

# Global upper ocean heat content analyses for use in tropical cyclone intensity forecasting

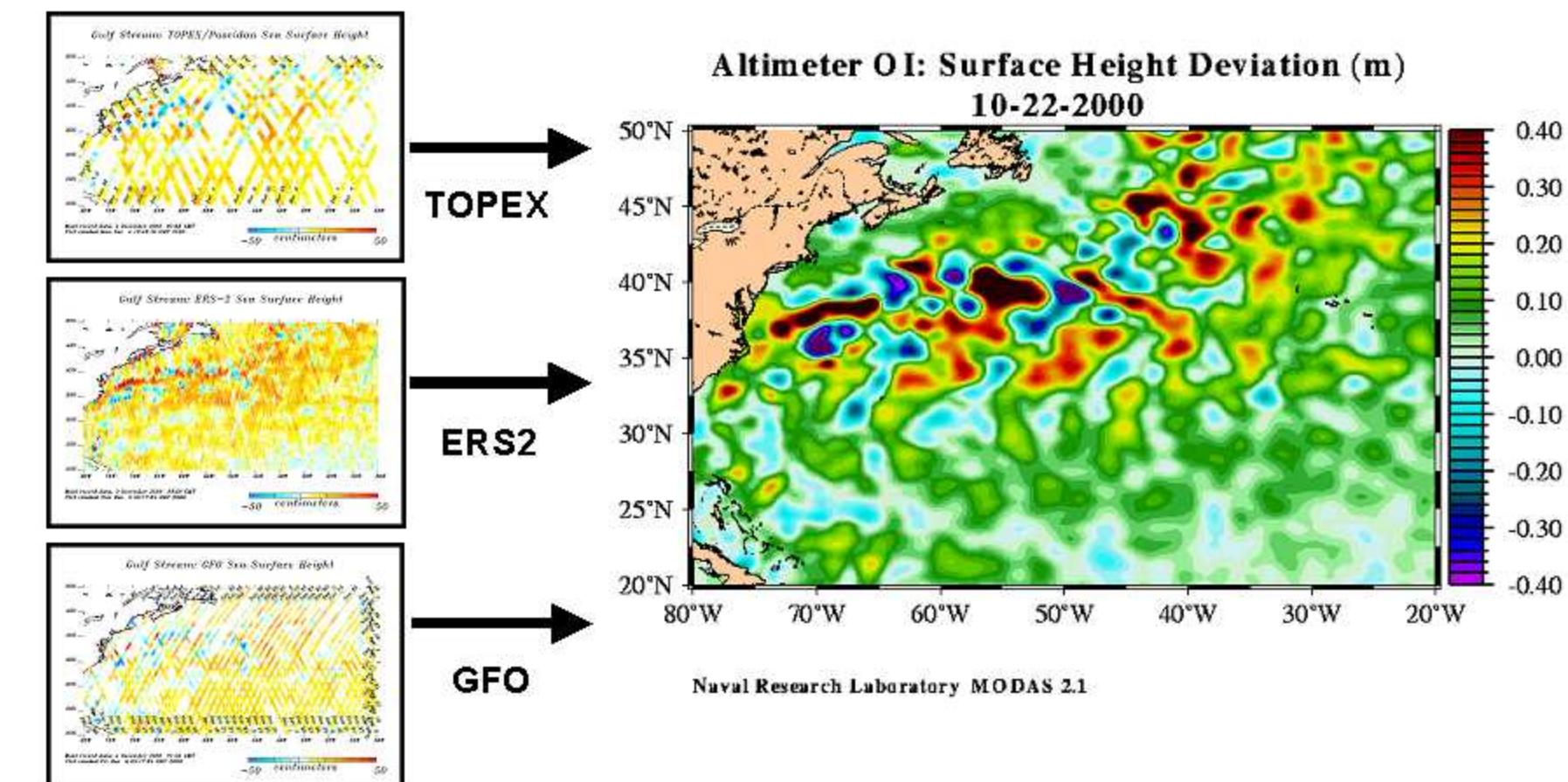
## Abstract

It is widely acknowledged that ocean surface temperatures play an important role in determining the intensity of tropical cyclones, but a measure of the thickness of the layer of warm ocean surface water is a more useful indicator of the energy available for storm intensification. It has also been demonstrated that using upper ocean heat content as a predictor improves the skill of statistical hurricane intensity models. The Naval Oceanographic Office produces daily operational three-dimensional analyses of ocean temperature and salinity that can be used to determine the upper ocean heat content. Here, we describe an experimental system being used to present upper ocean heat content information to tropical cyclone forecasters.

The development system derives the hurricane heat content by integrating the ocean heat content from the surface down to the 26°C isotherm, referenced to the heat content of 26°C water. The heat content, surface temperature, and surface height anomaly fields are presented graphically on an internet WWW site for selected regions, and values are extracted along the forecast track for active storms. Independent in situ profile data are used to validate the hurricane heat content values, and the validation results are provided on the site as well. The URL for the site is <http://www7320.nrlssc.navy.mil/hhc/>.

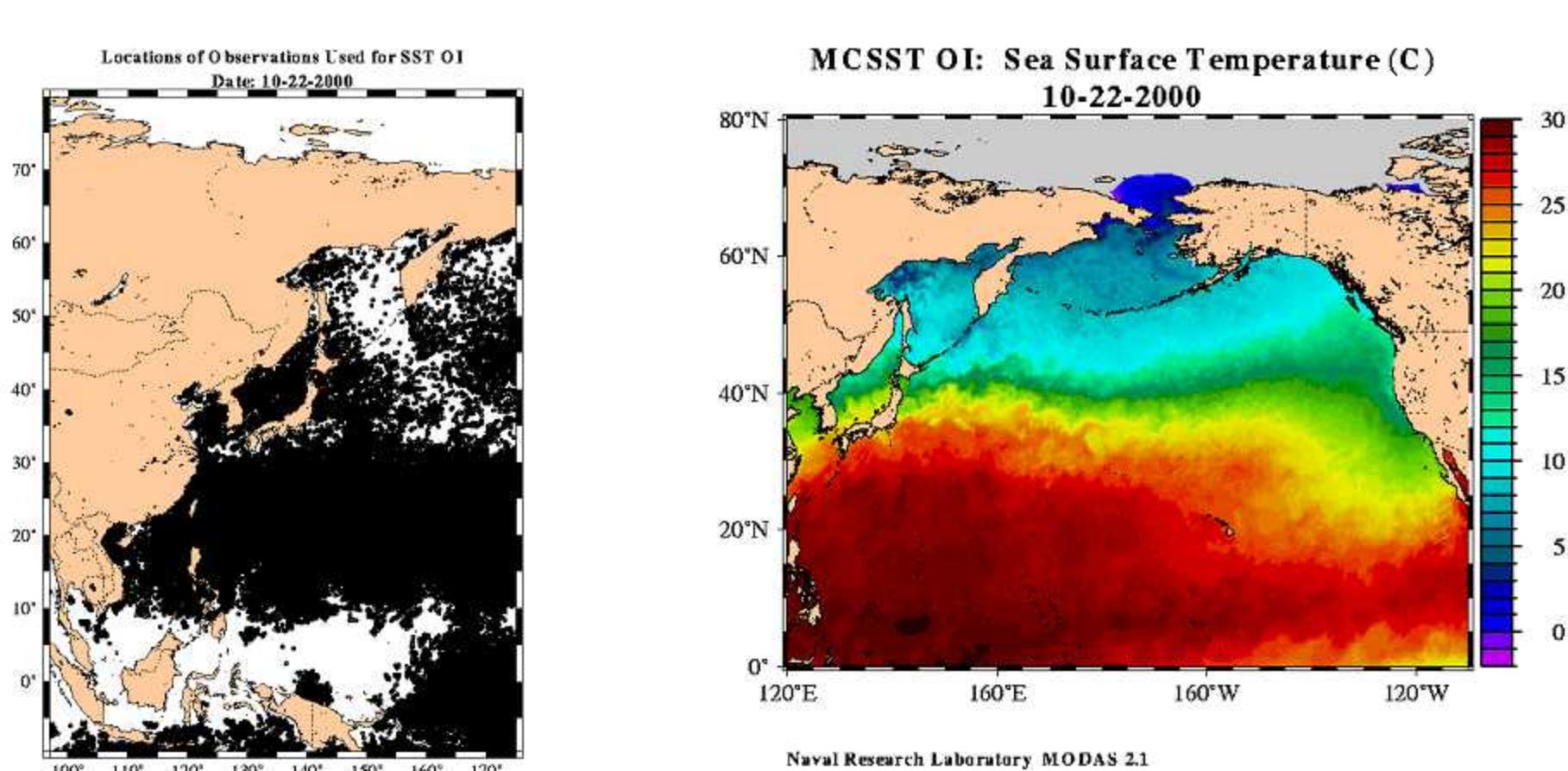
## The operational global ocean analysis

### 1/8° MODAS2D SSHA ANALYSIS



A first guess field and tracks of TOPEX, ERS and GFO sea surface height deviations are combined in an optimal interpolation procedure to produce daily global 1/8° SSHA fields. See <http://www.ocean.nrlssc.navy.mil/altimetry>

### 1/8° MODAS2D SST ANALYSIS

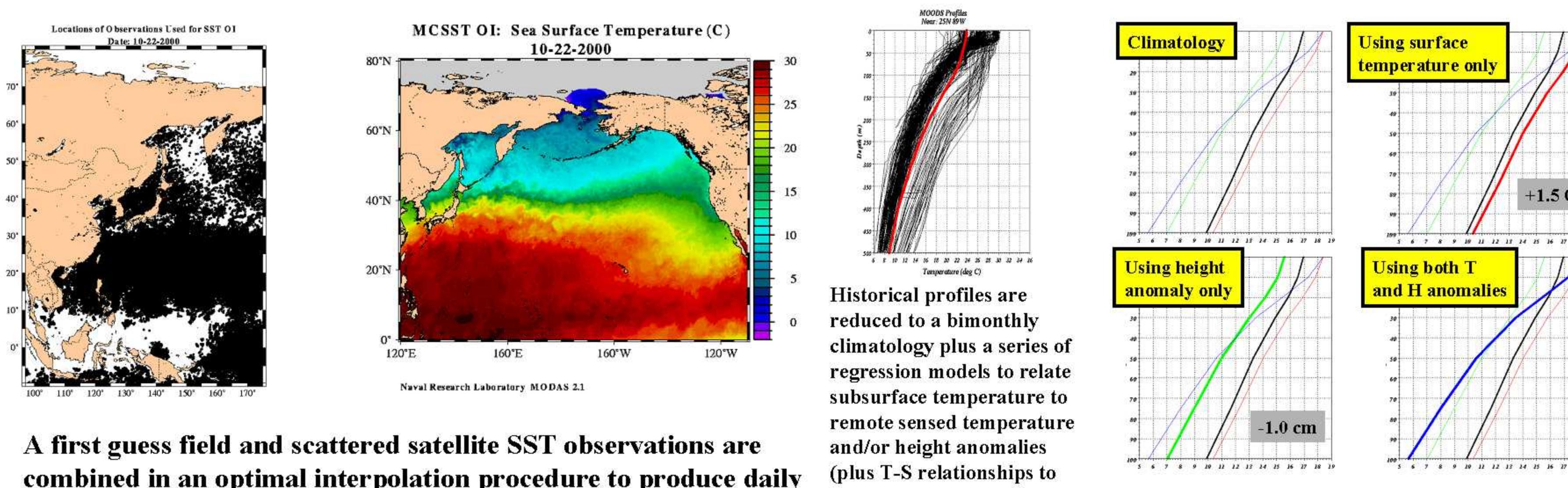


A first guess field and scattered satellite SST observations are combined in an optimal interpolation procedure to produce daily global 1/8° SST fields. See <http://www.ocean.nrlssc.navy.mil/altimetry>

### The global analysis consists of

- A 1/8° global 2D analysis of sea surface height anomaly (SSHA) based on satellite-measured SSHA.
- A 1/8° global 2D analysis of sea surface temperature (SST) using multichannel SST observations from NOAA satellites (MCSSTs).
- A 1/8° global grid of synthetic T/S profiles on 35 levels using the MODAS dynamic climatology.

### 1/8° MODAS3D Synthetics

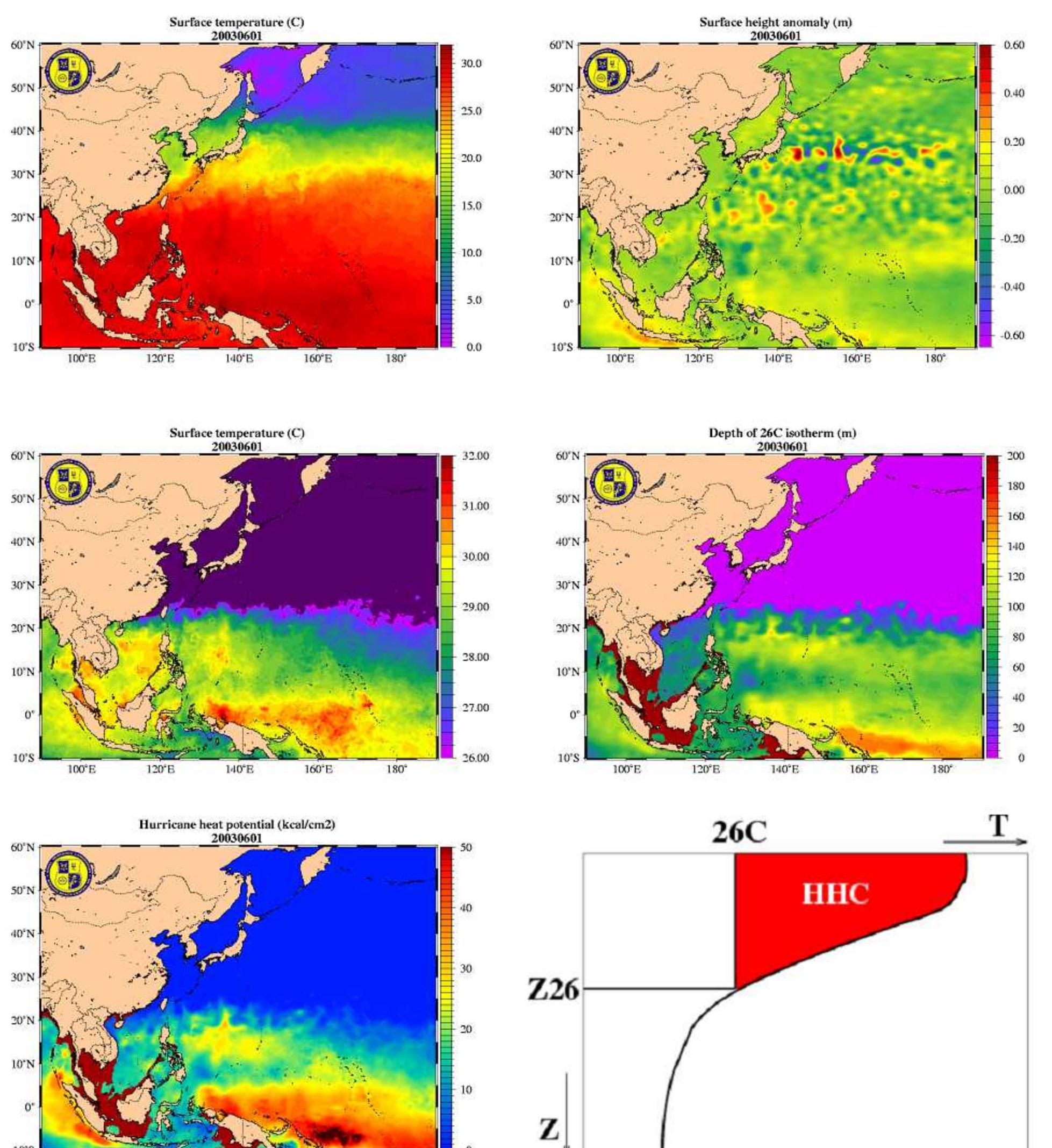


Historical profiles are reduced to a bimonthly climatology plus a series of regression models to relate subsurface temperature to remote sensed temperature and/or height anomalies (plus T-S relationships to convert temperature to salinity).

This work is supported by the Oceanographer of the Navy via Space and Naval Warfare Systems Command PMW155. The operational analyses are produced at the Naval Oceanographic Office, and processed at the Naval Oceanographic Office Major Shared Resource Center of the DoD High Performance Computing Modernization Program.

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Naval Research Laboratory

## The upper ocean heat content analysis



Four fields are extracted in regions of operational interest:

- The SST from the global analysis of MCSSTs
- The SSHA from the global analysis of altimetry data
- The depth of the 26°C isotherm, determined from the global 3D grid of synthetic profiles
- The hurricane heat content or hurricane heat potential, estimated from the global grid of synthetic T/S profiles

The hurricane heat content is the integrated heat content from the surface down to the 26°C isotherm, referenced to water of uniform 26°C.

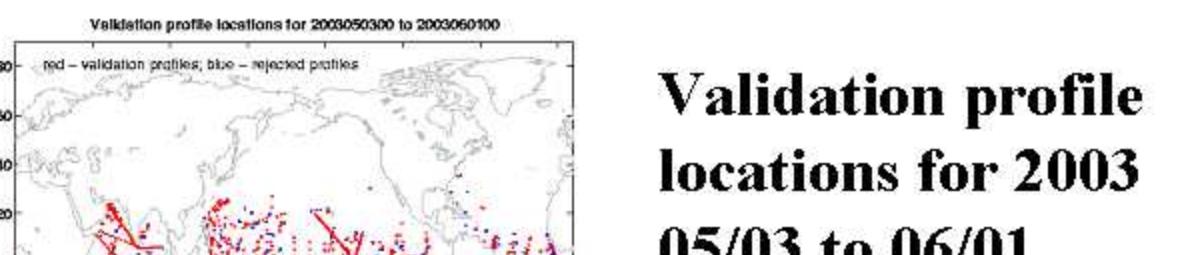
## Evaluation using *in situ* profile observations

### The fields validated are:

- Z26 - depth of the 26°C isotherm
- HHC - "hurricane heat content" or "hurricane heat potential"

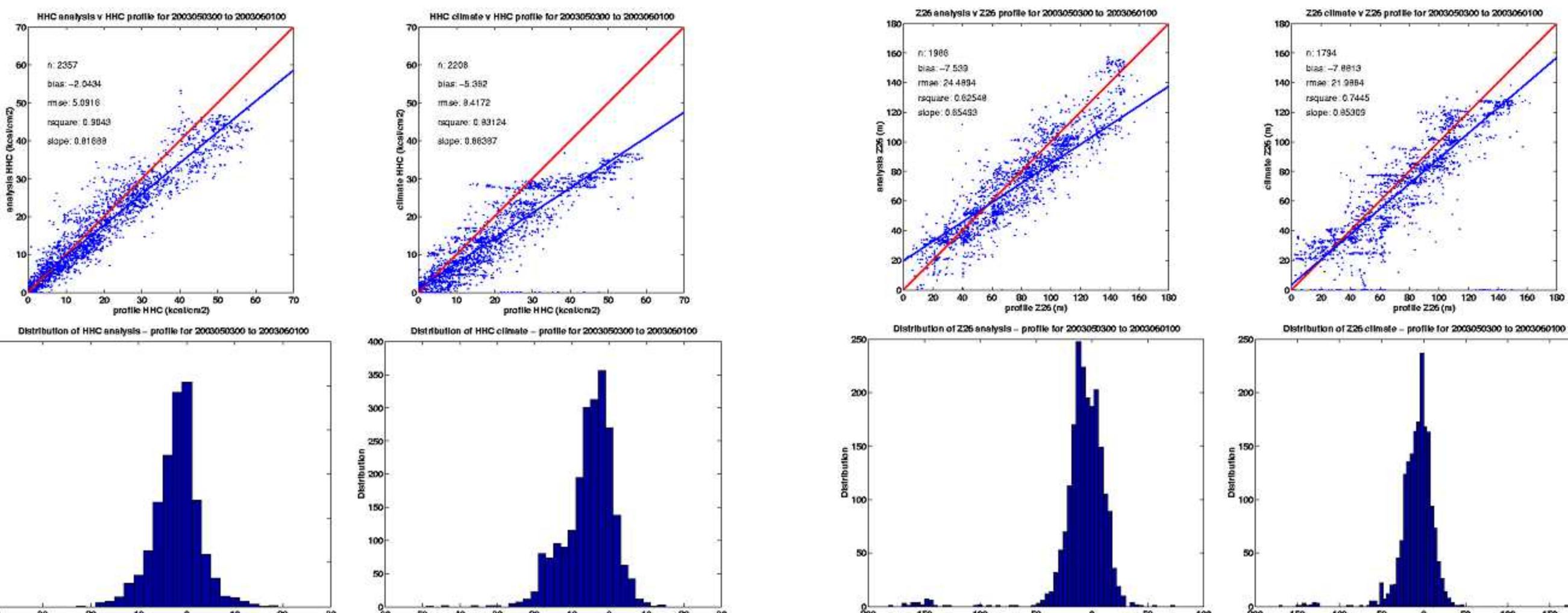
*In situ* profile data processed at Fleet Numerical Meteorology and Oceanography Center (FNMOC) and made available on the GODAE FTP server are used for validating these fields. No *in situ* data are presently used in the 3D T/S analyses used to calculate the Z26 and HHC fields, so these are independent observations. Profiles used are those that pass the FNMOC quality control check at all levels with 99% probability, with at least three levels, with the top level within 25m of the surface, and either extending below the 26°C isotherm or within 25m of the bottom. Only the first daily report from the same call sign within 0.1° latitude/longitude is used.

Matches between observed and analyzed values are gathered using a 30d window, and the statistics and plots are updated daily.

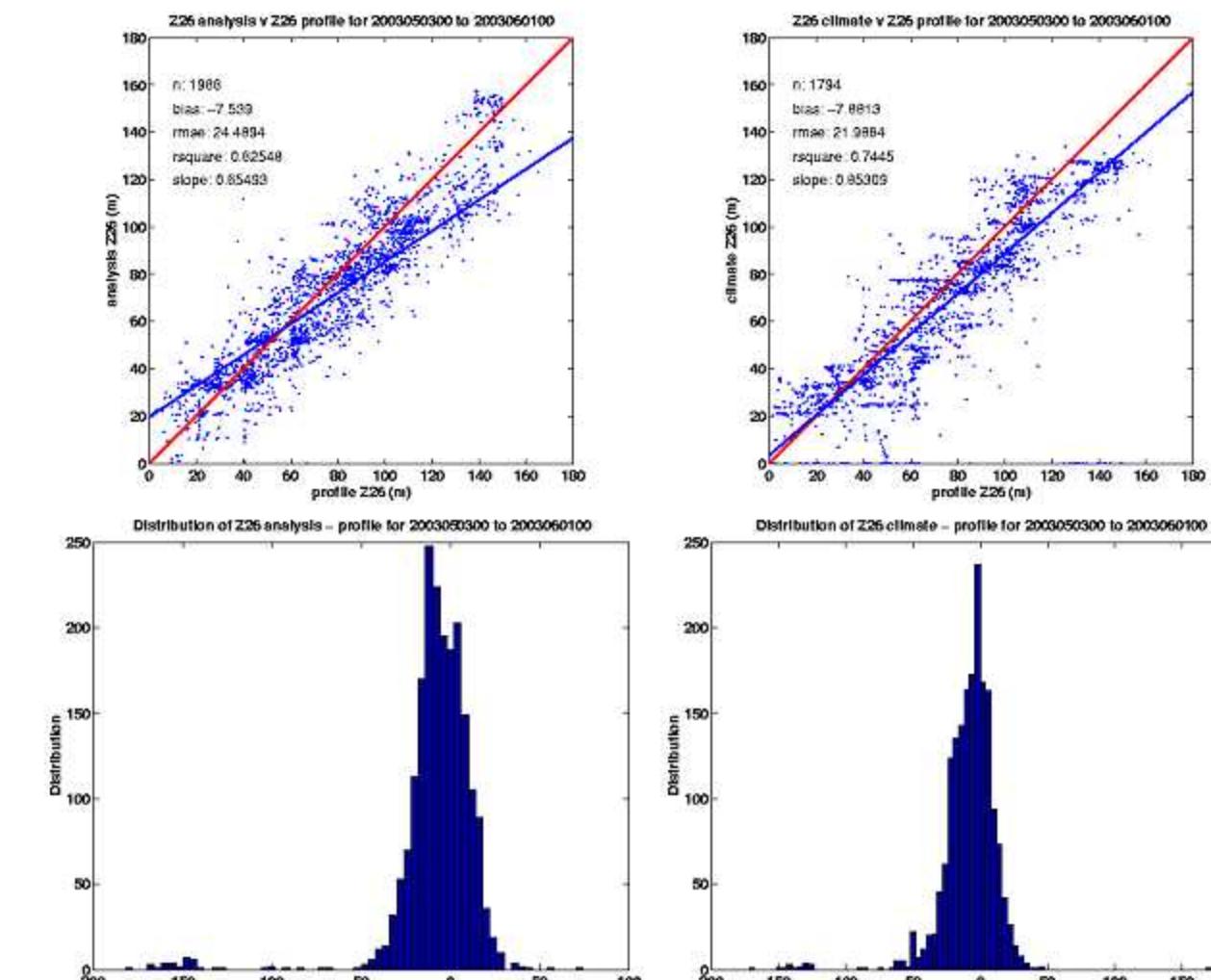


Validation profile locations for 2003 05/03 to 06/01

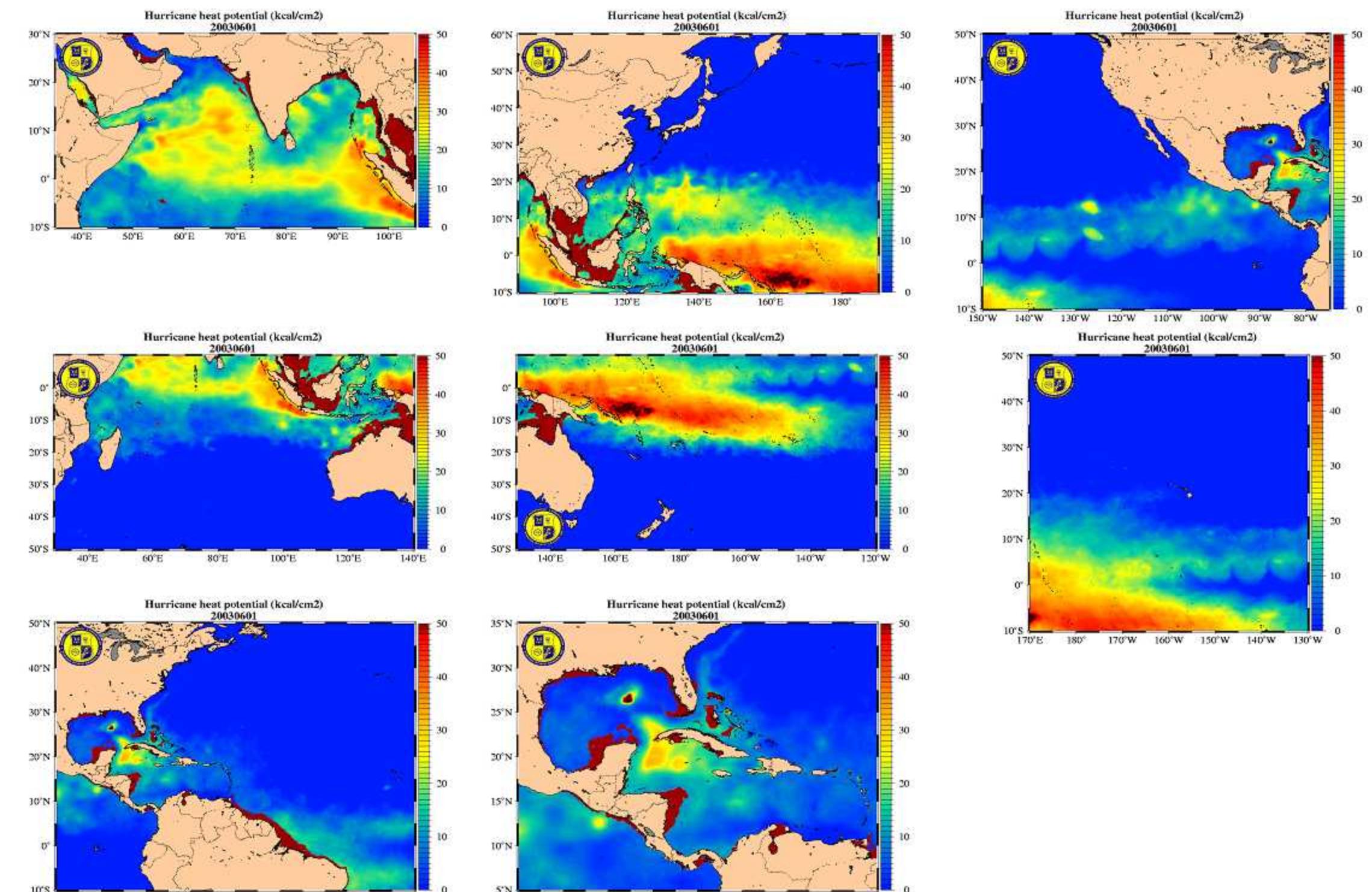
### HHC validation for 2003 05/03 to 06/01



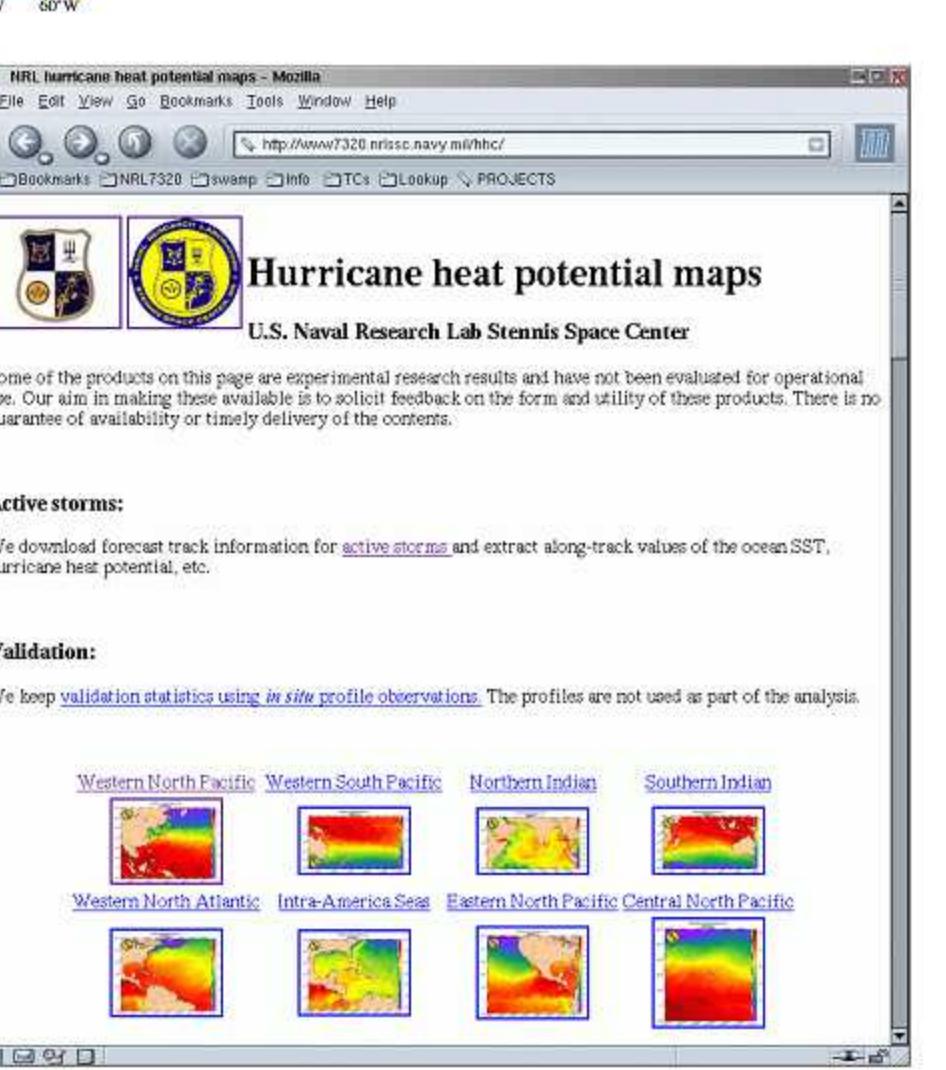
### Z26 validation for 2003 05/03 to 06/01



## Operational areas



The global upper ocean heat content analyses are extracted for eight areas of operational interest in the Indian, Pacific, and North Atlantic oceans. These are determined largely by the warning center Area of Responsibility.

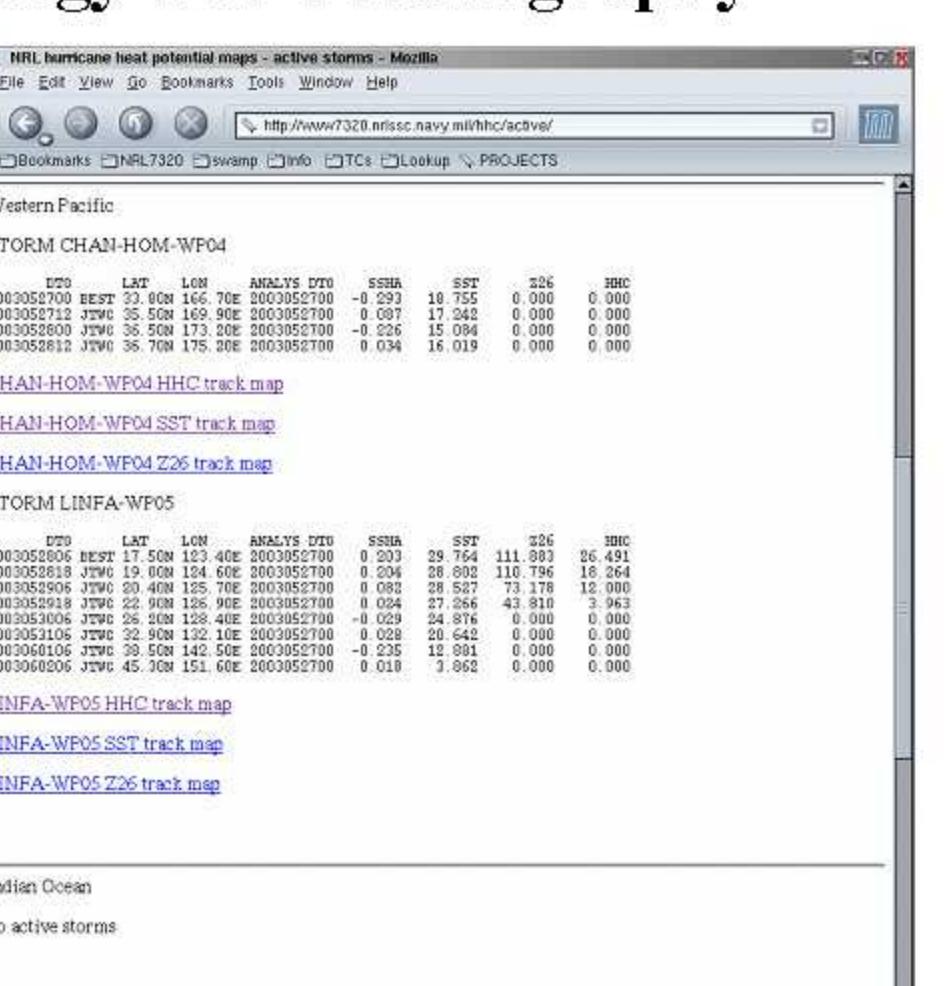


Heat content analyses on the web page are updated daily.

## Combining ocean data with track forecasts

The upper ocean heat content analyses are combined with track forecasts as an intensity forecast aid. The track information for active storms is updated every 6h. Forecast track data are obtained either through Naval Research Lab Monterey or directly from the Joint Typhoon Warning Center / Naval Pacific Meteorology and Oceanography Center.

Storm history and forecast tracks are plotted over the analyzed fields for each active storm (below, for Hurricane Lili on 00Z 30 Sep 2002), and along-track values of the surface temperature, 26°C isotherm depth, and hurricane heat content are listed in a text file (right).



Best track (black) and forecast track (here, a numerical model forecast) for Hurricane Lili (forecast time 00Z 30 Sep 2002), plotted over the ocean heat content analysis fields valid 29 Sep 2002.

