GENESIS STAGE EXPERIMENT
Science Description

Experiment/Module: Pouch Evolution during Genesis 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 importance of the pouch, including the shear sheath, which tends to indicate a tropical storm, and its relationship to a low-level circulation and organized deep convection within the pouch [*IFEX Goal 3*]

Motivation: A longstanding challenge for hurricane forecasters, theoreticians, and numerical weather forecast systems is to distinguish tropical waves that will develop into hurricanes from tropical waves that will not develop. The Naval Postgraduate School (NPS) Montgomery Research Group (MRG) has been tracking pouches in the Atlantic since 2008 in numerical models. Airborne observations provide much-needed data for analysis of processes critical for TC genesis, as well as an opportunity to compare our much-used numerical models with reality.

Background: The scientific basis for the methodology is given in Dunkerton et al. (2009), which describes how to view genesis in the semi-Lagrangian frame co-moving with a parent wave. Recent years have seen several field campaigns aimed at understanding the science of tropical cyclogenesis and new lessons have emerged from these experiments, as summarized by Montgomery et al. (2012), Smith and Montgomery (2012), Wang (2012) and Rutherford and Montgomery (2012). Subsequent work by Rutherford et al. (2015) defined a new key tool, called the Lagrangian Okubo-weiss OW (OW_{Lag}) parameter, that shows frame-independent saddles and flow boundaries, along with solid-body vortex cores in a single scalar field. In Rutherford et al. (2017) these principles were applied to six years of ECMWF forecasts to determine objective values for the OW_{Lag} parameter indicative of TC genesis. Another noteworthy finding from the latter work was the existence of a “shear sheath” of negative OW_{Lag} at 700 hPa that develops as a protective ring around a pouch at the onset of tropical storm intensity. The new Lagrangian characterization tested extensively during 2017 allows many pouch products to be automated and objectively defined in order to produce more accurate forecast evaluations. These evaluations should provide reliable, consistent targets for research flight operations. The “pouch” is defined as a proto-vortex cyclonic eddy associated with a parent wave’s critical latitude in the lower troposphere that is protected to some degree from lateral intrusion of dry air and impinging vertical wind shear.

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Hypotheses:

1. The pouch contains a favorable region of cyclonic rotation and weak straining/shearing deformation in which synoptic waves and mesoscale vorticity anomalies, moving westward together, amplify and aggregate on a nearly zero relative mean flow in the lower troposphere.
2. The pouch provides a set of quasi-closed material contours inside of which air is repeatedly moistened by convection.
3. The parent wave is maintained and possibly enhanced by diabatically amplified eddies within the wave (proto-vortices on the mesoscale), a process favored in regions of small intrinsic phase speed.
4. The time at which the protective boundary transforms from one that is determined by the pouch's wave to that of the shear sheath indicates a system that can be self-sustaining without the parent wave (this change can be seen as the Lagrangian manifolds transition from a cat's eye pattern to a circular shear sheath visible in the Lagrangian OW field).

Aircraft Pattern/Module Descriptions (see *Flight Pattern* document for more detailed information): Advanced staging in Barbados would most likely be required for pouches tracking westward in the Atlantic main development region (MDR), but flights from Lakeland may be possible for tropical transition cases east of Florida. Patterns discussed below would be centered on the consensus forecast pouch center location based upon all available numerical models used in the pouch-tracking routine.

P-3 Pattern 1: A lawnmower pattern would be appropriate for an initial flight into a wave-pouch exhibiting scattered convective activity without much organized convective activity near the pouch sweet spot. *The P-3 would need to fly at roughly 20,000 ft*. The proposed pattern is similar to the standard Lawnmower pattern with a few modifications. First, if possible, extend the zonal legs an additional degree longitude. Second, double the number of drops per zonal leg. After extending the legs and adding more drops, each zonal leg would have six drops, for a total of 24 drops in the lawnmower portion of the pattern. Finally, include dropsondes at the same resolution (~1° latitude/longitude) for three degrees on both the inbound and outbound legs in order to capture a cross-section of the outer boundary of the pouch, resulting in a total of 30 drops.

P-3 Pattern 2: Observations from the first lawnmower flight, accurate positioning of the pouch center, and indications of some recurrent convective activity near the sweet spot location would allow subsequent flights to utilize the standard square-spiral. Many follow-on flights, with as little temporal gap as possible within operational constraints would be ideal (ideally, once-a-day sampling at approximately the same UTC is optimal). Again, *the P-3 would need to fly relatively high, around 20,000 ft*. Increasing the drop resolution to about 1° latitude/longitude would double the number of drops to 26 in the square, and including three additional drops in each of the inbound/outbound leg would total 32 drops.

The sequential combination of the lawnmower and square-spiral patterns, with the suggested number of dropsondes, proved invaluable during the 2010 PREDICT field experiment. These observations proved adequate for sampling the meso-alpha and meso-beta scale flow kinematics and thermodynamics of the targeted wave pouch.

G-IV Pattern 1: As with the P-3 lawnmower pattern, a lawnmower pattern would be appropriate for an initial flight into a pouch with scatted convective activity. The G-IV would fly at typical operating altitudes. The proposed pattern is similar to the standard Lawnmower pattern with a couple of modifications. First, if possible, extend the zonal legs an additional degree longitude. Second, double the number of drops per zonal leg. After extending the legs and adding more drops, each zonal leg would have six drops, for a total of 24 drops. Adding three drops to each inbound/outbound leg would result in 30 total drops.

G-IV Pattern 2: Using observations from the first lawnmower flight, accurate positioning of the pouch center would allow subsequent flights to utilize the standard square-spiral pattern. As many follow-on flights, with as little temporal gap as possible within operational constraints would be ideal. Again, the G-IV would fly at the typical operating altitudes. Increasing the drop resolution to about 1° latitude/longitude would double the number of drops to 26 in the square. Including three additional drops in each of the inbound/outbound leg would total 32 drops.

Links to Other Genesis Stage Experiments/Modules: This experiment is ideally suited to include sampling of the precipitation within the proximity of the pouch (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 a pouch for this experiment should also accomplish goals within the "Precipitation Mode" experiment of the Genesis Stage, as well. One possible configuration is to fly a G-IV pattern sampling in support of the "Favorable Air Mass" experiment, with the P-3 pattern sampling in support of the "Precipitation Mode" and "Pouch Evolution during Genesis." The Pouch Evolution during Genesis 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: Kinematics of the developing pouches will be revealed by circulation calculations using the wind data from the dropsondes around circuits in the resulting drop pattern. Analyses of observed wind and thermodynamic dropsonde data will provide information about how the protective shear sheath serves as a barrier to lateral mixing. Thermodynamic information from the drops can be partitioned by location and assigned to pouch center, shear sheath, or environment. An example of such analysis is given here in Fig. GN-1 for Cristobal (2014) using model analysis, along with actual research flight data. The results highlight the relatively moist central core, dry outer environment, and details in the profiles of the shear sheath and partial pouch regions, such as relatively moist lower and upper levels but drier midlevels. Fig. GN-1 shows that the core, shear sheath, and environment have different moisture values. The foregoing sampling strategies will help ensure that we are able to capture each of these important regions.

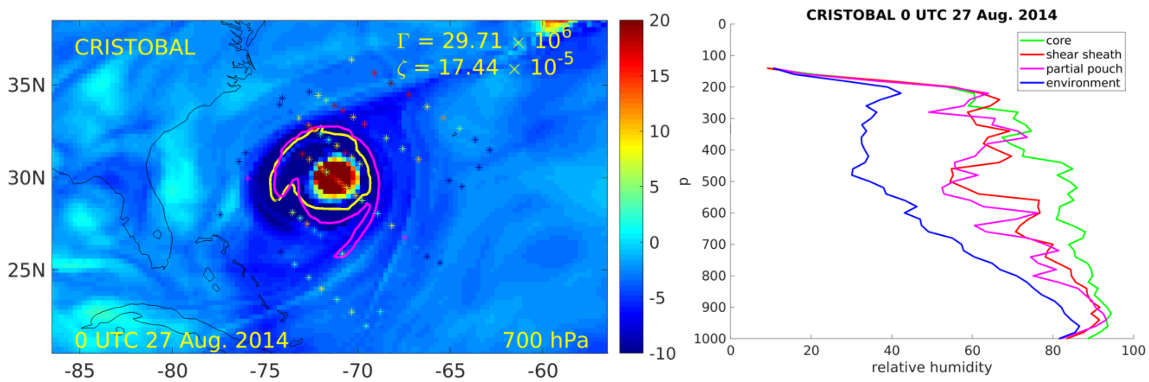

Figure GN-1. *(Left) GFS 700-hPa OW_{Lag} field for Hurricane Cristobal at 0000 UTC 27 August 2014. OW_{Lag} units are dimensionless. Positive values (red) in the center are surrounded by negative values of the shear sheath (blue). The overlaid 700-hPa (yellow) and 850-hPa (magenta) manifolds also indicate pouch boundaries. 700-hPa circulation and relative vorticity values calculated along a circuit corresponding to the 700-hPa manifold are in the upper-right corner. Overlaid drops (*) are color-coded by their 700-hPa relative humidity values, with darkest red indicating 100% and blue indicating anything less than 40%. (Right) Corresponding composite of the drops in four regions: Inside the core (green), in the shear sheath and either within both manifolds (red) or just one manifold (magenta), and outside of both manifolds (blue).*

References:

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