EXPERIMENT DESCRIPTION

7. Saharan Air Layer Experiment (SALEX): Dry Air Entrainment

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Links to IFEX: This experiment supports the following NOAA IFEX goals:

- **Goal 1**: Collect observations that span the TC lifecycle in a variety of environments;
- **Goal 3**: Improve our understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle;

Saharan Air Layer Experiment: This is a multi-option, single-aircraft experiment which uses GPS dropsondes launched from the NOAA G-IV (flying at ~175-200 hPa/~45,000-41,000 ft) to examine the thermodynamic and kinematic structure of the Saharan Air Layer (SAL) and mid-latitude dry air intrusions (MLDAIs) and their potential intrusion into/impact on tropical cyclone (TC) genesis and intensity change. The GPS dropsonde drop points will be selected using real-time GOES SAL tracking imagery from UW-CIMSS, mosaics of microwave-derived total precipitable water from the Naval Research Laboratory and the UW-CIMSS MIMIC TPW product. GOES 6-hr infrared brightness temperature difference imagery will also be used to track "cool rings" in the cloud top region of the storm (Fig. 7-1). These cool rings have been noted to propagate outward from the inner 100-200 km of the storm and appear to be associated with the formation of arc clouds several hours later (400-600 km form the storm center). Arc clouds signify that a dry air-TC/AEW interaction has occurred and will be targeted as opportunities present (see SALEX Arc Cloud Module). Infrared "cool rings" will be monitored in the context of low TPW (<45 mm) positioned upshear of the storm. When an expanding infrared "cool ring" becomes collocated with these upshear dry air locations, arc cloud formation appears to be favored. Specific effort will be made to gather atmospheric information within the SAL as well as regions of high moisture gradients across its boundaries and the region of its embedded mid-level easterly jet. The goals of this experiment are to better understand and predict how SAL and MLDAI dry air, the SAL mid-level easterly jet, and suspended mineral dust in the SAL affect Atlantic TC intensity change and to assess how well these components are being represented in forecast models.

Program Significance: The SAL has been investigated fairly extensively during the past several decades, buts its role in influencing Atlantic TCs has not been thoroughly examined. The SAL is characterized by a well-mixed layer that originates over the arid regions of the Sahara and often extends up to ~500 hPa (~19,000 ft) over the African continent. This air mass is extremely warm and dry, with temperatures that are markedly warmer (~0.5-5.0ºC in the central/western North Atlantic and ~5-10ºC in the eastern North Atlantic) than a typical moist tropical sounding. Additionally, the RH (mixing ratio) in the SAL is ~45-55% (~25-35% RH, ~1.5-3.5 g kg^{-1}) drier than a typical moist tropical sounding from 500-700 hPa. The SAL is often associated with a 20-50 kt mid-level easterly jet centered near 600-800 hPa (~14,500-6,500 ft) and concentrated along its southern boundary.

SAL outbreaks typically move westward off the western coast of North Africa every 3-5 days during the summer months. There are several characteristics of these frequent outbreaks that can act to suppress Atlantic TC formation:

1) The SAL (and MLDAIs) contains **dry, stable air** that can diminish local convection by promoting convectively driven downdrafts in the TC environment;

2) The SAL contains a **mid-level easterly jet** that can significantly increase the local vertical wind shear. The low-level circulations of TCs under the influence of this jet tend to race out ahead of their mid and upper-level convection, decoupling the storm and weakening it;

3) **Mineral dust** suspended within the SAL absorbs solar energy and subsequently releases longwave infrared energy. These thermal emissions act to warm the SAL and can re-enforce the tropical inversion that already exists in the tropical North Atlantic. This warming helps to stabilize the environment and also limits vertical mixing through the SAL, allowing it to maintain its distinctive low humidity for extended periods of time (several days) and over long distances (1000s of km). Recent studies also suggest that mineral dust may impact the formation of clouds in both the ambient tropical and tropical cyclone environments. Data from previous studies have indicated that the particle size of the SAL's suspended mineral typically ranges from 0.4 - 40 μm;

Objectives: The main objectives of SALEX Dry Air Entrainment are to:
- Better understand how the SAL's (and MLDAIs) dry air, mid-level easterly jet, and suspended mineral dust affect Atlantic TC intensity change;
- Include the moisture information from the GPS dropsondes in operational parallel runs of the NOAA Global Forecast System (GFS) model. The impact of this data on the GFS (and GFDL) initial/forecast humidity fields and its forecasts of TC track and intensity will be assessed;
- Investigate the representation of the SAL's temperature structure, low- to mid-level dry air, and embedded easterly jet in the GFS, GFDL, and HWRF-X models compared to GPS dropsonde data;
- Investigate how the TC environment becomes modified when substantial arc clouds are present. Improve the predictability of arc cloud events;
- Investigate the relationship between vertical distributions of dust detected by the DWL and temperature profiles/anomalies captured by collocated GPS dropsonde (pending P-3 DWL availability);

Mission Description: The NOAA G-IV (flying at ~175-200 hPa/~45,000-41,000 ft) GPS dropsonde drop points will be based on a flight pattern selected using information from the UW-CIMSS/HRD GOES SAL tracking product, mosaics of microwave-derived TPW from NRL Monterey, the UW-CIMSS MIMIC TPW product, and "cool rings" identified in 6-hr infrared BT difference imagery (Fig. 7-1). Theoretical trajectory analysis suggests that the front left and rear left quadrants of a TC/AEW are the favored entry points for mid-level dry air intrusions (Fig. 7-2). TPW imagery (≤45 mm) and this basic trajectory theory will be used to monitor the progress of dry air intrusions around the TC-AEW circulation. Specific effort will be made to gather atmospheric information within the SAL (and MLDAIs), the transitional environment (regions with high gradients of humidity) across its boundaries, its embedded mid-level easterly jet, and the immediate surrounding moist tropical environment. When possible, SALEX missions will be coordinated with the HRD Tropical Cyclone Genesis Experiment (GenEx). This coordination will involve the WP-3D and G-IV and be executed on a case-by-case basis. Additionally, HRD's Saharan Dust Microphysics Module and/or Arc Cloud Module should be conducted during SALEX should opportunities present. The following SAL-TC/AEW interaction scenario is the ideal candidate for SALEX missions:

Single TC located along the southern edge of a SAL outbreak (or MLDAI, Fig. 7-3). Depending on the proximity of these two features, the SAL's (or MLDAI's) mid-level dry air may be wrapping into the TC's low-level circulation (western semicircle). The G-IV **IP** will preferably (but not necessarily) be west of the TC (preferably west of the SAL's (or MLDAI's) leading edge) and the initial portion of the 1st leg (**IP-2**) will focus a GPS dropsonde sequence across the high gradient region of humidity at the SAL's (MLDAI's) leading edge. The spokes of this star pattern (**IP-2/12-FP**, **3-5**, **6-8**, and **9-11**) will include sampling of the environment between ~200-400 nm from the center and will be adjusted according to the storm size. The inner-most portion of the track will be roughly defined by convective areas that are below the flight level (GOES and Meteosat IR brightness temperature values warmer than ~-55^{o}C). The tangential legs at ~200 nm will observe the variability of possible dry air and shear that has penetrated close to the inner core (**2-3**, **5-6**, **8-9** and **11-12**). These inner tangential legs should be positioned as close to the outer edge of the inner core convection as safety permits. The region east of the storm along the southern edge of the SAL is a favored location for the SAL's mid-level easterly jet. The region will be sampled to observe the moisture gradients and variability of the mid-level easterly jet across this portion of the SAL (**4-5-6**). Intermediate GPS dropsondes will likely be requested along these legs of the mission.

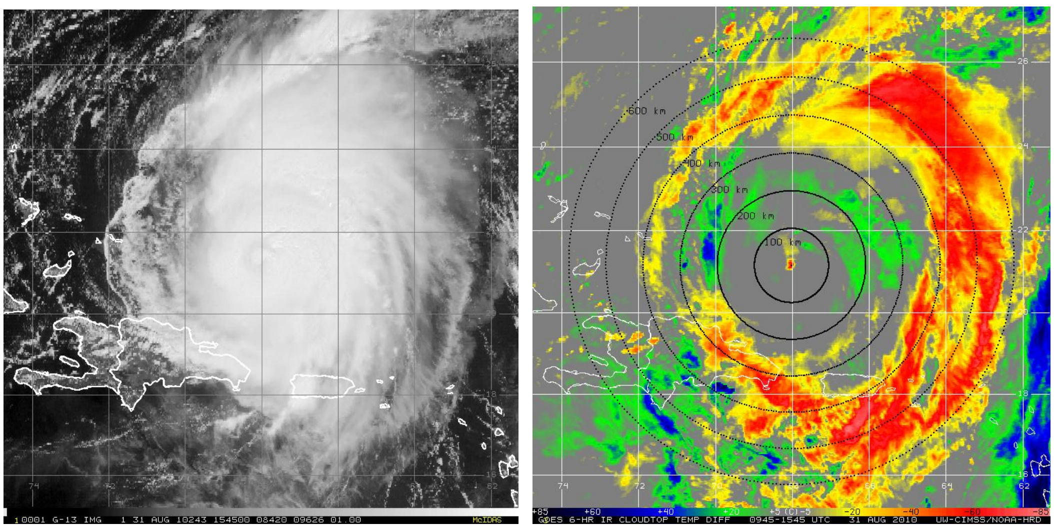

Figure 7-1: (Left) GOES visible and (right) 6-hr infrared brightness temperature (BT) difference imagery for Hurricane Earl on 31 August 2010 1545 UTC. Negative (positive) temperature changes [yellows to reds (greens to blues)] in the BT difference imagery indicate cloudtop temperatures and cirrus clouds that have cooled (warmed) over the past 6 hours.

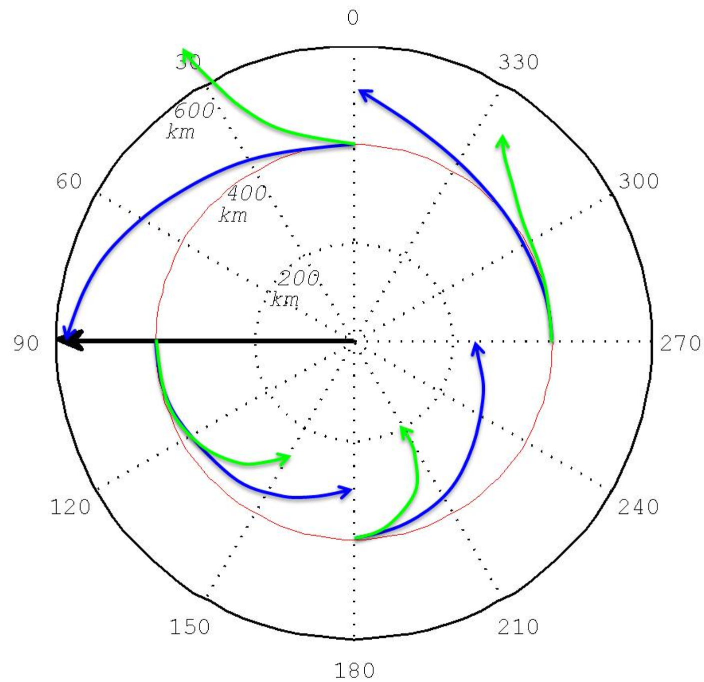

Figure. 7-2: Trajectories for points originating 400 km north, south, west, and east of the storm center based on simple trajectory theory where the radius of curvature of the trajectories relates to the radius of curvature of the streamlines (R_s), the tangential wind speed at the radius of interest, the forward motion of the disturbance (C), and the angle (ϒ) of the storm relative parcel starting position relative to the forward motion of the disturbance. Blue (green) trajectories are calculated from C=V/2 (C=V*2).

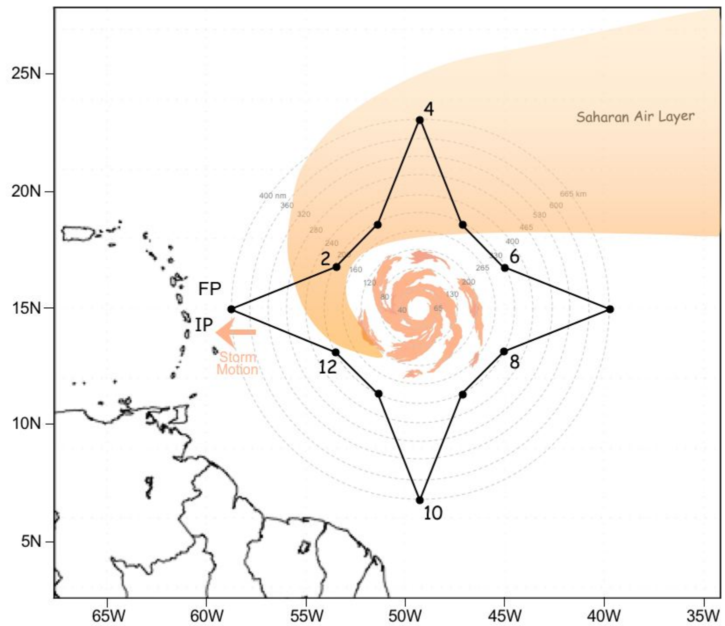

Figure 7-3: Sample G-IV flight track for sampling a dry SAL intrusion around the western semicircle of the storm.

- *Note 1*: During the ferry to the **IP**, the G-IV should climb to ~200 hPa/41,000 ft as soon as possible and climb as feasible to maintain the highest altitude for the duration of the pattern
- *Note 2*: In order to capture the SAL's (or MLDAI's) horizontal/vertical structure, particular attention should be paid to regions of high moisture gradients across its boundaries (**IP-2**, **2-3**, and **4-5-6**) and possible penetration of dry air and vertical wind shear toward the inner core (**IP-2**, **3-5**, **6-8, 9-11** and **12-FP**).
- *Note 3*: The SAL's mid-level easterly jet (~20-50 kt at 600-800 hPa/14,500-6,500 ft) may be evident from GPS dropsondes dropped near the SAL's southern boundary (**2-3-4 and 4-5-6**).