Simulating Dropsondes to Assess Moist Static Energy Variability in Tropical Cyclones

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Cloud-radiation and surface flux feedbacks affect TC development[1-4]. We can quantify these if we know how the column-integrated moist static energy (MSE) varies. Can dropsondes from aircraft reconnaissance give us this knowledge, despite their limited coverage?

EXPERIMENTAL DESIGN

- 4 TCs simulated over 3 days in a cloud-resolving model[5] (SAM); 3 undergo RI after spontaneous genesis:
  1. CTRL: Baseline
  2. LARGE: Larger TC than CTRL
  3. SMALL: Smaller TC than CTRL
  4. WEAK: Maximum intensity of 33.6 m s^{-1}
- First, we identify the necessary column depth for these calculations, integrating MSE through 3 columns:
  1. Full: Surface to 17 hPa (top of model)
  2. G4: Surface to 200 hPa (upper-level recon)
  3. P3: Surface to 680 hPa (low-level recon)

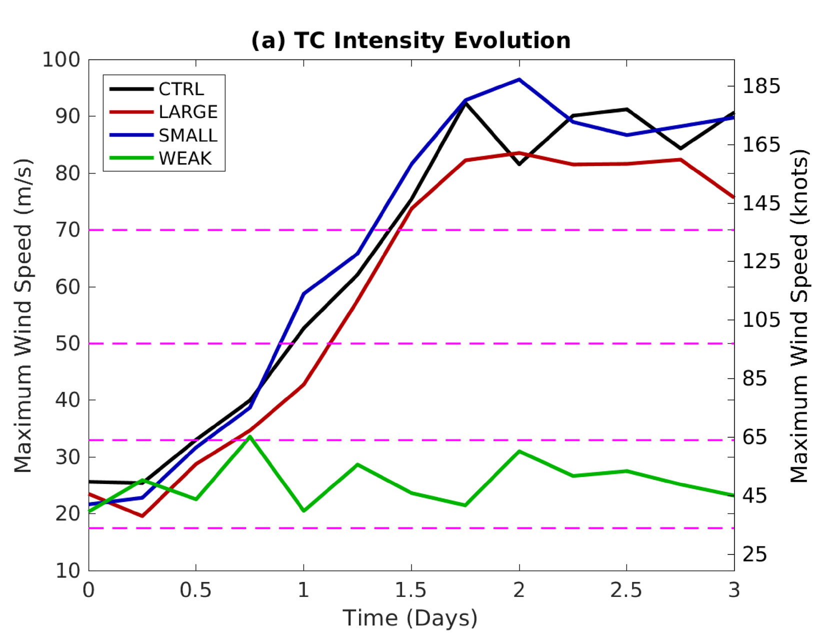
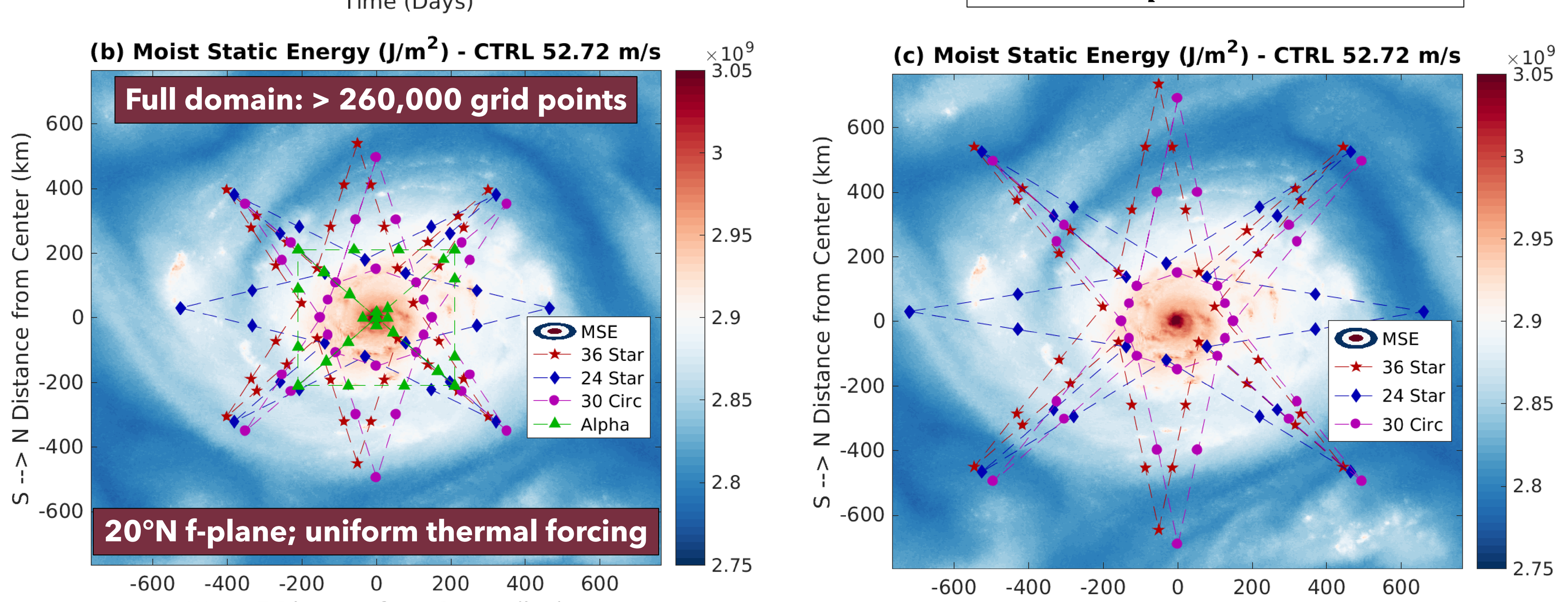


Figure 1: (a) 6-hourly intensity evolution for the four TCs. (b-c) Simulated flight patterns on a map of column-integrated MSE. (b) shows the versions of the patterns with smaller outer radii, while (c) shows larger versions.

$$MSE = c_pT + gz + L_vq_v$$



Develop patterns of grid points resembling recon flights. Calculate MSE variance and feedbacks from these, and compare to what we get w/ the full domain:

1. *36 Star: 36 "dropsondes" in a star shape offset slightly NW*
2. *24 Star: 1 less dropsonde in each radial leg*
3. *30 Circ: Symmetric; 6 additional sondes near 150 km radius*
4. *Alpha: Intercepts eye/eyewall, MSE integrated in P3 column*

MSE VARIANCE BUDGET[6]: $\frac{1}{2}\frac{\partial \hat{h}'^2}{\partial t} = \hat{h}'SEF' + \hat{h}'NetSW' + \hat{h}'NetLW' - \hat{h}'\nabla_h \cdot \widehat{\vec{u}h}$

Tendency of MSE Variance | **Surface Flux Feedback** | **Shortwave Feedback** | **Longwave Feedback** | **Advective Feedback**

- Positive feedbacks occur when anomalies of MSE and radiative/surface enthalpy flux have matching signs

SENSITIVITY TO COLUMN DEPTH

- G4 resolves full column's MSE spatial variability well; P3 does not, capturing ~40% of MSE variance.
- Main contributor to MSE variance is water vapor, but warm core temperature anomalies aloft are non-negligible.

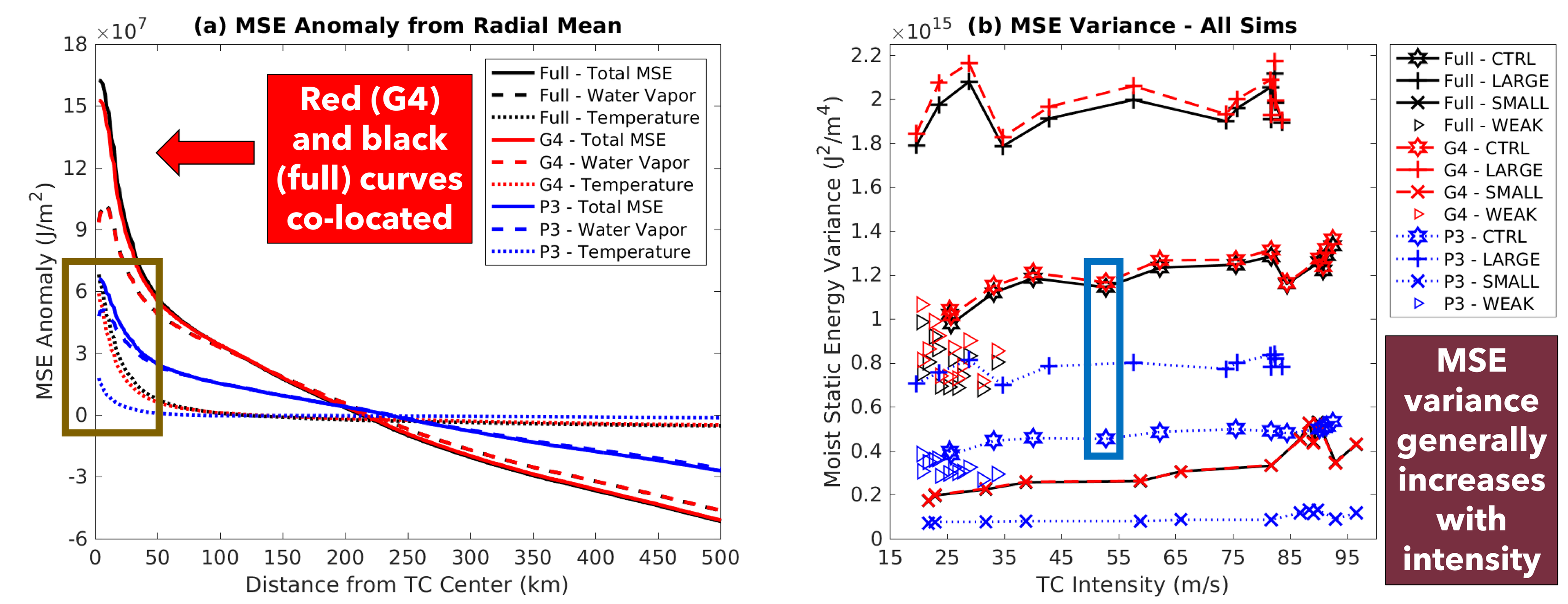


Figure 2: (a) Composite radial profiles of MSE anomaly (from 0-500 km radial mean) for the Full, G4, and P3 columns. (b) MSE variance as a function of intensity for all simulations, time steps, and column depths.

RADIAL TRANSECTS

- NW → SE line through the TC center. Reference transect includes all 511 grid points along this line.
- Need inner-core sampling to fully capture MSE variability, but few data points needed at outer radii.

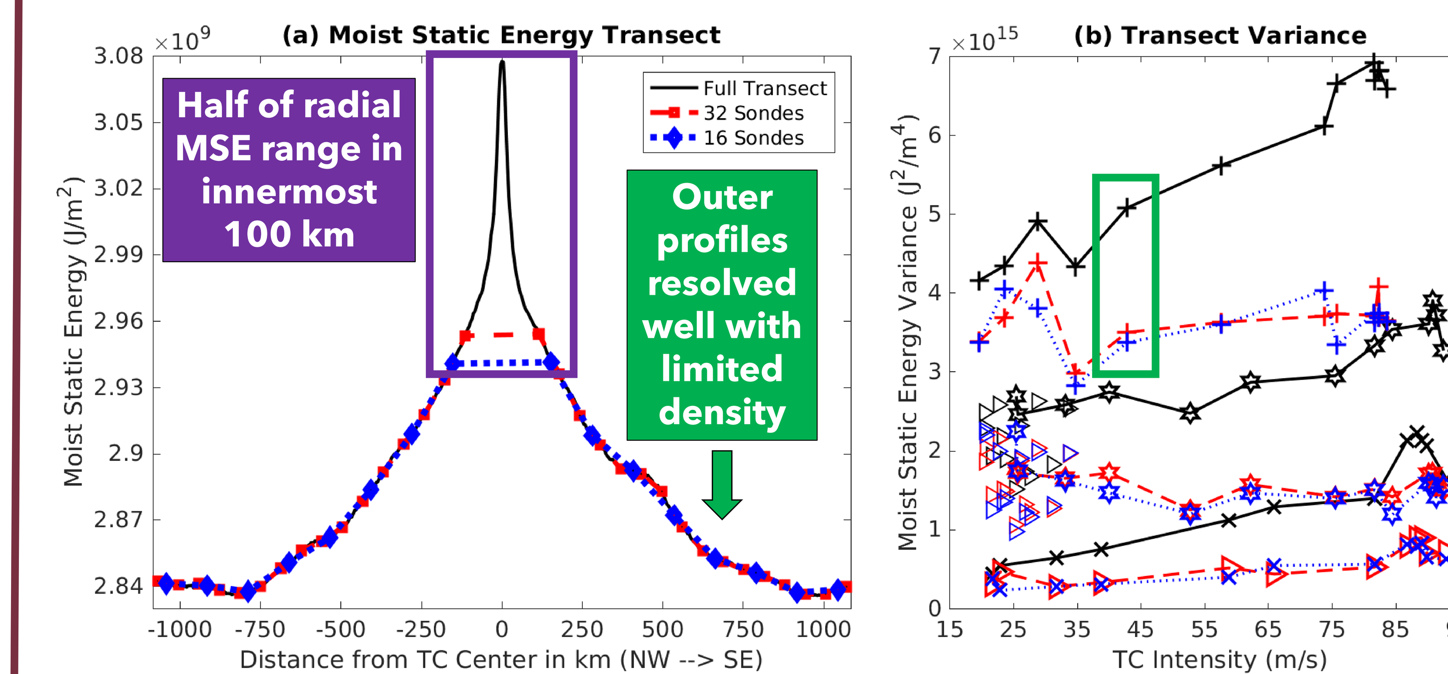


Figure 4: (a) Transect radial profiles of G4 column MSE. (b) MSE variance as a function of intensity for transects in each simulation and time step.

KEY POINTS

1. **Upper-level recon samples enough depth to capture the full atmosphere's MSE variance.**
   - ***Low-level recon does not → warm core aloft contributes significantly.***
2. **Estimates of MSE variance/feedbacks are sensitive to spatial distribution of dropsondes.**
   - ***But they generally agree on the sign and order of magnitude, relative to full domain.***
3. **A standard number of dropsondes (20-40) can assess MSE variability, provided...**
   - ***...A wide range of radii is sampled; TC core is approached as closely as safely possible.***

SENSITIVITY TO FLIGHT PATTERN

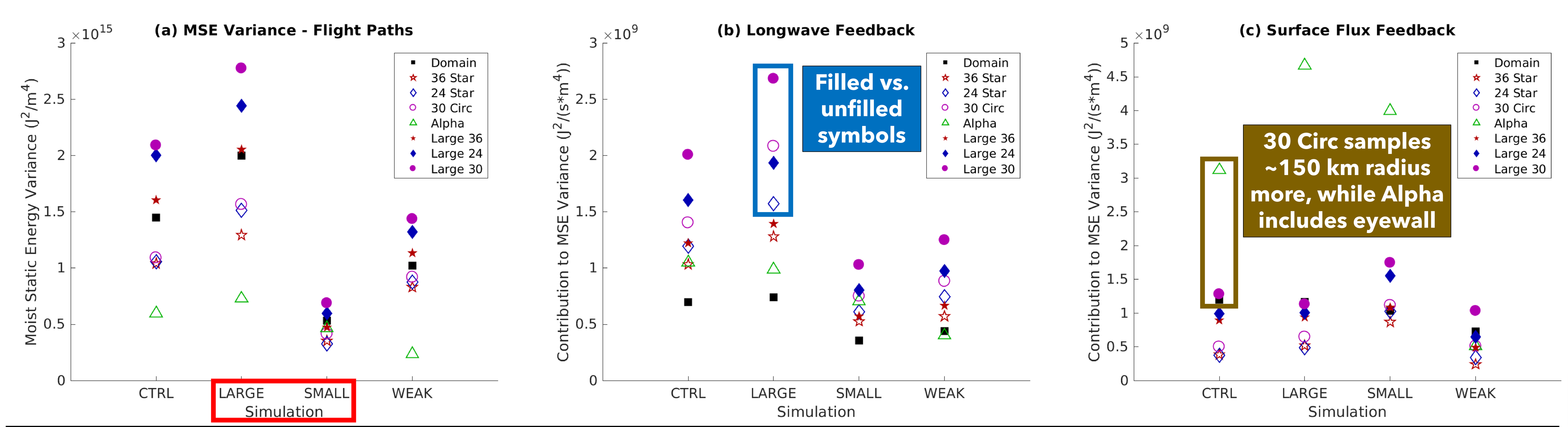
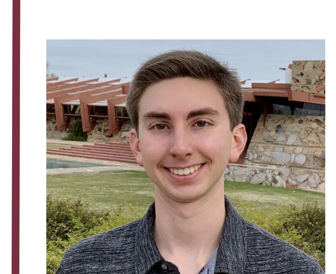


Figure 3: (a) MSE variance, (b) longwave feedback, and (c) surface flux feedback for each simulation, comparing the full domain value to flight pattern estimates. MSE is integrated in the P3 column in Alpha, and G4 in all others.

- Higher estimates of MSE variance, longwave, and surface flux feedbacks for: more intense/larger TCs (usually), larger outer pattern radius, more dropsondes at inner radii.
- Disagreement on sign of shortwave feedback, but this is much weaker.

ONGOING WORK



Michael Kopelman

Dropsonde MSE observations from 2020-21 Atlantic TCs

TALK: 17C.2 – Friday, 13 May at 11:00 AM

Tsung-Yung Lee

TC-radiation interactions from CloudSat overpasses

TALK: 16C.3 – Friday, 13 May at 9:00 AM

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