Evaluation, Validation and Transition of the 1/12° Global HYCOM/NCODA/PIPS System

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

HYCOM = HYbrid Coordinate Ocean Model
NCODA = Navy Coupled Ocean Data Assimilation
PIPS = Polar Ice Prediction System

Delivery:

- Scheduled for transition to the Naval Oceanographic Office in 2008

Capability:

- Provide accurate 3D temperature, salinity and current structure
- Depict the location of mesoscale features: fronts and eddies

Progress:

- 1/12° global HYCOM/NCODA running in real-time in the NAVOCEANO operational queues since 22 Dec 2006
- Produces daily 5-day hindcast up to the nowcast time, then a 5-7 day forecast
- Graphical and digital output available through the HYCOM consortium web pages: http://www.hycom.org
- Validation efforts underway – comparing against operational 1/8° global NCOM (Navy Coastal Ocean Model)

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 σ_2*
- KPP mixed layer model
- Thermodynamic (energy loan) sea-ice model – switching to PIPS
- Surface forcing: FNMOC NOGAPS 0.5° wind stress, wind speed, thermal forcing, and NOGAPS 1.0° precipitation
- Monthly river runoff (986 rivers)
- Initialized from January climatology (GDEM3) T and S, then SSS relaxation from PHC 3.0
  - No subsurface relaxation to climatology

Validation Tasks

A. Large scale circulation features
   - Determine correct placement of large scale features

B. Sea Surface Height (SSH) variability / Eddy Kinetic Energy (EKE)
   - Determine if the system has a realistic level and distribution of energy at depths

C. Mixed layer depth (MLD) / sonic layer depth (SLD) / deep sound channel (DSC) / below layer gradient (BLG)
   - Compare simulated vs. observed for non-assimilated buoys

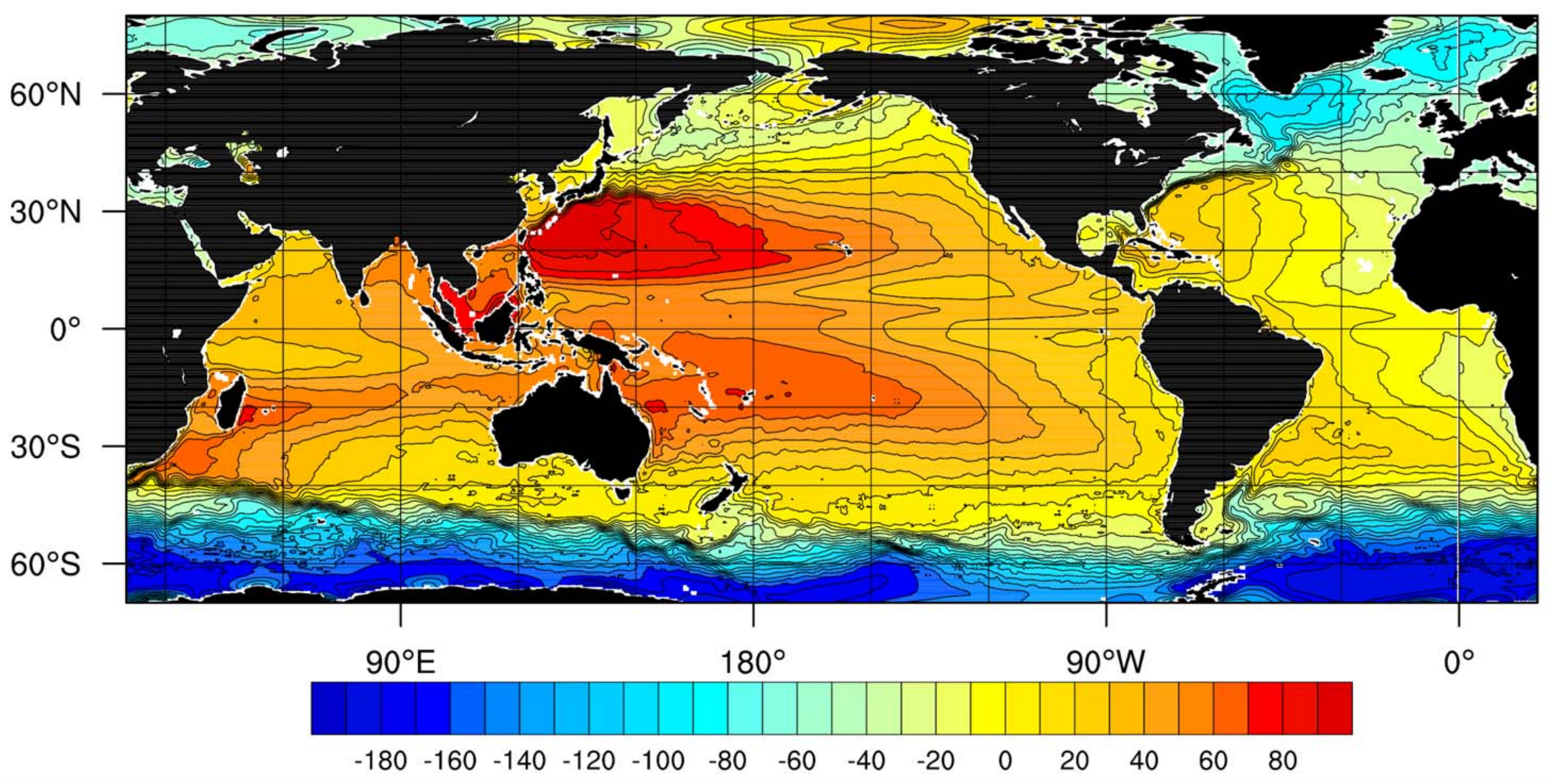
D. Vertical profiles of T&S
   - Quantitative comparison of simulated vs. observed for non-assimilated buoys

E. Sea surface temperature
   - Evaluate whether the models are producing acceptable nowcasts and forecasts of sea surface temperature

F. Coastal sea level
   - Assess the model's ability to represent observed sea surface heights

Large Scale Circulation Features

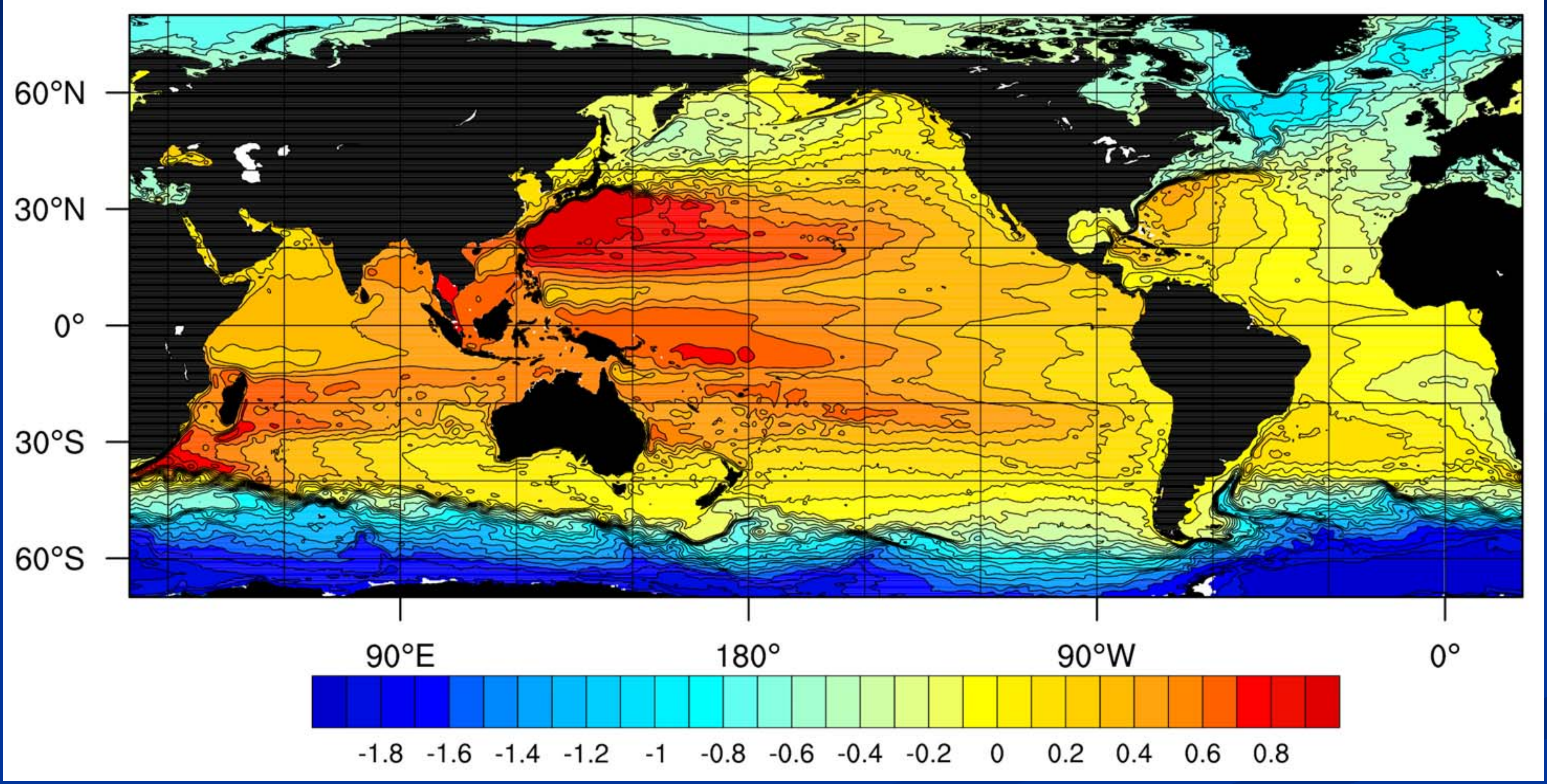
1992-2002 Mean Dynamic Ocean Topography (MDOT)



from Maximenko and Niiler (2005)

Large Scale Circulation Features

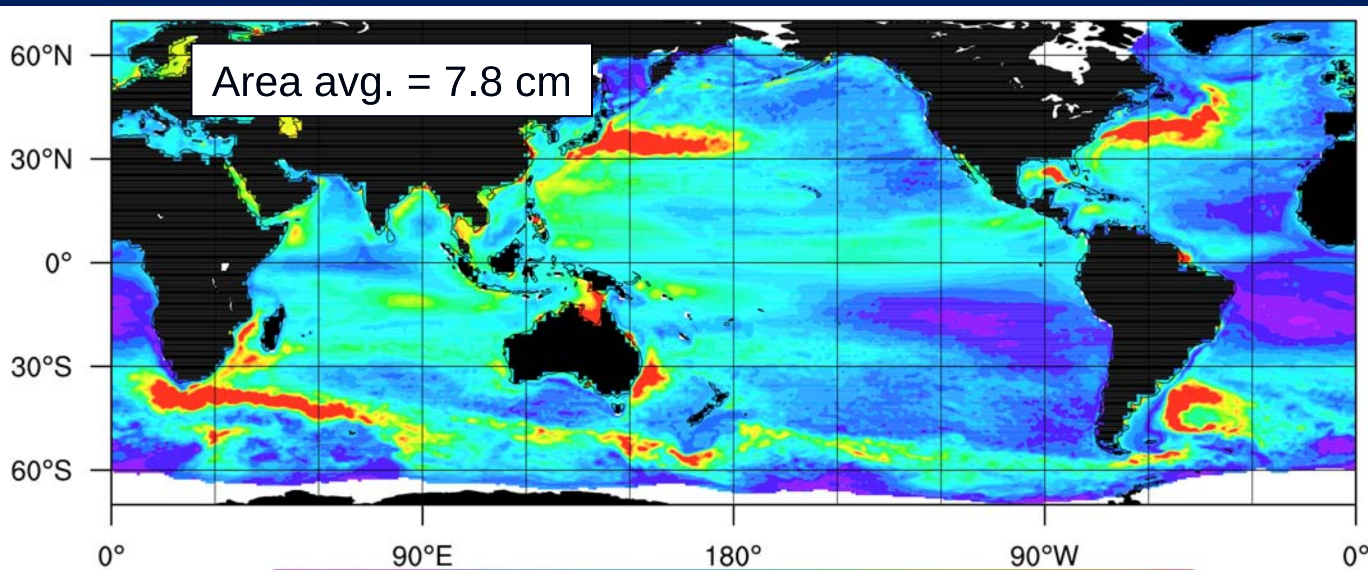
2004-2006 mean sea level from 1/12° global HYCOM/NCODA



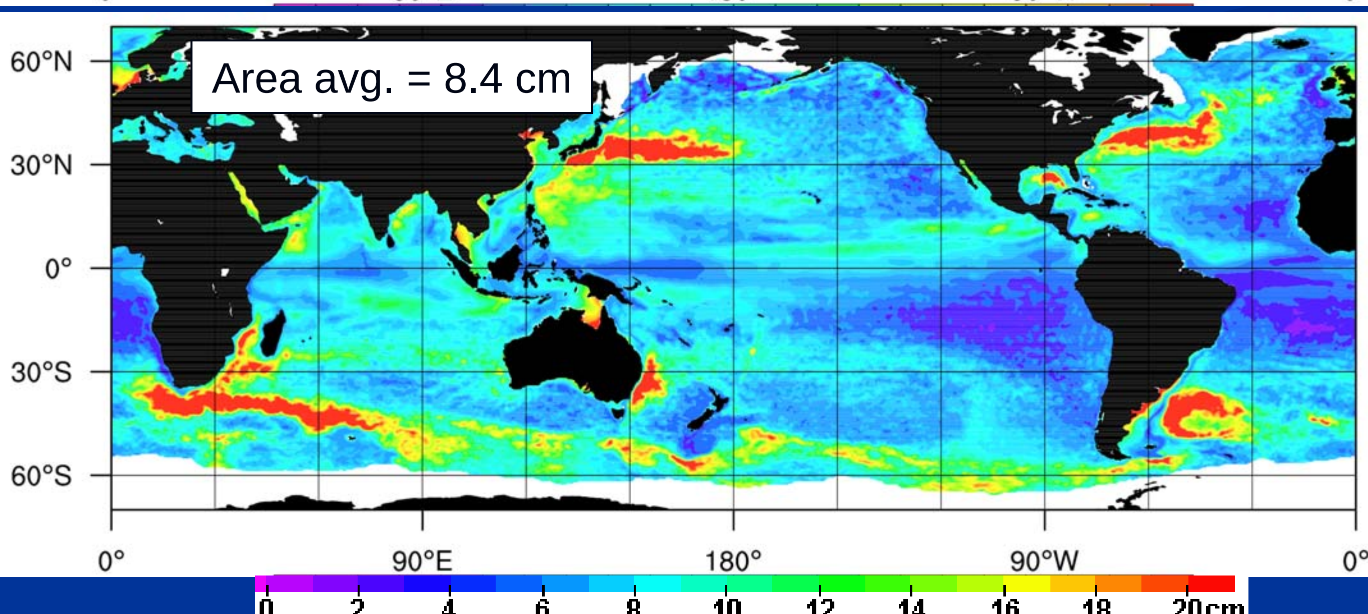
From the 1/12° global HYCOM/NCODA hindcast simulation
standard deviation of difference (MDOT – HYCOM) = 9.2 cm
standard deviation of difference (MDOT – NCOM) = 13.0 cm

SSH Variability Evaluation

Measure of the mesoscale eddy field



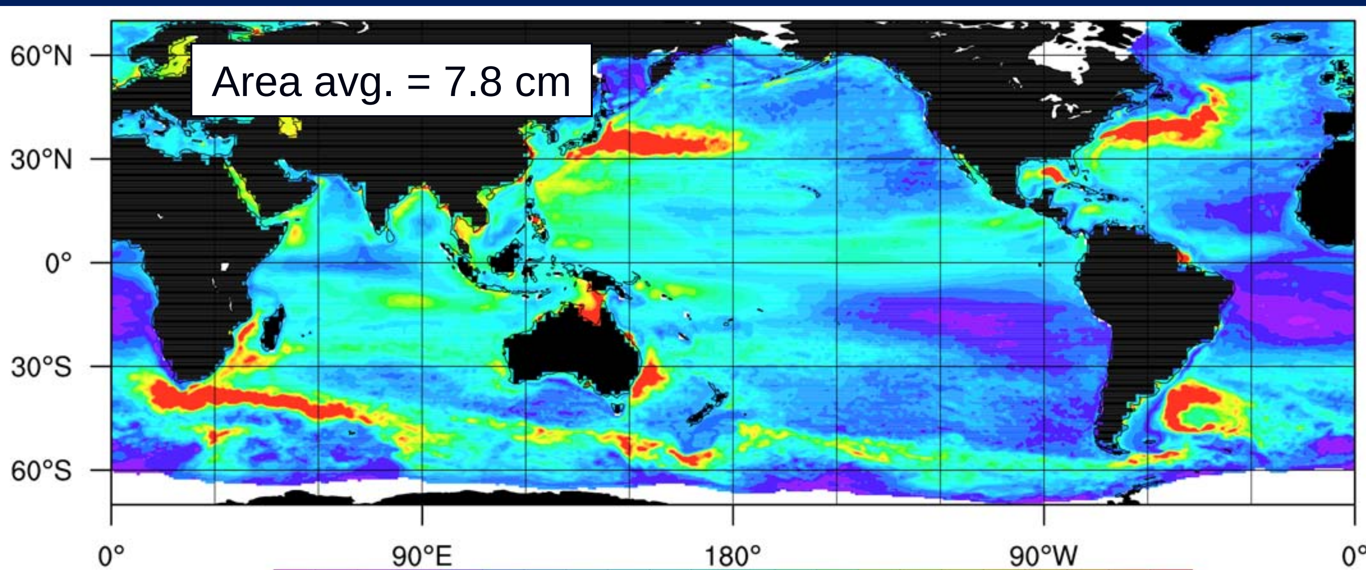
Oct 92 – May 07 SSH variability based on T/P, ERS-1 and ERS-2 altimeters (from Collecte, Localisation, Satellites (CLS))



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

SSH Variability Evaluation

Measure of the mesoscale eddy field



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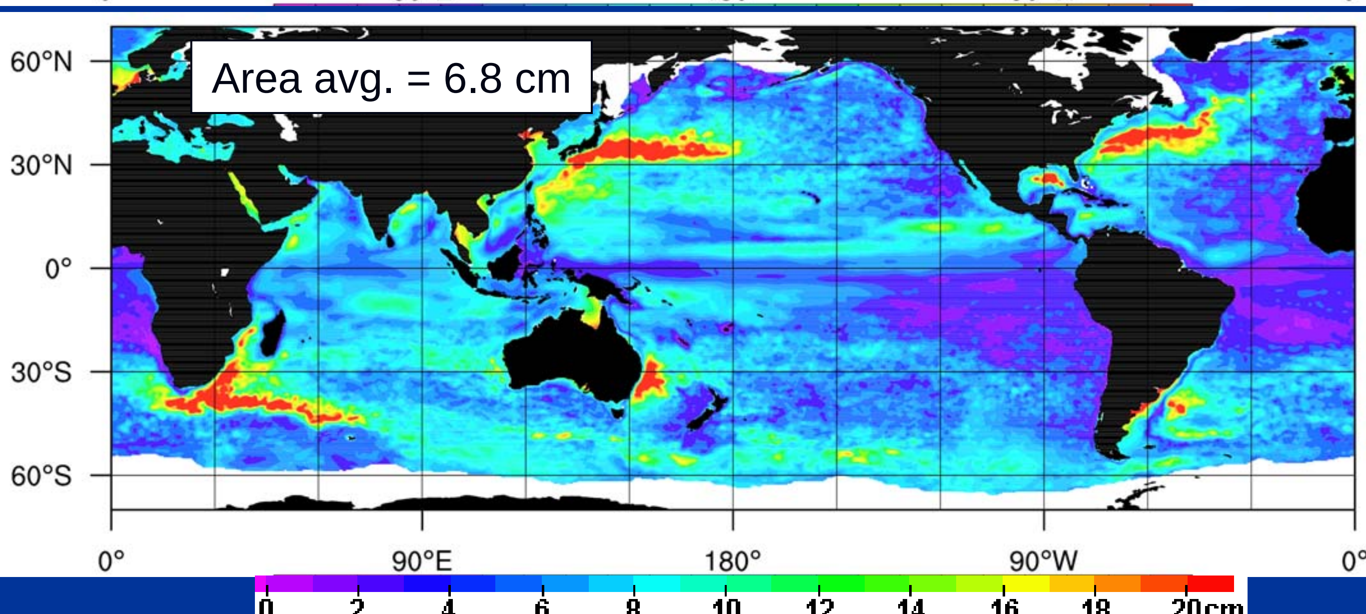
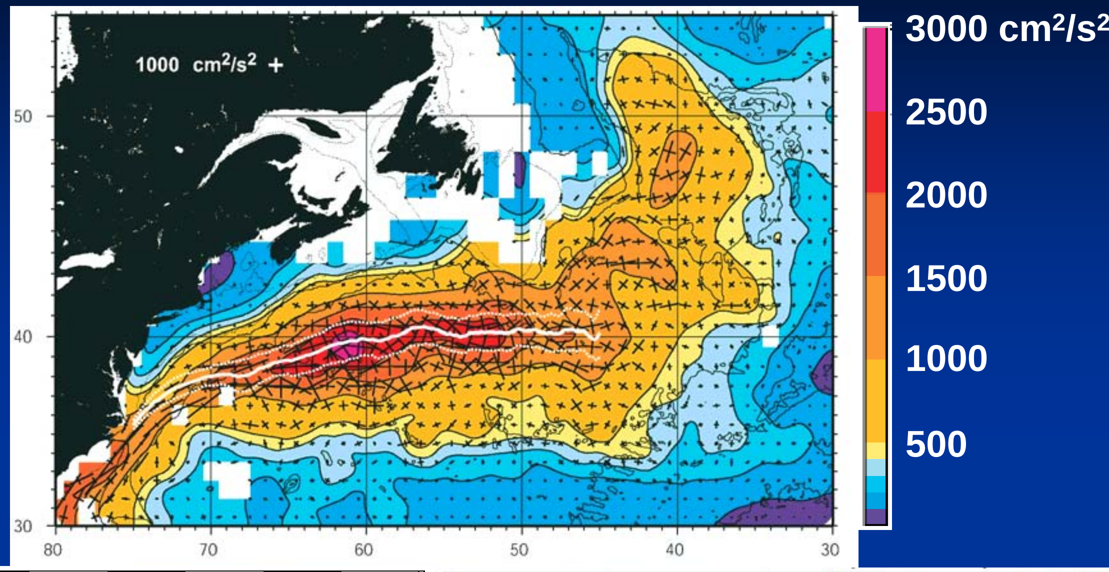
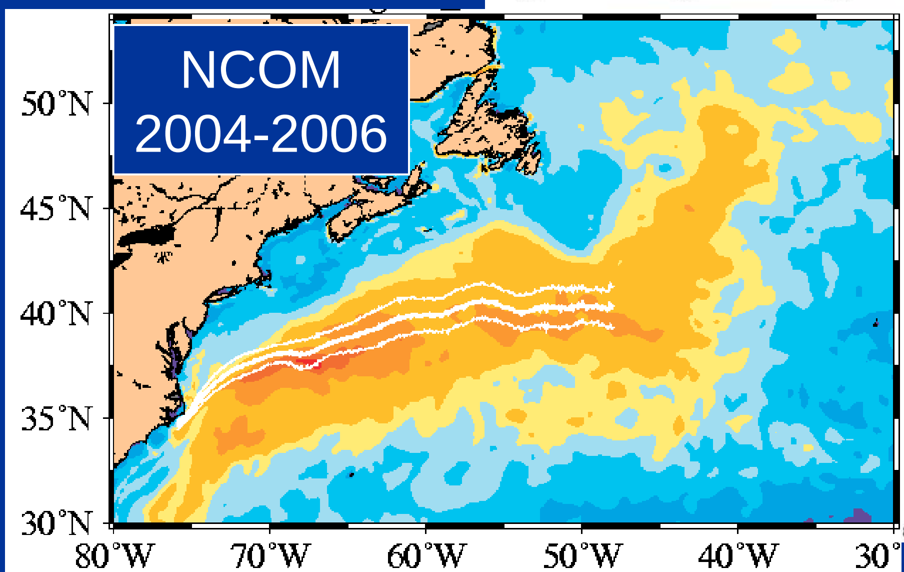


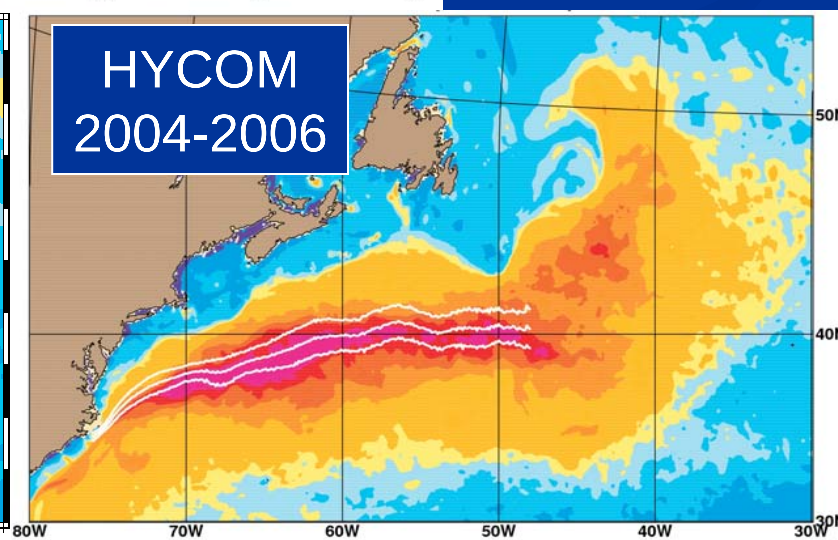
SSH variability over 2004-2006 from the 1/8° global NCOM real-time simulation

Surface EKE in the Gulf Stream

Observations from Fratantoni (2001) – based on 1990-99 surface drifters

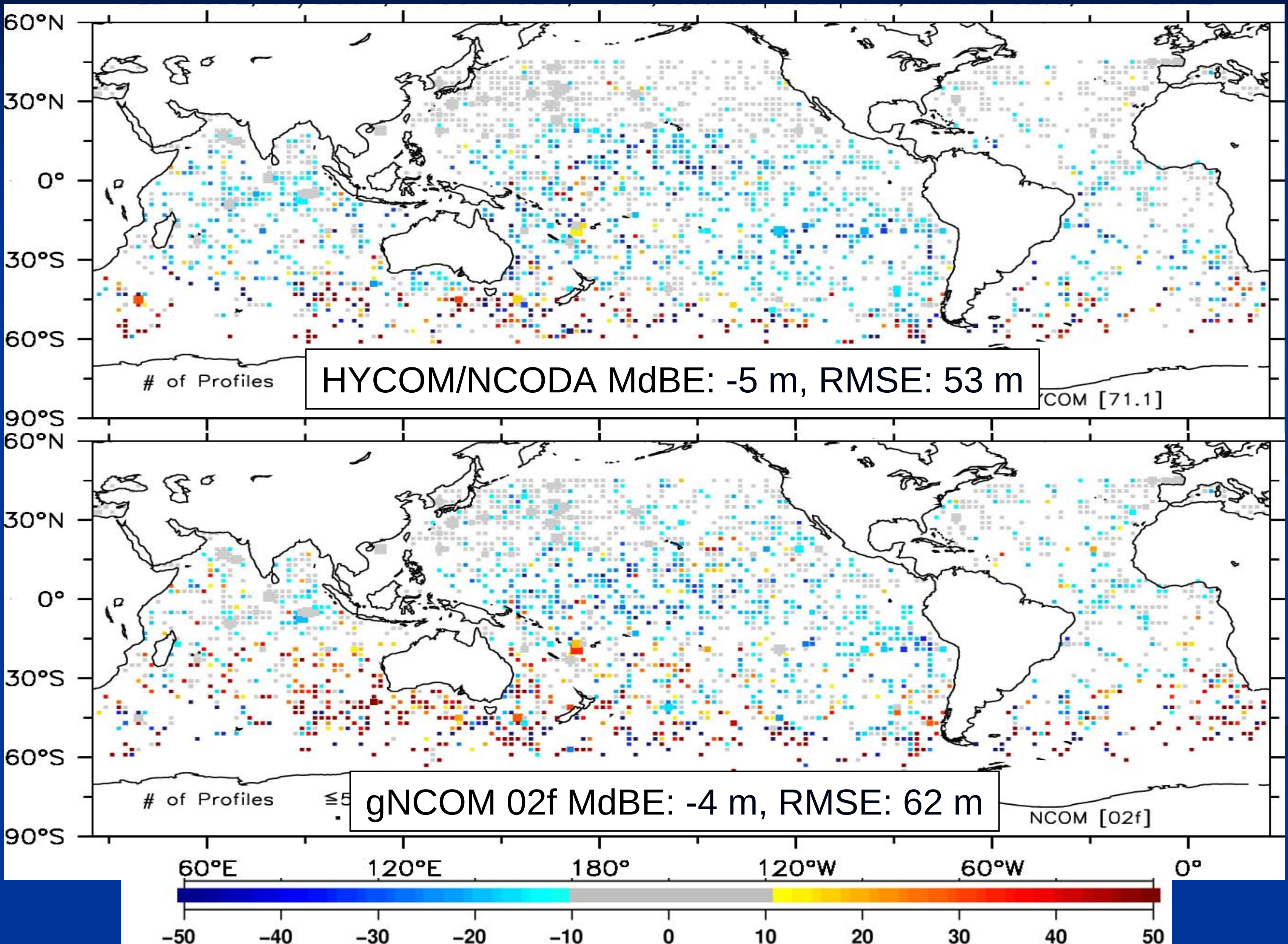






MLD Error Analysis

JJ/2007 MLD Median Bias Error (MdBE): model vs. ~6K assim. profiles

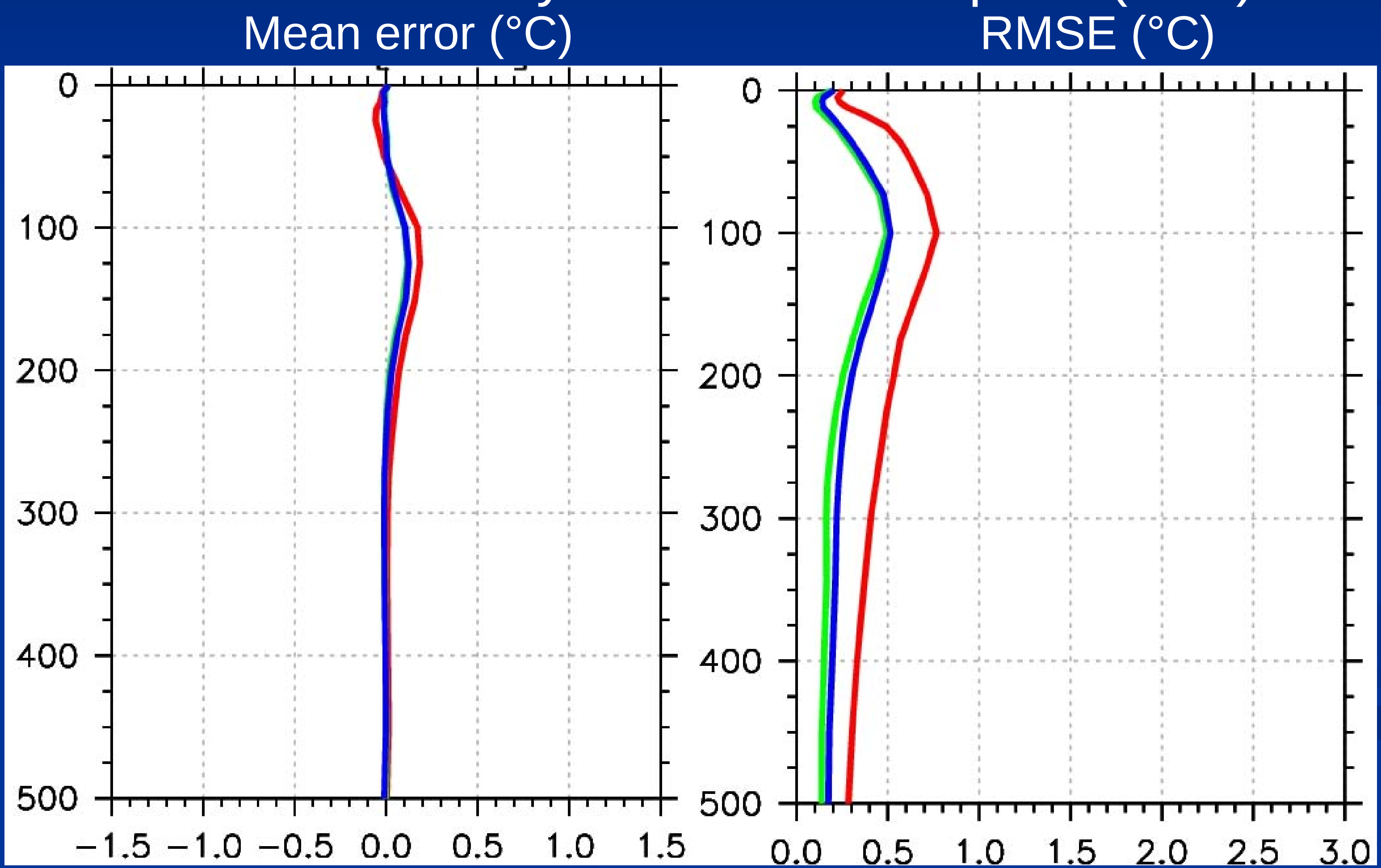


Temp vs. Depth Error Analysis

HYCOM/NCODA (red)

vs. NCODA analysis in z-space (green)

vs. NCODA analysis in HYCOM space (blue)



Based on ~5300 assimilated profiles over the period June-July 2007

Sea Surface Temperature Evaluation

Data type: **MCSST**, ~19,000,000 observations

	Mean Error		RMSE	
	HYCOM	NCOM	HYCOM	NCOM
Analysis	-.12	-.24	.55	.60
1-d fcst	-.17	-.25	.61	.63
2-d fcst	-.19	-.25	.66	.64
3-d fcst	-.21	-.26	.70	.66
4-d fcst	-.22	-	.74	-

Data type: **Drifting buoys**, ~520,000 observations

	Mean Error		RMSE	
	HYCOM	NCOM	HYCOM	NCOM
Analysis	-.08	-.25	.61	.67
1-d fcst	-.13	-.26	.73	.68
2-d fcst	-.16	-.26	.78	.69
3-d fcst	-.19	-.26	.83	.71
4-d fcst	-.21	-	.88	-

Based on thirty 4-day / 3-day forecasts from HYCOM / NCOM over the period June-July 2007; Limited between 45°S – 45°N

Sea Ice Simulation in HYCOM

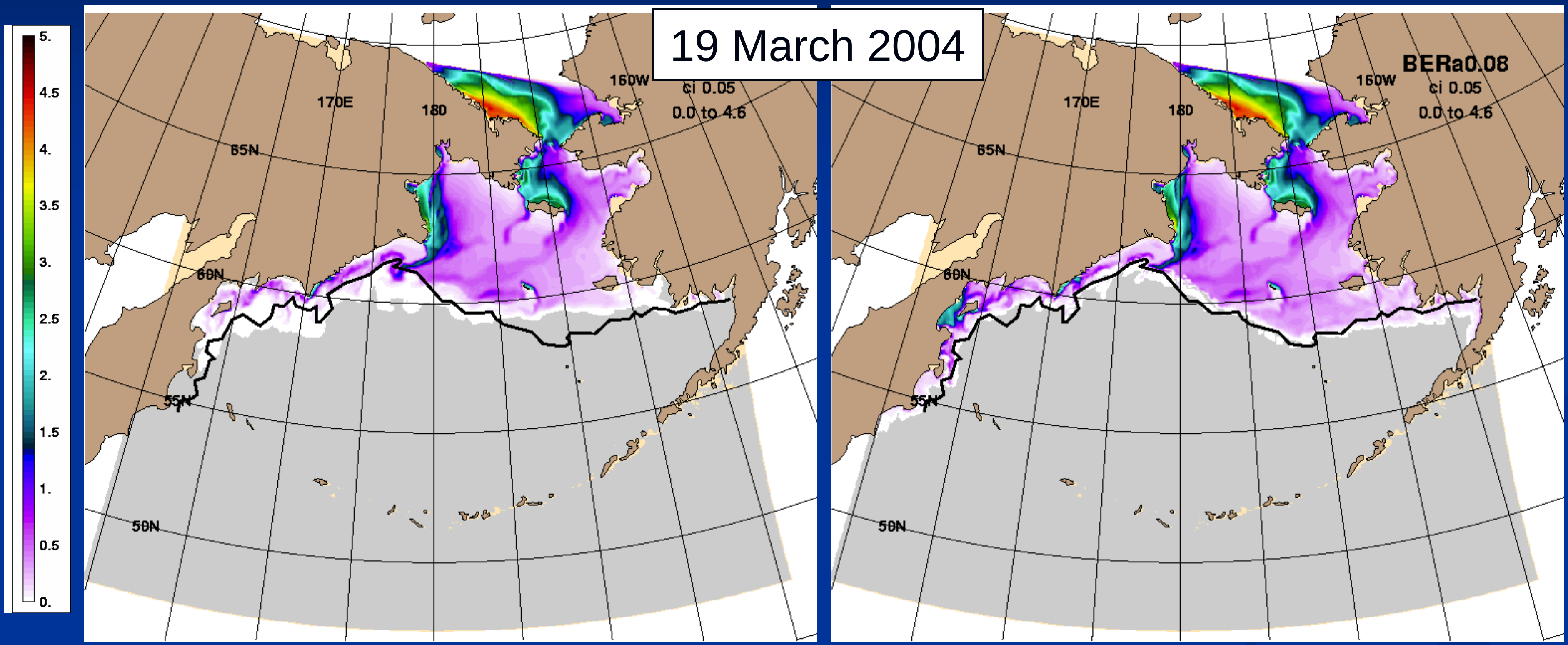
- Existing public domain version of HYCOM is configured with a thermodynamic energy-loan sea ice model built in
  - First generation system
  - No ice rheology – ice grows/melts as a function of heat flux & SST

- Couple HYCOM/NCODA with a sea ice (CICE) model developed by Los Alamos
  - Next generation, advanced system
  - Additional ice physics
    - Energy-based ice ridging scheme
    - Energy-conserving thermodynamics
    - Multi-category, linearly remapped ice thickness
  - 2-way coupling between ocean and ice via the Earth System Modeling Framework (ESMF)
  - In Navy parlance: Polar Ice Prediction System (PIPS)
  - Assimilate SSMI ice concentration in PIPS

Bering Sea HYCOM/NCODA/PIPS

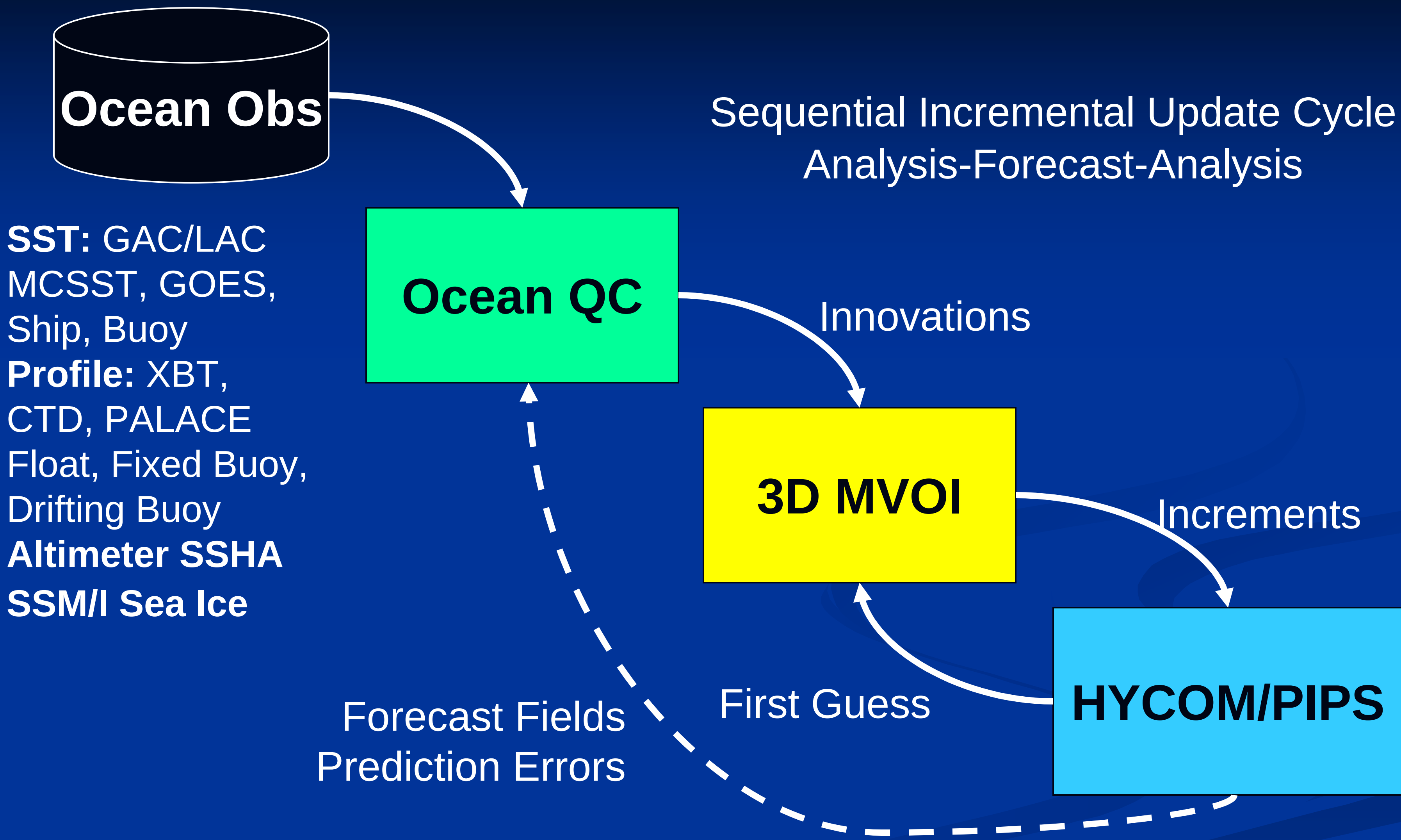
Ice thickness (m) and independent NIC ice edge (black line)

No SSMI assimilation | SSMI assimilation



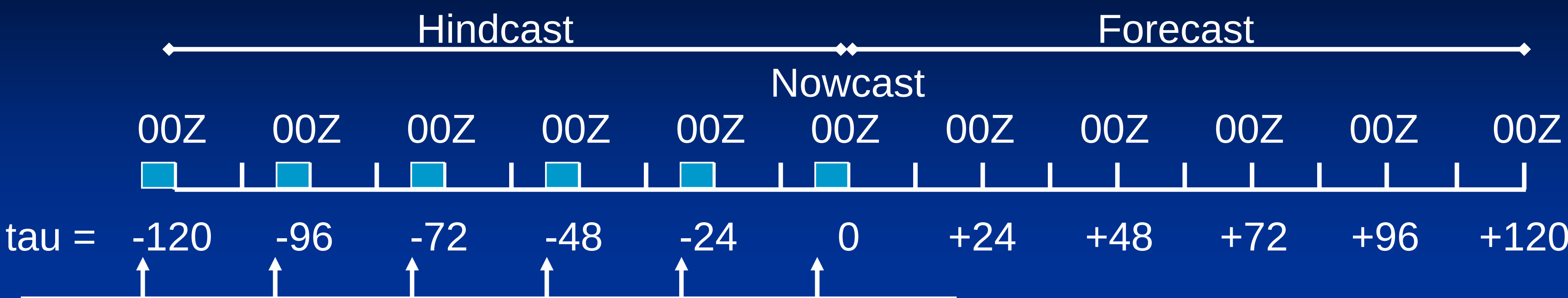
- HYCOM/NCODA/PIPS currently only working for regional domains
- PIPS is a clear improvement over energy-loan ice model
- SSMI ice concentration assimilation simulations produce a better fit to independent ice edge analysis

Navy Coupled Ocean Data Assimilation (NCODA)



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

HYCOM/NCODA Runstream



NCODA analysis windows centered at these times
±36 hours for altimeter data
±12 hours for all other data

1) Perform first NCODA analysis centered on tau = -126
2) Run HYCOM for 24 hours using incremental updating ( ) over the first 6 hrs
3) Repeat steps 1) and 2) until the nowcast time
4) Run HYCOM in forecast mode out to tau = 120

Approximate run times* (using 379 IBM Power 5+ processors):

1) Six NCODA analyses: 1.1 hrs/analysis = 6.6 hrs
2) Five HYCOM hindcast days @ 240 sec Δt: 0.8 hrs/day = 4.0 hrs
3) Five HYCOM forecast days @ 240 sec Δt: 0.8 hrs/day = 4.0 hrs
4) Total: 14.6 hrs

* Timings do not include PIPS coupling

MLD/SLD/BLG/DSC Evaluation

Mixed Layer Depth (MLD): change in temperature of .25°C from the surface

Sonic Layer Depth (SLD): near surface sound speed maximum

Below Layer Gradient (BLG): fit a line to sound speed points between SLD and SLD + 100 m

Deep Sound Channel (DSC) axis: deepest sound speed minimum