ARMOR Dual-Polarimetric Radar Data Assimilation with WRF 3DVAR

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Dual-Polarimetric Radar

- **Horizontal and vertical signals: more info about the type, shape, and size of the hydrometeors – more accurate estimates of precip and cloud particles.**

Standard Variables from ARMOR:

Z_h: Horizontal reflectivity

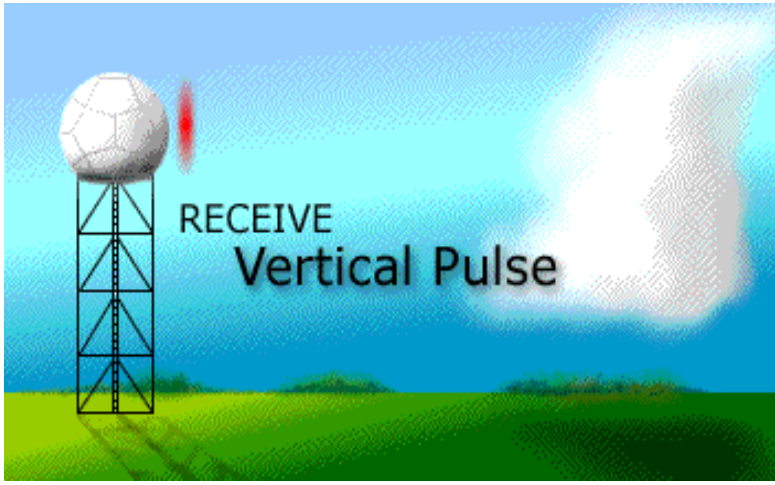
V_r: Radial velocity

Z_{dr}: Differential reflectivity $Z_{dr} = 10 \log10(Z_h/Z_v)$

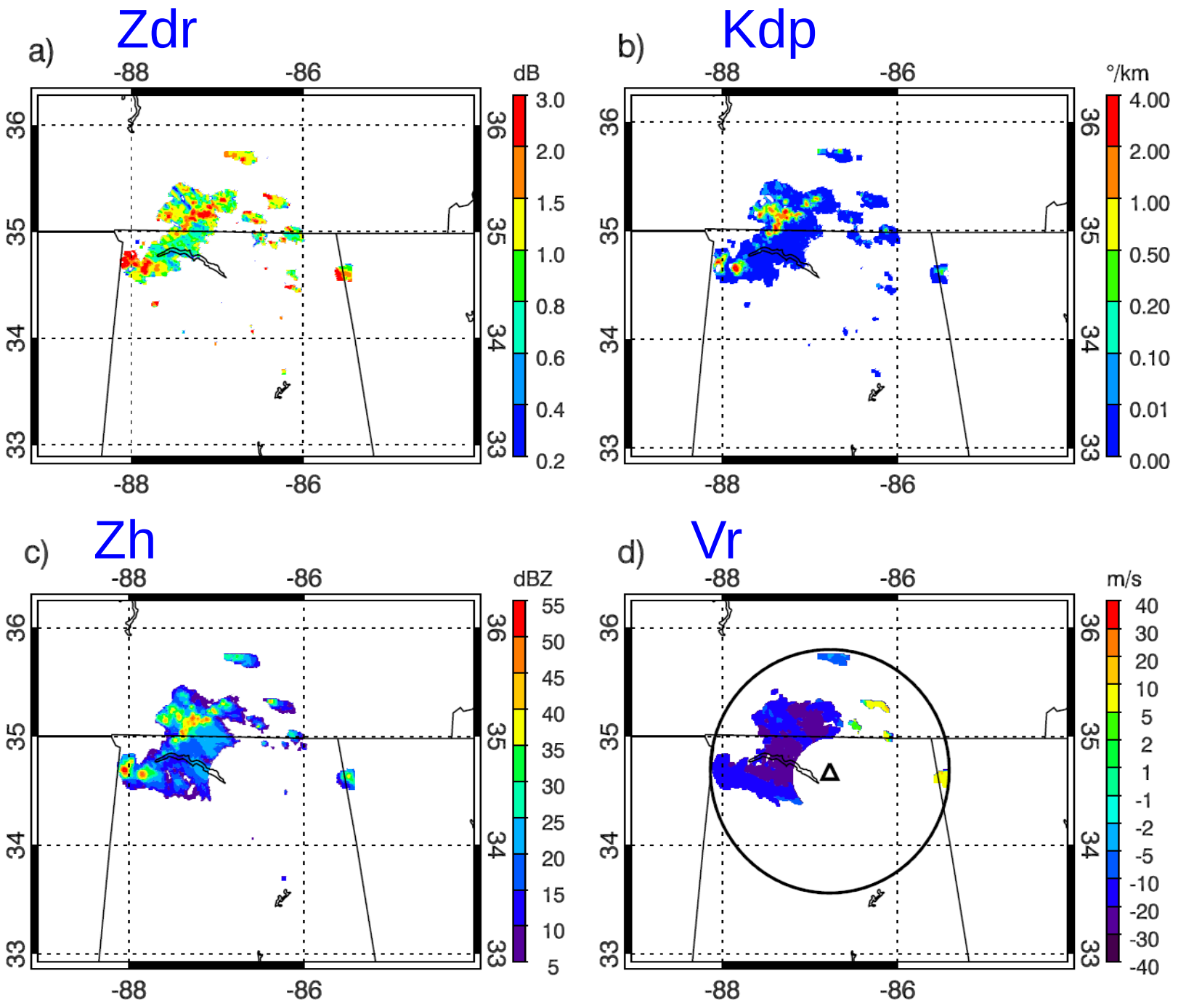
ρ_{hv}:Correlation coefficient, the coefficient between the horizontal and vertical power returns.

Φ_{dp}:Differential phase, the measured phase shift between horizontal and vertical pulses

K_{dp}:Specific differential phase, the range derivative of Φ_{dp}



Sample Data : 23 June 2008



Motivation & Goals

- ***Only a few*** **works have been done.**
  Wu et al. (2000) indirectly assimilated Zdr.
  Jung et al. (2008; 2010) assimilated Zdr, Kdp in OSSEs.
- **NWS starts to upgrade current NEXRAD radar network to include dual-polarization capabilities.**

- **To assimilate dual-pol Doppler radar observations for real cases and seek better performance in radar data assimilation.**
- **To study how to use radar data more efficiently? What is the best strategy to assimilate dual-pol variables for model initialization? How and by how much could dual-pol variables influence the initial fields? How long could the influence last?**

Model & Radar Data Assimilation Package

- WRF ARW v3.0
- WRF 3DVAR system
- Warm-rain forward operator
- Cycled assimilation of ARMOR data
- Dual-pol variables:
    - horizontal reflectivity (Zh)
    - differential reflectivity (Zdr)
    - specific differential phase (Kdp)
    - radial velocity (Vr)

Radar Forward Operator

Radial velocity

$$VR = u\frac{x - x_i}{r_i} + v\frac{y - y_i}{r_i} + (w - v_T)\frac{z - z_i}{r_i}$$

$$v_T = 5.40a \times q_r^{0.125}$$

Reflectivity & dual-pol variables

$$Z_H = 2.04 \times 10^4 q_r^{1.75}$$

$$\frac{q_r}{Z_H} = 1.28 \times 10^{-4} Z_{DR}^{-1.94}$$

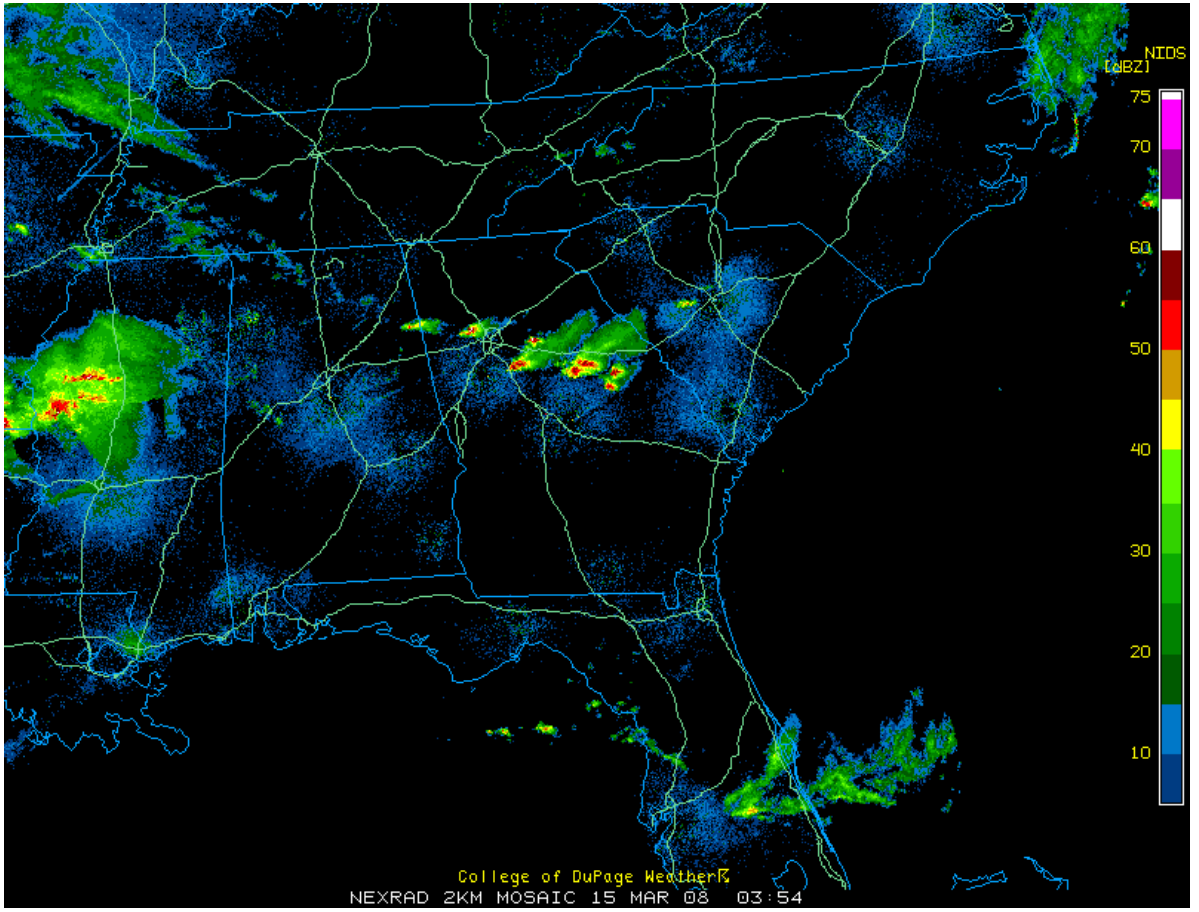
$$q_r = 3.11 \times K_{DP}^{0.918} \times Z_{DR}^{-0.764}$$

Methods

- High resolution (~1 km) comparison experiments:
  - WRF model control run (CTRL)
  - with Zh+Vr assimilation (RF)
  - with Zh+Zdr+Vr assimilation (RD)
  - with Zdr+Kdp+Vr assimilation (KD)

- Case studies:
  - Tropical Storm Fay remnant (08/25/2008)
  - MCS on 03/15/2008
  - Thunderstorm on 06/23/2008

Results

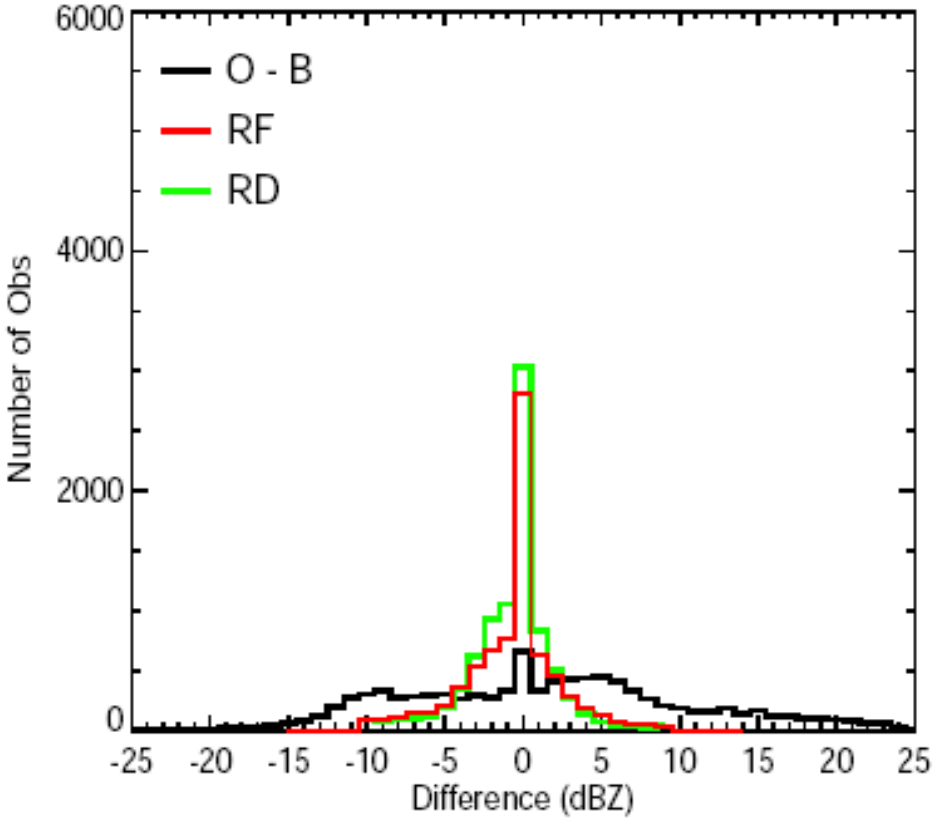


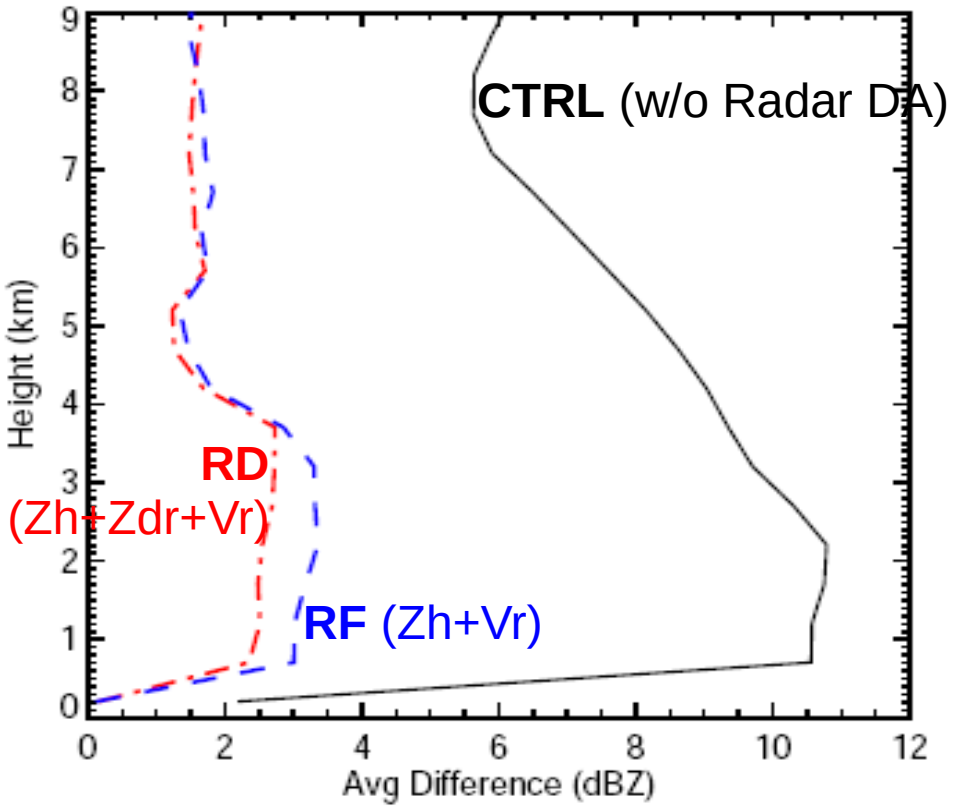
- MCS on 03/15/2008
- Impact of ARMOR radar data assimilation
- Impact of Zdr data assimilation

Zdr Data Assimilation: 03/15/2008 MCS

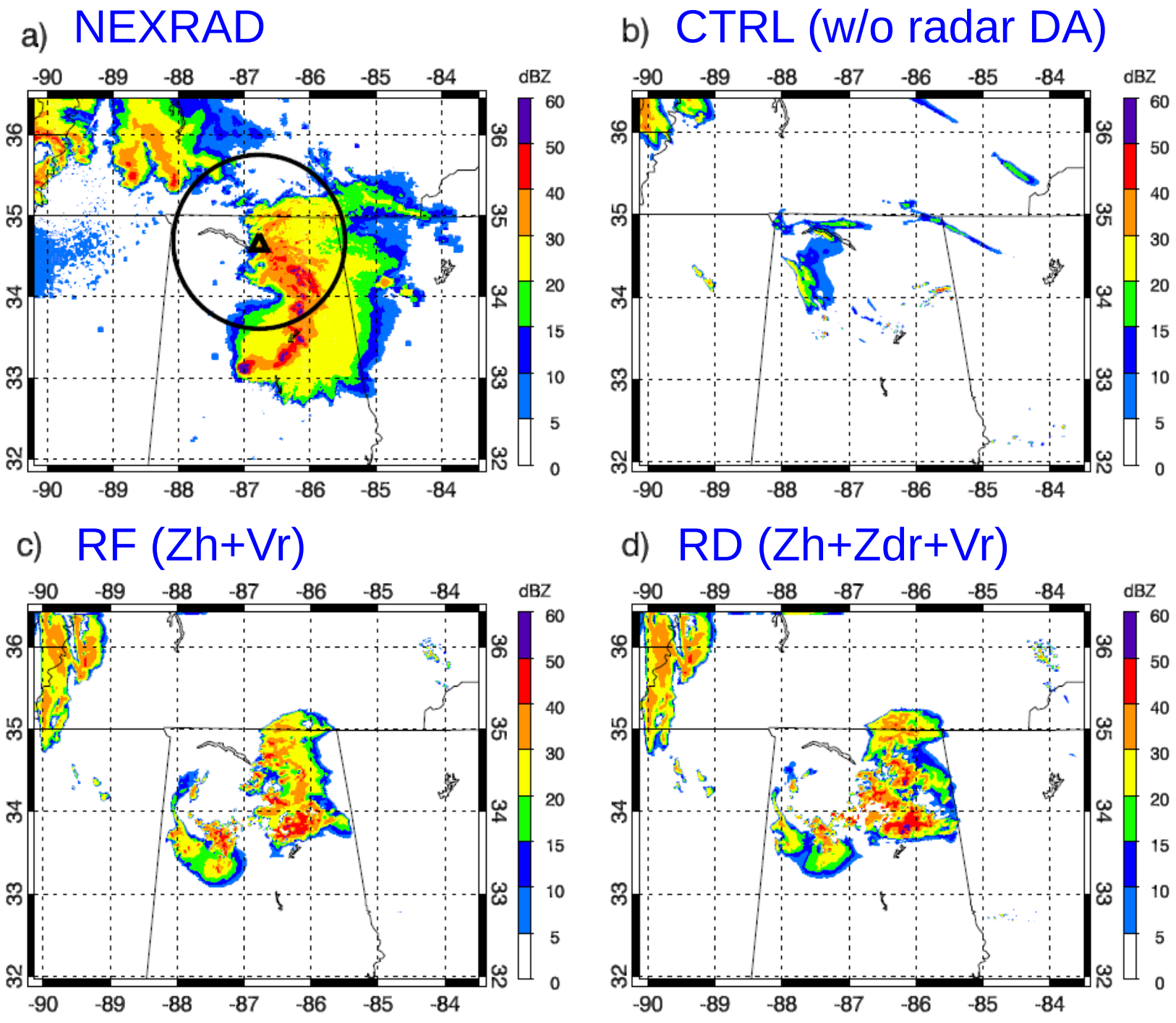
Experiments	Data Assimilation Time	Variables
CTRL	N/A	N/A
RF	0730 UTC, 0800 UTC, and 0830 UTC 15 Mar 2008	Zh and Vr
RD	0730 UTC, 0800 UTC, and 0830 UTC 15 Mar 2008	Zh, Zdr, and Vr

O – B & O – A Comparisons: 03/15/2008 MCS

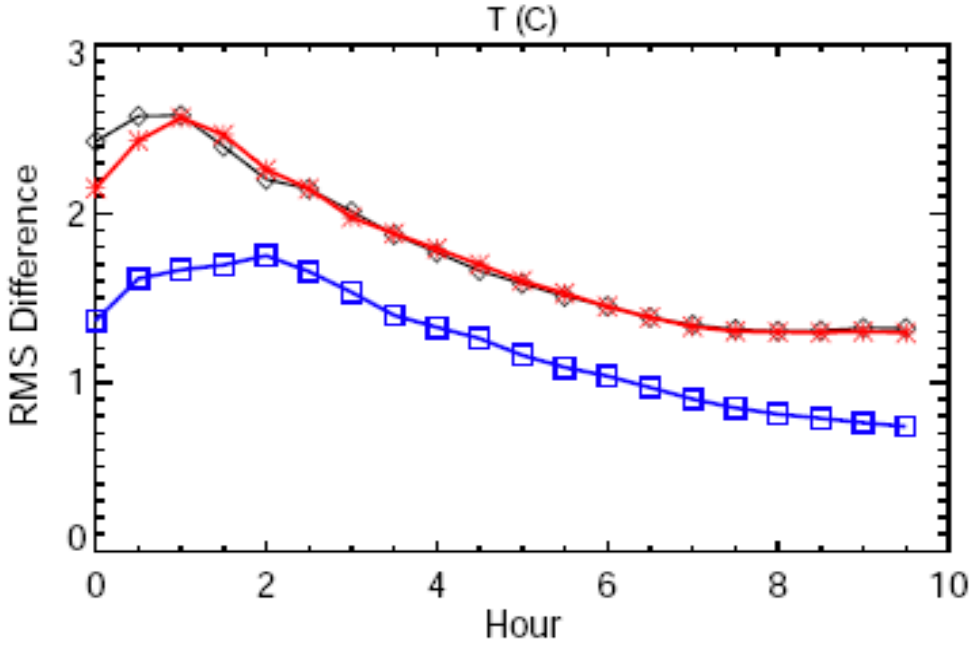


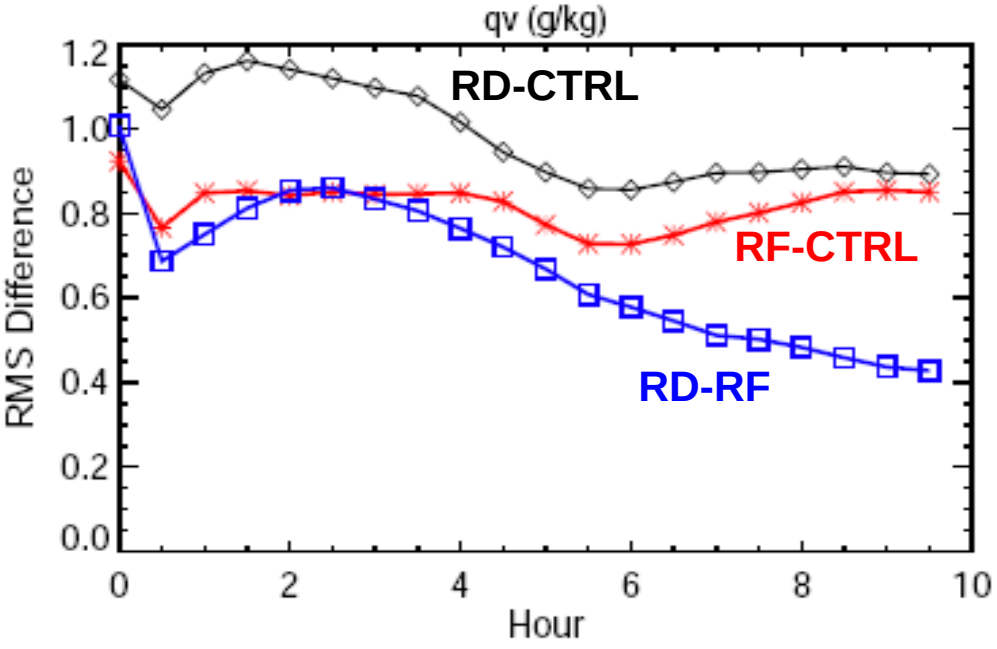


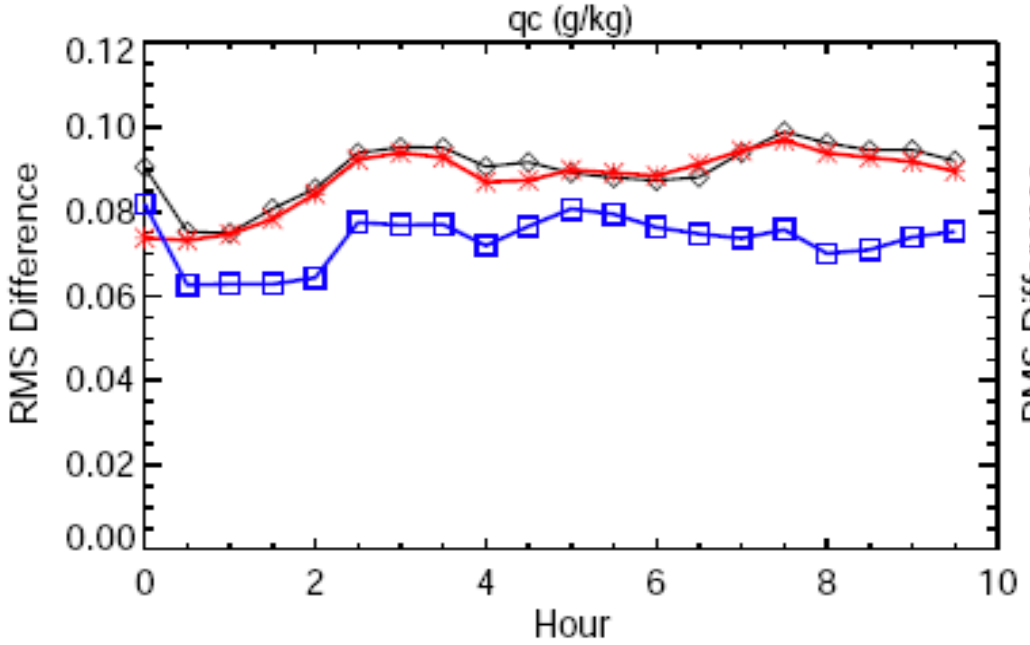
Radar Reflectivity 0830Z 03/15/2008

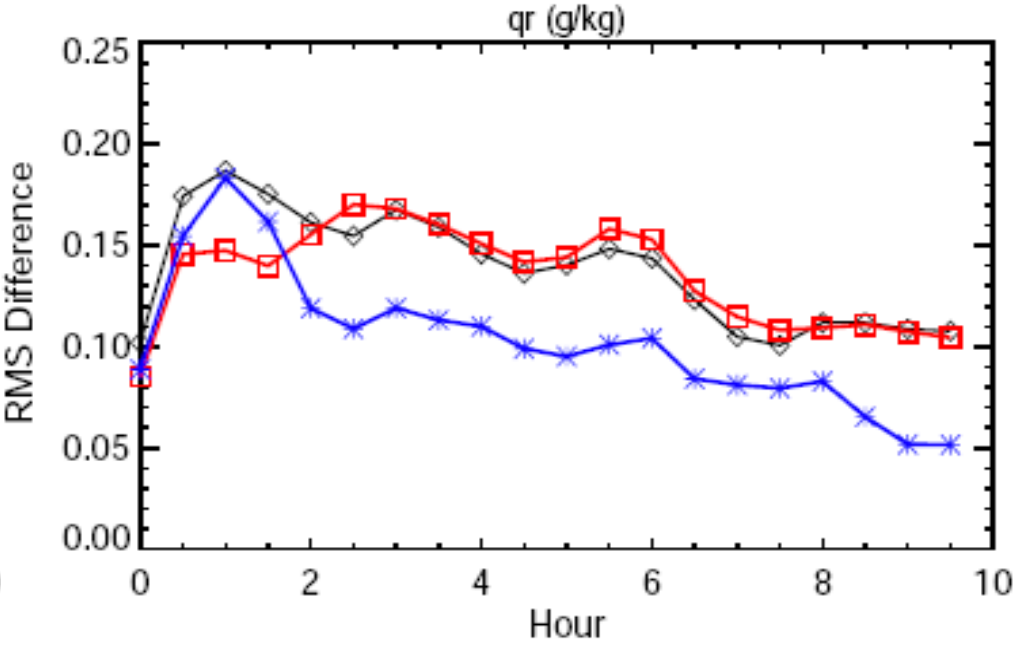


RMS Differences



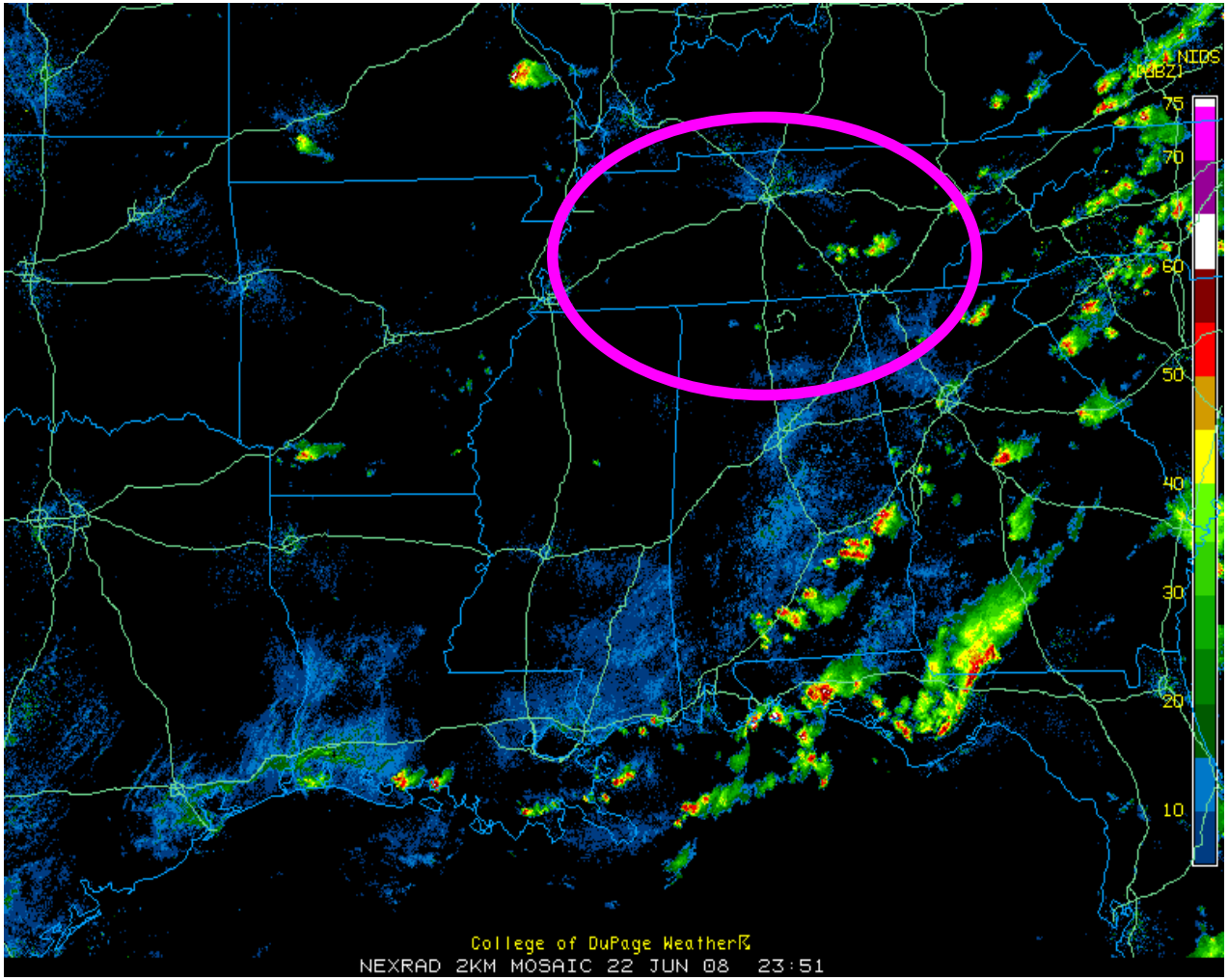






Major radar data impact lasts ~2-4 hours

Results



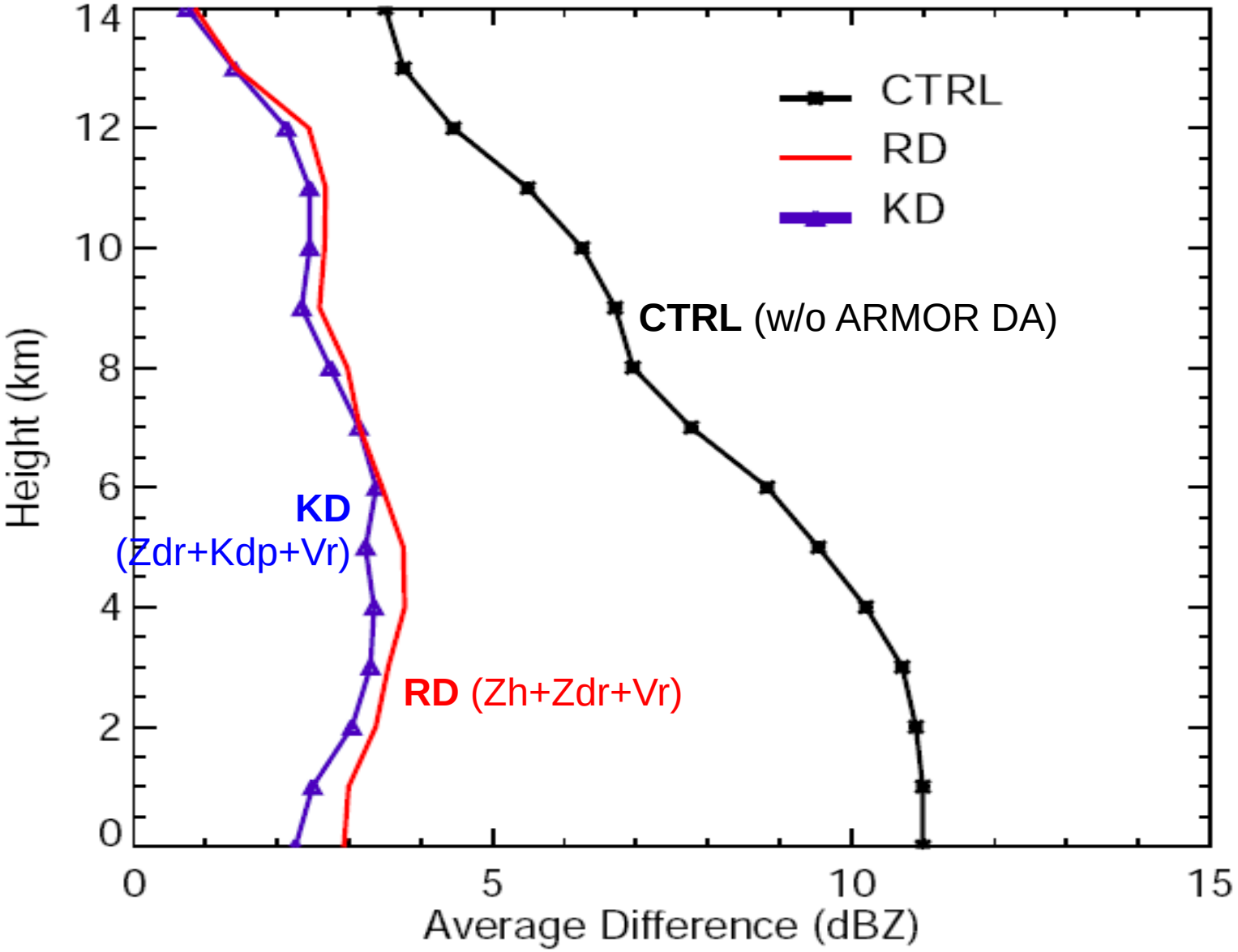
Thunderstorm on 06/23/2008

Impact of Zdr+Kdp data assimilation

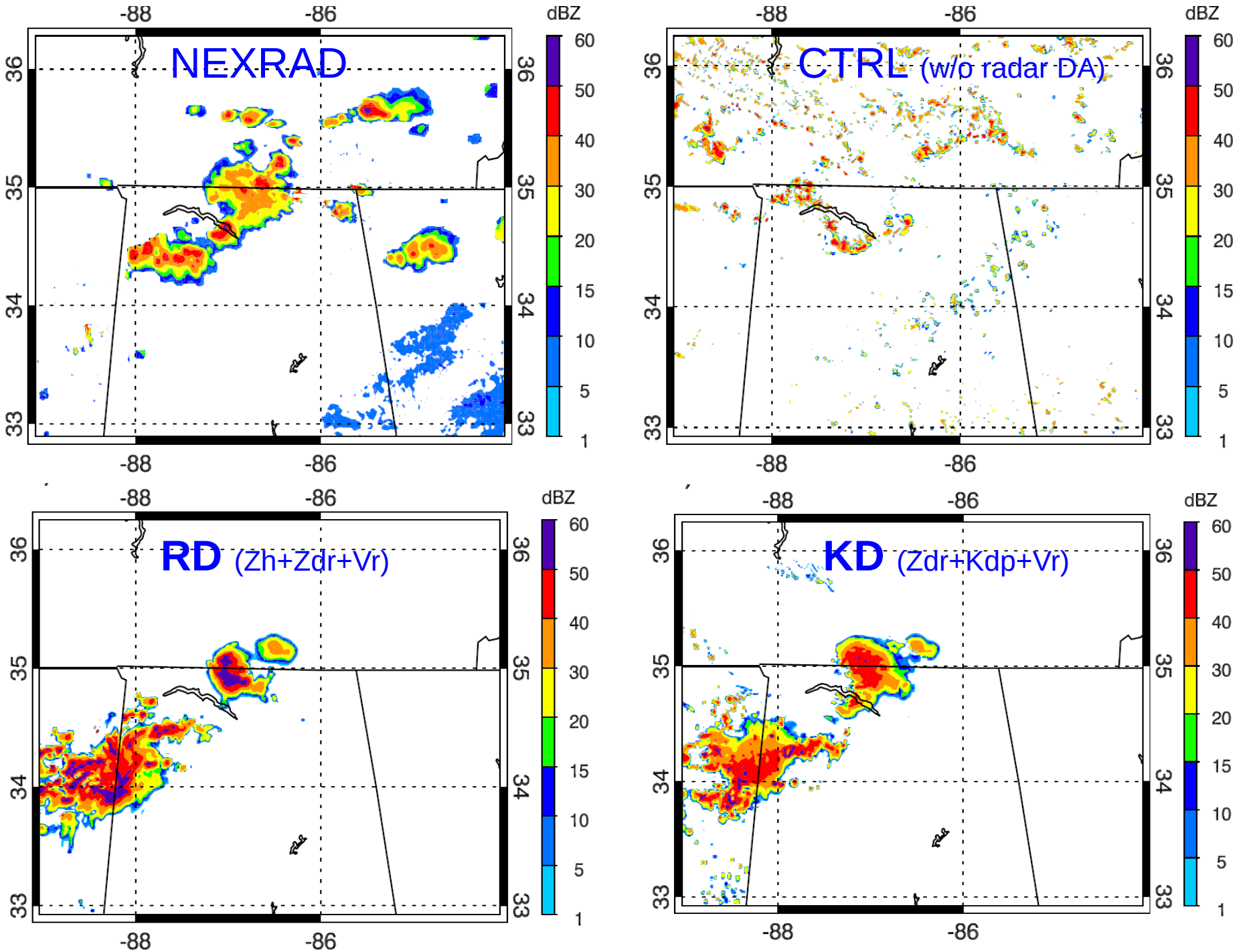
Kdp+Zdr Data Assimilation: 06/23/2008 Thunderstorm

Experiments	ARMOR Data Assimilation Time	Variables
CTRL	N/A	N/A
RD	1930 UTC, 2000 UTC, and 2030 UTC 23 Jun 2008	ARMOR Zh, Zdr and Vr
KD	1930 UTC, 2000 UTC, and 2030 UTC 23 Jun 2008	ARMOR Kdp, Zdr, and Vr

O – B & O – A Comparisons: Thunderstorm 06/23/2008

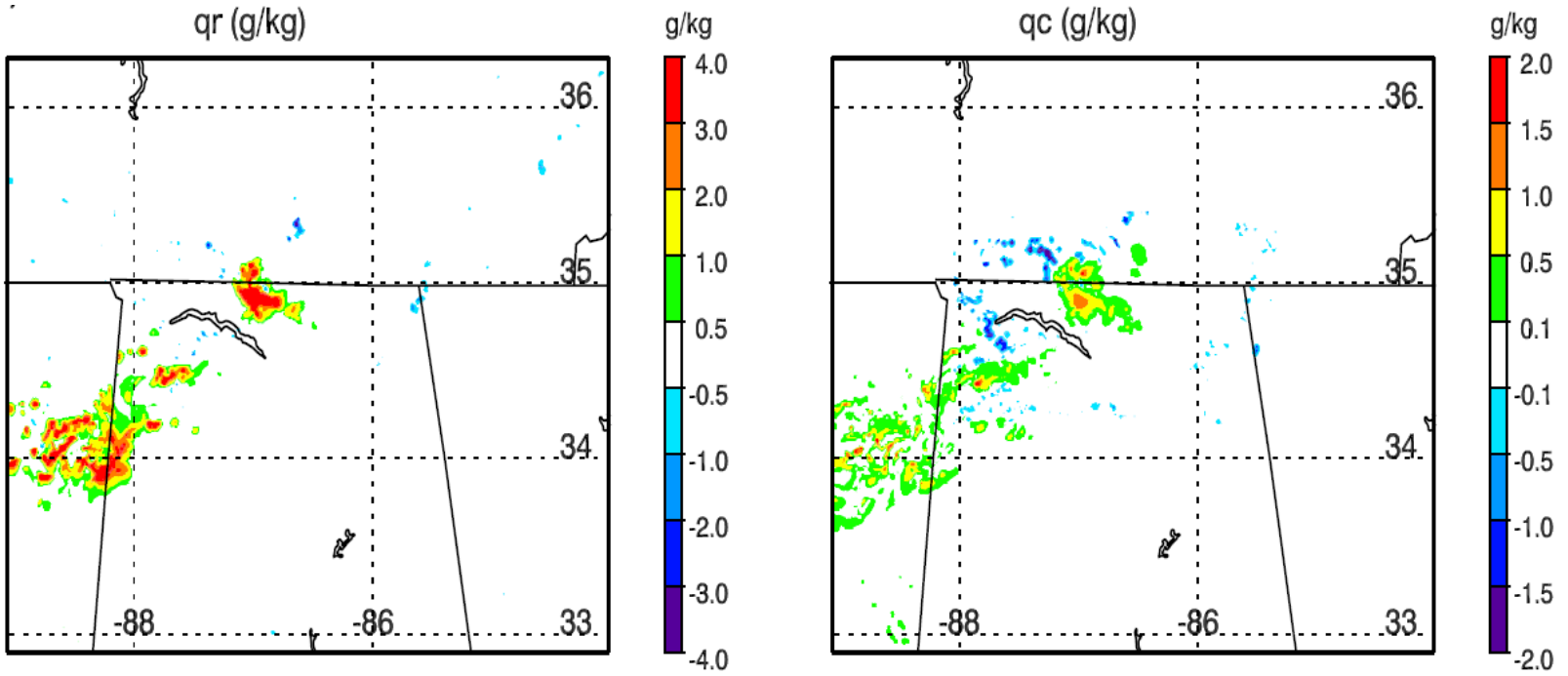


Radar Reflectivity 2030Z 06/23/2008

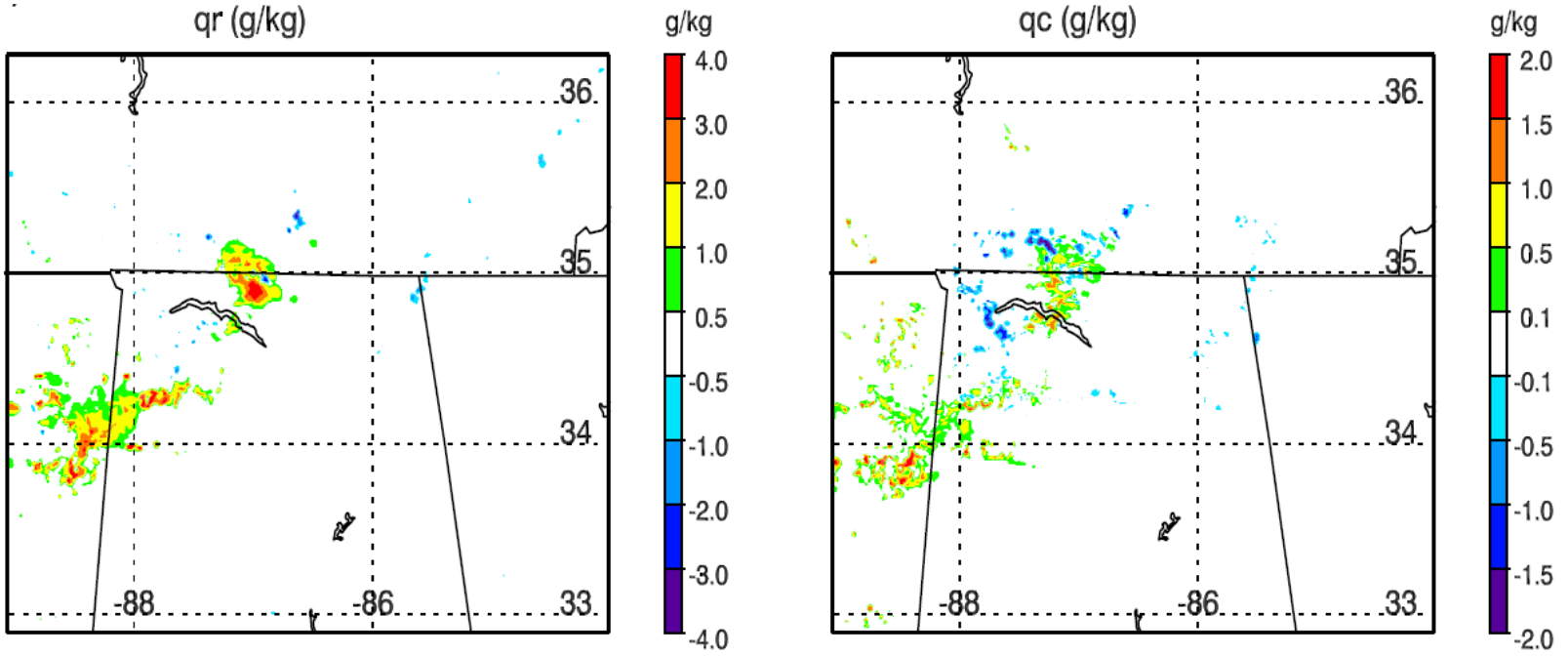


Increment 2030Z 06/23/2008

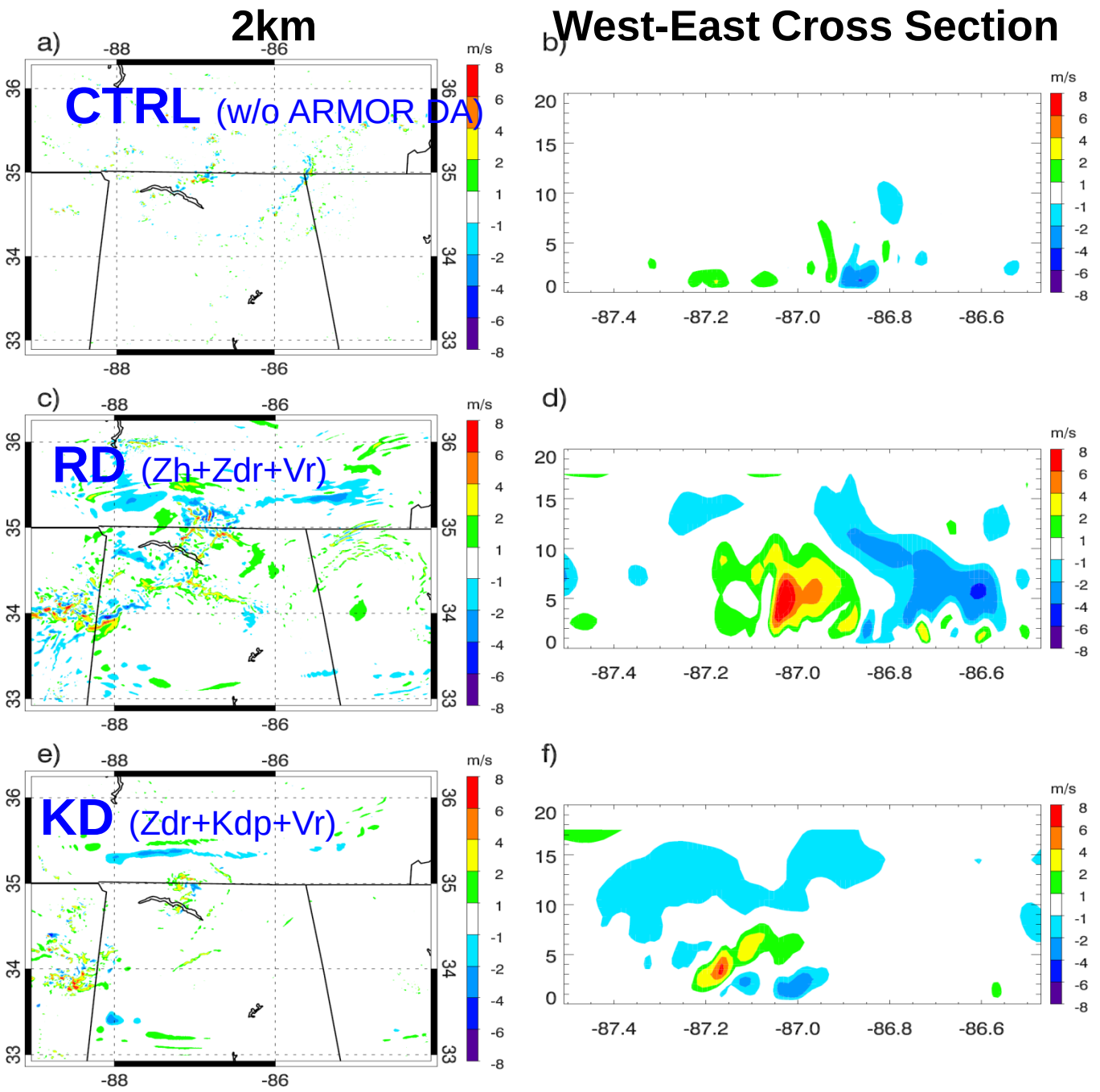
RD (Zh+Zdr+Vr)



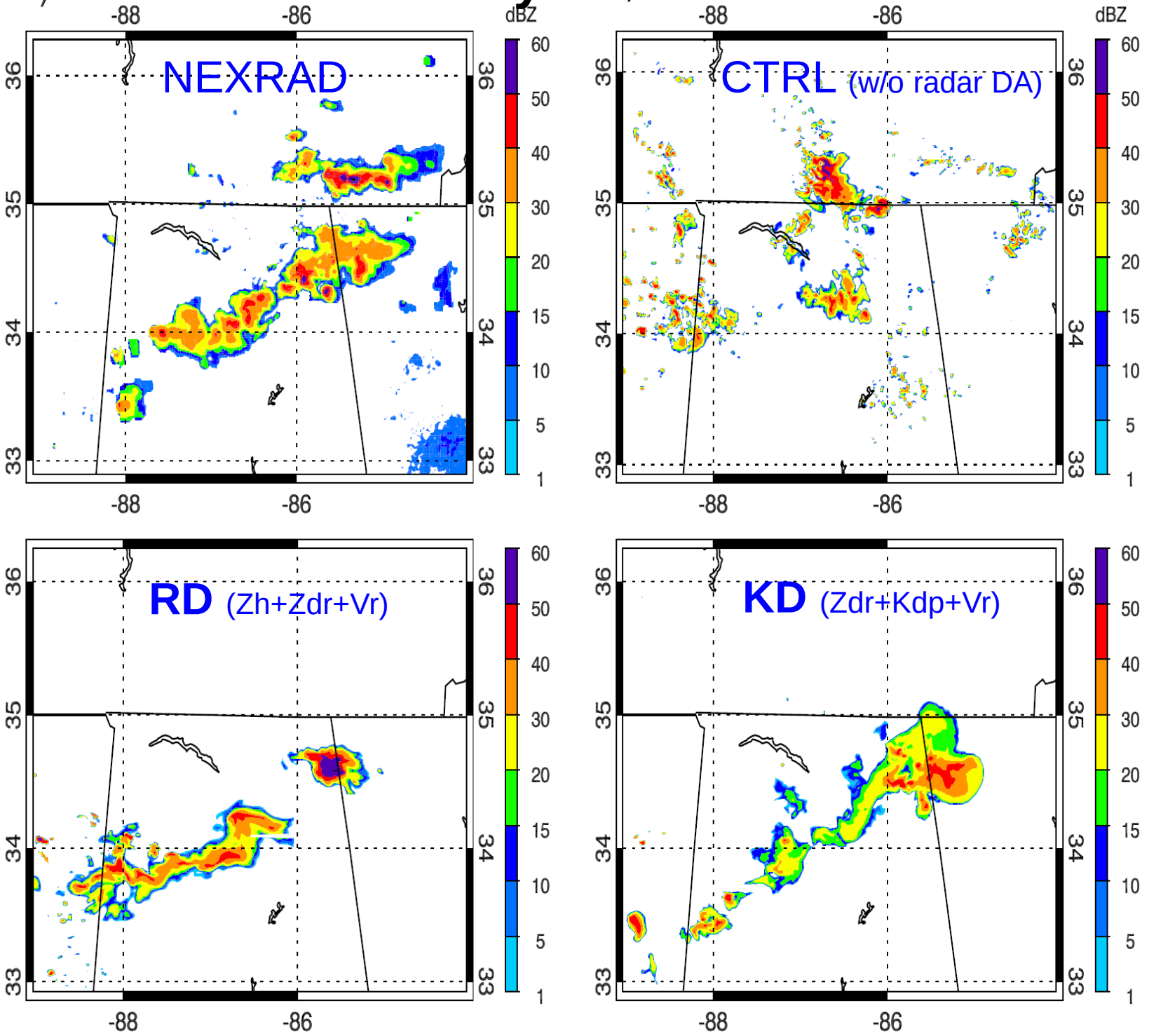
KD (Zdr+Kdp+Vr)



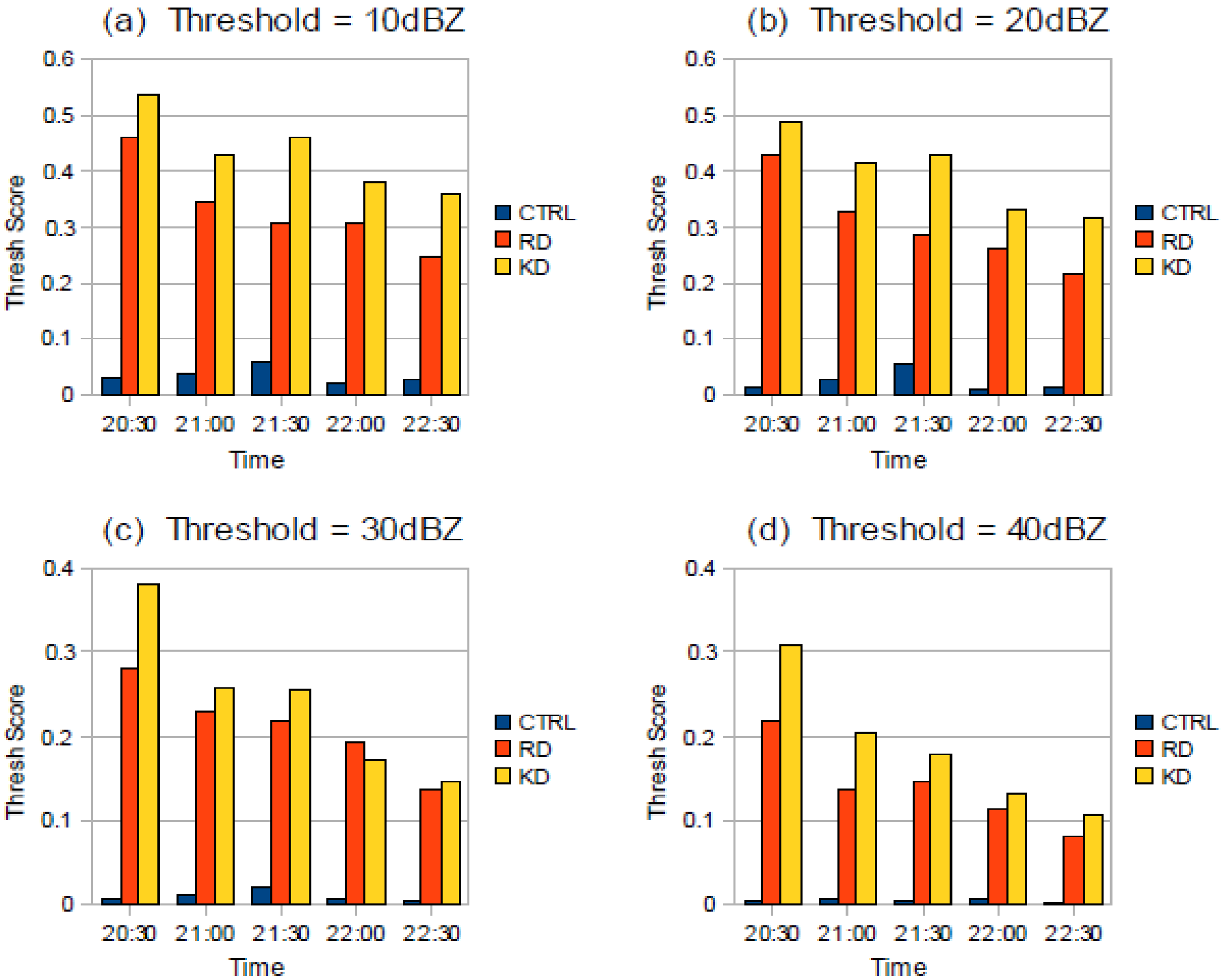
Vertical Velocity:Thunderstorm 06/23/2008



Radar Reflectivity 1.5h Forecast



Forecast Validation



Summary & Conclusions

- Zh, Zdr, Kdp and Vr data have been successfully assimilated with the WRF 3DVAR system.
- Dual-pol variables, Zh+Zdr, Zdr+Kdp assimilation brought additional benefits to storm initialization (compared to when only Zh and Vr data are assimilated)
- Kdp and Zdr data assimilation is superior to Zh and Zdr data assimilation in the initialization of the simulated convective storms

Future works:

- Ice-phased processes (wsm3, wsm6) in radar DA
- Formulate relationships between ARMOR variables and liquid/ice water contents
- Investigate strategies for assimilating the dual-pol variables

Publications:

- Li, X., and J. R. Mecikalski (2010), Assimilation of the dual-polarization Doppler radar data for a convective storm with a warm-rain radar forward operator, J. Geophys. Res., 115, D16208, doi:10.1029/2009JD013666.
- Li, X., and J. R. Mecikalski (2010), Impact of the Dual-Polarization Doppler Radar Data on two convective storms with a warm-rain radar forward operator. (Submitted to J.G.R.)