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Approach to Balance between Greenhouse Gas Emission Reduction and Adaptation to Climate Change

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Abstract: The paper offers an analysis of global greenhouse gas emission dynamics and CO_2 absorption. Stable levels are likely to remain until 2030. Enhanced emission reduction requires a comparison of related expenses against the damage from climate change and the costs of adaptation. This requires long-run probability prognoses of extreme weather events and an assessment of their correlation with emission reduction. Examples of such assessment are already available.

Keywords: Climate Change, Greenhouse Gas Emissions, Adaptation, Extreme Temperature Prognoses, Paris Agreement

The Paris Agreement of the UN Framework Convention on Climate Change (UNFCCC) came into force in 2016, and at COP-23 in late 2017 each and every country once again confirmed its confidence in that Earth's climate system is experiencing dangerous anthropogenic impacts. The RF President, too, has more than once confirmed Russia's commitment to the principles of the Paris accord. The U.S. and Turkey's withdrawal from the Paris climate deal was determined by the flaws of the UNFCCC financial system, rather than by the denial of human impact on climate. While the Paris Agreement replaced the UNFCCC's Kyoto Protocol, it is fundamentally different [1]. The Kyoto Protocol was only about the leading economies' commitments to reduce their greenhouse gas (GHG) emissions; at the signing stage, it seemed enough to address climate-related problems. However, history shows it was not: in the 2000's, GHG emissions grew up so drastically and climate change manifested so clearly, that a new accord was required. The Paris Agreement specifies two goals: GHG emissions reduction (to avoid further climate change) and adaptation (adjustment to the new living conditions). While adaptation will obviously require substantial funds [2], considerable financing will also be needed to ensure mandatory GHG emission reductions [3]. So the question is about the strategy: how to balance mitigation and adaptation?

This paper describes the global situation with GHG emissions and CO_2 absorption by forests and formulates an economic concept of balance between mitigation and adaptation. The largest economies demonstrate their dedication to such approach by taking action in UNFCCC and by setting national GHG targets. However, this approach requires a new generation of climate prognoses that will be described at the end of the paper. This refers to the calculation of probabilities of extreme temperatures or precipitation for a specific locality in a specific month over a decade, for example, in the 2030's or 2050's. Importantly, such probability can be estimated for a variety of human impact levels on the climate system.

Evolution of global greenhouse gas emissions: leveling off

Mid-2010's marked a change in the global GHG emission dynamics. Firstly, CO_2 emissions from fuel combustion and cement production (which amount to 2/3 of all anthropogenic GHG emissions in $CO_{2\text{-eq.}}$) no longer follow global GDP evolution trends. While there is still a certain correlation with global GDP evolution pathway determined by the weakest economies' development, the general dependence is different (see Fig. 1 [4]). This change primarily resulted from the shift from coal to natural gas in China and U.S. and by worldwide renewable energy development [4]. Secondly, global anthropogenic emissions of all GHG have stabilized (see Fig. 2 [5]). This is also true for Russia [6]. All projections agree that these trends are sustainable and GHG emissions stabilization should be viewed as a long-term effect [3, 5-7]. Albeit interannual variability is inevitable of course driven by a variety of market and climate factors (fuel consumption for space heating; operation of hydropower plants affected by wet or dry conditions; etc.), the general finding is that global GHG emissions have leveled off [3-5]. However, it is too early to speak about a descending trend [6-7].

GHG emission trends in India and in a whole array of small developing countries (‘other countries’ in Fig. 2) are such that it is too early to speak about global emission reduction. All national commitments were assessed in [9] to allow for a conclusion that 57 states that are responsible for 60% of the global emission will have reached their national emission peaks by 2030. Therefore, the ‘level off’ period will likely last at least 15 years. A small reduction is surely possible earlier than that, yet not a dramatic drop.

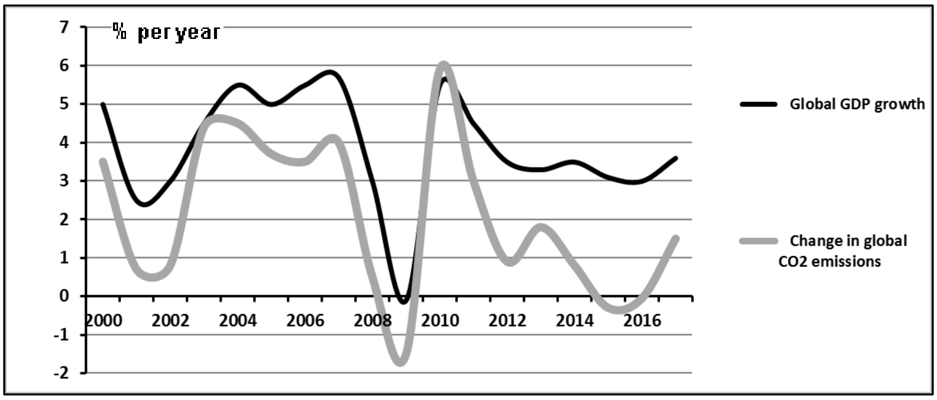


Figure 1. CO_2 emissions from fuel combustion and cement production as compared to global economic growth in 2000-2017

Sources: 2000-2016 data based on [4]; 2017 estimates: CO_2 based on [8], GDP growth based on https://data.oecd.org/

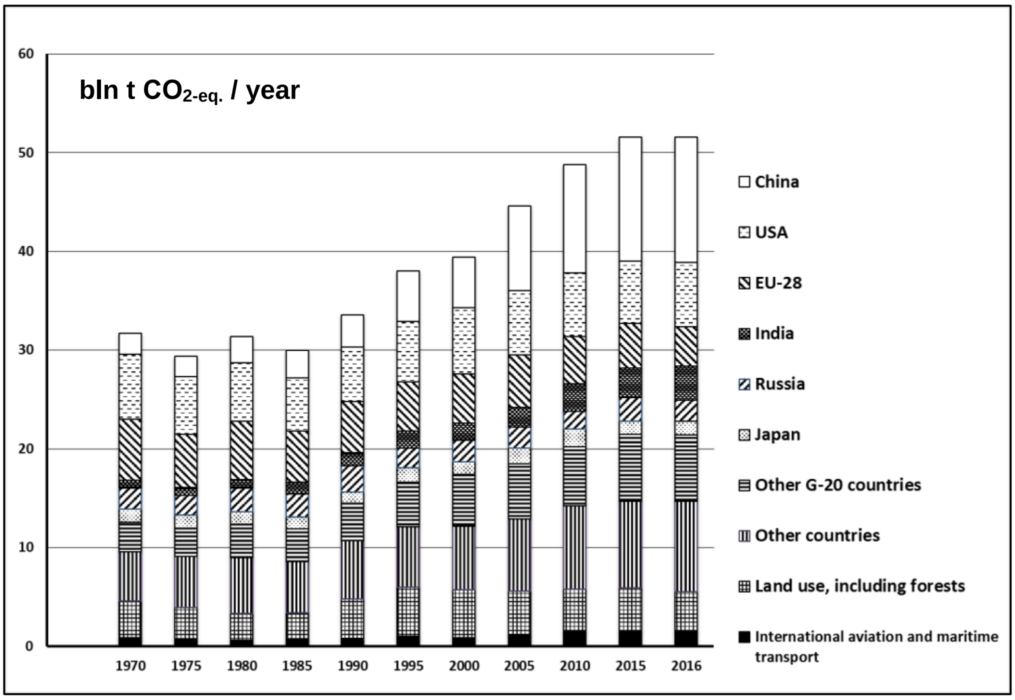


Figure 2. Global anthropogenic emissions of all GHG in 1970-2016

Note: Estimates of national energy-related emissions (major emission source) are ±3-5% accurate. Since land use sector including forests is a global net emitter (emission is higher than absorption), the estimates are ±30-50% accurate, so this sector is considered separately.
UNFCCC does not distribute international aviation and maritime transport by countries
Source: based on data from [3].

Inability to achieve substantial GHG emissions reduction in the coming 15-20 years is a huge problem for the long-term GHG goal – holding global warming to below

2°C by the end of the 21st century [3]. On the other hand, a much better progress is currently seen and projected, than that expected by many experts involved in the development of the Paris Agreement. Global warming scenarios that anticipate 4.5-6°C temperature rise (RCP 8.5 [3, 7, 8, 10]), Fig. 3, and involve highly negative projections (disastrous heat waves, droughts and wildfires, floods, flooded waterfront areas, large-scale migration, etc.) for all countries, rather than just for the most vulnerable ones, are very unlikely [2, 6, 11].

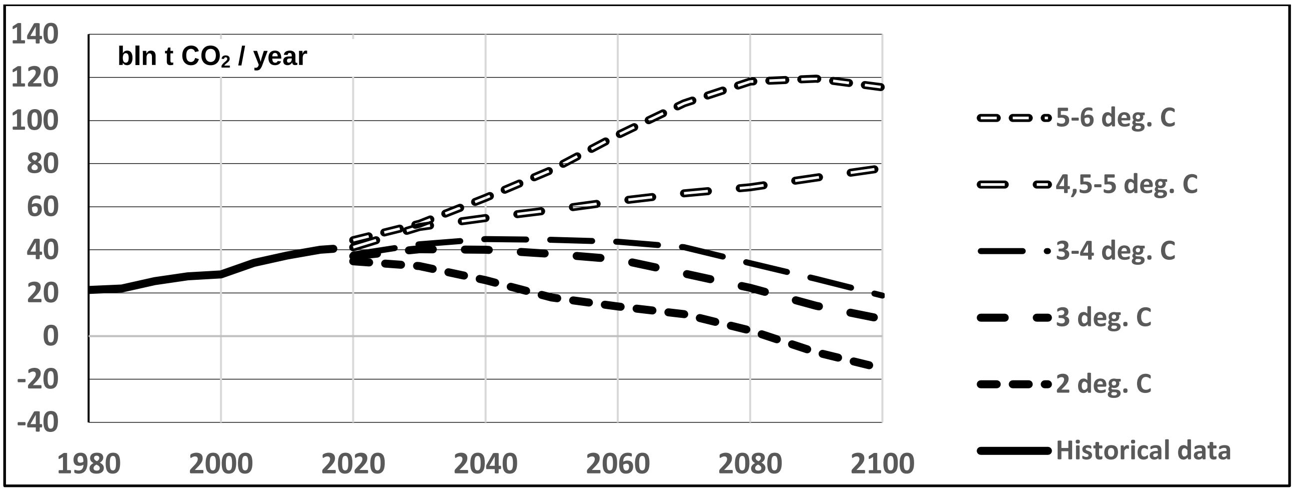


Figure 3. Global CO_2 emission pathways that by 2100 will lead to 2-6°C global surface temperature rise from the early 21st century level

Source: based on data from [8].

Until 2030, the progress will likely to be along the path to holding the warming at 3°C [3, 9, 10]. However, being absolutely insufficient for the weakest and most vulnerable states [2], this urges to search for additional possibilities, ranging from quite feasible reforestation to hypothetic global 'protection' of Earth from solar radiation [12].

The role of Russian and global forests

In Russia, much emphasis is put on CO_2 absorption by forests. And not surprisingly, since Russian forests cover more than 800 million ha of land and store more than 100 billion tC [6]. 2015 net absorption (the difference between gross absorption by growing biomass and emissions from cutting, wildfires, and biomass degradation) was estimated at around 500 million tCO_2/year, or 20% of economy-wide GHG emissions.

The forest issue is particularly important for Russia, not least because our 2030 GHG emission target, as specified for the UNFCCC, is *'limiting anthropogenic greenhouse gases to 70-75% of 1990 levels by the year 2030, subject to the maximum possible account of absorbing capacity of forests'* [6].

Reduction in net absorption by about 2 times could be expected by 2040. It is driven mostly by the changing age structure of domestic forests [6].

In the 1960-1980's, extensive cutting determined immense CO_2 emissions, and subsequent reforestation resulted in young and fast growing forests with large CO_2 absorption. However, today the forests are ageing, and their per ha absorption capacity is decreasing. This effect can be diminished through vigorous transition to intense forest management in secondary forests and simultaneous prohibition of large-scale clear cuts in primary forests which store huge amounts of carbon [6].

Other net absorption estimates are based on forest stands average lifecycle effect (net ecosystem production is the result of dividing total live and dead phytomass stock (by age groups, net of soil organics) by the average age of forest stands [13]). Decades-averaged absorption stays at around 2 billion tCO_2/year and keeps growing to reach 2.4 billion tCO_2/year by 2040. With this approach, forests currently compensate 80% of our GHG emission and will be covering 100% in 25 years. UNFCCC requires estimates that are most closely matched to a specific year, rather than long time-averaged calculations, so this approach cannot be used for UNFCCC reporting. However, the problem is not about the 'incorrect' UNFCCC regulations; as will be shown later, it is about the fact that neither absolute Russia's net-absorption, nor its evolution is an economic reason that impacts national GHG targets or global action [1, 3].

Globally, forests are a net source of CO_2 and other GHG emissions to the atmosphere responsible for approximately 4 billion $tCO_{2\text{-eq.}}$/year, which is about 8% of total anthropogenic GHG flow, see Fig. 2 [3]. The main factor is the vandal destruction of tropical forests. This process has slightly slowed down, partially due to UNFCCC-launched mechanism to encourage projects aiming to prevent destruction and degradation of forests in developing countries. This mechanism implies result-based payments under individual contracts based on mutual trust and cooperation between countries. This is why such projects are very successful in Latin America, yet not so advantageous in Africa.

In the 2020's, when the Paris Agreement mechanisms are launched, such projects may become feasible in Russia. They will require calculations of net absorption resulting from specific project activities by years of implementation. Unlike in the Kyoto Protocol, which included national GHG emission allowances, under the Paris climate accord countries rejected any idea of international quotas, etc. Therefore, Paris projects are market deals only in name, since the costs of CO_2 absorption per ton is a secondary factor, and overall national absorption is not relevant whatsoever [1]. What counts most is general mutual interest of investors and contractors.

Emissions and adaptation from the economic perspective

Analysis of current climate policies in Russia and other largest countries shows, that the states do not ignore the climate change problem, but are taking their time while addressing this challenge [1; 3, 6, 10]. GHG emission reduction to a certain level does not require additional funding and is achieved as a 'side effect' of implementing national development plans [1, 6, 7, 14]. Deployment of new technologies, air protection measures, etc. automatically brings down GHG emissions per unit of production. It is exactly such effects that underlie national GHG emission targets specified for 2025-2030 [1, 6]. However, more substantial reduction in emissions would involve additional costs – relatively small, yet requiring substantiation.

From the economic perspective (for example, according to the RF Ministry of economic development), there are two 'balance scales' [15]. Potential costs of some specific measures to reduce emissions (which are generally well-analyzed already) are on one balance scale [3, 7]. The other scale is loaded up with the costs of adaptation, although not immediate, but required in some 30-40 or more years, when the effect of accelerated reduction of emissions manifests. These do not involve the total costs, rather the difference determined by the divergent emissions evolution, Fig. 3. These should be added up with the damage caused by future adverse events – not the whole damage either, but that determined by the divergent emissions evolution. Then we should subtract the benefits brought along by the divergent dynamics of GHG emissions (which need to be achieved first). In fact, we face a long-term economic optimization problem [1], Fig. 4, which requires far more knowledge than we currently have. No wonder that under the circumstances, the RF Ministry of economic development and RF Ministry of energy suggest that we start from energy efficiency improvements that are obviously needed by the country [6, 15].

Costs of specific measures to reduce GHG emissions	+	Costs of climate change adaptation	+	Damage from adverse climate effects	-	Benefits from favorable climate effects	=	Total long-term costs to be optimized

Figure 4. Tentative formula to calculate total long-term costs
(time horizon: at least 30-40 years, ideally to the end of the 21st century)

However, the damage grows year by year, and so does funding demand to handle emergencies and implement adaptation measures [2]. Now the cost effectiveness of adaptation, monitoring and verification measures is at issue [16]. All this is being largely discussed by the UNFCCC, particularly with an account of higher vulnerability of the weakest states which require assistance.

UNFCCC: adaptation and insurance

At COP-23 in November 2017, a conflict recurred between the most vulnerable states and the largest countries (both developed and developing ones). Small and weak developing countries are most vulnerable to the rising sea level and enhancing hazardous weather events. They can see the growing damage to their economies and irrecoverable losses, as well as the risk of complete disappearance of some island states. Therefore, they demand urgent emission reduction to achieve the ultimate goal of the Paris Agreement, namely – '*holding the global warming to below 2°C while pursuing efforts to limit the temperature increase to 1.5°C*', Fig. 3.

However, the largest countries are taking their time, for so far they cannot see any substantial damage to their own economies from following the 3°C path [10]. They are generally aware of the costs of radical action to reduce GHG emissions and to shift to the 2°C path [3, 7]. What they cannot see is how much larger their damage and adaptation costs will be with the global warming amounting to 3°C, rather than 2°C. They do not have enough data to address the long-term optimization problem (Fig. 4).

Very important is the 30-50 years time lag between the emission reduction and the expected effect.

For small island states, which face the risk of disappearing, the loss can be 'easily' calculated: in the worst case, it is the total value of everything they have, and the costs should include relocation and living arrangements for the residents. For other countries, it is much more complicated, particularly if the damage is caused by hazardous weather events, rather than by gradually developing processes, such as the rising sea level, melting glaciers, etc. [11]. In each concrete locality, hazardous weather events are of probabilistic nature (they may or may not happen), and the damage depends on the preparedness levels (adaptation measures) and human action in emergencies. Many countries have insurance protection from hazardous weather events; it is not by chance that emergency-caused damage is primarily estimated by the world largest insurance companies, such as Munich Re Group [11].

UNFCCC has a trend of resetting adaptation to the insurance track. Involvement of insurance companies is expected to promote effective and earmarked spending of funds allocated by the developed economies for adaptation in other countries. Besides, long-term insurance will help assess future damage. This, of course, is not an ideal method to estimate the costs; faults and problems associated with insurance are very well known, but other approaches have even more serious drawbacks. All this is well understood by UNFCCC, and practical action is being taken. For example, successful projects were reported at COP-23 as implemented in three Caribbean states with support provided by the International Climate Initiative of Germany [17]. It was highlighted, that mutual trust and 'transparency' are extremely important for insurance.

'Transparency' of reporting and monitoring all aspects of climate activities have become the main banner for the development of the Paris 'code', which is to be approved at COP-24 in late 2018. However, there are at least two barriers to addressing the adaptation problem through insurance. Firstly, not everything can be covered by insurance or adapted to. What can be done if the loss is nearly 100% likely? While this issue is covered by Article 8 of the Paris Agreement, an active discussion took place at COP-23, and no solution has been developed so far, for the financial aspect is very complicated.

Secondly, insurance requires more than projected average temperatures or precipitation. It needs estimates of probabilistic distribution of hazardous weather events, i.e. potential claims, over a specific period of time, with a sufficient spatial resolution (the whole territory of a country or a large region is not acceptable). This is a new generation of climate projections which are being actively developed today.

UNFCCC has already gained experience in the direct use of climate data. This primarily implies index-based insurance schemes, which tailor insurance benefits directly to weather conditions (precipitation or heat waves in excess of those specified in the contract), rather than to the actual damage; such schemes are already practiced in Mexico, Peru and in the Caribbean states [17]. These insurance practices also spike interest in effective adaptation measures, since if adaptation has allowed it to avoid damage, policy holders may use the payments received at their own discretion or to achieve the goals specified in the national law or insurance contracts.

New generation of climate projections

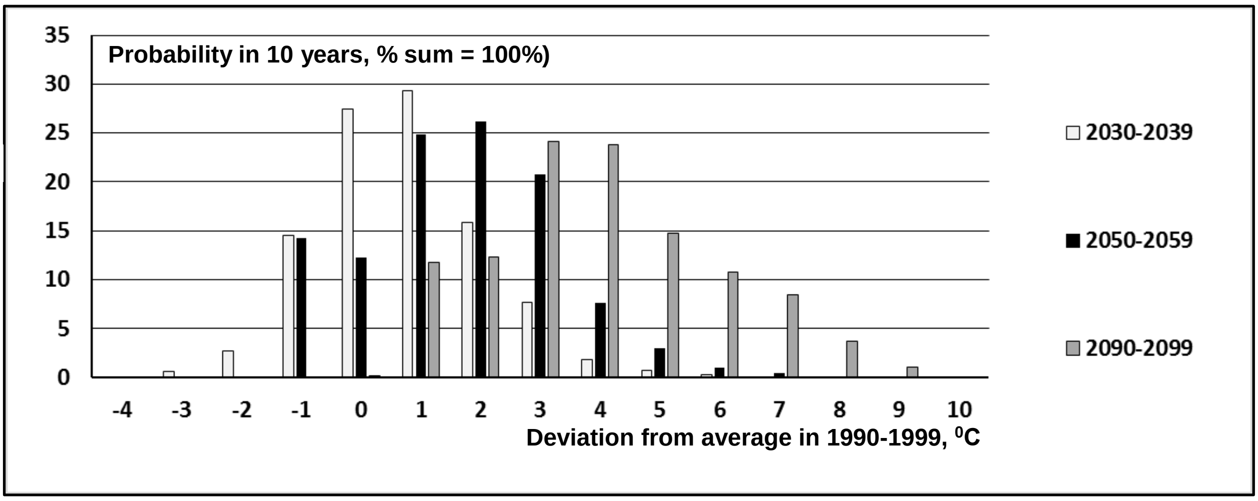
Starting from certain values, net impact of climate change (balance of adverse and favorable effects, i.e. damage and benefits) becomes negative even for the northern states. Between 1976 and 2016, Russia's average annual temperature changed 2.5 times more substantially, than the global value, and the number of hazardous weather events (both those which incurred, and which didn't incur any damage) doubled over the recent 15-20 years – from 150-250 to 500-600 per year [11]. Projections of average temperature change (annual and seasonal) have been developed for a long time. Same is true for very rough estimations of the growing frequency and strength of weather events, yet often averaged by a very large territory, for example, the whole of North Eurasia [18]. Such estimates could not help assess the frequency of abnormal weather events in a specific locality. But now information regarding statistically significant regional changes in heat/cold waves is available, for example, from Voeikov Main Geophysical Observatory (MGO) [19]. However importantly, extremely cold periods will be occurring in the 'warming' climate for at least several more decades, and there is no controversial with the anthropogenic warming [11].

Estimated probabilities are pivotal. If we take the Arctic for example, high temperatures in spring are a risk factor, as they affect the state of roads and reindeer migration, so we need to know the probable number of very warm May-June periods over 10 years. If we are to assess the number of temperature anomalies in winter, then we should consider periods from October to April. Such estimations have been obtained by MGO for a number of Russia's regions [11, 20], and one example is shown in Fig. 5.

Fig. 5 shows, *inter alia*, that in Yamalo-Nenets District there is only a 10% probability (once over 10 years) that in the 2030's spring will be 3 or more ^{o}C warmer, than in 1990-1999 (average May-June temperature will rise by 1.2±0.8^{0}C). The situation will change by the mid-century, and maybe 3 (instead of 1) years over a decade will be this abnormal. However, winter temperatures will show a much more substantial change even in the 2030's. Every third year winter will be 4 or more ^{o}C warmer, than in 1990-1999, and once over a decade it will be 7-9^{o}C warmer. Average winter temperatures in the 2030's and 2050's will be 3.5±1.7^{0}C and 6.5±2.1^{0}C higher, than at the end of the 21st century, giving the evidence of a dramatic change [20].

MGO is doing similar probabilistic calculations for precipitation. Besides, it develops projections of decades' average snow cover parameters (maximum height and duration) and vegetation period (duration, temperature sum above 0ºC and above 5ºC); changes in the number of heat/cold waves; maximum precipitation over 5 subsequent days; number of days with air temperature diurnal transition over 0ºC; ice regime; etc. [11, 20]. For the middle (and particularly for the end) of the century it is very important to select the anthropogenic impact scenario, so calculations are made both for the maximum (RCP 8.5) and practically minimum (RCP4.5) scenarios [11]. This provides a totally different, and much more detailed, information basis for adaptation measures, relevant costs analysis, and estimation of potential damage, while at the same time allows for the deployment of insurance mechanisms and then for addressing the long-term optimization problem that deals with GHG emissions reduction, Fig. 4.

а)



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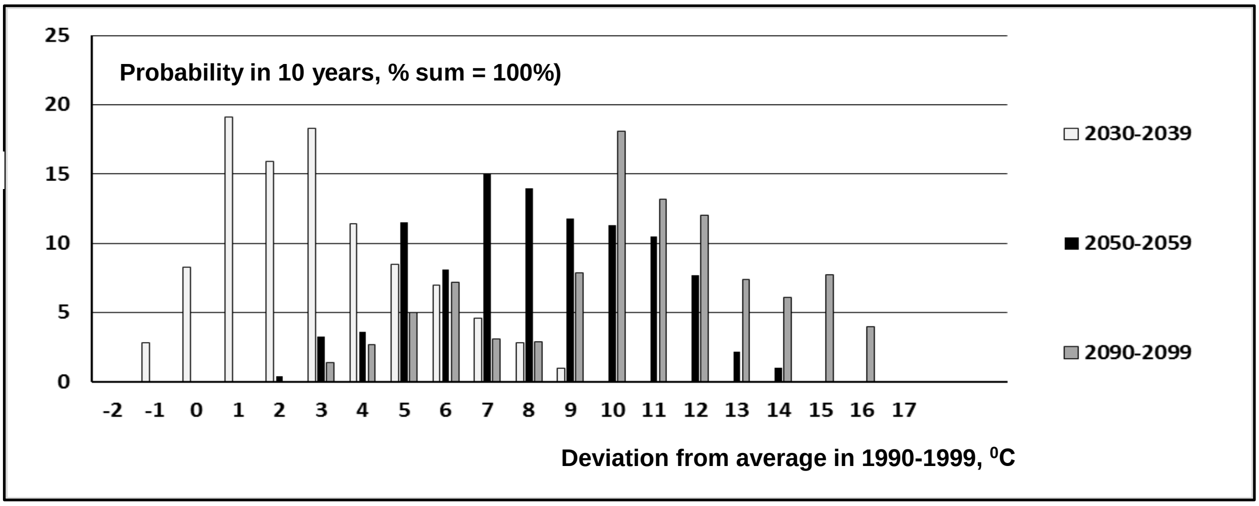

Figure 5. Probabilistic distribution of average air temperatures in Yamalo-Nenets Autonomous District in May-June (a) and October-April (b))

Source: [20]

Conclusion

Despite the fact that nearly all countries are committed to the principles of the Paris Agreement, and irrespective of the positive dynamics of GHG emissions that is taking place since the mid-2010's, it is very unlikely that a substantial decline in global emissions can be expected before 2030. The role of Russian and global forests is relatively not significant. Action to be taken under the Paris Agreement should concentrate on specific forest projects with high environmental and social value, rather than on total CO_2 absorption by forests or calculation methods.

At this point, the largest economies are not putting all their effort to reduce global GHG emissions or enhance total CO_2 absorption. So far they cannot see any substantial damage to their own economies from following the current GHG path. It will get global temperatures up by approximately 3^{o}C by the end of the 21st century, whereas the Paris Agreement long-term goal is to get them down by more than 2^{0}C, which is critical for the weakest and most vulnerable developing states.

This situation can be changed by finding a balance between the costs of accelerated reduction in emissions and a long-term effect, which for each country must be shown as reduced damage and smaller costs of domestic adaptation measures. What makes it difficult is a large time lag between emissions reduction and the effect achieved (at least 30-40 years). Therefore, long-term optimization of total climate costs is a very difficult challenge for any large country, particularly if the largest damage is related to enhanced hazardous weather events (like in Russia), rather than to slow processes, such as rising sea level.

Adaptation to more frequent and stronger weather events is very important for most countries, including Russia. This is a pivotal topic in UNFCCC and the Paris Agreement, which are developing an insurance-based approach to adaptation. This approach is not lacking in problems or faults, yet ideally it can help improve the effectiveness of spending and develop more detailed and verified estimations of damage and costs.

However, adaptation to hazardous weather events requires a new 'generation' of climate projections. It needs probabilistic calculations of abnormal temperatures and precipitation for a specific locality for this or that season (month) over a certain decade, for example, the 2030's or 2050's. And probability should be estimated for a variety of human impact levels on the climate system. Such estimates are made, for example, by Voeikov MGO, and they have already obtained results that describe a large range of climate parameters [11, 20].

The new generation of climate projections can help obtain an economic perspective of adaptation and long-term reduction in GHG emissions. This forms a reliable foundation for the implementation of principles of the Paris Agreement, which sets two global tasks at the same time: mitigation of climate change (emissions reduction) and adaptation. However, today we see a global trend for increasing the gap between actual and required adaptation capacity [2, 16]. This urges the development of adaptation strategies for Russia's regions and economic sectors, including environmental protection and forestry. It is important to develop National plan of adaptation to observed and expected climate change in connection with national programmes and relevant financing. And the role of detailed and reliable climate projections remains pivotal, as they are a linchpin that launches the entire chain of adaptation and GHG emissions reduction measures.

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