EXPERIMENT DESCRIPTION
10. Rapid Intensification Experiment (RAPX)

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Links to IFEX goals:

- **Goal 1**: Collect observations that span the TC lifecycle in a variety of environments
- **Goal 3**: Improve understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle

Motivation:
While some improvements have been made in operational tropical cyclone intensity forecasting in recent years (DeMaria et al. 2007), predicting changes in tropical cyclone intensity (as defined by the 1-min. maximum sustained wind) remains problematic. Moreover, the operational prediction of rapid intensification (RI) has proven to be especially difficult (Kaplan et al. 2010) and given the significant impact of such episodes, has prompted the Tropical Prediction Center/National Hurricane Center (TPC/NHC) (NOAA 2008) to declare it as its top forecast priority. The difficulty of forecasting RI stems from a general lack of understanding of the physical mechanisms that are responsible for these rare events. Generally speaking researchers have attributed RI to a combination of inner-core, oceanic, and large-scale processes. The SHIPS Rapid Intensification Index (RII) presented in Kaplan et al. (2010), the best predictive scheme for RI to date, relies mainly on large-scale fields and broad characteristics of the vortex, such as environmental vertical wind shear and departure of the vortex from its empirical maximum potential intensity (which is itself largely derived from sea-surface temperature (SST)), as well as some characteristics of deep convection within the inner core, including the symmetry of inner-core convection around the storm center. This scheme is able to explain roughly 30% of the skill in RI forecasts in the Atlantic basin, with the remainder being attributable either to other processes not being accounted for in this methodology or constrained by predictability limits. The goal of this experiment is to collect datasets that can be utilized both to initialize 3-D numerical models and to improve our understanding of RI processes across multiple scales, with the overarching goal of improving our ability to predict the timing and magnitude of RI events.

Objective:

To employ both NOAA P-3 and G-IV aircraft to collect oceanic, kinematic, and thermodynamic observations both within the inner-core (i.e., radius < 220 km) and in the surrounding large-scale environment (i.e., 220 km < radius < 440 km) for systems that have been identified as having the potential to undergo RI within 24-72 h. The SHIPS RII will be the primary guidance that is used for selecting candidate systems for the short-term time periods (24-48 h) while both the RII and 3-D numerical models will be used for the longer time ranges (i.e. beyond 48 h).

Hypotheses:

- By gathering observations that span spatial scales from 10s to 100s of kilometers it is possible to improve our understanding of the atmospheric and oceanic conditions that precede RI, particularly within the less observed inner-core region.

- Characteristics of the tropical cyclone inner core, both on the vortex- and convective-scale, contribute a non-negligible amount to explaining the variance in the prediction of RI.

- The aforementioned multi-scale RAPX data sets can be used both to initialize and evaluate numerical model forecasts made for episodes of RI and that successful completion of these tasks will lead to improved numerical/statistical model predictions of RI.

Mission Description:

The P-3 aircraft will dispense AXBTs and GPS dropsondes and collect Doppler radar data while flying a rotating figure-4 pattern (see sample pattern shown in Fig. 1) in the inner-core with leg lengths of ~90-180 km at the maximum safe altitude (~8k-12k feet) for avoiding graupel. The AXBTs and GPS dropsondes should be dispensed on each leg with a spacing of ~30-40 km to provide adequate coverage for deducing the radial variations in kinematic and thermodynamic storm properties. The desired AXBT/GPS dropsonde deployment strategy is for both an AXBT and GPS dropsonde to be dispensed in tandem at both the endpoints and midpoint of each leg of the figure-4 pattern so that a total of 3 (12) AXBTs/GPS pairs are dropped during the course of each completed figure-4 leg (pattern) as shown in Fig. 10-1. The P-3 may also fly a Convective Burst Module (similar to that flown for the tropical cyclone genesis experiment) or an Arc Cloud Module if the opportunity to conduct such flight patterns presents itself.

The G-IV should fly the environmental pattern shown in Fig. 10-2 at an altitude of ~ 42-45 K ft dispensing dropsondes at radii of 220, 330, and 440 km to measure the thermodynamics and kinematic fields in the near storm environment. These particularly radii were chosen since collecting data in this region is crucial for computing the vertical shear and upper-level divergence both of which have been shown to be strongly correlated with RI. The radii of the innermost ring of G-IV drops shown in Fig. 10-2 can be adjusted outward if necessitated by safety considerations. However, the radii of the other rings of drops should then also be adjusted to maintain the specified spacing. Depending on the time of day, aircraft duration limitations, and safety considerations, the lengths of the G-IV inner (outer) points could be shortened (extended) to ~200 km (~500 km) if an opportunity to sample a diurnal pulse “cool ring” presents itself (see TC Diurnal Cycle Experiment).

As noted above, this experiment requires that both the P-3 and G-IV be utilized. In addition, it is highly desirable that the P-3 aircraft fly a rotating figure-4 pattern (see Fig. 10-1) in the inner-core while the G-IV simultaneously flies the environmental surveillance pattern shown in Fig. 10-2 every 12 h. Although this mission can still be conducted if the G-IV aircraft flies a synoptic surveillance pattern instead of the one shown in Fig. 10-2, such a flight pattern should only be flown in the event that the G-IV has been tasked by the NHC to conduct an operational synoptic surveillance mission and thus would otherwise be unavailable for use in conducting research type missions. Furthermore, if either the P-3 or G-IV aircraft cannot fly every 12 h the experiment can still be conducted provided that the gap between missions for any one of the two aircraft does not exceed 24 h. Finally, when possible this experiment may also make use of the NASA Global Hawk aircraft.

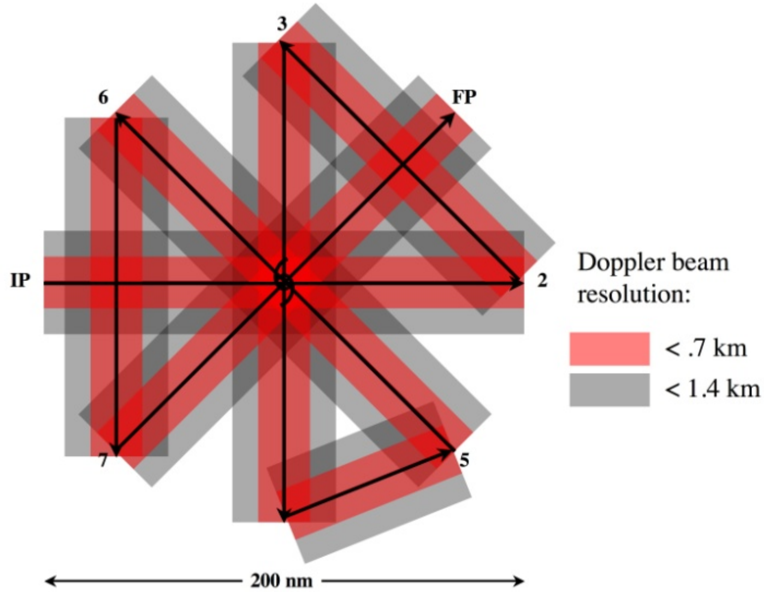


Figure. 10-1. Sample rotated figure-4 flight pattern for RAPX mission. The red shading denotes locations where vertical spacing of Doppler beam < 0.7 km, grey shading where vertical spacing < 1.4 km. GPS dropsondes should be released at all turn points (past the turn after the aircraft has leveled), at midpoints of inbound/outbound legs, and at center point between IP/2 and 5/6. If available, release AXBT's coincident with dropsondes at turn points, midpoints, and center points. Note that the above in-storm P-3 flight pattern requires about 3-4 hours to complete.

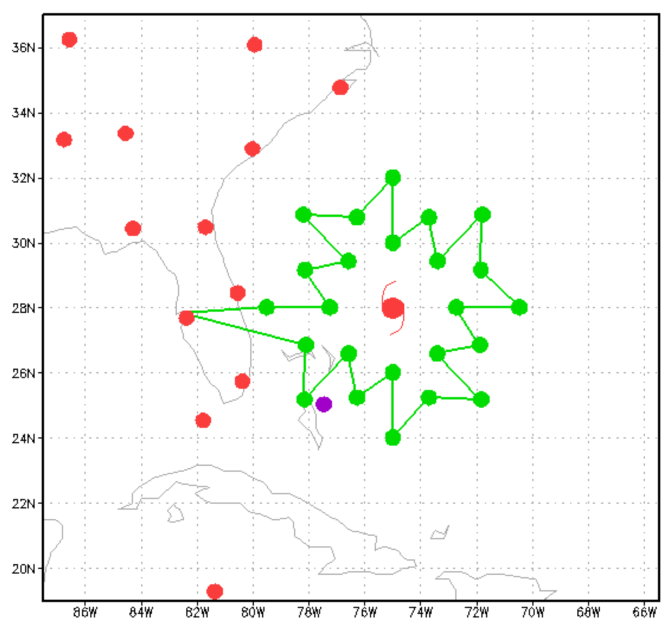


Figure 10-2. A sample G-IV flight pattern for the RAPX mission. The green dots denote the desired dropsonde locations at 220, 330, and 440 km radius from the storm center. Note that the end points of each leg can be rounded slightly as required for aircraft flight considerations. The flight pattern shown in Fig. 2 (excluding ferry time to and from the storm) requires about 6 hours to complete.

Analysis Strategy

This experiment seeks to perform a multi-scale analysis of the conditions both before and during RI. Specifically, we will use GFS, GPS dropsonde, and ocean buoy observations to analyze the changes in energy transfer at the ocean-atmosphere interface during the time period of the experiment. Also, changes in the inner-core kinematic and thermodynamic structure will be examined using NOAA P-3 Doppler radar, flight-level, and GPS dropsonde data within the inner-core region (i.e., radius <220 km). Inner-core analyses will include an analysis of the symmetric and asymmetric vortex structure, vortex tilt, and inner-core vertical shear derived from airborne Doppler and dropsonde data and statistics of vertical velocity, vorticity, and reflectivity from airborne Doppler. Finally, an analysis of the near-storm large-scale environment (i.e., 220 km < radius < 440 km) will be conducted using the high-resolution GFS analyses that contain the assimilated GPS dropsonde data deployed from NOAA G-IV aircraft. The overarching hypothesis of this analysis strategy is that by performing similar analyses for multiple RAPX data sets collected during both RI and non-RI events it will be possible to determine the conditions that are triggers for RI and to evaluate numerical model performance during such events.

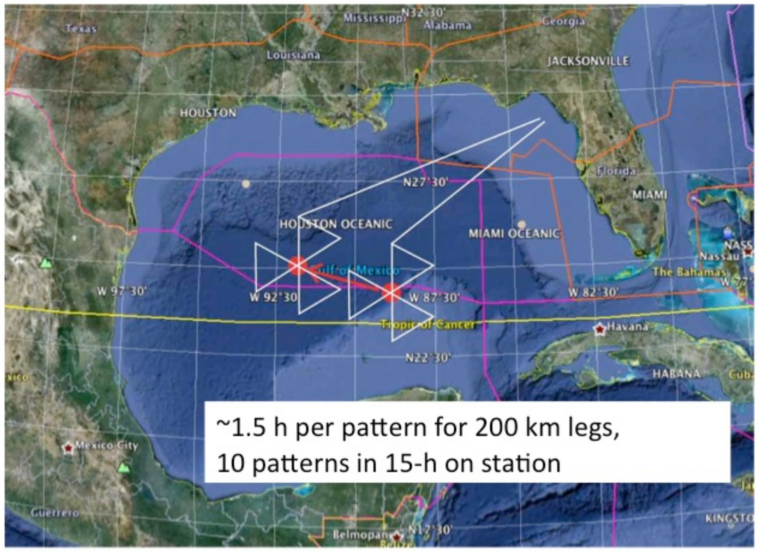
Coordination with Supplemental Aircraft

NASA will be conducting their Hurricane Severe Storm Sentinel (HS3) mission from Sept. 1 – Oct. 5. This mission will consist of two unmanned Global Hawk (GH) aircraft, flying at approximately 60,000 ft altitude with mission durations of up to 30 h. One GH will focus on flying patterns over the inner-core of tropical cyclones, while the other GH will focus on patterns in the environment of TC's. The primary science goals of HS3 are to better understand inner-core and environmental processes important in TC genesis, intensification, and extratropical transition.

When possible, it will be desirable to fly patterns with the NOAA aircraft that are coordinated with the GH aircraft. For the NOAA P-3, "coordinated" means flying radial penetrations where the P-3 and GH are vertically-stacked for at least a portion of the flight leg, preferably when the aircraft are approaching the center of the TC. The across-track displacement during such coordination should be kept as small as practicable, e.g., no greater than 5-10 km. In practice, the NOAA P-3 will likely fly its planned figure-4/butterfly/rotating figure-4 patterns as indicated in Fig. 10-1. The inner-core GH can fly patterns that are similar in geometry to the NOAA P-3 patterns (Fig. 10-3). To achieve coordination the inner-core GH would align its legs such that the GH will be stacked with the P-3.

Potential Flight Modules

Over-Storm Global Hawk Flights



Red dot represents storm center moving westward. Crossing angles at headings of 180, 300, and 60 degrees. Leg lengths can be varied depending on how frequently we want to repeat the pattern.

Figure 10-3. Sample flight pattern for inner-core GH over a TC in the Gulf of Mexico.