Response to Editor's Comment

Weakening of Antarctic Stratospheric Planetary in Early Austral Spring Since the Early 2000s: A Response to Sea Surface Temperature Trends

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Response to Editor

Dear authors, Please include any figures -- in the response to reviewers but not yet included in the supplement -- in the supplement itself, so that ACP readers will have access to them. Then, modify main text to match numbering of the revised supplement. Examples: R1(d-f), R2, R3, R8, R9. The last two of these are especially important. Many thanks for your diligent efforts thus far. The manuscript will be acceptable for ACP after these minor revisions. –TD

Response:

Thank you very much for further helpful comments. We have added all the figures and the table in the reply file (Fig. R1(d-f), Fig. R2, Fig. R3, Fig. R8, Fig. 9 and Table R2) to the supplementary file (corresponding to Fig. S10(a-c), Fig. S9, Fig. S10(d-i), Fig. S11, Fig. S4 and Table S2).

We also modify the relevant text in the manuscript to match them. The modifications which are highlight in blue are listed below:

1. About L488-L490:

"The results of these experiments are summarized and displayed in Figure 14, which are quantified by the frequency distribution of southern hemisphere stratospheric vertical wave flux derived from the 100 ensemble members of each experiment."

change to:

"The results of stratospheric vertical wave flux over 50°S-70°S derived from the 100 ensemble members of each experiment are shown in Figure S4, and the frequency distributions of them are displayed in Figure 14."

2. The last paragraph in section 7 is expanded into two paragraph:

"The southern hemisphere stratospheric wave activity trend from the early 1980s to the early 2000s has been investigated by Hu and Fu (2009) (hereafter HF2009) and hence is not discussed in detail in the above. HF2009 attributed the strengthening of stratospheric wave activity in austral spring during 1979-2006 to the SST trends as well, however, they gave no more details about the trends of tropospheric wave sources. In

this study, trends of tropospheric wave sources in September during 1980-2000 derived from MERRA-2 data is analyzed, and we also conducted an experiment (sstSHtrop80) forced by the changes of September SST during 1980-2000 over 20°N-70°S (see Fig. S9 for applied SST anomalies). The model result indicates that the SST changes over 20°N-70°S contribute to intensification of wave-2 component of tropospheric wave sources (Fig. S10f) and weakening of the wave-1 component (Fig. S10e), which is overall analogous to the trends derived from MERRA-2 data (Figs. S10b, c). Accordingly, the simulated wave-2 component of wave flux increases significantly in the stratosphere (Fig. S10h), while the response of the wave-1 component is not significant (Fig. S10i). In a word, the results from sstSHtrop80 suggest that the SST changes over 20°N-70°S induce a strengthening of stratospheric wave activity in September during 1980-2000. But it cannot explain the intensified wave-1 component of the stratospheric wave activity shown in Fig. 1b. A more detailed attribution of the trend of Antarctic stratospheric wave activity during 1980-2000 needs much more efforts.

The simulated stratospheric eddy heat flux (Fig. 11b in HF2009) forced by observed time-varying SST in HF2009 is relatively weak compared to that derived from reanalysis data (Fig. 6b in HF2009). Similarly, Wang and Waugh (2012) (hereafter WW2012) used stratosphere-resolving chemistry-climate model forced by time-varying factors to evaluate the trends of stratospheric temperature, residual circulation as well as wave activity during recent decades, and the trend of cumulative eddy heat flux shown in their paper is not significant (Fig. 6 in WW2012). Additionally, Polvani et al. (2018) used time-varying ODSs that cover the period from 1960s to 2080s to simulate Brewer-Dobson circulation and attained an obvious trend transition around 2000. We had also tried to conduct transient experiments forced by time-varying SST derived from ERSST v5 with different initial conditions. However, the trends of wave activities in the transient simulations are so weak, though opposite trend signs exist during 1980-2000 and 2000-2018 (Table S2, Fig. S11). The significance of simulated trend may be related to model performance and the length of simulating period. As the period we focus is relatively short and our purpose is attribution rather than generating

a real trend, we perform the ensemble time-slice experiments in this study, which are also used in many other previous researches (e.g., Hu et al., 2018; Kang et al., 2011; Zhang et al., 2016) to attribute trends in the atmosphere. In addition, most of the current climate models cannot generate a realistic wave activity trend as waves in the atmosphere are linked with various processes and factors (e.g., Baldwin & Dunkerton, 2005; Garcia & Randel, 2008; Labitzke, 2005; Shindell et al., 1999; Shu et al., 2013; Xie et al., 2008)."