Storm-scale Flow Regimes in Supercell Thunderstorms as Visualized Using a Trajectory Mapping Technique

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Introduction

- This study is an attempt to compare and contrast behavior in classic (CL) and high-precipitation supercell (HP) thunderstorms.
- The 29 May 2004 Geary, OK tornadic supercell was chosen as the high-precipitation case and the 20 May 2013 Newcastle-Moore, OK tornadic supercell was chosen as the classic supercell case.

Methods

29 May 2004 Geary, OK (0016-0052 UTC):

- Two mobile C-band SMART (Biggerstaff et al. 2005) Radars collected 3 minute, synchronized volumes.
- Domain: 100km x 60km x 17km, 750m x 750m x 500m
- An F2 tornado began around 0052 UTC and lasted for ~20 minutes.

20 May 2013 Moore, OK (1943-2004 UTC):

- Radars: KTLX (88D), KOKC (TDWR), and KOEX (exTDWR)
- Domain: 40km x 40km x 4.5km, 150m x 150m x 150m
- EF-5 tornado began around 1956 UTC and last ~40 minutes.

Trajectories

- Dual-Doppler analyses were generated using traditional (29 May) and variational (20 May) methods.
- They were calculated using a 4th order Runge-Kutta integration in time between analyses, with a 5 second time step.
- The mapping visualization is achieved by initializing backward trajectories on a fine, regular grid and then plotting prior values at the original locations.

Storm Overviews

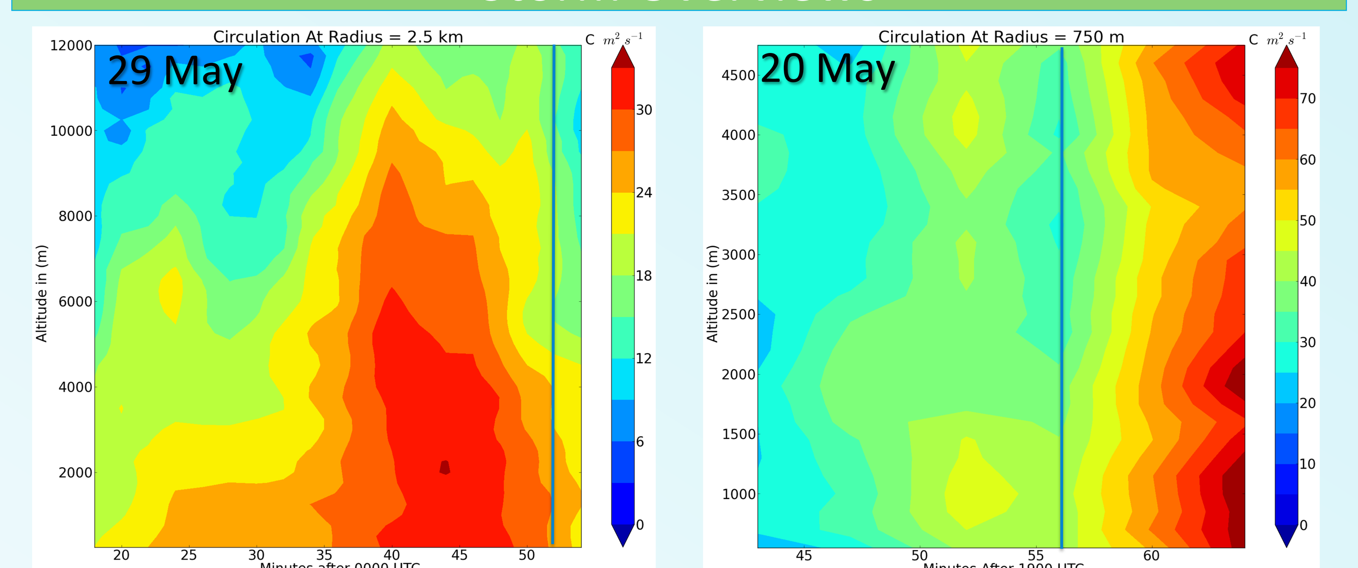

Figure 1: Time-height plot of circulation for the 29 May (left, 1x10^6) and 20 May (right, 1x10^5) supercells.

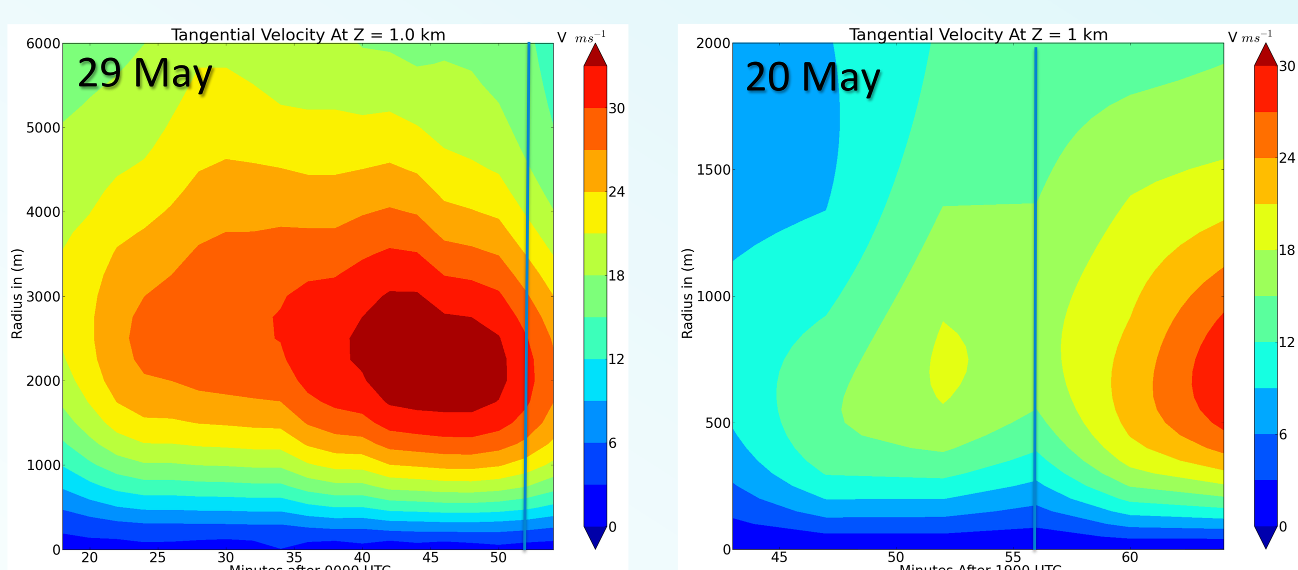

Figure 2: Time-Radius plot of tangential velocity for the 29 May (left) and 20 May (right) supercells. Vertical lines denote reported touchdown time of tornadoes.

- Prior to rapid and deep intensification of their respective circulations, both storms had a negative vertical circulation gradient that promoted downward directed vertical pressure gradients (Fig. 1).
- Tornadogenesis occurred earlier on in the occlusion process in the CL storm whereas it occurred well into the occlusion process in the HP storm.

29 May 2004

Multiple-Doppler Analyses

20 May 2013

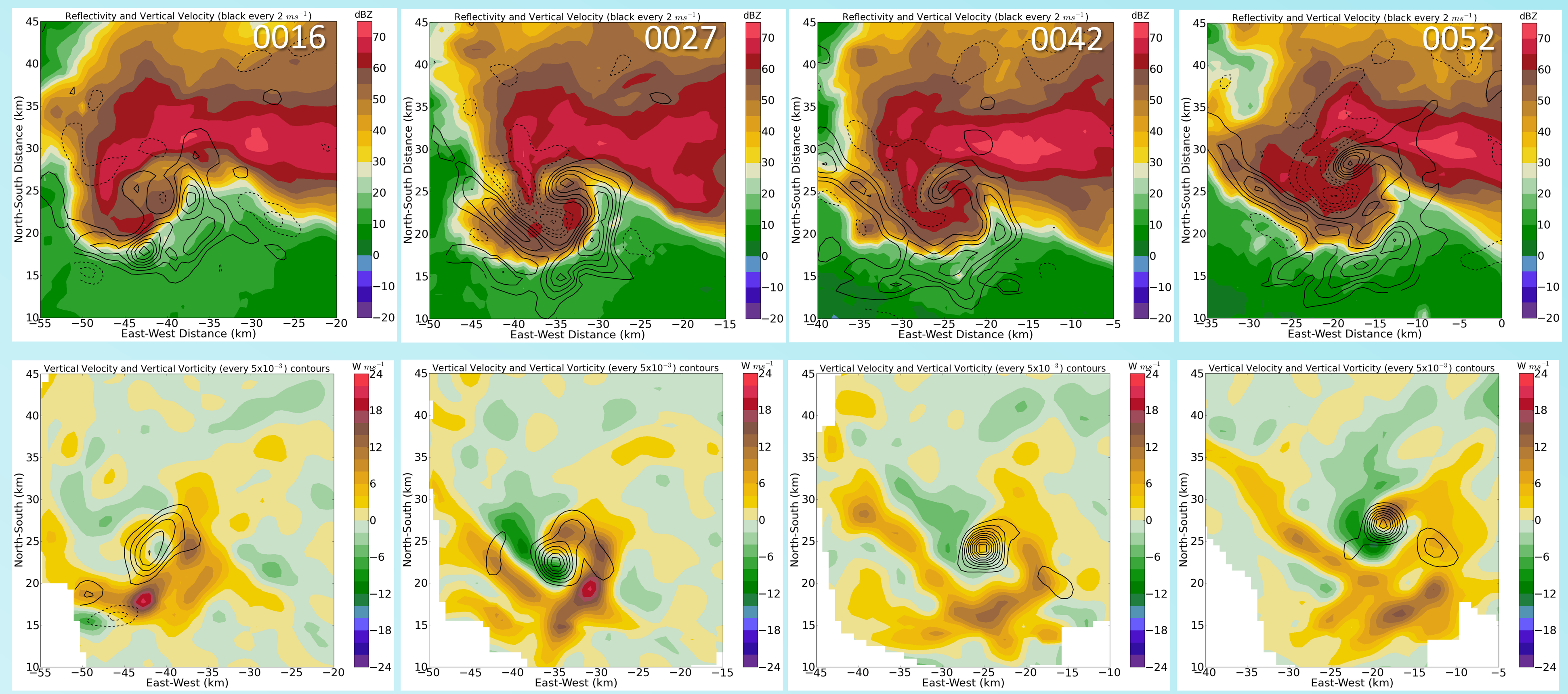

Figure 3: May 20th 2013 radar reflectivity and vertical motion (contoured in black every 2 ms^{-1}) (top panels) and vertical motion and vertical vorticity (contoured in black every 5x10^{-3}) (bottom panels). Plots are at an altitude of 1000m.

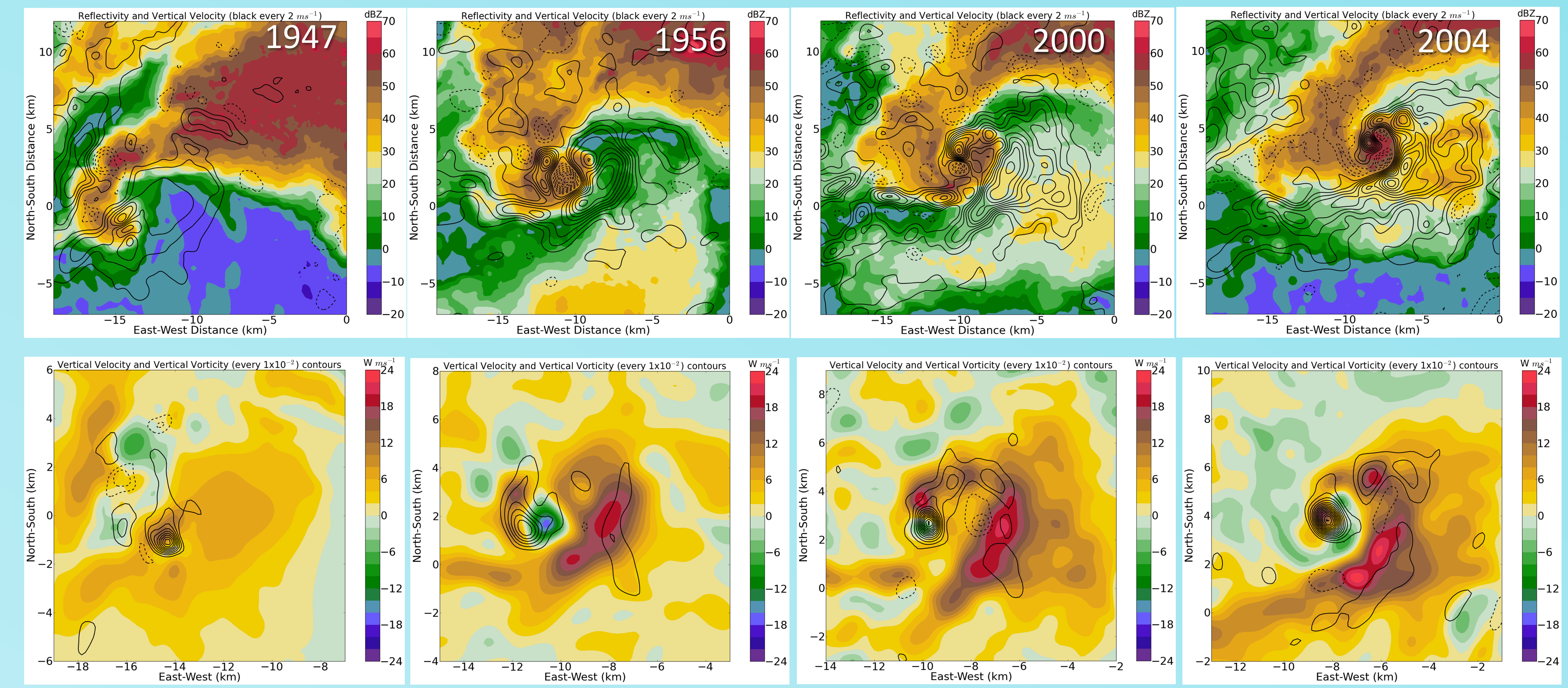

Figure 4: Same as Fig. 3 but for May 20th 2013 and vertical vorticity is contoured every 1x10^{-2}).

Trajectory Mapping

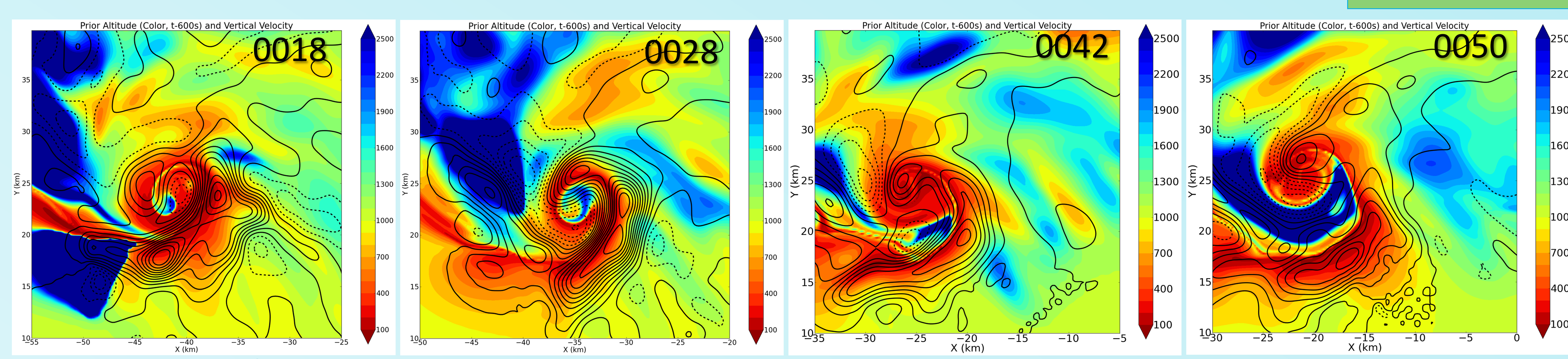

Figure 5: May 29th 2004 prior altitude (t-600s) is color contoured (every 100m) and vertical motion is contoured in black (every 2 ms^{-1}).

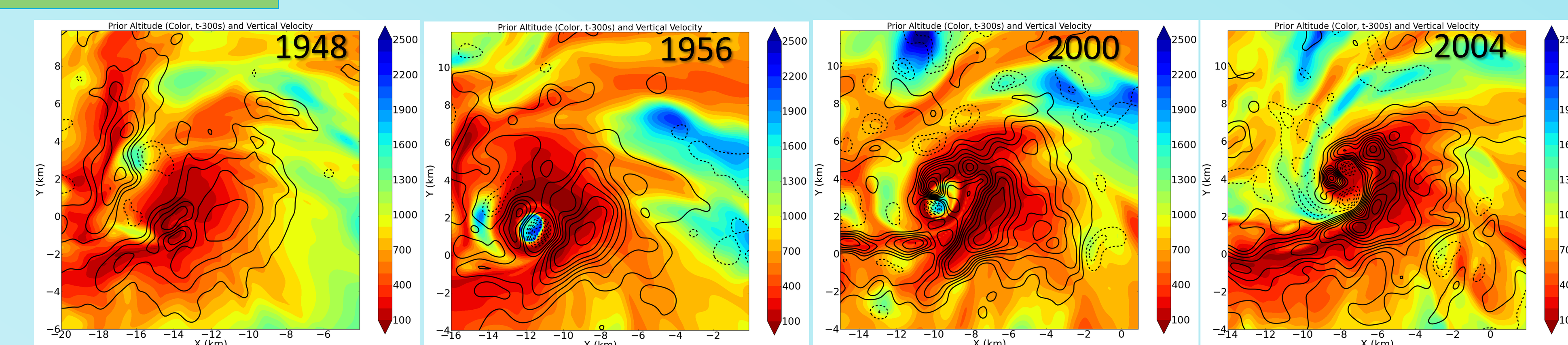

Figure 6: May 20th 2013 prior altitude (t-300s) is color contoured (every 100m) and vertical motion is contoured in black (every 2 ms^{-1}).

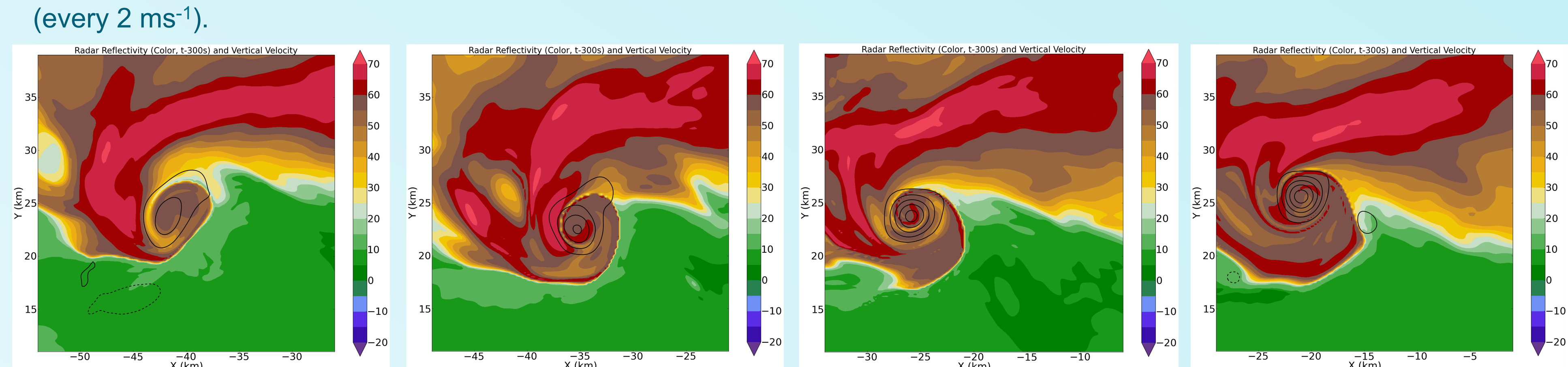

Figure 7: May 29th 2004 prior radar reflectivity (t-300s) is color contoured (every 100m) and vertical motion is contoured in black (every 2 ms^{-1}). Plots are at an altitude of 1000m.

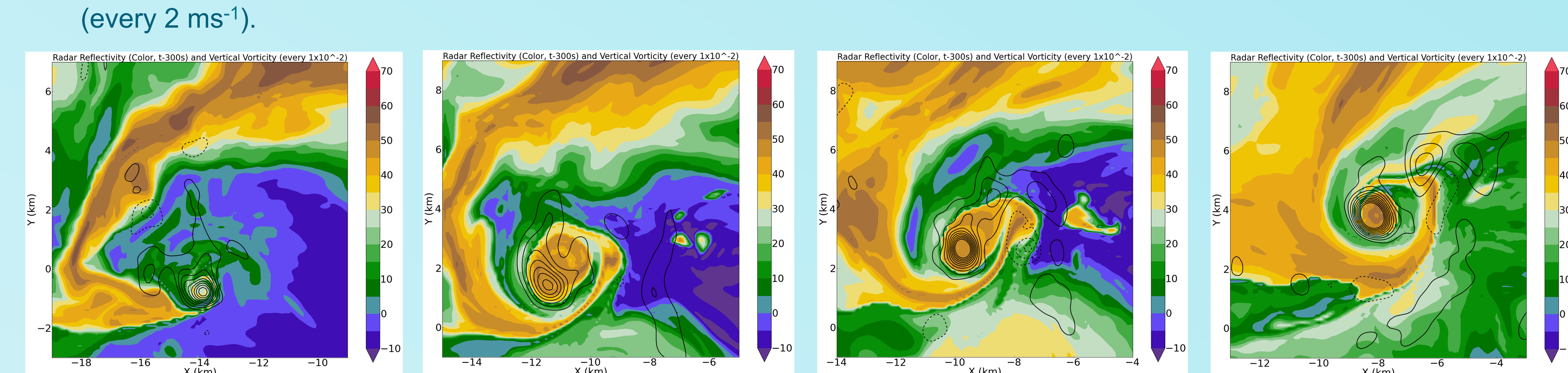

Figure 8: Same as Fig. 7 but for May 20th 2013.

Conclusions

Similarities

- The primary, storm-scale updraft shifted south during the occlusion stage, which coincided with a southward shift, relative to the circulation, in both the forward and rear reflectivity cores (Fig. 3 and Fig. 4).
- The occlusion downdraft in both cases transitioned from being axial in nature (2-cell) to being focused on the outside of the core (1-cell) (Fig. 5 and Fig. 6).

Differences

- The HP storm maintained a strong updraft on the western flank throughout this mesocyclone cycle, while the CL storm did not. The absence of a western flank updraft could have left the rear-flank downdraft more exposed to the environment in the CL storm than in the HP storm.
- The width of the inflow at 1 km that had not spent substantial time passing through rain was significantly smaller in the HP storm (Fig. 7 and Fig. 8). However, at 250m (Fig. 9), air from the forward flank region was tightly wrapped around the circulation in the CL case, indicating a strong vertical gradient in source regions within the inflow region of the storm. The vortex was also more compact at 250m compared to 1000m. This type of behavior was not noted in the HP storm.
- The boundary layer was similar in depth but significantly more moist, in the CL case (not shown). Thus, more evaporation probably occurred with air from the forward flank core that was on the periphery of the circulation in the HP case than the CL case, potentially leading to lower thermal buoyancy.

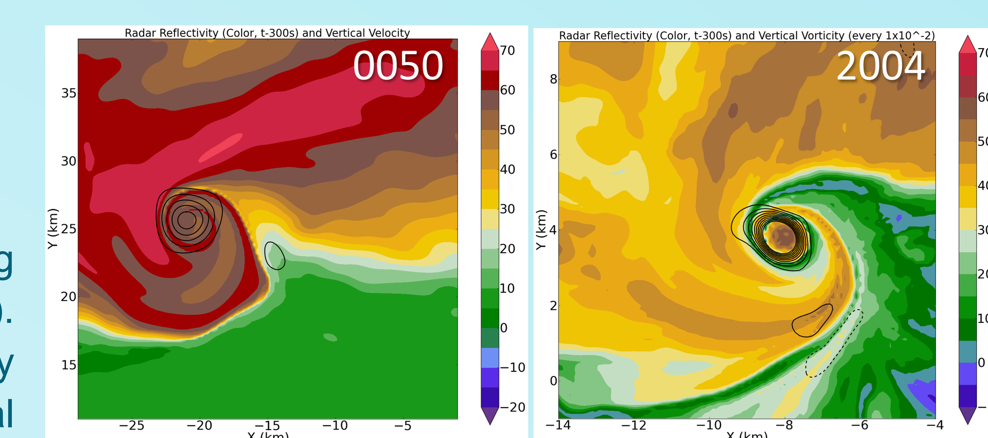

Figure 9: The same as Fig 7 and Fig 8 but at an altitude of 250m.

References

Biggerstaff, M. I., L. J. Wicker, J. Guynes, C. Ziegler, J. M. Straka, E. N. Rasmussen, A. Doggett IV, L. D. Carey, J. L. Schroeder, and C. Weiss, 2005: The Shared Mobile Atmospheric Research and Teaching Radar: A collaboration to enhance research and teaching. Bull. Amer. Meteor. Soc., 86, 1263 - 1274.