Atmos. Chem. Phys. Discuss.,
doi:10.5194/acp-2016-633-RC1, 2016

Atmospheric Chemistry and Physics
Discussions

Interactive comment on "The major stratospheric final warming in 2016: Dispersal of vortex air and termination of Arctic chemical ozone loss" *by* Gloria L. Manney and Zachary D. Lawrence

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Received and published: 17 August 2016

Review of

The major stratospheric final warming in 2016: Dispersal of vortex air and termination of Arctic chemical ozone loss

by Gloria L. Manney and Zachary D. Lawrence

This paper is a well-written, comprehensive study of the fate of the northern hemispheric polar vortex in spring 2016. The paper is well-structured into an Introduction, a Data and Method section, overviews the 2015/2016 polar vortex evolution in Section 3, and, finally, focusses on the early vortex breakup in March 2016 and the subsequent

mixing of vortex air with mid-latitude air. Section 5 summarizes and concludes the paper with clear statements and with a friendly wink and hint to follow the NH vortex evolutions in the future with care. I'm sure, the authors will do so as they possess the suitable diagnostic tools to analyze global satellite and meteorological data in an efficient way.

The Arctic winter 2015/16 was extraordinarily cold and the vortex-wide temperatures felt as low that the conditions in January resembled those of the Antarctic in terms of chemical composition and PSC appearances. Besides the fascinating subject of the recent winter, it is the clarity in structure and writing which make the paper a joy to read.

The Introduction sets the scene by stating "that SSWs affect Arctic lower stratospheric chemical ozone loss in ways much more complex than a simple association of low (high) temperatures with more (less) ozone loss". So it is consequent to read the motivation as: "Thus, understanding the complex relationships between SSW dynamics, stratospheric vortex evolution, and chemical composition and processing, is critical to diagnosing and predicting ozone loss and recovery in the Arctic and its climate consequences." After a short historical view, the authors come back to the topic by discussing the interannual variability of NH winters (minor/major SSWs and dates of final warmings) in close relation to the chemical ozone loss. Some of the main results are already anticipated in the fourth paragraph: (1) "the 2015/16 Arctic winter was the coldest on record (since at least 1979)"; by the way, Matthias et al. (The extraordinarily strong and cold polar vortex in the early northern winter 2015/16, GRL, under review) showed that it is was indeed the coldest in the recent 68 years. (2) a major final warming "beginning in early March 2016 resulted in the breakup of and dispersal of chemically processed air from the vortex, which halted chemical loss much earlier than in 2011".

Section 2 reviews the data sources and the methods. It is impressive to see that the latest versions of MERRA-2 and MLS data are used. The diagnostic quantities and tools are presented systematically. Even newer developments which are in the process of publishing are explained in a comprehensive way. The authors apply a broad spectrum of well-established and newly developed diagnostics to quantify the spatio-temporal variation of the various trace gases and dynamical quantities specifying the mixing in the surf zone of the polar vortex.

The Overview of the 2015/16 vortex evolution and composition focusses on thermal and chemical aspects. For a reader not so familiar with all the peculiarities of the previous winters less direct comparison would be advantageous. Maybe, sentences like (around line 320) "Ozone continued to decrease in the vortex at a rate slightly faster than that in 2011 until the beginning of March 2016. If uninterrupted, ozone values would have been expected to drop lower than those in 2011 by mid-March." could be slightly reformulated to give for example explicit values of rates. But this, for sure, is only a matter of taste. At the end, main results for the winter 2015/16 (in relation to previous ones) are presented and key words are: "leading to unanticipated extremes in Arctic polar processing, the 2015/16 winter stands out as yet another unexpected extreme in variability of the Arctic winter stratosphere." , "The period of over a month, from late December through early February, with temperatures below the ice PSC threshold was unprecedented in the Arctic", "much greater degree of dehydration", and "extreme denitrification", "extensive early winter chlorine activation", and "chemical ozone loss began early". And finally, we read: "Thus, the critical factor resulting in less ozone loss than in 2011 was the much earlier increase in temperatures and vortex breakup in 2016."

The Section 4 about the 2015/16 major final warming and the resulting vortex breakup and mixing exemplifies the trace gas evolution and the strength of the transport barrier, and the mixing especially in the surf zone by refined analyses at different isentropic surfaces representing the conditions in the middle and lower stratosphere. I'm not the expert to evaluate the details of the applied diagnostics but the text reads logical and the conclusions are based on well-funded results from the respective simulations.

Altogether, the paper can be published in the present form!

Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-633, 2016.