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Exploration of noctilucent clouds in the polar mesosphere with SCIAMACHY

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The Earth's polar atmosphere is a pristine environment, making it vulnerable to external perturbations and thus, serving as a good indicator for global change. Its specific state, including the remote location, is the cause for natural and man-made processes usually not found at low latitudes. At the end of the past century, the detection of the ozone hole in Antarctica's stratosphere stirred great public concern. It not only illustrated anthropogenic impact onto our environment but also emphasized extreme conditions present at high altitudes over both poles. A detailed view of the polar atmosphere that includes its topmost layer, the mesosphere, is essential to understand the global role of the atmosphere in the Earth system. Spaceborne remote sensing of the polar atmosphere is a valuable method since it provides almost permanent access to otherwise inaccessible areas.

Provided jointly by the German Aerospace Center (DLR) and the Netherlands Agency for Aerospace Programmes (NIVR), the SCIAMACHY instrument (SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY) is one of the payload instruments of ESA's

ENVISAT mission (Gottwald et al., 2006) with the prime objective to improve the knowledge of global atmospheric change by observing a large number of geophysical parameters, i.e. trace gases and properties of aerosols and clouds. SCIAMACHY is an 8 channel absorption spectrometer for the ultraviolet (UV) to the short-wave infrared (SWIR) range between 214 and 2,386 nm. It measures scattered and reflected spectral radiance in nadir and limb geometry, spectral radiance transmitted through the atmosphere in solar and lunar occultation geometry, as well as extraterrestrial solar irradiance and lunar radiance. SCIAMACHY operates continuously during ENVISAT's orbit, covering the polar regions (between in-orbit sunrise and sunset) by nadir and limb scans for ca. 20 min. In order to retrieve trace gas information from absorption spectra, recording spectra with good signal-to-noise ratios is of key importance. By adjusting SCIAMACHY's exposure parameters to the light levels expected along the orbit, it compensates for low light (due to high solar zenith distances when crossing polar regions). Current retrieval methods have become rather robust such that even spectra obtained under those conditions provide detailed insight into the chemistry and physics of the polar atmosphere.

The uppermost region of the layered atmosphere—the mesosphere—is a still poorly understood environment. Its density is very low, as 99% of the mass of the atmosphere can be found below 40 km. Temperatures in the mesosphere decrease with increasing altitude. At the base of the mesosphere the temperature is ca. 0°C, while at the top, around 80–90 km, usually the lowest mean temperatures in the Earth's atmosphere can be found with –95°C. Chemically, the mesosphere is characterized by a rather constant mixture of gases with nitrogen, oxygen, argon and carbon dioxide (CO₂) being the most abundant species.

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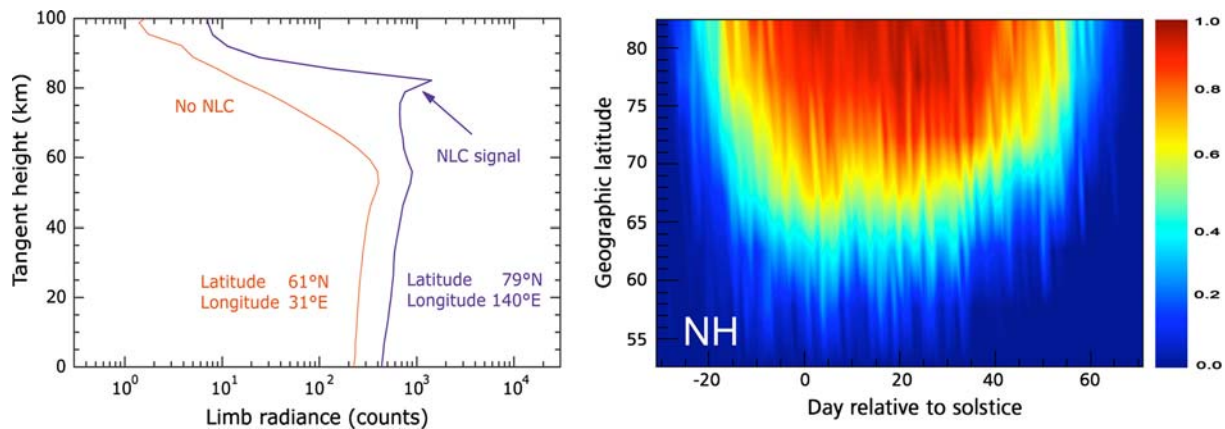


Fig. 1 *Left:* NLC signal in SCIAMACHY UV limb profiles. Scattering by the NLC ice particles increases the limb radiance and leads to a pronounced peak at the NLC altitude. *Right:* Mean NLC occurrence rates over the northern hemisphere for 2002–2007. The

NLC phenomenon is strongly correlated with the summer solstice due to the low temperatures occurring in mesospheric summer. ©Institute of Environmental Physics, University of Bremen

The mesosphere is considered to be rather sensitive to climate change. This is due to enhanced radiative cooling, induced by anthropogenic CO_2 . Furthermore oxidation of methane (CH_4) is expected to lead to higher levels of water vapour (H_2O). Both CO_2 and CH_4 have their sources in the troposphere where concentrations increase. In addition to these anthropogenic impacts, solar-terrestrial phenomena also affect the state of the mesosphere. At phases of solar maxima for example, temperatures tend to be higher while the H_2O content is reduced. Surprisingly polar mesospheric temperatures are lowest around summer solstice. In the middle atmosphere the meridional residual circulation results in adiabatic cooling of the polar hemisphere exposed to sunlight. Thus, temperatures can reach even extreme values as low as -160°C at altitudes of 80–90 km.

Noctilucent clouds (NLCs), also known as polar mesospheric clouds (PMCs), consist of H_2O ice particles with radii <100 nm occurring polewards of 50° latitude at altitudes of 82–85 km on both hemispheres around summer solstice. They form at ca. -120°C with their existence being strongly dependent on the thermal conditions and the abundance of H_2O in the polar mesopause region. Therefore, NLCs are a good means for exploring the mesosphere's climate change sensitivity. Indeed a long-term increase of the NLC nadir reflectivity is shown by satellite measurements with SBUV instruments (DeLand et al. 2007). This increase is modulated with a rate coinciding well with the solar cycle.

Since NLCs scatter solar radiation efficiently, they can easily be detected in SCIAMACHY limb profiles (Robert et al. 2009), permitting their mapping both over the northern and southern polar hemispheres. Apart from this,

SCIAMACHY observations also allow the estimation of the NLC particle size. Multiple scattering is negligible for wavelengths below ca. 300 nm and the limb spectra are simply determined by the solar irradiance spectrum and the spectral dependence of the scattering cross-section. Figure 1 displays, as an example, the mean NLC occurrence rates over the northern (NH) hemisphere as a function of geographic latitude in the seasons 2002–2007 as determined from SCIAMACHY measurements together with the NLC signature in limb profiles. SCIAMACHY has now regularly observed the polar mesosphere since August 2002. With the currently planned extension of the ENVISAT mission until 2013, we envisage to obtain a continuous dataset of more than 11 years. This even provides an opportunity to study solar impacts on the upper atmosphere over a complete solar cycle. Further information can be found at the following URLs: <http://www.iup.physik.uni-bremen.de/eng/>, <http://atmos.caf.dlr.de/projects/scops/>, <http://www.envisat.esa.int/> and <http://www.knmi.nl/samenw/sciamachy/>.

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