Tropical Cyclone Applications of NPOESS Soundings*

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INTRODUCTION

Tropical cyclones (TCs) form and move over the tropical and subtropical oceans where in situ measurements are scare. When supplemental observations from storm environments, such as the GPS soundings from the NOAA Gulfstream IV (G-IV) jet aircraft, are assimilated into TC models the track forecasts improve (Aberson 2002). This result indicates that the TC environment is not adequately sampled. The temperature and moisture soundings from the ATMS and CrIS on NPOESS will be very valuable for TC analysis. In this study AIRS/AMSU retrievals are used to demonstrate three tropical cyclone applications of NPOESS soundings. These include (1) analysis of the storm thermodynamic environment, (2) intensity estimation from eye soundings, and (3) wind structure analysis.

SOUNDING DATABASE

Version 4.0 AIRS/AMSU retrievals were obtained from the AIRS Science Team (2007) for cases from 2002 to 2005 for which there were matching soundings from the NOAA G-IV jet aircraft to be used as ground truth (Table 1). The AIRS and GPS soundings were required to be within 5 hours and 100 km of each other. Figure 1 shows two AIRS granules and the locations of the GPS soundings for a typical case, and Fig. 2 shows an example of matching AIRS and GPS soundings.

Storm Name	Year	# Matching Soundings
Lili	2002	158
Fabian	2003	24
Isabel	2003	94
Ivan	2004	145
Emily	2005	43
Irene	2005	37
Katrina	2005	138
Ophelia	2005	81
Rita	2005	52
Wilma	2005	88
Total	02-05	860

Table 1. Number of cases with matching AIRS and NOAA Gulfstream Jet soundings

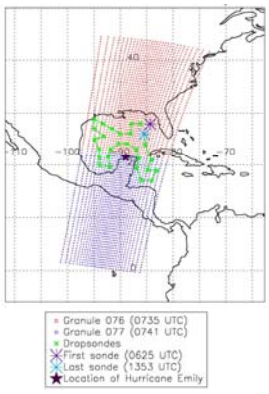

Figure 1. AIRS granules and locations of GPS soundings from a synoptic surveillance mission of the NOAA G-IV Jet on 18 July 2005 for Hurricane Emily.

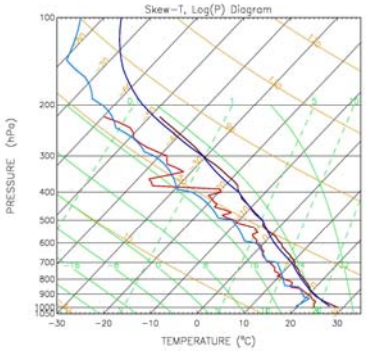

Figure 2. Temperature and dew point temperature soundings from a matching set of AIRS (dark blue, light blue) and GPS (brown, red) soundings from the environment of Hurricane Katrina on 24 August 2005.

ANALYSIS OF THE STORM ENVIRONMENT

The NPOESS soundings will be valuable for analyzing the thermodynamic properties of the storm environment, which is important for prediction of tropical cyclone formation and intensity change. As a first test of the utility of the soundings, the mean absolute error (MAE) and bias of the AIRS temperature and dew point temperature retrievals for the matching cases were calculated (Fig. 3). Results show that the retrievals are accurate enough to provide useful thermodynamic information. The temper-ature has a low bias and errors generally less than 2 °C. The dew point errors are a little larger and have a slight moist bias . These errors are larger than those found for AIRS retrievals evaluated over global domains (e.g,. Suskind, et al 2003), which may be related to the higher moisture content and increased cloudiness in the hurricane environment. The next step is to stratify the soundings by the retrieval quality control flags and compare the results with soundings from global model analyses to evaluate the "value-added" information.

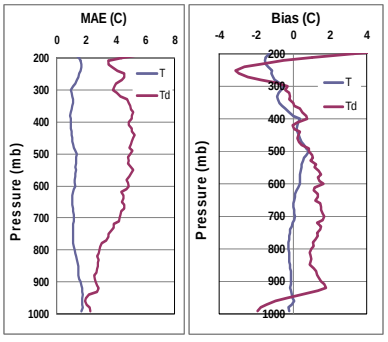

Figure 3. Mean absolute error (left) and bias (right) of the AIRS temperature and dew point temperature retrievals using the GPS soundings from the NOAA G-IV Jet as ground truth.

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HURRICANE EYE SOUNDINGS

The AIRS Science Team cloud mask algorithm routinely blocked out the area near the storm center, even in cases where there was a fairly clear eye. Special versions of the AIRS/AMSU retrievals were obtained from C. Barnet of NESDIS/StAR that included all soundings for a few selected cases to study hurricane eye soundings. Six soundings from two storms (Lili in 2002 and Isabel in 2003) were investigated. Figure 4 shows IR imagery for these six cases. Lili was a fairly small storm while Isabel was a large storm.

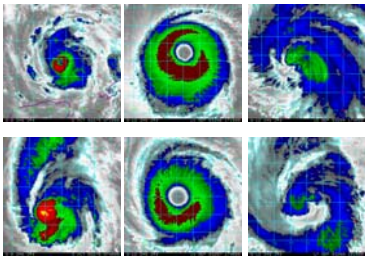

Figure 4: Enhanced IR imagery for six cases with hurricane eye soundings. Hurricane Lili(2002) cases are in the left column and Hurricane Isabel (2003) cases are in the center and right columns.

Using a boundary condition from the NCEP GFS model at 100 hPa, the hydrostatic equation was used to integrate the AIRS eye soundings downward to the surface to estimate the surface pressure. Figure 5 compares the retrieved minimum sea level pressure estimated from the AIRS retrievals and those observed from aircraft reconnaissance. The Isabel cases were very accurate. The Lili cases were less accurate due to the small eye. The ATMS and CrIS will have improved horizontal resolution compared with AIRS and AMSU, so the eye soundings from NPOESS should be very useful for large to moderate sized storms.

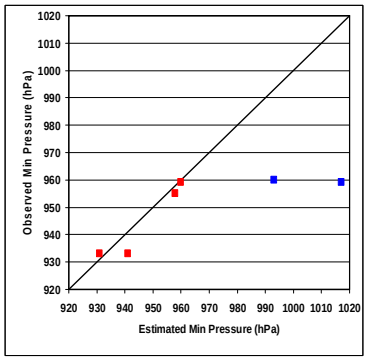

Figure 5: Comparison of the minimum sea level pressure (MSLP) estimated by hydrostatic integration of AIRS/AMSU soundings with the observed MSLP from aircraft observations for Hurricane Isabel and Lili.

WIND STRUCTURE ANALYSIS

The retrievals map the three dimension structure of the temperature and moisture fields. Through a downward integration of the hydrostatic equation the pressure field can be estimated. Using the nonlinear balance equation, the wind field can be then be determined from the pressure gradient (Bessho, et al 2006). This technique has been applied to AMSU soundings from the NOAA POES satellites, and is being adapted to the AIRS/AMSU retrievals. Figure 5 shows an example of the 850 hPa wind field retrieved from this technique. Surface winds can be estimated from the 850 hPa winds using a boundary layer model. Given the improved resolution of the ATMS and CrIS on NPOESS, this technique will provide valuable information about the TC outer wind structure.

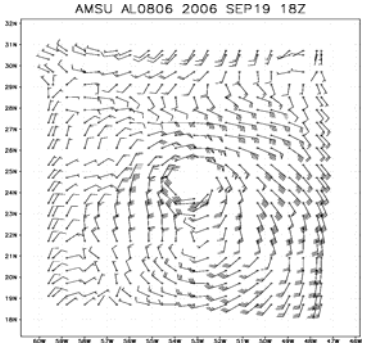

Figure 6. Nonlinear balance winds at 850 hPa from AMSU soundings for Hurricane Helene (2006).

FUTURE PLANS

The storm environment retrieval analysis will continue by stratifying the cases by the quality control flags. The corresponding soundings from the NCEP GFS model analysis will be evaluated against the GPS soundings to determine if the AIRS/AMSU retrievals are providing additional information. The retrievals will also be used as input to a simple Lagrangian cloud model to further investigate their information content. The hurricane eye sounding and wind structure studies will continue by analyzing additional cases. These algorithms will also be tested in real time when data from the NPOESS Preparatory Project (NPP) becomes available.

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