On the contributions of incipient vortex circulation and environmental moisture to tropical cyclone expansion

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Overview

- What are the primary factors influencing tropical cyclone expansion rates?
- Expansion – process whereby the radius of gale-force winds (17 m s^{-1}) increases
- Approach – Idealized simulations in CM1: Vary incipient vortex circulation and environmental moisture

Experimental Design

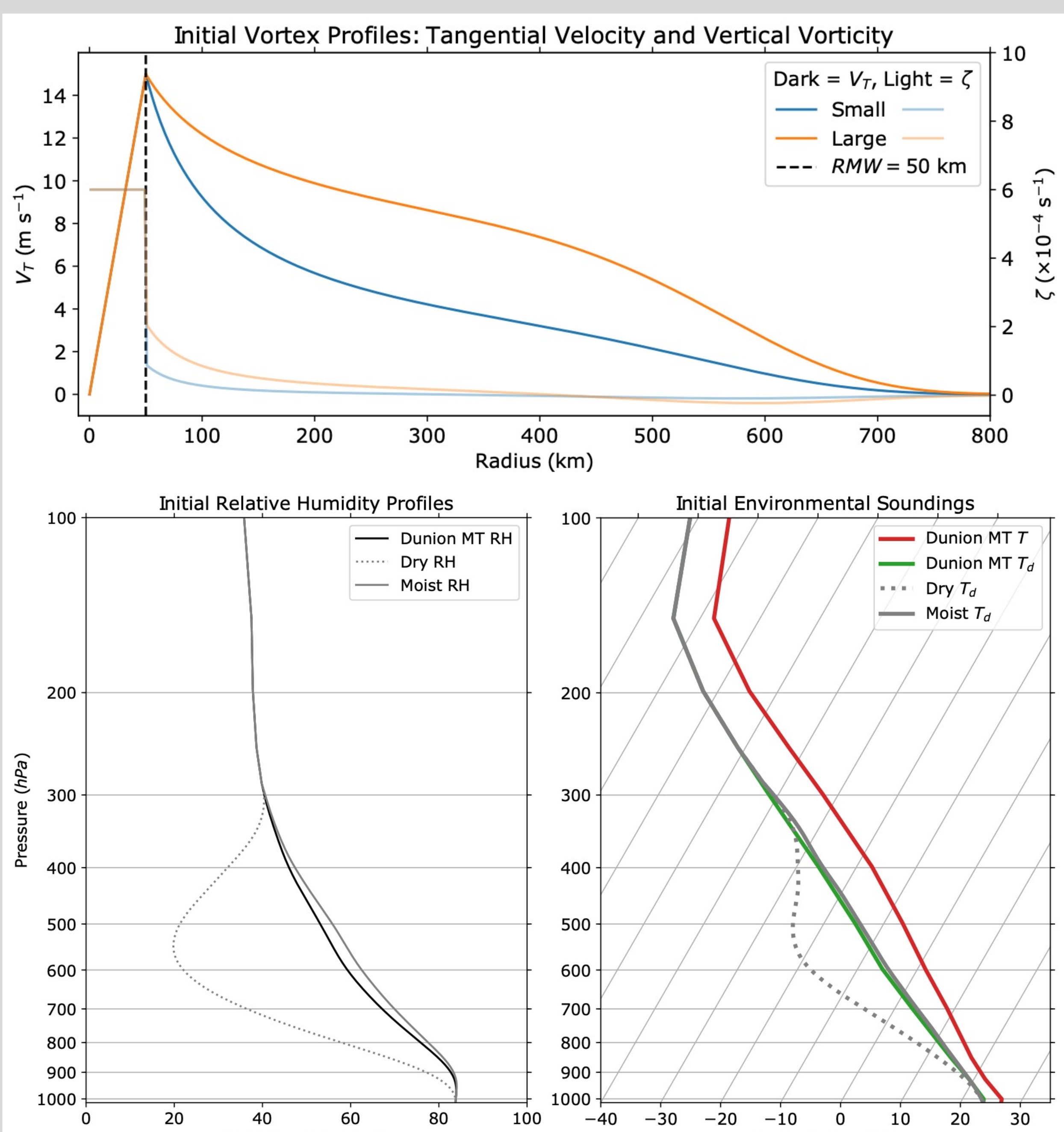


Fig. 1. (Top) Axisymmetric radial profiles of tangential velocity (dark colors) and vertical vorticity (light colors) for each incipient vortex circulation. (Bottom) Relative humidity, temperature, and dewpoint temperature for each of the initial environmental profiles and the Dunion Moist Tropical sounding (Dunion 2011).

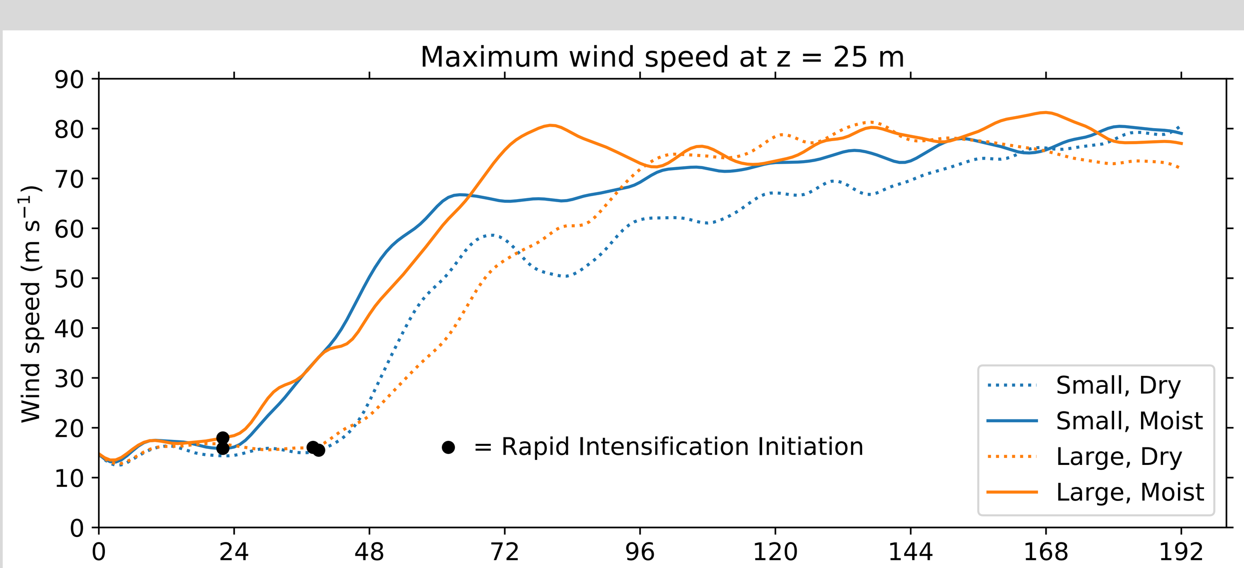
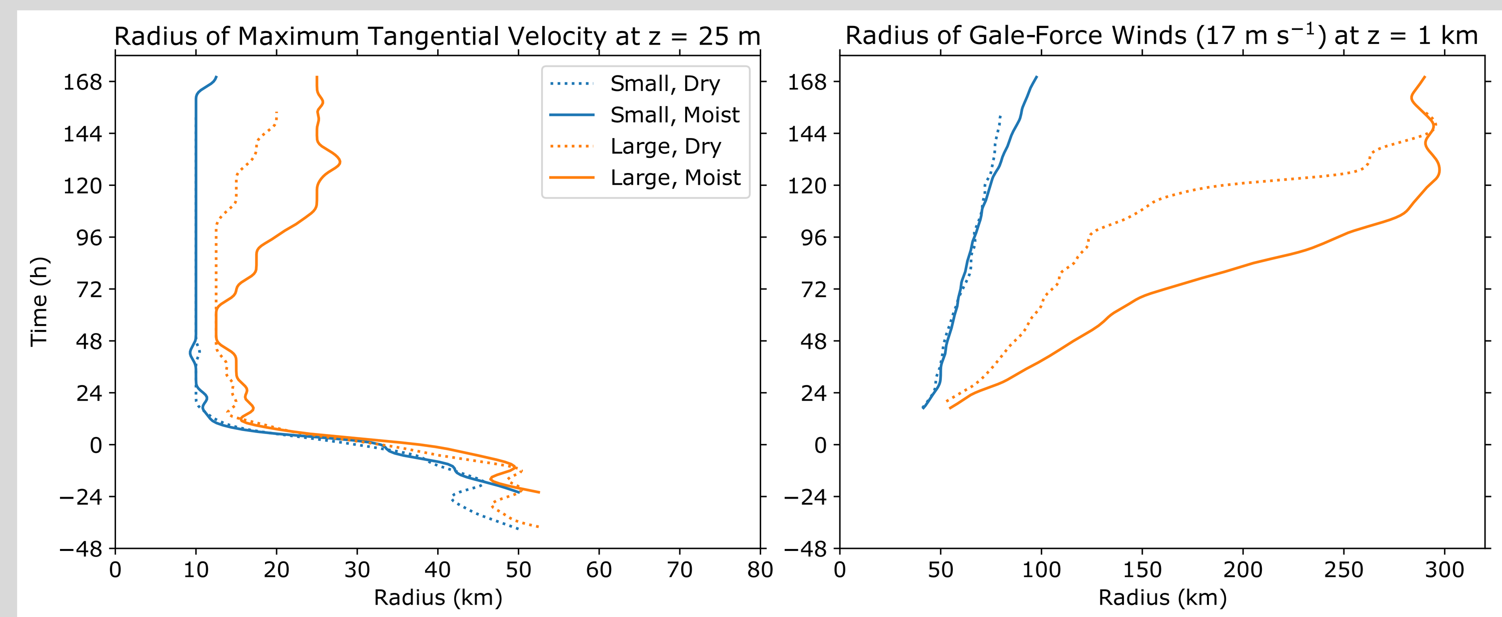


Fig. 2. Maximum azimuthally averaged wind speed at the lowest model level (25 m) for each simulation. Each time series is smoothed using a 12-h low-pass Lanczos filter with nine weights.

Size evolution: Radius of Max Winds and Gales



- Increasing incipient vortex circulation associated with larger expansion rate
- Increasing moisture modulates expansion of large vortex, but has minimal influence on small vortex

Fig. 3. (Left) Radius of maximum winds and (right) radius of gale-force winds are shown as a function of time with respect to initiation of rapid intensification.

Principal Findings

Initially large vortex expands more quickly than initially small vortex

Cumulative effect: Contrast in size between large and small vortex *increases* with time

Incipient vortex circulation primarily establishes the expansion rate

Mid-level moisture variations are a secondary modulator of the expansion rate

Azimuthal-average Angular Momentum and dBZ

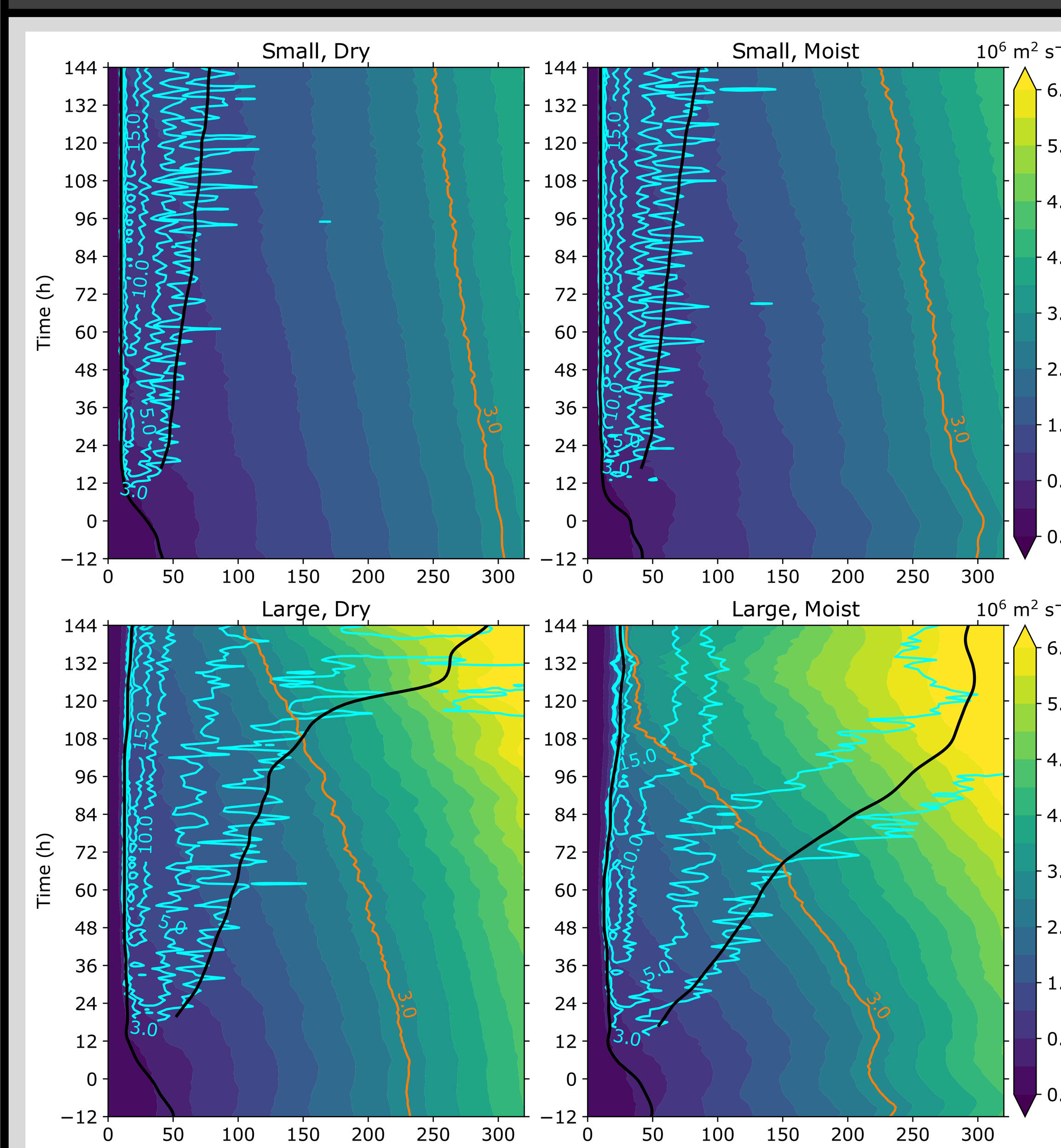


Fig. 4. Azimuthally averaged angular momentum at 1-km altitude. Cyan: Radial inflow (m s^{-1}). Orange: M = 3.0×10^6 m^{2}s^{-1}. Innermost black line: radius of maximum winds. Outermost black line: radius of gale-force winds.

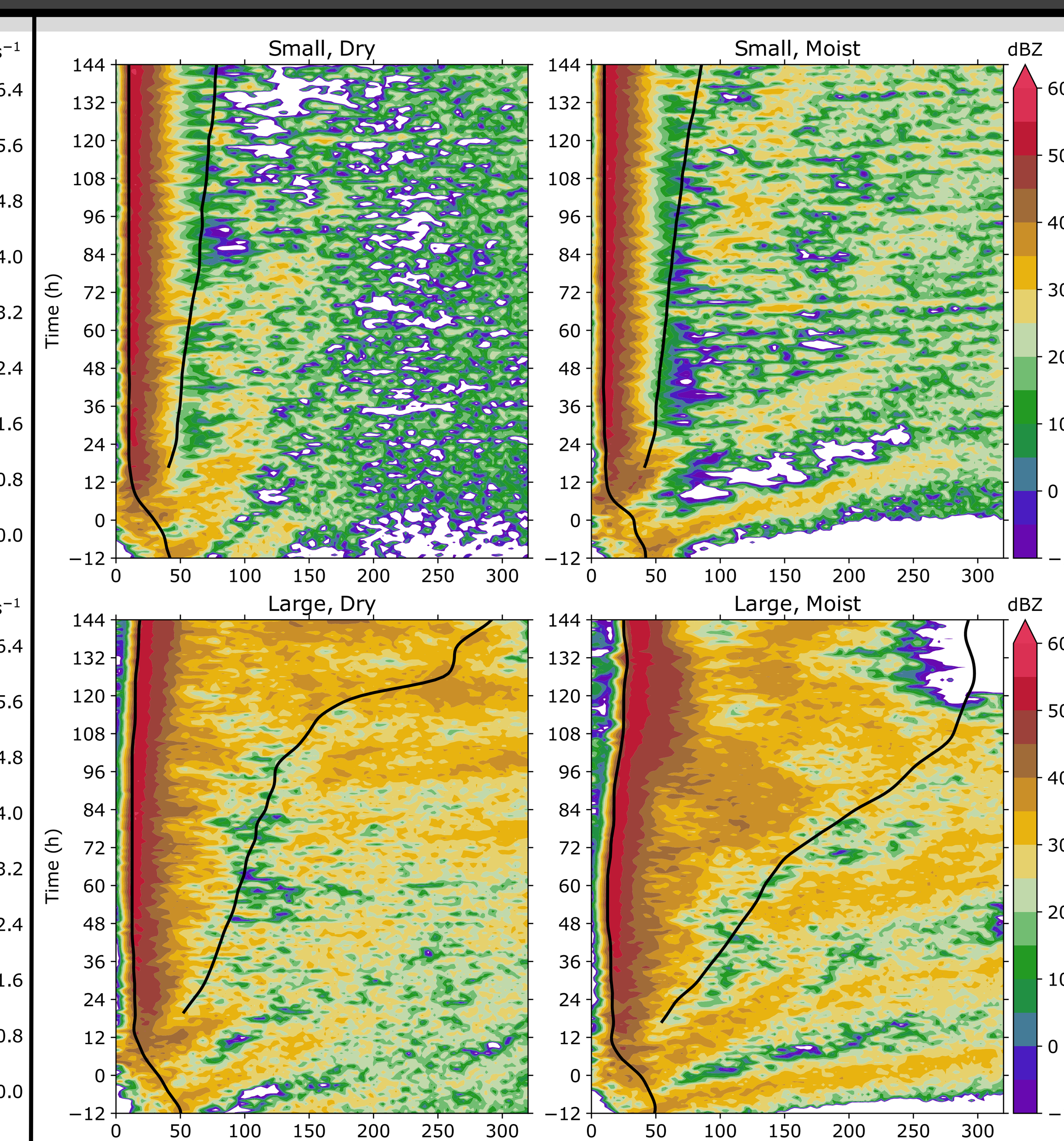


Fig. 5. Azimuthally averaged radar reflectivity (dBZ) at 2-km altitude. Innermost black line: radius of maximum winds. Outermost black line radius of gale-force winds.

Circulation and moisture influence scale of convection

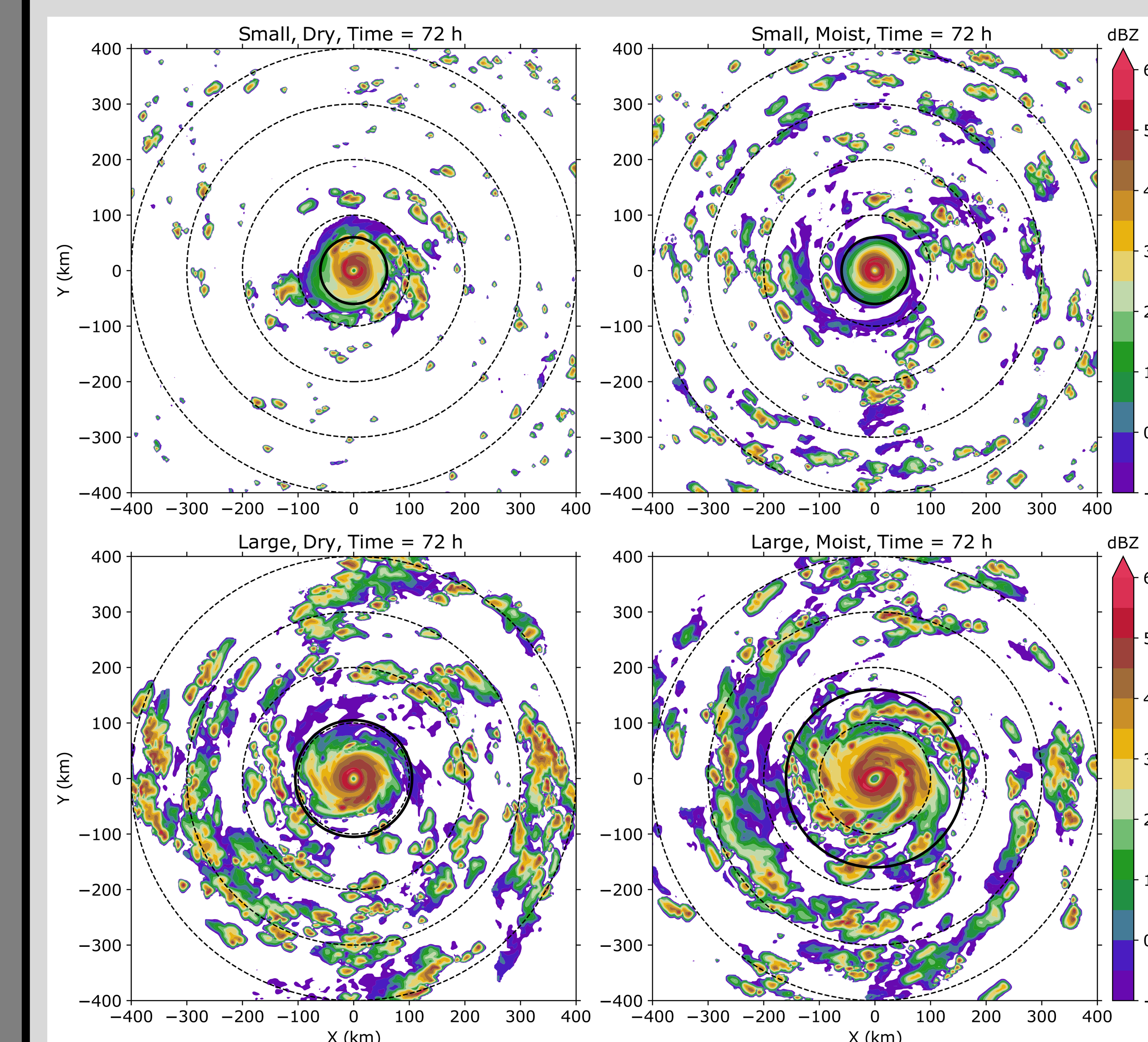


Fig. 6. Cartesian snapshots of radar reflectivity (dBZ) at 2-km altitude for each simulation 72 h after the initiation of rapid intensification. Solid black ring: radius of gale-force winds. Dashed black rings are shown every 100 km.

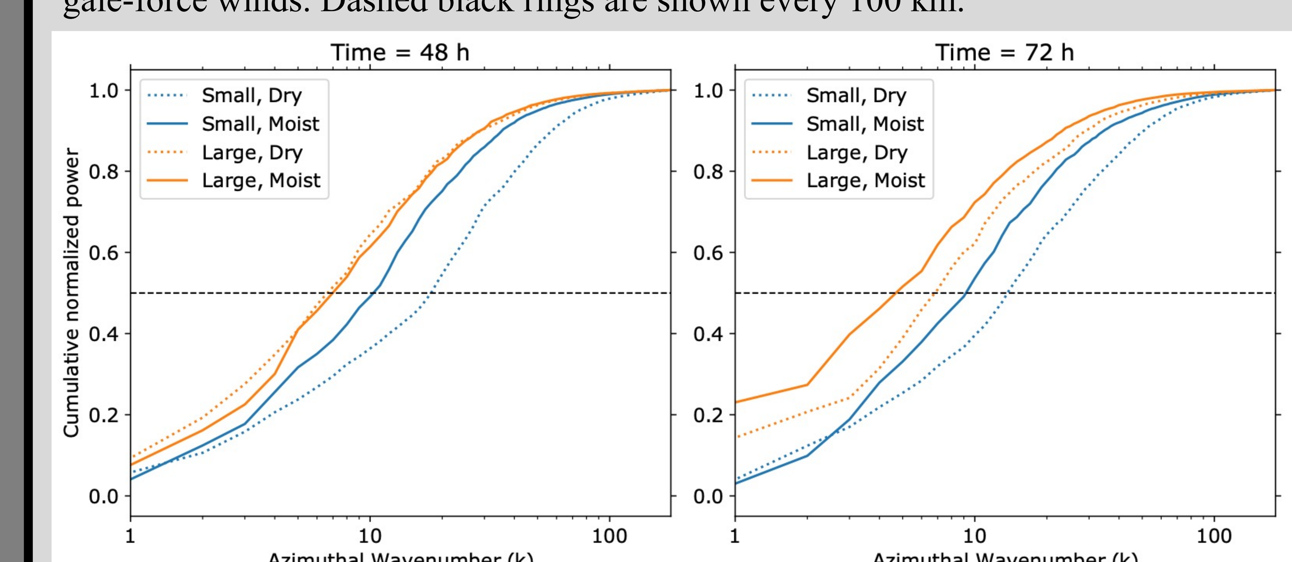


Fig. 7. Cumulative normalized power spectra of 2-km radar reflectivity between r = 100–300 km at (left) 48 h and (right) 72 h after the initiation of rapid intensification.

Conclusions

- Conventional wisdom: Large vortices stay large and small vortices stay small
- Principal finding: Large vortices expand more quickly than small vortices
- Vortices possess "memory" of their incipient circulations and their expansion rate is modulated by the environmental moisture
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References: Dunion, J. P. (2011), Rewriting the climatology of the tropical North Atlantic and Caribbean Sea atmosphere, *J. Climate*, **24**, 893–908, doi10.1175/2010JCLI3496.1.