Glider exploration of the SW Pacific: Towards monitoring the meridional circulation

W.S.Kessler, R.E.Davis, J.Sherman and L.Gourdeau

(NOAA/PMEL, Scripps, IRD Nouméa)

The LLWBCs of the Pacific:

- Are a major feature of the climate system, both in the mean and for interannual and decadal variability;
- Are poorly-observed (and are hard to observe because they are narrow and near coasts, and may wander in time);
- Require regular, ongoing monitoring to extract the climate signal.

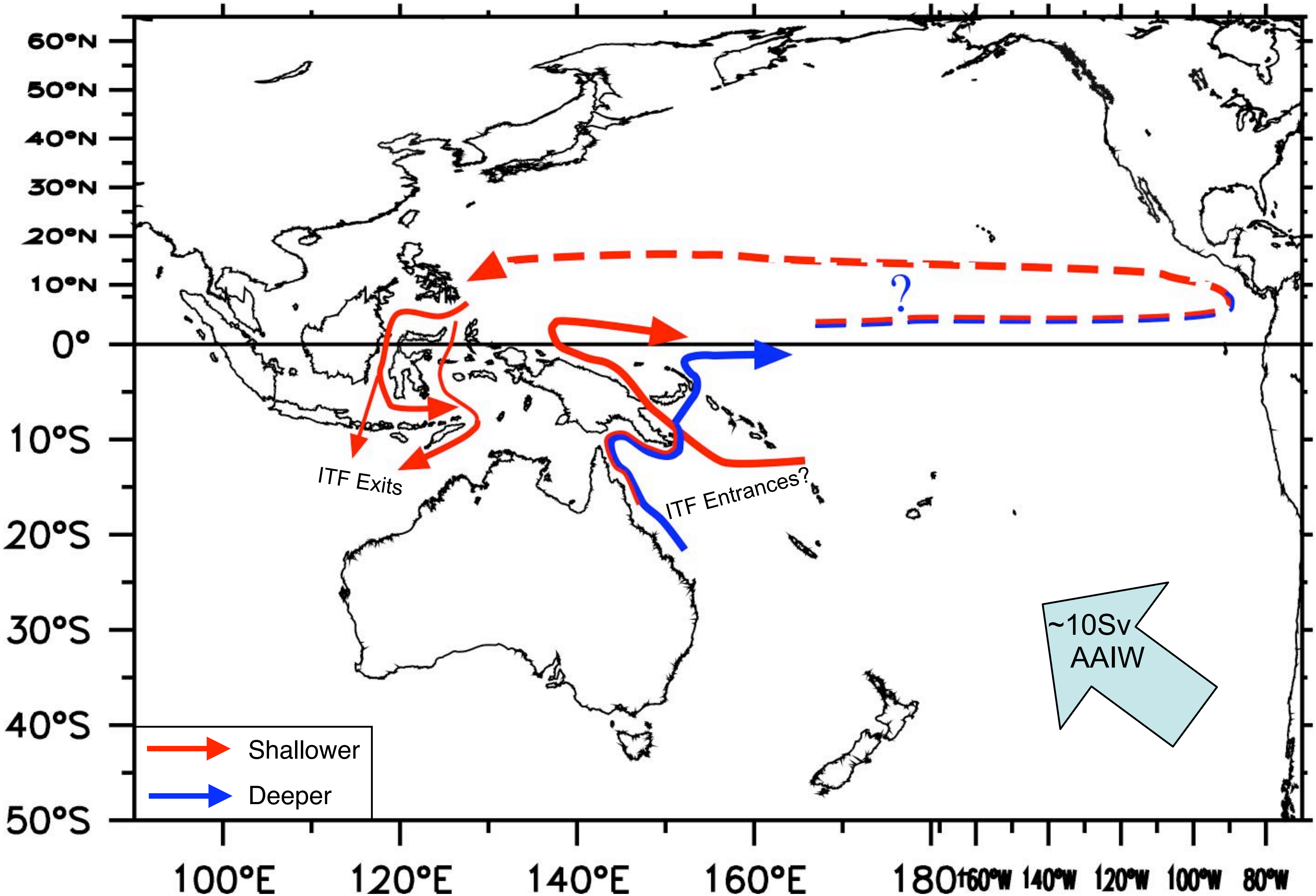
PMEL

SCRIPPS INSTITUTION OF OCEANOGRAPHY UCSD 1903 · CENTENNIAL · 2003

IRD Institut de recherche pour le développement

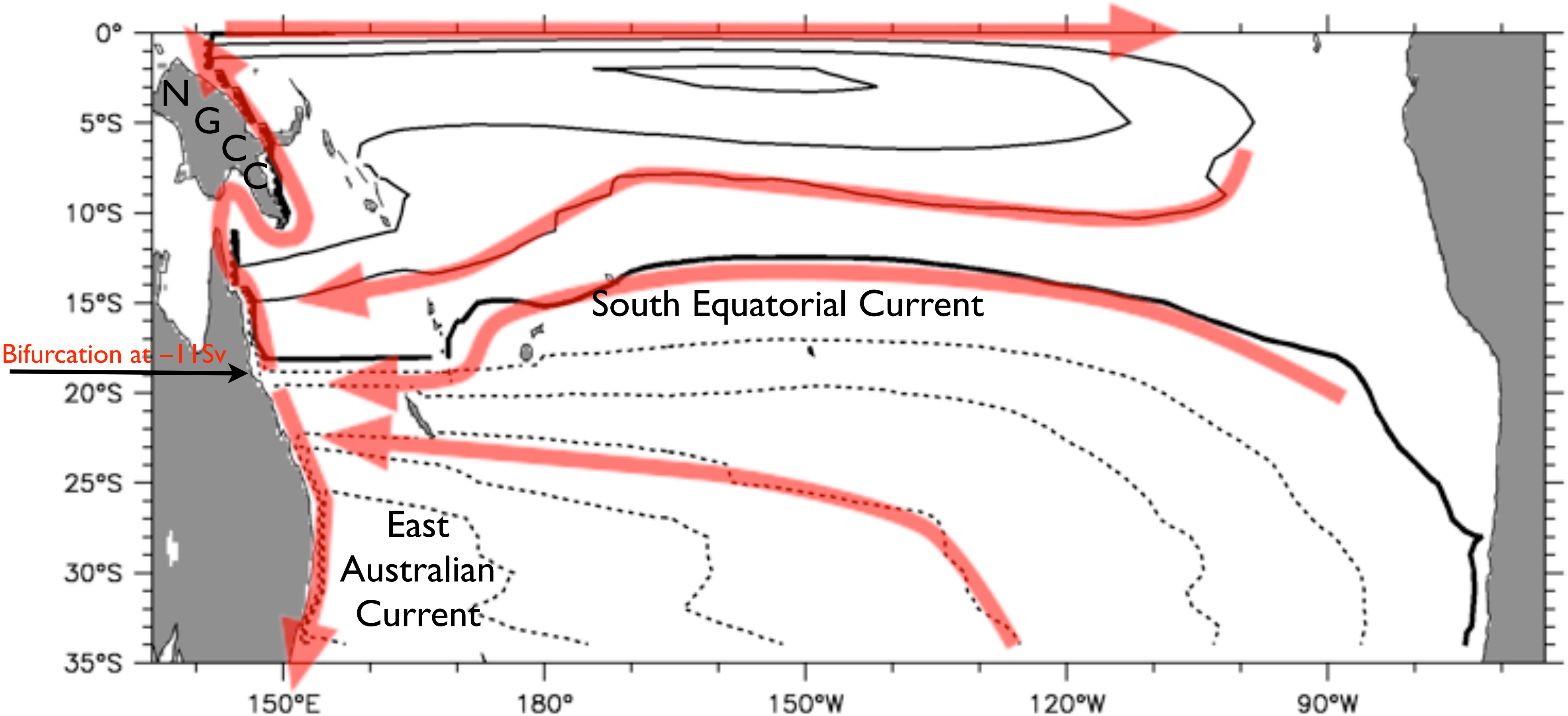
The biggest picture is the circulation around Australia

⇒ Transformation of South Pacific intermediate water to the shallower, warmer water that exits into the Indian Ocean.



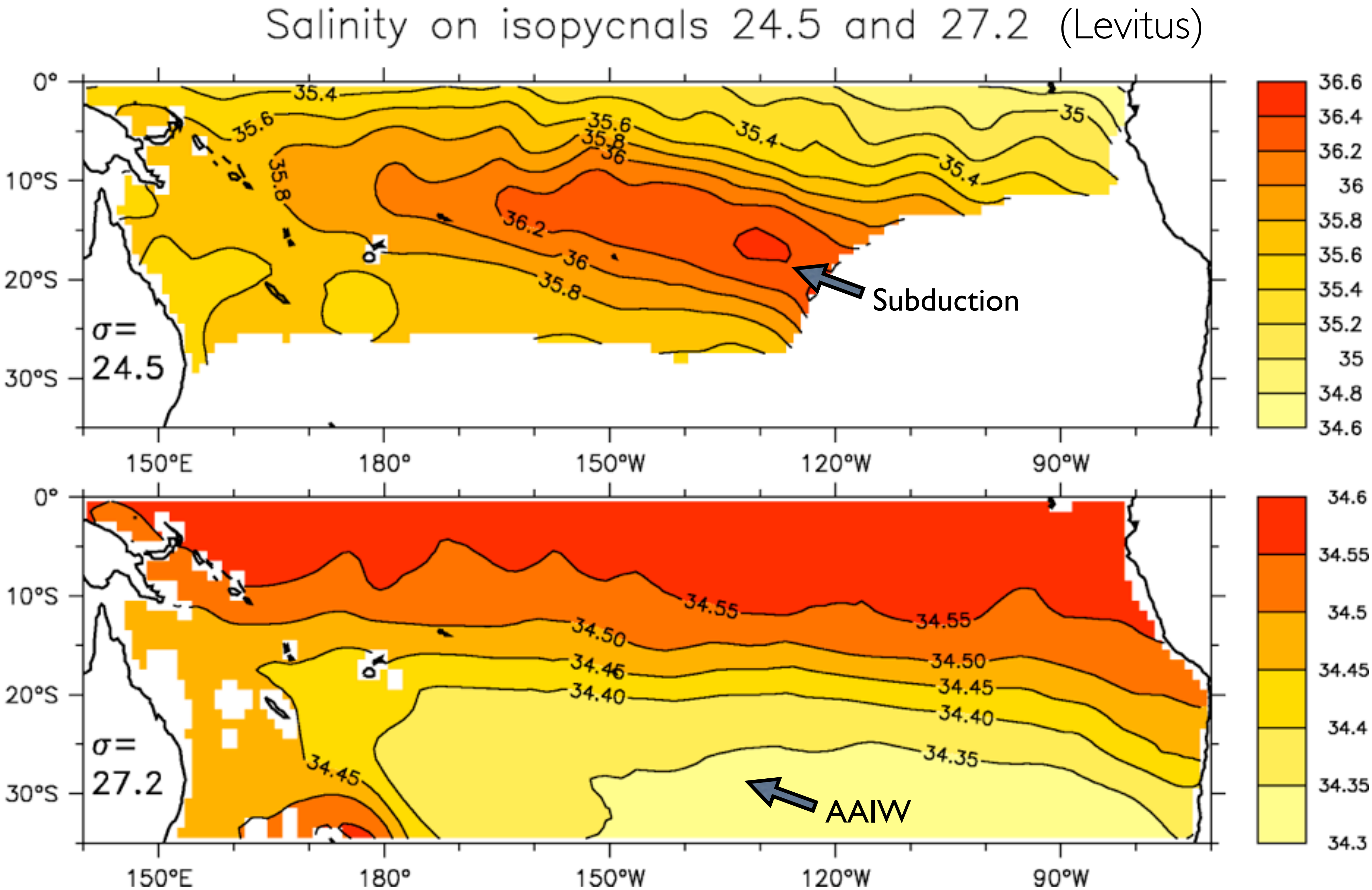
The basin picture:
Redistribution of mass at the western boundary

Island Rule (generalized Sverdrup) streamfunction (ERS winds)



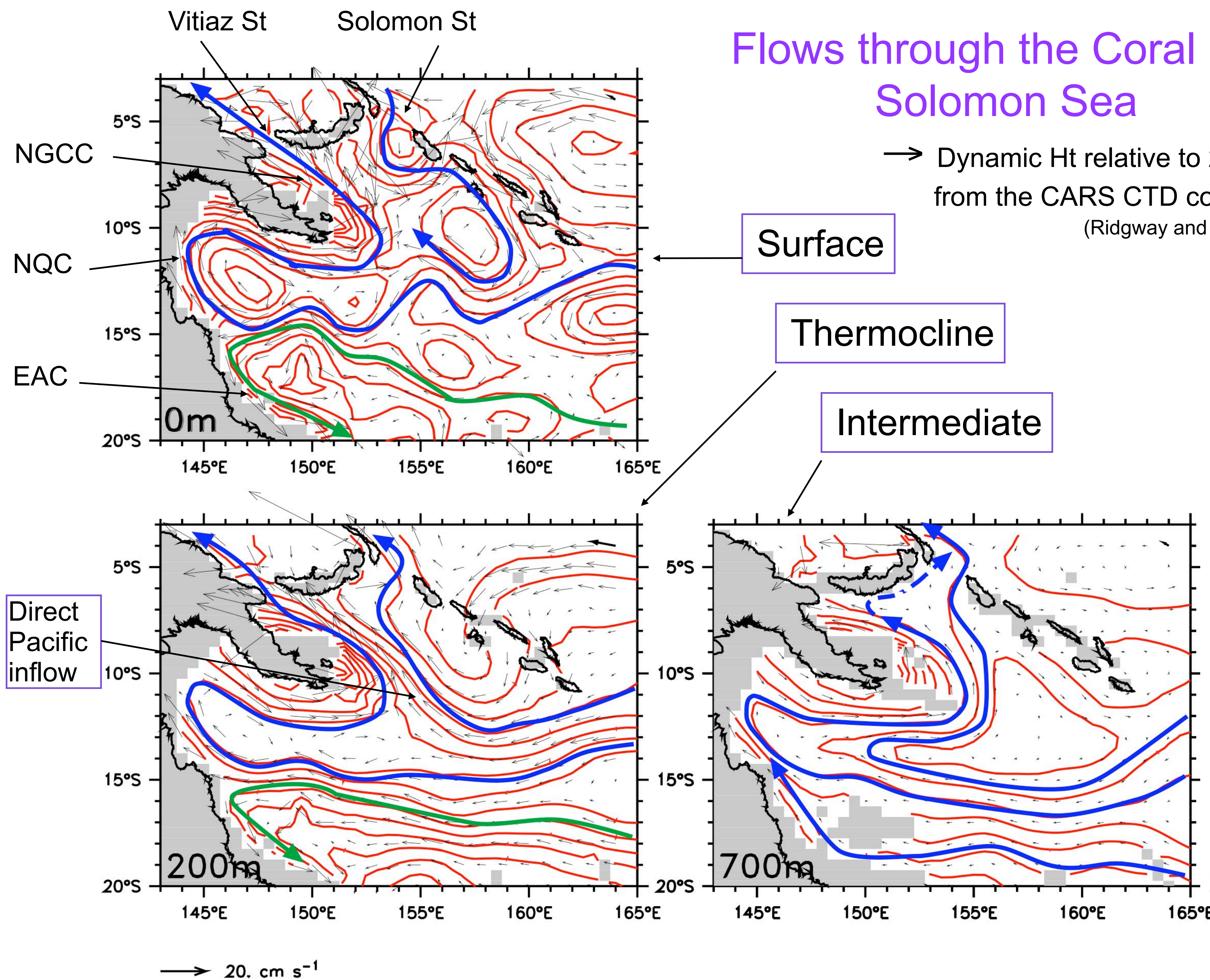
About half the SEC transport goes north through the Solomon Sea to the equator.
According to the Island Rule, ~11 Sv of this goes around Australia.

Water mass redistribution in the SW subtropical Pacific



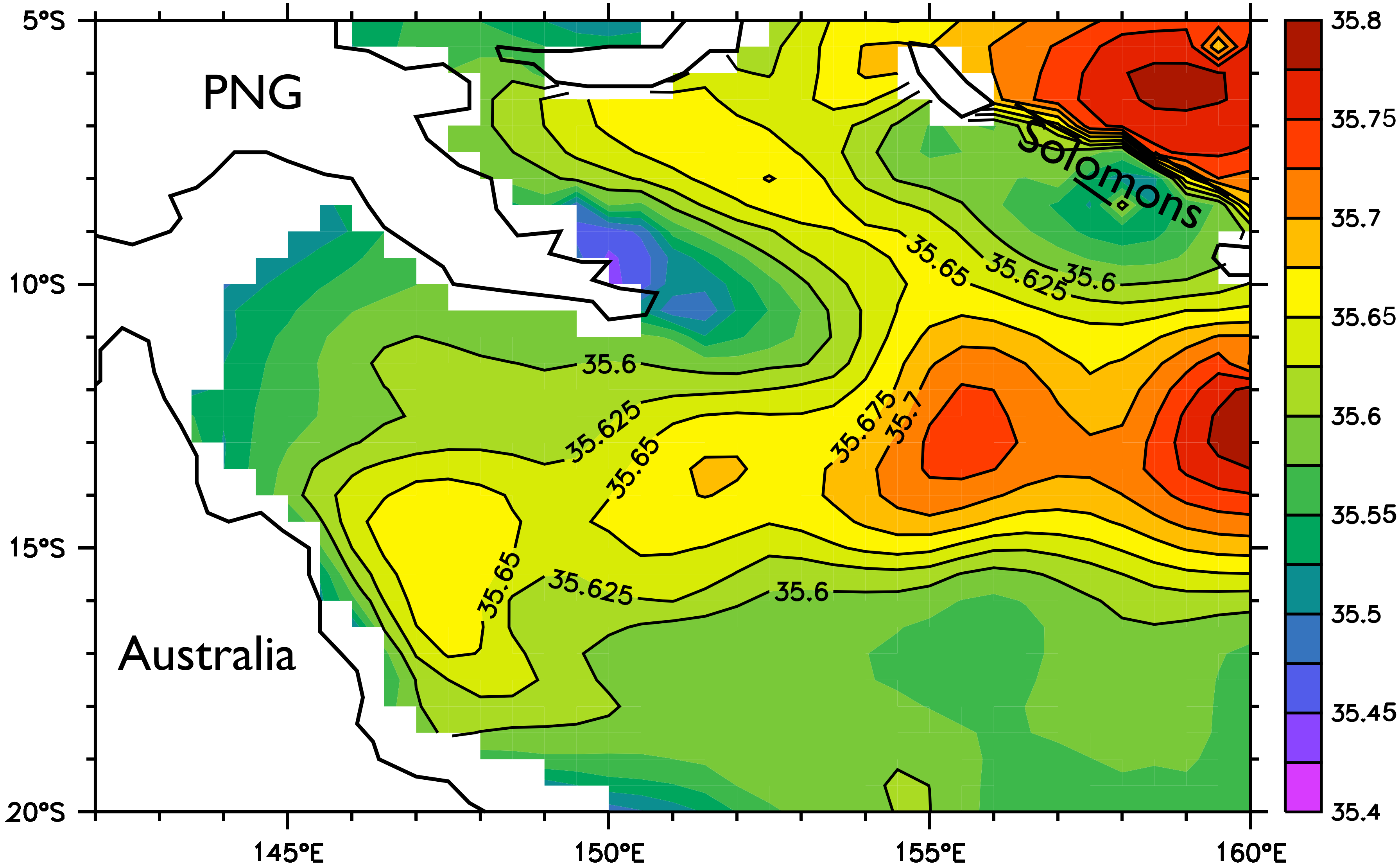
Flows through the Coral and Solomon Sea

→ Dynamic Ht relative to 2000m from the CARS CTD compilation.
(Ridgway and Dunn 2003)



Salinity at thermocline level

A high-salinity tongue extends into the Solomon Sea

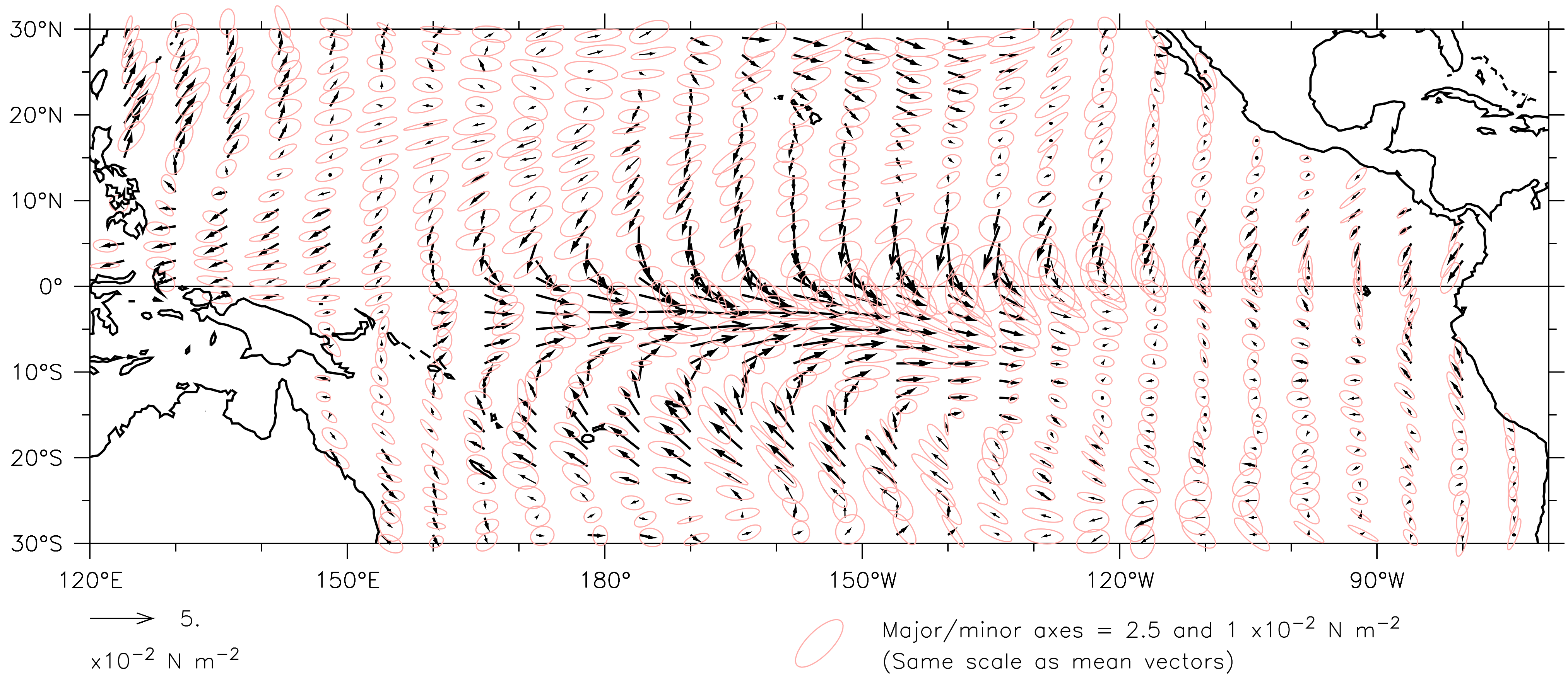


CARS data. Salinity on sigmatheta 24.5

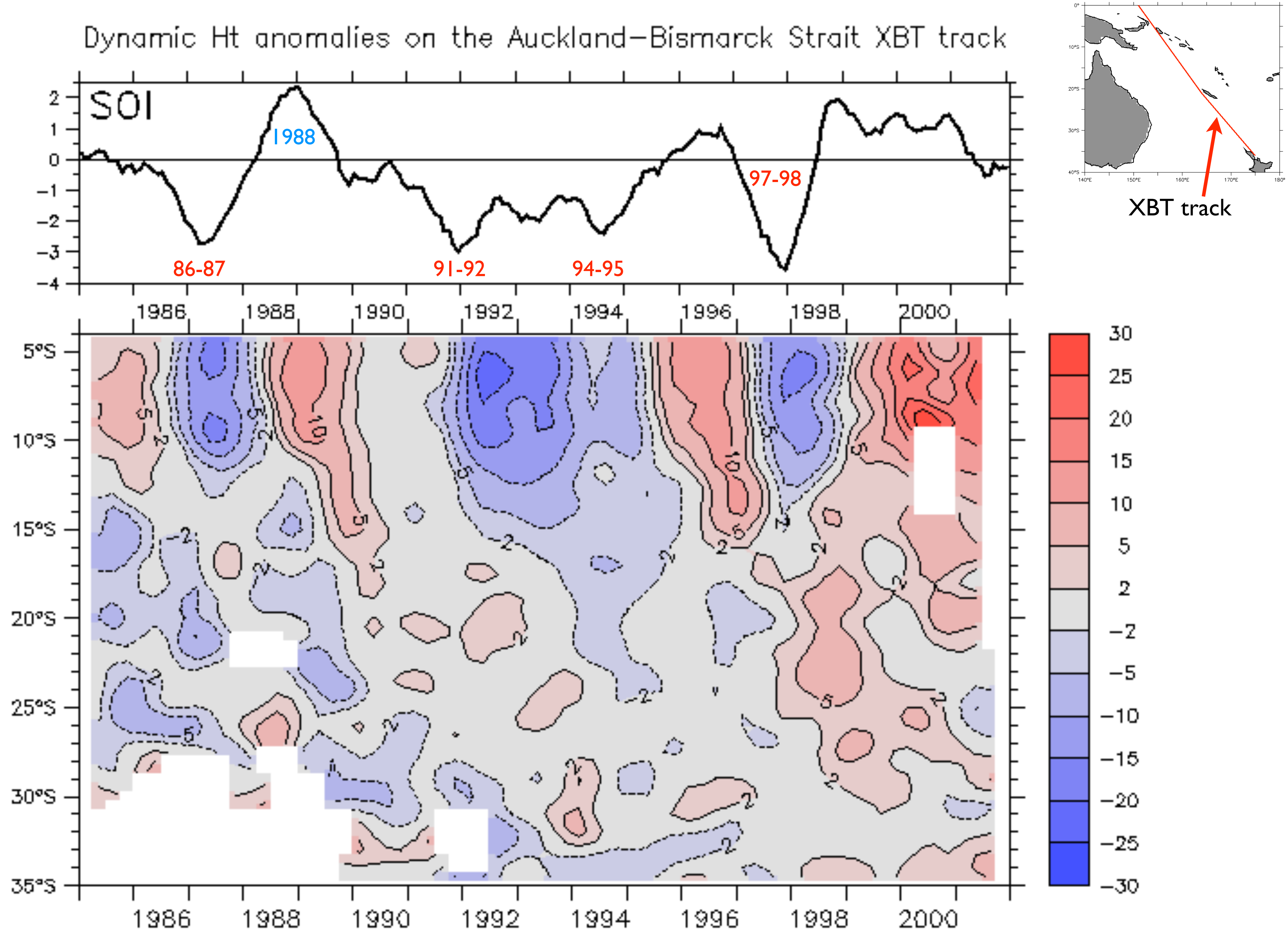
El Niño winds (and curl) are large in the Southern hemisphere

Mean and RMS of El Niño composite winds during the peak of the event (Nov Yr 0/Apr Yr +1)

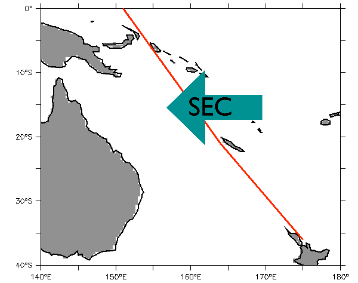
Ellipses show the variance among the events of 1965, 1972, 1982, 1986, 1991, 1997



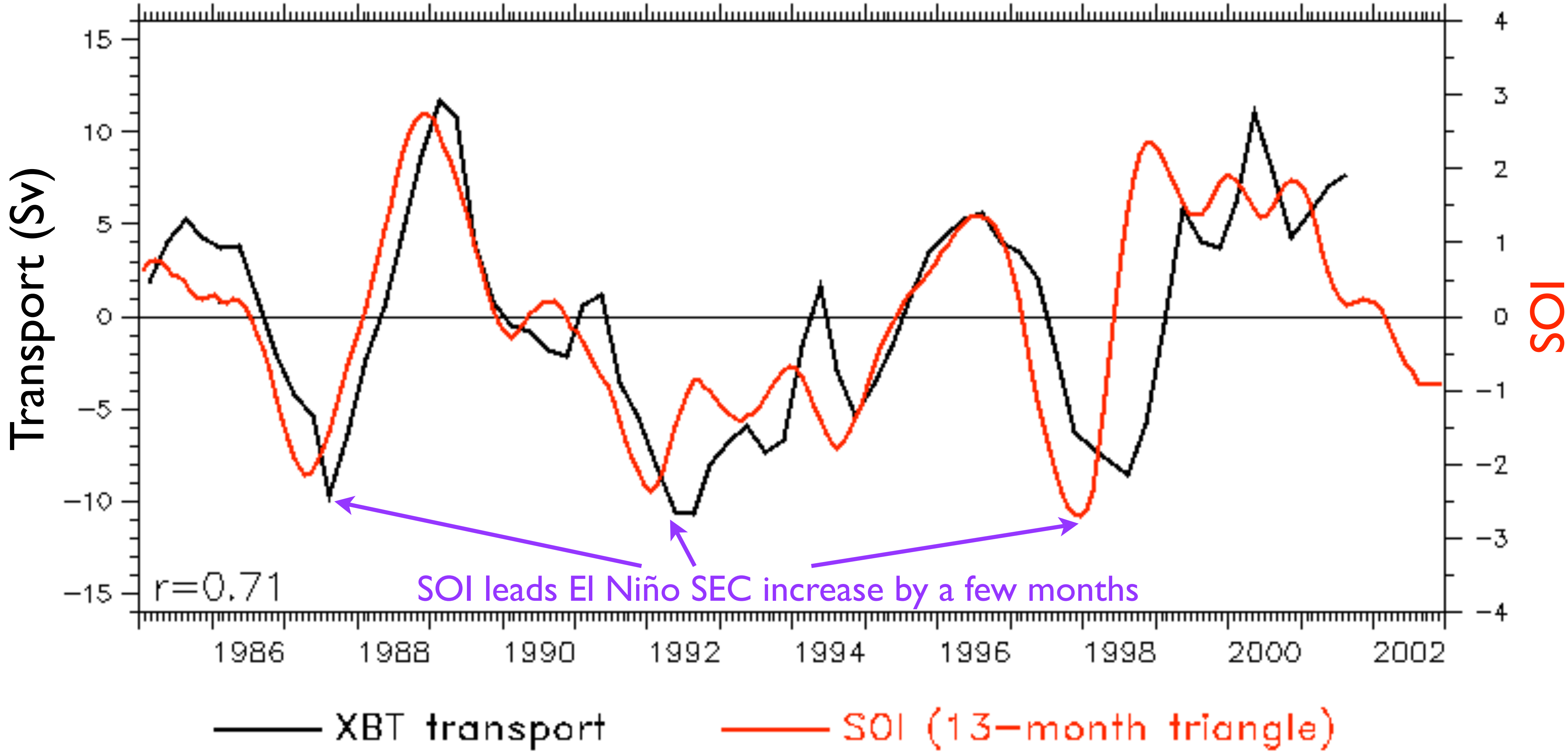
Large upwelling curl near 5°-15°S ⇒ Upwelling Rossby wave affects the far west a few months later


Dynamic Ht anomalies on the Auckland–Bismarck Strait XBT track
SOI
1988
86-87
91-92
94-95
97-98
XBT track
1986
1988
1990
1992
1994
1996
1998
2000
5°S
10°S
15°S
20°S
25°S
30°S
35°S
30
25
20
15
10
5
2
−2
−5
−10
−15
−20
−25
−30

SEC transport has a strong ENSO signal

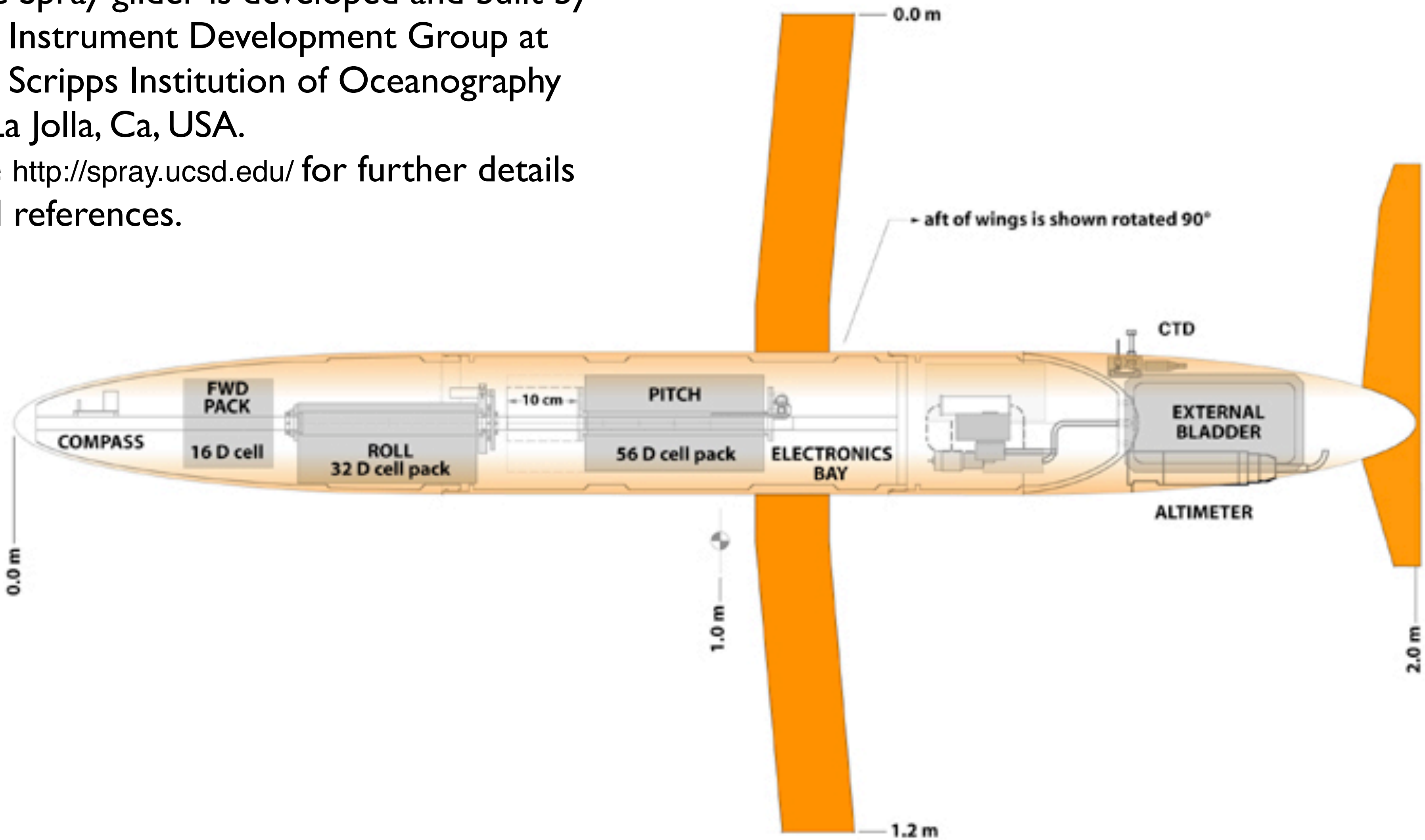


SEC on the Auckland-Japan XBT track, over 10°S-20°S. Demeaned.



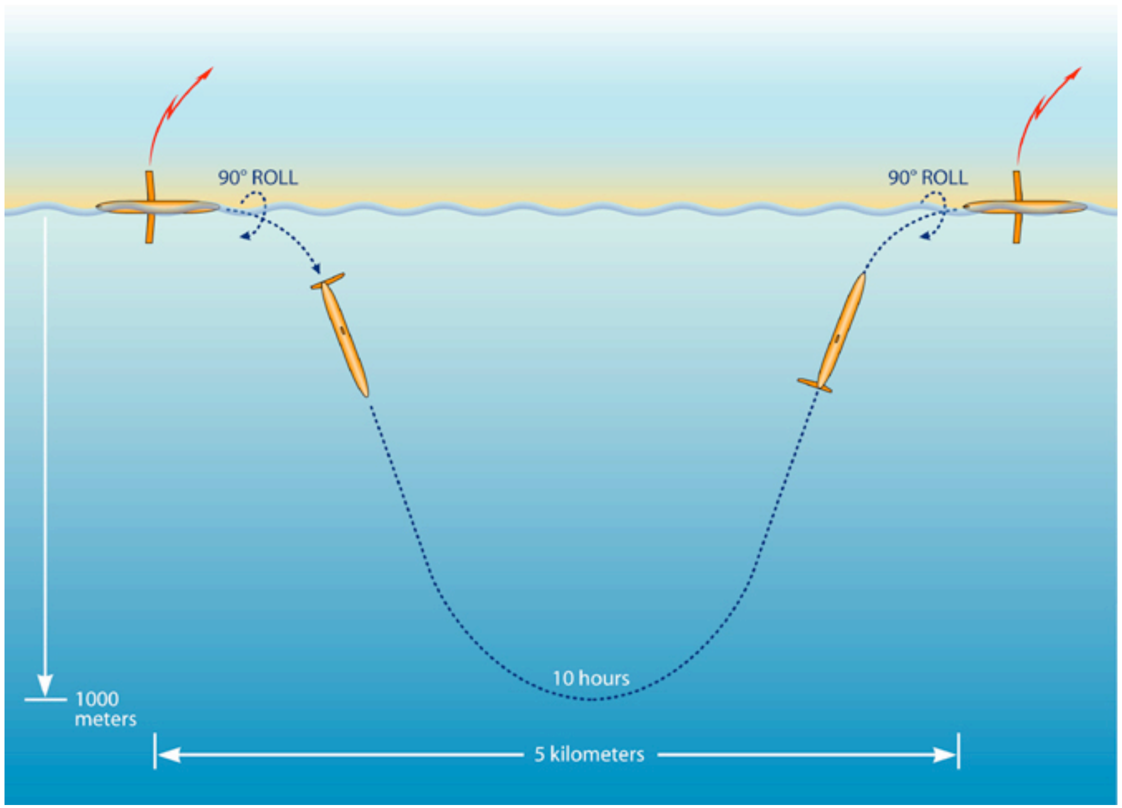
The ocean glider “Spray”: Schematic diagram

The Spray glider is developed and built by the Instrument Development Group at the Scripps Institution of Oceanography in La Jolla, Ca, USA.
See http://spray.ucsd.edu/ for further details and references.



‘Spray’ glider

500-1000 m



4 km

25 cm/s
(3-5 hr)

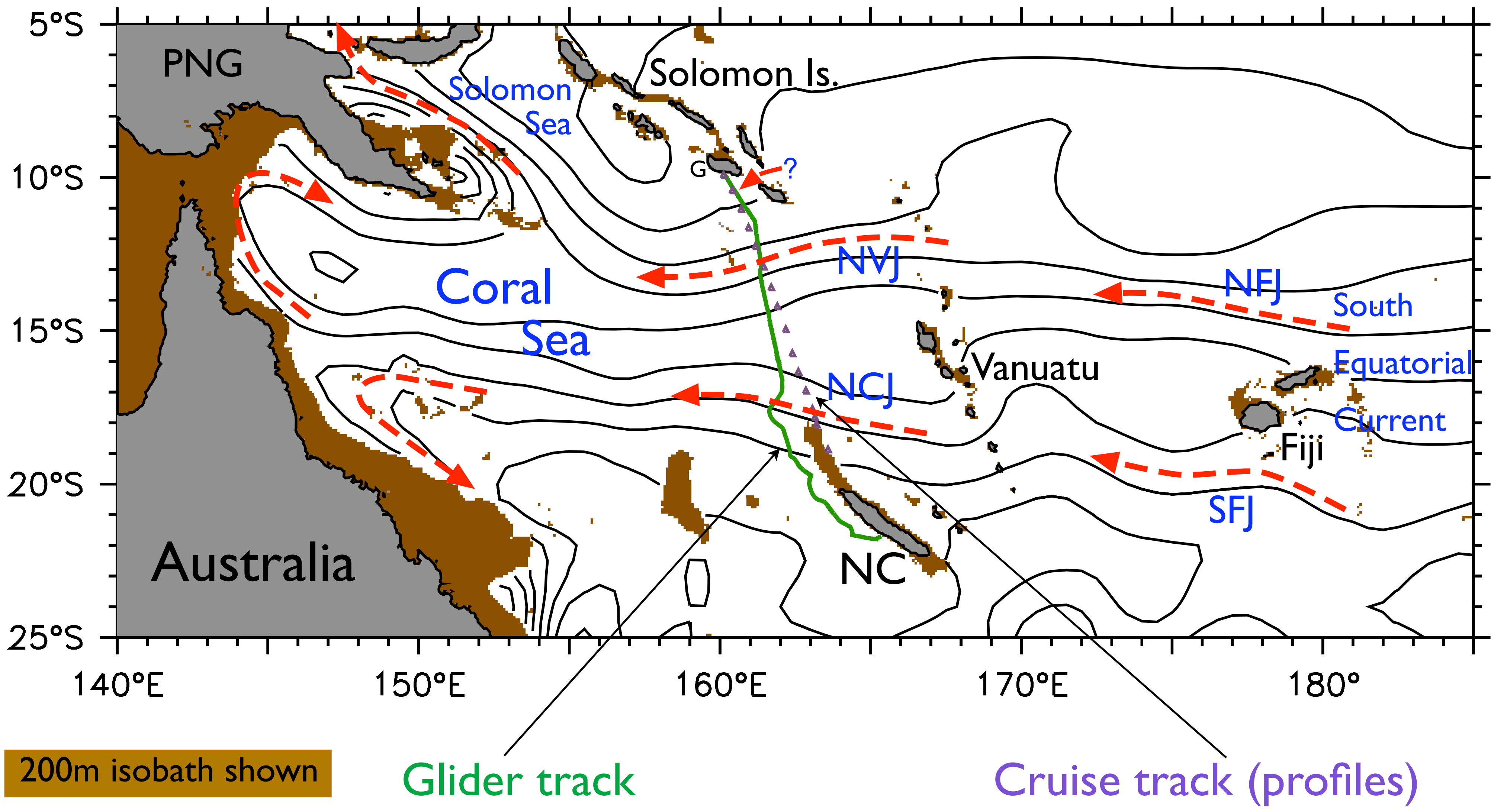
- The glider is based on Argo float technology, modified to maintain a specific course.
- The glider makes profiles of temperature and salinity like Argo, but rather than drifting freely, wings control its path through the water.
- The drift of the glider is an estimate of absolute current.
- Deploy from small boats, within a few km of shore.

Shipboard and glider section between Guadalcanal and New Caledonia

A coordinated experiment

July-October 2005, glider repeated Nov 06-Mar 07

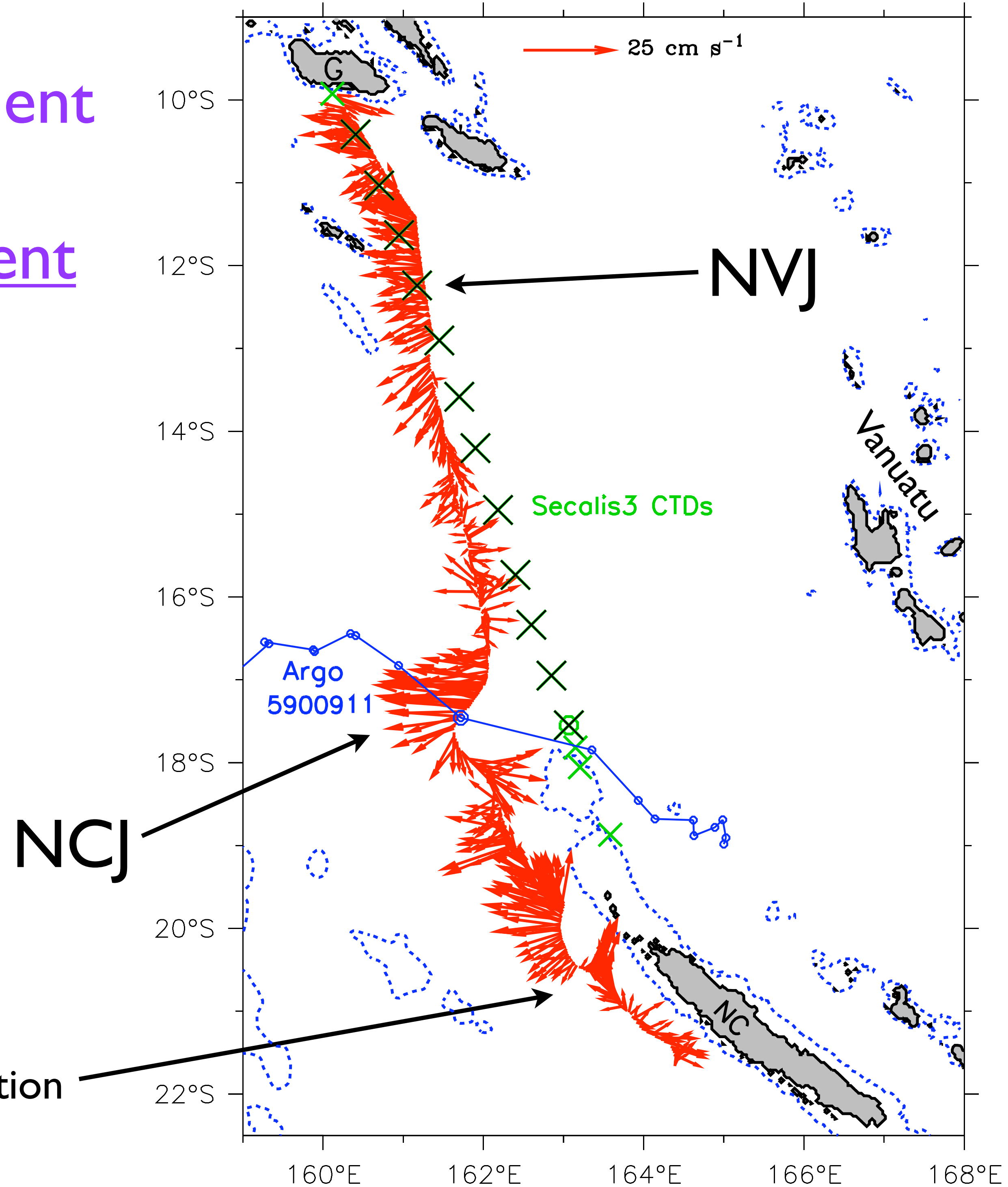
(Gourdeau et al, in press, JPO)



First mission: A coordinated experiment to study the South Equatorial Current

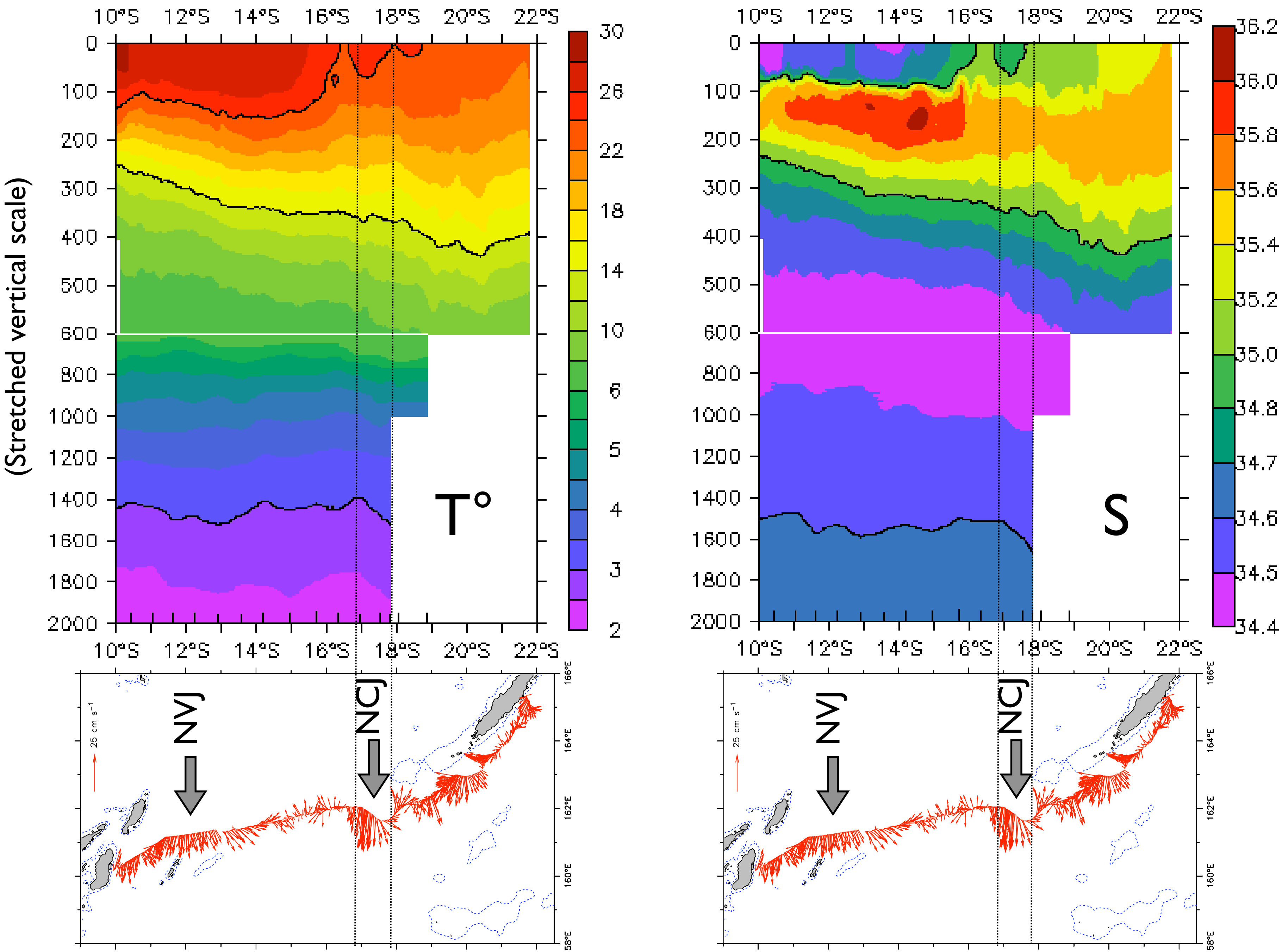
Jul-Oct 2005

- A shipboard section made 14 profiles to 2000m.
- A glider section made dense profiles to 600m.
- An Argo float drifted through the NCJ.



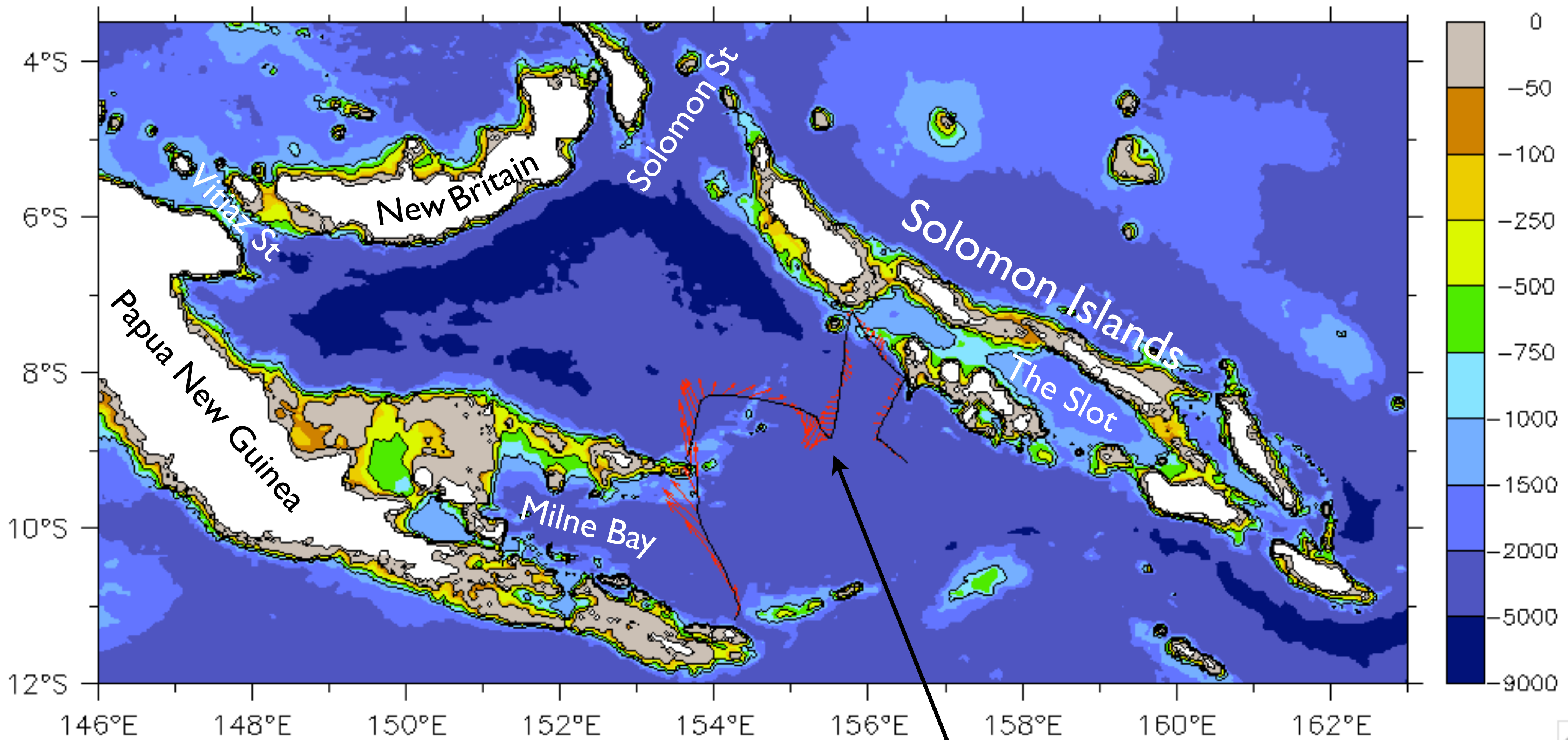
Shipboard profiles show that the NCJ extends very deep

The signature of the jet is still seen at 1750m



Glider monitoring of the Solomon Sea

Funded for 4 deployments starting Aug 07. Today: first mission in progress



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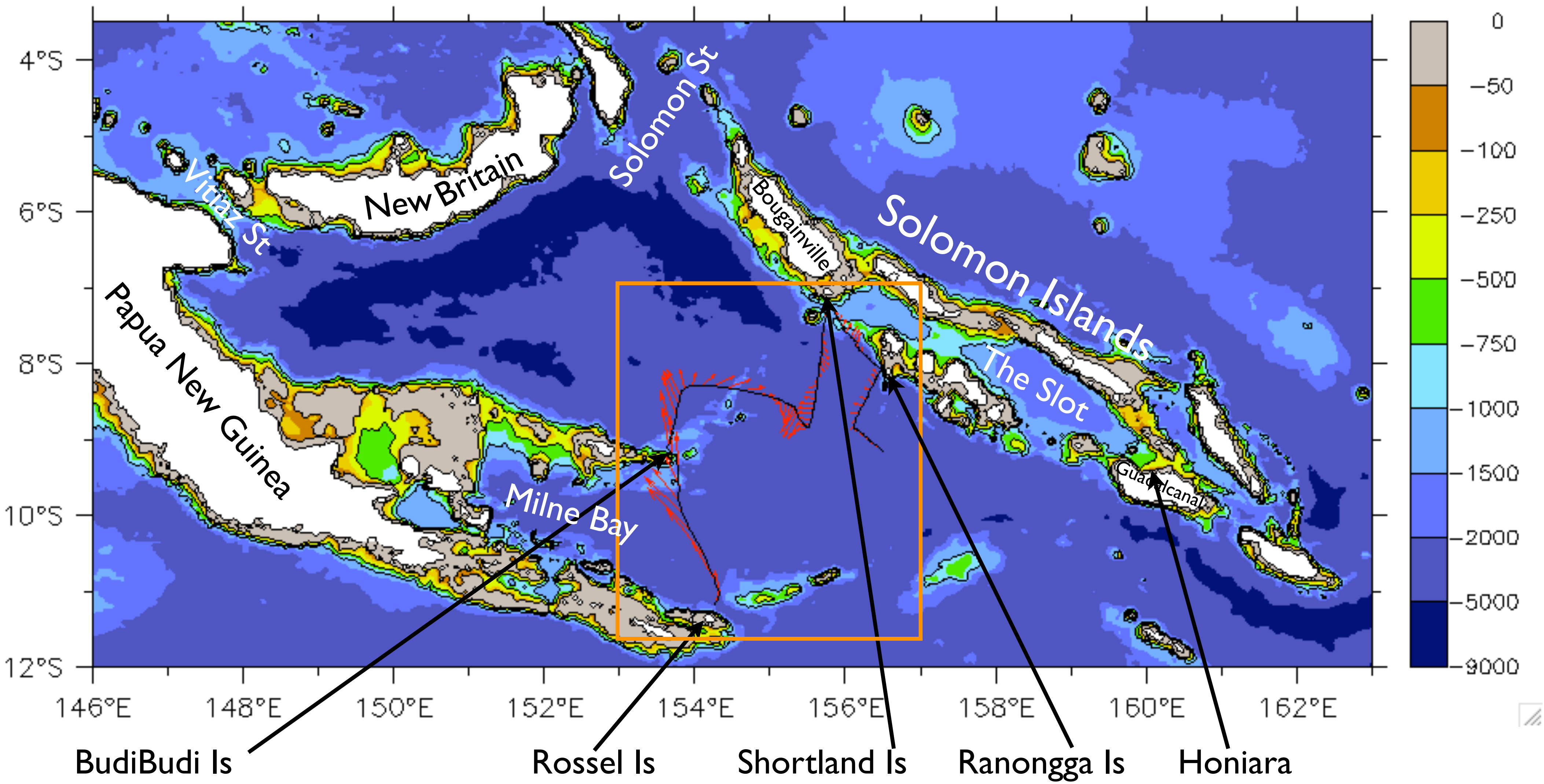
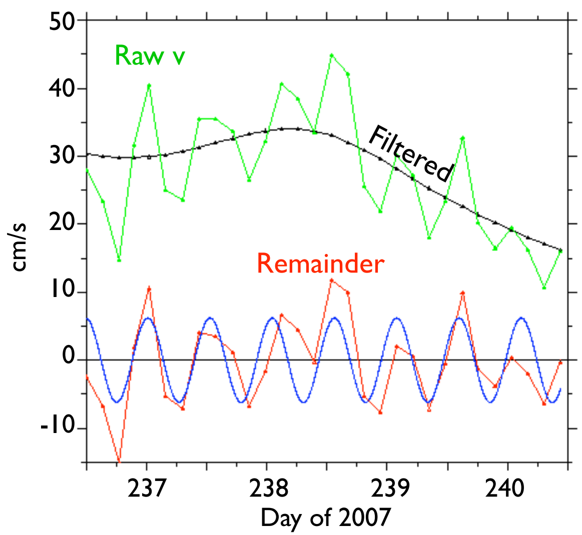
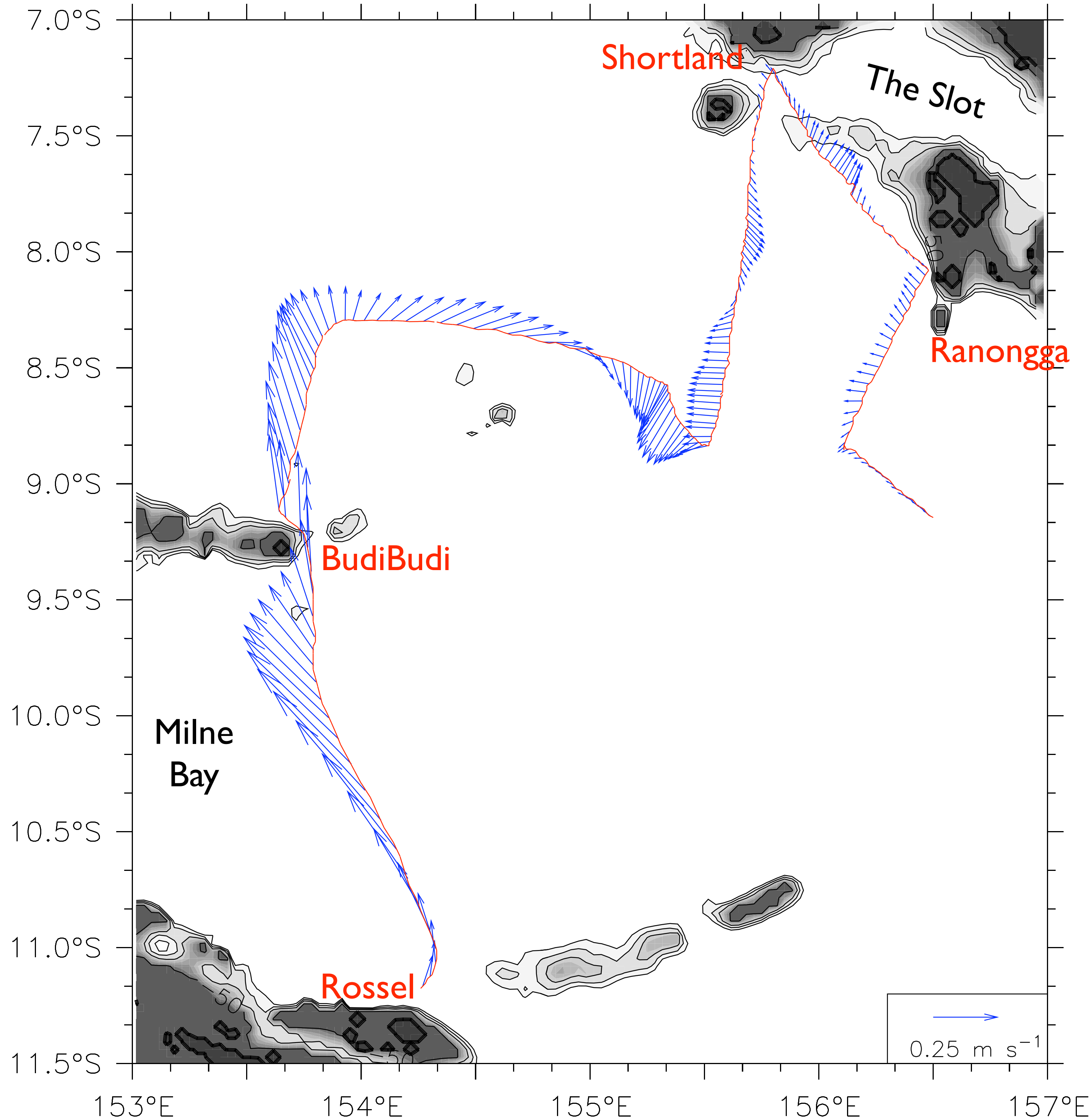


Vector absolute current above 500m

(Tide-filtered)

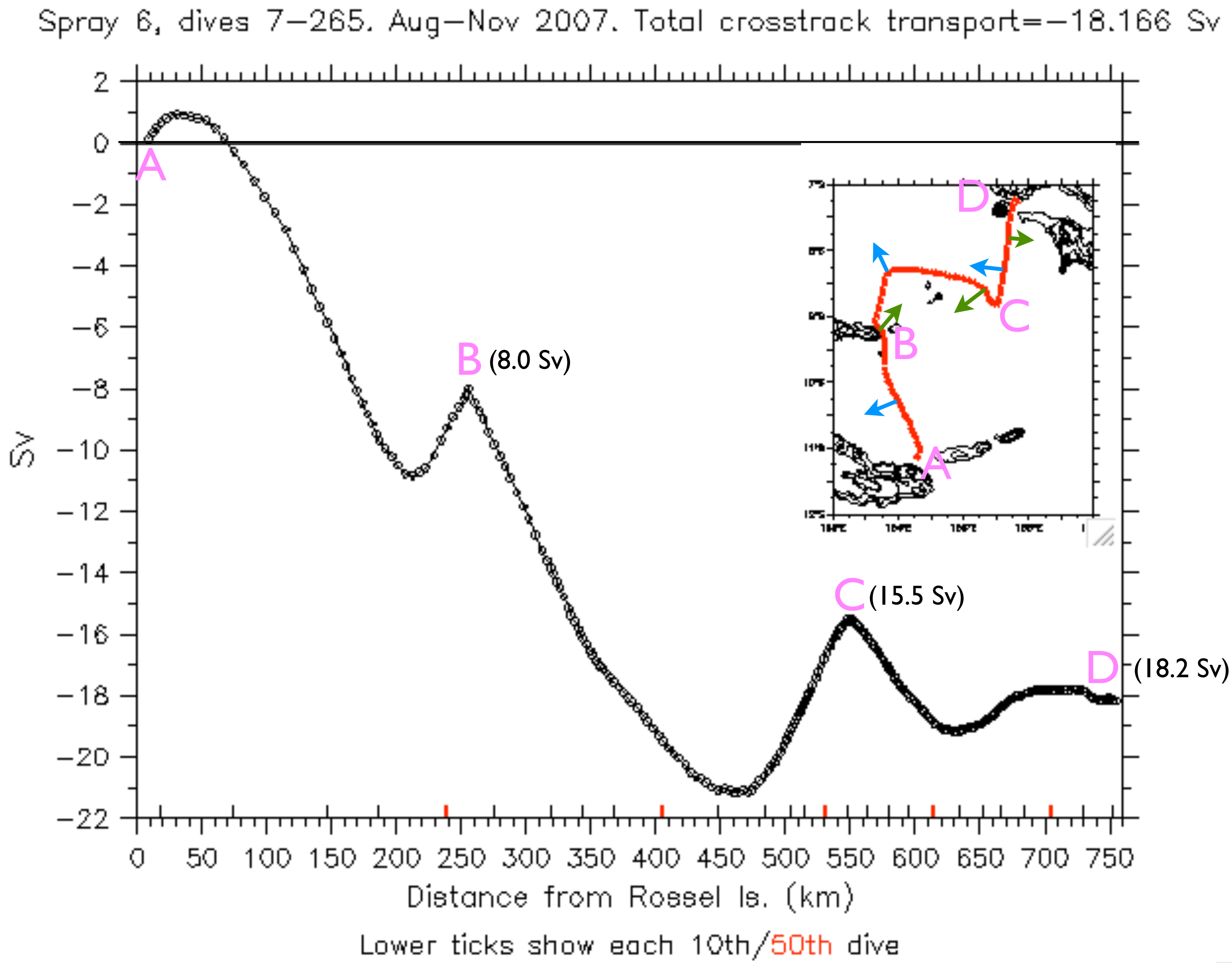


Tide-filtering by a Gaussian objective mapping on time with a time-scale of 1.5 days.

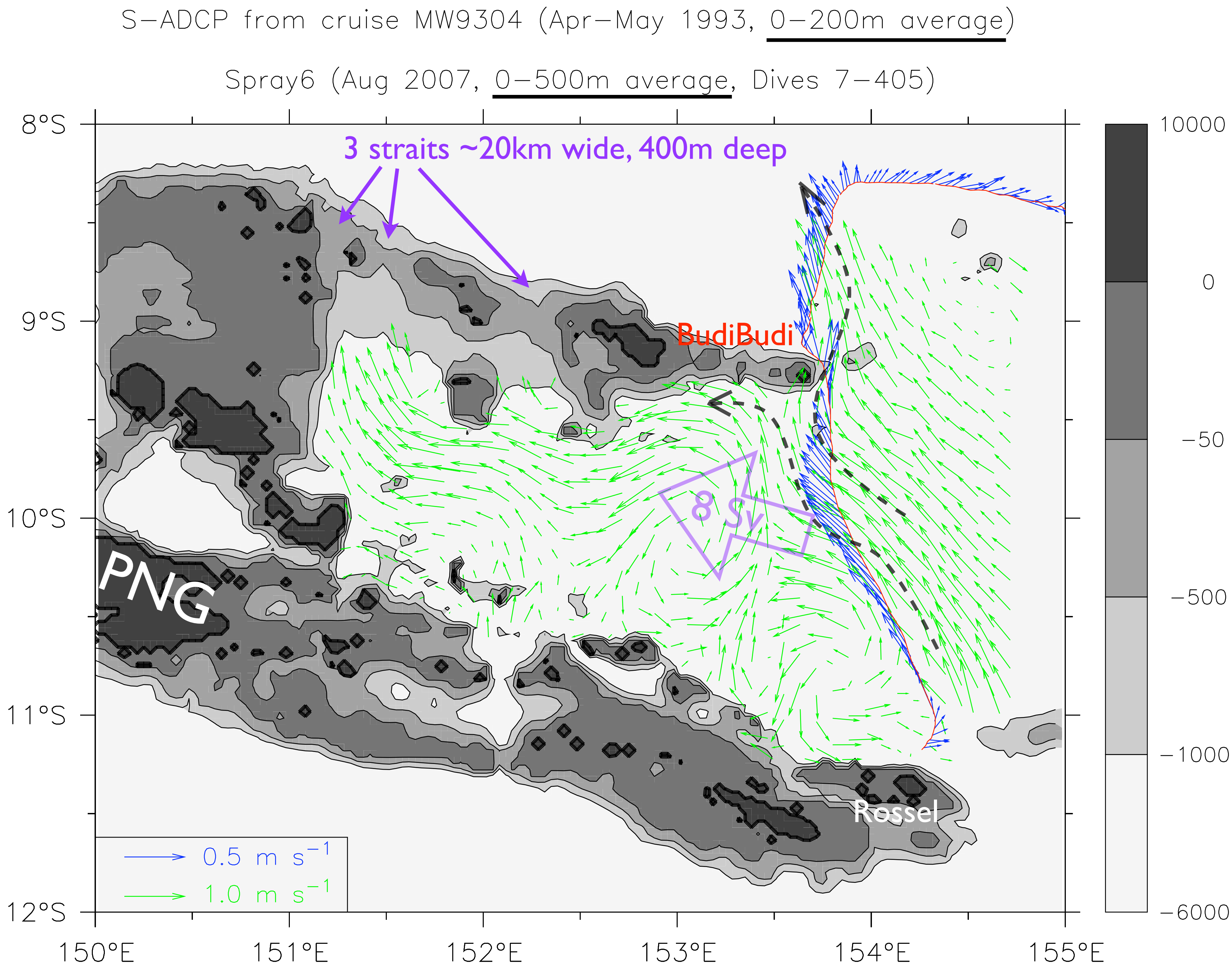


(Every other vector plotted)

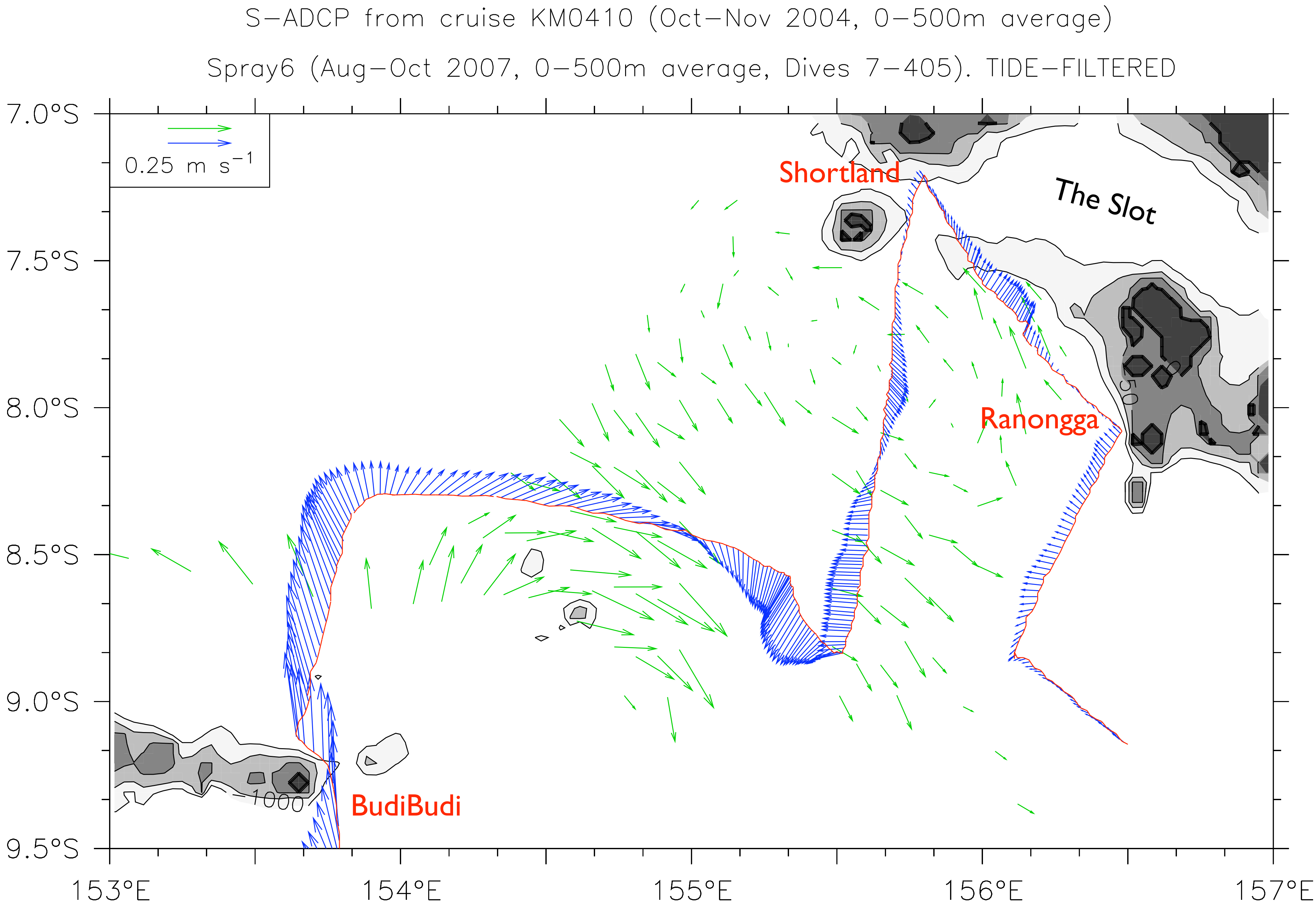
Crosstrack transport accumulated from Rossel Is.



ADCP and glider currents in Milne Bay, PNG



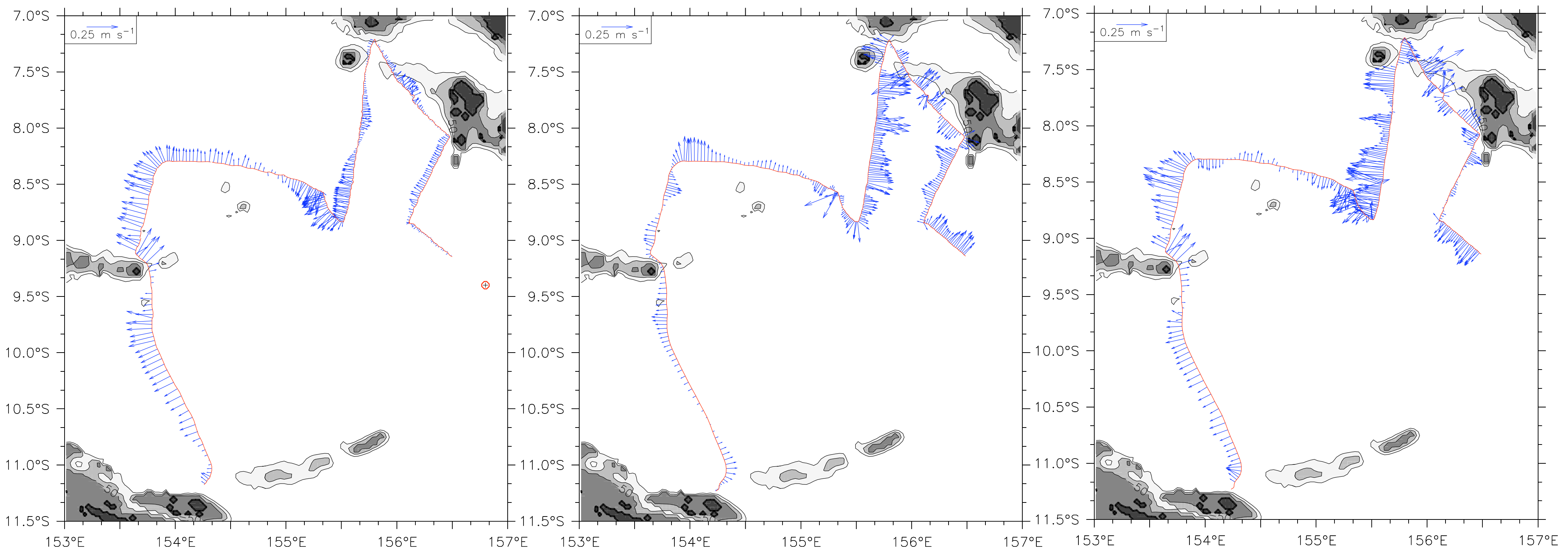
ADCP and glider currents in the eastern Solomon Sea



Absolute crosstrack u_g

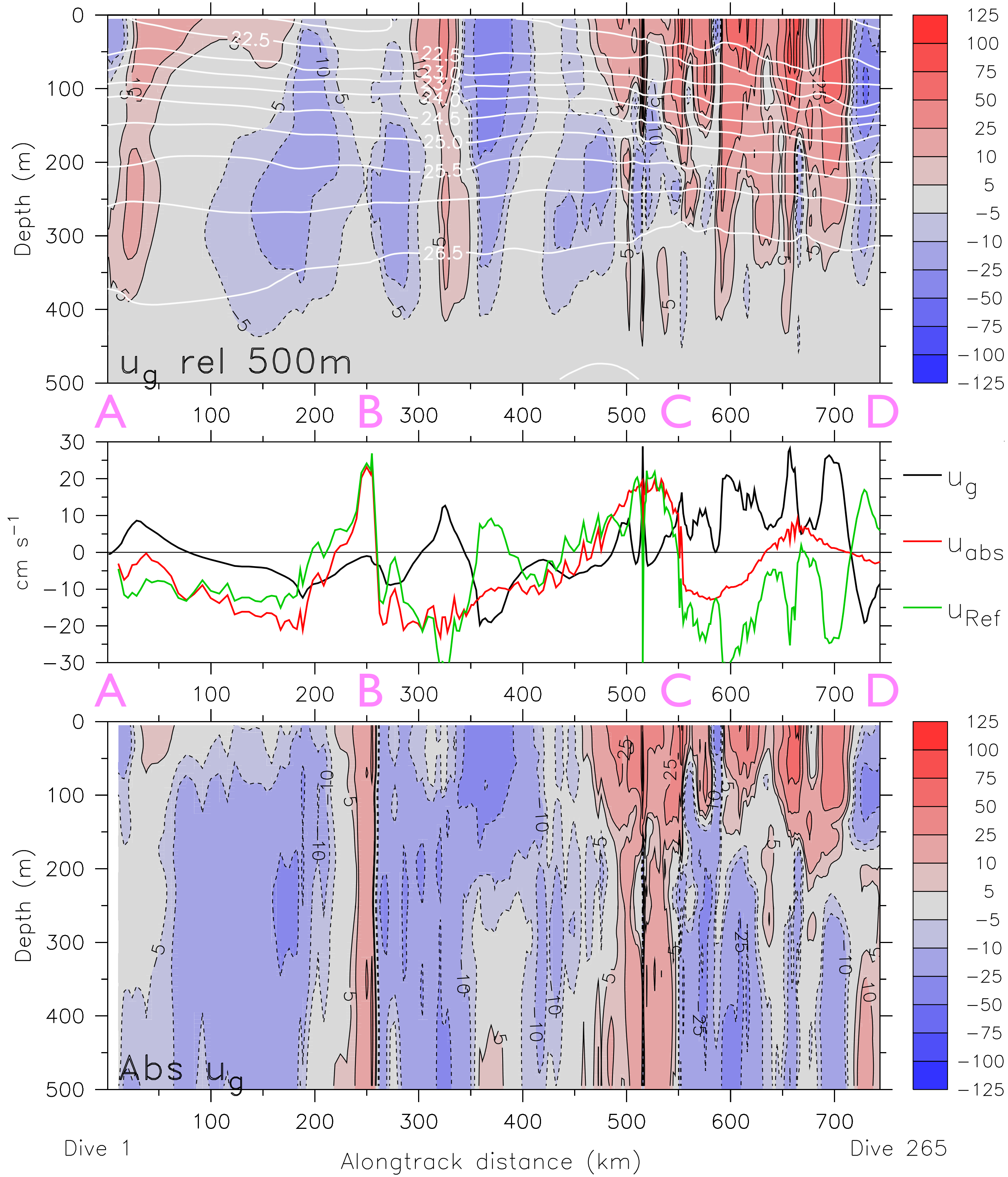
$$ug_{abs}(z) = ug_{rel}(z) - \overline{ug_{rel}}^{z} + \overline{u}^{z}_{cross_{abs}} \; (- u_{Ekman})$$

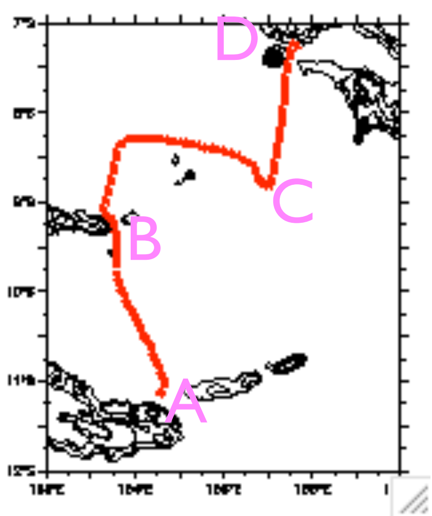
Absolute Crosstrack | Geostrophic Crosstrack | Reference level Crosstrack



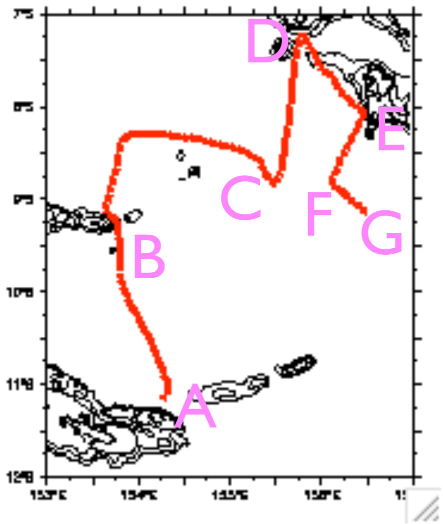
Absolute crosstrack geostrophic currents from glider motion and relative geostrophy

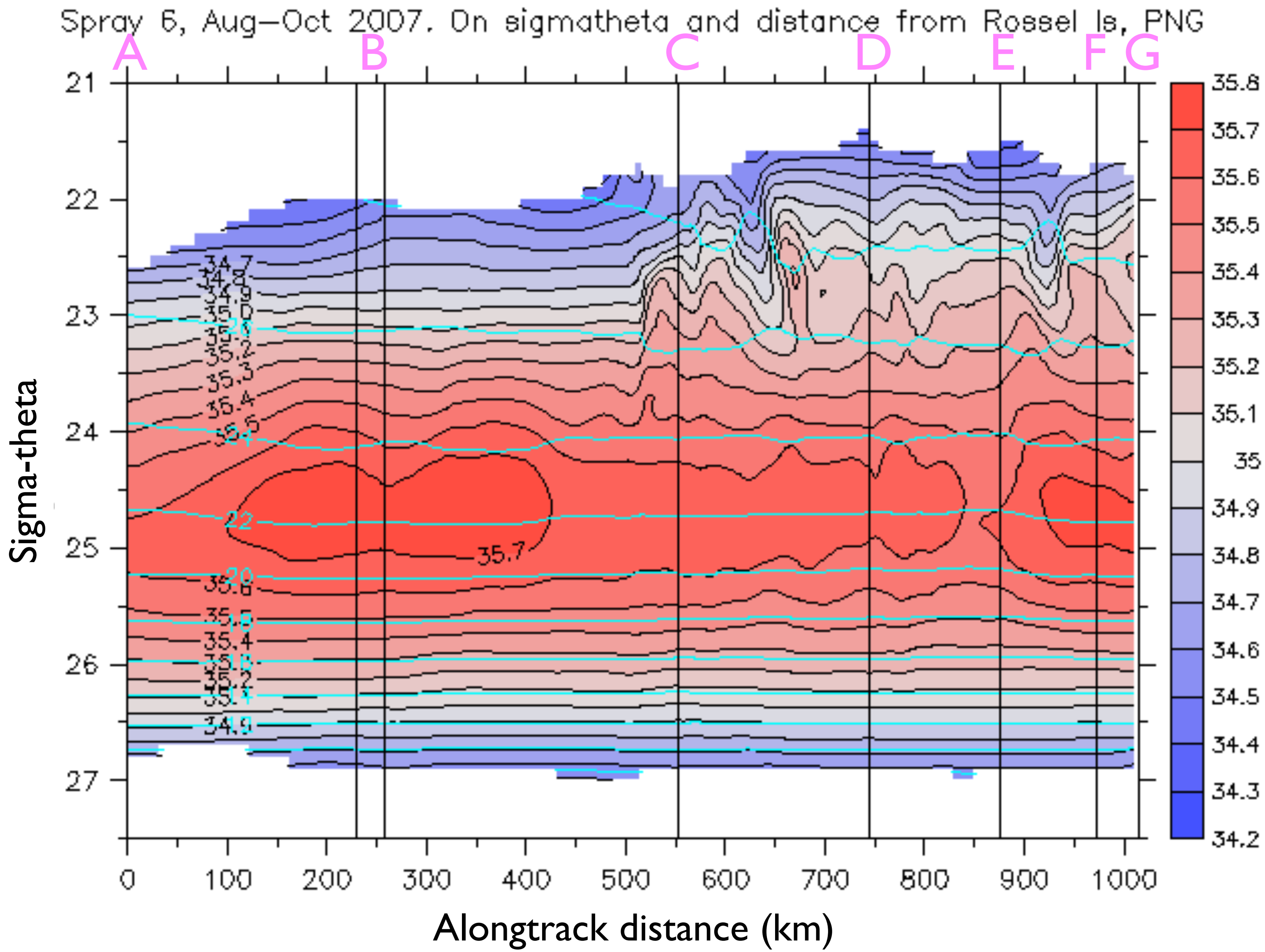
Isopycnals above 25 slope down across the Solomon Sea.
upper shear is *southward*:
WBC is an undercurrent





Salinity along the glider track



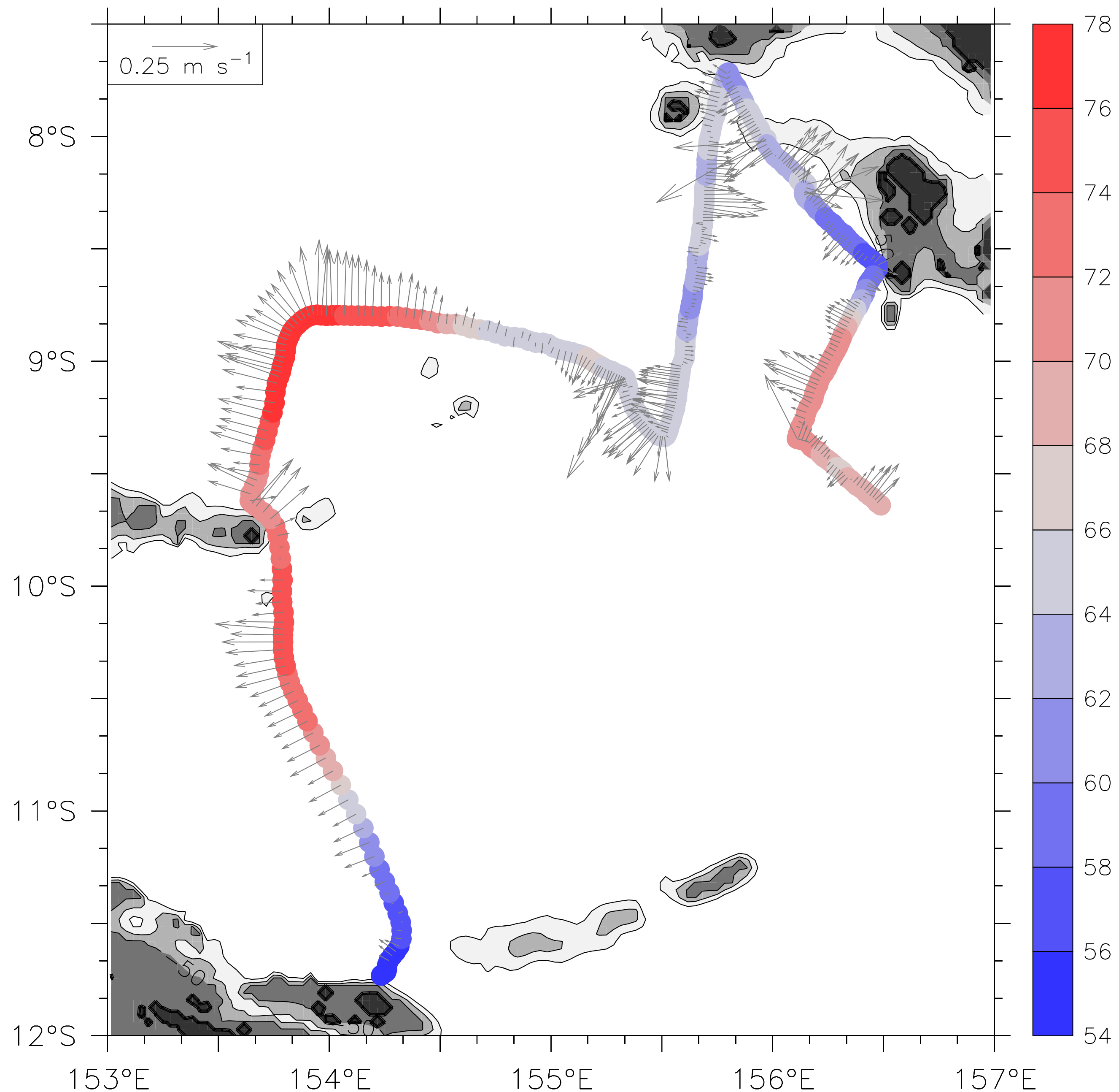


(Light-blue lines show temperature)

Salinity and absolute u_g at σ_θ 24.5

Crosstrack component vectors. Plotted S' = (S-34)/100

Tide-filtered



Schematic (speculative!) circulation

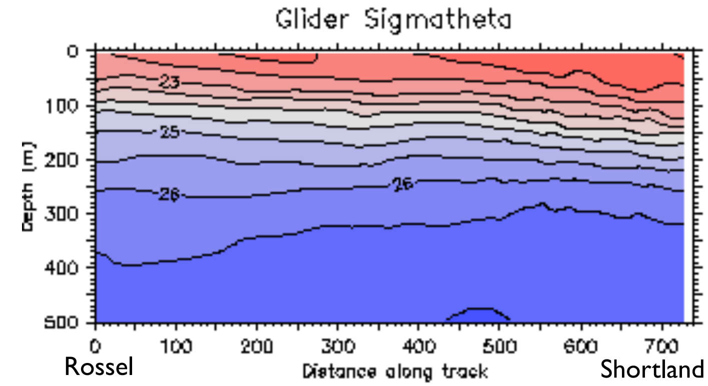
Shallow

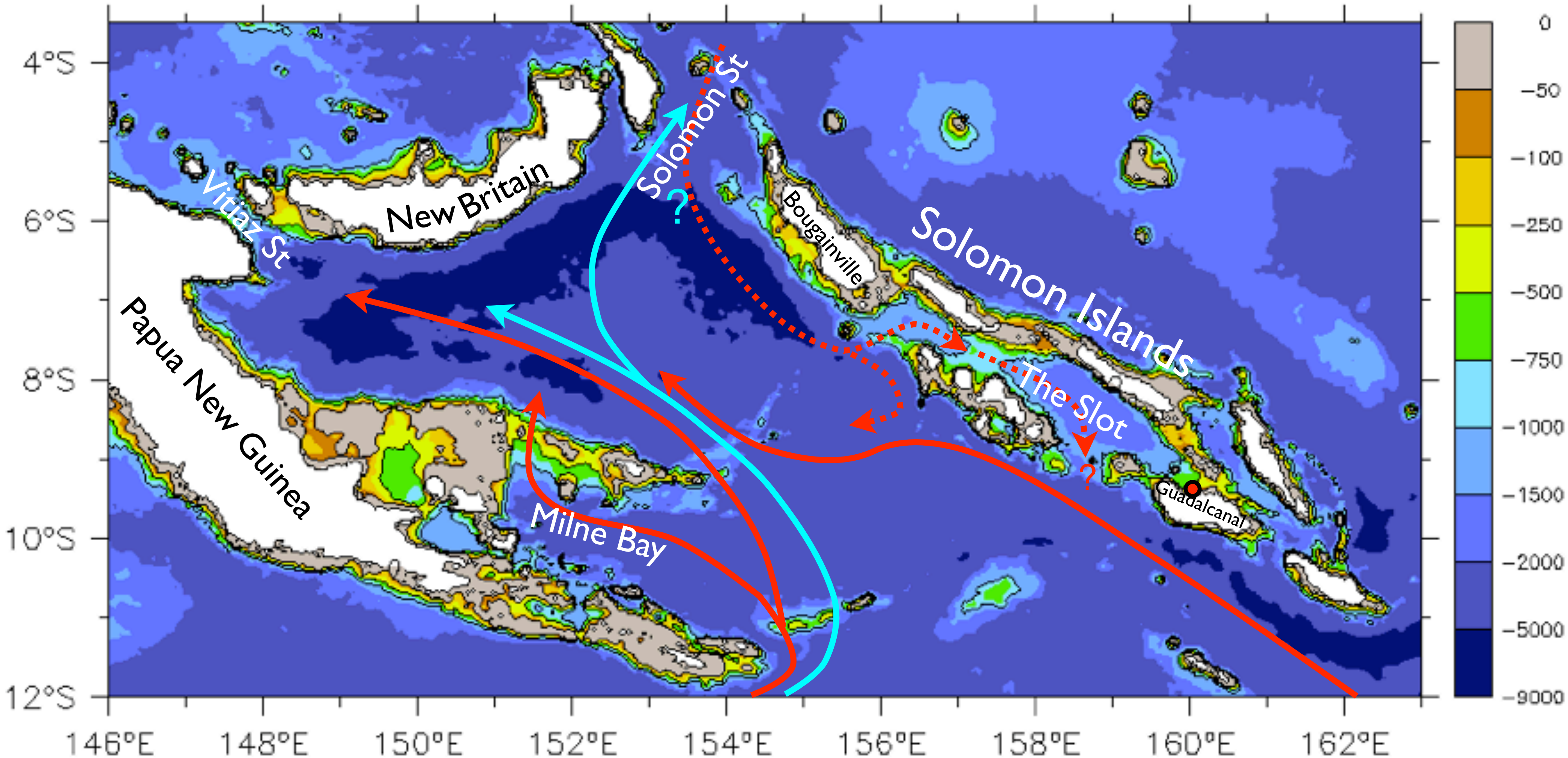
Subthermocline

(Dotted lines are even more speculative!)

Why is there shallow southward flow in the eastern Solomon Sea?

- A mini-warm pool?
- Inflow from Solomon Strait?



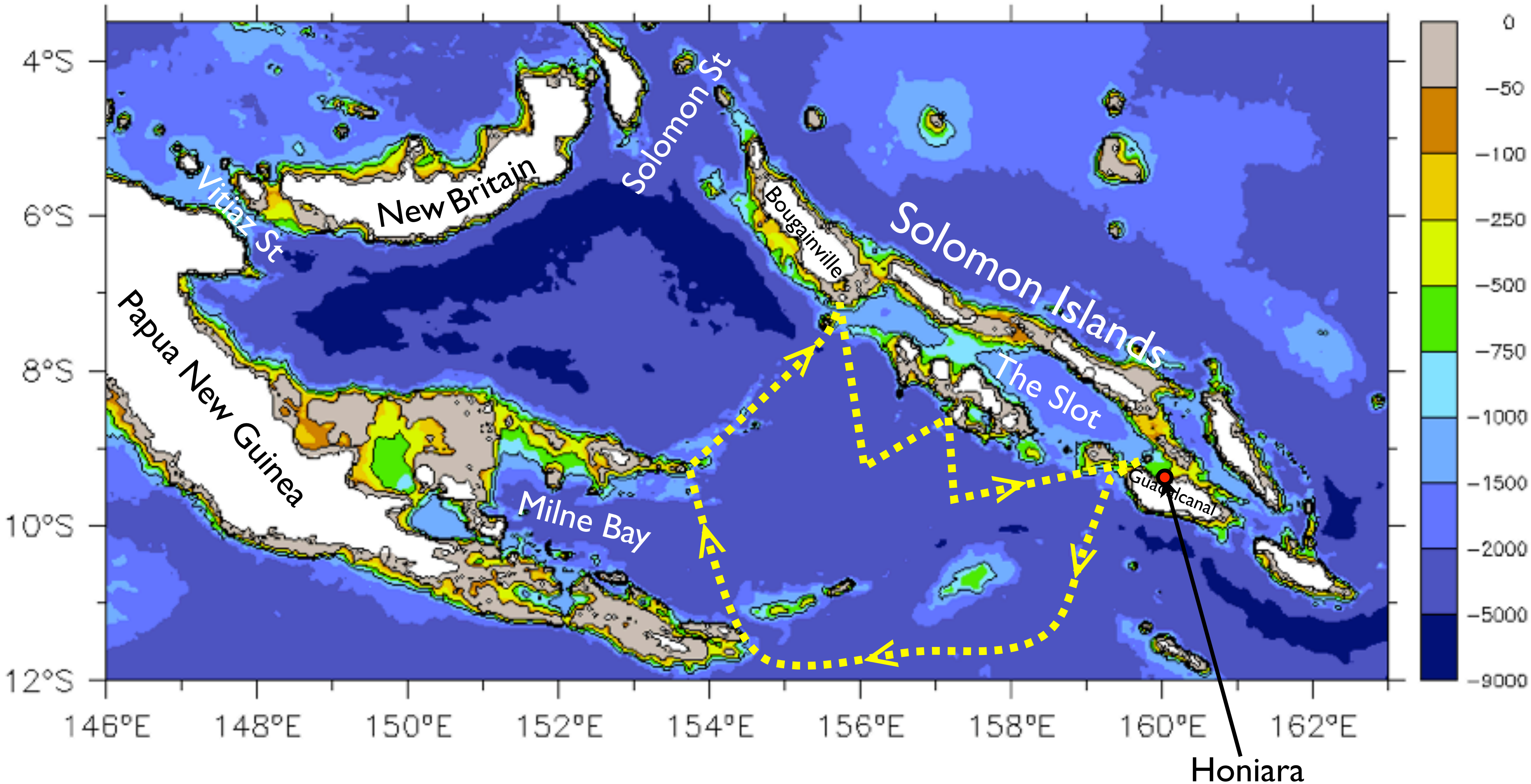


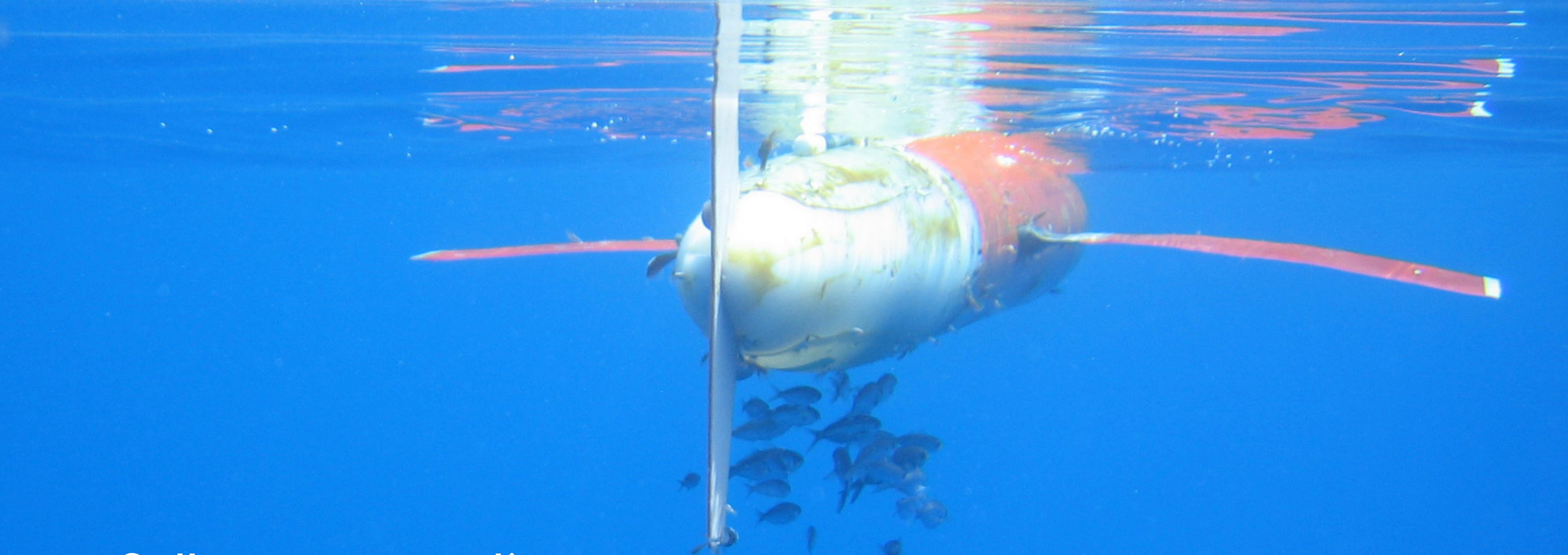
Future missions

Funded (NOAA/Scripps CORC/IRD) for 3 more deployments

➙ Redeploy in Nov 07, Feb 08, May 08. Recover in Aug 08 after sampling a complete annual cycle.

..... Digest results, then propose ongoing monitoring. Explore further north?





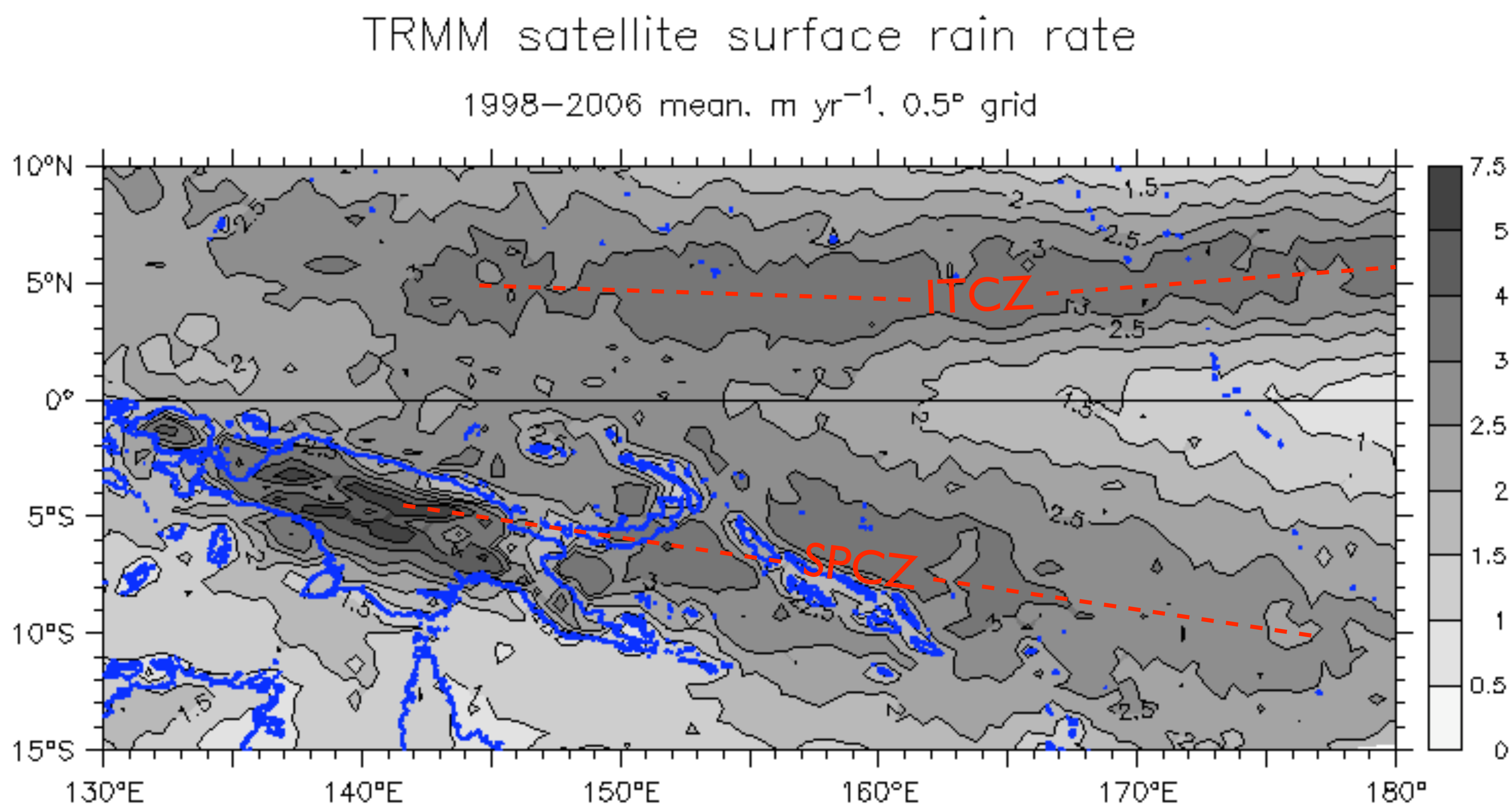
- Still experimental!
  But proof of concept that the glider can measure the LLWBC.
- The SW Pacific is characterized by narrow, swift currents, often close to coastlines, that carry much of the transport. These will be difficult to monitor except by instruments that can control their position.
- Continuous monitoring is crucial to the climate signals that determine the properties of the equatorial thermocline.

Extra

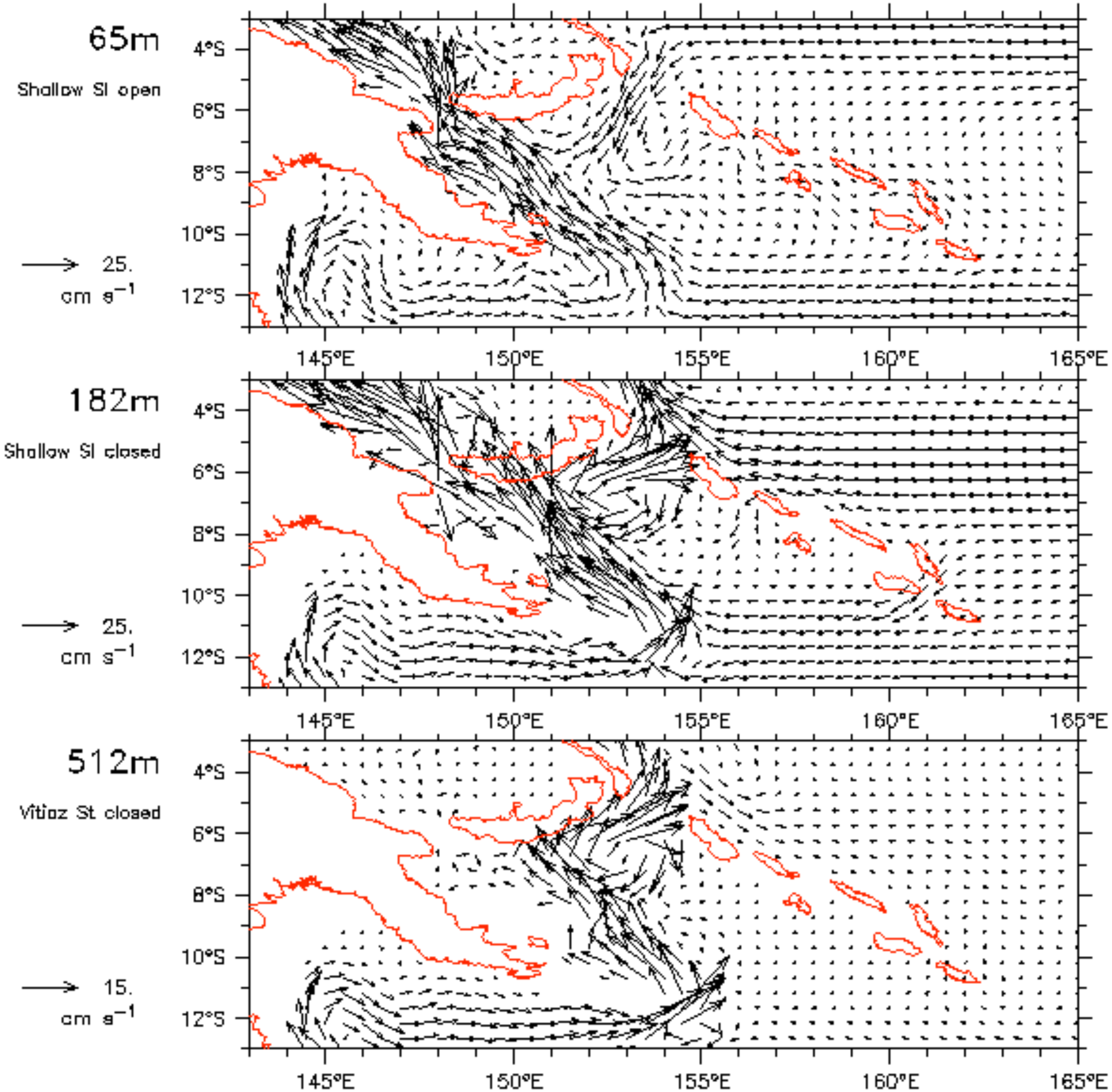
Figures

Follow ...

Does extreme rainfall in the Solomon Sea produce a mini-warm pool?



ORCA model circulation at surface, thermocline and below



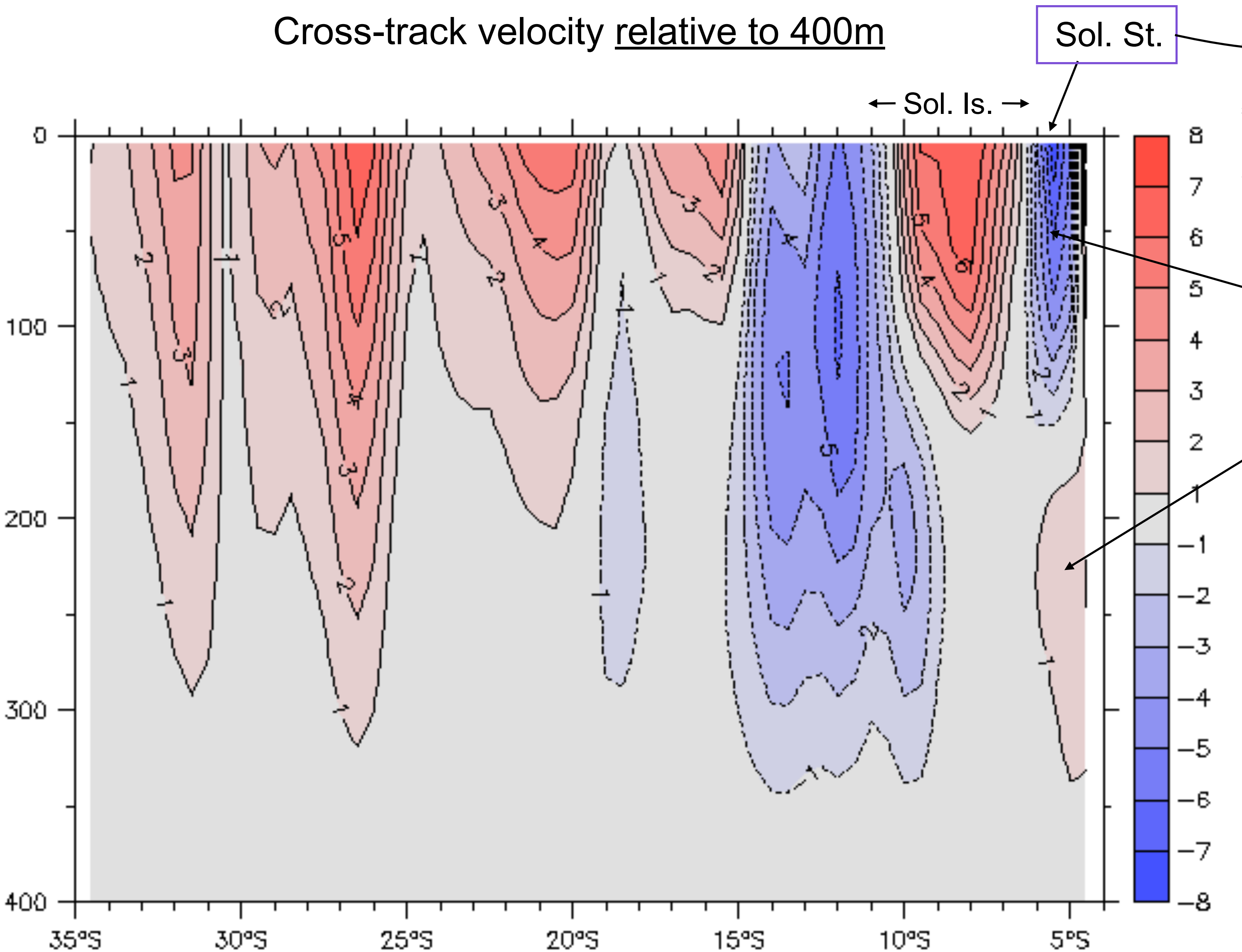
Above 100m:
Flow through Sol. St.
is *southward*.
(Consistent w/ obs).

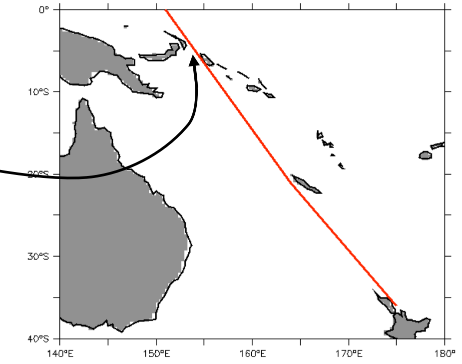
Thermocline level:
Sol. St. flow is northward
(Pacific inflow ~1/2 total).

Below Vitiaz St:
Entire WBC exits
Solomon Sea via Sol. St.
(No Pacific inflow).

Mean u_g on the Auckland-Solomon St XBT track

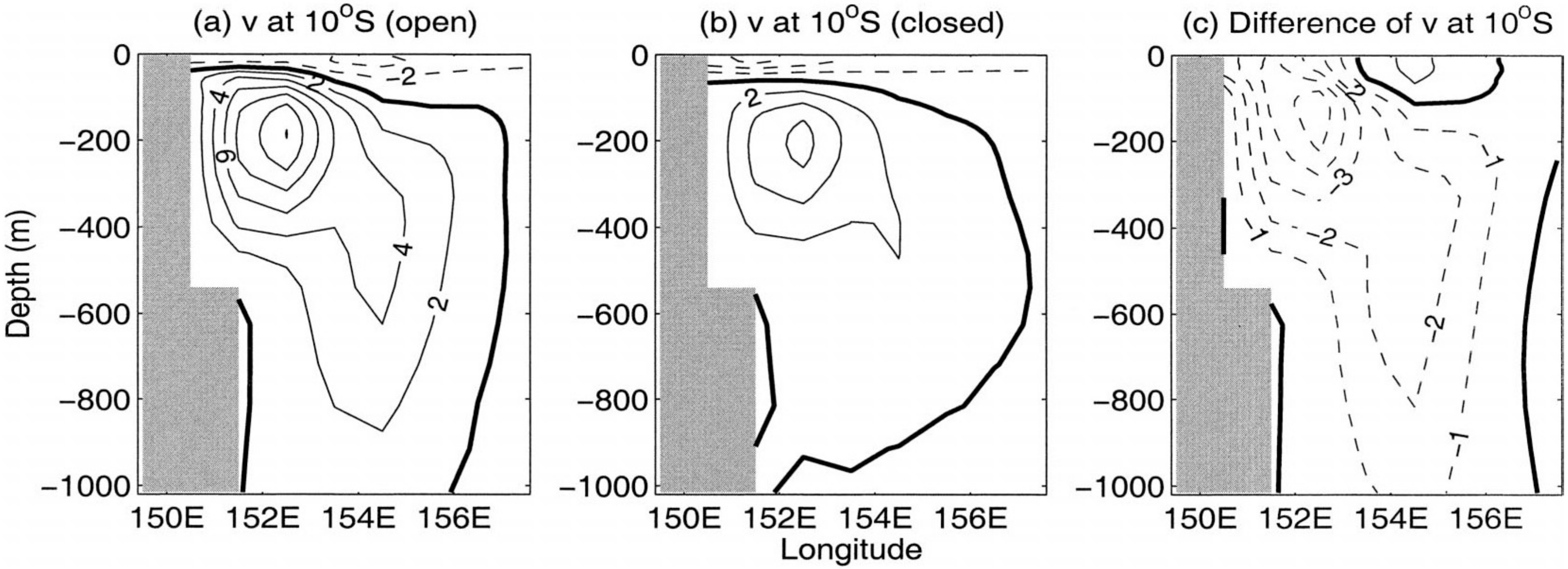
Cross-track velocity relative to 400m





An oblique XBT crossing of the Solomon Strait confirms ORCA model current reversal above the thermocline.

OGCM meridional current at 10°S with and without an ITF:

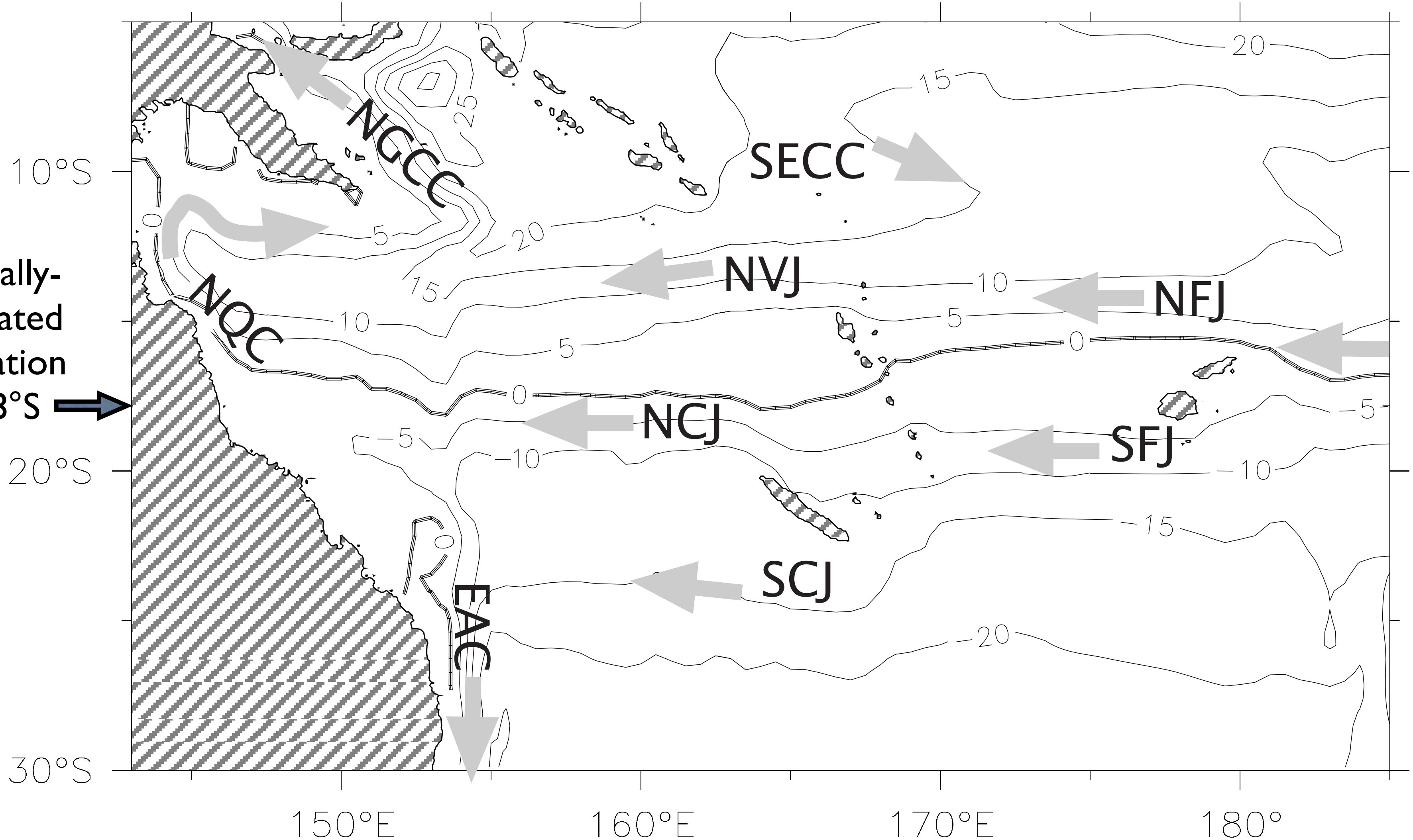


(Difference = effect of closing ITF)

Lee et al (2002)
MIT OGCM

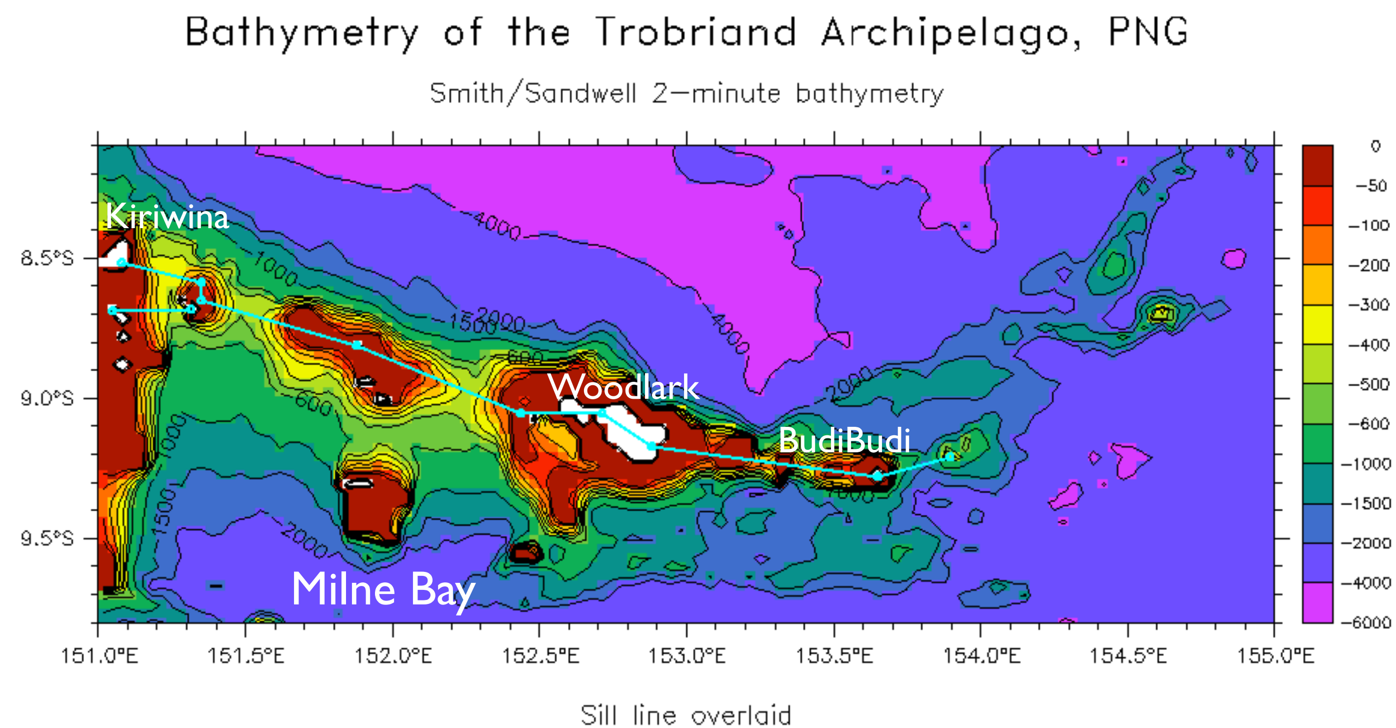
ORCA model streamfunction

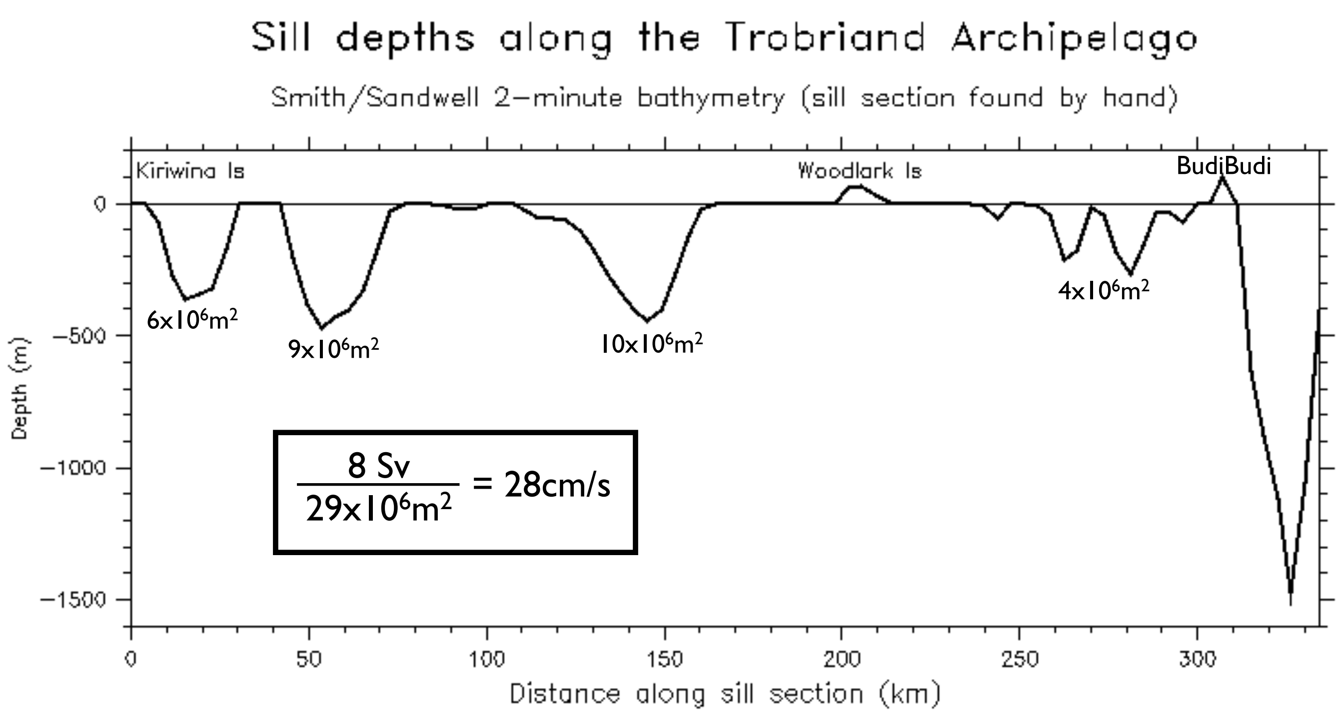
Vertically-integrated bifurcation at 18°S



Western Boundary Currents
EAC = East Australian Current
NQC = North Queensland Current
NGCC = New Guinea Coastal Current

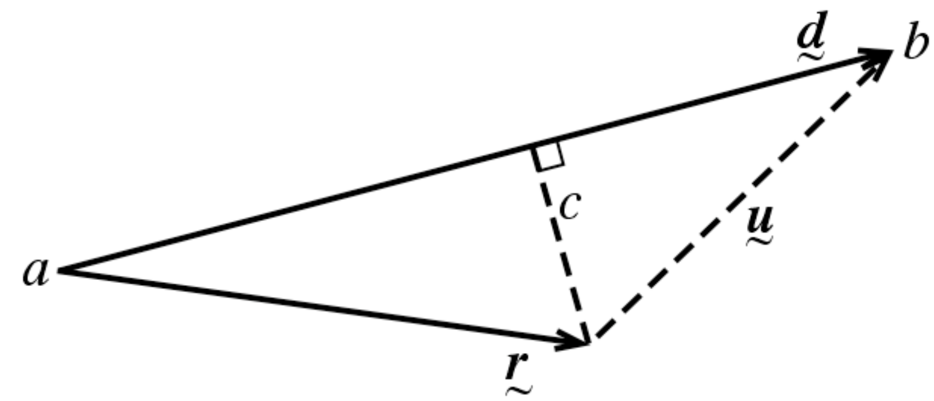
SECC = South Equatorial Countercurrent
N, SFJ = North, South Fiji Jet
NVJ = North Vanuatu Jet
N, SCJ = North, South Caledonian Jet





$$\frac{8\ \text{Sv}}{29\times10^{6}\text{m}^2} = 28\text{cm/s}$$

Absolute crosstrack geostrophic currents from glider motion and relative geostrophy



a,b = start,end points of dive

$\underset{\sim}{\boldsymbol{r}}$ = dead reckoning displacement

$\underset{\sim}{\boldsymbol{d}}$ = actual displacement

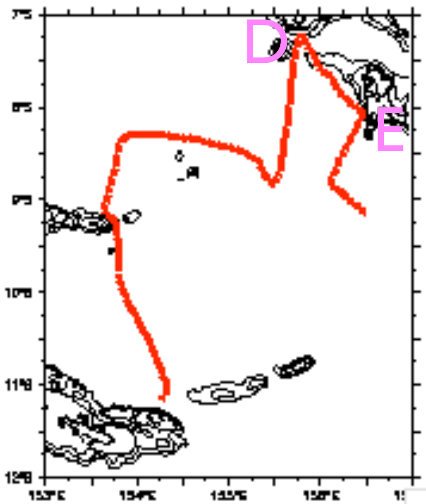
$\underset{\sim}{\boldsymbol{u}}$ = vector absolute velocity

c = crosstrack component of $\underset{\sim}{\boldsymbol{u}}$

The crosstrack absolute geostrophic current is:

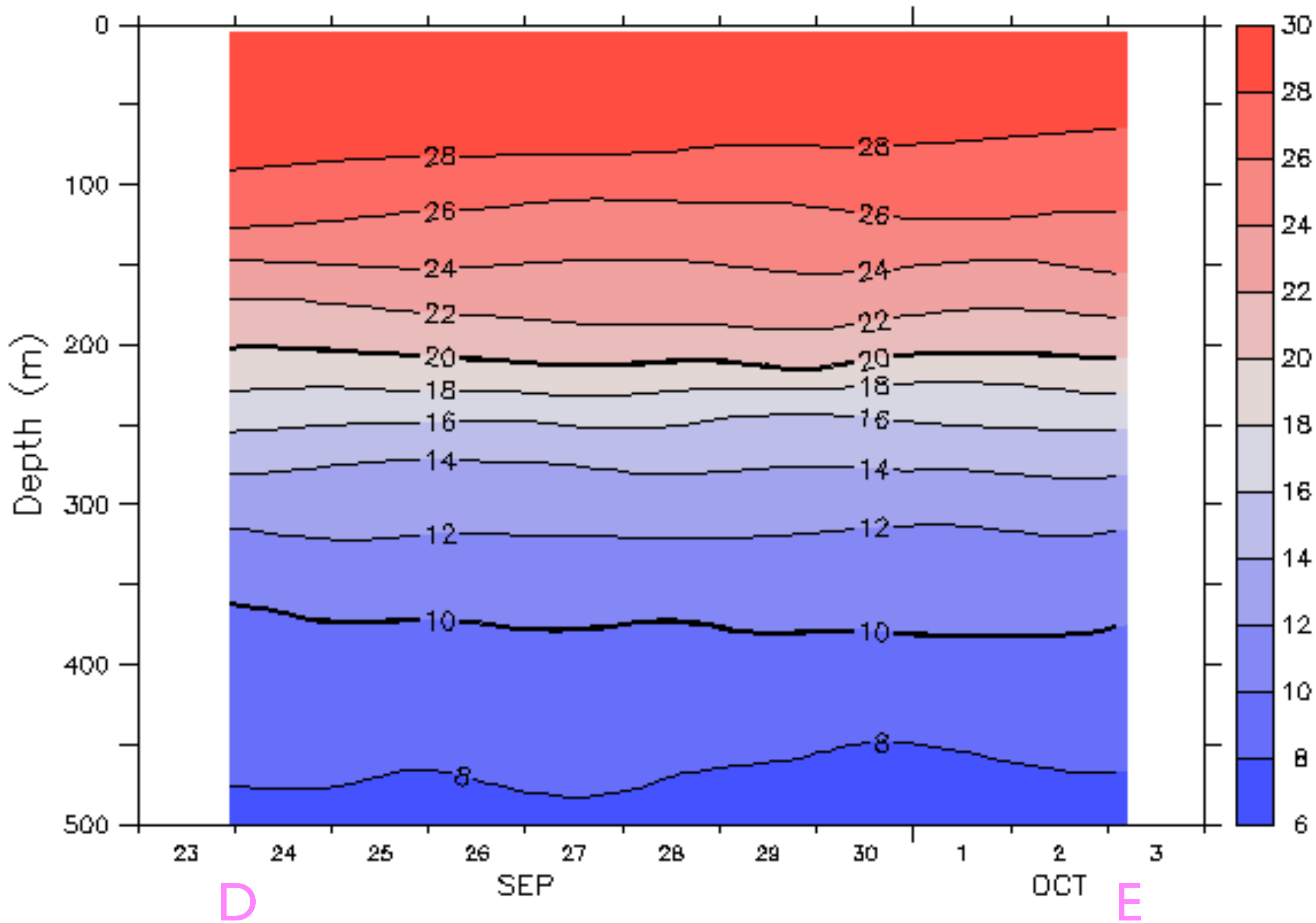
$$u_{g_a}(z) = u_g(z) - \overline{u_g}^{z} + c \qquad (1)$$

($u_g(z)$ = relative geostrophic shear, from DH difference from a to b, and $\overline{u_g}^{z}$ its vertical average)



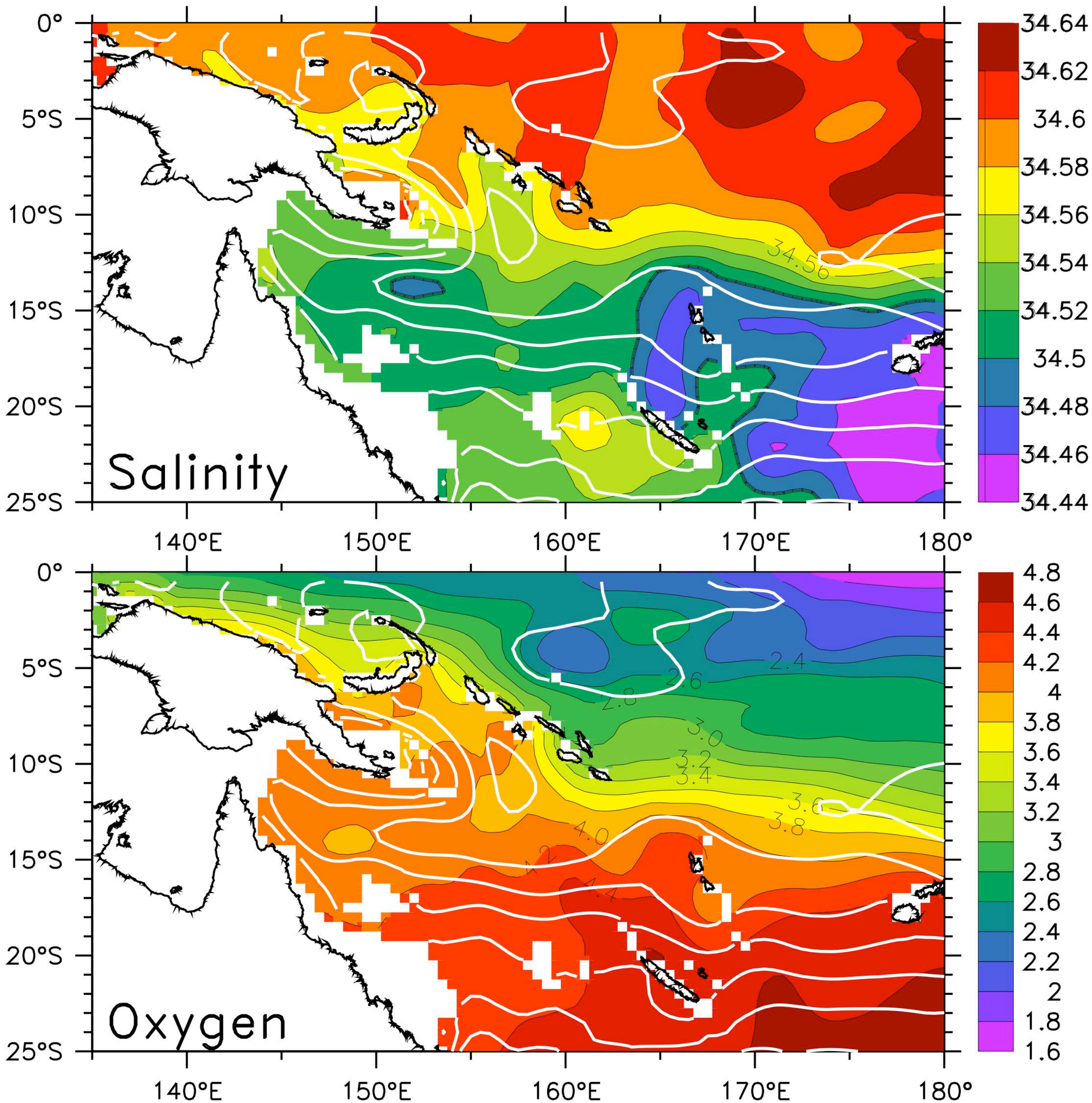
Temperature between Shortland and Ranongga

Tide-filtered. Dives 265-333



Salinity and Oxygen on Sigma-theta = 27

CARS data. Overlay streamlines on isopycnal

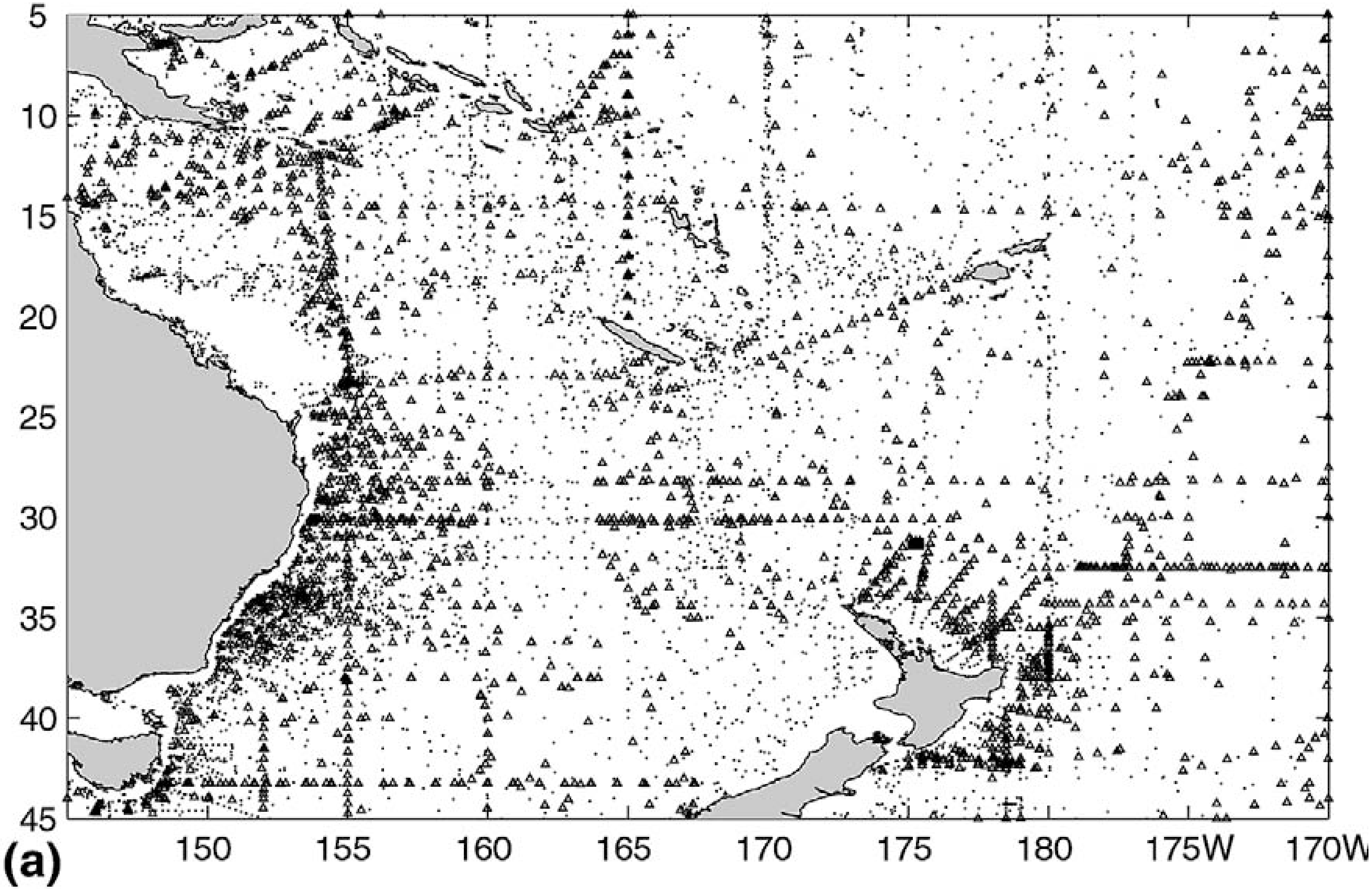


At sigma 27 (~6-800m), the sparse available data suggests that a low-S, high-O_2 tongue penetrates out of the Solomon Sea into the equatorial Pacific via the Australian WBCs.

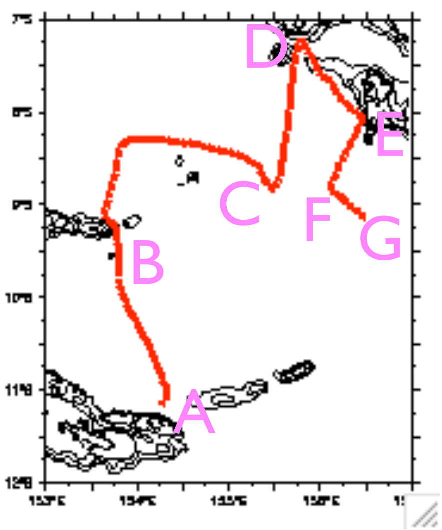
Available T/S profiles (CARS climatology)

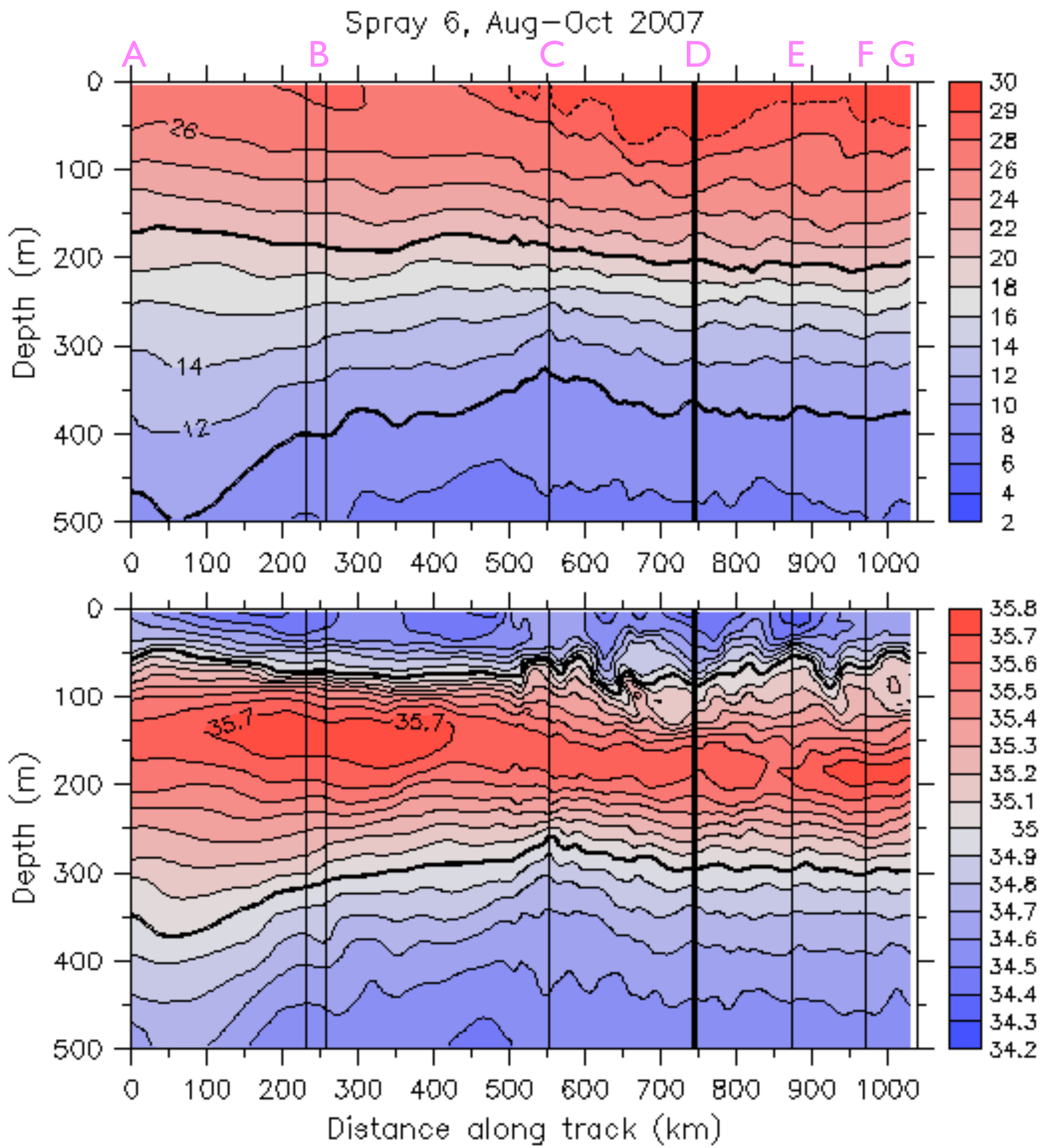
K.R. Ridgway, J.R. Dunn / Progress in Oceanography 56 (2003) 189–222

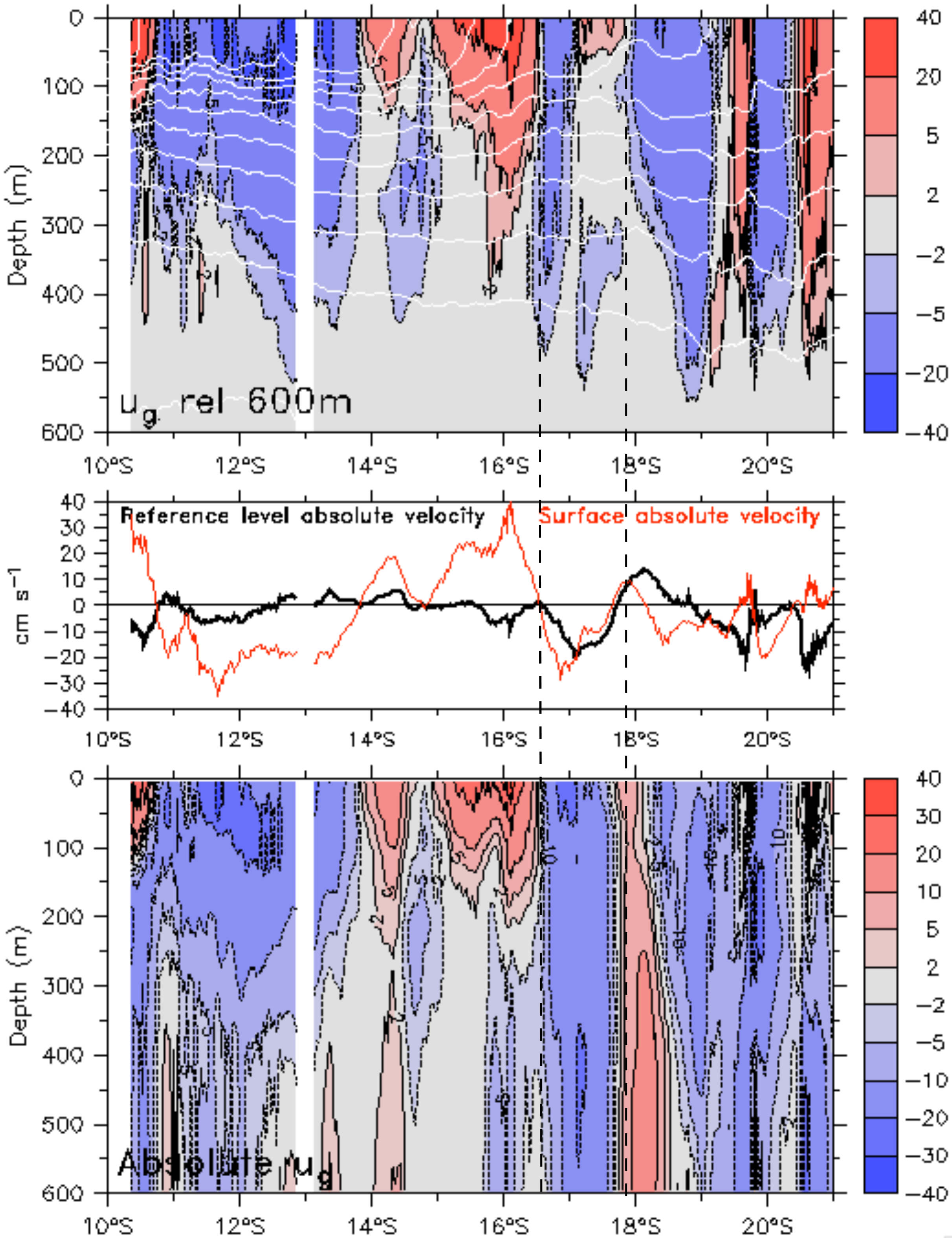
Dots > 500m; Triangles > 2000m



Temperature and salinity along the glider track





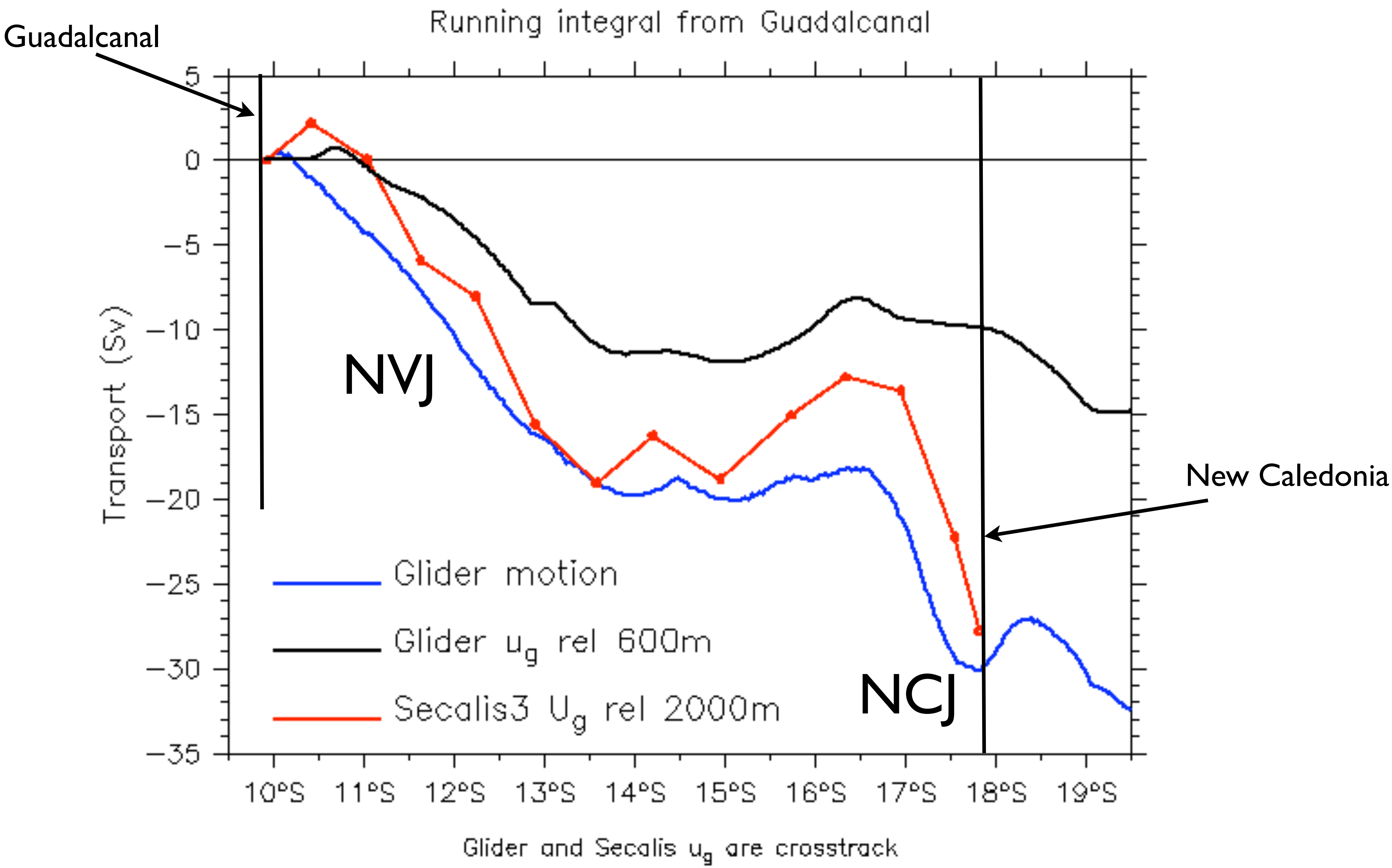


Knowing the glider motion gives the absolute geostrophic velocity

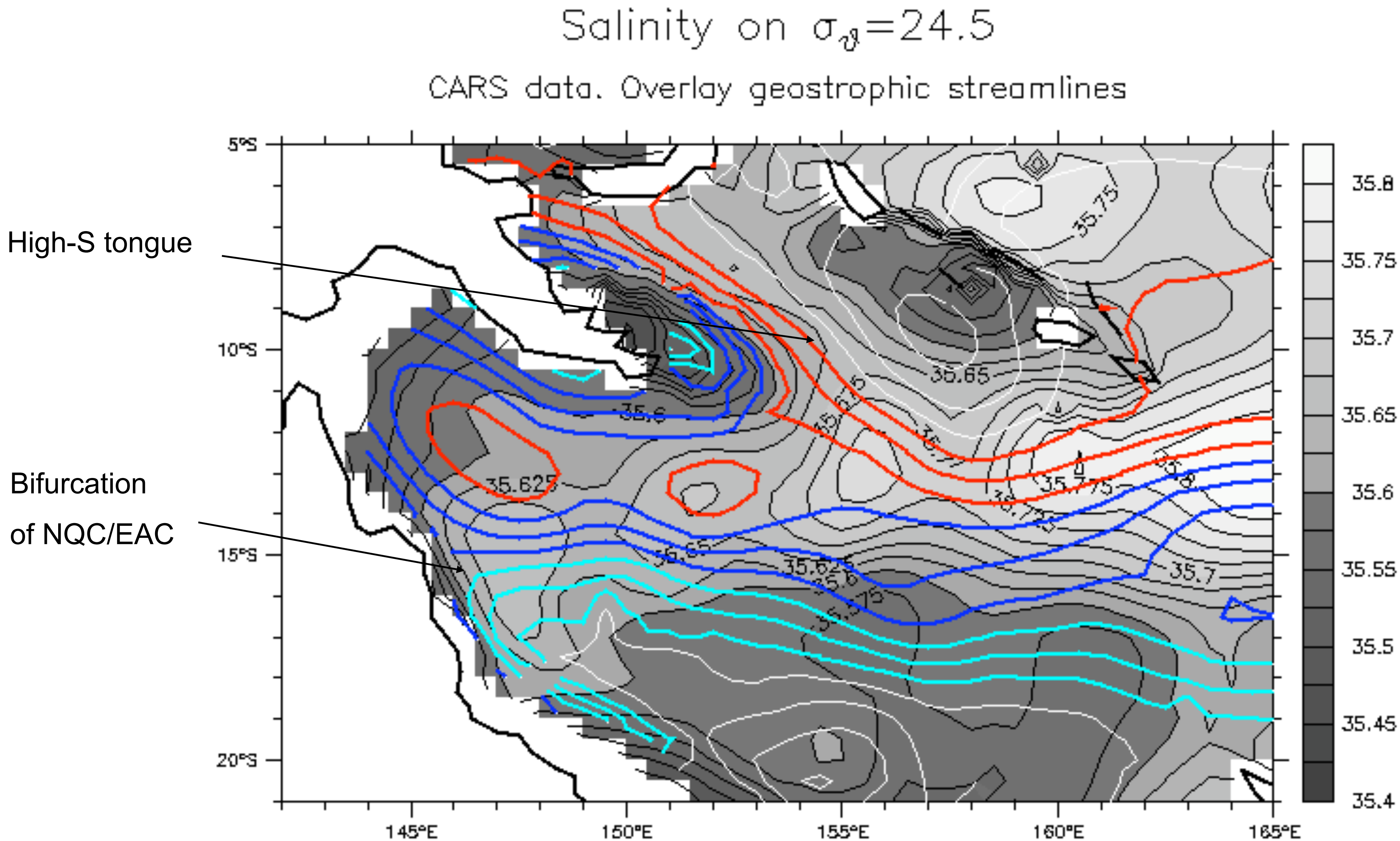
Traditional means of monitoring currents (XBTs) will not see the North Caledonian Jet.

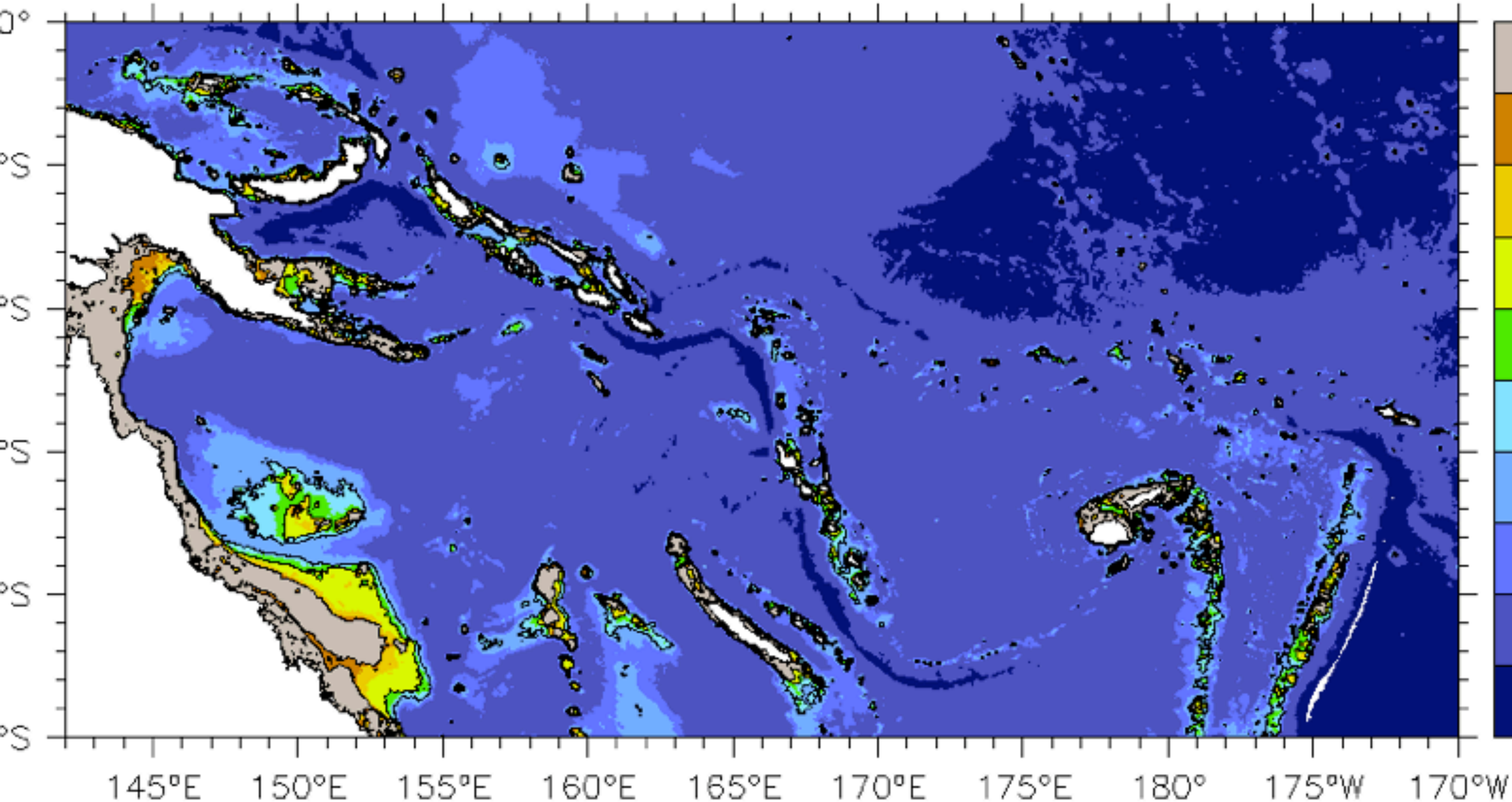
Zonal transport along the glider track

There are several ways to measure the transport



The high-S tongue enters the Solomon Sea from the open Pacific




0°
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160°E
165°E
170°E
175°E
180°
175°W
170°W