2021 NOAA/AOML/HRD Hurricane Field Program - APHEX

MATURE STAGE EXPERIMENT
Science Description

Experiment/Module: Eye-Eyewall Mixing

Investigator(s): Sim Aberson

Requirements: Very intense tropical cyclones, intensity category 4 or 5

Plain Language Description: Small features in the 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*].

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. Signatures of such mesovortices have been seen in cloud formations within the eyes of strong TCs, in radar reflectivity signatures (Hurricane Fabian), from above during aircraft penetrations (Hurricanes Hugo and Felix), and in damage surveys (Hurricane Andrew). Doppler radar was able to sample such features in Hurricanes Hugo and Felix, though interpretation with sparse observations through the small features has been difficult. Dropwindsondes released in very intense tropical cyclones, in conjunction with large-eddy simulations, have provided some thermodynamic data, especially in instances with multiple soundings sampling the same feature. However, the kinematic and thermodynamic structures of these features have never been directly observed, nor do we know whether these features ultimately impact intensity changes. Observations within the eye near or below the inversion can allow for the study of these mesovortices and improve knowledge of small-scale features and intensity changes in very strong TCs.

Hypotheses: Eyewall mesovortices play an important role in TC intensity change.

Aircraft Pattern/Module Descriptions: The proposed aircraft pattern has two parts. The two parts do not need to be completed during the same pass or even during the same flight.

1. The first 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 ≥ 25 n mi in diameter, and for asymmetric or non-circular eyes, the narrowest cross section from eyewall to eyewall must be ≥ 25 n mi. Additionally, a 2-n mi standoff distance should be maintained from the radar displayed inner eyewall. The P-3 will penetrate the eyewall at the standard-pattern altitude. Once inside the eye, the P-3 will maintain the flight level of

the main mission and perform a single orbit of the eye with a separation distance of 2 n mi from the edge of the eyewall. The flight level of the orbit and 2 n mi minimum distance from the edge of the eyewall can be adjusted for safety considerations at the pilot's discretion. For non-circular eyes, maintaining a circular orbit is preferred (i.e., portions of the orbit could be >2 n mi from the eyewall). If a center fix is required, this pattern can be done either before or after the center fix.

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, seven or eight dropwindsondes will be released as fast as possible to try to obtain kinematic and thermodynamic observations in a single small-scale vortex. The sondes should be space as close together as possible. *The goal is to have the second-outermost sonde to be coincident with the flight-level radius of maximum wind speed, and the second-innermost sonde 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. Analyses with an advanced data assimilation system will also be conducted.

References:

Aberson, S. D., J. A. Zhang, and K. Nunez-Ocasio, 2017: An extreme event in the eyewall of Hurricane Felix on 2 September 2007. *Mon. Wea. Rev.,* in press.

Aberson, S. D., J. P. Dunion, and F. D. Marks, 2006: A photograph of a wavenumber-2 asymmetry in the eye of Hurricane Erin. *J. Atmos. Sci.*,**63**, 387–391.

Aberson, S. D., M. T. Montgomery, M. M. Bell, and M. L. Black. 2006: Hurricane Isabel (2003): New insights into the physics of intense storms. Part II: Extreme localized wind. *Bull. Amer. Met. Soc.,* **87**, 1349–1354.

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.,* in press.

Stern, D. P., G. H. Bryan, and S. D. Aberson, 2016: Extreme low-level updrafts and wind speeds measured by dropsondes in tropical cyclones. *Mon. Wea. Rev.,* **144**, 2177– 2204.