Reply to Referee 1 Comments

Manuscript-No: acpd-2015-172 - Revised

Sensitivity of polar stratospheric cloud formation to changes in water vapour and temperature

We thank reviewer 3 for the constructive, helpful criticism and the suggestion for revision. We followed the suggestions of reviewer 3 and revised the manuscript accordingly.

This paper reports on the effect on simulated temperature and H_2O water vapor changes on PSC formation and PSC existence time using trajectory calculations in two Arctic winters 2009 and 2011, that are considered cold Arctic winters with extensive denitrification. An additional drop of 1 K and increase of 1 ppmv in H_2O strongly increases the PSC existence time. I think that this part of the study is sound and extends on earlier work, that have suggested such relationship. Using satellite time series it is shown that in Arctic winter months with negative polar temperature anomalies (cold Arctic winters), water vapor mixing ratios are enhanced. The reverse seems to be also true that in warm Arctic winters, H_2O VMRs are lower. This anti-correlation is, however, not always clear to see in the timeseries due to to the uncertainty in the satellite data, but Fig. 14 is convincing.

The weak point of the paper is the attempt to draw any conclusions on long-term polar water vapor trends as was already criticised by the earlier reviewers. The water vapor variability in the polar region is quite large, so that it is indeed difficult to draw any firm conclusions here. Figure 13 shows that the water vapor trends are positive in the last decade, but mostly statistically insignificant for MIPAS, but significant for MLS for most altitudes. Looking at the winter months only (DJF) (Fig. 1 in author's reply to the editor), which is relevant for PSC formation, trends are insignificant for most altitudes in both datasets. As we observe in the tropics very clearly that water vapor can change trends from one decade to the next (including jumps), I would be very cautious to discuss long-term polar winter trends here. The added sentence on significant changes in water vapor should be removed from the abstract or add, at least, that trends are insignificant in winter months (and add the above mentioned DJF figure to the paper). The text related to the decadal trends throughout the paper should be also modified to properly reflect this.

The text in the abstract has been changed as follows: *Performing a linear regression analyses we derive from the Envisat/MIPAS (2002–2012) and Aura/MLS (2004–2014) observations predominantly positive changes in the potential temperature range 350 K to 1000 K. The linear changes in water vapour derived from Envisat/MIPAS observations are largely insignificant,*

while those from Aura/MLS are mostly significant. For the temperature neither of the two instruments indicate any significant changes. Given the strong inter-annual variation observed in water vapour and particular temperature the severe denitrification observed in 2010/11 cannot be directly related to any changes in water vapour and temperature during the past decade. However, the observations indicate a clear correlation between cold winters and enhanced water vapour mixing ratios. This indicates a connection between dynamical and radiative processes that govern water vapour and temperature in the Arctic lower stratosphere.

We added the DJF figure to the supplement and added the following text to section 6 to refer to this figure. *Similar results are derived when instead of all seasons only the winter months DJF (the predominant time for PSC formation) is considered (see supplement).*

Additionally, we changed the parts in the text where we referred to long-term changes and modified the text to: *.....changes water vapour and/or temperature since the millenium.*

Minor point:
The hypothesis by Rex et al. that cold Arctic winters are getting colder in a changing climate is strongly debated, see paper by Rieder and Polvani, DOI:10.1002/grl.50835.
We agree that the hypothesis by Rex et al. has been challenged by the study from Rieder and Polvani. To make clear that the results from Rex are rather a suggestion than a fact we changed the text as follows: *However, if cold Arctic winters will become colder in the future as suggested by Rex et al. (2004, 2006), ice formation will also become more common in the Arctic.*