Mesovortices within the 8 May 2009 Bow Echo over Central United States: Analyses of the Characteristics and Evolution based on Doppler Radar Observations and a High-Resolution Model Simulation

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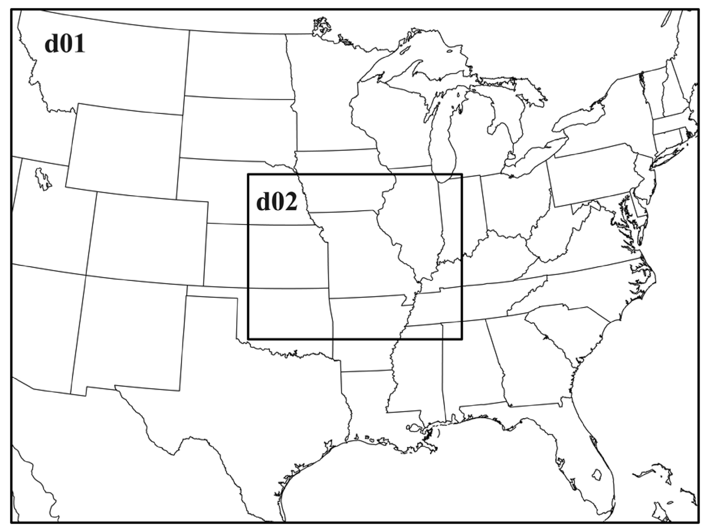
Features of mesovortices (MVs)

- meso-γ-scale (2~20 km)
- in the low level below 1 km AGL
- on the leading edge of quasi-linear convect-ive systems (QLCSs), e.g., squall lines and bow echoes
- playing an important role in the generation of derechoes

WRF Model domain & setup of numerical experiment



	Domain 1	Domain 2
nx	901	1401
ny	673	1081
nz	51	51
dx	4 km	0.8 km
dt	25 s	5 s
Model time	2009-05-08_00:00 2009-05-08_18:00	2009-05-08_11:00 2009-05-08_16:00
Physics	MP: Thompson; PBL: MYJ ; sf: Noah; No cu	

Radar analysis of 8 May bow echo

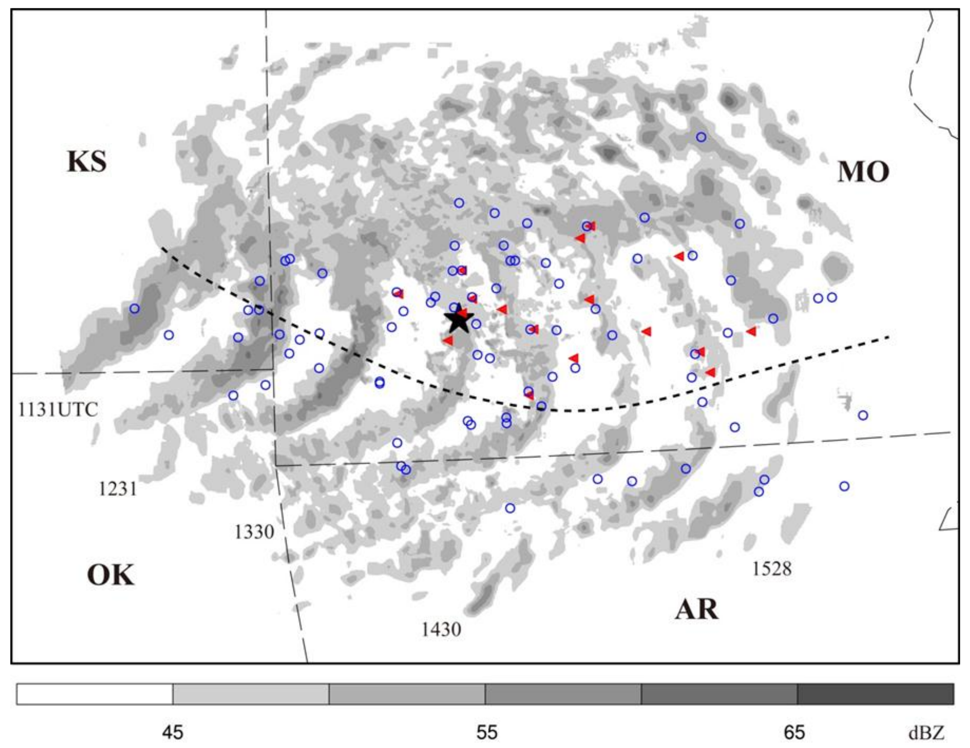


Figure 1. Half-hourly composite reflectivity from the WSR 88D radar KSGF (black star), high winds (>33.5 ms^{-1}, blue circles) and tornado (red triangles) reports from SPC for the 8 May 2009 bow echo from 1131 UTC to 1528 UTC.

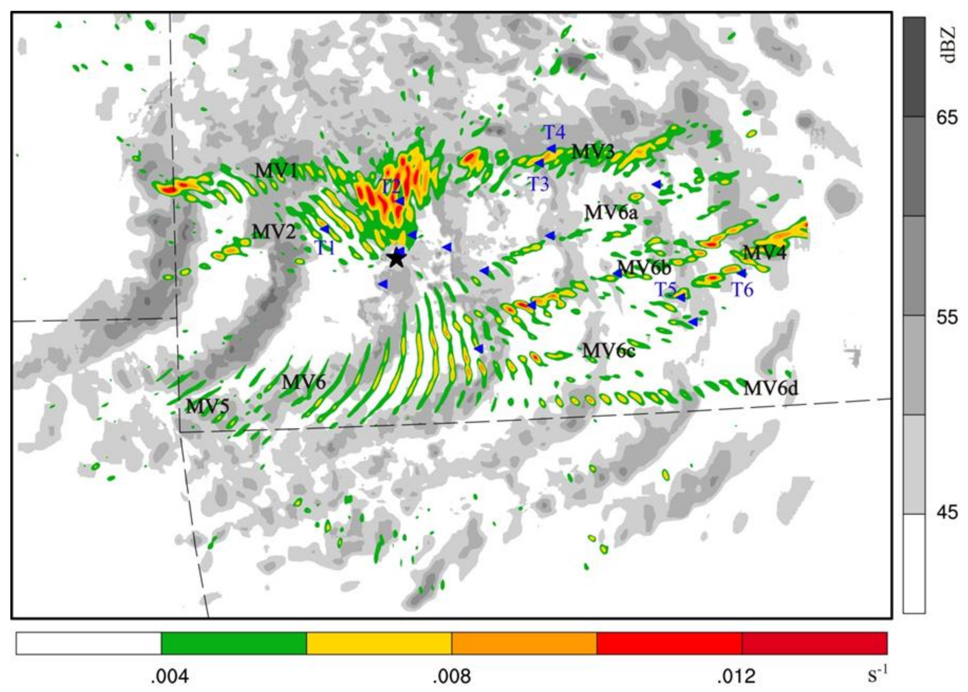


Figure 2. Radar composite reflectivity (gray shading) and ground-relative tracks of radial velocity azimuthal shear (color shading) at the lowest elevation between 1203 and 1533 UTC. Significant MVs are labeled. Blue triangles are tornadoes reported by SPC. The azimuthal shear is obtain-ed by the linear least square derivatives (LLSD) method.

Simulated 8 May bow echo and MVs

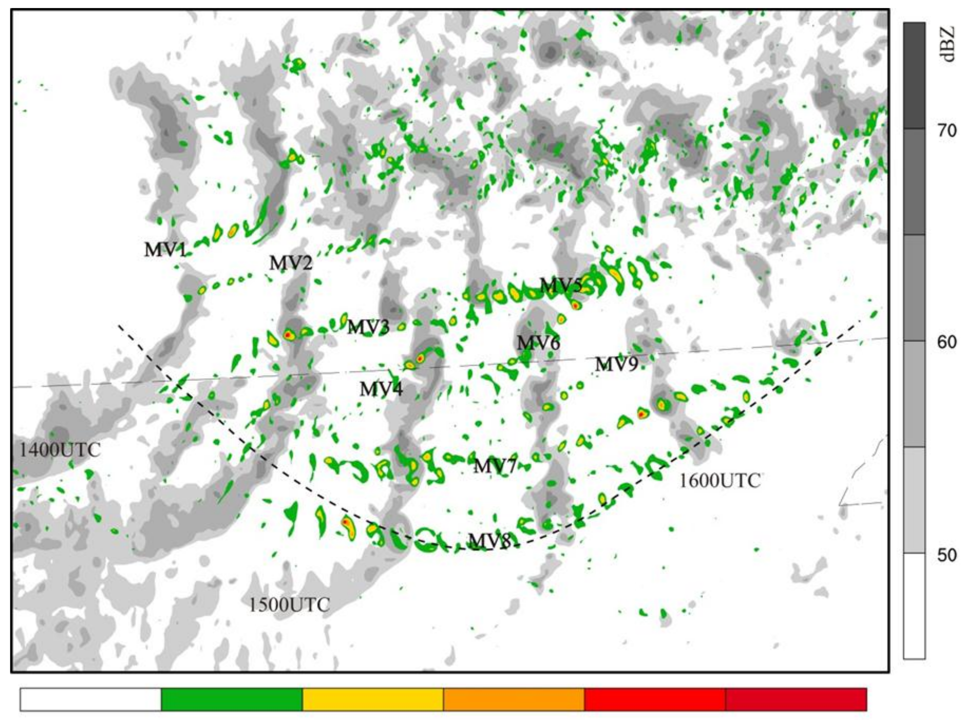


Figure 3. Composite reflectivity (gray shading) and ground-relative tracks of the maximum vertical vorticity below 2 km AGL (color shading) for the simulated 8 May 2009 Central US bow echo from 1400 UTC to 1640 UTC

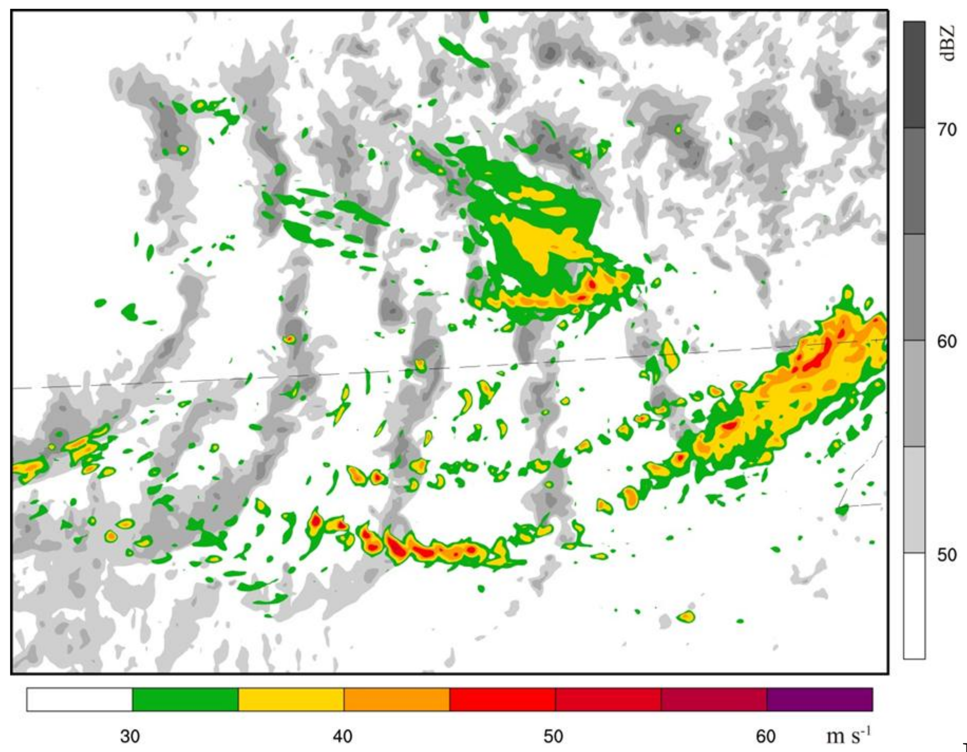


Figure 4. Same as Fig. 3 except that the color shading is for the ground-relative wind speed at 200 m AGL

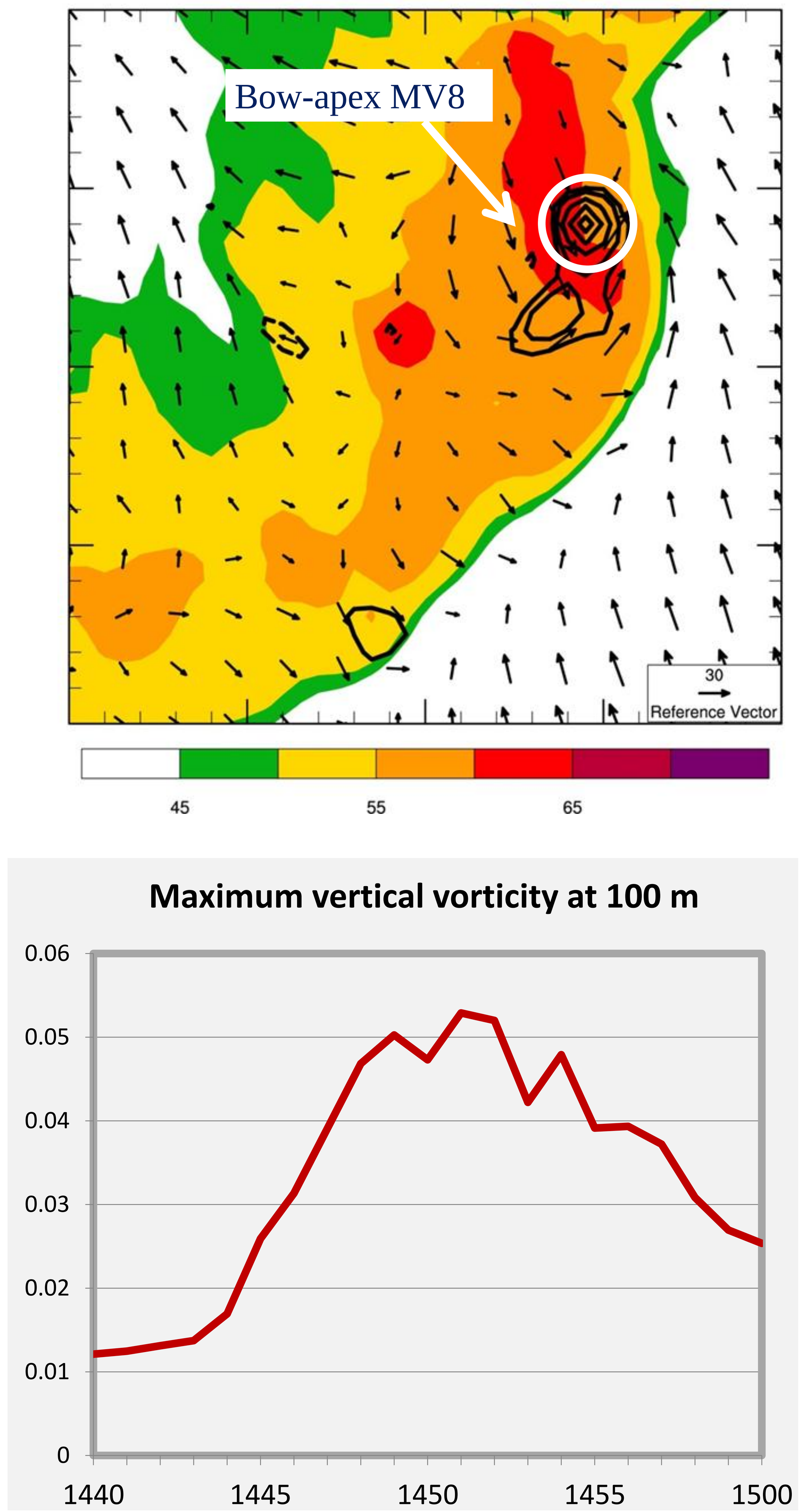


Figure 5. MV8 at 100 m AGL at 1448 UTC (top) and time evolution of its maximum vertical vorticity (bottom). Vectors are the vortex-relative wind at 100 m AGL. Color shading is the composite reflectivity. **White circle is the material circuit analyzed in Fig. 6**.

Lagrangian circulation and vorticity analyses for bow-apex MV

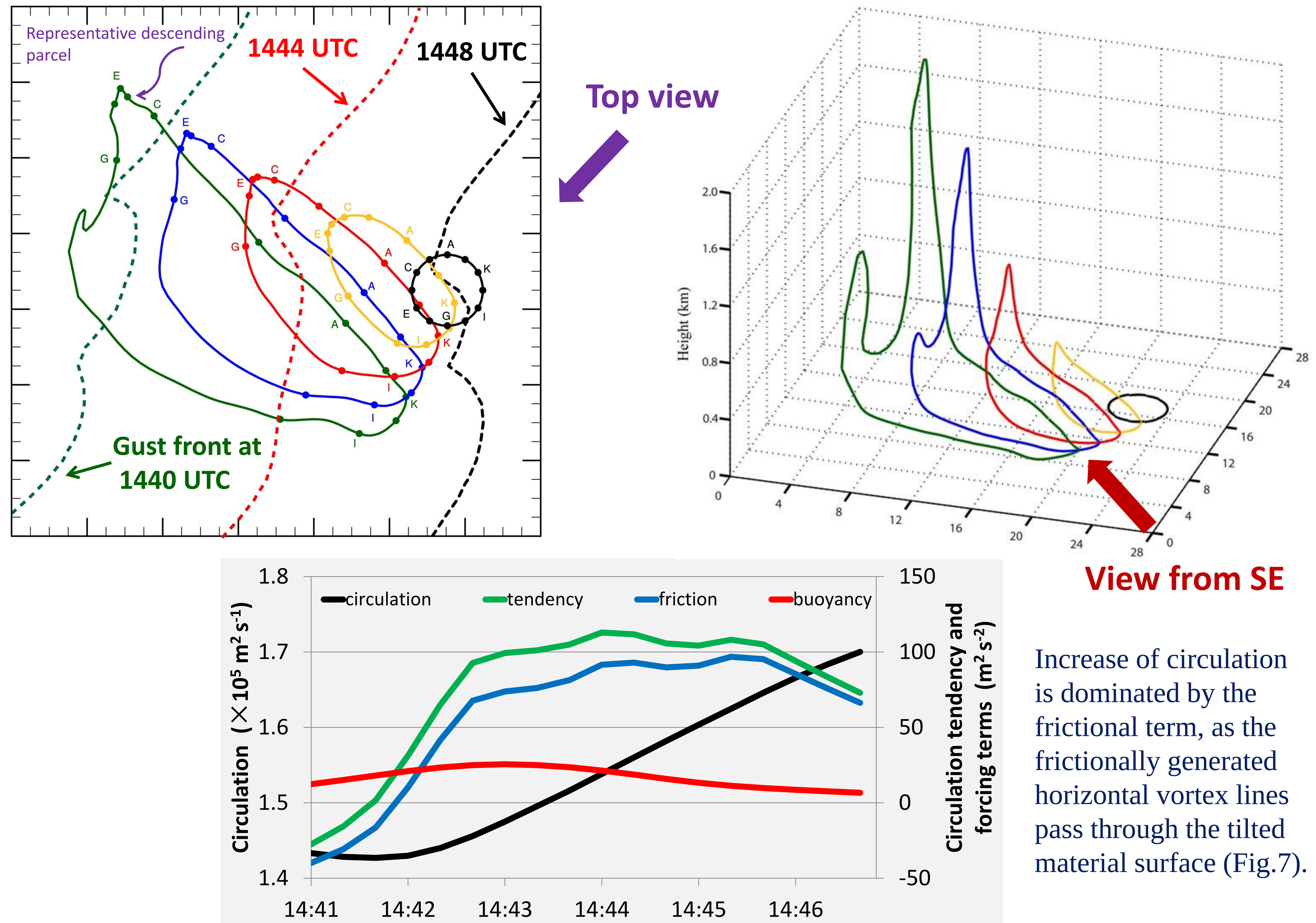


Figure 6. Tracks of material circuit for MV8 from 1440 to 1448 UTC and evolution of circulation about this circuit.

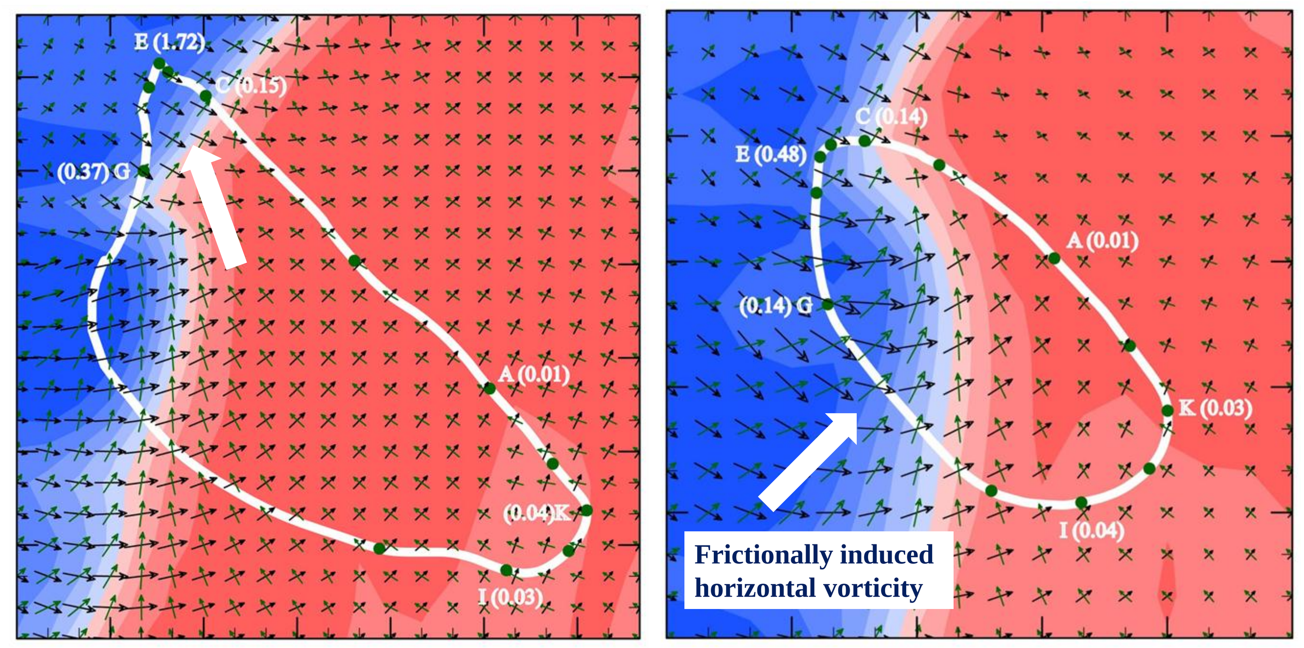


Figure7. Material circuit at 1441 and 1445 UTC. Black (green) vectors are ground-relative wind field (horizontal vorticity) at 50 m AGL. Shadings are the virtual potential temperature field (>300K in red)

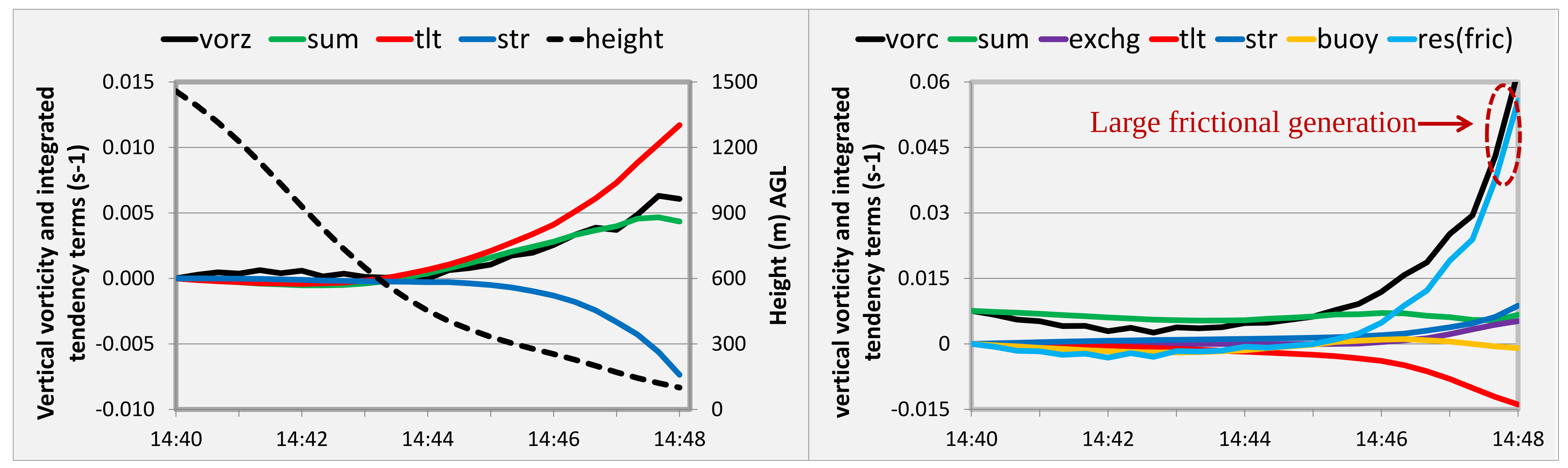


Figure 8. **Vertical vorticity** (left) and **crosswise vorticity** (right) budgets along a representative, **descending** parcel.

- The existence of MVs within the 8 May 2009 Central US bow echo is documented by Doppler radar analysis as well as a real-data, high-resolution WRF simulation.
- The bow echo MVs predominantly form north of the bow apex, with the most long-lived MVs being located at/near the bow apex. Damaging straight-line winds are found in the simulation during both the mature and weakening stages of the system. The strongest surface winds occur with a bow-apex MV that is embedded in, and promoted by the system rear-inflow jet (RIJ).
- This bow-apex MV intensifies rapidly as the RIJ descends toward the surface (Fig. 9), accompanied with a growth in its low-level circulation. Lagrangian circulation analysis reveals that friction plays a dominant role in the increase of circulation. The descending parcel within the RIJ acquires a vertical vorticity during descent via the tilting of horizontal vorticity which is largely generated due to friction as it descends to near the ground.
- The descending RIJ also operates to enhance the low-level convergence and thus increases the stretching of vertical vorticity significantly (no shown).

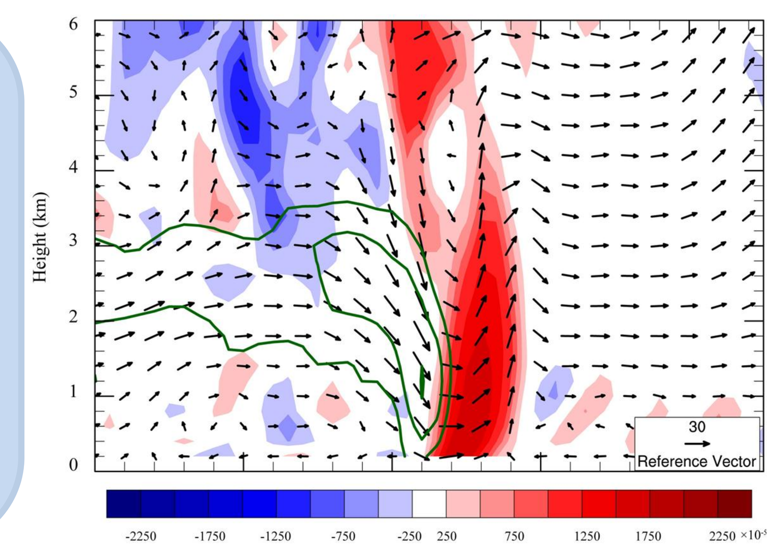


Figure 9. Vertical cross section through MV8 at 1445 UTC. Shading is the vertical vorticity. Green contours are theta-e from 320 K to 328 K at 4-K interval. Vectors are vortex-relative wind.

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