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Is there evidence for a direct impact of electron precipitation onto the middle atmosphere ?

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Precipitation of highly energetic protons from the sun into the polar middle and upper stratosphere in large sporadic events - so-called Solar Proton Events (SPEs) - are well known sources of atmospheric disturbances. Most important is the release of reactive NOx (N, NO, NO2) from N2, as NOx can be fairly long-lived in the polar middle atmosphere, and is one of the key species controlling stratospheric ozone.
There is increasing evidence that the precipitation of electrons from the terrestrial magnetosphere into the middle and upper atmosphere in sporadic events - so-called Energetic Electron Precipitation events (EEPs) - can have a similar or possibly even larger impact than solar particle events, because they occur much more frequently. However, it is to date not clear in which altitudes NOx is produced by EEPs, because not many direct observations have been reported so far.

We use data from three data sets measuring NO in different altitude regions over longer time-periods - HALOE / UARS (1991-2005), MIPAS / ENVISAT (2003-2004) and SCIAMACHY / ENVISAT (2002-2005) - to investigate whether a direct impact of energetic electron precipitation onto middle atmosphere NOx can be observed.

We find that a clear response of NO to enhanced electron fluxes is observed above 70 km for a number of events from SCIAMACHY / ENVISAT, but no clear evidence is found for NOx production due to precipitating electrons below 70 km from either MIPAS / ENVISAT or HALOE / UARS. This suggests that while electron energies may reach several 100 keV to MeV, sufficient to precipitate into the lower mesosphere and upper stratosphere, significant amounts of NOx are produced only in the upper mesosphere and lower thermosphere (> 70km).