EARLY STAGE EXPERIMENT
Science Description

Experiment/Module: Flight-Level Assessment of Intensification in Moderate Shear [FLAIMS] Module

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Requirements: TD, TS, Category 1

Plain Language Description: This module repeatedly samples the region of maximum wind speed for weak, but intensifying tropical cyclones (TCs), in order to assess the temporal evolution of both the wind and precipitation fields. Such TCs are often asymmetric, and substantial intensification can occur on short time scales (1-2 hours or less). By focusing on the part of the storm where the strong winds and rain exist, we can be able to capture these changes, which is important for understanding how intensification begins.

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 [*APHEX Goals 1, 3*].
2. Obtain a quantitative description of the kinematic and thermodynamic structure and evolution of intense convective systems (convective bursts) and the nearby environment to examine their role in TC intensity change [*APHEX Goals 1, 3*].

Motivation: Understanding how intensification begins and proceeds in asymmetric TCs in moderate wind shear is important and not fully understood. In order to make progress on this problem (and to better compare observations to numerical simulations), it is necessary to be able to fully document how the kinematic and convective structure evolve during periods when substantial intensification is ongoing or is imminent. This module is motivated by the facts that (1) intensification of TCs in moderate shear often proceeds in a highly asymmetric manner (at least initially), and (2) that conventional survey patterns typically sample the same region of the storm only once or twice during a flight, 3-6 h apart. By repeatedly sampling the region of maximum winds every 30-60 minutes, this module is able to overcome this problem.

Background: Although TC intensification is most favored in environments of weak vertical wind shear (e.g., Kaplan et al. 2010), intensification can and quite often does occur in moderate wind shear (e.g., Rios-Berrios and Torn 2017), and as such environments are more common, a large fraction of rapid intensification events actually begin and proceed in moderate shear. Shear results in a tilting of the vortex (e.g., Jones 1995, Finocchio and Rios-Berrios 2021), and an asymmetric kinematic and convective structure, with the strongest winds being focused on one side of the storm, in association with a shear- and tilt-induced mesoscale convective complex. This structure can sometimes persist for several days, but eventually, many such TCs are able to overcome the shear, vertically align, and begin a period of substantial or rapid intensification (e.g., Rios-Berrios et al. 2018, Alvey et al. 2020). The timescale of both alignment and intensification can be quite sudden, and can occur within a single flight. As the intensification itself often remains asymmetric during this period, the evolution of intensification and the processes that contribute to it may not be properly captured by conventional (e.g., Figure 4, Butterfly) survey patterns. Being able to pinpoint when intensification actually begins and how it proceeds is important for being able to test and validate numerous hypotheses concerning which physical processes and structural changes are actually important for causing or allowing for TC rapid intensification.

Goal(s):
Obtain a quantitative description of the three-dimensional kinematic and convective structure of the inner core during periods of substantial (or rapid) intensification, with sufficient temporal sampling to properly document when intensification begins and how it proceeds on time scales of a few hours or less.

Hypotheses:

1. TCs in moderate shear can slowly intensify while misaligned, but substantial intensification will typically only begin when the TC becomes nearly aligned.
2. Once near-alignment occurs, intensification (possibly rapid) can begin suddenly.
3. Such intensification can still proceed highly asymmetrically even if the vortex is nearly aligned.
4. For TCs that fully align, there can be a brief (a few hours) period where intensification appears to be halted (or reversed), as the tilt-induced convection decays and is replaced by less vigorous (but more symmetric) convection that is forced by the surface vortex frictional convergence.

Objectives: The objectives of this module are to repeatedly sample the kinematic, convective, and thermodynamic structure of the region of strongest winds in an asymmetrically intensifying TC, using airborne Doppler radar, in-situ measurements, dropsondes, and SFMR.

1. Sampling will either be along the same azimuth that is repeatedly flown inbound/outbound (if maximum temporal resolution is desired or if this module is performed coincident with VAM), or along a triangular path that includes two radial legs separated by 45 degrees (when a ~1 h separation between repeated legs is deemed sufficient).

Aircraft Pattern/Module Descriptions (see *Flight Pattern* document for more detailed information): This is a stand-alone module that takes 1–3 h to complete. Execution is dependent on system attributes, aircraft fuel and weight restrictions, and proximity to the operations base. It can be flown at any point during a mission, but optimally it would be flown following either 1 or 2 initial passes of a survey pattern, to establish that intensification is indeed either ongoing or imminent (e.g., alignment has just occurred). The azimuth(s) where FLAIMs will be flown will typically be known in advance based on satellite data (and any previous flight missions). P-3

Pattern #1 consists of repeated radial legs along the same azimuth, and can be initiated either inbound or outbound depending on the logistics of the preceding survey pattern. P-3 Pattern #2 consists of repeated triangles that connect a pair of radial legs (separated by 45 degrees) with a downwind leg. This pattern can also be initiated either inbound or outbound, but this must be chosen such that the inbound portion of the triangle is downwind of the outbound portion.

Links to Other Early Stage Experiments/Modules: FLAIMS can be flown in conjunction with *AIPEX*, *TDR Experiment*, and other vortex survey experiments. FLAIMS can be flown *coincident* with VAM, as it shares the same objectives of repeated sampling along what is often the same azimuth.

Analysis Strategy:

During the flight, the surface pressure changes from any initial survey fixes (along with data from prior flights and any other available information) will be used to infer whether or not substantial intensification is either ongoing or believed to be imminent, and this will inform whether or not to proceed with a planned FLAIMS module. Note that when intensification is not ongoing, it may still be advantageous to conduct the VAM module, which is similar in its objectives to FLAIMS. Radar analyses will be performed for each radial leg of FLAIMS, and a center fix will be performed at the end of each inbound leg. Dropsondes will also be released at the RMW, mid-point, and outer point of each radial leg.

Optimally, either the G-IV or the other P-3 will be flying a coincident mission. If the G-IV is available, then it could fly a standard Figure-4 with a double circumnavigation, in order to fully assess the deep-layer kinematic and thermodynamic structure of both the storm and its near environment. If the other P-3 is available, it could fly a standard Figure-4 (repeated if there is time), in order to cover all quadrants of the inner core. In this configuration of a dual P-3 mission, the P-3 that is devoted to FLAIMS can optionally proceed to the FLAIMS patterns (#1 or #2) for the duration of the mission, without the initial survey passes.

References:

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