Characteristics of QLCS Downdrafts and Environments Observed during the VORTEX-Southeast Project

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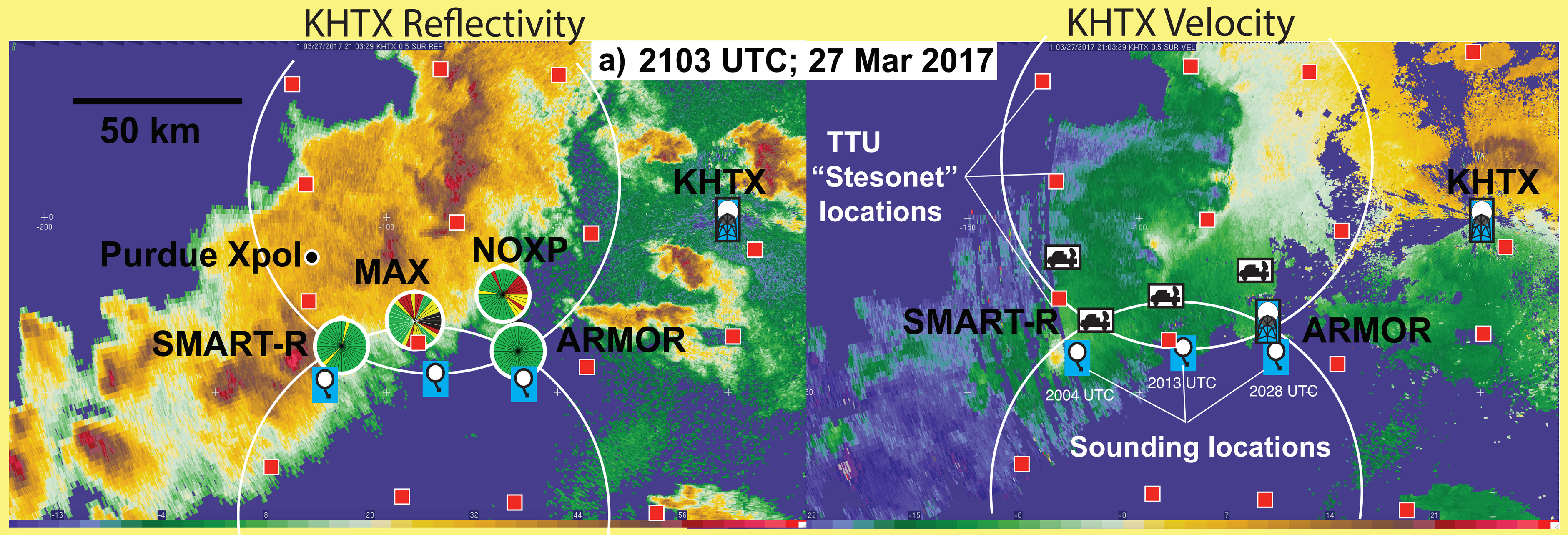
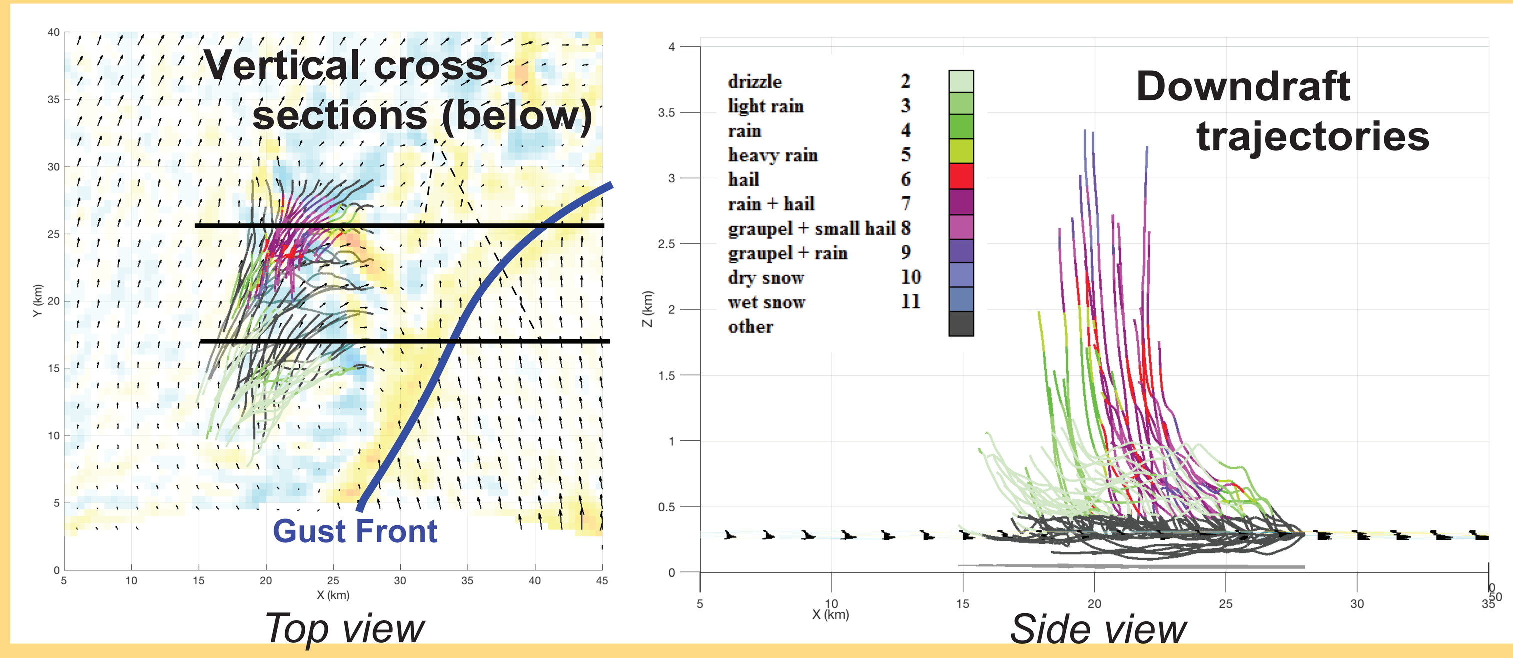
Project Goal: Dual-Doppler, surface (sticknet or "stesonet"), and sounding observations collected in multiple 2017 storms targeted by VORTEX-SE are examined to determine environmental sensitivities of downdraft properties in severe convective storms in the Southeast United States. Two QLCS storms, a storm type commonly associated with tornadoes in the SE U.S., were analyzed, 27 March and 30 April 2017. The 27 March case is the focus of this poster because of the superior observation density ahead of and within the storm. Current focus is to relate surface outflow temperature, downdraft strength, and hydrometeor types in downdrafts to environmental profiles and heterogeneity in the SE U.S.



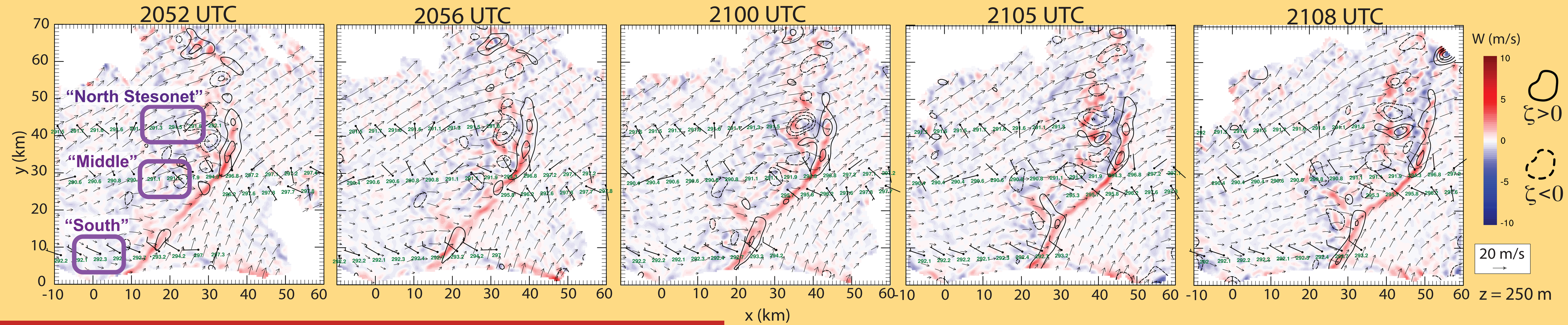
(*LEFT*) Deployment diagram of the 27 March case. A QLCS with weak surface vertical vorticity and bowing segments passed through the northern portion of the radar and surface observing network. Although a multitude of mobile and fixed radars were coordinated, tree and building blockage at most radar sites precluded dual-Doppler coverage in most parts of the storm (green/yellow/red pie charts in the left-most panel indicate quality of data within each azimuth sector). The best dual-Doppler coverage of this storm utilizes the SMART-R and ARMOR radars, with a large baseline of approximately 50 km. Mobile soundings were launched in an E-W-oriented line near the SMART-R/ARMOR baseline, roughly 45-60 min prior the gust front passing through the dual-Doppler region.

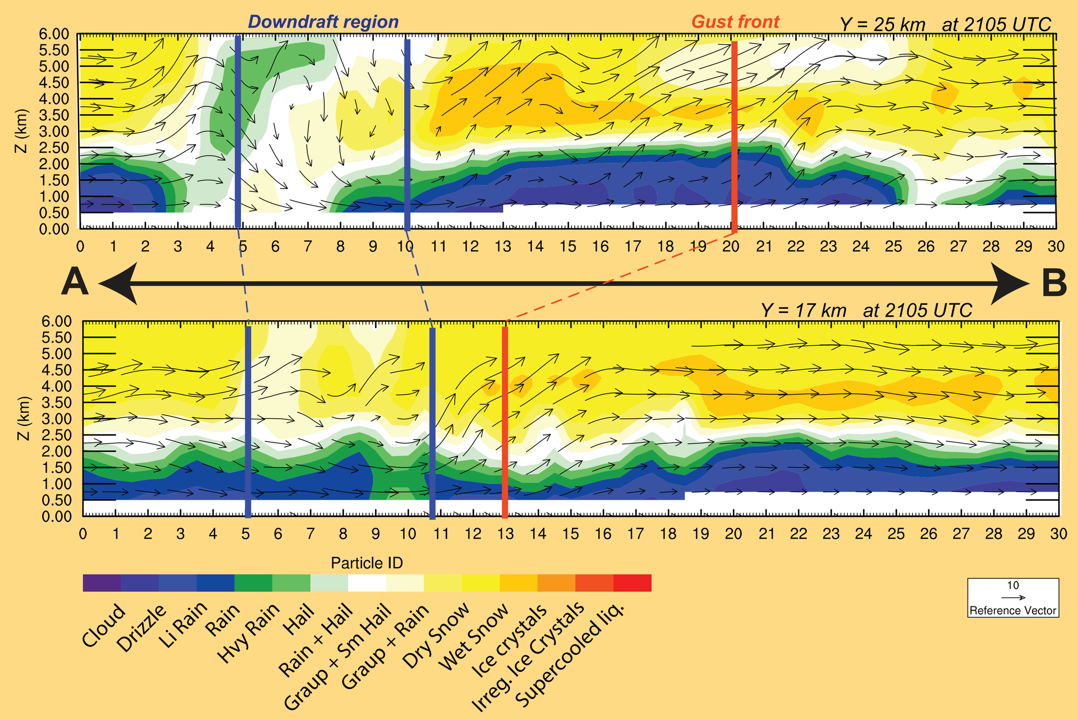


(*LEFT*) 4D airflow is probed via calculations of ***parcel trajectories within the strongest downdrafts*** located near areas of low-level rotation. Trajectories are traced backward in time from 2108-2052 UTC. Among the tested regions, parcels display two primary downward vertical excursions during the 16 min integration period: 1) from z > 3 km (which could be higher, given the large amount of smoothing of Doppler velocities during objective analysis owing to the range from each radar), or 2) from much shallower depths, z < 1.5 km. Parcels descending from the higher altitudes contain larger rain and hail (dual-pol-retrieved) than those descending from lower altitudes.

(*RIGHT*) 3D Dual-Doppler wind syntheses are performed using an upward integration of mass continuity. Radar velocity coefficients are assumed constant between the lowest radar beam and the ground to implement the lower BC (w = 0 m/s at z = 0 m). Wind syntheses illustrate updraft/downdraft structure and near-surface vertical vorticity located near the gust front. A few areas of enhanced downdraft are seen near the ground behind bowing segments of the line (.e.g, y ~ 20 km and ~40 km). Areas of positive and negative vertical vorticity are relatively weak, but these are likely underestimates of the true value owing to the relatively coarse resolution of the radar data.

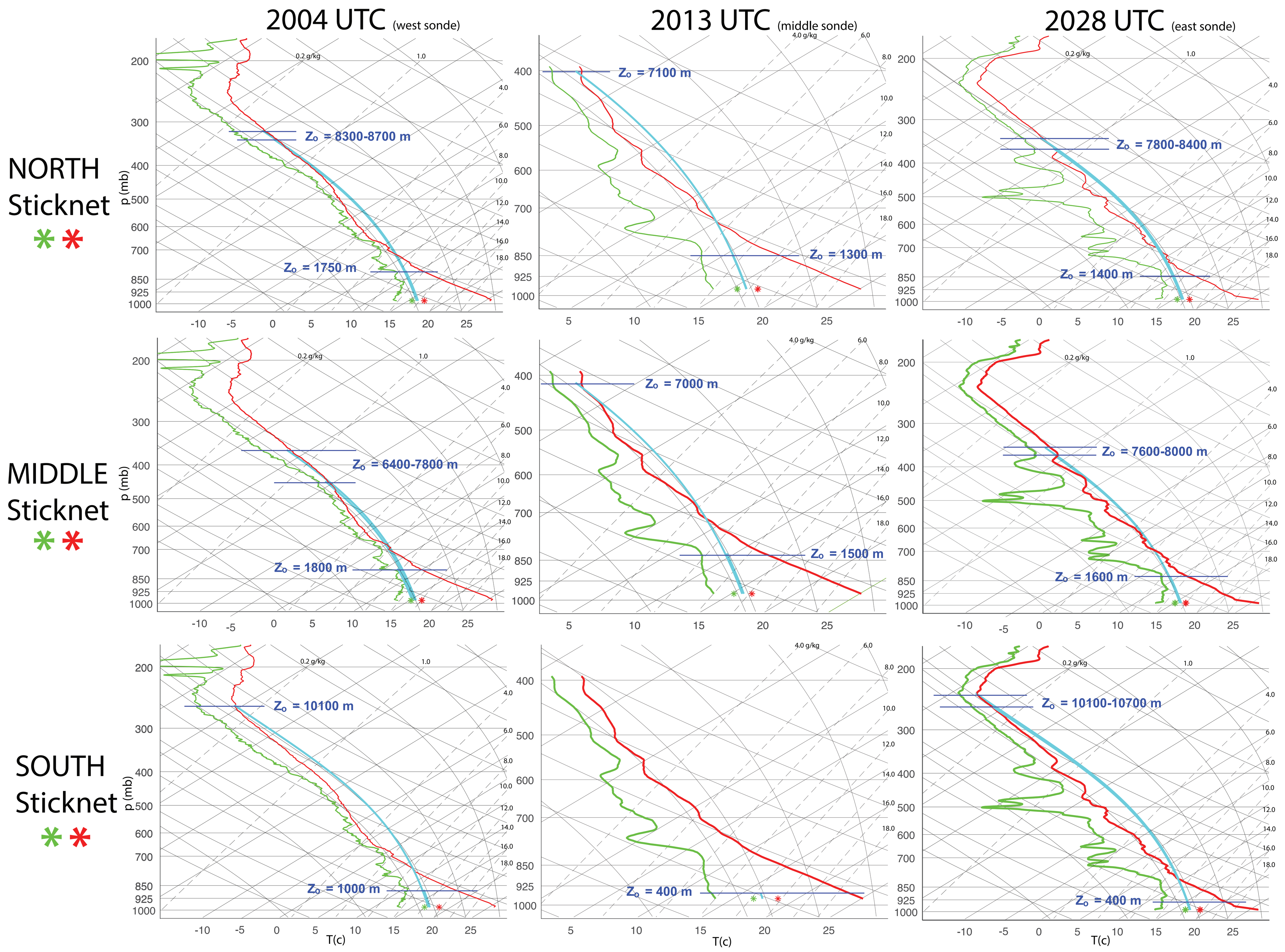
Winds and thermodynamic observations from the "stesonet" are shown (time-space corrected, using a mean gustfront motion, within a +/- 45 min window). These analyses indicate outflow air with a 5-7 K temperature deficit from the environment. Low-level winds observed by the stesonet typcially are significantly weaker and directionally-different from the dual-Doppler winds at the lowest common radar level.





(*LEFT*) Vertical cross sections of retrieved dual-pol hydrometeor classification from the SMART-R radar. Slices include the approximate regions of downdraft measured with the trajectory calculations shown above.

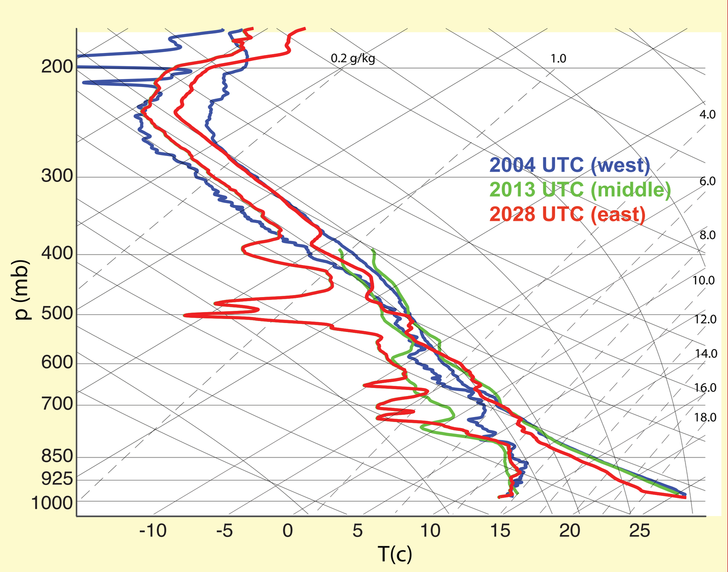
The deepest downdrafts are located in regions of mixed heavy rain, hail, and graupel. Shallower downdrafts contain a distribution of hydrometeors more consistent with typical stratiform rain (low-levels) and snow (aloft) conditions reported in trailing/leading regions of many QLCSs.



(*LEFT*) A combination of 3 proximity soundings in the near-storm inflow and 3 stesonet surface observations of outflow thermodynamics are used to constrain and pinpoint possible downdraft origin heights in the QLCS, and to address the sensitivity of these estimations to different environmental base states. Wet-bulb potential temperature is calculated for a variety of heights on each sounding and parcels brought down to the surface pseudo-moist-adiabatically for comparison with stesonet observations. This method utilizes typical parcel theory assumptions (e.g., neglects mixing of environmental/cloudy air, pressure gradient forces) to estimate downdraft/outflow thermodynamics, constrained by surface observations.

A variety of possible downdraft origin heights are identified using this method. In general, downdrafts initiated from two main regions have thermodynamic properties that are consistent with surface observations: 1) from certain heights within the boundary layer (approximately 400-1800 m AGL), or 2) from various layers at upper levels (6.5-10 km AGL). Saturated air from mid-levels (~2.0 km - 6.0 km) is much colder at the ground than surface observations. Air originating from the upper most of the identified layers (z ~ 6.5-10 km) are positively buoyant for a deep layer aloft, suggesting that this air does not reach the surface as a downdraft (without significant downward-oriented pressure gradient forces present). Downdraft air with thermodynamics consistent with surface data from the "Middle" and 'North" stesonet stations have similar origin altitudes; thus, there is only subtle outflow heterogeneity on the northern half of the dual-Doppler coverage region. However, parcel-theory-determined altitudes generally are lower for the "South" stesonet station.

(*RIGHT*) There is not an obvious sensitivity to the altitudes at which parcel theory predicts a surface temperature similar to stesonet observations for downward displaced air (altitude difference of only 100-400 m) based on which sounding is used. This is likely because mesoscale heterogeneity in the inflow is not particularly large. Indeed, temperature and vapor mixing ratios are qualitatively similar (differences < 3 K and 0.002 g/kg within the boundary layer and most of the tropospheric depth). The largest mesoscale variability comes from the moisture profiles between ~700-400 mb, where downward displaced air is too cold no matter which sounding is used.



CONCLUSIONS: Our project goal is to relate characteristics of severe QLCS downdrafts with local environments observed during VORTEX-Southeast. Downdrafts proximal to near-surface vorticity in the 27 March 2017 case, interrogated with backwards parcel trajectory analysis, indicated along-QLCS downdraft heterogeneity, and origins from generally two altitudes (from within the lowest kilometer and from > 3 km AGL). As a second method of downdraft origin estimation, pseudo-equivalent potential temperatures from various proximity soundings that yield thermodynamic conditions at the surface consistent with stesonet observations suggest that air descended from within the lowest 2 km of the atmosphere, or from the mid-upper levels (> 6 km AGL); however the vertical distribution of DCAPE suggests the former. It is possible that a combination of significant hydrometeor loading and significant downward-oriented pressure gradient forces could force descent of positively buoyant air from mid-upper levels. It is unclear to what degree downdraft temperature and origin altitude varies by environment in the along-QLCS direction on scales < 30 km owing to a limited surface and sounding network; however, sensitivities of downdraft properties estimated by parcel theory are subtle based on the use of 3 different soundings, and hydrometeor observations may point to intra-storm heterogeneity to explain variable downdraft strength rather than heterogene of the environment.

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