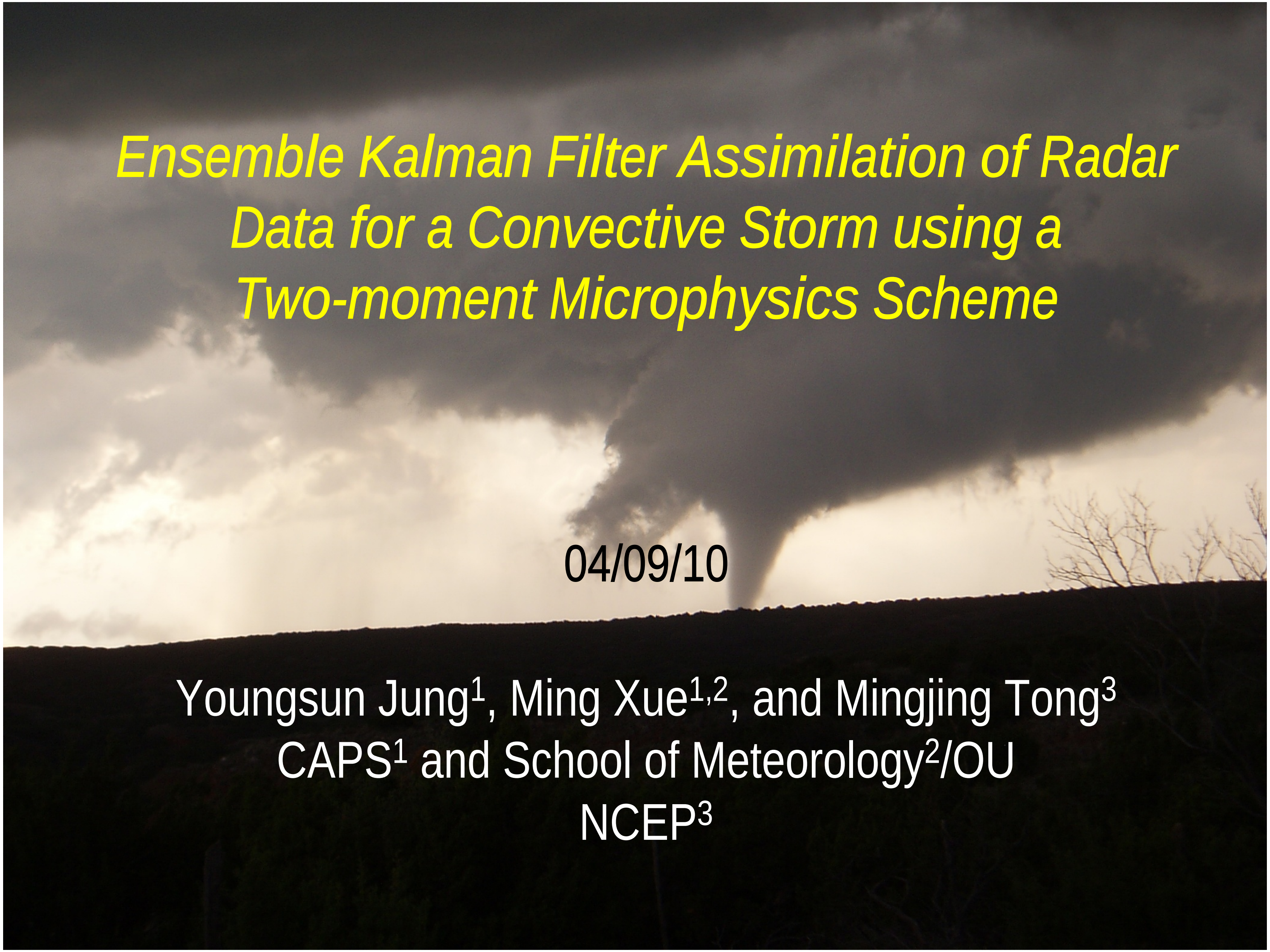

Ensemble Kalman Filter Assimilation of Radar Data for a Convective Storm using a Two-moment Microphysics Scheme

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Youngsun Jung[1], Ming Xue[1,2], and Mingjing Tong[3]
CAPS[1] and School of Meteorology[2]/OU
NCEP[3]

Outline

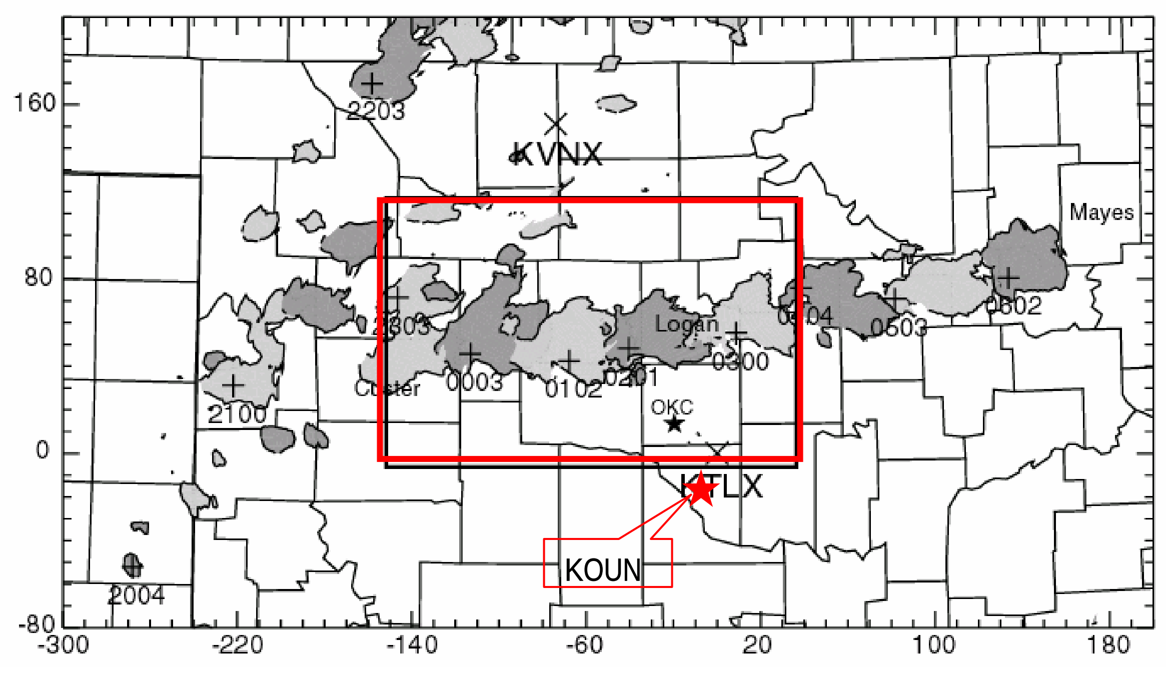
- Background
- Case overview: 29-30 May 2004 tornadic supercell storm
- Model and experimental design
- Results
- Summary and conclusion
- Future plan

Background

- For convective scale NWP, microphysics represent one of the most important physical processes.
- Single-moment (SM) parameterization is not capable of handling the change in shape of the DSD in time and space as a result of the size-sorting and other mechanisms.
- Dawson et al. (2010) and Jung et al. (2010) show that the double-moment (DM) schemes produce more realistic supercell storm structures than the SM schemes.
- Xue et al. (2010) show that the increased number of state variables associated with a DM scheme can be reasonably well estimated through OSSEs.

Case Overview

- Long-lasting tornadic thunderstorm (22:00 UTC May 29 to 07:30 UTC May 30)
- 11 tornadoes reports



From Tong (2006) Ph.D. Dissertation

Experimental setup

- The Advanced Regional Prediction System (ARPS) is used in both simulation and analysis.

- Physical domain is 180x120x16 km^3 ($\Delta x = \Delta y =$ 1 km, 40 vertical layers with stretched grid).

- Full model physics are included.

- External boundaries are created using the scaled lagged average forecasting (SLAF) technique (Kong et al. 2006).

- Microphysics scheme: double-moment of Milbrandt and Yau (2005):

  $q_c, q_r, q_i, q_s, q_h, Nt_c, Nt_r, Nt_i, Nt_s, Nt_h$

- 60 ensemble members initialized at 0000 UTC on 30 May 2004

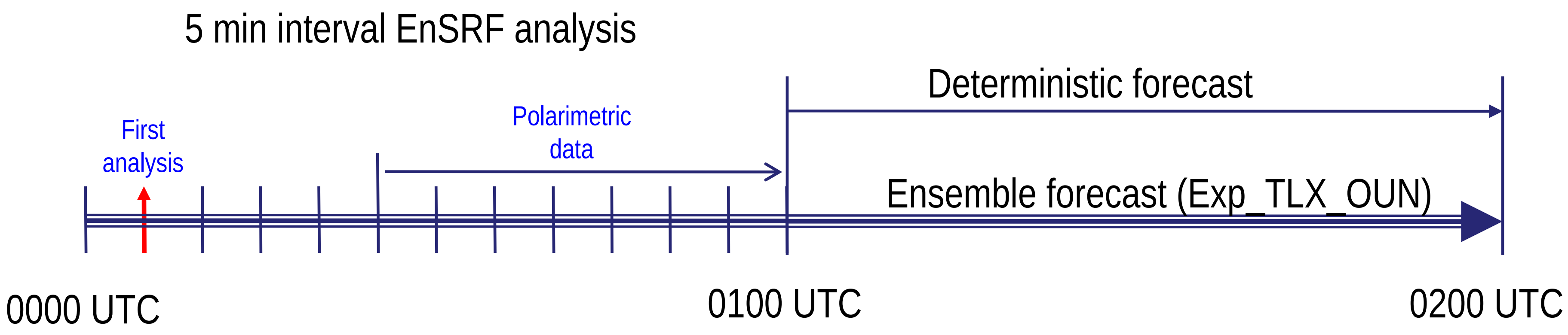
- EnSRF after Whitaker and Hamill (2006)

- Polarimetric radar observation operator: Jung et al. (2008a)

Experimental setup

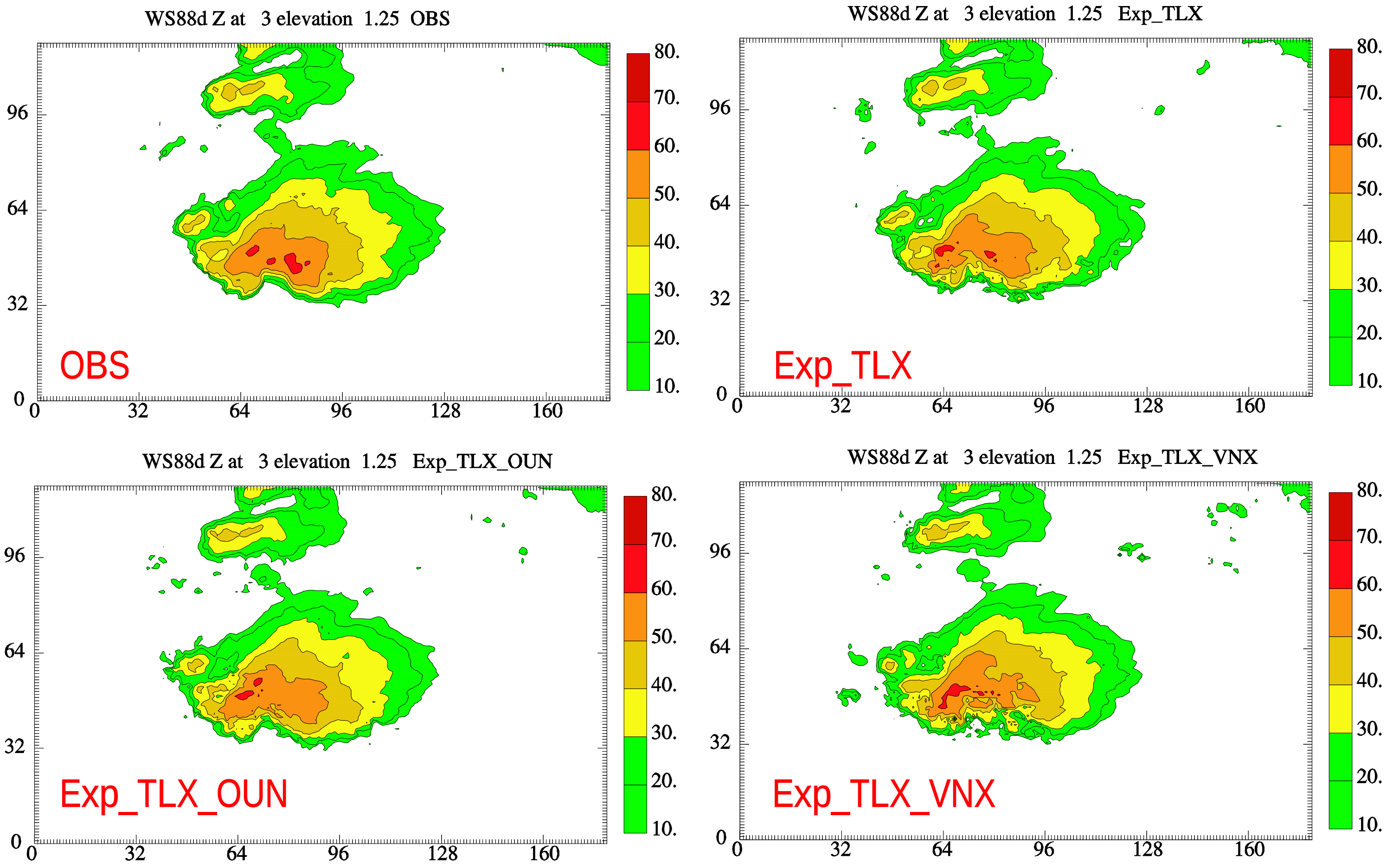
- Observations: V_r (Z > 5 dBZ) and Z_H (everywhere) from KTLX and KVNX, Z_{DR} and K_{DP} from KOUN
- The stochastic perturbations to *u, v, w, T, qv, qc, qr, qi, qs*, and *qh* are added to the first guess.
- Using 2D recursive filter in horizontal with 6 km length scale and a homogeneous Gaussian filter with a 3 km length scale in the vertical to generate initial ensemble.
- Shape parameters of gamma-DSDs of rain and hail are perturbed in the ensemble members.
- 15 % multiplicative inflation is applied to all model state except number concentrations.
- Additive noise (Dowell and Wicker, 2009) are added to *u, v*, and *T* with 0.5 m/s, 0.5 m/s, 0.5 K STD, respectively, during assimilation window.

Experiment setup



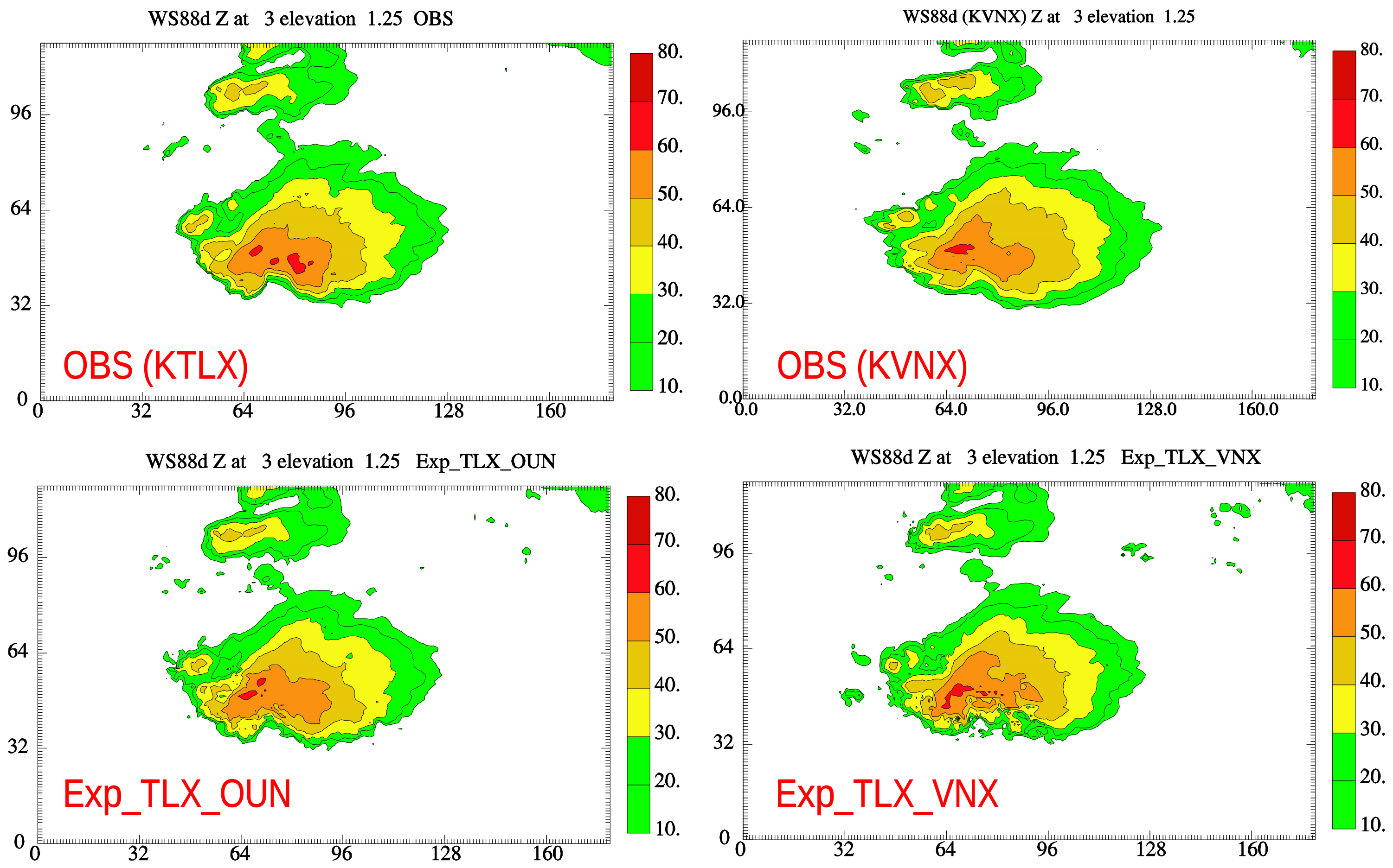
- Exp_TLX: KTLX only (*Z* and *Vr*)
- Exp_TLX_VNX: KTLX (*Z* and *Vr*) and KVNX ($Z \geq$ 5 dBZ and *Vr*)
- Exp_TLX_OUN: KTLX (*Z* and *Vr*) and KOUN ($Z_{DR} \geq$ 1.5 dB and $K_{DP} \geq$ 0.5 deg/km)

Reflectivity as viewed from KTLX at 60 min.

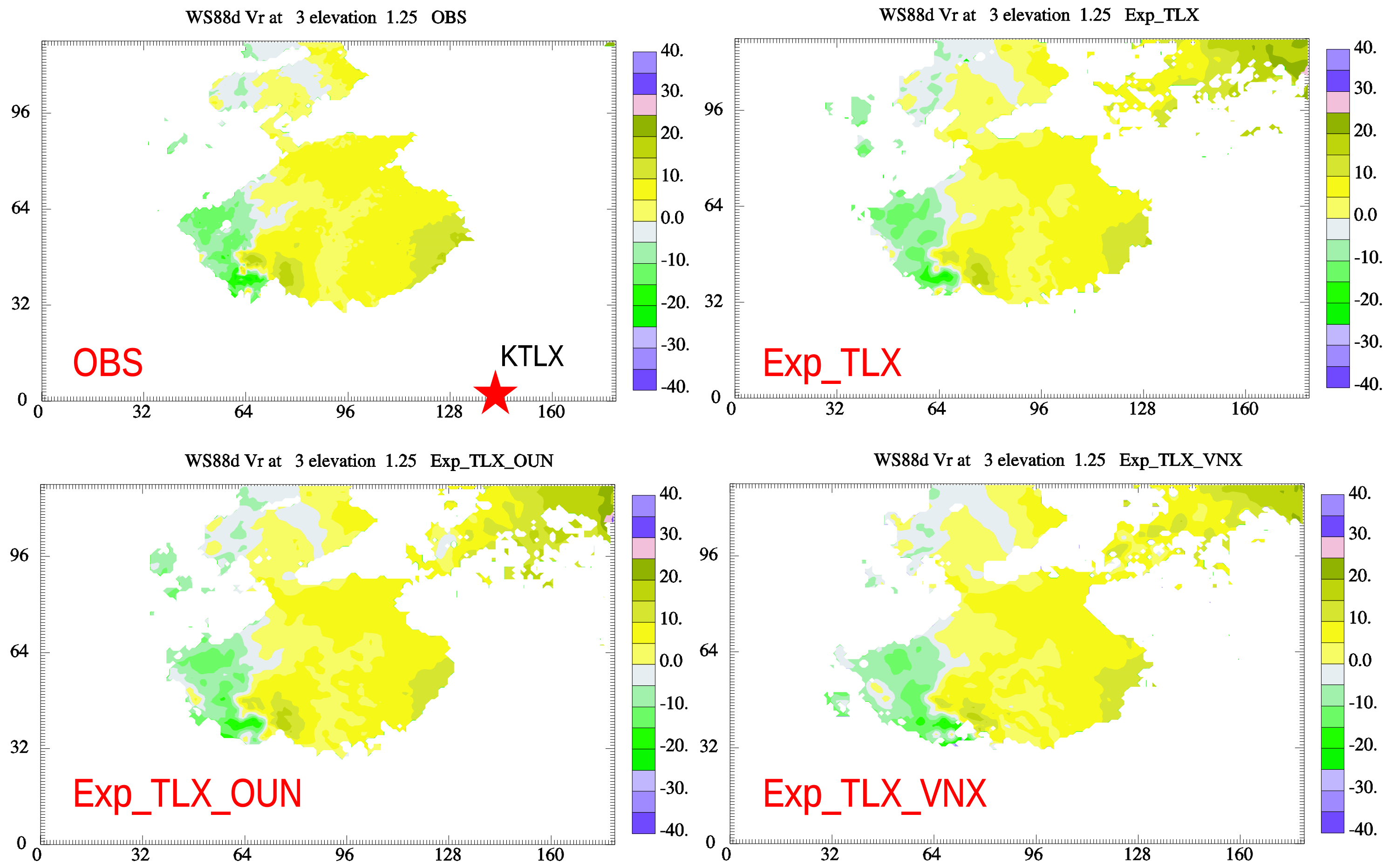


3rd elevation = 1.25 °

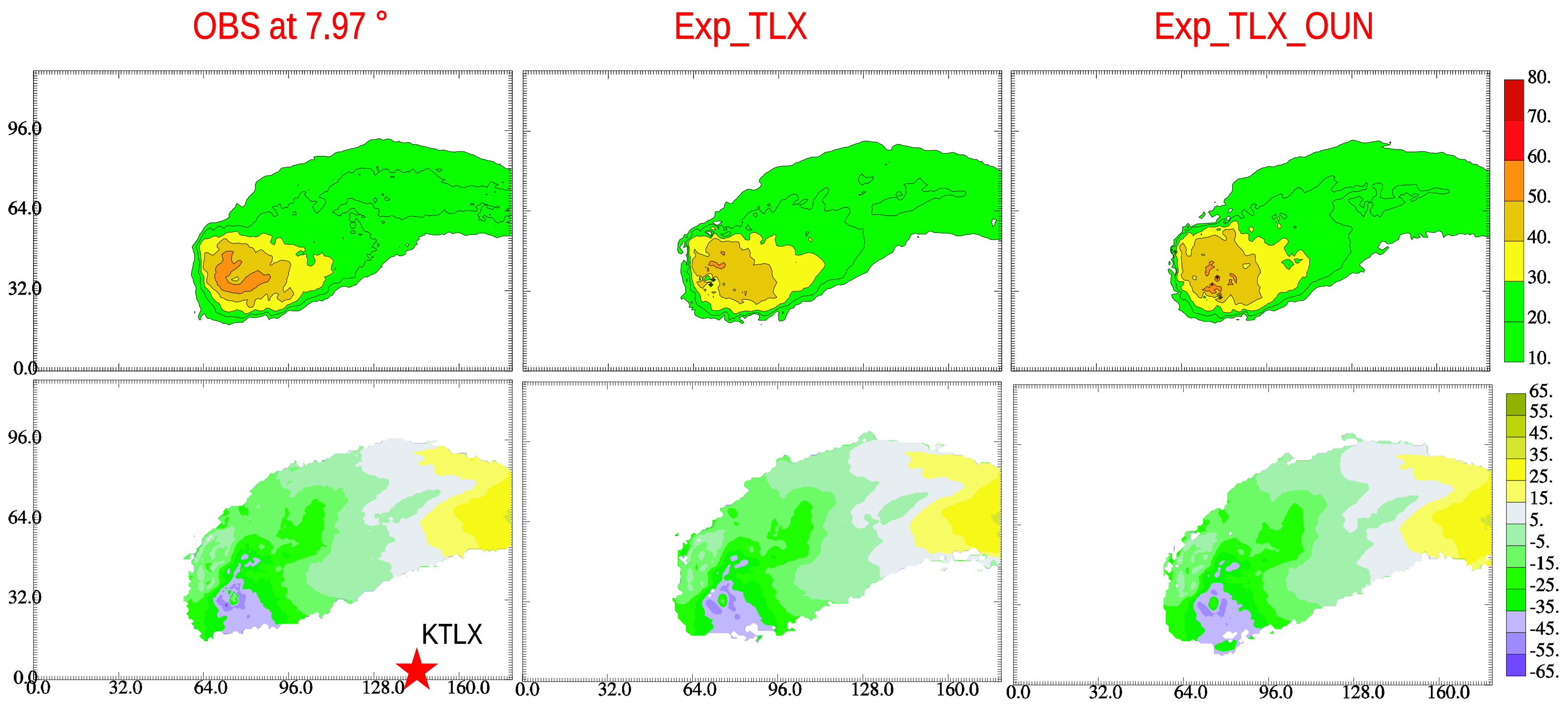
Reflectivity as viewed from KTLX at 60 min.



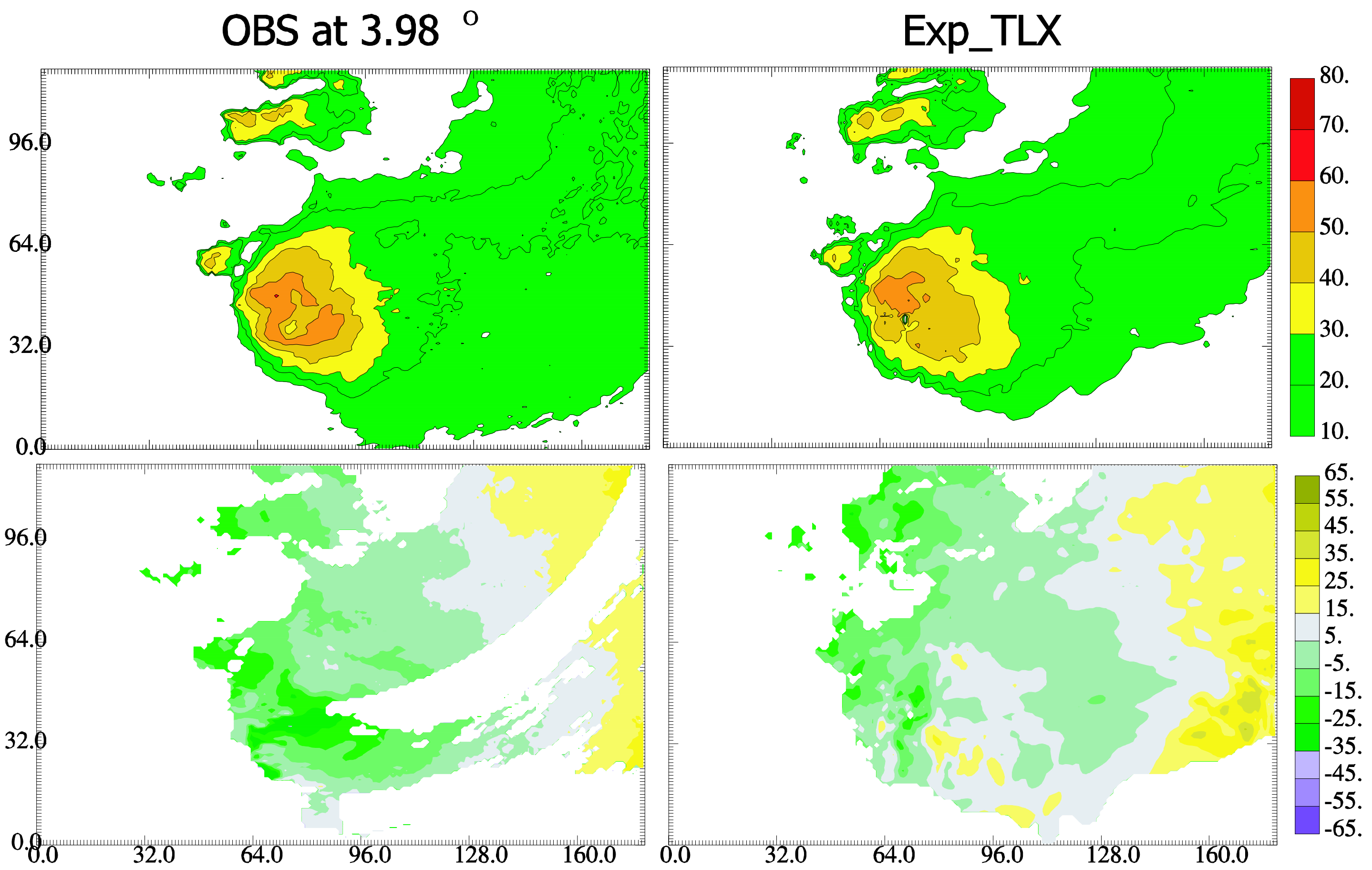
Radial velocity as viewed from KTLX at 60 min.



View from KTLX at 60 min.

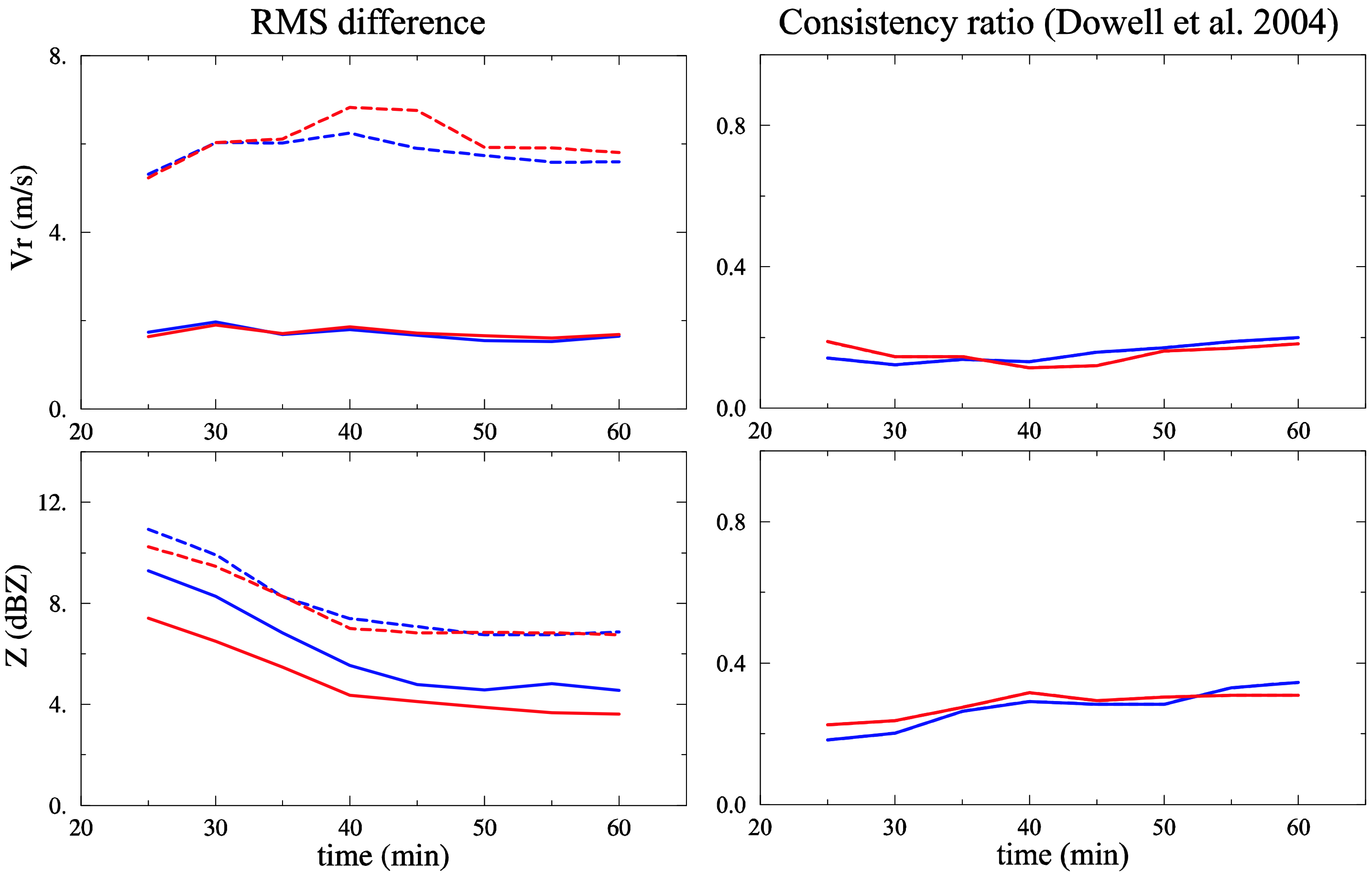


View from KVNX at 60 min.



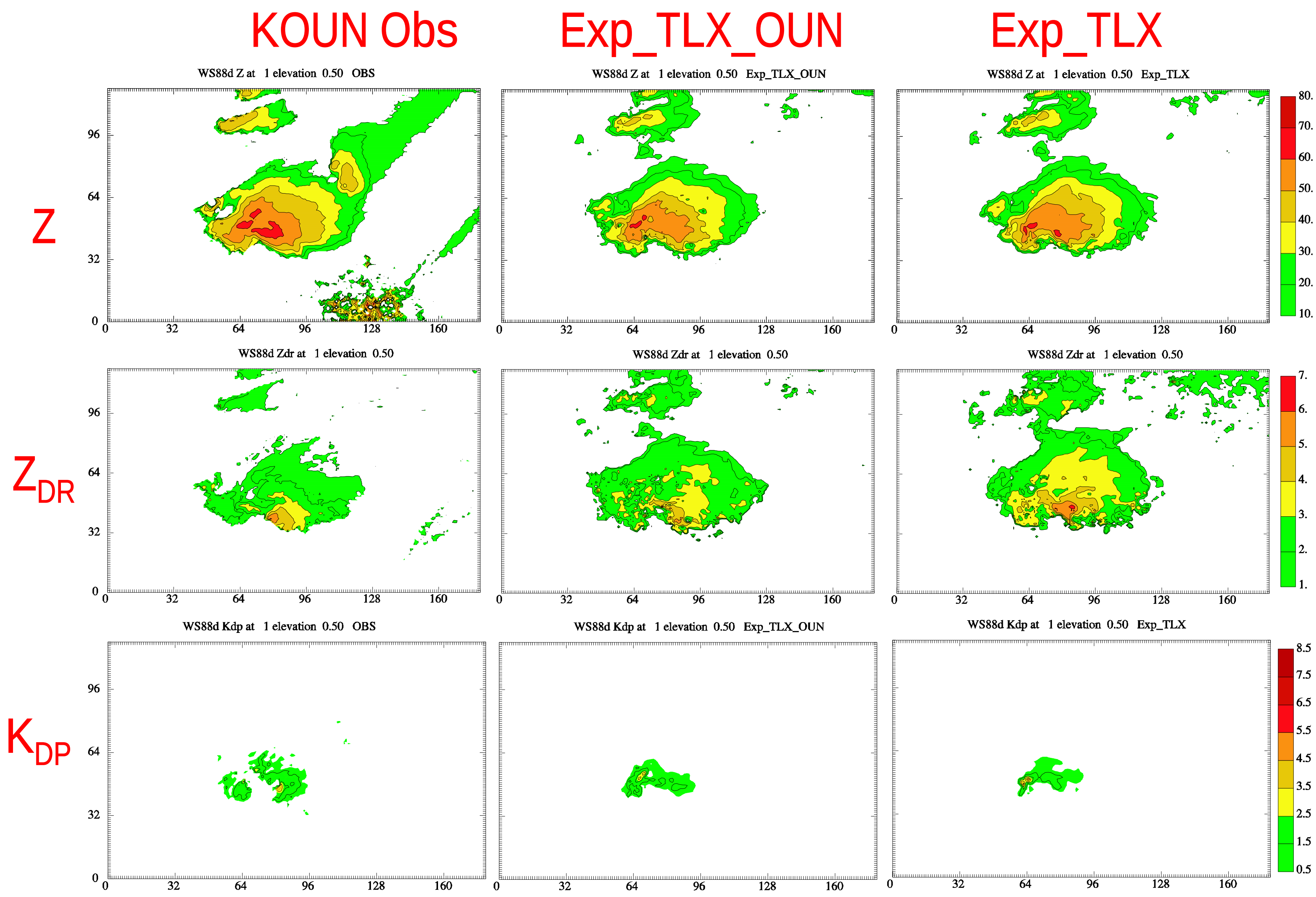
Diagnostics with respect to KTLX

blue: Exp_TLX **red: Exp_TLX_OUN**

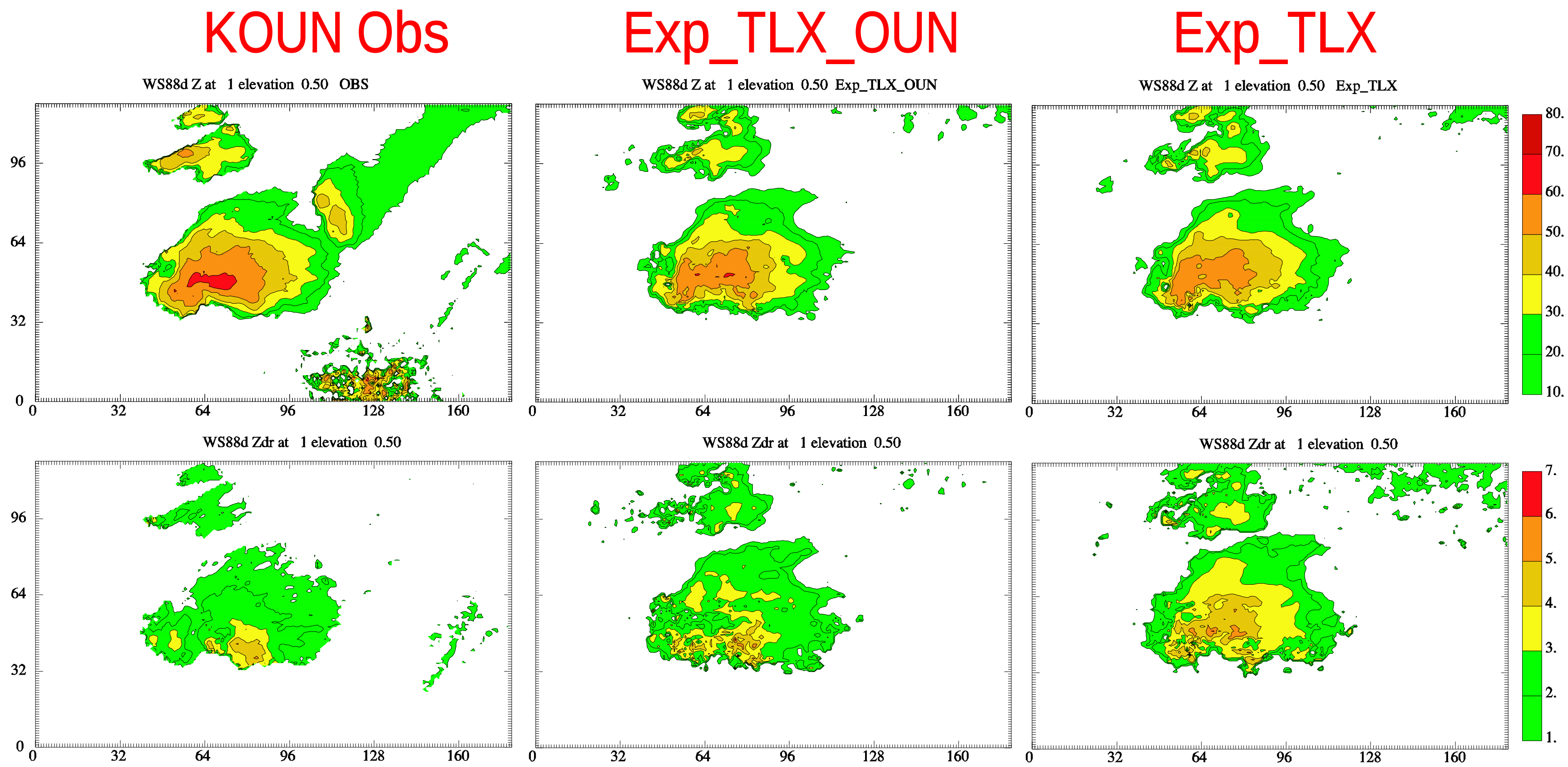


dashed: forecast solid: analysis

Z, Z_{DR}, and K_{DP} as viewed from KOUN at 60 min.

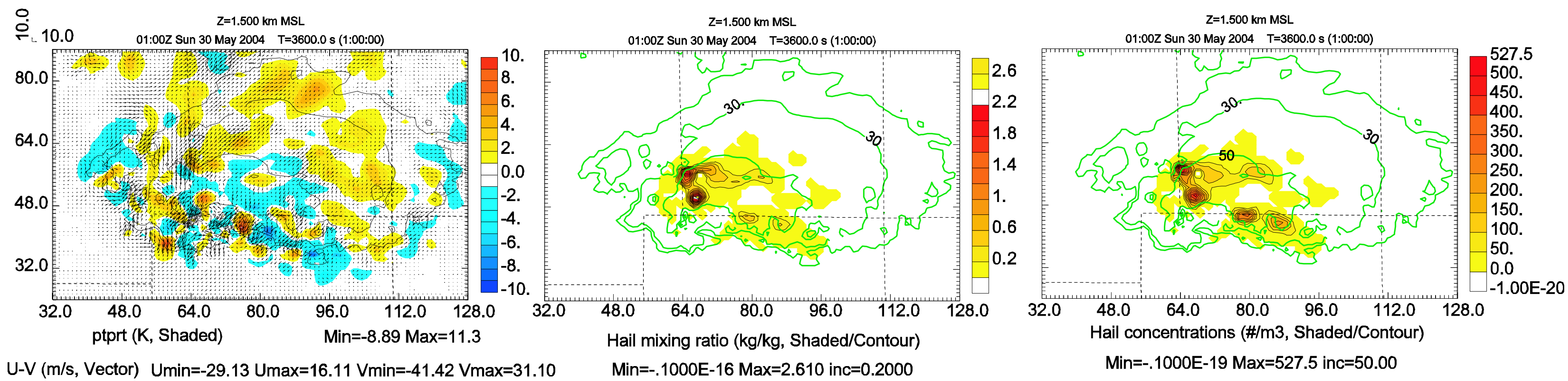


Z and Z_{DR} as viewed from KOUN at 50 min.

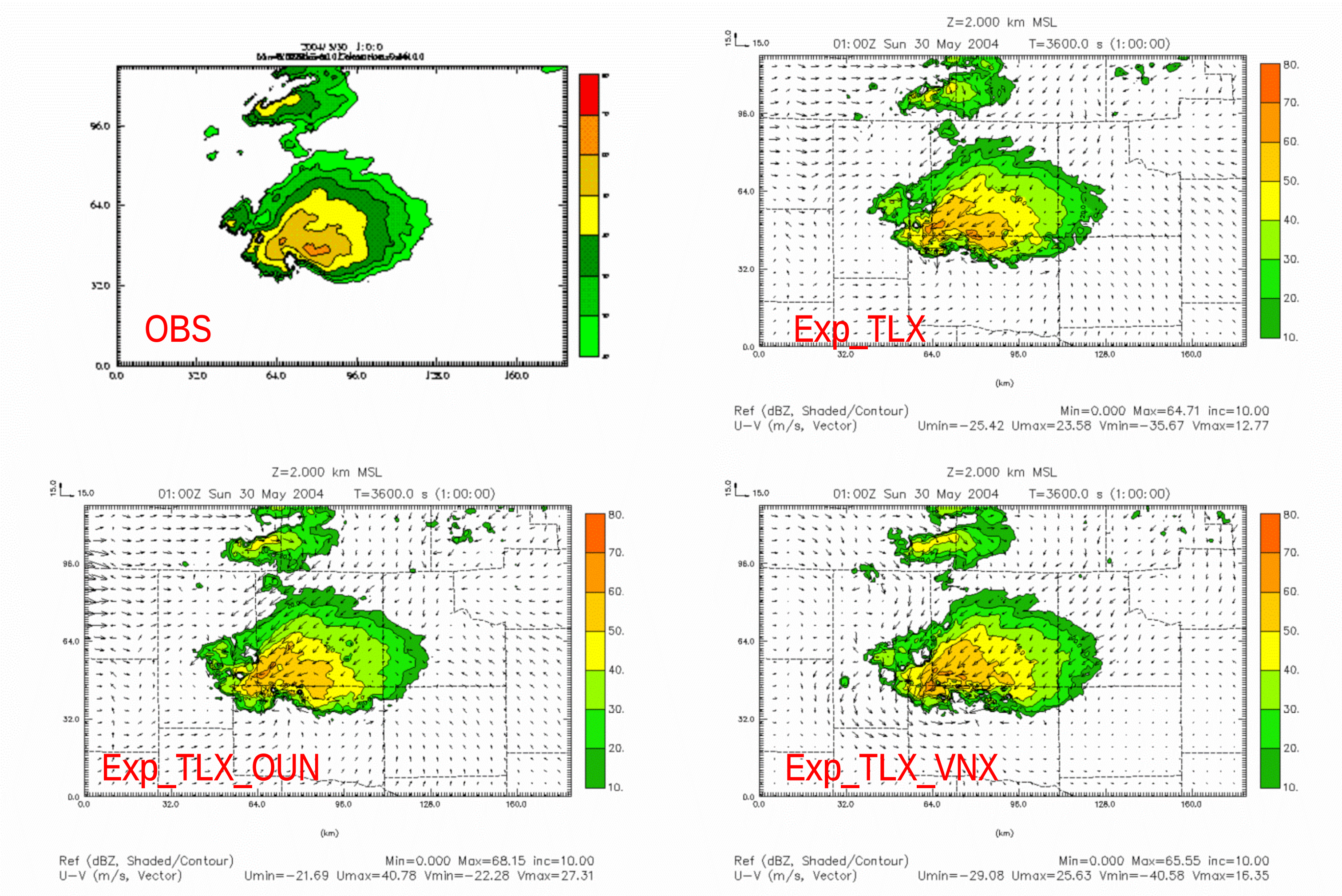


Comparison of Exp_TLX and Exp_TLX_OUN

$$x_{diff} = x_{Exp\_TLX} - x_{Exp\_TLX\_OUN}$$



60 min. deterministic forecast



Ensemble forecast

- Start from the ensemble analysis at 3600 sec of Exp_TLX_OUN

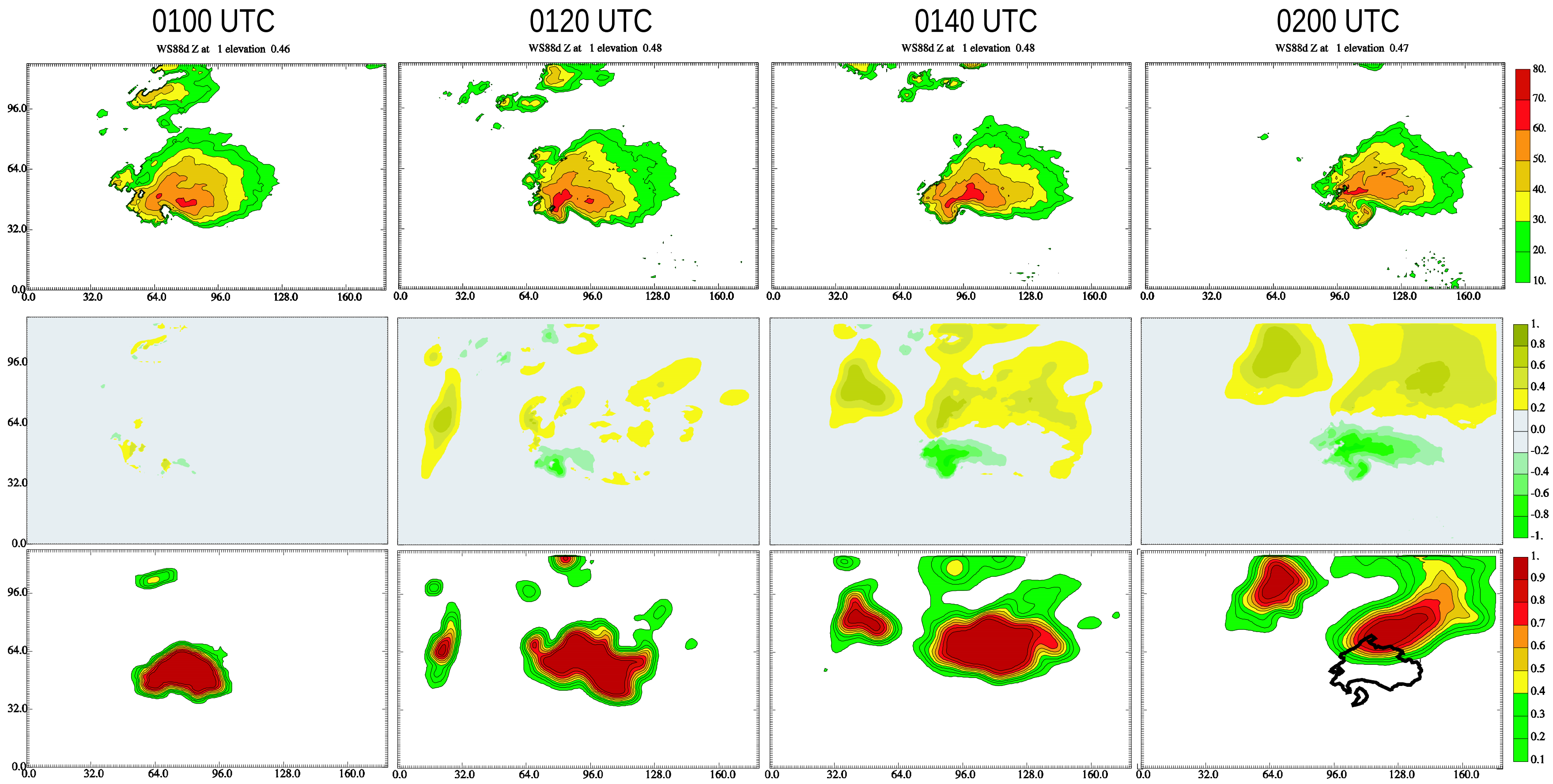
- A neighborhood method is used to compute probability with a 7x7 km^2 neighborhood and $Z_{threshold}$ = 40 dBZ.

- Normalized reflectivity difference (*NRD*):

$$NRD_{i,j,k} = \frac{1}{N \cdot M \cdot Z_{\max}} \sum_{m=1}^{M} \left(Z_{i,j,k,m}^{fcst} - Z_{i,j,k}^{obs} \right)$$

where N = # of ensemble member, M = # of grids in the neighborhood, Z_{max} ~ approximate maximum reflectivity difference (70 dBZ).

60 min. ensemble forecast



Top: OBS   Middle: NRD(forecast - obs)   Bottom: probability (Z > 40 dBZ)

Comparison with results using a SM scheme

- Lin et al. (1983) scheme

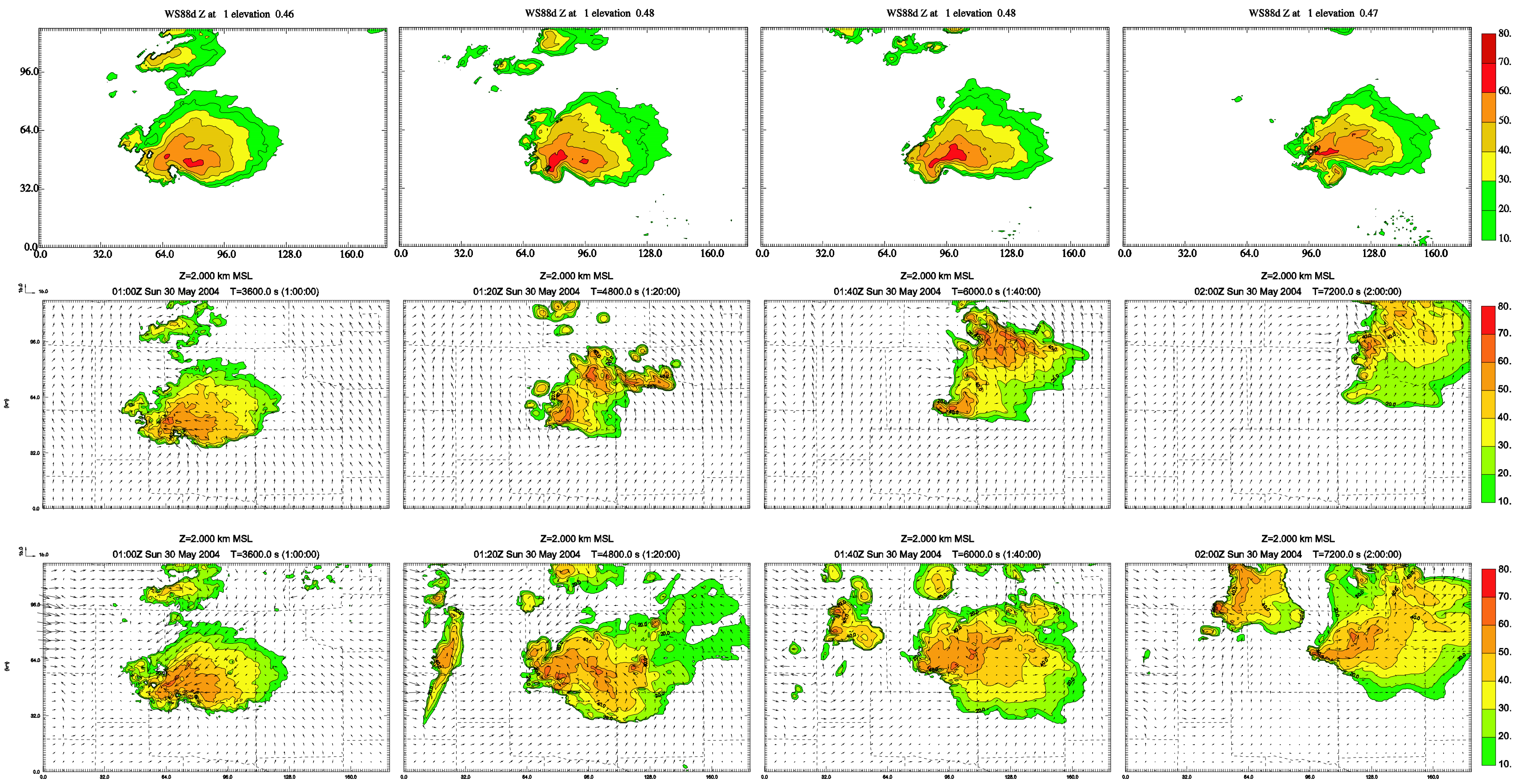
- Observations: *Vr* (Z > 5 dBZ) and *Z* (everywhere) from KTLX and KVNX

- Perturbed intercept parameters of rain, snow, and hail and densities of snow and hail following Tong and Xue (2008b).

- 50 % multipilicative inflation is applied to all model state .

- Additive noise to *u, v, w, T, qv, qc, qr, qi, qs*, and *qh* every other cycles during assimilation. The STD of random noise are 0.2 m/s for *u, v, w*, 0.2 K for *T*, and 0.1 g/kg for *qv, qc, qr, qi, qs, qh*.

Deterministic forecast using a SM scheme



Top: OBS Middle: SM Bottom: Exp_TLX_OUN

Summary and discussions

- Filter divergence due to under-dispersion is a major issue with real data cases. Multiplicative inflation, additive error, and parameter perturbations are used all together to prevent filter divergence. Errors in the environment and in the model that are not adequately accounted for are the likely causes.

- A good fit of analyzed reflectivity to the observations was obtained using a two-moment microphysics scheme.

- Experiment that assimilates Z_{DR} and K_{DP} from KOUN radar shows smaller RMS difference with respect to KTLX in analyzed reflectivity.

- Results suggest that polarimetric data may help improve the analysis and forecasting when using a multi-moment scheme.

- The reflectivity structure of the forecast storm using a DM scheme appears to compare better to the observations than that using a SM scheme.

- Errors in the forecast model, observation operator, storm environment, and observations may dominate the inaccuracy of the analysis and forecast. Much research is still needed in this area.


Thanks!
Any questions?