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THE SAHARAN AIR LAYER- INSIGHTS FROM THE 2002 AND 2003 ATLANTIC HURRICANE SEASONS

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1. INTRODUCTION

The Saharan Air Layer (SAL), an elevated (~500-850 hPa) layer of Saharan air and mineral dust, has been investigated for several decades, but its link to Atlantic tropical cyclone (TC) activity has never been fully examined. Recently developed GOES split-window and SSM/I basin wide total precipitable water (TPW) satellite imagery now permits 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).

Recent research efforts have been focused on various aspects of the SAL's role in influencing TCs and lower tropospheric moisture in the tropical North Atlantic. This work includes development of a SAL detection algorithm for the new GOES-12 satellite, basin wide TPW mosaics created from the constellation of SSM/I satellites to help supplement SAL detection, a re-examination of the Jordan mean tropical sounding and how the SAL may have influenced the results of this 1958 study, and utilization of GPS sondes launched from NOAA aircraft to investigate the SAL's low humidity and how effectively this dry air is being represented in the global models.

2. SAL TRACKING SATELLITE IMAGERY

In the spring of 2003, GOES-12 replaced GOES-8 as the operational GOES East satellite. Among other changes in its configuration, GOES-12 no longer has the 12.0 μm longwave IR channel. The original SAL tracking imagery developed with GOES-8 used the 10.7 and 12.0 μm channels to detect the dry, dusty air contained in the SAL (Dunion and Velden 2004). Therefore, a new algorithm was developed for GOES-12 that uses the 3.9 and 10.7 μm channels to track the SAL. This algorithm relies on the same principals for tracking the SAL, but is limited to nighttime use because of the affects of solar reflectance in the 3.9 μm channel. To supplement SAL detection, NRL has developed a mosaic of TPW imagery derived from the constellation of SSM/I satellites to track the SAL's low humidity air.

3. DEVELOPMENT OF A NEW MEAN JORDAN TROPICAL SOUNDING

The original work by Jordan in 1958 included the calculation of a climatological sounding for the West Indies during the "hurricane season" (July-October). In light of recent advances in our understanding of the SAL and its ability to advect extremely low humidity as far west as the western Caribbean Sea (~7,000 km from its source over northwest Africa), it was hypothesized that the Jordan mean tropical sounding may not capture the true bi-modal nature (SAL vs non-SAL) of the moisture found in the tropical North Atlantic. Therefore, Jordan's study was replicated for the 2002 "hurricane season" using data from 4 West Indies and Caribbean raob stations (Cayman Islands, Guadeloupe, Jamaica, and San Juan). GOES SAL imagery was used to distinguish between raobs (00/12 UTC) taken in SAL versus non-SAL environments. GOES split window temperature differences between -4 to 4^{o}C were used to denote the SAL atmosphere, while temperature differences above 4^{o}C were selected to represent non-SAL tropical environments. Figure 1 shows the distribution of these soundings (709 total) for the period June-October 2002 and suggests that the peak SAL activity occurs in the early summer months and steadily decreases during the hurricane season.

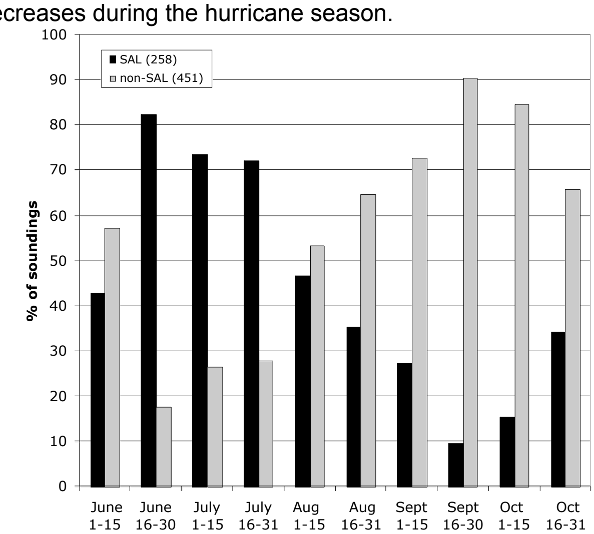

Figure 1: Occurrence of SAL and non-SAL soundings during the 2002 hurricane season.

Mean soundings were determined from the SAL and non-SAL twice daily raobs for the months of July-October. These results shown in Fig. 2 suggest that the tropical North Atlantic contains a bi-modal distribution of moisture soundings: dry SAL and moist tropical. Not surprisingly, the Jordan mean sounding lies between these two distinct moisture soundings. Because of the ratio of SAL (36%) to non-SAL (64%) soundings in the sample, the Jordan sounding is skewed slightly toward the non-SAL moist sounding.

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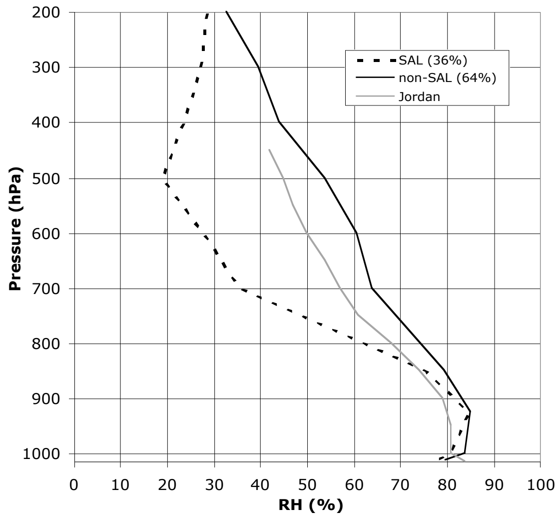

Figure 2: Mean bi-modal July-October 2002 moisture soundings vs the Jordan mean tropical sounding.

Figure 3 depicts the frequency distributions of the 700 hPa RH for the July-October SAL and non-SAL soundings. This figure shows that at 700 hPa (the approximate vertical center of the SAL), 89% of the SAL soundings had RHs of ≤50%, while 92% of the non-SAL soundings had RHs of ≥50%. For reference, the mean Jordan 700 hPa RH is 57%.

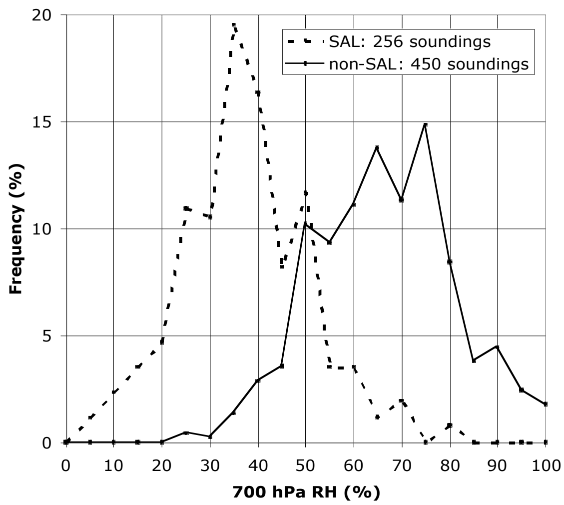

Figure 3: Frequency distribution of 700 hPa RH for SAL vs non-SAL soundings (July-October 2002).

3. FIRST EVER NOAA G-IV TARGETED SAL OBSERVATIONS: IMPLICATIONS FOR GLOBAL MODEL MOISTURE FIELDS

During Hurricanes Fabian and Isabel, first ever SAL-targeted observations using GPS sondes were made with the NOAA G-IV jet. GOES SAL tracking imagery and NRL's TPW satellite imagery were used to select GPS sonde drop points around the environments of these hurricanes. This satellite imagery was used to determine GPS sondes launched in SAL (26 sondes) vs non-SAL (87 sondes) environments.

Comparisons were made between the GPS sondes and collocated moisture data from 1 degree GFS and 0.5 degree NOGAPS initial fields. The non-SAL GPS sonde/model comparisons (Fig. 4) show that the GFS and NOGAPS models effectively captured the moist non-SAL environment around the TCs, especially below 400 hPa (notice the slight improvements over the Jordan mean sounding in representing the moisture around the storm). Overestimates (~10-25%) of the moisture above 500 hPa suggest that the TC upper-level outflow was being over represented.

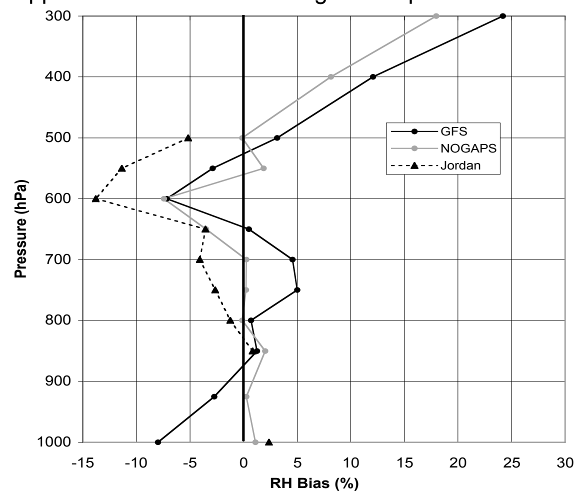

Figure 4: Bias of the Jordan mean tropical sounding and GFS/NOGAPS initial fields relative to non-SAL GPS sondes launched from the NOAA G-IV during Hurricanes Fabian and Isabel.

The SAL GPS sonde/model comparisons (Fig. 5) show that both the GFS and NOGAPS models had difficulty representing the low moisture in the SAL. This is especially evident near 700 hPa, where both models overestimated the moisture content by ~25%. In fact, the model overestimates of RH were on the order of 2 to as much as 3 times too large from 500-750 hPa and showed little to no skill over the Jordan mean sounding at representing atmospheric moisture. These results suggest that limitations may exist for TC intensity models such as SHIPS that rely on the GFS model for atmospheric moisture information. Also evident is the importance of including moisture information from GPS sondes in the global model initializations. GFS does not currently assimilate this information in real-time.

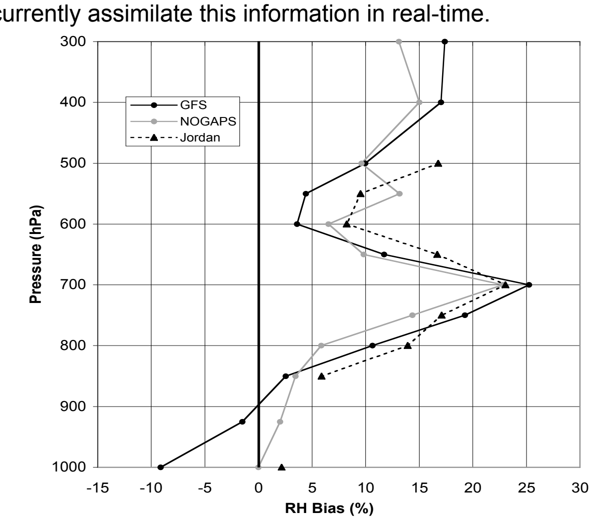

Figure 5: Bias of the Jordan mean tropical sounding and GFS/NOGAPS initial fields relative to SAL GPS sondes launched from the NOAA G-IV during Hurricanes Fabian and Isabel.

6. REFERENCES

Dunion, J.P, and C.S. Velden, 2004: The impact of the Saharan Air Layer on Atlantic tropical cyclone activity. *Bull. Amer. Meteor. Soc.*, (in press).