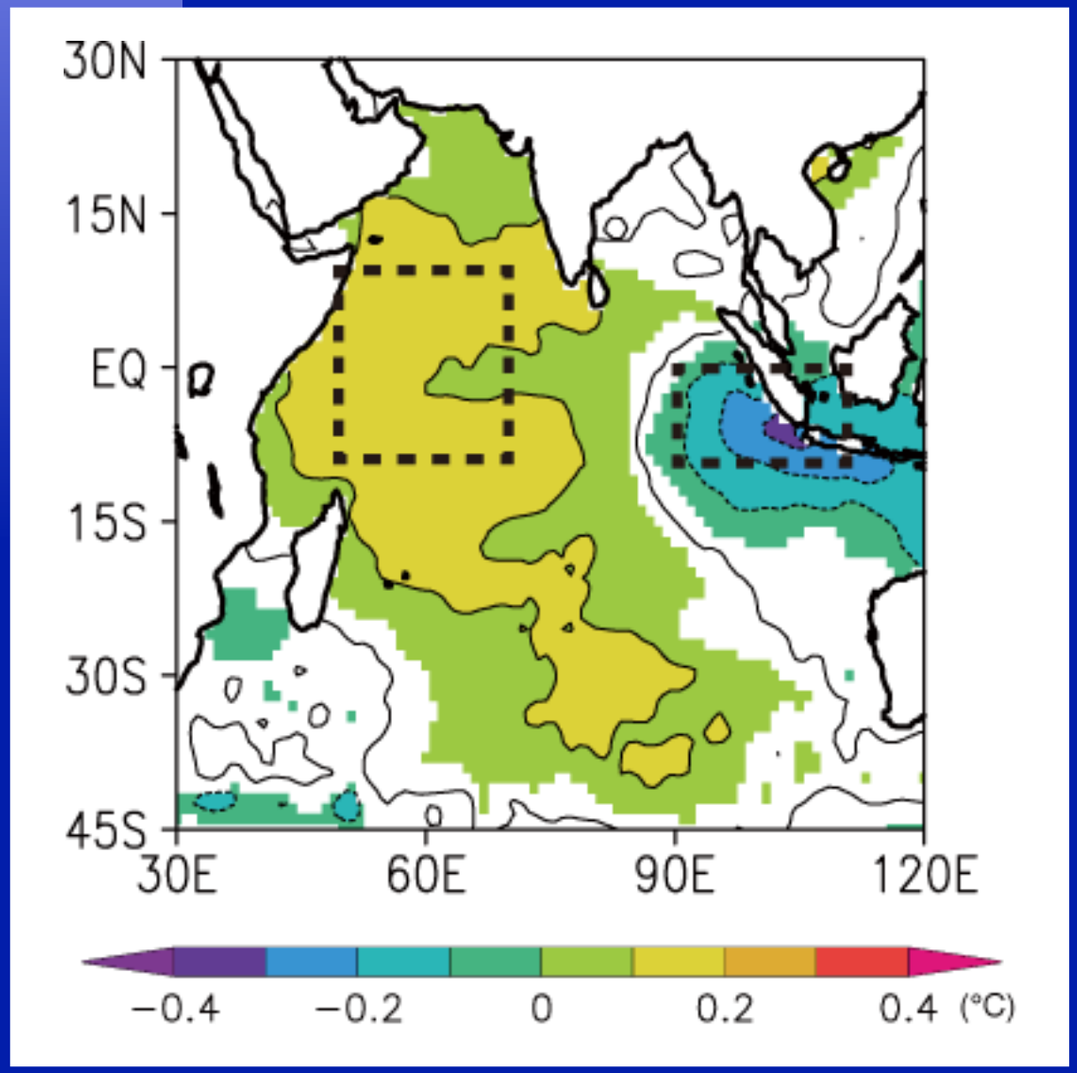
Interannual variability and predictability

Tomoki Tozuka (Univ. of Tokyo)
Takeshi Doi (JAMSTEC)
Michael J. McPhaden (NOAA/PMEL)

Four climate modes in the Indian Ocean

- Indian Ocean Dipole (IOD)
- Indian Ocean Basin Mode (IOBM)
- Indian Ocean Subtropical Dipole (IOSD)
- Ningaloo Niño/Niña

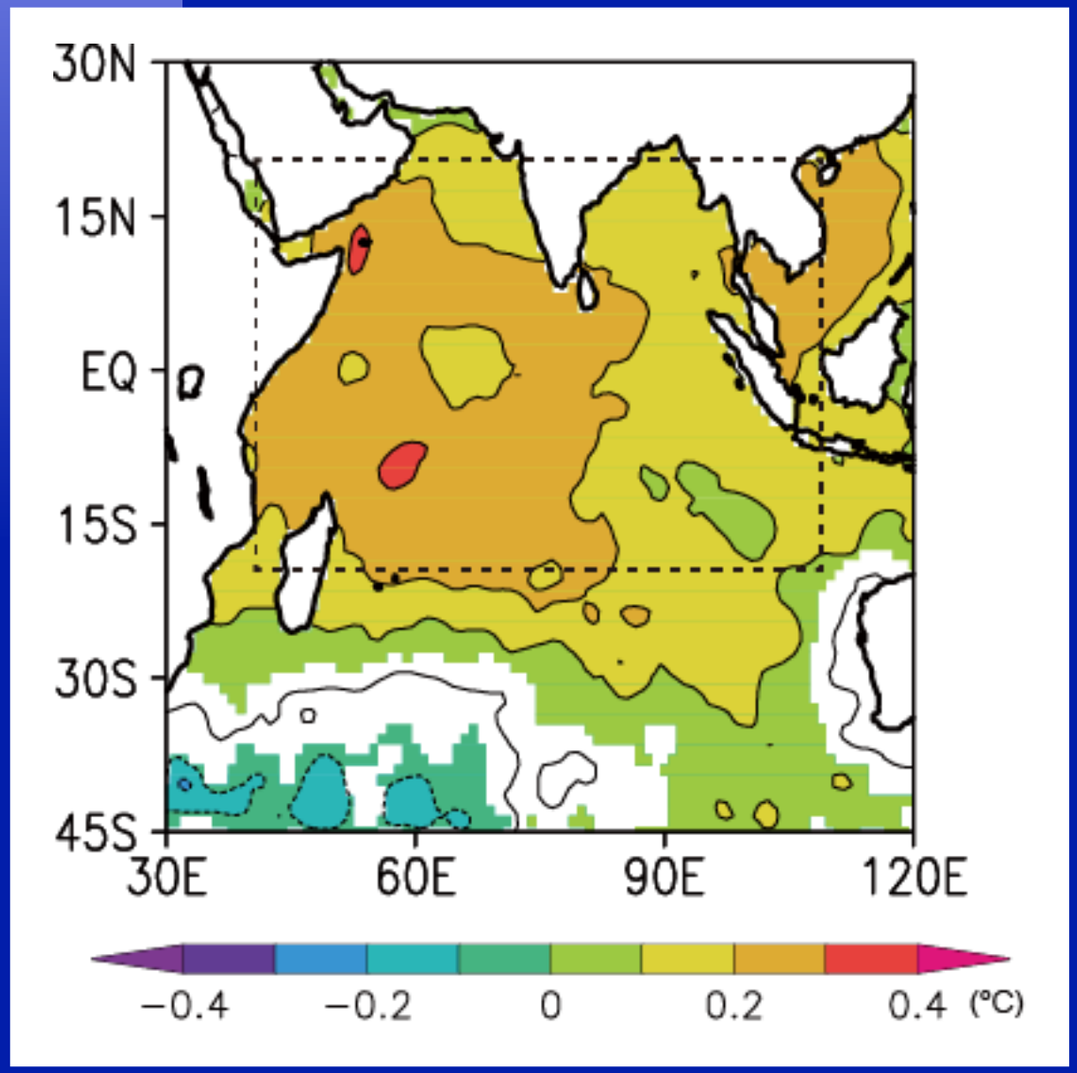
Indian Ocean Dipole (IOD)



SST anomalies regressed against the DMI. Regression coefficients significant at the 99% confidence level by a two-tailed t-test are shaded.

- Peak: boreal autumn
- Develop through the Bjerknes feedback
- Although the IOD sometimes co-occurs with the ENSO, it can occur independently.
- Impact on both local and global climate
- Future projection: Skewness decreases
- Salinity may play an active role through its influence on barrier layer thickness and vertical mixing anomalies.
- Prediction: ACC becomes lower than 0.5 only after 3 months.

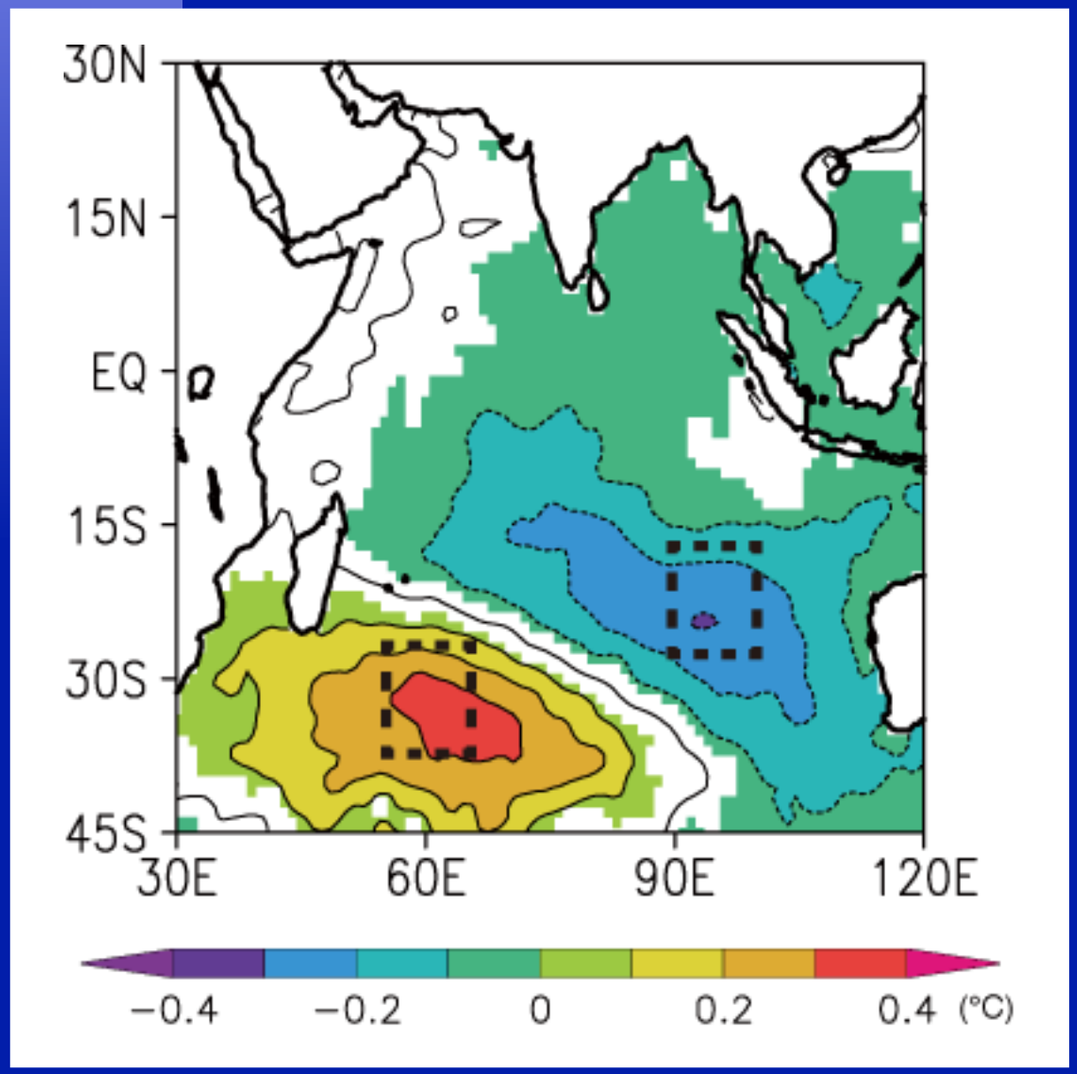
Indian Ocean Basin Mode (IOBM)



SST anomalies regressed against the IOBMI (PC1 of SST anomalies). Regression coefficients significant at the 99% confidence level by a two-tailed t-test are shaded.

- Peak: Feb.-Mar.
- Predominantly driven by surface heat fluxes, although ocean dynamics plays an important role in the southwestern tropical Indian Ocean
- The IOBM has been shown to influence climate over the Indo-western Pacific and East Asia in the summer following ENSO events and the effect is known as the “Indian Ocean capacitor effect”.
- Prediction: The best-predicted climate mode because of its strong link with the well-predicted ENSO

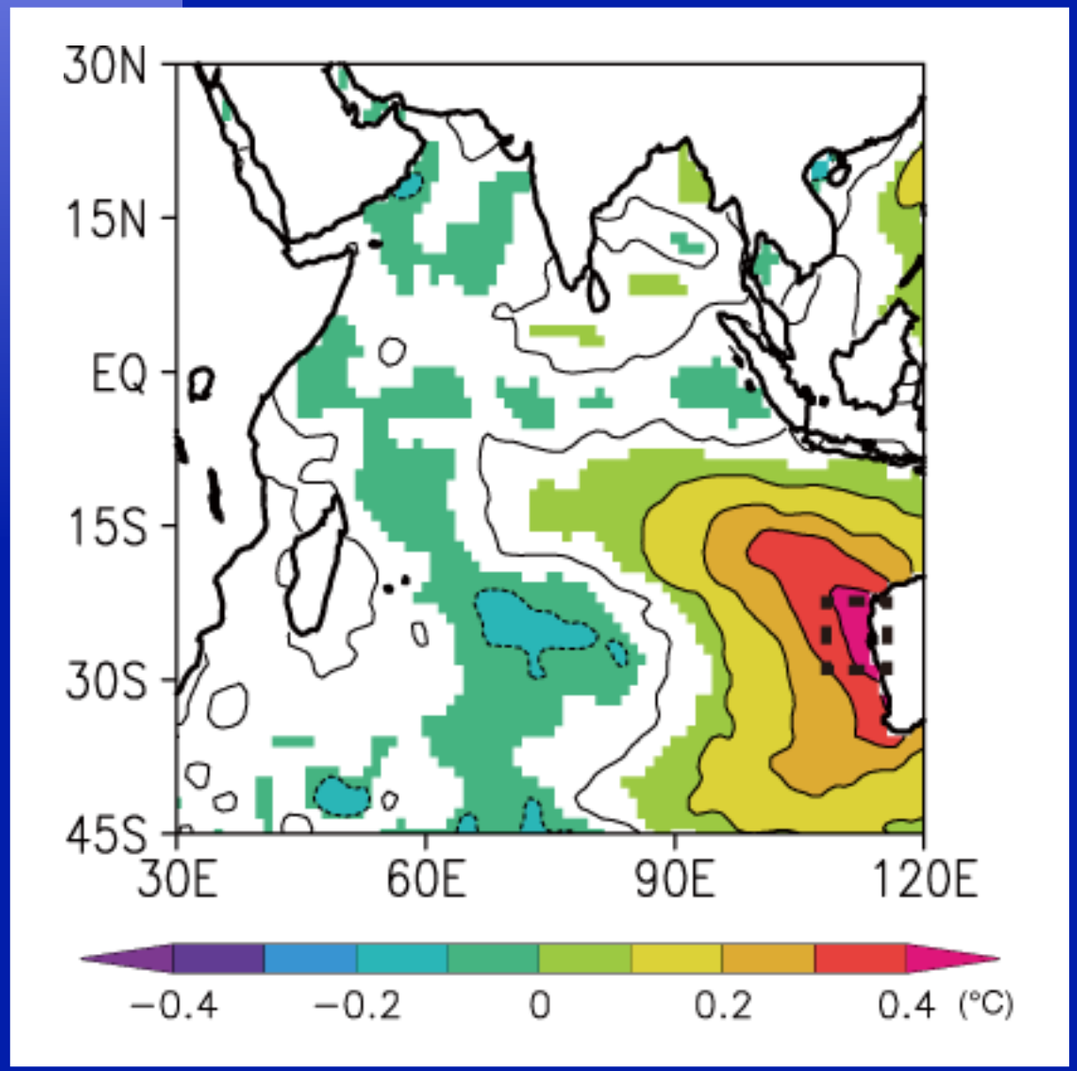
Indian Ocean Subtropical Dipole (IOSD)



SST anomalies regressed against the IOSDI. Regression coefficients significant at the 99% confidence level by a two-tailed t-test are shaded.

- Peak: austral summer
- Mechanism: The mixed layer warming by the shortwave radiation is enhanced (suppressed) as a result of negative (positive) MLD anomalies over the southwestern (northeastern) part, and these MLD anomalies are induced by anomalous winds associated with changes in the Mascarene High
- Influence southern African precipitation
- Prediction: ACC is not much different from the persistence, although some strong events were successfully predicted one season ahead.

Ningaloo Niño/Niña



SST anomalies regressed against the NNI. Regression coefficients significant at the 99% confidence level by a two-tailed t-test are shaded.

- Peak: austral summer
- Both local ocean-atmosphere positive feedback and remote forcing from ENSO via atmospheric and oceanic teleconnections contribute to its development.
- Salinity anomalies may contribute to its amplification.
- Recent increase in its occurrence may be related to the negative IPO.
- Large impacts on local marine ecosystem and precipitation.
- Prediction: Only events that co-occur with ENSO events were relatively well predicted

Required Essential Ocean Variables (EOVs)

- EOVs: ocean surface stress, sea surface height, SST, subsurface temperature, surface and subsurface currents, sea surface and subsurface salinity, and ocean surface heat flux
- Considering that coastal currents and upwelling in the eastern basin play an important role in the development of the IOD and Ningaloo Niño/Niña, it is desirable to obtain the above variables with a horizontal resolution of 0.5° or higher in these regions.
- Daily data are required especially for the IOD and Ningaloo Niño/Niña, because intraseasonal variations including the MJOs significantly influence evolution of these climate modes.
- Subsurface data in addition to surface data is valuable for improved prediction of these climate modes.

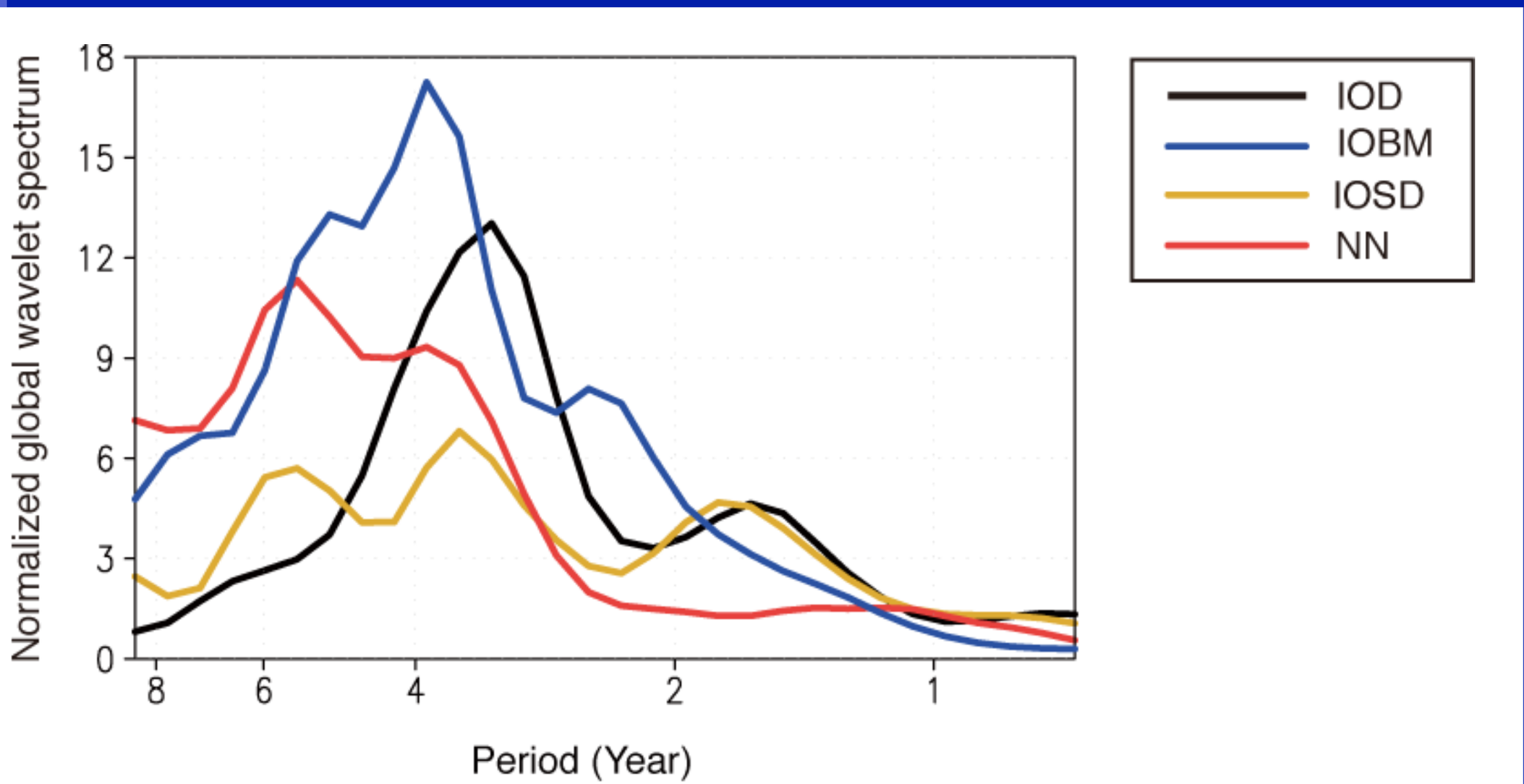
Actionable recommendations

1. Sustain the existing satellite and in situ measurements from the IndOOS as well as the Argo network in the entire Indian Ocean to advance our understanding of and ability to predict these climate modes.
2. Complete and maintain the RAMA buoy network. Deployment of the RAMA buoy in the western tropical Indian Ocean allows us to better understand the dynamics and thermodynamics of the western pole of the IOD. The RAMA buoys in the eastern pole of the IOD are essential for further understanding of the IOD as well as improved prediction of the IOD.
3. Near-coastal enhancement (0.5° or higher) of EOV observations in the eastern pole of the IOD and in the formation region of the Ningaloo Niño would also be desirable.
4. Maintain the IX01 XBT line with a fortnightly resolution. This will be helpful for monitoring the Pacific influence on the Ningaloo Niño/Niña via the oceanic channel.

(Underline: revised following reviewers' comments)

Supplementary Figures

Normalized global wavelet spectrum



Normalized monthly standard deviation