Bull. Nov. Comp. Center, Num. Model. in Atmosph., etc., 15 (2015), 23–28

Calculation of the East Siberian subarctic rivers runoff in the XXIst century*

V.I. Kuzin, N.A. Lapteva

Abstract. This paper discusses the results of calculation of climatic river runoff for the subarctic East Siberia region obtained with a linear reservoir model. For the verification of the model, the measurements data as well as the MERRA reanalysis data for the XXth century were used. For the XXIst century, the calculations with the data of the INM, the CRNM, the GFDL, the HadGEM, the MIROC5, the MPI models of the scenario RCP 8.5 of the Project CMIP5 IPCC were carried out. The results give a remarkable increase of the annual runoff for all the models. The annual variability has the positive trend during the XXIst century.

Keywords: mathematical modeling, climatic river runoff, East Siberia rivers basins.

1. Introduction

The climatic changes happening in Siberia and in the Arctic became an important phenomenon in the last decades. Essentially, it belongs to a hydrological component of the Arctic climate and its key part — to the Arctic Ocean, containing, according to the estimates [1], on average about 84,000 km^3 of fresh water. As an example of the role of the Arctic Ocean in the Earth's climatic system it is possible to mention the occurrence of the positive anomalies of salinity in the 60–70s of the XXth century [2]. Such an anomaly had the impact on the intensity of deep convection that led to a change in the mode of meridional thermokhaline circulation of the World Ocean. Therefore, the interest in hydrological processes of the Arctic in the last decades has significantly increased.

An essential source of inflow of fresh water to the Arctic Ocean is the river runoff. The estimates given in [1] make 54 % of the whole inflow of the fresh water coming to the pool per one year year. From this volume about 1,900 km^3 that makes 59 % of all river runoff is due to the Siberian rivers. Such rivers as Ob, Yenisei and Lena give the greatest contribution to the flow input. The simulation of a river runoff for these rivers was carried out in [3, 4]. Based on the data provided in R-ArcticNET [5], other rivers of Siberia give the average runoff value about 381.7 km^3 a year that gives rather significant inflows of fresh water to the Arctic Seas of the Arctic

*Supported by the RFBR under Grant 14-05-00730.

Ocean. At the same time, the total annual expense of the Siberian rivers during the second half of the XXth century undergoes essential changes. For certain rivers, this makes up 60 %. Water flows of the East Siberia rivers owing to the permafrost are generally replenished with snow melting and rains which makes 60–80 % of the whole amount of arriving water. Along with the interannual variability in hydrological characteristics of the Siberian rivers, steady positive trends are observed [6].

All these facts testify that the influence of the hydrological characteristics variability in the East Siberian part of the Arctic on the balance of fresh water in the Arctic Ocean (see, e.g., [7]) demands supplementary research.

Along with the analysis of changes in a hydrological component of the climatic system of Siberia in the XXth century [4] made on the basis of the reanalysis data of the MERRA, it is of interest to consider a projection of the development of hydrological characteristics of East Siberia and, in particular, the river runoff in the XXIst century as is discussed in [8] for the largest rivers of Siberia.

The present paper deals with consideration of separate aspects of the problem of climatic changes of the runoff of the sub-arctic rivers of East Siberia in the XXIst century on the basis of the calculations for the models of the CMIP5 IPCC project for the scenario RCP-8.5. In this paper, we present the results obtained with the climatic model of the river runoff that was developed in the Institute of Computational Mathematics and Mathematical Geophysics of the Siberian Branch of the Russian Academy of Sciences. The conducted experiments were based on the simulation results obtained with several climatic models: the INM models (Russia), CNRM (France), GFDL (USA), HadGEM2 (Great Britain), MIROC5 (Japan) and MPI-ESM (Germany).

The river runoff model used for calculations is linear, the Kalinin–Milyukov reservoir model [9]. The soil and river discharge is defined using the solution of this model reduced to the Duhamel integrals. The realization of the model is presented in [3, 10].

2. Simulation results

When carrying out numerical experiments on a climatic model of a river runoff, the resolution of 1/3 degrees in latitude and in longitude respectively was chosen. The model covers the Siberian region. In this study we consider the basins of such seven East Siberian sub-arctic rivers as Lena, Khatanga, Anabar, Olenyok, Yana, Indigirka, Kolyma. The rivers of the sub-arctic region belong to the rivers with a high water in the spring period and floods in a warm season. The soil flow is insignificant, in the winter season in many rivers, except Lena River, the flow actually stops. The high water begins in the second half of June and even at the beginning of July. The runoff

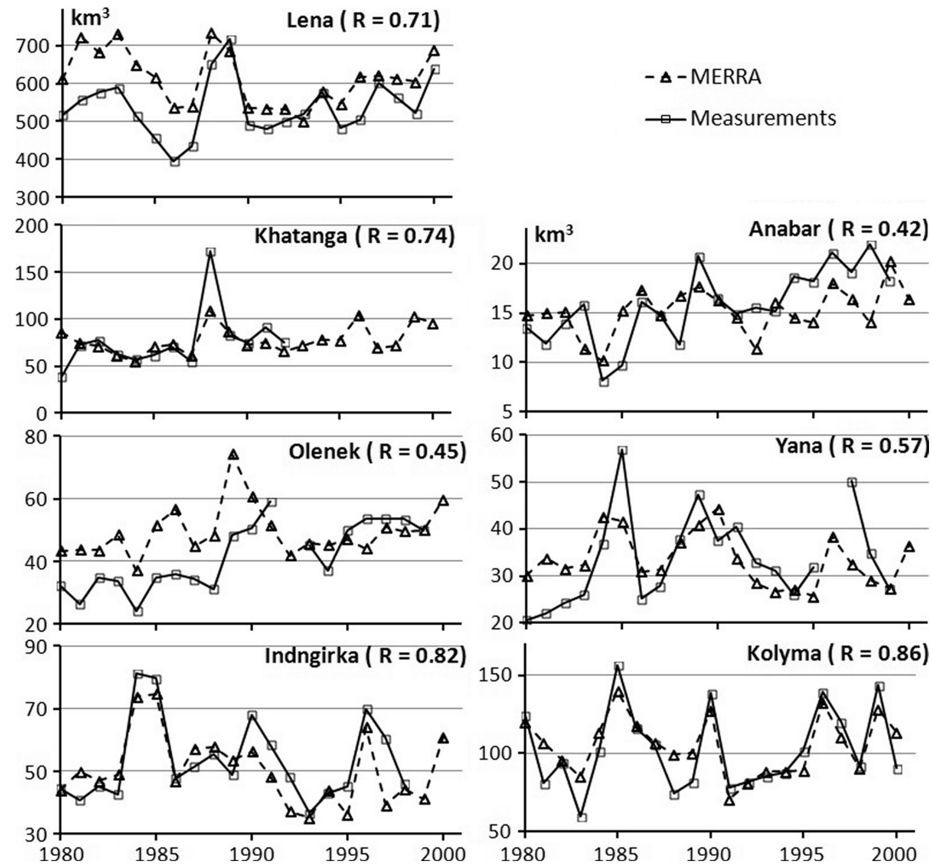

Figure 1. Interannual variability of the subarctic rivers runoff in the XXth century

coefficient is 0.4 for the Lena River and 0.6–0.8 for the others. So, a high rate is provided due to the existence of permafrost. The runoff of the Lena River, largest in East Siberia, was calculated and analyzed earlier in [11].

Previously, the analysis of the climatic and hydrological characteristics of the runoff of the East Siberia rivers in the second half of the XXth century based on the data of the MERRA reanalysis was carried out. According to the interannual variability of the runoff of the subarctic rivers correlations between the measurements data and model calculations, which have rather high values (Figure 1), are established.

The climatic annual hydrographs for the Laptev Sea and the East Siberian Sea basins are presented in Figure 2. Vertical lines denote the amplitudes of interannual variability in the measurements data.

The results given above show a sufficient adequacy of the model for calculations of climatic runoff of the rivers of the subarctic region.

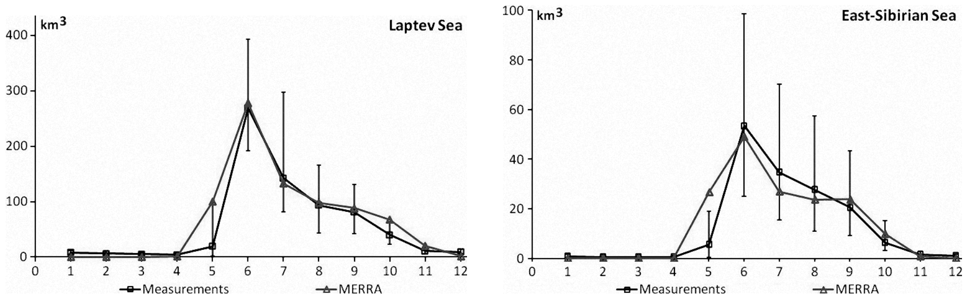

Figure 2. Annual hydrographs of the runoff in the Seas of the Arctic Ocean

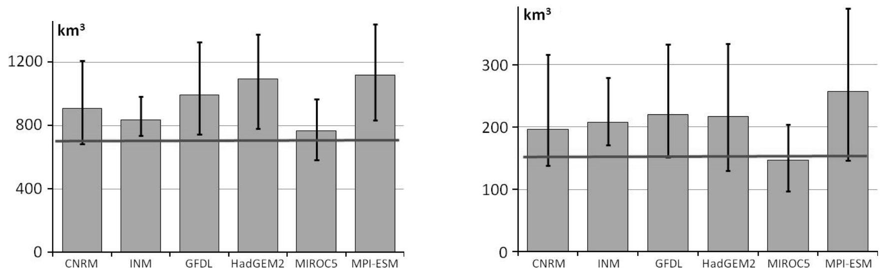

Figure 3. An annual runoff into the Laptev Sea (left) and the East Siberia Sea (right) basins

At the second stage a numerical experiment for the XXIst century was carried out. For the specified watersheds, we have simulated the river runoff for the period of 2006–2100 based on the atmospheric characteristics by the results of calculations with six models participating in the CMIP5 Program of the Scenario RCP-8.5 presented in the IPCC project [12].

In Figure 3, possible changes in the global mean annual runoff for models of the XXIst century are presented. The vertical lines denote the amplitudes of interannual variability. The horizontal line denotes the climatic runoff in the XXth century. All the models show the growth of an average annual runoff as compared to the measurements data in the XXth century, except the runoff into the East Siberian Sea in the MIROC5 model.

In Figure 4, the hydrographs by multi-model calculations as compared to the measurements data are presented. It, on the average, qualitatively reproduces the main phases of intra-annual distribution of a river runoff for the analyzed basins.

Results of calculations of the interannual variability of the runoff of the rivers of the Arctic seas basins in the XXIst century for all the models have positive trends (Figure 5). For the MPI, the GFDL, and the HadGEM models, the discharge of fresh water to the Arctic Ocean has significantly increased.

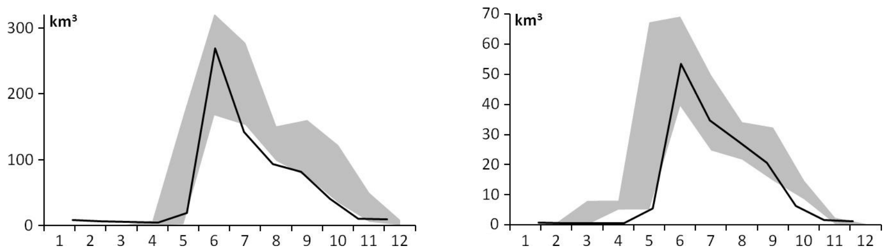

Figure 4. Hydrographs by multi-model calculation for the XXIst century as compared to the measurements data for the Laptev Sea (left) and the East Siberian Sea (right)

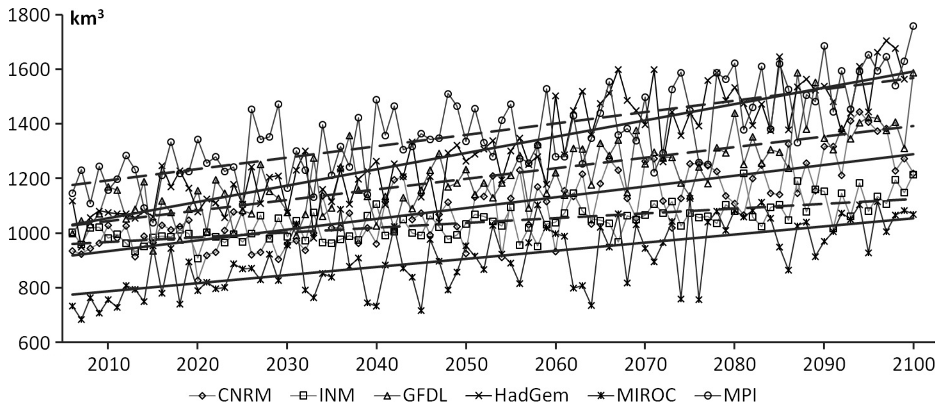

Figure 5. Interannual variability of the runoff of the rivers in the XXIst century

3. Conclusion

Calculations of the river runoff for the XXIst century by the six models data have shown an increase in the annual runoff of the East Siberian rivers by the end of the XXIst century for all models. This fact can be a response to the climatic changes in Siberia leading to the growth of a runoff of the Siberian rivers observed in the last decades. However, the results obtained have manifested a difference in the description of hydrological characteristics of the East Siberia for different models.

References

[1] Serreze M.C., Barrett A.P., Slater A.G., et al. The large-scale freshwater cycle of the Arctic // J. Geophys. Res. — 2006. — Vol. 111. — P. 1–19.

[2] Dickson R.R., Meincke J., Malmberg S.-A., Lee A.J. The “Great Salinity Anomaly” in the Northern North Atlantic 1968–1982 // Progr. in Oceanogr. — 1988. — Vol. 20. — P. 103–151.

[3] Kuzin V.I., Lapteva N.A. Mathematical modeling of a climatic river runoff from the Ob-Irtysh basin // Atmospheric and Oceanic Optics. — 2012. — Vol. 25, No. 6. — P. 539–543 (In Russian).

[4] Kuzin V.I., Lapteva N.A. Mathematical modeling of flow of the main rivers of Siberia // Atmospheric and Oceanic Optics. — 2014. — Vol. 27, No. 6. — P. 525–529 (In Russian).

[5] A Regional, Electronic, Hydrographic Data Network For the Arctic Region. — http://www.r-arcticnet.sr.unh.edu/v4.0.

[6] Peterson B.J., Holmes R.M., McClelland J.W., et al. Increasing river discharge to the Arctic Ocean // Science. — 2002. — Vol. 298. — P. 2171–2173.

[7] Kuzin V.I., Golubeva E.N., Platov G.A., Influence that interannual variations in Siberian River discharge have on redistribution of freshwater fluxes in Arctic Ocean and North Atlantic // Izv. Atmos. Ocean. Phys. — 2010. — Vol. 46, No. 6. — P. 770–783 (In Russian).

[8] Kuzin V.I., Lapteva N.A. Calculations of a runoff of the rivers of Siberia in the XXI century // Proc. Intern. Congress "Interekspo GEO-Siberia 2015". — Novosibirsk, 2015 (In Russian).

[9] Kuchment L.S. Mathematical Simulation of River Runoff. — Leningrad: Gidrometeoizdat, 1972 (In Russian).

[10] Hagemann S., Dumenil L. Hydrological Discharge Model. — 1998. — (Hamburg: MPI / Technical Report; 17).

[11] Kuzin V.I., Lapteva N.A. Modeling of a climatic runoff from a Lena river basin // Materials XX of the International Symposium "Optics of the Atmosphere and the Ocean. Physics of the Atmosphere" [Electronic resource]. — Tomsk: V.E. Zuev Institute of Atmospheric Optics, 2014. — 1 CD ROM, D5–D8 (In Russian).

[12] CMIP5 Coupled Model Intercomparison Project. — http://cmip-pcmdi.llnl.gov/cmip5.