11.5 **Impact of AMSU and AMSR-E Measurements on Hurricane Prediction**

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1. INTRODUCTION

Currently, the National Centers for Environmental Prediction (NCEP) operational hurricane model uses a vortex replacement scheme to initialize hurricanes (Kurihara et al. 1995; Liu et al. 2004). The scheme performs well for initializing strong hurricanes but has difficulties for weak systems. NCEP hurricane modeling group is recently requested to generalize the scheme for weak and diffuse systems that do not display strong rotational circulation. In this study, we develop a new hybrid variational scheme, which directly assimilates microwave radiances in rain-affected areas to produce a best analysis for hurricane circulation. The satellite microwave radiances are obtained from the Advanced Microwave Sounding Unit (AMSU) on board NOAA-15, 16 and 18 satellites and the Advanced Microwave Scanning Radiometer (AMSR)-E on board NASA EOS Aqua satellite.

2. HYBRID VARIATIONAL SCHEME FOR HURRICANE VORTEX ANALYSIS

A statistical algorithm was first developed to retrieve three-dimensional atmospheric temperature, and a dynamically constrained model was developed to obtain the geopotential height, wind, and moisture fields for a hurricane system from AMSU measurements (Zhu et al., 2002). Positive impacts have been shown in the simulation of Hurricane Bonnie (1998). This study will explore a direct assimilation of rain-affected microwave radiances for further improvement of hurricane analysis using a new hybrid variational scheme.

Earth Observing System (EOS) Aqua satellite was launched in 2002. On board, AMSR-E is one of important satellite-based microwave sensors to observe global atmospheric and surface parameters. It is a conically scanning passive microwave radiometer at 6.925, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz frequencies with both horizontal and vertical polarization. The spatial resolution of the individual measurements varies from 5.4 km at 89.0 GHz to 56 km at 6.9 GHz. The sea surface wind (SSW) speed under hurricane atmospheric conditions is derived with a new physical based algorithm using AMSR-E measurements (Yan and Weng, 2005). Figure 1 displays the SSW retrieved at 0600 UTC, August 25, 2005. It is then verified against the NOAA Hurricane Research Division (HRD) surface wind analysis. In general, the two figures show similar wind speeds in both environmental and storm core regions. The retrieved SSW shows strong winds in the north side of the storm, which is similar to the pattern in the best analysis field. The AMSR-E retrieved maximum wind speed is 37 kts, which is close to the best analysis value of 41 kts.

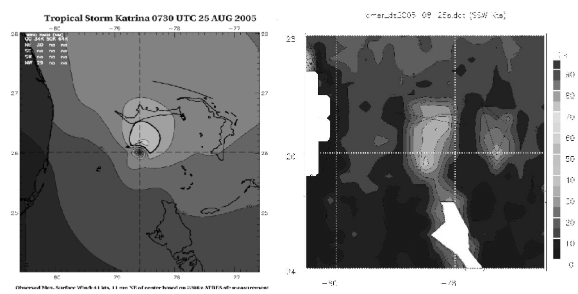

Figure 1. Sea-surface wind speed (m/s) for Hurricane Katrina at 0600 UTC 25 Aug 2005 (a) HRD best analysis, (b) AMSR-E retrieved.

1DVAR Retrieval System: satellite radiances from AMSU are assimilated to provide atmospheric temperature profiles. In the presence of clouds and precipitation, the assimilation requires an advanced forward radiative transfer models with the state vectors as inputs (Weng and Liu 2003). The assimilation of rain-affected microwave radiances requires the development of a fast RT model (Bauer 2002; Moreau et al. 2002) that accounts for scattering effects due to raindrops and ice particles.

Sensitivity study to test impacts of the raindrop and ice particle scattering with the real data from Hurricane Isabel (2003) is performed. It is found that the temperature retrieved without precipitation scattering have a very cold (<-12^{o}C) anomalies within the eyewall, which is physically unreasonable (not shown). Once the scattering model is used, the retrieved temperature is improved (not shown). The upper level warm core is about 12^{o}C, which is reasonable for a category 5 hurricane with 922 hPa minimum central pressure. The lower level cooling structure within the hurricane eyewall is reduced. So it is important to treat the precipitation

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scattering effects in order to improve temperature structure in cloudy and precipitation regions.

4DVAR Assimilation System: The Pennsylvania State University–National Center for Atmospheric Research (PSU–NCAR) mesoscale forecast model version 5 (MM5) and its adjoint system are used in this study (Zou et al. 1998). The cost function from AMSU and AMSR-E satellite observations, and can be expressed as:

$$J_o(X) = \sum_{t_x} \sum_{i,j \in R} (H(T) - T_{obs})^T W_T (H(T) - T_{obs}) + \sum_{t_y} \sum_{i,j \in R} (H(V) - V_{obs})^T W_V (H(V) - V_{obs})$$

where *Tobs and Vobs* are the AMSU temperature and AMSR-E SSW; *T and V* are the model analysis fields. H is the operator used to transform the model girded analysis fields to observation points. The t_x *and* t_y are the satellite observation times within the 4DVAR assimilation window, and R represent the cloud-affected microwave radiances region where the satellite data is assimilated. *R* is defined as the region where satellite retrieved cloud water path (*CLW*)> 0.3 mm. The strategy for defining R means that only satellite observations near hurricane core region are assimilated. The background fields (GDAS data) in the hurricane environmental region will not be changed because AMSU and AMSR-E data are already assimilated under clear sky condition. The W_T and W_V are the empirically determined diagonal weighting matrices for AMSU temperature and AMSR-E SSW data.

3. CASE STUDY

The hybrid variational (HVAR) scheme is applied in creating hurricane model initial vortices in 2005 hurricane season to examine the effectiveness of the scheme. In the following, we present some analysis results for Hurricane Katrina. The NHC official track forecasts issued within about two and half days of Katrina's second landfall were very accurate. However, the 3 and 4-day track forecasts issued between 25 and 26 August had relatively large errors. The errors were associated with the southwestward motion during the Katrina's first landfall, which is mainly attributed to the difficulty of upper level northeasterly flow. The official intensity forecast errors were considerably larger than the Atlantic 10-year average, especially during the rapid intensification period from 26 to 28 August. Therefore, we select 0600 UTC 25 August as the analysis time to examine the improvement for hurricane initial vortex by HVAR scheme. At 0600 UTC 25 August, Katrina was at tropical storm intensity with the minimum central pressure of 997 hPa. Figures 2a and b compare GDAS analysis temperature field near 250 hPa with HVRA analysis field. It is shown that the hurricane warm core temperature is increased for about 1.5 degree in the new vortex. In associated with the enhanced warm core, the upper level divergent winds and northeasterly flow near storm center are also increased. Near model surface level (Fig. 2c and d), the HVAR analyzed temperature field shows asymmetric distributions, with a 2 K cooling rainband at northeastern side, which is consistent with the deep convections shown on NOAA-17 satellite AVHRR channel 4 image (not shown).

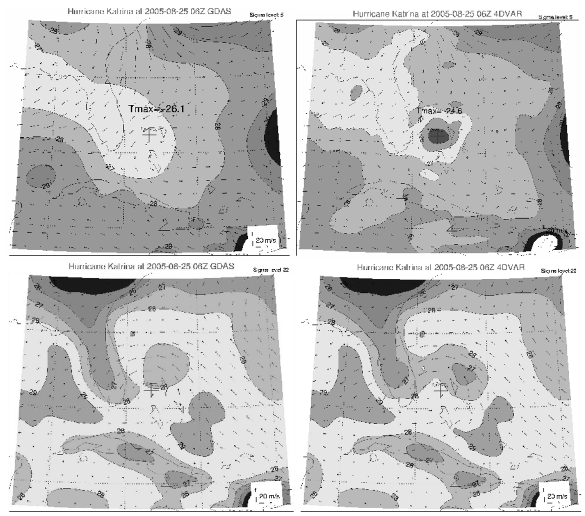

Fig. 2. Atmospheric temperatures and wind vectors at 250 hPa from (a) GDAS, (b) HVAR analysis, at surface from (c) GDAS analysis and (d) HVAR analysis at 0600 UTC 25 Aug 2005.

4. SUMMARY AND CONCLUSIONS

According to the impact study, it is found that HVAR can effectively assimilate the AMSU cloudy radiances and produce large positive impacts on hurricane upper warm core structures and therefore upper level divergence. HVAR effectively assimilates the AMSR-E cloudy radiances and improves lower level wind circulation. HVAR also develops reasonably asymmetric structures of hurricane mass and wind fields. HVAR generates well-balanced atmospheric fields and allows a smooth start for numerical model forecast with significant reduction in model spin-up time. More case study results will be given in the presentation.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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