

Considerations for Designing an Numerical Experiment

Wei Wang

Nansha, Guangdong, China

December 2015

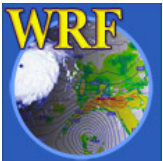
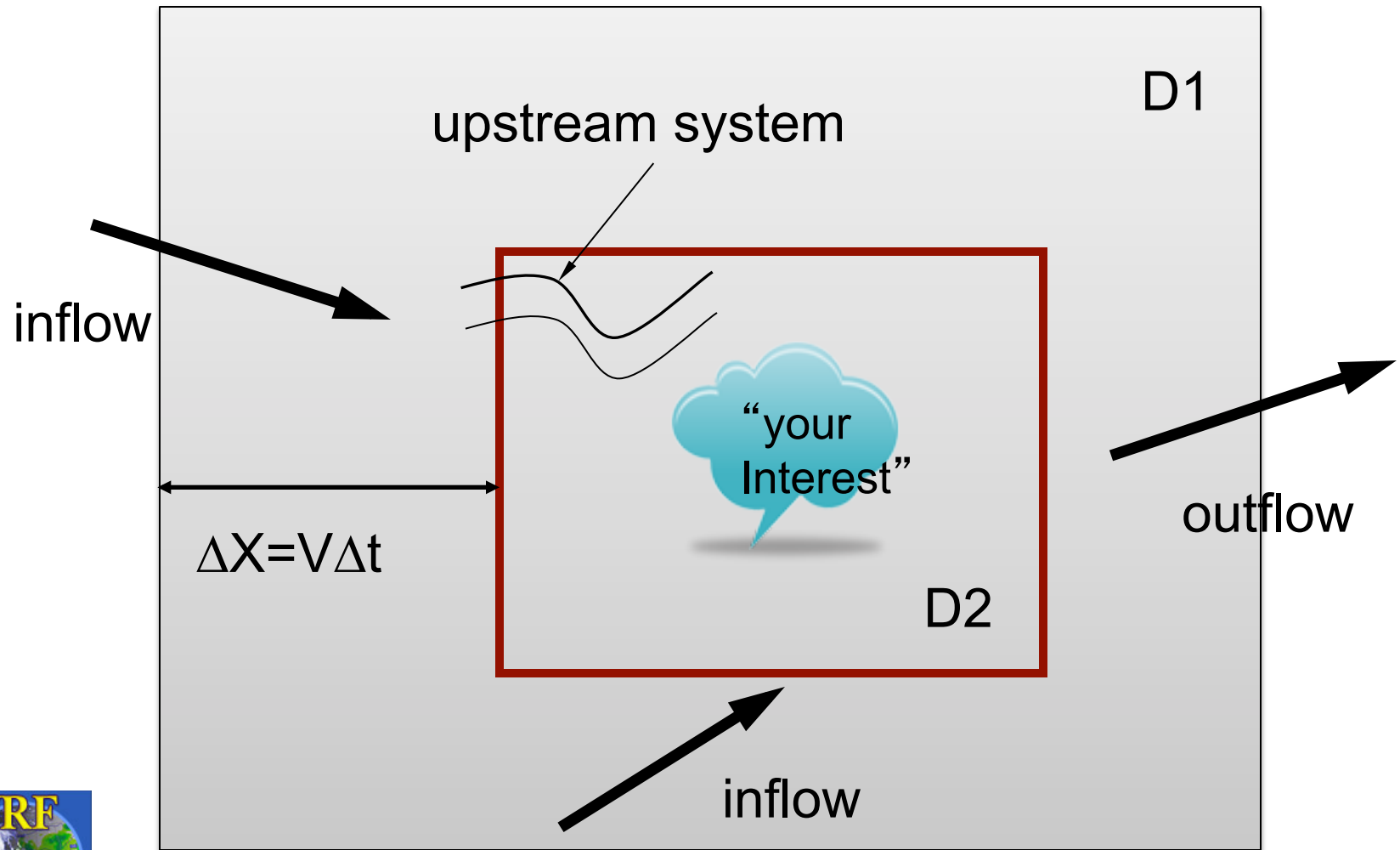


Domains

- In general,
 - IC is more important for simulations of a few days;
 - BC is more important for longer simulations.
- 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

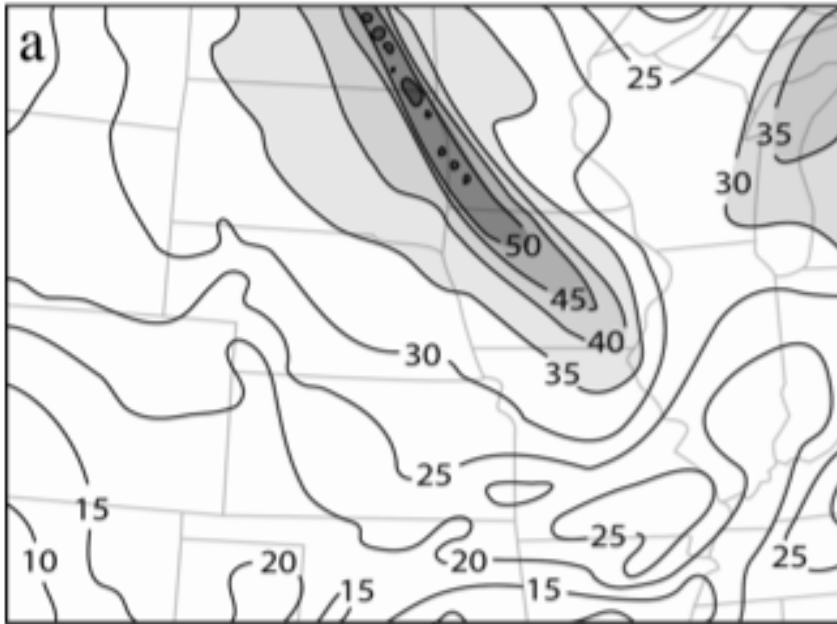


Note on Configuring Domains: Horizontal

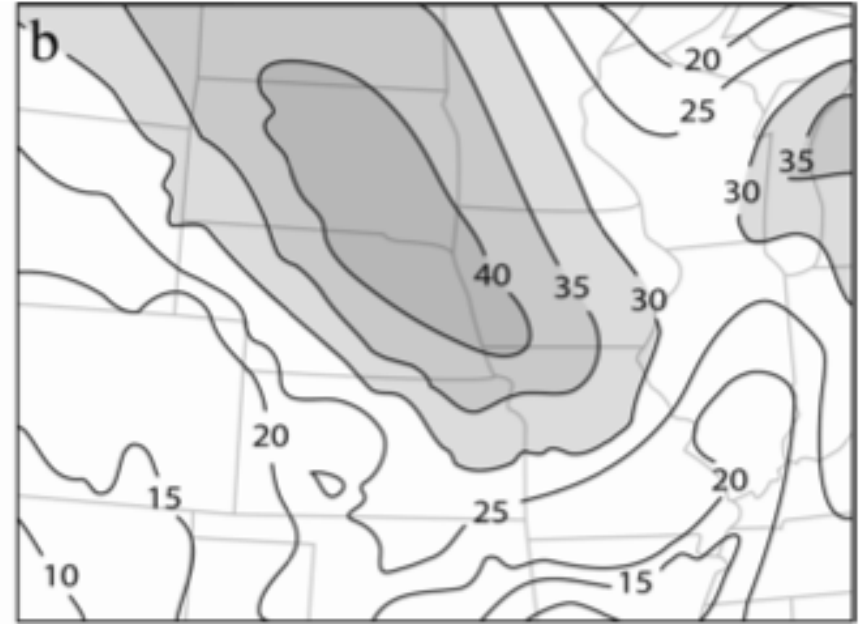


Note on Configuring Domains: Effect of domain sizes

Large regional domain

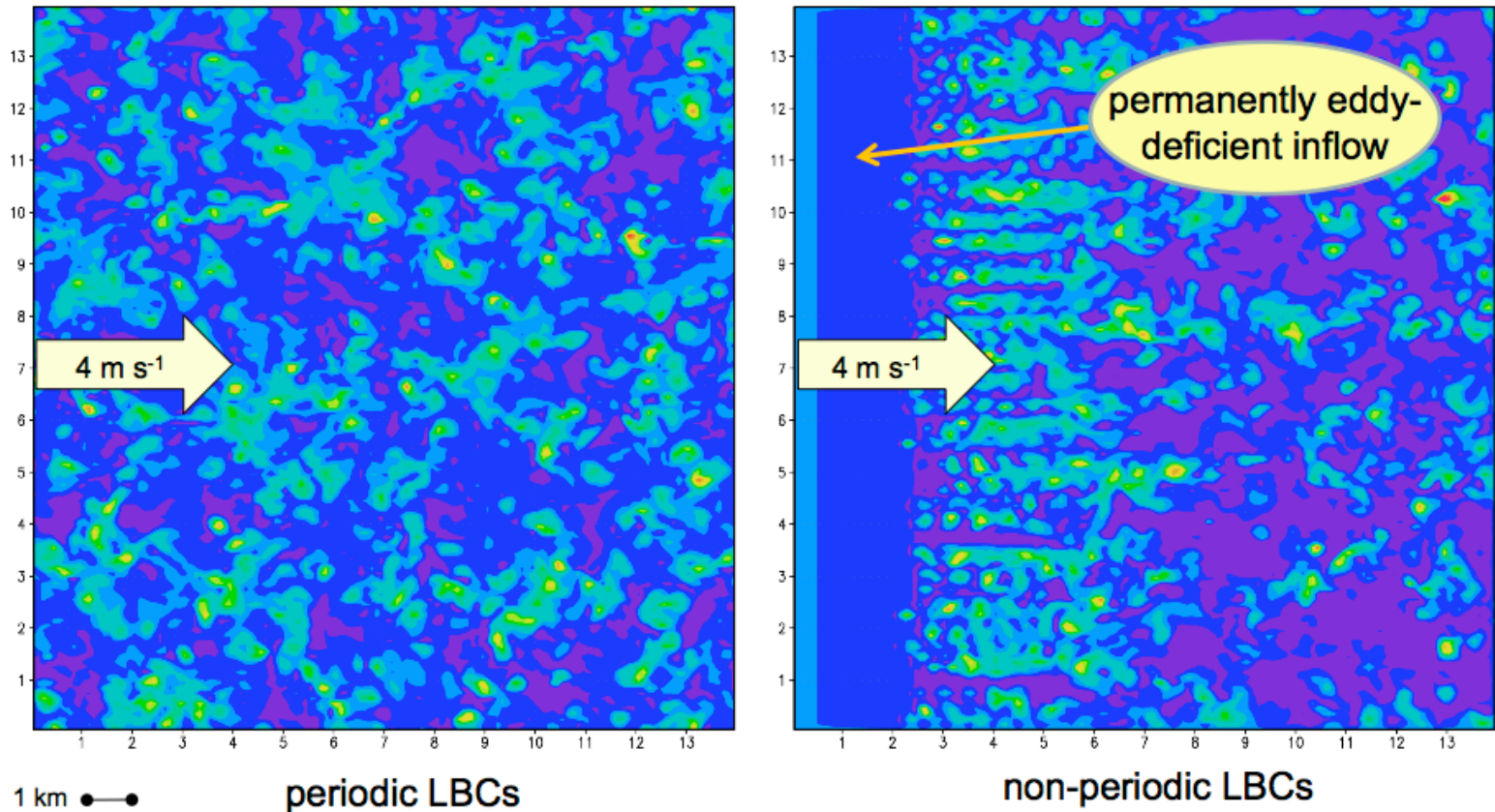


Smaller regional domain



(From Warner, 2011)

Note on Configuring Domains: Effect of lateral boundary conditions



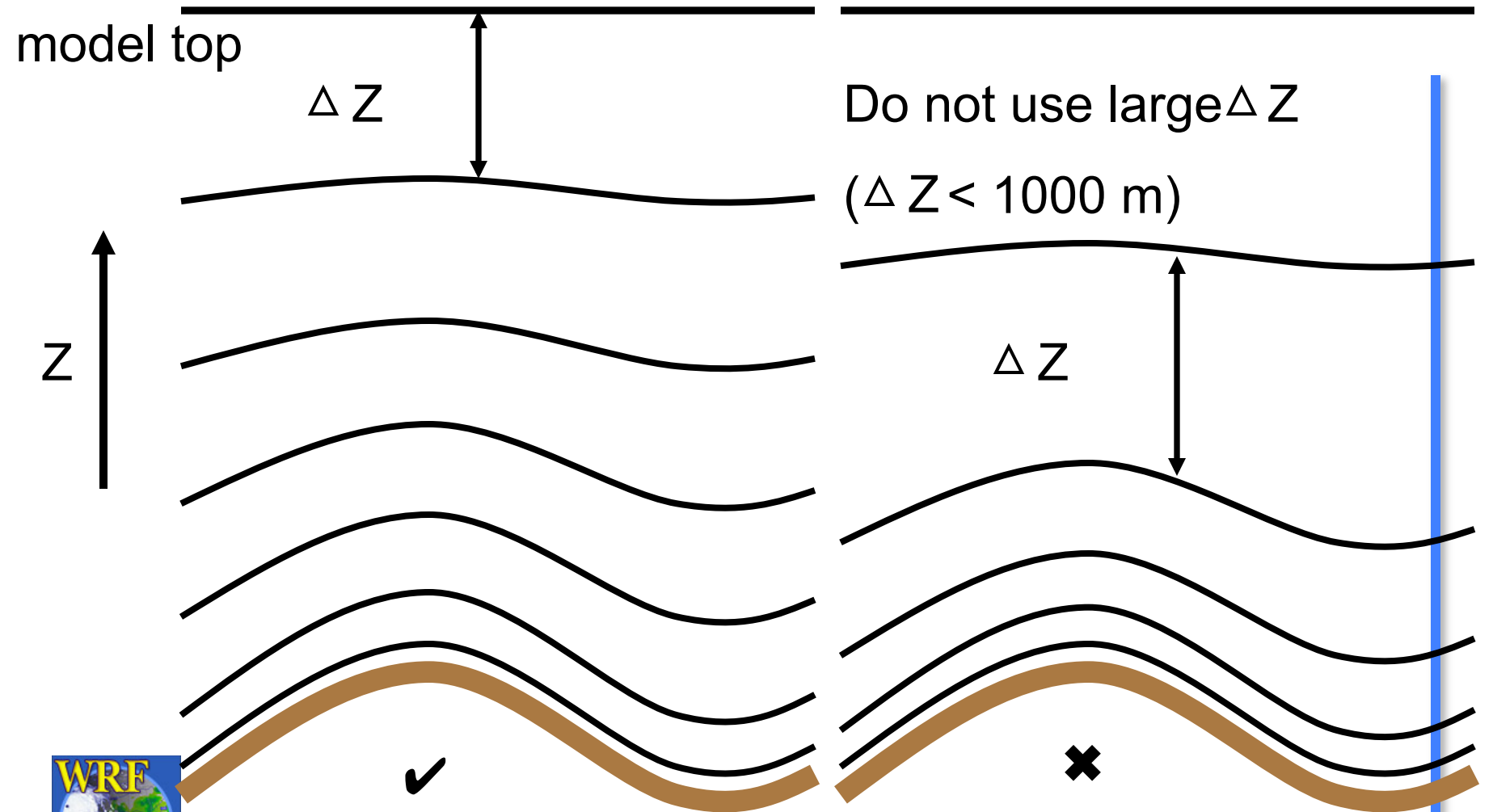
(From Gaudet et al. WRF Users' Workshop 2012, talk 3.5)

Domains

- How many vertical levels should I use?
 - At least 30 or more levels for model top at 50 mb
 - 50 mb model top is recommended
 - Vertical grid distance should not be larger than 1000 m:
 - Radiation, microphysics, less accurate lateral BC
 - Related to horizontal grid size too: if finer horizontal grid size is used, consider adding a few more levels in the vertical
 - Make sure $dz < dx$



Note on Configuring Domains: Vertical levels



Domains

- Consider the placement of your domains:
 - What map projection to use?
 - Check the range of the map scale factor after running *geogrid*
 - Values should be close to 1

* Placement of the domain will affect the time step used in the model.



Nests:

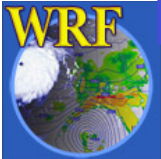
- When should I use nests?
Some of the reasons may be:
 - Input data resolution is too coarse
 - Input data may not be adequate as LBC
 - There isn't sufficient computing resources
- Nest domain sizes should not be too small;
- Nest boundary should be kept away from coarse domain boundary, and steep topography;
- If you use a nest, do not save on coarse domain – it's cheap (and may scale better when using large number of processors)



Input Data

- 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
- How frequent do I need to have boundary conditions?
 - More frequent is better

* Good data will go a long way to ensure good outcome.

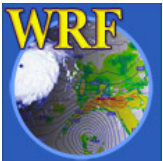


Model Options

- What do I start with?
 - What other people have success with?
 - References, papers
 - Consider well-tested options first
 - Simple options first:

For example,

 - Graupel may not be important if $dx \gg 10$ km
 - mixed layer ocean model may not be needed if the modeled track isn't correct
 - Use analyses from weather centers before trying to create your own (via either *obsgrid* or DA) for both initial and lateral boundary conditions
 - Single domain first, before using many nests



Model Options

- Choose physics for appropriate grid sizes
 - Use a cumulus scheme if grid size > 10 km
 - A cumulus scheme isn't needed when grid size < 4 km
 - Avoid grid sizes 5 – 10 km
 - Use a PBL for grid size > 500 m
 - Use LES options for grid size < 100 m
- Consider other options:

For example,

 - Upper level damping over topography
 - Gravity-wave drag if resolution is coarse
 - Slope effect on radiation when grid size < 2 km



Verification:

- Important to verify:
 - Knowing where model is biased can be very useful
- Verifying high-resolution model can be tricky:
 - e.g. phase error, which punishes higher resolution model more
 - Neighborhood method more appropriate



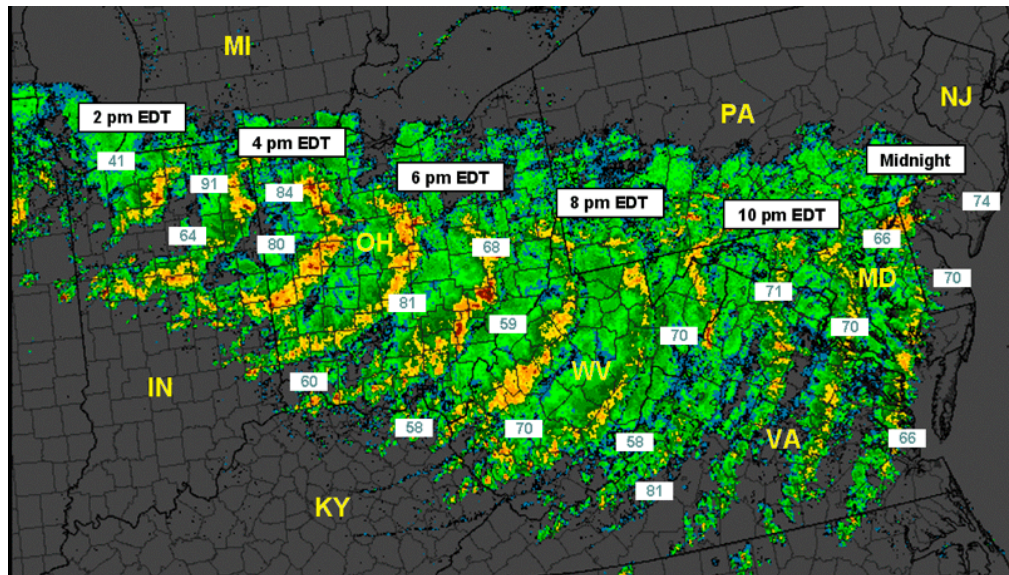
A forecast example

-- What can we learn from this example?



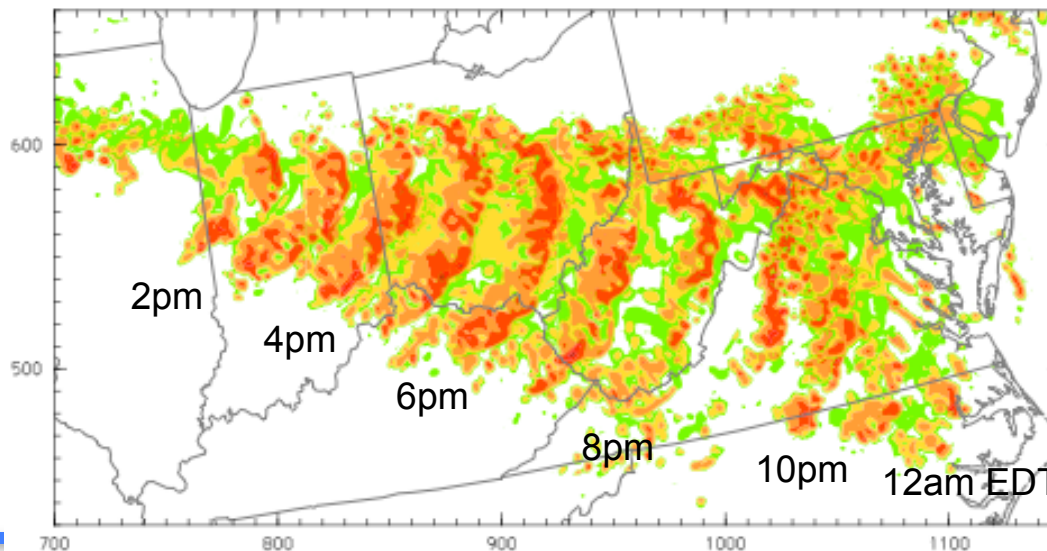
Derecho forecast from NCAR's 2012 RT

Observed
radar
composite

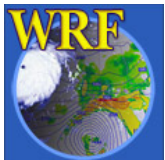


(from NOAA/SPC)

Forecast max-
column
reflectivity from
3 km model,
starting from
1200 UTC
June 29



IC: Fully
cycled
analysis
starting from
late April
using WRF-
DART



IC

F06

F09

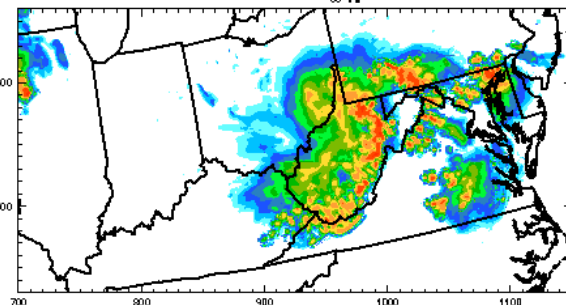
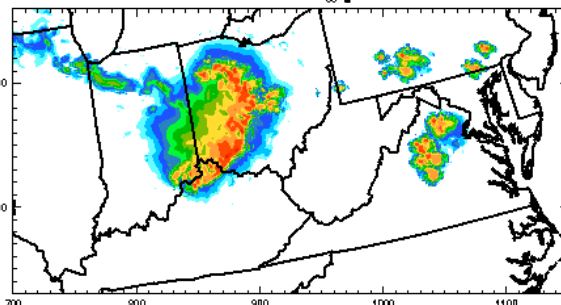
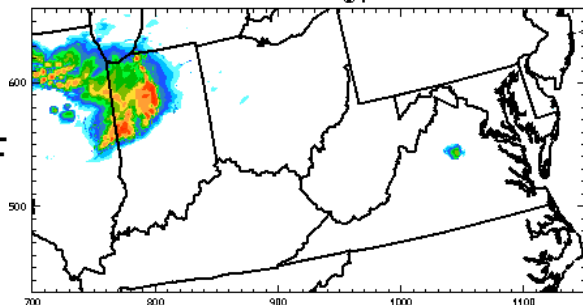
F12

1800 UTC, 2 pm EDT

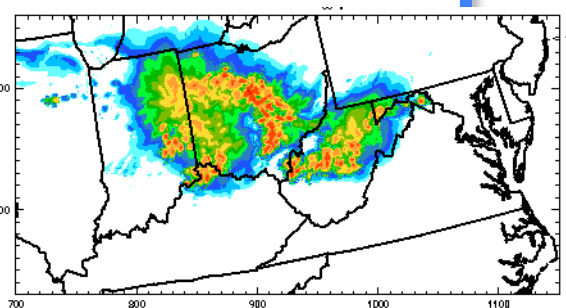
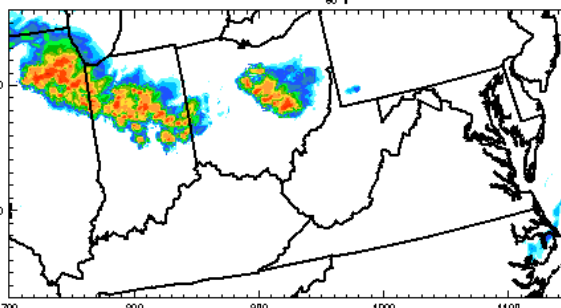
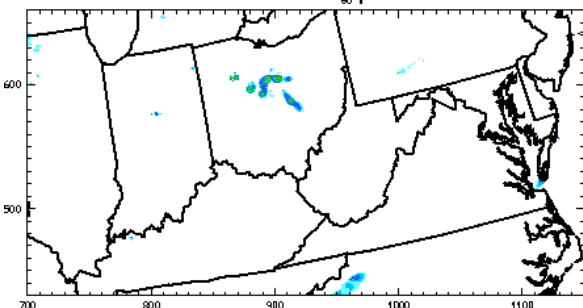
2100 UTC, 5 pm EDT

0000 UTC, 8 pm EDT

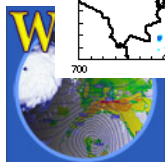
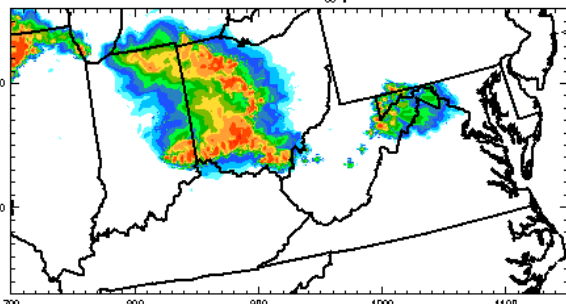
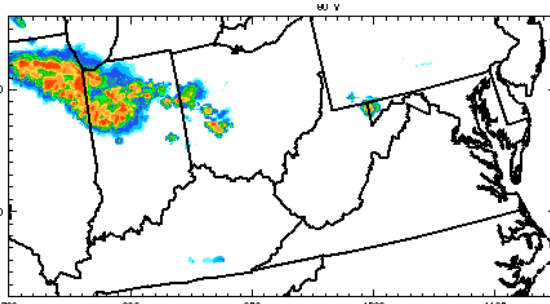
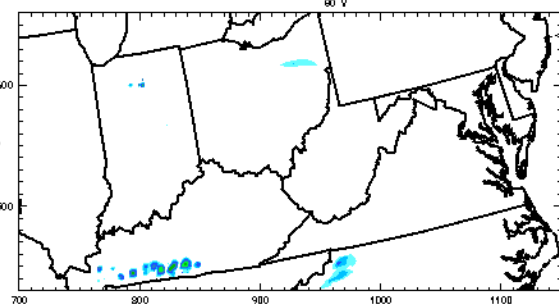
EnKF



NAM

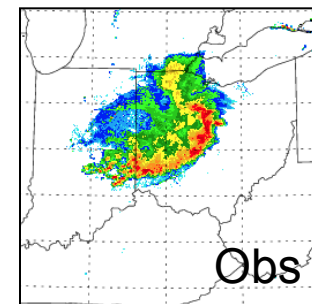


GFS

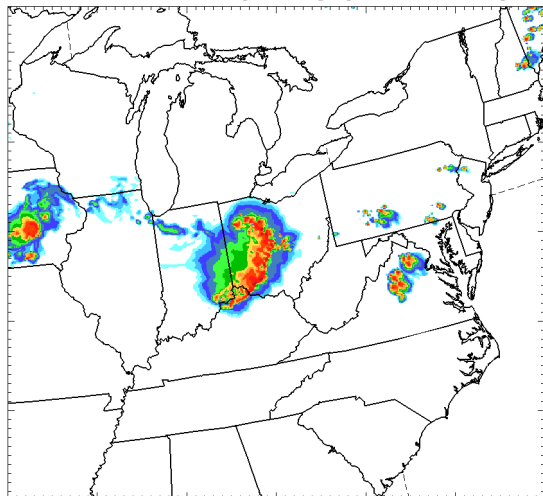


Sensitivity to physics and initial conditions:

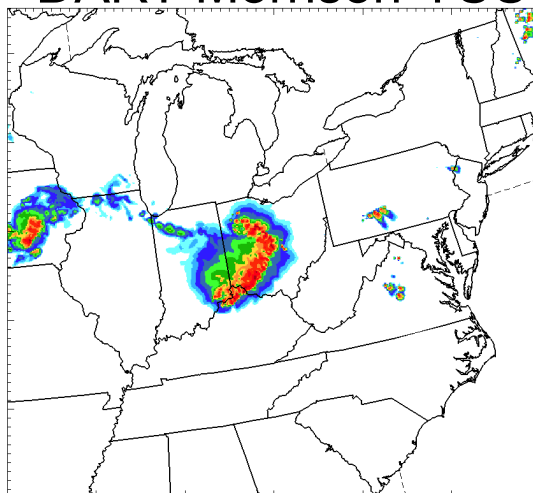
29 June 2012
Derecho



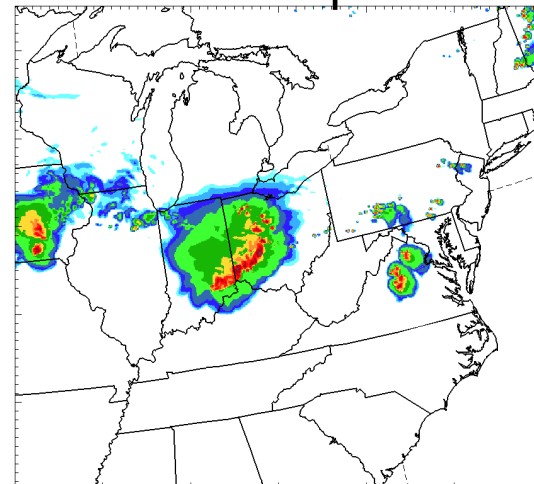
DART-Morrison-MYJ



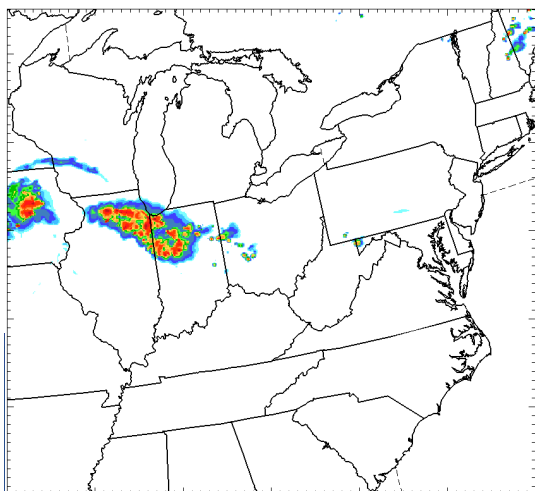
DART-Morrison-YSU



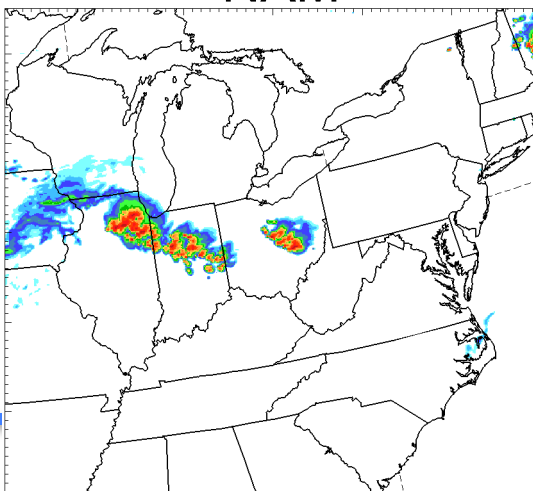
DART-Thompson-MYJ



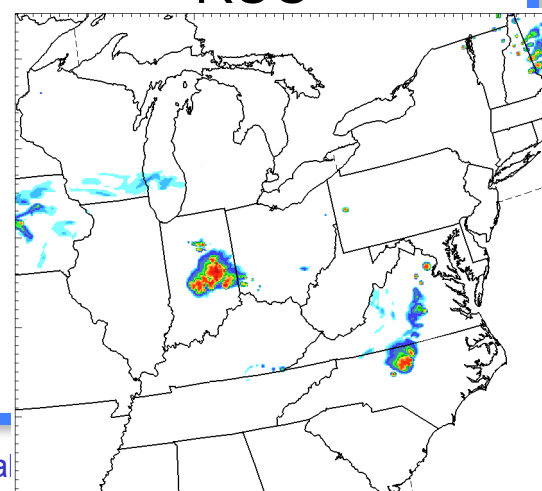
GFS



NAM



RUC

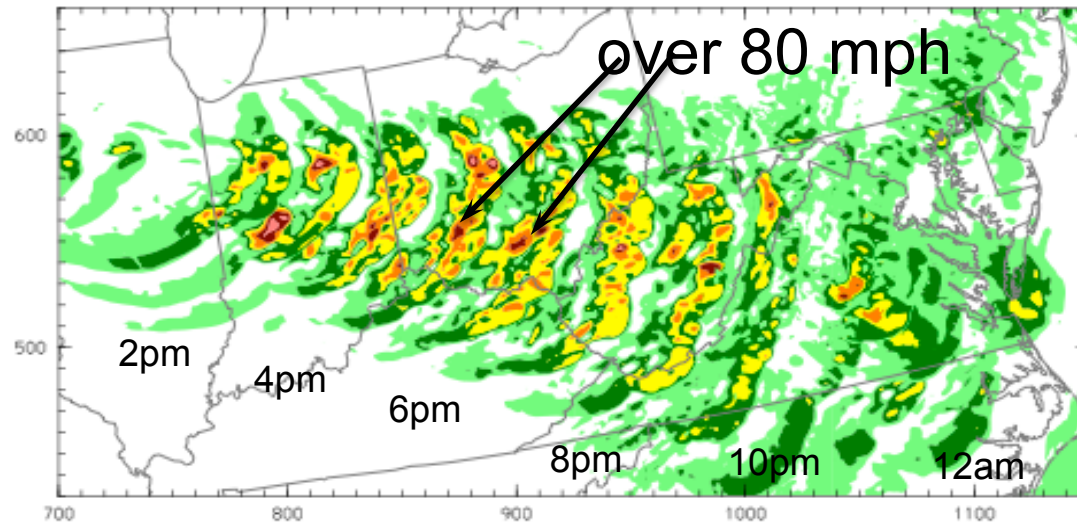


sca

(From Weisman)

Resolution Differences: simulated max winds

3 km results



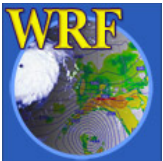
15 km results



NCAR Real-time Forecast Domain (2013)

15 km

3 km



What this case show:

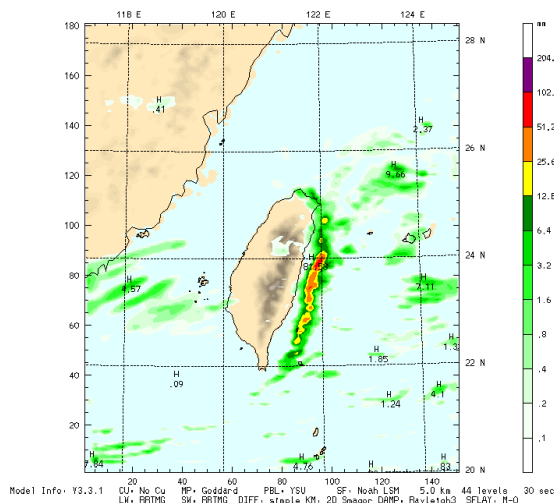
- Initial conditions are important
- Different initial conditions will likely give different solutions
- Compared to model runs using different physics options, changing initial conditions is likely to have larger impact
- Model resolution matters



An example of nest feedback

00z SST, TSK
Fcst: 60 h
Total precip. in past 6 h

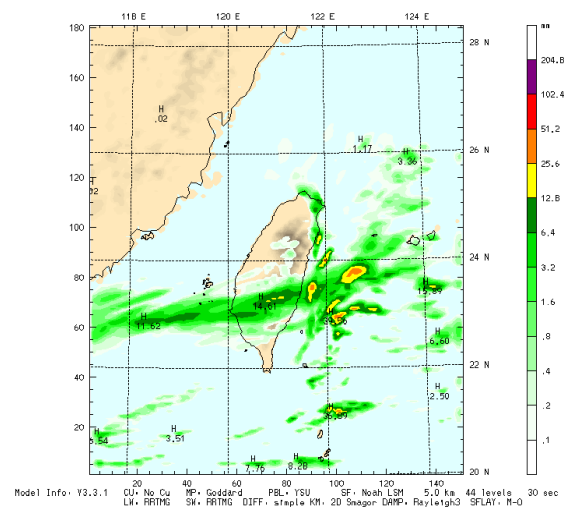
Init: 06 UTC Sun 04 May 14
Valid: 18 UTC Tue 06 May 14 (02 LST Wed 07 May 14)



feedback = 0

e04: feedback=1. 00z SST, TSK
Fcst: 60 h
Total precip. in past 6 h

Init: 06 UTC Sun 04 May 14
Valid: 18 UTC Tue 06 May 14 (02 LST Wed 07 May 14)



feedback = 1

60-h forecast of the 6-h rainfall for the period ending
18 UTC 6 May 2014 (courtesy of J. Bresch)



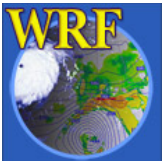
Bottomline..

- Model results can be affected by many choices:
 - Domain configuration, both horizontal and vertical;
 - Input data;
 - Initial and lateral boundary conditions.
- Model has limitations:
 - Physics: biases, may not represent certain process well, etc.
 - Limitation of the lateral boundaries
- **Always check the output after each program**



Other Best Practice Reading:

- *“12 steps toward improving the outcome” by C. Davis:*
<http://www2.mmm.ucar.edu/wrf/users/workshops/WS2012/ppts/discussion1.pdf>
- *“WRF Advanced usage and Best Practices” by Dudhia and Wang:*
http://www2.mmm.ucar.edu/wrf/users/workshops/WS2014/ppts/best_prac_wrf.pdf



References:

Numerical Weather and Climate Prediction, 2011. By Thomas Warner, *Cambridge University Press*.

Warner, T., 2011. Quality assurance in atmospheric modeling. *Bull. Amer. Met. Soc. Dec. issue, p1601 – 1611.*

Stensrud, D., 2007. Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models. *Cambridge University Press*.

Haltiner G. and R. Williams, 1980. Numerical Prediction and Dynamic Meteorology. *Wiley*.

