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Modification of the Stratification and Velocity Profile within the Straits and Seas of the Indonesian Archipelago

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LONG-TERM GOALS

To improve our understanding of the energetic ocean physical processes within the northeastern Indonesian seas, as needed to improve our simulation of the regional circulation and mixing patterns.

OBJECTIVES

The gap in understanding basic ocean physics of the Indonesian seas is most acute in the northeastern seas: the Halmahera Sea, Maluku Sea, the Seram Sea and the northern Banda Sea. Besides the monsoonal forcing there is an abundance of intraseasonal features of varied scales, derived from: the energetic Pacific western boundary currents that project into the region way of the Mindanao and Halmahera Retroflectionms (Eddies); localized winds blowing through the gaps between the islands composing the "Spice Island" configuration, inducing submesoscale clockwise and counterclockwise wind stress structures; strong tidal currents amidst the array of small seas and narrow passages. These factors make for a vigorous turbulent environment, one that is poorly understood, yet it is necessary to develop a quantitative grasp of the associated small scale ocean processes to properly model the regional circulation, and its role in the climate and marine ecosystems.

APPROACH

Use existing observational data sets and model output to produce an overview of the ocean circulation and mixing within the northeastern Indonesia seas; to identify gaps in our understanding that hinder quantitative grasp of the regional oceanography; and to develop plans for an exploratory research cruise into the region to obtain some basic parameters of the circulation/mixing environment. Included in this approach was a visit to Indonesia in July/August 2011 of A.L.Gordon and A.Ffield to present lectures and meet with local researchers knowledgeable of the Spice Island oceanography.

WORK COMPLETED

During the 2nd year of the program we met with representatives of the Indonesian agency BPPT to developed plans for an exploratory research cruise in mid-2012 (June) aboard an Indonesian research

vessel, Baruna Jaya IV, into the Seram, Halmahera and Maluku Seas, the Spice Islands domain, to obtain an initial 'snap-shot' view of the stratification and circulation within these seas. While such a snapshot in this otherwise data void has merit in its own, it provides essentially 'exploratory' information to compare to HYCOM model output and to build a more targeted observational, modeling program (and could contribute to ONR FY2012 MURI Topic #16 "Extended-Range Environment Prediction using low-dimensional dynamic modes"). In addition, we arranged, as part of the 2012 research cruise to recovery, in coordination with the Ariane Koch-Larrouy, the French IndoMix ADCP mooring at the northern sill of the Halmahera Sea.

RESULTS

The gap in understanding basic ocean physics of the Indonesian seas is most acute in the northeastern seas, Spice Island domain: the Halmahera Sea, Maluku Sea, the Seram Sea and the northern Banda Sea (Figure 1). These seas are exposed to the energetic Pacific western boundary currents rich in intraseasonal activity (Figure 2), that project into the region by way of the Mindanao and Halmahera [Eddies] Retroflections. The complex submarine topography coupled with the strong tidal action (Figure 3) and wind textured by the island topography lead to a vigorous turbulent environment, one that is poorly understood, yet it is necessary to develop a quantitative grasp of the associated small scale ocean processes to properly model the regional circulation, and its role in the climate and marine ecosystems (Figure 4, 5).

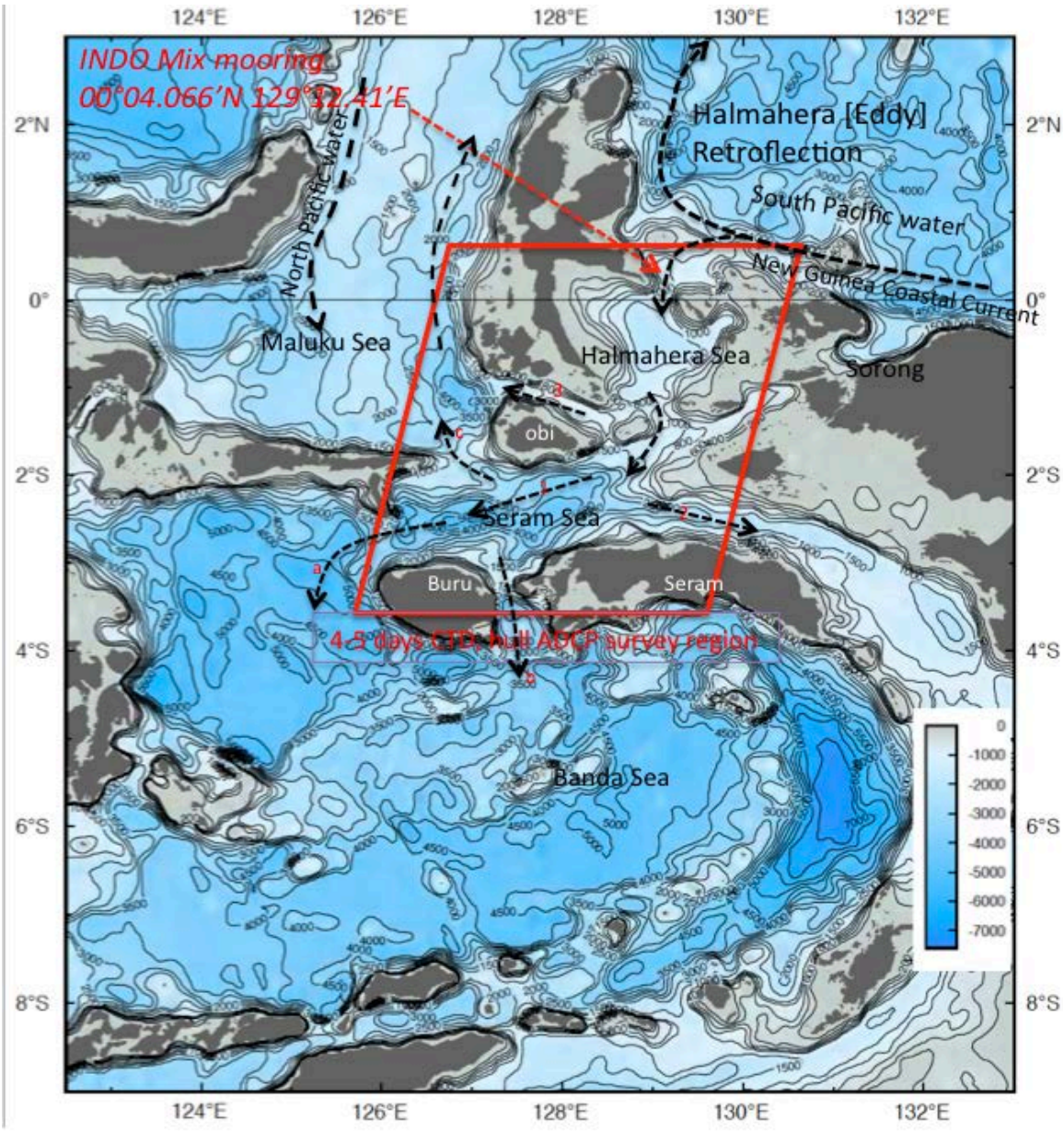

Figure 1. The Region. South Pacific water passes into the northern Halmahera Sea over the 580 m sill (Gordon et al. 2003; near the position of the 650 m deep French IndoMix mooring to be recovered by this proposed program), splitting off from the New Guinea Coastal Current, a component of the Halmahera Retroflection ("Retroflection" is more proper than "Eddy" often used to identify this feature) . The southern exit is more complex and highly time variable (inference from HYCOM). Three paths are likely: 1: south of Obi, westward into the region of the western Seram Sea north of Buru, from which the flow may follow three paths (a,b,c); 2: eastward along the northern coast of Seram, into the eastern arc of the Indonesian Seas; 3: Within the narrow channel north of Obi towards the Maluku Sea. While Arlindo 1993/94 data (Ilahude and Gordon, 1996) suggests that the Maluku (North Pacific) and Halmahera (South Pacific) inflow mainly returns to the Pacific in the eastern Maluku, with some leakage (La Nina?) into the Banda Sea around Buru Island is likely. It is also likely that some Halmahera Seas inflow may follow the eastern arc of the Indonesian seas to the Timor Passage and Indian Ocean.

HYCOM the surface currents in the Halmahera/Seram Seas display strong intraseasonal (<90 days) fluctuation, with subject to periods of strong surface currents, 2-3 knot, probably extending through the thermocline. The model output frequently shows a zonally elongated circulation cell encompassing Seram Island. From March to October, it is likely to be counterclockwise; in the November to February, a clockwise circulation is more likely. However, there are fluctuations in strength and rotational sense on shorter, intraseasonal, time scales, at scales of weeks to months, defying a simple seasonal approach. The flow in the Halmahera group varies with season, but the path followed on water ejected southward from Halmahera into the Seram Sea varies seasonal but also at intraseasonal scales, with flow directed westward north and south of Obi island (Figure 1) or into the Seram Sea to enter into the circulation cell around Seram island. The Seram Sea is a 'traffic cop' directing the Pacific inflow into multiple possible exit passages. The energetic intraseasonal features are most likely imported from neighboring regions, e.g. the western Pacific, but may also be a response to the Madden-Julian Oscillations (MJO). The shift and change in wind strengthen associated with MJO may alter the wind stress curl field and induce some intraseasonal signal to the Spice Island region.

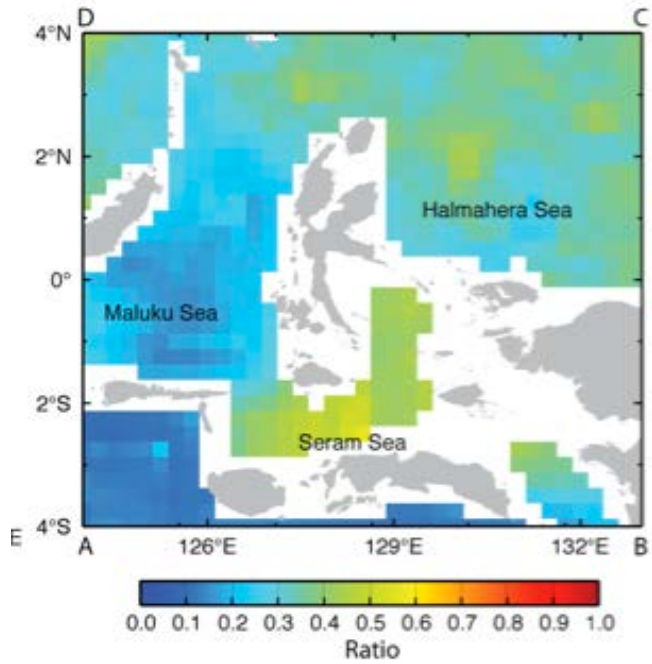

Figure 3. Ratio between the SST variance for intraseasonal timescales and the total SST variance over the maritime continent (left panel). Right panel demonstrates an expanded view of the ratio in the Spice Islands region. [Figure produced by Kandaga Pujiana] The ratio is computed using the

following formula: $$\text{Ratio} = \frac{\int_{T=20\text{-day}}^{T=90\text{-day}} SST^2(T)dT}{\int_{T=20\text{-day}}^{T=365\text{-day}} SST^2(T)dT}$$

Intraseasonal features are most intense in the Seram Sea, immediately south of the Halmahera Sea.

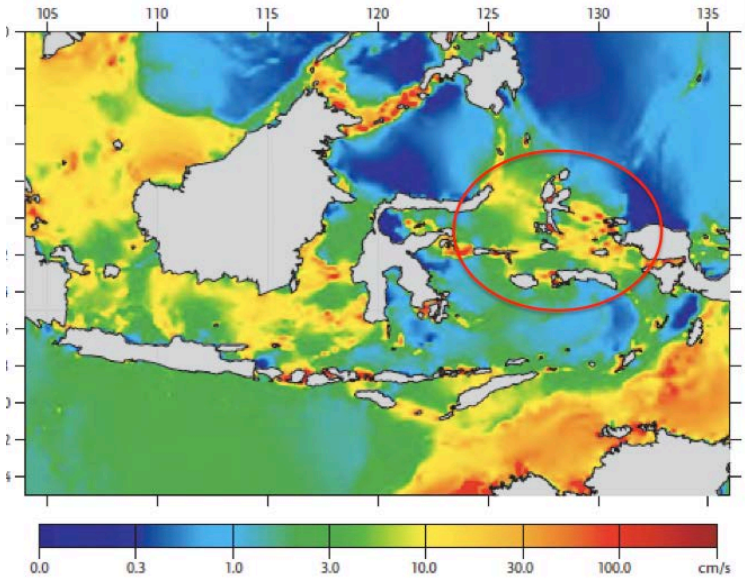

Figure 3. Maximum Barotropic current velocity of M2 tide [note the nonlinear color bar] tidal current. In the Spice Island region there is much tidal energy; the Spice Island regional along with the region near Timor, display the highest M2 current speeds over deep water within the Indonesian Seas (Ray et al, 2005)

The Marine Ecosystems of the Spice Islands is vibrant. Ocean Color from SeaWifs (Figure 4): There is a seasonal signal in the ocean color, with higher values in the Spice Island Seas in the SE monsoon (June-September) than in the NE monsoon (December-March). While high ocean color is typical of the near coastal zones, there is persistent color over the northern and southern ridges defining the Halmahera Sea. These we propose are sustained by high vertical fluxes induced by high Kz.

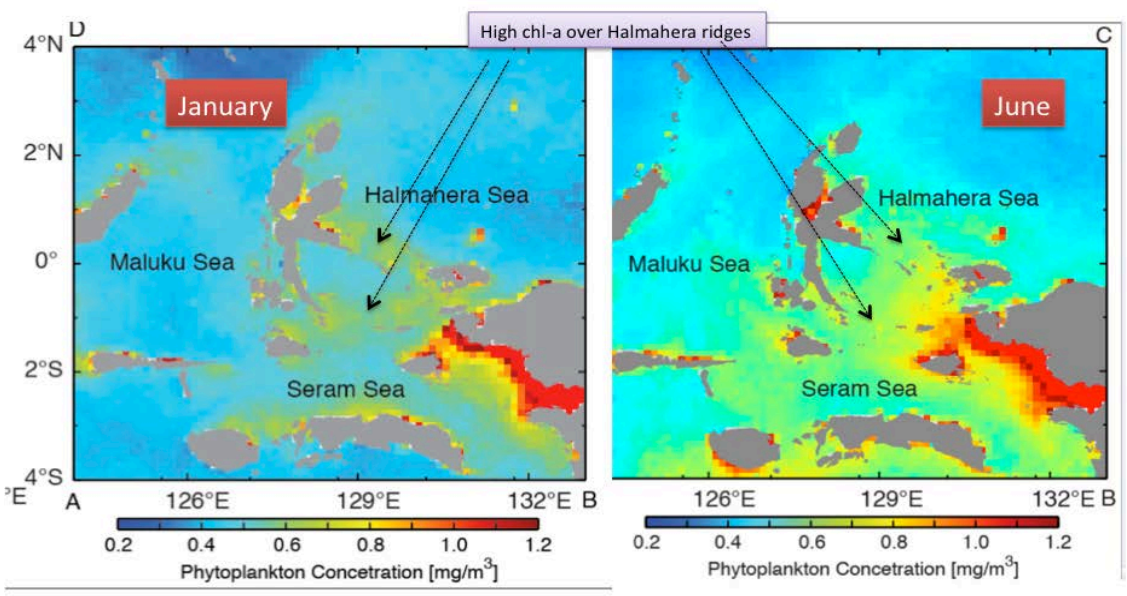

Figure 4. Monthly composite of phytoplankton concentration. The composites are computed from datasets during years of 2004-2008. [Figure produced by Kandaga Pujiana]

The Spice Island domain lies at the center of the Coral Triangle (Figure 5; http://www.coraltrianglecenter.org/en/page/about-ctc

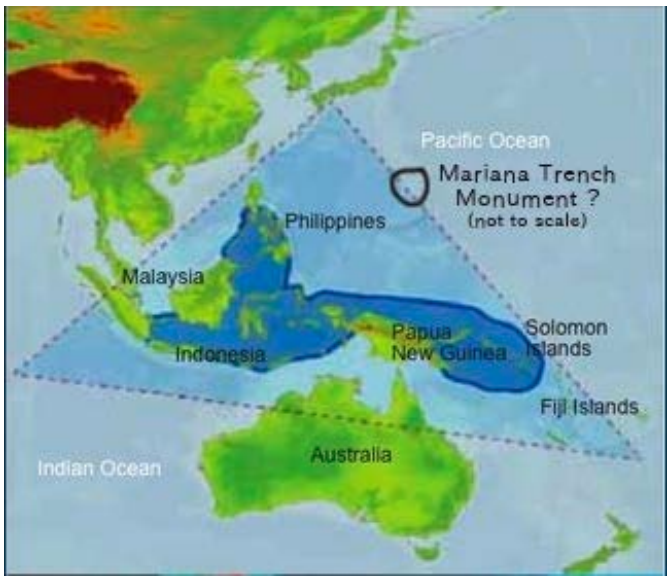

Figure 5. The Coral Triangle is a region , covering over 6 million square kilometers that holds the greatest number of corals, sponges, crustaceans, mollusks and fish on this planet. There are over 600 types of coral, 3000 species of fish, sea turtles, whales, and dolphins. It is now known as the global centre for marine diversity.

The goal of the June 2012 cruise (Figure 6) is to obtain a quick look 'snap-shot' (over 5 to 7 days) view at the stratification and circulation patterns primarily within the varied choke points connecting the Halmahera to the Seram and to the open Pacific, and of the Seram exchange with the Banda and Maluku seas. The broader research questions to be addressed are: How does the stratification, velocity/transport respond to remote and local forcing? What are the dominant physical and dynamical balances that characterize the flow & mixing at different locations and scales? How well do models simulate the observed characteristics?

The 2012 observational data will be compared to the HYCOM products for the cruise period to determine how well HYCOM captures the features. The data will be compared to the IndoMix data set of July 2010, as well as linking into the other Indonesian Throughflow (ITF) programs. This information will be of great value in designing a broader scoped field program sometimes within 2013-2015 time frame, and therefore in a sense can be considered as an exploratory program.

The justification of the program is the premise that: improved understanding of the ocean processes within the northeastern seas of Indonesia, keyed to the complex geography and intraseasonal ocean/atmosphere activity, will provide the basis improved high resolution ocean modeling with applications to such areas as understanding of the nutrient fluxes and larvae trajectories, and associated food chain structures that will allow for informed management of marine living resources: e.g. fisheries and coral reefs, for food and recreation. There would be improved prediction of pollution spreading and improved understanding of the flux of carbon dioxide between ocean and atmosphere (question: are the Indonesian seas a source or sink of atmospheric CO_2?). The research will lead to improved ocean and climate modeling for better predict hydrological changes affecting Indonesia.

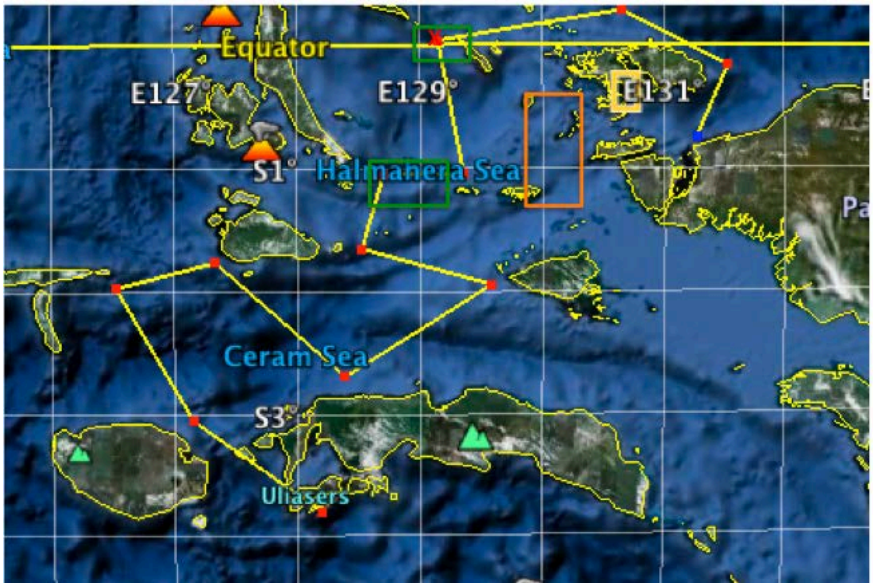

Figure 6. Spice Island 2012 Conceptual cruise plan. We assume a ship speed of 7.5 kts, with a total of 5 days Ambon to Sorong. See figure 1 for expected non-tidal surface current patterns. The US group boards the ship in Ambon (southern point of the yellow cruise track), departs in Sorong. Data collection along yellow lines with underway systems: ADCP, T/S surface water with XCTD probes. There will be ~15 CTD stations to 1000 m across key "Choke-Points" including repeat of IndoMix stations 1-3 (see Figure 10; IndoMix stations 4 was in the Banda Sea). The position of the CTD stations other than the repeat of IndoMix 1-3, have not been determined. In an energetic region it is often better to do time series at a few sites than to confuse space/time variability with a transit. 36 XCTD to 1000 m will be obtained between the multiple casts [yo-yo stations] CTD station. The program includes: recovery of the IndoMix ADCP mooring (X, at 00°04.066'N 129°12.41'E; Green Box: survey of primary Halmahera sills; Orange box: possible underway only survey of Raja Ampat Islands

IMPACT/APPLICATIONS

The program has direct applications for the development of a quantitative and coordinated field program for Indonesia and its international partners, in the relatively unknown northeastern seas of Indonesia.

TRANSITIONS

None

RELATED PROJECTS

None

PATENTS

None