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Climate anomalies in the southern high latitudes associated with the Subtropical Dipole Mode

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Abstract Climate anomalies in the southern high latitude associated with the Subtropical Dipole Mode (SDM) are investigated using a 23-year database consisting of SLP (sea level pressure), surface air temperature (SAT) and sea surface temperature (SST). The analysis depicts, for the first time, the spatial variability in the relationship of the above variables with the Subtropical Dipole Mode Index (SDI). It suggests that the SDM signal exists in the southern high latitudes and the correlation fields exhibit a wavenumber-3 pattern around the circumpolar Southern Ocean. Lead-lag correlation analysis is used to the SLP, SAT, and SST anomalies with the SDI time series at the positive and negative correlation extremes shows that the southern-high-latitude climate responses to SDM almost instantaneously proposing the connection is by atmospheric and not by oceanic propagation.

Key words southern high latitudes, climate anomaly, subtropical Dipole mode

1 Introduction

Enough has been said about the teleconnection of ENSO (*El Niño*-Southern Oscillation) in the tropical Pacific Ocean and the climate in the southern high latitudes (Fletcher *et al.* 1982; Smith and Stearns 1993; Simmods and Jacka 1995; Liu *et al.* 2002; Kwok and Comiso 2002). In resent years, much attention was focused on the Indian Ocean (Webster 1999, Saji 1999, Swadhin and Toshio 2001) suggesting the Indian Ocean plays a very active role in the global climate system. The relationship between the Indian Ocean, especially the subtropical Indian Ocean, and the climate in the southern high latitudes has not been discussed in the literature. Are there any signals of the subtropical Indian Ocean in the southern-high-latitude climate anomalies? The present study is to explore the relationship through analyzing the linear correlation of the Subtropical Dipole Mode Index (SDI) (Swadhin and Toshio 2001) with the polar climate anomalies

2 Data analysis and results

Monthly SLP, SAT are got from the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCAR-NCEP) reanalysis output (Kalnay 1996). The SST data are from dataset GISST 2 2b of the British Atmospheric Data Center (BADC) (Rayner *et al* 1996). At each grid point, monthly anomalies of each variable were found by the method that subtracting the climatological seasonal cycle from each monthly mean value

The anomalies fields in the global NECP 2 5° 2 5° grids and GISST 1° 1° grid are resampled onto a polar stereographic grid for better visualization over the circumpolar Southern Ocean The datasets used here all span a 23-year period from January 1981 to December 2002

Based on the definition of the Subtropical Dipole Mode Index (Swadhin and Toshio 2001), it is obtained by computing the SST anomaly difference between the western (55-65°E, 37-27°S) and eastern (90-100°E, 28-18°S) subtropical Indian Ocean In the following analysis, three-month running average of the SDI, as shown in Fig 1, is employed in order to avoid a significant portion of the noise due to small-scale and transient phenomena which are not associated with the large-scale coherent SDM signal

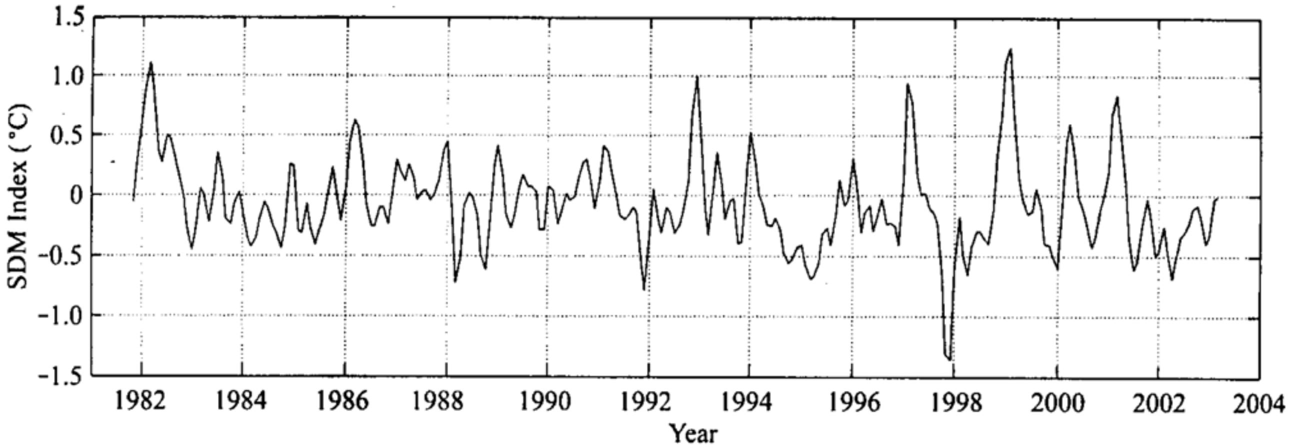

Fig 1 The Subtropical Dipole Mode Index time series from Nov 1981 to Mar 2003 The line shows the 3-month moving average of the time series

2 1 *Correlation analysis*

In this section, we will examine the polar climate anomalies associated with the SDI time series. The correlation coefficients between the time series of SLP, SST, SAT anomalies and SDM time series are computed. The resulting correlation fields are shown in Fig. 2. The correlation maps show distinct centers of action (positive and negative extremes of the correlation coefficient). Most striking from the figure is that, all of the correlation maps exhibit a wavenumber-3 pattern around the circumpolar Southern Ocean. We are interested in the whole areas of the southern ocean except the southern Indian Ocean where SDM locates. There are two positive correlation centers of action in the following regions: the northern of Weddell Sea and the southern of Australian land along 50°S. There are also two negative correlation centers in the northern of the Bellingshausen Sea and in the southern-western Atlantic Ocean. Furthermore, we can find that the most positive and negative correlation values of SST are higher than SAT and SLP. The locations of the action center and the corresponding correlation coefficients are showed in Table 1.

2.2 *The lead-lag correlation analysis*

The lead-lag correlation analysis is used to study the response time scale of the correlation. We examine only areas with strong correlation where we have an interest. The plots of lead-lag correlation between the time series of SDI and the climate anomalies at the locations of strongest positive and negative correlation south of 40°S are shown in Fig. 3. The longitude and latitude of the selected locations have been showed in Table 1.

Table 1 Locations of the action center and the corresponding correlation coefficients on the correlation maps of SLP, SAT, and SST anomalies with SDI time series (1981-2003).

	Positive		Negative	
	Location	Correlation Coefficient	Location	Correlation Coefficient
SLP	175°W, 50°S	0.24	92.5°W, 65°S	−0.17
SAT	22.5°W, 45°S	0.41	130°W, 55°S	−0.26
SST	15°W, 45°S	0.48	110°W, 50°S	−0.34

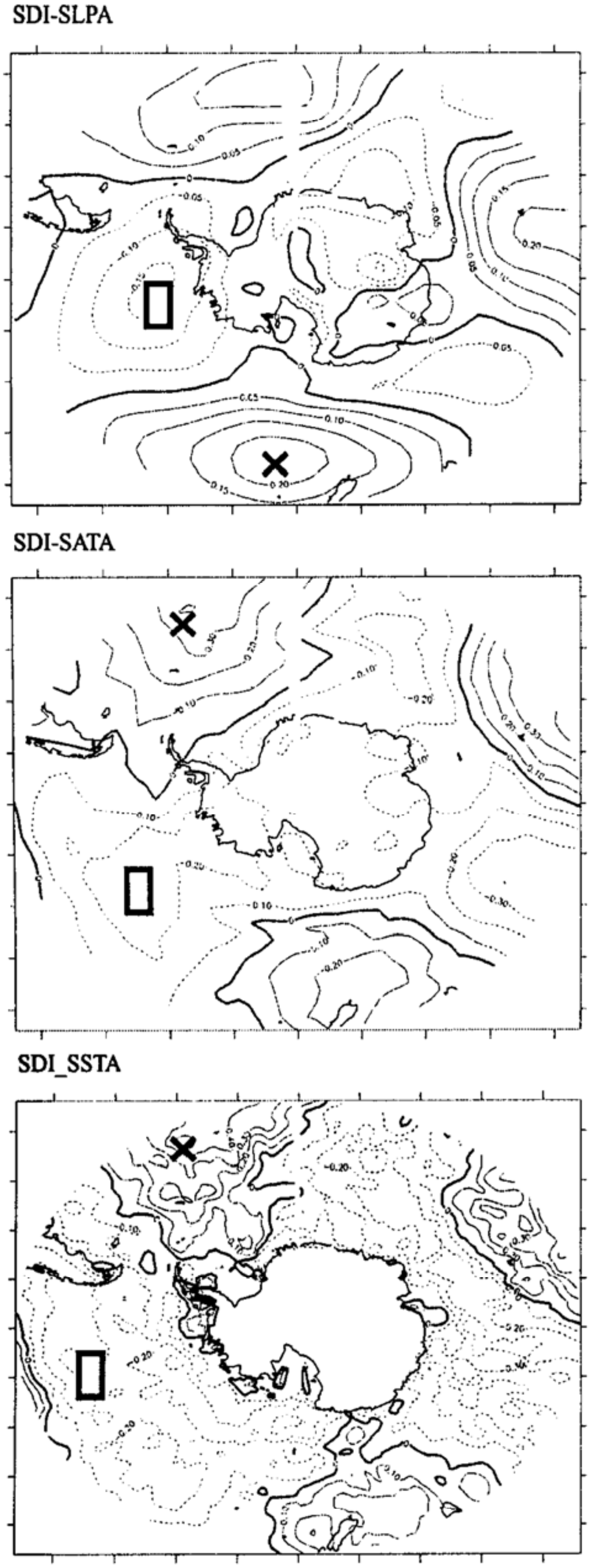

Fig 2 Correlation maps of SLP, SAT, and SST anomalies with SDI time series (1981-2003) and the location of the positive (black X) and negative (black rectangular) extremes on the correlation maps The correlation levels associated with the observed correlations are shown in a correlation map

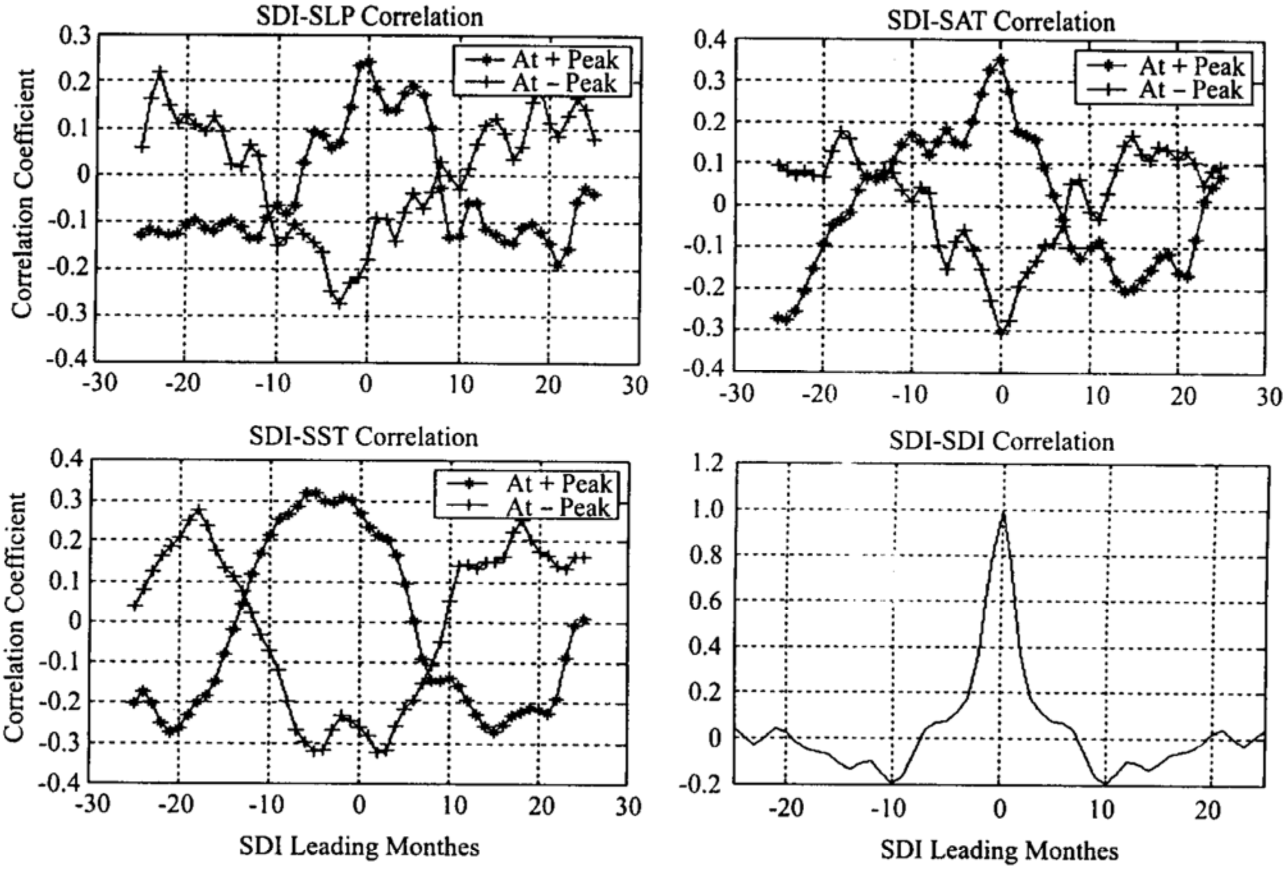

Fig 3 Lead-lag correlation plots of the SLP, SAT, and SST anomalies with the SDI time series at the positive and negative correlation extremes (positive indicates SDI leads). The autocorrelation of the SDI time series is also shown

As seen in the lead-lag correlation plots the spatial peaks are also distinct in time and the broad correlation structure shows its similarity to the autocorrelation signature of the large-scale coherent SDI signals There is no observable leading and lagging between SDI and the SST anomalies at the location of the negative and positive peaks An approximate 3-month head, with the SLP and the SAT anomalies lagging the SDI, is evident at the positive and negative peaks Martinson and Iannuzzi (2003) and Liu *et al* (2002) implied an atmospheric mechanism of the propagation between ENSO in the tropical Pacific Ocean and the climate anomalies in the southern high latitudes through the instantaneous correlation results So from the above analysis we can see that the climate anomalies in the southern high latitudes responses the SDM almost instantaneously. So it can be suggested the fact that the propagation of the connection proceeds fast, implies not oceanic but atmospheric mechanism.

3 Conclusions and Discussion

Through our analysis by correlation analysis to investigate the relationship between SDM and climate anomalies in the southern high latitudes, it is clear that (1) evident teleconnection between SDM and SLP, SAT and SST anomalies in the southern high latitudes exists Correlation fields exhibit a wavenumber-3 pattern around the circumpolar Southern Ocean; (2) the climate anomalies in the southern high latitudes responses the SDM almost instantaneously suggesting the teleconnection proceeds not by oceanic but atmospheric mechanism.

Now we can conclude that not only ENSO signals in the tropical Pacific Ocean but also subtropical Dipole Mode signals are found in the southern high latitudes Peterson and White (1998), in a case study, show ENSO can be a possible source of the inter-annual anomalies for sustaining the ACW in the western subtropical South Pacific More studies on investigating whether the subtropical Dipole Mode can also be a source of ACW will be done in the future

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