Analysis of total ozone content for 2010-2019 in Russia

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Abstract. The article analyzes the annual observation data of the Federal Service for Hydrometeorology and Environmental Monitoring (RosHydroMet) from 2010-2019. RosHydroMet constantly monitors and selects reliable information from various systems: national network stations, as well as foreign terrain and satellite stations, by which data of total ozone content have a high degree of reliability, accuracy and detail. Quantitative indicators of total ozone content over the territory of the Russian Federation are considered, the values of which are expressed by the reduced thickness of the ozone layer. Deviations of the average annual total ozone content from the norm for this period in percentage are also presented in graphic form and corresponding conclusions are made based on the analysis results.

1. Problem setting
In the article, based on information and analytical materials on the results of monitoring environmental pollution, namely reviews of the state and pollution of the environment in the Russian Federation for 2010-2019, an analysis of the state of the ozone layer over the territory of Russia was carried out.

The urgency of the problem is the need to constantly regulate and monitor the state of the ozone layer not only in the Russian Federation, but throughout the world. Continuous monitoring of the state of the ozone layer prevents large-scale threats and accompanies rapid response when necessary.

In general, the international community has done a lot to achieve positive results in combating the negative anthropogenic impact on the environment on an industrial scale. The development of such an attitude towards the existing problems was facilitated, first of all, by the extremely difficult situation with the natural environment, expressed in the depletion of the ozone layer [1].

Under current conditions, different systems allow more accurate and detailed transmission of information about the states of observed objects.

The analysis of the results of the annual monitoring will allow us to look at the situation as a whole and make a forecast about the further state of the ozone layer.

2. Purpose, objectives and methods of the research
The purpose of this article is to analyze the total ozone content over the territory of Russia over ten years according to annual observation data.

The object of the study is deviation of the average values of the total ozone content from the norm in percentage.

The Federal Service for Hydrometeorology and Environmental Monitoring (RosHydroMet) monitors the state of the ozone layer over the territory of the Russian Federation.
The strategic importance of the ozone layer lies in its ability to absorb rays harmful to the biosphere, thereby protecting the planet from ultraviolet radiation from the sun and cosmic radiation [2].

The destruction of ozone occurs as a result of air pollution with oxides of chlorine, freon, nitrogen, methane [3].

The total ozone content is an important characteristic of the Earth's ozone layer. It determines the absorption of ultraviolet (UV) radiation of the Sun in the wavelength region 290-315 nm (the so-called UV-B region).

The total ozone content is quantified by the reduced thickness of the ozone layer. But an important condition here is that this thickness of the ozone layer is considered as if all ozone contained in the atmosphere leads to normal pressure at a temperature of 0 ° C. On average, this thickness is 3 mm, but can vary from 1 mm to 6 mm depending on the period of the year, the location of the territory and ozone anomalies.

The unit of measurement of total ozone is the Dobson unit (unit D.) [4].

Operational data collection, archiving, visualization (mapping of total ozone and ultraviolet radiation fields), analysis of total ozone and ultraviolet radiation fields, sending operational data of the CIS network to the World Ozone and Ultraviolet Radiation Data Center (WOUDC; Canada) are produced at the Central Aerological Observatory (CAO) of RosHydroMet.

RosHydroMet uses data from national network stations equipped with M-124 filter ozonometers, the measurement error of which is estimated at ± (5-8) %. The main advantages of these ozonometers are the simplicity of design and operation.

The method of calculating the total content of the ozone layer using filter instruments with rather wide spectral intervals undergoes constant improvement. This allows, firstly, to reduce measurement errors, and secondly, to minimize omissions in observations. The latter fact significantly increases the reliability of the results of averaging data by time and territory of the region.

In addition, the Central Aerological Observatory uses data from foreign terrain stations (with an error of 1-3%) and satellite ones measured using OMI equipment (NASA, USA; their error at temperate latitudes is estimated at ± 3%); the latter are also used to assess the quality of observations on the national ozone network.

Due to the uniform measurement methodology, continuous monitoring and retrieval of reliable information, total ozone data have a high degree of reliability.

![Figure 1. Range of deviations of the average total ozone content from the norm, %](image)

The stability of the scale of measurements of the total ozone content and the homogeneity of the data series are maintained thanks to a well-functioning system of observations and metrological support [5].
When calculating deviations in total ozone content, the averages for the period 1973-1984 are used as "norms.”

The existence of standards makes it possible to objectively assess long-term changes in the thickness of the protective ozone layer, trends and tendencies in ozone content over a given period.

Range of deviations of the average total ozone content from the norm for 2010-2017 is presented in figure 1.

Results of monitoring the state of the ozone layer over the territory of Russia by year:

1. In general, for 2010, the field of deviations of the average annual values of the total ozone content from the norm is quite even.

Deviations of the average annual total ozone content from the norm range from -7% to +6%. The total annual average value of ozone over the entire territory of the Russian Federation turned out to be closest to the average long-term (+0.4%).

2. For 2011, the field of deviations of the average annual values of the total ozone content from the norm is negative.

Throughout the territory of the Russian Federation, these deviations range from -16 to +2%. The largest deficit of annual average total ozone content (-16%) was recorded at the Tura station. The only excess of the average annual total ozone content over the norm (+2%) was recorded at the Feodosia station.

In 2011, the average annual value of ozone over the territory of the Russian Federation was among the lowest ozone values for the observation period (-5.8%).

The thickness of the protective ozone layer over the territory of the Russian Federation was significantly lower than normal. The largest decrease was observed in March-April 2011 (up to 19% in Western Siberia). Very rarely, the area of very low ozone throughout the territory of the Russian Federation occupied such a vast territory.

A significant decrease in ozone was observed not only over the territory of Russia. The area of very low ozone has also spread to western and central Europe. The danger of the appearance of an "ozone hole" over densely populated areas was widely discussed.

At the same time, a comprehensive analysis of the fields of total ozone content according to the Russian Federation ozone network and satellite measurements, combined with stratospheric circulation analysis, suggests that, despite a fairly extensive area of low ozone, the observed ozone decrease is only a local manifestation of the total ozone content of stratospheric circulation features in the winter-spring period of 2011.

3. In general, for 2012, the field of deviations of the average annual values of the total ozone content from the norm is mainly negative.

Deviations of the average annual total ozone content from the norm range from -8 to 3%. The largest deficit (-8%) was recorded at the Bolshaya Elan station in southern Sakhalin. The maximum excess of the average annual total ozone content above the norm (3%) was recorded at Olenek station, in the territory of the Republic of Sakha (Yakutia).

In 2012, the average annual ozone value was 3.2% lower than normal, and in all regions except Eastern Siberia, the average deviation from the norm for the year was about -4%.

4. In 2013, deviations of the annual average total ozone content from the norm for all analyzed stations range from -5 to +4%. The largest deficit (-5%) was recorded at the Bolshaya Elan station in southern Sakhalin. The maximum excess (+4%) is registered at Olenek station in the north of Central Siberia.

In 2013, the thickness of the ozone layer throughout the territory of the Russian Federation was close to normal, the average deviation of the total ozone content was -0.5%. The average annual total ozone levels in all five regions have become closer to normal.

Thus, the thickness of the protective ozone layer in 2013 increased compared to 2012 and significantly approached the norm. The increase in ozone content is typical for all regions of the Russian Federation.
5. In general, for 2014, the field of deviations in the average annual total ozone content from the multi-year average for 1973-1984, taken as the “norm”, turned out to be slightly reduced.

Deviations of the average annual total ozone content from the norm for all analyzed stations range from -8 to 1%.

The largest deficit of the average annual total ozone content (8%) was recorded at Samara and Tura stations. Maximum exceedances of the average annual total ozone content over the norm (1%) were recorded at stations close to the borders of the CIS countries: Hayes Isl., Pechora, Ashgabat and Nagaev.

Thus, a lower-than-normal ozone content was observed in all five regions.

Over the entire territory of the Russian Federation in 2014, the average thickness of the ozone layer for the year was below the norm, the average deviation of the total ozone content from the norm was 2.6%.

6. In general, for 2015, the field of deviations of the average annual values of the total ozone content from the norm is quite even.

Deviations of the average annual total ozone content from the norm for all analyzed stations range from -9 to + 4%. The largest deficit (9%) was recorded at Nikolaevsk-on-Amur station. The maximum excess of the norm (4%) was registered at the stations Nagaev, Aral Sea and Kiev-Ukraine.

Over the entire territory of the Russian Federation in 2015, the annual average thickness of the ozone layer is 350 D.U. turned out to be below the norm (353 D.U.) by less than 1%.

7. For 2016, the field of deviations of the average annual values of the total ozone content from the norm is quite even.

Deviations of the average annual total ozone content from the norm range from -9 (Tura) to + 2% (Magadan-Nagaev).

In 2016, the ozone field over the Russian Federation in February noted abnormally low ozone content over all regions of the Russian Federation (except the Far Eastern region) and increased ozone content over the Far East.

Over the entire territory of the Russian Federation in 2016, the annual average thickness of the ozone layer is 345 D. U. turned out to be below the norm (353 D. U.) by less than 0.3%.

8. In 2017, deviations of the average annual total ozone content from the norm are in the range from - 7 to + 1%.

The largest deficit of the average annual total ozone content (-7%) was recorded at the Tura and Olenek stations in northern Central Siberia. The maximum excess of the average annual total ozone content over the norm (+ 1%) was recorded at the Karaganda station in northeastern Kazakhstan.

Over the entire territory of the Russian Federation in 2017, the average thickness of the ozone layer for the year was 346 D. U. and turned out to be below the norm (353 D. U.) by 2%.

9. Since 2018, RosHydroM has been analyzing not the average annual values, but the average monthly values of deviations in the total ozone content from the norm according to the data of reanalysis ERAINTERIM.

Deviations of the average monthly values of the total ozone content from the norm over the territory of Russia in 2018 range from −11% to + 26%.

Over the entire territory of the Russian Federation, the average thickness of the ozone layer for the year was 357 D. U. and turned out to be above the norm (353 D. U.) by only 1.1%, although in all regions significant periods were observed with abnormally low and abnormally high values of total ozone content.

The anomaly was observed against a high background of total ozone in the month of February. Apparently, the accumulation of ozone in the atmosphere in 2018 will affect the average annual value of the total ozone content and the continuation of the positive trend in the total ozone content that has emerged in the last decade [6].

10. In 2019, deviations of the average monthly values of the total ozone content over the territory of Russia from the norm are in the range from -8% to + 37%.

Over the entire territory of the Russian Federation in 2019, the average thickness of the ozone layer for the year was 358 D. U. and turned out to be above the norm (353D. U.) by only 1.2%.
Deviations of annual average total ozone content for ten years are shown in figure 2.

Figure 2. Deviations of annual average total ozone content, %.

3. Conclusions
In the last decade, not counting 2018 and 2019, deviations of the average annual values of the total ozone content from the norm are rather even over the territory of the Russian Federation, except for an abnormally low value (-16%) in 2011. More such strong deviations were not observed over the period considered.

It can also be noted that over the years the average thickness of the ozone layer has approached the norm, and since 2018 it has been above the norm by only 1.2%.

In 2016, a steady increase in annual averages was recorded, which RosHydroMet noted the beginning of a new period.

Since 2018, RosHydroMet has been analyzing the average monthly values of deviations in the total ozone content from the norm according to the data of reanalysis ERAINTERIM, which will give more accurate results.

Thus, the ozonometric network of RosHydroMet provides reliable monitoring of the state of the protective ozone layer over the Russian Federation. Long-term series of observations clearly showed significant differences in the seasonal course of the total ozone content in the long territory of the Russian Federation.

There is a lot of work to be done on the transition to automated measurements of the total ozone content and the spectral composition of ultraviolet radiation, maintaining a single scale for measuring the total ozone content in order to continue the long-term series of observations obtained by filter ozonometers [5].

For the further preservation of the ozone layer, it is necessary to continue monitoring the ozone layer, cooperate in the development and application of measures to control activities that lead to adverse effects in the ozone layer, and in the development and transfer of technologies and scientific knowledge [7].

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