Transport anomalies through their relation with Warm Water Volume in the western equatorial Pacific at the ENSO time scale: An altimetric study

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1. Introduction

The Solomon Sea (Fig. 1) is identified as a key region of waters feeding the equator, and is of interest in understanding and predicting climate variability (Ganachaud et al., 2007). Its main inflows occur in a western boundary current - the New Guinea Coastal Undercurrent (NGCU), fed by the South Equatorial Current (SEC) and the North Queensland Current (NQC). Its main outflows reach the western equatorial Pacific through three channels: Viltaz, St Georges, and Solomon Straits. It is a region of High Sea Level Anomalies (HSLA, Aviso product) variability and most of the energy in the Solomon Sea is at an annual and interannual (ENSO) periods (Fig. 2). In the following, all datasets have been low pass filtered with a 7-month triangle filter.

2. Relation with the ENSO variability

At basin scale, two main ECOF's modes characterized the ENSO variability (Meinen and McPhaden, 2000). The first mode can be viewed as an East-West tilting mode in phase with ENSO (such as the Southern Oscillation Index, SOI) representing the exchange of warm water between the eastern and western Pacific. The time series of the ECOF mode 1 is well approximated by the Annual Warm Water Volume (AWWV) changes as determined for the equatorial region (5°S-5°N) west of 155°W (WWVv) (Fig. 3). The ensemble of SLA averaged over the Solomon Sea is highly correlated with the ECOF mode 1 (Fig. 4). More than 99% of the variance in SLA in the Solomon Sea is explained by this basin-scale mode. Therefore, there is a strong relationship between WWVv anomalies in the western equatorial basin and SLA in the Solomon Sea.

3. Circulation deduced from the ENSO mode 1

Because the zonal gradients of SLA have opposite signs on each side of the Solomon Islands (Fig. 3), the corresponding geographical meridional flow is in phase opposition inside and outside the Solomon Sea. Where there is a meridional divergence in the equatorial basin, an anomalous western saddle surface geostrophic flow south of 10°S enters the Solomon Sea, and goes north (Fig. 5). It bifurcates at the New Britain coast before escaping through Viltaz and Solomon Straits. Just a small part of this westward flow continues to the Australian coast, decreasing the NQC. It seems that a part of the interannual variability of the Australian HYBCs is in part controlled by the SEC inflow. A similar conclusion has been depicted by Kessler and Gourdeau (2007) for the annual cycle.

4. Relation with other variables

The variability in sea level in the Solomon Sea is largely forced by the wind curl anomaly developing in phase with ENSO in the South West Pacific (Fig 4). During the negative phase of beta, the wind curl anomaly is locally associated with an upwelling fall in sea level at the Solomon Sea (Fig. 7), and a northward transport inside the Solomon Sea which is the return flow from the very broad southward flow that occurs across the central Pacific (Fig. 9). Heat content anomalies (0-500m) from the TAO mooring at 5°S-156°E is well correlated with the "regional" Sverdrup forcing. There is also a reasonably clear connection with SST anomalies estimated over the Solomon Sea which are associated with the zonal shift of the South Pacific Convergence Zone (SPCZ) (Fig. 7).

5. Transport anomalies

The geostrophic mass transports into the Solomon Sea are estimated from the sea level between each side of the basin scaled by the depth of the upper thermocline estimated at 150 m (Ridgway et al., 1993). These estimates are assessed with the use of a numerical simulation (ORCA05). The inflow is estimated at 10.5% of the southeastern extremities of Papua New Guinea to Guadalcanal (Solomon Islands) and has peak amplitude of approximately 10 Sv during the 1997-98 ENSO event (Fig. 9). Anomalous transports are computed for the outflow separated for two parts: West (Viltaz and East of New Brit (St Georges channel) and Solomon strait (Fig. 9). If both outflows balance the inflow, most of the time they are not in phase, except during the 1997-1998 ENSO event. The anomalous transports in the Solomon Sea have similar magnitude and are relatively well correlated (with opposite sign) with the rate of change of equatorial WWV. Therefore, the strong WBC in the South Hemisphere can be observed to oppose the WWV changes when taking part in the general draining (filling) of the warm pool during El Nino (La Niña).

6. Conclusion

We have attempted a regional description of the interannual variability in the Solomon Sea based on altimetric data. The variability evolves in the same way as the temporal function of the first ECP ENSO mode in phase with the SOI. This variability is locally forced by wind stress curl anomaly in the South West Pacific that develop during the peak phase of El Nino. The effect is to change the strength of horizontal circulation and the result is a variation of boundary flow in the Solomon Sea that is opposite in direction to that of the interior flow more to the east. At regional scale, this study supports most of the results on ENSO variability, and notably those based on WWV changes in the equatorial Pacific. Altimetric provide estimation of anomalous transports associated to the NGCU in the Solomon Sea reaching up to 10 Sv during the 1997-98 ENSO event. The boundary transport evolves in phase opposition with the development of depletion/replenishment of the western equatorial WWV ranging from 4 to 14 Sv. It is separated in two branches exiting the Solomon Sea through Viltaz and Solomon Straits. Both outflows have similar magnitude and are poorly correlated between them. Different pathways once they leave the Solomon Sea are supposed to impact the western equatorial Pacific.