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AVERAGE OZONE VERTICAL DISTRIBUTION AT SODANKYLA BASED ON THE 1988-1991 OZONE SOUNDING DATA

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Abstract:

The study presents the statistical analysis of ozone sonde data obtained at Sodankylä (67.4°N, 26.6°E) from the beginning of the sounding program on March 1988 to the end of December 1991. The Sodankylä sounding data offers the longest continuous record of the ozone vertical distribution in the European Arctic. In this paper we present the average ozone partial pressures within each 1 km column obtained for different seasons during the almost four year long period. We believe that the data represented here are useful as an interim reference ozone atmosphere, especially considering the fact that northern Scandinavia has become a popular campaign site for the big international ozone experiments.

Introduction

The Finnish Meteorological Institute (FMI) has run a regular sounding program at Sodankylä in northern Finland since March 1988. Despite the fact that the time span is short in the climatological sense, the mean profiles obtained here could be useful in many other applications. Several ozone monitoring techniques, e.g. UV spectroscopy of scattered sky light, are sensitive to adopted ozone vertical distribution, especially when the solar zenith angle is large. One example is represented in Figure 1 where the ratio TOMS/Brewer from the intercomparison made at Sodankylä over the years 1988-1991 is presented. The seasonal variation of the ratio, probably caused by variation of the airmass, is obvious. Because only direct sun observations up to the airmass values 5 or the focussed moon observations up to the airmass 3 have been used for Brewer, it is reasonable to believe that the seasonal difference is caused by the airmass dependence of TOMS data [Kyrö, 1992].

The same concerns the zenith sky observations with Dobson or Brewer when lower than 10 degrees sun elevation is used. It is even possible that so called ozone "miniholes" or anomalously low total ozone values often measured during polar winter are partly instrumental artifacts. The important source of error is the method by which the sky charts for winter observations have been prepared traditionally . One takes series of observations over the wide range of airmass values throughout the day when the ozone layer is stable. The chart, obtained predominantly during summer, is then used for the observations made in winter when the vertical ozone distribution, especially in the higher part of the ozone layer, is a significiantly different [Taalas and Kyrö, 1992].

It should be possible to improve the zenith sky ozone retrievals by using the radiative transfer model instead of the classical chart. It can be shown that at the low sun elevation the retrieved total ozone value will be particularly dependent on the assumed vertical distribution [Frank and Platt, 1990]. Therefore the improved knowledge of the vertical distribution of the polar ozone and its seasonal variation could improve accuracy of the polar winter time total ozone measurements, both ground-based and satellite-based.

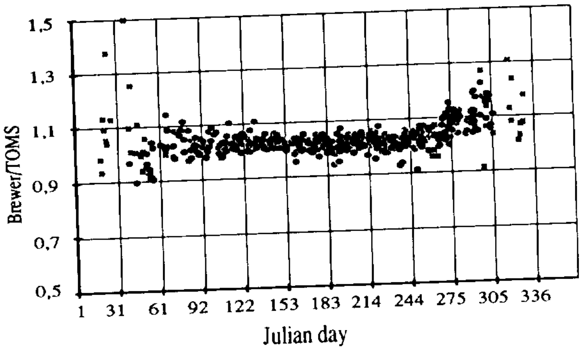

Fig. 1. The ratio Brewer/TOMS obtained from the comparison of the daily values from May 1988 to December 1991. Dots represents Brewer direct sun measurements and asterixes Brewer moon measurements [adapted from Kyrö, 1992].

Experimental

The Vaisala ozone sounding system is used at the Sodankylä observatory. It consists of the Vaisala Oy Micro Cora ground unit with additional PC computer for the telemetry and data acquisition. The ozone sondes are electrochemical concentration cells of type ECC5A from the Science Pump Co. Radiosondes of Vaisala are used to measure pressure, temperature, humidity and wind. Further, the ground check unit TSC-1 by Science Pump Co is used to calibrate the ozone sensors at the ground conditions. The small rubber balloons, Totex 1200 g, have been used to lift the payload up to the required 15 to 5 hPa altitude. During winter, however, it is necessary to use "oil dipping" , i.e. the method of soaking of the rubber balloons in the mixture of kerosene and lubricant oil, in order to plasticize the rubber to stand the coldness and heavy winds of the polar winter stratosphere. It must be mentioned here that the significant improvement in

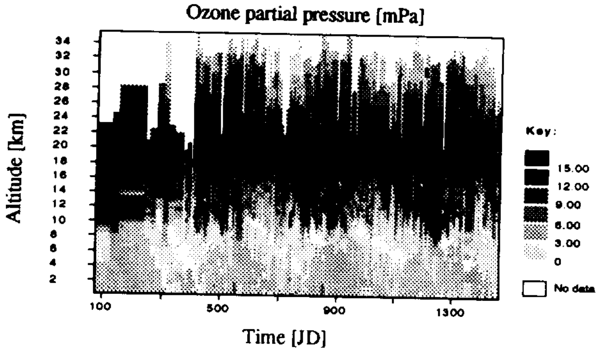

Fig. 2. Overall view of the 167 soundings used in the analysis. The number of day runs from Jan 1, 1988. Each sounding is coded according to the grey scale shown on the right.

the burst altitudes in winter 1990 (33 km in January) as compared with the earlier winter 1989 (20 km respectively) is a consequence of the introduction of the oil soaking treatment at the Observatory from 1990 onwards (see Figure 2).

The preparation of ozone sensors for the flight follows closely the guidelines presented by Komhyr [1986]. The quality of the soundings is continuously checked by comparing, whenever possible, the total ozone value integrated from the sounding profile with that obtained by simultaneous Brewer measurements. The statistics of the correction factors (ratio Brewer vs. integrated sounding) from Sodankylä show good agreement between the two independent methods. The average correction factor for 98 simultaneous measurements is 0.995±0.068 (one sigma). However, the sensors are not calibrated at low pressures. This implies that more scatter may be present in the middle stratosphere because the tightness of the sensor pumps is varying.

Results and discussion

Figure 2 gives an overall view of the data set used in the analysis. The sounding program started 1988 and during the first year on average at the rate of one sounding each month. The denser sounding schedule, at least one sounding a week, started in the beginning of 1989. In order to evaluate the representativeness of the data set, the integrated ozone values from the soundings are compared, in Figure 3, with the long term total ozone measurements at Tromsø, which probably closely approximate the conditions at Sodankylä as well [Henriksen, 1992]. The total ozone values obtained by uv/vis spectroscopy at Sodankylä during 1988 to 1991 (instruments: M-83, Brewer, SAOZ) are shown, too. Because 65% of the soundings fall within the normal variation limits of Tromsø long term record one can conclude that the time period of the analysis represent rather typical conditions in northern Scandinavia. Also, if one integrates the mean profile of all the soundings used in the analysis one obtains the total ozone value of 346 DU which can be compared with the Tromsø long term annual mean of 336 DU. There is a possibility that the exceptional weather pattern of winter 1991/92 in Europe together with the Pinatubo eruption could have depleted ozone layer but by the end of 1991 the effect at Sodankylä was not as large as in Central Europe or southern Scandinavia. Similarly the exceptionally strong stratospheric mid winter warming increased the ozone in polar region during late December 1990/early January 1991.

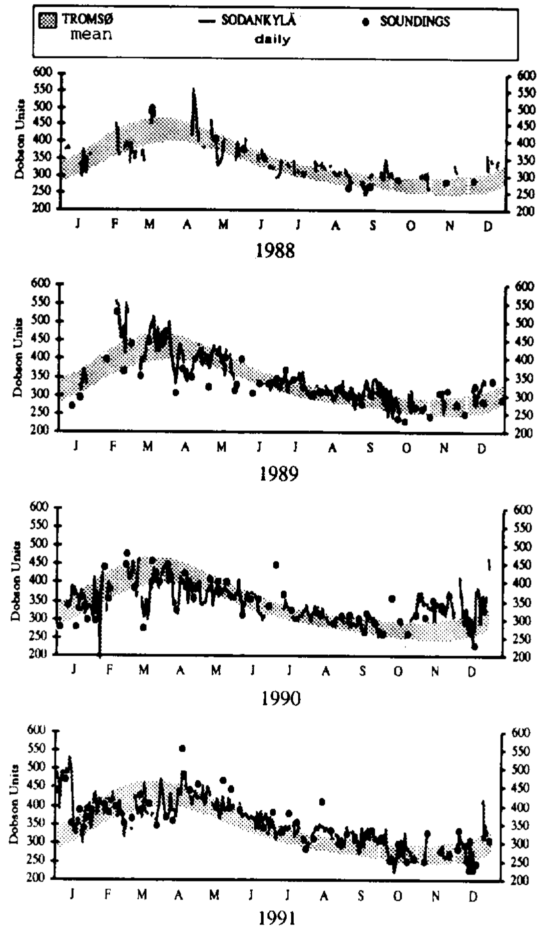

Fig.3. The total ozone observations at Sodankylä 1988 to 1991 compared with the Tromsø long term mean over the period 1935 to 1969 (grey band shows ±1 sigma limits).Sodankylä spectrophotometric observations (thin line) are made either with M-83 (early 1988) or Brewer (from May 1988 on) and supplemented with SAOZ winter time observations (from Feb 1990 on). The dots represent total ozone retrieved from the ozone soundings.

For the analysis the individual sounding profiles were smoothed by computing 1 km columnar averages. Because of the varying balloon burst altitude the higher levels are not statistically as good as the region below 28 km (100 soundings or more). The data for the highest level 32 to 33 km consists of only 39 soundings. The seasons in this analysis are defined as follows: Summer: *May, June, July;* Autumn: *August , September , October* , Winter: *November , December, January,* and Spring: *March, April.* February is usually the transition period from winter to spring. If there is a final warming during February then the period before the warming is included in the winter and the period after the warming is included in the spring. In 1989 the transition time was set at Feb 6 and in 1990 at Feb 20.

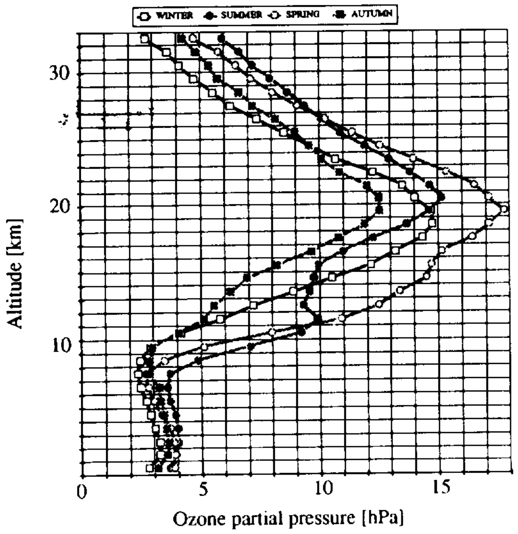

Fig. 4. The seasonal mean values of the ozone vertical distribution at Sodankylä based on the ozone soundings made during the period March 1988 to December 1991.

The mean partial pressures within each 1 km column are presented for different seasons in Figure 4. The characteristically large seasonal variation of the Arctic ozone layer is seen in this picture. In the lowest part of the ozone layer dynamical factors dominate. The largest values are obtained during spring and the smallest during autumn and this height region also determines the behaviour of total ozone seasonal variation seen in Figure 3. Troposphere and the region above the maximum seem to be more controlled by photochemistry. There the largest partial pressures are measured during the summer and the smallest during the winter.

When the present study is compared with our early analysis based on much shorter time span very little change can be seen in the dynamicallly quiescent autumn period whereas other seasons have changed more and the profiles appear to be much smoother [Taalas and Kyrö, 1992]. However, also according to the present analysis there exists a persistent "notch" in the summer profile in the lower part of the layer. A closer analysis reveals that the most probable explanation for this feature comes from two dynamical factors, first: The greatly varying tropopause altitude associated with the synoptic scale weather phenomena, and second: The strong layering/stratification in the individual profiles several soundings showing deep minima at the altitude range of 14 to 16 km. A typical example of the strongly stratified sounding profile together with the associated 5-day back trajecto-ties are presented in Figure 5 which show that the source regions of the airmasses observed in a single sounding can be very different at different altitudes. It is typical in almost all the cases that the depleted layers in lower stratosphere originate from low latitudes along the slowly ascending surfaces and could therefore be of tropospheric origin. If the "notch" seen in the summer profile is completely due to the weather phenomena then it should gradually average out when more observations in different synoptic conditions are gathered over the coming years.

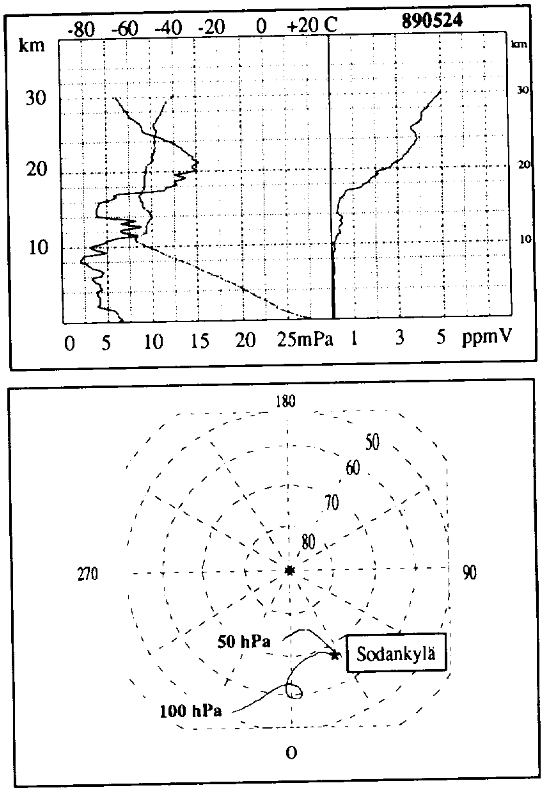

Fig. 5. An example of strongly layered sounding obtained on May 24/89 (a) and 5-day back-trajectories for the same sounding based on the ECMWF-analysis fields (b). Around the partial pressure maximum at 20 km (50 hPa) one finds Arctic airmass whereas the "notch" at 16 km (100 hPa) is a result of the southern advection.

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