# How Is the Solomon Sea Impacted By ENSO ?

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## 1. Motivation

The **Solomon Sea** is a key region of the southwest Pacific where Low Latitude Western Boundary Currents (LLWBCs) connect the subtropical and equatorial circulations through narrow straits (Fig 1). Since the LLWBCs are the main sources of the Equatorial Undercurrent (EUC), they could play a major role in the low frequency modulation of El Niño Southern Oscillation (ENSO). Therefore, the Solomon Sea is of particular interest in a climatic context and is a focal point in the South Pacific Circulation and Climate Experiment (**SPICE**). In recent work, the mean circulation and the seasonal cycle have become better known from modelling studies (*Melet et al. 2010a, 2011, Fig 3*) whose results are confirmed by increasing observational evidence from in situ (*Cravatte et al. 2011*) and satellite data (*Melet et al. 2010b*). But, as shown by altimetry, the **highest variability is at interannual time scales** and represents a response of the LLWBCs in phase with ENSO that counterbalances equatorial-driven changes in western Pacific warm water volume. At this stage, little is known about the sensitivity of the Solomon Sea circulation to ENSO. In this work we investigate **how the pathways of the LLWBCS and their water masses are affected by ENSO**.

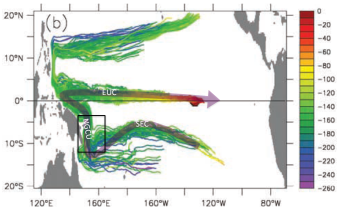


**Fig 1.** *Origins of water particles emerging in June 1998 in the Nino-3 region in a numerical simulation (Izumo et al, 2002). The Solomon Sea is located in the black rectangle.*
*EUC : Equatorial UnderCurrent*
*SEC: South Equatorial Current*
*NGCU : New Guinea Coastal UnderCurrent*

## 2. Methodology

An original modeling strategy based on **model nestings** (Fig 2) has been implemented to realistically resolve the complex bathymetry of the Solomon Sea, notably the network of narrow straits connecting it to the Equatorial Pacific.
A 1/12° model of the Solomon Sea is interactively nested (AGRIF software, 2-way) in a regional ¼° model of the southwest Pacific, itself embedded in a ¼° global simulation (Drakkar project).

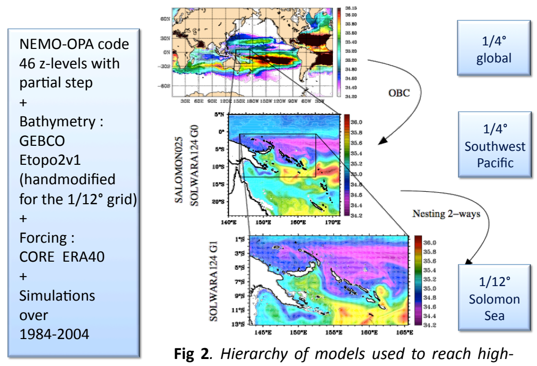


**Fig 2**. *Hierarchy of models used to reach high-resolution modeling of the Solomon Sea.*

## 3. Thermocline circulation and ENSO

The interannual variations of the Solomon Sea WBC thermocline transports are related to ENSO. A comprehensive diagnosis of ENSO influence on the thermocline circulation is performed through the construction of **composite anomalies** for El Niño (Apr 87, 92, 98, Jan 2003) and La Niña (Apr 89 & 97, Jan 2000) states. The ENSO related thermocline circulation variability in the Solomon Sea mainly consists in a modulation of the WBC strength. Due to the ENSO wind curl anomalies, the **NGCU** (Fig 3) **strengthens during El Niño and weakens during La Niña** (Fig 4). Vitiaz Strait (Fig 4, 5) thermocline transport exhibits a weak interannual variability: the NGCU variations are mainly transmitted to the NBCU (Fig 3) and Solomon Strait (Fig 4).

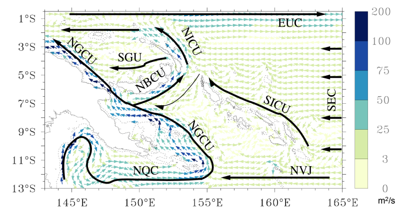


**Fig 3.** *Solomon Sea circulation vertically integrated over the thermocline ($24.0 \leq \sigma_0 \leq 26.5$) from a 1/12° model (see section 2) for the 1986-2004 period.*

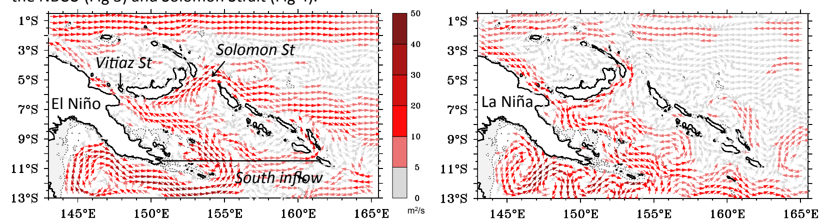


**Fig 4.** *Composite of the anomalies of the circulation integrated over the thermocline ($24.0 \leq \sigma_0 \leq 26.5$) in $m^2/s$ for El Nino conditions (left) and La Nina conditions (right). Anomalies are relative to the 1986-2004 mean (Fig 3).*

The asymmetry of the composites of El Niño/La Niña anomalies (Fig 4) suggests a **bathymetric control** at Vitiaz Strait. To test this assumption, a sensitivity simulation was run in which Vitiaz St was widened (from 42km at 200m depth to 67km). A lagrangian analysis was used to analyze the **partition of the thermocline south inflow** between Vitiaz and Solomon straits (Fig 4), and its response to the bathymetric constraint. Fig 5 shows that when Vitiaz St is widened, the interannual variability of the transport through this strait is increased while the one through Solomon St is weakened. Thus, the transport limitation at Vitiaz St impacts the partition of the south inflow between the different equatorward straits. It plays a stronger role during El Niño, when the NGCU is strenghened.

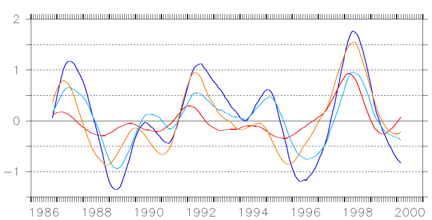

**Fig 5.** *Interannual anomalies of thermocline transport (Sv) for water initially at the south inflow between $\sigma_0$ 24.0 and 26.5 for the:*
*- regular Vitiaz St bathymetry : Vitiaz St, Solomon St.*
*- widened Vitiaz St : Vitiaz St, Solomon St.*

## 4. Temperature modifications

The variability of the temperature of the water masses entering the Solomon Sea is maximum in the upper thermocline, at $\sigma_0$ 24.4 (Fig 6).

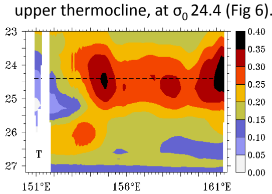

**Fig 6**. *Section of the RMS of the temperature (in °C) at the south inflow (10.5°S, Fig 4) from the 1986-2004 monthly fields. The y-axis is the density.*

The temperature modifications from the south inflow to Vitiaz St were analyzed in a Lagrangian framework. Numerical particles were seeded in the Solomon Sea south inflow (10.5°S, Fig 4), between $\sigma_0$ 24.2 and 24.6, and integrated forward in time. Only the particles joining Vitiaz St were selected. Fig 7a shows that the **interannual variability of the transit time between the south inflow and Vitiaz St is strongly correlated with the SOI** (proxy for ENSO), in agreement with the strenghening/weakening of the NGCU during El Niño/La Niña (Fig 4). The Lagrangian analysis allows to follow the temperature variations along the path from the south inflow to Vitiaz St. fig 7b shows that the thermocline **temperature modifications are weaker during El Niño** (SOI < -0.5), with weak warming, **whereas a cooling is observed during La Niña** (SOI > 0.5). This could be related to the time transit anomalies : the longer the water stays in the Solomon Sea, the more it could be modified.

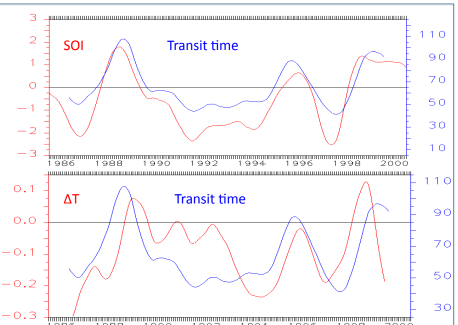


**Fig 7**. *Interannual variability of the transit time between the south inflow and Vitiaz St (in blue for the two plots, unit in days, left axis). In red : (top) SOI and (bottom) temperature difference (ΔT, °C) between Vitiaz St and the south inflow.*

## References

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## 5. Conclusions

The highest variability in the Solomon Sea circulation is at the interannual time scale, in relation to ENSO. In this study, we investigate the variability of the Solomon Sea circulation at thermocline level (which is where the WBCs connect to the EUC, Fig 1) and the modifications of water masses in response to ENSO using both Eulerian and Lagrangian analysis of a high-resolution simulation (Fig 2). We show that although the subtropical water entering the Solomon Sea from its south inflow preferentially join the Equatorial Pacific through Vitiaz St in the mean state, the interannual variability is mainly transmitted to Solomon St, especially during El Niño events (Fig 4). This is partly due to transport limitation through Vitiaz St (Fig 5). During El Niño, the NGCU is increased, leading to shorter transit times of water masses from the south inflow to Vitiaz St (Fig 7). As a result, the cooling of the upper thermocline water, originating fromthe subtropics and concentrating the highest temperature interannual variability, is reduced (Fig 7). The reverse is observed during La Niña.