Fine-scale Radar Observations of West Texas Drylines and Embedded Misocyclones from Spring of 2012

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Introduction

Predicting convective initiation (CI) along the dryline has long proven difficult for operational meteorologists, as the dryline structure frequently produces an environment with strong potential for severe weather, though storms do not always occur. Prediction of the actual trigger of storms may improve with an increased understanding of the finescale structure and processes of the dryline—including those of dryline vortices. Although these vortices, or misocyclones, are known to vary in size and propagate along the dryline, only recently has radar technology improved enough to make observations in a detailed manner. Thus, little is known about their formation and evolution. Misocyclones are theorized to be caused by the intersection and tilting of horizontal convective rolls (HCR) along various air mass boundaries, such as drylines (Buban et al. 2007), and may be regions of enhanced vertical air motion—potentially catalyzing CI. If rolls are indeed responsible for these misocyclones, the size and spacing of misocyclones may be directly related to boundary layer depth. Likewise, vertical shear would be necessary for roll formation, and likewise, misocyclone formation. This research will consider these possibilities and the need, if any, for cross-dryline horizontal wind shear. Using dual-Doppler methodology and data from two Texas Tech Ka band (TTUKa) radars with 0.49 deg beam width, multiple dryline events are objectively analyzed to derive 2-D wind fields and regions of enhanced convergence and vorticity. RHIs are also utilized to record the vertical wind profile, slope of the dryline within the convergence zone, and depth of the moist boundary layer to the east of the convergence zone.

Objectives / Hypotheses

1. HCR-dryline intersection results in misocyclone genesis.
2. Strength and spacing of misocyclones are both proportional to boundary layer depth.
3. Horizontal wind shear is necessary for the existence of misocyclones within the dryline.
4. Individual cumuli are associated with misocyclones.

Methods

Two Texas Tech Ka band radars are utilized to collect high resolution dual-Doppler data on the dryline. Target observation locations include a 70 km radius from Lubbock, Texas on the Caprock (High Plains) where the ground is flat and ground clutter is minimal. The lowest possible elevation angles are used for PPI scans (0.5 - 1.5 degrees), while crossing RHIs are taken to profile the boundary layer wind structure. Radars are deployed in the moist side of the dryline where returned power from scattering boundary-layer targets is stronger, in a dryline-parallel (North/South) orientation with a 5-10 km baseline. In opportune conditions, the dryline advances over the radars moving from one dual lobe and into the other.

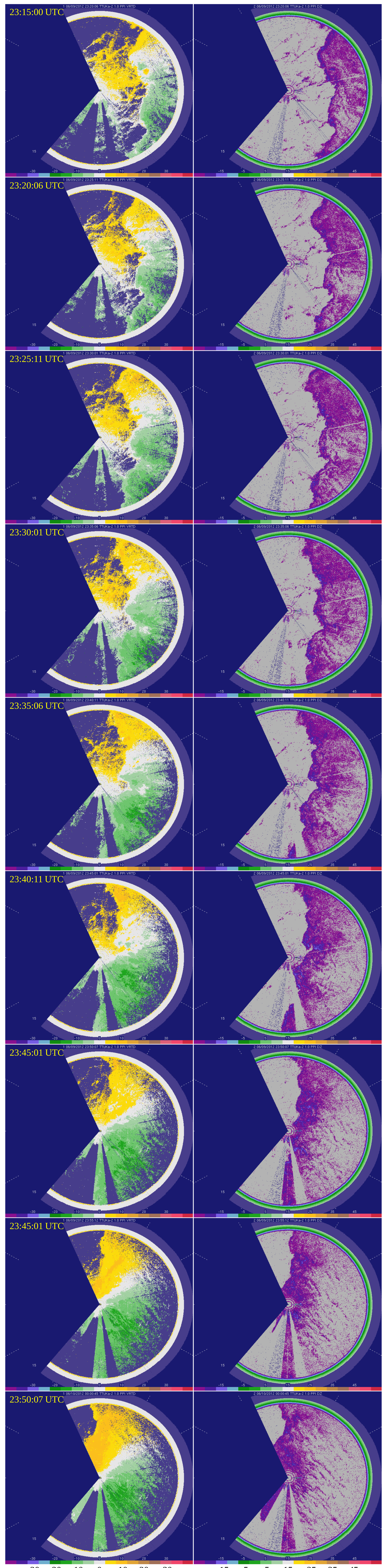


Figure 1. TTUKa radar (left) radial velocity (m s^{-1}) and (right) reflectivity (dBZ) from the June 9 2012 dryline event. Panels cover the time period 2315-2350 UTC. In this case, the dryline was moving westward with misocyclones. In a matter of minutes, as the sun lowered toward the horizon and solar surface heating diminished, the dryline began a rapid retreat westward, overtaking all misocyclones.

Results

Tilting of HCRs alone seems unable to account for the formation of all misocyclones. The most substantial misocyclones tend to exist when enhanced regions of reflectivity in the dry air intersect the dryline. However, these enhanced regions are not always linear in structure; rather, they appear to lie on a spectrum from linear to cellular organization. (Fig. 2, Fig. 4) Misovortices are also observed to exist within some of these secondary boundaries and then propagate into and up the dryline, making a turn at the intersection point (Fig. 2). This, to the authors' knowledge, has never before been observed.

In this study, misocyclones have been observed with diameters ranging from the lower limit of resolution (~200 m) up to about 4000 m in diameter (May 19, 2012; April 30, 2012). The largest of misocyclones have been observed to break down into a linear series of two or more smaller misocyclones (April 30, 2012). Both cyclonic and anticyclonic vortices are observed, though cyclonic vortices are observed more frequently and for longer durations. In one case, a small antimisocyclone was observed within (passing through) a larger dryline vortex (May 19, 2012).

Vortices are observed on advancing, stationary, and retreating drylines, though are most prolific on quasi-stationary drylines. Misovortices become much less apparent when the rate of dryline retreat increases, perhaps due to the cessation of boundary layer heating (Fig. 1).

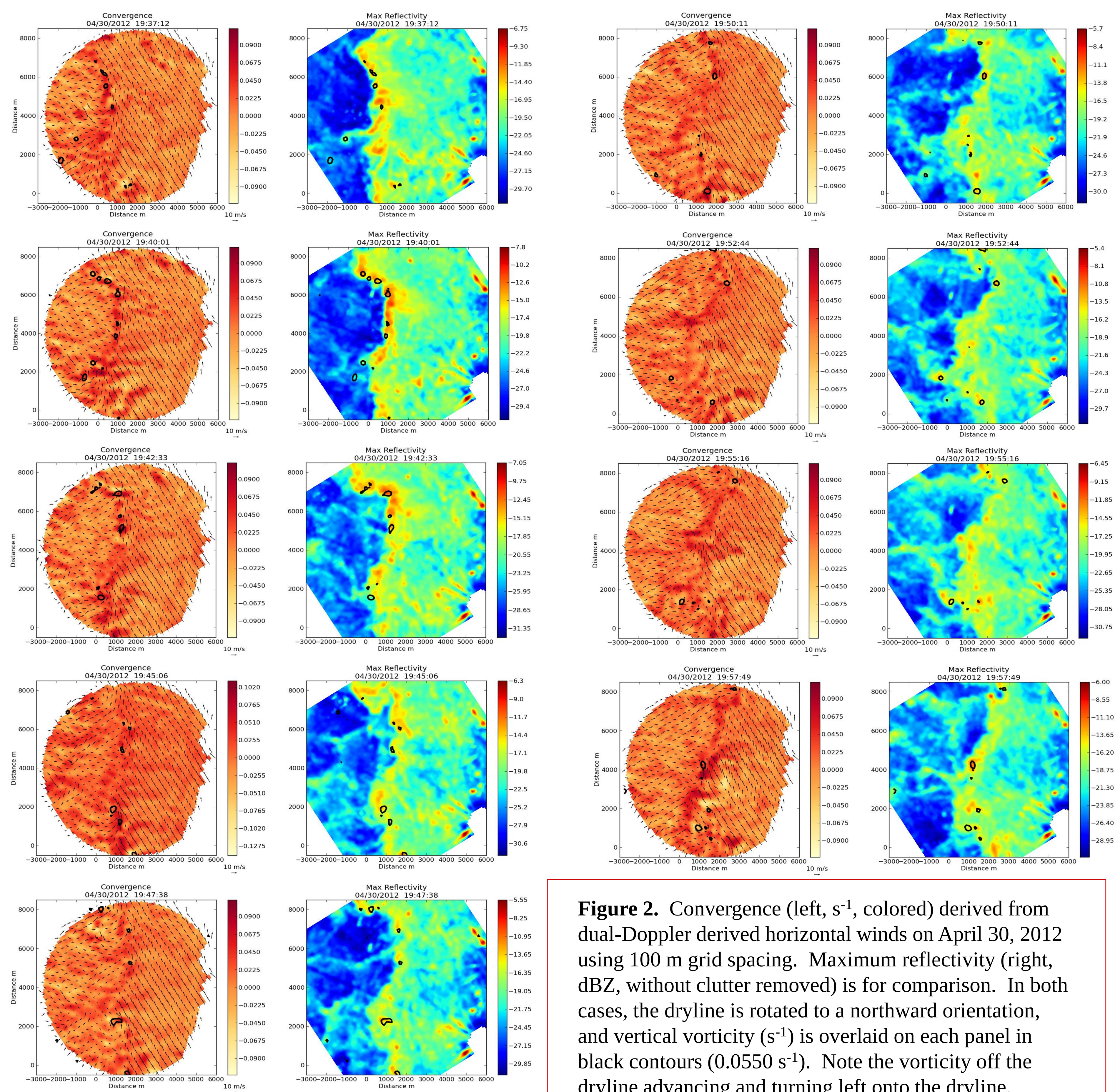
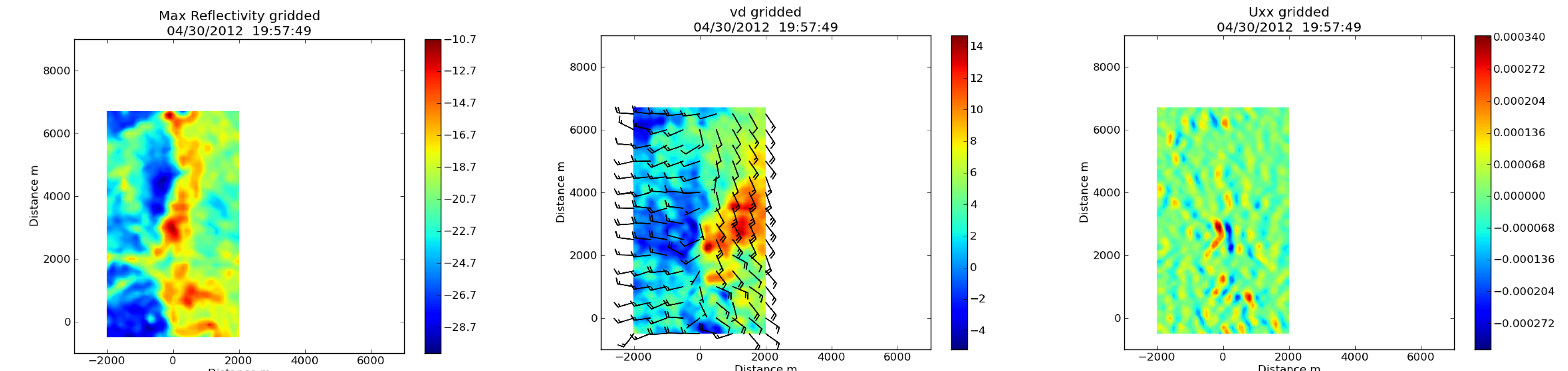


Figure 2. Convergence (left, s^{-1}, colored) derived from dual-Doppler derived horizontal winds on April 30, 2012 using 100 m grid spacing. Maximum reflectivity (right, dBZ, without clutter removed) is for comparison. In both cases, the dryline is rotated to a northward orientation, and vertical vorticity (s^{-1}) is overlaid on each panel in black contours (0.0550 s^{-1}). Note the vorticity off the dryline advancing and turning left onto the dryline.

Figure 3. (left) Reflectivity (dBZ, colored), (middle) dryline-parallel winds, v, (barbs in m s^{-1}, magnitude colored) and (right) d^2v/dx^2 (m^{-1} s^{-1}, colored). Dryline is rotated where a linear dryline segment can be analyzed.



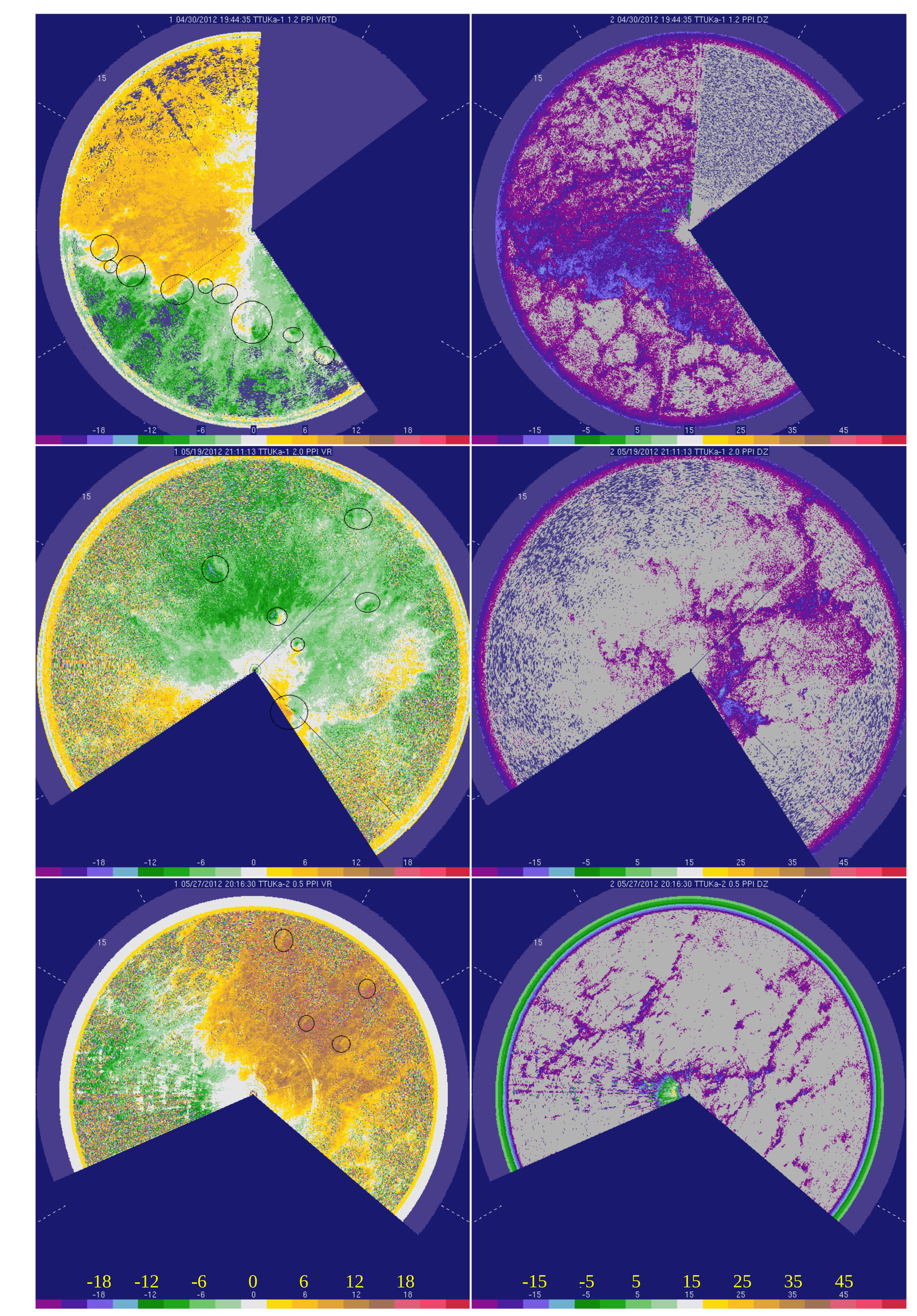


Figure 4. (left) TTUKa radar reflectivity (colored, dBZ) and (right) radial velocity (colored, m s^{-1}) for dryline cases on April 30, 2012, May 19, 2012, and May 27, 2012. Three distinct patterns of convection are evident within the boundary layer surrounding each dryline, with each case featuring dryline misocyclones (circled).

Conclusions and Future Work

As HCR tilting fails to account for all misocyclonegenesis, other hypotheses must be considered; e.g. current work is focused on comparing observed wind to the fluid flow instability criteria given by Rayleigh and Fjortoft (Fig. 4). Satellite data and RHIs also are in the process of being analyzed, in attempts to collocate vortices with clouds, and profile moist boundary layer structure. Furthermore, the physical governing processes of dryline motion and sharpening need a better understanding. There is a clear general diurnal pattern associated with dryline motion, but on smaller time scales the dryline may advance, halt, or begin retreating at different rates and times. Likewise, the dryline does not sharpen suitably for observation in a predictable manner.

Acknowledgements

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