EFFECTS OF GLOBAL WARMING ON WATER RESOURCES AND SUPPLIES

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Contents

Summary

Water resources are highly sensitive to climate variation in all time and space scales. The mean features of spatial variation of runoff related to climate zonality are presented for the present climate. During the last century the global runoff has increased by about 3%. The increase is in good agreement with the likely intensification of the water cycle worldwide. Statistical analysis of long-term time series made for regional or local scales does not provide proof of a significant change in the runoff. The methods of climate impact and sensitivity analyses can be classified as follows: (1) temporal analogues, (2) spatial analogues, (3) modeling approach, which may be simple empirical-statistical models or more sophisticated physically based causal (conceptual) models. The most widely available tools are the water balance models. The main problem of climate impact assessment is the limited possibility of model verification. Although climate and hydrological modeling has much uncertainty, some valuable conclusions can be made concerning the water resources change in case of global warming of the earth. All the major general circulation models indicate an intensification of the global hydrological cycle. From the global scale towards the continental, regional and local scale the uncertainties of prediction are rising. Despite these uncertainties it can be concluded that: (1) decrease of the runoff and the available water resources is expected mainly in the regions that at present climate have low resources and sometimes suffer from scarcity problems; (2) the redistribution of precipitation within the year in many regions of the world leads to reduction of the runoff in summer and to growth of runoff in winter and probably to increase of critical peak discharge; (3) in many parts of the world the soil moisture will be reduced in summer, which would lead to more frequent occurrence of droughts.

1. Introduction

Water is an indispensable element of life. Water resources are closely related to climate and are highly sensitive to climate variability and change.

Water occurs on Earth in many various forms as rivers, lakes, groundwater, or soil moisture. The variation of the hydrological characteristics of water resources in all time and space scales follows the variation of climatic events, mainly precipitation and evaporation, controlled by atmospheric processes. After rainfall or snow-melting, some water infiltrates into the soil, the infiltrated precipitation can be retained by forces of adhesion and capillary that is by forces of attraction between water and soil occurring is unsaturated soil and increase soil moisture, especially in root zones available for plants, or percolate to the groundwater storage and elevate the groundwater level. The portion of precipitation not infiltrated into the soil can be carried in a relatively short time after rainfall or snow-melting to streams in the form of surface runoff, increasing the water discharge and elevating the water level, leading to the formation of floods, and sometimes even catastrophic inundation. In periods with no or low precipitation, water resources, and in particular the soil moisture content, are reduced by evaporation. The evaporation rate depends on the meteorological conditions, mainly on solar radiation and air temperature and also on the amount of water available for evaporation mostly in the soil. An extension of the rainless period between rainstorms can bring about a large increase in the number of days with low soil moisture, in which crops suffer moisture stress.

As precipitation, temperature and the other climatic factors determining the hydrological processes are constantly and continuously varying with time, the hydrological characteristics of water resources such as water level or discharge of rivers, water amount in soil and so on, are similarly also varying. The variation of hydrological characteristics is of random character but the ordinary annual rhythms are connected with the seasonality of climate variation. Despite the constant and continuous variation of the hydrological characteristics with time, certain parameters of the hydrological processes remain relatively—in the statistical sense—constant for longer periods, provided that the processes affecting them, climate in particular, remain stable. For rivers these hydrological parameters are the long-term annual runoff, the interannual variability of annual flow, the distribution of annual flow within the year, the magnitude and frequency of extreme events such as floods and droughts, which are usually described by the probability function of mathematical statistics. The hydrological processes and the parameters of the water resources of any river can be considered stable for a longer period if their main statistical parameters are also stable for the same period. The question of how climate change will affect the water resources of the rivers is identical to the question of how the main parameters of the hydrological regime of the rivers will be changed. In contrast, the change in these hydrological parameters could detect, and maybe verify, climate change.

The answer to the question how climate change will affect hydrological processes and water resources is a hard one because, besides the difficulties of predicting climate change itself, the variation of the hydrological characteristics, and the climate–water resources relationship, it depends also on nonclimatic factors, mainly on land factors such as morphology, geology, soil, and vegetation cover. These factors play an important role in mediating climate variation and fluctuations in the hydrosphere. The spatial variability of land factors can explain the sometimes significant differences between the hydrological processes of areas with the same climate conditions. In the case of permeable and sandy soil, a relatively higher portion of precipitation infiltrates into the soil than in the case of impermeable clay soil. Soil properties greatly affect the magnitude of the subsurface rate of the stream flow and the magnitude of the stream flow itself. Human activity influences the hydrological processes mainly through change in land factors such as deforestation, changes in land cultivation, urbanization, whereas their effects can be commensurable with the effect of the expected climate change. Some of the land factors, especially plant cover, are climate dependent, too. Natural vegetation is always adapted to the climate and forms its morphology in agreement with climate. For example, in areas with dry climate, vegetation is developed that tries to retain water as much as possible and to minimize evapotranspiration. Vegetation plays an active role in the formation of climate and the water regimes. For given climate conditions, there is equilibrium between climate, water regime, vegetation, and the other land factors; if the climate changes, a new equilibrium between these ecological elements is established.

The problem of climate change is very important for water management because it is also highly sensitive to climate variation in all timescales. Many tasks of water management in the present climate arise because of climate variability, so that sometimes the problem is water abundance and at other times it is water shortage. Water resources depend strongly on climate and the available water resources vary from one region to another in relation to the spatial variation of climate. Some kinds of water demand are also climate dependent, such as the water demands of the living systems, including humans, animals, and crops. Historical experience shows that the water consumption of living organisms rises with temperature rise. Water management activities vary in their sensitivity to climate and are affected by climate events depending on their timescale. Soil moisture management, irrigation, and protection against floods are highly sensitive to within-year climatic events, especially the extreme ones. The reservoir systems are more sensitive to the interannual variability of climate, while the deep groundwater or water transfer systems are more sensitive to long-term fluctuation of climate. Climate change will affect society mainly through changes in extreme weather events, more so than through changes in the average weather conditions. The water management infrastructure built in the past (for flood protection, irrigation systems, and so on) has evolved within the limits of weather variability. As climate changes, a mismatch will appear between climate and the existing infrastructure.

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Biographical Sketch

Nováky Béla (born March 6, 1944) is an engineer-hydrologist—MSc. (Leningrad Hydrometeorology University 1967), Candidate for technical science (Hungarian Academy of Science 1993), Ph.D. (Technical University of Budapest 1994). Research activities include: development of hydrological forecasts, water balance investigation in Tisza River basin, investigation of river network structure, development of the method for improvement of the measured water discharges, engineering-hydrological characterization of water resources of Hungary, effects of climate change on water resources condition of Hungary and on irrigation water demand of plants, stability of hydrological regime of rivers. Publications include: 11 monographs or chapters of books, 8 university lectures notes or chapters of lectures notes, 25 scientific articles, 17 conference and 10 other articles.

Teaching activities: 1985–1991—University for Agricultural Sciences, Gödöllõ: invited lecturer on subject "Technical basis of agricultural management" (in Russian); 1988–1991—Pollack Mihály Technical College, invited leader of practical training on field-hydrology; 1988–1997—Research Centre for Water Management, Budapest: invited lecturer on "Erosion" in postgraduate hydrological course supported by UNESCO (in English); 1991– University for Agricultural Sciences, Gödöllõ, responsible for the lectures on subjects "Agrohydrology" and "Hydrogeography of Hungary", lecturer on subjects "Natural resources," "Water Management " "Aquacultura," "The Basics of Water Quality Control." *Membership of professional organizations:* board of Section for Hydrology and Hydraulic at Hungarian Hydrological Society (1985–), National Committee of International Hydrology Programme (1993–), Water Management Committee of Hungarian Academy of Science (1993–), Hydrology Committee of Hungarian Academy of Science (1999–), contact person of Tempus EWA-Ring project (1991–1994).