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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Denitrification and polar stratospheric cloud formation during the Arctic winter 2009/2010" *by* F. Khosrawi et al.

Anonymous Referee #1

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Khosrawi et al. discuss the denitrification of the Arctic winter stratosphere 2009/10 by using data from two ground-based Lidars, one space-borne Lidar, space-borne HNO3 observations and a microphysical box model. They reach the conclusion that the formation of ice-particles on NAT could have been the reason for the observed strong denitrification.

Without major revisions and further analysis I cannot recommend publication in ACP due to the following reasons:

-The discussion of many major aspects of the paper is superficial.

-It is not clear why trajectory calculations have been included at all since (1) only few examples have been shown at all and (2) the main analysis from which conclusions

are drawn (i.e. where temperatures below Tice appeared in relation to CALIPSO and ODIN measurements) could be based on T-analysis data alone.

-The mechanism of denitrification through the formation of NAT 'mother clouds' by mountain waves (Fueglistaler et al., ACP, 2002; Dhaniyala et al., GRL, 2002; Mann et al., JGR, 2005) is not mentioned at all. However, this process might be rather important in winter 2009/10 since in the first half of January there has been major mountain wave activity with formation of high-number density NAT-clouds as described by Pitts et al., ACP, 2011. It is necessary that this mechanism is discussed in relation to possible denitrification caused by the synoptic sub-Tice temperatures in the second half of January.

-The main argument from which it is concluded that 'ice formation on NAT particles with subsequent sedimentation of these particles caused the denitrification as observed by Odin/SMR' is not at all convincing since (1) the low ODIN/SMR HNO3 values are not a direct signal of denitrification when particles are still present in the sounded air, and, (2) even lower HNO3 values are observed before the appearance of synoptic ice PSCs.

Detailed comments:

p.11383, l. 12:

In an introduction on denitrification in the Arctic, the papers by e.g. Fueglistaler et al., ACP, 2002; Dhaniyala et al., GRL, 2002; Mann et al., JGR, 2005 on the denitrification caused by large NAT particles which originate from high number density NAT clouds ("mother clouds") formed by nucleation on mountain wave ice particles should be mentioned.

p.11385, l. 15:

Could you give the information on the horizontal and vertical resolution of the CALIPSO PSC observations which are, due to averaging, not identical to the original single shot measurements?

p.11386, l. 16:

closing bracket missing

p.11388, l. 3: 'a five-day period ending on 19 January'

Pitts et al., 2011 states that the period with synoptic temperatures below Tice is 15-21 Jan. (At least on 20 Jan there was still a large area below Tice according to ECMWF temperature analysis.)

p.11389, l. 10, 19:

The translation of potential temperatures to absolute altitudes is not correct for a typical Arctic winter atmosphere: 450K $\sim$ 18 km (instead of 19 km), 575 K $\sim$ 23 km (instead of 27 km), 465 K $\sim$ 19 km (instead of 20 km), 585 K $\sim$ 23 km (instead of 28 km)

p.11389, l. 15-19: 'The denitrification observed in January 2010 was also the strongest denitrification observed in the entire Odin measurement time period' and Fig. 3:

This statement is not obvious and the discussion of the Figure is much too short. What are about other winters with similar low HNO3 values as 2009/10? E.g. 2007/08 and 2004/05 at lower altitudes and 2006/07 at higher levels? Further, from these plots the other winters seem to have similar low values in e.g. February which does not support the statement that denitrification in 09/10 has been much stronger than in other winters. (There are lowest values at several levels in mid-Jan 2010, but these are not signals of pure denitrification, but also contain the reversible uptake from the gas-phase into particles). The effect of dynamics should be further discussed. Correlation plots of HNO3 with a dynamical tracer to prove and possible quantify the extend of denitrification in 2009/10 might help.

Why are the MLS values of gas-phase HNO3 during the winter months 1991-98 higher than those of Odin/SMR between 2001 and 2010? Has the Arctic stratosphere during all winters 1991-98 been warmer or the vortex weaker than in 2001-2010?

p.11393, l. 1:

Why are these trajectories selected here? One should discuss all (or at least a major part) to get an impression on similarities/differences between the ground-based PSC observations.

p.11393, l. 4: 'was originating'

This is very arbitrary since it depends on the time of the backward trajectories.

p.11393, l. 7: 'was transported furthest'

Is this really the case? Have you determined the absolute length?

p.11395, l. 25:

Why are the temperatures on the (restricted number of) trajectories used for such kind of analysis? I do not see that the information that CALIPSO has observed ice along the trajectories is used to analyse more closely the ground-based lidar observations for which the trajectories have been calculated. In this entire paragraph the analysis could be performed based on temperature analysis fields alone.

p.11396, l. 3: 'temperatures below Tice were caused by waves on 2 January'

Could you discuss here the resolution of the model you've used for the trajectories and how well mountain waves can be resolved by the model?

p.11396, l.12: 'Further, the PSC formation north of Scandinavia agrees spatially and locally quite well with the area where denitrification was observed by Odin/SMR'

This is not right: Odin/SMR observes only the missing HNO3 in the gasphase: this might be due to uptake into the PSC and due to denitrification. It cannot be decided how strong the denitrification has been when particles are still present.

p.11396, l.13: 'Thus, from this coincidence we suggest that ice formation on NAT particles with subsequent sedimentation of these particles caused the denitrification as

observed by Odin/SMR'

This argumentation is not convincing: strong HNO3 depletion has also been observed by ODIN on 9 and 13 Jan (see Fig. 1) . As can be seen from Fig. 2, lowest vortex mean HNO3 values are reached before mid-January, i.e. before the period of synoptic sub-ice temperatures starting on 15 Jan. Further, even on 15 Jan, lowest HNO3 values are also visible in the region NE-of Novaya Zemlya where no temperatures below Tice are visible in ECMWF analysis maps.

p.11396, l.24: 'showed that the air masses were dehydrated during 16 to 19 January'

A personal communication is rather weak. Is there a paper or could the measurements be discussed here a bit in more depth? What was exactly measured by the balloon? Only gas-phase H2O or gas-phase+particulate? What is the accuracy of these measurements? What does ODIN/SMR measurements tell about dehydration?

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 11379, 2011.