On ozone contents in the surface layer over the Spitsbergen Archipelago in 2005–2006

V.I. Demin, M.I. Beloglazov, and V.A. Shishaev

Polar Geophysical Institute,
Kola Scientific Center, Russian Academy of Sciences, Apatity

Received March 2, 2007

The results of measurements of surface ozone on the Spitsbergen Archipelago in 2005–2006 are presented. The seasonal ozone variation shows a pronounced maximum of monthly mean values in late spring (April–May) and a minimum in summer (July–August). The surface ozone concentration during the polar day period does not exceed that in the polar night period. The daily mean surface ozone concentrations range between 25 and 35 ppb in more than 50% cases and between 20 and 40 ppb in 86% cases. The diurnal ozone variation in the surface layer was not detected for the most part of the year and is very weak in summer. The mean amplitude of diurnal variation is smaller than 2–4 ppb even during summer months.

Introduction

In 2005–2006, the Polar Geophysical Institute KSC RAS has conducted the measurements of the surface ozone concentration (SOC) on the Spitsbergen Archipelago. The Institute's observatory is situated on the west coast of Island West Spitsbergen, 3 km north from Barentsburg, near Heerodden (Cape Heer) and roughly 1 km from Granfjorden and Isfjorden, at a height of 95 m above the sea level; geographic coordinates are 78.09°N, 14.20°E.

The study of SOC dynamics over Spitsbergen fills, to some extent, the gap caused by the absence of ozone monitoring stations in the Russian sector of the Arctic. It is especially important, since the Spitsbergen Archipelago, despite the coal mining, is one of the most ecologically clear regions.

Environmental conditions

The Spitsbergen (Svalbard) Archipelago is a group of large and small islands lying between 74° and 81°N, 10° and 35°E in the western part of the Central Polar Basin. Its total area is 63 000 km^2. Almost 60% of the land is covered by ice. West Spitsbergen is the largest island of the Archipelago.

It is a typical mountain country with numerous aiguilles and ridges. The mountains are not high (the height of the highest peak is 1717 m), but strongly separated; in the east they turn into a plateau up to 800 m high. Western and northwestern coasts of the island are indented by fjords cutting deep inland.

The climate on the Archipelago is arctic, mitigated by a branch of the Norwegian stream passing near the western coast of Spitsbergen. Owing to the warm stream, the sea and fjords near western coasts of Spitsbergen are sometimes free of ice even in winter; often they do not freeze until January–February and become free of ice already in May–June, while eastern straits are usually iced even in summer.

The mean temperature in March (the coldest month) is –12.6°C, while the mean temperature of July (the warmest month) is +4.5°C. In the winter period (from September to April), the temperature rarely is below –30°C, and in the summer period (July–August) it usually does not exceed +10°C.

Spitsbergen is situated rather close to the region of active cyclonic activity. Therefore, its weather is characterized by frequent variations of air temperature and humidity, atmospheric pressure and wind velocity. In the western part of the Archipelago, thaws and rains may occur at the height of winter.

A feature of Spitsbergen is a significant cloud amount in summer (on the average, low-level cloud amount of 8).

The polar day at latitude 78° lasts from April 19 to August 24, and the polar night lasts from October 27 to February 15.

Instrumentation

Surface ozone over Spitsbergen was measured simultaneously by two gas analyzers. The first one – a chemiluminescent ozonometer (made in the Polar Geophysical Institute) made readings every 10 s with an accuracy of about 15% [Ref. 1]. A device of similar type was used earlier in investigations of surface ozone in Arctic.[2] The second gas analyzer – electrochemical ozonometer (designed by PBOYuL V.V. Rudakov No. 30477000037631, Moscow), by the technique described in Ref. 3, made every-hour or six-hour readings with an error no higher than 10%. The ozonometers were calibrated using a generator of the ozone–air mixture designed and produced in the Polar Geophysical Institute.[4]

0235-6880/07/10 827-04 $02.00

The measurement system of the observatory includes also a M-49M automatic meteorological station, but to reconstruct the complete meteorological pattern, we used also the observations of the Barentsburg Meteorological Station situated 3 km south (78.1°N, 14.2°E, 75 m above the sea level).

Results of measurements

The annual behavior of the monthly mean SOC over the Spitsbergen Archipelago is shown in Fig. 1. The pronounced spring ozone peak caused by the intense ozone income from the stratosphere upon breakdown of the winter circumpolar vortex is typical of most stations of the Arctic region.

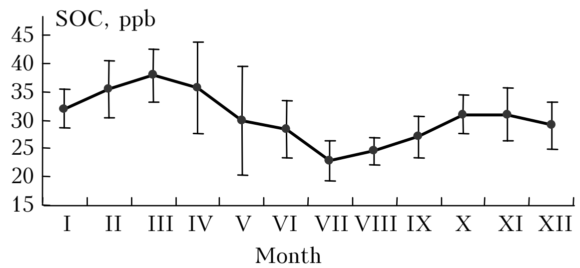

Fig. 1. Annual behavior of monthly mean SOC in the Barentsburg observatory (vertical bars show rms deviations).

The comparison of, for example, daily mean SOCs on Spitsbergen and on the Kola Peninsula (PGI Observatory in Lovozero (67.97°N, 35.02°E) [Ref. 5]) shows that in spring and summer (March–July) they are nearly identical, but in fall and winter (August–February) SOC at the Spitsbergen Archipelago is 5–10 ppb higher due to the most intense turbulent exchange because of the closeness to the region of high cyclonic activity and higher instability of air masses over the warm sea surface free of ice (the nonfreezing surface of the Greenland Sea is 10–15 km from the Observatory). The annual SOC behavior similar to that at Spitsbergen was observed, for example, in Iceland (station Heimaey, WDCGG (World Data Centre for Greenhouse Gases) data).

To be noted is the fact that summer SOCs at the Spitsbergen Archipelago turn out, as a rule, to be the lowest in a year and even in the polar day they do not exceed concentrations characteristic of the polar night.

Seasonal variations of SOC on the Barentsburg Observatory and at the Zeppelin Mountain Station in New Olesunn (northwestern part of Spitsbergen, 78°54′N, 11°53′E, 475 m above the sea level) are similar, but daily mean SOC values at the PGI Observatory are, on the average, by 3–4 ppb lower than those at the Zeppelin station.

Despite the weather conditions at Spitsbergen change quite frequently, the day-to-day SOC variability is small: in June–February the difference in daily mean SOC values between neighboring days does not exceed 2 ppb in more than 50% and 3 ppb in almost 70% cases. Only in April–May this difference achieves, on the average, 6 ppb. The day-to-day variations at the Zeppelin station have nearly the same character. This may be indicative of rather homogeneous SOC fields in the region from June to February and the more complex spatial distribution in the late spring.

The daily SOC variations on the Spitsbergen Archipelago are absent for the most part of a year, and they are very weak even in summer, including the period of the polar day (Fig. 2).

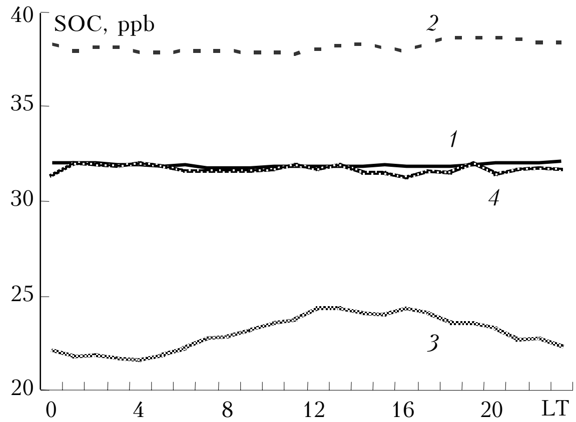

Fig. 2. Daily SOC variations at the Barentsburg observatory in different seasons: January (*1*), April (*2*), July (*3*), October (*4*).

The SOC variations manifest themselves only in May–September, when the radiation balance of the surface in the region is positive and turbulent exchange processes regularly alternate during a day. However, the amplitude of these daily variations is low: 2–4 ppb. In our opinion, low amplitudes are caused by the low daytime temperature of the surface air, which determines the intensity of thermal turbulence, and by relatively high day-by-day wind velocity. Thus, for example, term-average wind speeds in July in all periods (including the night) turned out to be about 3 m/s. At such wind speeds under the conditions of strongly rugged terrain, the surface layer is well mixed, turbulent flows are large enough and prevent the formation of the ozone-depleted air layer near the surface (for example, in night), especially because the emission of ozone-destructive substances from soil and plants in Arctic is low.[6,7]

The analogous investigations at the Kola Peninsula show that at wind speed higher than 3 m/s the diurnal SOC variations do not manifest themselves in Lovozero as well.[8]

Figure 3 shows the occurrence of daily mean SOC on Spitsbergen. For more than 50% of all time, SOC varies from 25 to 35 ppb, and 86% of all time the SOC values are in the range 20–40 ppb.

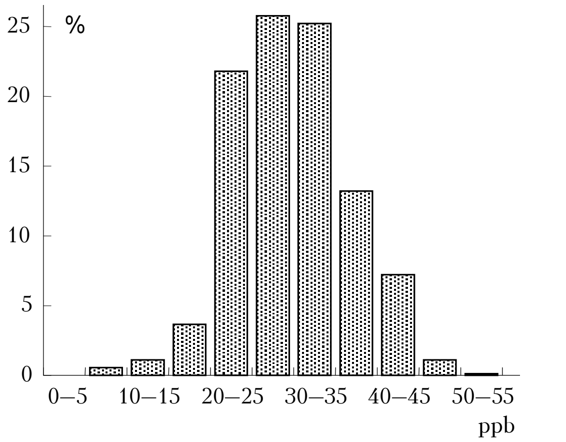

Fig. 3. Occurrence of daily mean SOC at the Barentsburg observatory in 2005–2006.

For the period of measurements of the ozone content in the surface layer over Spitsbergen in 2005–2006, the highest values were observed in late April of 2006: on April 26 and 27 the SOC level at the Barentsburg Observatory achieved 55–60 ppb. On May 1–5 of 2006 the SOC values might be even higher (according to the data of the Zeppelin station, the hourly mean SOC values on May 5 achieved the record level of 83 ppb), but the data of the PGI Observatory for this period are lacking by technical reasons.

The episode with so high and nontypical (of Arctic) ozone concentrations was caused by the advection of polluted air from East Europe (Baltic countries, Belarus, the European part of Russia), where ozone was produced photochemically from nitrogen oxides and volatile hydrocarbons incoming in mass amounts from extensive agricultural fires under the conditions of increased pressure and sunny weather (see the Report of the Finnish Meteorological Institute: http://www.fmi.fi/uutiset/index.html?Id=1146827202.html). This event was analyzed in detail in Ref. 9. It should be noted that in that period very high SOC values were observed all over Northern Europe[9] and at the European part of Russia.[10]

A number of papers (see, for example, Refs. 11–13) reported the long (up to several days) periods with the abnormally low, nearly zero ozone content in the surface layer at the arctic coasts upon the advection of air masses from ice spaces and ozone decomposition in reactions with bromides. Despite such periods are reported as quite ordinary phenomena, no one such case was observed at the Barentsburg Observatory for the period of observations in 2005–2006. Instead, intermittent SOC drops down to 5–10 ppb for several minutes to several hours were observed. However, in our case the SOC drop was most probably caused by local incomes of polluted air, for example, from the Barentsburg settlement. Nevertheless, the Barentsburg is very small (only about 500 people), there are very few cars (only service ones), and, consequently, it is unlikely that this settlement can affect strongly the surface ozone field in the region. Among the most polluting sources, to be noted are fires on coal dumps and, to the much lower degree, smoke plumes from boiler rooms observed sometimes near the Observatory. However, strong winds and significant terrain ruggedness, in particular, the isolation of the Observatory from the town by hills, favor the fast dispersion of pollutants, due to which the cases of low SOC are quite rare. By this reason, the anthropogenic impact of the Barentsburg on SOC is low and not seen in statistical processing, for example, in the monthly mean daily variations (see Fig. 2) or in analysis of SOC dependence on the wind direction.[14] For illustration, in January of 2006 the daily mean SOC values at the Observatory averaged 34.7 ppb at wind directions of 170–185° (sector of income of gas and aerosol pollution from the Barentsburg settlement) and 35.7 ppb at wind directions from “clear” territories.

This result is not surprising. Thus, the analysis of the anthropogenic impact on SOC near the large industrial city (Apatity, Kola Peninsula, population of 80000, more than 12000 cars) has shown that the anthropogenic impact on surface ozone virtually does not go out the city territory, and even at the city center it does not manifest itself at wind speeds higher than 3 m/s [Refs. 5 and 8].

Conclusions

Based on the analysis of measurements of the surface ozone concentration in 2005–2006 over the Spitsbergen Archipelago near Barentsburg, the following conclusions can be drawn:

– in the annual behavior, the highest concentrations are observed in spring, while the minimal ones are observed in July–August, as well as at other arctic stations;

– the maximal ozone concentrations in the polar day period are lower than those in the period of polar night;

– daily SOC variations are absent during the most part of the year and very weak even in the summer months (amplitude lower than 4 ppb);

– day-to-day variability of daily mean SOC values is low (2 ppb on the average and only in April–May it is as high as 6 ppb), which is indicative of the low-gradient surface ozone field in the studied region in June–February;

– cases of the highest ozone concentrations are observed in spring upon advection of air masses from the continent;

– no obvious signs of the anthropogenic impact from the Barentsburg settlement on the ozone content in the surface layer near the Observatory were revealed.

Acknowledgments

The authors are grateful to leading engineer A.A. Galakhov and to the staff of the Barentsburg

Observatory for instrumentation installation and maintenance.

This work was supported in part by the Russian Foundation for Basic Research (Grant No. 05-05-64271).

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