Circulation in the Philippine Archipelago simulated by 1/12° and 1/25° global HYCOM and EAS NCOM

presented by Harley E. Hurlbert[1]
co-authors: E. Joseph Metzger[1], Janet Sprintall[2],
Shelley Riedlinger[1], Robert A. Arnone[1],
Toshiaki Shinoda[1], and Xiaobiao Xu[3]

[1] Naval Research Laboratory, Stennis Space Center, MS
[2] Scripps Institution of Oceanography, La Jolla, CA
[3] University of Southern Mississippi, Stennis Space Center, MS

Contribution to ONR Philippine Straits Dynamics Experiment (PhilEx)

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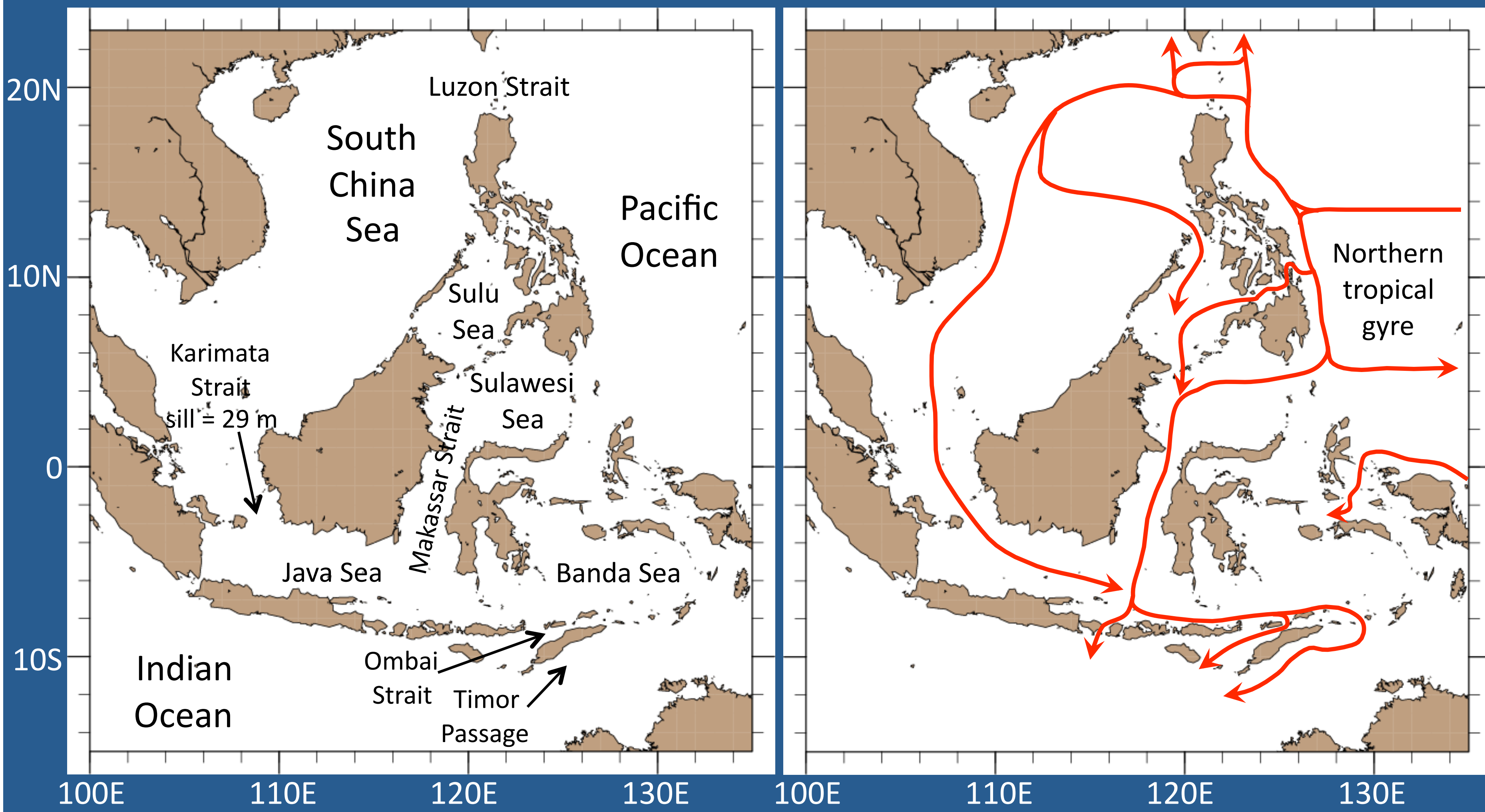
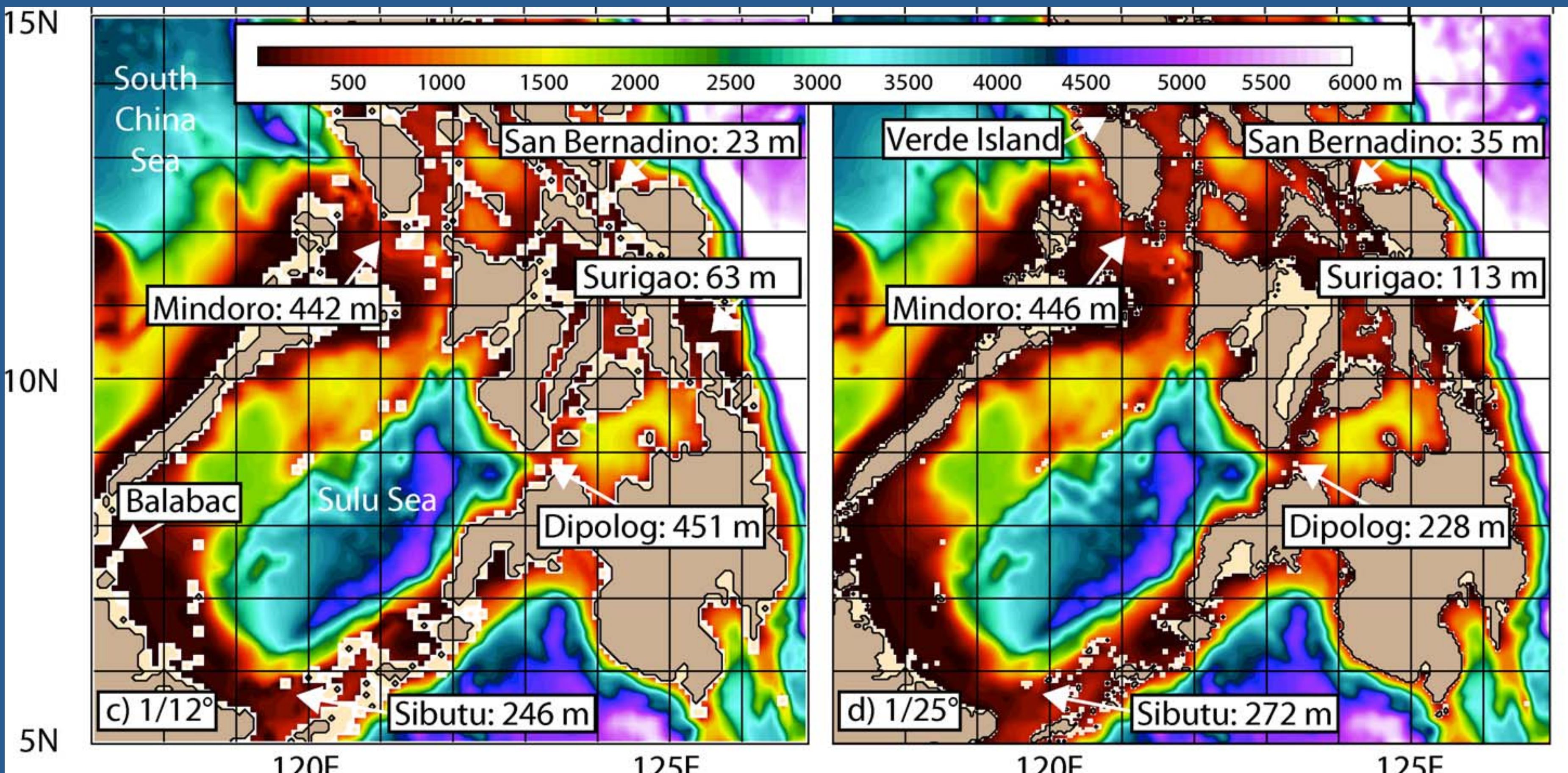
Geography and mean surface currents of the Indo-Philippine Archipelago region



Seafloor Topography of the Philippine Archipelago

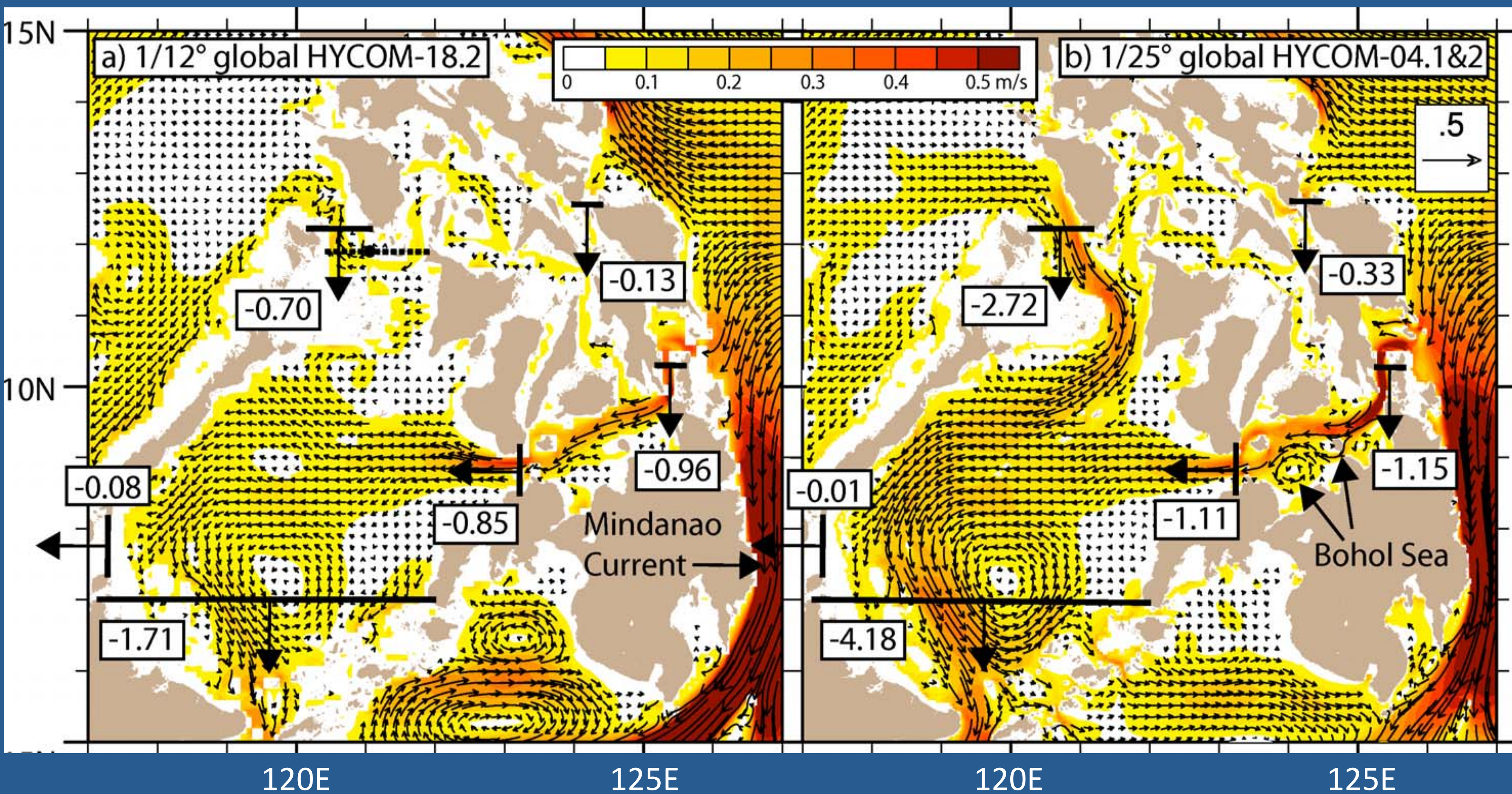
1/12° global HYCOM-18.2 1/25° global HYCOM-4.1&2



Adapted from Hurlburt et al. (2011) Figure 1

Philippine Archipelago mean 2004-2009 currents at 20 m depth simulated by 1/12° and 1/25° global HYCOM with QuikSCAT-corrected ECMWF ERA-40 forcing

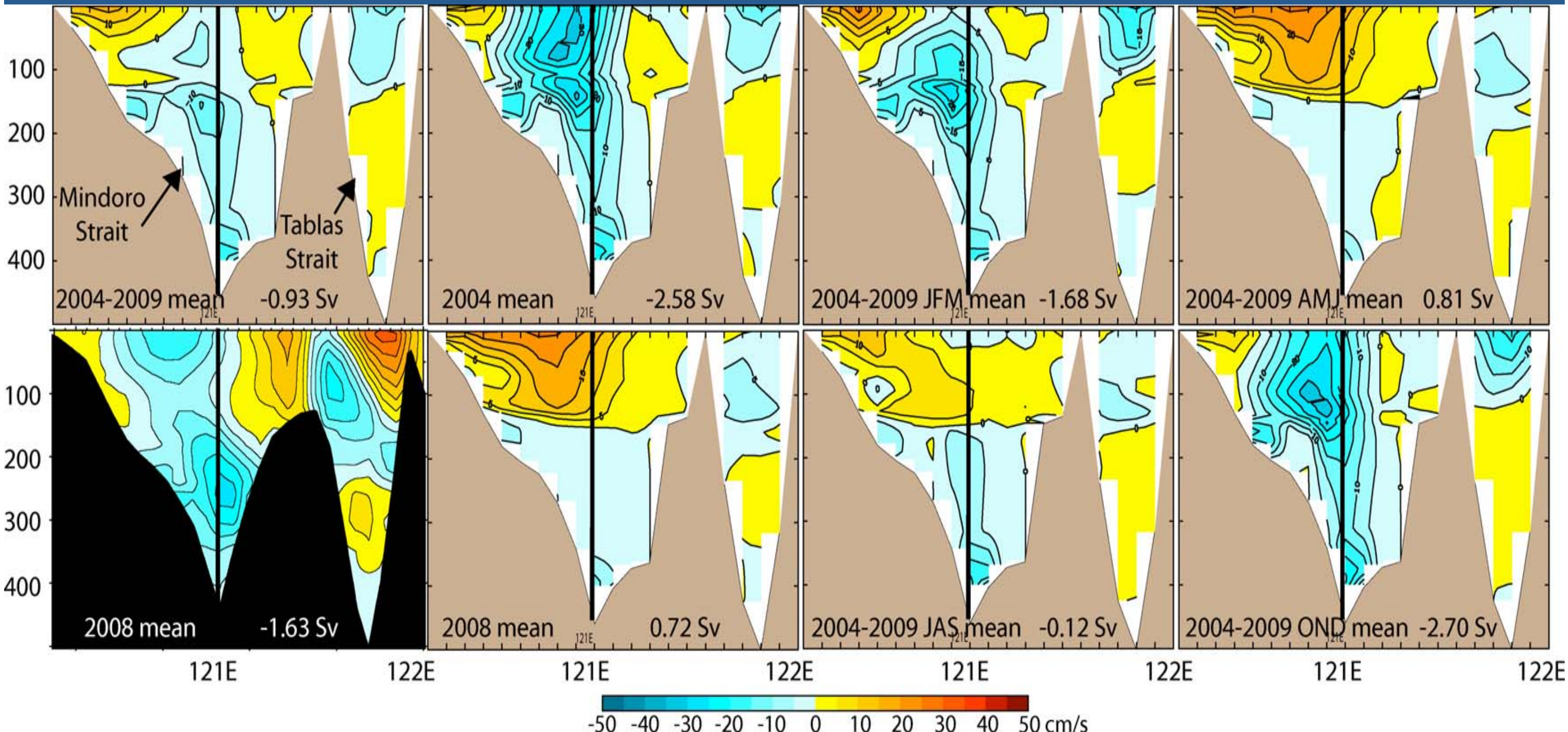
1/12° global HYCOM-18.2 1/25° global HYCOM-4.1&2



Mean currents (arrows) and speed (color) in m/s Mean transports in Sv

Mindoro-Tablas Strait Mean Meridional Velocity Cross-sections at 11.9°N

Vertical black line – PhilEx mooring at the Mindoro sill



EAS NCOM

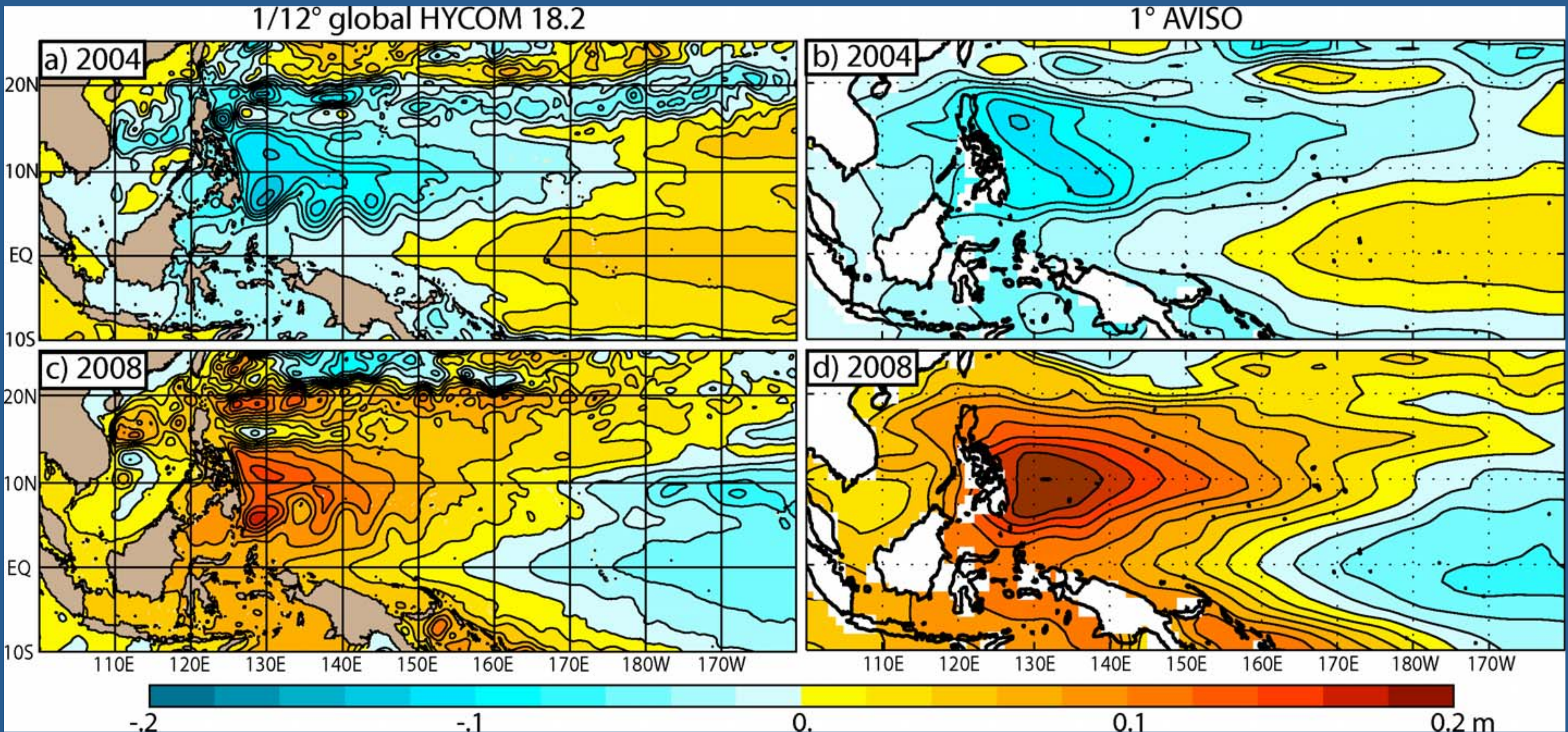
1/12° global HYCOM-18.2

Adapted from Hurlburt et al. (2011) Figure 2

2004 and 2008 Mean Sea Surface Anomalies
1/12° HYCOM-18.2 vs. Satellite Altimetry

1/12° global HYCOM-18.2

1° AVISO analyses of satellite altimeter data



HYCOM anomalies with respect to a 2004-2009 mean

AVISO anomalies with respect to a 2002-2008 mean

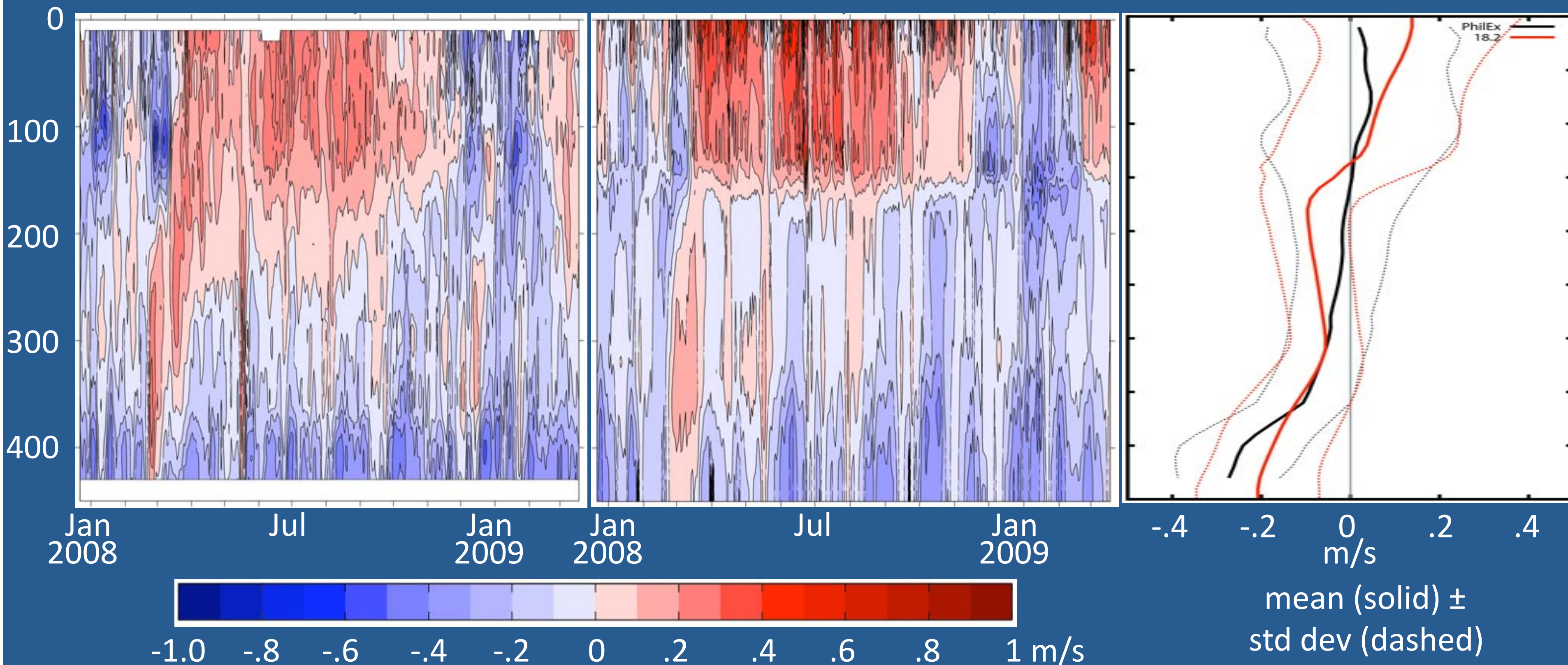
Meridional Velocity vs. Depth at the Mindoro Mooring Location

Daily means over 22 Dec 2007-18 Mar 2009

PhilEx mooring

1/12° global HYCOM-18.2

mooring vs. model mean over obs. period



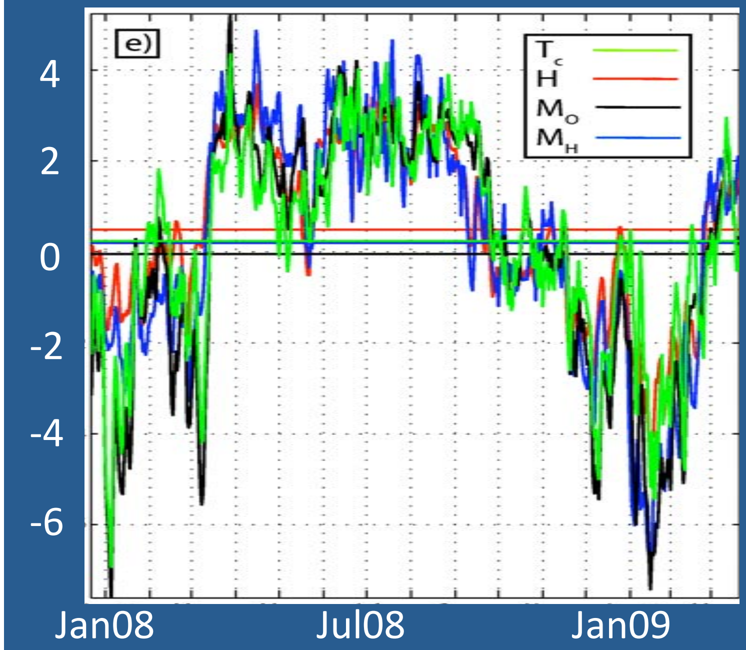
mean (solid) ± std dev (dashed)

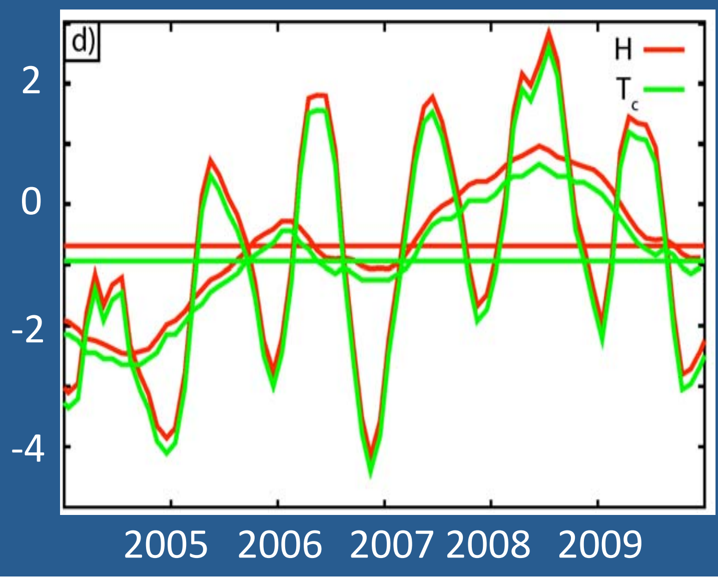
HYCOM

Mooring

Adapted from Hurlbert et al. (2011) Figure 4

Estimation of Mindoro Strait Transport





Mindoro Strait mean transport estimates

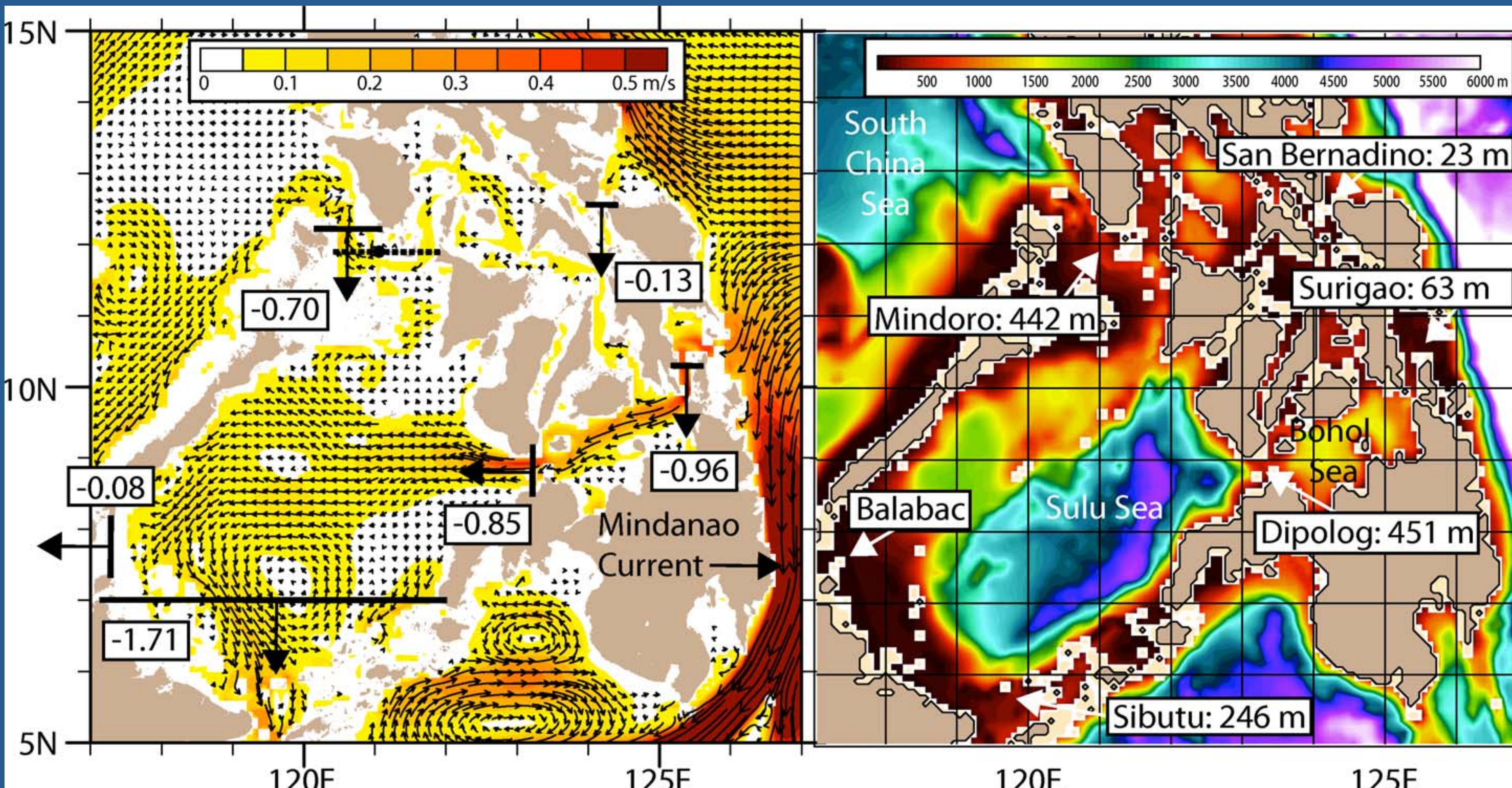
Transport estimate source	Symbol	Total transport estimate (Sv)	Overflow transport estimate (Sv)
Estimates over time period of obs. (Dec 07-Mar 09)			
Mooring alone	M_O	-0.055	-0.24
Co-located HYCOM-18.2 mooring	M_H	0.20	-0.14
1/12° global HYCOM-18.2	H	0.49	-0.18
Combined mooring/ HYCOM-18.2	T_C	0.24	—
Estimates over 2004-2009			
1/12° global HYCOM-18.2	$\overline{H}$	-0.70	-0.22
Combined mooring/ HYCOM-18.2	$\overline{T_C}$	-0.95	-0.28

Negative southward / Overflow below 350 m

1/12° Global HYCOM-18.2

2004-2009 mean currents at 20 m

Seafloor topography



Mean currents (arrows) and speed (color) in m/s

Mean transports in Sv

Why is Surigao transport >> San Bernardino despite similar widths and sill depths?

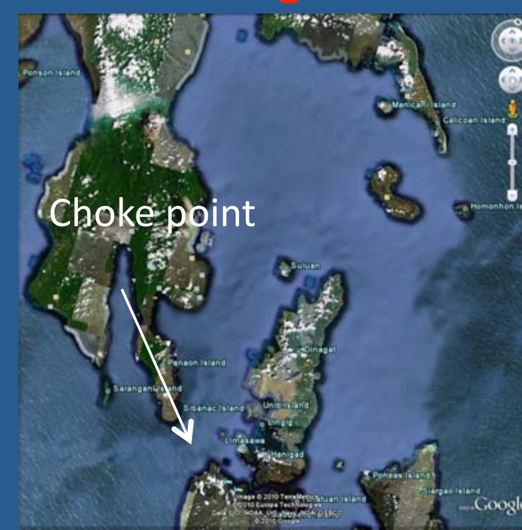
Barotropic theory from Mattsson (1995), Metzger and Hurlburt (1996)

$$\Delta\eta = \frac{f}{gH}Q_T + \frac{1}{2gH^2W^2}(1+2C_b\frac{L}{H})Q_T\,|Q_T|$$

	San Bern.	Surigao	
$\Delta\eta$ (model)	-8	-6	Sea surface height (SSH) setdown (cm)
$\Delta\eta$ (theory)	-8.1	-30.1	
Q_T	-0.13	-0.96	Transport (Sv)
f	$3.2\text{x}10^{-5}$	$2.5\text{x}10^{-5}$	Coriolis parameter (s^{-1})
H	23	63	Sill depth (m)
W=L	8.66	8.75	Strait width = length (km)
C_b	$2.5\text{x}10^{-3}$	$2.5\text{x}10^{-3}$	Bottom friction coefficient
g	9.8	9.8	Gravity acceleration (m/s^2)

San Bernardino

Surigao



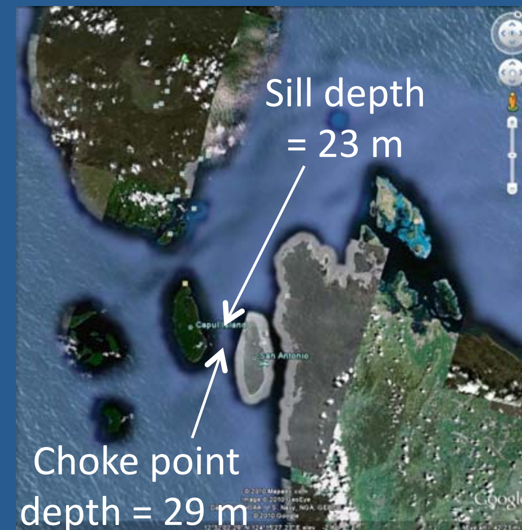
Why is Surigao transport >> San Bernardino despite similar widths and sill depths?

Barotropic theory from Mattsson (1995), Metzger and Hurlburt (1996)

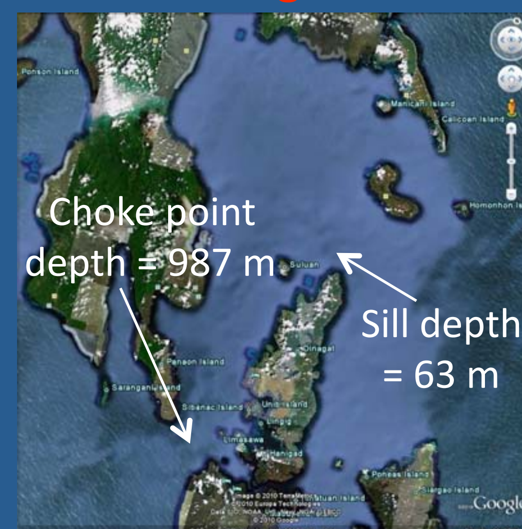
$$\Delta\eta = \frac{f}{gH}Q_T + \frac{1}{2gH^2W^2}(1+2C_b\frac{L}{H})Q_T\,|Q_T|$$

	San Bern.	Surigao	
Δη (model)	-8	-6	Sea surface height (SSH) setdown (cm)
Δη (theory)	-8.1	-6.3	
Q_T	-0.13	-0.96	Transport (Sv)
f	3.2×10^{-5}	2.5×10^{-5}	Coriolis parameter (s^{-1})
H	23	120	Thermocline depth (m)
W=L	8.66	8.75	Strait width = length (km)
C_b	2.5×10^{-3}	0	Bottom friction coefficient
g	9.8	9.8	Gravity acceleration (m/s^2)

San Bernardino

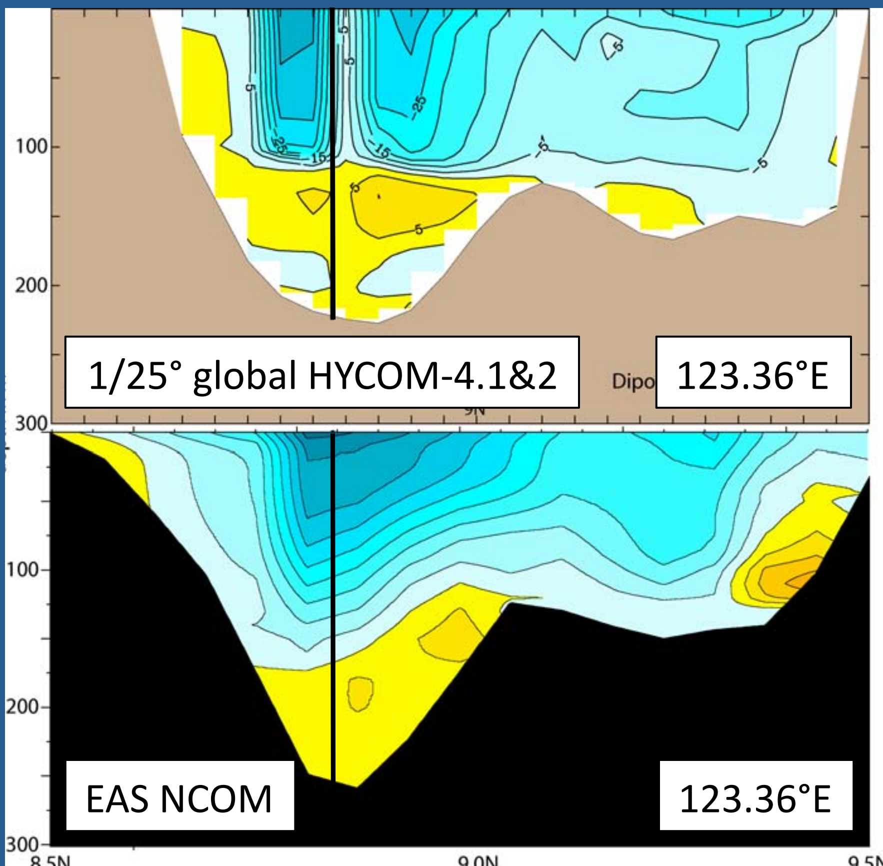


Surigao

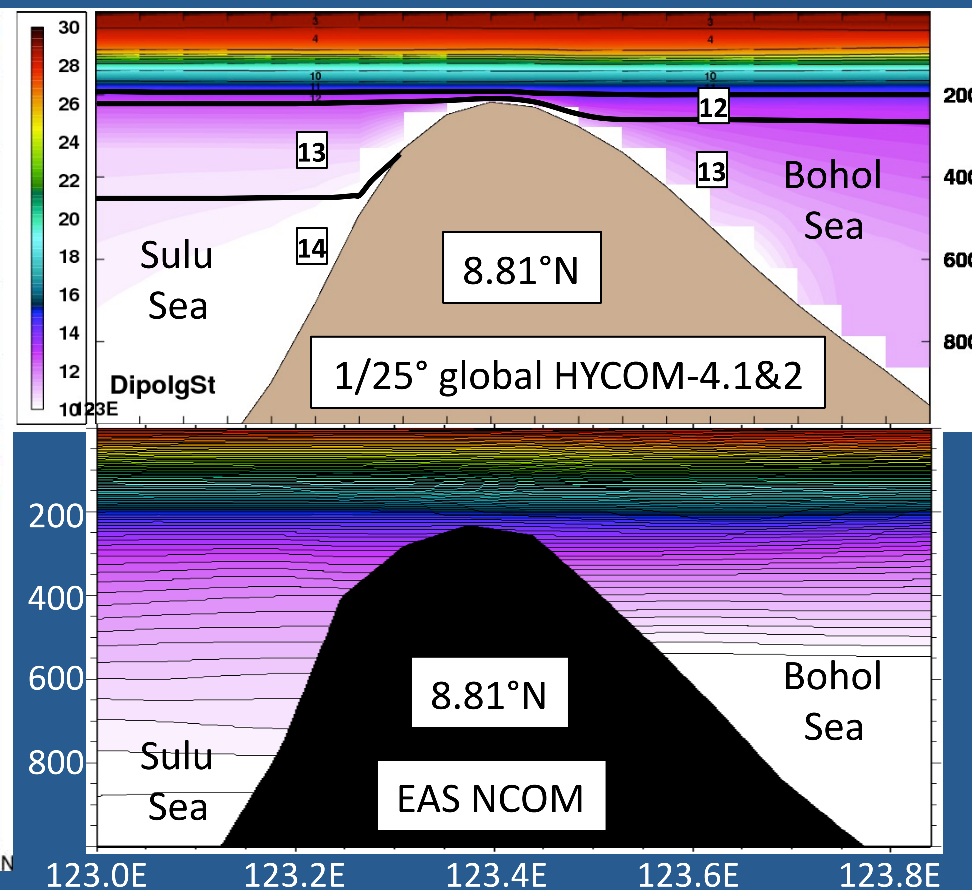


Four-layer Flow through Dipolog Strait

2004-2009 mean zonal velocity



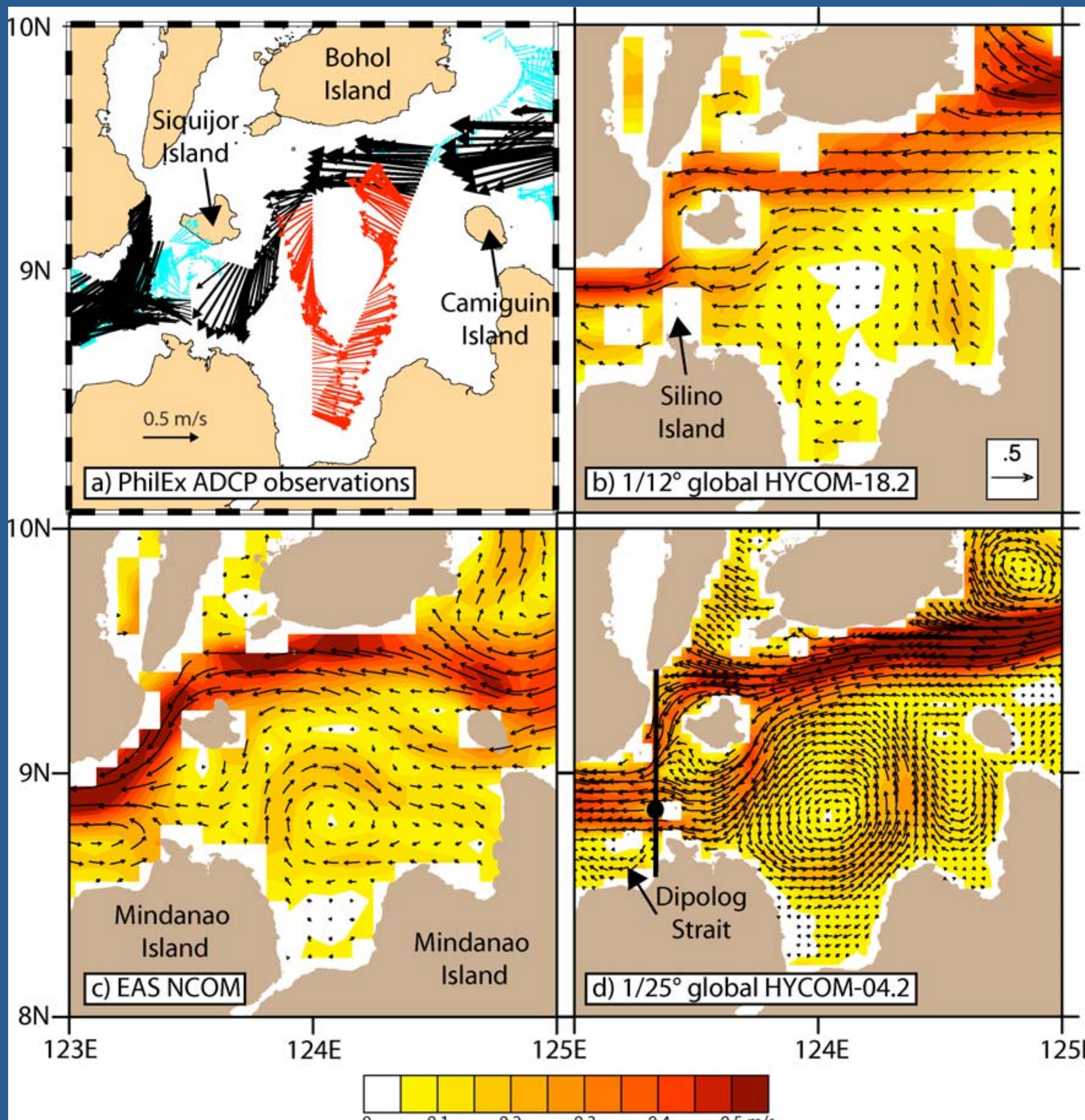
2004-2009 along strait mean temperature



PhilEx mooring marked by vertical line

Adapted from Hurlburt et al. (2011) Figure 5

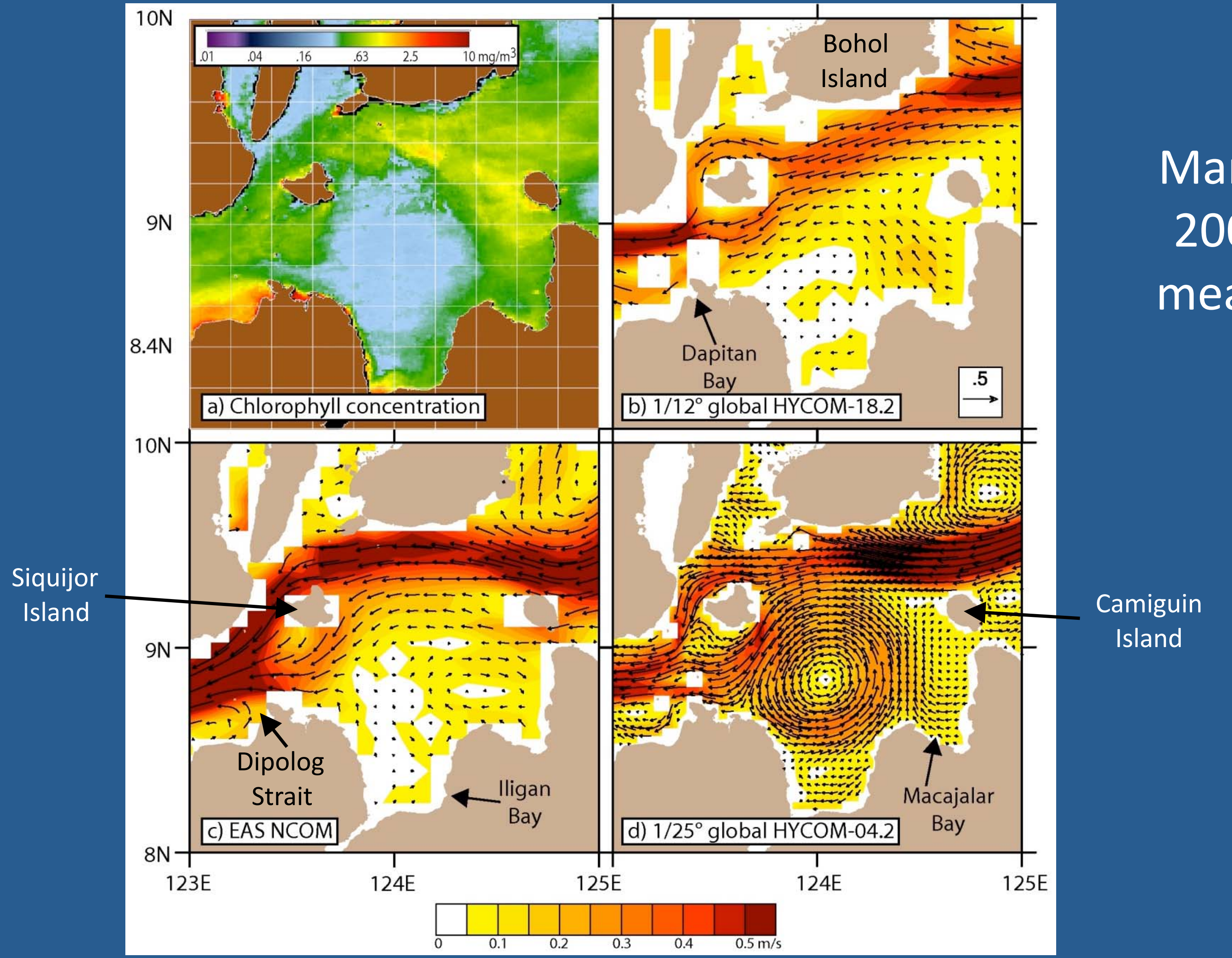
PhilEx ADCP measurements vs. 1/12° and 1/25° global HYCOM and EAS NCOM at 20 m depth



Bohol Sea currents 1-8 March 2009

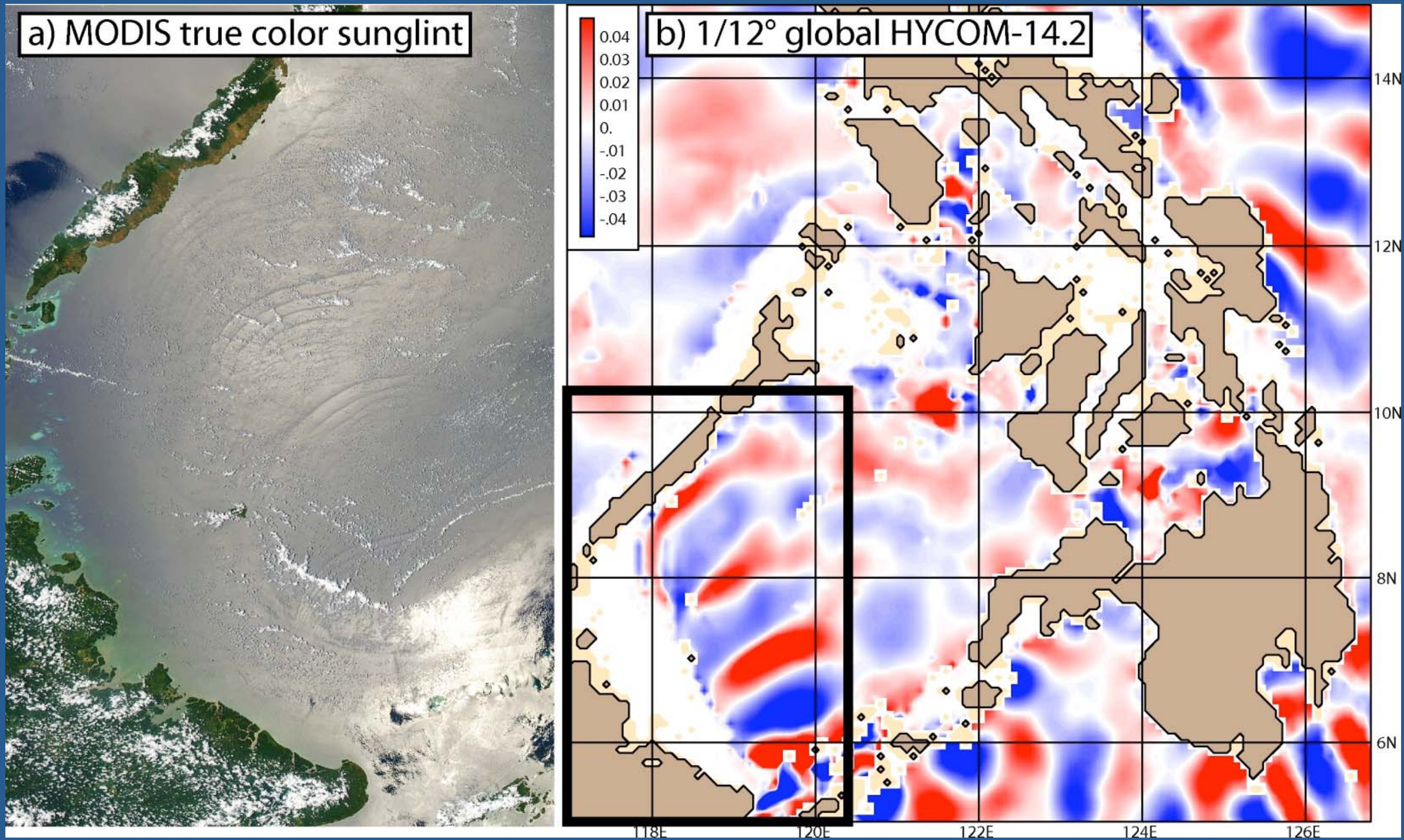
Cross-section and mooring location (dot) in the lee of Silino Island

Ocean color vs. 1/12° and 1/25° global HYCOM and EAS NCOM currents at 20 m depth



March 2007 means

Internal tide snapshots in the Philippine Seas from 1/12° global HYCOM-14.2 and MODIS sunglint imagery



MODIS sunglint 8 Apr 2003 in western Sulu Sea

Sea surface height signature of internal tides in HYCOM 15 May 2004; Black box marks the location of the sunglint image

The HYCOM simulation includes both the atmospherically-forced circulation and tides. HYCOM is hydrostatic and thus does not simulate the soliton aspect of the observed tidal beam. Sunglint image provided by Chris Jackson (Global Ocean Associates).

Summary and Conclusions - 1

- ONR Philippine Straits Dynamics Experiment (PhilEx) observations and modeling → 0(1) increase in oceanographic knowledge and data in this poorly studied region
- Global HYCOM simulated Philippine Archipelago circulation in a global context
  - Two significant secondary routes
    - For Pacific to Indian Ocean throughflow
      - More important than Karimata Strait (i.e. route through Java Sea)
    - For Pacific northern tropical gyre western boundary currents
    - South China Sea → Mindoro → Sibutu
    - Newly identified Pacific → Surigao → Dipolog → Sibutu
      - Explained theoretically why Surigao, not San Bernardino provides stronger shallow Pacific → Philippine inflow

Summary and Conclusions - 2

- Global HYCOM simulated Philippine Archipelago circulation in a global context (continued)
  - Extremely challenging region to simulate in a global ocean model
    - Models can be sensitive to resolution and topographic errors
    - Only 1/25° global HYCOM robustly simulated the persistent Bohol Sea gyre
      - 2^{nd} largest interior Philippine Sea

Summary and Conclusions - 3

- 2004 and 2008 were extreme opposite anomalous years
  - 2008 was the central year of PhilEx observations
  - Profound impact on Mindoro Strait and Sibutu Passage transport but not Surigao transport
    - Mean northward transport through Mindoro in 2008
      - Vs. southward transport in other years
  - 1st estimate of Mindoro Strait transport using in situ data
    - Single 15 month nearly full depth mooring
    - HYCOM corrections for cross-sectional flow structure and interannual variability

Summary and Conclusions - 4

- 1/12° global HYCOM with tides simulated the hydrostatic aspect of strong internal tidal beams observed crossing the Sulu Sea

See Hurlburt et al. (Oceanography, 2011, in press) for more information. March Special Issue on PhilEx.