

Best Practices of WRF

Wei Wang Jimmy Dudhia Ming Chen
National Center for Atmospheric Research

Best Practices of WRF

- WRF is well-tested and documented. It can be used by people who have no experiences or formal training.
- However, in spite of advanced parameterization schemes in WRF and high-resolutions permitted by faster computers, correct choice of options is still a prerequisite for successful application of WRF

Best Practices of WRF

- A Thorough Analysis of the Research Topic
 - Conclusions and approaches in previous studies? Questions not answered? Incomplete knowledge? Important processes (convection, radiation, surface forcing, etc.?)
 - extensive literature review
- Your Scientific or Practical Objectives?
 - Scientific questions you want to answer
 - What can you do with WRF? Where and how WRF simulations may be helpful

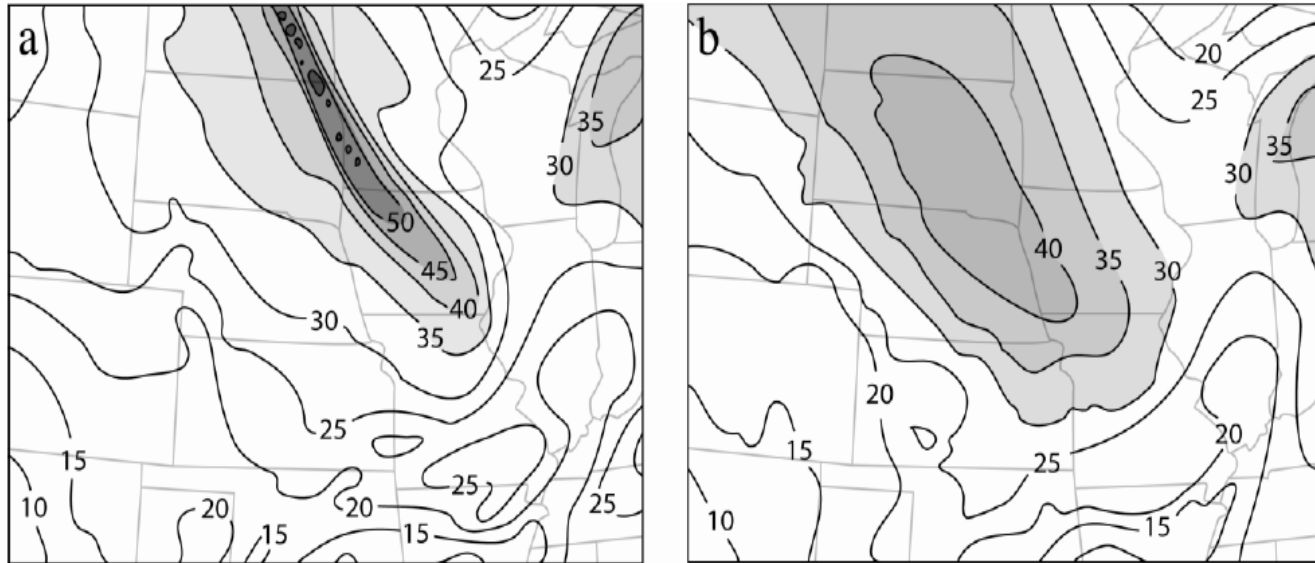
Best Practices of WRF

- The Model Configuration
 - Domain – often have profound influences
 - Resolution (horizontal and vertical)
 - Time and method of initialization
 - Cold start?
 - Variational data assimilation?
 - Spinup time?
 - Lateral Boundary Locations
 - 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 determined by forcing data
 - No less than 100x100 (at least 10 grid points are in the boundary zone)
- Where to place my lateral boundaries?
 - Avoid steep topography
 - Away from the area of interest

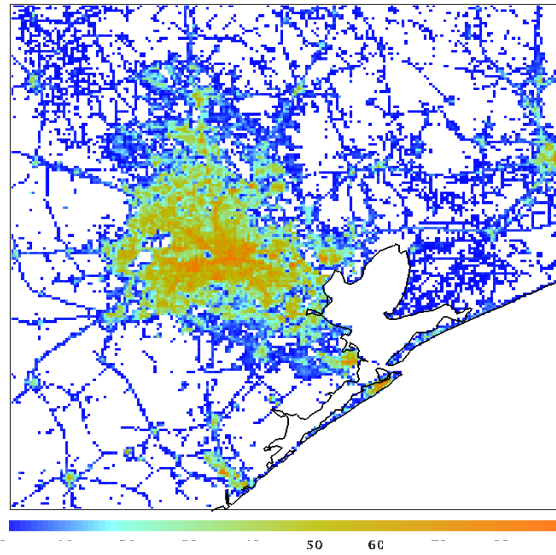
Importance of domain



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)

Initialization and Spin-up Issues

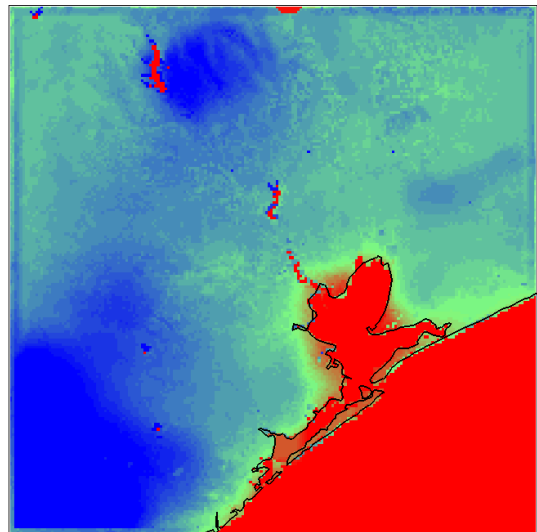
- Model problems often arise from poor initial condition
 - Appropriate initial time
 - Quality of initial condition
 - Check land data:
e.g. landuse: *does it represent my area well?*
 - Know about the data: *how good are the data?*
 - Forecast data
 - Reanalysis data
 - Climate model data
- In the first few hours, expect noise in pressure fields
 - Mostly sound waves adjusting winds to terrain. No harmful lasting effects



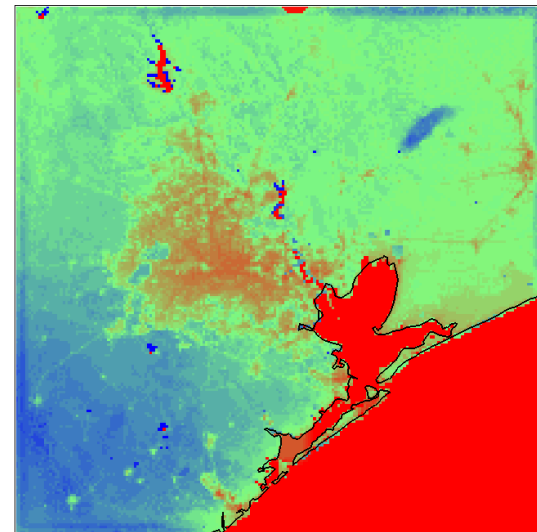
Impervious fraction
(%)

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

Pleim et al., 2012



297 298 299 300 301 302

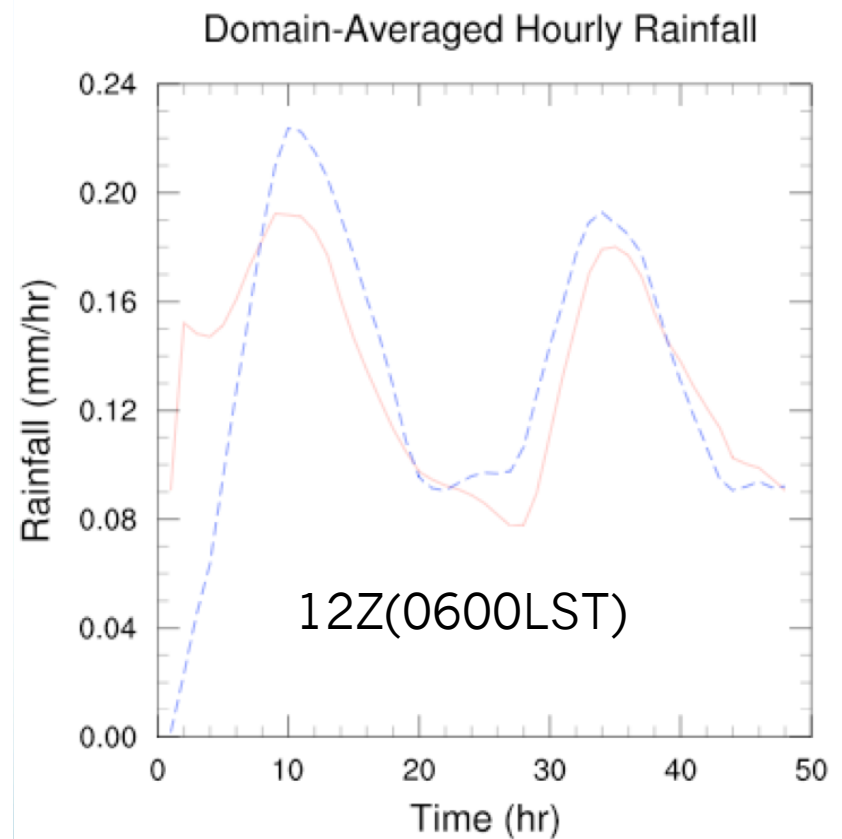
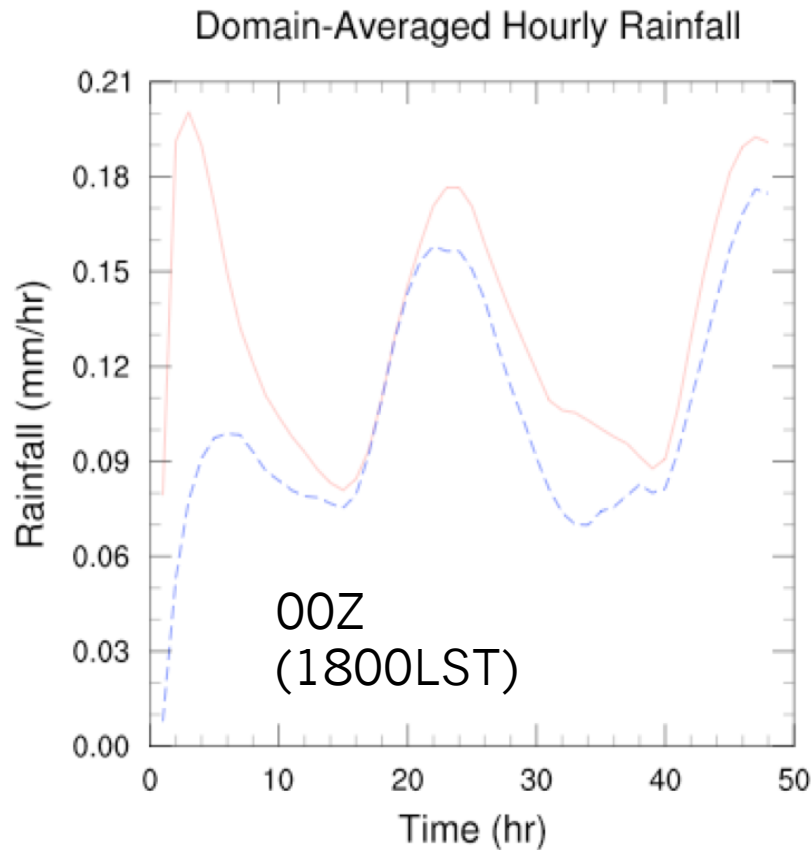


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Initialization and Spin-Up

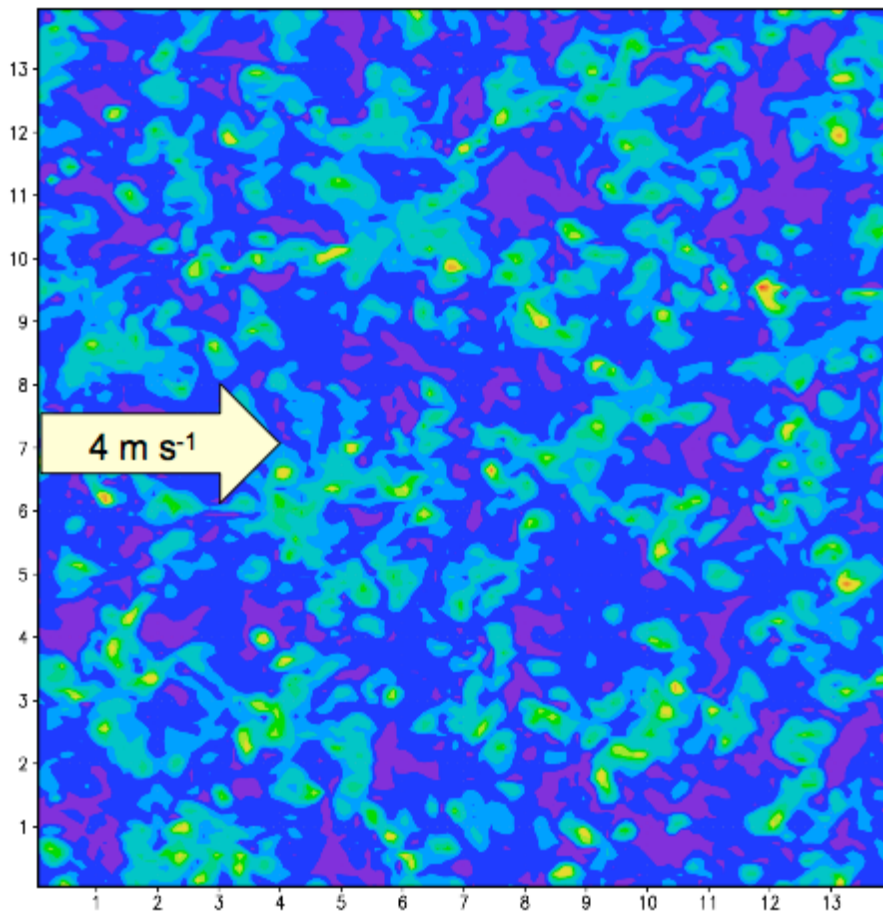
Convective Spin-Up:

An example of NCAR's 3-km convective runs (RUC: red; GFS: blue)



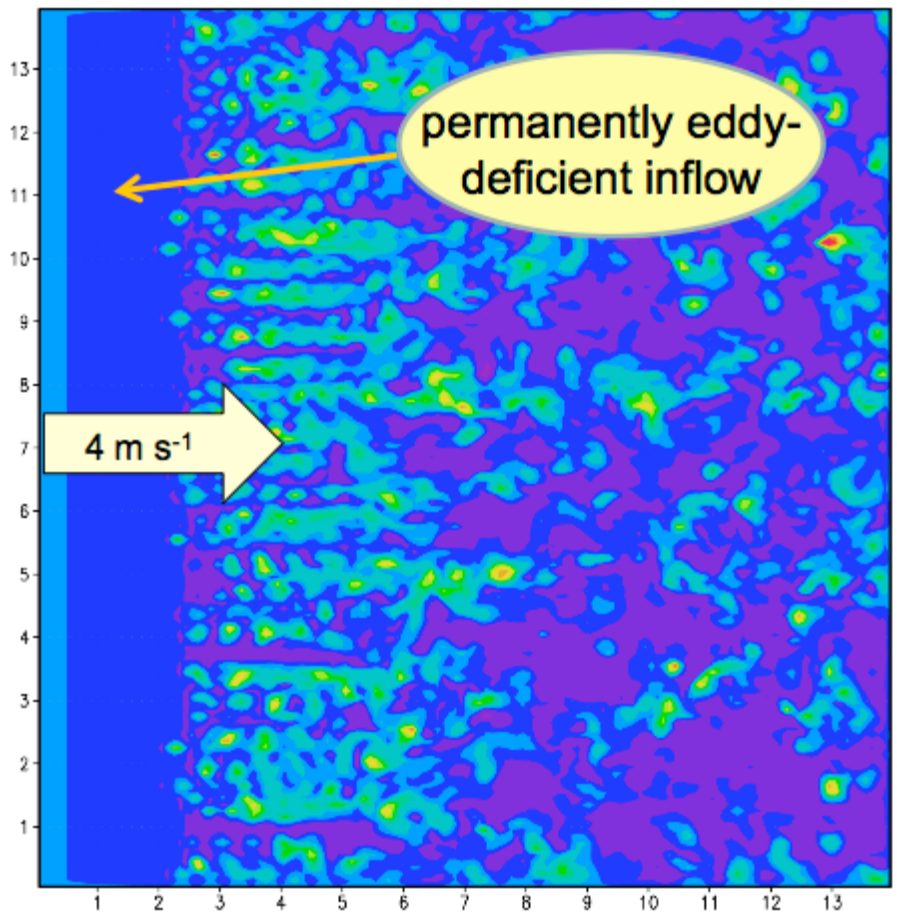
Lateral Boundary Condition

- 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



1 km ●—●

periodic LBCs



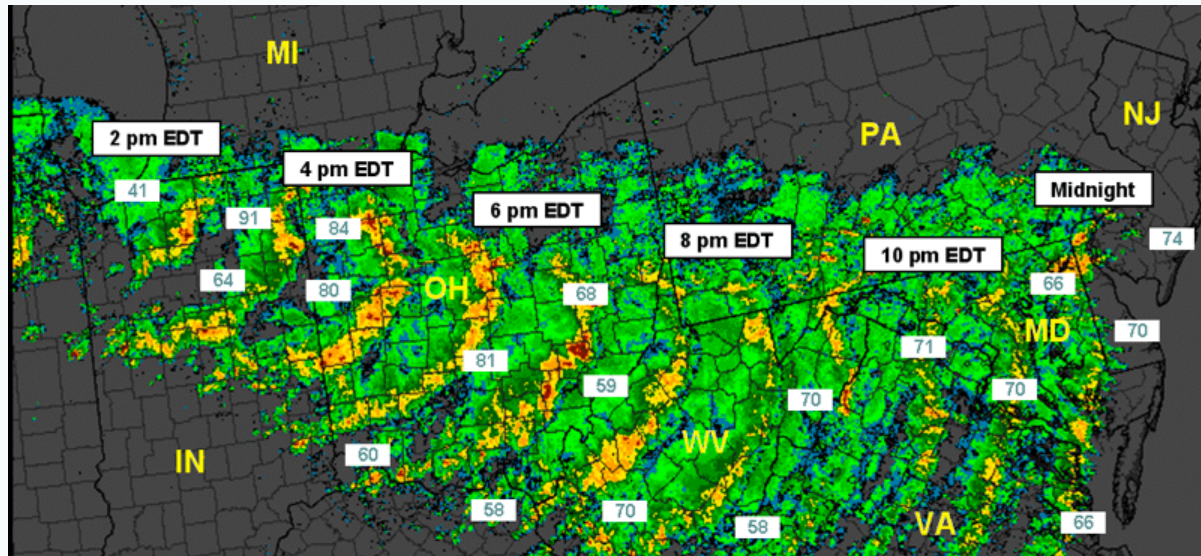
non-periodic LBCs

Grid Size and Impact

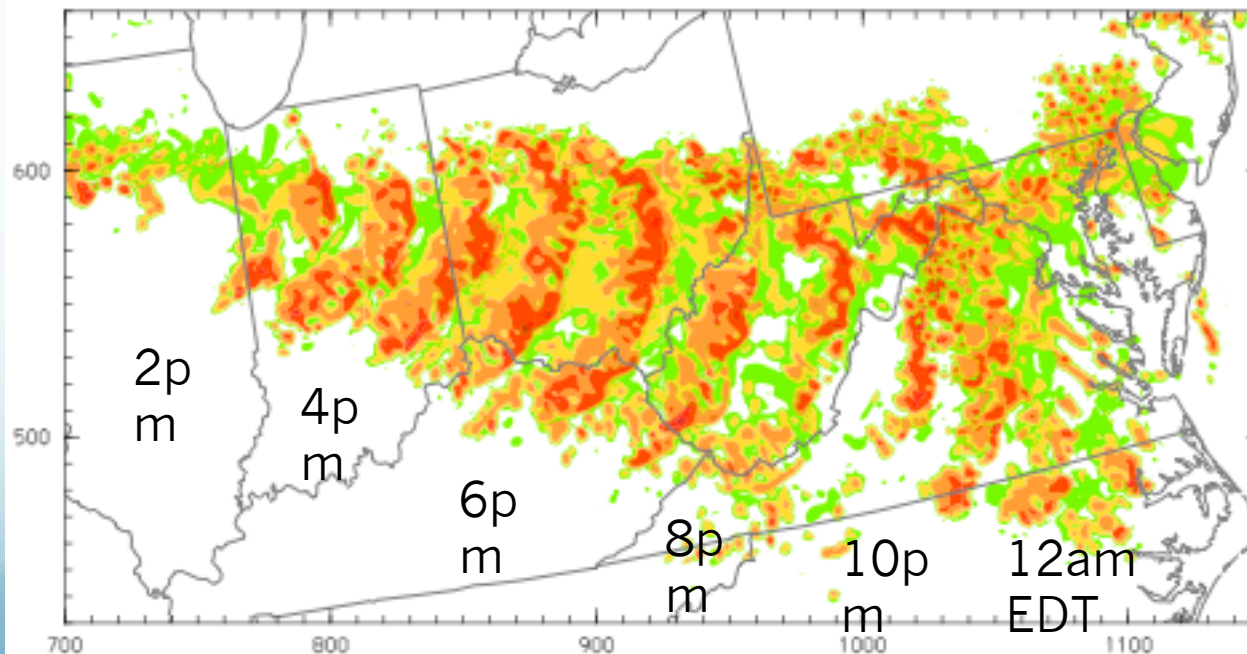
- Extreme weather event forecast
 - The Derecho of 29-30 June 2012
- $\Delta \approx 3$ km: Traditional cloud-permitting resolution
 - No need for deep-convective parameterization
- $\Delta \approx 30$ m: Traditional large-eddy simulation (LES) resolution
 - No need for a planetary boundary layer (PBL)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

(Bryan, 2014)

Case Study: The Derecho of 29-30 June 2012

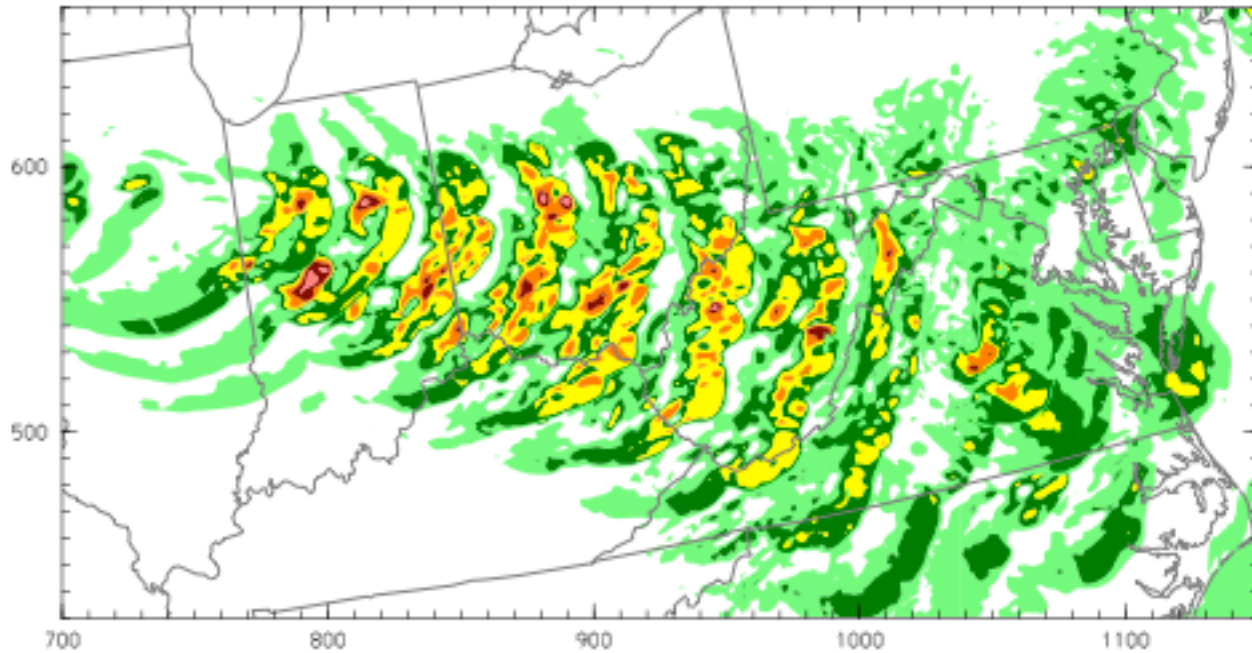


Radar
composite
reflectivity

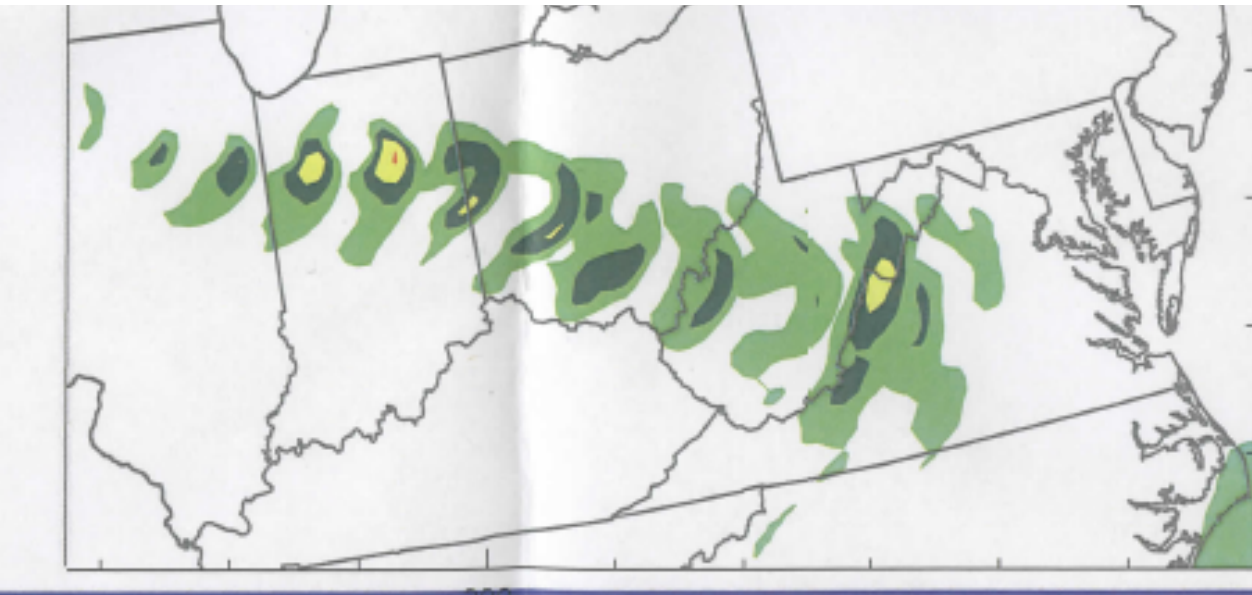


WRF
simulation of
maximum
reflectivity,
DX=3km,
initialized at
1200 UTC 29
June

Simulated maximum wind



3-km run



15-km
run

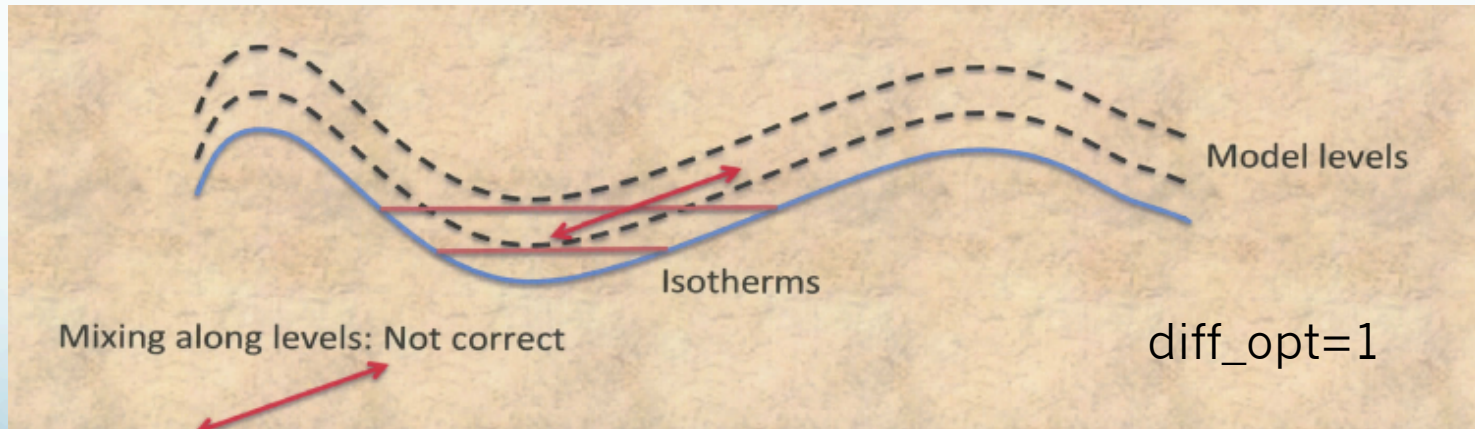
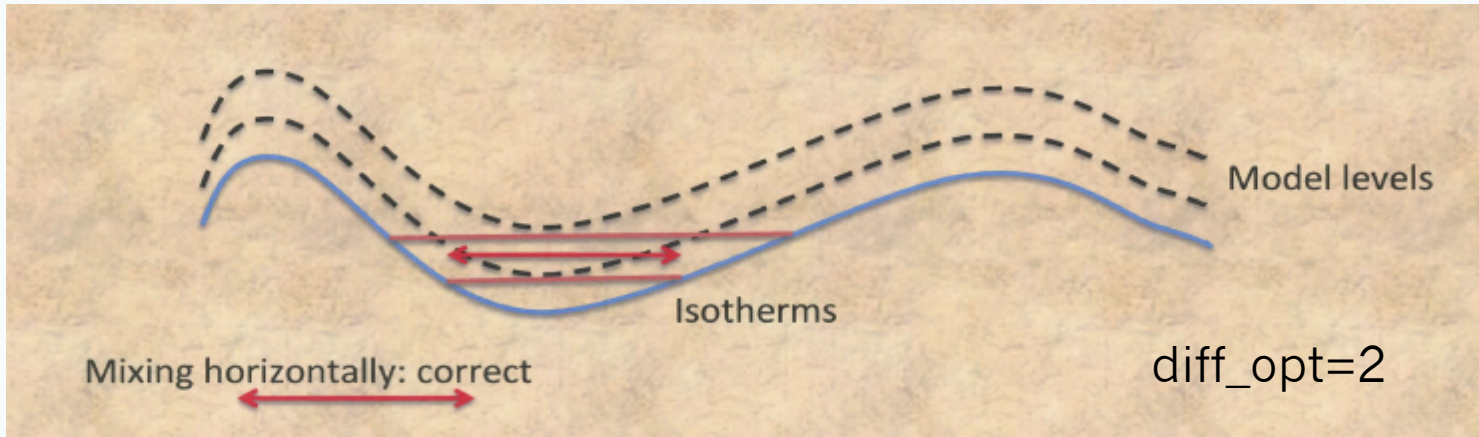
Model Levels and High Tops

- At least 30 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 30 hPa, 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- \rightarrow 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



Selecting Model Physics

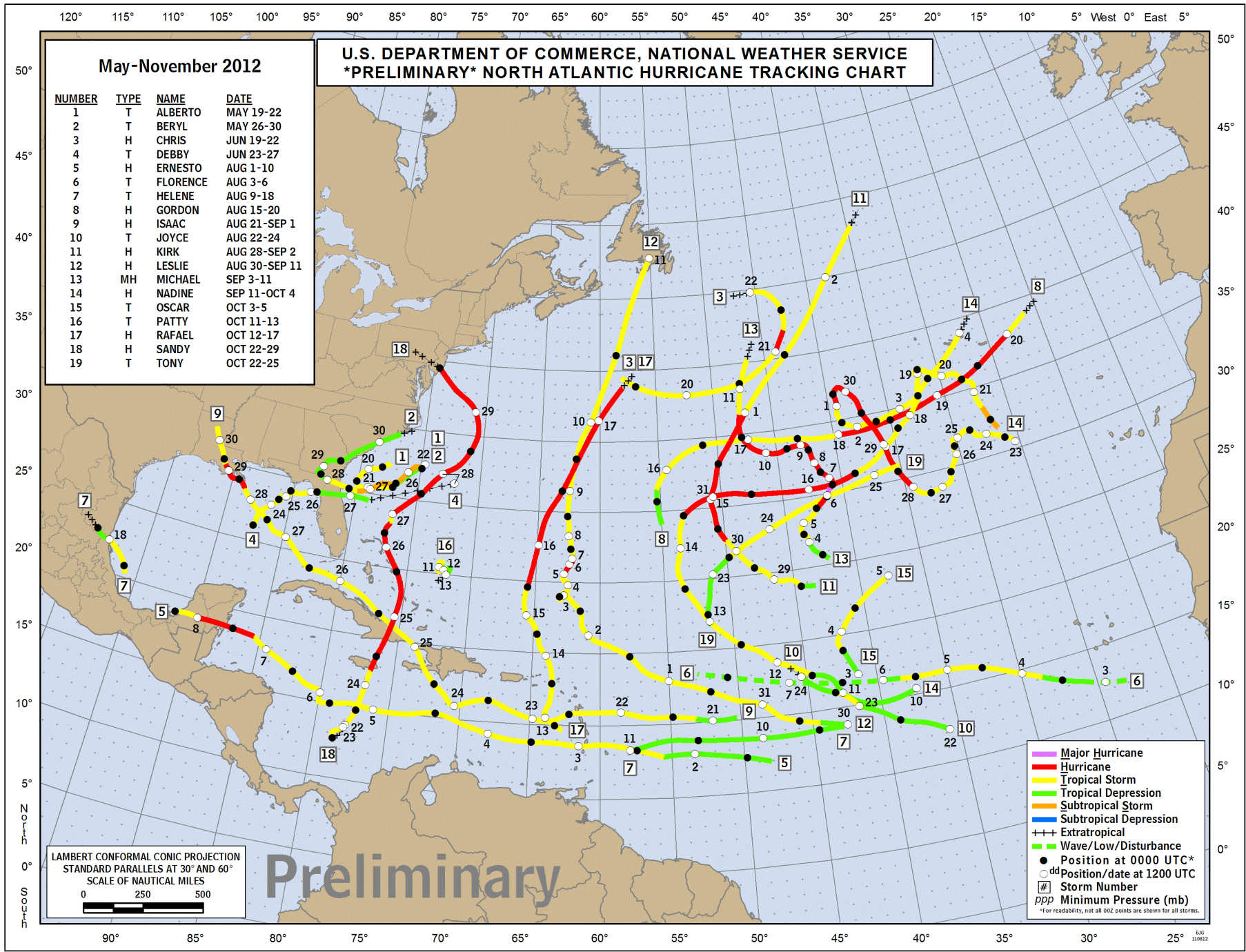
- Many options = more works
 - http://www2.mmm.ucar.edu/wrf/users/phys_references.html
 - <http://www2.mmm.ucar.edu/wrf/users/docs/wrf-phy.html>
- Testing of multiple options for a particular application
 - A given set of physics will perform differently depending on domain size, location, initialization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

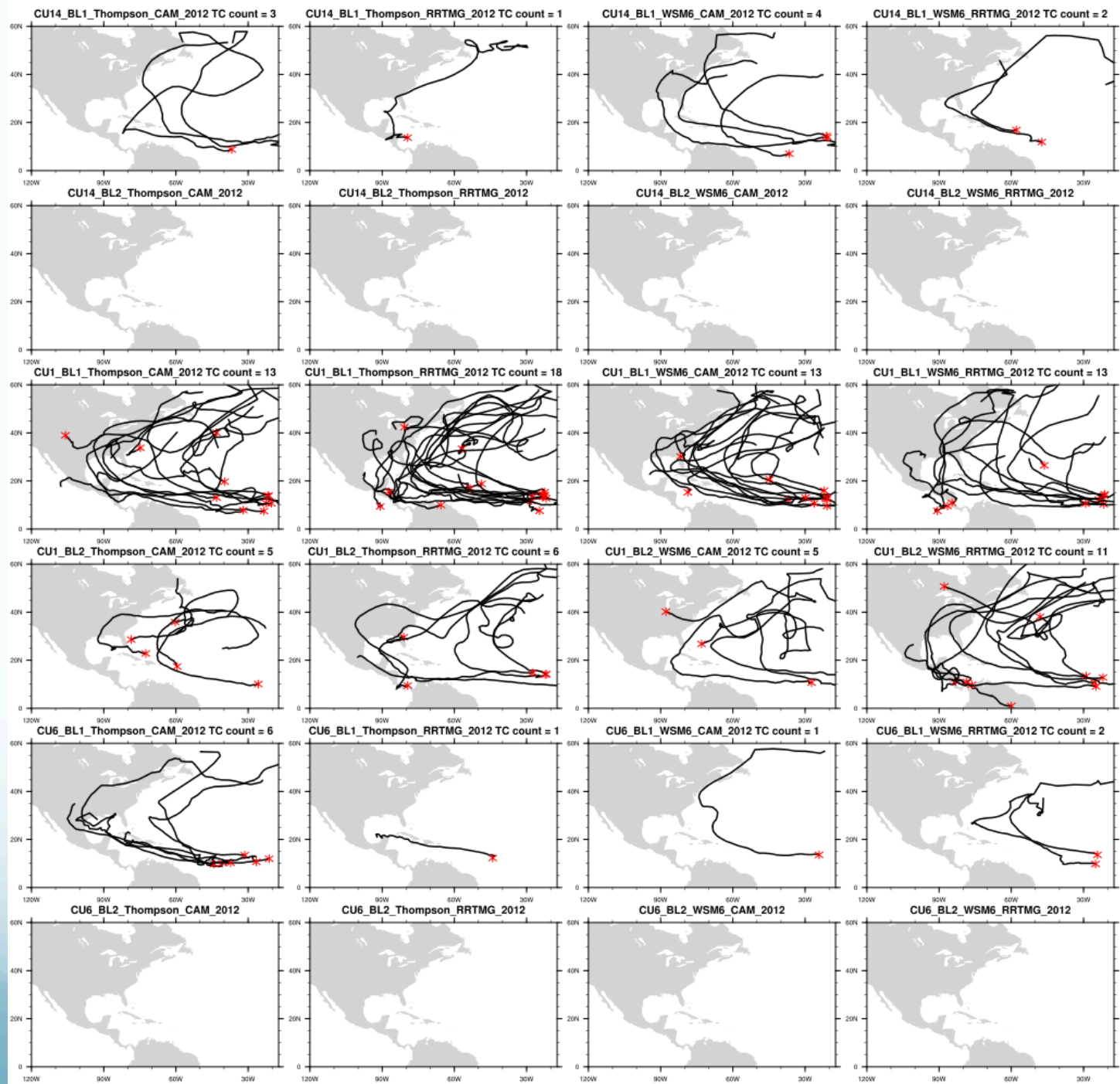
Physics in multi-scale model

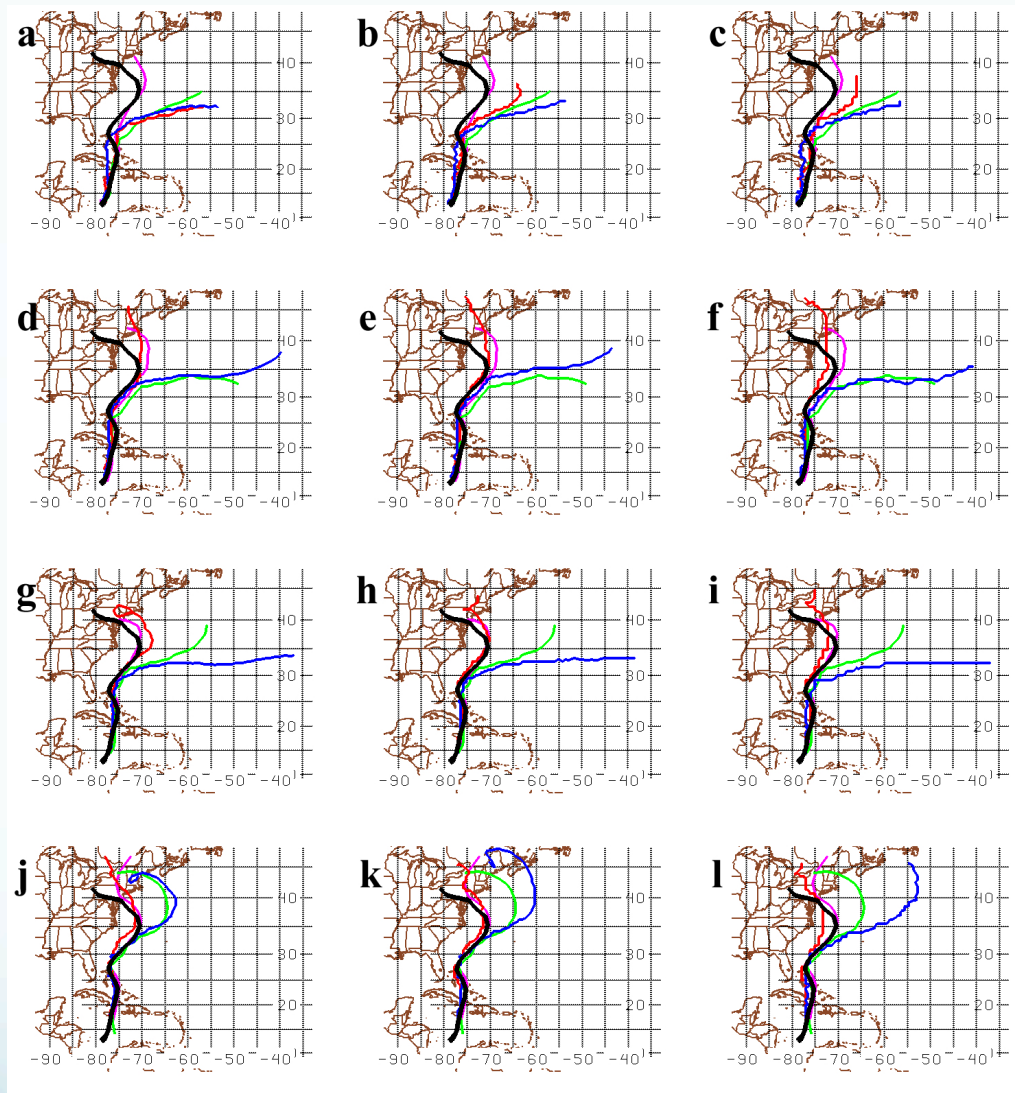
- Grid size and cumulus
 - $DX > 10\text{km}$, yes
 - $DX < 4\text{km}$, probably not
 - Grey Zone: 5-10km, no consensus, may try to use scale-aware cumulus scheme, such as GF, MSKF.
- Grid size and microphysics
 - For $DX > 10\text{km}$, no complex scheme is necessary
 - For $DX < 4\text{km}$ (convection-resolving),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

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
 - Terra incognita: resolved CISCs, violation of PBL assumption, and unresolved interaction between CISC and smaller scale turbulence.







- 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)

Test of Sandy Simulation

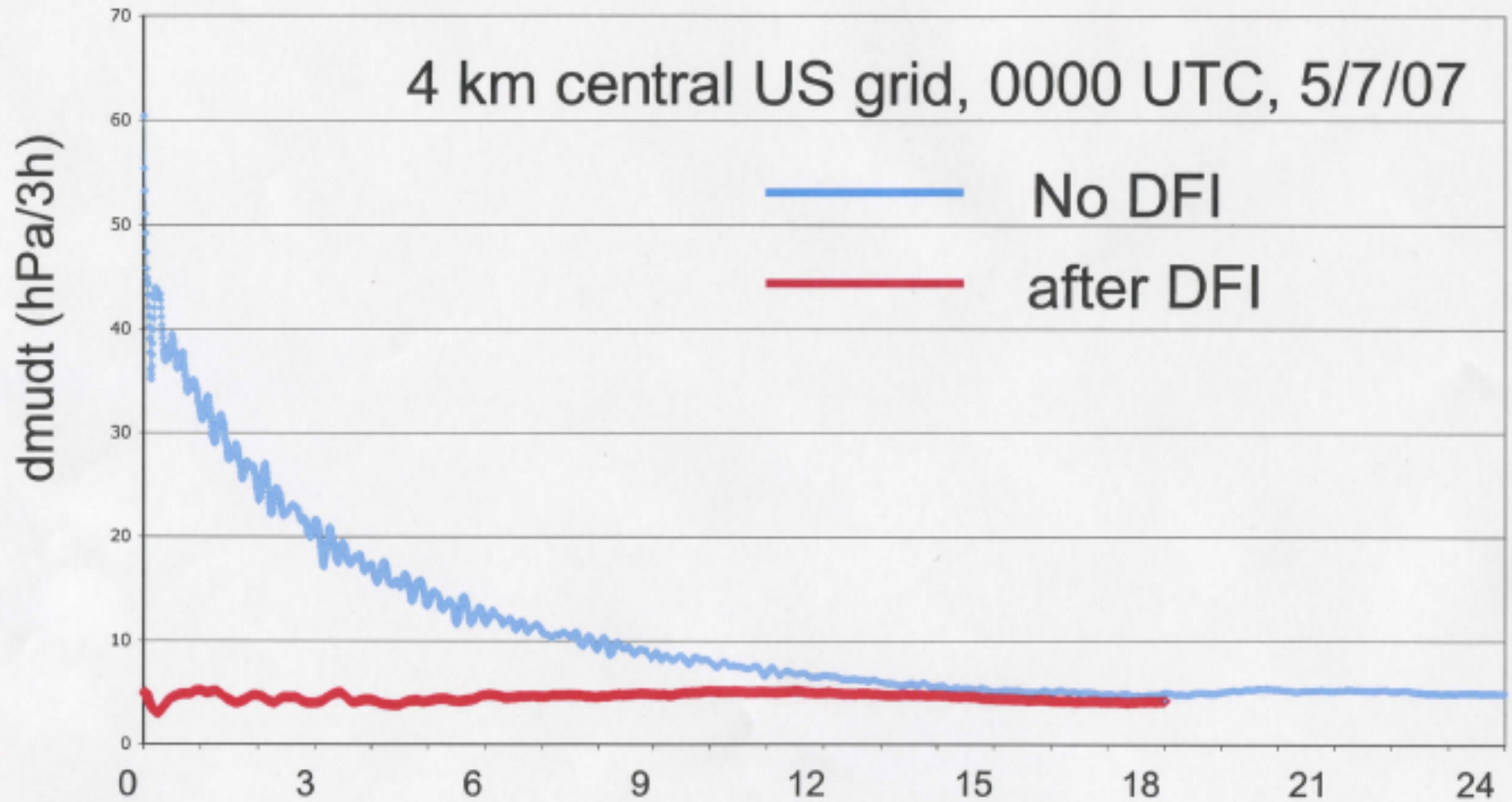
- *For this case*, cumulus parameterization is the dominant driver of forecast track accuracy
- Poor track forecasts by the GFS/GEFS are not due to ‘inappropriate’ initial conditions, nor are they consequences of the differences in model resolution
- These types of examples serve to emphasize the importance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

Other Options That May Be Considered

Example:

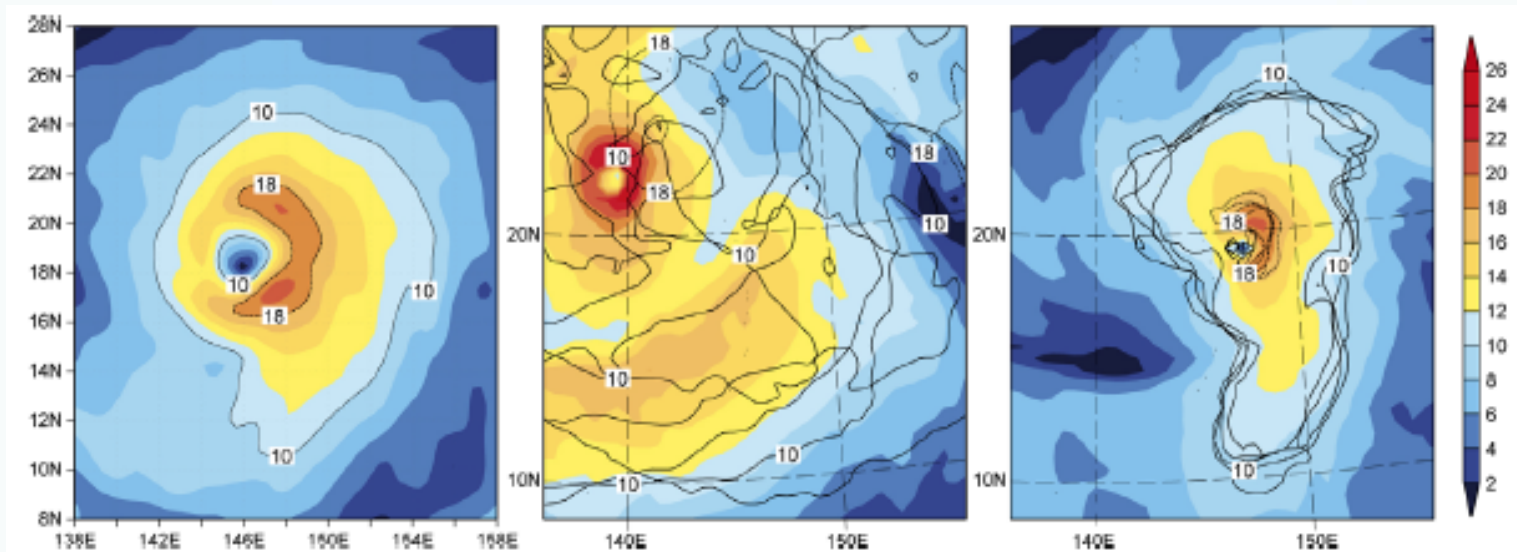
- Upper level damping over topography
- Gravity-wave drag if resolution is coarse
- Digital Filter Initialization
- Horizontal Diffusion
- Spectral Nudging

Domain average 3-hourly dry-hydrostatic column pressure tendency



Spectral Nudging

- It is useful for controlling longer wave phases. Compensates for errors due to low-frequency narrow lateral boundaries
- The “spectral nudging” method imposes time-variable large-scale atmospheric states on a regional atmospheric model
- Spectral nudging may be seen as a suboptimal and indirect data assimilation technique.
 - Wave number is selected so that domain size/wavenumber $\approx 1000\text{km}$ in X and Y direction
 - Nudge U, V, THETA, Geopotential (not QV, since it has no wave pattern)
 - Can nudge in all levels or use ramp above a specified model level (if_zfac_ph, k_zfac_ph, etc.)
- However, strong nudging may reduce or filter out extreme events since nudging pushes the model toward a relatively smooth, large-scale state.



Horizontal 10 m wind speed fields (m s^{-1}) for typhoon Songda (200418), on 1 September 2004, 0:00.

From left: CFSR reanalysis, CCLM-NN, CCLM-SN.

(Frauke Feser¹ and Monika Barcikowska, Environmental Research Letters, 2012)