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Modeling hydrological regimes of lakes under climate change conditions using heat-water balance method by Budyko

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Global climate change will lead to increasing air temperatures over the next decades and is expected at least to be 1-2°C above the pre-industrial values in near future. Close relationships between the physical processes in the atmosphere and the surface of the planet cause not only temperature changes, but also changes in other parameters of the climate system including hydrosphere. In this context the investigations of a possible change in moisture regime with global warming are very important for assessment of the future changes in the hydrological cycle.
A steady-state hydrological model has been developed for evaluation of the changes in climate and hydrological parameters with the progress of global warming. This model is based on the heat-water balance method by M. Budyko and paleoclimatic scenarios. The Budyko's heat-water balance method is based on the combined solution of energy and water balance equations, as well as two empirical dependences: the evaporation rate on soil water content and the surface runoff on precipitation and soil moisture. This method is a universal one as it was developed using empirical data of different climates, including specific humid and arid ones. The method allows to calculate the mean monthly values of evaporation, runoff and water content of the active soil layer (1 m) using data on mean monthly values of surface air temperature, air humidity, precipitation, cloudiness, surface albedo and solar radiation, both for the actual climatic conditions, and for climatic conditions different from the present ones. Some additional assumptions have been made to adapt the method for scenarios of climate change. The paleoclimate scenarios are considered to a certain extent as analogs of future climates. The scenarios used consist of regional deviation from actual climate of annual precipitation, winter and summer air temperatures for Holocene optimum (6-5 KA B.P.) and Last Interglacial (about 125 KA B.P.), which correspond to global temperature increase by 1º and 2ºC, respectively. The results are presented by maps of annual runoff, evaporation, seasonal soil moisture in 1-meter soil layer, duration of snow cover and warm period changes with the progress of global warming for the Northern Hemisphere. The obtained mean values of potential evaporation and evaporation (monthly, seasonal, annual), runoff (annual) have been compared with observed data. The comparison show good agreement. Deviation from annual potential evaporation, evaporation is about 8-10%. The obtained climate change signals have been used for the assessment of the lakes level change with global warming by 1°C and 2°C. Two shallow lakes in different climates have been examined: Lake Neusiedler See (Austria) and Lake Ilmen (Russia). According to the results the water level of Lake Ilmen would be a little lower then current mean annual and it should not significantly change for Neusiedler See with 1ºC warming, but increase by 0.5-1.0 m for both lakes with 2ºC global warming.