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Short Contribution

Teleconnection of IOD Signal in the Upper Troposphere over Southern High Latitudes

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Evidence has been found for the teleconnection of Indian Ocean Dipole mode (IOD) events in the southern high latitude sea surface pressure field, although the mechanisms that might lead to such far-reaching links remain unresolved. Based on the teleconnection pattern between IOD and the climate anomaly in the upper troposphere, we propose one such mechanism here: the energy propagation theory of the atmospheric planetary wave. Ray traces of the atmospheric planetary waves suggest that the energy propagation of the waves could be responsible for the teleconnection between IOD and tropospheric climate anomalies in southern high latitudes.

Keywords:
· Indian Ocean Dipole Mode,
· southern high latitudes,
· upper troposphere.

1. Introduction

An interannual climate anomaly characterized by SST anomaly of opposing sign in the western and eastern tropical Indian Ocean has been documented in the tropical Indian Ocean (Saji *et al*., 1999; Webster *et al*., 1999; Murtugudde *et al*., 2000). Such anomalies are referred to as Indian Ocean Dipole Mode (IOD) events. Recently, the impacts on austral climate anomalies of the IOD events have attracted a great deal of interest (Saji *et al*., 2005; Liu *et al*., 2005). Liu *et al*. (2005) showed that not only ENSO signals in the tropical Pacific Ocean but also the IOD signals are found in southern high latitude SLP anomaly fields. Considering that there are few effects from both local boundary layer variations and remote influences arising in the southern polar latitudes, we will explore here whether if there is an IOD signal in the upper troposphere and provide a corresponding dynamic view of the teleconnection pattern.

2. Data and Method

GH (geopotential height) fields from the NCEP-NCAR reanalysis data (Kalnay *et al*., 1996) are used, which are monthly means covering a 45 yr period from January 1958 to December 2002. In this paper, the 200 hPa level stands for the upper layer of the troposphere. At each grid point, monthly anomalies of each variable are found by subtracting the climatological average from each monthly mean value. Subsequently, overlapping 3-monthly anomalies are computed by applying a 3-month running mean on the anomalies to avoid a significant portion of the noise.

Since 1958 there have been 5 years (1961, 1967, 1977, 1983, 1994) in which IOD phase is positive and 6 years (1958, 1960, 1974, 1989, 1992, 1993) with negative IOD phase (Saji and Yamagada, 2003) since 1958. Composite analysis is employed to investigate the teleconnection. An average of the GH anomaly is found for all positive and negative IOD events and the difference between these composites is then calculated.

3. Spatial Teleconnection Pattern and the Corresponding Mechanism

The spatial teleconnection pattern between the GH anomalies at the tropospheric layer of 200 hPa and the IOD events is examined using the composite analysis during SON—the peak season of IOD evolution. Figures 1(a) and (b) present the spatial patterns south of 40°S for positive IOD events and negative IOD events, respectively. The composite field shows evident GH anomalies in southern high latitudes. During positive IOD events, positive GH anomalies exist in the central Pacific sector and in the Indian Ocean sector of the Antarctic. Two negative centers are also recognized, located around the Drake strait and in the southwest Indian Ocean sector off the Antarctic landmass. As Fig. 1(b) shows the positive action centers are located in the southwest Indian Ocean

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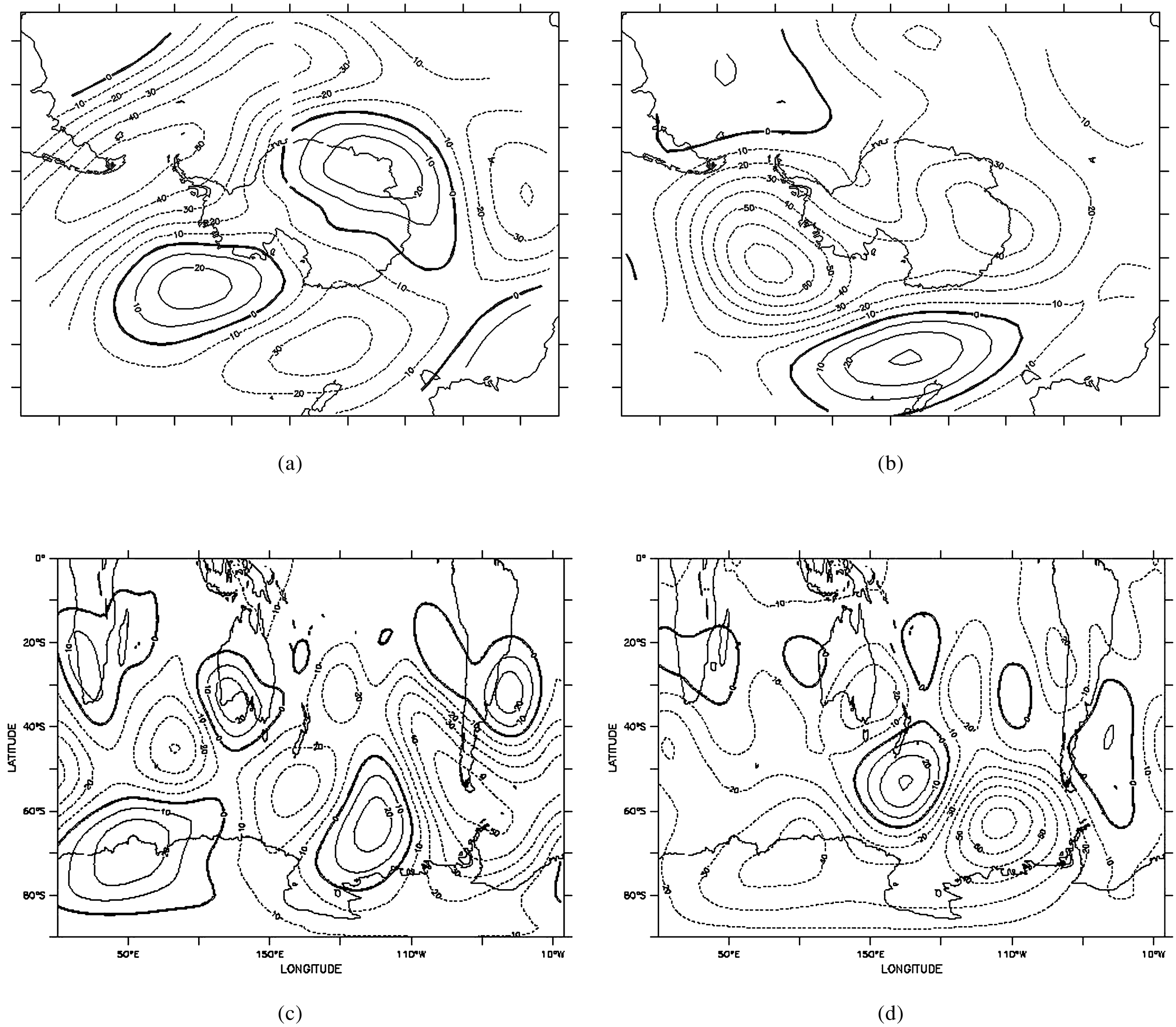

Fig. 1. Composite maps of geopotential height anomalies during positive IOD (1961, 1967, 1977, 1983, 1994) and negative IOD (1958, 1960, 1974, 1989, 1992, 1993) years from the NCEP/NCAR reanalysis. (a) during the positive IOD events in southern high latitudes; (b) during the negative IOD events in southern high latitudes; (c) during the positive IOD events in the southern hemisphere; (d) during the negative IOD events in the southern hemisphere.

and the southwest Pacific Ocean sectors off the Antarctic landmass while the negative ones are in the central and east Pacific part and in the Indian Ocean part of the Antarctic during the negative IOD events.

To give a dynamic view of the teleconnection pattern, the composite map of positive and negative IOD events in southern high latitudes is extended to the entire southern hemisphere. As shown in Figs. 1(c) and (d), we can see that the pattern is dominated by a stationary Rossby wave train structure, not only during the positive but also during the negative phase. The wave train extends from the tropical Indian Ocean over the subtropical regions of the Pacific Ocean to the southern high latitudes and then to the subtropical region of the Atlantic Ocean, which is similar result to that shown in figure 5 of Saji *et al.* (2005). Comparing Fig. 1(c) with Fig. 1(d), one sees that the teleconnection action centers over southern high latitudes and except the one in the Indian Ocean part off the Antarctic, all belong to the Rossby wave train associated with IOD.

Diagnostic and model analyses both suggest that tropical convective anomalies in the Indian Ocean dur-

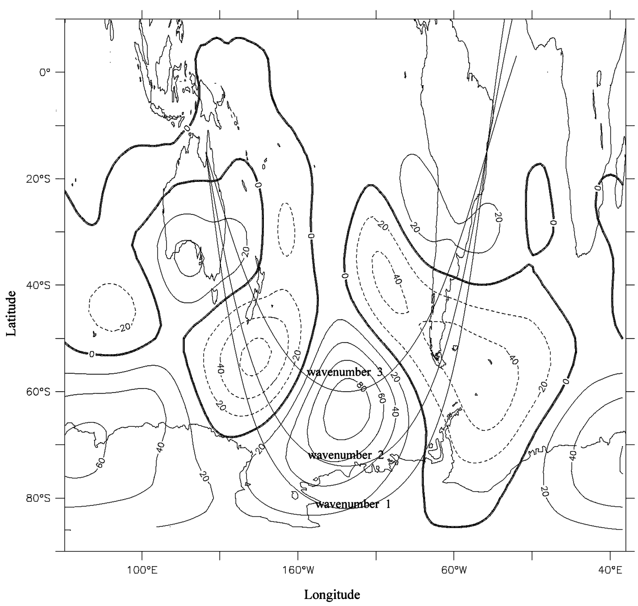

Fig. 2. Ray traces of Rossby wave with wavenumbers 1, 2 and 3 at the tropospheric level of 200 hPa in boreal autumn (SON). The contour map is the composite GH differences between positive and negative IOD years.

ing IOD events likely affect the austral climate anomalies through stationary Rossby wave propagation (Saji *et al.*, 2005). In this paper, we give a dynamic view of the teleconnection pattern between IOD and southern high latitude GH anomalies the layer in 200 hPa using the energy propagation theory of the atmospheric planetary wave according to Hoskins and Karoly (1981). Ray traces of a Rossby wave with wavenumbers 1, 2 and 3 drawn on the composite GH differences map between positive and negative IOD years are given in Fig. 2. They have the starting points at (15°S, 145°E), which references the Rossby waveguide in the upper troposphere (Saji *et al.*, 2005). This shows that the energy propagation path of the planetary waves is approximately along the path of the Rossby wave train, which implies that the energy propagation of the atmospheric planetary wave is probably a dynamic explanation for the teleconnection pattern.

4. Conclusions and Discussion

The analysis in this paper allows two conclusions to be drawn. First, composite analysis shows that an IOD signal exists in GH anomalies in the upper troposphere over southern high latitudes in the active season (boreal autumn) of the IOD events. Secondly, the energy propagation of the atmospheric planetary wave could be responsible for the observed teleconnection pattern.

As mentioned in Section 3, there is another teleconnection action center in the Indian Ocean part of the Antarctic, besides those belonging to the Rossby wave train. Many studies suggest that the sea surface temperature anomalies in the tropical oceans can affect the atmospheric cells in middle and high latitudes, which leads to the polar and tropical communication (Wang, 2002; Liu *et al.*, 2002). Based on these results, a study of the mechanism underlying the teleconnection action center in the Indian Ocean part of the Antarctic between IOD and GH anomalies in the upper troposphere will be completed in the near future.

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