Radar Observations and Analysis of Misocyclones Along Spring 2012 West Texas Drylines

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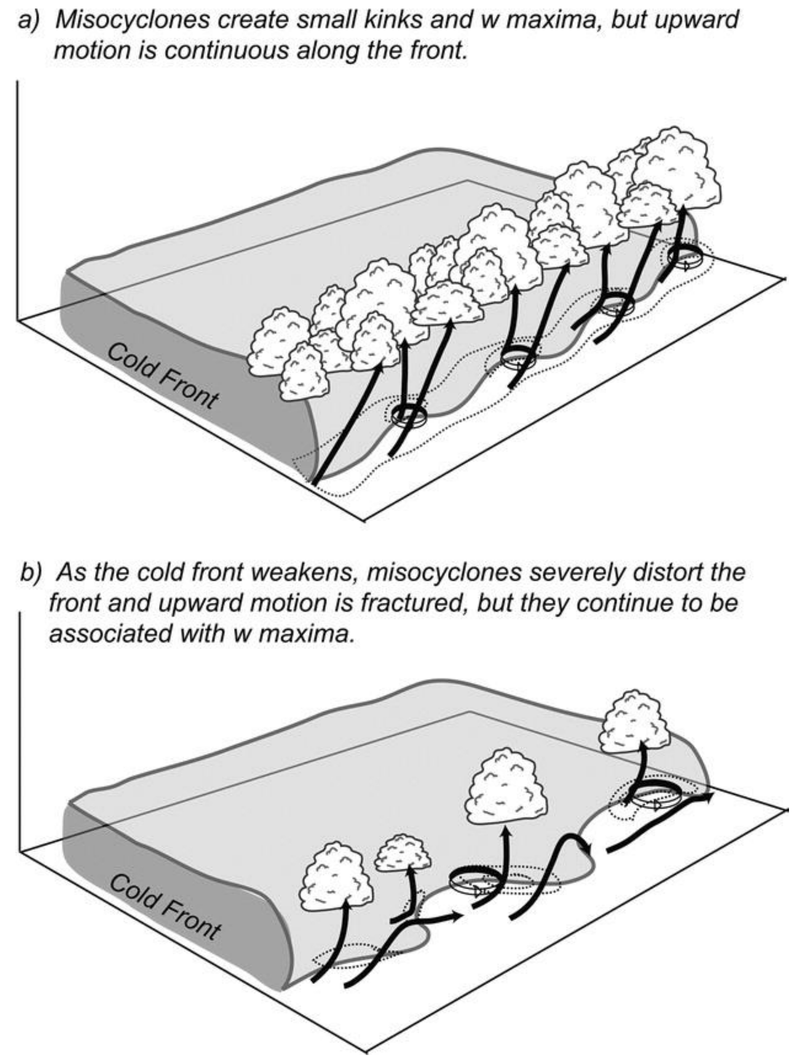
Introduction

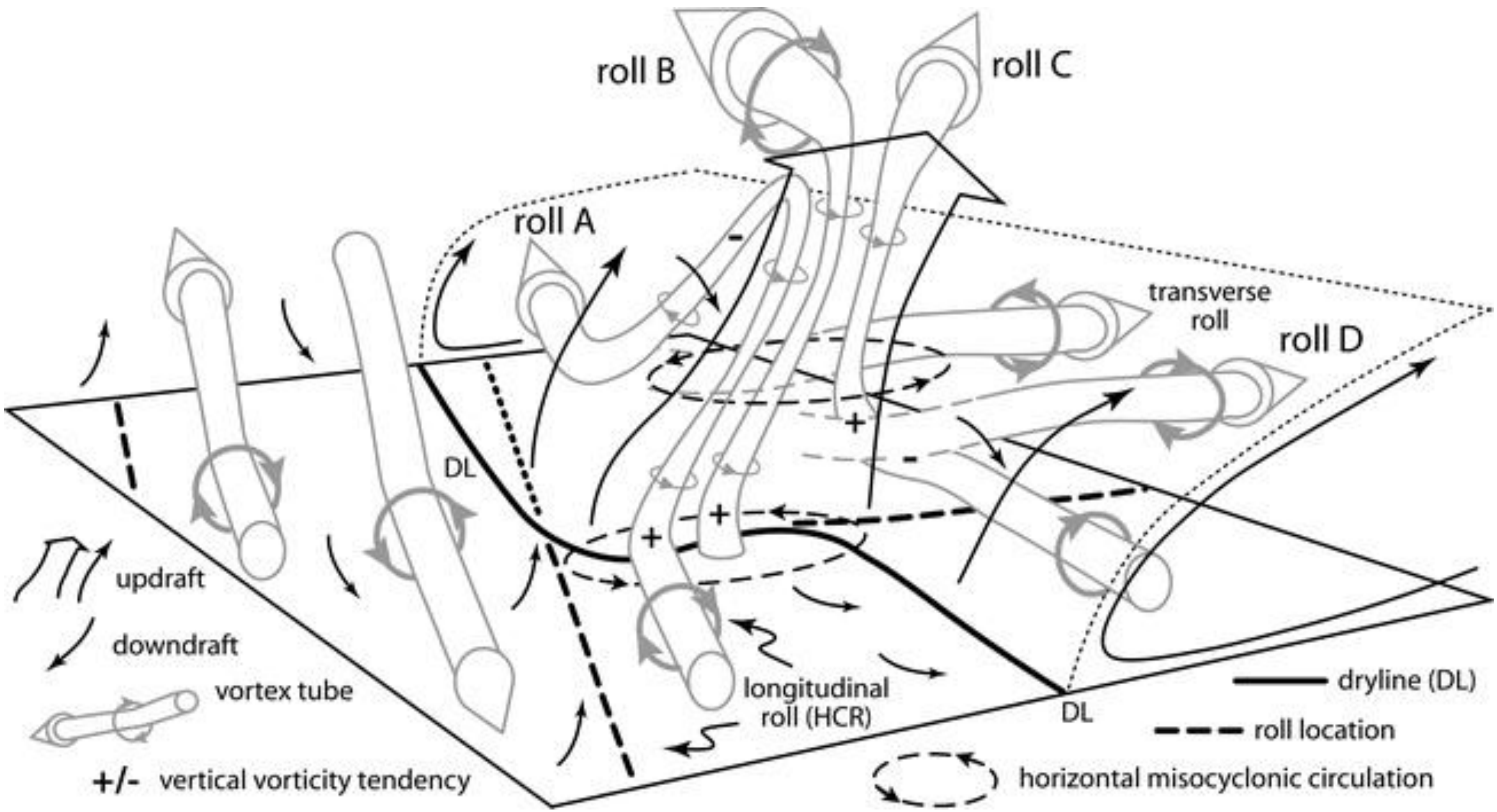
- The dryline is known to be associated with clouds and thunderstorms.
- Vorticity maxima (misocyclones) have been observed to exist and propagate along fronts such as cold fronts and drylines.
- Horizontal Convective Rolls (HCRs) are often associated with Convective Initiation (CI) along boundaries.
- Dryline CI is difficult to predict, and the mechanisms are poorly understood.
- Is HCR tilting and stretching responsible for misocyclones? CI?



Arnott et al. 2006

Misocyclogenesis Theory

Buban et al. 2007



Hypotheses

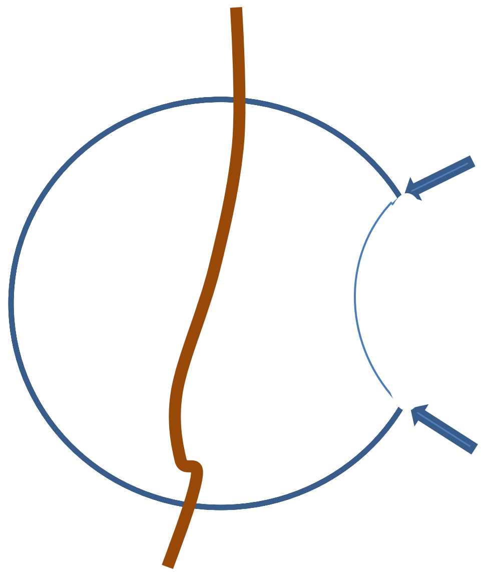
1. HCR-dryline intersection results in misocyclone genesis.

2. Horizontal shear is necessary for the existence of misocyclones within the dryline.

3. Individual cumuli are associated with misocyclones.

2012 Field Campaign

- Use two high resolution TTUKa radars for dual-Doppler synthesis to derive 2-D wind field.
- 4-7 km baseline
- Scan at lowest possible elevation angle.
- Collect Range Height Indicators (RHI) for vertical cross-section of dryline.



Two TTU Ka radars positioned at the two arrows with a baseline of 4-7 km. The dual Doppler field is enclosed in the circular figure while a simulated dryline is drawn in brown.

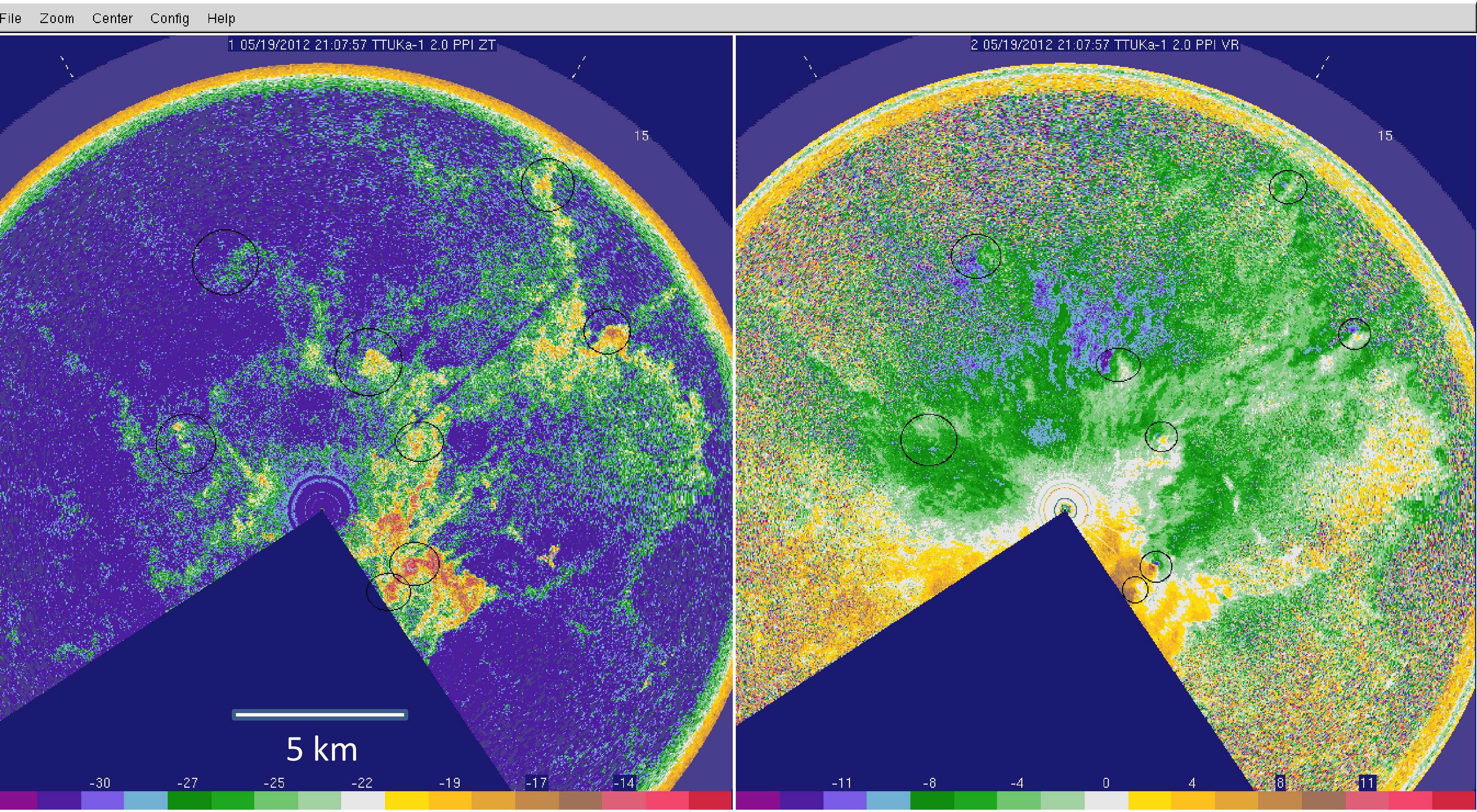
TTUKa Radars

- **3 dB beamwidth:** **0.33°**
- **Gate spacing:** **9-15 m**
- Maximum PRF: 20 kHz
- Antenna Gain: 52 dB
- Transmitter Type: TWTA
- Transmitter Freq.: 34.86 GHz (λ=8.6 mm)
- Duty Cycle: up to 50%
- Pulse compression ratio, $T / T' = T\Delta f$: $20 \leq T\Delta f \leq 30$

Photo credit: Patrick Skinner

Dryline Variability:
Example Observations

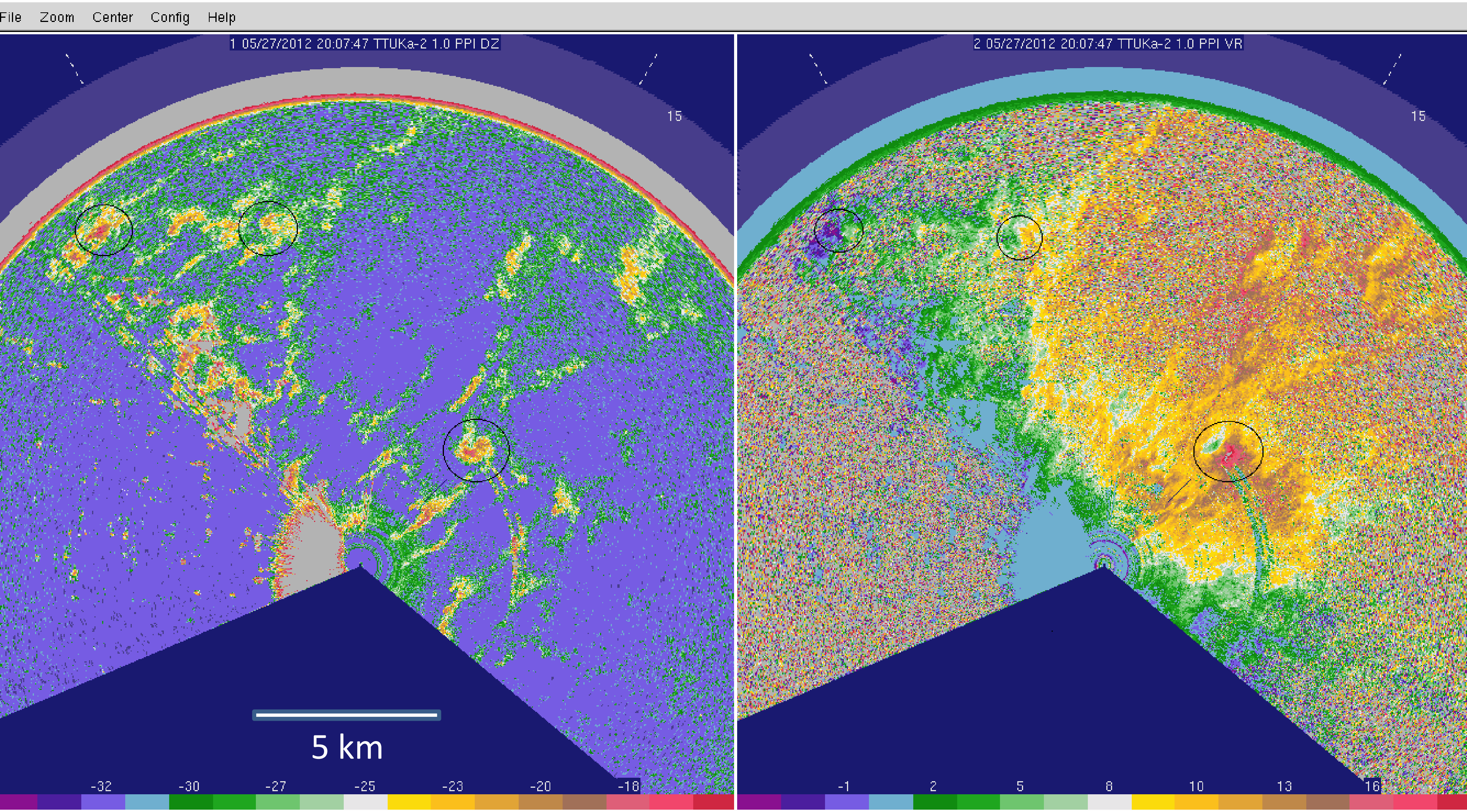
19 May 2012



Reflectivity

Radial Velocity

27 May 2012

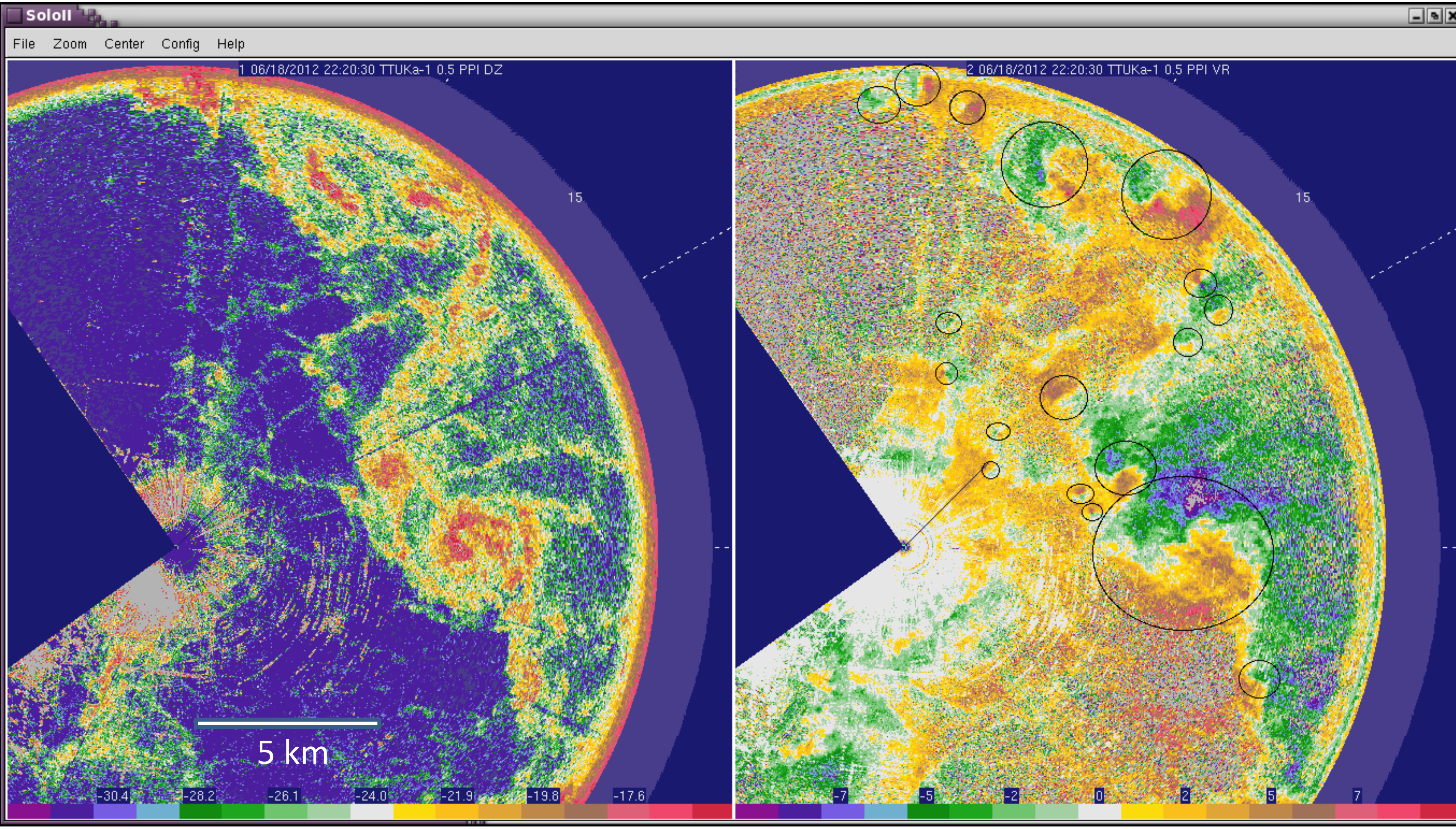


Reflectivity

Radial Velocity

18 June 2012

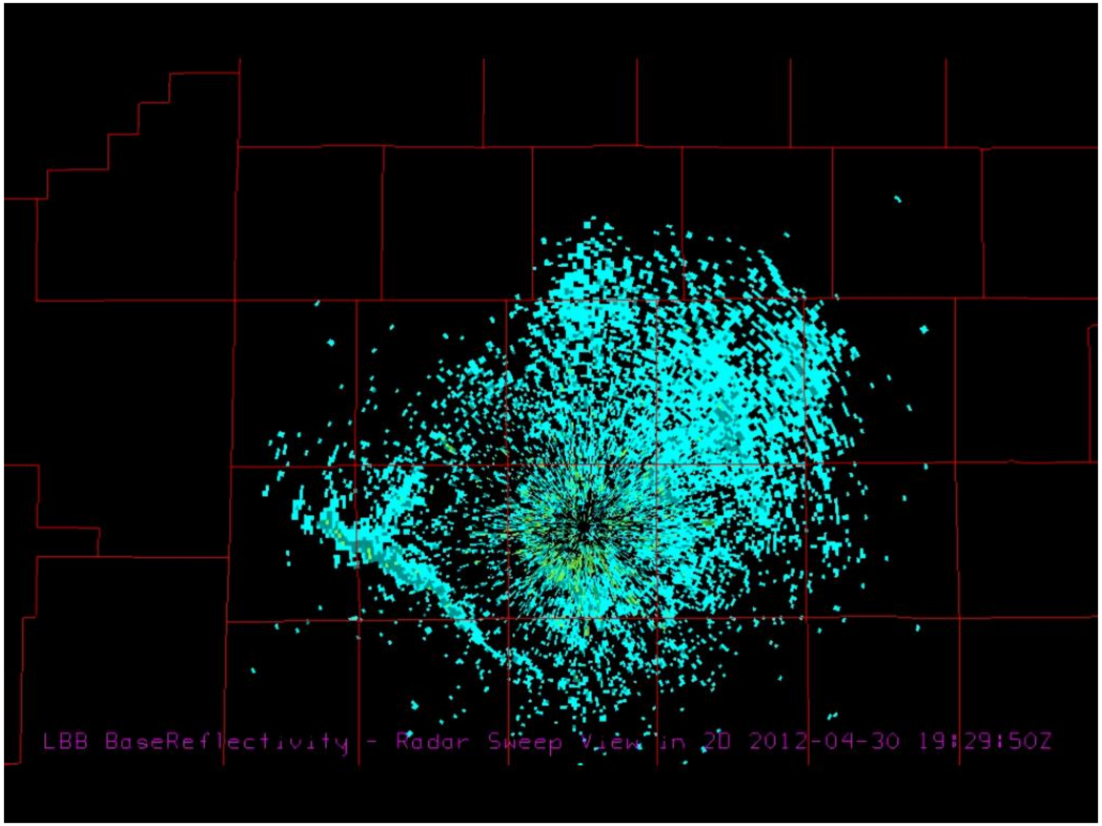
Dryline Orientation



Reflectivity

Radial Velocity

Case Study: 30 April 2012

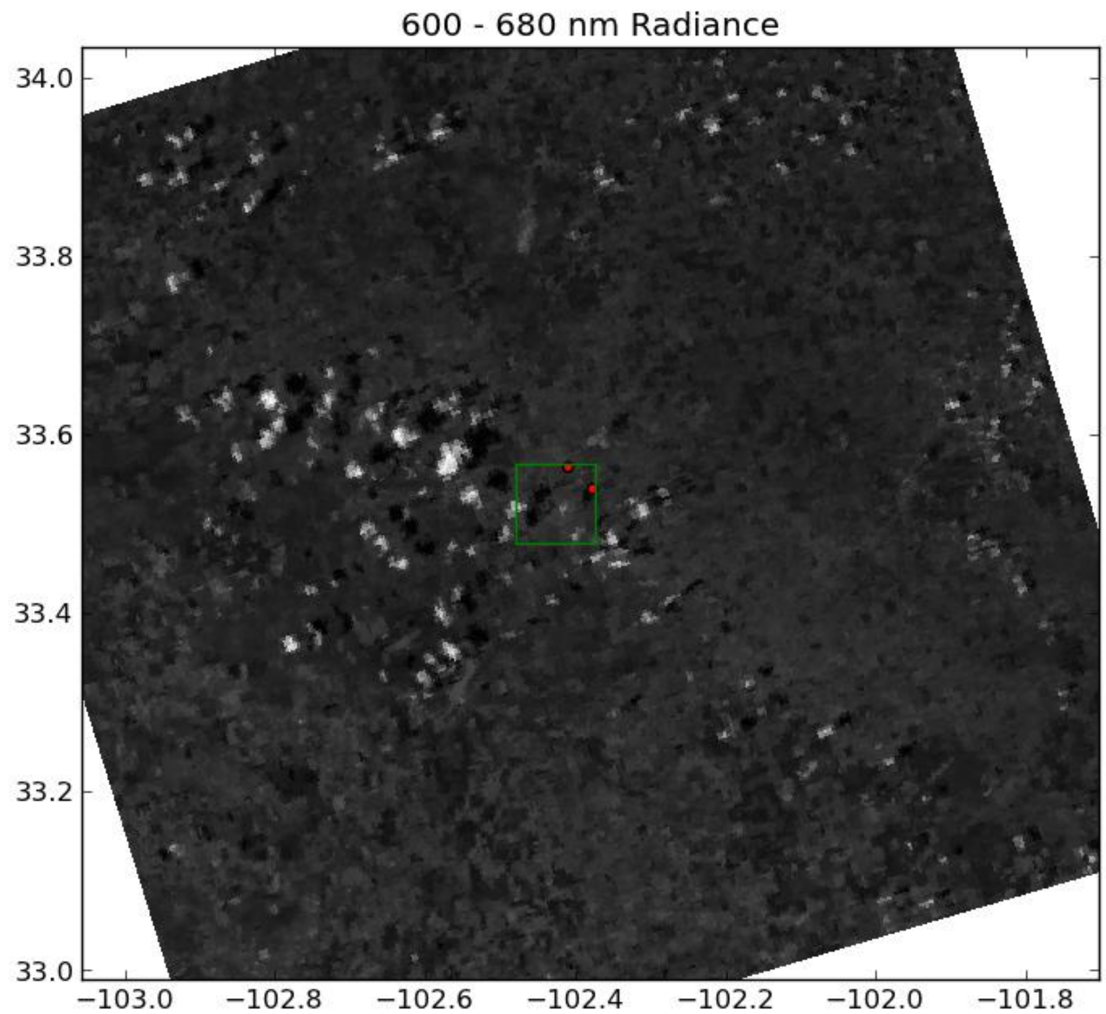


- Moderate CAPE (~1600 J/kg) and high CIN (~200 J/kg)
- Late AM / Early PM: Dryline sharpens
- 1925 UTC: Deploy TTUKa radars southwest of Levelland, TX
- 2035 UTC: CI along dryline at ~100 km north and south of observation domain

Case Study: 30 April 2012

1928 UTC satellite image of West Texas from the 375 m resolution Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (NPP) satellite.

The green box indicates the 10x10 km observation domain while the red dots indicate the position of the two radars, with a 4 km baseline.



Data Analysis

- SOLO, DREADER algorithms, and hand editing used to clean data.

- Barnes 2-pass filter objective analysis

  $K = .018\ km^2$

  $\gamma = .4$

- 40 m grid spacing

Case Notes

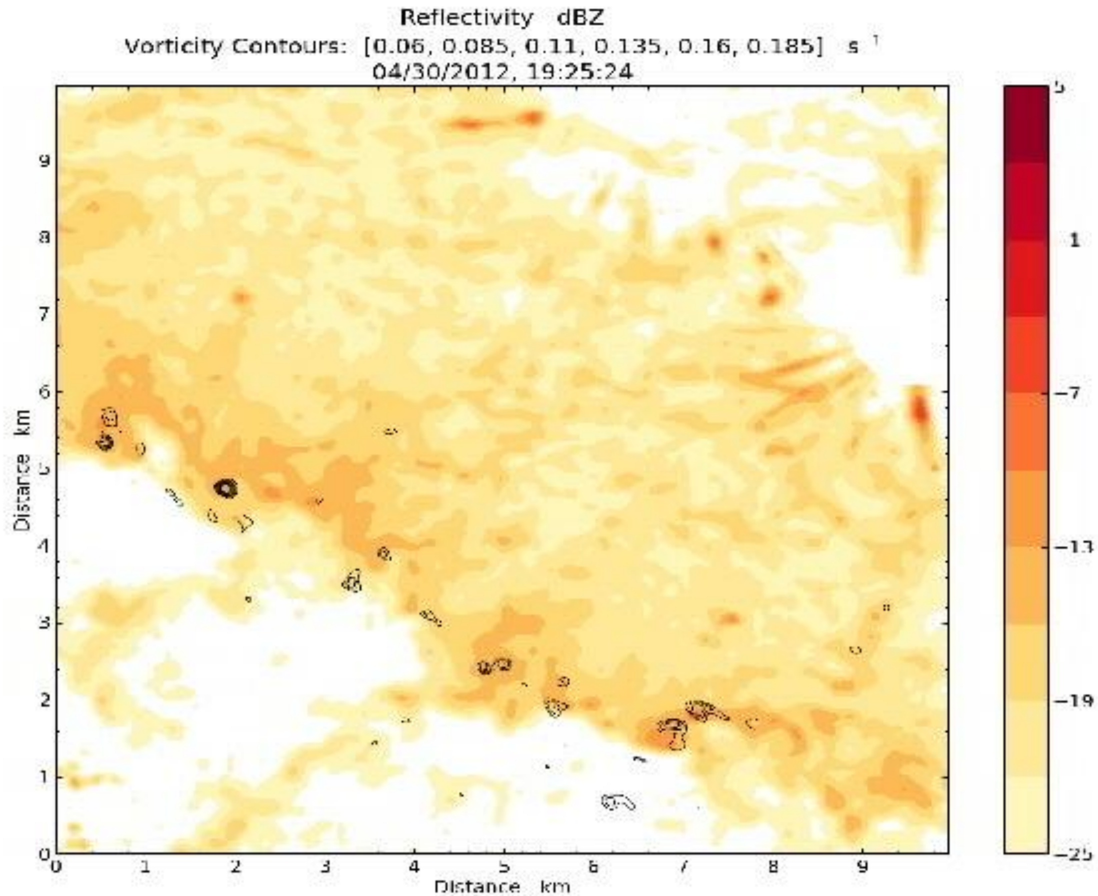
- Role of reflectivity structures intersecting the dryline:
  - Linear Horizontal Structures (LHS)
  - Quasi-linear structures
  - Open cellular convection

- Misocyclone mergers, splits, and Fujiwhara interactions

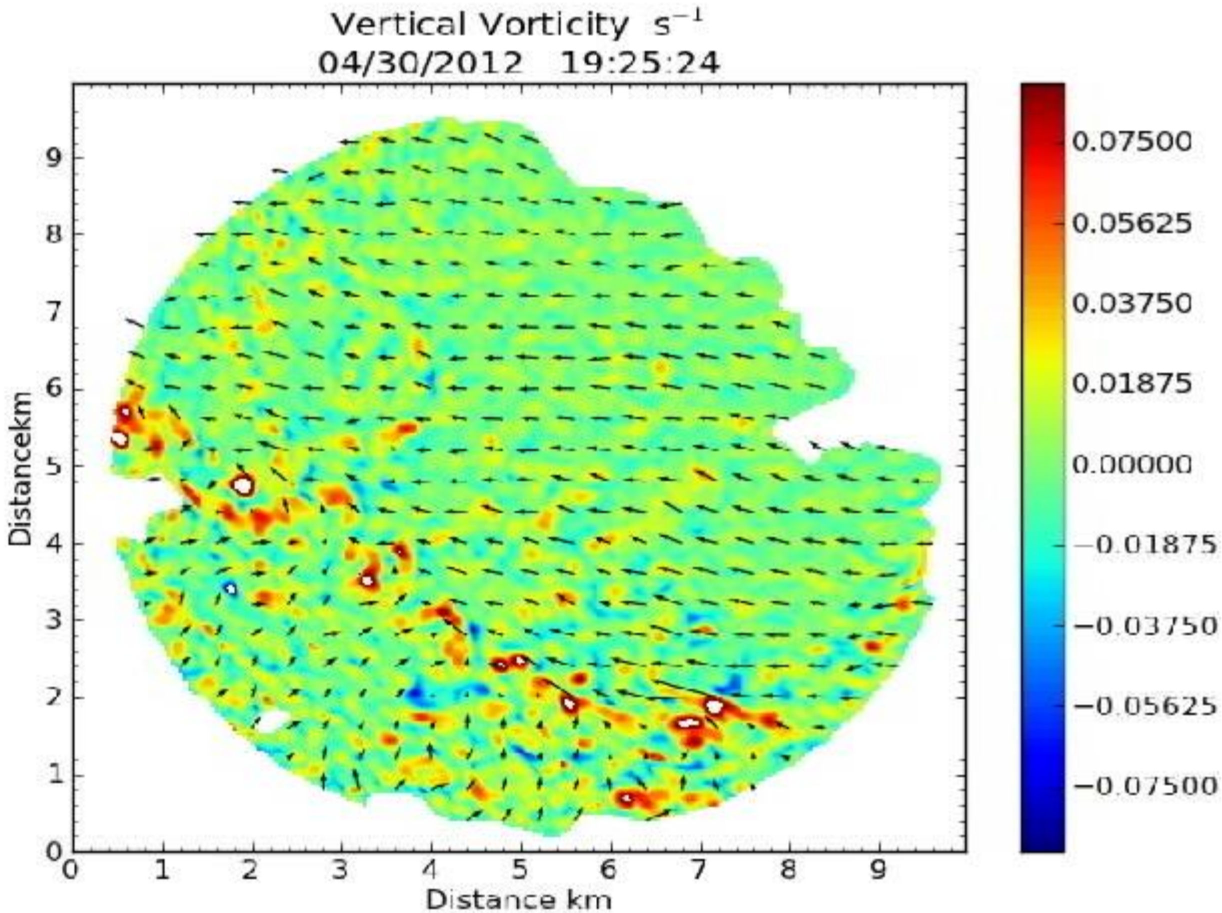
- Propagation of misocyclones along LHSs and continuing into and along dryline

- Offset of convergence maxima relative to misocyclones

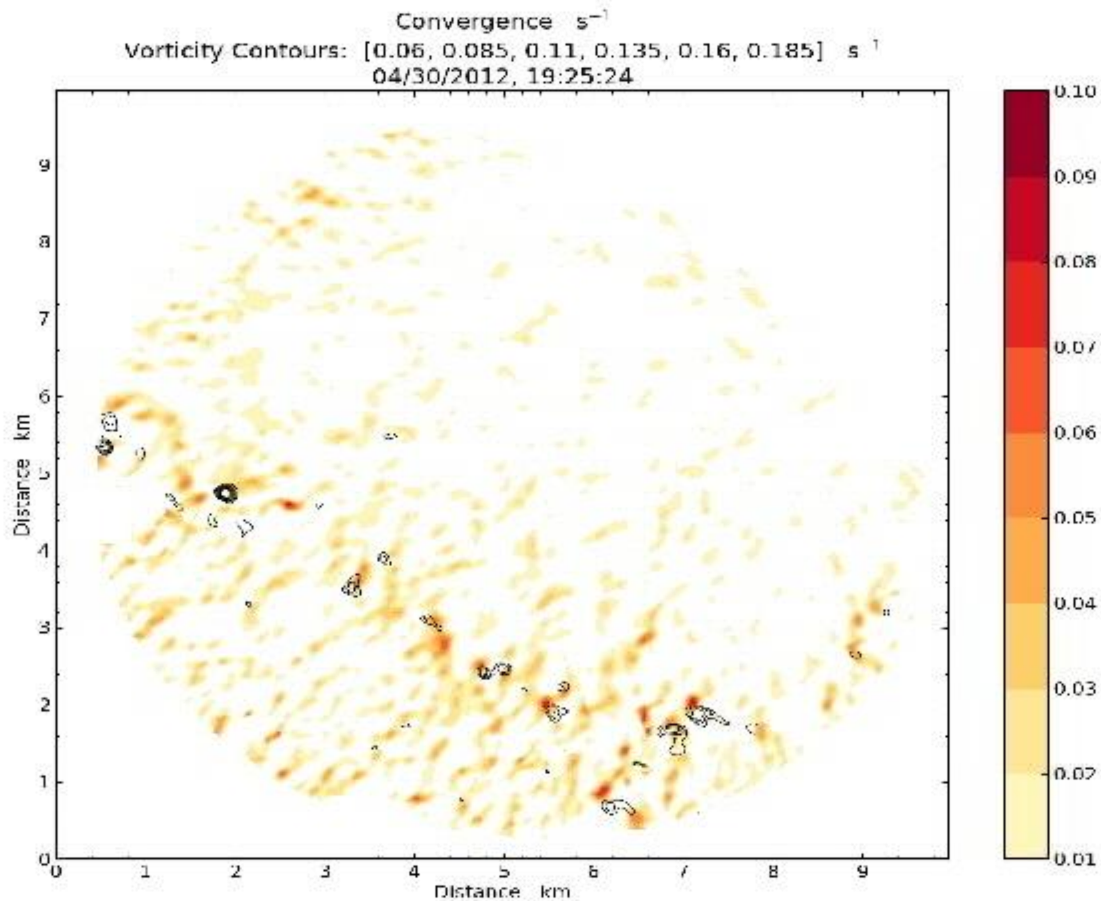
30 April 2012 – Reflectivity

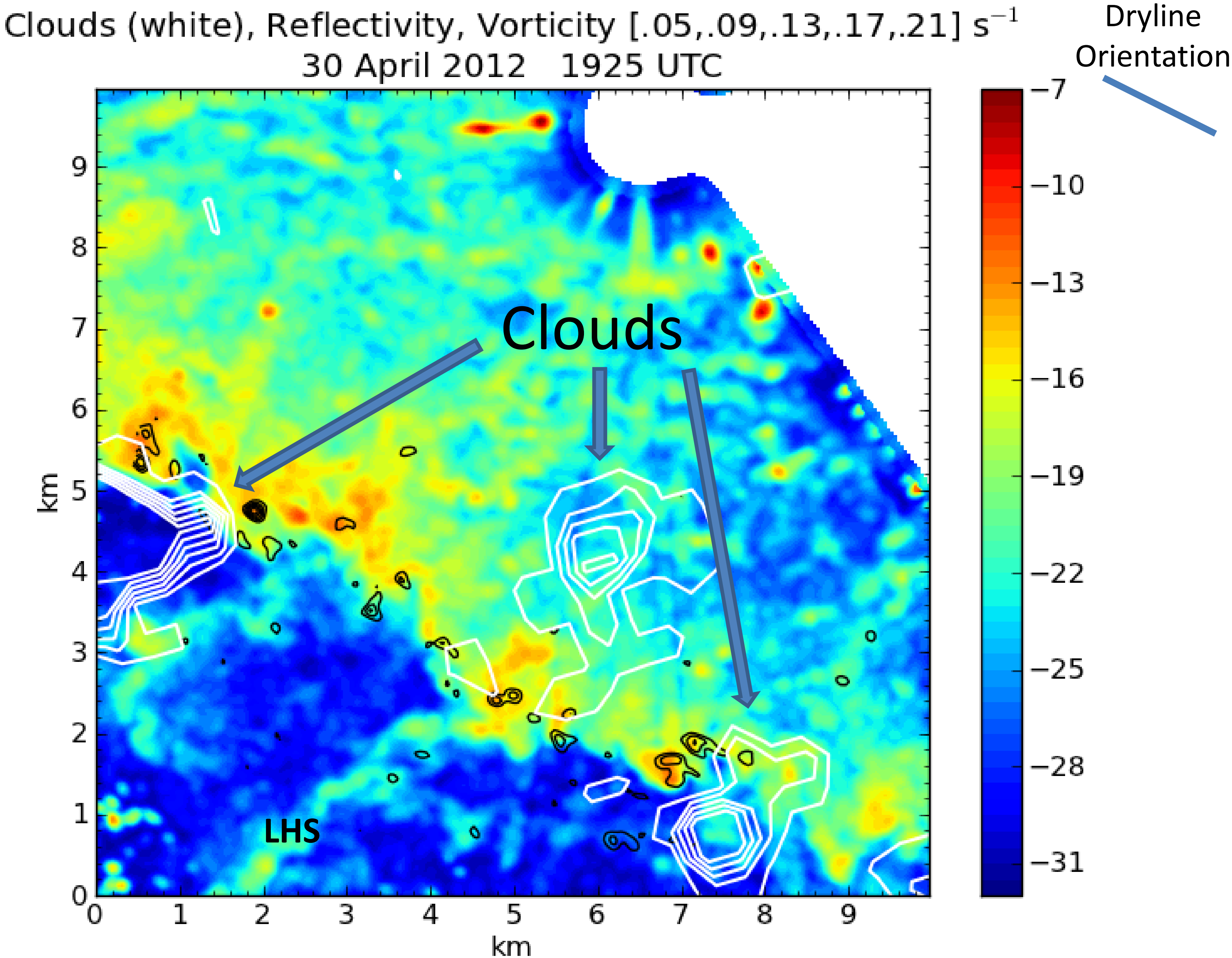


30 April 2012 – Vertical Vorticity



30 April 2012 – Convergence





Clouds (white), Reflectivity, Vorticity [.05,.09,.13,.17,.21] s^{-1}
30 April 2012 1925 UTC
Dryline
Orientation
Clouds
LHS
km
km

Clouds, Misocyclones, and HCRs

- LIMITATION: resolution of satellite compared to resolution of radar data

- No objective correlation between vorticity and clouds.

- In one case, cloud aligned well with an LHS.

HCR Tilting Theory of Misocyclogenesis

Arguments in Favor:

- Cloud in middle of domain well-aligned to LHS.

Arguments against:

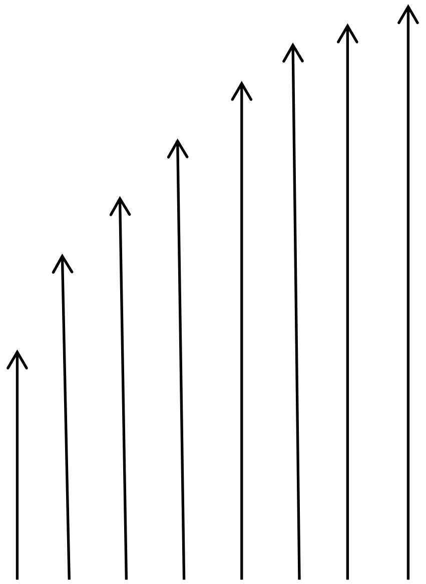
- LHSs not always associated with observed misocyclones.
- Misocyclones exist on LHSs themselves.

Misocylogenesis: Alternative Theory

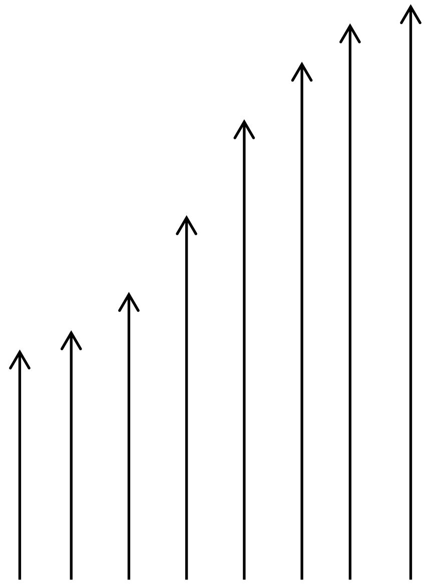
- Could classic fluid dynamics explain observed 30 April 2012 misocyclones?
- **Hypothesis:** parallel-flow shear instabilities, e.g., Rayleigh and Fjortoft instabilities, generate misocyclones.

Rayleigh Instability

$$\frac{d^2v}{dx^2} = 0$$



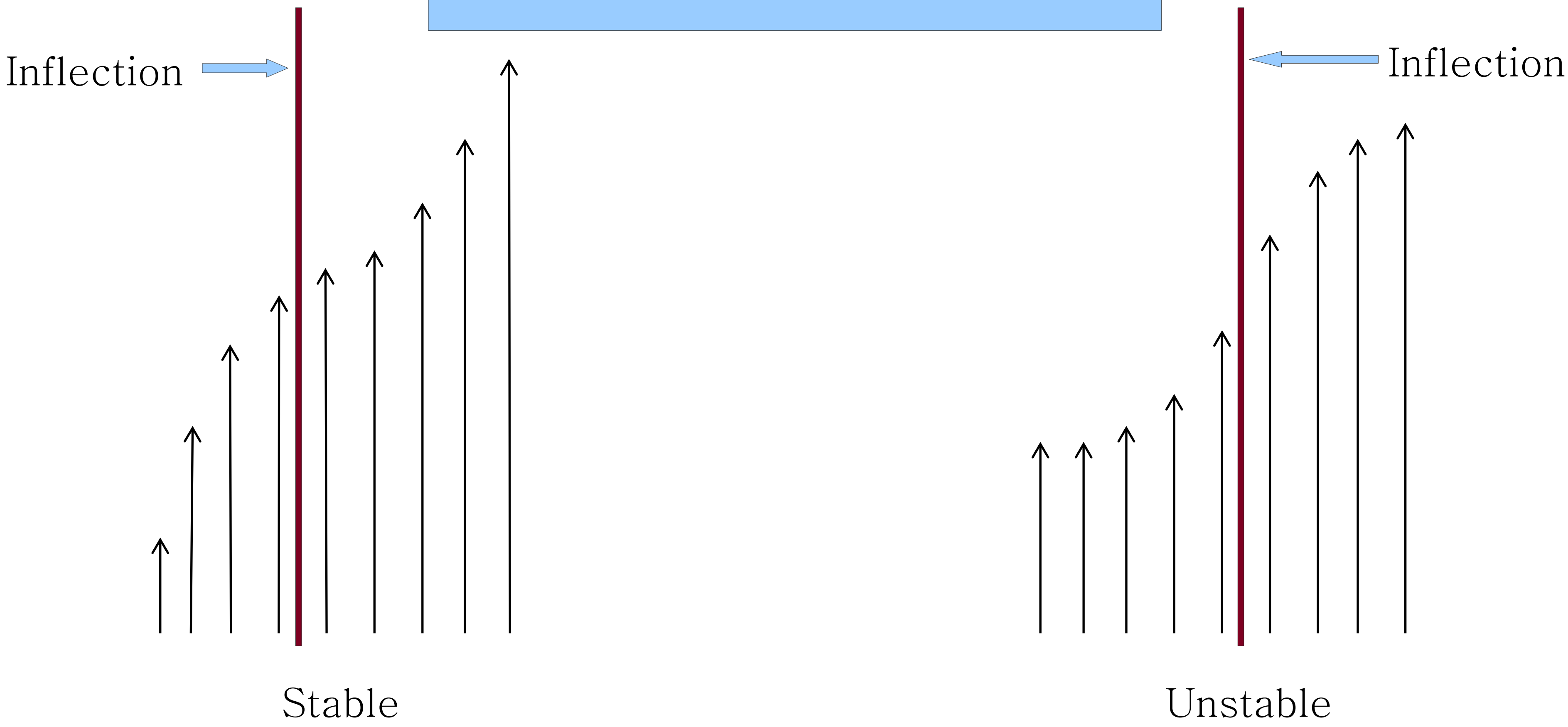
Stable

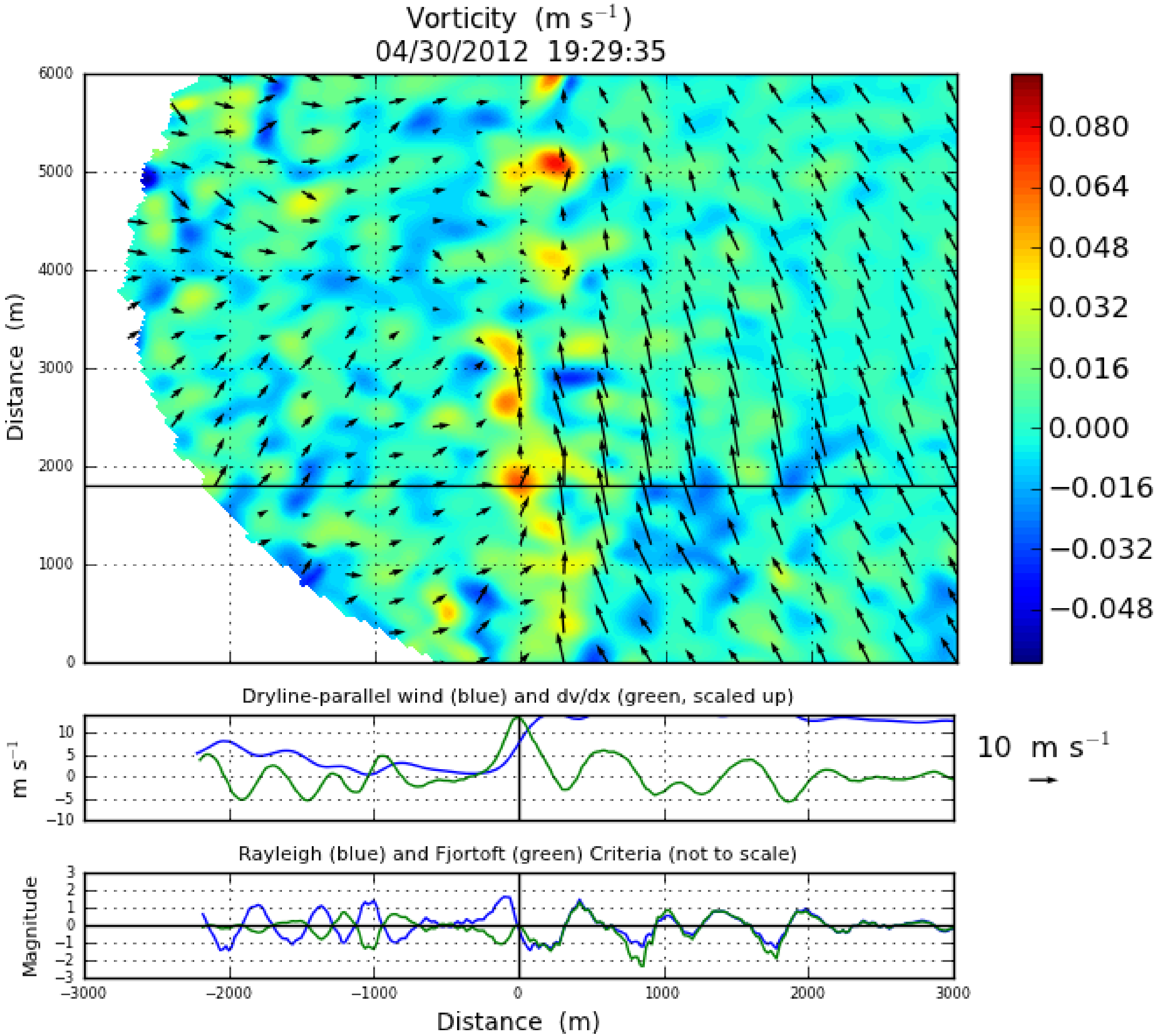


Unstable

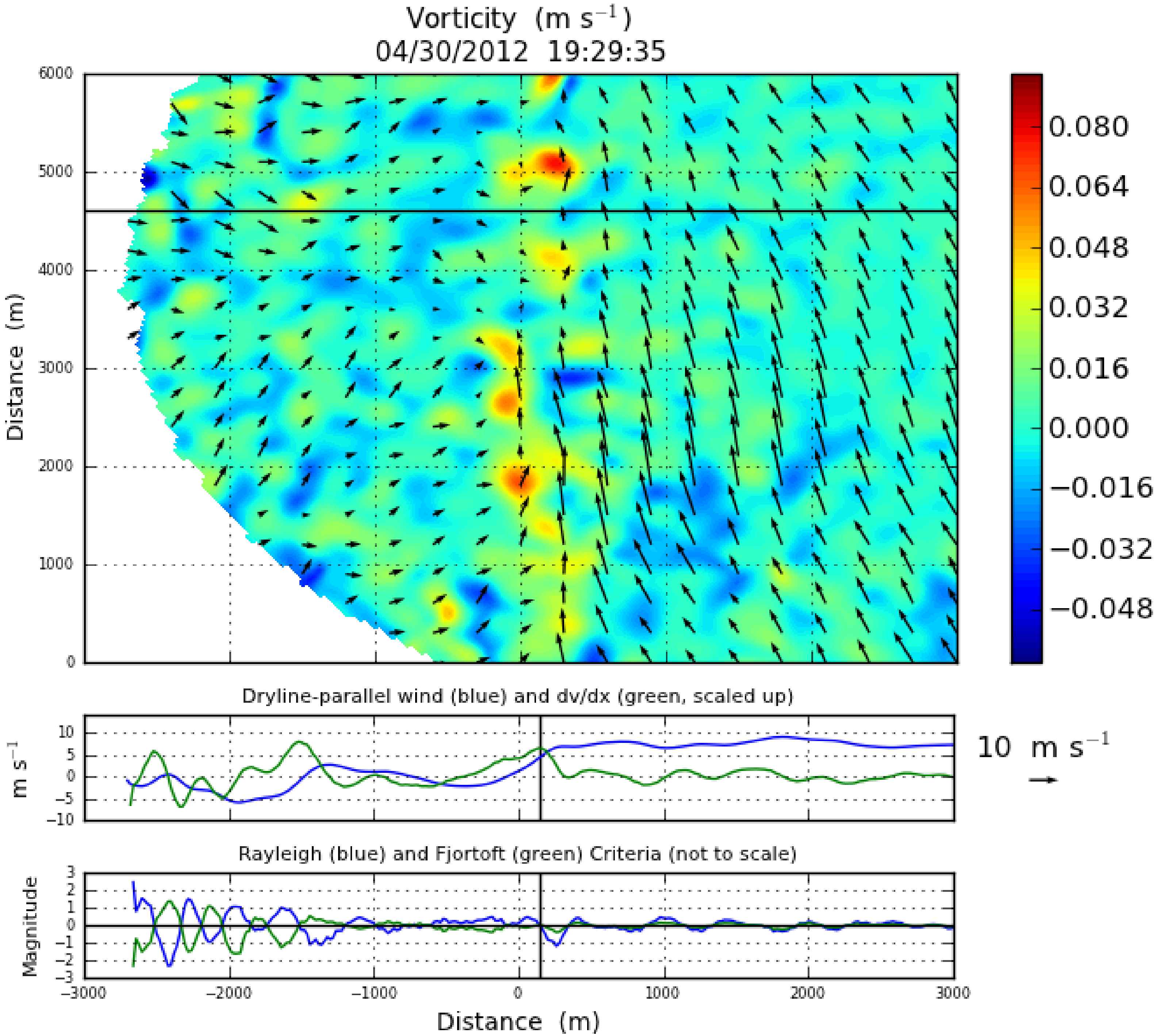
Fjortoft Instability

$$(V - V_i)\,\frac{d^2 v}{dx^2} < 0$$





Vorticity (m s^{-1})
04/30/2012 19:29:35
Distance (m)
0.080
0.064
0.048
0.032
0.016
0.000
−0.016
−0.032
−0.048
Dryline-parallel wind (blue) and dv/dx (green, scaled up)
m s^{-1}
10 m s^{-1}
Rayleigh (blue) and Fjortoft (green) Criteria (not to scale)
Magnitude
Distance (m)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m s^-1
10 m s^-1
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Magnitude
Distance (m)

Ongoing Analysis

- Objectively correlate HCRs (reflectivity) with misocyclones, clouds.

- Correlate Rayleigh, Fjortoft instability with misocyclone intensification.

- Compare boundary layer depth from Range Height Indicators (RHIs) to misocyclone spacing.

Conclusions

- More than HCR tilting is at play in the genesis of misocyclones.
- Misocyclones are observed propagating along LHS, left turning onto dryline.
- Horizontal shear may be necessary for misocyclones to form in that flow instabilities may be tied to vertical vorticity intensification.
- Vertical velocity is likely offset from misocyclones because both convergence maxima and clouds are both offset. Direct comparison, however is challenging due to single level radar analysis and large differences in resolution between satellite and radar data.