GENESIS STAGE EXPERIMENT
Science Description

Experiment/Module: Precipitation Mode (PMODE) Experiment

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Requirements: Pre-genesis disturbances (pre-TDs), including NHC-designated "Invests"

Genesis Stage Science Objective(s) Addressed:

1) To investigate the precipitation modes that are prevalent during the genesis stage and the response of the vortex to that precipitation organization [*IFEX Goal 3*]

Motivation: One of the fundamental requirements to achieve a more accurate prediction, and understanding, of tropical cyclogenesis events is an improved knowledge of the precipitation organization and the developing vortex response, in the context of environmental forcing, during the formation process.

While true that the favorable environmental conditions for tropical cyclogenesis have been well accepted for decades, those conditions also frequently exist in non-developing disturbances. An understanding of the sequence of events, and thus more informed prediction, of tropical cyclogenesis is still very much constrained by our inability to describe the relative contributions of precipitation organization (e.g., deep convection vs. stratiform rain), in the context of the environmental properties, to the evolution of the developing incipient vortex. Numerical models are a convenient platform to study tropical cyclogenesis events, and are often able to reproduce them, but the processes — particularly the relative roles of various precipitation modes involved — that contribute to genesis have generally been unobserved. Satellites are a convenient tool for identifying precipitation properties, particularly with the availability of the Dual-frequency Precipitation Radar (DPR) on the core satellite of the Global Precipitation Measuring Mission (GPM) and multiple higher resolution passive microwave sensors (AMSR2, GMI, SSMIS), but the vortex itself is not well observed; thus the co-evolution of precipitation and vortex cannot be described using satellites alone. Dedicated aircraft missions (outside of the GRIP-PREDICT-IFEX, tri-agency field program effort in 2010) have historically been too few.

Background: Results from previous observational case studies suggest that convergence (spin-up) is initially maximized in the midtroposphere, and as genesis nears the troposphere moistens (humidity increases to saturation) and stabilizes (warming at upper levels and cooling near the surface) (Raymond and Sessions 2007; Davis and Ahijevych 2012; Komaromi 2013; Zawislak and Zipser 2014a). The stabilization apparently coincides with a lowering of the peak in the vertical mass flux profile, and thus a more bottom-heavy mass flux profile whereby convergence and spin-up is maximized at low levels (Raymond and López Carillo 2011; Raymond et al. 2011). Upper-level warming, either through compensating subsidence from deep convection or latent heating, also favors surface pressure falls and enhanced low-level convergence (Zhang and Zhu 2012), which is required to overcome surface divergence that would otherwise persist from mesoscale downdrafts (Komaromi 2013). Research using observations from developing cases (Karl, Matthew, and Fiona) and nondeveloping cases (ex-Gaston, PREDICT/GRIP/IFEX -27, -30) in

2010 (Davis and Ahijevych 2013; Zawislak and Zipser 2014b), suggest that (at least initially) contributions from the larger, more persistent stratiform raining areas could initially be more influential during the genesis stage, particularly since the Rossby radius of deformation is large. Once the troposphere stabilizes and the Rossby radius is reduced, the role of deep convection becomes more influential. Another pathway to genesis has emerged from modeling studies (e.g., Montgomery et al. 2010; Wang et al. 2010a; Wang 2012), and suggest a greater influence from intense deep convection throughout the genesis process.

Using Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) data, Fritz et al. (2016) identified the evolution of various precipitation modes (i.e., shallow, mid-level, and deep convection, as well as stratiform rain) during the genesis stage. Their conclusion was that multiple precipitation modes are responsible for tropical cyclogenesis. Although stratiform rain accounted for 80% of the raining area, convective precipitation made a nearly equal contribution to overall rainfall, given the larger rain rate. While they did not discount the important role of deep convection, they highlighted the potentially larger and unique role of mid-level convection, which was to moisten the lower to middle troposphere and spin up the surface circulation.

The goal of this objective is, thus, to obtain observations on the distributions of various precipitation modes and the environmental characteristics that govern those modes. Then, through a sequence of missions, measure the time evolution of those modes and the vortex kinematic and thermodynamic responses.

Hypotheses:

1. A low-level center can develop rapidly as a result of deep convective bursts in a region of anomalously high vorticity.
2. Mid-tropospheric moistening through stratiform and/or moderately deep convection enhances the mid-tropospheric circulation, reduces downdrafts through saturation, and favors lower-tropospheric convergence prior to tropical cyclogenesis.
3. Persistent latent heating in the middle-to-upper troposphere focuses convergence in the lower troposphere.
4. The presence of a mid-level circulation, either pre-existing (e.g., African easterly waves, upper-level lows) or developed in situ in response to convection, is a necessary condition for a TC to develop.

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

P-3 Pattern 1: This pattern ideally uses a repeated, standard single Figure-4 or a standard Rotated Figure-4 pattern to maximize coverage of the pre-TC disturbance and convective features of interest. The pattern should be centered on either: a) the convective burst center (or in close proximity to it) for larger, more organized mesoscale convective systems (MCSs) or b) the estimated mid-level circulation center, which can be determined from a model analysis or satellite imagery. The pattern should translate with the phase speed of disturbance (circulation) center, as determined by satellite or model analysis. This pattern is ideally flown with a coinciding G-IV mission in the environment (consistent with other Genesis Stage objectives and their flight patterns).

G-IV Pattern 1: P-3 Pattern 1 may be adapted for the G-IV, while ensuring hazard avoidance around the convective areas. The G-IV mission will only be necessary if the P-3 is unavailable, and is not otherwise chosen to fly other experiments in the Genesis Stage.

Links to Other Genesis Stage Experiments/Modules: This experiment is ideally suited to include sampling of the larger-scale environment encompassing the pouch or vorticity maximum, such that the precipitation properties identified from the TDR can be placed in the context of the thermodynamic and kinematic characteristics of the potentially developing disturbance. In theory, any flight designed to sample for the "Pouch Evolution during Genesis" experiment should also accomplish goals within the "Precipitation Mode" experiment detailed here. The PMODE Experiment can also be flown in conjunction with the Synoptic Flow Experiment, the NESDIS JPSS Satellite Validation Experiment, and the ADM-Aeolus Satellite Validation Module.

In 2019, Genesis Stage missions may be flown collaboratively with the National Science Foundation (NSF) Organization of Tropical East Pacific Convection (OTREC) field program. Operating out of Liberia, Costa Rica between August 5 and September 30, 2019, the goal of OTREC is to understand the large-scale factors that control the formation and organization of tropical convection in the East Pacific and southwest Caribbean, and includes a component focusing on the formation/intensification of easterly waves in the same region. Genesis Stage and OTREC objectives share a common theme: understand the important environmental factors that drive convection, and understand how convection subsequently feeds back on its environment. OTREC will utilize the National Center for Atmospheric Research/NSF high-altitude G-V aircraft, deploying dropsondes and carrying the (W-band) Hiaper Cloud Radar, and will have an extensive radiosonde network in Costa Rica and Columbia. There are 3 pre-designed lawnmower patterns in OTREC, two small boxes (one west of Columbia, one east of Costa Rica in the Caribbean) to be flow one day, followed by a larger, north-south oriented box to flown west of Costa Rica the next day. Additional details on OTREC can be found at NCAR/EOL: https://www.eol.ucar.edu/field_projects/otrec

Analysis Strategy: Three-dimensional analyses of wind and reflectivity from the TDR will facilitate an analysis of the precipitation structure (i.e., mode) within precipitation areas of the disturbance, and the identification of low- and mid-tropospheric circulation centers. If possible, repeated sampling of a convective burst area over multiple missions (every 12 h) will allow us to identify the relationship between low- and mid-level circulations and the precipitation mode evolution (e.g., stratiform v. deep, moderately-deep, and shallow convective fractions). Dropsonde observations (ideally from both the G-IV and P-3) provide key measures of the thermodynamic (e.g., moisture, relative humidity) properties in, and around, the burst and mid-level circulation centers. They will allow us to identify if (when) the low and middle troposphere become nearly saturated, the timing and vertical location of the formation of the warm anomaly, quantify the vertical mass flux profiles, and characterize any potential relationships between observed vortex and precipitation evolutions.

References:

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