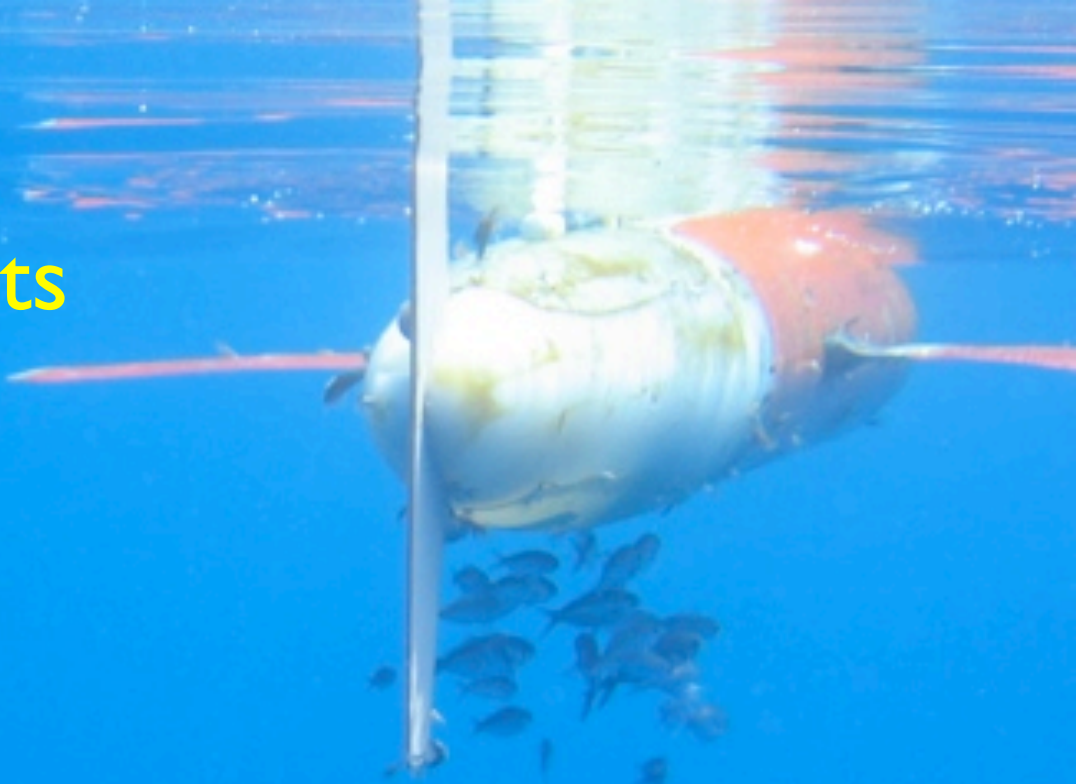
Measuring South Pacific low-latitude western boundary currents with ocean gliders: A pilot study

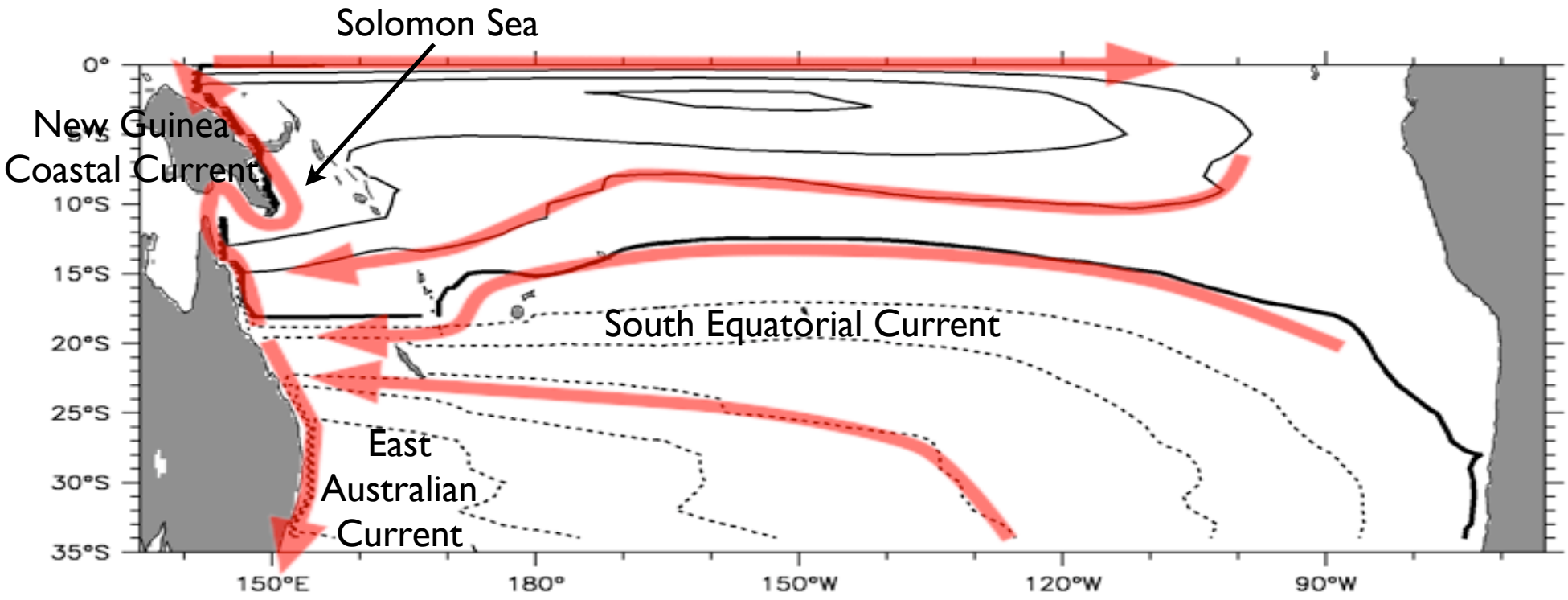


William S. Kessler
NOAA / PMEL, Seattle USA

Russ Davis and Jeff Sherman
(Scripps Institution of Oceanography, La Jolla USA)

Lionel Gourdeau
(Institut de Recherche pour le Developpement, Noumea, New Caledonia)

Scientific context: South Pacific circulation

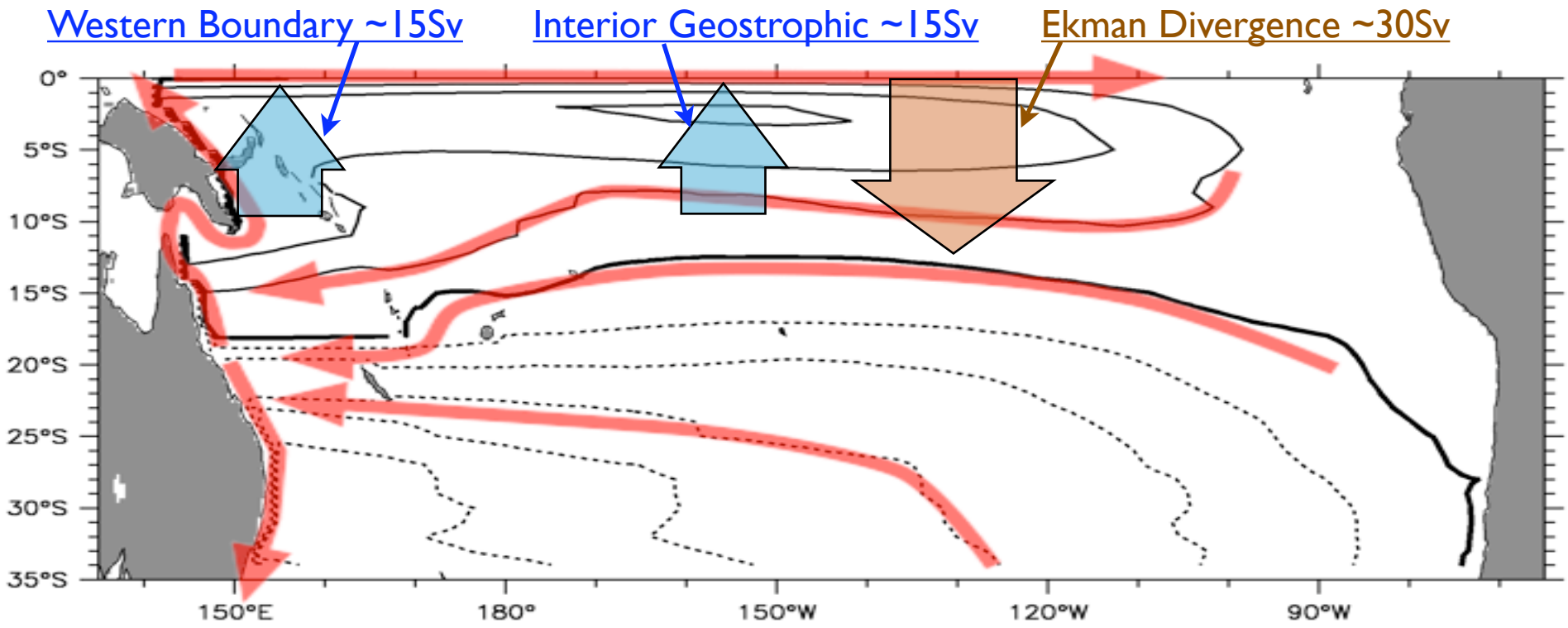


The vertically-integrated circulation shows two gyres with a bifurcation near 18°S.
(Sverdrup/Island Rule transport from scatterometer winds).

About half the SEC transport goes north through the Solomon Sea.

Mean Solomon Sea transport is 15-20 Sv.

Scientific context: South Pacific circulation



Work on the subtropical-equatorial exchange* points to the importance of the western boundary limb of the circulation: Transport that determines the properties (temperature, salinity, carbon content) of the equatorial cold tongue.

Our goal is a sustained time series of the western boundary transport to the equator.

* Papers by Johnson, McPhaden, Zhang

Programmatic context: Climate prediction

NOAA Strategic Plan - Mission Goal (Climate):

A predictive understanding of the global climate system on time scales of weeks to decades, with quantified uncertainties sufficient for making informed and reasoned decisions.

NOAA Research Plan - (Climate goal):

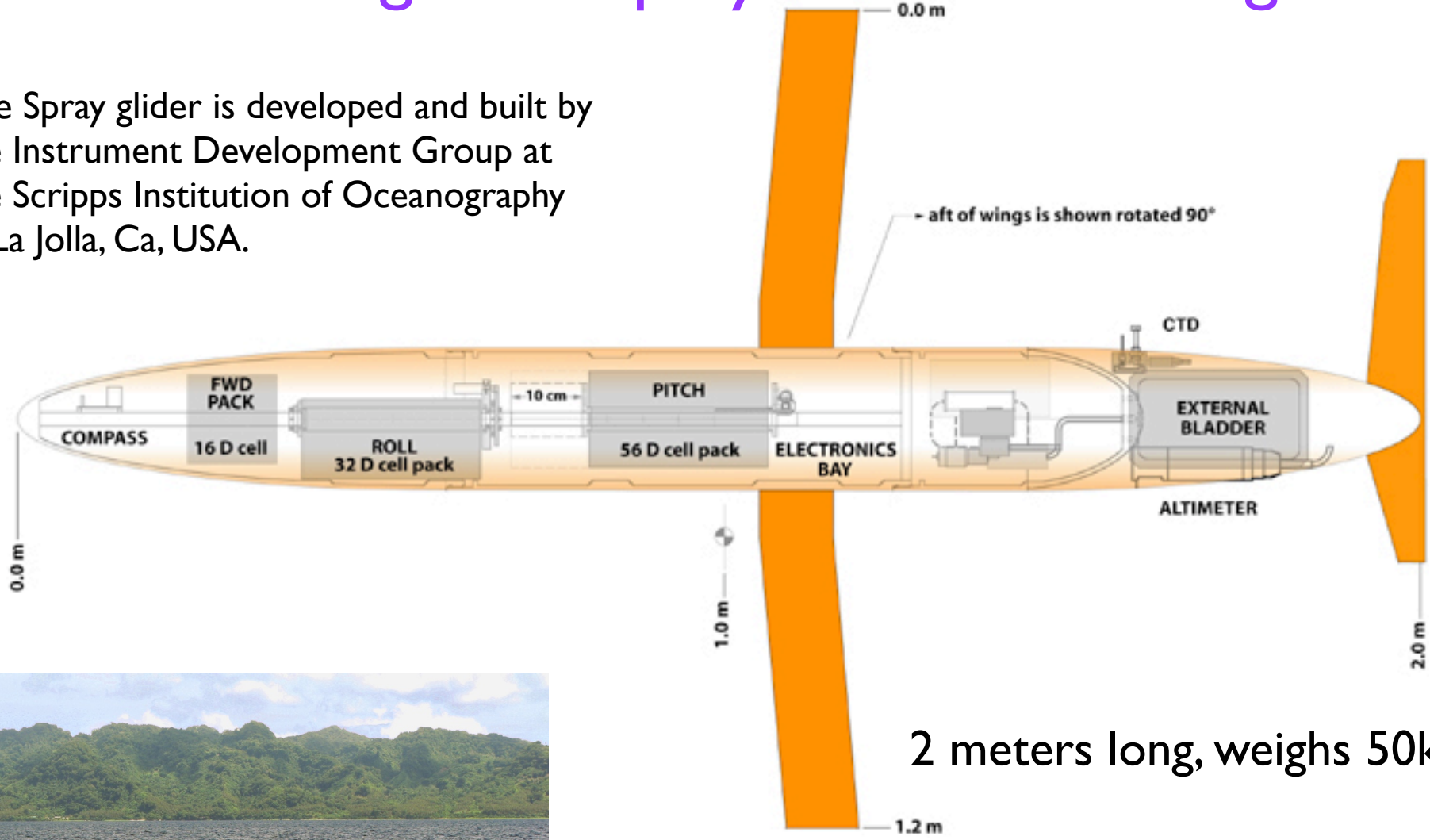
- Describe and understand the state of the climate system through integrated observations, analysis and data stewardship.
- Improve climate predictive capability from weeks to decades.
- Increase number and use of climate products and services to enhance public and private sector decision making.

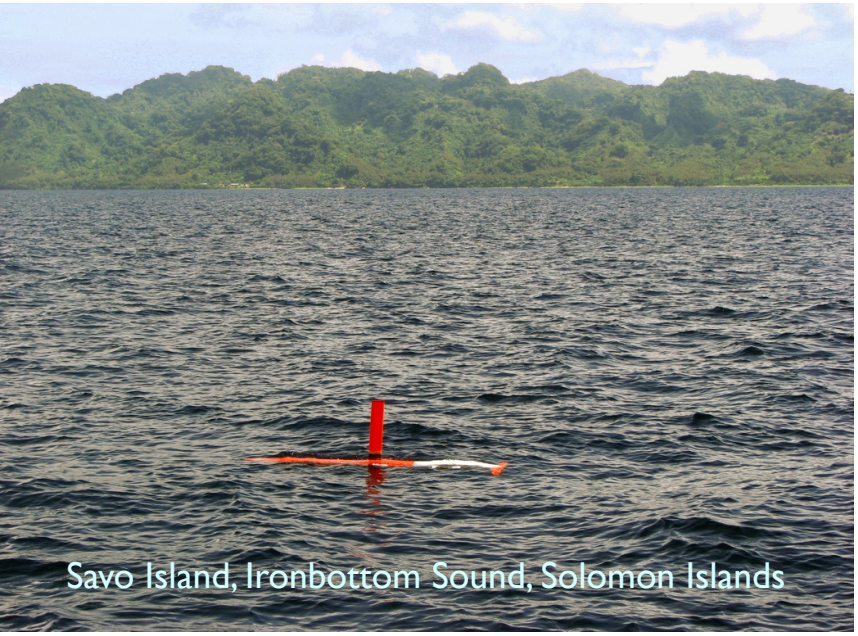
Funding

CPO Climate Observations funds to Scripps CORC and PMEL

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.



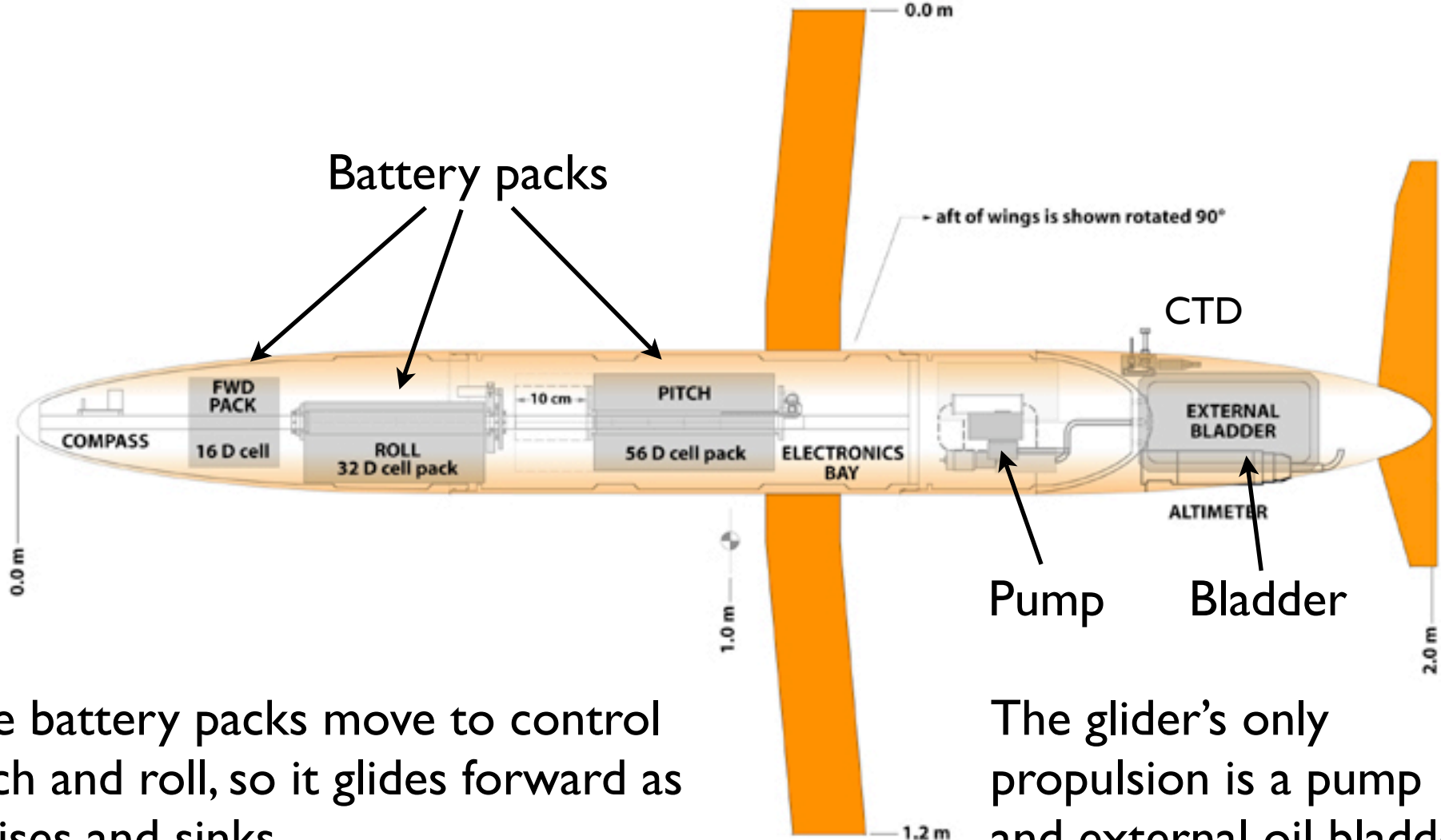

Savo Island, Ironbottom Sound, Solomon Islands

2 meters long, weighs 50kg

⇒ Work from small boats near shore, much cheaper than a ship.

Cost to build: about $50K

The glider is essentially an Argo float with wings and moveable batteries

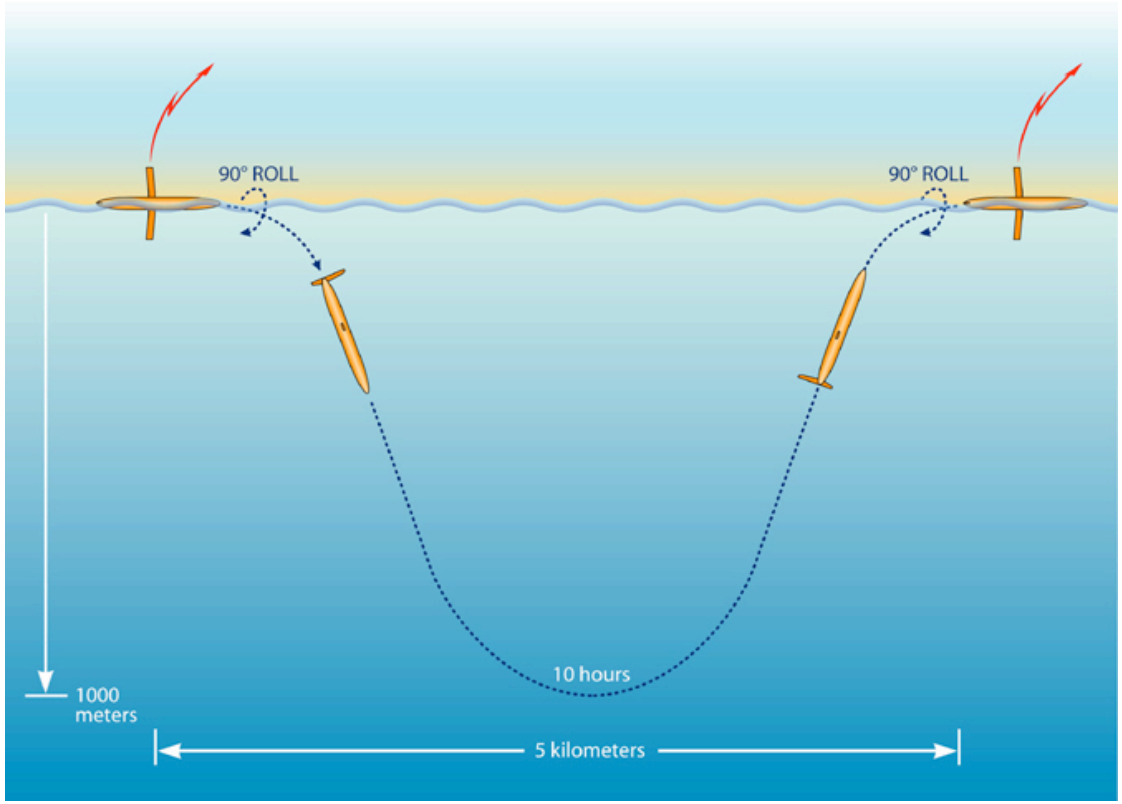


The battery packs move to control pitch and roll, so it glides forward as it rises and sinks.

It moves very slowly (20 km/day).

The glider's only propulsion is a pump and external oil bladder. The pump inflates and deflates the bladder to change its density.

A dive of the Spray glider



500-1000 m

← 3 km →

20 cm/s

(3-5 hr)

Range about 4 months or 2000km

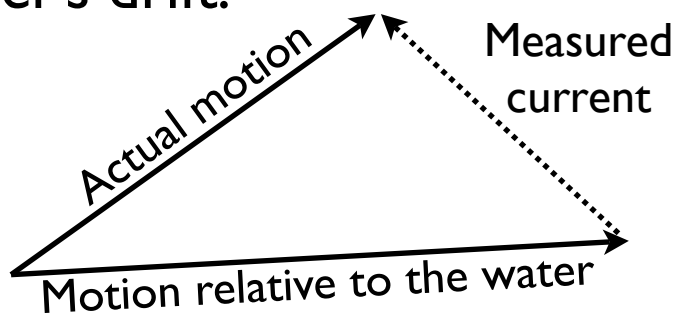
A glider dives to 500-1000m, taking 3-5 hours, and moves forward about 2-4 km.

→ Very dense sampling

CTD measures, plus ....

Data reported by Iridium satellite each time it surfaces.

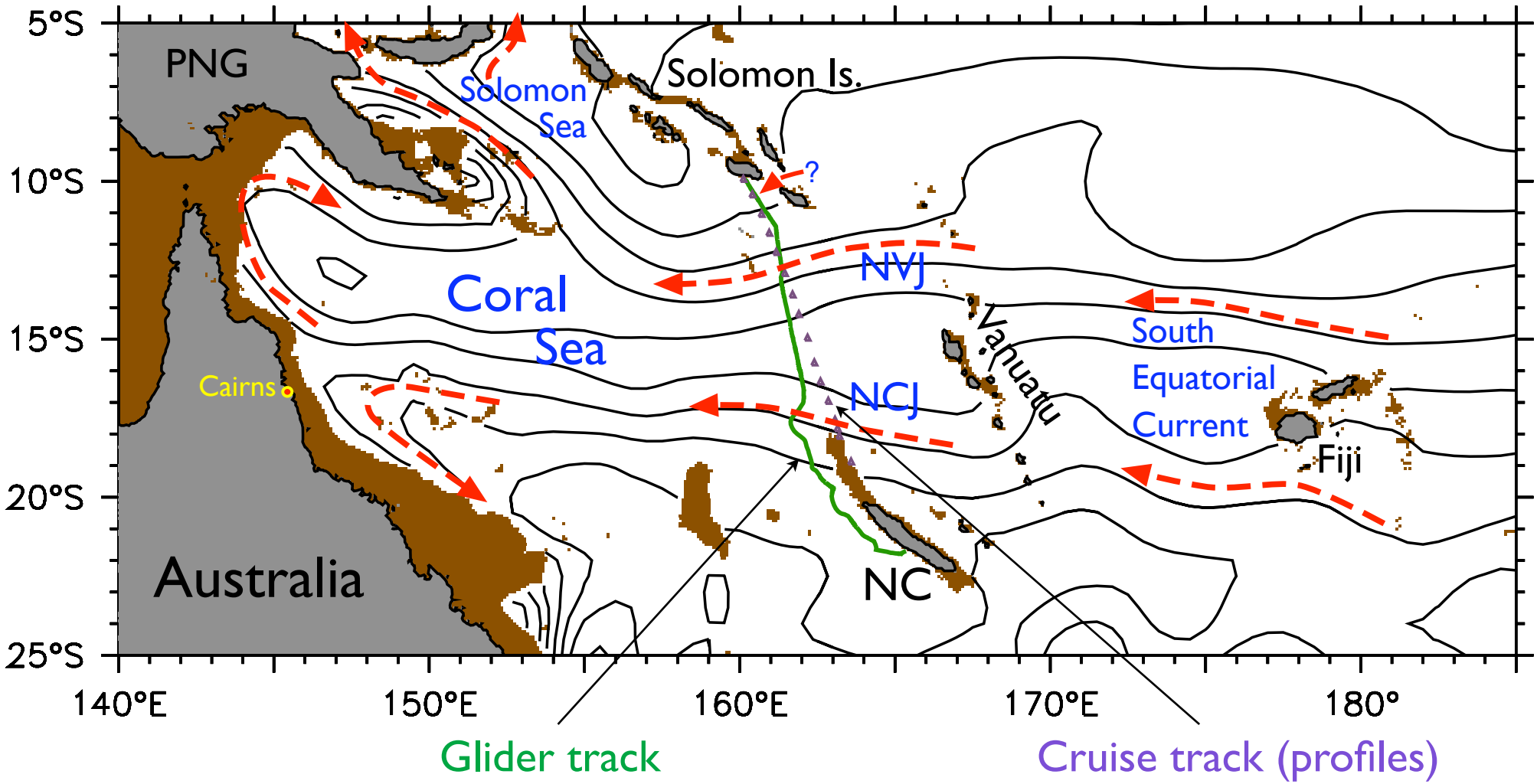
Estimate vertical-average absolute currents by the glider's drift:



First 2 missions from Guadalcanal to New Caledonia in 2005-6,
but this is an inappropriate use of the technology.

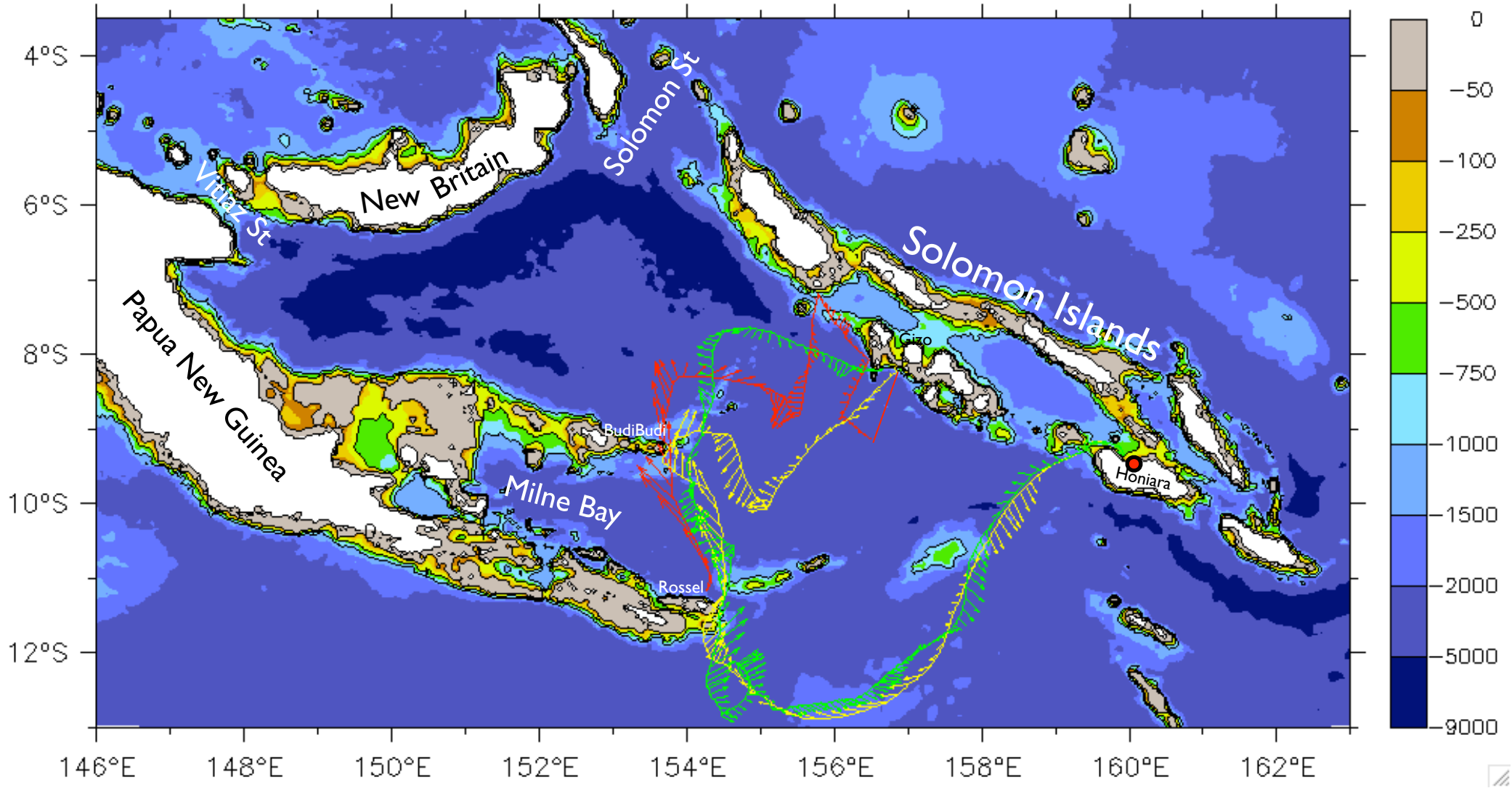
The 3km/3-4hr dives of the glider oversample the ocean interior,
and its slow travel time aliases time variability.

⇒ Best used in coastal regions and for boundary currents



(Gourdeau et al, JPO 08)

4 glider surveys so far (3 completed, 1 in progress)



Red = Aug-Nov 07 (Rossel, PNG to Gizo, Solomon Islands)

Yellow = Nov 07-Feb 08 (Honiara to Gizo via Rossel)

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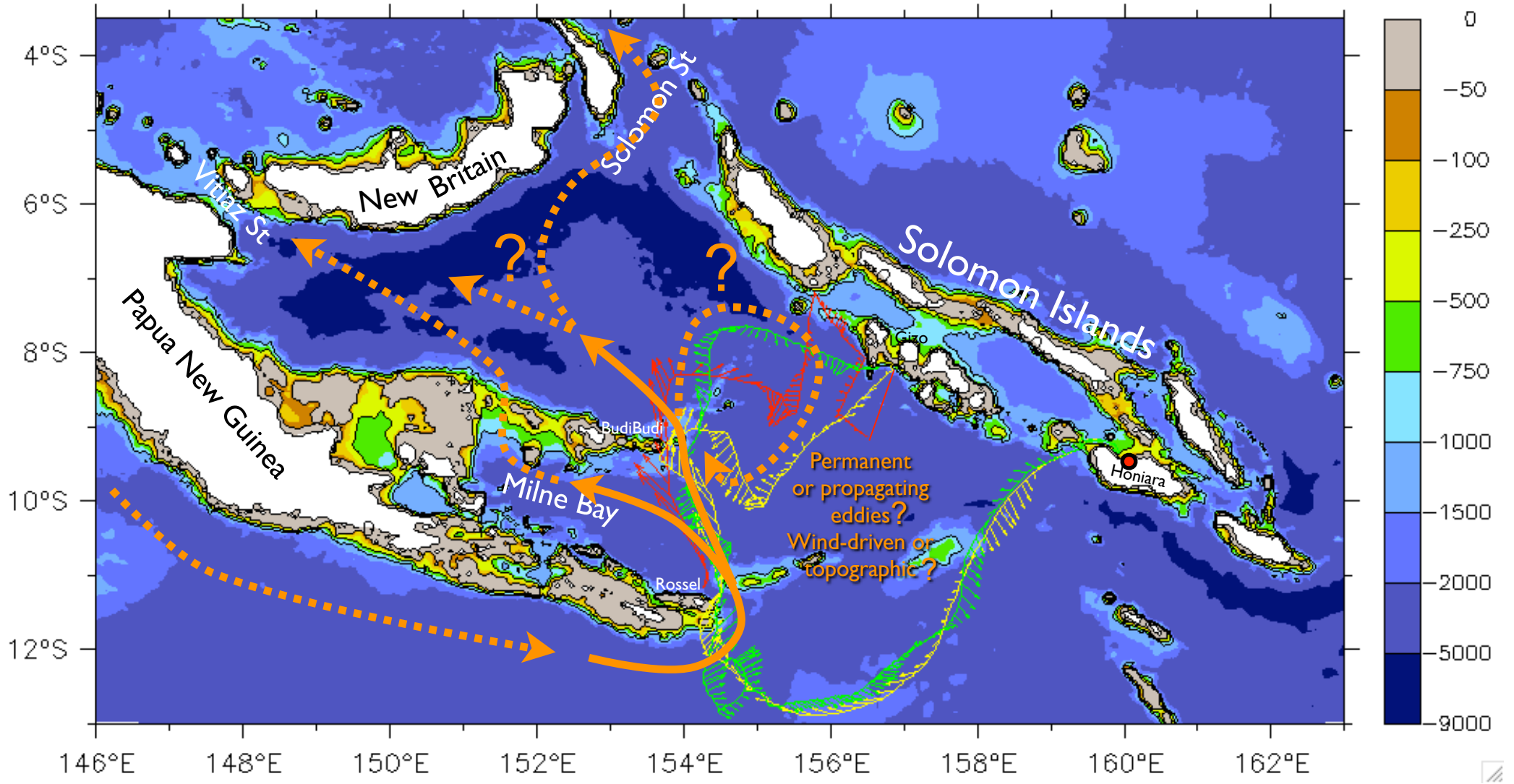

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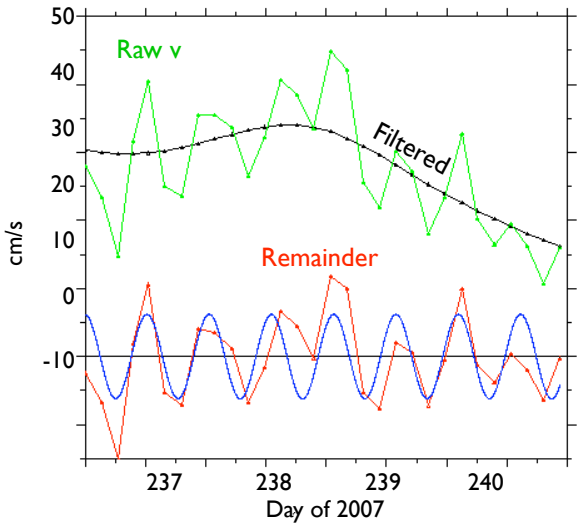
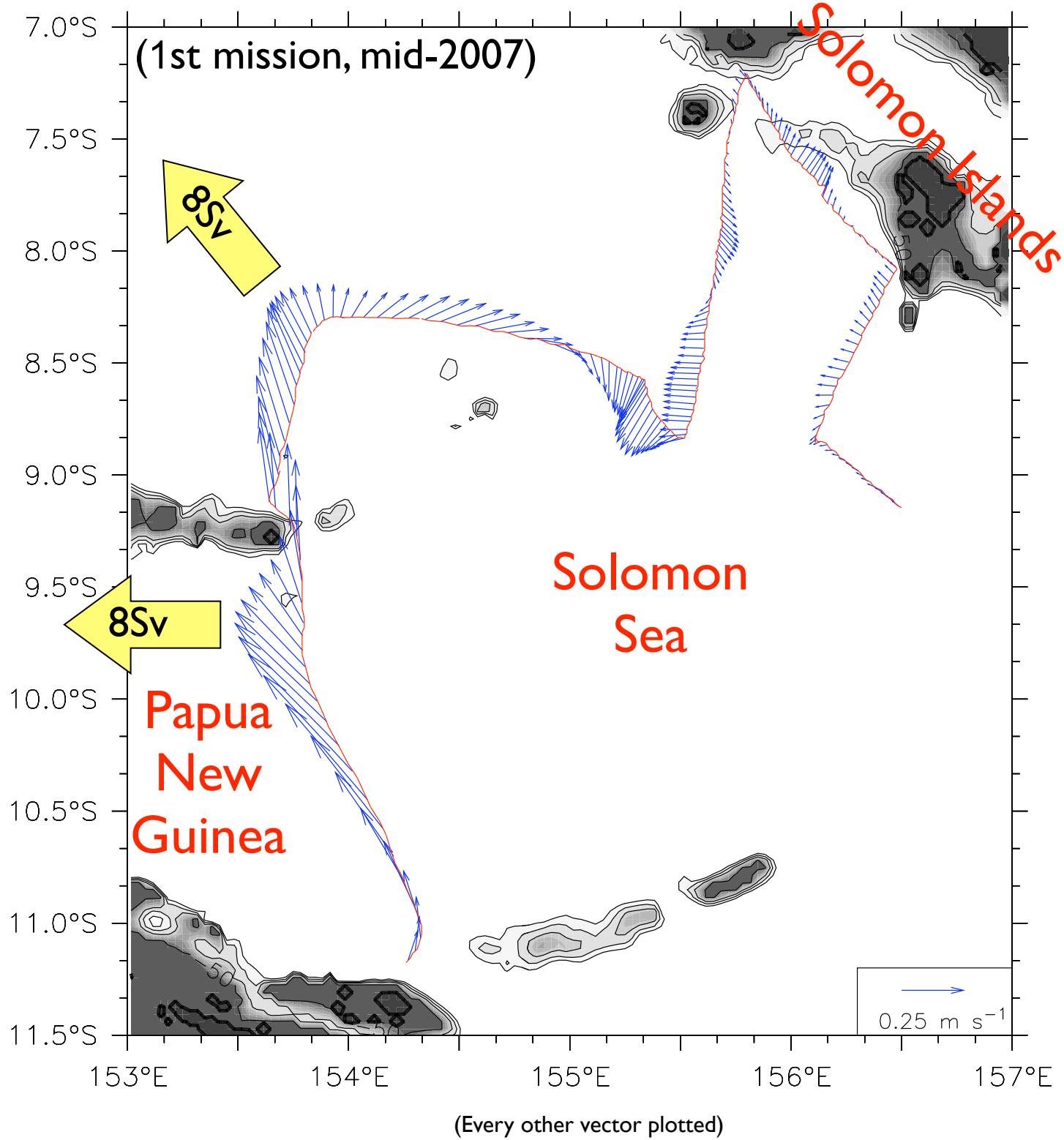
Vector absolute current above 500m

(Tide-filtered)

An example of tide-filtering

Gaussian objective mapping with a time-scale of 1.5 days.

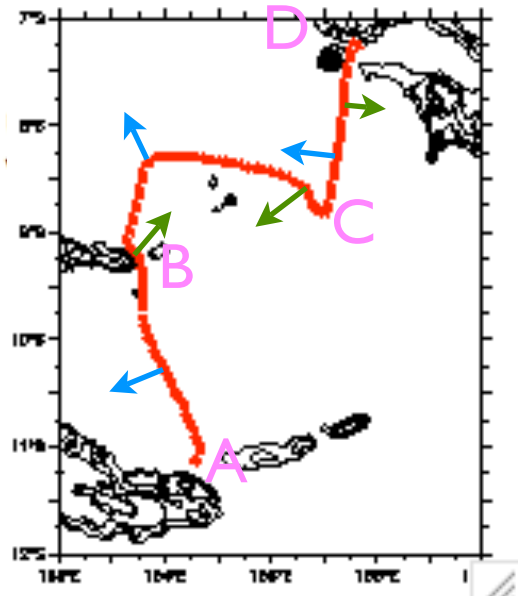




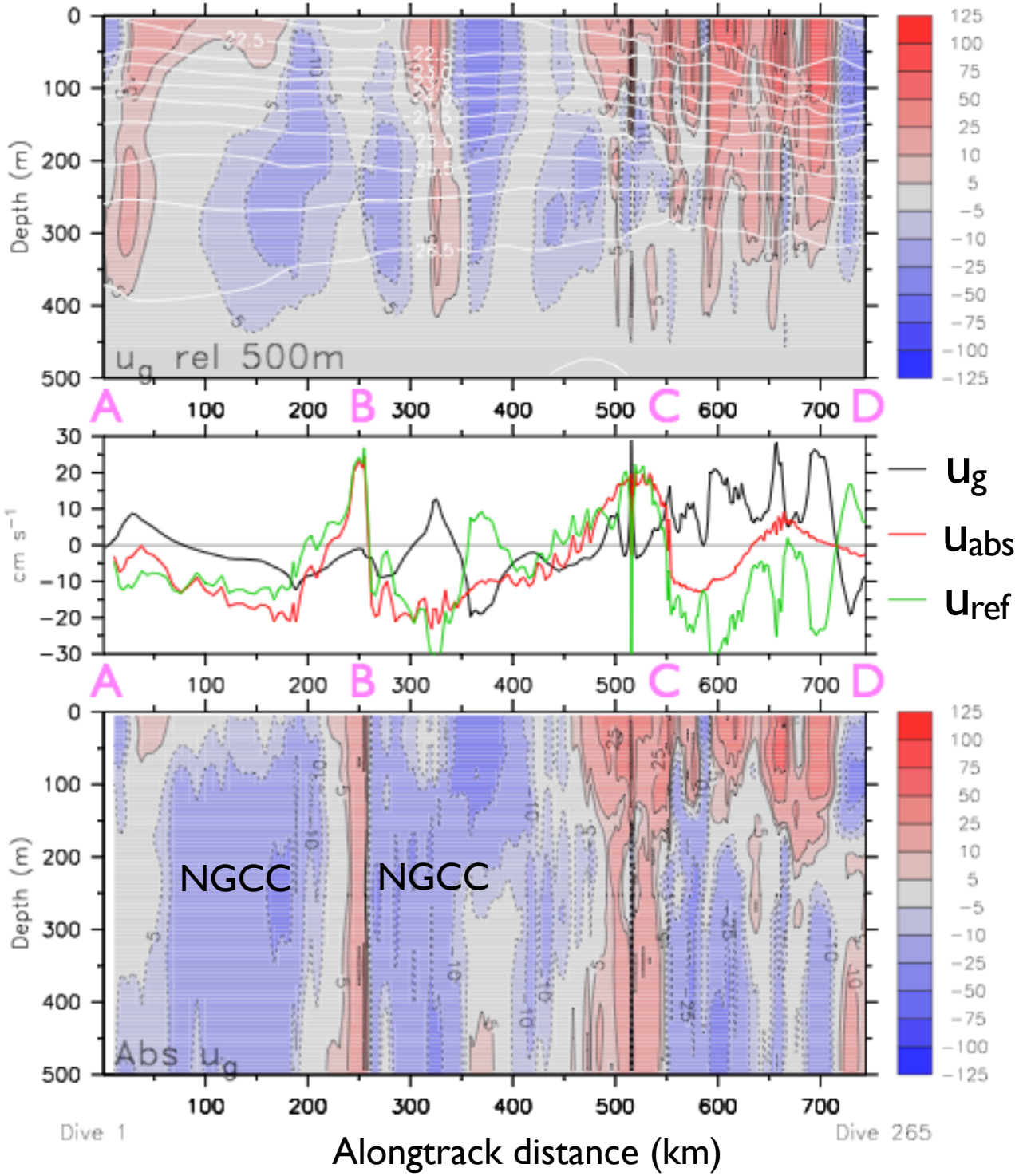
(Every other vector plotted)

Absolute crosstrack geostrophic currents from glider motion and relative geostrophy

1st mission



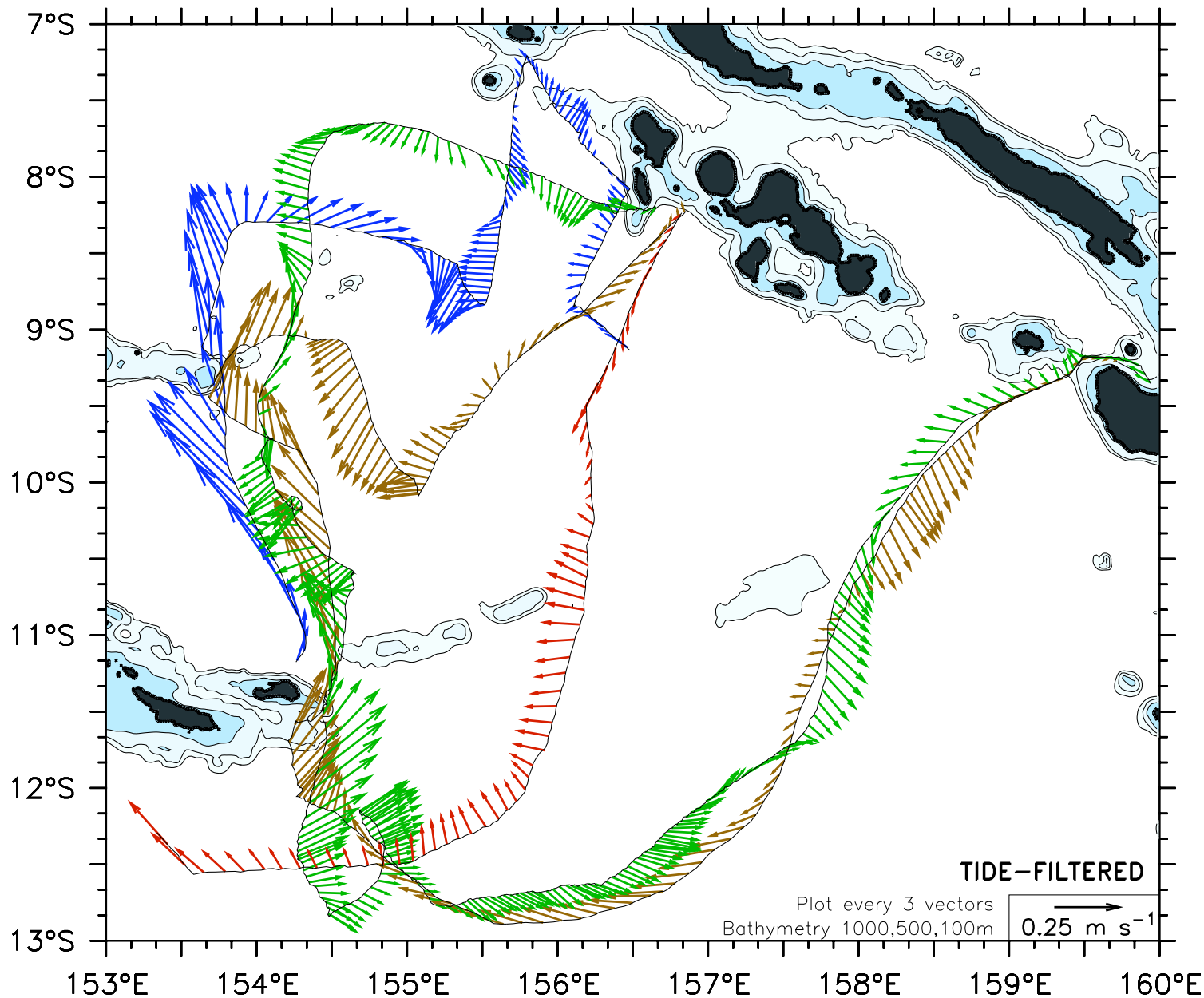
Isopycnals above 25 slope down across the Solomon Sea.
Upper shear is *southward*: WBC is an undercurrent.



Glider currents in the Solomon Sea

After 4 missions, is there a discernable "background"?

- The only consistent feature is a strong NGCC.
- Perhaps a consistent SW-ward flow in the northeast.

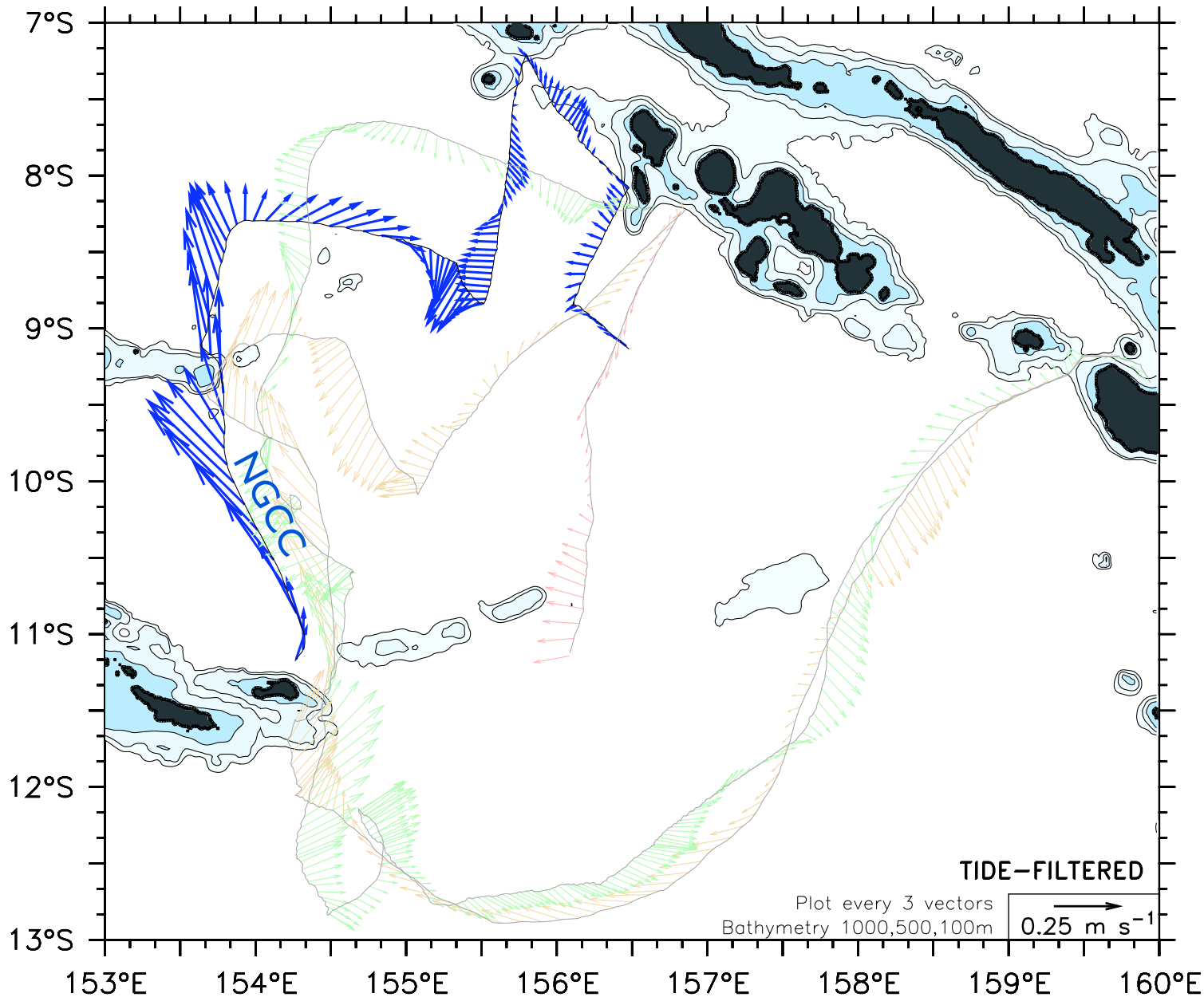


Glider currents in the Solomon Sea

Spray6 (Aug–Oct 07). Spray18 (Nov 07–Feb 08), Spray1 (Feb–Jul 08) Spray6 (Launch 4 July 08)

Pre-La Niña, "normal"

- Strong NGCC, ~18Sv.
- Surprising that perhaps half the transport flowed through the narrow channels and reefs of PNG.

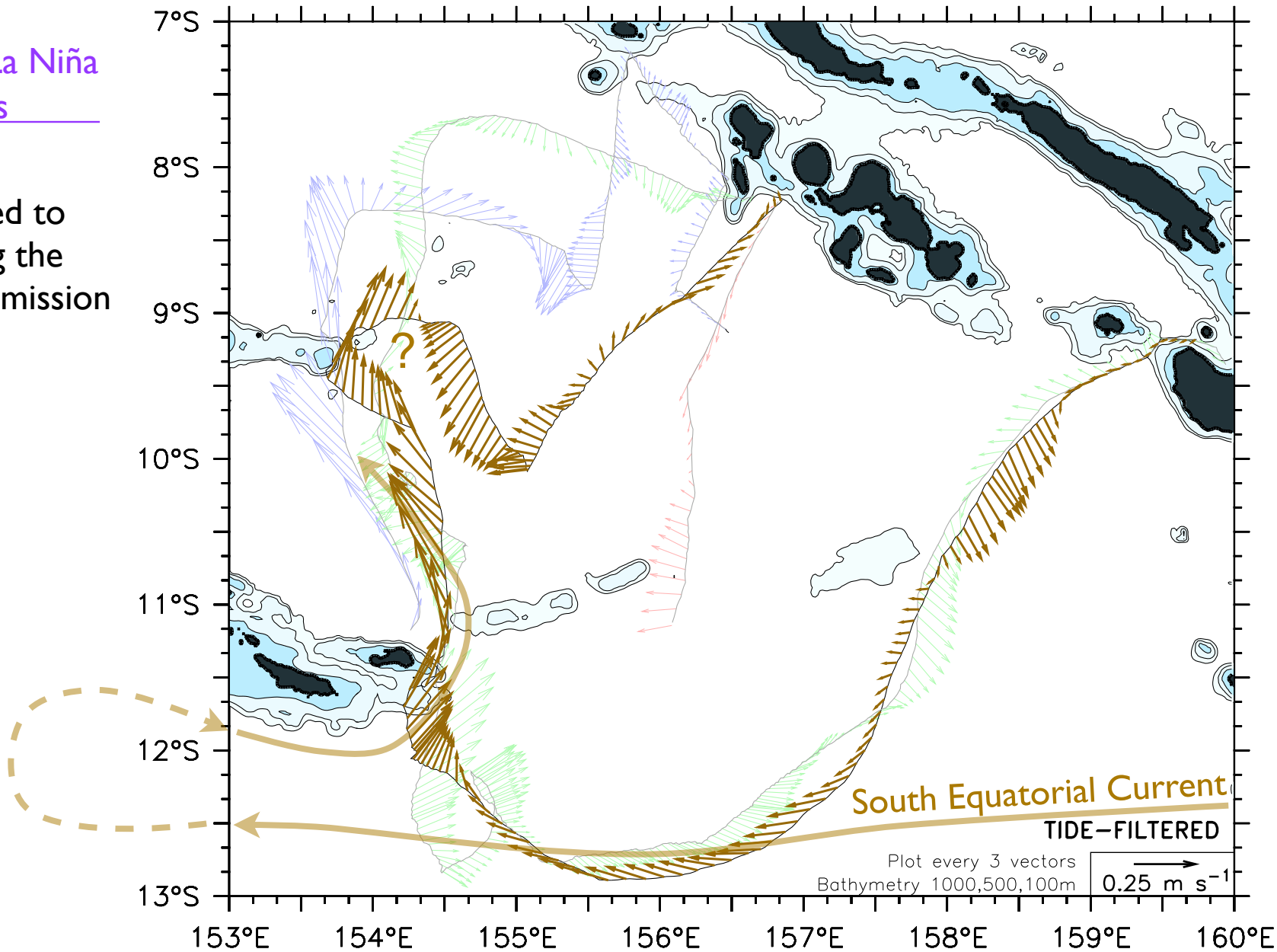


Glider currents in the Solomon Sea

Spray6 (Aug–Oct 07), **Spray18 (Nov 07–Feb 08),** Spray1 (Feb–Jul 08) Spray6 (Launch 4 July 08)

Arrival of the La Niña Rossby waves

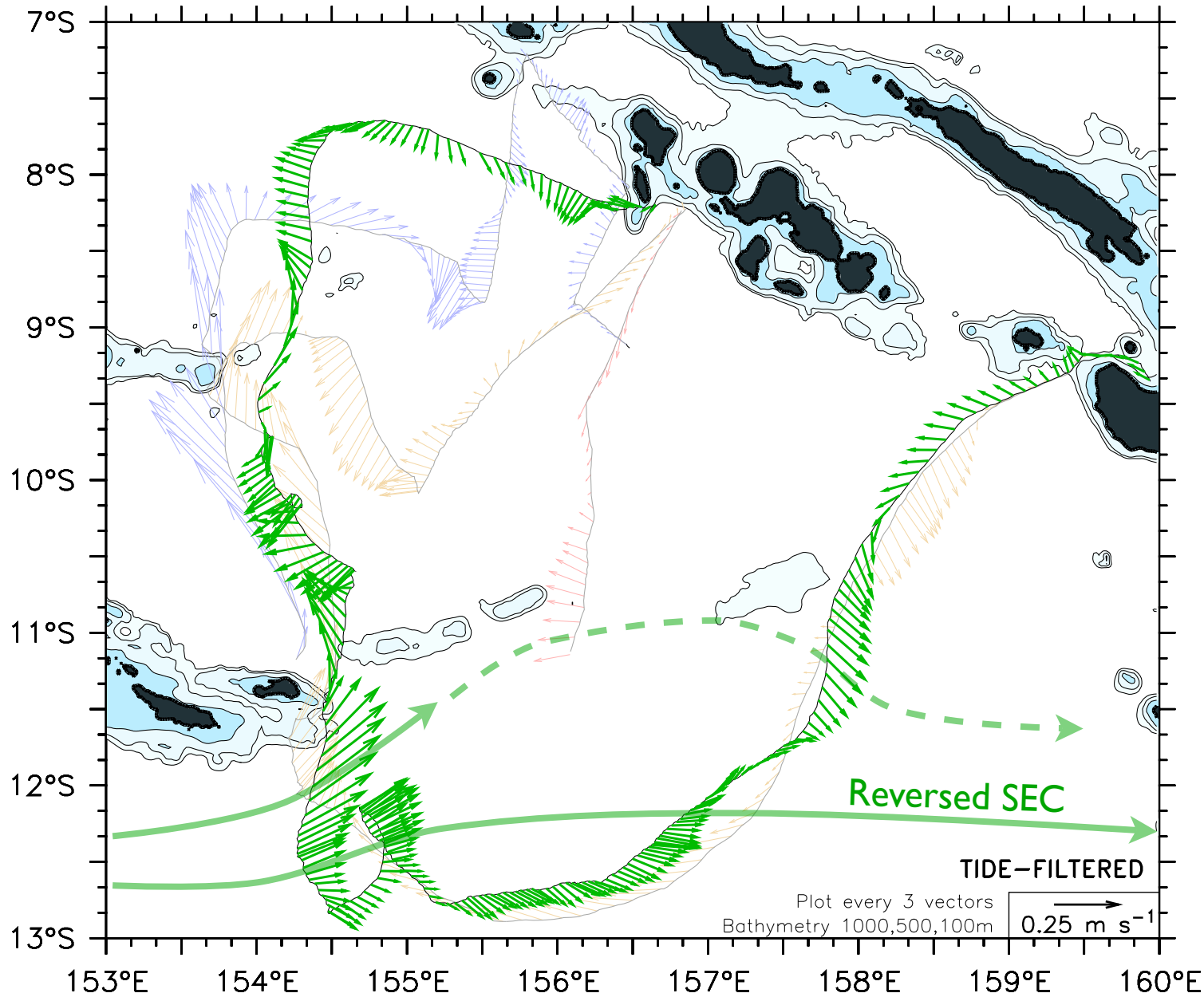
- Strong SEC
- NGCC seemed to reverse during the course of the mission (???)



Glider currents in the Solomon Sea

Late in the La Niña

- SEC reversed !
- Weak, disorganized NGCC.

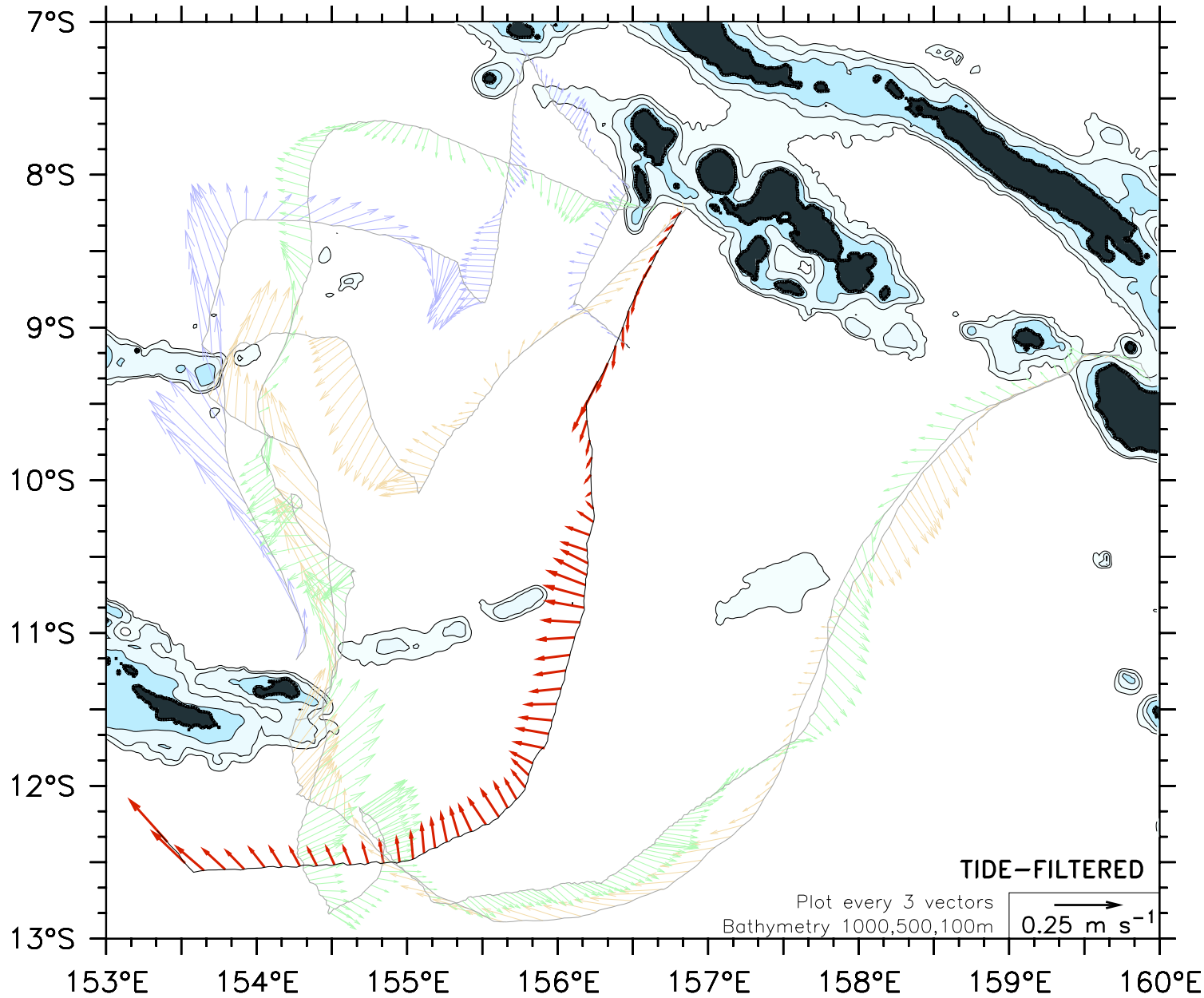


Glider currents in the Solomon Sea

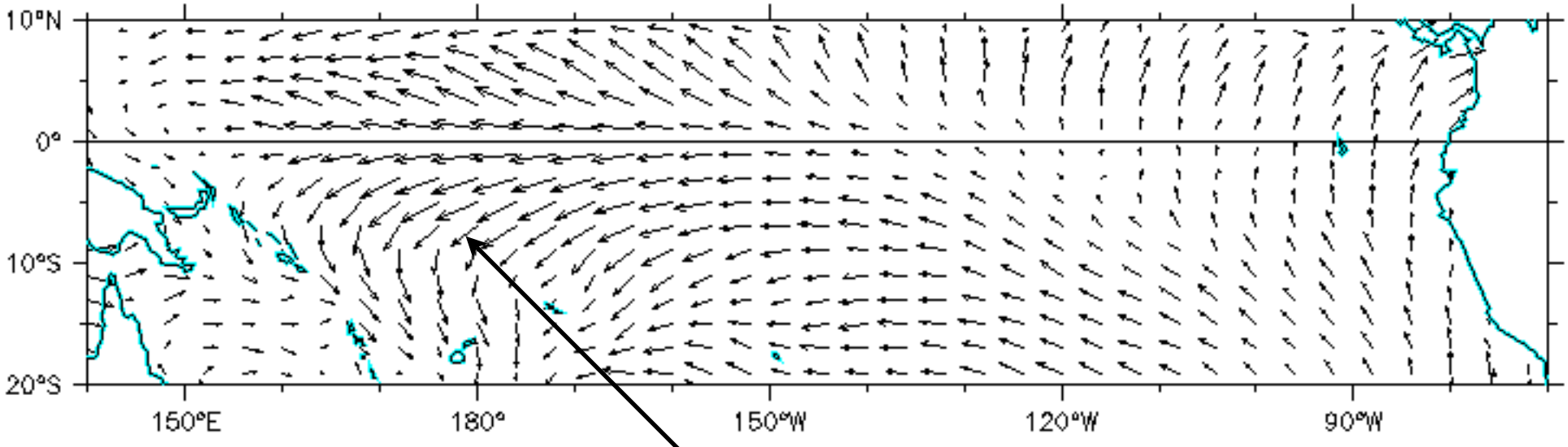
Spray6 (Aug–Oct 07), Spray18 (Nov 07–Feb 08), Spray1 (Feb–Jul 08) **Spray6 (Launch 4 July 08)**

Post-La Niña

- SEC restored
- NGCC will be too?

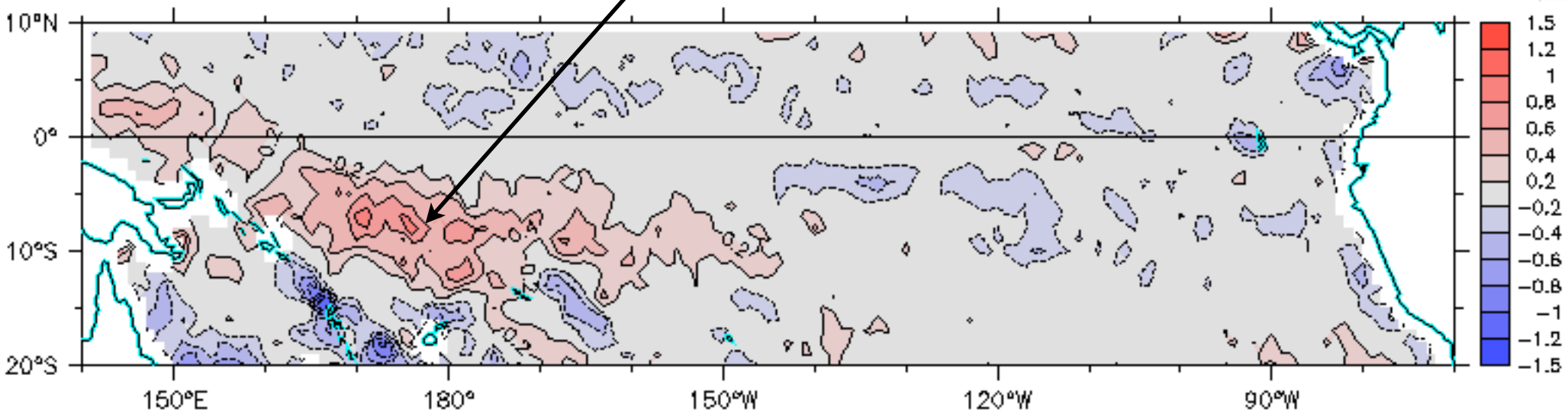


Anomalous winds and curl during Aug 07-Mar 08



$\longrightarrow \tau\ (5 \times 10^{-2} Nm^{-2})$

Strong downwelling curl at 4-12°S



$Curl(\tau)(10^{-7} Nm^{-3})$

(Quikscat winds, anomalies from the 99-08 annual cycle)

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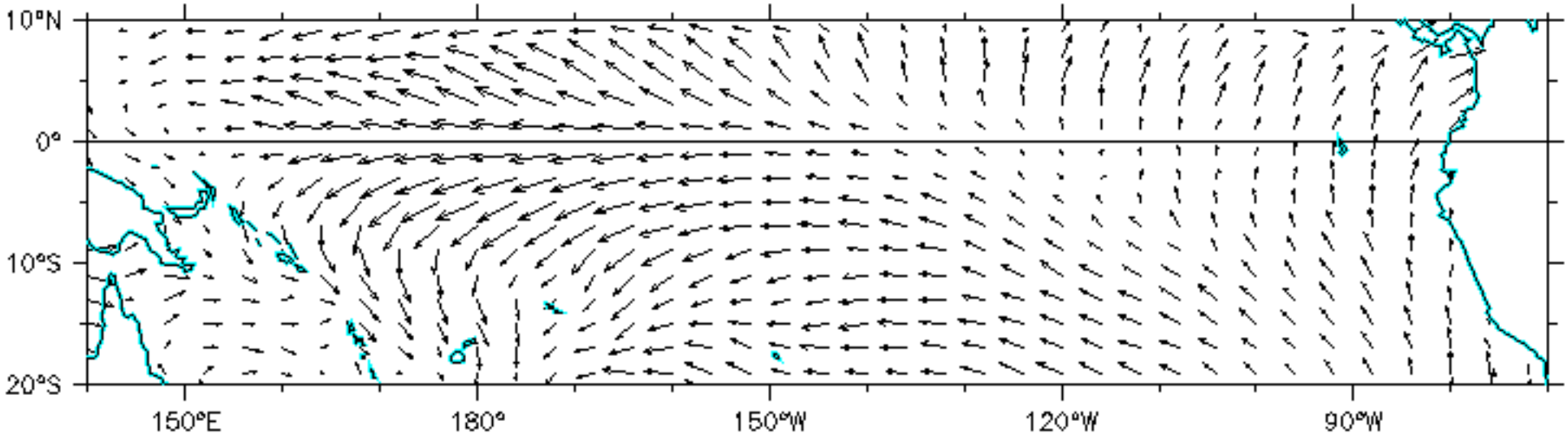
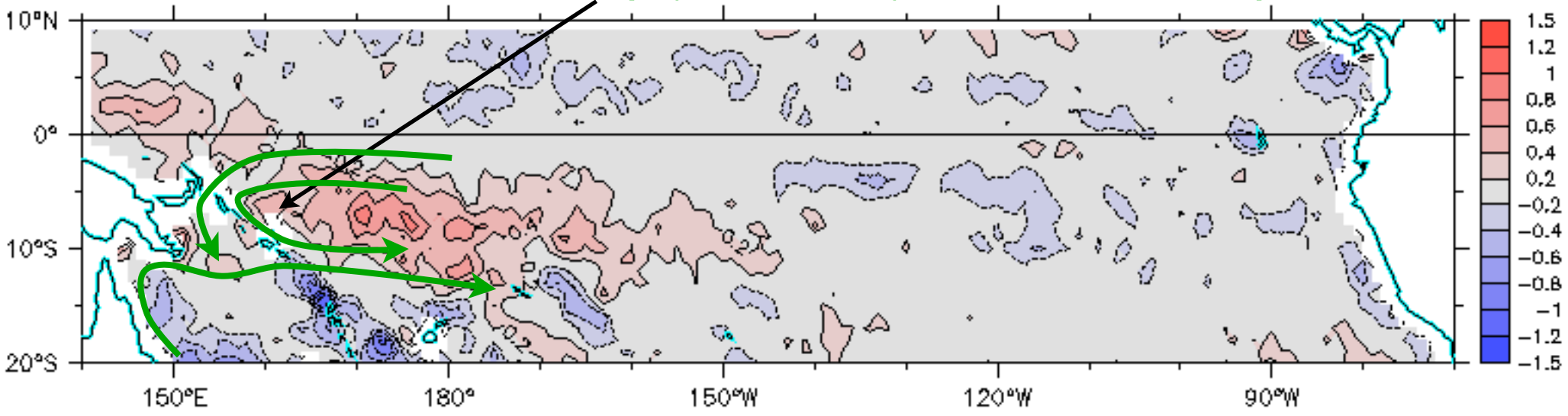


$\longrightarrow \tau\ (5 \times 10^{-2} Nm^{-2})$

Rossby (Island Rule) solution driven by these winds

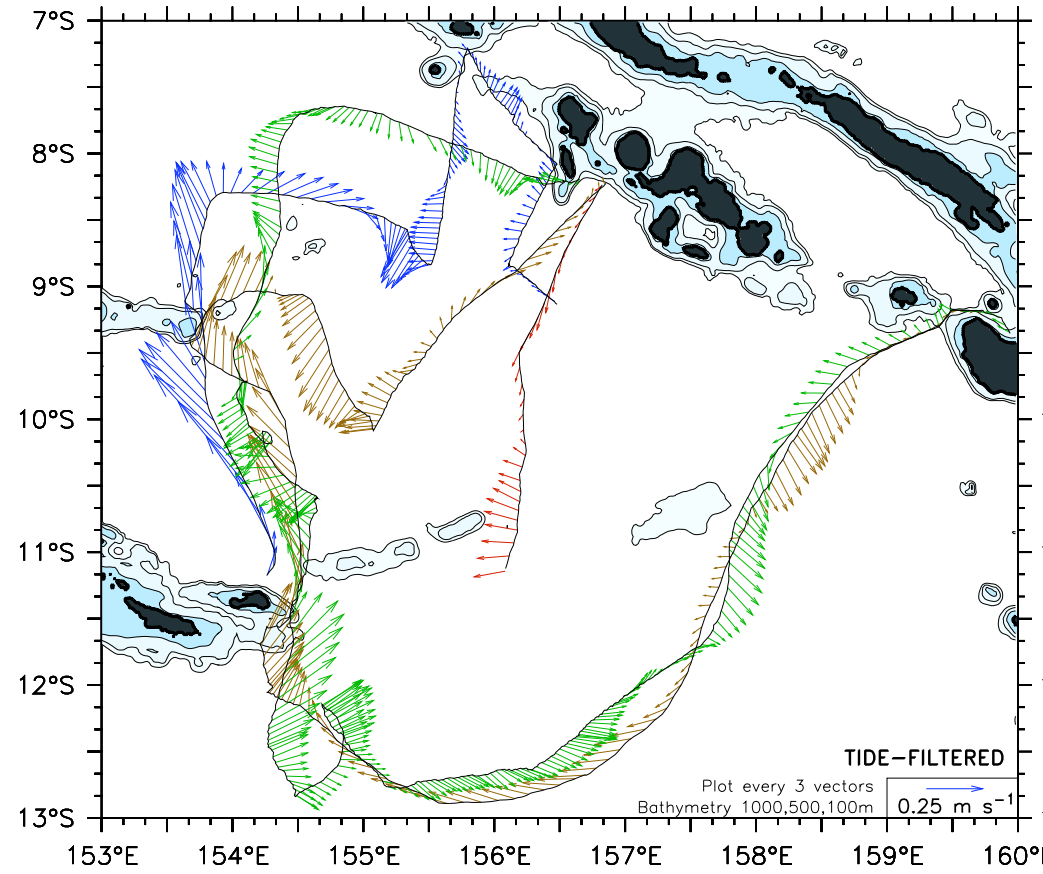


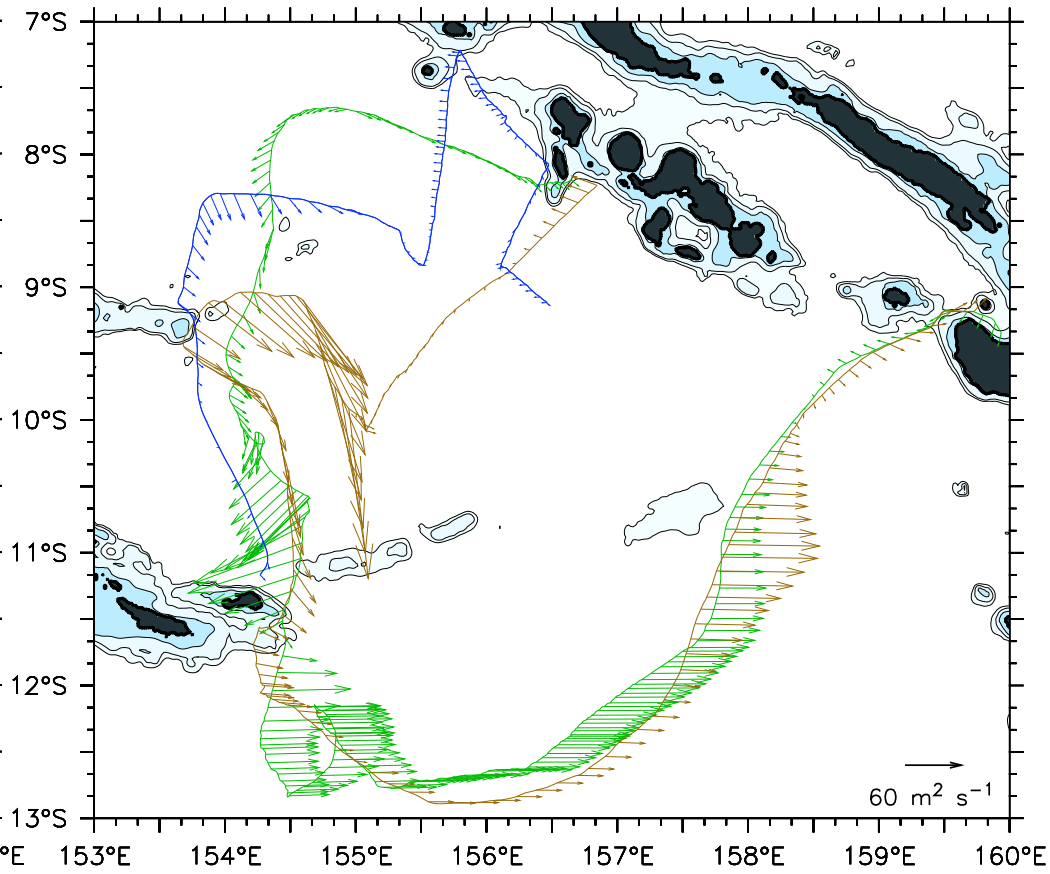
$Curl(\tau)(10^{-7} Nm^{-3})$

(Quikscat winds, anomalies from the 99-08 annual cycle)

Observed Total currents

Anomalies simulated by a Rossby model sampled on the glider time/position

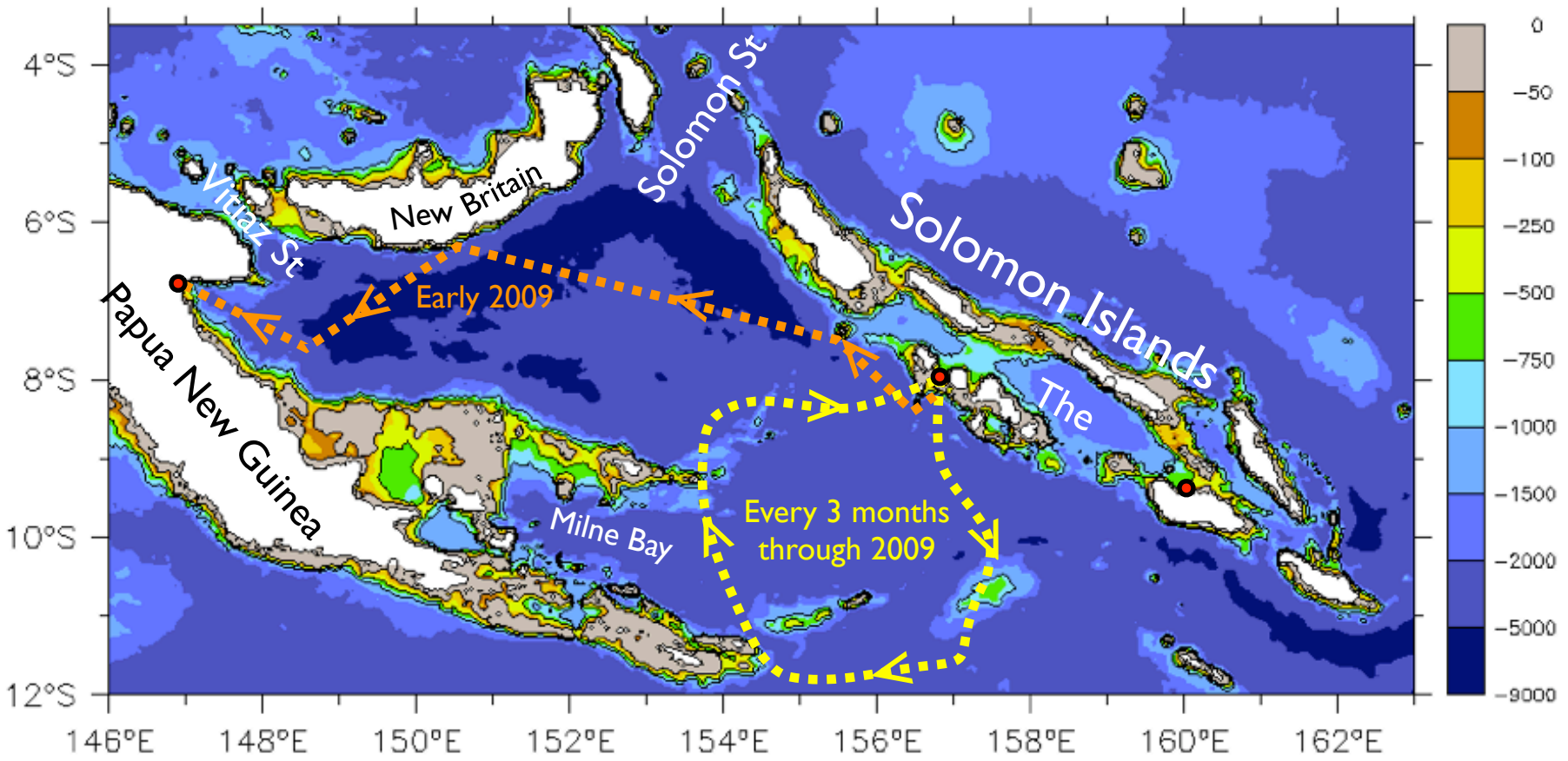




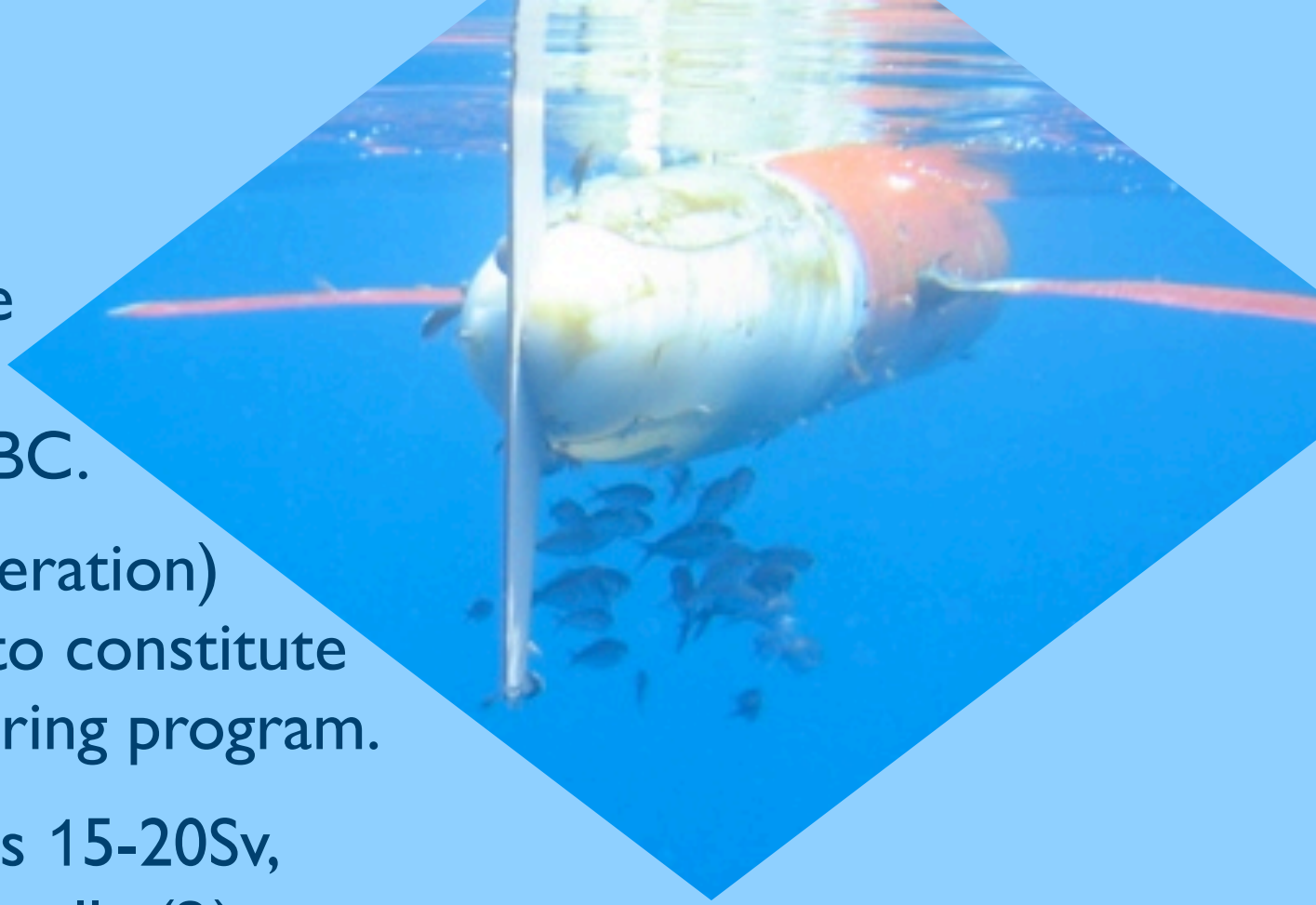
The downwelling curl signature of the La Niña was strong.
Its remote effects were fairly well simulated by a Rossby model,
using the Firing et al (1999) Time-dependent Island Rule
and a Godfrey 1975 formulation for the Australia coastal signal.

Future plans

- Funded (NOAA/Scripps/IRD) for deployments every 3 months through 2009. A test mission will attempt approaching Vitiaz St.
- A France-Australia experiment (SPICE) funded for 2010-2011.
- Over the next 2-5 years, the pilot will evolve towards sustained monitoring.



Conclude



- Gliders are capable of sampling the South Pacific LLWBC.

  They (and their operation) are cheap enough to constitute a sustained monitoring program.

- NGCC transport is 15-20Sv, and varies interannually (?) to near zero.
- Temporal sampling still not good enough for short timescales.
- Deeper dives would be desirable (but are hard to accomplish).

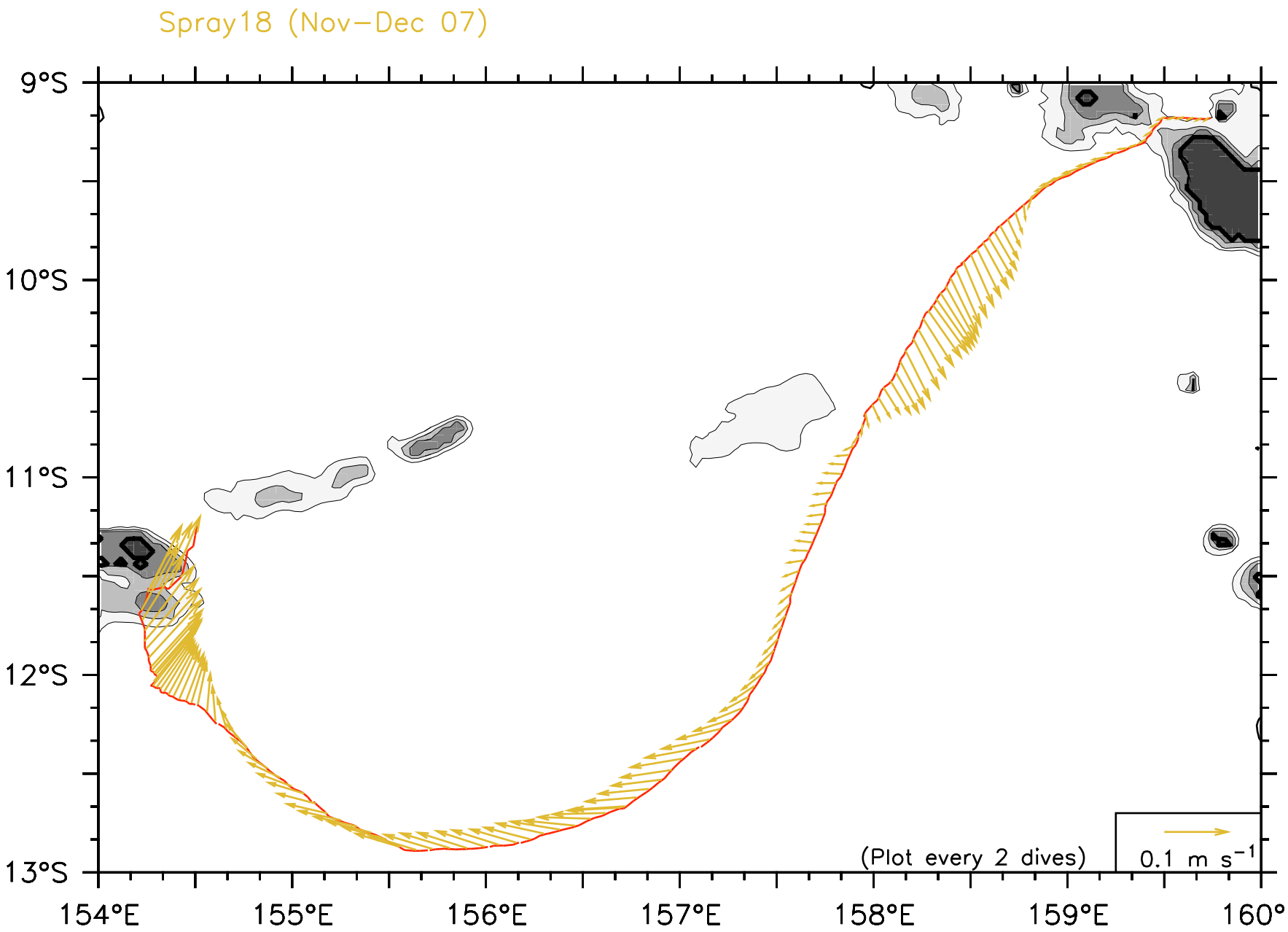
PMEL

IRD
Institut de recherche pour le développement

Extra Figures Follow ...

Currents during Nov-Dec 2007

Glider currents in the Solomon Sea



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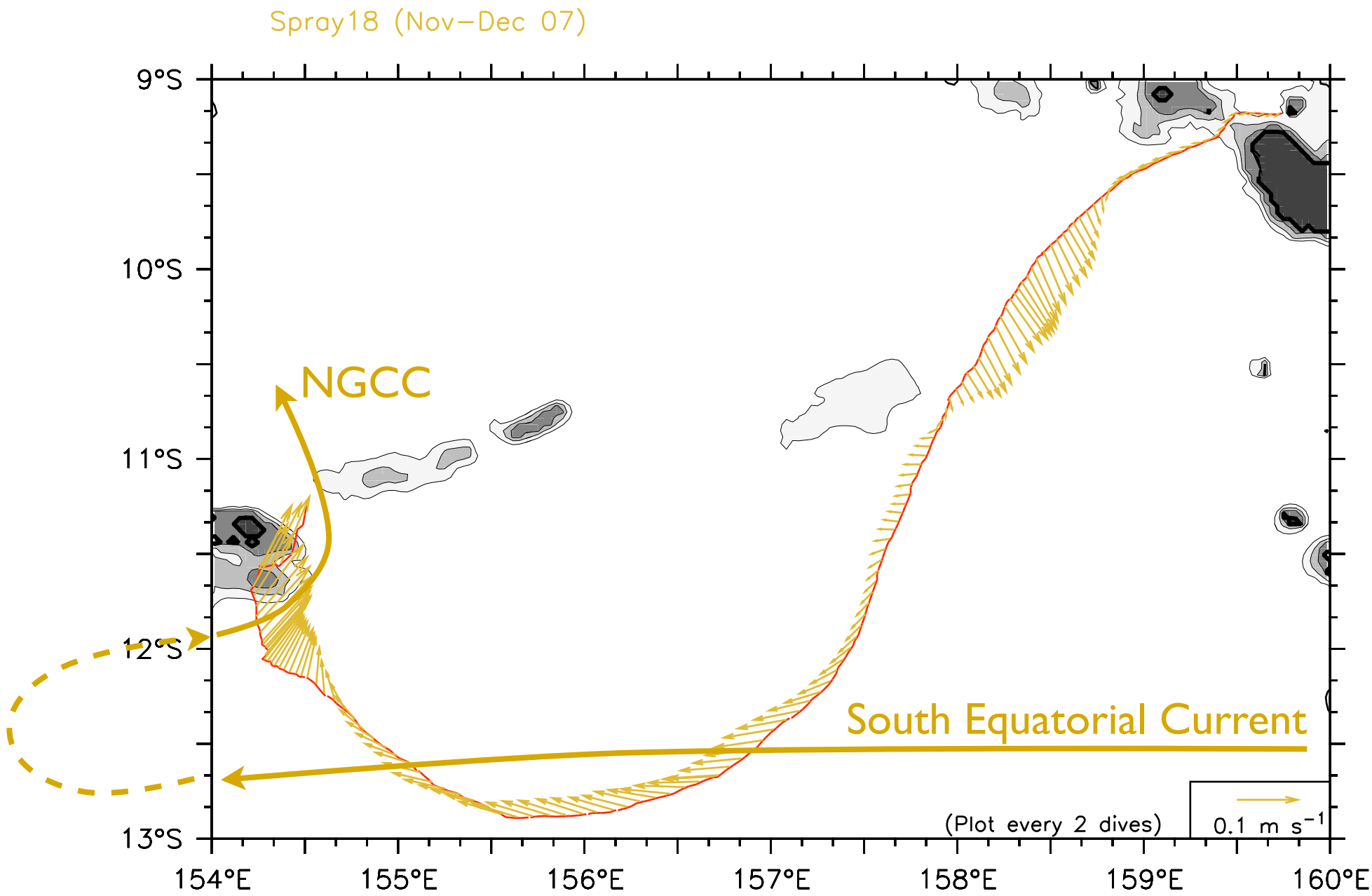
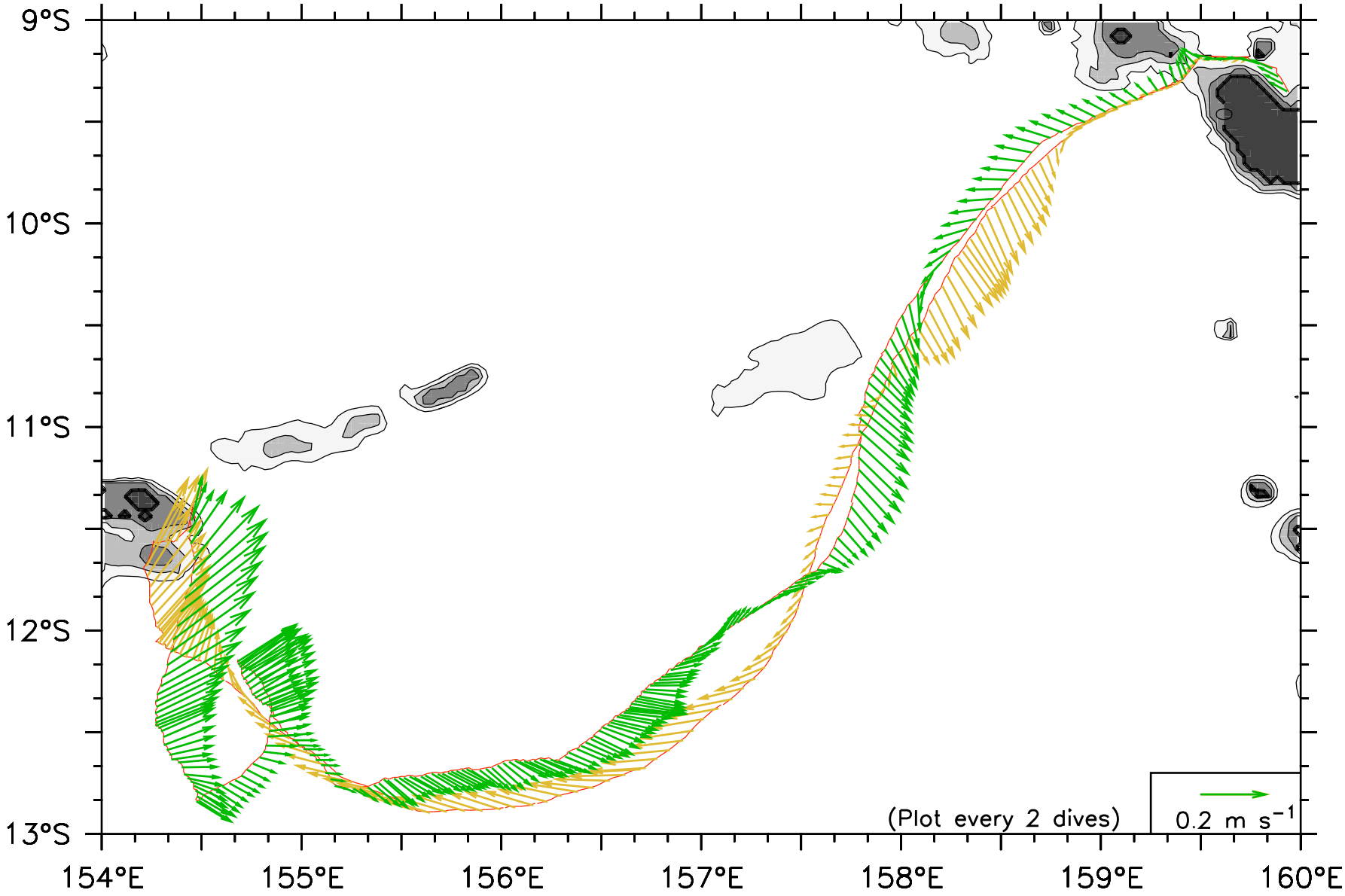


Currents during Mar-Apr 2008

Glider currents in the Solomon Sea

Spray18 (Nov–Dec 07) and Spray1 (Feb–Mar 08) TIDE–FILTERED



Currents during Mar-Apr 2008

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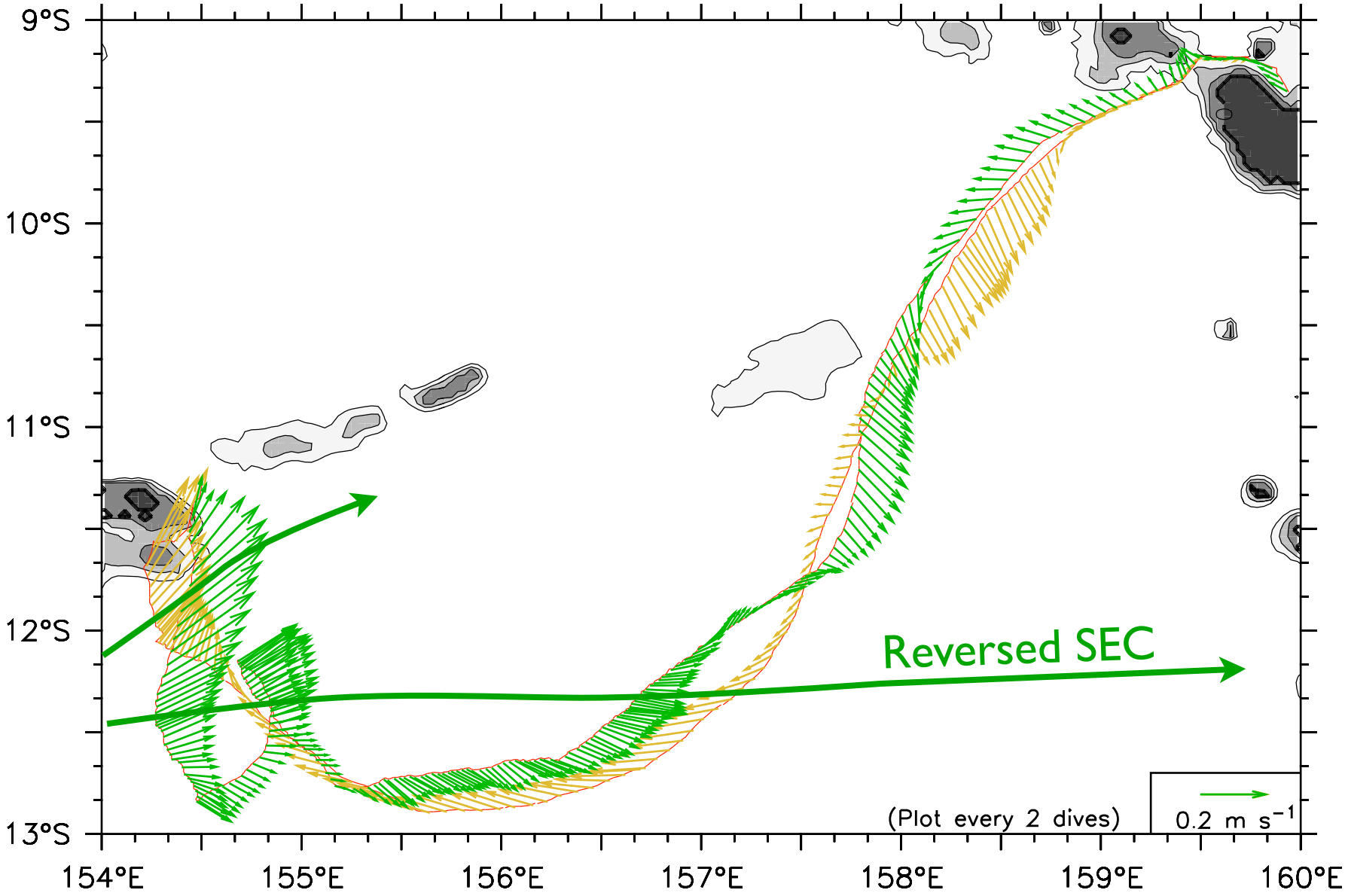

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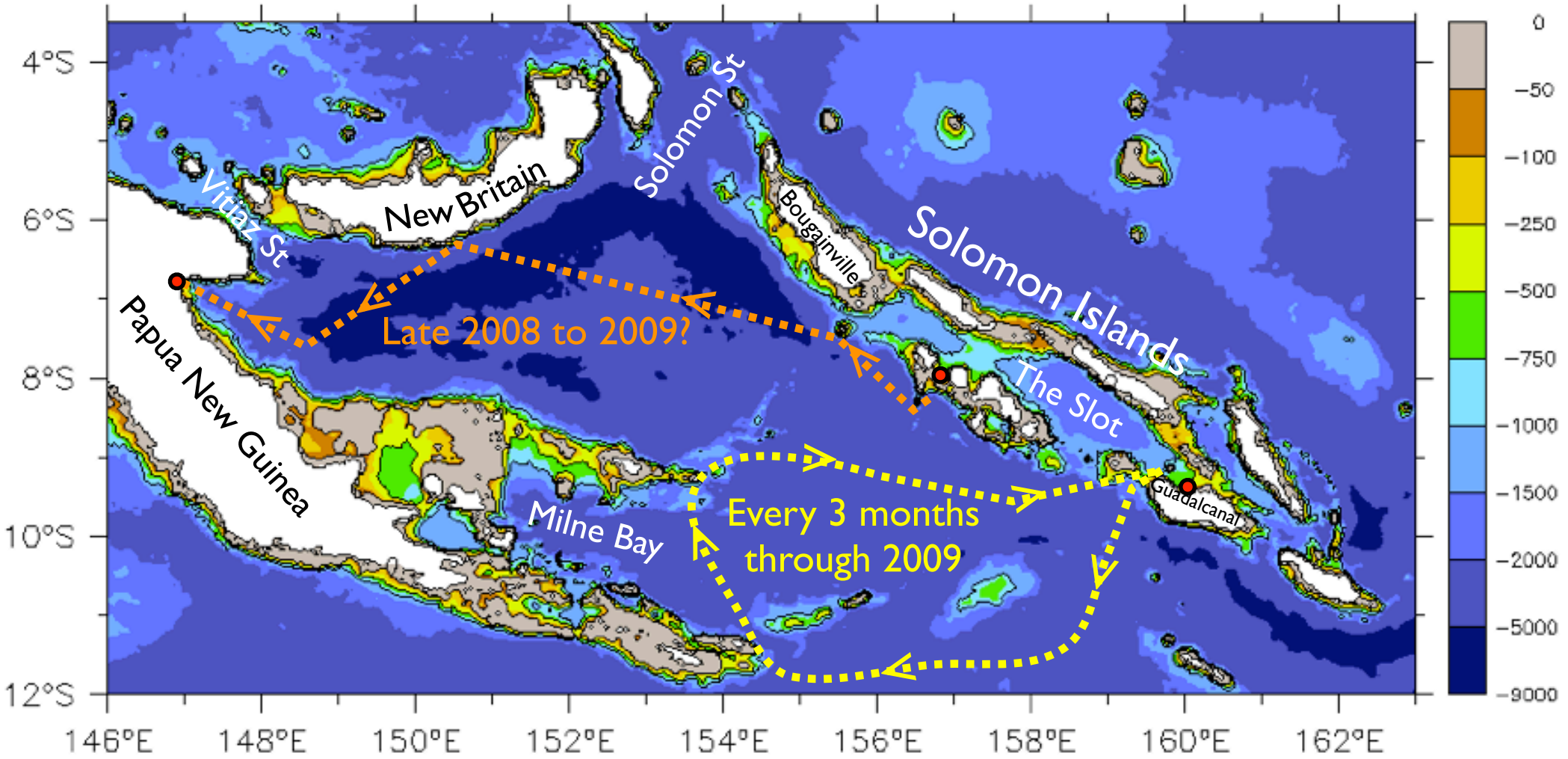
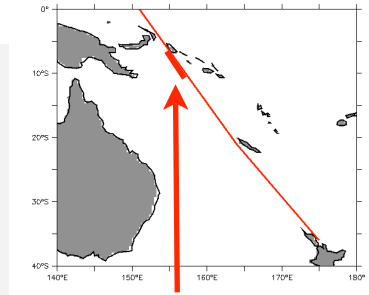
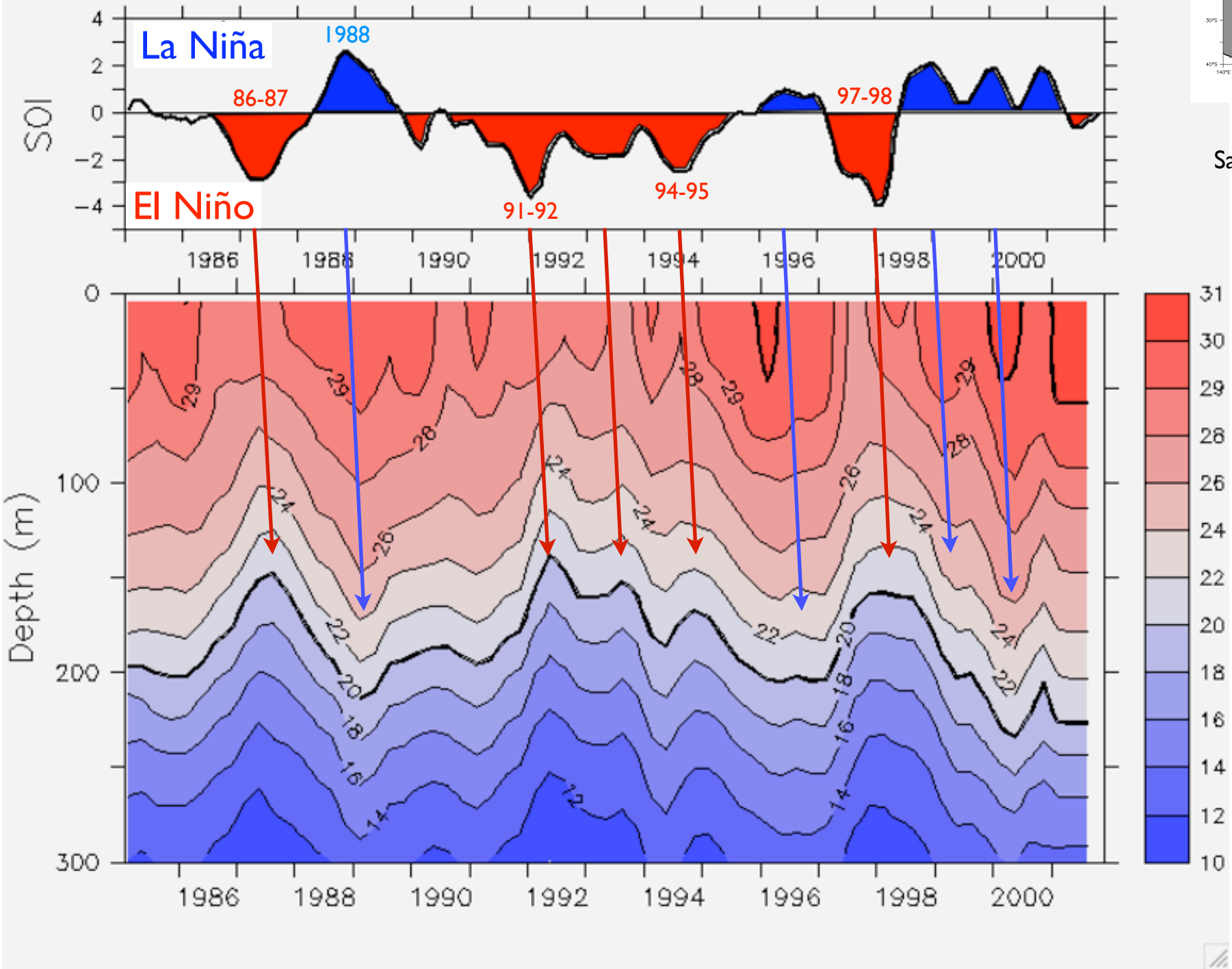


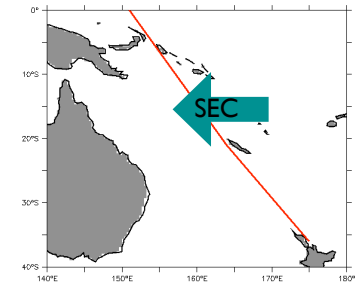
Solomon Sea temperatures and El Niño



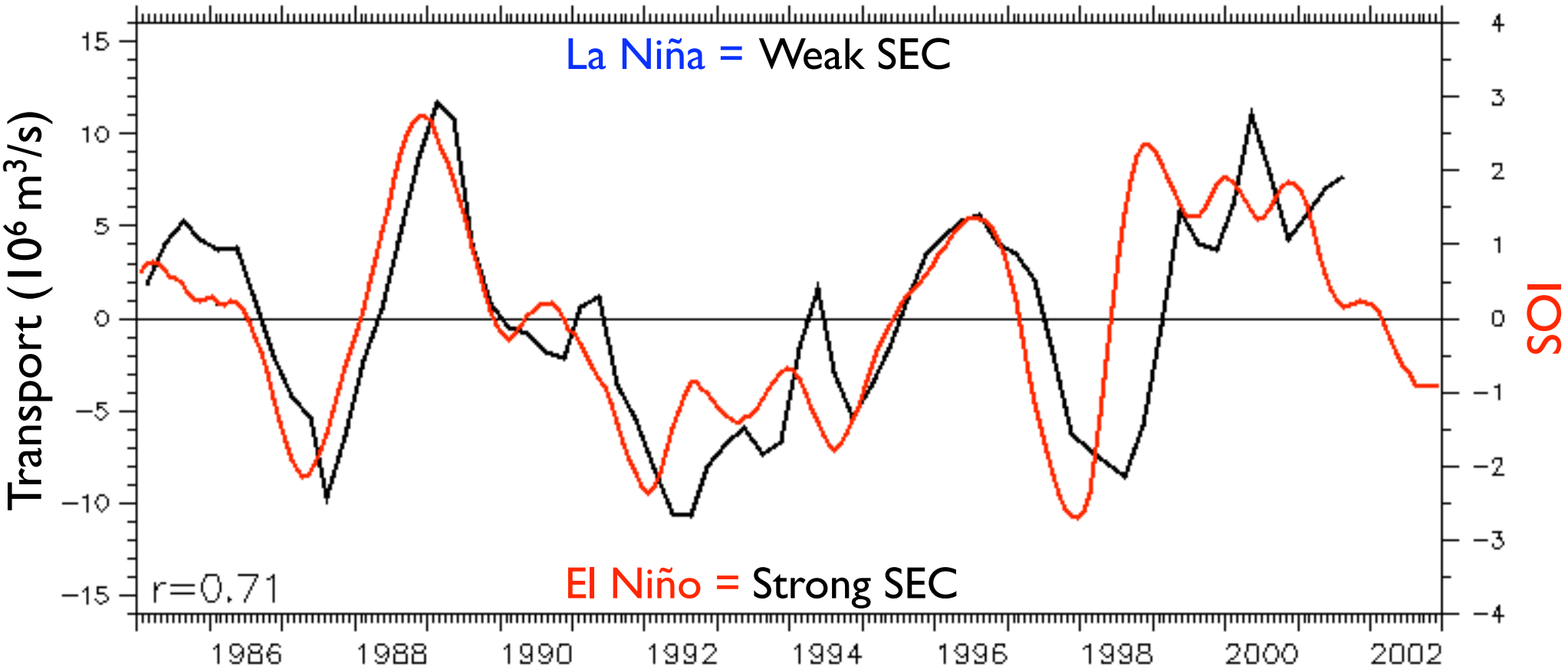
XBT track
(Merchant ship)
Sampled from 6-10°S



South Equatorial Current transport has a strong El Niño signal

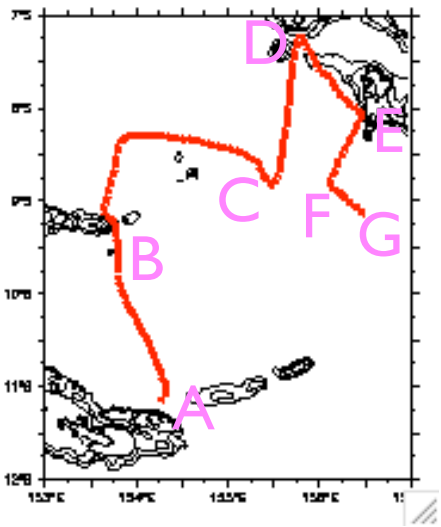


SEC on the Auckland-Japan XBT track, over 10°S-20°S. Demeaned.

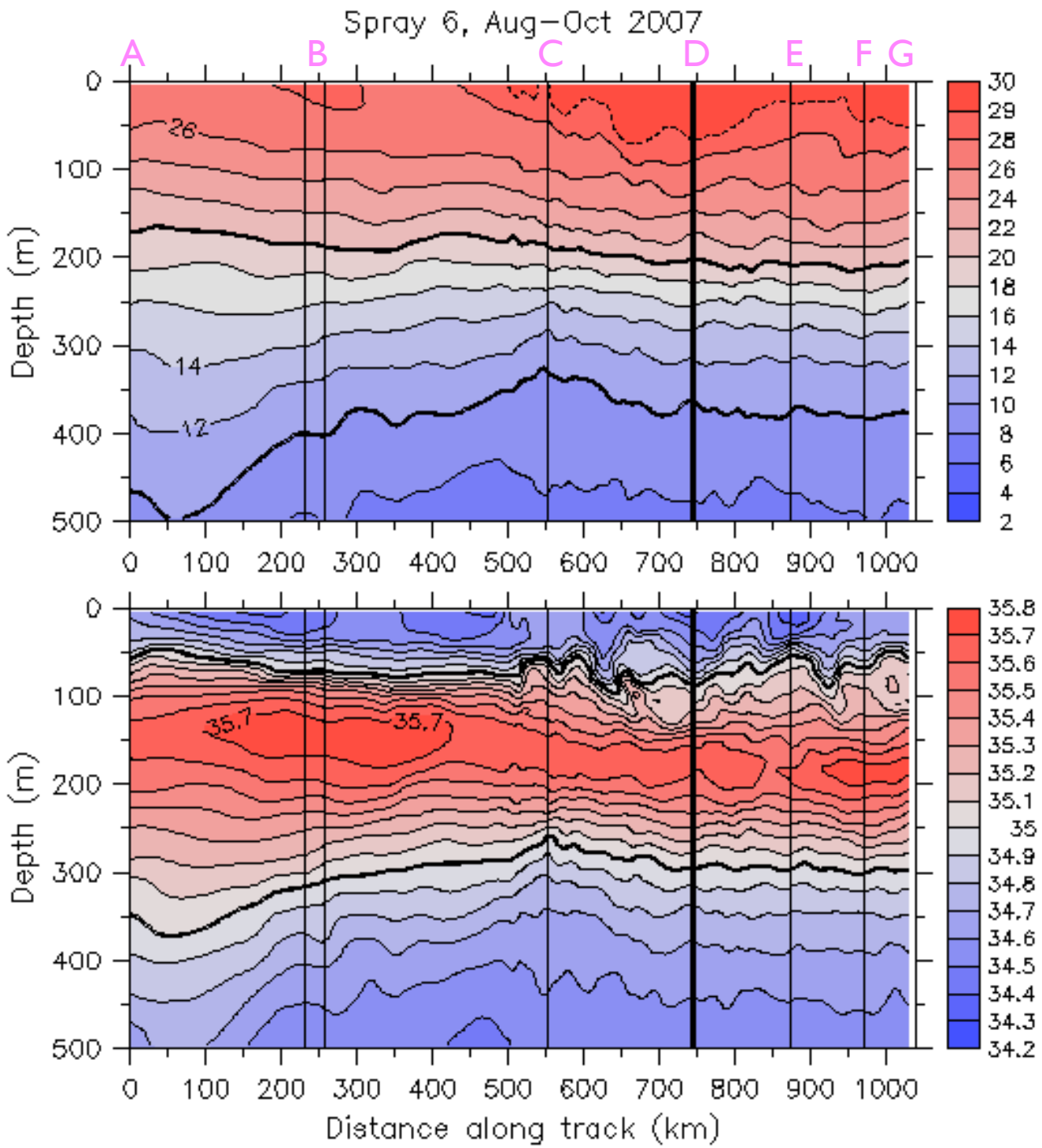


South Equatorial Current flow

The Southern Oscillation Index (time history of El Niños)



Temperature and salinity along the glider track

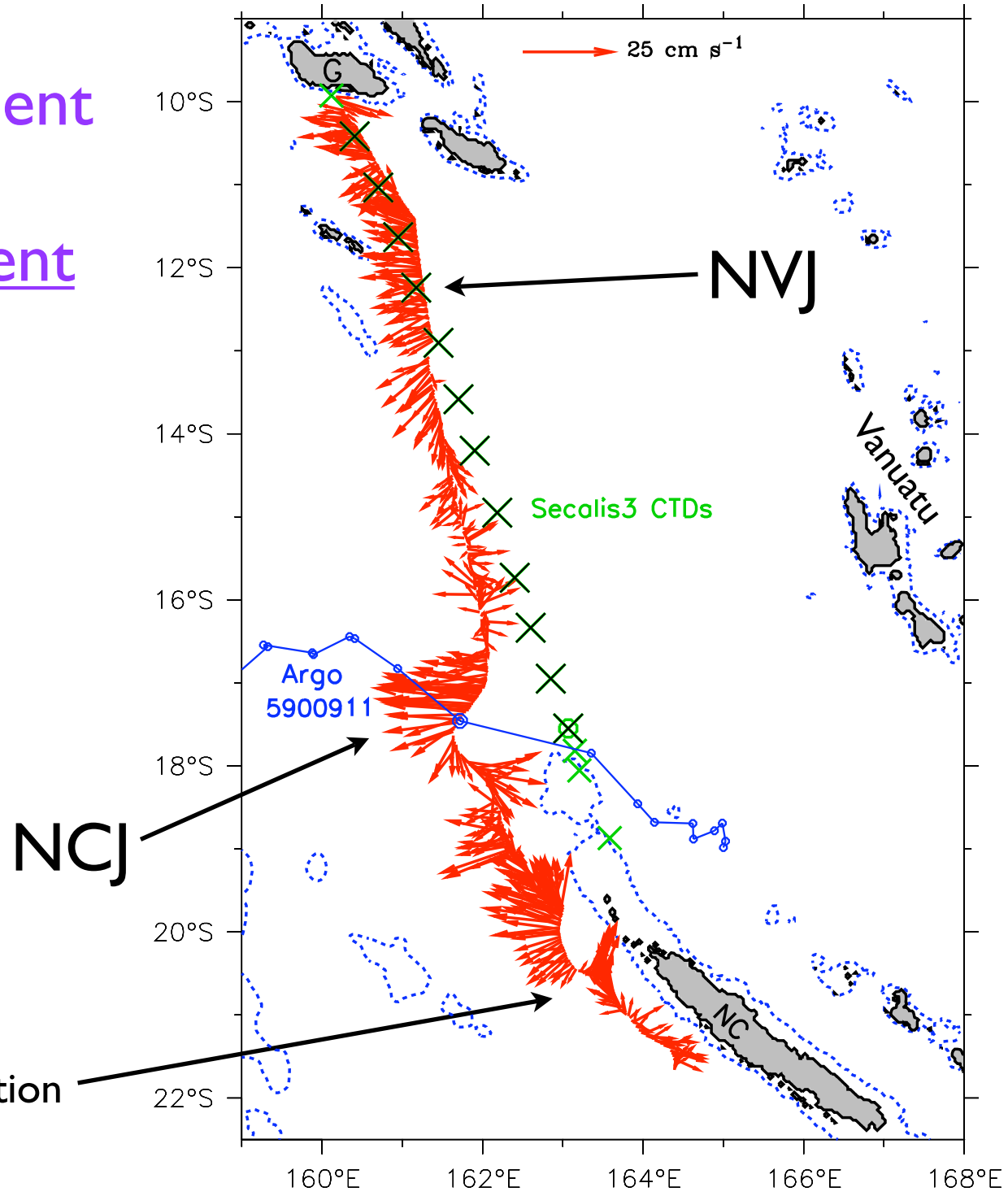


First mission:
A coordinated experiment to study the South Equatorial Current

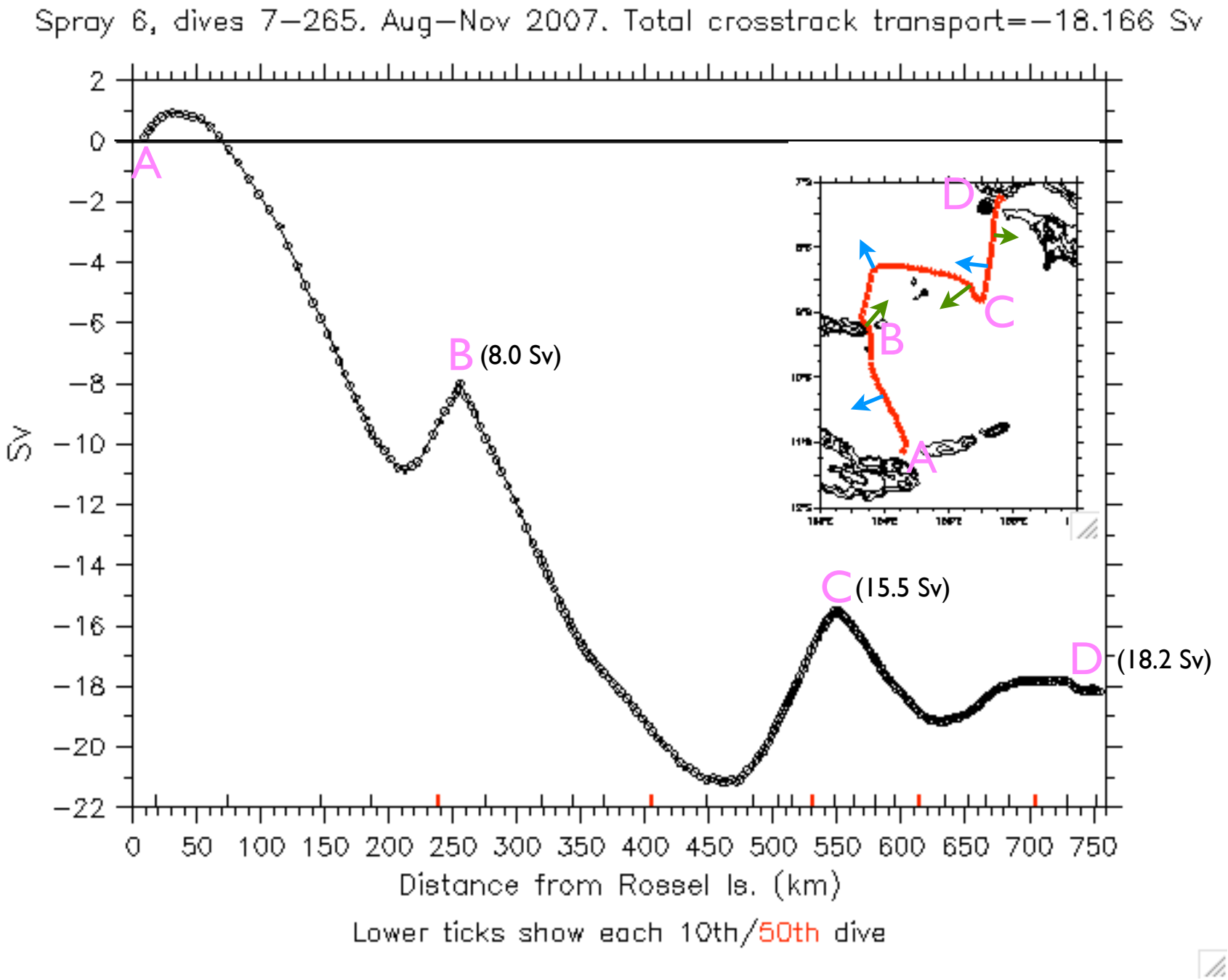
Jul-Oct 2005

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

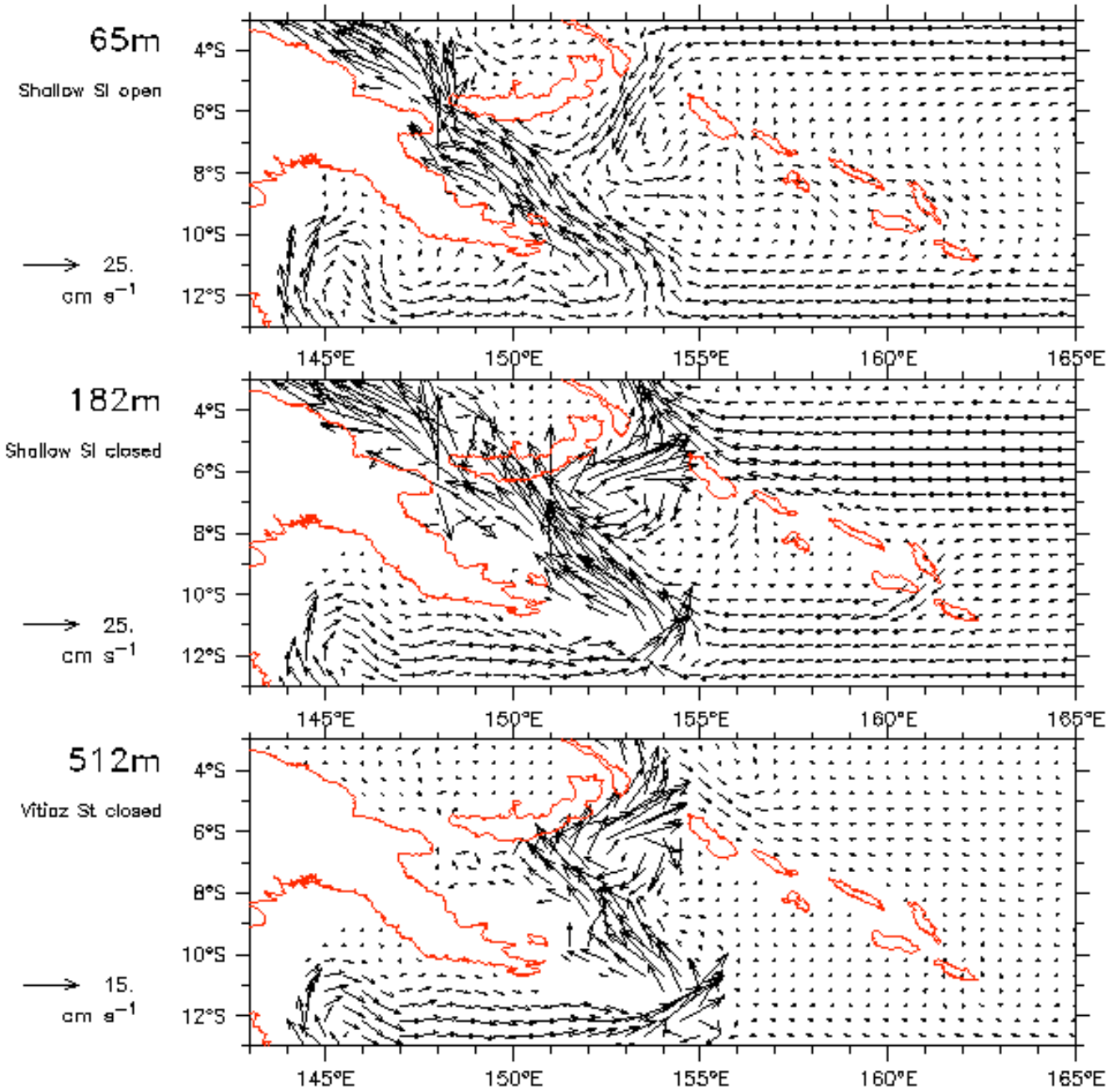
Strong near-coastal circulation



Crosstrack transport accumulated from Rossel Is.



ORCA model circulation at surface, thermocline and below



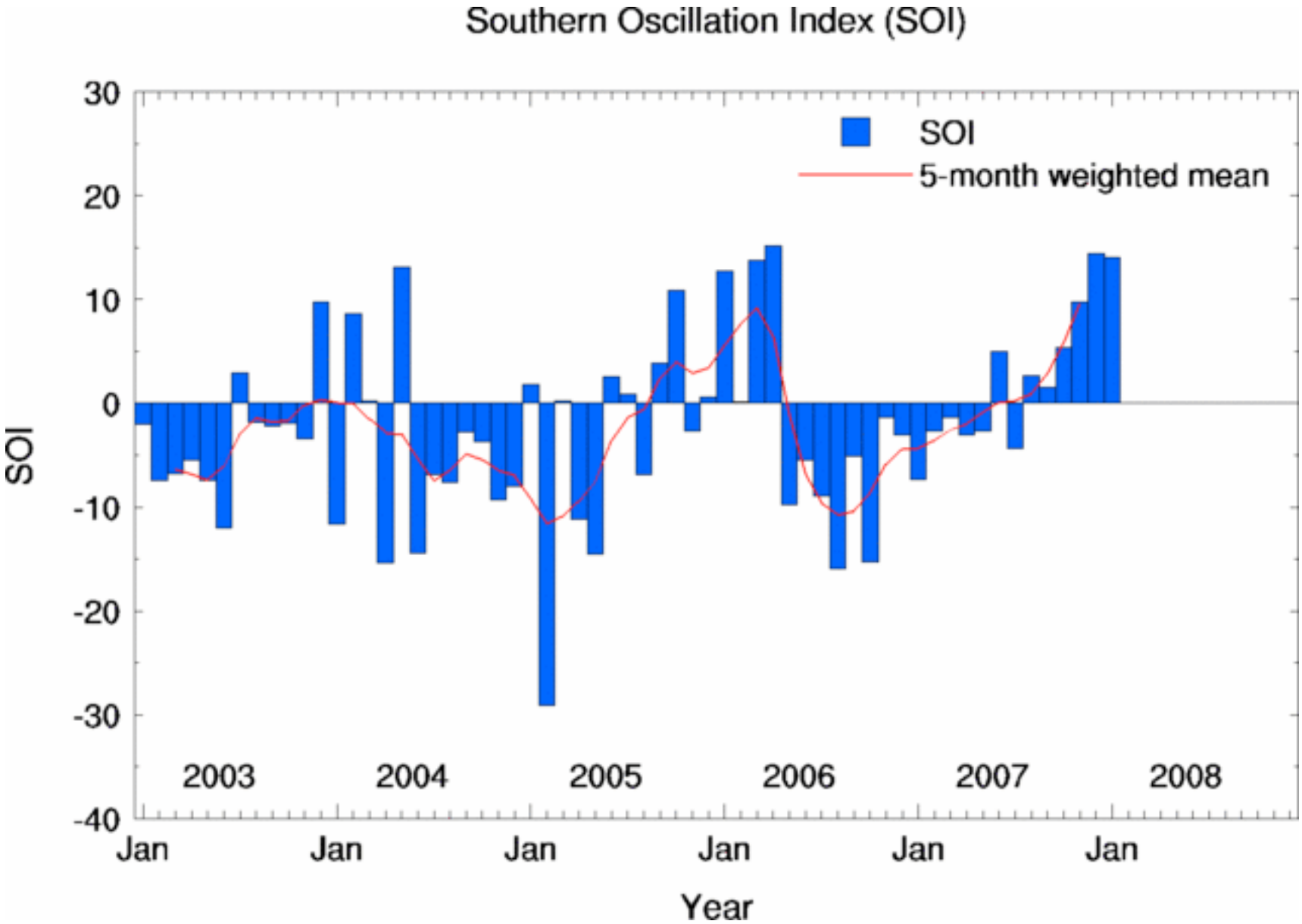
Above 100m:
Flow through Sol. St. is *southward*.
(Consistent w/ obs).

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

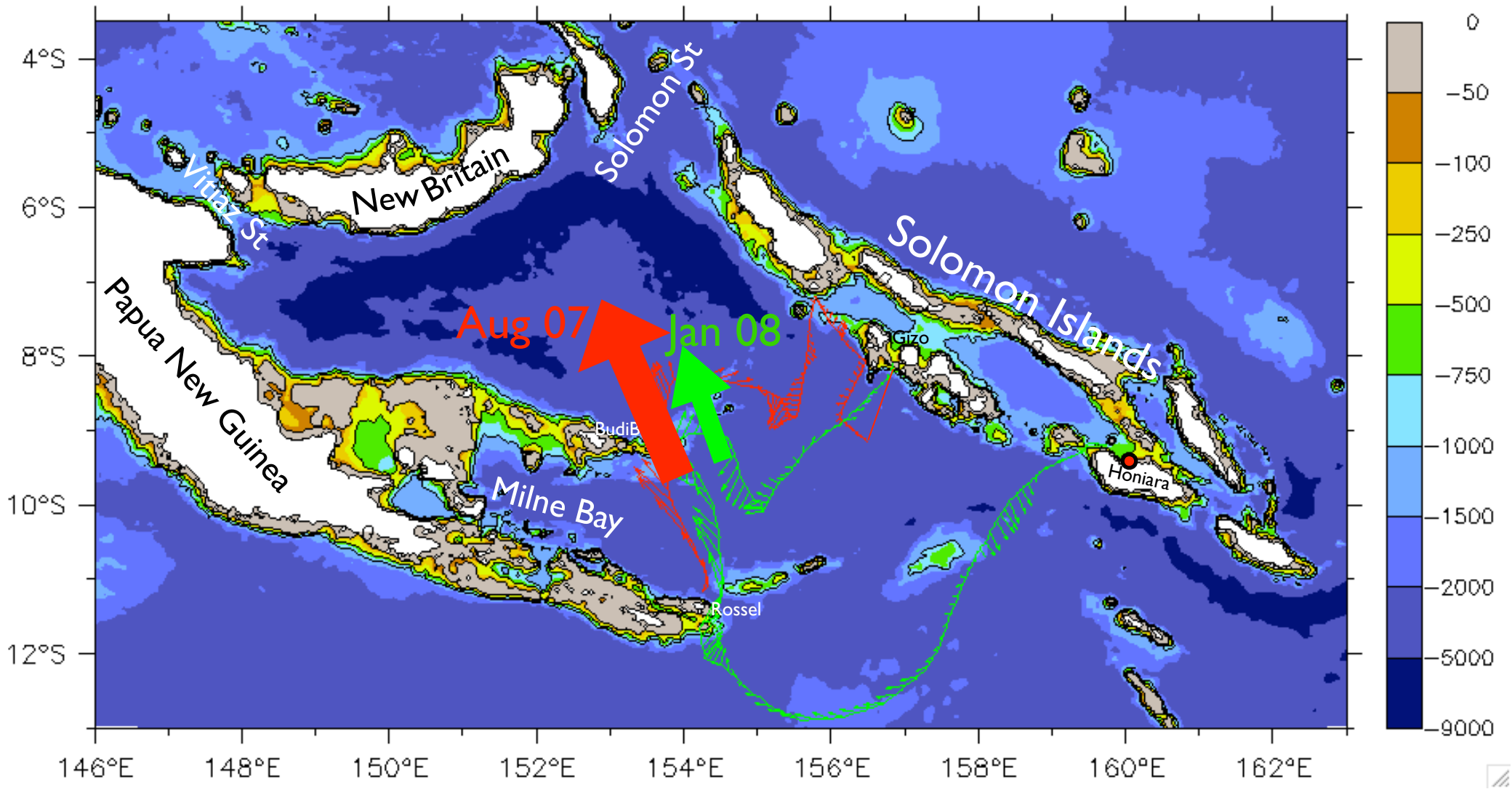
Below Vitiaz St:
Entire WBC exits Solomon Sea via Sol. St.
(No Pacific inflow).

Where are we now?

A La Niña began in late 2007. We would expect a weak NGCC.

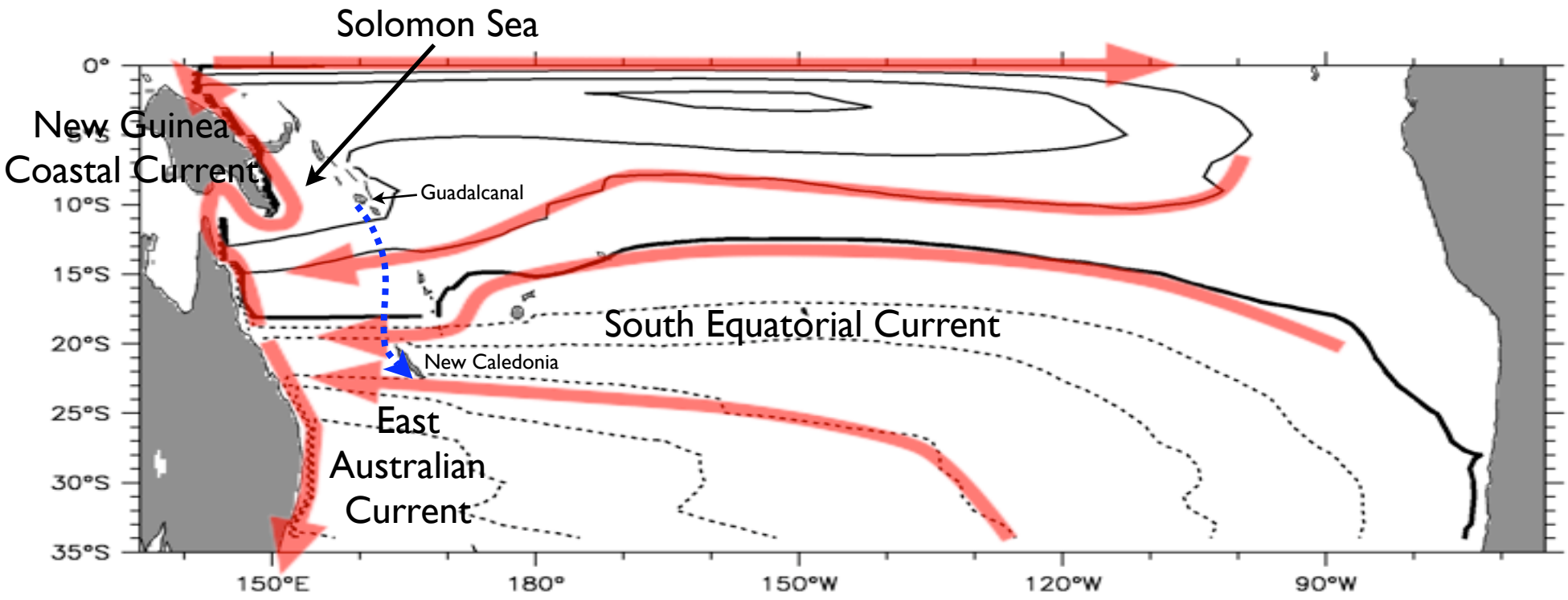


The glider observations show that the NGCC is weakening



The transport of the NGCC declined by about 60% between August 2007 and January 2008 as the La Niña grew

South Pacific circulation



First 2 missions from Guadalcanal to New Caledonia in 2005-6, but this is an inappropriate use of the technology.

The 3km/3-4hr dives of the glider oversample the ocean interior, and its slow travel time aliases time variability.

⇒ Best used in coastal regions and for boundary currents