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

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(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.
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.

~10Sv AAIW

ITF Entrances?

ITF Exits

Shallower

Deeper
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

Salinity on isopycnals 24.5 and 27.2 (Levitus)

Subduction

AAIW
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 sigmaθ 24.5
El Niño winds (and curl) are large in the Southern hemisphere.


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

97-98

86-87

91-92

94-95

XBT track

Legend:

-30 -20 -15 -10 -5 0 10 15 20 25 30

-3 -2 -1 0 1 2 3

-30 -20 -15 -10 -5 0 10 15 20 30

-3 -2 -1 0 1 2 3
SEC transport has a strong ENSO signal

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

SOI leads El Niño SEC increase by a few months

Transport (Sv)


XBT transport

SOI (13-month triangle)
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

- 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.

25 cm/s (3-5 hr)
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.

Strong near-coastal circulation
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.
Crosstrack transport accumulated from Rossel Is.


Lower ticks show each 10th/50th dive
ADCP and glider currents in Milne Bay, PNG

S–ADCP from cruise MW9304 (Apr–May 1993, 0–200m average)

Spray6 (Aug 2007, 0–500m average, Dives 7–405)

3 straits ~20km wide, 400m deep
ADCP and glider currents in the eastern Solomon Sea

S–ADCP from cruise KM0410 (Oct–Nov 2004, 0–500m average)

Absolute crosstrack $u_g$

$$u_{g\, \text{abs}}(z) = u_{g\, \text{rel}}(z) - u_{g\, \text{rel}} + u_{\text{cross\, abs}} - u_{\text{Ekman}}$$
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

Spray 6, Aug–Oct 2007. On sigma-theta and distance from Rossel Is, PNG

(Light-blue lines show temperature)
Salinity and absolute $u_g$ at $\sigma_\theta$ 24.5

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

Tide-filtered
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?
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.

Continual monitoring is crucial to the climate signals that determine the properties of the equatorial thermocline.

- 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.
Extra

Figures

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

TRMM satellite surface rain rate
1998–2006 mean, m yr$^{-1}$, 0.5° grid

ITCZ
SPCZ
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.

SW-ward at surface

NE-ward below
OGCM meridional current at 10°S with and without an ITF:

(a) \(v\) at 10°S (open)
(b) \(v\) at 10°S (closed)
(c) Difference of \(v\) at 10°S

(Difference = effect of closing ITF)

Lee et al (2002)
MIT OGCM
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
Bathymetry of the Trobriand Archipelago, PNG

Sill depths along the Trobriand Archipelago

\[
\frac{8 \text{ Sv}}{29 \times 10^6 \text{m}^2} = 28 \text{cm/s}
\]
Absolute **crosstrack** geostrophic currents from glider motion and relative geostrophy

\[ a, b = \text{start, end points of dive} \]
\[ \tilde{r} = \text{dead reckoning displacement} \]
\[ d = \text{actual displacement} \]
\[ u = \text{vector absolute velocity} \]
\[ c = \text{crosstrack component of} \ u \]

The crosstrack absolute geostrophic current is:

\[ u_{g,a}(z) = u_g(z) - \overline{u_g} + c \quad (1) \]

\( u_g(z) = \text{relative geostrophic shear, from DH difference from} \ a \text{ to} \ b, \)
\( \text{and} \ \overline{u_g} \text{ its vertical average} \)
Temperature between Shortland and Ranongga

Tide-filtered, Dives 265–333
At sigma 27 (~6-800m), the sparse available data suggests that a low-S, high-O₂ tongue penetrates out of the Solomon Sea into the equatorial Pacific via the Australian WBCs.
Available T/S profiles (CARS climatology)


Dots > 500m; Triangles > 2000m
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

Running integral from Guadalcanal

Guadalcanal

NVJ

New Caledonia

NCJ

Glider motion

Glider \( u_g \) rel 600m

Secalis3 \( U_g \) rel 2000m

Glider and Secalis \( u_g \) are crosstrack
The high-S tongue enters the Solomon Sea from the open Pacific.

**Salinity on \( \sigma_g = 24.5 \)**

CARS data. Overlay geostrophic streamlines.

- **High-S tongue**
- **Bifurcation of NQC/EAC**