Synoptic Influence on High Shear Low CAPE Convective Events

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Introduction:

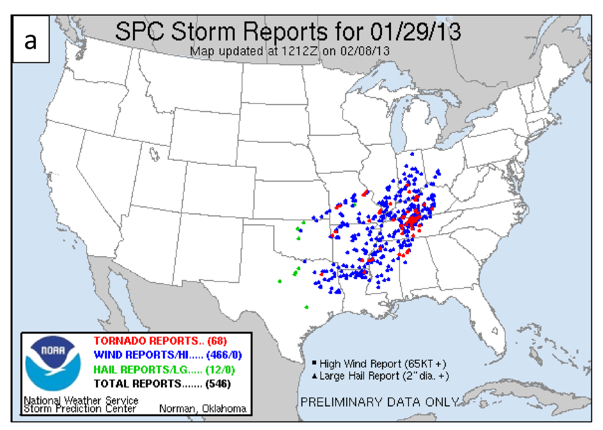
High shear, low CAPE (HSLC) convective events are prevalent in the southeastern United States, predominately during the cool season (Sherburn and Parker 2014). These events are defined as having CAPE < 1000 J/kg and extremely high vertical wind shear, and can cause significant wind, tornado and hail damage. It has been suggested that HSLC events may be heavily influenced by synoptic scale forcing (e.g., Wheatley and Trapp 2008, Evans et al 2010). In order to test this hypothesis, two HSLC case studies were simulated in WRF. A single sounding from one of these simulations was initialized in an idealized model to examine the development and evolution of convection absent synoptic forcing.

Methods:

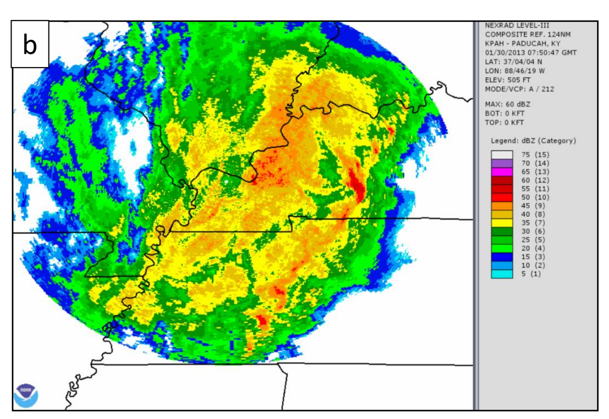
Two case studies were simulated in the Weather Research and Forecasting Advanced Research in Weather (WRF-ARW) model version 3.5.1. The simulations were run for 36 hours on a domain with 9km horizontal grid spacing nested down to a smaller domain with 3km grid spacing. NAM analysis data were used for initial and boundary conditions.

A sounding from one case study WRF simulation ~4 hours prior to convection was initialized in Bryan's Cloud Model (CM1) version 17. The initialization method was a -8K cold air "wedge" with a maximum height of 4km, sloping to the surface over a horizontal distance of 100km. Horizontal grid spacing of 1km was used.

Case Study 1: January 29-30, 2013



A deepening surface low and upper level trough tracked eastward across the central United States. A quasi-linear convective system pushed ahead of a cold front into widespread HSLC conditions, producing high winds and several EF0-EF2 tornadoes in the Mississippi and Ohio Valleys.



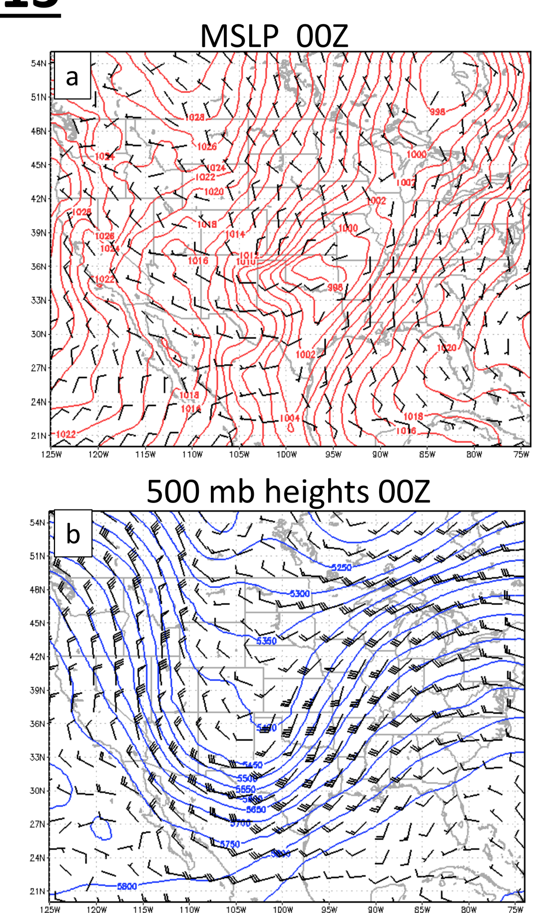


Figure 1 (Left): (a) SPC storm reports from 12Z on January 29 to 12Z on January 30, 2013. (b) KPAH NEXRAD Level-III Composite Reflectivity for 0750Z on January 30, 2013.
Figure 2 (Right): (a) Mean sea-level pressure and 10 meter winds, and (b) 500mb heights and winds at 00Z on January 30, 2013 (NARR analysis data).

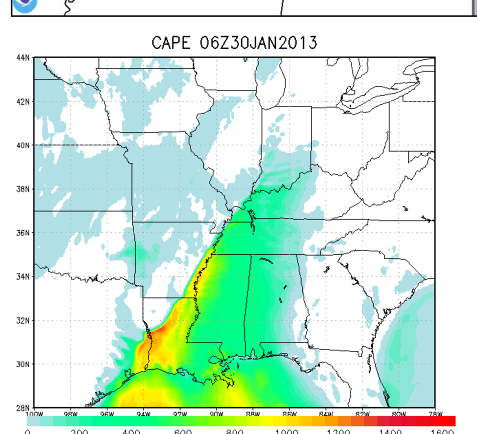
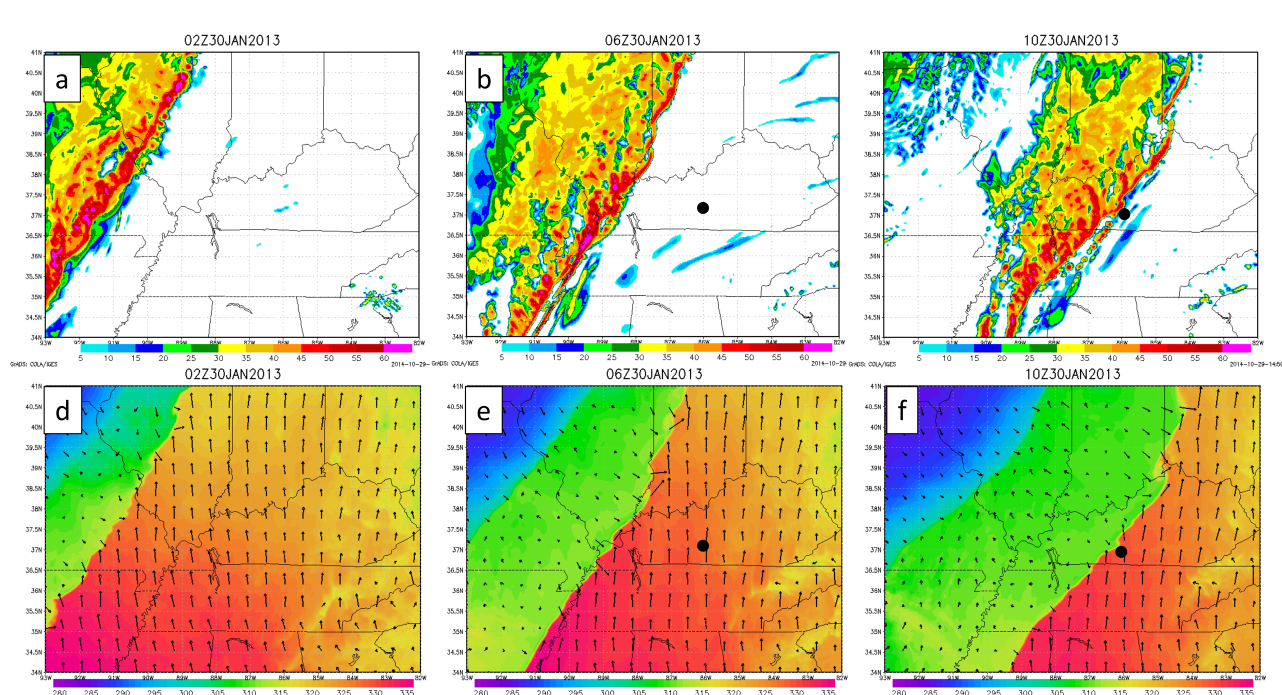
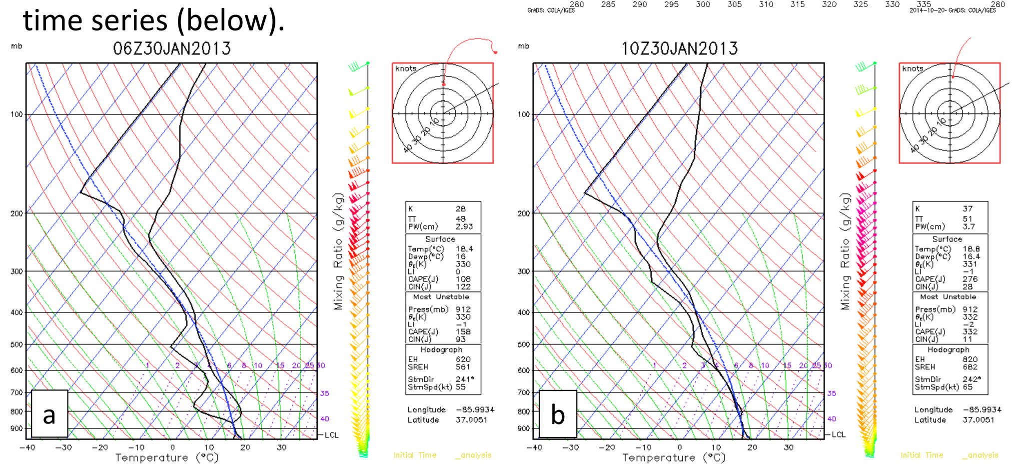


Figure 3 (Above): CAPE [J/kg] at 06Z January 30.
Figure 4 (Right): Composite reflectivity (a)-(c) and surface θ_e [K] (shaded) and surface winds (d)-(f) from 02Z to 10Z. Black circles indicate location of soundings and time series (below).





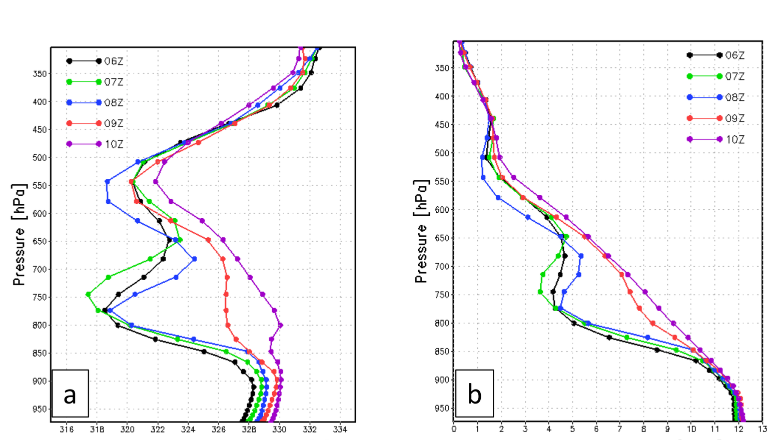
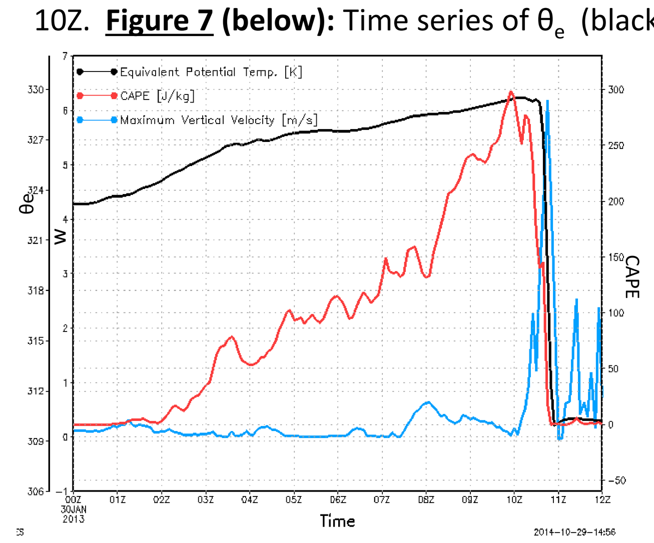


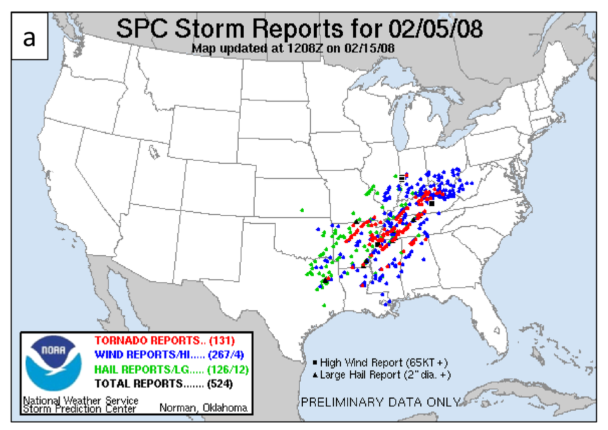
Figure 5 (above left): Soundings from 06Z (a) and 10Z (b). **Figure 6 (above right):** Vertical time series of (a) θ_e and (b) q_v from 06Z to 10Z. **Figure 7 (below):** Time series of θ_e (black), CAPE (red), and maximum w (blue) from 17Z to 05Z.



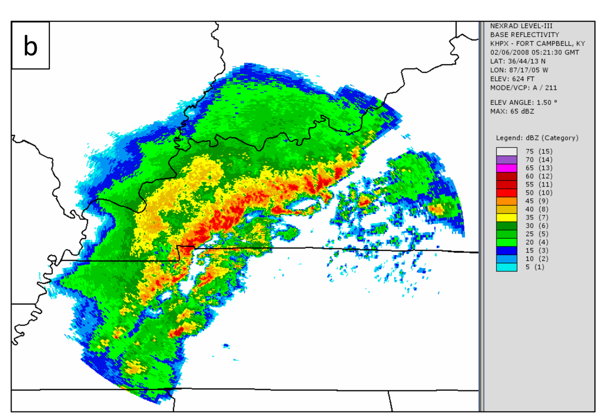
Case Study 1 Conclusions:

- A severe QLCS occurred in an environment with widespread HSLC conditions. Outflow from upstream higher CAPE convection helped the QLCS advance ahead of the cold front.
- The low-mid levels (850-700 hPa) moistened and destabilized over a relatively short period of time (4 hours), leading to substantial increases in CAPE prior to the arrival of convection.

Case Study 2: February 5, 2008



A surface low and cold front tracked eastward across the central US downstream of a positively tilted trough. Many tornadoes and severe winds occurred in association with a QLCS. Higher CAPE values resided to the south, but most of the tornadoes occurred in HSLC to the north.



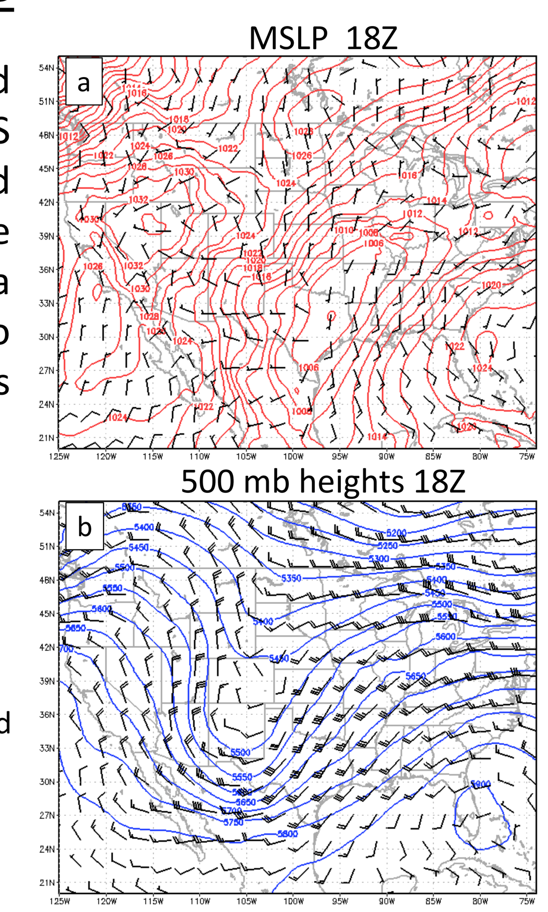


Figure 8 (Left): (a) SPC storm reports from 12Z on February 5 to 12Z on February 6, 2008. (b) KHPX NEXRAD Level-III Base Reflectivity for 0521Z on February 6, 2008.
Figure 9 (Right): (a) Mean sea-level pressure and 10 meter winds, and (b) 500mb heights and winds at 18Z on February 5, 2008 (NARR analysis data).

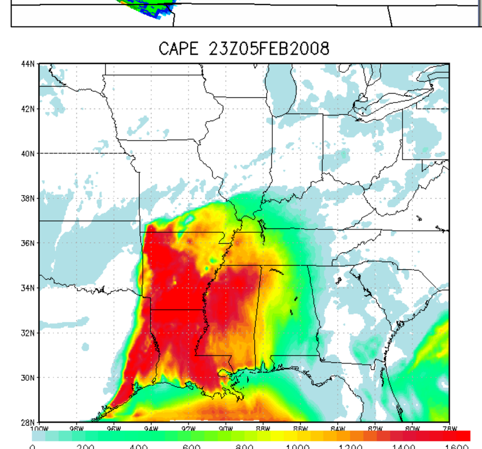
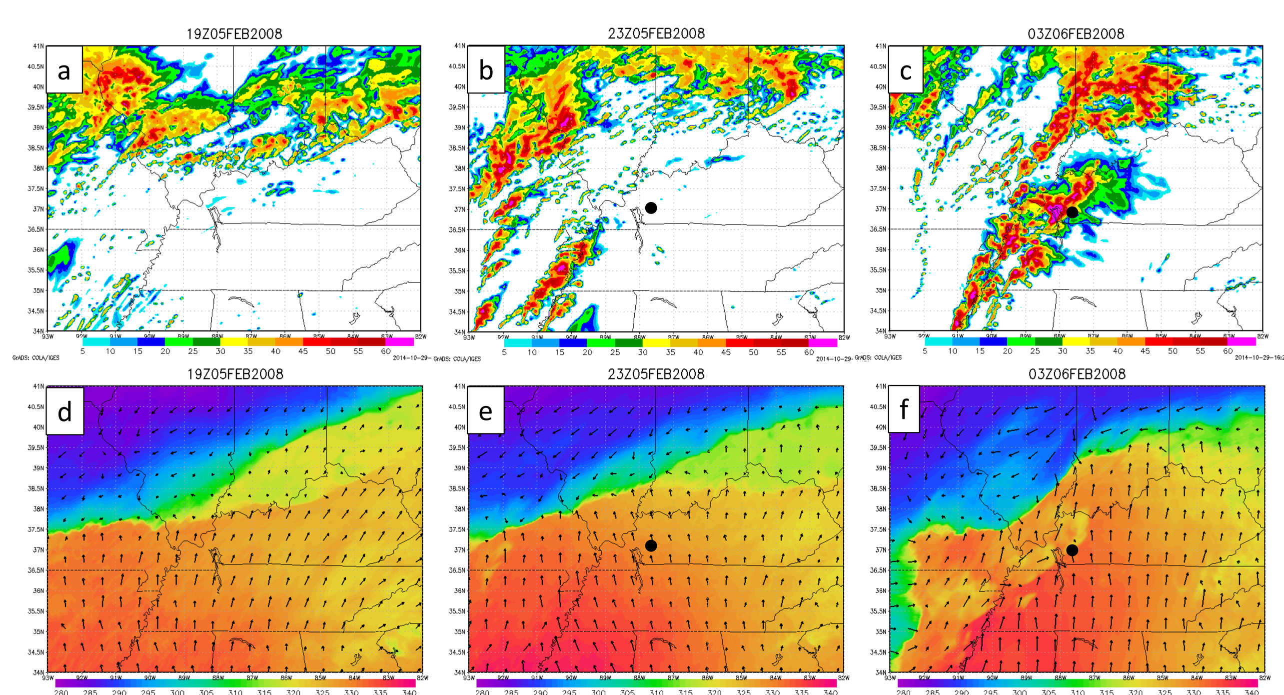
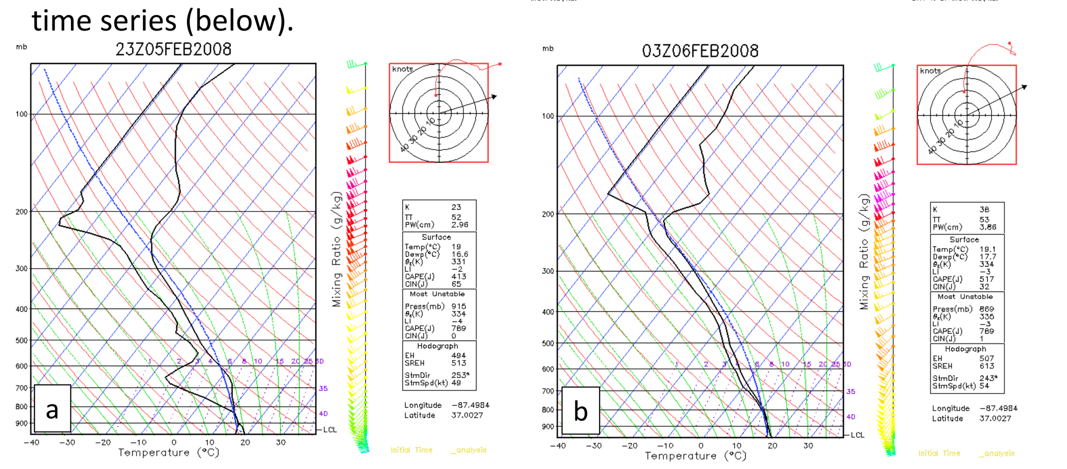


Figure 10 (Above): CAPE [J/kg] at 23Z February 5.
Figure 11 (Right): Composite reflectivity (a)-(c) and surface θ_e [K] (shaded) and surface winds (d)-(f) from 19Z to 03Z. Black circles indicate location of soundings and time series (below).





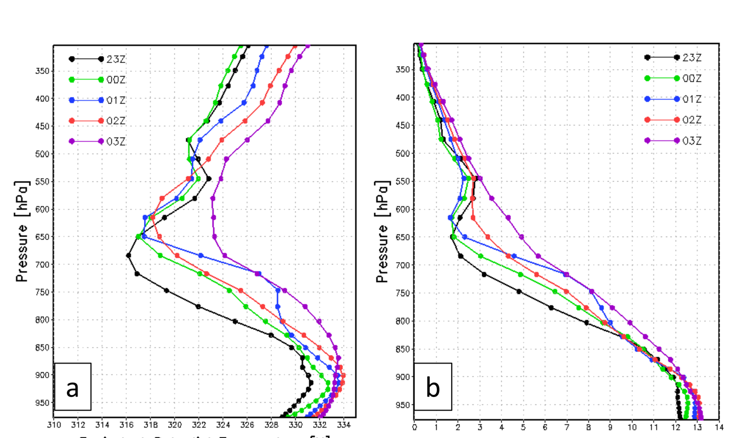
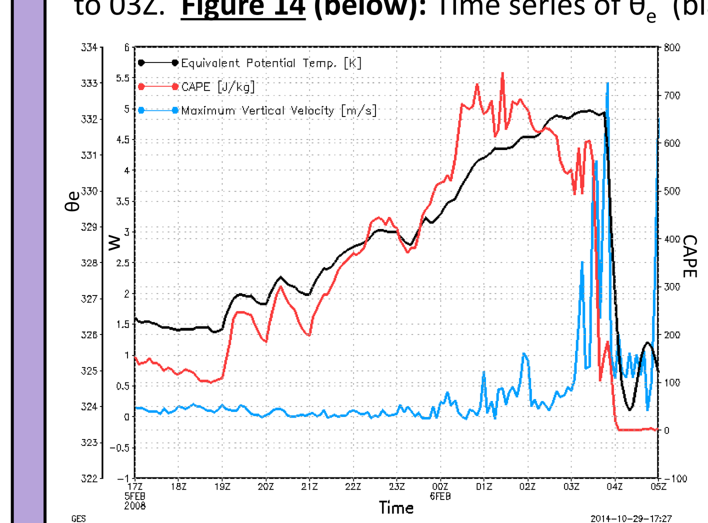


Figure 12 (above left): Soundings from 23Z (a) and 03Z (b). **Figure 13 (above right):** Vertical time series of (a) θ_e and (b) q_v from 23Z to 03Z. **Figure 14 (below):** Time series of θ_e (black), CAPE (red), and maximum w (blue) from 00Z to 12Z.



Case Study 2 Conclusions:

- A severe QLCS advanced into the warm sector, with most of the tornadoes occurring in the higher-shear lower-CAPE environment to the north.
- The low-mid levels (900-650 hPa) moistened and destabilized over a relatively short period of time (4 hours), leading to substantial increases in CAPE prior to the arrival of convection.

Idealized Simulation

The dry sounding from Figure 5 (06Z on January 29, 2013) was initialized in CM1.

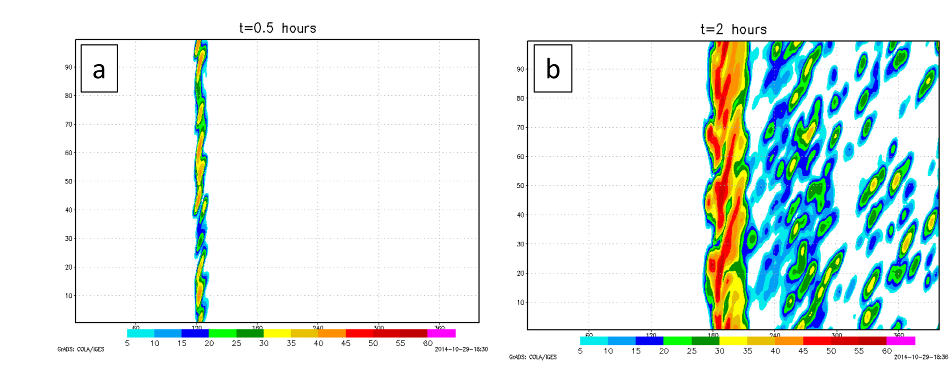


Figure 15 (Above): Reflectivity shaded for (a) t=0.5 hours and (b) t=1.5 hours into the simulation. Once convection was initiated by the cold air wedge, only broad, relatively weak updrafts formed.

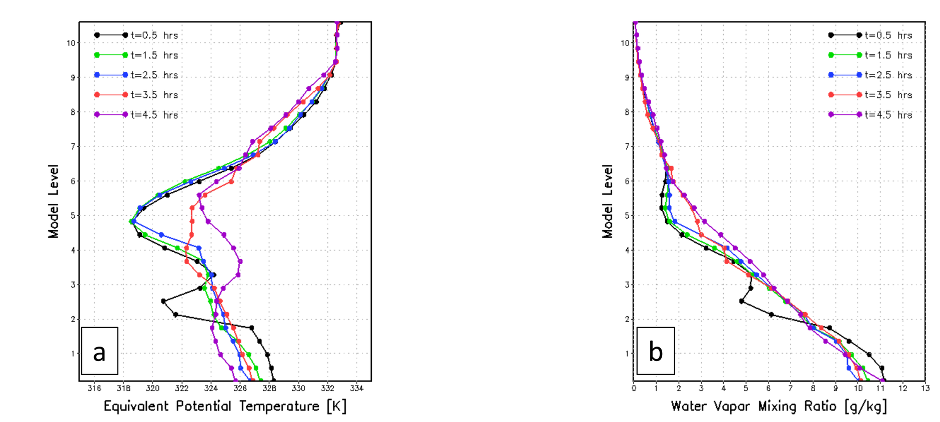


Figure 16 (Above): Vertical time series of (a) θ_e and (b) q_v from t=0.5 hours to t=4.5 hours from the same point in Figure 15.

Idealized Simulation Conclusions:

- Convection was initiated only when a significant cold slab was used in the idealized simulations.
- Without the inclusion of the synoptic environment, convection was widespread and relatively weak compared to the convection produced in the case study simulations. Substantial destabilization did not occur in the idealized model.

Implications and Conclusions:

In the real-data case study WRF simulations, it is evident that the synoptic environment is playing a significant role in the evolution of the convective environment in these particular HSLC events. The intense low- and mid-level moistening and lifting that occurred acted to destabilize the environment. In the idealized model, intense moistening and destabilization does not occur. Upstream convection may also be important in generating outflow and modifying the low-level flow fields (i.e. via diabatic PV generation) ahead of the HSLC storms.

Future work:

We seek to clarify the roles of the upstream convection (which may often be higher-CAPE convection) in conditioning the environment for the HSLC storms that occur. We are also using thermodynamic budgets to quantify the roles of advection vs. lifting in the moistening and destabilization of the pre-convective soundings. The short timescale on which the thermodynamic changes occur in these 2 cases would represent a significant operational challenge, so we are also working on a number of other cases to assess how common such rapid evolution may be.

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