Real-time ocean assimilation and prediction with global NCOM

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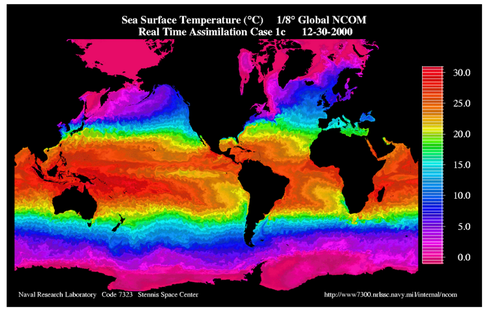
Abstract

Real-time assimilative global ocean models at resolutions sufficient to be useful for a wide range of Navy operations have recently become viable due to continuing improvements in computational capacity, model development and data acquisition and processing. A global implementation of the Navy Coastal Ocean Model (NCOM), developed by the Naval Research Laboratory (NRL) at Stennis Space Center for transition to the Naval Oceanographic Office (NAVOCEANO), is at the forefront of global ocean modeling. Global NCOM encompasses the open ocean to 5 m depth in a curvilinear global model grid with 1/8 degree grid spacing at 45N, extending from 80 S to a complete arctic cap with grid singularities mapped into Canada and Russia. Vertically the model employs 41 sigma-z levels with sigma in the upper ocean and coastal regions and z in the deeper ocean. The Navy Operational Global Atmospheric Prediction System (NOGAPS) provides 6-hourly wind stresses and heat fluxes for forcing, while the Modular Ocean Data Assimilation System (MODAS) provides background climatology and tools for data preprocessing. Operationally available sea surface temperature (SST) and altimetry (SSH) data are incorporated into NAVOCEANO global MODAS and Navy Layered Ocean Model (NLOM) analyses and forecasts of SSH and SST. These in turn are combined with the MODAS synthetic database to yield three-dimensional fields of temperature and salinity for assimilation into global NCOM.

Global NCOM nowcasts and forecasts provide a valuable resource for rapid response to the varied and often unpredictable operational requests for 3-dimensional fields of ocean temperature, salinity, and currents. In some cases, the resolution of the global product is sufficient for guidance. In cases requiring higher resolution, the global product offers a quick overview of local circulation and provides initial and boundary conditions for small-scale relocatable models that may be more specialized for a particular task or domain. Nowcast and forecast results are presented globally and in selected areas of interest. Model results are compared with historical and concurrent observations and analyses.



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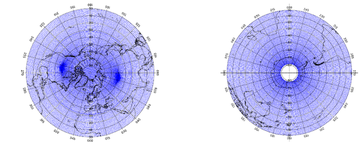
- 40 vertical sigma-z levels (19/21)
- 1m max upper layer thickness
- Fully global ocean with polar overlap and depth to 5m.
- Forced by real-time NOGAPS surface wind stress and heat fluxes
- Assimilates SST, SSS and 3D T&S from MODAS3D analysis of MODAS2D SST and MODAS2D or NLOM SSH
- Provides nesting with coastal ocean and relocatable models and improved coastal and upper ocean forecast capability

Results are included from:

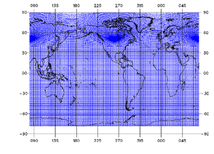
1/4° global assimilative case 0c from Jan. 2000 to the present. Forced with nowcast quality NOGAPS 3-hourly wind stresses and heat fluxes. Assimilates MODAS2D SST and synthetic T&S from MODAS2D SSH and SST. Uses 2nd order advection.

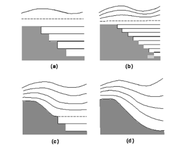
1/8° global climatological case 1a from years 2-8. Forced with Hellerman-Rosenstein monthly unsmoothed surface wind stress and relaxation using surface fluxes to MODAS bimonthly climatological SST and SSS. Uses 3rd order upwind advection.

1/8° global assimilative case 0c from Oct. 2000 to the present. Forced with nowcast quality NOGAPS 3-hourly wind stresses and heat fluxes. Assimilates MODAS2D SST and synthetic T&S from MODAS2D SST and 1/16° NLOM SSH. Uses 3rd order upwind advection.



The global NCOM grid produces a global overlap by transforming the northern hemisphere around poles over land in Canada and Russia. The 1/8° grid resolution refers to an average midlatitude spacing of the 2048x1280 grid.





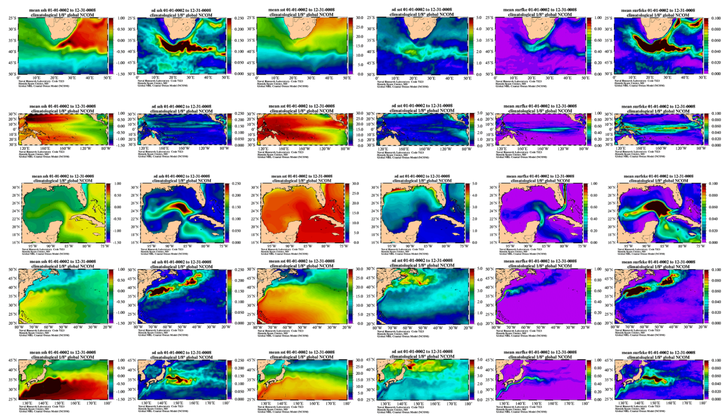
The figures at left indicate options for configuring the sigma-z vertical coordinate in NCOM:
(a) z levels with free surface
(b) sigma levels over z levels
(c) more sigma over z levels
(d) sigma levels only

Data Assimilation Procedure

- **Acquire sea surface temperature (sst)**
  Use daily SST analysis from the Naval Oceanographic Office (NAVOCEANO) MODAS2D optimal interpolation (OI) of MCSST observations.
- **Acquire sea surface height (ssh)**
  Use either
  daily SSH analysis from the NAVOCEANO MODAS2D OI of TOPEX, ERS and GFO altimetry
  or
  daily steric-SSH nowcast from the 1/16° Navy Layered Ocean Model (NLOM)
  A mean correction is added to the height fields so that the resulting ssh is a deviation from the MODAS climatological mean steric height anomaly.
- **Produce 3D T&S fields**
  Estimate subsurface temperature and salinity using MODAS3D synthetics. Regressions relate sst and/or steric ssh deviations from climatology with subsurface temperature deviations. Since the non-steric fraction of altimetric ssh tends to increase in shallow water and the NLOM boundary is at the 200m isobath, ssh is smoothly removed from synthetic temperature estimates as depths become shallower than 600m. Salinity is estimated using climatological T&S relations.
- **Assimilate in-situ observations**
  MODAS3D OI can assimilate subsurface observations to improve the analysis.
- **Adjust for vertical stability**
  Convert to potential temperature, adjust salinity to produce vertical stability.
- **Modify surface heat and freshwater fluxes**
  Surface temperature and salinity is assimilated by adjusting surface freshwater and heat fluxes.
- **Relax temperature and salinity at depth**
  Relax 3d potential temperature and salinity toward the specified fields using weighting functions which allow 3d variability. Present weighting decays to 0 at the surface and is e^{-1} at 200m.

Statistics from the 1/8° climatological global NCOM experiment glb8_1a

Mean, standard deviation and kinetic energy fields from years 2-8 of the 1/8° climatological global NCOM experiment glb8_1a. The model was forced with Hellerman-Rosenstein unsmoothed climatological surface wind stress and relaxed to MODAS climatological SSS and SST.

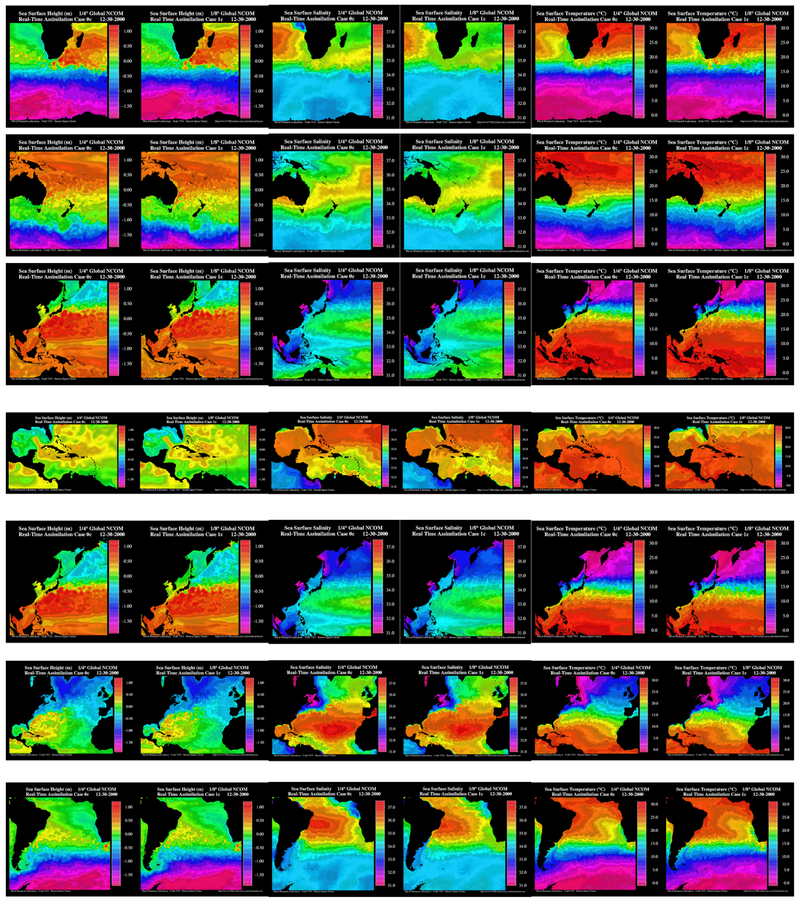


Transports from the 1/8° global NCOM climatological experiments.

glb8_1a transport years 2-6		
Section	Mean	Std. Dev.
Yucatan St.	21.9 Sv	2.3 Sv
Florida St.	21.9 Sv	2.3 Sv
Gulf Stream 26.6N	22.4 Sv	1.4 Sv
Gulf Stream 31N	27.0 Sv	2.5 Sv
Kuroshio 24N	26.8 Sv	2.7 Sv
Kuroshio 135E	53.9 Sv	5.5 Sv

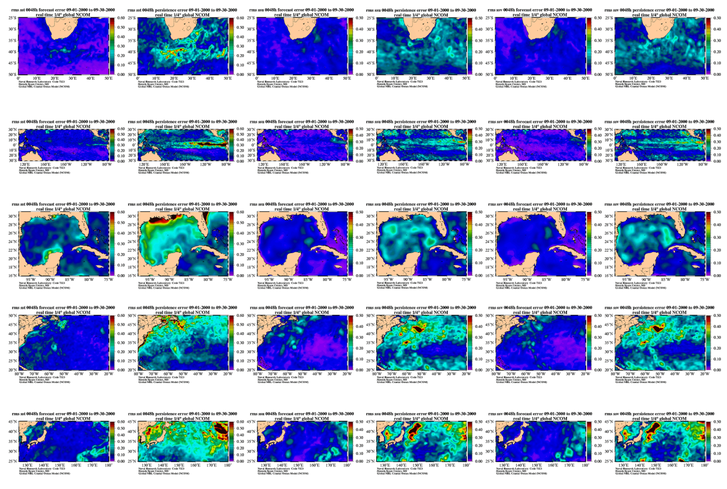
glb8_1a transport years 2-6		
Section	Mean	Std. Dev.
Luzon St.	-6.2 Sv	2.8 Sv
Taiwan St.	1.6 Sv	0.7 Sv
Tushima St.	2.2 Sv	0.3 Sv
Bering St.	0.0 Sv	0.1 Sv
Drake Passage	170.6 Sv	3.6 Sv
Indonesian Thrflw.	-14.3 Sv	2.1 Sv

Comparison of snapshots from the 1/4° glb4_0c and 1/8° glb8_1c global NCOM assimilative runs. Both are forced with NOGAPS wind stress and heat fluxes and both assimilate MODAS2D SST. Both assimilate MODAS synthetic T&S, but these are derived using MODAS2D SSH in the glb4_0c case and NLOM 1/16° SSH in the glb8_0c case. Both cases use MODAS2D SST in deriving the synthetics.

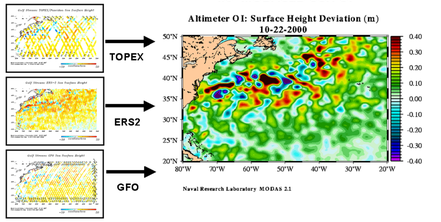


48 hr Forecast and Persistence Error Statistics for 1/4° real time global NCOM

The analysis fields from the 1/4° real-time global NCOM are used to evaluate the skill of prior 48-hour forecasts in comparison with the skill in persistence of 48-hour prior analyses. The model shows forecast skill well above persistence to at least 48 hours, the duration of forecasts in these cases.

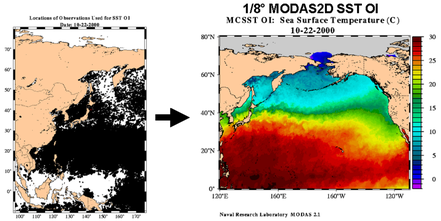


1/8° MODAS2D SSH OI



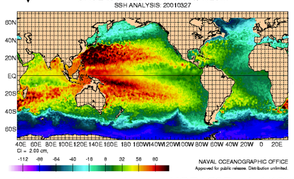
A first guess field and tracks of TOPEX, ERS and GFO sea surface height deviations are combined in an optimal interpolation procedure to produce daily global 1/8° SSH fields. See http://www7300.nrlssc.navy.mil/altimetry

1/8° MODAS2D SST OI



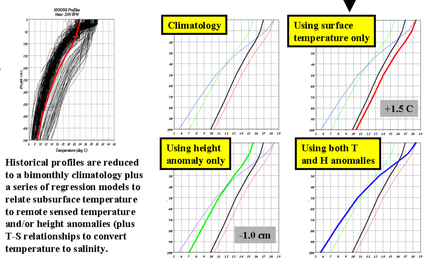
A first guess field and scattered satellite SST observations are combined in an optimal interpolation procedure to produce daily global 1/8° SST fields. see http://www7300.nrlssc.navy.mil/altimetry

1/16° GLOBAL NLOM



Assimilating altimeter heights and MODAS2D sst, 1/16° NLOM provides an alternate source for steric heights in MODAS3D.

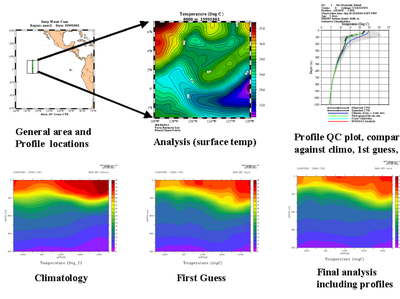
1/8° MODAS3D Synthetics



Historical profiles are reduced to a bimonthly climatology plus a series of regression models to relate subsurface temperature to remote sensed temperature and/or height anomalies (plus T-S relationships to convert temperature to salinity.

A mask controls the degree to which height is used in the synthetics.

MODAS 3D OI



General area and Profile locations

Analysis (surface temp)

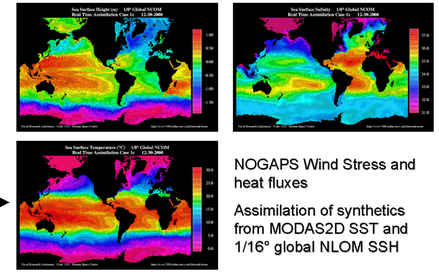
Profile QC plot, comparison against climo, 1st guess, etc

Climatology

First Guess

Final analysis including profiles

Additional in situ observations may be assimilated in this stage.



NOGAPS Wind Stress and heat fluxes

Assimilation of synthetics from MODAS2D SST and 1/16° global NLOM SSH

After regridding to the model grid, capping at the pole and adjusting for vertical stability, the data is nudged into the model according to the weighting field.

For additional information: http://www7320.nrlssc.navy.mil.html/7320-home.html