Sensitivity Studies of the Impact of the Environmental Variability on GRASP

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LONG-TERM GOALS

The long-term objectives are 1) to meet the Navy's requirements to produce rapid estimates of present and near-term forecast of the ocean environmental fields in support of real-time applications, and 2) to investigate how the nowcast from Modular Data Assimilation System (MODAS) affects the accuracy of acoustic prediction and propagation models solutions in support of the ASW search planning missions.

OBJECTIVES

The Modular Ocean Data Assimilation System (MODAS) is one of the Navy's tools for producing rapid estimates of 3-D temperature and salinity fields. MODAS includes a static climatology from historical profiles and a dynamical climatology, which is a means of assimilating near real-time remote-sensed data and in situ observations. MODAS estimates of Sea Surface Height (SSH), Sea Surface Temperature (SST), and temperature and salinity fields are routinely assimilated into operational global models (Rhodes et al., 2002). MODAS has been extensively applied and validated. The static climatology is at least as high quality as comparable fields from Levitus data set, but with increased horizontal resolution. The dynamical climatology provides increasingly accurate estimates of the ocean temperature and salinity, depending on the accuracy and availability of the observations (Fox et al., 2002).

The objective is to evaluate the sensitivity of the acoustic prediction and propagation models to the environment and associated variability. More specifically, this study aims to 1) analyze the skills and limits of MODAS nowcast in coastal and shallow-water regions, 2) evaluate the impact of MODAS fields on the detection capability in littoral regions, 3) verify the sensitivity of MODAS nowcast to the spatial and temporal variability of the ingested observations, and 4) determine the network of observations necessary for accurate predictions in coastal areas.

APPROACH

MODAS code is a modular collection of over 200 programs that can be combined to perform the desired task. Namelist files and use of allocated memory allow the same executable (on a given platform) to be used for all simulations. Switches and flags control the numerical and physical parameters. The major challenge is providing a default set of parameters that provides accurate solutions for any given configuration. Our work has focused on the evaluation of 1) the physical accuracy of MODAS nowcast and 2) the sensitivity of MODAS solutions to the model parameters.

WORK COMPLETED

The principal objective of MODAS is to provide a description of ocean conditions where and when little or no in situ measurements are available. The main source of real-time observations is remote sensing data. We have analyzed (documentation is in progress) the sensitivity of the nowcast to the spatial and temporal resolution of the ingested data and to MODAS assimilation algorithms.

RESULTS

MODAS relies on default data sets, such as the remote sensed observations processed at the Naval Oceanographic Office (NAVOCEANO), the DBDBV2 global bathymetry, and the NOGAPS winds. However, switches and flags allow the use of more accurate, high-resolution data sets, when available. The configuration depends heavily on the availability of accurate bathymetry databases. Difficulties associated with the treatment of topographic features on a scale ranging from 2˚ to 0.5˚ grid resolution are well known, and the solution cannot be easily generalized to a wide range of applications. To partially alleviate these potential problems, we recommend the development of graphic tools to quickly access, merge, and manually edit bathymetry files.

The operational MCSST data set from NAVO is also inadequate for the coastal and littoral region. The data, processed on a global scale, are stored at approximately 9 km resolution. However, a new product, at approximately 2 km resolution, has recently been released and its validation is in progress. Fig. 2 compares the MCSST data set processed at NAVO and at Rutgers University. Data are for the day 18 July 2000, during the LEO-15 exercise. Fig. 2 illustrates MODAS analyzed SST from the two data sets.

(a) *(b)*

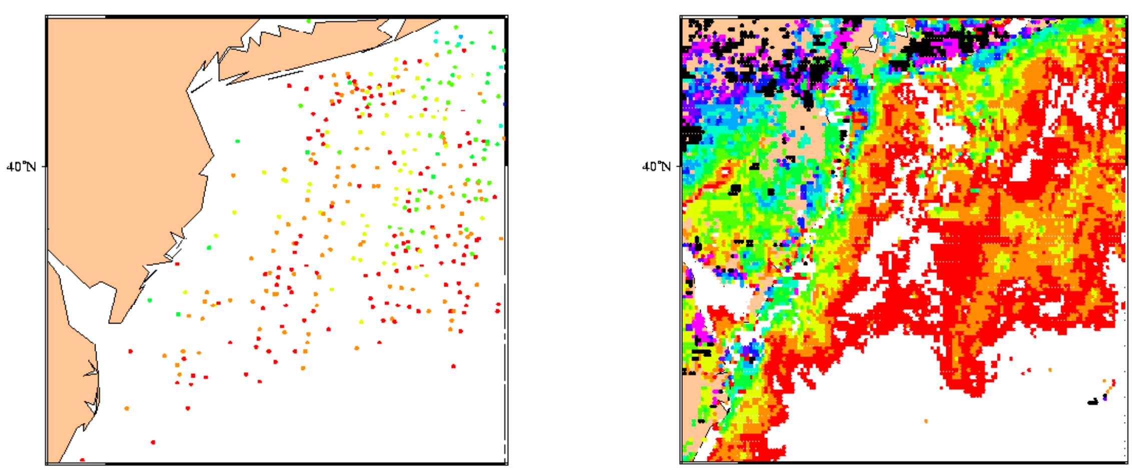

Fig. 1. The MCSST data set for the day 18 July 2000 in the NY Bight processed at NAVO (a) and Rutgers University (b).

The difference between the two data sets requires no further comments. Peggion et al. (2002a) discusses the impact of the MCSST temporal resolution on MODAS and illustrates how persistent cloud coverage may relax MODAS fields toward the static climatology.

(a) ***(b)***

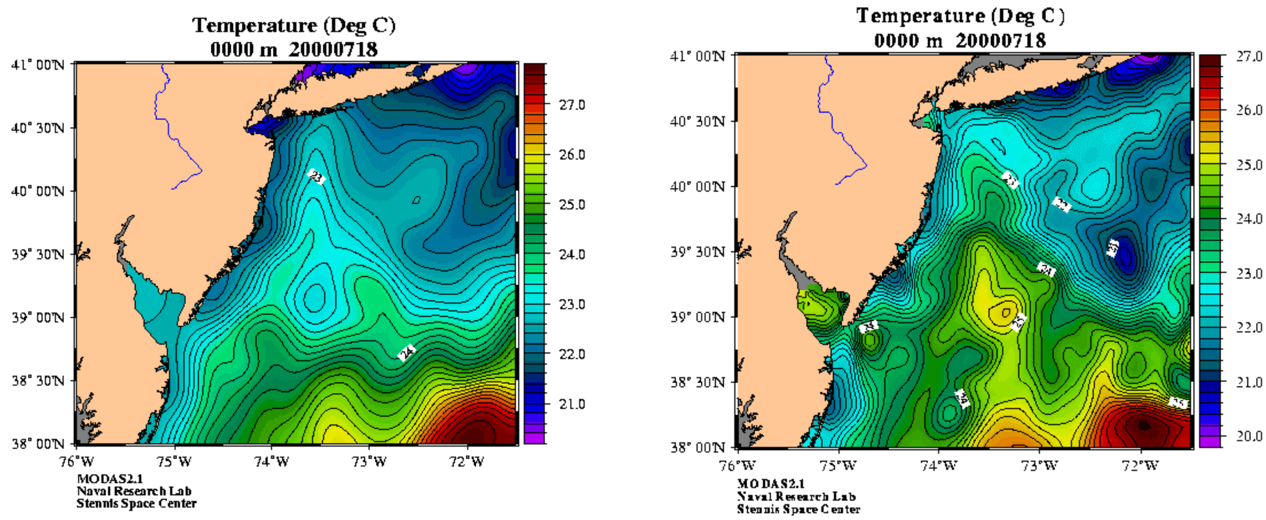

Fig 2. MODAS analyzed SST from the NAVO (a) and Rutgers University (b) MCSST data set.

MODAS also has the capability of assimilating the raw MCSST data as in situ observations. The procedure requires an estimate of the temporal and spatial scales. We have conducted sensitivity studies with respect to the parameters. Fig. 3 illustrates two solutions associated with Fig. 2b.

(a) ***(b)***

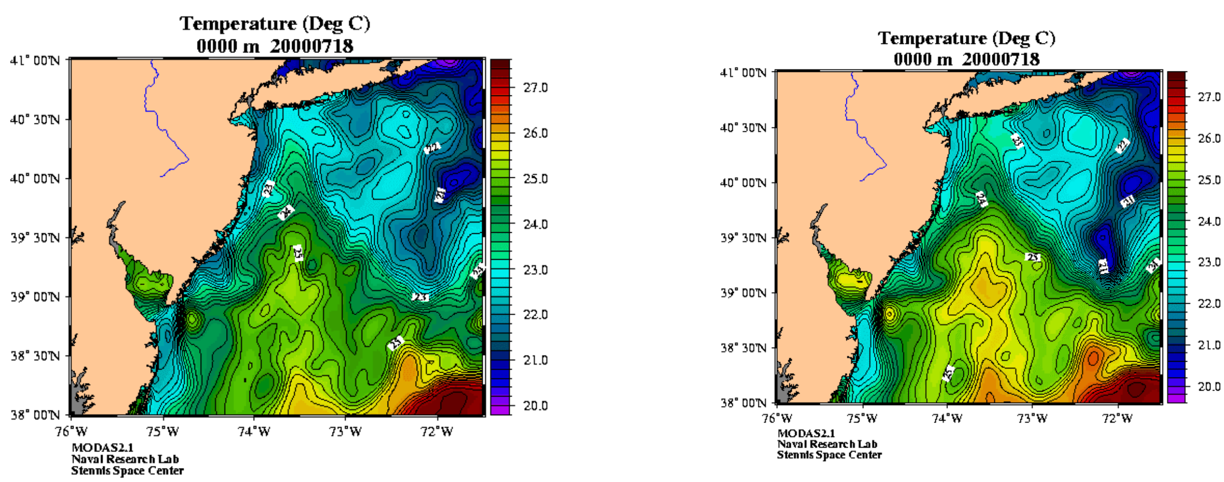

Fig. 3 The SST field with assimilation of the MCSST raw data.
Estimated Rossby radius 4 km (a) and 20 km (b).

It is evident that the solution is quite sensitive to the choice of the parameters. Unfortunately, it is not possible to generalize the optimal estimate of the Rossby radius of any given area. Therefore, it may be necessary to add a new module in MODAS to obtain some estimates from the MCSST raw data directly.

One of the major tasks in evaluating a real-time nowcast (and forecast) system is the lack of data available for validating the results. Most applications already lack in situ data to be ingested into MODAS, so the model-data comparison is virtually impossible. Exercises such as the Littoral Environmental Observatory at 15m (LEO 15) are unique examples. A posteriori analysis and hindcast simulations are necessary for an overall evaluation of the model performances, but they cannot provide the information necessary during naval operations. In this regard, the goal is to evaluate the solution and make the necessary changes in the model calibration to improve the quality of ensuing simulations. Therefore, a timely, useful validation requires real-time, easily accessible data, such as those accessible from the web. Moreover, a stringent model evaluation also requires independent (i.e. not assimilated nor used in the initialization) data sets. As part of the evaluation, MODAS nowcast SST was compared with real-time observations from the National Data Buoy Center (NDBC) network (www.ndbc.noaa.gov). The process highlighted significant differences between the MCSST observations and the buoy values and emphasized that one aspect, often neglected or underestimated, is the comparison between the ingested and validating data (Peggion et al., 2002b).

The problem is illustrated in Fig. 4 by comparison of buoy measurements with MCSST observations from different sources, and the SST at the buoy location from the global (approximately 9 km resolution) MODAS-2D field. The latter product is routinely assimilated into operational forecast systems, such as the 1/16˚ NLOM (www.ocean.nrlssc.navy.mil/global_nlom) and the 1/8˚ NCOM (www.ocean.nrlssc.navy.mil/global_ncom).

It is implicitly assumed that the infrared measurements are representative of the temperature beneath the surface layer (about 0.02 mm thick) in which the upwelling radiation originates. Therefore, the apparent infrared temperature, henceforth referred to as the skin temperature, may not be representative of the temperature at a slightly greater depth, henceforth referred to as the SST. Several phenomena that warm or cool the surface of the ocean may contribute to the mismatch. The error may be estimated using one of the correction schemes proposed by several authors.

Typical differences between the skin temperature and the SST are less than 1˚ in the open ocean. In coastal and shallow water, the problem has not been extensively investigated. However, preliminary studies indicate that the mismatch is more severe in shallow and coastal areas, especially during the cooling season. The discrepancies appear to be independent of the source and resolution of the data set. No systematic differences have been found between NOAA-16 and NOAA-14 observations, nor has a significant day/night bias been noticed (L'Heureux, personal communication).

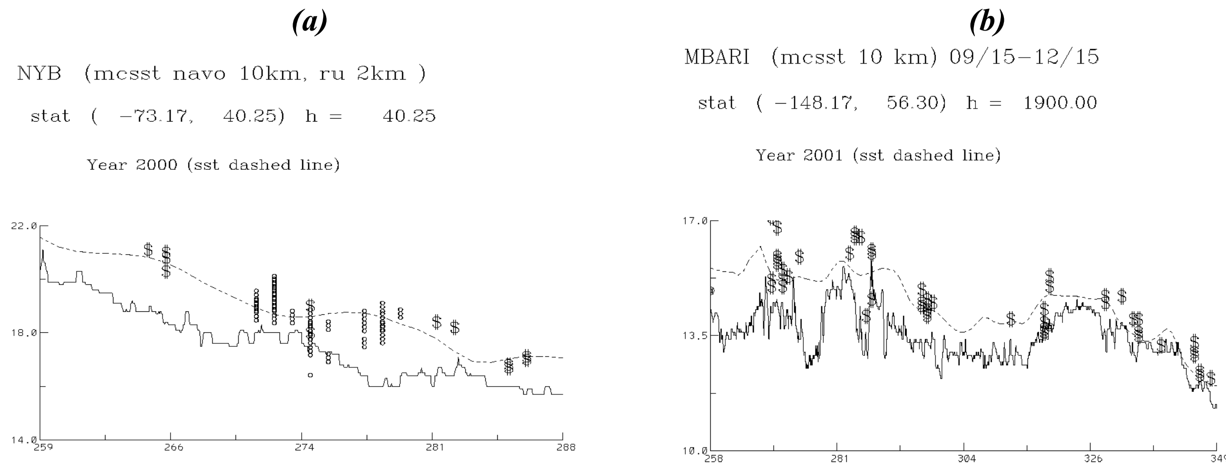

Fig. 4 a) Comparison of the SST from NOAA buoy #44025 in the NY Bight (solid line) with the MCSST from two independent data sets: the NAVOCEANO operational unclassified product ($) and 1-week high-resolution (1 km) product processed at Rutgers University (o). The dashed line is the SST from MODAS-2D at the buoy location. (September 16-October 15,2000). b) Comparison between the Buoy #46042 and the MCSST data in the Monterey Bay area.

The ambiguity between the interpretation of skin temperature and SST has a clear impact in the model evaluation and model-data comparison. Tables 3 and 4 summarize the statistics among buoy observations (i.e. the independent data set), the SST from MODAS-2D, and the solution from the NCOM 1/4˚ global model. Values are relative to the data depicted in Fig. 4a Clearly, the skin temperature is not representative of the SST, and it is necessary to evaluate possible solutions. One of the major problems is how to calibrate the MCSST on a global scale and yet provide a more accurate representation locally. At this stage, we have not yet fully estimated the impact on MODAS temperature 3-D field. We anticipate, that the assimilation of in situ measurements, such as XBT or CTD, would create a bulls-eye effect with spurious.

IMPACT/APPLICATIONS

The capability of efficient real-time nowcasting and forecasting has important implications for ocean sciences, technology, and ecosystem monitoring. It makes knowledge of the present and future state of the ocean possible with minimal observational resources. Unfortunately, realistic operational applications may lack the necessary network of observations for both an accurate description and evaluation of the model performances. MODAS Version 1.0 was first incorporated into the Navy's Oceanographic and Atmospheric Master Library (OAML) in November 1995. The latest version of MODAS is available to U.S. government agencies and scientists collaborating with the Navy's laboratories.

TRANSITION

Transition to NRL Code 7183 is in progress.

Table 1. Basic statistical variables and cross-functions between observations and model outputs in the NYB. Error is defined as the difference between first and second argument of each column.

	Buoy #44025	**MODAS-2d**	**NCOM**
Mean	18.59	19.31	19.60
Minimum	16.50	17.23	17.30
Maximum	21.20	21.72	21.77
St. Dev.	1.74	1.77	1.68

	Buoy/ MODAS2D	**BUOY/ NCOM**	**MODAS2/ NCOM**
Mean error	-0.72	-1.01	-0.29
Max. error	-1.52	-2.18	-1.29
Correlation	0.98	0.97	0.98
St. Dev.	0.36	0.44	0.36

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