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Investigation of the relation between snow cover and ozone concentration in the surface layer nearby Tomsk

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ABSTRACT

In this work on data of measurements of ozone near Tomsk communication of snow cover and change of ground concentration of ozone during 1990-2017 is investigated. It is revealed that it is possible to allocate 4 types of the seasonal course of ozone. Concentration growth which comes to an end with a spring maximum concerns the first. He is observed in 53,9% of cases. The second is characteristic the slow growth and surge in concentration after a snow descent (19,2%). The third differs in the neutral course at snow and sharp surge in concentration after his descent (15,4%). The neutral course without spring maximum (11,5%) is carried to the fourth type. Thus, at the end of the snow period the spring maximum of concentration is observed in 88,5% of cases. Differences in the seasonal courses in different years is explained by temperature dependence of photochemical generation of ozone in the atmosphere.

Keywords: Atmosphere, spring maximum, air, gases - precursors, concentration change, ozone, snow cover, temperature.

1. INTRODUCTION

Physico-chemical properties of ozone determines its special role in the atmospheric processes[1,2]. The potent oxidation capacity, leading to the destruction of many materials. The presence of absorption lines in the infrared region of the spectrum, making a significant contribution to the greenhouse effect. In high concentrations ozone is a poisonous compound dangerous to humans and animals. Possible negative consequences for the environment due to its high concentration lead to the need for a detailed study of the mechanisms of formation of ozone in the atmosphere.

The global warming of the climate that has been observing in recent decades raises the urgency of the ozone research, because according to the available estimates [3,4], with increasing air temperature its concentration should increase. For example, according to [5], an increase in global air temperature by 3 degrees will lead to an increase in surface ozone concentration by 135% in industrial centers and 87% in background areas. In connection with this, the role of meteorological processes in the change in the surface ozone concentration was intensified [6-8].

In this direction, the series of studies is devoted to the study of ozone changes in the presence of snow cover on the earth's surface [9-11]. Interest in the snow cover is due to the following reasons. First, for one and the same surface, the rate of ozone flow significantly changes. According to the data collected in [12], the differences in the rate of ozone flow to the surface can reach two orders of magnitude. Secondly, since the source of ozone-forming substances is on the surface of the earth [14], the presence of snow will lead to its screening. Accordingly, the amount of precursor gases in the air, from which ozone is formed, must sharply decrease. Thirdly, it should be taken into account that in parallel with the screening of the source, the appearance and loss of the snow cover correlates with the vegetative vegetation activity period, which delivers organic gases - ozone precursors [13,14]. Organic gases can account for more than half of the initial volume for ozone formation [15].

To the problem of the interaction of ozone with the snow cover can also be attributed to the phenomenon of the spring maximum of its concentration, recorded in a number of places [16-18]. Its peculiarity is that it does not coincide with the solar maximum of the arrival of solar radiation, which, given the photochemical nature of ozone formation, is not yet understandable [19]. At the same time, in the already mentioned paper [20] it is shown that the presence of the spring maximum is associated with the early or late loss of the snow cover. There is another point of view that is not related to the snow cover. In [21], the arrival of the spring maximum of the ozone concentration in the ground layer of air is due to advection and downward movements.

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In the present work, the dynamics of ozone concentration in the period of seasonal snow cover in the Tomsk region is considered and its determining factors are estimated.

Data of measurements of temperature and surface ozone concentration from a TOR-station (Tropospheric Ozone Research) are used for analysis. An initial version of the station is described in [22]. The TOR-station coordinates are 56°28'41"N., 85°03'15" E. This is an automatic station located in the north-eastern outskirts of the Academic City (Akademgorodok) of Tomsk in the building of a high-altitude atmospheric sounding station at the V.E. Zuev Institute of Atmospheric Optics of Siberian Branch of the Russian Academy of Sciences (IAO SB RAS). There are no industrial facilities or motorways near the station, which reduces the influence of local sources of gas and aerosol. The station is located in the zone of boreal forests and surrounded by small woodland of deciduous and coniferous species.For comparison, data on the height of the snow cover carried out on Tomsk meteorological station (№29430), measured by the standard method, were used. The analysis period covers 1990-2017, which is 26 annual courses.In order to avoid short-term variations in the surface ozone concentration and air temperature, the measurements were preliminary averaged over 5 day intervals.

2. RESULTS

The data processing performed showed that during the considered period all types of seasonal behaviour can be conditionally divided into 4 types.

Table 1.Frequency of annual variation of ozone concentration of different types in Tomsk in 1991-2016.

Type	**Growthwithout a splash**	**Growthandsplash**	**Splash**	**Neutral**
Number of cases	14	5	4	3
%	53,9	19,2	15,4	11,5

The first type should include those seasons where, in the presence of snow cover, the ozone concentration growth which comes to an end with a spring maximum after its complete loss. As an example, fig. 1a shows the dynamics of O_3 and the height of the snow cover in 2013-2014. Such cases turned out to be the most of all and is observed in 53,9% of cases.From Fig. 1a that the surface ozone concentration in presence of snow cover has continuously increased from a minimum in February to a maximum at the end of May. Nevertheless, the snow cover completely disappeared in the second decade of April. It is also seen that after the loss of snow, ozone concentration received a boost to growth. Consequently, during this period the sink, if it increased, the photochemical generation became much stronger. Apparently, the supply of precursor gases increased sharply from the open surface.

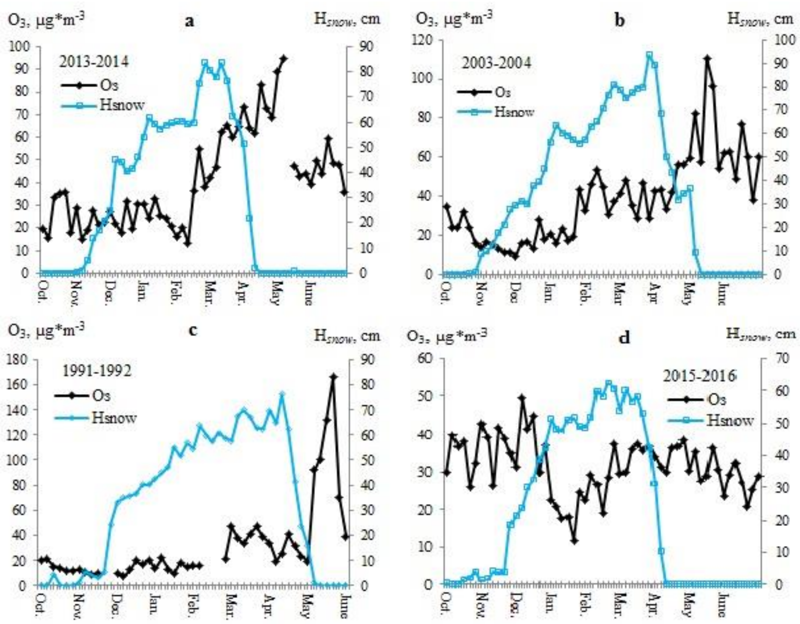

Figure1.Change in the surface ozone concentration and the height of the snow cover nearby Tomsk.

The second type is not much different from the first. It is characterized by a slower increase in the ozone concentration in the presence of snow cover and a sharp splash after its loss (Fig. 1b). Such cases were 5 or 19.2%.
The third type of seasonal variation includes cases when the temporal dynamics of ozone during the snow cover was close to neutral and the concentration increased sharply after the loss of snow cover (Fig. 1c). During the period under review, a similar course of ozone concentration was recorded 4 times, which is 15.4%.
The fourth type differs significantly from the previous ones. It is shown in Fig. 1d and is characterized by a relatively neutral course of the surface ozone concentration. It is seen that as the height of the snow cover increases, its screening effect increases and the O3 concentration decreases. Then a slight increase is observed. Loss of snow cover does not significantly affect the ozone content. There is no increase in sink to the underlying surface, since ozone does not fall. There is also no surge in concentration, which reflects the absence of a sharp increase in the intake of ozone-forming compounds. Most likely, the processes of sink and generation in such years were balanced. Such Such cases were 3 or 11.5%.
Consequently, in spite of the variety of seasonal courses of ozone concentration in the presence of snow cover, in 88.5% of cases a clear spring maximum of the surface ozone concentration is recorded and in 11.5% of cases it is absent (Table 2).

Table 2.Frequency of the spring maximum of ozone concentration nearby Tomsk.

Seasonal course	Spring maximum	Neutral
Numberofcases	23	3
%	88,5	11,5

Thus, the presence of a snow cover on the underlying surface leads to its shielding action. With snow covered land, much less ozone-forming substances enter the air [26], which affects its concentration. Loss of the snow cover "turns off" the screen and this is reflected in the formation of a spring maximum of ozone concentration.

3. DISCUSSION

Carried out comparison of the seasonal course of the surface ozone concentration in the presence of a snow cover did not reveal a predominance of sink on the underlying surface after its loss, shown in [20]. Perhaps this is due to the physiographic features of the regions for which the analysis was carried out. So, in the period under consideration, nearby Tomsk, not a single case of early loss of snow cover was recorded.With that, the data in Fig. 1a-c show that after a spring maximum of ozone concentration, a significant decrease is observed over a long period. Apparently, such a situation is created at the cost of resumption of vegetative vegetation activity, namely, the appearance of leaves on trees, the growth of grass. In this case, as shown in a number of works [23-26], the surface for sink of ozone increases substantially and the flow rate increases by 2-3 orders of magnitude.
From Fig. 1, differences in the seasonal variations of ozone concentration in the snow cover are not completely understood. This question is partially off, if we return to the results of [27]. In Fig. 2, in addition to data on surface ozone concentration and snow cover height, air temperature data are given.

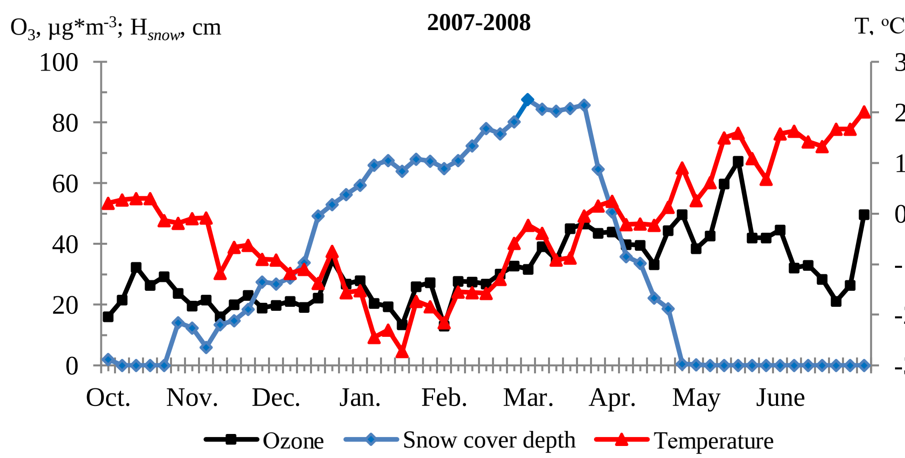

Figure2.Change in the surface ozone concentration, snow cover height and air temperature nearby Tomsk in 2007-2008.

From fig. 2 it can be seen that during the seasonal snow cover , changes in surface ozone concentration and temperature occur almost synchronously. Differences are observed in the summer and autumn periods. This confirms the conclusion [27] about the leading role of air temperature in the generation of surface ozone.

For the assessment this relationship, we use the procedure proposed in [27]. The difference in approach will be that the difference in air temperatures will be found between the low value in the period of snow cover and the highest value that corresponds to the spring maximum of ozone. The difference in ozone concentrations will also be found between the low value in the period of snow cover and the highest value in the period of the spring maximum. Since the periods between the minimum and the spring maximum differ in different years, as well as differences of distinction, then for comparability we normalize ΔO3 by ΔT to obtain the rate of increase in ozone concentration as a function of the rise in air temperature in the spring period. The estimates obtained are shown in fig. 3.

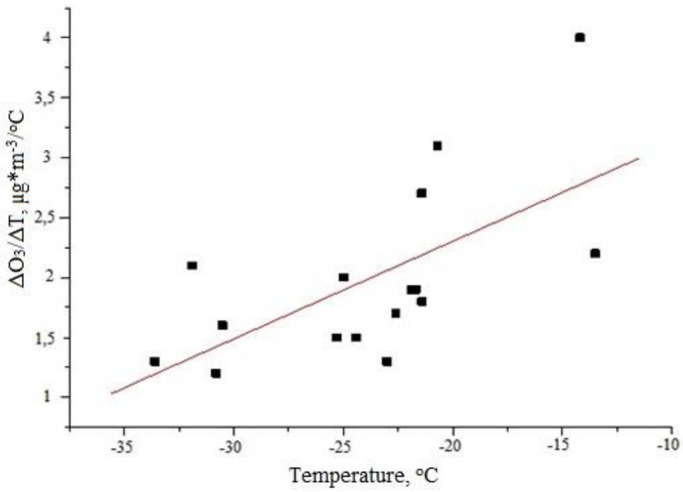

Figure3.Change in the rate of ozone formation as a function of air temperature.

From fig. 3 that there is a linear dependence of the change in the rate of ozone formation on the change in air temperature. Thus, at a temperature of -35 ° C it is 1.2 μg / m^3/1°C, at a temperature of -10 ° C it increases to 3.0 μg / m^3/1°C. This is considerably less than that obtained in [27]. But it should be noted that the whole process is at negative temperatures and the assessment is carried out for a period of several months.

4. CONCLUSIONS

The analysis of the relationship between the snow cover and surface ozone concentration for the period 1990-2016 showed the following.

In this work according to ozone concentration measurements near Tomsk investigated the relationship between the snow cover and surface ozone concentration for the period 1990-2016 is investigated. Data of measurements of ozone concentration and temperature in the surface layer carried out on the TOR station for 1990-2016, as well as RIHMI-WDC data on the height of the snow cover carried out on meteorological station №29430 for 1990-2016 are used.

In this region, the snow cover performs the screening phenomenon for emissions to the air ozone-forming substances. As a result, the ozone concentration is significantly reduced. The loss of snow cover causes an increase or even a splash of ozone. It is revealed that it is possible to allocate 4 types of the seasonal course of ozone. Concentration growth which comes to an end with a spring maximum concerns the first. He is observed in 53,9% of cases. The second is characteristic the slow growth and surge in concentration after a loss of snow cover (19,2%). The third differs in the neutral course at seasonal snow cover and sharp surge in concentration after loss of snow cover (15,4%). The neutral course without spring maximum (11,5%) is carried to the fourth type. Thus, at the end of the snow period the spring maximum of concentration is observed in 88,5% of cases. Differences in the seasonal courses in different years is explained by temperature dependence of photochemical generation of ozone in the atmosphere.

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