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Short- and medium-term atmospheric constituent effects of very large solar proton events

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Abstract. Solar eruptions sometimes produce protons, which impact the Earth's atmosphere. These solar proton events (SPEs) generally last a few days and produce high energy particles that precipitate into the Earth's atmosphere. The protons cause ionization and dissociation processes that ultimately lead to an enhancement of odd-hydrogen and odd-nitrogen in the polar cap regions (>60° geomagnetic latitude). We have used the Whole Atmosphere Community Climate Model (WACCM3) to study the atmospheric impact of SPEs over the period 1963–2005. The very largest SPEs were found to be the most important and caused atmospheric effects that lasted several months after the events. We present the short- and medium-term (days to a few months) atmospheric influence of the four largest SPEs in the past 45 years (August 1972; October 1989; July 2000; and October–November 2003) as computed by WACCM3 and observed by satellite instruments. Polar mesospheric NO_x ($NO+NO_2$) increased by over 50 ppbv and mesospheric ozone decreased by over 30% during these very large SPEs. Changes in HNO_3, N_2O_5, $ClONO_2$, HOCl, and ClO were indirectly caused by the very large SPEs in October–November 2003, were simulated by WACCM3, and previously measured by Envisat Michelson Interferometer for Passive Atmospheric Sounding (MIPAS). WACCM3 output was also represented by sampling with the MIPAS averaging kernel for a more valid comparison. Although qualitatively similar, there are discrepancies between the model and measurement with WACCM3 predicted HNO_3 and $ClONO_2$ enhancements being smaller than measured and N_2O_5 enhancements being larger than measured. The HOCl enhancements were fairly similar in amounts and temporal variation in WACCM3 and MIPAS. WACCM3 simulated ClO decreases below 50 km, whereas MIPAS mainly observed increases, a very perplexing difference. Upper stratospheric and lower mesospheric NO_x increased by over 10 ppbv and was transported during polar night down to the middle stratosphere in several weeks past the SPE. The WACCM3 simulations confirmed the SH HALOE observations of enhanced NO_x in September 2000 as a result of the July 2000 SPE and the NH SAGE II observations of enhanced NO_2 in March 1990 as a result of the October 1989 SPEs.

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