EARLY STAGE EXPERIMENT
Science Description

Experiment/Module: Boundary Layer (BL) Module

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Requirements: TD, TS, Category 1

Plain Language Description: The atmospheric boundary layer is a crucial region of a tropical cyclone (TC), because it is the area of the storm in direct contact with the ocean moisture and heat sources which power the storm. This module aims to collect observational data to improve our understanding of physical processes in the BL that control the TC intensity change. These data can be used to evaluate the performance of TC forecast models.

Early Stage Science Objective(s) Addressed:

1. Collect datasets that can be used to improve the understanding of intensity change processes, as well as the initialization and evaluation of 3-D numerical models, particularly for TCs experiencing moderate vertical wind shear [*IFEX Goals 1, 3*].

Motivation: The boundary layer has been identified in prior studies to be of critical importance to TC intensity and intensity change (Smith et al. 2009; Tang and Emanuel 2010; Riemer et al. 2010; Bryan 2012; Zhang et al. 2017; Zhang and Rogers 2019). Despite the critical nature of this environment, routine collection of kinematic and thermodynamic observations in the boundary layer remains elusive. The optimal successful experiment will yield a synoptic view of the boundary layer over a series of consecutive missions. Our research goal is to better understand details of the boundary layer structure and evolution before and during TC intensification.

Background: An improved knowledge of mechanisms across the boundary layer is essential for interpreting physical processes that are tied to TC intensity change. Recent composite analyses of dropsonde data have improved our understanding of general TC boundary layer characteristics, including asymmetries (Zhang et al. 2011, 2013; Zhang and Uhlhorn 2012). However, it has also become clear that there are few individual cases that contain enough observations to develop an accurate view and comprehensive understanding of boundary layer evolution as a TC intensifies, especially in a sheared environment (e.g., Rogers et al. 2015). This BL module aims to fill this data gap. Specific questions we wish to answer are: 1) How are boundary-layer inflow and thermodynamic fields related before TC intensification? 2) How do boundary layer height scales evolve before and during TC intensification? 3) How might environmental shear modulate the boundary layer asymmetry during TC intensity change? 4) What is the role of boundary layer recovery in TC intensity change in shear?

Goal(s): To better understand details of boundary layer structure and evolution before and during TC intensification.

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Hypotheses:

1. TCs that have a deeper boundary layer, stronger inflow, larger boundary-layer convergence, larger surface enthalpy fluxes, and less degree of asymmetry in boundary-layer enthalpy and inflow, tend to intensify faster in a sheared environment.

Objectives:

1. Collect observations in the boundary layer before and during TC intensification to identify key boundary-layer structure and dynamics that are tied to TC intensity change.
2. Use the observational data collected in this module to evaluate TC model simulations and forecasts.

Aircraft Pattern/Module Descriptions (see *Flight Pattern* document for more detailed information):

P-3 Pattern 1: Rotated Figure-4
For early stage TCs, this module complements standard Tail Doppler Radar missions. Dropsondes are deployed at the storm center, 105 n mi (195 km, i.e., end point) and 60 n mi (110 km) radii, and the radius of maximum wind (RMW) along each of 8 radial legs (rotated Figure-4 pattern).

P-3 Pattern 2: Butterfly
For early stage TCs, this module complements standard Tail Doppler Radar missions. Dropsondes are deployed at the storm center, 105 n mi (195 km, i.e., end point) radii, the RMW, and the mid-point between the RMW along each of 6 radial legs (Butterfly pattern).

P-3 Pattern 3: Circumnavigation
For early stage TCs, this module complements standard Tail Doppler Radar missions. Dropsondes are deployed at the storm center, the end points of Figure-4 [105 n mi (195 km)], vertices of octagon, and the RMW.

Links to Other Early Stage Experiments/Modules: The boundary layer module can be flown in conjunction with the following Early Stage experiments: TDR Experiment and sUAS modules.

Analysis Strategy: This module seeks to observe the characteristics of the TC boundary layer during TC intensity change. Dropsonde, AXBT and Doppler radar profile data will be analyzed. The dropsonde data will be analyzed in both an axisymmetric and asymmetric framework. In the axisymmetric framework, the dropsonde data will be azimuthally averaged at a given radius where dropsonde data are collected. Radius-height plots of the azimuthally averaged tangential and radial velocities, equivalent potential temperature and virtual potential temperature will be made. Boundary layer height scales will be estimated based on the method used by Zhang et al. (2011). The dropsonde measured data will be plotted as a function of radius and azimuth at each altitude in both a shear-relative and motion-relative framework.

References:

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