Surface circulation and dynamics in the Philippine Archipelago region

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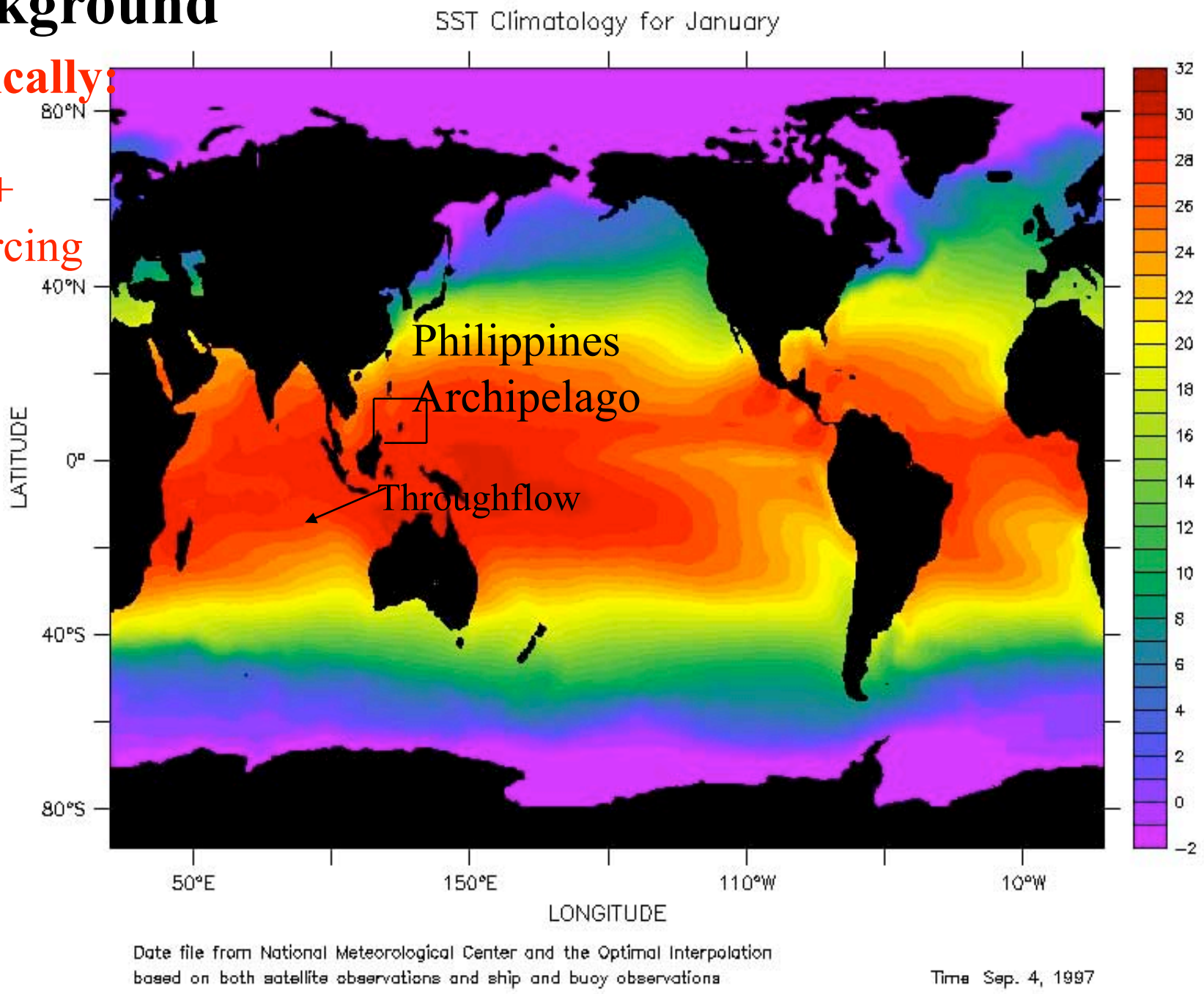
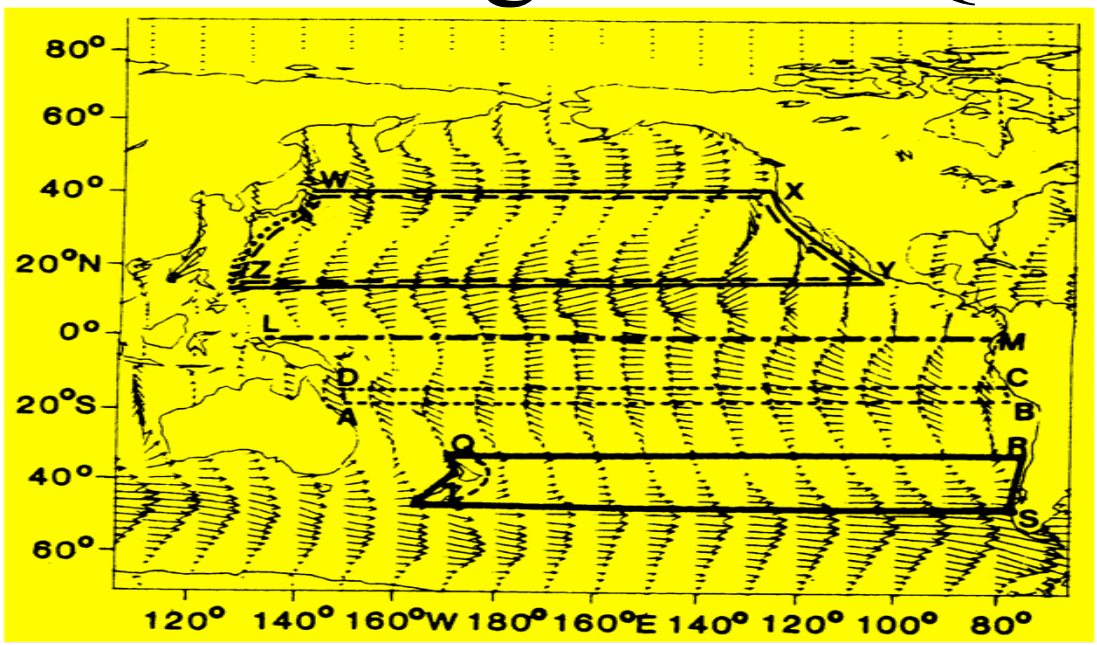
1. Background

Dynamically:

Remote +
Local forcing



Remote forcing from EQ Pacific



Godfrey 1989

Assumptions:

1) Sverdrup interior - friction is negligible;
   Friction is only important along the western boundary.
2) No bottom topography.

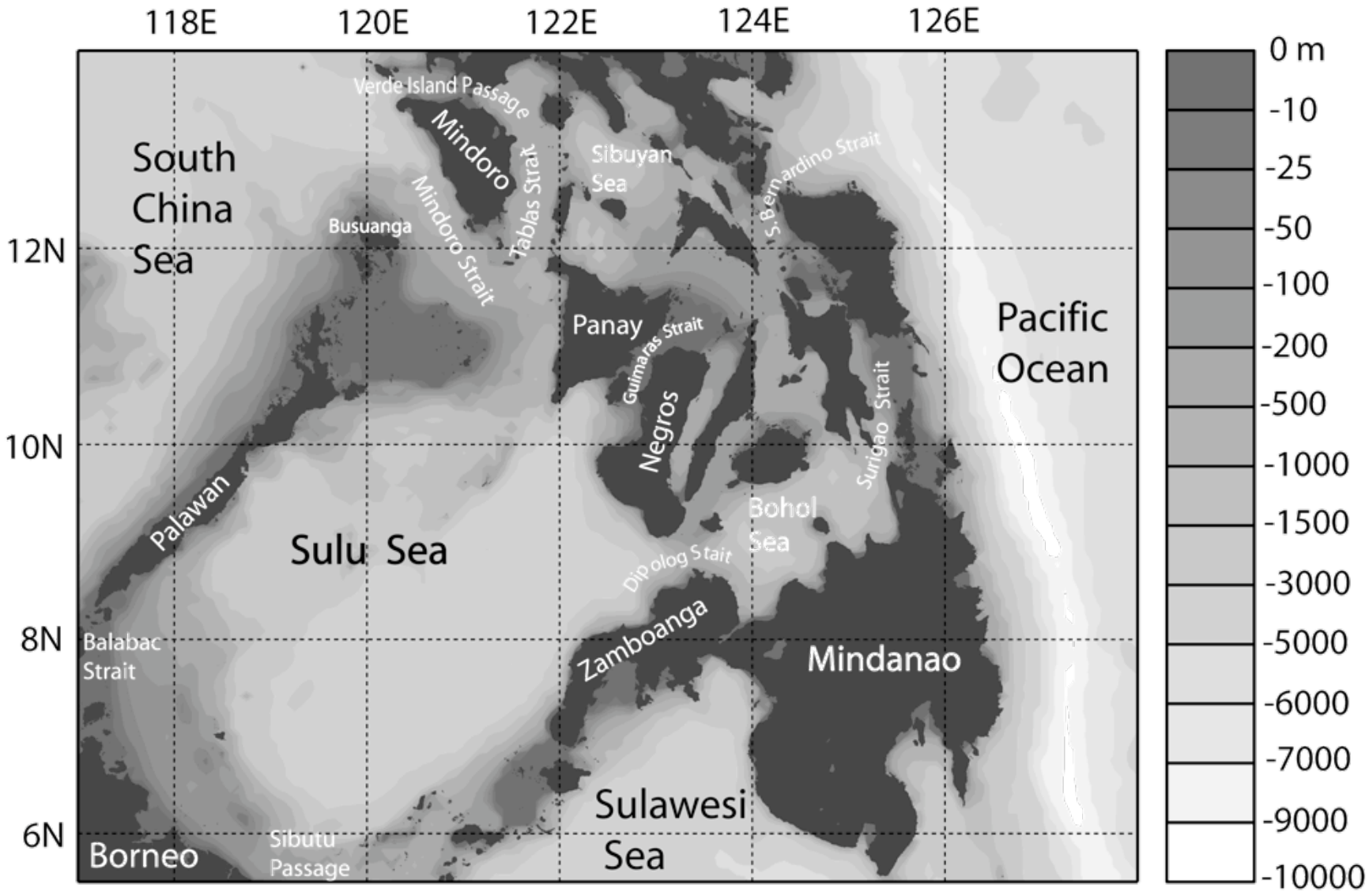
No Gap at WB:

$$P_Z - P_W = \int_{WXYZ} \frac{\tau^{(l)}}{\rho_0} dl$$

Gap at WB:

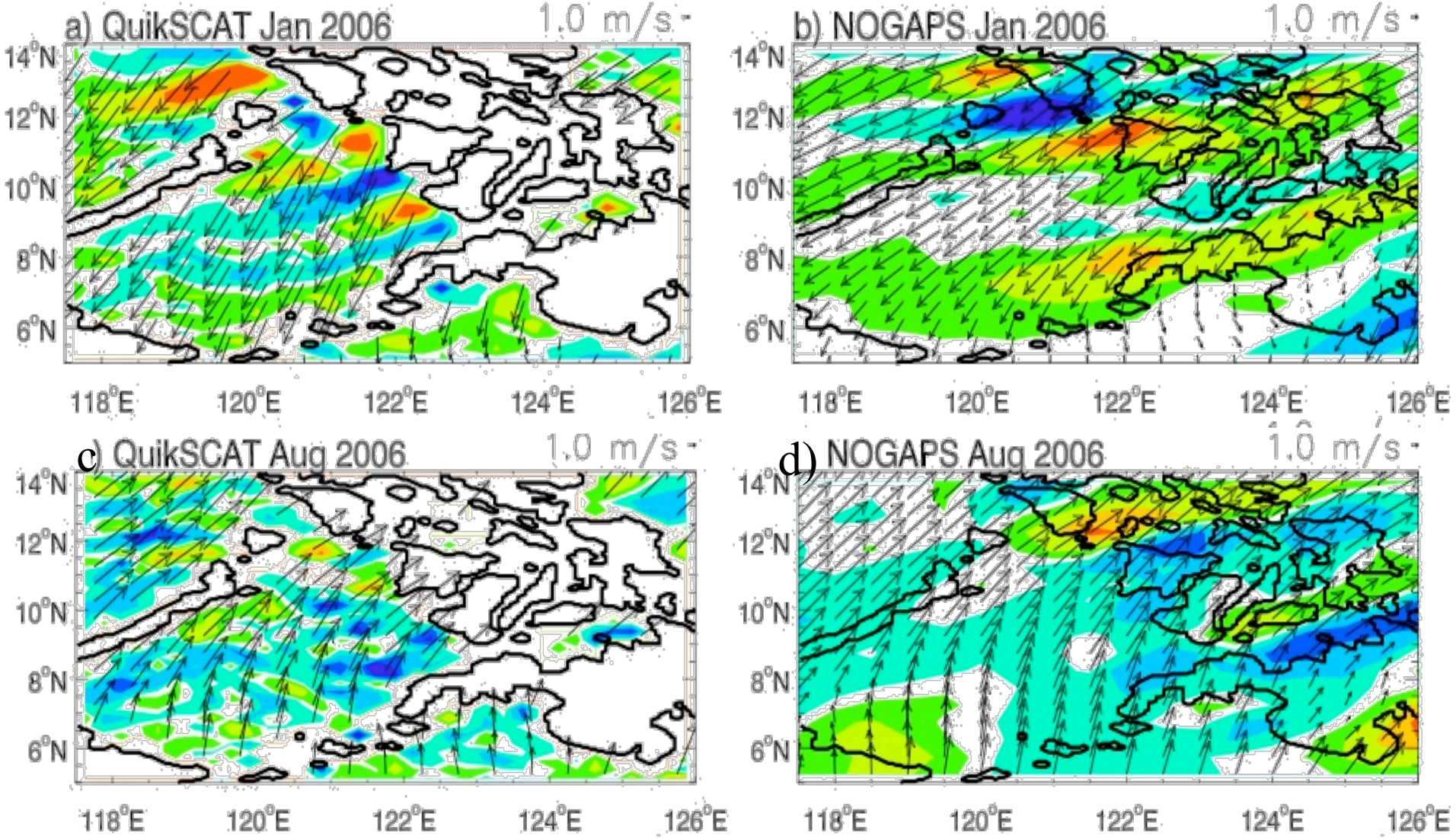
$$T_0 = \int_{TSRQ} \tau^{(l)} dl / \rho_0 (f_Q - f_T)$$

Complex topography in the Philippines Archipelago region



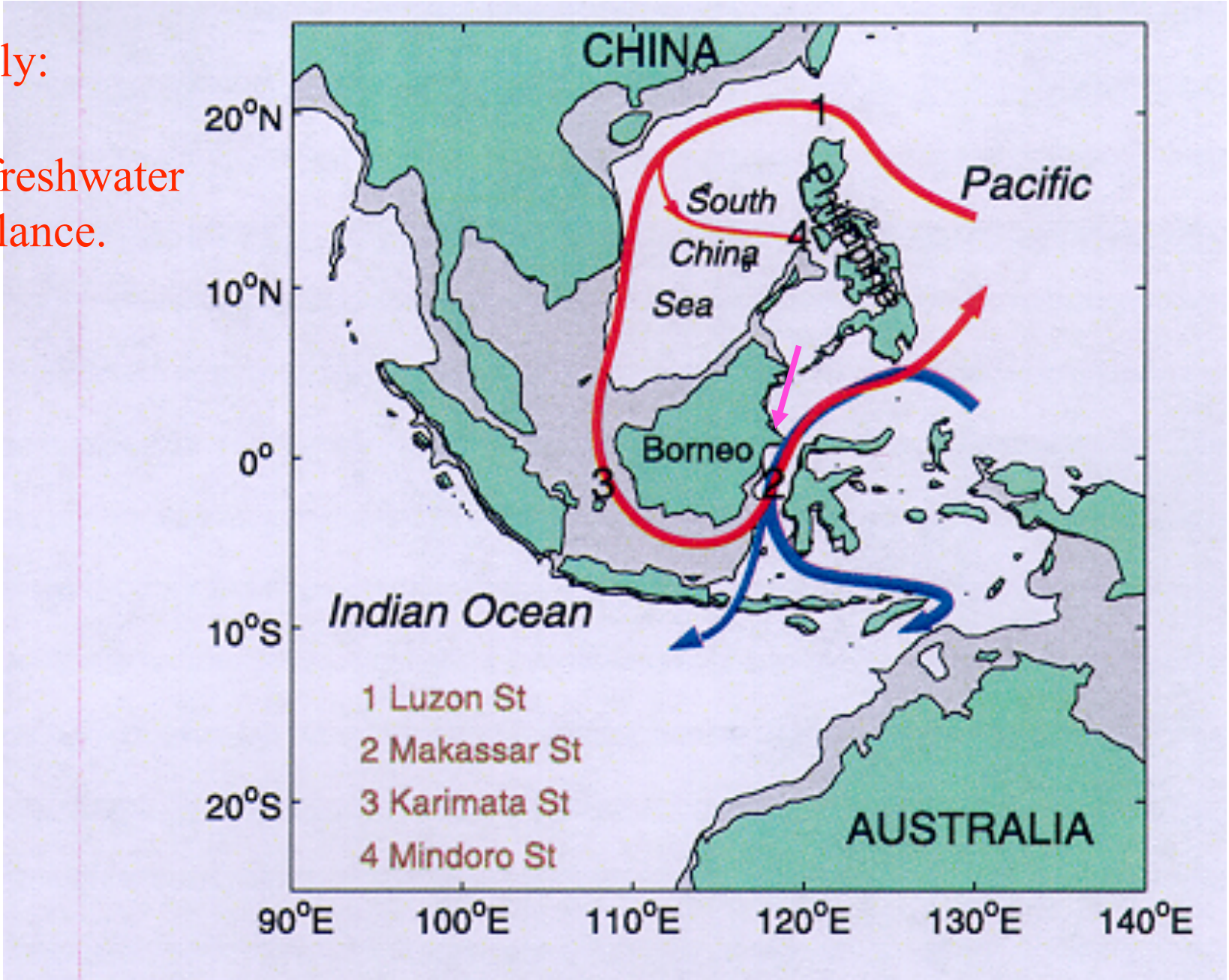
Island rule calculation: 10 times of the observed mean strait transport!

Locally: Prevailing winds



Climatically:

Heat and freshwater buffer, balance.



Qu et al. 2005

Goal

A high resolution OGCM - the ROMS) - & PhilEx observations to understand:

Surface circulation and dynamics in the Philippine Archipelago & Sulu Sea:

Remote versus local forcing on seasonal variations, tidal rectification

2. The ocean model

The ROMS (*Shchepetkin and McWilliams* 2005);
Domain: 117°E-128°E, 0°N-14°N,
~5km x 5km resolution, 42 vertical levels.

Initial & Lateral Boundary Conditions:
1/12° x 1/12° HYCOM.

Surface Forcing:
NOGAPS 3 hourly 0.5 deg fields

Barotropic tidal forcing:
OSU Tidal inversion software, Topex/Poseidon, Jason satellite altimetry: M2, S2, N2, K2, K1, O1, P1 and Q1

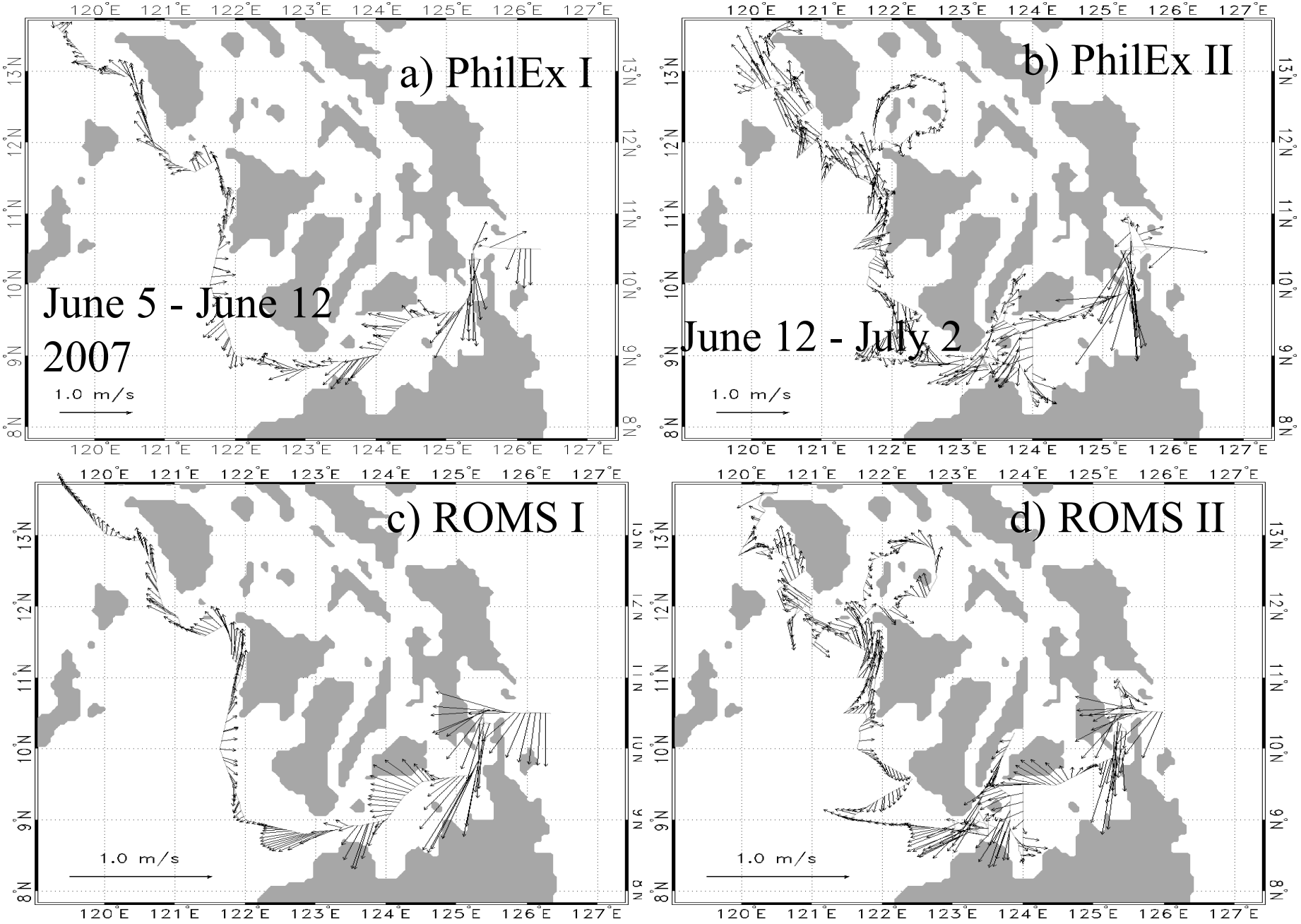
Experiments	Period	Description
CR	01/2004 - 03/2008	Complete
EXP1	01/2004/ - 12/2006	Fix boundary to 2004-06 mean
EXP2	01/2004 - 12/2006	No tides

CR - EXP1 => Remote forcing on temporal variations of circulation

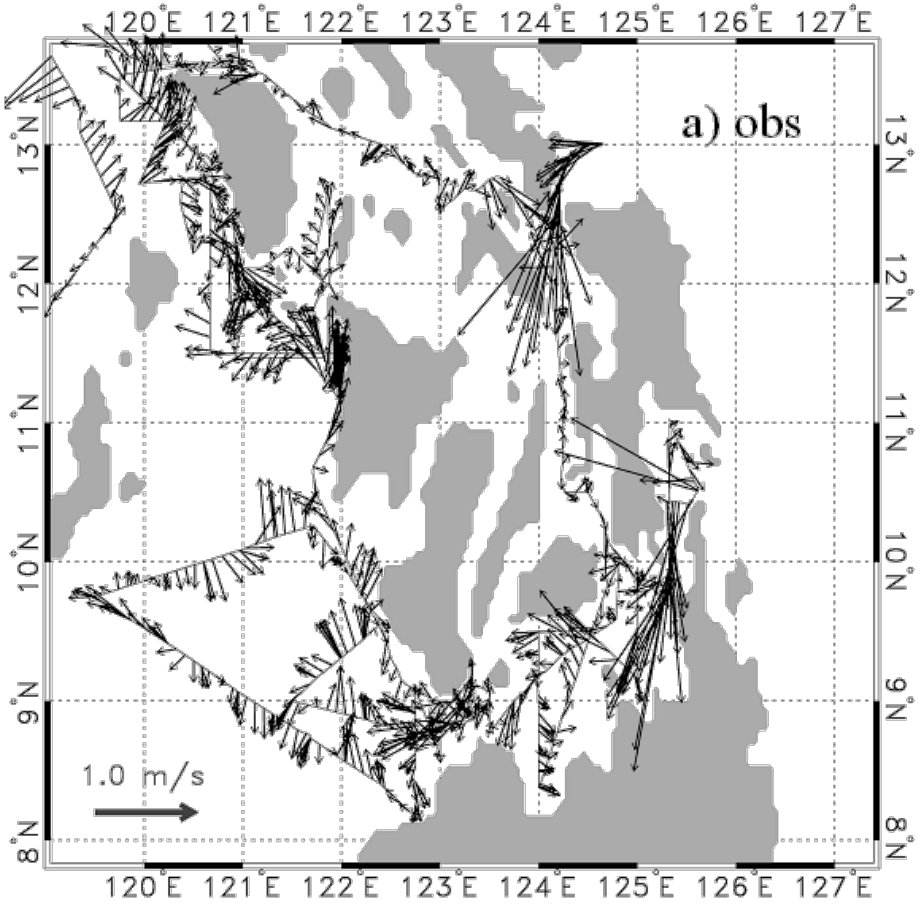
CR - EXP2 => Tidal rectification

EXP2 - (CR - EXP1) => Local forcing

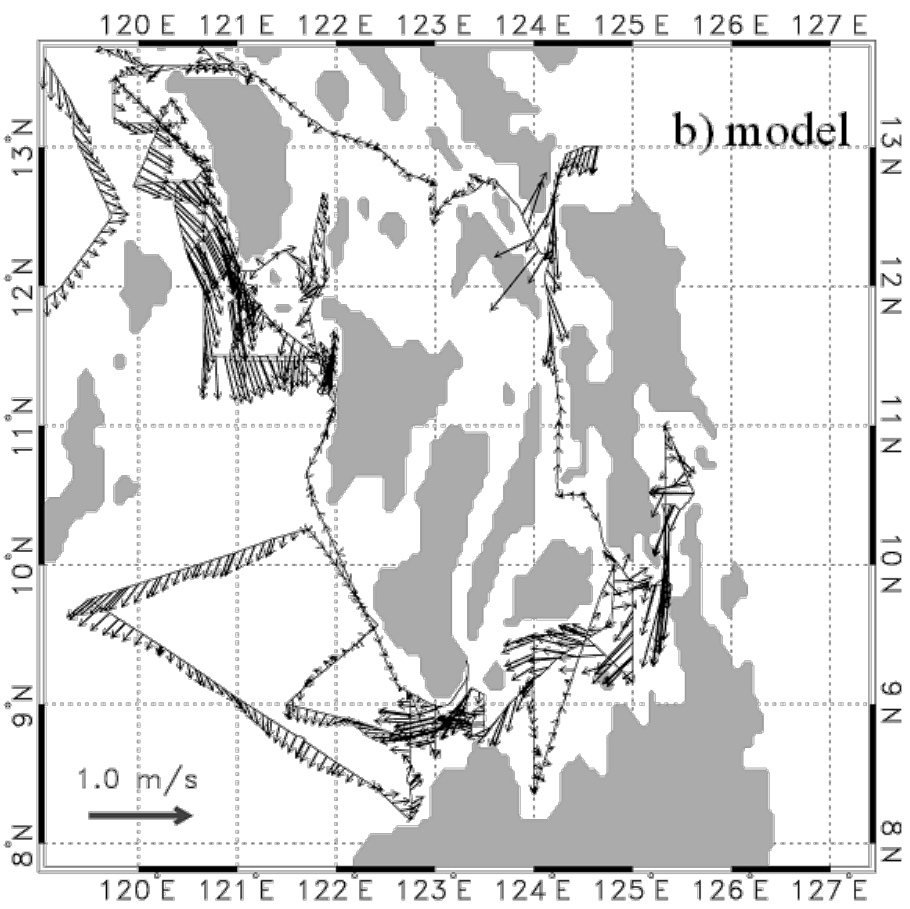
3. Results


a) PhilEx I
June 5 - June 12
2007
1.0 m/s
b) PhilEx II
June 12 - July 2
1.0 m/s
c) ROMS I
1.0 m/s
d) ROMS II
1.0 m/s
120°E 121°E 122°E 123°E 124°E 125°E 126°E 127°E
13°N 12°N 11°N 10°N 9°N 8°N

ROMS CR/PhilEx data comparison: Winter Jan 9 - Feb 1, 2008

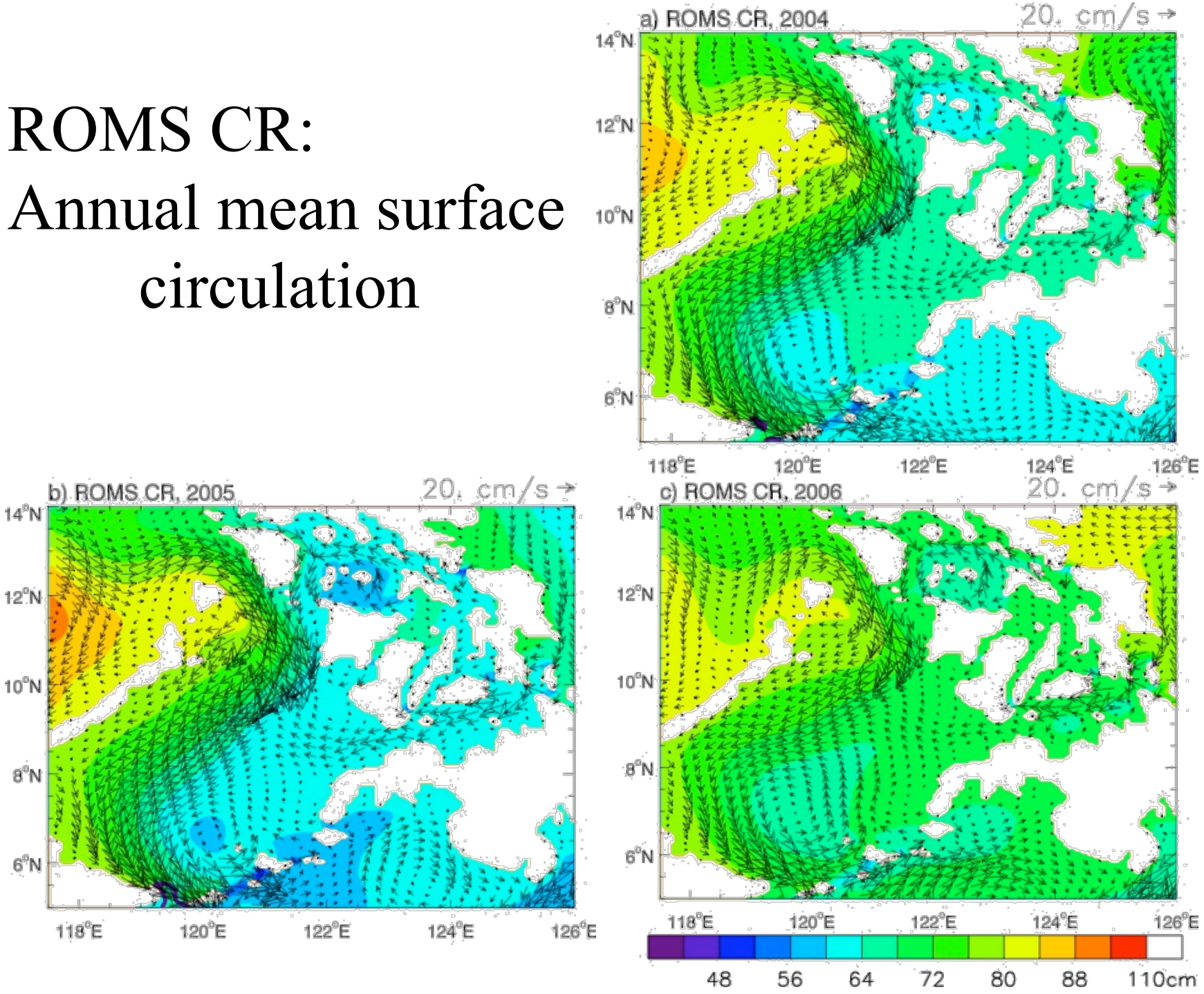


25-55m average



40 m

ROMS CR:
Annual mean surface circulation



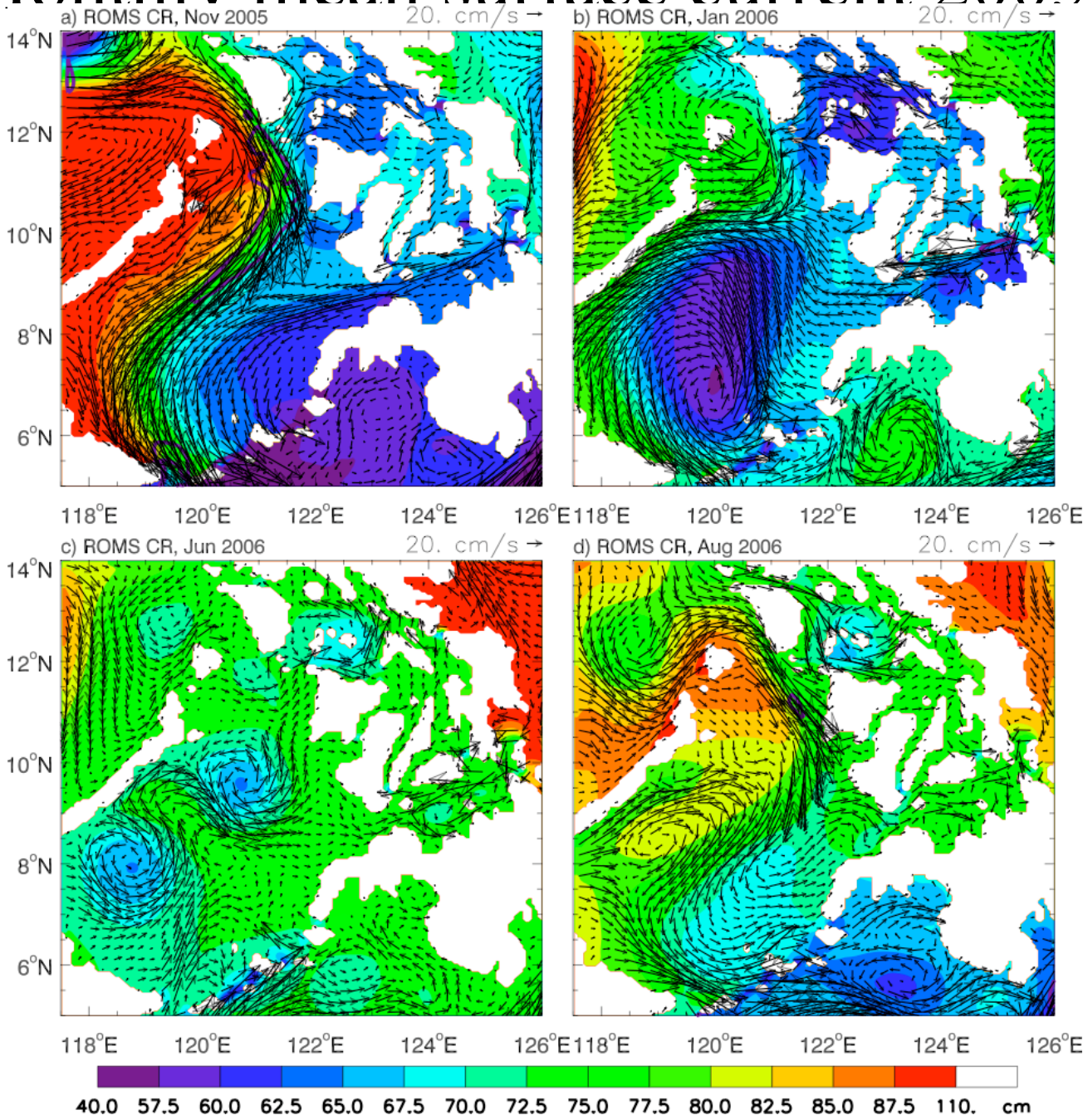
CR Monthly mean surface current 2005-06

Nov 2005

Jan 2006

June 2006

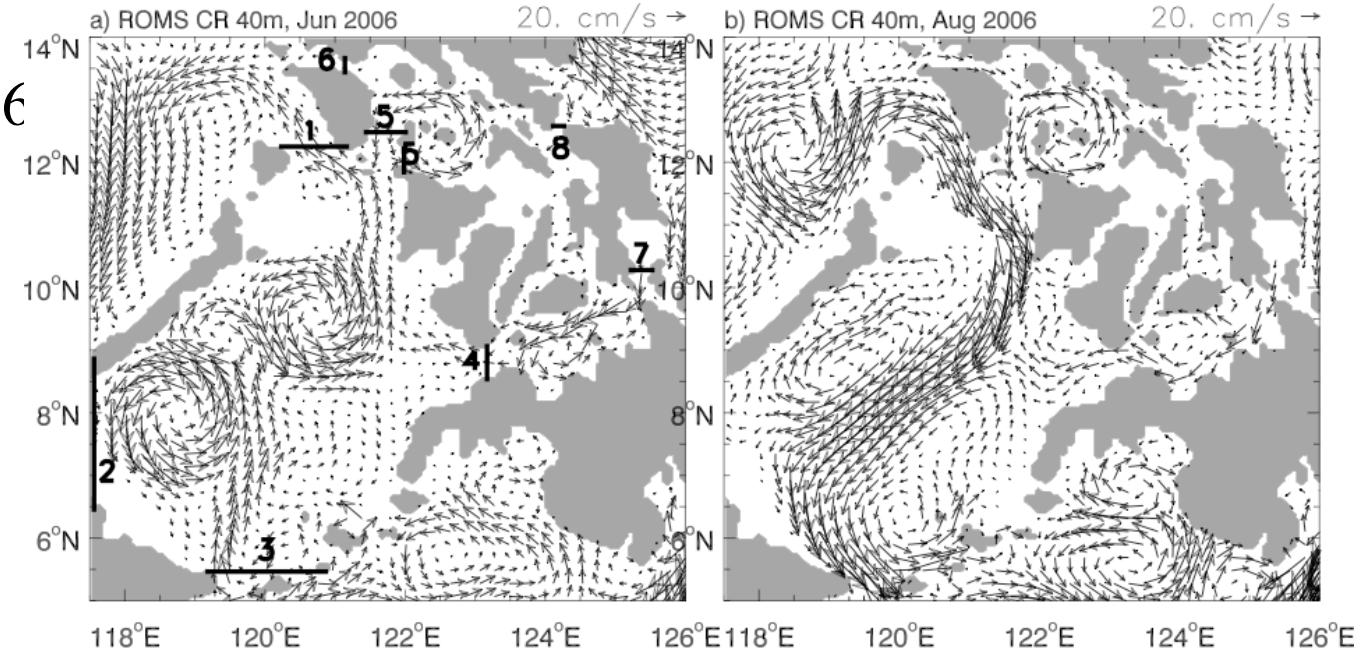
Aug 2006



ROMS CR 40m currents

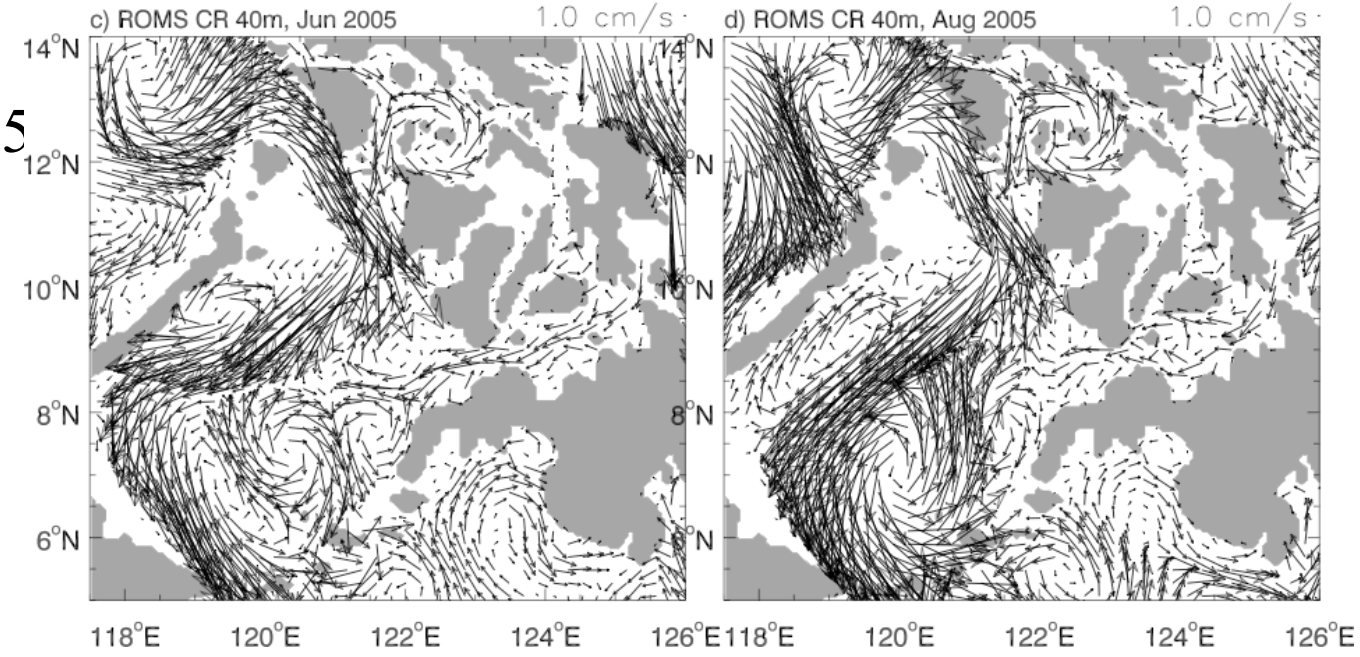
June 2006

Aug. 2006



June 2005

Aug. 2005



Geostrophic current vs Ekman drift

Geostrophic Current

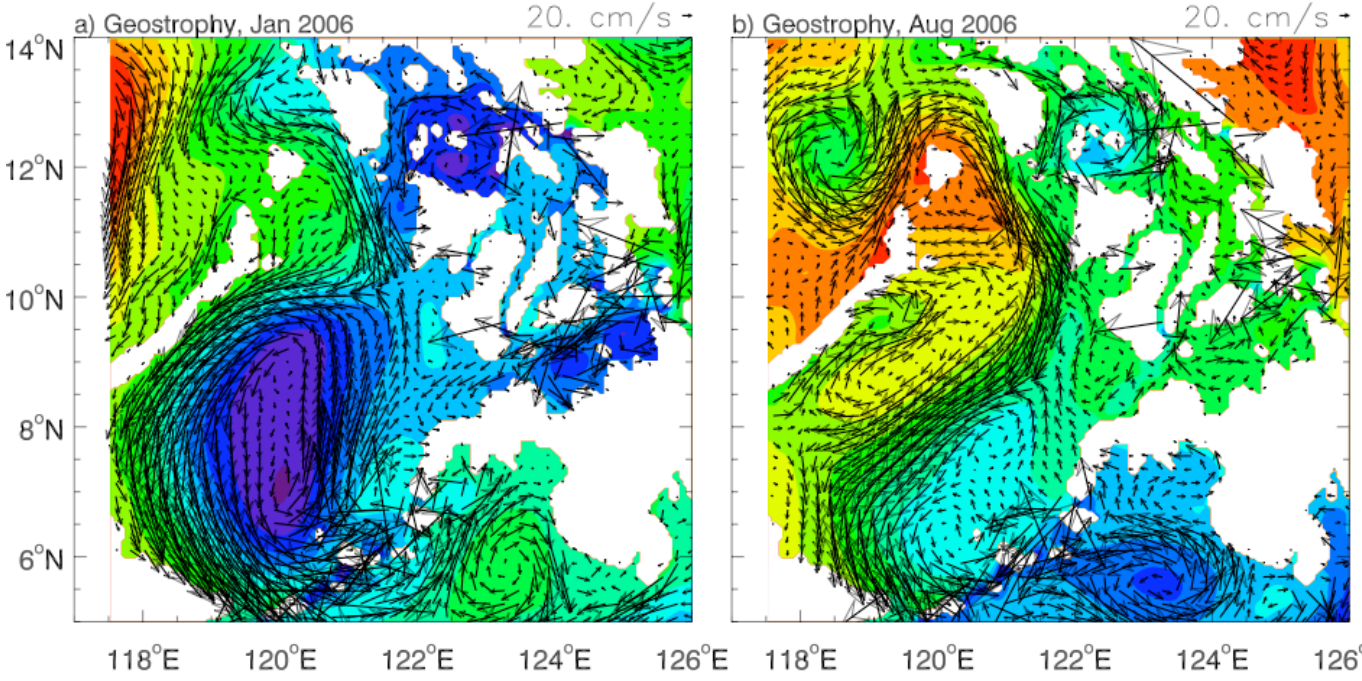
$$u_g = -\frac{g}{f}\frac{\partial h}{\partial x}, v_g = \frac{g}{f}\frac{\partial h}{\partial y},$$

Ekman drift

$$u_e = \frac{\tau^y}{f\rho H_e}, v_e = -\frac{\tau^x}{f\rho H_e},$$

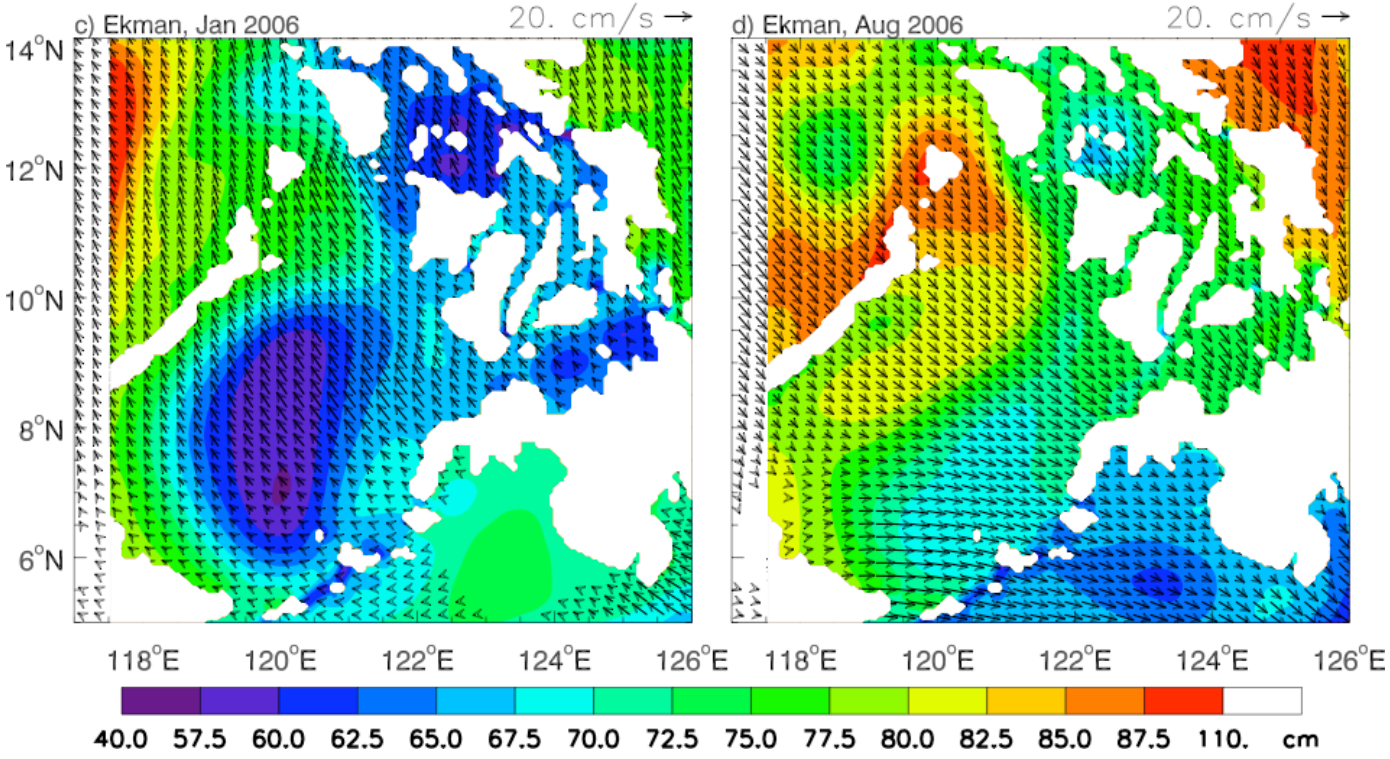
Geostrophic Current Jan 2006

Aug. 2006



Ekman drift Jan 2006

Aug. 2006



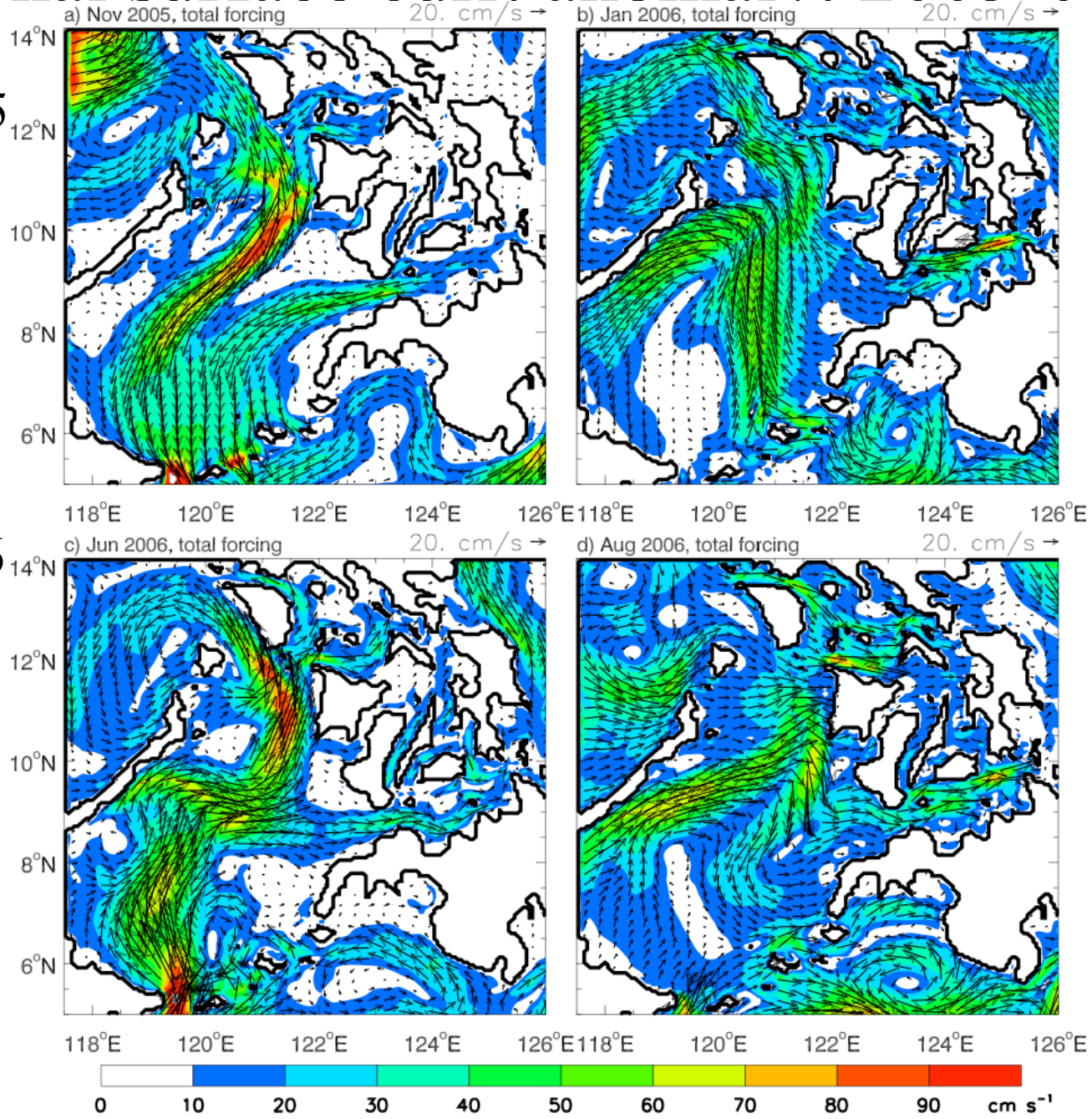
Seasonal surface curr. anomaly: 2005-06, CR

Nov. 2005

Jan 2006

June 2006

Aug. 2006



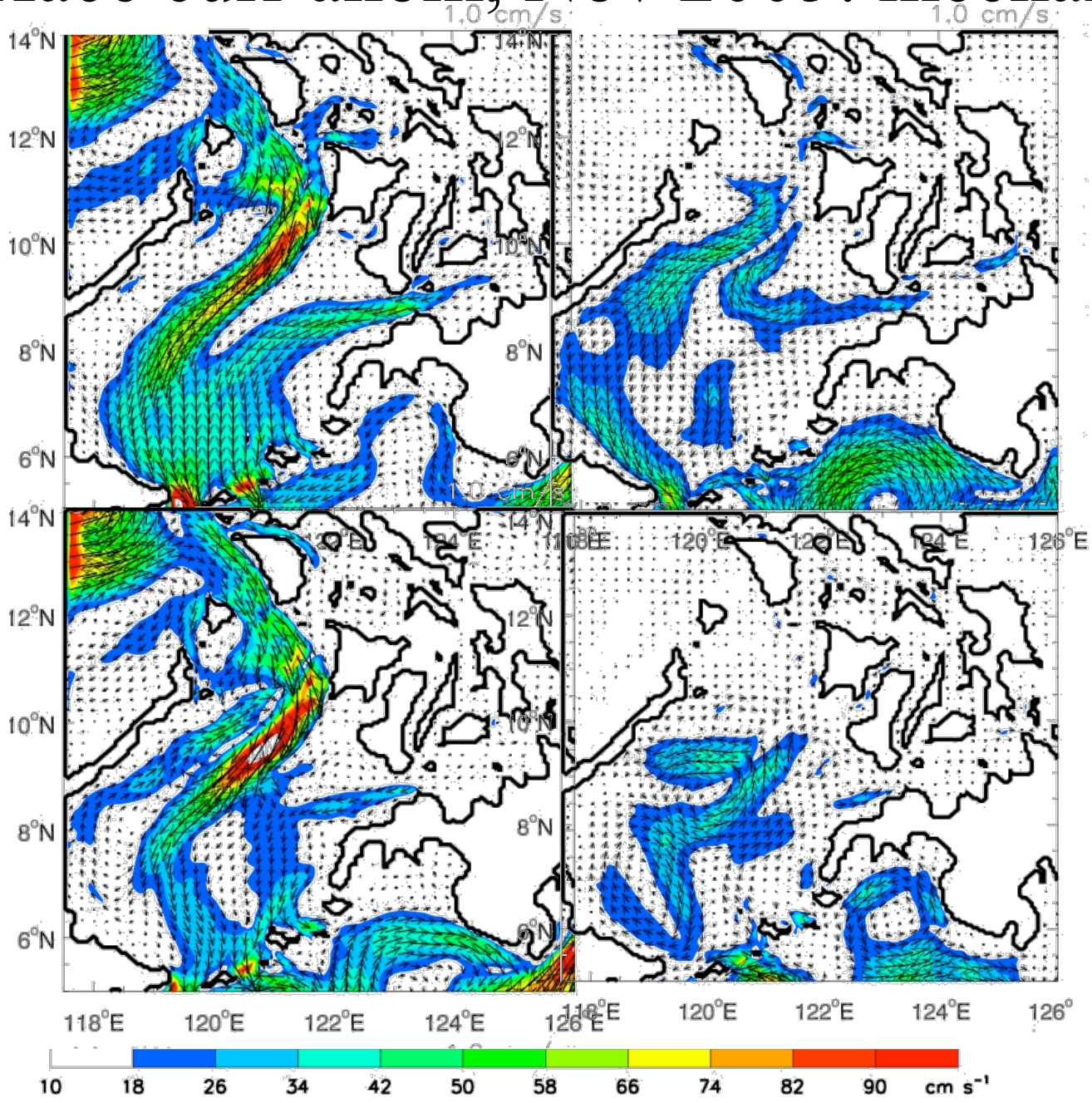
Surface curr anom, Nov 2005: mechanisms

Total

Local + tide

Remote

Tide



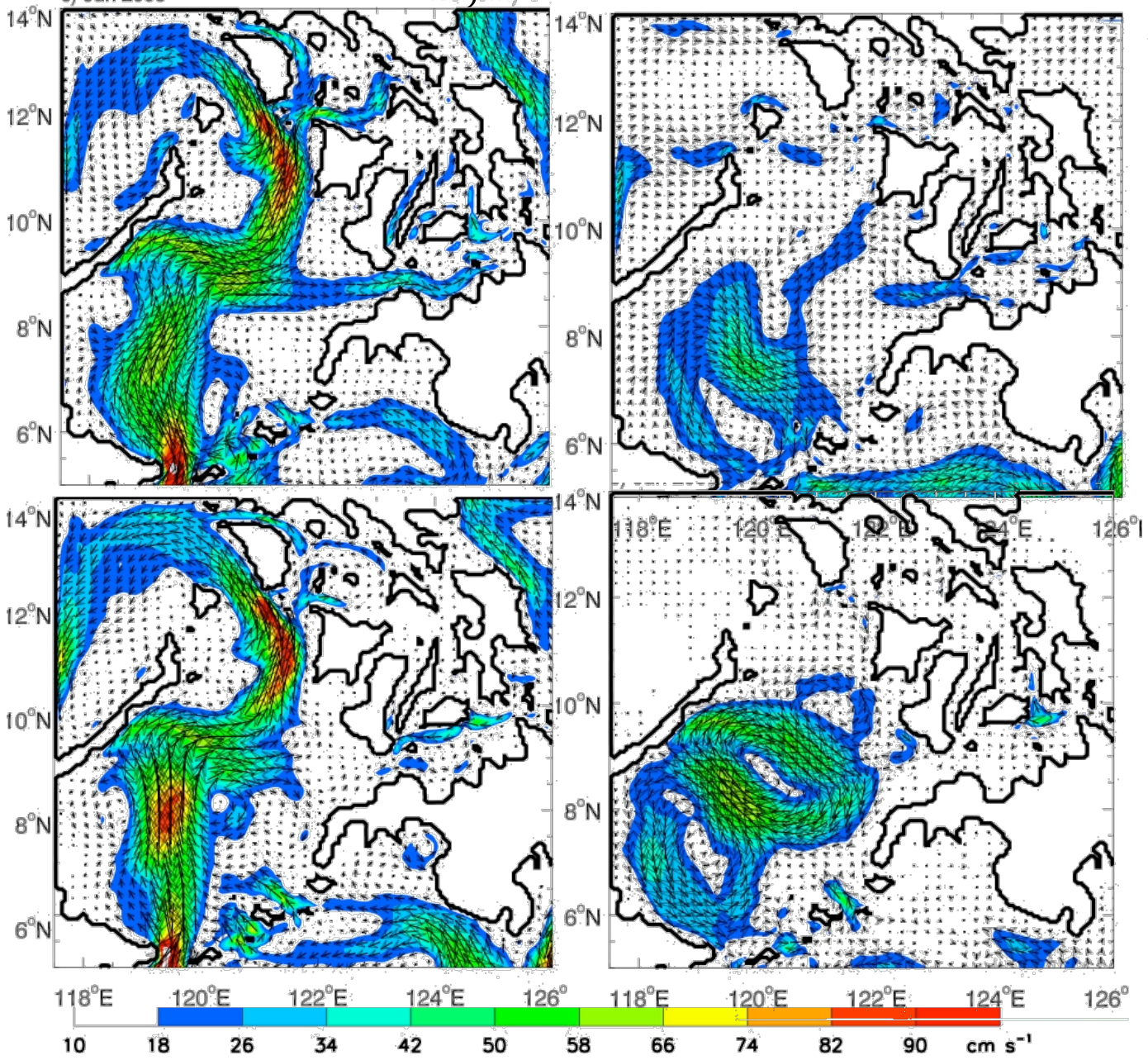
Surface curr anom, June 2006: mechanisms

Total

Local + tide

Remote

Tide



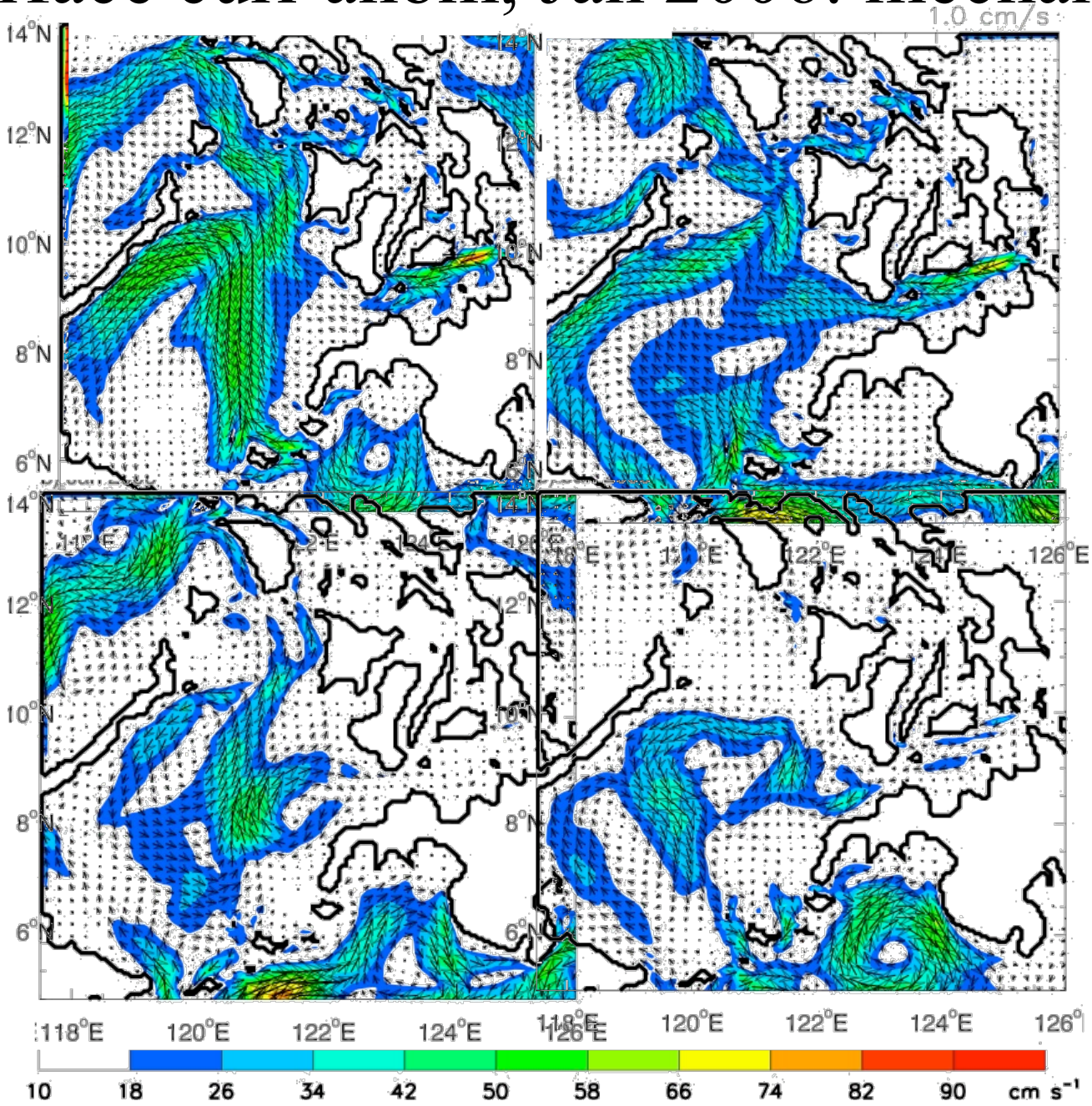
Surface curr anom, Jan 2006: mechanisms

Total

Local + tide

Remote

Tide



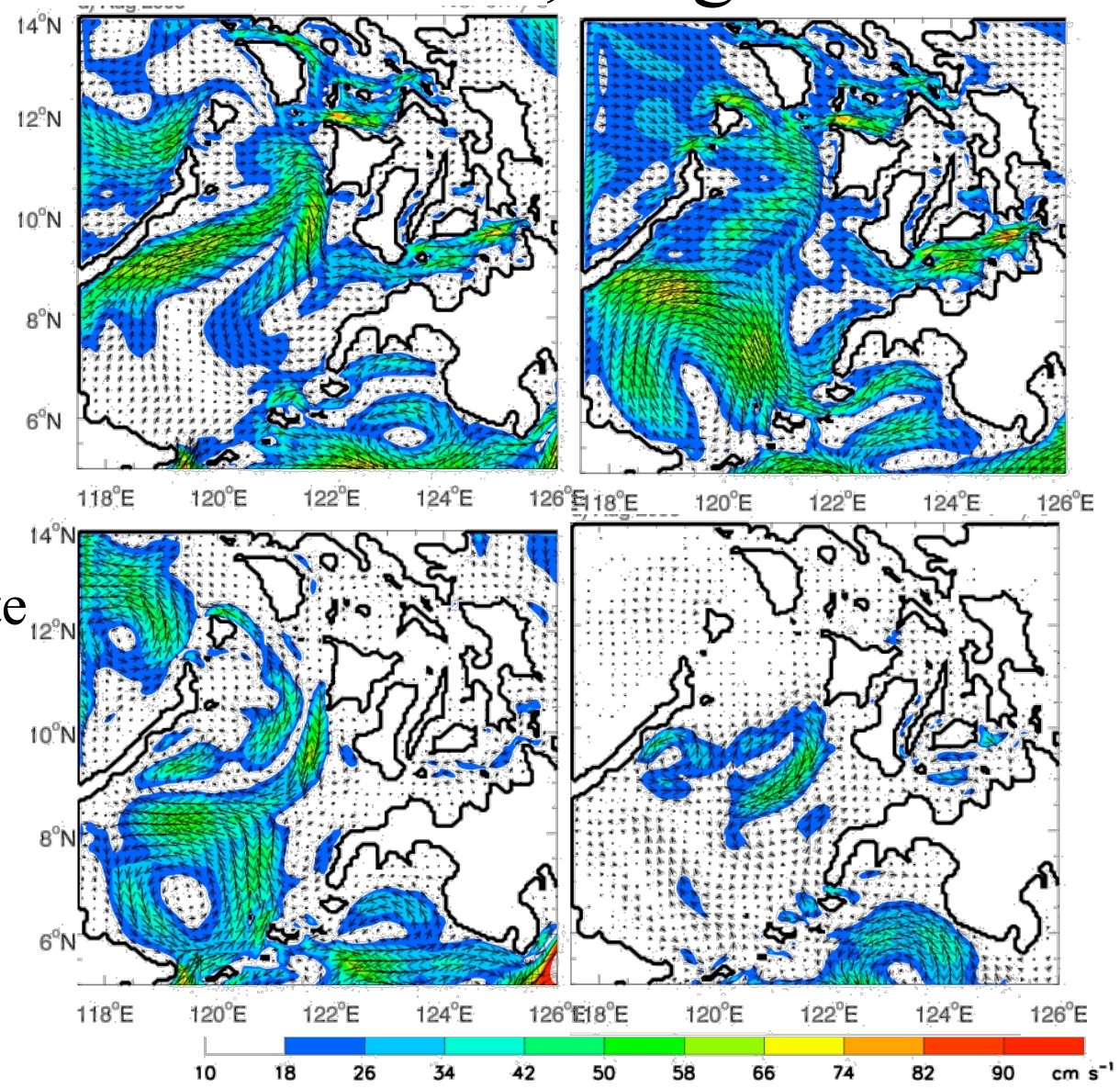
Surface curr anom, Aug 2006: mechanisms

Total

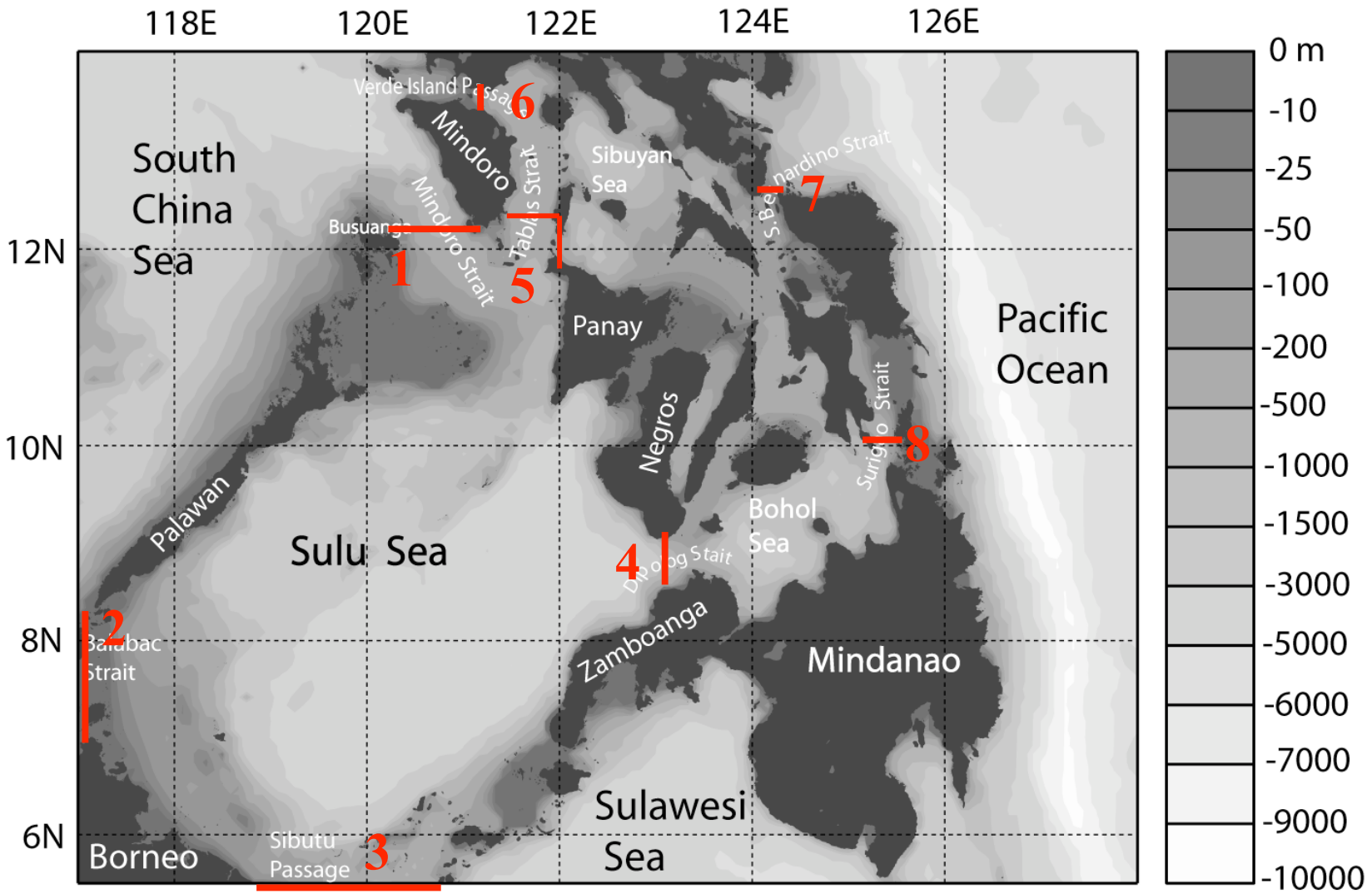
Local + tide

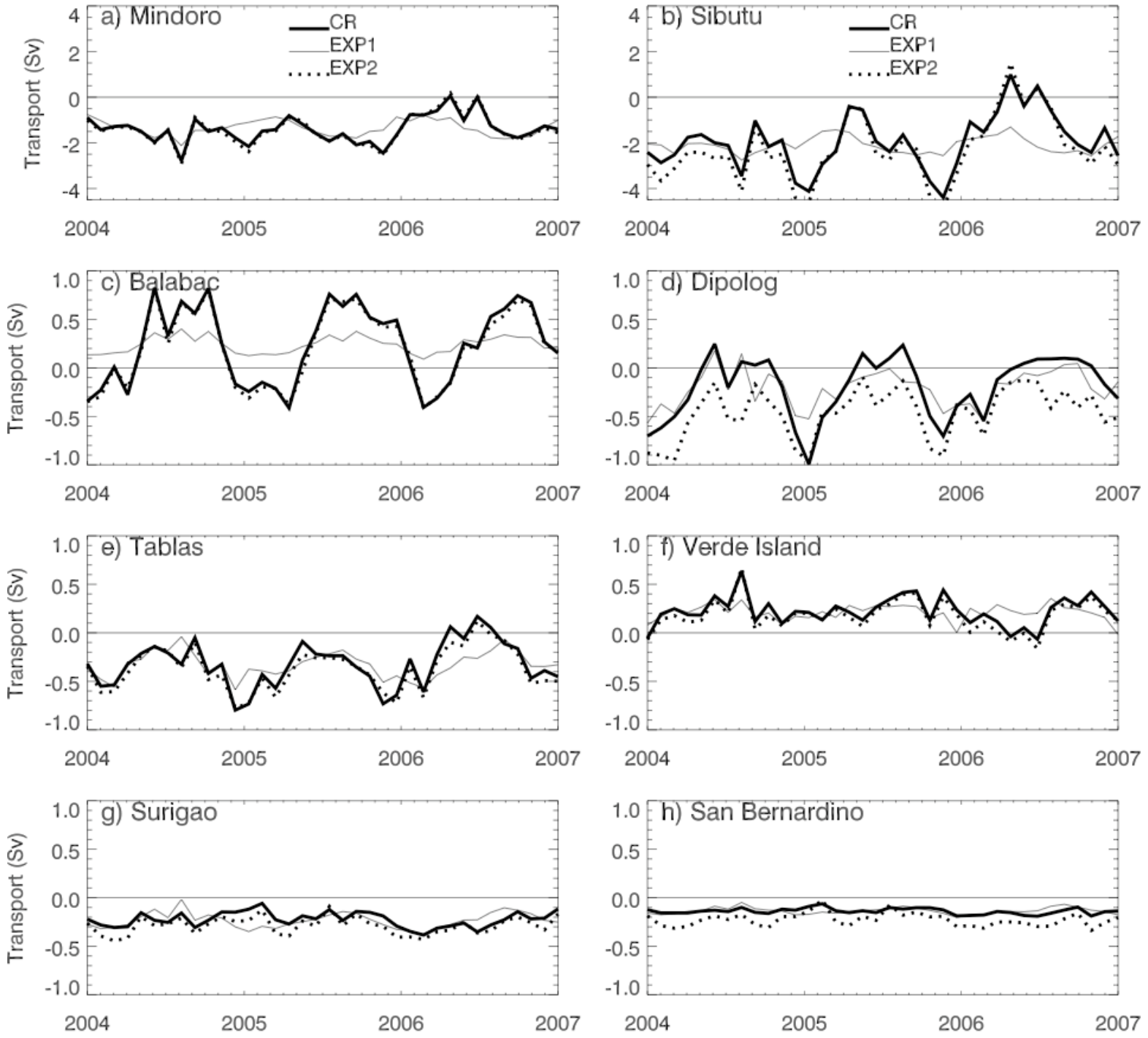
Remote

Tide

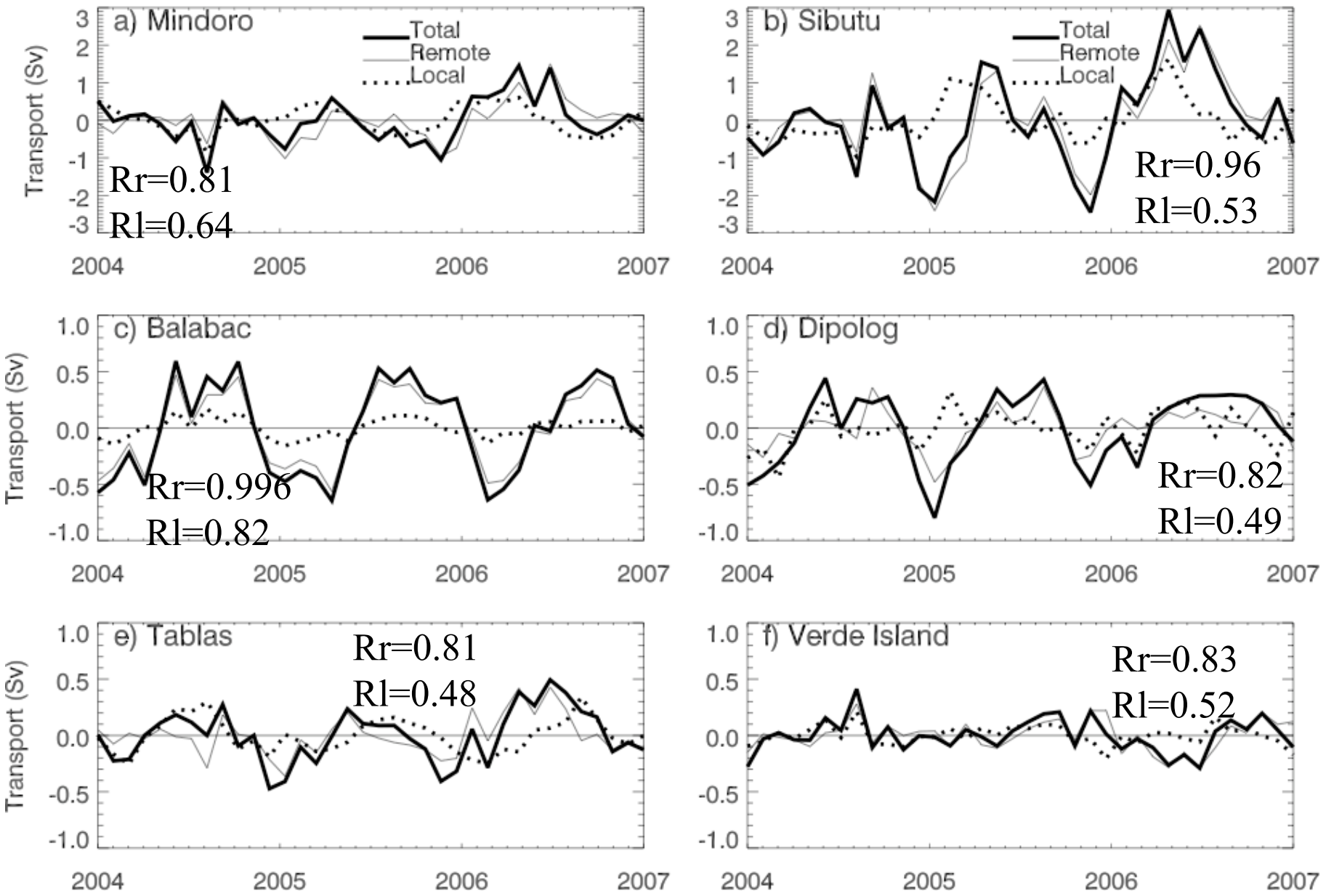


Eight major straits

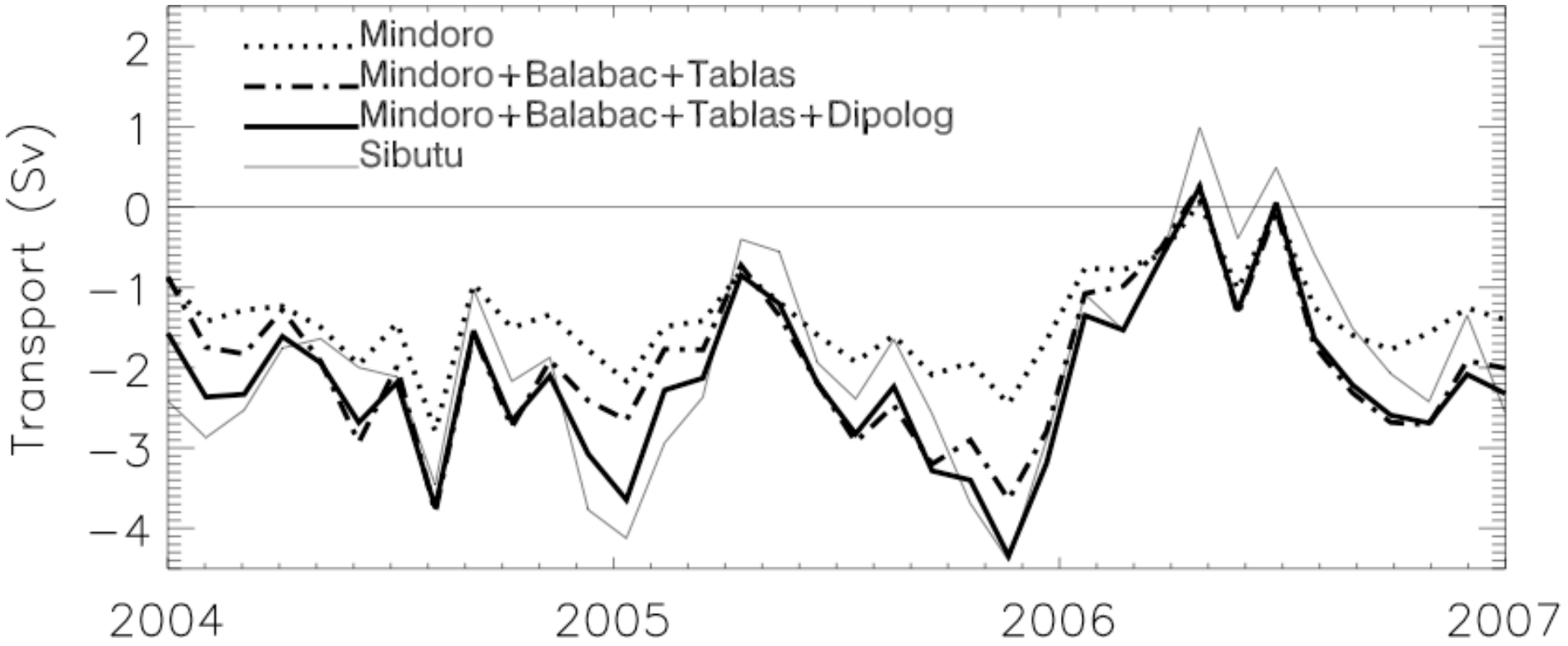



a) Mindoro
b) Sibutu
c) Balabac
d) Dipolog
e) Tablas
f) Verde Island
g) Surigao
h) San Bernardino
CR
EXP1
EXP2
Transport (Sv)
2004
2005
2006
2007

Seasonal variations of strait transports above 40m



Volume transport in and out of the Sulu Sea



4. Summary and conclusions

- The near-surface currents from the ROMS agree reasonably well with the PhilEx observations;
- Remote effects dominate the local forcing for the seasonal variations of volume transports in the upper 40m at all eight major straits; while local winds play a deterministic role in causing the seasonally-reversing surface currents in the Philippine Archipelago region, including the eddy north of Mindoro;
- Diurnal and semi-diurnal tides reduce the Pacific-to-Archipelago transports at the Surigao and San Bernardino Straits, and they can also rectify onto the seasonal circulation in the Sulu Sea.

Locally: Prevailing winds

QuikSCAT

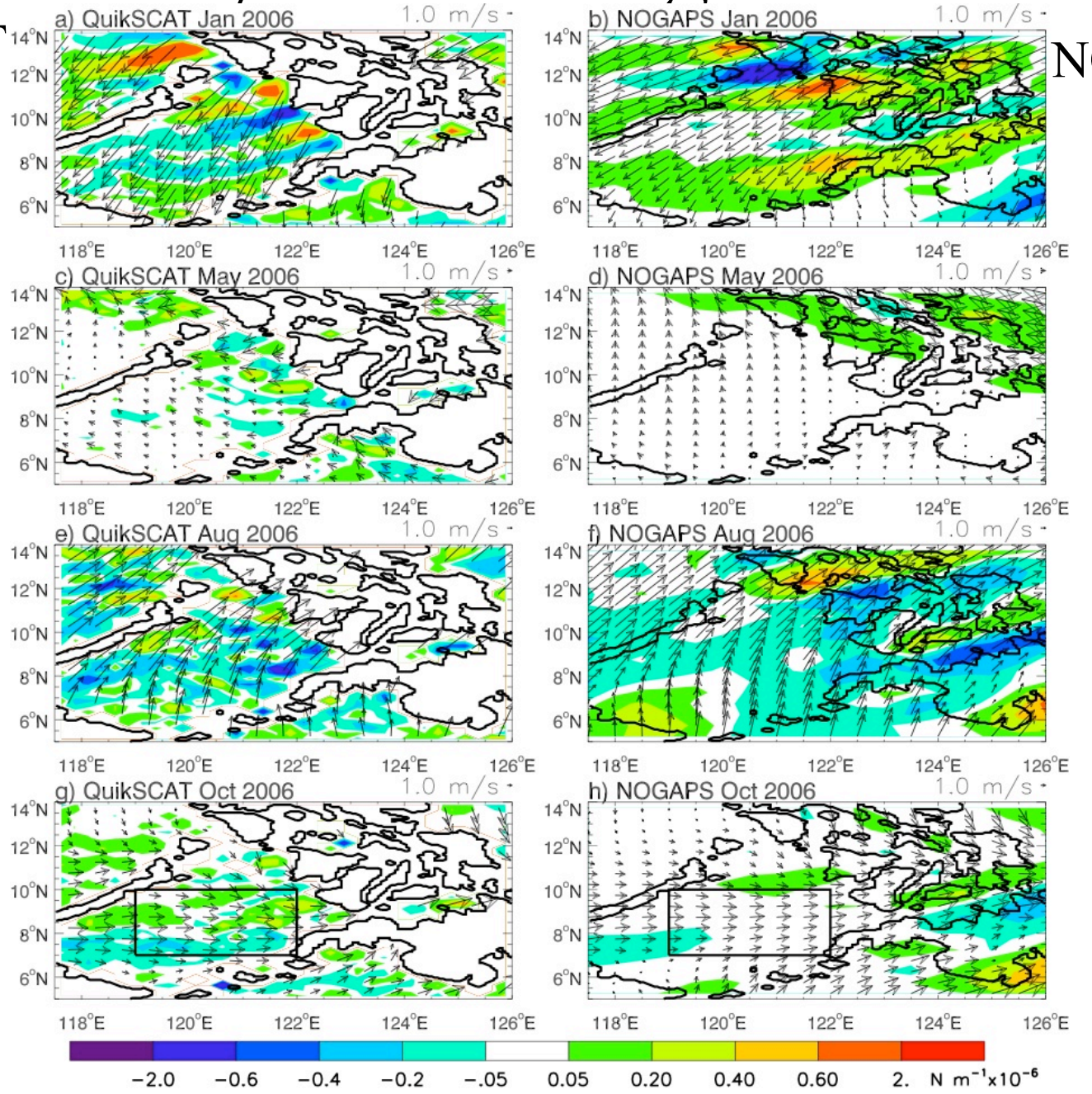
NOGAPS

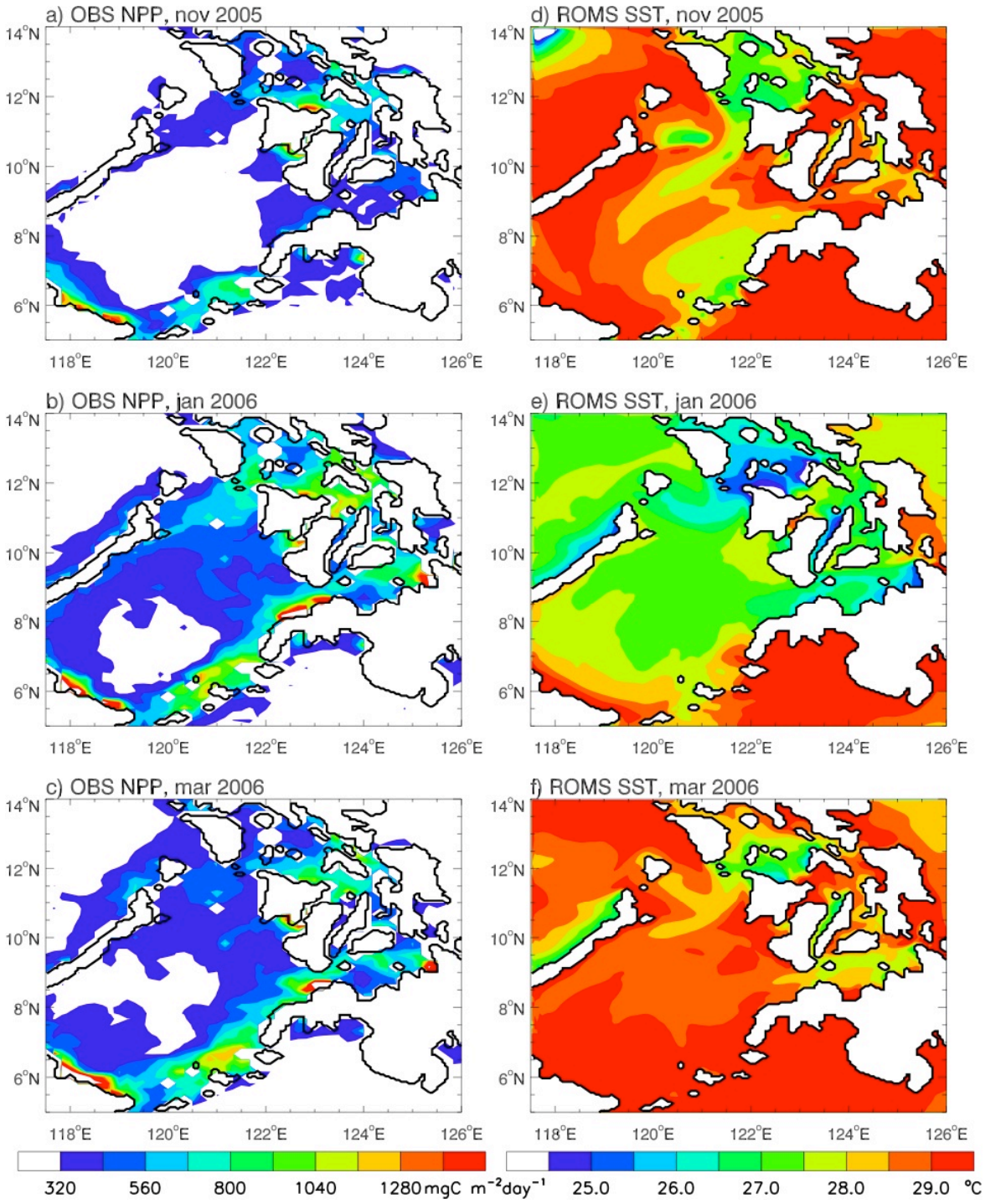
Jan

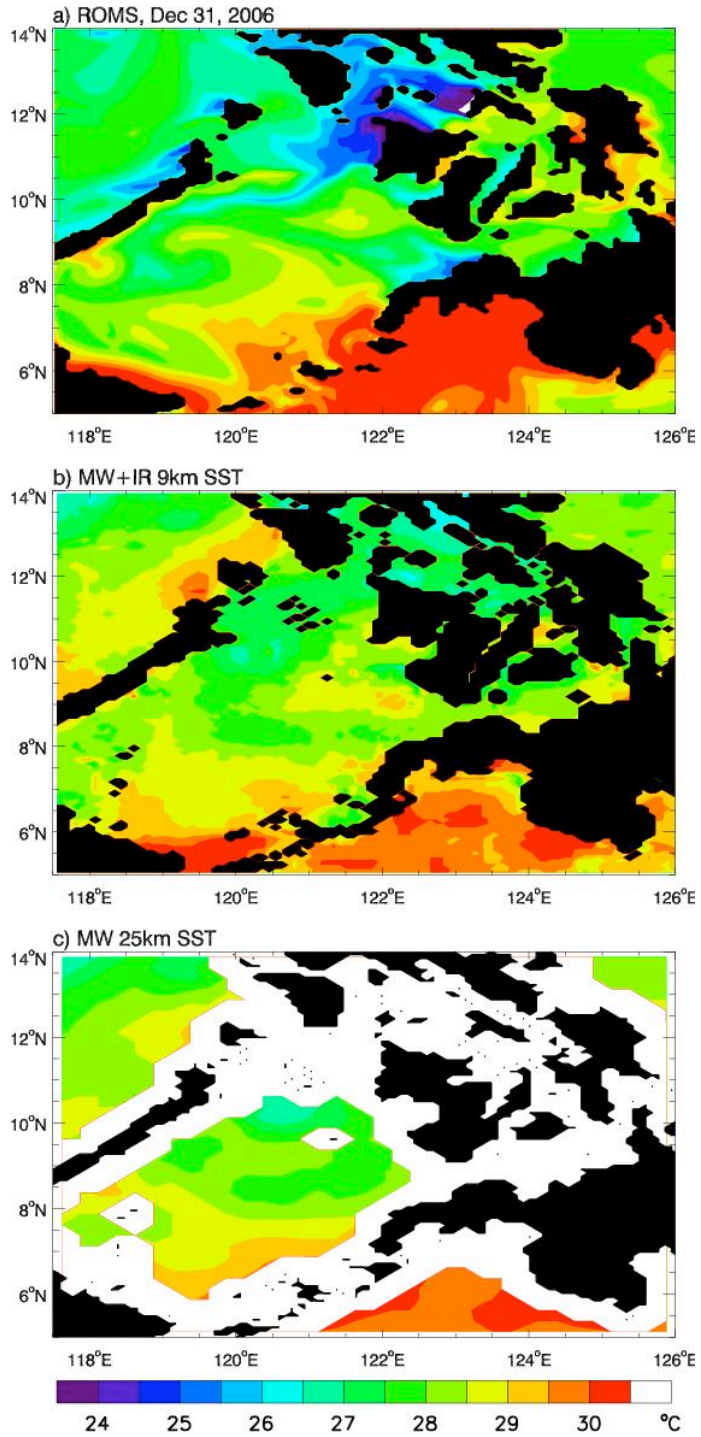
May

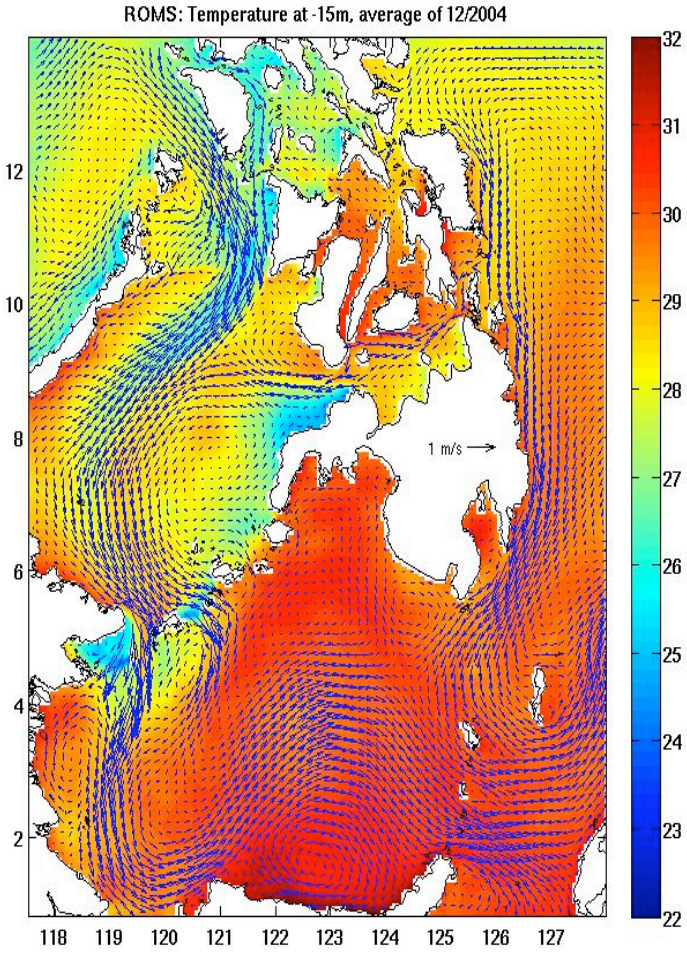
Aug

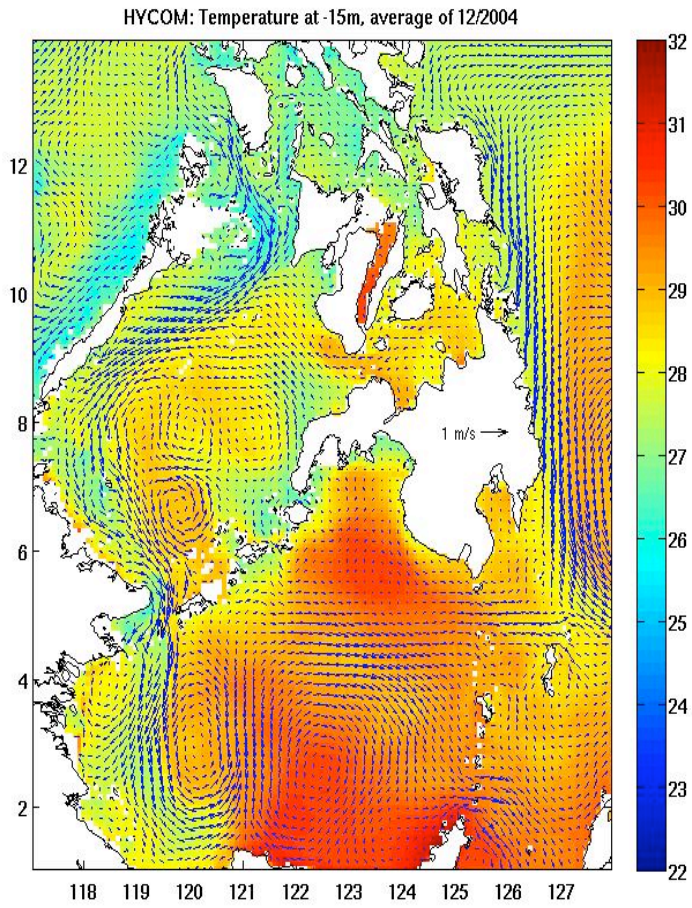
Oct.

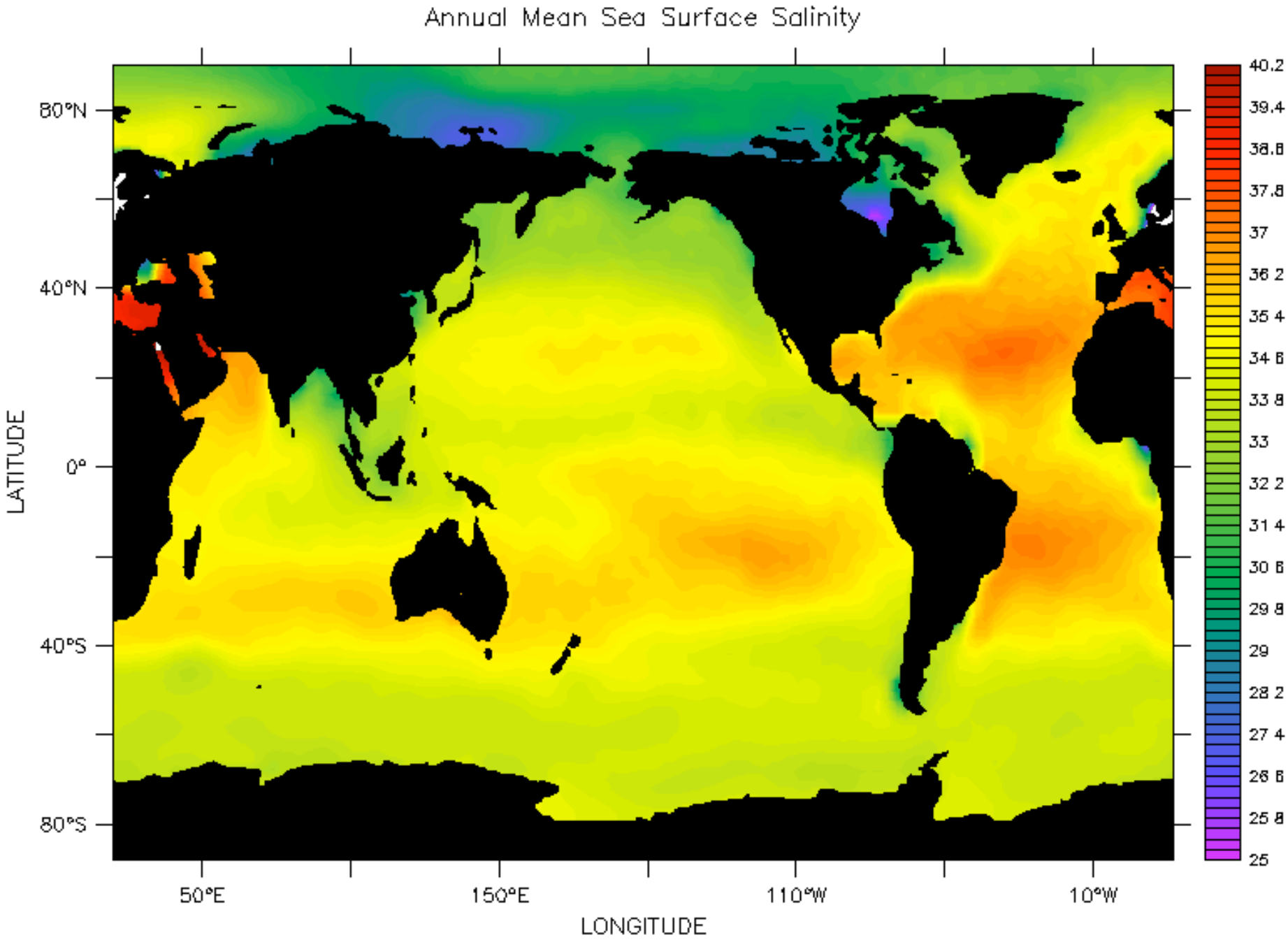



a) OBS NPP, nov 2005
d) ROMS SST, nov 2005
b) OBS NPP, jan 2006
e) ROMS SST, jan 2006
c) OBS NPP, mar 2006
f) ROMS SST, mar 2006
14°N
12°N
10°N
8°N
6°N
118°E
120°E
122°E
124°E
126°E
320
560
800
1040
1280 mgC m-2day-1
25.0
26.0
27.0
28.0
29.0 °C


a) ROMS, Dec 31, 2006
14°N
12°N
10°N
8°N
6°N
118°E
120°E
122°E
124°E
126°E
b) MW+IR 9km SST
14°N
12°N
10°N
8°N
6°N
118°E
120°E
122°E
124°E
126°E
c) MW 25km SST
14°N
12°N
10°N
8°N
6°N
118°E
120°E
122°E
124°E
126°E
24
25
26
27
28
29
30
°C


ROMS: Temperature at -15m, average of 12/2004
1 m/s
12
10
8
6
4
2
118
119
120
121
122
123
124
125
126
127
32
31
30
29
28
27
26
25
24
23
22


HYCOM: Temperature at -15m, average of 12/2004
1 m/s
12
10
8
6
4
2
118
119
120
121
122
123
124
125
126
127
32
31
30
29
28
27
26
25
24
23
22


Annual Mean Sea Surface Salinity
80°N
40°N
0°
40°S
80°S
LATITUDE
50°E
150°E
110°W
10°W
LONGITUDE
40.2
39.4
38.6
37.8
37
36.2
35.4
34.6
33.8
33
32.2
31.4
30.6
29.8
29
28.2
27.4
26.6
25.8
25
Salinity Data from Levitus
Time: Sep. 4, 1997

Winds averaged over the Sulu Sea