Atmos. Chem. Phys. Discuss., 8, S11841–S11844, 2009
www.atmos-chem-phys-discuss.net/8/S11841/2009/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Nitric acid in the stratosphere based on Odin observations from 2001 to 2007 – Part 2: High-altitude polar enhancements" *by* Y. J. Orsolini et al.

Y. J. Orsolini et al.

Received and published: 23 March 2009

We are grateful to the reviewers for careful reading of the manuscript and useful suggestions.

Response to referee 4.

1. We have mentioned relativistic electrons in the Abstract. 2. The term 2-stage enhancement was misleading. We have now chosen to refer to direct and indirect nitric acid enhancements, by analogy with what is used for NOx. Direct enhancements are observed for a short period (1 week) after a SPE event, upwards of a level typically around 1000K. Indirect enhancement are triggered by the descent of mesospheric air and NOx into the stratosphere. In both cases, nitric acid is created in the stratosphere

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

though (unlike the NOx). Both direct and indirect enhancements are shown following three cases of strong SPEs, but the order in which they appear (direct first, or indirect first) depends on the timing of the SPE wrt the seasonal dynamical evolution. 3. A summary of the proposed leading mechanisms has been provided, referring to the most recent literature (e.g. Verronen 2008), and questions have raised where outstanding issues remain. 4. The sentence on NOx enhancements not being always followed by nitric acid enhancements has been rewritten in a clearer way. NOx descents occurring in late winter or spring (like in 2004 or 2006) do not give rise to large nitric acid enhancements. 5. We have avoided using the term polar cap 6. We have discussed in greater detail the SH 2002 event, and the NH 2006 event. 7. We have discussed the vortex recovery from stratospheric warmings in 2004 and 2006, and the impact of the NOx indirect effect. 8. While in the SH winter, descending enhancements reach the main nitric acid layer near 20-25km, when it is low due to sequestration in PSCs, the amount seems too low to significantly re-nitrify the air. 9. We have now mentioned that mixing ratios increase during descent, down to a certain level.

Response to referee 3.

1. We now discuss in more detail the NOx descents in late winter and spring in 2004 and 2006. 2. The asymmetry between NH and SH due to the different vortex strengths has now been mentioned.

Response to referee 2.

1. We have added on figure 1 a time series of high-latitude nitric acid at 1600K in both hemispheres throughout the SMR observation period considered (2001-2007), hence in all seasons. This allows for inter-hemispheric comparisons during specific periods.

Response to referee 1.

The aim of this paper is not to make a detailed modelling study on the chemistry underlying the high-altitude nitric acid polar enhancements. The aim of the joint papers (Part

ACPD
8, S11841–S11844, 2009

I and Part II) is to present new satellite data. Arguably, they could have been merged into a single paper, but we preferred to split it into two parts because of the excessive length and number of figures. It also makes senses as the second part is focused on high-altitude polar enhancements, and is specialised in nature.

We would like to re-iterate that satellite measurements on upper-stratospheric nitric acid have not been made over such an extensive period so far. The data presented here is novel. We also question how well-known these findings are: only MIPAS has observed the two types of enhancements after the Halloween solar storms of 2003, hence there have been only observations of one event. We present here two more clear cases where both direct and indirect enhancements are observed in the same winter.

1. The term 2-stage enhancement was misleading. We have now chosen to refer to direct and indirect nitric acid enhancement, by analogy with what is done for NOx. Direct enhancements are observed for a short period (1 week) after a SPE event, upwards of a level typically around 100K. Indirect enhancement are triggered by the descent of mesospheric air and NOx into the stratosphere. In both cases, nitric acid is created in the stratosphere though (unlike the NOx). Both direct and indirect enhancements are shown following three cases of strong SPEs, but the order in which they appear (direct first, or indirect first) depends on the timing of the SPE wrt the seasonal dynamical evolution. 2. The sentence on NOx enhancements not being always followed by nitric acid enhancements has been rewritten in a clearer way. 3. There is no possible way to carry out the quantitative analysis of how nitric acid enhancements depend on NOx flux, dynamics, … as we only have 7 events. In an early draft, we had drawn scatter plots of nitric acid versus the A-p index, but with so few events the scatter is large, and results cannot be statistically significant. Factoring in dynamical variability, would even lower the number of events that you can composite. The only way to proceed is to make a detailed dynamical/chemistry model simulation, but this is not the objective of this paper. That would require different modelling tools. This is a paper presenting

ACPD

8, S11841–S11844, 2009

Interactive Comment

satellite data that should be useful for future modelling investigations. 4. A summary of the proposed leading mechanisms has been provided, referring to the most recent literature (e.g. Verronen 2008), and questions have raised where outstanding issues remain. 5. New literature has been cited : Verronen (2008), Kawa (1995), Semeniuk (2005). 6. We mention that the enhancements appear in the upper stratosphere/lower mesosphere.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 9591, 2008.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper