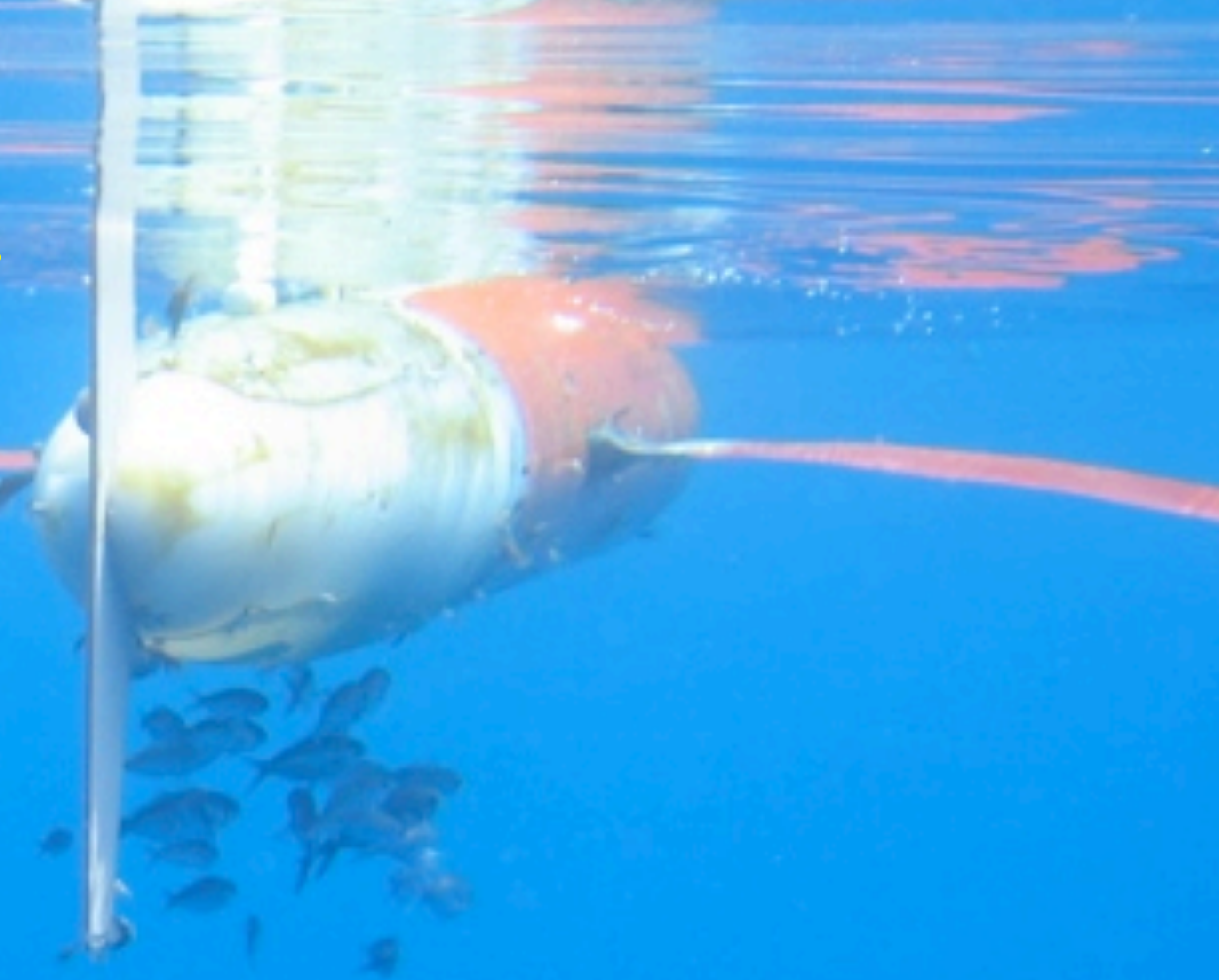
Measuring South Pacific western boundary currents with ocean gliders



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PMEL

SCRIPPS INSTITUTION OF OCEANOGRAPHY UCSD

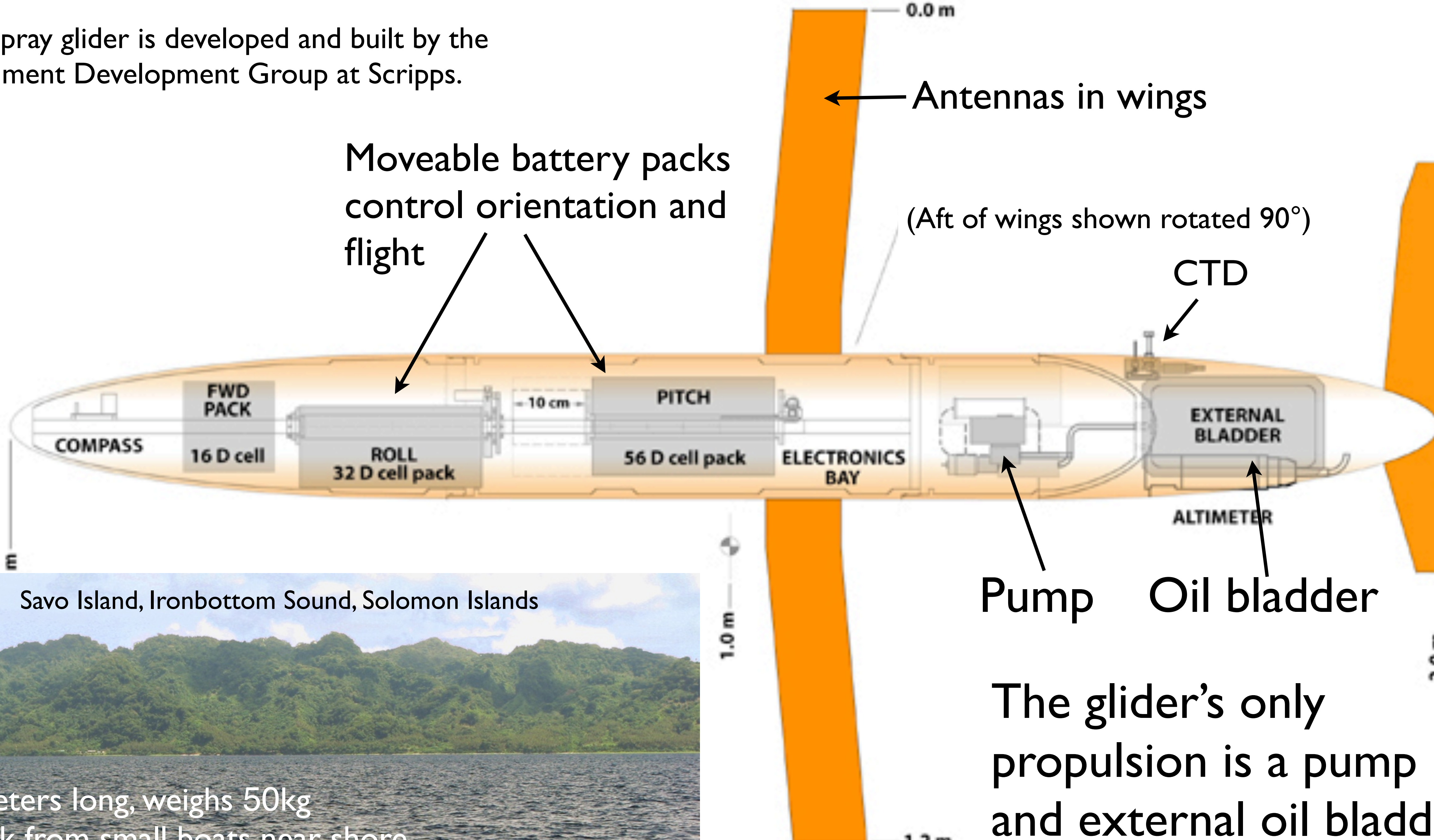
IRD Institut de recherche pour le développement

Essential collaborators:

- Solomon Islands Meteorological Service
- University of Papua New Guinea
- Bureau of Meteorology (Australia)

The Spray glider is a small, autonomous instrument with no forward propulsion

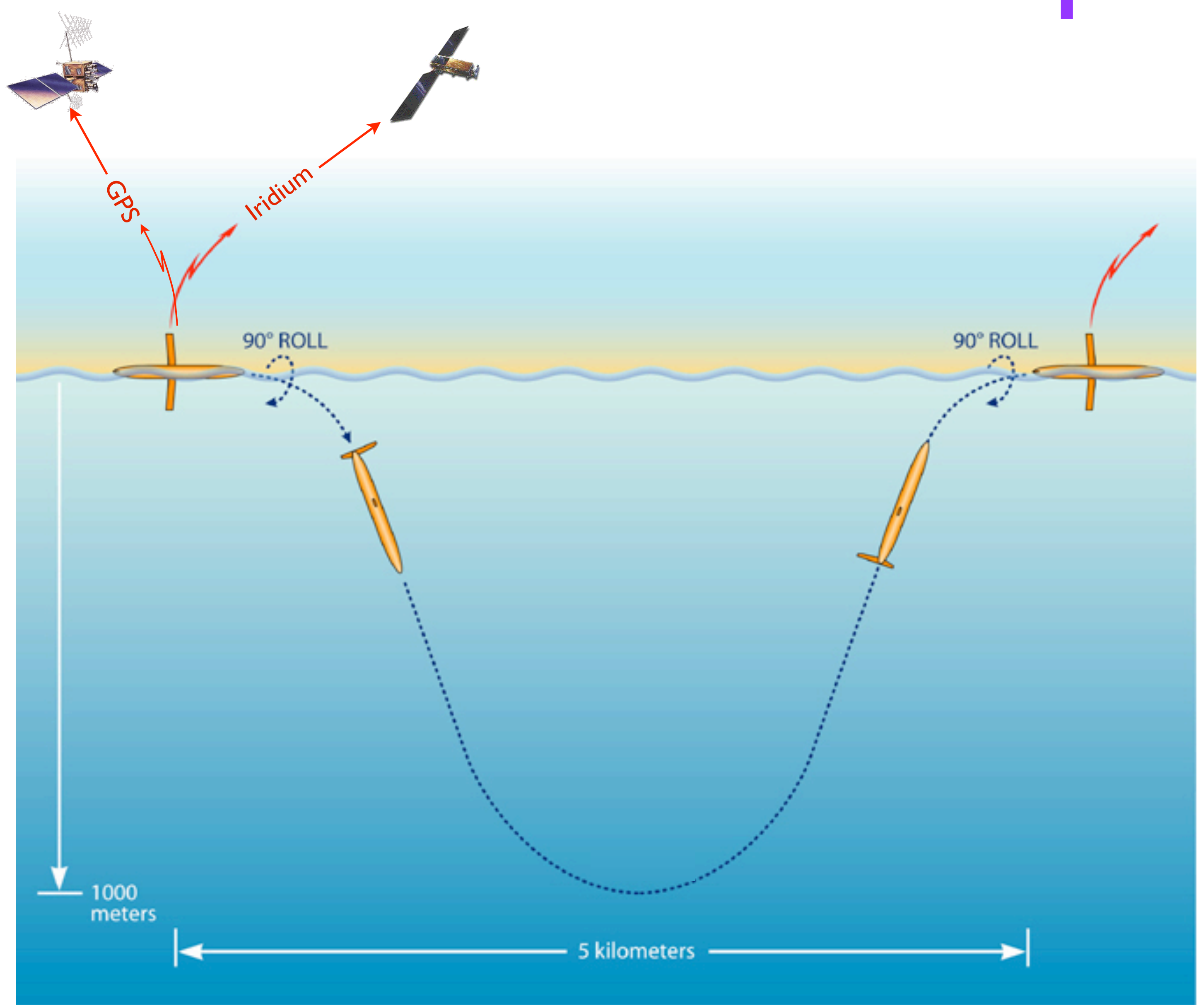
The Spray glider is developed and built by the Instrument Development Group at Scripps.



The glider's only propulsion is a pump and external oil bladder (flooded compartment). The pump inflates and deflates the bladder to change its buoyancy.

A dive of the Spray glider

↑ 500-1000 m ↓



← 3 km (3-4 hr) →

20 cm/s (11 miles/day)

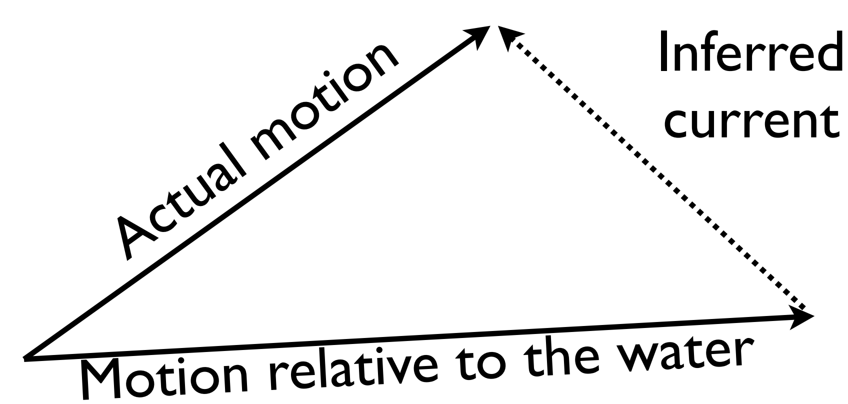
Range 4-5 months = 2500+km

Very dense sampling
(~ resolve tides)

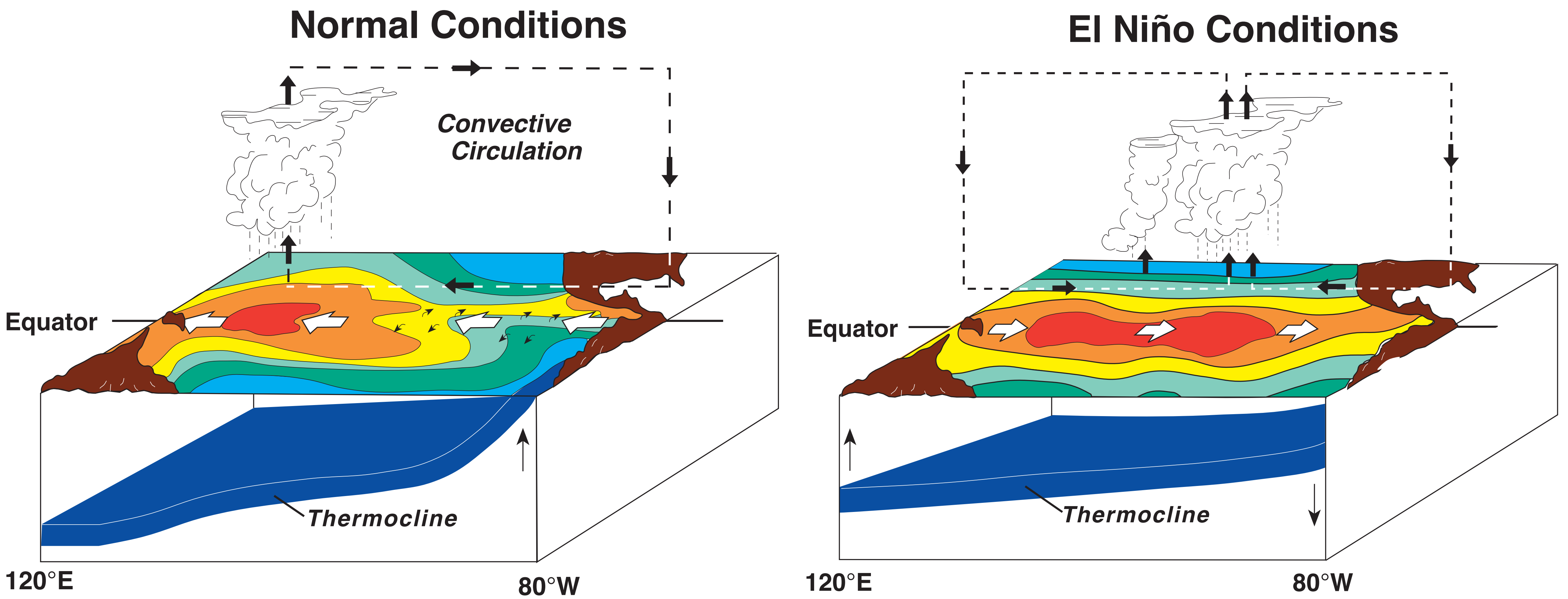
Data reported by Iridium satellite each time it surfaces

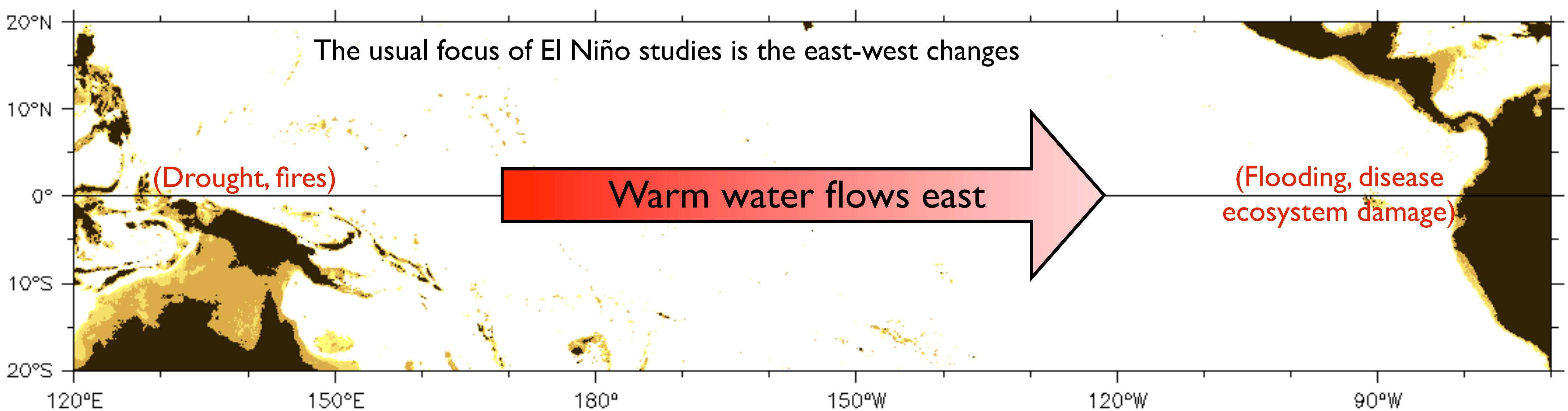
Temperature-salinity profiles: "geostrophic" relative currents

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



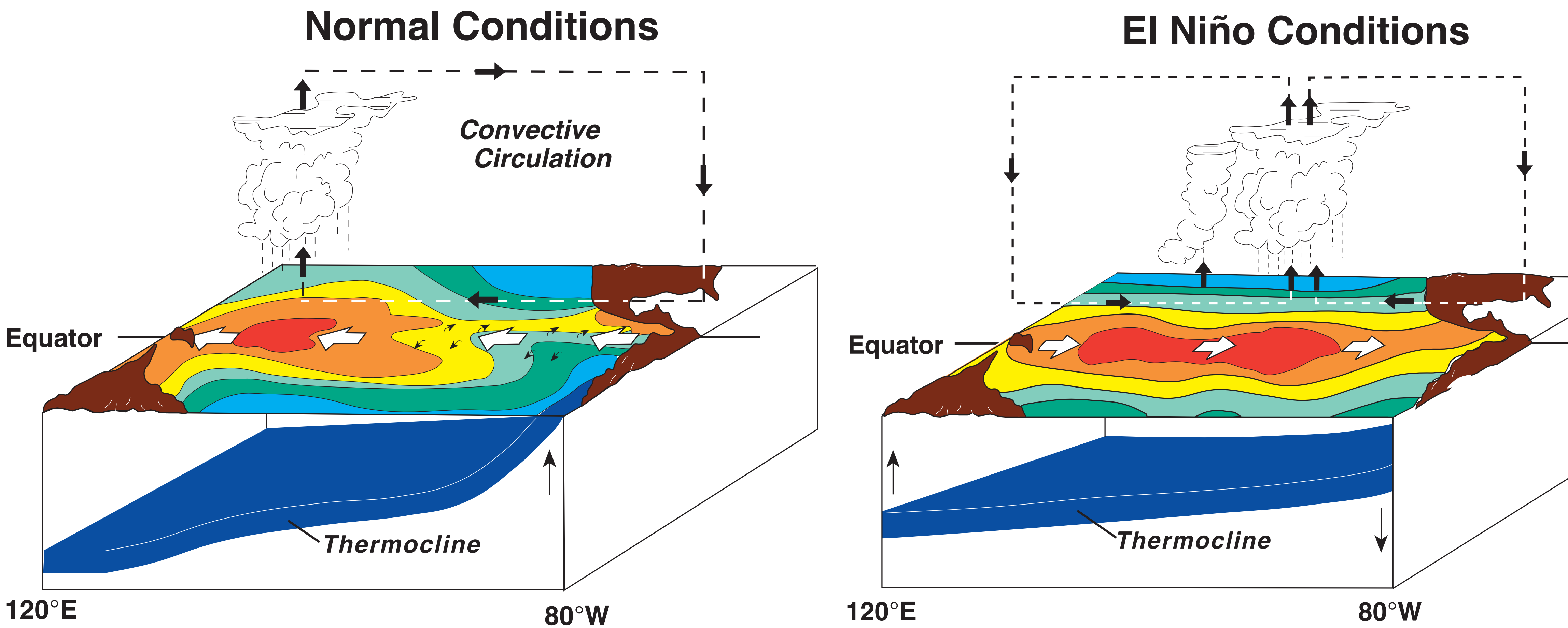
El Niño

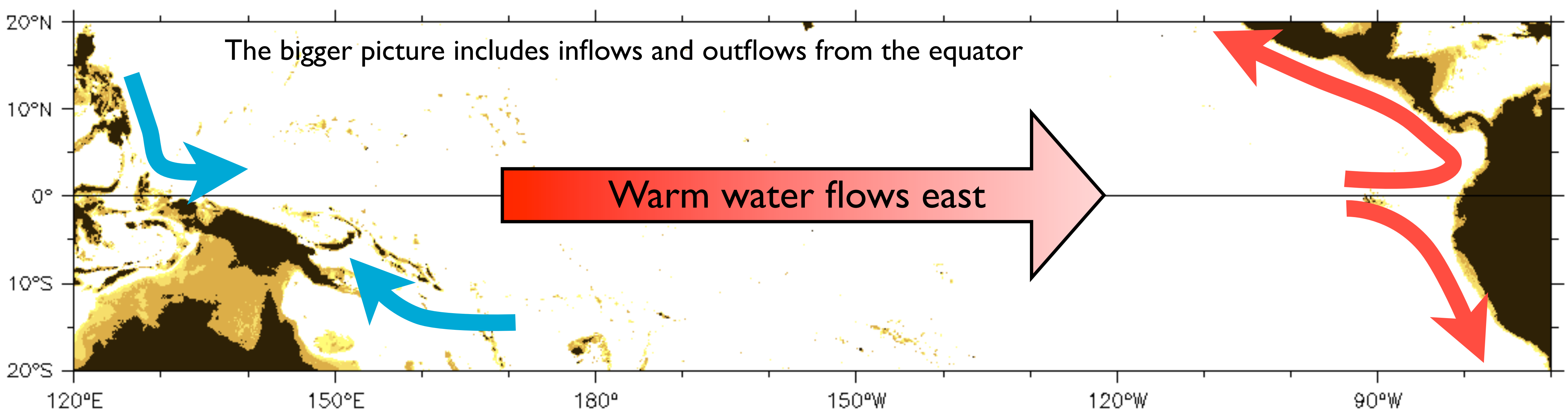




Plus indirect effects around the world ...

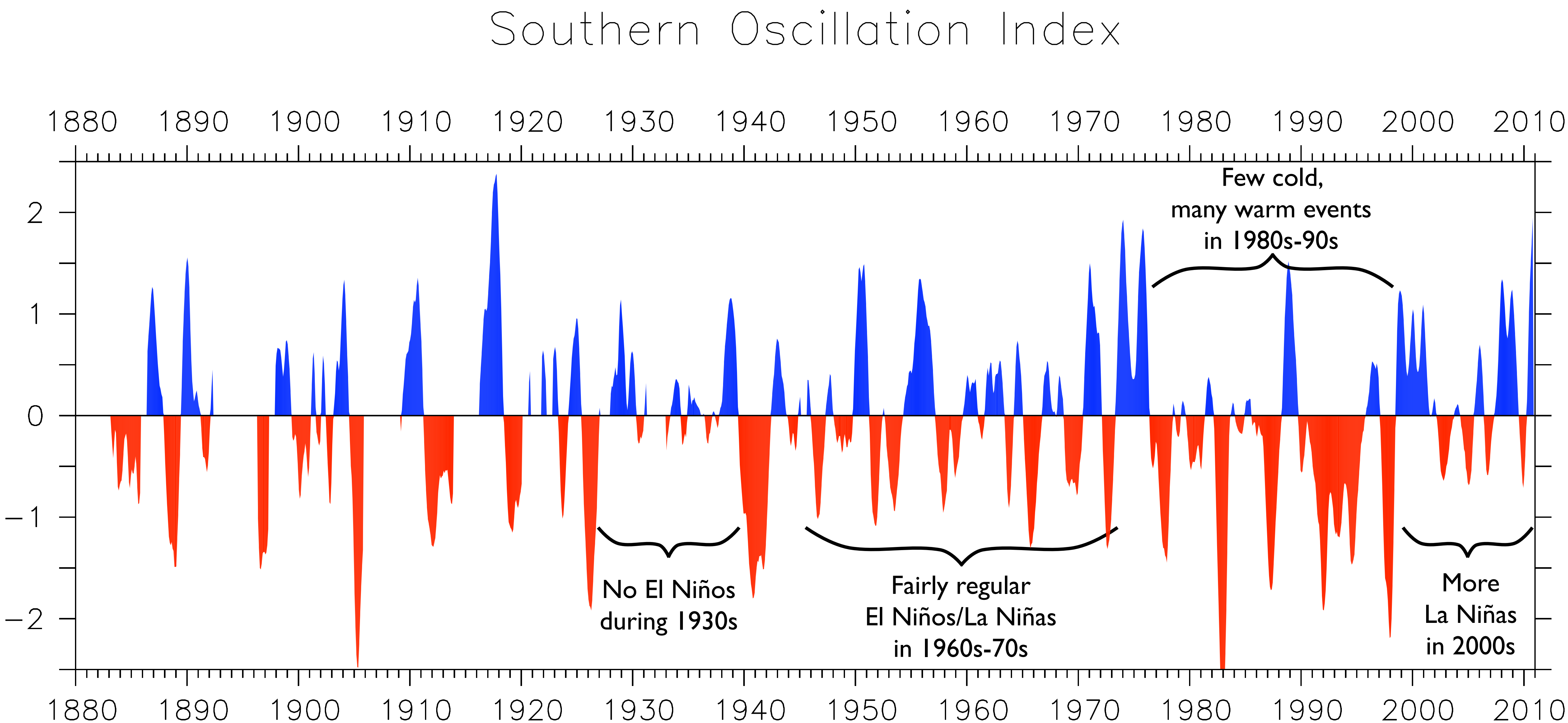
El Niño





Slow changes of these in/outflows modifies the equatorial background

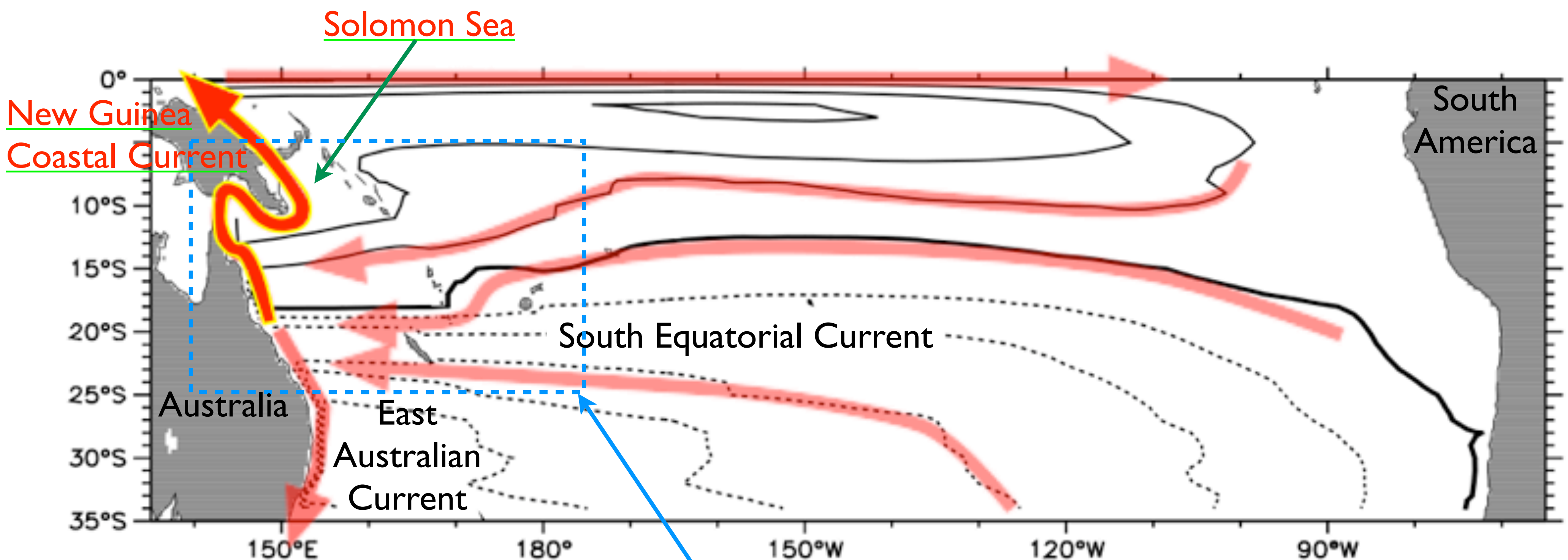
El Niño is irregular!



We think the irregularity of El Niño might be explained by changing inflows from the subtropics: mostly through the Solomon Sea. (Convection over warm water is very sensitive to the underlying SST.)

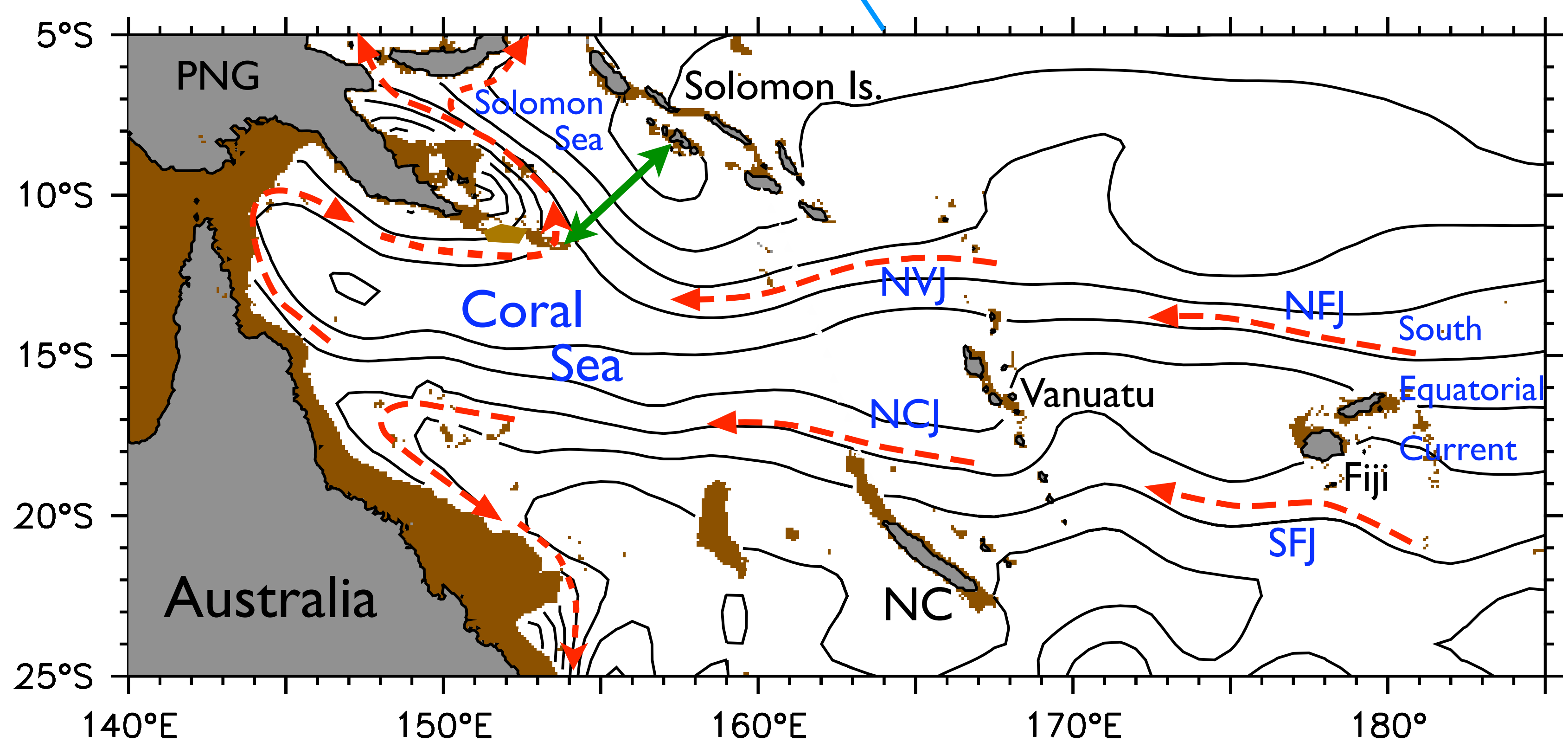
→ The glider program aims to monitor these inflows

South Pacific average circulation

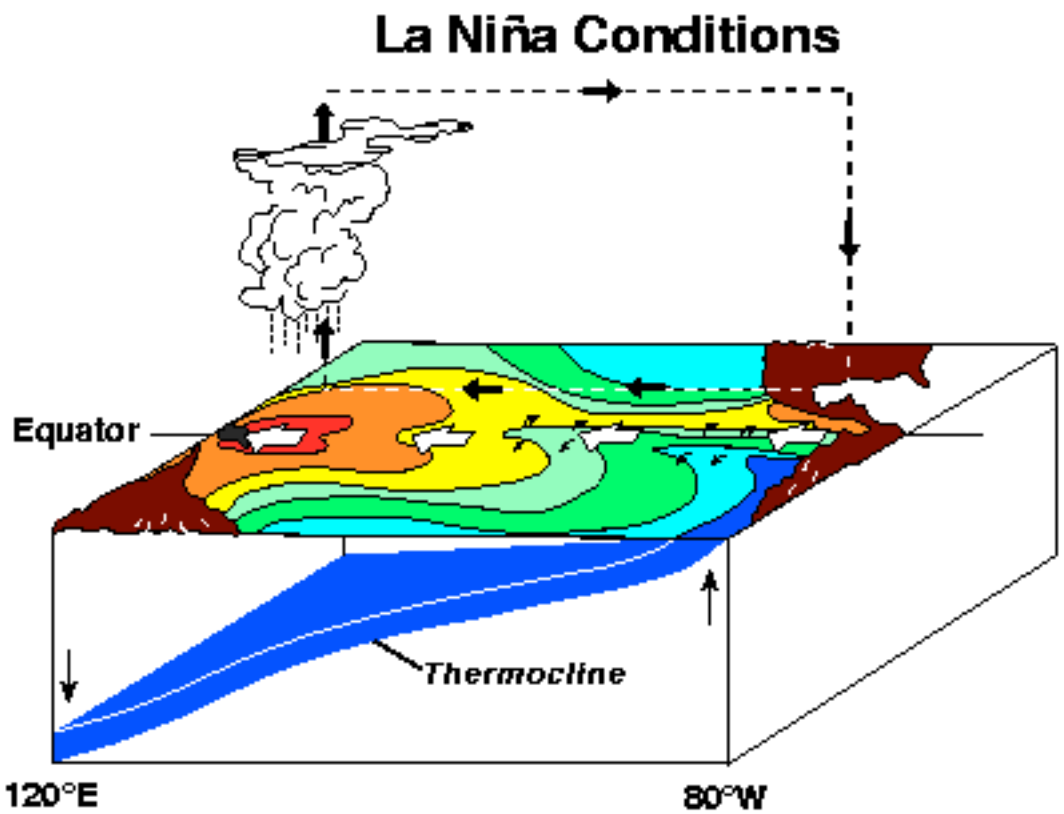


Oceans mostly have broad, slow currents. Except along their western edges!

Zoom in



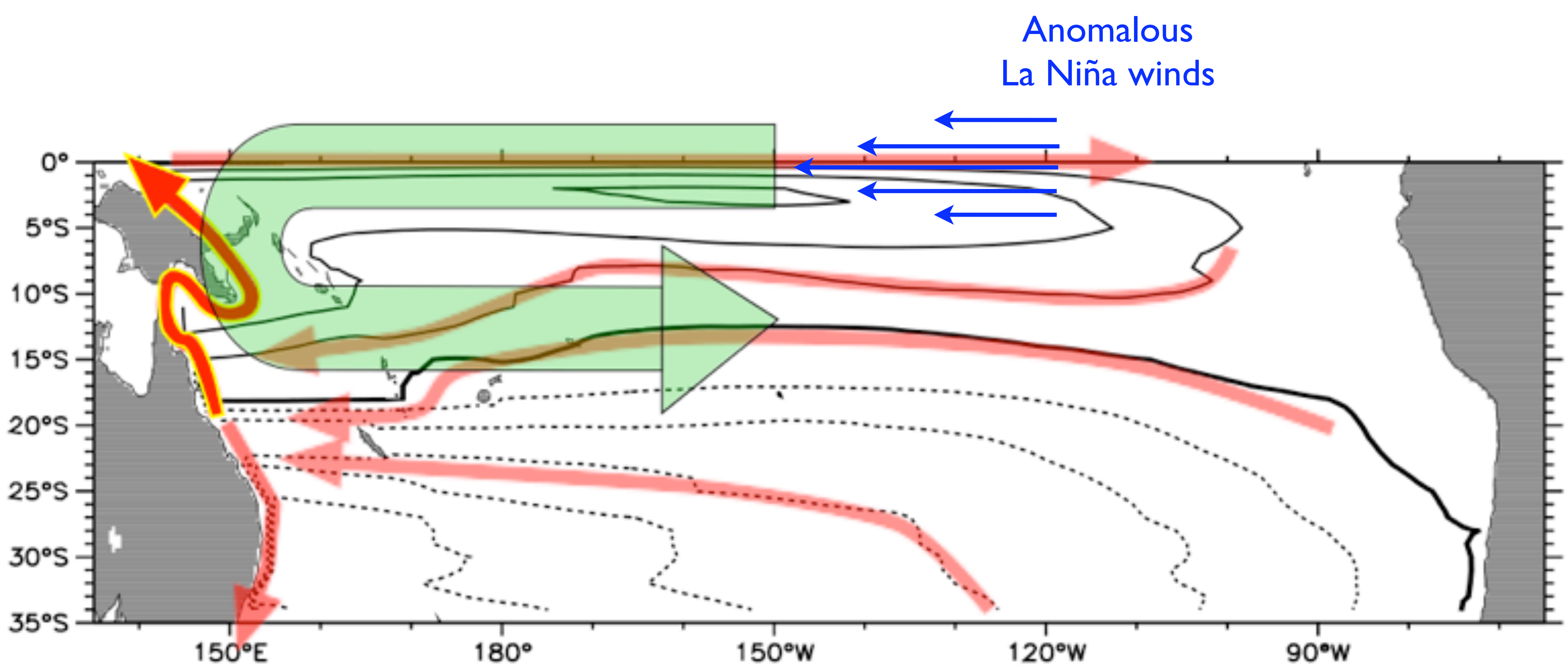
Glider experiments cross the Solomon Sea and measure the flow towards the equator.



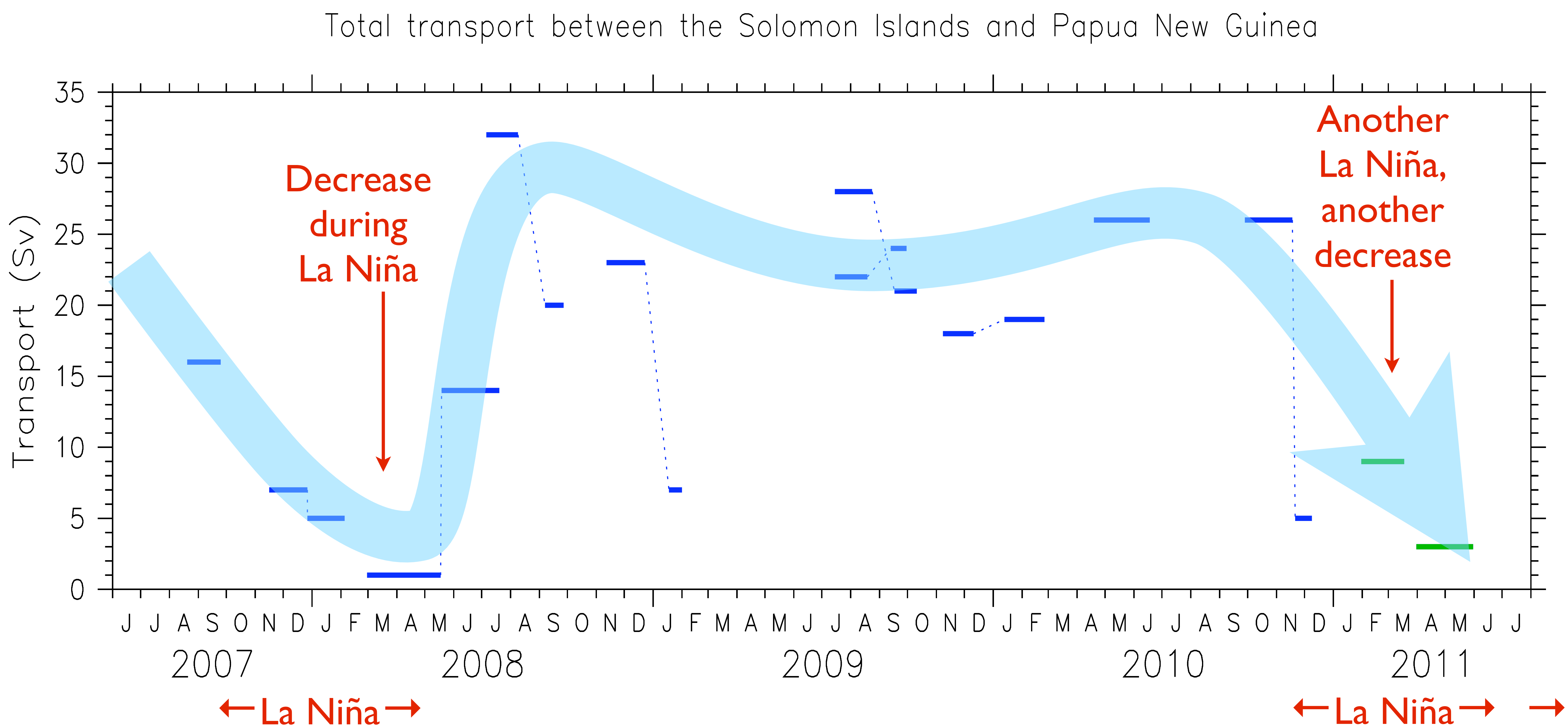
La Niña current anomalies

There was a strong La Niña in 2007-8, again in 2010-11, and again this winter.

La Niña does the opposite of El Niño: it tends to weaken currents in the west.

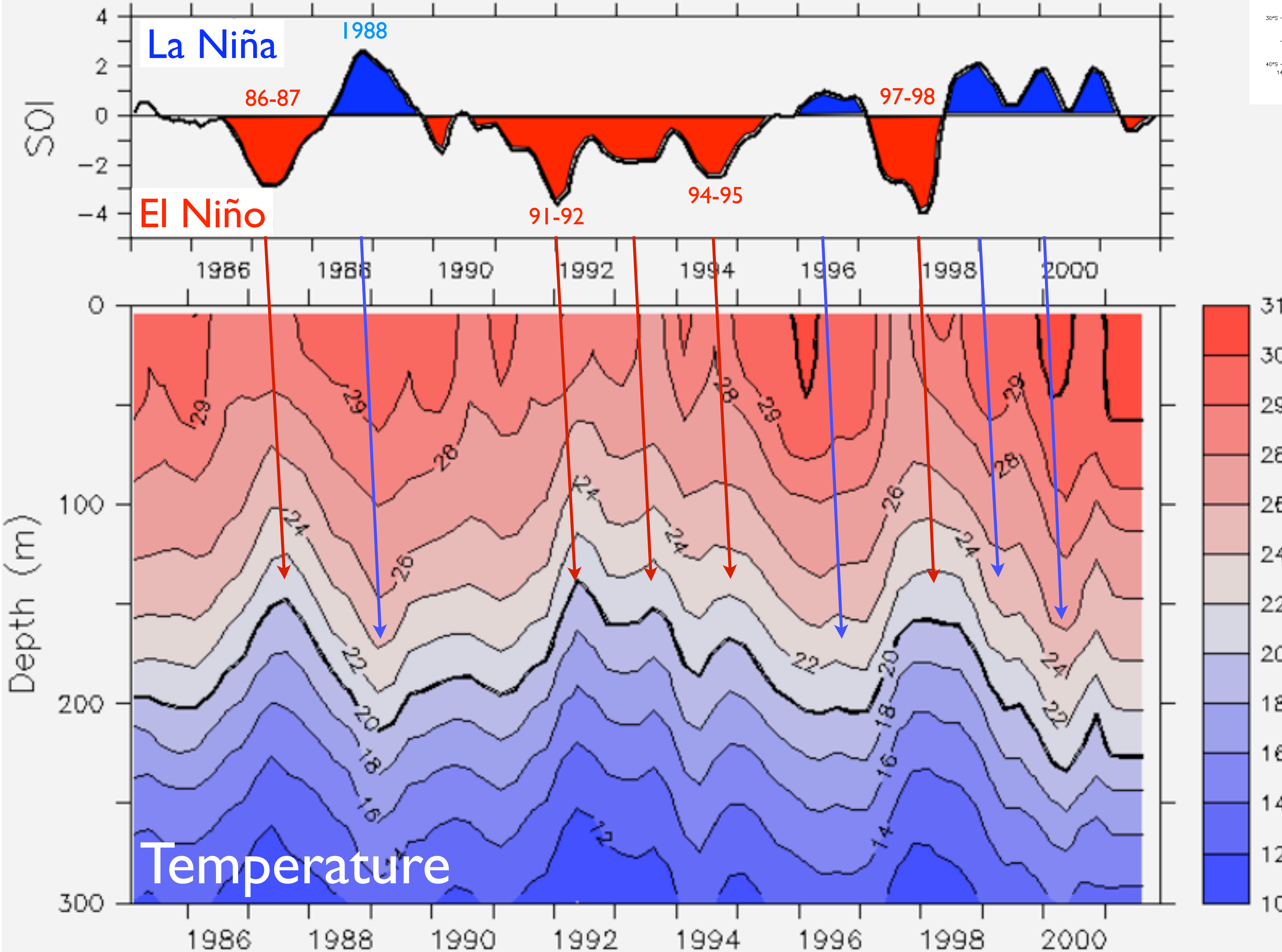


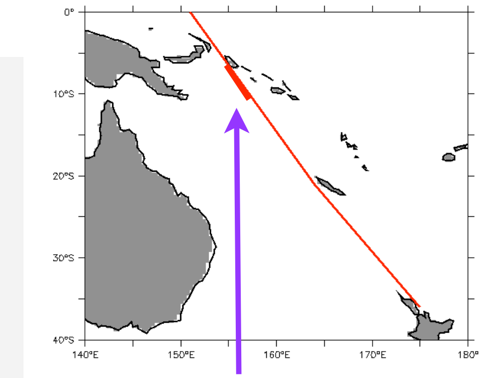
Solomon Sea transport measured by the Spray glider



(Mississippi River transport is about 0.02 in these units (1 Sv = 1 million m^3/s)

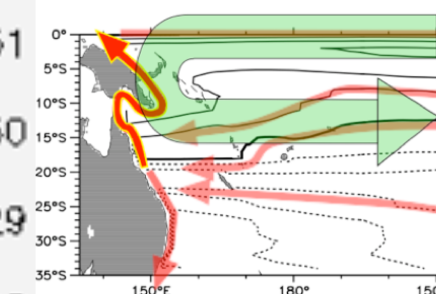
Solomon Sea temperatures and El Niño





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

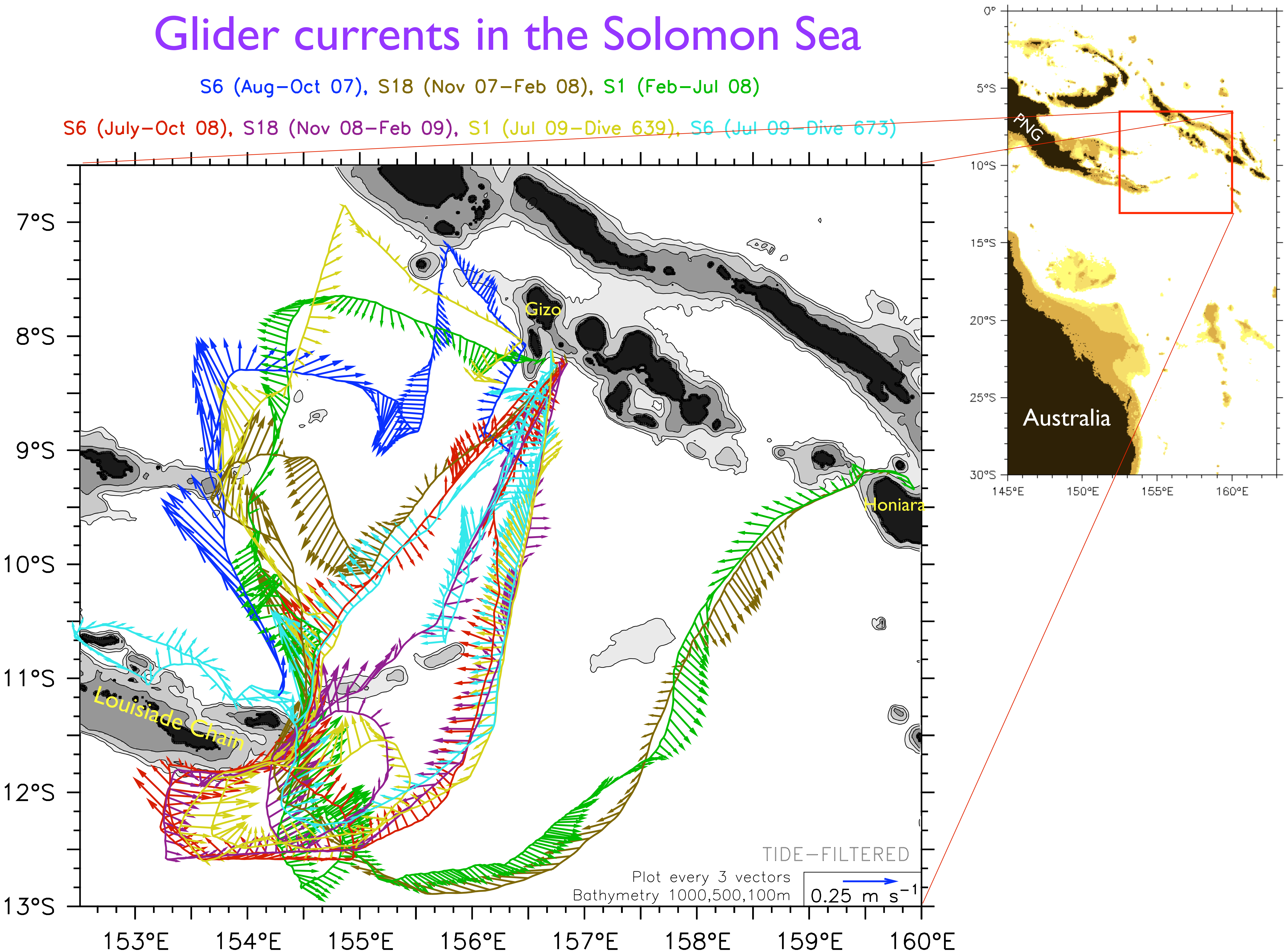
La Niña schematic flow



Glider currents in the Solomon Sea

S6 (Aug–Oct 07), S18 (Nov 07–Feb 08), S1 (Feb–Jul 08)

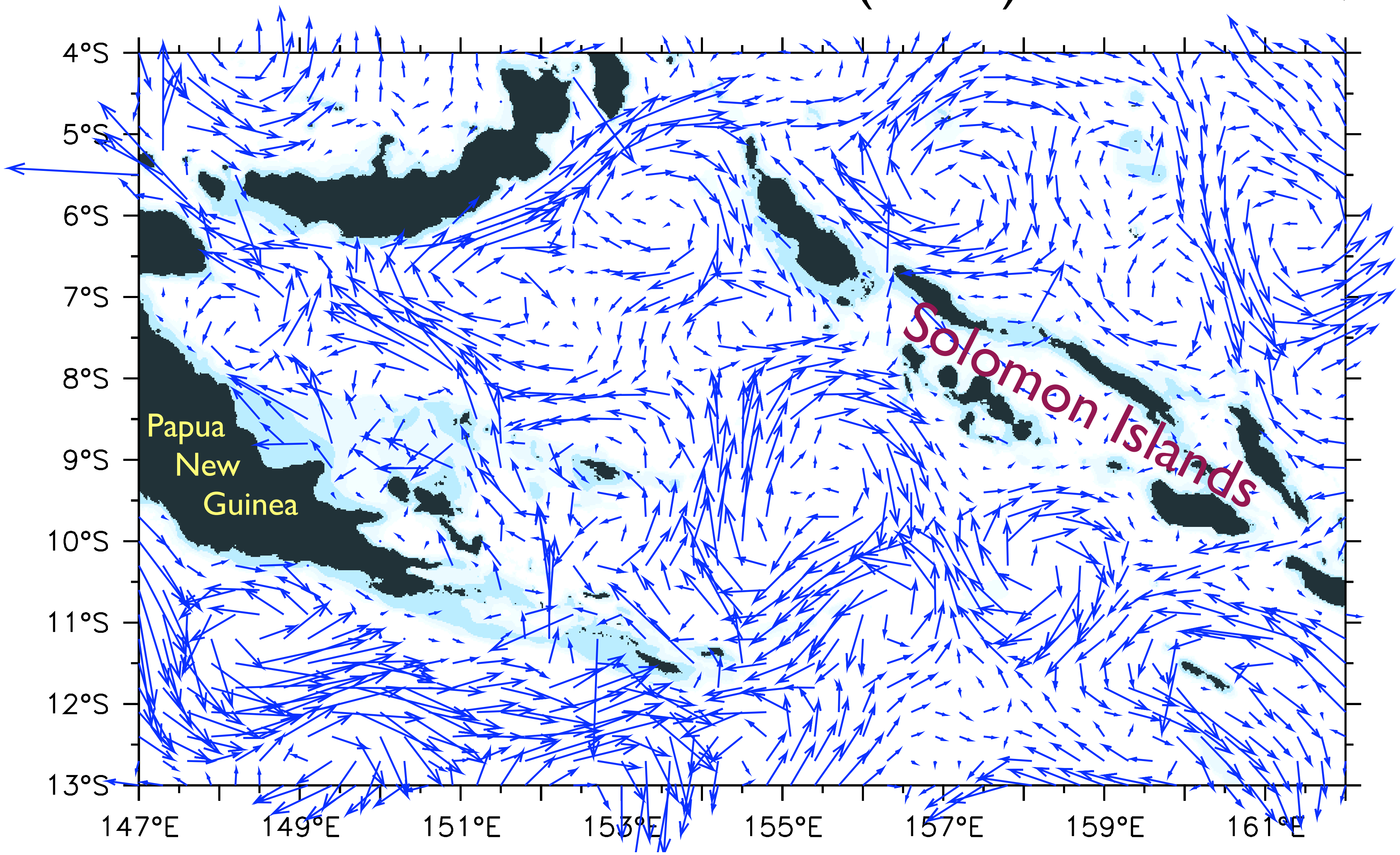
S6 (July–Oct 08), S18 (Nov 08–Feb 09), S1 (Jul 09–Dive 639), S6 (Jul 09–Dive 673)



Ocean model solutions show intense eddies.

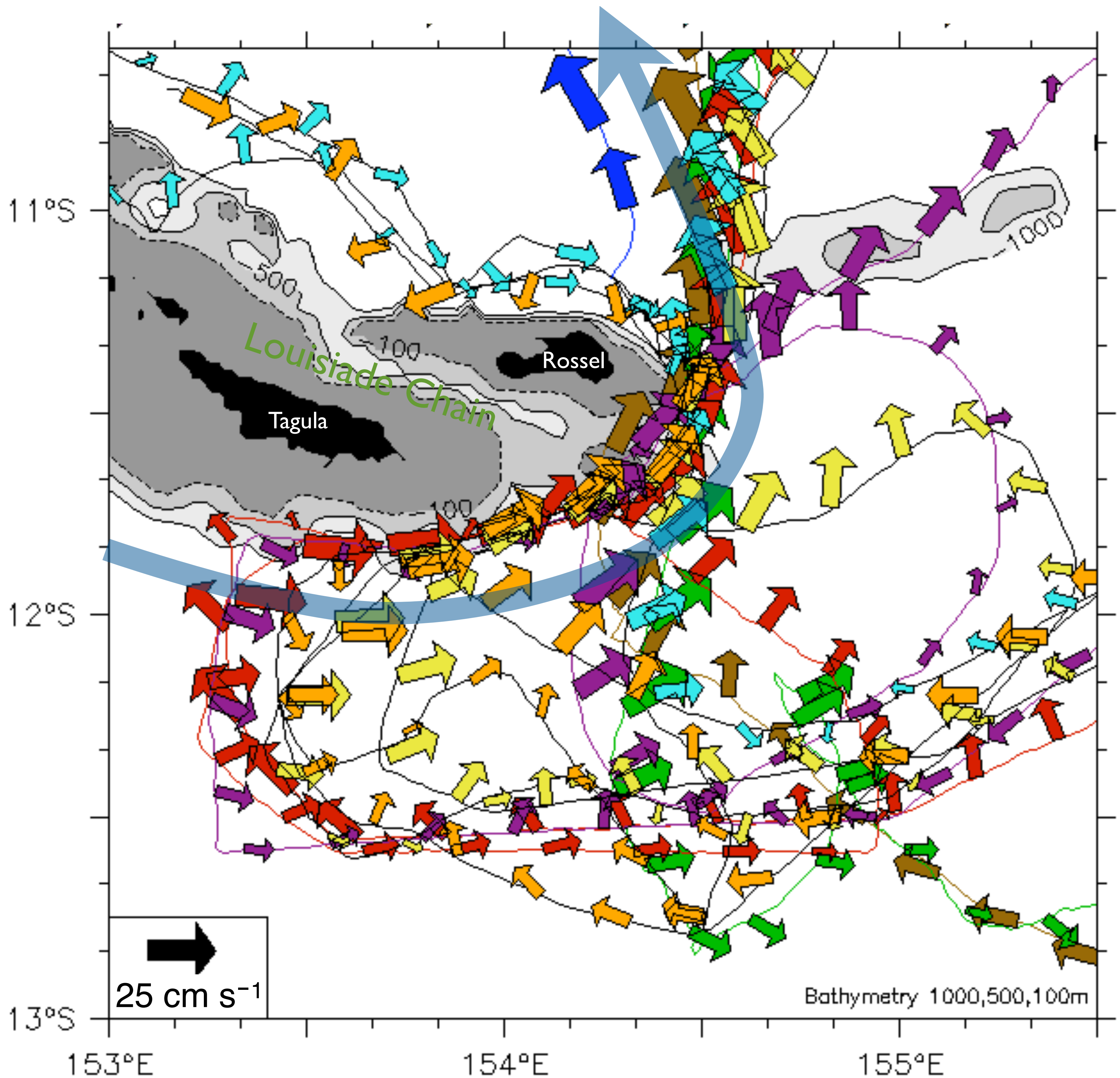
⇒ Collaboration with modelers!

Example of velocity from the Bluelink model (BOM)



Bluelink example for 15-20 Oct 07

Vertical-average currents at the tip of Papua New Guinea



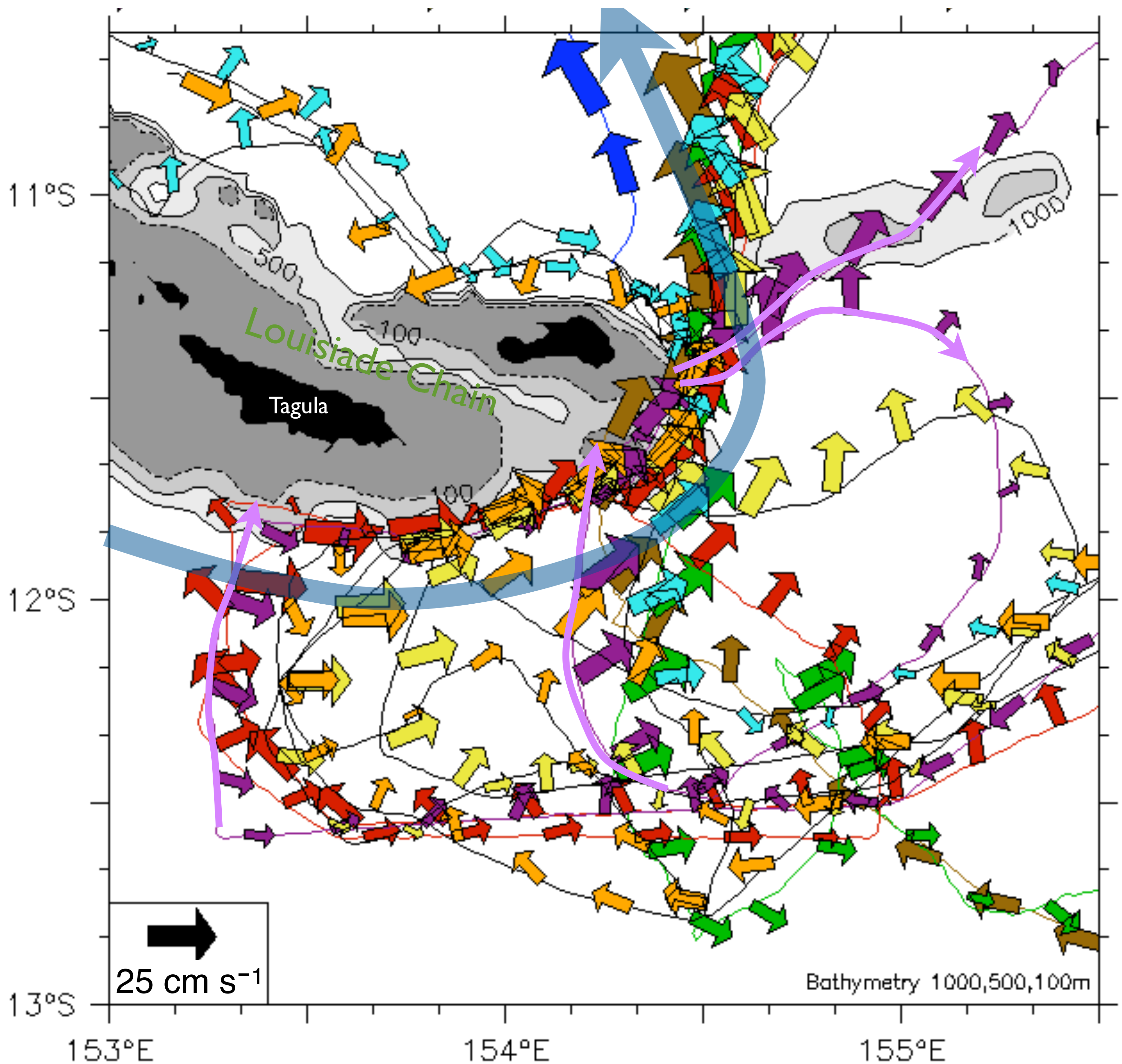
The most consistent observation is a strong current towards the equator at the tip of the Louisiades.

The current is very close to the reef line.

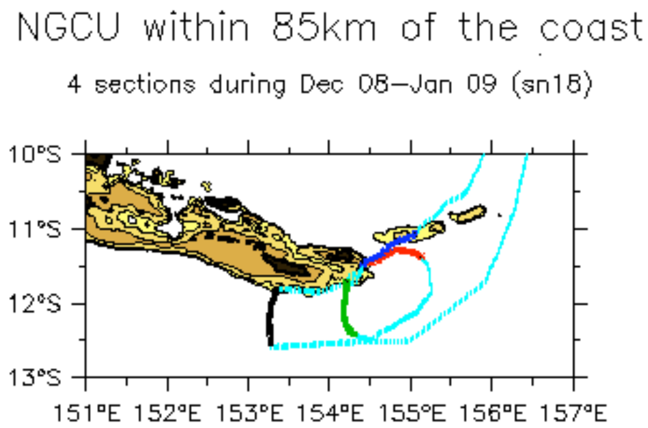
(Light-gray shade shows shallow water)

25-km along-track averages

Vertical-average currents at the tip of Papua New Guinea



Now, we'll look at the
vertical structure
of the NGCU ....
four 100km sections
(light purple lines)



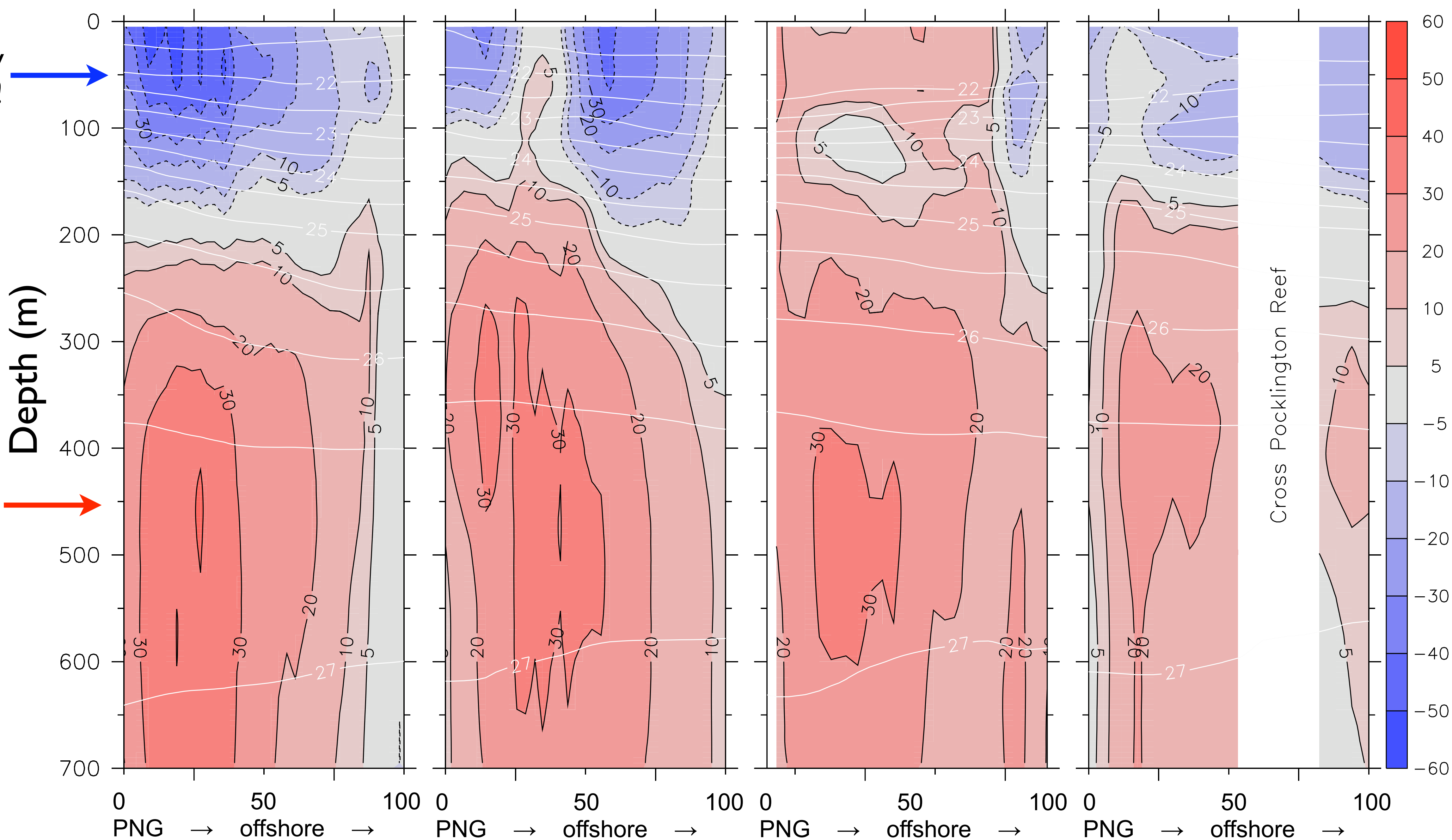
The equatorward flow is an <u>undercurrent</u>

Currents at the tip of the Louisiades

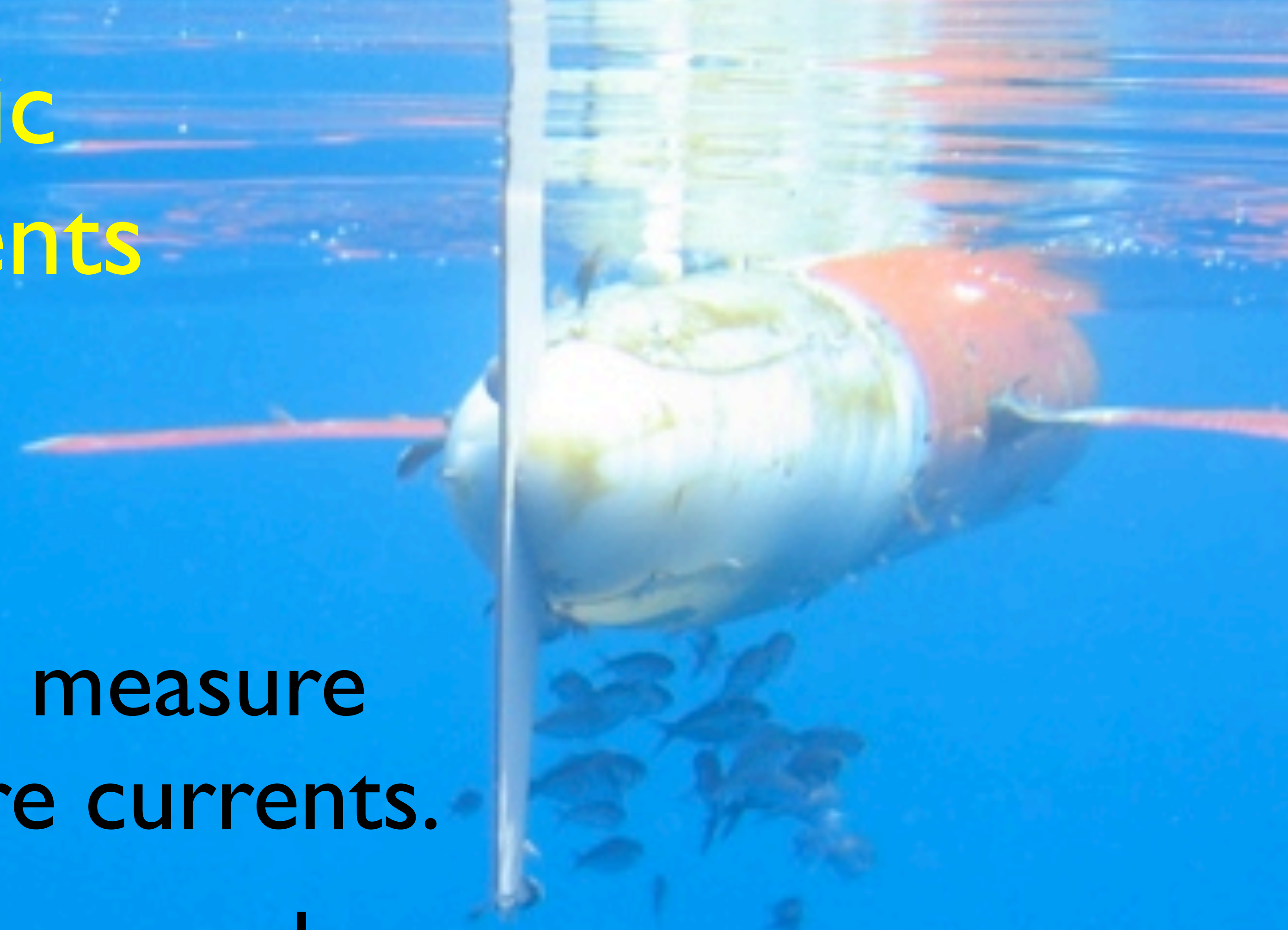
Vertical sections with the <u>coast of PNG at the left side of each panel</u>

Opposite flow at the surface!

Maximum near 450m

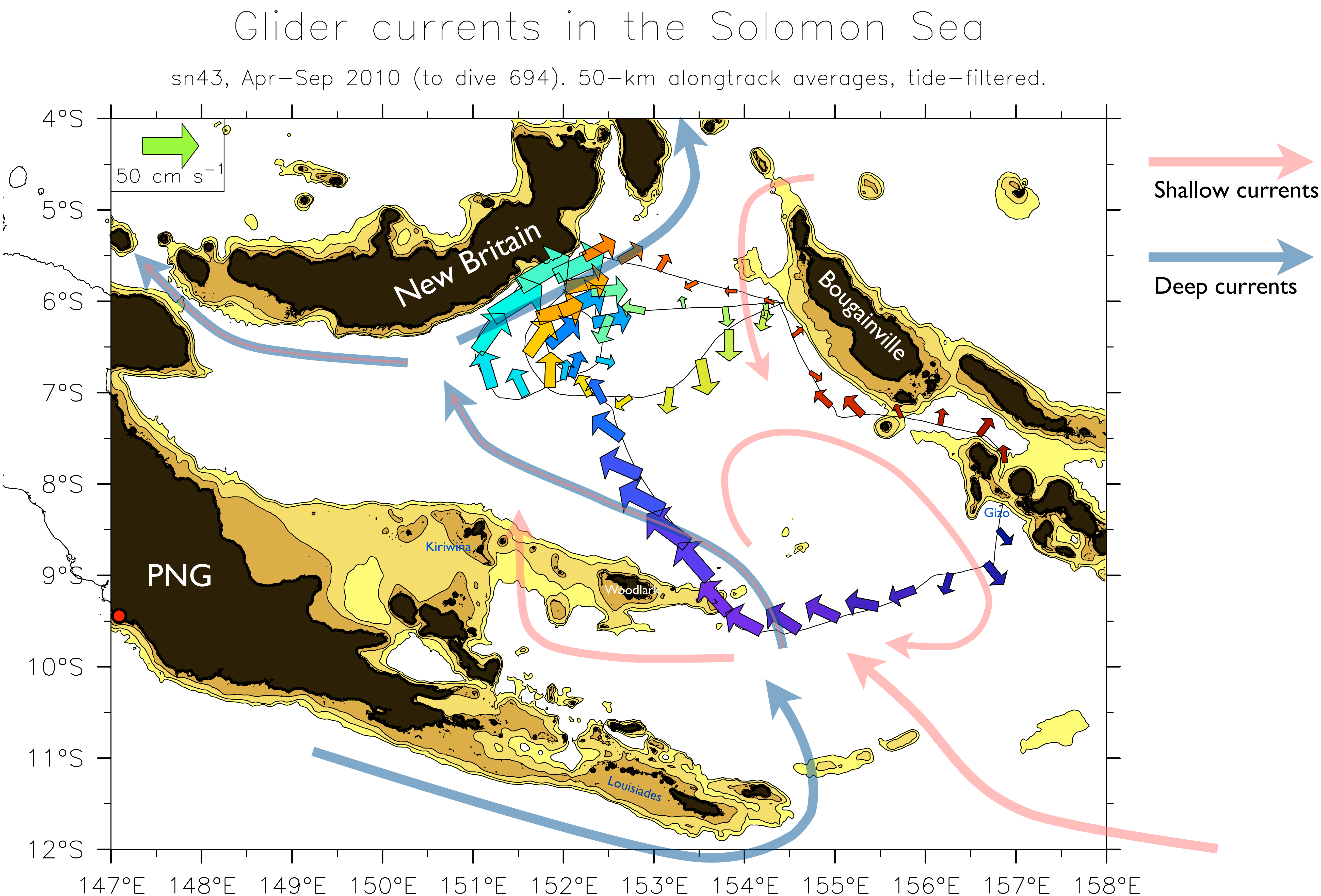


Measuring South Pacific western boundary currents with ocean gliders



- Gliders are the only way to measure these narrow, close-to-shore currents.
- This is a new model of oceanography: small, cheap, autonomous instruments that produce a time series.
- Measuring variations of the New Guinea Coastal Undercurrent will give important clues to the working of El Niño and the climate system.

Extra
slides
follow ...

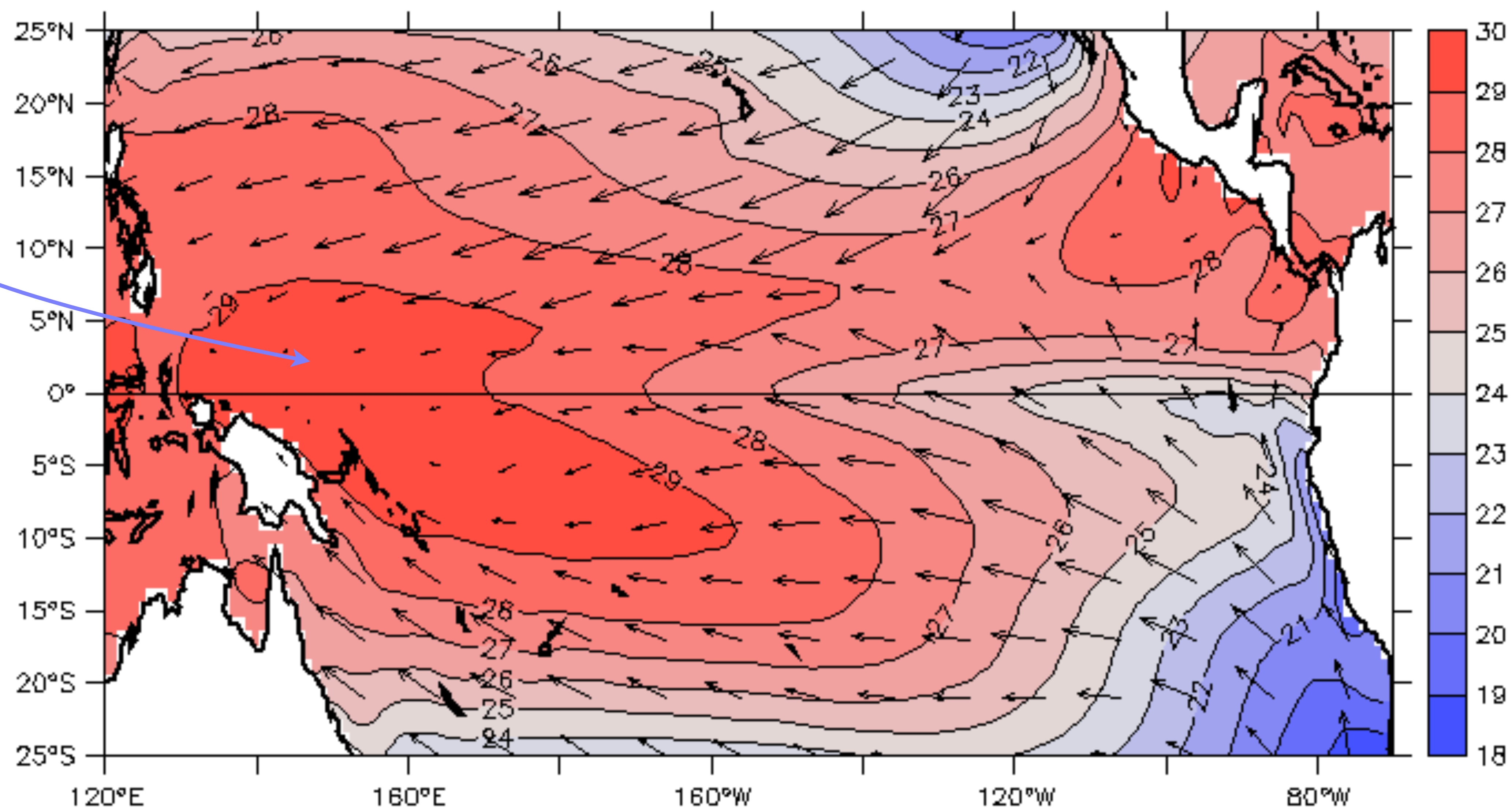


Glider currents in the Solomon Sea
sn43, Apr–Sep 2010 (to dive 694). 50–km alongtrack averages, tide–filtered.
50 cm s^{-1}
New Britain
Bougainville
PNG
Kiriwina
Woodlark
Gizo
Louisiades
Shallow currents
Deep currents
4°S
5°S
6°S
7°S
8°S
9°S
10°S
11°S
12°S
147°E 148°E 149°E 150°E 151°E 152°E 153°E 154°E 155°E 156°E 157°E 158°E

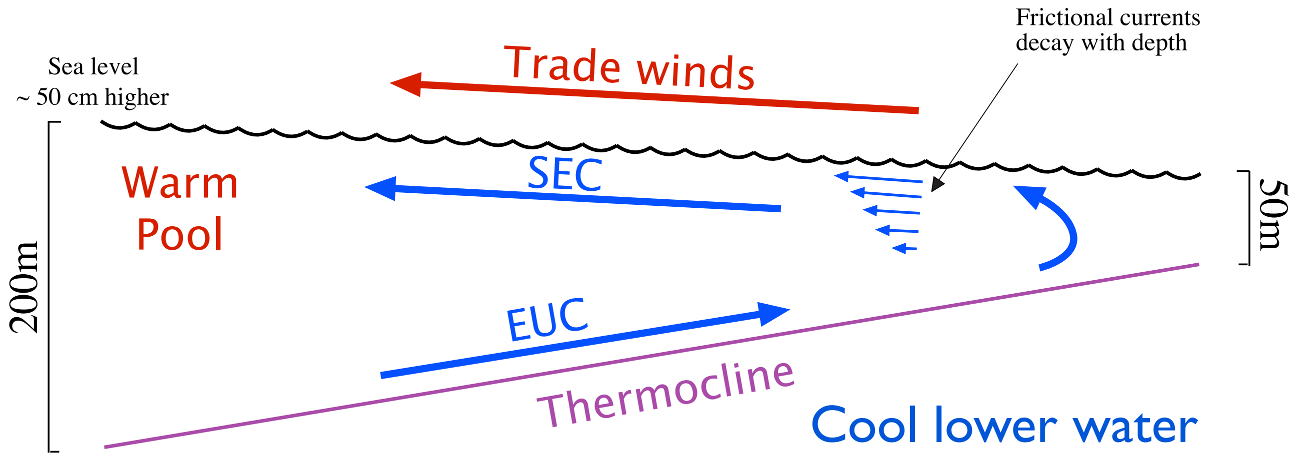
The normal situation:

- The warmest water is not at the equator.
- There is a roughly 5°C temperature contrast from west to east.
- Winds blow from the cooler to the warmer water, and converge on the West Pacific Warm Pool. These winds push water to the west.

Temperature and winds in the tropical Pacific



Currents and temperature on the equator

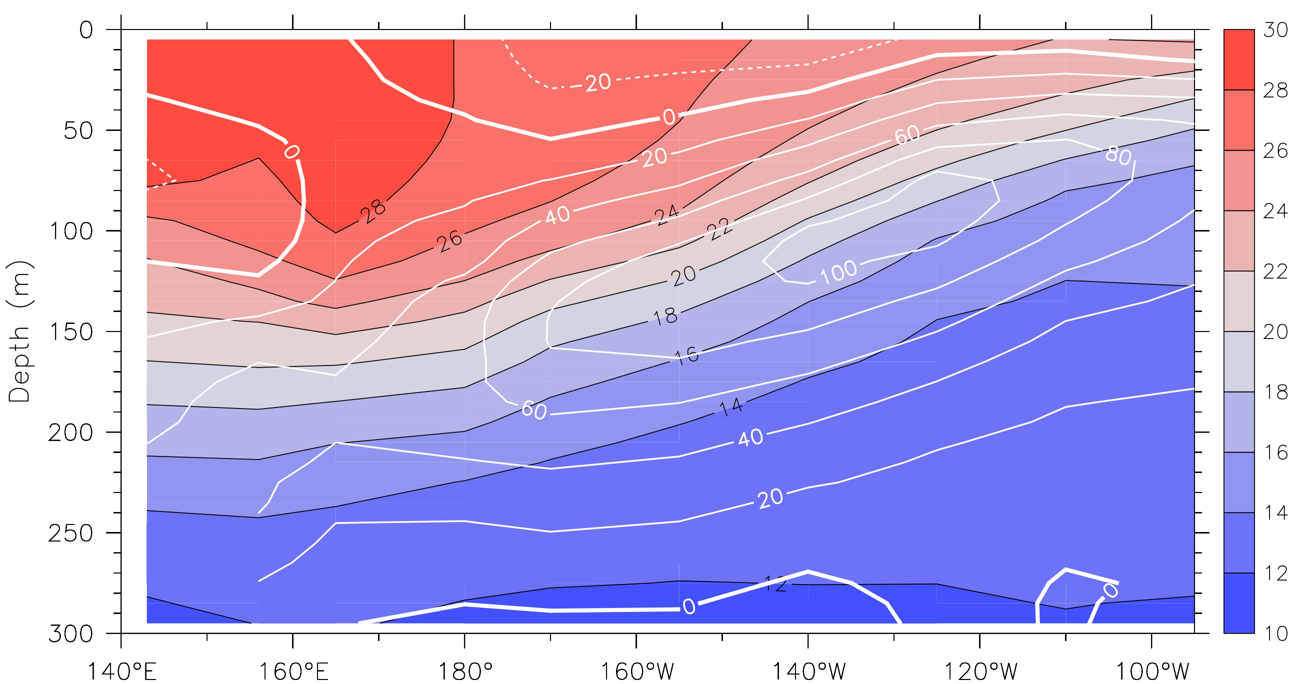


The trade winds 1) Pile up water in the west.
2) Drive the SEC by direct friction.

Below the frictional layer (25m?) pressure due to the high sea level in the west pushes the EUC eastward below the surface.

(SEC = South Equatorial Current
EUC = Equatorial Undercurrent)

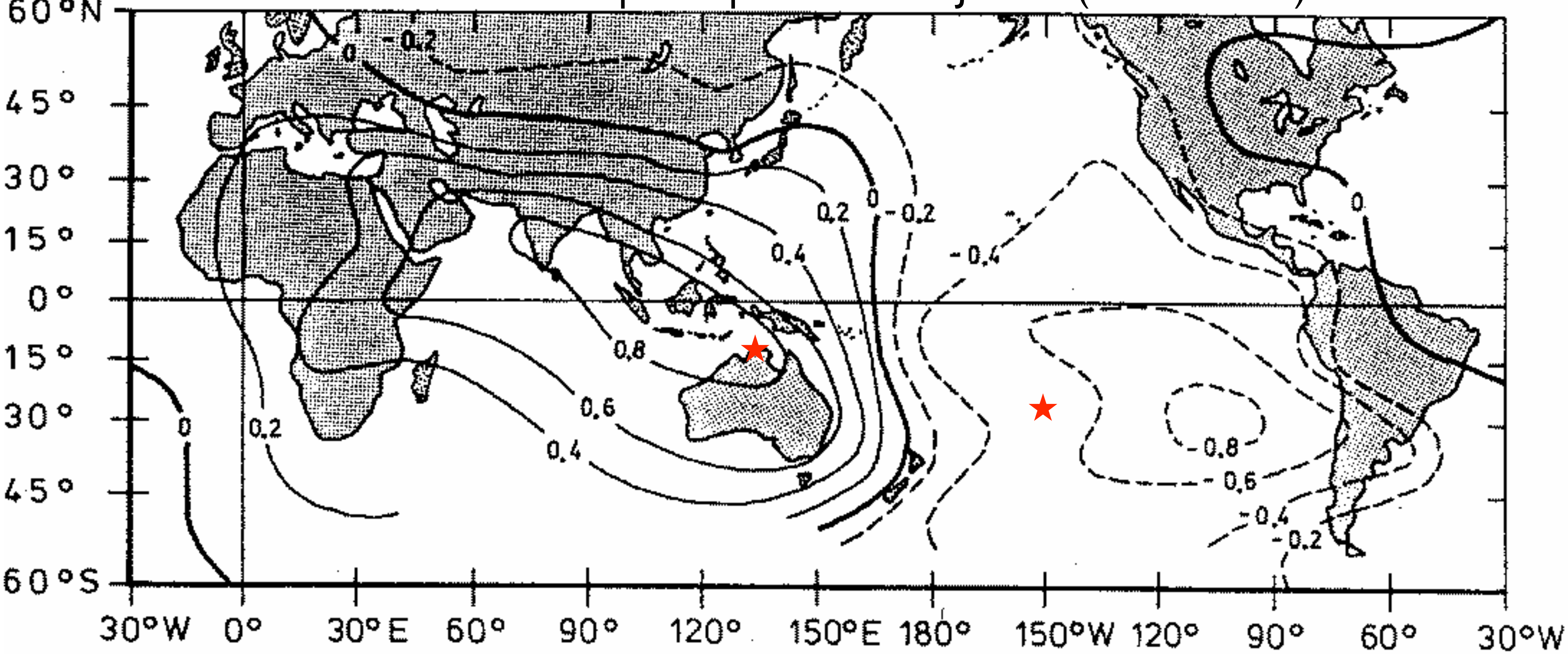
Observed mean temperature (colors)
and currents (white contours)
along the Pacific equator



Johnson et al (2001)

The Southern Oscillation Index gives a time history of El Niño, first used in 1923 by Sir Gilbert Walker, Director of Observatories in British India, who noted that "when pressure is high in the Pacific Ocean it tends to be low in the Indian Ocean from Africa to Australia".

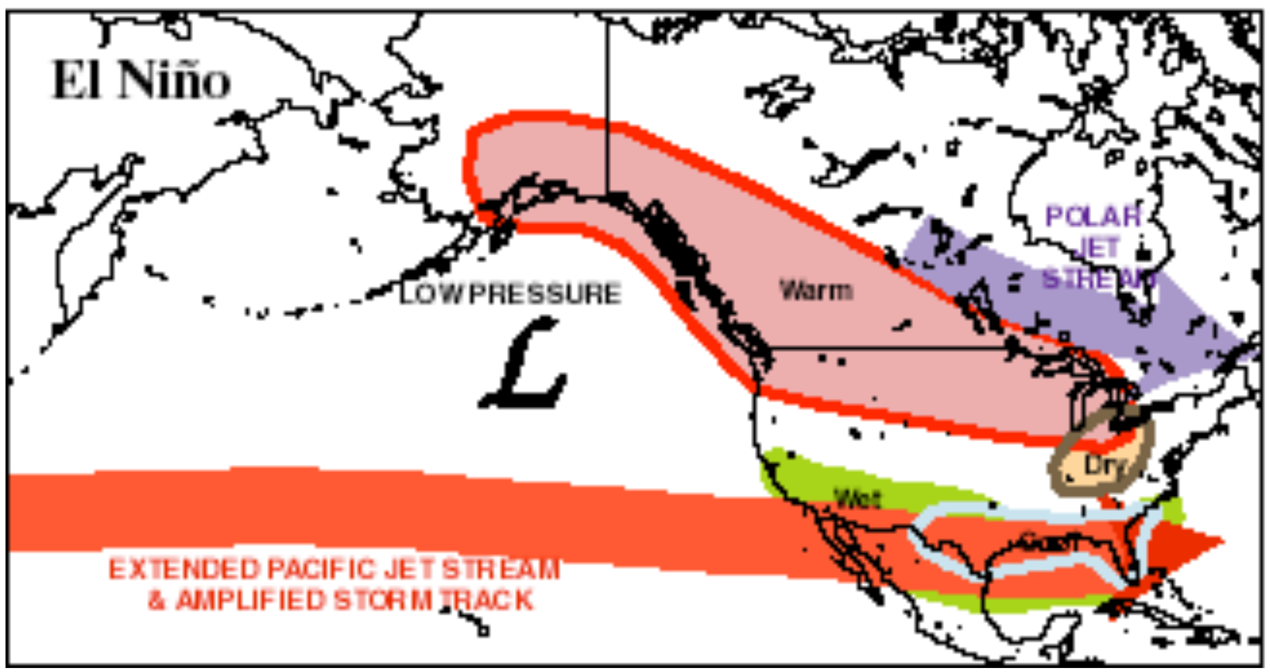
Correlation of atmospheric pressure with Jakarta (Walker 1924)

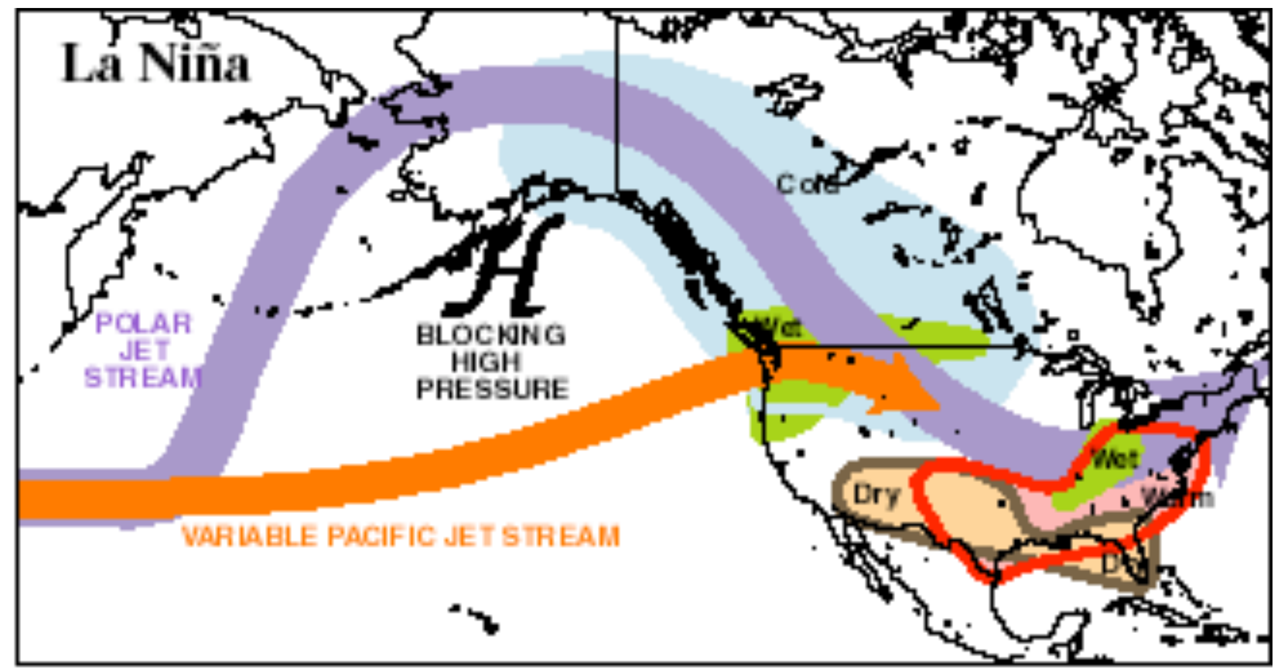


The Southern Oscillation Index is the air pressure difference between Darwin, Australia and Tahiti

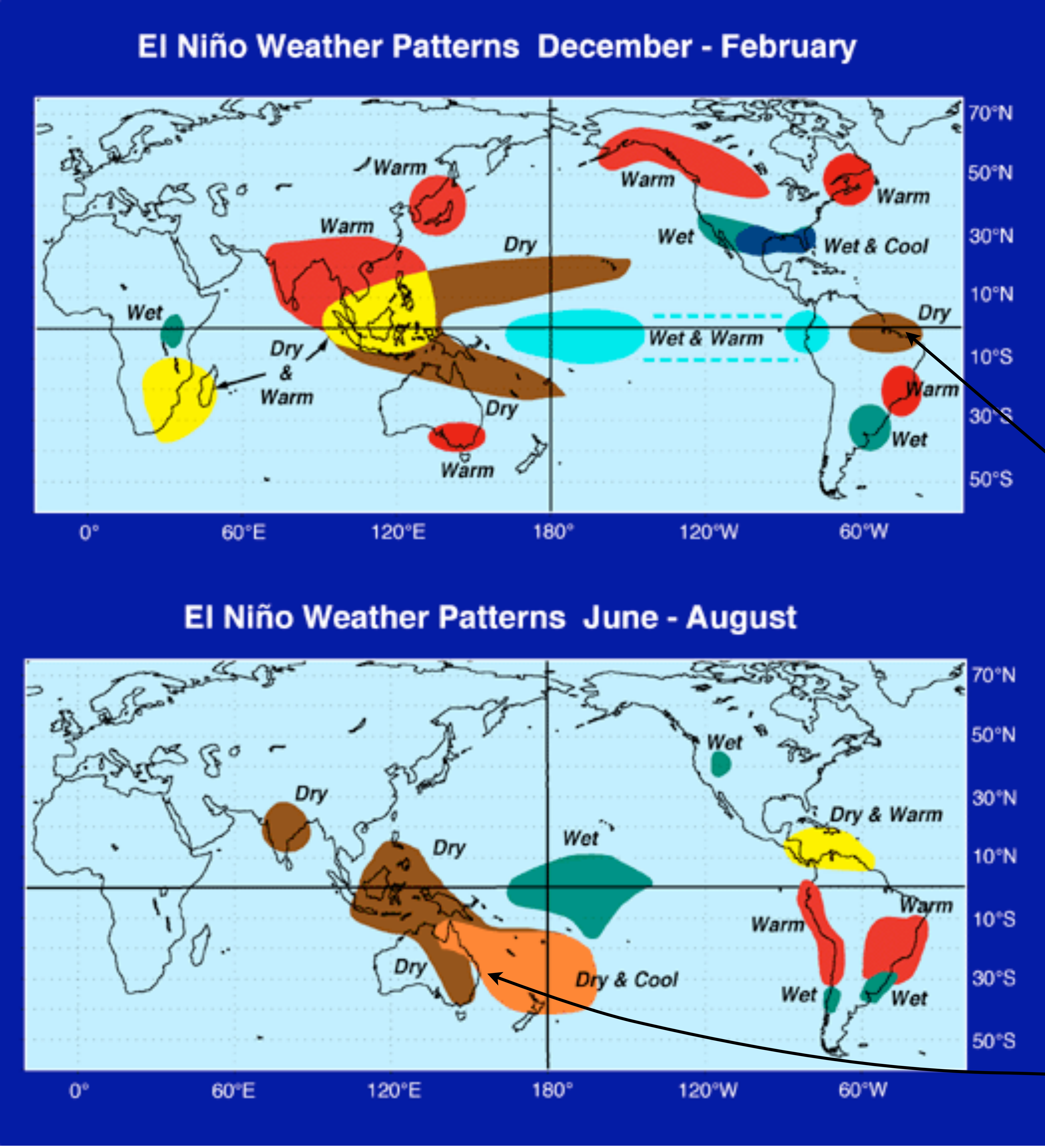
How are El Niño's effects spread from the tropics?

The west Pacific warm pool is a principal heat source driving much of the global winds. When it shifts east, it distorts the jet streams, much as a rock placed in a creek causes waves that extend well downstream from the rock itself.





In North America, the effects of the warm SST during El Niño are not felt directly. Instead, mid-latitude weather is modified because the eastward-shifted warm water changes the path of the winter jet streams that bring us our weather systems.



Great benefit around the world if these events (and their subsequent effects) could be accurately predicted.

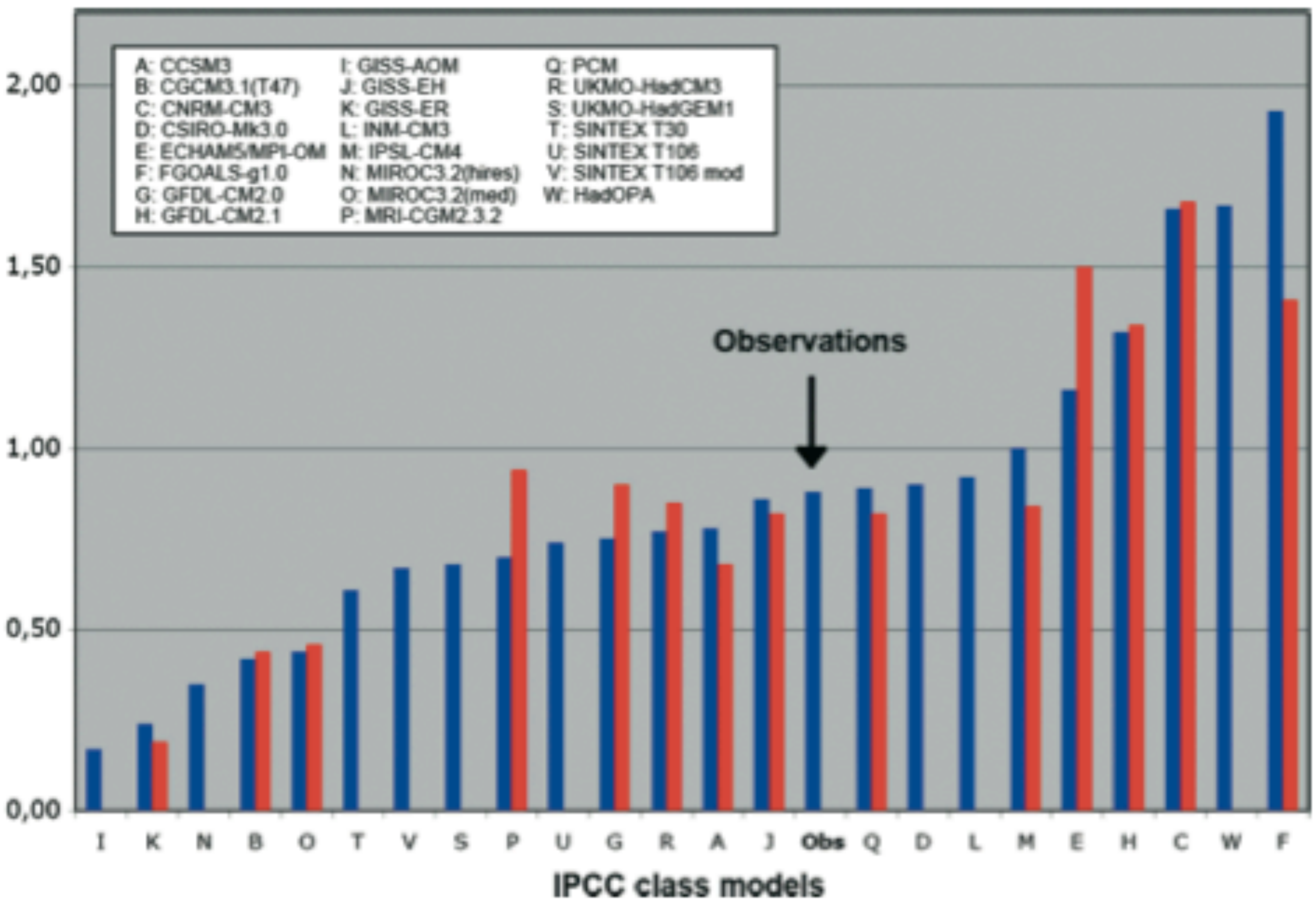
NE Brazil

El Niño droughts used to reduce crop yields by 75%. With predictions, famers plant drought-tolerant beans and crop losses are much less.

On the other hand, predictions are not always correct (Australia 1997).

Uncertain ENSO simulations in climate change models

ENSO amplitude



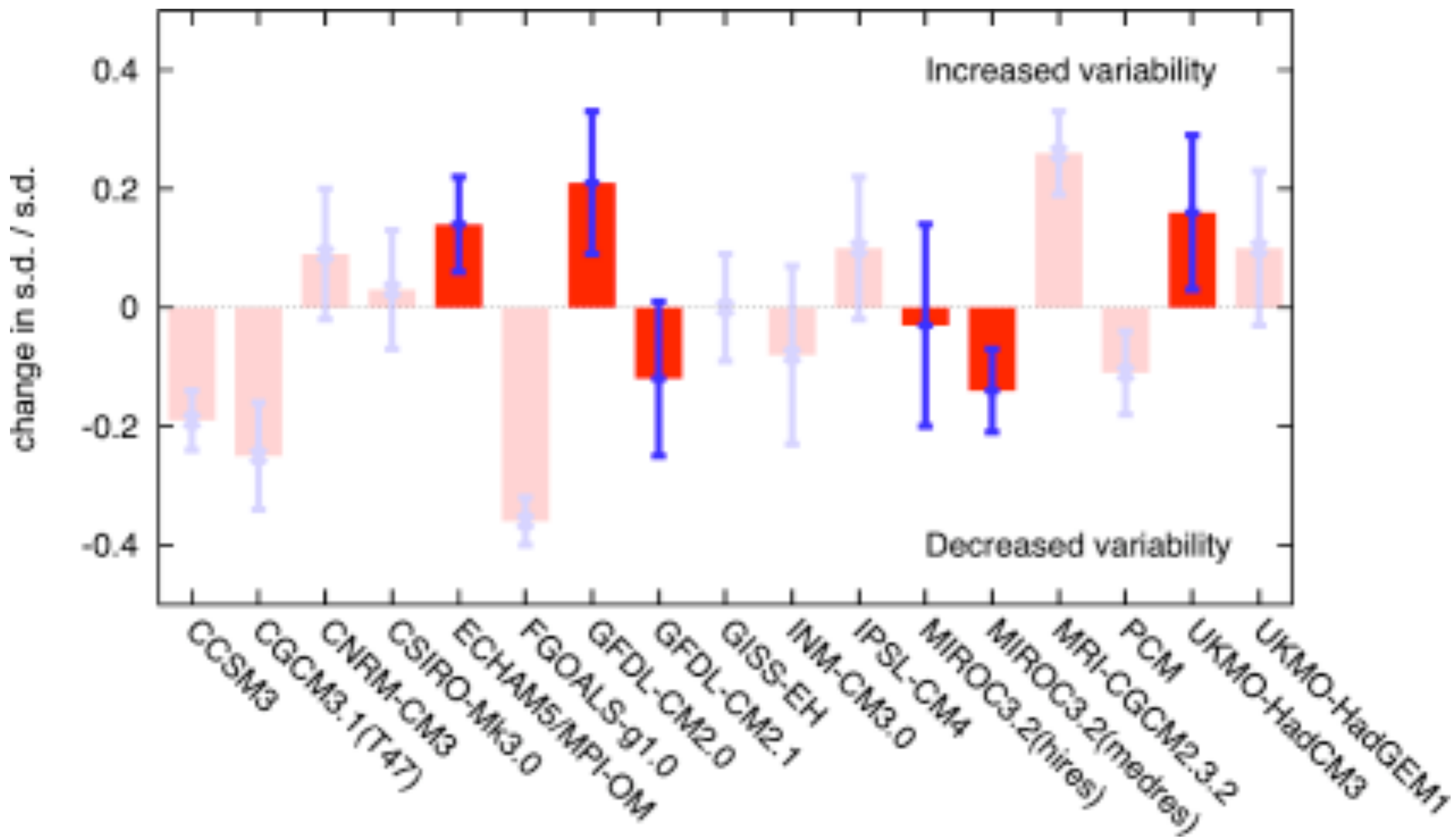
Blue bars = preindustrial

Red bars = $2xCO_2$

FIG. 5. ENSO amplitude in 23 coupled CGCMs, including those used for the IPCC AR4, as measured by the Niño-3 SST anomaly std dev in preindustrial simulations (blue bars) and equilibrated 2 × CO_2 scenarios (red bars).

Guilyardi (2009)

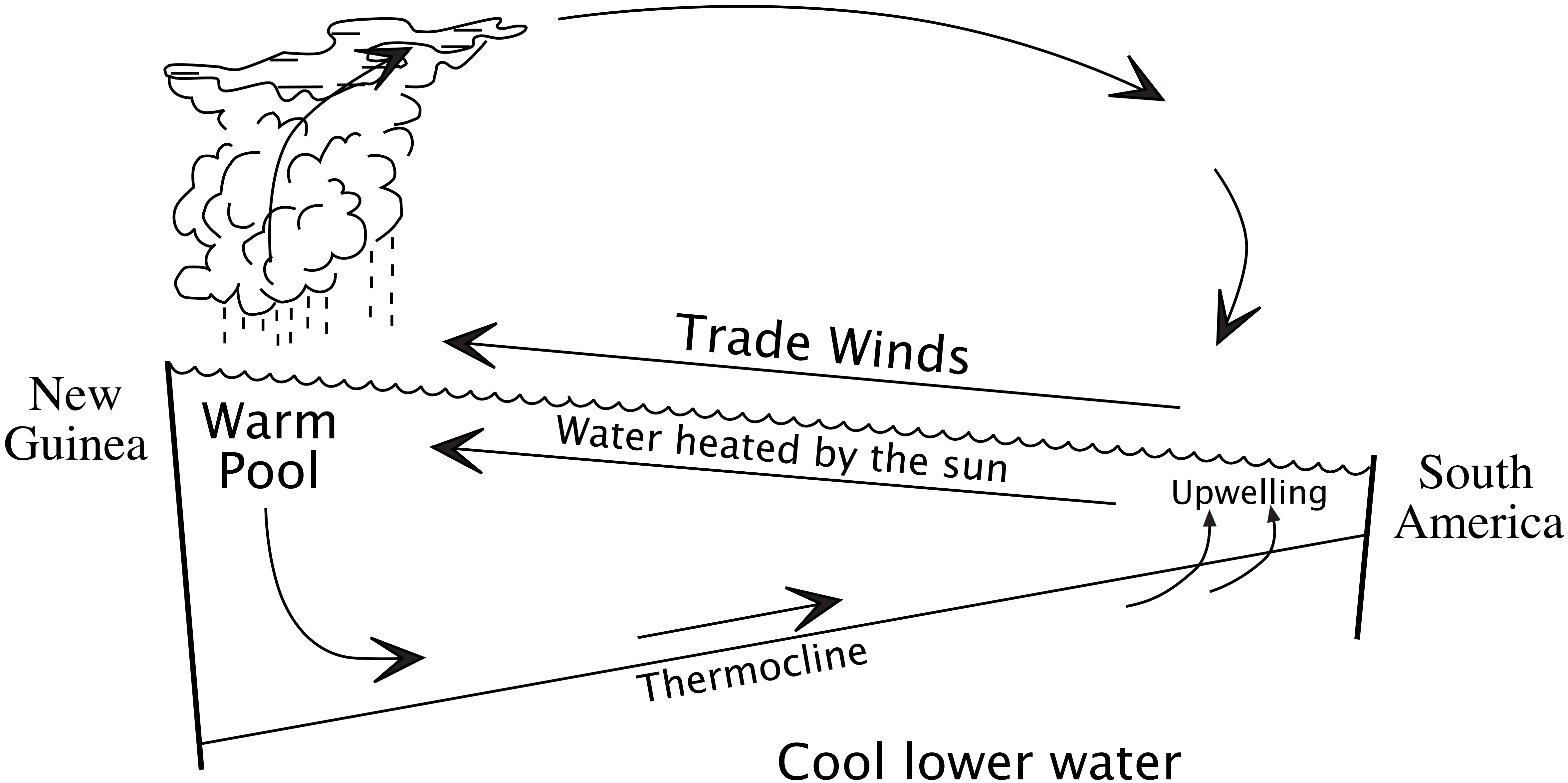
We don't know what will happen to ENSO under climate change!



The forecasts for ENSO variability in IPCC models .... all over the place.

van Oldenborgh &
Collins (2007)
(KNMI & U.K. Met Office)

Schematic diagram of the coupled interaction along the Pacific equator (normal situation)

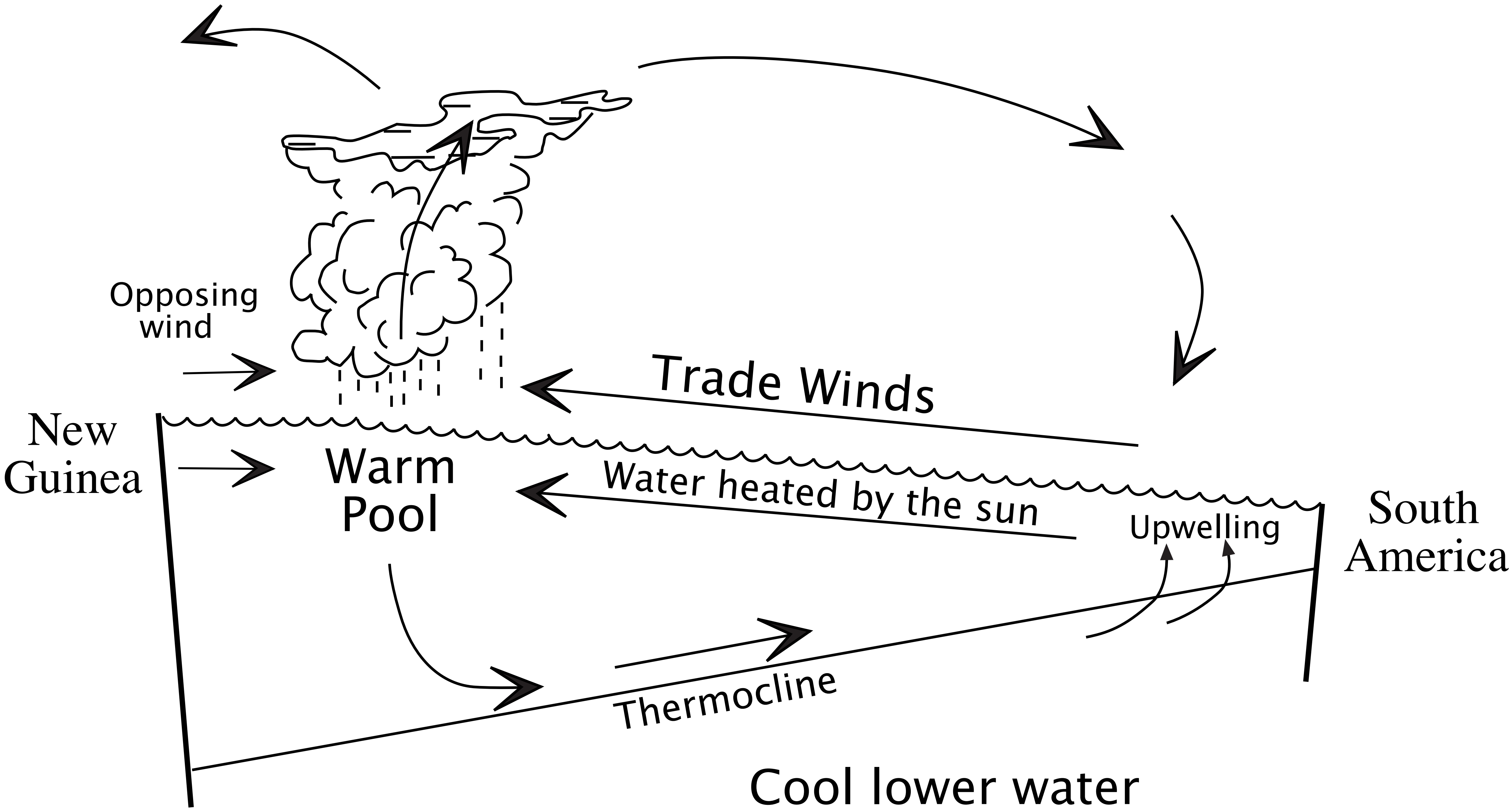


Why are there trade winds? Because the warmest water is in the west.

Why is the warmest water in the west? Because there are trade winds.

Schematic ocean-atmosphere interaction during El Niño onset:

For unknown reasons, a westerly wind event in the far western Pacific pushes the warm pool a little bit east. The convection follows the warmest water.



We don't know why El Niños start!

Schematic ocean-atmosphere interaction during El Niño peak:

Once the warm pool moves east, the overlying convection now draws winds from both east and west. That pushes the warm pool further east, and the whole system collapses.