Subtropical Cells and Vertical Structure:

Observations and implications

Implications are fundamental:

- Vertical structure of SW Pacific circulation

  Spreading of thermocline, subsurface jets
- Bifurcation of western boundary currents
- Shape of EAC outflow
- How is water fed to the Equator?

  (How does the subtropics ⇔ Equator exchange

  spinup and spindown during ENSO?)

Fundamental dynamics (LPS ➜ McCreary and Lu)

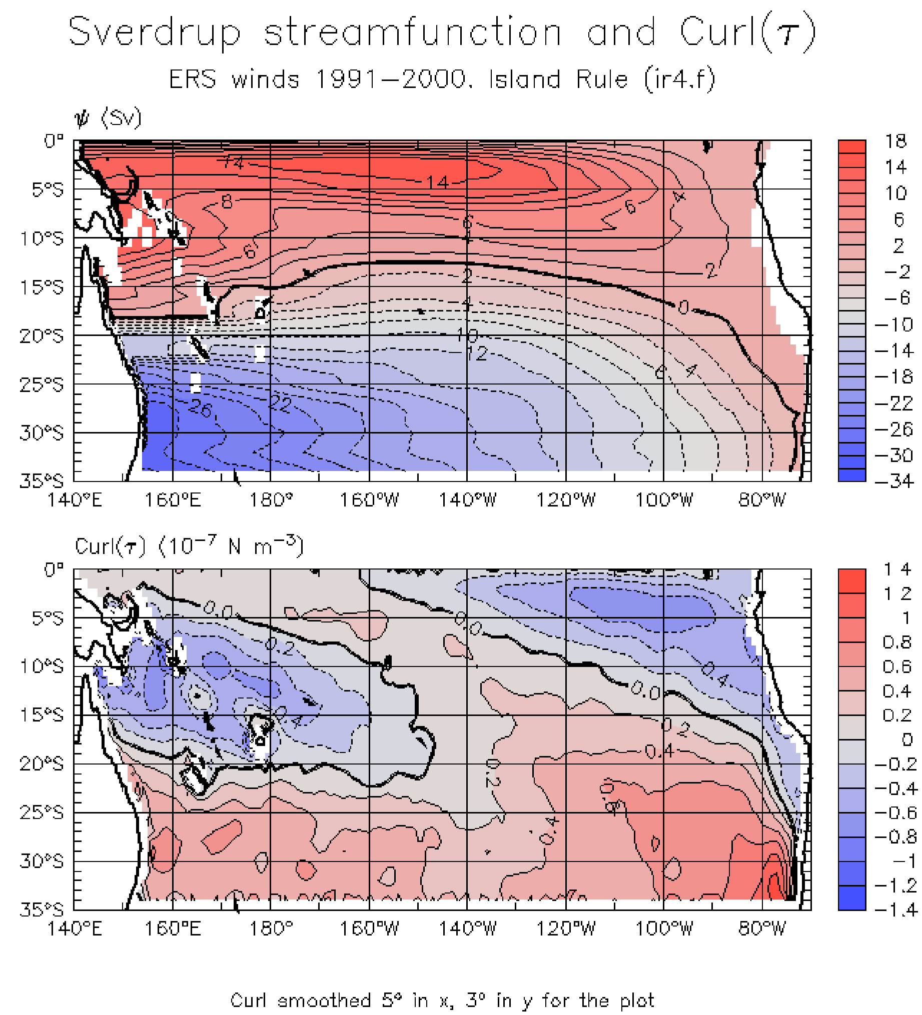
Overall Sverdrup balance, get solution integrating due west:

$$\psi = \frac{1}{\beta}\int_{EB}^{x} Curl(\tau)dx$$

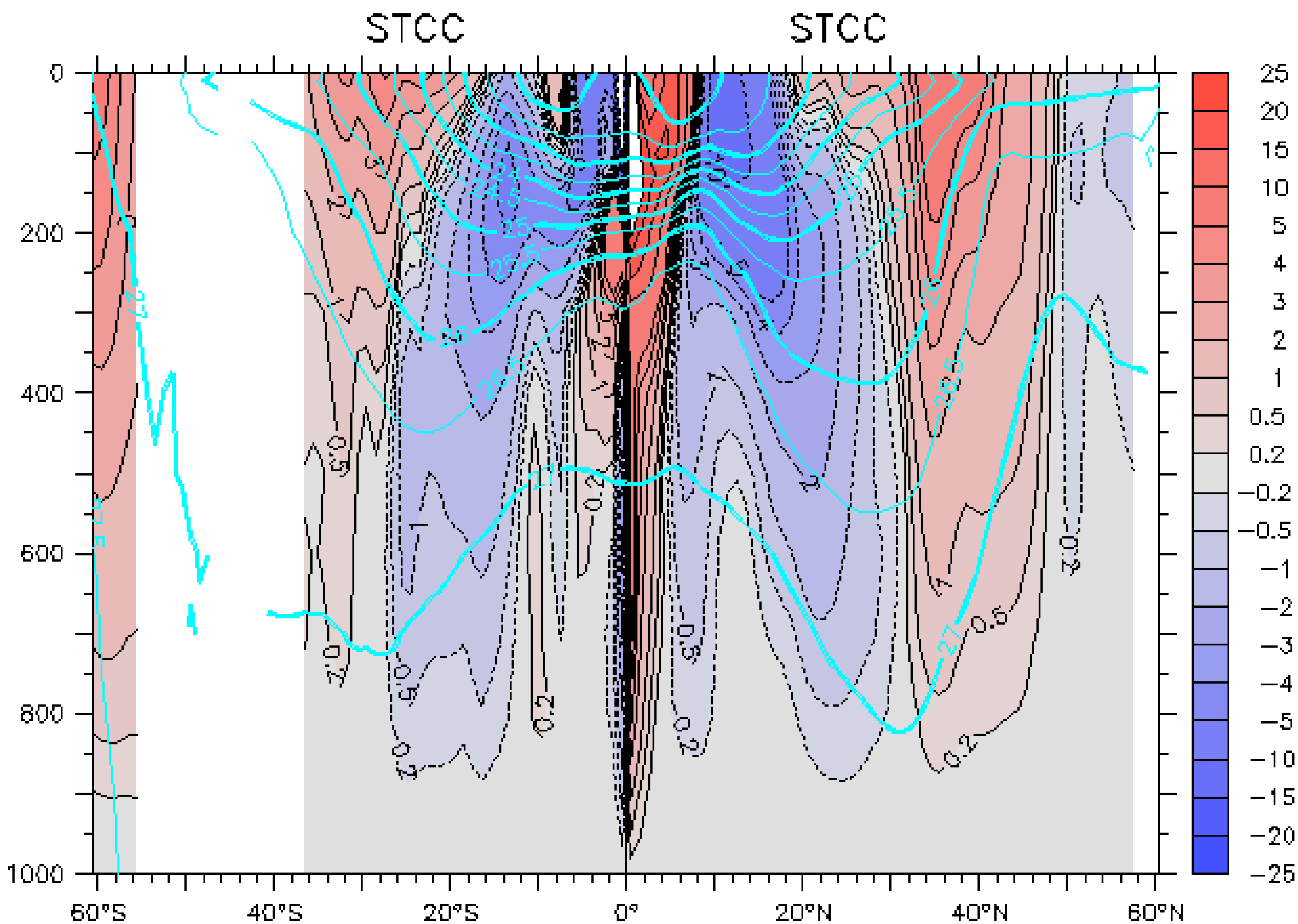
Sverdrup v_g bends 2nd-mode Rossby wave characteristics (equatorward in subtropical gyre)

➔ 2nd-mode features under gyre center:

- Thermocline spreading
- Vertical shear and subsurface SEC maxima
- Tilted bifurcation of WBC



Mean u_g and sigma-theta along 170°E (WOA94)

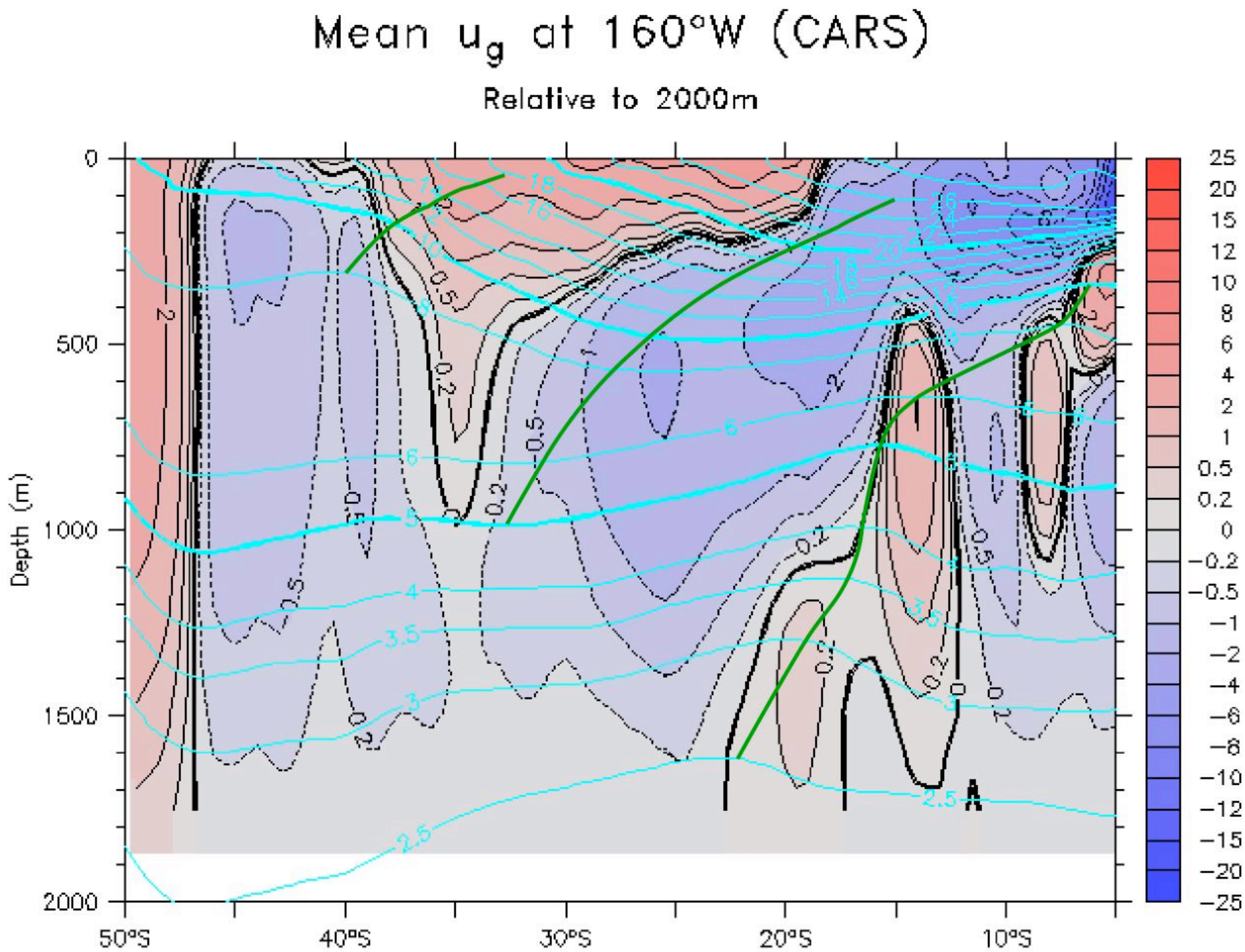


Define Subtropical Countercurrent as E-ward u_g above W-ward SEC/NEC

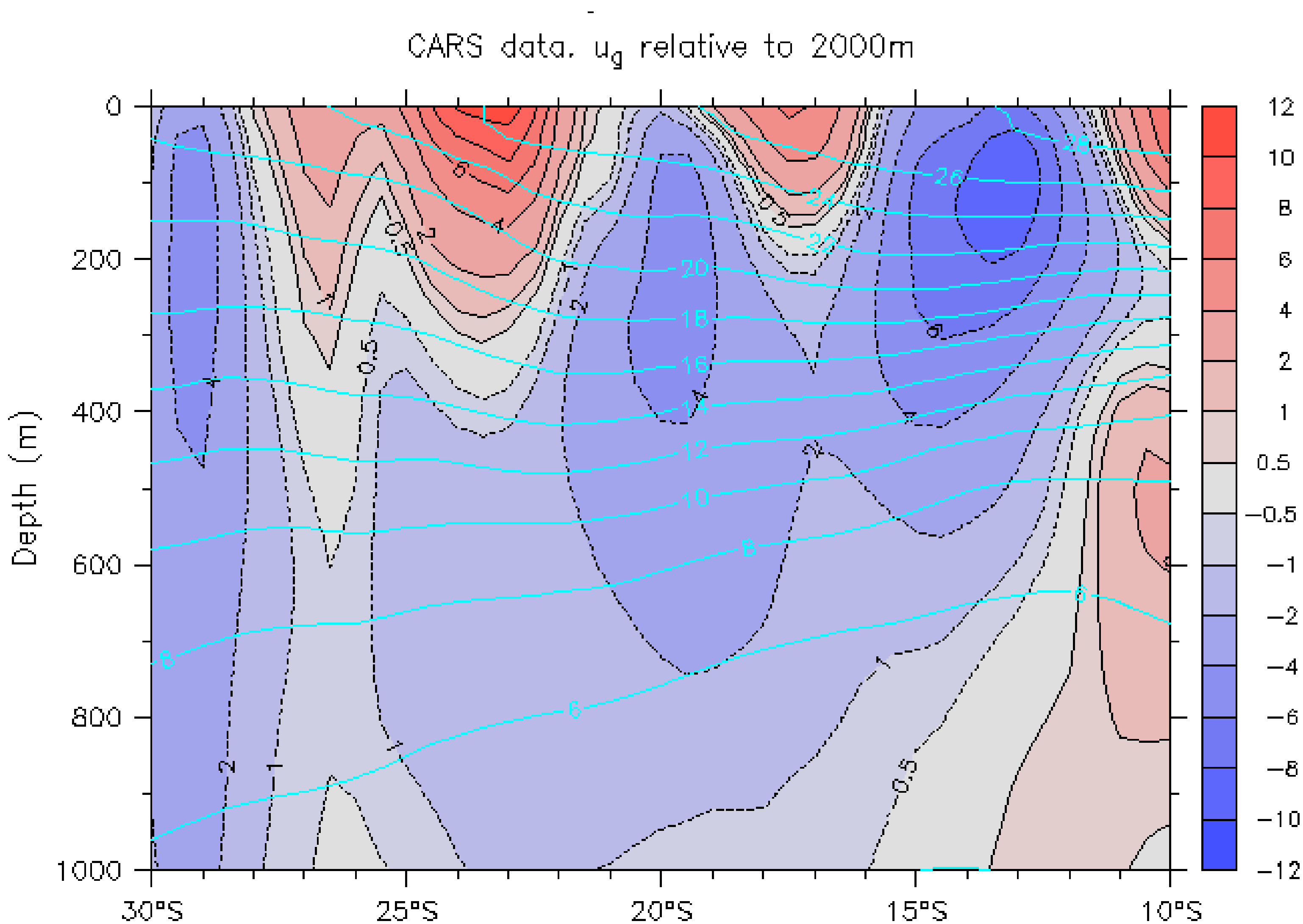
➔ Due to tilt of gyre

All the thermal structures of the subtropical gyre are tilted poleward with depth.

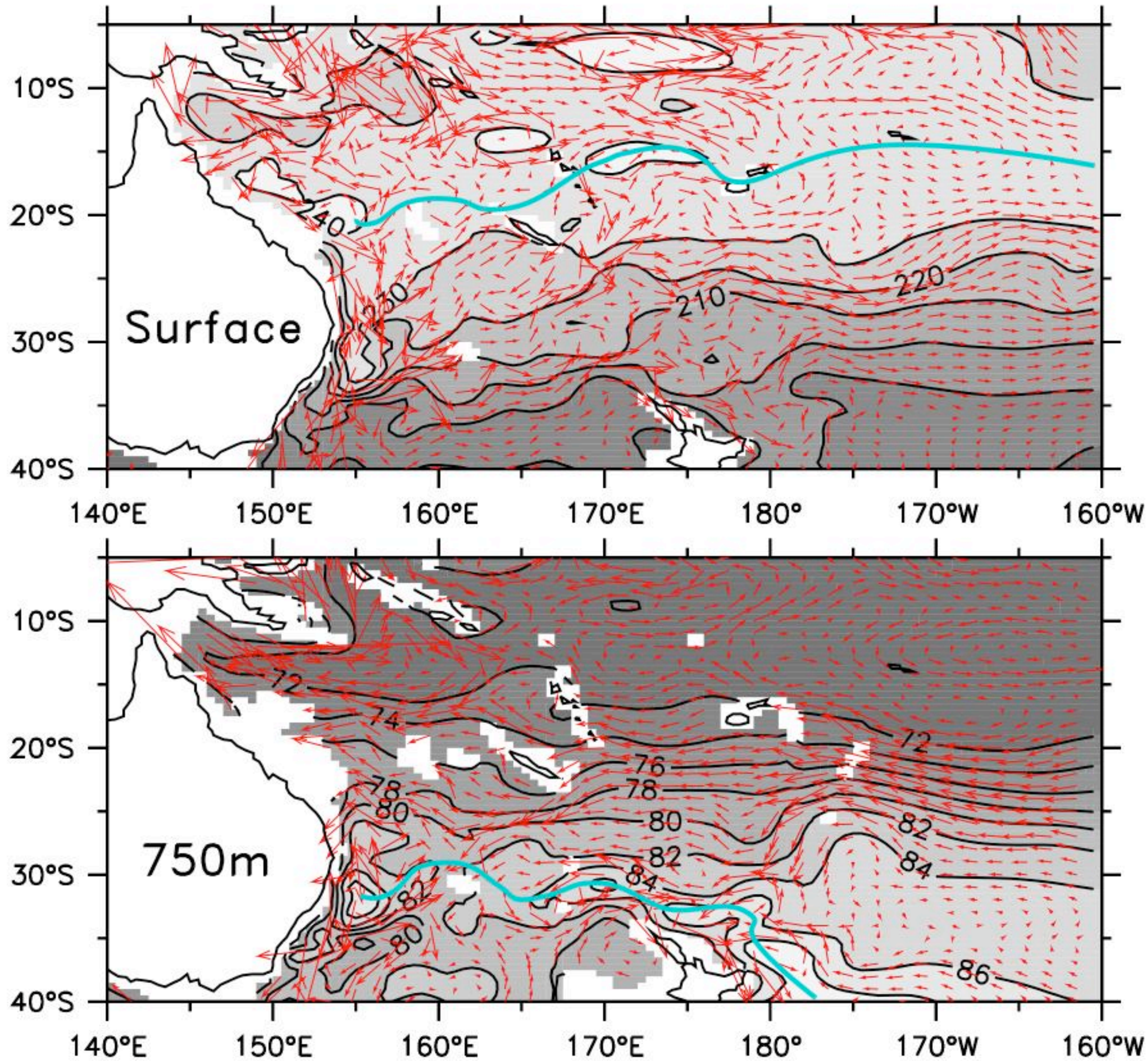
The tilt is deep enough that it must have a dynamic origin (mode 2).



u_g and T along 170°E: Subsurface jet maxima



Mean u_g from CARS data



Blue line divides E-ward and W-ward flow

At the surface, u_g is eastward south of about 15°S

At 750m, u_g is westward south to at least 30°S

The STCC is clearly defined as a band of enhanced eddy KE.

The spreading thermocline and resulting eastward shear change the sign of Q_y in the column, favoring baroclinic instability.

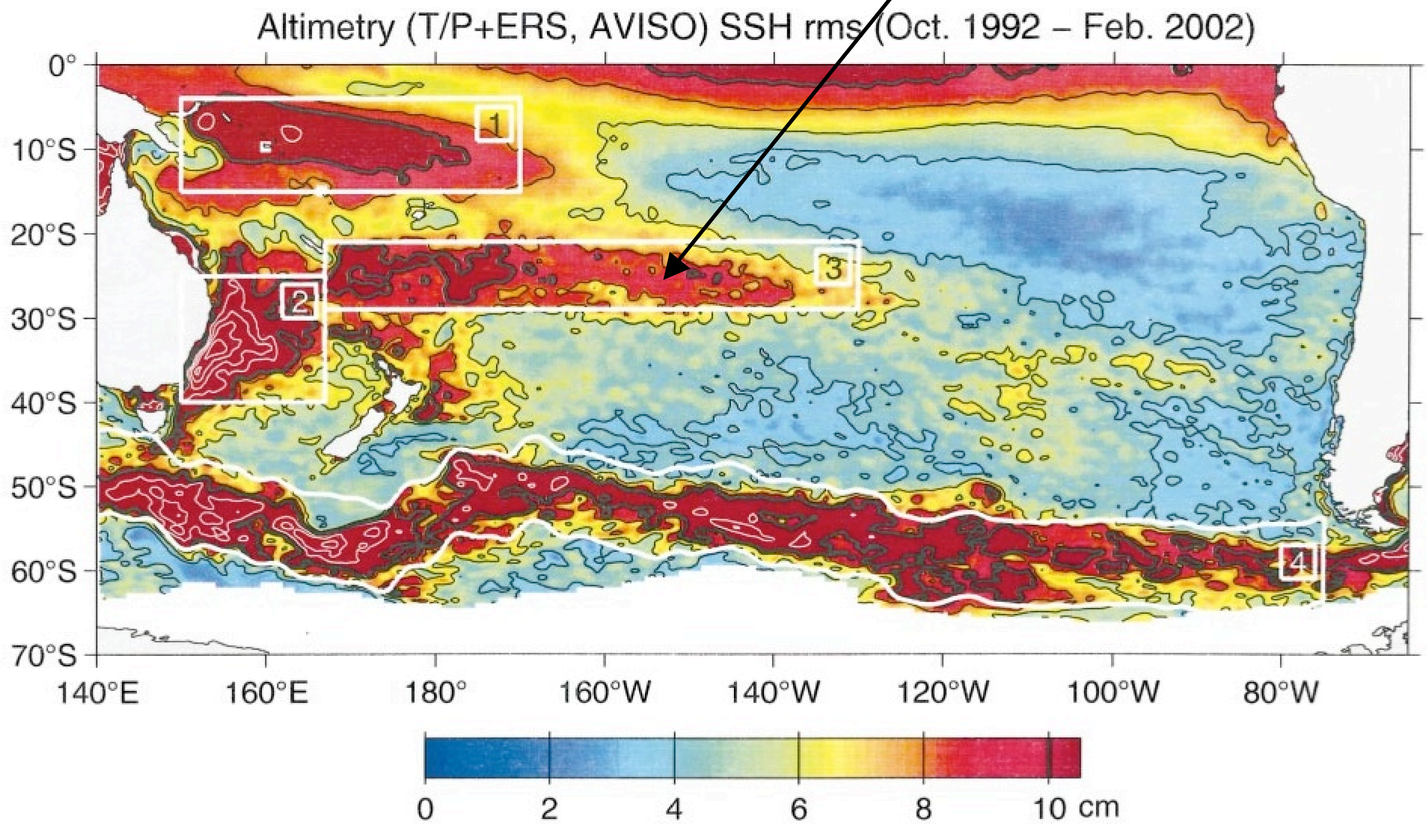


FIG. 1. Map of the rms sea surface height variability in the South Pacific Ocean. Based on the combined T/P and *ERS-1/2* altimetric data from Oct 1992 to Feb 2002. Thick solid lines denote the 0.1-m contour. In regions above 0.1 m, thin white lines denote contours at a 0.05-m interval.

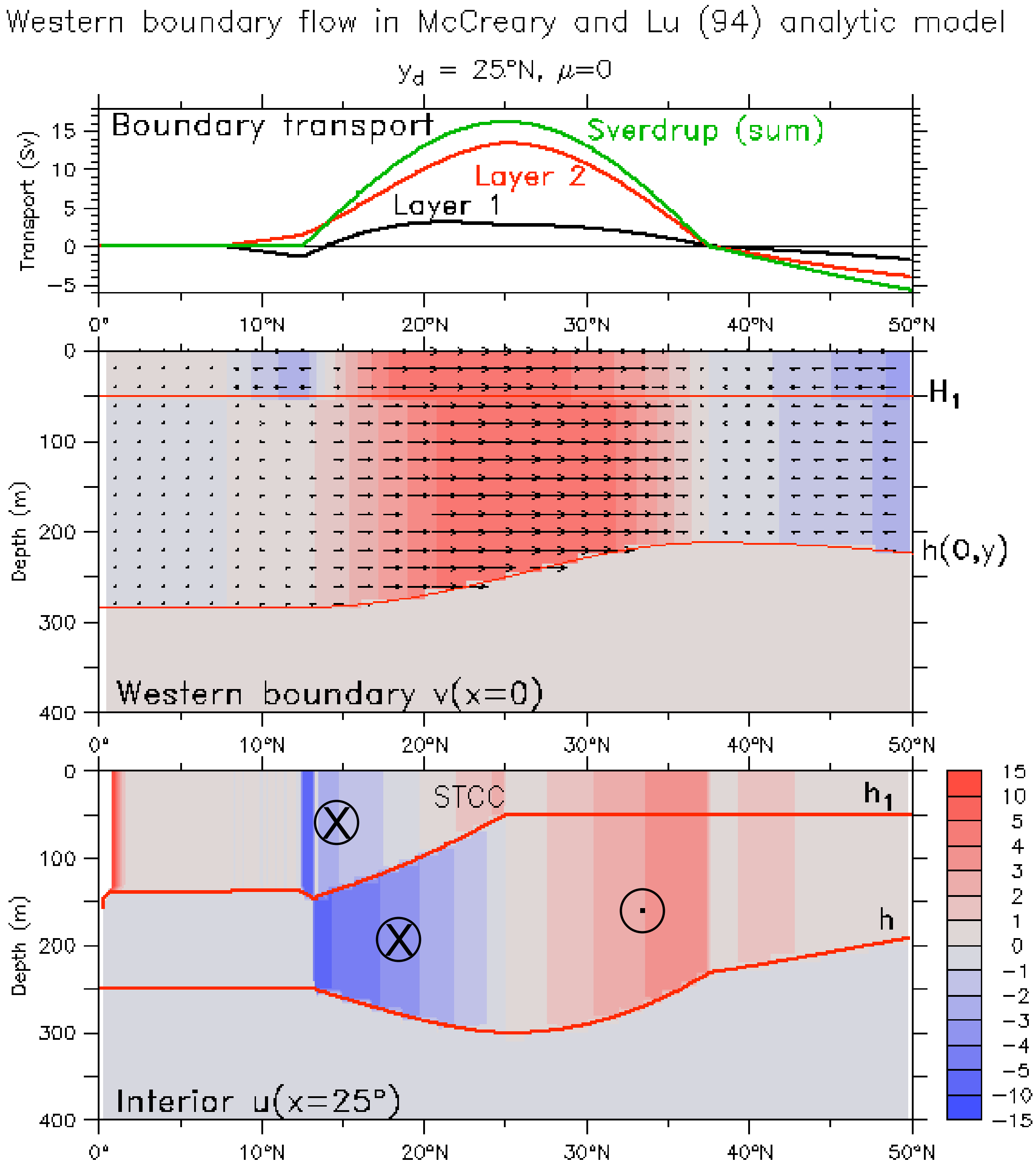
Qiu and Chen (2004)

An analytic model of the STC based on LPS

(McCreary and Lu 1994)

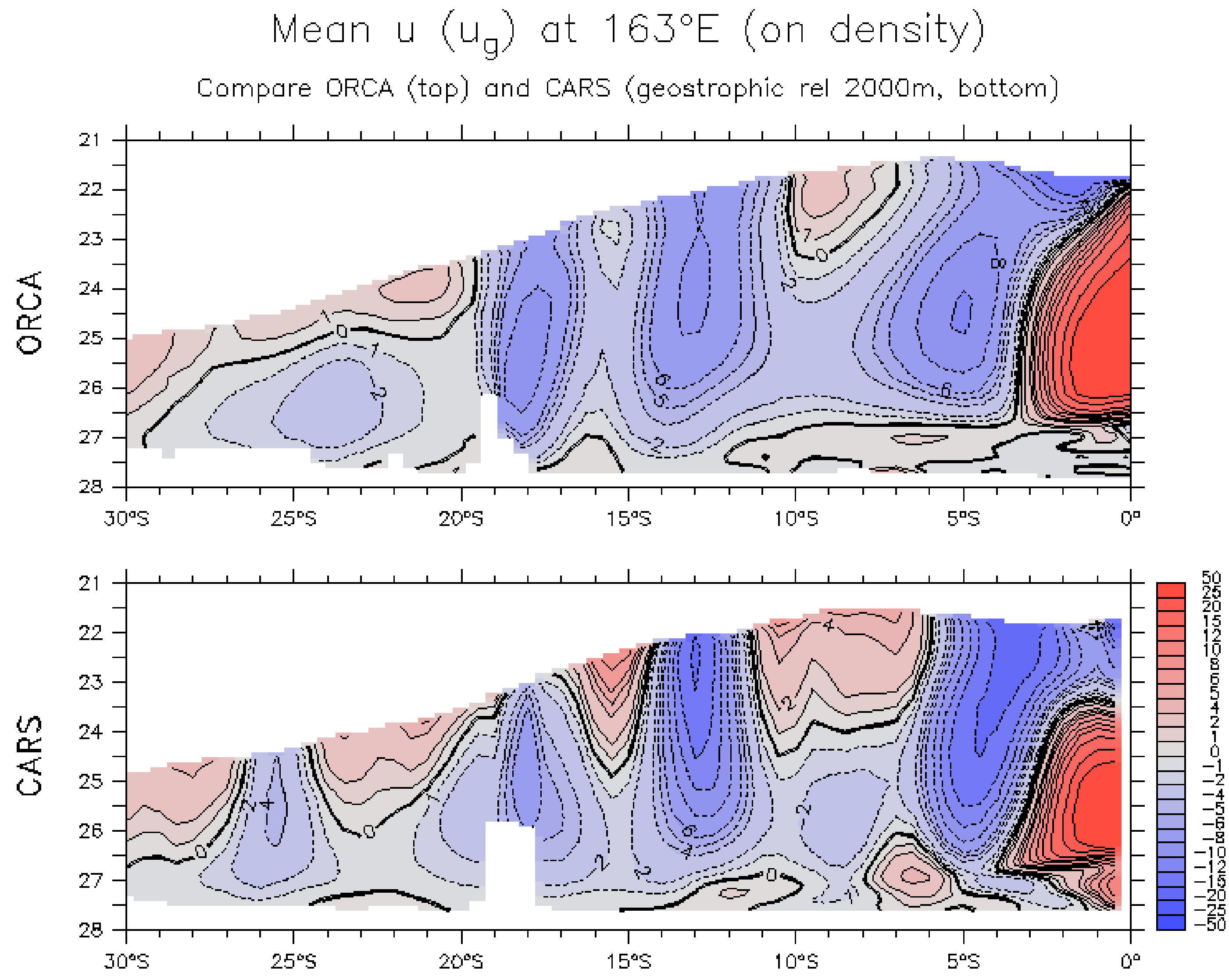
• The model gives an STCC near the center of the gyre (bottom).

• The WBCs are tilted poleward with depth. (Since this model has no tropical gyre, there is no bifurcation in the lower layer, but the maximum poleward WBCs are tilted).



Estimating the WBC from the Firing et al (1999) principle

based on ORCA model u(163°E)



The Firing et al (1999) Island Rule

• In the absence of a circumisland wind, the I.R. states that the streamfunction value at the island equals the average Sverdrup transport V_{Sv} to the east of the island.

Therefore:

→ There must be a zero point of the island WBC.

→ The island WBC is due only to the *variation* of V_{Sv} with y.

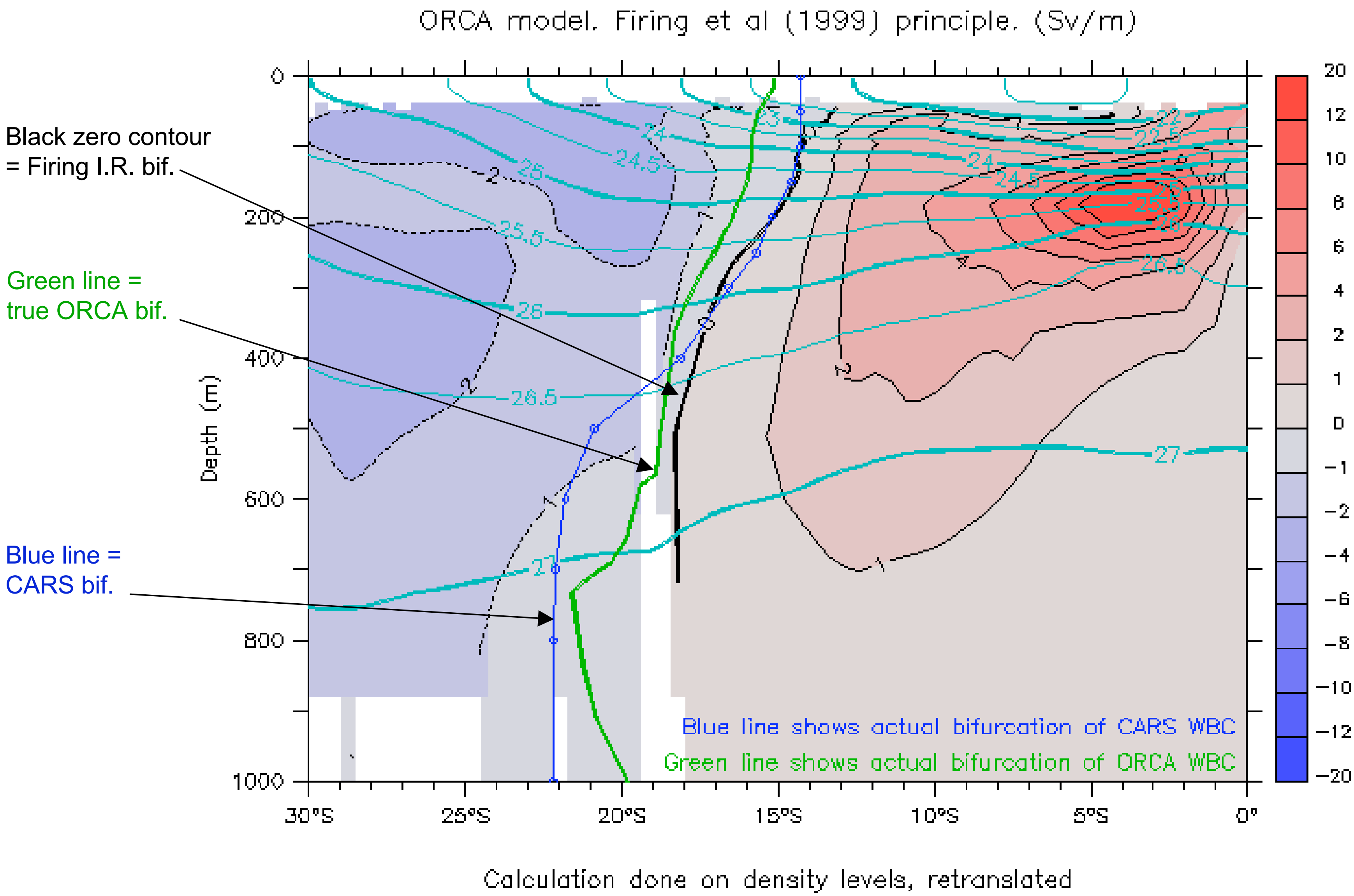
→ Since $U_{Sv} = -\int(dV_{Sv}/dy)dx$, the WBC can be derived from the zonal transport feeding mass into the boundary layer. (Firing et al found this from a Rossby model).

→ "… an inflow to the boundary layer will split, with fraction $(y-y_s)/(y_n-y_s)$ going north, and the remainder going south."

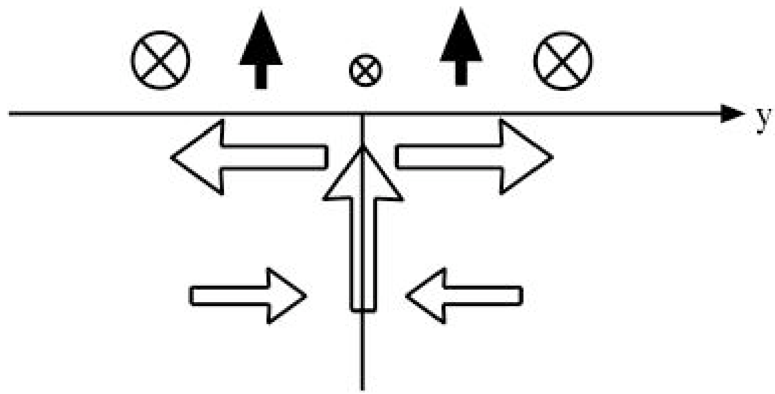
• Apply this principle *in each isopycnal layer*, with the inflow chosen as the ORCA model u at 165°E

WBC based on 163°E inflow:

Bifurcation tilt results from vertically-sheared SEC/STCC



Sheared vs Sverdrup changes during ENSO



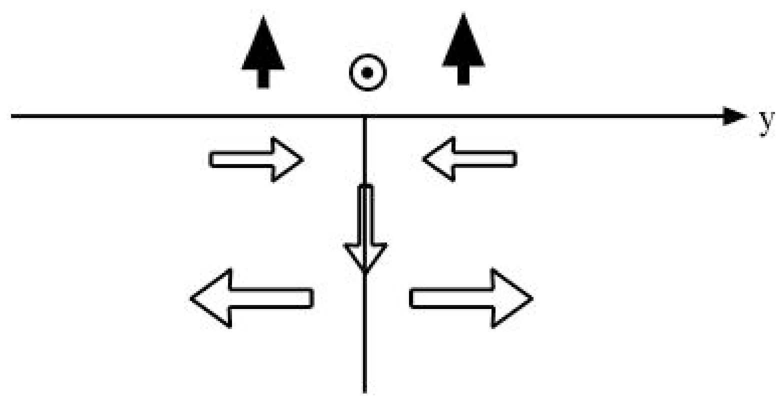
Normal regime:

Upwelling curl (▲) on both sides of Eq

➞ Interior Ekman divergence larger than geostrophic convergence.

See this as a sheared tropical cell plus poleward Sverdrup flow.

Equatorward WBC required.



El Niño anomalies:

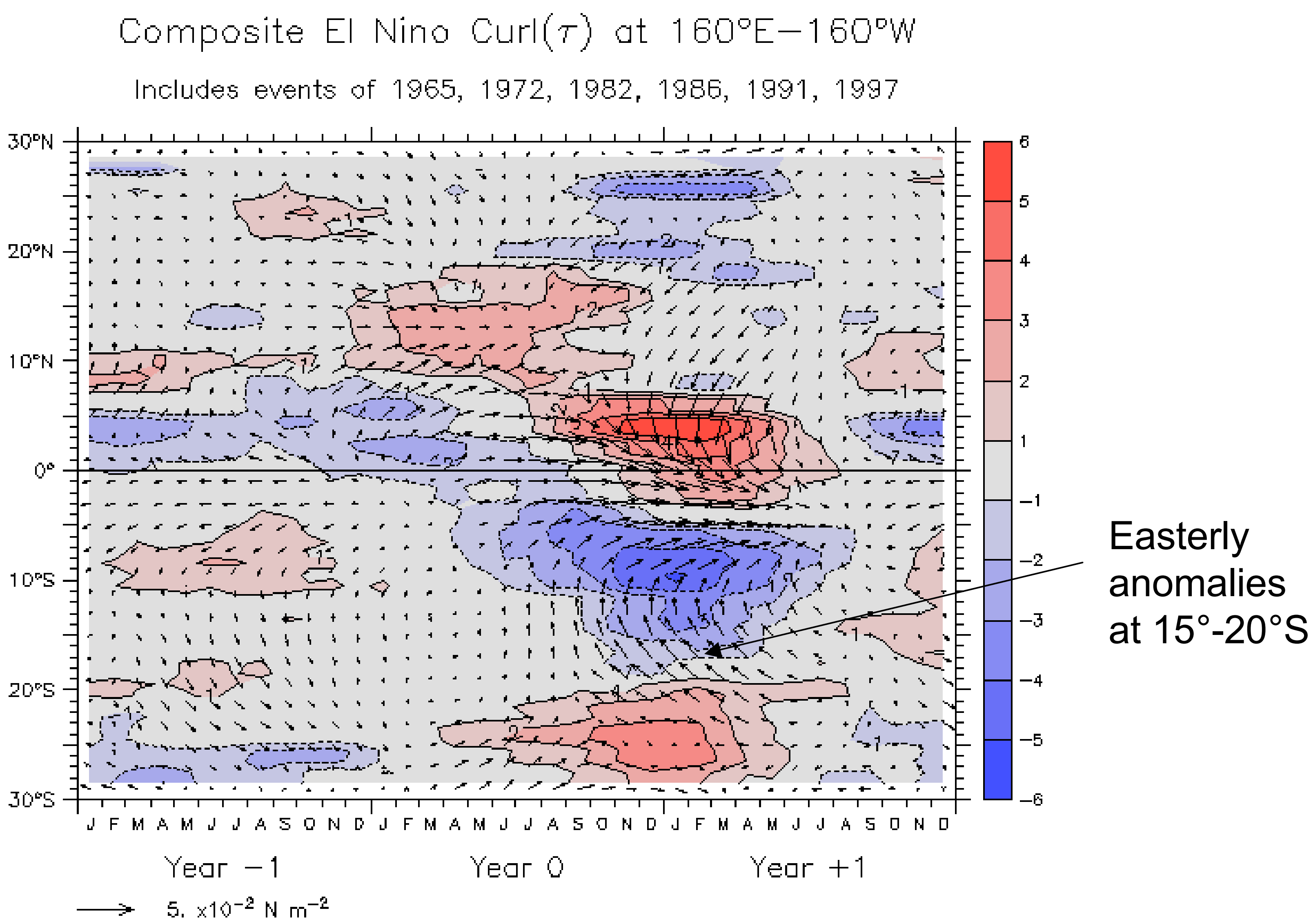
Anomalous upwelling curl

➞ Interior geostrophic divergence larger than Ekman convergence.

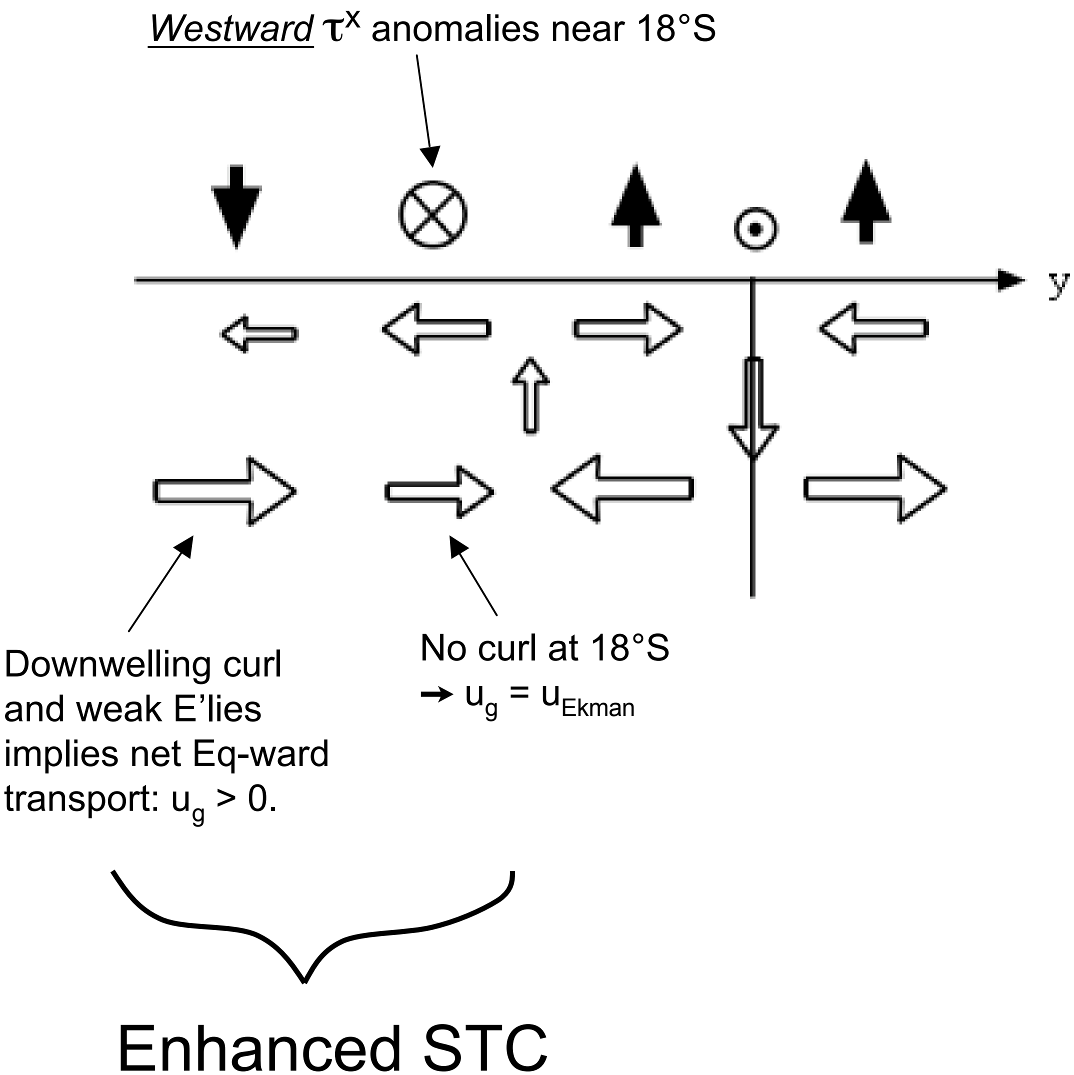
Weakened cell plus anomalous poleward Sverdrup flow.

Anomalous Eq-ward WBC required.

El Niños produce strong wind and curl anomalies in the South



The effect of off-equatorial ENSO wind anomalies



Observations suggest stronger E'lies near 18°S during the peak of El Niño.

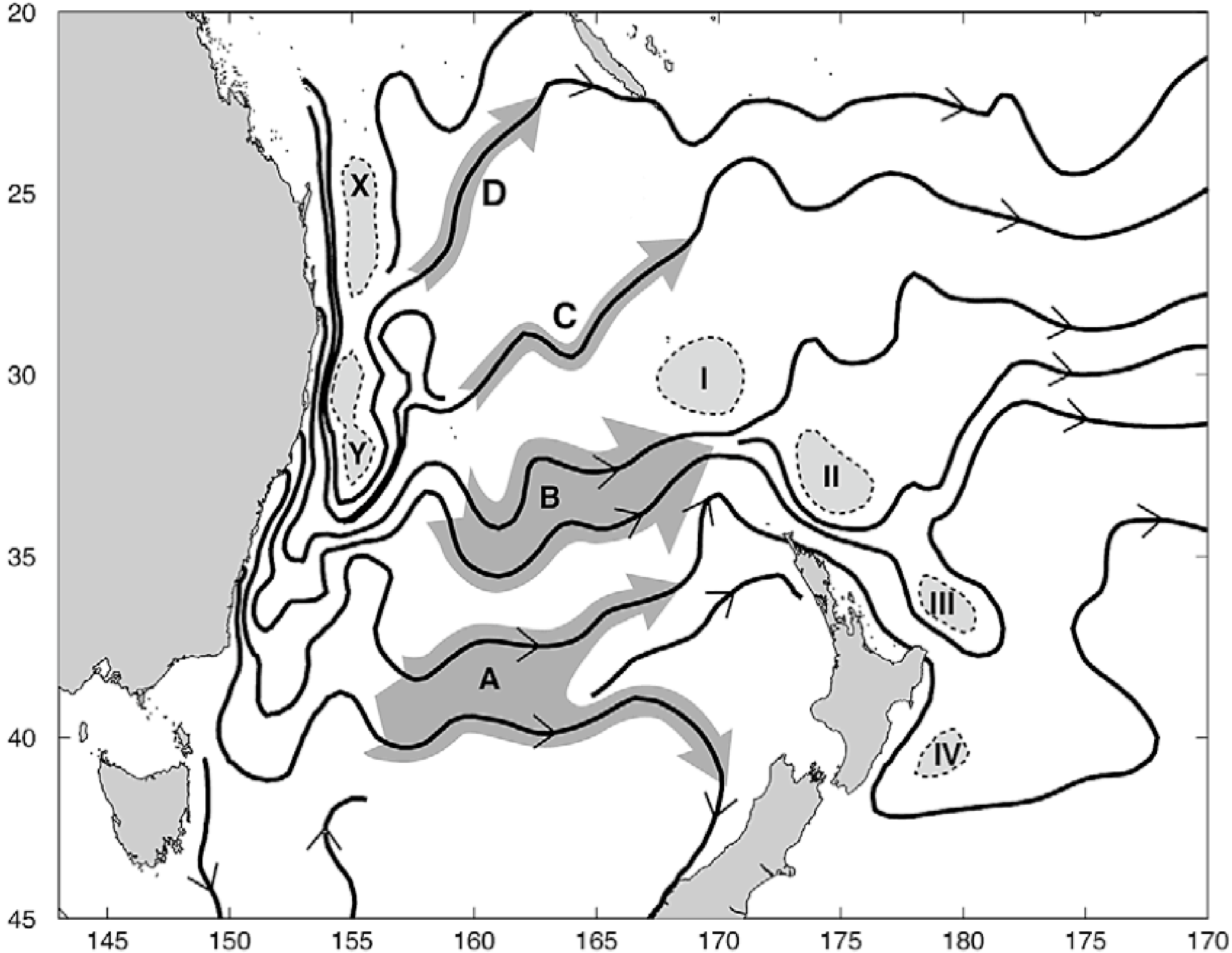
This would produce an enhanced STC, with net Eq-ward flow. It would eventually require a stronger EAC (after a longer lag).

What happens to the STCs during El Niño?

- It is likely that ENSO produces a mix of changes involving both the STCs and the n=1 flow.
  - ➞ How far from the equator do these extend?
  - ➞ Do decadal anomalies prefer Sverdrup or baroclinic patterns (McPhaden and Zhang)?
- The meridional and modal structure of the anomalies will produce complex lag relations. especially as the WBCs adjust.
- Understanding these will require <u>subsurface time series</u> to sample the shear, both in the interior and the boundary currents.
- About half the STC transport in the McCreary and Lu formulation occurs in the WBCs.
  What would we call enhanced interior shear not completed by a WBC?

Extra
Figures
Follow

Outflows from the EAC



(Ridgway & Dunn 2003)