MODULE DESCRIPTION

14. Eyewall Sampling and Intensity Change Module

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Links to IFEX Goal 3: Improve our understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle

Hurricane intensity, defined by either minimum sea-level pressure or maximum sustained wind speed, is determined by processes in the core (radial distance < 100 km). These processes include, but are not limited to, enhanced sea to air fluxes near and under the eyewall, eye-eyewall mixing, convective outbreaks in the eyewall, increased mass and moisture inflow to the eyewall, contraction of the eyewall, and the interaction of the upper-level flow with the eyewall. To more fully understand these processes the research community needs detailed monitoring of the core of several hurricanes. The observations can also serve some real-time needs of NHC.

This module is designed to address the following questions:

(a) How variable is the inflow equivalent potential temperature around the TC?

(b) Is mass and moisture flux to the eyewall correlated with TC intensity? If we sample the same TC twice during the flight or twice or more during its lifetime we can correlate inflow traits with intensity change. With the collection of several circumnavigations around several different TCs we could build a relationship between inflow traits and TC intensity. This would take a number of years to collect but could show a range of behaviors from a tropical storm to a high category TC.

(c) Where are the main updrafts with respect to the maximum mass and moisture horizontal flux into the eyewall?

(d) Is the eyewall driven by convective updrafts or is it better described as a mesoscale ring of ascent?

(e) How variable is the radial and tangential flow outside and in the eyewall as a function of azimuth?

(f) How do inflow rate, azimuthal extent and depth vary with TC speed and direction?

(g) How do the inflow rate, azimuthal extent and depth vary with respect to the large-scale vertical shear of the horizontal wind?

Dropwindsondes, when combined with the TC track, will allow the calculation of storm-relative variables. Each dropwindsonde will provide estimates of inflow rate and depth, and energy content. These profiles can then be assembled to construct an azimuth-height surface that extends from a few hundred meters below aircraft altitude to the sea surface around the eyewall. The azimuth-height surface allows the estimation of fluxes of mass, moisture, and energy flux to the eyewall for the entire inflow. If the module is repeated at other radii (e.g., 100 km or just inside the eyewall), net vertical transports through a given altitude, or net fluxes through the sea surface can be determined using divergence to infer processes between the two surfaces. The surface fluxes may be solved as a residual or estimated using the data collected at 10 m by the dropwindsonde. Mixing across the top surface remains an issue, but if the aircraft is equipped with turbulence sensors, this exchange can be determined.

The plan views of the eyewall region from the lower fuselage radar are used to estimate net LHR. As the aircraft moves around the eyewall it will get views of each quadrant. These quadrants are assembled for a complete view of the eyewall region that limits beam filling or attenuation issues. A Z-R relationship is then applied to this map of reflectivity to estimate LHR. LHR can be compared to other standard measures of TC intensity such as MSLP and maximum sustained wind speeds estimated from the aircraft. LHR has the advantage that it does not rely on a single pass or reading, instead it is the integration of the net LHR from the entire eyewall region. The lower fuselage radar also reveals if the eyewall consists of one or more cumulonimbus clouds, is more mesoscale, or is asymmetric. The tail radar provides estimates of echo top, and echo slope. These also serve as measures of TC intensity – higher, less sloped systems are expected for higher category TCs. As the aircraft circumnavigates the eyewall F/AST can be applied. F/AST provides approximately 2-km horizontal resolution wherever there are scatterers. Continuity applied to these windfields results in an estimate of the vertical velocity field. The dropwindsondes provide data that can be used as an initial condition for the lowest 500 m where sea clutter may contaminate the Doppler wind estimates.

The pattern is a circumnavigation around the eyewall with the P-3 flying counterclockwise to exploit strong tailwinds (Fig. 14-1). The aircraft would maintain a ~10 km separation from the eyewall that places the aircraft in an excellent position to obtain tail radar data for both reflectivity and Doppler wind measurements. In addition to providing the necessary azimuthal dropwindsonde observation, another advantage of a circumnavigation of the eyewall is 360-degree Doppler-radar coverage of the eyewall, while a single linear pass through the eyewall often does not cover the full circumference of a large eyewall. Altitude may be 8500 feet to 11,500 feet (750 to 650 hPa). Circumnavigation around the eyewall can be done relatively quickly, on the order of one-half hour, for an eyewall radius of about 35 km, and a tailwind of minimal hurricane force. About 12 dropwindsondes would be deployed during circumnavigation that provides estimates of the depth, rate and thermodynamics of the inflow. AXBTs should also be deployed at points 1, 5, 8, and 11. The circumnavigation can be done as part of the standard figure-4 pattern used routinely during reconnaissance missions and often at the start and finish of research missions.

There are several possible variations. More dropwindsondes could be released in the eyewall in rapid succession. It would also be possible to do multiple rings. For hurricanes with a large eyewall a circumnavigation along the inner edge of the eyewall would be possible to ascertain more about the interaction of the eye and eyewall. More distant circumnavigations allow for an assessment of where the inflow is gaining or losing energy as the inflow approaches the eyewall.

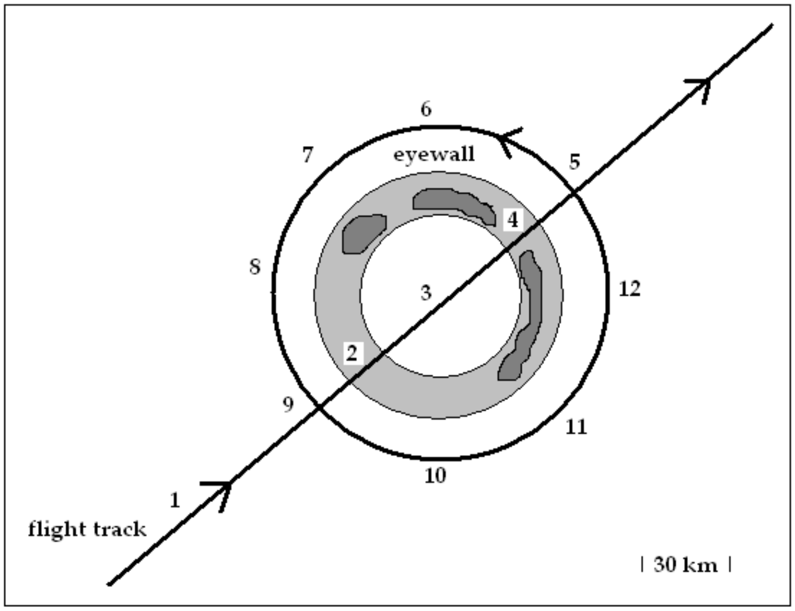

Figure 14-1: Flight track (bold line), eyewall (gray region), and GPS dropwindsondes (numbered)

Note 1. Unless specifically requested by the LPS, tail Doppler radar should be operated in F/AST with a fore/aft angle of 20 degrees relative to fuselage.
Note 2. IP (1) can be at any desired heading relative to storm center, preferably one that maximizes the continuity of the module with the rest of the flight plan. IP should be about 30 km out from the eyewall.
Note 3. To maximize dropwindsonde coverage, aircraft should operate at highest altitudes that still minimize the likelihood of icing or graupel damage.
Note 4. Radius from storm center should be enough to accommodate about 10 km standoff from the eyewall, to maximize the observation of boundary layer inflow and upper-level outflow.
Note 5. Both dropsonde and Doppler capability are required for this flight module
Note 6. PRF should be single at 2400 for hurricanes, and 2800 for major hurricanes
Note 7. Sondes should be dropped at points 1-12, and should be backed up
Note 8. AXBTs should be dropped at 1, 5, 8, and 11