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LONG-TERM TRENDS OF THE ANNUAL AND DAILY DEPTHS OF THE PRECIPITATION LAYER IN KYIV, ODESA, AND LVIV

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Abstract. *A comprehensive analysis of long-term series of daily precipitations in Kyiv, Lviv, and Odesa in 1945-2021 is performed. Similar trends in the change of base rainfall parameters are obtained for all cities. The annual depth of precipitation layer systematically increase, with average speed of 1.61 mm·yr^{-1} for Lviv, 1.25 mm·yr^{-1} for Odesa and 0.22 mm·yr^{-1} for Kyiv. The annual number of wet weather days has a still tendency for decreasing, with the highest rate for Kyiv (0.42 yr^{-1}), and lowest rate for Odesa (0.08 yr^{-1}). The average daily depth of precipitations for 1945-2021 increases at almost the same rate, from 0.014 to 0.016 mm·day^{-1}·yr^{-1}. Dependences of the maximum daily rainfall depths on the return period 0.1-10 yr are obtained using the Weibull model.*

Global climate changes are the most important threat to sustainable development of the modern world. Trends in the change of the average annual depth of the precipitation layer can vary significantly in different countries and, moreover, even within one region. For some cities in recent decades, there has been a systematic decrease in the average annual rainfall and other increases. However, the frequency of high-intensity rainfall events and, consequently, large-scale flooding, is increasing every decade in most European countries.

Thus, there is an increase in the irregularity and growth of the parameters of the maximum rainfall and runoff, which has a noticeable negative impact on the engineering infrastructure, agricultural lands, hydraulic and hydropower facilities, ecosystems reservoirs and adjacent territories. An increase in the rainfall depth and the intensity of maximum rainfall events in urbanized areas directly affects the reliability and efficiency of stormwater drainage systems. Therefore, considering the trends and quantitative parameters describing these changes is particularly important when modeling stormwater runoff at urbanized catchments and affects the effectiveness of stormwater management practices.

A number of big-scale studies of the long-term trends of the precipitation parameters across Europe were done in the early 21st century, e.g. by Klein Tank and Können [1] and Cortesi et al. [2]. Some results concerning the changes in parameters of precipitation in Ukraine, e.g., all-Ukrainian trends analysis for 2002-2011 were presented in [3], and the results for the transboundary region for Ukraine, Moldova, and Romania in [4], as well as the analysis of long-term changes in rainfall parameters in Lviv [5].

At the same time, to obtain an overall picture, there is a need for a broader comparative analysis of trends regarding changes in the quantitative parameters of precipitation in different cities of Ukraine. The purpose of this study is a comparative statistical analysis of the long-term trends in changes of the annual, average and maximum daily depths of the precipitation layer for three large cities of Ukraine, namely Kyiv, Odesa, and Lviv.

Statistical processing of daily values of the depth of the precipitation layer in the cities of Kyiv, Lviv, and Odesa during the years 1945-2021, obtained at the meteorological stations

of these cities and represented on the relevant databases, is performed. Data sets with annual depths of the precipitation layer and the number of wet weather days per year were processed by standard statistical methods; long-term trends of these parameters were determined by the method of least squares using linear regression analysis.

A comprehensive analysis of long-term series of daily precipitations in Kyiv, Lviv, and Odesa in 1945-2021 showed the presence of similar trends in the change of each of the common parameters, but with a significant difference in the speed of their change over time. The annual depth of precipitation layer in all three cities is systematically increasing, at the same time for Lviv and Odesa this rate is 1.61 mm·yr^{-1} and 1.25 mm·yr^{-1}, while for Kyiv it is low as 0.22 mm·yr^{-1}.

The annual number of wet weather days has a still tendency for decreasing, and the highest rate of such decrease was obtained for Kyiv (0.42 yr^{-1}), while for Lviv it is equal to 0.24 yr^{-1}, and for Odesa only 0.08 yr^{-1}. The average daily depth of precipitations for 1945–2021 in analyzed cities increases at almost the same rate, from 0.014 to 0.016 mm·day^{-1}· yr^{-1}.

The statistical analysis of the distribution of the highest daily rainfall depths showed the effectiveness of using the Weibull model to describe the dependence of the maximum daily depth on the return period *P*. Corresponding dependencies (1)–(3) are obtained for Kyiv, Lviv, and Odesa respectively for the range of return period 0.1–10 year:

$$h_{d.max} = 106.9 - 127.0\,exp(-0.576P^{0.27}) \quad (1)$$

$$h_{d.max} = 88.7 - 95.5\,exp(-0.631P^{0.40}) \quad (2)$$

$$h_{d.max} = 101.2 - 108.5\,exp(-0.500P^{0.416}) \quad (3)$$

Dependencies (1)−(3) can be used for estimation of hydrological balances, maximum daily runoff from urbanized catchments, and other important applied problems.

Statistical analysis of changes in annual precipitation parameters in Kyiv, Lviv, and Odesa for the period from 1945 to 2021 indicates a significant difference in the dynamics of the annual depth of the precipitation layer within the same climatic region, which is qualitatively consistent with the results of similar studies for other European regions.

Used information sources:

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