Seasonal Sea Level Cycle around the South China Sea

Abd Muhaimin Amiruddin[1,3], Ivan Haigh[1], Mikis Tsimplis[1,2] and Francisco Calafat[2]

1. Ocean and Earth Science, National Oceanography Centre, University of Southampton, UK. E-mail: a.amiruddin@noc.soton.ac.uk

2. National Oceanography Centre, University of Southampton, UK

3. Faculty of Environmental Studies, Universiti Putra Malaysia, Malaysia

Introduction

- The seasonal cycle is a prominent component of sea level time series, mainly causes by meteorological and oceanographic forcing. The seasonal sea level cycle potentially affects the frequency and magnitude of extreme event, influencing the risk of coastal flooding.
- A comprehensive analysis of the seasonal sea level cycle around the South China Sea is presented. The seasonal cycle is considered as the sum of the annual and semi annual components. It is estimated from the analysis of tide gauge records and altimetry data. The contribution of temperature and salinity changes is based on the calculation of steric height.

Results from Tide Gauge and Altimetry

Coastal Seasonal Sea Level Cycle from Tide Gauges (1950-2012)

- The annual amplitude range covering different periods between 1950-2012 is between 1 cm at Tawau, Malaysia to 24 cm at Ko Mattaphon, Thailand. The annual cycle peaks between July to December.
- The semiannual amplitude ranges from 1 up to 7 cm at Lumut, Malaysia. It peaks between December to June.
- The seasonal sea level cycle accounts on average for 61% of the sea level variability at the tide gauges. This ranges between 5% at Tawau and 92% at Tanjung Gelang, Malaysia

Open Ocean Seasonal Sea Level Cycle from Altimetry (1993-2012)

- The annual harmonic shows significant spatial variability. The area average value is 7 cm however, amplitudes larger than 22 cm are located at the western part of Gulf of Thailand (Fig. 2A).
- In the central part of the South China Sea, the annual harmonic peaks between January to September. At the northern and southern shelves the annual cycle peaks between November to December (Fig. 2B).
- The semiannual harmonic has a basin average value of 2 cm. It also shows spatial variability with amplitude in excess of 6 cm at the Malacca Strait and the northern coast of Vietnam (Fig. 2C). .
- The semiannual phase in the southwest region peaks between May and June while the central deep basin and northern region generally peaks between January to June (Fig. 2D).
- Comparison of seasonal sea level cycle between altimetry and barometrically corrected tide gauge stations for the period 1993-2012 is generally in good agreement except for a few cases such as higher semiannual amplitude at Zhapo, Macau and Tai Po Kau stations

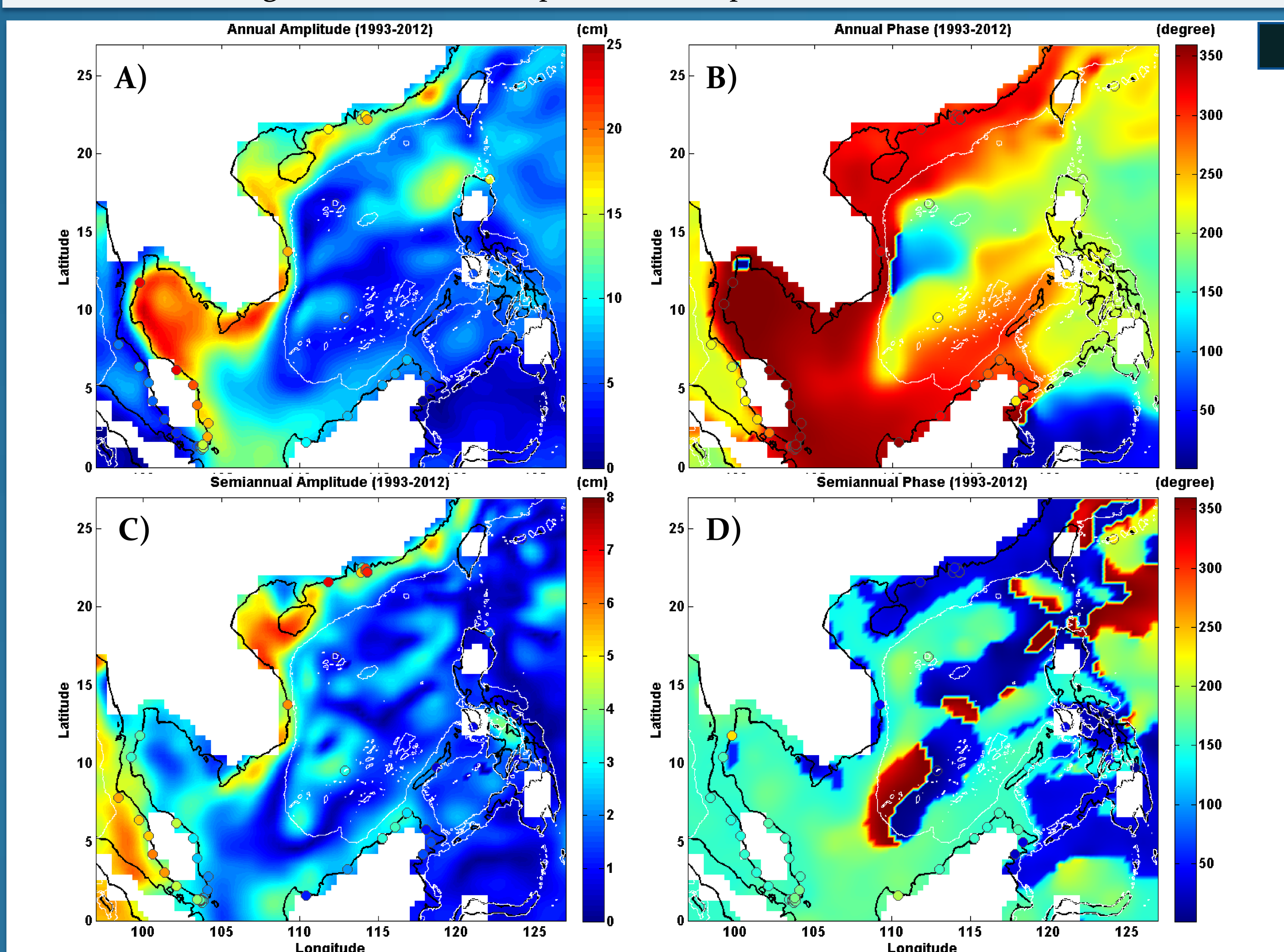

Figure 2. Spatial distribution of annual and semiannual amplitude and phase from tide gauge station (circle) and altimetry for the period of 1993-2012. The white line represent the isobath of 200 m depth.

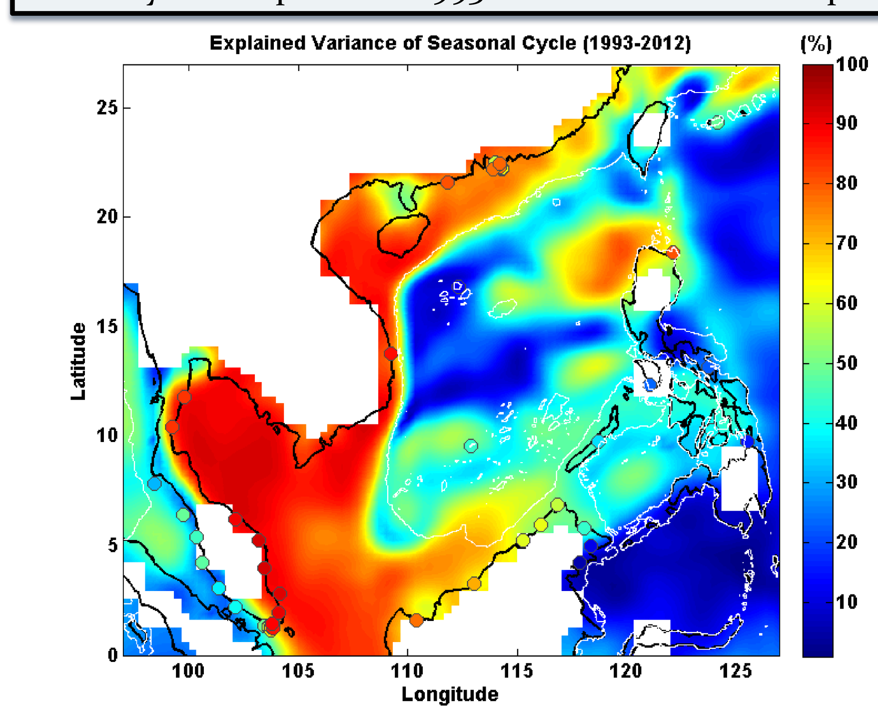

Figure 3. As in Fig. 2. but for the explained variance of seasonal cycle.

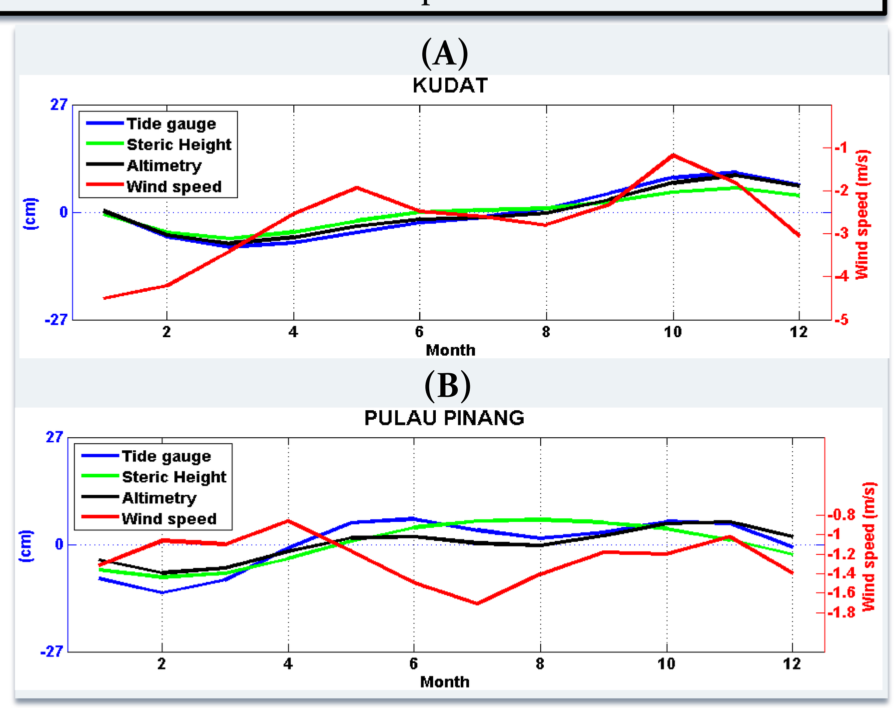

Figure 4. The normalized mean seasonal cycle (1993-2012) of barometrically corrected tide gauge, steric height, altimetry and inverse wind speed.

Method

- We used 74 tide gauge stations from PSMSL (Fig. 1), altimetry data from AVISO, steric data from Ishii and Kimoto (2009) and meteorological reanalysis data from NCEP/NCAR.
- The tide gauge data covers different periods and contains gaps. Therefore the interpretation of the obtained seasonal components must include the possibility of persistent changes in the seasonal signals.
- The annual (amplitude (A_{sa}), phase (P_{sa})) and semi-annual (amplitude(A_{ssa}), phase (P_{ssa})) harmonic of the mean removed and detrended tide gauge, altimetry and steric height were estimated using the following regression equation:
  - $\bar{M} = A_{sa}\ \cos(\frac{2\pi}{365.25}(t - P_{sa})) + A_{ssa}\ \cos(\frac{2\pi}{182.63}(t - P_{ssa}))$

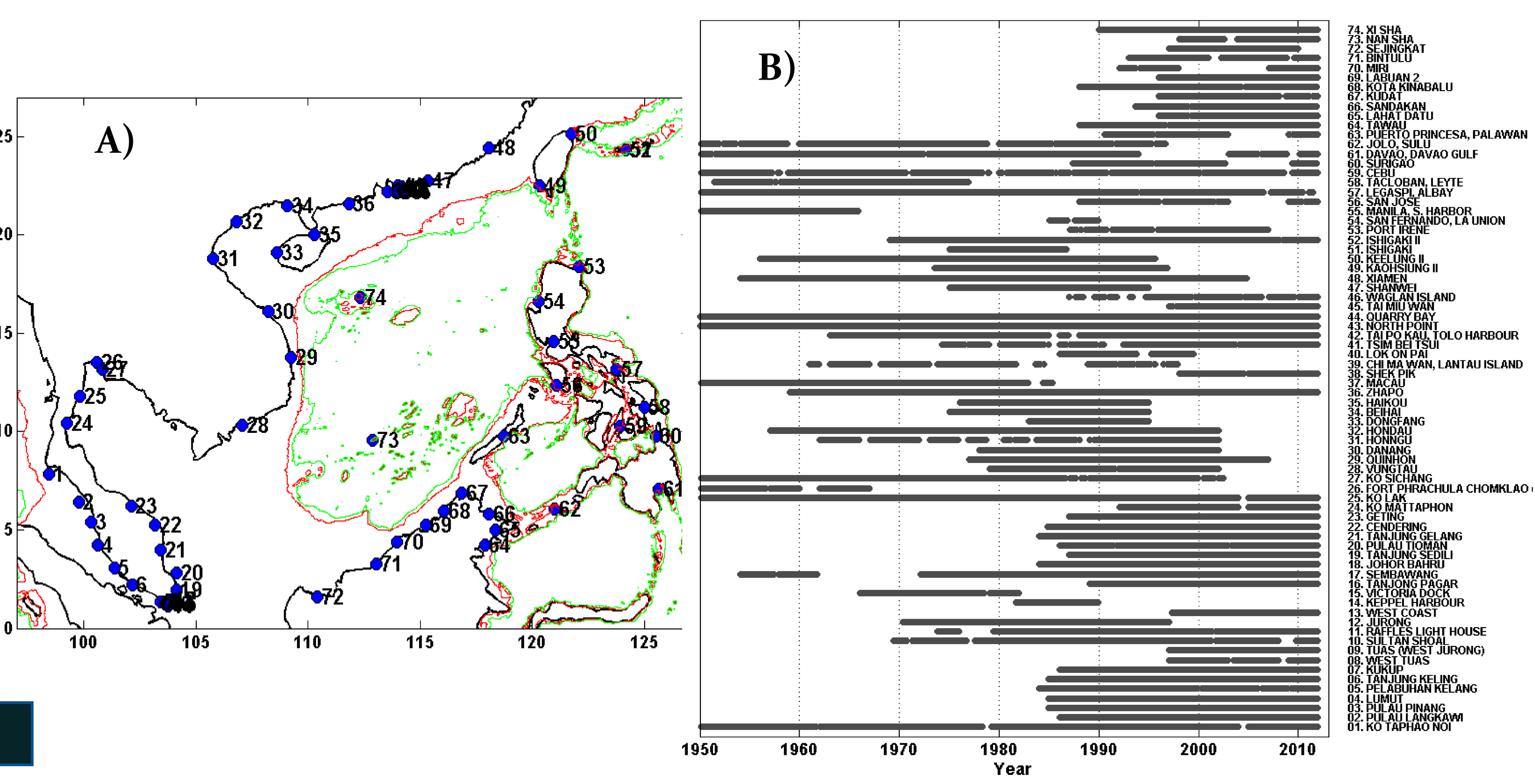

Figure 1. Location of tide gauge stations (A) and their data length (B). The 200 m (red) and 1000 m (green) are shown

Results from Steric Height

Comparison with the estimated steric sea level (1993-2012)

- The annual component of steric height calculated down to 700 m depth has a basin average value of 5 cm (Fig. 5A). The central deep basin has a range between 4 and 15 cm comparable to that at the Kudat tide gauge (Fig. 4A).
- The annual steric component peaks between January to September, which compares well with the annual sea level signal from altimetry.
- The semiannual steric component is a high contribution in the northern Malacca Strait (Fig. 5B) with an amplitude of about 5 cm comparable with the tide gauge at Pulau Pinang (Fig. 4B).

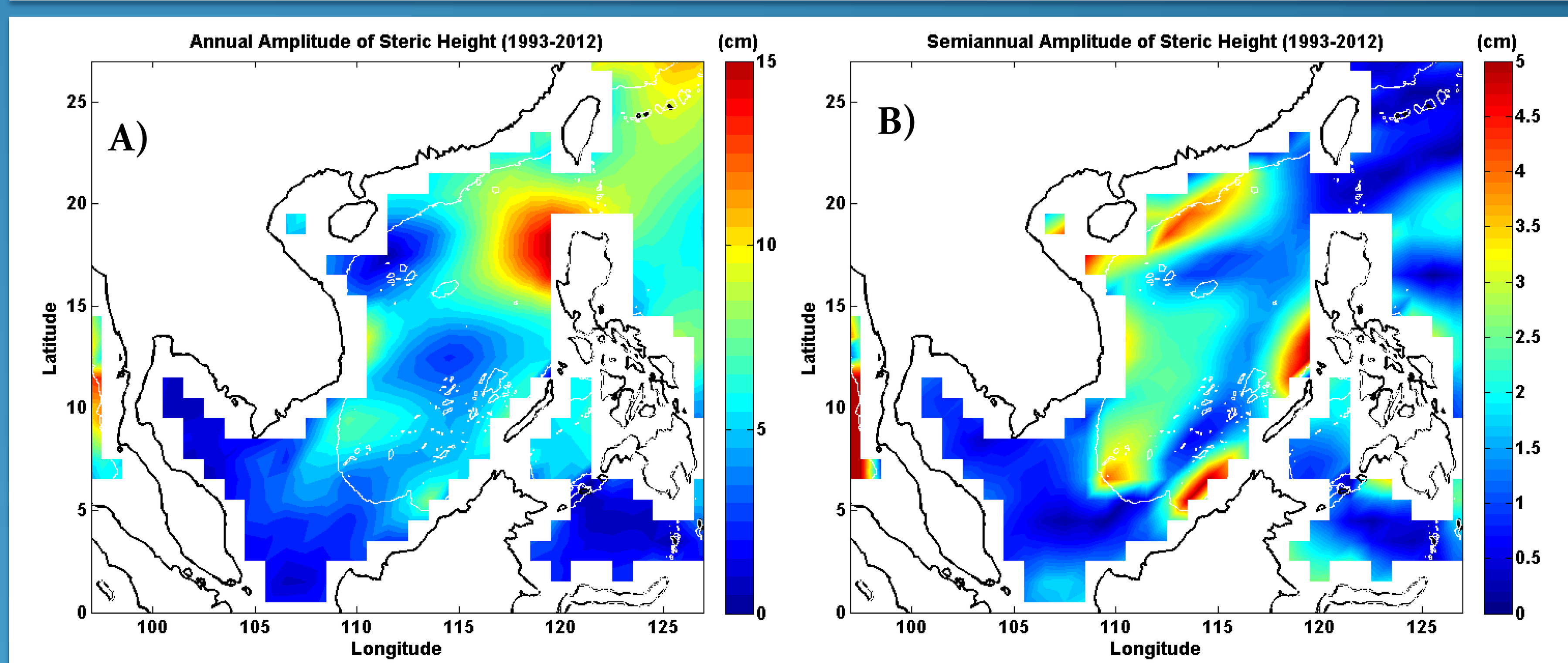

Figure 5. As in Fig. 1, but for the steric height.

Conclusion

- The seasonal sea level cycle around the South China Sea exhibits high spatial variability.
- The annual harmonic in particular shows significant difference between the continental shelves and central deep basin.
- The seasonal steric signal is comparable in size with the observed sea level signal in the Malacca Strait and at the central deep basin in the South China Sea.
- Further research will quantify the contribution of the wind component, steric variation, mass addition and oceanic circulation.

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