Regional Ocean Model Validation in Simulating the Low Frequency Variability Over the Maritime Continent

EGU23-10629

Johnson Zachariah[1], Daiane Faller[1], Nidheesh Gangadharan[2], Bijoy Thompson[1,3] and Pavel Tkalich[1]
[1]Tropical Marine Science Institute(TMSI), National University of Singapore,[2]Center for Climate Research Singapore(CCRS),[3]Technology Center for offshore and Marine ,Singapore(TCOMS)
Email:johnz.07@nus.edu.sg

ABSTRACT

Resolving the regional ocean circulation is a key factor in understanding climate-driven oceanic variability. Accurate sea level simulation, in the areas at the interface between land and ocean, could help to mitigate the environmental, social and economic damages caused by sea level rise and extremes. This is particularly the case for the seas in the Maritime Continent (MC), where the ocean circulation is complex owing to unique geographic and oceanographic features of the region. In order to overcome the caveats due to sparse sampling of this domain regional configuration of the ocean model (NEMO) is set up for the MC (90ºE-142ºE; 18ºS-26ºN) with 51 vertical sigma levels and hindcast simulations are performed for the period 1959–2022 using the downscaled ERA5 (surface forcings) and ECMWF global ocean reanalysis (ORAS5) data as lateral boundary conditions. This paper describes the dominant phenomena and model performance in simulating the low-frequency variability of the seas in the MC with a focus on sea level. The comparison of simulations with tide gauges and satellite altimetry observations yields good match. Correlation analysis between the simulations and air-sea coupled phenomena like El Nino southern Oscillation (ENSO) and Interdecadal Pacific oscillation (IPO) reveals significant correlation which provides the confidence for further research of the low-frequency ocean variability in the MC.

1. Model Domain and Configuration

(a) Domain & Resolution: 90º-142ºE/18ºS-26ºN; 4.5 km x 4.5 km horizontal resolution, 51 vertical sigma levels

(b) Surface Boundary Conditions: ERA5

(c) Lateral Boundary Conditions: ORAS5

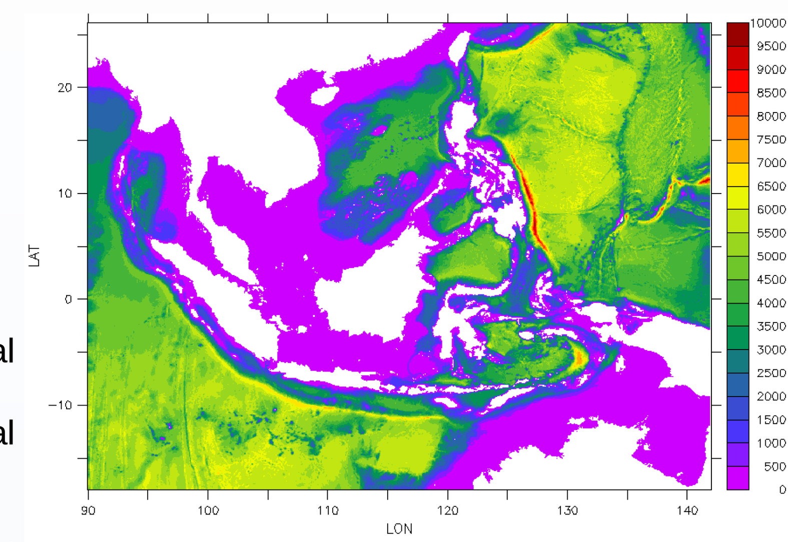

Fig-1. NEMO domain and bathymetry (m)

2. Data used

(a) Hadley Center Ice-SST (HadISST), **1º x 1º** horizontal resolution

(b) UKMO EN4 objectively analyzed subsurface Temperature & Salinity, **1º x 1º** horizontal resolution

(c) Sea surface height (SSH) from Satellite multi observation, **0.25º x 0.25º** horizontal resolution.

(d) Tide Gauge (TG) SSH from PSMSL

(e) El Nino-Southern Oscillation (ENSO, Nino3.4), Dipole mode index (DMI), Interdecadal Pacific Oscillation (IPO) and Pacific Decadal Oscillation (PDO) indices.

3. Model Validation

(a) Vertical error analysis of Temperature and Salinity profile

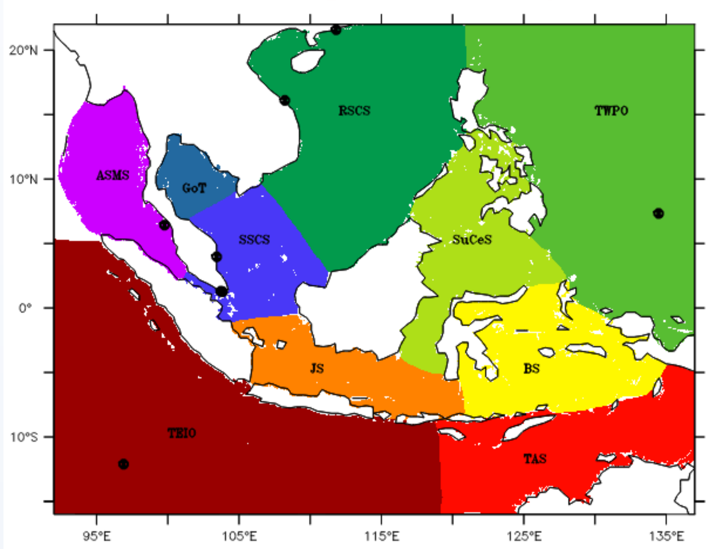

Fig-2a. Sub regions of the domain with TG locations.

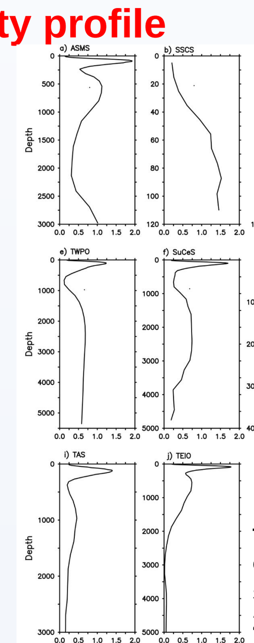

Fig-2b. Temperature RMS error between the model and EN4 observation at the sub regions in Fig 2a.

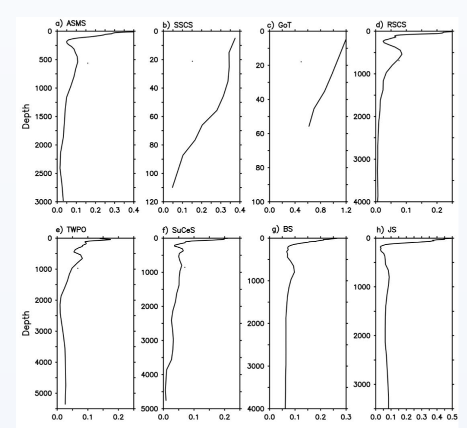

Fig-2c. Salinity RMS error between the model and EN4 observation at the sub regions in Fig 2a.

The domain is divided into different sub regions **[Fig-2a]**. For the Vertical error analysis, RMS error for vertical temperature and salinity profiles are estimated by averaging the profiles over the each sub regions in the domain. The mean and RMS errors for the vertical temperature profiles are -0.11 & 0.6 **[Fig-2b]** and for salinity profiles 0.14 & 0.21 **[Fig-2c]** respectively

(b) Sea Surface Temperature (SST) and Sea surface Height (SSH)

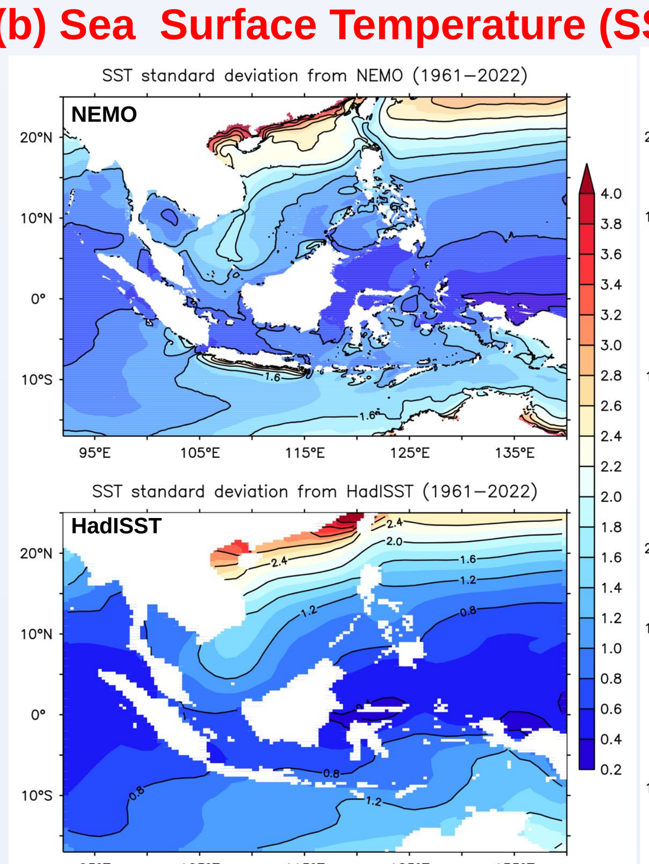

Fig-3. SST Standard Deviations from NEMO & HadISST,1961-2022

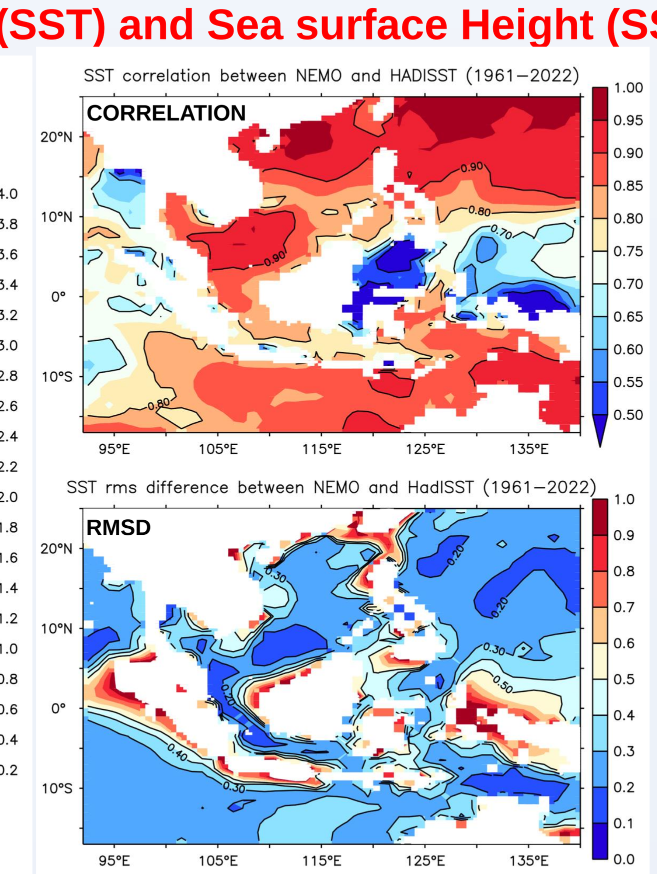

Fig-4. Correlation of SST between NEMO and HadISST & RMSD (seasonal cycle and linear trend removed),1961-2022

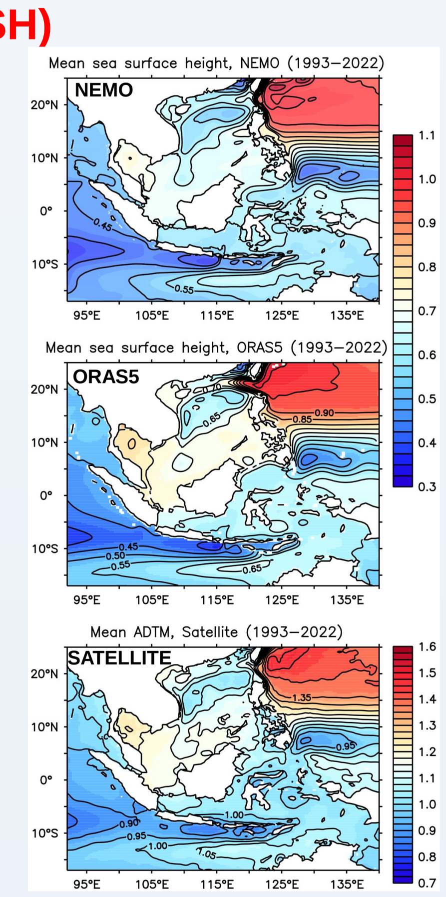

Fig-5. Mean SSH from NEMO, ORAS5 & SATELLITE (1993-2022)

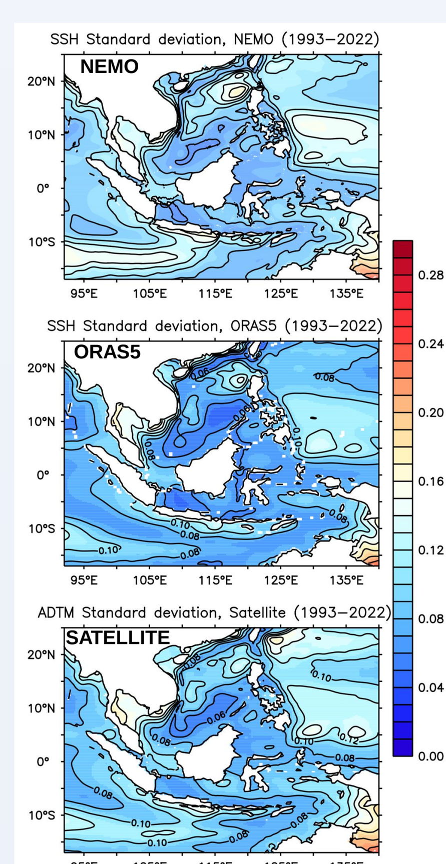

Fig-6. SSH standard deviations from NEMO,ORAS5 & SATELLITE (1993-2022)

- SST correlation between NEMO and HadISST is > 0.5
- Maximum amplitude of SST variation is seen over the northern part of the domain and minimum over the equatorial region
- SST RMS error difference (RMSD) < 0.5 ºC
- Spatial pattern of mean SSH and SSH standard deviation from NEMO, Satellite and ORAS5 are identical

4. Low-frequency sea level variability over the MC

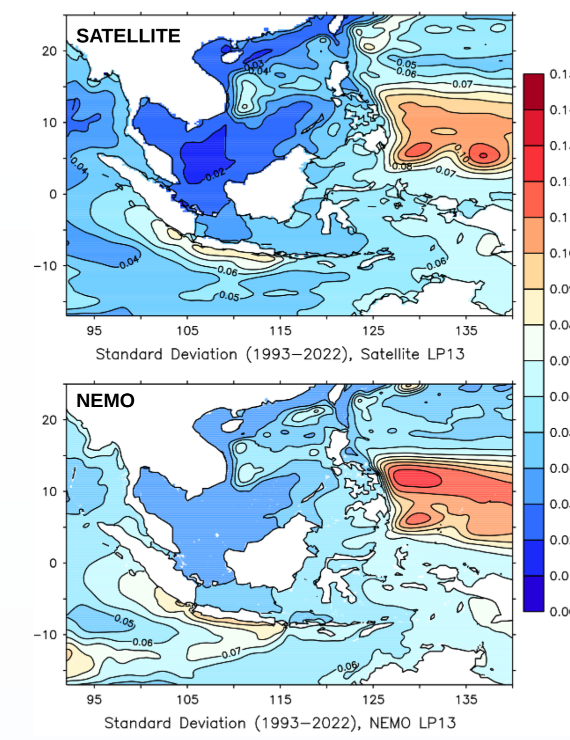

Fig-7. SSH standard deviation for NEMO and Satellite (seasonal cycle removed by applying a low pass filter (13 months, Lanczos) (1993-2022)

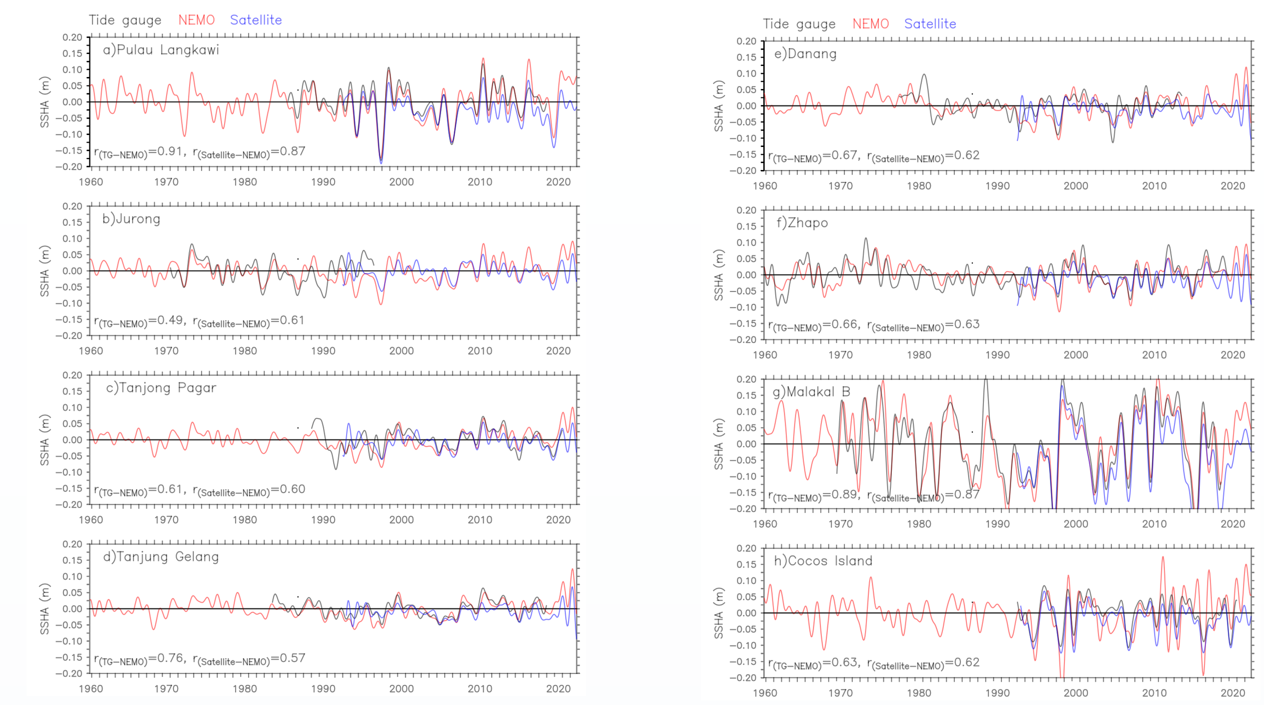

Fig-8. Time series of TG SSHA (m) (Black) overlaid with NEMO (Red) and Satellite SSH (Blue) at the stations shown in Fig-2a. Seasonal cycle is removed by applying a 13-month low pass filter. Correlation observed between the TG and NEMO, and satellite and NEMO are included.

Largest amplitudes of SSH variability (**±20 cm**) without the seasonal cycle are observed in the stations in the Eastern Indian and west Pacific Oceans. Over the SCS, maximum non-seasonal variability is less than **±10 cm**. Statistically significant (> 99.9%) correlation is seen between the model and TG observations, **[Fig-8]**

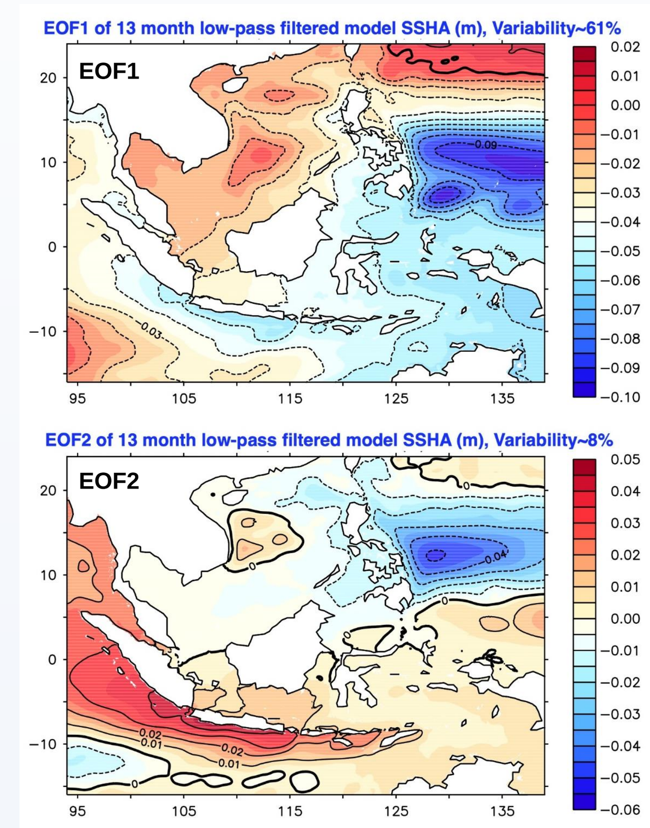

Fig-9. EOF1 and EOF2 of NEMO SSHA (seasonal cycle removed) (1961-2022).

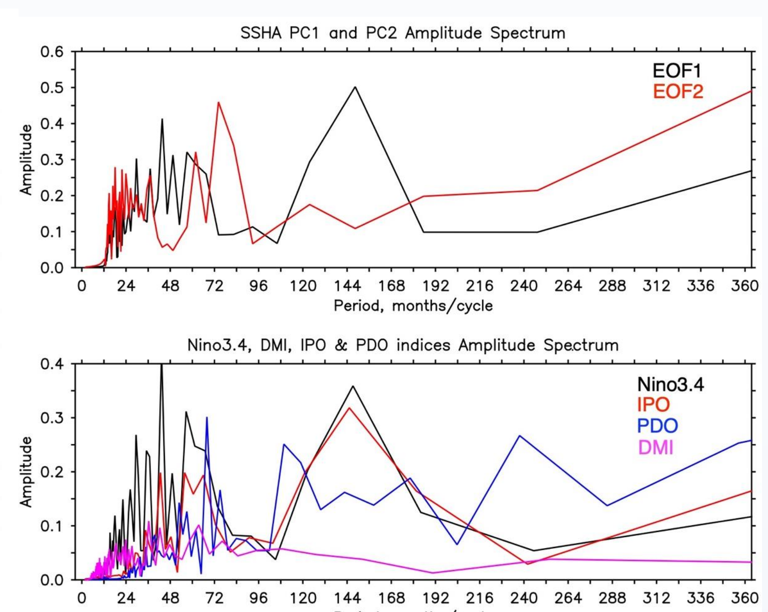

Fig-10. Amplitude spectrum of PC-1 and PC-2 of lowpass filtered NEMO SSHA (top panel) and Nino3.4, DMI, IPO and PDO indices (1961-2022) (bottom panel).

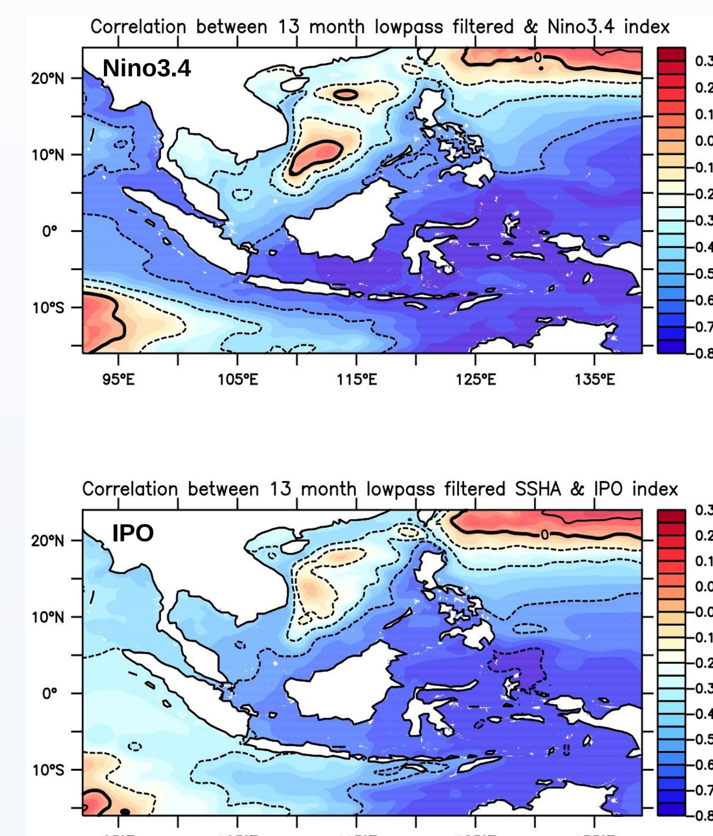

Fig-11. Correlation of NEMO SSHA with Nino3.4 (top) and IPO indices (bottom) .

- EOF1 (61%) shows spatially uniform variability with peak variability (10 cm) over tropical Northwestern Pacific Ocean
- EOF2 (8%) shows opposite variabilities over the eastern Indian Ocean/tropical Southwestern Pacific Ocean and tropical Northwestern Pacific/South China Sea
- Amplitude spectrum of PC-1 denotes 12 -13 years periodicity, identical to low-frequency ENSO or IPO
- Amplitude spectrum of PC-2 shows 1.5 - 5 years periodicity, similar to the ENSO periodicity
- Significant correlation observed between the lowpass filtered NEMO SSHA and IPO/Nino3.4 Indices.

5. Summary

- The low-frequency sea level variability over the Maritime Continent is dominated by the low-frequency ENSO or the IPO with 12-13 years of periodicity.
- The ENSO related sea level variability over the Maritime Continent show opposite variabilities over the Northwestern tropical Pacific Ocean and eastern Indian Ocean/tropical Southwestern Pacific Ocean with 1.5 - 5 years periodicity

Acknowledgements

This research project is supported by the National Research Foundation, Singapore, the Ministry of National Development, Singapore, and National Environment Agency, Singapore under the National Sea Level Programme(NSLP) Initiative as part of the Urban Solutions & Sustainability – Integration Fund (Award No. USS-IF-2020-4).
The computational work for this article was fully performed on resources of the National Supercomputing Centre (NSCC), Singapore.