12A.5 TROPICAL CYCLONE INTENSITY ESTIMATION USING THE NOAA-KLM ADVANCED MICROWAVE SOUNDING UNIT (AMSU): PART I -- INITIAL FIELD TEST AND LESSONS LEARNED

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1. INTRODUCTION

This paper discusses the results of an independent test of a new method to estimate tropical cyclone (TC) intensity from NOAA polar-orbiting satellite AMSU information. The technique was developed jointly by scientists from USAF/UW-CIMSS/USN, and is described in detail by Brueske and Velden, 2002. Briefly, AMSU-A 54.9GHz (Channel 7) limb-corrected brightness temperatures (Tb7) reflect upper-tropospheric temperature (warm) anomalies in TC cores. The measured anomalies (dTb7) are used to estimate TC minimum sea level pressure (MSLP) using linear least squares regression coefficients developed from a large sample of storms in 1999/2000 (n=64) in which AMSU-A dTb7 and in situ MSLP observation pairs were collocated in time.

Two sets of AMSU-based TC MSLP estimates were produced in 2001 using a fully automated, objective processing scheme. The first set estimated TC MSLP using raw dTb7 values and regression coefficients whereas the second scheme produced TC MSLP estimates using retrieved dTb7 values and regression coefficients. In theory, the latter should be 'better' owing to the author's explicit characterization and removal of AMSU-A instrument related TC warm anomaly (UTWA) subsampling and diffraction effects discussed by Merrill (1995). The 2001 independent test results suggest that the Merrill method adds-value to the TC intensity estimation process possible provided that (1) precise TC position and eye size estimates are available at the time of AMSU observation/algorithm execution, and (2) true TC UTWA peak warming occurs within the layer sensed by the AMSU-A 54.9GHz channel. The former issue can be addressed using multi-sensor satellite analysis (visual or quantitative) and/or aircraft/radar estimates. The latter issues can be addressed using multiple AMSU channels, which is the focus of Part II of this study (paper 12A.6 in this volume).

2. RESULTS

In 2001, AMSU-based MSLP estimates were generated for 72 TCs (7 eastern Pacific (EPAC) and 65 Atlantic (ATL) basin) with the results summarized in Table 1.

	Raw	Ret	Ret+ ATCF	Ret (weak)
Mean	10.4	11.5	8.7	5.6
Std Dev	11.1	12.3	7.1	4.1
n	72	72	72	53

Table 1. Independent test errors (hPa) for 2001. AMSU MSLP estimates generated using raw 54.9GHz AMSU-A limb corrected brightness temperature anomalies (Raw = $dTb7_{raw}$), retrieved anomalies (Ret = $dTb7_{ret}$), retrieved anomalies using ATCF eye size information (Ret = $dTb7_{ret}$+ATCF), and retrieved anomalies for weak (<980hPa) TCs (Ret = $dTb7_{ret}$).

Intensity estimates using raw AMSU-A dTb7 observations ($dTb7_{raw}$) marginally outperformed those derived from scan geometry/diffraction corrected dTb7 values ($dTb7_{ret}$) for several reasons. First, as discussed in Part II of this study (12A.6), peak upper tropospheric warming often occurred at levels other than AMSU-A 54.9GHz used by the regression equations to predict MSLP. An example of this is provided in Fig.1 for Hurricane Michelle. MSLP estimates for Michelle derived from $dTb7_{ret}$ were systematically higher than reconnaissance observations during the period when raw AMSU-A 55.5GHz (~150hPa) brightness temperature anomalies ($dTb8_{raw}$) exceed $dTb7_{raw}$ values. Another factor limiting automated retrieval performance was the inability to estimate eye size using AMSU-B 89GHz water vapor window channel radiance data for compact TCs. For example, during peak intensity, Juliette (EPAC) and Iris (ATL) had eye sizes less than 10nm (18km) diameter exceeding even the most optimal horizontal resolution of AMSU-B 89GHz (16.3km at nadir) under ideal viewing conditions.

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Analysis also suggests that degradation of AMSU-B 89GHz horizontal resolution for less compact TCs

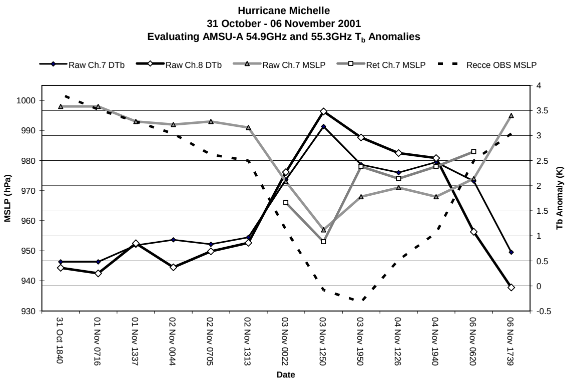

Figure 1. A comparison of reconnaissance and AMSU-based MSLP estimates derived from raw ($dTb7_{raw}$) and retrieved ($dTb7_{ret}$) brightness temperature anomalies for Hurricane Michelle. During a period of maximum intensity between 00UTC 02 Nov to 20UTC 04 Nov 2002, raw 55.5GHz anomalies ($dTb8_{raw}$) are greater than those used by the retrieval.

located near the scan swath limb may suffer from poor automated eye size estimates as well. Finally, due to the sensitivity of the retrieval to TC position, errors in the linear extrapolation of TC position between forecast center initial position at time (t_o) and AMSU observation time (t) lead to inaccuracies in the antenna gain/first guess warm core structure forward model which ultimately degrade MSLP estimate performance.

3. ANALYSIS

Owing to the relatively poor performance of the automated retrieval ($dTb7_{ret}$) versus MSLP estimates generated from using raw AMSU-A radiance anomalies ($dTb7_{raw}$), a study was performed to determine the impact of improved eye size estimates on retrieval performance using ancillary eye size information provided by Automated Tropical Cyclone Forecast (ATCF) records. As indicated by $dTb7_{ret}$+ATCF values in Table 1, the availability of ATCF eye size estimates (albeit subjective) improved retrieval performance with $dTb7_{ret}$+ATCF-derived MSLP estimate mean error and variance less than both $dTb7_{ret}$ and $dTb7_{raw}$-derived values. For less intense TCs (i.e., observed MSLP values less than 980hPa), AMSU estimates performed quite admirably with mean error and variance values of 5.3hPa+/-4.6hPa respectively without the assistance of ancillary eye size information.

The need to explicitly account and correct for AMSU-A upper tropospheric warm anomaly subsampling effects is well illustrated by Hurricane Juliette (Fig. 2). Juliette's compact warm core was largely unresolved by AMSU-A upper tropospheric channels. As a result, automated $dTb7_{ret}$ and $dTb7_{raw}$-derived MSLP were substantially higher than reconnaissance observations. The absence of automated $dTb7_{ret}$ -derived MSLP estimates on 26 September is due to the Juliette's position on the outer-most edge of the scan swath. Under these circumstances, the retrieval is not run due to the difficulty of determining realistic eye size estimates from AMSU-B 89GHz radiance data. Once again, incorporation of improved ATCF eye size information dramatically improved $dTb7_{ret}$-derived MSLP estimate values and overall representativeness of the true intensity and intensity trends. Furthermore, evidence also suggests that peak upper tropospheric warming was better represented by dTb8 – information that was unavailable to the single-channel form of the retrieval algorithm in 2001.

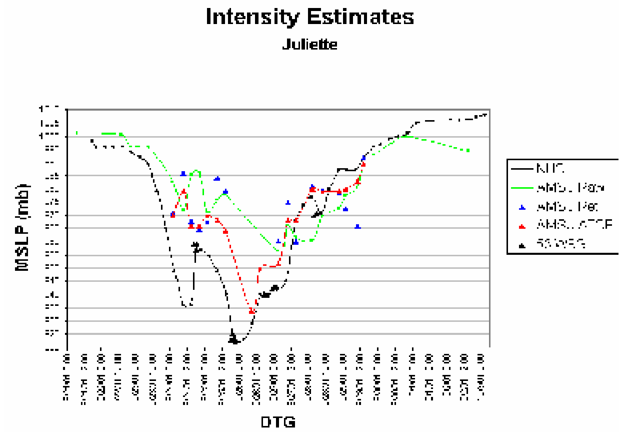

Figure 2. A comparison of AMSU, NHC/TPC intensity estimates with reconnaissance observations for Hurricane Juliette, 21 Sep-03 Oct 2001.

4. SUMMARY AND CONCLUSIONS

In summary, the 2001 independent test results of the AMSU intensity estimation algorithm suggest that an automated, objective satellite-based passive microwave technique can provide additional, value-added TC intensity estimate information capable of supplementing multi-spectral geostationary techniques provided that accurate TC position and eye size information are available to the retrieval algorithm in near real-time. In the event that the aforementioned preconditions aren't satisfied, improvements are possible through the incorporation of superior position and eye size estimates using available ancillary information. The latter issues, as well as the incorporation of AMSU-A 55.5GHz radiance information (dTb8) into the retrieval, will be addressed prior to algorithm use during the upcoming 2002 northern hemisphere season.

Merrill, R.T., 1995: Simulations of Physical Retrieval of Tropical Cyclone Thermal Structure Using 55 GHz-Band Passive Microwave Observations from Polar-Orbiting Satellites. *J. App. Meteor.*, **34**, 774-787.

Brueske, K.F., and C.S. Velden, 2001: Satellite-based tropical cyclone intensity estimation using the NOAA-KLM series Advanced Microwave Sounder Unit (AMSU). *Preprints, 11th Conference on Satellite Meteorology and Oceanography*, 1-15 October, 2001, Madison, WI, AMS, 228-233.