Coherent approach on radial oscillation indexes with AAOI for environmental ecosystem in the Southern/Antarctic Ocean

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Large change of environment and ecosystem in the Southern/Antarctic Ocean happens frequently in recent decades (as general reviews, Turner *et al*., 2009; Rintoul *et al*., 2012; IPCC, 2001, 2007, 2013). A key factor that brings the change of the environmental ecosystem in the Southern/Antarctic Ocean seems to be a large change of the circum-westerlies around the Antarctica connecting with Antarctic Oscillation (AAO) alias Southern Annular Mode (SAM). We are interested in the relationships between climate-ocean environment and the ecosystem of Antarctic krill, a keystone species in the Antarctic Ocean (Fig. 1). A fundamental issue is how to take approaches for understanding of the relationships between climate, ocean and krill ecosystem in various specific phenomena.

Naganobu *et al*. (1999) found a significant correlation between krill recruitment and DPOI (Drake Passage Oscillation Index determined from sea level pressure differences between Rio Gallegos in South America and Esperanza Station in the Antarctic Peninsula) in time-series variability using world metrological standard data. The strength of the westerlies affects krill recruitment; years with the strong westerlies resulted in high, and years with the weak westerlies resulted in low. IPCC (2001) evaluated DPOI as the environmental index associated with the Antarctic ecosystem.

Therefore we have tried similar approaches on climate indexes in the other regions by further extension for KDOI (Kerguelen Islands - Davis Station Oscillation Index) in the Indian sector and CMOI (Christchurch - McMurdo Station Oscillation Index) in the Pacific sector of the Southern Ocean. We created SHOI (South Georgia – Halley Station Oscillation Index). We additionally examined relationships between these regional radial OIs and AAOI (AAO Index) (Fig. 1). The correlation coefficients between each OI and AAOI with time series of 12-month running mean during 2006 and 2015 respectively indicated DPOI (r=0.50), SHOI (r=0.93) (Fig. 2), KDOI (r=0.79) and CMOI (r=0.87) to AAOI. AAOI in the entire scale is closely related to DPOI, SHOI, KDOI and CMOI in the each regional scale.

In additional, we attempt to find the relationship between AAOI and historical data of Antarctic fur seals, krill predator, from South Georgia (Fig. 3) as a biological element. Although it is generally hard to collect long-term biological data, these are impressive datasets. Boyed and Robarts (1993) suggested the relationship between the fur seals variation and SOI (Southern Oscillation Index). We found the relationship between the fur seals variation and SHOI (r=0.45) coinciding with both phases. We proceed with these coherent approaches for DPOI-SHOI-KDOI-CMOI connecting with AAOI on the environmental ecosystems in the Southern/Antarctic Ocean.

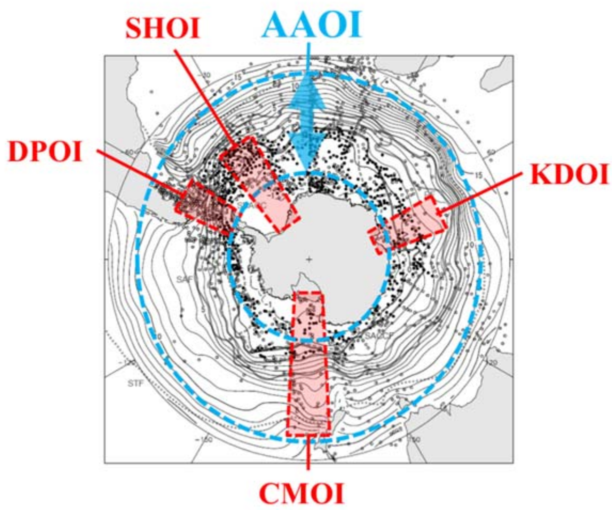

Fig. 1: DPOI-SHOI-KDOI-CMOI connecting to AAOI with Antarctic krill distribution and MTEM-200 (Mean TEMperature from the surface to 200m,℃) (Naganobu *et. al.*, 2008) including multiple oceanic fronts.

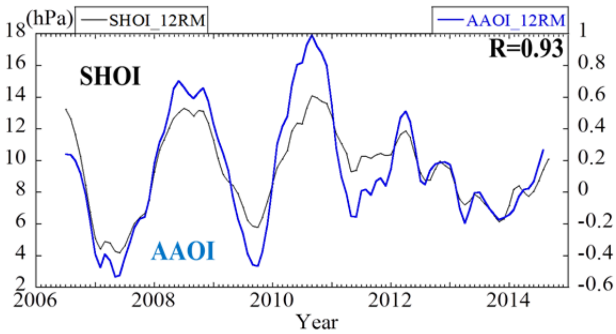

Fig. 2: Time series of SHOI and AAOI, 12-month running mean from 2006 to 2015 (R=0.93).

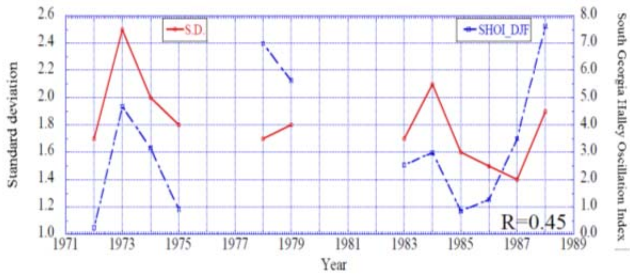

Fig. 3: Comparison between SHOI (Dec. - Feb.) and tooth growth of Antarctic fur seals from South Georgia (data from Boyd and Roberts 1993, J. Zool., London; Tooth growth in male Antarctic fur seals (*Arctocephalus gazella*) from South Georgia: an indicator of long-term growth history).