Impact of ASTER Sea Surface Temperature Observations in the Coupled Ocean Atmosphere Mesoscale Prediction System

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LONG-TERM GOALS

Our long-term goal is to develop a new capability to assimilate the high-resolution Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data to improve the sea surface temperature (SST) analysis and forecasts in the Navy’s Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®).

OBJECTIVES

The objective of this project is to evaluate the accuracy, utility, and impact of sea surface temperature observations from ASTER to improve the analysis and prediction of the submesoscale sea surface temperature (SST) variability associated with the coastal ocean eddies, local upwelling, river plumes, tide, and internal waves in the Navy Coupled Ocean Assimilation (NCODA) and COAMPS. ASTER is a 90-m resolution imaging instrument on board the Terra satellite which measure the land surface temperature, reflectance, and elevation. Over the coastal zone, SST can be retrieved from five ASTER infrared bands and Moderate-resolution Imaging Spectroradiometer (MODIS) precipitable water.

APPROACH

We will acquire ASTER visible and infrared images and brightness temperature data from APL/UW for the same time period and geographic area as Naval Research Laboratory (NRL) deployments of Airborne eXpendable Bathy Thermographs (AXBTs) and NOAA deployments of dropsondes in support of CalWater2. These deployments were made during January-February, 2015 off the northern California coast. The combination of AXBT and dropsonde observations provides co-located atmospheric and ocean temperature profiles that can be used to verify the improvement of air-ocean coupled COAMPS from ASTER assimilation. In addition, ASTER visible and infrared imagery will be evaluated through comparison against contemporaneous SST and sea surface height (SSH) forecasts from COAMPS running in full air-ocean coupled mode. In addition, ASTER brightness temperatures and SST retrievals will be assimilated by NCODA, which is the ocean analysis component of COAMPS. The impact of ASTER data on reducing coupled model forecast error (both ocean and atmosphere) will be estimated using NCODA adjoint and COAMPS moist adjoint models. These adjoint-based data impact procedures characterize the forecast impact of every observation assimilated,
and allow observation impacts to be partitioned by data type, geographic region, and vertical level. Sensitivity metrics obtained from the COAMPS atmospheric moist adjoint are used in the NCODA adjoint to assess the impact of assimilating ASTER SST observations on the error growth of the atmospheric model. The COAMPS moist adjoint model provides forecast sensitivity of atmospheric wind, temperature, and moisture, in addition to sea surface temperature. These sensitivity maps were used in CalWater2 to help guide the deployment of the AXBTs and dropsondes. In addition, a series of ASTER data denial experiments will be performed using the newly developed coupled air-ocean-lsm COAMPS to investigate reduction of nonlinear error growth in COAMPS before, during, and after the Atmospheric River (AR) events.

WORK COMPLETED

- Implemented the Radiative Transfer for TIROS Operational Vertical sounder (RTTOV) in NCODA, which contains coefficients for ASTER.
- Completed processing of the 146 AXBT profiles collected during the P3 flights in conjunction with the 2015 CalWater2 experiment for validation of the ASTER data.
- Received ASTER sea surface temperature and ASTER channel brightness temperature data from Andy Jessup and Ruth Branch at the Applied Physics Laboratory, University of Washington (UW). Converted the ASTER data to the NCODA input data format.

RESULTS

In-situ AXBT profiles collected during the P3 flights in conjunction with the 2015 CalWater2 experiment were processed through the NCODA ocean data quality control (QC) system, which applied some specific AXBT instrumentation error checks (wire stretch, wire breakage, insulation damage) and several background field checks. The background checks compared the profiles against the Navy GDEM climatology using climate variability limits, and a cross validation analysis of all AXBTs dropped during the reconnaissance missions. The warmer water extends down to above 150 m depth (Fig. 1). This unusual warm SST existed also cross much of the North Pacific in 2013-2015 from the Baha California coast up to Gulf of Alaska. It has been suggested the large mass of offshore warm water (Blob, http://www.nwfsc.noaa.gov/news/features/food_chain/index.cfm) are suggested to relate to an unusually strong and persistent atmospheric high pressure in the region that caused less than normal heat lost to the atmosphere, increased energy gain from shortwave radiation from less cloud cover, and decreased ocean circulation. The reason for the Blob is not clear, but some suggest that it is related to the Pacific decadal oscillation or the building of El Nino conditions in the eastern Pacific and California Current. As a result, many of the January-February CalWater2 AXBTs had anomalously warm water in the upper 100 m of the water column. These warm layers were significantly different from climatology and would have resulted in the AXBTs being rejected. However, the cross validation analysis confirmed that most of the AXBTs collected during the experiment were consistent. In many cases the cross validation analysis changed the climate background check QC outcomes and validated profile levels that otherwise would have been rejected. An example of this process is shown in Figure 1. The observed AXBT profile is well outside the 2 standard deviation climate variability envelope in the upper 80 m. The cross validation profile, however, shows that the AXBT is consistent with an optimum interpolation analysis of nearby CalWater2 profiles, excluding the AXBT in question.
Figure 1. NCODA ocean data QC outcomes for a CalWater2 AXBT. Location of the profile is in the upper left; anomaly profiles are in the lower left; observed and background profiles are on the right. The observed profile is shown in blue. The GDEM climate and climate anomaly profiles are shown in green with shaded ±2 std limits. The cross validation analysis and anomaly profiles of nearby CalWater2 AXBTS are shown in orange.

We have received ASTER sea surface temperature and ASTER channel brightness temperature data from UW. The ASTER satellite data have been selected to coincide in space and time with the coupled COAMPS model runs and AXBT flights during the CalWater2 experiment. Examples of ASTER channel brightness temperature data are shown in Figure 2 for two areas off central and northern California.

Figure 2. Examples of ASTER channel T14 brightness temperatures. (left) central California near San Francisco and Monterey Bay on 8 Feb 2015. (right) northern California near Point Arena on 24 Feb 2015. (prepared by Ruth Branch, APL).
The ASTER data will be assimilated in COAMPS using radiative transfer modeling. The NCODA variational analysis system was previously modified for direct assimilation of satellite SST radiances using the Community Radiative Transfer Model (CRTM). CRTM is a shared software system developed and maintained by the Joint Center for Satellite Data Assimilation (JCSDA) for national operational use by NOAA, NASA, Air Force, and Navy. CRTM contains the spectroscopic parameters that embody measurements of the many weak absorption features of the spectral response function that characterizes the sensor. These parameters and other sensor characterizations are contained in satellite specific coefficient data bases that are loaded when CRTM is initialized for a specific satellite and instrument package. Unfortunately, at the beginning of this project the CRTM sensor data base did not contain coefficients for the ASTER sensor on Terra. In June we submitted a problem ticket to the CRTM development team to add ASTER to their sensor data base. In the meantime we began implementation of RTTOV (Radiative Transfer for TIROS Operational Vertical sounder) in NCODA. RTTOV is the radiative transfer model developed by EUMETSAT (European Organization for the Exploitation of Meteorological Satellites). It is freely available to registered users. RTTOV already contained coefficients for ASTER. In early September we received notification from the JCSDA that the ASTER sensor had been added to CRTM. So we now have the capability to assimilate ASTER radiances using either CRTM or RTTOV. Having two radiative transfer models in NCODA is an advantage. For example, currently there are what appear to be calibration issues with the GOES-15 and METOP-B SST radiance data received from NAVOCEANO. These problems could be due to erroneous calibrations performed by the Terrascan software used at NAVOCEANO, or the problems could be due to errors in the radiative transfer model sensor data base. If the problems persist when processing the same data through two different radiative transfer models then that would suggest that the problem is with the satellite data and not the radiative transfer model. Adding RTTOV to NCODA as an alternative to CRTM was a valuable exercise.

Work continues on developing code for processing nested COAMPS atmospheric model fields in support of the radiative transfer modeling. The NCODA SST radiance assimilation operator takes as input prior estimates of SST from an ocean forecast model and profiles of atmospheric state variables known to affect satellite SST radiances. The atmospheric variables include specific humidity and air temperature on pressure levels, which are available from COAMPS as mixing ratio and potential temperature fields on sigma levels. Once conversion of these COAMPS fields to the expected radiative transfer model inputs is complete we will begin assimilation of ASTER radiances and perform the adjoint-based data impact calculations for CalWater2 using the coupled COAMPS.

**IMPACT/APPLICATIONS**

New capability to assimilate high-resolution ASTER data to improve the coupled COAMPS costal forecast.

**TRANSITIONS**

The transition path for this project is to FNMOC via 6.4 Small-scale COAMPS.

**RELATED PROJECTS**

This project is related to the ONR 6.2/6.3 CalWater project which collected the AXBT data during the CalWater2 field campaign.