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

Dr. C.L. Gentemann
Remote Sensing Systems, 444 Tenth St., Suite 200; Santa Rosa, CA 95401
Phone: (707) 545-2904x14 Fax: (707) 545-2906 E-mail: Gentemann@remss.com

Co-I: Dr. Kenneth Casey
NOAA/NODC, 1315 East-West Highway, Silver Spring MD 20910
Phone: (301) 713-3272x133 Fax: (301) 713-3300 E-mail: Kenneth.casey@noaa.gov

Co-I: Dr. Peter Cornillon
U. of Rhode Island, Graduate School of Oceanography, South Ferry Road Narragansett, RI 02882
Phone: (401) 874-6283 Fax: (401) 874-6728 E-mail: pcornillon@gso.uri.edu

Contract Number: NA11NOS0120167
http://www.misst.org

LONG-TERM GOALS

Sea Surface Temperature (SST) is vital to coastal and marine spatial planning, global weather prediction, climate change studies, search and rescue, and ecosystem based management. SST is derived from measurements taken by numerous satellites carrying infrared and microwave radiometers, and measured from moored buoys, drifting buoys, and ships. This project focuses on completing research to improve the quality of the satellite SSTs from existing and new sensors, produce multi-sensor blended gap-free SSTs from US and international datasets, and successfully broaden the use of these products within specifically targeting coastal applications and the Integrated Ocean Observing System (IOOS).

OBJECTIVES

The objectives of this project are to (1) improve and continue generation of satellite SST data and SST analyses in the IOOS DMAC and CF compliant Group for High Resolution Sea Surface Temperature (GHRSST) Data Specification GDS format; (2) distribute and archive these data; and (3) use this improved SST data in applications, many specifically targeted for the Integrated Ocean Observing System (IOOS).

APPROACH AND WORK PLAN

In the full proposal, each task has been assigned to one or more partners. This partnership consists of 28 scientists from industry, academia, and government with wide ranging experience spanning the initial calibration of satellite sensors, development of SST algorithms, assessment of SST uncertainties, production of NRT satellite data, research into data fusion methodologies and the production of blended data sets, research into diurnal warming and the cool skin effect which both affect satellite SST measurements, and applications that utilize SSTs.

FY2 6/1/2012-5/31/2013: Task 1.2 Process and distribute L2P AVHRR HRPT SSTs for the eastern N. Pacific, 2000-present (Cornillon), NPP VIIRS (May), METOP-B GAC (May and McKenzie) in GDS

2.0. Analyze VIIRS SST metadata with AVHRR SSTs (Emery). **Task 1.5** Reassess SSES of AVHRR and MetOp SST L2P (Castro). **Task 1.6.1.1** Implement new and existing FNMOC/NCODA SSTs in GDS 2.0 (Cummings). *Process and distribute 1km SST (Chao).* **Task 1.6.2** Produce MUR L4 (Chin), NAVOCEANO/NCODA SST (Barron) in GDS 2.0. Include new NAVOCEANO/ MISST data sets (METOP-B GAC; NPP VIIRS; GCOM-W AMSR2) in NCODA analysis (Cummings). **Task 2.2** Continue archiving, providing access to, and discovery of all MISST products. Create virtual aggregations for all gridded MISST products. Enable LAS access to gridded MISST products (Casey). **Task 2.3** Make MISST L3 and L4 products available to the IOOS community via NOAA/SWFSC/ERD data services (Foley and Mendelssohn). **Task 3.1** Prepare and submit manuscript on Florida reef tract and Caribbean reefs coral bleaching indices based on existing MISST and additional remote sensing data. (Gramer). **Task 3.3** Determine gradients and fronts for 1982-present AVHRR HRPT SST fields for the western N. Atlantic (Cornillon). **Task 3.5** Disseminate NOGAPS diurnal SST model output for validation (Cummings).**Task 3.6** Add new MISST data sets and error estimates to coupled model system. Evaluate atmospheric model sensitivities to MISST data (Cummings).

WORK COMPLETED

Funding for only part of the proposal was received August 2011. This funding was used for subcontracts to several partners. Work from these funded partners is discussed below.

Task 1.2: *Process and distribute L2P AVHRR HRPT SSTs for the western N. Atlantic, 2000-present (Cornillon).* We have acquired all of AVHRR HRPT data for the western North Atlantic (Wallops Island receiving station) from 2000 through 2010. These data have been processed through the Pathfinder retrieval algorithm yielding L2 SST fields. These fields have been analyzed and a problem with the daytime quality flag has been detected. The problem will be fixed and the data rerun through the retrieval algorithm. On completion of the reprocessing, the data will again be validated, then sent to NODC for the addition of GHRSST-recommended fields and reformatting to GDS 2.0. *Process and distribute L2P NPP VIIRS (May), METOP-B GAC (May and McKenzie) in GDS 2.0.* NAVOCEANO is in the final stage of making NPP VIIRS SST operational. L2P datasets in GDS 2.0 will be produced soon after NPP VIIRS SST is operational. METOP-B data has yet to arrive at NAVOCEANO due to the delay in launch. *Analyze VIIRS SST metadata with AVHRR SSTs (Emery).* On-going work.

Task 1.5 *Reassess SSES of AVHRR and MetOp SST L2P (Castro).* On-going work.

Task 1.6.1.1 *Process and distribute 1km SST (Chao).* G1SST is continuously being distributed to the community through the OurOcean portal, http://ourocean.jpl.nasa.gov/SST. *Implement new and existing FNMOC/NCODA SSTs in GDS 2.0 (Cummings).* Due to limited funding, this task has been combined with the very similar Task 1.6.2.

Task 1.6.2 *Produce MUR L4 (Chin),* Scripts have been written in python which use OPeNDAP to efficiently subset MUR data. Can be applied to any L4 data set. Code has been written to implement GDSV2.0 netCDF4.0 for the MUR data set. Plans are for future conversion of all MUR data to GDSV2.0 netCDF4.0 (Chin). *Include new NAVOCEANO/ MISST data sets (METOP-B GAC; NPP VIIRS; GCOM-W AMSR2) in NCODA analysis (Cummings).* METOP-B and GCOM-W retrievals are not yet available but the data types have been added to NCODA. NPP VIIRS retrievals are available operationally from NAVOCEANO and are currently being assimilated in beta-test mode at FNMOC. The NCODA analysis and quality control systems at NAVOCEANO must be updated to version 4.0 in

order to access and use NPP VIIRS data. This work has been delayed with the move to a new computer system at the NAVOCEANO DSRC.

Task 2.2 *Continue archiving, providing access to, and discovery of all MISST products. Create virtual aggregations for all gridded MISST products. Enable LAS access to gridded MISST products (Casey).* The LTSRF now accepts GDS2 data and OPeNDAP/TDS services are provided. All GHRSST/MISST data provided to the LTSRF are archived and made available daily. Virtual aggregations have been created for all L3 and L4 data and are in the NODC Live Access Server (http://data.nodc.noaa.gov/las). A rich inventory (RI) is now being computed for the GDS2-compliant Pathfinder Version 5.2 data. The RI contains total valid observation number, observation number over a 3-sigma edit, mean, standard deviation, minimum, maximum, and median for SST, 10 m wind speed, sea ice fraction, and aerosol dynamic indicator globally and for these geographic subsets: 540 x 540 pixel tiles, low latitudes, Southern and Northern mid-latitudes, Arctic, Antarctic, and Nino34 (note: the rich inventory is a "red" item and not funded by MISST, but we are continuing to make progress on it with NODC-provided resources).

Task 2.3 *Make MISST L3 and L4 products available to the IOOS community via NOAA/SWFSC/ERD data services (Foley and Mendelssohn).* Several additional MISST L3 and L4 products have been placed for fully interoperable access on the ERDDAP server at NOAA/SWFSC/ERD (http://coastwatch.pfel.noaa.gov/erddap). We continue to establish partnerships with fisheries and protected species researchers to ensure that they are aware of these data sets, and can readily access and use them. These have resulted in the inclusion of MISST products in peer-reviewed publications, providing a pathway to establish MISST products in resource management. MISST products have been put forward at a series of National and International Training Workshops; the next is planned for Oregon State University in March 2013.

Task 3.1 *Prepare and submit manuscript on Florida reef tract and Caribbean reefs coral bleaching indices based on existing MISST and additional remote sensing data. (Gramer, Hendee).* Based on results from ongoing research on thermal stress related to coral bleaching using improved MISST products, a manuscript prepared by Gramer and Hendee, together with an outside collaborator (Dr. Arthur J. Mariano of Univ. of Miami) , was submitted and accepted for publication in *Proceedings of the 12th International Coral Reef Symposium*, Cairns, Australia, 2012. An additional manuscript is currently in preparation (November, 2012) for submission to journal *Coral Reefs*, describing these methodologies in more detail, together with additional new results.

Task 3.3 *Determine gradients and fronts in 1985-2000 AVHRR HRPT SST fields for the western N. Pacific (1985-2000) and eastern N. Pacific (1990-2000) (Cornillon).* In previous work we have developed a workflow for to determine the gradients and fronts (using the Cayula-Cornillon edge detection algorithm) from SST fields. This workflow has been applied to the 1981-2010 SST fields generated as part of Task 1.2 above. When the data have been reprocessed as described above, the workflow will again be applied to the time series and the data made available to the community.

Task 3.5 *Disseminate NOGAPS diurnal SST model output for validation (Cummings*). This task has been dropped since the Navy emphasis is now on development of a fully coupled global ocean-atmosphere prediction system (Earth System Prediction Capability), not an atmospheric system coupled to a diurnal warming SST model. However, a limited time period of NOGAPS diurnal SST

model output is available from the NOGAPS ensemble prediction system running at T119 spectral resolution.

Task 3.6 *Add new MISST data sets and error estimates to coupled model system. Evaluate atmospheric model sensitivities to MISST data (Cummings)*. As NCODA version 4.0 is updated to use additional satellite SST data the data are automatically assimilated in the coupled model system. The coupled model system is running in beta-test mode at FNMOC in several ocean areas. The evaluation of the COAMPS atmospheric model sensitivities to SST using the adjoint method was not funded by CenCOOS. However, the adjoint-based data impact system is running in real-time for global HYCOM. The impact of all SST data assimilated by NCODA v4.0 in reducing global HYCOM 48-hr forecast errors is routinely being assessed. The impact of satellite SSTs can be mapped and specified in terms of satellite observing system (NOAA-18, NOAA-19, METOP-A, GOES-13, GOES-15) or retrieval type (day, night, relaxed day). The impact of in situ SSTs is also being calculated. Results are available for buoy (fixed and drifting) and ship (hull contact, engine room intake and bucket) data.

RESULTS

A new valuable high-resolution AVHRR dataset that covers the Western North Atlantic is being developed and should be distributed soon. We continue to establish partnerships with fisheries and protected species researchers to ensure that they are aware of these new data sets.

IMPACT AND APPLICATIONS

National Security

SST is routinely used both directly in Naval fleet operations and as an input to weather forecast models used to support Naval operations. The improved SST products and better understanding of the associated errors resulting from this project will provide a more accurate description of environmental conditions enabling better planning of operations. A key aspect of this project is directly evaluating the impact of the improved SSTs on Naval applications. SSTs are also a key parameter for identifying the location and strengths of thermal fronts and eddies, information crucial to assessing the acoustic environment for submarine and antisubmarine operations, as well as for Homeland Security considerations of coastal currents and eddies for public health and safety in the advent of deliberate dumping and dispersion of hazardous material.

Economic Development

SST data is a significant consideration for planning and conducting commercial fishing operations, as well as fisheries management and monitoring efforts. Likewise, SST data is relevant to marine protected species monitoring and de-conflicting protection efforts from commercial fishing.

Quality of Life (Delete this section if there are none)

The potential for producing more accurate SST products has important application to areas including environmental monitoring and weather forecasting. More accurate knowledge of the SST can lead to improved understanding of coral health, better forecasting of routine and severe weather events, improved recreational fishing, and increased ability to monitor climate change. Improved understanding in these areas will lead to a more informed public and better decision-making.

Science Education and Communication (Delete this section if there are none)

The NASA Earth Observatory (EO) provides an online magazine includes feature articles, daily news and images, breaking news Earth Sciences events (www.earthobservatory.nasa.gov). MISST SSTs provide visuals for a variety of media updates, alerts (the most common of which are hurricane-related), and a number of museum projects. These data are quite useful for periodic requests from NASA/GSFC Public Affairs Office, staff scientists wanting to talk about events with reporters, etc. The MISST SSTs has also been appearing in flagship NASA productions, (eg: Hurricane Watch (www.nasa.gov/mission_pages/hurricanes/main/index.html), of which one of the most intriguing visualizations uses MISST SSTs, GOES clouds, and recorded storm tracks to show the 2005 hurricane season: (http://learners.gsfc.nasa.gov/mediaviewer/27storms/).

TRANSITIONS

National Security: Through direct project partnership with US Navy efforts, the improved SST products and methodologies will be directly integrated into Naval SST products and numerical weather forecasting procedures both in use and under evaluation. To accomplish the goal of determining the impact of the SST improvements in Naval applications, transitioning results to the Naval partners is a central focus of this project.

Economic Development: Satellite IR SST data are already in use by the National Marine Fisheries Service. Improved coverage in persistently cloudy regions will facilitate protected species and fisheries management efforts. The merged IR-MW SST product will be provided when available via the NOAA CoastWatch program. MISST SST fields will be used for targeted applications including IOOS regional partners, coral reef research and monitoring, fisheries planning, commercial fisheries.

RELATED PROJECTS

The need for a uniform approach to SST measurements and estimation of measurement errors resulted in the formation of the international Group for High Resolution SST (GHRSST), with partners in Japan, Europe, Australia, and the United States. This groups acts to coordinate international collaboration, research, and SST data sharing. A full description of GHRSST can be found at http://www.ghrsst.org.

NASA's Physical Oceanography Data Active Archive Center (PO.DAAC) is the GHRSST global data assembly center (http://ghrsst.jpl.nasa.gov). After 30 days, all of the data are sent to the GHRSST Long Term Stewardship and Reanalysis Facility (LTSRF) at NOAA's National Oceanographic Data Center (NODC, http://ghrsst.nodc.noaa.gov) for long term preservation and to support climate-oriented applications. This global, collaborative system supports the research necessary to estimate and reduce uncertainty in SST retrievals and improve the multi-sensor blending methodology, which in turn results in enhanced societal benefits.

MISST SST fields will be used for targeted applications including IOOS regional partners, coral reef research and monitoring, fisheries planning, commercial fisheries, Navy fleet operations, naval and civilian NWP, operational oceanography including coastal applications, and climate monitoring and forecasting. More information on IOOS is available at www.ioos.gov.