Effect of high energetic particles on Nitric Oxide measured by Odin-SMR and AIM-SOFIE

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Abstract:
High energetic particles originating from our Sun affect the Earth’s atmosphere by for example increasing the amount of reactive nitrogen NOx. Through catalytic reactions this reactive nitrogen can lead to an increased ozone break down and temperature gradients, which implies altered atmospheric dynamics.

The Sub-Millimeter Radiometer (SMR) onboard of the Odin satellite measures trace gases in the strato-, meso- and lower thermosphere via limb scanning. Odin is a polar sun-synchronous satellite, operational since 2003, with 14 orbits a day and 35 scans per orbit. Since 2007 Odin measures NO for 3 observational days in a two week cycle in the altitude range of 20-120 km. Via detection of thermal emission lines SMR is able to determine the NO concentrations. This technique allows measurements during the polar night. Odin passes the same latitude band every 96 minutes, so it proves to be difficult to judge whether the evolution of mesospheric NO concentrations is due to temporal or spatial changes or a combination of both.

The Solar Occultation For Ice Experiment (SOFIE) onboard of the AIM satellite measures similar trace gases as SMR but via the amount of solar energy passing through the atmosphere at sunrise and sunset, which limits the latitudinal coverage of AIM from 65° to 85° North and South. NO is retrieved daily since 2007 in the 10-150 km altitude region, so we have 7 years of coincident measurements between Odin and AIM. NO is retrieved daily since 2007 in the 10-150 km altitude region, so we have 7 years of coincident measurements between Odin and AIM. Combining NO data from SMR and SOFIE results in a better spatial and temporal coverage of Earth.

The geomagnetic planetary $A_p$ index is an indicator for geomagnetic storms, caused by the arrival of Coronal Mass Ejections (CME) or Corotating Interaction Regions (CIR) originating from the Sun, and is an indication for the flux of precipitating particles. Figure 2 shows a Supersposed Epoch Analysis, also known as composited analysis, for the variation in $A_p$ and NO. Increases in $A_p$ follow the 27-day cycle of solar rotation, as does the variation in NO but with a delay of 1 to 2 days. This is an indication that NO and $A_p$ will have a maximum correlation with a 1 or 2 day lag.

In summer time NO gets broken down by sunlight so a nearly constant correlation is found in the lower thermosphere, with highest correlations found for 1 or 2 days lag in $A_p$. A smaller correlation further down is found as well: this may be due to relativistic electrons which are able to penetrate deeper into the atmosphere. In winter time NO has a lifetime of about a month and concentrations are able to build up. Both hemispheres show a maximum correlation with $A_p$, at around 110 km which decreases in altitude as the lag becomes larger. This suggests a downward transport of NO, most likely due to molecular and eddy diffusion. We also noticed a difference in the slope of the performed linear fit between winter and summer time conditions. The change in NO per $A_p$ change (not shown here) is higher in winter than in summer which indicates that in summer time less NO will be produced per $A_p$ change due to NO breakdown by sunlight.

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In summary, NO gets transported downwards into the stratosphere: this happened in the winters of 2003-2004, 2005-2006, 2008-2009, 2012-2013 and can be seen as a green line in the Figure 3 shows the correlation between NO and $A_p$ in function of altitude in winter and summer time and for the Northern and Southern Hemisphere. Linear correlation coefficients are calculated for 90 days of SOFIE NO and $A_p$, centered around the solstices in June and December. Only correlations that were significant at the 95% significance level are shown.

Conclusion and outlook:
We have confirmed the existence of a linear relationship between Nitric Oxide and the geomagnetic planetary $A_p$ index. This correlation is most pronounced at an altitude of approximately 110 km and is maximal with a 1 or 2 day lag in $A_p$. A smaller correlation further down is found as well: this may be due to relativistic electrons which are able to penetrate deeper into the atmosphere. In winter time NO has a lifetime of about a month and concentrations are able to build up. Both hemispheres show a maximum correlation with $A_p$, at around 110 km which decreases in altitude as the lag becomes larger. This suggests a downward transport of NO, most likely due to molecular and eddy diffusion. We also noticed a difference in the slope of the performed linear fit between winter and summer time conditions. The change in NO per $A_p$ change (not shown here) is higher in winter than in summer which indicates that in summer time less NO will be produced per $A_p$ change due to NO breakdown by sunlight.