This is the response of H.E. Rieder on behalf of all authors to the comments of Robert Lund (Referee 1) (marked with R1).

First off all we thank the referee for his positive judgment and comments and valuable suggestions on the paper. The points raised by the Referee are addressed in the point to point reply below.

Specific Comments:

R1:"It is not clear whether autocorrelation is accounted for in the analysis. Is any declustering of threshold exceedence runs done? Certainly, one expects daily ozones to be heavily correlated in time."

The referee states that daily ozone data is heavily correlated and therefore autocorrelation has to be taken into account in the analysis. We completely agree and excuse that this was not clearly mentioned in the methodology part of the paper. Fawcett 2005 showed that if one ignores temporal dependence, estimates for the GPD parameters are still consistent but the standard errors have to be inflated. However to work in a more conventional statistical framework (i.e. independent realizations) the authors decided to take into account for autocorrelation as a declustering procedure was applied prior to threshold selection. The method applied (as suggested by Davison and Smith, 1990) was to formally identify clusters of extremes and then use only the maximum (minimum) of each cluster in the analysis. A cluster is defined as consecutive exceedances above/below a certain threshold u. Once an observation falls below/above u the cluster is deemed to have terminated. A declustering parameter κ (a separation interval between neighboring clusters) is introduced to mitigate the potential dependence between clusters. For our analysis we found that κ = 1 day was sufficient to remove any serial dependence.

R1: "While daily ozones have seasonal means and variances, it is not evident to me that a seasonally varying threshold is physically appropriate here. I thought the health hazard involved ozone lows. This would seem to suggest a constant threshold — and then an analysis of a periodic process crossing this time-homogeneous threshold, irrespective of season of threshold exceedence. This said, I don't object to the seasonal threshold as the authors seem more interested in trends."

Within this study the focus was on extreme low and high total ozone and the influence of atmospheric dynamics and chemistry. Therefore a time varying threshold was applied. However we agree that for studies dealing on the health hazard resulting from an increased erythemal UV-dose caused by low ozone values only, a constant or UV-oriented threshold would be the proper choice. Recently we published another paper (Rieder et al., 2010) exactly dealing on this topic analyzing the relationship between high daily erythemal UV-dose, low total ozone, surface albedo and cloudiness for the Central Alpine Region. Within this publication the choosen ozone threshold is health hazard oriented and depends on UV-doses.

R1: "For purposes of extremes, I think the authors would have been better to convince me that the tails of the detrended and deseasonalized data are non-Gaussian rather than the entire distribution. This could have been accomplished with a kernel density estimate comparison overlayed with a normal density fit. I don't think the quoted p-values are appropriate for correlated data anyway."

The authors do think that it can be seen that the detrended and deseasonalized data are far from being normal from Figure 2. However, to focus only on the tails we provide here an additional figure based on the comments of R1 (see Fig. 1 below) where the tails of the detrended and deseasonalized data (observations below/above the 0.05/0.95 quantiles) are compared with a normal distribution.

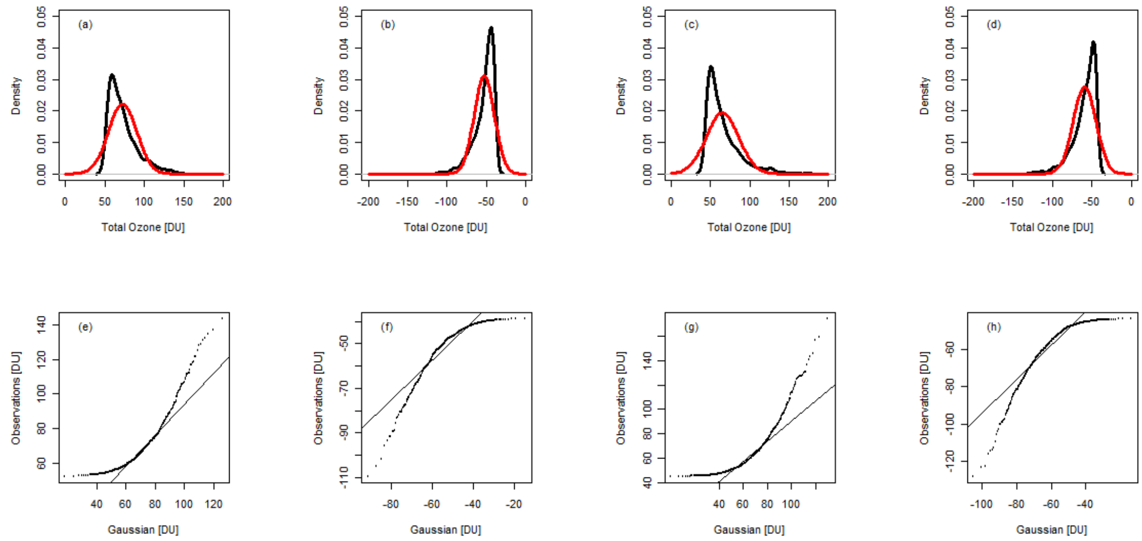

Figure 1: Density Plots for (a) high days (above the 0.95 quantile), (b) low days (below the 0.05 quantile) for detrended and deseasonalized data of 1927-59, (c) and (d) as (a) and (b) but for data of 1960-2008, (e)-(h) QQ-Plots for data shown in (a)-(d). Note: Solid black lines in (a)-(d) show density curves for the detrended and deseasonalized Arosa data while red solid lines show the corresponding Gaussian.

R1: "Given the near sinusoidal shapes in Figure 8, why not fit a a seasonal GPD model of form

$$F_v(x) = 1 - \left[1 + \xi\left(\frac{x - u_v}{\sigma_v}\right)\right]_+^{-1/\xi}$$

Where v represents the season and satisfies 1≤v≤365 = T (ignore leap year data) and the seasonal parameters have the sinusoidal form

$$u_v = A + B cos\left(\frac{2\pi(v-\tau)}{T}\right);\ \sigma_v = C + D\ (cos\left(\frac{2\pi(v-\xi)}{T}\right)\ ?\ \text{"}$$

Here R1 proposes a different and more complicated model. Our model, which is simpler, has the merit of emphasizing more on the use of EVT for ozone problems rather than obscuring it with a more complex statistical model. As R1 states within the model he proposes one would be forced to choose 3 coefficients (A,B and τ) kind of "ad hocly" which makes the analysis more complicated in practice.

We agree that such class of models is interesting and should be considered in further analysis. However, this type of modeling is probably better embedded in a point process framework which is beyond the scope of this paper. Our main goal was to introduce for the first time the concept of the extreme value theory in column ozone research.

R1:"I would appreciate the authors stating the LOESS smoothing parameters so that their analysis could be reproduced. It do not think it matters much, but the trend seems undersmoothed. It might be worth noting that the so called hinge function used in meteorology — a constant up until the onset of ozone depleting substances and then linear thereafter — is a parametric trend perhaps worth investigating.”

Within the stl-R function the default settings have been used. Those correspond for our application on total ozone data from Arosa (in Figure 3) to t.window=549, t.degree=1, s.window=”periodic” and s.degree=0. This information will be also provided in the caption of the figure in the revised version of the manuscript.

R1 states application of a hinge function (R1: “constant up until the onset of ozone depleting substances and then linear thereafter”) as an alternative trend estimate. We think the use of local polynomial models is more flexible than assuming a linear trend starting from a certain point. Further the atmospheric burden of ozone depleting substances shows an increase from the 1960s/70s followed by a decline since 1997, which can also not be modeled by a hinge function (which would correspond to a linear trend).

Trite Comments:

We thank the Referee for addressing these typos and small corrections. All these changes will be done accordingly.

References:

Davison, A. C. and Smith, R. L.: Models for Exceedances over High Thresholds, J. Roy. Stat. Soc. Ser. B, 52(3) 393–442, 1990.

Fawcett, L.: Statistical Methodology for the Estimation of Environmental Extremes, PhD Thesis, University of New Castle, 2005.

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