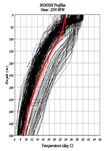
A Rapidly Relocatable Ocean Analysis and Forecasting Capability

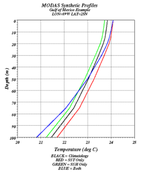
Daniel N. Fox and Charlie N. Barron — Naval Research Laboratory
Germana Peggion — University of Southern Mississippi
www7320.nrlssc.navy.mil/modas/

The Modular Ocean Data Assimilation System (MODAS) combines remote sensed data (altimetry and sea surface temperature) with in situ temperature and salinity measurements to produce an analysis of the ocean that can be considerably more accurate than conventional climatological estimates. MODAS expands on the traditional climatology approach by including relationships between surface and sub-surface properties which have been derived from nearly 3 million historical profiles, almost one million of which include salinity. Using these "synthetic profile" algorithms, daily global analyses of height and temperature from satellites are used to provide a dynamic climatology that matches front and eddy features present on that day. These 3-D estimates of temperature and salinity are assimilated into a global implementation of the Navy Coastal Ocean Model (NCOM) to provide daily analyses and forecasts of the ocean at approximately 15 km resolution. MODAS includes a relocatable implementation of the Princeton Ocean Model (POM) which includes tidal forcing and which can obtain initial and boundary conditions from the MODAS dynamic climatology as well as the daily NCOM model. The combination of MODAS, NCOM, and POM allows high resolution nowcasts and forecasts of temperature, salinity, and currents (including tidal effects) to be produced anywhere in the world on short notice.

A new "dynamic" ocean climatology : 3-D ocean thermal structure estimates from remote sensing

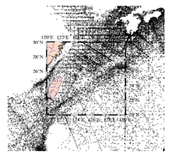


All historical profiles within 100 KM of reference location, compared to climatology. Note two modes that cannot be differentiated with surface temperature alone.

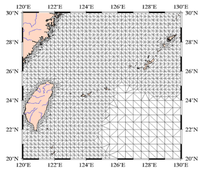


Linear regression relationships modify climatology based on all historical profiles in vicinity.

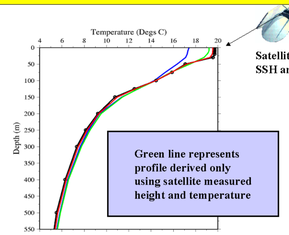
Climatology
SST
SSH
SST + SSH



Decades of edited MOODS profiles are used to derive statistical relationships between surface height and temperature and subsurface temperature and salinity

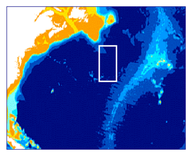


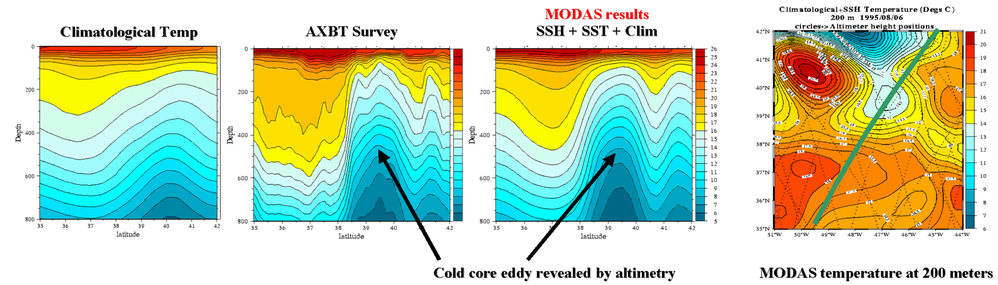
Relationships are stored on an irregular mesh, varying from 1 to 1/8 degree in resolution to permit high resolution analyses in shallow water regions



Satellite-Measured SSH and SST

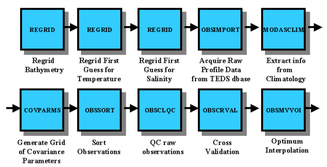
Climatology
MODAS Synthetic
Final Analysis
In Situ BT



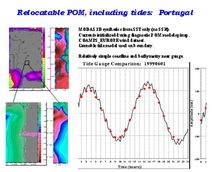


MODAS temperature at 200 meters

An easily extensible modular toolkit for modeling and assimilation



MODAS contains approximately 200 modules, covering the import and export of data in numerous formats, interpolating, smoothing and other grid manipulations. Recent modules include a fully relocatable version of the Princeton Ocean Model (POM), including tides. Relocatable POM obtains boundary condition transports from a global implementation of the Navy Coastal Ocean Model (NCOM), which in turn assimilates remotely sensed altimetry and temperature data using MODAS synthetic profiles. An example of the tidal heights compared to an in situ gauge is shown at right.



Scalable from global to regional to local needs

Satellite Measurements (Altimetry, MCSST)

Satellite Data Flow

Central Site

Global ocean data from satellites is used to estimate the T and S grids for specific areas of interest, into which recent BT and CTD data is assimilated using optimum interpolation. These final grids are transmitted to regional centers in a compressed format.

First Guess Fields

Regional Centers

MODAS uses the fields sent from Naval Oceanographic Office as first guess fields into which newer, regional profile data is optimally interpolated. These updated fields are distributed to on-scene units.

First Guess Fields

On Scene Analyses

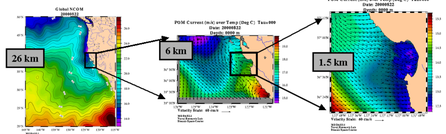
MODAS fields from the Centers are used "as-is" or as first guess fields for profiles and other data acquired on-scene in real time.

NRLPOM - A Rapidly Relocatable Princeton Ocean Model Implementation

MODAS-NRLPOM is a scalable, portable, and rapidly relocatable system for nowcast and short-term (2-day) forecast simulations. A version of this system is routinely applied at the Naval Oceanographic Office (NAVO) in several areas and configurations ranging from basin-scale to inlets, from deep to coastal domains, from open-sea to semi-enclosed areas. There are two major components: 1) the Modular Ocean Data Assimilation System (MODAS) to generate a nowcast field to initialize 2) the Naval Research Laboratory Princeton Ocean Model (NRLPOM). Major NRLPOM features include:

- estimates of tidal flow (tidal forcing is specified from the Grenoble Model),
- nesting/coupling option
- cold/warm/diagnostic (and combinations) initialization procedures
- user-friendly interface

Coupling/Nesting Example: Monterrey Bay



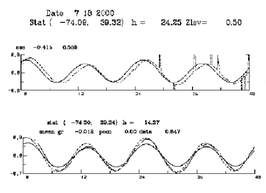
Global NCOM provides boundary conditions for regional model which provides BC for local model

Model - Data Comparisons at LEO 15

From July 12 – August 5, 2000, data from the LEO-15 site were ftp'ed to NRL-SSC, processed within MODAS to provide the initial and boundary conditions for NRLPOM. At the end of the dynamical model computations, the 48 hour forecasts were posted to the web page (www7320.nrlssc.navy.mil/modas), usually within 6 –10 hours from the nowcast hour. Independent data have been used to provide the following model/data comparisons.

Conclusions:

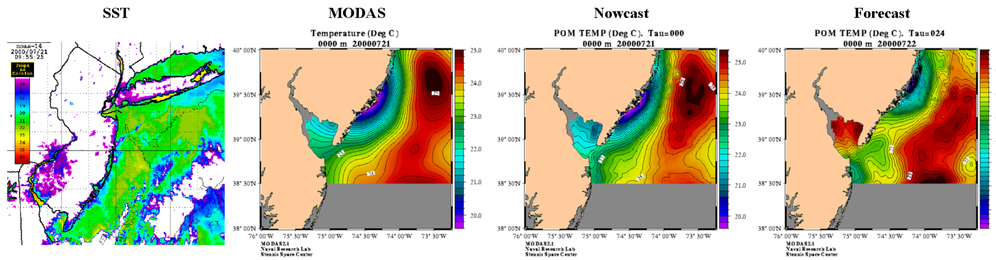
* MODAS initial field is accurate to allow NRLPOM to 1) spin-up the physics and 2) provide a more accurate hindcast.
* The tidal amplitude and phase computed by the model is in great agreement with observed fields at several stations (Fig. 1).



Model (solid line), Grenoble (small dash line) and data from tidal gauge

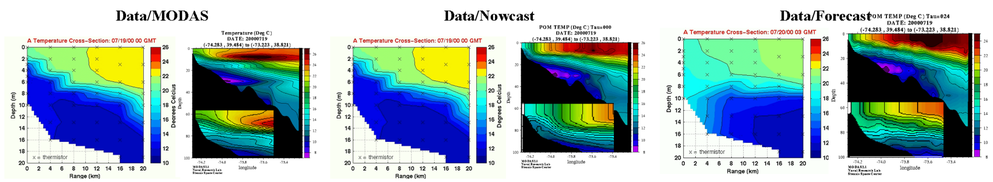
* MODAS-NRLPOM forecasted up- and down-welling events in the right locations and with a maximum of 3-4 hour lag. (Fig. 2).
* The quality of the model results also depends on the quality of the forecasted winds. The 27 km spatial resolution and the 3 hour time interval of COAMPS winds may not be sufficient for accurate forecasts in coastal areas.
* During upwelling events, data indicate a 2-layer system with a very sharp thermocline that is not fully reproduced by MODAS analysis. Although NRLPOM clearly shows the up- and down-welling sequences, the bottom waters were generally too warm with respect to the observations. However, the model was successful in reproducing the variability at the thermocline depth.

SST and MODAS-NRLPOM solution



MODAS locates upwelling more to the North
NRLPOM nowcast shifts the upwelling to the south
NRLPOM forecast (from previous day simulation) predicts upwelling correctly.

A-NODE Vertical Sections



Comparison with the thermistors from the A-node. The enlarged area in the model output is the upper left corner (20 m depth).

* Data indicates a two layer system (very sharp thermocline), not fully reproduced by MODAS.
* MODAS initial conditions allow NRLPOM to spin up the dynamics
* NRLPOM predicts the transition from up- to downwelling.