2019 NOAA/AOML/HRD Hurricane Field Program - IFEX

GENESIS STAGE EXPERIMENT

Science Description

Experiment/Module: Favorable Air Mass (FAM) Experiment

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

Genesis Stage Science Objective(s) Addressed:

The overarching objective is to investigate if a pre-genesis disturbance has matured into a TC, including the organization of convection and the development of a closed low-level circulation.

1) To investigate the favorability in both dynamics (e.g., vertical wind shear) and thermodynamics (e.g., moisture) for tropical cyclogenesis in the environment near a pre-TD, especially the downstream environment [*IFEX Goals 1, 3*]

Motivation: The environment near a pre-TD is critical to the favorability for tropical cyclogenesis to occur. The probability of cyclogenesis for a given pre-TD is dependent upon thermodynamics (e.g., moisture) and dynamics (e.g., vertical wind shear) in the adjacent air mass. Increased observations of lower-tropospheric humidity in the near-disturbance environment would shed light upon critical moisture thresholds important (or necessary) for tropical cyclogenesis and would help correct moisture biases in numerical weather prediction models. The downstream environment is most important for cyclogenesis predictions because that is the environment that a pre-TD moves into.

Background: As early as the 1930s, westward propagating disturbances in the lower troposphere were identified as seed circulations for most TCs in the North Atlantic Ocean (Dunn 1940). The origins of these pre-genesis disturbances, or pre-tropical depressions (pre-TDs), were traced back to North Africa and are now known as African easterly waves (AEWs; Riehl 1945). About 70% of all TCs and, more impressively, 85% of major hurricanes in the North Atlantic Ocean have been found to initiate from AEWs (Landsea 1993). On average, sixty AEWs exit the West African coast each year. However, determining which of these AEWs will develop into TCs has proven to be a forecasting challenge. For example, over 50% of TC genesis events in the Atlantic main development region predicted by the Global Forecast System (GFS) from 2004–2011 were false alarms (Halperin et al. 2013). Recent research has shed some light on the relationship between AEWs and TC genesis in the North Atlantic Ocean. The AEW-relative flow around an incipient disturbance has been hypothesized to be an important factor in protecting the disturbance from environmental intrusions, and thus creating or maintaining a favorable environment for TC genesis to occur (Dunkerton et al. 2009). Brammer and Thorncroft (2015) have shown that, as AEWs leave West Africa, the troughs are sensitive to the low-level environment to their west and northwest (Fig. 1). Although the vortex at 700 hPa typically has a closed circulation in the wave-relative reference frame, the AEW troughs are still cold-core in the lower troposphere and, therefore, there is relative westerly flow under the vortex and through the lower levels of the trough. In a composite analysis, significant differences in the moisture of the low-level environment to the northwest of the troughs were found between developing and non-developing waves. Favorable developing waves had significantly higher moisture content in the lower troposphere to the northwest of the trough as they exited the West African coast compared to favorable non-developing waves. Trajectory analysis for all the waves revealed that as the AEWs transition over the West African coast the troughs are typically open to the environment ahead and to the northwest of the trough. For developing waves this means that moist air (e.g. moist tropical sounding, Dunion 2011) is ingested into the lower levels of the system, while for non-developing waves dry air (e.g. SAL or mid-latitude dry air intrusion soundings) is ingested. At this stage in the AEW life cycle, moisture differences may be fundamental in determining whether a favorable wave will develop or not. The depth and the integrity of the closed circulation around the pre-genesis disturbance is an important consideration for providing a convectively favorable environment for TC genesis. Freismuth et al. (2016) argue that the vortex of ex-Gaston (2010) was susceptible to dry air above the vortex maxima, which hindered deep convection and led to a weakening of the vortex. In addition, non-developing disturbance (AL90, 2014) encountered lower tropospheric dry air to its west and northwest, which was ingested by the disturbance and was likely a major contributor in the failed genesis (Fig. 2). Preliminary results by Brammer (2015) suggest that as AEWs leave the West African coast, these troughs typically possess closed circulations at 700–600 hPa. Yet, these troughs remain open to the environment both above and below the 700–600-hPa layer. As AEWs propagate across the North Atlantic, the troughs are more likely to exhibit closed circulations at low-levels due to either increased vorticity within the trough or the changing background shear profile over the central Atlantic. It was therefore hypothesized that AEWs are especially sensitive to the low-level environment to the west and northwest of the trough during the first three days after leaving the West African coast. Since AEWs typically propagate at 7.5 m s^{-1} over the Atlantic (Kiladis et al. 2006), these waves are typically located near 35°W after three days.

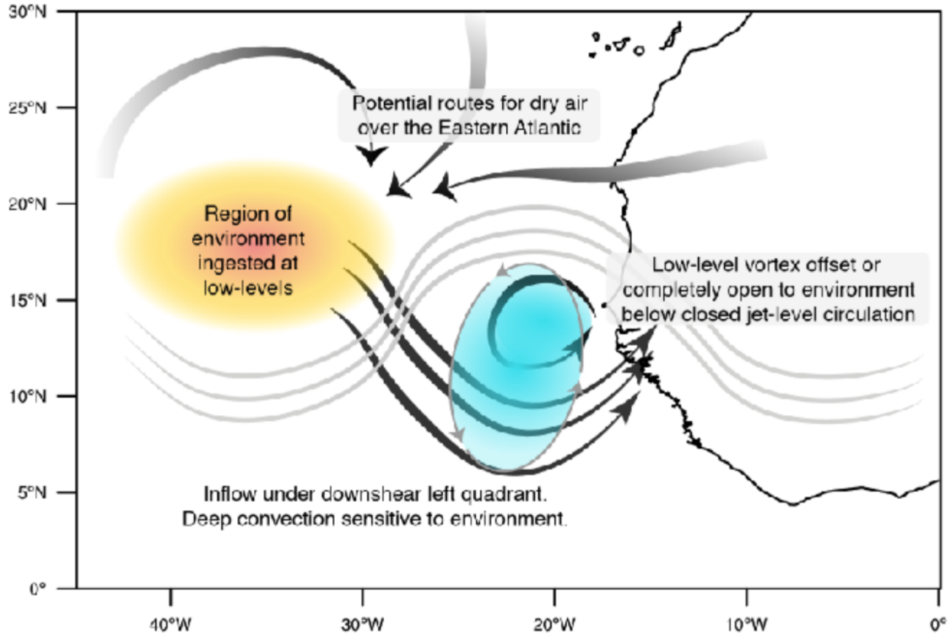

Figure 1. *Schematic of the ingestion of dry environmental air by an African easterly wave.*

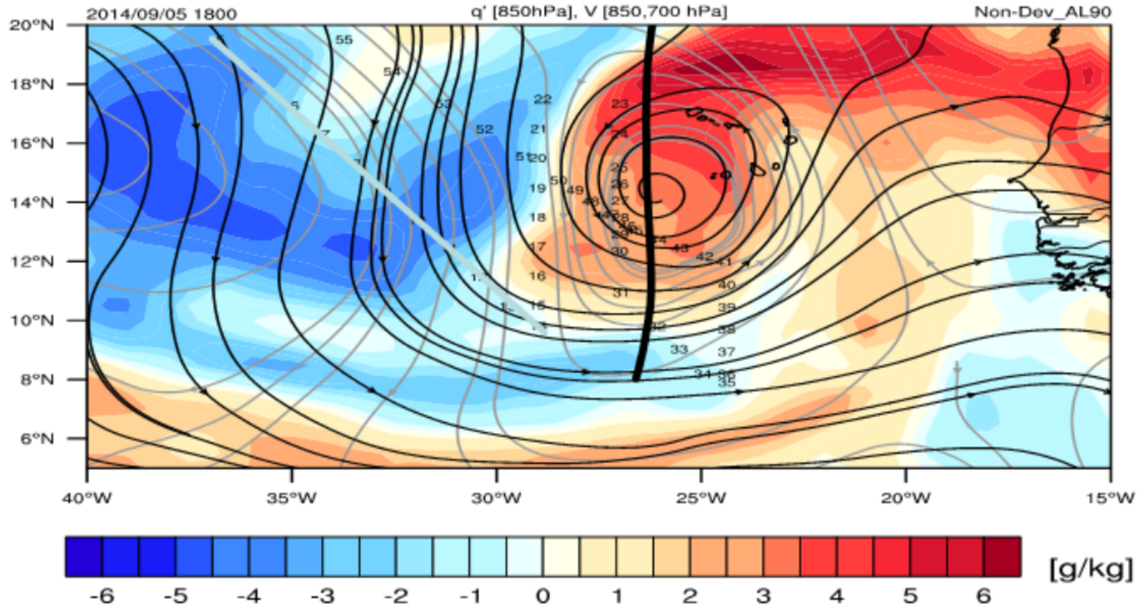

Figure 2*. 850-hPa specific humidity anomalies (shading), 850-hPa streamflow (black contours) and 700-hPa streamflow (grey contours) are shown for a non-developing case (AL90) at 1800 UTC 5 September 2014*

Hypotheses:

1. Environmental air downstream from a pre-TD is ingested before the low-level circulation is closed.
2. Environmental relative humidity to the west and northwest of a pre-TD is critical to the development of that disturbance.
3. Environmental vertical wind shear in the vicinity of a pre-TD is critical to the development of that disturbance.
4. Dry air associated with the Saharan Air Layer (SAL) inhibits or delays genesis of pre-TDs.
5. Dynamical models (e.g., GFS) are consistently too moist in the inflow layer to the west of a pre-TD, resulting in genesis false alarms.

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

G-IV Pattern 1: Sample the environment to the west of an easterly wave, especially if dry air is detected in that region. Sample when easterly wave is forecast to develop in reliable computer models or is showing signs of development in observations. Sample when easterly wave is located at or west of 35°W (to be within range of G-IV). Standard Lawnmower pattern should be used to setup a grid of observations and dropsondes, with drops every 150 n mi. The most likely orientation of the lawnmower pattern will be to the West or Northwest of the tropical disturbance/cyclone. Flight level is 40–45 kft. Long legs of pattern should be 600–1000 n mi (depending on flight time and resources) and short legs should be 150 n mi. To maximize the usefulness of the data, a minimum of two boxes should be flown. In some situations, the same box could be flown twice to maximize data coverage in a more specific region.

P-3 Pattern 1: G-IV Pattern 1 (described above) can be modified to accommodate the P-3. Flight level should be 15-20 kft to maximize the altitude of dropsonde data. P-3 missions will likely start later than G-IV missions due to the greater range of the G-IV, especially if the disturbance is in the Atlantic Main Development Region.

Links to Other Genesis Stage Experiments/Modules: This experiment is ideally suited to include sampling of the disturbance itself, including the pouch or vorticity maximum and precipitation properties identified from the Tail Doppler Radar. In other words, the “Precipitation Mode” and/or “Pouch Evolution during Genesis” Genesis Stage experiments can be flown in conjunction with the FAM experiment described here. Of course, special consideration must be given to the length of the flight and the distance of the disturbance from the takeoff/landing airport(s), if the FAM is sampling an air mass ahead of the disturbance. It may be especially fruitful to evaluate the relative humidity in the environment ahead of a disturbance and subsequently investigate the precipitation properties within the disturbance itself, as a tendency for precipitation and humidity increases in time could be an important indicator that genesis is becoming more likely. The FAM 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.

Analysis Strategy: Dropsonde profiles will be evaluated to determine the horizontal gradients and advection of environmental relative humidity. Characteristics of the dry air mass will be scrutinized, including the minimum relative humidity, the height/depth the dry air, and the horizontal extent of the dry air. Wind analyses from dropsondes and TDR will be evaluated to determine the impact of environmental vertical wind shear on the pre-genesis disturbance. This analysis will go beyond the traditional deep layer vertical wind shear metric, taking into account the hodograph to evaluate vertical wind shear through a number of different levels. The observations collected in this experiment will be crucial to evaluation of dynamics/thermodynamics and the diagnosis of genesis false alarms in numerical weather prediction models (e.g., GFS, HWRF).

References:

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