High Resolution Global Ocean Modeling and Prediction

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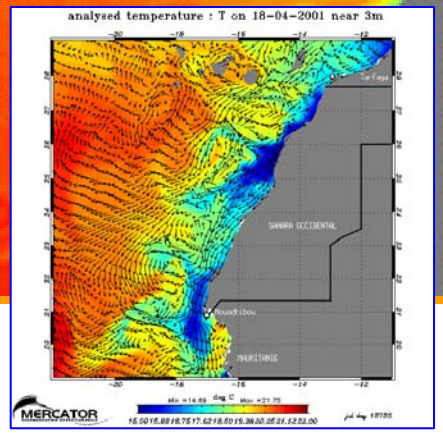
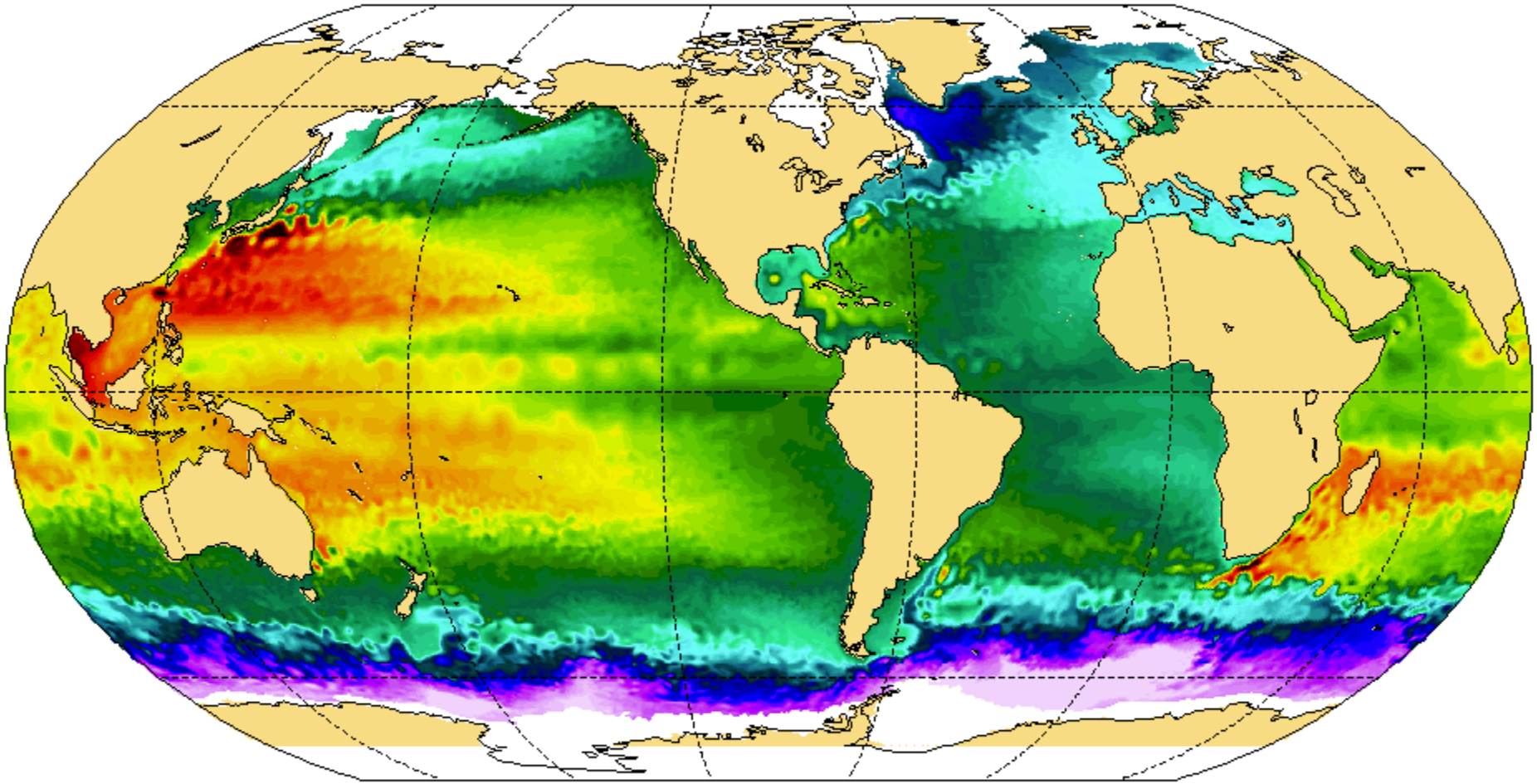
Florida State University



Theme of the Year - May 6, 2008



The Global Ocean Data Assimilation Experiment (GODAE)

Objective: **To provide a practical demonstration of real-time operational global oceanography**

- Regular comprehensive description of the ocean circulation at high temporal and spatial resolution
- Consistent with a suite of remote and in-situ measurements and appropriate dynamical and physical constraints

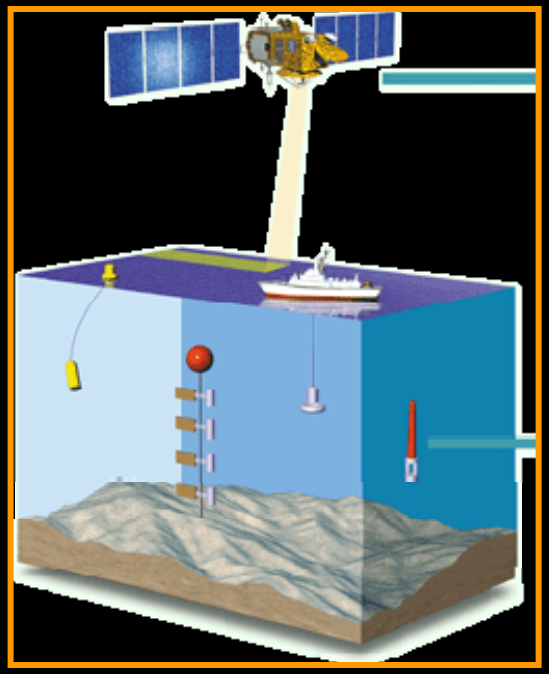
Includes the main operational and research institutions from Australia, Japan, the United States, and Europe (United Kingdom, France, Norway, Italy, …).

Main demonstration phase: 2003 - 2005 Consolidation phase: 2006 - 2008

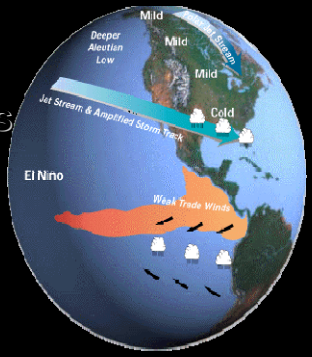
Climate and seasonal forecasting, marine safety, fisheries, the offshore industry, NOAA/Navy applications, and management of shelf/coastal areas are among the beneficiaries of GODAE.

The integrated description of the ocean that GODAE is providing is also highly beneficial to the research community.

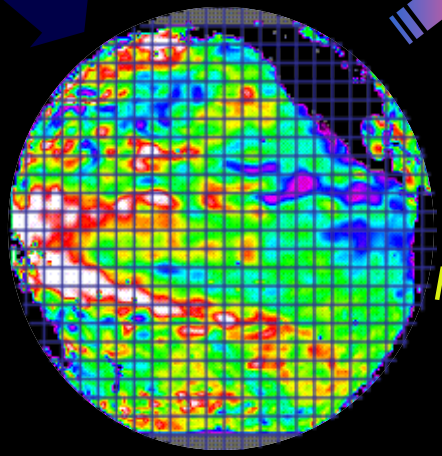
Building the Systems

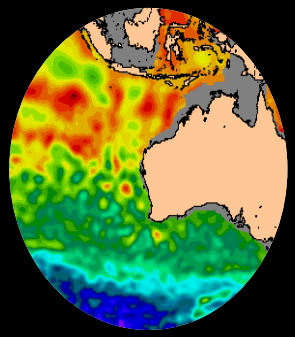


Climate Predictions



Regional Predictions





Models: consistent analyses

U.S. GODAE: Global Ocean Prediction with

Community Effort: NRL, U. of Miami, FSU, NASA-GISS, NOAA/NCEP, NOAA/AOML, NOAA/PMEL, PSI, FNMOC, NAVOCEANO, SHOM, LEGI, OPeNDAP, UNC, Rutgers, USF, Fugro-GEOS, Orbimage, Shell, ExxonMobil

HYCOM
HYbrid Coordinate Ocean Model

Objectives and Goals

- A broad partnership of institutions that collaborate in developing and demonstrating the performance and application of eddy-resolving, real-time global and basin-scale ocean prediction systems using HYCOM.
- In the process of being transitioned for operational use by the U.S. Navy at NAVOCEANO and by NOAA at NCEP.

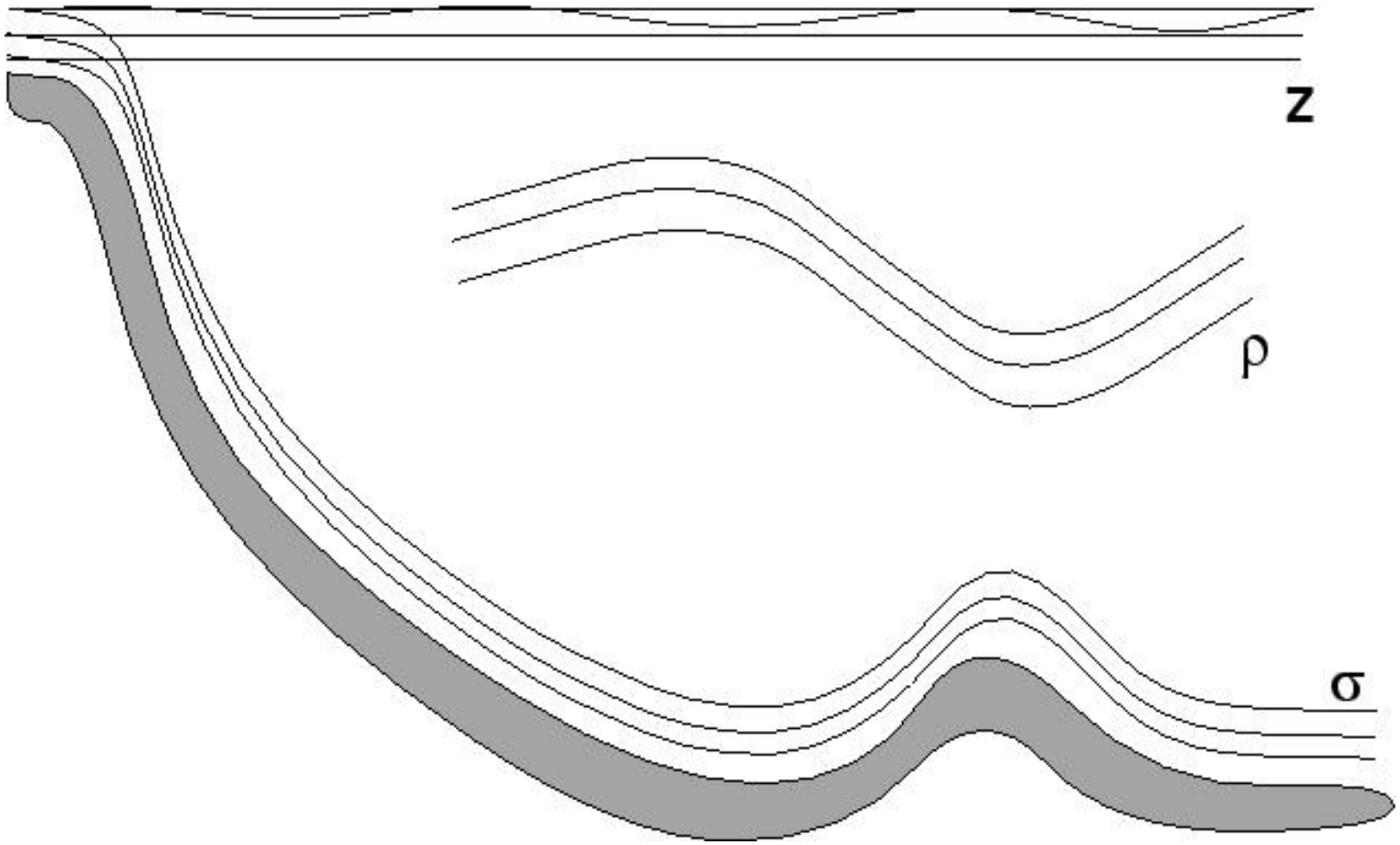
- Rotating and stratified fluids => dominance of lateral over vertical transport.

- Hence, it is traditional in ocean modeling to orient the two horizontal coordinates orthogonal to the local vertical direction as determined by gravity.

- The choice of the vertical coordinate system is the single most important aspect of an ocean model's design (DYNAMO, DAMÉE-NAB).

- The practical issues of representation and parameterization are often directly linked to the vertical coordinate choice (Griffies et al., 2000).

Currently, there are three main vertical coordinates in use, none of which provides universal utility. Hence, many developers have been motivated to pursue research into hybrid approaches.



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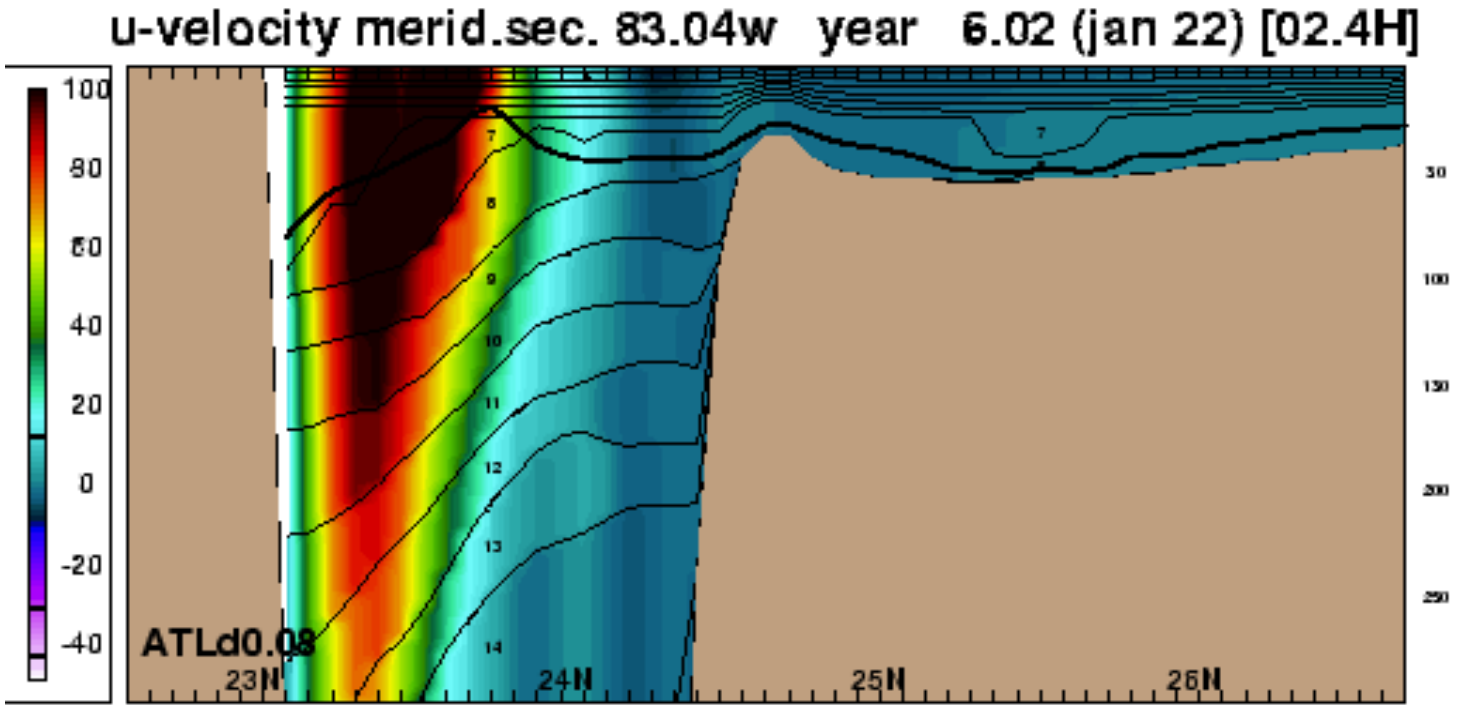
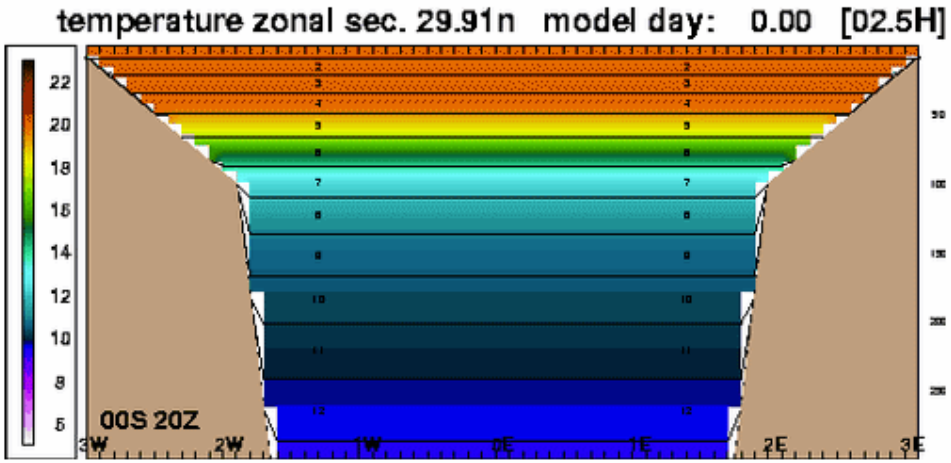
The hybrid coordinate in HYCOM is one that is isopycnal in the open, stratified ocean, but smoothly reverts to a terrain-following coordinate in shallow coastal regions, and to pressure coordinate in the mixed layer and/or unstratified seas

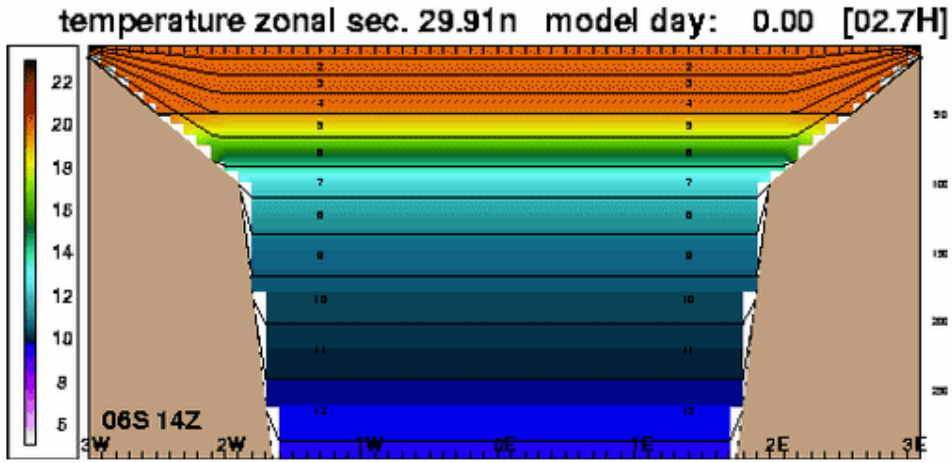


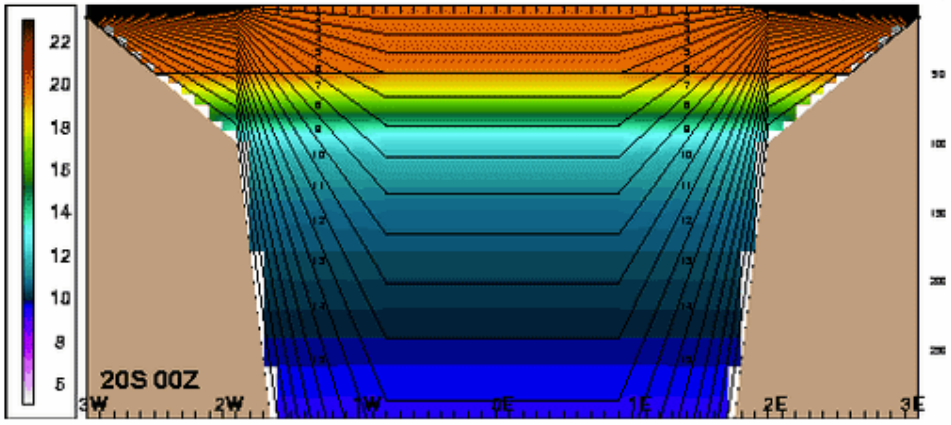
HYCOM

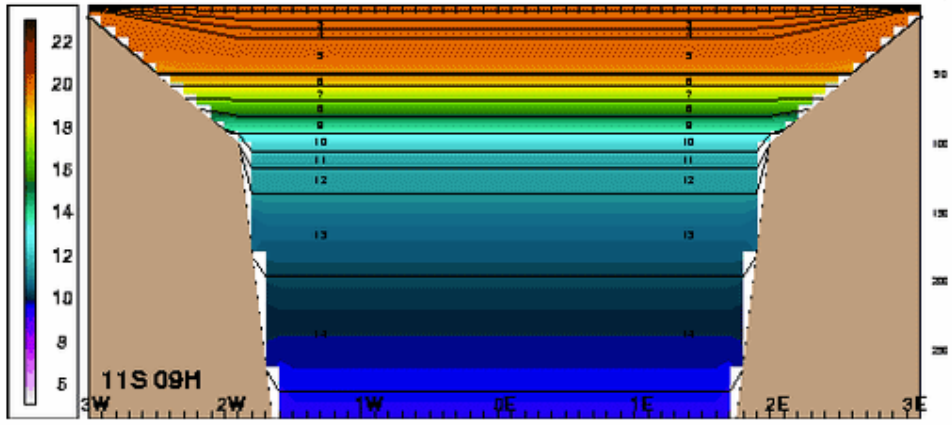
z

σ-z









σ

Hybrid

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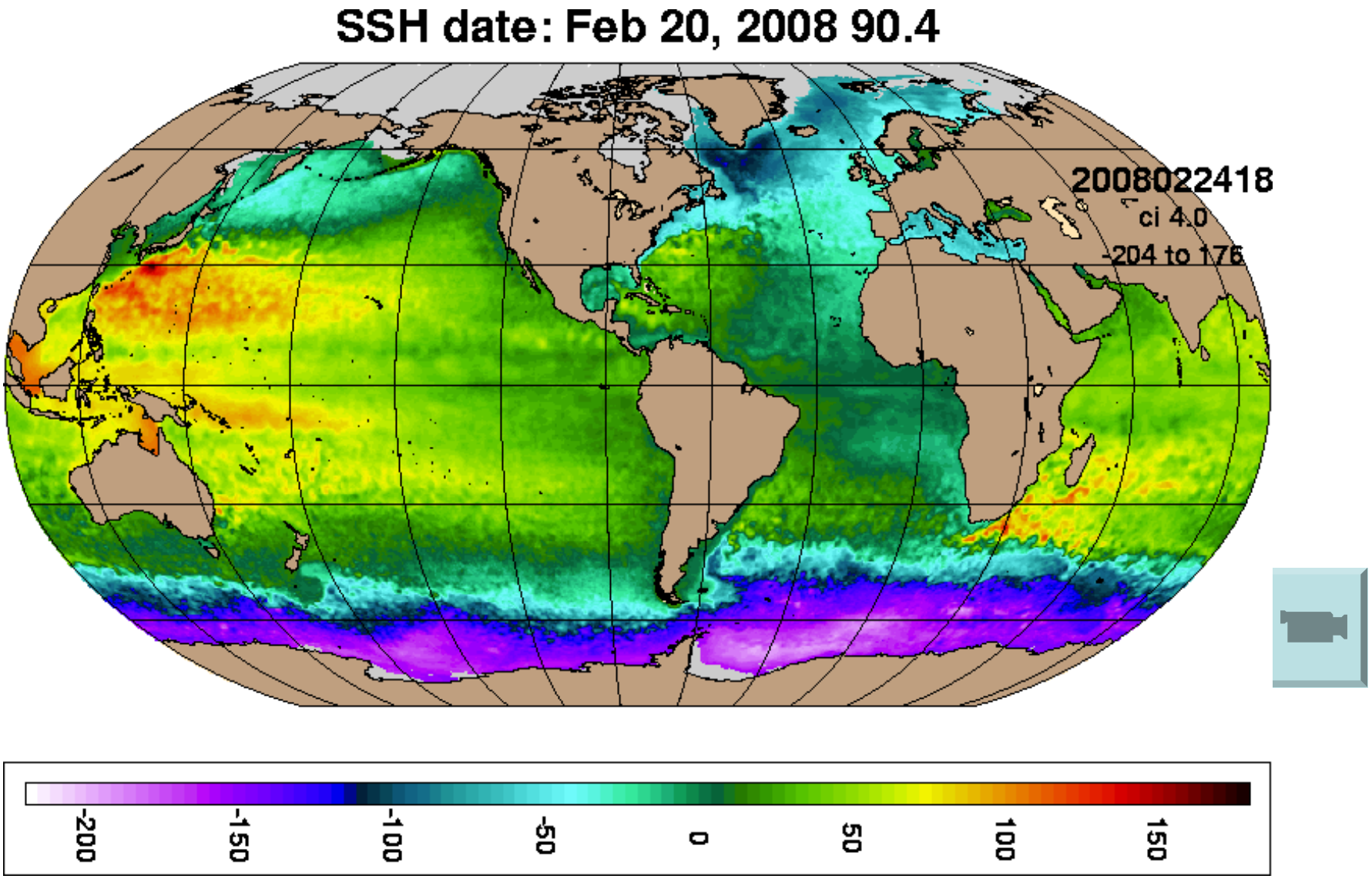
Global HYCOM configuration

- Horizontal grid: 1/12° equatorial resolution
  - 4500 x 3298 grid points, ~6.5 km spacing on average, ~3.5 km at pole, 5 m minimum depth
- Mercator 79°S to 47°N, then Arctic dipole patch
- 32 σ_2* vertical coordinate surfaces:
- GISS mixed layer model
- Thermodynamic sea-ice model
- Surface forcing: wind stress, wind speed, thermal forcing, precipitation, weak relaxation to climatological SSS
- Monthly river runoff (986 rivers)
- Initialized from January climatology (GDEM3) T and S

1/12° Global HYCOM Snapshot: SSH and ice (gray)



216,000 CPU hrs/model year on 784 IBM Power 4+ CPUs

7.2 TB/model year for daily 3-D output

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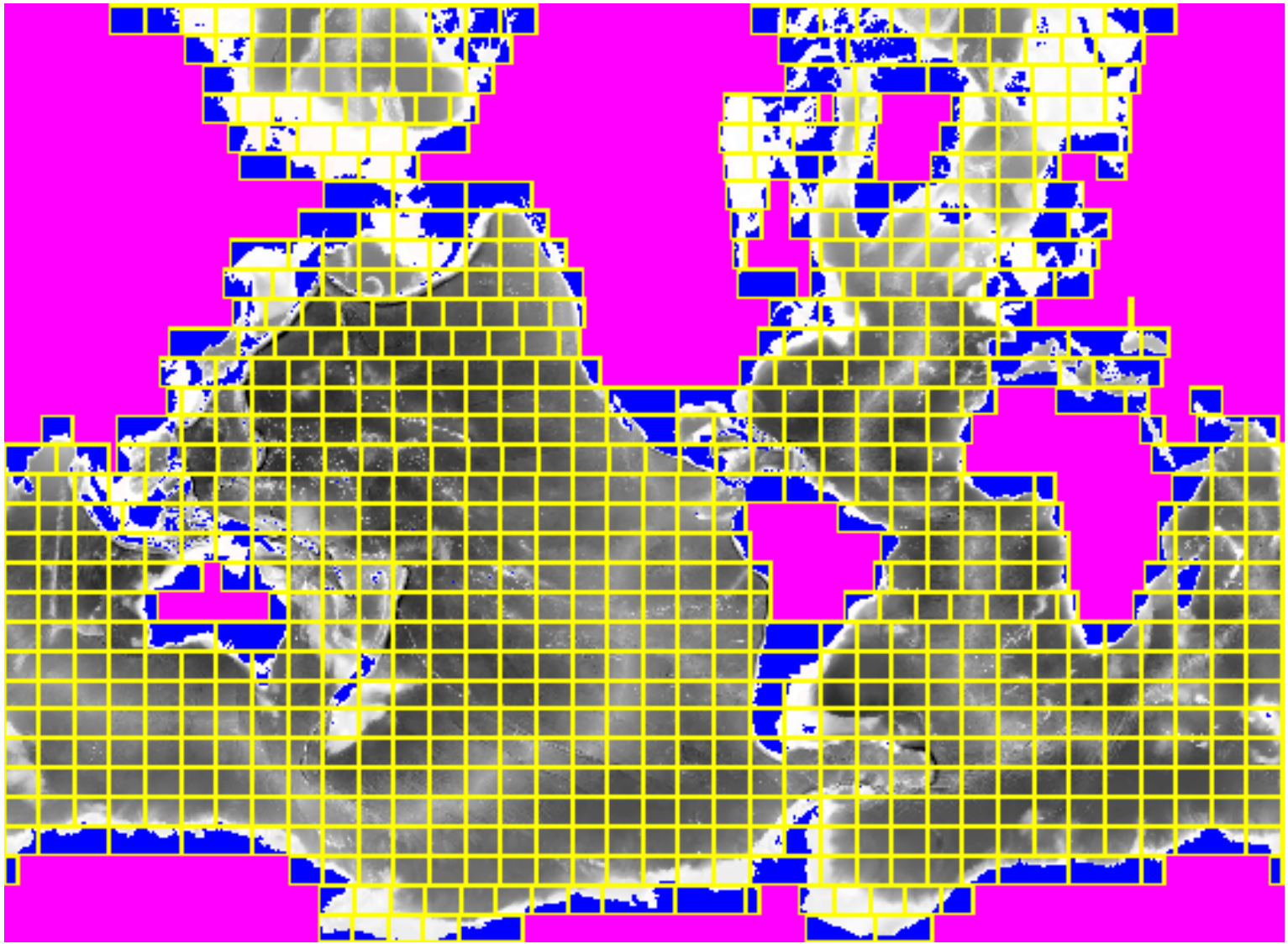
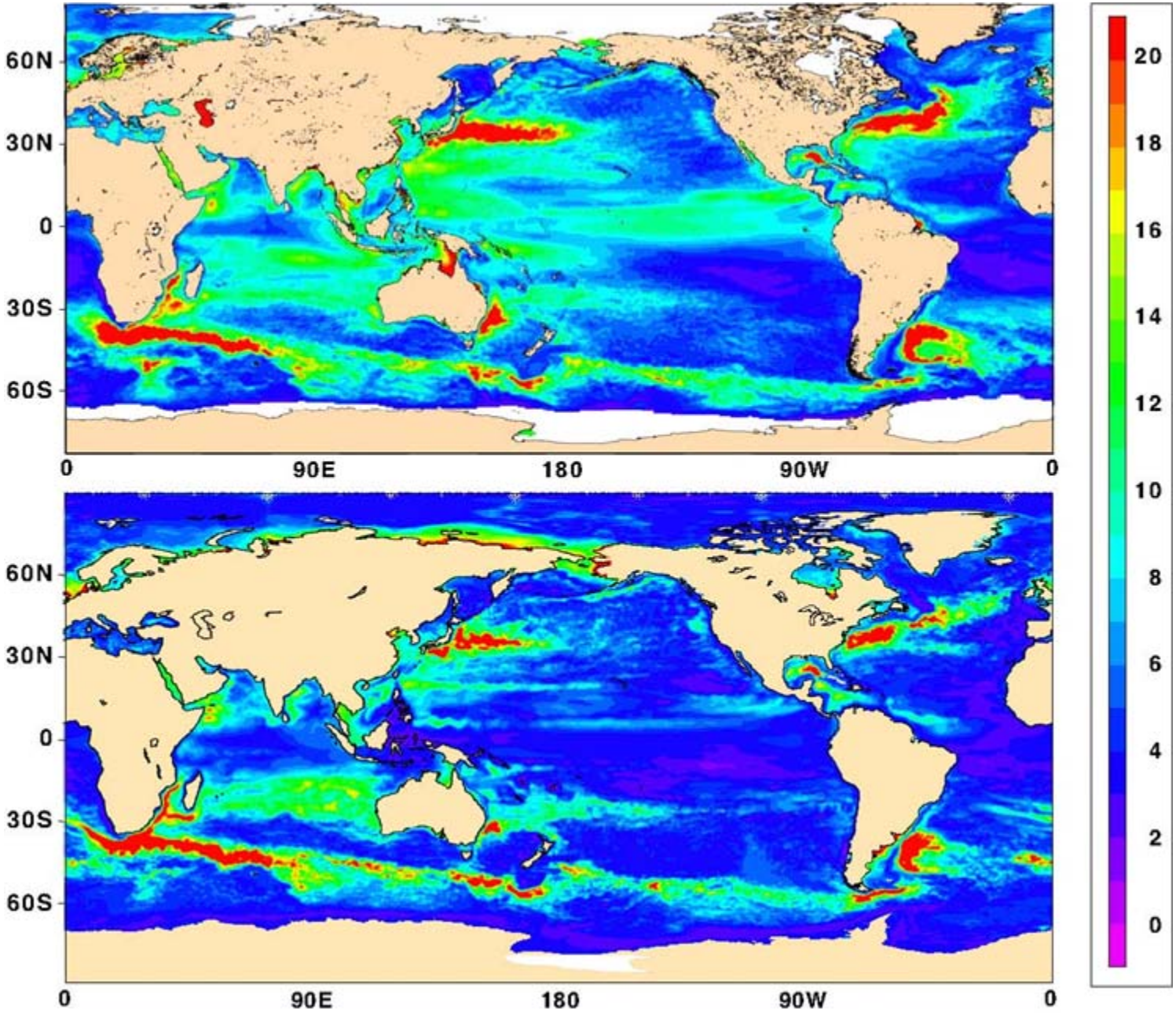
Current Tiling for the 1/12° Global Domain with Equal-Sized Tiles



Free Running Global HYCOM (Metzger et al.)



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

SSH variability from 1/12° global HYCOM σ_2* with climatological wind and thermal forcing

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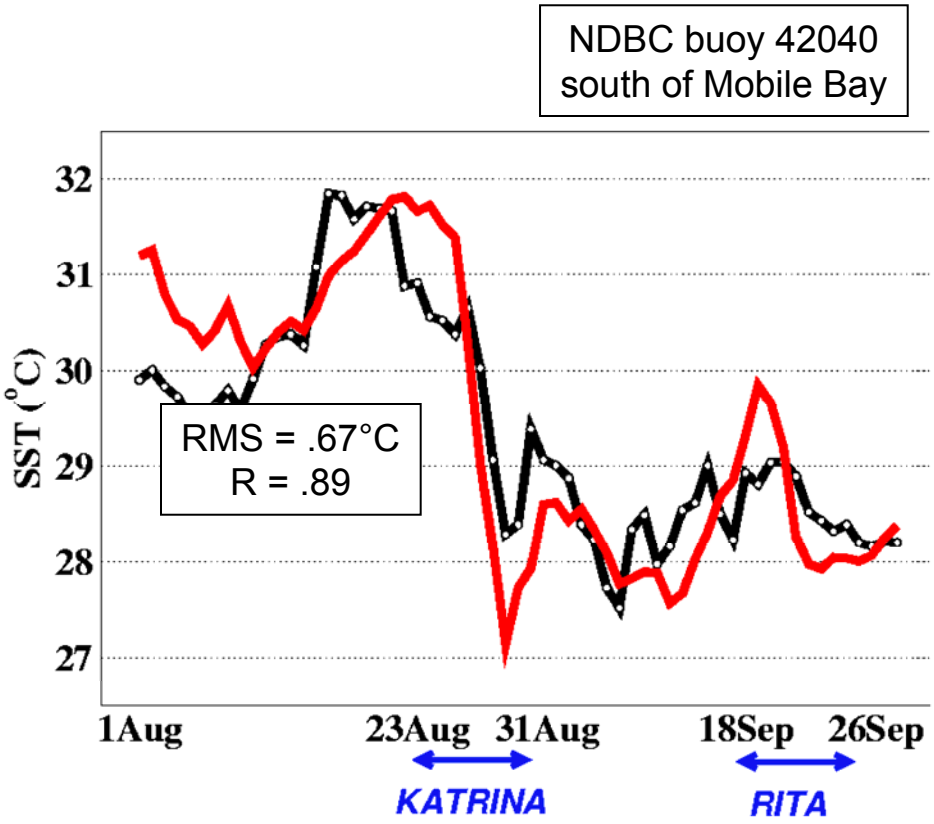
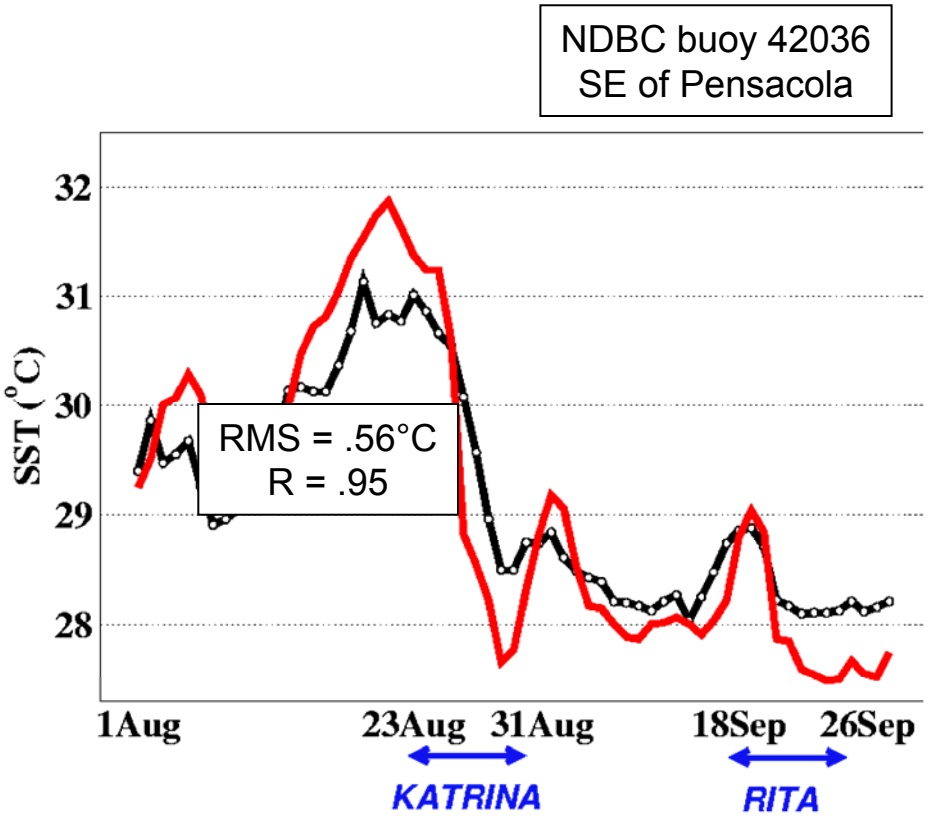
SST Response in 1/12° Global HYCOM to Hurricanes Katrina and Rita





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

Mixed Layer Response to Hurricane Forcing

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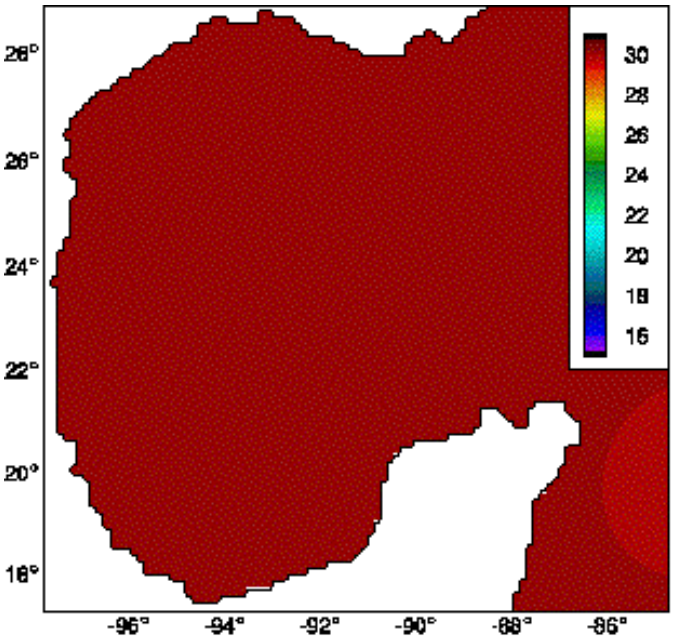
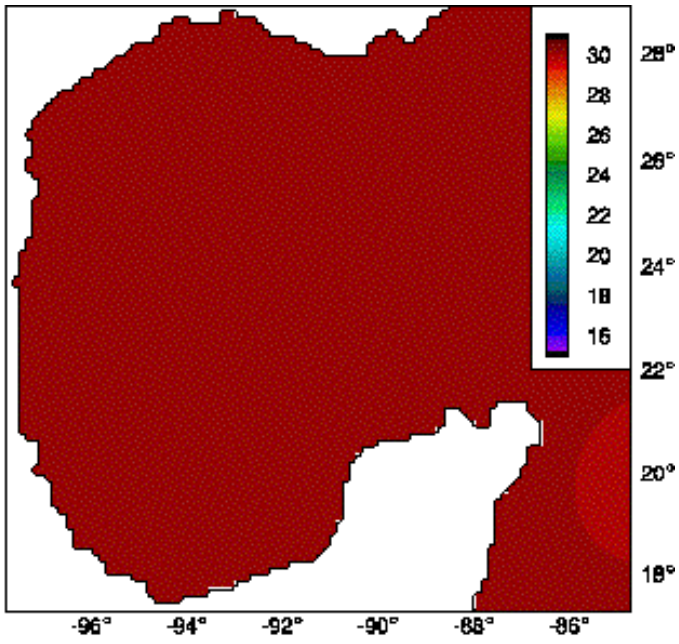
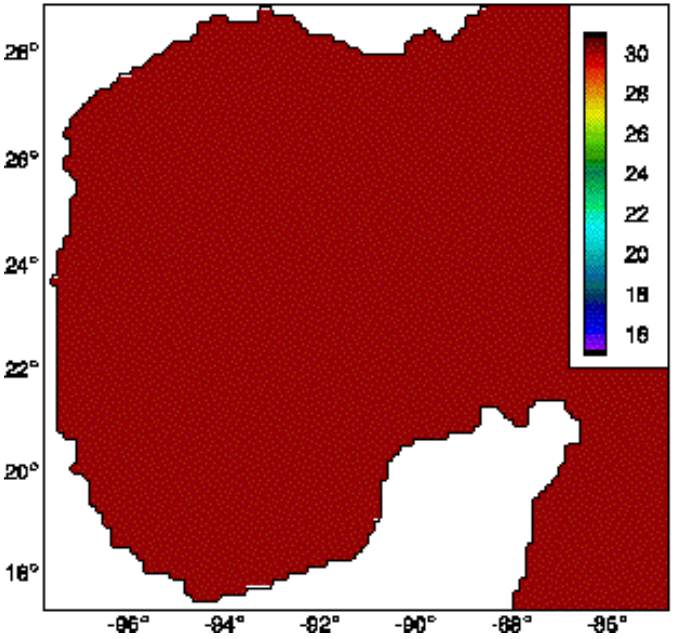
Kraus-Turner



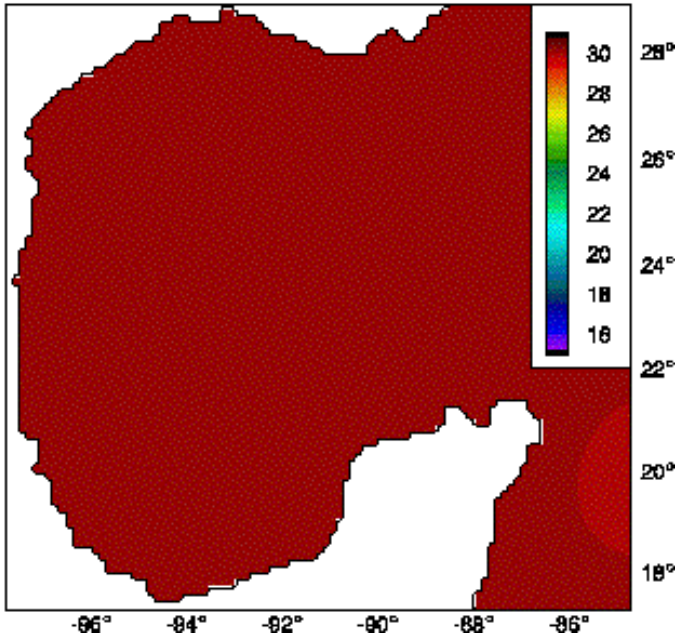
KPP



Mellor-Yamada 2.5

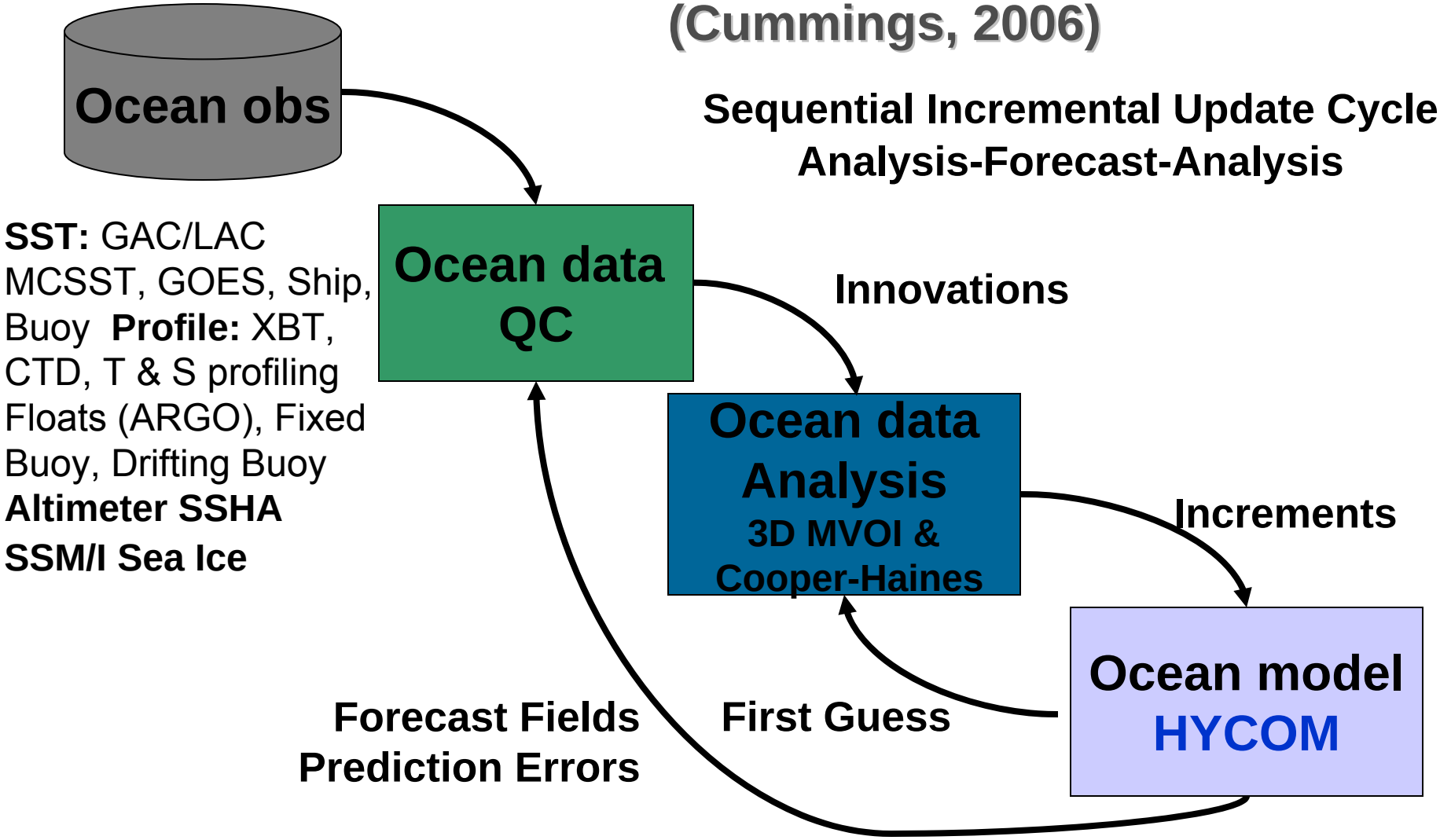


PWP



Data Assimilation (NCODA)

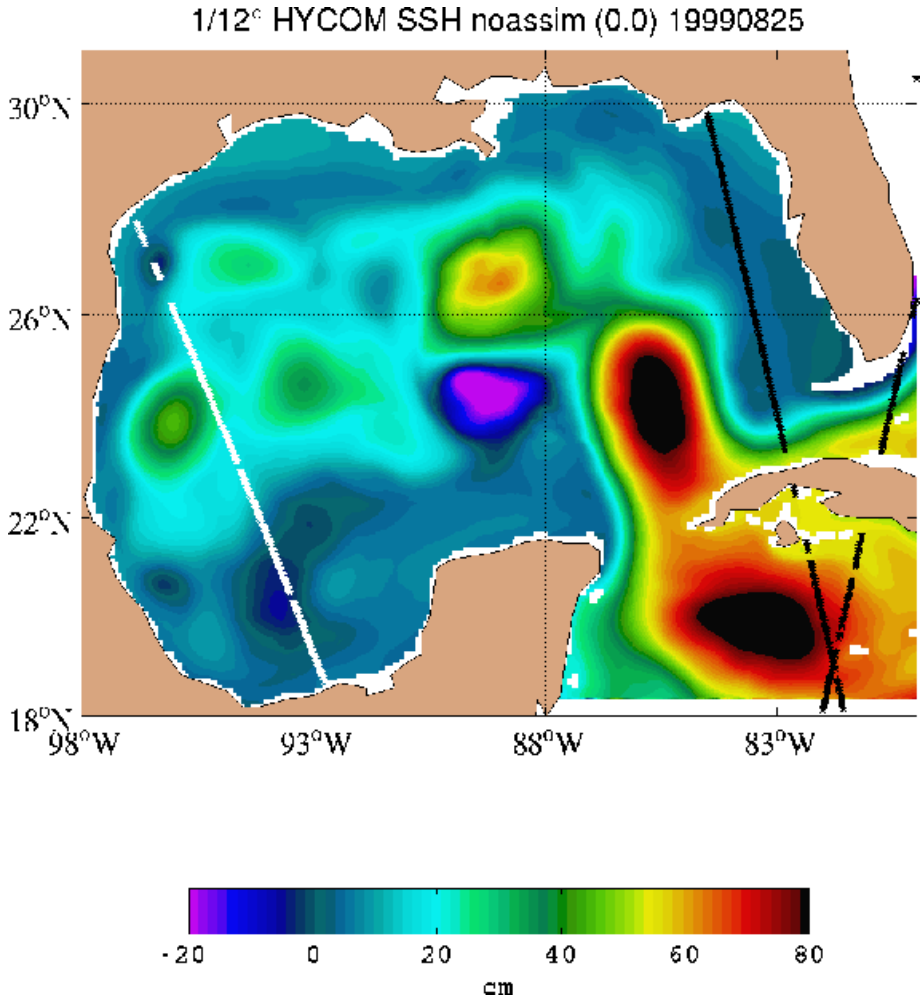
(Cummings, 2006)



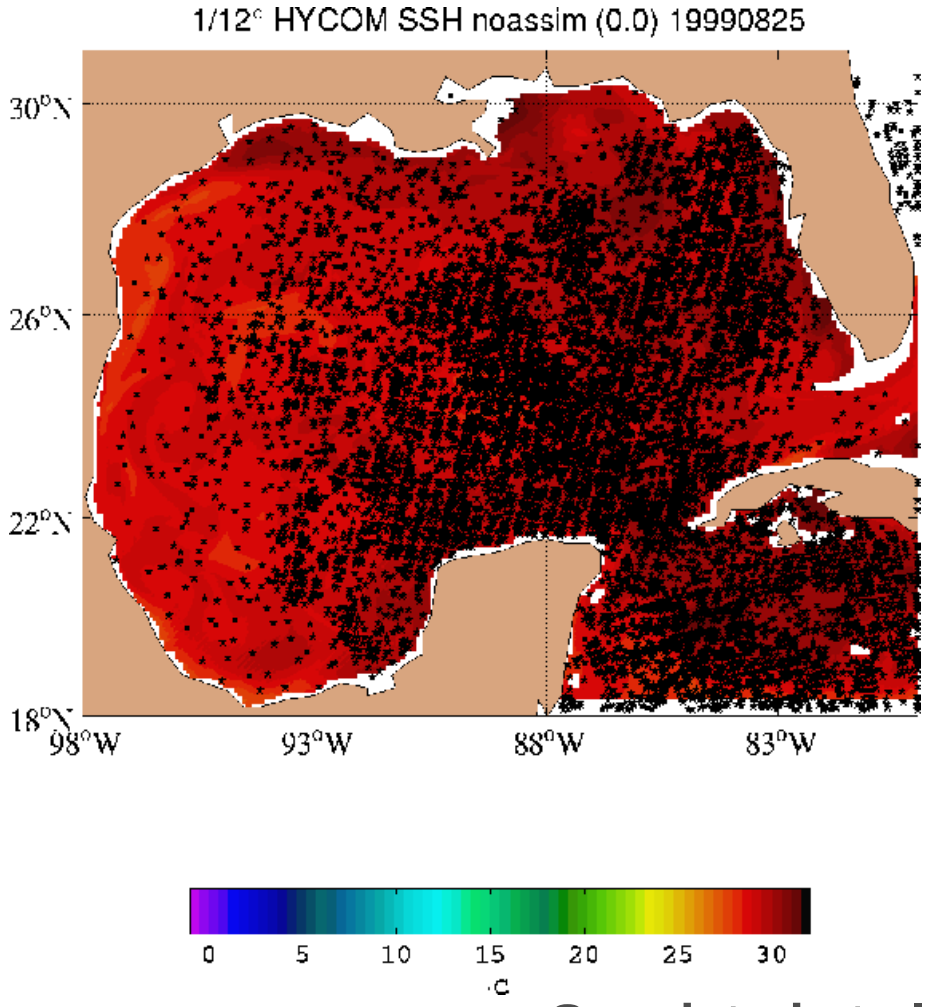
MVOI - simultaneous analysis 5 ocean variables
temperature, salinity, pressure, velocity (u,v)

1/25° Gulf of Mexico HYCOM

Observed SSH tracks



Observed SST Locations



Smedstad et al.

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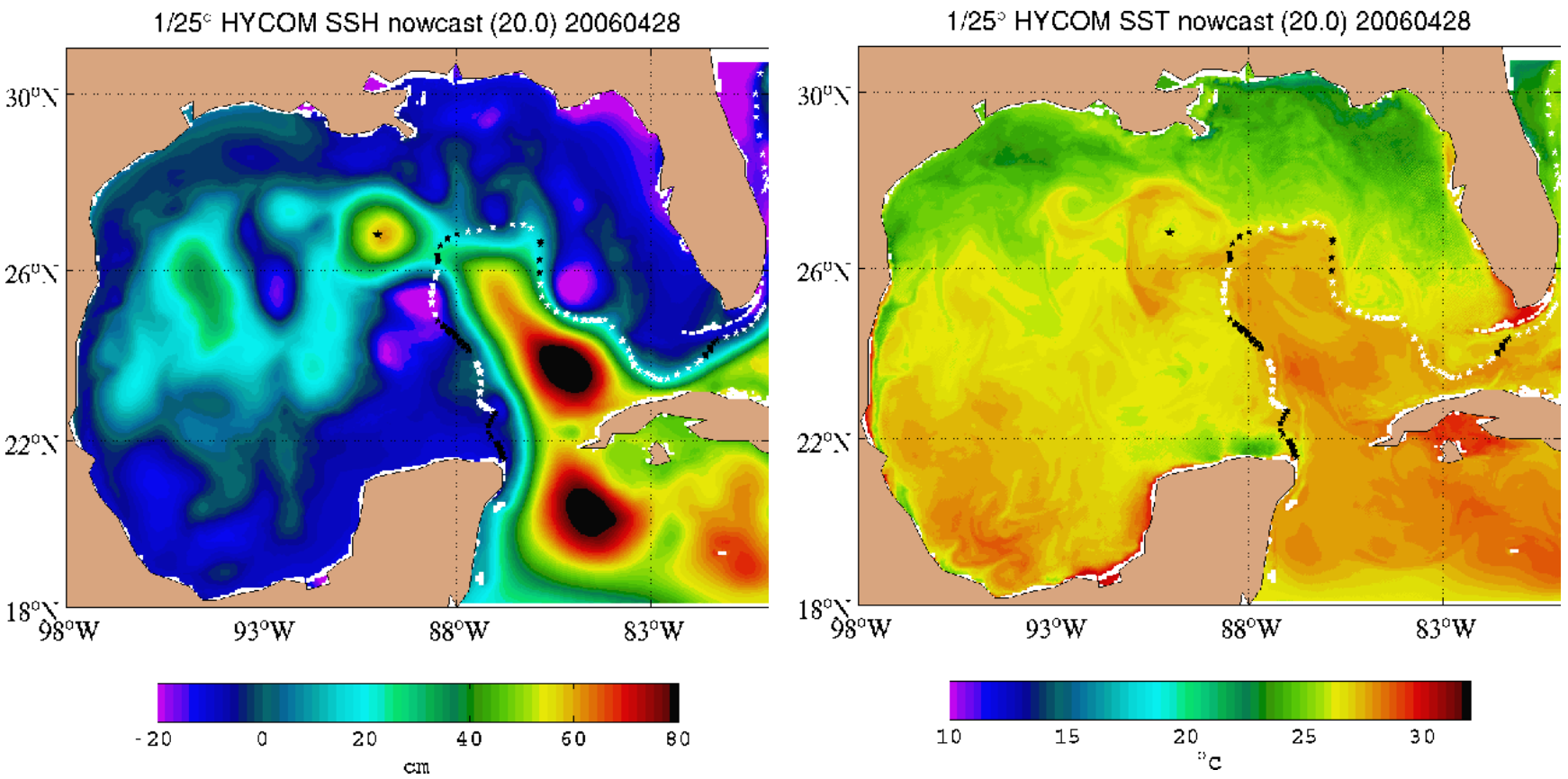
1/25º Gulf of Mexico HYCOM

Hindcast started 2 September 2003

SSH **28 April 2006** **SST**



HYCOM nowcast SSH with the NAVO frontal analysis of MCSST observations (white/black lines, black data > 4 days old)

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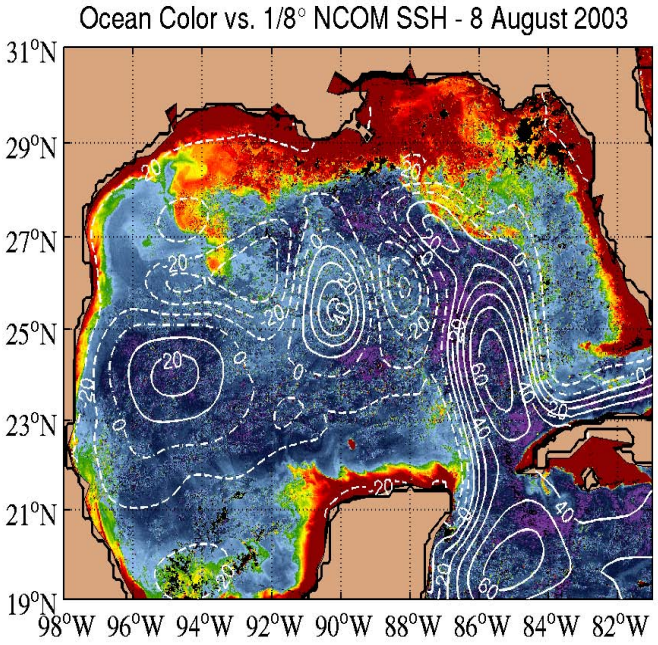

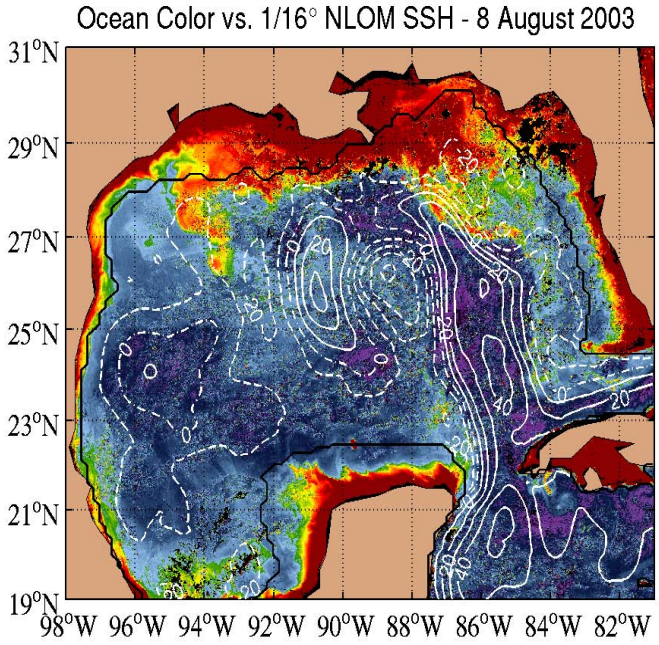

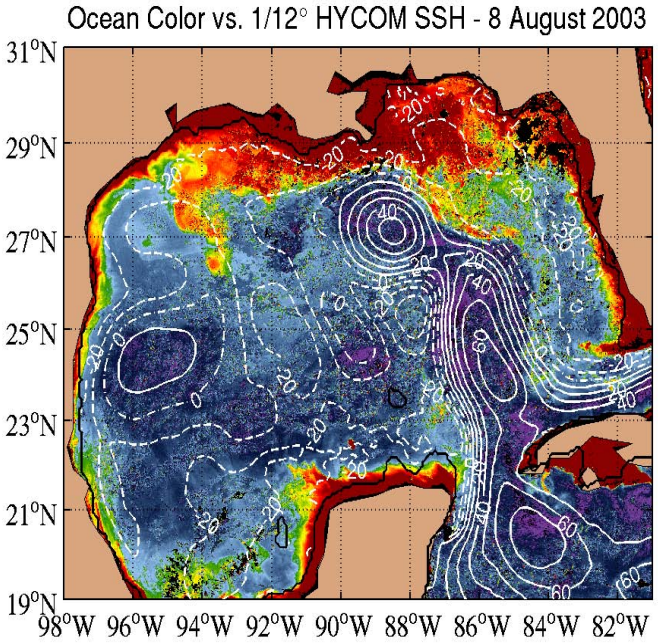

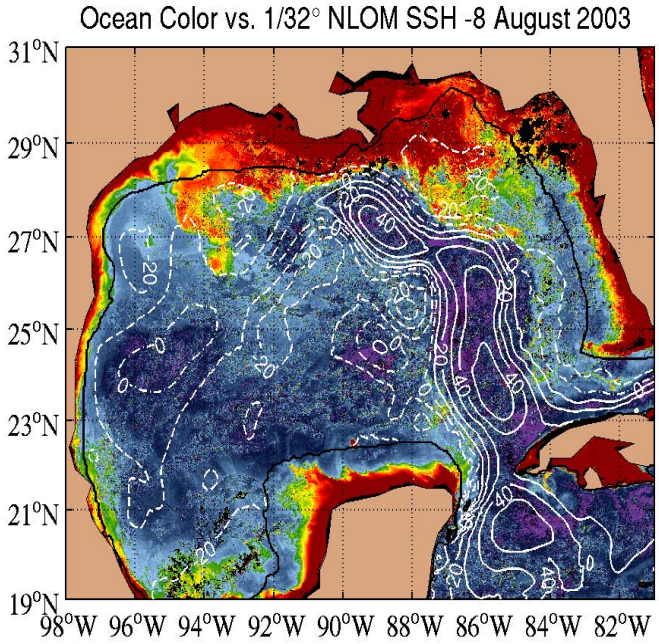

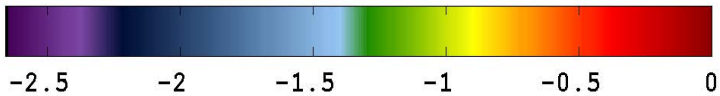

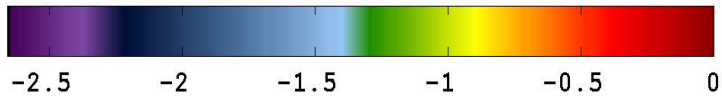

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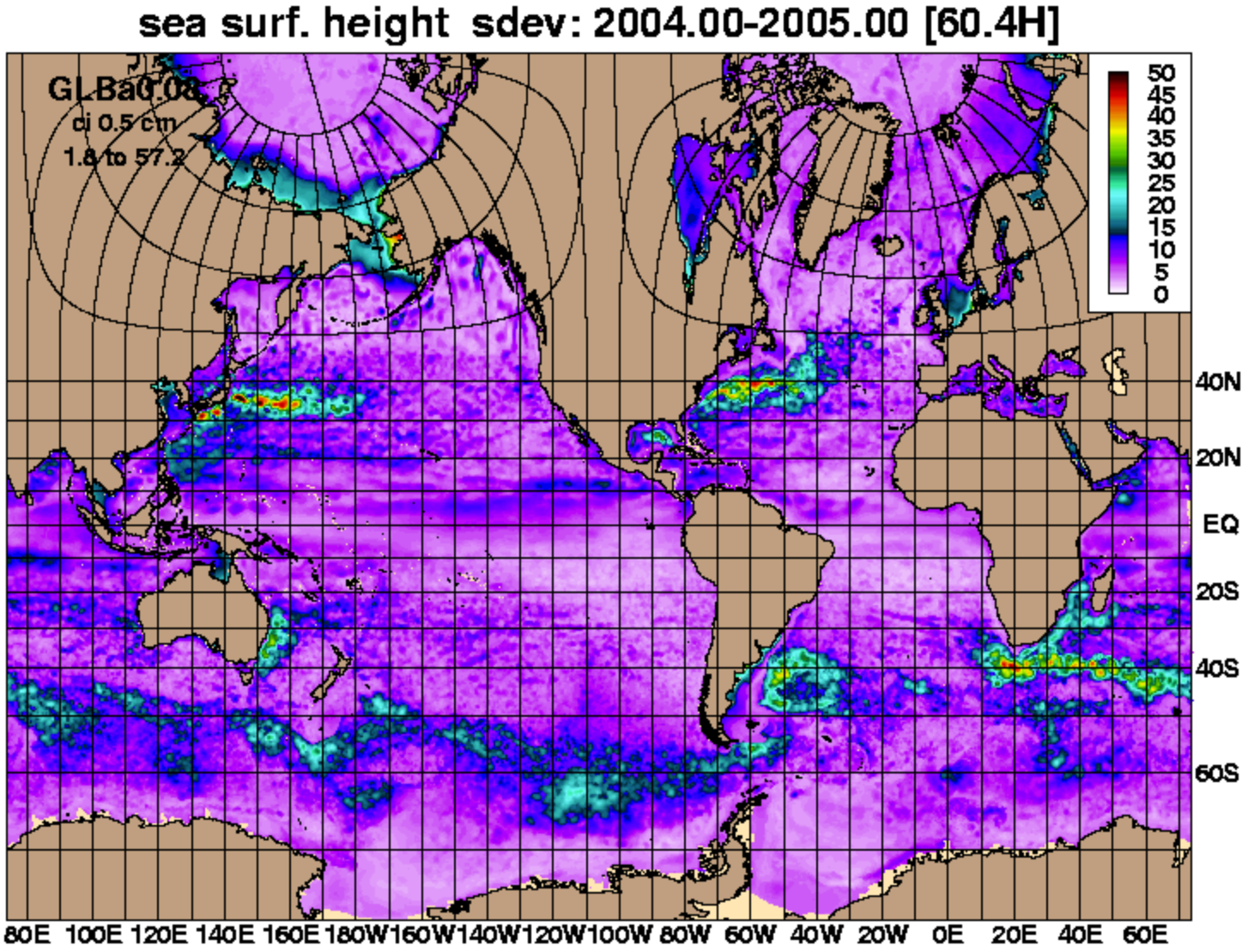

with assimilation (GLBa0.08-60.4)

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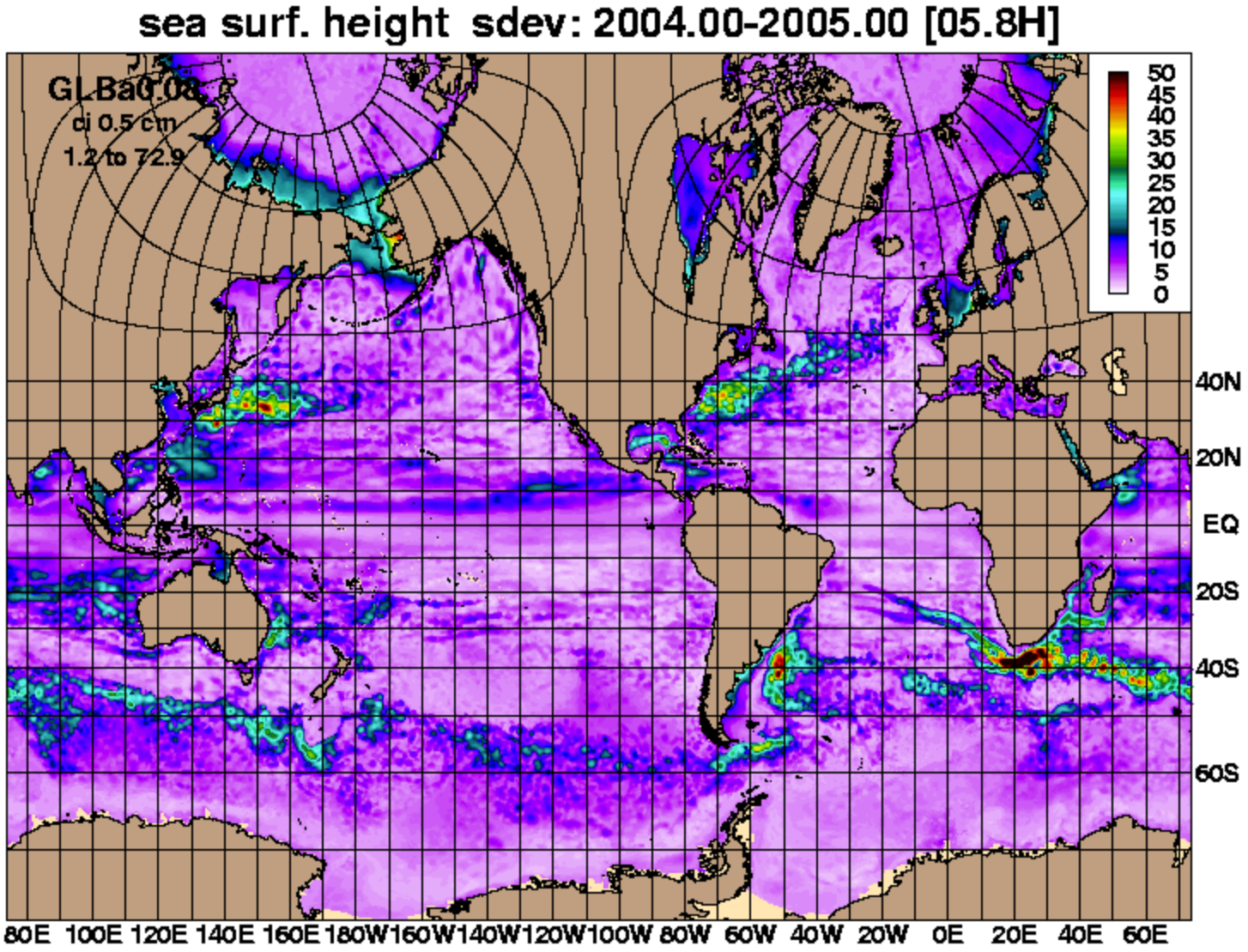
HYbrid Coordinate Ocean Model



without assimilation (GLBa0.08-05.8)

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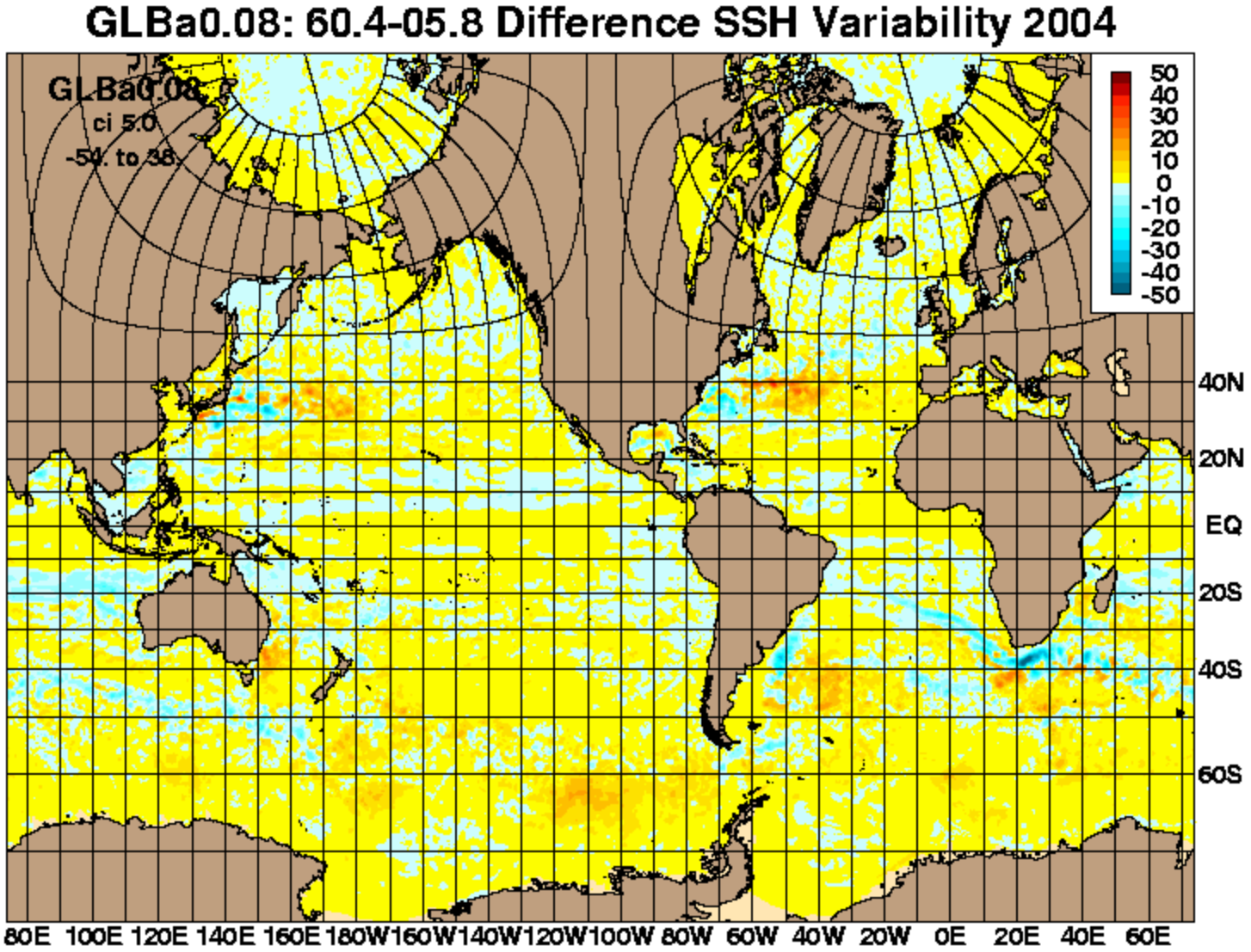
HYbrid Coordinate Ocean Model



Overall increase in variability - largest changes occur in the western boundary currents

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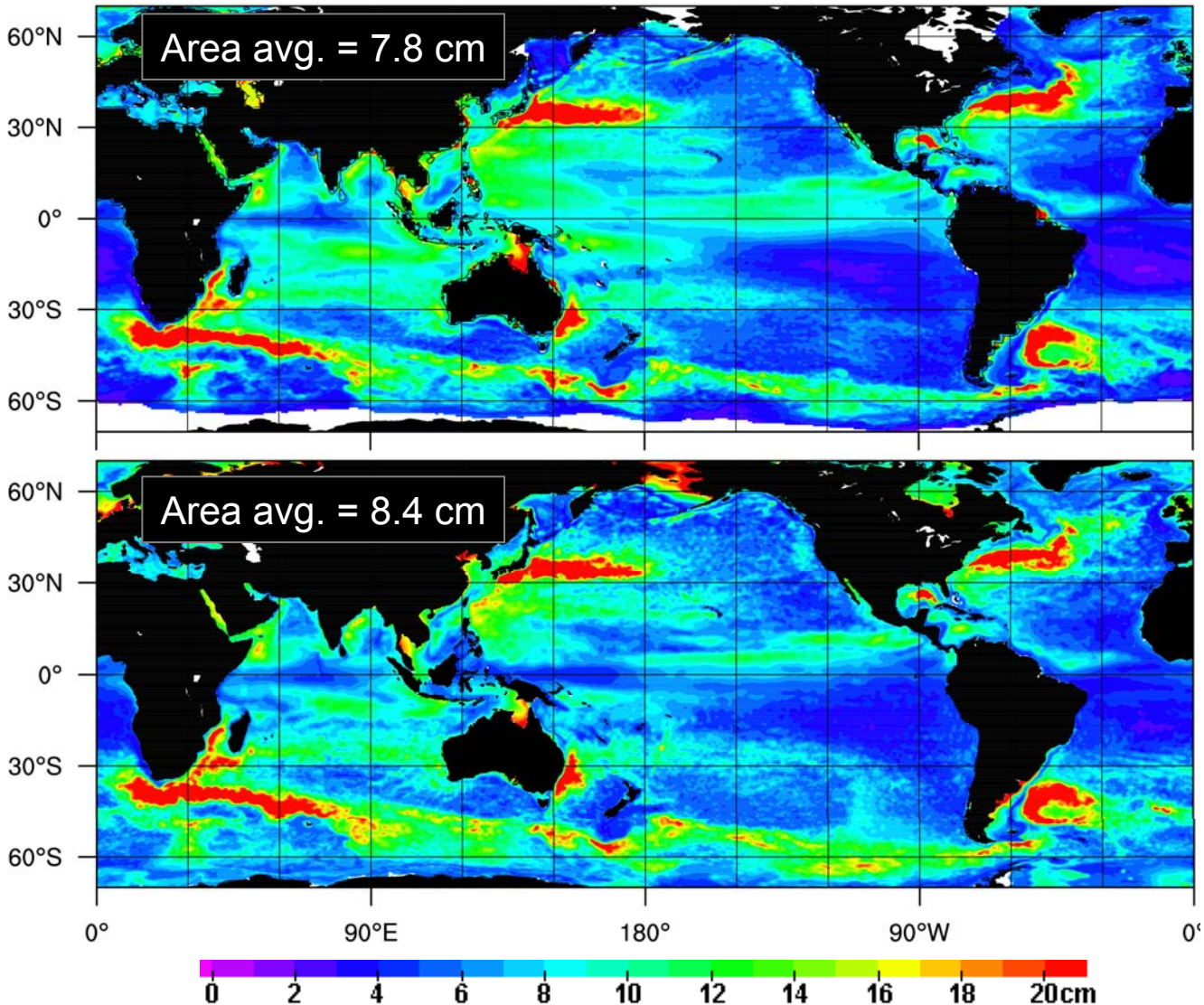
SSH Variability Field

Measure of the mesoscale eddy field



Oct 92 – May 07 SSH variability based on T/P, ERS-1 and ERS-2 altimeters (from CLS)

SSH variability over 2004-2006 from the 1/12° global HYCOM/NCODA hindcast simulation

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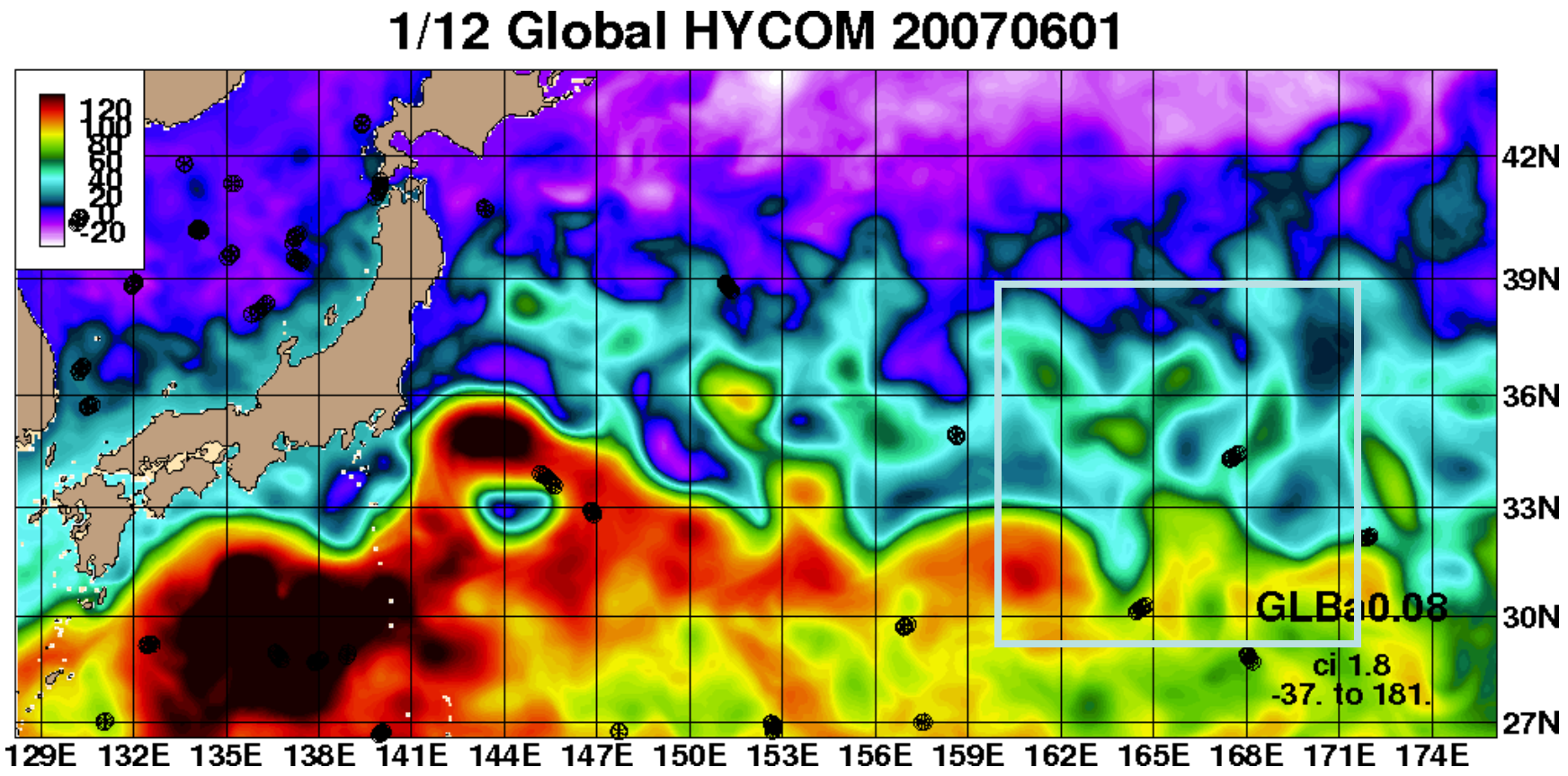
1/12º Global HYCOM

SSH and surface drifters



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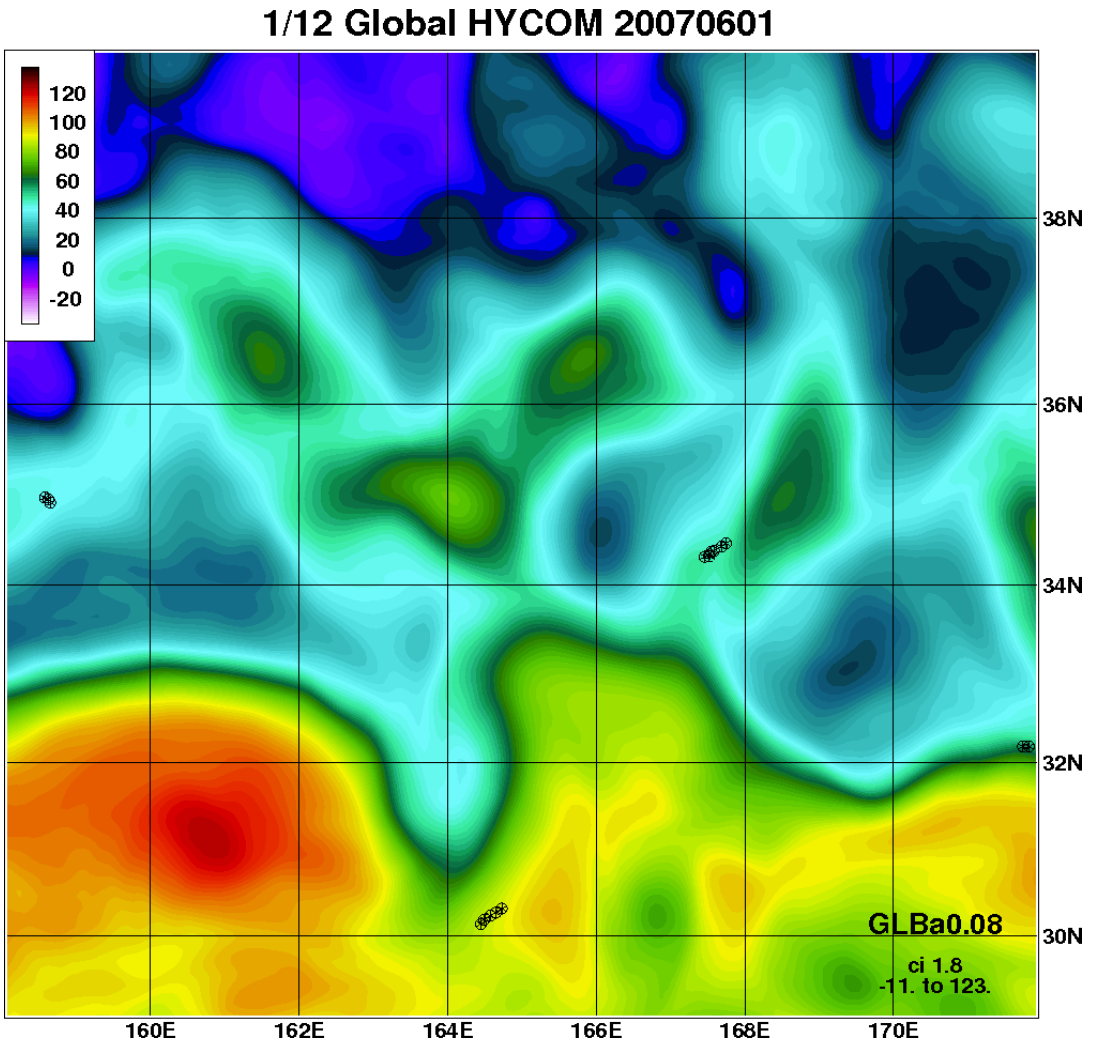
1/12º Global HYCOM

SSH and surface drifters



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Evaluation and Outreach

- Strong participation of the coastal ocean modeling community in using and evaluating boundary conditions from the global and basin-scale ocean modeling prediction systems
- Efficient data distribution (100 Terrabytes Storage Area Network)
  - The data are available to the community at large within 24 hours via Live Access Server (LAS), ftp, and OPeNDAP at http://www.hycom.org

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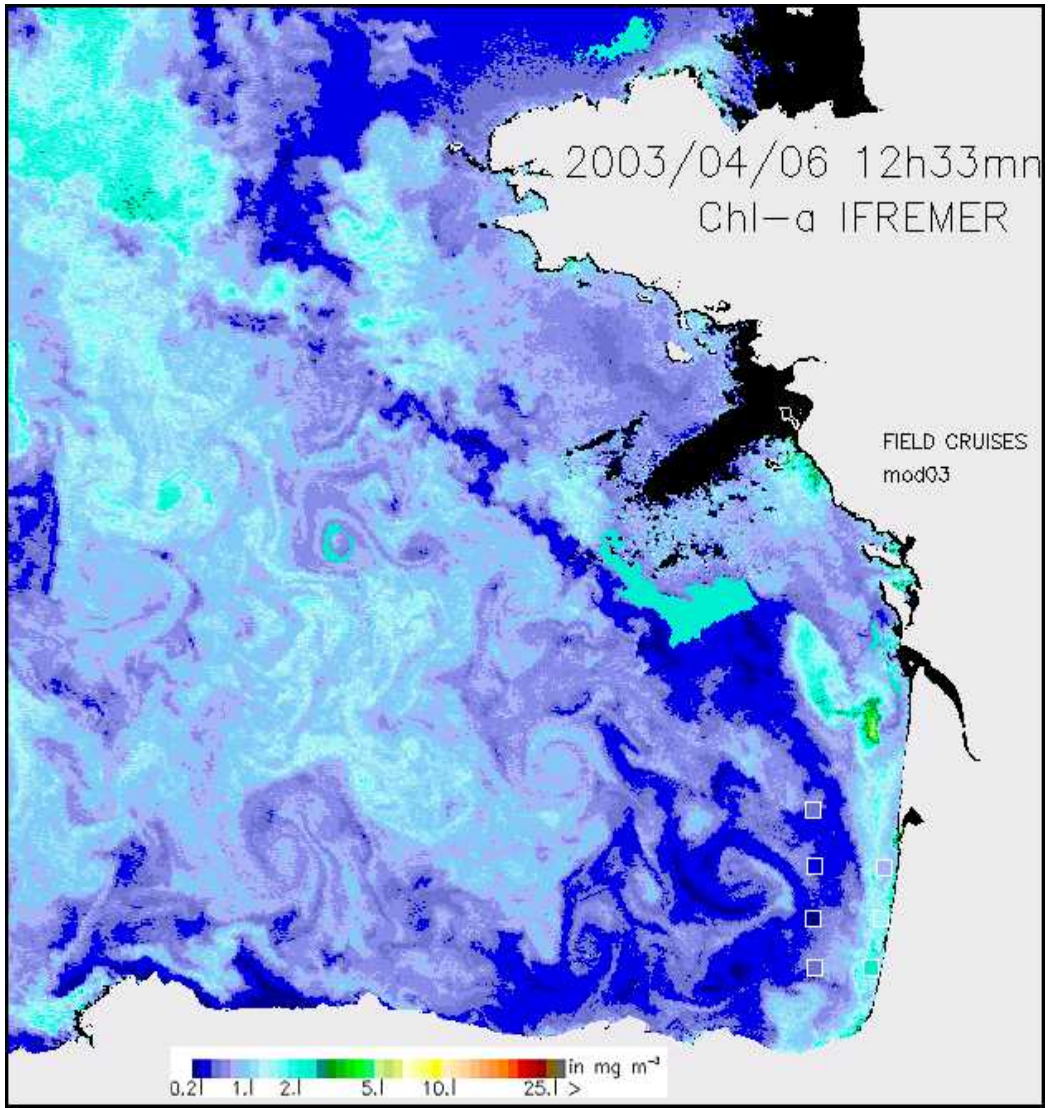
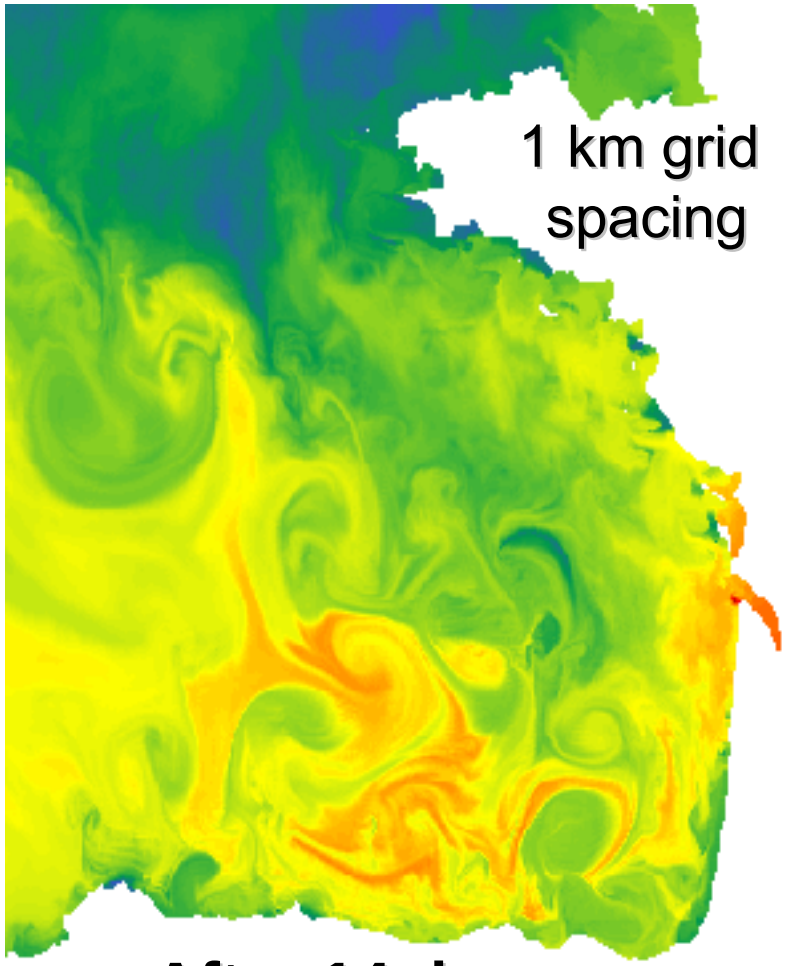
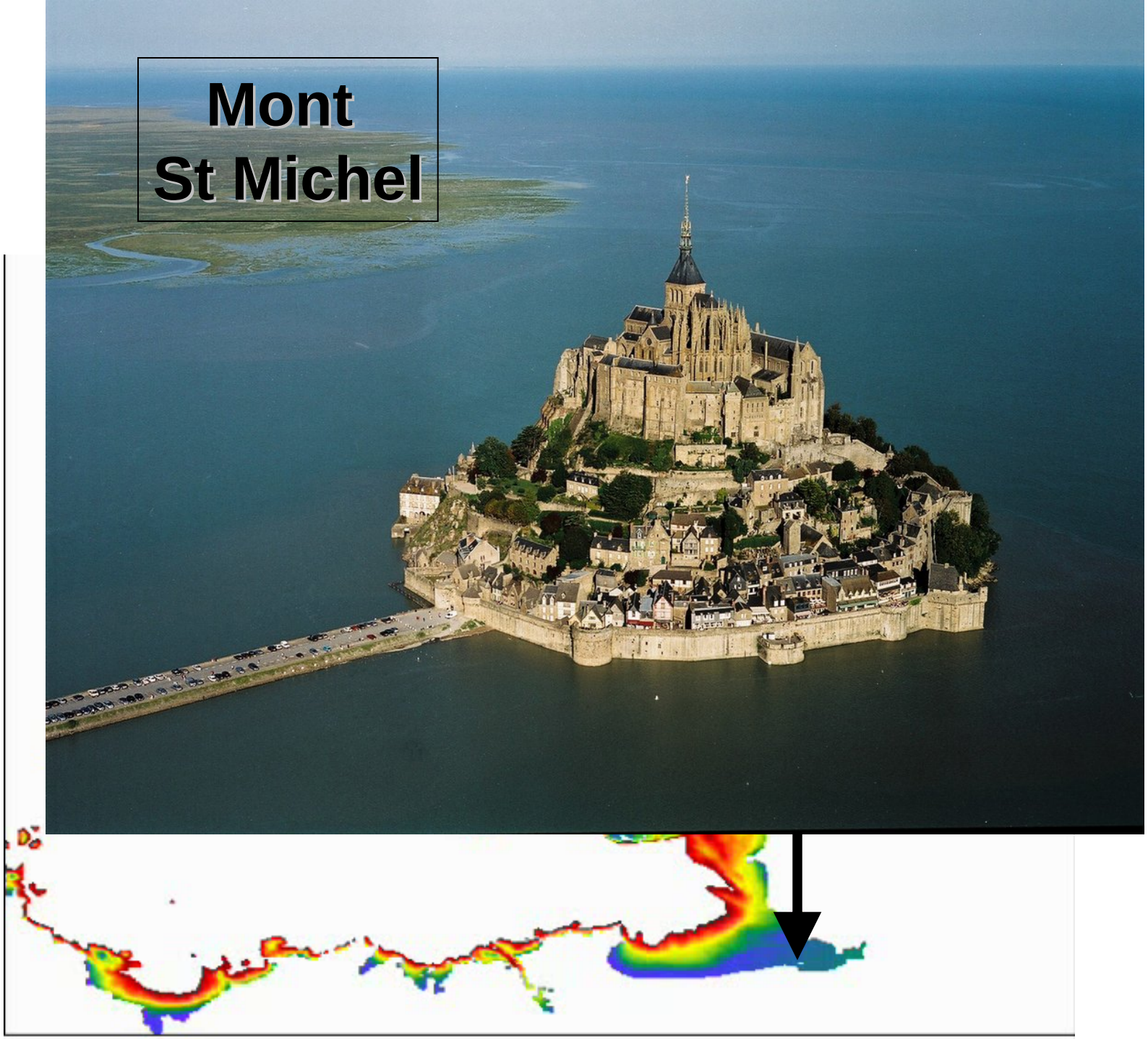
HYCOM Bay of Biscay Modeling





After 14 days of « spin up »


Mont
St Michel

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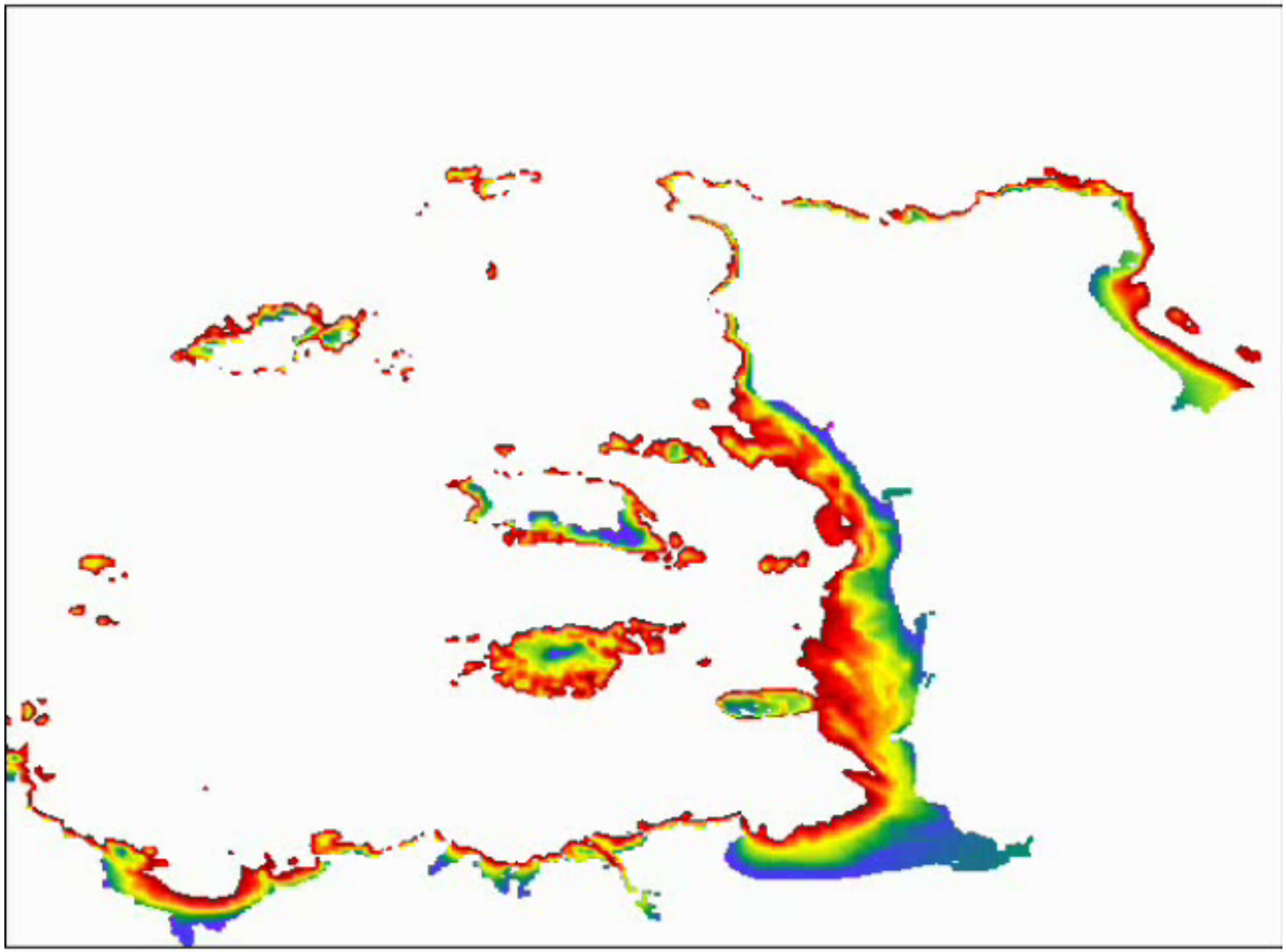
Wetting and Drying in HYCOM



Baraille et al. (SHOM)

0 meter layer thickness

Adding tidal capability to global HYCOM

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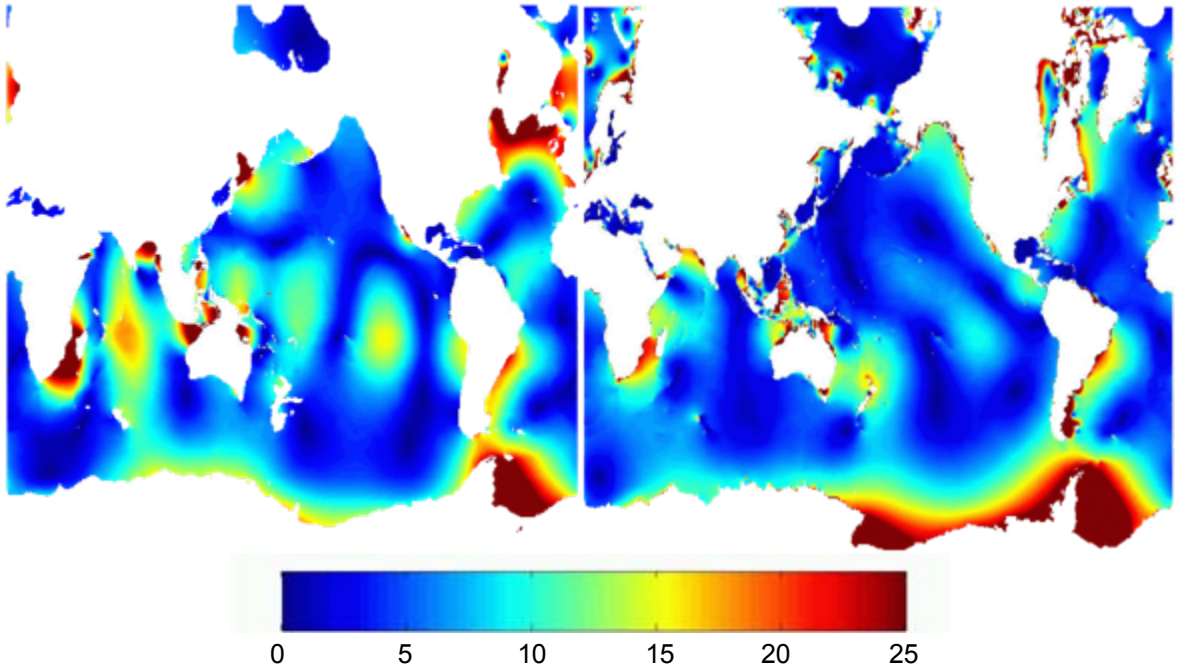
Collaboration with Brian Arbic (U. Texas)

HYCOM RMS errors for M_2 tide vs satellite altimetry

.72° resolution

.08° resolution

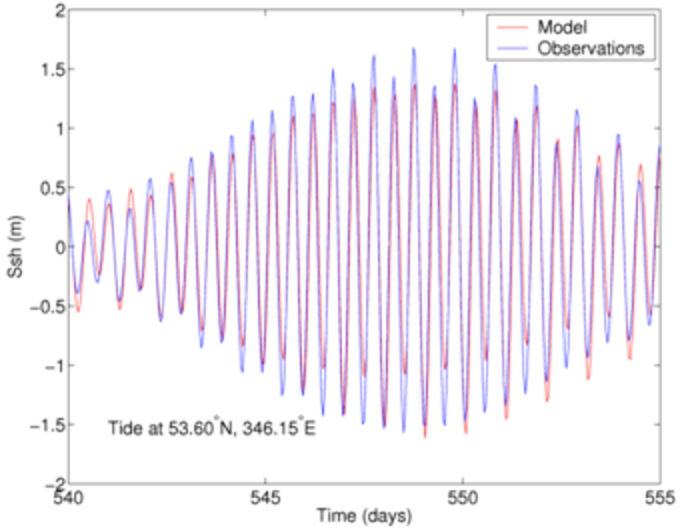


RMS error = 9.9 cm

RMS error = 6.7 cm

HYCOM with 8-component tide vs tide gauge

.72° HYCOM tide



model — tide gauge

Example with typical error:
89.6% of variance explained

Average RMS error over all 102 pelagic tide guages = 12.3 cm

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Future Directions

- 1/25° global HYCOM prediction system with tides and wetting and drying
- More advanced data assimilation
- Nested coastal ocean prediction with grid resolution < 1 km
- Range dependent acoustic prediction
- Coupled atmosphere – ocean prediction
- Bio – geo – chemical – optical and tracer/contaminant prediction
- Ecosystem analysis and prediction
- Earth system prediction: coupled atmosphere-ocean-ice-land

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Questions?