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Impacts of solar particle events on middle atmospheric chlorine compounds

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Solar particle events (SPEs) are well known sources of chemical perturbations in the middle atmosphere. A well-understood effect is the release of reactive NO_x and HO_x, and the subsequent destruction of ozone. Satellite measurements (HALOE, MIPAS, AURA-MLS) have shown that there is also chlorine activation in the stratosphere and mesosphere, and an increase of chlorine nitrate in the lower and middle stratosphere during SPEs. This cannot be explained by the NO_x and HO_x increase alone. Atmospheric models with standard parametrizations of NO_x and HO_x production due to SPEs fail to reproduce the magnitude of the observed chlorine disturbances.
Numerical simulations using the University of Bremen ion chemistry (UBIC) model show a much better agreement with measurements if full negative ion chemistry is considered additionally to the NO_x and HO_x production. The UBIC results in combination with atmospheric models indicate that reactions of negative cluster ions can have a significant impact on the middle atmosphere's chlorine chemistry during SPEs. There is a transformation of HCl into active chlorine via anion cluster chemistry. Additionally, the release of $O(^1D)$ through $N(^2D) + O_2 \rightarrow NO + O(^1D)$ has a considerable impact on chlorine species.
Results of UBIC simulations for different SPEs (July 2000, October 2003, January 2005) are presented. They are compared with the observed changes of chlorine compounds – HCl, HOCl, ClO and $ClONO_2$ – from the satellite instruments HALOE, MIPAS and AURA-MLS.