2008 NASA Carbon Cycle & Ecosystems JOINT SCIENCE WORKSHOP

A Bio-Physical Ocean Model for the Indian Ocean/Arabian Sea: Implementation and Initial Evaluation

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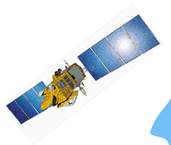

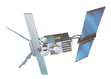

NOGAPS Navy Operational Global Atmospheric Prediction System is the primary source for forcing U.S. Navy ocean models, modeling atmosphere-ocean interactions, and providing boundary conditions for nested atmospheric models.

www.fnmoc.navy.mil/PUBLIC/

Momentum & Heat Fluxes

Momentum & Heat Fluxes

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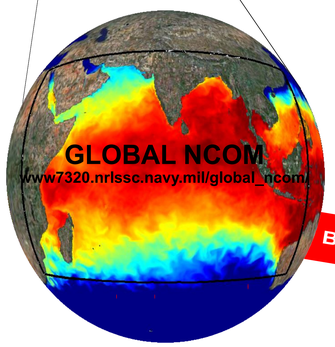
NLOM The 1/32° global Naval Research Laboratory Layered Ocean Model is an operational product run daily by the Naval Oceanographic Office (NAVOCEANO) with atmospheric forcing from NOGAPS and assimilation of SST and satellite altimeter data obtained via the NAVOCEANO Altimeter Data Fusion Center.

www7320.nrlssc.navy.mil/global_nlom/



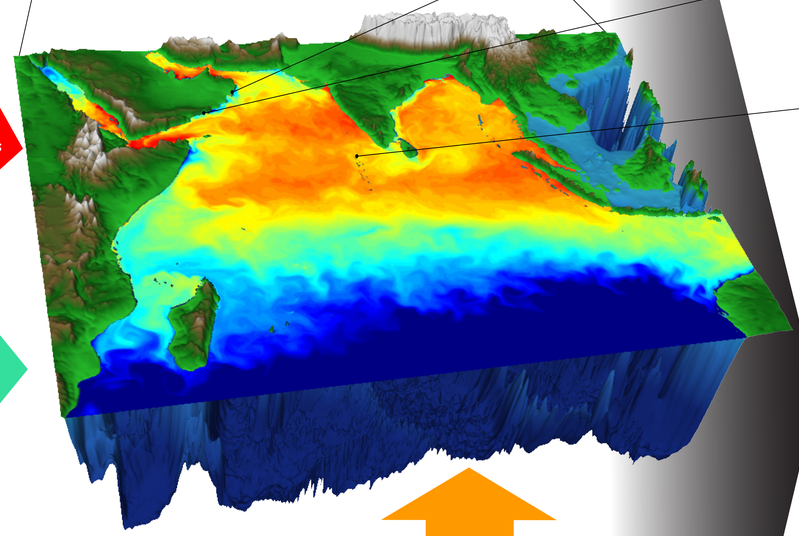
Boundaries

BCs

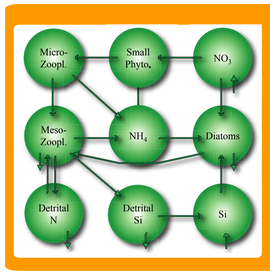
MODAS The Modular Ocean Assimilation System is an optimum interpolation (OI) system for estimating present and future conditions in the oceans. NLOM provides high-resolution SSH to derive MODAS synthetic temperature and salinity profiles which along with climatological data are used to general full MODAS 3-D temperature and salinity estimations.

www7320.nrlssc.navy.mil/modas/

MODAS T&S Relaxation



ECOSYSTEM Coupling



The NCOM-IO (Indian Ocean) model includes a 9-component ecosystem model implemented into NCOM in collaboration with Fei Chai of the University of Maine. The biological model, originally developed for the equatorial Pacific upwelling system, includes three nutrients (silicate, nitrate and ammonia), two phyto-plankton groups (diatoms and small phyto-plankton), two groups of zooplankton grazers (micro- and meso-), and two detrital pools (silica and nitrogen).

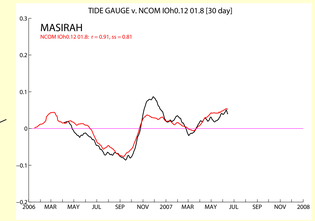
A general circulation numerical ocean model, based on the Navy Coastal Ocean Model (NCOM), has been implemented for the Indian Ocean/Arabian Sea region. The Indian Ocean regional model is setup on a Mercator grid with 1/8° equatorial horizontal resolution extending from 30S to 30N, 30E to 121.5E, and a 40-level hybrid vertical structure: 19 terrain-following sigma levels at the top, and 21 Z levels at the bottom. The terrain following levels, reaching from the surface to about 137m, allow higher vertical resolutions for resolving mixed layer/shallow waters, while the Z levels are used in the stratified ocean. The bathymetry is constructed from the NRL 2-minute database with the coastline set at 5 meters. The model gets initial and boundary conditions from the Navy's operational Global NCOM model with similar horizontal and vertical structure. The open boundaries are at the southern boundary (30S) bounded by Africa and Australia, and the eastern boundary (121.5E) at the Indonesian straights. Data (for both global and regional models) is assimilated via the Modular Ocean Data Assimilation System (MODAS) which generates temperature and salinity synthetic profiles by regressing satellite derived altimeter SSH and satellite SST observations. The physical model is one-way coupled to a 9-compartment ecosystem model (F. Chai, et al, 2002) which includes nutrients as well as large and small plankton. The ocean model is forced by atmospheric momentum and heat fluxes from the 1/2° Navy Operational Global Atmospheric Prediction System (NOGAPS).

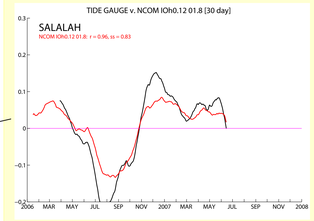
The bio-physical model simulation was executed for the period of 01/01/2006 to 07/01/2007. The model was initialized, and uses boundary values, from Global NCOM (SSH, Temperature, Salinity, and Currents), and from the World Ocean Atlas (WOA) monthly climatology (Silicate and Nitrate). This simulation was forced by 3-hourly NOGAPS momentum and heat fluxes, and data assimilation was implemented via relaxation to daily MODAS Temperature and Salinity fields. During the GONU event (May-June 2007), the model output was increased from 12-hourly to hourly in an effort to capture finer time scales to evaluate the bio-physical oceanic response to the storm.

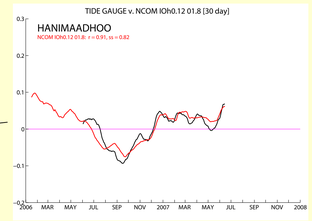
Initial examination of the model output indicates that the model is correctly representing the general features of the region. Although little observational data are available at this time for a comprehensive evaluation, preliminary results show that the skill of the model in representing sea-surface height is very accurate for the tide-gauge stations presented (Figure 1). It is also seen that the atmospheric and ocean models closely reproduced the Gonu event (Figure 2). The biological model results were not as satisfactory as the physical ones. Although the model produced reasonable values, initial examinations showed that the model was producing unrealistic high-values in places that were not expected, and some of the coastal blooms were offset in relation to the satellite chlorophyll fields, and at times, lacked the intensity seen in SeaWIFS imagery (Figure 3).

These initial results provided us with the basis to assess and remedy issues discovered in each simulation. Processes such as denitrification which are important in the Arabian Sea were not factored into the model. An imperative step towards the advancement of this effort is to acquire surface and sub-surface observational (in-situ and remotely-sensed) data to perform a full evaluation and validation of the model results. Future runs will include a newly developed ecosystem model and an improved relaxation scheme for temperature and salinity. Revised parameterizations of the biology and the physics are also being tested in new simulations, along with higher horizontal and/or vertical resolution nests in the regions of interest (Arabian Sea).

1

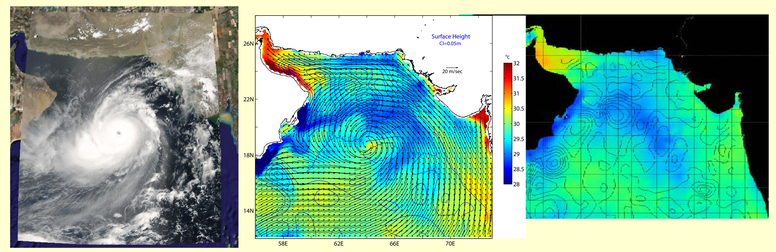






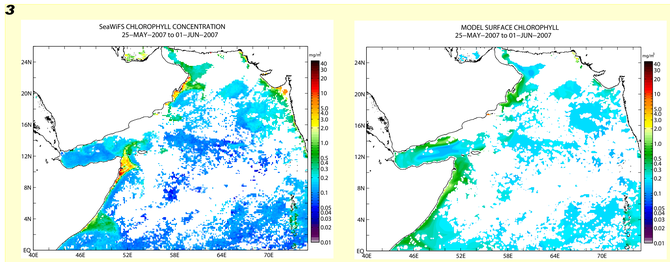
The above figures constitute the evaluation of the model Sea Surface Height (SSH) against three tide-gauge stations in the Arabian Sea region. The data have been pressure corrected, filtered (30-day running average) and de-meaned to provide an objective statistical measurement of the skill of the model. Although limited to only 3 stations, the model exhibits impressive results with consistent high correlations (r) and skill scores (ss) in east and west areas of the Arabian Sea.

2



A qualitative evaluation of the GONU event on June 4, 2007, 0900GMT. The model SST (color contour), SSH (line contour), and atmospheric model winds (vectors) are shown on the center figure and compared to satellite imagery (left), and SST from the Global High-Resolution SST Pilot Project (right). The figure illustrates that the atmospheric model winds (NOGAPS) accurately reproduce the location and intensity of the storm. The modeled oceanic response due to the atmospheric forcing, as expected, exhibits an upsurge of deeper colder water to the surface. The decrease in SST is clearly visible, where over a large area of the northern Arabian Sea SSTs dropped from average values of 32oC to <28oC.

3



An 8-day composite of the Arabian Sea region is used as a general comparison of the model computed chlorophyll to the imagery derived from SeaWIFS. The model (right), was cloud-masked to provide a better visual comparison to the observation (left). Although finer coastal features have not been correctly represented, the general mesoscale structure of the bio-mass is captured. Future experiments will be needed to determine the correct parameterization for the ecosystem model and improve the results further.

EXECUTION PERFORMANCE
(units per model year)

IOh0.12 DOMAIN SIZE: (730x550x40)
PLATFORM: IBM SP5 64-cpus
RUN TIME (600s time-step): 22.8 hrs
MEMORY: 12GB
INPUT DATA SIZE: ~35GB
OUTPUT DATA SIZE: ~600GB (12 hrly)