Federal Service for Hydrometeorology
and Environmental Monitoring
(Roshydromet)

STRATEGIC PREDICTION

FOR THE PERIOD OF UP TO 2010-2015 OF CLIMATE CHANGE EXPECTED IN RUSSIA AND ITS IMPACT ON SECTORS OF THE RUSSIAN NATIONAL ECONOMY

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MOSCOW • 2005

УДК 551.58:330.15(470+570)(042.3)

The prediction of climate conditions most likely expected by 2010-2015 in the Russian Federation and its regions is presented on the basis of the long-term instrumental observations of climate on the territory of Russia as well as the results from national and international studies of climate change in the near future.

The expected changes in the basic meteorological parameters appearing in the Strategic Prediction (surface air temperature and precipitation) as well as all other numerical values of hydrometeorological characteristics are given in comparison to similar characteristics of the real climate conditions experienced in Russia in 2000.

Both negative and positive impacts of climate change on some economy sectors such as power and energy (hydropower industry in the first place), agricultural industry, water resources management and water consumption, river and maritime shipping, construction and utilities are assessed. Special emphasis is made on the prediction of abrupt adverse weather changes and hazardous hydrometeorological events.

The recommendations on the priority adaptation measures aimed at preventing (reducing) losses from negative and increasing benefits from positive climate change impacts are formulated.

The Strategic Prediction can be used by governmental authorities and other organizations in policy-making as well as in planning of specific measures to develop economy sectors and draw out sustainable development programs for the territories and regions.

The Strategic Prediction has been prepared by the initiative and under the general editorship of the Head of Roshydromet Dr. A.I. Bedritsky. The basis of the Strategic Prediction is the results from the relevant research conducted in the period from 1993 to 2005 by the following Research Institutions (RI) of Roshydromet:

Institute for Global Climate and Ecology of Roshydromet and Russian Academy of Sciences (IGCE),

Voeikov Main Geophysical Observatory (MGO),

All-Russia Research Institute of Hydrometeorological Information – World Data Centre (RIHMI-WDC)
All-Russia Research Institute of Agricultural Meteorology (RIAM)

State Hydrological Institute (SHI)

Arctic and Antarctic Research Institute (AARI)

Hydrometeorological Centre of the Russian Federation (RF HMC)

Central Aerological Observatory (CAO)

Scientific and Production Association "Typhoon" (SPA "Typhoon)

State Oceanographic Institute (SOI)

Siberian Regional Research Hydrometeorological Institute (SibRRHI)

Far East Regional Research Hydrometeorological Institute (FERRHI)

Hydrochemical Institute (GHI)

Research Centre for Space Meteorology "Planeta" (RC "Planeta)

In preparing the Strategic Prediction the results published from the relevant national and international studies and materials from International Organizations have been used.

Collection, summarizing and analysis of information by subject areas was made as follows:

Hazardous hydrometeorological events	– RIHMI-WDC
Power and energy, housing and utilities	– MGO
Agricultural industry	– RIAM
Water resources management and water consumption, river shipping	– SHI
Northern Sea Route shipping, works on shelf, economics of northern territories	– AARI
Caspian Sea level fluctuations	– RF HMC

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FOREWORD

Studies performed by scientists from different countries on the basis of climate models allow the long-range (up to the end of XXI century) climate change predictions to be prepared. In preparing such predictions various scenarios of natural and anthropogenic impacts on the climate system are considered and changes in the climate system (as an expected response to the impacts) are assessed. Recognizing the importance of the above studies it should be noted however that the question of priority measures to response to the climate change experienced today and expected in the nearest future still remains undetermined.

The studies carried out by Roshydromet show that currently climate conditions on the territory of Russia are changing significantly and the tendencies of these changes will remain unchanged in the nearest 5-10 years. Such conclusions are supported by the findings of other Russian agencies, the Russian Academy of Sciences in particular, and by most of the foreign scientists.

The climate change being experienced on the territory of the Russian Federation is described by the considerable temperature rise in the cold seasons, growth of evaporating capacity with unchanged or even decreasing amount of precipitation in the warm period, increase in drought frequency, change in the annual river runoff and its seasonal redistribution, change in ice coverage in the Arctic ocean basin and mouths of northern rivers. The above tendencies as well as many other features of the changing climate in various parts of Russia have a considerable impact on living conditions and socio-economic activities.

Impacts of rapid climate change are manifested in the increase of hazardous event (floods and flooding, snow avalanches and mudflows, hurricanes and squalls and other events) frequency and abrupt adverse weather changes which cause huge socio-economic losses and have a direct impact on critically vital economy sectors such as power and energy (hydropower industry in the first place), agricultural industry, water resources management and water consumption, river and maritime shipping, housing and utilities.

Reports of the Intergovernmental Panel on Climate Change (IPCC) highlighted many times the need for the detailed analysis of the current and expected regional climate change. For Russia the detailed assessments of the current and expected regional climate change is of particular importance, since due to the nature-related differences in climate on the territory of Russia, manifestations of climate change in the regions vary over a wide range.

Working out measures for sustainable development of the regions it is necessary to take into account the regional features of climate change in combination with the structure of economy and lines of economic and social development in the regions (constituents of the Russian Federation). The expected climate change can have both negative and positive impact on each sector of economy and social sphere of specific regions. The fact that the current climate change trends will remain unchanged or even grow in the nearest future (at least within the next 5-10 years) should be today taken into consideration in the economic activities of weather-sensitive sectors and development of social infrastructure.

In the proposed Strategic Prediction climate change trends in various regions of the Russian Federation are considered and recommendations on the priority response measures to be taken in economic and social spheres on the regional level are put forward. The Strategic Prediction does not pretend to provide a fully comprehensive presentation of the problem. It contains only demonstrable results for those economy sectors, where, firstly, the impact of climate change on the regional level is most critical and, secondly, the conclusions on the change itself are reasonably well-founded. For other sectors, where data sufficient to make reliable conclusions are not available or adequate investigations and analyses were not carried out, recommendations are not given.

SECTION I.

PREDICTION OF CLIMATE CHANGE FOR THE PERIOD OF UP TO 2010-2015

In Russia the current climate monitoring data show that in recent years the tendency towards warming has grown significantly. For example, data collected by the Roshydromet surface network of hydrometeorological observations point to the fact that in the period of 1990-2000 the mean annual surface air temperature increased by 0.4^{o}C, whereas in the previous hundred years the increase was only 1.0^{o}C. Warming was more evident in winter and spring. In autumn there was hardly any warming (in recent 30 years even some cooling was noted in western regions). Warming was more intensive east of Urals.

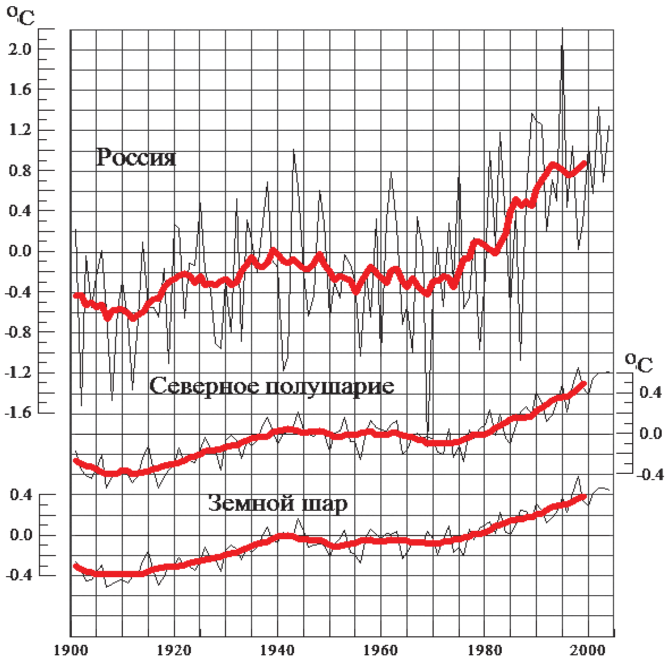

Fig.1. Time series of spatially averaged anomalies of the mean annual surface air temperature for the territory of Russia, Northern Hemisphere and the Globe, 1901-2004. Red lines – values of smoothed series (in accordance with the computations made by the Institute for Global Climate and Ecology of Roshydromet and Russian Academy of Sciences)

The method of assessing climate change in the beginning of XXI century used in the prediction under consideration implies that the climate change tendencies observed in recent decades are extrapolated to the future. In the time interval of 5-10 years (i.e. up to 2005-2010) it is entirely acceptable, the more so, as in the previous period of the same length the observed and computed (on the basis of models) air temperature changes are in good agreement.

Computations made with the ensemble of hydro-dynamical climate models under various scenarios of the global economy development (various amounts of emissions of greenhouse gases to the atmosphere) and computations for the next 10-15 years based on statistical models yield very similar results (significant disagreement begins from about 2030) consistent with the assessments of the Intergovernmental Panel on Climate Change (IPCC).

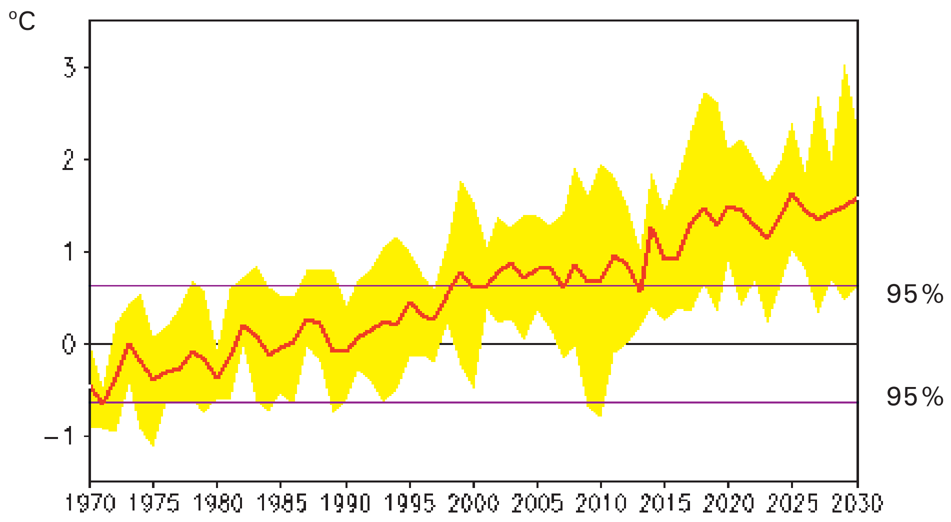

Fig.2. Surface air temperature rise in Russia computed with the ensemble of models for the period of up to 2030 relative to the reference values of 1971-2000 (based on the computations made by the Voeikov Main Geophysical Observatory). Dispersion of model assessments (assessments of different models included into the ensemble) is described by the yellow region comprising 75% of average model values. A 95%-significance level of temperature changes averaged over the ensemble of models is specified by two horizontal lines.

The climate change prediction based on extrapolation shows that the current trend towards warming on the territory of Russia by 2010-2015 will remain unchanged and lead to the rise of the mean annual surface air temperature by 0,6°C ± 0,2 compared with 2000. Other features of the prediction based on the combined use of extrapolation and climate modeling, show that on the territory of Russia changes in hydrometeorological conditions (temperature, precipitation, hydrological conditions of rivers and reservoirs, hydrometeorological conditions of seas and river mouths) will vary over different climate zones and different seasons.

By 2015 on most of the territory of Russia air temperature in winter is expected to further rise by about 1°C with some variations over different regions of the country. In summer in general the expected warming will be not as pronounced as in winter. Temperature will rise by 0,4°C.

The mean annual amount of precipitation is expected to further increase, mainly due to the increase in the cold period. On most of the territory of the country the predicted amount of precipitation will exceed that received at present by 4-6%. The most significant precipitation increase is expected in the north of Eastern Siberia (by up to 7-9%).

As for mass of snow accumulated by the end of winter the changes expected in 5-10 years have trends opposite in sign in different regions of Russia. On most of European Russia (except for Komi Republic, Archangelsk Region and the Ural area) and in the south of Western Siberia mass of snow is supposed to decrease gradually compared with the long-term mean values. By 2015 a 10-15%-decrease is expected and it will continue to decreases in the future. On the rest of the territory of Russia (Western and Eastern Siberia, Far East) snow accumulations are expected to increase by 2-4%.

Due to the expected changes in temperature and precipitation the annual river runoff will change most significantly in the Central and Volga Federal Districts and in the southwestern part of the Northeastern Federal District. Winter runoff here will grow by 60-90%, and summer runoff – by 20-50% as compared with that recorded today. In other Federal Districts the expected river runoff increase will vary from 5 to 40%. At the same time in the Black Earth area and in the south of the Siberia Federal District river runoff in spring will decrease by 10-20%.

The analysis of the climate change on the territory of the Russian Federation both observed in recent decades and expected in the years to come points to the fact that the variability of climate characteristics is increasing and this in turn increases the probability of extreme events, hazardous hydrometeorological events among them.

According to the estimates of the World Meteorological Organization, other international agencies, World Bank and some other organizations there is a stable trend towards the increase of loss of property and vulnerability of community due to the growing impacts of hazardous natural events. The most significant losses are caused by hazardous hydrometeorological events (more than 50% of the total losses caused by natural hazardous events). According to the estimates of the World Bank the annual losses suffered by Russia due to hazardous hydrometeorological events (HEs) amount to 30-60 billion roubles.

From statistical data on HEs that caused social and economic losses in 1991-2005 it is clear that on the territory of Russia a hazardous hydrometeorological event is reported almost every day during a year. 2004 and 2005 provided a convincing demonstration of this fact with 311 and 361 HEs respectively. A number of HEs grows by 6.3% annually. This tendency will persist in the future.

Most frequently various HEs are experienced in the Northern Caucasia and Volga-Vyatka economic areas, Sahkalin, Kemerovo, Ulyanovsk, Penza, Ivanovo, Lipetsk, Belgorod, Kaliningrad Regions and Republic of Tatarstan.

More than 70% of HEs that caused social and economic damage fall on the warm period (April-October). In this period the tendency towards the growth of HEs is most pronounced. A number of HEs in the warm period grows at the rate of 9 events per year. The tendency is expected to be unchanged in the future up to 2015.

More than 36% of the total number of HEs is accounted for by the group of four events: strong wind, hurricane, squall and spout. By the estimates of the Munich Re Insurance Group for instance in 2002 39% of the total number of great natural catastrophes falls on these four events. Such estimates are in good agreement with the statistics for Russia. Strong wind, hurricane, squall and spout are among the most hard-to-predict hazardous events and therefore they are not detected most often.

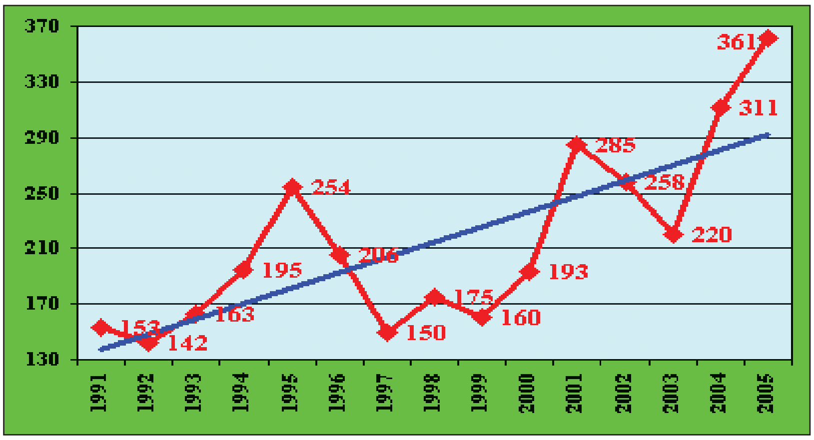

Fig.3. Total number of HEs in 1991-2005 (based on the information provided by RIHMI-WDC)

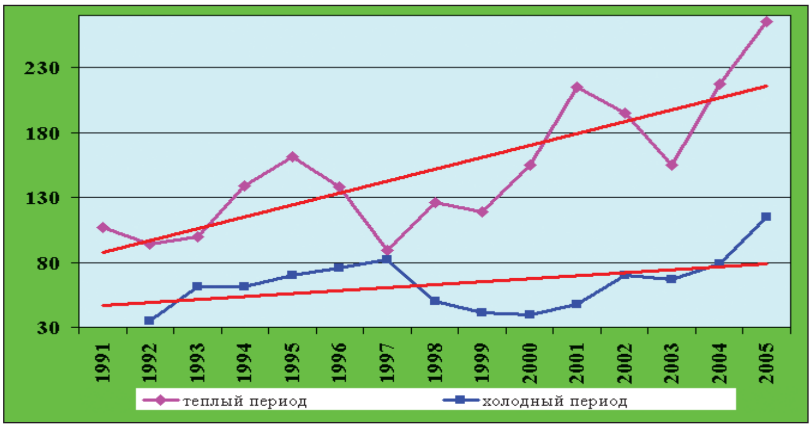

Fig.4. Total number of HEs (by periods) in 1991-2005 (November and December of the previous year and January, February and March of the current year are considered as the cold period) (based on the information provided by RIHMI-WDC)

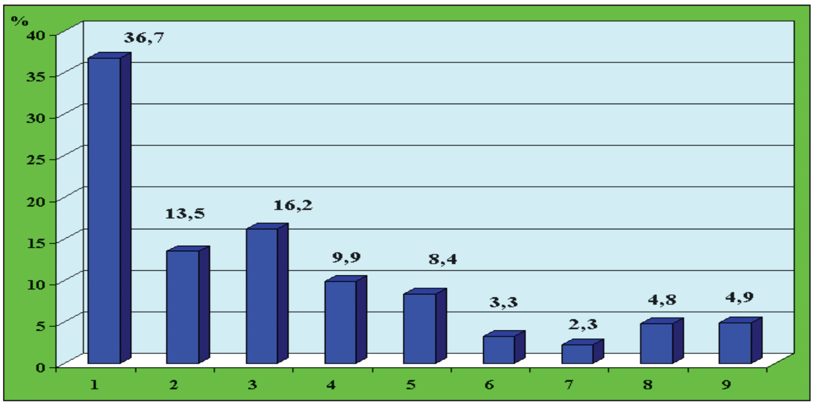

Fig.5 HEs (by types of events) in 1991-2005 (based on the information provided by RIHMI-WDC)

1 – strong wind, hurricane, squall, spout; 2 – blizzard, heavy snowfall, glaze; 3 – heavy rain, lasting rain, shower, heavy hail, thunderstorm; 4 – frost, cold spells, thaw, heatwave; 5 – spring flood, rain flood flow, flood; 6 – avalanche, mudflow; 7 – drought; 8 – emergency fire hazard; 9 – heavy fog, dust storms, sharp changes of weather, heave of sea, high waves and other.

The analysis of the HE prediction in the Russian Federation shows that in recent five years more than 87% of undetected HEs fall on hard-to-predict convective events (strong winds, showers, hail etc.) occurring on comparatively small territories.

Note. Some of convective events occurred in recent years, by their intensity and duration can be classified as rare or even very rare. For instance, the Kirov Region on July 17 experienced hail in the form of ice discs 70-220 mm in size resulted in the damage of crops on the territory of 1000 ha.

On the territory of Russia the most hard-to-predict areas (with the greatest number of undetected HEs out of the total number of HEs of all types) are Northern Caucasia, Eastern Siberia and the Volga region.

Despite some difficulties, in recent 5 years there was a positive tendency towards the rise of the HE warning verification scores. Joint investigations of Roshydromet and the World Bank demonstrated that by 2012 because of technical modernization of the Hydrometeorological Service the HE warning verification scores will rise up to 90%.

For the territory of Russia one of the most important problems resulted from the climate change impacts is related to floods. In terms of the total mean annual economic damage river floods rank first (direct flood-related economic losses account for 50% of the total losses from all types of HEs).

For many cities and settlements of Russia a typical frequency of partial inundation is once per 8-12 years. Such cities as Barnaul, Biisk (the submountain region of Altai), Orsk, Ufa (the submountain region of Ural) are affected by partial inundation once in 2-3 years. In recent years the particularly hazardous floods with large areas and long time of duration were reported. For example, in 2001 the country had to suffer the considerable damage from floods on Lena and Angara, and in 2002 from those on Kuban and Terek.

Due to the expected increase of water storage in snow cover by 2015 the intensity of spring floods may grow on rivers of Archangelsk Region, Komi Republic, the Ural area and in the basins of Enisei and Lena. In the areas prone to disastrous and hazardous spring floods, where maximum discharges are compounded by ice jams (central and northern parts of European Russia, Eastern Siberia, northeastern parts of Asian Russia and Kamchatka), the maximum duration of the flood plain inundation can increase up to 24 days (now it is 12 days). At that maximum discharges can exceed the long-term means twofold. By 2015 the frequency of ice jam-induced floods on Lena can increase also twofold.

The areas with high spring and spring-summer floods (the submountain areas of Ural and Altai, rivers in the southern part of Western Siberia) in some years can experience a flood with the maximum discharge exceeding the long-term mean fivefold.

On densely populated territories of Northern Caucasia, in the basin of Don and its interstream area with Volga (Krasnodar and Stavropol Territories, Rostov, Astrakhan and Volgograd Regions), where now a flood plain is intensively flooded once in 5 years and a flood exceeding the long-term mean annual water discharges sevenfold occurs once in 100 years, in the period of up to 2015 the frequency of disastrous spring and spring-summer floods accompanied by the large-scale damage is expected to increase.

The frequency of floods caused by heavy rains is expected to increase two-threefold in the Far East and the Maritime area (Maritime and Khabarovsk Territories, Amur and Sakhalin Regions, Jewish Autonomous Region). In the mountain and submountain regions of Northern Caucasia (Republics of North Caucasia, Stavropol Region), Western and Eastern Sayan Mountains the flood, mudflow and landslide hazards are supposed to grow.

Due to the current and expected climate change in Saint Petersburg the probability of disastrous floods with the water level rise of more than 3 m will increase in the next 5-10 years (such floods occurred once in 100 years, the last one was experienced in 1924). With this in view it is necessary to finish and put into operation the flood protection system as soon as possible.

On the Lower Terek (Republic of Dagestan) the disastrous flood hazard is also expected to grow (such floods occur here once in 10-12 years). The situation is aggravated by the fact that in this area the river bed is located higher than surrounding territories and the river bed evolution is very active. Dams here should be strengthened significantly to eliminate the dam failure and damage to settlements and agriculture.

To reduce damage from floods and to protect people the priority efforts of the Government of the Russian Federation and local authorities should be focused on the following: building of advanced forecasting, warning and flood protection systems (on rivers of Northern Caucasia and Maritime area first of all); regulation of land use in the zones of risk; establishment of the up-to-date flood insurance systems similar to those available in all developed countries; improvement of the regulatory legal basis, where the areas of flood-related responsibilities is clearly determined.

A number of hazardous events will occur due to the changes in permafrost expected by 2015. In Irkutsk Region, Khabarovsk Territory and the northern part of European Russia (Komi Republic, Archangelsk Region) on the territory several dozens kilometers wide, as well as on the 100-150 km wide territory in Khanty-Mansi Autonomous Area melting of the permafrost islands will begin and persist for several decades. Various adverse and hazardous processes will increase such as landslides, slow downslope flow of melting ground (solifluction), significant hummocky topography in frozen ground caused by melting of ice (thermokarst). Such processes will affect the economy of the regions (especially buildings and engineering and transport facilities) and living conditions.

By 2015 a number of fire-hazard days will increase by 5 days in a season on most of the territory. Moreover a number of both high-intensity and mid-intensity fire-hazard days will grow. Most of all the duration of fire-hazard situation (more than 7 days in a season) will increase in the south of Khanty-Mansi Autonomous Area, in Kurgan, Omsk, Novosibirsk, Kemerovo and Tomsk Regions, Krasnoyarsk and Altai Territories, Sakha-Yakutia Republic.

SECTION 2.

IMPACTS OF EXPECTED CLIMATE CHANGE ON ECONOMY SECTORS

2.1. POWER AND ENERGY, HOUSING AND UTILITIES, PUBLIC HEALTH

The climate change expected by 2015 will have both adverse and favorable impacts on various components of power and energy, housing and utilities and public health in the Russian Federation.

2.1.1. Fuel and energy resources

Positive impacts of the climate change expected by 2015 imply that it will primarily allow for reducing the heating season and saving fuel and energy resources.

By 2015 in Russia the heating season will be 3-4 days shorter on the average and this can bring a substantial saving in resources. Most of all it is expected to shorten (up to 5 days) in the southern parts of Maritime Territory, Sakhalin and Kamchatka. It will virtually be the same in Taimyr Autonomous Area.

Climate warming will improve heating of buildings with the fuel consumption being unchanged. Heat resistance of walls of buildings in the cities of European Russia and in the coastal areas of Maritime Territory, dependent on the coldest day and the coldest five-day period temperatures, will increase by 20% making it possible to maintain the desired indoor temperature with the lower consumption of fuel.

Despite the shortening on the average of a heating period, when making strategic decisions climate natural variability should be taken into account due to which in some years of the period of up to 2010-2015 in some constituents of the Russian Federation a real heating period can exceed its average duration set for the regions today. Here the tendency towards the growth of climate variability can have an effect manifesting itself in the deviation of real heating demands from the average duration of a heating period.

2.1.2. Wind Loads and Wind-Driven Power Potential

In most of the regions of European Russia, in Tomsk, Novosibirsk and Kemerovo Regions, in Altai Territory and western regions of Maritime and Khabarovsk Territories positive impacts of the expected climate change will lead to the decrease of wind loads on electric power lines and high-rise buildings (as compared to current loads). At that, for instance, on the territory of Asian Russia by 2015 the frequency of accident-causing "beyond the design basis" loads on buildings and structures (energy, industrial, public utility and transport), which is specified by the Science and Technology Centre for Anti-Seismic Construction and Engineering Structures Against Natural Disasters of the Federal Agency for Construction and Housing and Public Utilities, will decrease 1.1 times. A number of days with the critical wind speed at low air temperature, when extra payment for work or suspension of work is required, will be reduced. This will save resources on construction, repair and handling operations.

At the same time in the above regions there is a current trend for the decrease in the wind-driven power potential, which by 2015 is expected to decrease almost by a factor of 2. This will impose severe restrictions on operation and further development of wind-driven generators in these regions.

In some regions, where wind loads are expected to increase 1.2 times by 2010-2015(Northern Caucasia (Chechen Republic, Republic of Dagestan, Stavropol Territory), Murmansk, Archangelsk, and Leningrad Regions, coastal zones of Khanty-Mansi and Evenki Autonomous Areas), a number of electric power accidents can grow. This will make outdoor building and construction works more expensive. At the same time in these regions some conditions to develop the wind-driven power potential are created, where economically and technologically feasible.

2.1.3. Hydropower Industry

Changes in the seasonal river runoff resulted from the current and expected climate change should be taken into account in the hydropower industry.

The projected changes in river runoff will influence the inflow of water to large reservoirs. It is expected that the mean annual inflow of water to reservoirs will increase as follows: Volga-Kama chain of reservoirs – 10-20%; reservoirs of the Northwestern Federal District – 10%; Angara-Enisei reservoirs – 0-15%; Vilui-Kolyma-Zeya reservoirs – 0-15%. At the same time the mean annual inflow of water to Tsimlyanskiy, Krasnodar and Novosibirsk reservoirs is expected to decrease in the range of 5-15%.

Negative impacts of climate change on the situation near reservoirs include: probable flooding and rising water tables affecting settlements; increasing of downstream polynya accompanied by deterioration of climate conditions on the shores (growth of air humidity and fog frequency, visibility reduction etc.); increased formation of slush ice; probable ice jams downstream from polynya, cracks and leads on ice of reservoirs.

The expected changes in inflow of water to reservoirs will make it necessary to review the mode of reservoir control in the interests of main users, primarily hydropower industry and protection of the environment.

2.1.4. Pipeline transport

At present about 50 000-km oil pipelines and about 150 000-km gas pipelines have been laid in the country which cross many hundreds and thousands of rivers. Most of these pipelines were constructed before the 1980s and their projected lifetime intended for steady climate is close to expiration. The most disturbing sections of submerged crossings are located in the Upper- and Mid-Volga and its tributaries in the Nizhni Novgorod, Orenburg, Perm, Samara, Saratov, and Ulyanovsk regions, as well as in republics of Bashkortostan, Mari El, Mordovia, Tatarstan, Udmurtia and Chuvashia. These problems are also characteristic of the rivers in all constituent entities of the Russian Federation in the Southern Federal District, as well as in the Tyumen Region, the Krasnoyarsk Territory, the Novosibirsk, Omsk, Tomsk and Irkutsk regions, in the Khabarovsk Territory, and on Sakhalin.

The increased annual and seasonal runoffs of many Russian rivers and the change in their ice conditions predicted by 2015 will raise significantly the load on submerged pipelines. In the period to 2015, the probability of faulted damages of pipelines (down to their ruptures) will become higher. These will be accompanied by oil spills and gas shows that may cause severe ecological disasters.

To prevent possible damages, it is necessary to:

• reduce the projected service life of submerged crossings constructed before 1980-1990;

• run monitoring of the pipeline state to avoid emergency situations;

• apply present-day technology, i.e. controlled directional drilling, in replacing and laying new pipelines across rivers;

• carry out an obligatory expertise of the projects of new crossings (of both long-distance and flow pipelines) by skilled hydrologists.

2.1.5. Safety and maintenance of buildings and structures

In the autumn-winter and winter-spring periods, some of the regions (in European Russia, the Maritime Territory, etc.) face degraded operational conditions of buildings and reduction in their lifetime due to higher frequency in thaws and frosts. By 2015, this tendency can halve the period of repair-free operation of buildings.

The increased depth of seasonal thawing in the permafrost regions will reduce the bearing power of permafrost soil, which can pose threats for the structures in the region. Structures in the following regions will be exposed to the severest danger: Chukotka, upstream sections of the Indigirka and the Kolyma, southeastern Yakutia, much of the West Siberian Plain, coast of the Kara Sea, Novaya Zemlya, and the Far North of European Russia. These regions have a well-developed infrastructure, particularly, gas and oil producing complexes, Nadym-Pur-Taz pipeline system in the northwest of Siberia, and Bilibin Nuclear Power Plant and the related power lines extending from Chersky to Pevek. A particular threat is represented by diminishing permafrost in Novaya Zemlya, in the vicinity of radioactive waste storages, as well as in the Yamal peninsula, in the potential oil production region. In elevated-risk areas, it is necessary to carry out the monitoring of the state of understructures of buildings and support blocks of line structures (pipelines, bridges) so as to timely detect their deformation and to take measures for underpinning.

A sharp winter increase (to 60-90%) and summer increase (to 20-50%) in river runoff in the Central, Volga and the southwest of Northwestern Federal districts, as well as a significant increase in winter and summer runoff in other regions of Russia (5 to 40%), which is predicted to occur by 2015, along with a decreased depth and reduced period of straight soil freezing, will contribute to the groundwater level rise. For the flat areas of Russia, that are characterized by overmoistening, small groundwater depth and low drainage capacity, this can cause the impoundment of the vast areas, as well as the deformation and weakening of understructures of different buildings and structures.

Valuable historical centres, monuments and architectural complexes over the territory of the Russian north, including the Arkhangelsk, Vologda and Leningrad regions, as well as individual structures around the Golden Ring of Russia in the Kostroma and Nizhni Novgorod regions and in the other regions of the Northwestern and Central Federal districts may be particularly affected. The above processes are already occurring, and owing to climate change, these are expected to be intensified in the near future.

In the above-mentioned constituent entities of the Russian Federation, it is urgent to organize a comprehensive inspection of the most valuable historical monuments, buildings and structures, and to take measures for their protection, including actions for water management in the submerged territories.

2.1.6. Environmental comfort and public health

By 2015, zones of environmental discomfort* are expected to have shifted northwards. Specifically, a southern boundary of the extremely discomfortable zone, close to the border of the Far North, is expected to shift by about 60 km in northwestern Russia (Komi Republic, Arkhangelsk Region), by 150 km in the Khanty-Mansi and Evenki Autonomous areas, and by 250 km in the Republic of Sakha-Yakutia and in the north of the Irkutsk Region and the Khabarovsk Territory. Environmental discomfort of people living near the southern boundary of the Far North region will diminish.

In summer seasons up to 2015, nearly the whole of the Russian territory is expected to see the increased number of days with high air temperatures. Extremely long periods of critical air temperatures, the so-called "heat waves", will be most likely (by 2015, the annual maximum duration of these periods will increase by 1.1 to 1.5 times). This will have an adverse effect on the operation of heat absorption systems at power plants and raise the cost of full air-conditioning in buildings. Again, the increase in extremely long periods of critical air temperatures, particularly in large cities, can affect adversely the public health.

Taking the appropriate timely measures by city and public health authorities can decrease an adverse effect of high air temperatures on

Note: *Discomfort zones are identified from analyzing a combination of climatic indices. The Far North region includes administrative territories in the Russian Federation whose population is paid special wage and granted privileges.

public health, which is particularly important to children and old people. These measures are as follows:

- responding to warnings of the approaching "heat waves";
- developing recommendations for the people exposed to critical air temperatures;
- providing better preparedness of medical staff;
- making architecture- and construction-related decisions;
- making contacts with mass media, etc.

2. 2. AGRICULTURAL INDUSTRY

Climate change is expected to have both positive and negative effects on agriculture in the Russian Federation. Positive effects are primarily connected with the expected climate warming. Negative effects are exhibited by higher probabilities of the warming-related droughts and extreme hydrometeorological events that can prove to be harmful to farming.

Nowadays one of the most important effects of climate warming is a significant decrease in frequency of winters with minimum soil temperatures hazardous to winter crops. In the Central Black-Earth and Volga regions, the frequency of these winters has been reduced from 18-22% to 8-10% and in the Northern Caucasia, from 10% to 4% (as compared with climatic conditions recorded in these regions in the period to 1990). There are favourable conditions to extend winter crop acres in the Northern Caucasia, steppe regions of the Volga area, the Southern Urals, and individual regions of Western Siberia.

Climate-related crop productivity has changed. For example, the calculated climate-related corn yield in the Stavropol Territory has increased by 30% for the past 20 years. The improved corn growing conditions are recorded in many regions of European Russia against a significant increase in winter air temperatures (to 2^{0}C for the past ten years) and a slight rise in summer air temperatures in the south of the region.

At the same time, the ongoing climate warming in some regions of Asian Russia is not always accompanied by productivity increase. For example, under summer warming (to 0.5^{0}C for the past ten years), the Baikal and Trans-Baikal regions show a tendency to corn yield decrease.

The growing season (a period of air temperatures above +5^{0}C) has become longer for the past 30 years of the 20th century over most of European Russia (except the area of the Southern Federal District), as well as over the Urals and Siberian Federal districts (except the northern regions: the Yamal and Taimyr peninsulas and the adjacent territories). The increase in growing season duration is, on the average, five to ten days. However, against the longer growing season, no increase in the duration of frost-free periods was recorded in many of the regions. The reduction in the duration of frost-free periods (on the average, by 5-15 days) is only recorded in the northeast of the Northwestern Federal District, as well as in the Central and Volga Federal districts.

With these tendencies preserved, by 2015 the expected climate changes are to modify significantly agricultural and climate conditions of crop production. Available heat supply will increase everywhere (cumulative active temperatures will rise by 350-400^{0}C). The duration of growing and frost-free periods will increase by 10-20 days, which will improve the conditions of farming operations and reduce production losses during harvesting operations. The boundary of growing of mid-season maize varieties and late-season sunflower varieties will move northwards as far as the latitude Moscow – Vladimir – Yoshkar-Ola – Chelyabinsk.

Due to more favourable temperatures, it is expected that by 2010-2015 the productivity of feed and corn crops will increase by 10-15% in the Northern and Northwestern regions and by up to 10-15% in the Central and Volga-Vyatka regions and in the Far East. The content of organic carbon (humus) in agrogenic soils in the Non-Black Earth Belt of European Russia is expected to increase, which will contribute to the long-term sustainability of arable farming. In these regions, the farming productivity growth can be achieved by extending the areas under thermophilic, and thus, more productive varieties. Specifically, the areas under later-season and more productive varieties of corn, maize, and sunflower and under late-season varieties of potato can be extended. It is also possible to extend the areas under beet and more thermophilic varieties of feed crops (soy, medick, etc.). Areas under second crops (crop remains) can also be extended, which will reinforce the fodder supply of the animal industry. However, favourable effects of climate change on the farming production growth in these regions are only efficient in combination with a more extensive application of fertilizers, chemicals and other means that make crops less vulnerable to blasts and diseases.

Considering the expected climate warming, an extended zone of intensive irrigated farming can be created in the Northern Caucasia and Lower Volga regions to grow the crops that are now cultivated in Uzbekistan and Azerbaijan (cotton growing, grape culture, horticulture, production of citrus fruit crops and tea).

Arid conditions in nearly the whole of the country, that are related to the warming processes, is the most important negative feature of the expected climate change. By 2015, the drought frequency in the major corn-producing regions of Russia may increase by 1.5 to 2.0 times. The expected growth in climate aridity can contribute to yield decrease in the major corn-producing regions of Russia, but is likely not to have a significant adverse effect on agriculture in the sufficiently humid Non-Black Earth Belt of the country. Considering the existing technologies of farming industry, the arid conditions developing in the Northern Caucasia, the Volga and Ural regions, the Central Black Earth Region, as well as in the south of Western Siberia and in the Altai Territory are likely to decrease considerably the yield of corn and feed crops. For example, the yield decrease by up to 22% of the present level for corn crops can occur in nearly all the constituent entities of the Russian Federation in the Northern Caucasia. In the Volga and Ural regions and in the south of Western Siberia, the decrease in corn yield may prove to be as low as 13, 14 and 12% of the present level, respectively. The Central Black Earth Region can experience a 7- to 7.5-percent decrease in feed– and corn-crop yield. At present a contribution of the Northern Caucasia, Volga, Ural, south of Western Siberia, and Central Black Earth regions to the gross corn harvest is about 19.3, 17.6, 15.7, 13.7, and 10.6%, respectively. Thus if no actions are taken to combat the predicted intensification of aridity in the major corn-producing regions, the corn losses may attain about 11% for the whole of the country.

In the zone of higher probability of enhanced aridity (the Northern Caucasia, the Volga, Rostov and Volgograd regions, and steppe regions of the Urals and Western Siberia), actions are to be taken to use larger areas under droughtproof crops, primarily maize, sunflower, panicum, etc., and under droughtproof winter corn crops. The following is necessary to be done in these regions: early implementation of irrigation operations, taking actions aimed at water resources conservation, and introducing water resources conservation technologies.

2.3. WATER RESOURCES MANAGEMENT AND WATER CONSUMPTION

All the estimates of predicted changes in hydrological characteristics, which were primarily obtained for river basins or water bodies, are generalized for regions or constituent entities of the Russian Federation and given in percent or quantitative indices relative to mean values as of the late 20th century. The available water supply of public and the load on water resources are estimated with respect to the current period (2002-2005).

For the whole of the Russian territory, an eight- to ten-percent increase in renewable water resources is to be expected by 2015, with the available water supply per capita increasing by 12-14%. This situation is to be recorded in most of Russia: in the north and northwest of European Russia, the Volga Region, the Non-Black Earth Belt, the Urals Region, and in most of Siberia and the Far East. These are the regions that account for more than 95% of national water resources.

However, a number of high-density areas experience limited water resources which are expected to further decrease to 10-20% in 2015. Among these areas are the centre of the Black Earth Belt (Belgorod, Voronezh, Kursk, Lipetsk, Oryol, and Tambov regions), the Southern Federal District (Kalmykia, Krasnodar and Stavropol territories, Rostov Region), and southwest of the Siberian Federal District (Altai Territory, Kemerovo, Novosibirsk, Omsk and Tomsk regions). This should be taken into account in the further social and economic development of these regions under increasing needs for water supply and a higher load on water resources (5 to 25%).

In the coming five-ten years, the frequency of low-water years in the Belgorod and Kursk regions, in the Stavropol Territory, and Kalmykia will increase, resulting in reduced public water supply (to 1000-1500 m^3 per capita a year and even under), which, according to international classification, is considered very low or extremely low. This can give rise to a severe water deficit that will require a strict regulation and restriction of water consumption, as well as additional water-supply sources involved. In these regions, water deficit becomes a factor that retards the economic and public welfare growth.

In the Voronezh, Lipetsk, Oryol, Tambov and Rostov regions, the annual water supply is expected to be 2000-4000 m^3 per capita, which is considered low. In these regions, primary attention should be given to the problems of water supply and water saving control.

The Altai Territory, as well as the Kemerovo, Novosibirsk, Omsk and Tomsk regions face serious water problems in low-water periods. Although reduced water resources will not result in low water supply and high load on water resources here, the water-related problems can be severe enough in the future. This is primarily connected with a high space-time variability of water resources, as well as with an intensive use of runoffs of transboundary rivers in China and Kazakhstan. To solve these problems, it is necessary to consider the issues of runoff control and international agreements on the joint water resources management of the Irtysh River.

Despite the predicted noticeable increase in water resources, by 2015, the Non-Black Earth Belt of the Central Federal District, primarily the Moscow Region (including the city of Moscow), will face a considerably increased load on water resources and decreased water supply (which have now attained a critical value) due to economic development and the growth of population and public welfare. Currently the annual water supply here is 1000-1500 m^3 per capita and its further decrease can have adverse effects.

Thus the main drawback of the Russian water resources – their extremely nonuniform distribution over the territory, that is inappropriate with their demands, – will be further aggravated. By 2010-2015 onward, water supply problems will become particularly severe in a number of regions (the city of Moscow, the Moscow, Belgorod, Voronezh, Kursk, Lipetsk, Oryol, Tambov and Rostov regions, the Krasnodar and Stavropol territories, and the Republic of Kalmykia), as well as in the Altai Territory and the Kemerovo, Novosibirsk, Omsk, Tomsk, Kurgan and Chelyabinsk regions in low-water years. The solution of these problems will require appropriate actions taken, including the control and restriction of water consumption and the use of additional water supply sources.

2. 4. RIVER SHIPPING

Further increase in annual and low runoffs and a shorter freeze-up period for nearly all the major rivers of Russia, which is predicted to occur by 2010-2015, will contribute to the development of river shipping and stimulate cargo traffic on rivers and bodies of water.

However, in recent years, due to the impact of climate change on river runoff, most of the navigable rivers in Russia experience great changes in bed evolution, which makes shipping difficult. By 2010-2015, this situation will have aggravated.

To ensure continuous navigation, it is necessary to maintain the required depths on bars during low-water periods by river canalization and deep dredging in navigable river portions. According to the Ministry of Transport of the Russian Federation, the scope of work has decreased by a factor of nearly seven, as compared to that in 1991. This has an adverse effect on shipping, particularly in delivering cargo on Siberian rivers under the National Northern Communities Supply Programme.

To solve the problem, it is necessary to increase successively the annual amount of work on deep dredging on the bars of navigable rivers from the present level of 45,000,000 m^3 to no less than 300,000,000 m^3. The second (or additional) way of solving the problem (when river canalization and deep dredging operations are economically inefficient) is to use low-capacity ships or shallow-water vessels.

Due to the ongoing climate warming, a 15- to 27-day reduction in a freeze-up period on the Siberian rivers and in the Kama River basin is to be expected by 2010-2015, with the maximum ice depth diminishing to 20-40%. Significant changes in periods of freeze-up and breakup on rivers and water bodies are also expected. On the one hand, these changes extend substantially the period of river navigation and on the other hand, reduce the period and capabilities of delivering goods to hard-to-reach regions through winter motor roads laid along frozen channels of large rivers. These processes are of great importance for the Siberian and Far East Federal districts, particularly for Yakutia, the Magadan Region and the Chukchi Autonomous Region, where most of freight is delivered through river channels – by ships in summer and by motor vehicles in winter. It is particularly important for the authorities of the above regions to take into account the expected changes of ice conditions in planning cargo traffic operations for hard-to-reach communities.

2.5. NORTHERN SEA ROUTE SHIPPING, SHELF OPERATIONS, AND ECONOMICS OF THE NORTHERN TERRITORIES

The prediction of changes of ice conditions in the Arctic seas for 5-10 years and up to the mid-21st century, which is made from natural 60-year cyclic variations in ice coverage, shows that before 2015, ice conditions in the Arctic seas will form against decreased ice coverage.

Before 2010-2015, a freeze-up period along the Northern Sea Route (NSR), from the Kara Strait eastwards, will last as long as more than six months. This will ensure grounds for full sovereignty of Russia over NSR, which agrees with article 234 of the UN Convention on the Law of the Sea. Therefore, in the period to 2010-2015, all the existing grounds for applying the Rules of NSR Navigation, i.e. for preserving special NSR navigation conditions, are valid.

With ice and hydrometeorological conditions existing to at least 2010-2015, there is a probability of complicated and extremely complicated ice conditions (10- to 20-percent frequency) in the straits of Vilkitsky, Shokalsky, Dmitriy Laptev, Sannikov, and Long, which restrict the NSR navigation without icebreakers involved. Under severe ice conditions, the period of point-to-point NSR navigation without icebreaker assistance is reduced to 10-15 days a year (compared with the ordinary two-month period) or point-to-point navigation without icebreaker assistance is quite impossible. The following wind- and wave-derived hazardous phenomena will be aggravated: frequency of ice storms (storms in the cold season over the water areas of open pack ice); intensity of spray freezing; and intensity of wearing away of coasts composed of loose permafrost rocks.

Considering this, as well as the growing demand for icebreaker assistance of petroleum transshipment in freezing seas (the Baltic Sea, the White Sea, and the Sea of Okhotsk), which will be even higher with the Arctic shelf field development, subsurface users and transport companies are to build new icebreakers and ice-reinforced ships and to develop regional and local systems of hydrometeorological support of marine operations so as to ensure safety navigation.

The probability of iceberg occurrence in the vicinity of northern offshore fields, including the Stockman field, is expected to further increase. This tendency was recorded in the late 20th – the early 21st centuries. The risk remains of penetrating the Arctic pack ice into the southern areas of the sea.

Subsurface users are to create special services for iceberg and ice risk control, including protection against icebergs and ice monitoring. It is necessary to revise the previous estimates of the extreme wave heights that are included in design choices of drilling platforms for oil-gas fields, such as Stockman, Prirazlomnyi, etc.

In designing offshore structures according to the current construction standards and codes, it is necessary to stand to requirements for hydrometeorological engineering survey and to take into account changes of hydrometeorological factors in 1980-2005 and their trends for the coming 5-10 years.

The major economic sectors of the Russian Arctic include oil and gas industry, mineral resource industry, and transport. Much of the territory is covered by tundra and forest tundra. Therefore, agriculture is represented by deer breeding and fishery. Forest industry is developed in individual regions of taiga in the south of the Russian Arctic. The economy of the Russian Arctic is exposed to direct and indirect impacts of climate warming for the past 25 years.

Climate change also affects the infrastructure of human settlements and the public health in the northern territories. In this connection it is essential to develop new procedures of risk assessment and management strategies under current climatic changes that affect both the industrial and social infrastructures and the public health. Particular attention is to be given to reliable heat insulation and water proofing of foundations of residential buildings and industrial facilities under increased depth of seasonal permafrost thawing.

In the period 2010-2015, no significant climate-related changes are expected in deer breeding, fishery and its structure, and forest industry in the Far North. Changes in these industries are caused by factors other than climatic.

Climate change is recorded to be responsible for morbidity rate of the population in the northern territories, since this change contributes to more frequent meteopathic reactions of even healthy people. Abrupt variations in major meteorological characteristics (air temperature, air humidity, air pressure, precipitation, wind speed, solar radiation) are most dangerous to human. The frequency of these characteristics has increased under current climate warming. Alarm reactions and continental climate with sudden temperature and air pressure swings are the main causes of cardiovascular diseases in the Far North. Again, enhanced UV radiation doses due to ozone layer depletion may contribute to the cataract incidence rate and increase the risk of skin cancer. It is essential to develop the public health monitoring system in the Far North under conditions of climate change and to develop methods of adaptation to these conditions. A well-developed infrastructure of life support and rehabilitation of people who work under extreme conditions should be created.

2.6. CASPIAN SEA LEVEL FLUCTUATIONS

The extreme fall and rise in the Caspian Sea level have an adverse effect on different economic sectors in the region making it necessary to invest heavily to preventive actions in the coastal regions of the Sea.

Abrupt sea-level falls and rises are particularly adverse in the northern shallow part of the Sea, especially in river deltas of the Volga, Terek and Sulak, where valuable households, fishery regions and large industrial centres are concentrated.

The level regime of the Caspian Sea is strongly dependent on its affluents, atmospheric precipitation and evaporation whose state and conditions undergo changes under current climate change.

In the coming 10-12 years, the Caspian Sea level will vary within the range of actual elevations between -27.08 and -27.58 m (from 92 to 42 cm in reference marks) and show a downward trend (at an average rate of about 4 cm/yr). By 2016, the sea level may exhibit an average of the 50-cm decrease, having attained the actual elevation of -27.5 m.

Despite the fact that no abnormal sea-level changes are expected in the coming years, the risks of flooding and impoundment of the sea coast, particularly in the case of wind surge, are real. The flooding and impoundment of the territories can aggravate considerably ecological, sanitary-and-epidemiological and medicobiological conditions in the coastal Caspian zone, i.e. this will raise a probability of accidental toxic and oil pollution of surface and ground waters, accelerate soil salinization and flora hydromorphization, make drinking water supply conditions worse, etc. These processes can show up to the greatest extent in the Astrakhan Region and in the republics of Kalmykia and Dagestan.

The zone exposed to long-period sea-level variations comprises the town of Kaspiisky (Republic of Kalmykia), the Astrakhan conservation area in the coastal part of the Volga delta (the Astrakhan Region), the towns of Makhachkala, Caspiisk and Derbent, and Sulak settlement (Republic of Dagestan), as well as the following infrastructure facilities: sewer and water-supply systems, railway Kizlyar-Astrakhan, irrigation systems, fishery facilities, several tens of communication and power engineering facilities, oil fields and other structures.

The sea-level change may have an adverse effect on conservation of potential natural resources, primarily land, fishing and recreation resources, oil and gas resources, as well as on life support and conservation of available housing and social infrastructure.

The most important thing to be done in the nearest future is to create the management system capable of reacting adequately to the Caspian Sea level changes. This system is to ensure protection of individual human settlements and the most important portions of the coastal zone and be able to remove production facilities from risk regions in short time and without high economic losses.

Considering that any significant change of the Caspian Sea level variations affects the interests of all Caspian states, it seems quite good to provide international regulation of any projects whose implementation can affect the water balance and morphometry of the Caspian Sea.

CONCLUSION

According to the Strategic Prediction of Roshydromet, manifestation and impacts of climate change on different economic sectors and human life conditions are of pronounced regional character. This is to be taken into account in developing and implementing medium- and long-term programmes of the social and economic development of Russia, its regions and constituent entities.

It is of primary importance to:

• further improve the estimates of climate change effects as applied to each of the constituent entities of the Russian Federation;

• identify economic sectors most greatly exposed to abrupt unfavourable weather and climate changes;

• improve the National Early Warning System for Hazardous Hydrometeorological Events (HE); and

• predict the HE evolution.

With the increasing number and intensity of HE, one of the most important activities aimed at protecting human, society and state against hazardous extreme weather and climate events is to ensure a higher level of hydrometeorological safety which is important for the sustainable economic development.

The effectiveness of the hydrometeorological safety strategy is to solve the problems of economic loss minimization. The efforts to implement the strategy are to be primarily aimed at performing and improving information service activity related to early detection, prediction and warning the society and decision makers of hazardous hydrometeorological events. Of primary importance here is technological upgrading of the national environmental monitoring system (including modern HE detecting systems, such as radars, satellite observation systems, etc.).

Adaptation measures taken in due time are to make the economy and production more resistant to the ongoing climate change and its negative impacts and to avoid, or at least reduce, wherever possible, the losses caused by HE and adverse effects of climate variability, as well as to improve production efficiency by taking into account favourable climate changes.

The conclusions and recommendations of this Prediction taken into account in carrying out national actions are to be a great contribution of the Russian Federation to the fulfillment of international obligations as to climate and climate change, obligations on reducing the risk of and mitigating natural disasters, and obligations related to other international conventions, contracts, protocols and agreements, including decisions taken by the UN General Assembly at the World Summit on 14-16 September 2005.