Implementation and testing of WRF DFI

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Outline

- What is DFI
- Why use DFI
- DFI development and examples
  - Past work on WRF V2.2
  - What went into WRF V3
- Future work

What is DFI?

- Digital Filter Initialization (DFI) is not:
  - Interpolation scheme,
  - Bogusing of data,
  - Quality, or buddy checking,
  - Or an analysis technique
    - Nudging,
    - Optimal Interpolation,
    - 3D-Var, 4D-Var
    - etc.

What is DFI?

- Roger Daley (Atmospheric Data Analysis, 1991):

  "Integration of the primitive equations requires the modification of the initial state to prevent the excitation of inertia-gravity modes. This process is called initialization."

- Examples of initialization methods:
  - Nonlinear Normal Mode Initialization (Machenhauer, 1977, Williamson and Temperton 1981)
  - Digital Filter Initialization (Lynch and Huang, 1992)
    - By applying a simple filter to a sequence of values centered on the initial time, an effective noise control can be achieved within a relatively short time span.

Why use DFI?

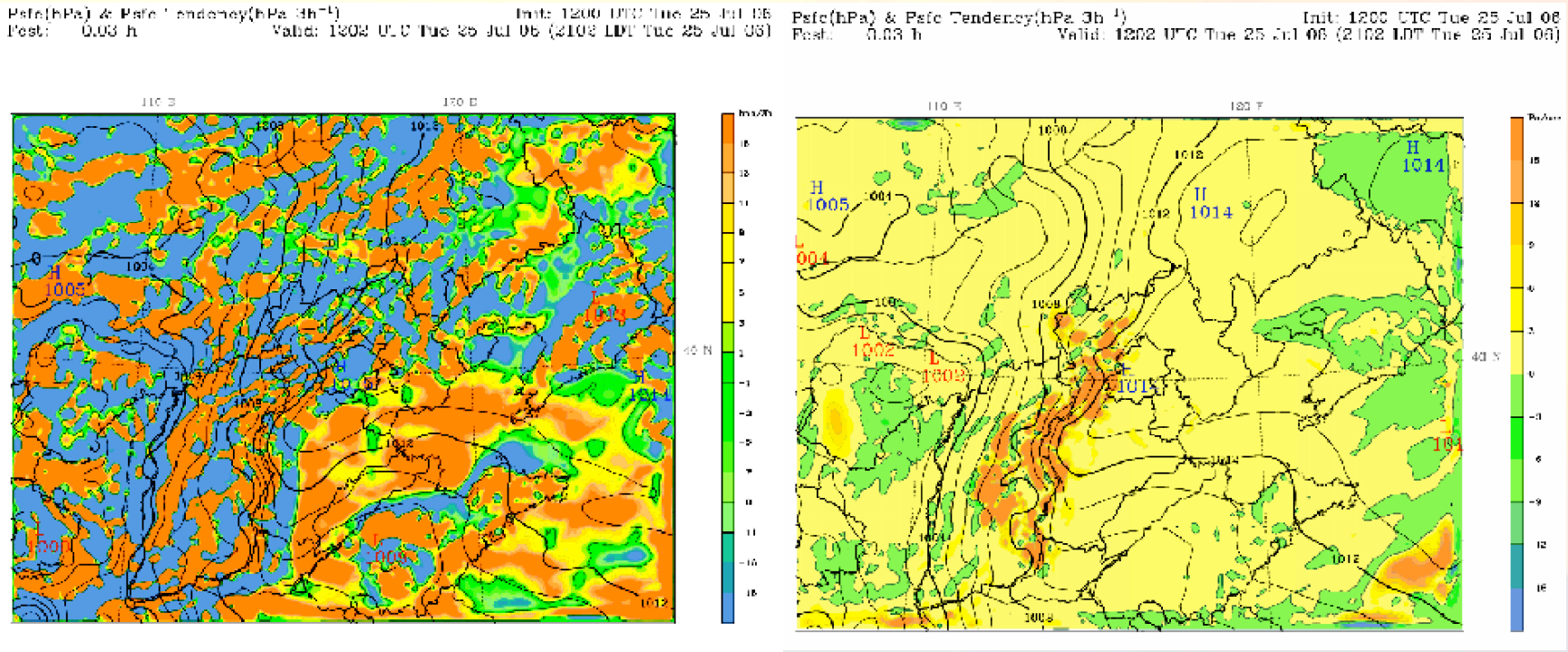
- To remove noise due to the imbalances between the momentum and mass
  - The imbalance can be introduced through objective analyses, or interpolation.
- To produce initial fields consistent with the model's dynamics.
  - e.g., hydrometeors, vertical velocity
- Can be used to reduce the spin-up time for clouds and precipitation (if not available in the initial conditions)

- Advantages:
  - Relatively simple to implement in the model and to use
  - Works for forecasts/simulations starting with files from WPS
  - Changes to the numerical model are automatically applied to the DFI
- Disadvantages:
  - Adds additional computational time
  - Filter too much/too little (some tuning may be necessary for a specific application)

Example from WRF V2.2 DFI

Without DFI

With DFI



Initial **surface pressure tendency** (**shaded**) of the first cycle in hPa/3h and sea level pressure (contoured) in hPa for the no DFI simulation (left) and the with DFI simulation (right). (Huang et al. 2007, WRF workshop)

Example from WRF V2.2 DFI

- Results from early version of WRF DFI showed:
  - A satisfactory amount of noise reduction
  - A reasonable reduction of model spin-up
  - Improved conventional observation verification scores
  - Improved precipitation scores

Huang et al. (2007, WRF workshop)

WRF DFI: Beyond V2.2

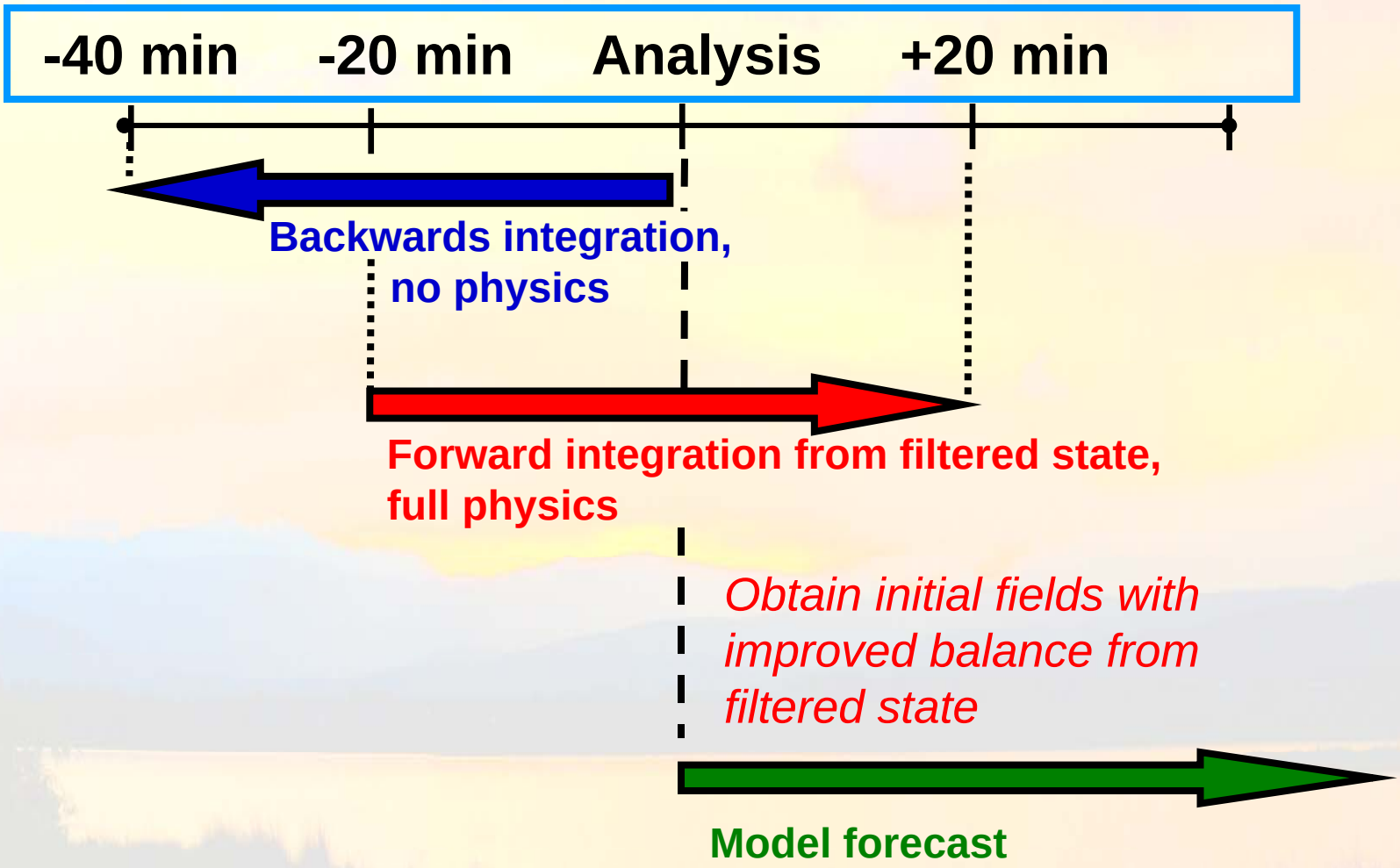
- NOAA/ESRL DFI efforts
  - DFI applied in RUC model –
    - Adiabatic DFI used in NCEP RUC - 1998
    - Diabatic “twice-DFI” used in NCEP RUC - 2005
    - Initial assistance from Xiang-Yu “Hans” Huang
  - Essential for RUC 1-h intermittent assimilation cycle
  - Do not use all of the filtered variables in favor of analyses

WRF DFI: Beyond V2.2

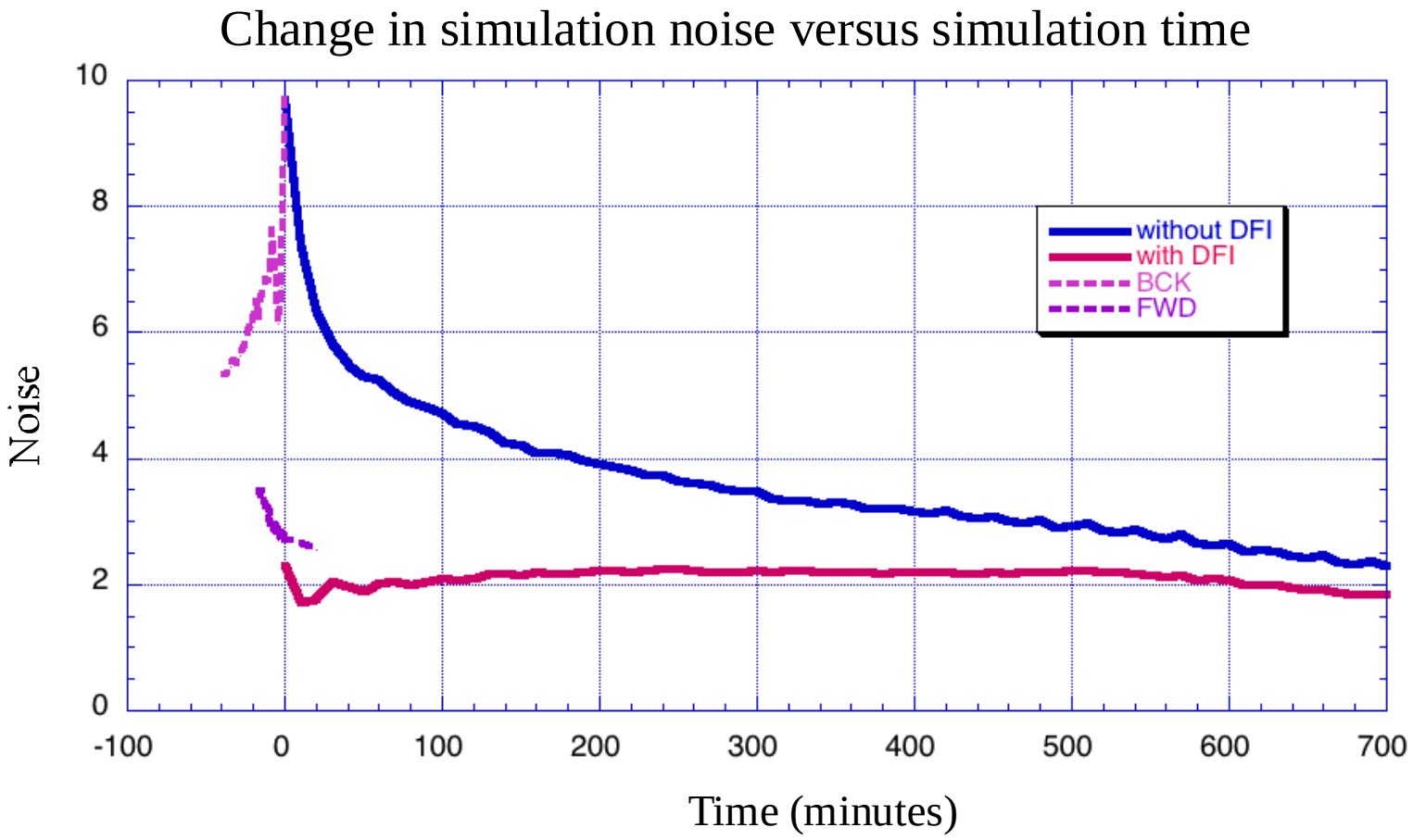
- NOAA/ESRL DFI efforts
  - Needed DFI for RUC to WRF-Rapid Refresh transition
    - No use of restart files after filtering
    - Appropriate for operational applications
  - Added DFI namelist variables
    - Allowed for different DFI options
  - Followed WRF coding guidelines
    - Commit code to WRF repository
    - Additional flexibility for future development

Twice-Digital Filter Initialization implemented into WRF ARW

(Tanya Smirnova and Steven Peckham, NOAA/ESRL)



$$\left|\frac{\partial p_{sfc}}{\partial t}\right|$$

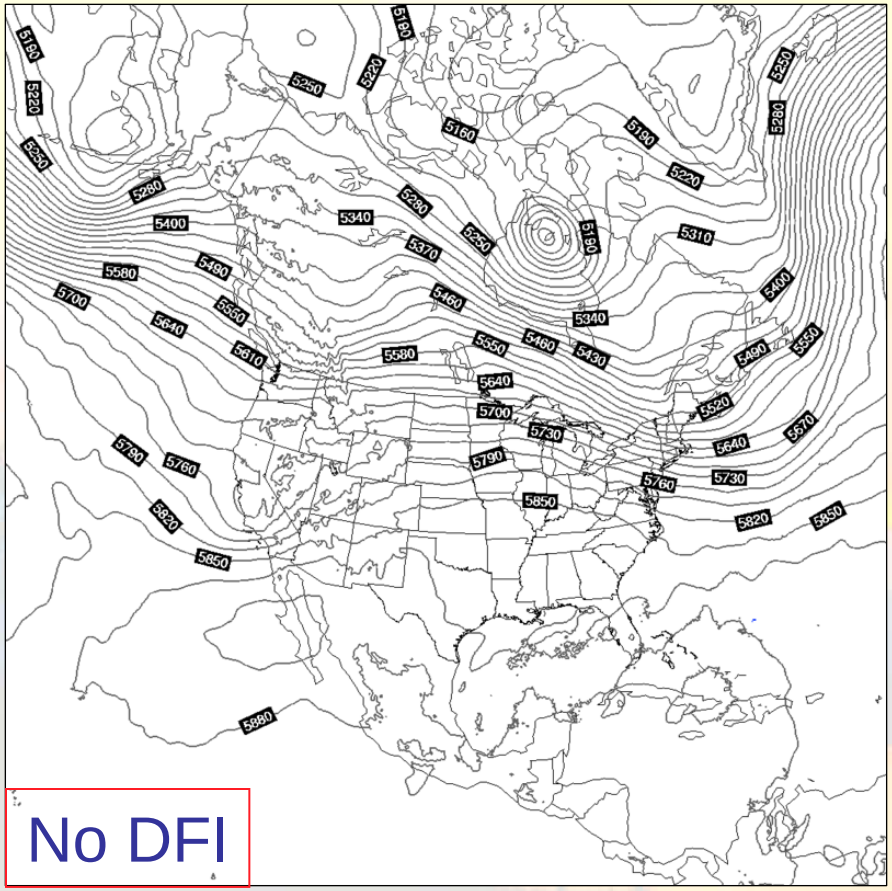


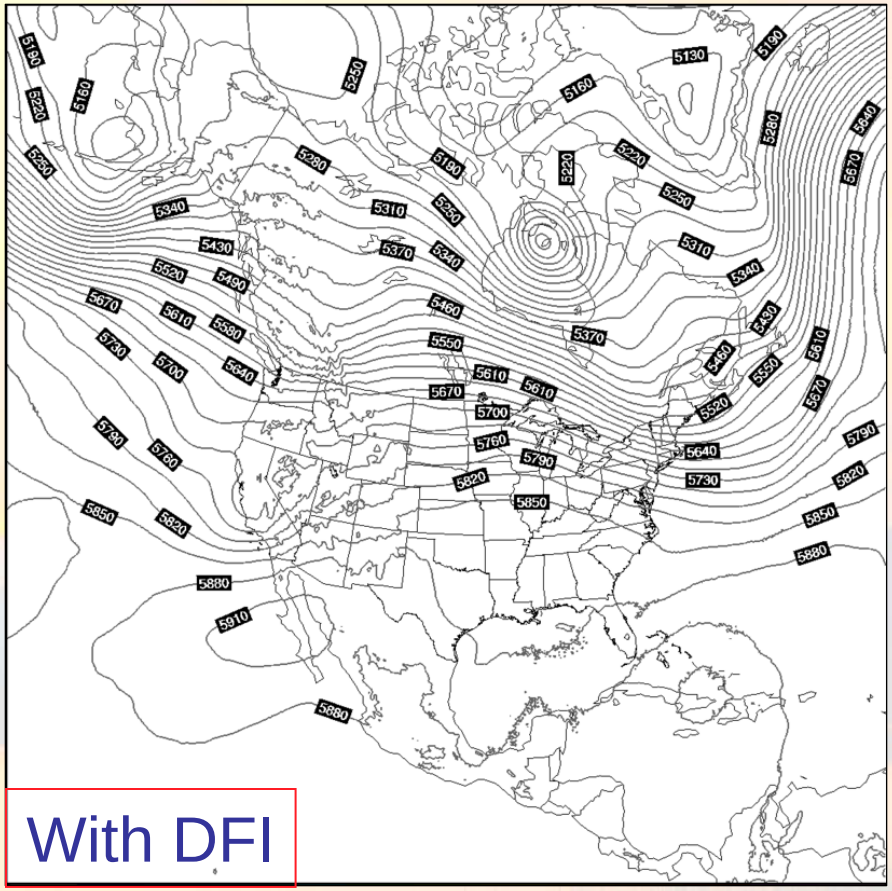
WRF-13km Rapid Refresh over N. American domain

Noise = domain mean absolute sfc pressure tendency (hPa/h)

500mb Height 3-h Fcst for 03Z 30 Oct 07

Away from terrain and deep convection, height contours are smoother with DFI





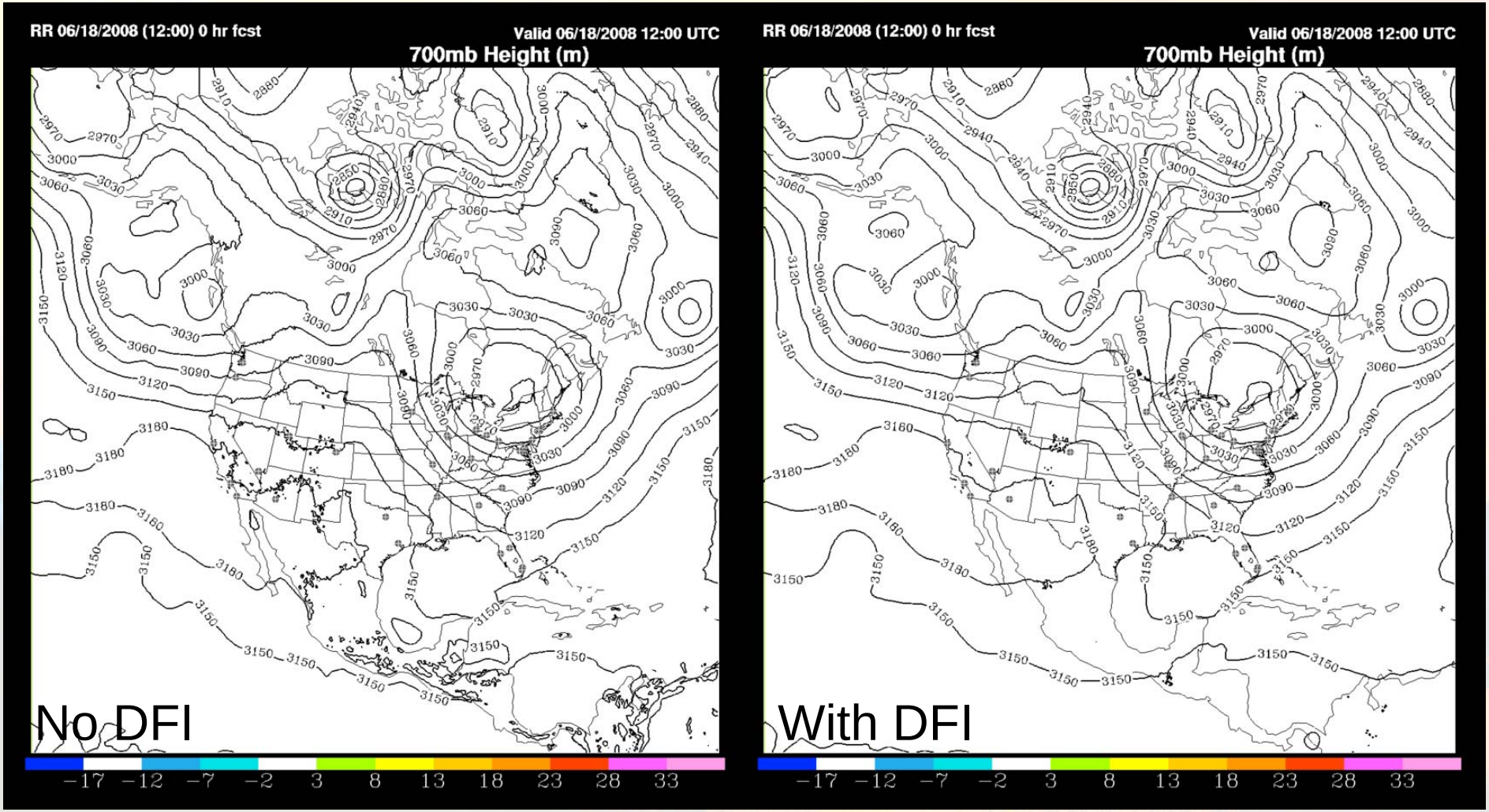
WRF DFI: Towards V3

- NOAA/ESRL and NCAR Collaboration
  - Added the best features from both to WRF V3
  - From NCAR
    - DFI options
    - DFI window functions
  - From NOAA/ESRL
    - No restart files after filtering
    - Followed WRF coding guidelines
    - Design that facilitates possible future NMM application

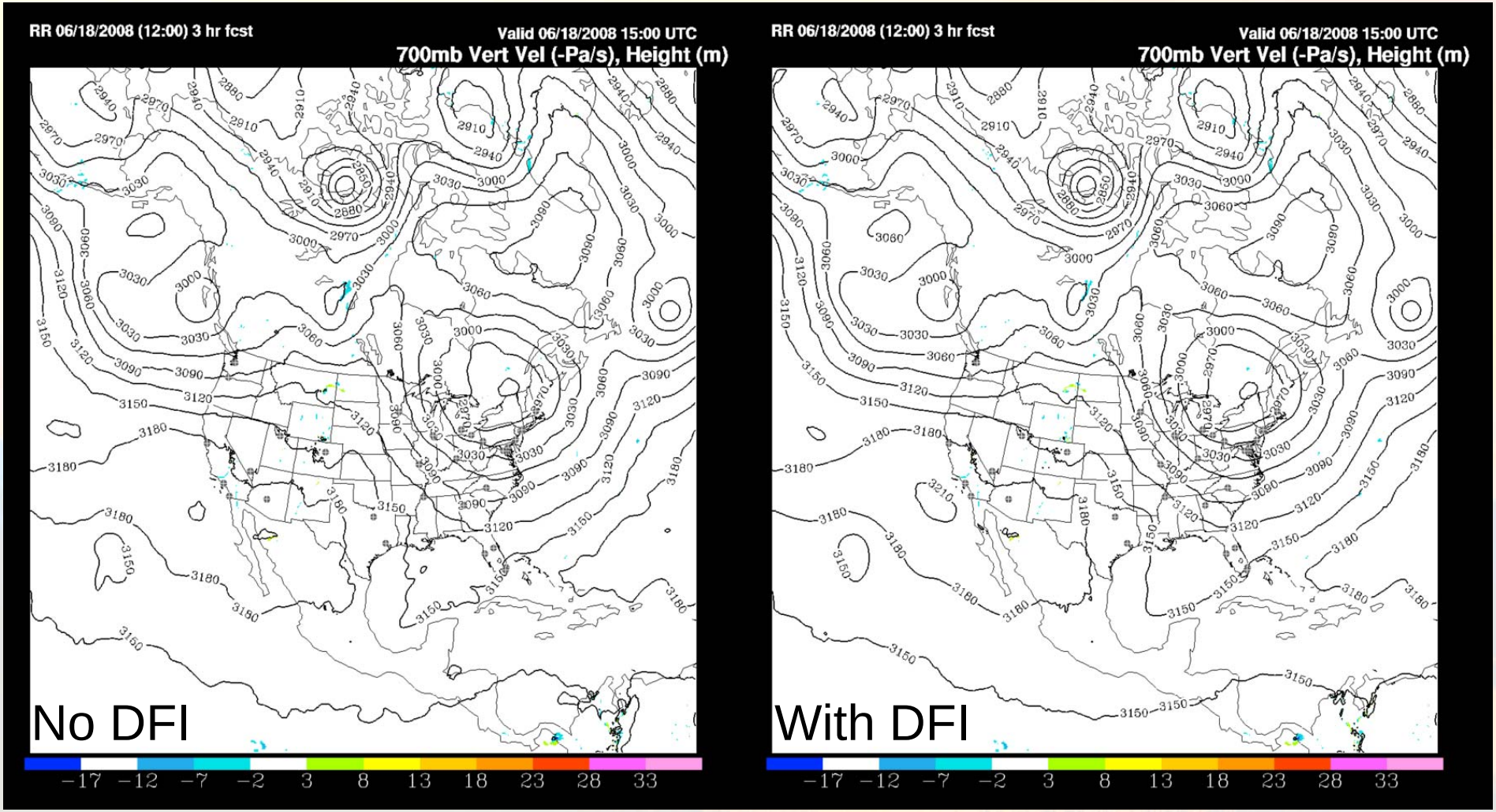
Examples from WRFV3 DFI

- Simulations made at NOAA/ESRL
  - 13 km horizontal grid spacing
  - North America domain
- DFI
  - Twice-DFI option and Dolph2 window function.
  - 80 minutes DFI time window (40 minutes backward integration)
- DFI uses roughly 10% of the computational time for a 12 hour fcst.
    - Results may vary

700 mb Height; 0 h forecast



700 mb Height; 3 h Forecast



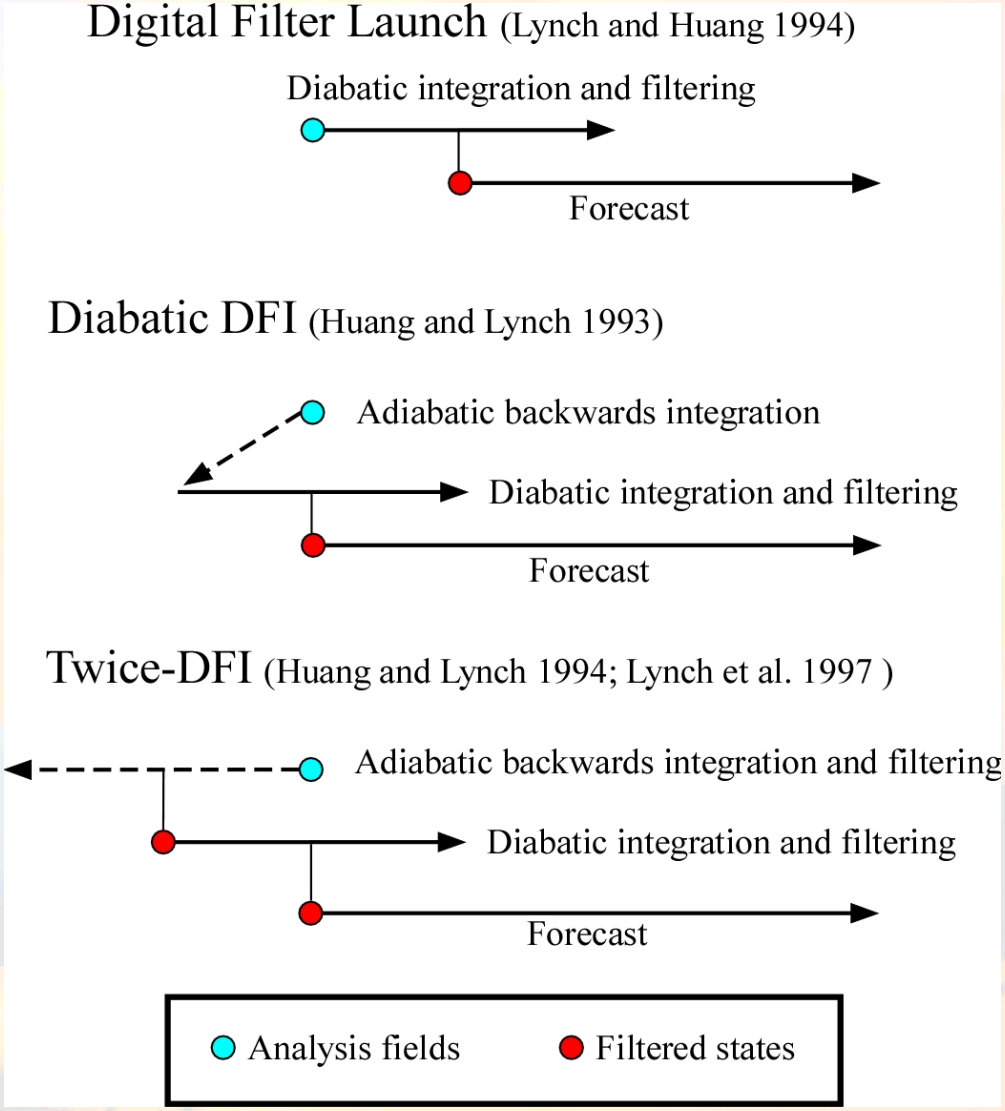
Future work

- NOAA ESRL interested in adding additional functionality to WRF DFI
  - Option to add/delete fields from filtering (e.g.,clouds) if analysis is available
    - Weygandt et al. (presentation 2.4) showing impact of adding radar information

Summary

- Digital Filter Initialization available in WRF ARW V3
- Quick and efficient initialization methodology
- Applicable for downscaling initial conditions (e.g., 40km NAM to 2km WRF)
- Easy to use – set namelist variables
- Several options and window functions to choose from
- Reduces gravity wave noise and improves forecast skill
- Suitable for operational forecasting and research – will be used in WRF-based Rapid Refresh
- Possible to adapt to user's need
- Tutorial and technical documentation available soon (already?)

DFI Options in WRF V3



DFI functions in WRF V3

- Besides the DFI option, one can select the window function
  - In WRF, one can use:
    - Uniform
    - Lanczos
    - Hamming
    - Blackman
    - Kaiser
    - Potter
    - Dolph (Dolph-Chebyshev)
    - Dolph 2 <= Recommended
    - Recursive High-Order