Microstructure Measurement within Indonesia's Seas

The Indonesian Archipelago is characterized as a region with the warmest sea surface temperatures (SST) in the world and is a key region of the climate system. This is because the atmospheric deep convection affecting the global climate occurs directly above this region. Previous studies showed that the SST patterns in the Indonesian Seas are highly influenced by tide-induced vertical mixing (hereafter called "tidal mixing"). The other role of tidal mixing is to change the character of the Indonesian Throughflow (ITF). These modified ITF waters cool and freshen the Indian Ocean and influence the Agulhas, Leeuwin and Eastern Australian Currents. Tidal mixing in the Indonesian Seas is, therefore, crucial for the predictions of the large-scale oceanic circulation as well as the global atmospheric circulation. In the Indonesian Seas, however, microstructure measurements have hardly been carried out, so that the distribution and magnitude of tidal mixing remain uncertain.

Turbulent mixing in the Indonesian Seas has long remained as one of the most important 'missing information' in predicting the large-scale oceanic circulation as well as the global atmospheric circulation, since it significantly affects the SST patterns in the Indonesian Seas and changes the character of the ITF. In order to clarify the distribution and magnitude of turbulent mixing in the Indonesian Seas, we have carried out the first extensive direct microstructure measurements in the Indonesian Seas, through which area the western (or eastern) path of the ITF penetrates westward (or southward). This project measure sea water turbulence level and vertical turbulence mixing. This measurement is importance because currently climate change and weather predition is less accurate due to parameterization of vertical mixing componenets due to internal tidal wave not yet included for the model.

This project is conducted using RV Hakuhomaru and BarunaJaya IV, with BPPT, Universitas Mataram, Universitas Hasanuddin, dan IPB

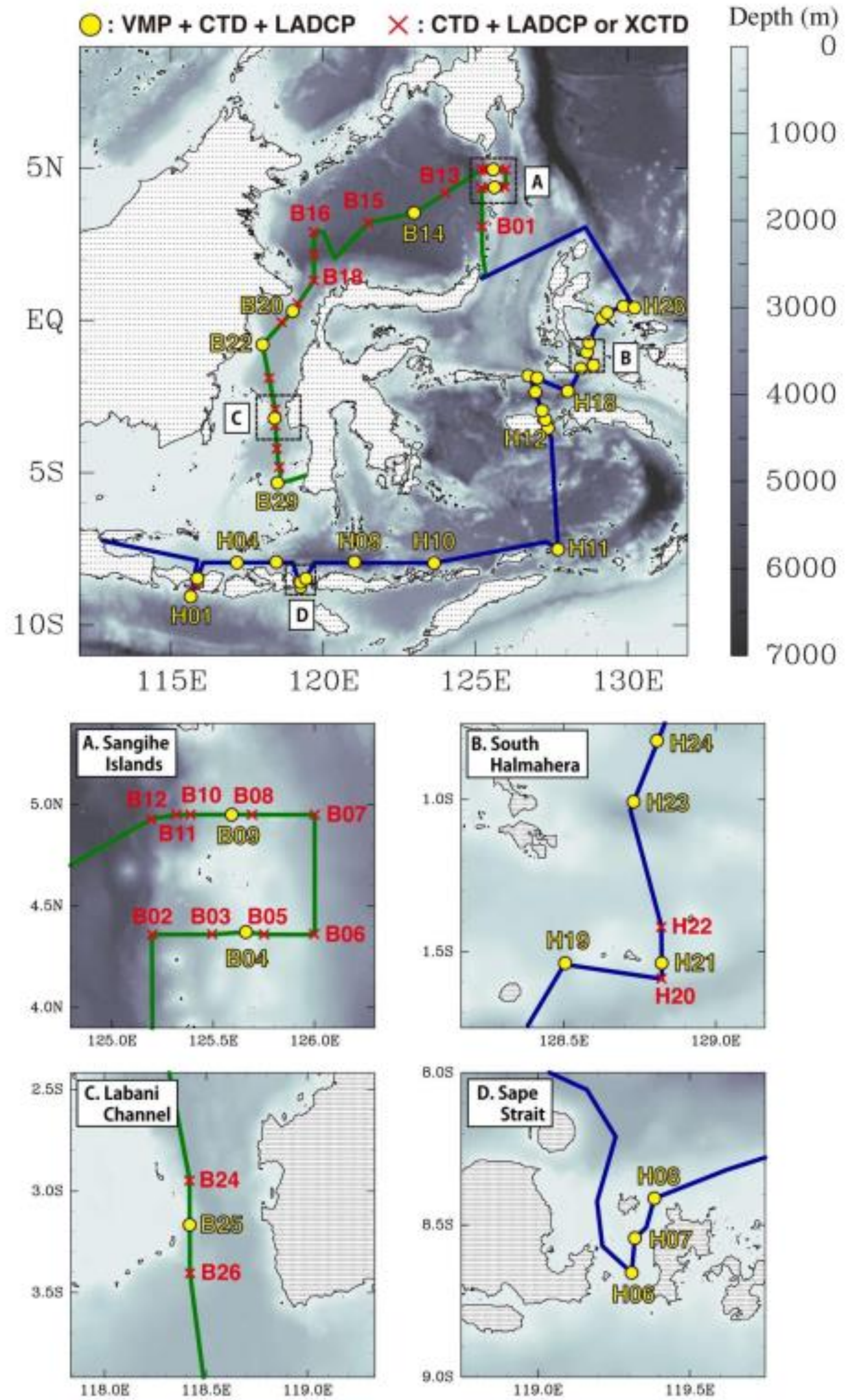

Fig. 1: Cruise tracks for all the period (blue line : Hakuhomaru-cruise, green line : Baruna Jaya IV cruise). Yellow circles and red crosses show the VMP and CTD/XCTD stations, respectively.

Results

Observed profiles of temperature, salinity, energy dissipation rates, and vertical diffusivities along the ship tracks of Hakuho-maru and Baruna Jaya IV are shown in Figs 2, respectively. At the entrance of the western route of the ITF (B07), we can find clear 'salinity maximum' and 'salinity minimum'; one of the characteristics of the North Pacific Tropical Water (NPTW) and North Pacific Intermediate Water (NPIW), respectively. This salinity maximum/minimum, however, rapidly disappeared downstream along the western route of the ITF at the narrow straits in the Sulawesi Seas and Makassar Strait, where strong mixing (energy dissipation rates/vertical diffusivities) was detected by VMP-5500 (B04, B25). This strong mixing is thought to be generated by internal tides (Nagai and Hibiya, 2015).

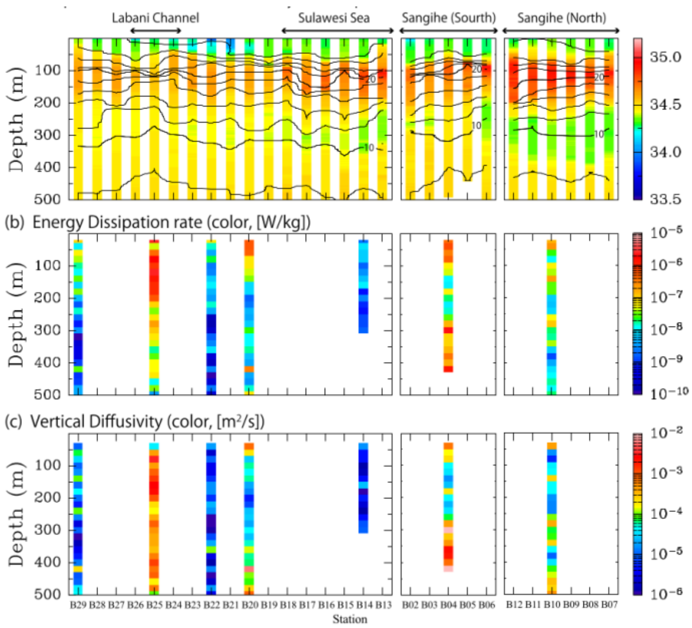

Fig. 2: Observed profiles of (a) temperature (contour), Salinity (color), (b) energy dissipation rates (color), and (c) vertical diffusivities (color) along the ship track of Baruna Jaya IV.

Similar water-mass transformation can be found in the eastern route of the ITF (Fig.5). Salinity maximum (SPTW : South Pacific Thermocline Water) found at the entrance of the ITF (H28) rapidly disappeared downstream along the eastern route of the ITF, where strong mixing (energy dissipation rates/vertical diffusivities) was detected by VMP-5500 and VMP-X. These results strongly suggest that the strong vertical mixing enhanced at the narrow straits promotes the water-mass transformation. This is the first observational research that clearly shows the relationship between the water-mass transformation and turbulent mixing.

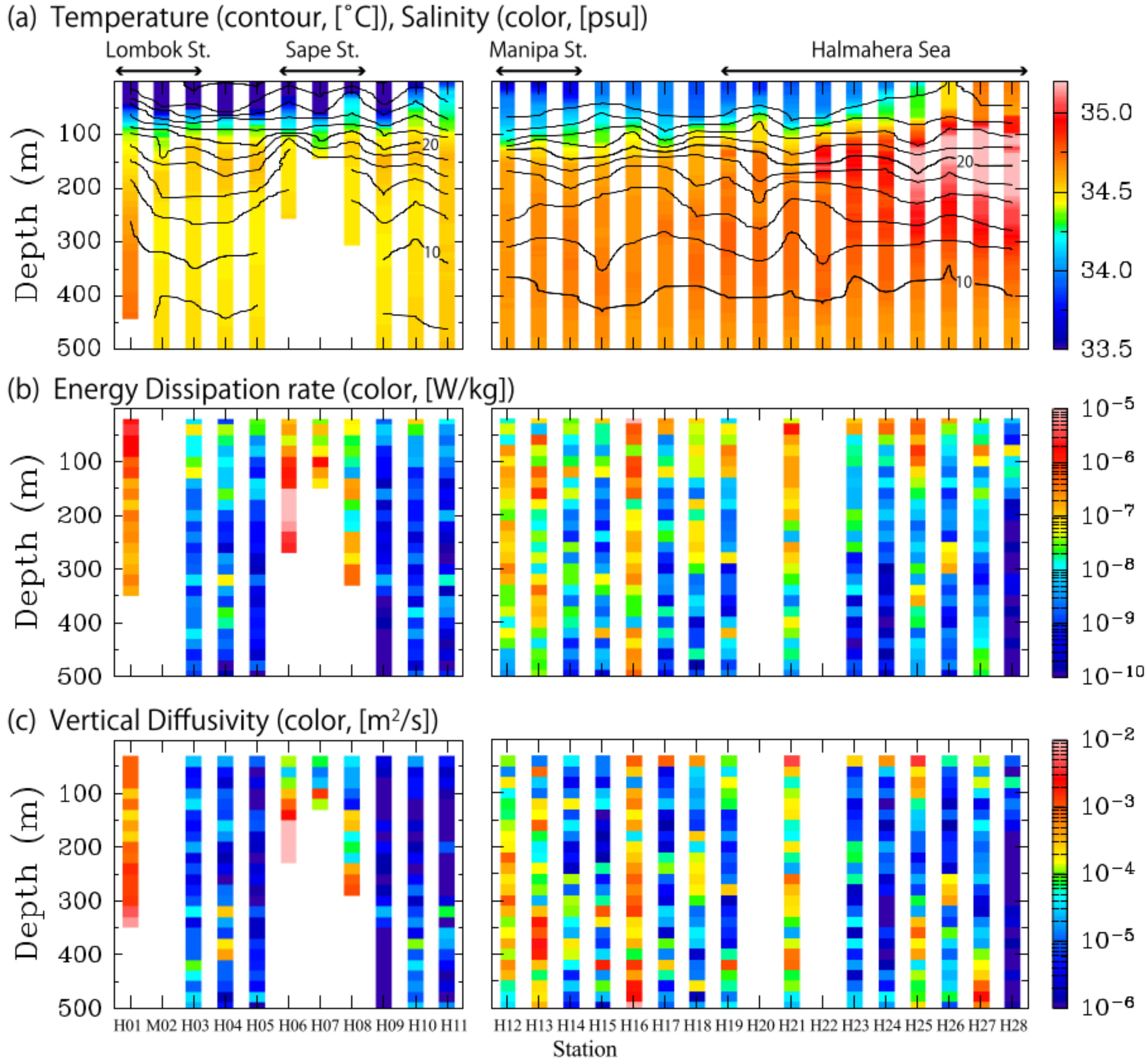

Fig. 5: Same as Fig4, but along the ship track of Hakuho-maru

(2.5.2) Turbulent mixing

Figure 6 shows the comparison of depth-integrated energy dissipation rates obtained from the observation and numerical model. We can see that mixing hot-spots are localized in the narrow straits (Lombok, Sape, and Manipa, Lifamatola straits, and Sangihe Islands) both in the observed and calculated results, suggesting that the numerical model can reproduce the general features of the mixing distribution very well. Scatter plots of observed and numerically simulated energy dissipation rates for each depth (Fig. 7) also show that the numerically predicted dissipation rates are generally consistent with the observed ones. However, we can see that the numerical model overestimates the dissipation rates by a factor of 7.6 on average. In order to clarify this model bias, we are planning to continue to analyze the observational data.

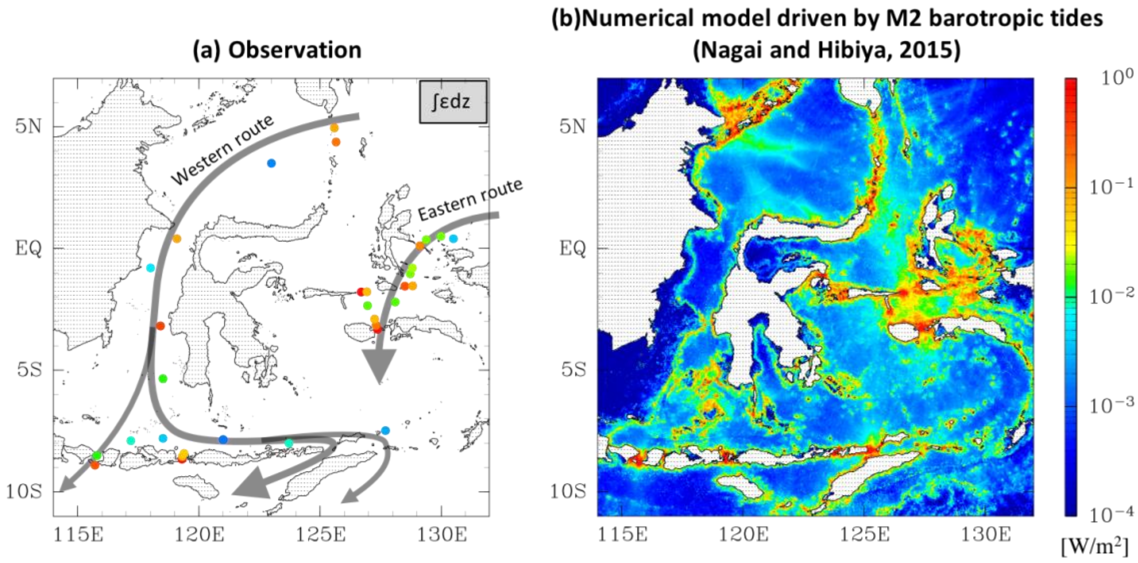

Fig. 6: Depth-integrated energy dissipation rates obtained from (a) the observation, and (b) numerical model.

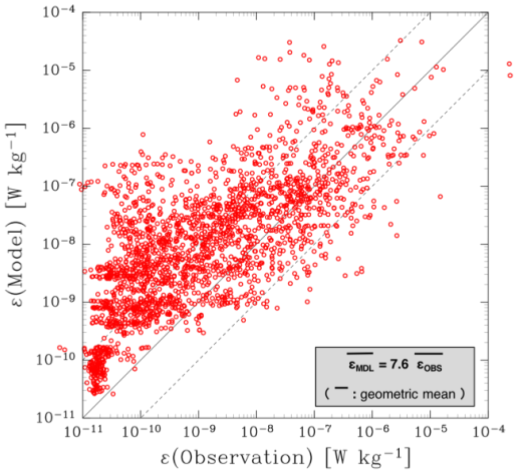

Fig. 7: Comparison between the observed and numerically simulated energy dissipation rates for each depth.

Summary

With our extensive direct microstructure measurements in the Indonesian Seas, through which area the western (or eastern) path of the ITF penetrates westward (or southward) to clarify the distribution and magnitude of turbulent mixing in the Indonesian Seas. Observed data has clearly shown that the significant water-mass transformation occurs along the ITF paths, and that strong mixing in the narrow straits plays an important role in the water-mass transformation. This is the first observational evidence that shows the clear relationship between the water-mass transformation and turbulent mixing in the Indonesian Seas. It has also been shown that the obtained distribution of energy dissipation rates is generally consistent with that predicted from the numerical model. The numerical model, however, overestimates the dissipation rates by a factor of 7.6 on average. Using the obtained data, we are currently investigating this model bias as well as the effects of turbulent mixing on the water-mass transformation and SST variations in the Indonesian Seas. This enables us to construct the numerical model showing the 'map' of the intensity of turbulent mixing throughout the Indonesian Seas, which is expected to contribute to our understanding and prediction of global climate change.