Comparisons of kinematical retrievals within a simulated supercell: Dual-Doppler analysis (DDA) vs. EnKF radar data assimilation

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Motivation

- High-resolution radar datasets (e.g., VORTEX-2) enable fine-scale supercell wind retrievals that are vital to illuminating supercell/tornado dynamics

- Knowledge of error characteristics of different wind retrieval techniques is needed to:
  - Select the most accurate method for a given dataset
  - Determine how much confidence to place in the analyses
  - Design mobile radar deployment and scanning strategies that mitigate wind retrieval errors

- **Maximizing the scientific value of kinematical/dynamical retrievals from mobile radar datasets requires understanding of limitations of different methods under different scenarios**

Primary Questions

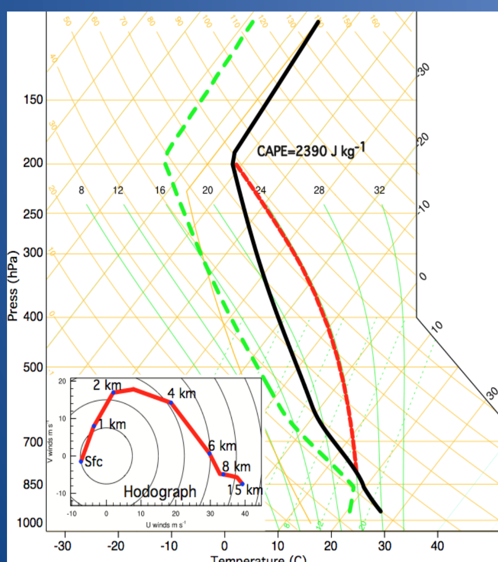
- When **dual-radar** data are available, does EnKF produce better wind estimates than DDA?
  - Or do model/IC/EnKF errors obviate advantage of constraining analysis with NWP model?
- When only **single-radar** data are available, can EnKF produce DDA-quality analyses?
  - Or is the solution too underdetermined?

OSS Experiments

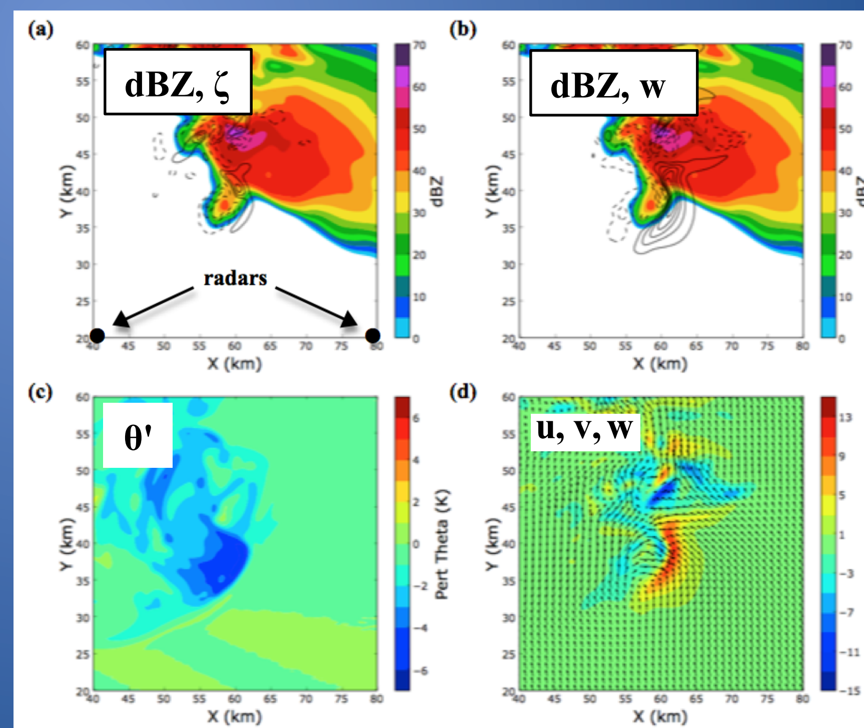
- Simulate supercell using NSSL Collaborative Model for Multiscale Atmospheric Simulation (NCOMMAS)
- Synthesize mobile radar V^{obs}, Z^{obs}
  - Storm-topping pattern, 2.5 min volume scans
- Input observations to:
  - NCOMMAS EnKF system
  - 3D-VAR DDA technique
- Compare wind analyses from the two methods
  - 2 vs. 1 radar
  - good vs. poor radar positioning
  - perfect (2-moment) vs. imperfect (LFO) microphysics

Supercell simulation

- NCOMMAS: nonhydrostatic, compressible numerical cloud model
- Roughly 100 × 100 × 20 km domain; Δ = 200 m
- Dual-moment microphysics (Mansell et al. 2010)



t = 60 min, *z* = 1 km



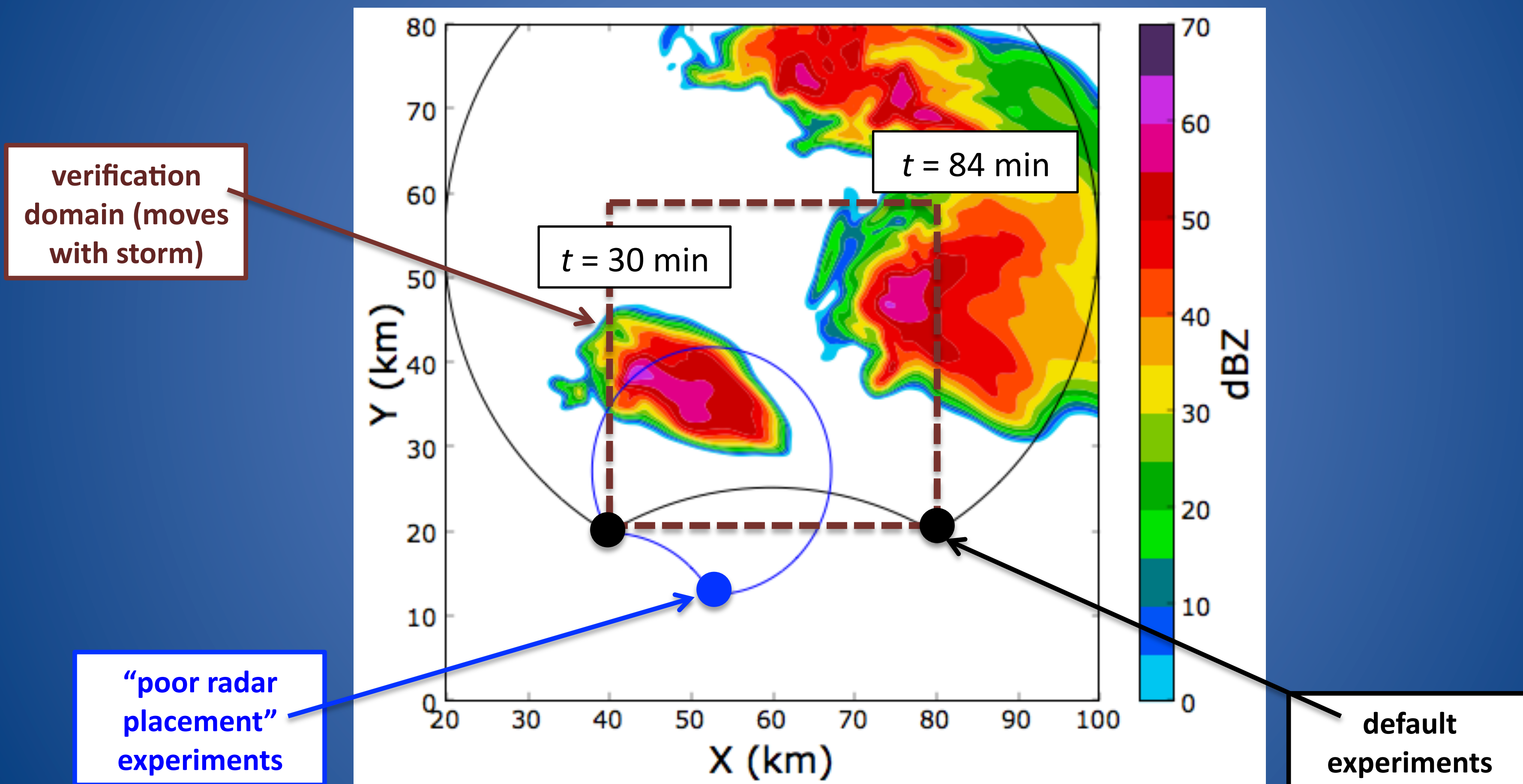
EnKF configuration

- Ensemble square root filter
- 40 members
- Δ = 600 m (model error)
- Data assimilated every 2 min from *t* = 30 min
- Ensemble spread maintenance:
  - additive noise (Dowell and Wicker 2009)
  - bubbles added where $Z^{obs} - Z^{ens} > 30$ dBZ

DDA Technique

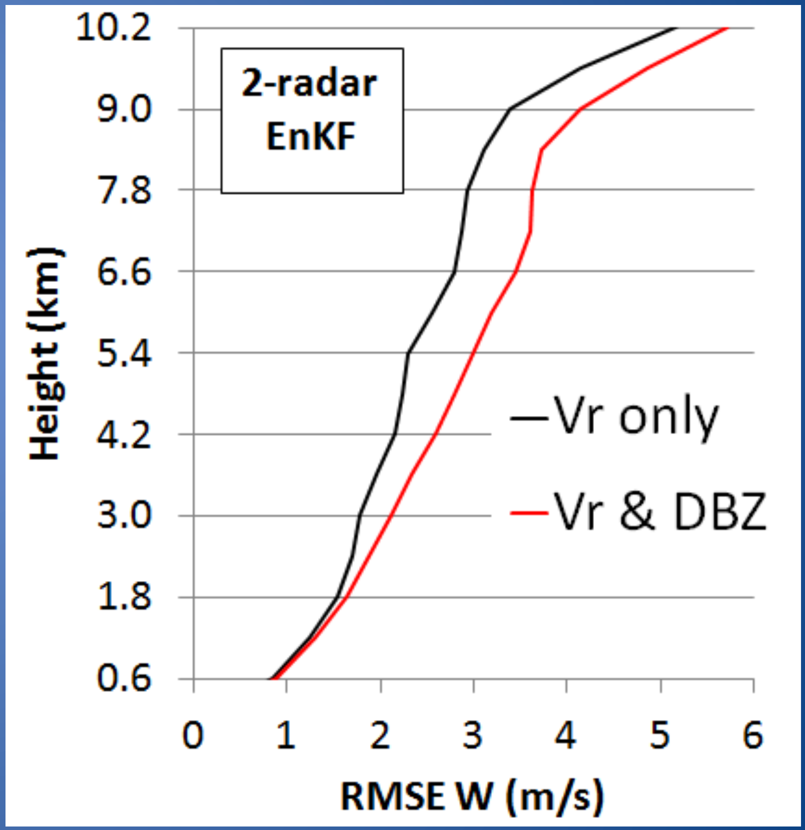
- 3D-VAR method (Shapiro et al. 2009; Potvin et al. 2011)
- Data, mass conservation, smoothness constraints weakly satisfied
- Impermeability exactly satisfied at surface
- Δ = 600 m; domain = 40 × 40 × 13.8 km (matches verification domain)

Experiment Domains



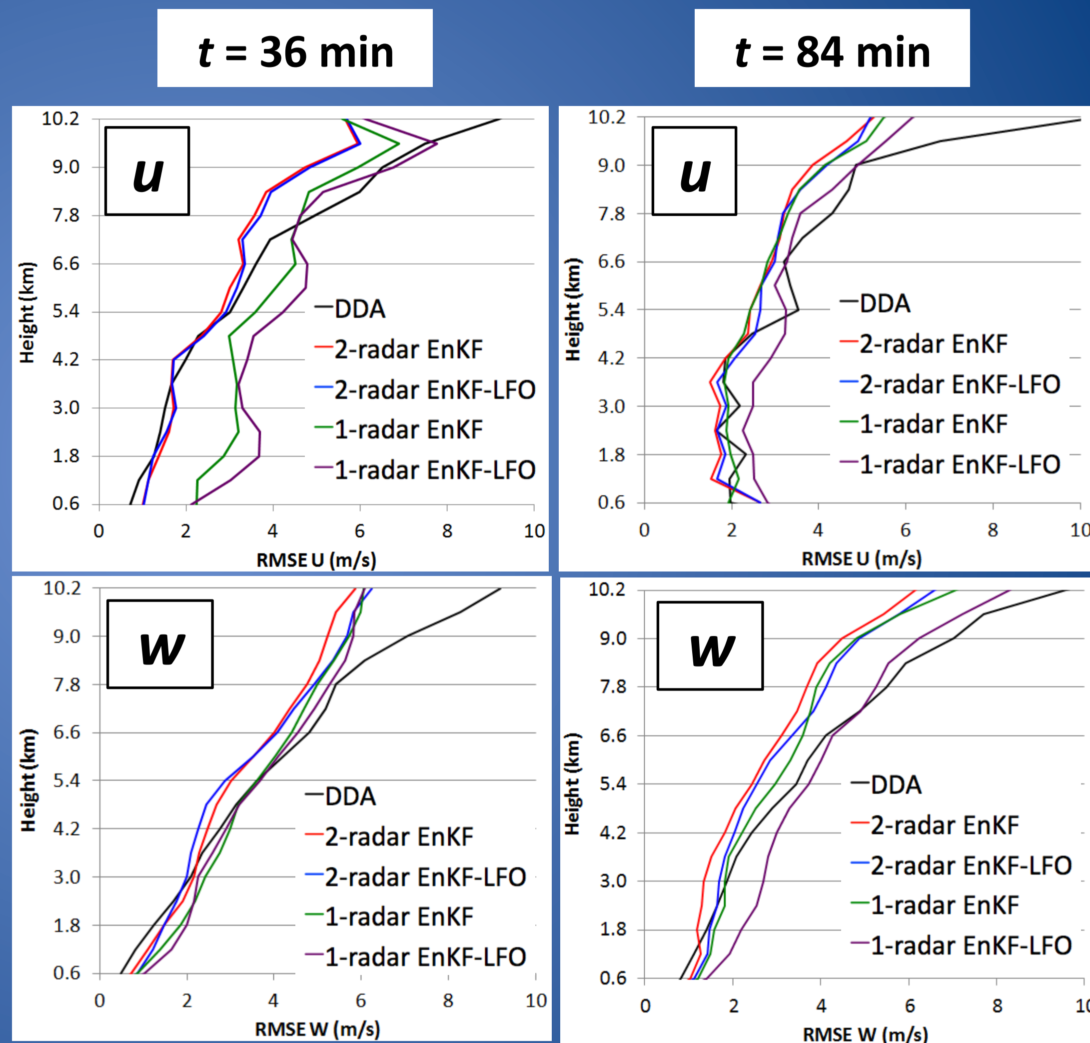
Reflectivity Assimilation

- Only helped single-radar EnKF; only V^{obs} assimilated in remaining experiments
- Improvement diminished by
  - – model errors
  - – non-Gaussian-distributed errors

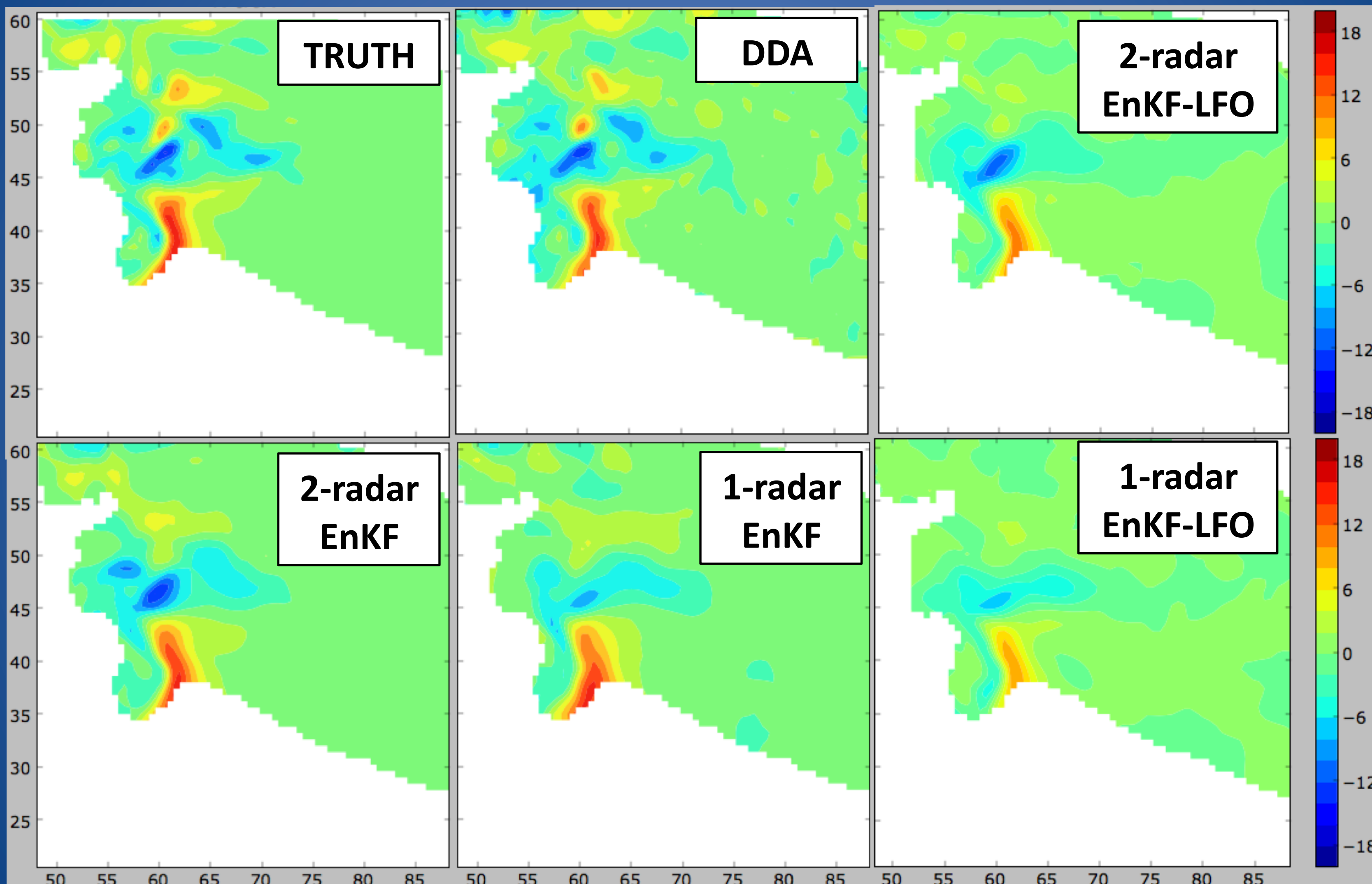


Vertical RMSE profiles

- 2-radar EnKF wind analyses insensitive to microphysics errors
- EnKF does not improve upon DDA at low levels
- EnKF errors increase less rapidly with height
- At upper levels, even 1-radar EnKF-LFO better than DDA



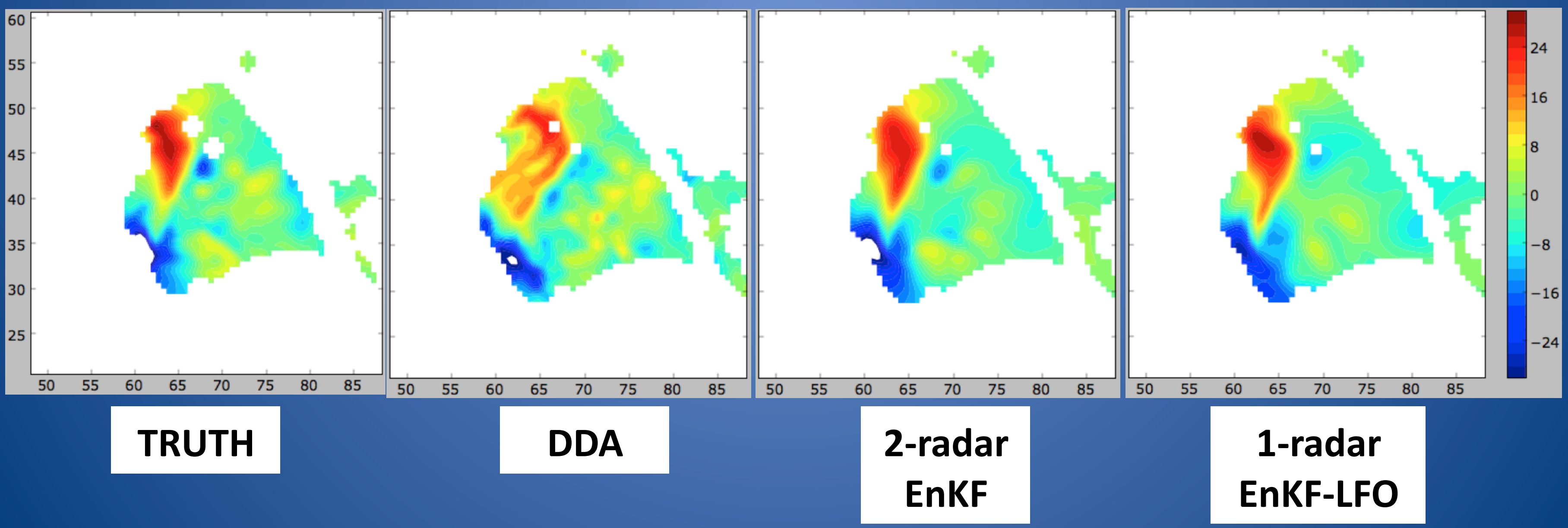
w at *t* = 60 min, *z* = 1.2 km



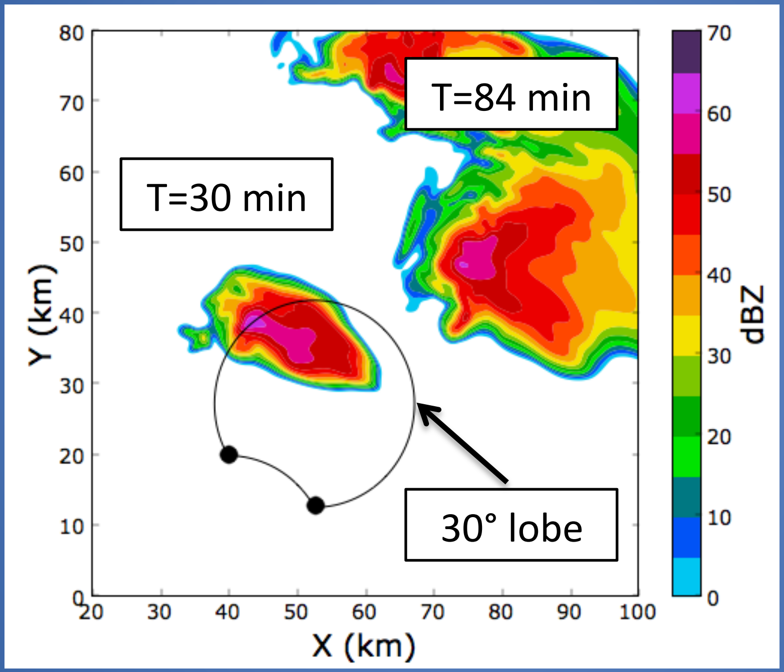
Non-simultaneity errors

- EnKF displacement errors and (at later times) pattern errors are much smaller than DDA errors aloft

***v* at *t* = 60 min, z = 9.6 km**

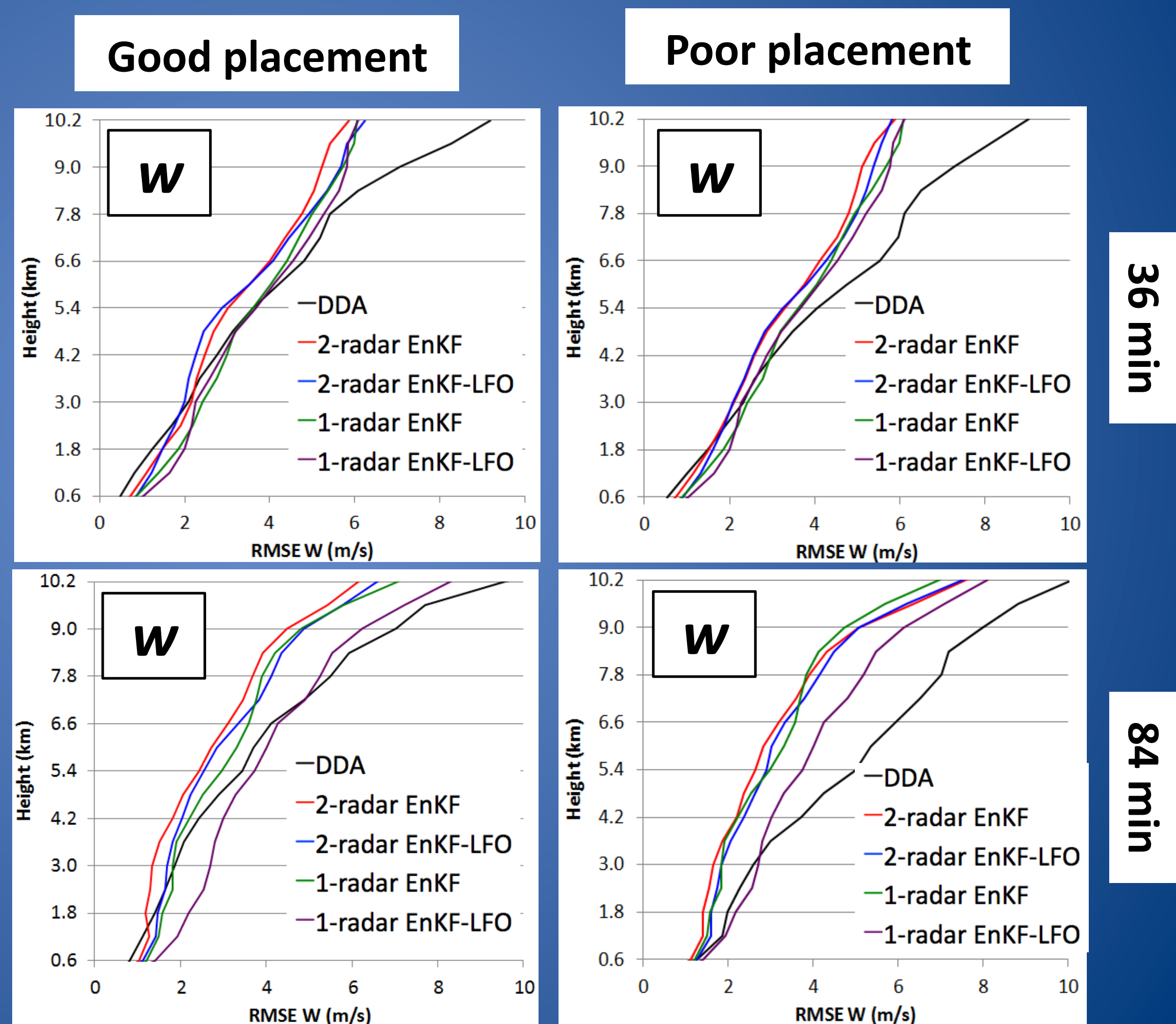


Poor radar placement



Poor radar placement

- 3-D winds much less constrained by V^{obs} alone
- EnKF far less degraded than DDA
- EnKF better than DDA even at low levels



Conclusions

- EnKF may not improve upon DDA at low levels
  - Good radar placement
  - Large model error
  - Early in storm's life
- Substantial improvement at higher levels (EnKF better accounts for flow evolution)
- Dramatic improvement when radar placement poor

Future Work

- Additional imperfect-model experiments
- Impact of initial condition errors
- Impact of rapid/shallow scanning
- Evaluate trajectories, vorticity analyses
- 29 May 2004 Geary, OK case