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Variations in the Aerosol Optical Depth above the European Russia Territory from the Data Obtained at the Russian Actinometric Network in 1976-2016 Years

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Abstract- Investigation results of the atmospheric aerosol over the Russia territory are of great interest for the ecology and climate developments. The regularities of spatial and temporal variations in the Aerosol Optical Depth (AOD) can be received by the Russian actinometric network data (Russian Hydrometeorological Research Center). Our analysis will be based on the "Atmosphere Transparency" special-purpose database created at the Voeikov Main Geophysical Observatory on the basis of observational actinometric data. Author has many years cooperation with MGO in the region of the processing and analysis of these observation data.

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I. Section 1

Network observation stations system and empirical data will be described in section 1. A map showing the location of 53 actinometric stations of the Russian network for which the AOD of vertical atmospheric column were estimating for a wavelength of 0.55 μ. These stations cover a large part of Russia and are located outside the zones of direct local anthropogenic sources of industrial and municipal aerosol emissions (suburbs, rural areas, uplands, etc.). An analysis of the AOD of a vertical atmospheric column can be made on the basis of data on the integral atmosphere transparency (P), because P variations are, to a great extent, determined by the aerosol component of the attenuation of direct solar radiation; other components of the attenuation (water vapor and other gases) have little effect on its time variations.

The integral air transparency:

$$P = (S/S_0)^{1/2} \quad (1)$$

where S is the direct solar radiation to the normal to flux surface, reduced to the average distance between the Earth and the Sun and a solar altitude of 30°; S_0 is the solar constant equal to 1.367 kW/m^2. On the basis of 1) data on the homogeneous (calibrated against a single standard and obtained with a unified method) observational series of direct solar-radiation fluxes at the land surface, 2) some semi-empirical approximations, 3) evaluations of the integral (total) and aerosol transparency, it is possible to analyze variations in the AOD of a vertical atmosphere. I shall analyze variations in the AOD of a vertical atmosphere on the basis of the 1976–2016 observational data obtained at 21 actinometric stations.

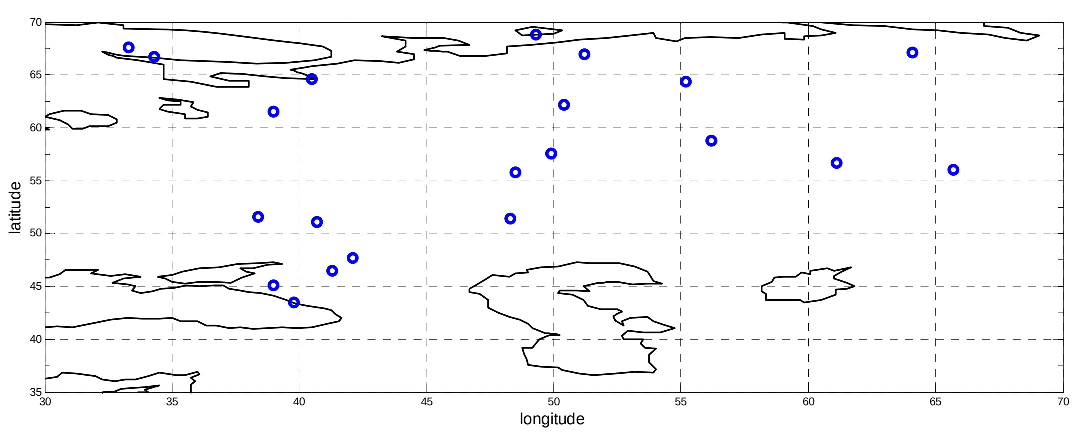

Fig. 1: Layout of 21 actinometric stations whose data will be analyzed in the article

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II. Section 2

The method of estimations of AOD, its limitations and errors will be described in section 2. Aerosol optical density of the vertical atmosphere is calculated with a method specially developed, using S -- direct solar radiation near earth surface reduced to the average distance between the Earth and the Sun, W/m^2 and some meteorological values (surface humidity et. al) above the earth surface.

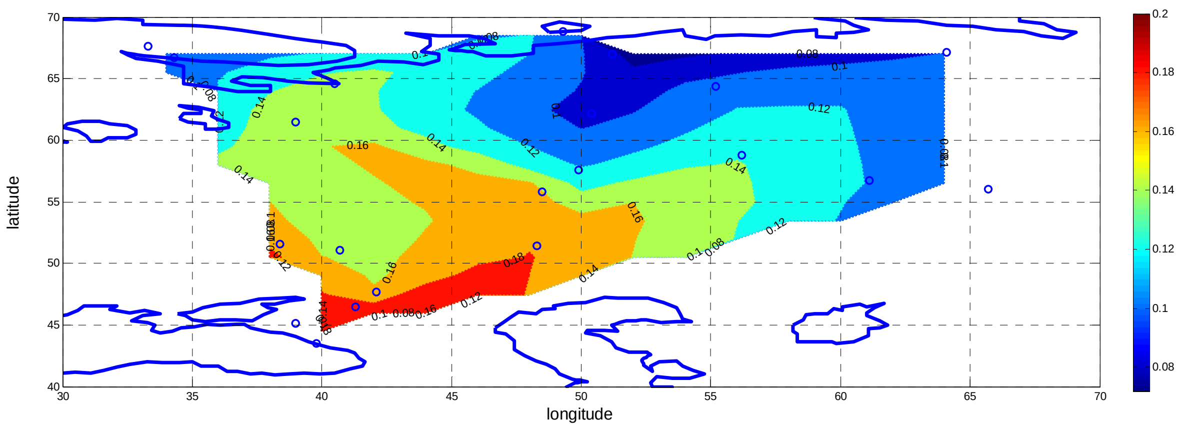
III. Section 3

The character of multiyear seasonal variations in AOD will be presented in section 3. The main statistical parameters (means, extremes, and variation coefficients) of the multiyear variations in annual and seasonal AOD means will be also assessed.

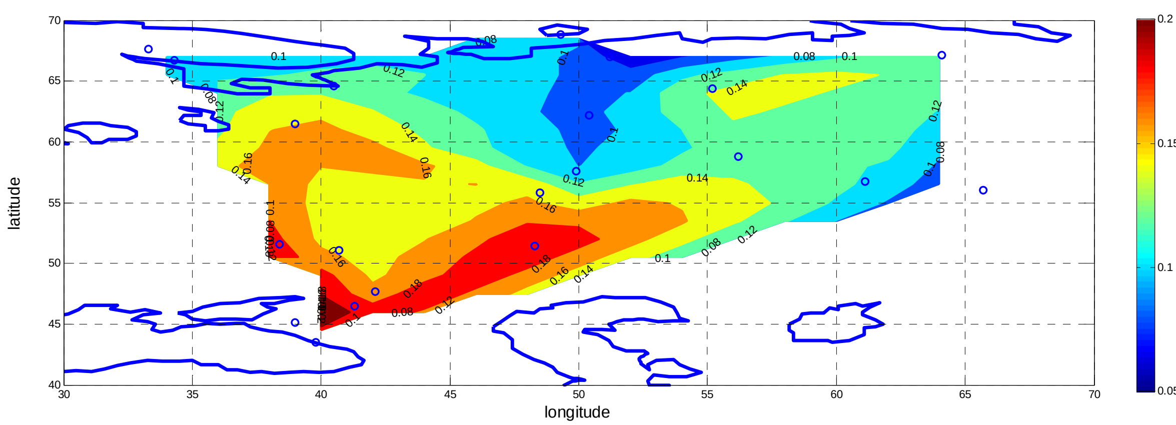
IV. Section 4

The results of an analysis of variations in the AOD of a vertical atmospheric column on the basis of a 21-year (1995–2016) series of observations will be presented in section 3. The general regularities of spatial variations in the aerosol optical depth over Russia are revealed: a monotonic decrease from the southwest to the northeast (see Fig.2), with localized areas having different aerosol loads due to the global and regional factors of their formation.

a) Years (1995-2016)



b) April (1995-2016)



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c) July (1995-2016)

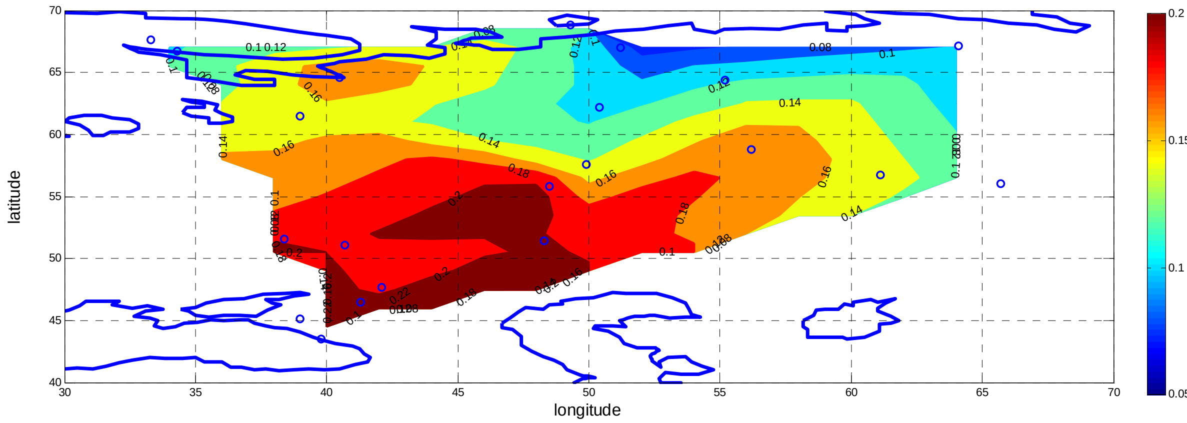


Fig. 2: Spatial distributions (east longitude - horizontal axis, north latitude – vertical axis) of the multiyear means of AOD over the observation periods: 1995–2016 for different seasons

V. Section 5

A spatiotemporal structure of the anomalies of AOD annual values within the time interval under consideration, including the El Chichon (1982) and Pinatubo (1991) eruptions and events of summer 2010 (abnormal heat and forest and peat bog fires) evidently changed both the average values of air turbidity and the character of its spatial variations will be studied in section 5. Two intensive volcano eruptions: (El Chichon – 1982 year, Pinatubo – 1991 year) affected on the atmosphere transparency regime during the analyzed period. Maximal effect of both volcano eruptions are revealed during the next year (1983 and 1992 years). It is evident that the periods of anomaly high turbidity are connected with the volcano eruptions cases. From the 1994 year the decreasing of integral (T_2) and aerosol (AOD) turbidity of the atmosphere in the different Russia regions is observed.

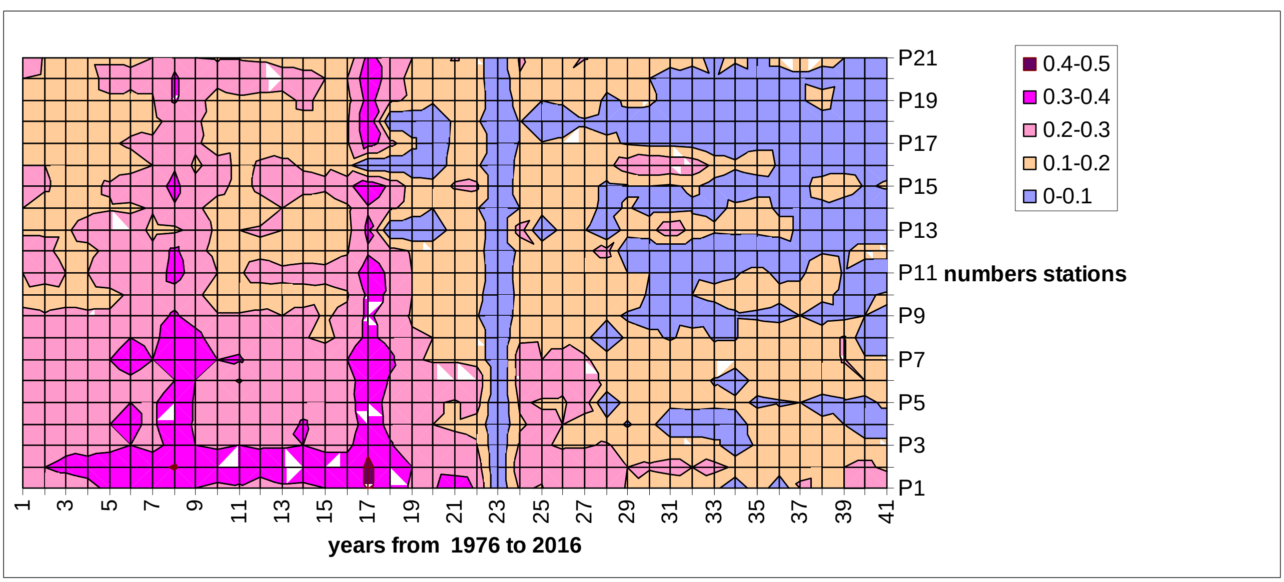
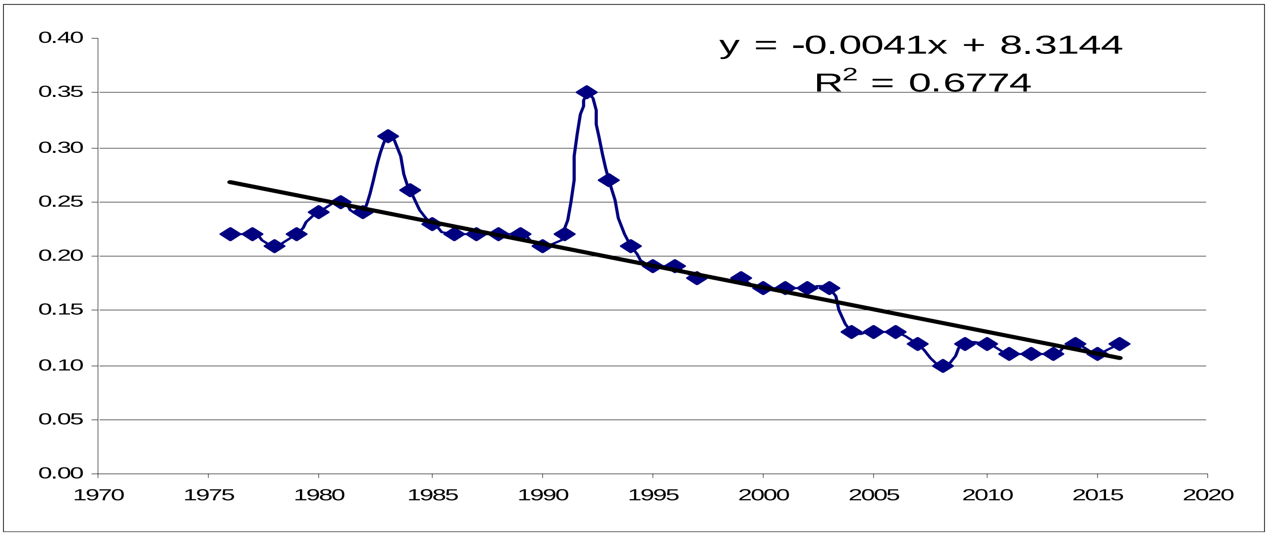


Fig. 4: Spatiotemporal distributions of the annual values of AOD over Russia during 1976–2006 (Year - horizontal axis, Number station – vertical axis)

A)



B)

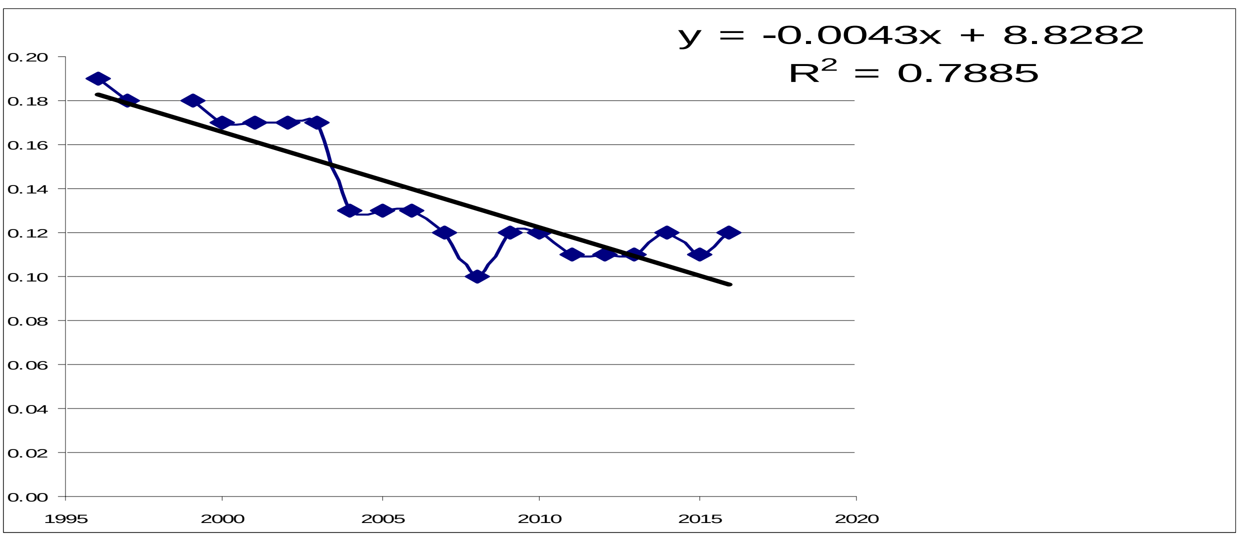


Fig. 5: Trends of the annual values of AOD over Russia during a) 1976–2016 and b) 1995 – 2016 (Year - horizontal axis, Number station – vertical axis)

VI. Some Conclusions

The aerosol optical thickness is an important characteristic of the atmospheric climate. The application of the AOT estimation technique for processing the results of observations at the actinometric network stations allows obtaining qualitatively new and detailed information on the level of aerosol pollution of the atmosphere in separate regions and in Russia as a whole. The analysis of AOT variations during the last 35 years shows the following results:

(1) The character of the long-period annual cycle of AOT did not change as compared with the preceding decades. For most stations, the AOT typically increases in spring and summer by 60–80% with respect to its minimum values in November–December. The AOT increase in spring and summer is associated with a seasonal increase in temperature and humidity and with changes in the underlying surface, as well as with a more intense photochemical and condensational generation of aerosol and with a flux of aerosol from the soil to the atmosphere;

(2) The main factors of space changes in the AOT annual cycle are a latitudinal succession of climatic and landscape zones, in combination with higher industrial loading of the southern regions of European Russia, as compared with the northern ones, and with higher industrial and urban

development of European Russia as compared with Asian Russia;

(3) Total averaged AOT over all stations and the whole period under study (0.19 or 0.14) is very close to the annual mean global AOT value (0.14) calculated from the ECHAM-HAM model and to the estimates obtained from satellite data (0.16);

(4) Average and maximum annual AOT values increase at the stations located from north to south in European Russia and decrease from west to east in the whole of Russia;

(5) "Purification" of the atmosphere from aerosol is caused by the absence of large volcanic eruptions and by industrial "calm" conditions during the last decade. The mean AOT for the last two decades is 30% lower than in the preceding ones, both for maximum and average values. Negative tendencies are almost similar for remote and urban (as well as for rural) stations; they are less pronounced in the fall than in spring and summer;

(6) Local effect of the AOT increase due to volcanic eruptions can reach 100%, while the average effects, within our consideration, are minimal.