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Review

Recent contributions to long-term atmospheric studies at Koldewey-Station

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Abstract: The Koldewey-Station at Ny-Ålesund/Spitsbergen is the German Arctic research station, which has two main tasks. It serves as a platform for research campaigns in many different scientific fields carried out by German scientists in the Kongsfjord area. It also serves as an observatory for long term measurements, mainly for atmospheric research. Herewith the station contributes to several global observing networks like NDSC, BSRN and GAW and others. Validation of the resulting data sets is a regular topic in order to achieve a constant high quality level. This in turn makes data from the Koldewey-Station attractive to others for the validation of remote sensing instrumentation *e.g.* on satellites or airborne platforms.

A brief overview is given on current atmospheric measurement capabilities at the station. Secondly recent crucial results of long-term measurements and campaigns are summarised, and their contributions to regional and bi-polar investigations are briefly discussed. Observations are focussed to measurements of aerosols and trace gases and the climate effect of their long-term development. Regional investigations are for example related to the stratospheric ozone loss, which is studied with a "Match" technique. The comparison with Antarctic observations reveals the different pattern in long-term development. Validation efforts and campaigns are summarised, which contribute to satellite experiments as well as to large international campaigns.

1. Introduction to facilities and research programmes

The Koldewey-Station at Ny-Ålesund/Spitsbergen is the German Arctic research station. It serves as a platform for a wide range of atmospheric, marine biological and geophysical investigations. It also serves as an observatory for long-term measurements, particularly for climate and atmospheric research. Balloon-borne observations and ground-based remote sensing techniques are applied to study dynamical and chemical processes. Because of its location, appropriate scientific equipment, and data quality, the station contributes as a Primary Arctic Site to the global Network for Detection of Stratospheric Change (NDSC). Meteorological and radiation programmes are run similarly to those at Neumayer-Station in the Antarctic. Data are also fed to networks of WMO like the Baseline Surface Radiation Network (BSRN) or the Global Atmosphere Watch (GAW). An automatic seismological station completes long-term observations.

Validation of the resulting data sets is a regular topic in order to achieve a constant high quality level. This in turn makes data from the Koldewey-Station attractive to others for the validation of remote sensing instrumentation *e.g.* on satellites or airborne platforms. Data from the station have contributed *e.g.* to the validation of satellite experiments like the Global Ozone Monitoring Experiment GOME or have provided auxiliary data like for the Improved Limb Atmospheric Spectrometer (ILAS) on board of the Advanced Earth Observing Satellite (ADEOS). The Koldewey-Station also participated in several major international campaigns investigating the Arctic ozone layer. This includes participation in the ozone campaigns European Arctic Stratospheric Ozone Experiment (EASOE), the Second European Stratospheric Arctic and Mid latitude Experiment (SESAME), and the Third European Stratospheric Experiment on Ozone (THESEO). Recently, the NASA Validation Team for the third Stratospheric Aerosol and Gas Experiment (SAGE III) included the contributions of the Koldewey-Station for the SAGE III validation as one of two "anchor sites" globally. Also for the 1999/2000 campaign SOLVE/THESEO 2000, which was organised by NASA and the European Union (EU) the Koldewey-Station was integrated (SOLVE=SAGE III and Ozone Loss Validation Experiment).

Key wintering staff consists of a scientific station leader and an engineer, who are running the meteorological and stratospheric observatories. They are also responsible for on-site station management. Beside atmospheric studies an increasing number of projects were dedicated to marine biology and geophysics. About 80 scientists and technicians work here with 1125 man days each year. The Koldewey station is also part of the Ny-Ålesund Large Scale Facility (LSF) funded by EU. Access is offered to researchers from EU member states. A major complement to the station in 1999 was the construction of a balloon preparation and launching house which improves the handling of meteorological balloons by making them less wind-dependent. A general description of the Koldewey-Station and it's facilities can be found on the WWW (http://www.awi-potsdam.de/www-pot/koldewey/kolnav.html).

2. Atmospheric sciences

The scientific programmes running at the Koldewey-Station are mainly related to climate research, focusing on meteorology and tropospheric and stratospheric investigations. Instrumentation used comprises ground based remote sensing instruments like multi wavelength lidar, Fourier Transform Spectrometer (FTS), spectrometers sensitive in the UV and visible spectral range, multi spectral photometers using sun and star light, and microwave radiometers. In situ sondes to measure meteorological parameters, ozone, and aerosol properties are launched regularly by rubber or plastic balloons from the dedicated balloon launch facility.

Stratospheric ozone, aerosol, temperature, and tropospheric aerosols are observed by a multi wavelength lidar facility, comprising two lasers, three telescopes and three detection systems. The investigations cover Polar Stratospheric Clouds (PSCs), volcanic aerosols and the tropospheric aerosol burden. Above the aerosol layers, *i.e.* above 30 km, the backscatter signal is used to derive temperature profiles. The Differential Absorption ozone Lidar (DIAL) uses the output from an XeCl Excimer laser at 308 nm which is partly Raman shifted to 353 nm. A multi channel detector records all signals simultaneously. The lidar

system participated successfully in NDSC related validation activities for ozone and aerosol measurements (Godin *et al.*, 1999; Steinbrecht *et al.*,1999; Neuber *et al.*, 2001). Main results of the stratospheric aerosol investigations revealed the occurrence of liquid and solid PSC particles, which sometimes can co-exist in the same air volume (Biele *et al.*, 2000), while some types of PSC, which have been found above northern Scandinavia, are only rarely observed above Spitsbergen.

The FTS measurements at Koldewey-Station are performed using a commercial Bruker 120 HR Fourier transform spectrometer with maximum spectral resolution of 0.0025 cm^{-1} and spectral coverage between 600 and 33000 cm^{-1}. In order to overcome the lack of measurements during polar night, the system and the observational procedures were tuned to use the moon as light source. Due to the low IR intensity of moon light, spectra have to be recorded at low resolution (typically 0.02 cm^{-1}). Nevertheless, up to 20 trace gases from the tropo- and stratosphere are retrievable from the lunar observations (Notholt, 1994). The multi year observations allow to establish the annual course of the various trace gases, which allows *e.g.* to validate chemical transport models for the ozone depletion reactions and which also allows the comparison of their development in both polar regions (Notholt *et al.*, 1997).

Quasi-continuous observations of several atmospheric species are performed by measuring the absorption of visible and near ultraviolet sunlight scattered from the zenith sky or that from direct moonlight. Vertical column abundances of molecules such as ozone, NO_2, OClO, BrO and IO are derived by means of a Differential Optical Absorption (DOAS) algorithm and a radiative transfer model. These activities contribute to the calibration and validation studies of data from the GOME instrument on the ERS-II satellite and from future ENVISAT instruments (Wittrock *et al.*, 1999; Richter *et al.*, 1998).

Monitoring of the strength of solar radiation is performed in the wavelength ranges 280–320 nm (UV-B) and 320–400 nm (UV-A) by two non-scanning spectrophotometers installed on top of the observatory building. As complete spectra are taken each second, short time variations, which regularly are produced by the variable cloud cover, can be resolved (Groß *et al.*, 2001).

Since March 1991 regular measurements of the spectral optical depth of aerosols have been performed using sun photometers. Since January 1996 measurements during the polar night have been firstly possible using a star pointing photometer, which was developed by AWI. Significant features of the annual aerosol variations could be detected, like spectral characteristics of Arctic Haze aerosols and formation of ice crystals in the lower troposphere (Herber *et al.*, 2000a, b).

The Radiometer for Atmospheric Measurements (RAM) has been developed by the Institute of Environmental Physics of the University of Bremen as an instrument for ground-based millimeter-wave observations of the trace gases like ozone, ClO, and water vapour in the stratosphere and lower mesosphere. These data sets allowed a close investigation of the relation between atmospheric motions and the ozone content (*e.g.* Sinnhuber *et al.*, 1999).

A rather important tool for frequent ozone observations is the balloon-borne ozonesonde. At the Koldewey-Station, ozone soundings are performed at least once per week, and during winter times normally three times per week. An electrochemical ozone

sonde of type ECC 6A is used together with radiosondes RS 80. Major achievements resulting from these long term measurements are related to tropospheric as well as stratospheric results (Gernandt *et al.*, 1997; Rex *et al.*, 2000).

Sampling of airborne aerosols by filter automated instruments, as well as deposition sampling in flasks is used to observe the chemical composition of particulate matter transported to the polar regions. GC-MS coupled analyses of the probes are performed at the home institute (Kriews *et al.*, 2000a,b).

Table 1. Instrumentation for long-term atmospheric observations at Koldewey-Station (79°N, 12°E) and Neumayer station (70°S, 8°W) operated by AWI, University Bremen[1] and University Heidelberg[2].

Parameter	Koldewey-Station	Neumayer station
Meteorology		
ground p, T, u, wind,	weather mast	yes
profiles of p, T, u, wind	balloon-borne sondes	yes
Radiation		
IR–vis balance	BSRN station	yes
UV	UV-A, UV-B spectral rediometer	yes
Air chemistry		
trace gases	-	sampling
heavy metals	deposition and filter samplers	filter samplers
Aerosols		
aerosol optical depth	sun photometer	yes
	star photometer	-
extinction profiles	tropospheric lidar (extinction)	-
backscatter profiles	stratospheric multi λ lidar	-
backscatter & number density profiles	balloon borne sondes	-
surface aerosol	filter sampler	yes
Ozone		
concentration profiles	balloon-borne sondes (ECC)	yes
	ozone lidar	-
mixing ratio profiles	microwave radiometer RAM[1]	-
column density	FTIR-spectroscopy	-
	UV-vis. spectroscopy-DOAS[1]	DOAS[2]
surface ozone	(by NILU, NIPR)	KJ cell
		UV-absorption cell
Trace gases		
column densities	FTIR-spectroscopy	-
	UV-vis. spectroscopy-DOAS[1]	DOAS[2]
Surface processes		
transport and energy flux	two instrumented field sites	-

3. Climate research and bi-polar approach

Long-term observations provide a reliable data record for climate studies. The combination of different methods provides an appropriate tool to study physical and chemical processes as well. At Koldewey-Station both objectives have been part of the comprehensive

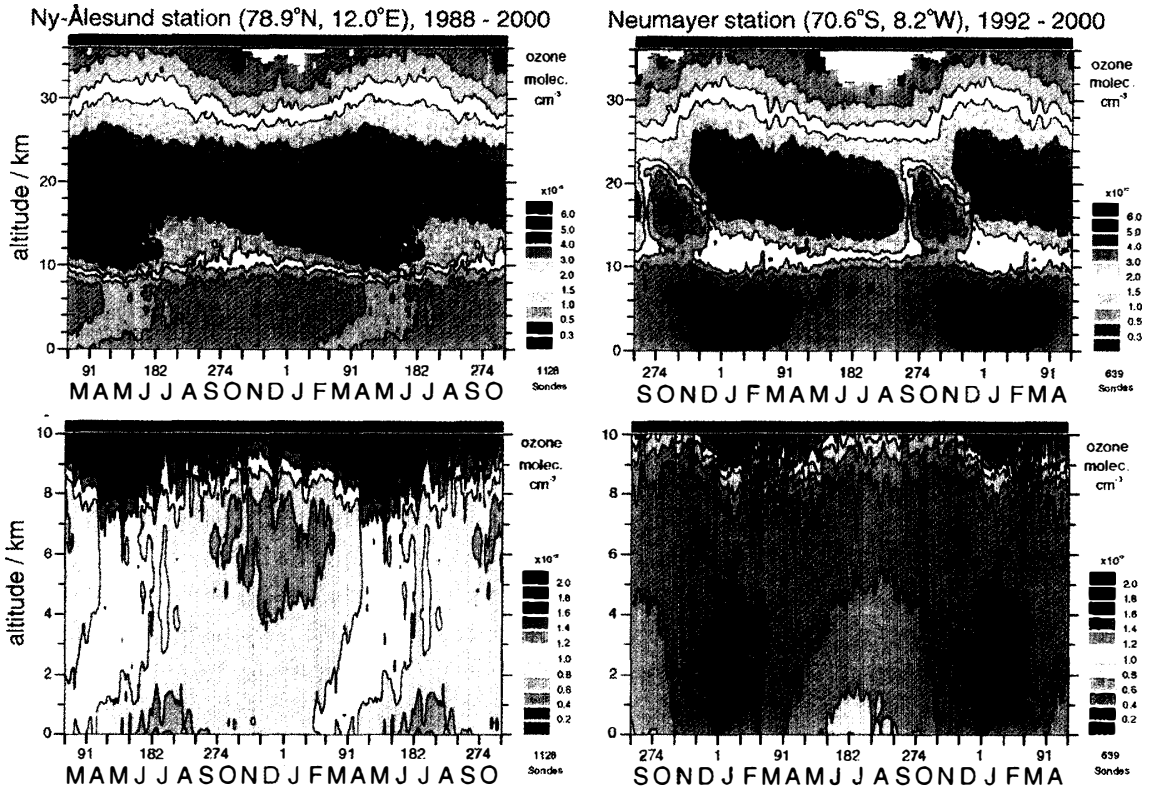

Fig. 1. Mean annual variation of ozone concentration recorded by balloon-borne sondes at Ny-Ålesund (79° N, 12° E) and Neumayer (71° S, 08° W); upper panels show the totally covered altitude range of observation; lower panels show tropospheric altitudes; ozone concentration is colour coded ($\times 10^{12}$ molecules/cm^3); time is scaled by days and months over 20 months period.

activities since its very beginning in 1988. In order to assess certain physical and chemical processes as well as long-term changes in the Arctic atmosphere, it is reasonable to include Antarctic observations for those studies (Gernandt *et al.*, 1998). Consequently certain observations and methods are additionally applied in a bi-polar approach, *i.e.* some instruments are also run at the German Neumayer station in the Antarctic. Atmospheric parameters recorded at Ny-Ålesund as well as the complement in the Antarctic are summarised in Table 1. These data records can be easily compared because identical instruments are used and attention is drawn to keep all procedures and evaluation algorithms at the same standard.

During the nineties for almost one decade a bi-polar record of vertical ozone distributions was obtained by regular balloon-borne observations in the Arctic and Antarctic. Altogether 1200 launches at Ny-Ålesund from 1989 until 2000 and about 640 launches at Neumayer from 1992 until 2000 have been performed. The updated mean annual variation of ozone concentration is shown in Fig. 1. The mean patterns show significant differences in the stratosphere as well as in the troposphere. The well known ozone depletion significantly and strongly appears in the Antarctic stratosphere. In the troposphere the mean annual variations also show an opposite seasonal course for both

regions.

3.1. Chemical ozone loss in the Arctic stratosphere

The physical and chemical processes causing the stratospheric removal of ozone has been extensively studied during the nineties. The term stratospheric ozone removal comprises a very complex interaction of complicated physical and chemical processes, which have been identified by the application of very sophisticated observations and modelling. Recently these processes are fairly well understood (Solomon, 1999).

Studies of the particular processes causing the removal of ozone were also performed at Ny-Ålesund. As an example FTIR measurements of the reservoir gas HCl from 1992 until 1997 are shown in Fig. 2. The comparison of observations with two different model runs clearly shows, that the so called heterogeneous chemistry has to be taken into account in order to model the observed seasonal variation of HCl.

As heterogeneous chemical reactions occur at the surface of the particles of polar stratospheric clouds (PSC), the physical formation and properties of these particles have been investigated by the multi wavelength lidar facility (Beyerle *et al.*, 1997; Biele *et al.*, 2000). In Fig. 3 the 10 year record of PSC occurrence is shown. A strong inter annual variability is observed in PSC occurrence. Intensive PSC formation was found for winters

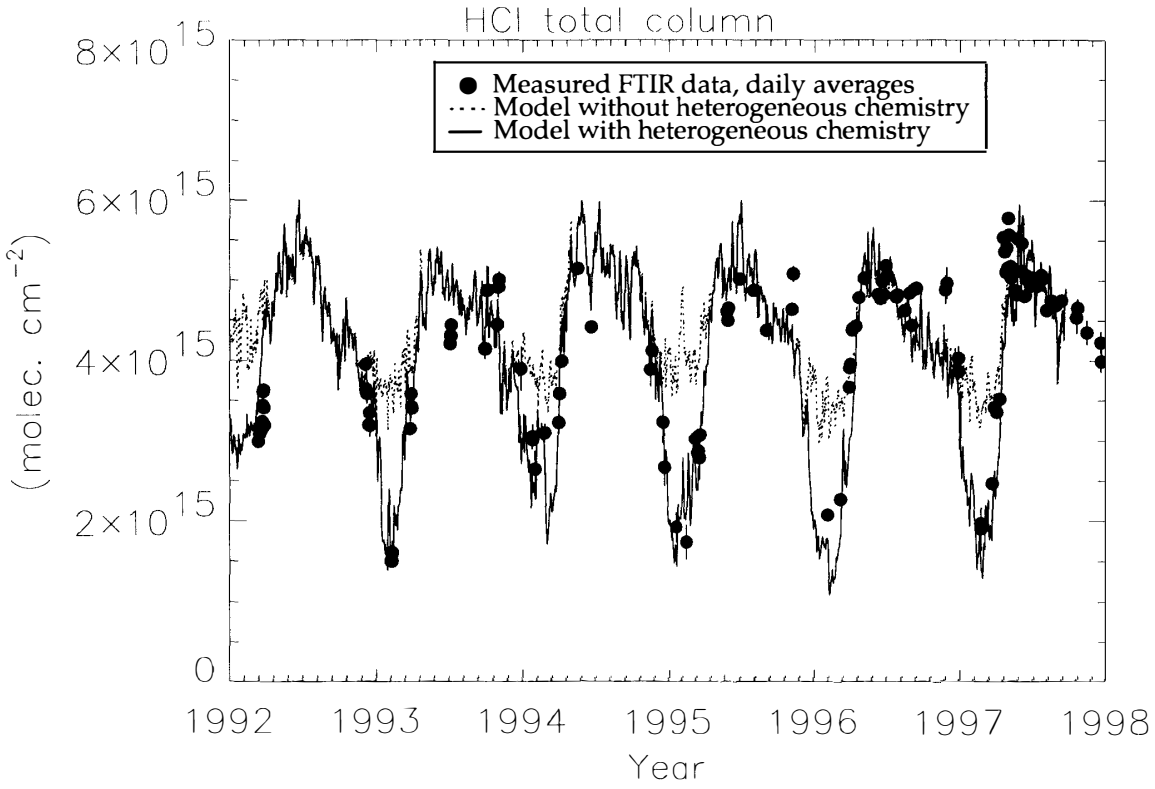

Fig. 2. Annual variation of HCl column densities recorded at Ny-Ålesund from 1992 until 1998 compared with runs of a three dimensional chemical transport model (SLIMCAT); broken line without heterogeneous chemistry; black line with heterogeneous chemistry (private communications by J. Notholt and M. Chipperfield, 1999).

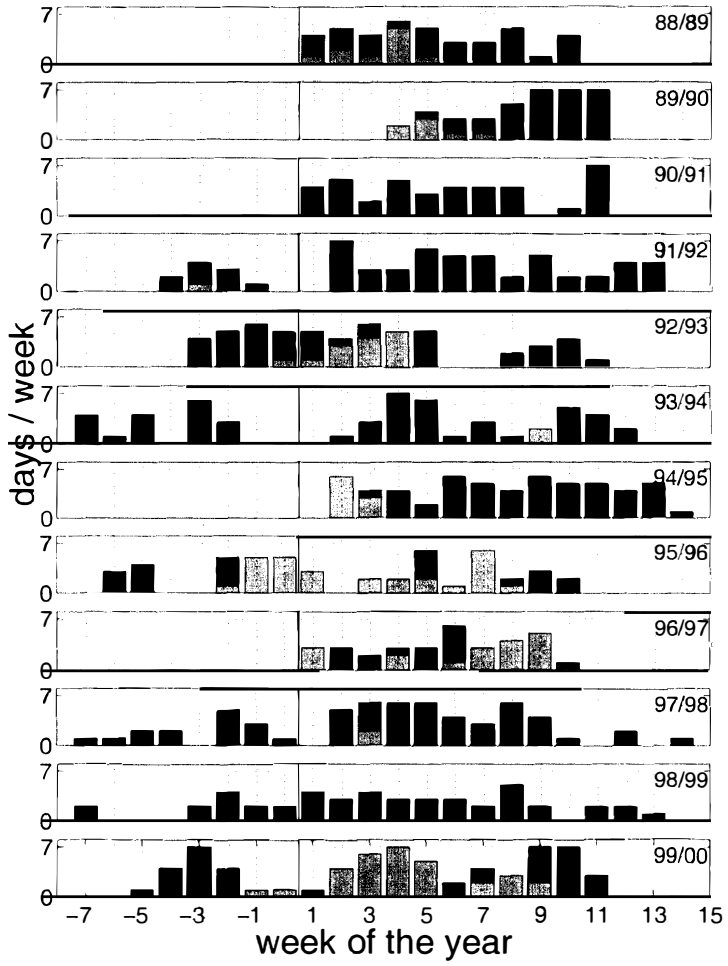

Fig. 3. Record of PSC observations by multi wavelength lidar at Ny-Ålesund for 12 winters from 1989 until 2000; dark columns indicate the total number of measurement days per week; light columns indicate observations of Polar Stratospheric Clouds (PSCs).

in 1992/93, and the winters following 1994/95 until 1996/97. As the existence of PSCs forces heterogeneous reactions at the particles' surfaces, strong removals of HCl into reactive chlorine were recorded for the respective winters (Fig. 2).

Although the preconditions to remove stratospheric ozone were observed in Ny-Ålesund, the ozone data do not show a corresponding decrease of ozone in the lower stratosphere (Fig. 1). The large dynamic variability in the Arctic stratosphere makes it more difficult to directly detect chemical ozone loss in comparison to Antarctic conditions. Thus, a much greater effort has been necessary to identify PSC related ozone losses in the Arctic stratosphere. Ozone loss rates can be directly measured by the so called Match technique (Von der Gathen *et al.*, 1995). A match is defined as a pair of ozonesonde measurements where sondes are launched from different stations and at different times but probe the same air parcel as it passes by. To identify the matches, calculated air parcel trajectories are used to track the motion of the air parcel between the measurements (Rex *et al.*, 1997).

Figure 4 shows an overview of the chemical ozone loss rates measured by Match

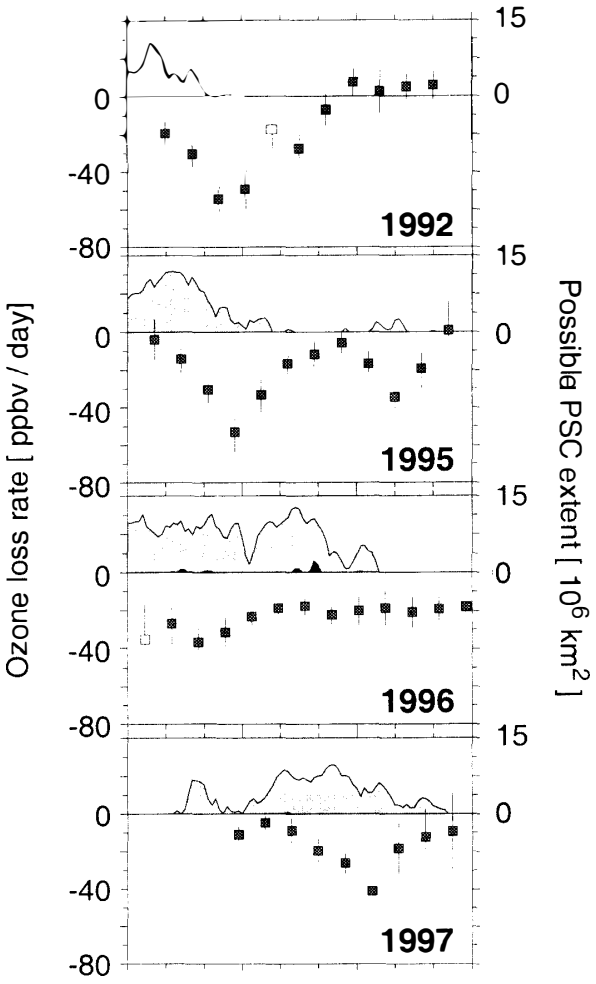

Fig. 4. Match results for 4 Arctic winters; points give the variation of ozone loss rates per day through the winter as retrieved for an isentropic level of 475 K potential temperature (approx. 20 km altitude); each point (square) is the result of a linear regression over a subset of matches which occurred during a period of 7 days before and after the date of the point; filled squares indicate that the subset comprises 10 or more matches; the shaded curves in the upper parts give the area of the northern hemisphere where temperatures have been below the temperature threshold to form Polar Stratospheric Cloud (PSC) particles (Rex et al., 2000).

technique during the covered winters. Chemical ozone loss was detected except for winters 1998 and 1999. The years with strongest loss rates coincide well with the above mentioned local observations of PSC occurrence (Fig. 3) and HCl reduction (Fig. 2) in Ny-Ålesund. In winter 1995 maximum local loss of approximately 60% occurred in about 20 km altitude. The accumulated loss in the ozone column reached 127 DU, *i.e.* approximately 30% (Rex *et al.*, 1997). That is significantly less than observed above Neumayer station, where it comes to 90% ozone loss every year.

Summarising the Match observations since 1992 and from 1995–1999 stratospheric ozone loss rates show a strong inter-annual variability in the Arctic stratosphere (Fig. 4). But the inter-annual variability is less pronounced in the Antarctic. Here the spring ozone loss is strong in every year. The interaction between dynamics and subsequent chemical processes is different in both polar regions mainly because of the different dynamical constraints in the Arctic and Antarctic (Rex *et al.*, 2000).

3.2. Tropospheric ozone in both polar regions

The mean annual courses of ozone concentration in the troposphere are strikingly different for the Arctic and Antarctic (Fig. 1). The records of both stations show how

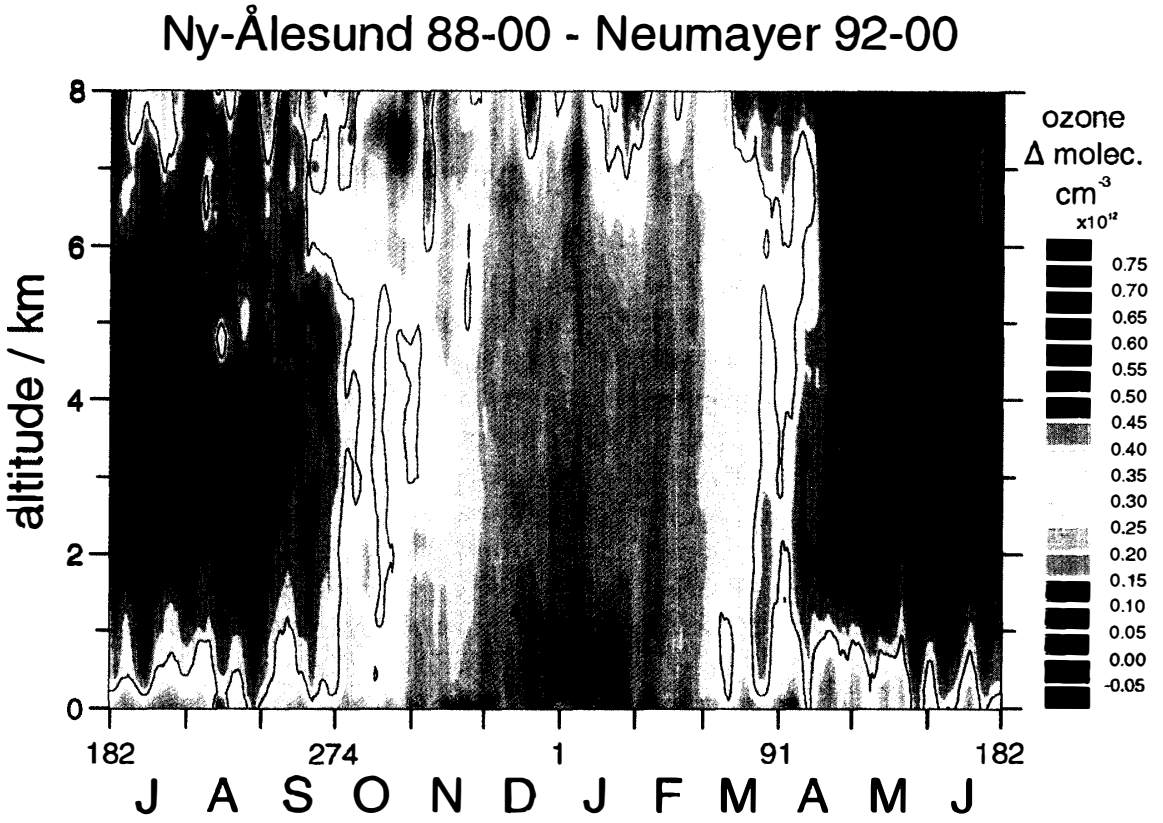

Fig. 5. Difference of mean tropospheric ozone concentration between Ny-Ålesund (1988-2000) and Neumayer (1992-2000) for corresponding seasons (e.g. Arctic spring-Antarctic spring) obtained by exactly left panel minus right panel of both bottom panels of Fig. 1; time scale indicates days and months for the Northern hemisphere.

differently tropospheric ozone appears in the remote and pristine Antarctic troposphere on the one hand and in the probably more perturbed Arctic troposphere on the other hand. The differences of ozone concentrations between the Arctic and Antarctic measurements for corresponding seasons clearly indicates the deviations in the Arctic with respect to the reference pattern of the pristine Antarctic region (Fig. 5).

In the Arctic tropospheric ozone concentrations are higher up to 0.60 molecules/cm^3 from April until September. Smallest differences are obtained for the winter season, *i.e.* for the polar night. But there is also an altitude dependence. In the boundary layer differences are smallest up to about 0.20 molecules/cm^3. That roughly corresponds to the mean difference of about 10 ppb less ozone in Antarctic regions as retrieved from surface ozone measurements (Oltmans *et al.*, 1998). However, as the ozone sonde observations show, these differences are three times greater, up to 0.60×10^{12} molecules/cm^3, above 1 km altitude in the whole troposphere.

The tropospheric ozone content is controlled by downward transport of ozone rich air from the stratosphere and additionally by *in-situ* photochemical production or reduction of ozone depending on certain levels of nitrogen oxid concentrations in the troposphere (Crutzen, 1970). The higher ozone content in the Arctic troposphere with respect to the

Antarctic reference might be mainly due to a net photochemical production of ozone because of sufficient high concentrations of nitrogen oxides. The transport of mid-latitude air masses towards Arctic latitudes is regarded as a possible source of those species (Solberg *et al.*, 1997). Considering this, the intercomparison of ozonesonde data shown here may be understood as an example showing the influence from northern mid-latitudes to the Arctic tropospheric ozone layer.

3.3. Tropospheric aerosols in both polar regions

Another difference between the Arctic and Antarctic refers to tropospheric aerosols. Since 1991 measurements of the spectral aerosol optical depth were performed by photometers in Ny-Ålesund and in parallel at Neumayer station. Tropospheric aerosol optical depth were retrieved using stratospheric background data from SAGE II measurements (McCormick, 1987; Herber *et al.*, 1993). The successful deployment of the star photometer technique now provides year round observations of atmospheric aerosols even during polar night conditions. The well known Arctic Haze, so far discussed as a spring phenomenon (Heintzenberg, 1989; Shaw *et al.*, 1993), appears with a frequency of about 40% in the lower troposphere at Ny-Ålesund. The polar night observation provided some new information on the climatology of the occurrence of Arctic Haze. It was discovered that the aerosol clouds even occur in February with a frequency of about 17% during late winter twilight conditions. But low optical depths comparable to those for summer conditions are also observed in spring (Herber *et al.*, 2000a).

The Arctic Haze causes a strong seasonal variability of aerosol burden in the Arctic troposphere. During late winter and spring high aerosol concentrations occur, but in summer and fall they are as low as for the clean air background levels recorded in the Antarctic during all seasons (Herber *et al.*, 1993; Gernandt *et al.*, 1997). The appearance of those aerosol clouds is also explained by long-range transport of air masses carrying species for the formation of aerosols from lower latitudes (Iverson, 1989). As the Arctic Haze frequently occurs even from February until the beginning of summer season, these elevated concentrations of aerosols may have some impact on radiative forcing in the Arctic troposphere (Wendling *et al.*, 1985). The impact of aerosols on Arctic climate recently became a major topic of atmospheric research. Preliminary model studies considering the existence of very simplified haze layers reveal a possible warming up to 2 K in the aerosol layer and a response in surface temperatures between ± 2 K depending on further conditions (Shaw *et al.*, 1993). More sophisticated model studies need appropriate input of optical properties, *e.g.* absorption and scattering coefficients, as well as temporal and spatial distributions of tropospheric aerosols. Such extended studies took place in spring 2000 in a co-operation between NIPR and AWI called the Arctic Study of Tropospheric Aerosol and Radiation (ASTAR). The joint ASTAR 2000 campaign comprises aircraft measurements above the Svalbard region and ground-based observations at Ny-Ålesund as well as SAGE II satellite data (Yamanouchi *et al.*, 2001).

3.4. Long-term ozone layer changes in both polar regions

Having performed regular ozone sonde launches at Ny-Ålesund and at Neumayer for a period of 8 years from 1992 until 1999, a simple estimate of long-term changes in the ozone layer has been made for both the Arctic and the Antarctic. Mean annual variations

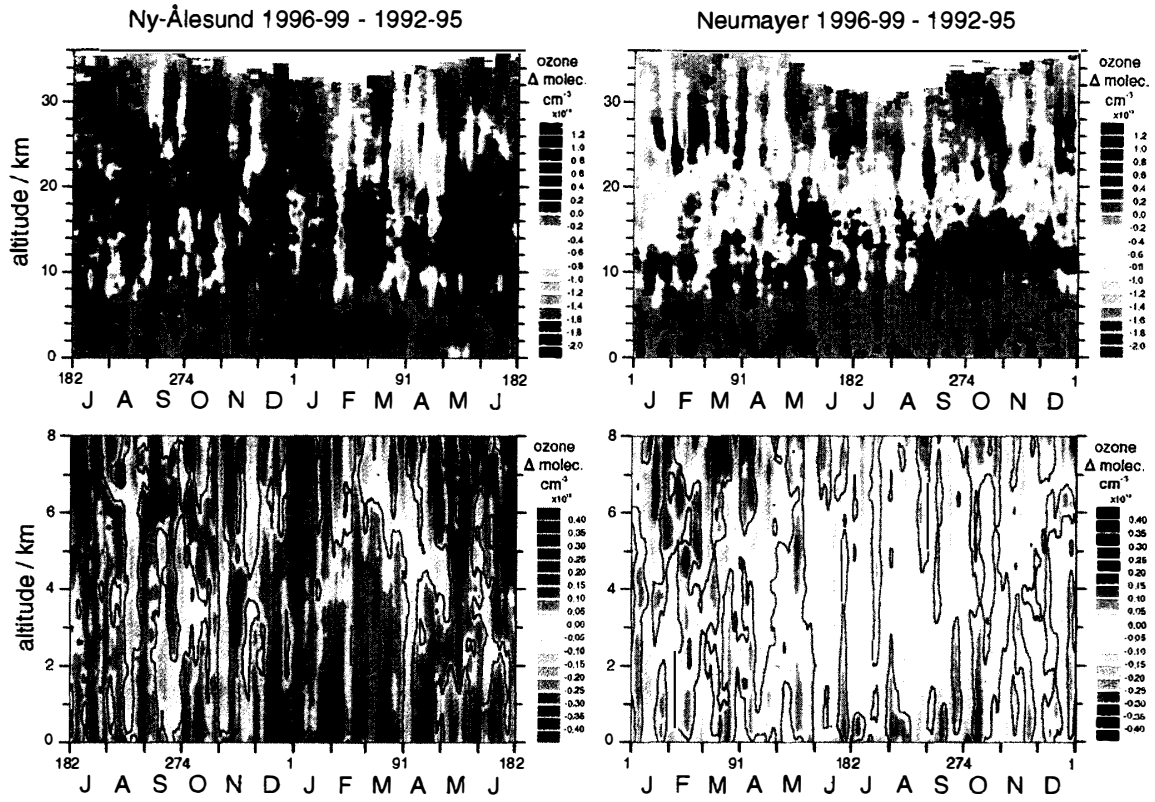

Fig. 6. Differences of mean ozone concentrations calculated for the period 1996/99 minus period 1992/95 for Ny-Ålesund and Neumayer; upper panels show the totally covered altitude range of observation; lower panels show tropospheric altitudes; differences of ozone concentration are colour coded ($\times 10^{12}$ molecules/cm^3); time is scaled by days and months related to the seasons of hemisphere.

were calculated for two subsections of 4 years time each, from 1992 to 1995 and for 1996 to 1999, respectively. The change of ozone is obtained by calculating the difference between these mean patterns as "mean 1996/99" minus "mean 1992/95". Results are shown in Fig. 6. The obtained changes of ozone concentration are colour coded.

The upper panels (Fig. 6) show the recorded changes in the stratosphere, which seem to be different for both polar regions during the considered period of time. In the Arctic stratosphere (upper left panel) a significant decreasing trend of stratospheric ozone can be identified between 16 km and 26 km altitude in March and April during spring season. Simultaneously even higher ozone concentration is recorded between 10 km and 20 km altitude in February as well as in May and June. Except for these limited changes the mean distribution of ozone did not significantly change during the considered period of years. A surprisingly different result was obtained for the Antarctic stratosphere. Since 1992 ozone concentration has decreased between roughly 14 km and 24 km altitude for all seasons of the year.

The lower panels (Fig. 6) show the same results in more detail for tropospheric altitudes. In the Antarctic (lower right panel) ozone concentrations have not significantly changed. But for the Arctic a slight increase of tropospheric ozone concentrations can be

stated from the ground up to about 5 km from December until March during the winter season.

This bi-polar assessment is very preliminary because of the temporally limited data records. But it shows a surprising result on a possible different long-term development of the ozone layer in both polar regions. Because records are getting continuously longer in time, those analyses might be more reliable and expressive in the future. Recently it can only be stated that balloon-borne observations show those changes from 1992 until 1999. To explain possible physical or chemical causes these observations need further confirmation.

4. Validation experiments

In order to fulfil the quality assurance requirements within global and regional networks, the data sets from individual stations have to be validated. Within the Network for the Detection of Stratospheric Change (NDSC) detailed rules have been established for the various instruments describing in detail the validation procedures. The FTIR, microwave, and lidar instruments and the balloon borne ozone sondes have been subject to individual, on site validation efforts, in addition to efforts aiming at the homogenisation of the data retrieval processes.

The results of the FTIR on site instrument intercomparison, which was the first in a series of on site comparisons conducted in recent years, have provided the basis for a study of the most significant sources of uncertainty in ground-based FTIR measurements (Paton-Walsh *et al*., 1997). Overall uncertainties for the column densities of the most important species were found to vary from 6% for N_2O over less than 10% for HCl and HF to 14% for HNO_3.

An international microwave intercomparison campaign was conducted at Ny-Ålesund in February to March of 1997 with four participating instruments from CRL (Tokyo), FZK (Karlsruhe), SUNY (New York), and IUP (Bremen). It was mainly focussed to measure chlorine monoxide in the stratosphere by ground-based microwave instruments and to compare the retrieval algorithms. Those measurements from the ground remain a great challenge and further improvement of instrumentation and applied retrieval algorithms is necessary (Neuber, 1999).

The Ny-Ålesund Aerosol and Ozone Measurement Intercomparison campaign in winter 1998 (NAOMI-98) was a major effort to validate all instruments making ozone profile measurements in Ny-Ålesund (Neuber *et al*., 2001). The travelling NDSC standard instrument, the mobile ozone lidar system from the NASA Goddard Space Flight Center, was installed at the Koldewey-Station. In addition to AWI's ozone and aerosol multi wavelength lidar, the balloon borne ECC sondes and the microwave radiometer RAM, were included in the comparison. The results reveal a strong altitude dependence of the quality of the retrieved ozone profiles. While for the main body of the ozone layer the difference of the methods is less than 5% for the average profiles, altitude range, resolution and error decrease differently for higher altitudes. While the microwave system shows the largest altitude range and best temporal coverage and resolution, the singular balloon borne measurements have the finest altitude resolution. The strength of the lidar instruments, which had an excellent agreement of less than 5% between 15 and 32 km altitude, relies on their capability to reveal short term variability in the ozone layer. Their data revealed *e.g.*

a stable wave pattern in the 17–22 km altitude range during the course of the campaign from mid-January to mid-February 1998 (Steinbrecht *et al.*, 1999).

The proven high quality of the data sets collected at Koldewey-Station in Ny-Ålesund qualify the station for satellite validation efforts. The GOME instrument onboard the ERSII satellite was validated with Spitsbergen trace gas columns, like bromine monoxide (Richter *et al.*, 1998), as will its follow-up instruments, the SCIAMACHY and MIPAS experiments onboard ENVISAT. The SAGE III instrument, scheduled for launch in 2001, will be mainly validated globally by two so called "anchor sites", namely Lauder, New Zealand and Ny-Ålesund, Spitsbergen. In addition to the validation efforts, ozone and aerosol data from Koldewey-Station were used as correlative data sets for the ILAS instrument onboard ADEOS and shall be used for the ADEOS II mission as well.

5. Conclusion

It could be shown that the atmospheric observations contribute to climate and process studies for the Arctic region. An important complement are the observations in the Antarctic to understand changes in a climatological scale as well as to identify the importance of different physical and chemical processes.

On the other hand local observations have to be connected with satellite measurements in order to study atmospheric phenomena in their regional and global scale. The ground-truth validations, which have been performed already, form the foundation for such upcoming investigations.

The analysis of the bi-polar ozone record presented in this paper revealed not only the differences in the stratospheric ozone loss processes, but gives evidence of chemical processes in the polar troposphères, which become more and more important.

The long-term activities at the Koldewey-Station in Ny-Ålesund will be continued in the future in order to help answering the questions raised when considering the changes in both polar regions.

Acknowledgments

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