Final Report

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According to Ulan-Ude weather station over 103 years the warming of the climate is estimated by the air temperature growth by 2.5° C (fig. 1). At the same time in Novoselenginsk the average annual air temperature rose by 1.8° C, while in Kyakhta it rose by 1.6° C [19].

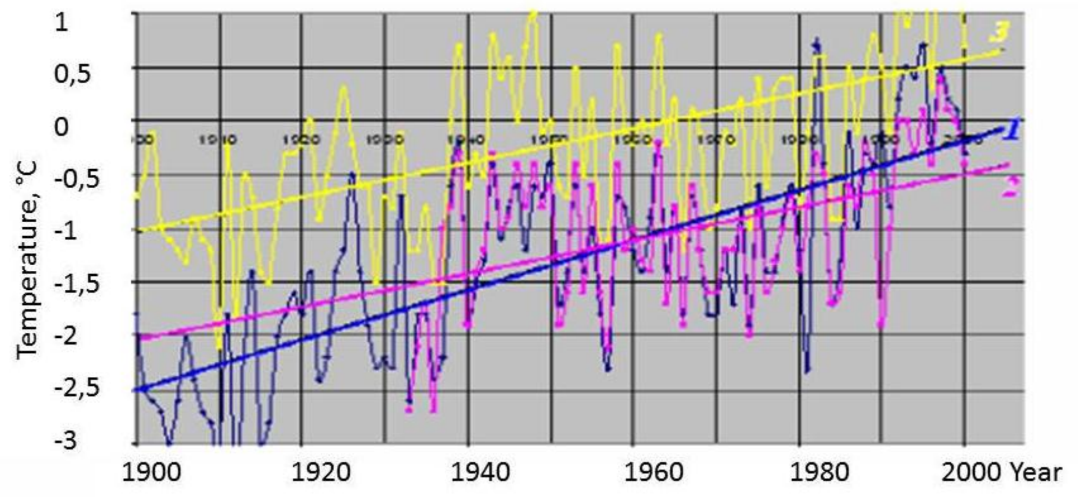

Fig. 2 Longstanding dynamics and trends of the average annual air temperature in Western Transbaikalia. 1 – Ulan-Ude, 2 – Novoselenginsk, 3 – Kyakhta.

The longstanding data of the weather station in Ulan-Ude note a stable positive trend of winter temperatures beginning from the 1920s while in summer temperatures such trend is absent.

Global changes reflect in the length of seasons (fig. 2). Increases of spring, summer and autumn and, consequently, decrease of the winter period were established. If in the early 1970s the length of seasons with positive and negative temperatures was approximately equal to 180-185 days, in the early 2000s the length of period with temperatures exceeding 0° C amount to over 200 days [19].

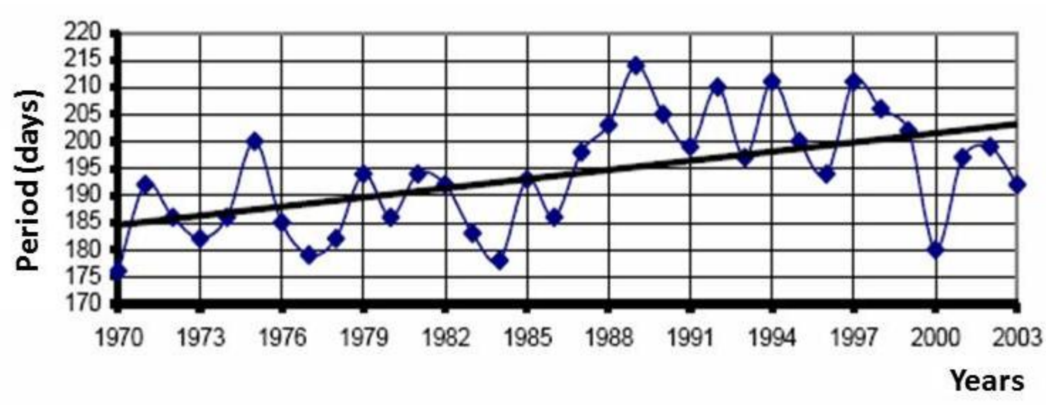

Fig. 2. Dynamics of period length between the dates of transition through 0° C and trend line.

According to the data of the Limnological Institute of the Siberian Branch of the Russian Academy of Sciences annual air temperature growth at Lake Baikal (1.2° C over 100 years) turned out to be twice higher than the globe's average (0.6

° C). This corresponds to the known fact of intensification of warming pace from low to middle to high latitudes. It may be expected that the annual air temperature at Lake Baikal by 2025 will rise by 2° C, and by 2100 by 4° C [28].

Air temperature increase resulted in a change of wetness in the basin of Lake Baikal and an increase of river inflow into the lake. The positive trend value amounted to 300 cubic m/sec. over 100 years. [28].

Reconstruction of hydrological regime show that over the recent 250 years the dynamics of precipitation and water level did not undergo significant (trend) changes. A growth of winter temperatures has not yet led to a drastic changes of hydrological budget of the Transbaikalian territory, where natural changes prevail. [1]. Cyclicity is the most characteristic part of the longstanding regime of annual run-off of the rivers of the Baikal region and changes in atmospheric precipitation.

From the middle of the last century average duration of snow cover in Transbaikalia shortened approximately by 5 days. This was caused by an increase of warm period duration connected with the increase of air temperature. The most significant decrease of the duration of snow cover is observed in the regions adjacent to Lake Baikal. On the contrary, in eastern regions the increase prevails. At the same time some precipitation enhancement during the cold season of the year results in a growth of snow cover depth. A tendency to increase is exposed in the longstanding changes of snow cover depth by 2-4 cm in average since the mid-1960s. [10, 13].

Climate change influences ice conditions on the lake. It is manifested in delayed freezing time and earlier breaking up of ice. At this time the change of freezing time in 1896-2000 was higher (by 11 days over 100 years) than for break up (7 days over 100 years) due to more active late autumn warming – early winter (November-December by 1.6° C) in comparison with the second half of spring (in April-May by 0.9°). The duration of an ice-free season increased, while that of the ice season decreased by 18 days. According to the observations, in 1949-2000 a maximum ice thickness in winter decreased by 2.4 cm over 10 years in average [25]. During the observation period from 1950 to 2007 a steady decrease of maximum ice-thickness on Lake Baikal amounts to 15-24 cm by different points. The duration of ice-formation decreased from 12 to 25 days for various areas of Lake Baikal and, consequently, the duration of ice-free period increased by 12-25 days [5].

According to forecasts the maximum ice-thickness on Lake Baikal will decrease to ~ 50 cm by 2050 and ~ 31 cm by 2100 [5]. Meanwhile the duration of ice season will decrease by 1 and 2 months respectively and by the end of the century will total 56-60 days on South and Middle Baikal and 76 days on North Baikal. It may be expected that in the end of the century in southern and middle areas of the lake there will be winters with short or unstable ice-formation [25].

In Cisbaikalia by the southern boundary of the cryolithic zone a process of permafrost degradation is observed, manifesting itself in an increase of land surface temperature, reduction of the period of registering negative temperatures on different depths of mollisoil, decrease of depth and speed of seasonal freeze [3]. A gradual shifting of the permafrost zone to the north and in a vertical direction, into Siberia's mountains starts to be seen [16]. As the frosted aquiclude is destroyed the surface of underground water and lakes is going down, swamplands dry out.

The global warming caused a visible growth of temperature of the uppermost water layers of Lake Baikal, especially over the last three decades. In the upper zone of the lake down to the depth of 300 m a tendency of a gradual temperature increase was observed [29].

The occurring changes of the aqueous run-off render influence on the dynamics of chemical components concentration in river waters and determine their intake in Lake Baikal. In the conditions of low hydraulicity the content of the main ions (HCO_3^-, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+}) elevates [22].

The dynamics of biogeneous elements concentration and their export to Lake Baikal depends, unlike the main ions, not only on the hydraulicity, but also on the intensity of biological processes. The maximum of nitrate nitrogen, mineral phosphorus, and silicon concentrations was registered in wintertime, when the development of phytoplankton is extremely low. Yet in the period of free flowing channel as the numbers and biomass of phytoplankton grows their content decreases. On the contrary, minimal concentrations of ammonium nitrogen in the water of the Selenga is observed in winter when its intake from the water-collecting area is limited, but the maximum is registered during snow melt flood.

If the warming causes an increase of the climate's continentality and the aqueous run-off drops, this, in the first place, will lead to a reduction of biogeneous elements intake in Lake Baikal and this may affect the intensity of phytoplankton growth. For example, a reduction of silicon run-off may lead to its deficit in the lake and this, in turn, will affect the development of diatomic algae [26].

If the air temperature increase is followed by an increase of precipitation, which itself may lead to floods, then the export of chemical components with river waters will increase. In this case, a considerable intake of biogeneous elements into the lake in the conditions of warming up of air and water may lead to intensified growth of algae, primarily in the estuary area of the Selenga shallow[20].

A change of the temperature of the upper layers of the lake and a shortening of ice-cover period may endanger the growth of the endemic diatomic algae blossoming under ice in spring, which makes the ice cover very important for their multiplication and growth. They are the main food for small crustaceans *(Epischura baicalensis)*, which, in its turn, is food for Baikal fishes.

Shrinking of the ice cover and changes in ice transparency may also harm the Baikal fresh water seal. It is the major predator of the lake at the top of food chain and it is also the only fresh water mammal. Because seals breed on ice, its premature melting forces them into the water before its starts casting the coat. This sharply decreases their birth rate and affects the number of their population [32].

In the recent decades alongside warming aridization of climate takes place on the entire territory of Transbaikalia. This phenomenon reflects the general situation against the background of which a partial degradation of forest-steppe birch woods took place in Transbaikalia and North Mongolia [2].

Influence of the climate change have most brightly manifested itself in the changes of forest fire situation. Droughts, whose frequency and length increased over the recent years, contribute to fire development and impede forest reproduction. Forest fires destroy not only plant life, but also soil mantle, contributes to the development of erosions and aridization. Besides, forest fires contribute to the increased emission of carbon raising greenhouse gas concentration in the atmosphere, and smokiness of the air harming peoples' health. Transboundary fires are of special concern. Out of 1201 forest first that started out on the territory of forest reserves in 2009, 7 were transboundary fires since they either came from the territory of Mongolia, or from Buryatia to Mongolia[30].

In agriculture the climate change lead to both negative and positive consequences. Soil and atmospheric drought specifically frequent in the recent decade can be related to the negative manifestations of climatic changeability. As a result, there is a reduction in yields, which depend on the changes in heat-moisture rate, and a growing destruction of crops. Extension of vegetation period may be related to the positive effects of climate change. This extension equaled 4 to 15 days in various areas since the mid-twentieth century and 11 days in average in the agricultural zone [11]. The extension of vegetation period together with the growth of effective temperatures create favorable conditions for the development of plant industry, plantation of more warm-season crops. There is an opportunity of extension of spaces for winter crops. The use of the exposed tendencies will allow increasing efficiency of agricultural production.

In the connection with warming almost everywhere in autumn the dates of the heating season shifted to later dates of air temperature transfer over 8° C. On the contrary, in spring earlier dates of this transfer are registered. Consequently the duration of the heating season shrank by 12 days [7].

The exposed tendency of elevated snow cover depth points at a possibility of emerging problems with wintering of cattle. In the conditions when pasture forage is unavailable mass loss of cattle is becomes possible. An increase of snow depth in the winter of 2008-2009 in the Zabaikalskii region resulted in a loss of 2000 heads of cattle and 15000 sheep [12]. A more massive loss of cattle took place in Mongolia in the winter of 2009-2010 when deep snow hid the vegetation that had suffered from the summer drought. 8 million heads of cattle died [18].

Inefficiency and energy consumption of the energy system in the basin of Lake Baikal, physical wear of its main equipment only increase climatic risks. On the other hand, a necessity to be ready for the changes of climatic conditions creates new possibilities, in particular, the development of renewable energy sources.

Implementation of new energy-efficient technologies, reconsideration of standard rate of energy consumption in winter, and norms of calculation of a required fuel storage in the connection with the prognosticated shortening of the heating season, improvement of heat insulation of residential and office buildings, industrial objects, replacement of obsolete equipment by the new, more energy-efficient equipment, development of renewable sources of energy may solve two objectives – adaptation and smoothing out of climatic changes by the reduction of greenhouse gases emissions.

Based on the passed “Comprehensive Plan of Action for the Implementation of the Kyoto Protocol to the UN Framework Convention on Climate Change in the Russian Federation” the Government of the Republic of Buryatia passed two decrees:

- Dated 6 February 2008 N46-r, according to which a coordination organ was appointed for the implementation of the Kyoto Protocol in the Republic of Buryatia (Ministry of Economics) and a Comprehensive Plan of Actions for 2008 for the implementation of the Kyoto Protocol to the UN Framework Convention on Climate Change provisions in the Republic of Buryatia;
- Dated 25 July 2008 N 384-r, according to which a workgroup on the problems of the implementation of the Kyoto Protocol in Buryatia was formed and a Workgroup Provision as well as its staff were approved;

In accordance with the Comprehensive Plan an energy saving program was worked out for the coming decade (2020). In this program there is an objective to limit the GDP energy intensity by 40 per cent in comparison with 2008 due to a policy of stimulating energy saving, implementation of energy-efficient technologies, materials, and development of renewable sources of energy (their ratio in the electric energy production should increase up to 4.5 per cent in 2020 in comparison with 2008).

Measures to reduce the GRP energy intensity are aimed at modernization of heating sources, implementation of a new energy-saving equipment, technology and materials, re-laying of decrepit heating pipe networks, creation of solid-waste recycling facilities. The main measures are concentrated on the housing and public utility enterprises, energy and transport enterprises.

On the initiative of the Government of the Republic of Buryatia a proposal to electrify in 2010-2014 the railroad “Ulan-Ude-Naushki” connecting Russia and Mongolia was included into the Strategy of Railroad Development in Russia until 2030.

In 2007 in the timber complex of the Republic of Buryatia measures were taken aimed at the increase of absorption and limit of emission of greenhouse gases on the territories of the State Forestry:

- forest reproduction 2.4 thousand hectares;
- for assistance to natural reafforestation – 29.3 thousand hectares;
- for carding of plantations – 3.0 thousand hectares

Fig. 3 displays the dynamics of greenhouse gas emissions in Carbon Dioxide Equivalent from the main sources of greenhouse gas emission in energy production, timber industry and agriculture of the Republic of Buryatia in the period from 1990 to 2004 [22, 24].

According to the preliminary calculations the gross anthropogenic emissions of the main greenhouse gases in the republic in 1990 in Carbon Dioxide Equivalent amounted to 18.75 million tons. Beginning in 1990 their considerable decrease took place: 52.6 per cent in comparison with 1990. Energy production is the largest carbon dioxide emitter in the republic. Its share in 1990 was about 64 per cent and in 2004 – 78.7 per cent of the main greenhouse gases. Timber industry is also a considerable contributor to the gross emission of greenhouse gases. Forest fires have a large impact on the dynamics of greenhouse gas emissions. For instance, in 2000 their share amounted to 29 per cent, in 2003 – to 43 per cent and to 16 per cent in 2004.

Carbon dioxide emission, thousand tons

--♦-- Total emission of greenhouse gases in Carbon Dioxide Equivalent, million tons

--■—Emission of carbon dioxide from fuel combustion for energy needs, million tons

--▲—Emissions of carbon dioxide from timber industry, million tons

--■—Emissions of carbon dioxide from agriculture, million tons

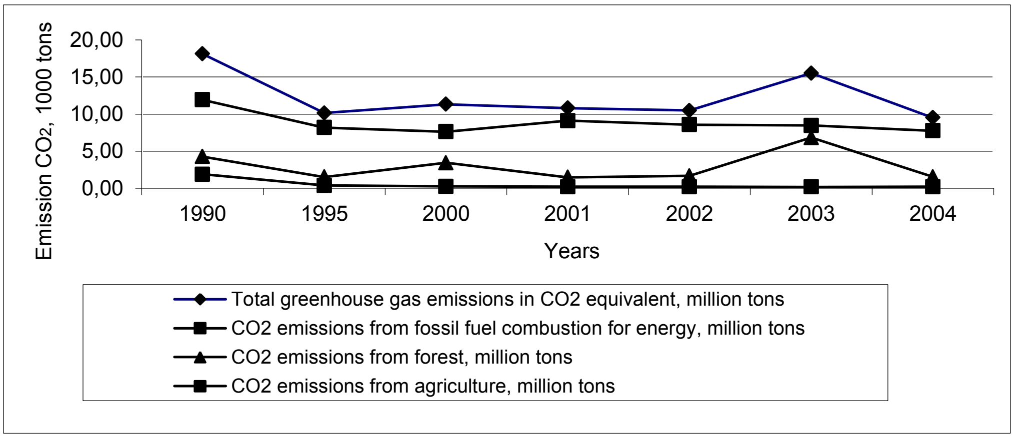

Fig. 3 The dynamics of the main greenhouse gas emissions in Carbon Dioxide Equivalent in the Republic of Buryatia

Despite a very active and, generally, successful development of global models and scenarios of climatic forecasts over the recent years, they are still insufficient for the development of a forecast to such an extent of detalization that is required for the Baikal region. There are uncertainties in the evaluations of climate change as well as uncertainties related to sustainability of natural ecosystems, its vulnerability to climate changes and adaptation capabilities.

The available forecasts, undoubtedly, representationally describe a climate change on a considerably large territory in general. However, the data used in them are not representative enough for the description of climate change in a certain place, in particular, in the basin of Lake Baikal. This gap forces to develop and plan measures of adaptation to climate changes based on the precautionary principle and rough estimates of future changes.

Insufficient awareness about the transboundary problems of Lake Baikal basin negatively reflects in the understanding of current impact of climate change on the society, nature, economies of both countries and the tendencies of change in the future.

The existing economic estimates of climate change are also insufficient. This causes troubles in substantiation of adaptive measures and measures to mitigate the climate change.

General Conclusions

The data on climate change in the territory of Lake Baikal basin presented in the this report correspond with the data on global warming of the climate.

In the Russian territory of Lake Baikal basin a stable positive trend of winter temperatures is detected beginning with the 1920s by 2 degrees Celsius in average, while there is no such thing in summer temperatures. The growth of annual air temperature at Lake Baikal (1.2º C in 100 years) turned out to be twice higher than the global average (0.6º C), which corresponds to the well-known fact of increasing warming tempos from low latitudes to middle latitudes and then to high latitudes. It may be expected that the annual air temperature at Lake Baikal will rise by 2º C by 2025 and by the year 2100 by 4º C. The amount of precipitation and humidity will not change considerably.

Climate changes result in both negative and positive consequences. Changes in the water ecosystem (shrinking of the ice cover, reduction of ice thickness on Lake Baikal , chemical and biological contamination of transboundary water bodies), soil and atmospheric droughts, as a result of which a reduction of yield and destruction of crops and drought yielding trees take place can be related to negative consequences of climate change. To the same consequences one should relate more frequent dangerous weather phenomena, including floods, steppe and forest fires, health deterioration of the population, degradation of permafrost, etc.

To positive consequences of climate change one may relate an increase of vegetation period creating favorable conditions for the development of plant-breeding, shortening of the heating season (reduction of needs and fuel costs and heating) etc.

The transboundary character is a specific feature of the Baikal region. There were no special joint Russian-Mongolian studies of climate change in the region and its impact on nature and economies of two contiguous countries. However, a cooperation of scientific organization of both countries in the study of aridization processes in the catchment area of the Selenga being one of the parameters of climatic changes showed that the aridization affects the Mongolian part of the Baikal region much more that the Russian territory, and that extremely serious socio-economic problems of Mongolia also have an effect on the expansion of the Gobi desert contributing to the processes of aridization. Due to insufficient information it is difficult to speak about the correlation of climatically induced aridization of steppe terrains and a direct human-induced burden (grazing of domestic animals and other influences).

Of specific importance for the solution of the climatic problem are the two main types of activity. One is the reduction of greenhouse gases' emissions as well as measures to increase the absorption of carbon dioxide by forests and other ground ecosystems and the adaptation to those consequences of climate change that are already taking place or will happen in the nearest future.

In the Russian part of the basin the efforts are made to develop measures to react to climate change. The high priority measures are those to increase energy efficiency and energy conservation, especially in energy production, housing and public utilities sphere, industry and so on. Solar energy is the most reasonable source of renewable energy for the use in Buryatia.

It should be noted that due to the uncertainty of prognostication estimates of the proposed measures against climate change, there is an increase in risk in the process of decision making aimed at the adaptation and reduction of greenhouse gases emissions. In the first place, this will have an impact on investments into these measures. Yet at the same time a delay in decision making will mean a considerable increase of adaptation costs.

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