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# INVESTIGATION OF THE STRUCTURE AND DYNAMICS OF THE OZONE LAYER IN THE EASTERN ARCTIC REGION DURING EASOE CAMPAIGN

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Abstract. Balloon measurements of the vertical distribution of ozone and aerosol were made at Dickson Island (73°N, 81°E), Kiruna (68°N, 20°E) and Heiss Island (81°N, 58°E) from December 1991 to March 1992. To acquire data on the seasonal variability of the vertical ozone distribution, electrochemical ozonesondes ECC-4A were flown three times a week. With ozonesondes on the same balloons, backscattersondes [1] were flown on the average of two or three times per month. Using these instruments, altitude profiles of backscatter ratio were measured at two wavelengths centered at 490 nm and 940 nm. Additionally, at Heiss Island, Dickson, and Yakutsk (63°N, 130°E) regular total ozone measurements were obtained using Brewer spectrophotometers. Based on measurements of backscatter ratio it was found that after the Pinatubo eruption in June 1991 significant amount of stratospheric aerosols were formed and transported to the Arctic before the polar vortex was well developed. Analysis of ozone data has shown a deep decrease of ozone concentration in the lower stratosphere in times of intensive transportation of air masses from low latitudes to the polar region in the second half of January and also for some periods in February and March of 1992. When the values of backscatter ratio $\beta$ were more than 8-10 at a wavelength of 940 nm strong anticorrelation occurred between aerosol loading and ozone concentration in the lower stratosphere. At 50-70°N the mean monthly values of total ozone in winter-spring 1992 proved to be much lower than the climatic mean values.

## Introduction

The principal scientific objective of this campaign was to obtain data relevant to possible chemical processes influencing ozone destruction in the stratosphere over the Arctic and mid-latitudes during winter and spring. The geographical locations of the selected stations were favorable for implementing the planned investigations, since it was possible to obtain data measurements simultaneously over the central part of the Arctic circumpolar vortex, at its periphery, and outside of this zone.

In the two previous winter seasons (1988-89 and 1989-90), similar balloon measurements of ozone and stratospheric aerosol were conducted at Heiss Island and Dickson. Two types of vertical distributions of the backscatter ratio $\beta$ at a wavelength of 940 nm were observed by the authors during two of the preceding winter seasons in the Arctic [2]. When the temperature in the stratosphere was warmer than -80C over the Heiss and Dickson Islands a background level of stratospheric aerosol was observed, with maximum values of the ratio $\beta$ of about 1.3 in the 15-20 km altitude range. During winter months when temperature in the lower stratosphere was below or close to -80 C, polar stratospheric clouds were observed over the stations. In these periods, maximum values of $\beta$ in the lower stratosphere increased to 6-15. Such cloud formations were most often observed at a 18-20 km level. The analysis of the balloon measurements of ozone and aerosol scattering obtained in two winter field campaigns in 1989-91 has failed to reveal definitive correlations between the changes in ozone content in the lower stratosphere and the formation of polar stratospheric clouds.

The winter season of 1991-92 was marked by the fact that after the Pinatubo eruption in June, an enormous amount of aerosols and sulfur compounds were ejected into the atmosphere, which spread globally during the months afterward, reaching the polar regions of the northern hemisphere by early winter. The total $SO_2$ amount released to the stratosphere in June 1991 due to the Pinatubo eruption is estimated at 15-30 MT [3].

## Results and Discussion

Figures 1a and 1b show the vertical profile of the backscatter ratio $\beta$ obtained using backscattersondes at Rylsk (52°N, 35°E) and Laramie (41°N, 105°W) at the end of September 1991. The thickest layer of the volcanic aerosol was observed between 15 and 20 km. A maximum value of 5-7 of the ratio $\beta$ was measured in this altitude range over Rylsk and Laramie. Thus, as a consequence of global circulation patterns, the volcanic aerosol reached mid-latitudes of the northern hemisphere and considerably enhanced the stratospheric aerosol loading.

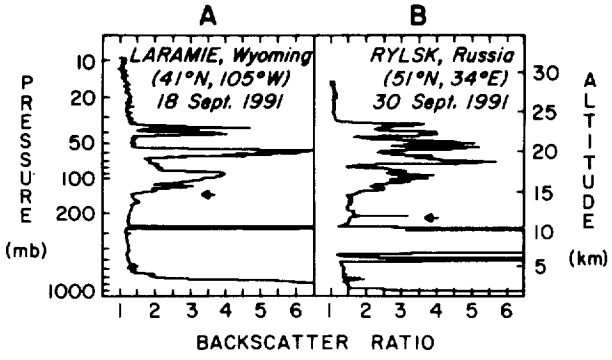


Figure 1. Backscatter ratio determined from backscattersondes launched at Laramie, (a) and Rylsk (b) in September 1991.

As shown by the measurements of backscatter at Kiruna, Heiss Island and Dickson, a significant portion of volcanic aerosol spread globally and by early winter reached the Arctic polar latitudes.

Figure 2 presents a number of profiles of the vertical distribution of ozone and backscatter ratio obtained over Heiss Island and Kiruna in January, February and March 1992. Ozone concentrations in the lower stratosphere at the same altitudes were decreasing dramatically concurrent with the appearance of dense volcanic layers at the same altitudes. Very similar results of reduced ozone concentrations in the lower tropical stratosphere after the eruption of Mt. Pinatubo recently were published by Grant and others [4]. Such an anti-correlation can be identified more readily in the 14-22 km altitude range for backscatter ratios $\beta$ greater than 8-10. During the first half of January 1992 Heiss Island was inside of a well defined polar vortex. As it is seen from Figure 2a, the backscatter ratio $\beta$ was 5-6 times the background values. At this period of time the temperature in the stratosphere was not lower than -76 C and polar stratospheric clouds probably did not exist over Heiss Island. This means that the backscattersonde observed volcanic aerosols which were transported to the Pole before the vortex was developed. The backscattering ratio data for 9 January and 14 January 1992 show that this aerosol layer did not change significantly when the vortex was stable. There is no correlation between aerosol and ozone concentrations in the lower stratosphere for this time. During the last part of January 1992 when the vortex weakened, some additional amount of volcanic aerosols were transported to the polar region from lower latitudes. The backscatter ratio $\beta$ over Heiss Island grew from 5-6 to 10-18 by February 1992. Figure 2b shows measurements made at Kiruna (ozone and aerosol variations in the lower stratosphere at Dickson are very similar to the data from Heiss Island when it is inside of the vortex and similar to Kiruna when both Dickson and Kiruna are near the edge of the vortex). When the values of backscatter

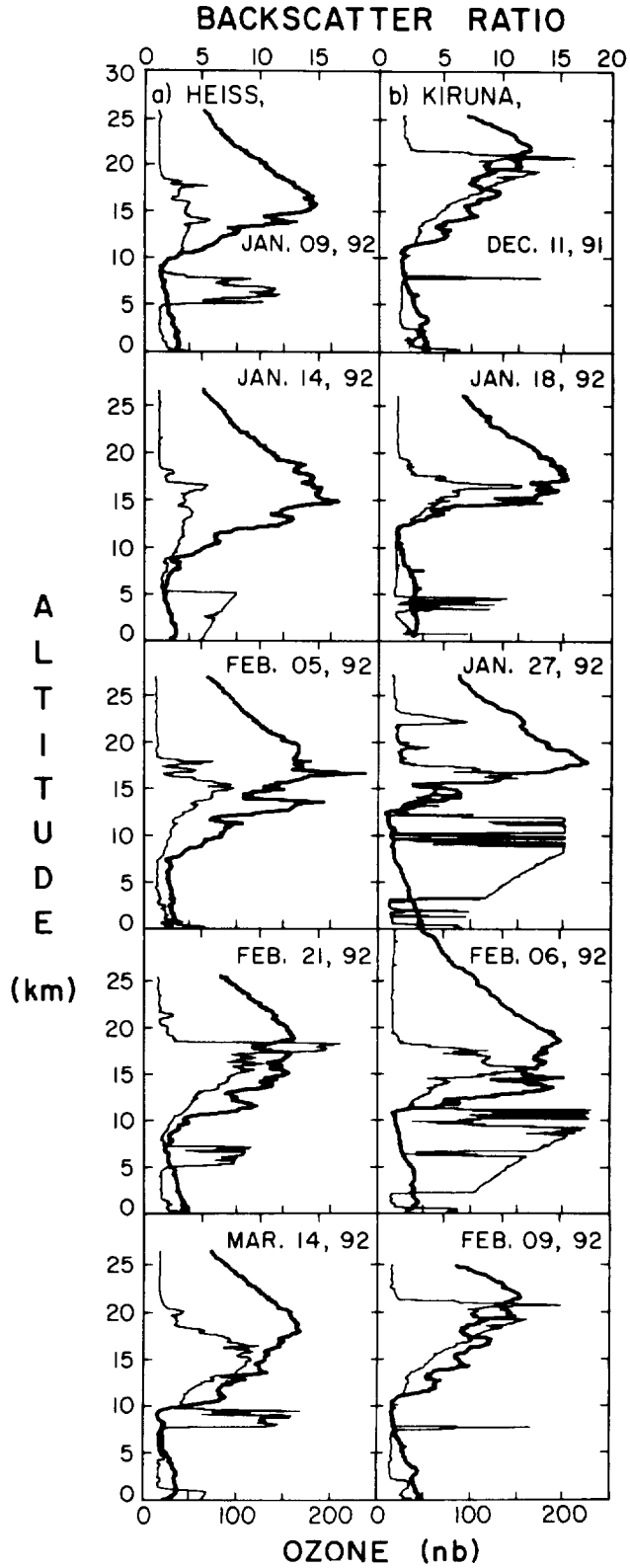


Figure 2. Comparison of ozonesonde and backscattersonde profiles for Heiss Island (a) and Kiruna (b) during winter-spring 1991-1992.

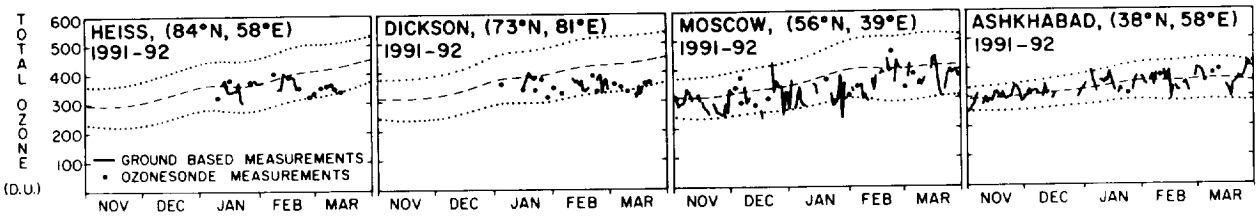


Figure 3. Climatic total ozone trends based on about 30 years of observations. The dashed line represents the mean daily values for November - March at Heiss Island, Dickson, Moscow and Ashkhabad ground stations located at high, middle and lower latitudes respectively. The dotted lines represent a two standard deviations from the mean. Measured values for November 1991 to March 1992 are also shown.

ratio were more than 8-10, strong anticorrelations occurred between aerosol and ozone concentrations in the lower stratosphere during winter and spring. When these stations were near the edge or outside of the vortex much higher values of backscatter ratio were measured (15-20).

To analyze the trends of total ozone content in the Arctic we used the data obtained with the Brewer instruments and integrated data of ozone soundings from the above ground stations. In addition, the data of ground ozonometric stations and TOMS data from meteorological satellite Meteor-3 were used for analysis of total ozone trends for high, middle and lower latitudes of the northern hemisphere. At 50°N to 70°N, the mean monthly values of total ozone in winter and spring 1992 proved to be much lower than the climatic mean values. Specifically, this decrease was 10% in December 1991, 10 to 15% in January and February, 1992 respectively, while the maximum decrease of the monthly mean ozone amount reached 20% in March (Figure 3). At lower latitudes in winter and spring, statistically meaningful anomalies in total ozone were not detected (Figure 3, Ashkhabad Station). For the stations at Heiss Island and Dickson, located at higher latitudes 72-81°N, the decrease of the mean monthly values of total ozone relative to the mean climatic values, with the amplitude more than twice the standard deviation, only began in early March 1992. Figure 3 presents typical results selected from about 40 ground stations in the former Soviet Union and about 10 European stations.

The low mean month total ozone values over the middle latitudes during winter and spring time and at high latitudes at the beginning of spring (Heiss and Dickson stations) in this year is highly suggestive of heterogeneous reactions involving nitrogen constituents and the sulfate aerosol from the Mt. Pinatubo eruption. Following this powerful eruption, the aerosol particle surface density allowing heterogeneous reactions to occur increased 10-100 fold [3]. Chemical reactions on the surface of aerosol particles may convert a significant part of nitrogen oxides ($NO + NO_2 + N_2O + N_2O_5$) into nitric acid $HNO_3$ [5]. The diminished amount of nitrogen compounds in the lower stratosphere due to heterogeneous reactions on the surface of sulfate aerosols may result in a more effective process of ozone destruction in the catalytic chlorine cycle.

It is also possible that the total ozone decrease observed at the middle latitudes of the Northern Hemisphere during the period under consideration is due to air masses being transported to this area of observation from lower latitudes where air contained more aerosol and a lower ozone concentration. This notion of a dynamic mechanism influencing ozone variability in the lower stratosphere could be verified by conducting the corresponding model calculations of the atmospheric circulation using measured wind and temperature fields as well as the observed initial ozone and aerosol distributions. In a direct sense, the possibility of such a mechanism of ozone depletion is indicated by the ten day calculated trajectory data for the air masses passing over Kiruna, Heiss Island, and Dickson. However, considering the dynamic mechanism alone, the occurrence of the statistically meaningful climatologically low ozone values at a time of exceptionally high values of volcanic aerosol at the same altitudes may be difficult to explain.

## Conclusions

1. Large amounts of volcanic aerosol in the lower stratosphere were observed near the wall of the polar vortex in the Arctic during winter-spring 1991-92. Measurements of backscatter ratio at Heiss Island has confirmed that a significant amount of volcanic aero sols were already present at the time of vortex formation.
2. Anomalously low total ozone values were observed in January, February and March 1992 at middle latitudes over the former Soviet Union and Europe. At high latitudes total ozone was lower than the climatic values only at the end of winter 1992.
3. A strong correlation of minimum ozone concentration in the lower stratosphere with the peak aerosol loading was observed with simultaneous ozonesonde

and backscattersonde measurements when the backscatter ratio was more than 8 - 10.

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