Response to Reviewer # 3

Review of "Flavor identification of the stratospheric sudden warmings based on the downward tropospheric influence" by Lu and Rao.

1. I agree with Reviewer 1 that the statistics are not sufficient to divide the SSWs into four categories. From Table 1, there are 13 BOTH, 14 EA, 6 NA and 19 NDW. Those are very small numbers. In addition, I noticed that 4 of the 6 NA occur in the 2000s, and 6 of the 13 BOTH also occur in the same decade (1970s). There are also many more EA towards the end of the considered time period than early on. Thus, besides the comments from Reviewer 1 that these numbers are not sufficient for statistical analysis and that data before 1958 is questionable, I wonder whether the composites include things like a climate change trend (EA) or potentially decadal variability (BOTH, NA), which both might have nothing to do with SSWs.

Response: When processing data, the long-term trend is removed to minimize the possible impact of climate change trend. We insert the processing procedure this time.

"The daily climatology is computed as the long-term mean for each calendar day, and the raw daily climatology is smoothed using 31-day means. The daily anomalies refer to the detrended deviation relative to the smoothed daily climatology." (L105-107)

The three DW types indeed show somewhat preference towards some decades. However, it is still unknown if this preference is related to global change trend or a random coincidence. To well address your concern, we mentioned this possibility.

"Further, the distribution of various types of events (see Table 1) shows strong interdecadal variability in past decades. Whether this change is an internal climate variability or forced by global warming due to anthropogenic emission is still unknown, worth exploring in the future." (L548-551)

Limitation of this study is discussed in our revisions. This article only uses ERA5 reanalysis to compare the possible impact of NDW and DW. The sample size is relatively small for NA events. However, the composite anomalies for the NDW and each type of NW is significant (see Figures 1, 3, 4, 5, 6, 7). The sample size really can impact the robustness of the composite results, but an increase of the sample size might not change the anomaly pattern.

To well address your concern, we made several revisions this time. Firstly, we discuss the possible issue resulting from the limited sample size in reanalysis. Secondly, we provide an insight into the future study that use more sample size from CMIP5/6 models to verify our research. Namely, we expected to increase the sample size and validate the conclusions using model data. However, due to the limited scope of this study, we did not insert too many figures. We can show the figure exclusively for your reference (Fig. R1).

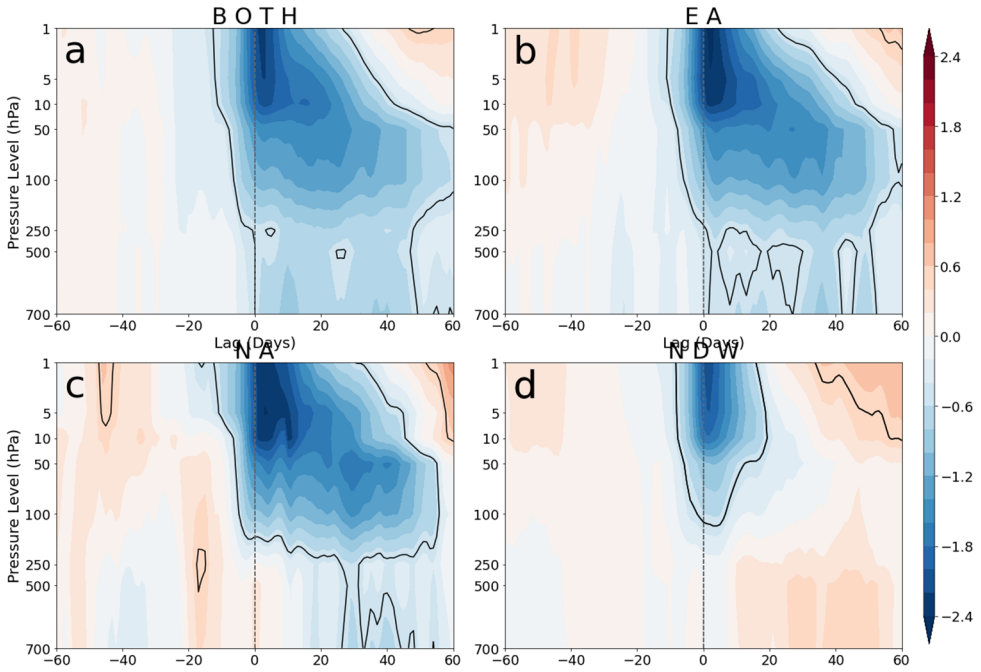

Fig. R1. Same as in Figure 1, but for model data. CESM2-WACCM historical simulations (r1i1p1f1 to r3i1p1f1) were used for composite (the sample size for each type exceeds 35).

Revision related to this comment can be found at Lines 21-22, L546-548, etc.

2. Furthermore, the cited paper by Jucker (2016) has shown that composite evolution and surface impact can be very different depending on the exact definition of "downward propagation". For instance, they show that simply checking for expected anomalies after SSW onset captures periods of internal variability where these anomalies might already exist before the SSW can influence the surface. Compare this, for instance, to the statement on lines 314-315, "The negative NAM pattern has well developed before the SSW onset for the type BOTH."

Response: We agree that the internal variability in the stratosphere and troposphere is mixed together, which is impossibly disentangled. Strictly speaking, the SSW is also a radical stratospheric variability. Certain tropospheric modes are a signal that often accompanies the development of SSW. As the precursor for SSWs, the tropospheric internal variability is inextricably linked to the onset of SSW. Therefore, it necessitates a study that well compared different types of DWs.

In this study, the pre-existing internal variability is regarded as one of aspects that well distinguish the DW types. Namely, we use surface anomalies as a classification criterion to classify the DW types. We show the 40-day mean, and the memory of troposphere itself can hardly exceed 40 days.

To well address your concern, we revised the method section.

"It is assumed that following the DW event onset, continental cold anomalies can develop over Eurasia and/or North America, implying an increase in cold air outbreaks

after the DW SSW onset. To better describe and distinguish the DWs, we further divide DWs based on the inland temperature anomalies within 40 days after the onset of DWs." (L139-142)

Jucker (2016) is also cited in our paper. Thank you.

3. I am also a bit sceptical about the use of the sign of the NAM as a measure of downward propagation (lines 125-129): The NAM is a zonal mean quantity, but EA and NA are explicitly defined as strongly zonally asymmetric surface anomalies (impact in one region but not another). So why to the authors think using the NAM is the best way to define downward influence of SSWs? Is it not possible that they are missing several occurrences where EA or NA are anomalously cool but the zonal mean is still neutral (and thus this would be classified as NDW)?
I think these are major points concerning the design of the study which need to be re-considered, and I therefore do not recommend publication in the current form.
Response: We use NAM to define DWs and NDWs, but we do not use NAM to define BOTH, EA, and NA. In our study, we are more concerned about the SSWs that show the downward impact on the troposphere. It has the possibility that the t2m over Eurasia or North America show cold anomalies during some NDWs. However, those cold anomalies are not related to the SSW according to the criterion in previous studies and our work.

Our study is more concerned with the cold anomalies associated with the SSW. In the NDWs, we have hypothesized that SSWs does not affect the troposphere and the near surface without downward propagation of NAM signal. The cold anomalies for some NDWs over Eurasia or North America, if they exist, are not associated with the SSW events. Therefore, it is more logical not to classify the NDWs any more. Another reason of not classifying the DWs is the too limited sample size.