

Real-time Ocean Data Assimilation and Prediction with Global NCOM

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www.ocean.nrlssc.navy.mil

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This presentation:

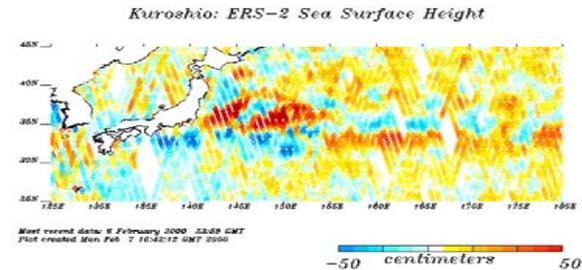
- **Goals: NCOM in the baseline system**
- **Global model configuration**
- **Validation examples**
- **Model development for transition and beyond**

Transitioned Systems

Running operationally at NAVO

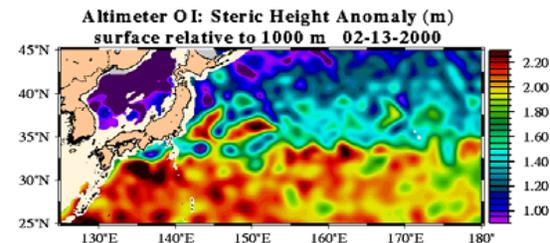
- **ALPS** processes real time altimeter data

www.ocean.nrlssc.navy.mil/altimetry

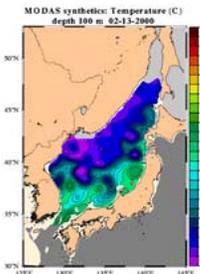


- **MODAS 2-D** interpolates the altimeter SSH horizontally to provide a SSH nowcast

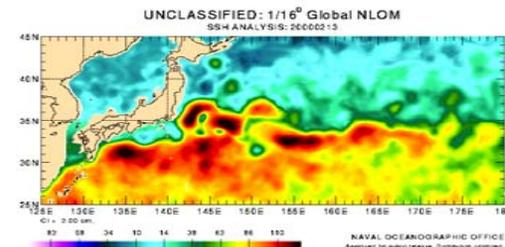
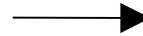
www.ocean.nrlssc.navy.mil/modas



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



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

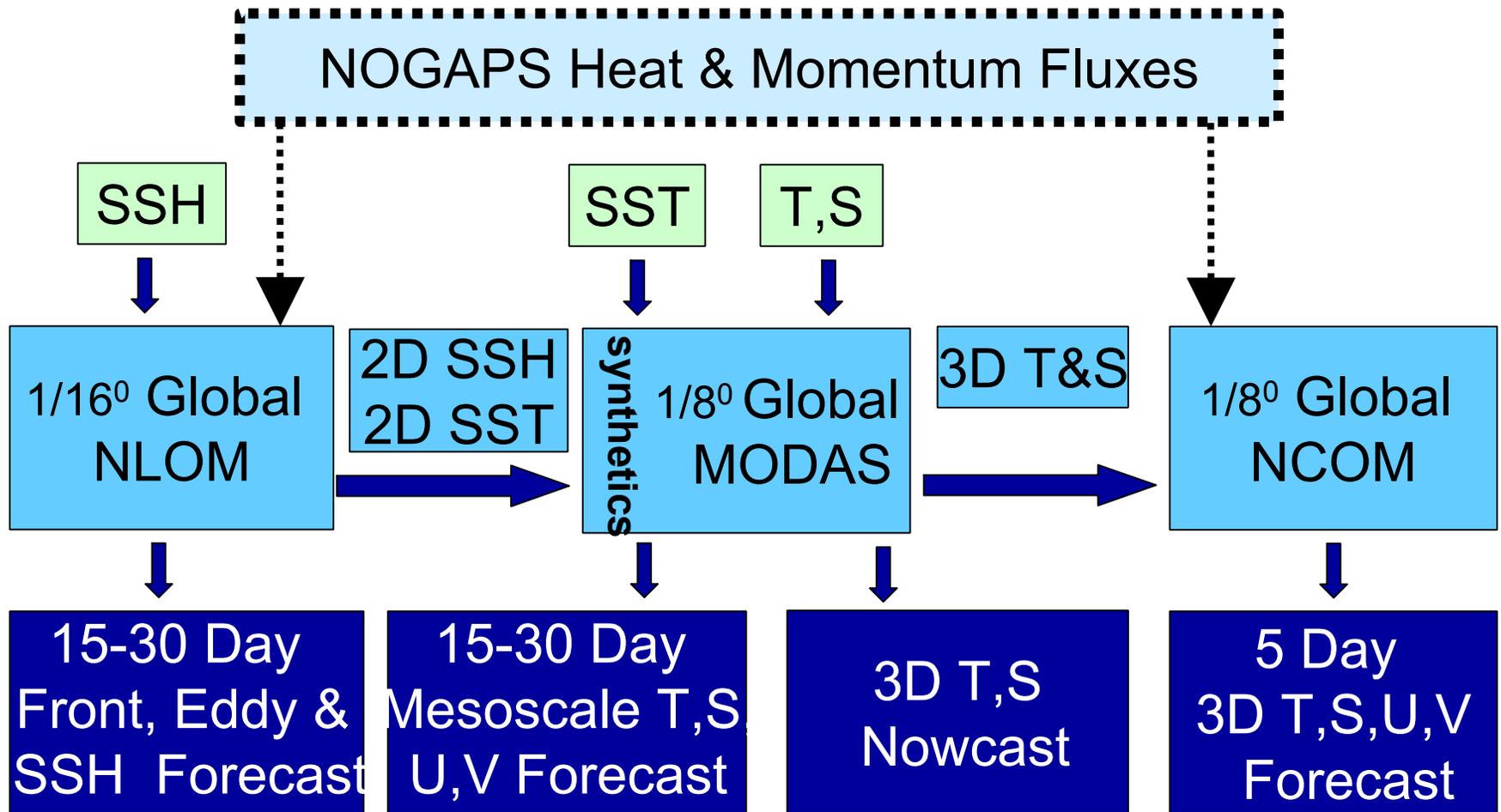


www.ocean.nrlssc.navy.mil/nlom

Global NCOM: Objective

- **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).**
 - **initial/boundary conditions for real-time regional and coastal models.**
 - **the infrastructure for the PIPS 3.0 ice model.**
 - **an ocean model capability suitable for coupling to NOGAPS in a global coupled air/ocean system.**

Global Ocean Prediction Baseline

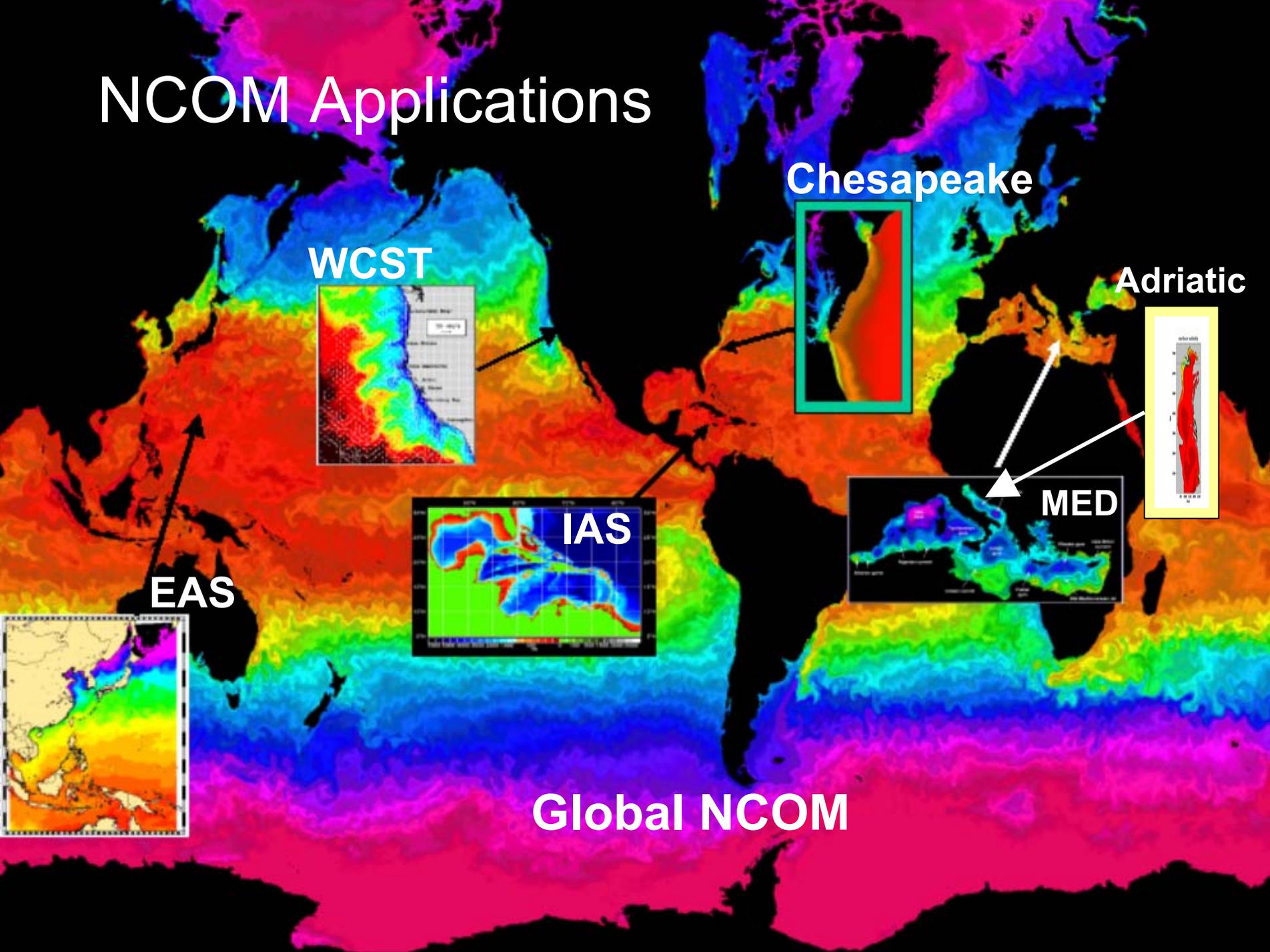


NCOM

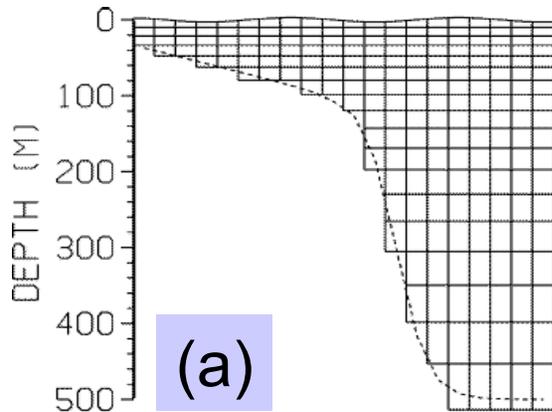
Navy Coastal Ocean Model

- A flexible variant of the Princeton Ocean Model (POM)
- Configuration managed by NRL
- Options for vertical coordinate
 - Sigma-level
 - Z-level
 - Combination of sigma levels over z levels
- Choices of boundary conditions
- Tide and river forcing
- Efficiently scalable and portable

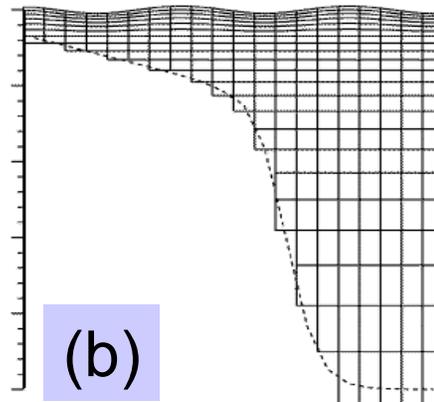
NCOM Applications



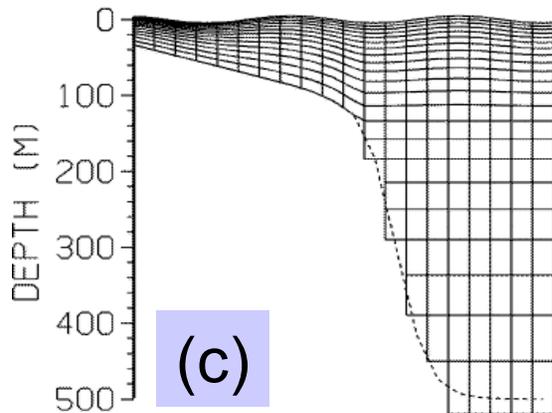
The sigma-z vertical coordinate in NCOM



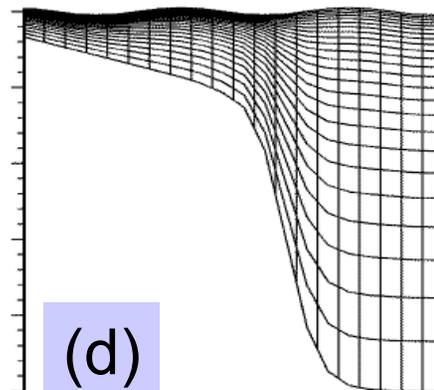
(a)



(b)



(c)



(d)

(a) z levels with free surface

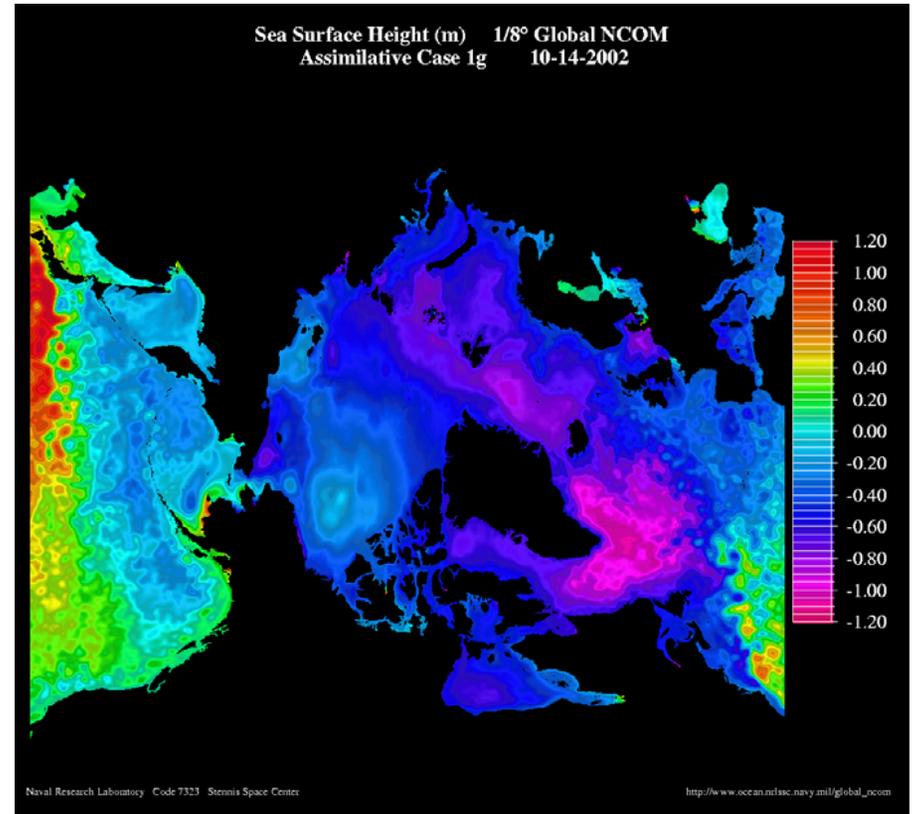
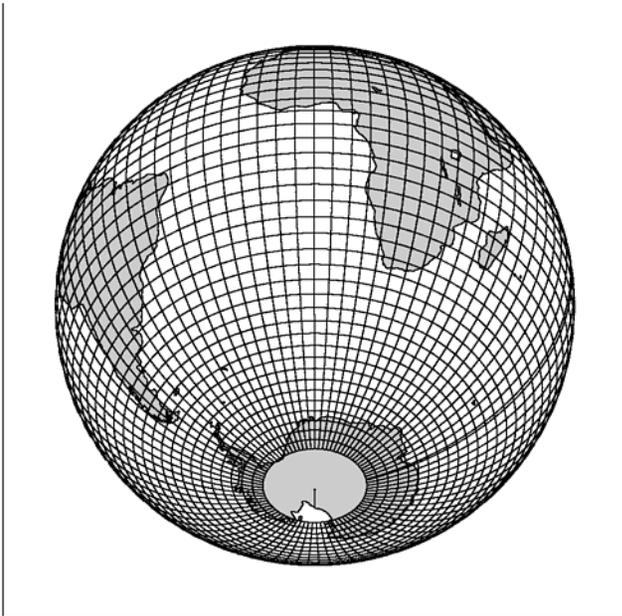
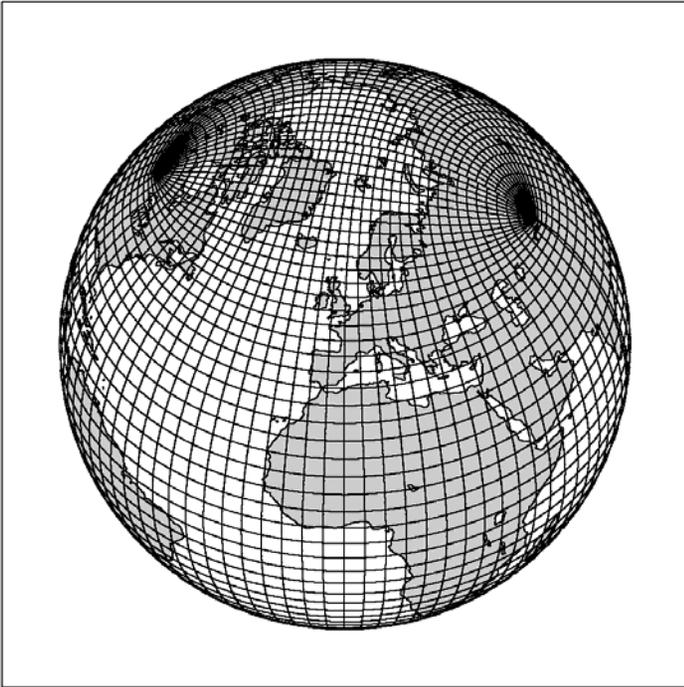
(b) sigma levels over z levels

(c) more sigma over z levels

(d) sigma levels only

For global NCOM: (C)

- 40 sigma-z material levels in the vertical
- 19 sigma-levels to 140 m
- 21 z-levels
- 1 m max deep-water upper level thickness
- NRL DBDB2 2-minute bathy



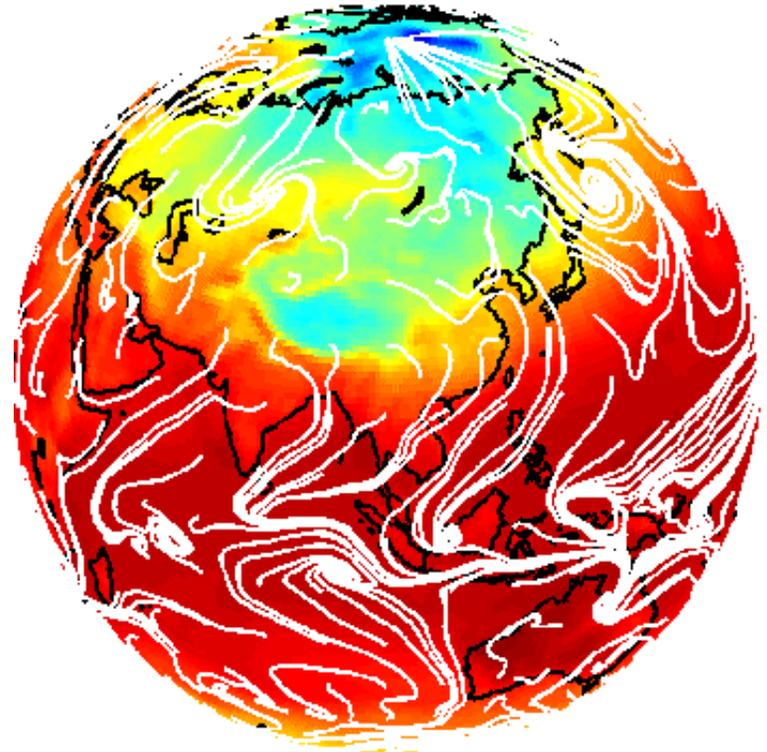
The global NCOM grid produces a global overlap by introducing an Arctic cap with poles over land in Canada and Russia.

The nominal 1/8° grid resolution refers to an average midlatitude spacing of the 2048x1280 grid.

Global NCOM Daily Forecast



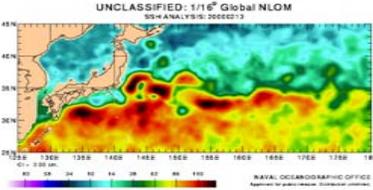
- 3 day hindcast with data assimilation
- 3 - 5 day forecast
- NOGAPS 3 h momentum flux
- NOGAPS 3 h heat flux
- Analysis-quality (τ 0-12 h) forcing for daily hindcast



Data Assimilation for Global NCOM



ALPS



1/16° NLOM

SSH

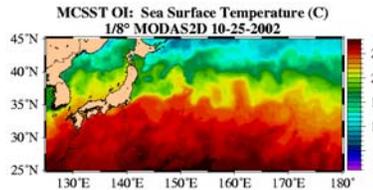
IN SITU DATA

MODAS 3D

SST

MODAS 2D

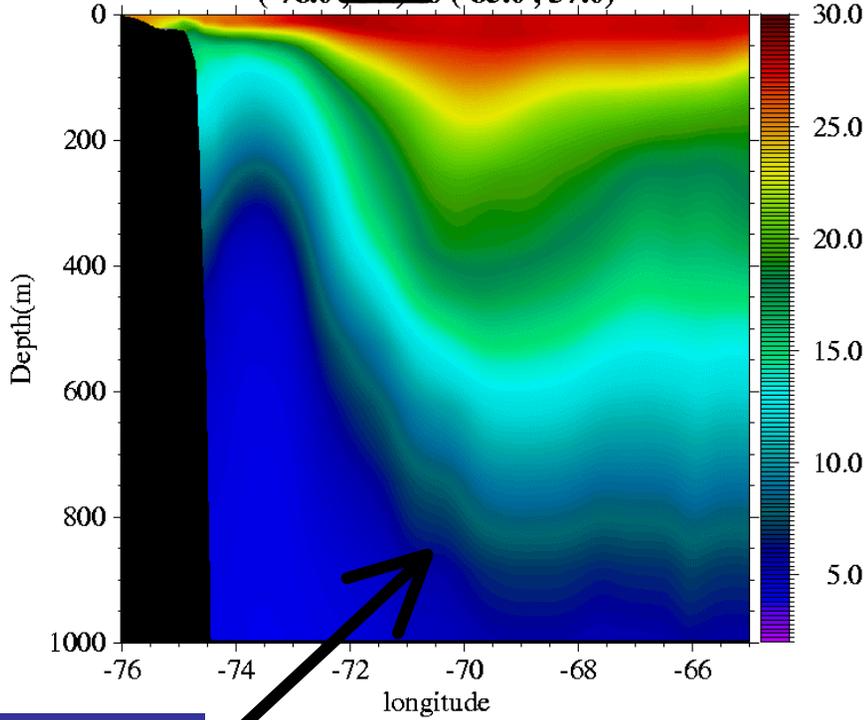
MCSST



SST & SSS

Surface flux

NRL global NCOM global 1/4 vert37N 08-28-2001 0000 GMT (-76.0, 27.0) to (-65.0, 37.0)



3D T & S

Relaxation

Global NCOM Real-time Run

Assimilating data October 2000 to present

Hindcasts

October 2000 to present

Forecasts to 72 h

February 2002 to present

Validation work:

- **Model climatology**
 - **EKE distribution**
 - **Transports through straits**
 - **Buoy time series**
- **Forecast skill**
 - **Model forecast vs. nowcast**
 - **Model-observation deviations**

Eddy Kinetic Energy from 1990s Drifter Trajectories

Fratantoni, JGR 106(C10), pp. 22067-22093, 2001

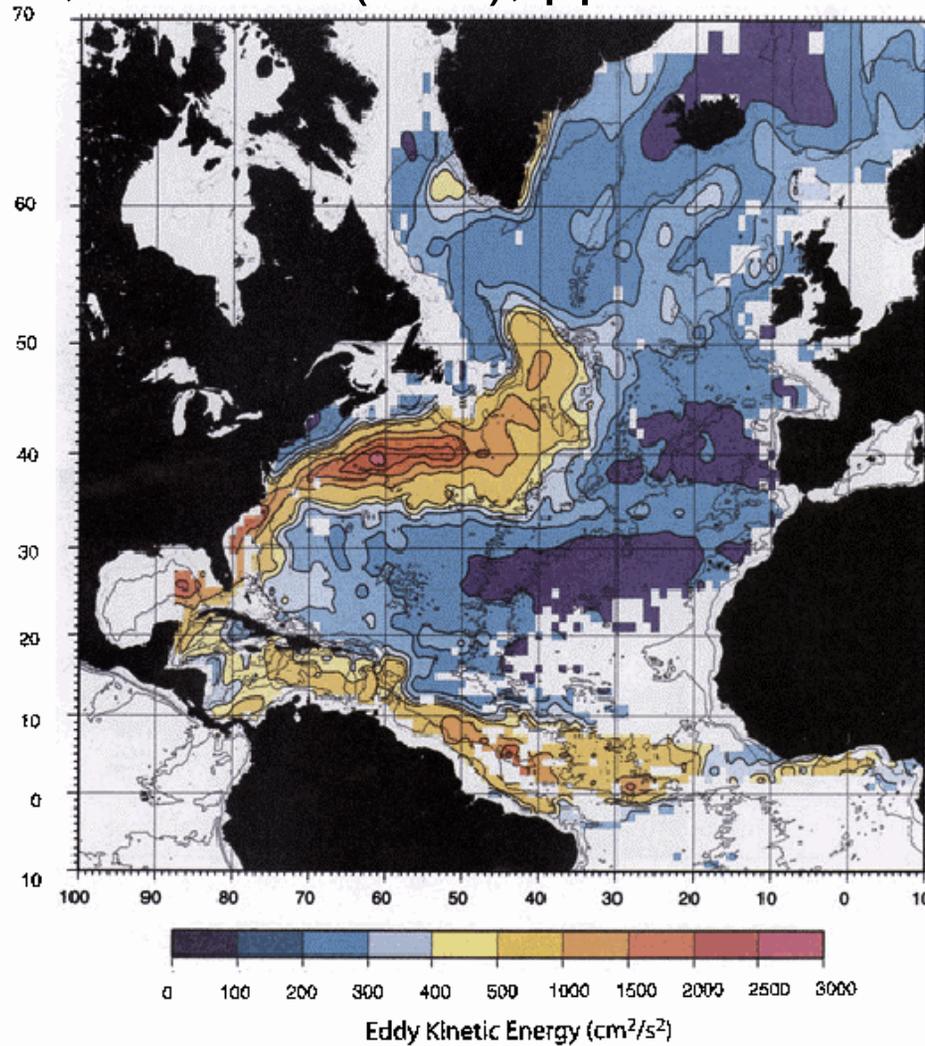
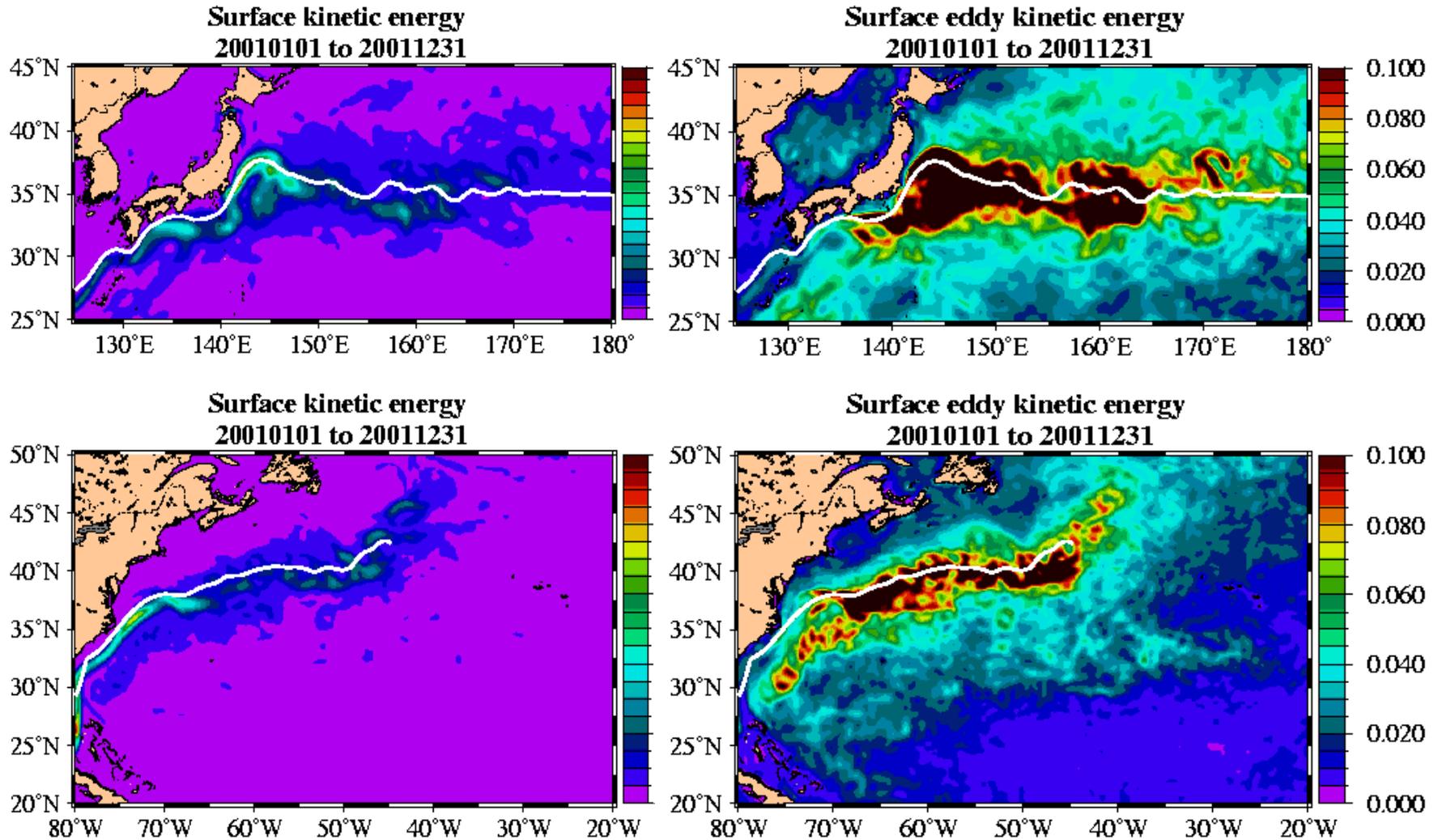


Plate 6. (continued)

Global NCOM 2001 means vs mean 2001 NAVO IR front bogus



Mean of daily results for global NCOM real-time run

2001 NCOM - buoy time series comparison

Year-long 3-D T
Time Series
Comparison At
Fixed TAO Buoy
Location for 2001

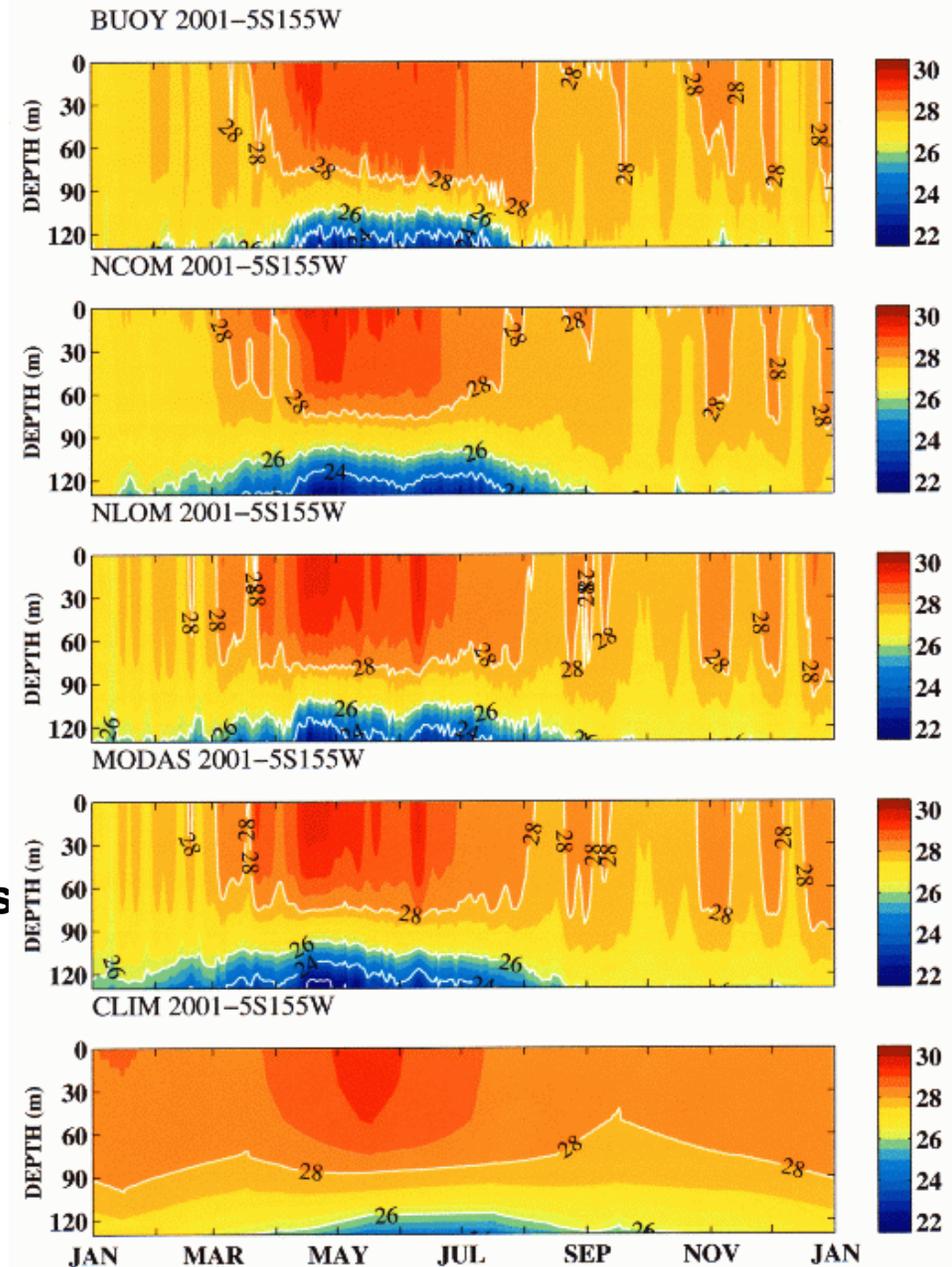
a. Buoy
5S, 155W

b. NCOM

c. NLOM-derived
synthetics

d. MODAS 2-D-
derived synthetics

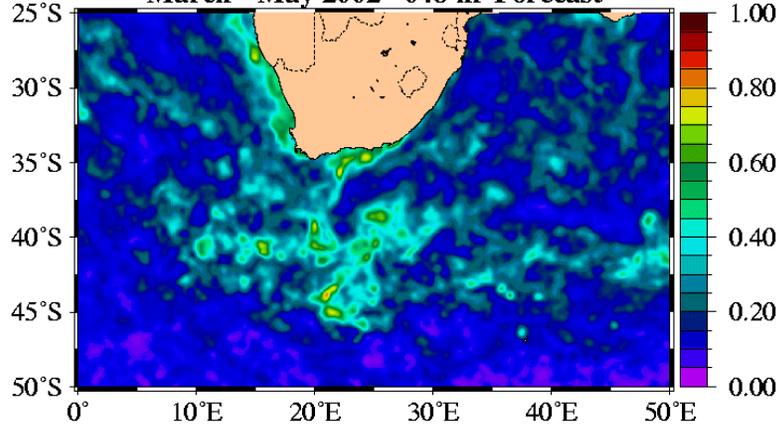
e. MODAS
climatology



SST Prediction Metrics from 1/8° Global NCOM

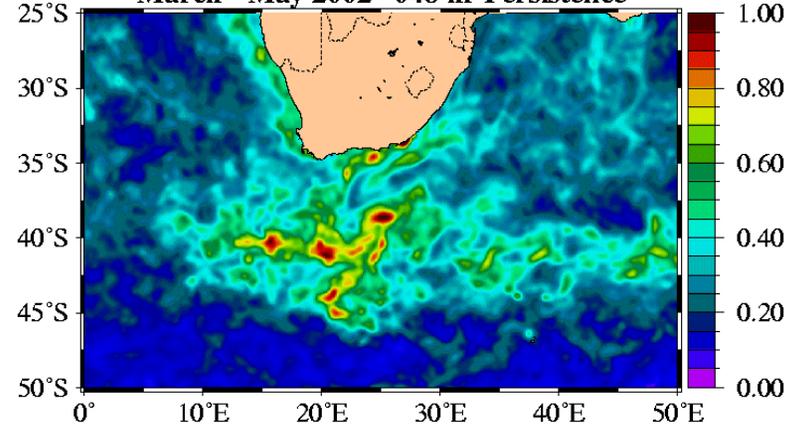
Agulhas Forecast

RMS Forecast Error Sea Surface Temperature (C)
March - May 2002 048 hr Forecast



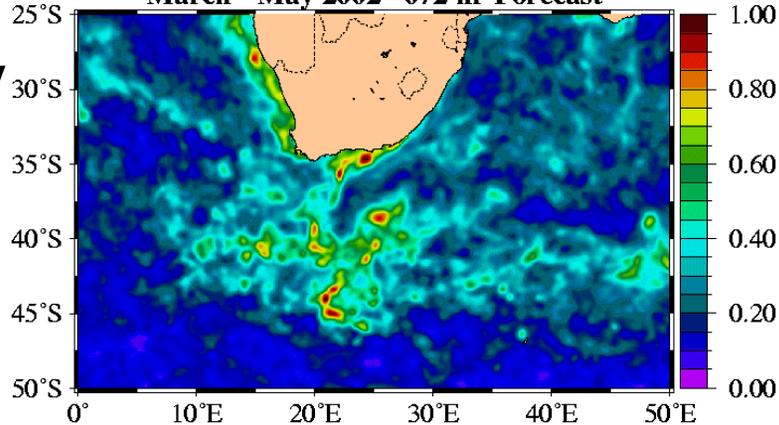
Agulhas Persistence

RMS Persistence Error Sea Surface Temperature (C)
March - May 2002 048 hr Persistence

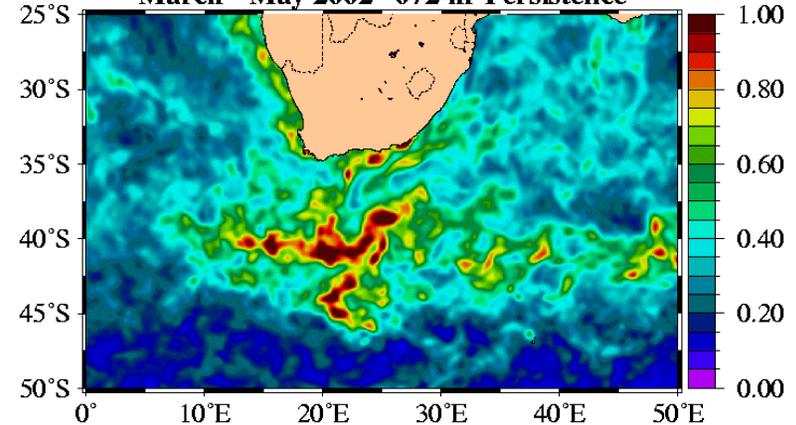


**2-Day
SST**

RMS Forecast Error Sea Surface Temperature (C)
March - May 2002 072 hr Forecast



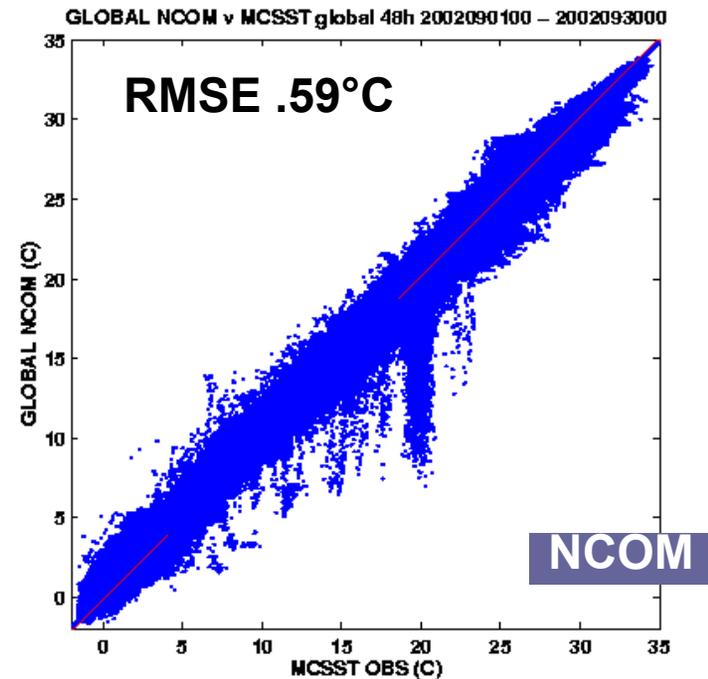
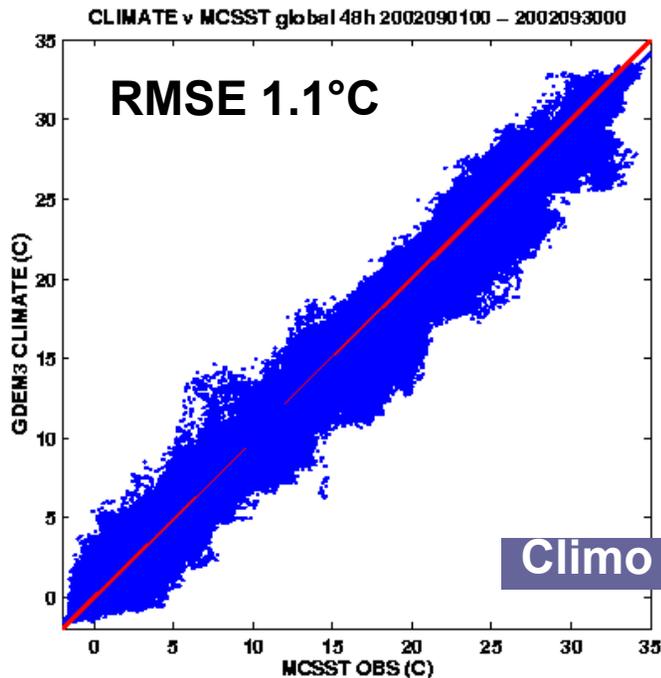
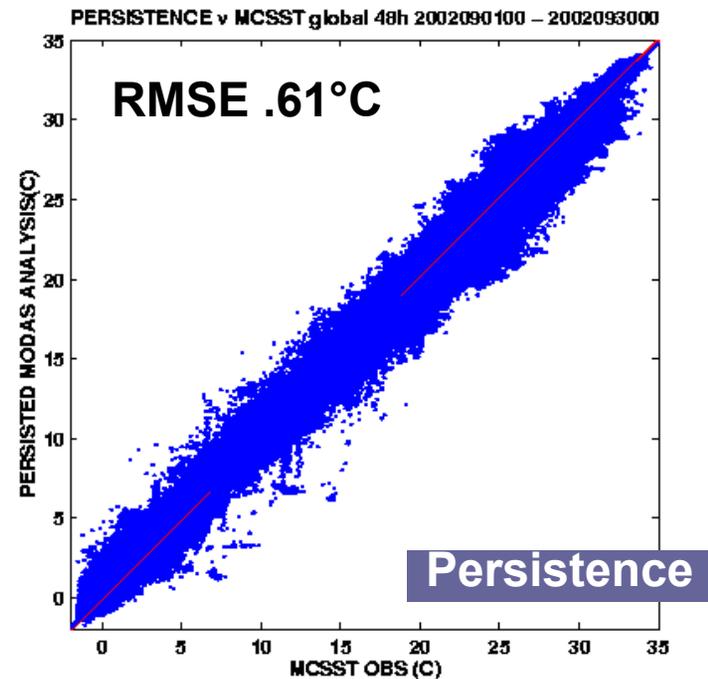
RMS Persistence Error Sea Surface Temperature (C)
March - May 2002 072 hr Persistence



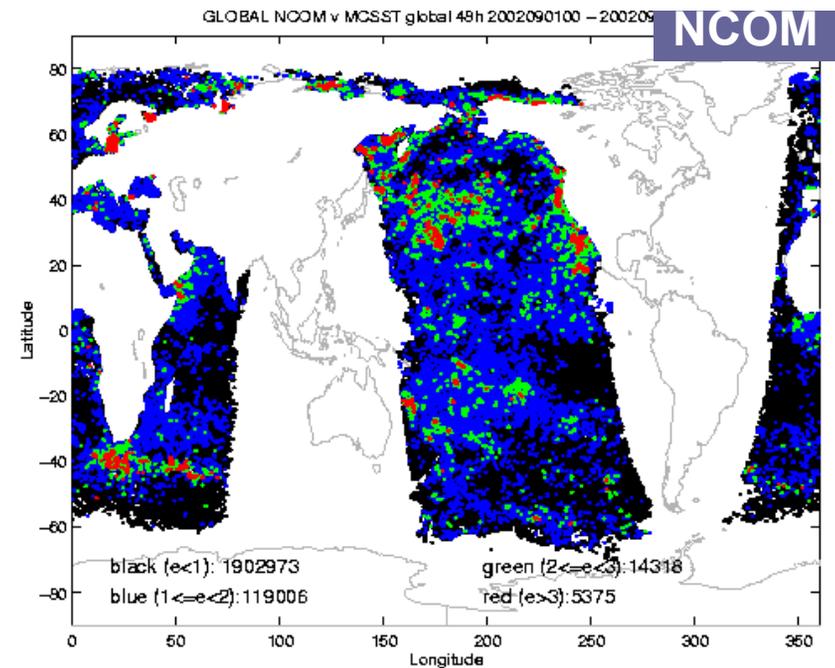
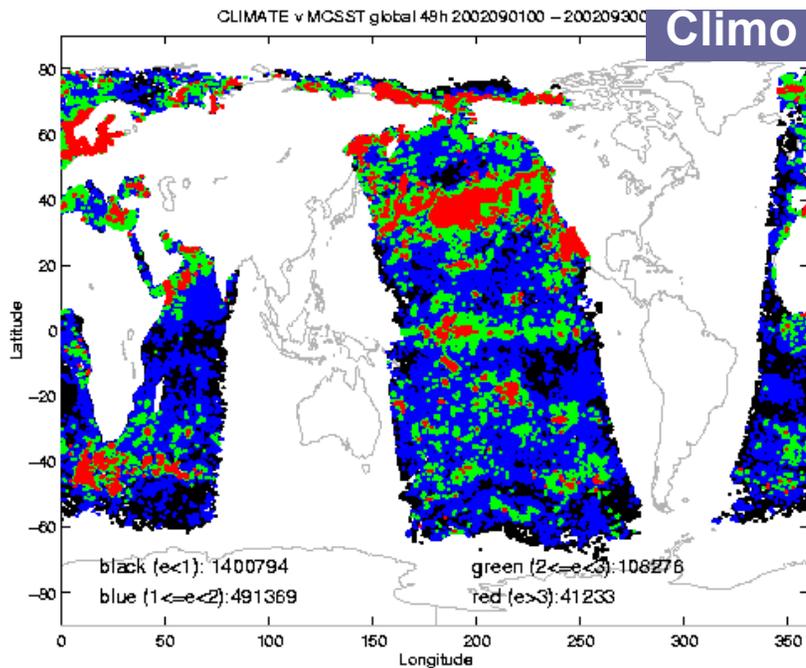
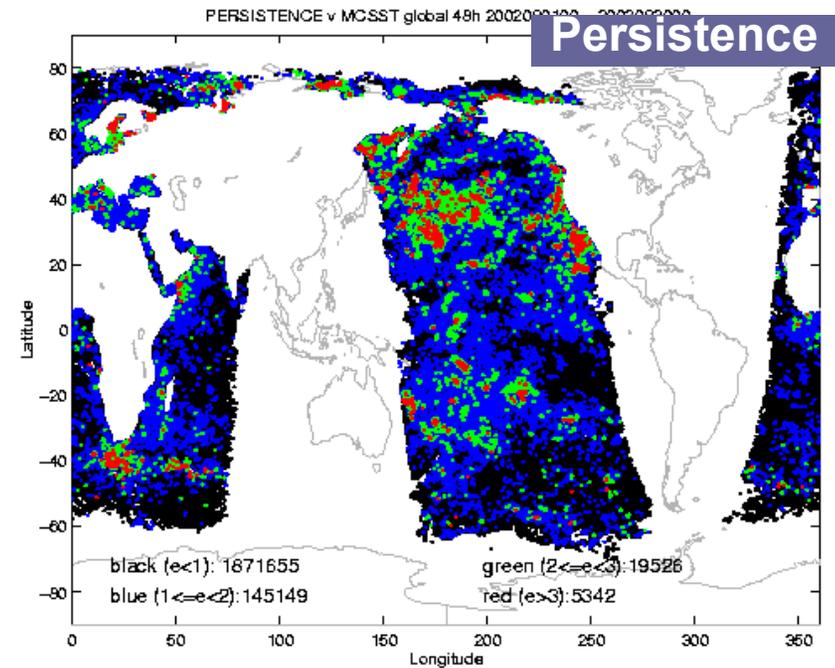
**3-Day
SST**

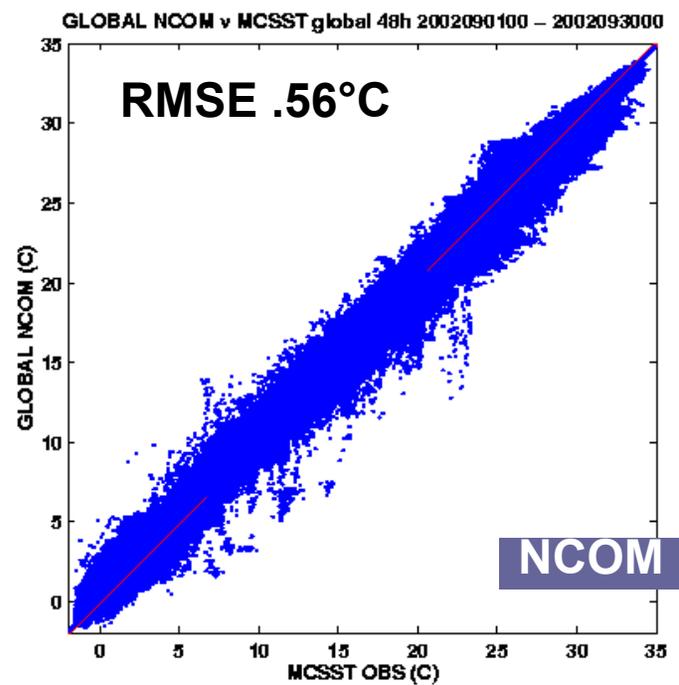
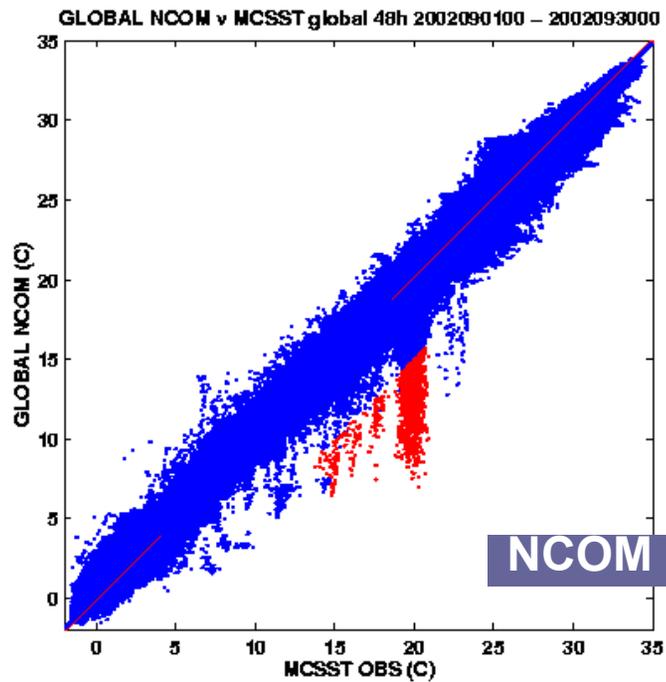
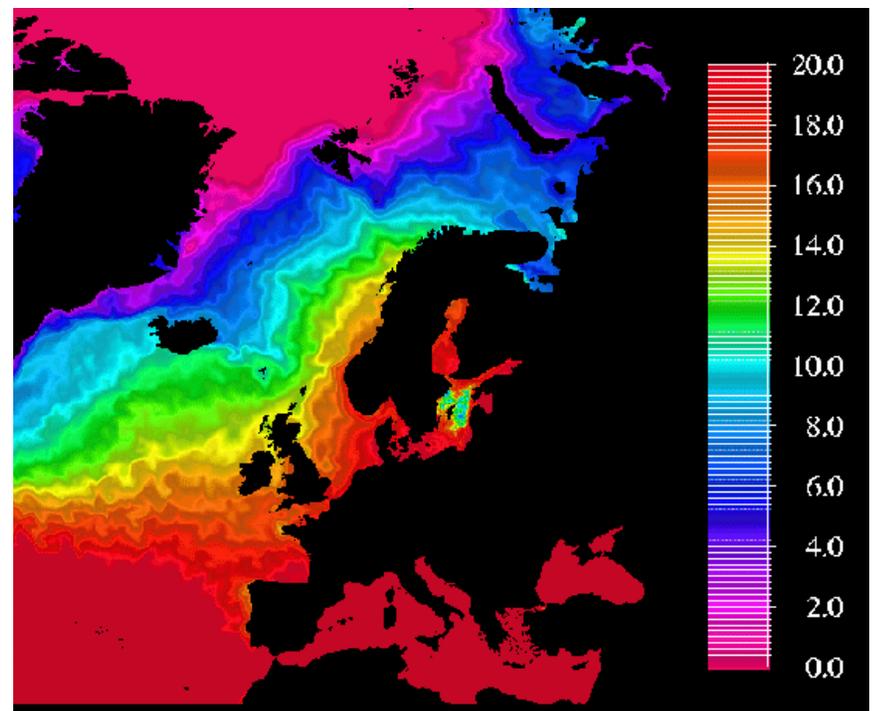
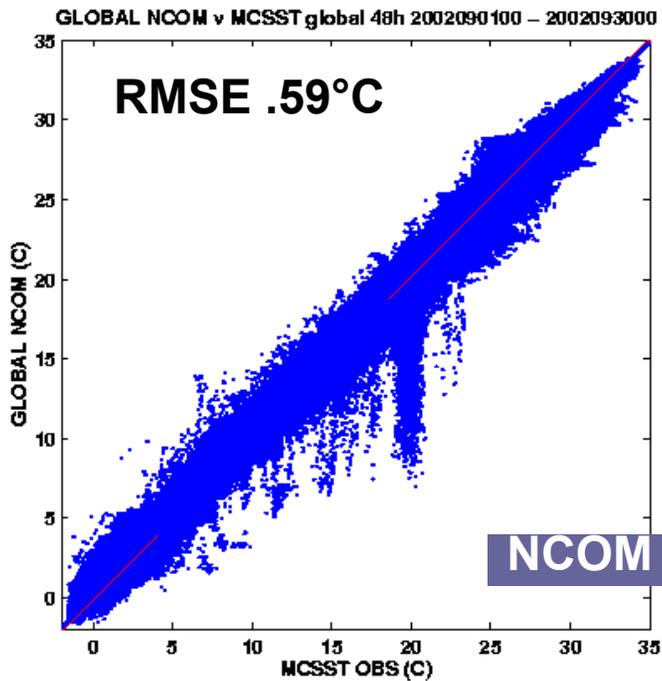
**Forecast Verification Statistics : RMS Errors
over 40 forecasts made 1 Mar 2002 – 31 May 2002**

Scatter plot comparisons of MCSST obs with analysis and model SST products for tau 48 h over the global domain, 01-30 Sep 2002.



Location of MCSST obs used in the previous plot at tau 48 h over the global domain. Points are color-coded by the magnitude of the deviation (red for deviation $> 3C$).

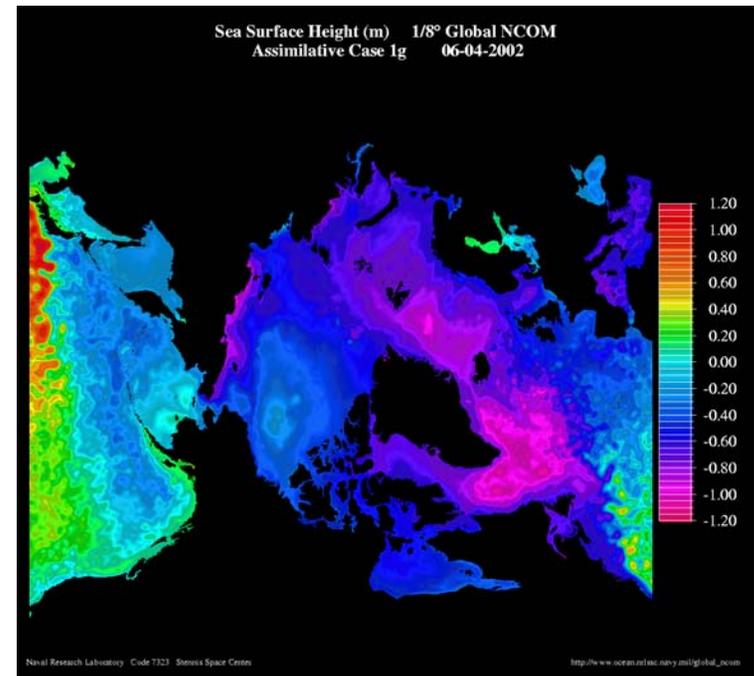




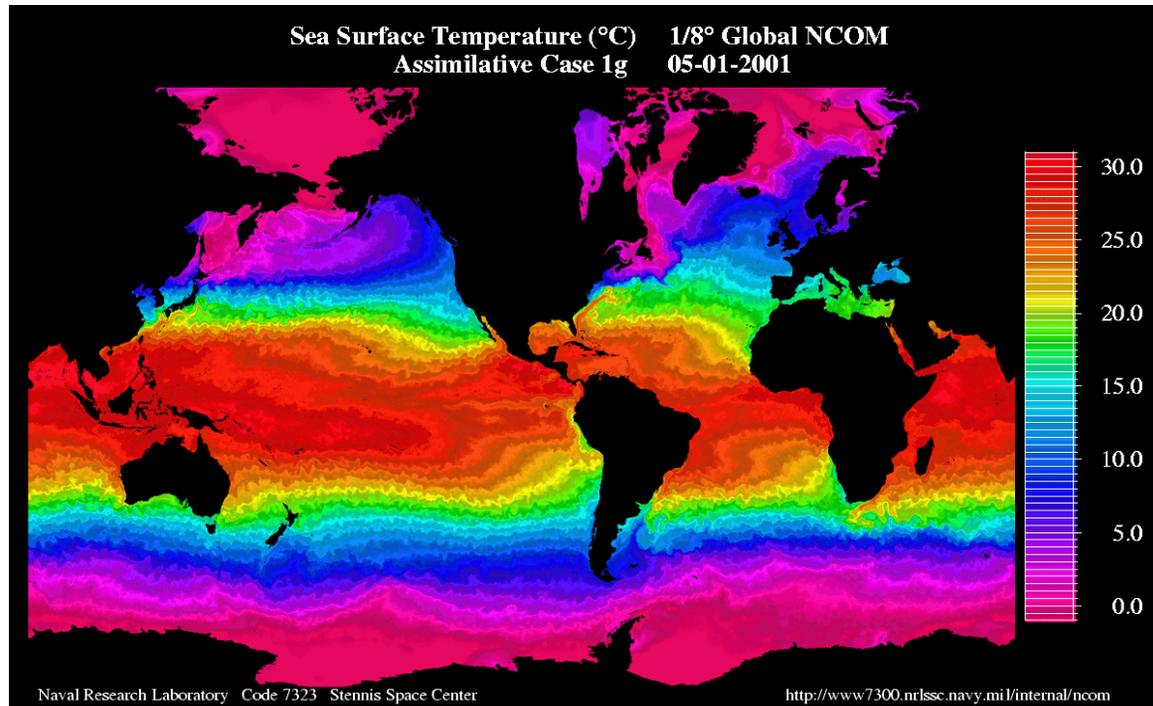
Global NCOM Development

Areas of active improvement in global NCOM include:

- data assimilation (time scales, *in situ* data)
- river input
- designing tidal interface
- Kara, et al. latent & sensible heat fluxes
- ice models
- validation/verification



Summary

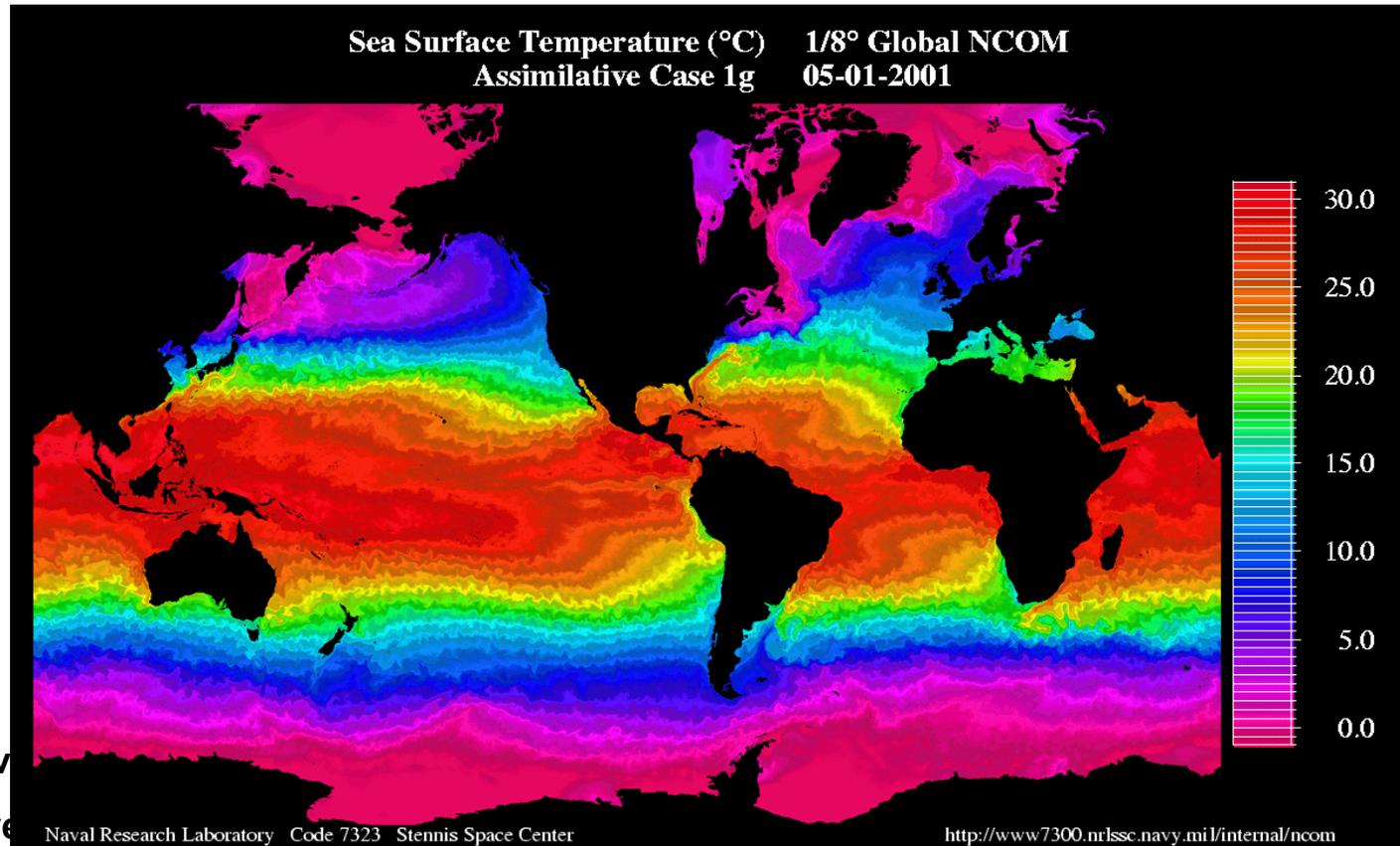


Real-time system assimilating data October 2000-present
Validation runs underway using 1997-2001 +
Active development in

- data assimilation
- forcing
- validation
- ice modeling
- nesting

www.ocean.nrlssc.navy.mil

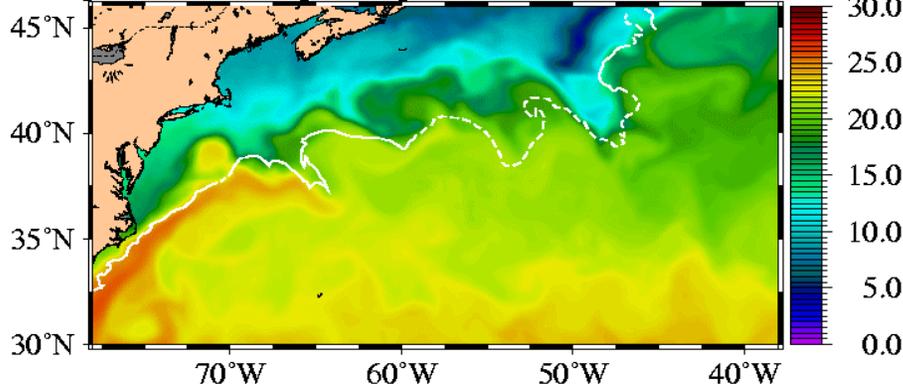
1/8° Global Navy Coastal Ocean Model (NCOM)



- . 40 (19/21) sigma/z levels
- . 1 m maximum top level
- . Assimilation of SST, SSS, 3D T&S from MODAS syn using 1/16° NLOM SSH and MODAS2D SST
- . NOGAPS wind stress, radiation, heat flux
- . generic grid extraction capability

Sea Surface Temperature (C)

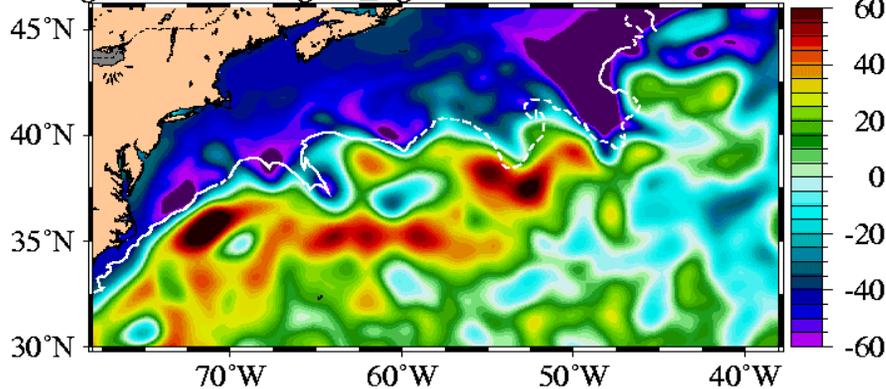
NRL global NCOM glb8_1g 0000 m 11-30-2001 0000 GMT



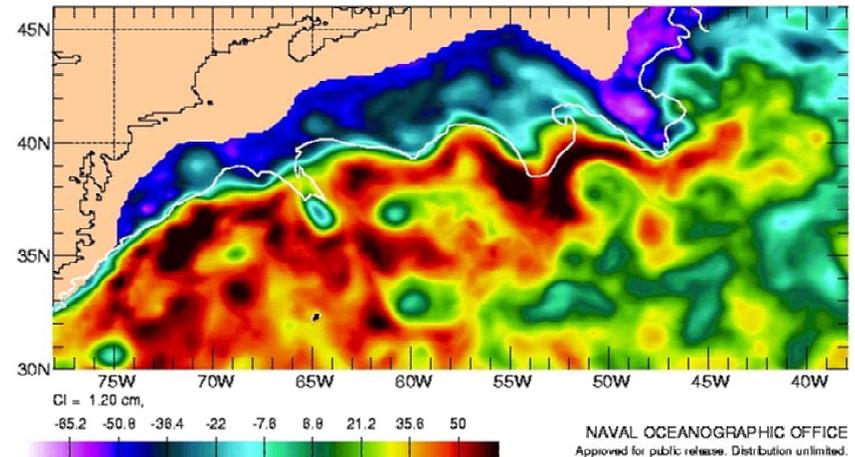
Comparison of global NCOM, global NLOM, and NAVO IR frontal analysis for the Gulf Stream north wall, 30 November 2001

Sea Surface Height (cm)

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

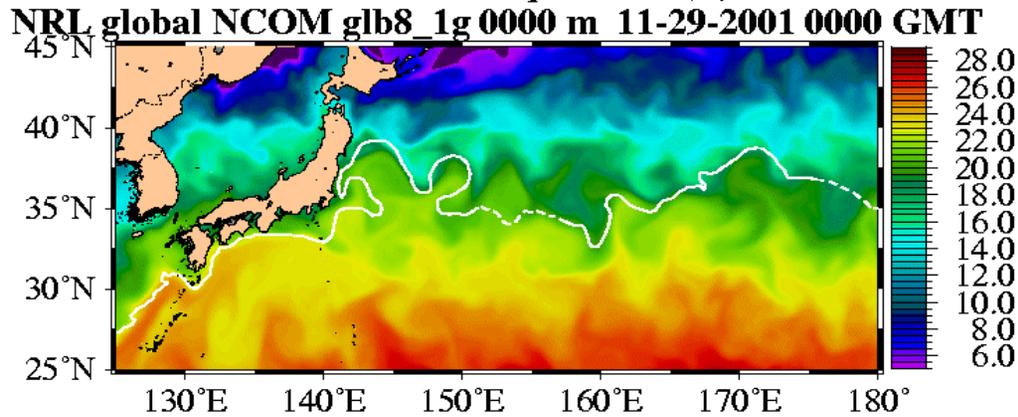


UNCLASSIFIED: 1/16° Global NLOM
SSH ANALYSIS: 20011130

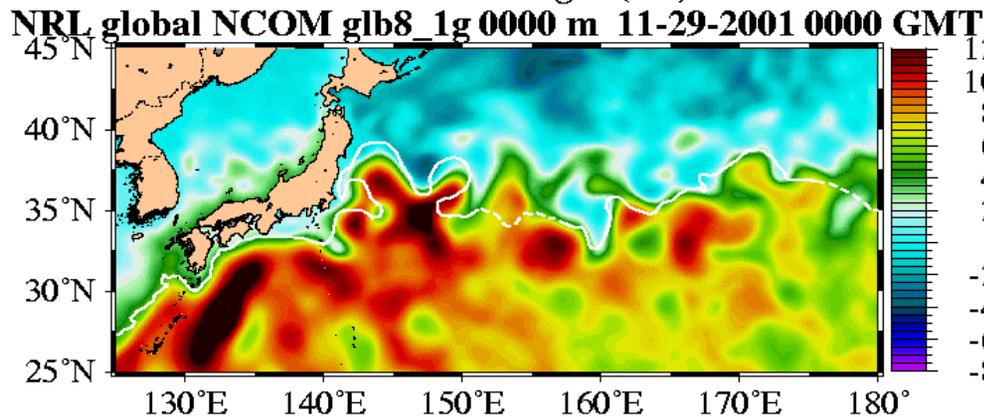


Comparison of global NCOM, global NLOM, and NAVO IR frontal analysis for the Kuroshio north wall, 29 November 2001.

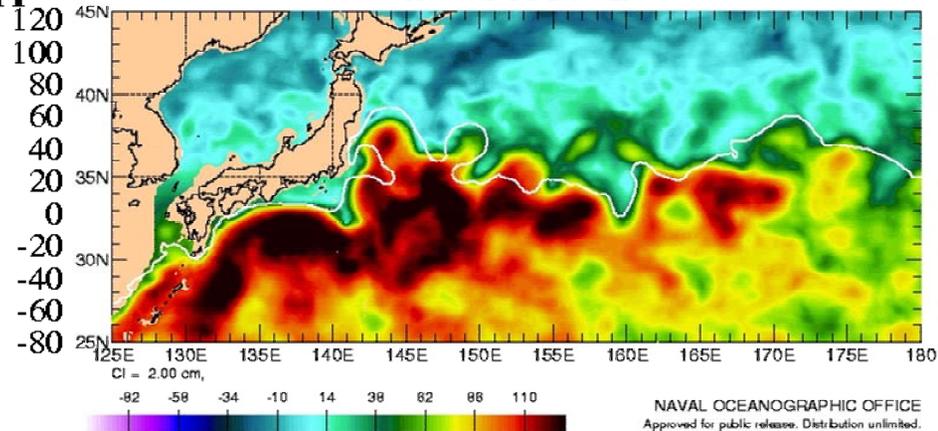
Sea Surface Temperature (C)



Sea Surface Height (cm)

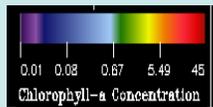
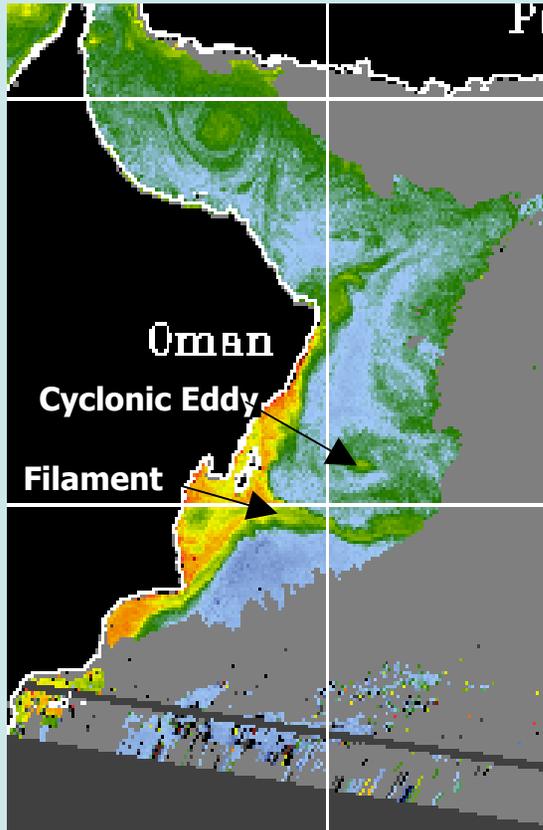


UNCLASSIFIED: 1/16° Global NLOM
SSH ANALYSIS: 20011129



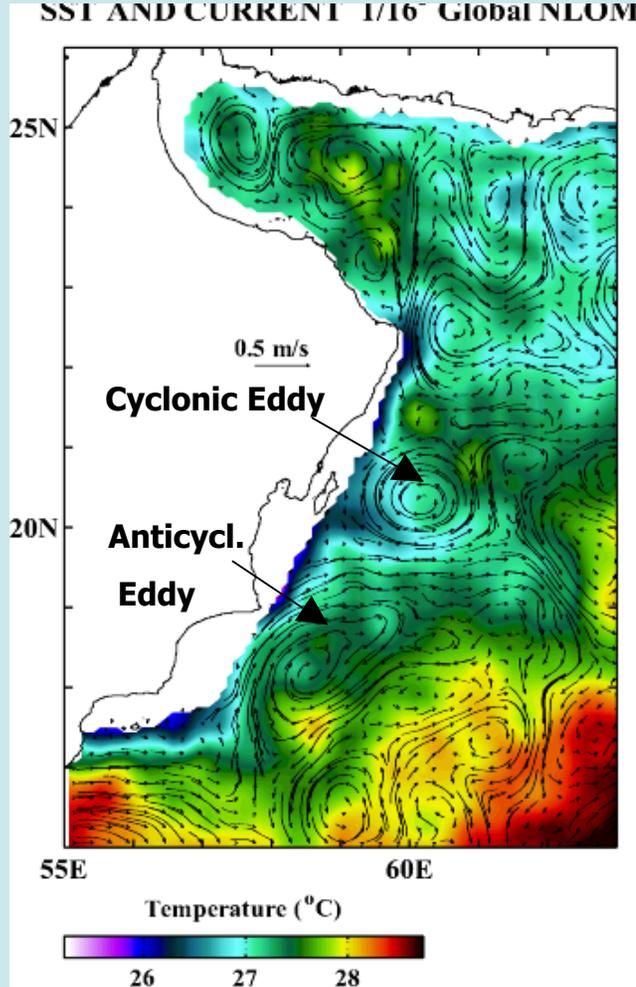
Oman Coastal Filaments During Spring Intermonsoon Comparison of SeaWIFS and NRL Real Time Models

SeaWIFS: 19 Apr. 01



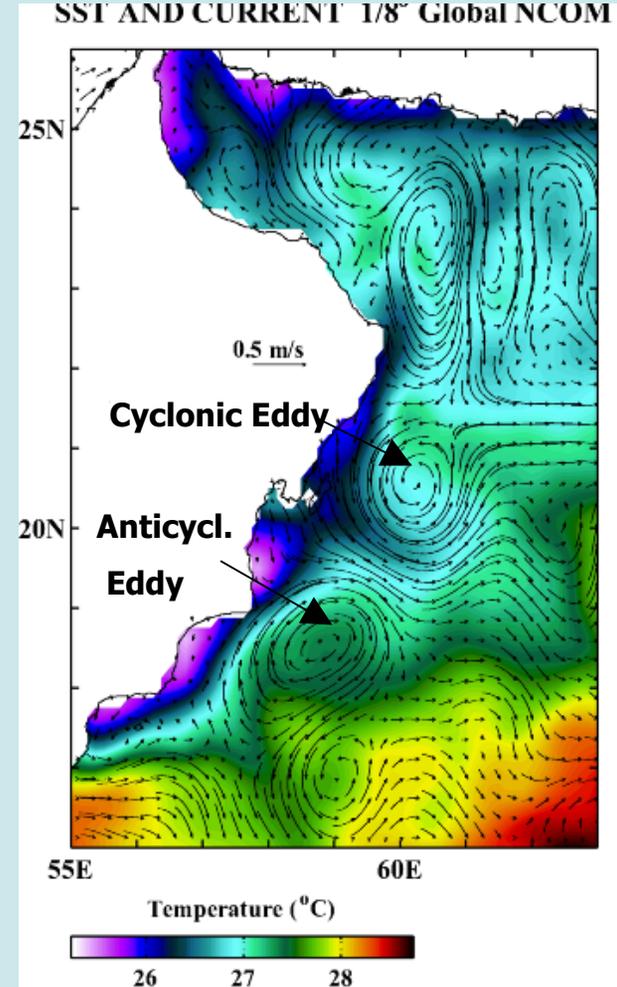
Chlorophyll from SeaWIFS

1/16° NLOM: 19 Apr. 2001



Model SST and Surface Currents

1/8° NCOM: 19 Apr. 2001



What sort of data streams feed the global operational oceanography?

Available in real-time or very near real time:

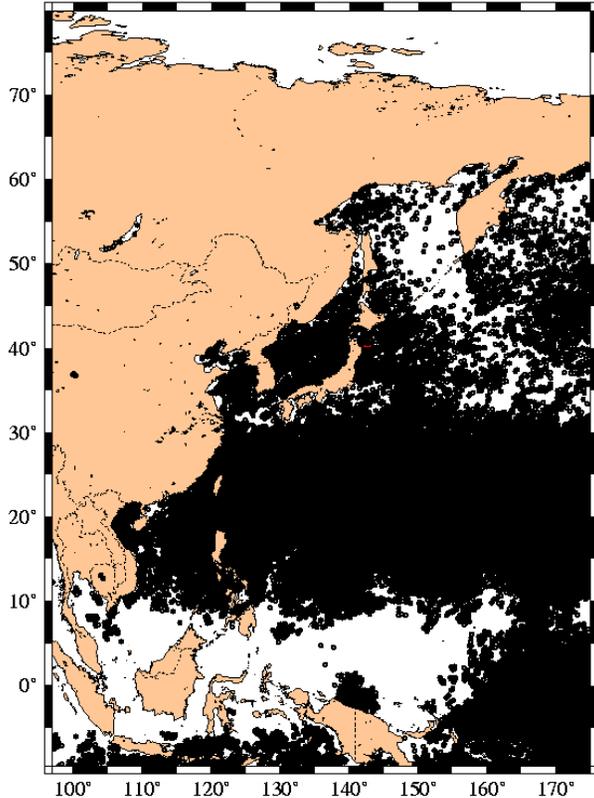
- Atmospheric fields (NOGAPS, COAMPS)
- Altimeter height deviations (ERS, GFO, Jason)
- Satellite Sea Surface Temperature (SST)
- In situ observations (buoys, floats, xbts)

Climatological data:

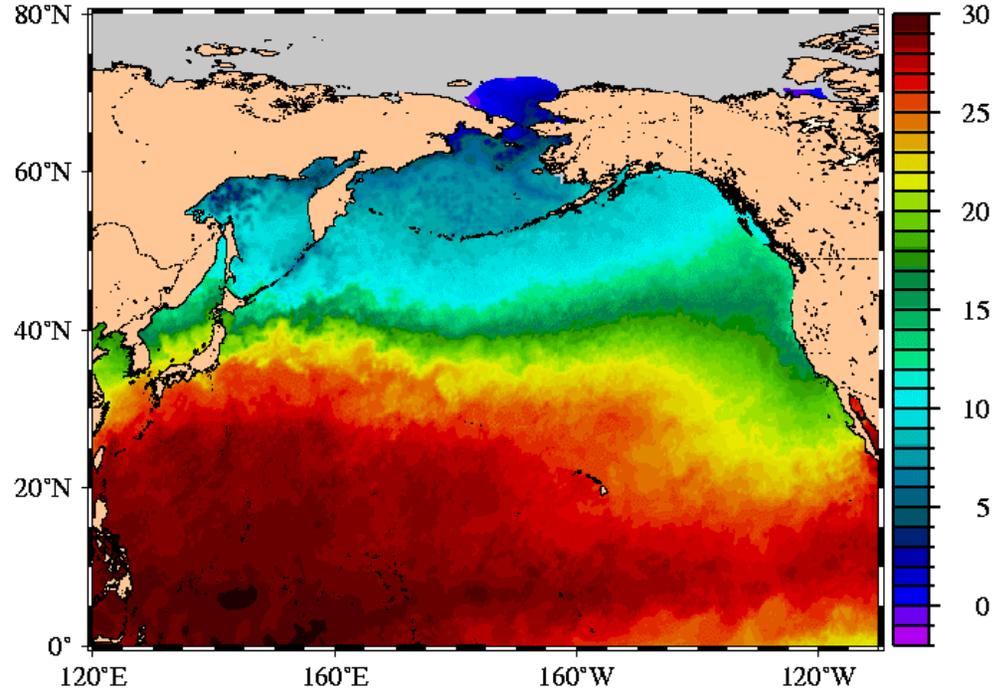
- Topography
- Climatological fields and correlations

Daily MODAS2D OI of SST

Locations of Observations Used for SST OI
Date: 10-22-2000



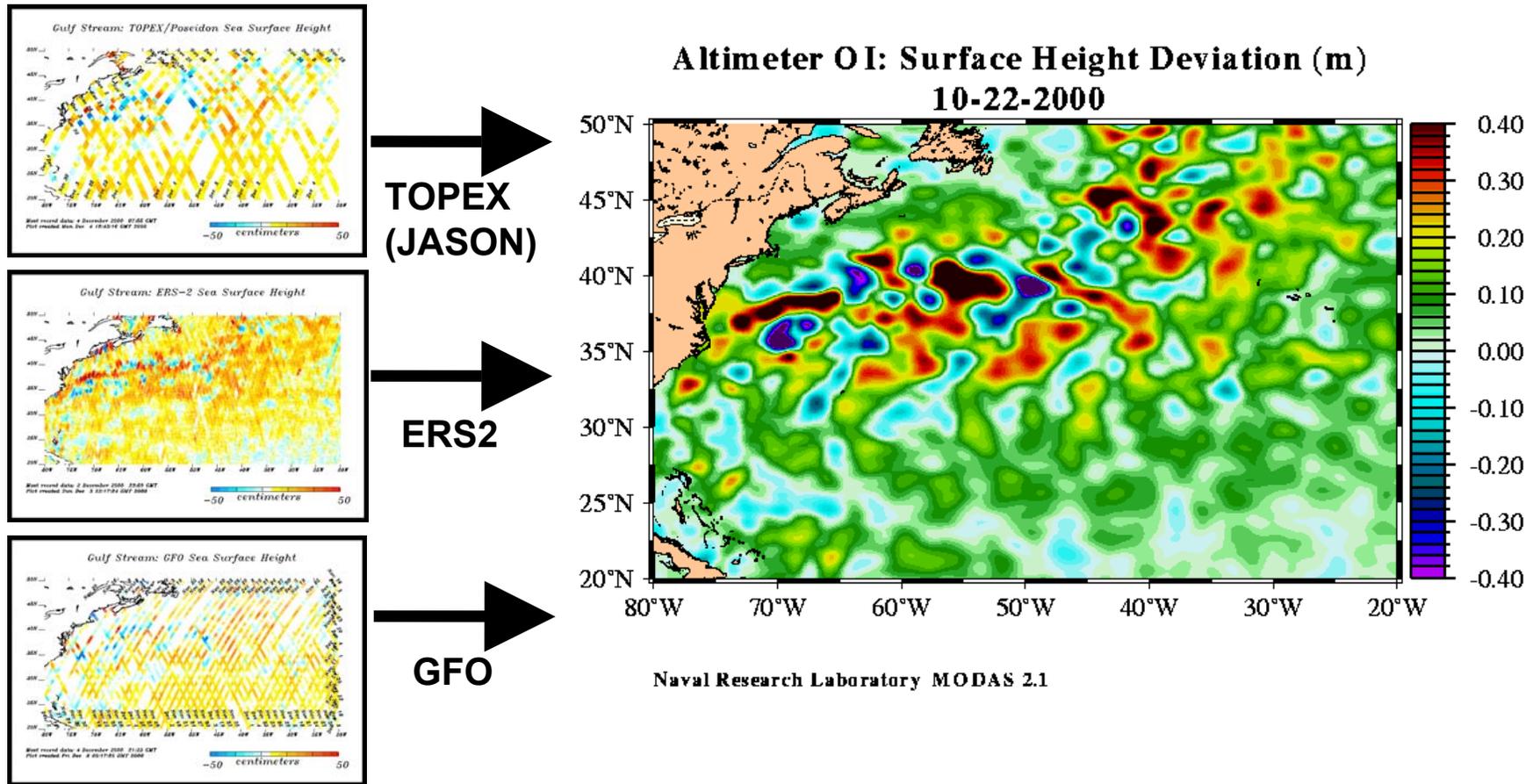
MCSST OI: Sea Surface Temperature (C)
10-22-2000



Naval Research Laboratory MODAS 2.1

A first guess field and scattered satellite SST observations are combined in an optimal interpolation procedure to produce daily global $1/8^\circ$ SST fields. see www.ocean.nrlssc.navy.mil/altimetry

Daily MODAS2D OI of SSH



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 $1/8^\circ$ SSH fields. See www.ocean.nrlssc.navy.mil/altimetry

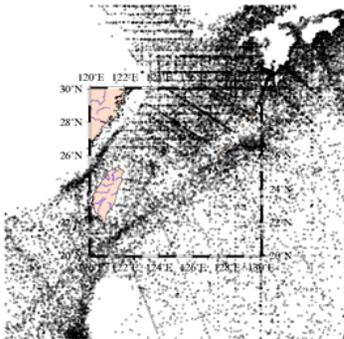
MODAS Climatology

- **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 NAVOCEANO profile database**
- **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**

MODULAR OCEAN DATA ASSIMILATION SYSTEM

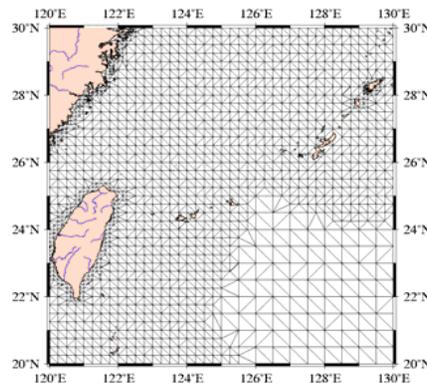


MOODS Profiles



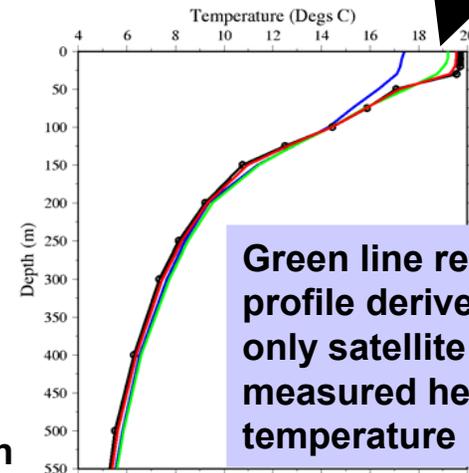
Decades of edited MOODS profiles are used to derive statistical relationships between surface height and temperature and subsurface temperature and salinity

MODAS Climatology



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

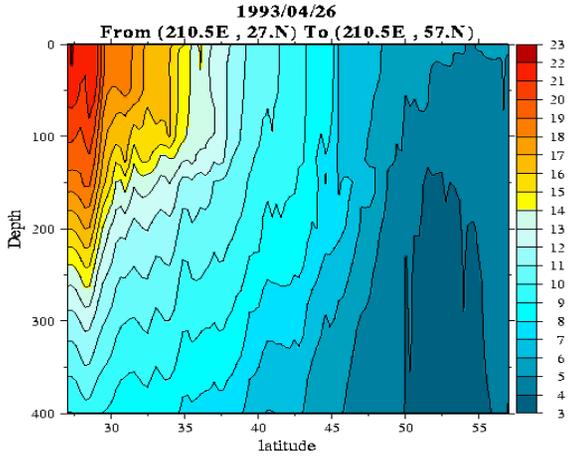


Green line represents profile derived using only satellite measured height and temperature

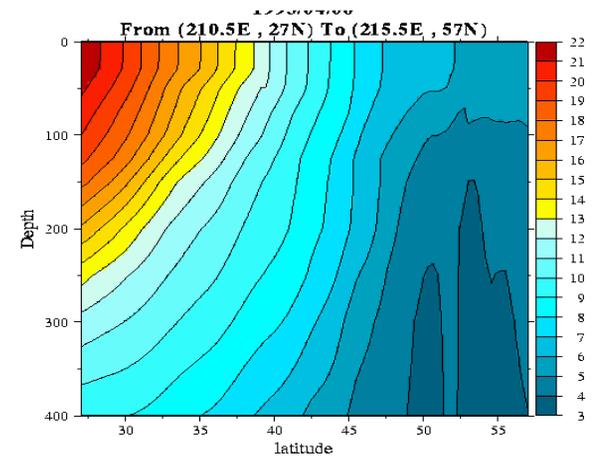
- Climatology
- MODAS Synthetic
- Final Analysis
- In Situ BT

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

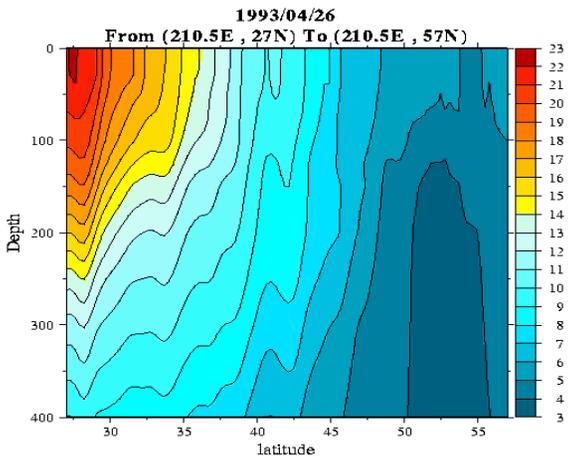
AXBT Temp



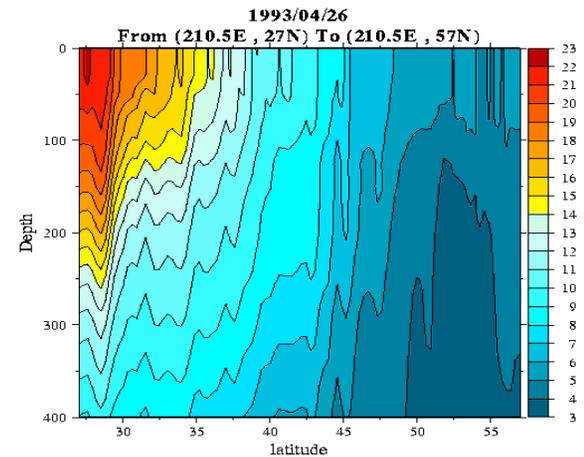
Climatological Temp



Clim + SSH + SST Temp



Temp Clim from XBT SSH + SST



Global NCOM 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 MODAS 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.

Data sources

Real-time SSH from ERS-2, GFO, T/P

The essential available data source for eddy-resolving global ocean circulation monitoring and prediction

Sea surface temperature from satellite IR

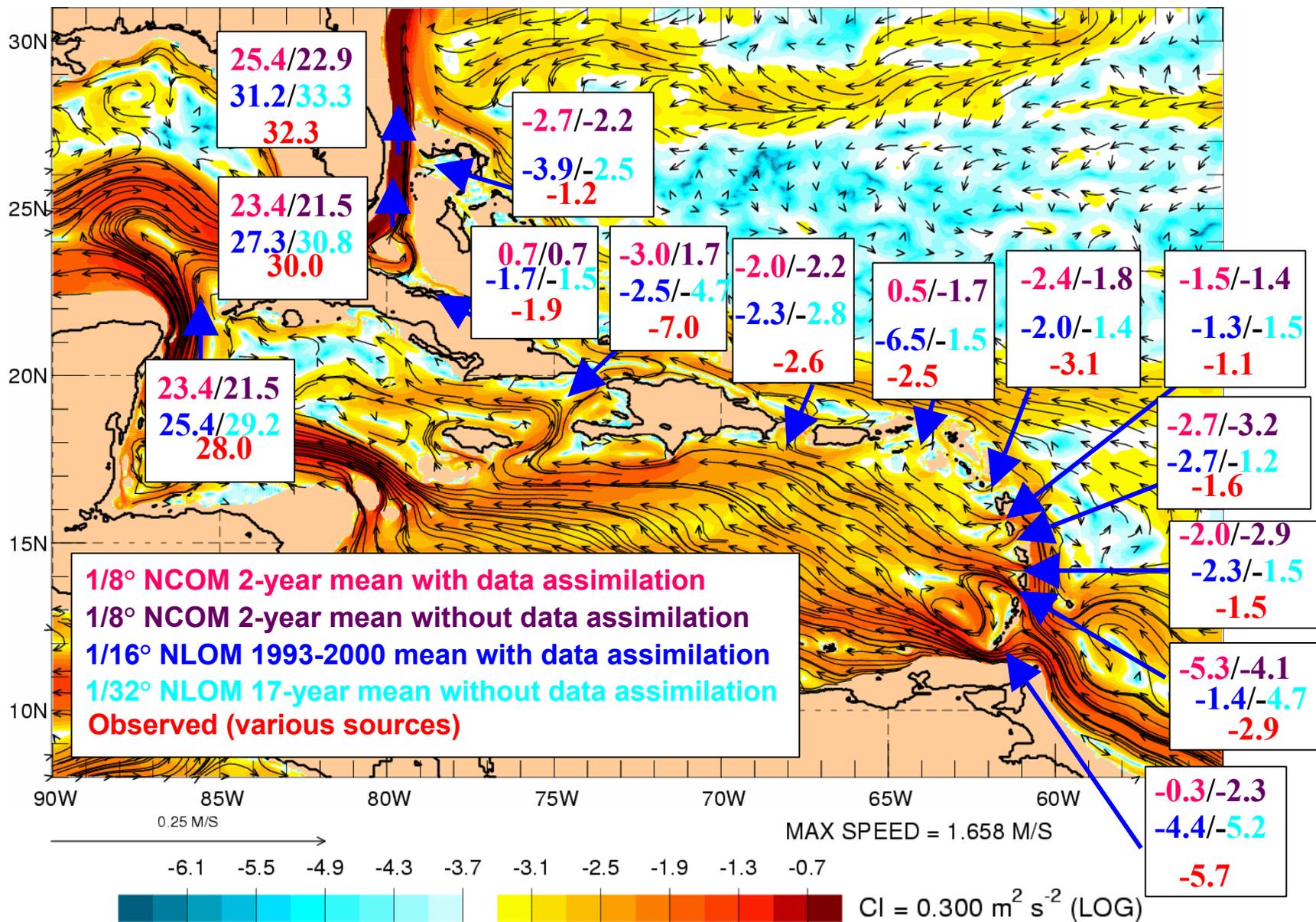
Atmospheric forcing from Fleet Numerical Meteorology and Oceanography Center

forcing for forecasts reverts toward climatology after 4 days
not a serious detriment for many ocean features

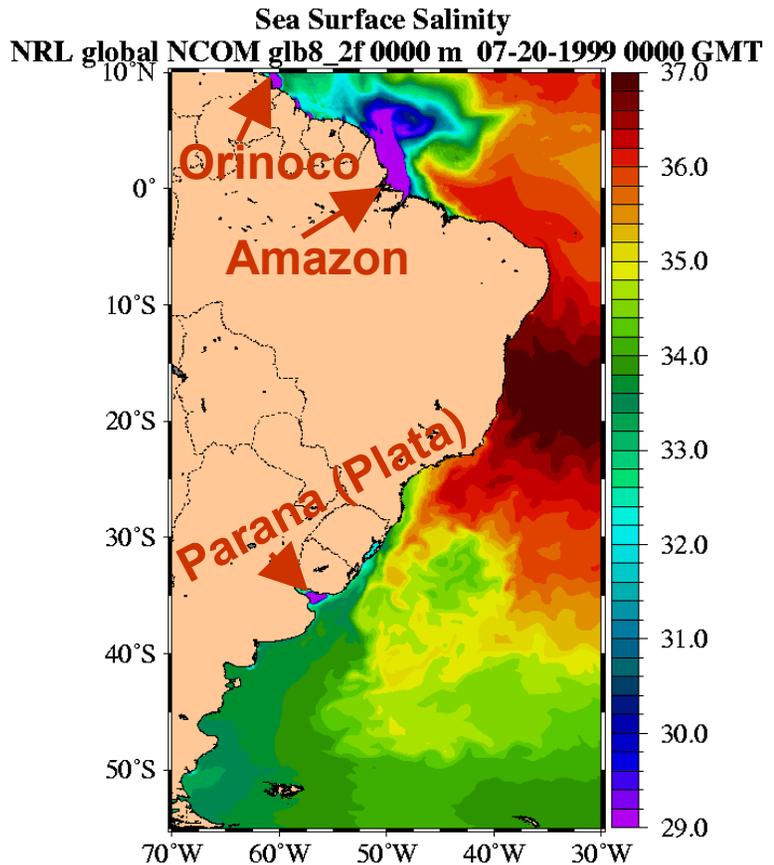
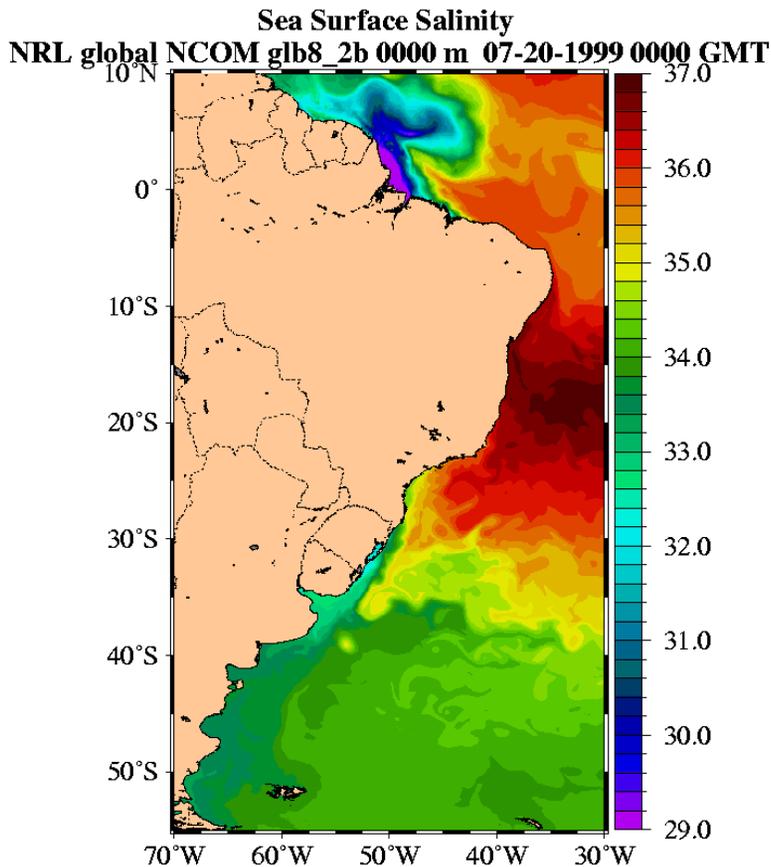
Historical hydrographic database

Used in generating synthetic T&S profiles from real-time SSH & SST
Used for downward projection in NCOM but not NLOM
Assimilation of real-time T/S profiles to be added

Comparison of Observed and Modeled Annual Mean Transports (Sv) Through The Intra-Americas Sea



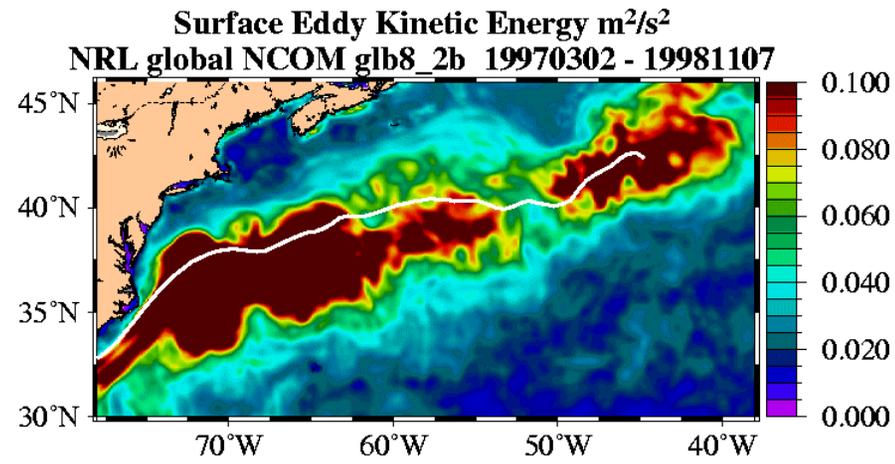
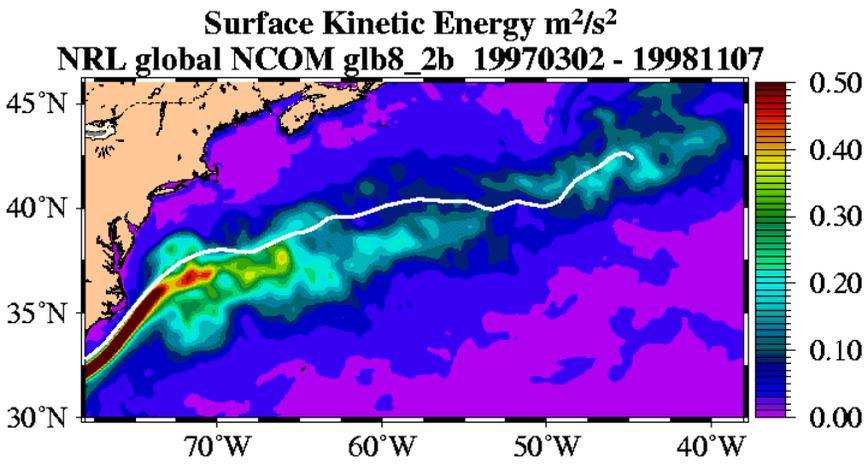
1/8° Global NCOM river database impact: *Amazon and other South American Rivers*



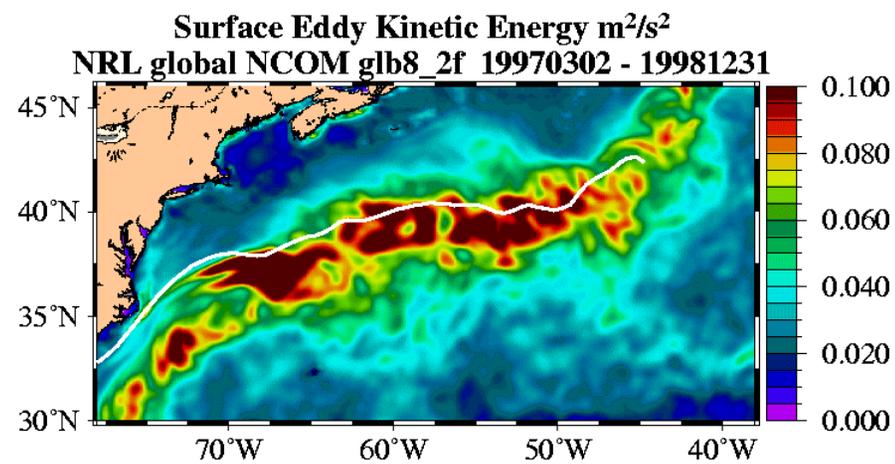
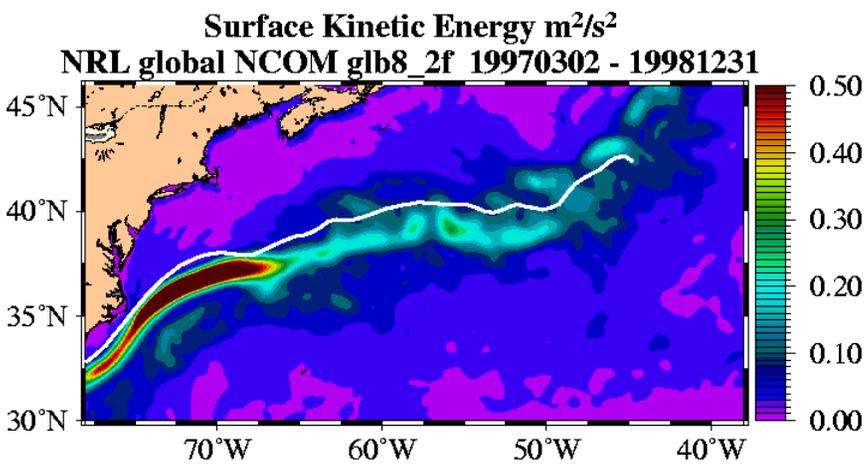
**There are 986 rivers in the global river database,
34 in this region**

Global NCOM 2 year hindcast means vs mean 2001 NAVO IR front bogus

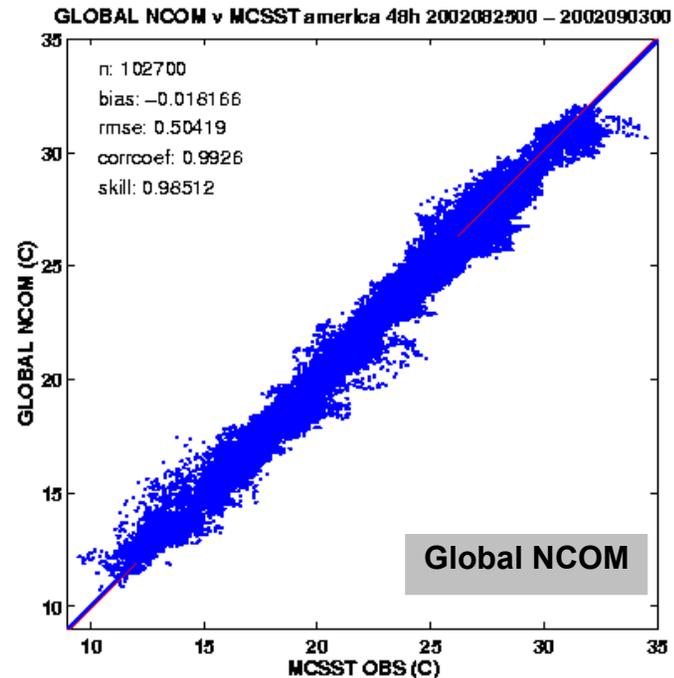
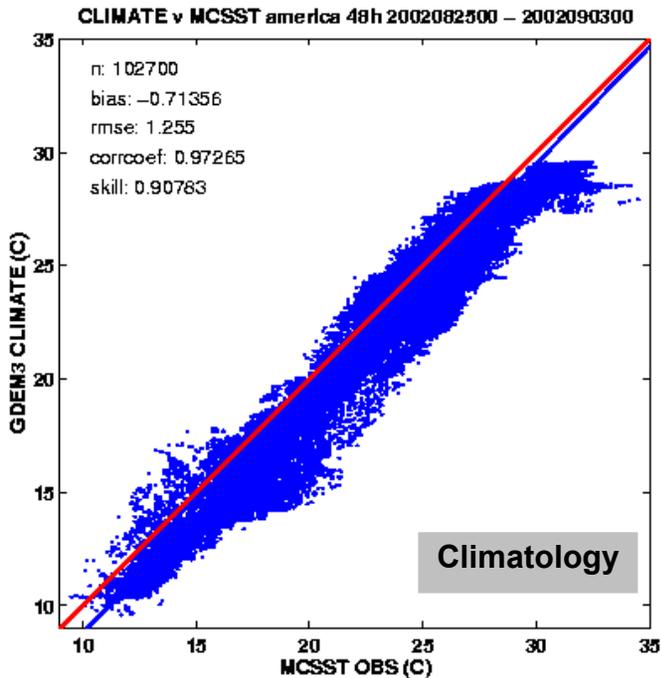
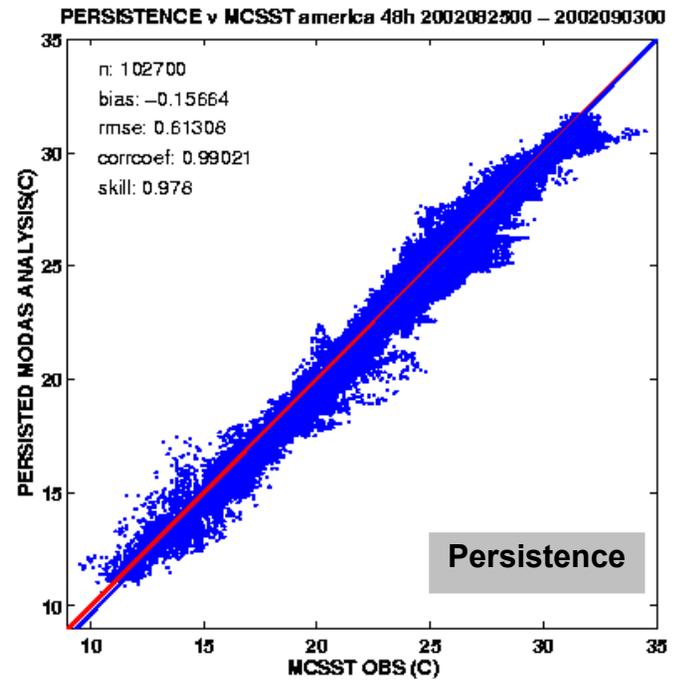
Mean of daily results for NCOM non-assimilative case glb8_2b



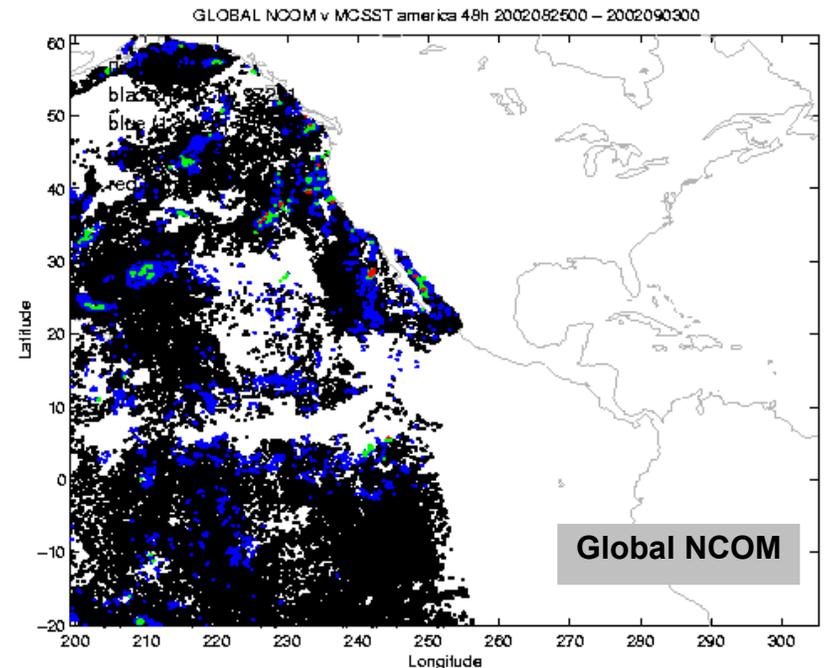
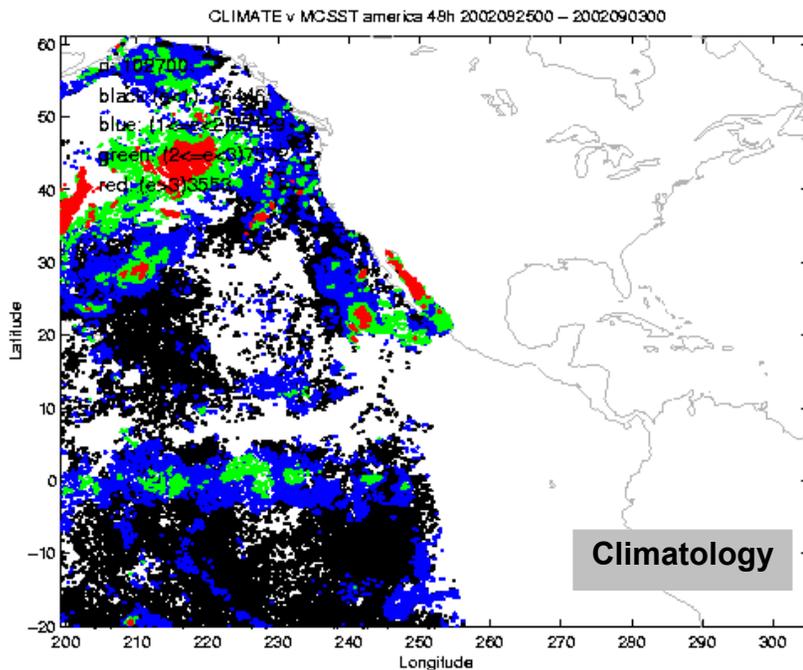
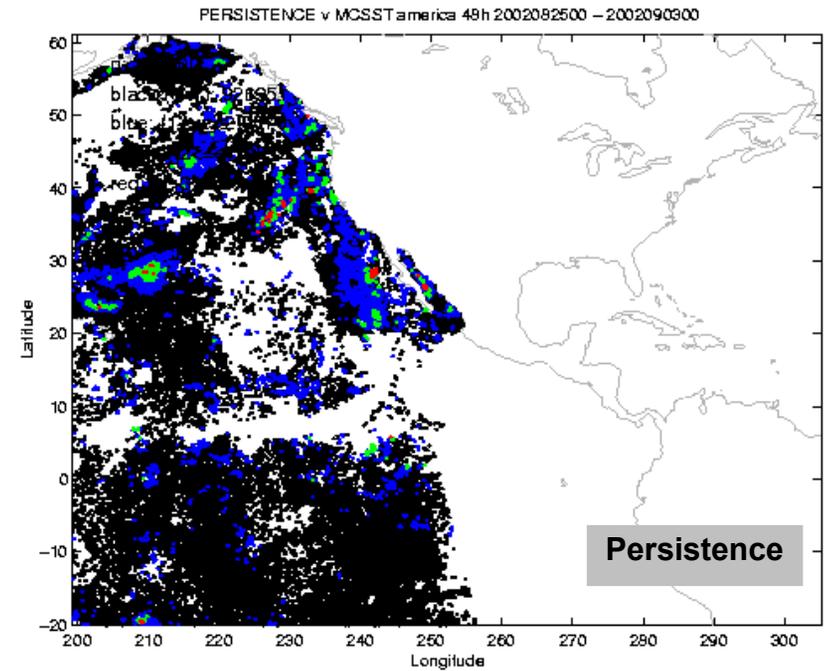
Mean of daily results for NCOM assimilative case glb8_2f



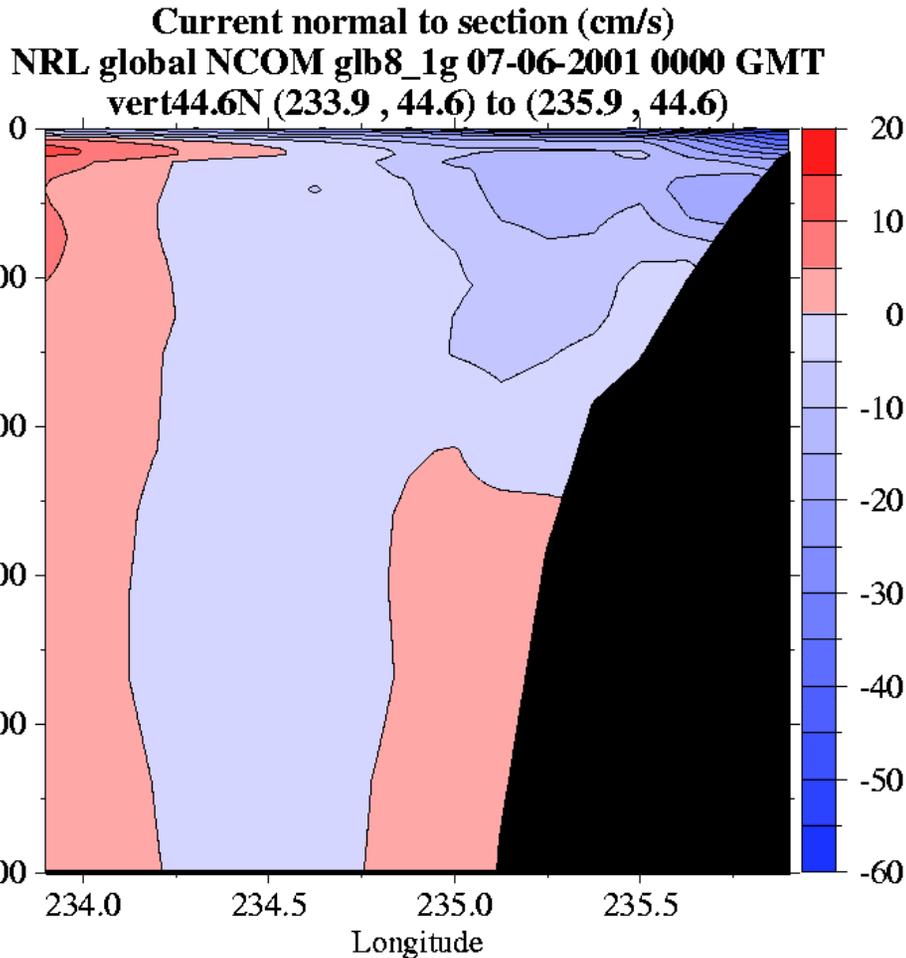
Scatter plot comparisons of MCSST obs with analysis and model SST products for tau 48 h over the “SWAFS Americas” domain. This is an example of metric software used to monitor the performance of various real-time products.



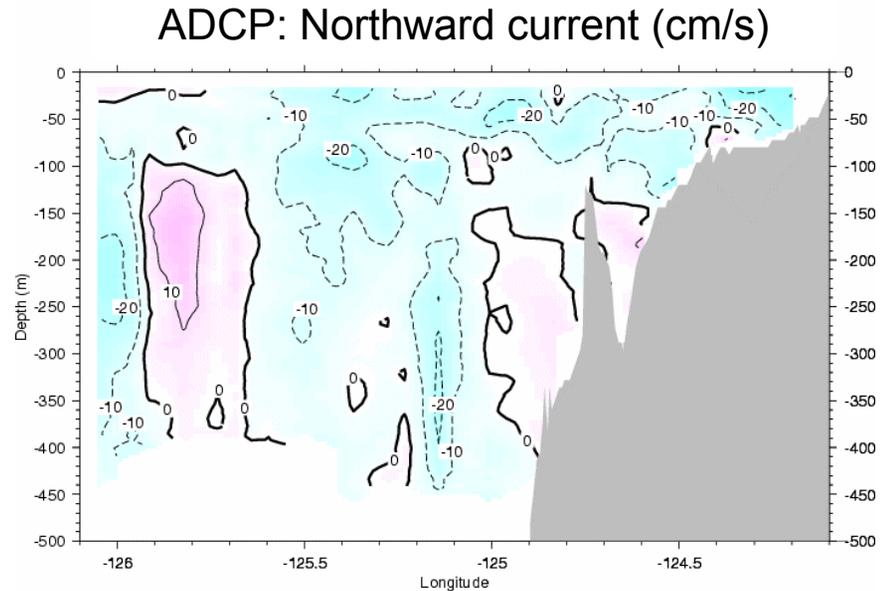
Location of MCSST obs used in the previous plot at tau 48 h over the “SWAFS Americas” grid. Points are color-coded by the magnitude of the deviation (red for deviation > 3C).



Comparison of Global NCOM and Observations Velocity section snapshot off the Oregon Coast



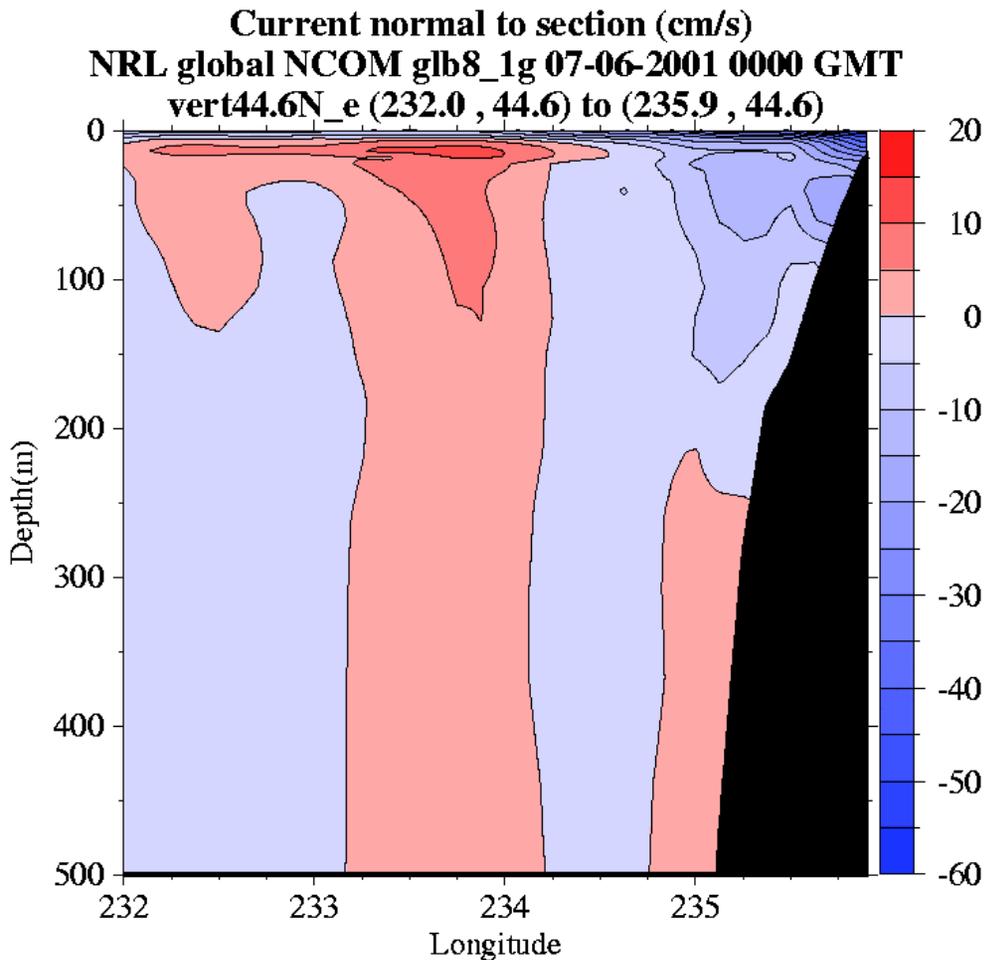
Newport Hydrographic Line 44.6°N
6-7 July 2001



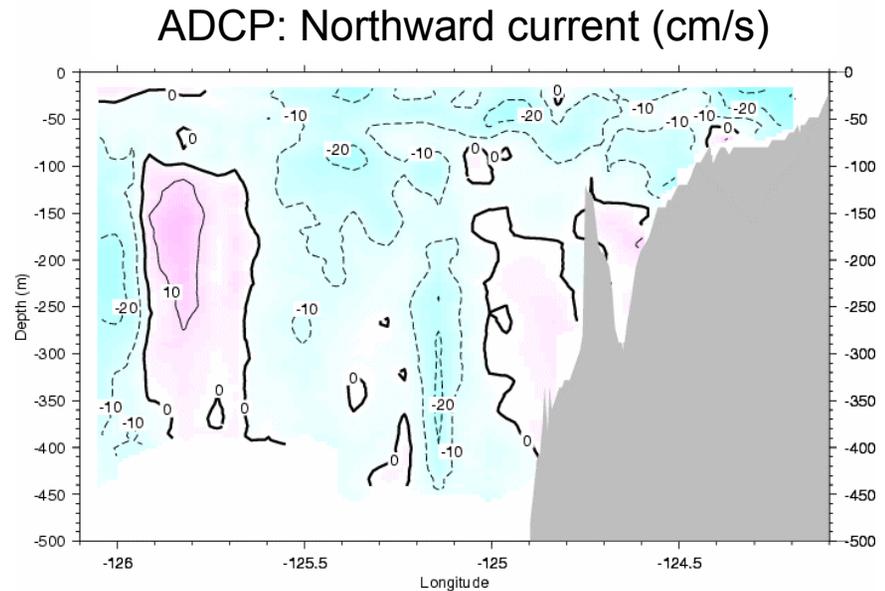
From the Northeast Pacific Long
Term Observation Program

Huyer et. al, Oregon State University

Comparison of Global NCOM and Observations Velocity section snapshot off the Oregon Coast Extended NCOM section



Newport Hydrographic Line 44.6°N
6-7 July 2001



From the Northeast Pacific Long
Term Observation Program

Huyer et. al, Oregon State University