Joint Hurricane Testbed Mid-term Report
April 1, 2006 – October 31, 2006

Assimilating Moisture Information from Global Positioning System (GPS) Dropwindsondes into the NOAA Global Forecast System

Principal Investigator: Sim D. Aberson NOAA/AOML/Hurricane Research Division
Collaborator: Jason P. Dunion NOAA/AOML/Hurricane Research Division

Accomplishments:
Year-2 goals of this JHT project include:

1. Finish performing parallel GFS runs that include dropwindsonde humidity and archive results (April-June 2006).
2. Assess performance of 2005 GFS operational vs parallel track/intensity forecasts and any other fields required by EMC (April-August 2006).
3. Assess how effectively the 2005 GFS operational vs parallel fields represent dry layers such as the SAL through direct comparisons with dropwindsonde data (April-Sept 2006).
4. Assess feasibility of performing targeted observations of humidity to improve GFS forecasts (Aug 2006-Mar 2007).

Goals 1 and 2 were completed using GPS dropwindsonde data from 2005 tropical cyclones (TCs) Arlene, Cindy, Dennis, Emily, Irene, Katrina, Rita, Wilma, and Gamma. Unfortunately, there were persistent failures in parallel GFS runs for a few of the 2005 TC cases (e.g. TCs Cindy, Dennis, and Gamma). These failures generally occurred during forecast days 4 or 5; all available forecasts were included in the assessments. NCEP did not have the resources to resolve the problem in the low-resolution runs on their temporary Research and Development Computer (aqua), but the sample was large enough without these few cases to consider the results conclusive. The runs were also made difficult by the computer transitions from snow to aqua to haze. Based upon work from this JHT project, the NOAA/National Centers for Environmental Prediction approved the assimilation of dropwindsonde humidity data into the GFS model from all dropwindsondes launched from NOAA's G-IV jet beginning on 22 August 2006 as stated in the following 04 August JIFMEMO:

> *"995. DATACARDS - IBM Jobs GFS_PREP, GDAS_PREP. (Keyser, NP22). This program PREPOBS_PREPDATA prepares observational data for subsequent quality control programs and for subsequent analysis in all forecast networks, using data card switches in the input parm cards to control processing based on the forecast network. The input parm cards for the GFS and GDAS networks, prepobs_prepdata.gfs.parm and prepobs_prepdata.gdas.parm, respectively, are being modified to no longer flag Gulf Stream dropwindsonde moisture data. These data, on all levels, will now be assimilated by the Global SSI analysis. USAF dropwindsonde moisture will continue to be flagged and not assimilated in all networks, as will Gulf Stream dropwindsonde moisture in the NAM, NDAS and RUC networks."*

Efforts related to Goal 3 have included comparing GFS analyses of humidity in which the humidity data from dropwindsondes launched during several of NOAA/HRD's 2005 G-IV Saharan Air Layer Experiment (SALEX) missions have not been assimilated. Two of these missions examined the interaction between the Saharan Air Layer (SAL) and Tropical Storm

Irene (07 and 08 August) and two missions investigated an interaction between the SAL and pre-Tropical Depression 19 [(TD 19); 27 and 28 August]. Total precipitable water (TPW) imagery derived from microwave satellite data was used to target where dropwindsondes were to be released in dry SAL and moist tropical non-SAL air masses around the storm. A preliminary study of these data identified a total of 26 (17) SAL and 13 (18) non-SAL drops from the Irene (pre-TD 19) missions. Composite moisture profiles were generated for the Irene missions (Fig. 1, left) and for the pre-TD 19 missions (Fig. 1, right). Several interesting characteristics of the mean SAL profiles and GFS moisture analyses (without the dropwindsonde humidity data assimilated) for the two sets of missions were evident:

- During the Irene missions, the SAL exhibited a classic vertical structure, with dry air evident in the low to mid-levels of the atmosphere (~500-850 hPa) [Fig. 1, left].
- During the later pre-TD 19 missions, the SAL was associated with an uncharacteristic deep layer of dry air (~300-850 hPa). This late season SAL outbreak may have mixed with mid to upper-level dry air associated with the mid-latitudes, though this has not yet been confirmed.
- Figure 2 shows the biases of the GFS model moisture analyses compared to dropwindsonde data. The differences between the GFS analyses and the dropwindsonde humidity observations were larger for the set of mid-summer Irene missions than for the subsequent SALEX missions in late September. This small sample suggests that the more "classic" SAL outbreaks that contain dry air in a relatively shallow layer (~500-850 hPa) may be more difficult to represent in the GFS.
- There are several possible reasons why the GFS may not have effectively represented the moisture in this "classic" SAL outbreak: these types of shallow dry layers may be more difficult to detect using water vapor imagery (e.g. 6.5 μm) from geostationary satellites that have peak weighting functions near ~400 hPa, well above the SAL; TPW information derived from microwave satellites (currently assimilated into the GFS) may not as readily detect shallow dry layers since the algorithm detects moisture in the entire atmospheric column below the satellite; and the GFS may not have as effectively represented shallow, elevated dry layers as it does deep layers of dry air that extend to the tropopause. These hypotheses need further investigation.

It is also interesting to note several characteristics of the composite non-SAL (moist) profiles from the SALEX missions:

- The mean non-SAL (moist) profiles for both sets of missions were significantly moister than the mean SAL profiles in the lower (above 950 hPa) to middle levels (Fig. 1).
- The GFS was drier in the non-SAL environment around TS Irene by as much as 30% RH than the observations, whereas the upper-level (~200-450 hPa) moisture was higher than the observations for both sets of missions by as much as 30-40% RH for both SAL and non-SAL environments (Fig. 2). This is similar to findings presented by Dunion et al. 2004 and suggests that the upper-level moisture in the TC environment appears to be consistently overestimated by the GFS.

The preliminary results associated with Goal 3 suggest that the GFS model was not effectively representing dry layers such as the SAL and overestimated the upper-level moisture in the TC environment. This dataset will be expanded as additional comparisons are be made between GFS moisture analyses and dropwindsondes launched in the environment of TCs during HRD SALEX missions conducted in 2006.

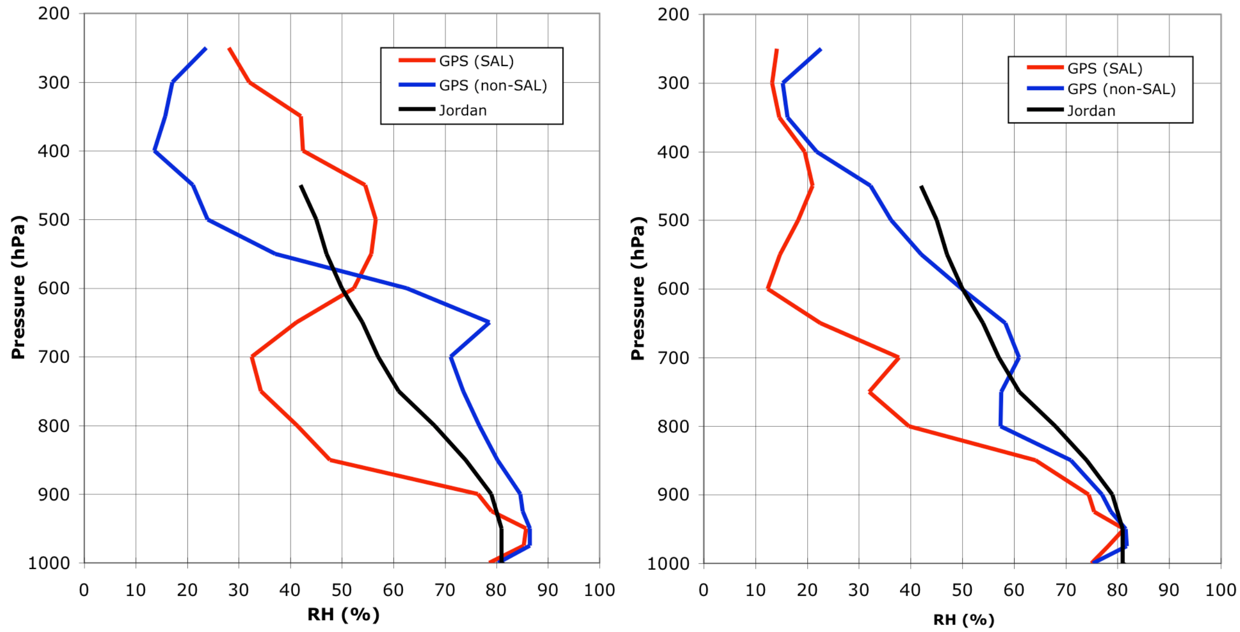

Fig. 1: Mean profiles of relative humidity (%) from dropwindsondes launched during 2005 HRD G-IV SALEX missions on (left) 07/08 August and (right) 27/28 September. The dropwindsondes are classified as dry SAL (red curve) or moist non-SAL (blue curve) and defined using microwave satellite TPW imagery. The black curve shows the mean Jordan tropical moisture sounding for reference.

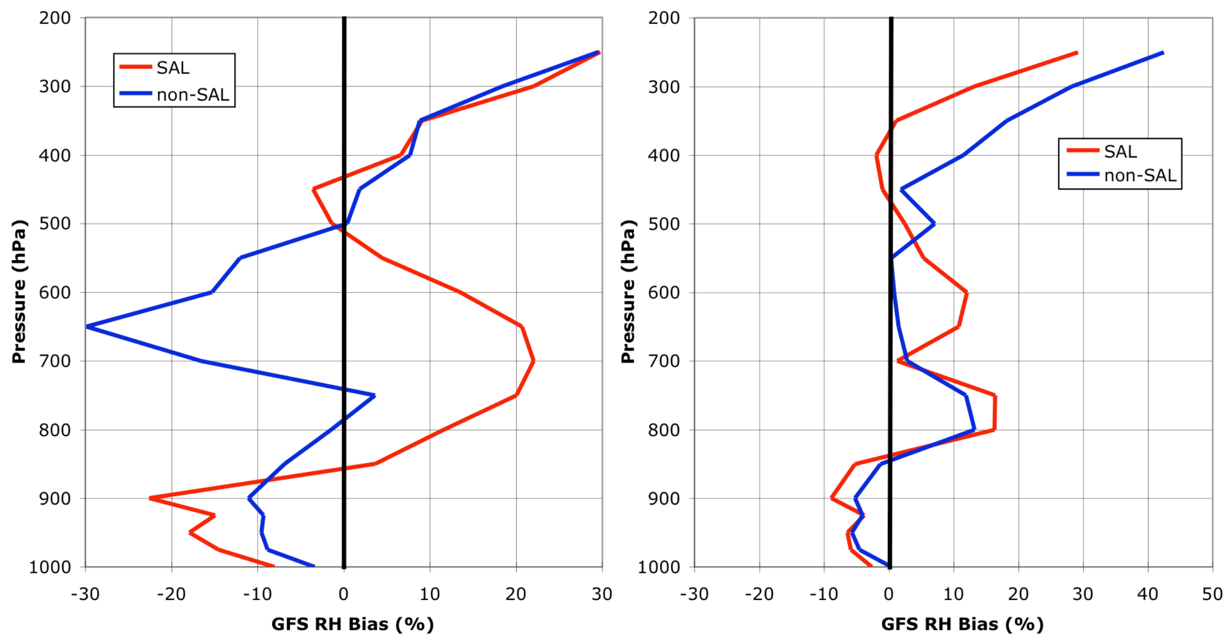

Fig. 2: Bias of the GFS model analysis of 700 hPa RH (%) relative to dropwindsondes launched during 2005 HRD G-IV SALEX missions on (left) 07/08 August and (right) 27/28 September. The biases are separated into dry SAL versus moist tropical non-SAL environments and defined using microwave satellite TPW imagery. The thick black line indicates the "zero bias" line.

Daily targeted observation guidance during August and September of 2006 using TPW water as the norm and the variance and Ensemble Transform Kalman Filter techniques are available at < http://orca.rsmas.miami.edu/~majumdar/amma/ >. In-depth investigation of the guidance will be a priority in the coming months and will address Goal 4 of this project.

Future Work:

Additional comparisons will be made between GFS moisture analyses and GPS dropwindsonde data from 2006 (Goal 3) and the feasibility of performing targeted observations of humidity to improve GFS forecasts will be assessed. This will require resources to make the models available on a stable NOAA Research and Development computer, something that has caused difficulties in recent months. Results will be presented at the upcoming 2007 Interdepartmental Hurricane Conference (IHC).

References:

Dunion, J.P., C.S. Velden, J.D. Hawkins, and J.R. Parrish, 2004: The Saharan Air Layer-Insights from the 2002 and 2003 Atlantic hurricane seasons. *AMS* 26^{th} *Conference on Hurricanes and Tropical Meteorology*, Miami, FL, American Meteorological Society, 495-496.