'
10. Post-process results…

WRF Model Products

- Detailed, physically-robust depictions of atmospheric phenomena for research and prediction applications
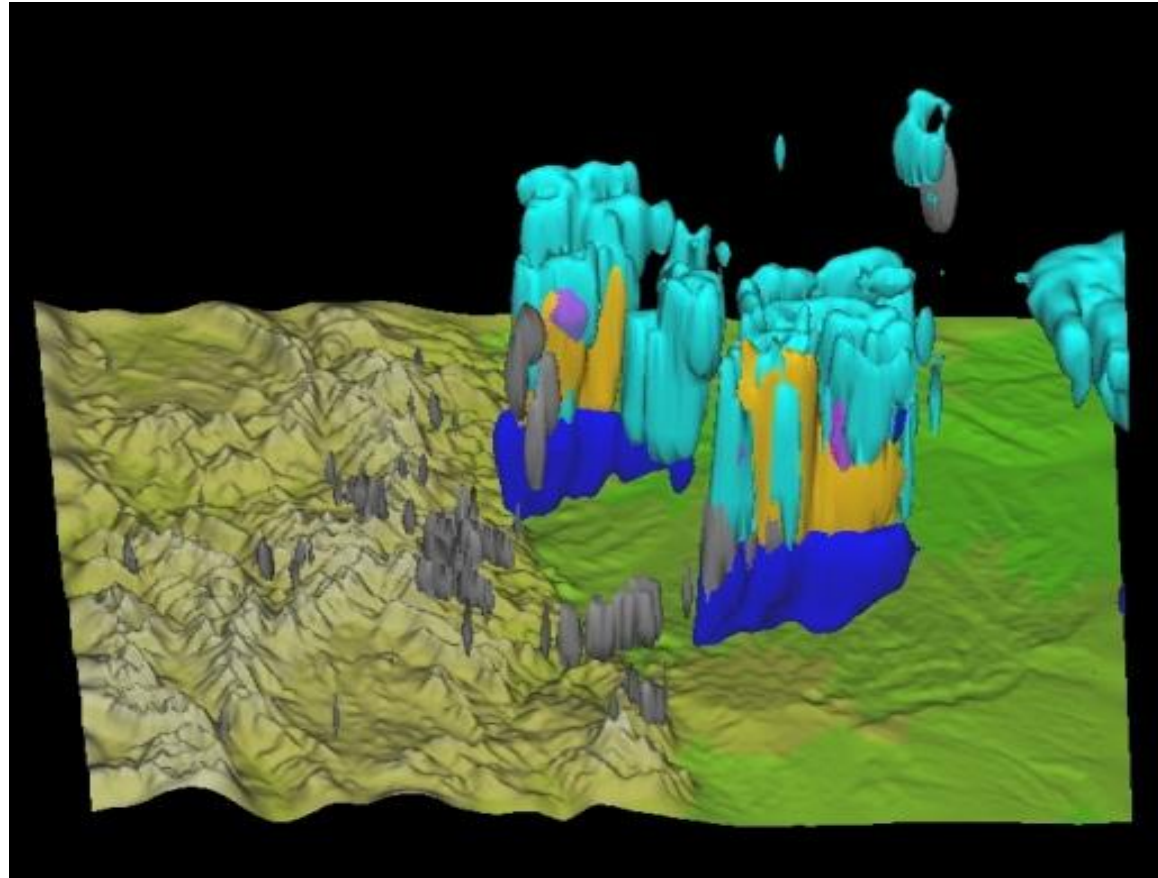
WRF Model Resources & Training
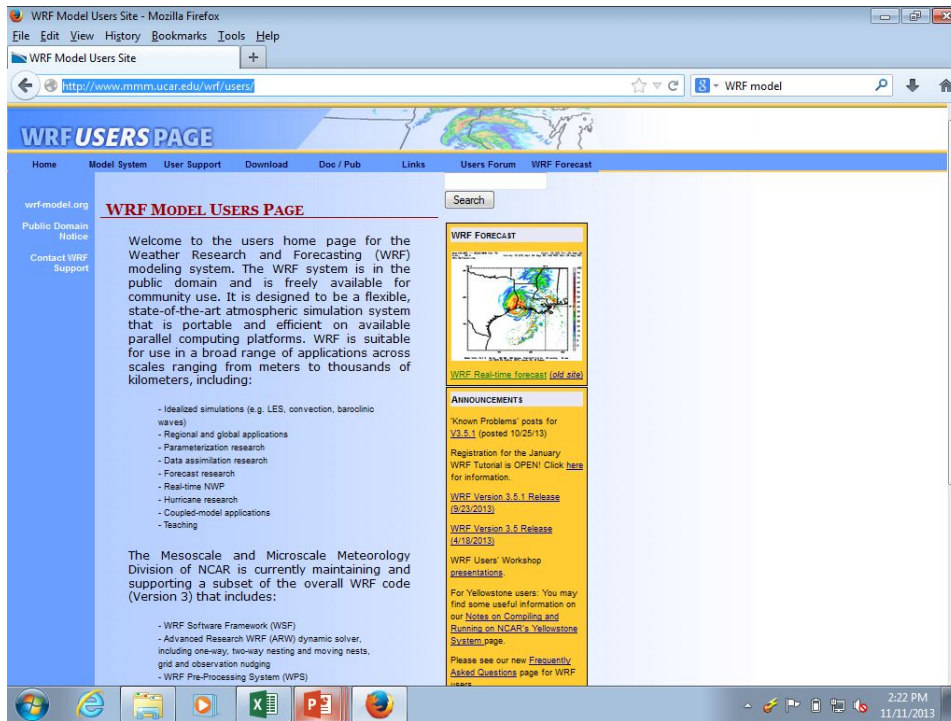
- **Web site for code, documentation, data, real-time forecasts, etc.**

- Training material, model tutorials are available through website
- Lots to WRF model utility tools available through the website
- WRF model development team holds 2 week-long tutorials 2x per year
- Annual WRF User's workshop
- Many international training workshops each year

http://www.mmm.ucar.edu/wrf/users

MET for all things Verification

http://www.dtcenter.org/met/users/

- Suite of data processing and analysis tools to provide:

- Standard verification scores comparing *gridded model data to point-based observations*
- Standard verification scores comparing *gridded model data to gridded observations*
- *Spatial verification methods* comparing gridded model data to gridded observations using neighborhood, object-based, and intensity-scale decomposition approaches
- *Ensemble and probabilistic verification* methods comparing gridded model data to point-based or gridded observations

Acknowledgements

References

WRF-Hydro

- Technical Description and Users' Guide

WRF and WPS

- Technical Note
- User Guide
- Online Tutorial

Model verification

- MET

WRF-Hydro: http://www.ral.ucar.edu/projects/wrf_hydro/