Analysis of water cycle changes in Siberian rivers basins in XX and XXI centuries from model simulations

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In this study, water cycle changes in the Siberian rivers basins, including rivers runoff, from transient runs of coupled general circulation models (CGCM) ECHAM4/OPYC3 with flux adjustment (Oberhuber 1993; Roeckner et al. 1996), HadCM3 without flux adjustment (Collins et al. 2001) and IAP RAS climate model (CM) of intermediate complexity (Petoukhov et al. 1998; Handorf et al. 1999; Mokhov et al. 2000) for the period 1860-2100 are analyzed (Mokhov and Khon 2000; Mokhov and Khon 2001b). Greenhouse gases changes in the atmosphere in these numerical experiments were taken from observations for the 1860-1990 and according to the IS92a scenario (Houghton et al. 1992) for the 1991-2100 period. For IAP RAS CM simulations with change only CO2 content in the atmosphere are analyzed.

The river runoff Q was characterized by a difference between precipitation P and evaporation E on river watersheds. Model simulations were compared with observations for the Ob (1930-1994), Yenisei (1936-1995) and Lena (1935-1994) rivers runoff Q (e.g., Duemenil et al. 2000). In addition, different climatological data for precipitation and evaporation in rivers basins and runoff were used (e.g., Korzun et al. 1974; Vuglinsky 1998).

Table 1 presents mean values and standard deviations, SD, (in brackets) of the Ob (1930-1994), Yenisei (1936-1995) and Lena (1935-1994) rivers runoff from model simulations in comparison with observations for the same period and with different climatological estimates. There is a general agreement between model simulations and observations for the runoff mean values of Ob, Yenisei and Lena rivers, except for Lena river in IAP RAS CM with a significant runoff underestimation. General underestimation of the Lena river runoff in models is related with a general model overestimation of evaporation in the basin.

In general, model results exhibit an increase of mean values and variances of regional precipitation in the Ob, Yenisei and Lena rivers watersheds and rivers runoff to the Arctic Ocean in the XXI century relative to XX century (Mokhov and Khon, 2000). The general increase of the Siberian rivers runoff under the global warming in XXI century is connected with an increase of precipitation, especially in the Lena river basin. Model simulations display significant increase of precipitation in XXI century to the north from 50N (especially in winter). Alongside with such a general tendency a remarkable interdecadal variations of regional water cycle characteristics have been noted from model simulations. For instance, ECHAM4/OPYC3 and HadCM3 exhibit some decrease of the Ob and Yenisei rivers runoff in the first half of the XXI century.

The increase of the Lena and Yenisei rivers runoff from CGCM simulations steady exceed the level of standard deviations from observations at the NH warming larger than 1÷1.7K and 2.5÷3K, respectively (Mokhov and Khon, 2001b). The corresponding “critical” level for the Ob river runoff is reached only at the end of XXI century for ECHAM4/OPYC3. The corresponding changes with a 30-year moving average from HadCM3 simulations at the end of XXI century are remarkably less than the SD level from observations.

Analysis of connection of the Siberian rivers runoff with characteristics of atmospheric circulation in the Northern Hemisphere from observations and simulations was also carried out, in particular, with indices of the North-Atlantic Oscillation (NAO) and Arctic Oscillation (AO), characteristics of the atmospheric centres of action, including Siberian High (Mokhov and Khon, 2001b). It was found, for instance, statistically significant relationship (at 95 % level) of the Yenisei river runoff with the AO index, obtained from the NCEP/NCAR reanalysis data for the 1958-1995 period. The positive statistically significant correlation between the annual-mean Lena (Yenisei) river runoff and the winter (December - March) NAO index at 99% (95%) level was also revealed from observations. The annual-mean Yenisei river runoff and intensity of the winter Siberian High show negative correlation from observations for the period 1936-1995. The positive statistically significant correlation of the runoff of Lena and Yenisei with the NAO index is also shown for modelling results, in particular for ECHAM4/OPYC3 simulations.

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References

Collins, M., S.F.B. Tett, and C. Cooper, 2001: The internal climate variability of HadCM3, a version of the Hadley Centre coupled model without flux adjustments. *Clim. Dyn.*, 17, 61-81.

Duemenil Gates, L., S. Hagemann, and C. Golz Observed historical discharge data from major rivers for climate model validation. *Max-Planck-Institut fuer Meteorologie, Rep.* No.307, 93 pp.

Handorf, D., V.K. Petoukhov, K. Dethloff, A.V. Eliseev, A. Weisheimer, and I.I. Mokhov, 1999: Decadal climate variability in a coupled atmosphere-ocean climate model of moderate complexity. *J. Geophys. Res.*,104, 27253-27275.

Houghton, J.T., B.A. Callander, and S.K. Varney (eds), 1992: *Climate Change: The Supplementary Report to the IPCC Scientific Assessment. Intergovernmental Panel on Climate Change*. Cambridge University Press, 198 pp.

Korzun, V.I., et al. (eds.), 1974: *World Water Balance and Water Resources of the Earth*, Gidrometeoizdat, 638 pp.

Mokhov, I.I., A.V. Eliseev, D. Handorf, V.K. Petoukhov, K. Dethloff, A. Weisheimer, and D.V. Khvorostianov, 2000: North-Atlantic Oscillation: Diagnostics and modelling of decadal variability and its long-term evolution. *Izvestiya, Atmos. Oceanic Phys.*, **36**, 605-616.

Mokhov, I.I. and V.Ch. Khon, 2000: Diagnostics and modelling of hydrological cycle changes of the Siberian rivers basins in XX and XXI centuries. In: *Ecology of Floodplains of the Siberian Rivers and the Arctic*, 8-16. (in Russian)

Mokhov, I.I. and V.Ch. Khon, 2001a: Projections of future changes of hydrological cycle in the Caspian Sea basin. *Research Activities in Atmospheric and Oceanic Modelling. H.Ritchie (ed.).* WMO/TD-No.1064. 9.20-9.21.

Mokhov I.I. and V.Ch. Khon, 2001b: Water cycle in basins of Siberian rivers: changes in XIX-XXI centuries from model simulatios // *Proc. Fifth Intern. Study Conf. on GEWEX in Asia and GAME*. Nagoya. V.2. No.31(2). P.328-333.

Oberhuber, J.M., 1993: The OPYC Ocean General Circulation Model. *Max-Planck-Institut fuer Meteorologie, Rep.*7, 130 pp.

Petoukhov, V.K., I.I. Mokhov, A.V. Eliseev, and V.A. Semenov, 1998: *The IAP RAS Global Climate Model*. Dialogue-MSU, 110 pp.

Roeckner, E., K. Arpe, L. Bengtsson, M. Christoph, M. Claussen, L. Duemenil, M. Esch, M. Giorgetta, U. Schlese, and U. Schulzweida, 1996: The atmospheric general circulation model ECHAM4: Model descripition and simulation of present-day climate. *Max-Planck-Institut fuer Meteorologie, Rep.*218, 90 pp.

Vuglinsky, V.S., 1998: River water inflow to the Arctic Ocean - conditions of formation, time variability and forecasts. *Proc. of the ACSYS Conf. on Polar Processes and Global Climate.* WCRP-106. WMO/TD-No.908, 277-278.

Table 1.

P-E, mm/yr	**Ob**	**Yenisei**	**Lena**
ECHAM4/ OPYC3	146 (±31)	217 (±25)	166 (±27)
HadCM3	151 (±30)	237 (±36)	181 (±37)
IAP RAS CM	146 (±41)	256 (±61)	76 (±25)
Runoff, Q Observations	134 (±21)	233 (±18)	216 (±26)
P-E Climatologies	130÷135	237÷244	190÷214