IMPLEMENTATION OF OBSERVATION-NUDGING BASED FDDA INTO WRF FOR SUPPORTING ATEC TEST OPERATIONS

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- Why observation-nudging
- NCAR/ATEC RTFDDA
- WRF implementation
- Preliminary results
- Summary and plans

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Issues for Mesoscale Analysis and Forecast

- Local circulations are complicated
  - Large-scale forcing and multiscale interaction
  - Local terrain forcing
  - Contrasts in surface heating/cooling
  - Land-soil moisture and thermal properties
- Data are sparse and irregular in space and time and they are not sufficient to describe the structures of local-scale circulations.
- A full-physics mesoscale model with accurate local forcing + use of all data.

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NCAR/ATEC RTFDDA Is Such a System

- **PSU/NCAR MM5** (and now, **WRF**) based,
- **Real-time and Relocatable,**
- **Multi-scale**: meso-γ → meso-α (δx = 0.5 – 45 km),
- **Rapid-Cycling**: at a flexible interval of 1 – 12 hours,
- **FDDA**: 4-D continuous data assimilation, and
- **Forecast** (0 – 48 hours) systems.

Main Objective: effectively combines the full-physics MM5/WRF model with all available observations to produce best-possible real-time local-scale analyses and 0 – 48 hour forecasts

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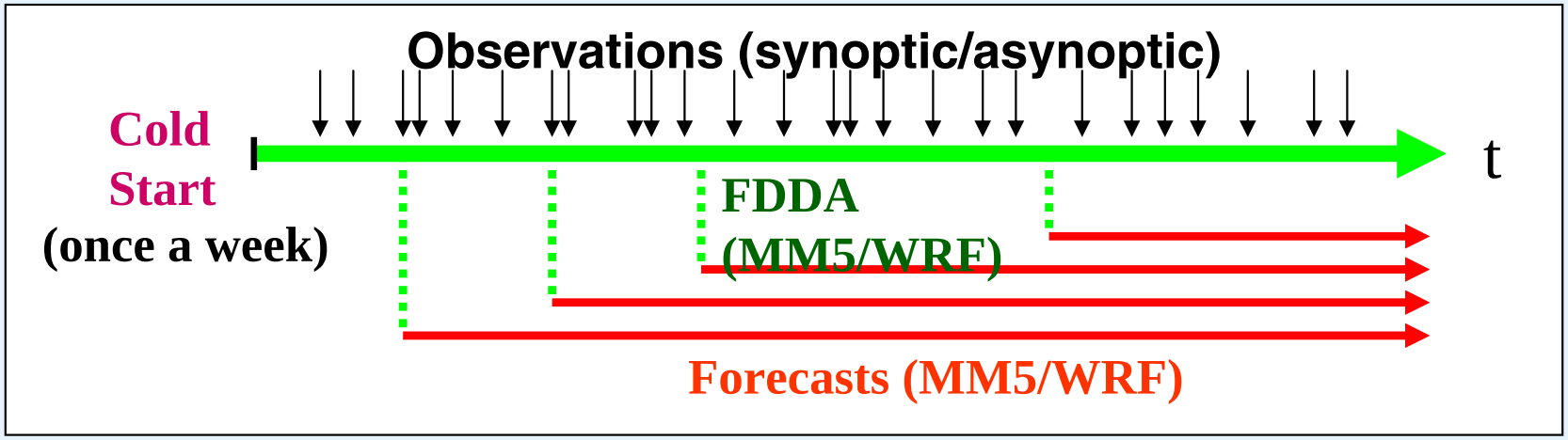
4-D Data Assimilation and Forecasting



FDDA is based on "Observation-Nudging" technique

- **Stauffer and Seaman (1995), and**
- **Numerous modifications and refinements by NCAR/ATEC modelers.**

(See ~20 pubs at
https://www.rap.ucar.edu/projects/4dwx/resources/publications.html)

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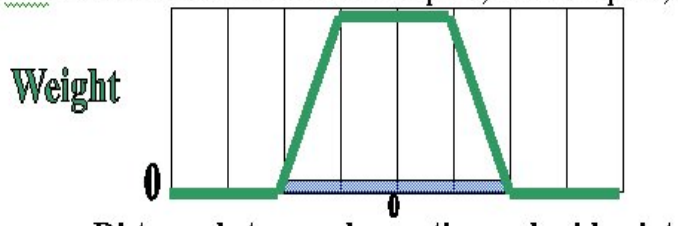
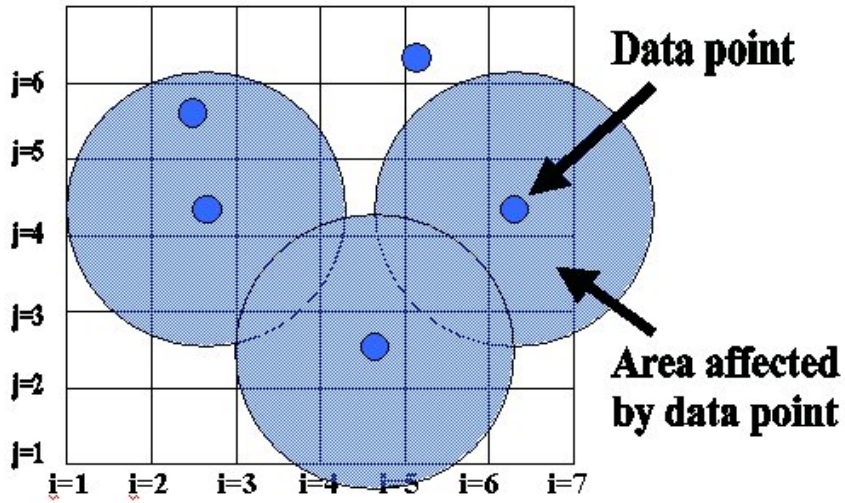
Obs-nudging: Weighting Functions

$$W = W_{qf}\, W_{horizontal}\, W_{vertical}\, W_{time}$$

The weights can vary with the distance between the grid points and the observation in horizontal space, vertical space, and time.





$$A_{ijk} = \frac{\sum_i W_i \cdot value_i}{\sum_i W_i}$$

At each grid point, the weighted effects from all the nearby observations are summed.

Advantages of Continuous Obs-nudging

- Allows for model-defined solution in data-sparse regions, but adjusts for observations where they exist.
- Combines the dynamic balance and physical forcing of a model, with all observations available at and before forecast time.
- Provides 4-D, continuous analyses with "spun-up" dynamics and cloud/precip, and as I.C. for forecasts
  - Local circulations and cloud and precipitation fields

- Note: "Analysis Nudging" technique may not be applicable in meso- β and γ scale models

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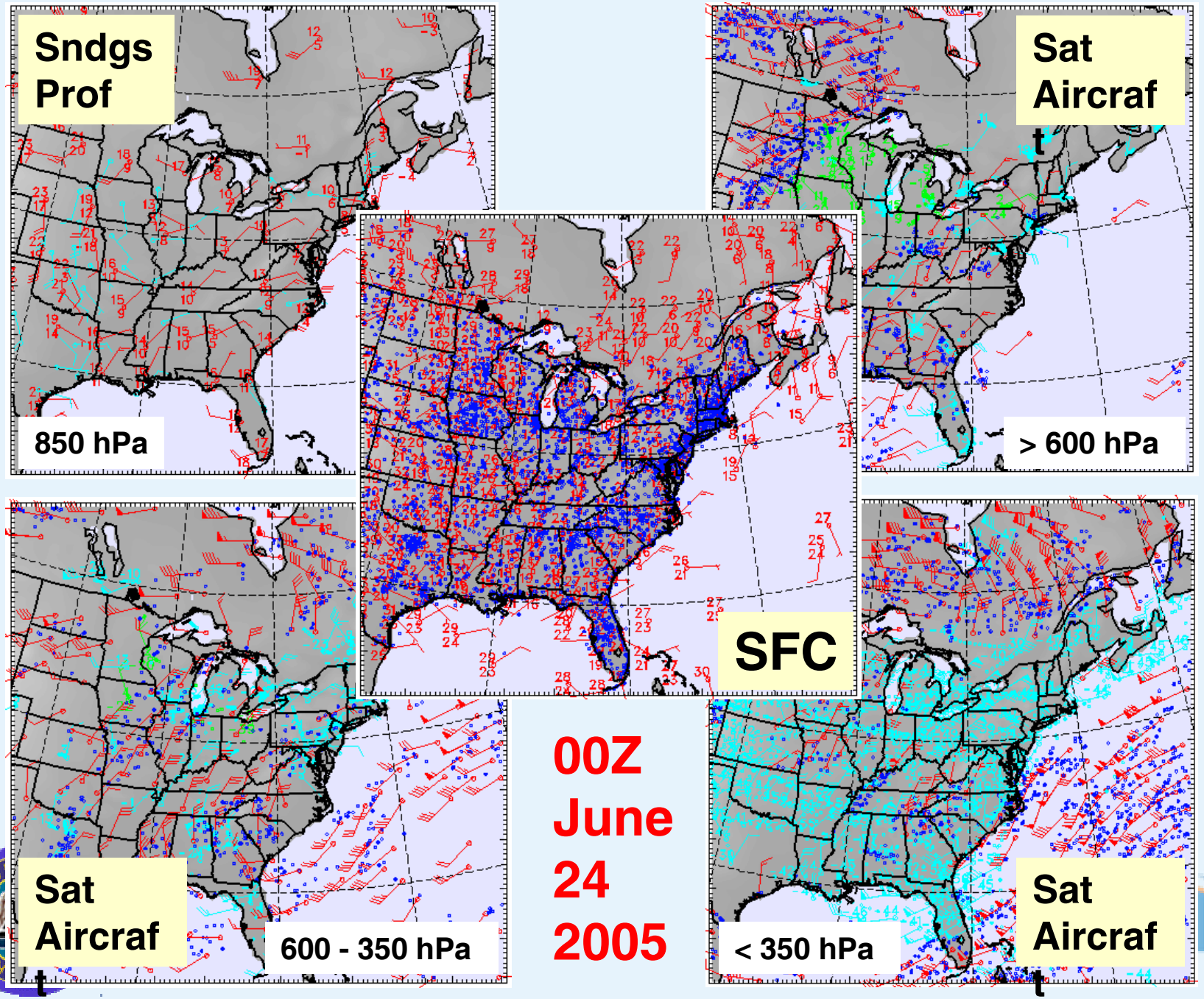
Incorporate Diverse and Frequent Observations



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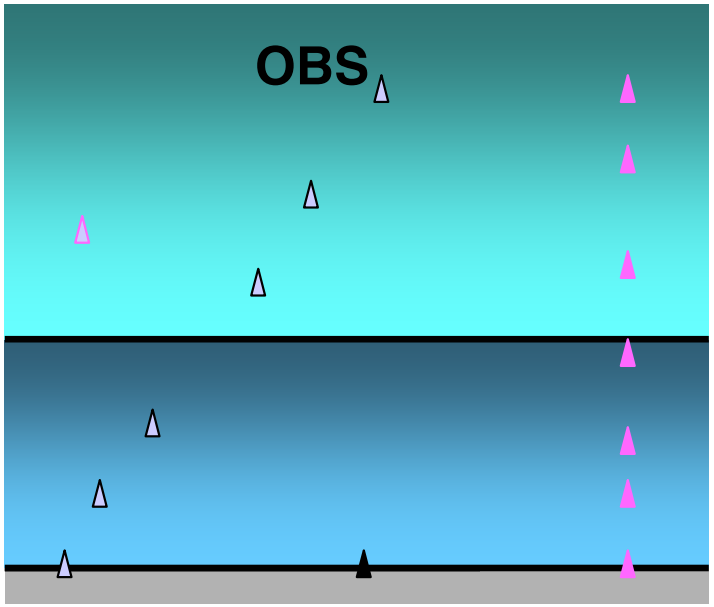
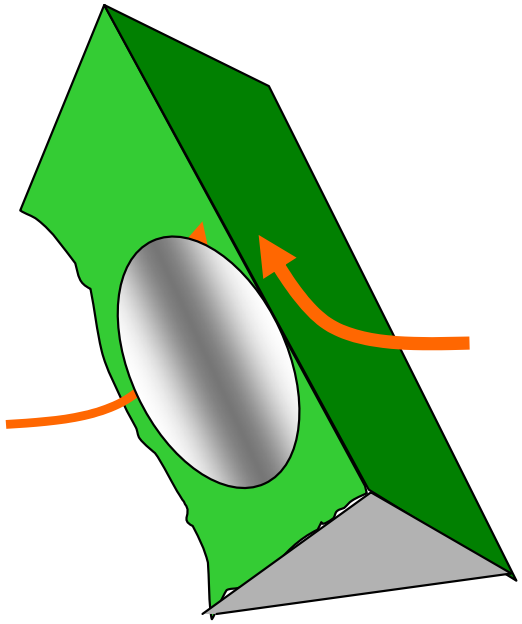
Obs-nudging: Weighting Functions

$$W = W_{qf}\, W_{horizontal}\, W_{vertical}\, W_{time}$$

Weighting functions should depend on grid sizes; local terrain; observation quality, location, time and platforms; and air stream properties.





ATEC Modifications to MM5 Obs-nudging Scheme

- Add ability to incorporate all observations for real-time applications and historical studies of any given period.
- Take advantage of vertically-coherent multi-level upper-air obs.
- Convert surface obs to the model surface according to Similarity Theory and "in-situ" surface layer properties.
- Weighting cut-offs across PBL top for both surface and single point upper-air observations.
- Revise terrain-dependent, anisotropic horizontal weighting function for surface observation.
- Extend the obs-nudging engine for multi-scale applications: "double-scans" and grid-dependent influence radii.
- Develop an effective and efficient data quality control (QC) scheme to filer out bad data, and estimate quality of each obs, which is then used to weight the obs in the nudging.
- Improve the innovation computation scheme to prevent the nudging from the "drawing-future-state backward effect" in the old scheme.

(**https://www.rap.ucar.edu/projects/4dwx/resources/publications.html**)

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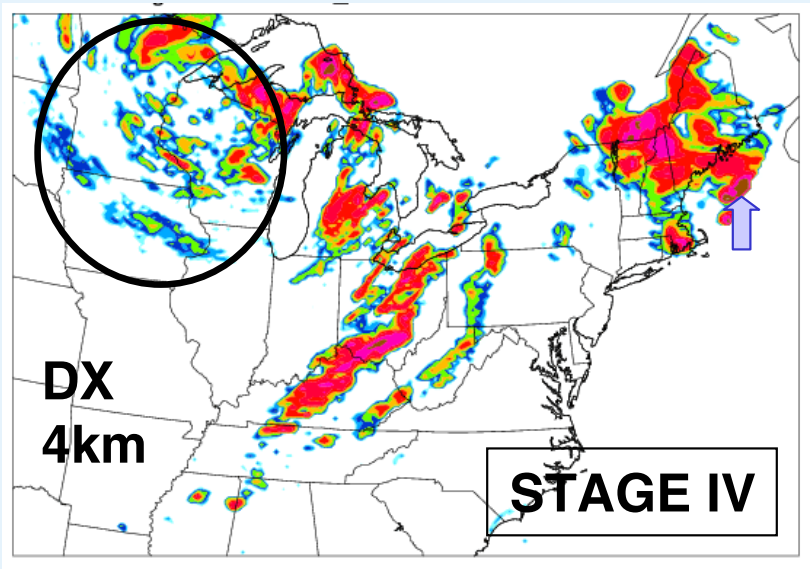
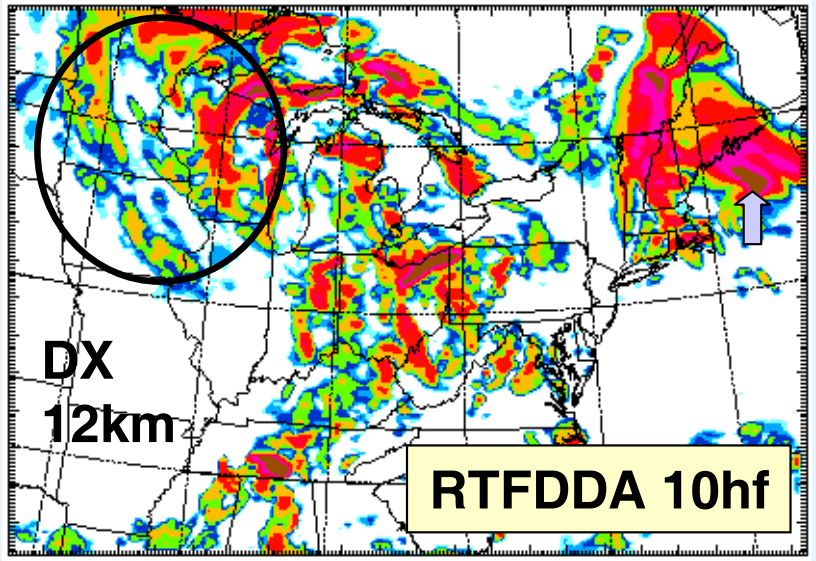
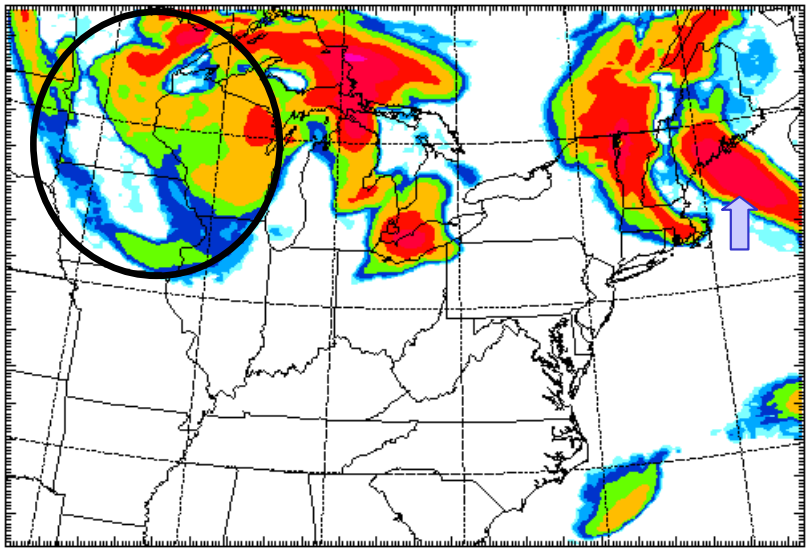
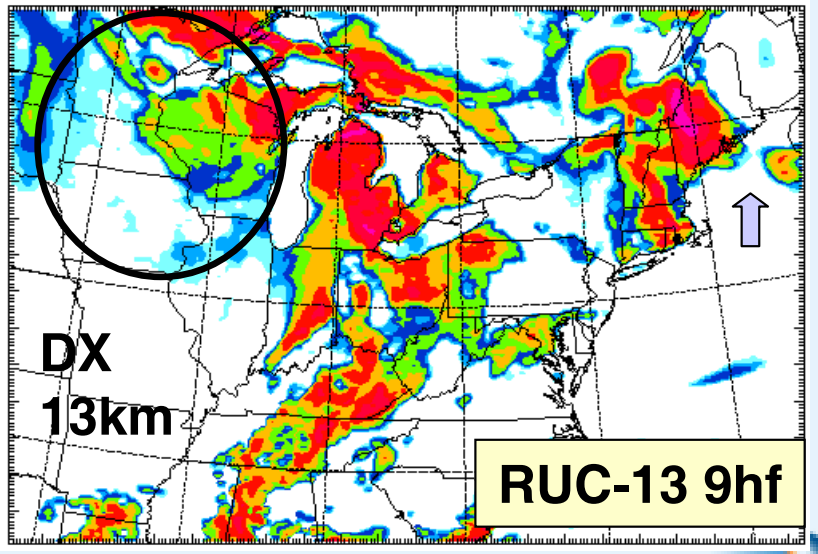
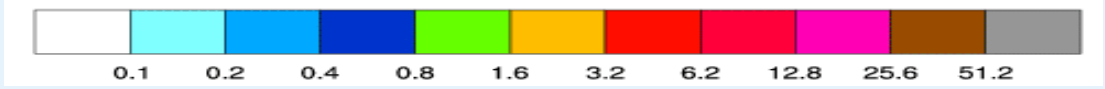
3h-Accumulated Precipitation of Short-Term Forecasts (18-21Z, 14 June 2005)











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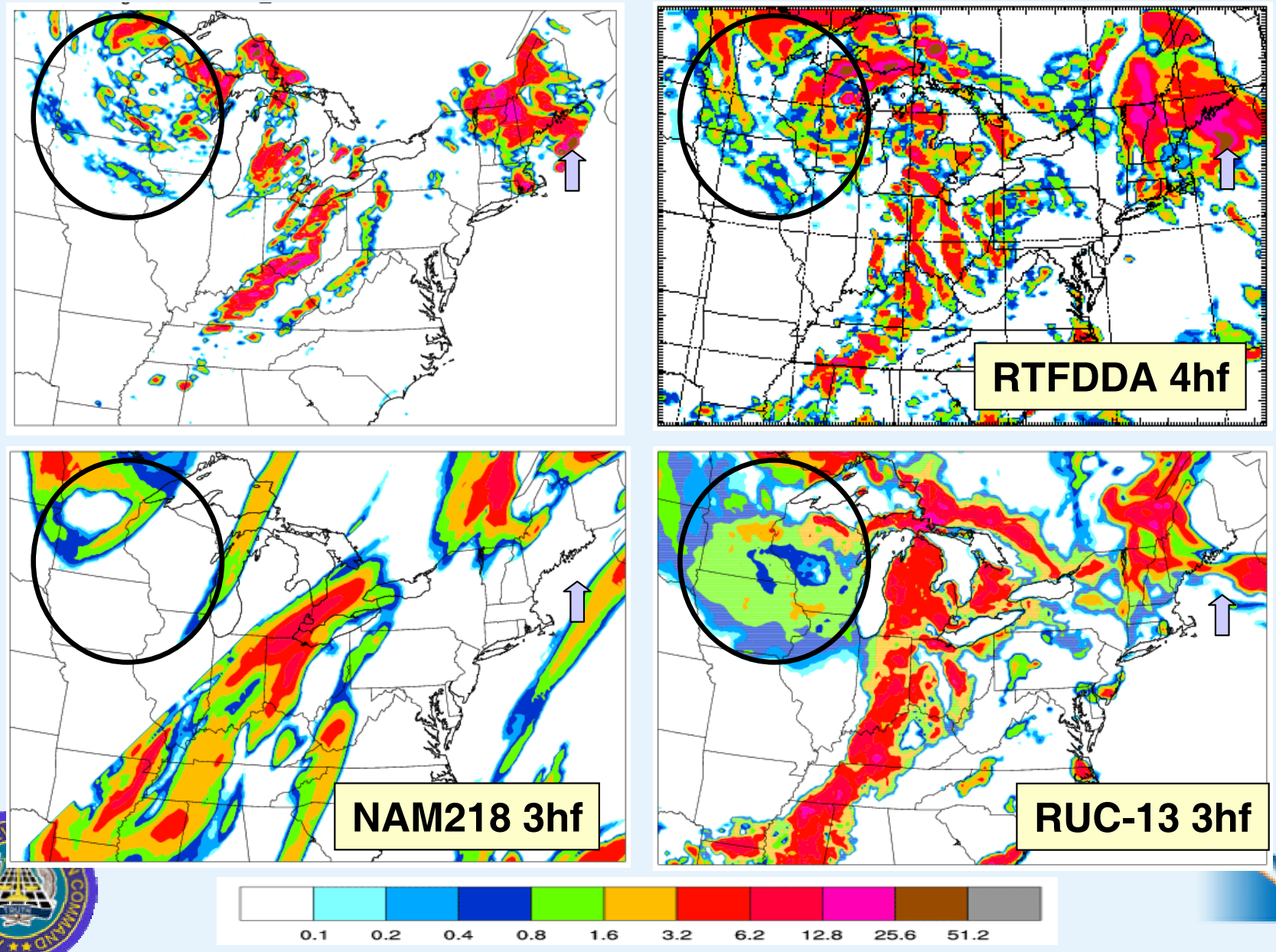
3h-Accumulated Precipitation of Model "Nowcasts" (18-21Z, 14 June 2005)



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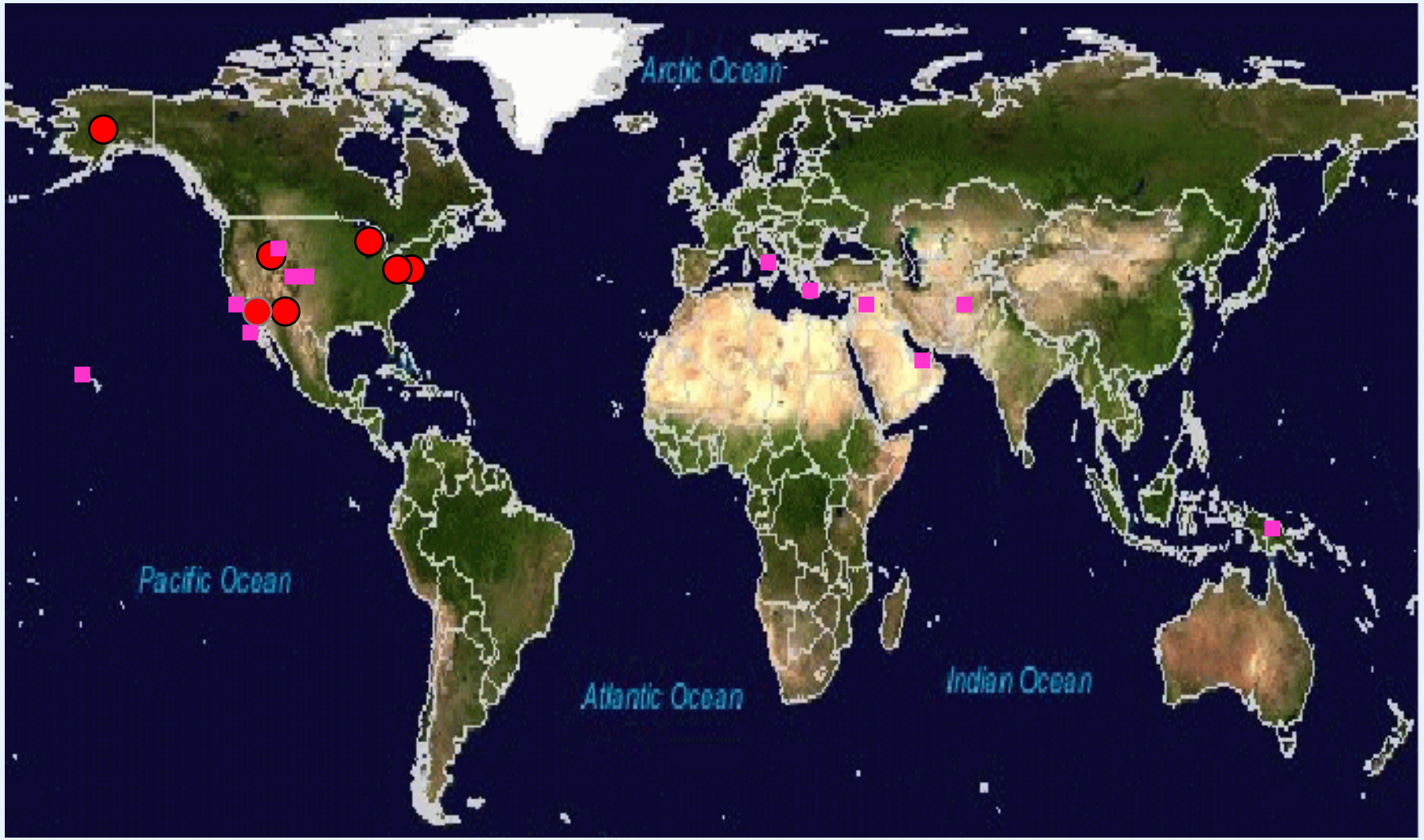
Operational RTFDDA Systems



- 7 Regular Operational RTFDDA Systems
- 12 Special Operation Sites

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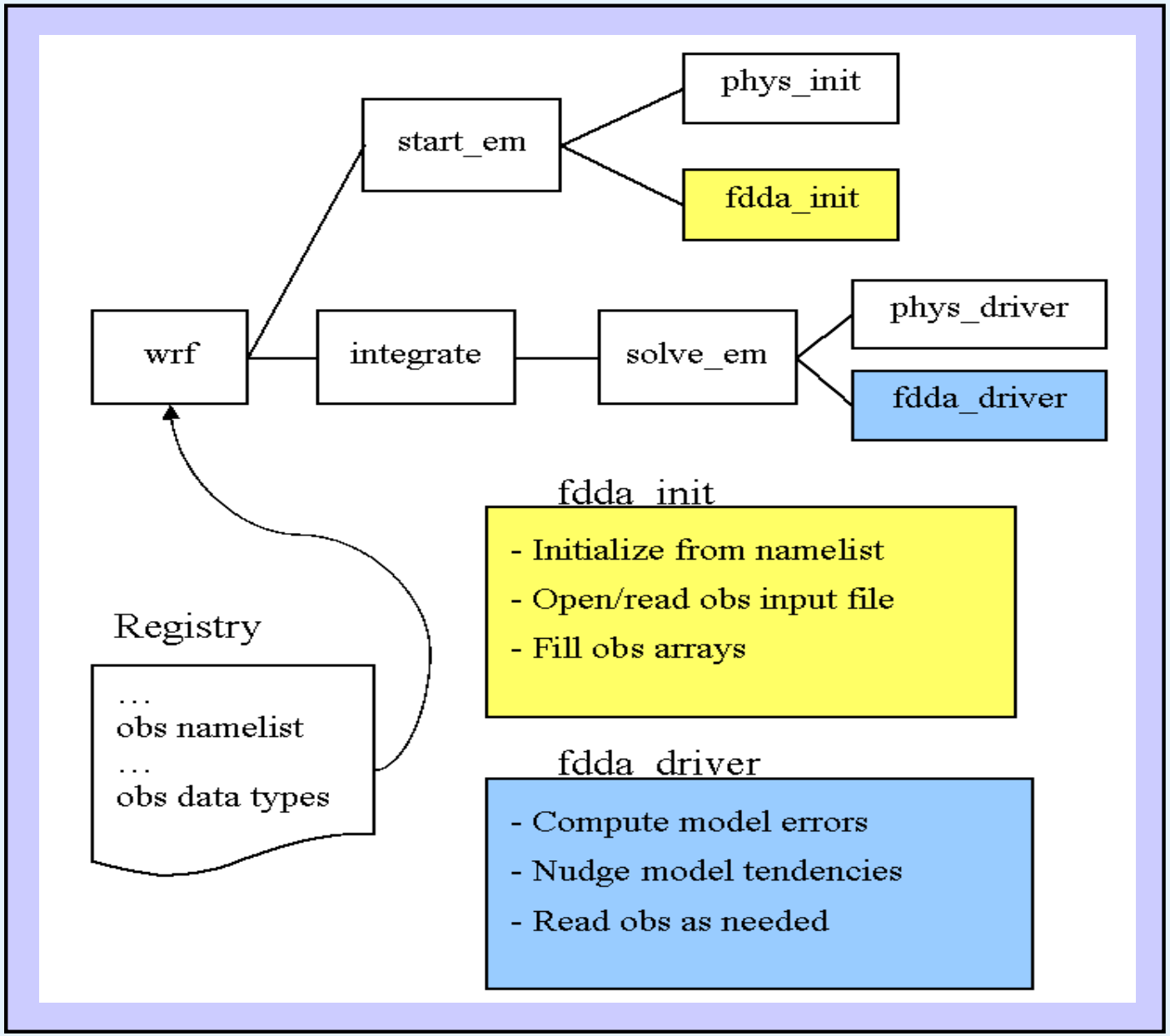
Implementation of WRF Obs-nudging



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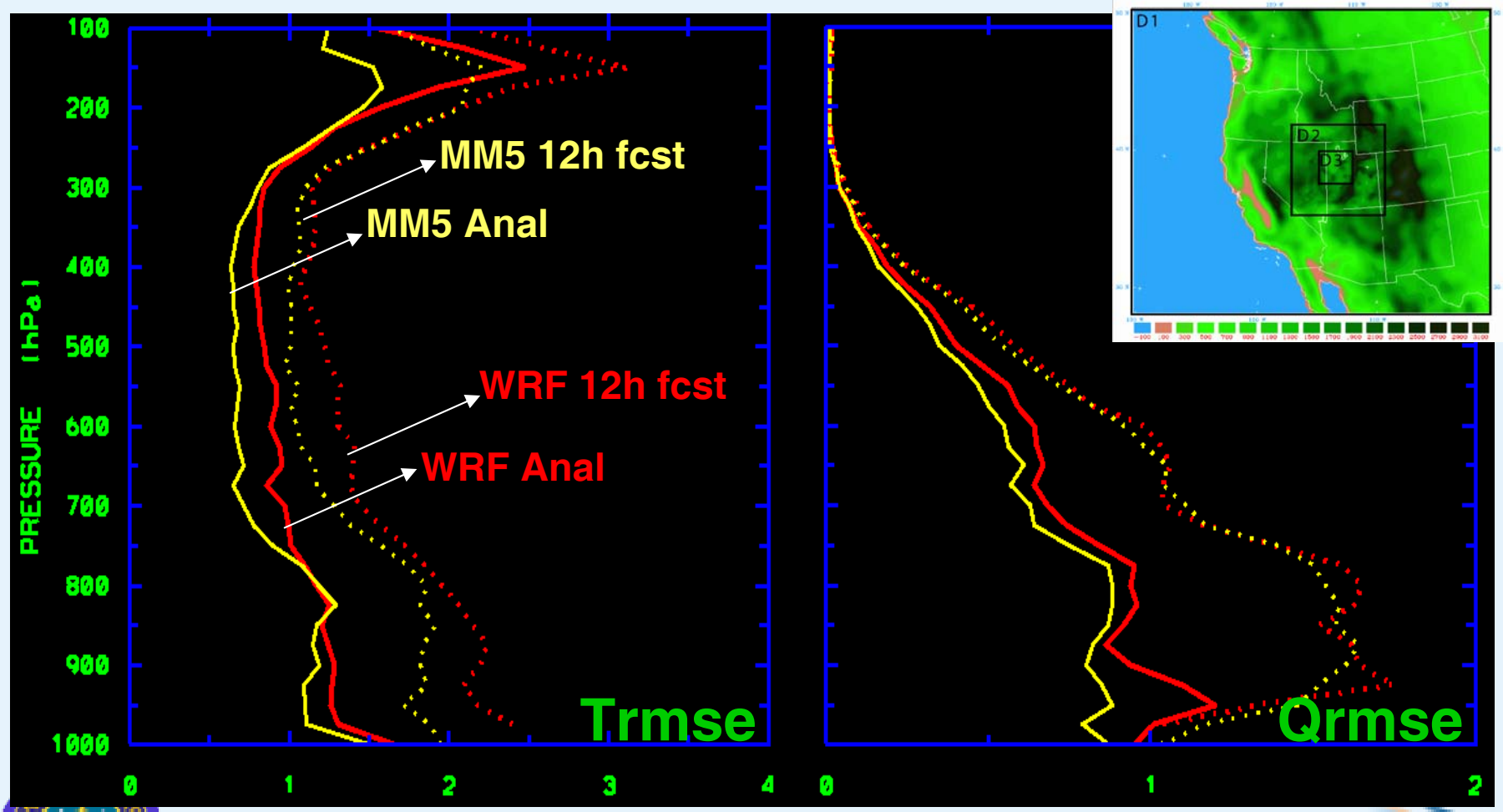
Verification of WRF- and MM5- RTFDDA operations at DPG, against 31 upper-air stations (~1000 soundings) in the Dom 1 between May 1 and May 16, 2005



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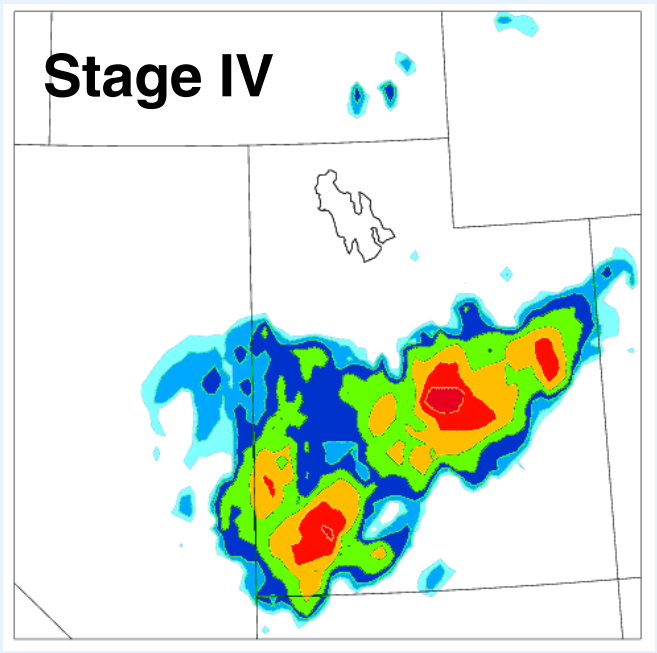
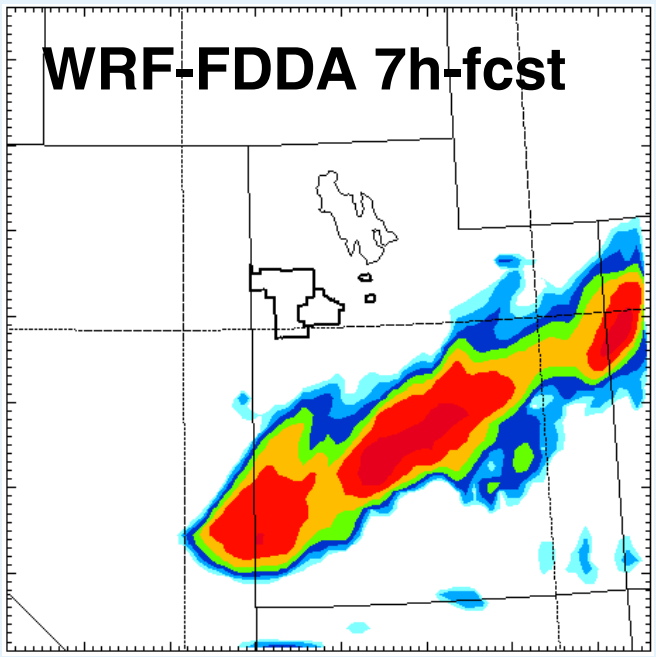
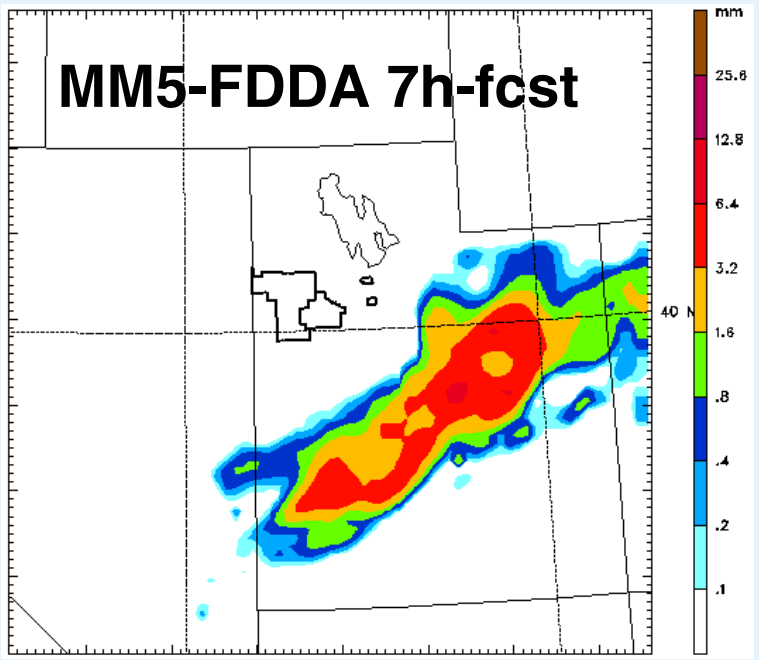
1h-Accumulated Precipitation, Valid at 09Z, 3 June 2005







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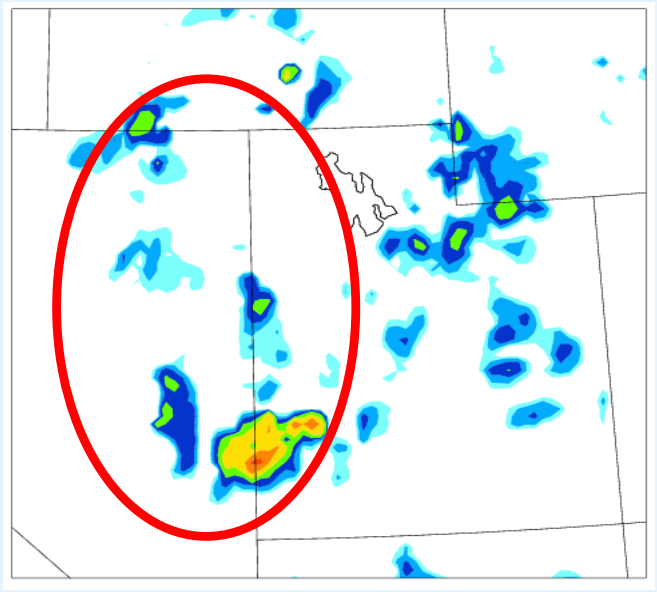
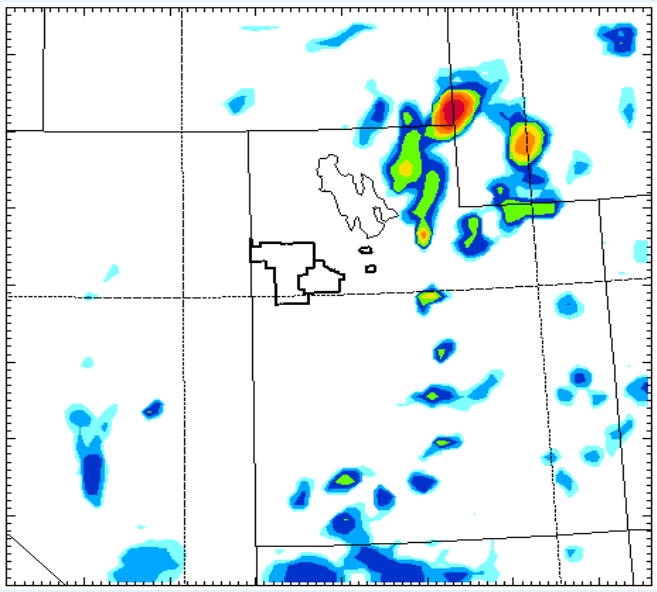
1h-Accumulation Precipitation, Valid at 22Z, 22 June 2005

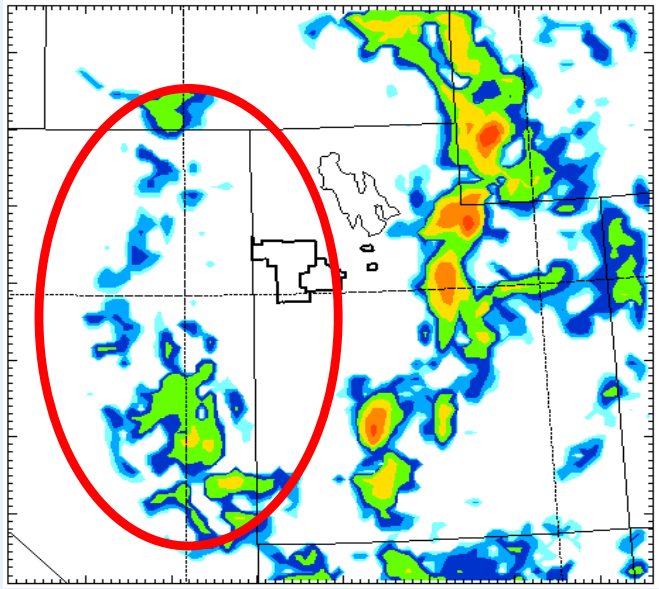
Stage IV Anal

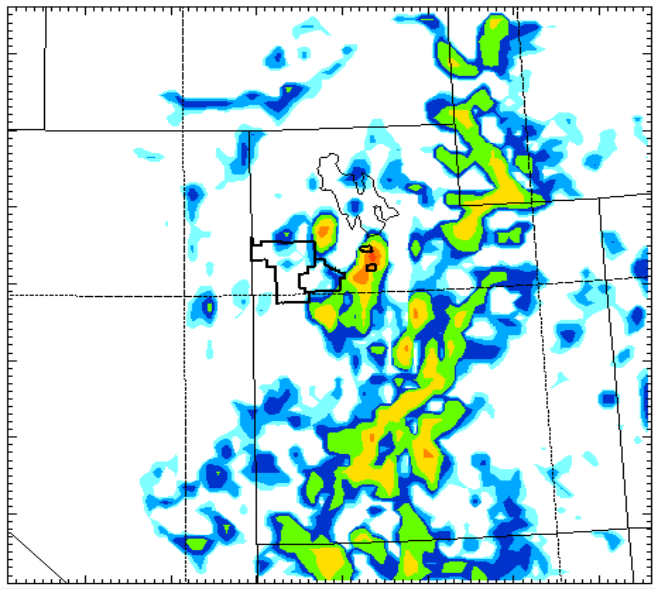




MM5 FDDA 7h fcsts

WRF FDDA 7h-fcst





WRF COLD 10h-fcst

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Summary

- **The NCAR/ATEC obs-nudging-based RTFDDA has been proven very effective and applicable for meso- and small scale data assimilation and prediction. The RTFDDA system has been used to produce multi-scale 4-D analyses and forecasts for various weather-critical applications, tests and events. It has become a dependable tool for the ATEC and other DoD users for their daily operations.**

- **The NCAR /ATEC obs-nudging module has been ported to the WRF ARW core. Preliminary tests with real-time cycling show promising results. However, further developments, code validation and real-time verification are needed before fully transitioning the ATEC operation systems to WRF-FDDA.**

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Plans

- **Releases**
  - **Complete WRF-FDDA code validation and development**
  - **September 05: to Penn State for joint beta testing**
  - **December 05: a research version to WRF (working group) community**
- **Future developments**
  - **Continue to refine the nudging weights, e.g. gradient-dependent weighting for upper-air observation.**
  - **Use local-scale, weather pattern–dependent background error (co)variances to construct/modify the nudging weighting function**
  - **Use ensemble or poor-man ensemble to calculate the flow-dependent background error (co)variances, and used them to improve the nudging weighting.**
  - **Work toward a full 4-D EnKF by combining EnKF and the "obs-nudging" approaches. And also, add ability to assimilate non-conventional data, including cloud/precip.**

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The end. Thank you!

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