ISSN 1746-7659, England, UK
Journal of Information and Computing Science
Vol. 17, No. 1, 2022, *pp*.019-027

Development of south Atlantic subtropical dipole and its relationship with ENSO

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(Received October 12, 2021, accepted January 29, 2022)

Abstract: Based on the monthly sea surface temperature (SST) data provided by Hadley Centre , the characteristics of Southern Subtropical Atlantic SST variation and its relationship with ENSO are discussed. The results of this paper show that: 1) In the summer of the southern hemisphere, the SST anomaly (SSTA) of the Southern Subtropical Atlantic presents a southwest-northeast antiphase dipole modes, that is, the South Atlantic Subtropical Dipole (SASD), which develops from September to November. It reaches its peak in austral summer(December January February ,the next year), weakens from March to May (the next year), and declines until austarl winter(June July August, the next year). 2) SASD is significantly correlated with ENSO, and positive SASD and negative SASD are correlated with El Niño and La Niña events respectively.

Key words: the South Atlantic Subtropical Dipole; ENSO; empirical orthogonal function; Composite analysis

1. Introduction

The ocean accounts for about 71% of the earth surface area and it is an important component that cannot be ignored in the global climate system. Ocean-atmosphere interaction is also an indispensable direction for studying the influence of the ocean on climate change[1]. The Atlantic is the second largest ocean and also the ocean with the largest latitude span. The entire basin is roughly "S" shaped. In an effort to understand the interannual variation of SST in the South Atlantic, Zhuang Hui et al.[2] showed that in the recent 140 years, the SST in the South Atlantic increases linearly at a significant annual rate of 0.0045℃ as a whole, and the SST in this area does not change significantly from 1870 to 1930. Venegas et al.[3] discussed the SST anomalies(SSTAs) for the first time in 1996. Morioka et al.[4] also pointed out that the Sea Surface Temperature Anomaly of the South Atlantic has an obvious spatial dipole mode, namely the South Atlantic Subtropical Dipole (SASD), and the locking season is austral summer. The mechanism of SASD formation is explained by discussing the variation of subtropical anticyclone, latent heat flux and mixed layer depth anomaly.

ENSO originates in the Tropical Pacific Ocean and oscillates between warm and cold with a period of 3~7 years[5]. It can have a significant impact on global weather converts through changes in the convection mode in the tropical Pacific[6-7]. The interaction between the atmosphere and the ocean in the tropical Pacific Basin plays an important role in defining the characteristics of ENSO[8], and many studies were also devoted to the relationship between ENSO and other tropical or subtropical oceans. Wu and Kug et al.[9-10] found that SST in the tropical Indian Ocean affects ENSO by regulating walker circulation in the Pacific and Indian Ocean in its coupling simulation.

Annamalai et al.[11] showed that the SSTAs in the Indian Ocean enhances the abnormal anticyclone generated in the northwest Pacific Ocean during the El Niño mature stage. By activating this anticyclonic mode, the east wind stress in the western Pacific Ocean is abnormal, and the warming of SST in the Indian Ocean leads to a faster transition to La Niña. Izumo et al.[12] also proposed that tropical Indian Ocean Dipole (IOD) events may contribute significantly to the long-term predictability of ENSO. Recently, Wang Lijuan et al.[13] proposed that there is a significant negative correlation between the South Indian Ocean Dipole and ENSO events. Fauchereau et al.[14] proposed that the SASD positive event is caused by the enhancement and southward movement of the South Atlantic subtropical high. Penland and Matrasova[15-16] found that the South Atlantic SST precedes the El Niño signal by 9 months using a linear inverse model. Wang[17] believed that the tropical Atlantic forces the equatorial Pacific through the interbasin SST gradient changes associated with the Walker circulation in the Atlantic. Jansen et al.[18] also came to similar conclusion. However, there are few studies on the relationship between the South Atlantic subtropical SST and ENSO.

In view of this, this paper will further explore the characteristics and development process of SASD and its relationship with ENSO. The South Atlantic Subtropical Dipole is expected to be further understood.

2. Data and methods

2.1 Data Description

SST data are based on global monthly average data provided by the Hadley Centre. The spatial resolution of data is $1° \times 1°$. The data were selected from January 1979 to December 2021.

Let X_{amij} is data of a certain grid point, where a is year, $a \in \{1979, 1980, \cdots\cdots, 2021\}$, a total of 43 years. m represents months, $m \in \{1, 2, \cdots\cdots, 12\}$; i represents longitude, j represents latitude. The longitude we selected here ranges from 60°W to 20°E and the latitude ranges from 45°S to 15°N.

The first step was to calculate the seasonal climate state, such as the calculation formula of the seasonal climate state of a certain grid point:

$$\bar{X}_{ij} = \frac{\sum_{a=1979}^{2021} \frac{1}{3} \sum_{m} X_{amij}}{n} . \tag{1}$$

The second step was to calculate the seasonal average, and then use the seasonal average to remove the corresponding seasonal climate state data to obtain the annual seasonal average outliers.

$$\bar{X}_{aij} = \frac{\sum_{a} \sum_{m} X_{amij}}{3} . \tag{2}$$

$$X_{aij} = \bar{X}_{aij} - \bar{X}_{ij} . \tag{3}$$