Atmos. Chem. Phys. Discuss., 10, C5748–C5751, 2010
www.atmos-chem-phys-discuss.net/10/C5748/2010/

Atmospheric Chemistry and Physics Discussions

ACPD

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Interactive Comment

Interactive comment on "Extreme events in total ozone over Arosa – Part 2: Fingerprints of atmospheric dynamics and chemistry and effects on mean values and long-term changes" *by* H. E. Rieder et al.

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Received and published: 27 July 2010

This is the response of H.E. Rieder on behalf of all authors to comments of Robert Lund (Referee 1).

First off all we thank the referee for his positive judgment and comments and valuable suggestions on the paper.

In the following point to point reply the Referee comments are marked with R1:

Specific Comments:

R1:"It would ne nice if the authors could arrange the subsections in Section 3.2 in their order of importance as factors (however gauged), or note this ordering somewhere in the text. It is not clear what the most important factors are."

Contrary to the conventional linear model framework, a ranking of the influencing factors is really difficult (if not impossible) in an extreme value analysis context. Therefore we decided to order them starting with atmospheric dynamics (ENSO, NAO) continuing with volcanic eruptions which have combined chemical and dynamical effects to chemical factors such as polar vortex ozone loss and ODS. Further we state on the difficulty of separating their importance also on P12812,L8: "It is further important to note that various chemical and dynamical factors sometimes occur simultaneously, partly compensating or amplifying each other (e.g. ENSO, NAO, and polar vortex ozone depletion), so that the individual contributions to a specific fingerprint are hard to distinguish."

R1: "The discussion on trends in Section 4 is not clear since LOESS is being used. What is the definition of a trend if it is not linear? How does one justify quantitative statements such as a 60% reduction, 1/3 of the trend, etc.? I would prefer a model that fits a linear trend and a seasonal mean to the post 1970 data. Then report a trend estimate and standard error that accounts for autocorrelation. This inference seems fundamental in quantifying ozone changes."

We apologize if section 4 was unclear. The trend results presented in Table 3 and discussed in section 4 have been derived by a linear trend model for the time period 1970-1990. No LOESS was applied for trend calculations. LOESS was only used for illustration purposes in Figure 4f where annual averages have been smoothed to provide a sketch of the differences between the entire observations and the extremes removed data set. This will be stated more clearly in the revised version of the manuscript.

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Linear trends where calculated for annual/seasonal data so data is not affected by autocorrelation.

The attribution of dynamics and chemistry was estimated through the attribution of the singular factors to either EHOs (e.g. ENSO, NAO- increase number of EHOs while polar vortex ozone loss and ODS decrease the number of EHOs) or ELOs (e.g. NAO+, ODS and volcanic eruptions increase the number of ELOs). As ODS are assumed to influence both tails a larger contribution of the anthropogenic influence to the overall trend was estimated. As we agree that this section can be confusing and the estimation is kind of “ad hoc” we will replace the text on Page 12809 L19 with the text below:

“For annual means, as well as for spring-summer-autumn, we find a stronger trend reduction for the time series without EHOs than for those without ELOs, while in winter the trend reduction is larger when ELOs are removed. Trend reduction is largest in spring, where especially contributions of low ozone from north (after the breakdown of the polar vortex) to Europe can be considered as major influencing variable. In contrast, in winter the time series without ELOs shows a stronger trend reduction which partly might be related to the mode of the North Atlantic Oscillation, as reported by Appenzeller et al. (2000). Ranking of the influencing factors is difficult in an extreme value analysis context and determination of the exact contribution of dynamical and chemical factors on ozone changes is difficult as they sometimes occur simultaneously, partly compensating or amplifying each other. However, as ozone depleting substances are considered to affect both types of extremes (due to chemical ozone depletion and enhanced polar vortex ozone loss) a larger attribution of anthropogenical chemical influence on column ozone is assumed than from dynamics. However, “fingerprint” analysis shows that dynamical factors influence column ozone too and much more frequently and strongly than previously thought. Several studies estimate an influence of 1/3 (or even higher) of dynamical contributions to ozone changes (e.g. Hood and Soukarev, 2005; WMO, 2007; Wohltmann et al., 2007). From the frequent “fingerprints” found for ENSO and NAO within the presented analysis we conclude that the presented results

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are in good agreement with these studies. For the individual seasons it seems that the winter trend is more strongly influenced by dynamical changes (through changes in the polar vortex) than those of spring. Importantly, strong ENSO events also contribute significantly to high column ozone during springtime, an effect that might be disguised by the dominating influence of polar vortex contributions during the past two decades. To quantify the importance of ELOs and EHOs for the Arosa record the influence of ELOs (Eq. 2) and EHOs (Eq. 3) on seasonal and annual averages in total ozone were calculated:...

Further we will exclude on P12812 L11 the sentence “However, comparison of trend reductions in the time series without ELOs and EHOs indicated that about two-thirds of the observed trend in total ozone has anthropogenic causes (ODS and polar vortex ozone loss contributions), while about one third can be attributed to changes in dynamics.“

We hope that these comments and following changes to the revised version of the manuscript improve its quality and clarify the points raised by R1.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 12795, 2010.

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