# Global Ocean Prediction Using HYCOM

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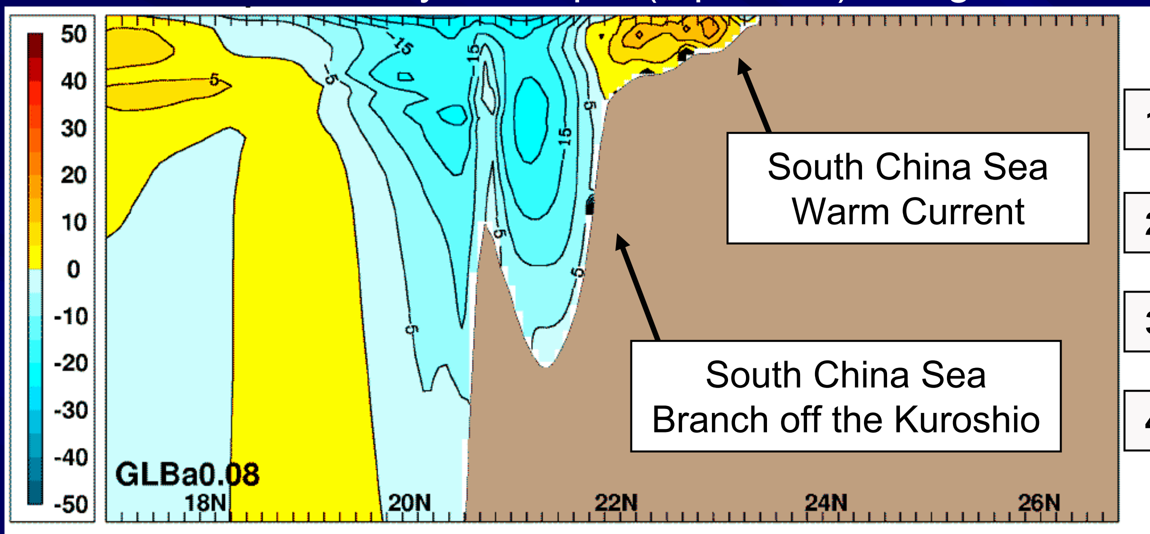
# HYCOM – HYbrid Coordinate Ocean Model

- Developed from MICOM by HYCOM/NOPP Consortium
  - Naval Research Lab, U. Miami, FSU, Los Alamos → GISS
  - Creating a true community ocean model
- Hybrid (generalized) vertical coordinate
  - Isopycnal in open, stratified ocean
  - Terrain-following in shallow coastal regions
  - Z-level in mixed layer and other unstratified regions
  - Generalized – not limited to these types
  - Dynamically smooth transition between coordinate systems
    - Coordinate choice varies in space and time
  - Isopycnals intersecting sloping topography by allowing zero thickness layers
  - Accurate transition between the deep and shallow water
- Existing mixed layer options
  - KPP    Mellor-Yamada 2.5    GISS
  - Kraus-Turner    Price-Weller-Pinkel

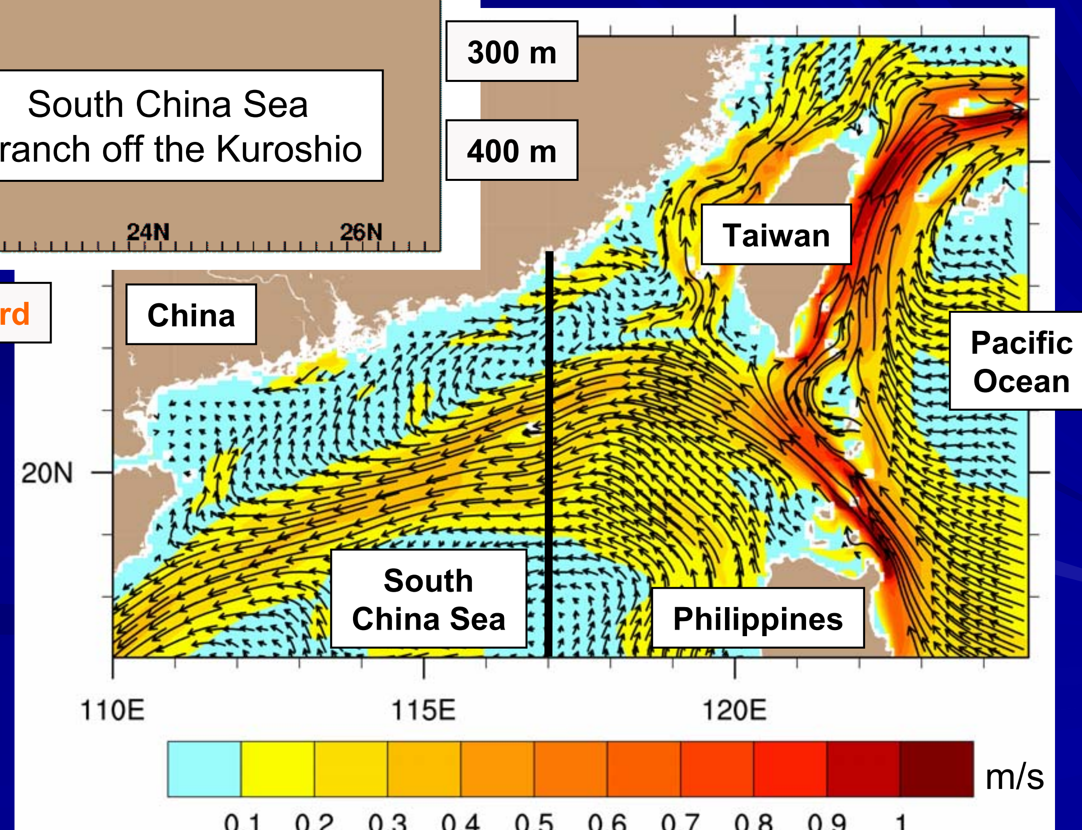
# South China Sea Warm Current Feeding the Taiwan Current

Mean Zonal Velocity vs. Depth (top 500m) Along 117°E




blue = westward, orange = eastward

Layer 1 speed with currents overlaid




HYCOM makes an accurate transition between the deep and coastal waters and can realistically simulate both

# HYCOM Long-term Goals for Operational Ocean Prediction

- 1/12° fully global ocean prediction system (~7 km mid-latitude) transitioned to NAVOCEANO in 2007
  - Include shallow water, minimum depth 5 m
  - Coupled sea-ice model (Los Alamos CICE)
  - Data assimilation (NCODA)

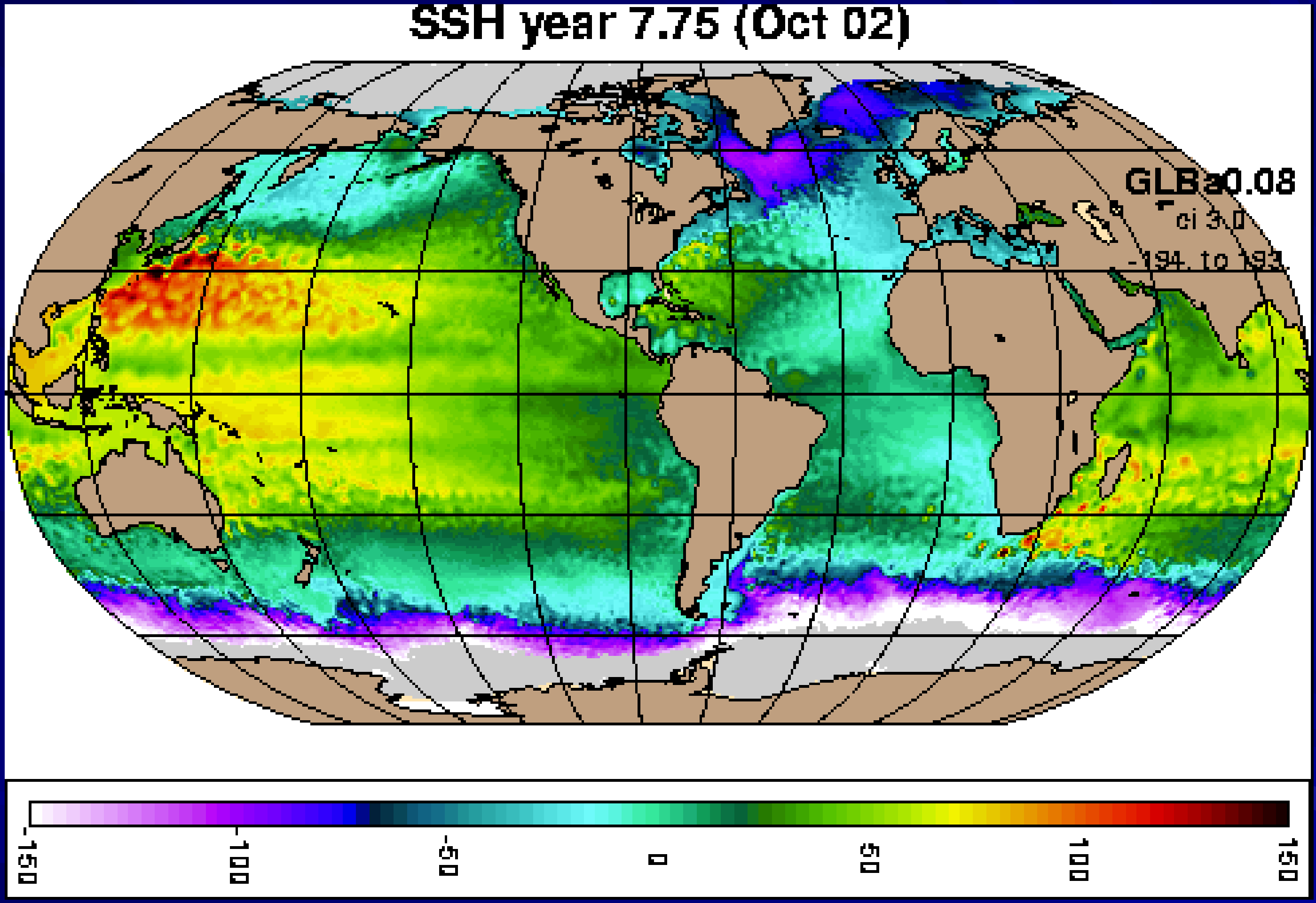
- Increase to 1/25° resolution globally (~3-4 km mid-latitude) by the end of the decade
  - Optimal resolution for basin-scale
  - Boundary conditions for coastal models

# Global HYCOM Configuration

- Horizontal grid: 1/12° equatorial resolution
  - 4500 x 3298 grid points, ~6.5 km spacing on average, ~3.5 km at pole
- Mercator 79°S to 47°N, then Arctic dipole patch
- Vertical coordinate surfaces: 32 for $\sigma_2$*
- GISS mixed layer model
- Thermodynamic (energy loan) sea-ice model
- Surface forcing: wind stress, wind speed, thermal forcing, precipitation, relaxation to climatological SSS
- Monthly river runoff (986 rivers)
- Initialize from January climatology (GDEM3) T and S, then SSS relaxation from PHC 3.0
  - No subsurface relaxation to climatology

# 1/12° Global HYCOM

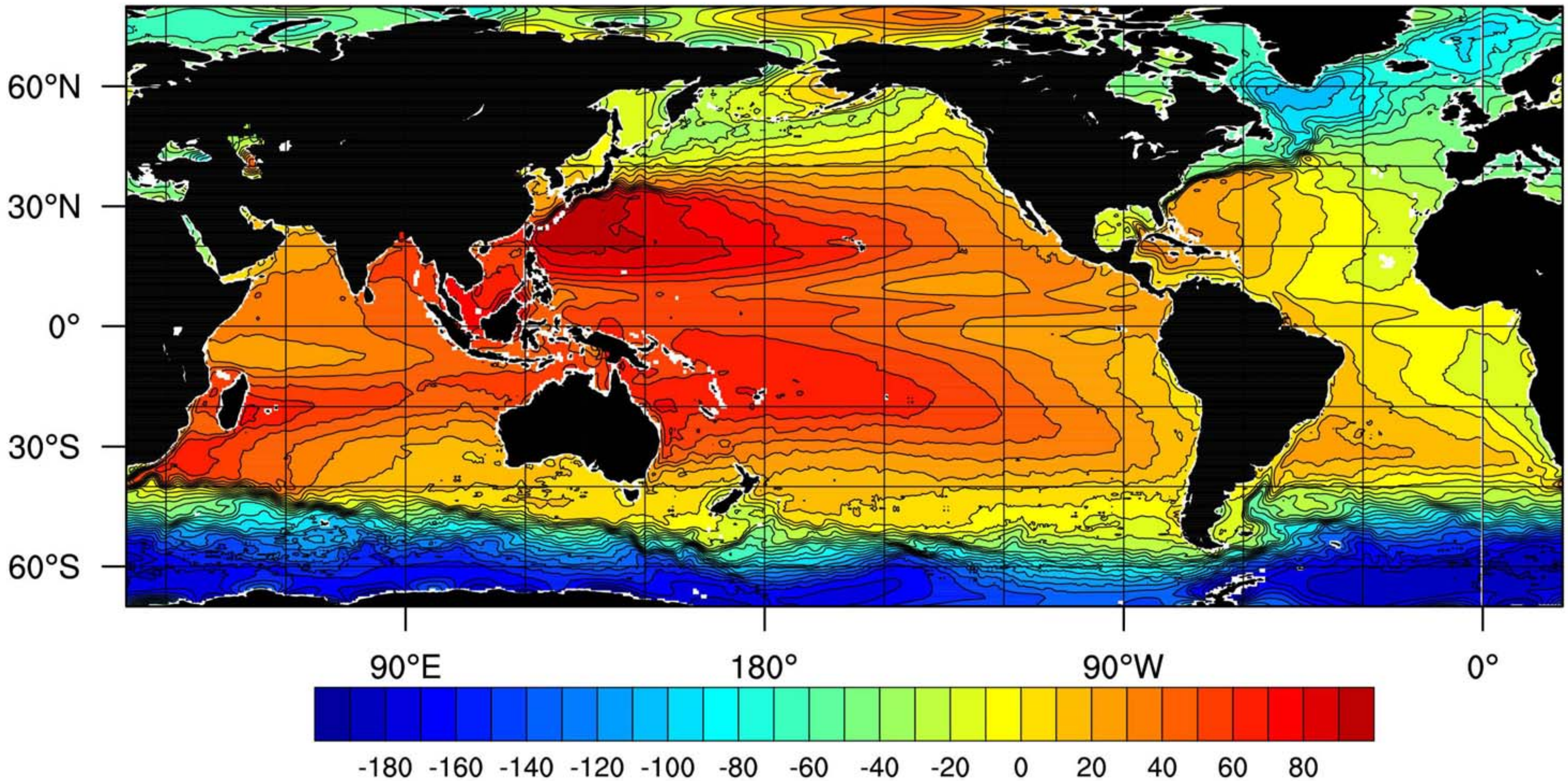
## Sea surface height and ice (gray)




- Running at NAVOCEANO on IBM Power 4+ (kraken)
- 216K CPU hrs/model year on 784 processors
- 3.1 Tb/model year for (compressed) daily 3-D output

# Long-term Mean Global Sea Level

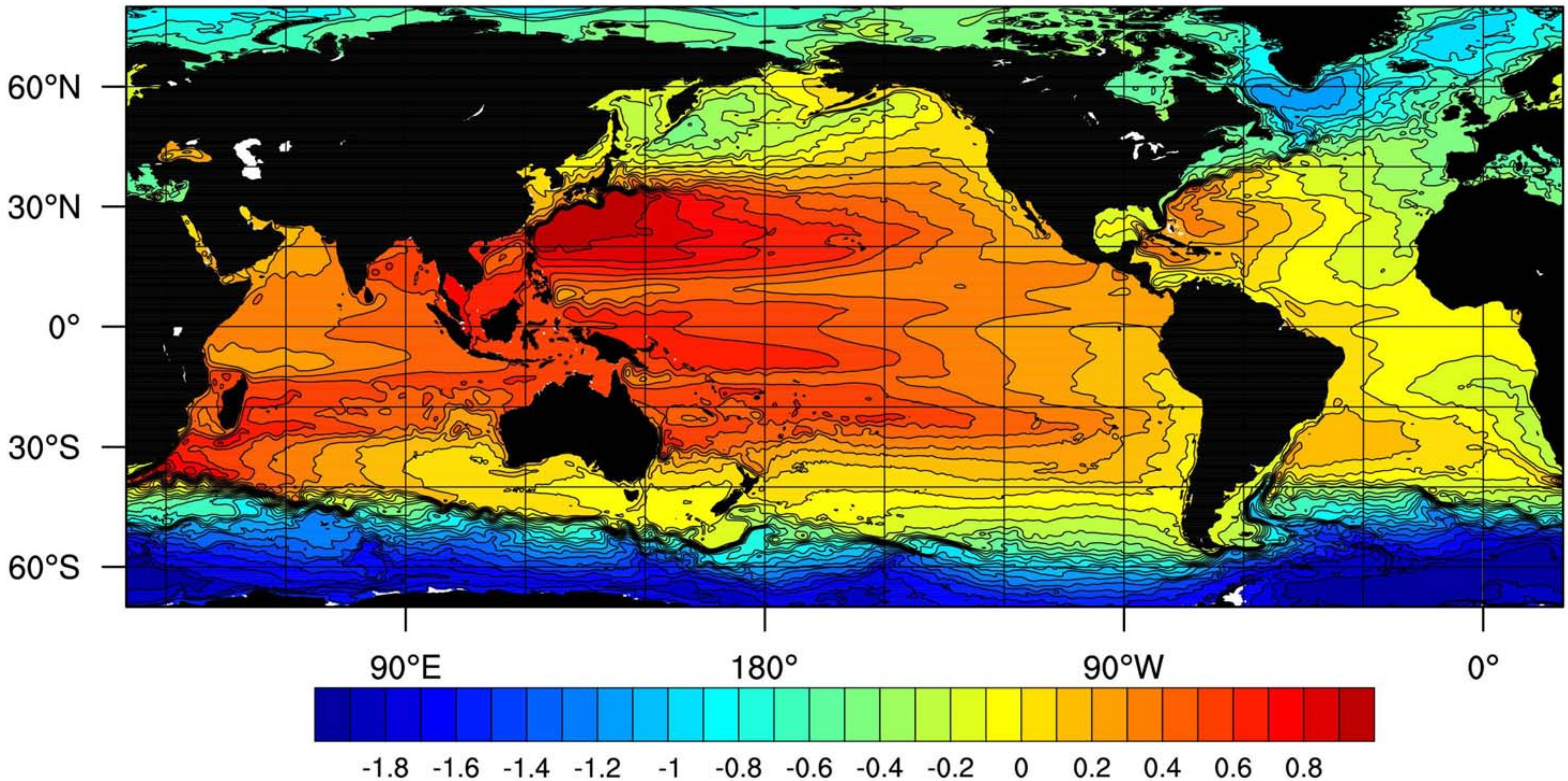
## 1992-2002 Mean Dynamic Ocean Topography (0.5°)




The 1992-2002 mean ocean dynamic topography data has been obtained from Nikolai Maximenko (IPRC) and Peter Niiler (SIO)

# Long-term Mean Global Sea Level

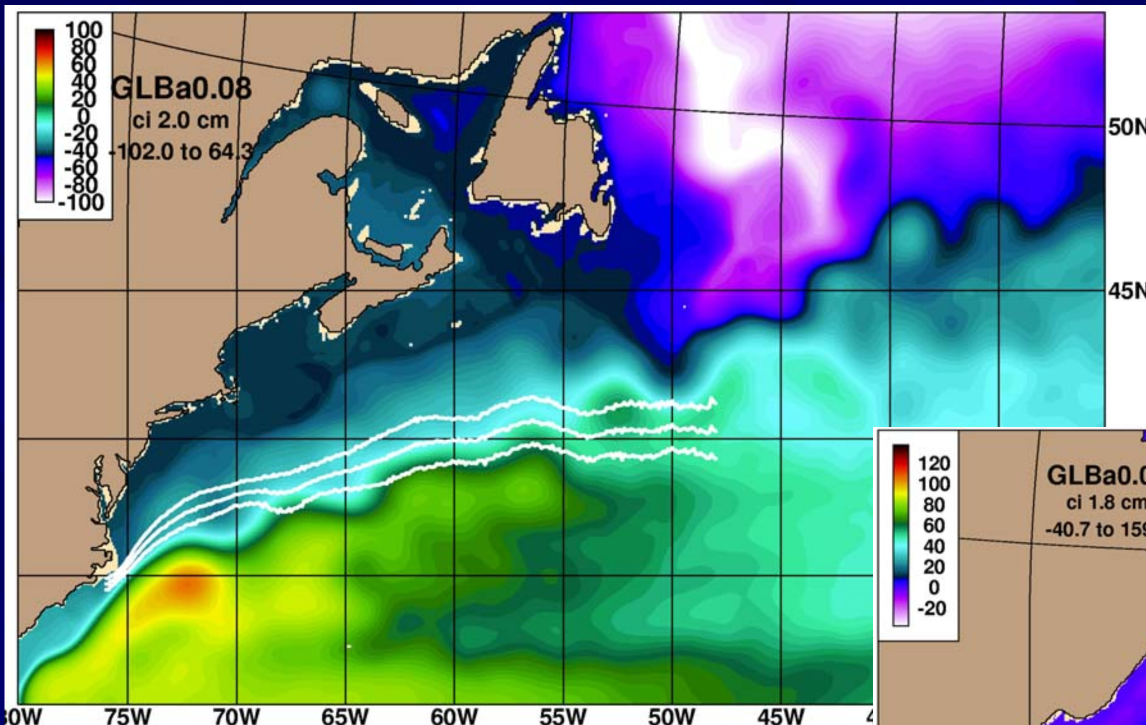
## 1/12° global HYCOM

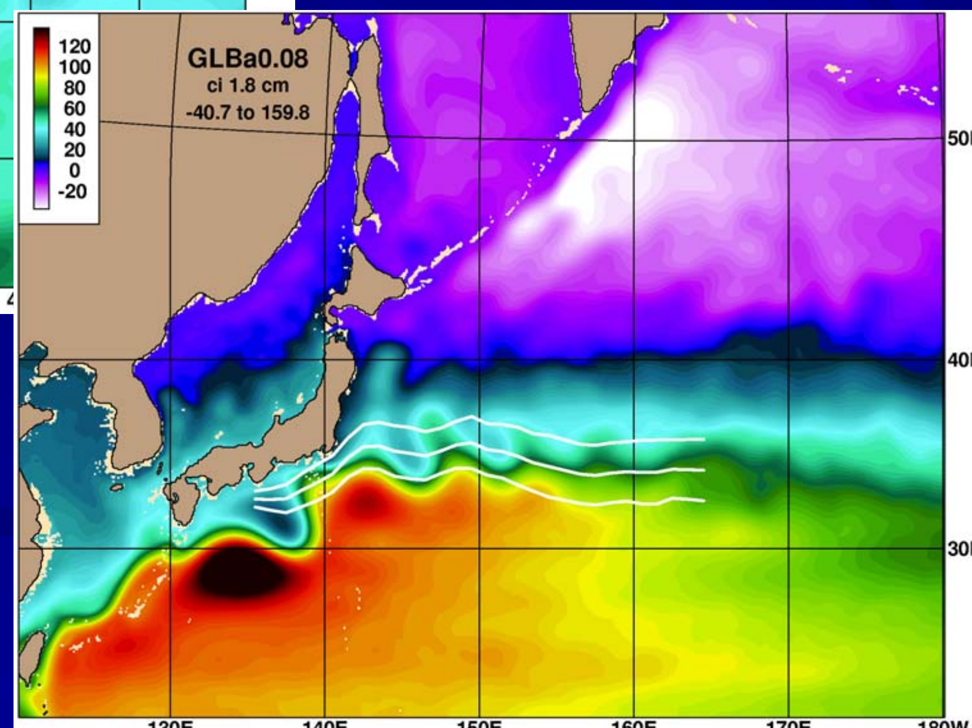



5 year model mean using climatological ECMWF wind and thermal forcing
HYCOM mean shifted by 10 cm

# 1/12° Global HYCOM

## Mean Gulf Stream and Kuroshio pathways



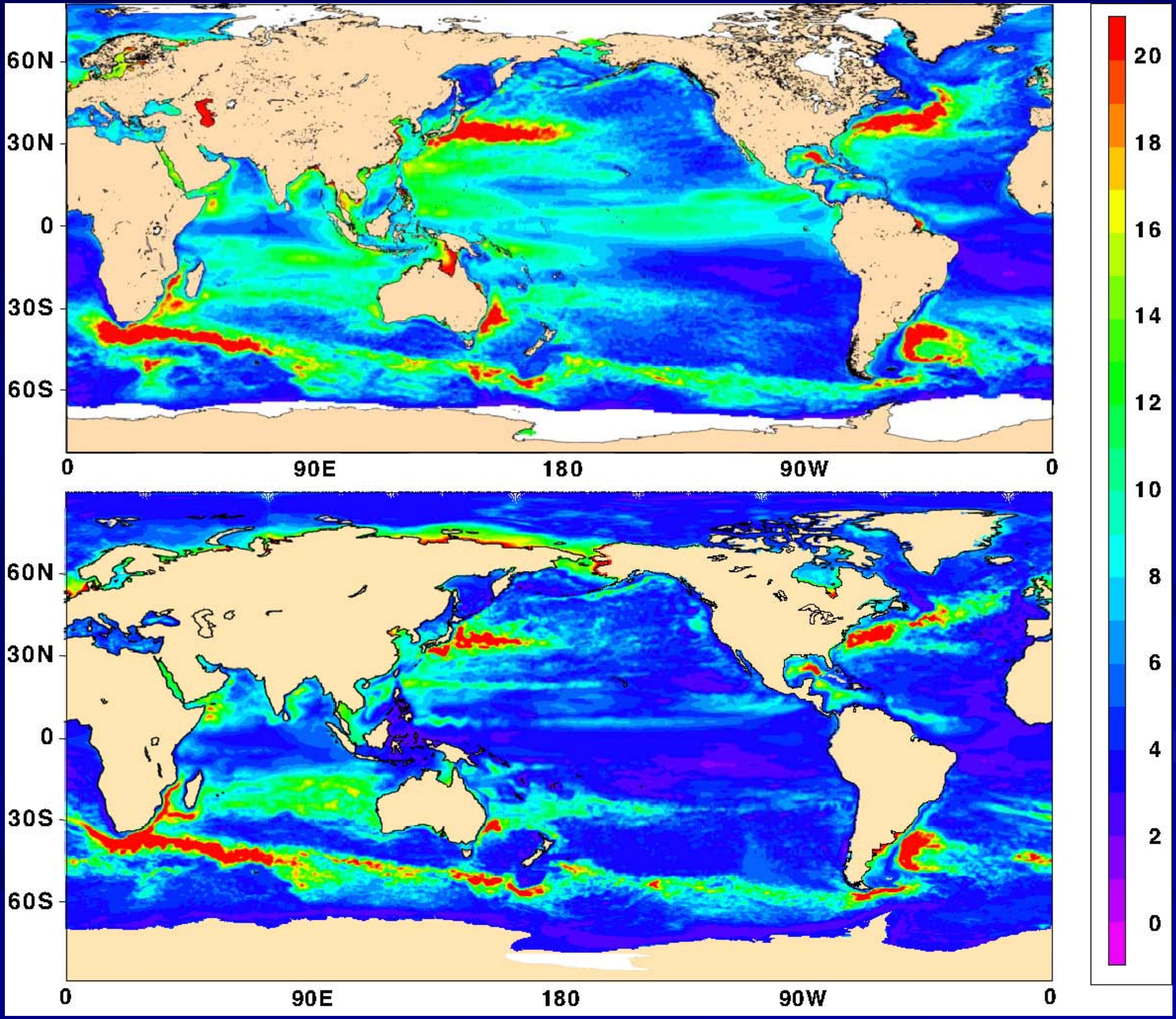




Mean over five model years

ERA15 climatological wind & thermal forcing

# Sea Surface Height (SSH) Variability

## Satellite altimetry (top) vs. 1/12° global HYCOM (bottom)



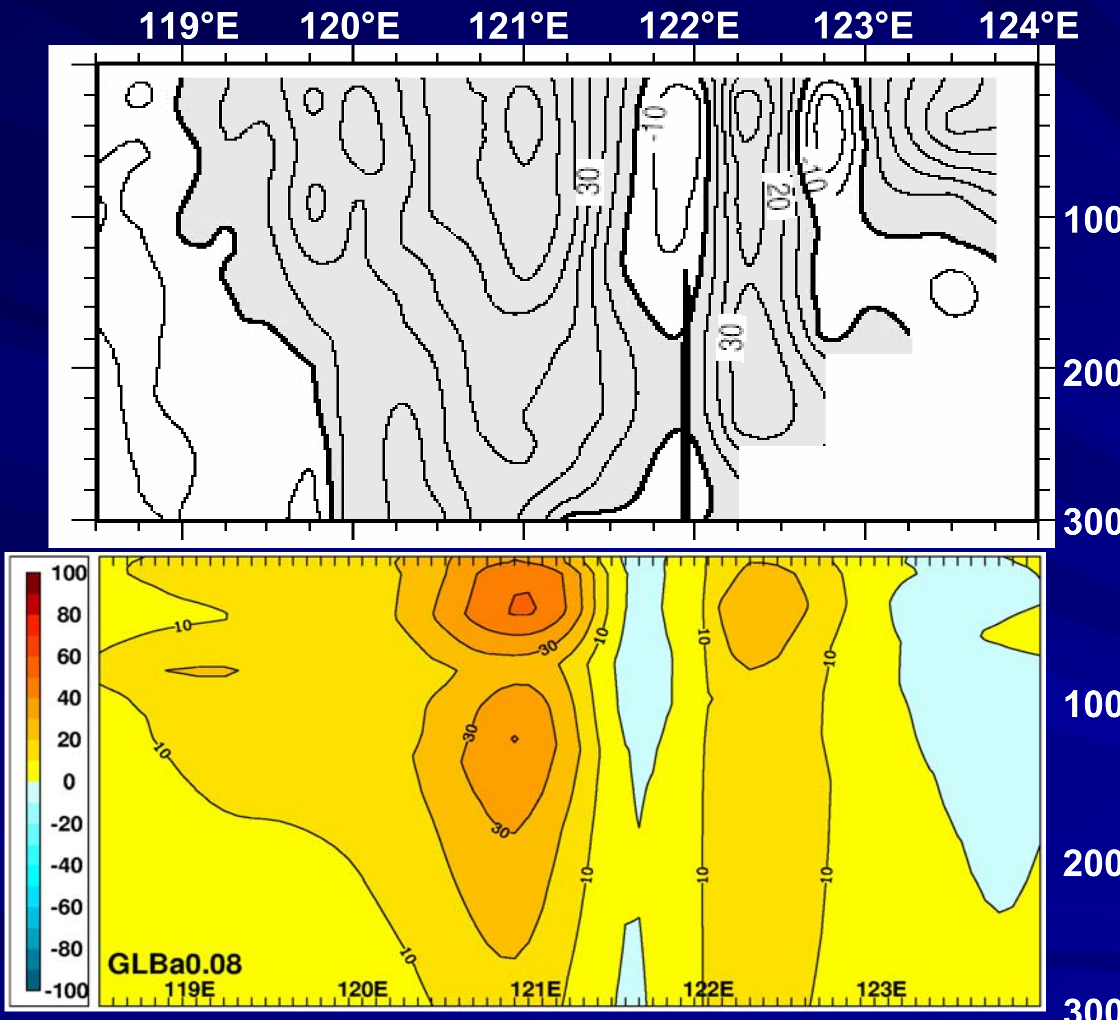

1992 – 2005 SSH variability based on T/P, ERS-1, and ERS-2 altimeters

SSH variability from 1/12° global HYCOM $\sigma_2$* with climatological wind and thermal forcing

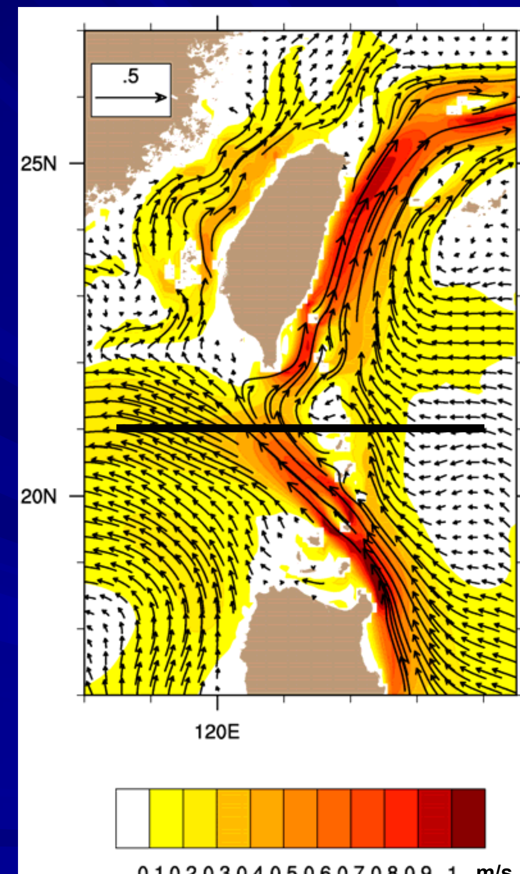
Global HYCOM is reproducing the expected eddy structure

# Velocity Cross-section Along Luzon Strait

## Sb-ADCP data (top) vs. 1/12° global HYCOM (bottom) in the upper 300 m
## Section along 21°N between 118.5°E and 124.0°E




Cross-section overlaid on mean currents and speed

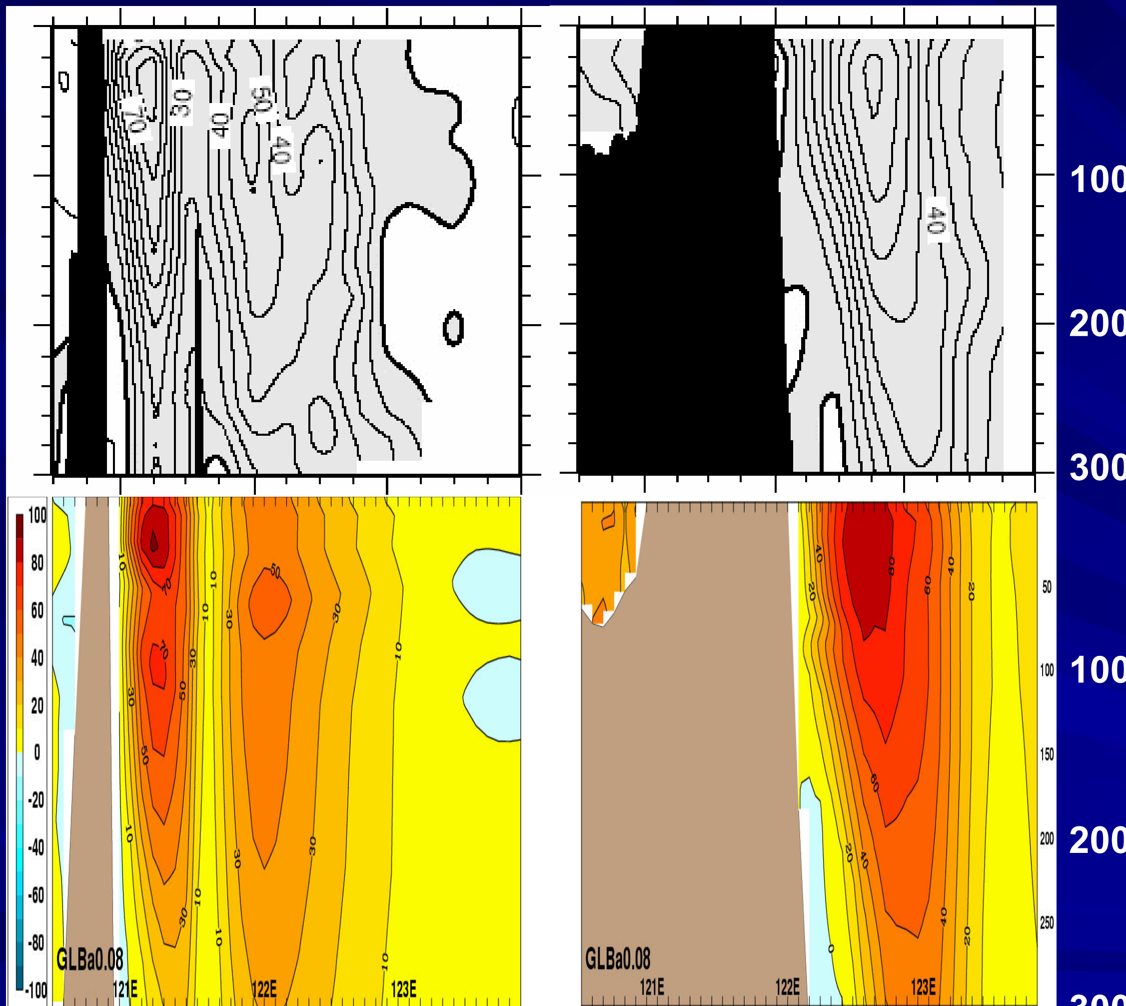



Sb-ADCP data from Liang et al. (2003, DSR Pt. II)
Mean from HYCOM with ERA15 wind and thermal forcing
No ocean data assimilation in HYCOM

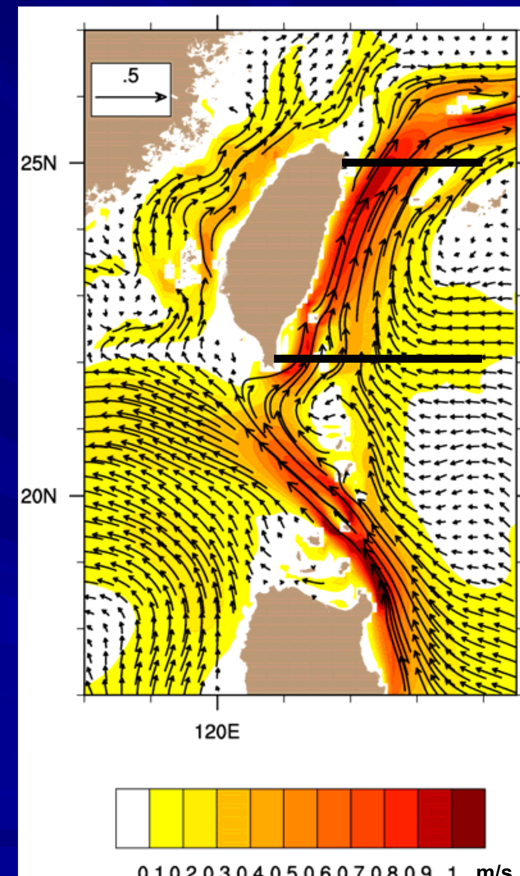
# Velocity Cross-section East of Taiwan

## Sb-ADCP data (top) vs. 1/12° global HYCOM (bottom) in the upper 300 m

## Sections at 22°N (left) and 25°N (right), Taiwan coast to 124°E



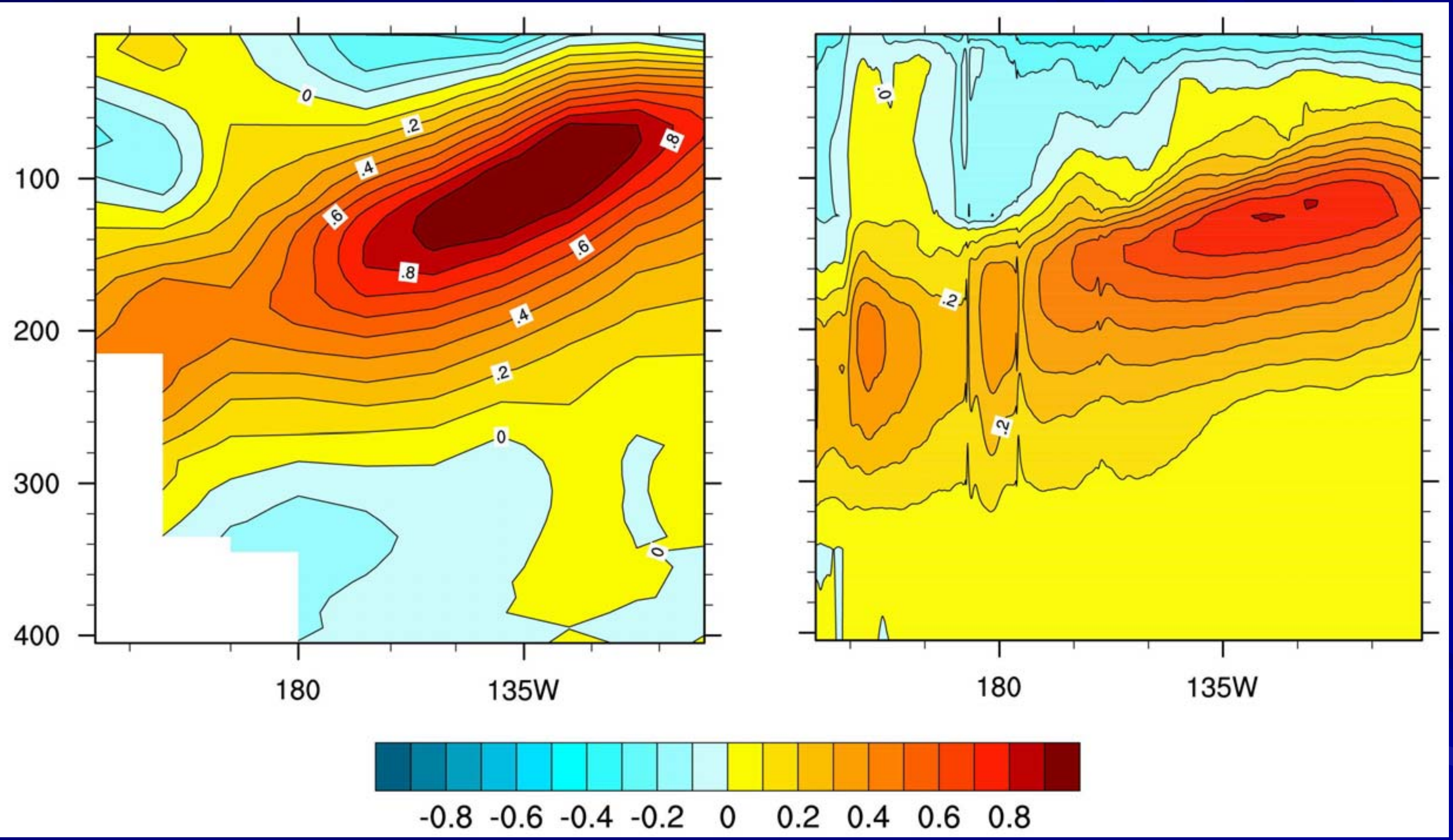

Cross-section overlaid on mean currents and speed




Sb-ADCP data from Liang et al. (2003, DSR Pt. II)
Mean from HYCOM with ERA15 wind and thermal forcing
No ocean data assimilation in HYCOM

# Velocity Cross-section Along the Equatorial Pacific

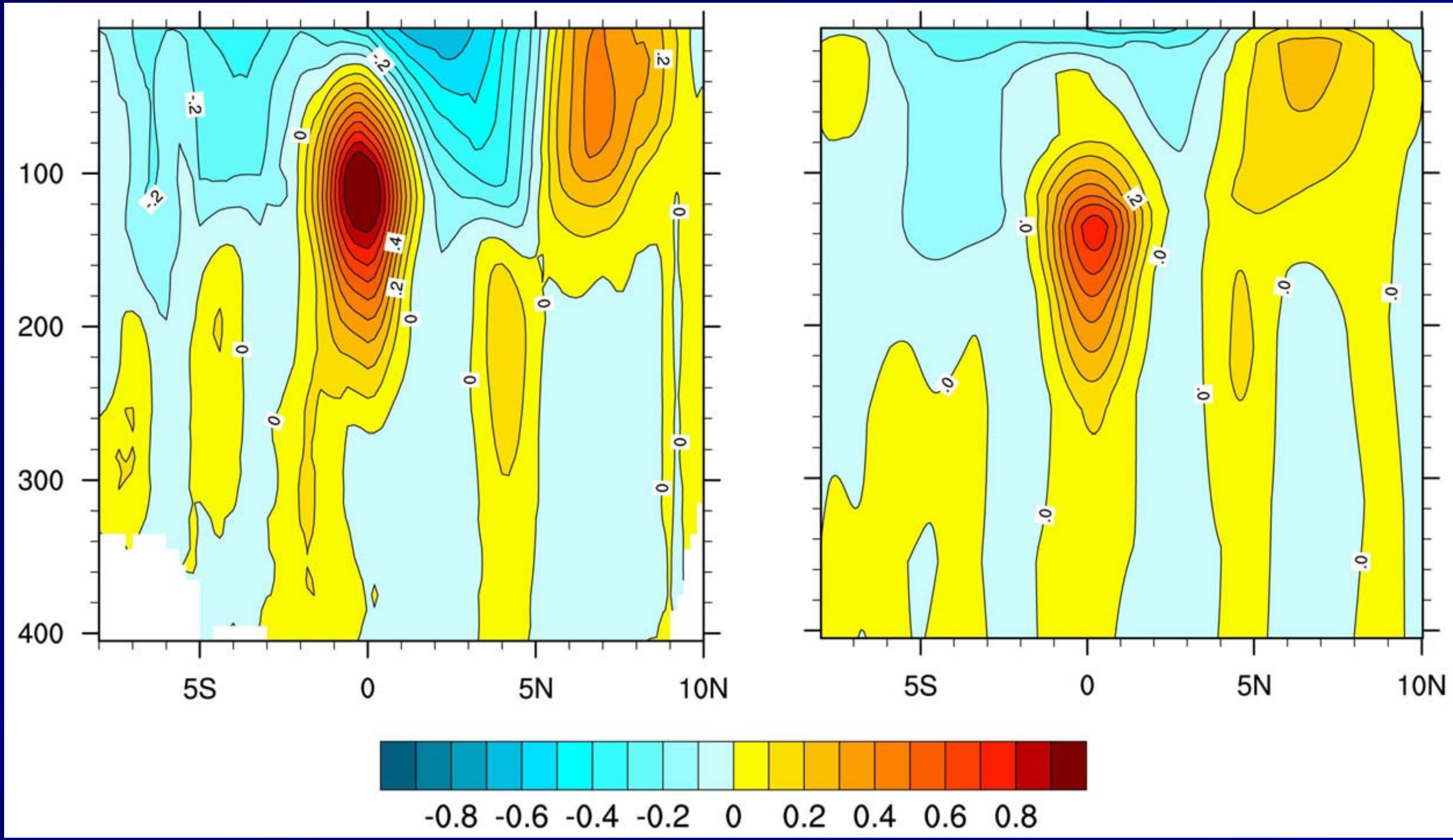
TOGA TAO data (left) vs. 1/12° global HYCOM (right) in the upper 400 m
Section between 143°E and 95°W




TOGA TAO data from Johnson et al. (2002, Prog. Oceanogr.)
5 year mean from HYCOM using high-frequency ECMWF winds and thermal forcing
No ocean data assimilation in HYCOM

# Velocity Cross-section Across Equator at 140°W

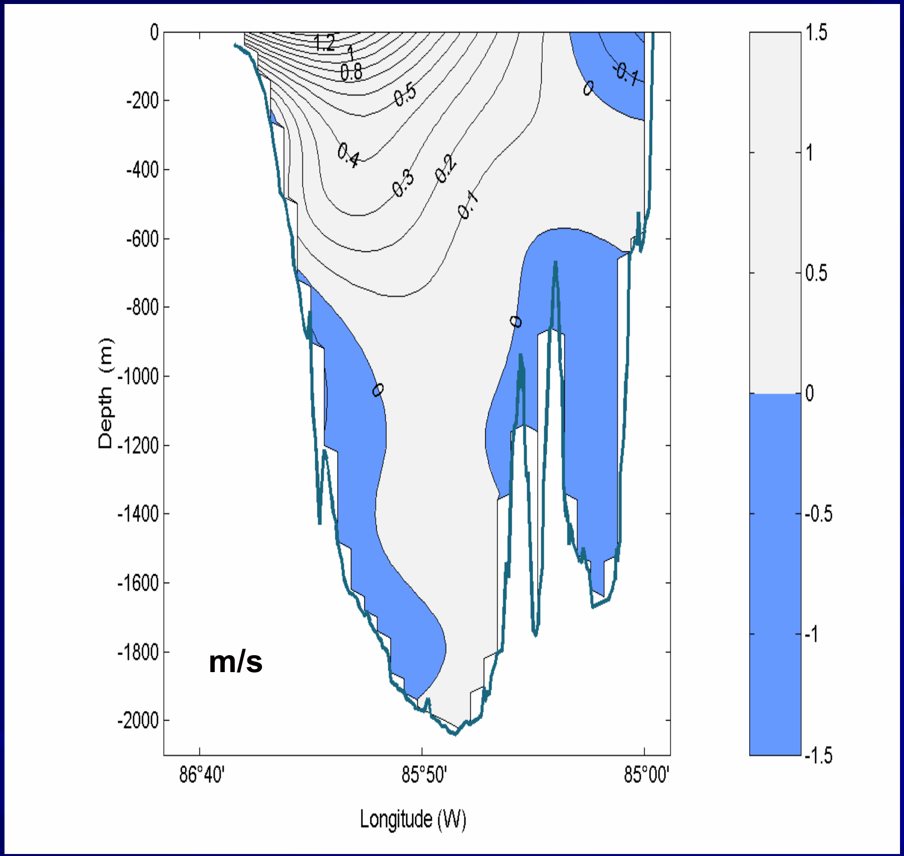
TOGA TAO data (left) vs. 1/12° global HYCOM (right) in the upper 400 m
Section between 8°S and 10°N

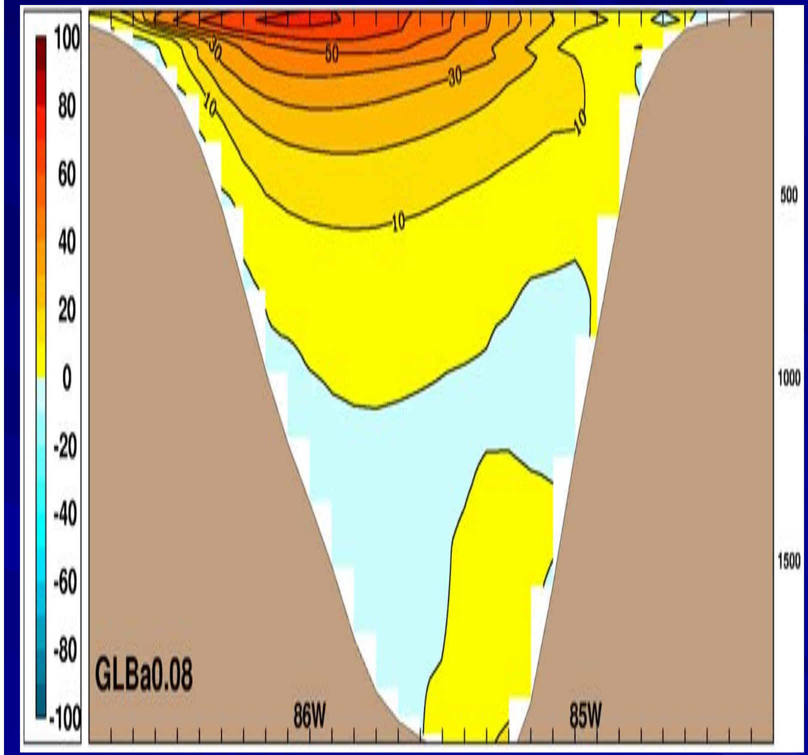



TOGA TAO data from Johnson et al. (2002, Prog. Oceanogr.)
5 year mean from HYCOM using high-frequency ECMWF winds and thermal forcing
No ocean data assimilation in HYCOM

# Velocity Cross-section Across Yucatan Channel

Mooring data (left) vs. 1/12° global HYCOM (right) in top 2200 m



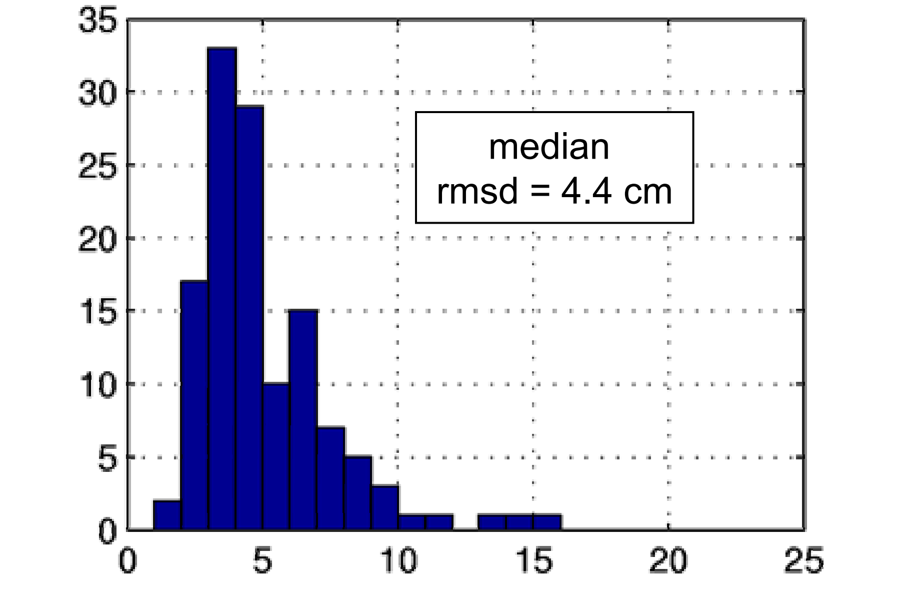




From Candela et al. (2002, GRL)

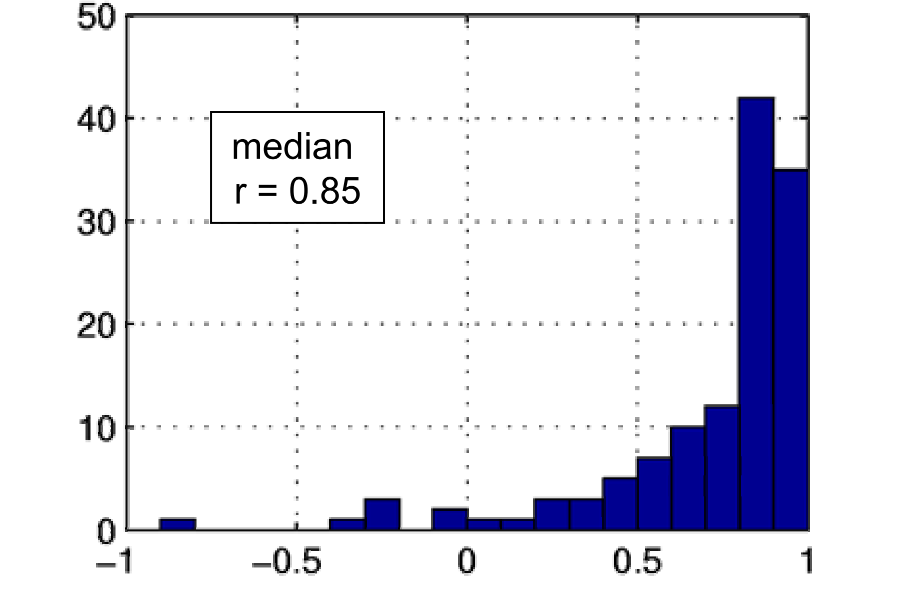
# Coastal/Island Sea Level Comparison From 1/12° Global HYCOM

2003 statistics at 126 tide gauge stations

RMS Difference

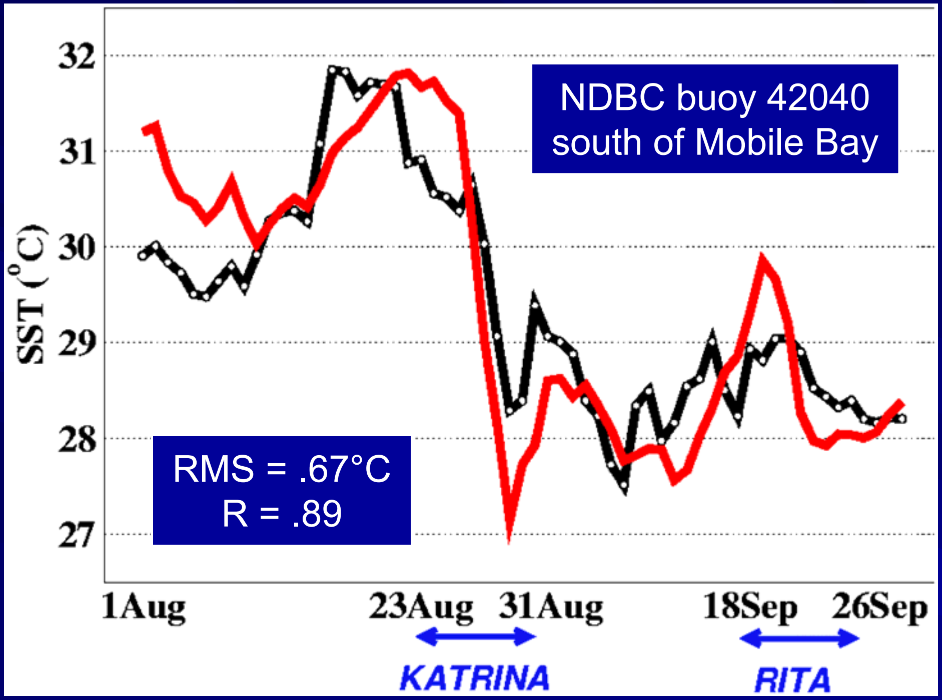


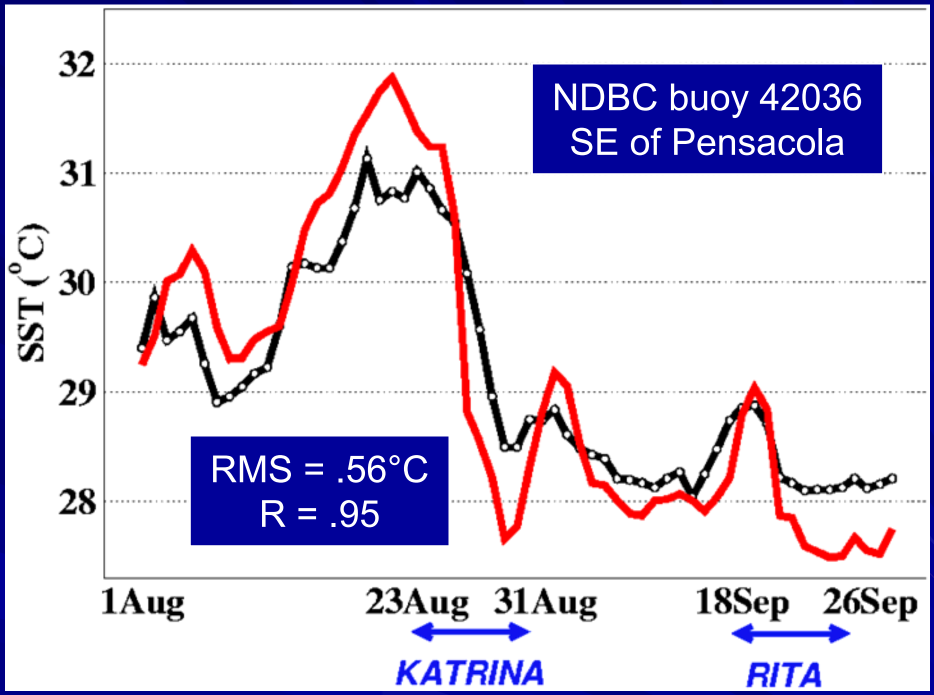

Correlation




Global HYCOM is reproducing the deterministic response to the wind-driven circulation

# SST Response in 1/12° Global HYCOM to Hurricanes Katrina and Rita



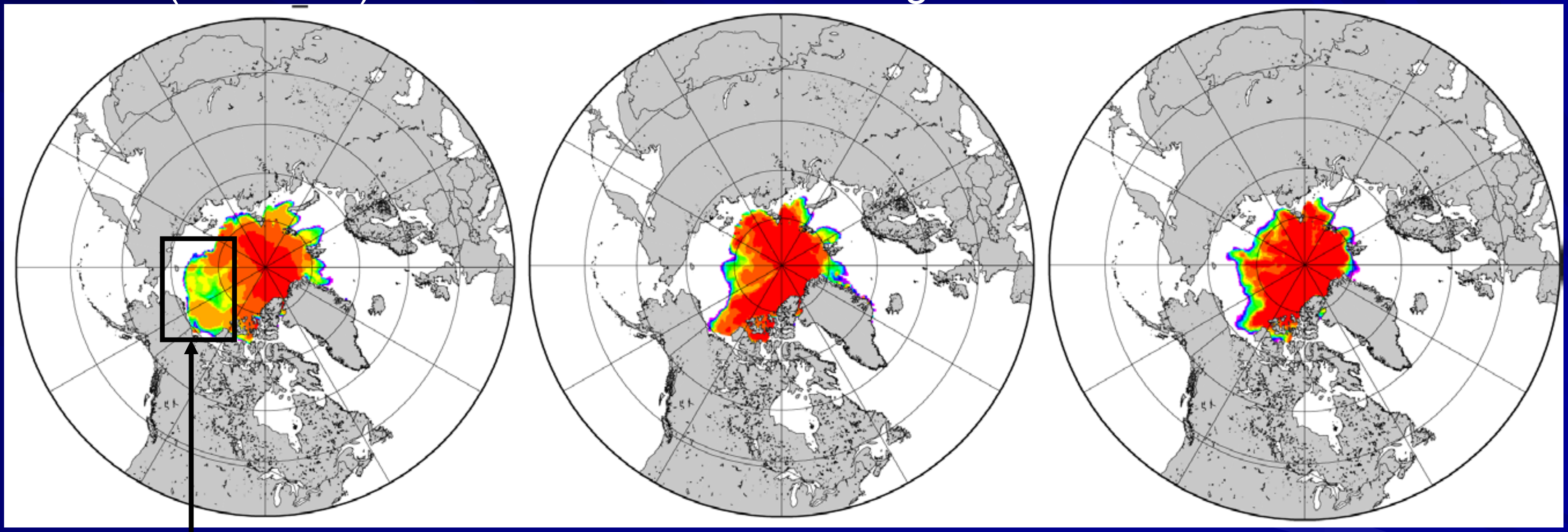




HYCOM reproduces the deterministic SST response to the wind forcing. Implies realistic upwelling and mixing of subsurface waters as well as realistic atmospheric wind and heat flux forcing in HYCOM.

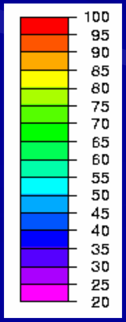
# One-way File-based Coupling Between HYCOM and CICE (PIPS 3.0)

## Sea Ice Concentration (%) - September 2003

CICE stand-alone (no ocean) | CICE with HYCOM forcing | SSMI observations



Too much ice

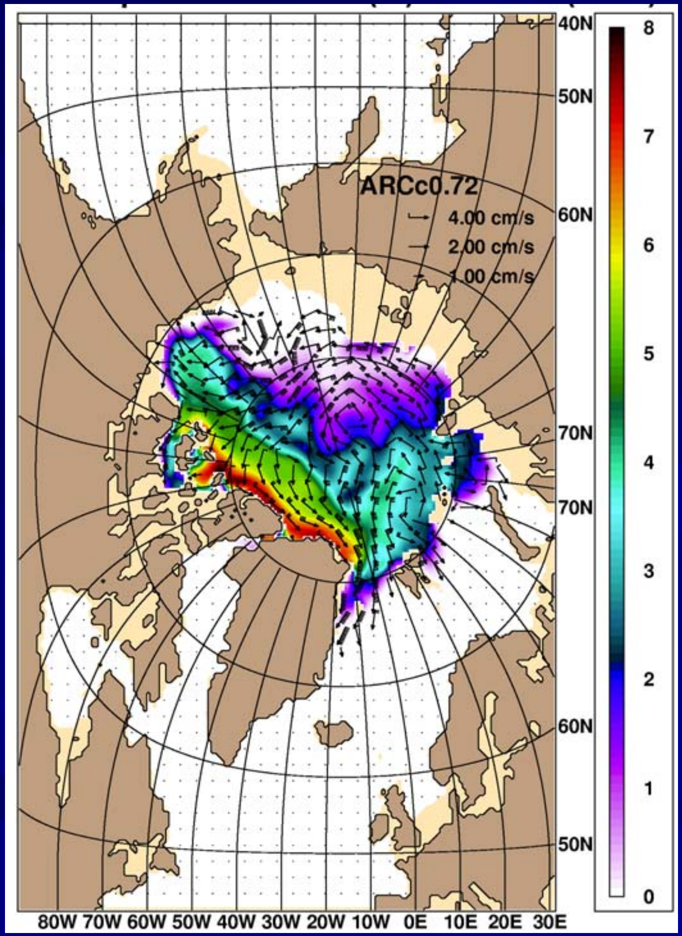



Coupling between the ocean and ice models more properly accounts for the momentum, heat and salt fluxes at the air/sea interface

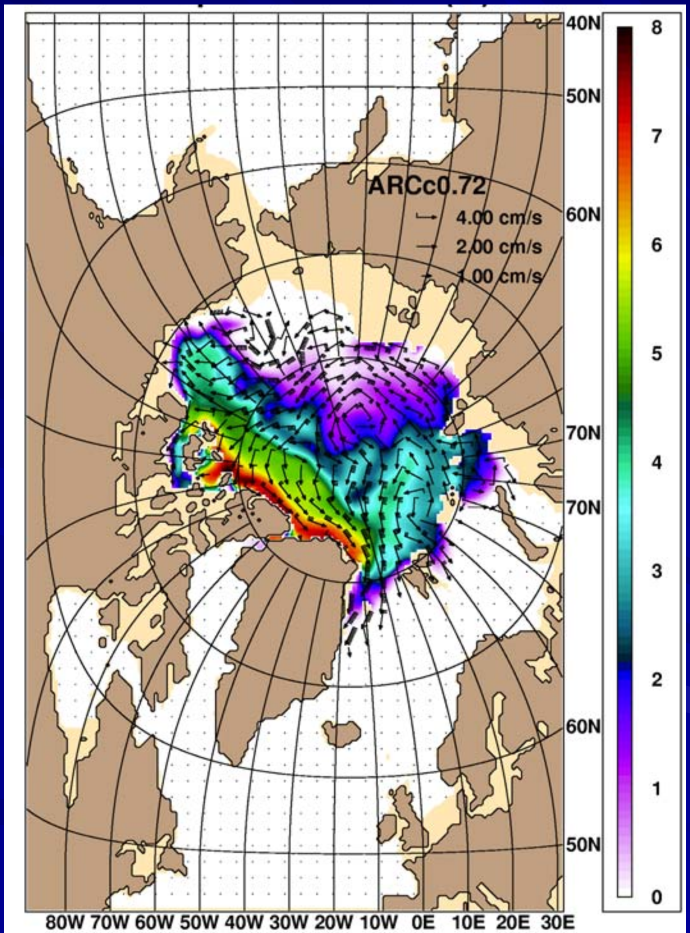
# ESMF-based Coupling Between .72° Arctic HYCOM and CICE

## Sea Ice Thickness (m) and Drift - September 2003

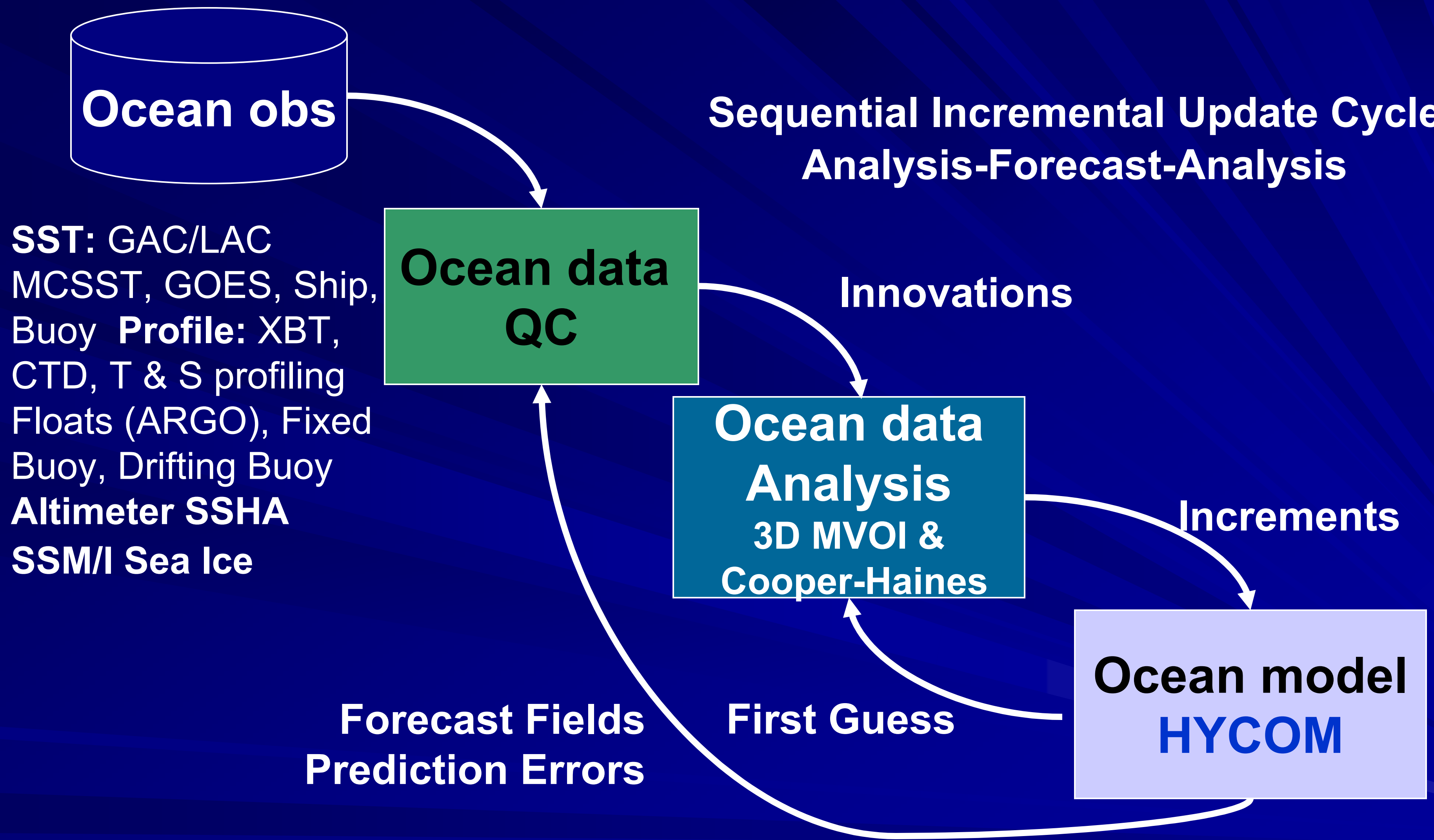
File-based coupling




ESMF-based one-way coupling



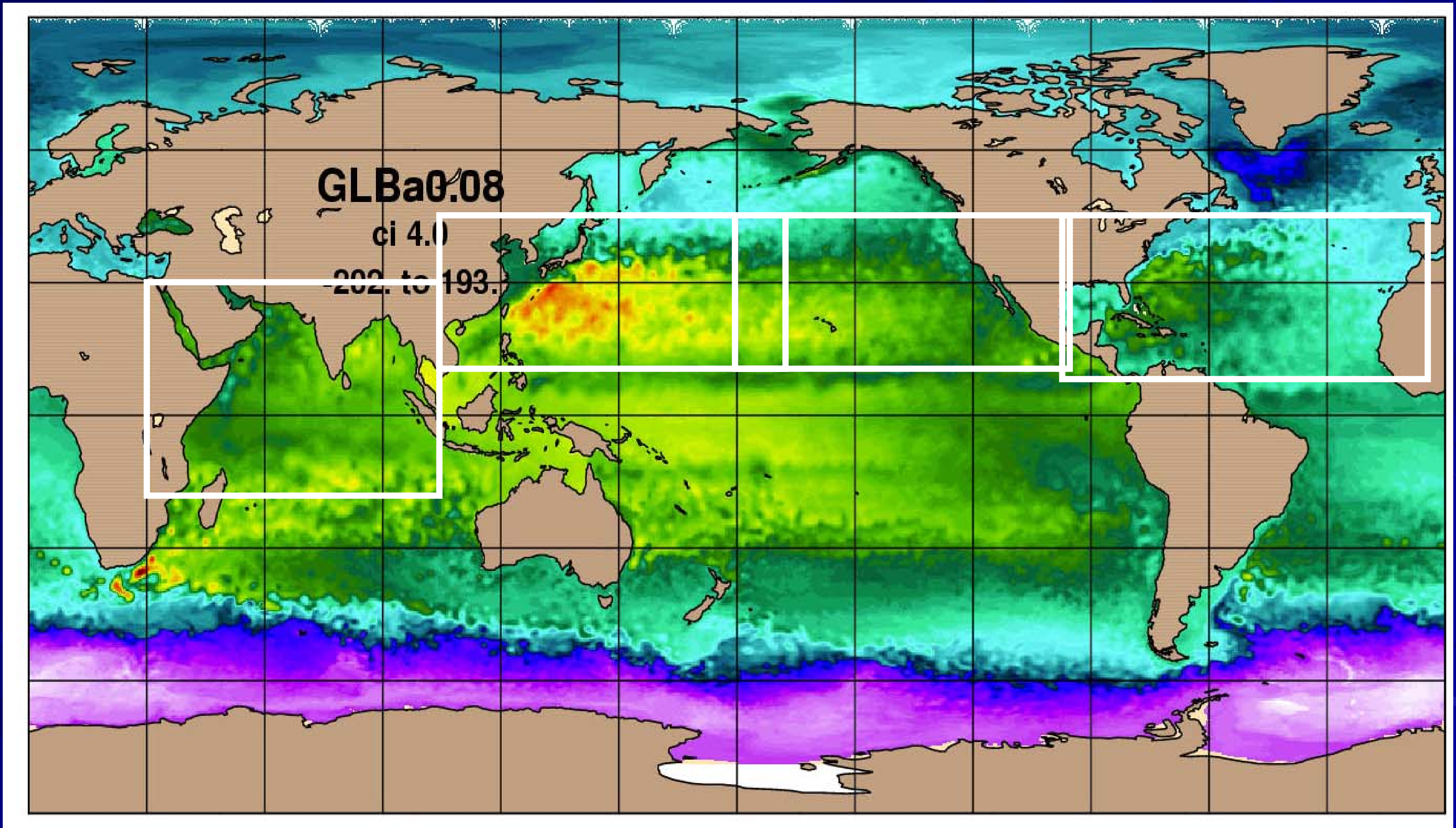
# NRL Coupled Ocean Data Assimilation (NCODA)




**MVOI - simultaneous analysis 5 ocean variables**
**temperature, salinity, pressure, velocity (u,v)**

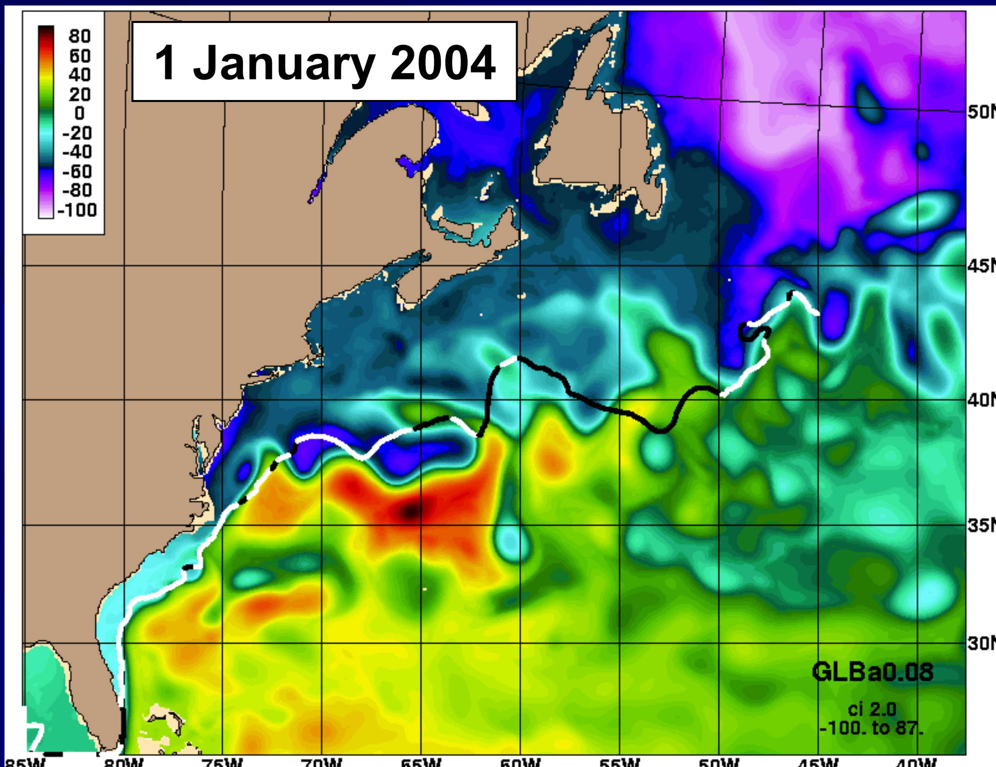
# Data Assimilation Subregions

## Overlaid on SSH valid at 5 January 2004



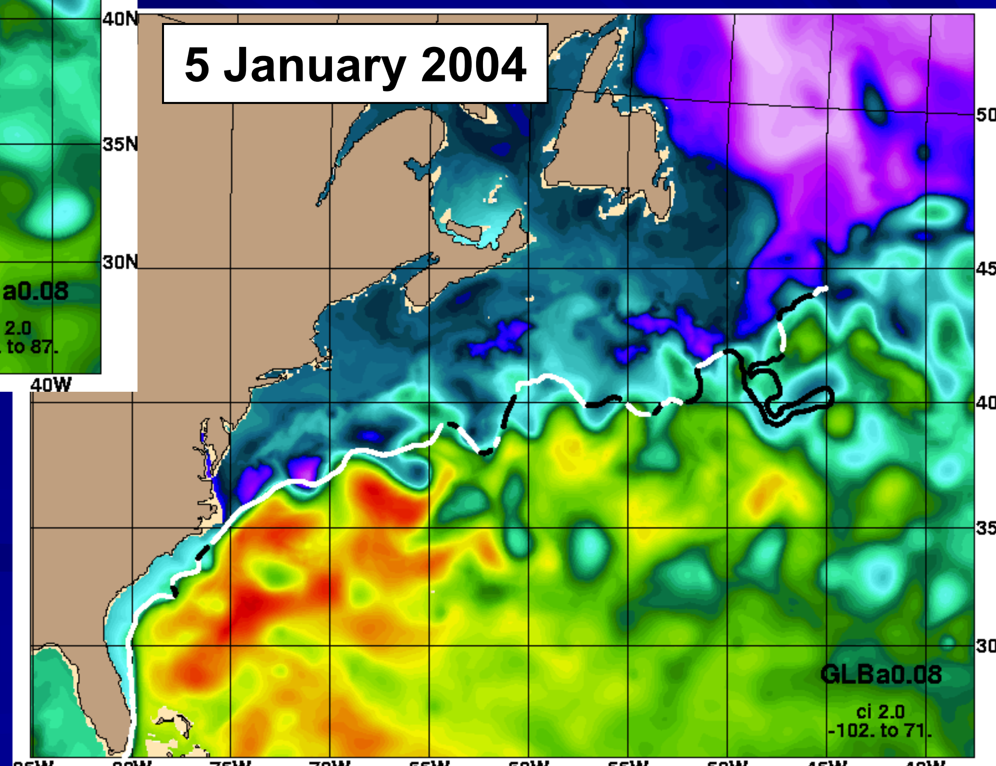
# Data Assimilation in Global HYCOM

## Gulf Stream SSH with SST-based frontal analysis overlaid




← **Initial state**

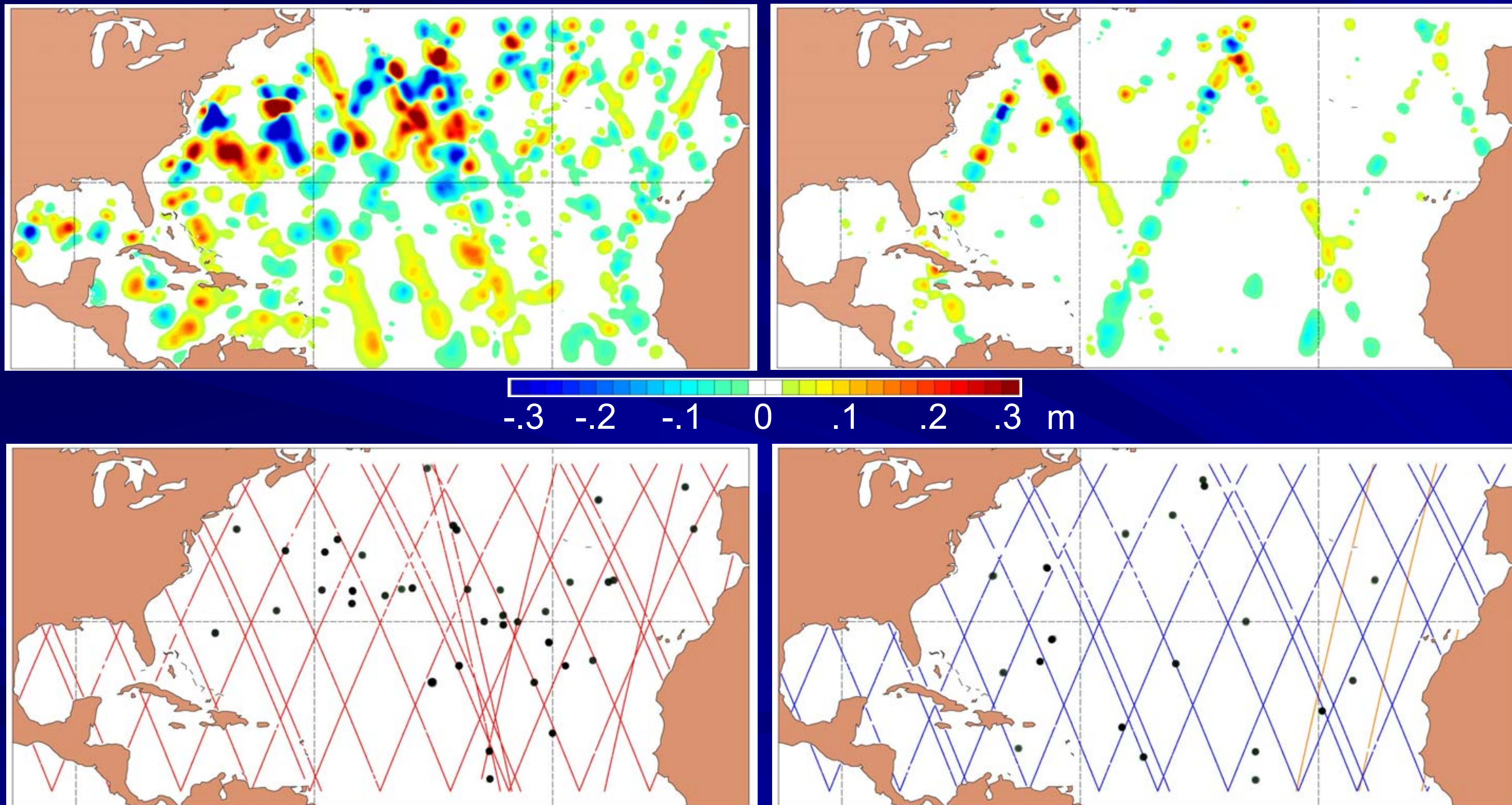
**After five assimilation cycles ↓**




Frontal analysis < 4 days old = white,
analysis ≥ 4 days old = black

# Sea Surface Height Increments (top) and Observation Locations (bottom)

1 January 2004 | 5 January 2004




Lines: altimeter tracks; black dots: *in situ* observations

# Future Plans

- FY06:
  - Final non-assimilative spin-up experiment (with improved wind/thermal forcing and CICE)
  - Multiple data-assimilative experiments over the period May 2001 – June 2002 to tune and refine the assimilation technique
  - May 2001 to present data-assimilative hindcast
  - Start a near real-time runs that mimic the expected operational procedure

# Future Plans

- FY07:
  - Continue May 2001-June 2002 experiments, some with “advanced” assimilation
  - Complete a 1993-present “ocean reanalysis” by running a data-assimilative hindcast from 1993 up through May 2001
  - Two non-assimilative simulations:
    - 1995-2007 NOGAPS forcing
    - 1979-2006 ECMWF forcing
  - Ten year 1/25° Atlantic demonstration