Interactive comment on "Observations of PW activity in the MLT during SSW events using a chain of SuperDARN radars and SD-WACCM" by N. H. Stray et al.

Anonymous Referee #2

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General Comments:

In this work, Stray et al. studied the planetary wave (PW) variation in the mesosphere and lower thermosphere (MLT) during SSW events using both SuperDARN radar measurements and SD-WACCM simulations. Both observational and simulation results show evidence of PW (S1 and S2) enhancement in the MLT after polar-cap zonal wind reversal at 50km, and the correlation between the PW enhancement and the wind change at 50km was found to be statistically significant. Previous studies have showed that PW in the MLT during SSW could change significantly, though mainly using simulations and some satellite observations, and have focused on case studies.

Interactive Discussion

Discussion Paper

The current study employed an observational network (SuperDARN) and examined events from 2000-2008, and demonstrated the value of ground-based observation networks in studying the MLT large-scale dynamics, in particular for studying the short term variability and establishing statistics.

Specific Comments:

1. Extraction of PW S1: The SuperDARN network used in this analysis covers a longitude range of 175 degrees (150W to 25E). I would think that this would cause uncertainty when deducing PW S1 using fitting method due to insufficient information, especially for stationary and slowly propagating S1 components. This is analogous to the difficulty/uncertainty involved in retrieving diurnal tides with night time only measurements. I would like to see this clarified and quantified in the paper and/or discussion.

The analysis has been validated and quantified in Kleinknecht et.al (2014). In this paper we showed that the amplitude and phase of the S_1 wave retrieved using the analysis was well correlated (correlation coefficient=0.9) with an ideal 360° longitude fit (2.5° spacing).

It was also shown that the amplitude of the S_1 and S_2 wave components agreed with the ideal fit to within the fitting uncertainties (± 20% and ± 10%, respectively). Consequently, we are confident that biases in the derived amplitudes are minimal.

The paper has been changed to include the *following statement* in line 25 on page 396:

… The resulting daily winds are fitted as a function of longitude to provide the amplitude and phase of the S_1 and S_2 PWs. *Kleinknecht et.al 2014 verified the amplitude and phase of the retrieved wavenumber components to correlate well (correlation coefficient: 0.9) with an ideal fit covering 360° of longitude (2.5° longitude spacing). The amplitude of the S_1 and S_2 wave components agreed with the ideal fit to within the fitting uncertainties (± 20% and ± 10%, respectively).* The wave number one (S_1) and two (S_2) components resulting from the fit to the chain of SuperDARN radars are shown in Fig. 1

2. Stratospheric polarcap wind: In this study, the authors decided to use the zonal wind at 50km as the "index wind" for the stratosphere, rather than the wind at 30km/10hPa as used traditionally in SSW literatures. The authors may want to briefly explain the rationale for this choice, and if/how the results would be affected if the 30km wind is used. And since 50km is to the top of MERRA, where there are less observations available for data assimilation, I wonder how reliable the wind there is compared with the 30km wind.

Tweedy et al. (2013) showed that onset day of the wind reversal of the polar-cap wind at 50 km in the MERRA data is better related to a wind reversal of the polar-cap wind over an extended altitude range in the mesosphere (50-80km) and the onset of anomalous vertical upwelling. To assure that the events used here were related to a reversal of the wind in the mesosphere, this same criterion was used to identify the SSW in this study. If the 30km/60N wind would be used, only the strongest reversals would be identified and many of the reversals affecting the mesosphere would potentially be ignored.

To make this clear, the text on page 398 line 8 has been changed to read: *The reversal of the polar cap wind at 50 km was used to identify the events following Tweedy et al, (2013), who found that this was a better indicator of the wind reversal extending into the mesosphere and the onset of vertical upwelling than the WMO (World Meteorological Organization) definition of SSWs* at 10 hPa and 60° latitude. *Using the polar cap wind reversal at 50 km, only two of the events classified as strong would be considered to be major stratospheric warmings according to the WMO definition.*
SSW events have been defined as strong events when their wind reversal in the stratospheric (50 km) polar cap wind (70-90 N) persists for 4 or more days and exceeds westward wind magnitude of 10 m s^{-1}.

3. MLT PW during SSW: It is well known that Rossby waves can survive only in an eastward wind field, and indeed by comparing Figure 2a with Figure 4 the large wave amplitudes in the MLT coincide with eastward wind reversal (between 80-100km during SSW) in SD-WACCM simulations. So I wonder (i): what is the correlation between PWs and zonal wind at 95km? (ii): if the increase of MLT PWs is simply a result of favorable propagation conditions, namely eastward wind, in the MLT region? (i) would involve a straightforward correlation calculation, using zonal wind derived from SuperDARN, and the result will help shed light on (ii).

(i) As shown in Kleinknecht et al. (2014), while the fitting technique can extract the S_1 and S_2 components of the wind, it is not able to retrieve the zonal-mean components (S_0) of either the zonal or meridional wind in the MLT due to the limited longitudinal extent of the radar chain. A correlation of the observed PW activity with observed zonal-mean winds is therefore not possible.

(ii) For the vertical propagation, the stratospheric wind becomes strongly westward from approximately 30 to 80 km during stratospheric warming events. Thus, while the MLT winds may be favorable for planetary waves, the strong westward winds below 80 km would inhibit any upward PW propagation into the MLT region. This would seem to limit the influence of any eastward mesospheric winds on the enhanced PW transmission into the MLT during this time. An exception would be any waves created by instabilities near the east-west shear zone, which are discussed in the paper.

The following sentence has been included on page 404 line 13:

While the enhancement in the observed PW amplitudes shown in Figure 2 occurs during times of zonal-mean eastward winds in the MLT, the wind below this region is strongly westward during the SSW event and would inhibit upward propagating PW into this favorable wind regime. Indeed, the modelled SD-WACCM PW activity clearly shows that the amplitudes of PWs propagating up from the stratosphere minimize…

4. PW-wind correlation in model: What is the correlation between PW and stratospheric polarcap wind in SD-WACCM simulations? Is it similar to that derived from SuperDARN/MERRA (0.4)?

The investigation presented in this paper is based on observational work and not validation of the SD-WACCM model capabilities. WACCM is only used to extend MERRA into the mesosphere so as to identify ES events and give an indication of the mechanism for the PW presence above 80 km (Figure 4).

Thus, the correlation with all wind reversals is based on data. We feel strongly that repeating the correlation analysis with model would not add value other than to demonstrate that the model could reproduce the events that are clearly present in the observation. Hence, we believe that the correlation analysis for SD-WACCM would not enhance the results presented here and would be beyond the scope of this observational study.

5. Elevated stratopause (ES) in composite: Figure 2 is a composite based on 7 SSW ES events. One would expect that the ES to be found in the composite too. But this is not so clear in Figure 4b. Please clarify the ES structure in figure 4b.

This is mainly due to:

1) Stratopause jumps between 20 km and 42 km are included in the composite of 7 events, “blurring” the altitude width of the jumps.

2) The composite is set to the onset of the wind reversal at 50 km and not to the occurrence day of the stratopause jump. Since the persistence of the wind reversals of the 7 events are different, the stratopause jump occurs at a different times relative to the zero-index point for the composite, This, as with the wind reversal at 10 hPa mentioned above, leads to a blurring of the elevated stratopause effect in the composite. However the elevation of the stratosphere is clearly visible at around 70 km after the event. (While a composite could be constructed to show the elevated stratopause more clearly, the focus of the paper is on the planetary wave enhancement following the wind reversal at 50 km, and the composite is constructed accordingly).

The following sentence has been added on page 400 line 5: *Although each of the 7 events shows a stratopause jump between 20 and 42 km, the composite shown in Figure 2 is indexed to zero on the day of the wind reversal at 50 km (defined to be the onset date) and not at the occurrence of the ES event. Therefore the mean elevated stratopause, although clearly visible at around 70 km after the warming, is not representative of the individual stratopause jumps in the composite.*

6. Undisturbed winter conditions: in the paper (page 5 around line 110) the undisturbed winter condition was described as time periods when there is no polar cap wind reversal within 40 days prior to the target period. The 40-day time period sounds arbitrary, and I wonder if there is any physical significance to this time scale. For the 2000-2001 season, for example, there were a series of strong wave 1 and 2 events in December and January (with intervals of 10-20 days), so dynamically it was a very disturbed time period. So I am not sure if it is valid to characterize 29 January 2001 as under undisturbed winter conditions. It also seems problematic to use the wind reversal to demarcate winter conditions, since the polar vortex could be strongly disturbed between two warming events.

"Undisturbed" was perhaps an unfortunate choice of adjective on our part. We wanted to point out that the 7 SSW ES events that were identified during the winters 2000/2001 to 2007/2008 all happened to occur at least 40 days after any previous wind reversal that lasted more than 4 days. The rationale is that the composite post-reversal enhancement shown in Figure 3 persists for approximately 10 to 15 days. Thus, another event within this time period would have an already elevated baseline of PW amplitude, washing out any subsequent enhancement. The 7 events used are therefore separated long enough in time from any previous reversal lasting 4-days to ensure that the baseline PW amplitudes are not enhanced.

The statement on page 398 line 19ff. has been changed to:

It should be noted that no polar cap wind reversals lasting at least 4 days occurred 40 days prior to the 7 SSW ES events studied, ensuring that the baseline was not disturbed by a previous event.

References used:

Kleinknecht, N. H., P. J. Espy, and R. E. Hibbins (2014), The climatology of zonal wave numbers 1 and 2 planetary wave structure in the MLT using a chain of Northern Hemisphere SuperDARN radars, *J.Geophys. Res. Atmos.*, *119*, 1292–1307, doi:10.1002/2013JD019850.

Tweedy, O. V.; Limpasuvan, V.; Orsolini, Y. J.; Smith, A. K.; Garcia, R. R.; Kinnison, D.; Randall, C. E.; Kvissel, O. K.; Stordal, F.; Harvey, V. L. & Chandran, A. (2013), Nighttime secondary ozone layer during major stratospheric sudden warmings in specified-dynamics, *J.Geophys. Res. Atmos.*, 118, 1-13