Considerations for Designing an Numerical Experiment

Wei Wang

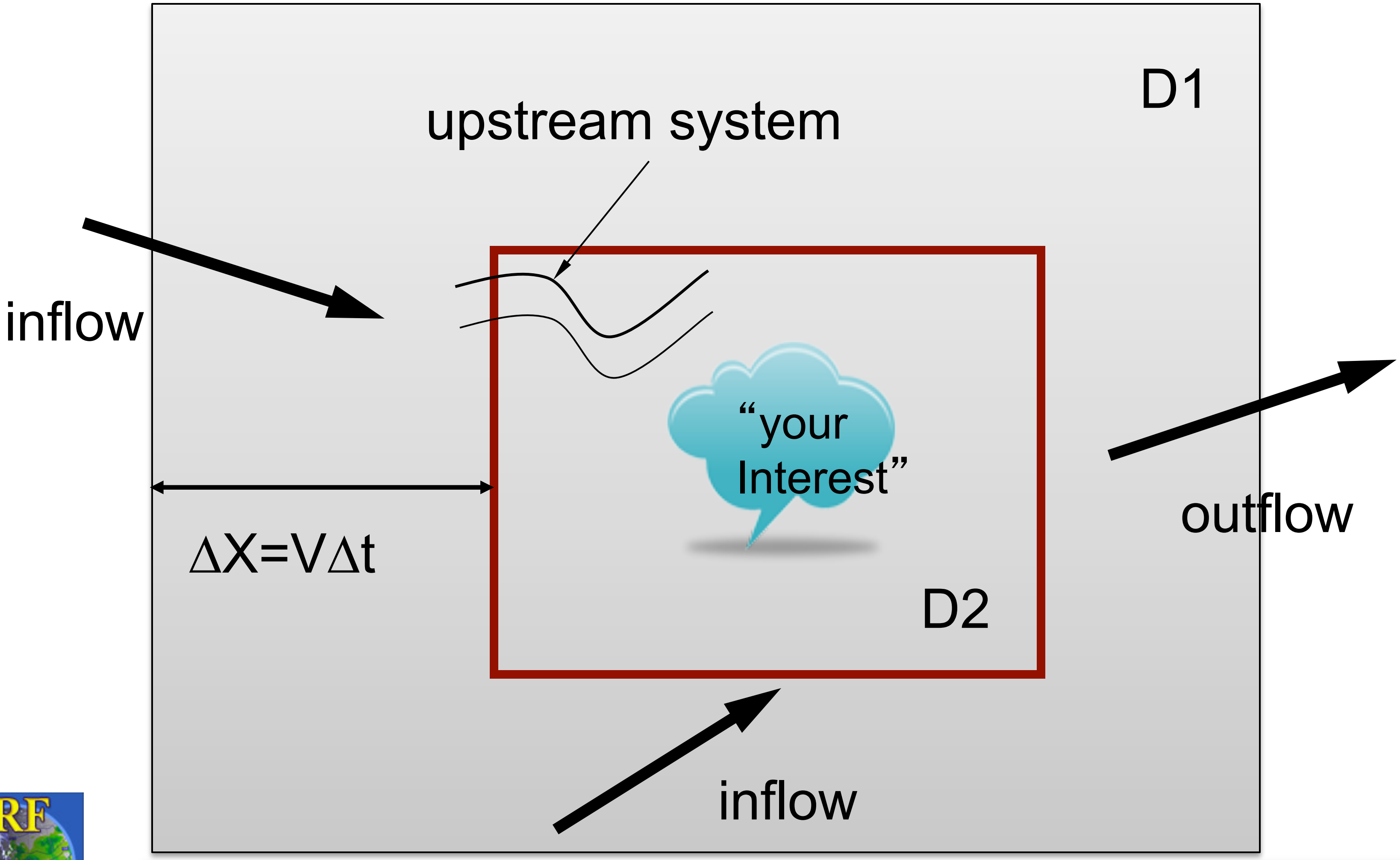
NCAR/MMM

July 2015

Domains

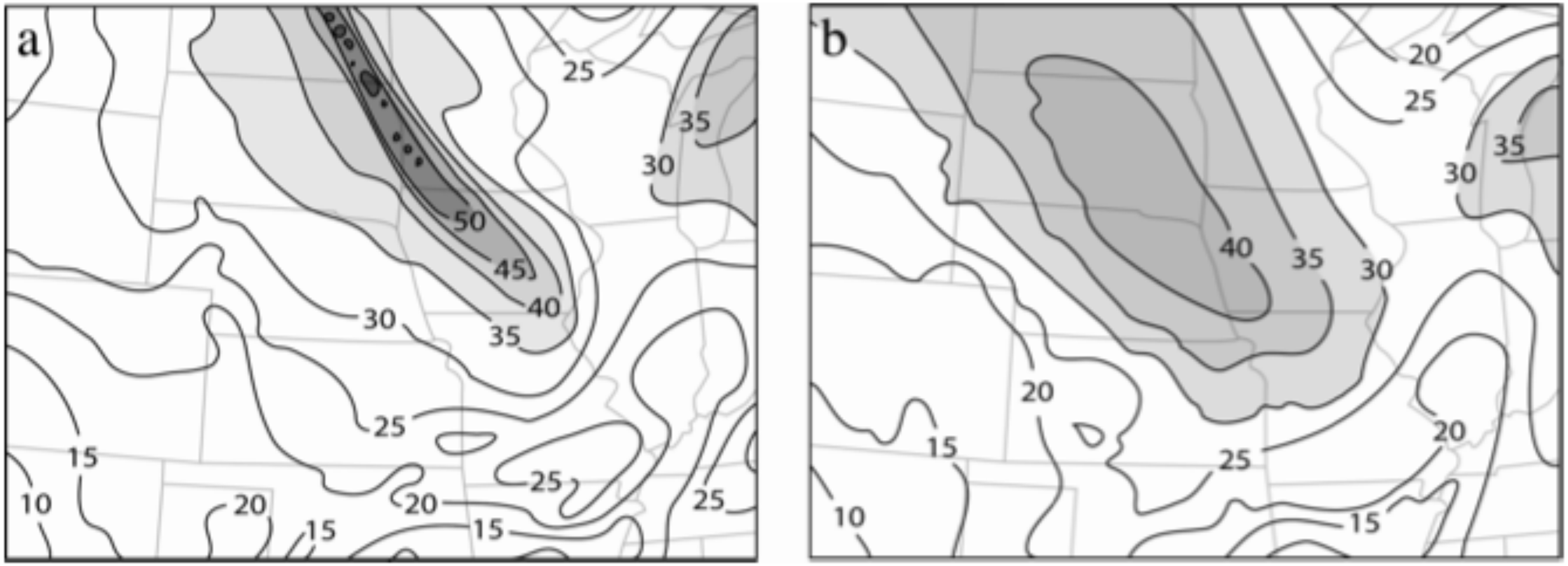
- In general,
  - IC is more important for simulations of a few days;
  - BC is more important for longer simulations.
- How large do they need to be?
  - Should not be too small, otherwise solution will be determined by forcing data
  - No less than 100x100 (at least 10 grid points are in the boundary zone)
- Where to place my lateral boundaries?
  - Avoid steep topography
  - Away from my interest

Note on Configuring Domains: Horizontal



Note on Configuring Domains:

Effect of domain sizes

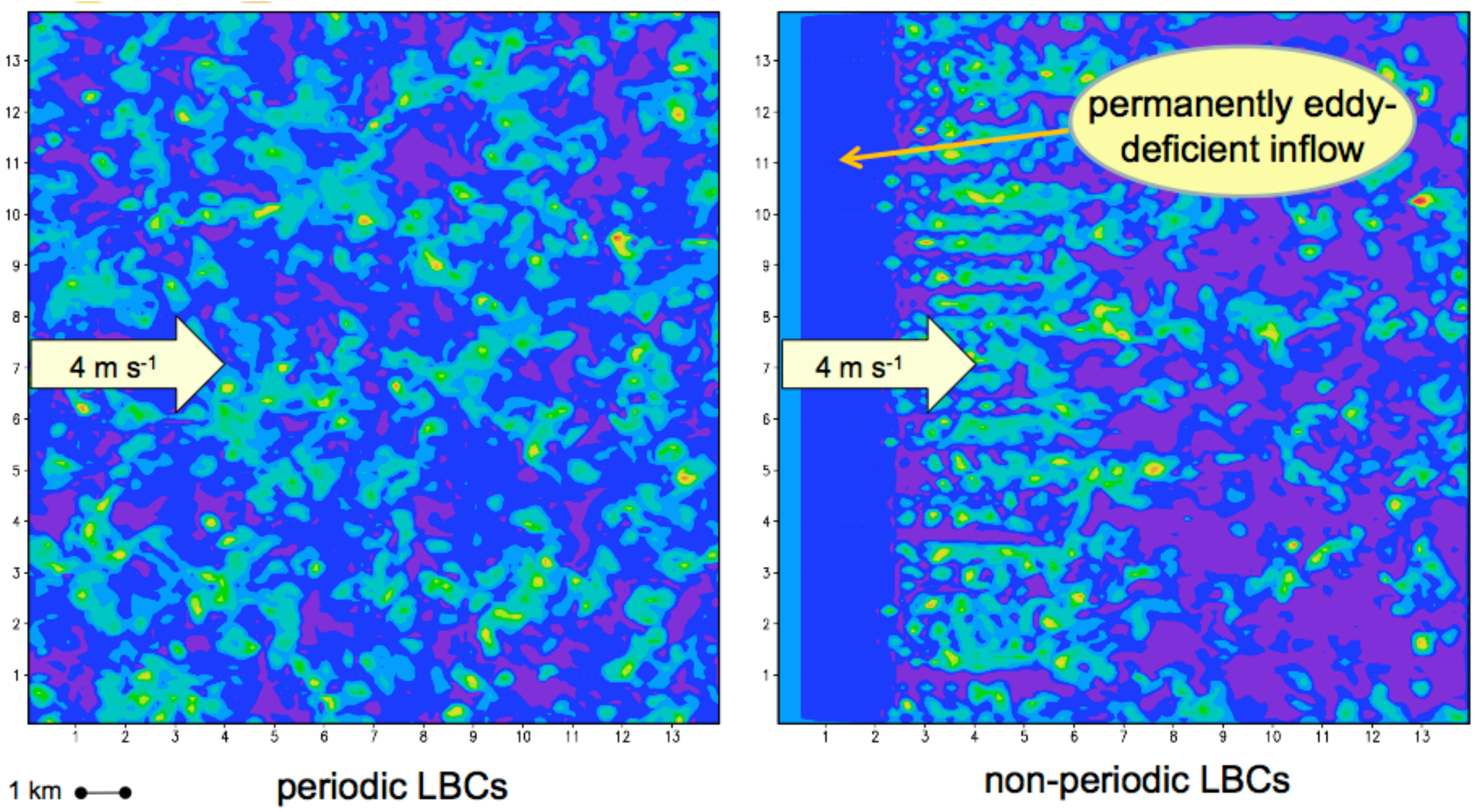


Large regional domain

Smaller regional domain

(From Warner, 2011)

Note on Configuring Domains:
Effect of lateral boundary conditions



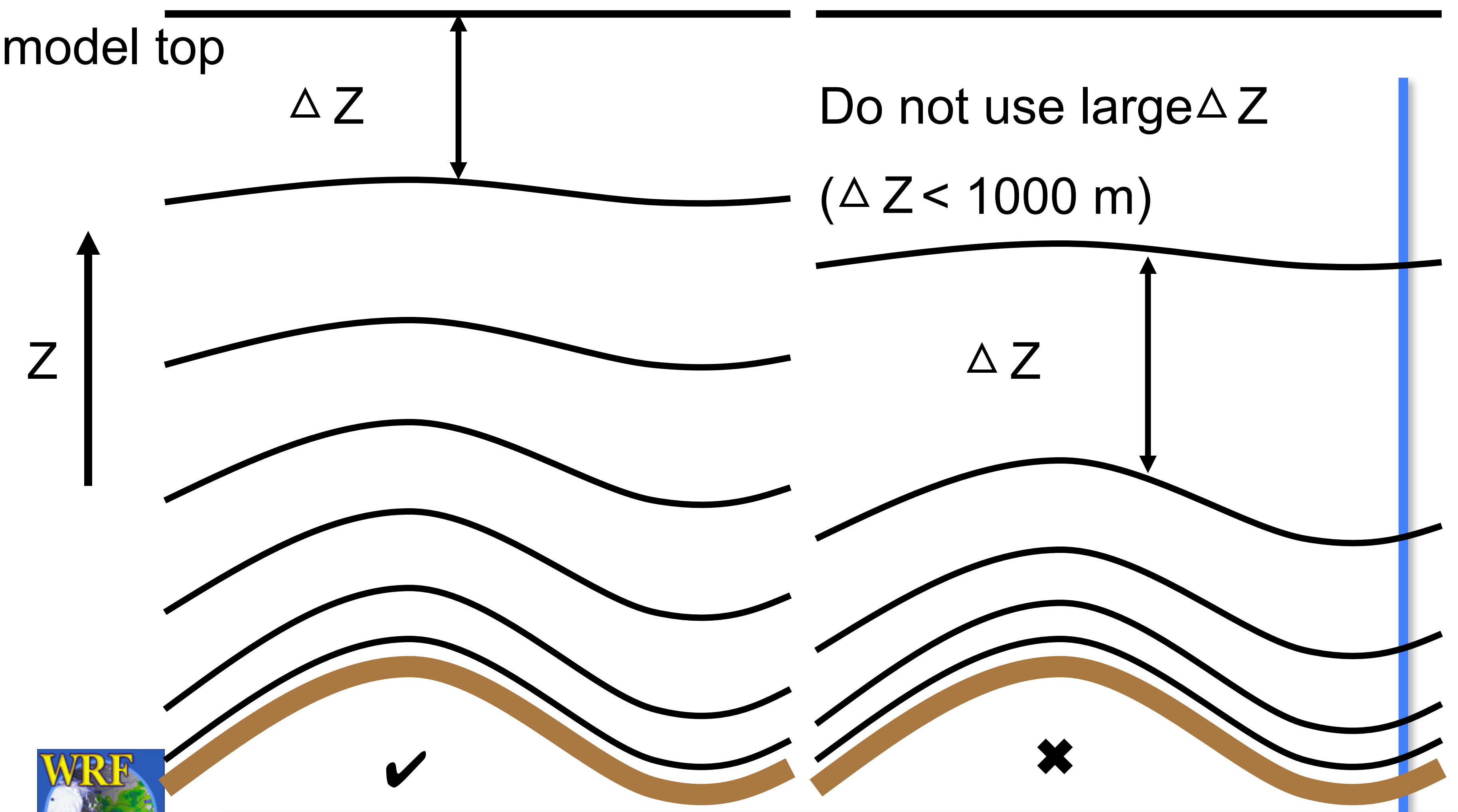
From Gaudet et al. WRF Users' Workshop 2012, talk 3.5

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



Do not use large△Z

(△Z< 1000 m)

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 >> 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

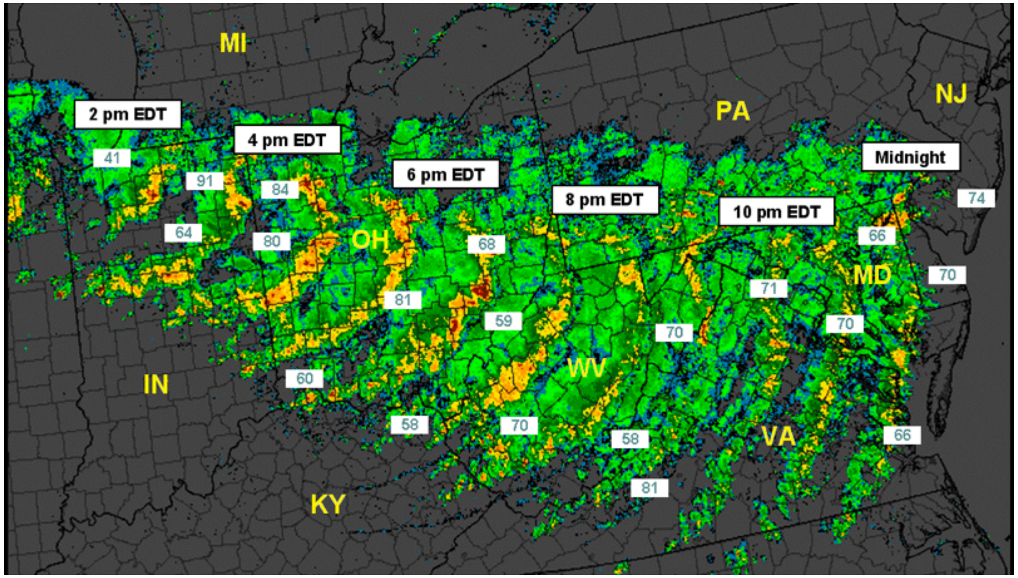
Verification:

- What to verify?
  - 500 mb height, or surface precipitation?
- Verifying high-resolution model can be tricky:

  e.g. phase error, which punishes higher resolution model more
  - Neighborhood method more appropriate

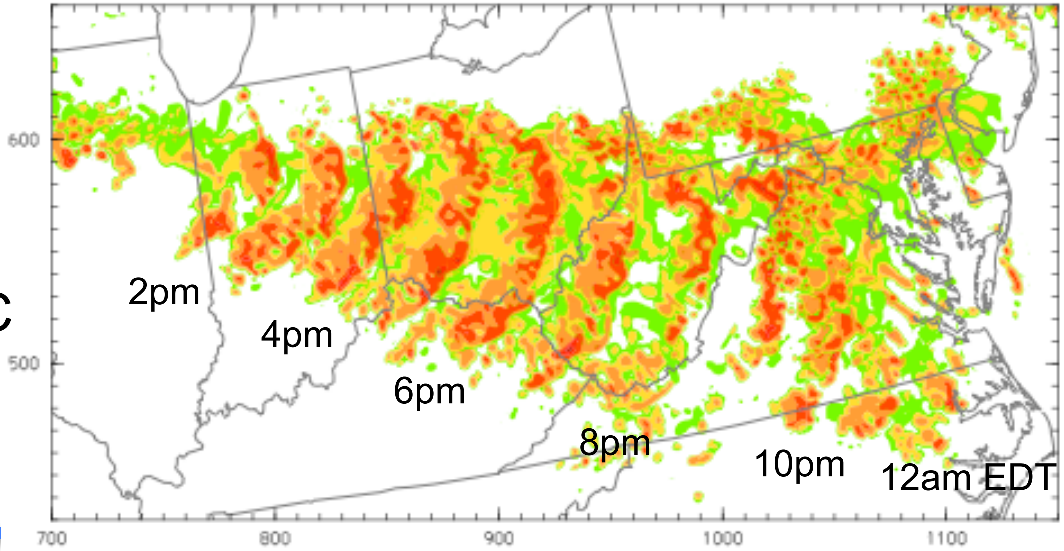
Derecho forecast from NCAR's 2012 RT

Observed radar composite



(from NOAA/SPC)

Forecast max-column reflectivity at <u>3 km</u>, 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

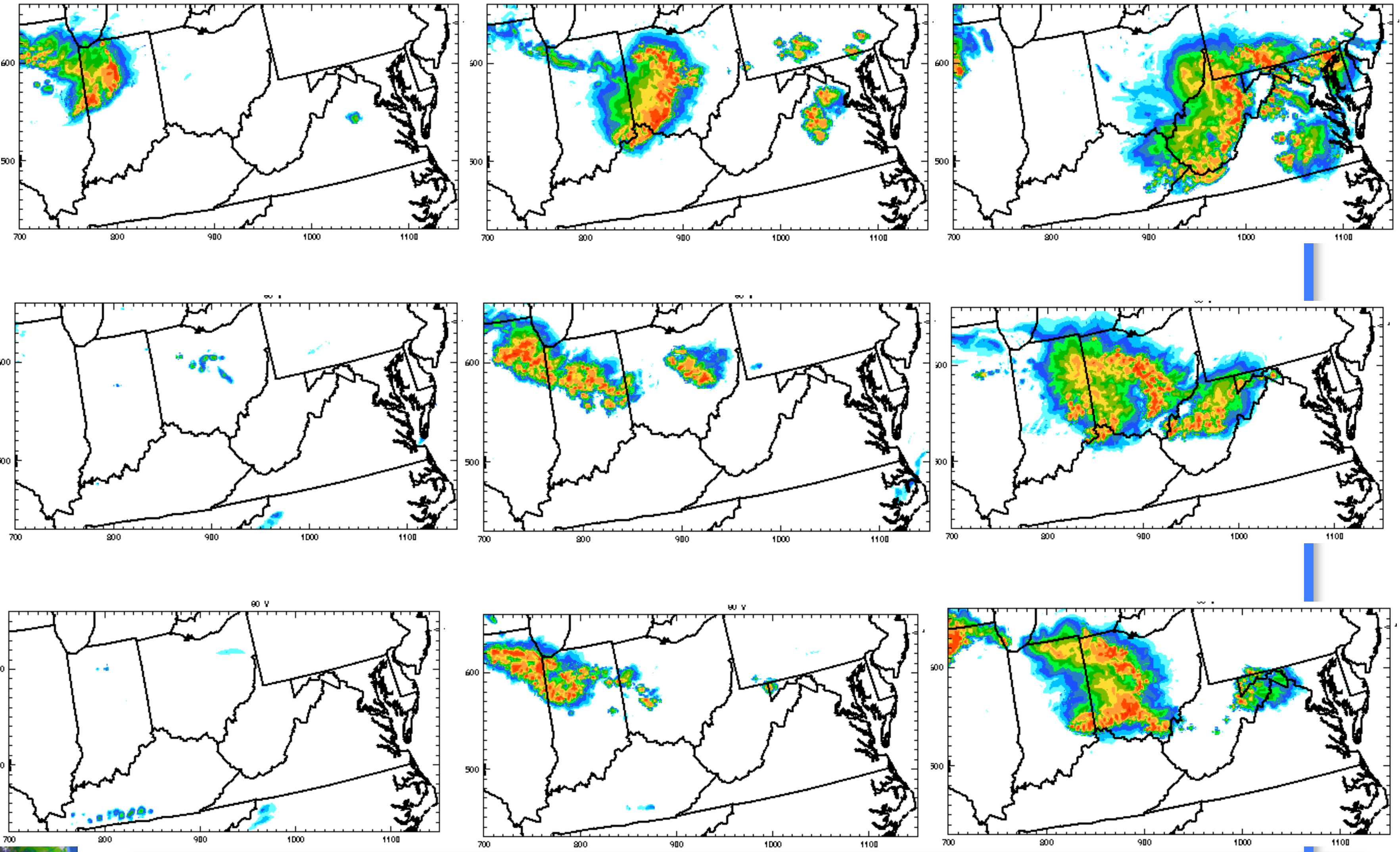
2100 UTC, 5 pm EDT

0000 UTC, 8 pm EDT

EnKF

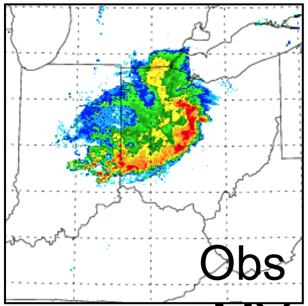
NAM

GFS

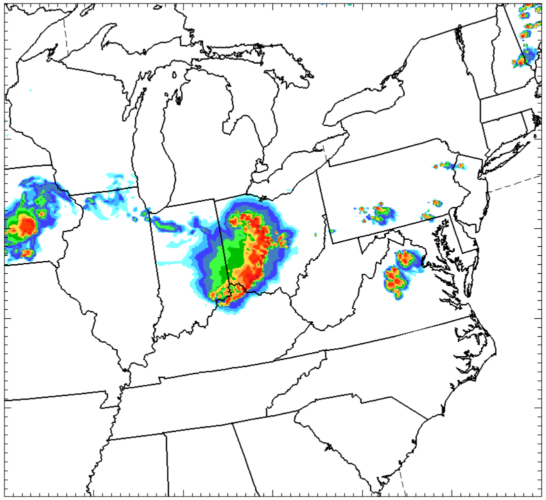


Sensitivity to physics and initial conditions:

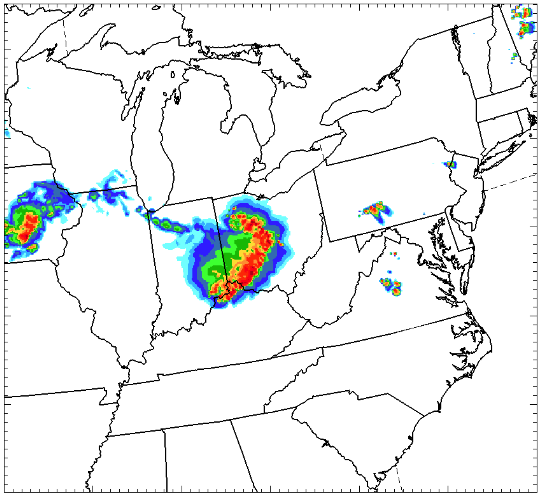
29 June 2012
Derecho



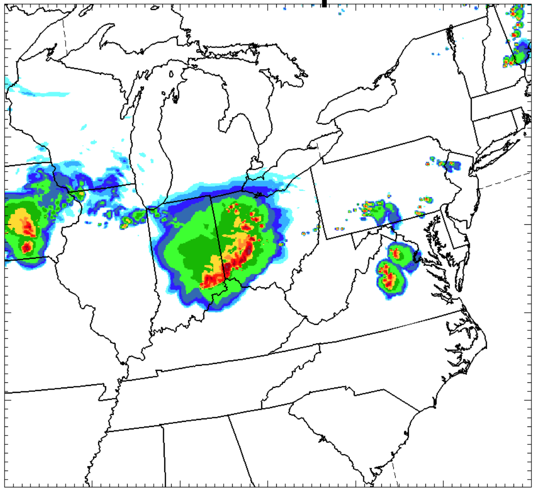
DART-Morrison-MYJ



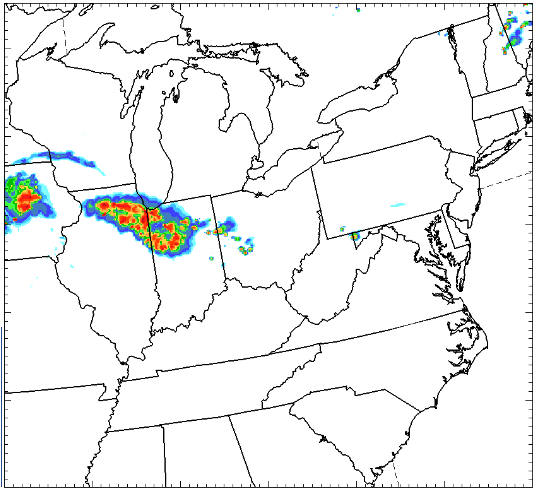
DART-Morrison-YSU



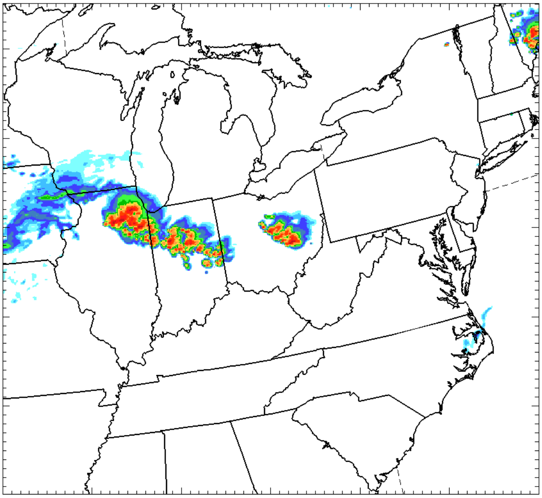
DART-Thompson-MYJ



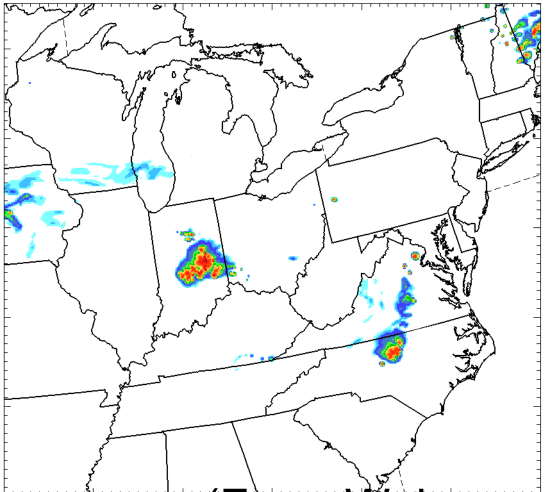
GFS



NAM



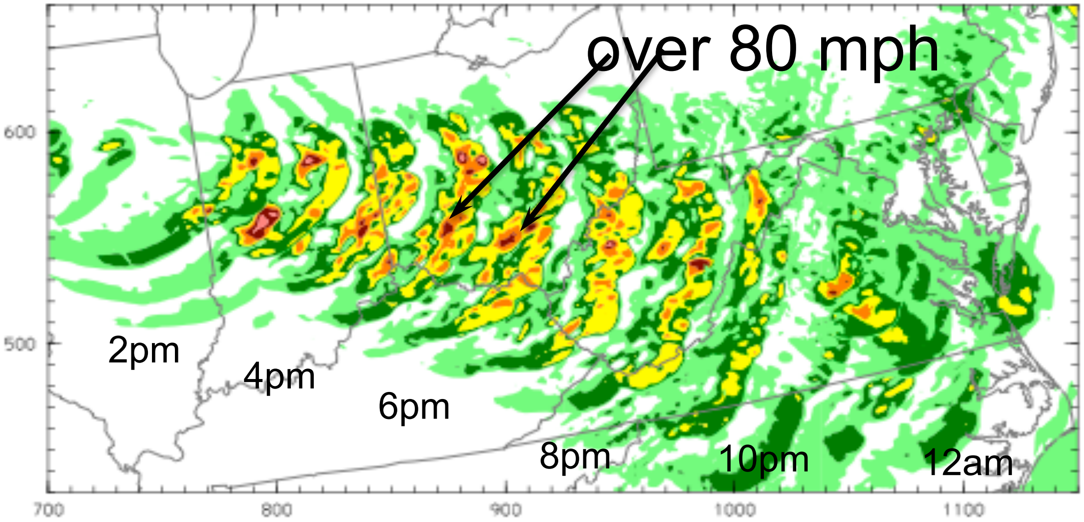
RUC



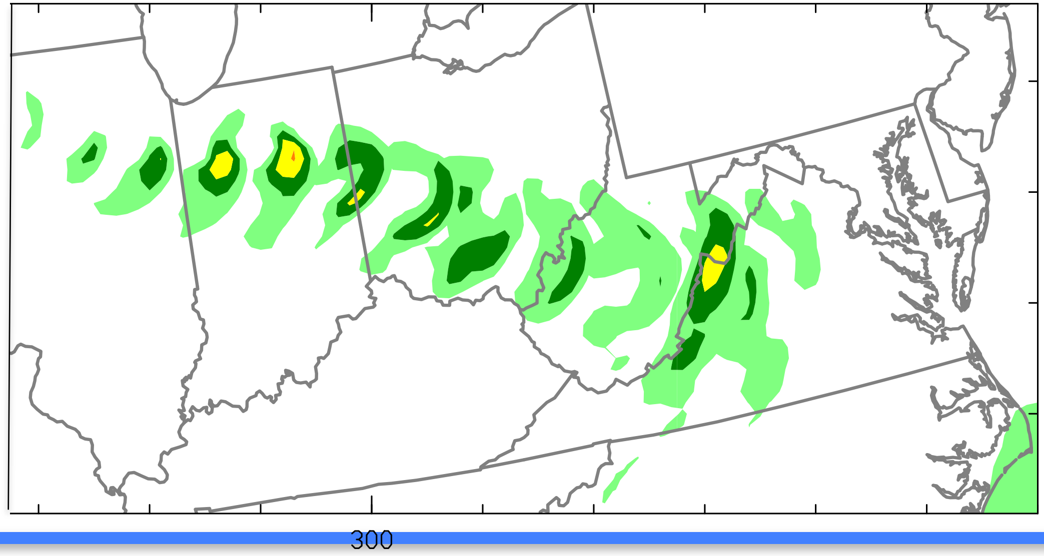
(From Weisman)

Resolution Differences: simulated max winds

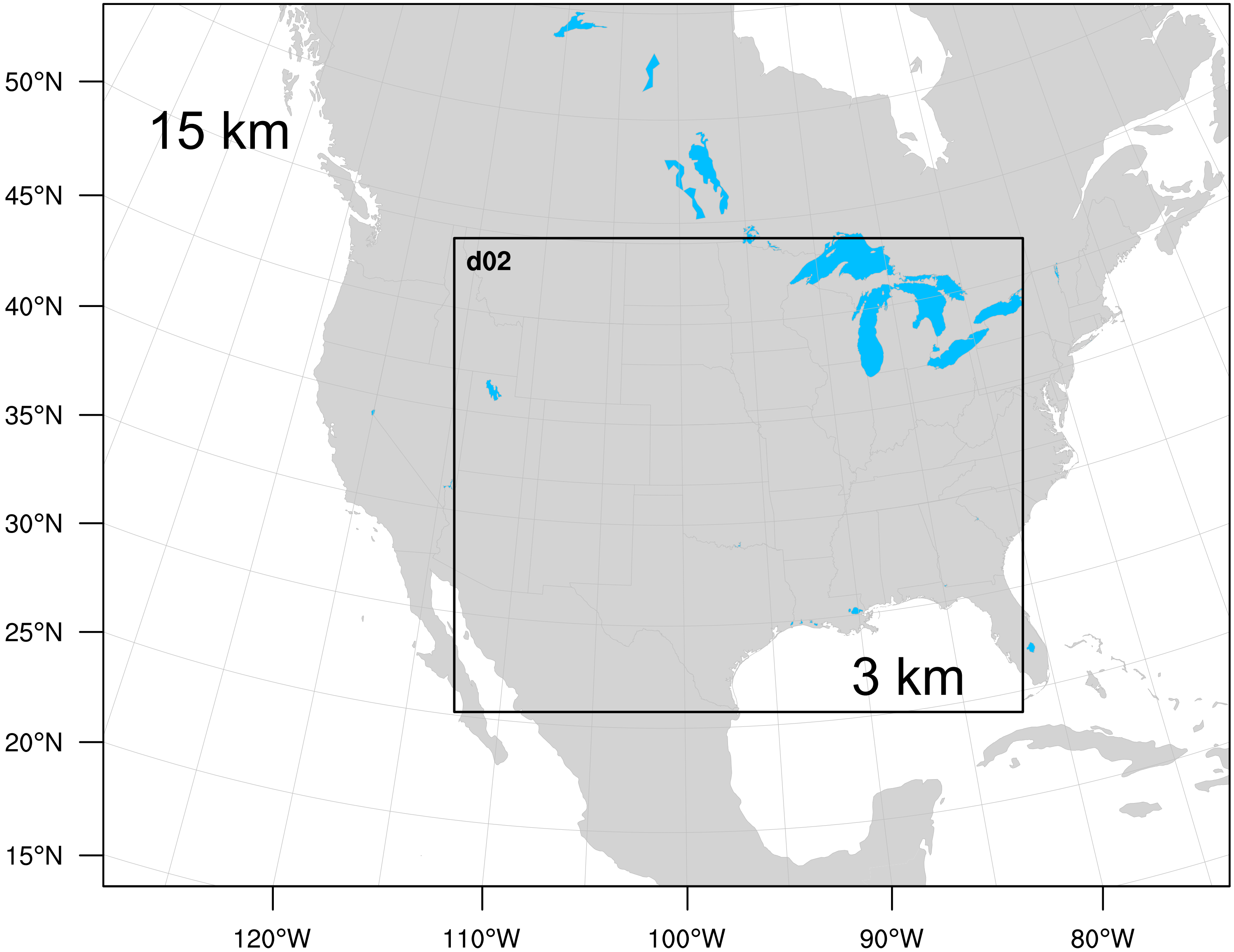
3 km results



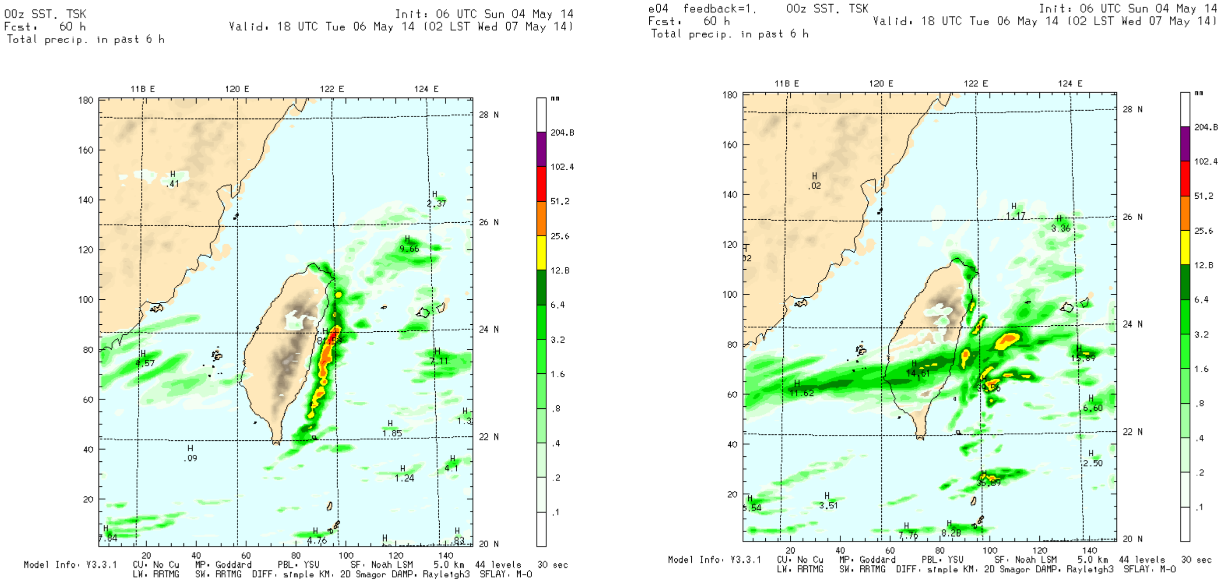
15 km results



NCAR Real-time Forecast Domain (2013)



An example of nest feedback



feedback = 0

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*.