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Results from GAW Station Neumayer

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The observations at Neumayer cover the following types of GAW-measurements: Aerosol, greenhouse gas, meteo, ozone, radionuclide, solar radiation. In the following, some examples from the long-term measuring programme will be shown. More information is available at <http://www.empa.ch/gaw/gawsis/reports.asp?StationID=54> or <http://www.awi.de/Polar/neumayer2.html>.

Air Temperature

Antarctica is frequently regarded to be very sensitive to climate changes. The positive albedo feedback mechanism between temperature and sea-ice extent is taken as one reason. The collapse of the Larsen Ice Shelf in 1995 and 2002 may be seen as an example. The event took place at the Antarctic Peninsular where a significant warming over the last 50 years was recorded.

The annually averaged air temperature 2 m above the snow surface from Neumayer is depicted in Figure 1. Within the last 25 years remarkable year to year variations were measured but no significant trend can be observed. This finding is in contrast to the measurements at the Antarctic Peninsular, but typical for the majority of all other Antarctic stations.

Recent publications denote a significant warming of the Antarctic winter troposphere [Turner et al., 2006]. The authors analysed long-time radiosonde measurements of 9 Antarctic stations covering the whole continent. The data from Neumayer - which have not been taken into account in this publication – show a comparable trend, but vice versa! Thus, at this moment it seems to be questionable whether the proposed warming of the Antarctic winter troposphere is significant or not.

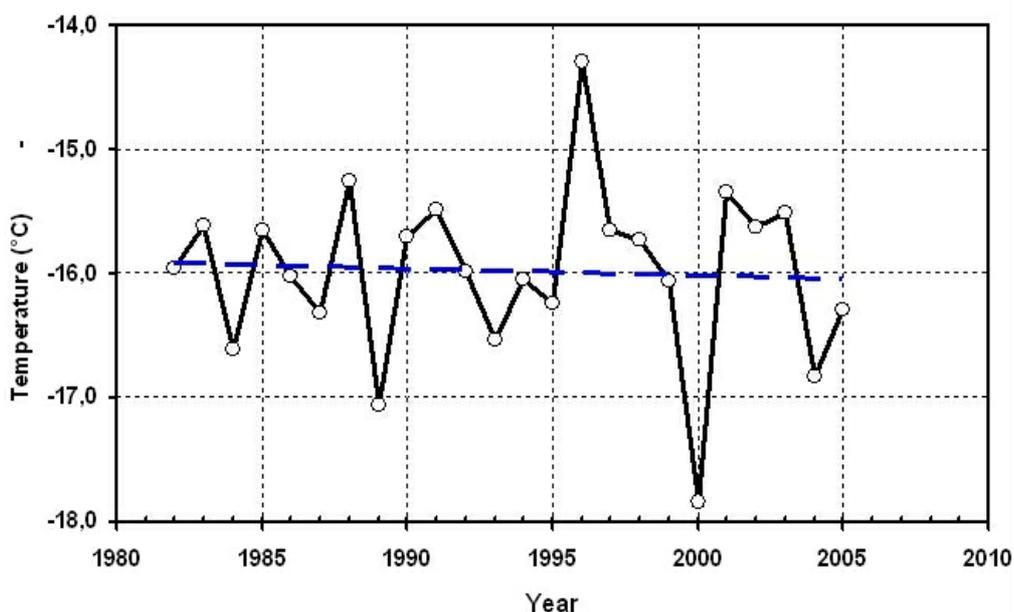


Figure 1: Time series of the annually averaged air temperature 2 m above the snow surface of Neumayer.

Radiation

The radiation measurements at Neumayer are performed within the framework of the "Baseline Surface Radiation Network" BSRN [Ohmura et al., 1996]. One goal of this network is to monitor the background short-wave and long-wave radiative components and their changes with the best methods which are currently available. Furthermore, the network is used to validate and evaluate satellite-based estimates of the surface radiative fluxes and for comparison to climate models.

Since 1992 validated high quality data are available from about 40 BSRN-stations around the whole world. The Neumayer data show slight increase of the global radiation and a slight decrease of the long-wave downward radiation. The significance of these trends is still under discussion.

Ozone Profiling

The dynamic of the upper atmosphere in Antarctica is strongly influenced by a belt of strong westerly winds which form a circumpolar vortex surrounding the whole continent. This vortex is normally rather stable and separates the air masses within the vortex from the air at lower latitudes. Although the lower boundary of this vortex lies within the middle of the troposphere the vortex is called Antarctic stratospheric vortex since it dominates the dynamic of the whole stratosphere including the ozone layer. Only during polar day the vortex vanishes completely.

While the vortex is established, the advection of ozone rich and warm air from lower latitudes into the stratosphere of Antarctica is strongly reduced. Thus, during polar night, when no solar uv-radiation can get absorbed from the ozone layer, the stratosphere cools down to temperatures below -78°C which allow the formation of polar stratified clouds. With the increasing meridional temperature gradient across the polar vortex the wind velocities of the vortex increase. This thermal wind has mean zonal values well above 50 m/s and lead to a further separation of the air-masses inside the vortex.

After the Antarctic winter, when the sun rises above the horizon and polar stratified clouds are frequent, the solar radiation has the potential to destroy ozone molecules very efficiently. This happens normally during the first half of September. Afterwards, the ozone layer within the whole vortex is severely depleted or locally destroyed completely. The area with a vertically integrated ozone amount of less than 200 Dobson is called ozone hole.

The ozone hole frequently covers the total area within the stratospheric vortex. The worldwide increasing anthropogenic CFC concentration lead to an increasing ozone depletion.

The decreasing ozone concentrations in the Antarctic stratosphere lead to a diminished absorption of uv-radiation. Thus, the warming of the Antarctic stratosphere during spring is reduced. The isolating polar vortex – a thermal wind – resists longer and the possibility for polar stratospheric clouds – needed for further ozone depletion – is rising.

This positive feedback mechanism ends when the stratosphere gets warm enough that polar stratified clouds cannot exist any longer. The temperature gradient across the polar vortex gets weaker till the vortex loses its isolating character and warm, ozone rich air from lower latitudes can penetrate into the Antarctic stratosphere. This happens normally during November. In rare cases the stratospheric vortex is dynamically unstable and gets destroyed during winter. Comparable high temperatures and high ozone concentrations during the following spring are the consequences.

Since 1982 daily upper air soundings take place at Neumayer. In 1992 a weekly ozone sounding programme – started in 1985 at the near by station Georg-Forster – was moved to Neumayer. Both stations are situated comparable within the area normally surrounded by the Antarctic stratospheric vortex. The measurements contribute to the "Global Atmospheric Watch" (GAW) as well as to the "Network for the Detection of Stratospheric Change" (NDSC).

As can be seen clearly in Figure 2, the ozone layer above Neumayer shows a pronounced annual cycle. High ozone partial pressures are measured at heights about 20 km from December/January till end of August. This ozone originates from lower latitudes while the polar stratospheric vortex did not exist. Later, it stays more or less without major concentration changes inside the isolated vortex. The ozone layer descends from January to August about 3 km. The prevailing katabatic winds at the surface of Antarctica – leading to a mass transport outside the area of the polar vortex - are the reason. During Antarctic spring (September till November) the ozone layer vanishes more or less completely.

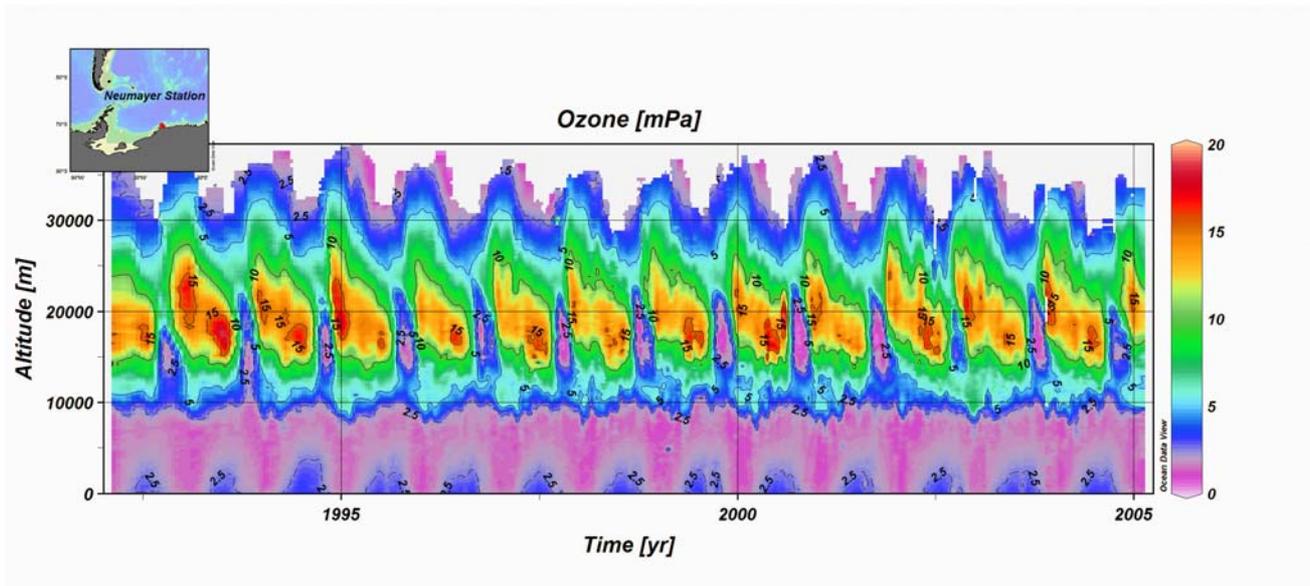


Figure 2: Time-height section of ozone partial pressure above Neumayer from 1992 to 2005.

Within the troposphere the ozone partial pressure is comparable constant with time and height. Close to the surface an annual variation with maxima during polar night and minima during polar day is evident.

The ozone layer during Antarctic spring shows remarkable inter-annual variations as well as an overall reduction of the ozone partial pressure with time. If the time series from Neumayer gets extended with the measurements taken from the near by station Georg-Forster these effects are even more pronounced, see Figure 3. The ozone reduction is strongly correlated with a cooling of the stratosphere. Corresponding variations or a significant trend during other seasons could not be ascertained.

From 1985 till 1989 a biannual oscillation of the spring ozone concentrations is evident. It is strongly correlated with the temperature in the height of the ozone layer. Labitzke et al. [1992] explained this behaviour as dynamically induced from the quasi biannual oscillation of stratospheric wind above the equator.

In the nineties, no biannual oscillation of the spring ozone concentration was measured any longer. The data show a more or less continuously reduction of the ozone concentration and a cooling of the air around 70 hPa. Crutzen et al. [1986] explained this kind of behaviour as a chemically effect with respect to the worldwide rising anthropogenic CFC concentrations.

During spring 2002 very high temperatures and ozone concentrations were measured. They result from a dynamically break down of the Antarctic stratospheric vortex during winter. This behaviour has nothing to do with a recovery of the ozone layer after the worldwide ban of nearly any CFC product. Although the CFC concentrations in the troposphere are significantly falling and

start to fall in the stratosphere the recovery of the ozone layer will most probably not take place within the next decade.

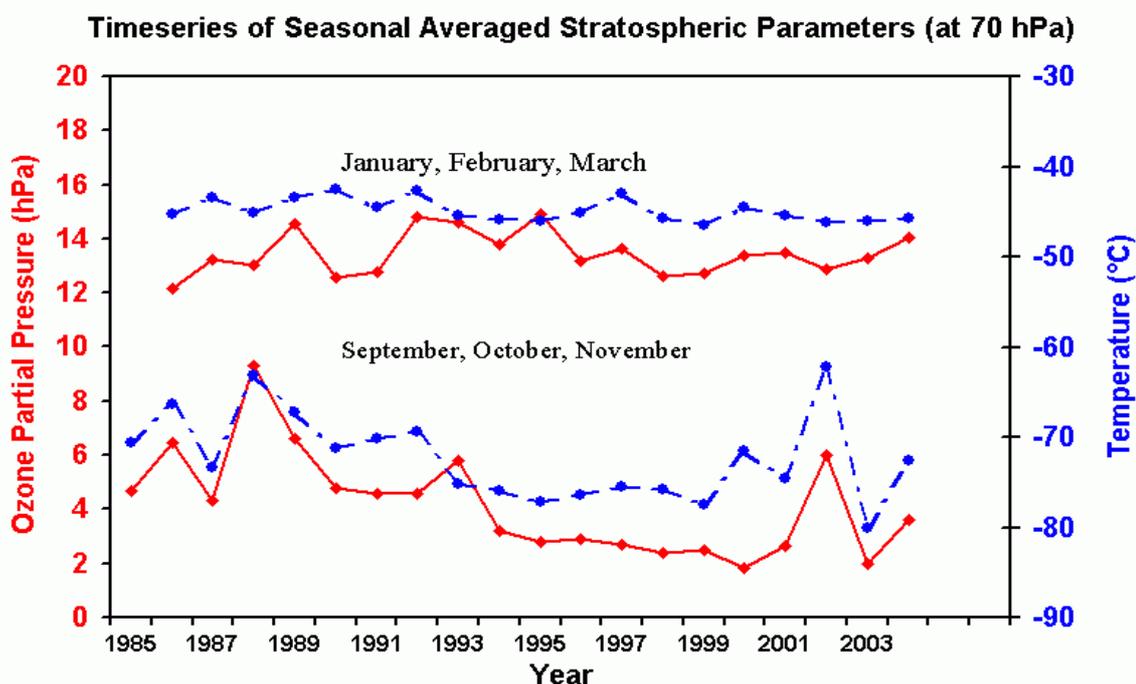


Figure 3: Time series of seasonal averaged stratospheric parameters (at 70 hPa) above Georg-Forster and Neumayer from 1985 to 2005.

Tropospheric Ozone

It is generally accepted that the photooxidation of trace gases to water soluble compounds, followed by rainout, is the major cleaning procedure of tropospheric air. Photooxidation in the troposphere consists of typical radical chain reactions which need to be initiated, mainly by OH radicals. OH in turn is primarily generated via ozone photolysis and subsequent reaction of the so produced O¹D (i.e. electronically excited oxygen) atoms with water vapour. Thus tropospheric ozone is certainly a key trace gas in controlling the chemical composition of the troposphere.

Surface ozone is continuously measured since 1982 at Neumayer Station by electrochemical concentration cells (ECC, until 1994) and uv-absorption from 1994 ongoing (Figure 4). O₃ mixing ratios measured at the former Georg-von-Neumayer-Station by ECC seem to be significantly lower before 1987, a probably artificial peculiarity which is not yet clarified. Nevertheless from this record, covering now 24 years of observation, no significant trend can be deduced.

A more detailed section of this times series is depicted in Figure 5. Maximum ozone values of about 32 ppbv are generally observed in August while during polar summer (December-January) a distinct minimum of around 13 ppbv is typical. In strong contrast to urban areas where nitrogen oxides (NO_x) levels are about three orders of magnitude higher, photochemical ozone destruction and not formation occurs in summer leading to surface ozone minima in pristine regions like Antarctica.

In addition, from August to September extraordinary tropospheric ozone depletion events can frequently be detected (Figure 5). Neumayer Station was the first Antarctic site where this peculiarity was described [Wessel et al., 1998]. Comparable to stratospheric ozone depletion, reactive halogen compounds, here especially BrO, are responsible for this anomaly [Friess et al.,

2004]. However, in contrast to the chemical processes occurring in the stratosphere, tropospheric ozone depletion in polar regions is a natural phenomenon most probably caused by release of reactive bromine compounds eventually derived from sea-salt over sea-ice. There is some recent evidence that frost flowers, which frequently grow on newly-formed sea ice, play an important, if not crucial role as a source for reactive tropospheric halogen compounds [Kaleschke et al., 2004].

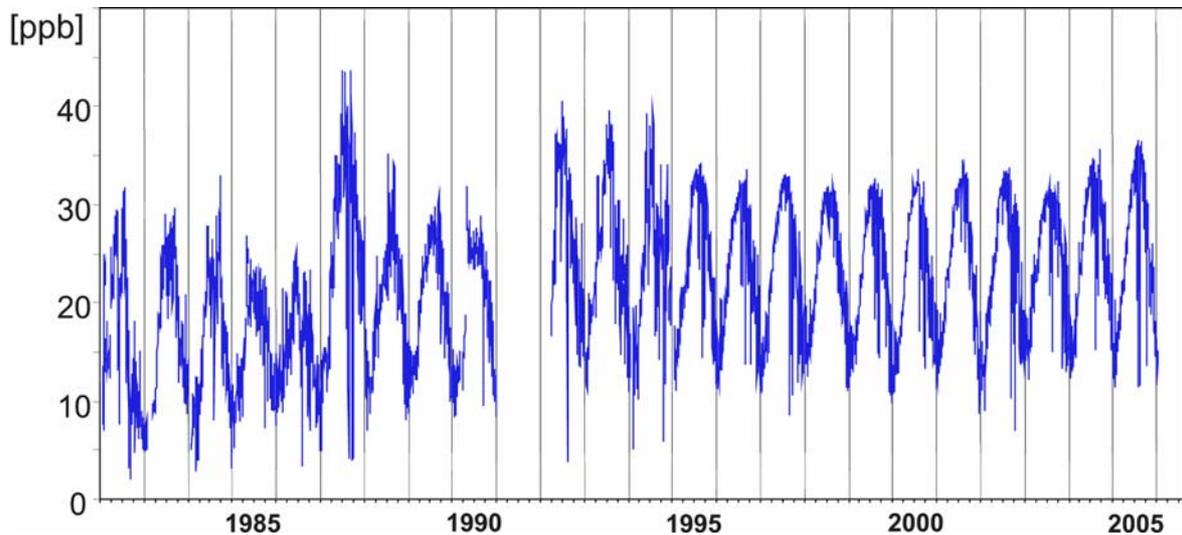


Figure 4: Surface ozone mixing ratios (daily means) record at Neumayer from 1982 to 2005.

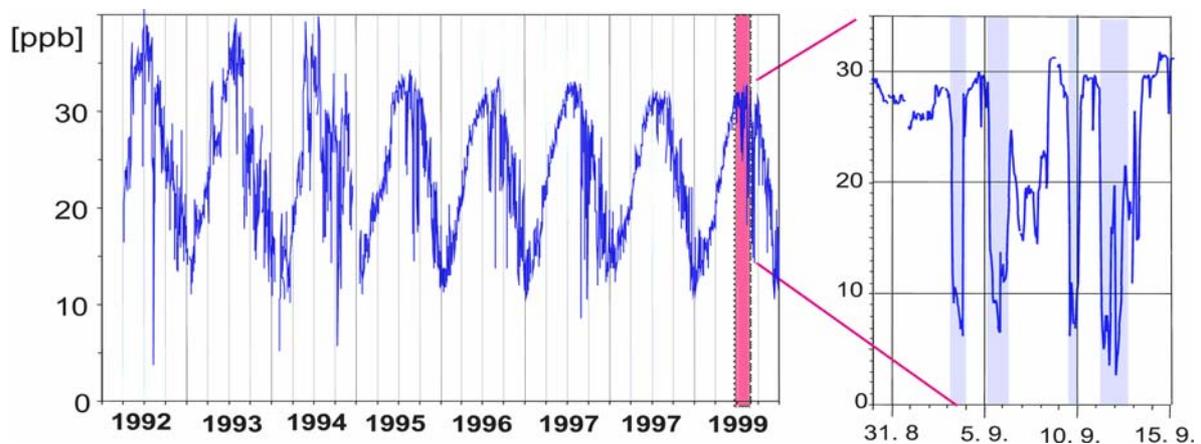


Figure 5: Surface ozone mixing ratios (daily means) record at Neumayer from 1992 to 1999. The enlarged section on the right hand side shows typical tropospheric ozone depletion events (shaded areas) in more detail (hourly averages).

Condensation Nuclei Concentrations

Condensation nuclei (CN) comprise all atmospheric particles which can act as nuclei for condensation of low volatile gaseous compounds most notably water vapour. Generally particles >3 nm in diameter can act as CN.

CN concentrations at Neumayer exhibit a stepwise increase from polar winter (below 100 particles/cm³) to a maximum in late austral summer of around 1000 particles/cm³ (Figure 6). During summer the chemical composition of these particles is mainly methane sulfonic acid (MSA) and non-sea salt sulfate (nss-sulfate), thus CN are formed in the marine troposphere by photooxidation of dimethyl sulfide (DMS) emitted by the phytoplankton.

During winter and stormy weather conditions, however, sea salt aerosols dominate. Interestingly, the maximum of condensation particle concentration typically appears in late February to early March, i.e. shifted by around 4-6 weeks compared to the MSA and nss-sulfate maxima. Our measurements suggest that during late summer the concentration of very small particles between 3 and 5 nm diameter (nucleation mode) is significantly enhanced, indicating new particle formation.

DMS could act via its photooxidation product sulfuric acid as gaseous precursor for nucleation mode particles, a process known as gas to particle conversion. Due to the relatively short atmospheric lifetime (a few hours) of nucleation mode particles, regional sources should dominate the measured signal. We believe that following the retreat of sea ice in the nearby Atka bay during late February, considerable amounts of DMS are released by the now emerging phytoplankton bloom in this area. Note that nucleation mode particles do not contribute much to the total aerosol mass due to their small size, therefore nss-sulfate and MSA concentration maxima must not coincide with the particle number concentration maximum!

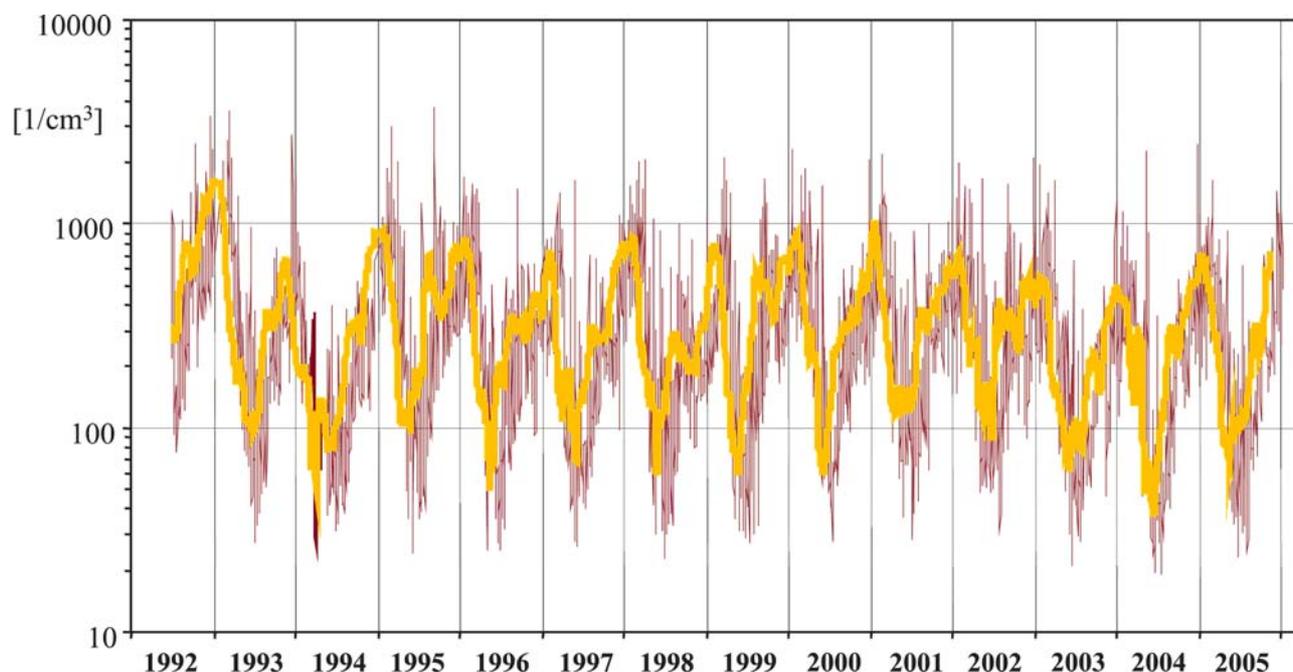


Figure 6: Daily means of condensation nuclei (particle diameter larger than 10 nm, measured with a TSI CPC 3022) concentrations at Neumayer. The bold yellow line is a low-pass smoothed representation of the data by a 30 points Gaussian filter.

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