We have compared composition changes of NO, NO$_2$, H$_2$O$_2$, O$_3$, CO, N$_2$O, HNO$_3$, N$_2$O$_5$, HNO$_4$, ClO, HOCI, and ClONO$_2$ as observed by MIPAS in the aftermath of the “Halloween” solar proton event (SPE) and simulations performed by the following atmospheric models: B2dM, B3dCTM, CAO, FinROSE, HAMMONIA, KASIMA, EMAC, SOCOL(i), and WACCM4. Particle-induced ionization rates have been taken from the AIMOS model. The large number of participating models allowed for an evaluation of the overall ability of atmospheric models to reproduce observed atmospheric perturbations generated by SPEs, particularly with respect to NOy and ozone changes. We have further assessed the meteorological conditions and their implications on the chemical response to the SPE in both the models and observations by comparing temperature and tracer fields. Observed and simulated ozone losses agree on average within 5%. Simulated NOy enhancements around 1 hPa, however, are typically 30% higher than indicated by the observations which can be partly attributed to an overestimation of simulated electron-induced ionization. The analysis of the observed and modeled NOy has demonstrated the need to implement additional ion chemistry. An overestimation of observed H$_2$O$_2$ enhancements by all models hints at an underestimation of the OH/HO$_2$ ratio in the upper polar stratosphere. The analysis of chlorine species perturbations has shown that differences between models and observations are related to a smaller availability of ClO in the polar night region already before the SPE. Further, differences in meteorology and/or initial state cause significant dispersion of modeled SPE responses, even on a short timescale.