Best Practices of WRF – How to Get Better Results

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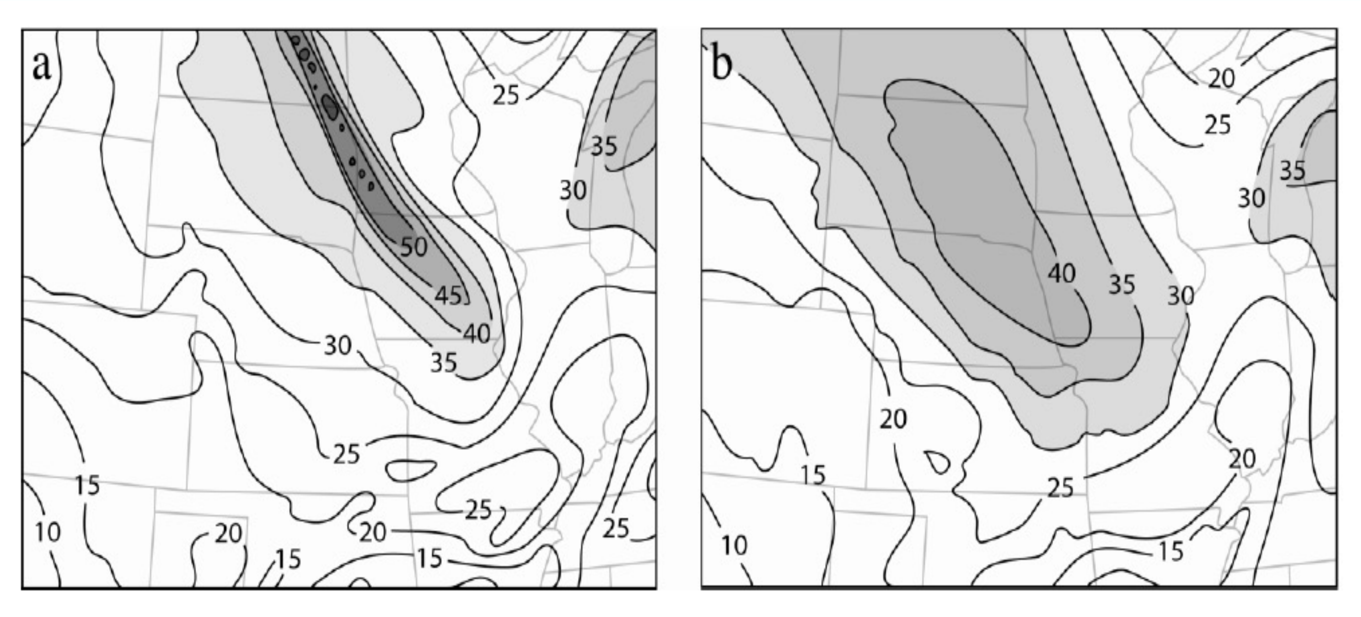
Best Practices of WRF

- The Model Configuration
  - Domain – often have profound impacts
  - Boundary location
  - Resolution (horizontal and vertical)
  - Time and method of initialization
    - Cold start?
    - Variational data assimilation?
    - Spinup time?
- Large-scale forcing
- Physics/dynamics options

How to determine the model domain

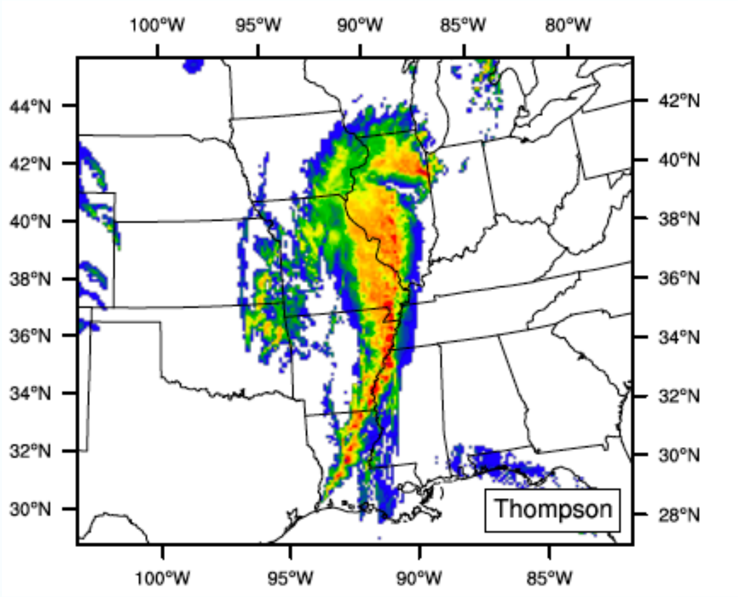
- How large do they need to be?
  - Should not be too small, otherwise solution will be affected by forcing data
  - No less than 100x100 grids (at least 5 grid points are in the boundary zone)
- Where to place my lateral boundaries?
  - Avoid steep topography
  - Away from the area of interest

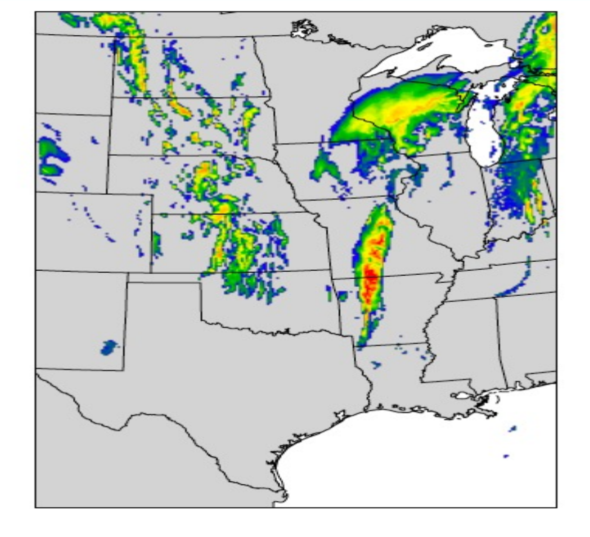
Importance of domain

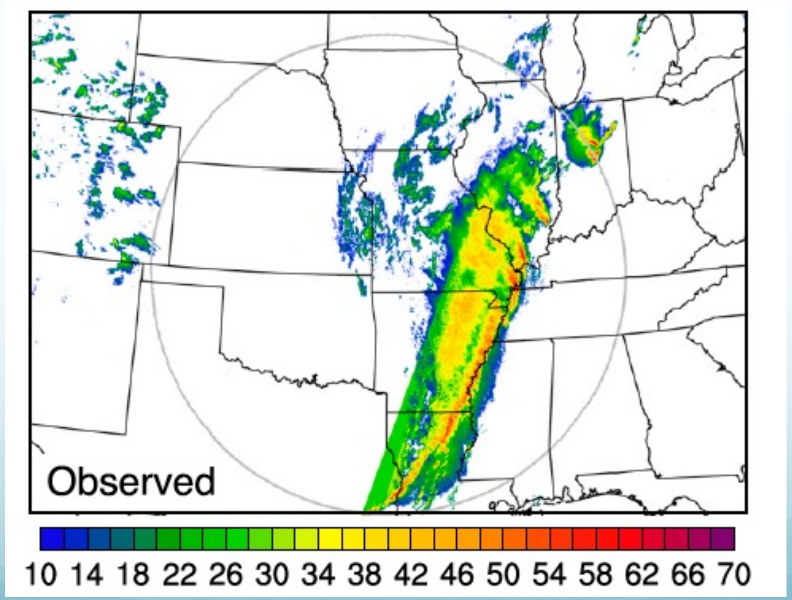


12-hour simulations of 250-hPa winds (m s-1) from the 40-km grid increment Eta Model initialized at 1200 UTC 3 August 1992, based on experiments that used a large (a) and a small (b) computational domain. (Warner, 2011)

Squall line simulation: Radar Reflectivity (dBZ)

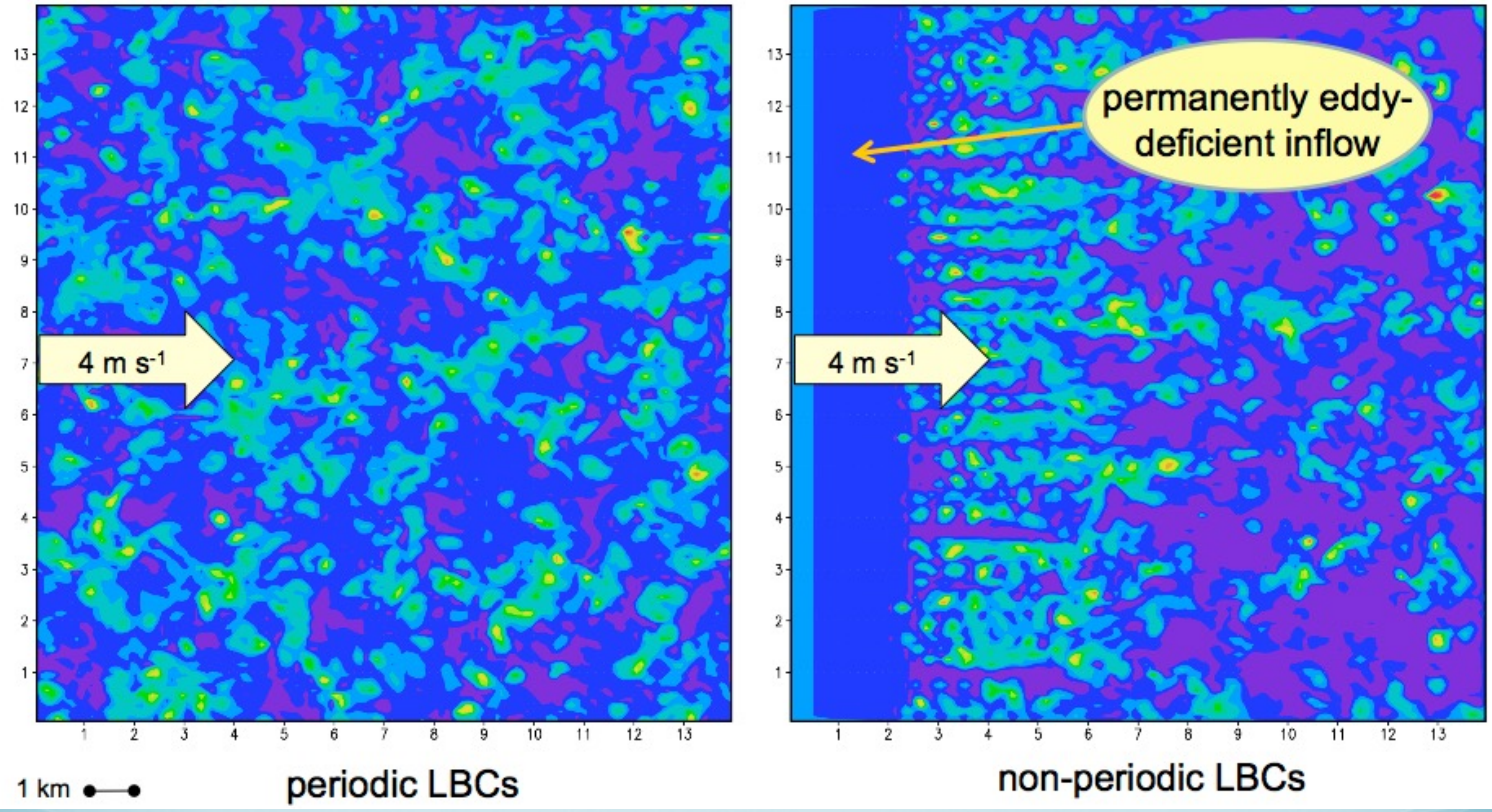






Lateral Boundary Condition

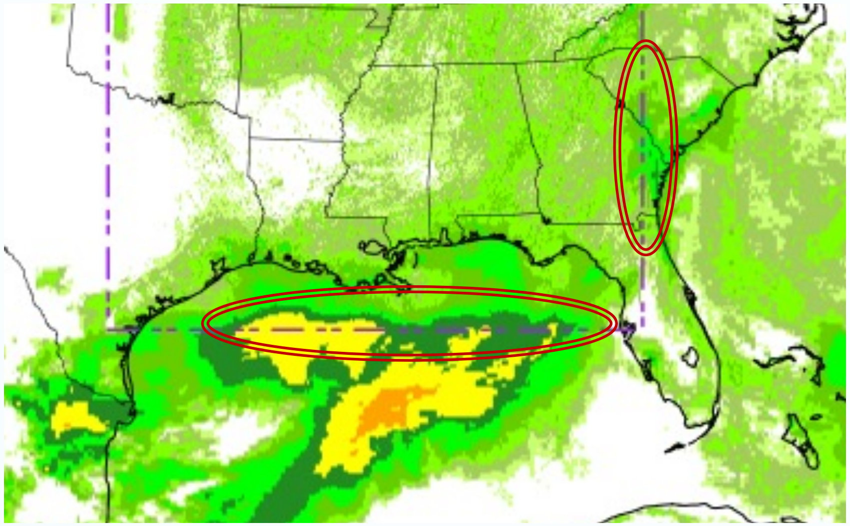
- A basic and potentially serious limitation to regional model simulation, including WRF
- Possible negative effects of LBC
- How to minimize the negative LBC impact on forecast quality: guidelines and cautions
  - Strong forcing should be avoided at lateral boundaries
  - Resolution-consistent input data should be used
  - More frequent is better
  - Interactive boundaries should be employed when possible



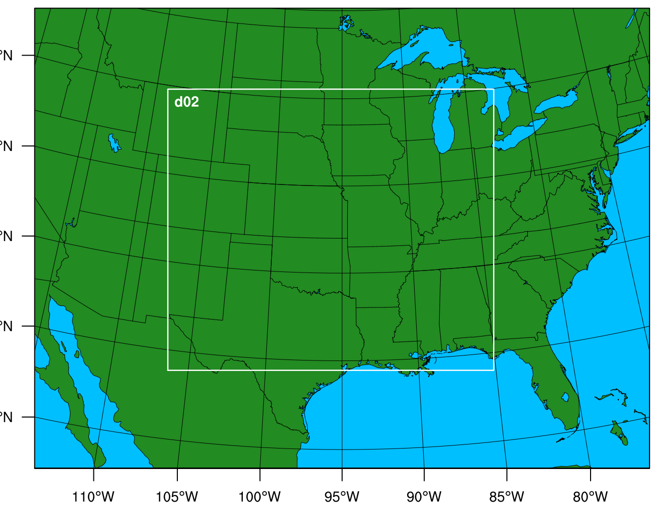
Gaudet et al. (2012)

Convective precipitation (24-48hr)

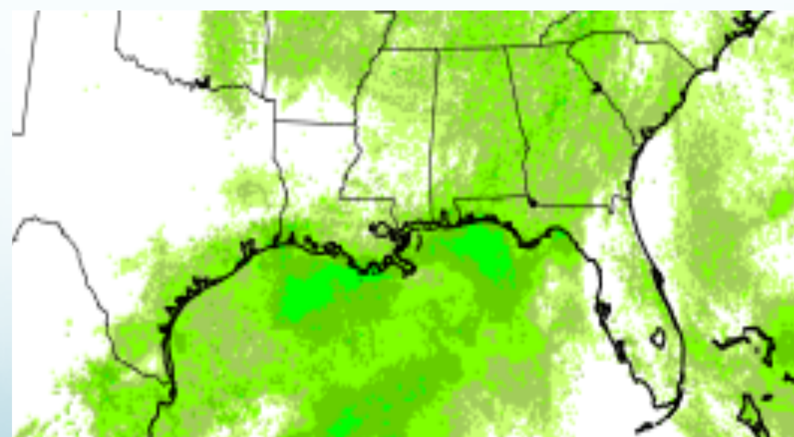
9-3km nesting



WPS Domain Configuration



WRF 3km D01



The effect of lateral boundary is obvious. We can see large discrepancy along the nested boundary. Inside the child domain, results demonstrate grid-dependence feature.

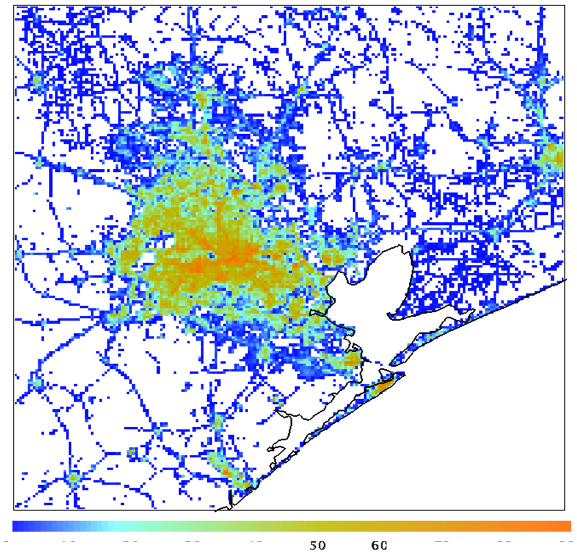
Significant differences in areas outside D02 are attributed to different physics used for the parent domain.

Initialization and Spin-up Issues

- Model problems often arise from poor initial condition
  - Appropriate initial time
  - Quality of initial condition
    - Check land data:

      e.g. landuse: *does it represent my area well?*
    - Know about the data: *how good are the data?*
      - Forecast data
      - Reanalysis data
      - Climate model data

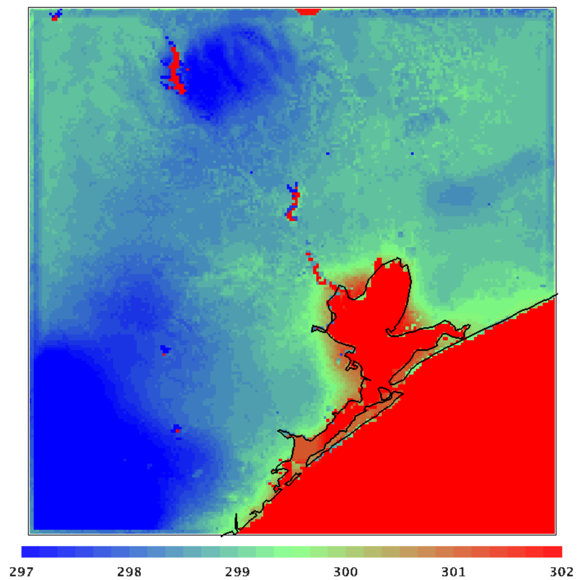
- In the first few hours, expect noise in pressure fields
  - Mostly sound waves adjusting winds to terrain. No harmful lasting effects

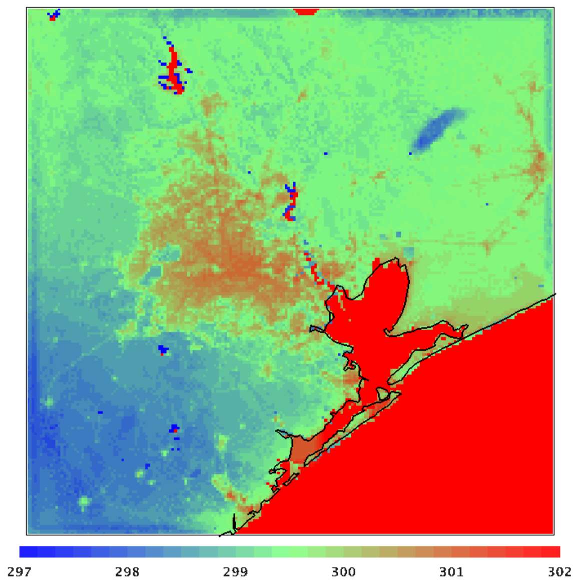


Impervious fraction (%)

Skintemp simulated with and without Impervious (Aug 26, 2006, 10Z)

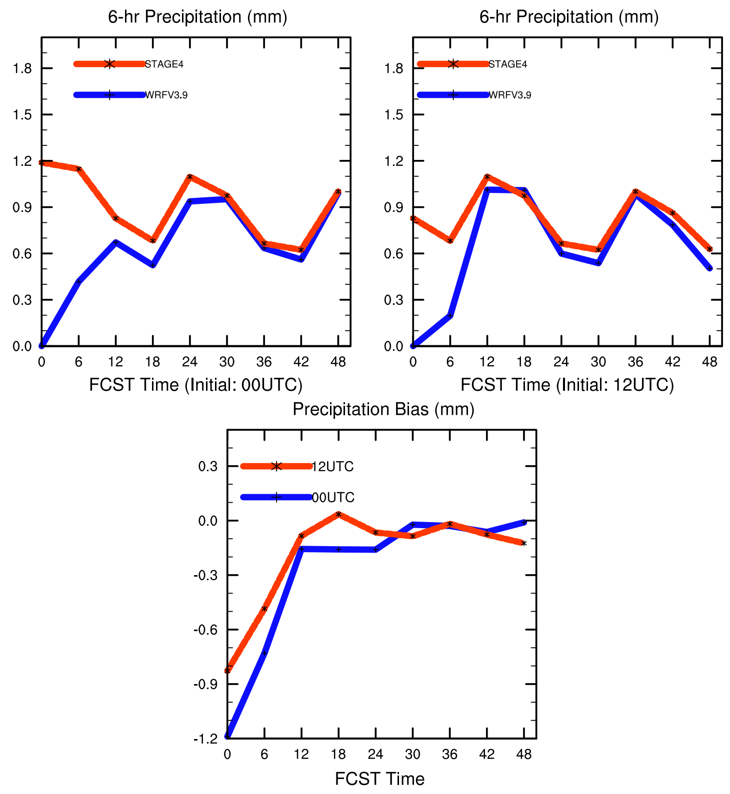
Pleim et al., 2012





Initialization and Spin-Up

Convective Spin-Up: An example of NCAR's 3-km convective runs



Red: StageIV

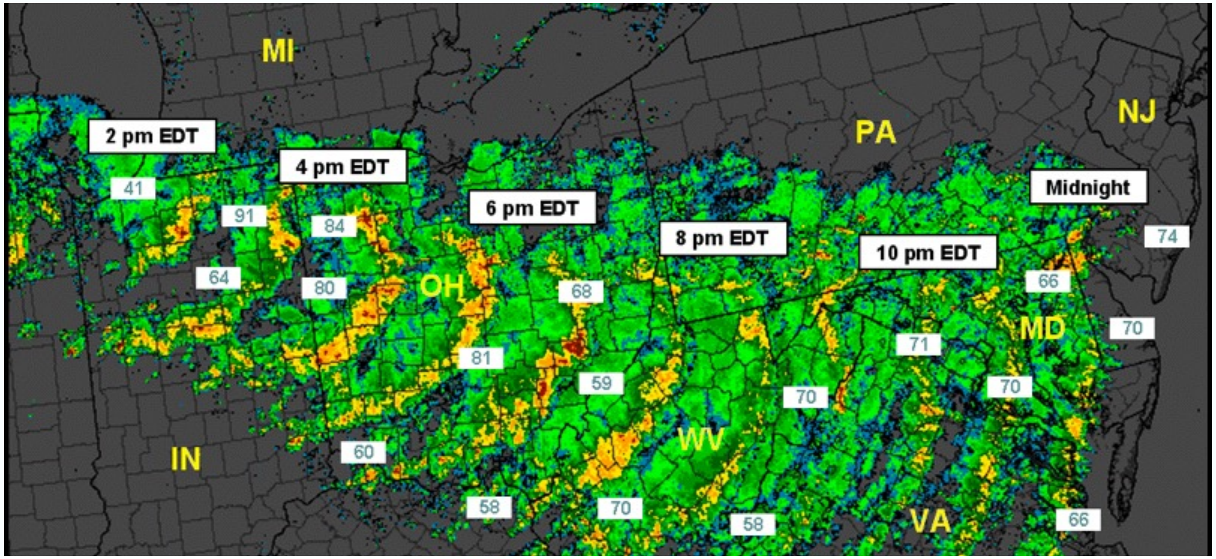
Blue: WRF

Grid Size and Impact

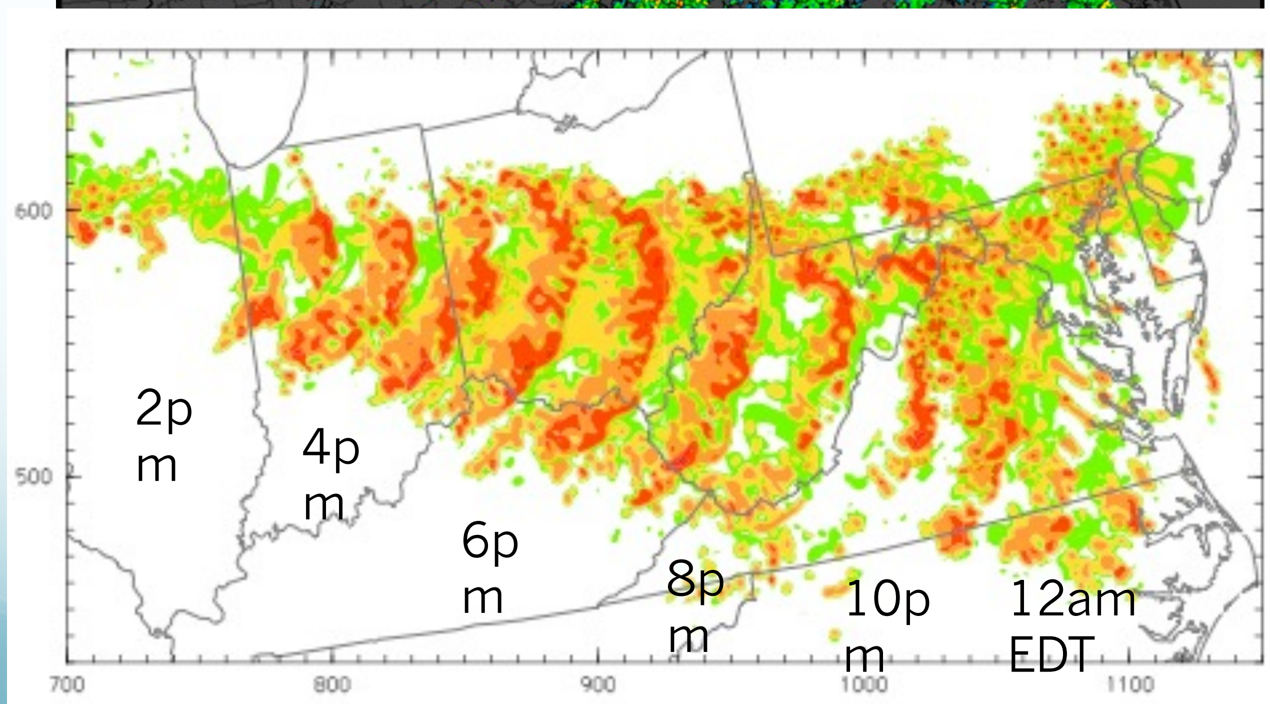
- Extreme weather event forecast
  - The Derecho of 29-30 June 2012
- $\Delta \approx 3$ km: Traditional cloud-permitting resolution
  - No need for deep-convective parameterization
- $\Delta \approx 30$ m – 100 m: Traditional large-eddy simulation (LES) resolution
  - No need for a planetary boundary layer (PBL) parameterization
  - Turbulent eddies (i.e., thermals, rolls, etc.) are handled by the model's governing equations [plus surface-layer and subgrid turbulence schemes]
- 100 m < Δ < 1 km
  - A PBL scheme will still be needed for most cases
  - Shallow cumulus probably can be turned off (not for Δ > 500 m)
  - Advection Scheme: better use a monotonic/non-osciallaory option (adv_opt ≥ 2)

(Bryan, 2014)

Case Study: The Derecho of 29-30 June 2012

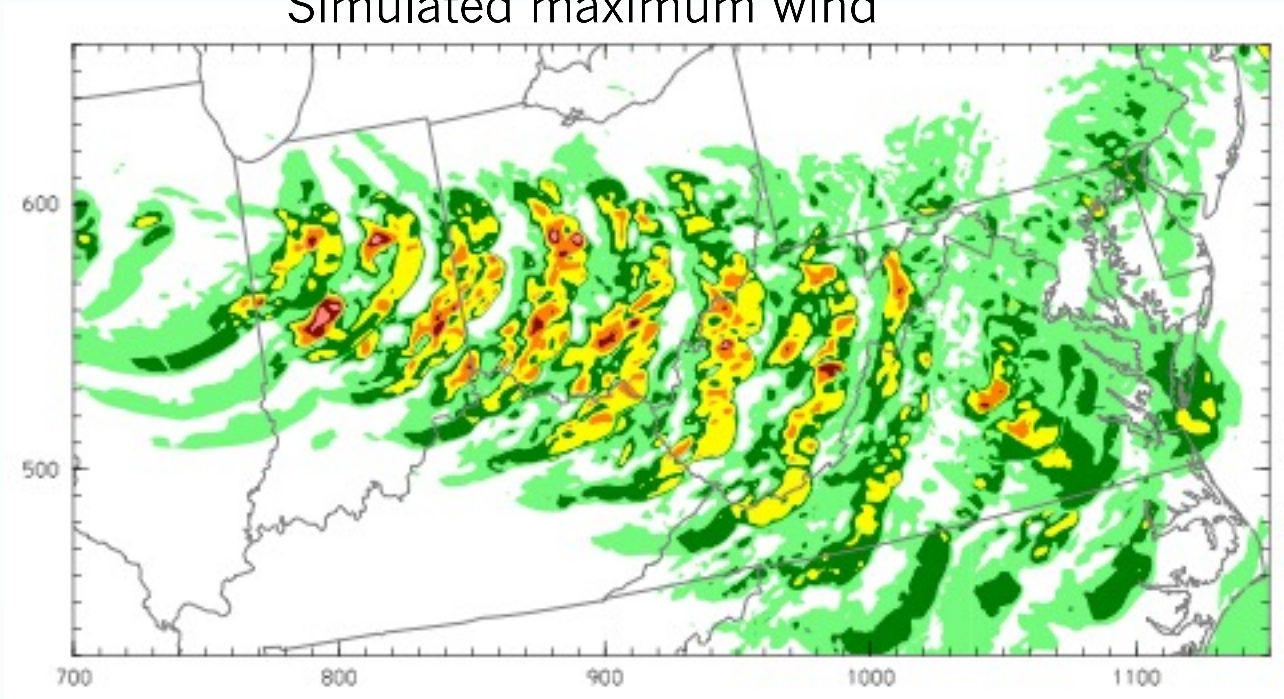


Radar composite reflectivity



WRF simulation of maximum reflectivity, DX=3km, initialized at 1200 UTC 29 June

Simulated maximum wind



3-km run

15-km run

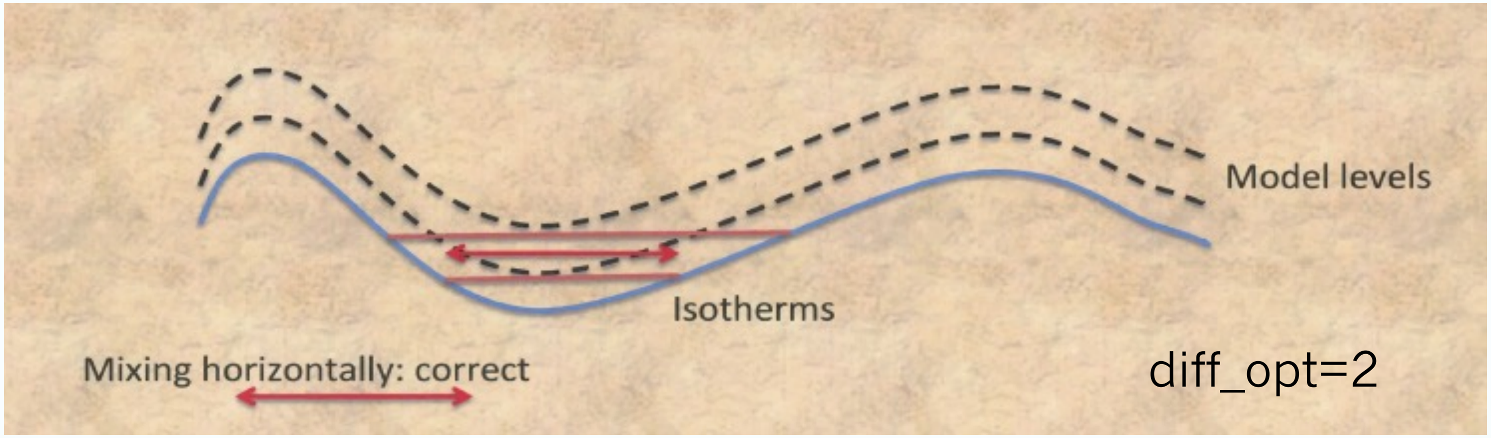
Model Levels and High Tops

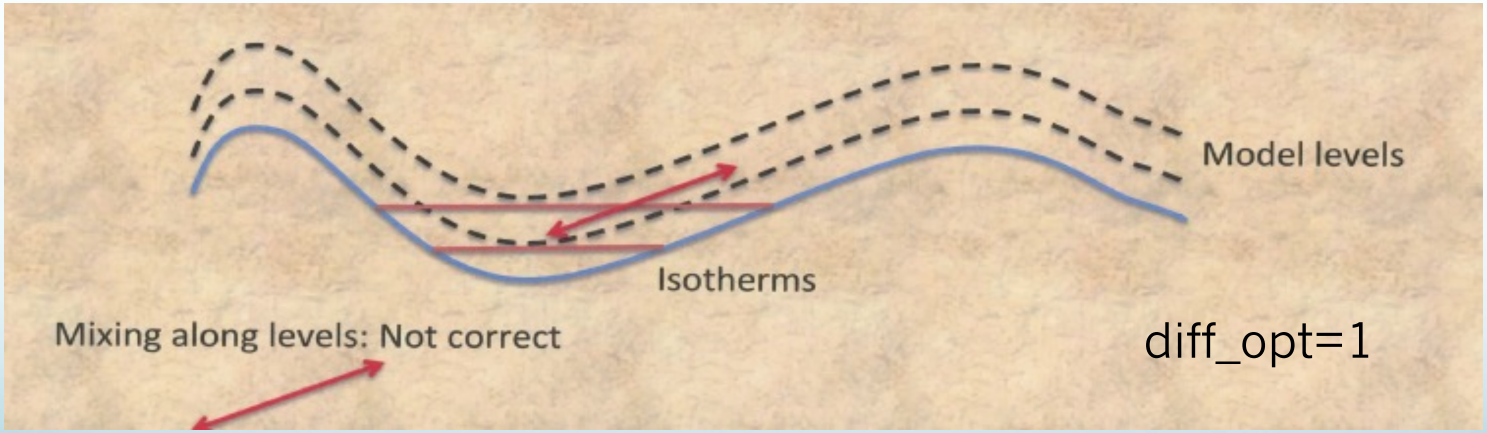
- At least 45 or more levels for a model top at 50 mb
  - For high tops < 50 hPa
    - Stratosphere option for base state: Iso_temp=200 K. This prevents base state from becoming unrealistically cold.
    - Since V3.6.1, a positive lapse rate is allowed in stratosphere
  - For tops near 1 hPa (45-50km), 60 or more levels are required.
  - Ozone climatology becomes important above 50hPa (~20km), where some or all of the ozone layer are included
    - Use RRTMG since CAM monthly ozone is available in RRTMG
- Vertical grid distance should not be larger than 1000 m (Radiation, microphysics, less accurate lateral BC)
- If finer horizontal grid size is used, more levels will be needed in the vertical
- Make sure dz < dx

Complex Terrain

- Steep terrain (> 45 degrees) may cause numerical stability problems.
  - Increasing epssm (0.1->0.5 or even larger)
    - This is a sound wave damper that can stabilize slope treatment by dynamics
  - For large slopes, set diff_opt=2
    - diff_opt=1 is less realistic than diff_opt=2, and diff_opt=2 used to be less stable but becomes more stable in recent versions
  - For V3.6 and later version, diff_opt=2 and km_opt=4 can be used together to improve stability

Diffusion





Dudhia (2014)

Selecting Model Physics

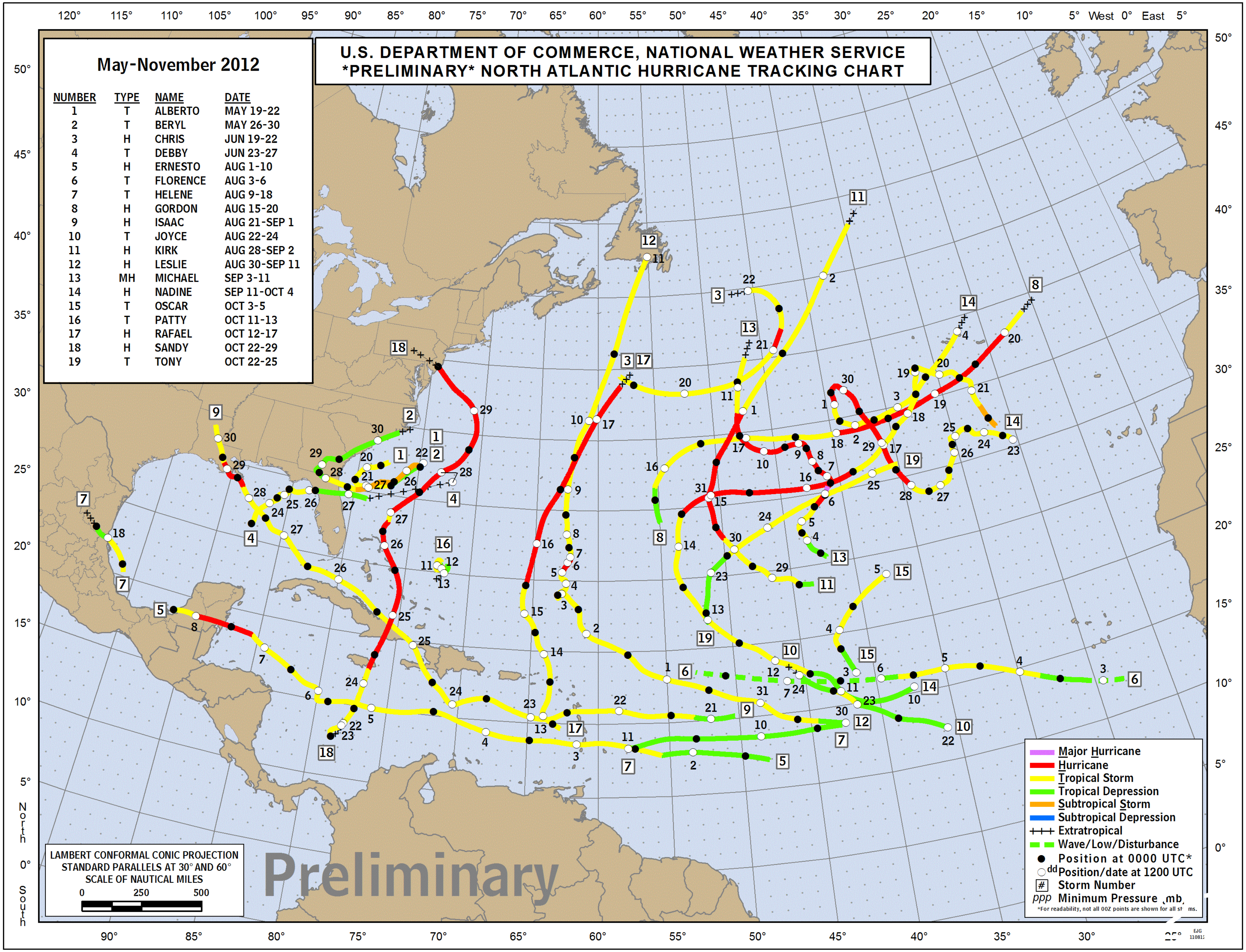
- Many options = more works
  - http://www2.mmm.ucar.edu/wrf/users/phys_references.html
  - https://www2.mmm.ucar.edu/wrf/users/physics/attic/wrf-phy.html
- Testing of multiple options for a particular application
  - A given set of physics will perform differently depending on domain size, location, initialization and phenomenon of interest
  - Certain combinations better tested than others, but still no guarantee for better performance

Physics in Multi-scale Model

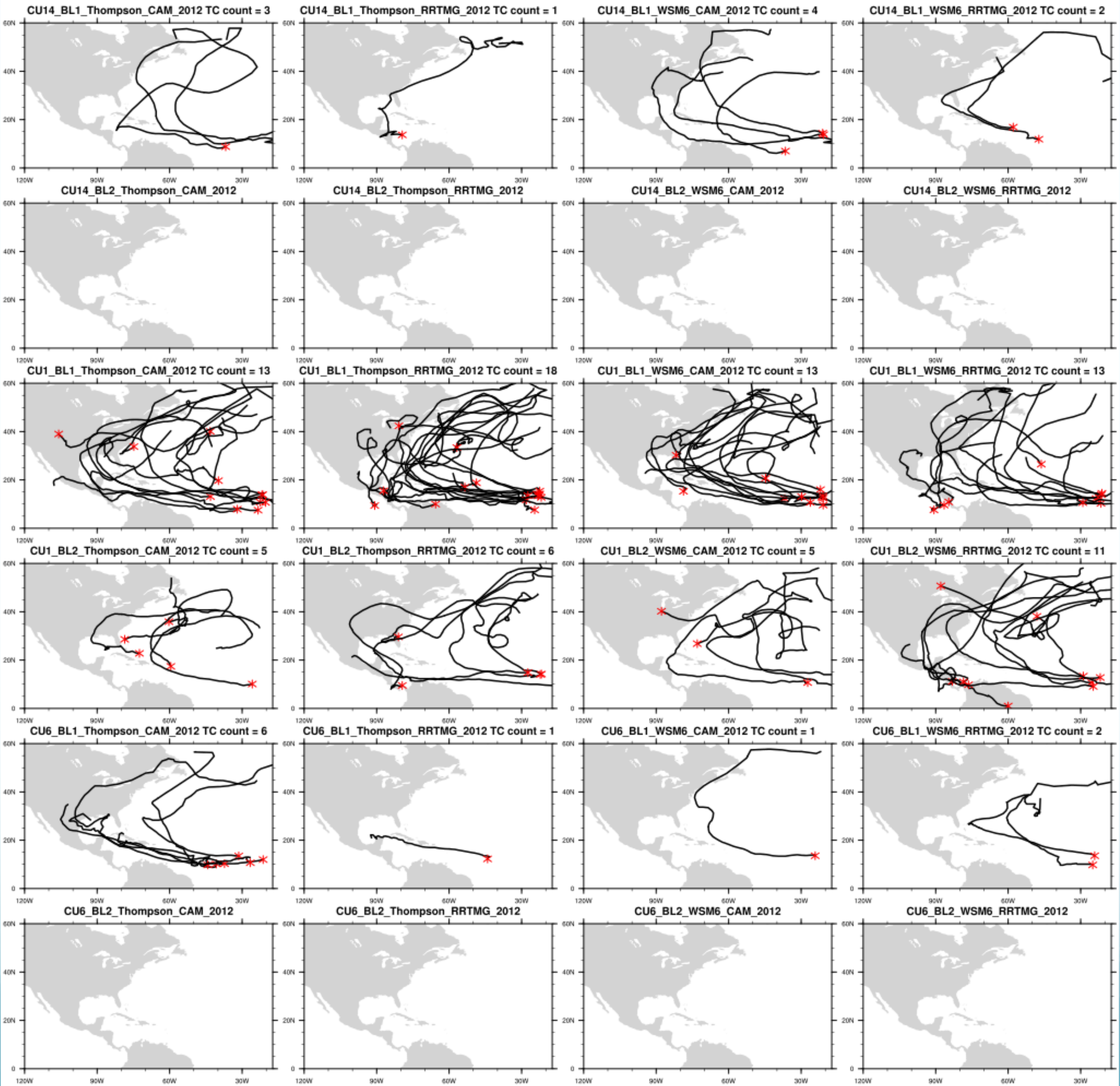
- Grid size and cumulus
  - DX > 10km, yes
  - DX < 4km, probably not
  - Grey Zone: 5-10km, no consensus, may try to use scale-aware cumulus scheme, such as GF, MSKF, scale-aware Tiedtke.
- Grid size and microphysics
  - For DX > 10km, no complex scheme is necessary
  - For DX <4km (convection-resolving), need at least graupels

Physics in Multi-scale Model

- Grid Size and PBL
  - PBL assumes all eddies are unresolved
    - DX > 500 m, PBL should be activated
  - LES assumes eddies are well resolved
    - DX < 100 m, LES should be applied
  - For DX 100-500 m, either may work to some extent
  - For multi-domain nested cases with large differences in grid intervals between parent and child domain, the SMS-3DTKE scale-adaptive LES/PBL scheme would be a better option.



U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
PRELIMINARY NORTH ATLANTIC HURRICANE TRACKING CHART
May-November 2012
NUMBER TYPE NAME DATE
1 T ALBERTO MAY 19-22
2 T BERYL MAY 26-30
3 H CHRIS JUN 19-22
4 T DEBBY JUN 23-27
5 H ERNESTO AUG 1-10
6 T FLORENCE AUG 3-6
7 T HELENE AUG 9-18
8 H GORDON AUG 15-20
9 H ISAAC AUG 21-SEP 1
10 T JOYCE AUG 22-24
11 H KIRK AUG 28-SEP 2
12 H LESLIE AUG 30-SEP 11
13 MH MICHAEL SEP 3-11
14 H NADINE SEP 11-OCT 4
15 T OSCAR OCT 3-5
16 T PATTY OCT 11-13
17 H RAFAEL OCT 12-17
18 H SANDY OCT 22-29
19 T TONY OCT 22-25
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Subtropical Storm
Subtropical Depression
Extratropical
Wave/Low/Disturbance
Position at 0000 UTC*
dd Position/date at 1200 UTC
Storm Number
ppp Minimum Pressure (mb)
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30° AND 60°
SCALE OF NAUTICAL MILES
0 250 500
Preliminary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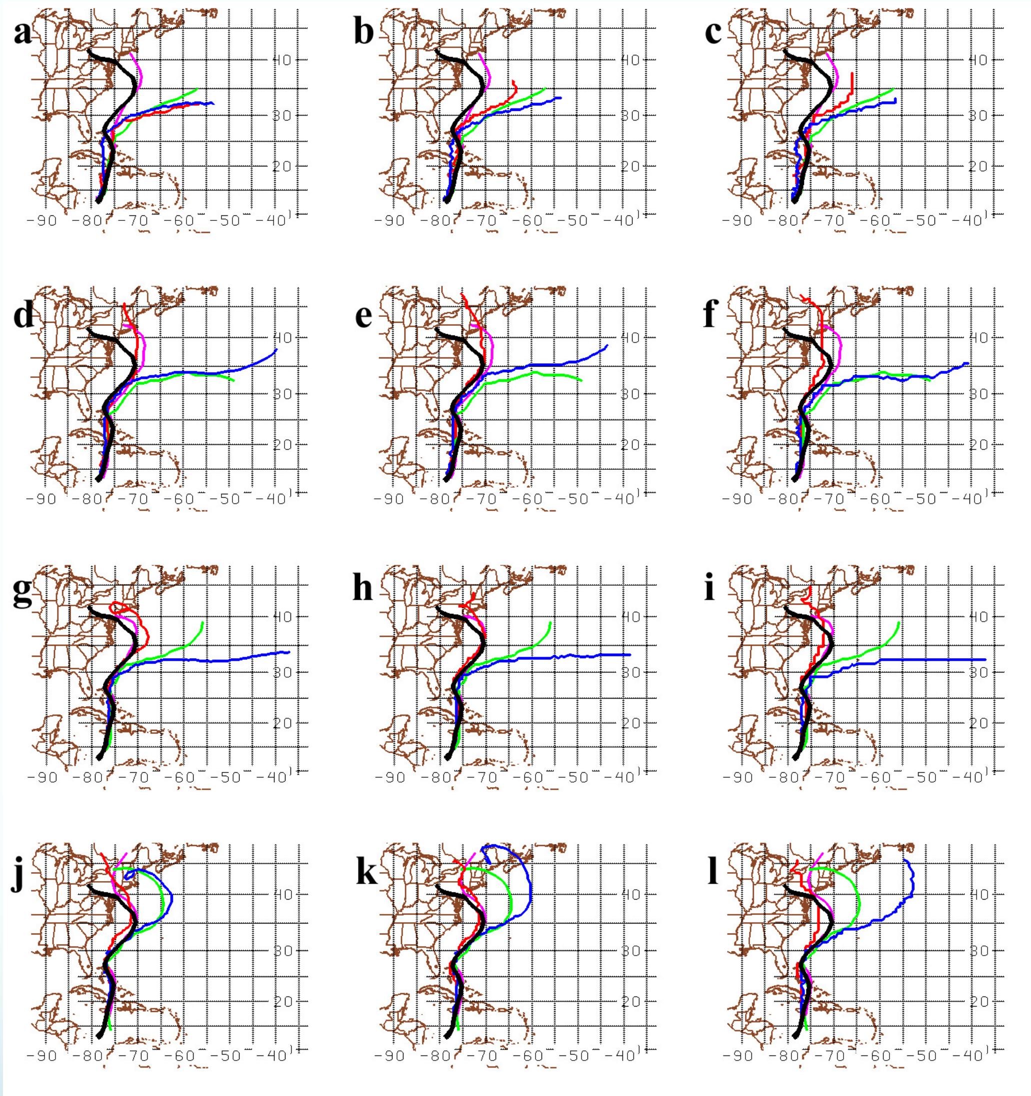


- ECMWF(pink)
- GFS(green)
- TWRF(red, Tiedtke)
- SWRF(blue, SAS)

(Grid interval from left to right: 30, 60, 90-km;
Top two: initialized at 0000 and 1200 UTC 23 Oct.;
Bottom two: initialize at 0000 and 1200 UTC 24 Oct.)

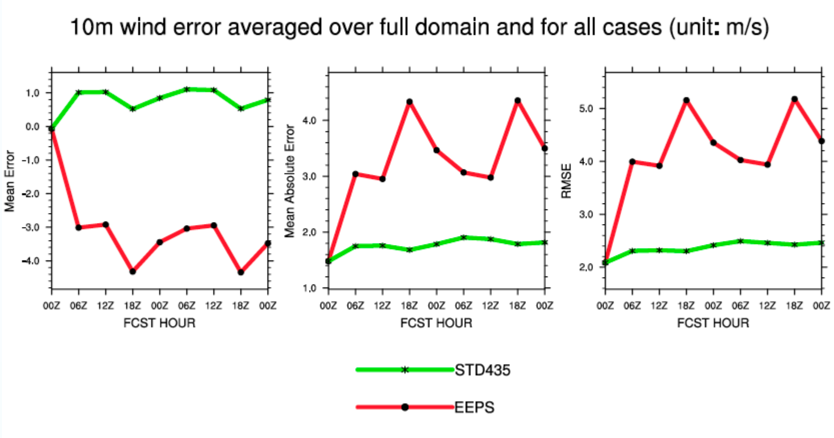
Simulation of Hurricane Sandy: why such a large difference?

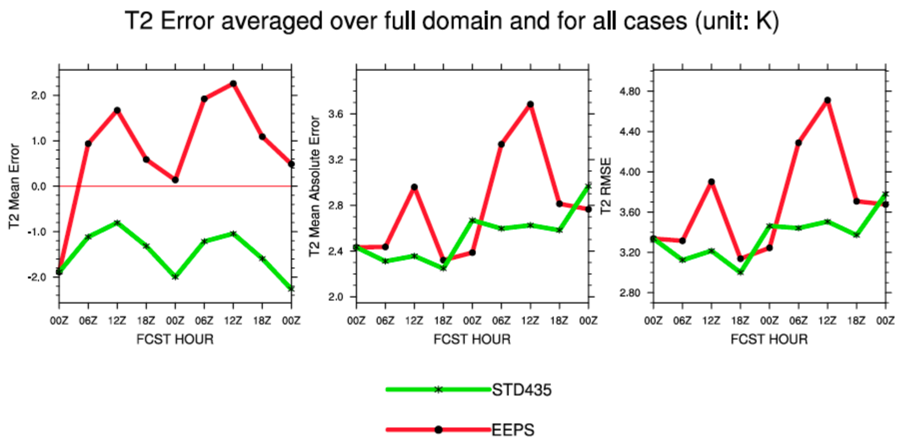
Bassill (2014)

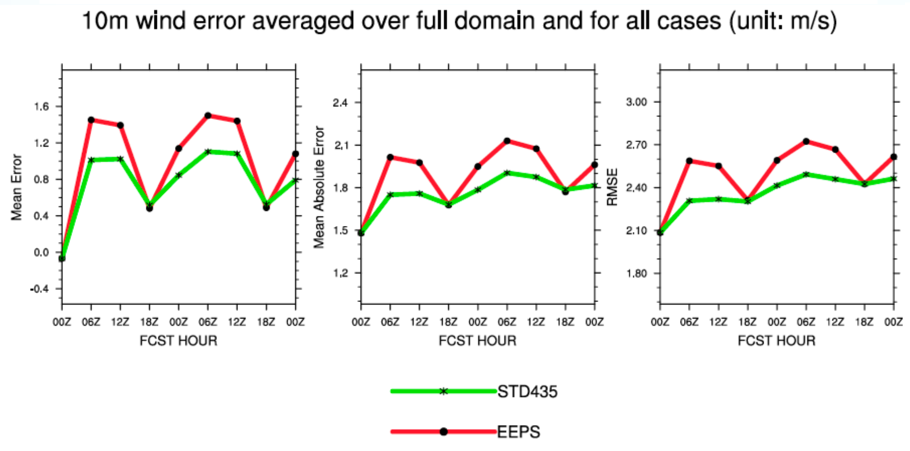
Lessons we learned from Sandy Simulation

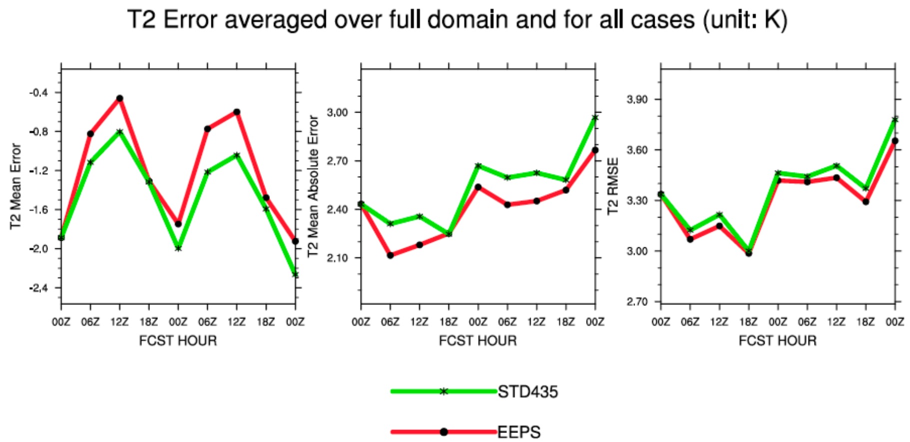
- *For this case*, cumulus parameterization is the dominant driver of forecast track accuracy
- Poor track forecasts by the GFS/GEFS are not due to ‘inappropriate’ initial conditions, nor are they consequences of the differences in model resolution
- These types of examples serve to emphasize the importance of parameterization development as a necessary condition for forecast improvement

Performance of the *E–ε* PBL (EEPS) scheme









Upper: EEPS + Monin-Obukhov (Janjic) scheme
Bottom: EEPS + Revised MM5 surface layer scheme

Other Options That May Be Considered

Example:

- Upper level damping over topography
- Gravity-wave drag if resolution is coarse
- Digital Filter Initialization
- Horizontal Diffusion
- Spectral Nudging