



Eyewall Replacement Cycle of Hurricane Matthew (2016) Observed by Doppler Radar

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Eyewall Replacement Cycle (ERC)

Distinctive Three phases:

- **Intensification**

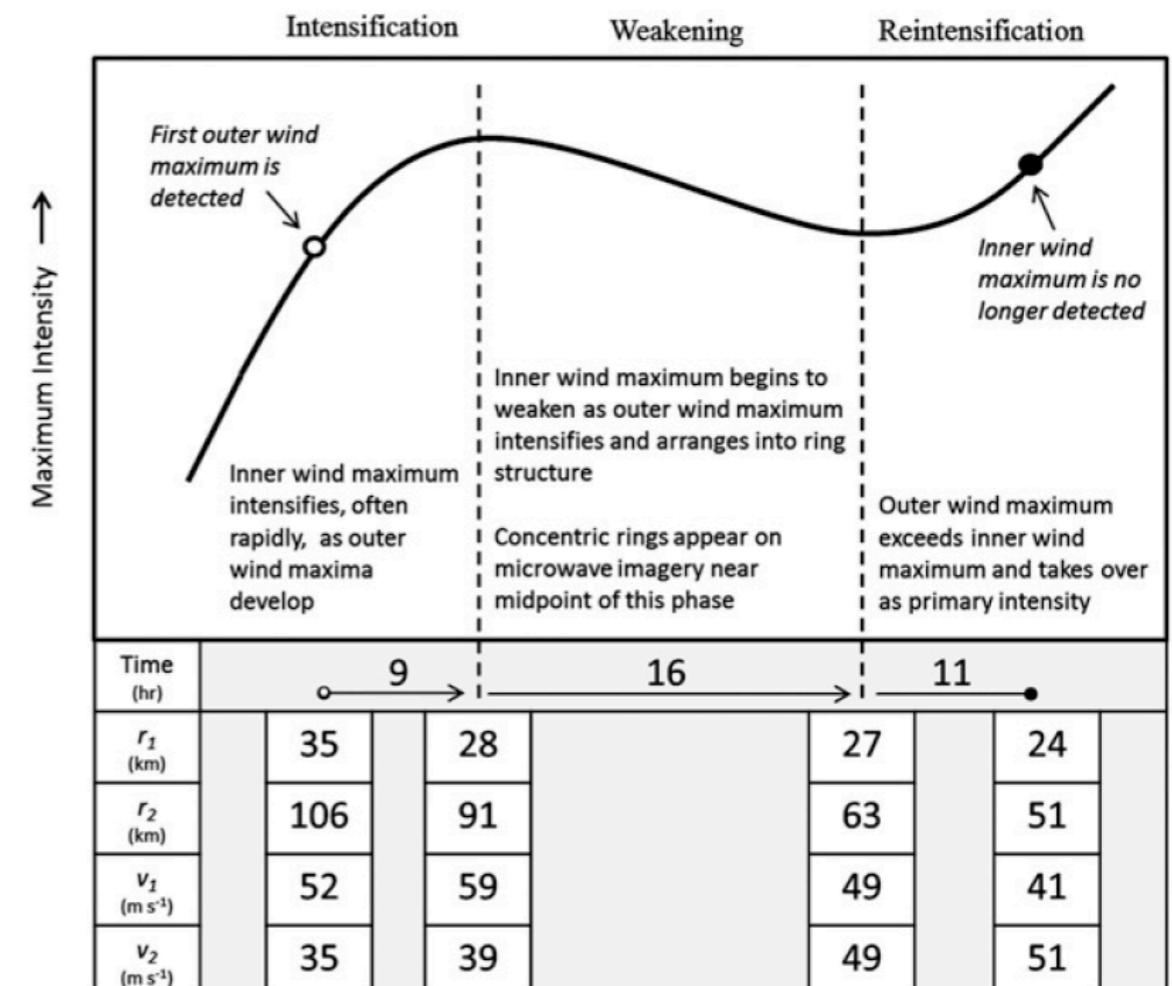
Both inner and outer wind maxima undergo contraction and intensification.

- **Weakening**

The inner wind maximum steadily weakens as the outer wind maximum continues to contract and intensify.

- **Reintensification**

The outer wind maximum intensity surpasses the inner wind maximum and continues to intensify.



Sitkowski et al. 2011

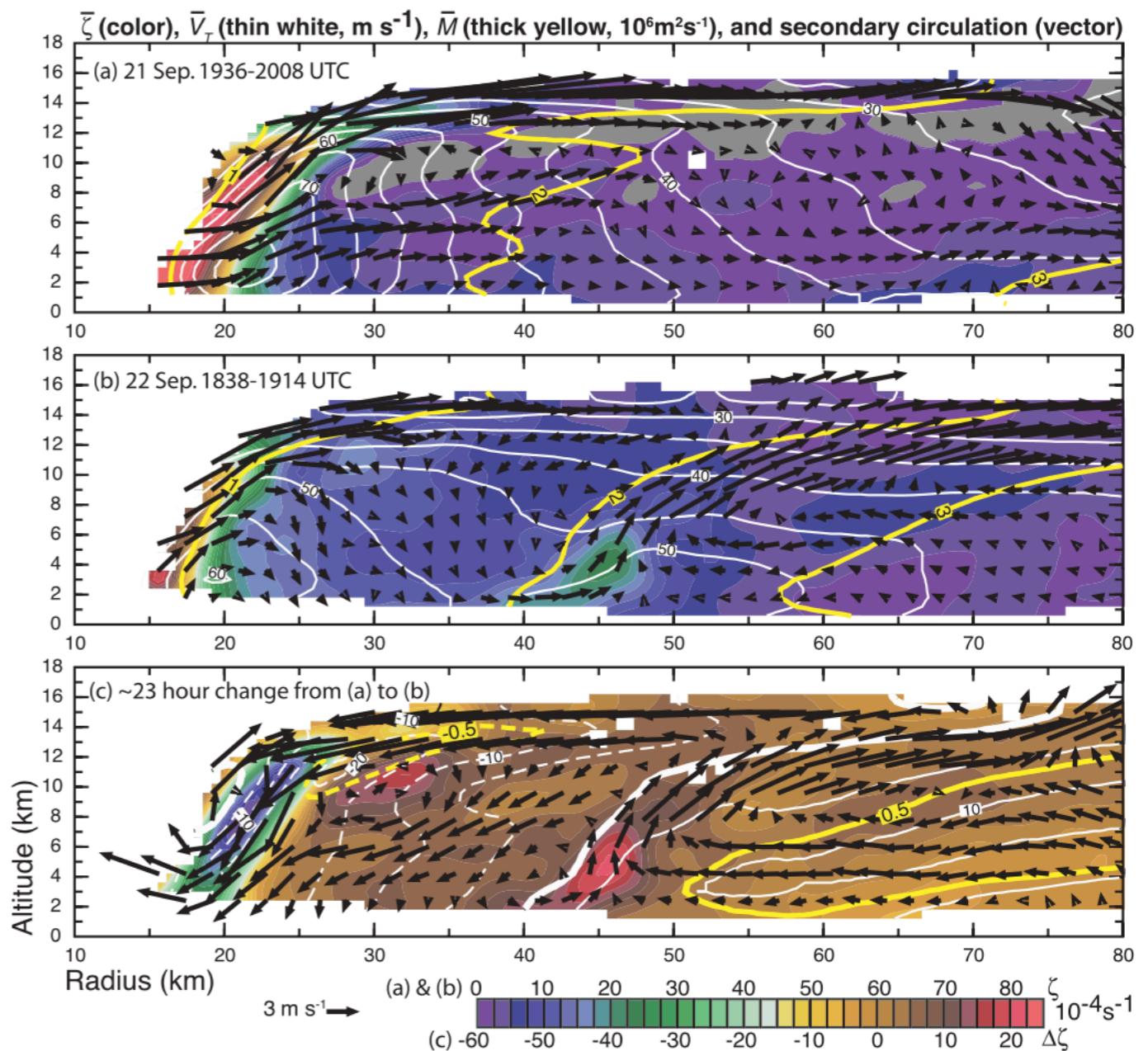
Axisymmetric View: Two axisymmetric intensification mechanisms

- First mechanism:

Radial convergence of M **above** the boundary layer spins up the outer circulation due to the balanced secondary circulation.

- Second mechanism:

Radial convergence of M **within** the boundary layer spins up the inner-core region of the storm due to unbalanced dynamics.



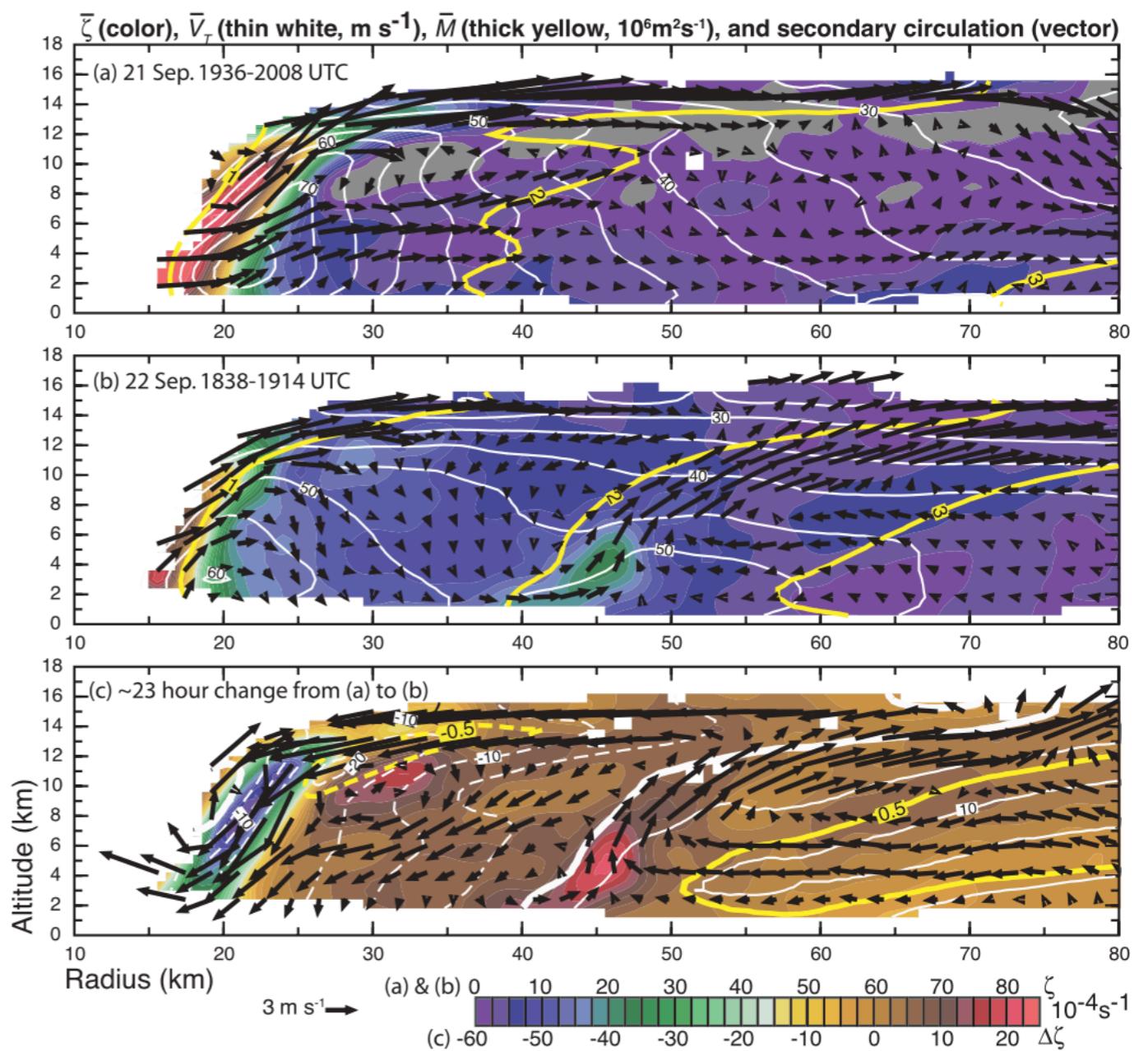
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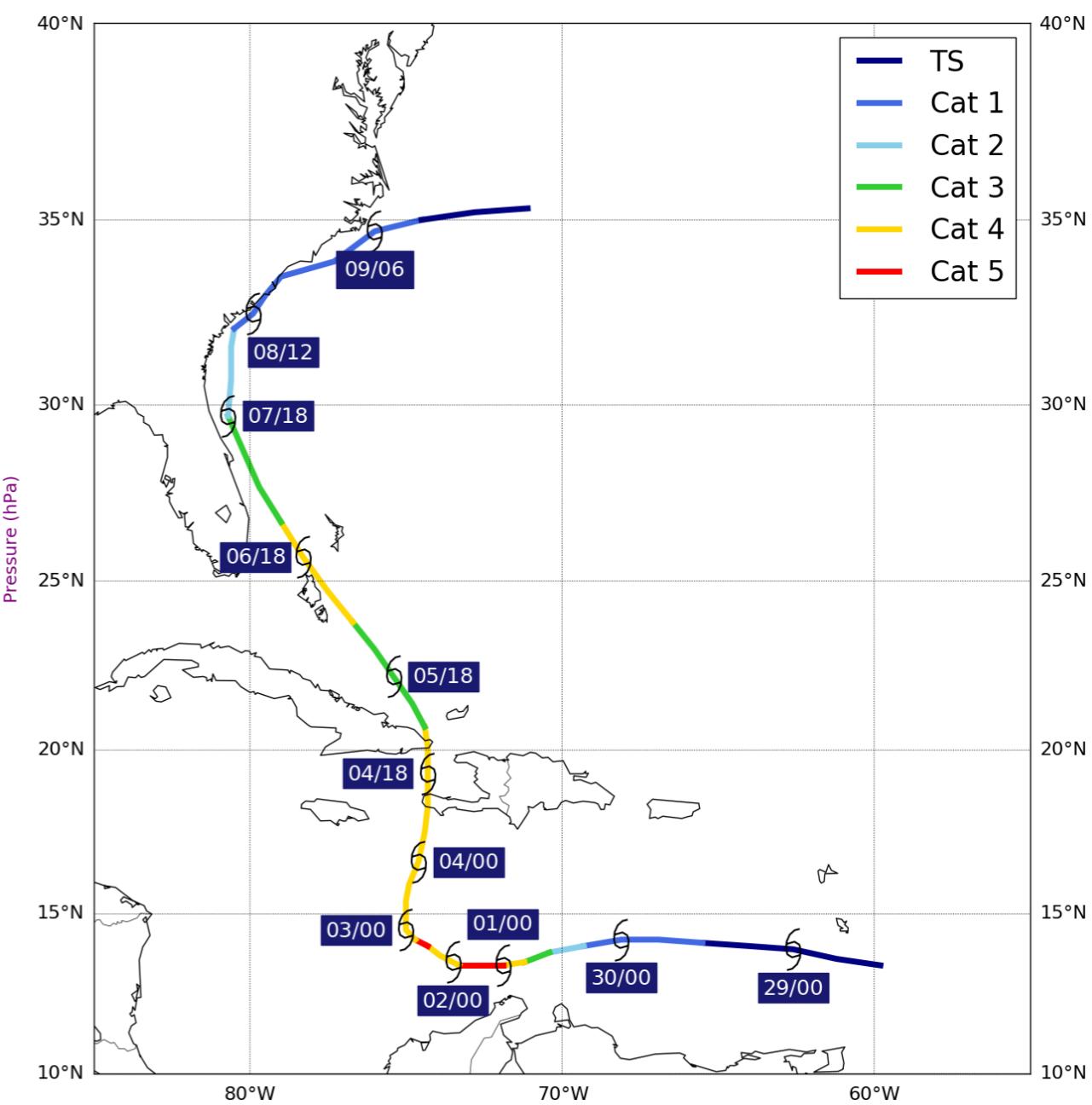
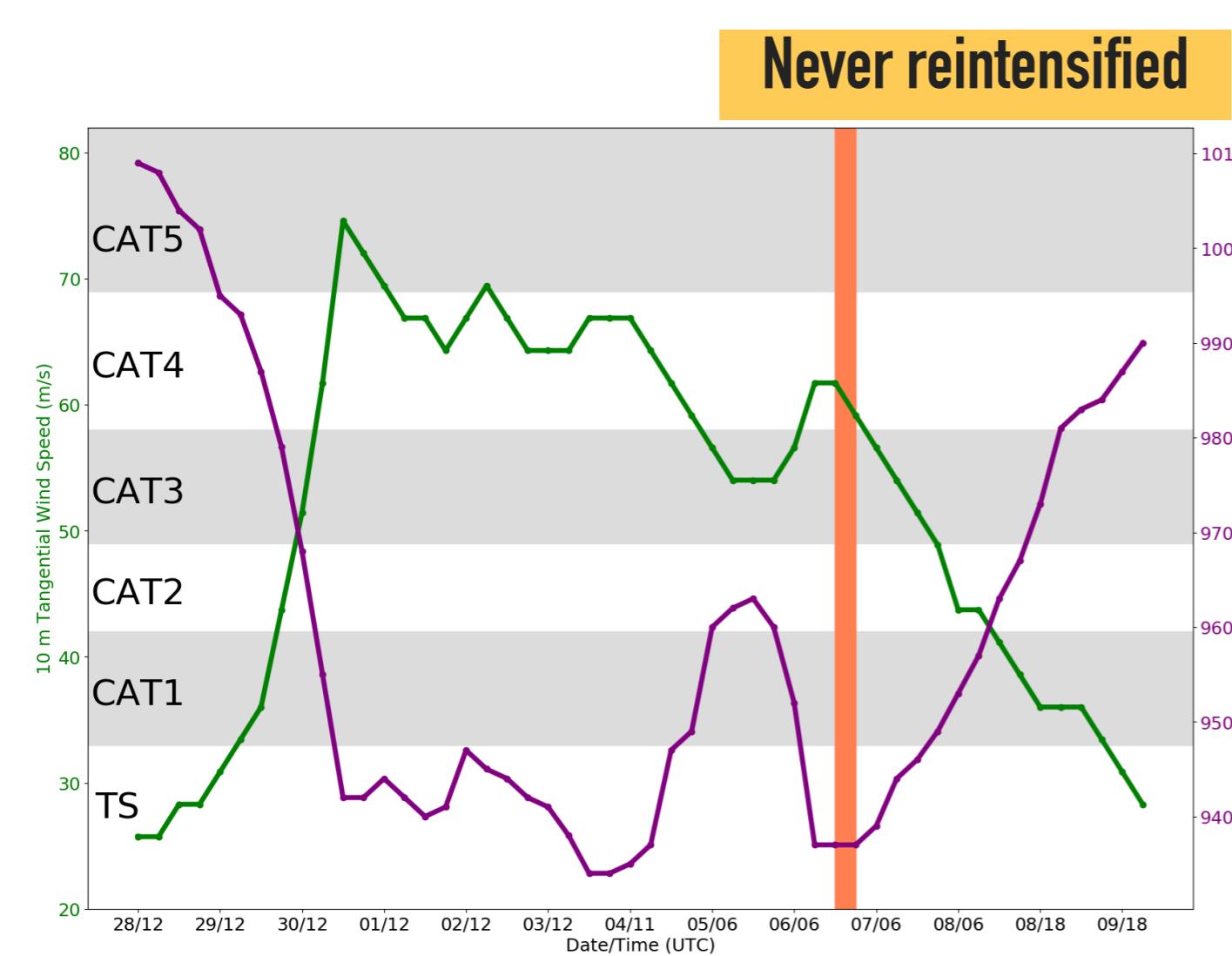
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- Second mechanism:

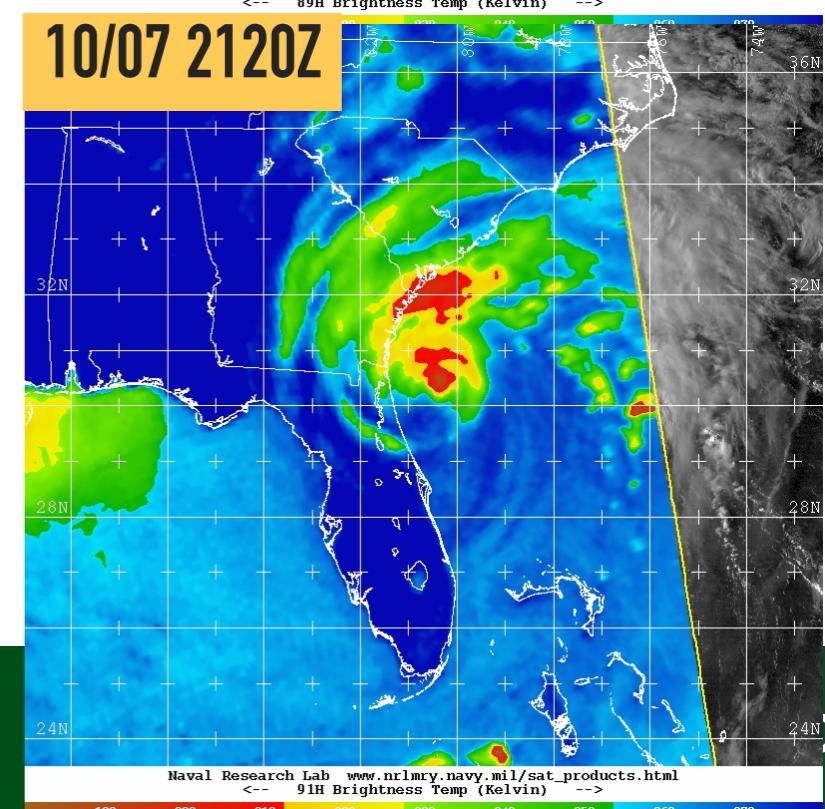
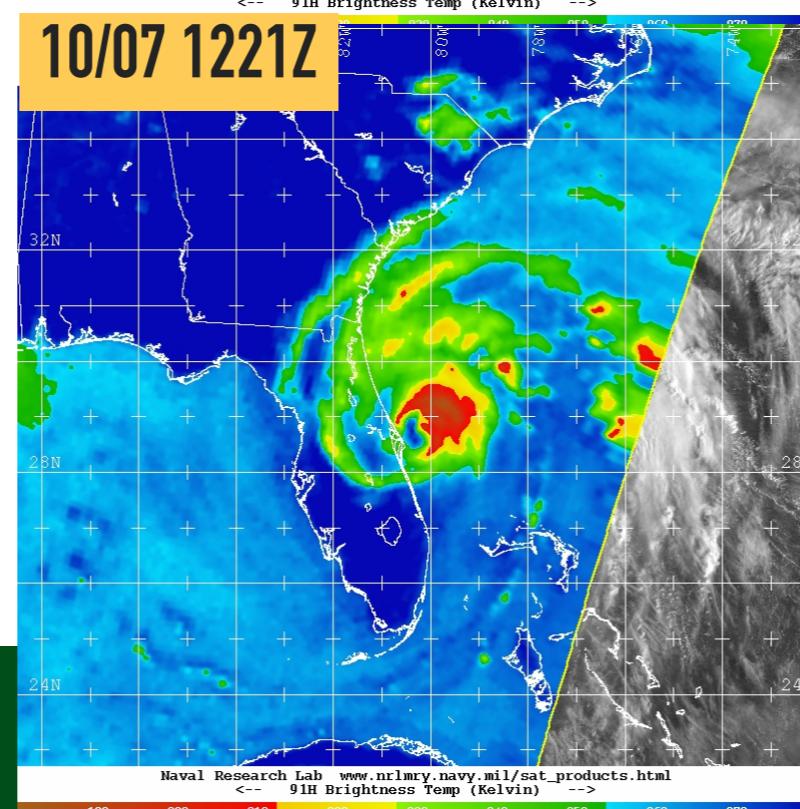
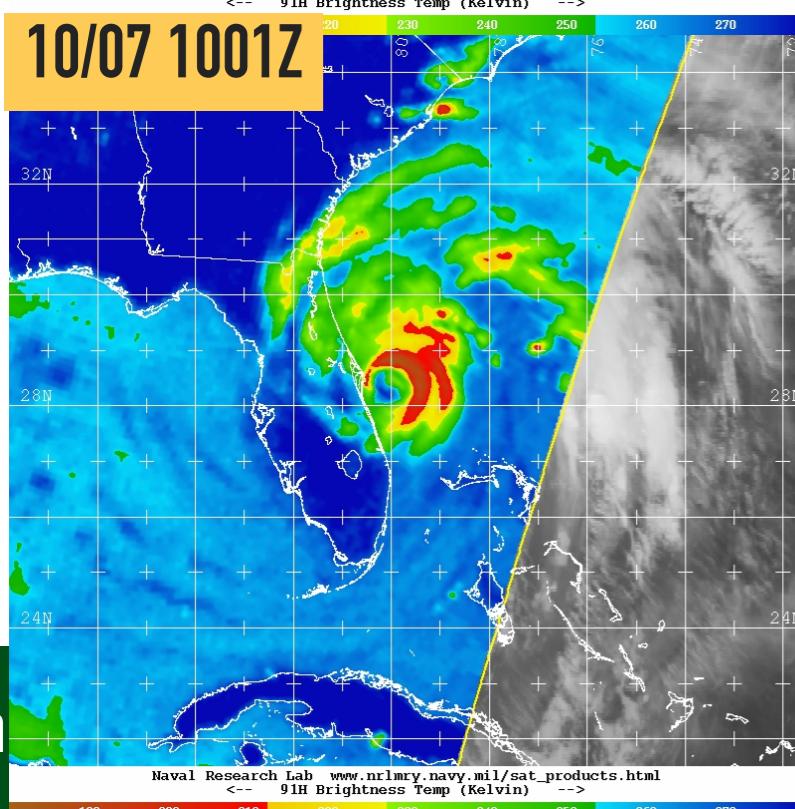
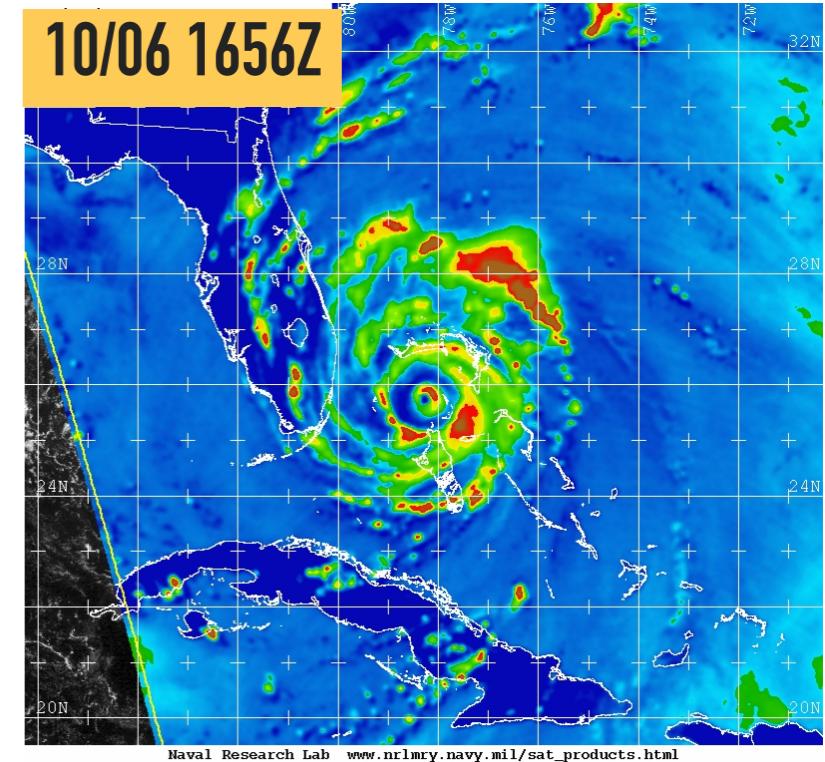
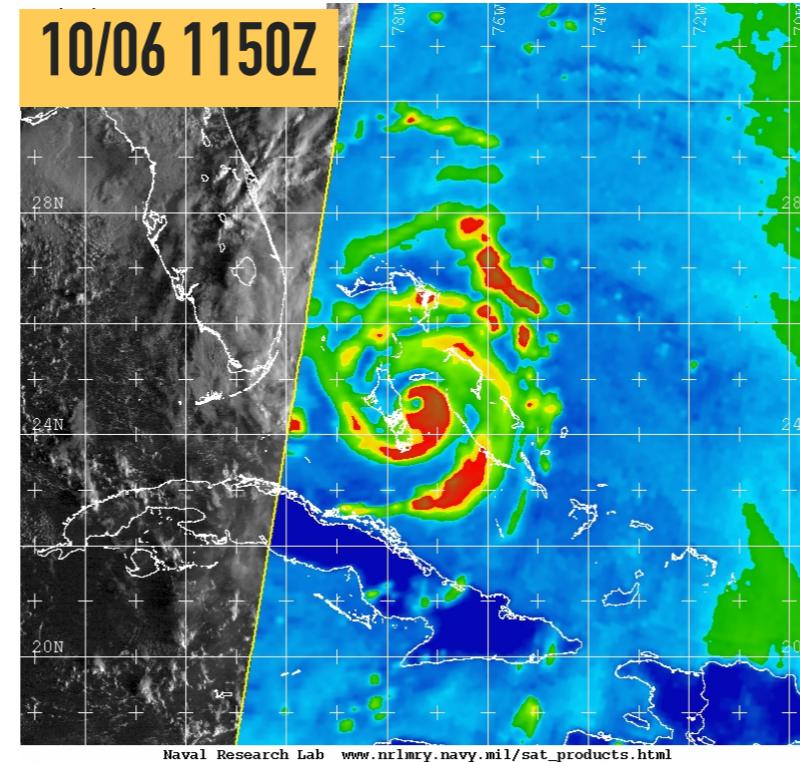
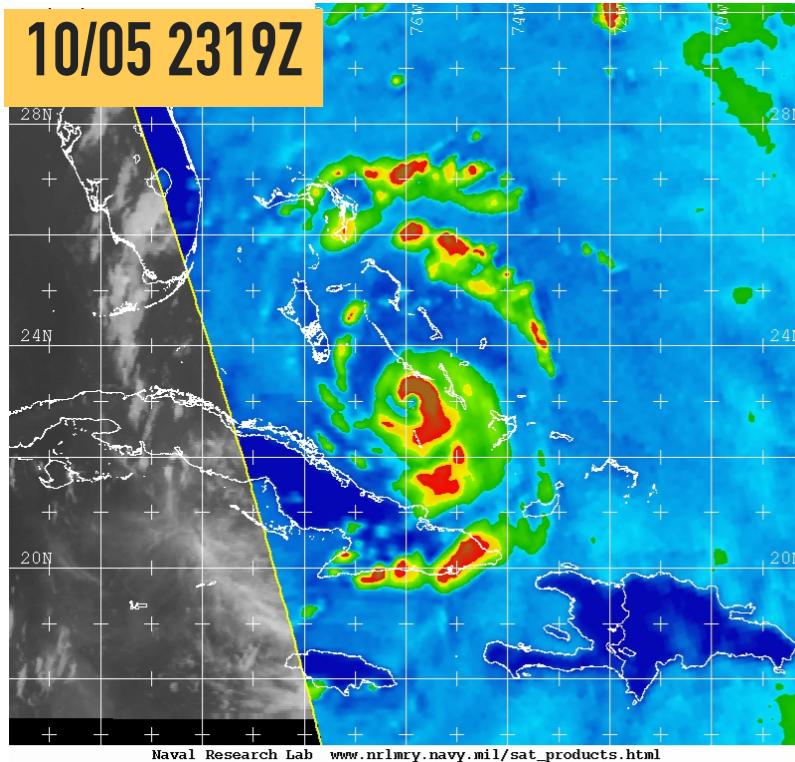
Radial convergence of M within the boundary layer spins up the inner-core region of the storm due to unbalanced dynamics.



Hurricane Matthew (2016)

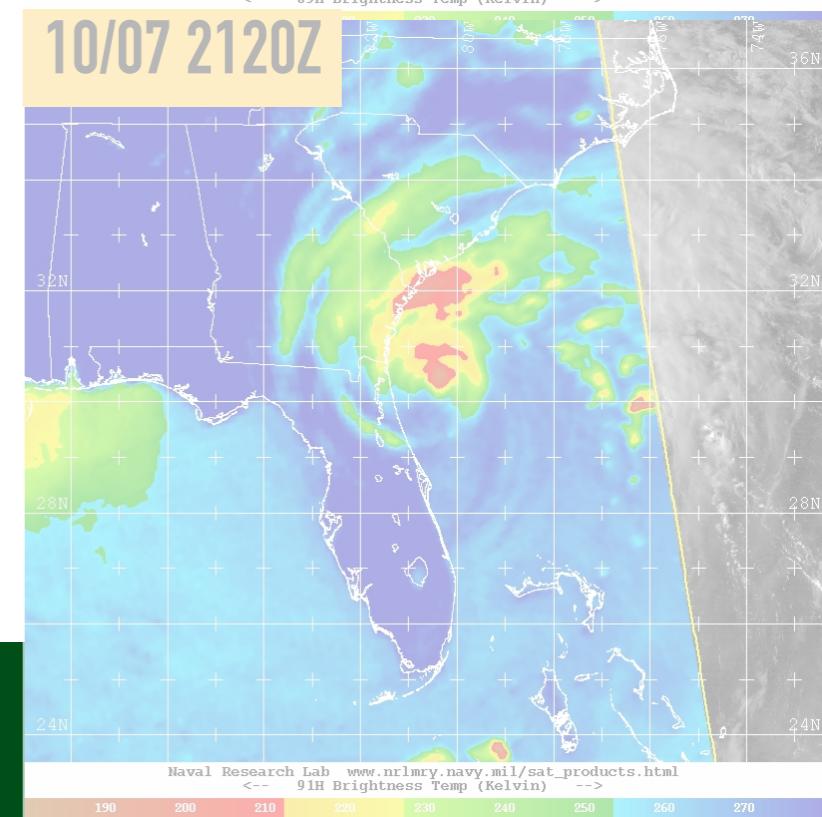
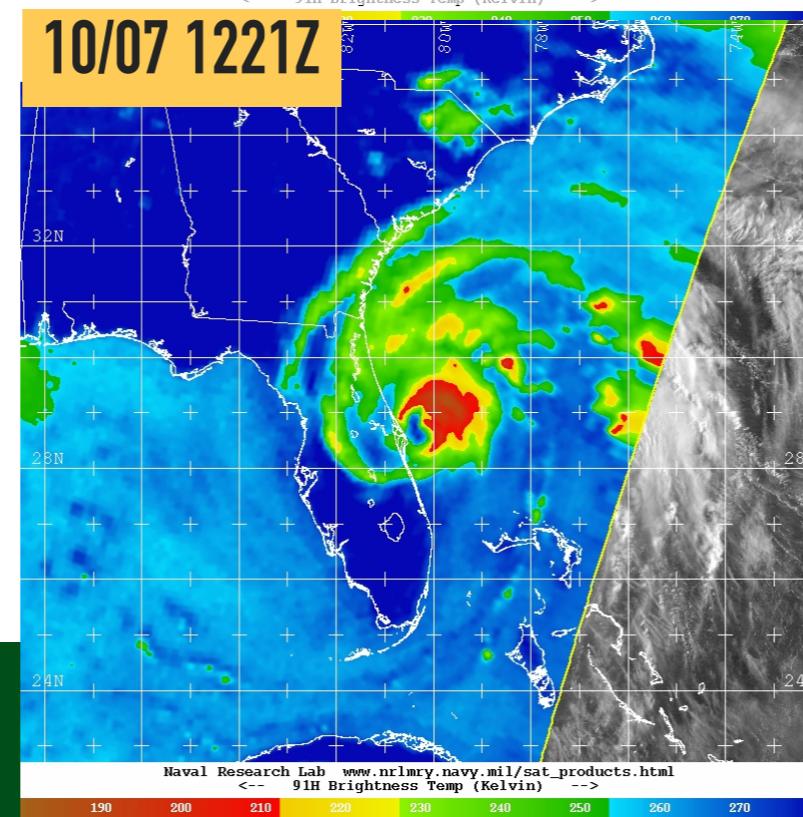
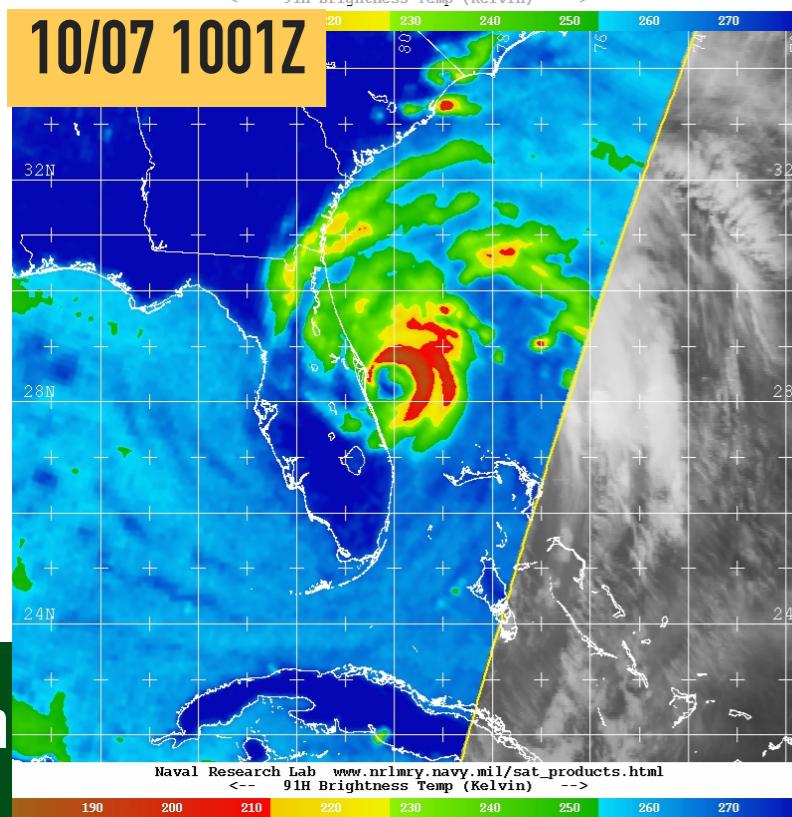
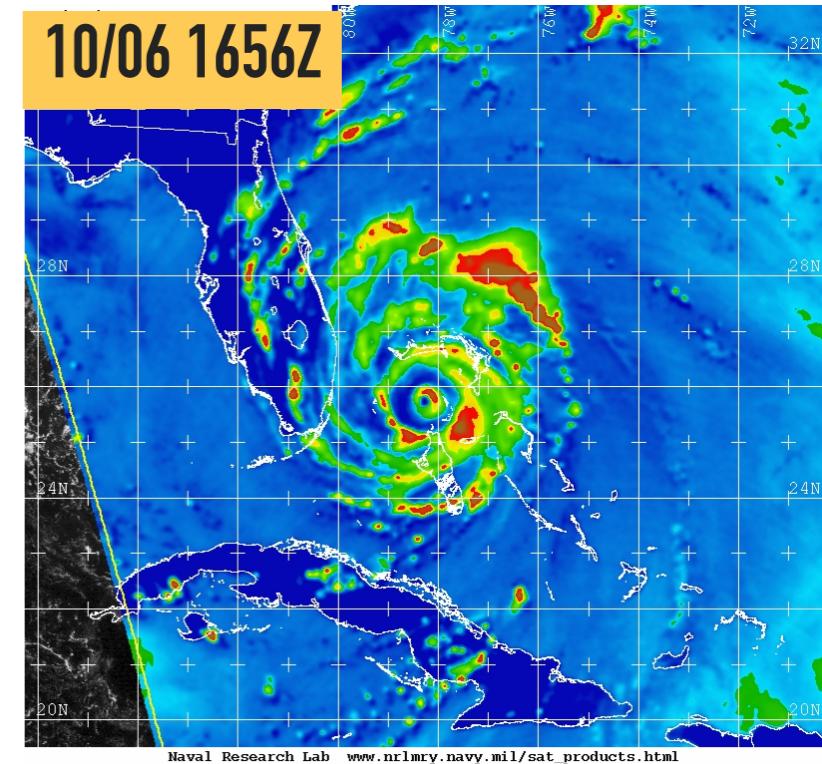
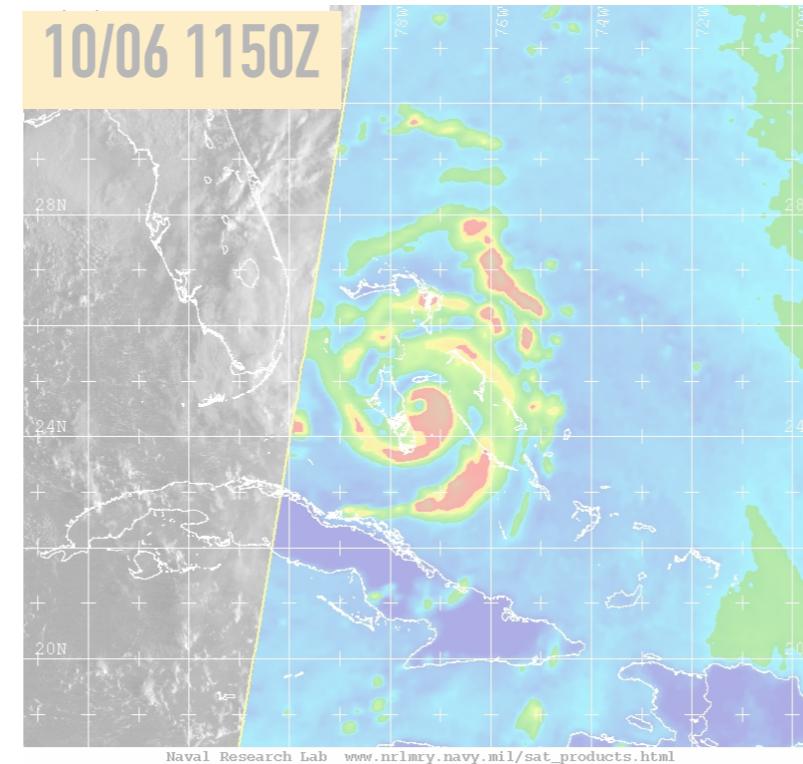
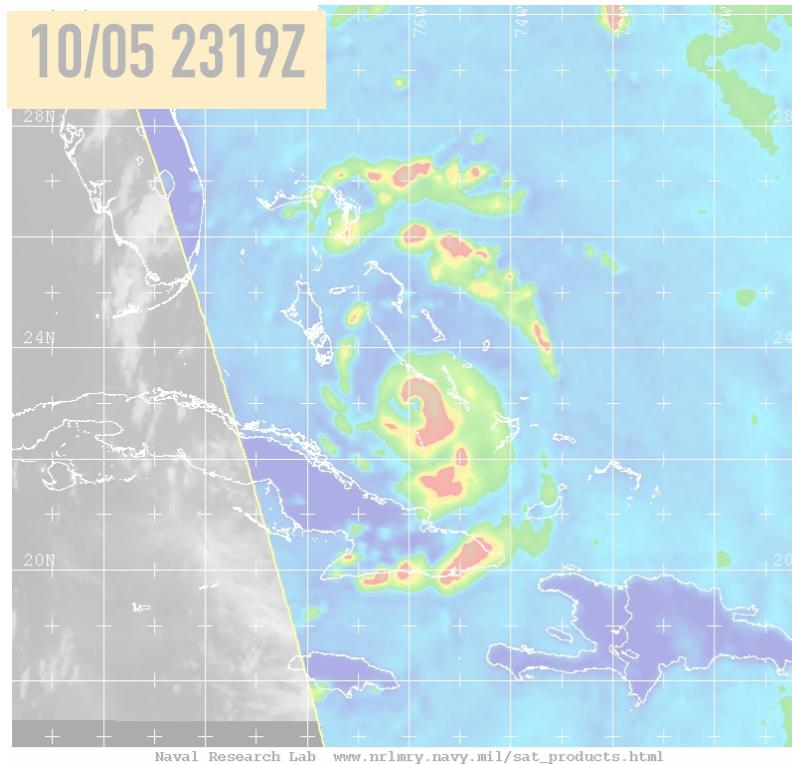


Microwave Satellite Image



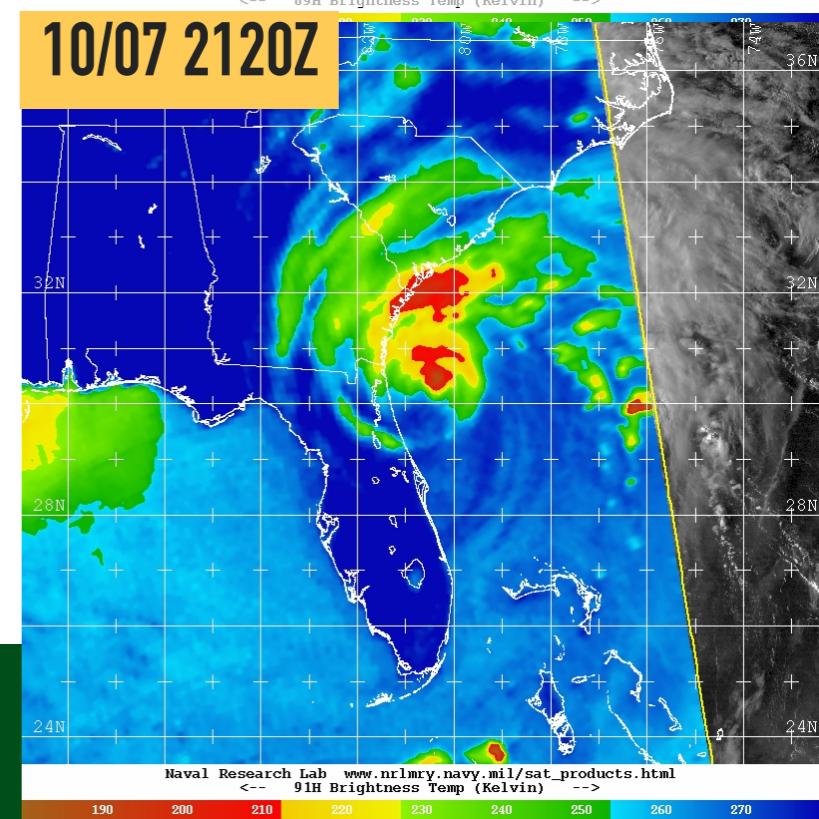
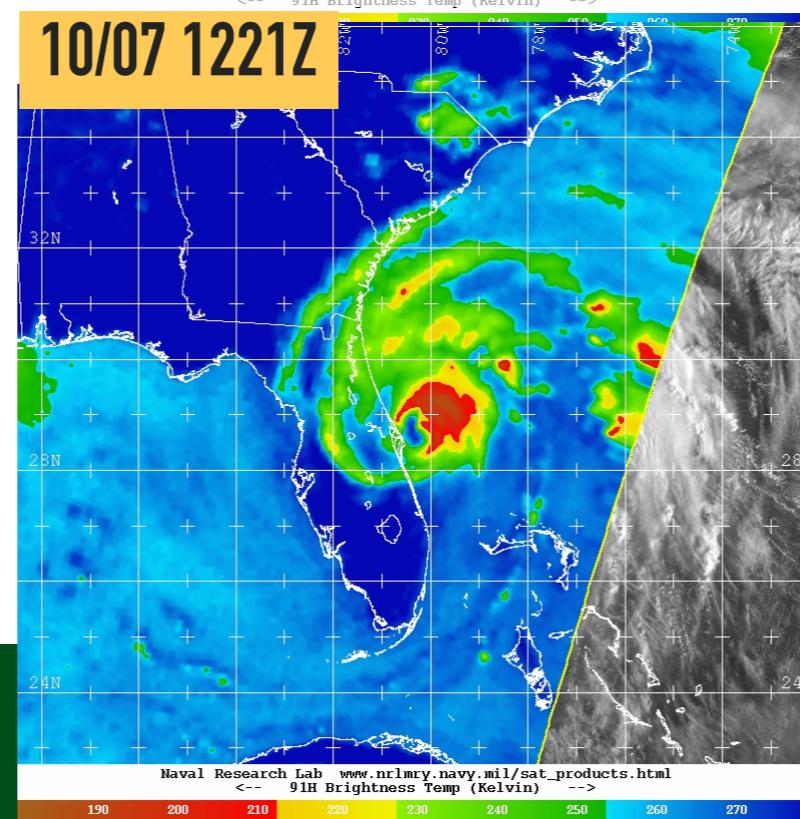
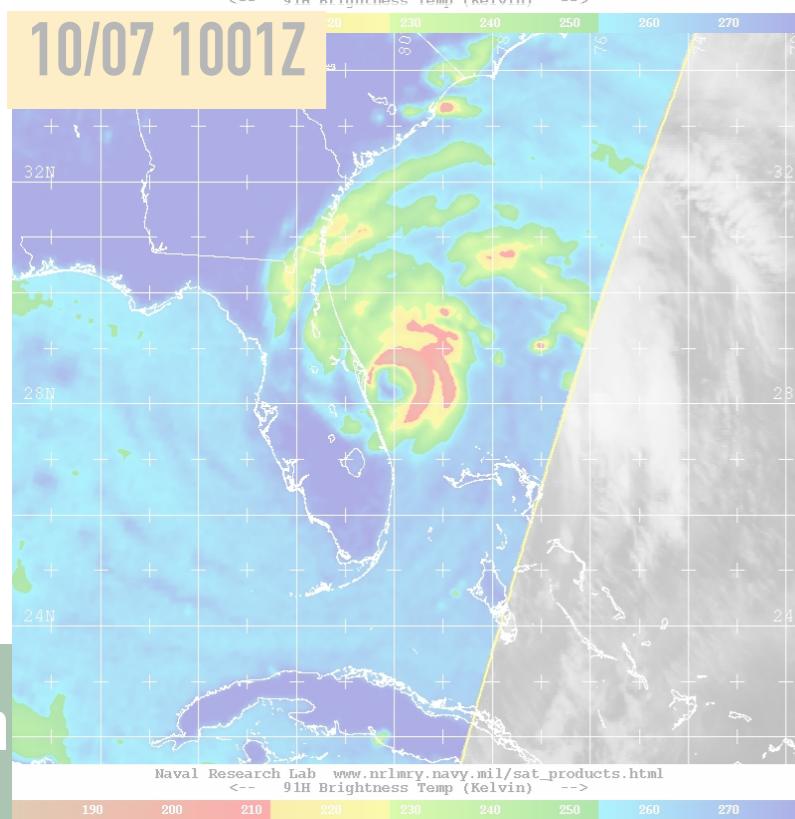
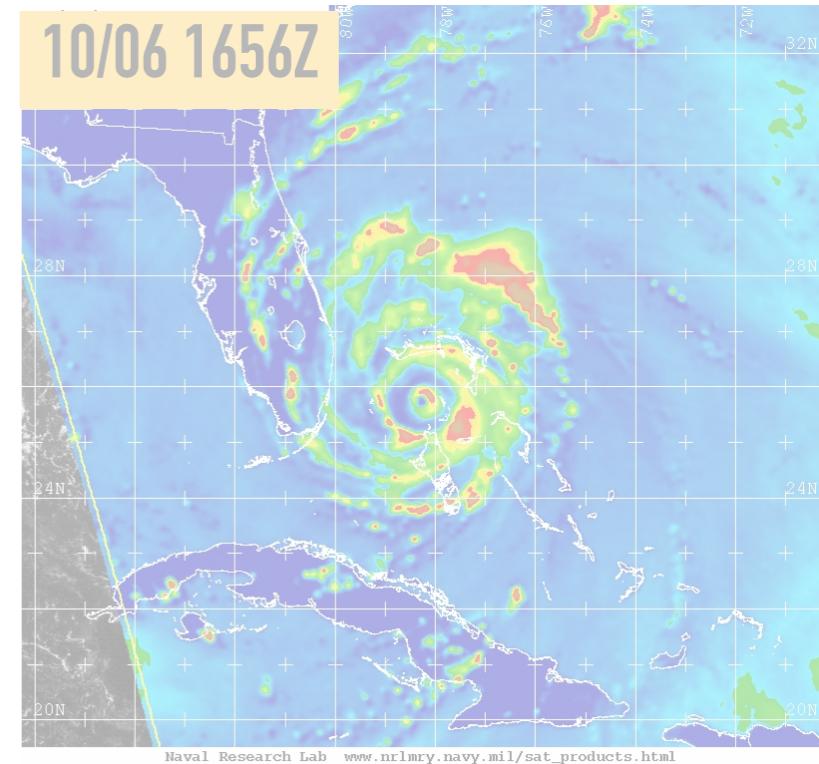
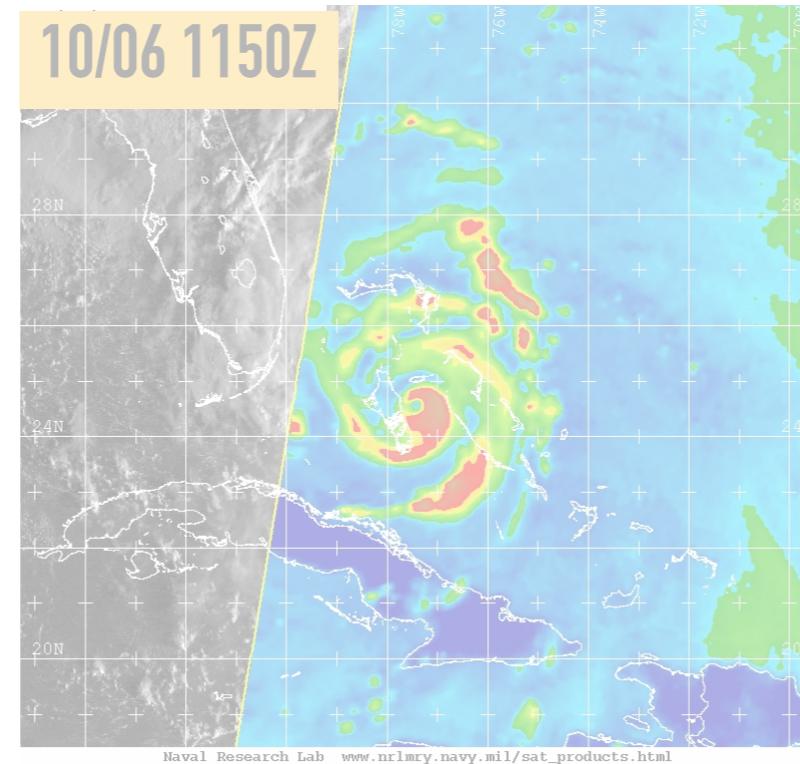
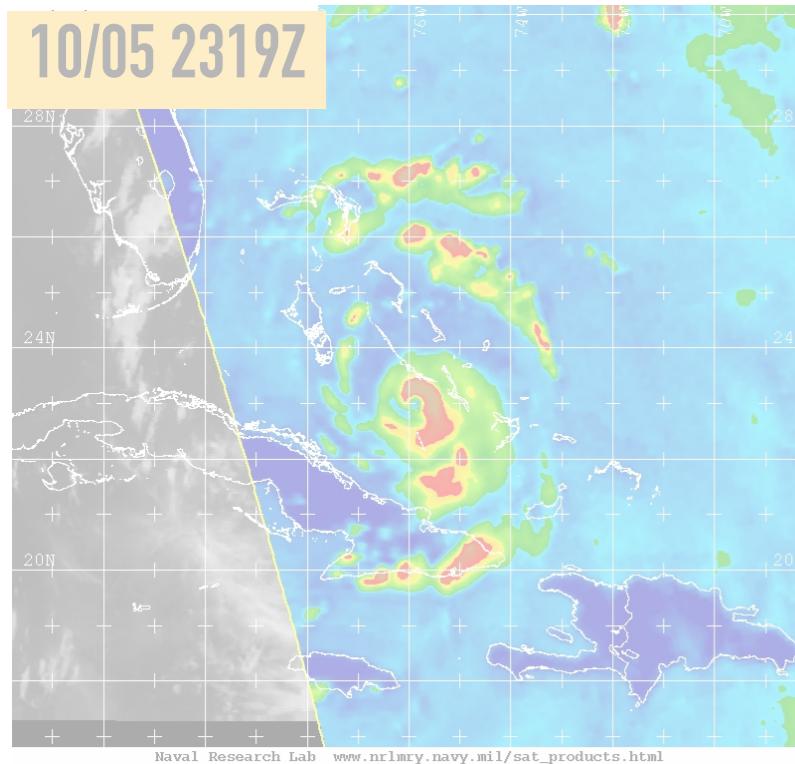
Images are from the Naval Research Laboratory Monterey Tropical Cyclones webpage

Microwave Satellite Image



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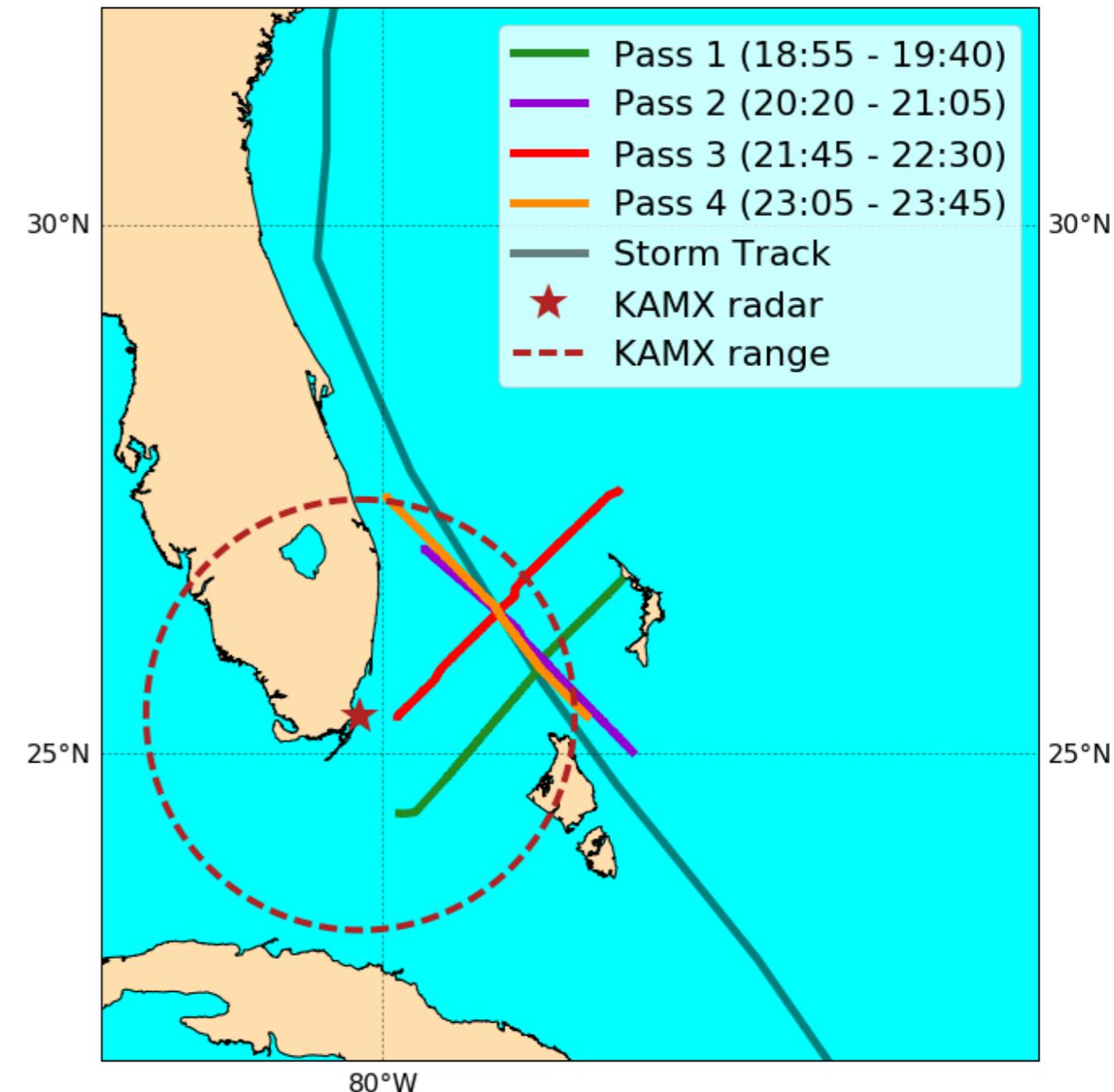
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Dataset

- ▶ NOAA WP-3D (P-3 tail radars)
- ▶ KAMX polarimetric radar
- ▶ Statistical Hurricane Intensity Prediction Scheme(SHIPS) database
- ▶ Best Track of Hurricane Matthew for the National Hurricane Center

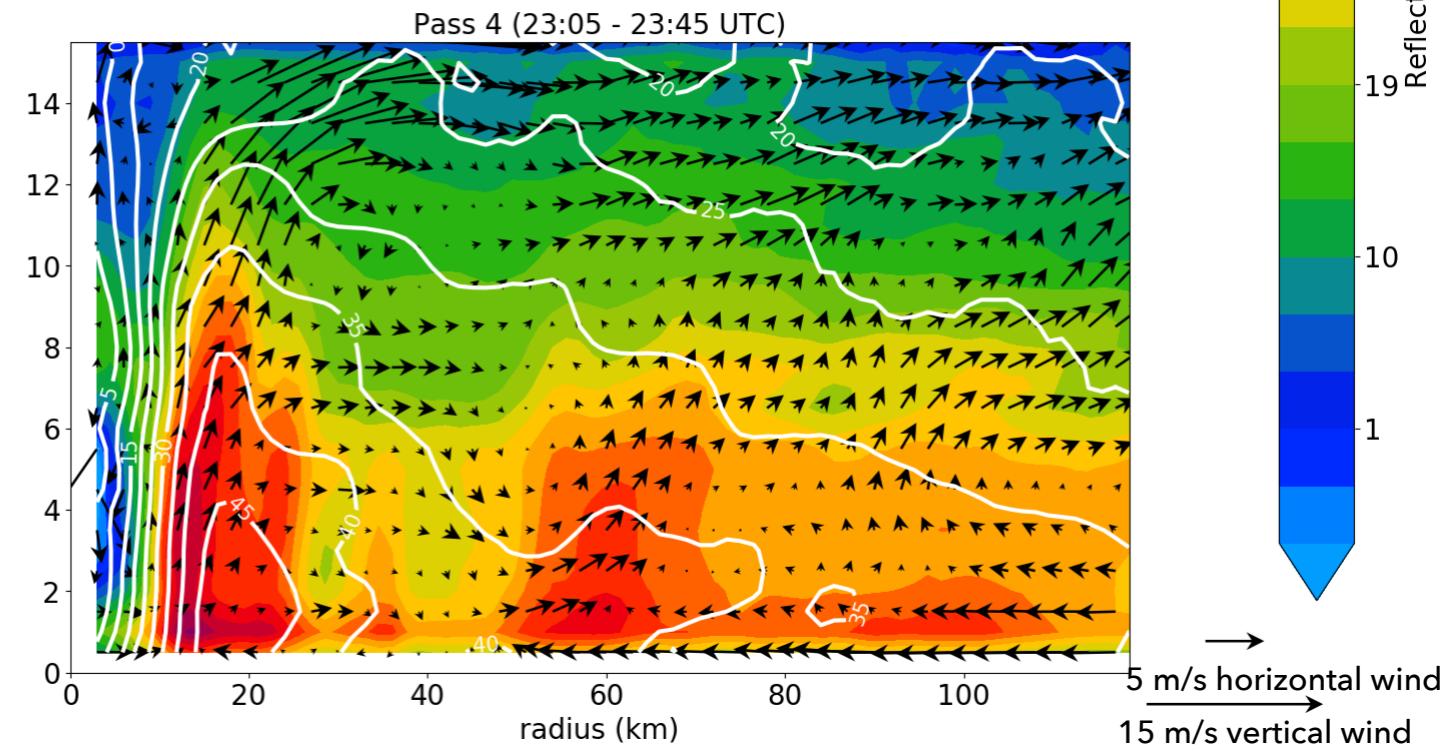
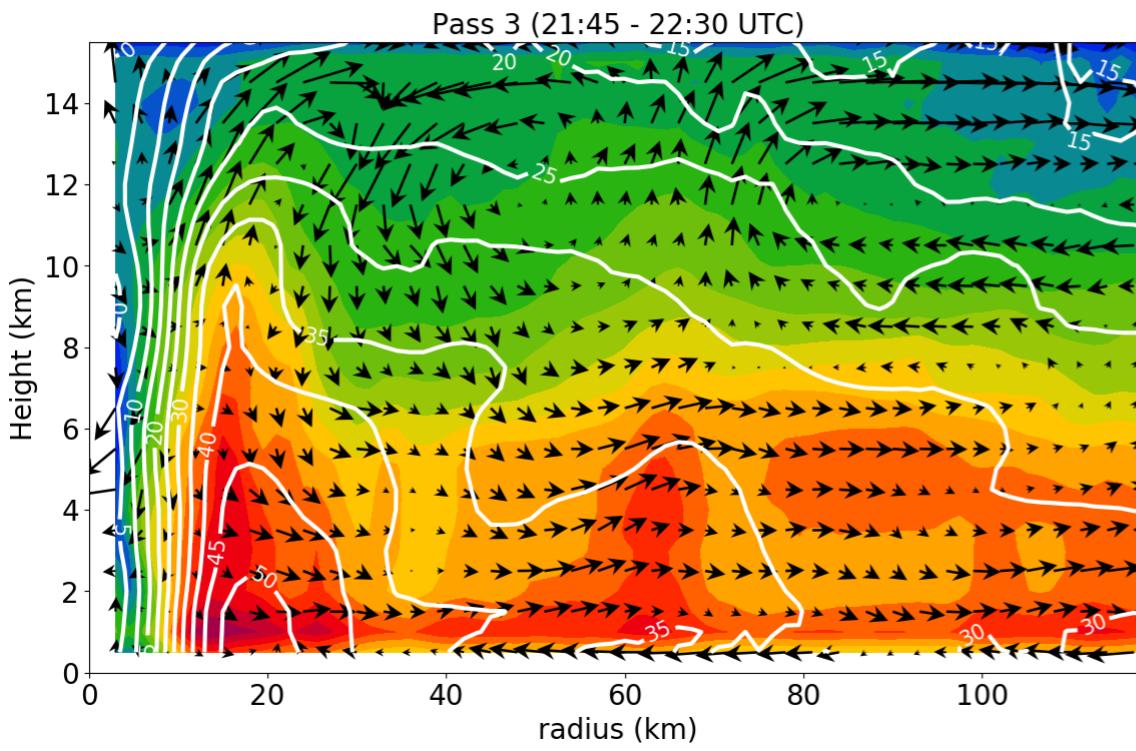
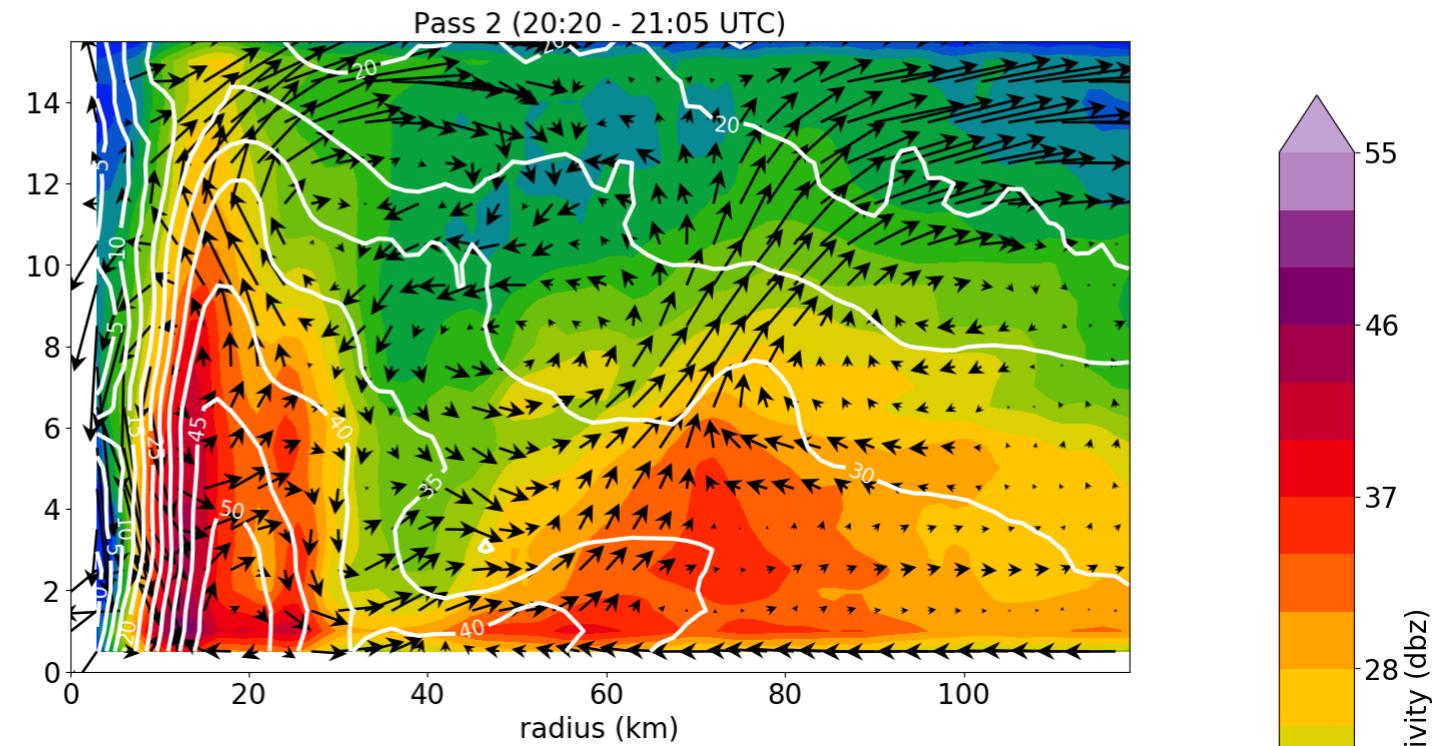
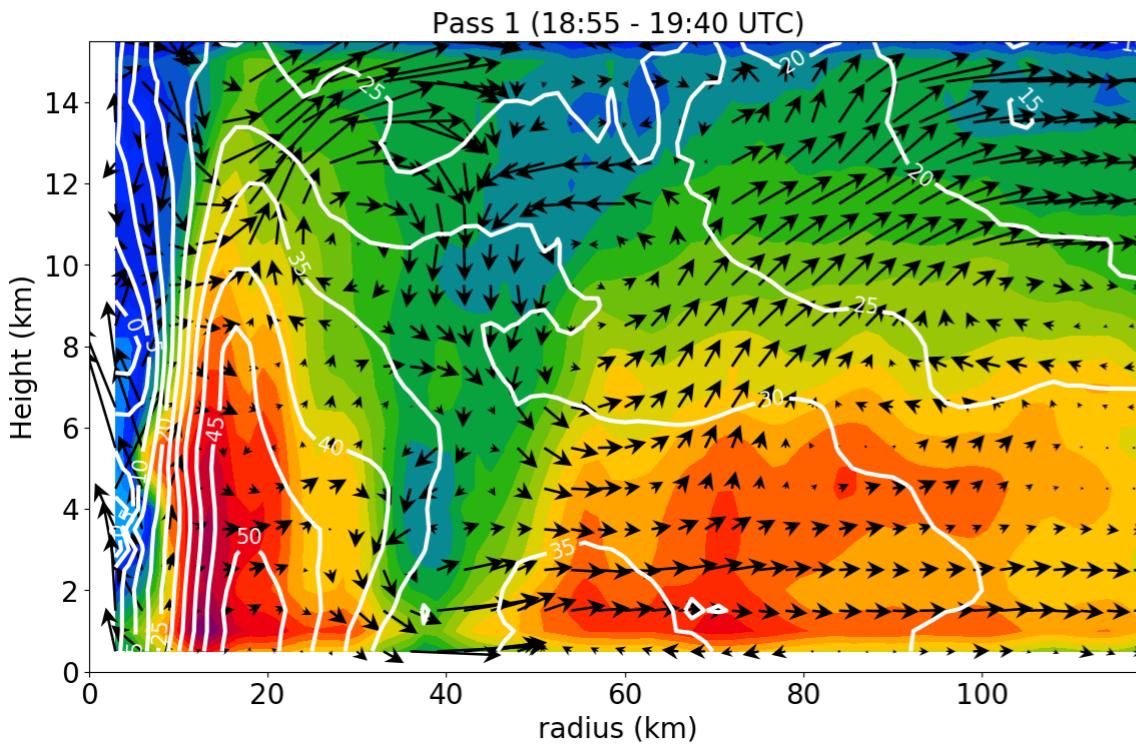
Methodology

- ▶ Triple Doppler Analysis
- ▶ SAMURAI 3D-VAR (Bell et al. 2012)
- ▶ Lidar Radar Open Software Environment (LROSE)



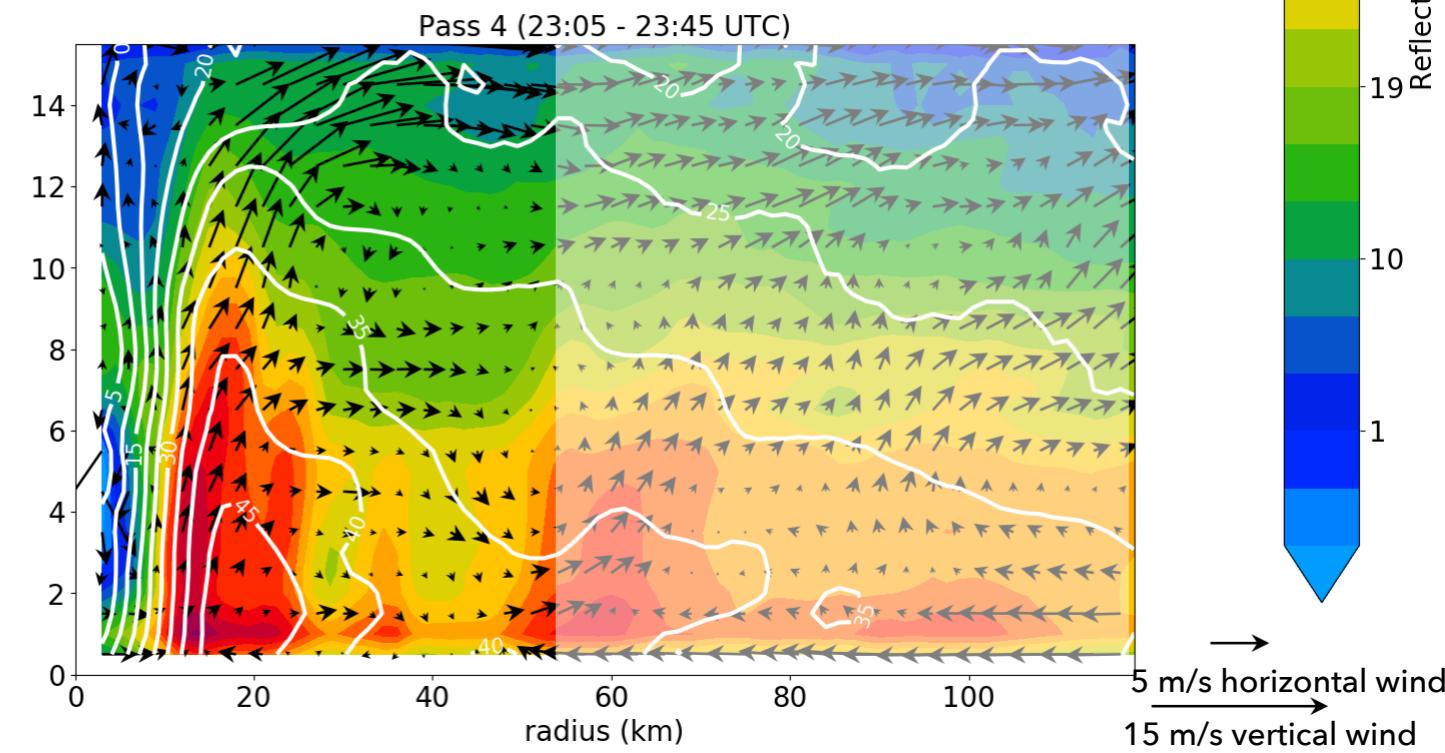
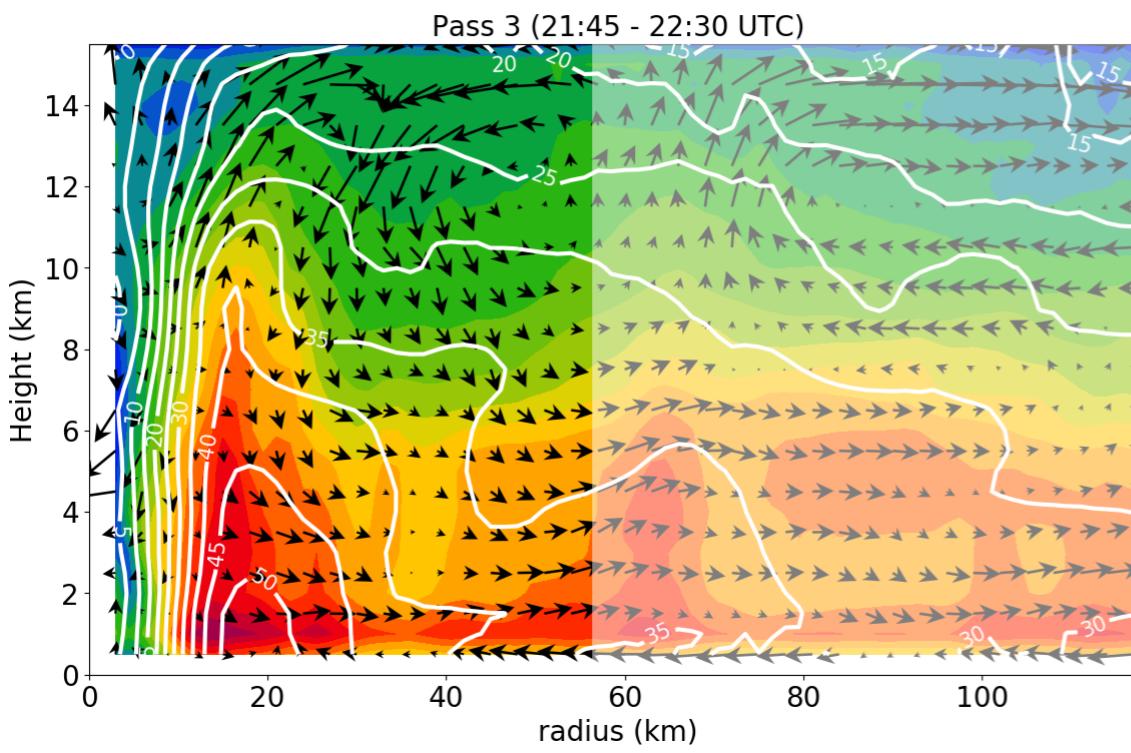
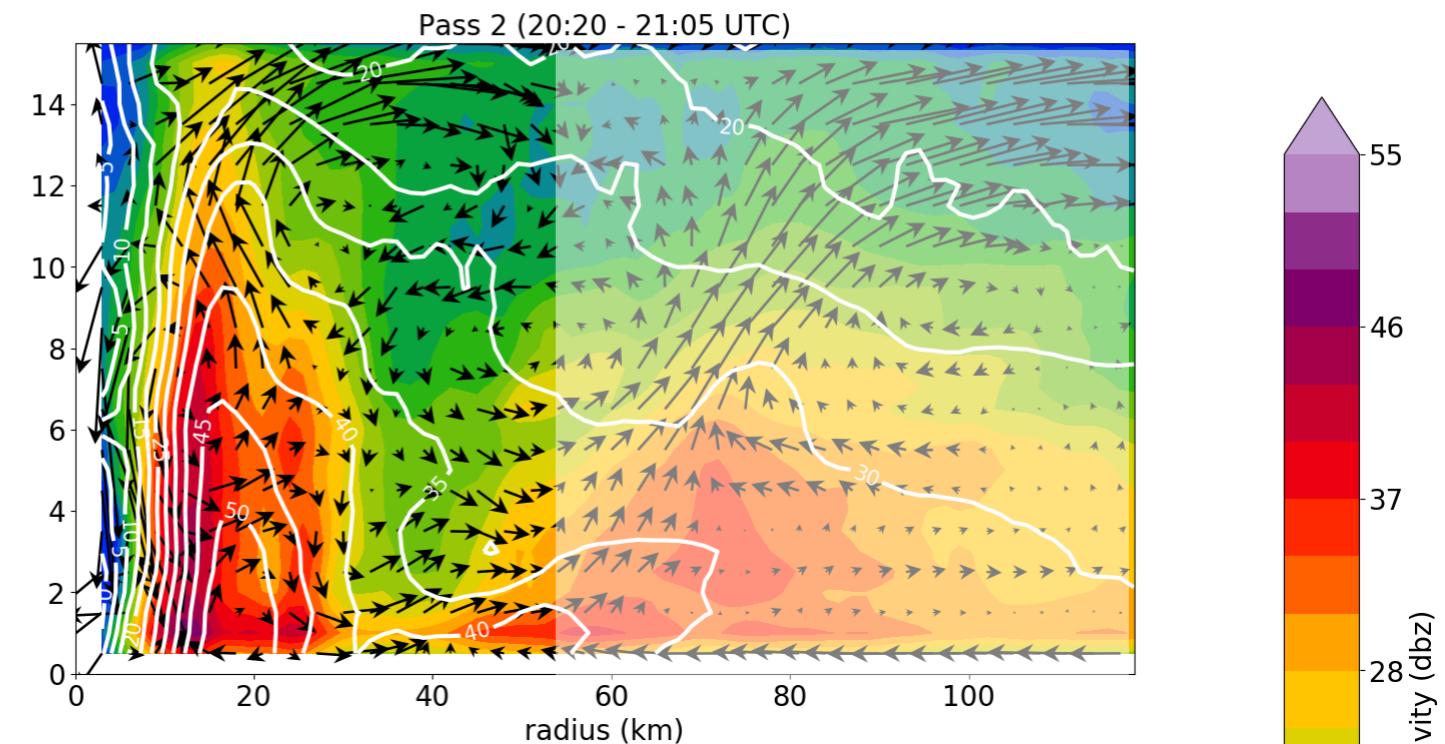
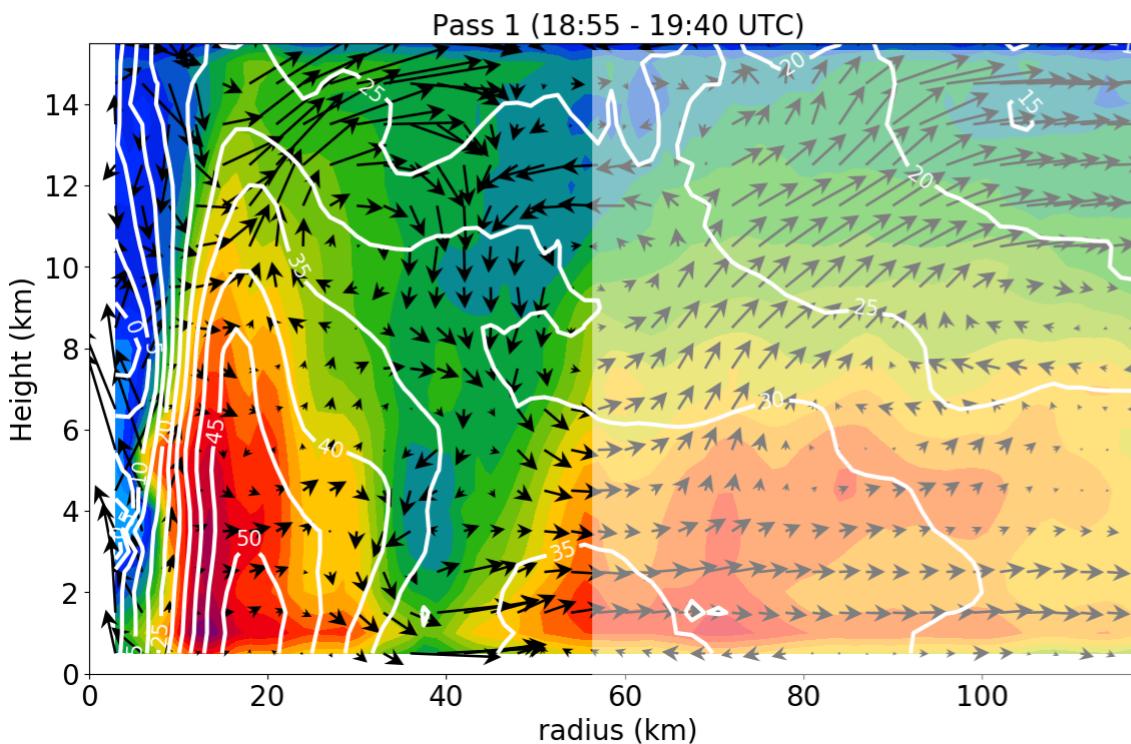
Axisymmetric View: Reflectivity, Primary and Secondary Circulation

filled contours: Reflectivity; white contour: Tangential wind; quiver plot: Secondary Circulation



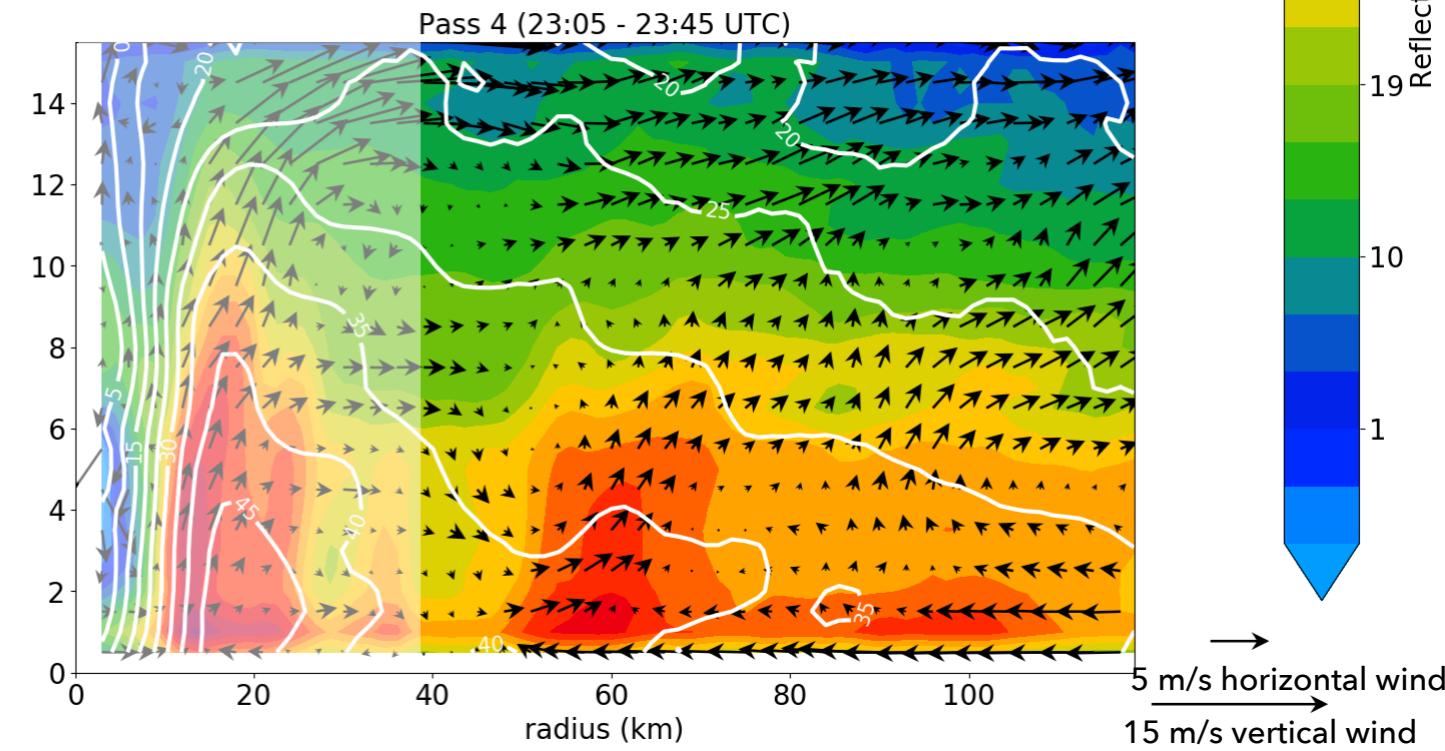
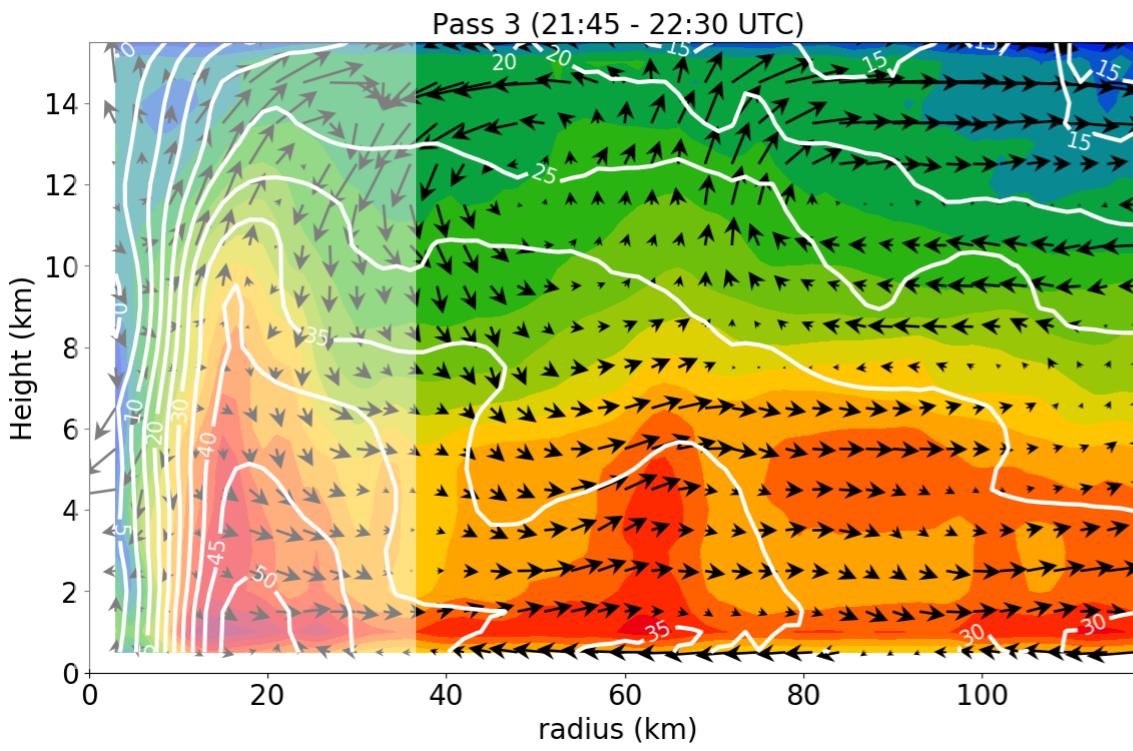
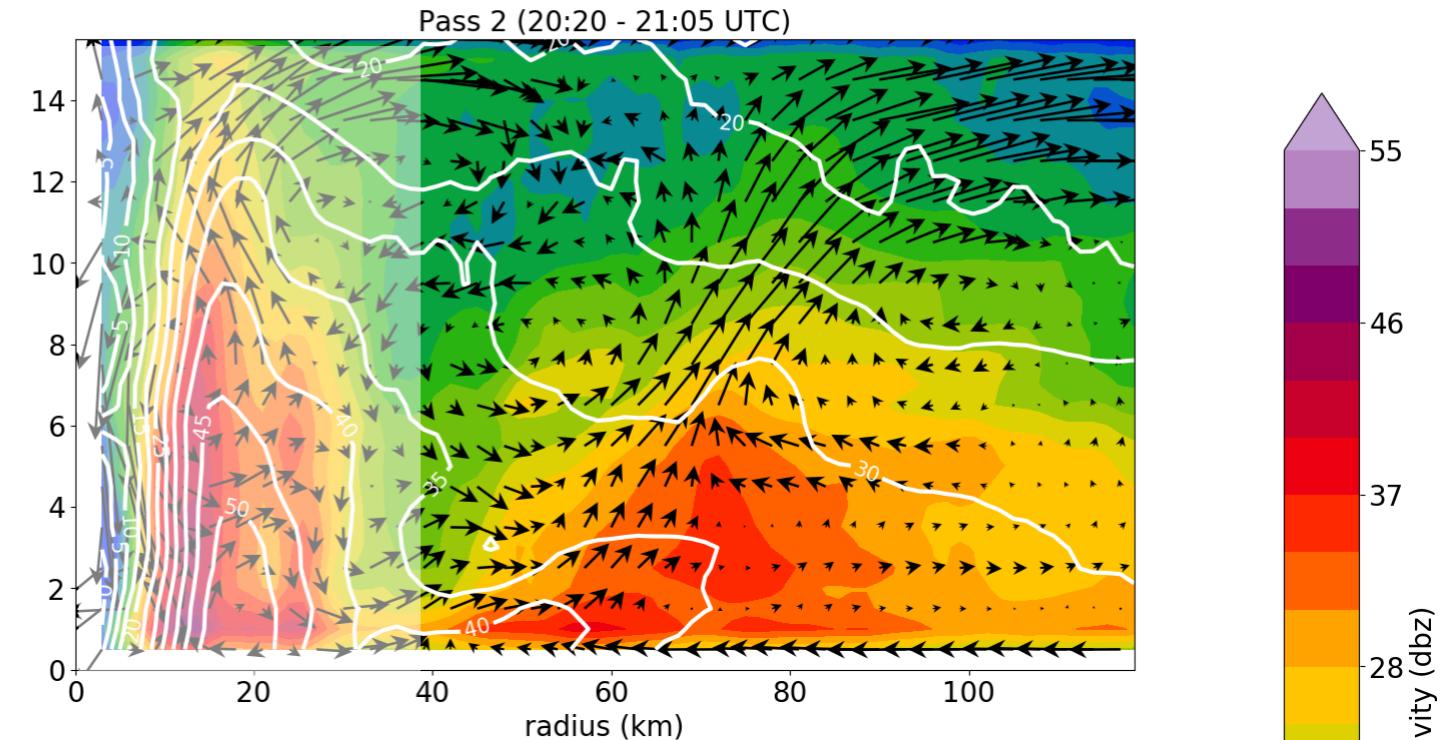
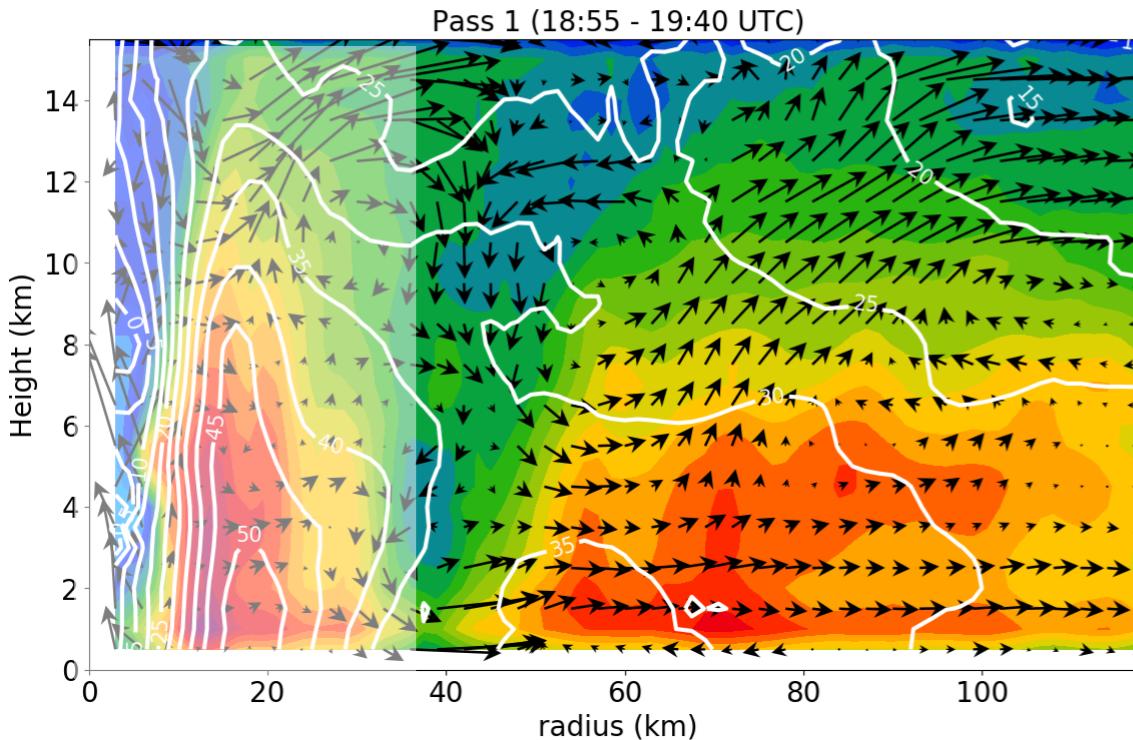
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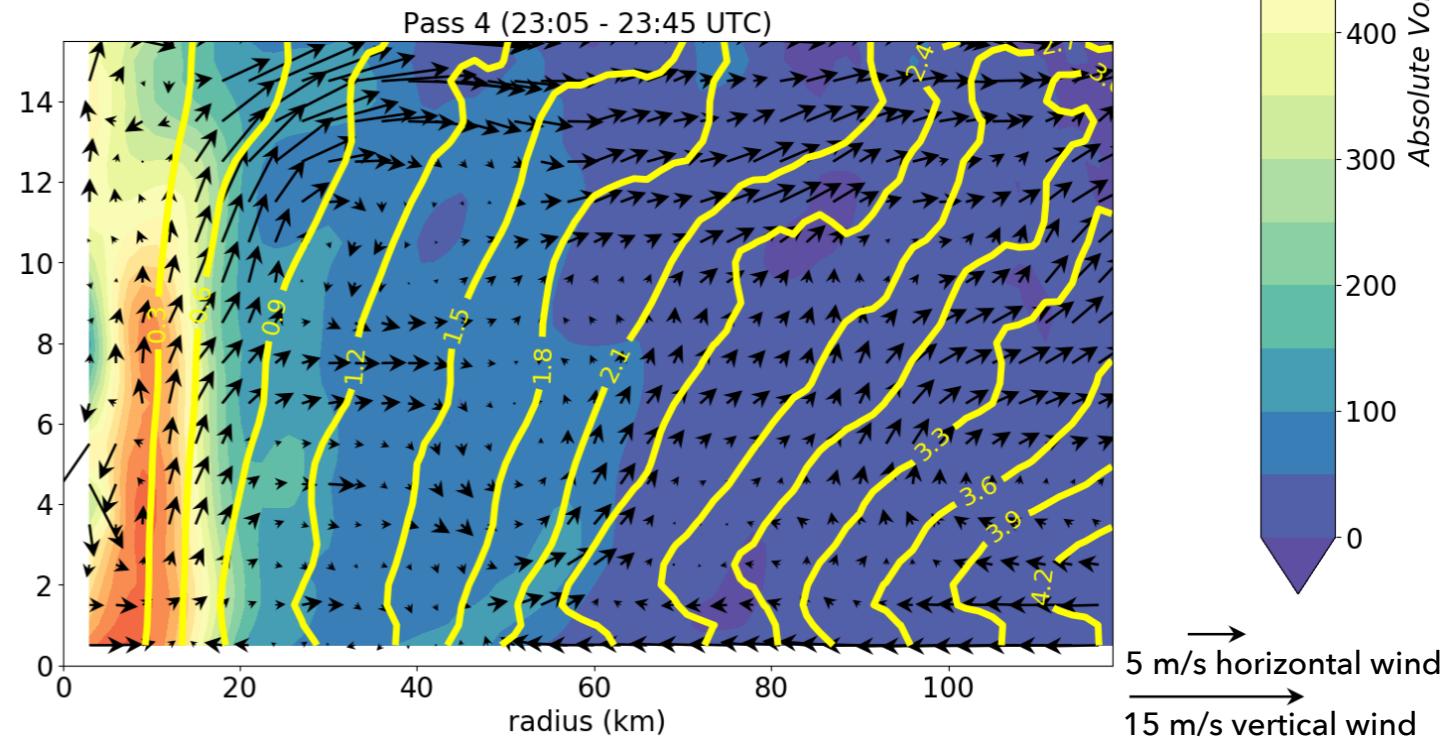
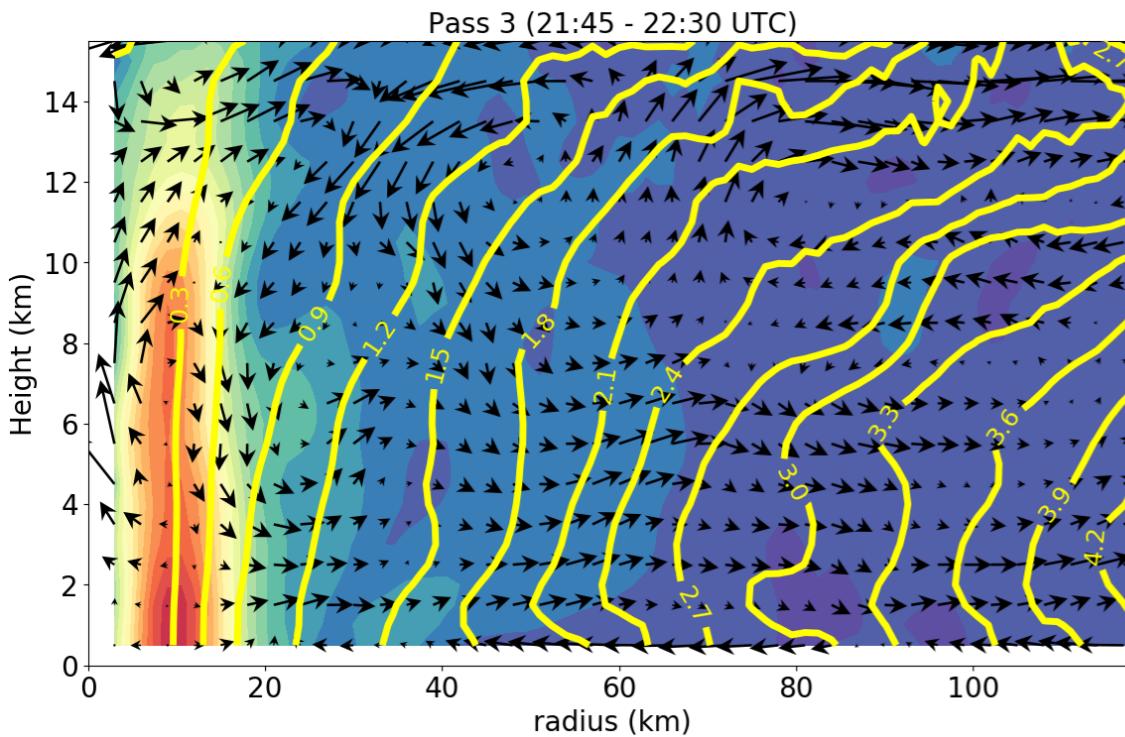
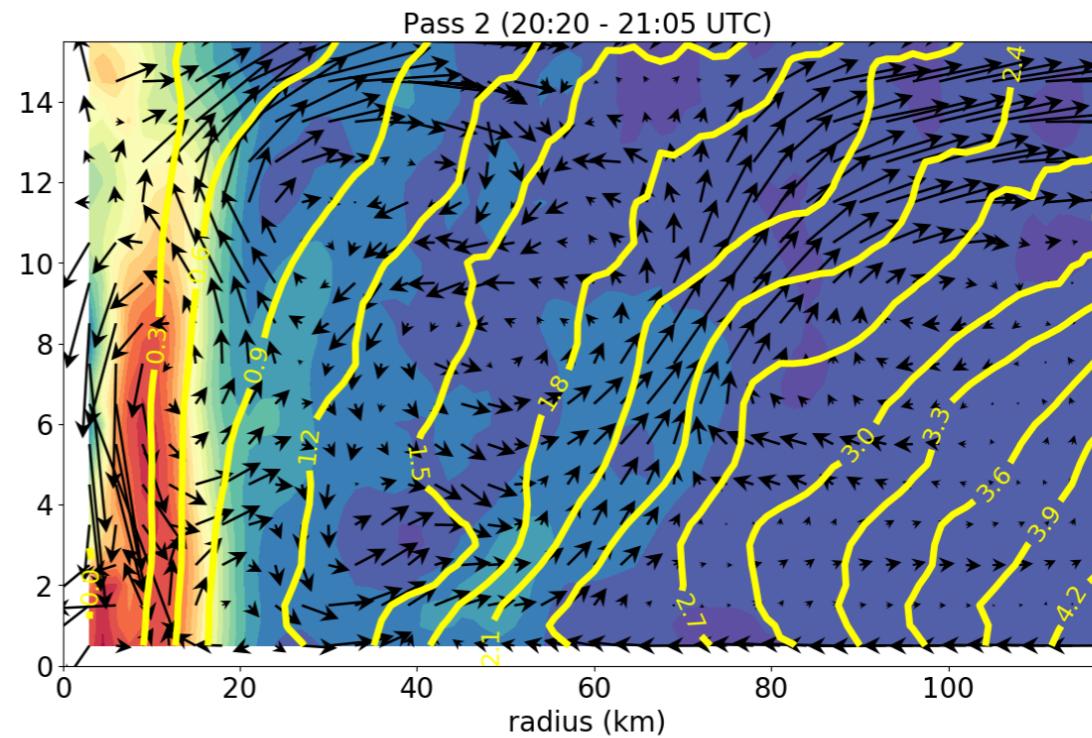
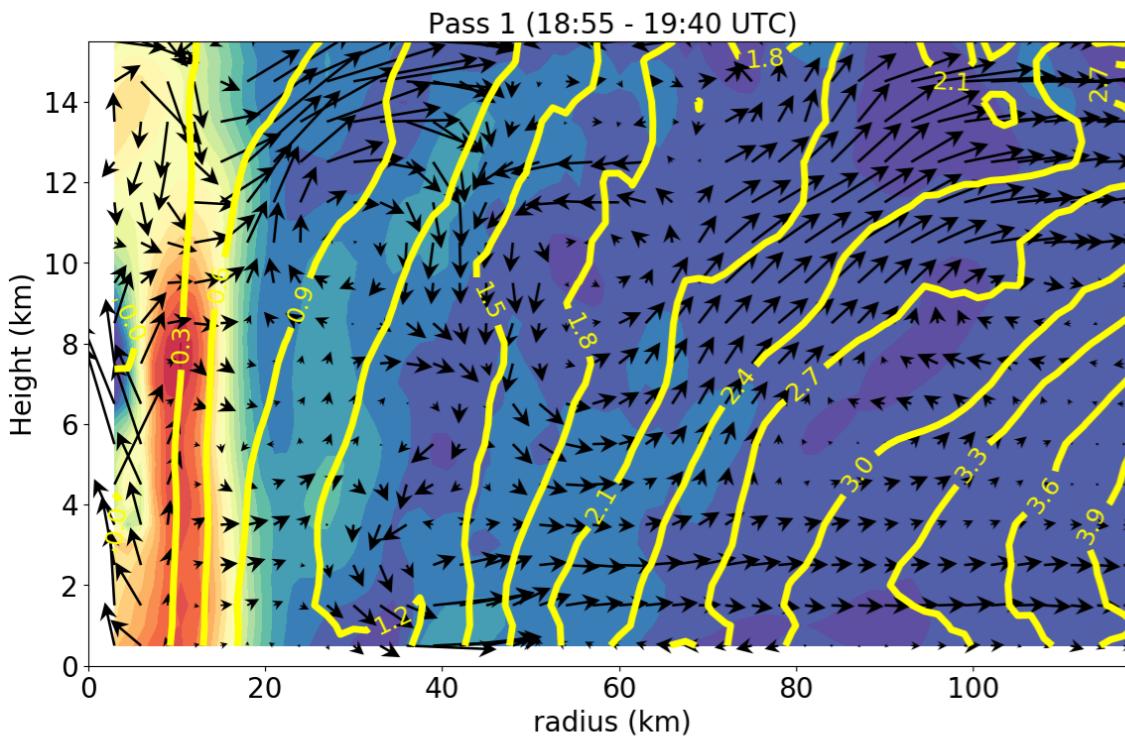
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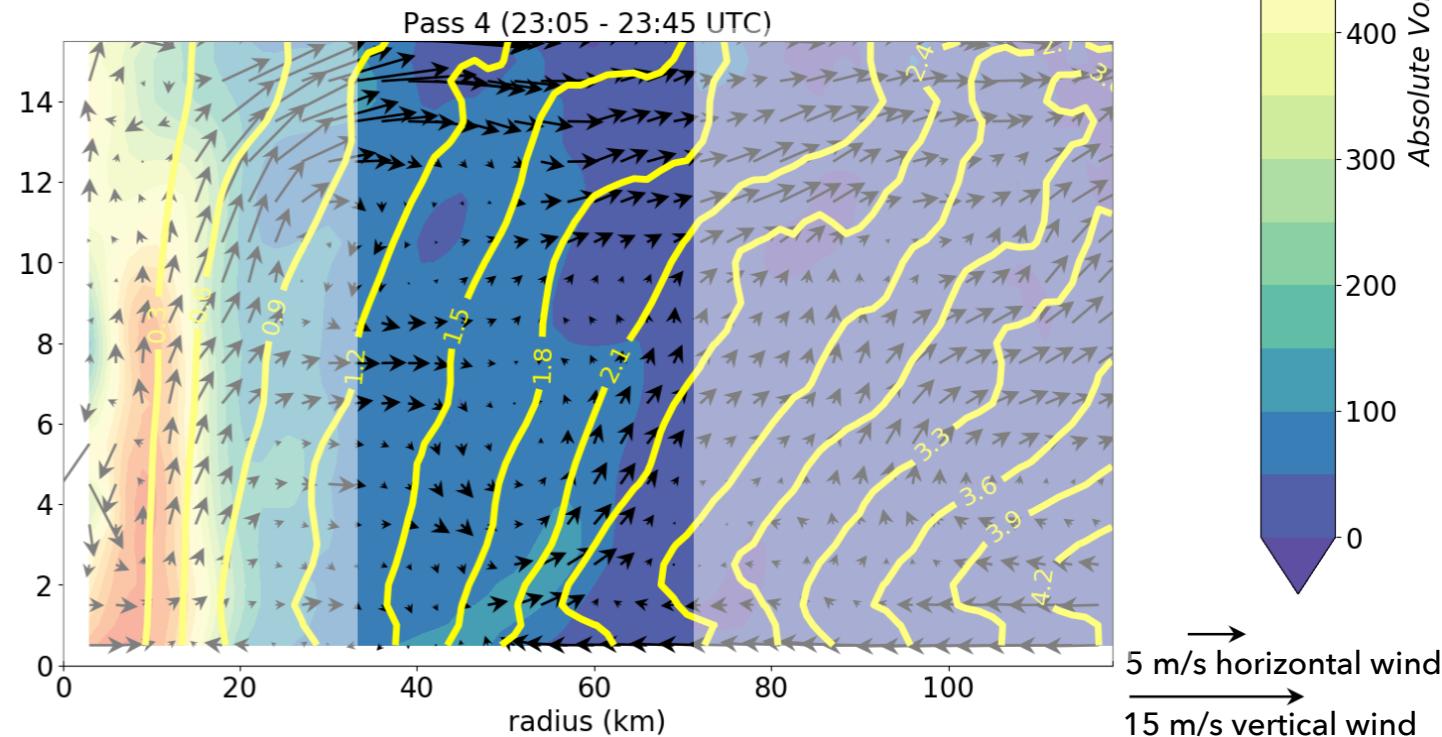
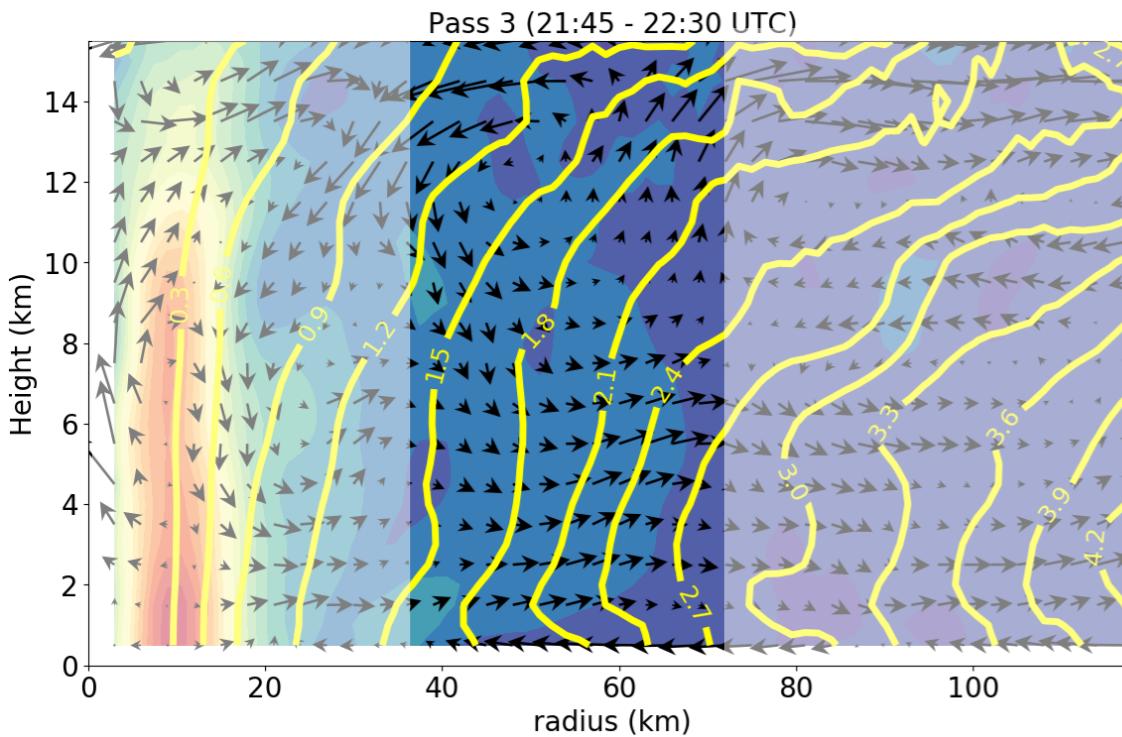
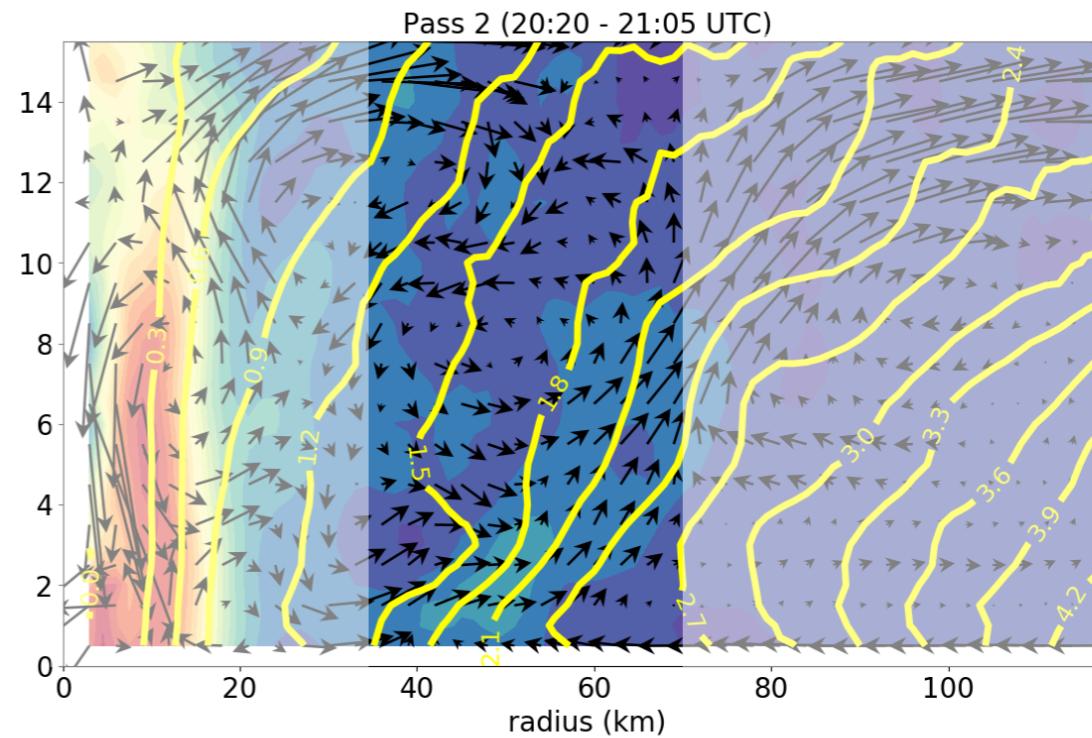
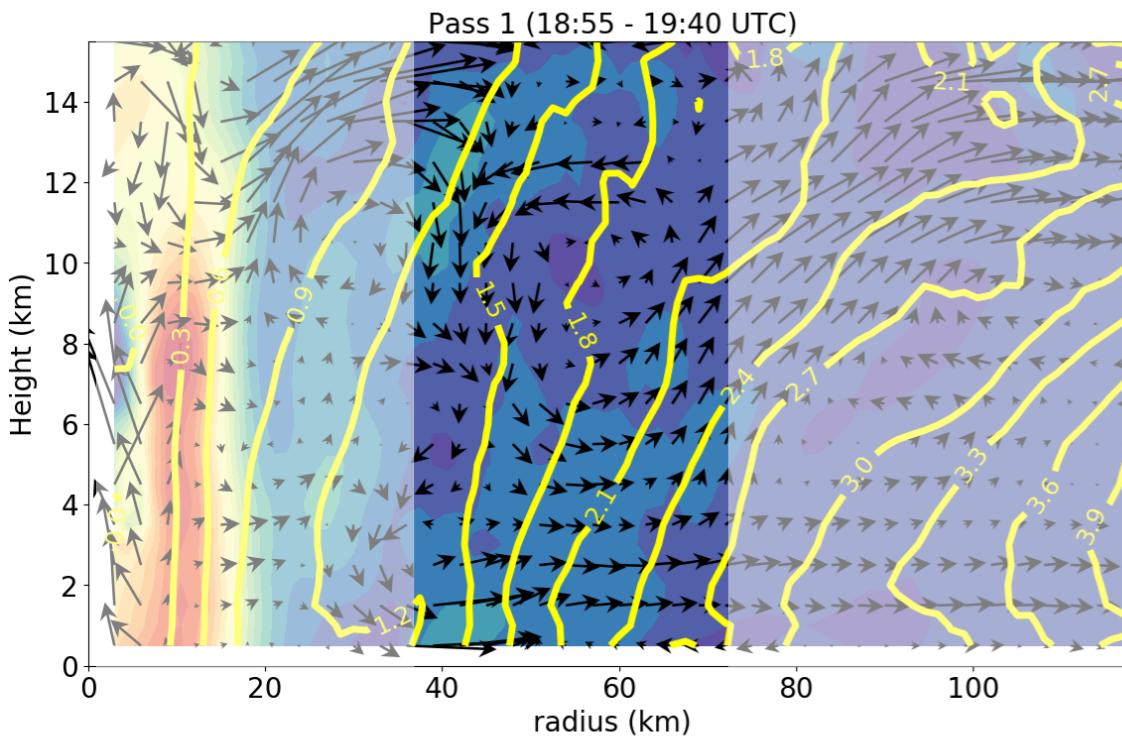
Axisymmetric View: Absolute Vorticity and Angular Momentum

filled contours: Absolute Vorticity; yellow contour: Angular Momentum; quiver plot: Secondary Circulation



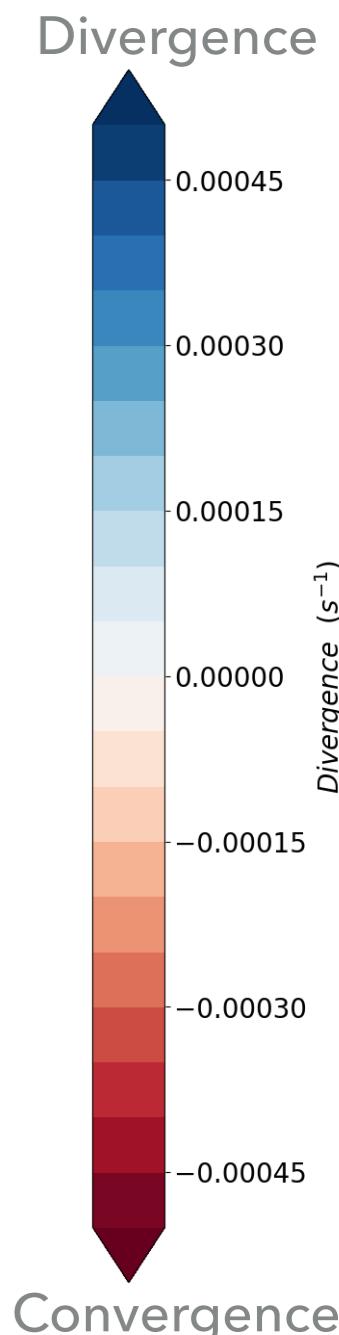
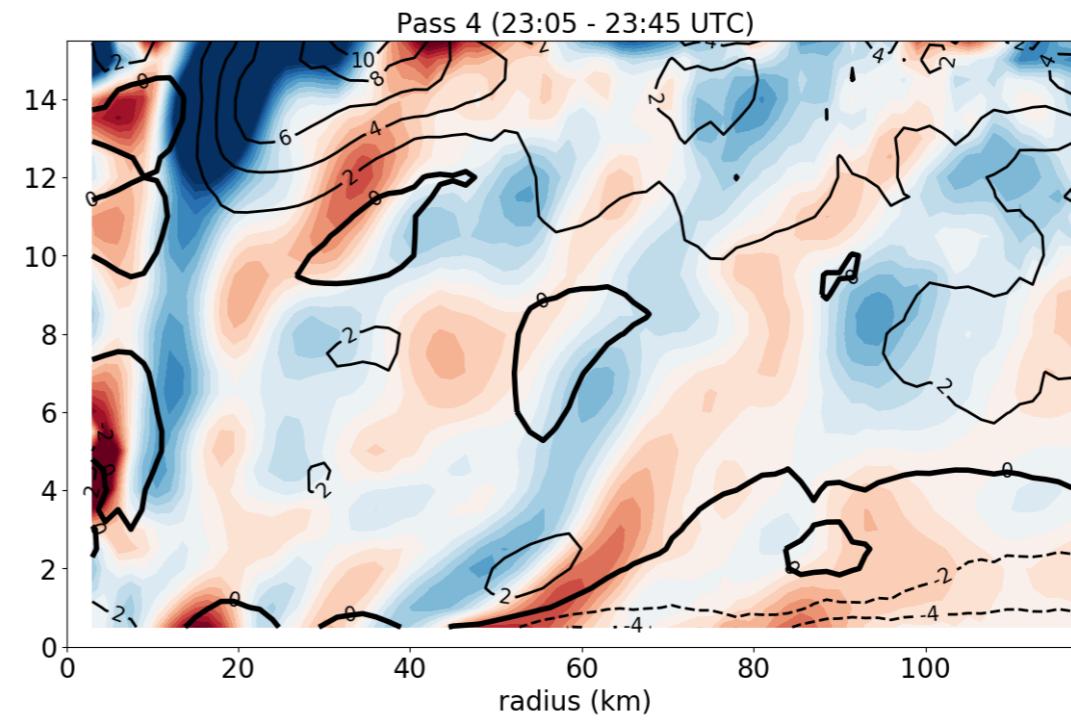
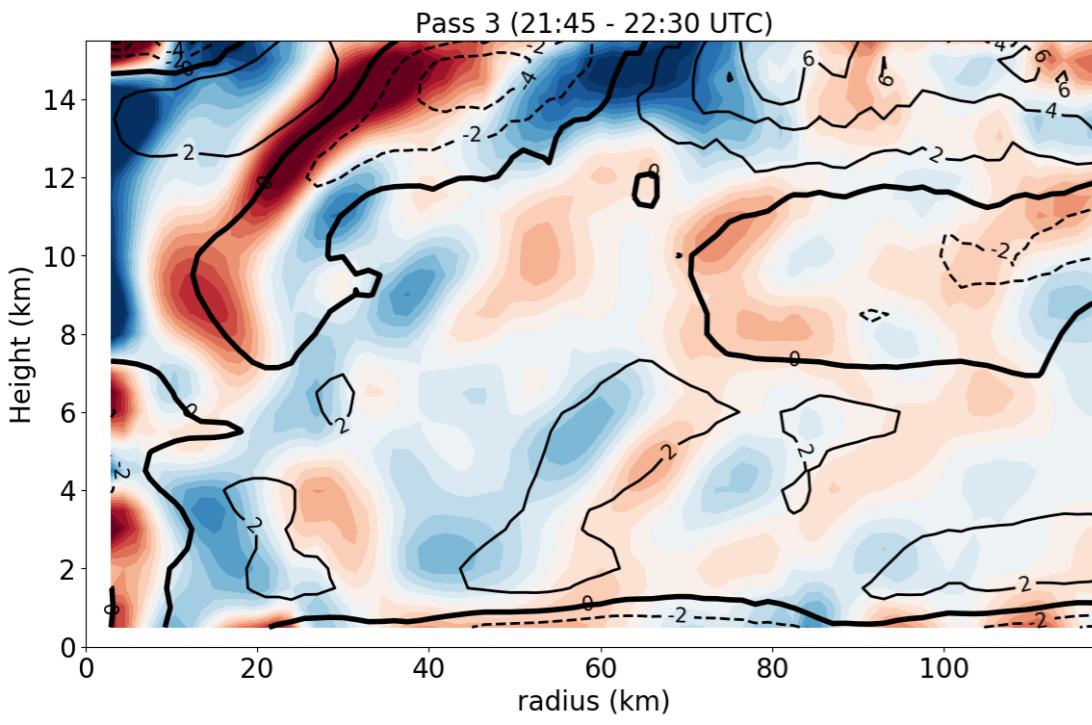
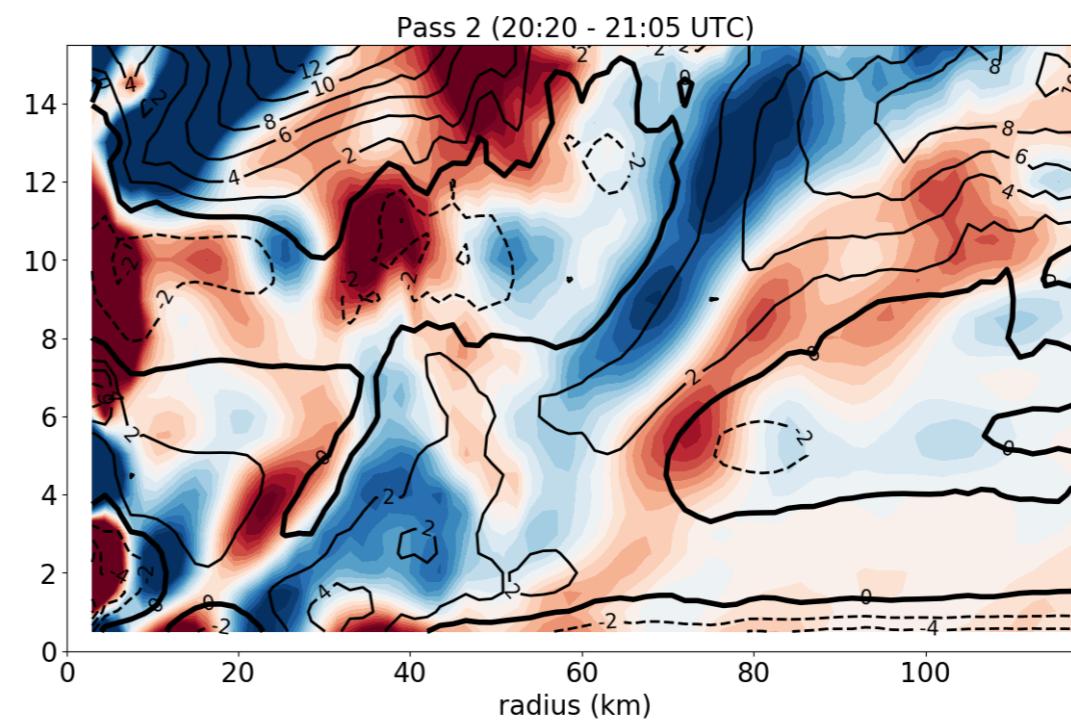
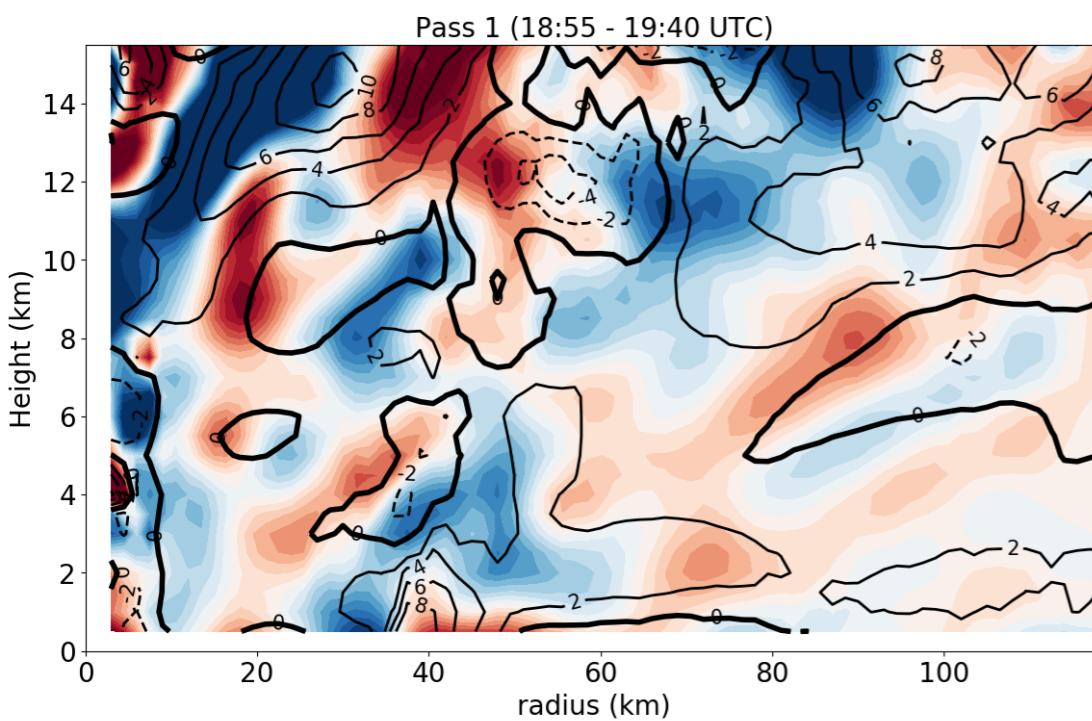
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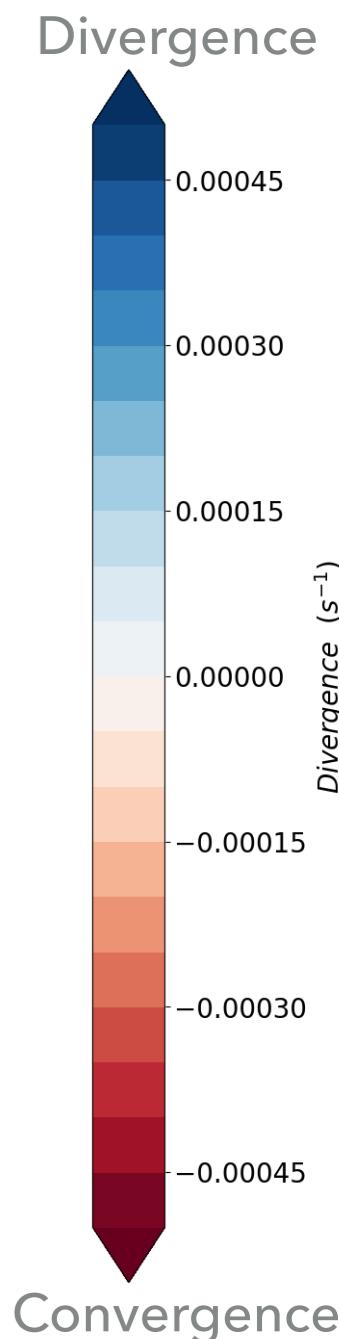
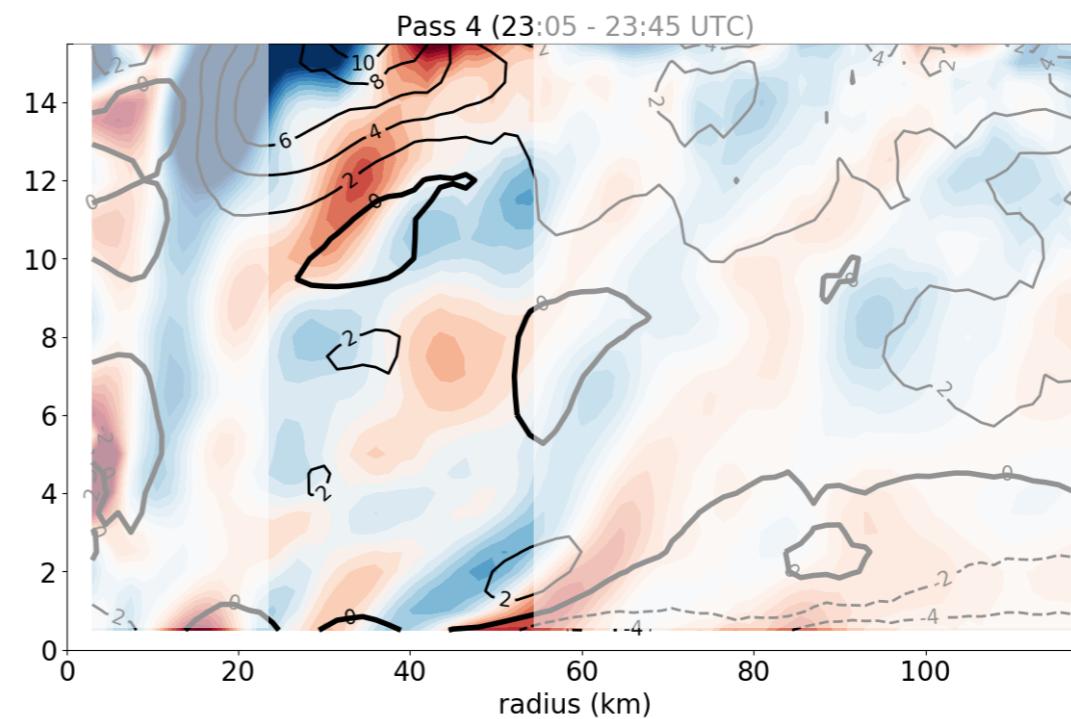
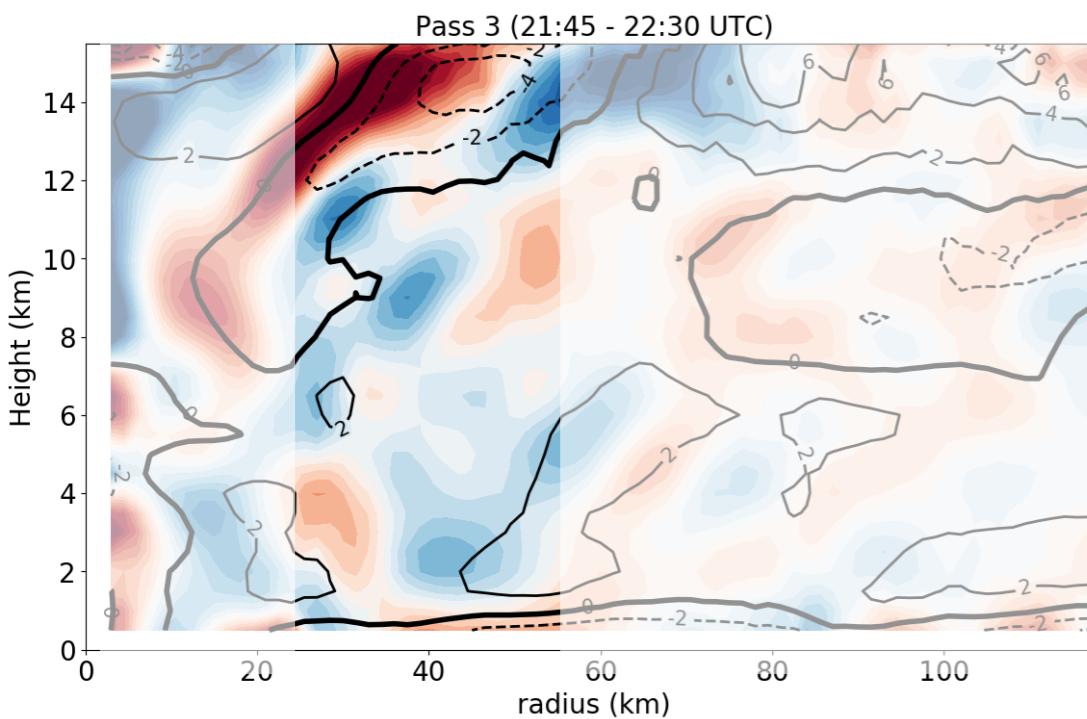
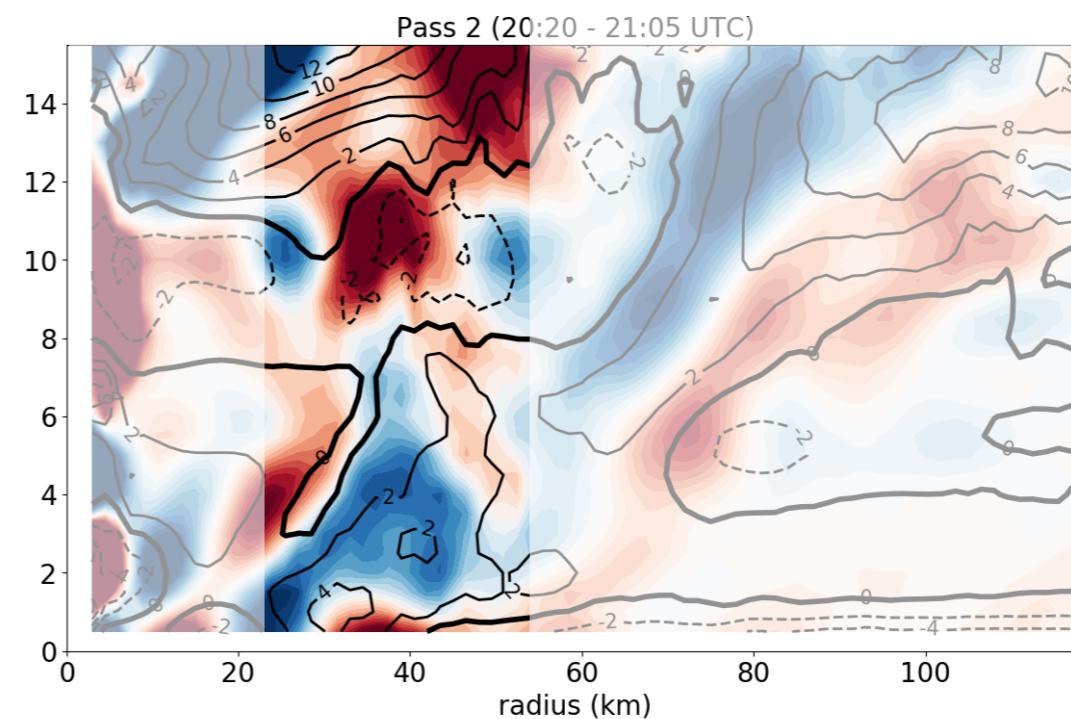
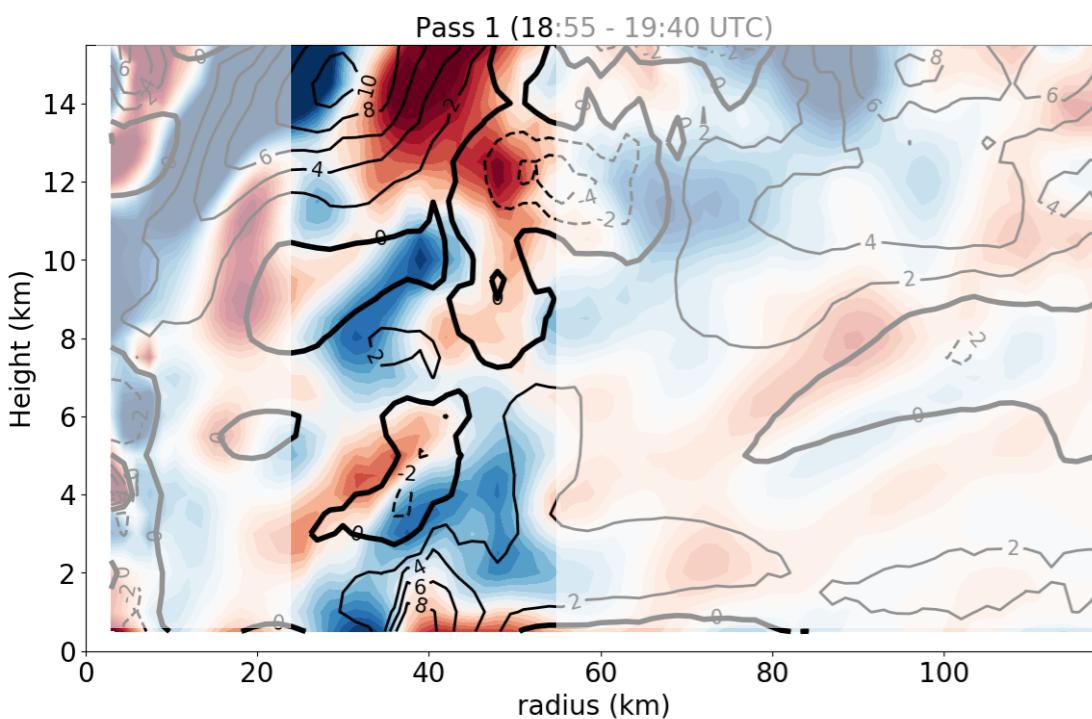
Axisymmetric View: Divergence and Radial wind

filled contours: Divergence; black contour: Radial Wind



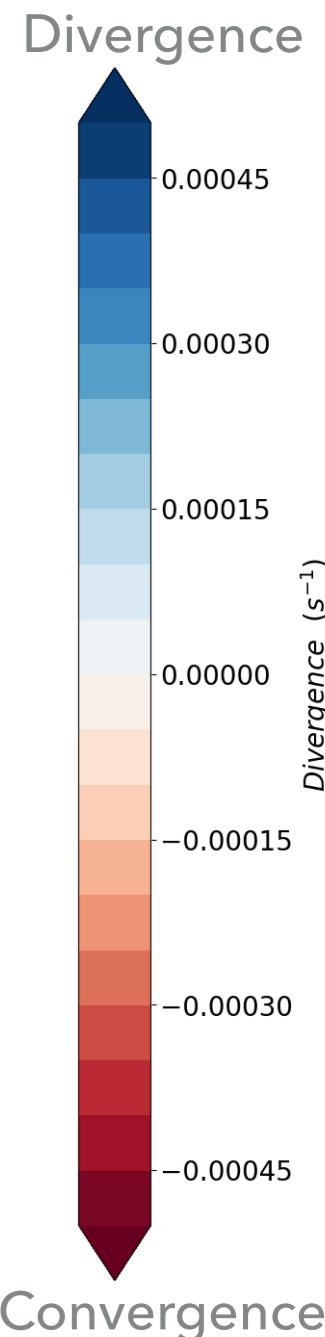
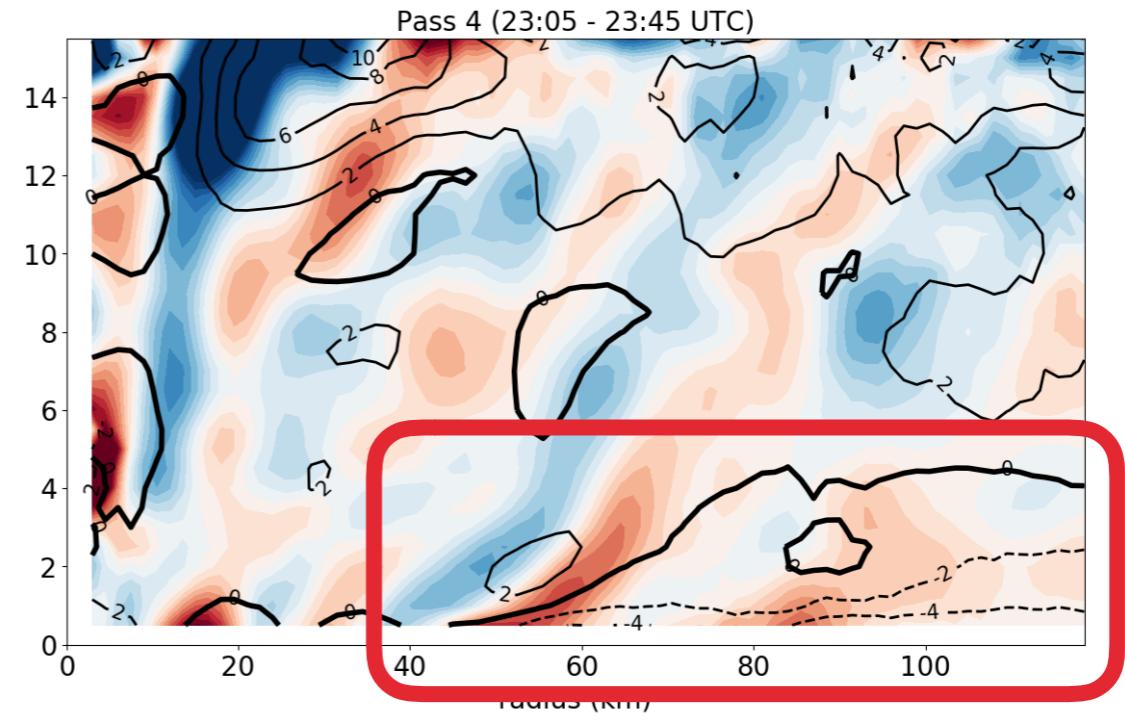
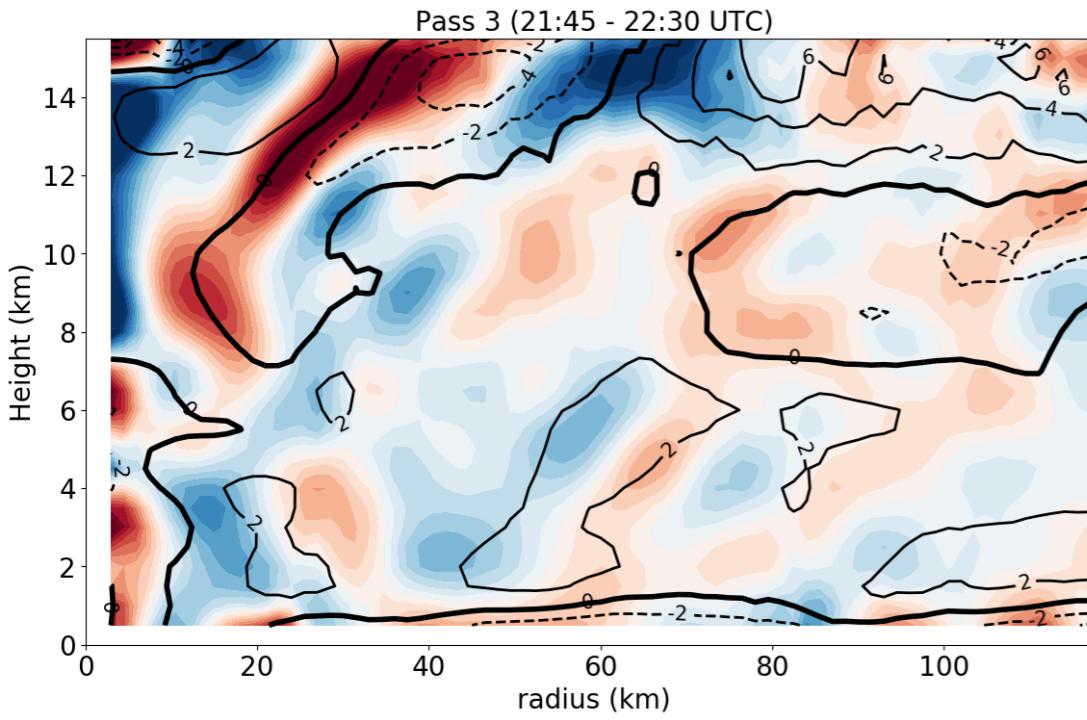
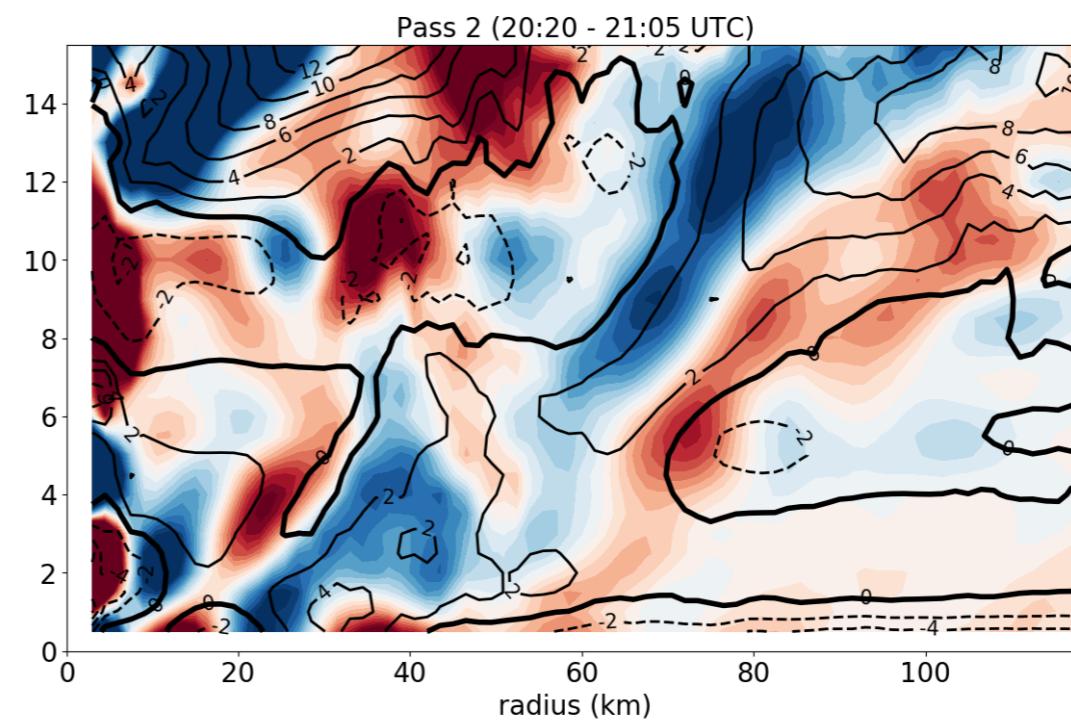
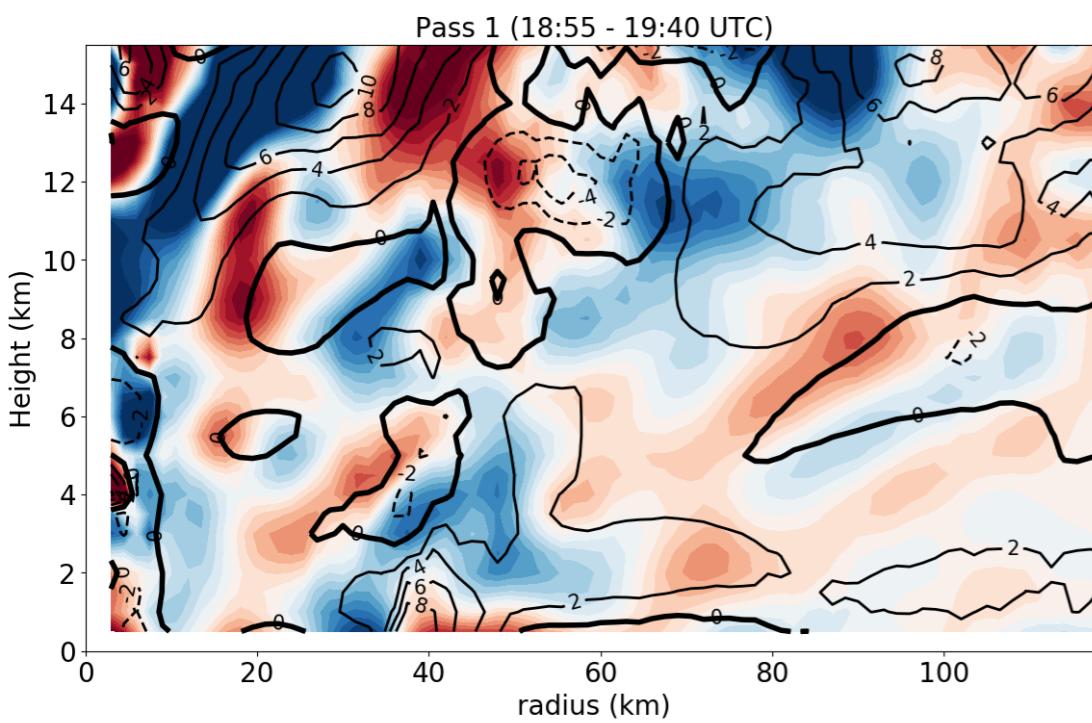
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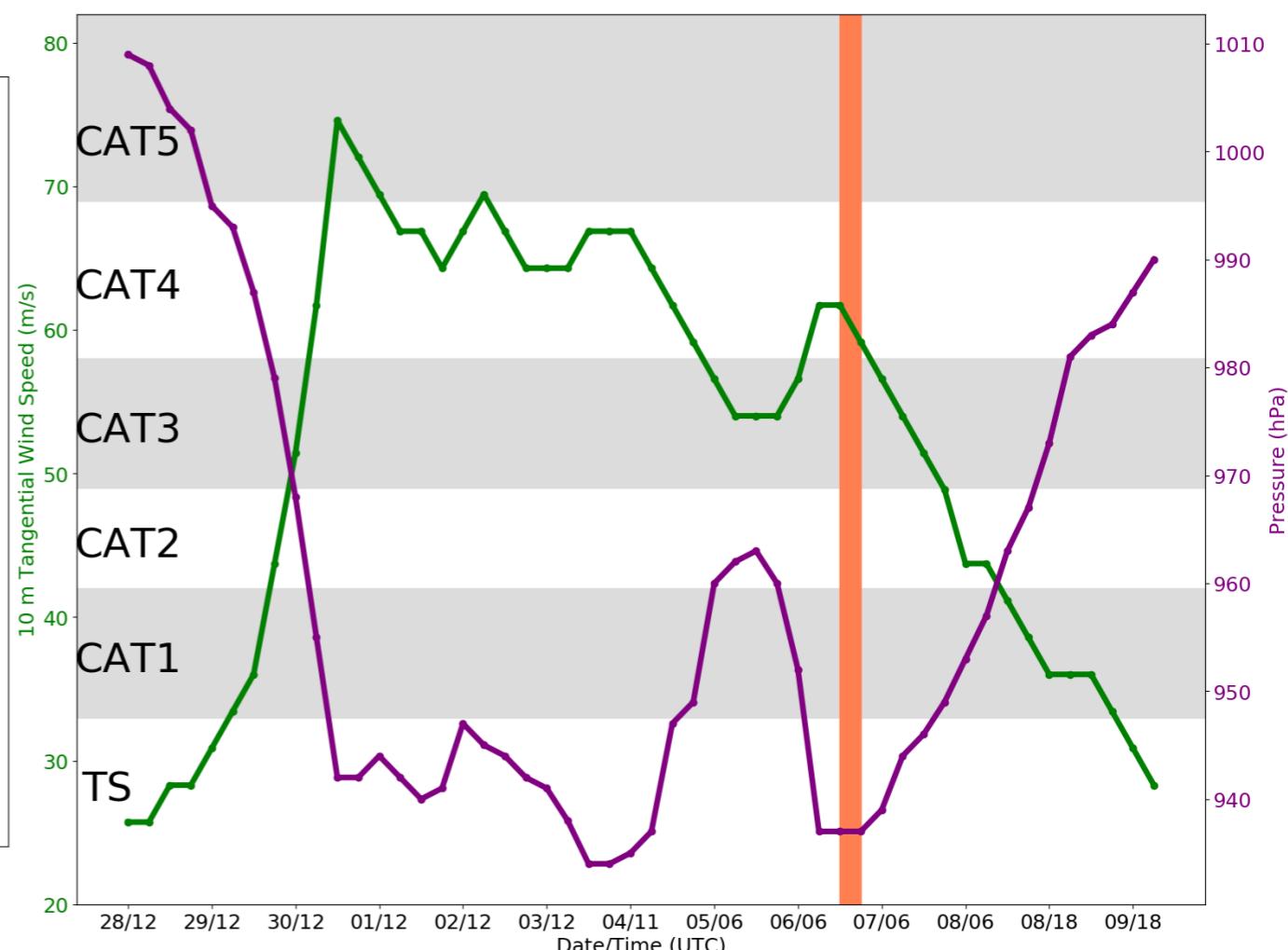
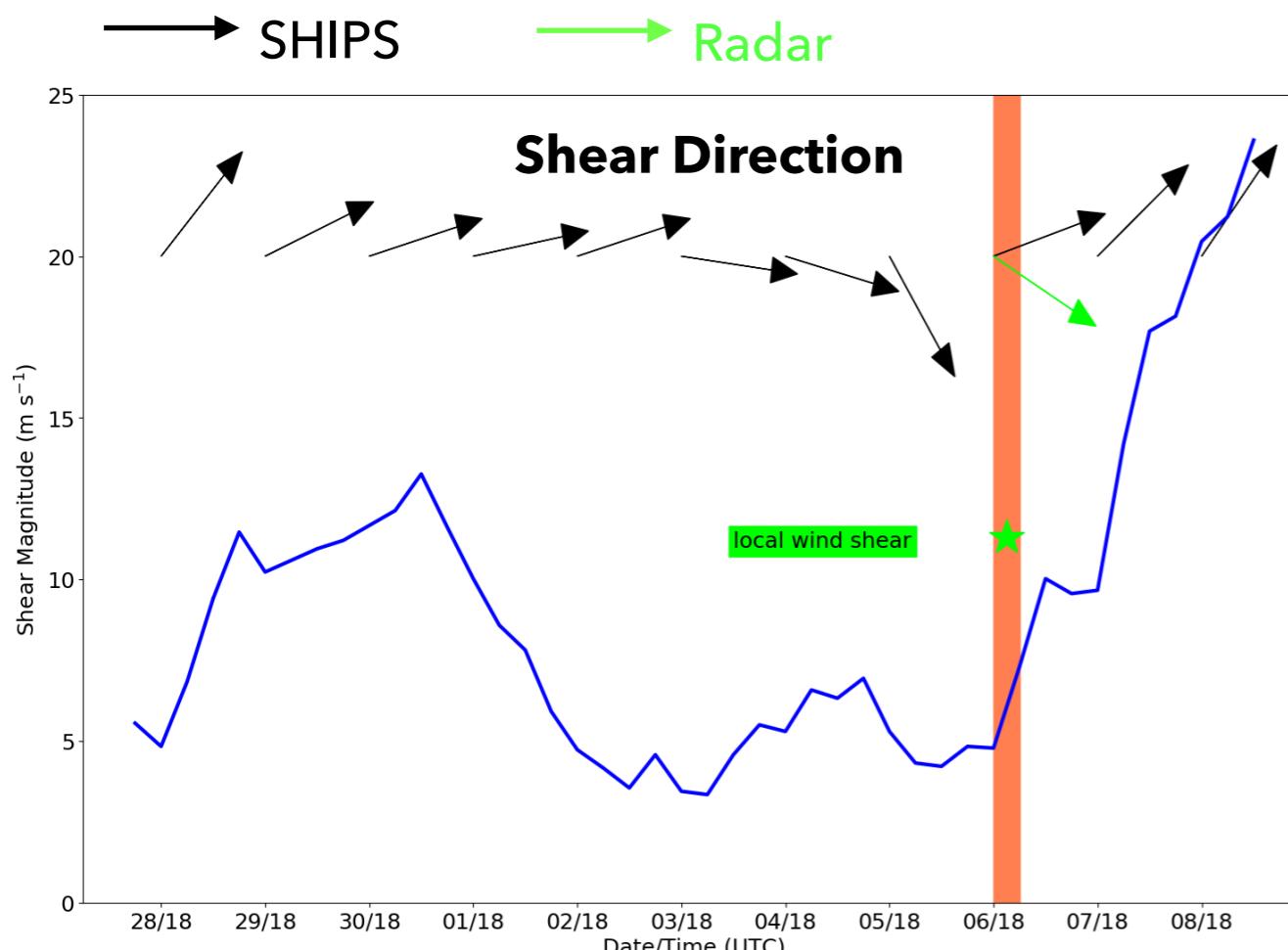


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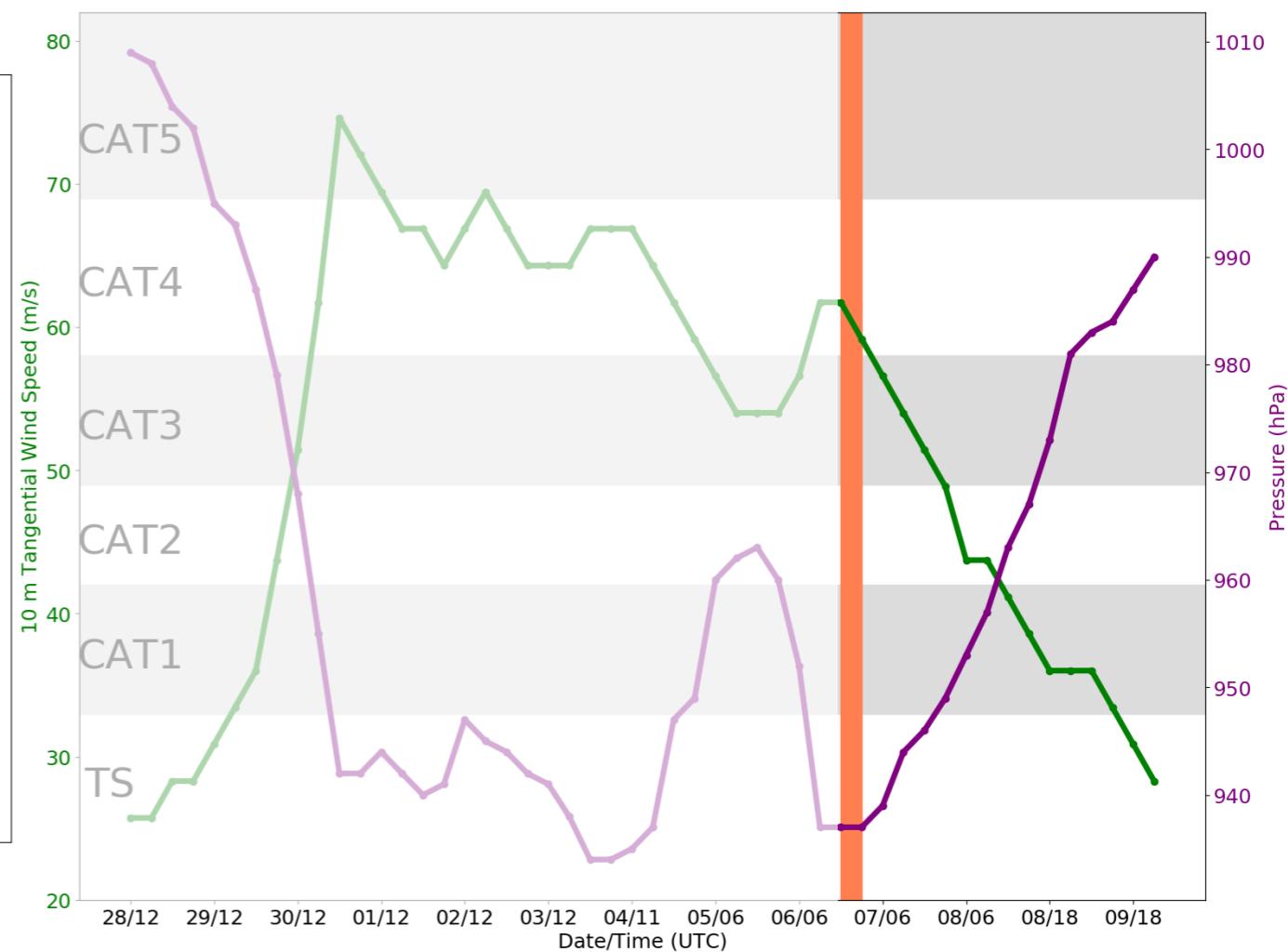
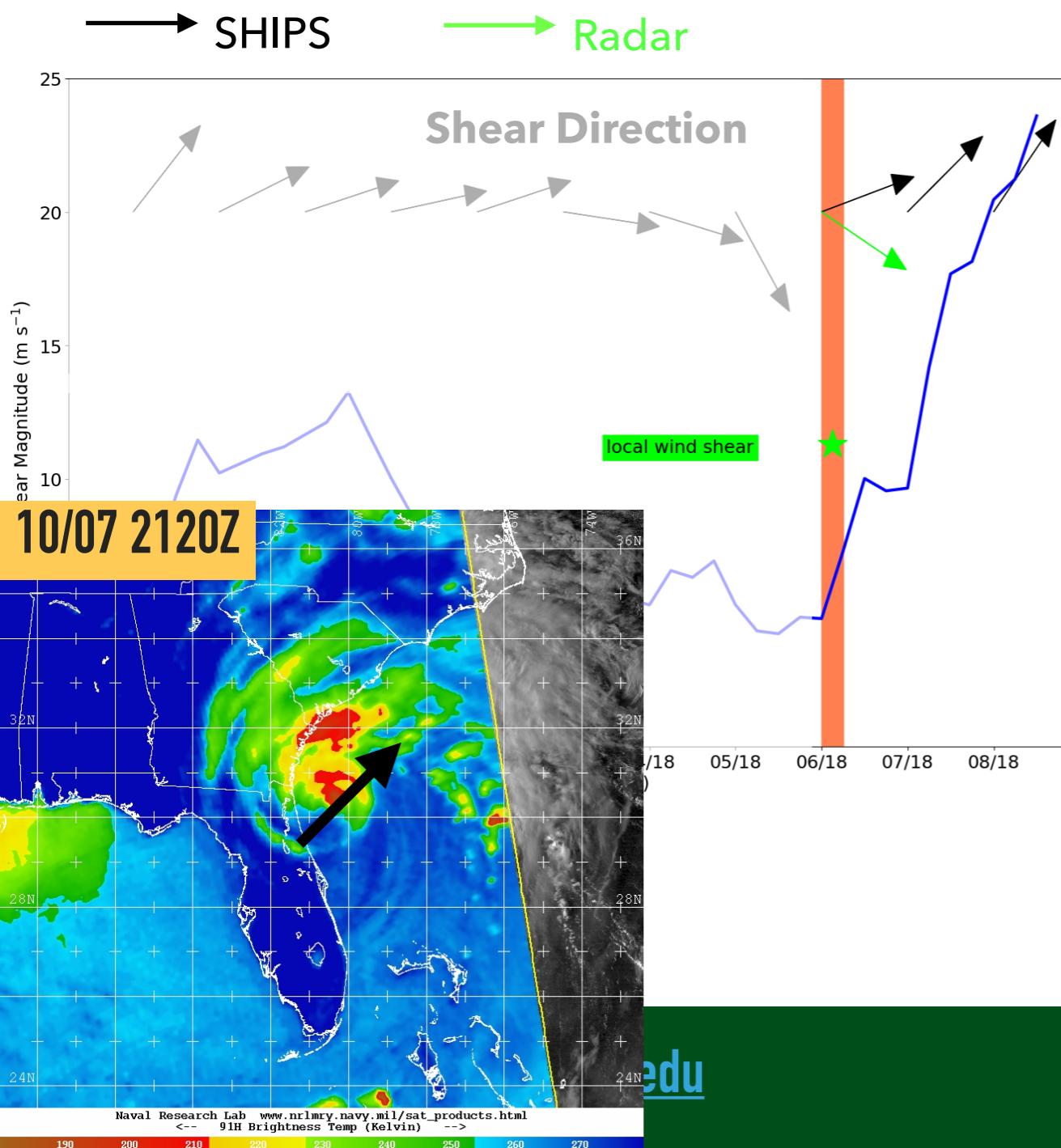


850-200 hPa Deep-Layer environmental vertical wind shear



↑ North

850-200 hPa Deep-Layer environmental vertical wind shear



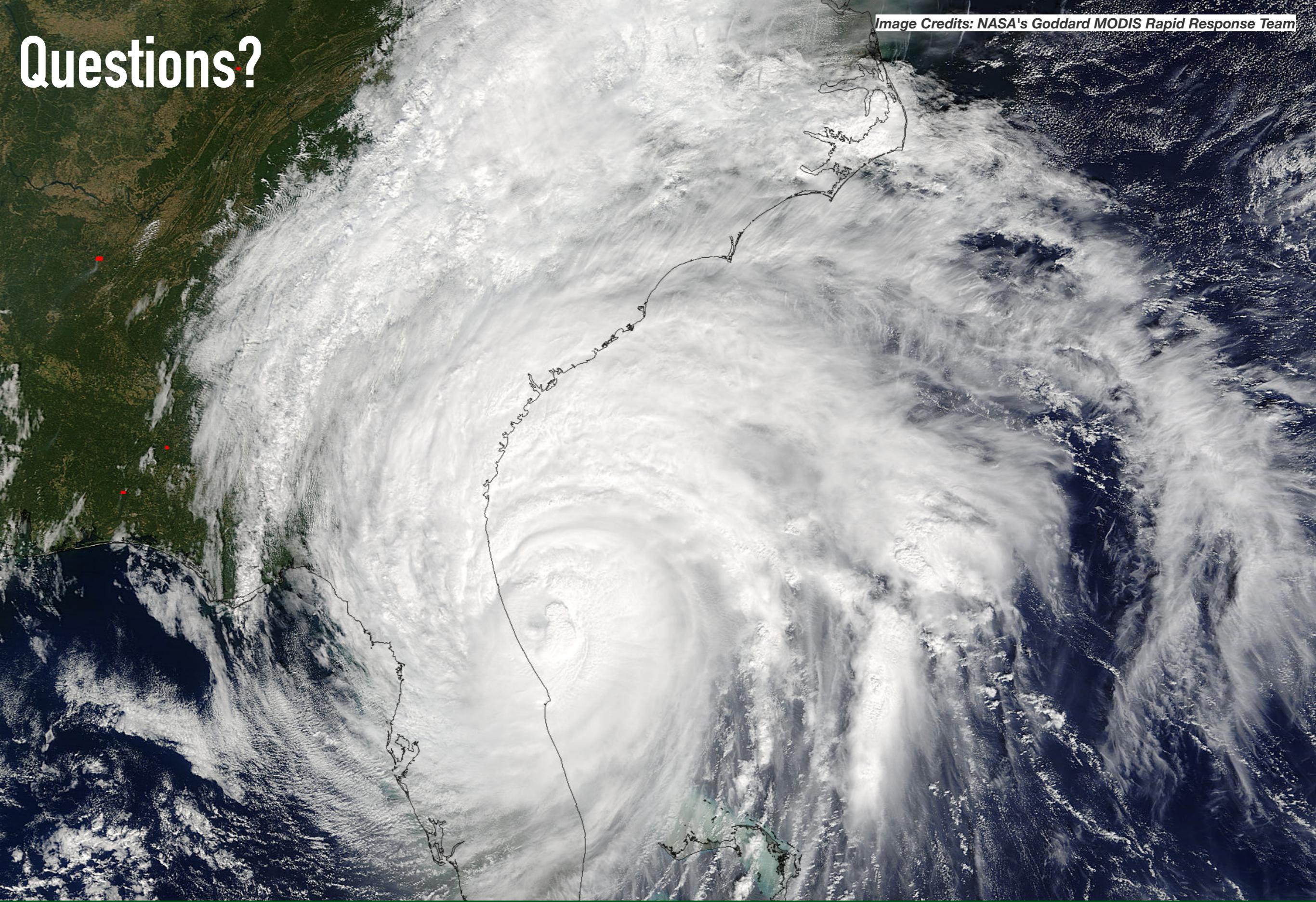
Conclusions

- ▶ Both the primary and secondary eyewall strengthened from 19 to 21 UTC, but then started to decay and become more asymmetric
 - ▶ *Evolution is consistent with Intensification and Weakening of classic ERC, but Reintensification was never realized due to increasing vertical wind shear*
- ▶ Downward motion in the moat region weakened over the analysis period. The clear moat signature disappeared, and began to fill with stratiform precipitation.
 - ▶ *Strong mid- and upper-level secondary circulation associated with balanced response to heating weakened as the eyewall convection decayed*
- ▶ Secondary eyewall vorticity was maximized at low-levels and closely coupled with low-level inflow and convergence of angular momentum
 - ▶ *Near-surface radial flow was not resolved by radar, but significant evolution below 2 km altitude suggest boundary layer dynamics play important role in ERC*

Future Work

- ▶ Single Doppler ground-based radar analysis underway to improve temporal resolution of the ERC evolution, but has limited data at low-levels due to range from radar
- ▶ Investigate dropsonde observations to better understand boundary layer processes.
- ▶ Analyze shear-relative quadrants to better understand the asymmetric evolution of ERC
- ▶ Improve radar analysis tools used to process hurricane data as part of LROSE project

Questions?

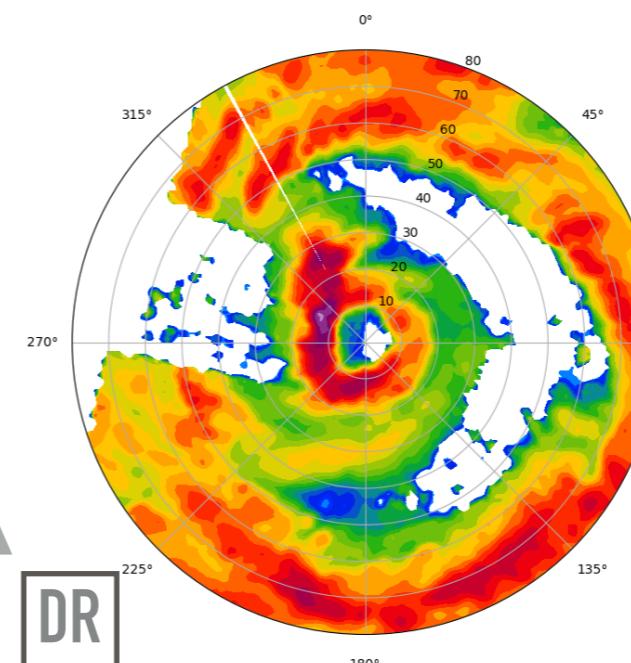
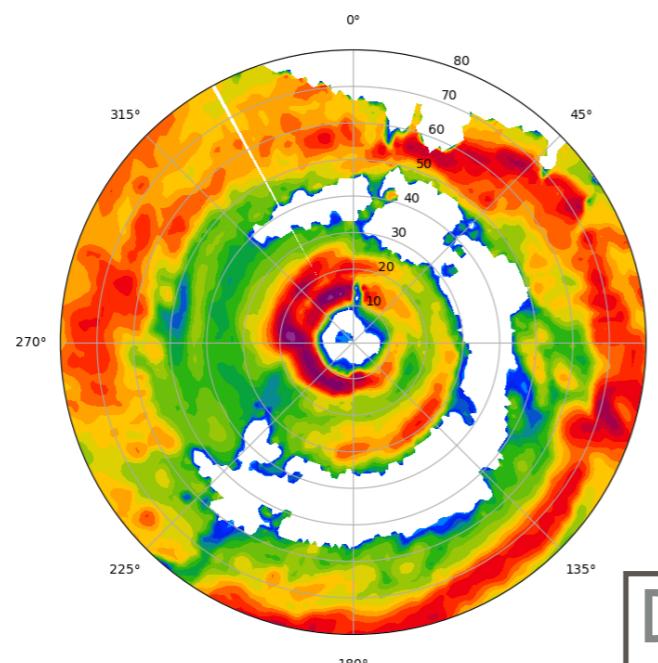


Colorado State University

Asymmetric View: Shear-Relative Reflectivity

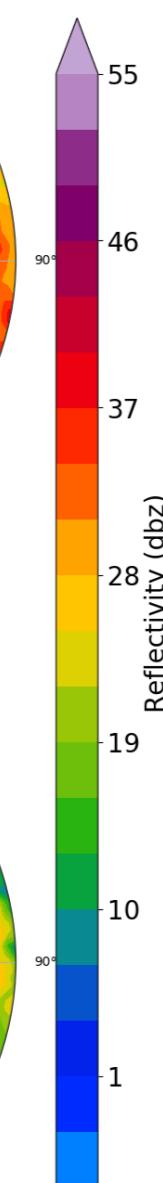
Pass 1

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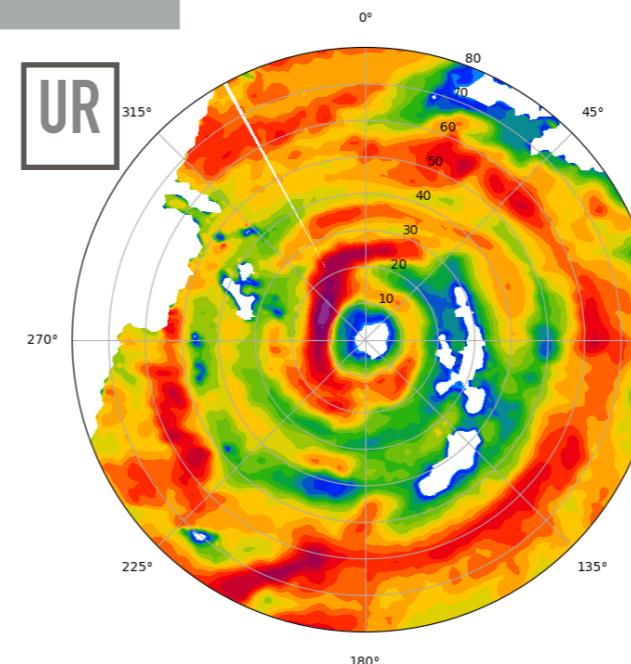
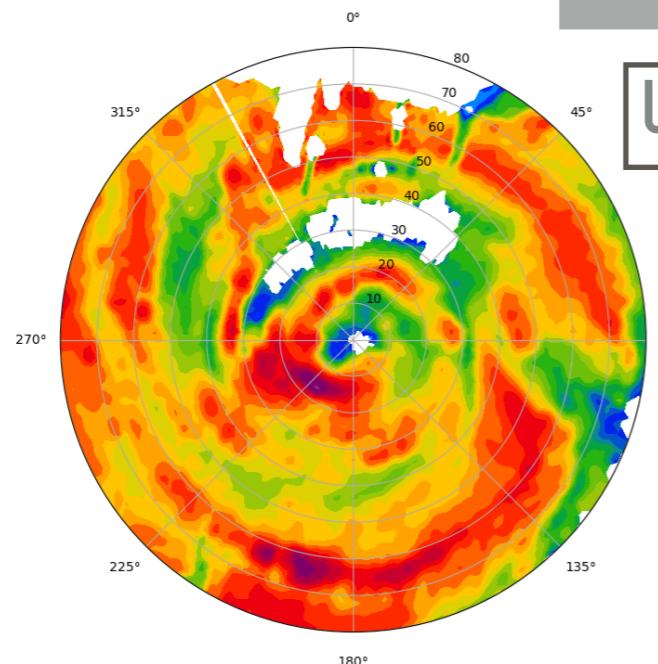
Pass 2

20:20-21:05 UTC



Pass 3

21:45-22:30 UTC



Pass 4

23:00-23:40 UTC