Upper ocean heat content variability in the Pacific Ocean during past 50 years

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Numerous studies on observed sea surface temperature (SST) and atmospheric anomaly fields have been done so far in order to investigate climate variations. However upper ocean variations related to the climate variations is not well understood at present. For the purpose to investigate such variations, upper ocean heat content (OHC), which well reflects variations of subsurface temperature change and thermocline depth change, is very useful. However a lack of datasets on observed subsurface temperature has not allowed us to analyze OHC variability on a basin scale and for long period until the mid 1990s. The aim of the present study is to investigate the OHC variability in the Pacific basin on interannual to decadal/multidecadal timescales during past 50 years.

The results show that dominant timescales of the OHC anomaly is ENSO (interannual), decadal and multidecadal longer than 30-year period. On the ENSO scale, it is shown that OHC anomaly propagates from the western boundary to the eastern boundary along the equator and from the eastern boundary to the western boundary along the off-equatorial North Pacific centered at 15N. Such anti-clockwise propagation is related to ENSO events. In addition, it is suggested that OHC anomaly spatially averaged over the entire equatorial Pacific (Teq) is generated by Sverdrup transport variations in the tropical Pacific. The Teq leads the eastern equatorial SST (Nino-3 index) by about a quarter of the ENSO period which is well consistent with the idea of the recharge oscillator model (Jin 1997 JAS).

On the decadal scale, the behaviors of the OHC anomalies are similar to those of ENSO scale. However, there are some different points among them. That is, the relationship between Teq and Sverdrup transport variations are more dominant in the tropical South Pacific. Further, westward propagation along the off-equatorial South Pacific is suggested in addition to the westward propagation along the off-equatorial North Pacific. A relationship between the decadal and ENSO scale OHC anomalies are also explored, and it is indicated that when Nino-3 index on the decadal scale is positive (negative), behaviors of ENSO as described above are clearly observed.

On the multidecadal scale, it is shown that OHC is also dominant in the mid latitudes. OHC anomalies display a clockwise propagation in the mid latitudes as follows. The positive (negative) OHC moves in the south-west direction from the central Pacific around 30N to the western boundary around 20N. After the positive (negative) OHC anomalies reach the western boundary, the Kuroshio transport begins to increase (decrease), and then positive (negative) OHC anomalies extend in the east of Japan including the Kuroshio Extension and then reach the central Pacific. It is interesting that OHC is in phase with SST and sea level pressure only in the region east of Japan. It indicates that this region is important for the coupled ocean-atmosphere climate variations on this timescale, which supports the idea of the Latif and Barnett (1994 Science). On the other hand, the effect from the tropics may also be important as proposed by Gu and Philander (1997 Science) since the OHC anomaly also shows large signal in the tropical Pacific.

As mentioned above, the present results for observed OHC anomaly after the mid 1950s show that dominant regions and behaviors of the Pacific OHC anomalies are different in each dominant timescale. It is impossible to analyze OHC variability in the same way as described above before the 1950s, because observations of subsurface temperature are very few. So, the analyses of the proxy data are expected in the period before the 1950s instead of the OHC data. The present results are mainly based on our published papers; Hasegawa and Hanawa (2003a JPO) for ENSO scale, Hasegawa and Hanawa (2003b GRL) for decadal scale and Hasegawa and Hanawa (2006 JO in press) for the relationship between ENSO and decadal scales.