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Aircraft Measurements of the Convective Properties of Tropical Cyclone Eye and Eyewall Clouds

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Observationally resolving tropical cyclone (TC) structure is essential for improving models and saving lives, yet operating instruments in this hostile environment is challenging [1]. Collecting measurements of the TC eye is particularly important, as the eye is linked to the eyewall and boundary layer, two regions that drive intensity change [2]. Yet, while TC eye variability was poorly resolved by previous methods, a more nuanced view of the eye is gained by using new remote sensing techniques.

In this work, TC inner-core cloud structure and thermodynamics are revealed by synergizing compact Raman lidar (CRL) measurements with existing aircraft-based observations. The CRL has 6-meter vertical resolution and can distinguish between precipitation and clouds, allowing us to determine cloud heights with unprecedented accuracy. The CRL also collects two dimensional curtains of temperature and water vapor, linking observed cloud structures to their thermodynamic environments.

Both case study and statistical approaches are used to understand the TC eye. For instance, NOAA P-3 flights through TC Sam (September 2021) provide multiple views of the eye. CRL data are combined with tail Doppler radar (TDR) and flight level measurements to resolve Sam's inner core evolution over time. Results suggest that Sam's eye is highly variable, with large changes in temperature and water vapor occurring over just one day. Eye clouds also range from low stratocumulus clouds to relatively strong cumulus towers. These results update our current conceptual model, where stratocumulus clouds are thought to uniformly fill the TC eye [3]. Flight level data verify these variations, with vorticity mixing adding moisture to the eye and weakening the central temperature inversion over time [4].

Furthermore, a statistical approach is used to find cloud top height distributions for different TC intensity categories. Weak tropical depressions and strong hurricanes exhibit the tallest clouds, likely due to a moist, primed environment and strong mixing, respectively. Flight level data from 1960 to the present day are used to characterize inner core differences between intensifying and weakening storms. Overall, this work updates our view of the TC eye, highlighting variable cloud structures and strong linkages to the eyewall and boundary layer.

Keywords: tropical cyclones, Raman lidar, synergizing observations, clouds, thermodynamics

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