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Is there a direct solar proton impact on lower-stratospheric ozone?

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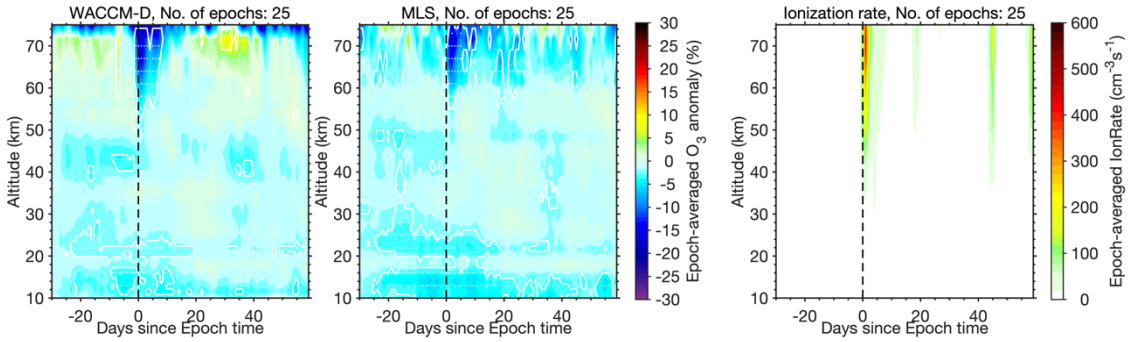

Figure S1. SEA of relative ozone anomalies (%) from MLS and WACCM-D during July 2004-December 2012 (left two panels) and the SEA result of the corresponding ionization rates (right panel). WACCM-D ozone profiles used in this figure are the profiles at MLS measurement time and locations.

The intention of this SEA comparison investigation is the same as the one of Fig.5. We use the fact that WACCM-D does not include proton input with energy >300 MeV, thus should not include any direct SPE impact below 25km, to identify the source of the observed ozone depletion at very low stratosphere. Below 25km, although the patterns of 95% significant level are different, the ozone anomaly patterns are consistent between the two data sets. We address the figure above as another supportive evidence that the ozone loss showed in SEA in Fig.2 is most likely not a result of direct SPE impact.

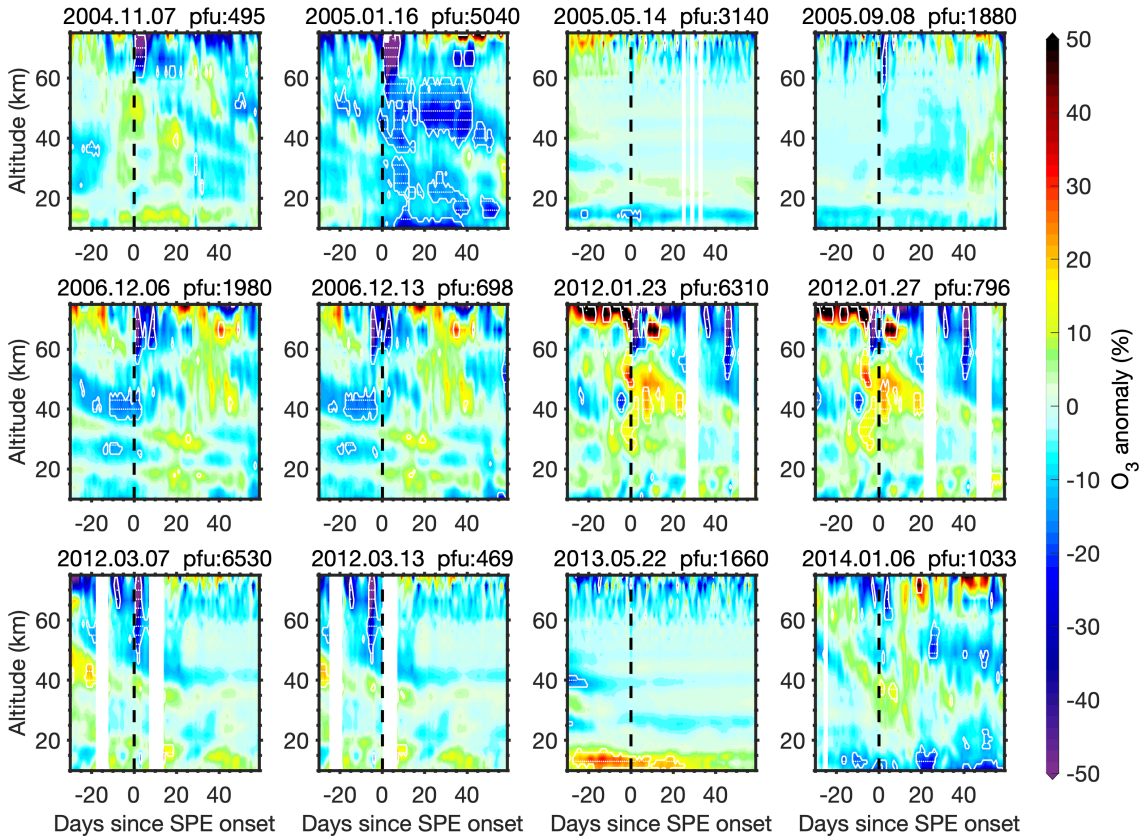

Figure S2. Same as Fig. 3 but the MLS ozone anomalies are reported as relative changes (%), the climatology was calculated during the whole observation period.

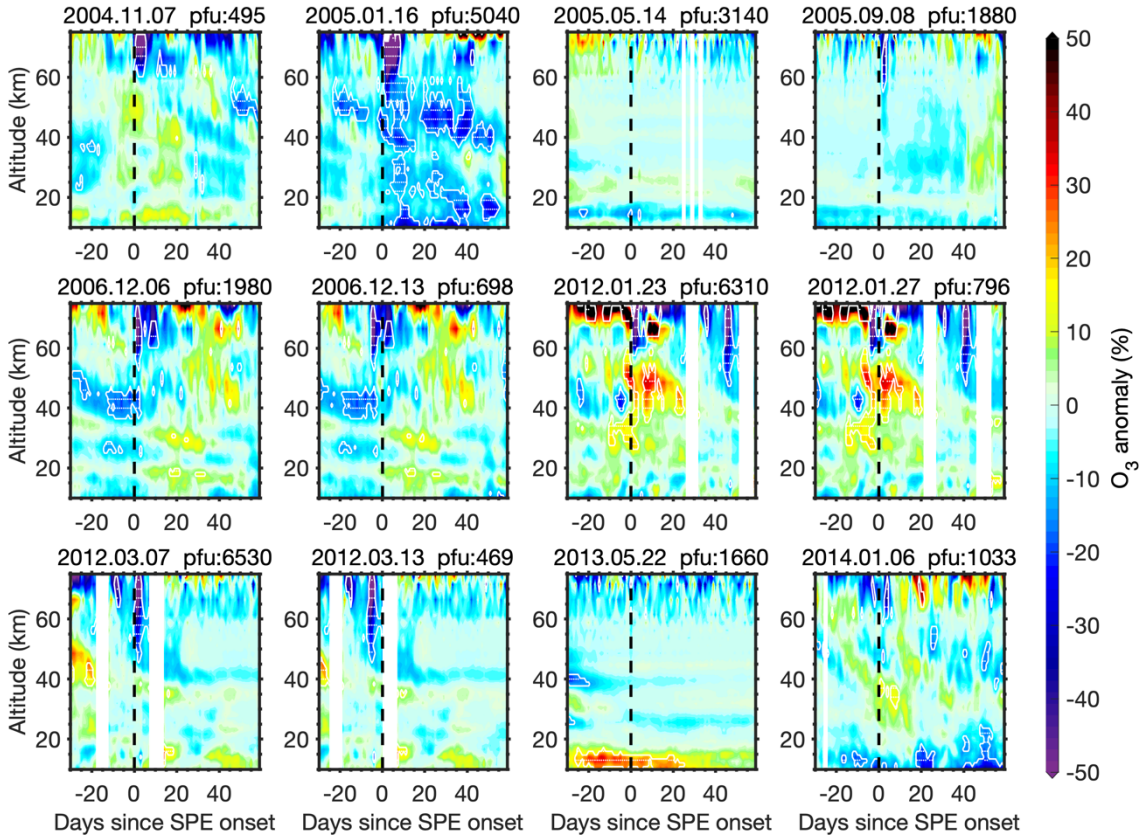

Figure S3. Same as Fig. S2 but the MLS ozone anomalies are calculated by subtracting a daily ozone climatology using median (instead of mean) values of MLS data from 2004 to date.

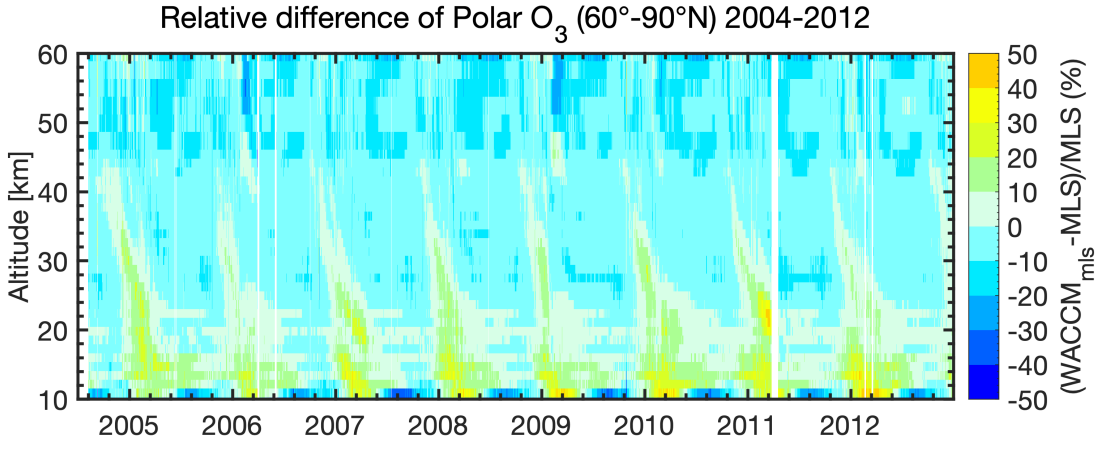

Figure S4. Relative difference of daily polar ozone between WACCM-D ozone simulation at MLS observation time and location and the MLS satellite observation.