Upper Ocean - Topographic Coupling in an Ocean Model with High Vertical Resolution

by

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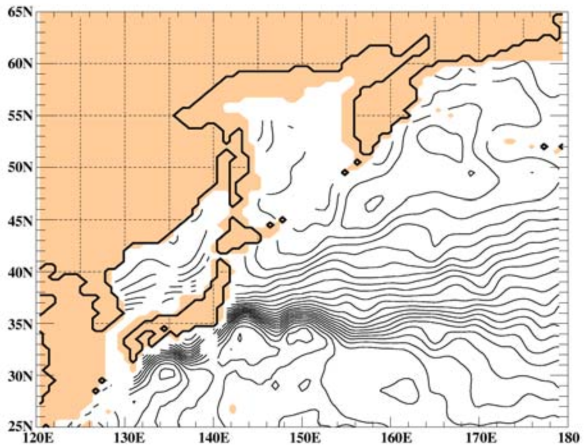
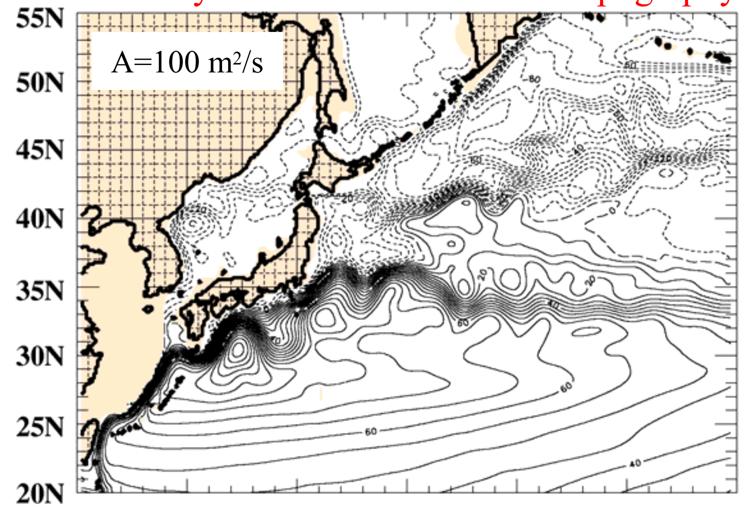
Kuroshio Pathway East of Japan
Impact of topography and model resolution

Navy GDEM Climatology
Annual Mean SFC Dynamic Height w.r.t. 1000 m.

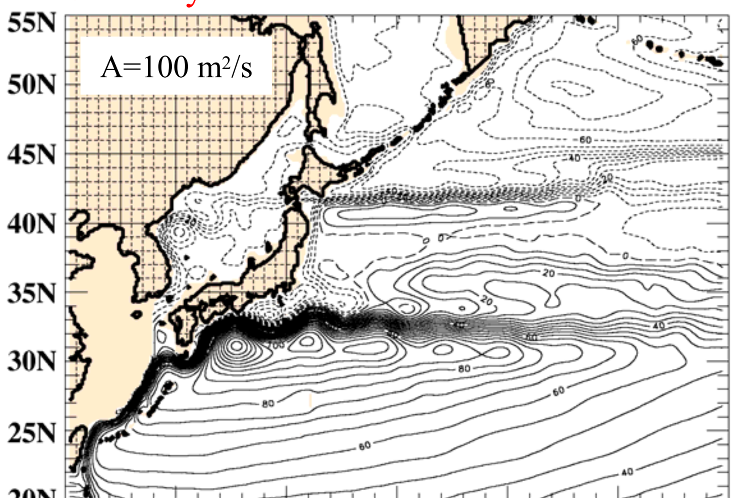


Teague et al. (1990; JGR-O)

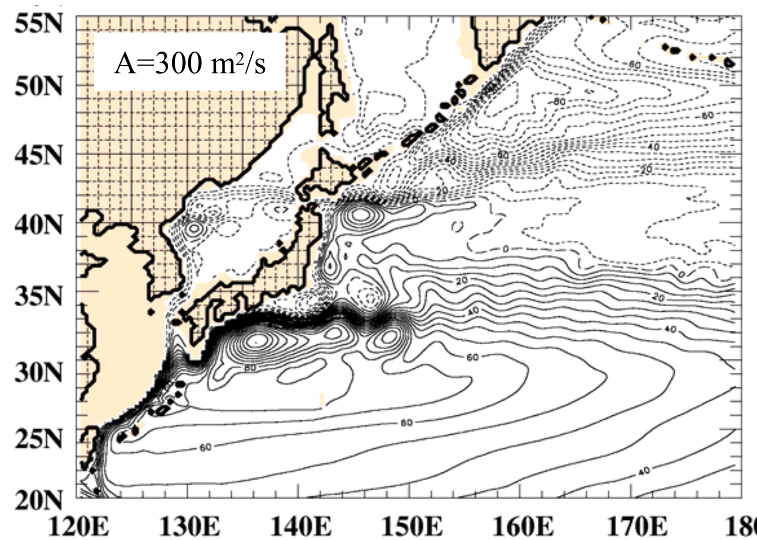
1/8° 6-layer with realistic bottom topography



1/8° 6-layer flat bottom



1/4° 6-layer with realistic bottom topography



Model mean sea surface height forced by Hellerman and Rosenstein (1983, JPO) wind stress climatology

From Hurlburt et al. (1996, JGR-O; 1997, Intl WOCE Newsletter)

Bottom Current Steering of Upper Ocean Currents

In a two-layer model, the continuity equation for layer 1 is

$$\frac{\partial h_1}{\partial t} + h_1 \nabla \cdot \vec{v}_1 + \vec{v}_1 \cdot \nabla h_1 = 0 \qquad (1)$$

The advective term in (1) can be related to the layer 2 velocity by

$$\vec{v}_{1g} \cdot \nabla h_1 = \vec{v}_{2g} \cdot \nabla h_1 \qquad (2)$$

$$\hat{k} \times f\left(\vec{v}_{1g} - \vec{v}_{2g}\right) = -g' \nabla h_1 \qquad (3)$$

Since $$\left|\vec{v}_1\right| >> \left|\vec{v}_2\right| \qquad (4)$$

∇h_1 is a good measure of $\vec{v}_1$.

From this, we see that abyssal currents affect the advection of upper layer thickness gradients and therefore upper layer currents.

(Hurlburt and Thompson, 1980, JPO; Hurlburt et al., 1996, JGR-O)

Application of the 2-layer Theory for Abyssal Current Advection of Upper Ocean Current Pathways to Models with Higher Vertical Resolution

Applies when all of the following are satisfied:

a) The flow is nearly geostrophically balanced

b) The barotropic and first baroclinic model are dominant

c) The topography does not intrude significantly into the stratified ocean

The interpretation in terms of surface currents applies when $\left|\vec{\mathbf{V}}_{\text{near sfc}}\right| \gg \left|\vec{\mathbf{V}}_{\text{abyssal}}\right|$

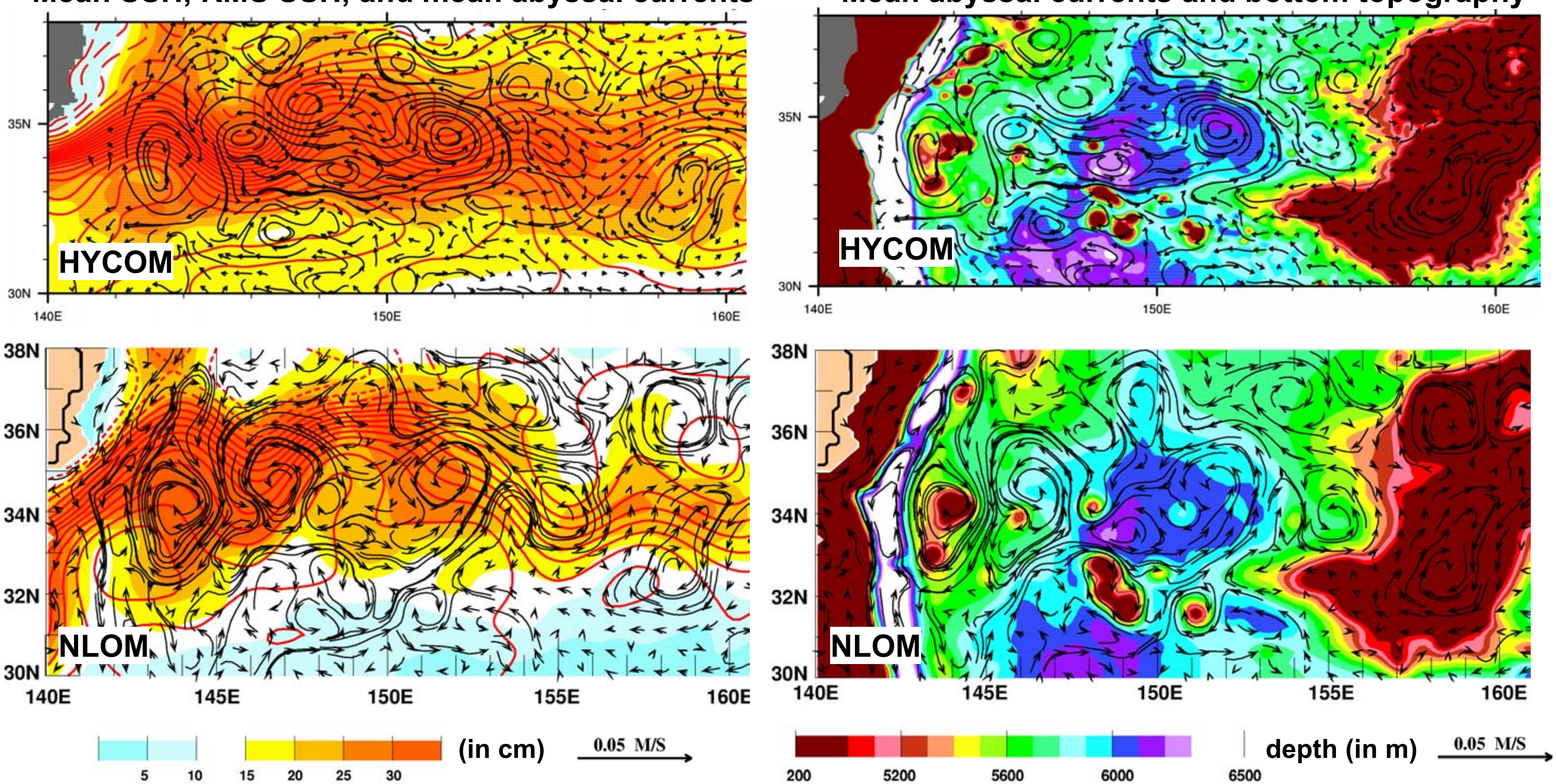
Notes:

1) The theory does not apply at low latitudes because of a) and b)

2) Abyssal current advection of upper ocean current pathways is strengthened when the currents intersect at large angles, but often the end result of this advection is near barotropy

Upper Ocean – Topographic Coupling in the Kuroshio Extension
1/12°, 20-Layer Pacific HYCOM vs. 1/8° 6-Layer NLOM

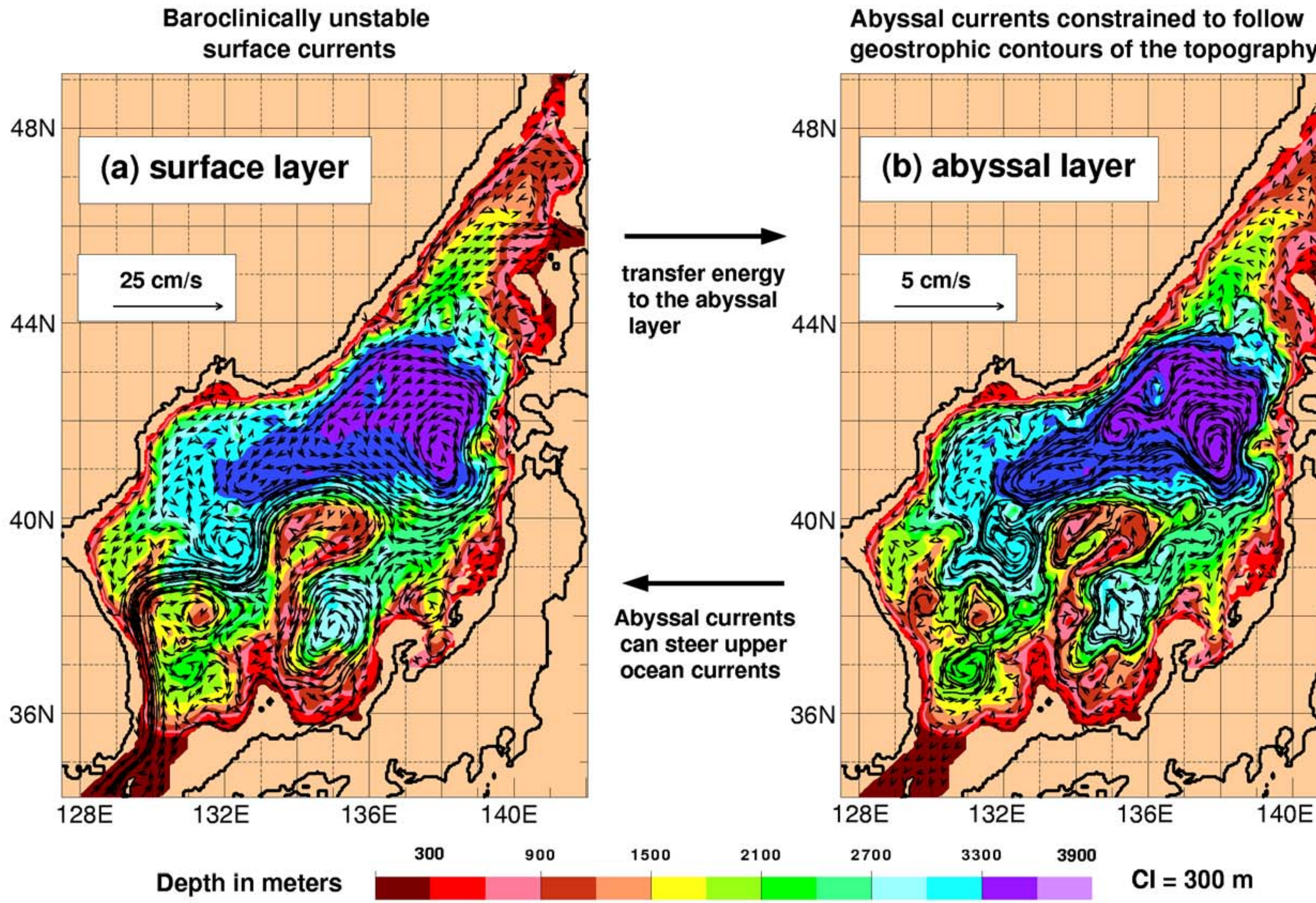
Mean SSH, RMS SSH, and mean abyssal currents | **Mean abyssal currents and bottom topography**



Adapted from Hurlburt et al. (2006; DAO submitted) and Hurlburt et al. (1996; JGR-O)

Upper Ocean - Topographic Coupling

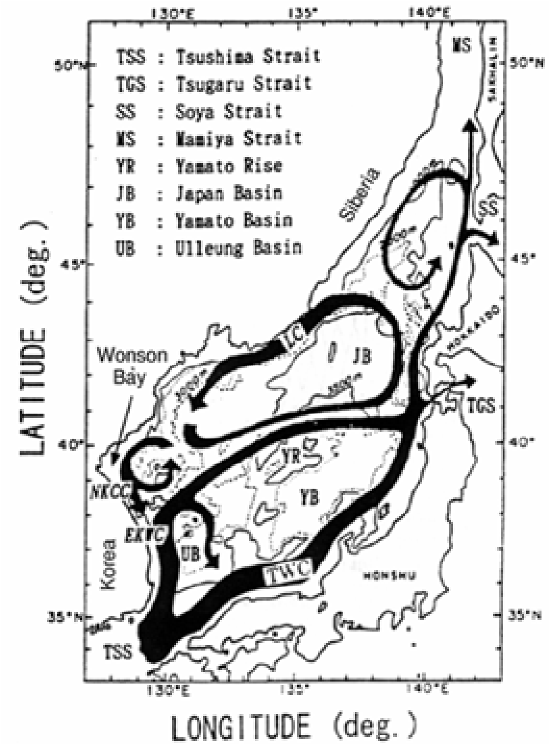
1/32˚ 4-layer Japan/East Sea Model



From Hogan and Hurlburt (2000, JPO)

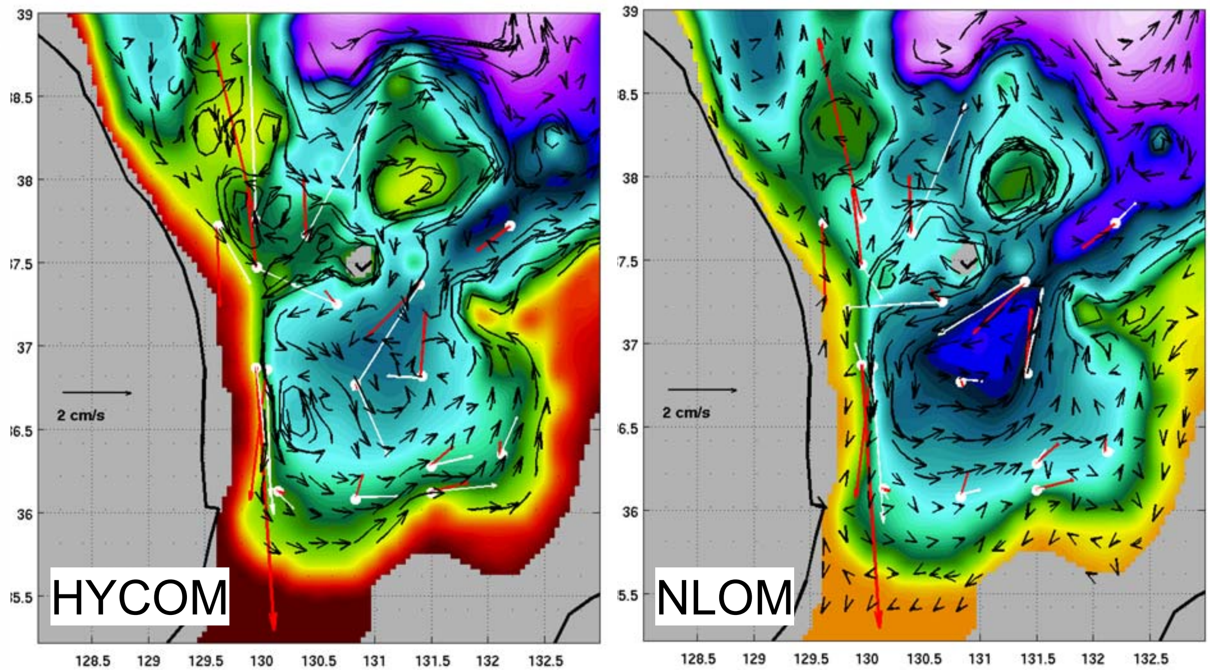
1/25°, 15-layer HYCOM and 1/32°, 4-layer NLOM vs Observations in the Japan/East Sea, Wind Forcing = EC10M

Schematic of mean surface currents



From Yanagi (2000) after Senjyu (1999)

Mean abyssal currents: observed vs models



Observed currents

Model currents, white at observed locations

Vector correlation, model vs obs

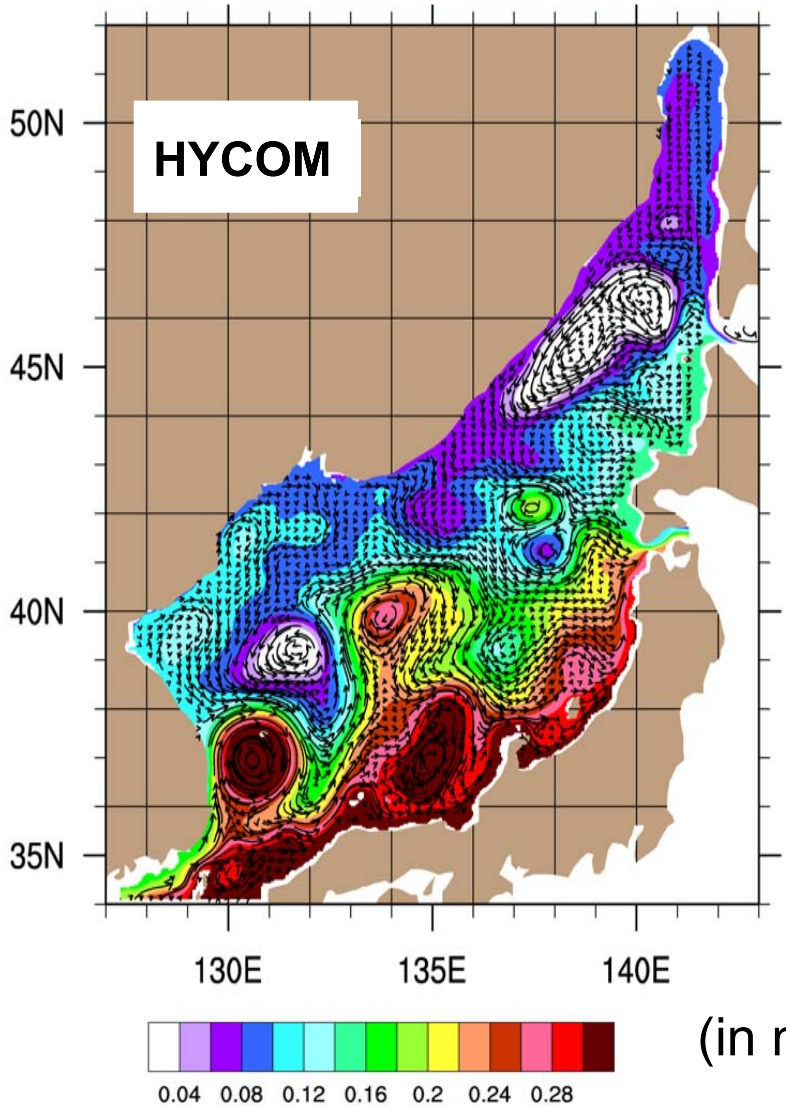
HYCOM layer 15 = .76

NLOM layer 4 = .33

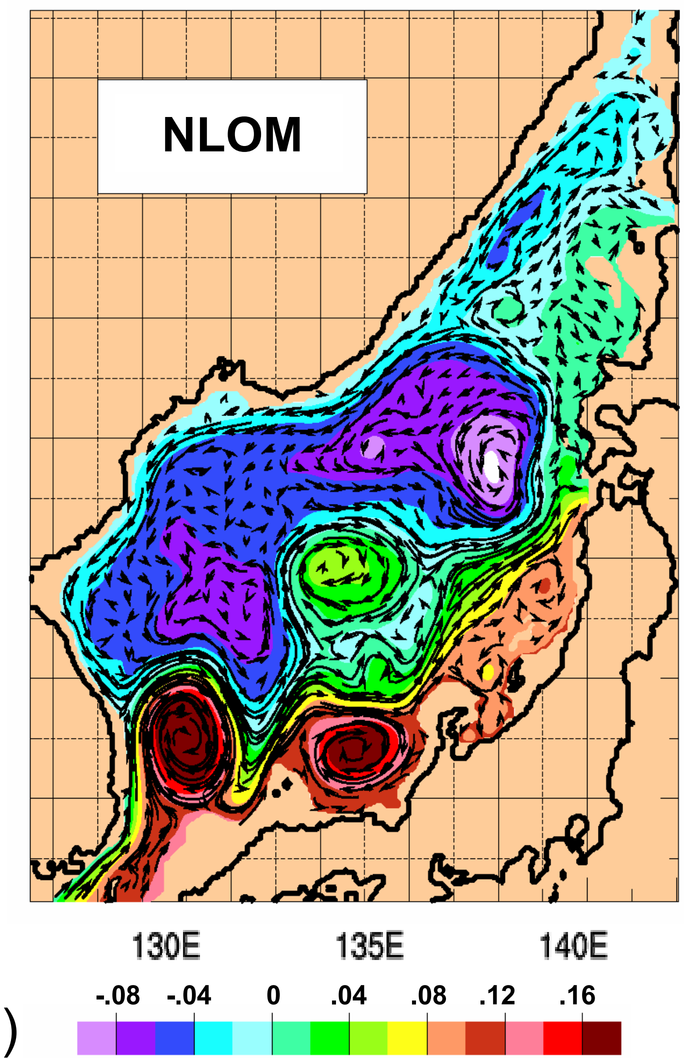
HYCOM layer 14 vs NLOM layer 4

vector correlation = .72 south of 41°N

Mean Surface Currents: 1/25°, 15-layer HYCOM vs 1/25°, 4-layer NLOM using EC10M Winds



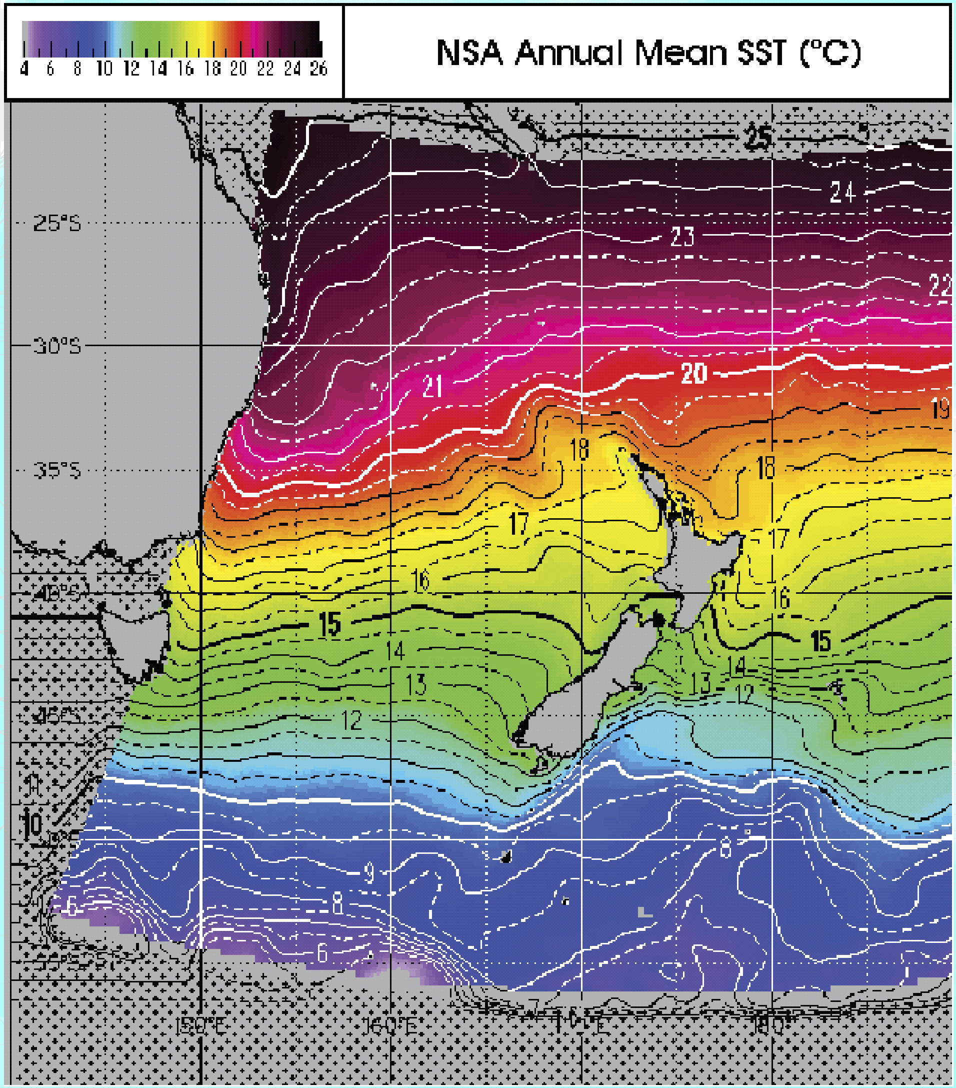
(in m)



SSH correlation = .83 south of 41°N

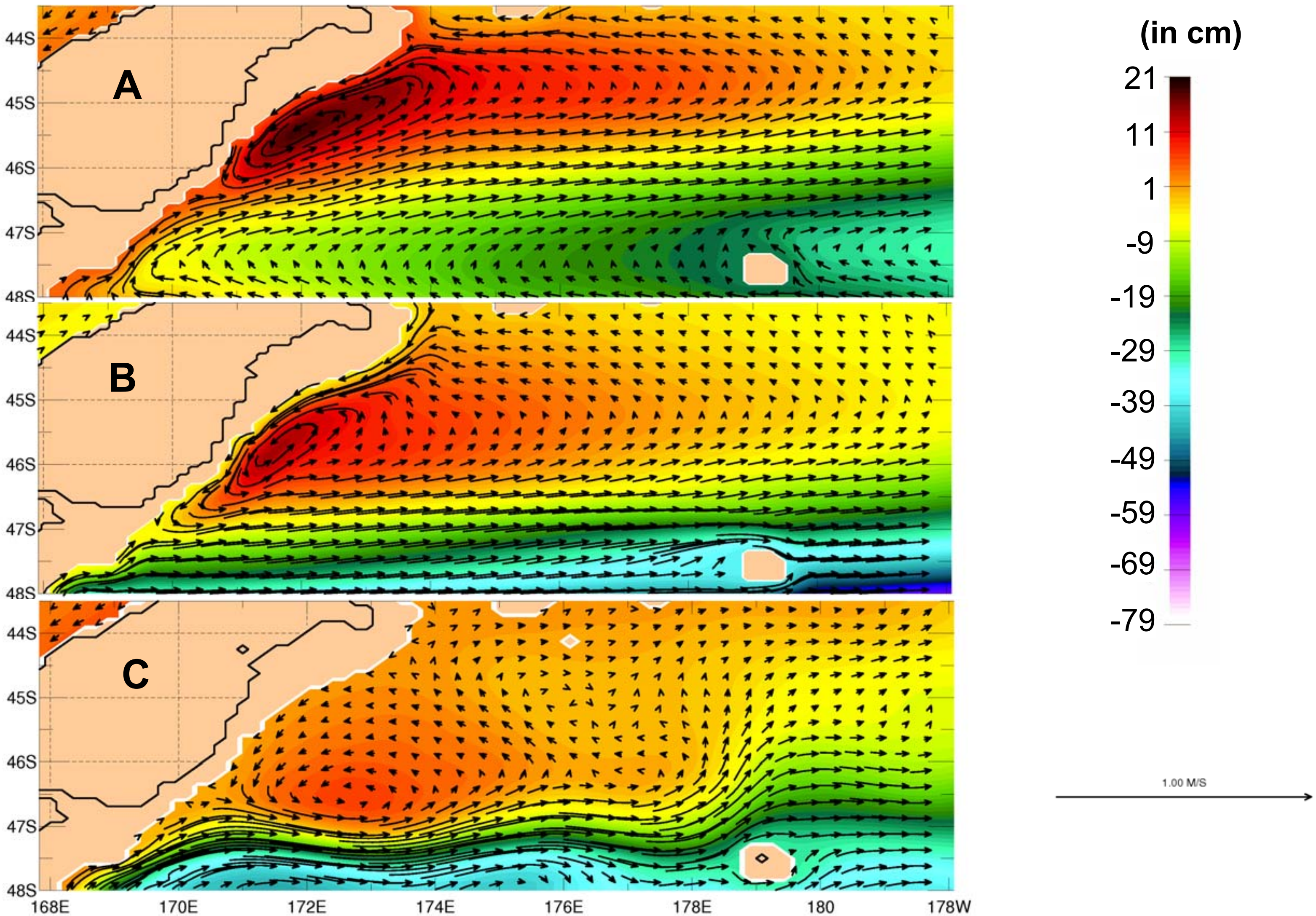
Current vector correlation = .61 south of 41°N

Mean Sea Surface Temperature Around New Zealand



- Uddstrom and Oien, JGR (1999)

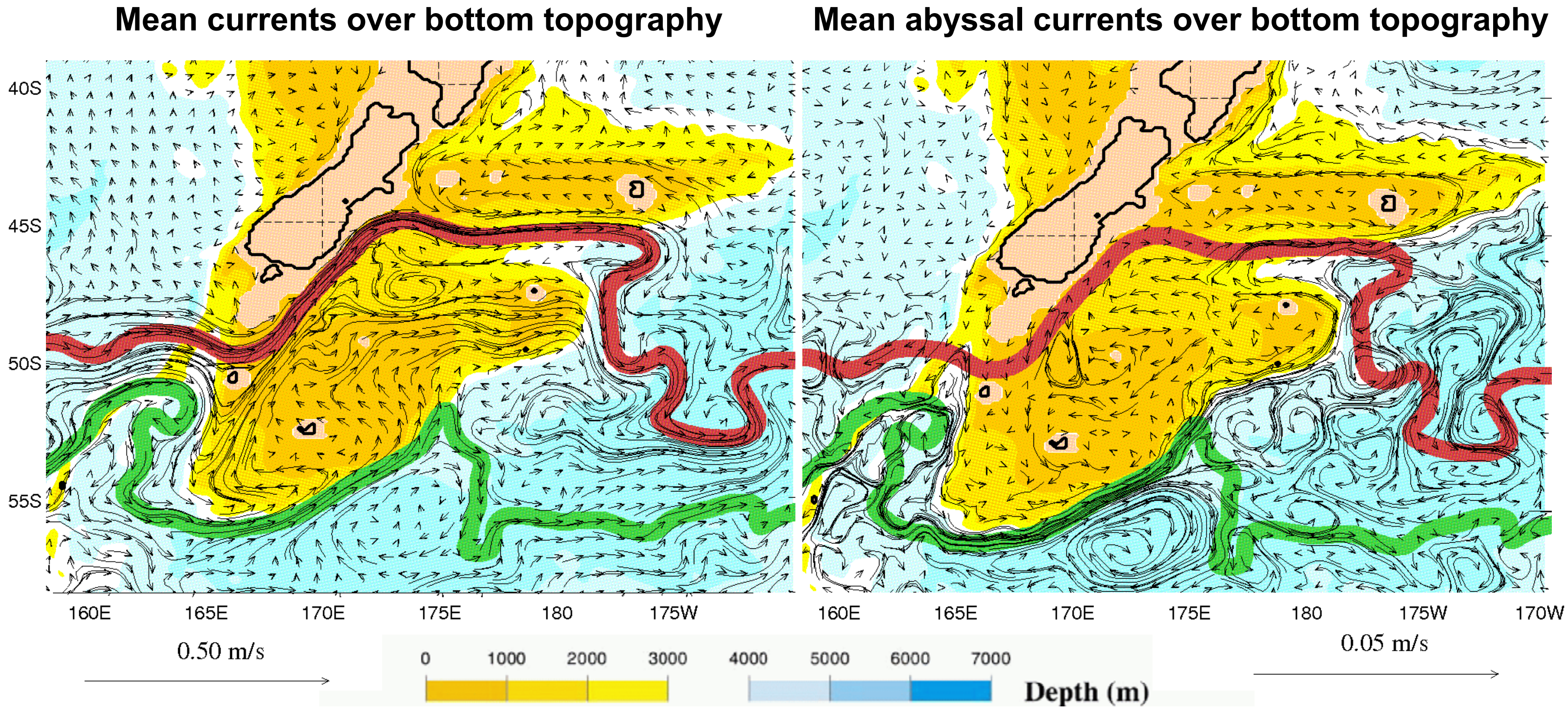
Mean Currents and Sea Surface Height Simulated by (A,B) 1/16° Linear Barotropic Model and (c) the Surface Layer from 1/8°, 6-Layer Flat Bottom NLOM



(A) QuikSCAT-corrected ECMWF ERA-40 climatological wind forcing

(B,C) Smoothed Hellerman and Rosenstein (1983) wind stress forcing

1/8°, 6-Layer NLOM Simulation of Mean Surface and Abyssal Currents East of South Island, New Zealand

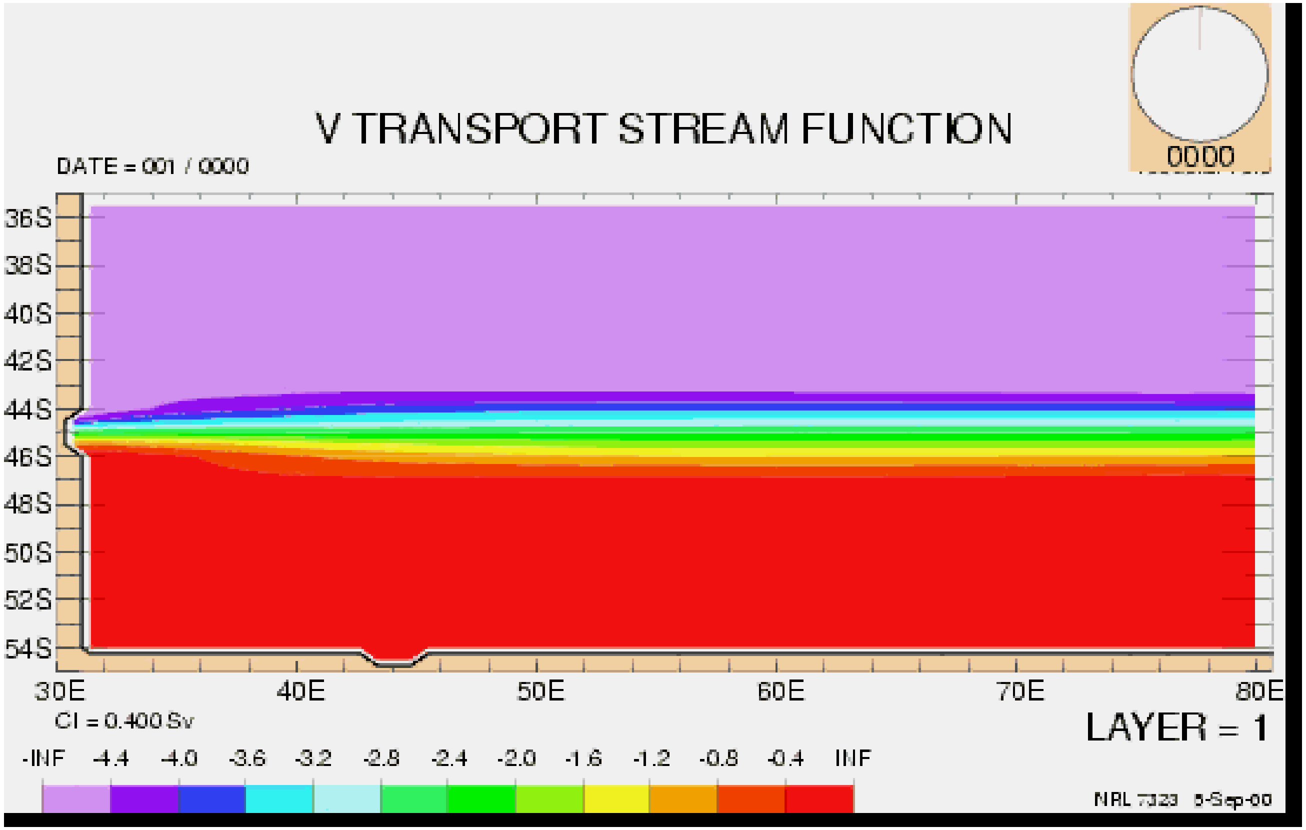


Mean subtropical front (STF)
Mean subantarctic front (SAF)

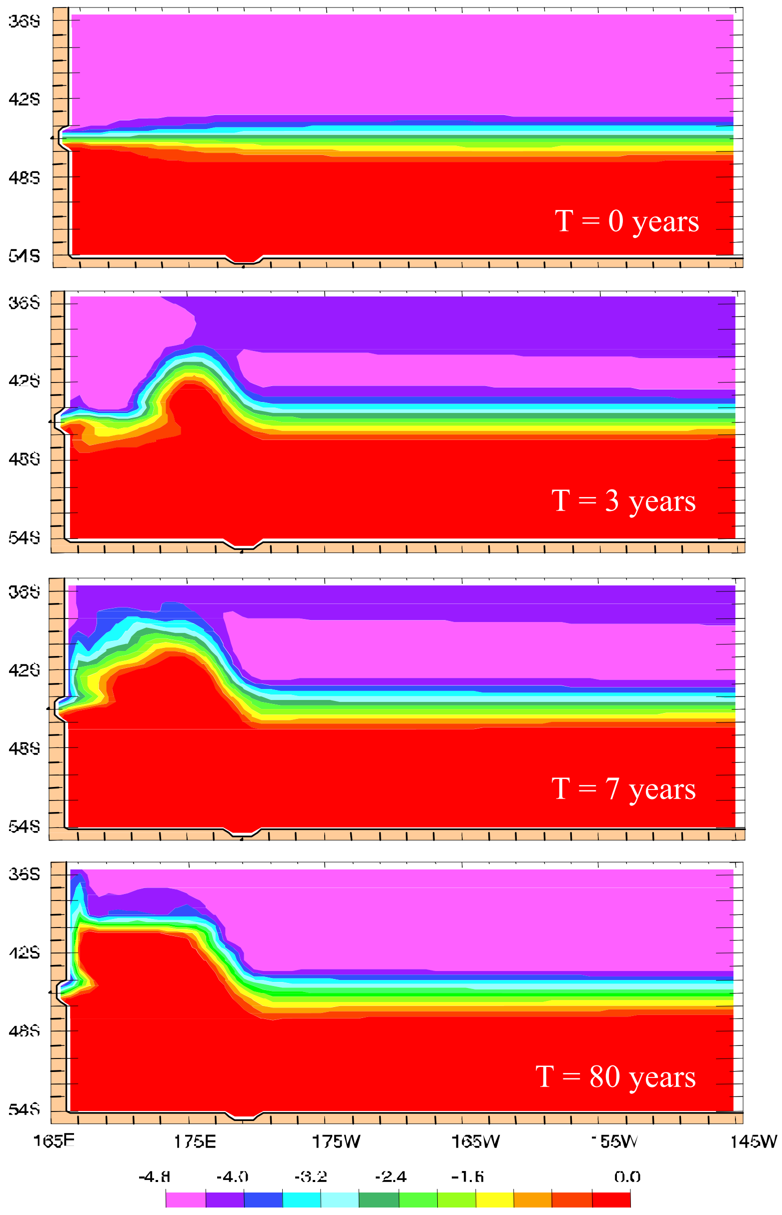
Smoothed Hellerman and Rosenstein (1983) (HRSM) wind forcing

From Tilburg et al. (2002; JPO)

Surface Transport Streamfunctions



Development of an Upper Ocean Western Boundary Current due to Remote Topographic Forcing

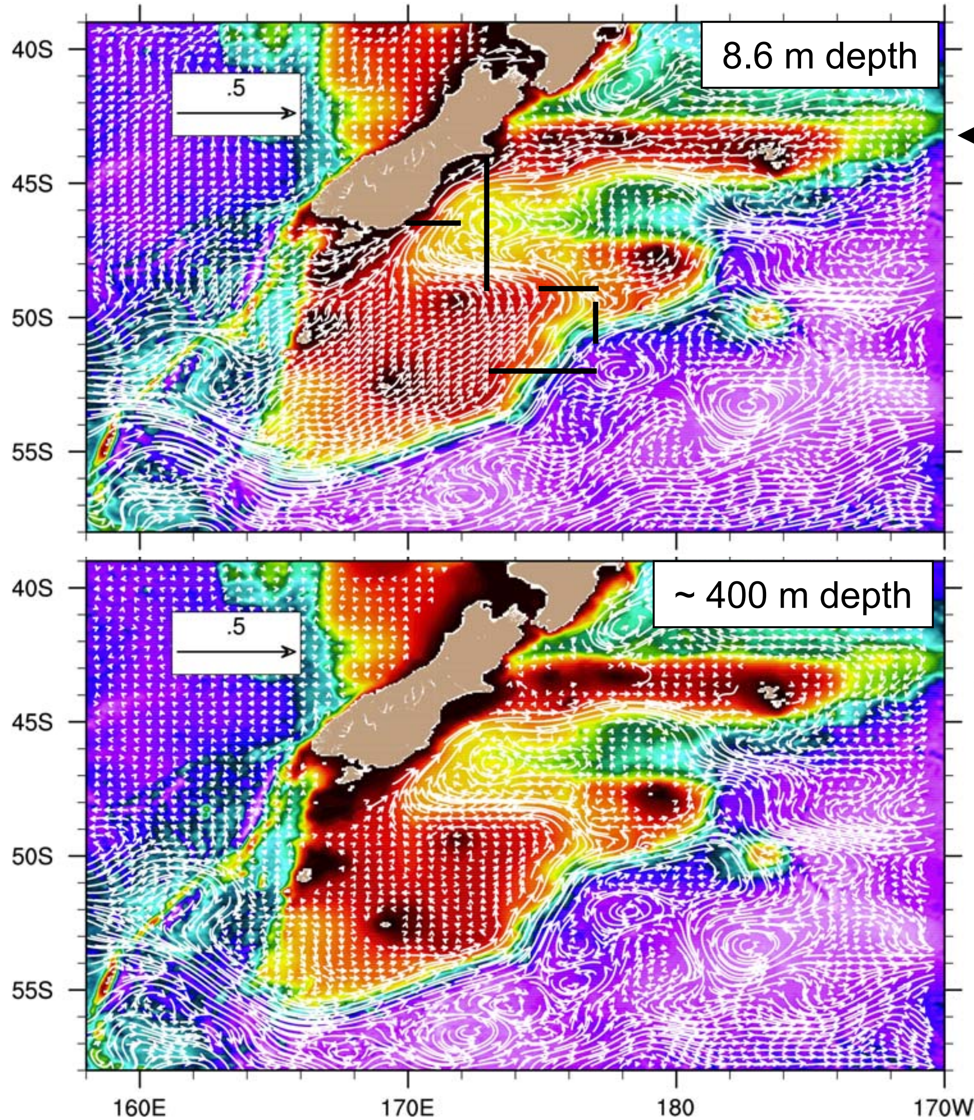


Centered at 177°E, a northward abyssal layer current along an escarpment is turned on at T=0. The model has two layers with topography confined to the bottom layer. A meridional plateau to the west slopes to deeper depths near 177°E.

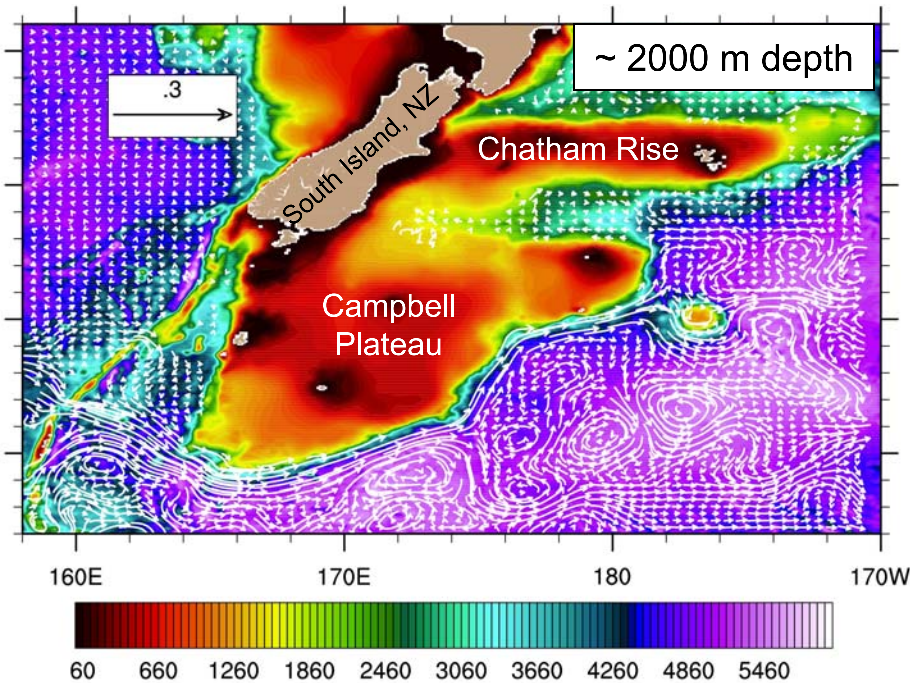
Surface layer transport streamfunction is shown.

From Tilburg et al. (2002, JPO)

Mean currents simulated by 1/12°, 32-layer global HYCOM in the New Zealand Region



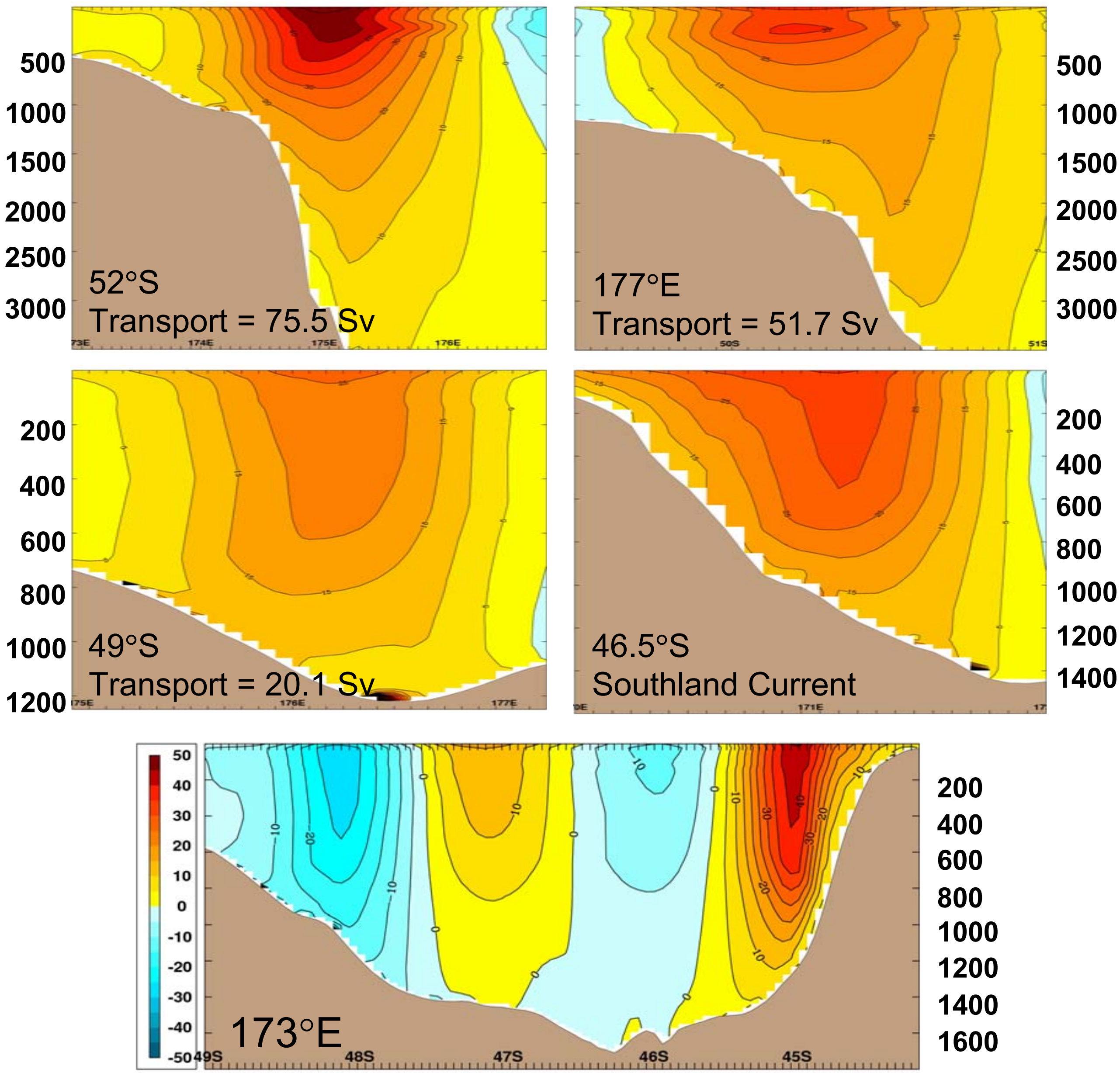
Black line segments mark vertical cross-sections shown on the next slide



Currents overlaid on bottom topography

From Hurlburt et al. (2006, DAO submitted)

Mean velocity cross-sections simulated by 1/12°, 32-layer global HYCOM southeast of New Zealand



Velocity contour interval = 5 cm/s
+ = N or E, yellow → red

Southland Current transports
Observed steric = 8.3 Sv
(Sutton, 2003; NZJMFR)
HYCOM steric = 7.8 Sv
HYCOM nonsteric = 16.2 Sv
HYCOM total = 24.0 Sv

Cross-sections are marked on the previous slide

Mean sea surface height in the New Zealand region