Variability of the Solomon Sea circulation from altimetric sea level data

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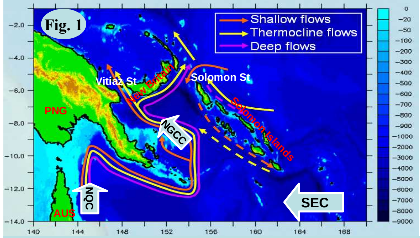

1.Introduction - SLA variability

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 (www.clivar.org/organization/pacific/pacific_**SPICE**.php). Its main inflow occurs in a **western boundary current** - the New Guinea Coastal Current (NGCC), fed by the South Equatorial Current (SEC) and the North Queensland Current (NQC). Its main outflow reaches the western equatorial Pacific through two main channels: Vitiaz, and Solomon Straits. It is a region of **high Sea Level Anomalies** (SLA, Aviso product) variability (Fig.2). Altimetric data are used to further explore the variability of both the sea level and the western boundary current of this relatively poorly known part of the ocean. As the geography of the region is extremely intricated with numerous islands and a complex bathymetry, specifically retreated Topex/Poseidon data are used as a complement to the AVISO gridded data. SLA evolves in phase in the Solomon Sea with a maximum variability in the eastern basin. The **dominant periods** of SLA variability are at **annual and interannual** (**ENSO**) time scales (Fig.2).

Fig. 2

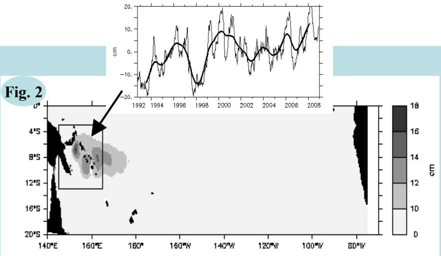

Fig. 2: SLA variability in the South Tropical Pacific, and time evolution of SLA signal averaged on the Solomon Sea (thin line: raw data, thick line: high frequencies filtered) from AVISO gridded data. Unit is in cm.

3. Interannual variability

At basin scale, the **first mode of SLA variability** (Fig.5) is viewed as an east-west tilting mode in phase with ENSO representing the exchange of warm water between the eastern and western Pacific as approximated by Warm Water Volume changes determined for the equatorial region (5°S-5°N) west of 155°W (**WWVw**) (Meinen and Mc Phaden, 2000). This mode explains more than **95% of the variance in SLA in the Solomon Sea**. The corresponding surface geostrophic **meridional flow** is **in phase opposition inside and outside the Solomon Sea** as shown at the peak of the 1997-1998 ENSO (in December 1997). Transport anomalies transiting in the Solomon Sea are estimated by SLA differences between PNG and Solomon Islands as in Ridgway et al. (1993) (Fig.6). Most of the time the transport anomalies are anti correlated with the temporal variation of the WWVw meaning that a **discharge of the WWVw** (dWWVw/dt < 0) is **compensated by WBCs** higher than normal bringing more water in the western equatorial Pacific. Both order of magnitude are similar with anomalies up to 10 Sv during the 1997-1998 ENSO.

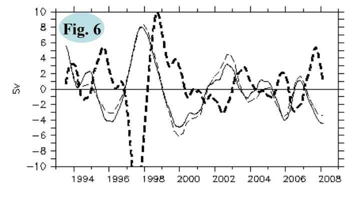

Fig.6: Thin line: Time evolution of transport anomalies entering the Solomon Sea as deduced by SLA differences between the two red points in Fig.5. Dash line: Transport anomalies estimated at both Vitiaz and Solomon straits. Thick dash line: dWWVw/dt.

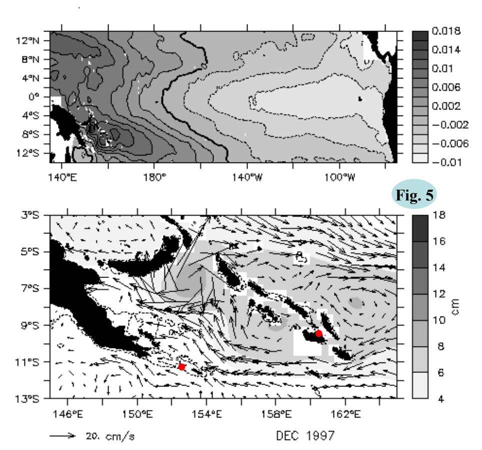

Fig.5: Top) Spatial structure of the EOF mode 1 of SLA variability over the tropical Pacific.

Bottom) Corresponding surface geostrophic velocity anomalies in December 1997 for the Solomon Sea region. Interannual SLA variability is in grey shading. Red dots locates the two points used to estimate transport anomalies in Fig. 6.

2. Annual cycle

The Solomon Sea SLA is in phase with the **annual Rossby waves** arriving **at Solomon strait**. The maximum SLA in March/April induces a **maximum southeastward surface geostrophic velocity anomaly during March-April** that traduces a decrease of the flow entering the Solomon Sea by the southern boundary (Fig. 3). In the same time, south of the Solomon Sea, the SEC decreases whereas the NQC in the Gulf of Papua increases. The opposite situation exists in September-October. Variability of the WBCs are repaired along the altimetric tracks by looking at the coherent cross track current anomaly extending off the western coast (Fig. 4). The **width of the WBCs is about 80 km with velocity anomalies ranging from ± 30 cm/s at Vitiaz strait** (C1). A two months phase lag exists between the NGCC entering Milne Bay (A2), in phase with the SEC south of 12°S, and the NGCC north of the Woodlarks (A1), in phase with the current anomalies at Indispensable strait (●), suggesting different water pathways. The phase opposition between the current anomalies south of New Britain (B2) and the NGCC at B1confirms the branching of the NGCC at Vitiaz strait with one branch continuing northward and one branch continuing eastward. This description of surface geostrophic velocity is very **close to the model study by Melet (2009) on thermocline transport**.

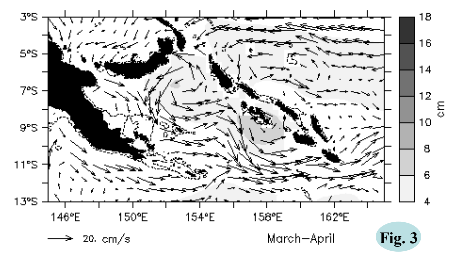

Fig.3: Surface geostrophic annual current anomalies at the time of maximum SLA deduced from the SLA AVISO gridded data.The annual SLA variability is in grey shading.

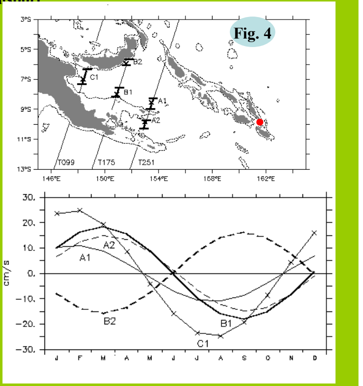

Fig.4:Top) the three T/P altimetric tracks used to repair the WBC signatures shown by the letters. The red point locates Indispensable strait. Bottom) Annual cycle of the cross track surface geostrophic current at the different locations.

4. EKE signal

The Solomon Sea is identified as a region of **high-eddy kinetic energy** (Fig.7), particularly in front of Solomon strait where surface cyclonic/anticyclonic geostrophic velocity anomalies developped (see Fig.3 and Fig.5). The EKE annual cycle is well defined (Fig.8), and it is in phase with the SLA signal: **maximum EKE in March** related to an anticyclonic eddy anomaly. The **highest EKE** is mainly associated to a peak that must be related to the 1997-1998 ENSO event. This peak, **in September-November 1998,** corresponds to a **transition period** where La Niña conditions prevail in the equatorial band whereas more to the south El Niño conditions are still present. Therefore it is hypothesized that the entering flow by the south cannot easily exit by the straits inducing an energy dissipation through high eddy activities (Fig.9).

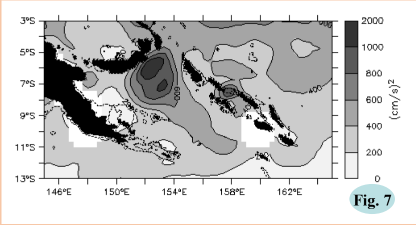

Fig. 7: map of mean EKE as deduced from the SLA Aviso gridded data. Unit in (cm/s) ^{2}.

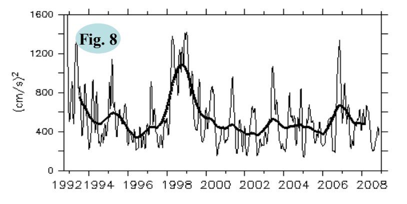

Fig. 8: Time evolution of the EKE signal averaged on the Solomon Sea. Unit in (cm/s) ^{2}. Thin line: raw data, Thick line: high frequencies filtered

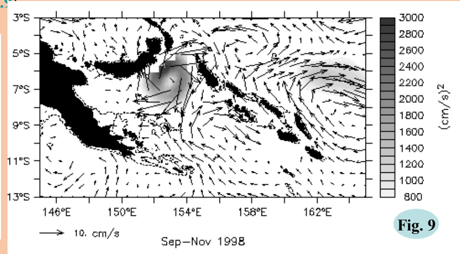

Fig. 9: Situation at the peak of EKE in September-November 1998. The grey shading is the EKE distribution. Superimposed are the surface geostrophic velocity anomalies.

5. Conclusion

The high sea-level variability, and the high eddy kinetic energy observed in the Solomon Sea give a strong incentive to look at the altimeter signal in this very poorly documented region. In addition to the classical Aviso gridded product a new along track data processing from CTOH/LEGOS has been applied to possibly gain additional and more accurate information near the coast. At annual time scale the circulation picture at the surface is quite close to the one proposed by Melet et al. (2009) for the thermocline circulation based on their high resolution numerical simulations. The NGCC is minimum during the austral summer, it is maximum in August at Vitiaz strait in good accordance with some observational evidence (Kuroda, 2000). At interannual time scales, surface current anomalies confirm that the WBCs of the South Hemisphere mostly compensate the interior transport. It is shown that altimetry may be used to estimate the anomalies of transport transiting through the Solomon Sea. The high eddy activity in front of Solomon Strait may be a source of water mixing particularly important along the pathway to the equator.

References: Melet et al., Thermocline circulation in the Solomon Sea: A modeling study, *submitted to J. Phys. Ocenogr.*; Ridgway et al., Sea level response to the 1986-1987 El Niño Southern Oscillation in the Western Pacific in the vicinity of Papua New Guinea, *J. Geophys. Res.*, 98, 16387-16395, 1993; Kuroda, Variability of currents off the northern coast of New Guinea, *J. of Oceanogr.*, 56, 103-116, 2000; Meinen and Mc Phaden, Observations of Warm Water Volume changes in the equatorila Pacific and their relationship to El Nino and La Nina, *J. of Climate*, 3551-3559, 2000.