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Climatological characteristics and long-term change of SST over the marginal seas of China

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ABSTRACT

Based on monthly mean HadISST data, climatological characteristics and long-term changes of sea surface temperature (SST) over marginal seas of China are analyzed for the time period 1870–2011. The results show that (1) The smallest and largest spatial SST differences among various areas are seen in August and January respectively, with the coolest month occurring in February for all of the seas and the warmest month occurring in August for all but South China Sea (SCS); (2) The warming trends of the marginal seas of China during the time periods analyzed are generally larger than the global and hemispheric averages, with the East China Sea seeing the largest warming of all seas; (3) All of the sea areas see significant rising trends of annual mean SST in the last 140 years and the last 50 years, with larger and more significant warming generally occurs in autumn and winter; (4) The last 30 years especially the last 14 years undergo a slowdown of warming in the marginal seas of China, and the slowdown in the last 14 years is more evident than the global and northern hemispheric averages; (5) A weak upwelling current exists in western SCS, and the upwelling intensity has a significant positive correlation with the SCS summer monsoon index, with both seeing a decreasing trend in the last 64 years.

1. Introduction

Ocean and atmosphere are important components of climate system. Sea–air interaction, especially that occurring between tropical oceans and global atmosphere has been a hot topic in climatology nowadays. There are many studies on global and basin scale SST climatology using different datasets (Reynolds, 1988; Reynolds and Marsico, 1993; Reynolds and Smith, 1995; Smith and Reynolds, 1998). IPCC AR4 showed that global SST exhibits significant increasing trend in recent 100 years, especially in recent 30 years (Trenberth et al., 2007). SST at gulf area and continental shelf area are also studied and dataset is optimized for these areas (Shea and Trenberth, 1992) and relation with large scale change is also analyzed (Belkin, 2009; Takeshige et al., 2013).

The marginal seas of China span tropical, subtropical and temperate zone and exhibit significant geographical diversities. There are many studies about SST change and variability of the region during different time periods (Tang et al., 2009; Huang et al., 2012; Wang et al., 2013). Different datasets are used to study the SST change and variability (Yan and Li, 1997; Hickox et al., 2000; Wu et al., 2005; Song et al., 2007; Jin and Wang, 2011; Liu and Zhang, 2013). It has been shown that the 1990s is the warmest decade of the past 100 years in the marginal seas of China (X.Z. Zhang et al., 2005; Feng and Lin, 2009), and water masses, currents and ENSO might have been the main factors for different modes of SST variability for the East China Sea (ECS) (Song et al., 2007). The SST variability might in turn affect other system, such as East Asian monsoon (Li et al., 2010). Xie et al. (2002) and Yeh and Kim (2010) examined winter SST variability of Yellow/East China Sea in recent years and explained it in terms of the associated atmospheric circulation anomalies and Bathymetric effect.

The previous studies are important for understanding climatological characteristics and change of SST on varied spatial and temporal scales. Most of the previous studies, however, have been limited to given areas or specific time periods. For the marginal seas of China on a whole, the general features of normal climate and climate change of SST over the past more than 100 years have not been well understood, in spite of the fact that a few studies examined the long-term trends of the SST for varied time periods and areas.

In this paper, we use the updated HadISST data to reveal the climatological characteristics and long-term change of SST over the marginal seas of China. Our analysis shows the distinct characteristics of SST climatology and rapid warming of the last 140 years in the region.

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2. Study region, data and methods

2.1. Study region

In this paper, marginal seas of China are defined as the offshore region of 5–41°N and 105–130°E. The region is further divided into three sub-regions: Bohai Sea and Yellow Sea (BYS, 117–127°E and 35–41°N), East China Sea (ECS, 120–130°E and 22–35°N) and South China Sea (SCS, 105–120°E and 5–22°N) (Fig. 1).

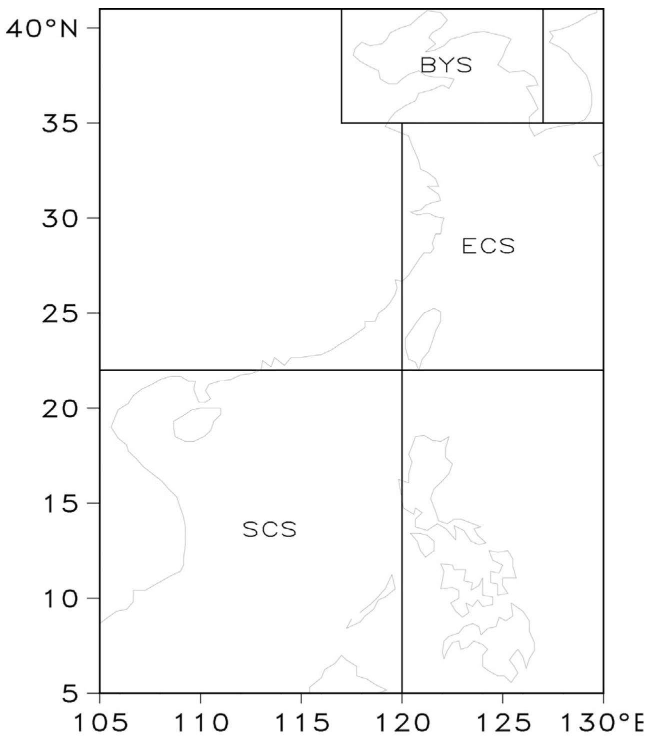

Fig. 1. Study regions defined in this paper. BYS: Bohai Sea and Yellow Sea; ECS: East China Sea; SCS: South China Sea.

2.2. Data and methods

Monthly SST data and SCS Summer Monsoon index series are used. 1 × 1 monthly HadISST (Rayner et al., 2003) data during 1870–2011 are from Hadley Centre, UK (http://www.metoffice.gov.uk/hadobs/hadisst/data/download.html). This dataset is the longest global historical and real time SST observations with the highest spatial resolution and coverage, and it has been widely used in studies of climate change and variability. In order to examine the relationship between the western SCS upwelling intensity and SCS Summer Monsoon (SCSSM), the SCSSM index data developed by Li et al. (http://ljp.lasg.ac.cn/dct/page/1) from the Institute of Atmospheric Physics, Chinese Academy of Sciences (Li and Zeng, 2002, 2003, 2005) is utilized in this paper. Monthly reanalysis data of 850 hPa zonal wind (u), 500 hPa geopotential height (hgt) and sea level pressure (slp) from the National Centers for Environmental Prediction (NCEP) during 1948–2012 are used for calculating the monsoon index series.

We made a quality check of the HadISST data, and found a few quality problems with the data in the Bohai Sea and the Yellow Sea. The absolute values of SST anomalies are larger than 2 times the standard deviation for a few months of 1977, 1980 and 1981 for the grids. These are proved to be wrong records by comparing them to the neighboring grid data. We replace these records with climatological average of the latest climate reference period (1981–2010).

Regional average is calculated by area-weighted averaging the grid data using latitude cosine as weights (Jones and Hulme, 1996). The reference time period 1981–2010 is applied to calculate mean SST values for analyzing climatological characteristics and the time period 1961–1990 as recommended by World Meteorological Organization (WMO) is used as reference time period for calculating SST anomalies for analyzing climate change. We use May, August, November and February as the representative months for spring, summer, autumn and winter respectively as sea water temperature change generally lags by a month or two behind land air temperature. The method of least-squares is used to calculate the linear trends of the SST anomalies series for given time periods, and student t-test is used to examine the significance of the linear trends of the time series (Hu, 1996; Von and Francis,

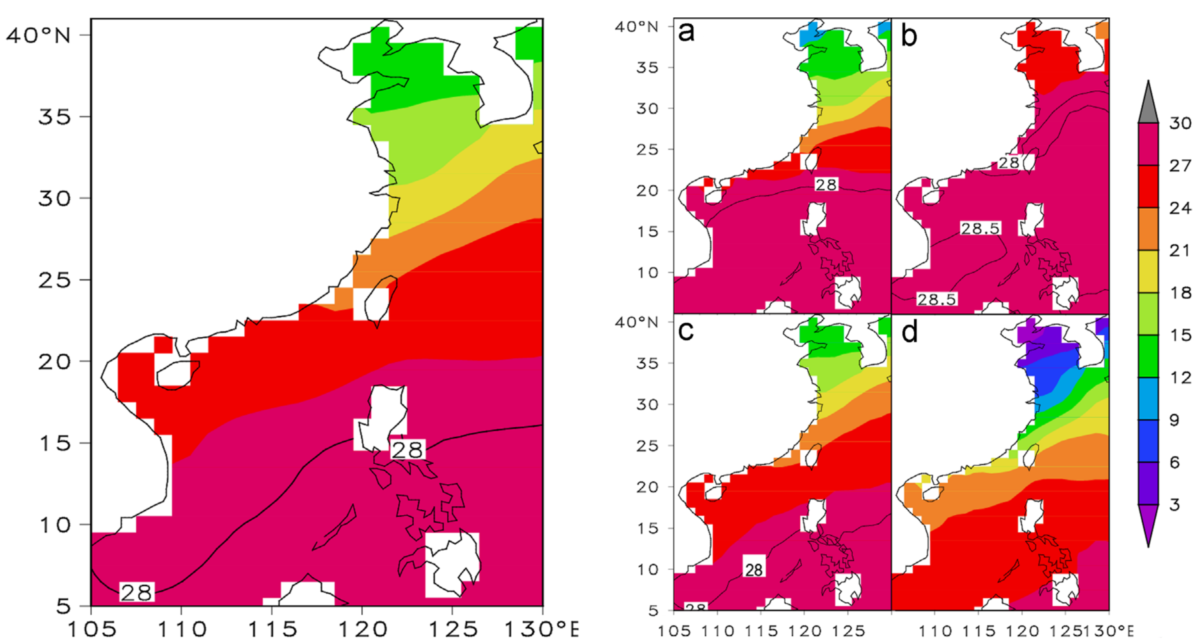

Fig. 2. Annual (left) and seasonal (right) mean SST distribution during 1981–2010 in the marginal seas of China. (a): Spring; (b): Summer; (c): Autumn; (d): Winter (Unit: °C).