P4.1 CONSENSUS ESTIMATES OF TROPICAL CYCLONE INTENSITY USING MULTISPECTRAL (IR AND MW) SATELLITE OBSERVATIONS

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1.0 Introduction

Accurate analysis of a Tropical Cyclone's (TC) current intensity is a critical part of assessing short-term intensity changes. The Dvorak Technique (DT), based on visible and infrared (IR) imagery, has traditionally been the primary satellite-based method for this task. However, the DT is at times subjective, resulting in conflicting estimates between different analysis agencies. TC analysts are often faced with the job of reconciling these disparate estimates and assimilating them with information from a variety of other sources when attempting to determine the current intensity of a TC. Objective satellite-based TC intensity estimate tools now used in this process include the CIMSS Advanced Dvorak Technique (ADT), along with the CIMSS and CIRA Advanced Microwave Sounding Unit (AMSU) methods. Trained analysts give more emphasis to one method or another based on personal experience and/or past performance of the method; however the process can vary from one analyst to the next. It is desirable to have an objectively-based tool that can produce situational guidance to analysts in determining how much emphasis to give each method.

Research at CIMSS has been directed toward the development of a fully automated and objective method designed to provide estimates of current TC intensity from a weighted consensus of objective satellite-based techniques. In this paper we introduce the SATCON (SATellite CONsensus) algorithm, and present first results on its performance during the 2005 Atlantic TC season.

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2.0 SATCON: Satellite Consensus Algorithm

The development of a consensus scheme began with a simple linearly-averaged consensus of estimates from the ADT, CIMSS AMSU and CIRA AMSU, based on 100s of cases from the 2001-2004 Atlantic TC seasons when reconnaissance ground truth was available. This simple consensus approach was found to be slightly superior in skill to the individual member estimates. As a further step, we sought to identify the conditions or situations under which each method performs the best, as often when one method performs poorly another method may excel. Each of the methods has unique error characteristics attributable to the input parameters for the respective techniques. For example, the ADT, which operates on IR observations, performs best in mature TCs when there is a clear eye, but not as well in less-organized developing systems (Olander and Velden, 2006). The CIMSS AMSU-based method (Herndon and Velden, 2004) employs microwave (MW) radiances and performs well for cases where the TC core (upper-level warm anomaly) is comparable in size or larger than the AMSU field of view (FOV, ~50km at nadir) used to produce the estimate. However, the performance deteriorates in cases when the center of the TC is near the edge of the scan swath and/or the eye size is small. CIRA's AMSU retrieval method (DeMuth et al. 2005) also suffers from sub-sampling issues related to storm core size but performs well when the area-averaged cloud liquid water (CLW) in the TC core/eye is low (< 1.0 mm).

Using various performance metrics for each of the three above methods over a wide range of TC intensities and scenarios (based on 100s of cases vs. reconnaissance minimum sea-level pressure verification), a consensus scheme was developed to weight each method according to its expected performance in a given scenario. For example, an error analysis of the ADT revealed that performance could depend on the scene type employed. Those scene types that produced similar error characteristics were binned together and confidences assigned according to the bins.

In regards to the CIMSS AMSU method, the most important input parameter is the radius of maximum winds (RMW), which is used as a proxy for the warm core size, and will act to adjust the estimate up/down when the eye is larger/smaller than the AMSU FOV. When a clear eye is present the ADT is used to estimate the RMW. The CIMSS AMSU method uses this value when it is available. The second RMW source is the value entered into the operational ATCF files by the responsible forecast center. Confidences in the estimates are highest when the RMW source is from the ADT and the eye is well resolved by the AMSU FOV.

While the CIRA and CIMSS AMSU methods share some common sources of error since they are based on measurements from the same instrument, the algorithms to extract intensity deviate at the processing stage. Therefore, it was possible to isolate unique error characteristics for the CIRA AMSU method. The errors were binned into two categories, those with an area-averaged (0-100 km) CLW of less than 1.0 mm and those with a value greater than 1.0 mm. The CIRA method gets more weight in cases when the CLW is less than 1.0 mm ('cleaner' retrieval of temperature profile).

The resulting weighted consensus we call SATCON. Occasionally, only two of the members of the consensus may be available. Because the CIRA and CIMSS AMSU methods are based on similar MW observations, a consensus is not performed if the ADT is missing (very rare). However, when the ADT and only one of the AMSU-based methods is available (e.g., due to differences in processing strategies), a two-member consensus can be derived. During the 2005 Atlantic season, this occurred about 25% of the time.

3.0 2005 Atlantic Season Performance

The 2005 Atlantic TC season was the most active on record and featured 15 hurricanes, including 3 of the most intense on record. For algorithm validation purposes, only cases that were sampled by aircraft reconnaissance within +/- 3-hours of the satellite estimates were used in the evaluation of MSLP estimates. To validate the maximum sustained wind (MSW) estimates, the best track MSWs coincident with reconnaissance reports were used. The results for the 3-member consensus are shown in Tables 1 and 2. On a 65-case sample from Atlantic storms in 2005, the estimates from SATCON are shown to be superior in skill to the individual method estimates. Examples of consensus estimates for Hurricanes Katrina and Ophelia are shown in Figs. 1 through 4.

(hPa)	CIMSS-amsu	CIMSS-aodt	CIRA-amsu	SATCON-consensus
Bias	-2.0	0.1	-6.2	-3.0
Ave diff	6.7	9.5	8.3	6.0
Rms diff	9.1	12.8	12.5	8.1
N	65			

Table 1. Accuracy of Minimum Sea-Level Pressure (MSLP) estimates derived from satellite-based methods compared to 3-member SATCON (weighted consensus) verified against reconnaissance aircraft-measured MSLP. Performance statistics based on 65 Atlantic TC cases in 2005 (independent test). Negative method bias indicates underestimate.

(kts)	CIMSS-amsu	CIMSS-aodt	CIRA-amsu	SATCON - consensus
Bias	0.5	-2.5	6.7	1.8
Ave diff	11.9	10.1	11.4	9.8
Rms diff	15.0	13.2	15.6	12.5
N	65			

Table 2. Accuracy of Maximum Sustained Wind (MSW) estimates derived from satellite-based methods compared to 3-member SATCON (weighted consensus) verified against best track MSW for times when reconnaissance was available. Performance statistics based on 65 Atlantic TC cases in 2005 (independent test). Positive method bias indicates underestimate.

4.0 Future Work

At times there may be a large difference between the three independent estimates. An analysis of the consensus errors compared to the consensus spread for the 2005 season revealed a robust relationship. Thus, as one might hope for, when there is little spread between the member estimates the confidence in the consensus estimate is higher than when the spread is large. This information will be further analyzed and used to assign confidence values to the consensus estimates in the future.

Estimates from other algorithms can be added to the consensus provided there is a robust statistical stratification of the algorithms input parameters (for weighting purposes). One promising addition would be a microwave imager-based method (e.g., SSMI, TRMM). Microwave imagers can provide unique information regarding the details of TC structure that the current 3 members lack. Objective methods are under development at NRL and JMA.

Issues relating to the temporal availability of SATCON (currently limited to AMSU overpass opportunities) and time lags associated with the availability of polar orbiter data will be addressed. At present, AMSU estimates of a target TC are available 4-5 times a day on average, with a nominal 2-4 hour delay after coincident ADT estimates. Projecting SATCON estimates forward in time to match the more current/frequent ADT values could help both calibrate the ADT and possibly provide more frequent time-weighted SATCON estimates.

A more complete analysis of the 2005 season results will be used to re-evaluate the weighting scheme. These results will likely also be used to improve the individual members of the consensus, leading to even more accurate estimates in the future.

5.0 References

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ACKNOWLEDGEMENTS: This research is being supported by SPAWAR PEO C4I&Space/PMW 180 under PE 0603207N

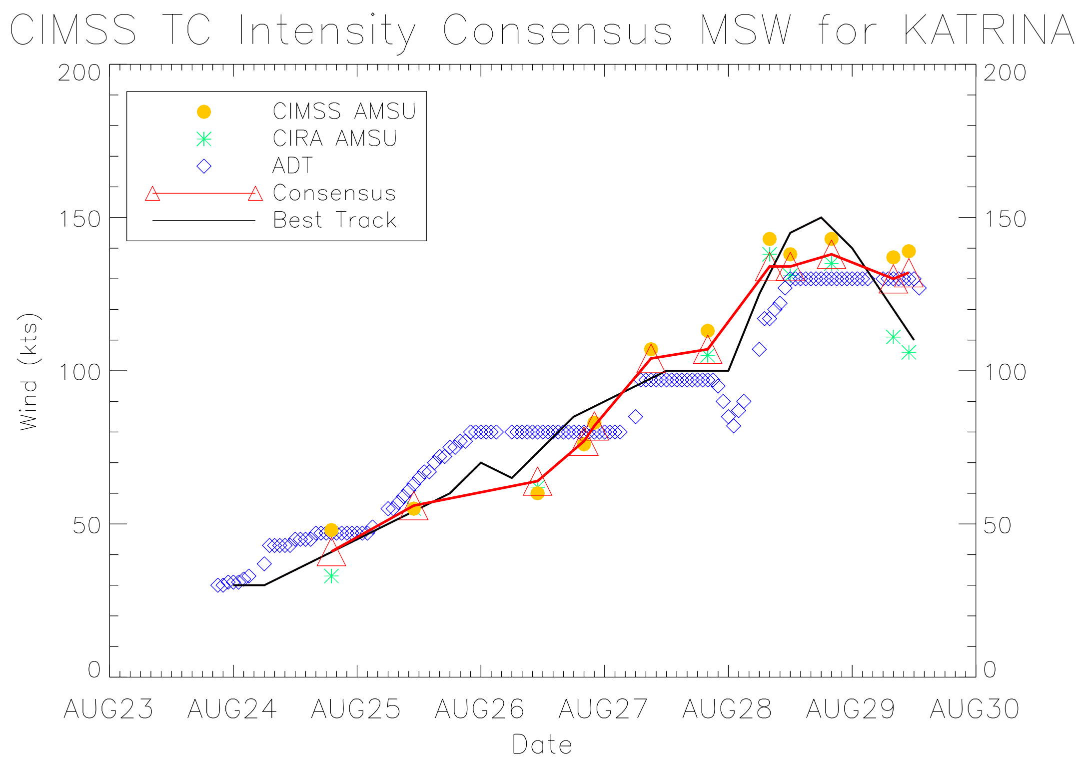

Figure 1. SATCON estimates of Maximum Sustained Winds for Hurricane Katrina. SATCON is shown in the solid red line and Best Track Winds in the black line.

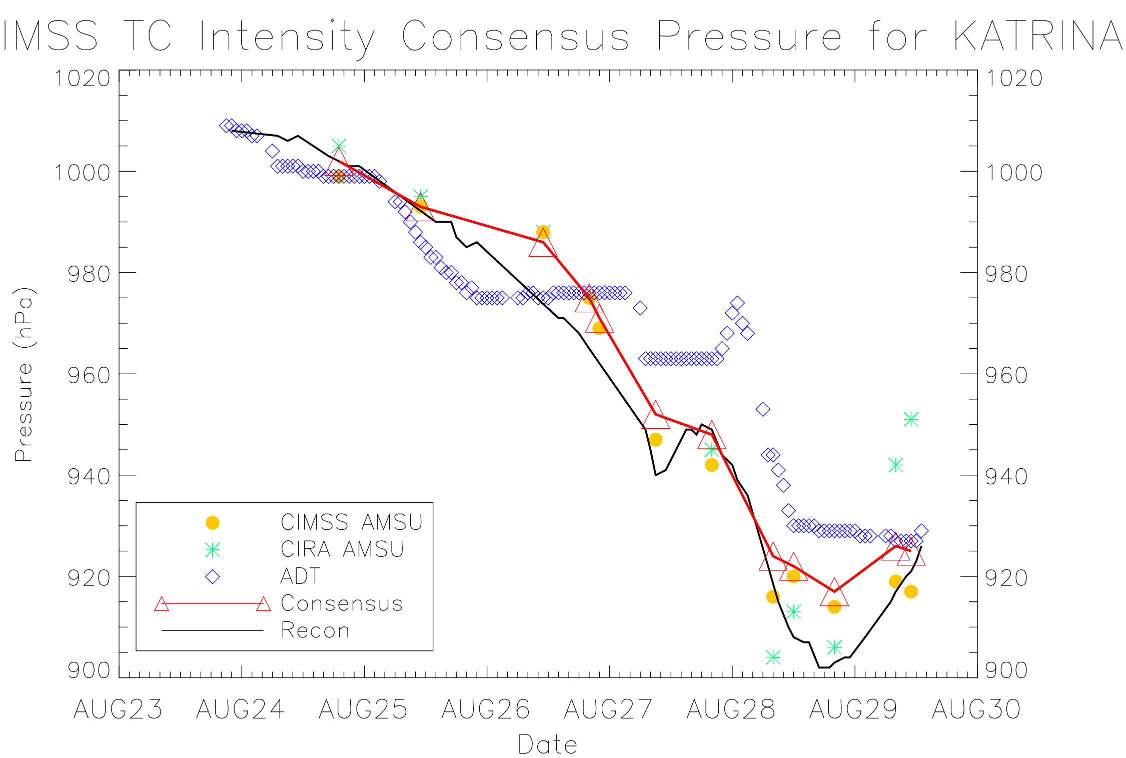

Figure 2. SATCON estimates of Minimum Sea Level Pressure for Hurricane Katrina. SATCON is shown in the solid red line and reconnaissance MSLP in the black line.

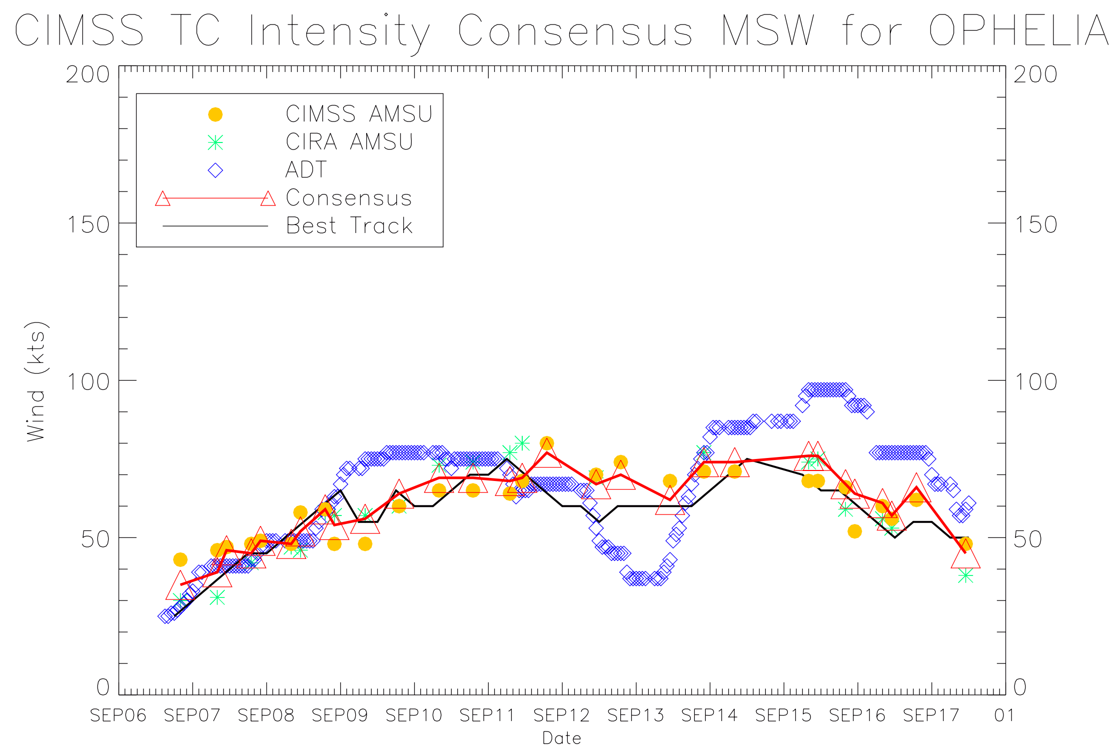

Figure 3. SATCON estimates of Maximum Sustained Winds for Hurricane Ophelia. SATCON is shown in the solid red line and Best Track Winds in the black line.

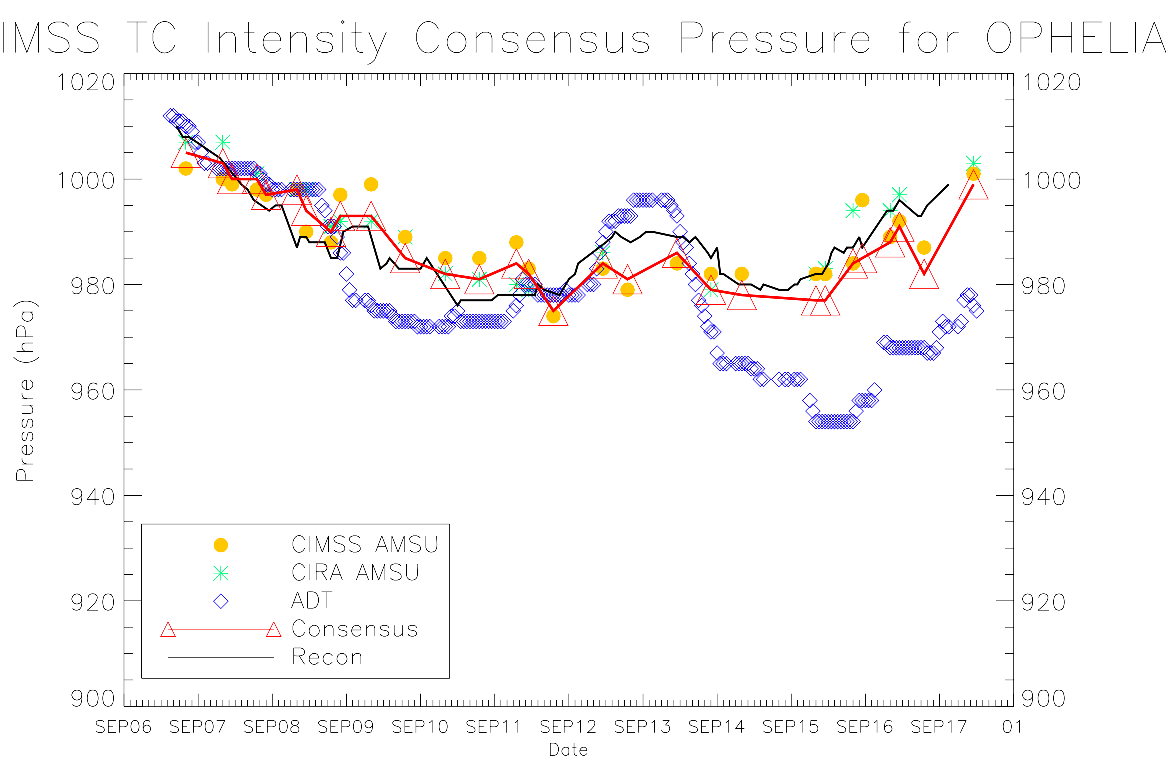

Figure 4. SATCON estimates of Minimum Sea Level Pressure for Hurricane Ophelia. SATCON is shown in the solid red line and reconnaissance MSLP in the black line.