Abstract. Energetic proton precipitation occurring during solar events can increase the production of odd nitrogen in the upper stratosphere and mesosphere. A very intense solar proton event (SPE) occurred on 28 October 2003. Its impact on the composition of the middle atmosphere was observed in details due to the availability of several space instruments. Here we present GOMOS observations of a strong NO$_2$ increase and a related ozone decrease in the upper stratosphere at north polar latitude. The perturbation of the chemical composition of the stratosphere was observed until the middle of December 2003. A strong NO$_2$ increase was also observed in the south polar vortex in June—July 2003. It is tentatively attributed to the effect of an SPE with protons of moderate energy occurring on 29 May 2003. If this hypothesis is confirmed, it will imply that the global effect of SPEs on the composition of the stratosphere is underestimated when only strong energy SPEs are considered.

Keywords: stratosphere, ozone, solar activity

1. Introduction

It is well recognized that energetic proton precipitation occurring during solar events can increase the production of odd nitrogen in the upper stratosphere and mesosphere (Crutzen, 1975). Odd nitrogen is important to the ozone balance due to catalytic reactions playing a role in ozone destruction. Effect of large solar proton events on ozone and odd nitrogen have been modelled by several authors (Rusch et al., 1981; Reid et al., 1991; Jackman et al., 2000; Verronen et al., 2002). Until very recent years, very few simultaneous ozone and odd nitrogen measurements from space were available. During the large July 2000 SPE space observations from HALOE and NOAA14 SBUV/2 showed a simultaneous NO$_x$ (NO + NO$_2$) increase and O$_3$ depletion in the upper stratosphere at north polar latitudes (Jackman et al., 2001). The large solar storm happened end October 2003 caused the fourth largest SPE in the last 40 years. The effect of this event on NO$_x$ and O$_3$ in the upper stratosphere has been reported by several authors due to the availability of measurements from various space sounders. Seppälä et al. (2004) and Verronen et al. (2005) from ENVISAT GOMOS observed a strong enhancement of NO$_2$ and depletion of O$_3$ in the north polar vortex until mid-December when the vortex
was destroyed by a stratospheric warming. Other observations were published by Rohen et al. (2005) from ENVISAT SCIAMACHY, Jackman et al. (2005) from HALOE and SBUV/2 and Semeniuk et al. (2005) from SciSat-I ACE. Degenstein et al. (2005) reported ODIN OSIRIS observations showing a strong mesospheric ozone depletion a few hours after the maximum proton flux. Orsolini et al. (2005) showed, from ENVISAT MIPAS data, a layer with a high HNO$_3$ mixing ratio in the upper stratosphere during early winter, descending to 30 km in January 2004.

An enhancement of stratospheric NO and NO$_2$ was observed in spring 2004 (March to May) in the north polar vortex by several space instruments (HALOE, MIPAS, SAGE II, POAM III) (Natarajan et al., 2004; Randall et al., 2005). The interpretation of these observations is still in discussion. Natarajan et al. (2004) attribute this enhancement to the large production of NO in the mesosphere/thermosphere during the October–November 2003 solar storm and its diabatic descent to the stratosphere during the following months when Randall et al. (2005) consider this hypothesis unlikely due to the strong mixing of stratospheric polar air after the December warming and propose a production of NO$_x$ by energetic particle precipitation in early 2004.

Here, using data from GOMOS star occultation spectrometer, on board the European satellite ENVISAT launched 1st March 2002, we give further observational evidences of the impact of the large October 2003 SPE on ozone depletion and NO$_2$ production in the North polar vortex. We present also observations of a strong upper stratospheric NO$_2$ enhancement in the south polar vortex in June–July 2004, tentatively attributed to an SPE with protons of moderate energy occurring in late May 2004.

2. Instrument

GOMOS (Global Ozone Monitoring by Occultation of Stars) is a stellar occultation spectrometer aimed to build a climatology of ozone and related species in the middle atmosphere (15 to 100 km) with a very high accuracy using the technique of stellar occultation (Bertaux et al., 2004). When a star sets behind the atmosphere, its light crosses quasi-horizontally the atmosphere in a limb geometry and travels a very long distance in layers just above the tangent point defined as the location of lowest altitude. During its travel, the star light is absorbed by the atmospheric constituents. Each constituent can be identified by its absorption spectrum. The atmospheric transmission spectrum is equal to the ratio between the star spectrum absorbed by the atmosphere and the reference star spectrum measured outside the atmosphere. As the reference spectrum is measured at the beginning of each occultation, we can consider that GOMOS is a self-calibrated instrument, independent of any radiometric calibration. Furthermore the stellar occultation technique allows a perfect knowledge of the tangent altitude, depending only on the geometry of the