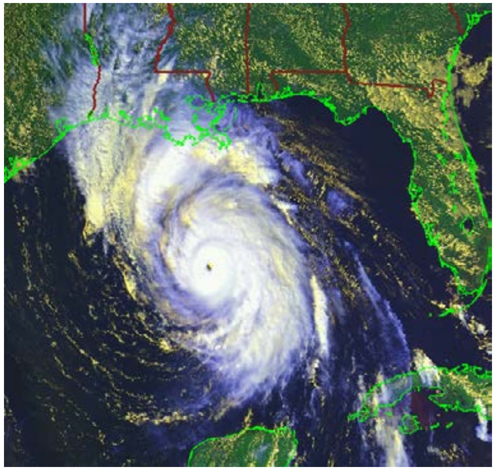
Operational Ocean Heat Content Variability From Satellite Radar Altimetry Measurements For Intensity Forecasting



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Goal: Build a global evaluated OHC product for forecasting intensity through SHIPS and initializing/evaluating coupled models by combining multiple altimeters with in situ data.

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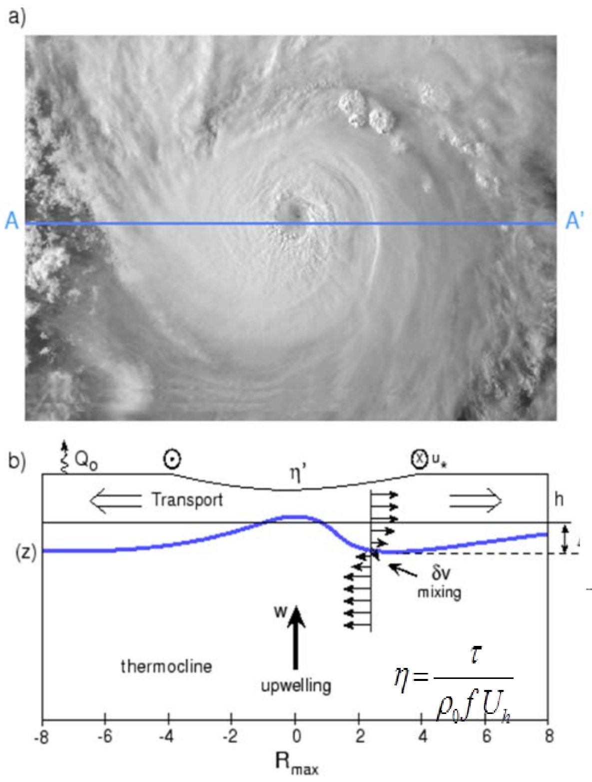
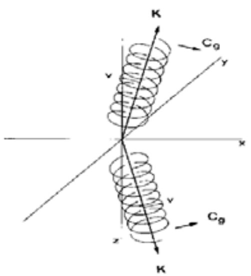
Outline

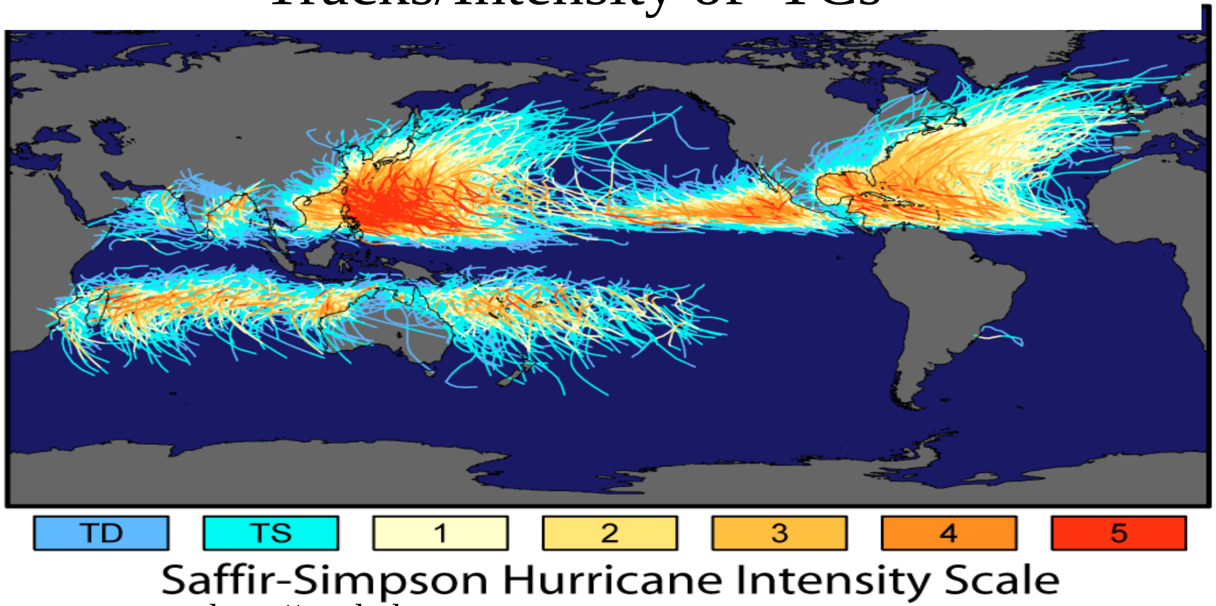
- Motivation
- Oceanic Heat Content Approach
- SMARTS-North Atlantic Ocean
- SPORTS/SPOC-Pacific Ocean
- Eastern Pacific: Blanca and Patricia (2015) **(El Nino)**
- Western Atlantic: Matthew (2016)
- In Situ Measurements/New Floats
- Summary



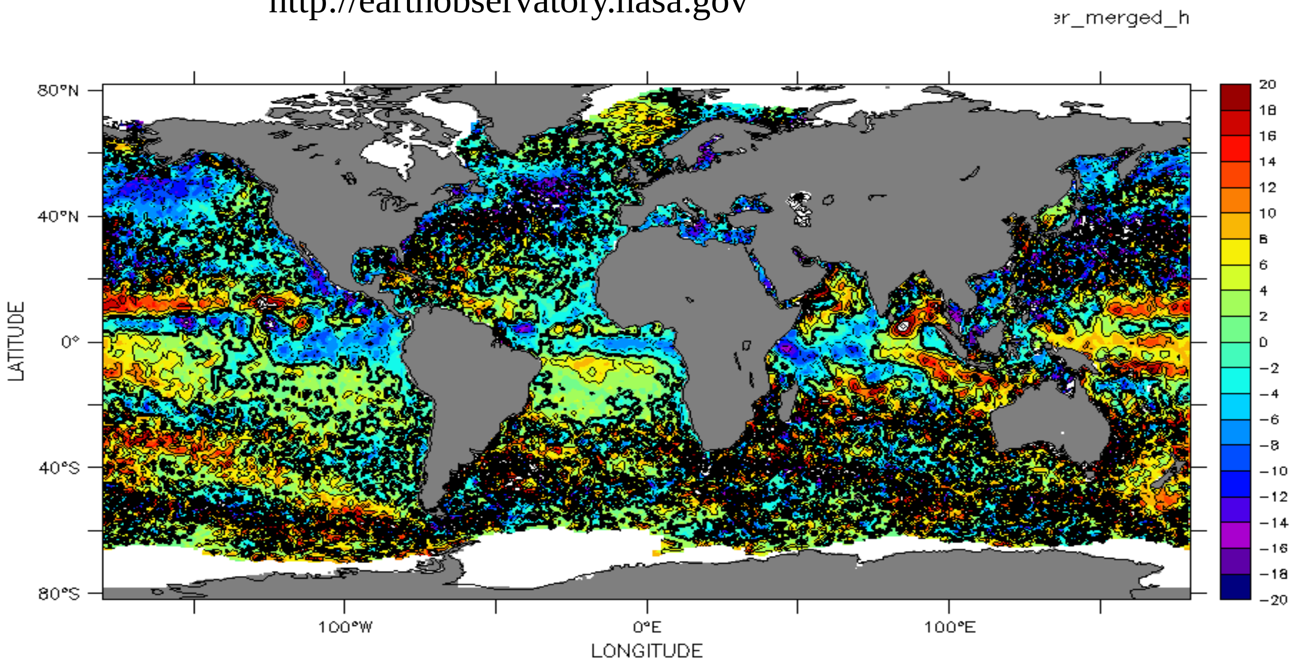


Key Finding: Evaluate the uncertainties and the biases of space-based estimates with in-situ ocean measurements.

Tracks/Intensity of TCs

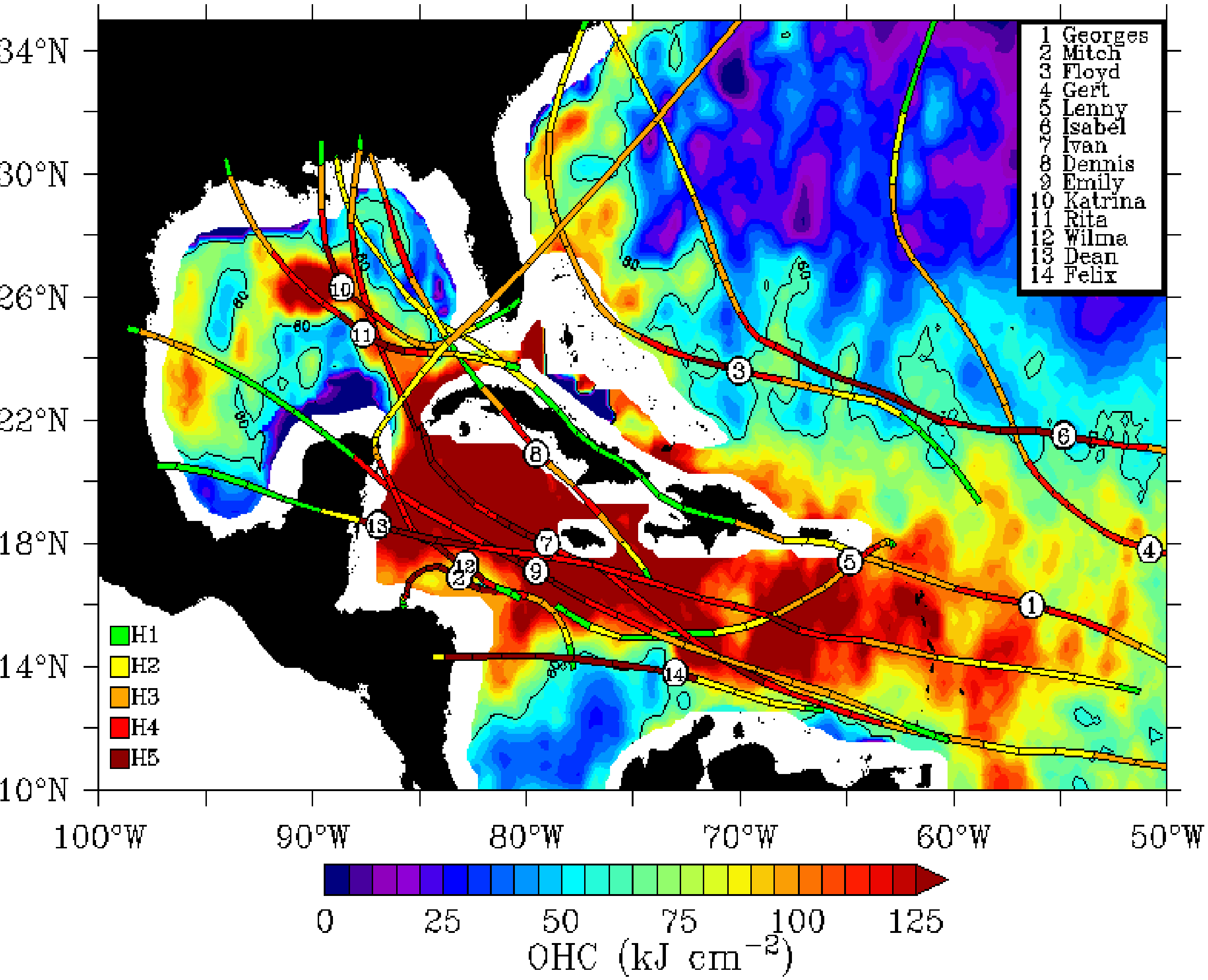


http://earthobservatory.nasa.gov



Sea surface height anomaly (cm) http://www.aviso.oceanobs.com

Global Problem of TC-Ocean Interactions.



Motivation:

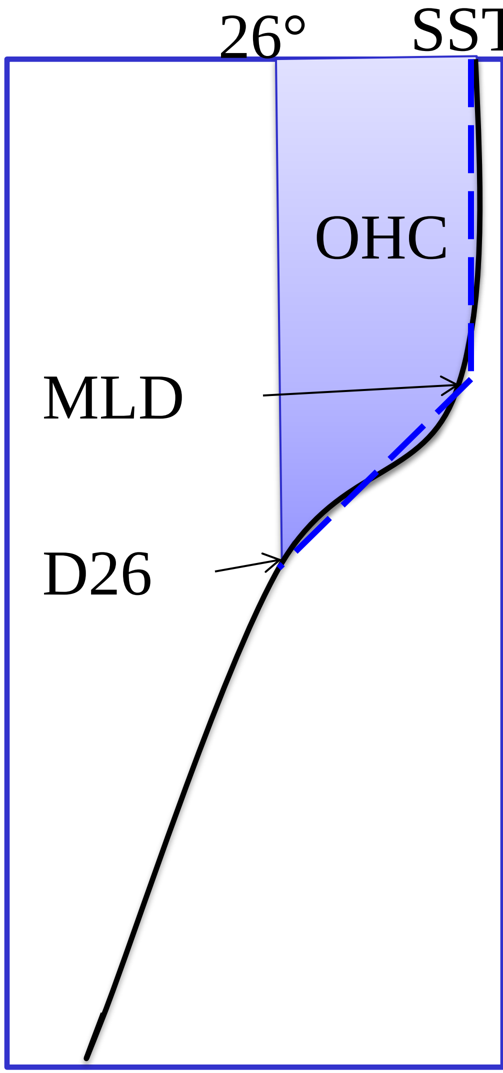
Tracks and positions of maximum intensity for fourteen of the strongest hurricanes recorded in HURDAT from 1998-2011, plotted over OHC for Sept 2005 from the Systematically Merged Atlantic Ocean Temperature and Salinity (SMARTS) climatology (Meyers et al., JAOT, 2014).

SST, MLD and OHC Background

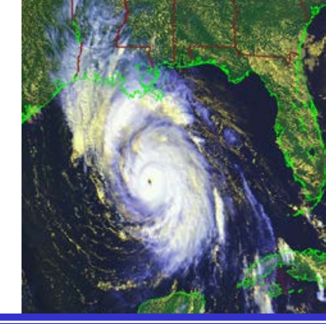
- Minimum sea surface temperature threshold for hurricane formation: SST >26ºC (Palmen, 1948)
- Leipper (1972) introduced Ocean Heat Content integrated thermal energy from surface to 26º isotherm:

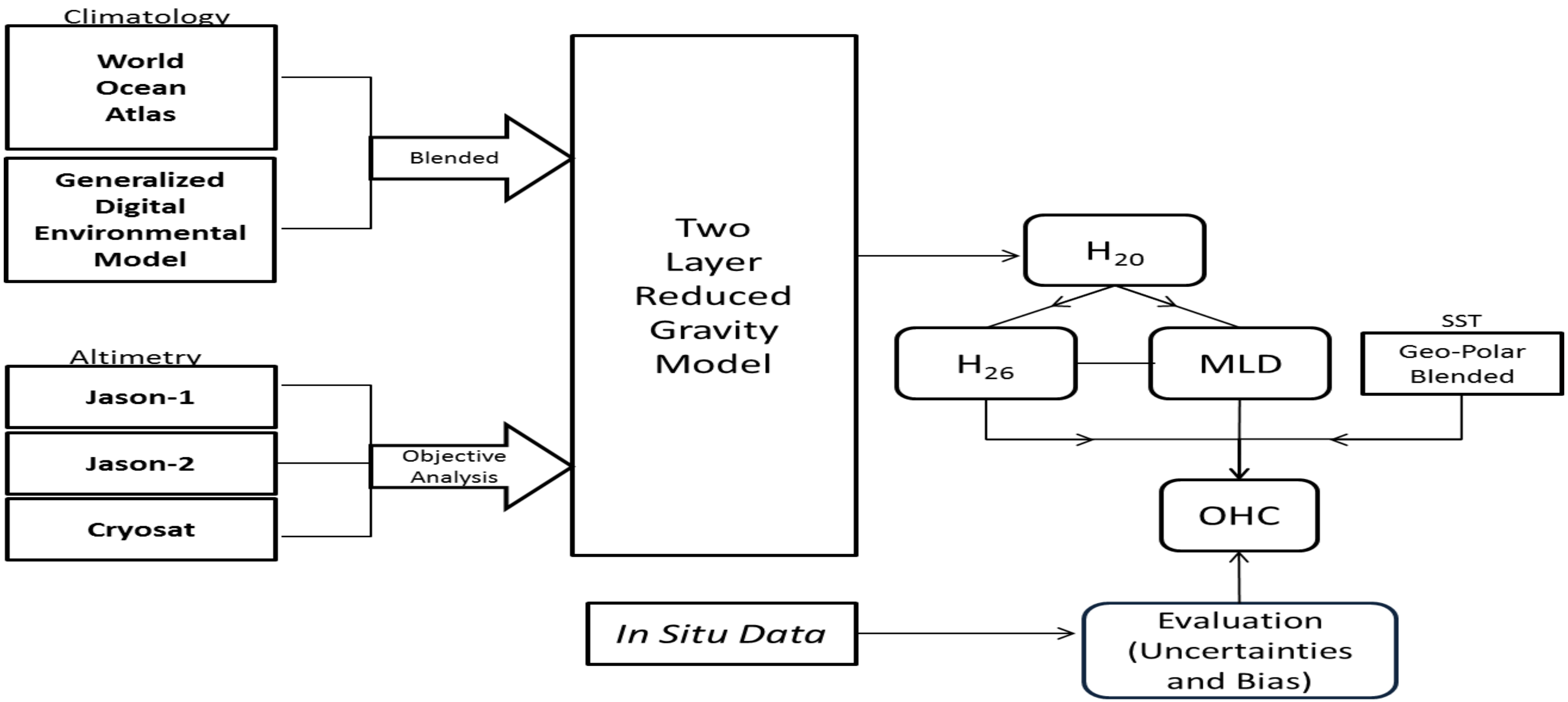
$$OHC = c_p \rho \int_{D26}^{\eta} (T_z - 26^\circ) dz$$

- Approach to estimate OHC from satellite derived SSTs and SSHAs for Operational and Research Products (Shay and Brewster, MWR, 2010)
- **Operational** Product-Uses NESDIS Geopolar SST product (Maturi et al., BAMS, 2008) and daily updated SSHAs.
- **Research** Product-Uses RSS Microwave product and or/GRHSST product with weighted SSHA field focusing on day of interest (+/- 5 day window for altimeter).
- Remotely sensed **products are evaluated** using ARGO floats, ship transects, mooring time series, drifters, and aircraft expendables - *establishes error bars/biases*..

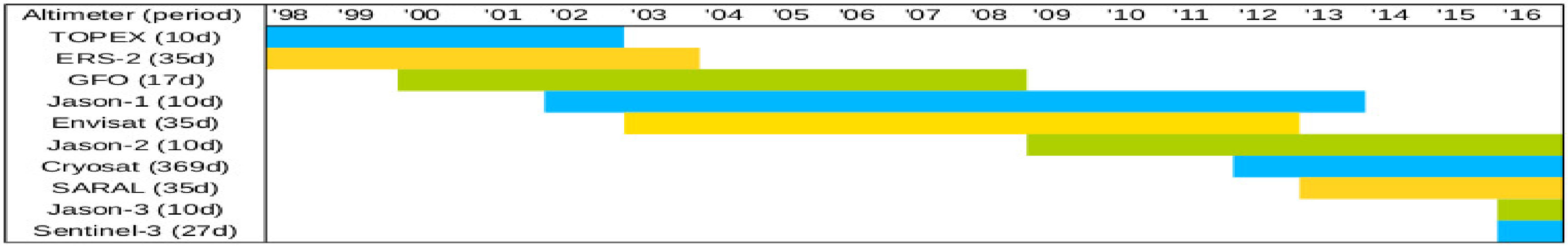


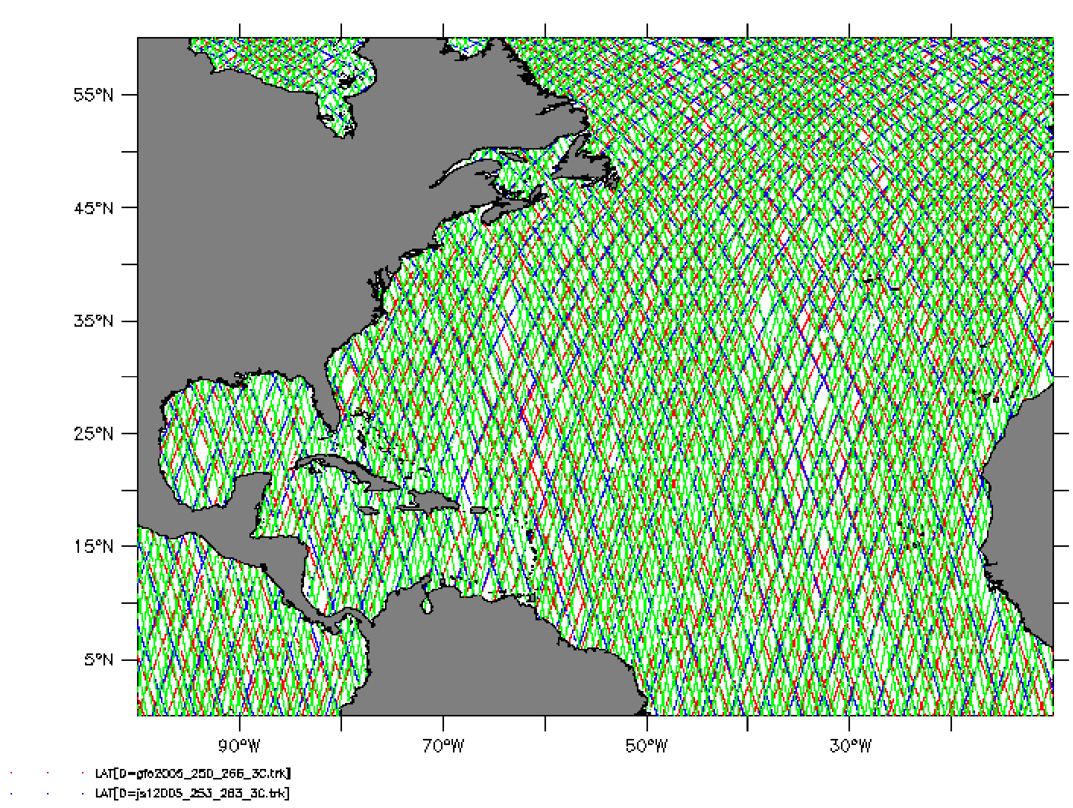
Operational Approach using SMARTS and SPORTS (Shay and Brewster, MWR, 2010; Meyers et al., JAOT, 2014; McCaskill et al. JAOT, 2016)

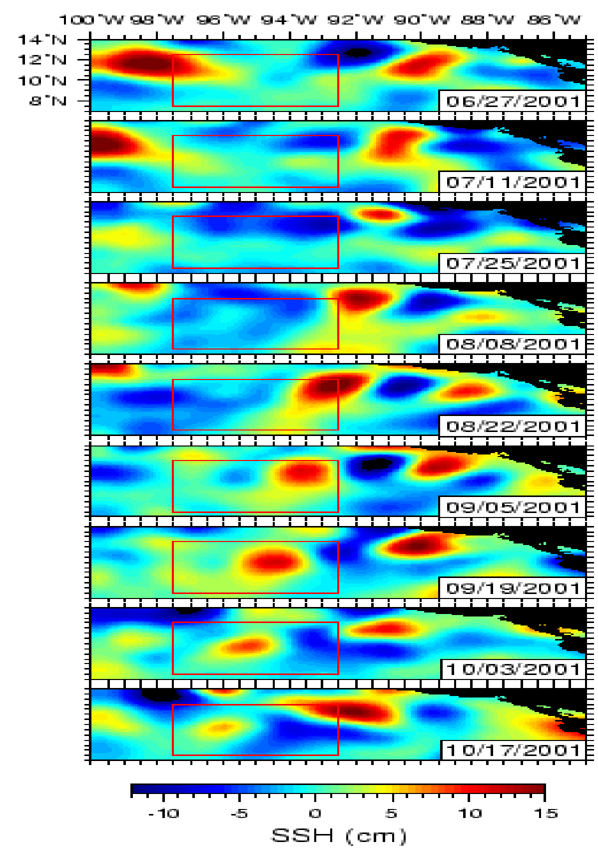




Satellite Altimetry Availability Since 1998
(19-year daily *EVALUATED* data set)







RMSD between **SPORTS** **(SMARTS)** by Systematically Blending of Climatologies of GDEM/WOA and In Situ Data

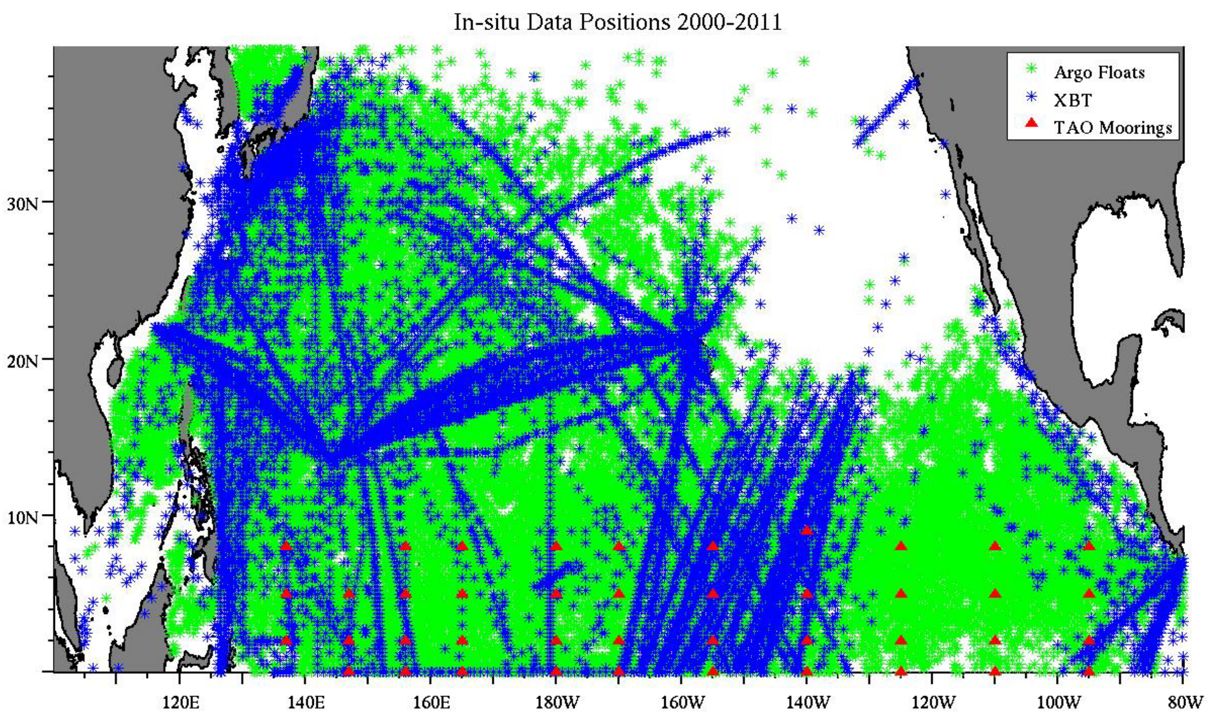
- Weighted blend of GDEM v2.1 and WOA climatologies
  - Based on > **300,000** (>75**,000**) quality controlled in-situ T(z) profiles:
  - Measuring accuracy of each climatology:

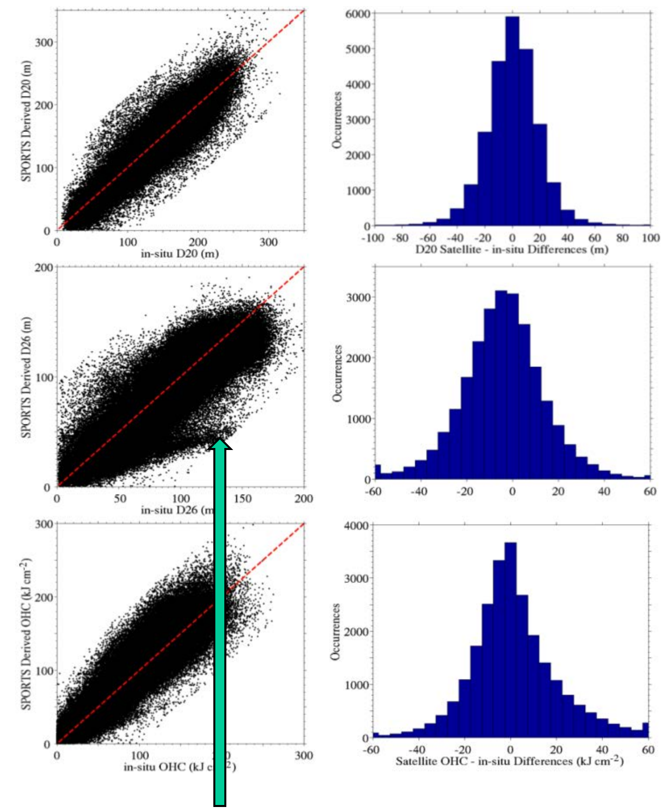
$$RMSD = \sqrt{\frac{\Sigma(x'_i - x_i)^2}{n}}$$

  - Weighting equation for **SPORTS**/**SMARTS** values.

$$x_{SPORTS} = \frac{x_{GDEM\,2} RMSD^2_{WOA} + x_{WOA} RMSD^2_{GDEM\,2}}{RMSD^2_{GDEM\,2} + RMSD^2_{WOA}}$$

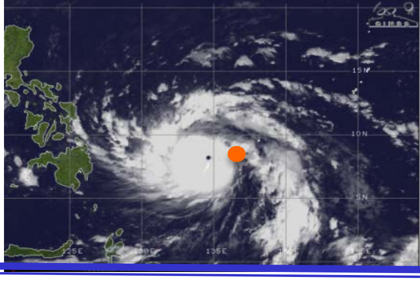
SPORTS In-situ Evaluation >267,000 Thermal Profiles From 2000 to 2013

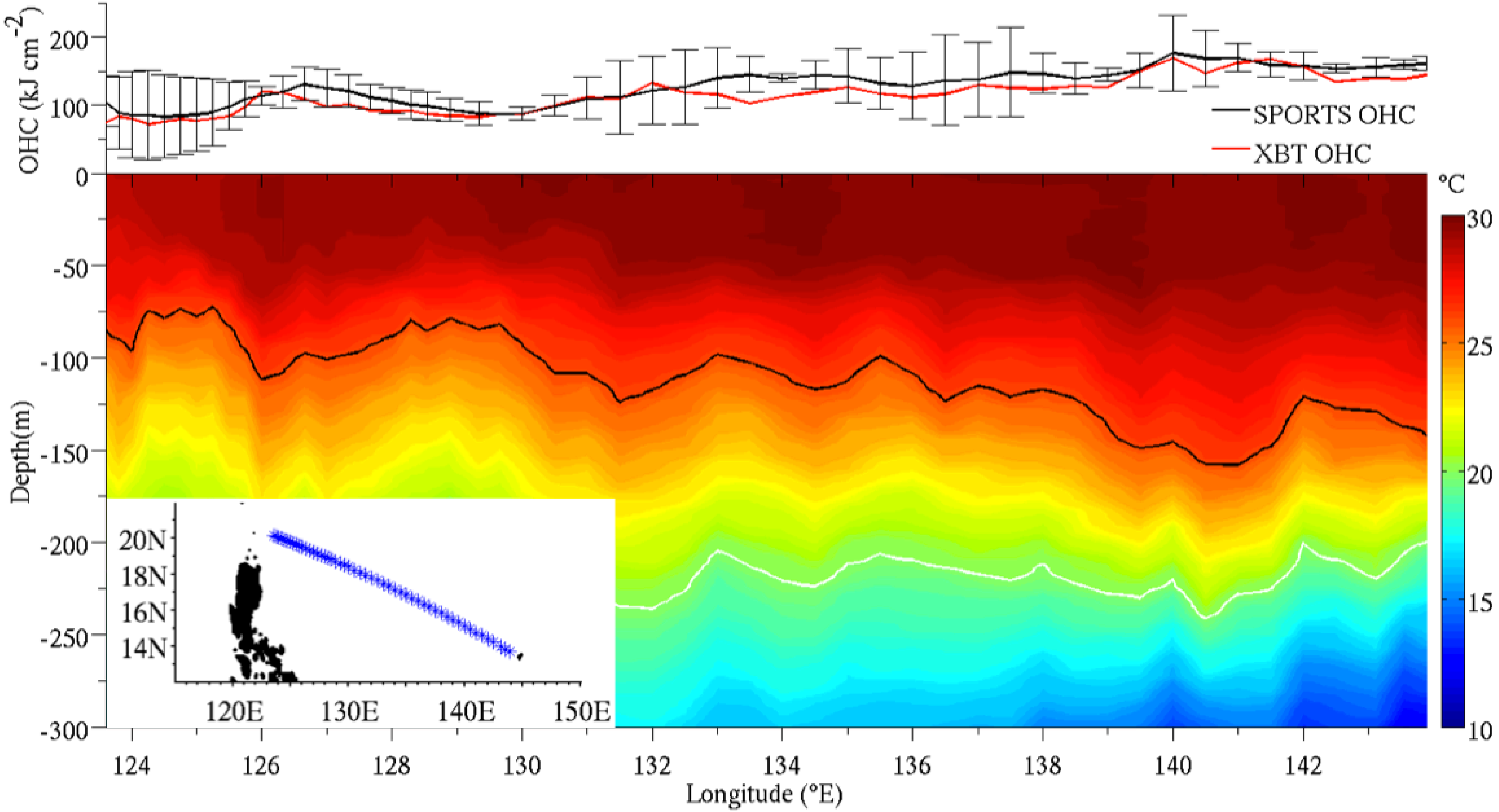


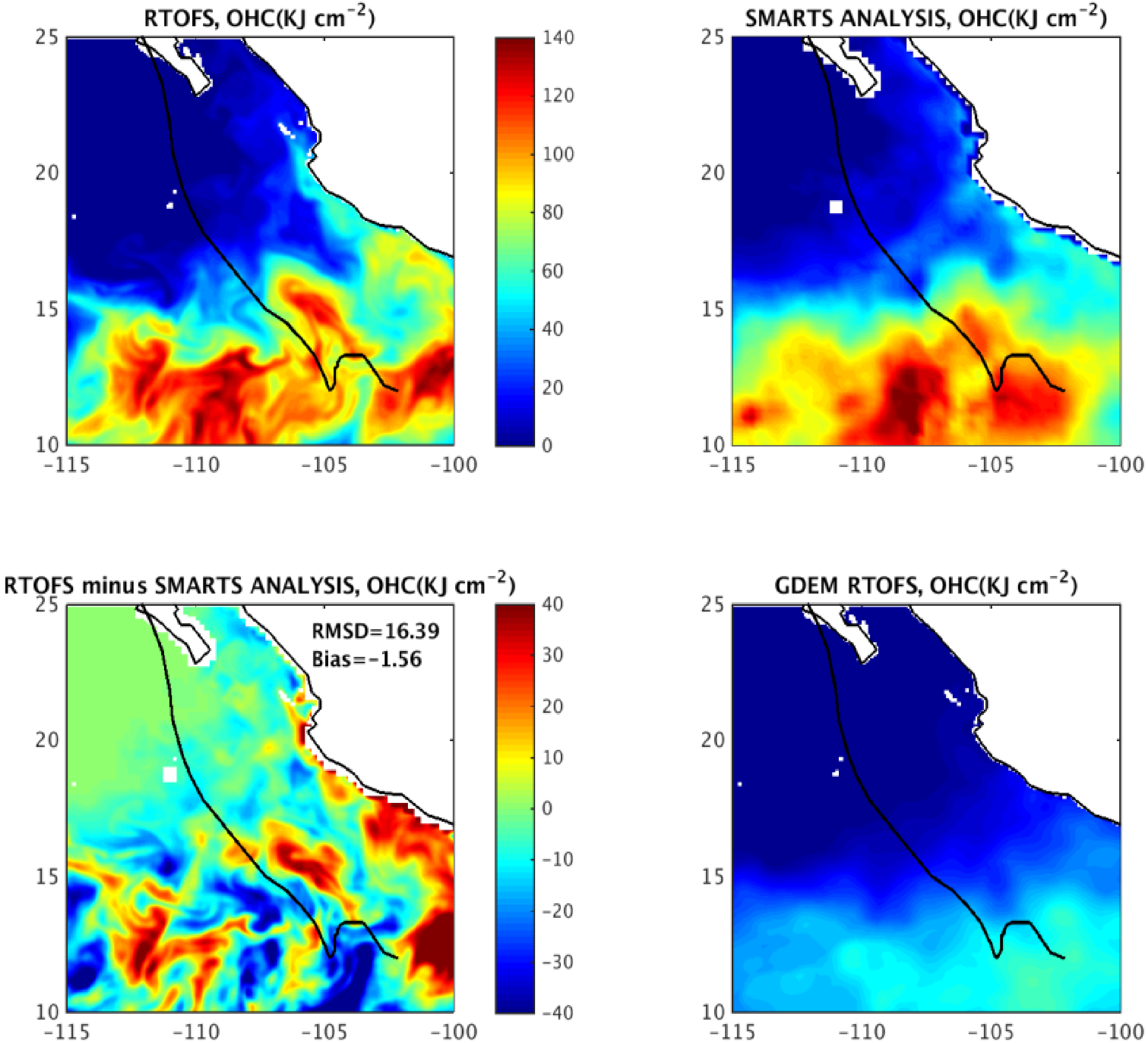


El Nino in **02**, 04, 06, 09

3-Year Average of XBT Transect Comparison from 2008-2010

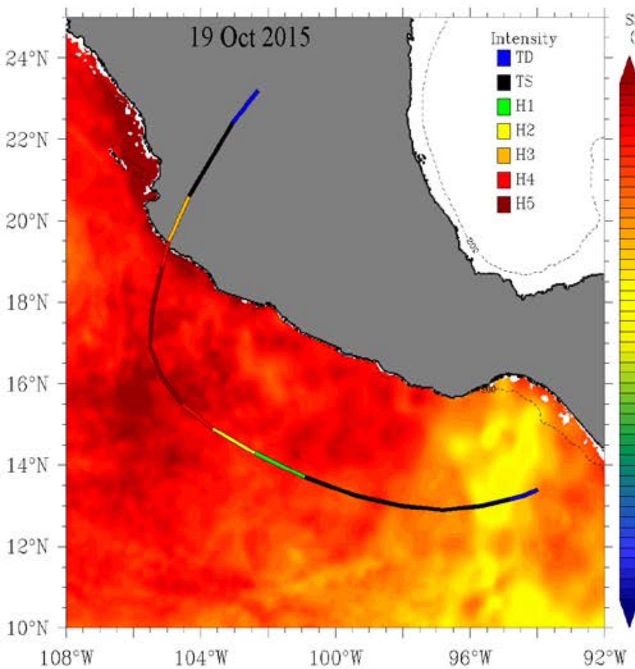


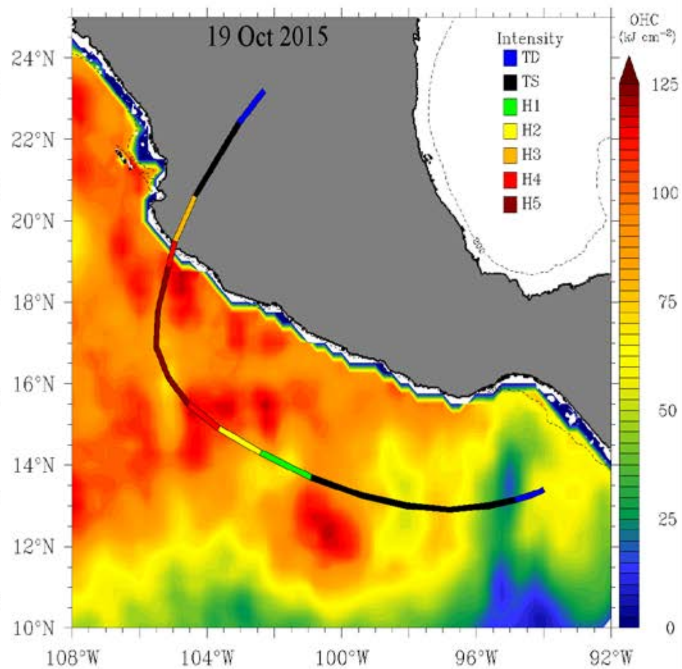




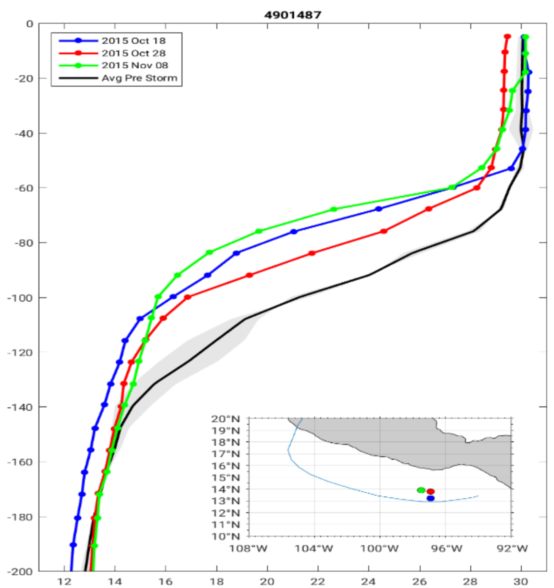
Pre-storm OHC conditions for Blanca: 1 June 2015 in the Eastern Pacific Ocean from RTOFS (upper left), SPORTS (upper right), Difference between RTOFS and SPORTS (lower left), and NCODA initial fields. SPORTS and RTOFS show a similar pattern and magnitude of the OHC compared to NCODA where OHC are quite low during a strong El Nino.

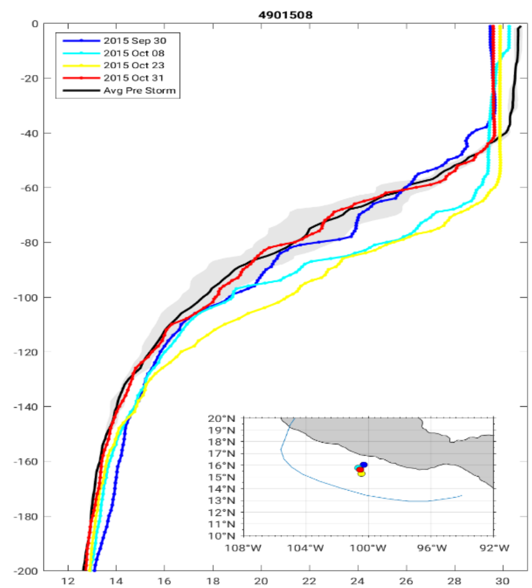
Product is an independent evaluation of the dynamical models!



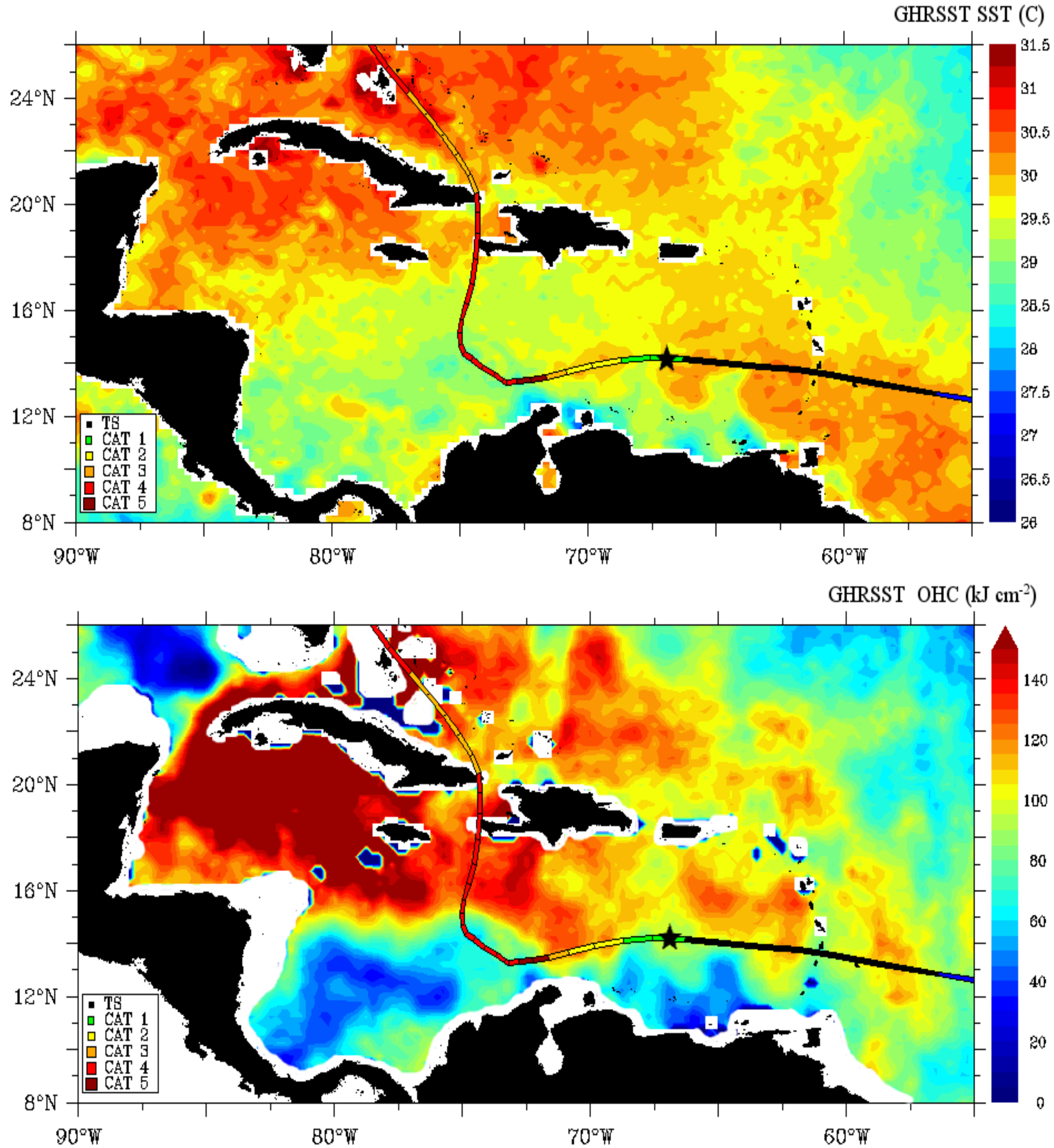


Pre-Patricia SST (left) and OHC (right) relative to the Track on 19 Oct 2015. These OHC levels were a factor of 2-3 times higher due to the 2015 El Nino (Rogers et al., BAMS, 2017).



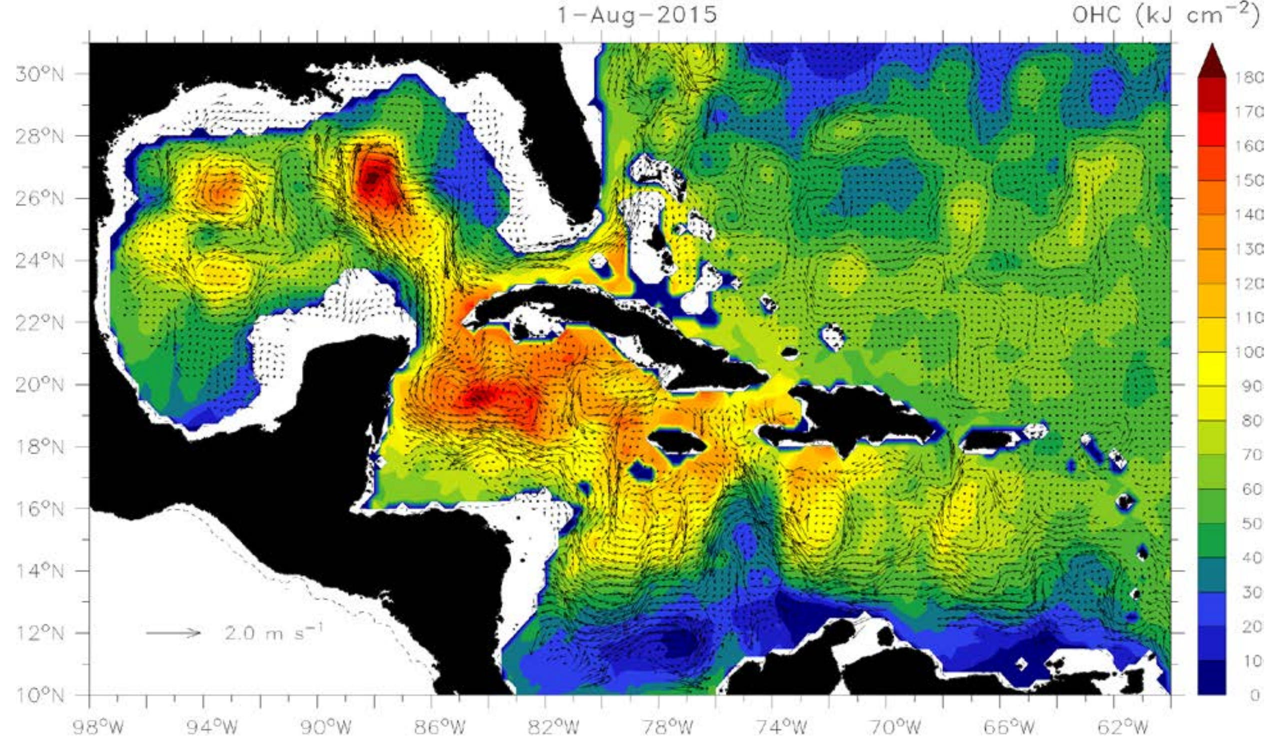


ARGO Floats underneath and on the right side of the track (see inserts) prior to explosive deepening.

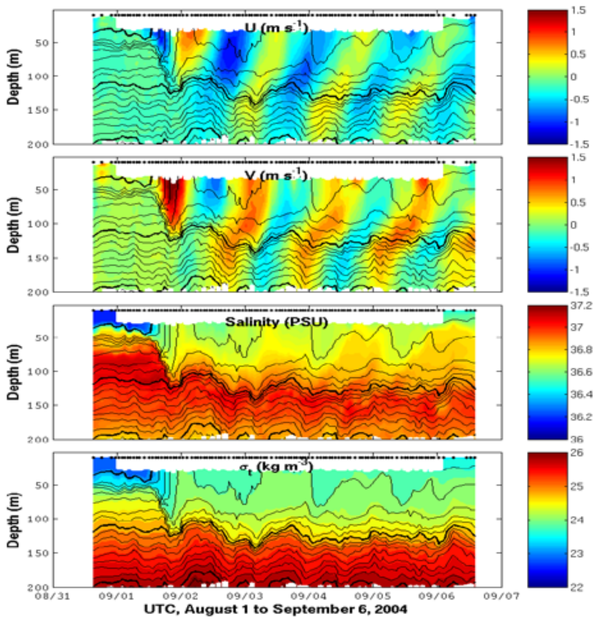


Track and intensity of Matthew (2016) relative to SST and OHC calculated with the GHRSST. The star is the day of the image from SMARTS data base when Jason-2 data were still on-line (Meyers et al., JAOT, 2014).

Notice how the SSTs do not suggest any subsurface ocean structure?



What is the role of mid to deep currents in strong oceanic frontal (OHC) regimes? What are rates momentum transfers leading to vertical mixing across the base of the ocean mixed layer during wind events? Are models getting that correct?



New *state-of-the-art* profiling floats with physical and biochemical sensors will be deployed in the Gulf as part of GoMRI support that uses the APEX-EM platform (Sanford et al., GRL, 2007).

Summary: 19yr Evaluated Data Set

Thermal profile data (~75,000 profiles) to evaluate SMARTS regionally and seasonally in Atlantic Ocean. SPORTS/SPOC > 600,000 thermal profiles in Pacific Ocean basin.

In Atlantic basin, RMSD range from 14.8 to 24.0 kJ / cm^2 over the basin and Gulf of Mexico (Loop Current) where biases ranged from -2.6 to -1.6 kJ /cm^2, respectively.

OHC exceeded 100 kJ/cm^2 in East Pacific (2-3 times higher than normal years) impacted both rapidly intensifying Blanca and Patricia during the strong 2015 El Nino (SSHA values were 12-14 cm higher than normal).

Matthew rapidly intensified over a warm pool in the Caribbean Sea where OHC values were > 90kJ /cm^2 under favorable atmospheric conditions.

Status: seeking funding to ingest both Jason-3 and Sentinel altimeters for operations this year that extends the product into 20 years (five altimeters in the product).