The Ensemble Scenarios Projecting Runoff Changes in Large Russian River Basins in the First Three Decades of the 21st Sentury


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Abstract. An approach is presented for carrying out a long-term projection of river runoff changes in large Russian river basins in the first three decades of the 21st century. These changes may be caused by climate warming and socio-economic factors. The approach utilizes a method for scenario estimation of runoff changes with ranging possible climate warming effects. This range is chosen by generalizing calculation results obtained by using an ensemble of global climate models for two contrasting scenarios (A2 and B1) of globally averaged air temperature rises. The approach also utilizes a method for alternative scenario estimation for water consumption as related to socio-economic changes. The estimates show that the expected runoff changes in the first third of this century due to climate warming scenarios can compensate the runoff decrease caused by the realization of some of the scenarios for socio-economic changes in the Volga river basin. The same compensation does not occur in the Don river basin, where negative effects are expected for the regional ecology.

Key words: scenarios of river runoff changes, global climate warming, large river basins

1. Methodology

The projection of river runoff changes for long-term period in the future (during XXI century) is complicated by uncertainties of future climate and socio-economic changes. That is why we choose scenario approach. Mean annual and seasonal river runoff changes due to climate warming are estimated for 2010–2039 period and due to social - economic changes for 2025-2030.

Method generating scenario estimations of runoff changes for a range of probable climatic warming scenarios based on the generalization of calculated results obtained by using an ensemble of global climate models.

Method for alternative scenario estimations for the water management system transformation caused by socio-economic changes and their impact on the river runoff.

2. Monthly Water Budget Model

The model is based on a conservation equation of average long-term monthly water balance of river catchments. In general it can be written down for each cell of a regular grid in the following way:

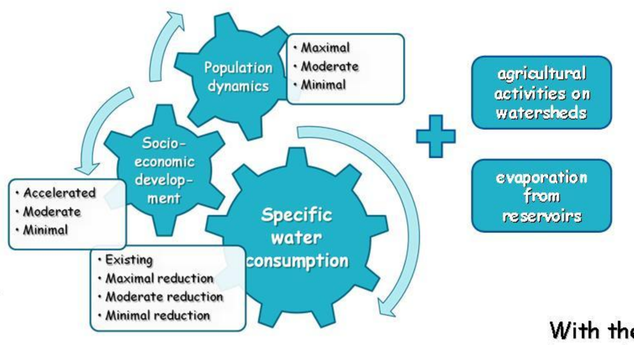
$$Qs(t)+Qgr(t)=P(t)-Id(t)-dW/dt$$

Qs(t) - the total surface and subsurface (seasonal active layer) flow (mm), ***Qgr(t)*** - groundwater flow (mm)
Qs(t) + Qgr(t) - full river runoff, ***P(t)*** - atmospheric precipitation (mm), ***E(t)*** - evaporation (mm)
Id(t) - infiltration of water to deep horizons of underground water outside of active water exchange zone (mm)
dW/dt - change of water amount in active water exchange zone of the river basin for the time interval *dt*

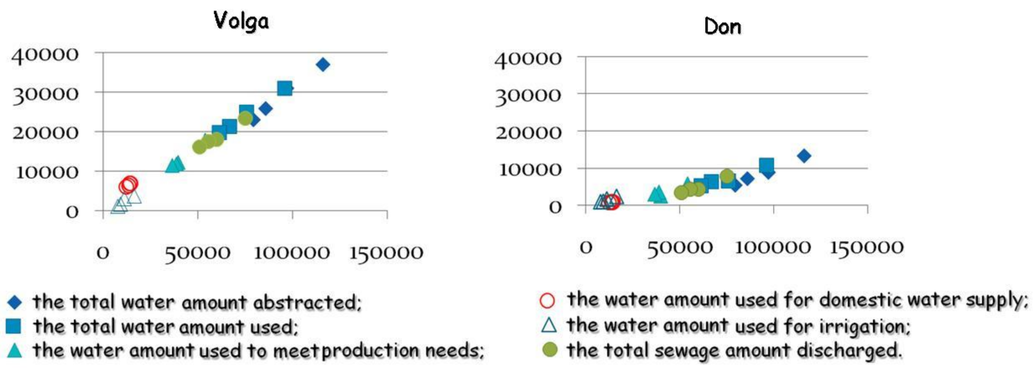
The range of probable climatic changes, which is estimated by calculating deviations of climatic elements from their recent values, is used as a climatic scenario.
The calculations are made for the two scenarios using the most (A2) and least (B1) intensive rises of globally averaged air temperatures.
Calculation results obtained by using 10 global climate models are employed. These were included in the IPCC program for their experiment "20C3M-20th Century Climate in Coupled Models" (CMIP3).
The climatic models were chosen from more than 20 climatic models by comparing the present-day observed climatic conditions with the simulated ones (Kislov et al., 2008).
The range of scenario deviations of mean monthly air temperatures and precipitation totals is determined for each of the scenario ensemble mentioned by averaging the calculated results obtained from each of the climate models chosen.

Climate Model	Country
CCSM3	USA
CNRM-CM3	France
CSIRO-Mk3.0	Australia
ECHAM5/MPI-OM	Germany
GFDL-CM2.0	USA
GFDL-CM2.1	USA
INM-CV3.0	Russia
MIROC3.2	Japan
MRI-CGCM2.3.2a	Japan
PCM	USA

3. Scenario for water consumption changes are based on:



Water consumption indices in Russia as related to those in the Volga and Don basins (in millions m³/year) in 1990, 1995, 2000 and 2005



Water consumption dynamics in the Volga and Don river basins are in many respects close to that which is typical for Russia as a whole. This makes it possible to use economic and water consumption changes predicted for the whole of Russia when working out basin scenarios.

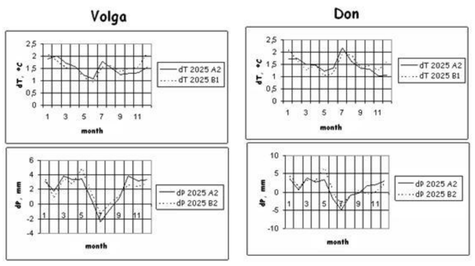
4. Regional Climate and River Runoff Scenario Changes in the First Three Decades of the 21st Century

Climatic changes

In Volga and Don river basins in the first third of the century under both scenarios (A2 and B1), we can expect very similar increases of annual air temperature that can be in the range 1,5-1,6 ° C.

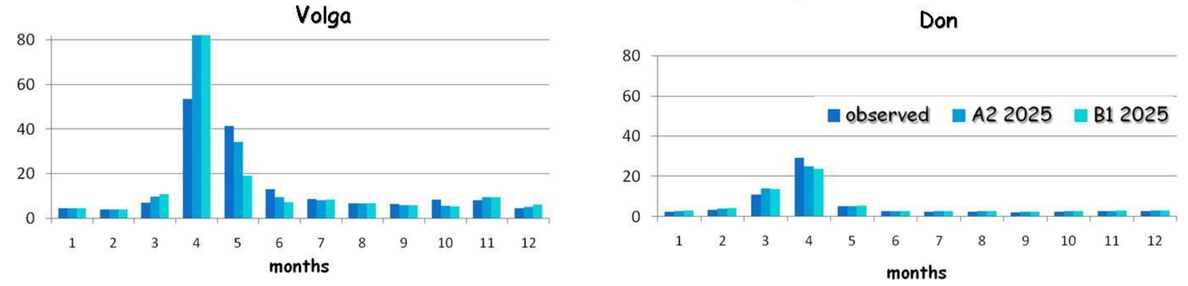
Annual sum of atmospheric precipitation can be increased, however, it will be within a few percent.

It is expected that for both scenarios the maximum increase in precipitation in both basins will be occur in the cold season. During the summer months it can be even decreased. This character of intraannual distribution for the two climate scenarios. Intraanual distribution of positive changes in air temperature is characterized by two comparable winter and summer "peaks". In the basin of the Don (scenario B1), the "peak" of summer temperature increase may exceed the winter.



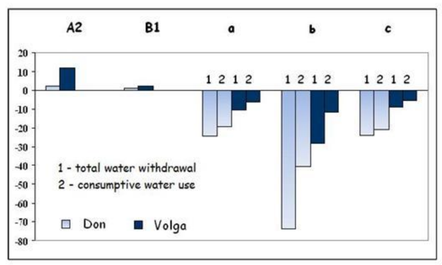
2025 denotes 2010-2039 period

Main trends of river runoff changes, mm



Considering the previously mentioned scenarios for climate changes, the mean annual Volga River runoff is expected to change slightly in the B1 scenario, but can increase by more than 10% under the A2 scenario, whereas the annual runoff in the Don basin remains almost unchanged under both the A2 and B1 scenarios.

Scenario of Mean Annual River Runoff Changes Due to Social-Economic Changes for 2025-2030

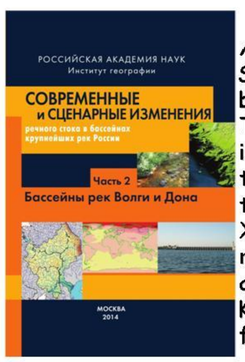


Observed and expected future (2025-2030) water abstraction in the Don and Volga basins, and the projected change in their mean annual runoff in the first three decades of the 21st century with contrasting A2 and B1 scenarios of the global climate warming (as % of the mean annual runoff):

a - the existing situation
b - the most favorable scenario of economic development and the current specific water consumption retained
c - moderate rates of economic development and reduced specific water consumption

With the most favorable scenario of economic development and the current specific water consumption retained, water abstraction, as compared to its current level, can increase by as much as three times and reach a critical level, which will have an adverse effect on the water management system and the environment. However, the current water abstraction levels can be retained with specific water consumption reduced by a factor of 1.5 and with moderate rates of economic development.

By recognizing global climate warming scenarios (A2), the mean annual Volga runoff can be increased, which, to a certain extent, offsets the negative impacts of water abstraction growth. Meanwhile the same compensation does not occur in the Don River basin, where negative effects are expected to take their toll on regional ecology.



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The results of studies for contemporary and scenario river runoff changes in the Volga and Don basins, probable in the first third of the XXI century, under the influence of the global climate change and socio-economic transformation are presented. Originality of these investigations lies in the fact that there were revealed long-term phases of changes for the naturalized annual and seasonal Volga and Don river runoff since the end of the XIX to the beginning of the XXI century, and their affection by the complex of anthropogenic factors are revealed, and the integrated assessment of changes for the river runoff, based on ensemble of climatic scenarios and alternative scenarios of water consumption is given as well.

Key words: river basins, river runoff, hydrological changes, long-term phase changes, climatic and anthropogenic factors, climate and hydrological scenarios changes, hydrological models