INFLOW TO THE LARGEST RESERVOIRS OF RUSSIA AT GLOBAL WARMING AS A FACTOR OF SUSTAINABLE DEVELOPMENT.

Natalia LEMESHKO

Tataiana GRONSKAYA

State Hydrological Institute 2-nd Liniya 23, 199053 St.Petersburg, Russia
Tel. 7(812) 3233343 Fax: 7(812) 3231028 e-mail: natlem@mail.ru

ABSTRACT

Inflow to the reservoirs is one of the sufficient components of sustainable functioning of hydropower plants, flood control, navigation, water and power supply, reservoirs biota and etc. That's why the problem of inflow change at global warming is very urgent in the 21st century. The air temperature empirical data show growth in different latitude zones, which is the most pronounced for high and temperate latitudes. This phenomenon is characteristic for the territory of Russia as well.

The common tendency of the mean annual temperature for Russia is evaluated by positive linear trend 2,6ºC/100years. The most considerable positive trends have been received for mean monthly temperature in February-April and monthly precipitation in January-March especially during last two decades.

The long-term variation of the inflow to the largest reservoirs of Russia in 20th century is analysed on the background of climate change. The period of analyses varies from 120-80 years for the reservoirs on the River Don and the Volga River to 28 years for the Khantayskoe Reservoir located at the northern tributary of the Yenisei River.

Analysis of time series shows that the most common regularity for all reservoirs of Russia is the sufficient duration (10-15 years) of periods with low and high inflow. Last two decades of the 20-th century are characterised by normal or high inflow to almost all reservoirs, excluding reservoirs on the Don and Ob rivers. The most high runoff is characteristic for rivers inflowing the Volga in its upper and middle parts. The most pronounced changes in inflow monthly distribution are observed for the reservoirs of the Volga-Kama catchment: decrease of the part of spring flood. The monthly distribution of inflow to the reservoirs of the Siberia and the Far East is above normal.

The historical analogue approach is used to examine the respond of inflow to the study reservoirs of Russia to the recorded extremes in the weather. The inflow of the extreme years when the mean year temperature is 2^{0}C higher than normal for each reservoir catchments is employed for these purposes. The future global warming by 2^{0}C should influence dramatically on inflow to the reservoirs of Russia, especially on its monthly distribution.

1 INTRODUCTION

During last decades the response of environment in different regions of the world to the global warming has become very urgent. The mean global air temperature has already grown to 0.6 ^{0}C since the end of 19th century. The last estimates by WMO (WMO Statement, 2001) show that the mean global air temperature in 2000 was higher than the norm (1961-1990) by 0.29 ^{0}C. The warmest years of the latest decade were 1990, 1991, 1995, 1997, 1998, 1999.

The positive trend of mean annual air temperature has been characteristic for Russia as well. In 2001 the mean temperature was 0,77^{o}C higher than normal. The growth of air temperature for the period 1951-2001 was equal to 0,27^{o}C per decade for the area of Russia as a whole. The most pronounced trends are evaluated for winter (0,48^{o}C per a decade in 1951-2001, and 0,70^{o}C per a decade in 1971-2001). The mean monthly air temperature in January has been higher than normal for 6-8 ^{o}C in the central regions of the European Russia. So one should conclude that the warming is going on for the territory of Russia, and its maximum has been observed in 1995 (Review of pollution, 2002), when mean annual air temperature has been 1,4^{o}C higher than in 2001.

The observed changes are important for the functioning of the study reservoirs as the most part of them are multipurpose and exercise seasonal regulation of flow. Future changes in inflow to reservoirs should have a direct impact on the amount of hydropower generated, because hydropower production decreases with lower inflow. During low inflow periods, political pressures on hydropower interests to provide water for the environment intensify (Appleton, 2002).

2 PRESENT CHANGES IN INFLOW

The database on the inflow to the largest reservoirs of the hydropower plants of Russia (Fig.1) has been developed in the State Hydrological Institute (Gronskaya et al., 2002). The period of inflow time series analysis varies from 120-80 years (for the reservoirs on the River Don and the River Volga) to 28 years for the Khantayskoye Reservoir located at the northern tributary of the Yenisei River. Analysis of time series shows that the most common regularity for all reservoirs of Russia is the sufficient duration (10-15 years) of periods with low and high inflow.

Last two decades of the 20-th century are characterised by normal or high inflow for the most part of the study reservoirs. The most significant increase of runoff has been observed for the reservoirs of the Volga-Kama catchment up to the dam of the Kuibyshev Power Plant. The inflow to the reservoirs of the lower Volga has been equal to normal, and only inflow to the Tsimlyanskoye Reservoir (R.Don) exhibits tendency to decrease (10% lower than normal) (Fig.2).

The inflow to the reservoirs of Siberia and Far East has been equal or slightly high than normal (Fig.3). The Novosibirskoye Reservoir has been an exclusion (the inflow 11% lower than normal)

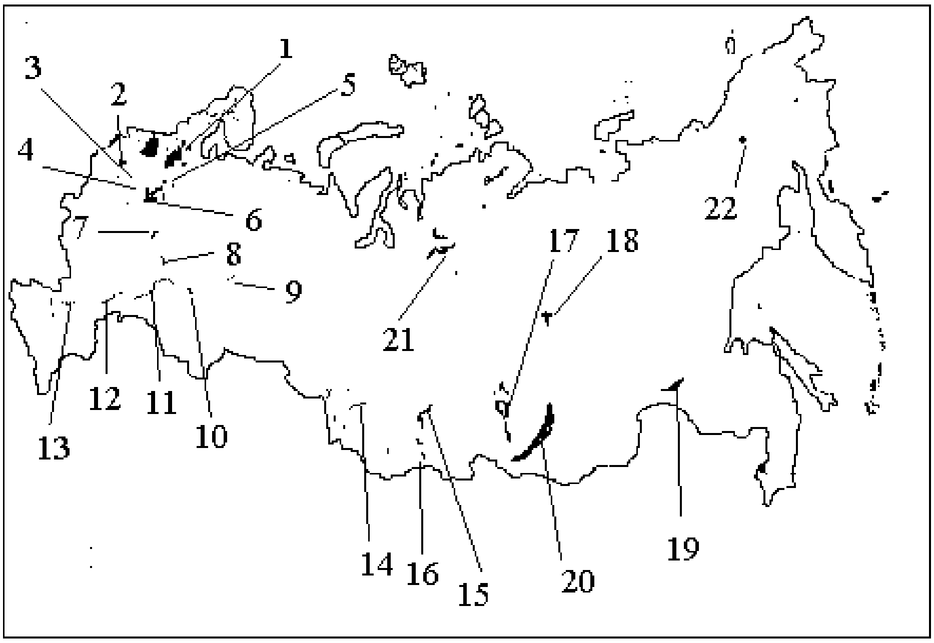
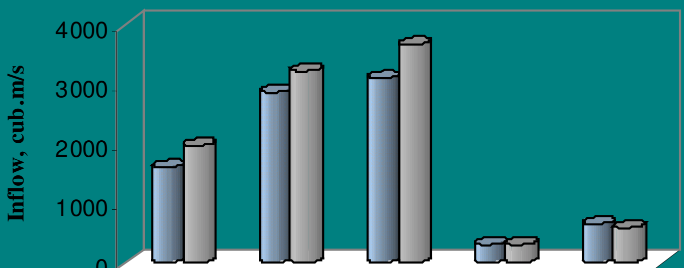


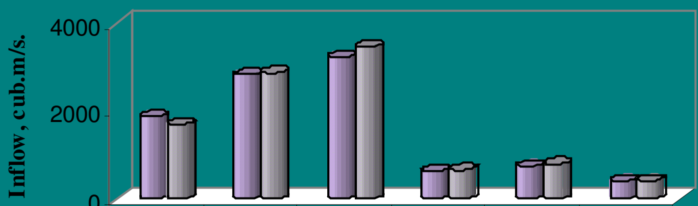
Fig. 1: Location of the study reservoirs :

1-Vygozerskoye Res., 2 – Lake Ilmen, 3 – Ivankovskoye Res., 4 – Uglichskoye Res., 5 – Sheksninskoye Res., 6 – Rybinskoye Res., 7 – Gorkovskoye Res., 8 – Tcheboksarskoye Res., 9 - Kamskoye Res., 10 – Nizhnekamskoye Res., 11 – Kuibyshevskoye Res., 12 – Volgogradskoye Res., 13 – Tsimlyanskoye Res., 14 – Novosibirskoye Res., 15 – Krasnoyarskoye Res., 16 - Sayano-Shoushenskoye Res. , 17 – Bratskoye Res., 18 – Viluyskoye Res., 19 - Zeiskoye Res., 20 – Lake Baikal; 21- Khantayskoye Res., 22 - Kolymskoye Res.



	Upper Volga Res.	Kama Res.	Middle Volga Res.	Low Volga Res.	Tsimlyanskoye Res..
1915-80	1600	2870	3100	302	647
1981-99	1970	3230	3670	300	585

Fig.2 Mean annual inflow (cub.m /s)to the Volga reservoirs and Tsimlyanskoye Res.

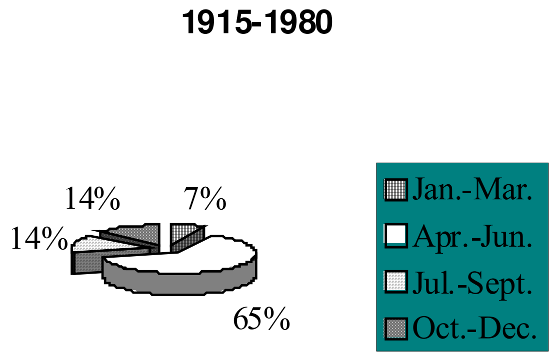


	Novosibirskoye Res.	R.Yenisei Res.	R.Angara Res.	Viluyskoye Res.	Zeiskoye Res.	Kolymskoye Res.
1932-80	1880	2840	3240	630	740	410
1981-99	1700	2880	3470	660	794	413

Fig.3 Mean annual inflow(cub.m/s.) to the reservoirs of Siberia and Far East

The comparison of within year inflow distribution for the period before 1980 with its values for last two decades shows increase of winter (January-March) runoff input and decrease of spring (April-June) input for practically all large reservoirs of Russia due to winter warming.

During last two decades the most pronounced changes in within year inflow distribution have been observed for the reservoirs of the Volga-Kama catchment: decrease of the part of spring inflow (April-June) for 12% (Fig.4).



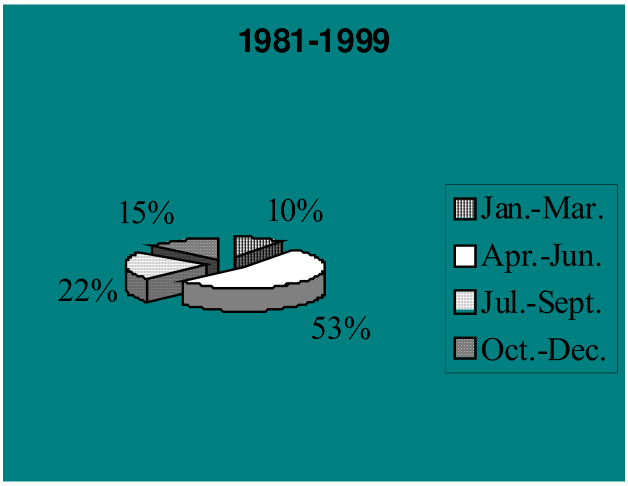


Fig. 4. Within year distribution of the total inflow to the reservoirs of the Volga-Kamacatchment mean for the periods 1915-1980 (normal) and 1981-1999.

3 CHANGES IN INFLOW AT 2 °C WARMING

In accordance with the forecast of changing global climate due to anthropogenic factors the global temperature is expected to be 1°C above the pre-industrial value by 2005-2010 and 2°C by 2025 (IPCC, 1996). Close relationship between the physical processes occurring in the atmosphere and on the surface of the planet is sure to cause not only temperature changes, but also the changes in other components of environment such as hydrological regime of reservoirs.

A hydrological model has been developed to calculate the changes in climate and hydrological parameters with the progress of global warming (Lemeshko, 2002). The model is based on the heat-water balance method and scenarios of global warming. The calculations are made using the data on deviation of annual precipitation, winter and summer air temperature for the Last Interglacial (125 KA B.P.) from the up-to-day ones. This period, when global air temperature was 2°C higher than modern one, is considered as the analogue of future climate (Borzenkova, 1992).

The method is universal as it is based on empirical data of different climate conditions and joint solution of energy and water balance equations together with two empirical dependencies for evaluation of evaporation and runoff.

The scheme of calculation is as follows:

1. Mean monthly values of radiation, heat and water balance of land surface have been calculated using data of observations on modern climate (long-term mean monthly air temperature, air moisture deficit, total cloudiness, surface albedo, total solar radiation, precipitation, the dates of formation and melting of permanent snow cover) for the meteorological stations in the catchments of the largest reservoirs of Russia. The obtained mean values of potential evaporation and evaporation (monthly, seasonal, annual), runoff (annual), soil moisture content (seasonal) were compared with observed data. The comparison showed their good agreement.

2. The calculations of runoff, evaporation and other parameters are carried out for the global warming by 2°C. In accordance with the scenario of regional changes; monthly air temperature and precipitation changes are introduced into the modern data from each meteorological station.

3. For potential evaporation, runoff and evaporation (monthly, seasonal, annual) are calculated the differences between the values with 2°C warming and mean long-term annual values.

Besides the historical analogue approach has been used to examine the response of the study reservoirs of Russia to recorded extremes in the weather. The inflow of the extreme years (when mean annual air temperature has been 2 °C higher than normal for the recording period for each reservoir catchment) has been employed for these purposes. The changes in runoff have been calculated as the difference between normal value for gauging period and the mean value for a number of extreme years

The results of such assessment are shown in Table 1.

Table 1. Changes in inflow to the largest reservoirs of Russia at climate warming by 2°C.

Reservoir catchment	Global warming by 2°C, method of paleoclimatic scenario		Warming by 2°C, method of historical analogues.
	Changes in annual precipitation, mm	Changes in annual runoff, mm	Changes in annual runoff, mm
Kamskoye	80	35	0
Kuibyshevskoye	90	50	5
Volgogradskoye	150	30	-21
Rybinskoye	75	35	13
Tsimlyanskoye	200	50	-4
Sayano-Shushenskoye	150	40	-24
Krasnoyarskoye	150	50	-64
Khantayskoye	100	0	0
Bratskoye	90	50	1
Viluyskoye	70	40	-15
Lake Baikal	100	40	10
Zeyskoye	90	50	58
Novosibirskoye	150	40	-38

According to the paleoclimatic scenario of 2°C global warming the increase of annual precipitation (75-200 mm/year) should be characteristic for the whole area of this country, and consequently increase of runoff to the reservoirs should be observed: from 20mm

(Khantayskoye Res.) to 50 mm (Kuibyshevskoye, Tsimlyanskoye, Krasnoyarskoye, Bratskoye, Zeiskoye).

The method of historical analogues exhibits more variable pattern of runoff changes: for the half of the reservoirs the decrease is observed, and for the Khantayskoye and Kamskoye reservoirs the changes are equal to zero. The most considerable negative changes of runoff are characteristic for the reservoirs of upper the Yenisei River (Krasnoyarskoye and Sayano-Shushenskoye Res.). The maximal positive changes are observed for the Zeyskoye Res.

The sufficient difference between two methods may be explained by not accounting precipitation in our case of historic analogues method. This research has a preliminary character and the results should be corrected by using the time series of precipitation.

4 CONCLUSIONS

- Climate changes influence sufficiently inflow to the largest reservoirs of Russia.
- The present and predicting changes in inflow should be taken into consideration for planning water resources management of reservoirs for sustainable development of the rivers catchment areas.
- The comparison of regional peculiarities of surface inflow to the reservoirs for the period of hydrometric observations with the data of paleoclimatic scenario of Last interglacial (125-130 KABP), when global air temperature has been 2^0C higher, makes it possible to decrease existing sufficient uncertainty in the forecast of future changes in the hydrological regime of reservoirs

5 REFERENCES

Appleton, B.(Ed.)(2002) Climate changes the water rules. Printfine Ltd., Liverpool,UK, 106pp

Gronskaya,T., Litova, T., Varfolomeeva,I., Goroshkova, N. (2002) Long-term characteristics of inflow, ice events and ice thickness for the largest lakes and reservoirs of Russia, Gidrometeoizdat, SPb, 50 pp. (in Russian)

Borzenkova, I.I., (1992). Cenozoic climatic change. St.Petersburg, USSR: Gidrometeoizdat, 247 pp.

IPCC. (1996). *Climate Change 1995* Ed.: Houghton, J.T. et al. Cambridge University Press. Cambrige, England. 572 pp.

Lemeshko, N.A. (2002). Land hydrological regime with doubling of atmospheric carbon dioxide. Climate changes and their consequences. St.Petersburg. “Nauka”, p. 251-259. (in Russian)

Review of pollution in Russian Federation during 2001. (2002). Rosgidromet. Moscow. p. 1-15.

WMO Statement on the status of the Global Climate in 2000. (2001). WMO No 920, 11 pp.