Assimilation of Reflectivity and Radial Velocity in a Convective-Scale, Cycled 3DVAR Framework with Hydrometeor Classification

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OUTLINE

I. Background and methodology

II. Assimilation and forecast experiments with an idealized case

III. Assimilation experiments with a real case

IV. Summary

Research Background

- Warn-on-Forecast concept (Stensrud et al. 2009): The time has come to develop warning methods in which numerical model forecasts play a much larger role in order to extend warning lead time.
- Warn-on-Forecast goal: Improve tornado threat prediction by using a 0-1 hour, 1-km resolution ensemble NWP forecasts (Lou Wicker, 2013 WoF workshop).
- One of the challenges: Current NWP forecasts (even at very high resolution) have a spin-up problem. The 0 to 2 hour forecasts usually contain no precipitation.
- This study focuses on resolving the spin-up problem by including hydrometer variables as analysis variables and assimilating reflectivity and radial velocity within a 3DVAR framework.

Research Background

Previous research:

> Cloud analysis method (Alber et al. 1996; Brewster et al. 2005; Hu et al. 2006; Weygandt and Benjamin et al. 2008)

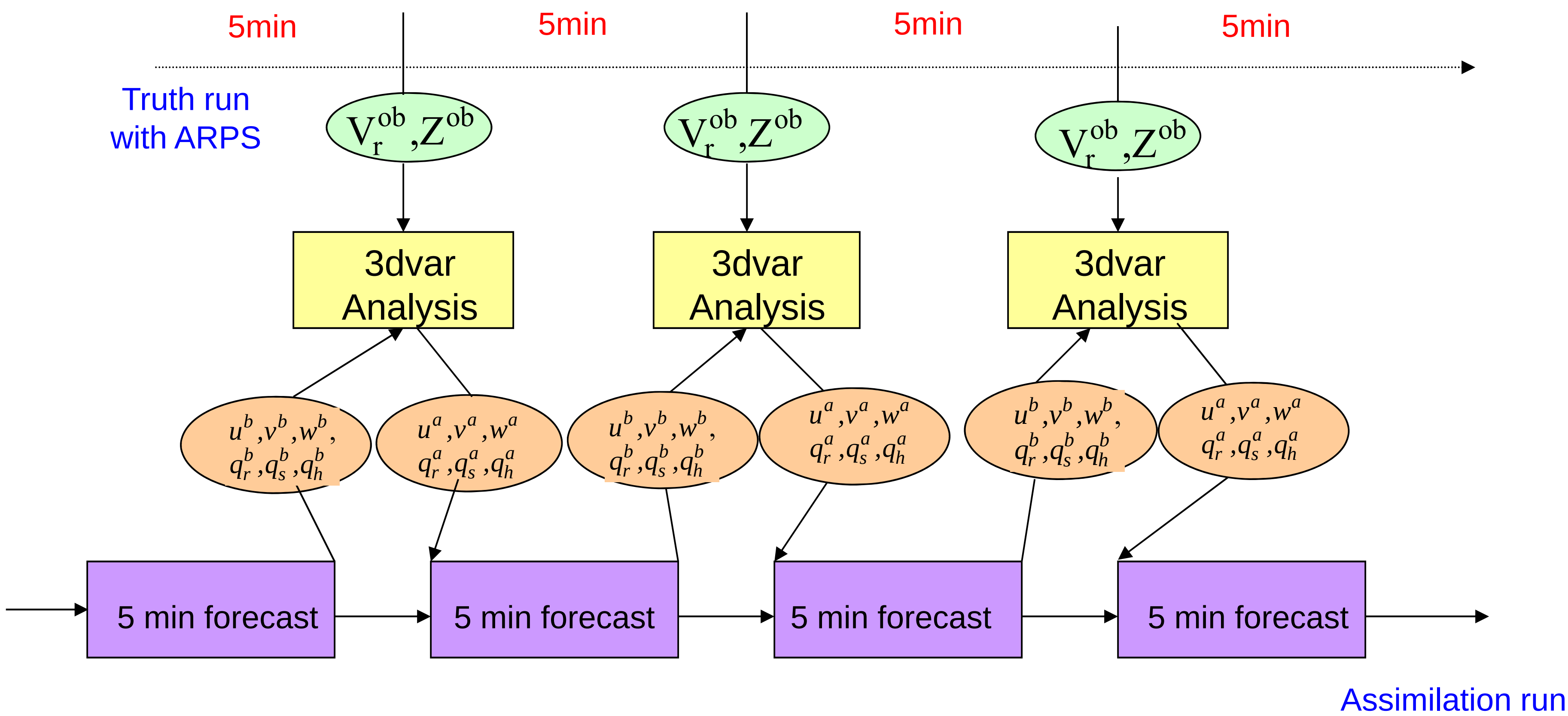
> 3DVAR (Xiao et al. 2005), 3.5VAR (Zhao et al. 2008)

> 4DVAR technique (Sun and Crook 1997; 1998)

> EnKF (Tong and Xue 2005; Dowell, Wicker and Snyder, 2011)

In this study, reflectivity is assimilated in a unified 3DVAR framework by including warm and cold hydrometeors (rain, snow and hail) and partitioning these hydrometeors using the temperature field from an NWP model (Gao and Stensrud 2012, *J. of Atmos. Sci*.)

Continuous cycles of radar data assimilation



Two step: analysis and forecast. All other model variables are updated (or retrieved) in a forecast step.

Assimilating reflectivity within 3DVAR framework

- First method (Z1)
  - totoal reflectivity computed as (Smith 1975);

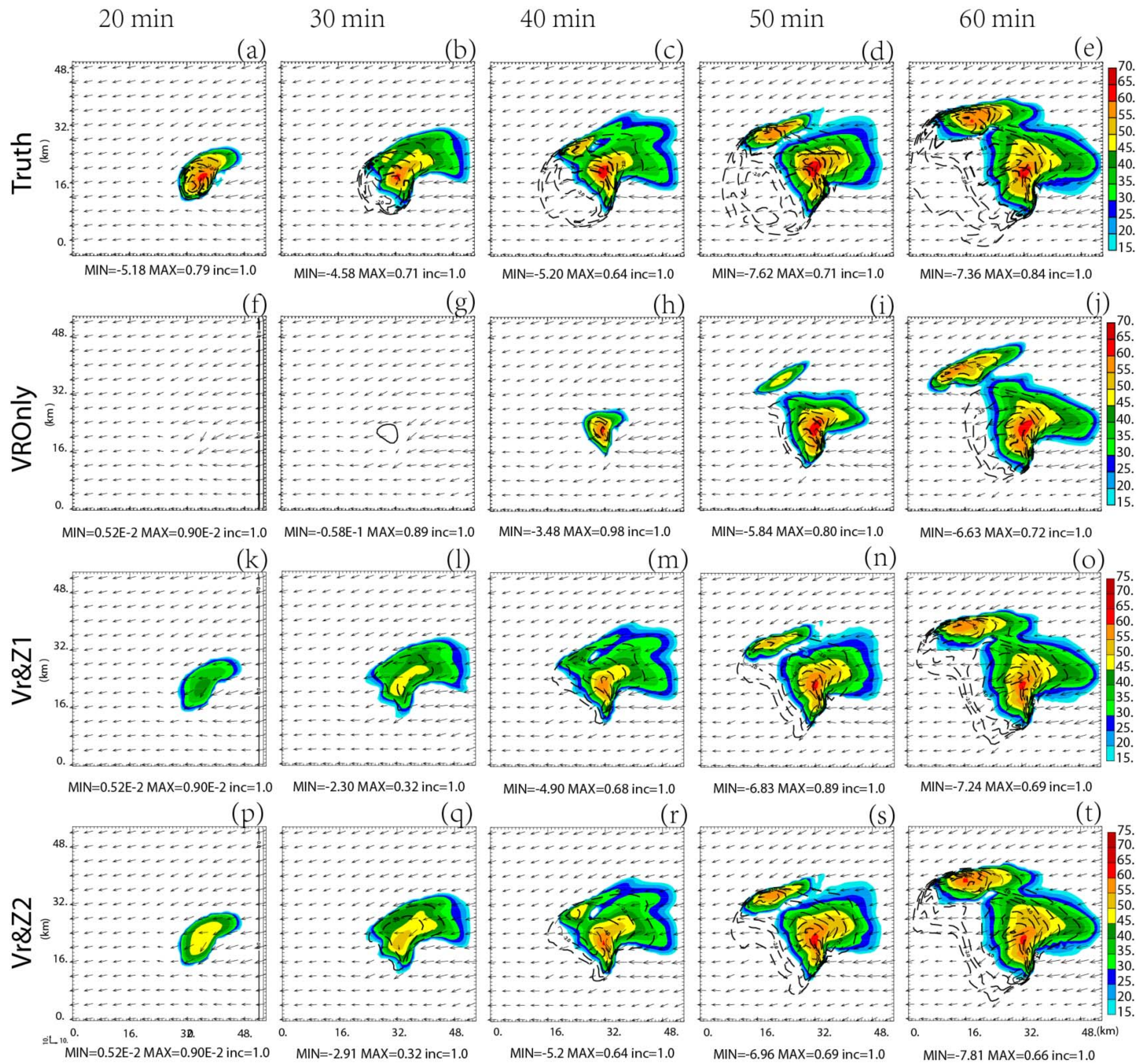
$$Z_e = Z_{er}(q_r) + Z_{es}(q_s) + Z_{eh}(q_h)\,, \qquad (1)$$

- Second method (Z2)
  – partition reflectivity via temperature from NWP model output.
    - T_b > +5 C: all rain
    - T_b < - 5 C: all snow and hail
    - -5 C < T_b < 5 C: mixed phase

  - linearly partition reflectivity between rain and ice (0<α<1).

$$Z_e = \begin{cases} Z_{er}(q_r) & T_b > 5^o C \\ Z_{es}(q_s) + Z_{eh}(q_h) & T_b > -5^o C \\ \alpha Z_{er}(q_r) + (1-\alpha)\left[Z_{es}(q) + Z_{eh}(q)\right] & -5^o C < T_b < 5^o C \end{cases} \qquad (2)$$

Idealized Case Study



5 min cycled 3dvar analysis

For an idealized Case

Z (color shaded)

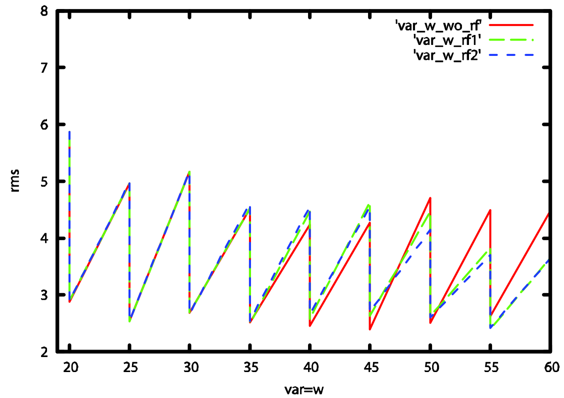
Wind (vectors)

θ (contours)

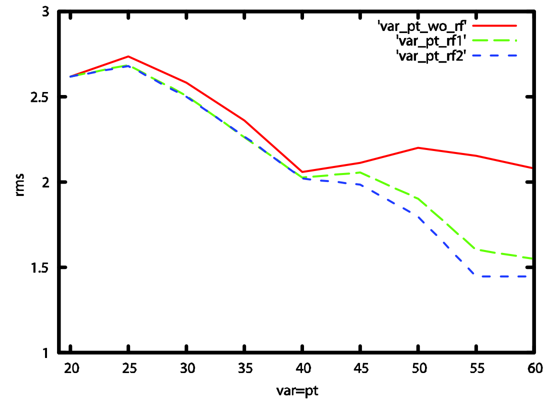
Near Surface

RMS Errors of the Analyses for 6 model variables

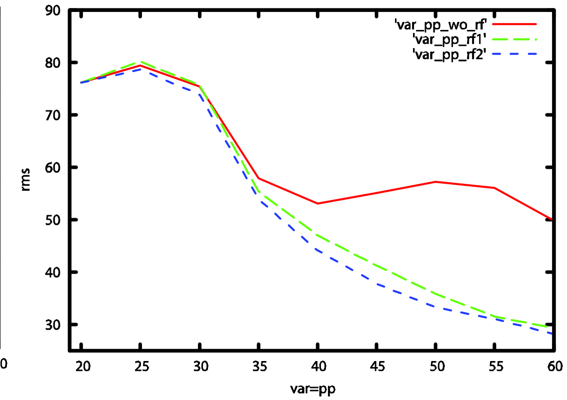
w (vertical velocity)

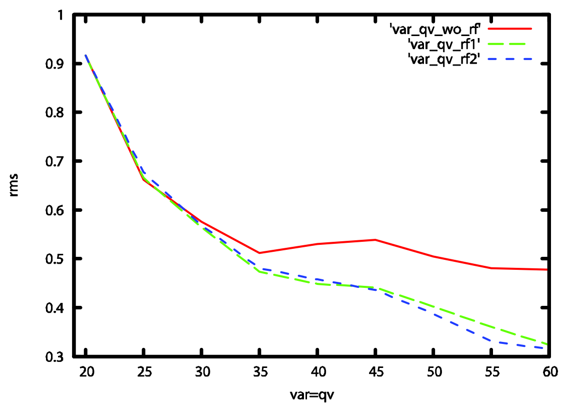


θ (potl. temperature)

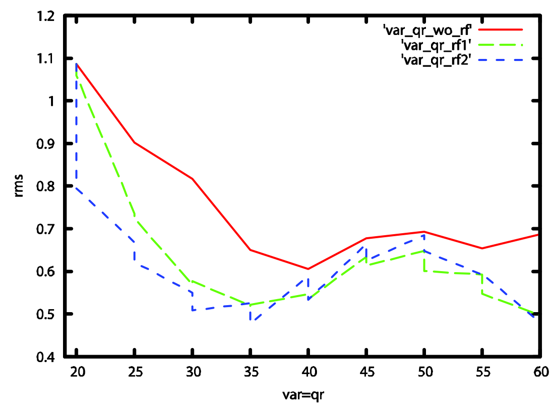


p (pressure)

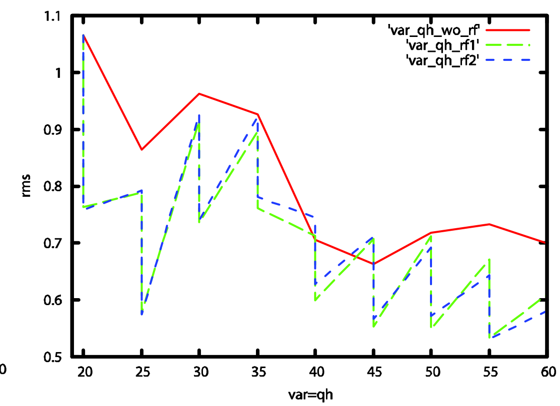




q_v (water vapor)



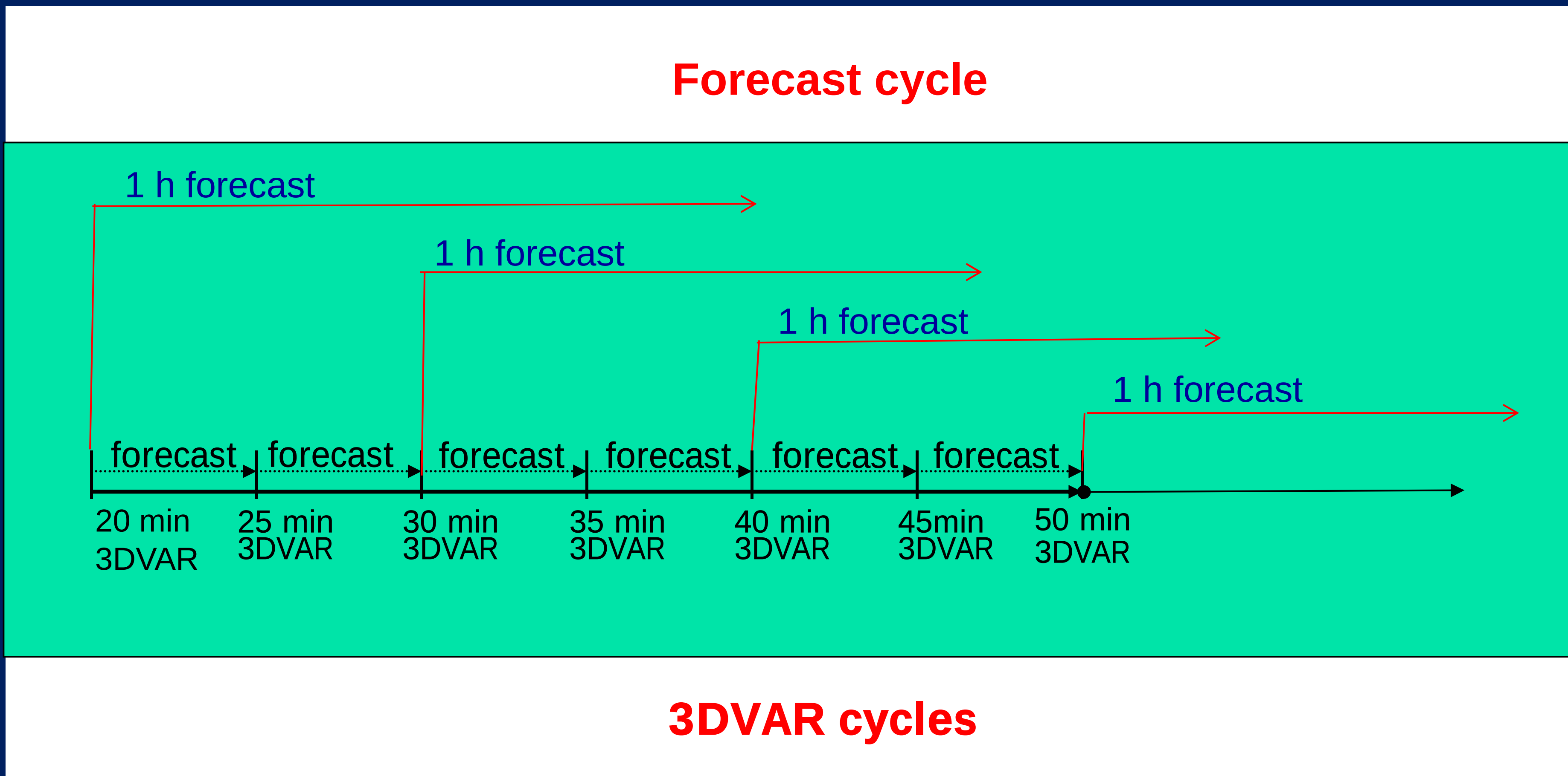
q_r (rain)



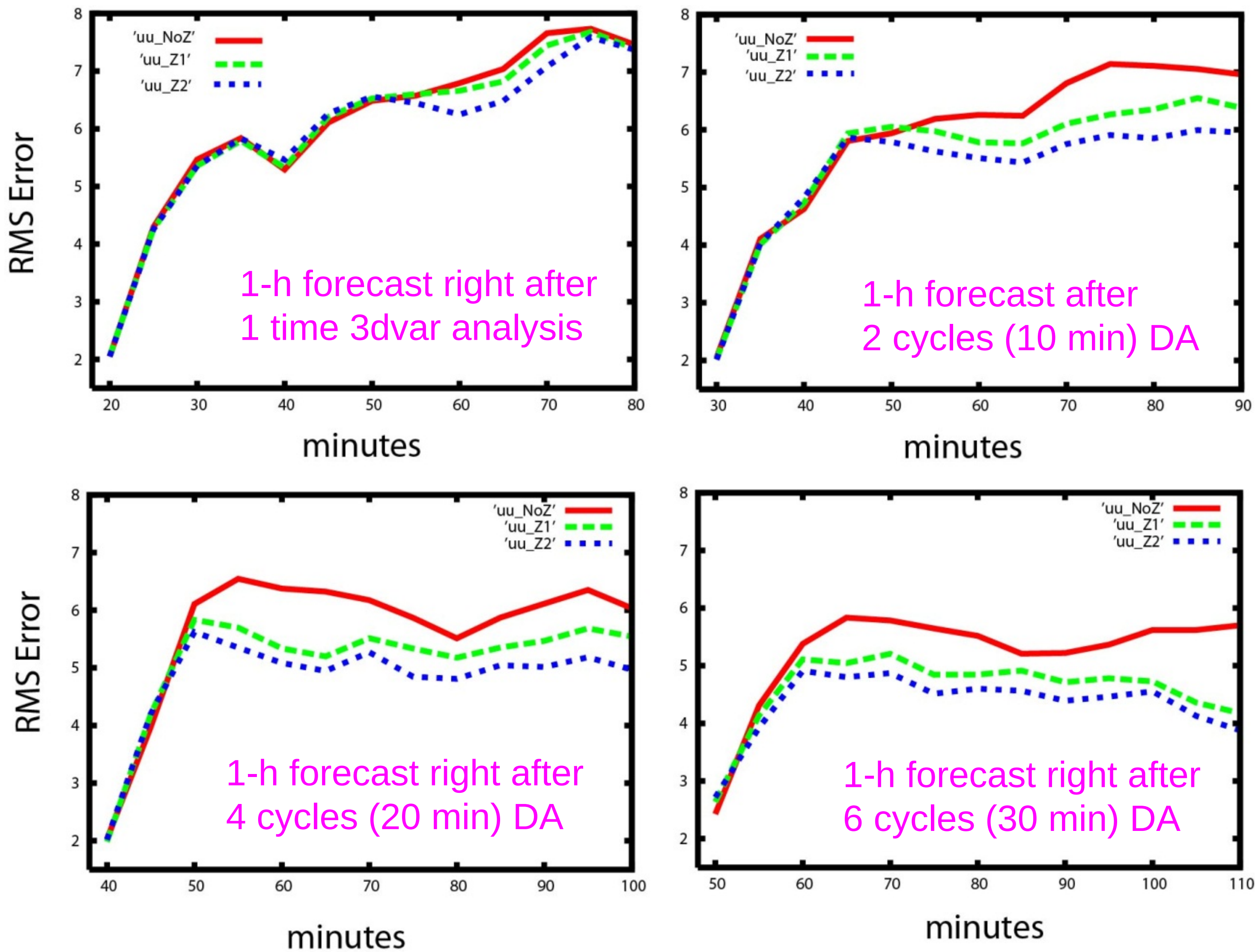
q_h (hail)

Results from Vr only, Vr&Z1 and Vr&Z2 suggest that smallest RMSEs occur when Vr&Z2 used.

Configuration of 1-h forecast experiment

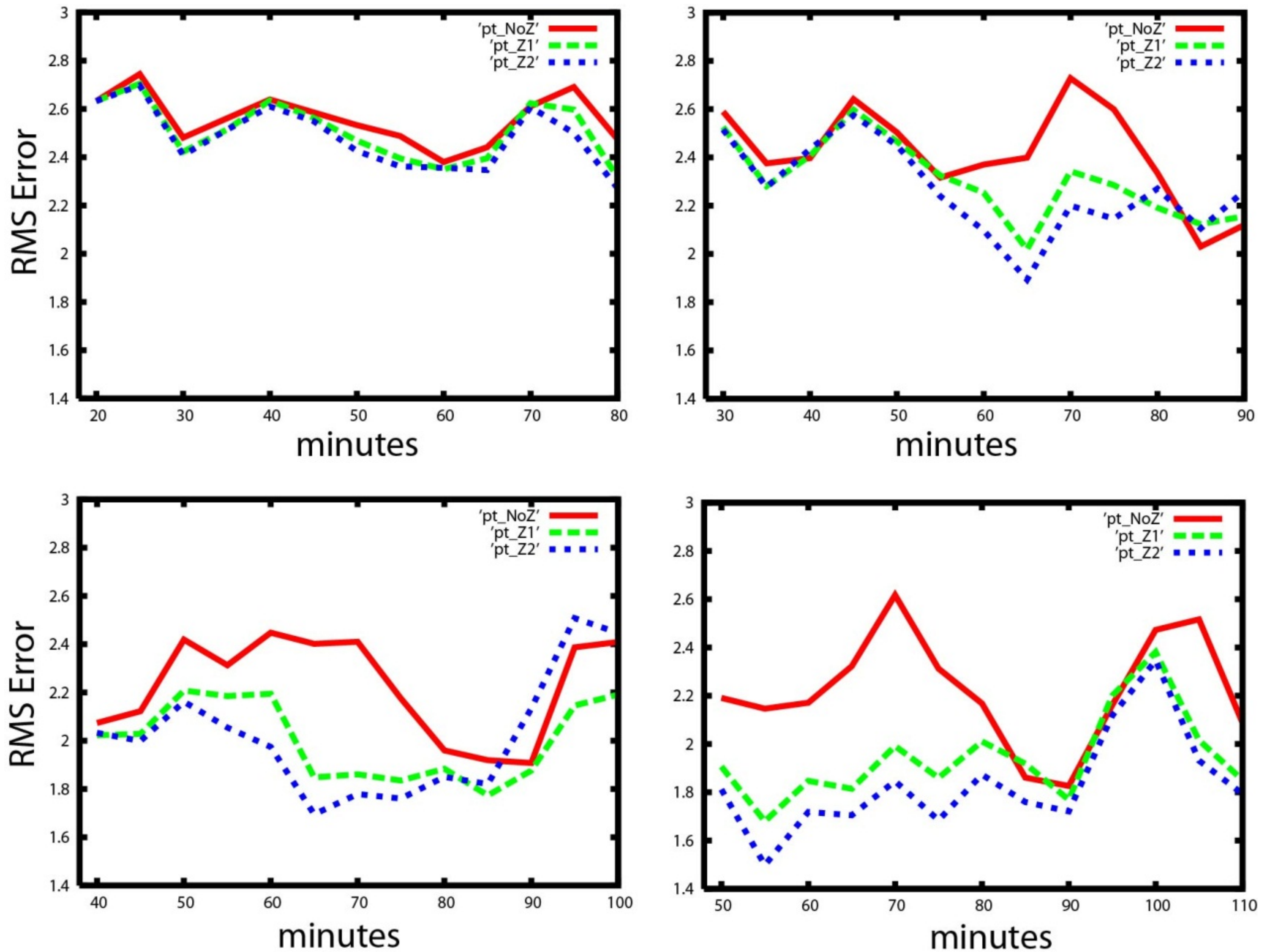


RMS errors for 3D u component of wind



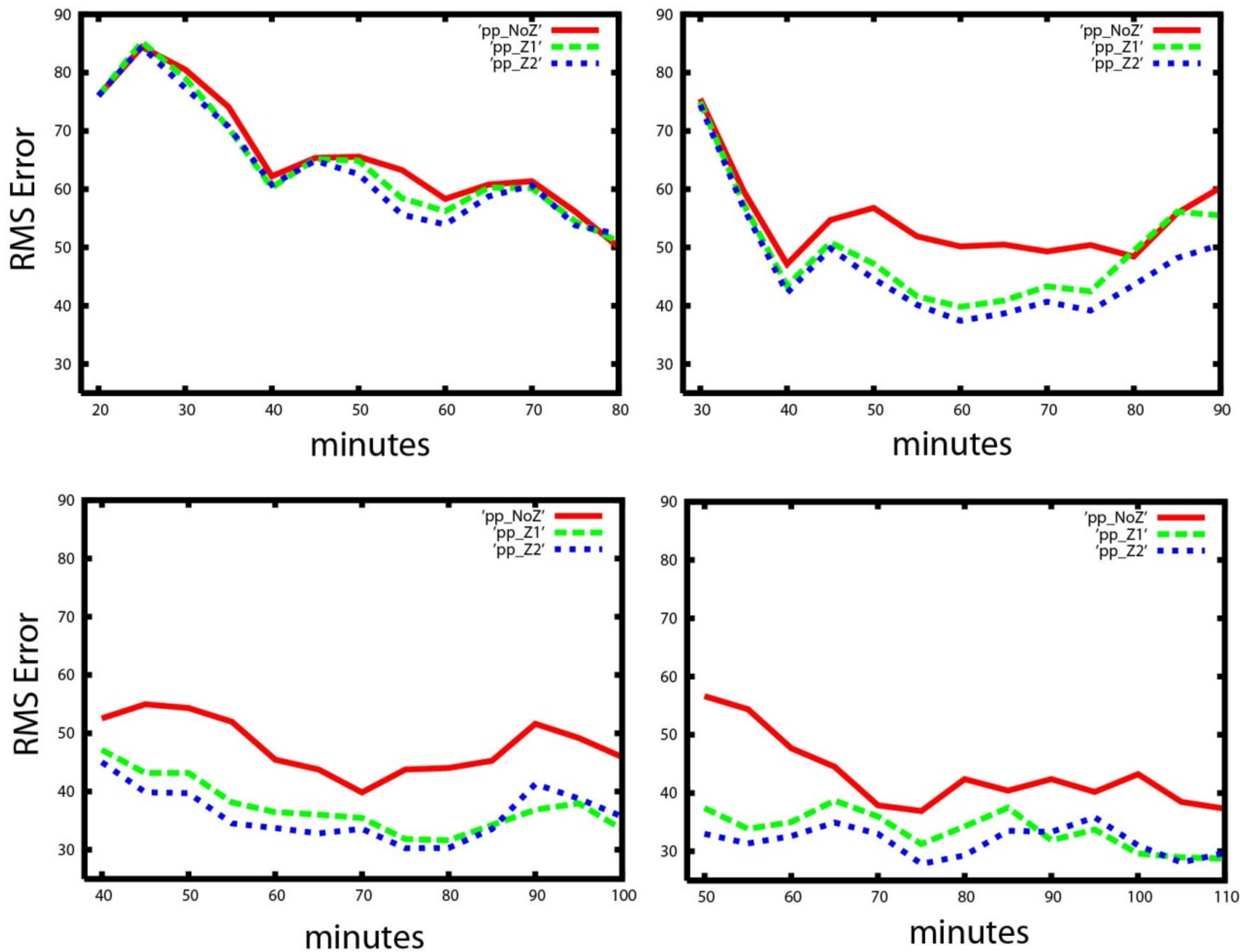
The smallest RMSEs with Vr&Z2

RMS errors for Perturbation Potential Temperature



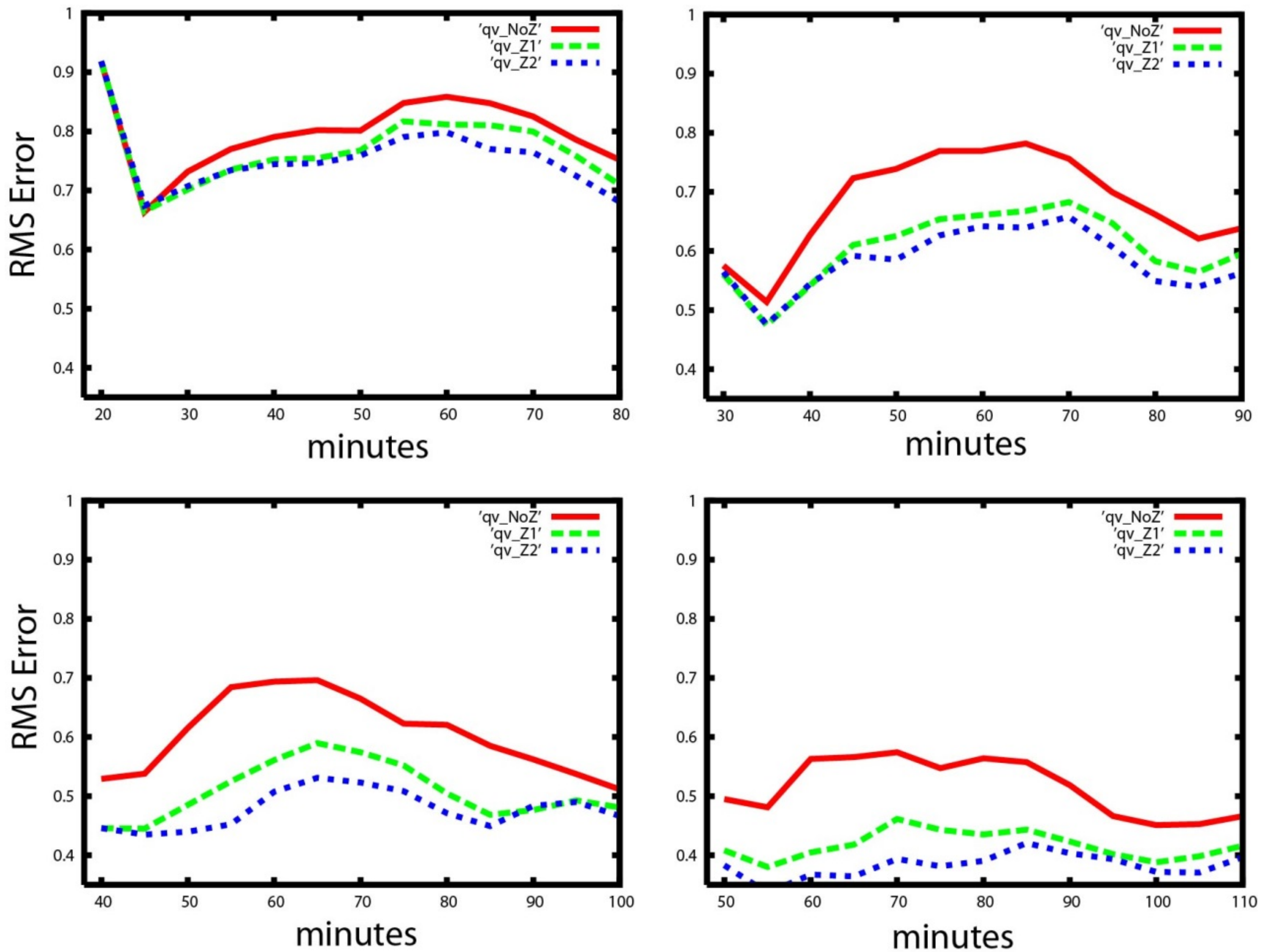
RMSEs for Vr only, Vr&Z1 and Vr&Z2

RMS errors for Perturbation Pressure



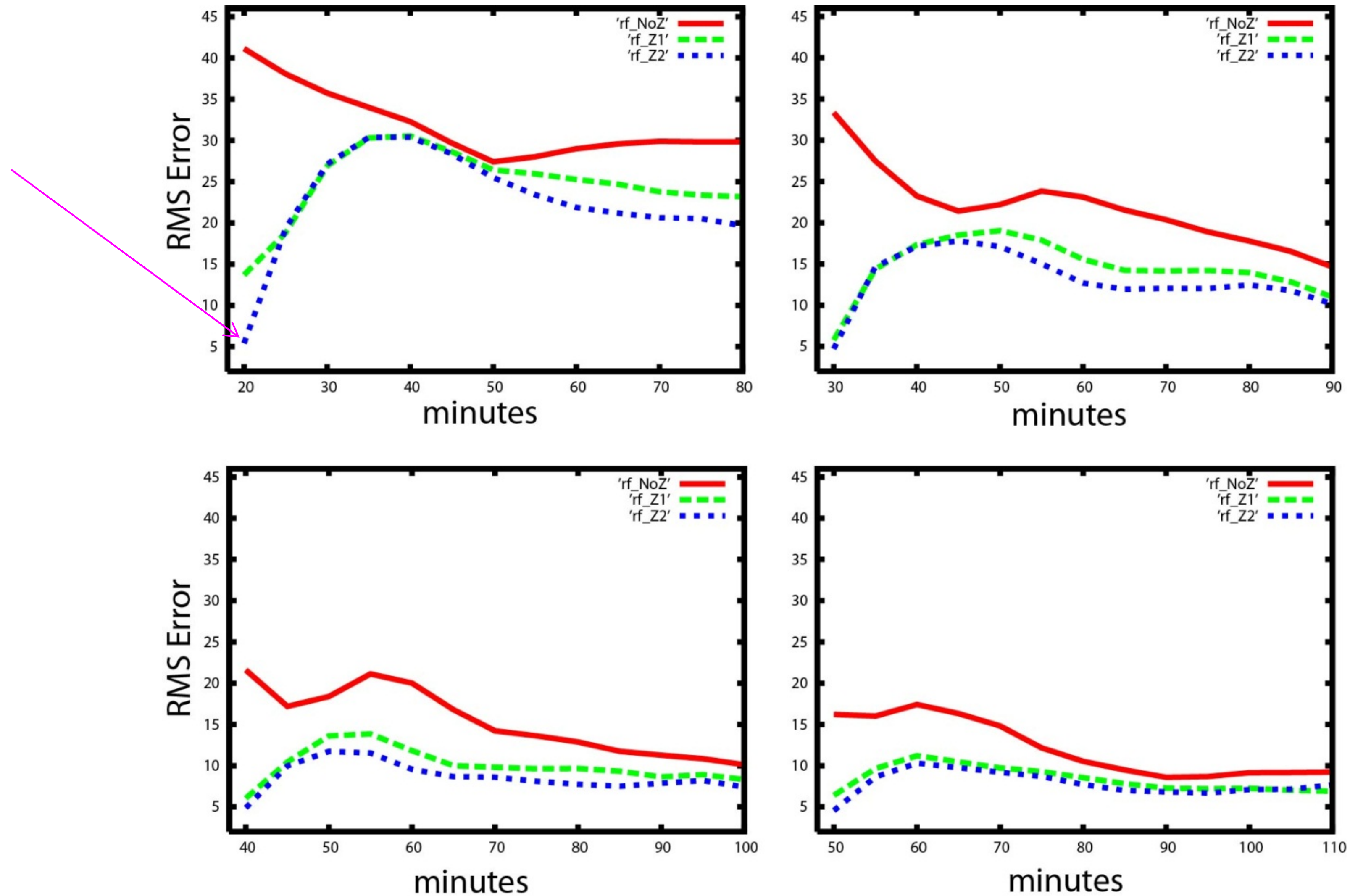
RMSEs for Vr only, Vr&Z1 and Vr&Z2

RMS errors for water vapor mixing ratio



1-h Forecast Results suggest that smallest RMSEs occur when Vr&Z2 used.

RMS Error for 3D Reflectivity fields (comparison of 3 schemes)



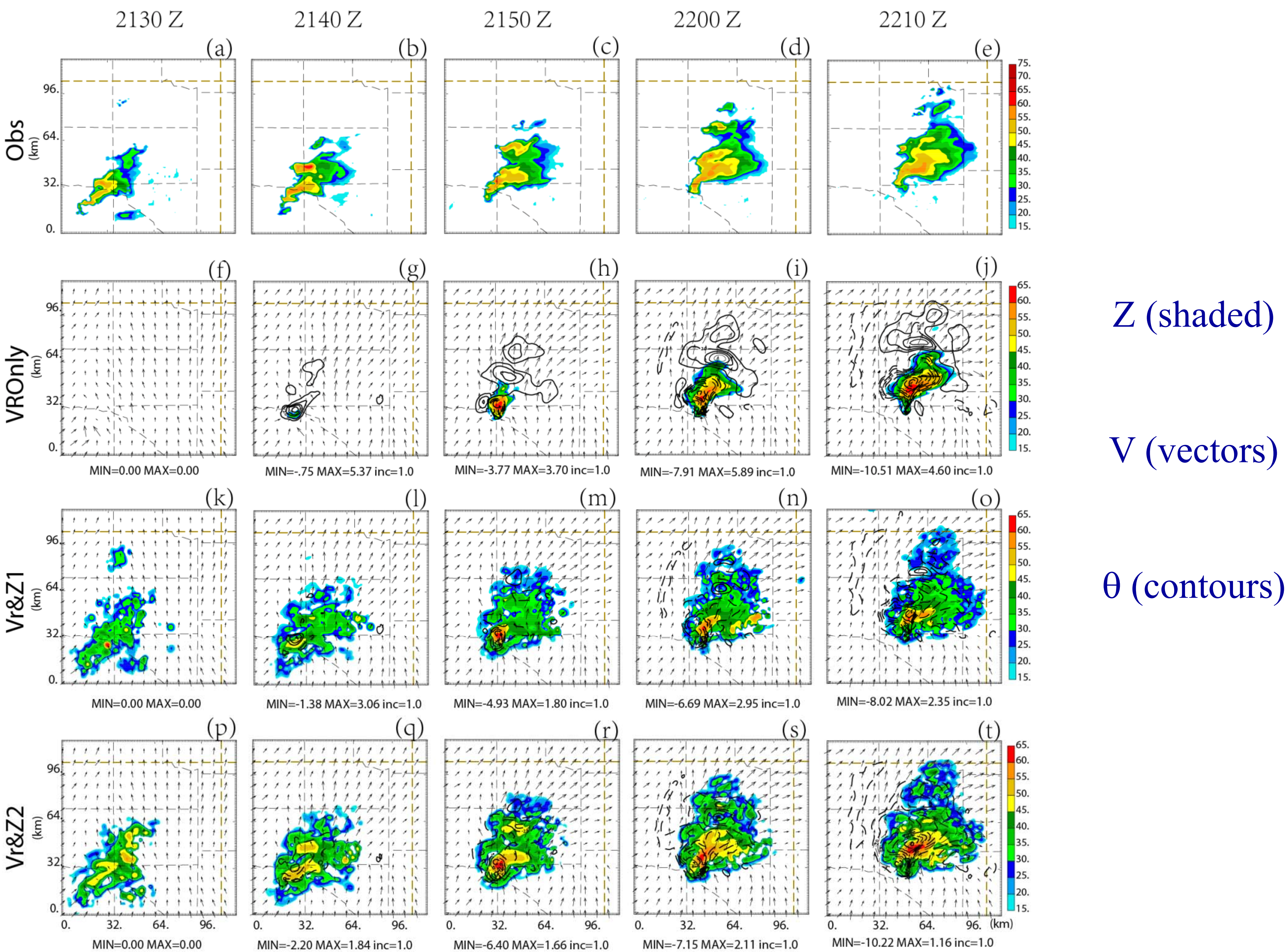
1-h Forecast Results suggest that smallest RMSEs

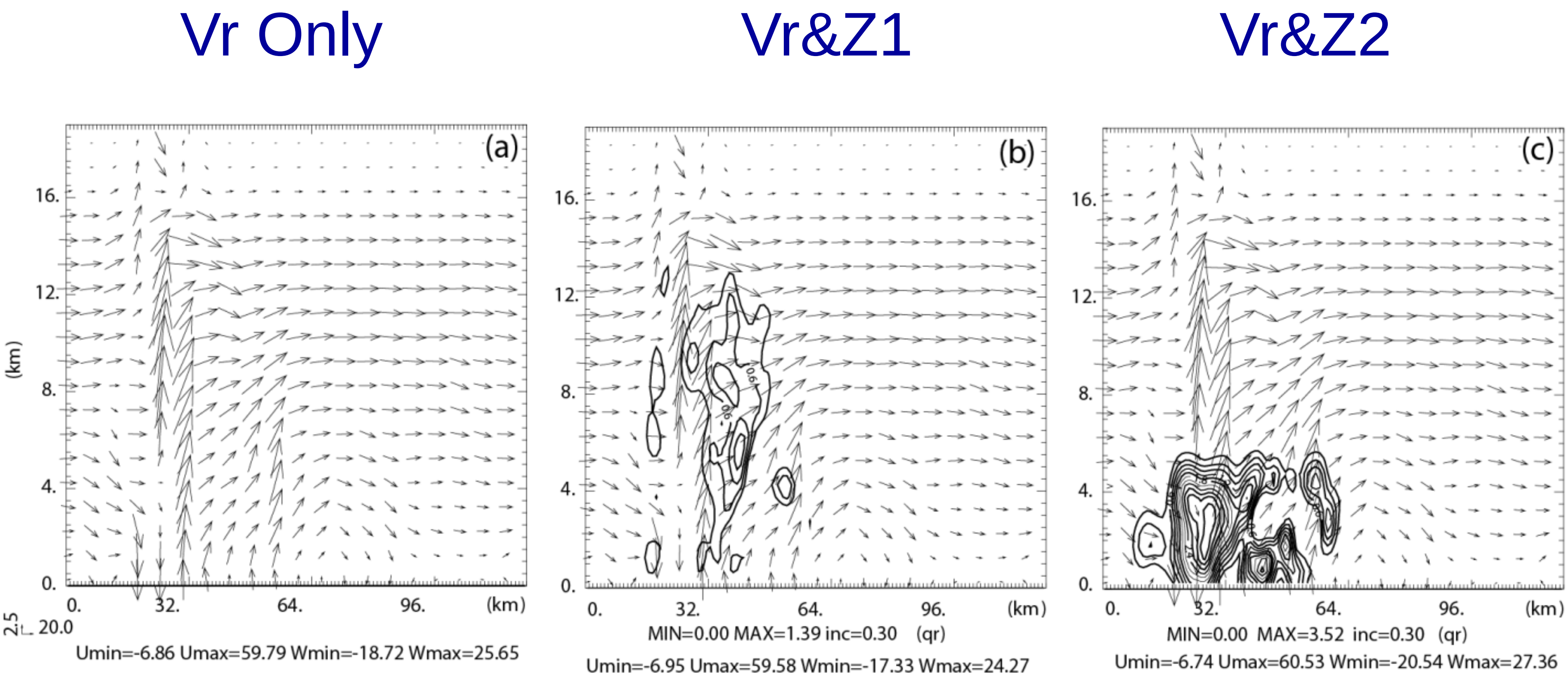
occur when Vr&Z2 used

May 8, 2003 OKC

Tornadic Supercell case

May 8, 2003 OKC Tornadic Supercell case





An x-z vertical slice for V-W (m s^{-1}) and q_r (contours)

at 2130 UTC 8 May 2003, OKC supercell storm

(First assimilation cycle for this case)

Summary & Future Work

I. Partitioning hydrometeor variables using a background temperature from a model is important for reflectivity assimilation.

II. Results show that the spin-up problem is greatly reduced when assimilating reflectivity.

III. In addition, the cold pool develops earlier and agrees better with the truth when using hydrometeor classification in both cases.

IV. More sensitivity tests are needed and we need to finish forecast experiments for the real data case.