Tropical Cyclone Moist Static Energy Structure in Idealized Simulations and Dropsonde Observations

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Data: NOAA Hurricane Dropsonde Archive from NCAR EOL (1996-2009), HRD Sonde Archive (2010-2021)

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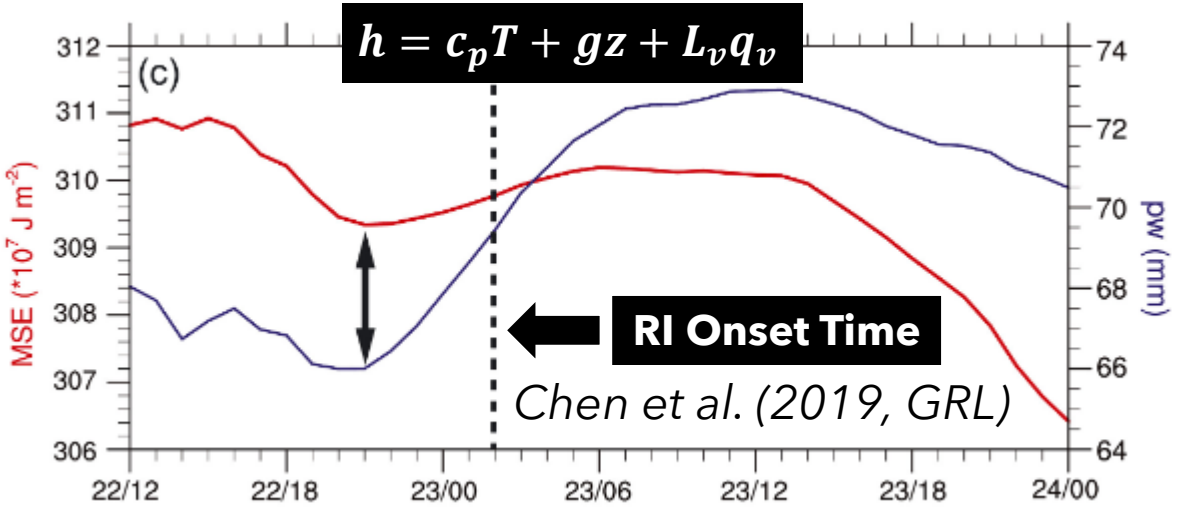
Using MSE to Understand TCs

$$h = c_p T + gz + L_v q_v$$



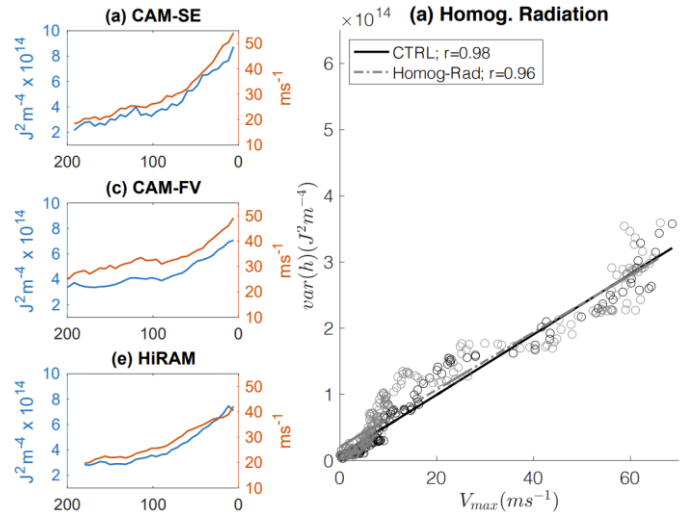
Chen et al. (2019, GRL)

Increased inner-core MSE (and therefore, **MSE variance**) often suggests intensification

$$\frac{1}{2}\frac{\partial \widehat{h}'^2}{\partial t} = \widehat{h}'SEF' + \widehat{h}'NetSW' + \widehat{h}'NetLW' - \widehat{h}'\nabla_h \cdot \widehat{\vec{u}h}$$

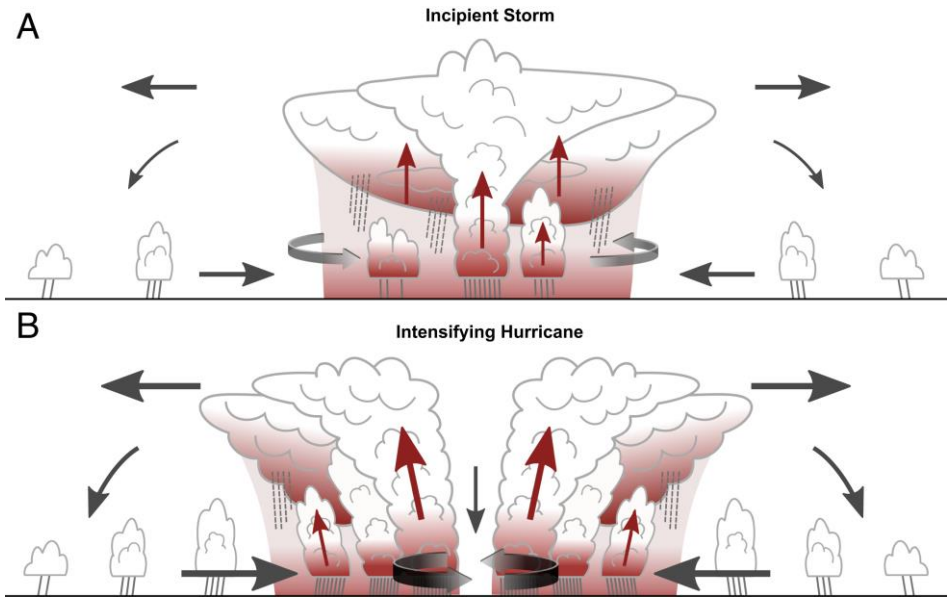
Wing and Emanuel (2014, JAMES)

We have a tool to assign tendencies in MSE variance to processes…



Strong relationship between MSE variance and TC intensity in GCMs and CRMs (*Wing et al. 2019, J. Clim.; Wing 2022, JAS*)

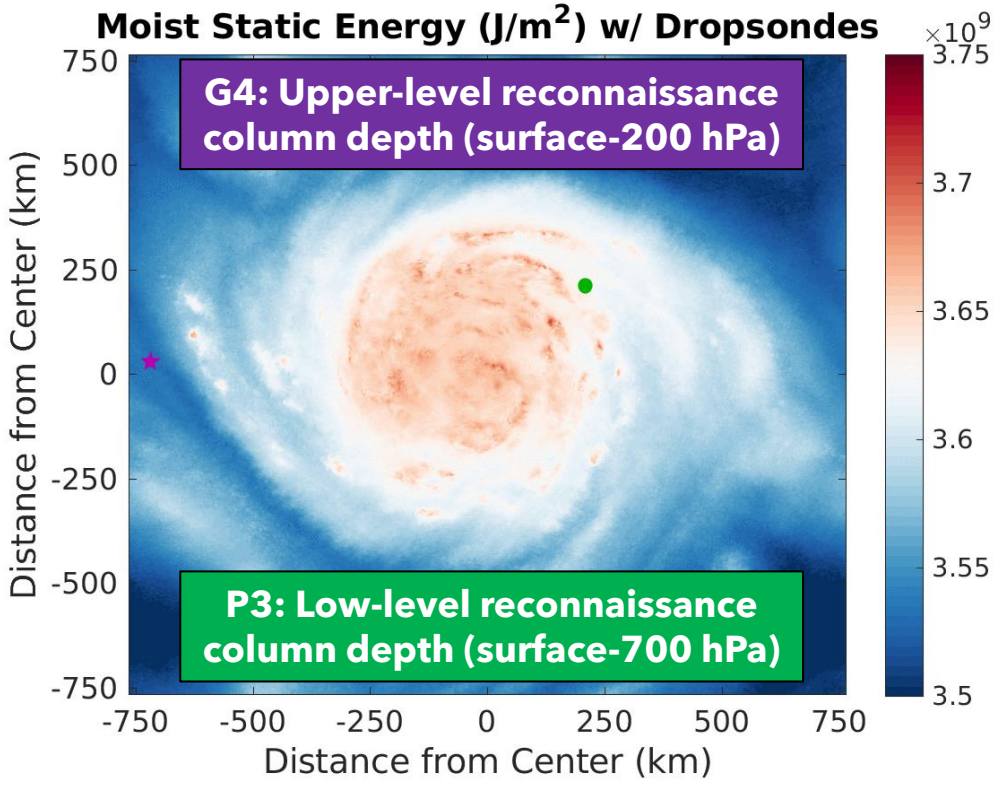
Ruppert et al. (2020, PNAS)



…like cloud-radiation feedbacks!

Assessing MSE Variability in Simulated TCs

Dropsondes yield detailed vertical profiles of MSE, but their spatial coverage is limited! How much can we really capture?



Carstens and Wing (2022, GRL)

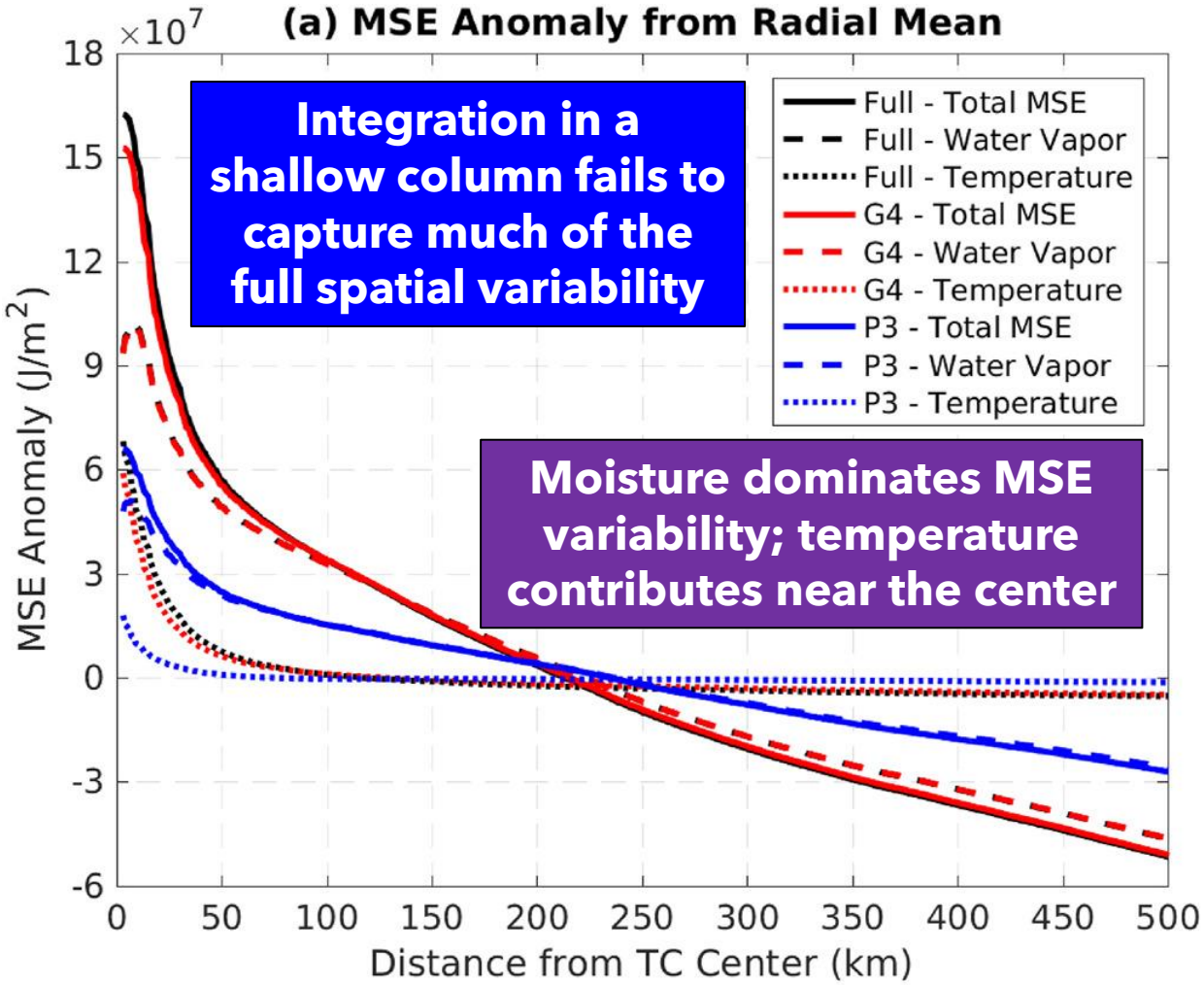
We address this with idealized TCs in SAM at 3 km resolution (Khairoutdinov and Randall 2003)

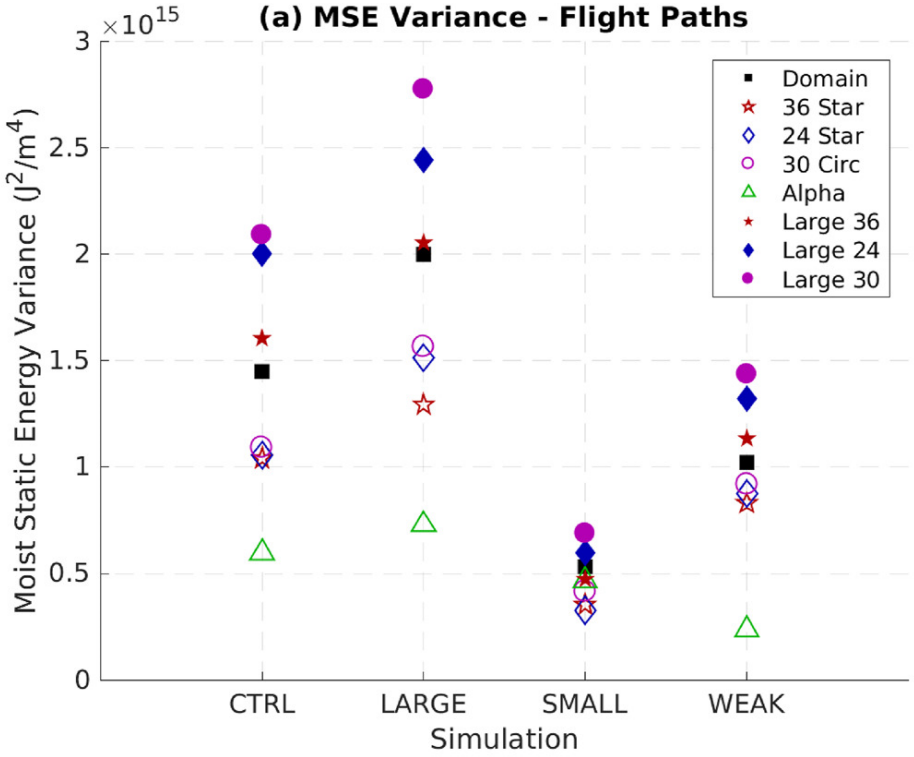
1. Choose patterns of grid points resembling recon flights
   - ➢ We want to capture a wide range of radii
2. At each point, calculate column-integrated MSE and radiative/surface flux feedbacks
3. Compare to results using all ~260,000 grid points in the model domain

Idealized Simulation Findings

$$h = c_p T + gz + L_v q_v$$

Carstens and Wing (2022, GRL)





With as little as 20 data points, we can correctly estimate the order of magnitude of MSE variance!

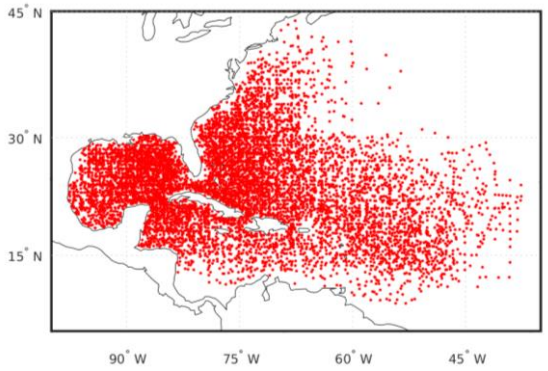
Moving to Dropsonde Observations

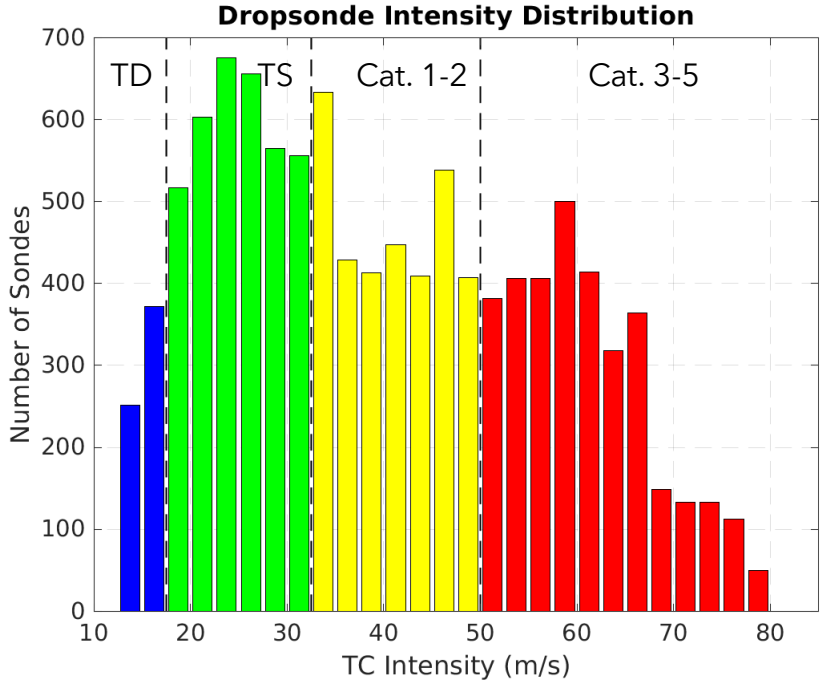
Recommendations based on simulations:

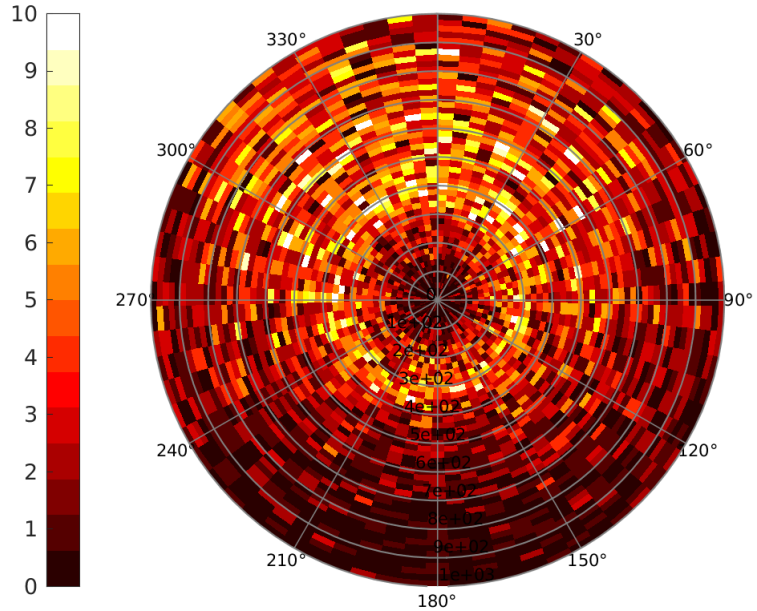
1. Capture a wide range of radii, approaching the TC center as closely as safely possible

2. ***Use dropsondes from upper-level reconnaissance (the NOAA G-IV)***

- 131 Atlantic TCs, over 10,000 sondes
  - 1996-2009: NCAR Hurricane Dropsonde Archive (Wang et al. 2015, BAMS)
  - 2010-2021: NOAA/AOML/HRD archive, QC performed via ASPEN software

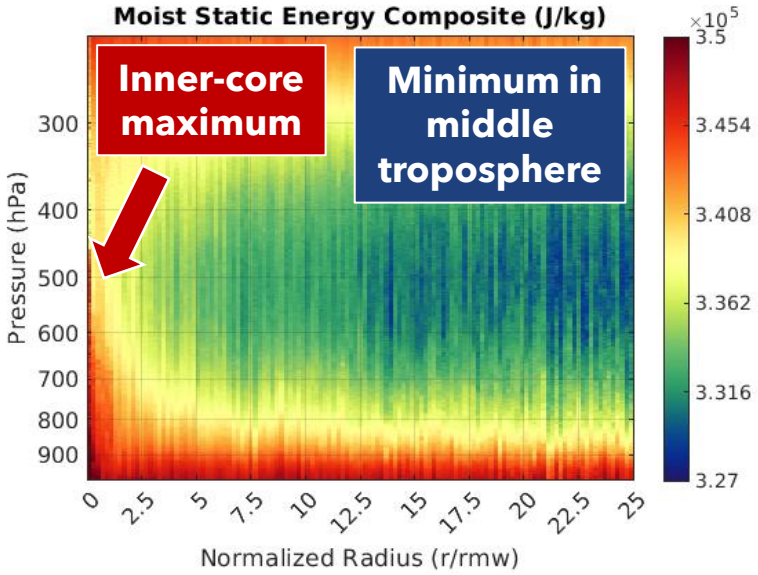


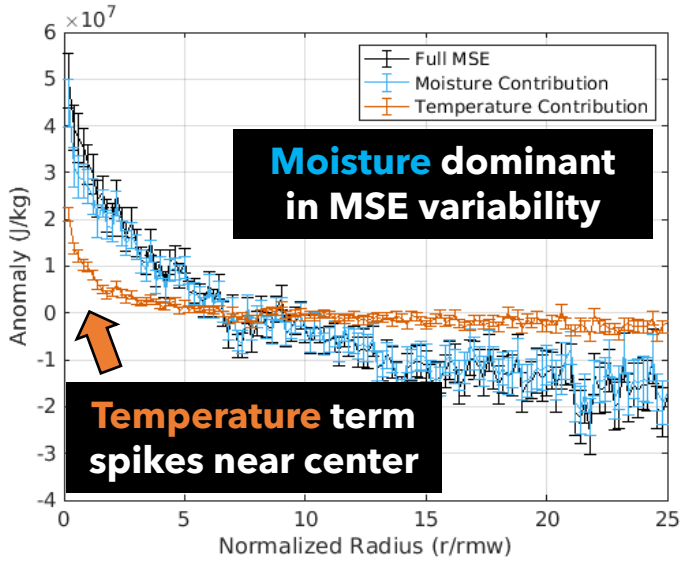


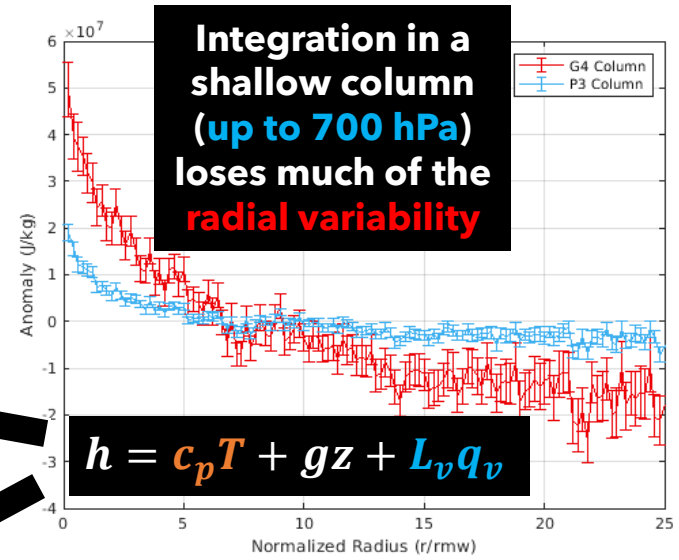


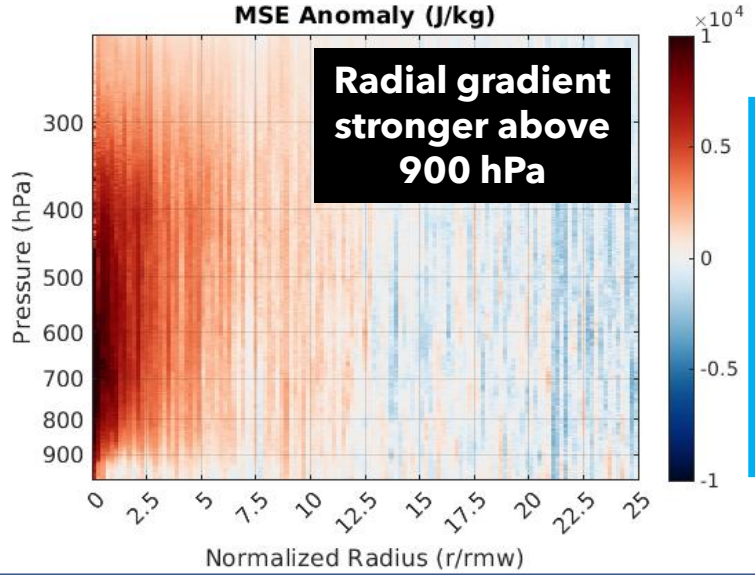
Right: Heatmap of storm-relative dropsonde launch points out to 1000 km radius

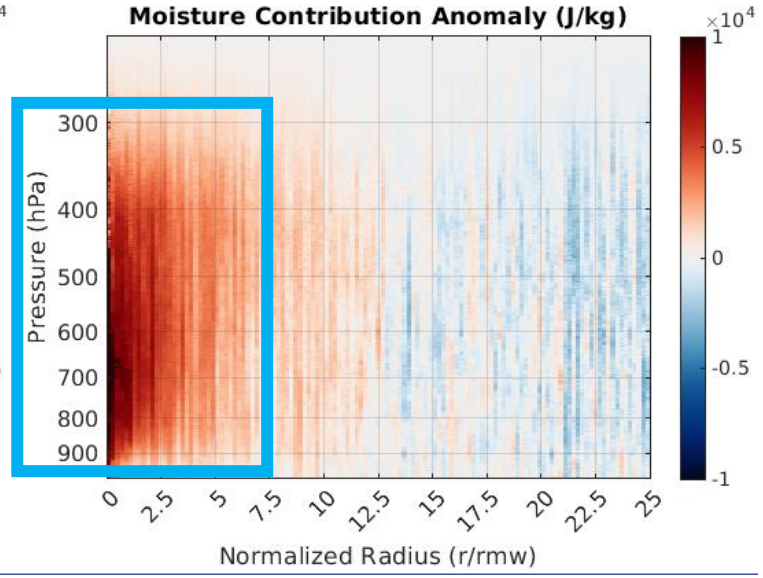
Composite MSE Structure in Observations

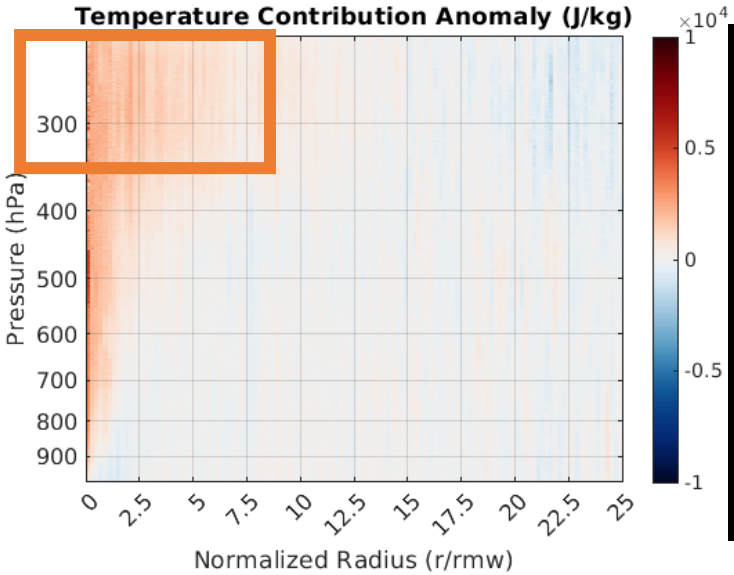








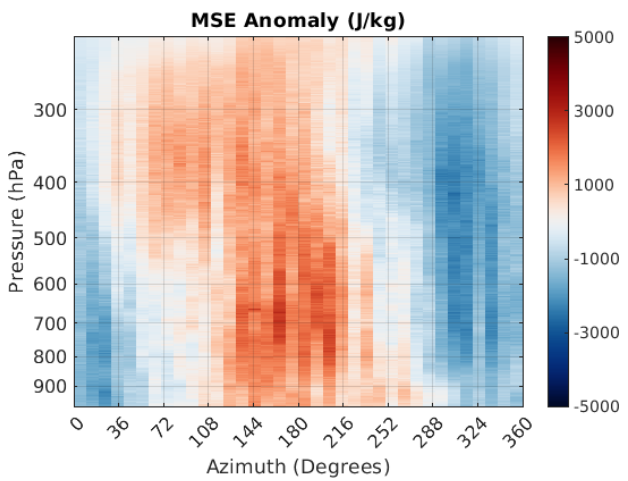


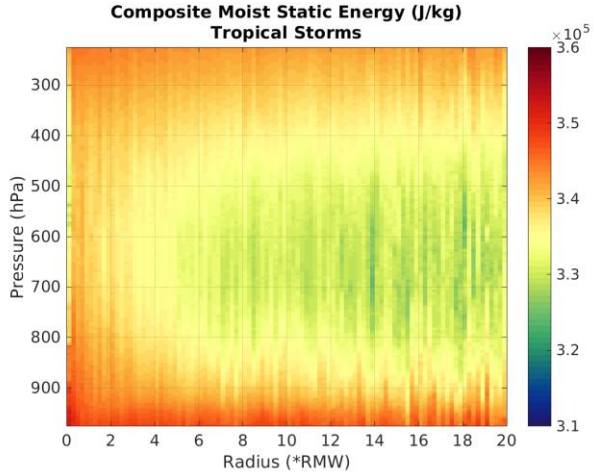


Warm core dominates MSE variability in the upper troposphere

Moisture term anomalies are amplified thru surface-300 hPa column

Looking Ahead





What structural features emerge in targeted composites? Examples could include intensity dependence, shear-relative asymmetries, etc.

Thanks for listening!

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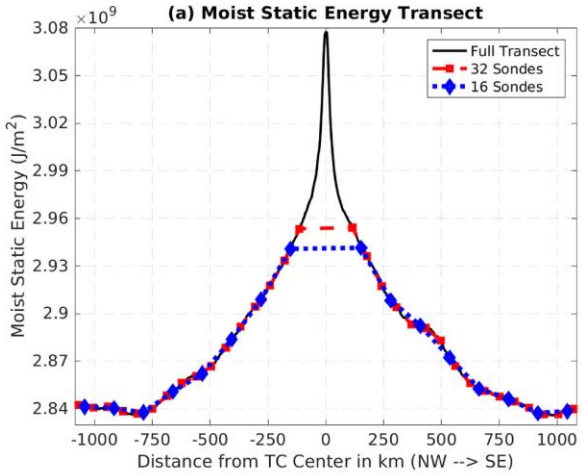

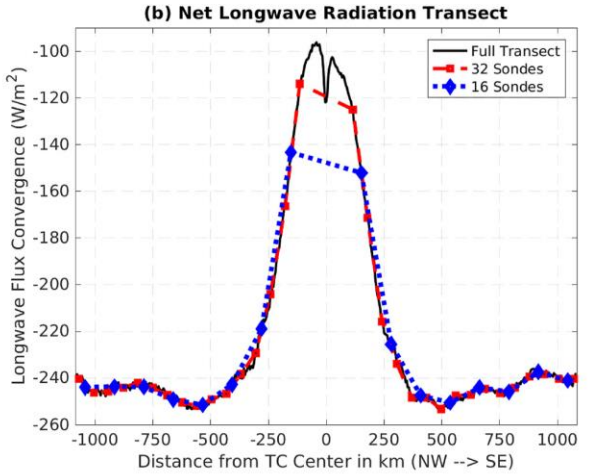

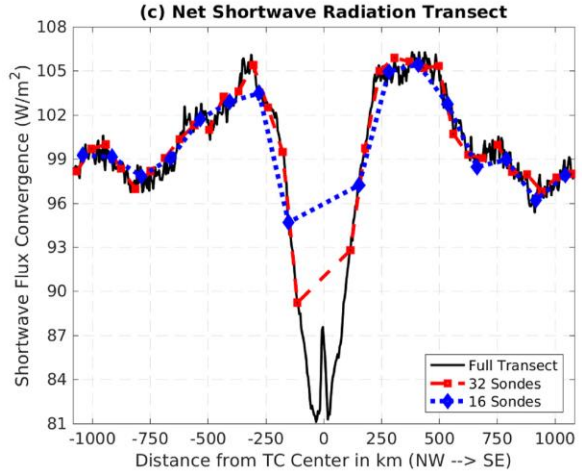

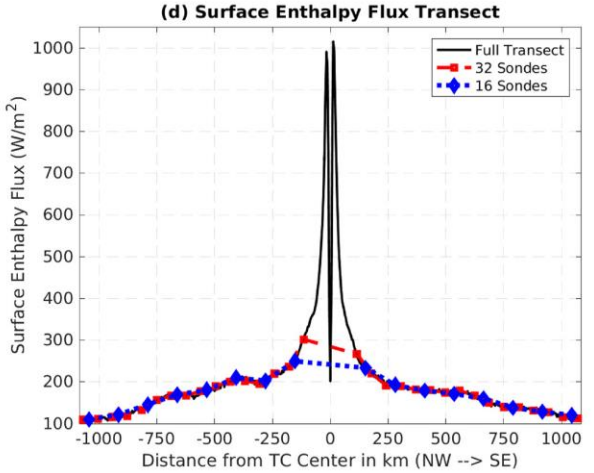

Developing a user-friendly dropsonde dataset for a much wider range of applications

Navigating challenges to calculate radiative and surface flux feedbacks in real time