Validation and Application of the Global Navy Coastal Ocean Model

Abstract

A global implementation of the Navy Coastal Ocean Model (NCOM) has recently been developed for transition into operations at the Naval Oceanographic Office (NAVO). The operational roles of global NCOM include providing standalone data where the resolution of the global product is sufficient for guidance, a quick overview of local circulation where refined products are operationally unavailable, and boundary conditions for regional or relocatable models that may be more specialized for a particular task or domain. Some global NCOM results of particular interest include sea surface temperature, mixed layer depth, current profiles and shelf circulation. Global NCOM is designed to be suitable for inclusion in a coupled ocean-atmosphere modeling system, and it will also serve as the host for an embedded ice model, PIPS3, which is in development for transition.

Global NCOM covers the world ocean to minimum depths of 5m, with midlatitude resolution of about 1/8° latitude. To improve resolution of upper-ocean dynamics, a maximum 1-m upper level thickness is maintained in a vertical configuration of 40 hybrid sigma-z levels. Data assimilation is based on global profiles of temperature and salinity derived using operational sea surface fields and *in situ* data within the Modular Ocean Data Assimilation System (MODAS). The Navy Operational Global Atmospheric Prediction System (NOGAPS) provides atmospheric forcing. Tidal heights and currents can be added using a separate user-specified model, including NAVO operational PC Tides.

Validation of global NCOM against unassimilated observations or climatologies provides a basis for estimating the accuracy of its nowcasts and forecast products and indicates directions for further model refinement and development.

Representative results selected from evaluations performed during the model development and operational test phases include eddy kinetic energy, transports, vertical sections of temperature and velocity, sea surface temperature, mixed-layer depth, sea-surface height and event comparisons. These results are used to assess present operational capabilities and indicate directions for future research and development.

NCOM G8 objectives

To develop a real-time global analysis/prediction system using NCOM which will provide:

- short-term (5 day) predictions of upper ocean processes (SST, mixed layer T&S, surface currents) with coverage of and connection between open ocean and coastal regimes.
- initial/boundary conditions for nesting real-time coastal models (NAVO SWAFS, relocatable).
- the host for the PIPS 3.0 Arctic ice model.
- an ocean model capability suitable for coupling in a global coupled air/ocean system (NOGAPS).

This work is supported by the Oceanographer of the Navy via Space and Naval Warfare Systems Command PMW155 though 6.4 Large Scale Ocean Models and 6.4 Advanced Data Assimilation Projects at NRL

For additional information on global NCOM, see our website:

http://www.ocean.nrlssc.navy.mil/global_ncom

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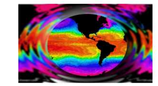
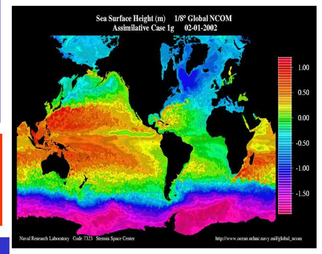




Results are included from three 1/8° global experiments:

Assimilative hindcast. Jan 1997 – April 2003 (glb8_2f)
Refined topography. Upgraded heat flux and assimilation. Includes rivers. Uses hindcast quality NOGAPS atmospheric forcing and MODAS +NLOM assimilation data. Used for system validation.

Free-running hindcast. Jan 1997 – Mar 2002 (glb8_2b)
Refined topography. Upgraded heat flux. no rivers. Uses hindcast quality NOGAPS atmospheric forcing. Used for system validation.

Assimilative real time. Oct 2001 – present (glb8_1g)
Initial topography. No rivers. No ocean feedback in heat flux. Uses real time NOGAPS atmospheric forcing and MODAS+NLOM assimilation data. Used for development of real time system.

NCOM Model Configuration

NCOM
- based on POM and SZM
- configuration managed by NRL
- coded for efficient scalability, portability on parallel architecture

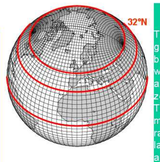
NCOM G8
vertical coordinate blends terrain following sigma + fixed depth z
- 40 material levels: 19 sigma over 21 z • 5 m – 5500 m
- sigma-z interface at 137m • free surface
- logarithmic stretching • 1m maximum upper layer thickness

curvilinear horizontal grid
- 2048x1280 • 14 km resolution at 45°N (~1/8° lat)
- NRL DBDB2 bathymetry • Arctic overlap • cell aspect ~1

forcing and assimilation
- NOGAPS wind stress, radiation flux, other atmospheric
- assimilates MODAS synthetic T&S profiles derived from MODAS sst, NLOM ssh • heat, salinity fluxes adjusted by MODAS fields
- ocean model calculates latent, sensible heat fluxes (Kara)

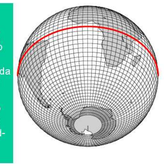
other options
- third-order upwind advection • MYL2 + Large mixing
- global rivers include ~1000 rivers with monthly climatology

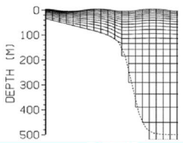
implementation
- 128 processors on NAVO IBM P4 • ~10 model days/2 hrs



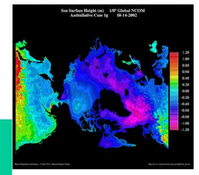
Horizontal Grid

The global NCOM horizontal grid includes a global overlap by introducing an Arctic cap with poles over land in Canada and Russia. A non-spherical zone begins at 32°N.
The grid is stretched to try to maintain a horizontal aspect ratio near 1. The ~14 km mid-latitude (45°N) spacing is approximately 1/8°latitude.





Arctic grid resolution is 5-10 km. Projection of the Arctic into model space is shown below.



Vertical Grid

The sigma-z vertical coordinate employed by global NCOM uses 19 terrain following sigma levels over 21 fixed-depth z-levels. The depth of sigma-z transition interface is 137 m, near the shelf break. The grid is logarithmically stretched in deep water from a 1-m rest thickness at the surface to a 5500m bottom depth.

Validation of Global NCOM

Validation of SSH

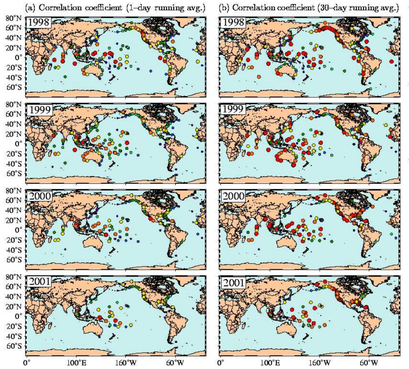
Sea surface height (SSH) from NCOM G8 from 1999-2001 was compared with Joint Archive for Sea Level (JASL) data. 612 year-long, detided JASL SSH time series are used in the validation. These include both coastal and open ocean island stations. Correlation with NCOM G8 is computed using running daily and 30-day boxcar filters. Assimilative median correlations are 0.70 daily, 0.84 monthly.

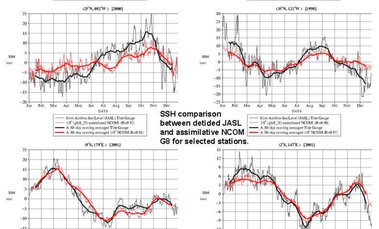
Correlation (daily)	glb8_2b free-run	glb8_2f assimilated	Number of tide gauges
1998	0.71	0.70	189
1999	0.63	0.69	181
2000	0.63	0.70	151
2001	n/a	0.76	91
1998-2000	0.64	0.70	521
1998-2001	n/a	0.70	612
(30-day)			
1998	0.77	0.79	187
1999	0.75	0.83	177
2000	0.81	0.88	137
2001	n/a	0.88	91
1998-2000	0.77	0.84	501
1998-2001	n/a	0.84	592

Distribution of SSH correlation between detided JASL and assimilative NCOM G8 data.

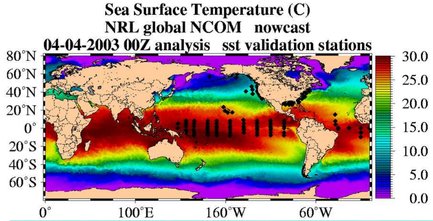
• <0.30 • 0.30-0.40 • 0.40-0.50 • 0.50-0.60 • 0.60-0.70 • 0.70-0.80 • 0.80-0.90 • 0.90-1.00

(a) Correlation coefficient (1-day running avg.) (b) Correlation coefficient (30-day running avg.)



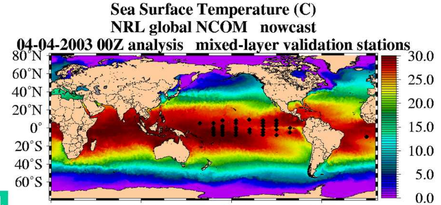


SSH comparison between detided JASL and assimilative NCOM G8 for selected stations.



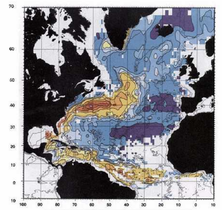
The SST plot above indicates locations of stations providing 219 unassimilated, year-long buoy SST time series used for NCOM G8 validation 1998-2000. Comparisons are shown below for MODAS and NCOM SST analyses. MODAS 2D optimal analyses of SST are assimilated into NCOM G8. Results include the extreme 1998 El Niño to La Niña transition.

Validation of Mixed Layer Depth

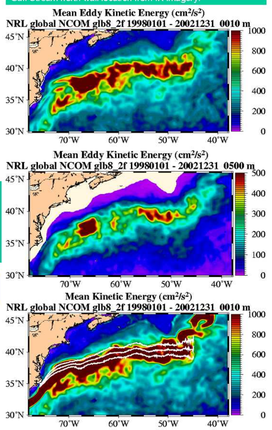


In comparison with 71 unassimilated, equatorial year-long time series of MLD (1998-2000), assimilative NCOM G8 had -8.6 m bias and 19.4 m RMS error for MLD on the order of 100 m. Compared with the MODAS-based vertical projections of surface data, global NCOM results better reflect the variability of the mixed layer depth.

Validation of Eddy Kinetic Energy



Eddy kinetic energy from (above) 1990s drifter trajectories (Fratantoni, JGR 2001) and from (below) assimilative NCOM G8 5-year means at 10 and 500 m. At bottom, NCOM G8 kinetic energy with mean and +/- 1 standard deviation DAMEE Gulf Stream north wall location from IR imagery.



Application of Global NCOM

Kursk Disaster

Initial application of global NCOM (NCOM G4) was to make support available for response to Kursk Disaster, August 2000, Barents Sea

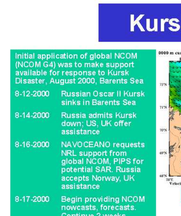
8-12-2000 Russian Oscar II Kursk sinks in Barents Sea

8-14-2000 Russia admits Kursk down; US, UK offer assistance

8-16-2000 NAVOCEANO requests NRL support from global NCOM. PIPS for potential SAR. Russia accepts Norway, UK assistance

8-17-2000 Begin providing NCOM nowcasts, forecasts. Continue 2 weeks.

9-06-2000 BRAVO ZULU from NAVOCEANO CO



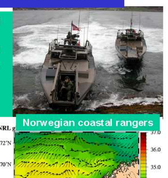
Currents, temperature from NCOM G4

← Kursk in port

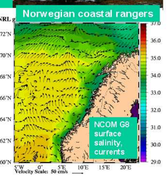
Kursk recovered 10-23-2001 →

Strong Resolve 2002

In March 2002, NRL pre-operational NCOM G8 fields in the Norwegian Sea provided ocean environment and boundary condition support for Norwegian Met. Institute (Bruce Hackett) in Strong Resolve 2002. The primary NATO exercise for the year, the Strong Resolve component in Norway simulated an Article 5 event, deployment following an attack on a NATO member.



Norwegian coastal rangers



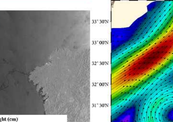
Norwegian ships in Trondheim

Prestige Oil Spill

When the MV Prestige split and sank off the coast of Galicia, Spain, NRL aided the response by providing currents from global NCOM. Facilitated by prior contacts between NRL Stennis and Spanish oceanographers, longer term collaboration has been funded to continue providing results from global NCOM and a nested, relocatable, higher resolution (4-5 km) NCOM with tides for the Galicia region.

- Nov 19, 2002 – Tanker breaks up and sinks off Spain as a strong storm system approaches
- Nov 19 1600 GMT – NRL requested to provide currents for spill tracking
- Nov 19 2200 GMT – First NCOM G8 results provided to cleanup planners
- Nov 20 – Start providing daily NCOM G8 72 hour forecasts to planners
- Nov 25 – Start providing daily relocatable, nested NCOM results to planners
- Collaboration with Enrique Alvarez, U. Cadiz, Spain

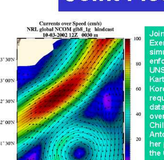
Prestige sinking

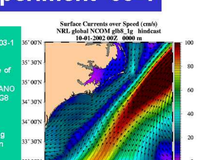


SAR view of spill

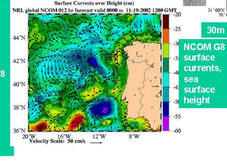
Joint Fleet Experiment 03-1

Joint Task Force Exercise (JTFEX) 03-1 simulated enforcement of UNSCR in defence of Kartuna against Koroma. NAVOCEANO requested NCOM G8 data to provide overlays for the Chilean vessel Antofagasta during her participation in the October 2002 exercise.





30m currents around Gulf Stream



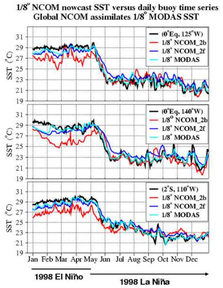
NCOM G8 surface currents, sea surface height

HS Truman Battle Group

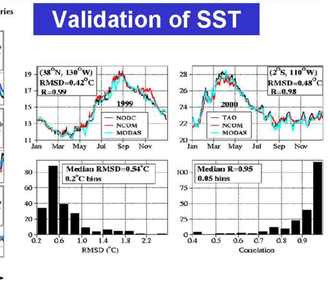
Currents near Cape Hatteras

Helicopter from anti-submarine squadron 7 engaged in ASW

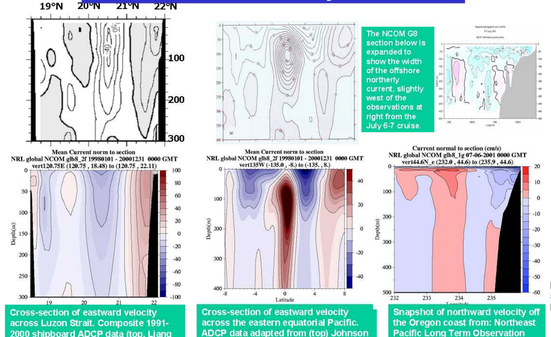
Validation of Sea Surface Height



Validation of SST



Validation of Velocity Sections



The NCOM G8 section below is expanded to show the width of the offshore northerly current, slightly west of the observations at right from the July 6-7 cruise.

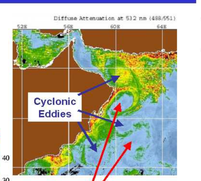
Cross-section of eastward velocity across Luzon Strait. Composite 1991-2000 shipboard ADCP data (top, Liang et al., 2003, DSR2) vs. mean 1998-2000 assimilative NCOM G8 (bottom).

Cross-section of eastward velocity across the eastern equatorial Pacific. ADCP data adapted from (top) Johnson et al. (2001, JPO) vs. (bottom) mean 1998-2000 assimilative NCOM G8.

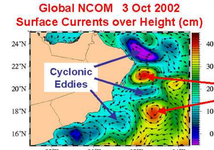
Snapshot of northward velocity off the Oregon coast from: Northeast Pacific Long Term Observation Program (Huyer et al.) and assimilative NCOM G8 (bottom).

Validation of Mesoscale Features

MODIS composite
30 Sep – 7 Oct 2002
Diffuse Attenuation
Coefficient at 532 nm



Global NCOM 3 Oct 2002
Surface Currents over Height (cm)

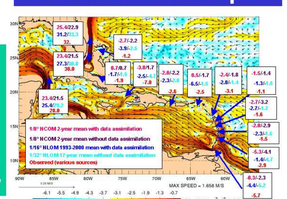


For additional information on nesting within NCOM G8 and regional NCOM applications, see TOS poster "Sensitivity of a Regional Coastal Model to the Resolution of the Wind Forcing" by Anderson, S.C., J.C. Kindle and S. deRada

Additional information is available on the Global NCOM web page:

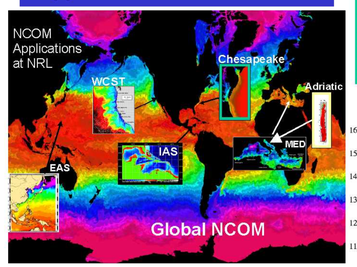
www.ocean.nrlssc.navy.mil/global_ncom

Validation of Transport



Right: Comparison of observed and modeled mean transports in the Intra-Americas Sea. NCOM and NLOM (Navy Layered Ocean Model) multi-annual mean transports (Sv) versus observed transports (Sv) over various time periods.

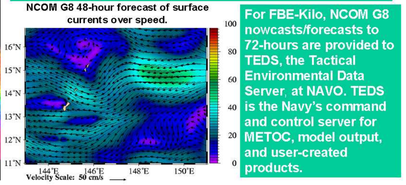
Support of NRL Nested Models



Fleet Battle Experiment Kilo

Fleet Battle Experiments (FBEs) are conducted to operationally examine and evaluate innovative warfighting capabilities for future development and rapid transition to the Fleet. NCOM G8 data was requested and provided for use in the April 2003 FBE Kilo around Guam. Objectives use CNO Seapower 21 guidance.

NCOM G8 48-hour forecast of surface currents over speed.



For FBE-Kilo, NCOM G8 nowcasts/forecasts to 72-hours are provided to TEDS, the Tactical Environmental Data Server at NAVO. TEDS is the Navy's command and control server for METOC, model output, and user-created products.