Consensus Estimates of Tropical Cyclone (TC) Intensity using Integrated Multispectral (IR and MW) Satellite Observations

Christopher Velden[1], D. Herndon[1], J. Kossin[1], J. Hawkins[2], and M. DeMaria[3]

[1]Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin, Madison, WI

[2]Naval Research Lab, Monterey, CA

[3]NOAA/NESDIS/RAMM, Fort Collins, CO

Motivation

- An accurate current intensity analysis of a TC is a critical component of subsequent short term intensity forecasts
- Operational TC intensity is currently determined through analyst qualitative merging of subjective Dvorak and objective methods
- Goal: Assist analysts in assimilating objective satellite-based TC intensity guidance from multiple algorithms
- Objective: Combine current suite of objective satellite intensity estimates into a single estimate using weighted consensus techniques

Requirements

- Weighted consensus must be more skillful than individual members
- Weighted consensus must be more skillful than a simple average of the members
- Skill measured by comparison to ground truth +/- 3 hours of satellite-based estimate

Approach

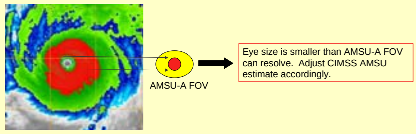
Current members of the weighted satellite consensus method (SATCON) consist of two Advanced Microwave Sounding Unit (AMSU) techniques developed at CIMSS and CIRA, and an infrared-based method -- the Advanced Dvorak Technique (ADT). Each member has documented error characteristics that are dependent on storm structure, scene type, or scan geometry. For example, the ADT performs best when a clear, well-defined eye is present in the IR. The AMSU-based methods can suffer from sub-sampling away from nadir owing to the relatively coarse (50-120 km resolution) of the AMSU instrument. Depending on the situation, these error characteristics can be used to weight each individual estimate accordingly in a consensus (ensemble) approach.

Each individual method uses a variety of parameters to produce an intensity estimate. The ADT has a number of IR parameters such as area-averaged cloud/eye temperatures. The ADT can also be used to estimate the radius of maximum winds (RMW). The AMSU methods contain information related to the magnitude of the TC warm core along with TC structure not observable from the IR. There is sharable information that SATCON can attempt to resolve to produce a superior estimate then from the individual methods alone.

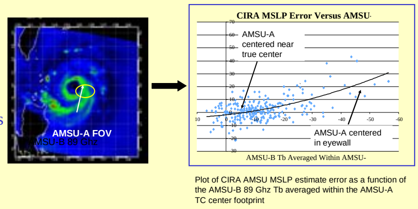
The first attempt at developing a consensus algorithm simply involved the establishment of situation-specific error characteristics for each method, and then using this information to create a member weighting scheme to produce the consensus estimate. A training data set consisting of estimates from all three members and ground truth (mostly recon reports) from 1999-2006 was assembled. This initial attempt at the weighted consensus approach yields estimates that are on average superior to the individual member estimates. Further improvements in the scheme are envisioned through more elaborate information sharing among the algorithms.

Information Sharing

ADT provides eye size information to CIMSS AMSU to correct sub-sampling



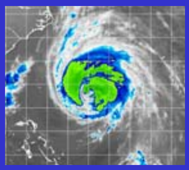
AMSU-B Tb are used by CIMSS to adjust the CIRA AMSU estimates when the AMSU-A TC center footprint location is mostly in the eyewall (as indicated by cold 89 Ghz Tb). This effect results in the CIRA estimates being too weak, so a bias correction is applied based on the figure at right.



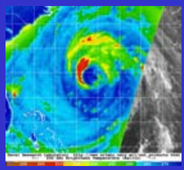
Plot of CIRA AMSU MSLP estimate error as a function of the AMSU-B 89 Ghz Tb averaged within the AMSU-A TC center footprint

An example: Hurricane Isabel 2003

Hurricane Isabel – a few days after reaching CAT 5. The IR presentation has degraded, however, 85 Ghz imagery still shows a broken eyewall. What is Isabel's current intensity?



Enhanced IR image

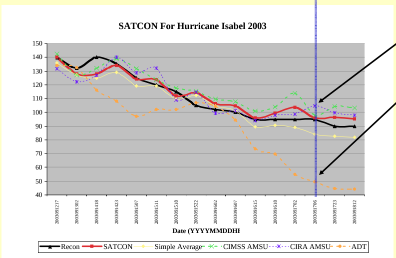


SSMI 85 Ghz

Intensity estimates (max sustained sfc wind) from various sources are:

ADT = 50 knots
CIMSS AMSU = 98 knots
CIRA AMSU = 105 knots

A simple average of these estimates yields 84 knots. Ground truth (recon) estimated the intensity at 95 knots. SATCON estimated 94 knots.



AMSU methods too strong. Isabel's eye is relatively large thus AMSU sub-sampling is less of an issue.

ADT too weak. ADT scene type is a CURVED BAND scene. ADT statistics indicate decreased performance for this scene type compared to other scene types.

SATCON uses this information. First any adjustments to the individual members are made using the information sharing. Then each estimate is a assigned a weight. For the example above the AMSU methods are given more weight in SATCON than ADT.

SATCON Performance vs. Individual Members
Validation: Coincident recon aircraft reports

Cases from 1999-2006 (MSLP, hPa)

	CIMSS AMSU	CIMSS ADT	CIRA AMSU	SATCON
BIAS	-0.3	-0.4	-2.9	-0.5
AVG ERROR	5.7	8.6	6.7	4.9
RMSE	7.5	11.7	10.3	6.9
N = 258				

Cases from 1999-2006 (MSW, knots)

	CIMSS AMSU	CIMSS ADT	CIRA AMSU	SATCON
BIAS	-3.9	- 4.9	-7.3	-1.2
AVG ERROR	8.9	12.3	11.1	7.5
RMSE	11.2	16.1	15.0	9.7
N = 258				

SATCON vs. Simple Average of Members

	SATCON MSLP	SIMPLE MSLP	SATCON MSW	SIMPLE MSW
BIAS	-0.5	-2.1	-1.2	-4.7
AVG ERROR	4.9	5.2	7.5	8.7
RMSE	6.9	7.8	9.7	11.1
N = 258				

Conclusion and Future Directions

- The SATCON weighted consensus approach yields TC intensity estimates that are more skillful than both the individual member algorithms, and a simple average of the members
- Further improvements to SATCON are being explored through the addition of new spectral information from microwave imagers, and additional information-sharing approaches

Funding Supported by Navy SPAWAR PEO C4I&Space/PMW 180 under PE 0603207N, and NOAA/NESDIS GIMPAP program