11C.8

HUNTING FOR SAHARAN AIR WITH THE NOAA G-IV JET

Jason P. Dunion[1], Jeffrey D. Hawkins[2], and Christopher S. Velden[3]
1 University of Miami/CIMAS- NOAA/AOML/Hurricane Research Division, Miami, FL
2 Naval Research Laboratory, Monterey, CA
3 UW/CIMSS, Madison, WI

1. INTRODUCTION

During the 2005 Atlantic hurricane season, NOAA's Hurricane Research Division (HRD) conducted the first-ever aircraft missions of its Saharan Air Layer Experiment (SALEX). A total of four SALEX missions were flown using NOAA's G-IV high altitude jet, operating out of Barbados. GPS dropwindsondes were launched during these missions to sample the Saharan Air Layer (SAL) and its interactions with Tropical Storm Irene and other areas of tropical convection. The main goals of SALEX are to better understand how the SAL's dry air, mid-level easterly jet, and suspended mineral dust affect Atlantic tropical cyclone intensity change and to improve SAL representation in forecast models such as NOAA's Global Forecast System (GFS).

The SAL, an elevated (~500-850 hPa) layer of Saharan air and mineral dust, has been investigated for several decades, but its link to suppressing Atlantic tropical cyclone (TC) activity is a relatively new area of research (Dunion and Velden 2004). Recently developed GOES split-window and Special Sensor Microwave/Imager (SSM/I) basin wide total precipitable water (TPW) satellite products now permit continuous tracking of the SAL's dry, dusty air across the North Atlantic, Caribbean, and Gulf of Mexico. These new types of satellite imagery reveal that the SAL may play a major role in suppressing TC activity in the North Atlantic (Dunion and Velden 2004).

2. SAHARAN AIR LAYER EXPERIMENT OBJECTIVES

HRD's 2005 SALEX experiments were designed to utilize the NOAA G-IV jet to investigate several aspects of the SAL and its interactions with African easterly waves (AEWs) and TCs. The main goals of SALEX include:

- Sampling the SAL with GPS dropwindsondes to determine its thermodynamic and kinematic characteristics, particularly its vertical structure and the gradients that exist along its boundaries.
- Sampling regions where the SAL is impinging on a TC or area of tropical convection to assess how effectively various satellite imagery and products [e.g. GOES-12, Meteosat-8, and the constellation of passive microwave imagers (e.g. SSM/I)] are representing the SAL.
- Including the moisture information from the SALEX GPS dropwindsondes in operational parallel runs of the NOAA GFS model and assessing the impact of this data on the GFS initial/forecast humidity fields and its forecasts of TC track and intensity.
- Perfecting G-IV sampling strategies that will be used during HRD's participation in the African Monsoon Multidisciplinary Analyses (AMMA) field campaign during the 2006 Atlantic hurricane season.

3. SALEX I (07-08 AUGUST 2005)

SALEX mission 050807n was conducted on 07 August 2005 using the NOAA G-IV jet to investigate the SAL and its interaction with Tropical Storm Irene. The mission originated from Barbados and the flight pattern was designed to sample three main features: 1) a region of SAL air west of Irene (SAL 2, Fig. 1) that had moved off of Africa approximately 1 week prior the mission; 2) moist tropical air located to the north and south of Irene (Fig. 1); and 3) a more recent SAL outbreak east of Irene (SAL 3, Fig. 1) that had pushed off of Africa on 02 August.

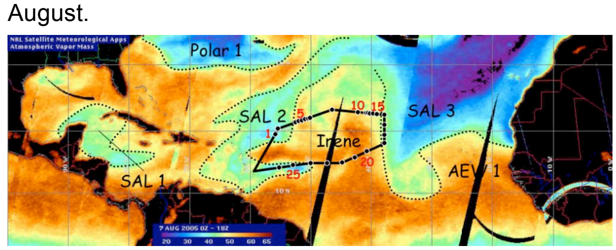

Figure 1: Mosaic of TPW derived from the constellation of SSM/I satellites showing the positions of several SAL airmasses (SAL 1/2/3), TS Irene, an AEW (AEW 1), and dry mid-latitude air (Polar 1). TPW values of <45 mm (greens to blues) represent dry air in the low to mid levels (~600-925 hPa). The 050807n G-IV flight track and 26 dropwindsonde points (black circles) are overlaid.

GPS dropwindsondes launched in the region of SAL 2 (Fig. 1) showed that although this airmass had emerged from Africa more than a week earlier, it had maintained its characteristic dry air in the lower to middle levels. Fig. 2 shows the profile of relative humidity (RH) associated with SAL 2 at drop #2 (~21^{o}N 56^{o}W) as well as the Jordan mean tropical moisture sounding. The dropwindsonde indicated ~10-20% RH in the middle levels (~600-800 hPa) of the SAL 2 environment, which is ~35-50% dryer than the Jordan mean tropical sounding. It is also interesting to note that the extreme dry air in this sounding extended well above the typical vertical extent of the SAL (~500-850 hPa). This ~300-500 hPa dry air may have origins that are unrelated to the SAL (e.g. subsidence associated with high pressure in the Atlantic) and requires further investigation.

**Corresponding author address:* Jason P. Dunion, NOAA/AOML/HRD, 4301 Rickenbacker Causeway, Miami, FL 33149; e-mail: Jason.Dunion@noaa.gov

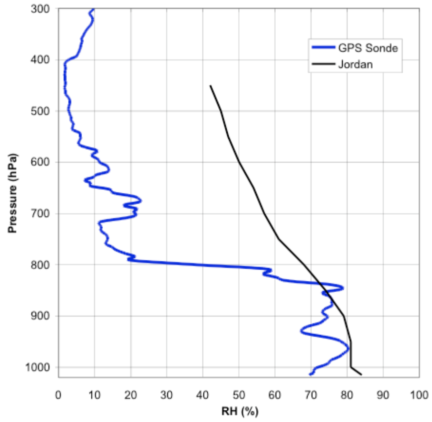

Figure 2: Profiles of relative humidity for a GPS dropwindsonde (drop #2, mission 050807n) launched in the SAL (SAL 2) [blue curve]. The Jordan mean tropical sounding (black curve) is include for reference.

Although the environment north of Irene was quite moist, a second SAL outbreak was impinging on Irene from the east (SAL 3, Fig. 1). A dropwindsonde launched southeast of Irene (drop #19, ~18^{o}N 38^{o}W) showed that this SAL outbreak also contained very dry air and was also associated with a strong temperature inversion at its base (Fig. 3). Figure 3 shows that the

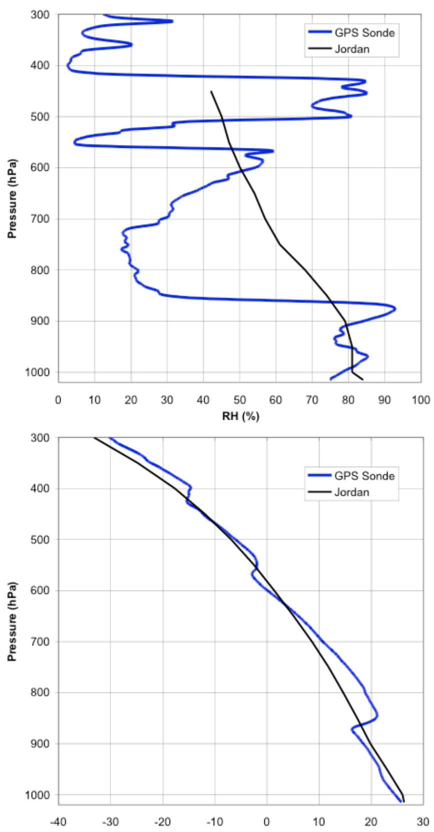

Figure 3: Profiles of (top) relative humidity and (bottom) temperature for a GPS dropwindsonde (drop #19, mission 050807n) launched in the SAL (SAL 3) [blue curve]. The Jordan mean tropical temperature and moisture soundings (black curves) are include for reference.

RH in SAL 3 was quite dry from ~500-850 hPa (the typical vertical extent of the SAL) and was bounded by moister air above and below. This sounding also indicated the existence of a strong (~4.7^{o}C from 845-875 hPa) temperature inversion at the base of the SAL 3 outbreak (Fig. 3).

Drop #19 also indicated that SAL 3 contained a strong mid-level easterly jet. Figure 4 shows that this 25-30 kt easterly jet was centered near ~700 hPa and suggests that this surge may have been enhancing the local vertical wind shear. Although the 200-850 hPa shear calculated from this sounding was ~17 kt, the relatively limited vertical extent of the SAL's mid-level easterly jet (Fig. 4) wasn't being well represented by the 850 hPa level. In fact, the 850 hPa winds were only ~16 kt, while the 700 hPa winds were ~29 kt. This suggests that the vertical wind shear (associated with SAL 3) that was affecting Irene may have been underestimated by a traditional 200-850 hPa calculation.

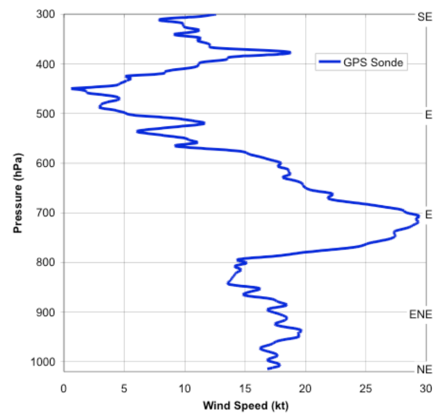

Figure 4: Profile of wind speed (blue curve) for a GPS dropwindsonde (drop #19, mission 050807n) launched in the SAL (SAL 3). The wind directions for 300 hPa, 500 hPa, 700 hPa, 900 hPa, and the surface are shown on the right side of the figure.

The combination of dry air, strong vertical wind shear, and a strong temperature inversion in this SAL airmass suggests a very stable environment that would not be conducive to convective development. Indeed, this portion of the flight track was characterized by shallow cumulus and low-level stratocumulus clouds. It should also be noted that drops 10-21 all indicated the presence of SAL air directly impinging on the area of convection east of Irene's center of circulation. This SAL air was sampled as close as ~250 nm from Irene's exposed center.

4. SALEX II (27-28 SEPTEMBER 2005)

SALEX mission 050927n was conducted on 27 September 2005 using the NOAA G-IV jet to investigate a SAL outbreak and its interaction with an AEW. The mission originated from Barbados and the flight pattern was designed to sample three main features: 1) a region of SAL air west of an AEW that had moved off of Africa on 20 Sep (SAL 1, Fig. 5); 2) moist tropical air associated with an AEW (AEW 1, Fig. 5) that had moved off of Africa on 22 Sep; and 3) a more recent SAL outbreak east of the AEW that had moved off of Africa on 23 Sep (SAL 2, Fig. 5).

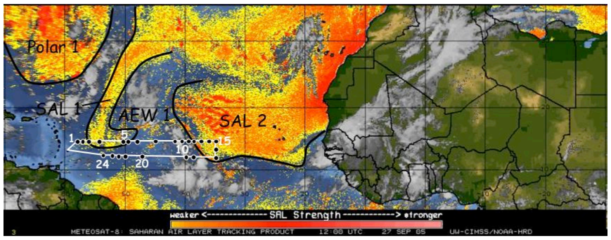

Figure 5: GOES SAL tracking imagery showing the positions of two SAL airmasses (SAL 1 and 2), an AEW (AEW 1), and dry mid-latitude air (Polar 1). Yellow to red shading represents dry (and possibly dusty) air in the lower to middle levels (~600-850 hPa). The 050927n G-IV flight track and 24 dropwindsonde points (black circles) are overlaid on the image.

GPS dropwindsondes launched in the region of SAL 2 (Fig. 5) showed that this airmass contained moist air below ~800 hPa and was quite dry above ~775 hPa. Figure 6 confirms this and shows the moisture sounding for drop #15 (~13^{o}N 35^{o}W). This sounding indicates that the SAL 2 airmass was significantly dryer than the Jordan mean tropical sounding above ~775 hPa.

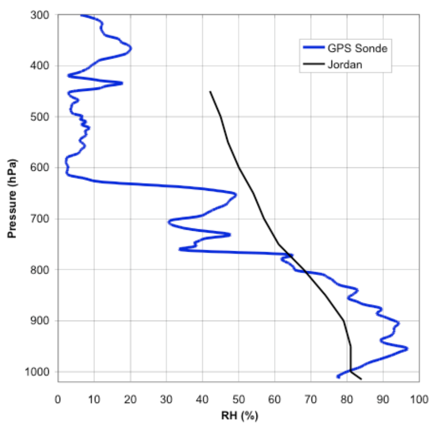

Figure 6: Profiles of relative humidity for a GPS dropwindsonde (drop #15, mission 050927n) launched in the SAL (SAL 2) [blue curve]. The Jordan mean tropical sounding (black curve) is include for reference.

A photograph taken from the NOAA G-IV near the time of drop #15 shows vast amounts of suspended mineral dust below flight level (~45,000 ft) associated with the SAL 2 outbreak. It should be noted that this dust originated over the African continent over 2,000 km east of this area.

Figure 7: Photograph of suspended mineral dust contained in the SAL 2 outbreak. The photo was taken at ~1820 UTC a few minutes before drop # 15 of the 050927n SALEX mission.

5. ASSESSING THE IMPACT OF GPS SONDE HUMIDITY ON THE NOAA GFS MODEL

NOAA has been conducting synoptic surveillance missions in and around TCs with the NOAA G-IV jet since 1997 (Aberson 2003). These missions use targeting techniques that focus GPS dropwindsonde sampling in regions of the surrounding TC environment that are associated with the most uncertainty in the GFS model. The main objective of these missions is to improve GFS TC track forecasts. However, humidity data from these missions has never been assimilated into the GFS. In light of recent findings related to the dry air contained in the Saharan Air Layer, a research proposal was submitted to the NOAA Joint Hurricane Testbed by Aberson and Dunion to assess the impact of GPS dropwindsonde humidity on analysis fields and TC forecasts produced by the GFS model. Figure 8 shows an example of the impact of GPS dropwindsonde humidity data from SALEX mission 050807n on the 08 August 0000 UTC GFS analysis field. This plot shows the difference field [operational (no sonde humidity) minus the parallel run (with SALEX sonde humidity)] for the mean analysis of 500-850 hPa RH. Even at the initial time, the dropwindsonde humidity information had a relatively large affect on the GFS field. Mean values of RH increased (decreased) in the vicinity of the Irene by as much as 15-20% (5-10%). These differences grew rapidly in subsequent GFS forecast periods (e.g. the 24 hr forecast, Fig. 8). Figure 8 shows that the mean 500-850 hPa differences in the 24 hr GFS forecast increased (decreased) to as much as 30-35% (20-25%) RH in the surrounding environment of Irene.

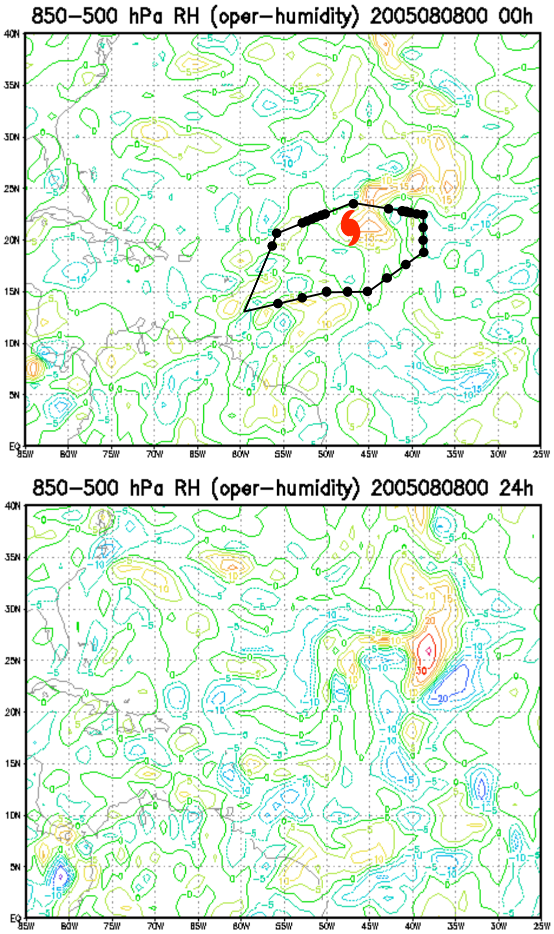

Figure 8: Difference field (operational GFS minus parallel GFS run with sonde humidity) of the mean 500-850 hPa RH for the (top) 08 Aug 2005 0000 UTC GFS analysis field and (bottom) 24 hr forecast field. The parallel run includes data from 26 GPS dropwindsondes launched during the 050807n SALEX mission. The G-IV flight track and sonde drop points, as well as Irene's center of circulation are overlaid.

6. REFERENCES

Aberson, S. D., 2003: Targeted observations to improve tropical cyclone track forecasts. *Mon. Wea. Rev.*, **131, No. 8**, 1613–1628.

Dunion, J.P, and C.S. Velden, 2004: The impact of the Saharan Air Layer on Atlantic tropical cyclone activity. *Bull. Amer. Meteor. Soc.*, **85, No. 3**, 353-365.