Space weather induced direct ionisation effects in the ozone layer?

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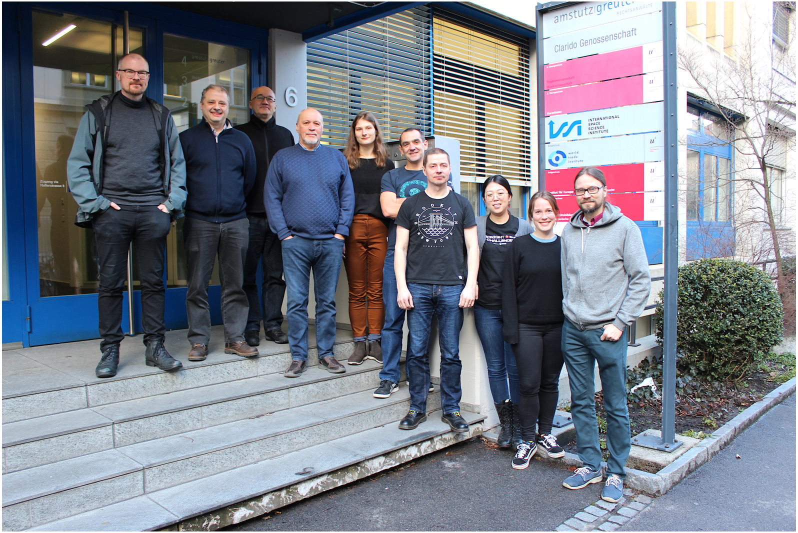
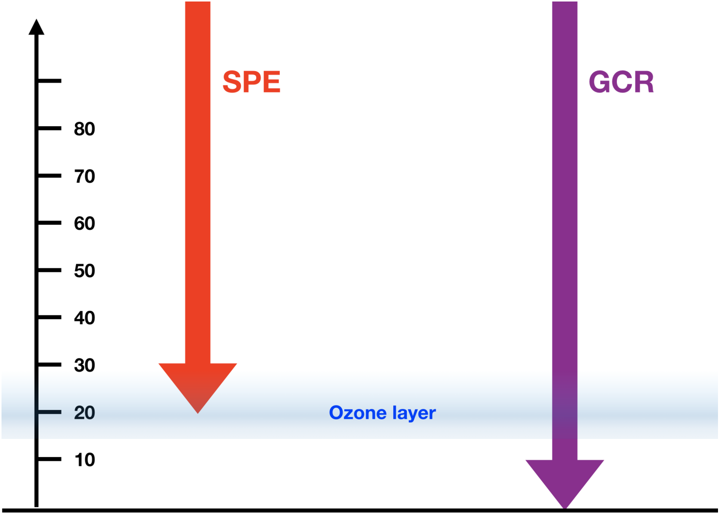
Group photo (5th of February 2020)



Basic ideas



SPE impact on the Ozone layer

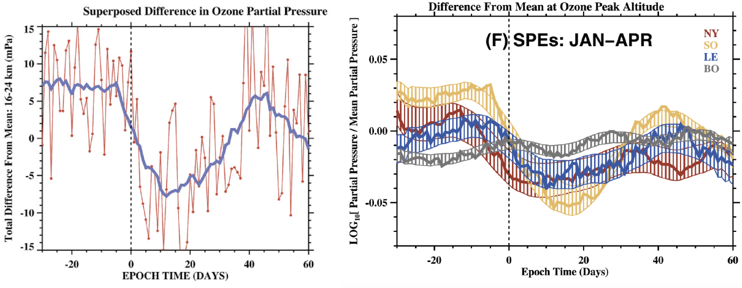


Fig. 1. Left: Superposed epoch analysis of Sodankylä Ozone sond partial pressure for a set of solar proton events that occurred during Jan-April (Denton+, JASTP, 2018). Right: Similar analysis carried out for several sounding stations: Ny Ålesund, Sodankylä, Lerwick and Boulder (Denton et al., GRL 2018).

GCR vs. Ozone layer

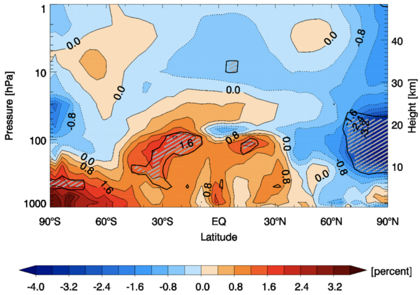


Fig. 5. Annual mean effect of GCRs on zonal mean ozone, $([O_3]_{GCR}-[O_3]_{control})/[O_3]_{control}$, given in percent. Results are averaged from 1978–2002 (after allowing for a 2-year model spin-up) with appropriate accounting for solar minimum and maximum periods. Hatched areas (enclosed by thick solid contours) indicate changes with at least 95 % statistical significance.

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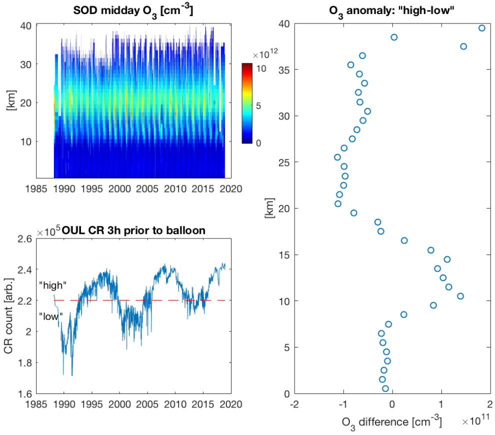
[1] Calisto, M., Usoskin, I., Rozanov, E., and Peter, T.: Influence of Galactic Cosmic Rays on atmospheric composition and dynamics, Atmos. Chem. Phys., 11, 4547–4556, https://doi.org/10.5194/acp-11-4547-2011, 2011.

GCR vs. Ozone layer: Sodankylä balloon soundings



Our outcomes so far ...

- Niilo's paper out!

  Kalakoski, Niilo & Verronen, Pekka & Seppälä, Annika & Szelag, M. & Kero, Antti & Marsh, Daniel. (2020). Statistical response of middle atmosphere composition to solar proton events in WACCM-D simulations: importance of lower ionospheric chemistry. 10.5194/acp-2019-1133.

- Kseniia's paper out!

  Golubenko, K., Rozanov, E., Mironova, I., Karagodin, A., & Usoskin, I.. (2020). Natural sources of ionization and their impact on atmospheric electricity. *Geophysical Research Letters*, 47, e2020GL088619. https://doi.org/10.1029/2020GL088619

- Jia's paper out!

  Jia, J., Kero, A., Kalakoski, N., Szeląg, M. E., and Verronen, P. T.: Is there a direct solar proton impact on lower-stratospheric ozone?, Atmos. Chem. Phys., 20, 14969–14982, https://doi.org/10.5194/acp-20-14969-2020, 2020.

Kolubenko et al., 2020: atmospheric electricity, SOCOL

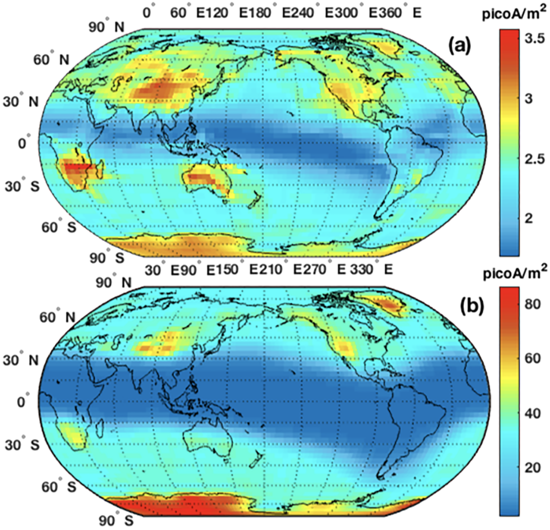


Figure 5. Global map of the vertical current density distribution for the quiet scenario 1 (GCR + Rn-222—panel a) and for the extreme scenario 2 (GCR + Rn-222 + SPE—panel b). Note the different scales in the two panels.

Kalakoski et al., 2020: SPE impact on composition, WACCM-D

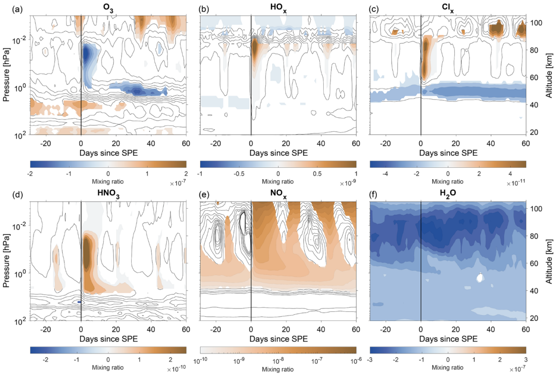


Figure 4. Area-weighted northern polar cap averages (latitude > 60° N) of composite means of $\widehat{\mathrm{WD}}$ for O_3, HO_x, Cl_x, HNO_3, NO_x and H_2O. The x axis shows the number of days before and after the event (day 0, solid black line) and the y axis pressure levels in the model (hPa, **a, d**) and approximate altitude (km, **c, f**). Note that the color scale for NO_x panel is logarithmic, and all contours shown in that panel indicate positive difference.

Jia et al., 2020: SPE impact on composition, MLS data

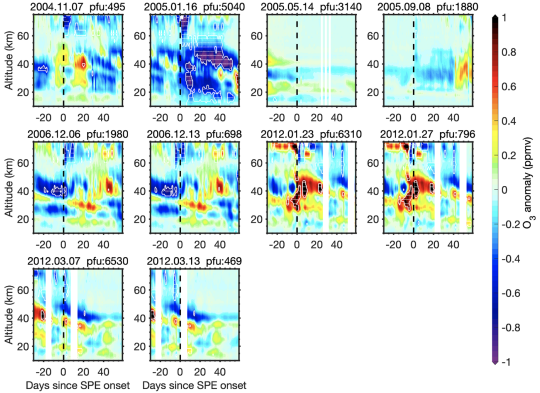


Figure 3. MLS ozone anomalies (in ppmv) along with altitude at 30 d before and 60 d after individual large SPEs (proton fluxes > 400 pfu) in July 2004–December 2012. The white thick line area demonstrates ozone anomalies with > 95 % confidence after the Monte Carlo test.

SPE impact on the Ozone layer, balloon sounding data revisited!

M.H. Denton et al. Journal of Atmospheric and Solar-Terrestrial Physics 177 (2018) 218–227

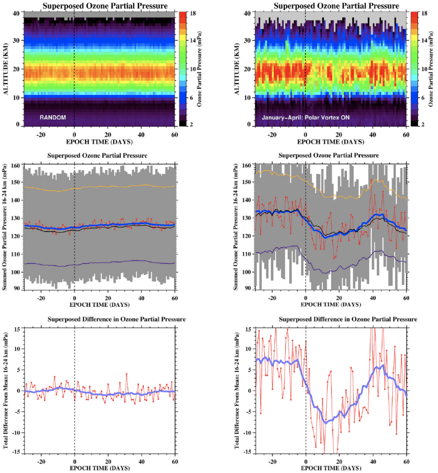
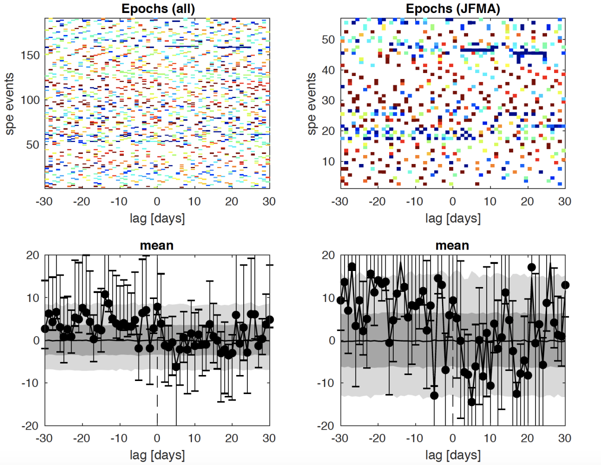
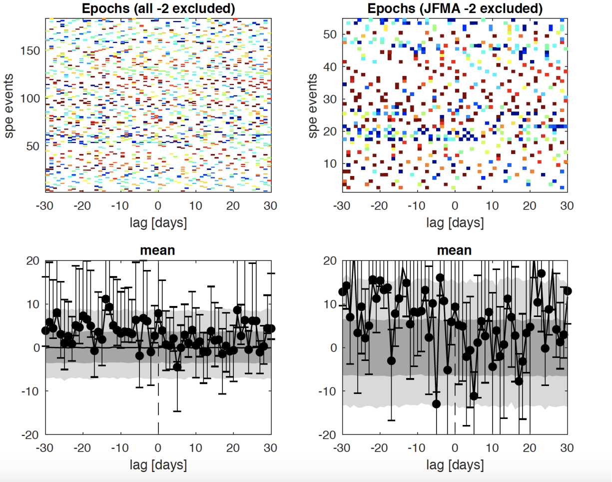


Fig. 6. The same format as shown in Figs. 4 and 5, but here data are only plotted for January, February, March and April, when the polar vortex is ACTIVE over Northern Finland. There is a clear trend for a decrease in the stratospheric ozone population following the SPEs.

The Sodankylä Ozone sonde dataset: SEA



The Sodankylä Ozone sonde dataset: SEA (-2 epochs)



Summary

- We have found (mostly) counterevidence on the overall direct SPE impact on the Ozone layer.
- GCR impact on the Ozone layer needs more investigation.
- An extreme SPE is expected to alter the atmospheric electricity!