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TROPICAL CYCLONE INTENSITY ESTIMATION USING THE NOAA-KLM ADVANCED MICROWAVE SOUNDING UNIT (AMSU): PART II: A MULTI-CHANNEL APPROACH

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1. INTRODUCTION

As discussed in Part I, upper-tropospheric brightness temperature anomalies observed by the AMSU-A 54.9 GHz channel (dTb7) in tropical cyclone (TC) cores are used to estimate intensity (minimum sea-level pressure (MSLP)). This technique assumes the maximum TC warming is adequately captured by emission from this single channel. However, the variance in this single channel approach suggests this assumption may not hold. Therefore, a second AMSU-A channel (55.5 GHz, peak radiance contributions just above the 54.9 GHz channel)) was examined in order to determine its possible contribution toward improving the existing single-channel algorithm.

In this study, a statistical relationship was derived between observed 55.5 GHz brightness temperature anomalies in TC cores and corresponding in situ measurements of MSLP. Cases from 1999 and 2000 were used to derive the relationship (linear regression). This paper discusses how this information can be integrated into a multi-channel algorithm and the results of applying that algorithm to an independent sample of TCs from 2001. Qualitative applications of the multi-channel analysis are also briefly described.

2. BACKGROUND

Both AMSU-A channels are located in a strong oxygen absorption band of the microwave spectrum. While the peak in radiance contributions from the 54.9 GHz channel corresponds approximately to 250 hPa, the 55.5 GHz channel peaks higher at approximately 130 hPa. There are primarily two reasons why TC warm anomalies are not always fully observed in the 54.9 GHz channel (even after the corrections outlined in Part 1). The first reason is fairly straightforward: the strongest warming often occurs elsewhere in the column (not near 250 hPa). Secondly, strong convection near the storm center may be attenuating (cooling) the 54.9 GHz radiances. By examining a channel which senses higher up in the storm environment, some of the warming occurring above ~250 hPa will be independently accounted for. This information will be particularly useful if the maximum TC warming which is occurring is displaced above 250 hPa. In addition, precipitation contamination effects become increasingly rare in the higher frequency channel.

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The single-channel TC intensity estimation algorithm described in Part I produces both 'raw' and 'retrieved' (corrected for scan geometry) MSLP estimates. This study focuses only on the former by incorporating 55.5 GHz channel limb-adjusted brightness temperature anomalies (dTb8). No corrections are attempted for convolution of the radiances with the antenna gain pattern and scan geometry (Brueske and Velden 2002).

3. DATASET AND METHODOLOGY

During the 2001 TC season, TC core brightness temperatures for each channel were obtained for 817 satellite passes over 49 TCs covering 4 TC basins. Table 1 shows the frequency of dTb8>dTb7 (55.5 GHz core temperature anomaly greater than the traditional 54.9 GHz core temperature anomaly), an obvious indicator of the 54.9 GHz channel under-sampling the maximum warm core anomaly. Nearly 30% of all passes met this condition. These results indicate a clear need for a two-channel approach to account for these situations.

	All	ATL	EPAC	NWPAC	SH
n	817	245	170	350	52
n of dTb8>dTb7	242	40	48	144	10
% dTb8>dTb7	29.6	16.3	28.2	41.1	19.2

Table1: Frequency of maximum TC core warming captured in the 55.5 GHz channel relative to the 54.9 GHz channel. n = number of cases. ATL-Atlantic basin, EPAC-Eastern Pacific basin, NWPAC-North Western Pacific basin, SH-Southern Hemisphere basin.

In an attempt to derive a multichannel approach, 49 AMSU passes from 1999 and 2000 were collected and used to develop new TC intensity relationships. TC core brightness temperature anomalies were extracted from the 55.5 GHz channel for each satellite pass and correlated with observed MSLP's. Linear regression coefficients were developed and used in conjunction with existing 54.9 GHz channel coefficients to estimate MSLPs on an independent data set of 64 cases from 10 TCs in the ATL and EPAC basins during 2001. The new algorithm can be described as follows: for cases in which dTb7>dTb8 (n=45), MSLPs were calculated using the existing algorithm's single channel approach; for cases in which dTb8>dTb7 (n=19), the new coefficients based on the 55.5 GHz channel relationship were invoked.

4. RESULTS

Table 2 shows comparative results between the single (current) and dual-channel (new) approaches.

Ch 7: 54.9 GHz *Ch 8: 55.5 GHz*	dTb7>dTb8 only	Current algorithm	Applying new algorithm
n	45	64	64
Mean Error (hPa)	8.6	11.1	9.9
Std Deviation (hPa)	8.1	11.1	10.0

Table 2: Algorithm performance during 2001. Isolating the cases where stronger warming was observed in Channel 7 (col. 1) shows how performance is degraded when cases where Channel 8 warming is stronger are included (col. 2). Using both channels improves algorithm performance (col.3).

Incorporating the information from Channel 8 reduces mean error by 1.2 hPa and standard deviation by 1.1 hPa. Included in this dataset are 14 passes over Hurricanes Iris (ATL) and Juliette (EPAC), which had extremely compact eyes on the order of 10-15 km diameter. With a maximum horizontal resolution of 48 km, the AMSU instrument cannot possibly capture the full magnitude of the true TC warm anomaly. As a result, severe sub-sampling occurs in both channels. Table 3 shows the algorithm performance without these cases. The performance of the new dual-channel algorithm improves considerably against the results in Table 2, and this suggests that "small-eye" storms are not suitable as candidates for this method.

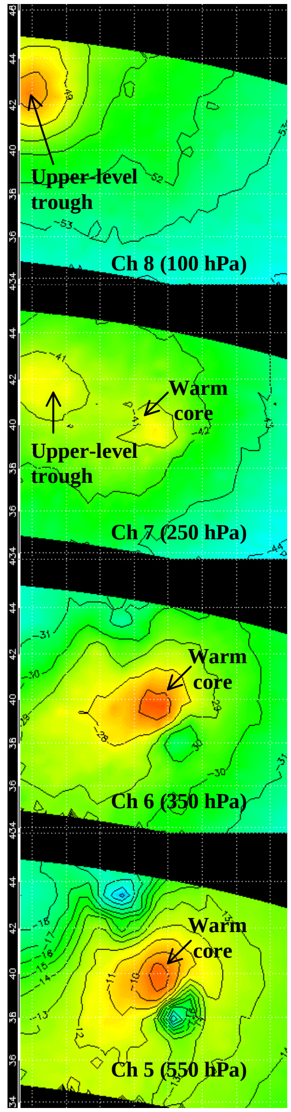
Ch 7: 54.9 GHz *Ch 8: 55.5 GHz*	Current algorithm	Applying new algorithm
n	50	50
Mean Error (hPa)	8.7	7.3
Std Deviation (hPa)	7.2	5.3

Table 3: Same as Table 2 excluding "small-eye" cases during Hurricanes Juliette and Iris.

5. QUALITATIVE ANALYSIS

In addition to quantitative MSLP estimates, it is possible to utilize the AMSU observations to capture elements of TC characteristics not immediately apparent in IR or VIS imagery. Deep-column convective bursts of mixed phase hydrometeors (commonly found in TC eyewalls) can strongly attenuate upwelling radiation sensed in AMSU-A Channels 5-7. This will lead to 'apparent' radiance cooling, which then can have the effect of reducing the resolvable TC core warming. Diagnosing this precipitation contamination is key in explaining (and correcting for) erroneously weak MSLP estimates in certain situations. An example is shown in Figure 1.

Another potential application is the ability of AMSU to capture a transitioning TC to an extra-tropical cyclone. Figure 2 depicts Hurricane Cindy's (1999) impending interaction with an approaching upper-level trough (signified by the warm anomaly from the accompanying tropopause undulation). The TC warm core and trough baroclinicity are becoming juxtaposed.



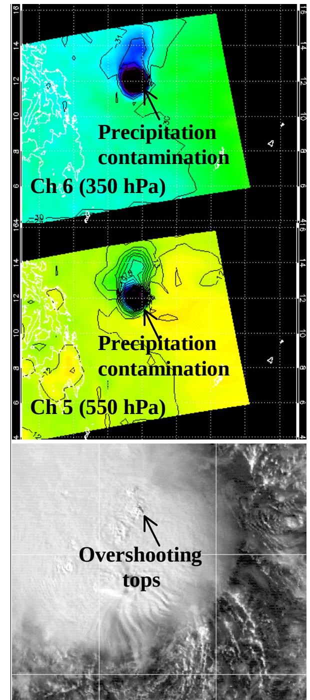


Figure 1 (above): Precipitation contamination from overshooting tops in Tropical Storm Tapah (01W) 11 Jan 2002.

Figure 2 (left): Transition of Hurricane Cindy to an extra-tropical system on 31 Aug 1999. Evidence of a tropopause undulation associated with an approaching mid-latitude trough appears in Channels 7 (54.9GHz) and 8 (55.5 GHz).

6. CONCLUSIONS

Clearly, a multi-channel AMSU approach to TC intensity estimation offers additional information over one based solely on the AMSU-A 54.9 GHz channel. The results of this preliminary study show the potential to improve MSLP estimates. Multi-channel AMSU analysis also offers unique views into the thermodynamic structure of TC's. Future work will be focussed on the explicit treatment of precipitation effects and inclusion of other AMSU channels into a multi-channel technique for deriving 'retrieved' MSLP's as described in Part I.

7. REFERENCES

Brueske, K.F. and C. Velden, 2002: Satellite-based TC intensity estimation using AMSU. Accepted in Mon. Wea. Rev.