Analysis of the current state of the issue of greenhouse gas emission monitoring

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Abstract. The question of the theory of global warming is being raised more and more every year. There are disputes, dialogues, and various conferences on this problem. Carbon grounds are being created everywhere for research. The world community is increasingly asking questions about decarbonization and carbon trace compensation, but the main problem is that there is no unified standardized methodology for accounting of production and absorption of carbon dioxide, there is no comprehensive monitoring system approved that allows us to receive real-time data from large territories at present. This review article examines the purpose of carbon grounds, the impact of greenhouse gases, the concept of a carbon trace, the goals of decarbonization and the existing monitoring problems. The actively used environmental monitoring posts are considered, and it is also proposed to supplement the existing list of posts with a mobile flying post (using an unmanned aerial vehicle). The planned structure of the information collection system and the block diagram of the unmanned aerial module are proposed. The article also notes that the more reliable the initial data will be in the calculation and forecasting, the more accurate the final result will be. Further necessary improvement of accuracy is possible only thanks to a deep integrated approach to monitoring the absorption and emission of greenhouse gases.

1 Introduction

Currently, the issue of monitoring greenhouse gas emissions is very urgent, mainly due to the introduction of proposals on cross-border taxes on carbon dioxide applicable to "environmentally dirty" goods, which will undoubtedly affect both the economy and the carbon trace compensation to follow the RCP2.6 scenario and bring net CO2 emissions to 0 until 2050, according to the Paris Agreement [1].

The available monitoring tools are expensive and do not allow covering the required areas, they often cannot be installed in remote and hard-to-reach places, and the information

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they collect is not always relevant, because real-time data is needed for correct forecasting and evaluation.

In this scientific work, the issues of carbon grounds, greenhouse gases, carbon trace, decarbonization, analysis of the current state of monitoring greenhouse gas emissions are considered and it is proposed to supplement the existing mechanisms with a new type of monitoring post with a structural diagram of the information collection system and a description of its composition and principle of operation.

1.1 Briefly about the carbon ground and its purpose

Specially allocated and equipped sites called "carbon grounds" began to be organized to carry out more accurate comprehensive research on absorption and release of anthropogenic gases, as well as a complete analysis of the state and changes of vegetation and soil, accounting for biomass, the influence of external factors on specific vegetation specimens [2]. Carbon grounds provide an opportunity to work out the necessary complex of scientific and technological solutions for the development of a system of reliable accounting of greenhouse gas and emissions absorption, as well as to collect a large amount of experimental data to create a refined methodology for assessing the carbon balance maintained by natural ecosystems.

Carbon grounds created for scientific and research tasks have been widely publicized and will allow such areas as industry, agriculture, forestry and many other industries to adapt much faster to new standards of environmental conservation and move to the path of greening, providing new technologies, as well as developments and knowledge on the problem of ecological balance.

1.2 The role of greenhouse gases

Greenhouse gases, due to their possibility of a high level of absorption in the thermal infrared range and throughput in the visible range of electromagnetic waves, warm the Earth and prevent the removal of heat from the atmosphere into space. In connection with this feature, greenhouse gases provide favorable climatic conditions on Earth, respectively, without greenhouse gases, conditions for emergence, development and existence of life would be impossible.

The main factors that disrupt the natural balance of greenhouse gases are such actions as extraction of fuel resources, active deforestation, burning of fossil fuels, agriculture and heavy industry [3]. Violation of this balance leads to such a negative phenomenon as an increase in the concentration of greenhouse gases, which increases the greenhouse effect. With the growing influence of the greenhouse effect on the environment, there is a gradual, proportional increase in the average air temperature on the planet, which can lead to the destabilization of the global climate.

The main composition of greenhouse gases includes methane, nitrous oxide, hydrofluorocarbons, carbon dioxide, as well as perfluorocarbons and sulfur hexafluoride, of which methane, nitrous oxide and carbon dioxide are closely related to human activity. All of the above greenhouse gases are covered by the Kyoto Protocol.

1.3 Carbon trace

The carbon trace is the total number of greenhouse gases produced during the life of an individual, the functioning of an organization or during the manufacture of a product for a certain period. It is measured in metric tons of carbon dioxide (CO2), and can be calculated for organizations and for each person individually [4].
The carbon trace can be reduced by using additional compensation methods, such as the use of energy-saving technologies, the popularization of the use of reusable products, the reduction of vehicles, the use of new technologies in production, etc.

Carbon trace compensation is feasible by absorbing the emitted pollutants, namely by planting various types of vegetation with a high degree of carbon absorption.

On July 14, 2021, the European Commission published a draft of cross-border carbon regulation (CCR), which provides for levying fees on imported EU goods depending on their carbon trace.

The document states that by 2050, as part of the pursuit of carbon neutrality, EU countries should become climatically neutral, so their CO₂ emissions into the atmosphere should be reduced to 0 or compensated [5].

1.4 Tasks and goals of decarbonization of the economy and energy systems

Decarbonization implies a reduction in the emission of carbon dioxide (CO₂) into the atmosphere (Figure 1). Since the signing of the Paris Climate Agreement in 2016, decarbonization of energy systems has been given great importance.

![Net CO₂ emissions](https://example.com/fig1)

**Fig. 1.** Scenarios of the progress of CO₂ emissions.

Only compensation of the carbon trace and global decarbonization of energy systems will reduce the harmful effects of the greenhouse effect, as well as stabilize the climate, reaching the RCP2.6 development scenario.

1.5 The need of greenhouse gas monitoring

CO₂ is a natural gas that by itself has no toxic properties. A feature of this gas is the ability to enhance plant growth through chemical reactions known as photosynthesis. Also, this gas causes an increase in the temperature of atmospheric air and water, affects the global average temperature level, due to the process of absorption of the emitted infrared range, simultaneously with which the process of transferring the received energy to the rest of gases' mixture in the atmosphere [6, 7].

Sulfur oxide IV (SO₂) with an increase in the proportion of its content in the atmosphere, in the long term, is also capable of having a negative effect. This gas has a depressing effect on such lower plants as blue-green algae, lichens, mosses, some fungi, due to the fact that the photosynthesis process of the presented flora slows down
dramatically. As an example of such an influence, the fact is given that in an area located in close proximity to industrial zones, the population of lichens is reduced. Conifers belonging to higher plants show a strong sensitivity to the influence of SO2 [8]. The effect of SO2 on photosynthesis and respiration results in a sharp decrease in the metabolic rate of higher plants, which entails acute leaf necrosis, as well as a decrease in the yield of wood growth.

An increase in the average temperature level with an increase in the concentration of greenhouse gases entails such consequences as accelerated degradation of land quality, resulting in crop loss, a decrease in the humidity of areas with unstable moisture, as well as an increase in the overall humidity level in places characterized by frequent heavy precipitation. In addition, the appearance of this negative factor will entail an increase in the frequency of extreme impacts, to which agriculture is particularly vulnerable, as well as an increase in the frequency of these impacts caused by natural disasters.

2 Materials and methods

2.1 Existing monitoring problems

Currently, different quantitative estimates of the carbon budget of forests are used in almost all countries. These indicators vary widely, differing in an extremely high degree of uncertainty and inaccuracy.

One of the methods of measuring carbon compensation of woodlands is the methodology of the International Institute of Applied Systems Analysis (IIASA) called Full Carbon Account (hereinafter FCA). The basis of this methodology is calculations based on information obtained from the integrated GIS and the IIASA database. The database in question includes a list of forests in Russia, including information such as the geographical reference of each forest area listed in the database and components of the natural environment.

The technique, called CBM-CFS, was developed and applied by the Canadian Forest Service and is an indicative model that has been implemented in 44 countries around the world. In the Russian Federation, the methodology was used for the average calculation of the ratio of the cubic capacity of woodlands to the total carbon budget of woodlands not only at the level of regions as independent entities, but also of the country as a whole. The model under consideration operates with a set of spatial units at the landscape level, so that classifiers are able to evenly distribute the parameters received for input into units to which administrative division can be applied.

The main reason of the discrepancy between the indications resulting from the work of the above methods is the lack of reliable and up-to-date information on the state of vegetation, the lack of accurate data on the ability to absorb carbon for various types of vegetation when taking into account the full life cycle and the lack of a unified standardized methodology for accounting of the absorption and synthesis of greenhouse gases for forests.

2.2 Monitoring tools and methods used

With the entry into force of the Kyoto Protocol, it will be possible to take into account not only carbon emissions, but also its absorption (conservation), which may allow the Russian Federation to enter as a supplier of compensatory carbon units, offering its forest areas as an absorbent of carbon dioxide.

Currently, the methods used to account for the absorption and emission of greenhouse gases differ greatly both in terms of calculation principles, accounting for additional
factors, and due to many missing information, such as the lack of accurate data on the absorption of specific plant species, the influence of external factors on changes in carbon production and absorption, the state and volume of phytomass in hard-to-reach areas, and many other factors [9]. Accounting of the absorption and emission of greenhouse gases is an essential part of international relations, which creates the need for global recognition of this factor.

According to the current GOST 17.2.3.01-86, three categories of atmospheric monitoring posts are established: stationary, route, mobile (under-the-torch), satellite.

The stationary post provides continuous active registration of the content of pollutants or takes air samples for subsequent analyses regularly, mainly exists in the form of a lockable equipped building with a separate backup power supply system and measuring devices normally connected to it.

The route station regularly takes air samples at a given point of the terrain during observations that are carried out using mobile equipment.

A mobile (under-the-torch) post takes samples under a smoke (gas) torch in order to identify the immediate zone of influence of this source.

3 Results

To increase the level of reliability and relevance of information on the state of vegetation, as well as the calculation of data on the absorption of specific plant species, the influence of external factors on changes in carbon production and absorption, the state and volume of phytomass in hard-to-reach areas and, as a consequence, the development of a unified methodology for calculating the absorption and production of greenhouse gases for forests, it is proposed to expand the types of posts used, set out in the current GOST 17.2.3.01-86 and introduce a new type of mobile post in the form of an aircraft post (using an unmanned aerial vehicle) [10]. The use of this type of post will allow remotely determining the level of the content of climatically active gases at the required height (for example, 100-150 meters from the Earth's surface), which at the same time will facilitate and reduce costs for measures to monitor the absorbing phytomass.

Simultaneously with data collection, autonomous monitoring platforms are supposed to be equipped with systems designed for burning and smoke detection, which will allow detecting, localizing and preventing large fires in the forest zone in advance.

3.1 Autonomous solar-powered monitoring platform

The autonomous monitoring platform is designed for autonomous, round-the-clock monitoring and registration of parameters in accordance with the established types of sensors with the provided possibility of detecting burning and smoke, which will allow detecting, localizing and preventing large fires of the forest zone in advance.

The autonomous solar-powered monitoring platform is made of materials capable of withstanding mechanical, electrical and thermal loads, as well as the effects of humidity of the climatic version of the placement category - UHL1 according to GOST 15150. The autonomous monitoring platform meets the reliability requirements in accordance with GOST 27.003 and indicators with a service life of at least 5 years and a failure time of at least 50,000 hours [11]. Thanks to the autonomous operation of the solar-powered monitoring platform, it is possible to locate it in remote areas where, in the absence of power supply and data transmission networks, it is necessary to carry out long-term, round-the-clock monitoring. The transmission of accumulated arrays of information from monitoring stations is possible in two ways, this is the organization of direct transmission
(if there are devices of transmitting information within reach) and the organization of hybrid transmission using UAVs [12]. Autonomous solar-powered monitoring platforms are equipped with receiving and transmitting modules capable of organizing an analogue of a simple, cellular network in the coverage area and relaying the received data within an organized network, which allows deploying and carrying out operational data exchange over a large area, regardless of local area networks and GSM networks [13]. When a UAV with an installed module for interaction with autonomous monitoring platforms appears in the visibility zone of the network, data synchronization is possible for further transmission to the data storage and processing server.

Monitoring stations are autonomous and do not require additional configuration to work with additional equipment.

3.2 Structure of the information collection system

Figure 2 shows the planned structure of information collection with the direct communication zone and the hybrid communication zone, the route of the UAV and the methods of data exchange with the data storage and processing server.

![Fig. 2. Structure of the information collection system.](image)

3.3 Block diagram of an unmanned aerial module

Figure 3 shows the planned block diagram of an unmanned aerial module, which displays the main control and communication modules, sensors and ways of interaction between them.
3.4 Sensors placed on board the UAV for monitoring

In order to conduct research and test the initial results, also due to the high cost of imported professional measuring instruments, estimated in millions, it is proposed to develop and produce model samples of the proposed concept from more common and widely used similar sensors with lower characteristics [14]. The use of similar sensors will significantly reduce the final cost of the project, conduct modelling, manufacturing and performing initial tests in the shortest possible time and without attracting investment from large organizations. Let us consider the sensors proposed for use in the project.

MH Z19B is a carbon dioxide sensor that analyzes the CO2 level according to the principle of non-dispersed infrared radiation (non-dispersive infrared sensor, NDIR), has built-in internal temperature compensation, compact dimensions, light weight compact metal housing and long service life. The measurement range of CO2 content is from 0 to 5000 ppm.

MICS 6814 – a sensor belonging to the type of air quality sensors, allows detecting the following types of gases: carbon monoxide CO (1 - 1000ppm.), nitrogen dioxide (NO2 0.05-10ppm.), ethanol C2H5OH (10 - 500ppm.), hydrogen H2 (1-1000ppm.), ammonia NH3 (1-500ppm.), methane CH4 (>1000ppm.), propane C3H8 (>1000ppm.), isobutane C4H10 (>1000ppm.)

– AM2302 is a digital sensor that allows temperature analysis in the temperature range from 40 to 80 °C and humidity in the range from 0 to 99.9%, a single - wire digital interface is used as an interface for information exchange.

BMP 180 is a digital sensor for measuring atmospheric pressure in the range from 300 to 1100 gPa with a measurement accuracy of ± 0.02 gPa and temperature measurement in the range from 0 to 65 °C. A two-wire I2C digital interface is used as an interface for exchanging information with the end device.

DS3231 is an autonomous real-time clock module, contains a replaceable CR2025 power supply, a built-in calendar up to 2100. It uses a built-in quartz oscillator and a temperature sensor as clock pulses, which compensates for temperature changes for the constancy of time intervals regardless of temperature changes. A two-wire I2C digital interface is used as an interface for exchanging information with the end device.

Parameters recorded from an unmanned aerial vehicle: CO, CO2, NH3, NO2, temperature recorded on two sensors, humidity, pressure, GPS location coordinates, exact time.

The prototype of the gas analyzer and recorder module being developed is mounted on an unmanned aerial vehicle. During the movement, according to pre-prepared key points, the UAV is kept at an altitude of 100-150 meters, the gas analyzer and recorder module polls the available sensors, with reference to the coordinates of the route. Thus, it becomes possible to register and determine the level of the content of climatically active gases at an
altitude of 100-150 meters from the earth's surface with reference to the coordinates of the route.

4 Discussion

Work in this area (measurement, accounting and registration of the level of greenhouse gases, their absorption and release) will allow Russia emerging as one of the leading suppliers of carbon units, offering its forest territories as an absorbent of carbon dioxide. With the emergence of a "carbon" tax and discussions related to the details of the implementation of this innovation, the Russian side will already have the opportunity to change the current situation in its favor and introduce the factor of absorption of climatically active gases by phytomass into the formulas for calculating the carbon balance, which will allow implementing forest-climatic projects in combination with projects for decarbonization of the economy, which have great potential [15]. Accounting of the absorption and emission of greenhouse gases is an essential part of international relations, so this problem needs to be recognized by the world community. Science is transnational, therefore, all representatives of the international scientific community should clearly understand how to keep records, make calculations and on what laboratory equipment to conduct research for the subsequent publication of research results in journals that are recognized by the world scientific community [16]. It is extremely important to initiate the creation of a network exchange of views and actively participate in the development of international research cooperation.

5 Conclusion

Despite the fact that the concept of monitoring as an activity has existed for a long time, at the moment there are a large number of unresolved issues related to monitoring and correct, all agreed and approved calculation of the volumes of absorption and emission of greenhouse gases. This state of affairs clearly shows that the monitoring methods used, as well as the means for carrying out this activity, provide insufficient information and need to be expanded and improved. The presented concept will significantly expand the coverage areas and increase the number of monitoring data collection points, eliminate the problem of inaccessibility of many previously unanalyzed locations with the simultaneous ability to collect data at different levels of the atmosphere and with the required frequency, which will allow getting up-to-date data in real time. It is also worth noting that the more reliable initial data is obtained during calculation and forecasting, the more accurate the result will be. Further improvement of accuracy is possible thanks to an integrated approach to monitoring the absorption and emission of greenhouse gases.

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