Response of the Antarctic sub-polar jet and the Southern Annular Mode to the El-Nino and La-Nina forcing in the Austral Summer Season

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1. Introduction

The southern annular mode (SAM) is the dominant pattern of large-scale variability in the extratropical Southern Hemisphere (SH) characterized by a north-south vacillation of the mid-latitude westerly jet (Thompson and Wallace, 2000). On inter-annual time scales, a linear relationship between the SAM and El-Nino Southern Oscillation (ENSO) has been reported in southern summer months (L'Heureux and Thompson, 2006). However, the level of dependency in Antarctic climate on the magnitude of ENSO remains unclear. It is still questionable whether the Antarctic circumpolar jet responds to ENSO is merely linear or not.

In this study, the sensitivity of the Antarctic sub-polar jet (SPJ) accompanied by the change in the SAM phase to the change in the tropical ENSO magnitude is examined for austral summer seasons (December-January-February, DJF) using a general circulation model.

2. Data and Methods

The observation-based SAM index are used (Marshall, 2003). The Oceanic Nino Index (ONI), simply 3-month running mean Nino 3.4 index, from Climate Prediction Center (CPC) are adopted as ENSO index. Both indices are a measure of the amplitude and sign of the SAM and ENSO. They are standardized and detrended prior to all analyses.

National Center for Atmospheric Research (NCAR) Community Atmospheric Model version 3 (CAM3) is used to examine the model response of the Antarctic SPJ to changes in ENSO amplitude. we prepare six annaual cycles of monthly sea surface temperature (SST) with different strength of El-Nino, characterized by the amplification factors from 0.25 to 1.5 with 0.25 interval, and one of monthly SST climatology. Each prescribed SST annual cycle is repeated for each model experiment during the simulation years. The model experiments are run for 140 years and output for the last 50 years are used in the analysis. The model results shown in this study are derived from a composite analysis for each variable field.

3. Results

Fig. 1 shows the normalized time series of the ENSO and SAM indices. During the extreme ENSO events (SL and SE), the SAM index clearly shows the opposite sign with correlation coefficient exceeding -0.8, which is significant at 99% confidence level. However, in years of less strong ENSO events, there is no such tendency. This result indicates that the negative relationship between ENSO and SAM only holds for strong ENSO periods, but for moderate ENSO periods, there is almost no relation between both indices.

The modeled anomalous zonal-mean zonal wind from the climatology in Fig. 2 has barotropic structure with opposite sign centered around 50^{o}S. It is clearly seen that the zonal-mean zonal wind response is not proportional to the linear increase of the SST foring. Rather, when the SST foring reaches the threshold of 1.5 amplification factor, the changes in zonal winds over the SH is largely enhanced (Fig. 2f). Compared with the zonal-mean zonal wind anomalies, the changes in the Eliasen-Pam (EP) flux divergence of synoptic waves in Fig. 2 matches well as the ENSO SST forcing becomes stronger.

Fig. 3 compares the baroclinicity anomaly with the EP flux divergence anomaly, and zonal-mean zonal wind anomaly. The anomalous eddy activities characterized by baroclinicity anomaly and EP flux divergence anomaly are almost consistent with zonal-mean zonal wind anomaly. It is noted that the anomaous eddy activities and the anomalous zonal-mean flow sharply increases with the largest amplification factor, while others show linearly increased amplitude in response to their amplification factors.

4. Summary and discussion

The responses of the Antarctic SPJ and the associated SAM to gradually increasing ENSO forcings are investigated for austral summer. Through a series of numerical experiments, we show that SPJ do not respond to a moderate ENSO forcing, but instead respond exponetially only to strong ENSO through the changes in eddy activities.

It can be inferred how the eddy-induced change in westerly flow accompanies the negative SAM phase for only extreme El-Nino periods as found Fig. 1. That is, if the tropical SST forcings are moderate, eddy-induced changes in westerly flow are too small to accompany the changes in the SAM phase. However, when the SST forcing are strong enough, the SPJ responses to the eddy activities associated with the SST forcing can be reflected in the negative SAM phase.

5. References

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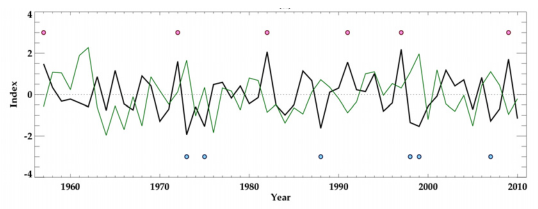

Fig. 1. Time series of DJF-mean SAM (green solid) and Nino 3.4 (black solid) indices for 1957-2010. Red and blue circles indicate the strong El-Nino (SE) and strong La-Nina (SL) years, respectively.

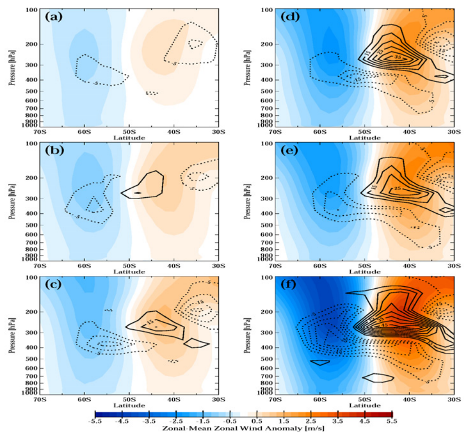

Fig. 2. Modeled monthly zonal-mean zonal wind anomalies (shaded) and EP flux divergence anomaly in 3-8 day eddies with different amplification factors a) α=0.25, b) α=0.5, c) α=0.75, d) α=1.0, e) α=1.25, and f) α=1.50 for aurstral summer.

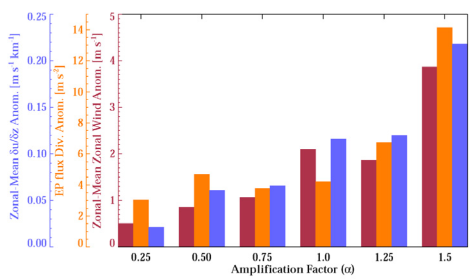

Fig. 3. Comparison between baroclinicity anomaly (blue, m s^{-1} km^{-1}), EP flux divergence anomaly (orange, m^2 s^{-2}), and zonal-mean zonal wind anomaly (red, m s^{-1}) averaged over 60°S-55°S and 300-200 hPa regions for amplification factor from 0.25 to 1.5. The values are inverted for comparison. The baroclinicity is defined as the difference in DJF-mean zonal wind speed between 510 and 867 hPa following the Inoue and Hori (2012).