The Mean and the Time-variability of the Shallow Meridional Overturning Circulation in the Tropical South Pacific Ocean

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Three scientific questions …

1) Evaluate the interannual variability of the volume transport towards the Equator.

1) Better understanding of southern sources of the Indonesian Throughflow.

2) Quantify the heat budget north of 7.5°S.

Shallow Meridional Overturning Circulation / Subtropical Cell (STC)

Argo float profiles [Roemmich and Gilson, 2009]

44 pressure levels between 0 and 1000 dbar.

Vertical resolution of 10 dbar near the surface increasing to 100 dbar at depth.

Mean and anomaly fields interpolated onto a 1° x 1° grid.

January 2004 to December 2010 period.
Pycnocline outcrops at lower latitude in the southeast Pacific (10-15°S) than in the northeast Pacific (35°N).

In the Northern Hemisphere, the ventilated subtropical waters in the interior Pacific deviate to the west.

In contrast, the ventilated waters in the Southern Hemisphere travel from the outcrop region directly to the Equator.

The equatorial waters originating in the south are much more ventilated than those from the north.
2004-2010 mean geostrophic transport in the interior at 7.5°S is equatorward.

31.7 ± 4.2 Sv **0-1000 m**.

14.5 ± 3.0 Sv **below the mixed layer** in agreement with Johnson and McPhaden (1999).

Ocean interior geostrophic anomalies exhibit an ENSO signature.

Geostrophic transport in the interior increases during La Niña and decreases during El Niño.

Correlation coefficient between the geostrophic transport and the Niño 3-4 index is -0.9.
In the Solomon Sea region, the 2004-2010 mean geostrophic transport is equatorward.

16.8 ± 2.0 Sv 0-1000 m, half of the interior.

Geostrophic transport in the Solomon Sea region decreases during La Niña and increases during El Niño.

Correlation coefficient between the geostrophic transport and the Niño 3-4 index is 0.8.

West of the Solomon Islands, the transport is

18.7 ± 1.4 Sv 0-700 m, 3.7 Sv higher than glider observations (Davis et al., submitted in JPO).
Geostrophic Transport at the surface using Argo compared with Aviso

The interannual variability of the geostrophic transport in the Solomon Sea region using Argo is half of the interior, but has opposite phasing relative to ENSO, in agreement with Davis et al., (submitted in JPO)

The interannual variability of the surface geostrophic transport using Argo similar to Aviso averaged for 5°-10°S. Lack of Argo data in the Solomon Sea.

Ongoing hydrographic (J. Sprintall, S. Wijffels) and glider (R. Davis, D. Rudnick) sampling in the Solomon Sea will provide additional geostrophic transport estimates.
Volume transport in the Indonesian Throughflow (ITF)

The $V_{\text{ITF}}$ variability resembles the vertical transport at 1000 m ($W_{1000}$) and is affected by the residual of the geostrophic transport and the Ekman transport.
Three Mass-balanced Components

**Surface Recirculation Cell (SRC)**

Geostrophic transport in the surface layer ($V_{g-ML}$) that recirculates in the surface layer as Ekman transport ($V_{Ek-SRC}$).

**Meridional Overturning Circulation (MOC)**

Geostrophic transport in the thermocline ($V_{g-Th}$) that upwells and returns as Ekman transport ($V_{Ek-MOC}$).

**Indonesian ThroughFlow (ITF)**

Geostrophic transport in the thermocline feeding the Indonesian Seas ($V_{ITF}$).

For all transport a Transport-weighted Temperature is computed to estimate the heat transport for each component.
2004-2010 mean Heat Budget north of 7.5°S

Ocean circulation cools the Pacific Ocean north of 7.5°S ($H < 0$).

2004-2010 mean heat storage ($S = S_{up} + S_{low}$) and vertical advection of heat ($Adv_z$) are minor compared to the heat transport ($H$).

The region north of 7.5°S loses heat in the MOC ($H_{MOC} < 0$).

Air-sea flux warms the box north of 7.5°S ($Q > 0$).

$(H - S + Adv_z + Q)$ residual for ECMWF and NCEP consistent with Grist and Josey (2003).

$Q$ in the NOCS 1.1a climatology balances, within errors, the mean residual of our estimated $H$ (using the mid-points $V_{Ek}$ and $V_{ITF}$), $S$, and $Adv_z$. 

Air-Sea Flux north of 7.5°S using NOCs 1.1a is 0.45±0.10 PW

$(H - S + Adv_z)$ computed using mid-points values of $V_{Ek}$ and $V_{ITF}$ for $H$ is -0.40±0.18 PW
Time-variability of the Heat Budget north of 7.5°S

Variability of H into the box is less than that of S, $\text{Adv}_z$, and Q in that region.

Anomalies of the heat storage in the upper 150 m ($S_{\text{up}}$) roughly in balance with Q.

Anomalies of the heat storage below 150 m ($S_{\text{low}}$) exhibit 2-year periodicity generally in opposite phasing with $\text{Adv}_z$.

Large anomalies in the $(H - S + \text{Adv}_z)$ residual appear in balance with the air-sea flux products.

A longer record is needed to assess the time-varying budget.
Three scientific questions …

1) **Evaluate the interannual variability of the volume transport towards the Equator.**

Time-variability of the STC at interannual time scales governed by transport change in the interior.

Geostrophic transport in the interior shows a strong ENSO signature.

Interannual variations of the geostrophic transport in the Solomon Sea region anticorrelated with and half the size of changes in the interior.

2) **Better understanding of southern sources of the Indonesian Throughflow.**

Limited amount of north Pacific water feeding the ITF.

ITF variability affected by the net transport in the South Pacific STC and the vertical transport at 1000 m over all the Pacific north of 7.5°S.

3) **Quantify the heat budget north of 7.5°S**

NCEP and ECMWF analyses indicate an oceanic heat gain from the atmosphere that is much larger than the heat transport out of the region by the ocean circulation.

Smaller heat gain in the NOCS climatology 1.1a is consistent with the present analysis.

In the time-varying heat budget, the heat storage above 150 m and the air-sea heat exchange tend to balance one another.
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