Theme 1 - Global Hydrological and Geochemical Processes is one of the main themes in the IHP-V Programme aimed at the solution of the problem of multipurpose water resources development in the vulnerable environment.

The very title marks a priority of this theme because an intensively variable human activity leads to a change in the hydrological cycle and in all environmental processes.

This comprehensive global theme consists of 4 projects contributed by well-know scientists from many countries. During the IHP-V period they achieved significant results within these projects.

In my presentation as a discusser, I am not going to speak what has been done or not done on these projects, and of course I am not going to analyse the obtained results. I shall only touch upon some aspects which, in my opinion, are not yet solved or inadequately gauged in hydrology, and they require a particular emphasis in the nearest future. I shall also present some new results to you obtained at the State Hydrological Institute within the framework of Theme 1 IHP-V where I work. Here, at this colloquium, I am present not only as a member of the group on Hydrology 2020, but as a representative of the State Hydrological Institute.

Project 1.1 Application of methods of hydrological analysis using regional data sets (FRIEND)

According to the assessment of the UNESCO Division of Water Sciences Section of Hydrological Processes and Climate, FRIEND made a major contribution to the Fifth Phase of the IHP during the third and fourth phases. The activities of 8 groups from about 100 countries cover a wide scope of problems on minimum flow, variability of regimes, floods and rainfall/runoff modelling, processes of streamflow generation, sediment transport, snow and glacial melt, climate change and land use impact. On the basis of regional database, each group has made a tremendous work, and results on the most important problems have been achieved for each region.

For example, Russia contributes to two FRIEND subprojects, develops a regional Archive, and makes studies on river runoff formation in small watersheds on the basis of data from water balance stations and from experimental catchments.

These studies are quite traditional in Russia, because we have not only water balance stations, but unique field experimental station in Valdai which is under the auspices of UNESCO; it is possible to make observations on each water balance component there (precipitation, evaporation, river runoff, groundwater levels, or soil moisture content); it is also possible to study the processes of soil freeze-up and thaw, to investigate chemical and isotope composition of surface and subsurface water, to study atmospheric air pressure.

It has been recently established that space-time dynamics of water exchange in rivers and in aquifers greatly affects streamflow formation and hydrological river regime. It has been also discovered that the global warming is accompanied by a greater contribution of small streams to river runoff formation, meanwhile the contribution of larger links of the hydrographic network is less.

Without going into detailed description of all the experiments made in Valdai, I shall only note, that in 1999 a monograph entitled "Experimental Hydrology with Reference to Hydrological Processes in Small Research Basins" edited by Andreas Herrmann was published; the results of long-term experiments made at the Valdai Field Experimental Station are described in this monograph.

There are many case studies of such kind for each regional group; they are published in the Final Report "Friend - a global perspective". But the problem is, if the major result is achieved. Are there any database for hydrological modelling on the global scale?

Our experience in the generalisation of runoff data all over the world shows that this problem is not yet solved.

One example, during the last 10 years a fundamental work was done at the SHI within the UNESCO IHP - 4 Project on runoff data collection, systematization and generalization all over the world (monthly data) to prepare a monograph entitled "World Water Resources at the Beginning of the XXIst Century". Besides the data available in the GRDC, much additional information on request was received from different countries of the world. Most data have been systematized; but this is not hydrological database required to study the global hydrological cycle: observation data are missing for the last 10-15 years for a major land area of the world.

Thus, there is no uniform database in the world where information from everywhere is received in an operational mode.

Reduction of hydrological network not only in developing countries but in developed countries too, is another aspect of the problem.

The main reasons for the network reduction in developing countries are as follows: ever-increasing costs for network maintenance and repair accompanied by insufficient financial resources; missing technical facilities to make observations; refusal of the observers to make measurements because of difficult conditions of the work and low salaries. This situation may be also explained by a poor knowledge of the situation by decision-makers and the persons responsible for funds, by their non understanding of the importance of making continuous observations of the hydrological regime.

In developed countries the network reduction is associated with automatization countries of most stations which in turn made the quality of the received information worse and with less funds for network operation.

One more acute problem concern reliable data on renewable water resources and water use. This information is essential for any analysis of water availability in any region, to determine water stress and deficit.

The materials published for individual continents and for the whole land area make a realistic picture; data on separate countries often differ greatly (sometimes, by one order). As to the data on water consumption, these are really missing.

All these problems are to be solved in future in a close cooperation with other international organizations, with the WMO in particular.

Now I shall briefly speak about some new results achieved at the SHI during the fifth phase of the IHP. First of all, this is the monograph “World Water Resources at the Beginning of the XXst Century” prepared during the fourth and fifth phases of the IHP and which is to be published during 2002 by the Cambridge University Press.

Using the materials which are being published in this monograph , as well as a new data on water use all over the world a new scenario has been developed and validated on the global water use before 2025, i.e. scenario of “Sustainable Development”. This scenario is an alternative to that used in the monograph developed in 1997 and known as “Conventional Scenario”.

According to computations by the scenario of the “Sustainable Development” , the world water use before 2025 would be practically stable; moreover, it would increase by about 6% before 2010, and then it would gradually decrease; and before 2025 it would equal 3900 km^3/year which would be greater than that in 1995 by 2.7 % only; moreover, industrial water use would be lower by 10%; agricultural water use would be practically the same, meanwhile the municipal water use would be by about 25% greater due to the developing countries.

According to the new scenario, more significant changes in the dynamics of water use may be expected on the continents. In Europe, North America and Australia a reduced water use may be expected by 22, 24 and 5 per cent, respectively, if compared with that in 1995. On the other continents the water use would be by 33% higher in Africa , by 21% higher – in South America and by 12% higher in Asia

Quite new assessment on the effect of reservoirs in the world on renewable water resources and water use has been obtained at the SHI. This estimations were made on the basis of systematization of the information about more than 800 reservoirs from 113 countries. The total reservoir capacity, active capacity and water areas of the reservoirs have been estimated in the dynamics for the following time periods: before 1940, 1941-1960, 1961-1980, 1981-2000 for all the continents, natural and economic regions and 57 selected countries. Ratios between total and active reservoir capacities and water resources (control indicators) and relations between water losses for additional evaporation from reservoirs and volumes of the total water withdrawal and water consumption (indicators of water resources use) have been determined for the same time periods.

Project 1.2 Development and Calibration of coupled hydrological/atmospheric models

It is very important problem from the viewpoint of the assessment of hydrological results of the global warming.

Besides, it is very difficult to develop hydrological models related to general circulation models which are used to forecast climate scenarios. A great number of hydrological models developed for river basins are available in hydrology. Even if a set of meteorological data is used as input for the models, they are not the models coupled to the GCM.

The difficulty is in the fact that the hydrological models are developed for river basins and give runoff at the output. The general circulation models require evaporation data, i.e. the parameter which is not connected with the boundaries of river basins. Therefore, most models from the presented “case studies” do not meet the main objective of the Project.

Project 1.3 Hydrological interpretation of global change prediction

Within the framework of this project much has been done to study the effect of the global climate change on hydrological characteristics. By the present time, numerous publications are available on the assessment of the climate effect on river and lake systems, snow and ice storage, on water use changes, etc. These assessments have been made on regional and global scales with the use of different climate scenarios. They are published in the Chapter 4 in the IPCC Report (2001).

In general, these studies are of a certain scientific interest because they reflect the response of water bodies to certain climate changes.

Unfortunately, a practical importance of these studies is not great for the moment, because the climate GCM scenarios give different values of the expected changes in air temperature and precipitation in particular, which determines hydrological characteristics to a great extent. This is explained by the following: when we study the climate effect on river runoff, we apply different hydrological models and scenarios of the climate change, we consider different scales of territories from a river basin to a continent. As a result, we have very great uncertainties. Firstly, the accuracy of the climate forecasts themselves.They give very different results especially for precipitations.

Secondly, accuracy of hydrological models. For some regions it is possible to receive quite inverse results.

Thus, a situation occurs that it is impossible to develop methods for an adaptation of water bodies to global changes and to suggest projects on mitigation of the effect of these changes in spite of the available numerous assessments of future hydrological results. Consequently, in my opinion, these problems are to be solved in the future taking into account a three aspects:

(1) it is necessary to have more reliable climate scenarios which would take into account the present trends towards climate change; this task for climatologists;

(2) it is necessary to emphasize studies on the assessment of runoff characteristics changes in different regions for the last 20 years, when the maximum air temperature rise was observed. Being aware of the present trends of the hydrological characteristics, it would be possible to make more accurate forecasts of their further development. This, in turn, would make our studies more reliable for those who make appropriate decisions on the protection of the environment;

(3) on the basis of studies it is necessary to select those regions in the world for which different scenarios of GCM and paleoscenarios provide similar assessments of hydrological characteristics changes. A number of project on adaptation to global change and mitigation of the expected results should be developed for these particular regions. In the case, if climate scenarios produce opposite results about future assessment, there is no sense to develop detailed adaptation measures. We can agree only with one American scientist who give recommendation “ to wait and see” when uncertainty will be less.

As to the first aspect, the experience of Russia, the experience of the SHI in particular, show that the use of paleoclimate scenarios (together with the GCM) provides more reliable forecasts. These studies were headed by Academician M.I. Budyko at the Institute.

According to the second aspect, multipurpose assessments have been made at the Institute on small and medium-size rivers regime changes observed during the last 20 years under the conditions of the global warming.

In the European territory of Russia and in the south of Siberia quite significant changes in streamflow variations during a year have been discovered; this mainly concerns the increased natural river runoff in winter due to higher air temperatures in winter time. This event was never observed in the past within such a vast territory for the whole observation period.

Therefore, it is possible to conclude for sure, that this is the consequence of the global warming.

When considering the third aspect, it is possible to show, as an example, the results of numerous studies with the use of various climate scenarios. They demonstrate a significant water resources increase in the conditions of the global warming almost within the whole territory of Russia; the exception is the Don river basin in the south of the European Russia. A similar study has been made for the Arctic regions of Russia, Canada and USA; it also shows an increased water inflow to the Arctic Ocean.

Within the framework of Project 1.3 it is necessary to mention the unique work of Russian scientists from the Institute of Geography, i.e. “The World Atlas on Snow and Ice Resources” . This is a great contribution to the IHP, though it does not contain the analysis of the dynamics of snow and ice resources by regions; such analysis should be made because of the global warming.

And finally Project 1.4 Strategies for water resources assessment and management under conditions of anthropogenic global climate change

This project is closely related to the previous project because a development of methodologies for a rational water resources use requires a knowledge of hydrological consequences resulted from the anthropogenic factors effect.

During the last 30-40 years practically all large river systems in the world were subject to an intensive man’s impacts (construction of reservoirs, irrigation systems, land use. intensified industrial and municipal water supply, etc.). Moreover, all these factors are subject to time changes and a certain extent affect natural hydrological characteristics, i.e. extreme water discharges, water exchange in the basin, monthly, seasonal and annual runoff.

These changes were initiated in some basins several decades ago and fundamentally affected all hydrological regime components; in some basins these changes are insignificant and concern some regime components only; in some basins the anthropogenic factors effect is within the accuracy of hydrological characteristics estimation. But in all these cases, however, in spite of available long-term observation series on large rivers, we still have no reliable quantitative assessments of the anthropogenic changes in the hydrological regime components in these rivers, i.e. we do not know if the river runoff regime is disturbed or undisturbed. Accordingly, we have no recovered runoff series for large rivers (with the account of man’s impact effect). The latter makes it impossible to study long-term variations in the hydrological regimes of large river systems due to natural and anthropogenic climate change and the effects of the expected global warming and economic developments on runoff.

All this hinders a solution of perspective water supply problems in many regions and a development of necessary adaptation measures.

It is possible to give some results of the SHI, as a case study, on the implementation of multipurpose studies on the Caspian Sea problem under the conditions of human activity and anthropogenic climate change. This problem was noted as one of the most important problems within the Project. It has been made in frame of International Grant "INCO-COPERNICUS" with participation of scientists from France, Great Britain and Germany.

1. As a result of intensive human activity, the Volga river discharge to the Caspian Sea during the 1980s decreased by 25 cu.km/year (or about 10 %). During the 1990s the reduced industrial and agricultural production resulted in a great decrease of water use in the basin. At present, the decrease of water inflow to the Caspian Sea from the Volga river due to man's activity equals 12-13 cu. km/year (including the additional evaporation from reservoirs).

2. During the last decades more precipitation was observed within the whole Volga basin, during the warm season in particular, as well as higher air temperatures are observed in winter, stimulating greater annual river runoff and streamflow variations during a year. At the background of the increased water availability in all watersheds with undisturbed water regime, identic (never observed before) and unusual changes in streamflow distribution during a year have been discovered, i.e. higher runoff during low-water period (summer-autumn and winter months) which attains 50-70 % of the norm in some regions.

3. The analysis of the Caspian Sea water balance makes it possible to conclude that:

- total river water inflow to the sea, water inflow from the Volga in particular, is the basic factor determining all significant changes in the Caspian Sea level (water level fall during 1930s and 1971-1977, and water level rise during 1978-1995);
- precipitation onto the sea surface and evaporation from the sea surface also affect long-term water level fluctuations, but this effect is not so important;
- water level rise during 1978-1995 by about 2.5 m is mainly explained by a greater water inflow, from the Volga river in particular (54 %), by less evaporation from the sea surface (29 %), by higher precipitation onto the sea surface (10 %), and by project related to artificial runoff control from the sea to Kara-Bogaz-Gol (7 %);
- the use of different climate scenarios based on paleoclimate data and general circulation models made it possible to get similar results for the changes in mean annual (climatic) runoff from the Volga river in the nearest 20-30 years, i.e. runoff increase by 5-10 %. On the other hand, evaporation form the sea, as well as water use in the region will be increased.

On the basis of the dynamic-stochastic model of the SHI, the water level in the Caspian Sea has been forecasted. Its fall is most probable in the future.

The expected water level before 2020 would be within -27.7 m and -28.1 m; before 2030 the water level would be probably within the marks of -28.4 and
-28.9 m.

Changing climate will obviously affect not only natural water resources but water requirements, water use and operation of water management systems, which depend on climate to a great extent.

In Russia, to assess changes in water management systems the same climate scenarios, hydrological and water management models are used. These assessments were carried out for water managements systems in the basins of Volga, Dnieper, Yenisei and Ural; assessments touched changes in power generation, navigation, water quality, flood protection and water use in basins.

In the case the scenarios produce a considerable increase in annual runoff, there are positive tendencies in navigation and power generation, however, the problems can arise with flood protection, areal flooding, and shallow water table around reservoirs.

Finally, it might be concluded that with intensive economic activities and developed infrastructure of water management, there are a lot of possibilities to adapt it to the conditions of changing climate.

Moreover, it is very important to develop an integrated system of adaptation measures to cover all sectors of economy, to take into account the population needs and to protect the environment.