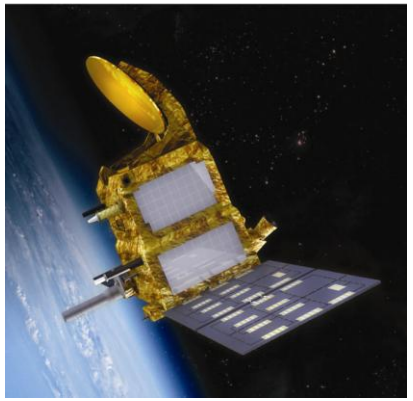
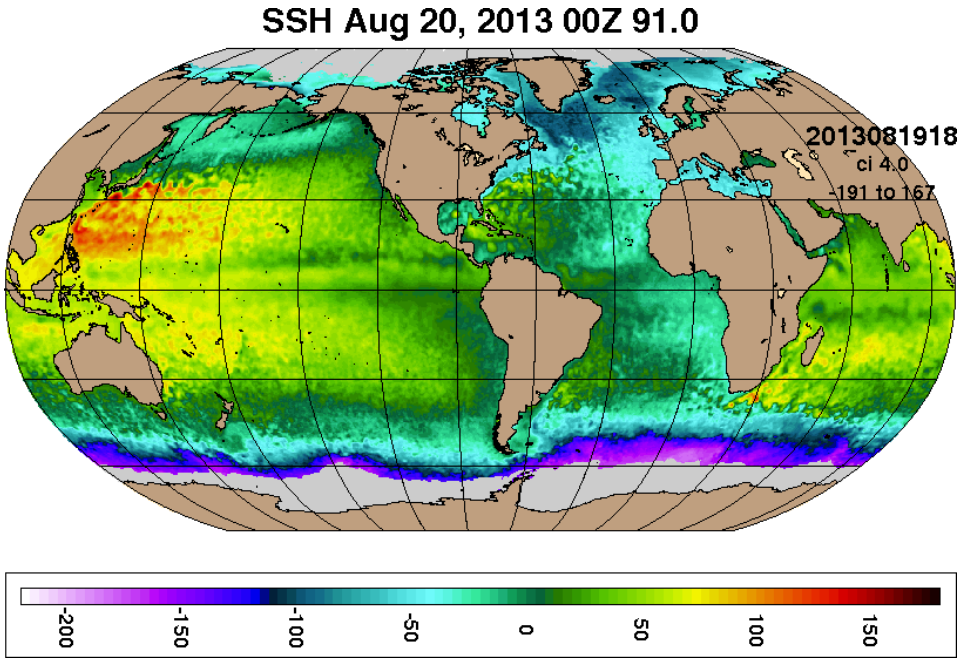
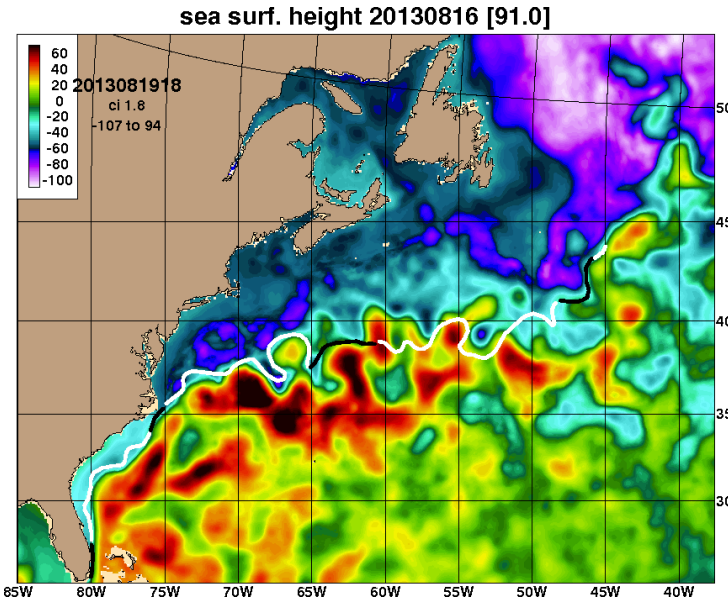
Monitoring the SARAL/AltiKa Performance in the Global Ocean Forecast System

James Richman and Gregg Jacobs
Oceanography Division
Naval Research Laboratory



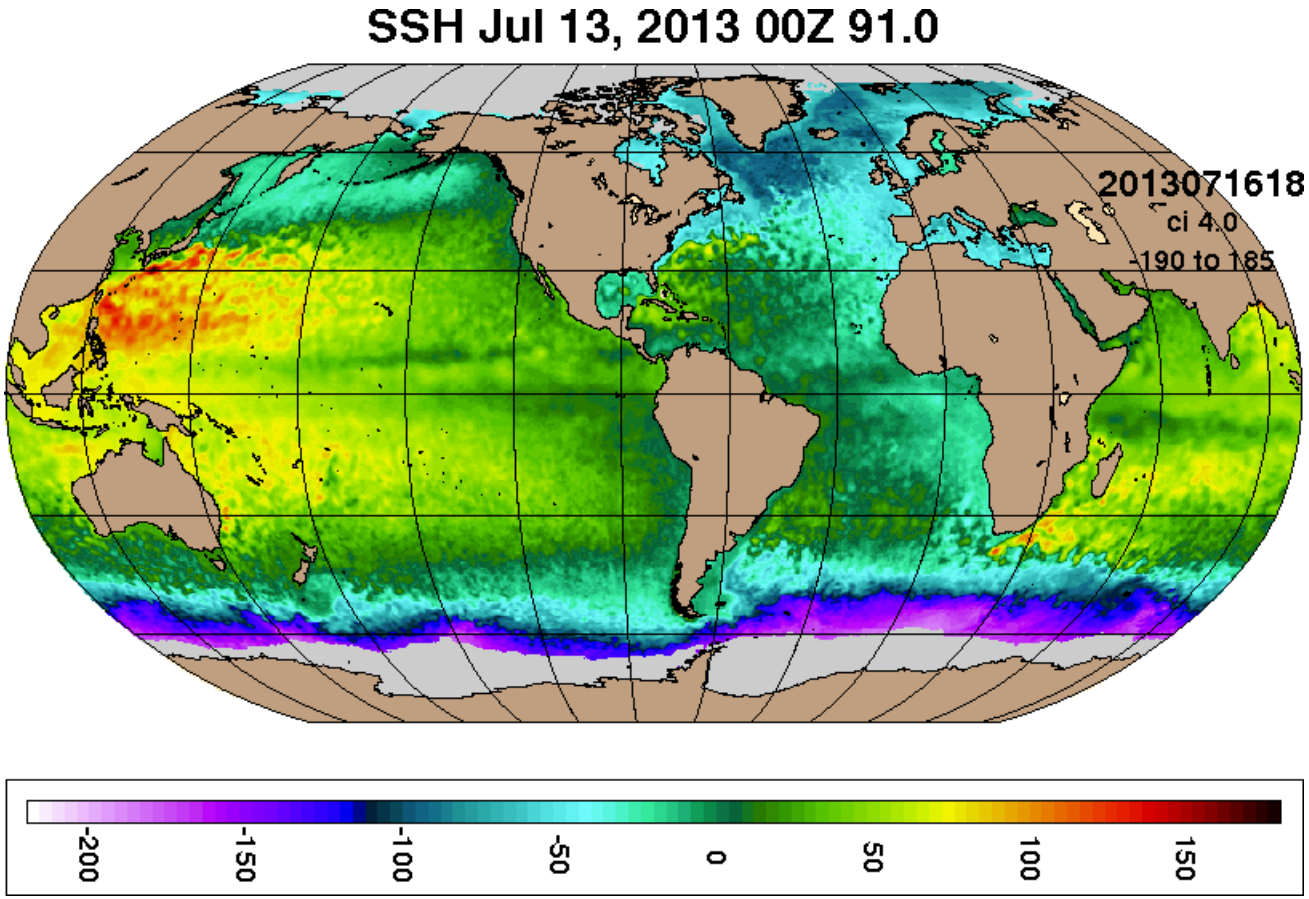




1/12.5 Operational Global Ocean Forecast System using Global HYbrid Ocean Coordinate Model (HYCOM) assimilating SSH, SST and in situ T,S profiles

Navy Global Ocean Forecast System 3.0

NRL is developing and improving the US Navy RealTime Ocean Forecast model. The model makes 7 day forecasts every day using the HYbrid Coordinate Ocean Model (HYCOM) and the Navy Coupled Ocean Data Assimilation (NCODA) 3DVar system. Altimetric SSH is a critical input to this system. NRL has a quality control system which monitors the input data. AltiKa has been added to this system.

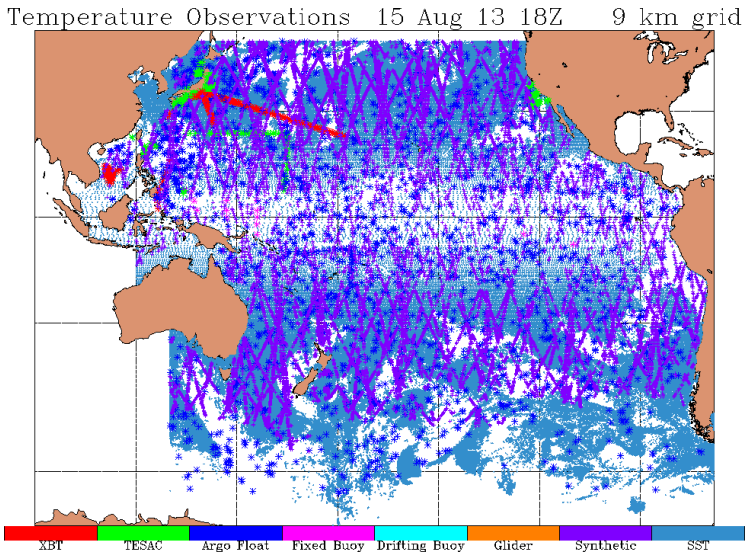


Processing of available data conducted daily

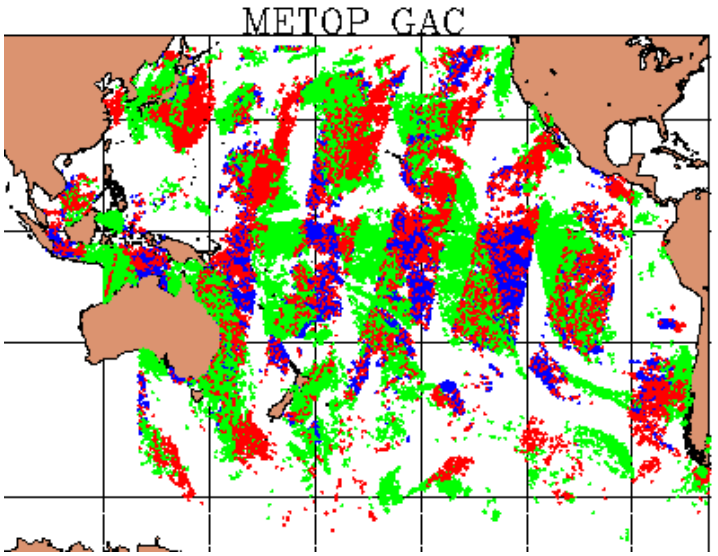
For daily forecasts, the prior 4 days are processed to account for latency

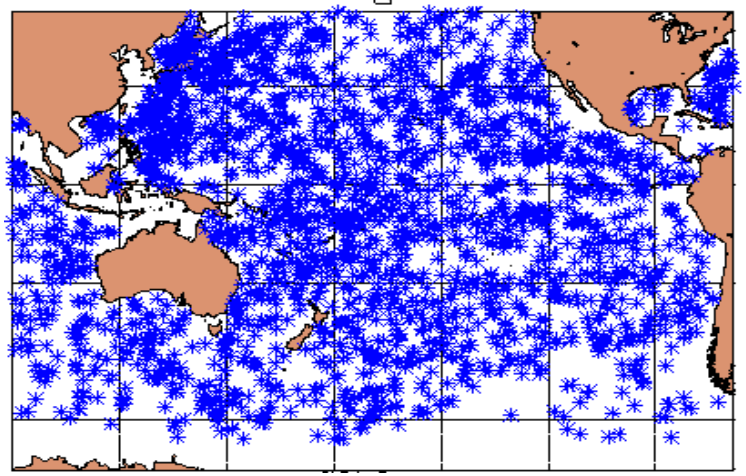
observations 19 Jul to 18 Aug 2013

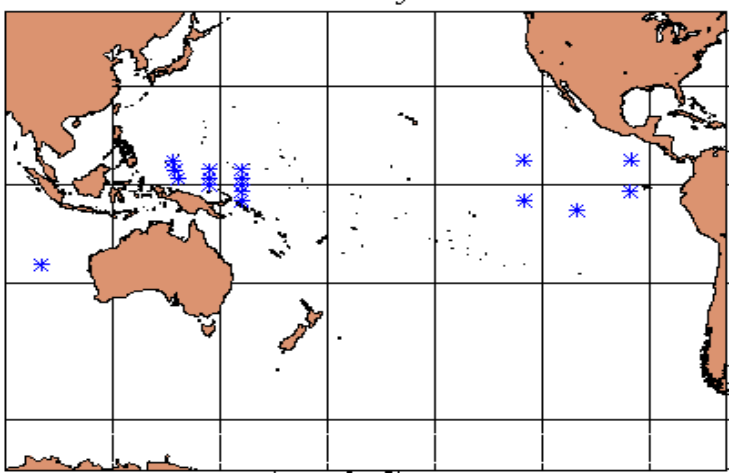
SSH and Temperature



SST

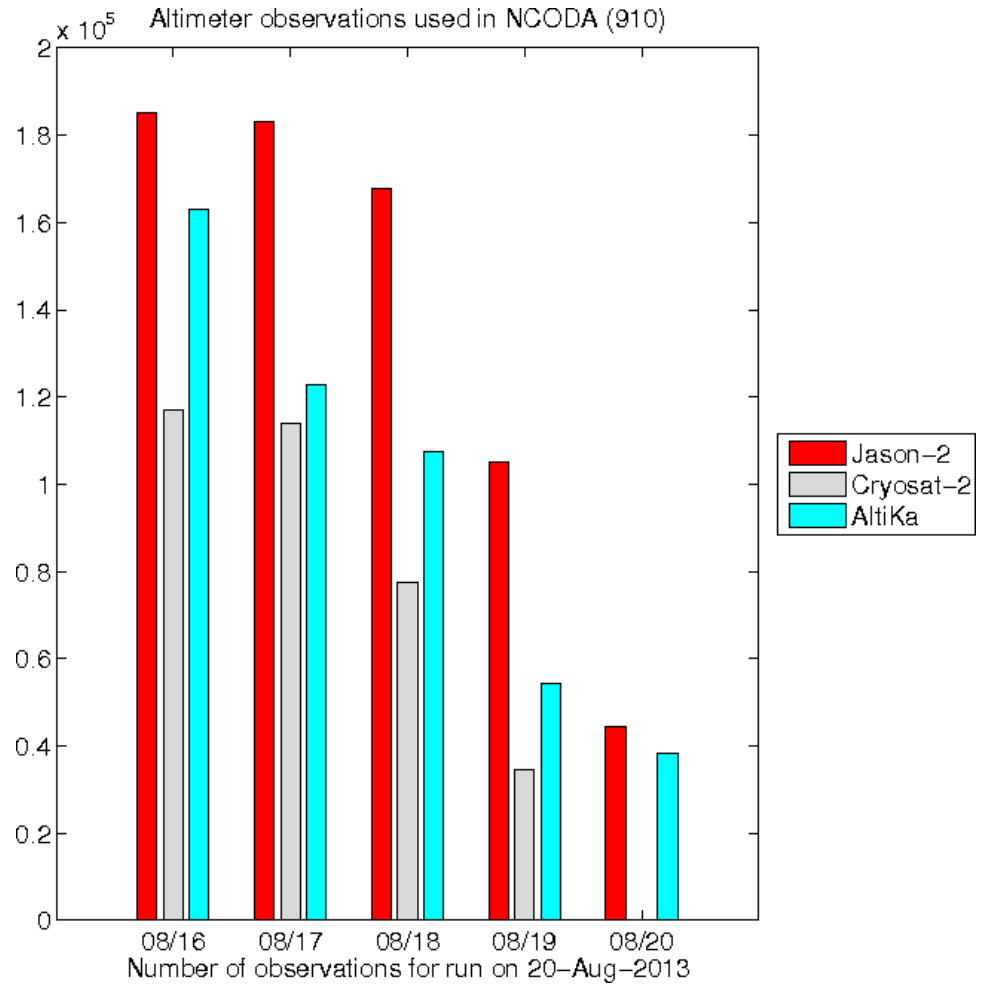






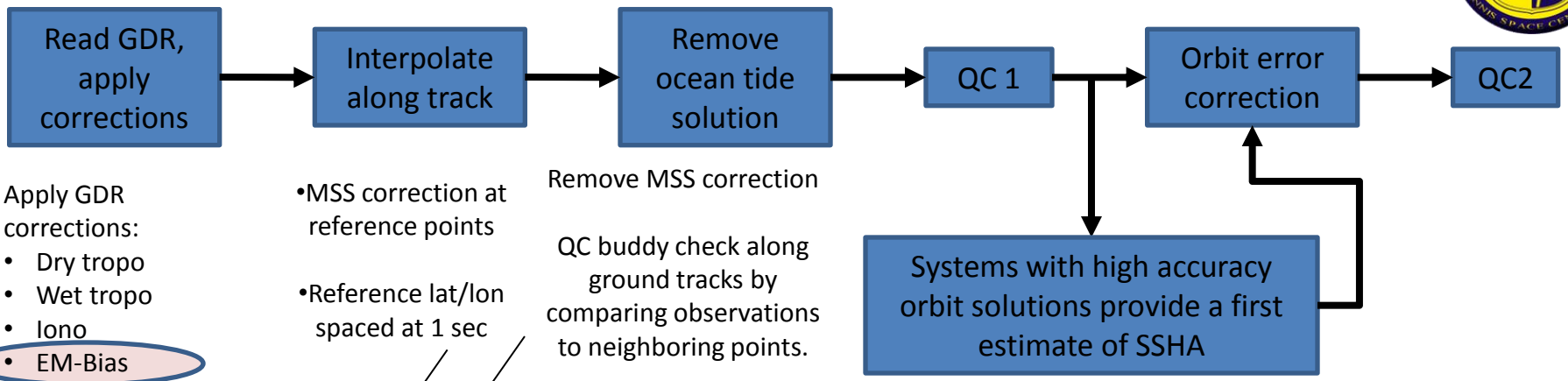
Processing of data daily

Number of SSHA observations available on 20 Aug 2013 for the prior 5 days



- Example of HYCOM assimilation cycle for Aug 20, 2013
- Latency depends on data source
- Improved quality arrives later, and replaces previous data
- Model assimilation / forecast cycle starts at -120 hours each day to bring in improved altimeter data
  - Low latency of AltiKa should allow us to shorten the cycle to -48 hours
    - Important cost saving
    - Next year we plan to move to ~4km global resolution

Processing of the GDR



Apply GDR corrections:

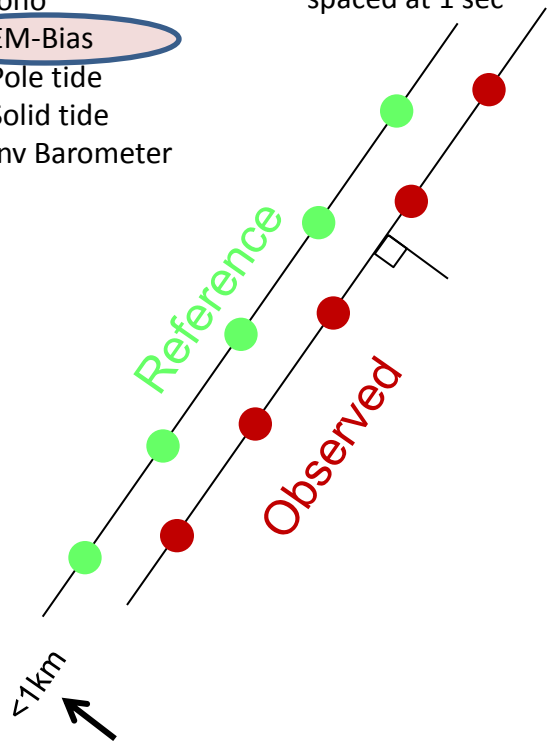
- Dry tropo
- Wet tropo
- Iono
- EM-Bias
- Pole tide
- Solid tide
- Inv Barometer

•MSS correction at reference points

•Reference lat/lon spaced at 1 sec

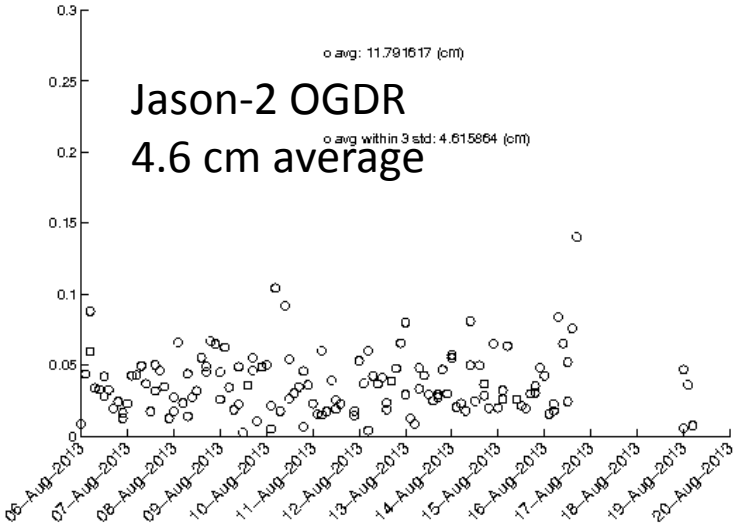
Remove MSS correction

QC buddy check along ground tracks by comparing observations to neighboring points.

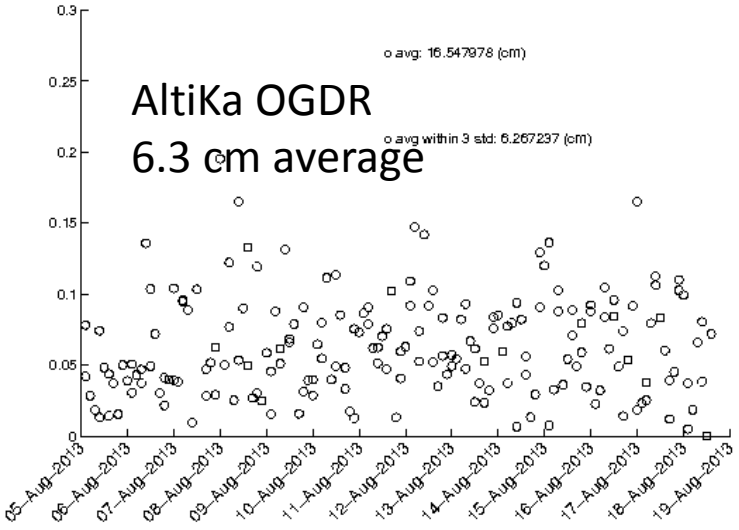


- For the near real-time altimeter data, after applying the GDR corrections
  - Data interpolated to a 1 sec reference latitude/longitude
  - First QC is a buddy check with neighboring points
- Once per revolution orbit error correction applied

Orbit Correction



Jason-2 OGDR
4.6 cm average

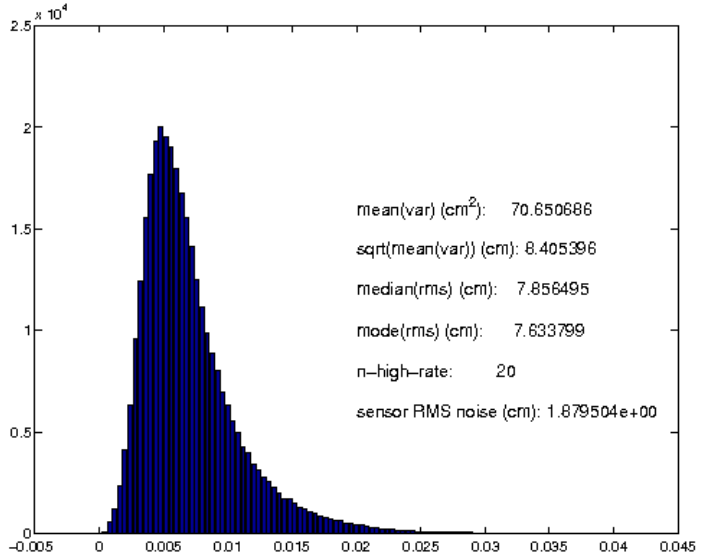


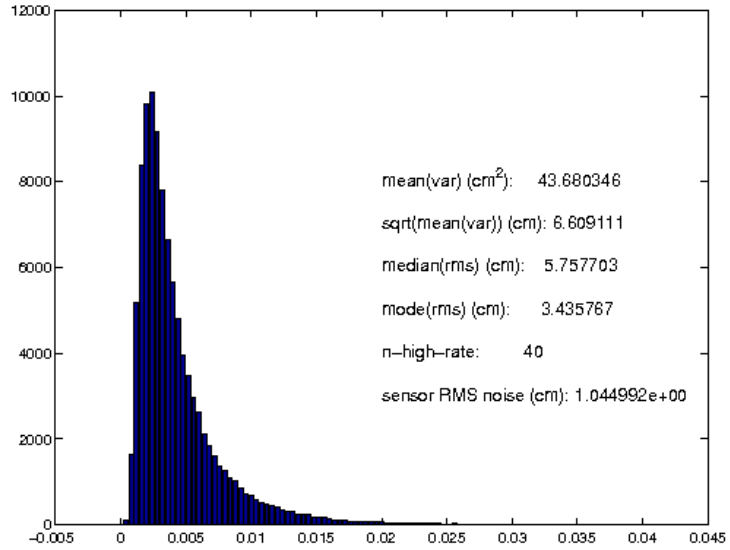
AltiKa OGDR
6.3 cm average

- Modeled as 1 cycle per orbital revolution sinusoid
- Estimated for each revolution independently
- Removes large scale interpolation of SSHA data prior to minimizing large scale variations in the ocean

Example for the last two weeks 5-19 Aug 2013

Precision Monitoring

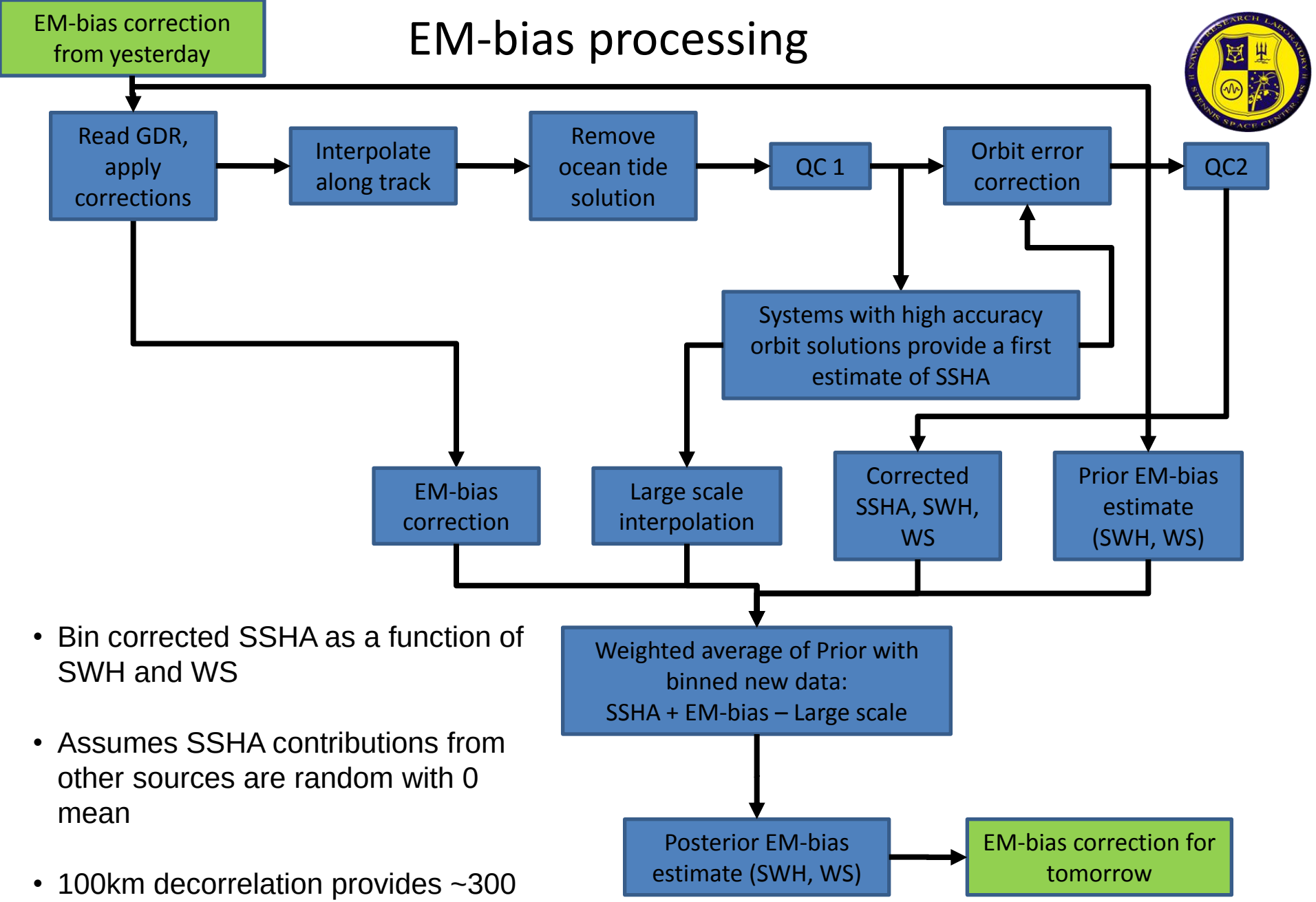




- Sensor noise is estimated from the variance about a linear fit of the 20 or 40 hz data over 1 second
- Jason-2 has 1.88 cm RMS noise
- AltiKa has 1.04 cm RMS noise

Example for the last two weeks 5-19 Aug 2013

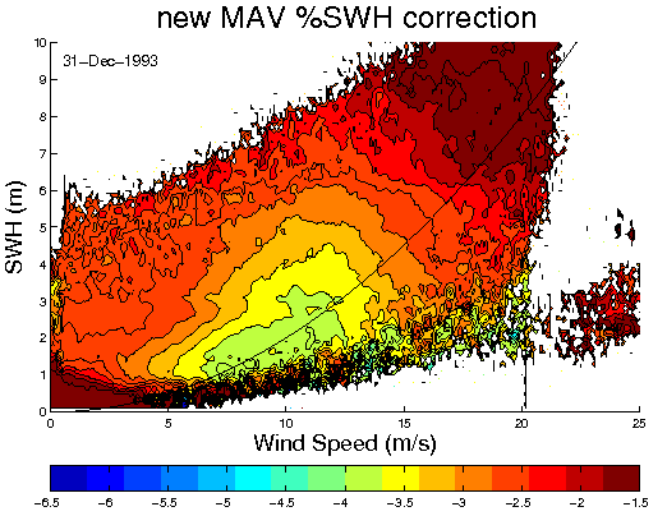
EM-bias processing

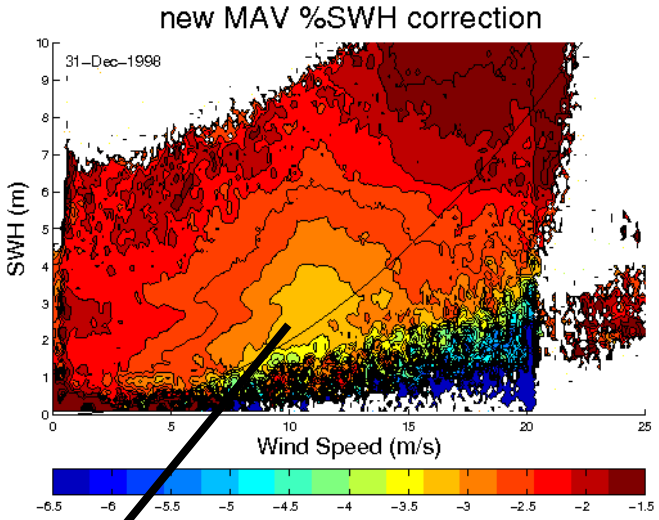


- Bin corrected SSHA as a function of SWH and WS
- Assumes SSHA contributions from other sources are random with 0 mean
- 100km decorrelation provides ~300 independent events in each orbit

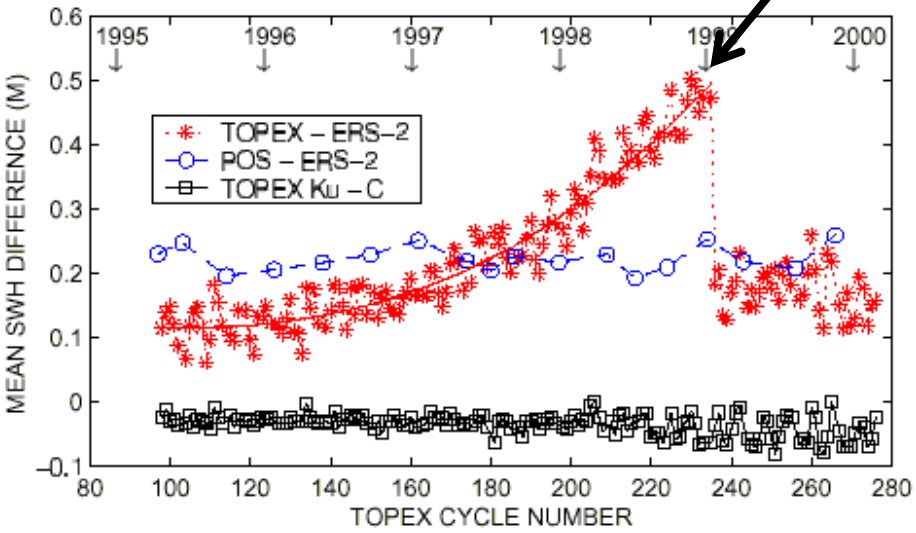
Evolving Sensor Performance

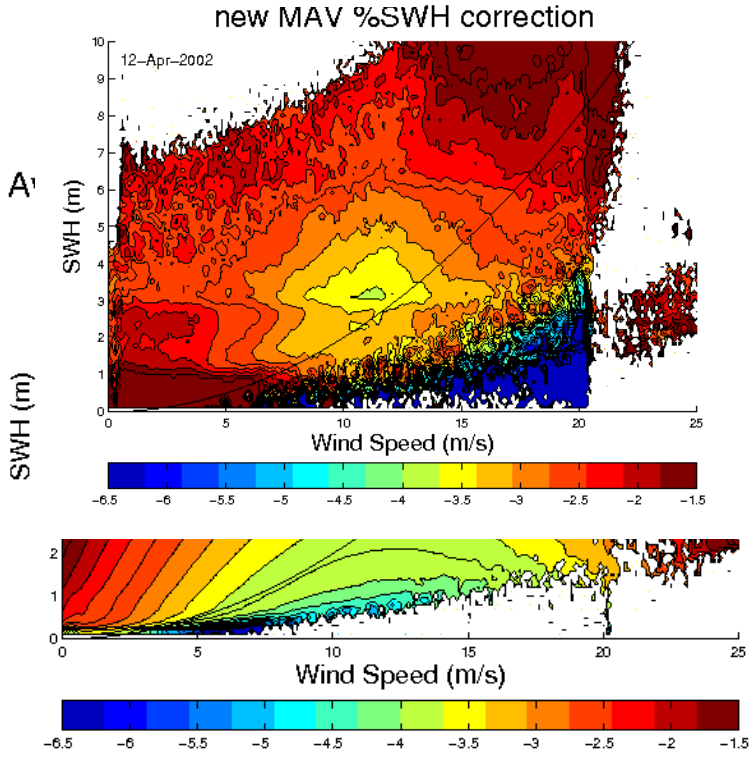
sor drift
coefficients





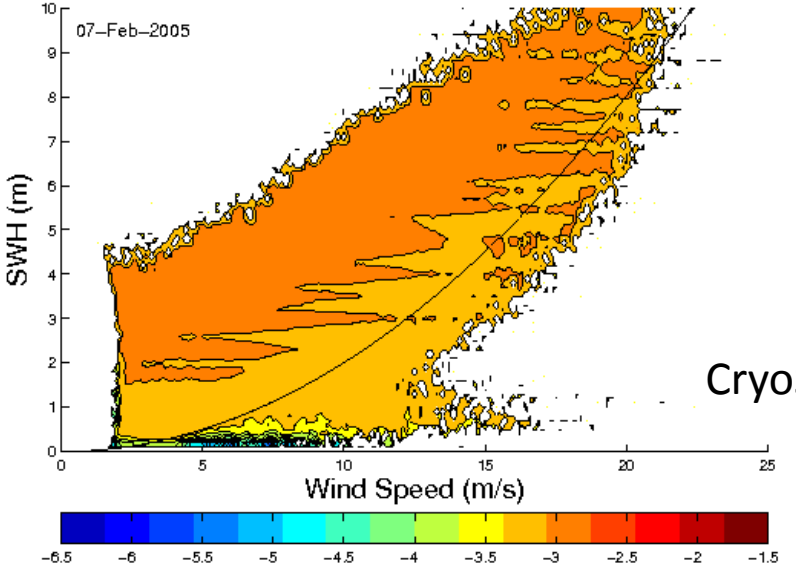
Difference in TOPEX and ERS-2 SWH





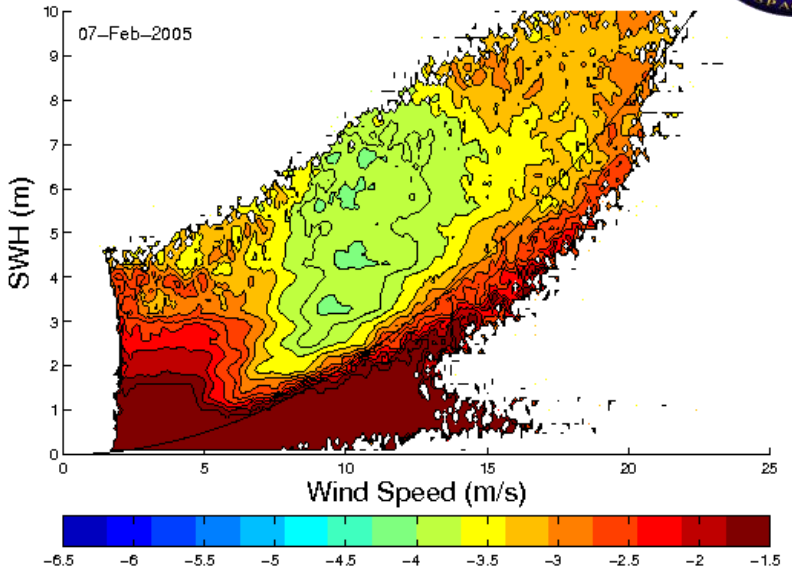
Time Varying EM Bias reduces X-over RMS

Prior EM-Bias correction



CryoSat-2

New EM-Bias correction

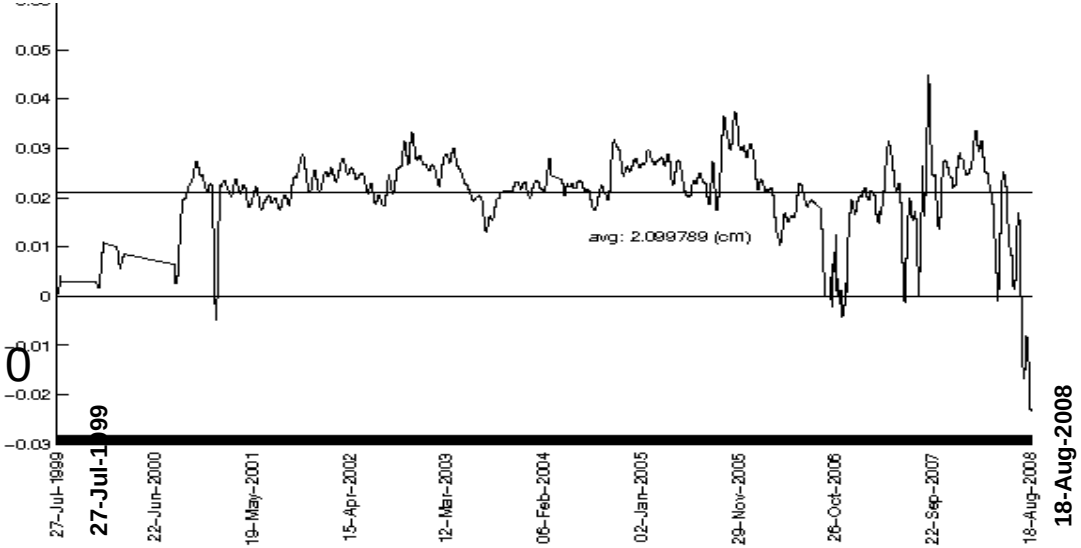


5cm

Avg: 2.1 cm

0

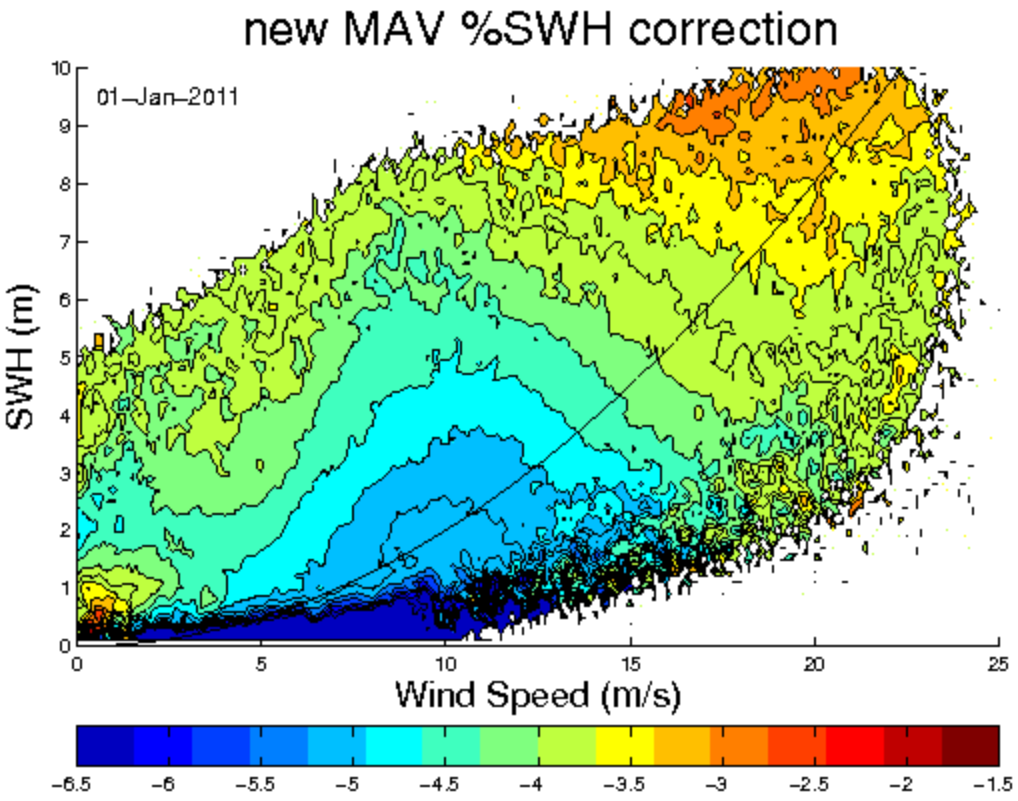
-3cm



Error removed
Measured by
Crossover RMS

Jason-2 EM Bias

Jason-2 Moving average EM-bias correction



- The EM Bias is updated daily with a correction derived from a 30 Moving Average (MAV)
- Without sensor performance changes the EM Bias correction remains stable

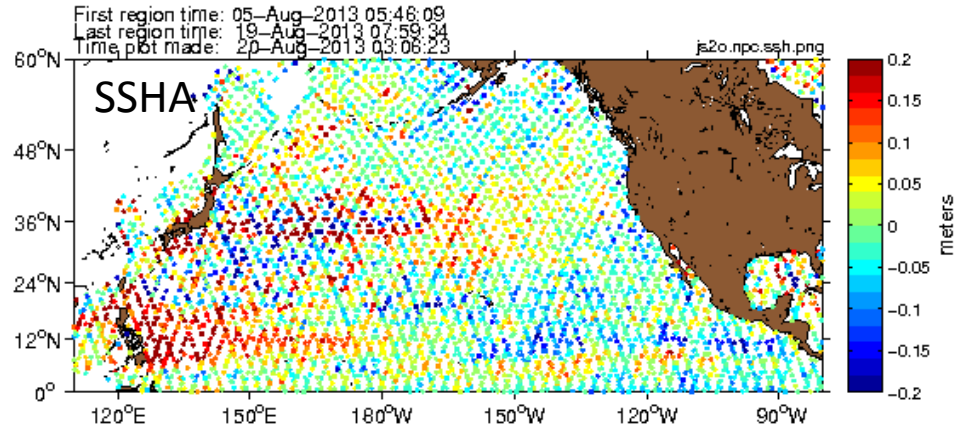
Wind Speed Algorithm

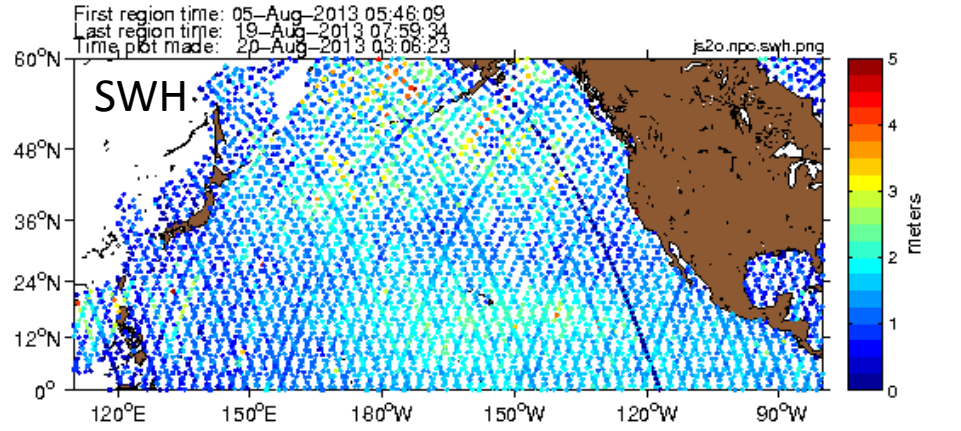
- Following the recommendation of John Lillibridge, Saleh Abdalla and Remko Scharroo implemented Abdalla (2007) wind speed algorithm modified for the attenuation corrected Ka σ_o

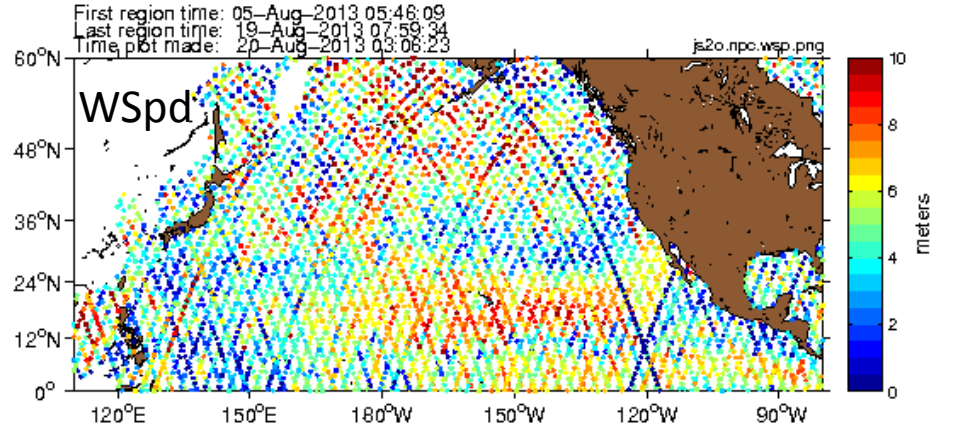
$$U_{10} = U_m + 1.4U_m^{0.096}\exp(-0.32U_m^{1.096})$$

$$U_m = \begin{cases} \alpha - \beta\sigma^\circ & \text{if } \sigma^\circ \le \sigma_b \\ \gamma\exp(-\delta\sigma^\circ) & \text{if } \sigma^\circ > \sigma_b \end{cases}$$

- With the coefficients
- $\alpha = 34.2$; $\beta = 2.48$; $\gamma = 720$; $\delta = 0.42$; $\sigma_b = 11.4$



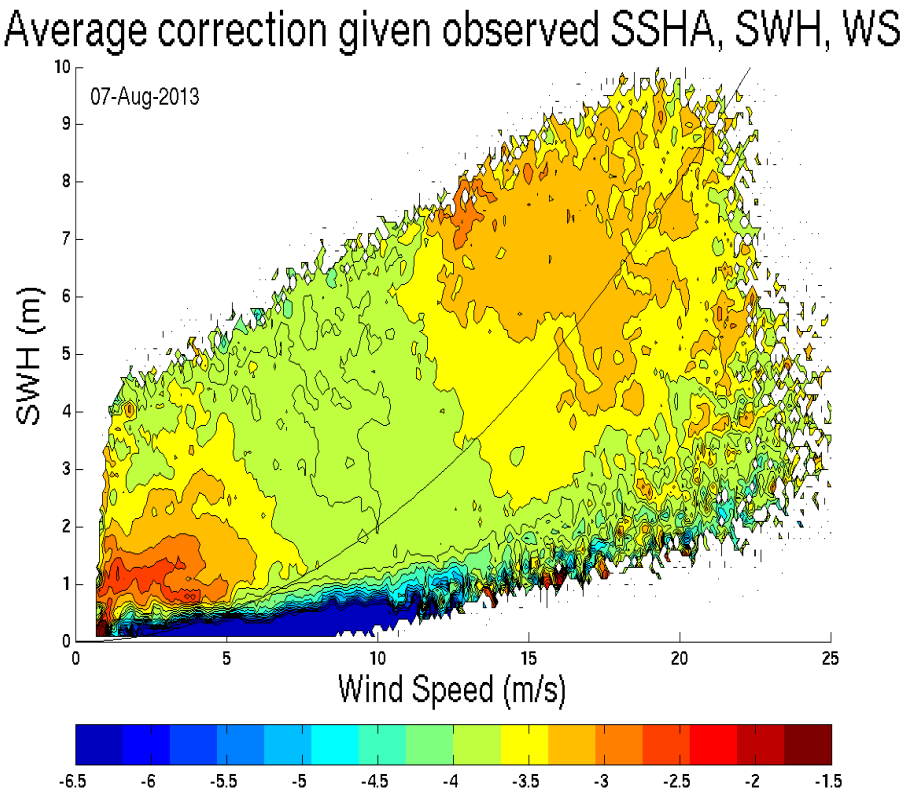




- The SSH anomaly, Significant Wave Height from GDR and the Wind speed from the Abdalla algorithm are used to estimate the EM Bias

Example for the last two weeks
5-19 Aug 2013

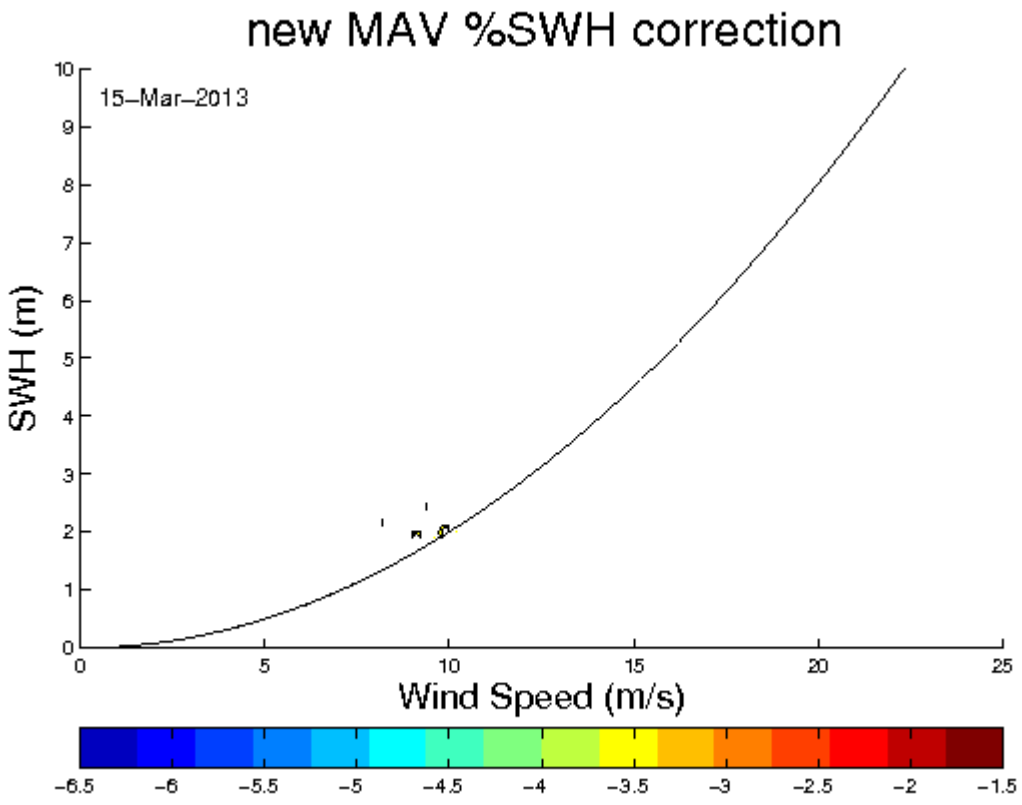
AltiKa EM Bias



- Aug 20, 2013
  - 30 day moving average EM Bias correction
- Still showing variability from insufficient data to converge on stable correction
- Shows tendency for increased bias around 10 m/s seen in Ku band altimeters

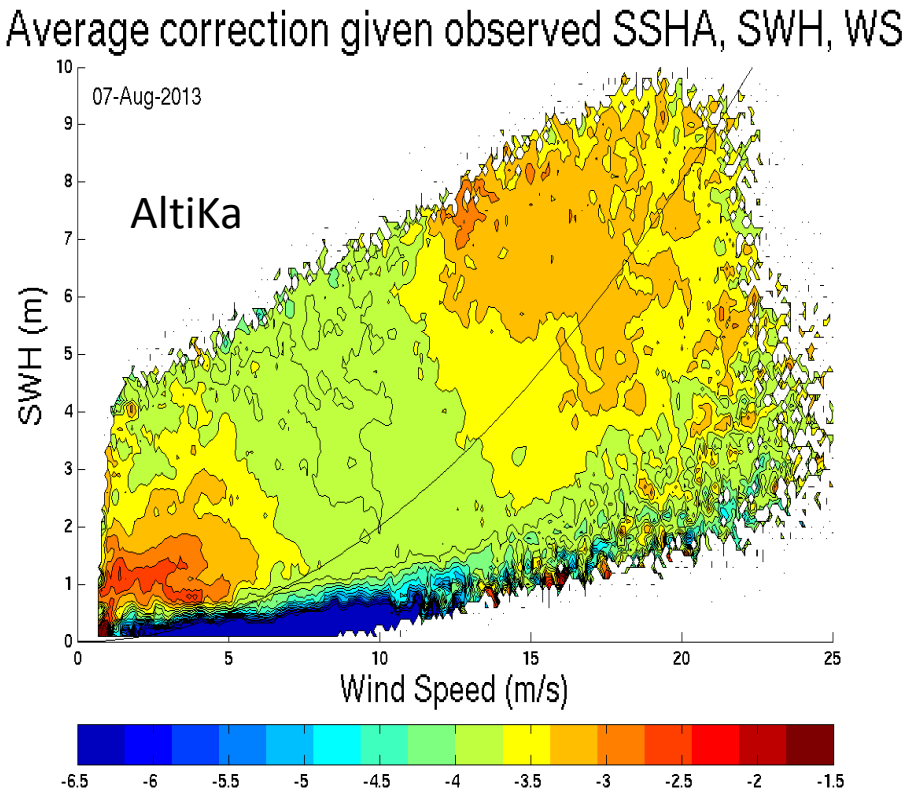
Evolution of AltiKa EM Bias

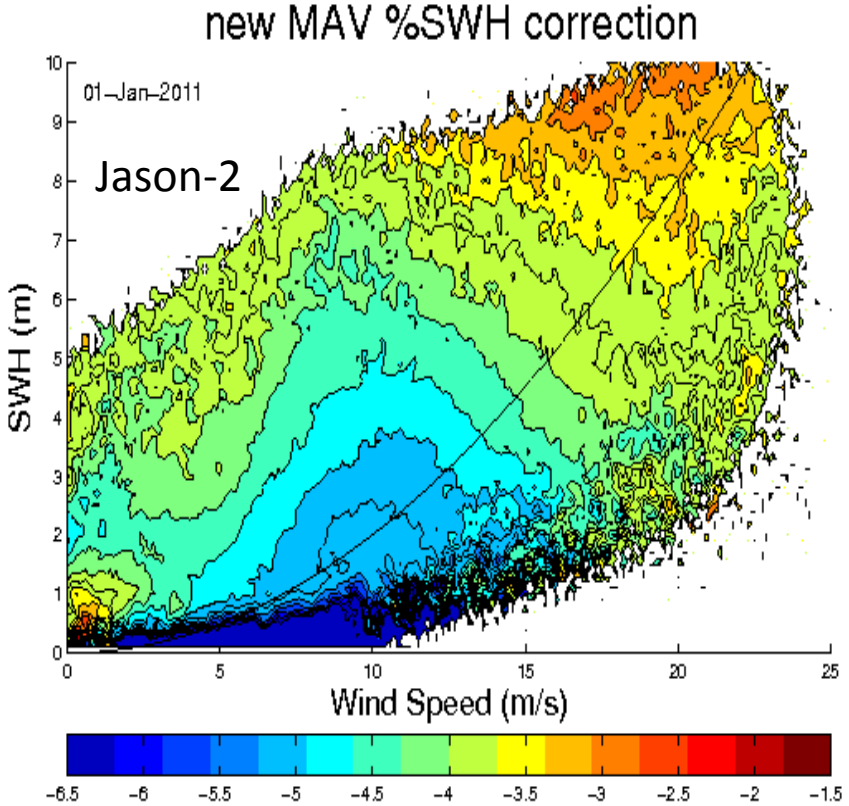
AltiKa Moving average EM-bias correction



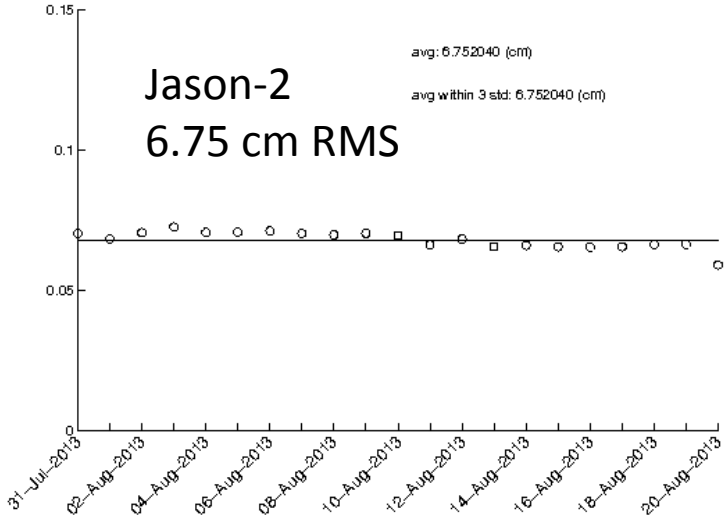
- The EM Bias is updated daily with a correction derived from a 30 Moving Average (MAV)

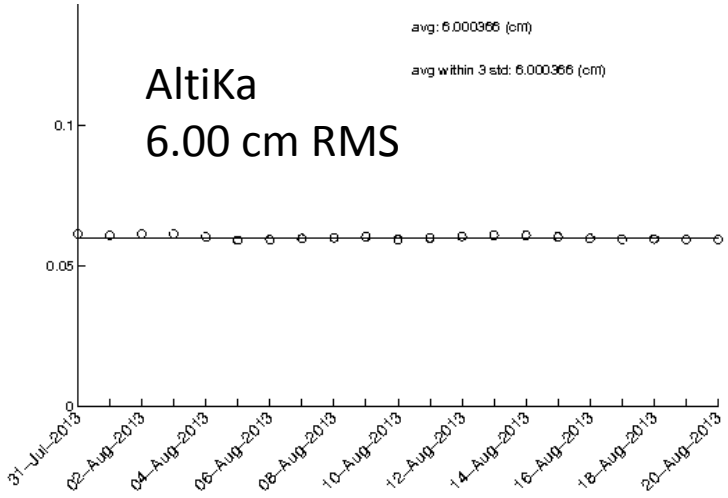
AltiKa EM Bias





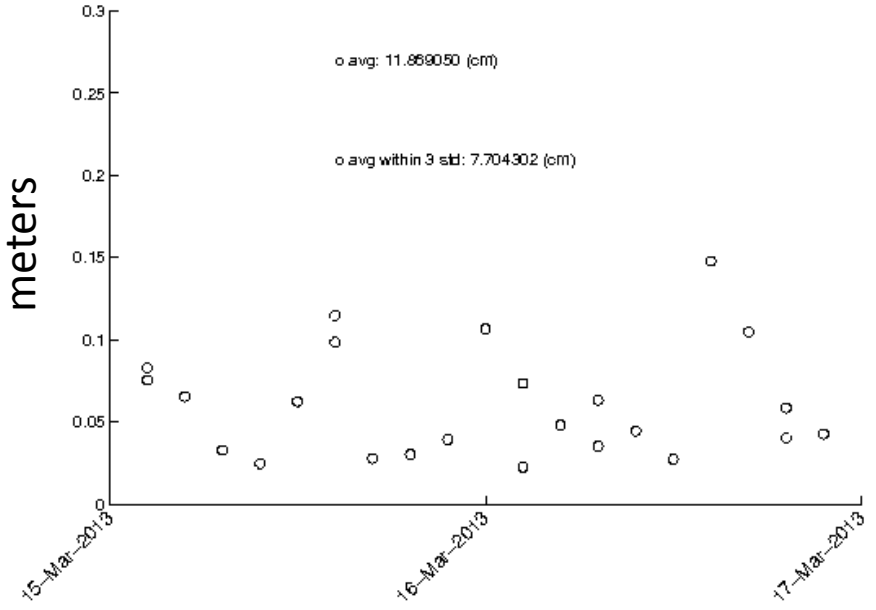
Crossover Differences



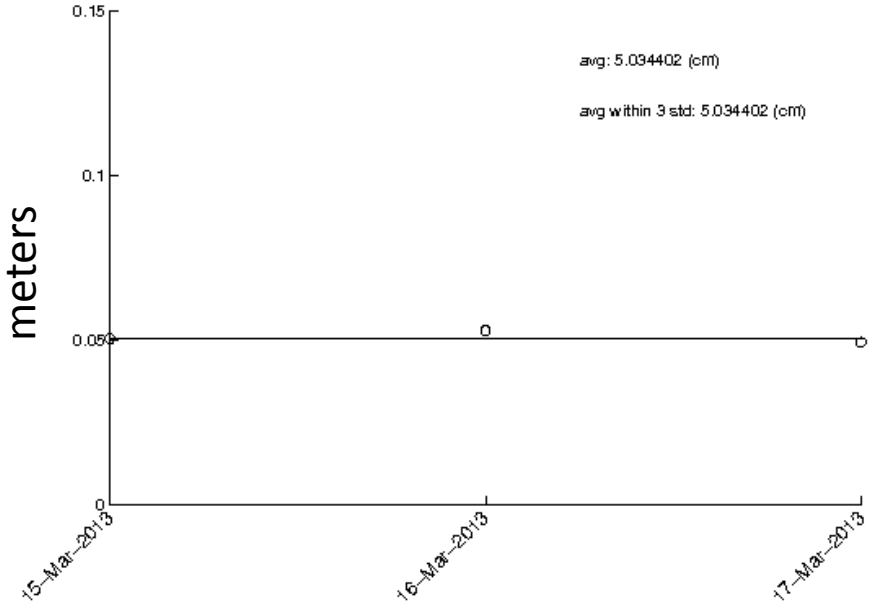


- Crossover Differences are computed daily using the prior 14 days of data
- AltiKa has a lower crossover difference (6.00 cm) than Jason-2 (6.75 cm) along with lower noise

Example for the last two weeks 5-19 Aug 2013



AltiKa orbit correction (for each full revolution of satellite data)



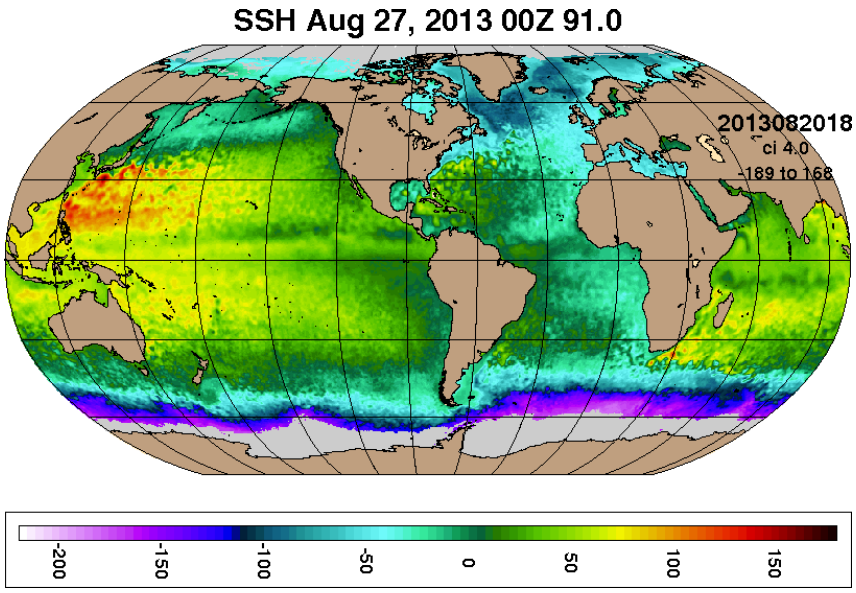
AltiKa crossover RMS (daily estimation using prior 14 days of data)

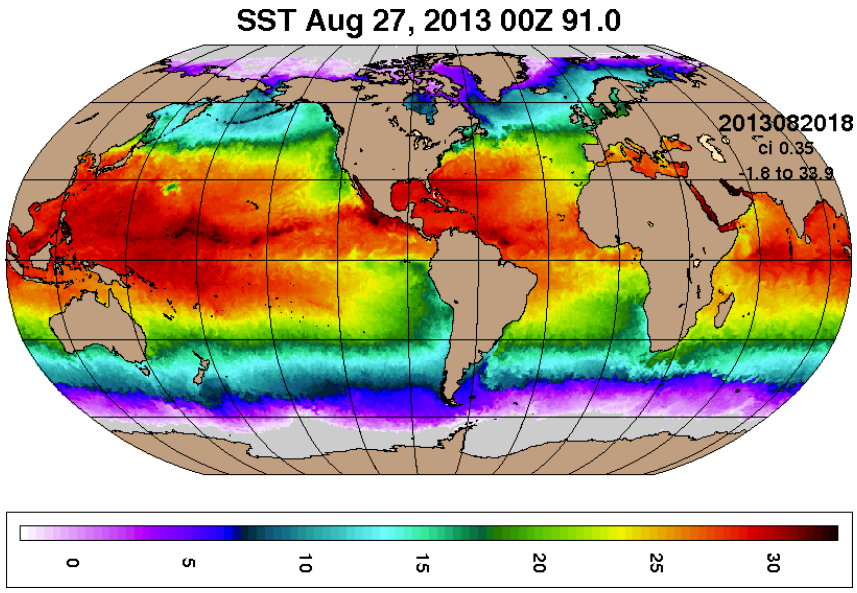
July 5
Crossover RMS (cm)
14 prior day's data

	js2i	cryi	atki
js2i	**7.1**	**9.0**	**7.2**
cryi	**9.0**	**7.7**	**8.0**
atki	**7.2**	**8.0**	**5.8**

Monitoring AltiKa is part of the QC for the Global Ocean Forecast System

AltiKa is performing as good as Jason-2 providing SSHA to the realtime forecast model. The addition of a second altimeter has a significant impact on the forecast skill of the model. The short latency of AltiKa will allow us to shorten our hindcast cycle, which is important as we look towards a higher resolution (1/25° or ~4km) global model.





Assimilation of Altimetric SSHA into the Ocean Model

- Innovations of SSH can not be directly inserted into the ocean model with a free surface
  - Corrections radiate away from the insertion region as long gravity waves
- The altimeter SSHA projected into vertical profiles of temperature and salinity using correlations from the Navy Global Digital Environmental Model (GDEM)
  - These synthetic T-S profiles are assimilated into the model
  - July 2013 a field campaign was held off Norfolk VA, in part to validate a new synthetic profile technique
    - Improved Synthetic Ocean Profiles (ISOP)
  - Campaign deployed 250 AXBTs on 4 flights crossing the Gulf Stream
    - Testing hypothesis about conditional predictability of mesoscale flow generated fronts and filaments
  - AXBT underflight of AltiKa pass on July 11, 2013

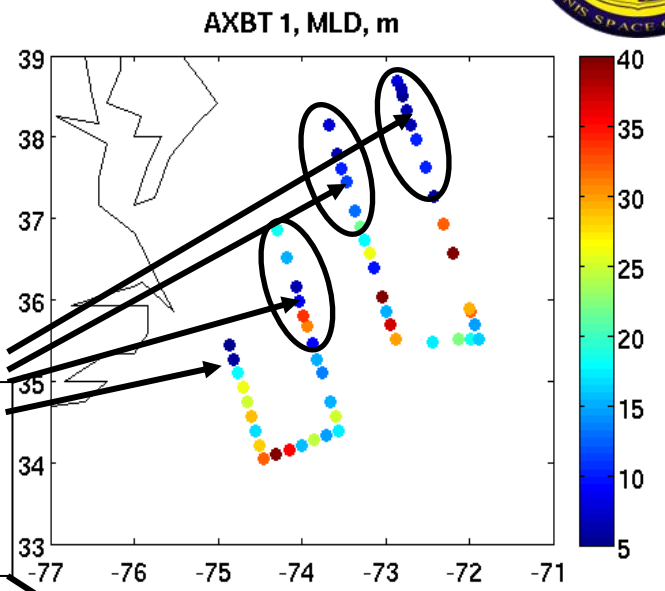
AXBT campaign used to demonstrate frontogenesis processes that result in shallow mixed layers along narrow filaments around mesoscale features

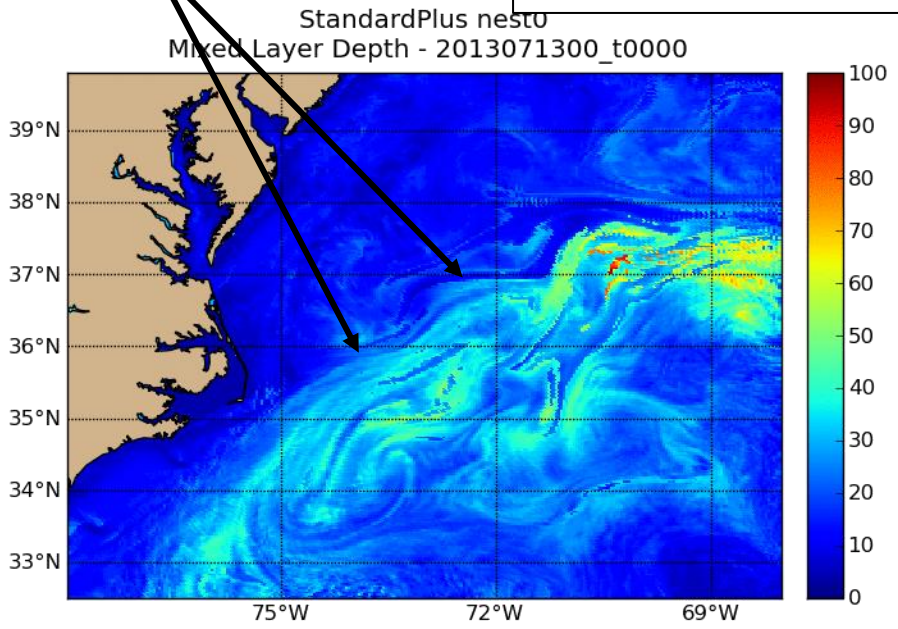
AXBT data assimilated in real time for place mesoscale feature and forecast frontogenesis effects on mixed layer resulting in thin mixed layer / sonic layer in filaments in the periphery of mesoscale features

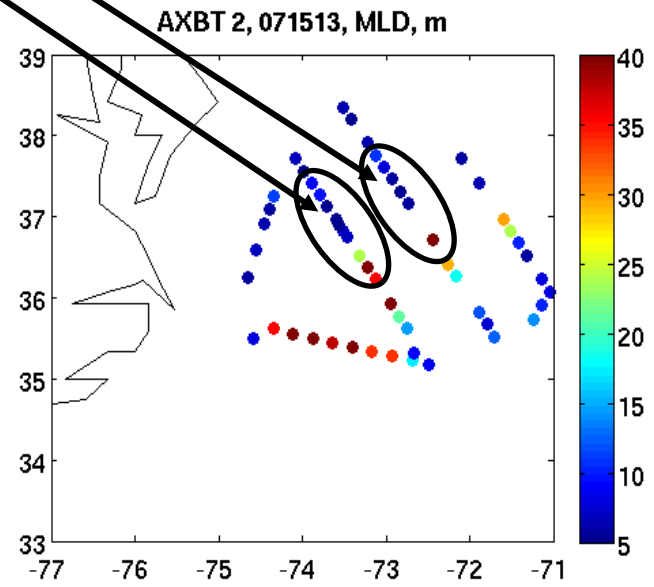
With an accurate placement of the mesoscale structure, is frontogenesis predictable in the ocean?

Frontogenesis on north wall of Gulf Stream forecasted in model

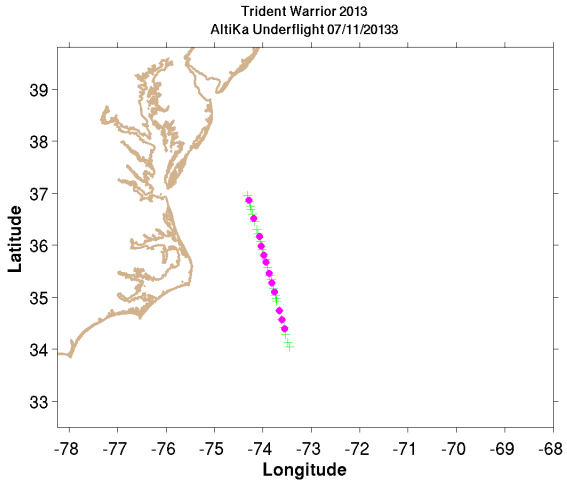
Consistent filament of thin mixed layer in observed data sets







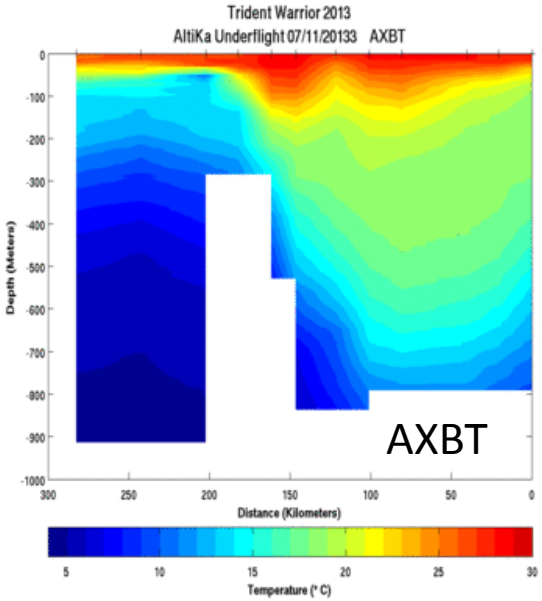
July 11 AltiKa Underflight

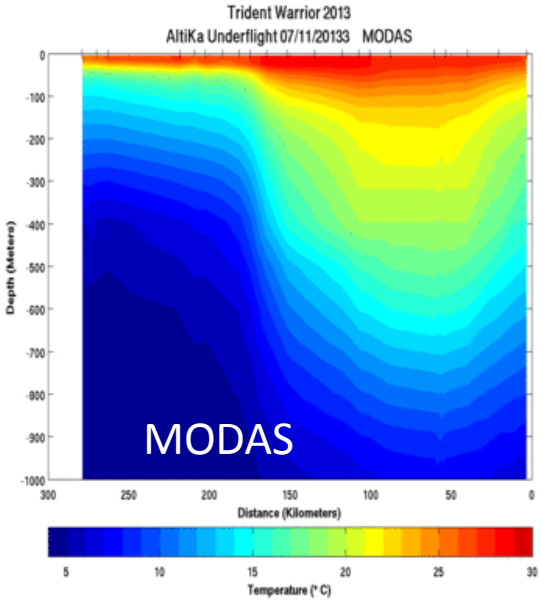


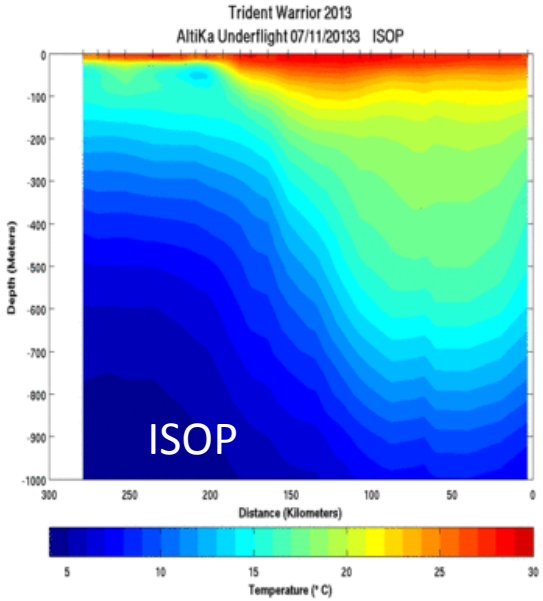
For July only 52 profiles are found in the GDEM database in this area

Old synthetics (MODAS) have a warm bias
New synthetics (ISOP) perform better

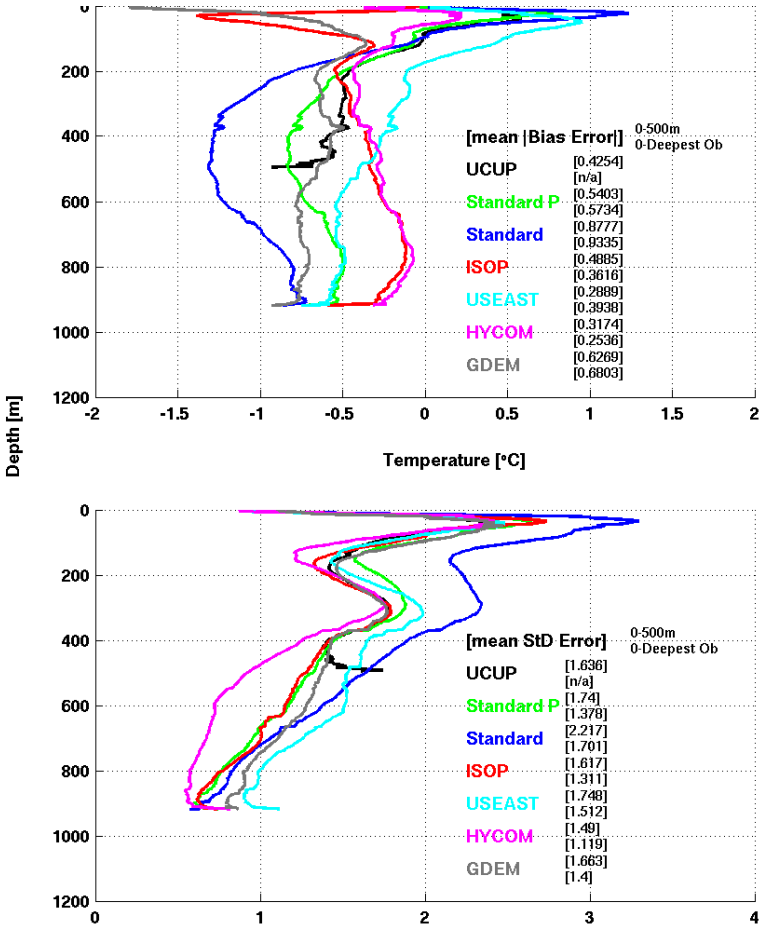
Gulf Stream front is weaker in the synthetics than observations



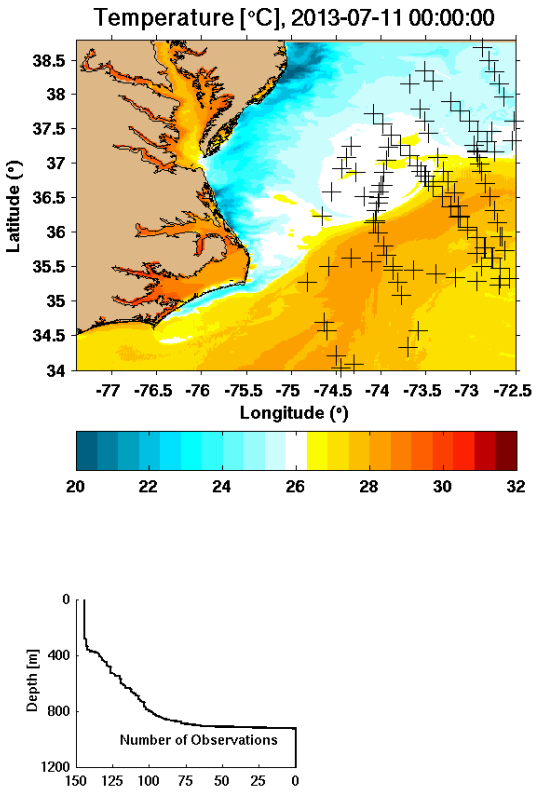




Model 24 hour forecast performance Using AXBT data to validate forecasts on days of last 3 flights (July 15, 17 and 18)

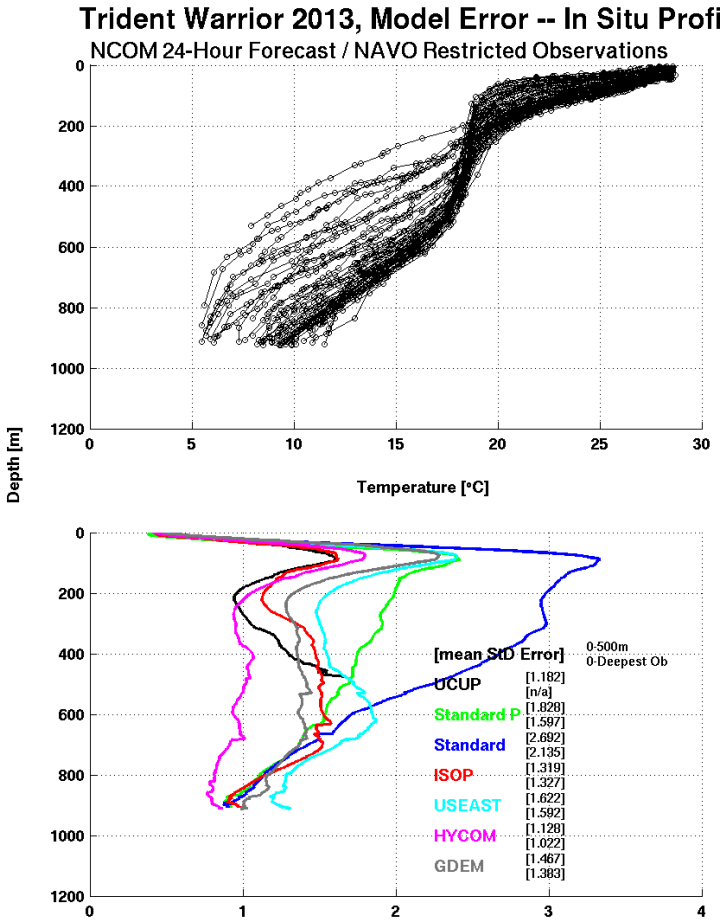


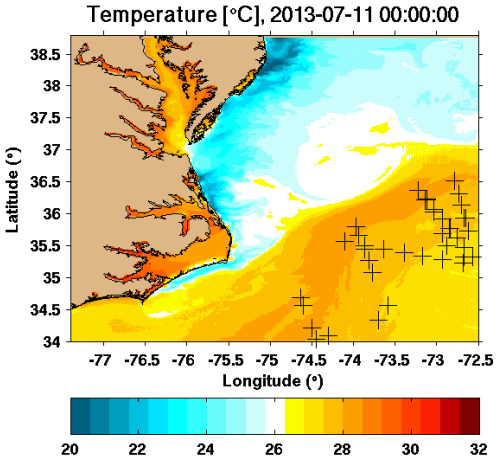
Global HYCOM 8km
Regional NCOM 3km

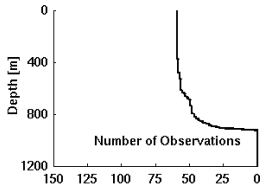


Global HYCOM and the new ISOP synthetics have the smallest bias and RMSE in Temperature

Model 24 forecast performance in Gulf Stream and Sargasso Sea







- AltiKa is providing valuable information to the realtime global and regional forecast models
- Realtime monitoring shows stable statistics for noise
- EM bias monitoring is stable, but concerns about σ_o make this work preliminary

Thanks to CNES and ISRO for putting together this very successful project