Response to the comments by Referee #1

We greatly appreciate the reviewer for his/her thorough review and constructive comments. We have revised our manuscript as much as possible following his/her comments. Our point-to-point response to them is described as follows:

Page 16969 Sentence starting on Line 22: Note that solar occultation satellite instruments have also been used extensively for monitoring PSC (e.g. Fromm et al., 2003). Though, it is also important to note that these measurements have a significant sampling bias.

We have added 'solar occultation satellite' to the 1st sentence and added the 2nd sentence about superiority of satellite lidar in context of PSC observation in the 3rd para. of Section 1.

Page 16970 Line 7: I am not sure that the work of Rex et al. (2004) validates the use of the TNAT threshold to identify PSC. Wouldn't the gradient between PSC volume and the ozone depletion metric just change for different temperature thresholds?

We have corrected the description about Rex et al. (2004) in the 3rd para. of Section 1:
The NAT formation temperature (T_{NAT}) is derived by Hanson and Mauersberger (1988), and although dominant nucleation mechanisms remain uncertain and controversial (Lowe and MacKenzie, 2008), the correlation coefficient between the potential PSC volumes using T_{NAT} and the Arctic ozone depletion is more than 0.9 (Rex et al., 2004).

Page 16977 Paragraph 1: The difference in the propagation speed of the PSCs and the zonal mean zonal wind is very interesting. Could the explanation for this pattern be related to a lack of concentricity between the cold pool and the vortex or changes in concentricity? See Mann et al. (2002). If so, this might be related to large-scale flow rather than modulation by the planetary wave field. If not can you explain in a little more detail the modulation idea please.

Because the high-PSC-frequency regions propagate eastward in association with low temperature (contours in Fig. 3b-d), the regions are related to the temperature modulation by planetary waves rather than large-scale flow.
The large-scale temperature modulation is likely to be related to the polar vortex shift. This point is discussed in Section 7, which we have newly added.

Page 16978 Line 7: Would other possibilities include a hysteresis effect in the microphysics (the rate of formation and evaporation of PSC particles differ for example) or the lack of representation of gravity wave perturbations in the ERA-interim data? If the latter could this cause issues in your quantification of the impact of gravity waves?

We agree that detailed cloud microphysics which cannot be expressed by threshold-based estimation and lack of representation of gravity wave perturbations in reanalysis data can bring about differences between the estimation and observation. We have added a sentence about the uncertainty resulting from these two factors to the 6th para. of Section 3.

For the quantification of the impact of gravity waves on PSC areal extent, we used only COSMIC and MLS observations. So, representation of gravity waves in reanalysis does can not affect analyses of gravity waves.

Page 16980 Line 27: The vertical wavelength filtering scheme used to identify gravity waves uses a cutoff wavelength of 6 km. Previous studies have used longer vertical wavelength cutoffs. For example, Baumgartner and McDonald (2007) and Alexander et al. (2011) used a cutoff of 15 km. How sensitive are your results to this value?

In addition, we reinvestigated and compared the effect of gravity waves using two cutoff wavelengths of 6 km and 15 km. When 15 km is chosen as the cutoff wavelength, ΔR_{GW} amounts to about 2% in the latitude for 55°S-70°S in 16-20 km corresponding to relative contribution of about 20%, which is comparable to the results of Alexander et al. (2011). However, in the present analysis, the cutoff length of 6 km is adopted to avoid contamination of planetary waves and synoptic-scale waves having similar vertical scales. We have added a discussion to the 2nd para. of ection 4.2 and 7th para. of Section 8.

Page 16981 Sentence starting on Line 3: References on the observational filter of the COSMIC observations would be relevant at this point.

We have added a sentence about the observational filter to the 1st para. of Section 4.2 and also added Alexander et al. (1998) as a reference.

Figure 7: Identifying the value of TNAT and TSTS on panel (a) would be useful for the reader.

We have added two lines showing T_{NAT} and T_{STS} to Fig. 7 (a).

Page 16982 Paragraph 1 and Figure 8: Why are the PSC areal extent values so large between 8 and 12 km? Is this really PSC or potentially a mixture of PSC and other clouds? I would be very careful of the interpretation of any data below 12 km. Do you have any comment on this point?

As the reviewer pointed out, cloud between 8 km and 12 km may be related to either PSCs or tropospheric clouds, depending on the seasonal and synoptic-scale meteorological conditions. For this reason, the analysis was restricted to the altitude range above 12 km, as mentioned in Section 2.1. We have added sentences to the 1st para. of Section 5.

Figure 11 and Figure 16: I see what seems to be an anti-correlation between the ΔRSW and the ΔRGW lines in

Figure 11 (a) and Figure 16. Does this suggest some difficulties in separating these two fields? See comments on conclusions.

We calculated the correlation coefficients between the two time series of ΔR_{SW} and ΔR_{GW}. The result was quite low, that is -0.02 for Fig. 11(a) and -0.015 for Fig. 16.

Page 16988 Summary and concluding marks: The overall conclusion that gravity waves play a relatively minor role in PSC formation relative to the mean temperatures and planetary wave perturbations seems reasonable. But, the values presented don't match very well with previous work (Mann et al., 2005; Juarez et al., 2009; McDonald et al., 2009; Alexander et al., 2011) using very similar data. The exception is your value of 3% to ΔR which means a 30% contribution to the total in September at high latitudes (see line 26 on Page 16989). The lack of a good match is a bit surprising. In particular, Alexander et al. (2011) uses exactly the same datasets and indicates:
"During winter 2007 in the latitude range 60◦S–70◦S, near the edge of the vortex and where temperatures are close to PSC formation thresholds, 30% of all PSCs are attributable to orographic gravity waves."
This is a big discrepancy which needs to be considered carefully. This could be associated with differences in the way that gravity waves or temperature thresholds are identified in the two studies. In particular, could the proportions for gravity waves be small because of the process used to identify the impact of gravity waves from the COSMIC observations. To look for some consistency between methodologies used to determine the impact of different waves, how do the total PSC areas in Figure 9 (c) and (d) compare. If they are very different, does this suggest that there might be some uncertainty of the attribution of PSC area between synoptic and gravity waves?

First of all, in the previous manuscript, we apologize that we printed an incorrect value for the contribution of gravity waves to PSC coverage ratio (0.5%) in the altitude of 15 km in late August through September by simple mistake. The correct value is 15%. Compared to the result of Alexander et al. (2011), however, the effect of gravity waves is still smaller and observed in the limited altitude range.

The difference between Alexander et al. (2011) and our study mainly results from the difference in a cutoff vertical wavelength, as mentioned above. We have added the comparison of our results with the result using a cutoff wavelength of 15 km to the 8th para. of Section 8, and added Alexander et al. (2011) as a reference.

Typographical corrections:
Page 16968 Sentence starting on Line 10: This sentence should be simplified and perhaps broken into two separate sentences.

We have revised the 5th sentence in Abstract:

'Among the three, the T_{STS} (a threshold for super cooled ternary solution)-based estimates of PSC frequency accord best with the observations in terms of the amount, spatial and temporal variation, in particular, for the latitude ranges of 55°S-70°S and 55°N-85°N.

Page 16970 Line 16: Replace 'Arctic is rarely' to 'Arctic are rarely'

The sentence has been revised following the comment.

Page 16975 Line 1: Change 'as accurate as possible, the observation data of HNO3 and H2O from' to 'as accurately as possible, HNO3 and H2O data from'

The sentence has been revised following the comment.

Page 16979 Line 15: Replace 'V is conserved' with 'PV is conserved'

The sentence has been revised following the comment.

Page 16990 Sentence starting on Line 12: This sentence should be rewritten because it is confused.

We have revised the 2nd sentence in the 10th para. of Section 8:
'The results in this study suggest that T_{NAT}-based PSC areal extent may overestimate actual PSC areal extent because T_{STS} is lower than T_{NAT}, which is consistent with Pitts et al. (2007).'