Improving Tropical Cyclone Track and Intensity Forecasting with JPSS Imager and Sounder Data

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Introduction

Project goal:

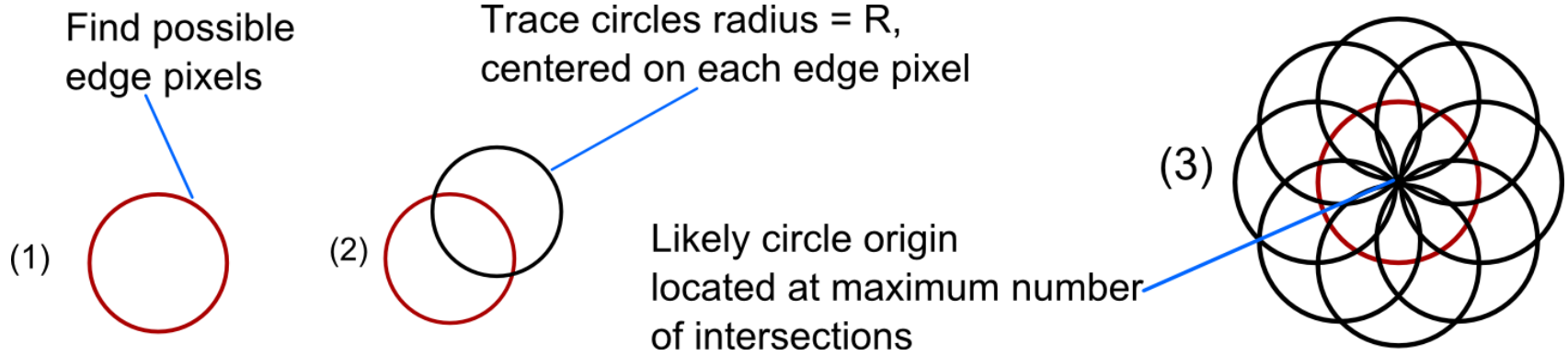
to improve tropical cyclone forecasts by utilizing new capabilities provided by JPSS SNPP (launched Oct, 2011)

- **Use data from two SNPP instruments**
  - Visible Infrared Imager Radiometer Suite (VIIRS)
  - Advanced Technology Microwave Sounder (ATMS)
- **Two basic methods exists for improving tropical cyclone forecasts with SNPP:**
  - assimilate data in numerical forecast models
  - improve analysis and statistical post-processing forecast products
- **Our group is developing two applications focusing on the 2nd approach**
  - **Develop automated center-fix method**
  - **Improve RII, SHIPS and LGEM forecasts**

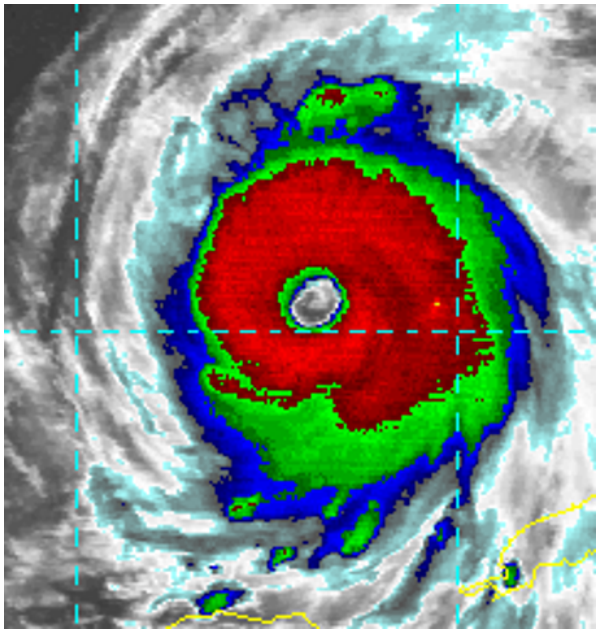
Improve center location estimates

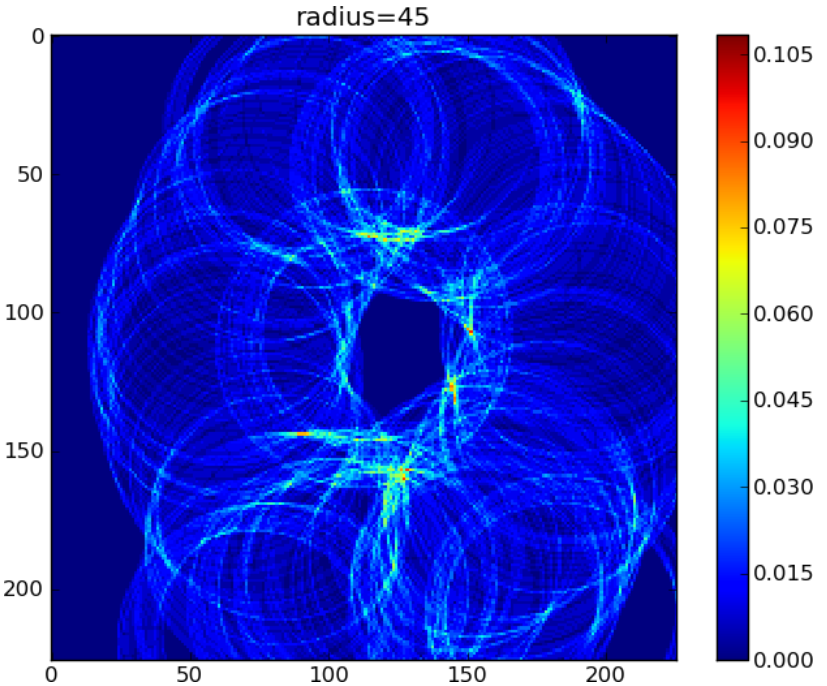
1. **Motivation:**
   - Aircraft reconnaissance only available in west Atlantic (about 30% of AL TC forecasts) and around Hawaii
   - Center fix is usually the first step in the forecast process
   - **Accurate center estimate impacts all downstream forecasts**
   - **Nearly all existing center fix methods are subjective**
     – Exception: CIMSS ARCHER method that fits spiral patterns to microwave imagery from LEO satellites
   - Many more geostationary images than center fixes
   - **Automatic method for estimating tropical cyclone location from imagery is highly desirable**
2. **Use image processing techniques to develop an objective center fixing algorithm from visible and IR data:**
   - Field of computer vision deals with extracting features from imagery
   - **Use of Circular Hough Transform (CHT) for automatic center-fixing is investigated**

Circular Hough Transform (CHT)

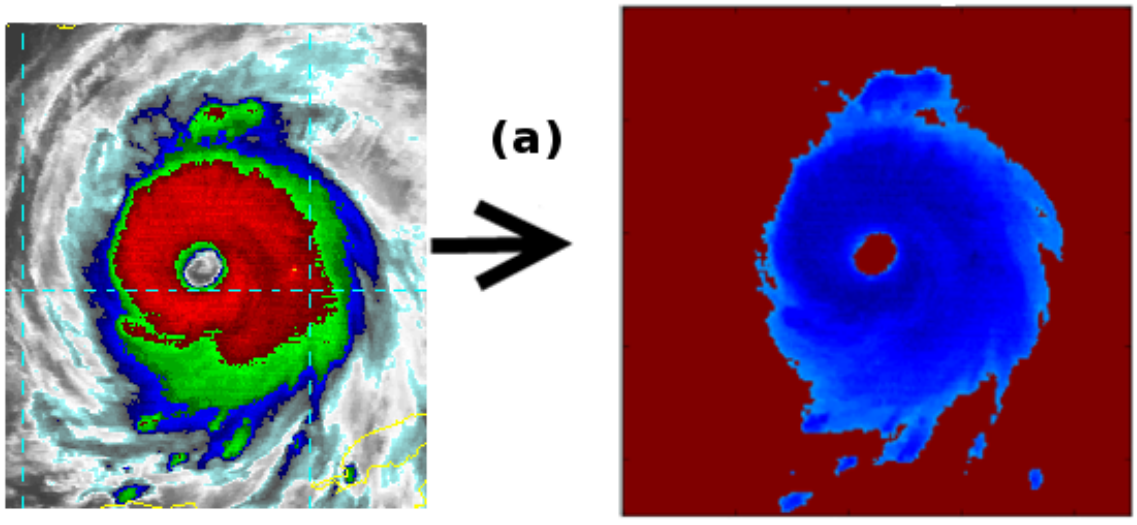


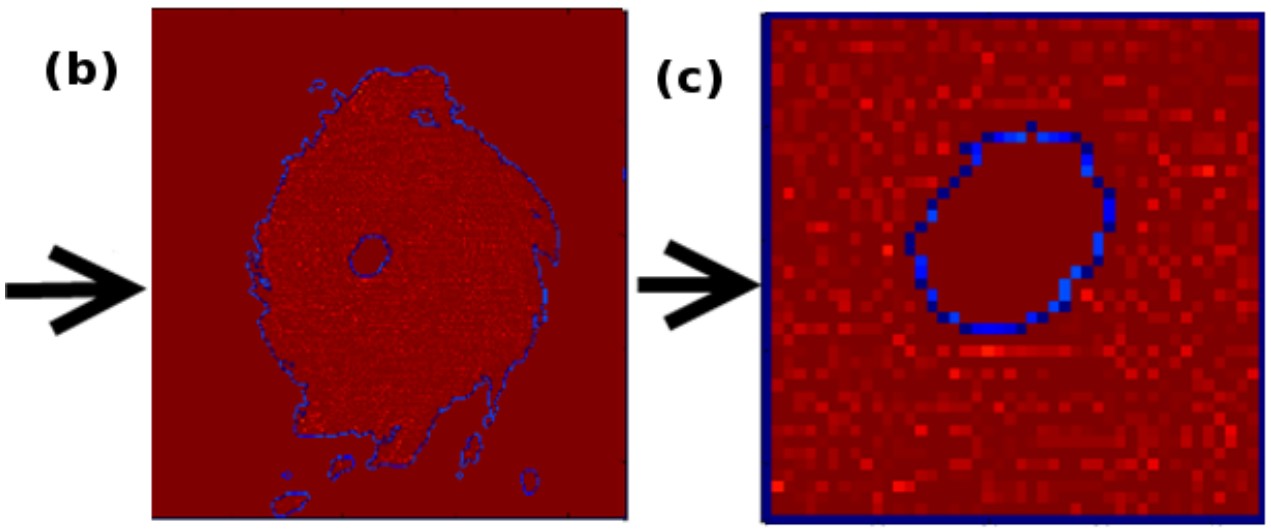
- If R is not known, perform CHT for range of R. Select R, origin from max number of intersections





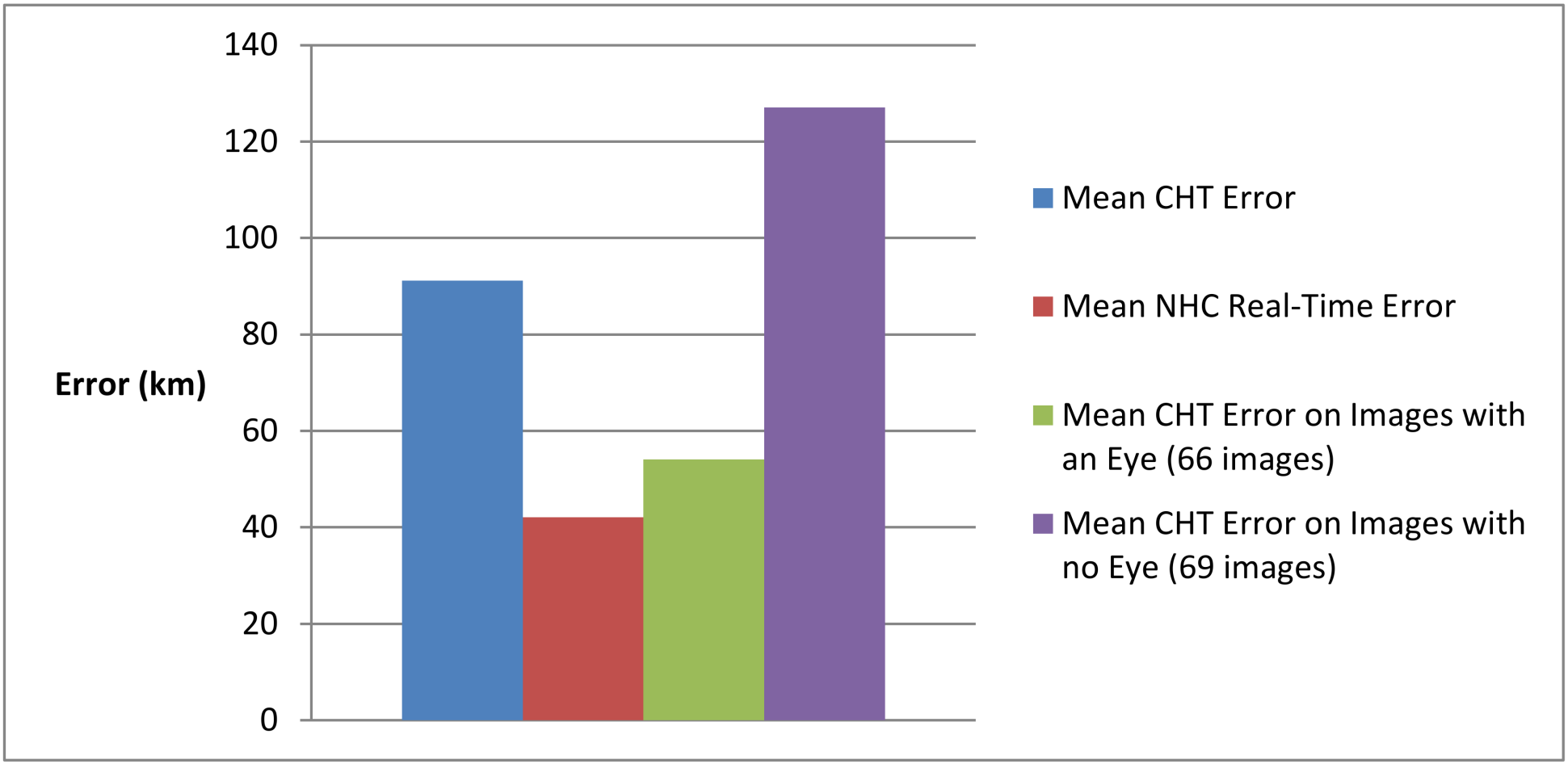
CHT: Hurricane Katrina





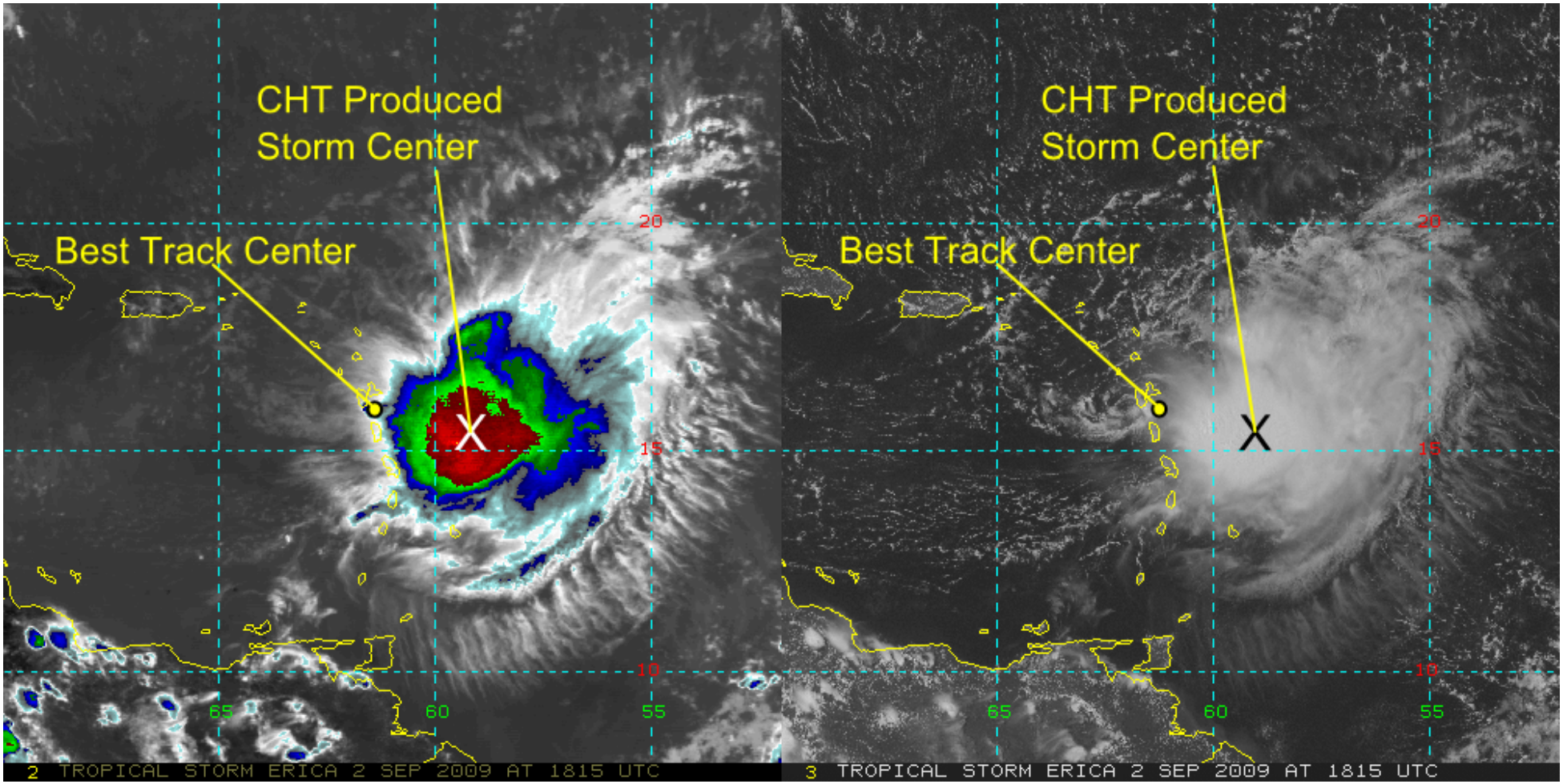
- Threshold IR image to isolate clouds
- Use Laplacian to detect edge pixels
- If #(edge pixels) near estimated storm center $>$ threshold, $\Rightarrow$ eye is present $\Rightarrow$ reduce image to smaller area
- Perform CHT

CHT: Results



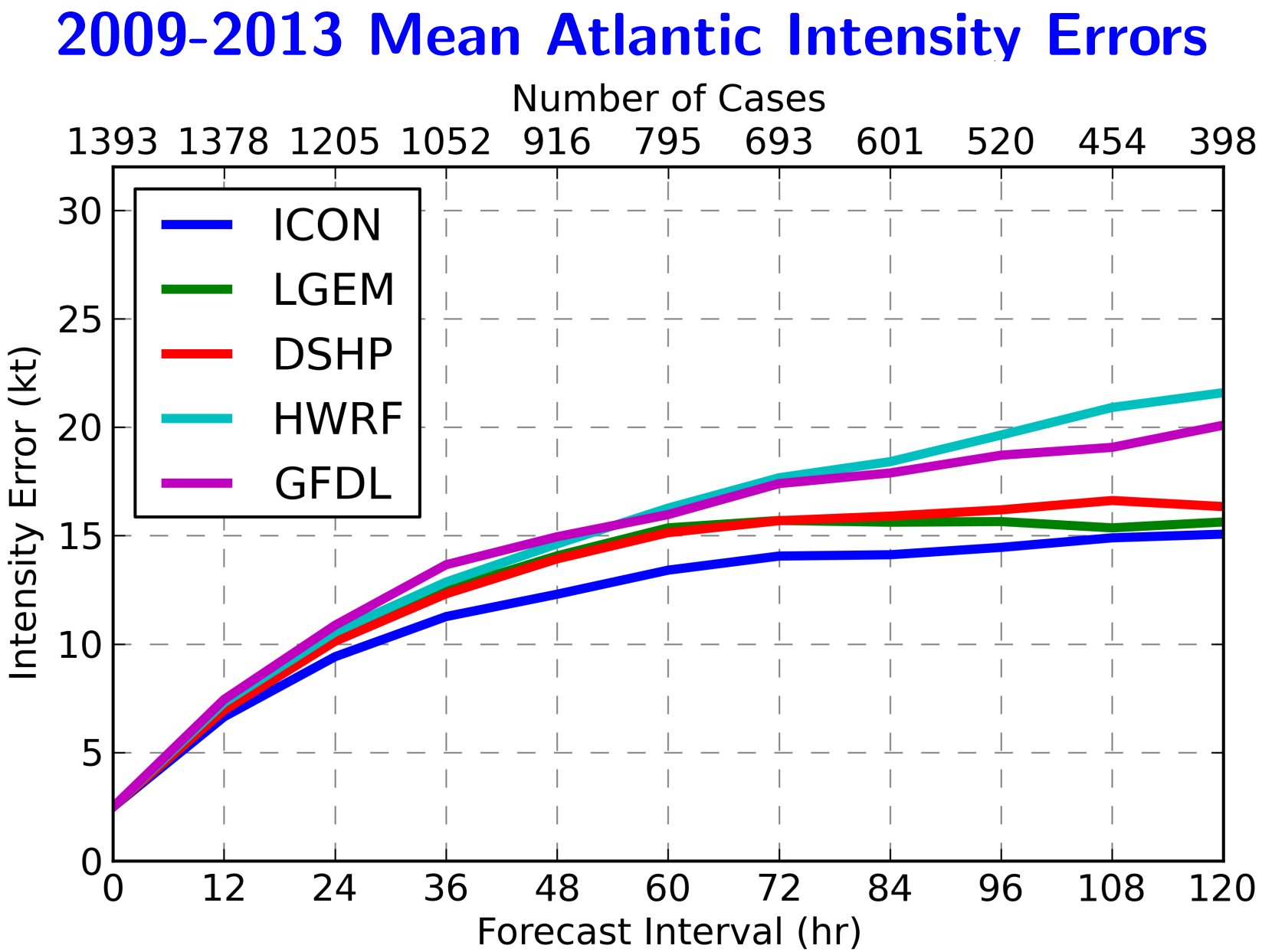
- 135 Images from Sandy, Earl, Erika, Charley, Katrina
- Mean CHT error: 91 km; for storms with eye: 54 km
- Bias X: 6km, Bias Y: 8.5 km; Bias explained by Parallax

CHT: TC Erica



- In the case of sheared storm center of the coldest clouds is found instead of the storm center

Improving RII and LGEM forecast



Maximum Potential Intensity (MPI) Estimates

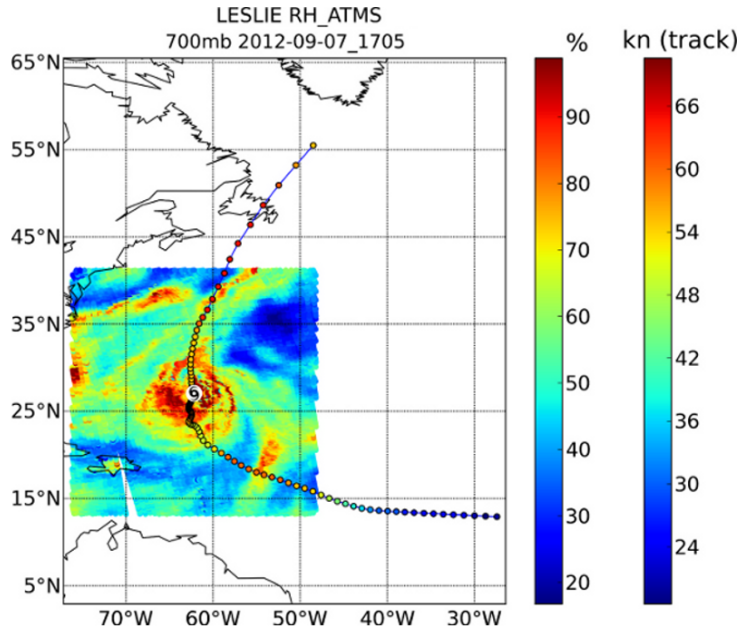
- **Statistical models, SHIPS and LGEM, use Maximum Potential Intensity (MPI) as one of the key parameters**
- Currently MPI is statistically calculated from SST only
- **Use ATMS-MIRS T,Q,SLP retrievals** together with SST **to estimate MPI** from ATMS and SST using algorithm by Emanuel (1988), Bister and Emanuel (1998):

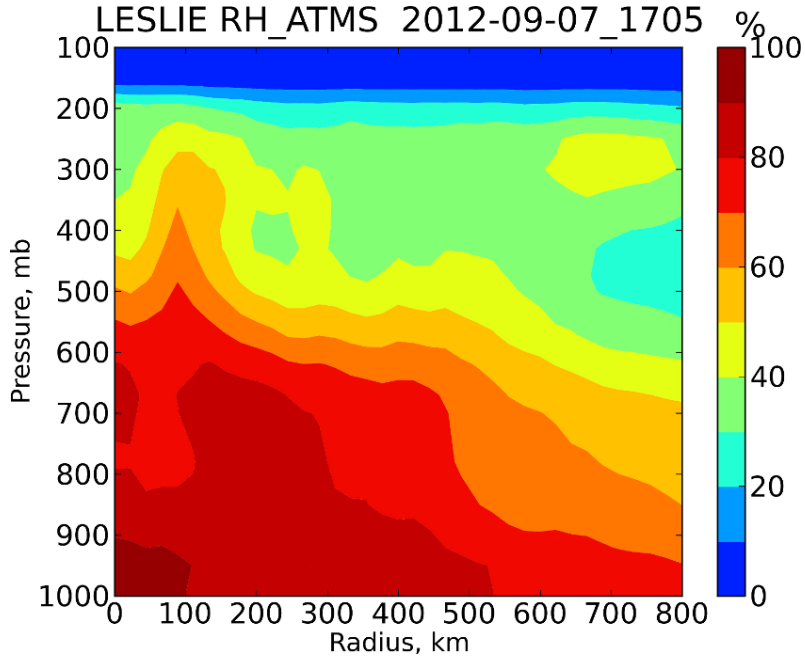
$$(MPI)^2 = \frac{T_s - T_o}{T_o} \frac{C_k}{C_D} (k^* - k)$$

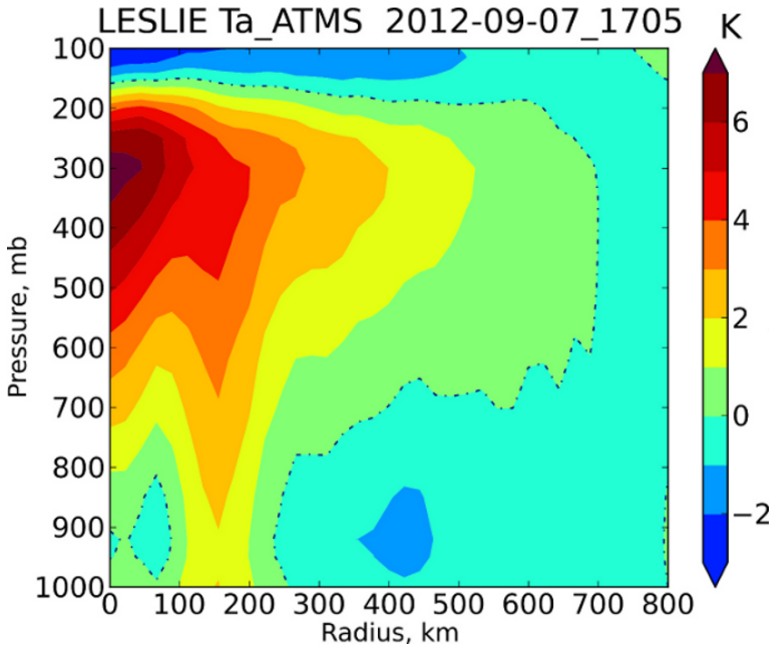
T_s, T_o, k^* and k: estimated from SST, sounding
C_k/C_D: specified ratio of surface exchange coefficients

- Incorporate **improved MPI estimates** into :
  1. Rapid Intensification Index (**RII**)
  2. Logistic Growth Equation Model (**LGEM**)
  3. Statistical Hurricane Intensity Prediction Scheme (**SHIPS**) Model

Temperature and RH profiles: Leslie

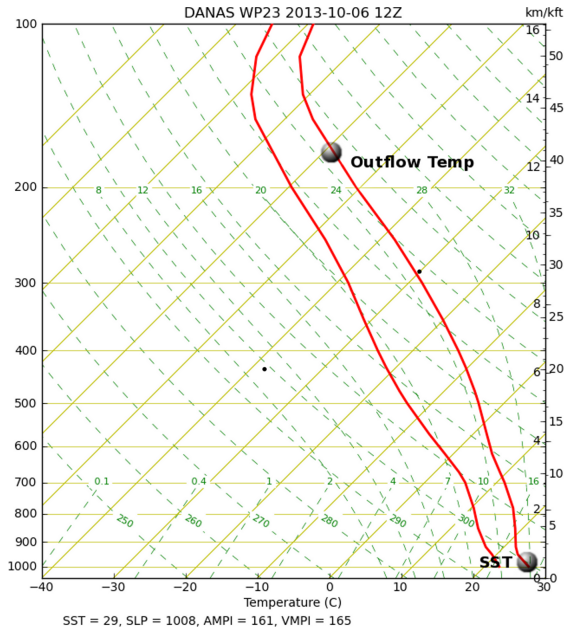


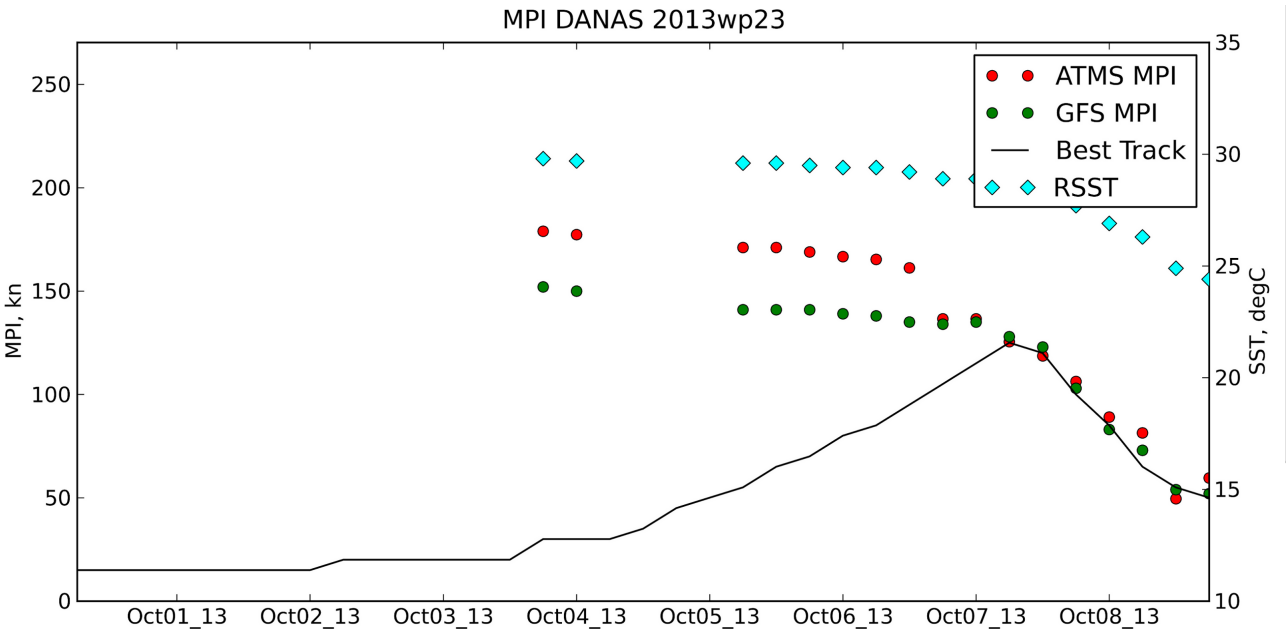


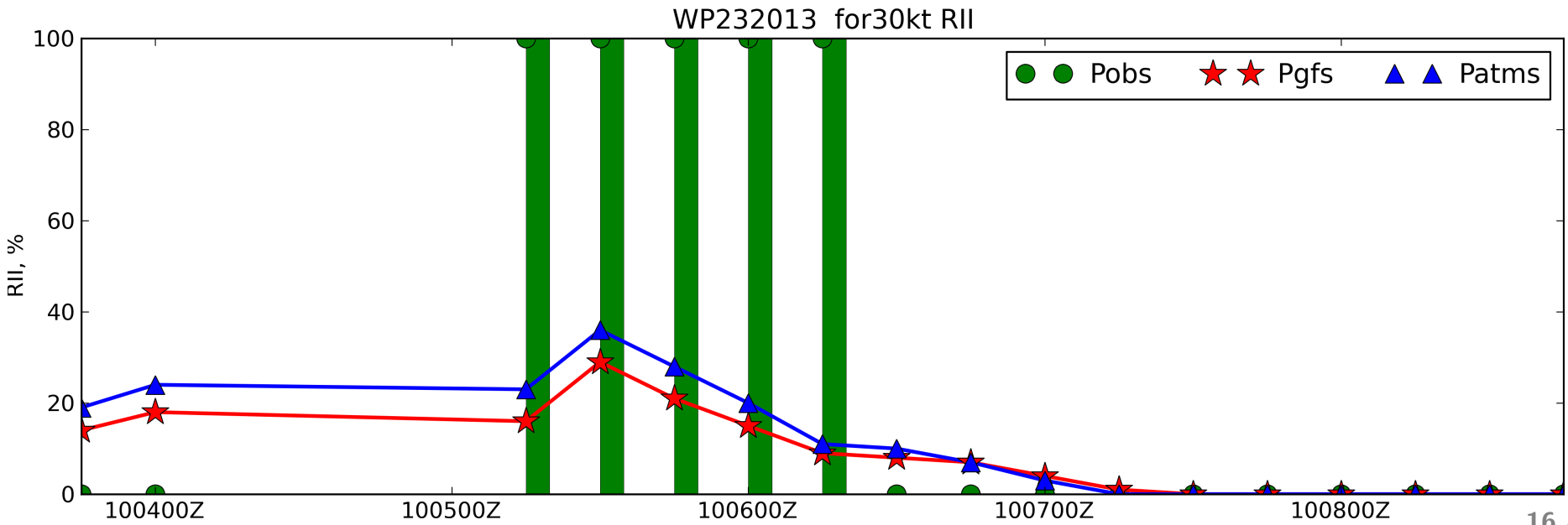


1. Average T, RH between r = 500 to 800 km to get $\overline{T}(p)$, $\overline{RH}(p)$
2. Input $\overline{T}(p)$, $\overline{RH}(p)$ environmental profiles to Emanuel (1988) MPI algorithm
3. Replace empirical MPI with ATMS MPI in RII and models

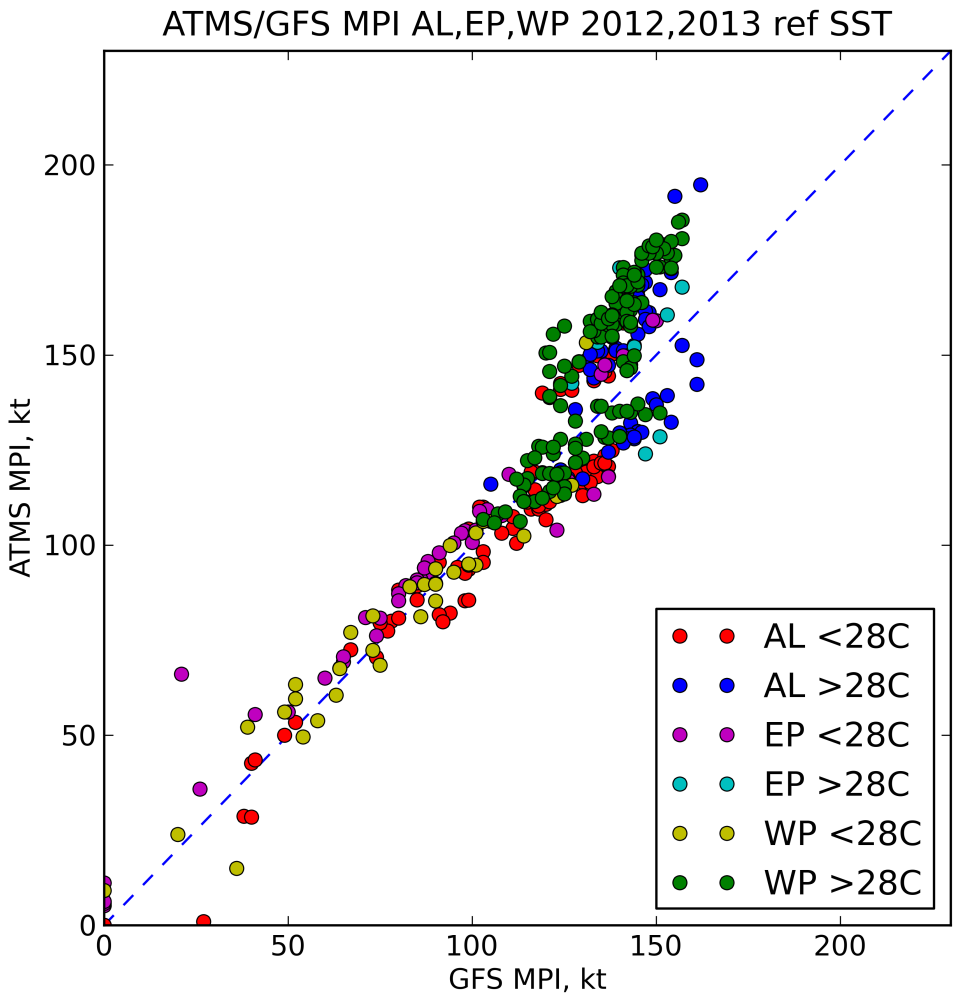
RII with ATMS MPI: WP232013 Danas

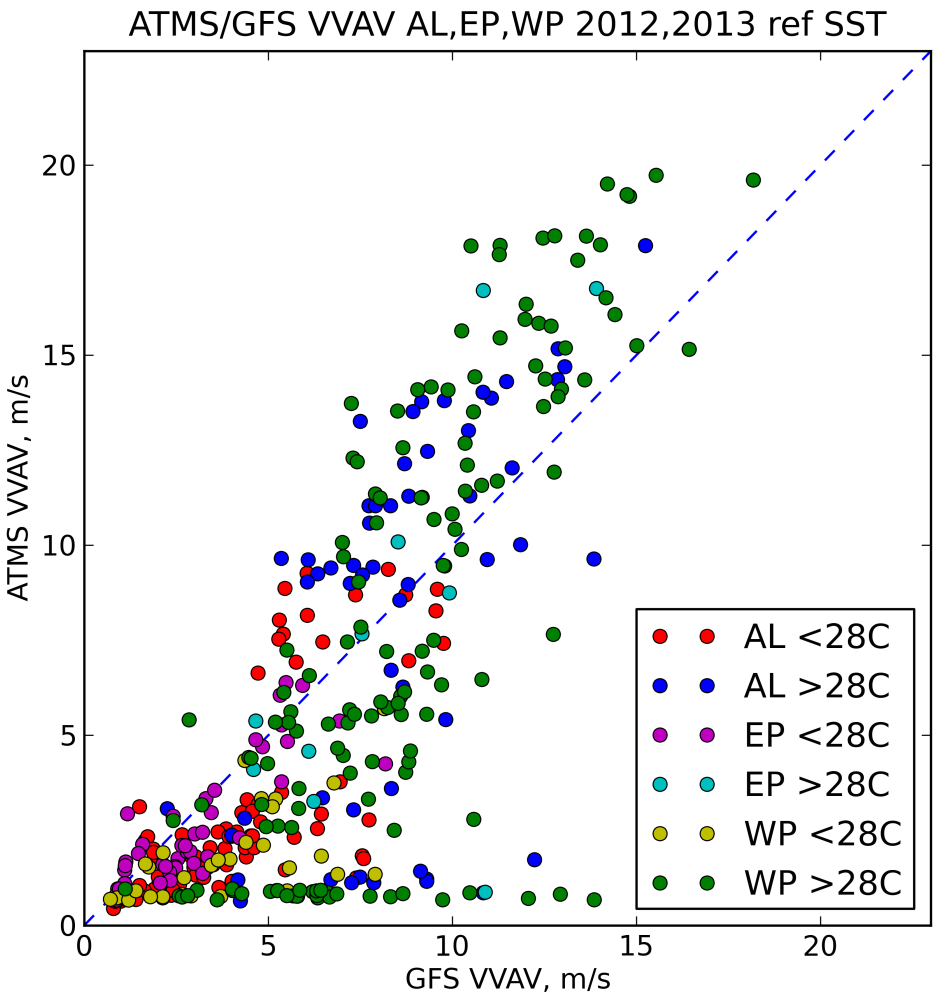






MPI and VVAV: ATMS vs GFS profile





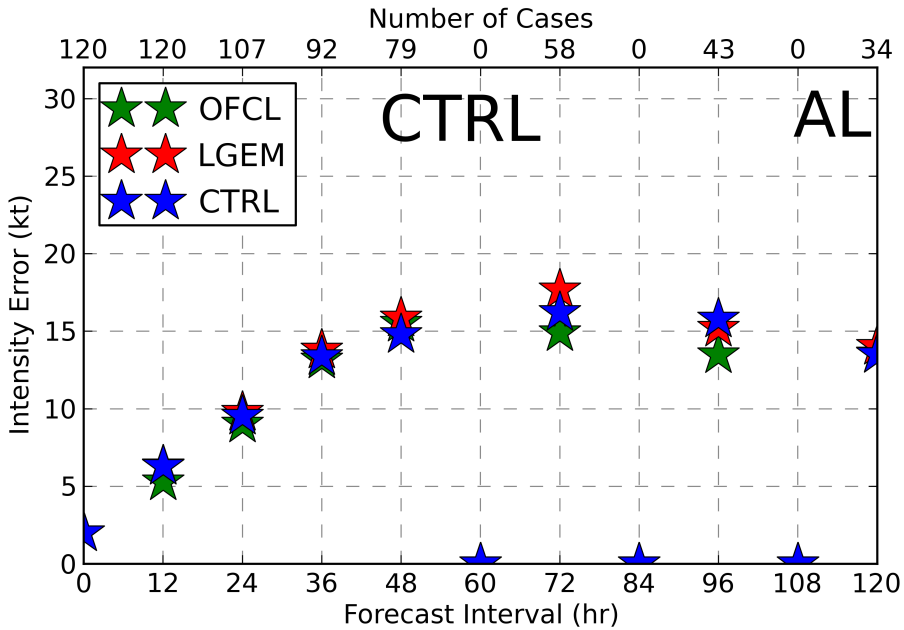
- T,q profiles calculated by azimuthally averaging T,q at $200 \div 800$km
- All other parameters same as operational, including weekly Reynolds SST

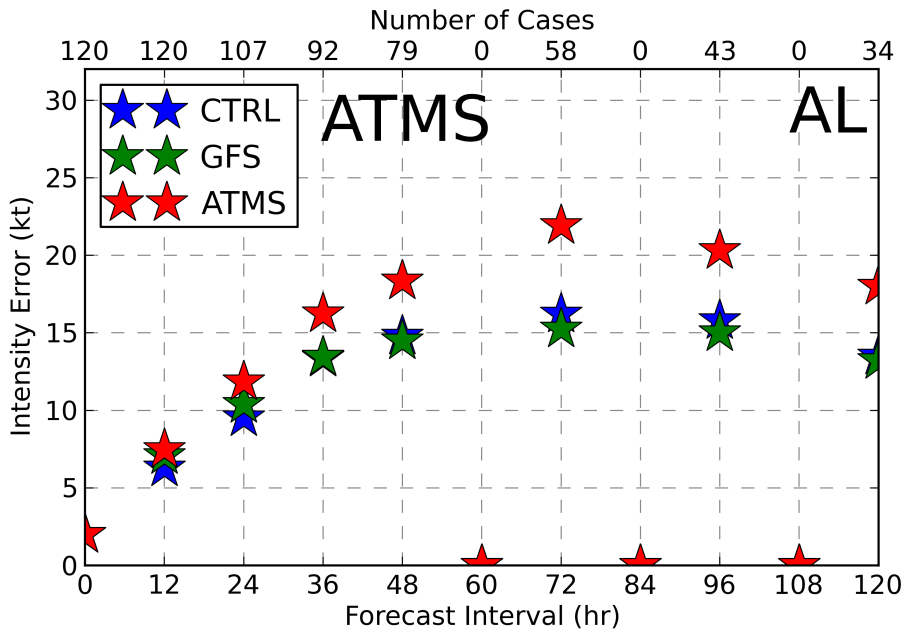
RII Statistics: GFS vs ATMS

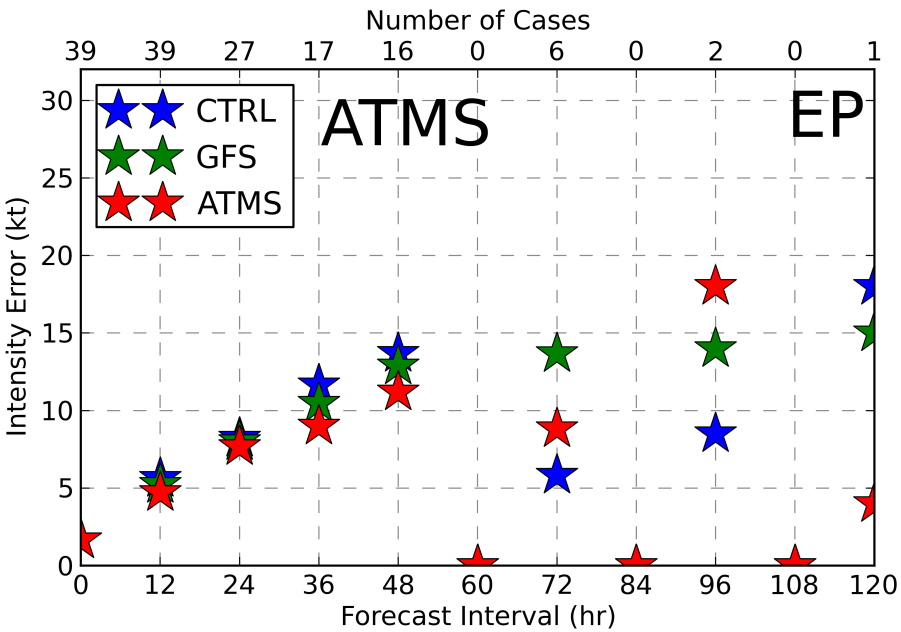
Basin		BS GFS	BS ATMS	BS Mean	BSS A/G	BSS G/M	BSS A/M	Bias GFS	Bias ATMS	# Cases	#RII
AL	25kt	964.55	957.98	854.27	0.68	-12.91	-12.14	1.63	1.44	130	13
	30kt	723.53	718.46	667.83	0.70	-8.34	-7.58	1.30	1.15	130	10
	35kt	477.11	467.65	413.10	1.98	-15.49	-13.20	1.26	1.00	130	6
	40kt	248.40	243.55	211.88	1.95	-17.24	-14.95	1.63	1.37	130	3
WP	30kt	1044.39	996.30	1586.00	4.60	34.15	37.18	0.56	0.61	176	31

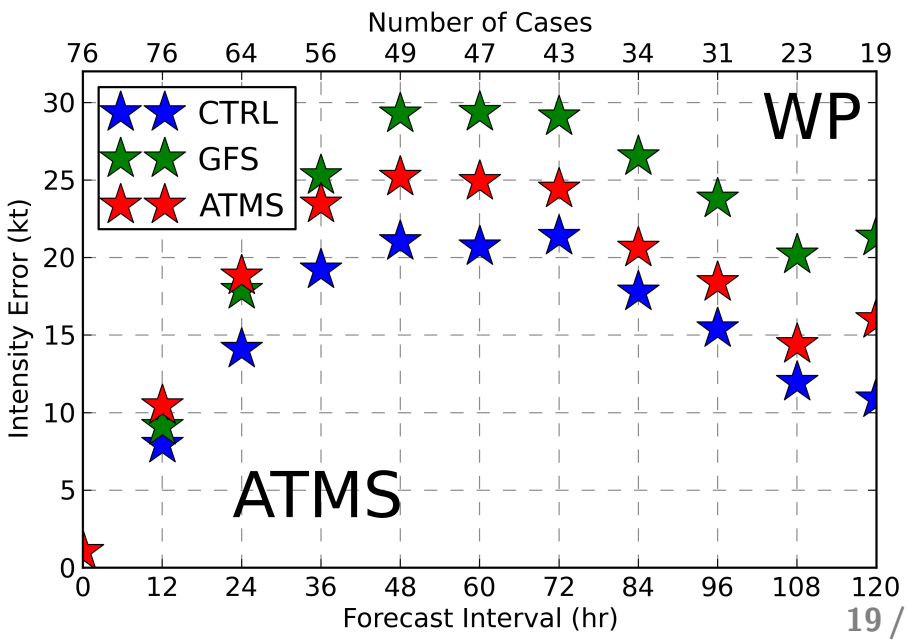
1. Statistics is preliminary: based on very small number of cases
2. AL
   - Brier Score: ATMS $<$ GFS
   - Brier Skill Score: ATMS/GFS > 0
   - Bias: ATMS better than GFS
3. EP: only 1 (one) RI cases available, unable to calculate statistics
4. WP
   - Brier Score: ATMS $<$ GFS
   - Brier Skill Score: ATMS/GFS > 0
   - Bias: ATMS better than GFS

LGEM Intensity Verification









Conclusions and Future Plans

Center Fix - CHT

- Good for storms with eye, bad for sheared storms
- Accumulation matrices may be useful for eye detection
- Future Plans
  - Use CHT from IR data as first guess for visible algorithm
  - Combine CHT with other information (shear vector, MW, DNB)

Improving RII and LGEM forecast

- ATMS data provide more realistic TC structure than AMSU
- RII: for AL,EP,WP forecast is slightly improved
- LGEM, SHIPS Intensity forecast: AL - worse; WP,EP - better in some cases
- Future Plans
  - Get more ATMS data for further testing and reliable statistics
  - Use combination of GFS and ATMS data to obtain most realistic soundings