Urban 'Dry Island' in Moscow

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The urban 'dry island' (UDI) phenomenon was first described in Berlin and Munich [1]. As it is known the relative humidity F in cities is as a rule less than in the surrounding rural zone around them [1,2]. The reason of this phenomenon is, firstly, limited areas of forest zones and less number of other water vapor sources inside a city and, besides, indirect influence of the urban heat island (UHI), i.e. higher air temperature T inside a city. In Moscow city the UDI has been studied and analyzed for the period since the end of the 19th century till recent years using the data of the ground meteorological network.

Mean-annual water vapor pressure E doesn't demonstrate systematic changes in Moscow during the last 146 years (see Fig.1). The linear regression coefficient K of its course is equal to only 0.0015 [hPa/year]. Thus, since 1870 the average water content in the ground air layer above Moscow increased on average only a little: by 0.2 hPa; such a small difference seems to be negligible and statistically non-significant. Unlike this parameter mean-annual relative humidity F demonstrates quick and systematic (time-stable) fall with the average rate of K = –0.06 [%/year] during the last 146 years; in other words, it decreased from 81 % in the 1870s to nearly 72 % in recent years. Inside the city it is the result of general T increase due to both global warming and, besides, intensification of Moscow UHI [3].

Long-term changes of the F spatial field in Moscow city have been studied for five periods since 1890s till recent years (Fig.2). As a result the UDI is found as a real physical phenomenon which is closely connected with UHI. Both the traditional (maximum) UDI intensity: $I_{MAX} = F_C - \frac{\sum_{j=1}^{m} F_{R_j}}{m}$ and the averaged one: $I_A = \frac{F_C + \sum_{i=1}^{n} F_{U_i}}{n+1} - \frac{\sum_{j=1}^{m} F_{R_j}}{m}$ were calculated, where F_C, F_U and F_R are the relative humidity mean-annual values at the city centre, urban periphery and the rural zone respectively.

As one can see in Fig.3, the absolute value of the maximal UDI intensity is increasing in time: from –4 % at the end of the 19th century to –8 ÷ –9 % now. For the period 1891–1897 the data only of two stations are available: 75.0 % at 'Landmark institute' in the city centre and 78.9 % at 'Mikhelson observatory' (close suburbs); I_{MAX} = –3.9 %. A quarter of a century later, during the First World War, the data of five stations in Moscow region (four of which are presented in Fig.2 b) are available. The lowest value of F on average of 2 years (76.9 %) was received just in the city centre whereas the second urban station 'Mikhelson observatory' (which appeared inside the city already) registered a little higher value – 78.4 %. At three rural stations mean F was 82.1, 82.0 and 78.7 % (on average – 80.9 %). So I_{MAX} remained nearly the same as before: –4.0 %. For the period of 1954–1955 the new central 'Balchug' station (close to Kremlin) registered the lowest F value on average of two years – 71.9 %, whereas other urban stations demonstrated intermediate values from 74 to 76 %, and rural stations – from 77 to 80 %. Therefore I_{MAX} = –5.8%; I_A = –3.0%

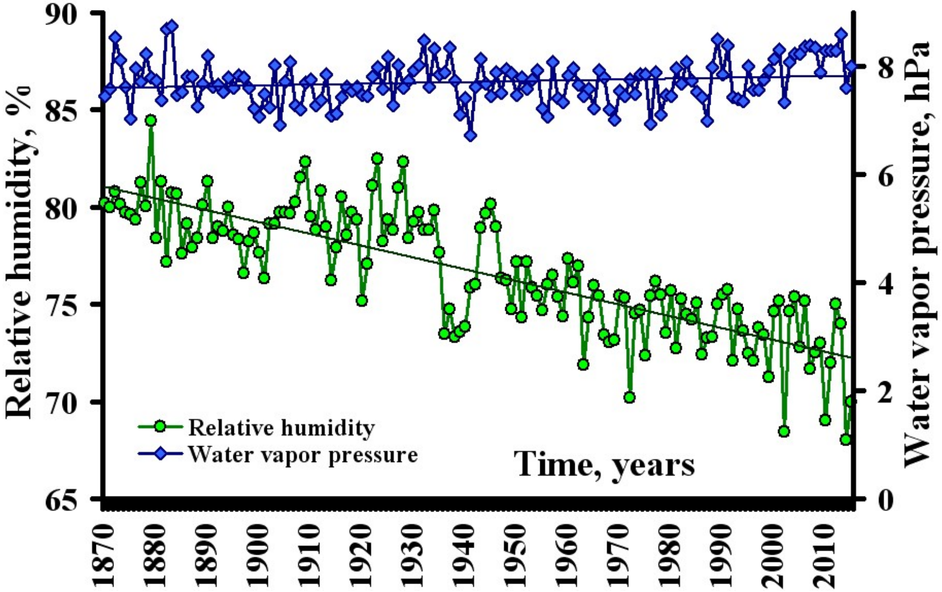
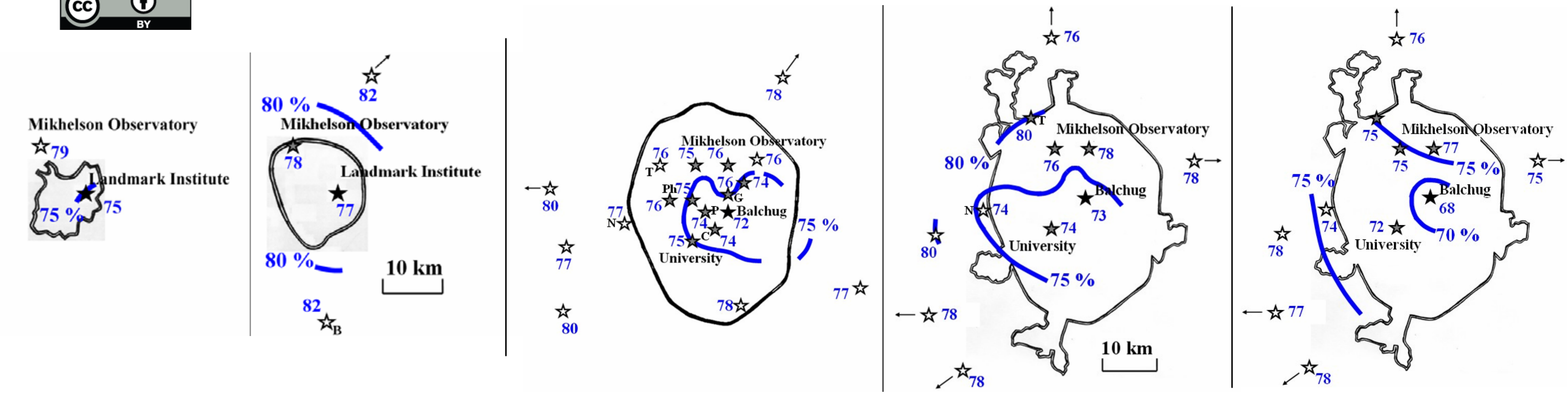


Fig.1. Long-term dynamics of mean-annual humidity parameters in Moscow in 1870-2015.



a) 1891-1897; b) 1915-1916; c) 1954-1955; d) 1991-1997; e) 2010-2014

Figure 2. Horizontal field of the relative humidity in Moscow and its long-term changes.

Double lines indicate the contours of Moscow city in 1890 (a), in 1916 (b), in 1960 (c) and from 1992 to 2011 (d,e); asterisks are weather stations; blue lines indicate mean annual isovapors (lines of the same relative humidity). Black asterisk is the closest to the city centre station, grey asterisks are other urban stations, white asterisks are rural stations. Stations: **B** ***–Biryulyovo;*** **T** ***– Tushino;*** **N** ***– Nemchinovka;*** **P** ***– Pogodinka;*** **C** ***– CPKR;*** **G** ***– GAMS;*** **Ph** ***– Phili. Arrows indicate the location of some stations outside the margins of the figure and their directions.***

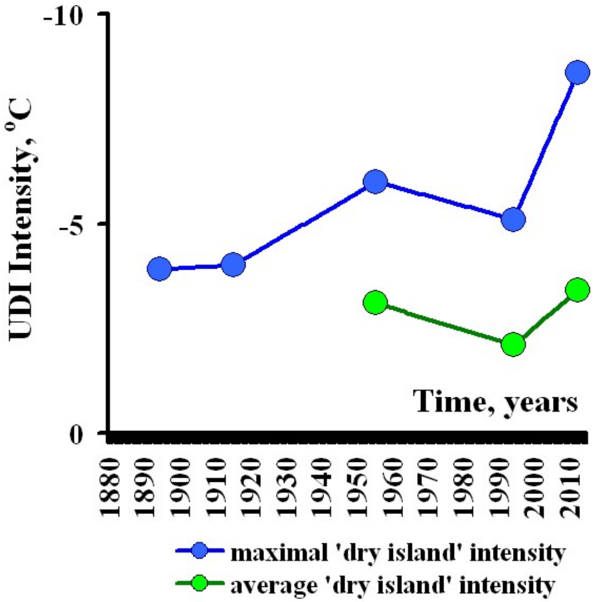


Figure 3. Dynamics of the urban 'dry island' intensity in Moscow city.

for n = 9 and m = 22. On average from 1991 to 1997 the F value at 'Balchug' was equal to 73.0 %; on average of all 5 urban stations 76.0 %; on average of all 13 rural stations – 78.1 %. Thus I_{MAX} = –5.1 % and I_A = –2.1 %. The reason of the UDI weakening from 1950s to 1990s in unclear because the total area of urban green zones remained nearly the same: 68.7 km^2 in 1958, 66 km^2 in 1978 and 65.6 km^2 in 1995. During last two decades UDI as well as UHI became much stronger in Moscow than before. On average from 2010 to 2014 the F value at 'Balchug' station at the city centre is the lowest among all other stations in the region: 68.0 %; the mean F values in urban and rural areas by the data of 5 urban and 13 rural stations for the same period are 73.2 and 76.6 % accordingly. Hence the I_{MAX} = –8.6 %; I_A = –3.4 %. Thus, the UDI in recent years is mapped by two isovapores: 70 and 75 %.

The difference between values of E inside and outside the city is small. For example, on average of 7 years from 1991 to 1997 it was only 0.1 hPa so it is not statistically significant. Thus, unlike average dryness, average humidity does not demonstrate time-stable local effects such as urban island.

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References:

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