Multi-sensor Improved Sea-Surface Temperature (MISST) for IOOS – Navy component

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LONG-TERM GOALS

Ensure that Navy capabilities for a new generation of sea surface temperature products are coordinated with and benefitting from international research and development embodied by the Group for High Resolution Sea Surface Temperature (SST; GHRSST) and domestic capabilities demonstrated in the U.S. Integrated Ocean Observing System (IOOS) regions and applicable to regions around the world. This project is the Navy component of a broad national NOPP/IOOS/NASA MISST for IOOS project led by Chelle Gentemann. The Navy Participants under the ONR funding are Charlie Barron (NRL), Bruce McKenzie (NAVOCEANO), and Doug May (NAVOCEANO).

OBJECTIVES

The overarching objectives in MISST for IOOS are to continue producing GHRSST compliant satellite SSTs from existing and new sensors and to produce multi-sensor blended gap-free SSTs from US and international GHRSST datasets. The objectives of the Navy component are to coordinate Navy research and development with GHRSST through complementary tasks and interaction at the annual meetings, use of GHRSST data sets for assimilation and validation, and intercomparison of Navy and other GHRSST products. The Navy participants have work elements that support the five MISST for IOOS project tasks:

1. Computation of sensor-specific observational error characteristics required for optimal application and data fusion techniques.
2. Parameterization of IR and MW retrieval differences, with consideration of diurnal warming and cool-skin effects required for multi-sensor blending.
3. Retrospective reanalysis, continued NRT production, and dissemination of sensor-specific SST products with associated retrieval confidence, standard deviation (STD), and diurnal warming estimates to the application user community in the new GDS 2.0 GHRSST format.
4. Retrospective reanalysis, continued NRT production, and dissemination of improved multi-sensor high-resolution SST analyses in the new GDS 2.0 format, to demonstrate and optimize utility in IOOS and operational applications.

5. Targeted applications of the SST analyses for the benefit of IOOS, including coral reefs, ocean modeling in the Gulf of Mexico, improved lake temperatures, numerical data assimilation by ocean models, numerical weather prediction, and operational ocean forecast models.

The Navy goal is to make more effective use of data streams and techniques developed by the collective MISST/GHRSST efforts. As a part of this cordination, the Navy component of MISST for IOOS evaluates regional application of Navy products that emphasizes performance in US coastal regions. This project will also work to leverage results of potential Navy interest from other MISST IOOS performers.

APPROACH

Under the Navy component of MISST for IOOS, specific tasks have been identified to leverage and extend existing work in a way that furthers development of operational Navy capabilites and supports the broader MISST for IOOS objectives. In addition to participating in the GHRSST meetings with the MISST team, the Navy tasks reflect reporting and coordinating with the internation SST community on related funded projects within NRL and NAVO. As such, the specific related projects may differ in details from the original SOW plans due to delays in satellte launches or other redirection.

The original (and redirected) tasking for FY16 is

1. Process and distribute JPSS-1 VIIRs in GDS 2.0. (Redirected Sentinel-3A SLSTR L2P and other data streams due to JPSS-1 launch pushed tp no earlier than March 2017.) (May and McKenzie)

2. Implement lake SST algorithms and regional L3 product improvements.

3. (continued from FY15) Investigate assimilation of sea ice concentration into NAVO K10 L4 analysis product (May and McKenzie).

4. Evaluate use of radiative transfer model in expanded 4DVAR assimilation to estimate satellite-corrected heat flux from NAVGEM and COAMPS. (redirected to focus on radiative transfer in NFLUX and SST assimilation in global coupled atmosphere/ocean models within global ESPC)

5. Report impact of new MISST sensors (Himawari-8, AMSR-2.)

diurnal SST forecasts from NAVOCEANO assimilative ocean models (NCODA/NCOM)

WORK COMPLETED

1. Software to evaluate Sentinel-3 SLSTR SST data has been completed. This software is being used in an evaluation of the pre-release Sentinel-3A SST data We are beginning evaluation relative to buoy SST of the SLSTR L2P data. Original plans to have started work on the JPSS-1 retrievals were redirected due to the JPSS-1 launch delayed until no earlier than March 2017. L2P retrievals continue to be provided for a number of operational satellite SST products.

2. The primary work on product inprovements in FY16 focused on coverage in frontal regions. Methods were introduced to reduce the effects of random noise and maintain cloud masks while returning valid retrievals and maintaining the strength of ocean fronts. Lake retrieval work awaited new retireval algorithms from other members of the MISST/GHRSST team.

3. Daily sea ice concentration forecasts from the Global Ocean Forecast System 3.1 have been approved for operational use by the National ice Center/Navy Ice Center. These are being produced in real time at NRL (Barron) and being evaluated for use in the K10 L4 analysis.

4. Evaluations were reported examining different GHRSST and NAVOCEANO data streams in the California Current and northern Arabian Sea comparing 3DVAR and 4DVAR assimilation with operational or satellite-corrected (NFLUX) heat fluxes based on NAVGEM (global operational) or COAMPS (regional operational) background atmospheric forcing. Report includied in proceedings to GHRSST XV and GHRSST XVI.

5. Initial work delivered new algorithms for Himawari-8 and AMSR-2 have been developed and are in pre-operational evaluation.
6. All results were reported during GHRSST XVII, the annual meeting held this year in Washington, DC.

RESULTS

NAVOCEANO is currntly providing 6 L2P SST retrieval products for distribution via the JPL PODAAC: NOAA-18 GAC, NOAA-19 GAC, NOAA_19 LAC, MetOp-A Gac, MetOp-B Gac, and S-NPP VIIRS. Sentinel 3A data will be provided as well once it passes its pre-operational tests and is declared operational.
Statistically comparing the performance of Sea Surface Temperature (SST) products typically ignores the problem that products containing fewer oceanic features often show better apparent accuracy than those retaining more features. Through the SST uniformity field, defined here as the field of the differences between the maximum and minimum SST values within a small neighborhood, this study highlights strengths and weaknesses of the NAVOCEANO and Advanced Clear-Sky Processor for Oceans (ACSPO) Visible Infrared Imaging Radiometer Suite (VIIRS) SST products. NAVOCEANO SST processing includes strict uniformity cloud detection tests and thus largely avoids cloud contamination and noise related to the Multi-Channel SST (MCSST) equations at the cost of discarding ocean fronts. ACSPO SST is much noisier but retains ocean frontal regions. We identified improvements to NAVOCEANO SST processing, which increase the retention of ocean fronts while also tightening the thermal uniformity test to remove contamination.The updated NAVOCEANO SST processing successfully improves the coverage of frontal regions while maintaining strong cloud detection. However more importantly it was noted that the uniformity and associated tests perform better with brightness temperature than SST. This may have implications for SST edge detection. Finally, replacing the standard correction term in the daytime SST equations by an nxn pixel average can significantly reduce the effect of random noise and striping while keeping the strength of the fronts in the resulting SST field to at least that of the level of the fronts in the brightness temperature field.
Satellite observations are used to guide forecasts of sea surface temperature (SST) through variational data assimilation and heat flux calibration. In the experiments considered, assimilation is conducted using the Navy Coupled Ocean Data Assimilation (NCODA) in either a standard 3D variational (3DVAR) or an alternative 4DVAR formulation. Heat flux for the forecasts follows the original operational highest-quality time series or modifies the flux-determining fields using the Naval Research Laboratory ocean flux (NFLUX) capability. These alternatives are evaluated relative to independent, unassimilated in situ sea surface temperature (SST) observations in two sets of year-long experiments, sets based on atmospheric fields from either the global or the regional operational atmospheric model. Each set begins with a control run with standard forcing and standard 3DVAR assimilation, and the experimental variants employ the various combinations of 4DVAR assimilation and NFLUX-modified forcing. Results in the California Current region demonstrate that the combination of 4DVAR assimilation with NFLUX-modified forcing tends to produce forecasts in best overall agreement with independent in situ observations.
Developments reported from COFFEE use satellite-based heat flux corrections and 3D/4D variational assimilation capabilities to enable more accurate SST forecasts. Year-long results (May 2013-April 2014) in the California Current indicate that forecast skill is generally improved through the use of NFLUX corrections combined with 4DVAR assimilation. Preliminary results in the northern Arabian Sea similarly support the use of NFLUX corrections; issues in longwave flux corrections will be

resolved before completing the Arabian Sea cases. Work is proceeding on extending corrections in a forecast mode in short term forecasts, providing a capability that is responsive to environmental and forecast system changes. Demonstration of these capabilities in these regional cases is a first step in establishing their applicability in other regions and globally. Such a capability is envisioned to play a role in mediating imbalances between components of regional and global coupled modeling systems.

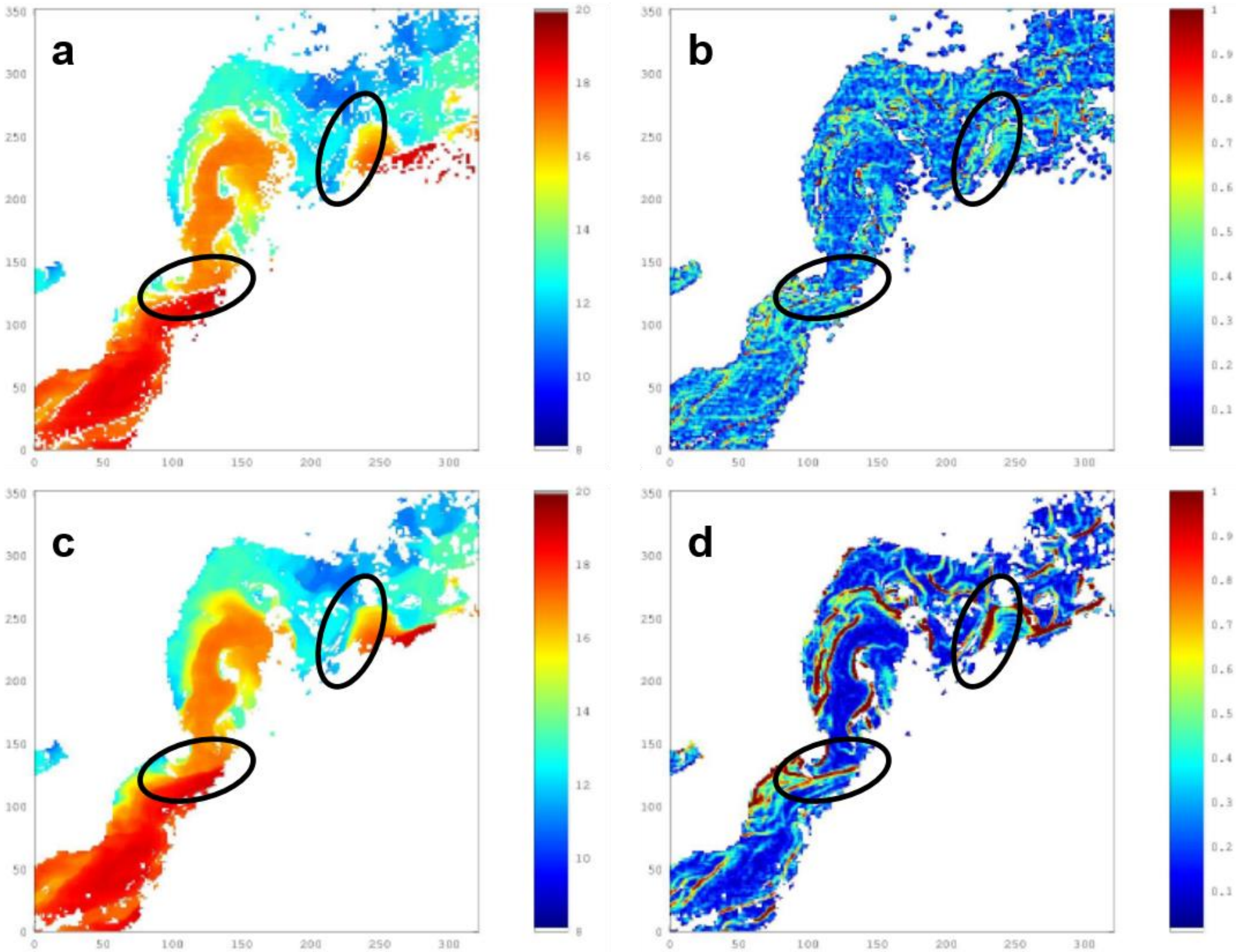

Figure 1 – Comparison of original (a) and updated (c) NAVOCEANO processing of VIIRS SST off of the east coast of Japan on 16 June 2016, 140-143°E and 35-37°N. Panels b and d show the corresponding SST uniformity fields for the original and updated processing. Regions of large values in the SST uniformity fields indicate strong local SST nonuniformity. Sample regions of strong SST fronts are circled in black. The original processing identifies the ;large variations near frontal boundaries as regions contaminated by clouds and fails to show the signals from strong fronts in the uniformity field. The new processing correctly identifies the fronts and returns coherent frontal boundaries consistent with expected patterns east of Japan.

IMPACT/APPLICATIONS

The research by NRL and NAVOCEANO reported under the MISST-IOOS project will enable developent of accurate sea surface temperature retrievals extending to areas of sharp ocean fronts and coastal variability that would previously have been rejected as a perceived risk of cloud contamination. Continuing work to interpret these observations and the model backrounds in terms of small scale variability, diurnal sea surface temperature variations, and a response to surface flux and in-water factors will lead to quantifiable accuracy and uncertainty in sea-surface temperature and derived ocean products sufficent to guide tactical Navy decisions.

RELATED PROJECTS

NRL projects:
6.2 Calibration of Ocean Forcing with Satellite Flux Estimates
6.4 Ocean Data Assimilation
6.4 Sea Surface Temperature

PUBLICATIONS

Barron, C.N., J.M. Dastugue, J. May, C. Rowley, S.R. Smith, P.L. Spence, and S. Gremes-Cordero, s: Forecast of SST: calibration of ocean forcing with satellite flux estimates (COFFEE). Proceedings of GHRSST XVI, 20-24 July 2015, ESTEC, Netherlands, 196-201.

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May, J.C., C. Rowley, and N. Van de Voorde, 2016: The Naval Research Laboratory ocean surface flux (NFLUX) system: Satellite-based turbulent heat flux products. *Journal of Applied Meteorology and Climatology*, **55**, 1221-1237, doi:10.1175/JAMC-D-15-0187.1.

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Rowley, C., C. Barron, G. Jacobs, and J. May, 2015: Ocean surface structure assimilation at NRL. *Joint Center for Satellite Data Assimilation Quarterly*, **51**, 1-4.

Van de Voorde, N., J.C. May, and C.D. Rowley, 2015: Validation Test Report for NFLUX PRE: Validation of new specific humidity, surface air temperature and wind speed algorithms for ascending/descending directions and clear or cloudy conditions. Nav. Res. Lab., Stennis Space Center, MS, NRL MR 7320-2015-9611.

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