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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Unusually strong nitric oxide descent in the Arctic middle atmosphere in early 2013 as observed by Odin/SMR" *by* K. Pérot et al.

Anonymous Referee #3

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This paper analyzes SMR/Odin observation of nitric oxide (NO) taken during the Arctic winter 2012/13 characterized by a strong midwinter stratospheric warming (SSW) and associated elevated stratopause (ES) event. During and after this event, SMR measured large amount of NO in the mesosphere and lower thermosphere (MLT) which descended in the following weeks to the upper stratosphere. The authors attribute these enhancements to the energetic particle precipitation indirect effect (EPP-IE). The EPP-IE-related NO enhancements in 2013 are compared to those observed during a similar event in the NH winter 2008/2009 and differences and similarities are discussed.

The results of this study are of high interest for the investigation of energetic particle

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impacts on the atmosphere, particularly because SMR on Odin is at present the only satellite instrument capable to measure MLT NO with full spatial coverage in polar winters and hence capable to provide a complete picture of EPP-induced impacts on odd nitrogen. The paper is well and concisely written, and the topic of the paper is well suite for ACP. I have only minor comments (listed below) which I would recommend to consider before publication. The most relevant comment is related to the authors' statement that the NO descent observed during the Arctic winter 2012/2013 corresponds to the strongest EPP indirect effect available on record. I feel that this conclusion is not sufficiently supported by the analysis provided in this paper. First, because the magnitude of EPP-IE should be best evaluated in terms of NOx total amounts (i.e. in Gmole) transported downwards in the winter hemisphere rather than looking at maximum volume mixing ratios, and secondly, because no quantitative comparisons between the EPP-IE in 2013 and that of the by now considered strongest NH EPP winter 2004 have been performed.

Specific comments:

p3565 l 8-9: I would not agree that the Ap index can be directly used to infer EPP -NOx production. It is rather a proxy for geomagnetic activity which, in turn, drives the auroral NO production.

p3566 l7-9: It should be made clear that it is not the SSW which brings down the NOx (rather the opposite effect) but the associated ES event afterwards.

p3567, section 2.1: It might be worth mentioning that, after communication with the Envisat satellite got lost, SMR/Odin is at present the only satellite instrument capable to measure NO with full global coverage (including the polar winter regions).

p3568 l18-19: Interestingly, GEOS-5 10 hPa zonal mean zonal winds in Manney et al. 2009 (Fig 1) show a stronger wind reversal in 2009 (easterlies exceeding 20 ms-1) than indicated here by ECMWF data.

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p3569 l14-15: "...this figure shows that the tongue of dry air extended at least 5 km lower in the stratosphere in 2013 than in 2009". Isn't this mainly due to the later onset of the ES event (and also due to the earlier final warming) in 2009 compared to 2013?

p3572 l7: "caused", maybe better: "associated with"

p3573 l15: "all of these values" Which values? All altitude x time points in Fig 4?

p3573 l19: Isn't it the associated ES event rather than the SSW which had a higher potential to affect the stratospheric composition. Of course, both are related, but since the SSW itself causes a polar NOx depletion (primarily by mixing polar and midlatitude air masses) this sentence might lead to confusion.

p3574 l11-12: "...but these results were inconclusive because of the unavailability of ACE data during the first half of the winter,...". I don't see why the unavailability of ACE data during the first half of the winter prevents conclusive results regarding the EPP-IE related to the 2004 ES event. Randall et al. (2009) showed that the upper stratospheric NOx amounts in Feb/March 2004 were at least 3 times higher than in 2009. López-Puertas et al. (2006, DOI: 10.1007/s11214-006-9073-2), looking at MIPAS NO2 data (covering the complete 2003-2004 winter), concluded that these upper stratospheric NOx enhancements were related to EPP-IE induced by the ES event following the SSW in early 2004.

p3575 l12-13: "...and also because there was a possible influence of the strong solar storms that occurred in late 2003..." . The MIPAS data presented in López-Puertas et al. (2006) clearly indicate that the Halloween SPE contribution in the stratosphere and mesosphere is vertically and temporally separated from the contribution caused by the 2004 ES event. Further, Semeniuk et al. (2005, doi:10.1029/2005GL022392) argued that NOx produced by this SPE in the lower thermosphere would hardly survive until January-February (the onset of the ES event). It is thus very unlikely that the October/November 2003 SPEs had a significant influence on the mesospheric and upper stratospheric NOx increases observed in February-March 2004.

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p3575 l14: "EPP-NOx enhancements were larger in 2009 than in 2006 according to Randall et al. (2009)". It is true that Randall et al. reported larger NOx enhancements in 2009 compared to 2006 in terms of maximum VMRs. However, the total amount of NOx (in terms of molecules (in GM) or density) brought into the stratosphere (i.e. , below 2000 K) was higher in 2006 (see Holt et al., 2012, doi:10.1029/2011JD016663).

p3575 l16-18 "SMR measurements presented in our paper confirm therefore that the NO descent observed during the Arctic winter 2012/2013 corresponds to the strongest EPP indirect effect available on record". I'm not sure if this can be concluded from the presented analysis without a comparison to the extremely efficient (in terms of EPP-IE) 2004 NH winter. The EPP-IE strength is not only given by the highest mixing ratios encountered but also by the area covered (vortex size) and the vertical position of the NOx layer (higher densities at lower altitudes). A quantitative comparison would require first to determine the total amount of NOx deposited into the stratosphere in 2013 (in terms of GM) and then compare to existing estimates for other winters (see, e.g., Holt et al., 2012). Why not simply stating that the 2013 winter was among the strongest EPP-IE winters on record?

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 3563, 2014.