

Real-time Assimilation of Altimeter
Derived Synthetic Profiles Into a Global
Version of the
Naval Research Laboratory's
Coastal Ocean Model (NCOM)

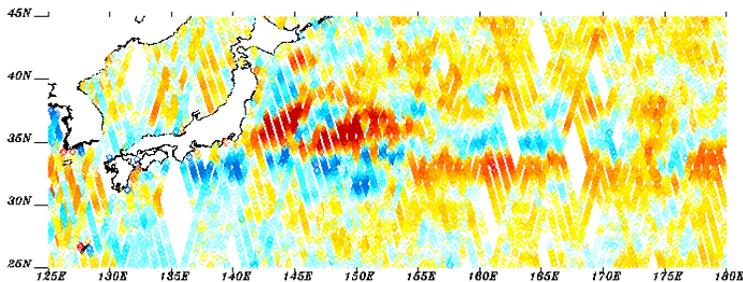
Robert C. Rhodes
Charlie N. Barron
Dan N. Fox
Lucy F. Smedstad

Naval Research Laboratory
Stennis Space Center, MS

Transitioned Systems

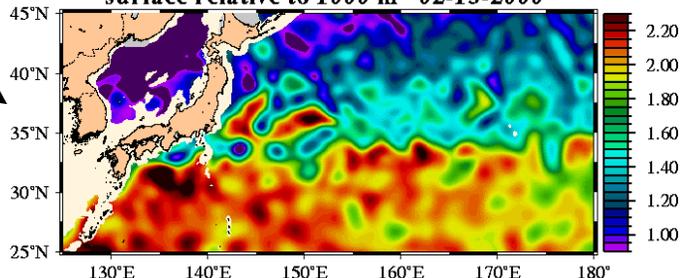
Running operationally at NAVO

- *ALPS* processes real time altimeter data



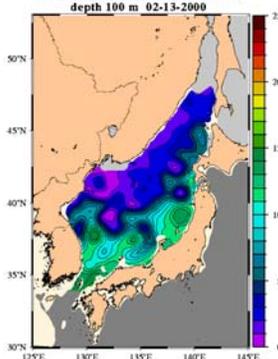
- *MODAS 2-D* interpolates the altimeter SSH horizontally to provide a SSH nowcast

Altimeter OI: Steric Height Anomaly (m) surface relative to 1000 m 02-13-2000



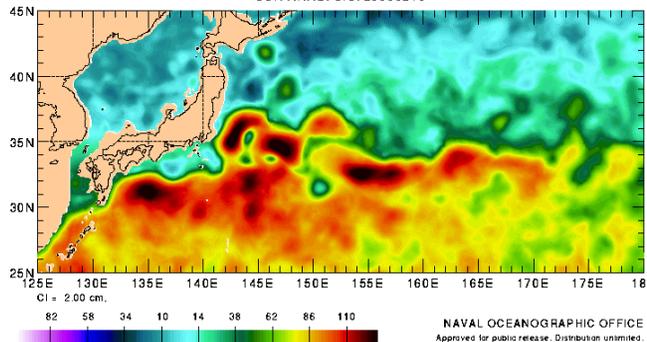
- *MODAS 3-D* extends the surface information to vertical temperature and salinity profiles

MODAS synthetics: Temperature (C) depth 100 m 02-13-2000



- *1/16° Global NLOM* assimilates altimeter SSH and MODAS SST to provide SSH, SST nowcasts and 30-day forecasts

UNCLASSIFIED: 1/16° Global NLOM SSH ANALYSIS: 20000213



Global Ocean Prediction Baseline

NOGAPS Heat & Momentum Fluxes

SSH

SST

T,S

1/16° Global
NLOM

2D SSH
2D SST

synthetics
1/8° Global
MODAS

3D T&S

1/16° Global
NCOM

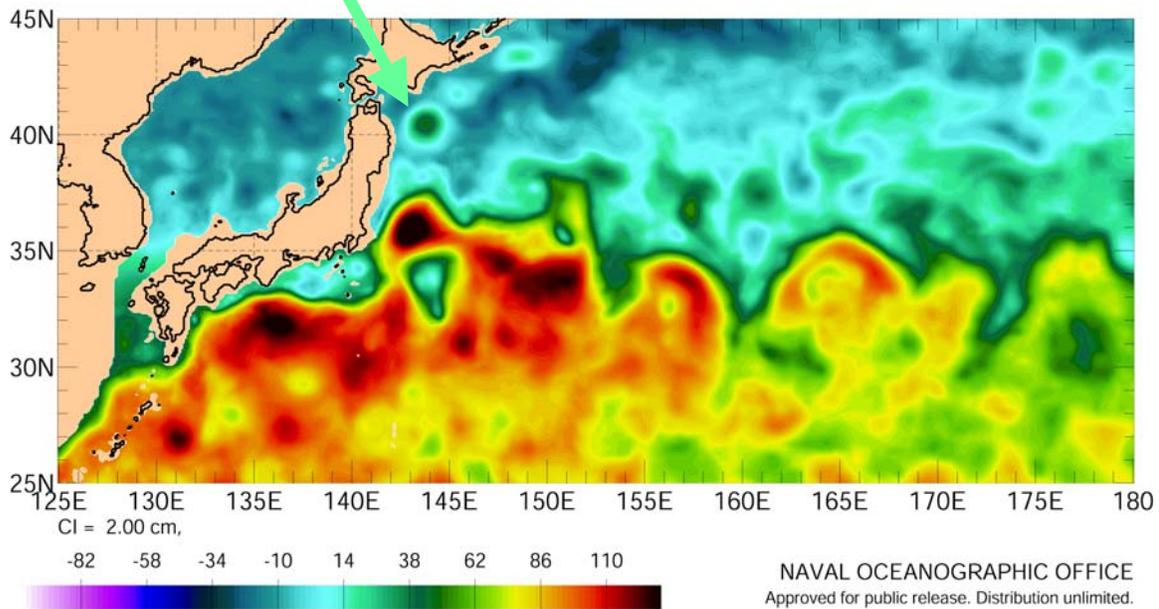
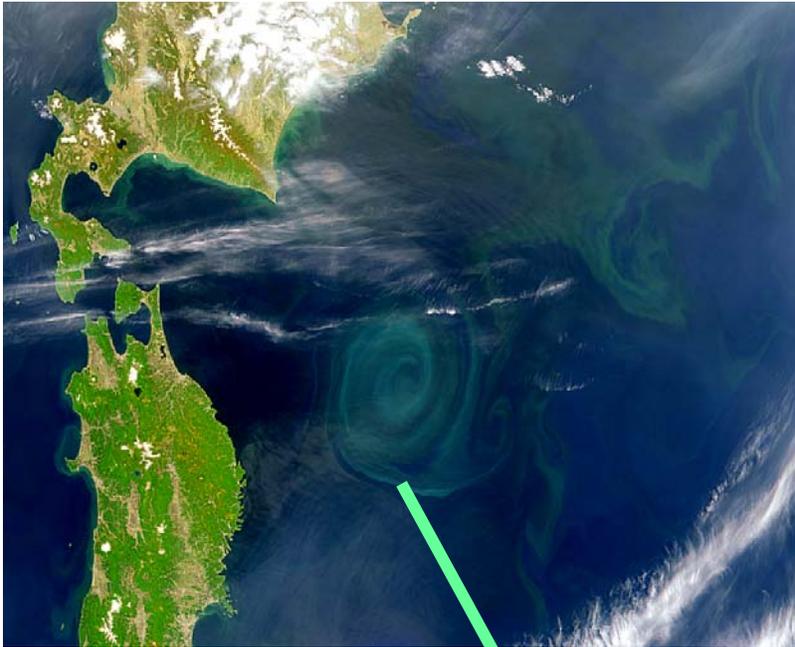
15-30 Day
Front, Eddy &
SSH Forecast

15-30 Day
Mesoscale T,S
U,V Forecast

3D T,S
Nowcast

5 Day
3D T,S,U,V
Forecast

NASA Color Image East of Tsugaru Strait compared to NLOM SSH on 5/22/99



Unclassified 1/16° Global NLOM
SSH Analysis: 19990522

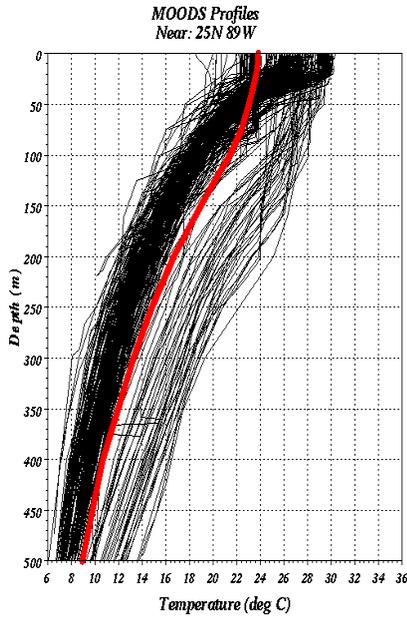
MODAS Climatology

- Temperature and salinity bimonthly means and standard deviations
- Variable Grid: $1/8^\circ$ nearshore; $1/4^\circ$ over most of domain; 1° in much of southern oceans
- Derived from historical GOODS database – 1998
- Relaxes to Levitus-94 below 1500m and in data-sparse areas
- 30+ additional parameters or regression coefficients are stored in climatological database at each grid point
- Upgrades continue

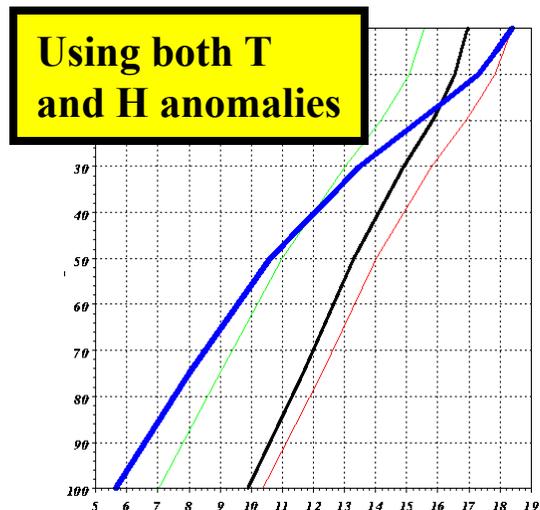
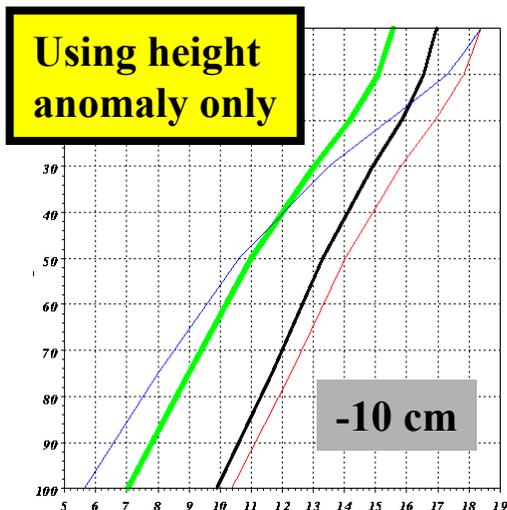
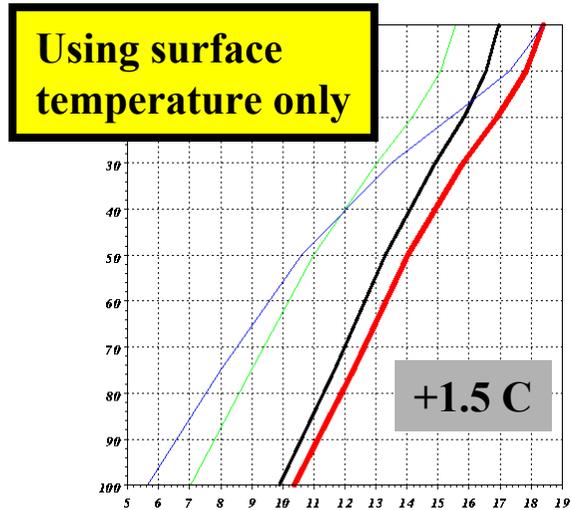
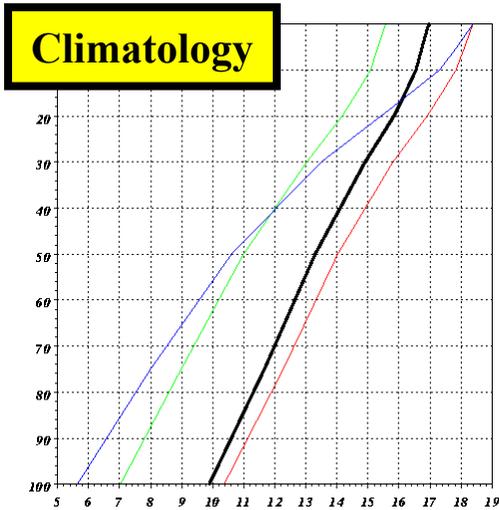


MODAS Synthetic Profiles

Extending Remote Sensed Measurements to Depth

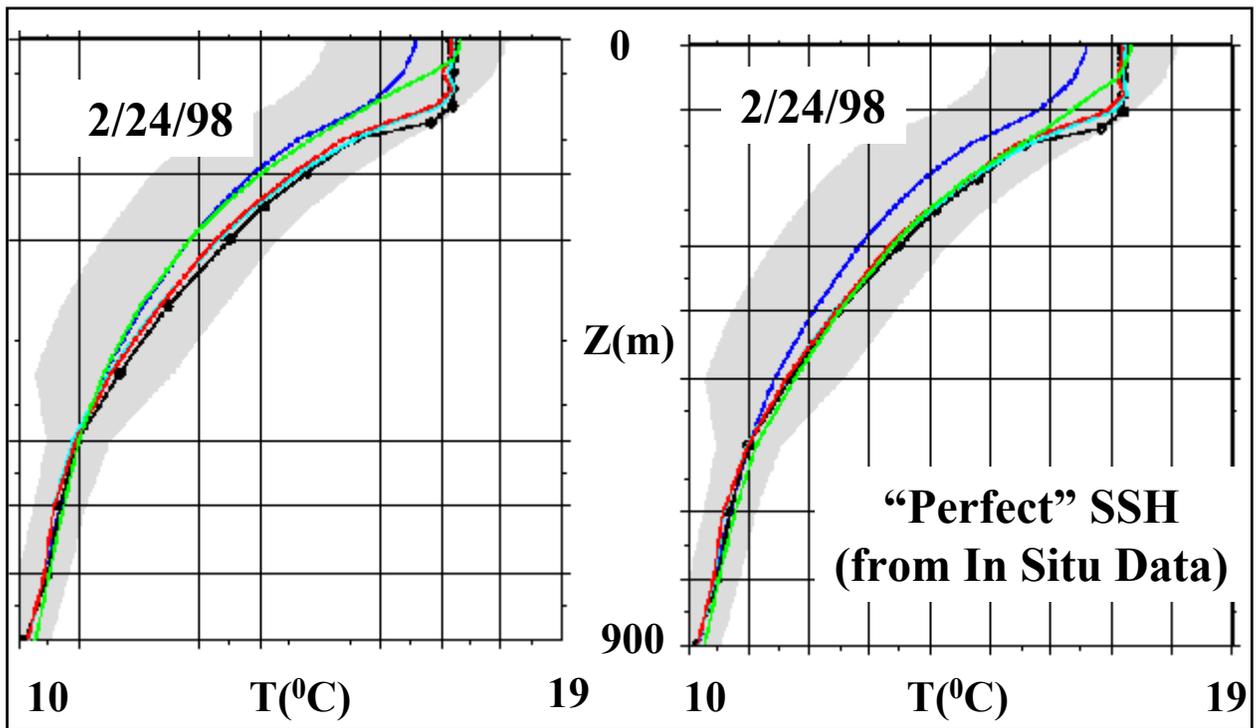


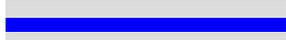
Historical profiles are reduced to a bimonthly climatology plus a series of regression models to relate subsurface temperature to remote sensed temperature and/or height anomalies (plus T-S relationships to convert temperature to salinity).



MODAS Altimeter Issue: *Impact of Limited Signal on Synthetics*

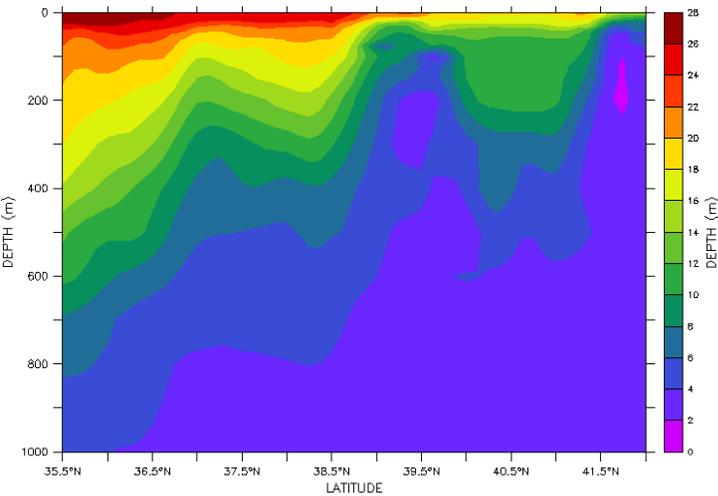
7.00W, 35.50N - Deep



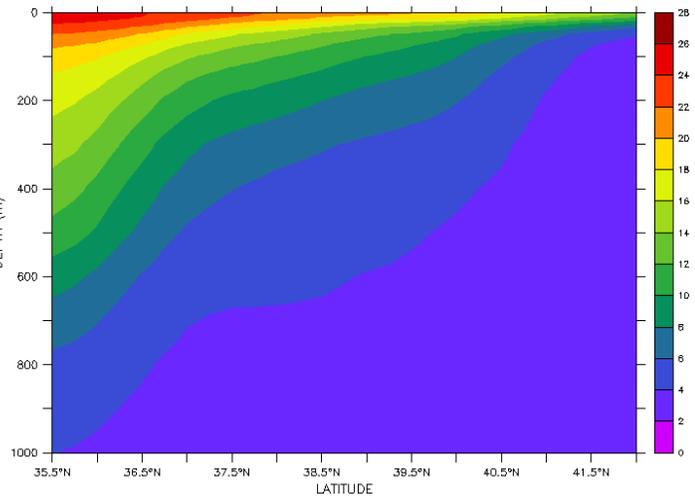
-  Observed CTD
-  Extended CTD
-  Climatology. Grey= ± 3 std.dev.
-  First Guess with SST & SSH
-  Cross Validation
-  MODAS 2 Analysis

Temperature Vertical Section Comparisons (Along 144°E, Across Kuroshio, July 1999)

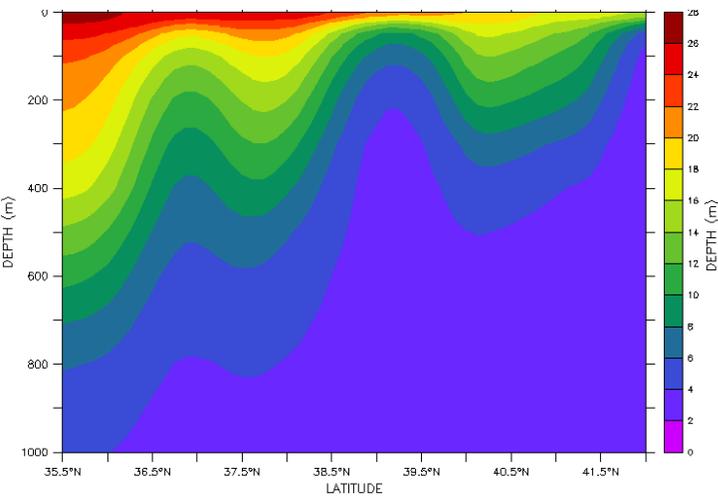
AXBT Temp



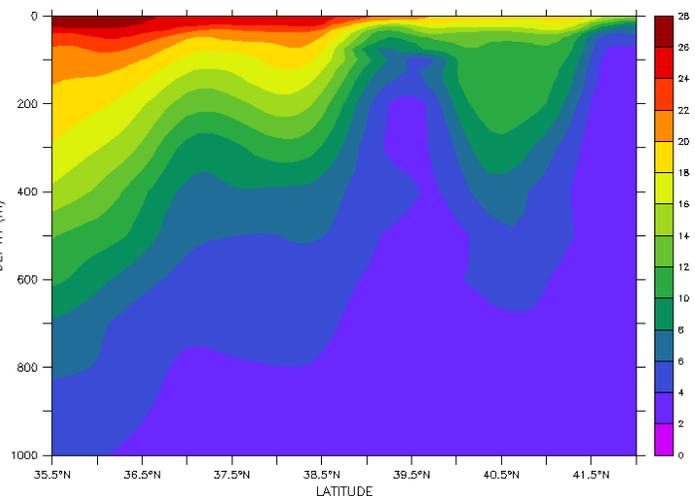
Climatology



MODAS 1st Guess (SSH & SST)

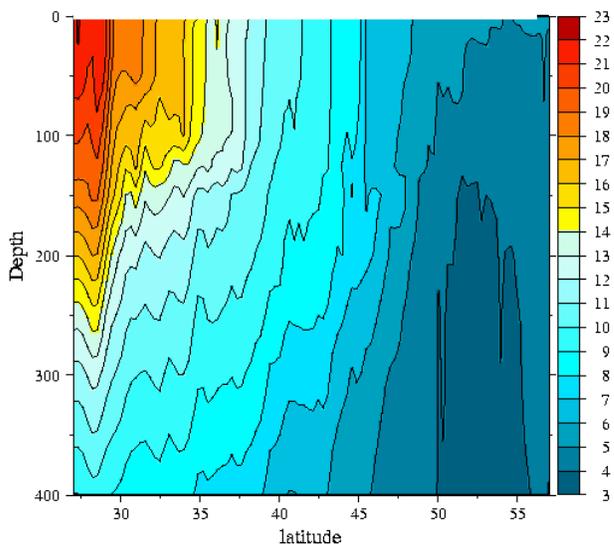


MODAS Analysis (1st Guess & AXBT)

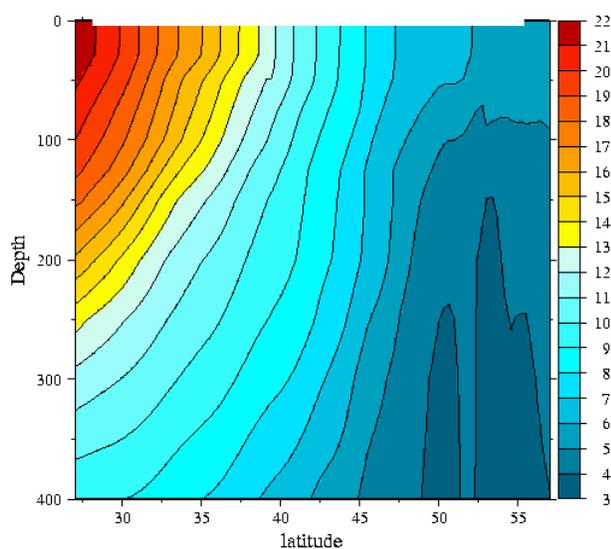


Temperature Vertical Section Comparisons Along 149.5° W, south of Alaska

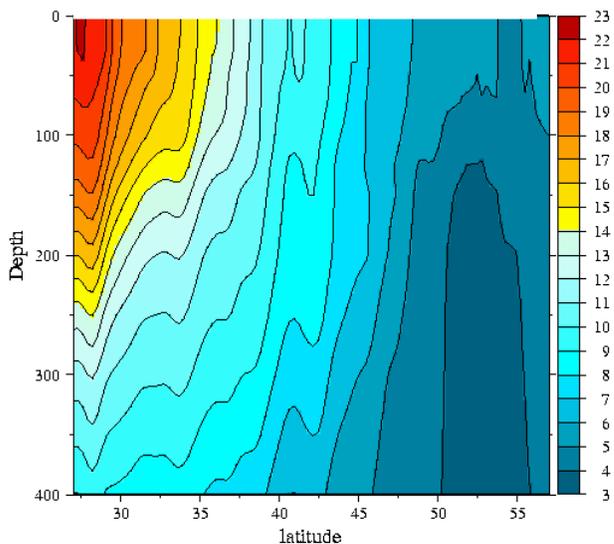
AXBT Temp



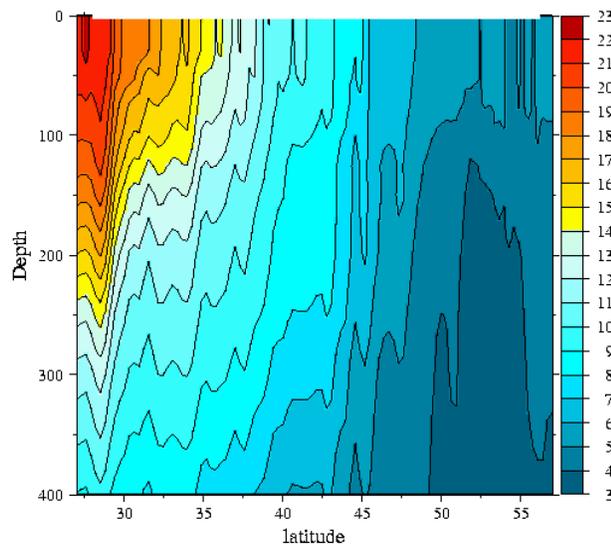
Climatological Temp



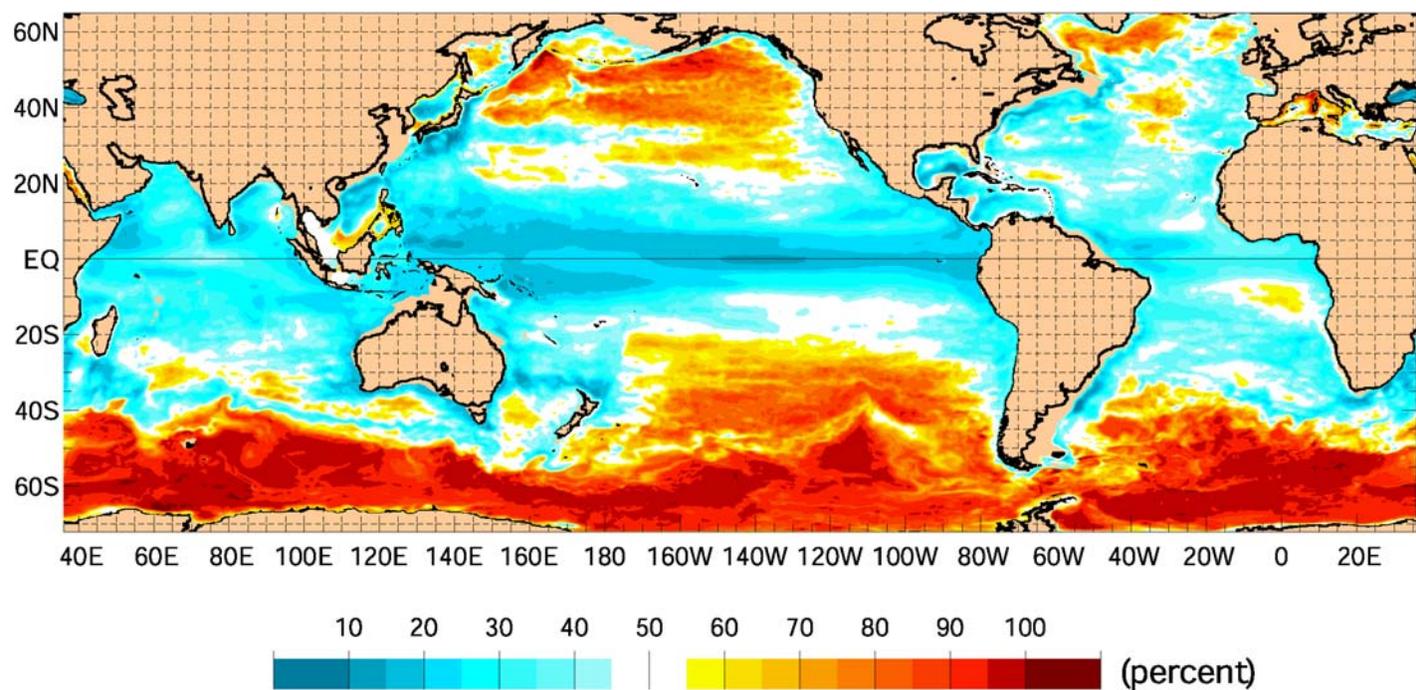
Clim + SSH + SST Temp



Temp Clim from XBT SSH + SST



1/16° 6-Layer NRL Global Ocean Model Fraction of RMS SSH Variability that is Non-Steric



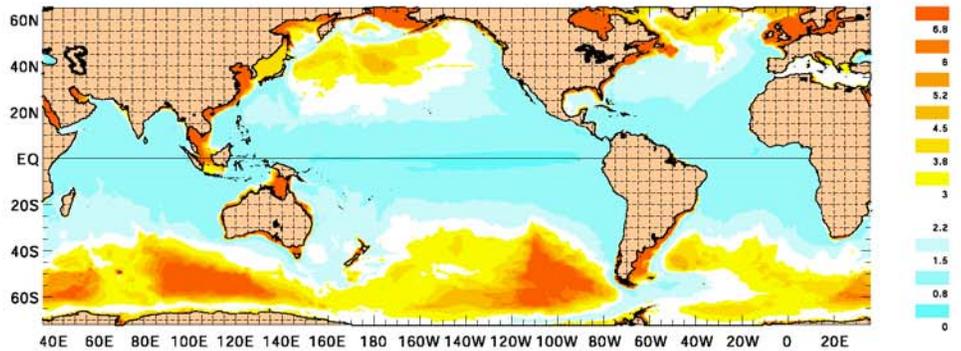
1979-97 ECMWF wind forcing

Shriver and Hurlburt, 2000
GRL (1 Sep 00)

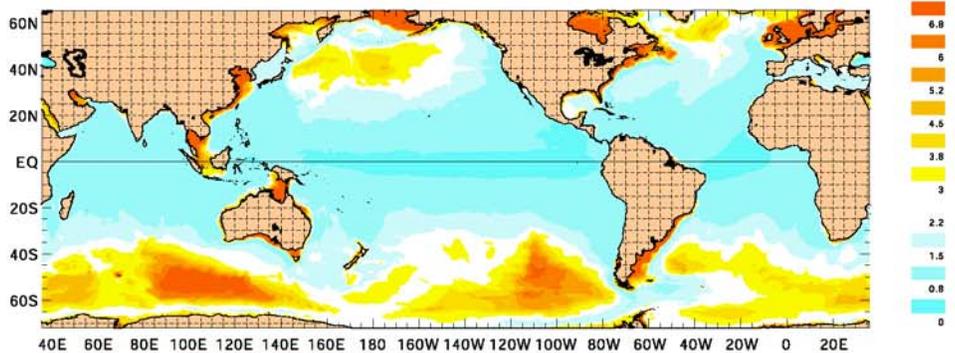
Simulated Non-Steric SSH Variability Does Not Depend Significantly On The Wind Forcing Used

SSH simulated using $1/16^\circ$ barotropic NLOM

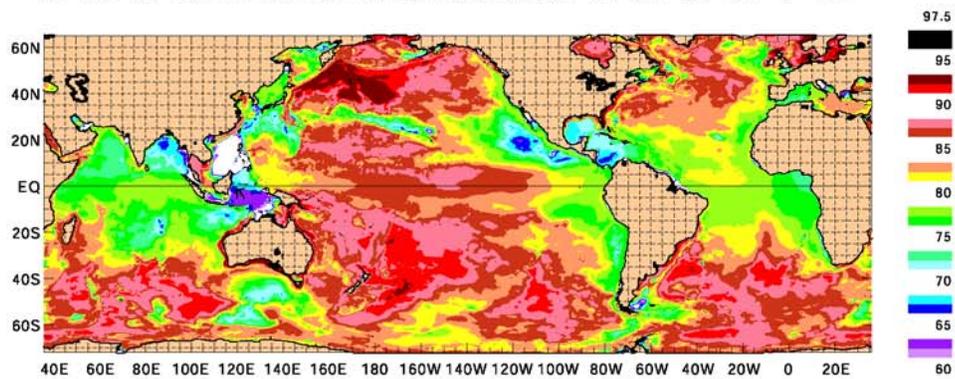
(A.)
RMS SSH
FNMOC
Wind
Forcing



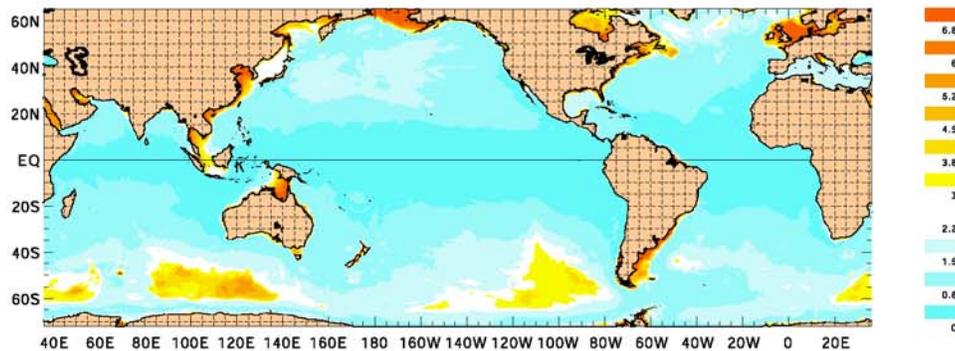
(B.)
RMS SSH
ECMWF
Wind
Forcing



Correlation
of A. and B.



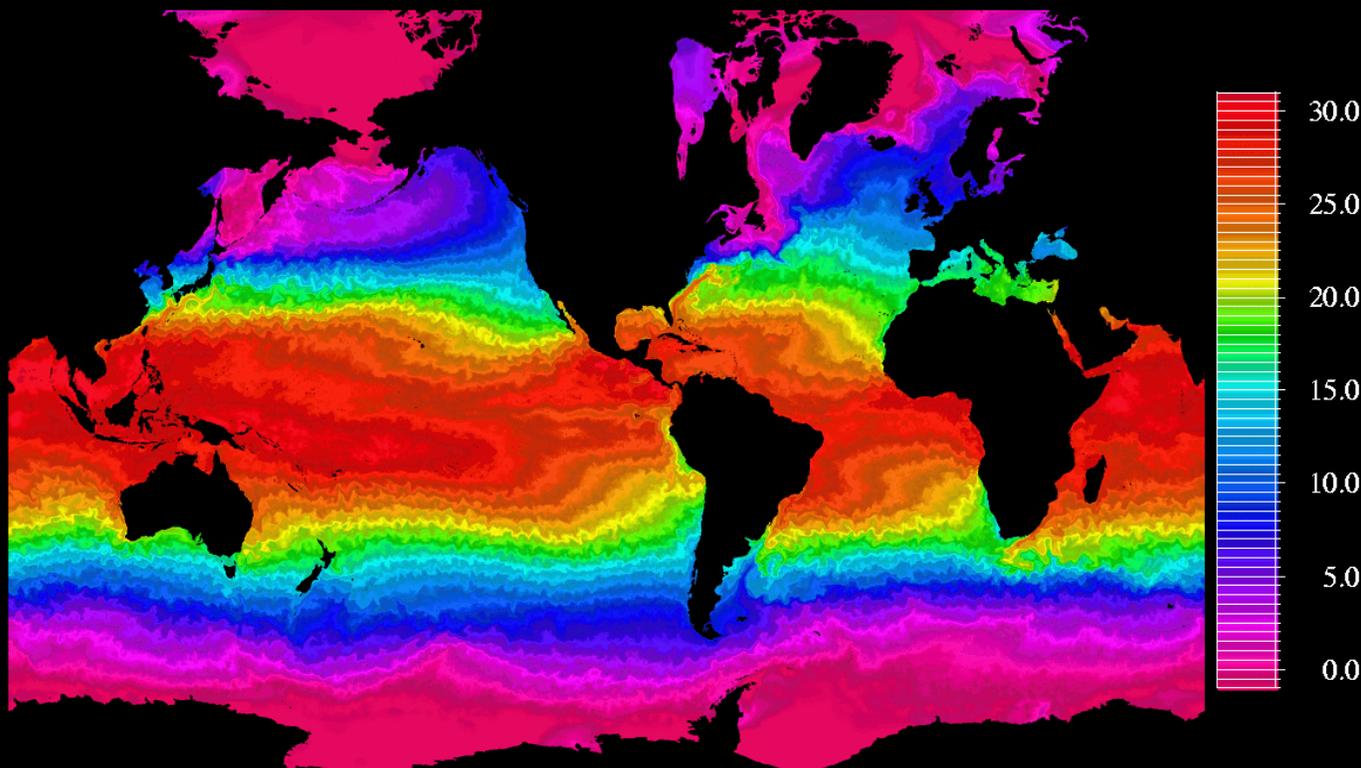
RMS
Differences
between
A. and B.



from Shriver and Hurlburt (2001)
submitted to *Geophysical Research Letters*

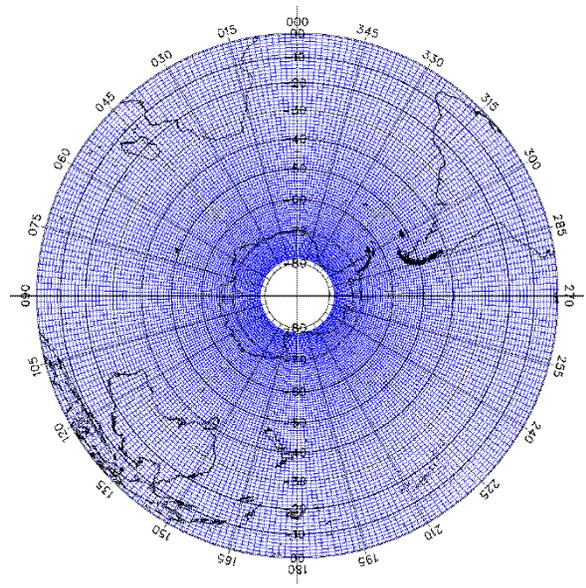
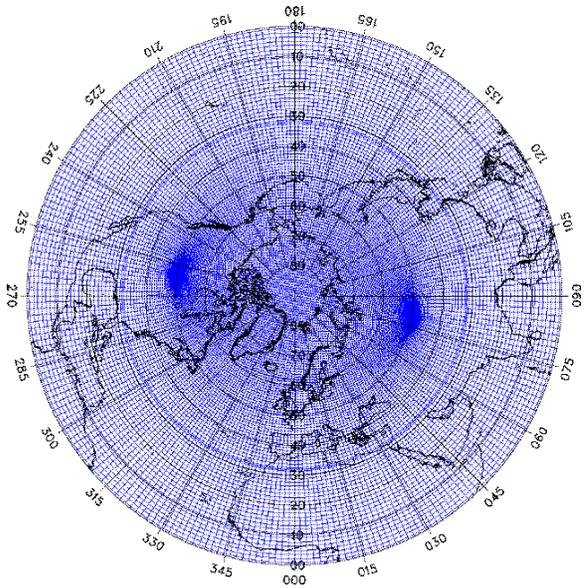
1/8° Global Navy Coastal Ocean Model (NCOM)

Sea Surface Temperature (°C) 1/8° Global NCOM
Assimilative Case 1g 05-01-2001

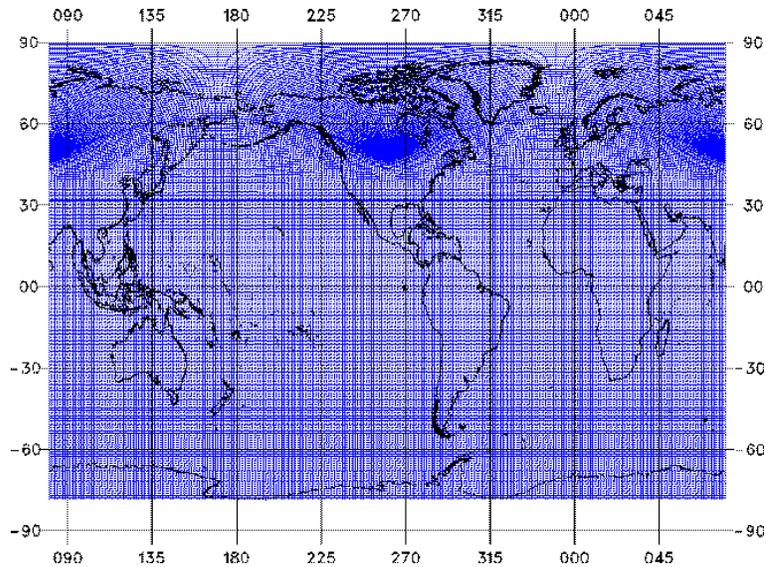


- 41 sigma-z levels in the vertical
- 20 sigma/1m deep-water upper level thickness
- assimilation of SST, SSS, 3-d T&S from MODAS using 1/16° NLOM SSH
- NOGAPS wind stress, radiation, heat flux
- generic grid extraction capability

Global NCOM: Horizontal Grid



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

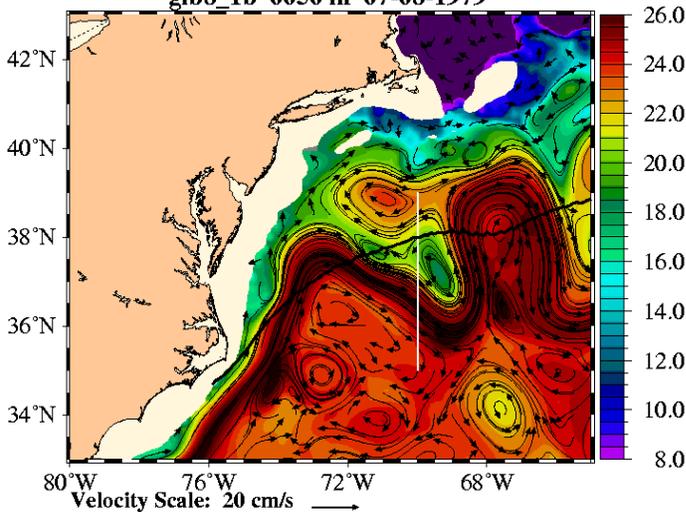


Data Assimilation Procedure

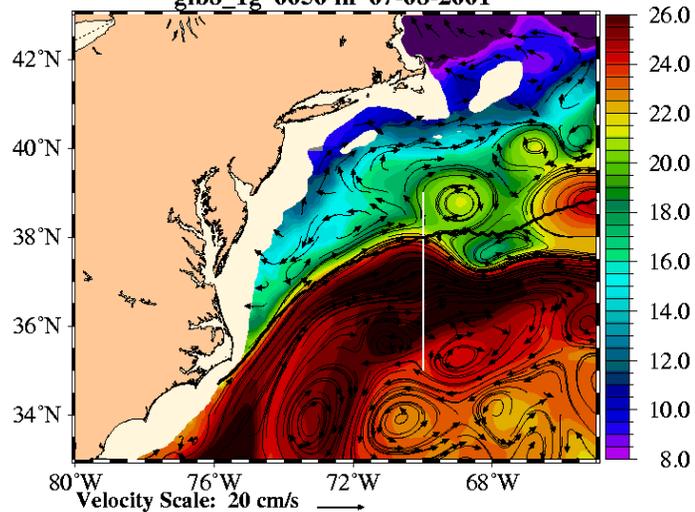
- Acquire sea surface temperature (sst)
Use daily SST analysis from the Naval Oceanographic Office (NAVOCEANO) MODAS2D optimal interpolation (OI) of MCSST observations.
- Acquire sea surface height (ssh)
Use either daily SSH analysis from the NAVOCEANO MODAS2D OI of TOPEX, ERS and GFO altimetry or daily 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 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.

Global NCOM: Effect of assimilation on Gulf Stream

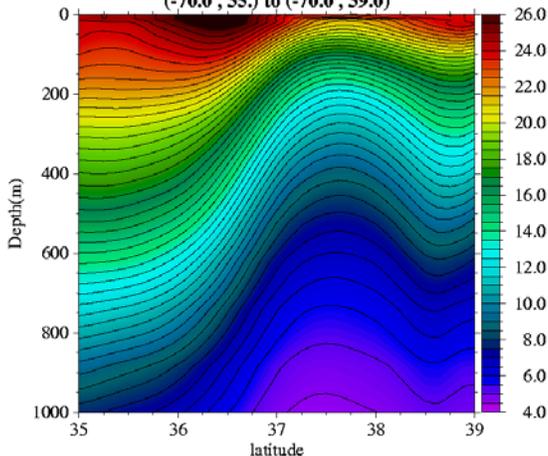
Climatological: Currents over Temperature (C)
glb8_1b 0050 m 07-08-1979



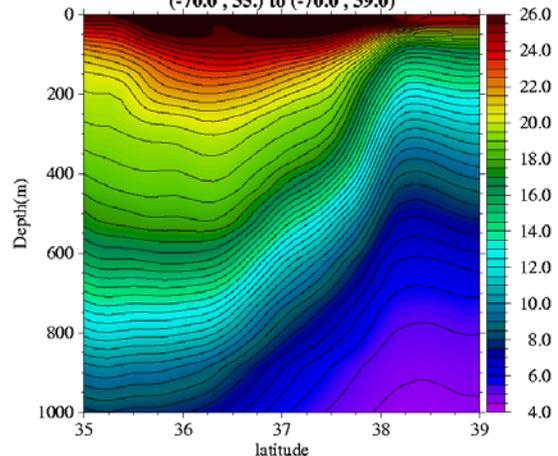
Assimilative: Currents over Temperature (C)
glb8_1g 0050 m 07-08-2001



Temperature
NRL global NCOM glb8_1b vert(70W 07-08-1979 0000 GMT
(-70.0, 35.) to (-70.0, 39.0)

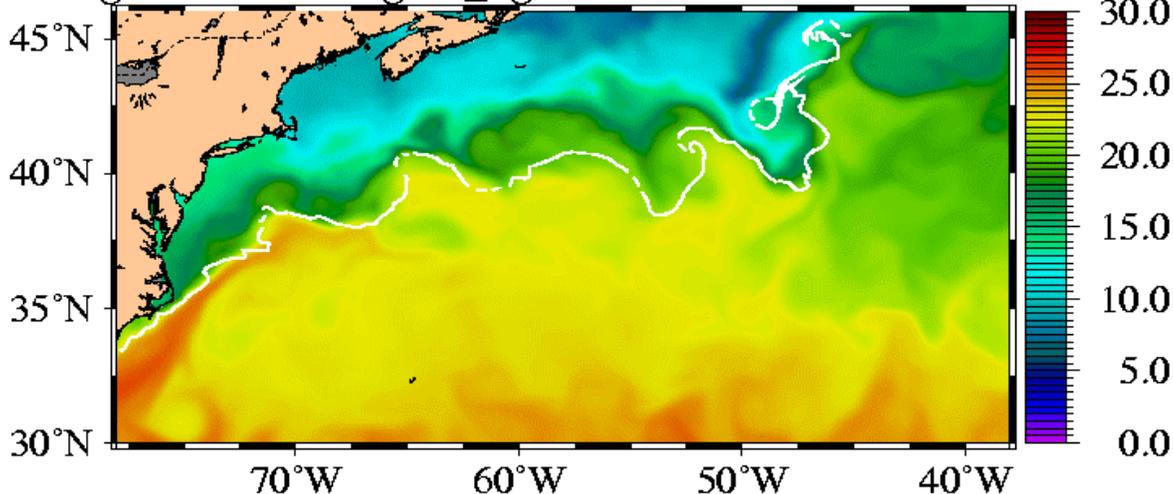


Temperature
NRL global NCOM glb8_1g vert(70W 07-08-2001 0000 GMT
(-70.0, 35.) to (-70.0, 39.0)



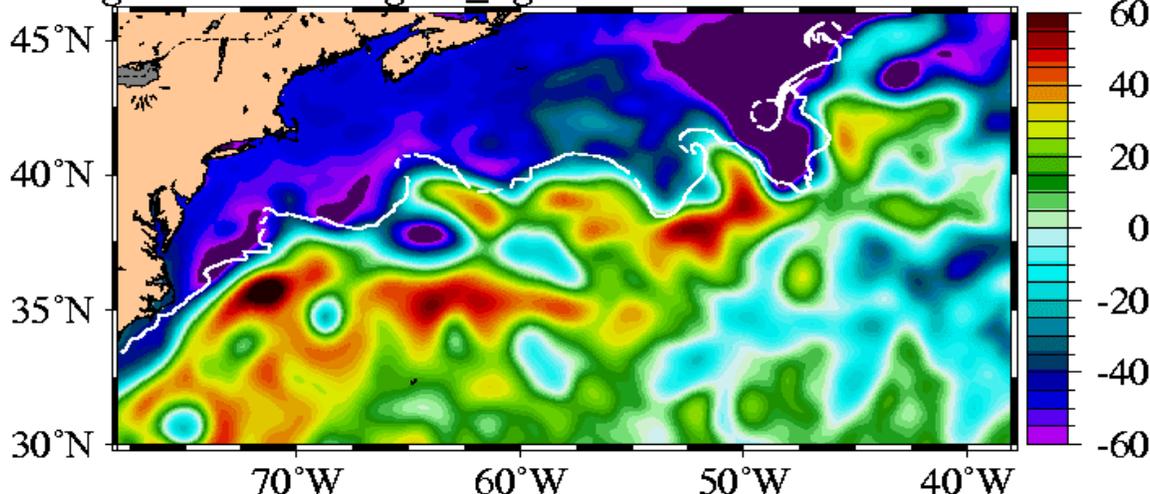
Sea Surface Temperature (C)

NRL global NCOM glb8_1g 0000 m 11-19-2001 0000 GMT



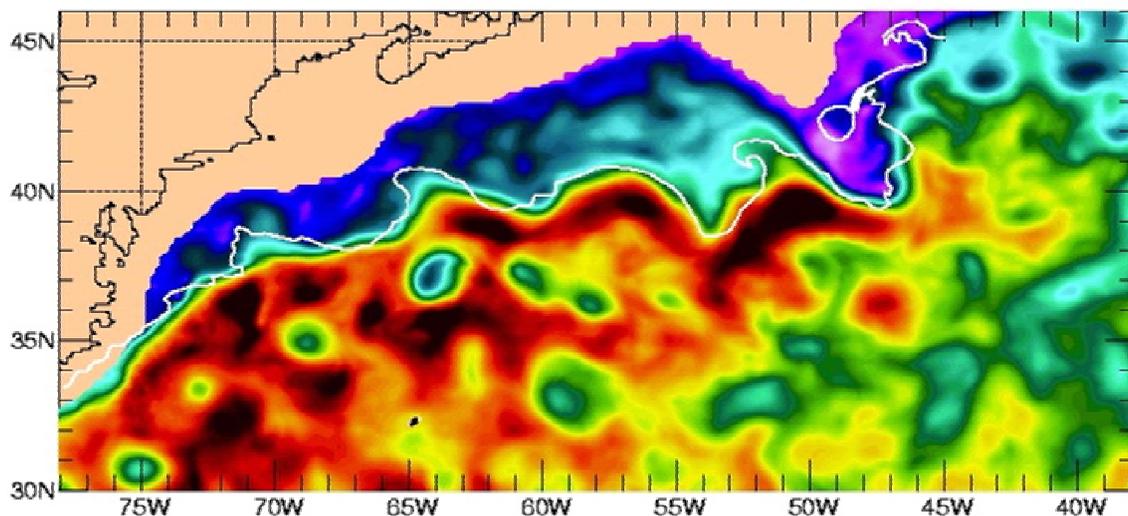
Sea Surface Height (cm)

NRL global NCOM glb8_1g 0000 m 11-19-2001 0000 GMT



UNCLASSIFIED: 1/16° Global NLOM

SSH ANALYSIS: 20011119

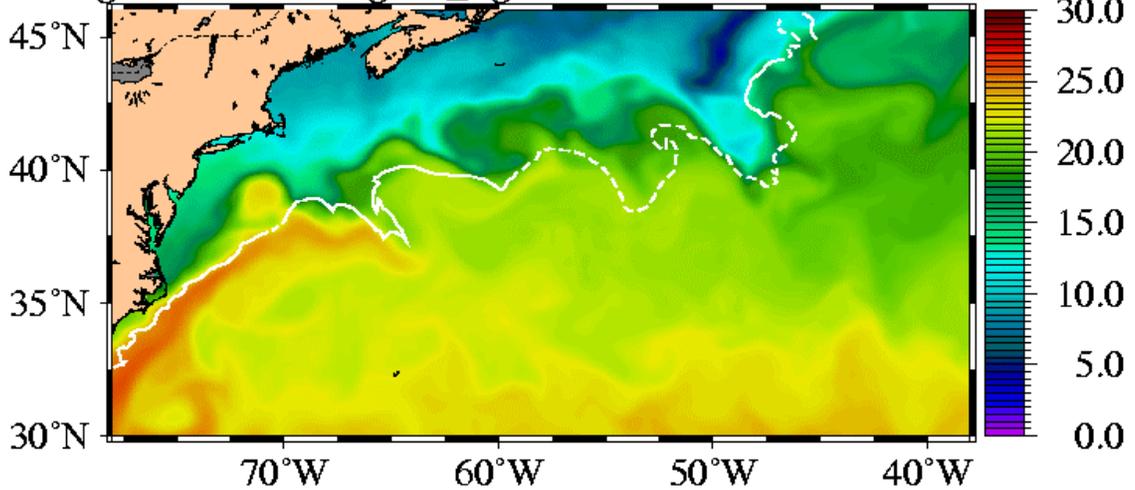


Cl = 1.20 cm,

-85.2 -50.8 -36.4 -22 -7.6 6.8 21.2 35.6 50

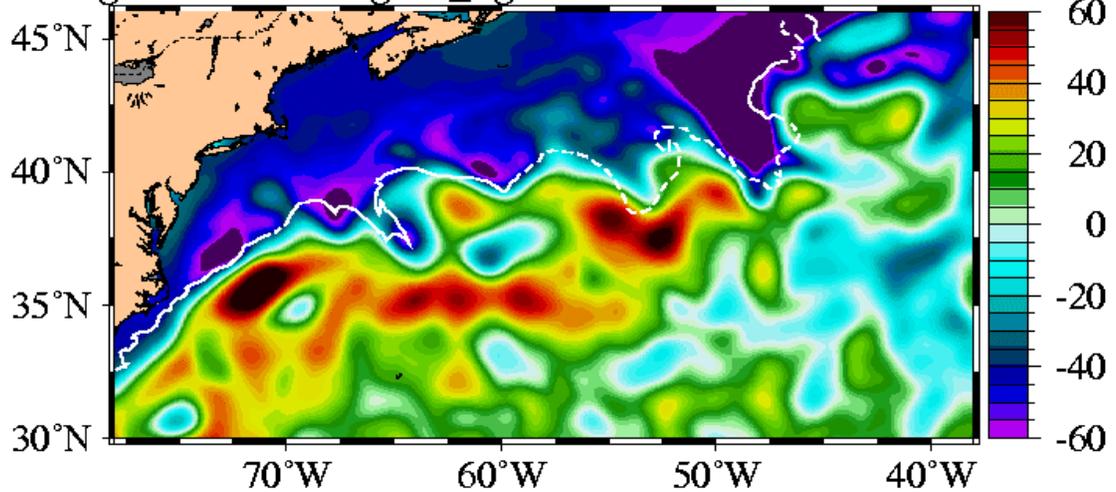
Sea Surface Temperature (C)

NRL global NCOM glb8_1g 0000 m 11-30-2001 0000 GMT



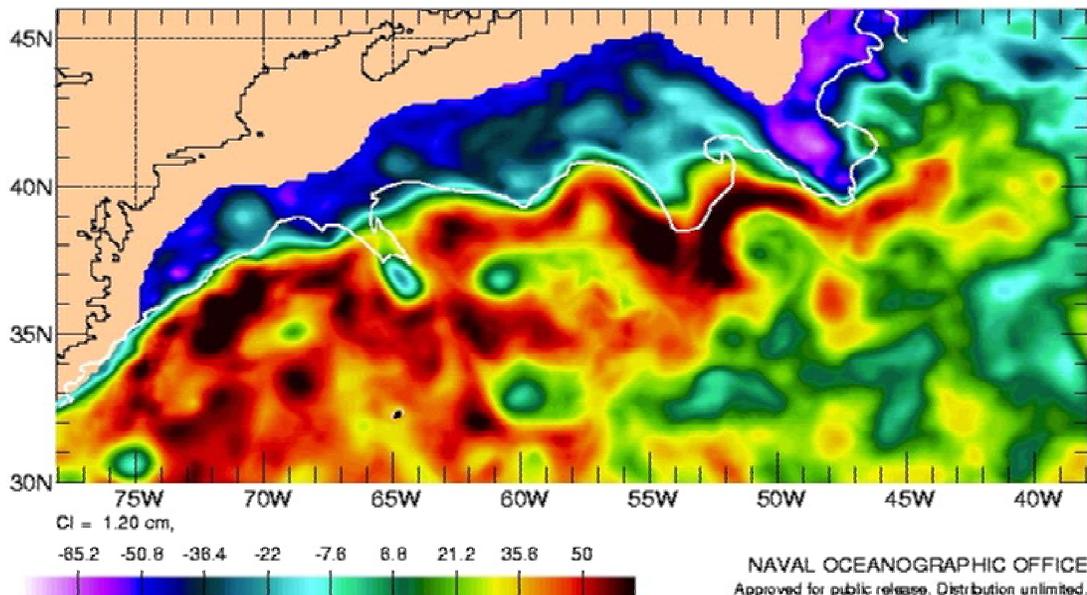
Sea Surface Height (cm)

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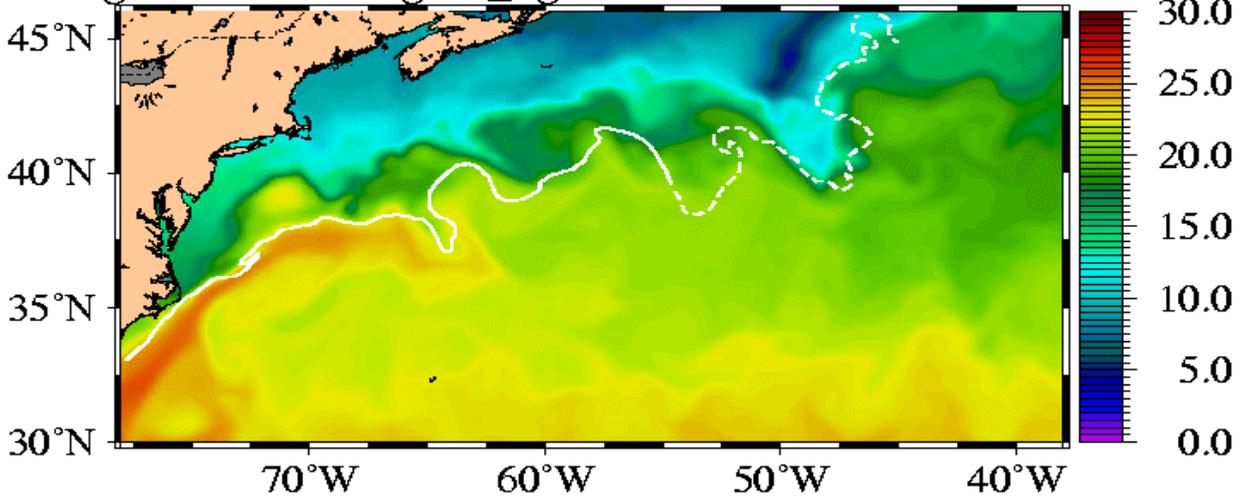
UNCLASSIFIED: 1/16^o Global NLOM

SSH ANALYSIS: 20011130



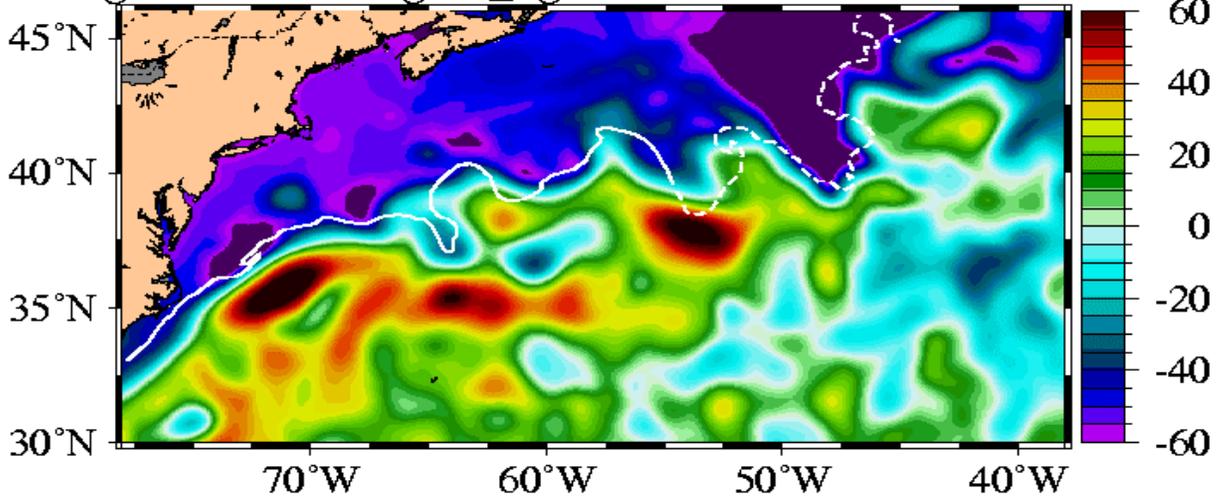
Sea Surface Temperature (C)

NRL global NCOM glb8_1g 0000 m 12-05-2001 0000 GMT



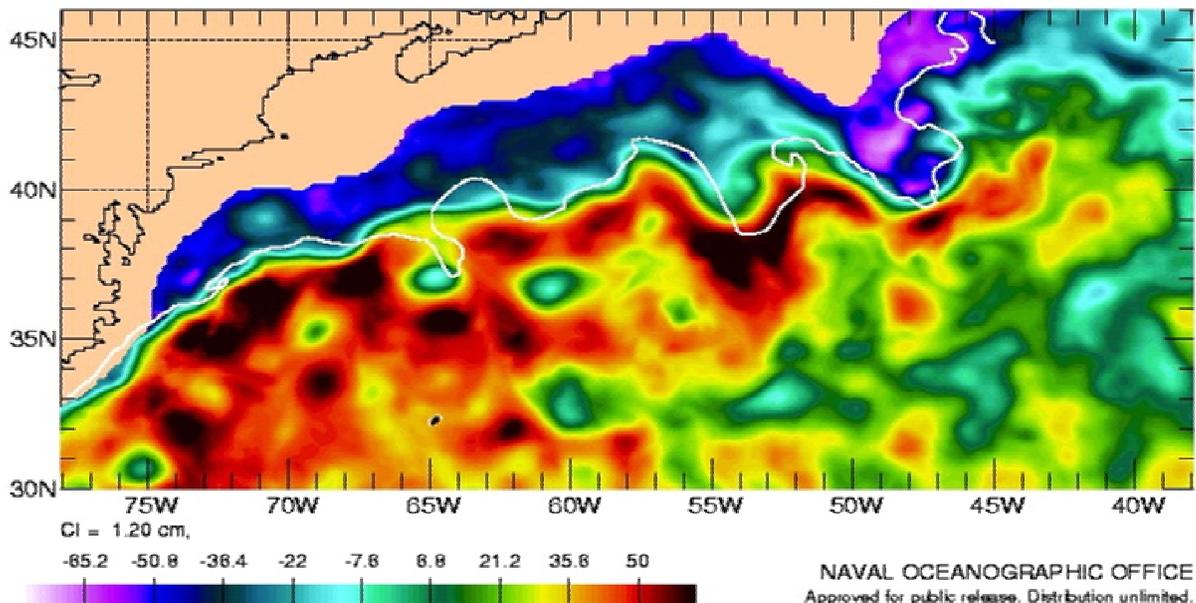
Sea Surface Height (cm)

NRL global NCOM glb8_1g 0000 m 12-05-2001 0000 GMT



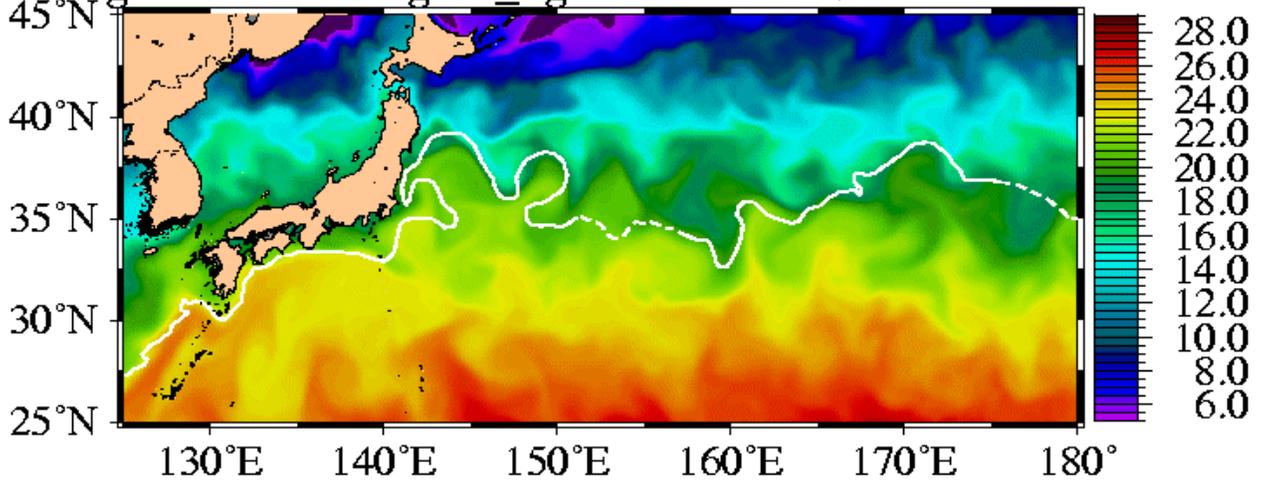
UNCLASSIFIED: 1/16° Global NLOM

SSH ANALYSIS: 20011205



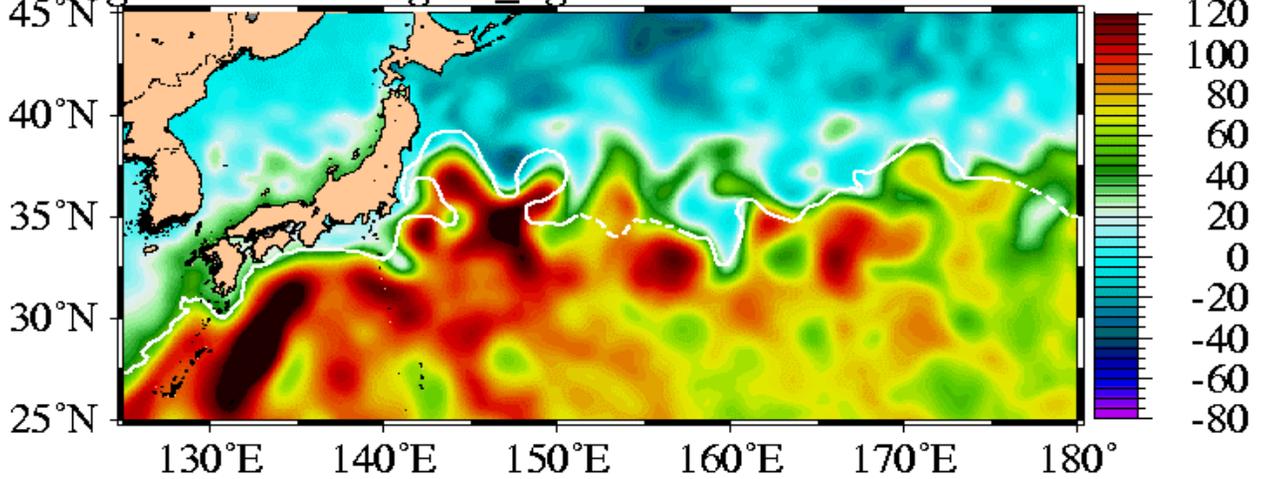
Sea Surface Temperature (C)

NRL global NCOM glb8_1g 0000 m 11-29-2001 0000 GMT



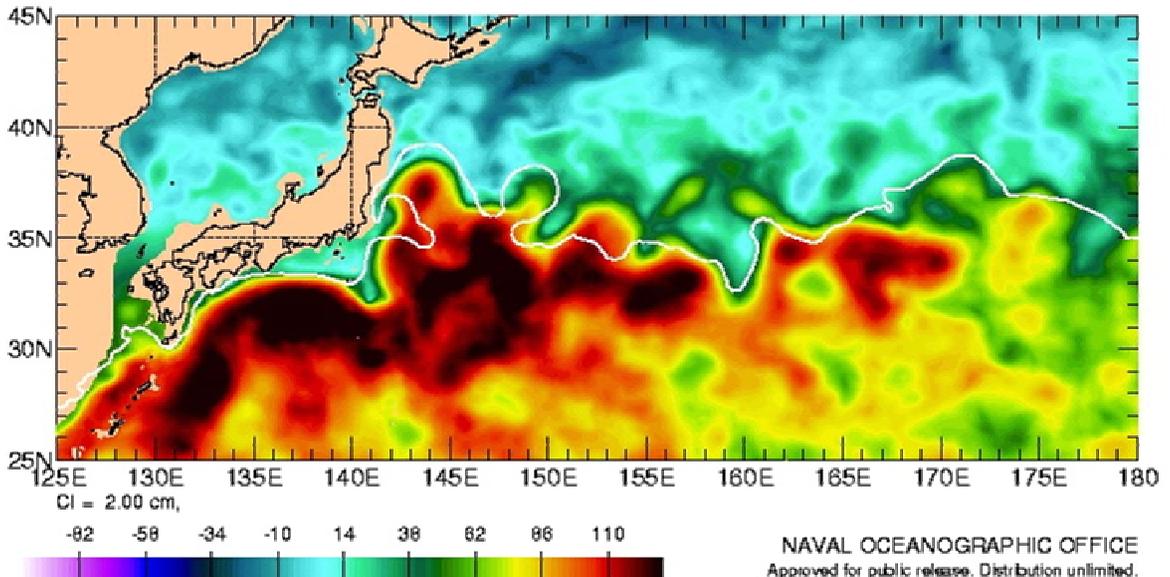
Sea Surface Height (cm)

NRL global NCOM glb8_1g 0000 m 11-29-2001 0000 GMT



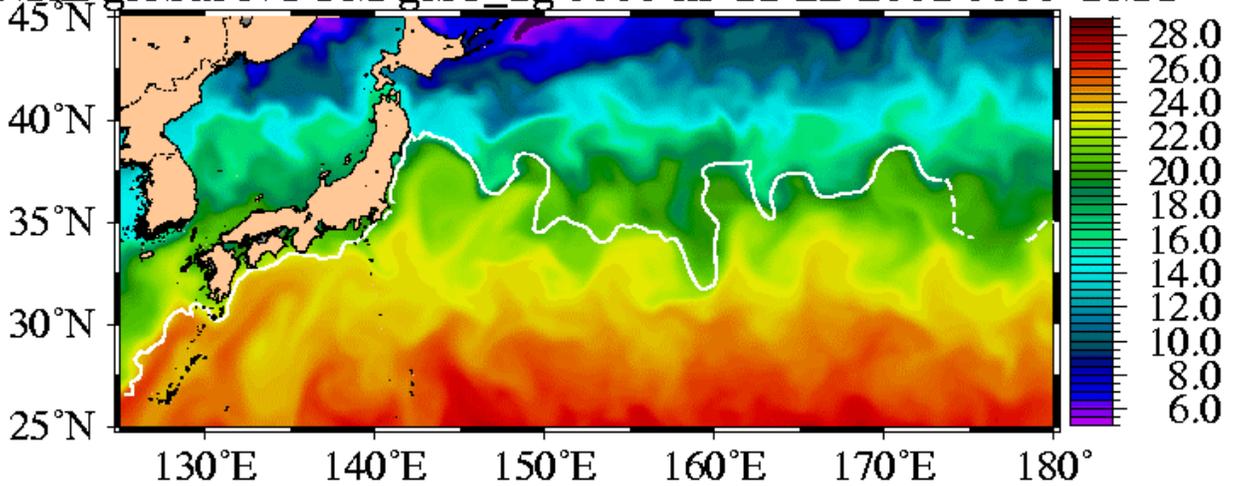
UNCLASSIFIED: 1/16° Global NLOM

SSH ANALYSIS: 20011129



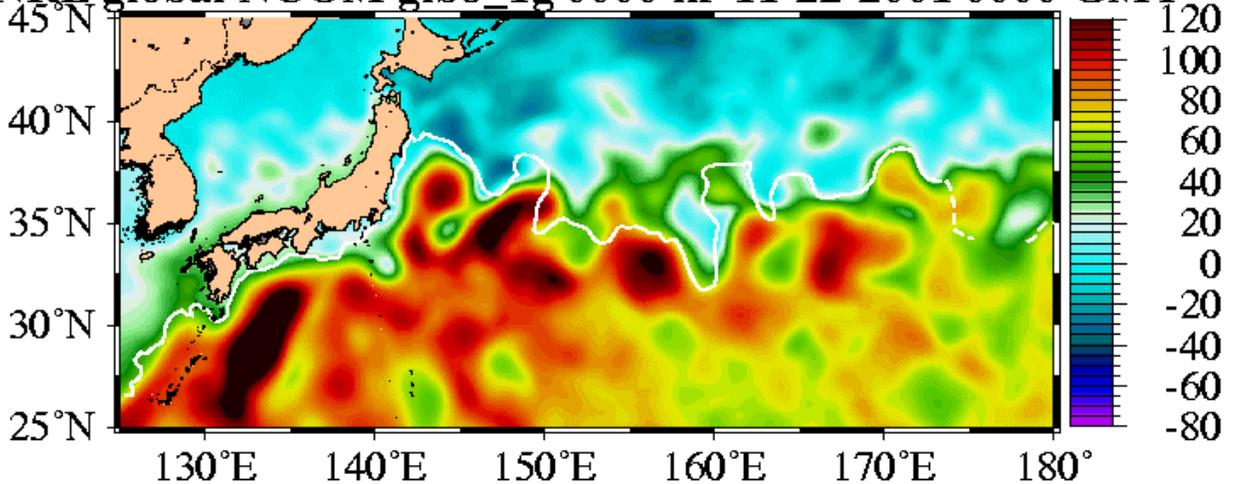
Sea Surface Temperature (C)

NRL global NCOM glb8_1g 0000 m 11-22-2001 0000 GMT



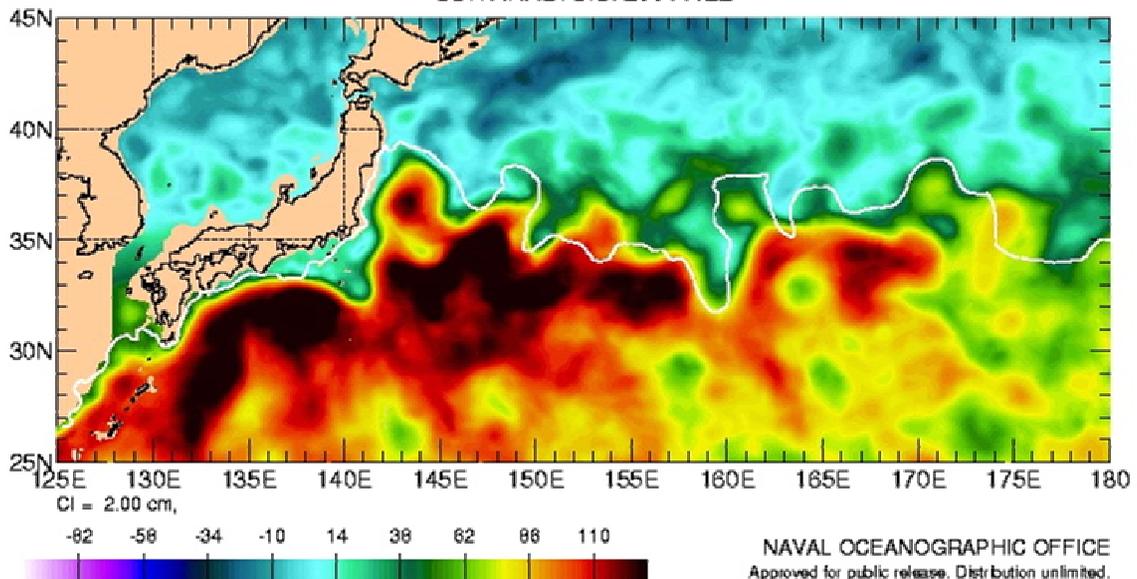
Sea Surface Height (cm)

NRL global NCOM glb8_1g 0000 m 11-22-2001 0000 GMT



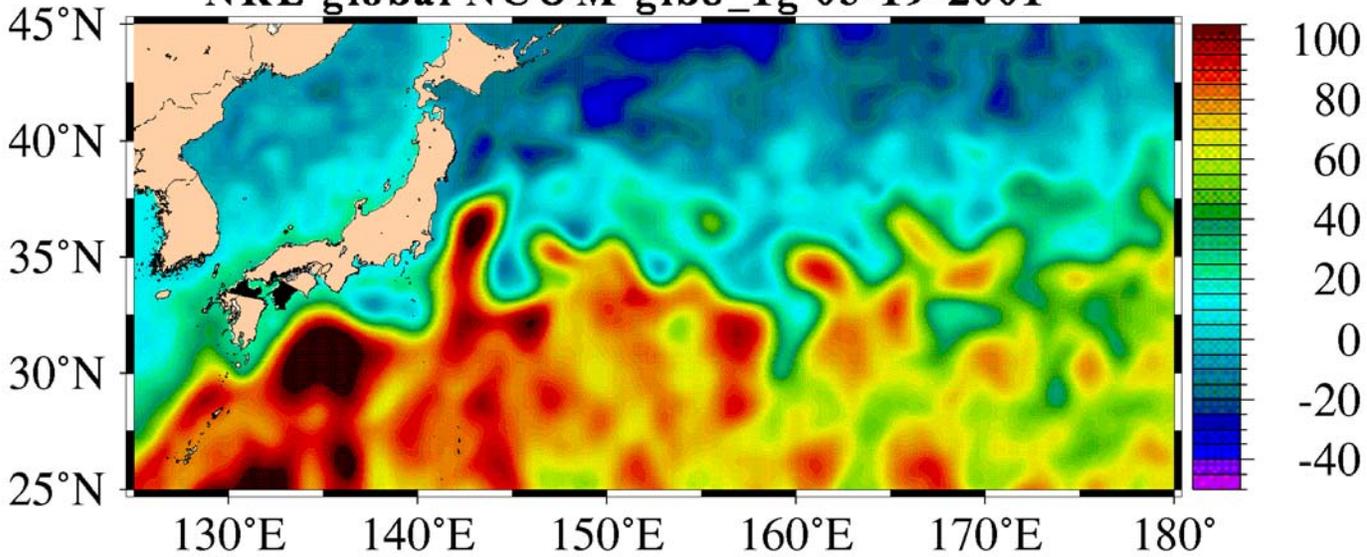
UNCLASSIFIED: 1/16° Global NLOM

SSH ANALYSIS: 20011122



Sea Surface Height (cm)

NRL global NCOM glb8_1g 05-19-2001



Sea Surface Height (cm)

Global NLOM 1/16 ° 05-19-2001

