Session 1: Context and objectives of the workshop

Marine geochemistry as part of PANDORA cruise

Catherine Jeandel, Lars-Eric Heimburger, Nicolas Metzl, Susanna Michael, Joe Resing, Géraldine Sarthou and Viet Pham.

In the Solomon Sea, water masses coming in contact with the coasts undergo not only dynamical transformations but also macro- and micro-nutrients and trace element enrichments through land/sea exchange, or boundary exchange, including river discharge, shelf inputs and submarine groundwater discharges. These nutrient enrichments have downstream impacts on the productivity of the Equatorial Pacific Cold Tongue. Trace elements and their isotopes that are injected from boundary exchange provide information on transformation and fate of particles and on water masses as well as mixing. During Pandora (also GEOTRACES section GP12), a comprehensive group of trace element samples were collected and are currently being measured. Some of them are micronutrients (essential for life), other are contaminants (Hg), other tracers of lithogenic inputs and/or particle dynamics. In addition, the broad geochemical context was assessed by the carbonate chemistry and macro-nutrient determination, revealing a significant penetration of the anthropogenic CO2 in this area. Dissolved and total aluminum, manganese, iron and mercury concentrations and fate in the Solomon Sea will also be discussed. Rare Earth concentrations will be presented in Viet Pham’s talk.

Session 2: Seasonal and interannual variability of transports
Interannual variability of Solomon Sea's circulations, heat transports, and water masses transformations.

A. Melet¹, J. Verron², L. Gourdeau³, N. Djath⁴, Ariane Koch-Larrouy¹,³

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The response of the Solomon Sea circulations to ENSO is investigated using both a numerical 1/12° regional ocean model and altimetric data. An asymmetric response of the circulation to El Niño and La Niña is observed, with implications for the feeding of the Equatorial Pacific through the double system of western boundary currents (WBC) at thermocline level. Specifically reprocessed along-track altimetric data adapted to coastal areas were analyzed in addition to standard gridded data to further explore the WBC interannual variability. We notably showed that their interannual transport anomalies counterbalance changes in western equatorial Pacific warm water volume, confirming the phasing of South Pacific WBCs to ENSO.

Modifications of water masses transiting through the Solomon Sea are characterized in a lagrangian framework for the mean circulation and at interannual timescales. Strong diapycnal mixing yields to a downward heat transfer and an erosion of the upper thermocline’s salinity maximum. This mixing is partly sustained by internal-tide dissipation. Temperature and salinity modifications are particularly notable for the thermocline water during El Niño conditions. Heat and salt fluxes of Solomon Sea water feeding the Equatorial Undercurrent and the Pacific Warm Pool can change by a factor of up to 2 between extreme El Niño and La Nina conditions.

9 years of glider surveys of the Solomon Sea

Billy Kessler, Hristina Hristova, Russ Davis and Jeff Sherman

1) Glider transects have provided an increasingly well-resolved time series of temperature, salinity and velocity across the southern Solomon Sea. They add significantly to Argo observations there, enabling credible combined mass flux estimates from the South Pacific (coast to coast) towards the equator. (Heat flux calculations in progress, perhaps by the workshop).

2) A linear wind-driven model accounts for much of the Solomon Sea transport variability on mean, annual and interannual timescales. The linearity of the model allows isolating different influences: Most of the annual signal is driven by tropical winds, but wind fluctuations over the subtropical gyre are crucial to simulate lower-frequencies.
The tropical signal is shallow and the gyre signal is deeper. It appears that wind forcing produces the largest uncertainty in these deductions.

3) Technical, methodological and personnel issues for sampling in remote areas, and near coastlines, have been worked out through the course of this work, providing a model for other such efforts. Where fine spatial information is required (e.g. boundary currents) this technique is appropriate and cost-effective.
Session 3: Downstream Impacts of the Solomon Sea LLWBC on the tropical Pacific Ocean

Origins and fates of the southwestern boundary currents: from the subduction areas to the Pacific Equatorial Undercurrent.

Sophie CRAVATTE, Mélanie GRENIER, Fabien DURAND, Angélique MELET, and Catherine JEANDEL

The hydrological and geochemical properties of the waters constituting the Pacific Equatorial UnderCurrent (EUC) determine the properties of the equatorial cold tongue. Understanding and quantifying the various EUC origins is therefore of prime importance. In this study, we focus on the pathways from the Western Pacific to the EUC, and on the water mass evolutions between the Low Latitude Western Boundary Currents (LLWBC) and the EUC. We also analyze the sources of the waters joining the Coral Sea and the Solomon Sea, from their subduction areas. A high resolution (1/4°) interannual oceanic simulation was analyzed using a Lagrangian framework. Waters from the LLWBC transiting from Vitiaz Strait (the main contributor), from Solomon Strait, and via the Mindanao Current are identified as the principal sources to the EUC. Their final locations in latitude and depth within the EUC are analyzed. At the entrance of the Solomon Sea, waters are shown to originate from two distinct subduction zones: the central waters (around sigma 26.2) are mostly subducted north of New Zealand, and flow through the North Caledonian Jet. The tropical waters (around sigma 24.8) are mostly subducted in the eastern Pacific (110°W, 20°S), before flowing through the North Vanuatu Jet. Implications for geochemical enrichment of the EUC are discussed and the interest of the physical/geochemical coupling is raised up.

Using virtual particles to understand tropical Pacific circulation and biogeochemical change
A. Sen Gupta

This talk will introduce the concept of Lagrangian modelling: viewing simulated oceans while floating with the prevailing circulation. I'll specifically review some insights gained regarding flow pathways through the Indonesian Throughflow and into the Equatorial Undercurrent. Ill also describe how this technique can be extended to test hypothesis about iron pathways to the iron limited eastern equatorial Pacific and by adding behaviour to lagrangian particles how we can even examine the movement of Pacific tuna.
SST and SSS seasonal changes in the western Solomon and Bismarck Seas
T. Delcroix
We analyze mean and seasonal change of Sea Surface Temperature (SST) and Salinity (SSS) in the Solomon and Bismarck Seas, using 1977–2009 in situ data collected from Voluntary Observing Ships. Covariability of these two variables with surface wind, altimeter-derived and model-derived horizontal currents, precipitation, and Sepik River discharge are examined. SST and SSS show large annual oscillations in the Solomon Sea, with the coldest and saltiest waters occurring in July/August mainly due to horizontal advection. In contrast, they show large semiannual oscillations in the Bismarck Sea. There, the coldest and saltiest waters happen in January/February, when the northwest monsoon winds drive coastal upwelling, and in July/August, when the New Guinea Coastal Current advects cold and high-salinity waters from the Solomon Sea through Vitiaz Strait. The low SSS values observed in April/May, stuck between the January/February and July/August SSS maxima, are further enhanced by the Sepik River discharge annual maximum. A high-resolution model strengthens the conclusions we derive from observations.
Session 4: Small-scale processes, mixing and enrichments

Spatial Patterns of Mixing in the Solomon Sea

Alberty, M.

The Solomon Sea is a marginal sea in the southwest Pacific that connects subtropical and equatorial circulation, constricting transport of South Pacific Subtropical Mode Water and Antarctic Intermediate Water through its deep, narrow channels. Marginal sea topography prevents kinetic energy from propagating out and into the open ocean, making these regions hot spots for energy dissipation and mixing. Data from two hydrographic cruises and from Argo profiles are employed to indirectly infer mixing from observations for the first time in the Solomon Sea. Thorpe and finescale methods indirectly estimate the rate of dissipation of kinetic energy ($\varepsilon$) and indicate that it is maximum in the surface and thermocline layers and decrease by 2-3 orders of magnitude by 2000 m depth. Estimates of diapycnal diffusivity from the observations and a simple diffusive model agree in magnitude but have different depth structures, likely reflecting the combined influence of both diapycnal mixing and isopycnal stirring. Spatial variability of $\varepsilon$ is large, spanning at least two orders of magnitude within isopycnal layers. Seasonal variability of $\varepsilon$ reflects regional monsoonal changes in large-scale oceanic and atmospheric conditions with $\varepsilon$ increased in July and decreased in March. Finally, tide power input and topographic roughness are well correlated with mean spatial patterns of mixing within intermediate and deep isopycnals but aren't clearly correlated with thermocline mixing patterns.

Internal tides in the Solomon Sea

M. Tchilibou$^1$, L. Gourdeau$^1$, B. Djath$^2$, F. Lyard$^1$, D. Allain$^1$, A. Koch Larrouy$^1$, Dwi Yoga Nogroho$^1$, and R. Morrow$^1$.

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In the south west Pacific, the Solomon Sea lies on the pathway of the Low Latitudes Western Boundary Currents (LLWBCs) that connect the sub-tropics to the equator. The Solomon Sea have a particular interest in a climatic context, since they are a critical pathway for ENSO and its low frequency modulation. The western Pacific is a place of energetic internal tides generated over its complex bottom topographic features. In the Indonesian Archipelago, they are particularly active in defining the properties of the waters that move from the Pacific to the Indian Ocean. The salinity maximum at the thermocline level, which is characteristic of the South Pacific Tropical Waters (SPTW) flowing within the LLWBCs and feeding the Equatorial
UnderCurrent, is largely eroded within the Solomon Sea. Different mechanisms could explain such salt erosion including current/bathymetry interactions, internal tides, and eddy activity. The motivation of this study is to investigate the potential role of internal tides for such water mass transformation. Results from a 1/36° resolution regional model including explicit tides are presented. As a first step, the generation and propagation of internal tides in the Solomon Sea are determined, and the conversion rate from barotropic to baroclinic energy is estimated.

Exploring mesoscale eddies in the Solomon Sea

L. Gourdeau

Mesoscale activity is an important component of the Solomon Sea circulation that interacts with the energetic low latitude western boundary currents of the South tropical Pacific Ocean. This study makes synergetic use of glider data, altimetry, and high-resolution model for exploring mesoscale eddies, especially their vertical structures, and their role on the Solomon Sea circulation. The description of individual eddies observed by altimetry and gliders provides the first elements to characterize the 3D structure of these tropical eddies, and confirms the usefulness of the model to access a synoptic view of such eddies. 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.

Wind-driven changes of surface current, temperature, and chlorophyll observed by satellites north of New Guinea

M.-H. Radenac, F. Léger, M. Messié, P. Dutrieux, G. Eldin, C. Menkes

We investigate the physical and biological variability of the ocean in the Bismarck Sea, north of New Guinea, taking advantage of the high spatio-temporal resolution of satellite data to expand on past studies. Wavelet analyses of satellite-derived wind and currents, sea surface temperature (SST), and chlorophyll show that seasonal time scale variations explain most of the variance north of New Guinea and that intraseasonal activity is mainly observed in austral summer. Interannual variability is weak. The combination of satellite observations further shows that SST and chlorophyll variability is mainly driven by two processes: coastal upwelling and penetration of Solomon Sea water.

Coastal upwelling is generated when winds are westerly (westerly wind event, northwest monsoon). Westerly wind events are observed seasonally between September and January and interannually during El Niño events. Upwelled coastal waters spread towards the equator and,
during some westerly wind events, these phytoplankton-rich waters can be advected toward the eastern part of the warm pool by the surface current. Penetration of Solomon Sea water occurs during the trade wind season when the enhanced New Guinea Coastal Current transports cold water through Vitiaz Strait in a narrow vein hugging the coast. At the interannual time scale, the upwelling influence in the Bismarck Sea combines with the coastal cold tongue influence on lowering SST and counteracts the penetration of low chlorophyll water from the Solomon Sea during El Niño.

**Rare Earth Elements in the Solomon Seas (Pandora, GEOTRACES cruise GP#12).**

Pham V. 1, Jeandel C. 1 and Grenier M. 3

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A substantial amount of water formed in the centre of the South Pacific subtropical gyre transits through the Coral and Solomon seas before joining the equatorial undercurrent (EUC) thereby preconditioning the El Nino variability and equatorial biological productivity. Within the Solomon Seas, land-ocean inputs are likely to occur, resulting from the water dynamic and the fact that this area of the world is among the most weathered. While these inputs are fertilizing the EUC Cold Tongue, the mechanisms yielding them are still not constrained. Understanding these mechanisms was one of the objectives of the PANDORA cruise (July-Aug 2012, R/V Atalante; www.geotraces.org). To this end, Trace Elements and Isotopes (TEIs) where collected, among them Rare Earth Elements (REE) and Nd isotopes as pertinent tracers of water mass transformations and land-ocean inputs. Here, we are presenting 22 dissolved REE (DREE) profiles in the Coral Sea (characterizing the North Caledonian and North Vanuatu Jets), inside and at the exit of Solomon Sea (Vitiaz, St.George and Solomon straits). Dissolved REE concentrations, patterns and their anomaly will be discussed. Their reliability will be assessed by comparison with preceding studies [Zang and Nozaki (1996), Grenier et al. (2013)]. Vertical DREE profiles confirm their nutrient-like behaviors except for the non-soluble Cerium. DREE maxima, consistent with dissolved Al and Mn ones, reveal strong coastal effects. Comparison of filtered and non-filtered samples allows estimating these inputs. On-going analyses of Nd isotopes will allow quantifying exchange versus net input fluxes.


**Radium isotopes and actinium-227 used as tracers of water masses and mixing processes in the Solomon Sea**