MATURE STAGE EXPERIMENT
Science Description

Experiment/Module: Eye-Eyewall Mixing

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Requirements: Categories 4–5

Plain Language Description: Small features in the eyes and eyewalls of very intense tropical cyclones have been hypothesized to increase the amount of energy available for hurricane intensification, or to be responsible for damaging surface wind at landfall or intense turbulence features impacting flight operations. However, the structures of these features, especially the temperature and humidity structures, have never been documented.

Mature Stage Science Objective(s) Addressed:

1) Collect observations targeted at better understanding internal processes contributing to mature hurricane structure and intensity change [APHEX Goals 1, 3].

2) Test new (or improved) technologies with the potential to fill gaps, both spatially and temporally, in the existing suite of airborne measurements in mature hurricanes. These measurements include improved three-dimensional representation of the hurricane wind field, more spatially dense thermodynamic sampling of the boundary layer, and more accurate measurements of ocean surface winds and underlying oceanic conditions [APHEX Goal 2]

Motivation and Background: Eyewall miso- and mesovortices have been hypothesized to mix high-entropy air from the eye into the eyewall, thus increasing the amount of energy available to the hurricane. They may also produce very high wind-speed signatures at the surface leading to small regions of extreme damage at landfall. Features widely described as eyewall mesovortices have been seen in satellite imagery within the eyes of strong TCs, in radar reflectivity signatures (Hurricane Fabian), from above during aircraft penetrations (Hurricanes Hugo, Erin, and Felix). Extreme miso-scale features have been seen at the surface in damage surveys (Hurricane Andrew), and in dropwindsonde data within and above the boundary layer; such features are also noted in large-eddy simulations. Meso-scale vortical features have never been observed, though miso-scale features in eyewalls of intense TCs are regularly seen. We do not know whether these features ultimately impact intensity changes. Observations within the eye and eyewall can allow for the study of these features and improve knowledge of intensity changes in very strong TCs.

Hypothesis: Eyewall meso- and miso-vortices play an important role in TC intensity change.

Aircraft Pattern/Module Descriptions (see Flight Pattern document for more detailed information): The proposed aircraft pattern has two parts. They do not need to be completed during the same pass or even during the same flight.

P-3 Pattern #1:
The purpose of this pattern is to gather Doppler radar data in the eye and eyewall at an approximately constant sampling rate in the search for signatures of possible low-level small-scale

features. It is a break-away pattern that is compatible with any standard pattern with an eye passage (all P-3 patterns except the Square spiral or Lawnmower). The eye must be large enough for the P-3 to safely perform circles within the eye. The P-3 will penetrate the eyewall at the standard-pattern altitude. Once inside the eye, the P-3 will perform at least three clockwise or counter-clockwise (no preference) orbits of the eye at an approximately constant bank with the flight-level circulation center within the orbits; distance from the eyewall need not be constant, and the only constraint is that the eyewall be within a distance to be sampled by Doppler radar. The size of all the orbits will be the same, and should allow for the completion of each orbit approximately every 6 min, 7.5 min, or 10 min (circle diameter about 7-13 n mi depending on ground speed) at crew discretion so that each circle fits within one model data assimilation cycle for easy data analysis. The flight level of the orbits can be adjusted for safety considerations at the pilot's discretion. If a center fix is required, this pattern can be done either before or after the center fix. It is highly desirable, though not required, that an sUAS be conducting an Eyewall/Radius of Maximum Winds Module while this pattern is being executed.

P-3 Pattern #2:
The second part of the module occurs during the eyewall penetration of what is believed to be the strongest part of the eyewall. During the penetration, up to eight dropwindsondes will be released as fast as possible to try to obtain kinematic and thermodynamic observations in a single small-scale vortex. The dropwindsonde releases should be spaced as close together as possible. The goal is to have the second-outermost dropwindsonde to be coincident with the flight-level radius of maximum wind speed, and the second-innermost dropwindsonde to be coincident with the surface radius of maximum wind speed.

Links to Other Mature Stage Experiments/Modules: This can be coordinated with any other mature-stage experiment or module.

Analysis Strategy: The data will be examined to look for meso- or miso-scale vortices at the eye-eyewall interface and characterize their structure. Analyses with an advanced data assimilation system will also be conducted when one becomes available.

References:

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Marks, F.D., P.G. Black, M.T. Montgomery, and R.W. Burpee. Structure of the eye and eyewall of Hurricane Hugo (1989). Mon. Wea. Rev., 136, 1237–1259.

Rogers, R. F., S. Aberson, M. M. Bell, D. J. Cecil, J. D. Doyle, T. B. Kimberlain, J. Morgerman, L. K. Shay, and C. Velden, 2017: Re-writing the tropical record books: The extraordinary intensification of Hurricane Patricia (2015). Bull. Amer. Met. Soc., 98, 2091-2112.

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