EXPERIMENT DESCRIPTION
8. Extratropical Transition Experiment

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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

Significance: The poleward movement of a tropical cyclone (TC) initiates complex interactions with the midlatitude environment frequently leading to sharp declines in hemispheric predictive skill. In the Atlantic basin, such interactions frequently result in upstream cyclone development leading to high-impact weather events in the U. S. and Canada, as well as downstream ridge development associated with the TC outflow and the excitation of Rossby waves leading to downstream cyclone development. Such events have been shown to be precursors to extreme events in Europe, the Middle East, and may have led to subsequent TC development in the Pacific and Atlantic basins as the waves progress downstream. During this time, the TC structure begins changing rapidly: the symmetric distributions of winds, clouds, and precipitation concentrated about a mature TC circulation center develop asymmetries that expand. Frontal systems frequently develop, leading to heavy precipitation events, especially along the warm front well ahead of the TC. The asymmetric expansion of areas of high wind speeds and heavy precipitation may cause severe impacts over land without the TC center making landfall. The poleward movement of a TC also may produce large surface wave fields due to the high wind speeds and increased translation speed of the TC that results in a trapped-fetch phenomenon.

During this phase of development, hereafter referred to as extratropical transition (ET), the TC encounters increasing vertical wind shear and decreasing sea surface temperatures, factors that usually lead to weakening of the system. However, transitioning cyclones sometimes undergo explosive cyclogenesis as extratropical cyclones, though this process is poorly forecast. The small scale of the TC and the complex physical processes that occur during the interactions between the TC and the midlatitude environment make it very difficult to forecast the evolution of track, winds, waves, precipitation, and the environment. Due to sparse observations and the inability of numerical models to resolve the structure of the TC undergoing ET, diagnoses of the changes involved in the interaction are often inconclusive without direct observations. Observations obtained during this experiment will be used to assess to what extent improvements to TC structure analyses and the interaction with the midlatitude flow improve numerical forecasts and to develop techniques for forecasting these interactions. Improved understanding of the changes associated with ET will contribute to the development of conceptual and numerical models that will lead to improved warnings associated with these dangerous systems.

Objective: The objective is to gather data to study the physical processes associated with ET and the impact of extra observations in and around an ET event on the predictability of the cyclone undergoing transition and of the environment. To examine the relative roles of the TC and midlatitude circulation, aircraft will be used to monitor the changes in TC structure and the region of interaction between the TC and midlatitude circulation into which it is moving.
Specific goals are:

- To obtain a complete atmosphere/ocean data set of the TC undergoing ET and interacting with the midlatitude circulation, especially at the cyclone outflow and midlatitude jet stream interface.

- To examine the interface between the upper-level outflow from the TC and the midlatitude flow, and how the interaction between the two affects the predictability of both the downstream flow and the enhanced precipitation in the pre-storm environment.
- To understand the dynamical and physical processes that contribute to poor numerical weather forecasts of TC/midlatitude interaction, including validation of forecasts with observations.
- To track the thermal and moisture characteristics of the evolving system and assess their impact on the predictability of TC/midlatitude interaction.
- To measure the influence of the increased vertical wind shear associated with the midlatitude baroclinic environment on the structural characteristics of the TC circulation.
- To gather microphysical and oceanic measurements along aircraft flight paths.

Requirements:
- The TC and its environment must have been sampled continuously by NOAA aircraft for at least one day prior to the ET event. Regular sampling by the P3s to get structure information from the Airborne Doppler Radar is required. Previous environmental sampling by the G-IV is helpful, but not necessary.
- The TC must have been of at least hurricane intensity during the previous sampling.
- The TC must not have had major land interactions during the previous sampling, or during the proposed experimental missions.
- Concurrent P3 and G-IV missions are helpful, but not required. Solo P3 missions would address vortex resilience issues. No solo G-IV missions would occur.

Hypotheses and questions:
ET depends upon the survival of the TC as it penetrates into midlatitudes in regions of increasing vertical wind shear.

- How is the TC vortex maintained in regions of vertical wind shear exceeding 30 ms^{-1}?
- How is the warm core maintained long after the TC encounters vertical wind shear exceeding 30 ms-^{1}?
- How does vertical shear exceeding 30ms^{-1} alter the distribution of latent heating and rainfall?
- Does vortex resilience depend upon diabatic processes. On subsequent formation of new vortex centers, or by enlisting baroclinic cyclogenesis?
- Does the vertical mass flux increase during ET, as has been shown in numerical simulations?
- Is downstream error growth related to errors in TC structure during ET?
- Is ET sensitive to the sea-surface temperatures?

Description: The mission is designed to use multiple aircraft to monitor interactions between the TC and the midlatitude circulation. The ideal storm will be a poleward-moving hurricane that is offshore the United States mid-Atlantic coastline. The optimal mission is designed to examine the TC core and the TC/midlatitude interface (Fig. 8-1). Aircraft will participate in staggered (12-hourly) missions until out of range, because of the possible rapid changes in structure.
TC region: The WP-3D will fly figure-4 or butterfly patterns as high as possible to avoid hazards such as convective icing. The aircraft will make as many passes as possible through the center of the TC undergoing ET, with a minimum of two passes necessary (Fig. 8-2). Legs can be shortened to the south of the storm center if necessary to save time. Dropwindsondes will be deployed at each waypoint and at evenly spaced intervals along each leg with optimal spacing near 60 n mi. AXBTs will be deployed at each waypoint and at the midpoint of each leg only in the northern semicircle from the cyclone center.

Due to a trapped fetch phenomenon, the ocean surface wave heights can reach extreme levels ahead of a TC undergoing ET. Therefore, primary importance for the WP-3D in the northeast quadrant of the TC will be the scanning radar altimeter (WSRA) to observe the ocean surface wave spectra, if available. Flight level will be chosen to accommodate this instrument.

TC/Midlatitude interface and pre-storm precipitation region: Ahead of the TC, important interactions between the midlatitude jet stream and the outflow from the TC occur. This region will be investigated by the G-IV releasing dropwindsondes every 120 n mi during its pattern. The Airborne Doppler Radar aboard the G-IV will be very helpful in determining the structure of the rain shield in this region, but is not a requirement.

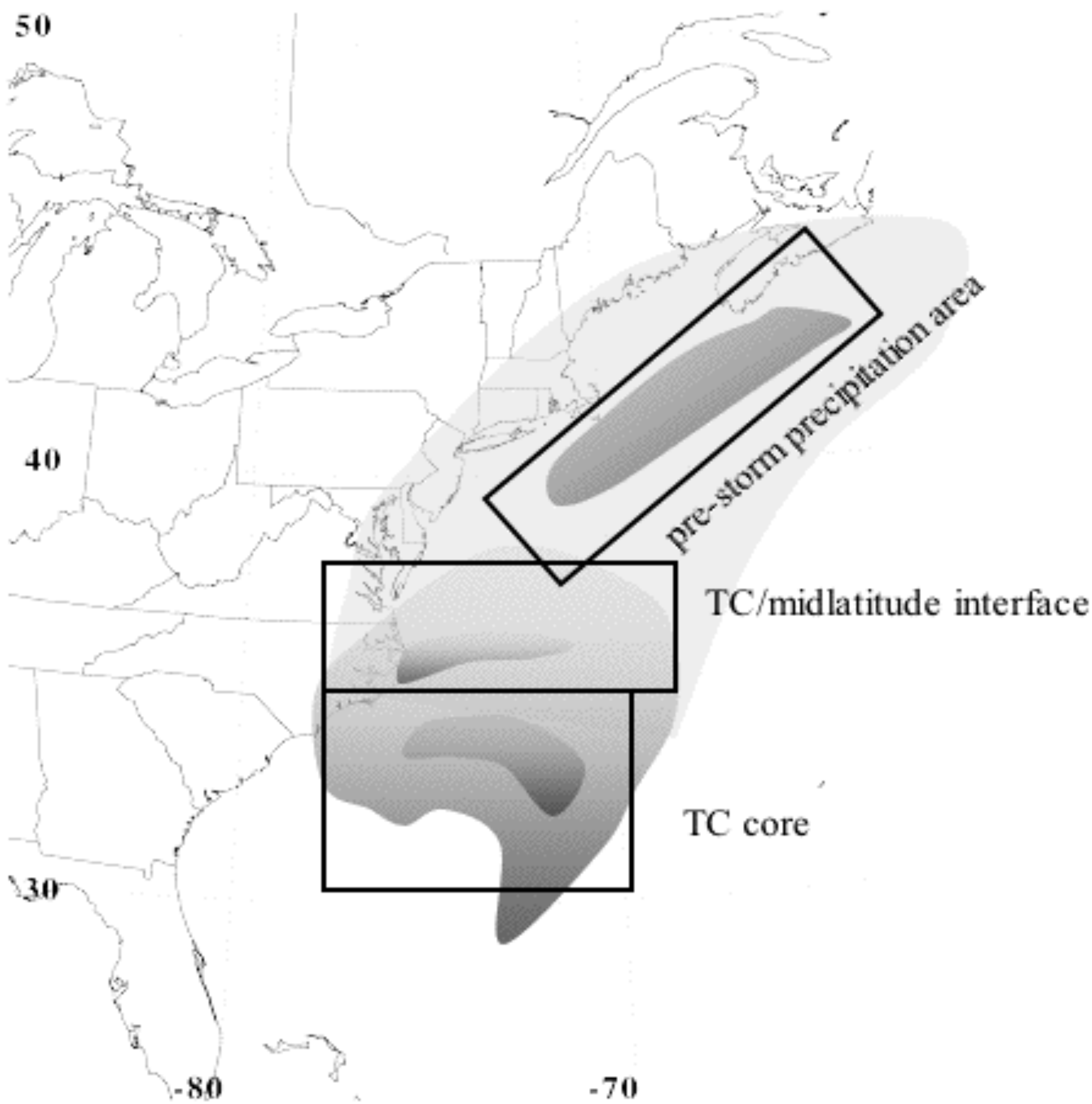

Figure 8-1: Schematic of Tropical Cyclone undergoing extra-tropical transition.

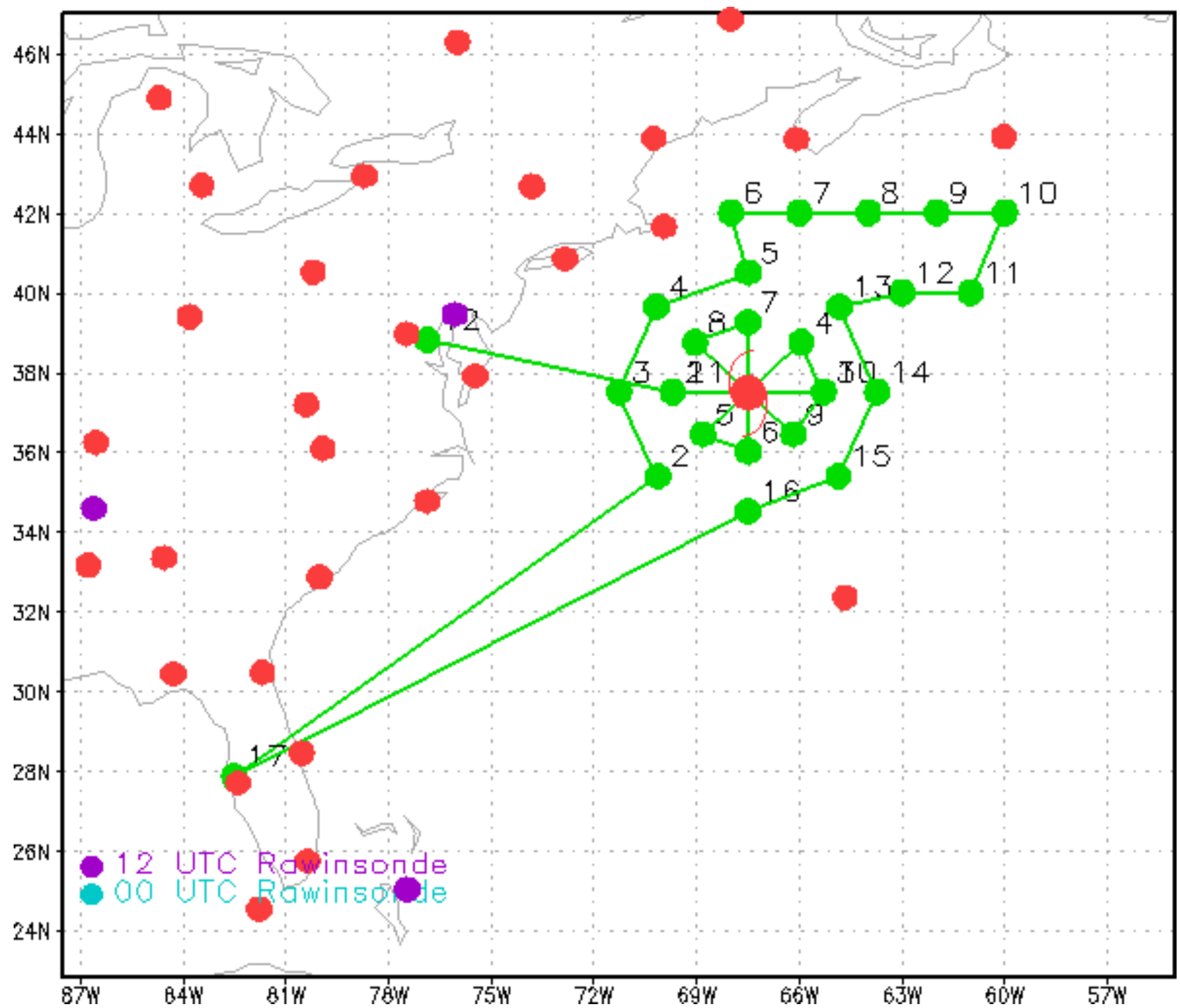

Figure 8-2: Proposed flight tracks for G-IV and P3 aircraft.