Complementary use of glider data, altimetry, and model for exploring mesoscale eddies in the tropical Pacific Solomon Sea

L. Gourdeau[1], J. Verron[2], A. Chaigneau[1], S. Cravatte[1], W. Kessler[3]

[1] LEGOS, Université de Toulouse, CNES, CNRS, IRD, UPS, Toulouse, France; [2] Université Grenoble Alpes, CNRS, IRD, IGE, Grenoble, France; [3] NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington, USA

1. Introduction

The Solomon Sea located in the tropical South West Pacific is a key pathway connecting the subtropics to the equator through the Low Latitude Western Boundary Currents (LLWBCs) (**Fig.1**, Ganachaud et al., 2014). Mesoscale activity is an important component of the Solomon Sea circulation (Gourdeau et al., 2014). Eddies could contribute to mix the different water masses entering the Solomon Sea.

This study combines glider data, altimetry, and model to investigate Solomon Sea eddies. Altimetric maps are used to detect mesoscale eddies, whereas glider data provide the vertical structure of some detected eddies. The model, validated against observations, is used to get new insights on their role on the Solomon Sea circulation and mixing.

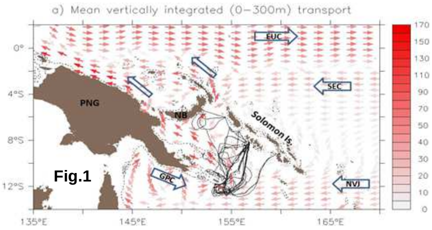
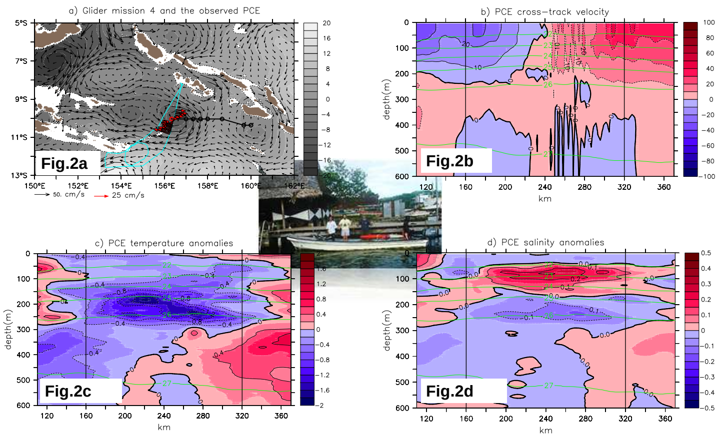


Figure 1: (a) Mean vertically integrated (0–300 m) transport (in m^2 s^{-1}) from the Drakkar ORCA12 simulation. Superimposed are the 11 glider tracks during the 2007-2011 period. The main currents surrounding the Solomon Sea are shown: the Gulf of Papua Current (GPC), the North Vanuatu Jet (NVJ), the South Equatorial Current (SEC), and the Equatorial Undercurrent (EUC).



2. Observed eddies

Since 2007, SPRAY gliders operate 3-4 missions per year. Eleven missions are considered for this study covering the 2007- 2011 period (**Fig. 1**). Most of the transects consist of sequential dives down to 700 m depth. only 7 eddies detected on the AVISO maps were sampled by gliders.

We present the signature of a cyclonic eddy (**Fig. 2**). The cyclonic eddy velocity extends from the surface to 250 m depth, and is maximum at the surface. It induces an upward displacement of isopycnals up to 20 m. The associated temperature anomaly reaches -1°C in the 150-270 m depth range. The salinity anomaly reaches +0.2 psu in the upper thermocline and -0.1 psu below, reflecting the upward displacement of the subsurface salinity maximum and the underlying water-mass.

Figure 2: Signature of a cyclonic eddy (CE) observed during a glider mission. a) The dot line is the trajectory of CE detected on the altimetric maps, and the red dot is the location of CE when it has been sampled by the glider. Grey shading and black arrows show the altimetric SSH field and the corresponding geostrophic velocity field. The glider track is in cyan whereas the red arrows correspond to the absolute cross track geostrophic velocity computed from the glider data, b) Vertical section of the glider cross track absolute geostrophic velocity (cm s^{-1}) across CE. c) and d) Vertical section of temperature (°C) and salinity anomalies, respectively. Density (Kg m^{-3}) are in green contours. The black vertical lines delineate the eddy.

3. Modeled eddies

The model is the ORCA12.L46-MAL95 configuration of the global 1/12° OGCM developed in the DRAKKAR consortium. Coherent mesoscale vortices are detected in AVISO maps and in modelled SSH fields using the method developed by Chaigneau et al. [2009].

It exists two types of CEs: "propagating" CEs generated in the southern basin and propagating northwestward (PCEs), and "stationary" CEs located in the northern basin (SCEs). AEs are generated in the eastern part of the Solomon Sea and propagate westward. These different eddy types are well presented in AVISO and modelled SSH fields (**Fig. 3**).

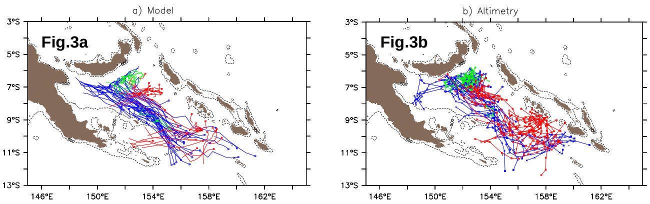


Figure 3: Distribution of the propagating CEs (in blue, defined by propagating distances > 300 km), stationary CEs (in green, defined by a life span > 5 weeks and by propagating distances < 200 km), and AEs (in red) for a) the model and b) altimetry.

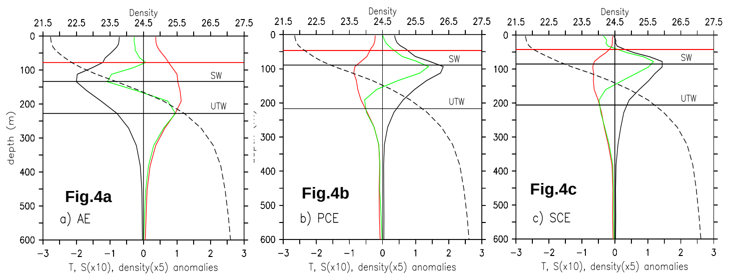


Figure 4: Mean temperature (red, °C), salinity (green, psu), and density (thick black, kg m^{-3}) anomalies within eddies as a function of depth for AEs (a), PCEs (b), and SCEs (c). The mean density profile is shown as a dashed line. Horizontal black lines delineate the Surface Water (SW) and Upper Thermocline Water (UTW). X-axis on top is for density (kg m^{-3}) whereas X-axis on bottom is for anomalies of temperature, Salinity (x10), and density (x5).

4. Eddy signature function of depth

For each modelled eddy, temperature and salinity anomalies are computed, and they are averaged at each vertical level. Their mean vertical profiles are presented for each eddy type (PCEs, SCEs and AEs) on **Fig. 4**.

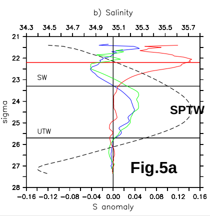
Temperature anomalies (red) are maximum at the interface between Surface Waters (SW, sigma< 23.3 kg m^{-3}) and Upper Thermocline Waters (UTW, 23.3 kg m^{-3} < σ < 25.7 kg m^{-3}), and extend to the core of the UTW. Salinity anomalies (green) show extrema values at the interface between SW and UTW and at the base of the UTW.

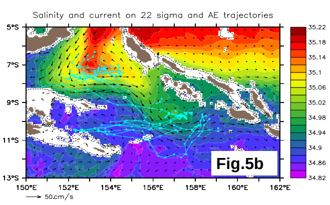
In terms of density (black), the eddy signatures are well visible with density anomalies from the surface down to ~300 m depth, maximum at the base of the SW. In fact, eddy signatures depend on the strong tropical stratification with a well-marked pycnocline in the 100-300 m depth range.

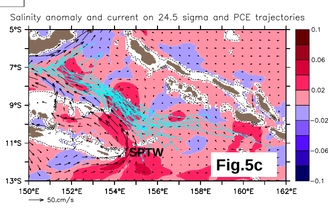
5. Eddy signature function of density

For AEs, temperature/salinity anomalies are localized in SW with an extreme at the mixed layer depth (the 22 sigma density level). For CEs, temperature/salinity anomalies exist both in SW and UTW with opposite sign. (**Fig. 5a**).

Mean oceanic conditions corresponding to AEs generation are characterized with an intrusion of warmer and saltier waters through the Solomon Strait (**Fig. 5b**). AEs trap this water mass, and have the potential to transport it when propagating across the Solomon Sea.
CEs are characterized by saltier/warmer UTW waters in relation with positive anomalies of the SPTW salinity maximum (**Fig. 5d**). It suggests that the role of Ces for isopycnal transport. CEs are characterized by fresher/cooler SW waters just below the mixed layer depth (**Fig. 5c**). The upwelled high salinity could be eroded by diapycnal mixing with the lower salinity at the base of the mixed layer depth.







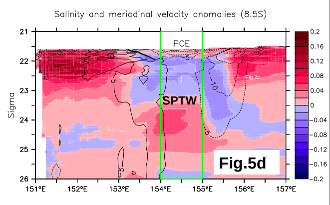


Figure 6: a) salinity anomalies as a function of sigma levels for AEs (red), PCEs (blue), and SCEs (green). The thick dashed line shows the mean salinity profile in the Solomon Sea. Horizontal black lines delineate the SW and UTW water-masses. The horizontal red line indicates the mixed layer level density.

b) Salinity and current fields at the 22 sigma level density averaged over the time where AEs are present. c) Salinity anomaly and current fields at the 24.5 sigma level density averaged over the time where PCEs are present. In b) and c) AEs and PCEs trajectories are superimposed in light blue.

d) Longitude/sigma density section at 8.5°S of salinity (psu, shading) and meridional velocity anomalies (cm.s^{-1}, contour) averaged over the time where PCEs are present. The green lines delineate the mean position of PCEs.

6. Conclusion

In the Solomon Sea, mesoscale eddies appear to have a vertical extension limited to the Surface Waters and the Upper Thermocline Water, i.e. the first 140-150 m depth. They do not seem to strongly interact with the deep New Guinea Undercurrent that is a key piece of the equatorial circulation. But temperature and salinity eddy signatures suggest that anticyclonic eddies could play a role on mixed layer characteristics and in return, on local air sea interaction, whereas cyclonic eddies could be particularly efficient in diapycnal and isopycnal mixing.

Email: lionel.gourdeau@legos.obs-mip.fr

References

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Gourdeau L. , J. Verron , A. Chaigneau , S. Cravatte , W. Kessler , Complementary use of glider data, altimetry, and model for exploring mesoscale eddies in the tropical Pacific Solomon Sea, submitted in J. Geophys. Res.