Geophysical Research Abstracts
Vol. 12, EGU2010-11469, 2010
EGU General Assembly 2010


# Extreme events in total ozone over the northern mid-latitudes: A case study based on long-term data sets from 5 ground-based stations

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In this study we analyze the frequency distribution of extreme events in low and high total ozone (termed ELOs and EHOs) for 5 long-term stations in the northern mid-latitudes in Europe (Belsk, Poland; Hradec Kralove, Czech Republic; Hohenpeissenberg and Potsdam, Germany; and Uccle, Belgium). Further, the influence of these extreme events on annual and seasonal mean values and trends is analysed. The applied method follows the new "ozone extreme concept", which is based on tools from extreme value theory [Coles, 2001; Ribatet, 2007], recently developed by Rieder et al. [2010a, b]. Mathematically seen the decisive feature within the extreme concept is the Generalized Pareto Distribution (GPD). In this analysis, the long-term trends needed to be removed first, differently to the treatment of Rieder et al. [2010a, b], in which the time series of Arosa was analysed, covering many decades of measurements in the anthropogenically undisturbed stratosphere. In contrast to previous studies only focusing on so called ozone mini-holes and mini-highs the "ozone extreme concept" provides a statistical description of the tails in total ozone distributions (i.e. extreme low and high values). It is shown that this concept is not only an appropriate method to describe the frequency and distribution of extreme events, it also provides new information on time series properties and internal variability. Furthermore it allows detection of fingerprints of physical (e.g. El Niño, NAO) and chemical (e.g. polar vortex ozone loss) features in the Earth's atmosphere as well as major volcanic eruptions (e.g. El Chichón, Mt. Pinatubo). It is shown that mean values and trends in total ozone are strongly influenced by extreme events. Trend calculations (for the period 1970-1990) are performed for the entire as well as the extremes-removed time series. The results after excluding extremes show that annual trends are most reduced at Hradec Kralove (about a factor of 3), followed by Potsdam (factor of 2.5), and Hohenpeissenberg and Belsk (both about a factor of 2). In general the reduction of trend is strongest during winter and spring. Throughout all stations the influence of ELOs on observed trends is larger than those of EHOs. Especially from the 1990s on ELOs dominate the picture as only a relatively small fraction of EHOs can be observed in the records (due to strong influence of Mt. Pinatubo eruption and polar vortex ozone loss contributions). Additionally it is evidenced that the number of observed mini-holes can be estimated highly accurate by the GPD-model. Overall the results of this thesis show that extreme events play a major role in total ozone and the "ozone extremes concept" provides deeper insight in the influence of chemical and physical features on column ozone.

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