FINNISH METEOROLOGICAL INSTITUTE

Changes in Chemical Composition of the Middle Atmosphere During January 2006 Sudden Stratospheric Warming

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Introduction

Sudden stratospheric warmings (SSW) are large-scale transient events which have a profound effect on the northern hemisphere stratospheric circulation in winter. During the SSW events the temperature in stratosphere increases by several tens of degrees and zonal winds decelerate or reverse in direction. Changes in temperature and dynamics significantly affect the chemistry of the middle atmosphere.

Objectives

The response of the middle-atmosphere trace gases during sudden stratospheric warming event in January 2006 is investigated using measurements from GOMOS instrument aboard Envisat satellite. Spatial and temporal changes in trace gas concentrations are analyzed in stratosphere, mesosphere and lower thermosphere.

Methods

GOMOS (Global Ozone Monitoring by Occultation of Stars) is a medium resolution spectrometer measuring in the ultraviolet, visible and infrared utilizing stellar occultation technique. GOMOS is dedicated the stratospheric and mesospheric ozone monitoring at global scales. Wide UV-VIS spectral range (250-675 nm) is used to determine vertical profiles O_3, NO_2, NO_3 and aerosols. We analyzed O_3 and NO_3 profiles during January 2006 SSW event. Number and latitudes of available GOMOS occultations are shown in figure 1.

Simulations with the 1D ion and neutral chemistry model SIC were used for estimating the response of trace gases to temperature changes during SSW.

Temperature profiles used were obtained from EOS Microwave Limb Sounder (MLS) aboard NASAs EOS Aura satellite. Latitudes of temperature profiles used are shown in figure 1.

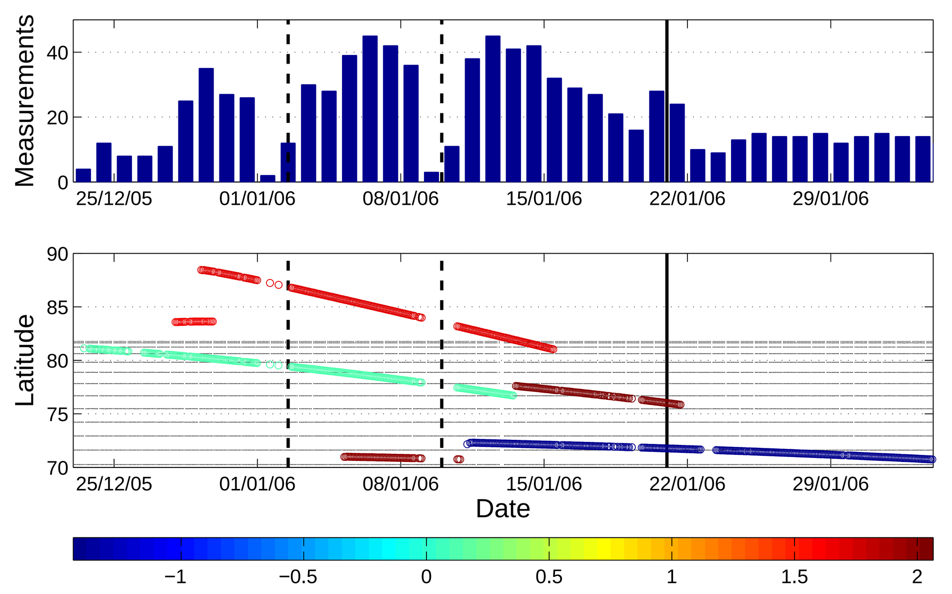

Figure 1. Top: Number of available GOMOS occultations from December 24, 2005 to February 4, 2006, latitude band 70°N - 90°N. Bottom: Locations of available GOMOS occultations (colored circles) and MLS temperature profiles (black dots). Color of the cirlces indicates the magnitude of the observed star.

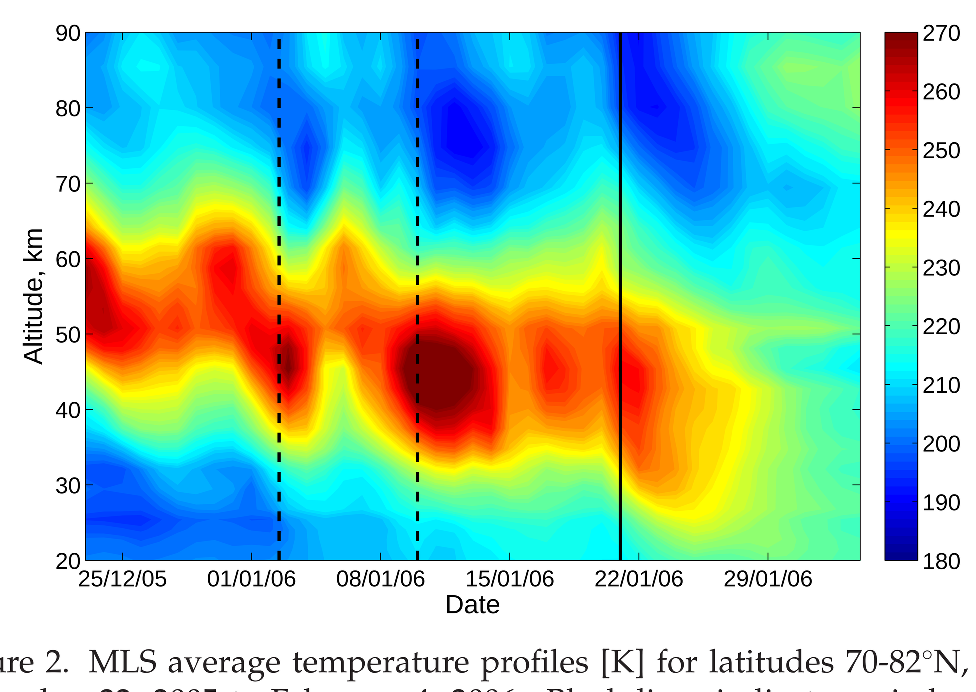

Figure 2. MLS average temperature profiles [K] for latitudes 70-82°N, from December 22, 2005 to February 4, 2006. Black lines indicate periods of enhanced temperatures, dashed lines minor SSWs, solid line major SSW.

Results and Discussion

Figure 2 shows the evolution of the MLS temperatures in northern polar region during the period of January 2006 SSW event. Three strong temperature enhancements periods can be identified, first two minor events on January 1 and 10 followed by major event on January 22. In the relatively narrow latitude band considered here, the strongest temperature enhancement is related to the January 10 event, when the temperature was observed to rise by 40-50°C in upper stratosphere. Mesospheric cooling associated with SSW events can also be seen.

Stratospheric O_3 concentrations show some increase after the January 1 temperature enhancements and slight decrease after January 10 (figure 3). The secondary and tertiary O_3 maxima at 90 km and 70 km, respectively, show clear decline during both minor SSWs. During the January 22 major SSW the observed behaviour is different. Stratospheric ozone shows clear enhancement immediately after the SSW. The secondary maximum is also strongly enhanced during the temperature enhancement. Tertiary maximum shows oscillatory behaviour during the SSW and enhancement afterwards.

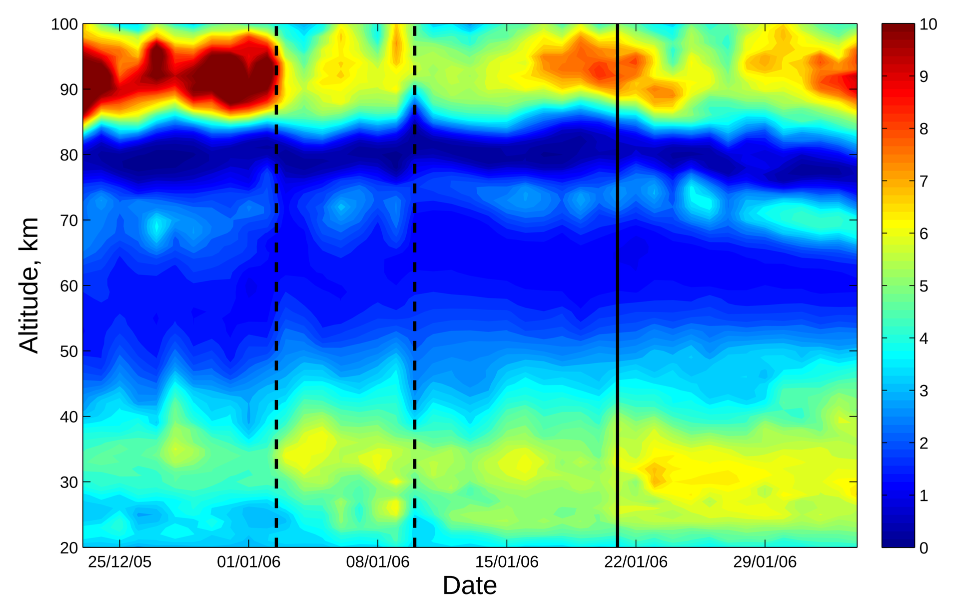

Figure 3. Average GOMOS O_3 profiles [ppm] for latitudes 70-90°N, from December 22, 2005 to February 4, 2006.

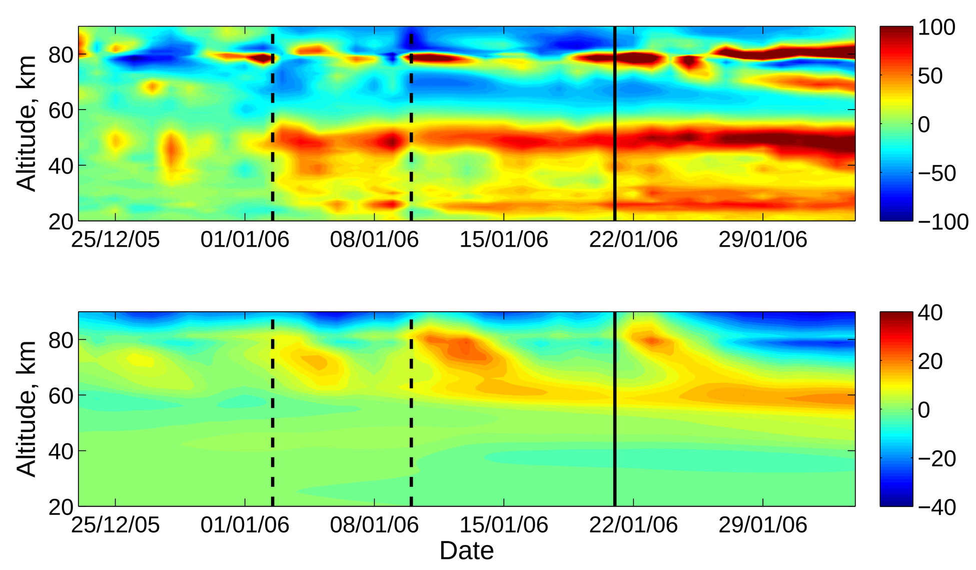

Figure 4. Relative change (in percent) with respect to Dec 24 2005 for O_3 profiles from GOMOS (70-90°N, top) ans SIC model (72°N), bottom).

Because of temperature dependence of O_3 production and destruction rates, the enhancement of mesospheric O_3 in high latitudes during SSW was expected instead of decline observed by GOMOS [1]. Expected enhancement can be seen on SIC results in figure 4. Unfortunately the number of available GOMOS occultations during the minor SSWs is very low. Differences seen in GOMOS and SIC, however, show that the response sometimes differs from the predictions by chemical models. This points to the influence of dynamics in the response of mesospheric chemistry to the sudden stratospheric warmings.

Figure 5 shows very strong NO_3 enhancement, especially during the January 10 period. This enhancement is in accordance with the current understanding of correlation between temperature and NO_3 concentrations [2]. These enhancements can also be seen in SIC results (figure 6), which confirms that NO_3 in the stratosphere is controlled by temperature.

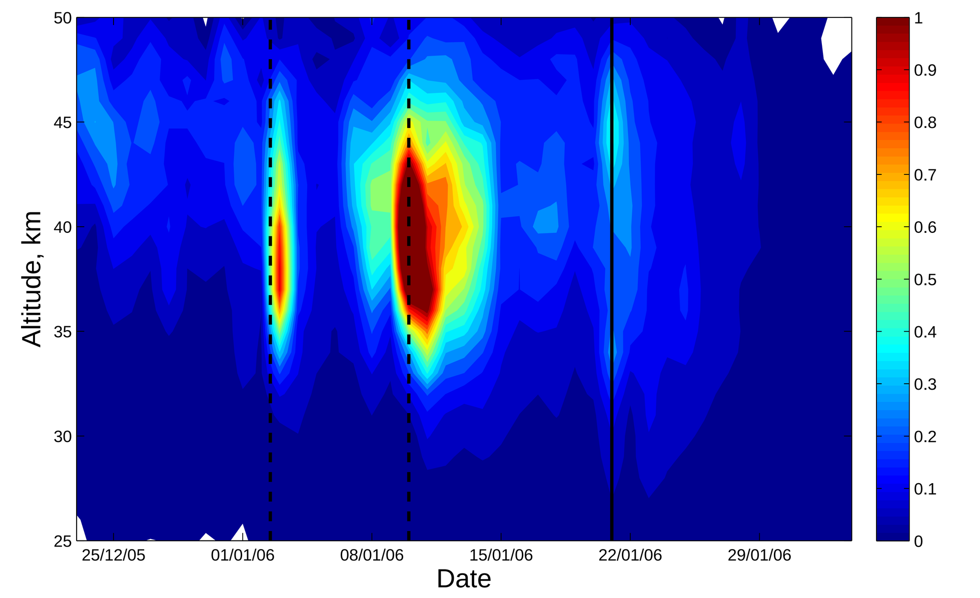

Figure 5. Average GOMOS NO_3 profiles [ppb] for latitudes 70-90°N, from December 22, 2005 to February 4, 2006, altitudes 25-50 km.

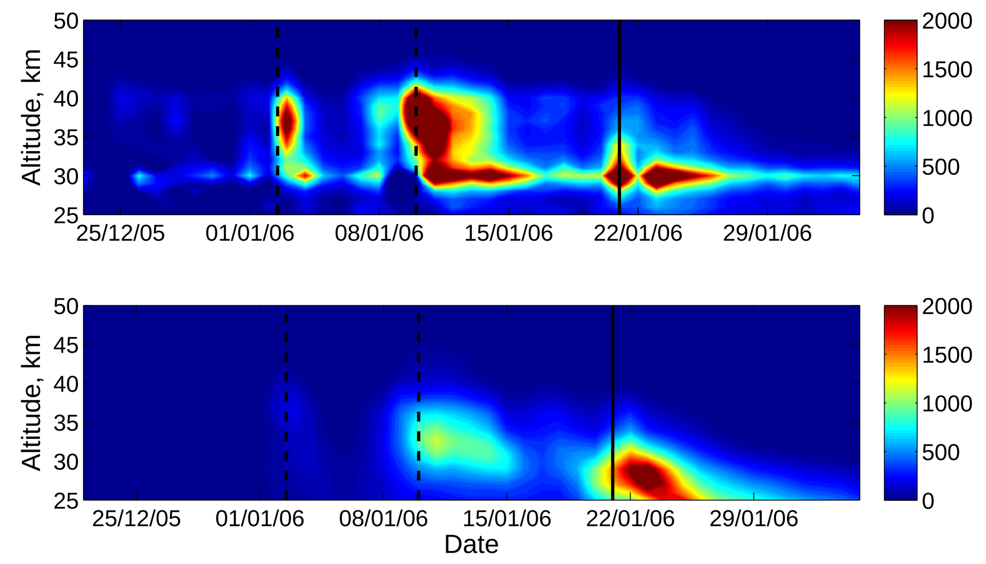

Figure 6. Relative change (in percent) with respect to Dec 24 2005 for NO_3 profiles from GOMOS (top) ans SIC model (bottom).

Conclusions

Sudden stratospheric warmings in January 2006 were accompanied by significant changes in the stratospheric and mesospheric chemistry. O_3 concentrations show clear decrease in mesosphere and lower thermosphere during two minor SSWs and enhancement during the Jan 22 major SSW. Stratospheric NO_3 shows very strong enhancement during stratospheric warming, which is expected since NO_3 enhancements are controlled by temperatures. SIC model shows good agreement with GOMOS measurements for NO_3 but does not show the decline of mesospheric O_3 concentrations. These disagreements point to influence of dynamics in response of middle atmosphere O_3 to SSW.

References:

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