A regional model of the Solomon Sea to explore the observability of high-resolution satellite altimetry

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Motivations

The Solomon Sea (SS) is a key region in the oceanic climate circuit that connects the equator to the subtropics through the Low Latitude Western Boundary Currents. In their pathway toward the equator, their changes in strengh or water masses properties could influence low-frequence modulation of ENSO. Besides, the SS is the region of the Southwest Pacific where the SSH variability is the greatest. Little is known about mesoscale and sub-mesoscale dynamics in this region although these processes are suspected to be a major mechanism for mixing water properties (Melet et al., 2011).

Two recent studies (Gourdeau et al., 2014; Hristina et al., 2014) have highlighted the eddy activity (generation/propagation and mechanism). The future wide-swath altimetric mission SWOT is expected to measure oceanic features with an unprecedented high resolution (∼km). Because of the large boundary currents close to islands and complex topography, no observations is adequate to document small scale features. So, we required high resolution modelling to provide an estimation of the variability and observability of the eddy field.

"Sub-mesoscale" permitting numerical model

We set up a $1/36°$ resolution numerical model using the NEMO code to represent and resolve mesoscale processes (Marchesiello et al., 2011) and to access the sub-mesoscales features that could be observed by SWOT. An original modeling strategy, based on model nestings configurations (Fig 1), is used to optimize the computational resources and manage technical constraints as the bathymetry which is very complex. The $1/36°$ regional model configuration is embedded (two way nesting) in a $1/12°$ regional model of the southwest Pacific through a two-way interactive connection (AGRIF software, Debreu et al., 2008), which is itself embedded (one way nesting) in the global $1/12°$ configuration from the DRAKKAR project.

- NEMO-OPA code 46 z-levels with partial step
  +
- Bathymetry: Etopo2 (for $1/12°$ grid) GEBCO08 + hand-reprocessing (for $1/36°$ grid)
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- Forcing field: ERA-Interim
  +
- Simulation over 1989-2007

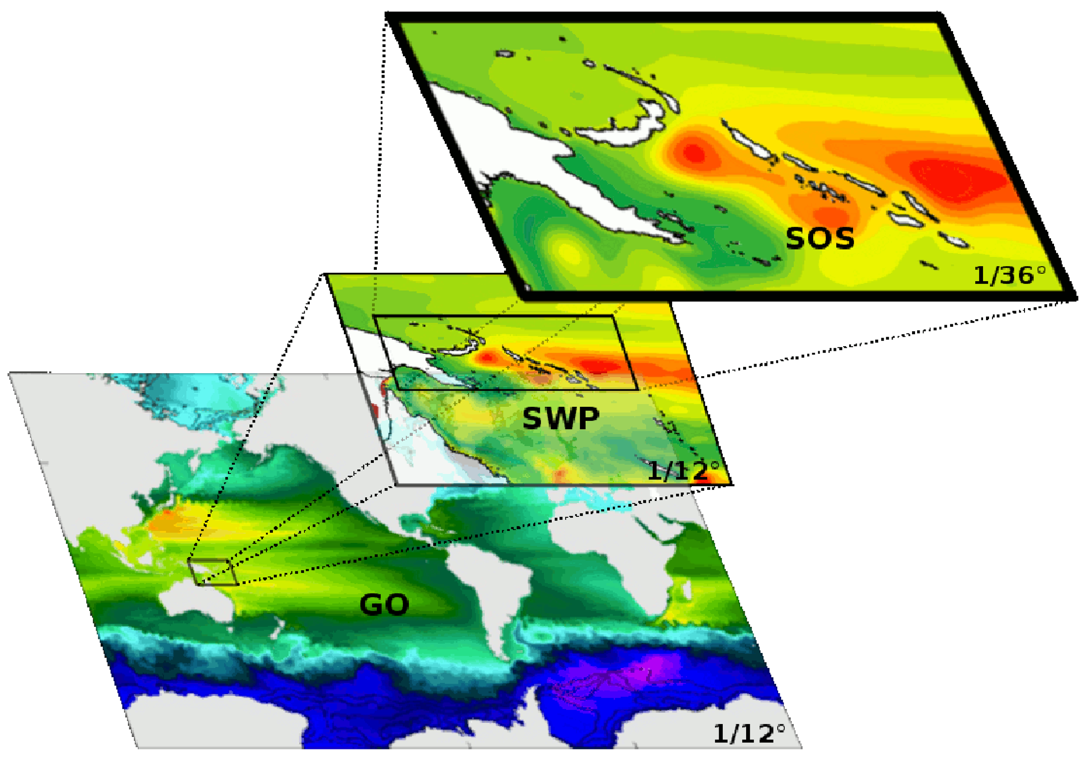

Fig 1: Embedded model configuration (Djath et al., 2014a).

Circulation and eddy variability

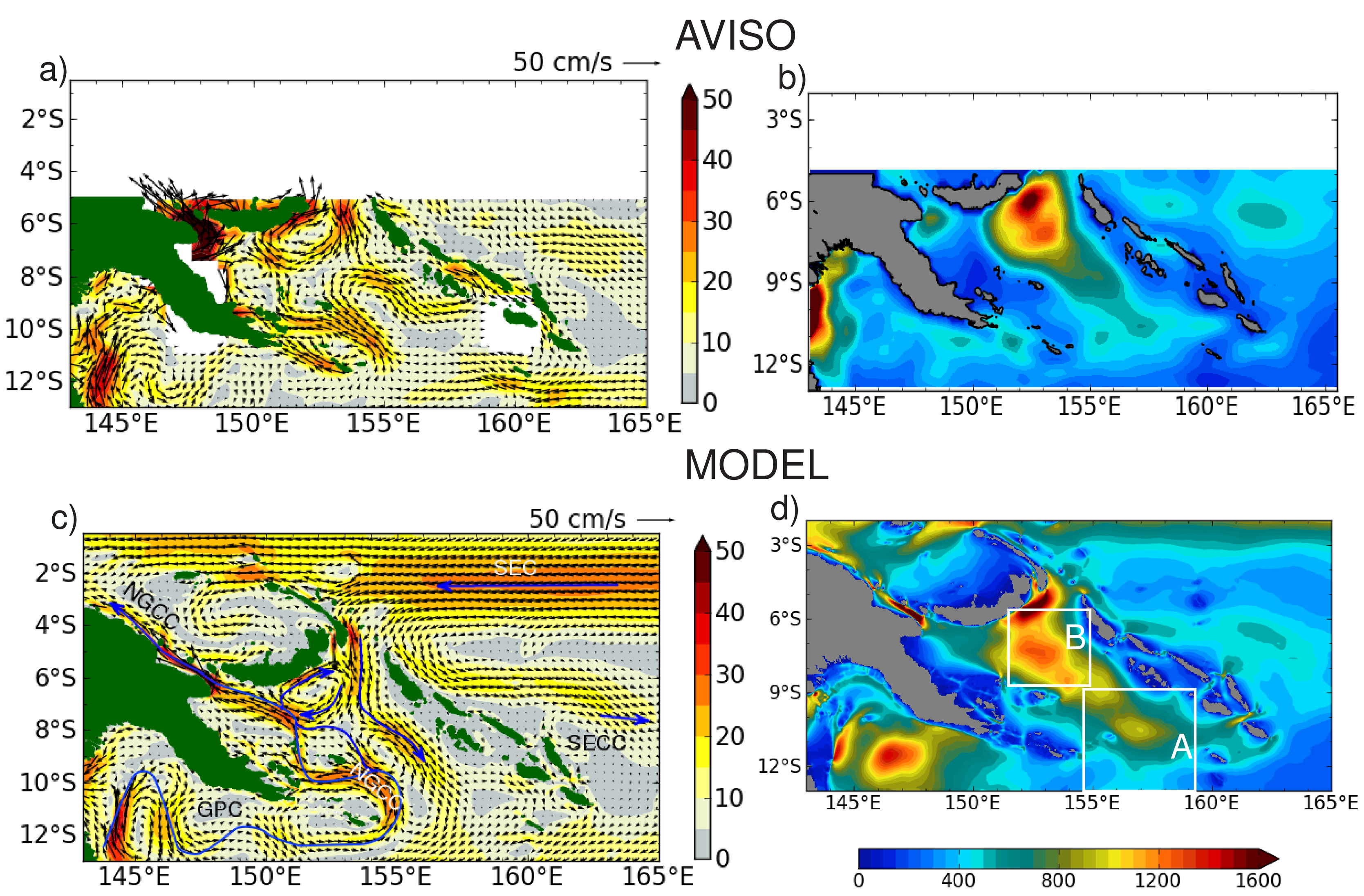

Fig 2: Mean surface circulation (in cm s^{-1}) over 1993-2007 from (a) AVISO data and (c) from $1/36°$ model. Surface EKE from over 1993-2007 from (b) AVISO absolute velocity and (d) from $1/36°$ model.

The model surface circulation and eddy variability are consistent with the altimetric data (Fig 2). The western boundary currents (WBCs) are better defined in the $1/36°$model, especially along the coast. The WBCs exit through Vitiaz (8.9 Sv), the Solomon (4.8 Sv) straits and S^t George channel (2 Sv) in upper 300 m depth. EKE is high inside the SS with maximum amplitude southeast of New Britain. Both model and observation show the strong mesoscale turbulence in the SS.

Mesoscale and sub-mesoscale at 3 km

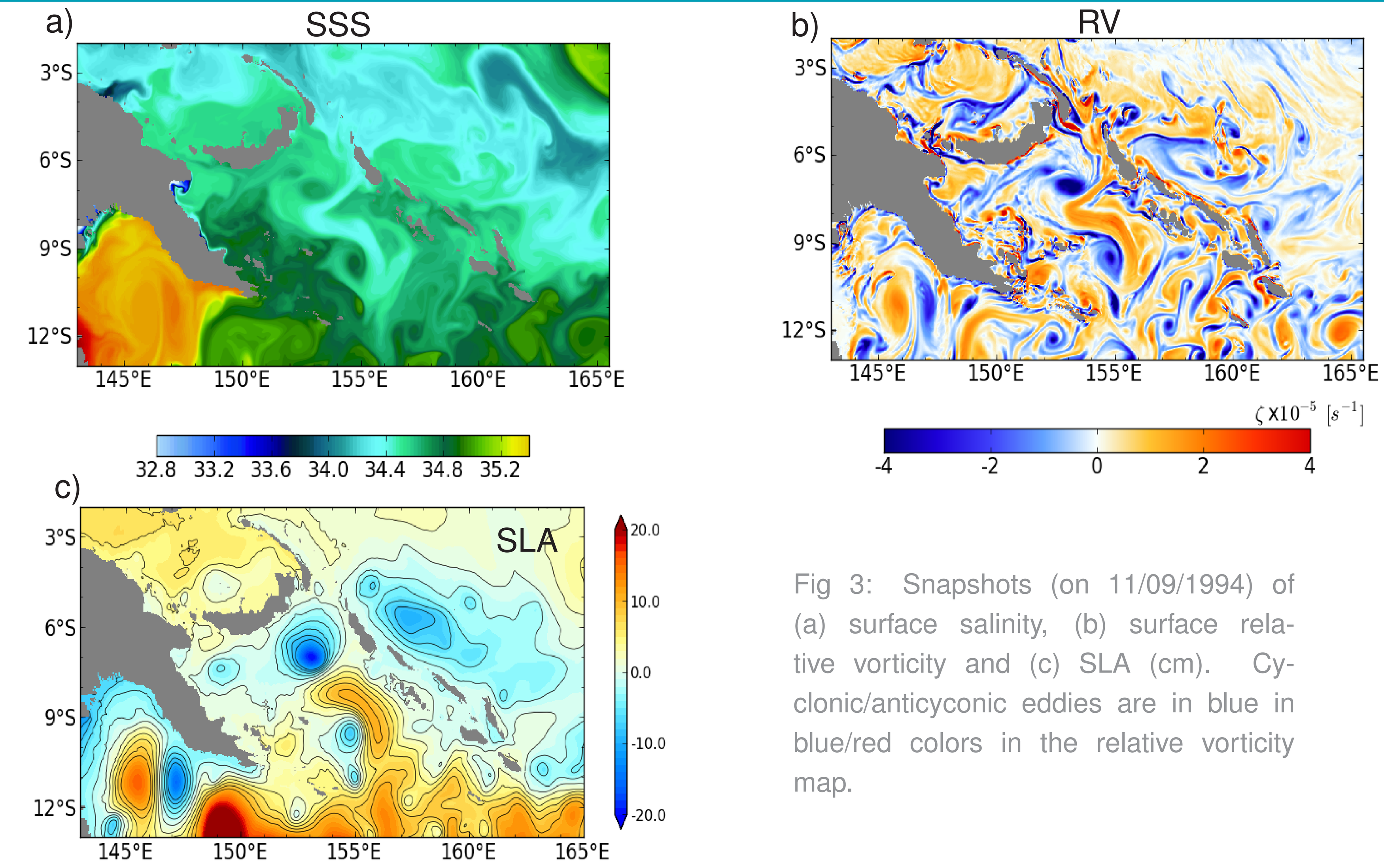

Fig 3: Snapshots (on 11/09/1994) of (a) surface salinity, (b) surface relative vorticity and (c) SLA (cm). Cyclonic/anticyconic eddies are in blue in blue/red colors in the relative vorticity map.

The emergence of smaller sub-mesoscales is clearly apparent in the Solomon Sea at $1/36°$ resolution (Fig 3). Eddies are detected on the relative vorticity field and have a signature on the surface salinity. They can also be observed on the sea level anomalies. The relative vorticity reveals also numerous elongated, thin filaments of 10-40km width. The complex topography clearly effects eddies structure.

Sea Surface Height Wavenumber spectrum

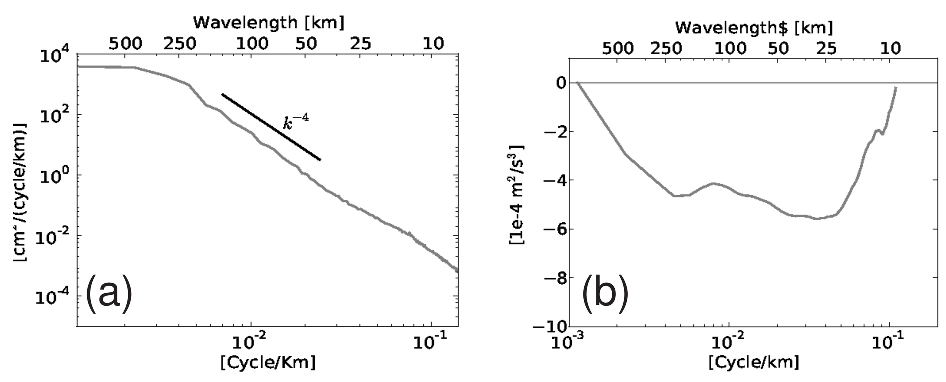

Fig 4: (a) SSH wavenumber spectrum and the corresponding spectral energy flux (b) in box A (see Fig 2d) from the $1/36°$ model over 1995-1996.

To further investigate the small scale dynamics in Solomon Sea and characterize the turbulence, a spectra analysis of Sea Surface Height (SSH) is performed. According to the complexity of the topography, wavenumber spectrum is computed within two boxes (shown in Fig 2d, box A and B). The figure 4a shows the wavenumber spectrum of SSH in box A. The spectral slope is of the order k^{-4}, consistent with the SQG theory (Sasaki et Klein, 2012). The corresponding spectral kinetic energy flux (Scott and Wang, 2005, Sasaki et al., 2012) computed over the two boxes give information on how the energy is transferring between scales. In the box A (Fig 4b), the energy cascades predominantly towards the large scales (negative values). This shows a clear impact of small scales on larger scales. These results are also representative of the box B.

Preliminary exploration of along-track SARAL/AltiKa observability

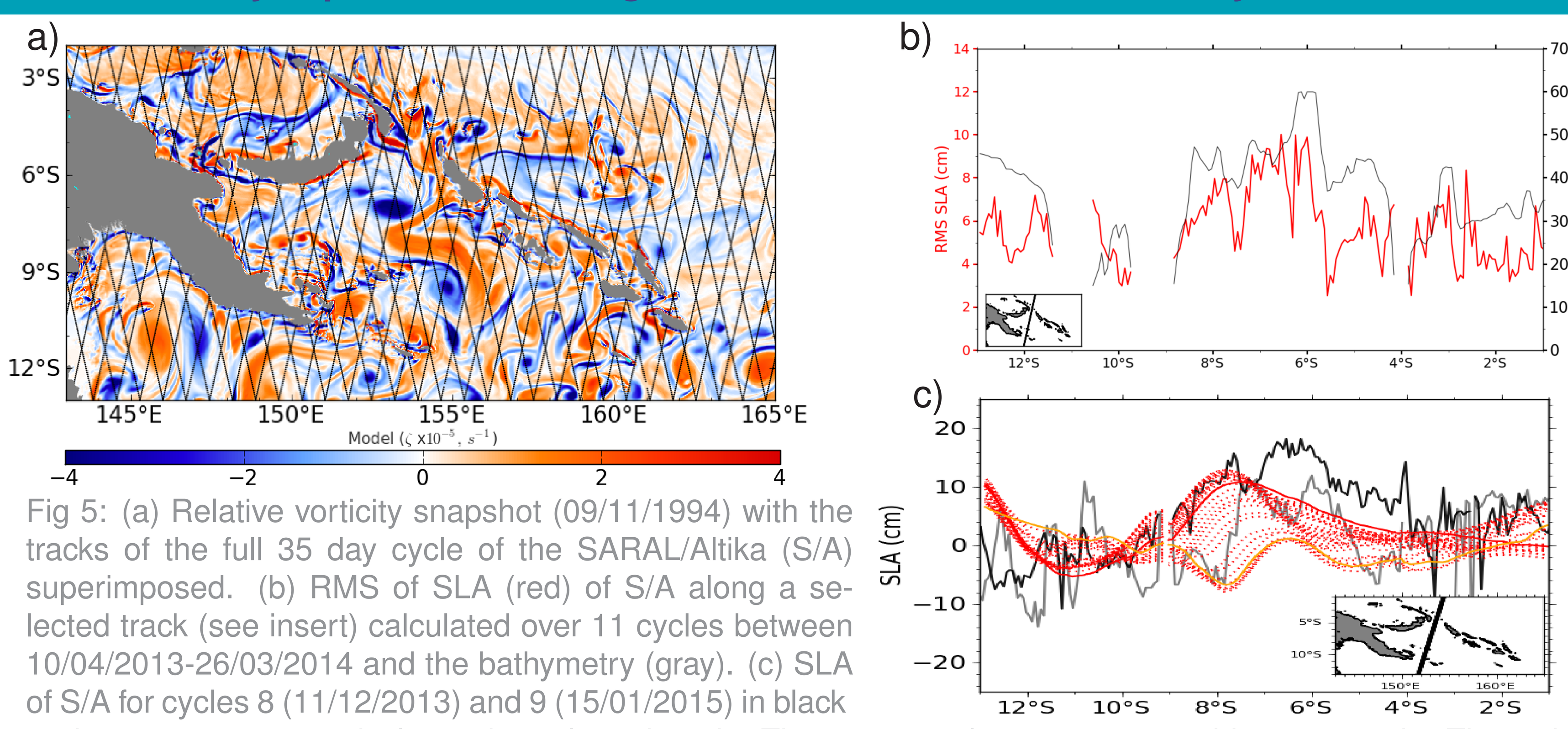

Fig 5: (a) Relative vorticity snapshot (09/11/1994) with the tracks of the full 35 day cycle of the SARAL/Altika (S/A) superimposed. (b) RMS of SLA (red) of S/A along a selected track (see insert) calculated over 11 cycles between 10/04/2013-26/03/2014 and the bathymetry (gray). (c) SLA of S/A for cycles 8 (11/12/2013) and 9 (15/01/2015) in black and gray curves repectively on the selected track. These two cycles are separated by ∼1 month. The red dashed lines show daily snapshots of SLA extracted from the $1/36°$ model along this S/A track for a period of 1 month (December 1996).

SARAL/Altika (S/A) altimeter data are used and processed in order to study the mesoscale activity. The S/A sampling of the Salomon Sea is shown in Fig 5a. The rms of S/A SLA over 11 cycles (∼1 year, Fig 5b) exhibits a high variability in the SS (i.e. between 9-6°S).The $1/36°$ daily-mean SLA data is extracted along the same tracks to explore the observability of S/A for 1 month (Fig 5c). The model signal is smoother because of the time avaraging. Nevertheless, this monthly variability is of the same order as the computed S/A SLA variability over S/A 11 cycles. This preliminary result illustrates the mixed of high and low frequency signal that is difficult to deconvolve. This raises the issue of the observability of S/A in such regions where high and low frequency signals are strong.

Conclusion

- The analysis of the sub-mesoscale permitting model allowed us to provide a first description of the fine-scale circulation in the Solomon Sea, and revealed numerous eddies, filaments and an intense meso and sub-mesoscale activity.
- The wavenumber spectrum of SSH shows a $\sim k^{-4}$ slope close to the SQG theory.
- Spectral kinetic energy flux gives a predominance of inverse cascade of the energy even from smaller scales.
- The preliminary processing of Saral/Altika track shows a high variability inside the Solomon Sea.
- On going work: exploring along track SARA/Altika observability with the numerical model:
  - Monitoring strong boundary currents and pathways toward the equator
  - Understanding mesoscale variability
  - Spatial and temporal mesoscale observability: can mesoscale signals be captured and what can be missed according to low frequency of Saral/Altika sampling?
- Prospect of SWOT observability.

References

- Djath, B., A. Melet, J. Verron, J.-M. Molines, B. Barnier, L. Gourdeau, and L. Debreu (2014a), A 1/36° model of the Solomon Sea embedded into a global ocean model : on the setting up of an interactive open boundary condition nested model system, J. Operational. Oceanogr., Volume 7, Number 1, pp. 34-46(13).
- Gourdeau, L., J. Verron, A. Melet, W. Kessler, F. Marin, and B. Djath (2014), Exploring the mesoscale activity in the Solomon Sea: A complementary approach with a numerical model and altimetric data, J. Geophys. Res. Oceans, 119, doi:10.1002/2013JC009614.
- Hristova, H. G., W. S. Kessler, J. C. McWilliams, and M. J. Molemaker (2014), Mesoscale variability and its seasonality in the Solomon and Coral Seas, J. Geophys. Res. Oceans, 119, 4669–4687, doi:10.1002/2013JC009741.
- Melet A., J. Verron, L. Gourdeau, and A. Koch-Larrouy (2011), Equatorward pathways of Solomon Sea water masses and their modifications, J. Phys. Oceanogr., 41, 810-826.
- Sasaki, H., and P. Klein (2012), SSH wavenumber spectra in the North Pacific from a high-resolution realistic simulation, J. Phys. Oceanogr., 42, 1233–1241.
- Scott, R. B., and F. Wang (2005), Direct evidence of an oceanic inverse kinetic energy cascade from satellite altimetry, J. Phys. Oceanogr., 35, 1650–1666.