Supporting Information for " The delayed response of the troposphere-stratosphere-mesosphere coupling to the 2019 southern SSW"

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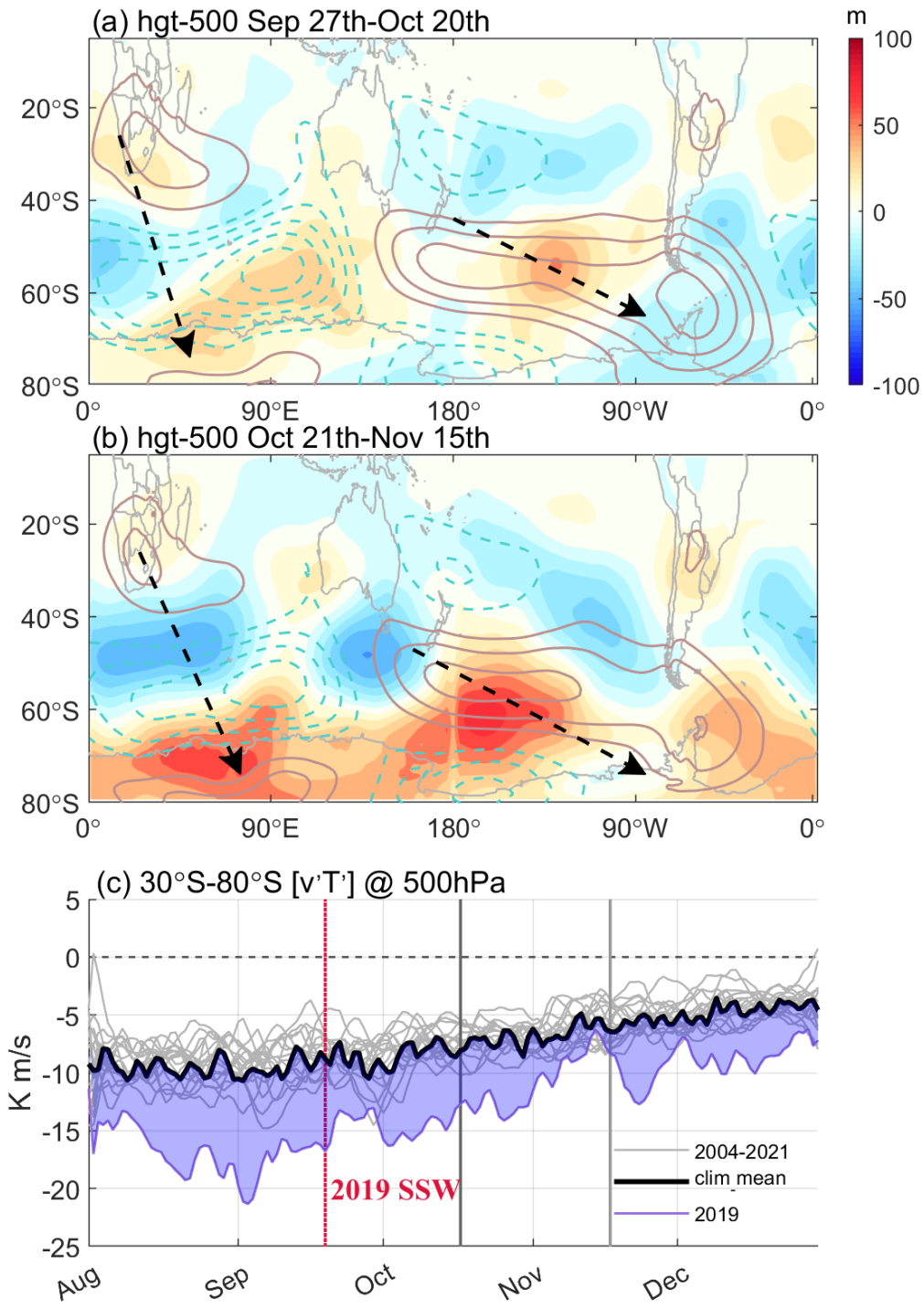

Figure S1. MERRA2 500 hPa anomalous geopotential height from (a) September 27th to October 21st and (b) September 27th to October 21st. The shadings indicate the anomalies during 2019, while the contours indicate the climatological distribution of the zonal anomalous geopotential height at 500 hPa. (c) Anomalous eddy heat flux averaged over 30-80°S, 500 hPa from August 2019 to December 2019. The purple line

denotes the year 2019, the black thick line indicates the mean from 2004 to 2018, and the red and blue shadings indicate positive and negative anomalies compared to the climatological mean.

Description:

To examine the variations of the tropospheric planetary wave source from October to November, the potential height anomalies at 500 hPa during two periods (from 27th September to 20th October and from 21st October to 20 October, respectively) after 2019 SSW, associated with the climatological mean for these periods are shown in Figure R1. During the two periods following the 2019 SSW event (corresponding to enhanced and suppressed upward propagating PWs in the stratosphere at mid-latitude and high latitudes, respectively, as shown in Figure 2 in the revised manuscript), the distributions of the tropospheric geopotential height anomalies are similar to each other, characterized by two PW train.

One is that the anomalous planetary wave train extending from southern Africa to Antarctica, consisting of positive anomalies to the south of Africa, negative anomalies extending from the south Atlantic to the south Indian Ocean between Africa and Antarctic, the positive anomalies over the Antarctic, coincides with the distribution of climatical zonal anomalous geopotential heights, leading to the increased planetary wave activity in the SH troposphere. The anomalous wave trains over the southern Pacific are different between the two periods. From September 27th to October 15th, the anomalous wave train consisted of negative anomalies to the east of New Zealand, positive anomalies over Southern Pacific centered at approximately 60°S, 130°W, and negative anomalies centered at the Antarctic Peninsula. From October 16th to November 15th, the anomalous wave train extends from the negative anomalies to the south of Australia to the positive anomalies over the central Southern Pacific. Although the wave train from the Southern Pacific is more intense in the latter period than in the former, the positive and negative anomalies together overlapping the climatological mean zonal positive anomalies that span the mid and high latitudes of the South Pacific implies little contribution to the

variation of the total planetary wave activity.

As a result, 500 hPa geopotential height anomalies generally lead to an enhanced planetary wave activity in the SH troposphere during October and November 2019, as also suggested by the anomalous eddy heat flux shown in Fig. R1c. Continuously stronger tropospheric planetary wave activity than usual is inconsistent with stratospheric PWs, which were first suppressed and then strengthened (Figure 2 in the revised manuscript). We, therefore, think that the change in the upward PW propagation process is the main reason for the variation in stratospheric PWs after SSW rather than the change of the tropospheric plane-wave source.

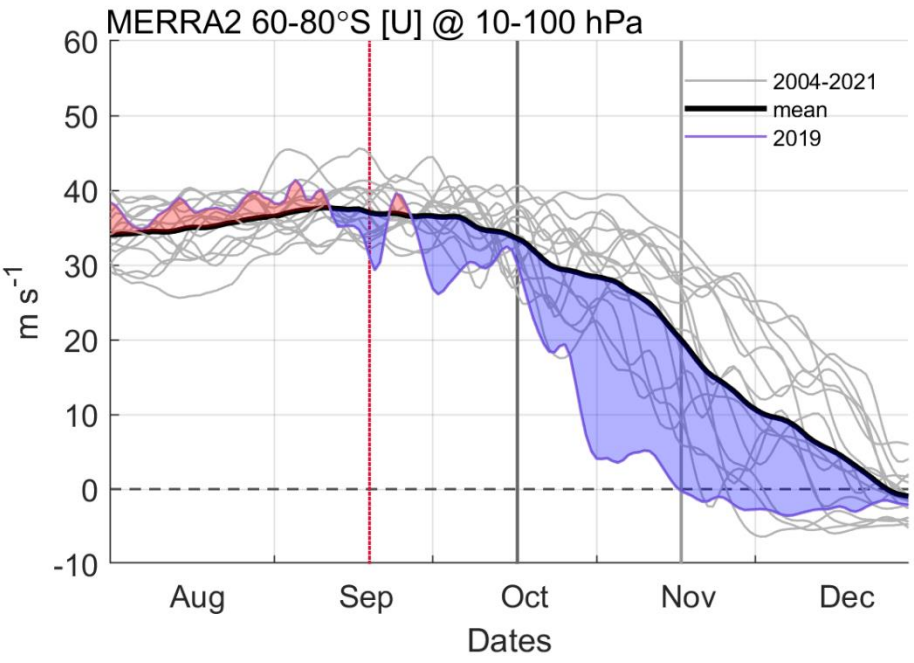

Figure S2. MERRA2 zonal mean zonal wind averaged at 60°-80°S, 10 hPa from August to December (light gray lines), the purple line denotes the zonal wind of 2019, the black thick line indicates the mean zonal wind from 2004 to 2018, the red and blue shadings indicate positive and negative anomalies compare to the climatological mean.