60 year variability in meteorological and environmental characteristics of the atmosphere in Moscow megalopolis

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We analyze the results of meteorological and air quality measurements over the 60-year period (1954–2013) at the Meteorological Observatory of Lomonosov Moscow State University (MSU MO) located in the megalopolis with more than 12 million population. A complex program of meteorological and radiadive observations as well as aerosol, air and precipitation quality measurements has been in operation there according to the guidelines and the standards established by WMO and Russian Hydromet Service.

The significant positive temperature trend (+0,041C/year over 1954–2013) was obtained, which has been increased up to +0,067C/year for 1976–2012. This trend is slightly larger than the rate of temperature increase in the Central Federal District (CFD) (0,059CS / year) and over the whole Russia (0,043C / year). In addition, a long-period variability in net radiation and particular, in long-wave net radiation over 1954-2013 demonstrated a dramatic increase in the last decades. We show the possible mechanism of larger temperature increase in Moscow compared with that in the Central Federal District which can be connected with the greenhouse effect of the urban atmosphere. This mechanism is in accordance with the observed tendency of increasing downwelling long-wave radiation during the last decades.

The long-term measurements of shortwave irradiance, natural illuminance, PAR and UV radiation demonstrate a pronounced decrease in the 1970s and the increase during the last decades due to changes in global scale circulation. The interannual changes in biologically active UV radiation are characterized, in addition, by the large influence of decreasing total ozone content since the end of 1980s. In 2011, for example, we observed the absolute maximum level in biologically active UV radiation (+11%) and especially high UV-B radiation in spring 2011, when the Arctic ozone hole spread over the Moscow district. We propose a method for evaluating the optimum UV level for human health. According to the estimates, in Moscow the UV optimum is observed from the middle of March to the end of April, and from the end of September to the middle October.

The analysis of chemical composition of precipitation and pH since 1980, shows a significant seasonal and inter-annual variability with large frequency of acid precipitation in 1980-1990s, its significant decline in 1999- 2004, and a noticeable increase - since 2005. These variations are accompanied by the change in chemical composition from sulphate to chloride dominating ions. The analysis has revealed the effects of local pollution of Moscow megalopolis and the significant role of de-icing salts in increasing the chloride ions concentration and the acidity of the precipitation.

Aerosol studies since 1955 demonstrate a pronounced negative trend in aerosol optical thickness (AOT) from 1990s. According to the AERONET measurements since 2001 in MSU MO the negative AOT trend is observed in the last decade as well. The trend is characterized by the substantial decrease in aerosol fine mode fraction. Long-term AERONET collocated measurements at the MSU MO and at the Zvenigorod Scientific Station of the IAP RAS, which is located in background conditions, have revealed the Moscow aerosol pollution effect of about 0.02 for AOT at 500 nm with the increase of up to 0.04 in winter time. According to RT modelling we show the consequences of this effect on solar radiation in different spectral regions. Column aerosol content as well as the surface concentrations of aerosol particles smaller than 2.5 microns (PM2.5) demonstrate a summer maximum due to the active processes of second aerosol generation. The analysis of daily average PM2.5 in Moscow shows that the excess of maximum allowable concentration was detected 4 times in 2011, 10 times - in 2012 and 31 times - in 2013. In comparison with other megalopolis areas of Eurasia and America a moderate level of gaseous air pollution in Moscow is observed. The worst air pollution provides by nitrogen oxides, which content is comparable to that in cities of the industrialized countries.

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