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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Vertical structure of Antarctic tropospheric ozone depletion events: characteristics and broader implications" *by* A. E. Jones et al.

Anonymous Referee #2

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General comments

The manuscript entitled "Vertical structure of Antarctic tropospheric ozone depletion events: Characteristics and broader implications" by Jones et al. investigates the meteorological conditions necessary for the built-up of ozone depletion events in Antarctica. The study is based on data from tethered balloon measurements and from historical ozone sonde records, supplemented by sodar measurements which provide information on the vertical structure of the boundary layer. To my knowledge, this is the first publication presenting ozone profile measurements from tethered balloons.

The paper illustrates again that the complex vertical structure of the boundary layer

during Austral spring has a strong impact on the extent of ozone destruction by reactive bromine. The manuscript is therefore well suited for ACP. However, there is a lack of conciseness and I recommend to shorten the manuscript significantly, focussing more on the interpretation of their own (and very interesting) data instead of recapitulating formerly published results.

The detailed interpretation of the observed vertical ozone profiles and the BL structure is followed by a discussion of the meteorological conditions leading to the observed ozone depletion events. The authors suggest that there is a link between low pressure systems and bromine release/ozone destruction, and speculate that this is driven by the heterogeneous bromine release on blowing snow during windy conditions. The measurements were performed in a distance of several kilometres from the coast. It is well known that frequency and properties of ODEs at coastal sites are distinctively different from offshore conditions. Therefore the question arises how representative the measurements at Halley are. While ODEs at coastal sites are mostly of episodic nature, ship-borne measurements of ozone by Bottenheim et al. (2009), but also direct measurements of BrO by long-path DOAS on the Arctic sea ice by Pöhler et al. (2010) reveal that bromine activation and ozone depletion occur almost continuously over the sea ice covered ocean, independent from meteorological conditions (except during situations characterised by high temperatures, when convection leads to the dilution of BrO). Therefore the question arises to what extent the episodic nature of ODEs at coastal sites is determined by transport of bromine activated and ozone depleted air from the ocean to the measurement site, rather than by the stability of the BL. I would appreciate if this aspect would be discussed in more detail. Is it also possible that low pressure systems do not increase the release of BrO into the atmosphere, but merely increase the probability that air is transported from the sea ice to Halley?

To further establish the link between low pressure systems and BrO activation, pressure charts are compared to BrO total column measurements from satellite. There is currently much debate about the influence of meteorology on the observed BrO total column from satellite. It has been shown by Theys et al. (2009) that enhancements in total BrO column can be caused by increases in stratospheric BrO due to a decrease in tropopause height at low surface pressure. It is therefore not possible to conclude on tropospheric BrO from satellite measurements of the total BrO column unless the tropopause height and the corresponding variation of the stratospheric BrO column are considered, as done in the study of Yang et al. (2010).

Apart from the interpretation of the ozone vertical profile measurements performed at Halley, a discussion of earlier published data from Arrival Heights (Kreher et al., 1997) and Neumayer station (Friess et al., 2004) is presented. Section 5.2 consists of a lengthy discussion of the BrO measurements at Neumayer by Friess et al. Based on back trajectory calculations, a comprehensive analysis of the meteorological conditions leading to BrO enhancements and ozone depletion at Neumayer has already been presented by Friess et al. His findings, including the retrieved vertical structure of the BrO, the discussion of the vertical structure of the boundary layer, and the meteorological prerequisites leading to the observation of ODEs and the development of lofted layers, are not mentioned here. Furthermore, GOME BrO satellite maps were already presented by Friess et al. for 24.8., 3.9. and 12.9.1999 as well as 12.9., 17.9. and 23.9.2000. There is no use in showing again some additional satellite maps of BrO from other days (9.9 and 11.9.1999), which exhibit exactly the same patterns. Even a BrO map of the same day as already presented by Friess et al. is shown (23.9.2000). I therefore suggest to remove the BrO maps shown in Fig. 19. Also shown by Friess et al. is that the vertical structure of ODEs measured by ozone sondes agrees well with air that was previously in contact with sea ice. It is not clear what can be learned by discussing additional ozone profiles not shown in the original publication.

There is not much use of showing satellite measurements of the sea ice extent in summer and winter (Fig. 20), unless these can provide new findings. It is sufficient to mention the annual maximum and minimum sea ice area and the dramatic change of sea ice cover with season, as done in Section 5.3, and I suggest to remove Figure 20.

During a major field campaign (CHABLIS) in 2004/2005, extensive ozone and BrO measurements were performed at Halley Bay. It is surprising to see that important findings from this campaign, in particular regarding the frequency and vertical distribution of boundary layer halogens (Saiz-Lopez et al., 2007, 2008), are not mentioned and not even cited, in particular since Jones, Anderson and Roscoe are co-authors of these publications.

Specific comments

Introduction: Measurements of the vertical distribution of bromine compounds in the Arctic have been recently published by Neuman et al. (2010).

P.8191, L11: The reaction cycle referred to as "Bromine Explosion" would be complete if the formation of HOBr by reaction of BrO with HO2 would be mentioned.

P8191, L25: Ship-borne BrO measurements were also performed by Wagner et al. (2007) and Pöhler et al. (2010).

P.8192, L12: The vertical structure of ODEs has also been discussed by Friess et al. (2004).

P.8199, L22: It should be mentioned that the BL features described here are only representative for winter/spring.

P8202, L7: I don't understand why a strongly positive potential temperature gradient indicates that heat is "flowing" from the atmosphere into the snow surface. Vertical heat flux should be strongly suppressed under these very stable conditions.

Section 4.2.2: Please provide some general details of the back trajectory calculations (meteorological fields, trajectory model, references). It would be important to show the altitude of the back trajectories in Fig. 10, as bromine activation should only be expected if the air parcel is in contact with the surface.

P8216, L10: The enhancement in light path observed by MAX-DOAS in Friess et al.

(2004) is certainly not due to sea salt particles (light extinction by sea salt is by far too small), but due to snow drift (which might of course contain a significant fraction of sea salt).

Figures 3-8: To allow for a better comparison, please bring all all axes (altitude, temperature, O3 VMR) in Figures 3 - 8 to the same scale. The x-axes of the ozone profile plots should all start with zero.

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