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

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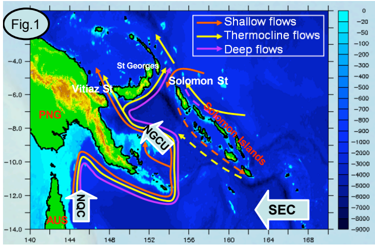
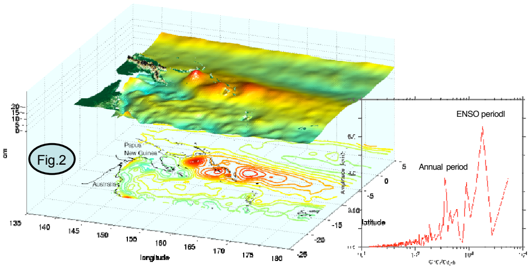


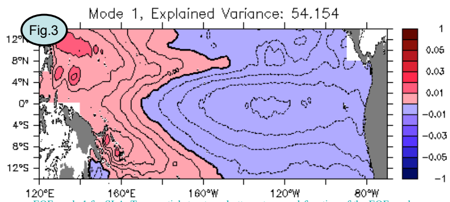
Solomon Sea topography, main currents

1.Introduction

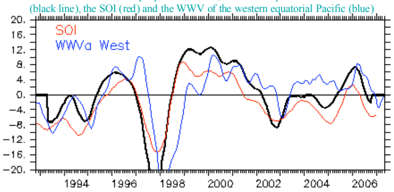
The **Solomon Sea** (Fig.1) is identified as a key region of waters feeding the equator, and is of interest in understanding and predicting climate variability (Ganachaud et al., 2007). Its main inflows occur in a western boundary current - the New Guinea Coastal Undercurrent (NGCU), fed by the South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



Left: Altimetric sea level variability in the South West Pacific (1993-2006). Right: Spectra of SLA averaged on the Solomon Sea. Units=cm

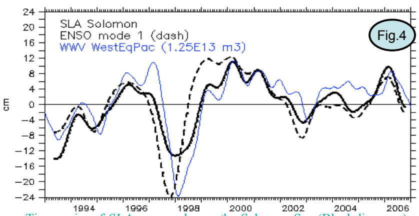


EOF mode 1 for SLA. Top: spatial structure; bottom: temporal fucntion of the EOF mode (black line), the SOI (red) and the WWV of the western equatorial Pacific (blue)



2. Relation with the ENSO variability

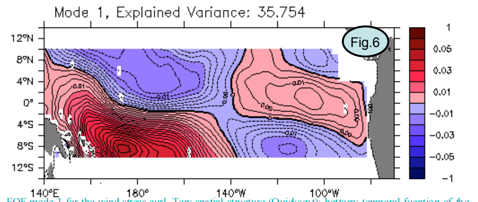
At basin scale, two main EOFs modes characterized the **ENSO variability** (Meinen and McPhaden, 2000). The **first mode** can be viewed as an East-West tilting mode in phase with ENSO (such as the Southern Oscillation Index, SOI) representing the exchange of warm water between the eastern and western Pacific. The time series of the EOF mode 1 is well approximated by Warm Water Volume changes as determined for the equatorial region (5°S-5°N) west of 155°W (**WWVw**) (**Fig.3**). The time series of SLA averaged over the Solomon Sea is highly correlated with the EOF mode 1 (**Fig.4**). More than **95% of the variance in SLA in the Solomon Sea** is explained by this basin-scale mode. Therefore, there is a strong relationship between WWVw anomalies in the western equatorial basin and SLA in the Solomon Sea.



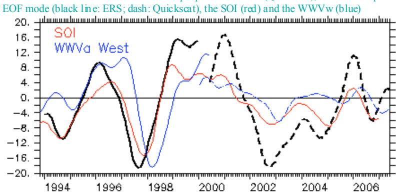
Time series of SLA averaged over the Solomon Sea (Black line, cm), of the EOF mode 1 temporal function (dash line), and of WWV_w anomalies $(1.25\,10^{13}\ m^3)$

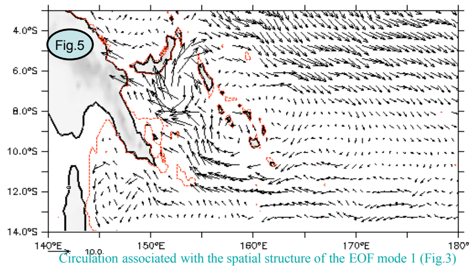
3. Circulation deduced from the ENSO mode 1

Because the zonal gradients of SLA have opposite signs on each side of the Solomon Island (**Fig.3**) the corresponding geostrophic **meridional flow** is **in phase opposition inside and outside the Solomon Sea**. Where there is a meridional divergence in the equatorial band, an anomalous westward 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 Vitiaz 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 WBCs is in fact controlled by the SEC inflow. A similar conclusion has been depicted by Kessler and Gourdeau (2007) for the annual cycle.



EOF mode 1 for the wind stress curl. Top: spatial structure (Quickscat); bottom: temporal fucntion of the EOF mode (black line: ERS; dash: Quickscat), the SOI (red) and the WWVw (blue)

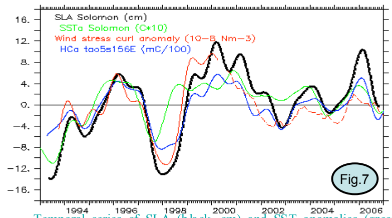




Circulation associated with the spatial structure of the EOF mode 1 (Fig.3)

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.6**). During the peak phase of El Nino the negative wind stress curl anomaly is locally associated with a fall in sea level (**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.5**). **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**).

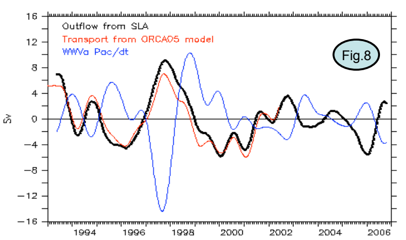


Temporal series of SLA (black, cm) and SST anomalies (green,°C) averaged over the Solomon Sea, wind stress curl anomaly (red: ERS; dash: Quickscat) averaged over the 150°E-180°E; 10°S-5°S domain, 0-500 mHeat Content anomalies (blue, °Cm) from the TAO mooring at 5°S-156°E.

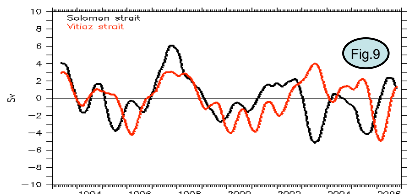
5. Transport anomalies

The **geostrophic mass transports** into the Solomon Sea are estimated from the sea level difference between each side of the basin scaled by the depth of the upper thermocline estimated at 150 m (Ridgway et al., 1993).These estimations are assessed with the use of a numerical simulation (ORCA05). The **inflow** is estimated at 10.5°S between the southeast extremity of Papua New Guinea to Guadalcanal (Solomon Islands) and has peak amplitude of approximately 10 Sv during the 1997-98 ENSO event (**Fig.8**). Anomalous transports are computed for the **outflow** separated in two parts: West (Vitiaz strait) and East of New Britain (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 WWVw. Therefore, the strong WBC in the South Hemisphere is observed to **oppose the WWVw changes** when taking part in the general draining (filling) of the warm pool during El Niño (La Niña).



Time series of anomalous transports entering/exiting the Solomon Sea estimated from altimetric data (black) and a model simulation (red, ORCA05: Kessler and Gourdeau, 2007). In blue, the rate of WWV changes in the western equatorial Pacific. Units: SV



Anomalous transports through the Solomon strait and St Georges channel (black), and through the Vitiaz strait (red) estimated from altimetry. Units in Sv

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 EOF ENSO mode in phase with the SOI. This variability is mostly 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 1997-1998 ENSO event. The boundary transport evolves in phase opposition with the depletion/repletion of the western equatorial WWV ranging from 4 to 14 Sv. It is separated in two branches exiting the Solomon Sea through Vitiaz and Solomon straits. Both outflows have similar magnitude and are poorly correlated between them. Their different pathways once they leave the Solomon are supposed to impact differently the western equatorial Pacific.

References: Ganachaud A. et al., Southwest Pacific ocean circulation experiment. Partt I. Scientific background. NOAA OAR Special report/International CLIVAR Project office, CLIVAR publication Series No111 (www.ird.nc/UR65/SPICE); Kessler W., and L. Gourdeau, 2007: The annual cycle of circulation of the southwest subtropical Pacific, analyzed in an ocean GCM, *J. Phys. Oceanogr.*, 37, 1610-1627,doi:10.1175/JPO3046.1.; Ridgway K.R., J.S. Godfrey, G. Meyers, and R. Bailey, Sea level response to the 1986-1987 El Nino-Southern Oscillation event in the western Pacific in the vicinity of Papua New Guinea, J. Geophys. Res., 98 C9, 16,387-16,395, 1993.; Meinen C.S, and M.J. McPhaden, Observations of warm water volume changes in the equatorial Pacific and their relationship to El Nino and La Nina, J. Climate, 3551-3559, 2000