Estimating Tropical Cyclone Intensity in the GOES-R/JPSS Era

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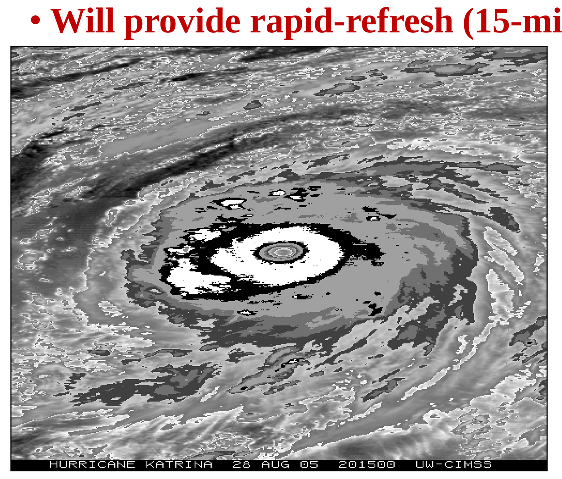
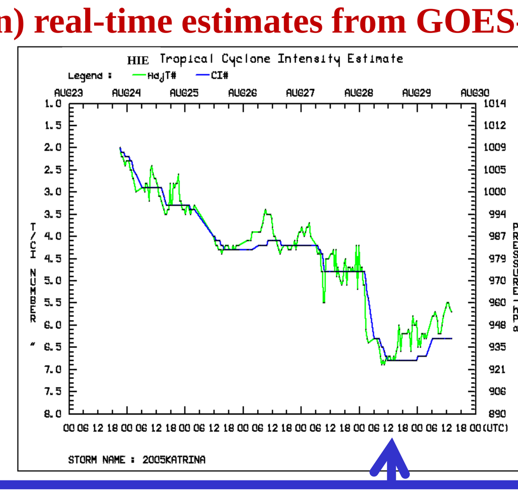
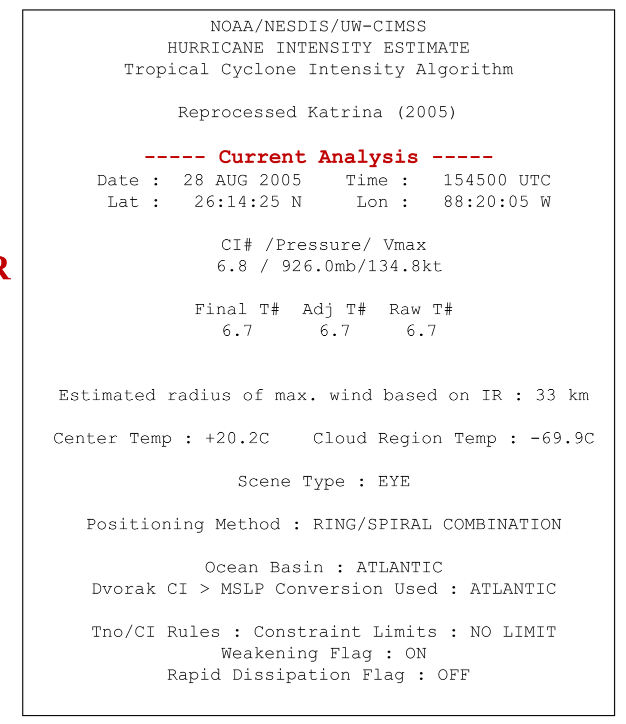
GOES-R Hurricane Intensity Estimation (HIE)

Features of the HIE algorithm

- Utilizes Geo longwave IR imagery; enhanced with Leo microwave data
- Based on operational Advanced Dvorak Technique (ADT)
- Completely automated and objective
- Will provide rapid-refresh (15-min) real-time estimates from GOES-R



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NOAA/NESDIS/UW-CIMSS
HURRICANE INTENSITY ESTIMATE
Tropical Cyclone Intensity Algorithm

Reprocessed Katrina (2005)

----- Current Analysis -----
Date :  28 AUG 2005     Time :   154500 UTC
Lat :   26:14:25 N      Lon :    88:20:05 W

CI# /Pressure/ Vmax
6.8 / 926.0mb/134.8kt

Final T#   Adj T#   Raw T#
  6.7       6.7      6.7

Estimated radius of max. wind based on IR : 33 km

Center Temp : +20.2C    Cloud Region Temp : -69.9C

Scene Type : EYE

Positioning Method : RING/SPIRAL COMBINATION

Ocean Basin : ATLANTIC
Dvorak CI > MSLP Conversion Used : ATLANTIC

Tno/CI Rules : Constraint Limits : NO LIMIT
      Weakening Flag : ON
   Rapid Dissipation Flag : OFF
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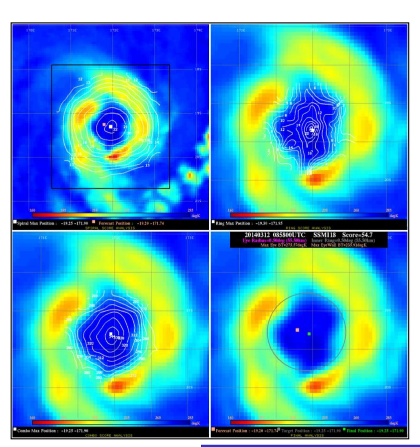
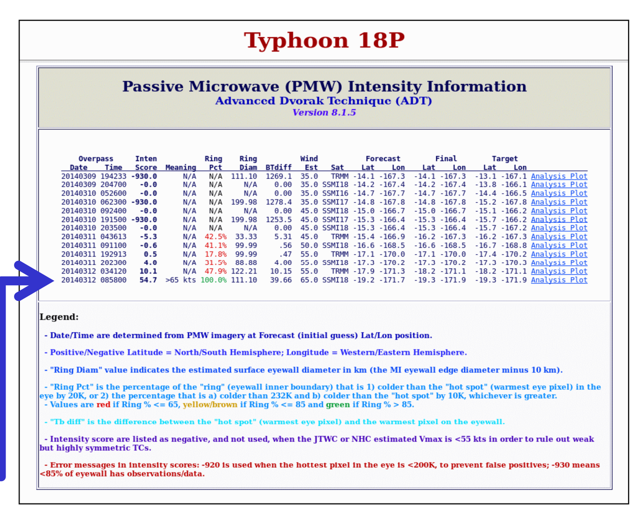
Example of HIE reprocessed on Hurricane Katrina (2005)

HIE Intensity Adjustments – Utilizing Passive Microwave (PMW) Information

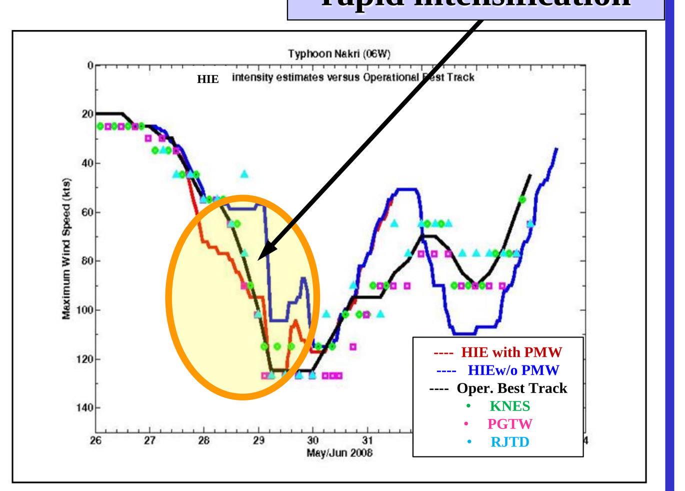
- Uses the CIMSS ARCHER algorithm to objectively position TC and extract structure information in 85-91GHz Tb signal (e.g. AMSR-2) from all available Leo overpasses of TC
- Deduces the vigor and organization of developing TC eyewall/eye structures and calculates organization scores
- Successful in loosely differentiating storm strengths
  - Greater than ~72 knots
  - Greater than ~90 knots
- *Information may be used to over-ride IR intensity estimate*

More accurate during rapid intensification





Example of PMW imagery (left) and diagnostics (right) for Typhoon Daphne (2014)

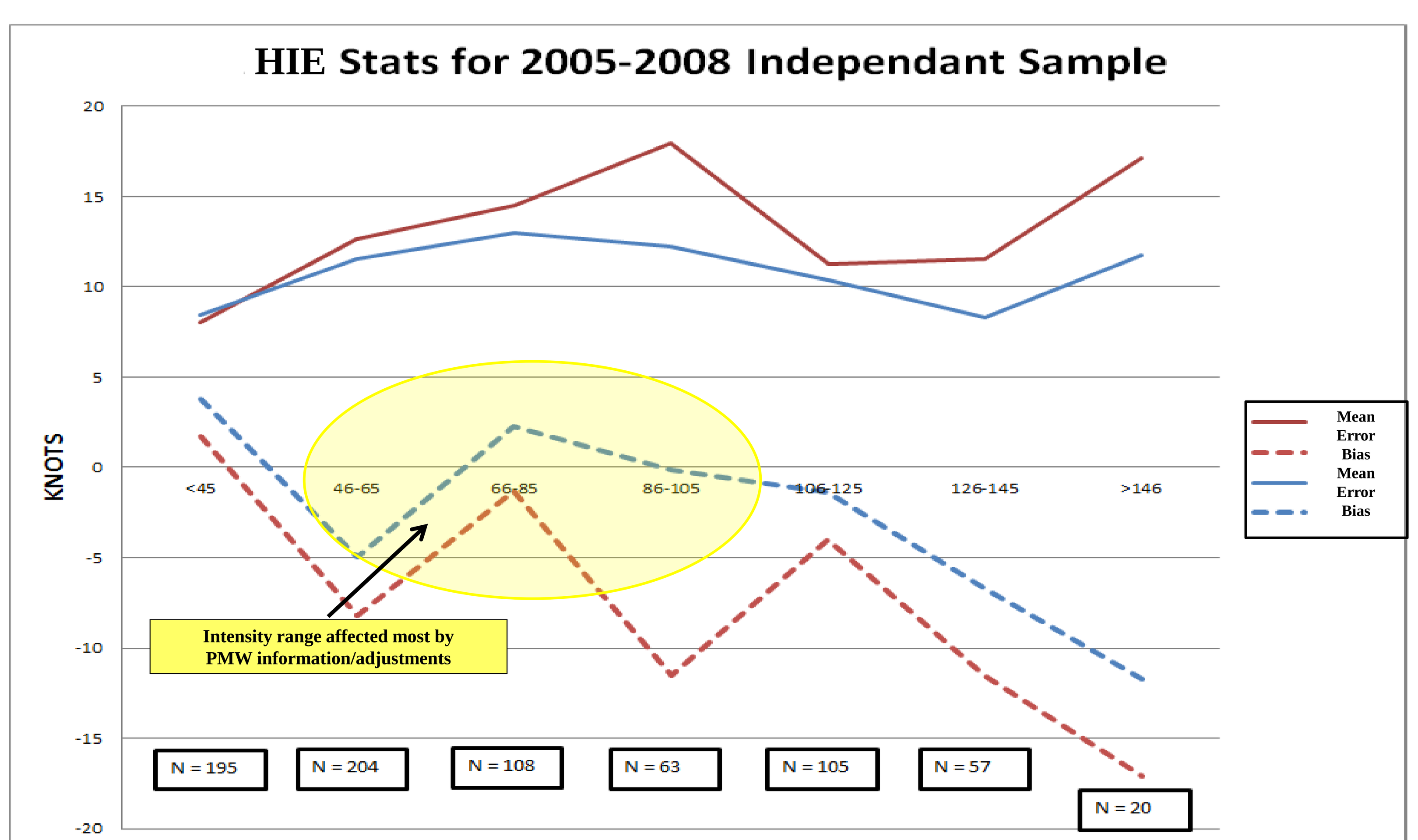


Example of HIE reprocessed with PMW data for Typhoon Nakri (2008)

HIE Validation

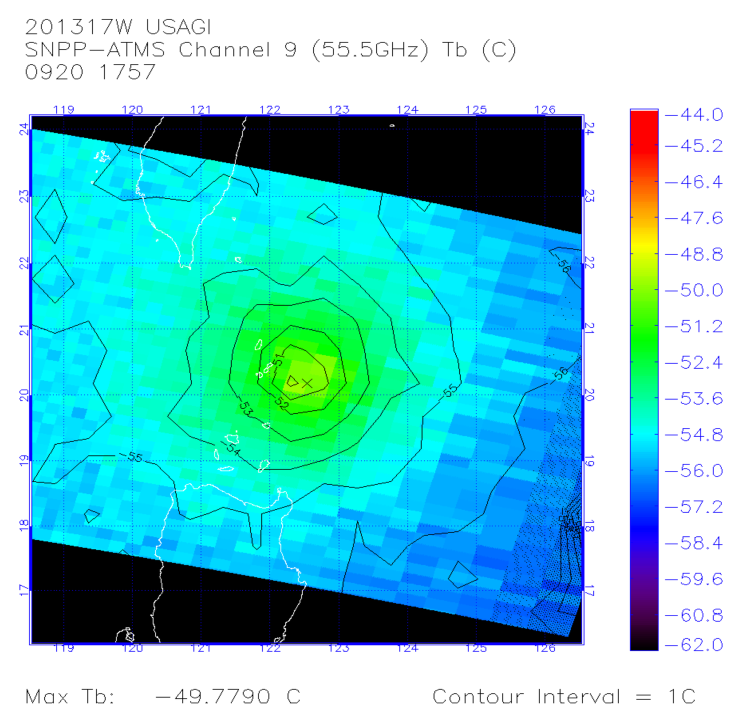
HIE estimates of TC maximum sustained winds (Vmax) vs. coincident recon –aided Best Track

Comparison of HIE with PMW and w/o PMW

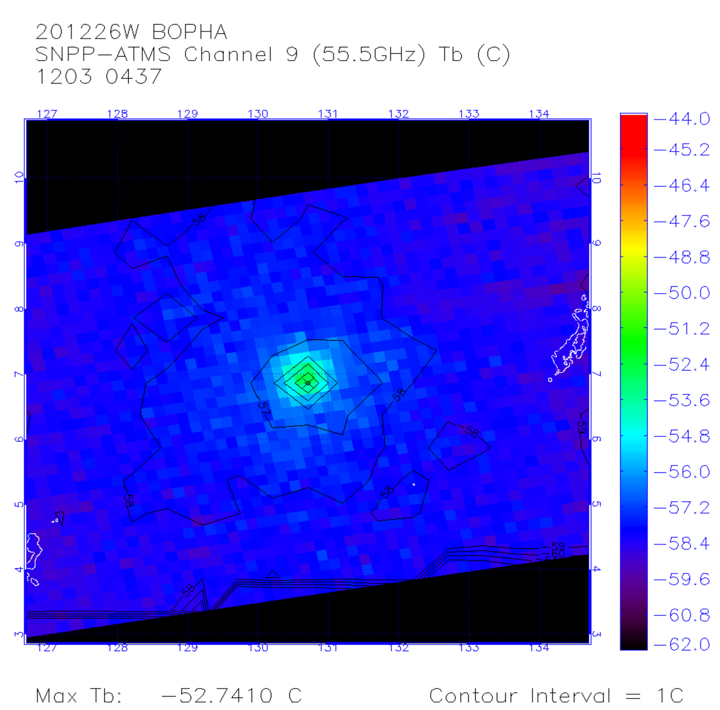


Suomi NPP ATMS TC Intensity Estimates

- Leo MW sounder-based estimates of TC intensity have been around since the 1980s
- Based on capturing the TC warm core anomaly magnitude and relating to intensity
- Suomi-NPP ATMS is first of improved MW sounders that will be available in JPSS era



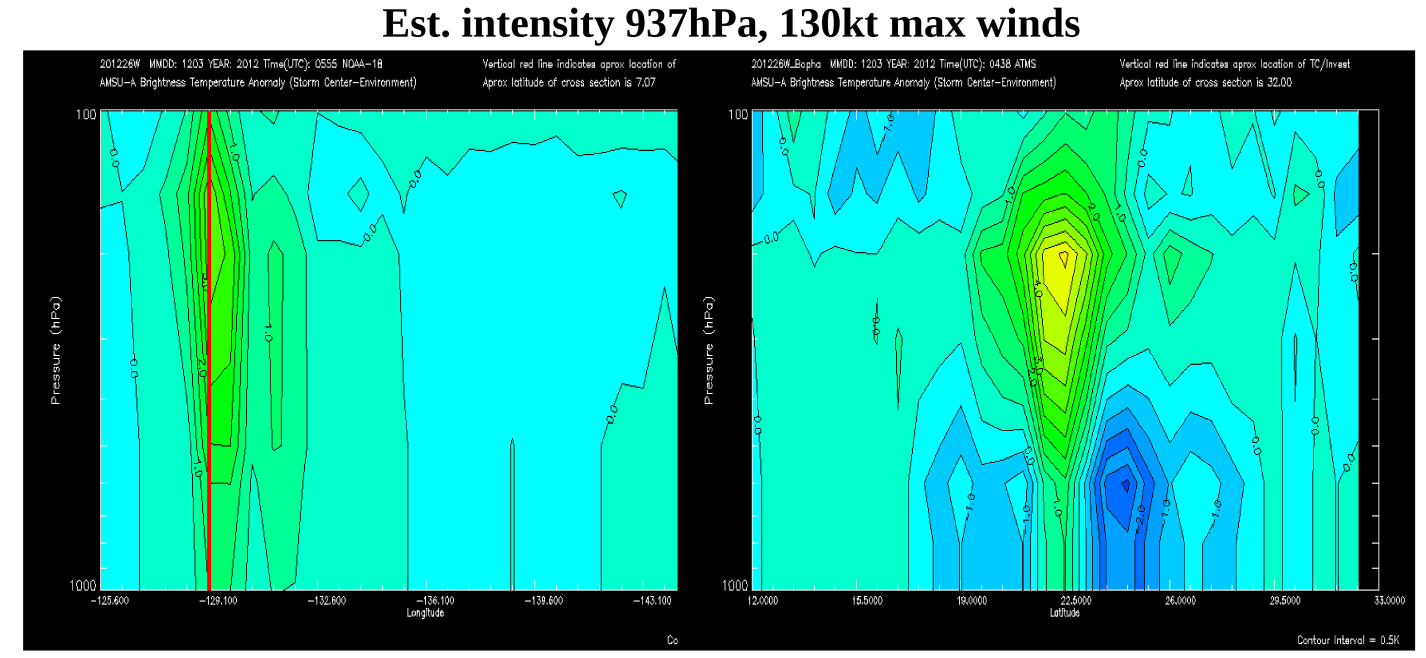
Large TC



Small TC—tight warm core still well resolved

- ATMS captures the thermal structures better than AMSU due to improved spatial resolution

AMSU 06UTC Typhoon Bopha, Dec 3 2012 ATMS 04UTC
Est. intensity 937hPa, 130kt max winds



Vertical cross-sections through TC Bopha center (red line on left panel indicates storm center)

- **Warm anomalies in green/yellows (contour interval=0.5C), with max around 200 hPa.**
- **Correction for rain scattering in ATMS not yet applied (cool/blue signal in lower levels (eyewall).**
- **NPP ATMS FOV resolution is 32km at nadir versus AMSU 48km >> Better depiction of warm core.**

- TC intensity estimation method developed at UW-CIMSS uses radiances from ATMS channels 7, 8 and 9 in a regression model to estimate the warm core anomaly magnitude
- These warm core magnitudes are then statistically related to a large sample of cases with recon-measured Vmax and MSLP to develop models to estimate intensity

ATMS Method Validation

Developmental Dataset Comparison vs. recon (MSLP) or recon-aided Best Track (Vmax)

N = 173	ATMS MSLP (hPa)	ATMS MSW (kts)	Oper DVK MSW (kts)
Bias	-0.9	-1.5	-3.8
Abs Error	5.7	7.7	8.6
RMSE	7.2	10.0	11.2

2014 Independent Dataset Validation

N = 63	ATMS MSLP (hPa)	ATMS MSW (kts)	Oper DVK MSW (kts)
Bias	-1.2	-3.0	-2.8
Abs Error	6.1	7.5	8.3
RMSE	8.1	9.9	10.5

Satellite-Based Consensus Approach -- SATCON

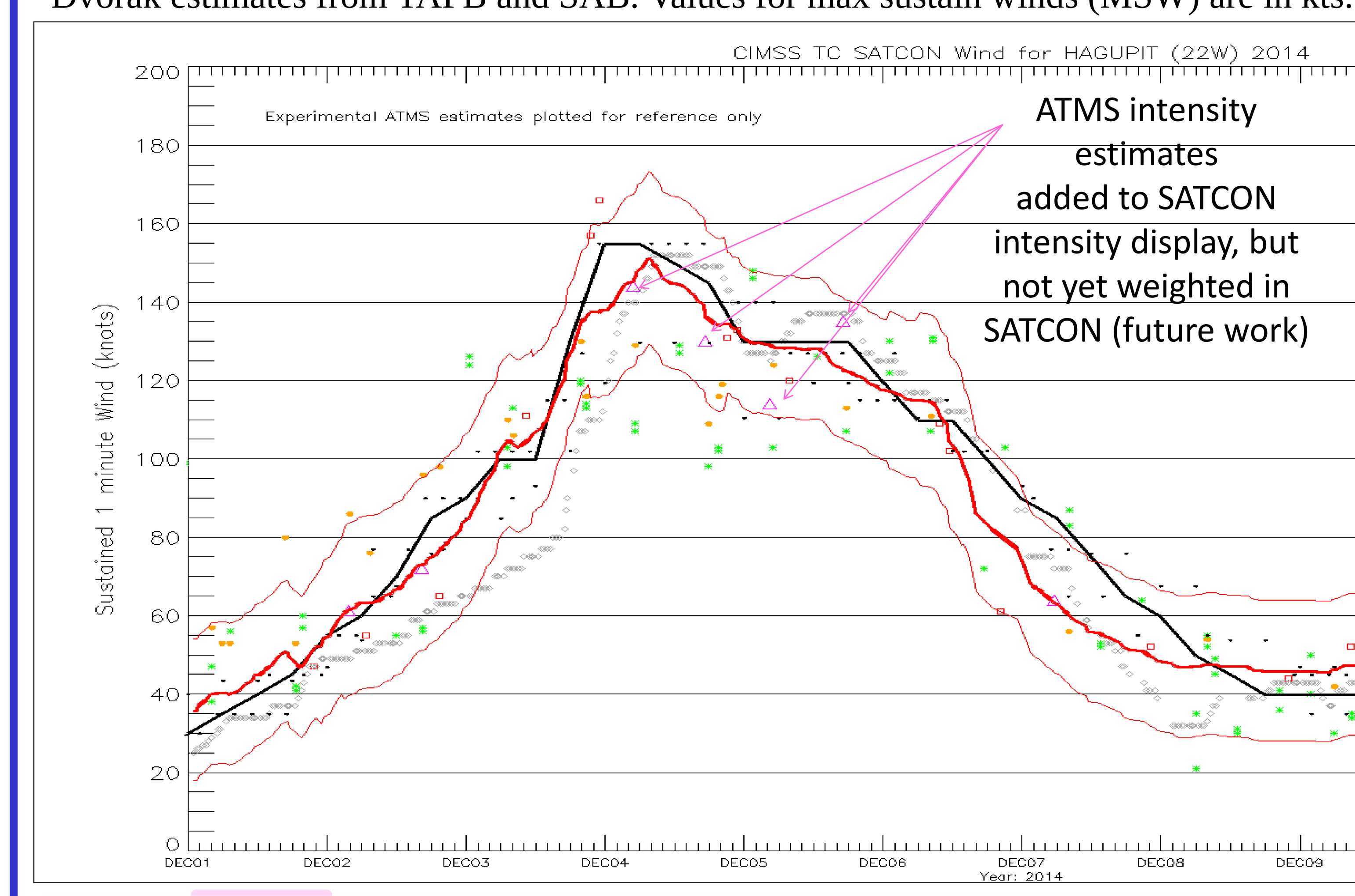
The SATCON algorithm being developed at UW-CIMSS combines TC intensity estimates analyzed from objective satellite-derived infrared and microwave-based methods to produce a weighted consensus estimate, which is more skillful than the individual member estimates or straight averaging. SATCON can provide 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 v8.1.5), AMSU sounder algorithms from CIMSS and CIRA, and an SSMIS sounder algorithm from CIMSS. ATMS sounder algorithms are in development.

The individual member weights used by SATCON are derived from the quality metrics associated with situational 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 intensity metric.

SATCON Performance (estimates of TC Max Winds)

MSW (Kts)	CIMSS AMSU	CIMSS ADT	CIRA AMSU	CIMSS SSMIS	SATCON	Subj. Dvorak (Operational)
BIAS	- 1.0	- 0.6	-5.23	- 0.6	- 0.7	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 for max sustain winds (MSW) are in kts.



Future Work

- Update SATCON weights and logic for new versions of 1) the CIMSS AMSU method which addresses a strong bias in early stages of TCs, 2) ADT v8.2, and 3) CIRA AMSU?
- Incorporate potential new members into SATCON: ATMS & Metop sounders, NRL MW, subj Dvorak? U of Arizona DVT?
- Further information sharing using ARCHER MW objective structure/organization scores

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

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