Extreme sea level rise off the northwest coast of the South China Sea in 2012

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1. Introduction

The South China Sea (SCS) is the largest marginal sea in the western Pacific region. It connects with the Sulu and Java Seas in the south through shallow passages and with the Pacific Ocean through the Luzon Strait in the north. The SCS is located in a dominant East Asian monsoon region, and local sea level variability is affected by seasonal monsoon wind forcing, which is northeasterly in winter and southwesterly in summer.

In 2012, an abnormal sea level rise event occurred along the northwest coast of the SCS with a maximum sea level elevation reaching up to 70 mm, which is much higher than any previously recorded in historical records. The event caused considerable problems for local societies and effected human coastal activities. In this article, reanalysis data and observations are used to address the possible mechanisms responsible for this anomalous event.

2. Sea level evolution

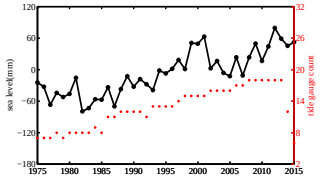

Fig. 1. Time evolution of annual mean sea level composite (line) along northwest coast of the SCS. Dots represent total numbers of tide gauge stations, which provided useful data in each year Remark: Note that the context of the highlighted text is unclear. Please check and clarify your intended meaning.

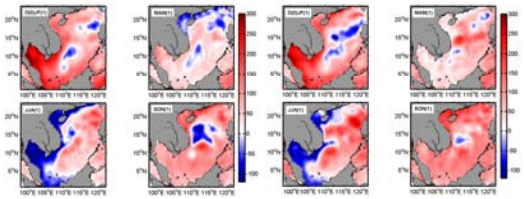

Fig. 2. Seasonal sea level anomaly in SCS during 2011. DJF, MAM, JJA, and SON represent different season in 2011 and 2012. Units: mm.

Monthly sea level anomalies from 2011 to 2012 were calculated. There were obvious seasonal variations in sea level during 2011, but the seasonal cycle was not significant during 2012. However, the sea level was high in the summer of 2012, which contributed to the annual maximum for the whole year.

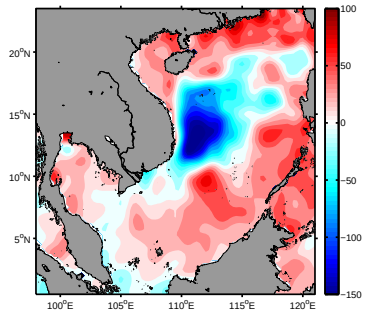

Fig. 3. Sea level changes between 2010 and 2012 from AVISO data

The significant increase in sea level occurred throughout the entire northwest coast of the SCS during 2012. A comparison between 2012 and 2010 shows that a significant sea level increase occurred in the northwest coast of the SCS, while a decreasing sea level occurred in the west to central SCS (Fig. 3).

3. Surface flux variations

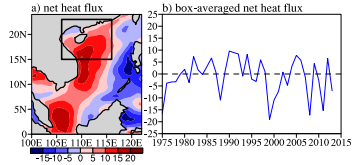

Fig. 4. Annual heat flux anomalies in 2012 relative to 1981–2010. (a) Heat flux anomalies (W/m²) over SCS in 2012; (b) time series of mean heat flux within black box in (a) from 1975–2013 (W/m²).

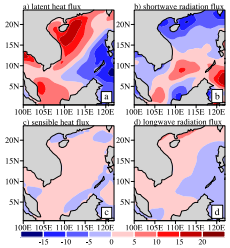

Fig. 5. Components of annual heat flux anomalies (W/m²) in 2012 relative to 1981–2010. (a) Latent heat flux anomaly into ocean (W/m²); (b) shortwave heat flux anomaly into ocean; (c) sensible heat flux anomaly into ocean; (d) longwave heat flux anomaly into ocean.

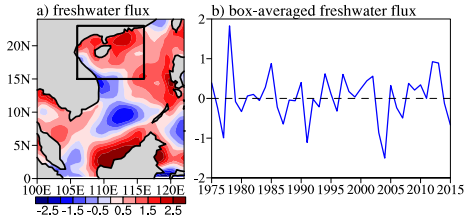

Fig. 6. Annual freshwater flux anomalies in 2012 relative to 1981–2010. (a) Freshwater flux anomalies (mm/day) in 2012; (b) time series of mean heat flux within black box in (a) from 1975–2013 (mm/day).

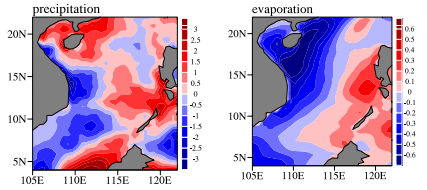

Fig. 7. Components of annual freshwater flux anomalies (mm/day) in 2012 relative to 1981–2010.

4. Summary

In this study, sea level variability off the northwest coast of the SCS is investigated using tide gauge data. Results show a significant elevation in the northwest SCS with a magnitude approaching 79 mm, which is higher than that of previous years (at 63 8mm).

Our analysis suggests the abnormal sea surface heat flux and the freshwater flux may have contributed to the abnormal rise in sea level. The abnormal heat flux in 2012 was positive in the northwestern part of the SCS, and it may have had a positive effect on local sea level elevation.

Further analysis illustrates that latent heat flux plays an important role in the heat flux effect. In addition to the heat flux, freshwater flux also contributes to this sea level rise, and the La Niña event also has a significant associated effect. Through dynamic and thermodynamic factors, the La Niña event induced NWP cyclone promotes sea level rise over the northwest SCS.