# An Update on the SATellite CONsensus (SATCON) Algorithm for Estimating Tropical Cyclone Intensity


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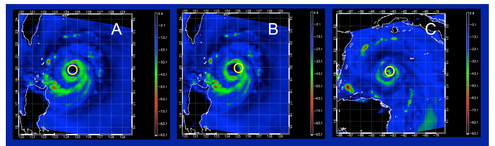
## MOTIVATION

The SATCON algorithm developed at UW-CIMSS objectively combines tropical cyclone (TC) intensity estimates analyzed from objective satellite infrared and microwave-based methods to produce a weighted consensus estimate, which is more skillful than the individual member estimates or straight averaging. SATCON can provide the TC analyst with the ability to quickly reconcile differences in objective intensity methods, and is a comparative guidance tool for evaluating various TC intensity estimates. Current members of the SATCON ensemble include the CIMSS Advanced Dvorak Technique (ADT v8.1.4), AMSU sounder algorithms from CIMSS and CIRA, and an SSMIS sounder algorithm from CIMSS. An ATMS sounder algorithm is in development.

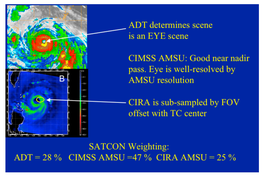
The member weights used by SATCON are derived from the quality metrics associated with intensity estimation error distributions for each individual algorithm. The performance behavior of each member can be characterized into situational bins. For example, intensity errors for the ADT depend on the objectively-determined scene type used. The microwave sounder-based methods have errors that are correlated with the sensor FOV resolution and scan geometry. These characteristics are modeled into the SATCON weighting scheme. Unique error characteristics exist for two TC intensity metrics, Minimum Sea Level Pressure (MSLP) and Maximum Sustained Winds (MSW), resulting in different SATCON weights for each metric.



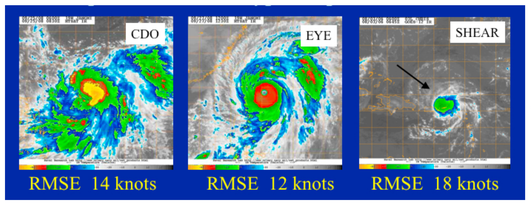

Example weighting scenarios for the AMSU and SSMIS sounder methods

$$SATCON = \frac{W_1W_2(W_1+W_2)E_3 + W_1W_3(W_1+W_3)E_2 + W_2W_3(W_2+W_3)E_1}{W_1W_2(W_1+W_2) + W_1W_3(W_1+W_3) + W_2W_3(W_2+W_3)}$$

$W_n$ = weight of method n
$E_n$ = estimate of method n




Example weighting structure



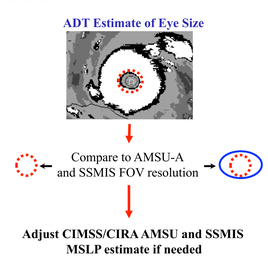

Example weighting scenarios for the ADT

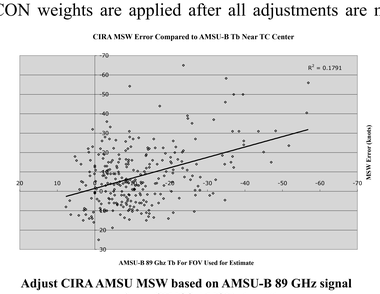
## APPROACH

The SATCON development sample consists of coincident intensity estimates from all input members. For purposes of validation, the sample only includes cases when aircraft reconnaissance was available within three hours of the SATCON estimate. This includes cases from 1999-2012 (SSMIS 2006-2012) in the Atlantic, Eastern Pacific and Western Pacific (field experiment aircraft data).

### Cross-algorithm information sharing and adjustments

Prior to producing a SATCON estimate, each individual method is evaluated to determine if information from the other members can be used to adjust that estimate. For example, eye size measurements from the ADT (when available) are used to correct the CIMSS/CIRA AMSU and SSMIS estimates of MSLP. In addition, Best Track TC size information is used as input to the SATCON pressure-wind member (discussed in Recent Upgrades section). Storm motion is added to those individual members that do not include a storm motion component (ADT and CIRA AMSU). SATCON weights are applied after all adjustments are made to the members.



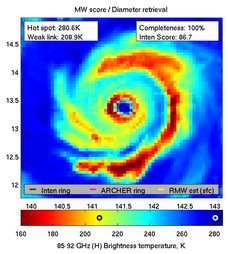




Adjust CIRA AMSU MSW based on AMSU-B 89 GHz signal output from CIMSS AMSU algorithm

## RECENT UPGRADES

• SATCON now employs interpolated intensity estimates from the microwave members in between the temporally sporadic observations (2-5 hour gaps are common from the polar-orbiting satellite sounder overpasses). These interpolated values are matched up with the routinely available 30 or 60-minute ADT estimates to produce concurrent SATCON estimates. The result is a much smoother transition between SATCON estimates, along with many more 3 and 4-member estimates.

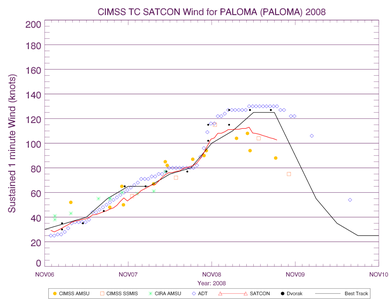
• The highly skillful SATCON MSLP estimates (RMSE = 5.4 hPa) are used to create a new member for the SATCON MSW estimate: a pressure-wind-derived MSW estimate. Eye size information from the ADT or ARCHER (see below) is used to adjust the P-W estimate. The final SATCON MSW estimate is then: 0.25*P-W_MSW + 0.75 *SATCON_MSW.

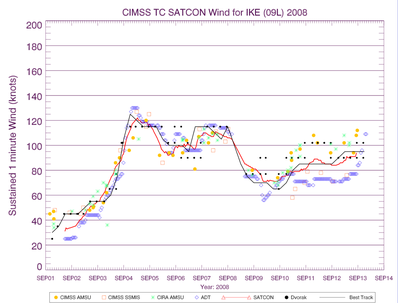


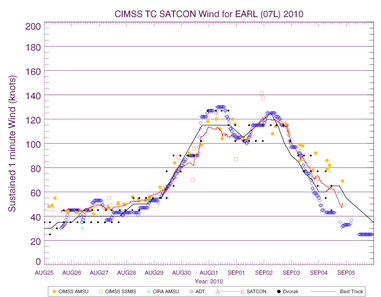

The ARCHER algorithm uses passive microwave imagery in the 85-92 GHz range to objectively estimate eye size and TC organizational/structure characteristics. Eyewall characteristics (intensity and completeness) are used by SATCON to determine any needed eye size corrections. ARCHER scores are used in the motion component logic of SATCON, and are also part of the SSMIS MSW algorithm. ARCHER is currently an integral component of the ADT v8.1.4.

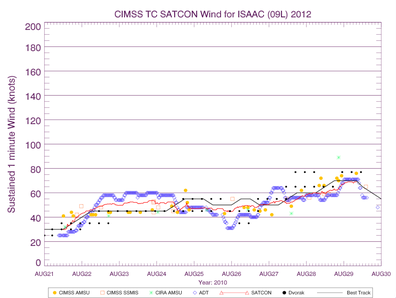
For more information on ARCHER see Wimmers and Velden, JAMC, 2010.

## EXAMPLES OF INDIVIDUAL TCs



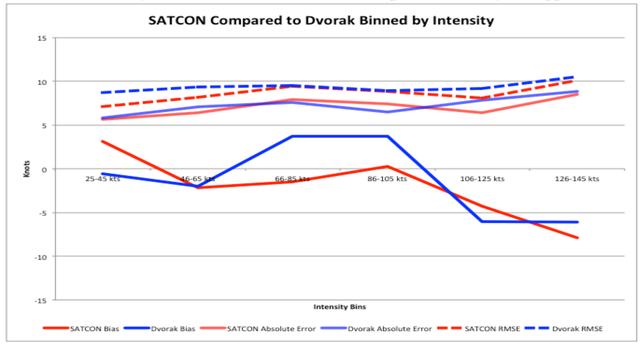




## SATCON PERFORMANCE RESULTS

| MSW (Kts) | CIMSS AMSU | CIMSS ADT | CIRA AMSU | CIMSS SSMIS | SATCON | Subj. Dvorak (Operational) |
|---|---|---|---|---|---|---|
| BIAS | -1.0 | -0.6 | -5.2 | - 0.6 | **-0.9** | 0.2 |
| AVG ERROR | 10.0 | 9.0 | 12.1 | 8.3 | **6.7** | 7.0 |
| RMSE | 12.4 | 11.6 | 16.0 | 10.5 | **8.3** | 9.2 |

Homogenous sample of N=275 matches (except CIRA AMSU=187) with NHC recon-aided Best Track estimates. "Subj. Dvorak" is the average of subjective operational Dvorak estimates from TAFB and SAB. Values are all in knots. Errors can be reduced further by combining SATCON and Subj. Dvorak. Based on the results below, if SATCON Vmax < 125 knots use 60% SATCON 40% Dvorak, otherwise use 50% for each. Result: Bias= - 0.3, Avg Err= 5.8, RMSE= 7.3 for the sample above using this approach.




| MSW (Kts) | CIMSS AMSU | CIMSS ADT | CIMSS SSMIS | SATCON |
|---|---|---|---|---|
| BIAS | -1.0 | 0.2 | -1.0 | **-0.9** |
| AVG ERROR | 9.8 | 9.3 | 8.2 | **6.9** |
| RMSE | 12.1 | 12.0 | 10.4 | **8.6** |

Full 2006-2012 sample (N=1467) statistics for three members, including time-interpolated sounder estimates. All values in knots, and matches use NHC Best Track MSW when recon is available within 3 hours of the SATCON fix. AMSU and SSMIS represent interpolated values matched to the ADT fix times. CIRA AMSU estimates are not interpolated at this time, so are not included in this comparison.

The SATCON **MSLP** stats for this sample are: Bias = - 0.6 Average error = 4.2 RMSE = 5.4 (all in hPa)

## FUTURE WORK

• Update weights and logic for new versions of 1) the CIMSS AMSU method which addresses a strong bias in weaker storms and 2) ADT v8.2.1

• Incorporate new members into SATCON: ATMS sounder, NRL PMW, subj Dvorak? Others?

• Re-Assess inclusion of CIRA AMSU algorithm in certain situations

• Further information sharing using ARCHER structure/organization scores

SATCON Homepage: **http://tropic.ssec.wisc.edu/real-time/satcon/**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