

Analysis of Sub-Mesoscale Features in Indonesian Seas

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LONG-TERM GOALS

The long-term goal of this research is to understand and to establish the importance of various physical drivers for the sub-mesoscale generation mechanism, dynamics, evolution and propagation in the Indonesian seas.

OBJECTIVES

The proposed research will focus on the analyses of sub-mesoscale features in the major straits of Indonesian throughflow pathways (Makassar, Lombok and Ombai Straits, Timor and Lifamatola passages). The main objectives are to describe the general features and analyze generation mechanism, evolution, propagation of sub-mesoscale ocean features; and to establish the relative importance of various physical drivers for the sub-mesoscale generation, evolution, propagation, and their variability, and to identify and quantify the underlying physical and dynamical processes affecting their variability.

APPROACH

In this research, the PI use both *in situ* and remotely sensed data. Historical *in situ* data are gathered from the various cruises of the Indonesian throughflow program (Murray and Arief, 1988; Murray et al., 1990; Field and Gordon, 1996; Chong *et al.* 2000; Hautala *et al.*, 2001; Gordon and Susanto, 2003; Susanto and Gordon, 2005) as well as on-going field measurement from the INSTANT (International Nusantara Stratification and Transport) program (Sprintall *et al.*, 2004). For the remotely sensed data, the main source is the synthetic aperture radar (SAR) carried by various satellites, i.e., ERS-1/2, Radarsat-1/2 and Envisat. High resolution NOAA AVHRR data and SeaWiFS, as well as data from Terra and Aqua satellites will also be used. For the analysis, for different features the PI plans to apply different data analysis methods, which best match the nature of these features i.e. wavelet transform, Hilbert Huang Transform, regression analysis, and Empirical orthogonal function.

WORK COMPLETED

More than hundreds quick-look SAR images have been obtained from various sources: i.e. The Center for Remote Imaging, Sensing and Processing, National University of Singapore, European Space Agency (ESA), and Radarsat. Analysis and interpretation of these images in combination with historical hydrographic data as well shallow pressure gauge array data in the Lombok Strait has been

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done. A manuscript (Susanto et al., 2005) on the internal wave characteristics in the Lombok Strait was published in *Oceanography*. Additional manuscript is being prepared.

Combination analysis of historical *in situ* data (XBT, CTD, moorings data) and remotely sensed data (SST, winds, Chlorophyll-a) over the Indonesian region has been done. Three papers have been published: *Susanto et al. (2006) in Geochemistry Geophysics and Geosystems* and *Susanto and Marra (2005) in Oceanography* and one manuscript (Susanto et al., 2006) is on review, in *Journal Geophysical Research-Oceans*. Analysis on interaction between South China Sea and Indonesian Seas (Fang et al., 2005) has been published in *Advances in Atmospheric Science*.

RESULTS

Because of complex coastline geometry and bathymetry, stratified water and strong tidal current Indonesian Seas are a favorable place for sub-mesoscale features generation such as internal waves, fronts and jets. Tidal conditions, Indonesian throughflow variability, and stratification control generation and propagation directions of the internal waves in the Lombok Strait. The internal wave dynamical parameters: the wavelength, number of solitons in a packet, characteristic half width, propagation direction, and phase speed are determined from both *in situ* and remotely sensed data. Depending on the tidal conditions and the throughflow variability, internal waves in the Lombok Straits could either propagate northward only, southward only or both directions. Figure 1 shows bathymetry of the Lombok Strait, internal waves observed from SAR, and tidal conditions at the time the images were taken. Figure 2 shows *in situ* observation during the INSTANT cruise in the Lombok Strait in 2005 when internal waves were observed using (a) regular camera of sea surface conditions (b) sonar onboard of the ship and (c) onboard echosounder.

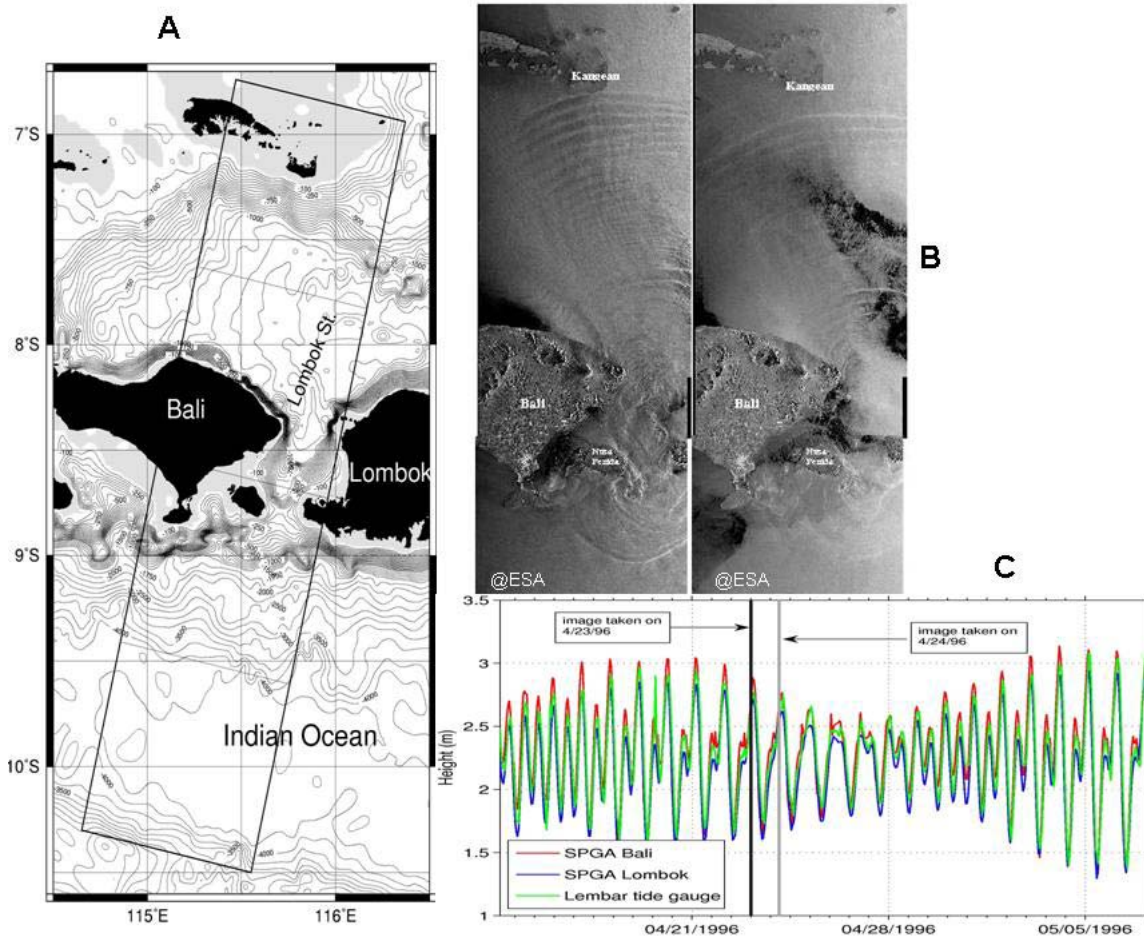
Analysis of *in situ* data (XBT, CTD, moorings) and remotely sensed data (SST from NOAA-AVHRR, chlorophyll-a from SeaWifs and Modis, winds from scatterometers, sea level from TOPEX/Poseidon and Jason-1 altimeters) over Indonesian region indicates that dynamics of Indonesian Seas strongly affected by monsoon and ENSO. Upwelling occurs during the southeast monsoon (April-October) along the southern coasts of Sumatra-Java and Nusa Tenggara (east-west series of islands from Lombok to Timor) and eastern Banda Sea. ENSO modulates the upwelling; during El Nino events, upwelling is stronger, cooler SST, shallower thermocline, lower sea level and higher chlorophyll-a concentration. Figure 3 shows SST and chlorophyll-a concentration during (a) the peak of northwest (February) monsoon and (b) southeast (August) monsoon and (c) during the peak of 1997/98 El Nino event.

IMPACT/IMPLICATIONS

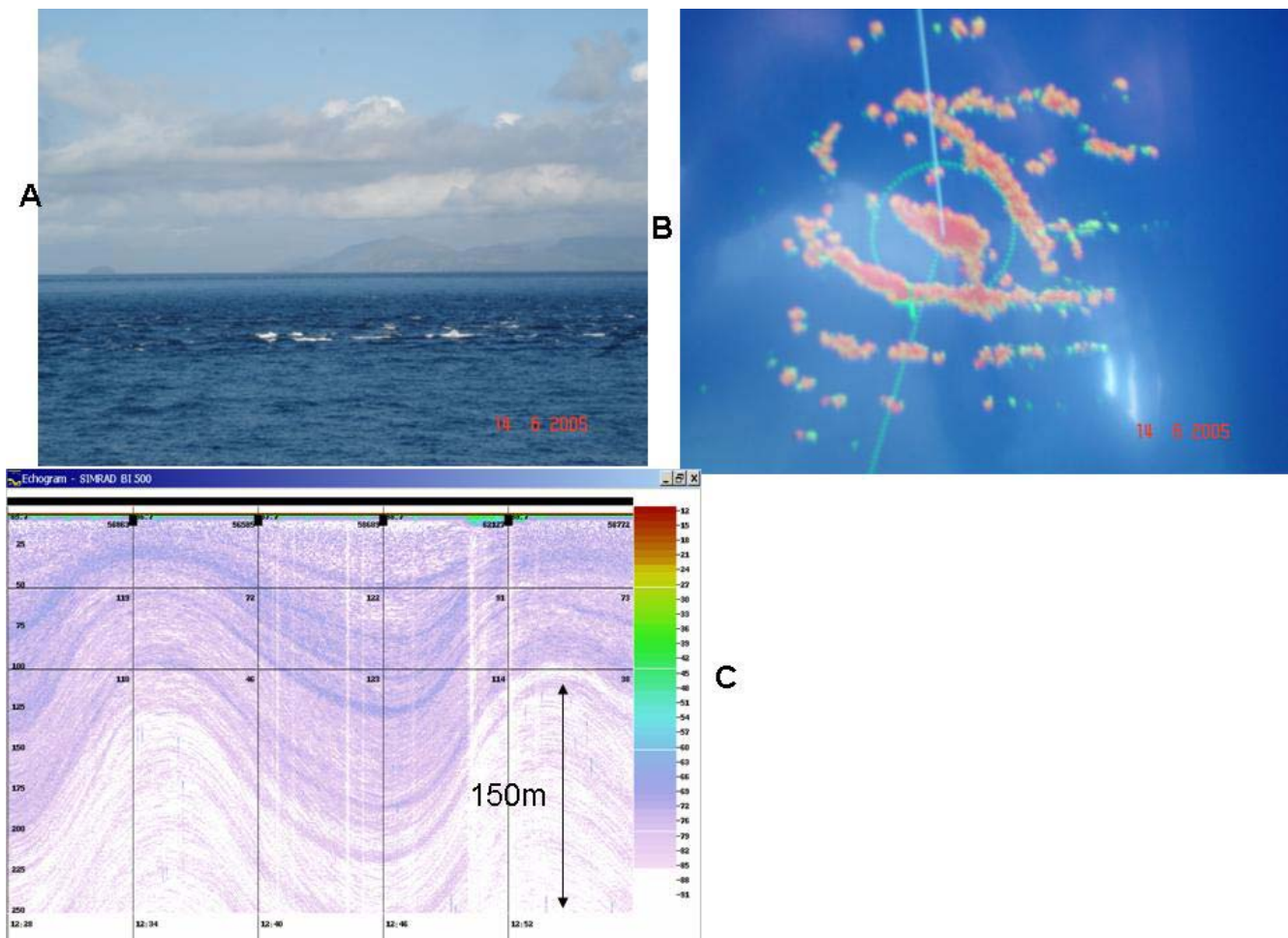
Major inflow and outflow straits of the Indonesian throughflow where sub-mesoscale may generated, are also the main routes for shipping from the Pacific to Indian Oceans and these sub-mesoscale features affect acoustic signals, therefore, flow pattern and sub-mesoscale feature studies in these straits not only an important component for understanding upper ocean dynamics but also for industrial, marine safety, and military uses. In addition, these the throughflow and sub-mesoscale features affect the chlorophyll-a concentration.

RELATED PROJECT

There is an ongoing international [Indonesia, United States, Australia, France, and the Netherlands] collaborative research called INSTANT. The US part supported by NSF. The primary objective of INSTANT is to measure the variability of the ITF and its associated heat and freshwater flux exported into the Indian Ocean. INSTANT PI's have deployed 11 moorings in major inflow passages from the Pacific Ocean (Makassar Strait & Lifamatola Passage) and outflow passages to the Indian Ocean (Lombok and Ombai Straits, and Timor passage; Gordon, 2004; Sprintall *et al.*, 2004). Turn around deployment conducted on June-July 2005 and the data are being processed. The final recovery is being plan for November-December 2006.



[Figure 1. (a) Bathymetry of the Lombok Strait, (b) internal waves observed from SAR, and (c) tidal conditions at the time the images were taken (Susanto *et al.*, 2005)]



[Figure 2. Internal waves observed in the Lombok Strait during the INSTANT cruise in 2005, observed using (a) regular camera of sea surface conditions (b) sonar onboard of the ship and (c) onboard echosounder. The wave amplitude is ~150m (Susanto et al., 2005)].

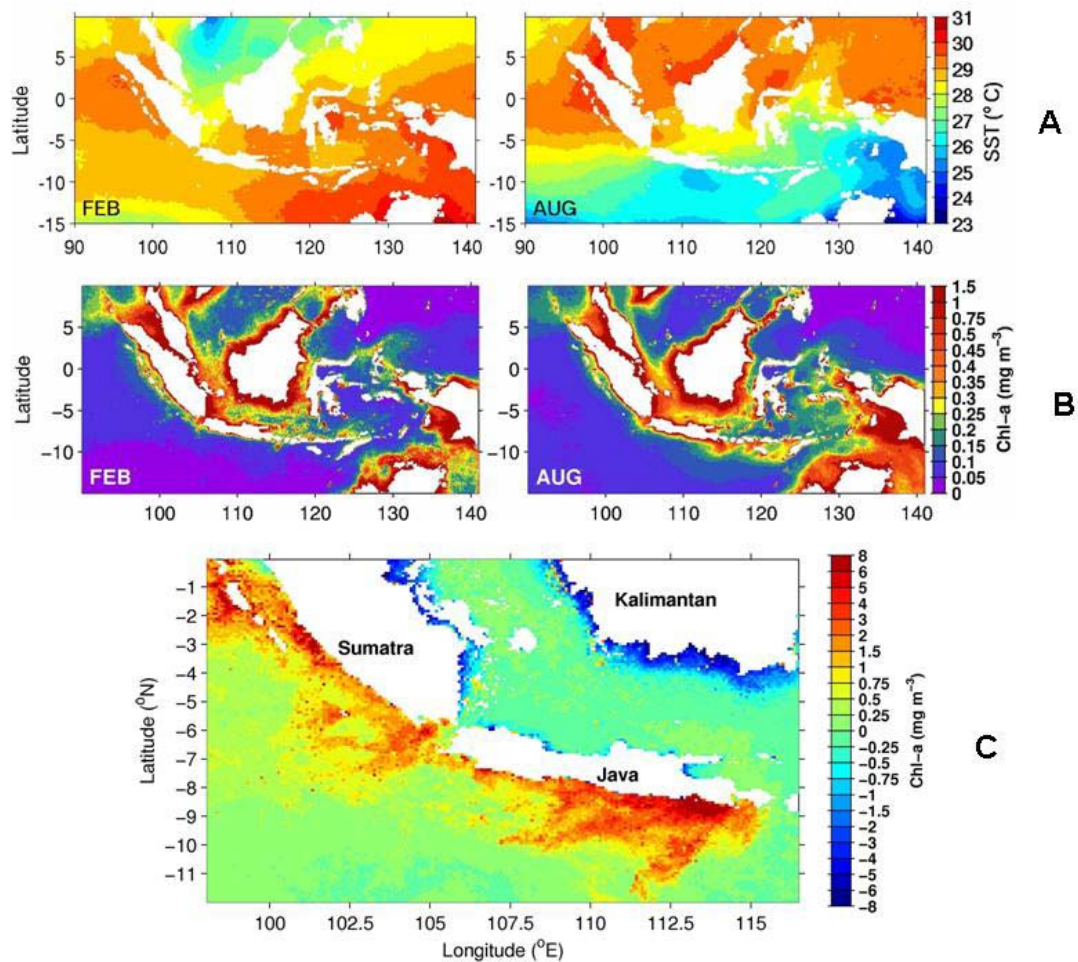


Figure 3. SST and chlorophyll-a concentration during (a) the peak of northwest (February) monsoon and (b) southeast (August) monsoon and (c) during the peak of 1997/98 El Niño event. [Susanto and Marra, 2005; Susanto et al., 2006]

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