Newsletter No. 6

Information from the German SCIAMACHY Validation Team

Lidar observations of atmospheric temperatures and aerosols for the SCIAMACHY validation

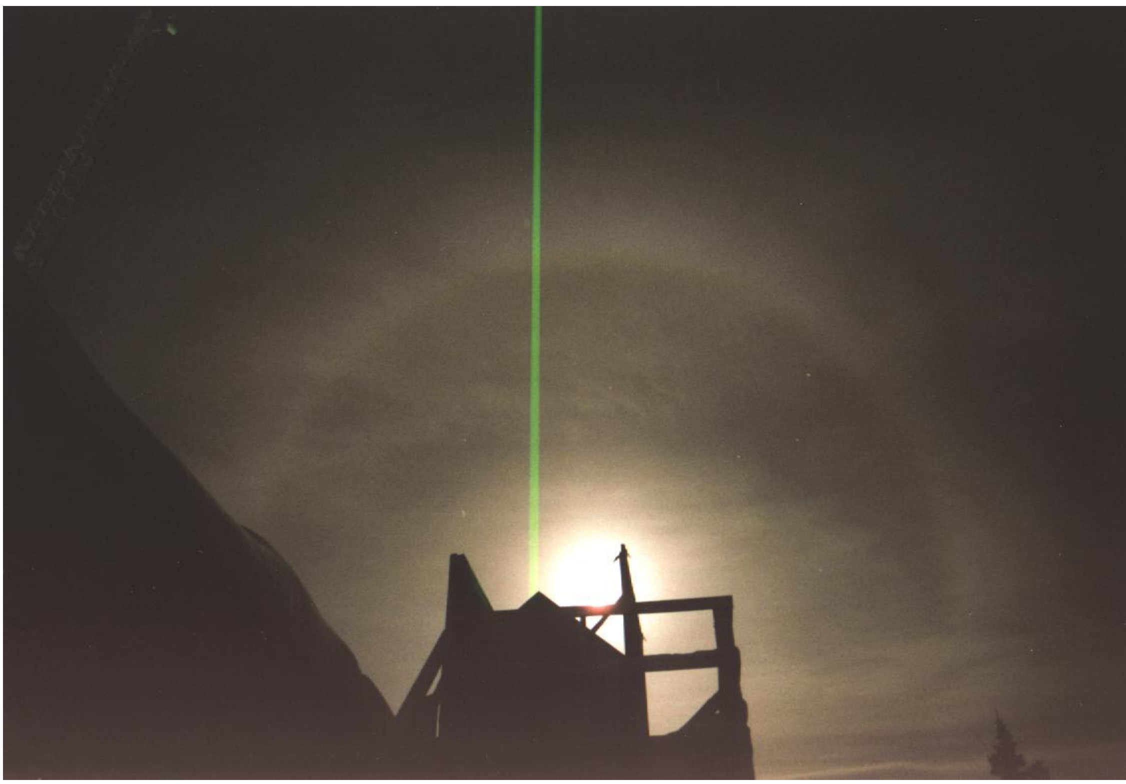

Fig. 1: The U. Bonn lidar at the Esrange in northern Sweden; laser beam and halo during moonlight.

The Bonn University atmospheric physics group uses a Rayleigh/Mie/Raman lidar experiment which is located at the Esrange (68° N, 21° E) near the Swedish city of Kiruna, about 100 km north of the Arctic circle to measure temperature profiles and aerosol load of the atmosphere [*Müller et al.*, 1997]. Fig. 1 shows a beautiful picture of the laser beam with a 22° halo in the background, caused by moonlight scattering on atmospheric ice crystals.

SCIAMACHY

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The lidar experiment is part of the German contribution to the validation of SCIAMACHY which is a spectrometer on ESA's environmental satellite Envisat. SCIAMACHY is designed to measure profiles of different trace gases, of the atmospheric pressure and temperature as well as the cloud coverage and the cloud top height. Envisat was launched successfully on March 1, 2002.

Lidar experiments are active remote sensing instruments for probing the atmosphere. The acronym lidar stands for **Li**ght **d**etecting **a**nd **r**anging. A lidar transmits pulses of photons into the atmosphere, collects the backscattered photons, and after analysis according to wavelength and polarisation the received intensity is registered as a function of round-trip time. This time is converted to a range, which for a zenith looking lidar is altitude. Depending on the scattering mechanism the lidar instruments are named differently (e.g. Rayleigh/Mie/Raman-, resonance- or differential absorption lidar).

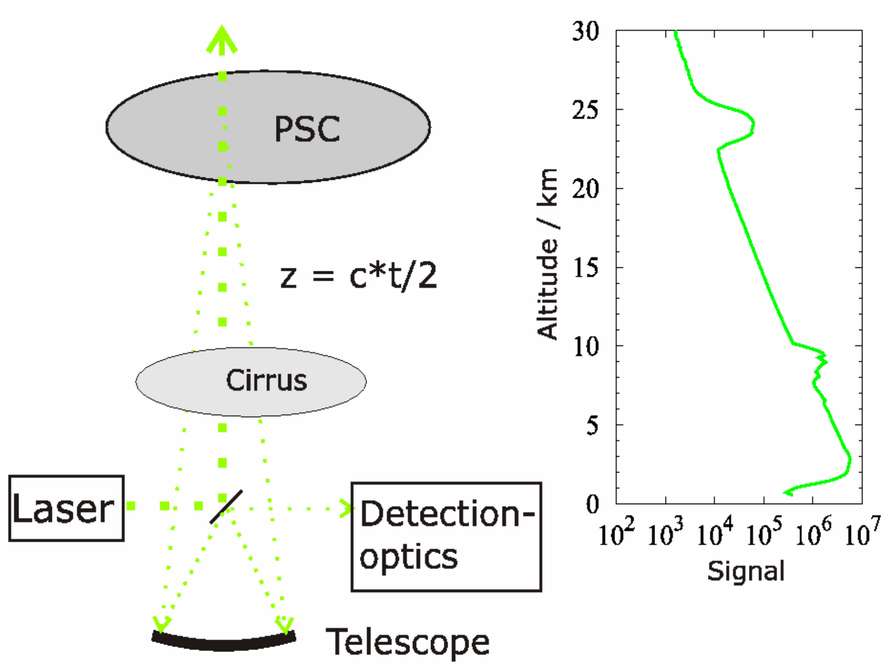

Fig. 2: Principle of a Rayleigh/Mie/Raman lidar experiment (left side) and the resultant raw-data profile (right side). The molecular signal drops of exponentially with altitude. The signal enhancements at 8 km and 24 km altitude are caused by clouds. The decrease of the signal below 3 km altitude is caused by an incomplete overlap between the laser beam and the field of view of the telescope.

The immediate data products of Rayleigh/Mie/Raman-lidar measurements are altitude profiles of the relative molecular density and the aerosol load including clouds. As shown in Fig. 2 the molecular signal of the atmosphere decays exponentially and an additional signal enhancement can be seen in the altitude marked by cirrus and polar stratospheric cloud (PSC) symbols.

In the aerosol-free part of the atmosphere (i.e. typically above 30 km altitude) the backscattered light is proportional to the molecular number density. Assuming hydrostatic equilibrium, the integration of the range corrected lidar net signal yields the temperature profile. During good measurement conditions temperatures up to 85 km altitude can be retrieved.

Since the launch of Envisat several measurement campaigns were performed with the U. Bonn lidar at the Esrange for the validation of SCIAMACHY. The campaign times were focussed on scientific unique times when extremely cold temperatures are reached in the atmosphere and thus unusual clouds can form: During summer noctilucent clouds at the polar mesopause and during winter polar stratospheric clouds.

Fig. 3: Operater console of the U. Bonn lidar. A CCD-camera observes continously the laser beam in the atmosphere (left monitor). The bright spot is from a tenuous low altitude cloud. The current measurement raw-data are shown on the right monitor.

During the last winter we performed two measurement campaigns for the validation of SCIAMACHY, one during December 2003 and the other during January and February 2004. This winter was characterised by an early stratospheric warming which led to temperatures of more than 300 K at the stratopause in about 50 km altitude, more than 30 K warmer than in undisturbed winter situations.

This stratospheric warming event was related to a wind reversal in the middle stratosphere leading to a breakdown of the polar vortex. This modified dynamical situation prevented cooling of the atmosphere which is necessary for the formation of polar stratospheric clouds, one particular feature of the polar winter stratosphere.

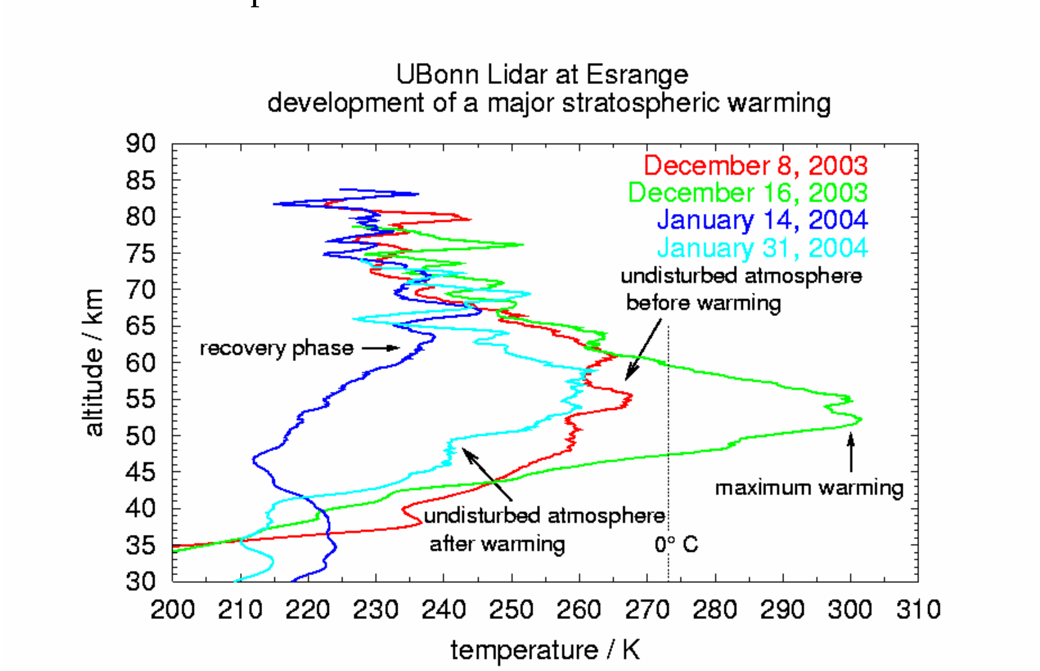

Fig. 4: The different stages of a major stratospheric warming observed with the U. Bonn lidar at the Esrange.

During the long campaign period of about 50 days we were able to carry out 20 measurement runs. We observed the development of the stratospheric warming from the undisturbed stage in the beginning of December up to the recovered temperature profile at the end of January (Fig. 4). In the beginning of December (red line) the temperature profile is undisturbed, similar to an expected model temperature profile. Eight days later a strong increase in temperature of about 30 K was observed (green line) associated with a slight descent of the stratopause altitude.

About one month later the observed temperature profile is quite isothermal from 30 to 85 km altitude, showing a variability of less than 30 K (dark blue line). This is the recovery state of the atmospheric warming. Subsequently to the recovery phase an undisturbed temperature profile was observed about two weeks later (light blue line). A comprehensive description of stratospheric warmings is given by *Labitzke* [1999].

Superposed on the temperature profiles in Fig. 4 one clearly sees atmospheric gravity waves. Measurements from a previous winter campaign for the SCIAMACHY validation (January/February 2003) were used for the analysis of such gravity waves [*Blum et al., 2004*].

The weather conditions during the campaign December 2003 – February 2004 were far from optimal, leading to only half of the measurement time compared to other winters. When bad weather situations prevented us from taking data we did some sightseeing around the Esrange (Fig. 5).

Fig. 5: On the street form the Esrange to Kiruna you will frequently meet reindeers.

References:
Blum, U., K. H. Fricke, G. Baumgarten, and A. Schöch, Simultaneous lidar observations of temperatures and waves in the polar middle atmosphere on both sides of the Scandinavian mountains: A case study on 19/20 January 2003, *Atmos. Chem. Phys. Discuss.*, 4, 969-989, 2004.
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