# SOME RESULTS OF WATER VAPOUR, OZONE AND AEROSOL BALLOON MEASUREMENTS DURING THE EASOE CAMPAIGN

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During EASOE regular measurements of ozone vertical distribution and aerosol were carried out at two Russian polar stations at Heiss Isl. (81N, 58E) and Dixon Isl. (73N, 81E) according to the program of field experiments. In addition, water vapor and aerosol balloon measurements were taken in Kiruna (68N,21E). The backscattersonde for aerosol observation, the electrochemical ozonesonde ECC4A for ozone measurements, optical fluorescent hygrometer for water vapor measurements were used. The vertical profiles of backscatter ratio were measured at two wavelengths centered at 490 nm and 940 nm. Two types of stratospheric aerosol polar stratospheric clouds and those of volcanic origin were observed over Kiruna. It was found that after Pinatubo eruption in June 1991 significant amount of stratospheric aerosol was transported to the Arctic. It was noted that over the period from of February to the mid of March 1992 total ozone values for Heiss Isl. and Dikson Isl. were lower the climatic norms for those stations. The significant total ozone decrease (with amplitude more than twice of the standard deviation from the climatic model) occurred on days with the baric situation characterized by the vortex intensity decrease (often with its parting ) and notable attenuation of zonal and strengthening of meridional circulations over the observational stations. When values of the backscatter ratio R were greater than 8-10 its local maximum and minimum values of ozone vertical distribution for the stratospheric aerosol of volcanic origin located at the same height. Balloon measurements of water vapor concentrations did not reveal dehydratation processes in the Arctic polar stratosphere. The minimum value of mixing ratio for water vapor (hydropause) located at 2-3 km above the tropopause on the days when sounding occurred.

Introduction.

Polar stratospheric clouds (PSCs) are considered to play an important role in the perturbed stratospheric chemistry insides the Antarctic polar vortex, which leads to the springtime ozone depletion observed over Antarctica [1]. They serve as a sink for stratospheric NOx compounds by sequestering HNO3 and additionally they provide catalytic surfaces for the transformation of HCl to compounds with higher chemical reactivity [2,3,4]. The principle scientific objective of this field campaign was to obtain data relevant to possible chemical or dynamic processes influencing ozone depletion in the stratosphere over the Arctic during winter and spring. The geographical location of polar stations was favourable for implementing the planned investigation, since it is possible to obtain data measurements simultaneously over the central part of the Arctic circumpolar vortex, at this periphery, end outside of this region.

In the two previous winter seasons (1988-88 and 1989-90), similar balloon measurements of ozone and stratospheric aerosol were conducted at Heiss and Dikson Islands. Two types of the vertical distribution of the backscatter ratio R at a 940 nm wavelength were observed by the authors in the Arctic [5]. When temperature in the stratosphere was warmer than -80oC over Heiss and Dikson Islands a background level of stratospheric aerosol was observed with the maximum values of the ratio R of about 1,3 in 15-20 km altitude range. In winter months when temperature in the lower stratosphere was below or close to -80C polar stratospheric clouds were observed over the stations. During these periods maximum R values in the lower

stratosphere increased up to 6-15. Such clouds formations were most often observed at a 17-22 km level. The major PSC activity was observed at an altitude noticeably below (2-3 km) the temperature minimum. Analysis of the balloon measurements of ozone and aerosol scattering made in two winter field campaigns in 1988-91 has failed to reveal any definite correlations between the changes of ozone content in the lower stratosphere and the formation of the polar stratospheric clouds during polar night.

The winter season of 1991-92 was marked by the fact that after Pinatubo eruption in June enormous amounts of aerosol and sulphur compounds were injected to the atmosphere, which spread globally during the following months, reaching the polar regions of the Northern Hemisphere. An additional ozone losses as a result of the spread volcanic debris could be occurred because the additional aerosol loading from the volcano enhances the heterogeneous reactions.

Instrumentation

The vertical ozone profile measurements were made with ECC4A ozonesondes using both plastic and ribbon balloons. Three times a week this balloon were flown. The standard procedure for preparation ECC4A before flight was used.

A balloonborne device called a backscatter sonde was used to observe the PSCs. Briefly the backscatter sonde measures the amount of the backscattered light from the local atmosphere which has been illuminated by a high intensity flash lamp[6]. The data products is essentially the same as that of an aerosol lidar system with high vertical resolution (30 m). The instrument was calibrated relative to clean air found at the maximum altitude of the sounding. The uncertainty in the calibration does not significantly affect the reported values of the scattering ratio for the PSCs. An ECC ozone sensor was also included as a part of the backscattersonde flight instrumentation. Thus simultaneous ozone, PSCs, and temperature measurements were obtained.

Optical fluorescent hygrometer [7] is a balloon borne instrument for night-time in situ measurements of water vapor in the stratosphere and upper troposphere, using technique of photofragment fluorescence. The krypton or hydrogen lamps for dissociation of water vapor molecules on hydrogen and OH fragment are used. The fluorescence from the electronically exited OH fragments is detected by photomultiplier. An interference filter centered at 315 nm with 6 nm bandwidth is used to select the spectral region of fluorescence. The use of the modulation of the lamp intensity and synchrodetecting of the photocurrent make it possible to carry out the balloon measurements in moonlit night. The noise of signal for 5 s averaging corresponds to the humidity of about 0,3 ppmv for the stratosphere.

Results and Interpretation

Measurements of increased aerosol in mid latitudes [8] after Pinatubo eruption gave evidence to assume that the Arctic stratosphere is also effected by strong aerosol before the formation of the winter polar vortex. PSC observations in the Arctic in 1989-1991 by means of balloon backscattersondes at Heiss Isl. under -80C temperature of the stratosphere showed that their height localization is seen in the range of 18 km to 22 km. which was discussed in the article [9]. A different picture in the polar stratosphere in the Arctic appeared during EASOE and that was due to Pinatubo eruption on a global scale. Fig. 1(a) shows balloon measurement data of atmospheric temperature, backscatter ratio R for wavelengths 940 nm and ozone obtained on December 11 in Kiruna. Here the mixing ratio for water vapor is also shown according to measurements data of the fluorescent hygrometer during the balloon experiment in Kiruna 6 hours later. At this time, according to the data analysis of the EASOE meteorology report[10] Kiruna was near the circumpolar vortex center shifted to the European Arctic sector at heights higher than 20 km

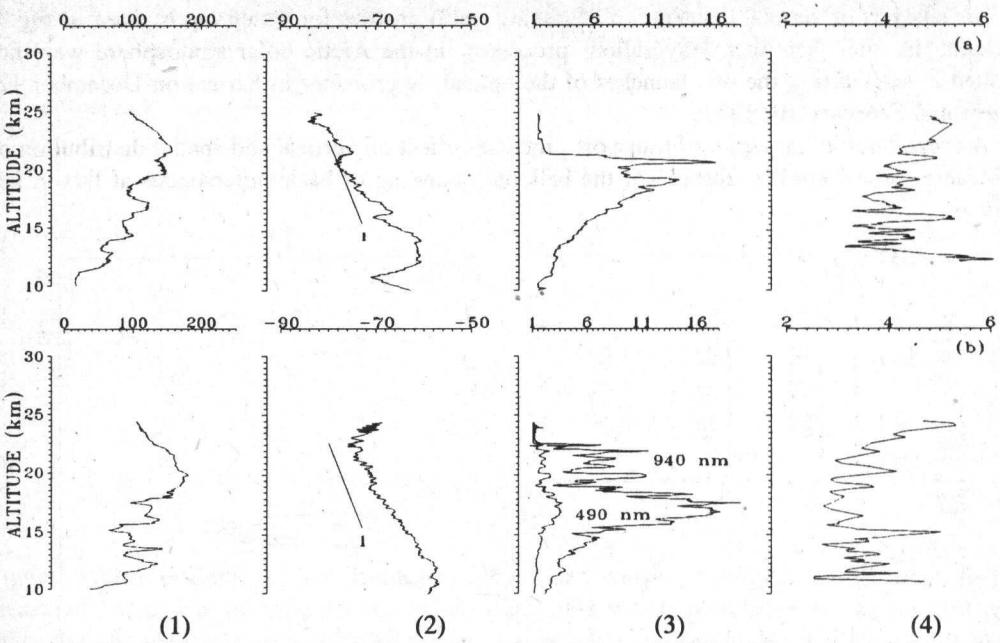


Figure 1. The results of baloon measurements over Esrange (68N,21E). Condensation curve for NAT is based on [11] : 1 - NAT 5 ppmv $H_2O$ , 20 ppbv $HNO_3$. a) 11/12 December 1991, b) 10 February 1992. See text for further details.(1) - Ozone partial pressure (nbars), (2) - T ($^oC$), (3) - Backscatter ratio, R (4) - $H_2O$ mixing ratio (ppmv)

At the same time in the low and mid stratosphere over Kiruna the region of minimum temperatures was observed. Below 20 km the stratospheric temperature conditions according to references curves [11] were not favourable for PSC formation of the first or second type. Therefore the maximum in backscatter ratio at 19 km seems to be determined by aerosol of volcanic origin present in the stratosphere at those levels. Meanwhile the narrow maximum of values at 21 km is connected to the PSC formation of the first type. Temperature values at this height and measured water vapor mixing ratio of 5 ppmv make it possible to generate PSC particles from nitric acid trihydrare. Thus during the balloon launch of December 11, 1991 over Kiruna it was noticed two stratospheric aerosol layers which have different origin of aerosol particles. The fact of coincidence of altitudinal location of local maximums in R values and minimums of partial ozone pressure is of great importance. Taking into account all measurement data using backscattersondes and ECC4A at Kiruna, Heiss Isl., and Dixon Isl., this fact may be considered as typical one if R is greater than 8-10 for aerosol of volcanic origin.

On February 10, 1992 in Kiruna balloon launches of the backscattersonde were made together with the ECC as well as launches of optical hygrometer with an interval of no more than 5-6 hours. The data obtained are given in Fig. 1(b). On February 10 Kiruna was influenced by the altitudinal ridge of higher pressure , the axis of which was directed from the Atlantic to Scandinavian where at the levels of the mid-stratosphere the region of lower temperatures was observed. In spite of the fact temperature conditions in the lower stratosphere over Kiruna were not favourable for PSC formation. A significant aerosol increase above 18 km is characterised by its layer structure which was typical for vertical distribution of volcanic aerosol in mid latitudes [8]. This testifies to the fact that of later volcanic aerosol penetration into the Arctic polar stratosphere at the heights above 18 km.

The analysis of vertical distribution of mixing ratio profiles for water vapor given in Fig. 1 results in the fact that dehydration processes in the Arctic polar stratosphere were not found at least during the two launches of the optical hygrometer in Kiruna on December 12, 1991 and February 10, 1992.

A characteristic example of transport processes effect on vertical and spatial distribution of volcanic aerosol are the results of the balloon sounding of backscattersondes at Dixon Isl. given in Fig. 2.

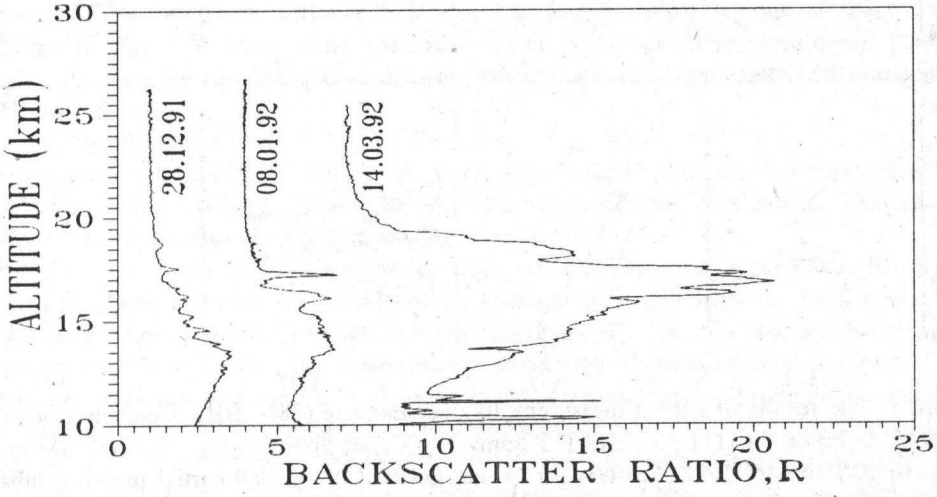


Figure 2. The results of backscattersonde sounding at Dixon Isl. (73N,80E). The values of the first (leftmost) profile corresponds to the scale used. The other two profiles are shifted by an offset of 3 each.

Over the two launching dates 28.12.91 and 08.01.92 Dixon Isl. was in the center of the circumpolar vortex and the stratospheric aerosol content of volcanic origin was practically unchangeable during this period. On March 14,1992 a significant stratospheric aerosol increase was measured. This fact, as it seems, had to do with the break of zonal atmospheric processes and significant meridionality of air fluxes in the stratosphere which was observed over the North of the Euro Asian continent. At the same time the results of vertical ozone distribution given in Figure 3 illustrate once again the existence of aerosol and ozone local maximums and minimums for Dixon Isl. which as it appears are of dynamic origin.

For the analysis of balloon regular sounding data made at Dixon Isl., total ozone integrated values are given in Fig. 4 along with model values for these stations. This empirical model allows us to estimate climatic norms for total ozone and standard deviation from their for any point of the Northern Hemisphere. The dotted lines in the Figures 4 represent a two standard deviation from the mean value. The analysis of synoptical situation for days with relative low ozone when total ozone values were close or exceeded in its variation from the model values of two standard deviation makes it possible to come to a conclusion that such a decrease of total ozone is connected ,as a rule, with vortex intensity decrease (often with its parting) and creation of the strong meridional transport from low and mid latitudes. Nevertheless it

should be noted that from February and up to the end

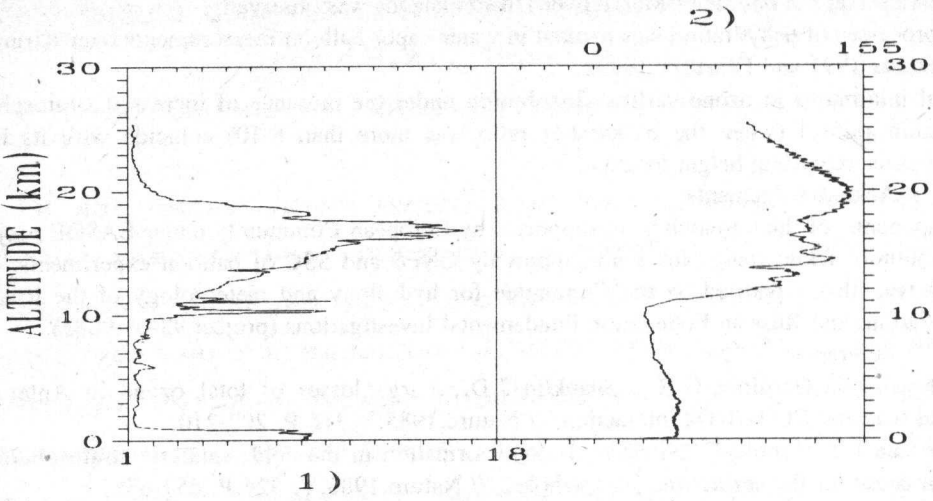


Figure 3. An example of the frequently observed inverse correlation of simultaneously measured ozone and volcanic aerosol in the 1991/1992 winter polar vortex. The backscatter ratio was obtained with a backscatter sonde / ozonesonde and refers to a wavelength of 940 nm. The souding was made from Dixon Isl. on March, 14, 1992.
1) - Backscatter ratio,R. 2) Ozone partial pressure (nbars)

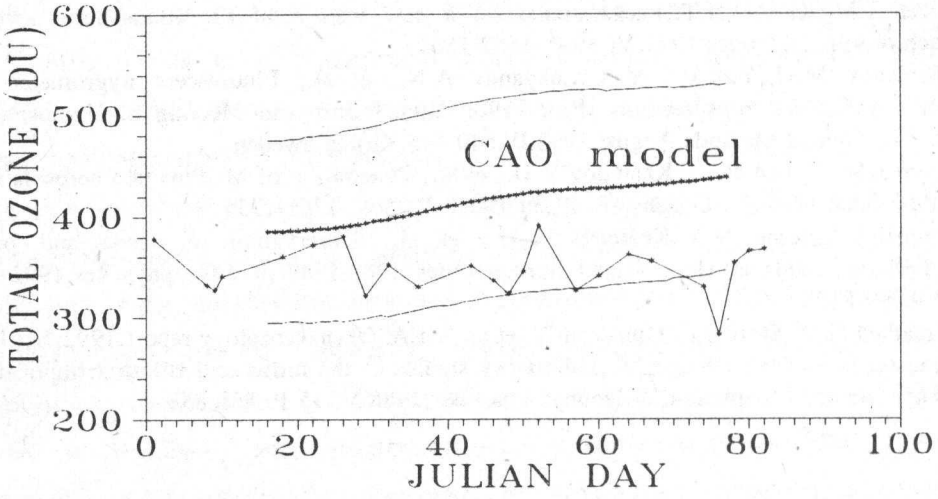


Figure 4. Total ozone and model mean daily values over Dixon Isl. for winter 1992.

of observations over these stations total ozone values were less than the climatic norm. Practically, the whole period of observations in the Arctic was distinguished by higher aerosol content of volcanic origin and therefore lower ozone values for these latitudes can be determined not only by dynamics but also by heterogeneous processes effect.

Conclusion

Two types of stratospheric aerosol - volcanic and PSCs - have been observed over Kiruna in December 1991 - January 1992.

Low total ozone (lower than the climatic norm) from February 1992 up to completing the observation at the middle of March over Dikson Islands was observed.

No processes of dehydration was marked in water vapor balloon measurements over Kiruna in December 1991 and February 19992.

Local minimums in ozone vertical distribution under the presence of increased stratospheric volcanic aerosol (when the backscatter ratio was more than 8-10) coincide with its local maximums regarding height location.

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