Finnish Meteorological Institute

Mesospheric ozone loss due to the energetic electron precipitation

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Abstract

Energetic electrons which originate from explosions on the surface of the Sun are stored and energized in the radiation belts. Strong acceleration and loss processes that occur during geomagnetic storms can boost the trapped population and lead to signicant loss of electrons into the atmosphere.

Energetic electron precipitation (EEP) affects the neutral chemistry of the middle atmosphere at magnetic latitudes 55-65° N/S, through the enhanced production of odd hydrogen (HO_x), and odd nitrogen (NO_x). Both, HO_x and NO_x play a major role in the ozone (O_3) balance via participating in the ozone-destroying catalytic reactions. Recent studies have provided clear evidence of the connection between EEP and mesospheric hydroxyl (OH) [Andersson *et al.*, 2012; Verronen *et al.* 2011].

Here, we combine 11 years of ozone measurements from the GOMOS/ENVISAT, SABER/TIMED, MLS/AURA and MEPED/POES instruments to show the signicance of the EEP to the mesospheric ozone variability at magnetic latitudes connected to the radiation belts. We examine 57 EEP events between 2002-2012 with daily mean 100-300 keV electron count rates (ECR) exceeding 150 counts/s in the outer radiation belt and show that strong EEP events can cause signicant ozone loss, being comparable with solar proton event (SPE).

Data

GOMOS

Global Ozone Monitoring by Occultation of Stars

Vertical resolution: 2 km
SEM: 18 % (NH) and 14% (SH)
Number of profiles: 3-50

SABER

Sounding of the Atmosphere using Broadband Emission Radiometry

Vertical resolution: 2 km
SEM: 13% (NH) and 9% (SH)
Number of profiles: 4-82

MLS

Microwave Limb Sounder

Vertical resolution: 5 km
SEM: 21% (NH) and 23% (SH)
Number of profiles: 7-199

MEPED

Medium Energy Proton Electron Detector

Observation processed to give precipitating electron counts from 100-300 keV
L shells: 3.0-5.6

Results

EEP and SPE between 2002-2012

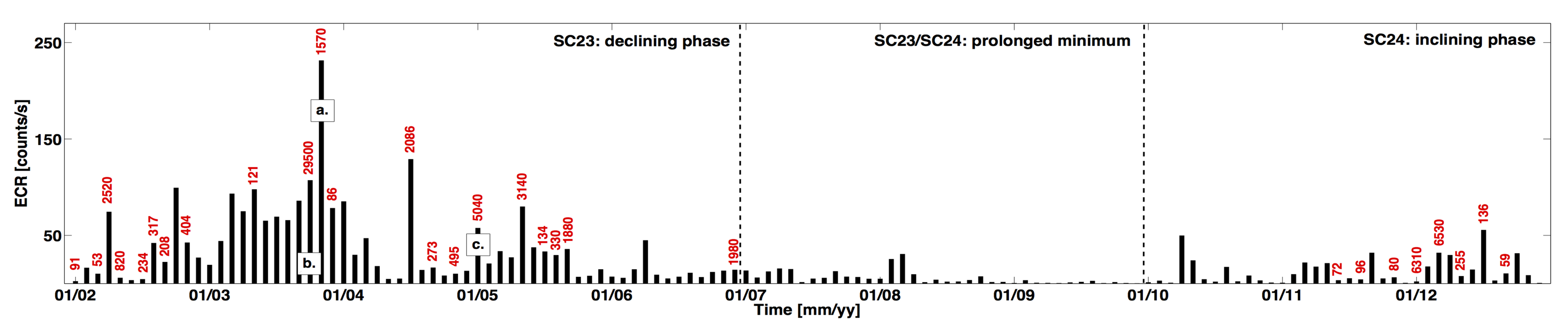

Fig.1. Monthly mean ECR (black bars) and maximum proton flux > 10 MeV in proton flux units(red numbers).

Ozone changes during EEP - examples

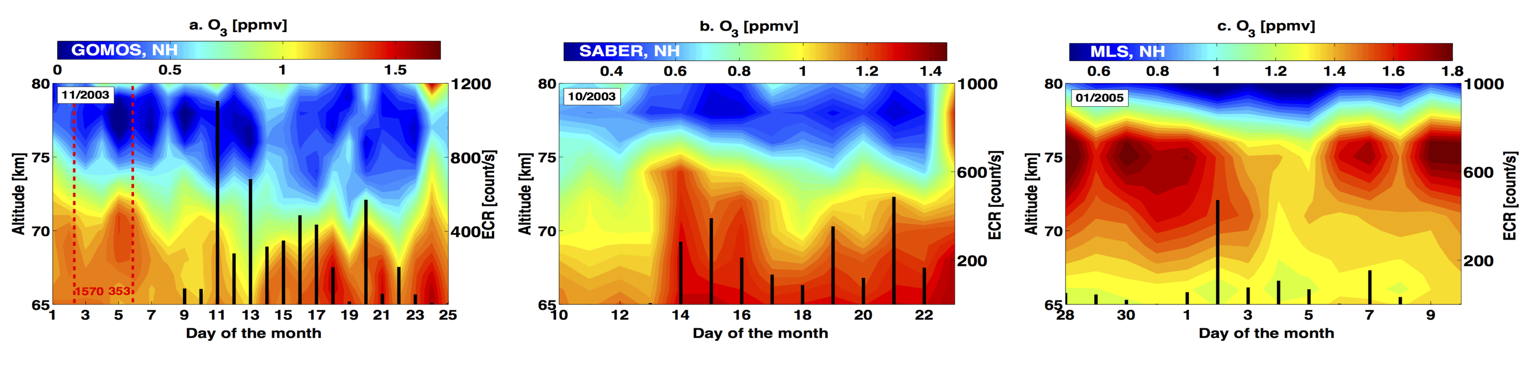

Fig. 2. Zonal mean O_3 mixing ratio during selected EEP events from: a. GOMOS, b. SABER and c. MLS. Black bar indicate daily mean ECR. Dotted lines and black numbers highlight the SPE event and the maximum proton flux.

Ozone anomalies during selected EEP - examples

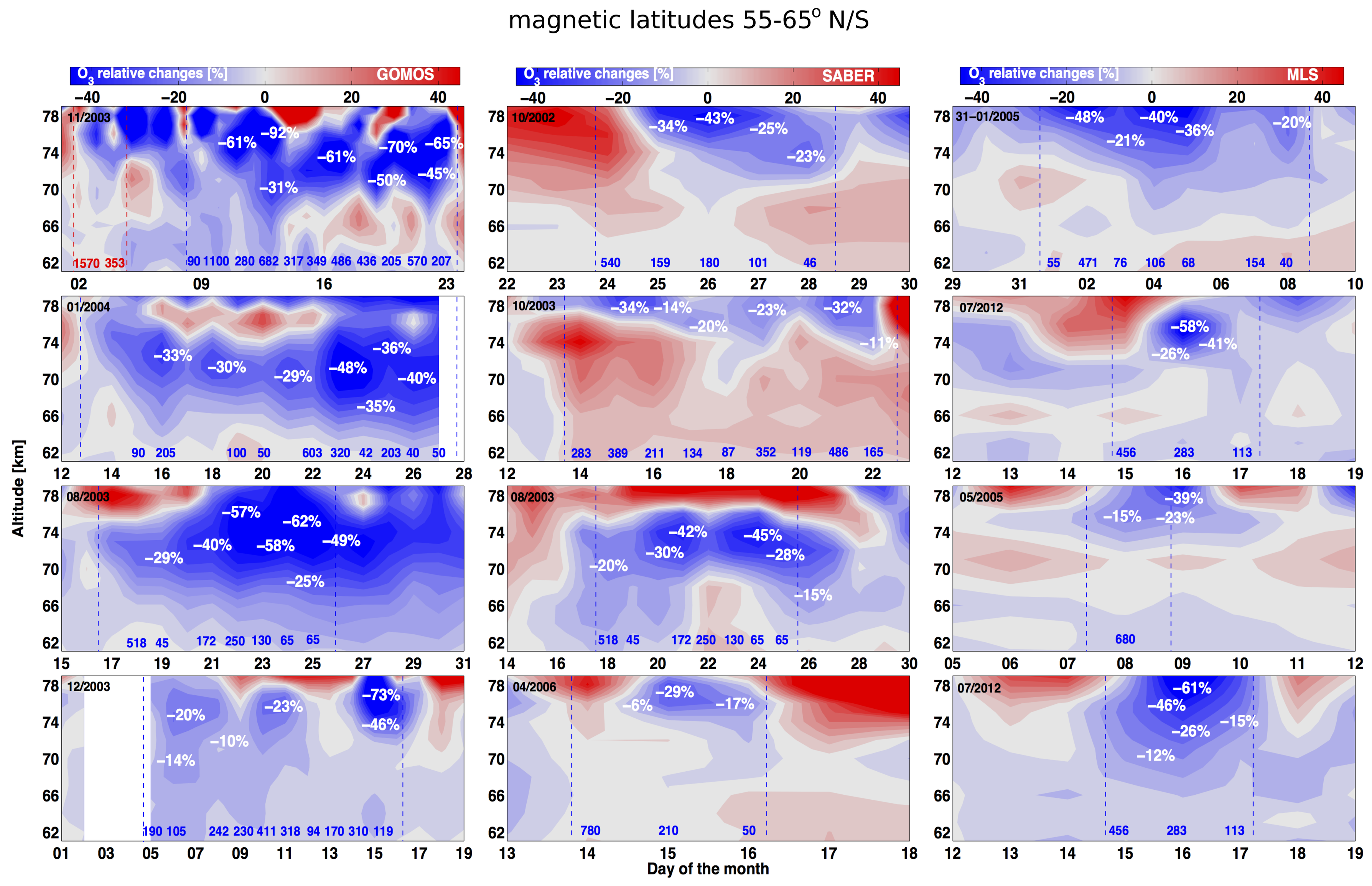

Fig. 3. Mesospheric O_3 anomalies [%] relative to a 5 day average before the EEP event. White numbers indicate O_3 loss at different altitudes.Blue lines and blue numbers highlight the EEP event duration and daily mean ECR. Two top rows show the NH, two bottom rows show the SH.

Ozone anomalies between 2002-2012 - summary

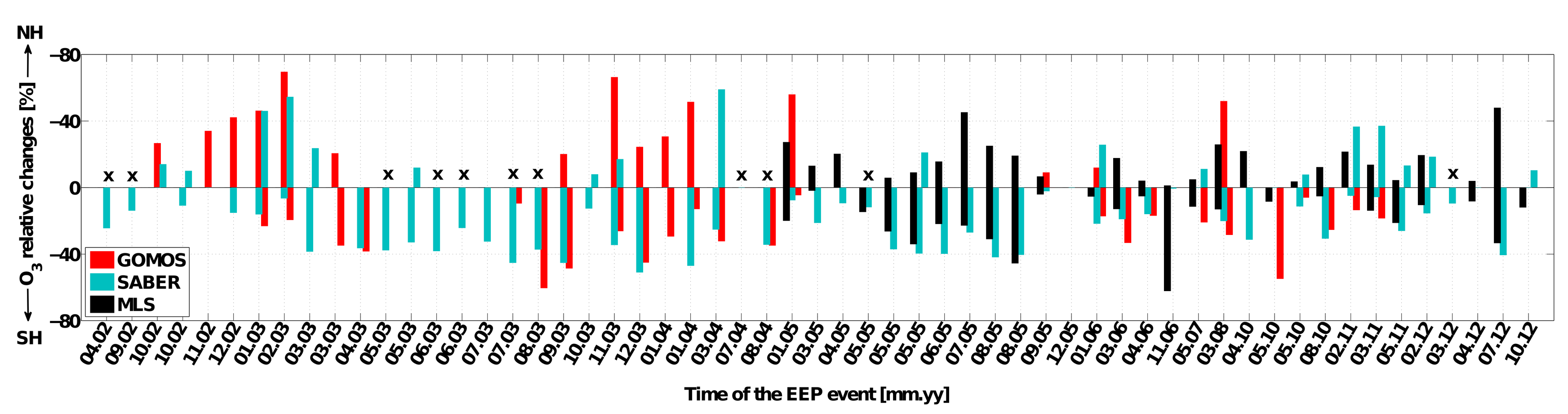

Fig. 4. Mean O_3 relative changes during 57 EEP events (ECR > 150 counts/s) at 75 km and magnetic latitudes 55-65° N/S from GOMOS, SABER and MLS. Missing data are marked by x.

Monthly mean O_3 profiles

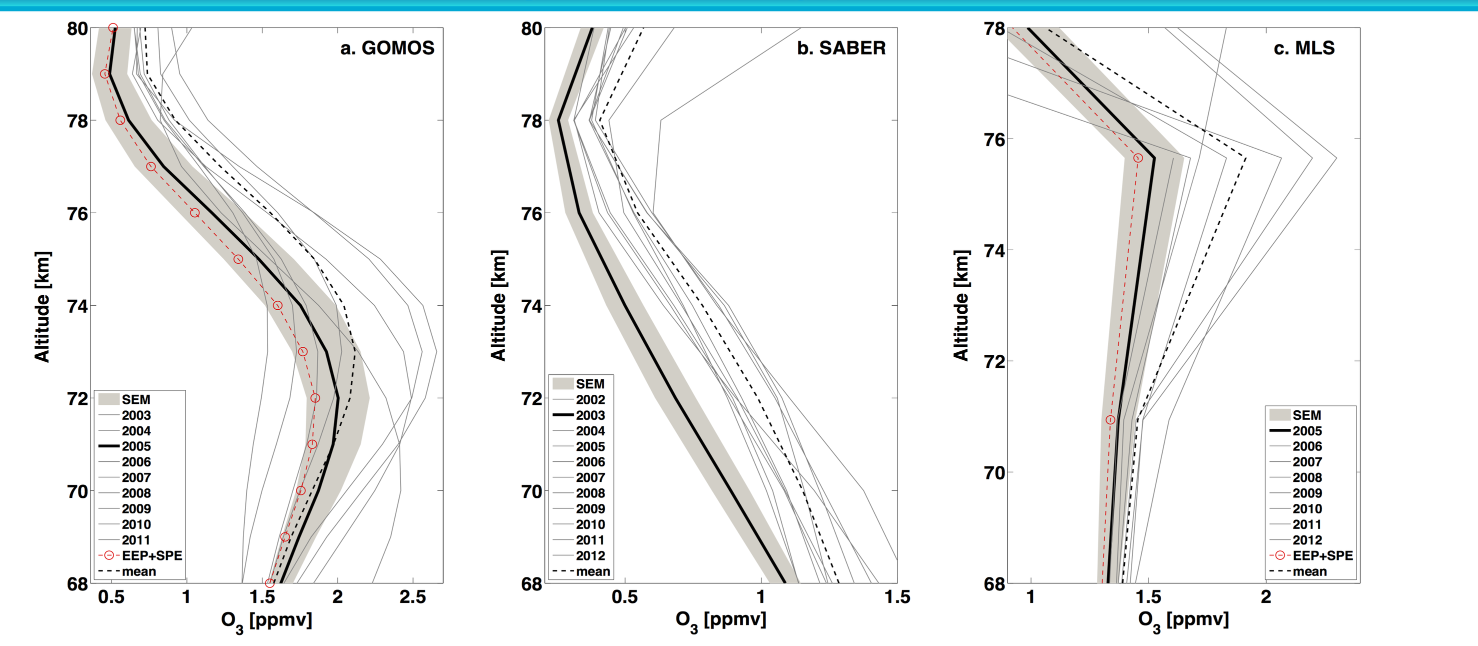

Fig. 5. Monthly mean O_3 night time profiles at magnetic latitudes 55-65° for (a). Jan 2003-2011 in the NH (GOMOS), (b). Jul 2002-2012 in the SH (SABER), (c). Jan 2005-2012 in the NH (MLS). SEM - standard error of the mean.

ECR and Dst - ONDJ

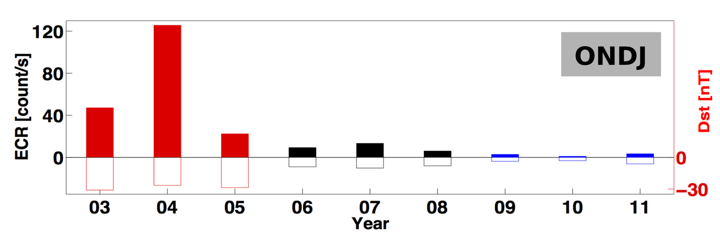

Fig. 6. 4 months mean (October, November, December, January) of ECR and Dst index between 2003-2011.

ECR and Dst - MJJ

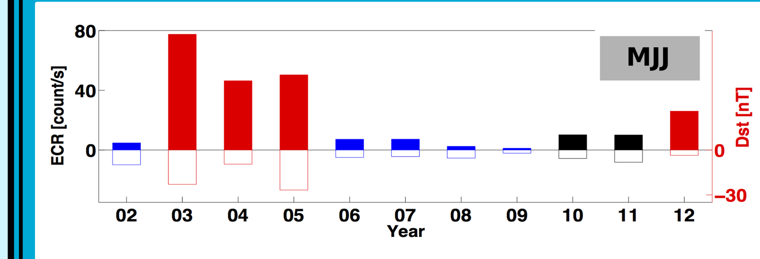

Fig. 7. 3 months mean (May, June, July) of ECR and Dst index bewteen 2002-2012.

O_3 profiles - ONDJ (NH)

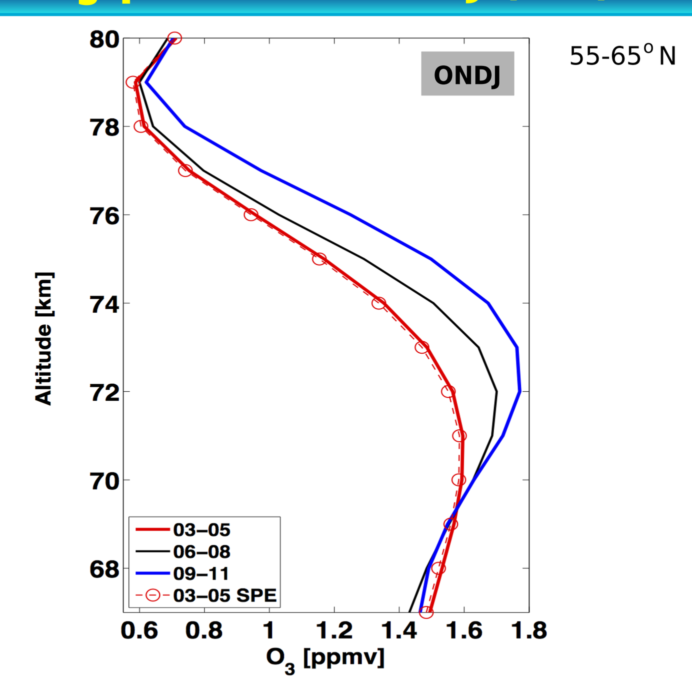

Fig. 8. O_3 profiles (ONDJ mean) for years with high (red), medium (black) and low (blue) ECR in the NH (GOMOS).

O_3 profiles - MJJ (SH)

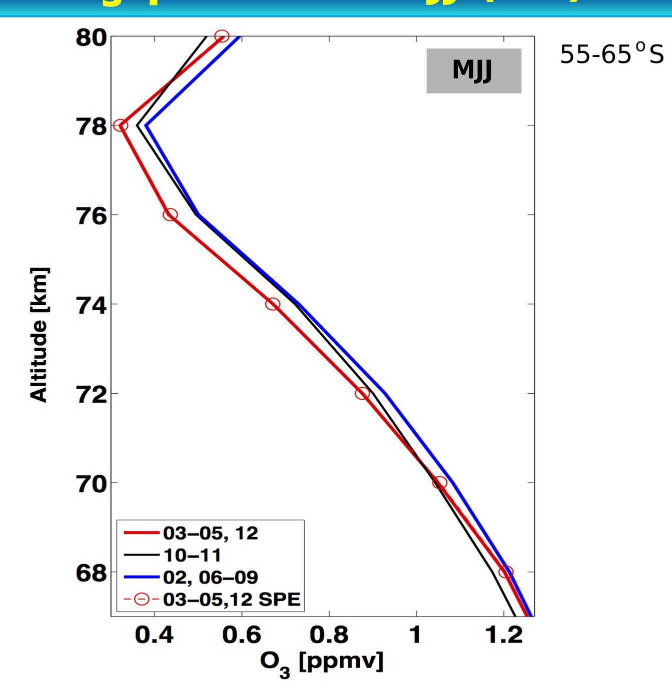

Fig. 9. O_3 profiles (MJJ mean) for years with high (red), medium (black) and low (blue) ECRin the SH (SABER).

Conclusions

- strong EEP events can cause signicant ozone depletion up to about 90% relative to the average values before the events, thus being comparable to the effects caused by SPE
- at 75 km, in about 90% of the strongest EEP cases (daily mean 100-300 keV ECR >150 counts/s), we observe ozone decrease of 5-72% in both hemispheres
- signature of EEP can be seen in monthly mean ozone profile at altitudes between 68-80 km
- the impact of strong EEP on ozone can reach down to about 60-65 km altitude
- high-EEP years shows about 25-30% (NH) and 10-15% (SH) less mesospheric O_3 than the low-EEP years
- EEP causes mesospheric ozone reduction in the polar regions on a long time scales which can have significant implications for the dynamics of the middle atmosphere with possible connections to regional climate

References

- Andersson *et al.* (2012) Precipitating radiation belt electrons and enhancements of mesospheric hydroxyl during 2004-2009, JGR. 117, **doi:10.1029/2011JD017246**
- Verronen *et al.* (2011) First evidence of mesospheric hydroxyl response to electron precipitation from the radiation belts, JGR. 116, **doi:10.1029/2010JD014965**
- Andersson *et al.* (under preparation) Mesospheric ozone loss due to the energetic electron precipitation between 2002-2012.

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