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Scientific note

An intercomparison campaign of ozone and temperature measurements in the Arctic (NAOMI-98, Ny-Ålesund/Spitsbergen)

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Abstract: The Ny-Ålesund Ozone Measurements Intercomparison (NAOMI) campaign for measurements of stratospheric ozone and temperature was conducted at the Primary Station of the NDSC in Ny-Ålesund/Spitsbergen during January–February 1998. Local instrumentation (ozone and aerosol lidar, microwave radiometer RAM, ECC-type ozone sondes) was complemented with the NDSC mobile ozone lidar from NASA/GSFC. The aim was the validation of stratospheric ozone and temperature profiles according to NDSC guidelines. The blind intercomparison of ozone profiles revealed good agreement ($<\pm5\%$) up to 31 km. At higher altitudes the different altitude ranges and resolutions of the instruments, as well as effects of retrieval algorithms have to be considered. Temperature data of the two lidar systems agreed well and revealed the stratospheric warming, which occurred in early February 1998. NCEP temperature analyses for Spitsbergen agreed very well with lidar data before, but not during this warming event.

1. Experimental procedures

At Ny-Ålesund/Spitsbergen (79°N, 12°E), a primary site within the Network for the Detection of Stratospheric Change (NDSC), observations of the stratospheric ozone profile are performed with lidar, microwave radiometer and balloon borne sondes, with temperature data also recorded by lidar. For the intercomparison the NDSC travelling ozone lidar maintained by NASA's Goddard Space Flight Center (GSFC) was deployed to Ny-Ålesund in winter 1997/98. The intensive measurement period for the campaign started on 19 January and ended on 10 February 1998. Weather conditions have been extremely favourable, with cloud cover never preventing measurements for more than 24 h. Accordingly lidar measurements could be taken on every day. As the ozone microwave radiometer is practically insensitive to clouds, this instrument has the best overall measurement statistics.

Due to optical interference problems, the two ozone lidars had to operate alternately on interleaving times. Due to high background levels of the approaching daylight, measurements were prevented around local noon.

Lidar raw data were integrated over 2–6 hours and the retrieved ozone profiles transferred via internet to the referee, as were the quasi automatically retrieved microwave ozone profiles (12 min data on every hour). The intercomparison of the ozone profiles was conducted blindly. Data from ozone sondes, however, which were performed almost daily during the intensive measurement period, were publicly available and accessible to the participants.

Although usually in January and February Polar Stratospheric Clouds (PSCs) occur above Spitsbergen, only one minor PSC event was observed during the intercomparison period. The lack of stratospheric aerosols prevented the originally planned intercomparison of aerosol profiles. However, the absence of large aerosol signals improves the ozone lidar data and allows to derive good atmospheric temperature data by lidar from elastically scattered laser lines *e.g.* at 353 nm in addition to the temperature data collected by Raman channels.

2. Instrumentation for the intercomparisons

2.1. The Ny-Ålesund Multiwavelength Lidar facility

The combined ozone- and aerosol-lidar instrument at Ny-Ålesund utilises a XeCl-Excimer laser for UV-wavelengths, running at 90 Hz and a Nd: YAG-laser for near IR- and visible wavelengths running at 30 Hz pulse repetition. Aerosol data is obtained at the wavelengths 353 nm, and 532 nm (including depolarisation at 532 nm, see Beyerle *et al.*, 1994), the 353 nm and the 532 nm data is used for temperature retrievals, and the ozone measurements are performed using the DIAL principle and employing the signals at 308 and 353 nm. All signals are collected by a telescope of 60 cm diameter and are guided into a detector system, which records up to eight wavelength channels simultaneously. A mechanical chopper suppresses high intensity signals from the troposphere, so that the photomultiplier tubes (Thorn EMI types) can be used in photon counting mode. Their dynamic range allows to cover the altitude range from 14 to 65 km. Data acquisition is done with eight multi channel scalers from EG&G ORTEC ("Turbo-MCS") which collect a preset number of laser pulses corresponding to an original time resolution of *ca.* 1 min. Data is then collected from each MCS individually by a PC and stored on hard disc within the local computer network of the Koldewey-Station, which in turn is connected to the internet.

2.2. The Ny-Ålesund Microwave Radiometer

The Radiometer for Atmospheric Measurements (RAM), developed by the Institute of Environmental Physics of the University of Bremen operates in the frequency range from 100–300 GHz. As part of the German ozone research program (OFP) and the European Stratospheric Monitoring Stations projects (ESMOS/Arctic I & II) this instrument is operated continuously according to the requirements for a primary NDSC station. The RAM is a heterodyne receiver consisting of two front-ends for the observation of ozone at 142 GHz and chlorine monoxide (ClO) at 204 GHz, which are operated in a time-sharing mode. Both front-ends consist of a rotatable mirror for calibration, a quasi-optics and a mixer-HEMT preamplifier stage which is cryogenically cooled to about 12 K. The back-end consists of a 2048 channel acousto-optical spectrometer (AOS) with a centre frequency of 2.1 GHz, a bandwidth of 945 MHz and a frequency resolution of ~1.3 MHz. This allows to retrieve trace gas volume mixing ratio profiles in the altitude range from 15 to 60 km from the shape of the observed signal. The whole system is computer controlled and can operate automatically (Langer *et al*., 1996).

2.3. *The Ny-Ålesund ozone sonde facility*

At Ny-Ålesund ECC ozone sondes of type 6A from Science Pump Corp. are launched with RS80 radiosondes from VAISALA. The sondes are flown with Totex rubber balloons, which are pre-treated during periods of low stratospheric temperatures resulting in burst altitudes usually above 30 km. Altitude resolution of the data transmittance is approximately 50 m depending on the balloon ascent rate. The altitude resolution, however, is reduced to about 300 m due to the response time of the sensor, which is filled with 3 cm^3 of 1% KI solution. The ECC data is treated according to the manufacturer's instructions, which follow those given by Komhyr (1986), including the tabled pump correction factors given there (that is *e.g.* 1.054 at 10 hPa). Due to polar night conditions for about half of the year total ozone correction by a Dobson spectrometer is never performed.

2.4. *The NASA/GSFC lidar*

The Goddard Space Flight Center mobile Stratospheric Ozone Lidar in Trailer Experiment (STROZ-LITE) was developed under the auspices of the Network for the Detection of Stratospheric Change as its travelling standard lidar instrument. It is a DIAL set up capable of making measurements of the vertical profiles of temperature, ozone and aerosols simultaneously (McGee *et al*., 1995). The lidar instrument uses excimer lasers with 200 Hz pulse repetition rate to generate the two wavelengths (308 and 351 nm) which are transmitted into the atmosphere. A 30″ Dall-Kirkham telescope collects the backscattered radiation, and a series of beamsplitters spectrally separate the light into four wavelengths; the elastically backscattered signal from each of the transmitted laser beams, and the N_2 Raman shifted wavelengths for each laser wavelength.

3. Results

3.1. *Ozone measurements*

The ozone measurements have been extensively analysed by Steinbrecht *et al*. (1999). Altitude resolutions vary from 0.3 to more than 14 km between balloon borne sondes, lidars and the microwave RAM, with lidar resolutions from 1 to 6 km, depending on altitude. Temporal resolution is less than 1 hour for the RAM, several hours for the lidars and days for the balloon launches. For this intercomparison, only temporally averaged profiles are considered. The results are summarised in Fig. 1a and 1b. They display the relative difference with respect to the average of the travelling standard, the GSFC lidar, for the period 26 January to 9 February 1998. Figure 1a reveals, that the lidars and ECC sondes agree to better than 5% up to the balloon burst height. The lidars agree to better than 5% in this altitude range, and within 12% up to 42 km, with rapidly increasing error bars with

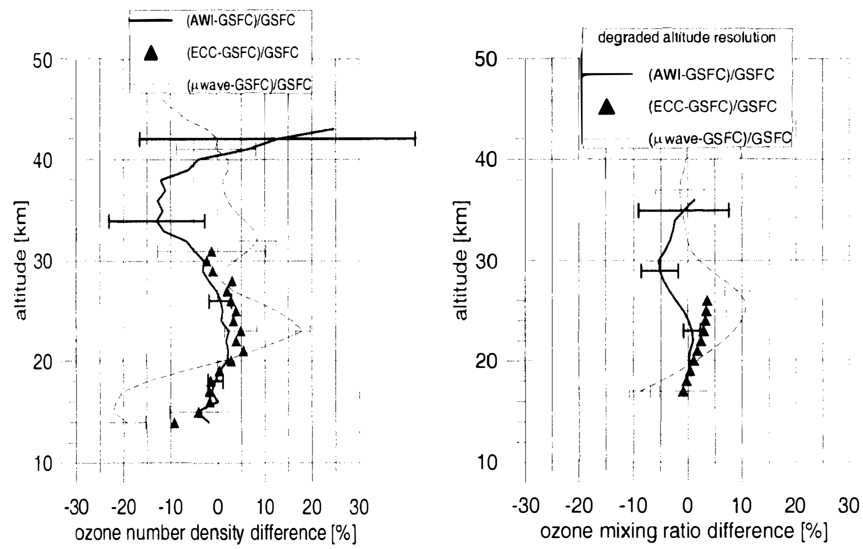

Fig. 1. Relative differences of the average ozone profiles: 1a (left) number densities with full altitude resolution, 1b (right) mixing ratios with reduced altitude resolution (see text), 2σ error bars. Figure taken from Steinbrecht et al. (1999).

increasing height. The comparison with the microwave radiometer looks worse, which is an effect of its much coarser altitude resolution. The agreement improves, when the lidar and sonde altitude resolution is reduced according to the retrieval kernels of the microwave analysis, as seen in Fig. 1b (for details of the procedure see Steinbrecht *et al.*, 1999). Now differences are less than 5% below 22 km and above 28 km altitude. The difference peaks with 10% at 25 km. At this altitude, the average ozone mixing ratio profile (not shown here) features an unusual plateau. As the apriori profile used for the microwave retrieval increases steadily here and is about 40% higher, it could be a reason for this bias, which was not found in earlier comparisons between ECC sondes and RAM.

3.2. Temperature measurements

Temperature data has been derived from the Rayleigh backscattered signals of the AWI and GSFC lidars, as well as from the N_2 Raman channel of the GSFC system for lower altitudes. In Fig. 2 the temporal development of the stratospheric temperature above Ny-Ålesund for the winter 1997/98 is displayed, using the AWI lidar data set. The figure reveals the strong warming pulse, which appeared above Spitsbergen in February, just towards the end of the NAOMI measurement phase. Both lidar systems covered this period very well and detected the warming. In Fig. 3 we compare temperature profiles retrieved by both instruments with the NCEP analysis temperatures before and during this warming event. Figure 3a displays an example of the derived temperature profiles together with the local radio sonde profile and the analysis of NCEP for Ny-Ålesund at 30 January. For the GSFC data set also the error is displayed as two additional curves at $T \pm \Delta T$. At *ca.* 28 km the shift between the low altitude Raman data and the high altitude Rayleigh data of the GSFC system is visible as a reduction in the error. The altitude range covered by the balloon borne radiosonde, the low and high altitude GSFC-Lidar channels and of the

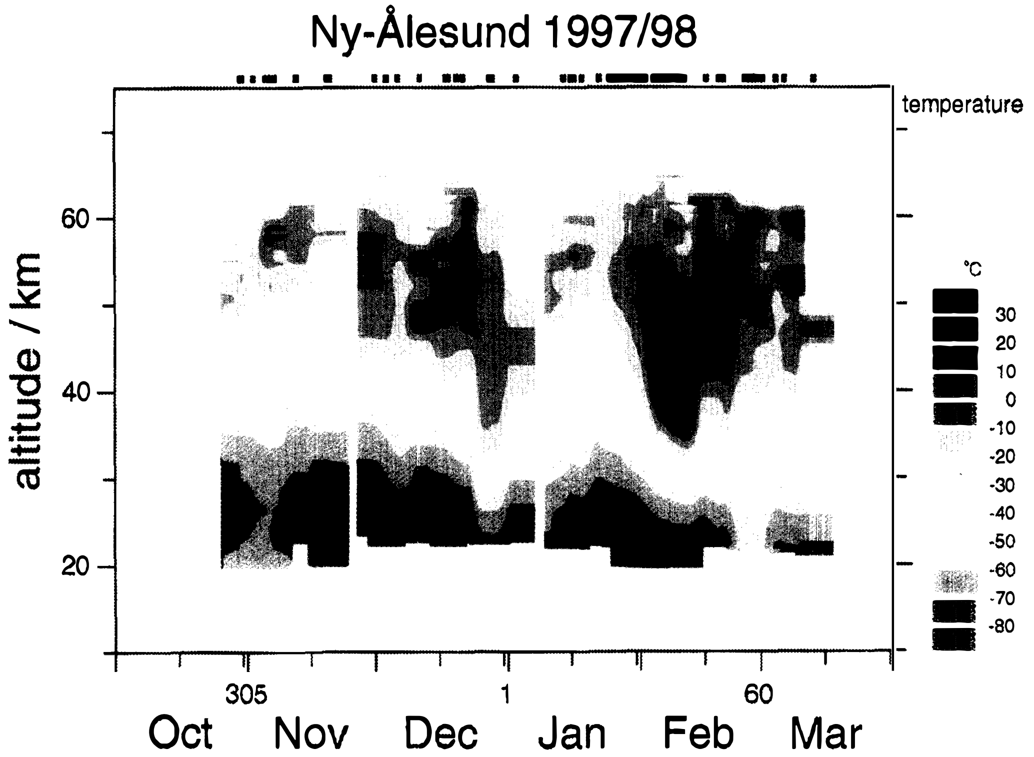

Fig. 2. *Temperature development above Ny-Ålesund during winter 1997/98 as measured by the AWI backscatter lidar. The bars above the figure indicate the measurement periods. The x-axis denotes the number of the days in 1997 and 1998, 1 corresponds to 1.1.1998.*

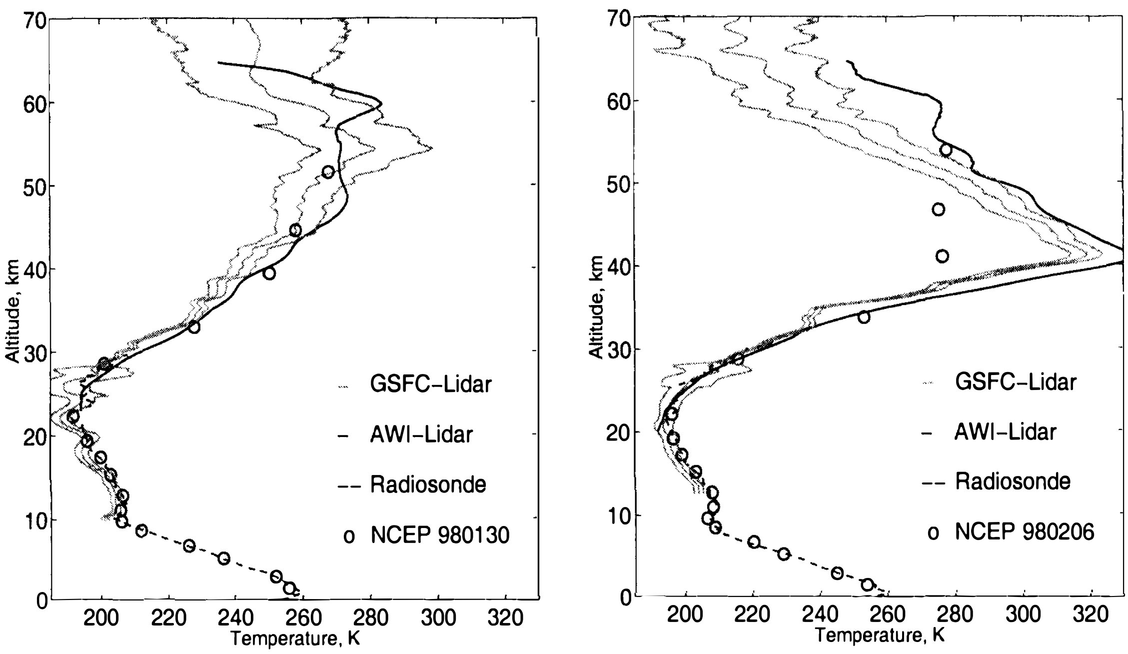

Fig. 3. *Temperature profiles and NCEP analysis for 30 January 98 (3a, left) and 6 February 98 (3b, right). Light grey: GSFC lidar, black: AWI lidar, dashed: radio sonde, circles: NCEP analysis.*

AWI lidar vary considerably. Their altitude resolution is much finer than that of the NCEP analysis. In the common altitude range the agreement between the different data sets is very good up to more than 55 km on this day. This is a typical result for a normal mid-winter situation. Figure 3b displays the same data sets for a day one week later, during the stratospheric warming. Both lidar data sets reveal a large descend of the stratopause from 55 to 40 km and an increase of the temperature maximum to more than 310 K. The NCEP analysis, however, found a more isothermal profile of 280 K between 35 and 55 km altitude, persisting for several days. Apparently the analysis does not resolve the full extend of the warming pulse and the change of the tropopause altitude above Spitsbergen. Lateron, when the warming decayed, the agreement between lidar data and NCEP analysis improved again considerably.

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References

Beyerle, G. *et al.* (1994): Multiwavelength lidar measurements of stratospheric aerosols above Spitsbergen during winter 1992/93. Geophys. Res. Lett., **21**, 57-60.

Komhyr, W. (1986): Operations Handbook-Ozone Measurements to 40 km Altitude with 4A Electrochemical Concentration Cell (ECC) Ozonesondes. NOAA Technical Memo. ERL ARL-149.

Langer, J. *et al.* (1996): A versatile millimeter wave radiometer for spectroscopic measurements of atmospheric trace gases. Atmospheric Ozone: Proceedings of the XVIII Quadrennial Ozone Symp. L'Aquilla, Italy, ed. by R.D. Bojkov and G. Visconti.

McGee, T.J. *et al.* (1995): Improved stratospheric ozone lidar. Opt. Eng., **34**, 1421-1430.

Steinbrecht, W. *et al.* (1999): Results of the Ny-Ålesund ozone measurements intercomparison NAOMI. J. Geophys. Res., **104**, 30515-30523.

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