Glider observations of the Solomon Sea

Work based on 13 years of (~monthly) glider sections

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Dan Rudnick and Russ Davis (Scripps), Chalapan Kaluwin (UPNG)
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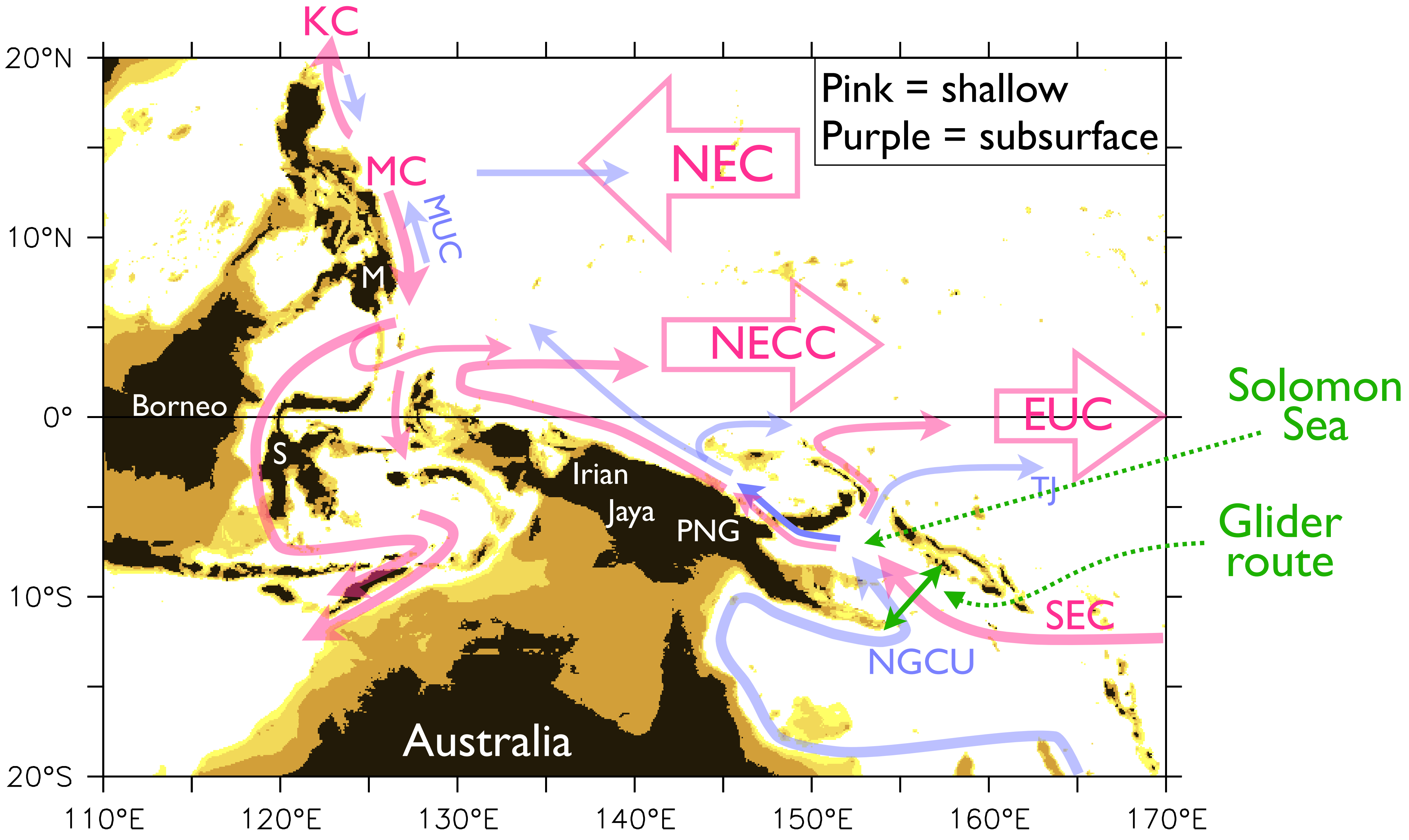


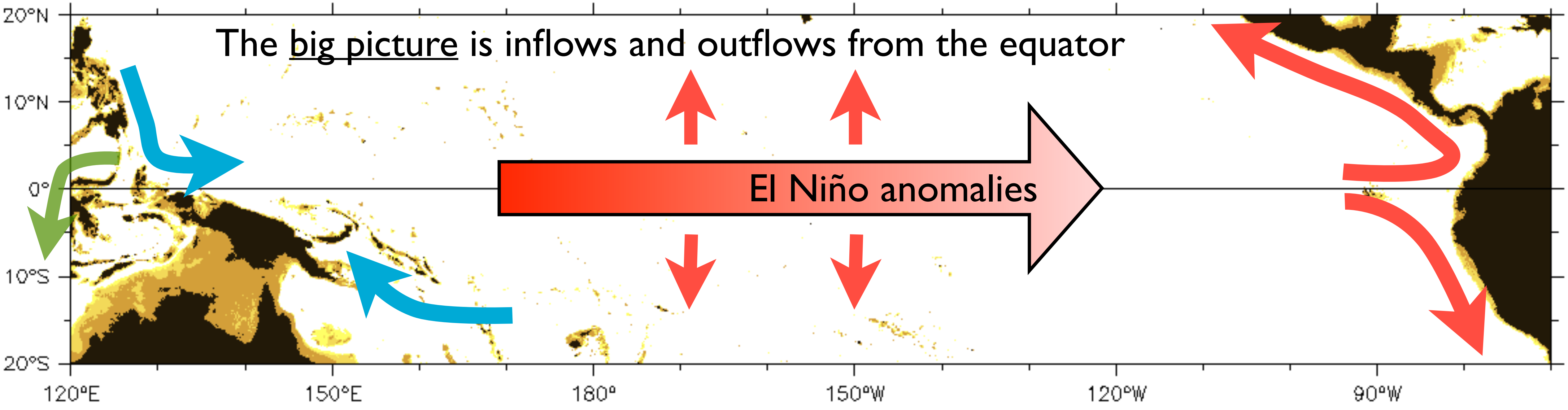
Why do we measure LLWBCs?

(Low-latitude western boundary currents)

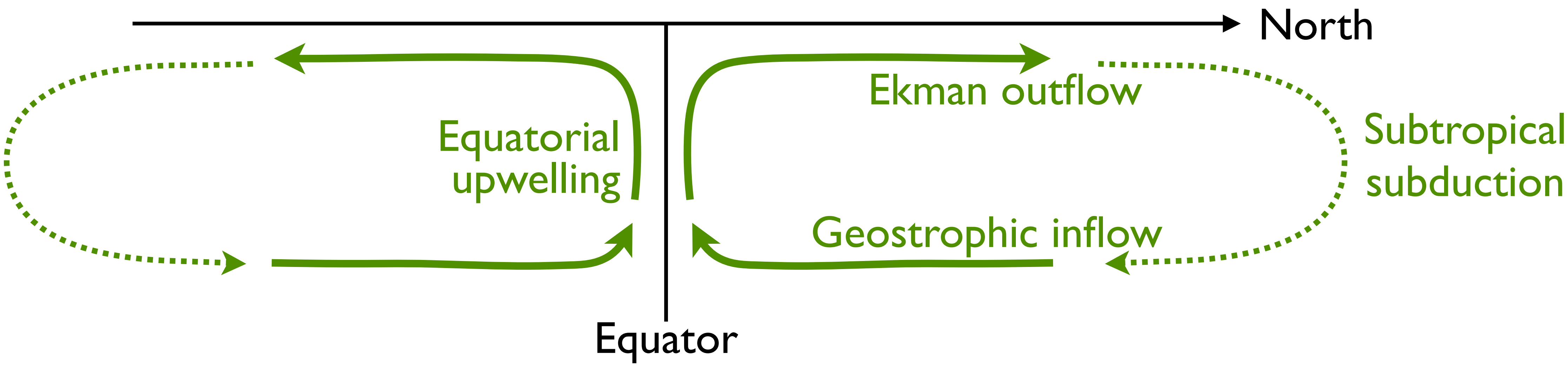
The big picture of ENSO is the accumulation (recharge) and discharge of mass and heat in the equatorial strip:

→ Exchanges between the subtropics and equator

Most discharge during El Niño occurs in the east and central Pacific, but most recharge occurs in the LLWBCs.

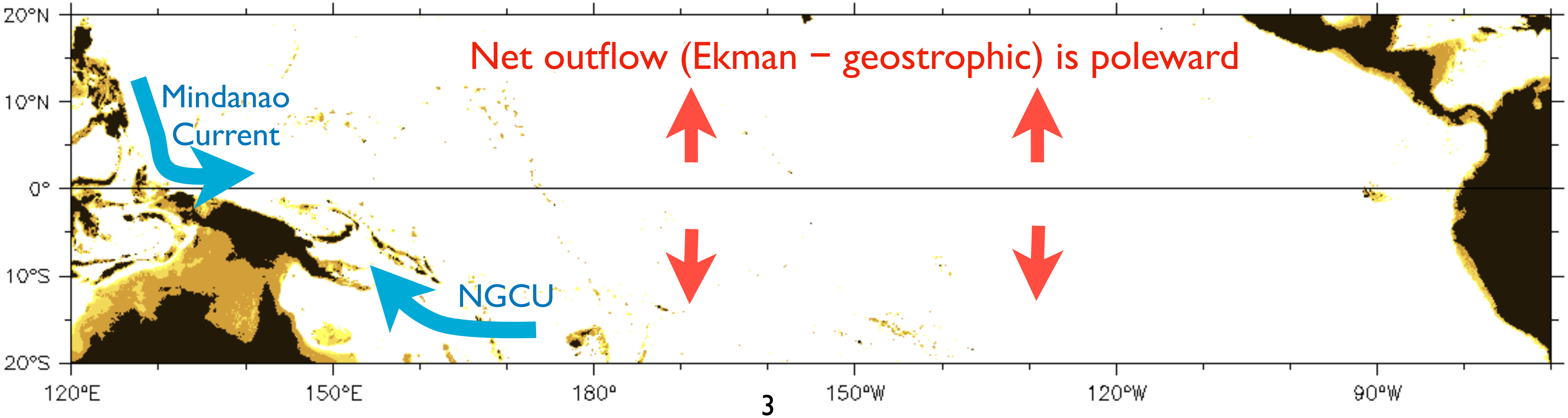


Our simple picture of the "mean overturning circulation" is only true for the basin-wide integral



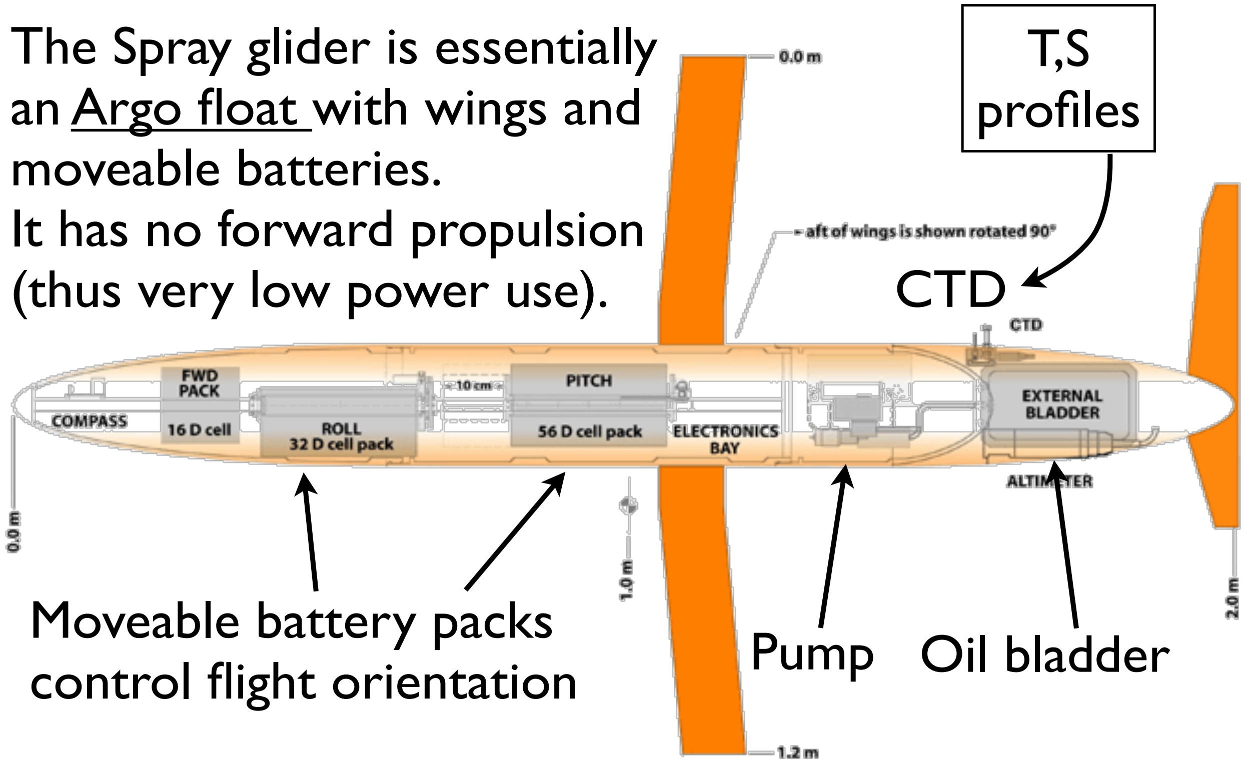
In mid-basin, the shallow outflow is larger than the subsurface inflow.
⇒ The difference is made up in the western boundary currents.

These are the Mindanao Current in the north,
and the New Guinea Coastal Undercurrent in the south.



The Spray glider used in the Solomon Sea

The Spray glider is essentially an Argo float with wings and moveable batteries.
It has no forward propulsion (thus very low power use).



T,S profiles

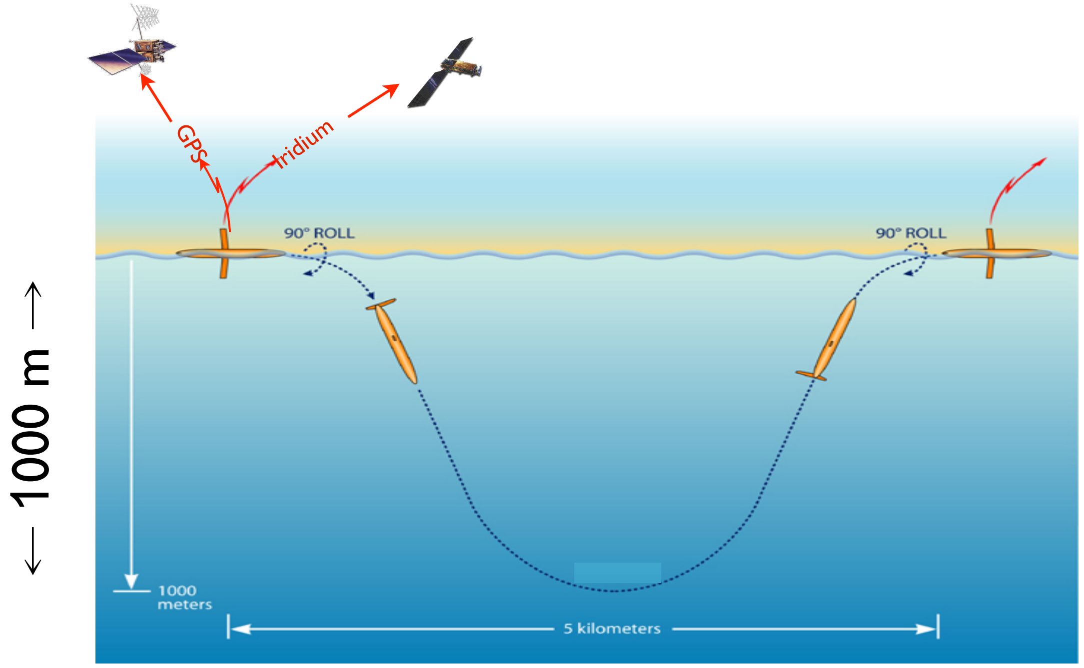
CTD

Moveable battery packs control flight orientation

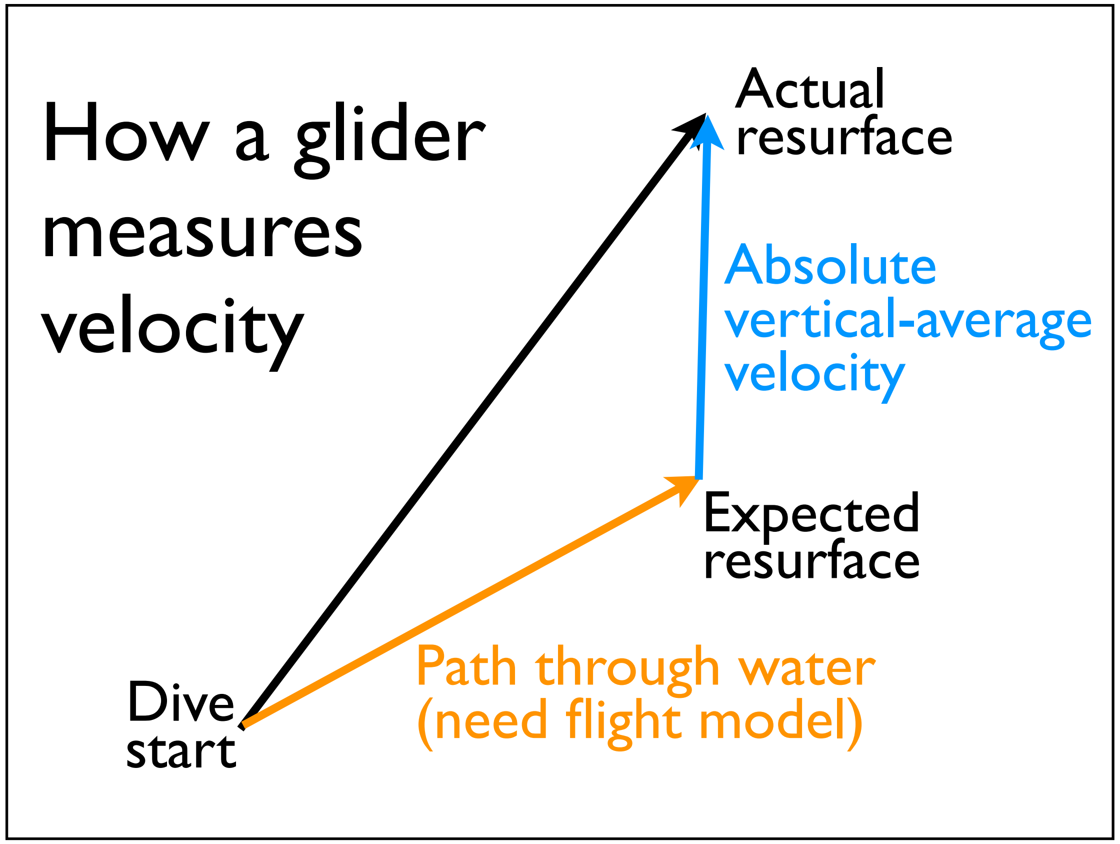
Pump

Oil bladder

← 2 meters long, weighs 50kg (2 people to operate) →



← 3-5 km (~4 hr) →
20-25 cm/s (~20 km/day)
Range 4-5 months = 2500+km



How a glider measures velocity

Actual resurface

Absolute vertical-average velocity

Expected resurface

Path through water (need flight model)

Dive start

Strengths:

- Flexible (no ship needed)
- Absolute velocity (with flight model)
- Fine-scale sampling (useful for WBCs)
- Relatively cheap (2-person operations)

Weaknesses:

- Slow (eddy aliasing, uncertain path)
- Infrequent sections (sampling errors)

Other ways to measure WBCs

Moorings

Strengths:

- Required for narrow straits
- Excellent time resolution
- Reliable absolute velocity
- Co-located T, S, Met (if surface)

Weaknesses:

- Single point (representative?)
- Subsurface-only in ship channels
- Expensive (need ship)

Aviso (satellite altimetry = SSH)

Strengths:

- Globally consistent grid
- Observe propagating eddies
- Free! (to us)

Weaknesses:

- Surface geostrophic velocity only
- Uncertain near coasts?

L24605 GORDON ET AL.: MAKASSAR STRAIT THROUGHFLOW L24605

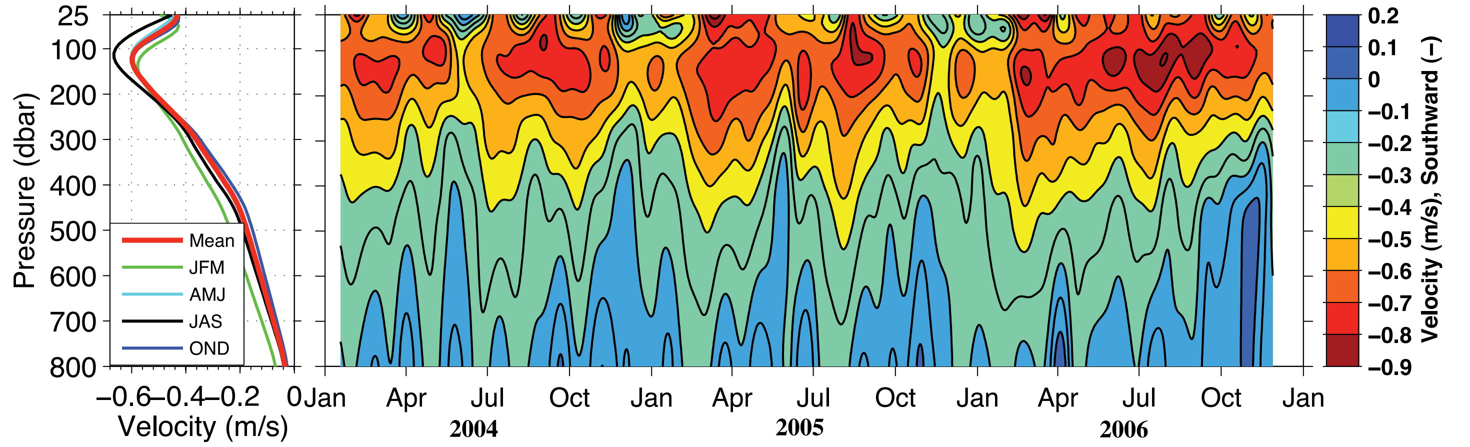
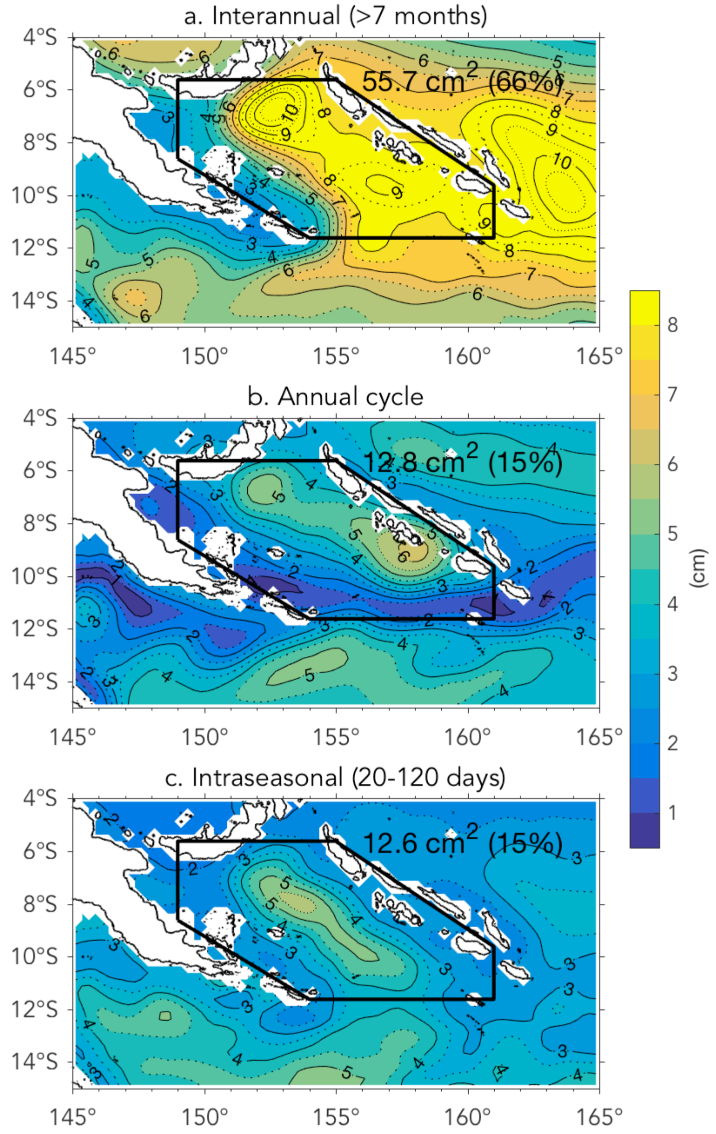


Figure 2. (left) The seasonal profiles and (right) along-channel velocity section. The velocities represent an average of MAK-west and MAK-east values. The vertical coordinates are given in decibar (dbar), which is approximately a meter (m).

Standard deviation of Sea Surface Height (2007-2016)



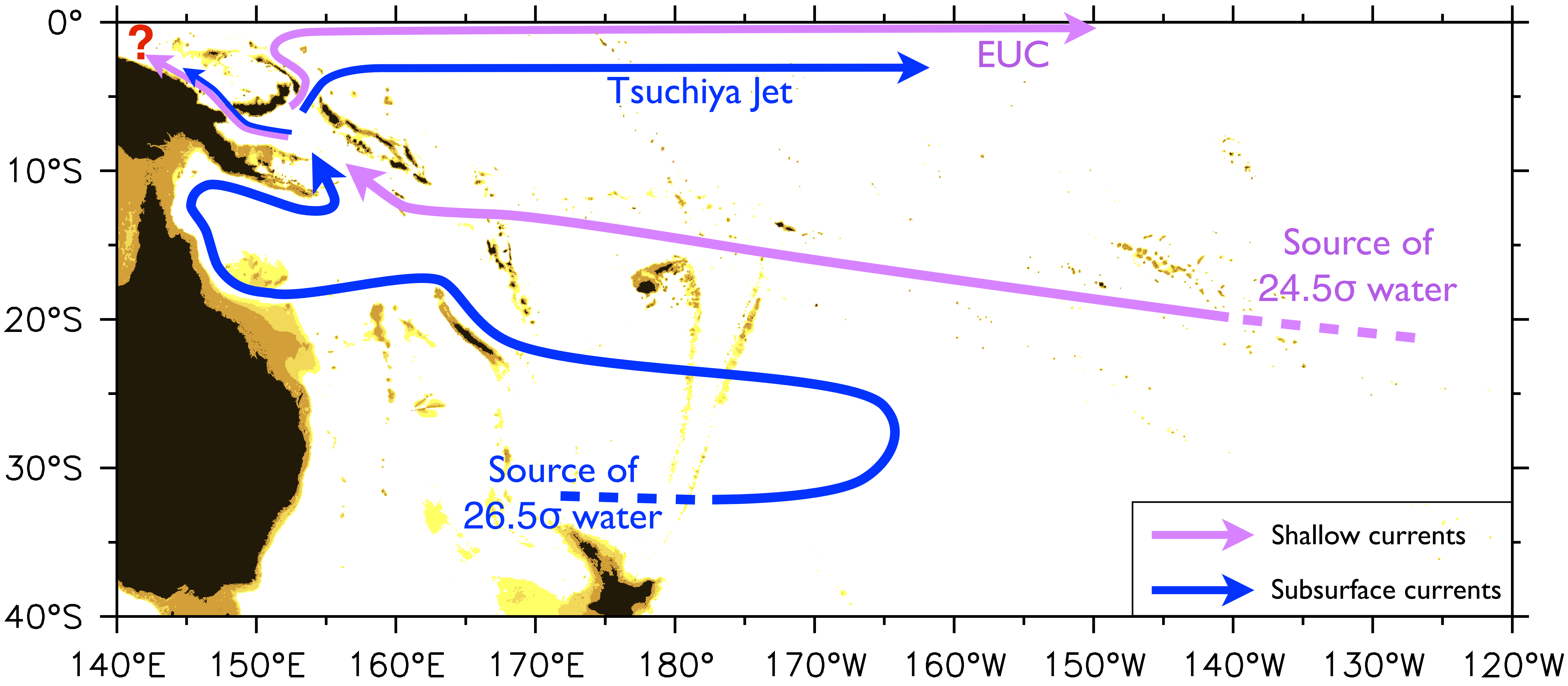
Data: Ssalto/Duacs DT maps of SLA height (MSLA-H)

Tsuchiya (et al ...) described two sources of high-salinity water flowing through the Solomon Sea feeding the equator

The high-evaporation region of the eastern subtropics supplies a shallow inflow at the density of the EUC.

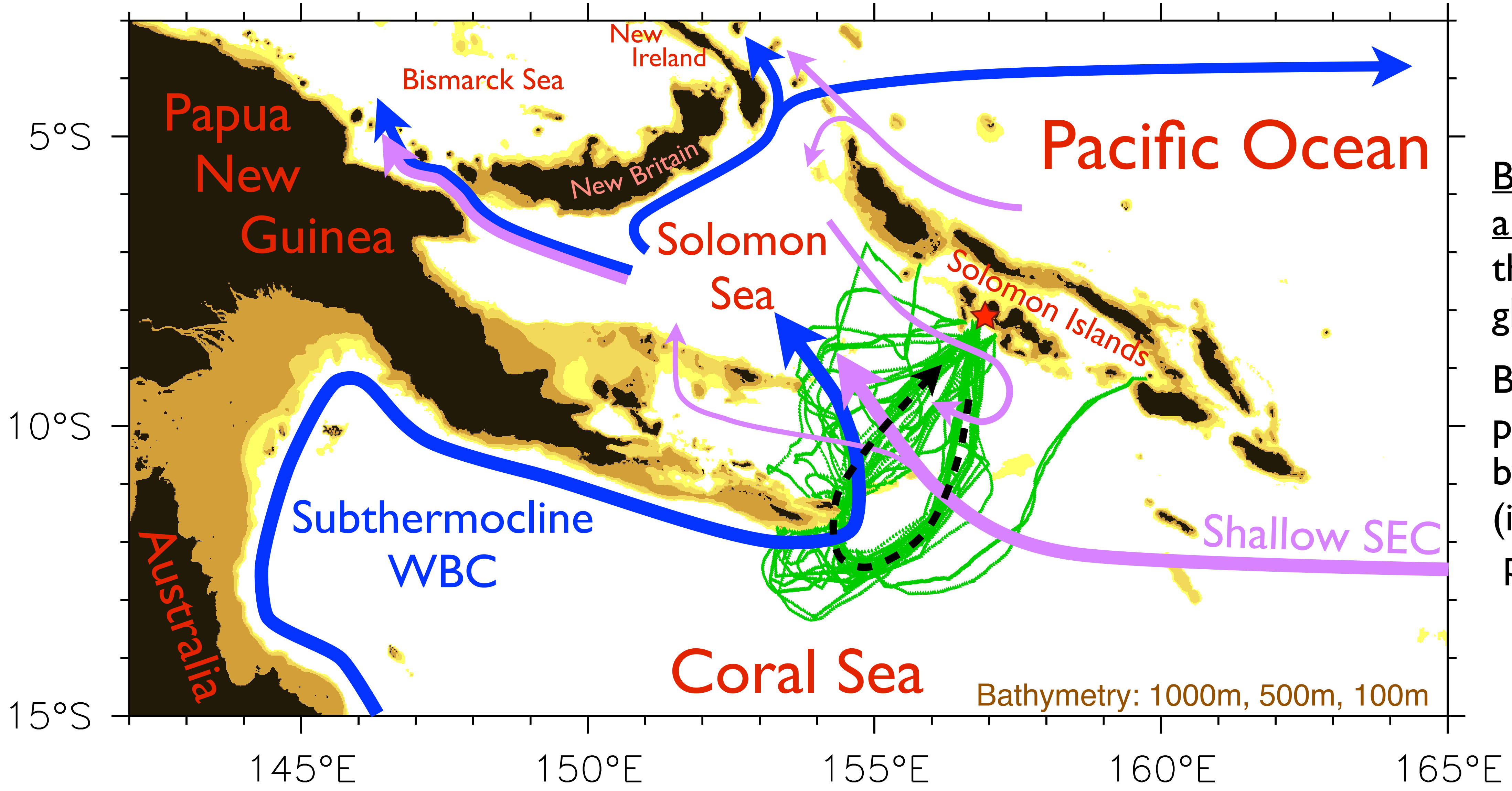
Winter subduction NE of New Zealand follows a long path around the islands and arrives at the Solomon Sea as a narrow, subsurface western boundary current.

Property variations at the subduction regions are transmitted to the equator via the Solomon Sea



13 years of glider crossings of the Solomon Sea

Billy Kessler, Hristina Hristova, Russ Davis and Jeff Sherman



Black dashed arrow shows the intended glider route.

But they are pushed north by currents, (inconsistent path)

Two sources of inflow:

Shallow currents

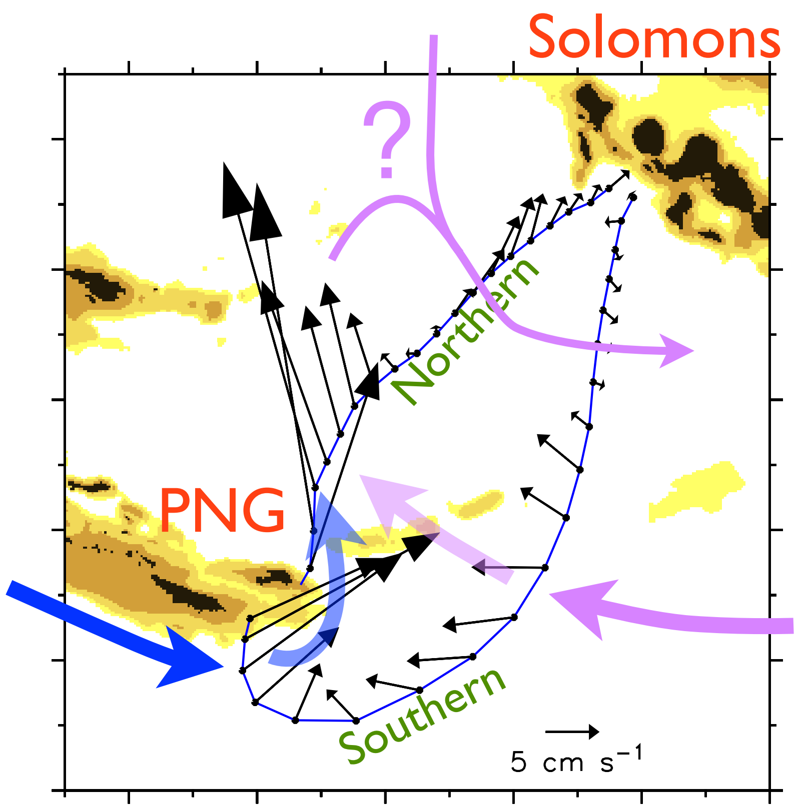
Subsurface currents

Green dots show glider dives.

136 coast-to-coast sections

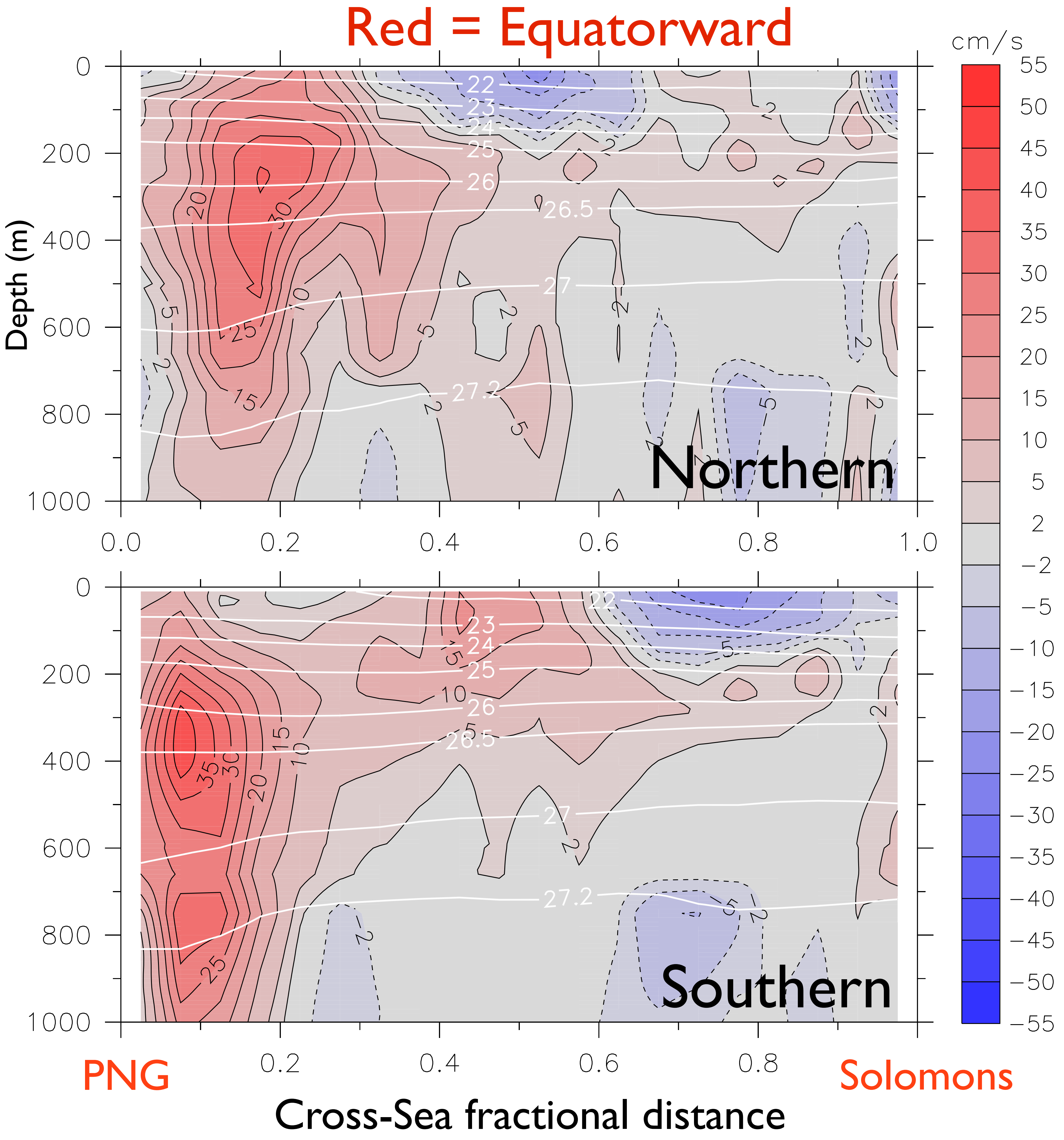
25,000 dives
116,000 km
} About 4.5km/dive

Mean crosstrack current on two tracks separately

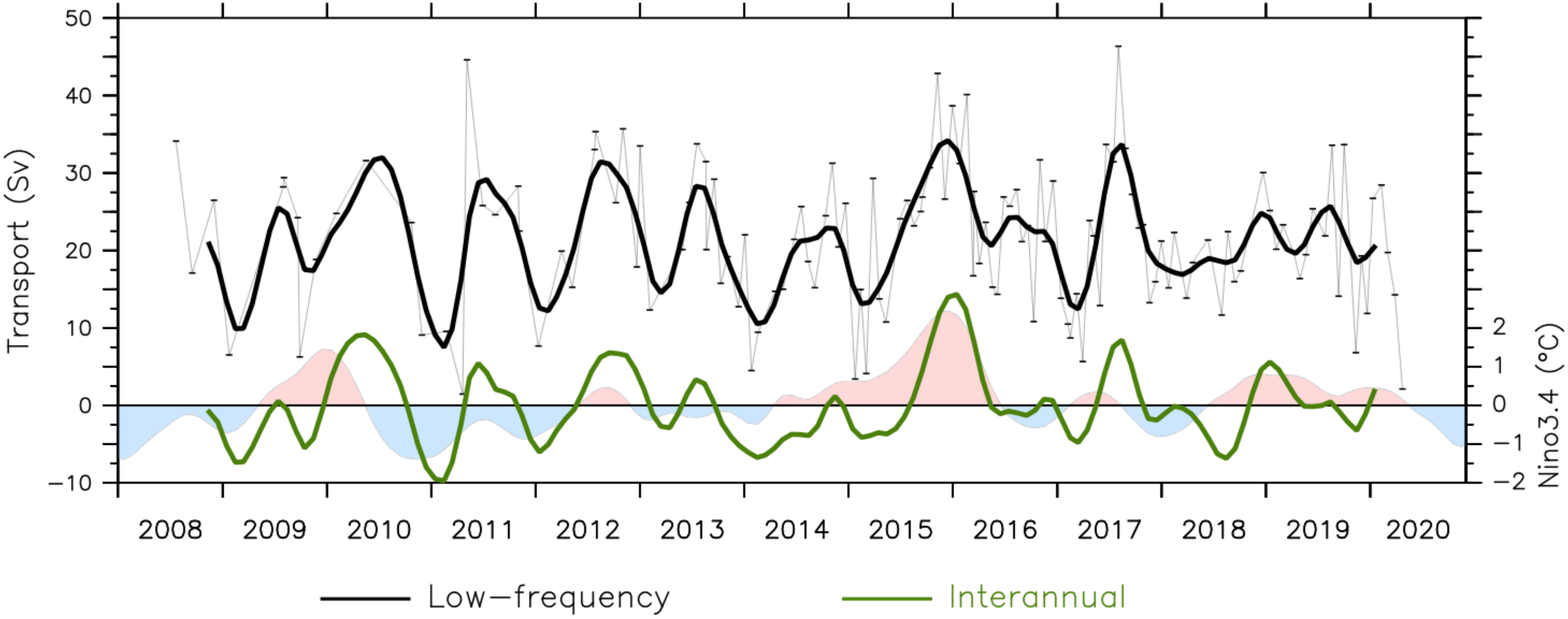


The two inflows join soon after they enter the Solomon Sea, forming a single WBC.

Both are high salinity, though they come from different source regions.


Red = Equatorward

Northward flow through the Solomon Sea



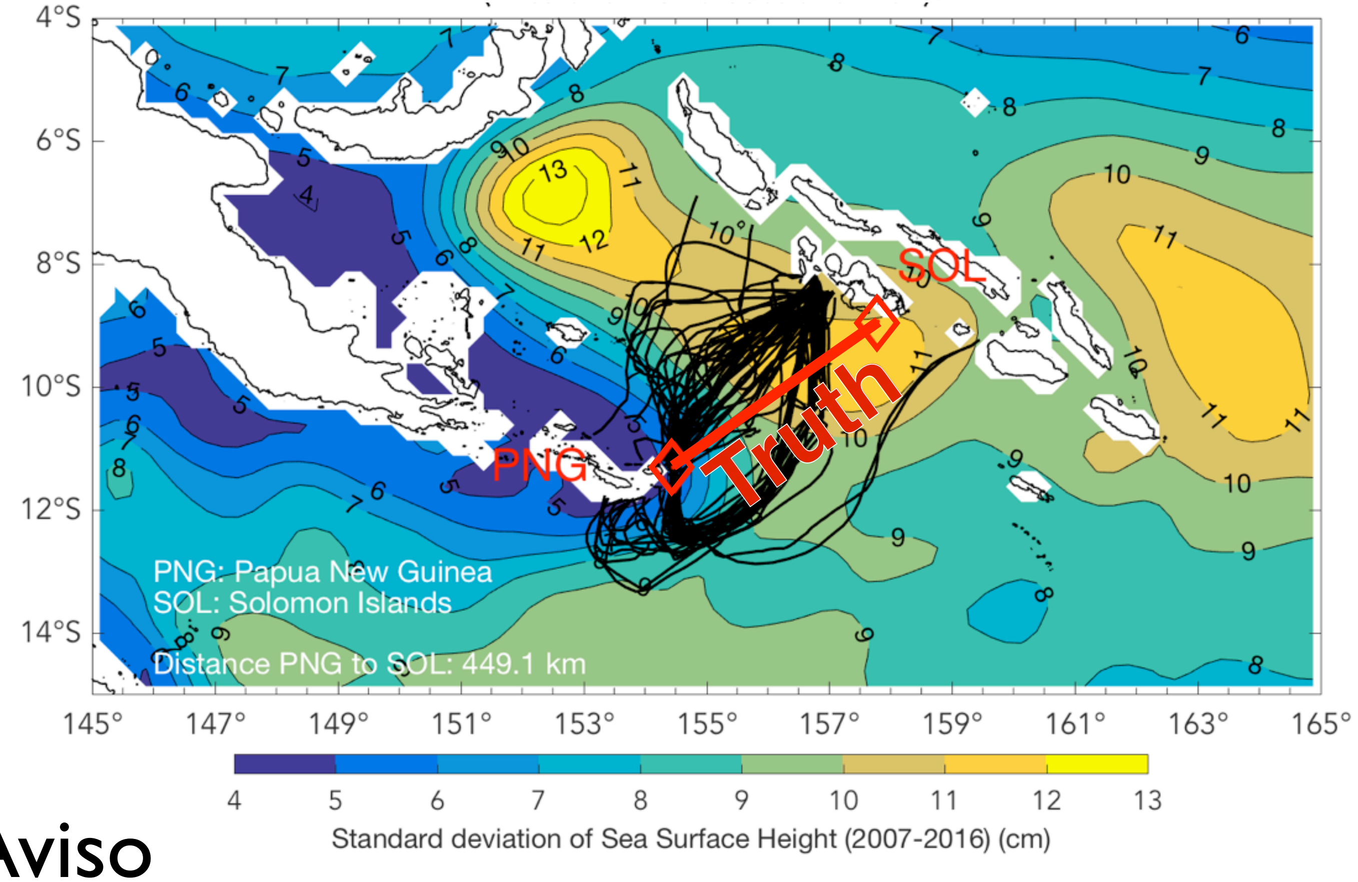
Individual glider sections are noisy (dots and thin line).
It takes more than 1 section/month to describe the low frequency.
(The sparser sections before 2012 weren't adequate).

Interannual anomalies are related to ENSO with a slight lag,
but the lag is not consistent among events. (r = 0.71, lag 2.5 months)

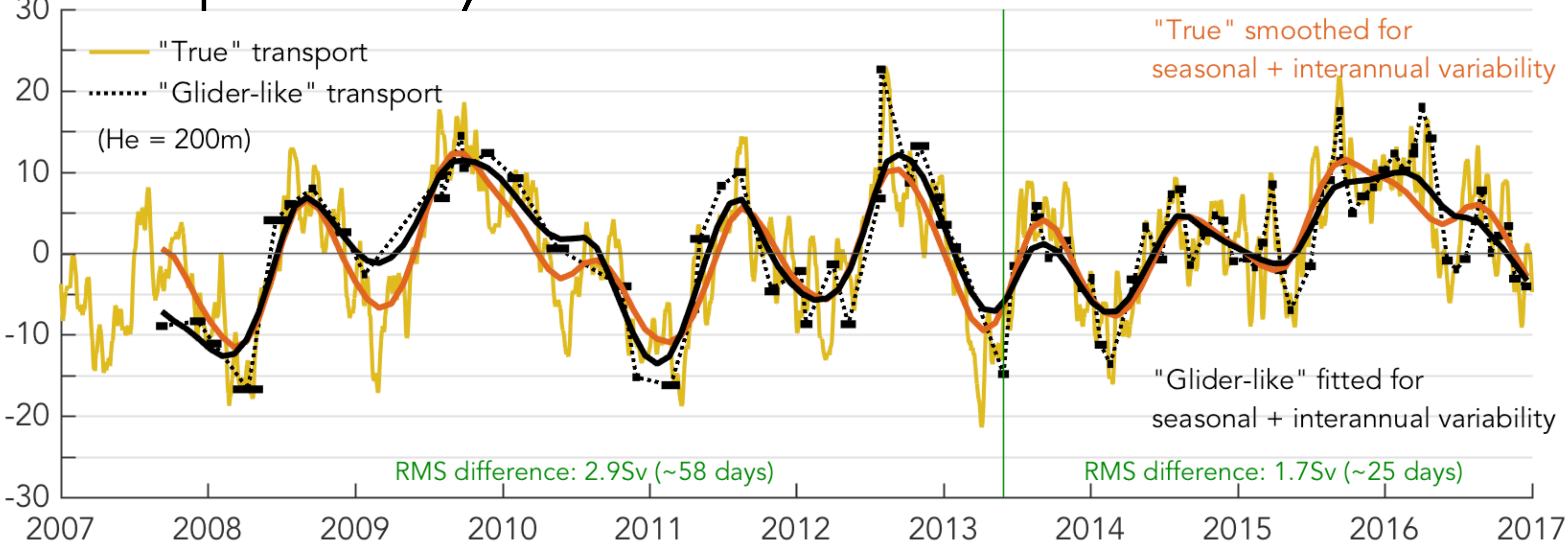
Quantifying sampling errors using Aviso (SSH)

Method:

- Sample Aviso at glider times/locations
- Find u_g each dive, integrate transport
  (${H_e} = 200$m: best fit to glider)
- Compare Aviso "truth" =
  simple cross-Sea difference (red)

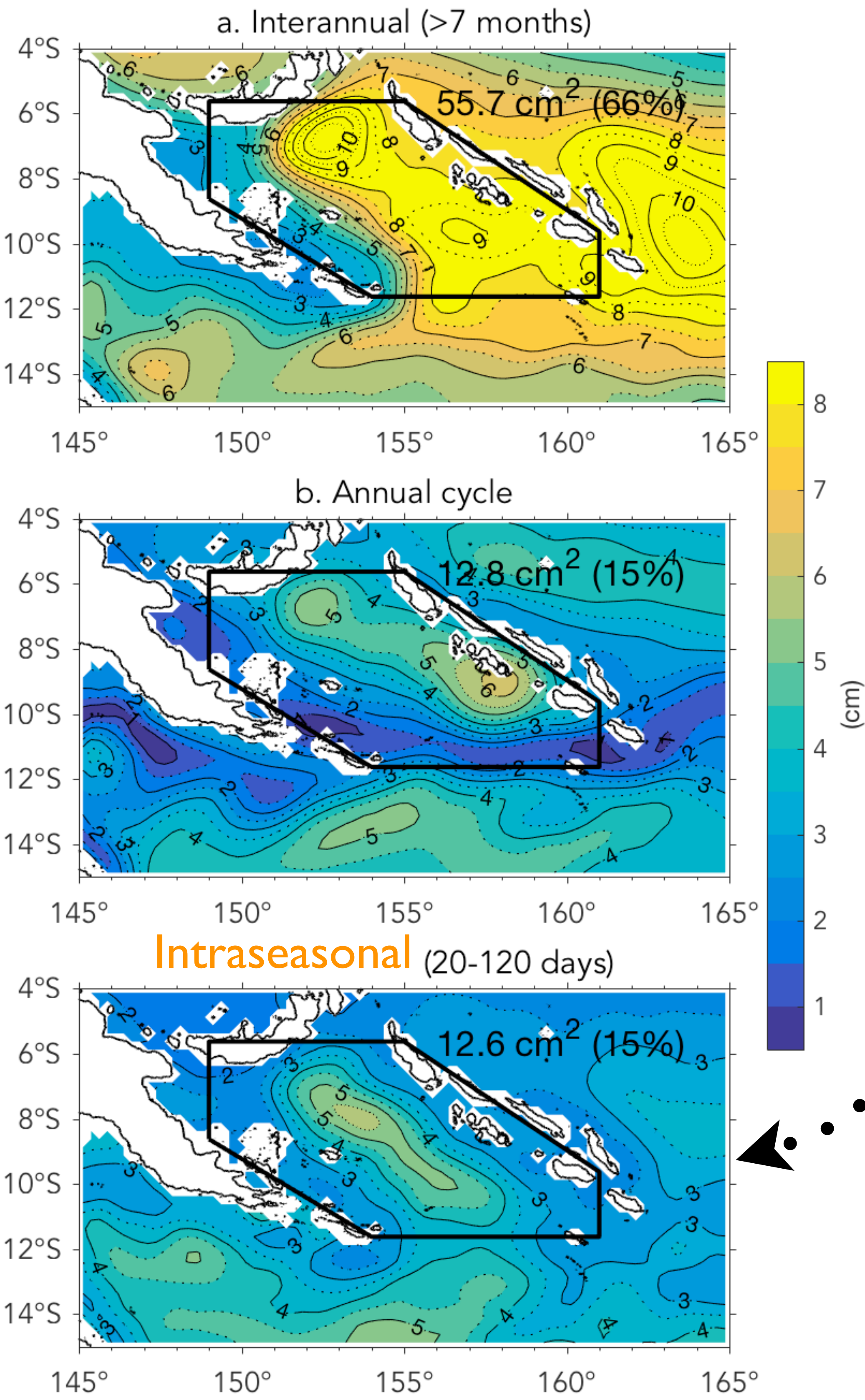


Transport anomaly estimate from Aviso

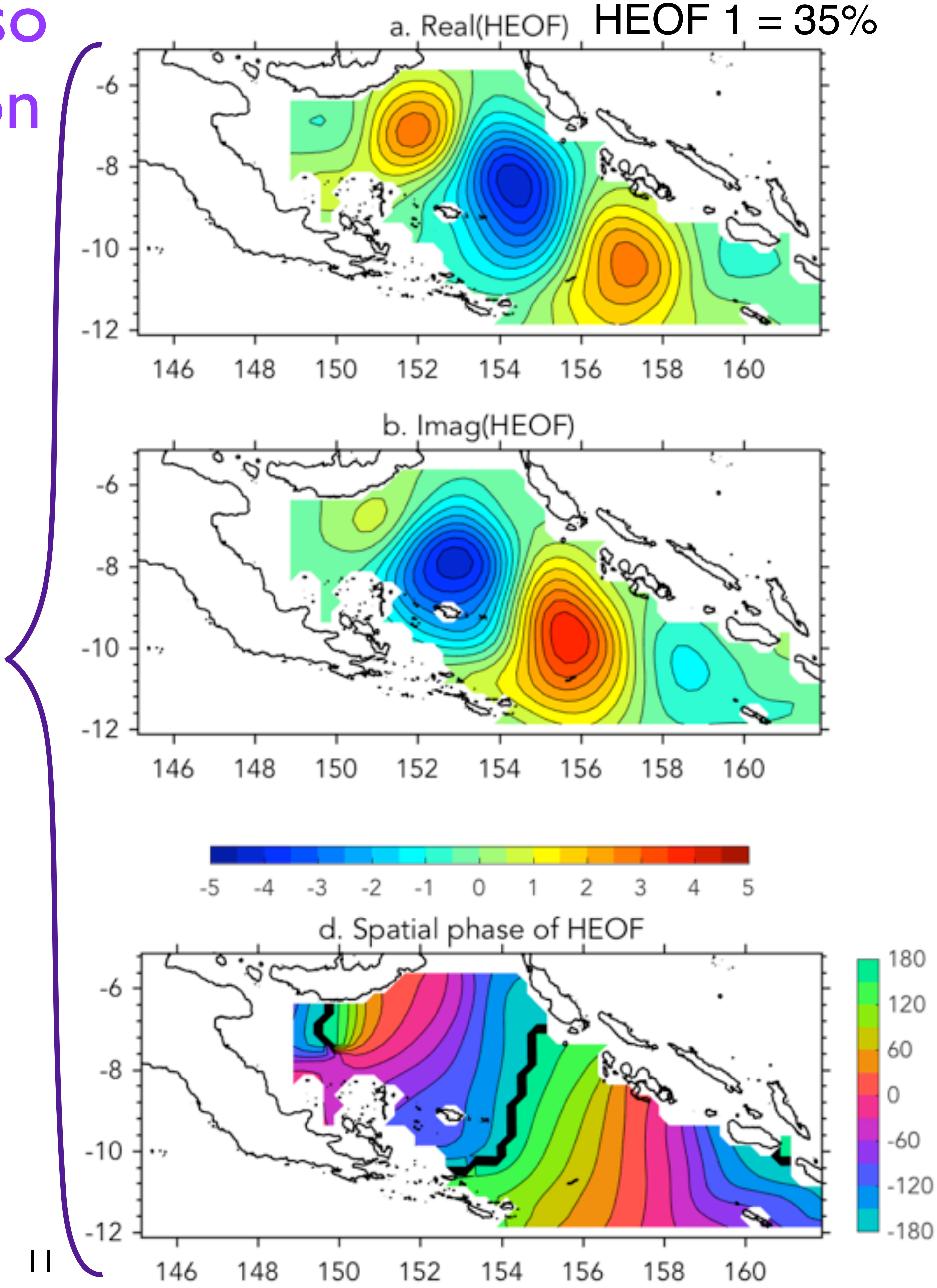


HEOFs of intraseasonal Aviso improve glider interpretation

Standard deviation of Sea Surface Height (2007-2016)

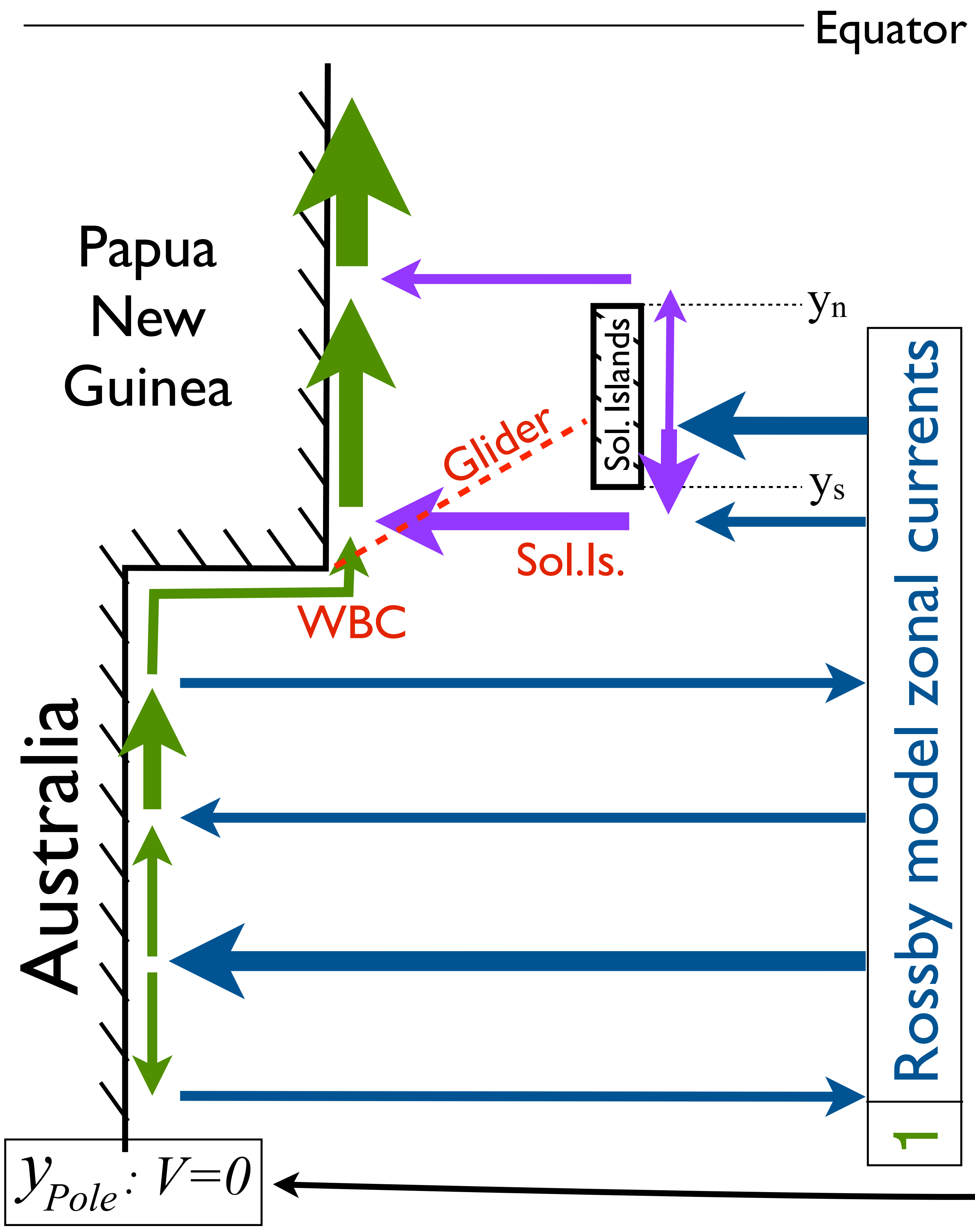


HEOF 1 = 35%



The simplest linear wind-driven model of Solomon Sea inflow

The glider crosses two distinct inputs to the western boundary: **tropical** and **subtropical**



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Against an island:
"This vorticity constraint says that,
in the absence of circumisland wind,
an inflow to the boundary current at latitude y will split,
with fraction $(y - y_s) / (y_n - y_s)$ going north
and the remainder going south."

Firing et al. (1999)

2

Against a continent,
WESTERN BOUNDARY TRANSPORT
is the equatorward integral of
INCOMING ZONAL TRANSPORT.
(Conserve mass integrating equatorward)

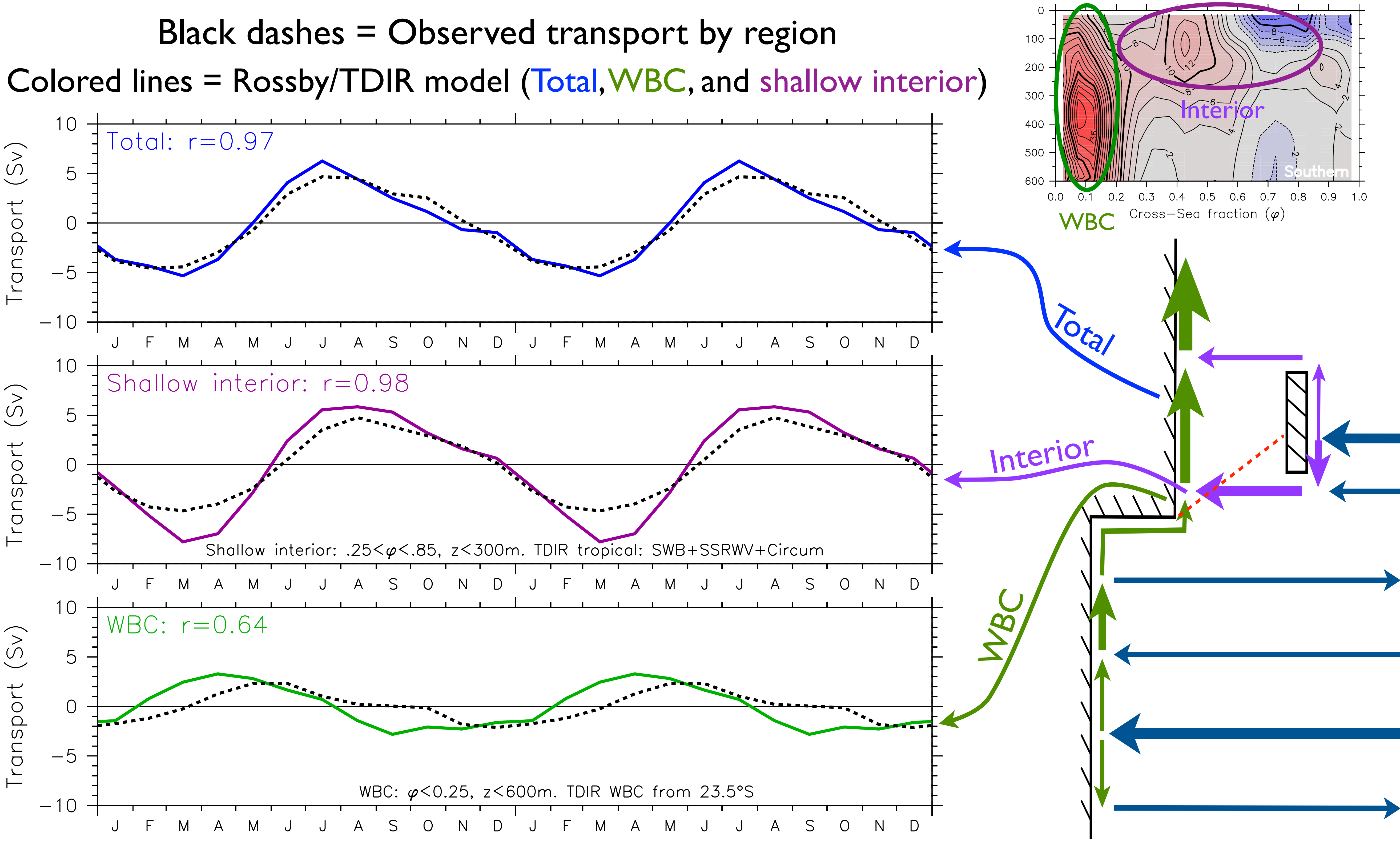
$$\int_{WB\ layer} V(y)dx = -\int_{y_{Pole}}^{y} U_{RW}\, dy$$

Godfrey (1975)

Observed and modeled transport: Annual cycle anomalies

Black dashes = Observed transport by region

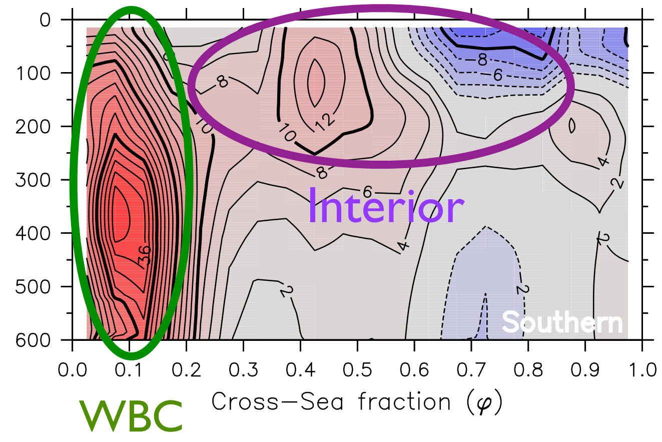
Colored lines = Rossby/TDIR model (Total, WBC, and shallow interior)

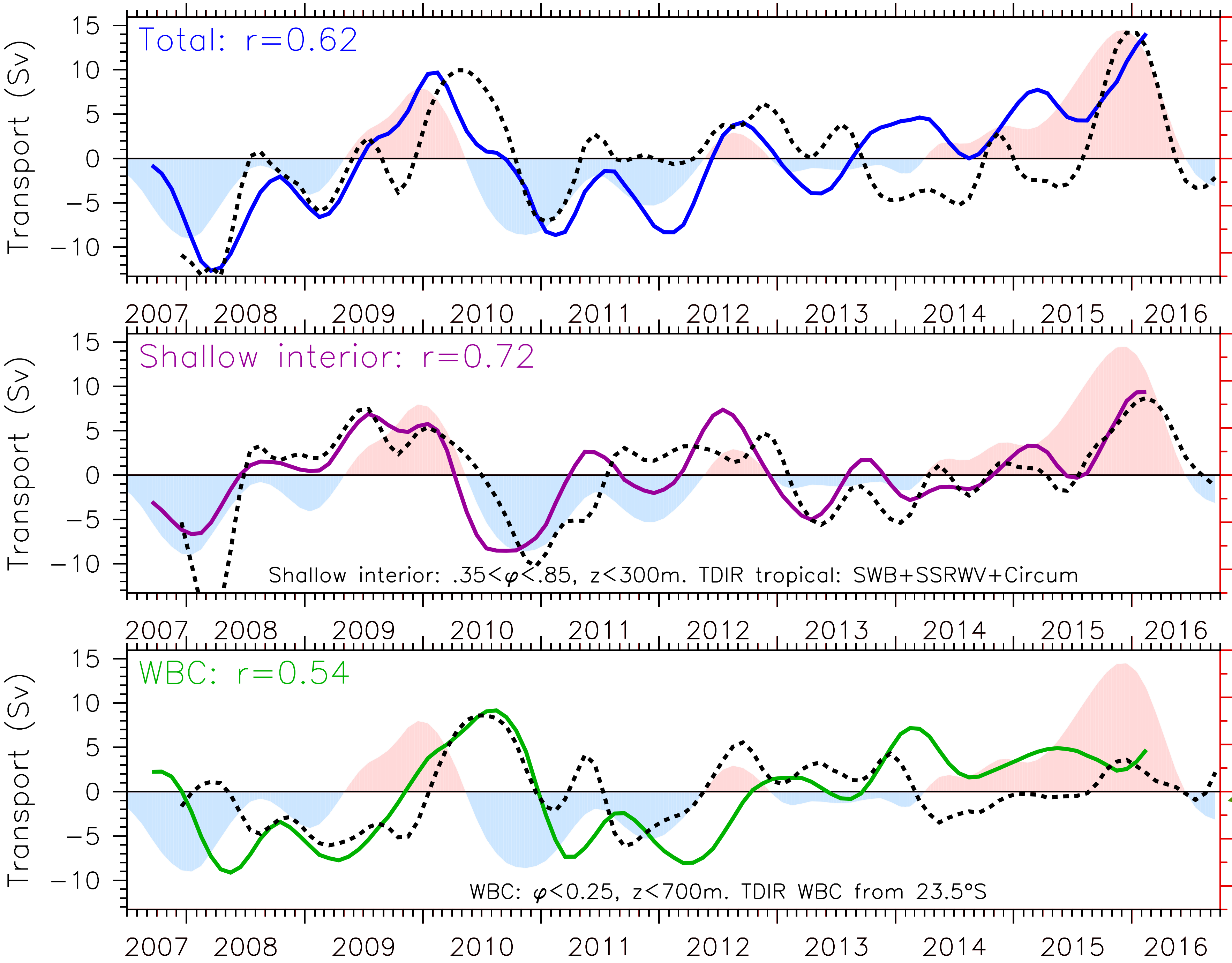


Observed and modeled transport: Interannual anomalies

Black dashes = Observed transport by region

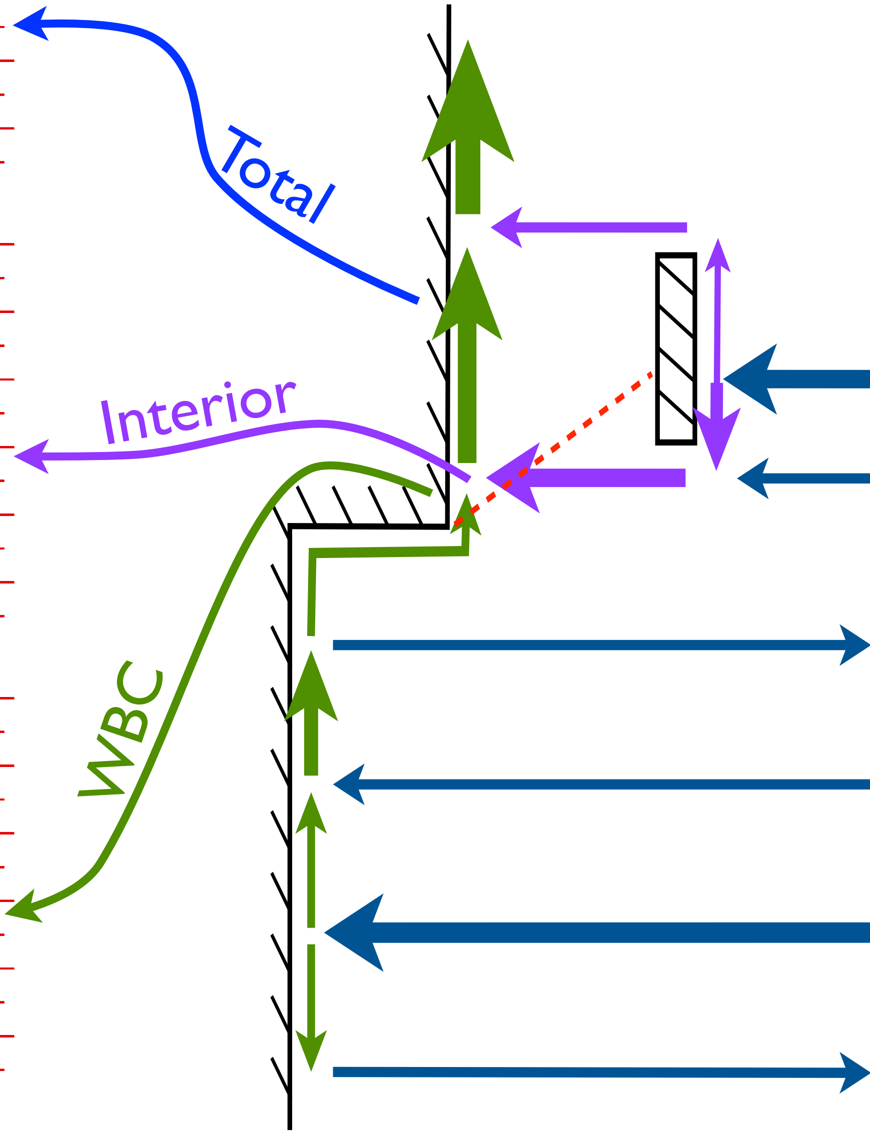
Colored lines = Rossby/TDIR model (Total, WBC, and shallow interior)





Shallow interior: .35<φ<.85, z<300m. TDIR tropical: SWB+SSRWV+Circum

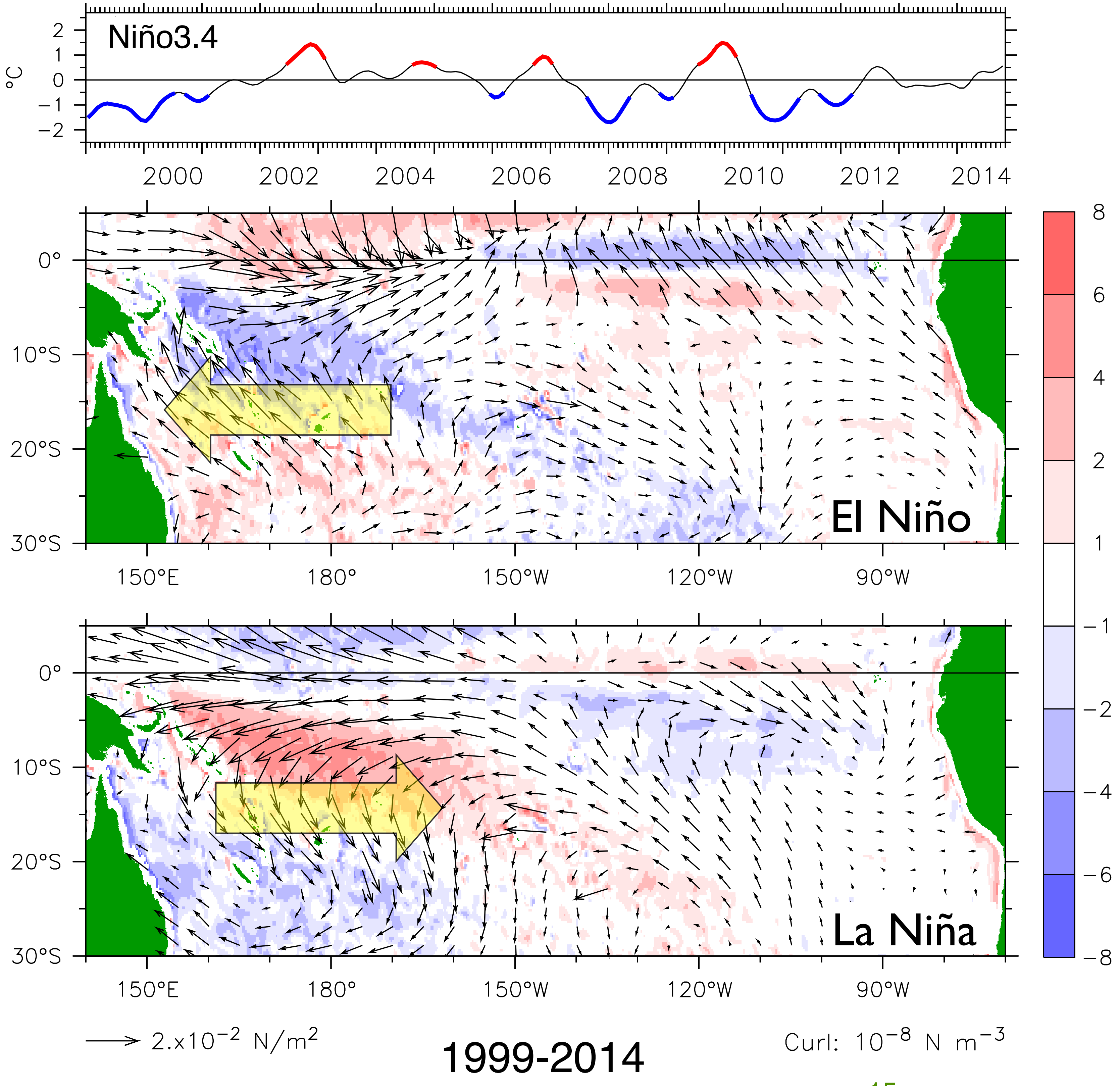
WBC: φ<0.25, z<700m. TDIR WBC from 23.5°S



Like everything else about ENSO, different events are quite different in the Solomon Sea!

Where are the ENSO anomalies affecting the Solomon Sea?

Winds and curl anomalies
averaged over El Niño and La Niña periods



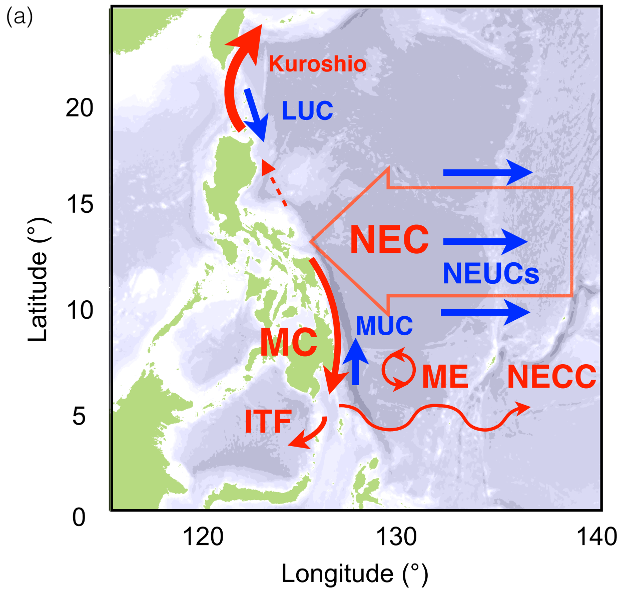
In addition to the familiar anomalies on the equator, ENSO gives opposite-sign wind/curl anomalies in the southern subtropics, thus a gradient of curl near 15°S.

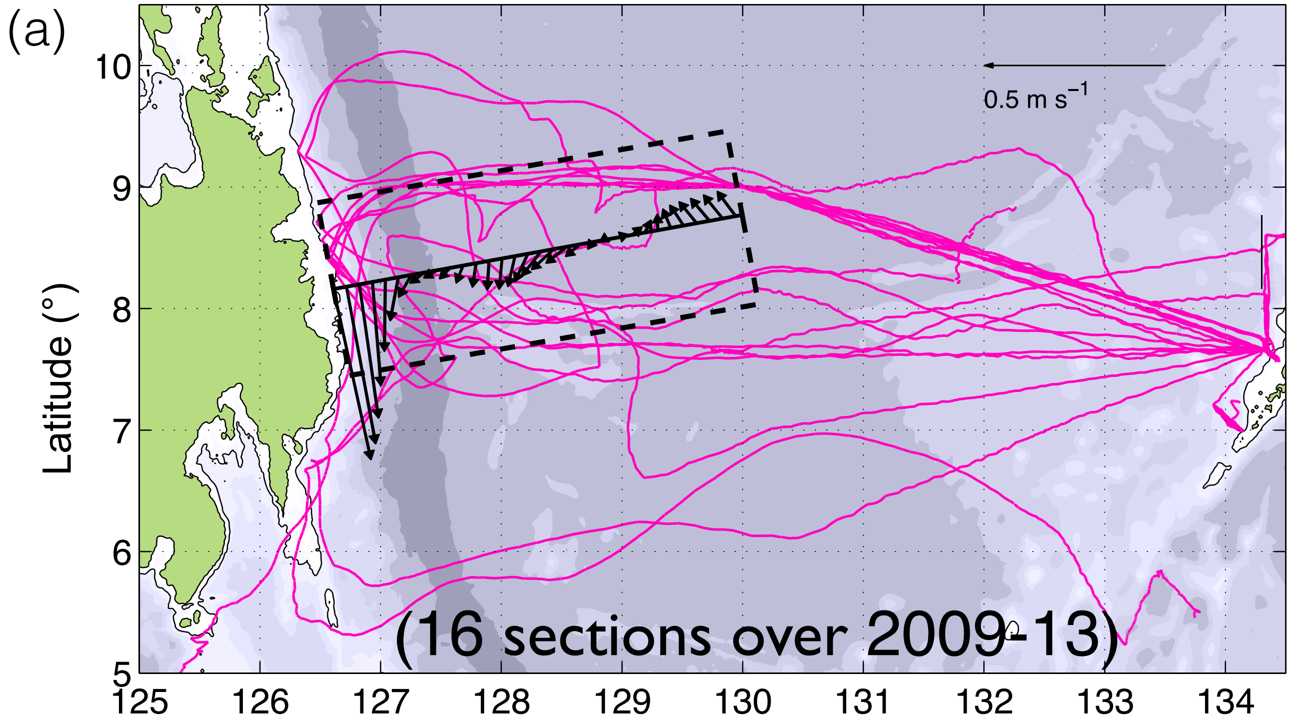
Sverdrupian currents occur with $d(Curl(\tau))/dy$.

Large ENSO flow anomalies of the Solomon Sea WBC are forced in the western subtropics.

4 years of glider crossings of the Mindanao Current

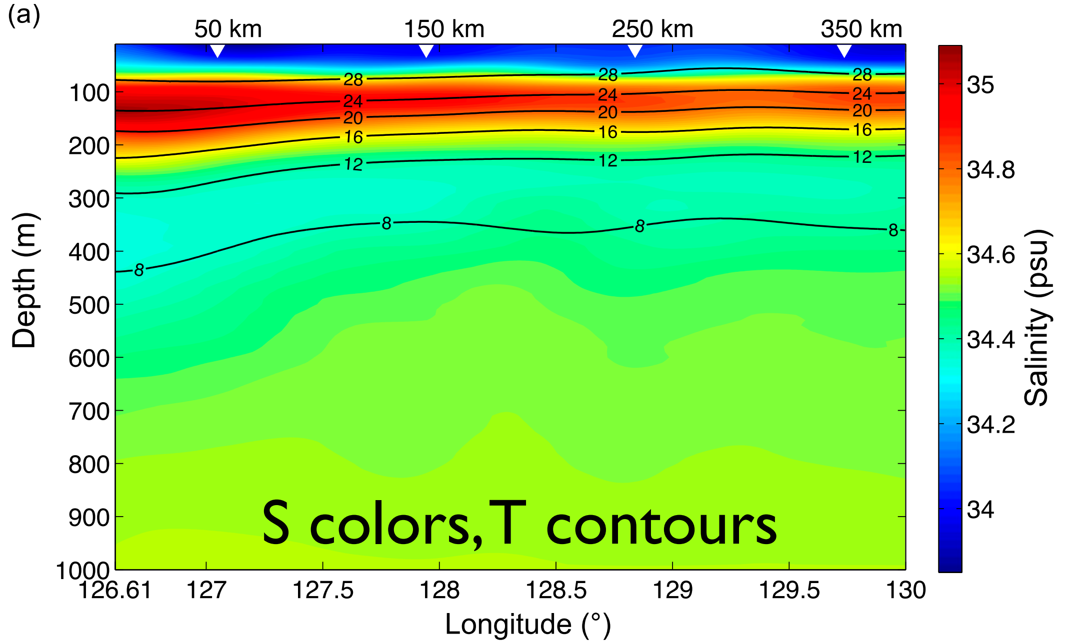
Martha Schonau and Dan Rudnick (JPO 2017)

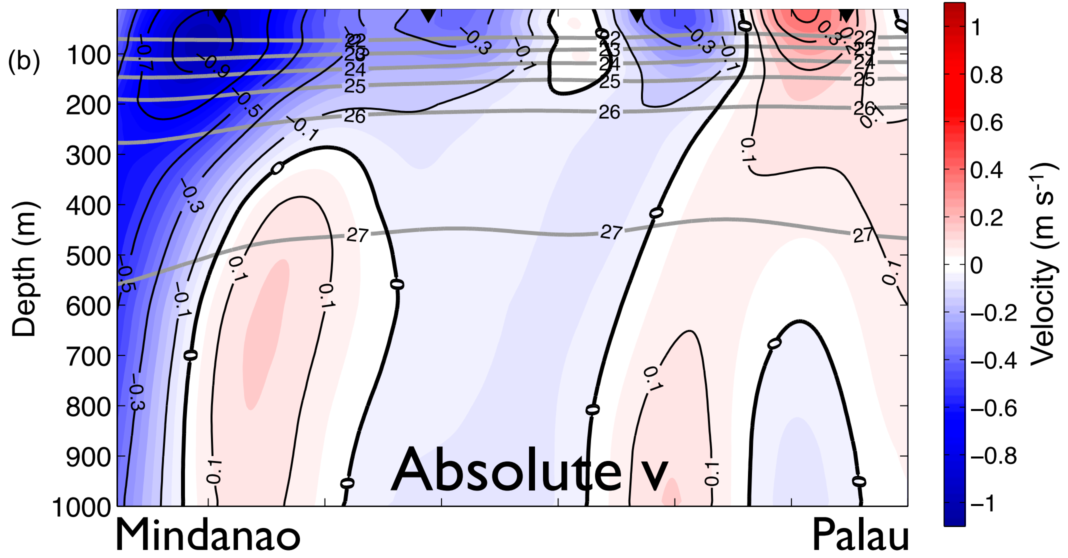


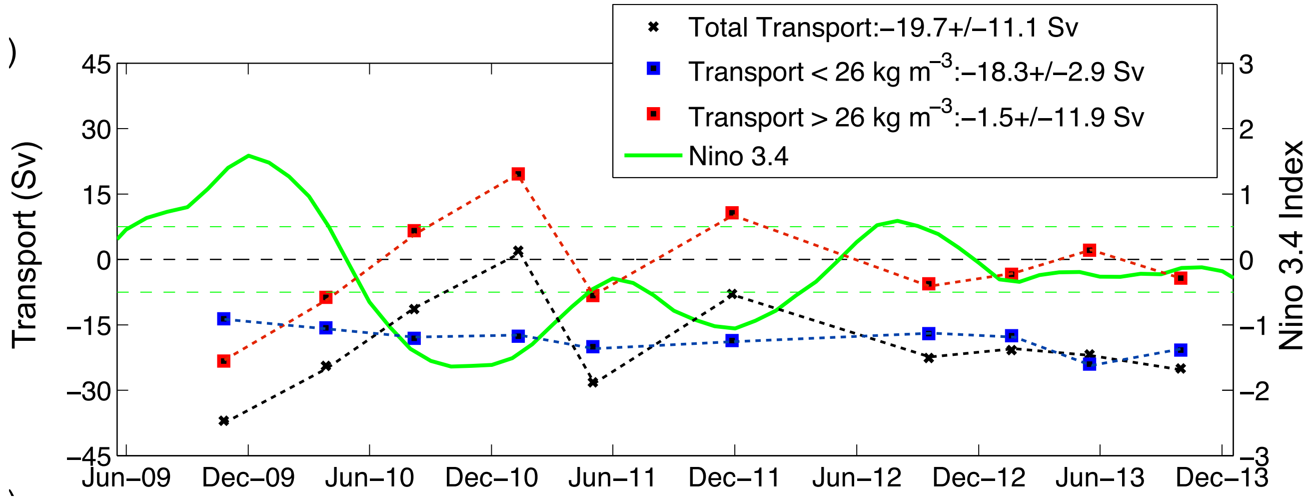


Glider pushed south by MC: Inconsistent path

Mean section: Mindanao-Palau



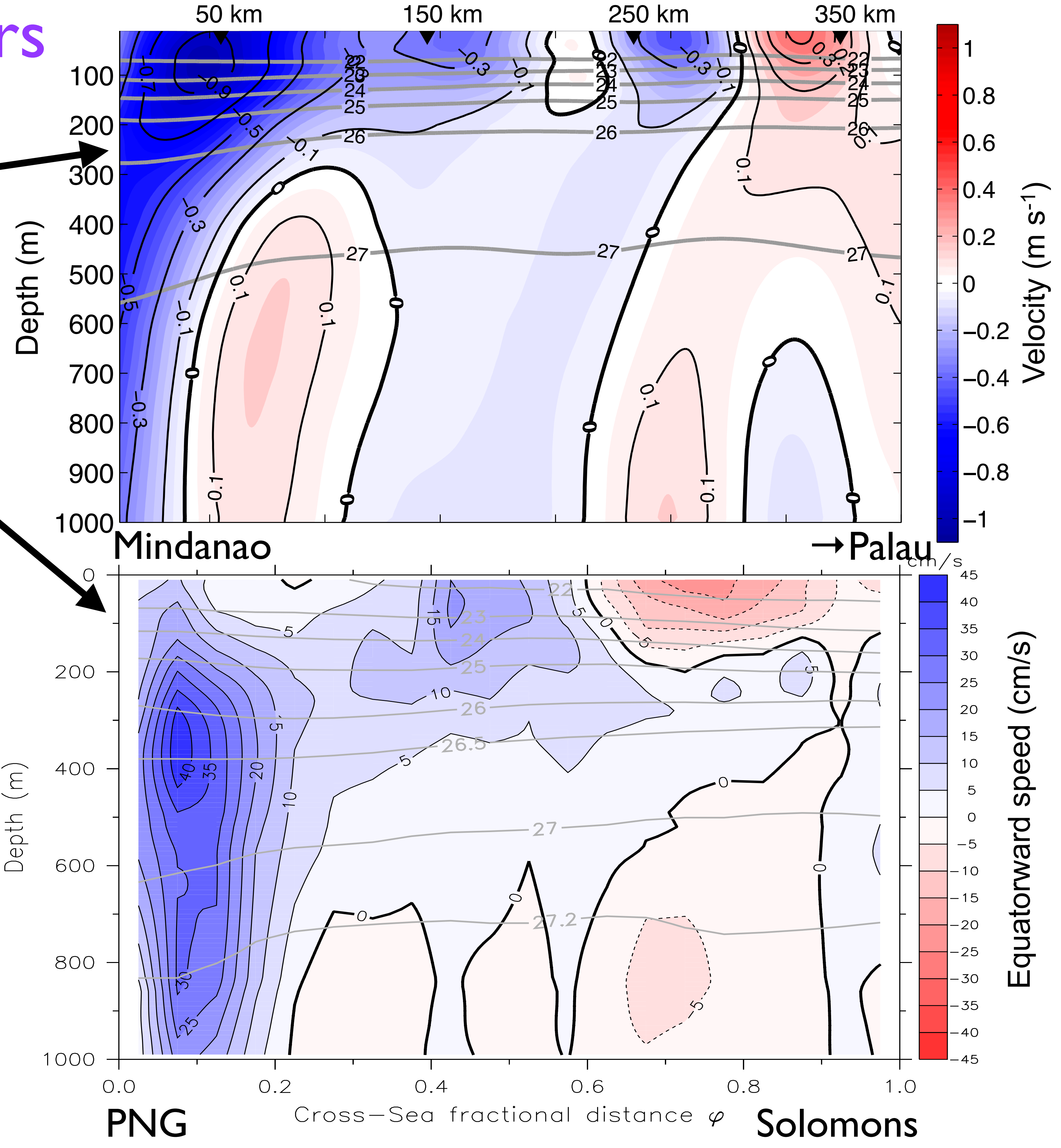




Transport time series (~4 sections/year) is not enough to define the annual cycle (if it exists), and only to weakly define interannual variability.
→ In the Solomon Sea, we need monthly transects.

Mean Mindanao Current and NGCU from gliders

Blue = equatorward



4 years of sections across the MC (top)

10 years of sections across the NGCU (bottom)

Same depth range.
Similar offshore ranges.

Same mean transport (20Sv).

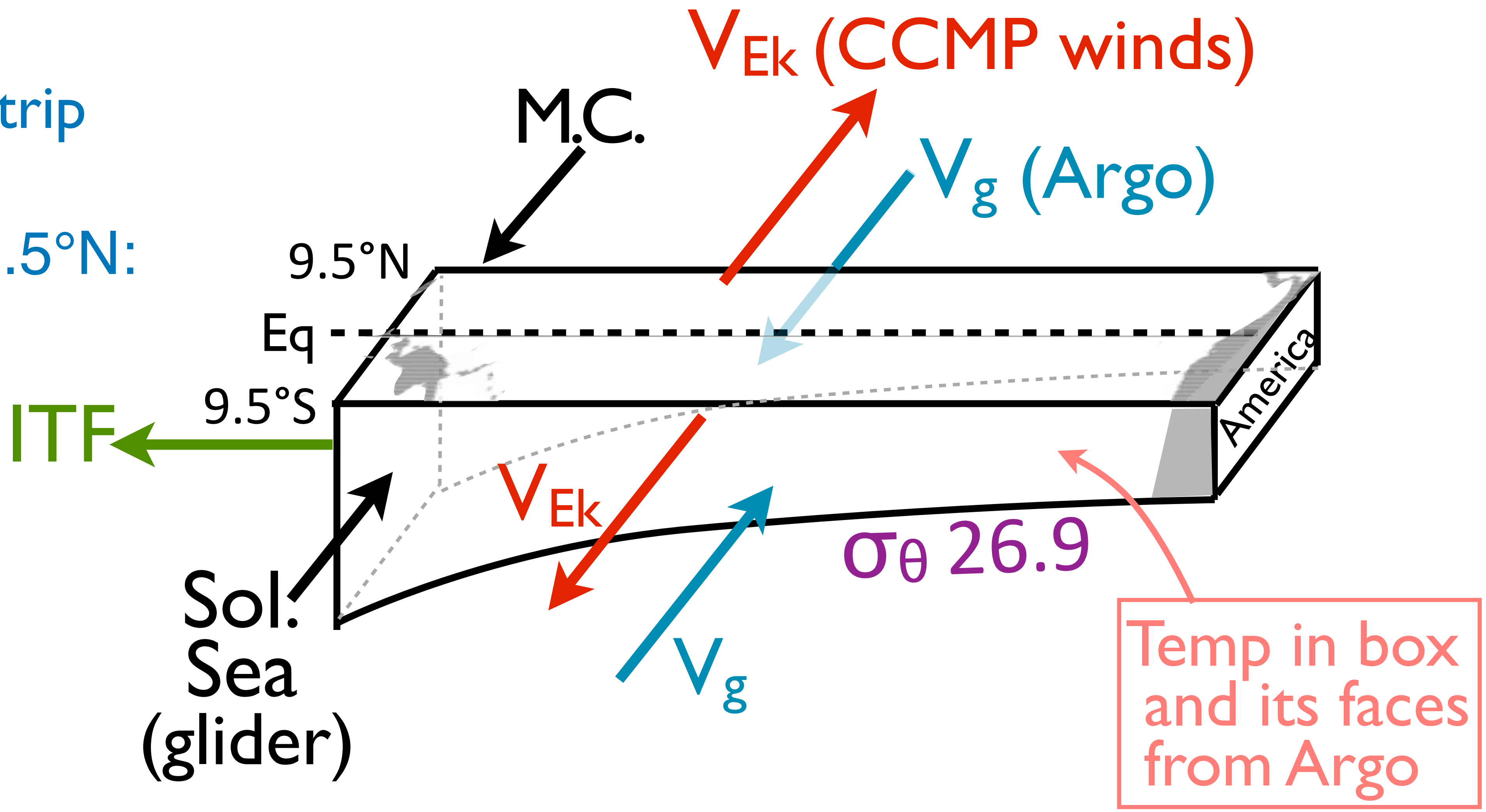
MC is faster and shallower:
(maximum above 100m)
MC has subsurface recirc.

NGCU is thicker (max near 400m, sigma 26.5, almost zero at the surface)

The calculation we would like to do:

Heat (and property?) budget of the equatorial strip

Consider
a tropical Pacific strip
across the basin
between 9.5°S - 9.5°N:



What is possible with present data?

Two problems: Non-constant volume, unknown "reference temperature"

But Tony Lee (JPL), had a good idea: An inflow changes the temperature of the box only if it has a different temperature than the box average.

Logic of the Lee et al calculation

Heating/cooling tendency due to the Solomon Sea partial interface

$$= \iint_{Sol.Sea} v(T - T_{ref})\, dx\, dz / V_D$$

Solomon Sea measurements

Basin-volume measurements

Where V_D is the volume of the equatorial strip.

If T_{ref} is the (time-varying) spatial-average temperature of V_D, this expression is meaningful <u>even if mass is unbalanced</u>:

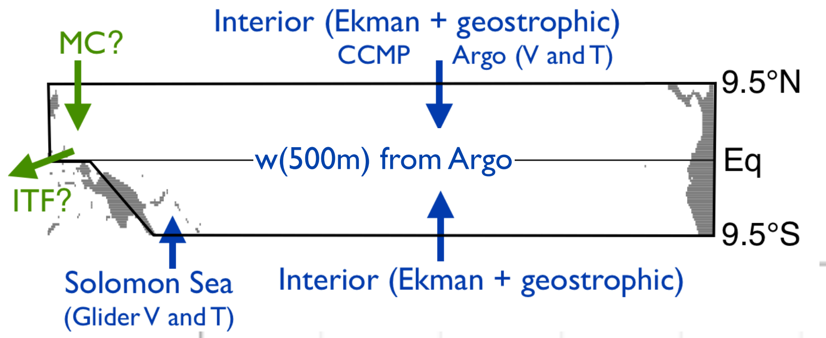
Heat advection across a partial interface can change the domain's temperature IF (and only IF) the interface temperature differs from the domain's average.

$\Longrightarrow$ Choose T_{ref} as $T_m(t)$, the domain-average T within V_D.

This avoids the problem of ambiguous referencing of T.

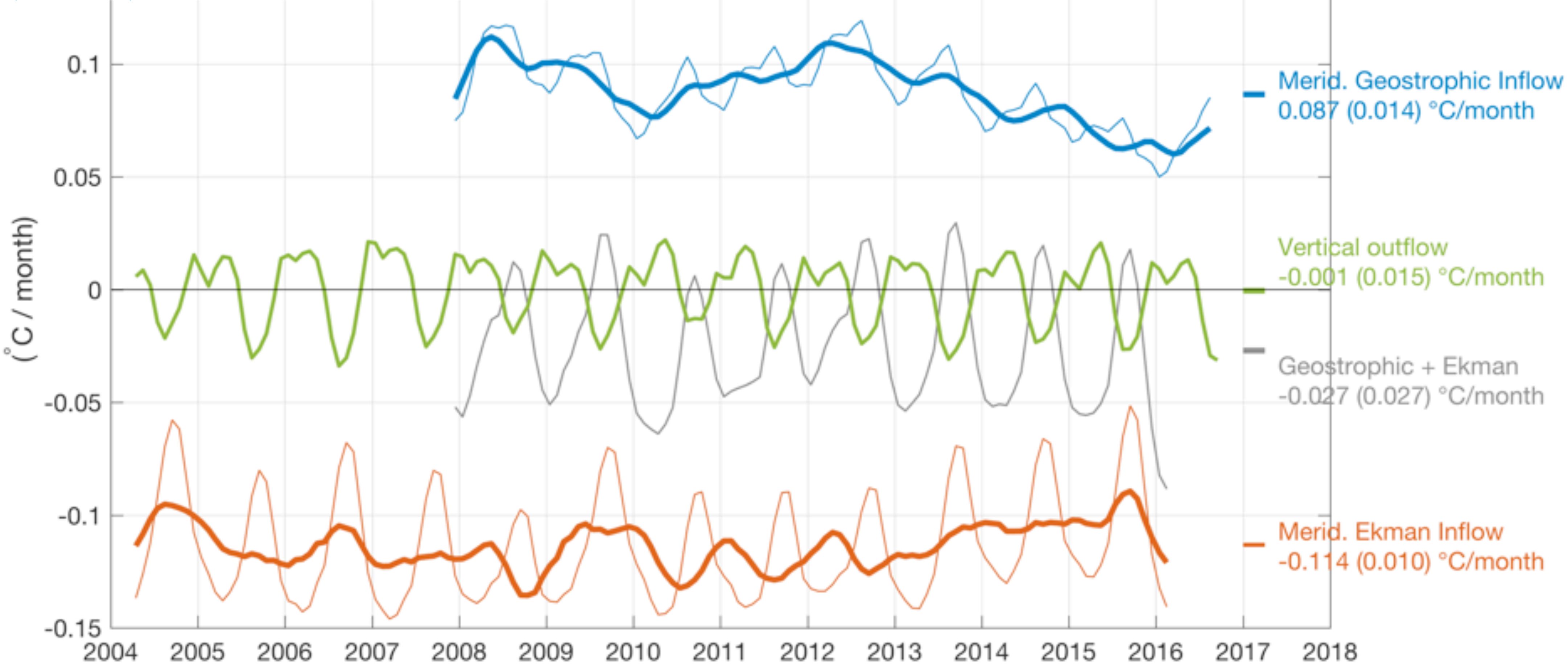
(Lee, Fukumori and Tang, JPO 2004)

Heat transport in the box 0-500m

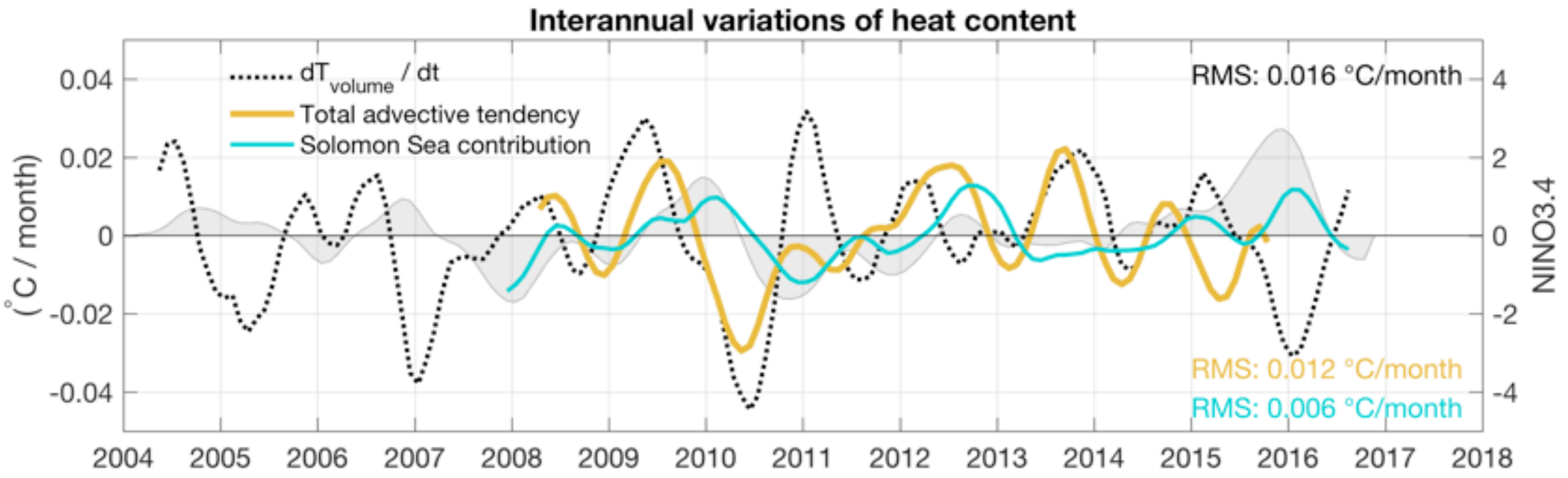


$$\iint_{Face} V(T_{Face}-T_m)\,dz\,dx$$

Sign convention:
Positive =
warmer-than-mean
water into the box.



Ekman+geostrophic are net outward, Vertical near zero.



Clear relation between total advective transport and dT/dt in the box.

The Solomon Sea face of the box carries about half the magnitude of the total transport.
It appears to more closely correlate with Nino3.4, and to lag the total signal.

The Solomon Sea as a testbed for LLWBC work

- Gliders are appropriate to monitor boundary currents (scales).
- They are relatively inexpensive and sustainable (10 years)
Two-person operation, no ship. 52 deployments, 1 lost glider.
- Slow gliders in a strong eddy field require frequent sampling to resolve annual cycle and interannual signals.
Aviso is useful to evaluate sampling errors.
- Our time series shows that transports in the Solomon Sea make a large contribution to basin-wide transport anomalies.
- Much of the low-frequency transport variation is linear (!).
- It is (almost) possible to estimate the advective contributions to the interannual heat budget of the tropical Pacific strip.
Simultaneous measurement of the Mindanao Current would be a big step forward.