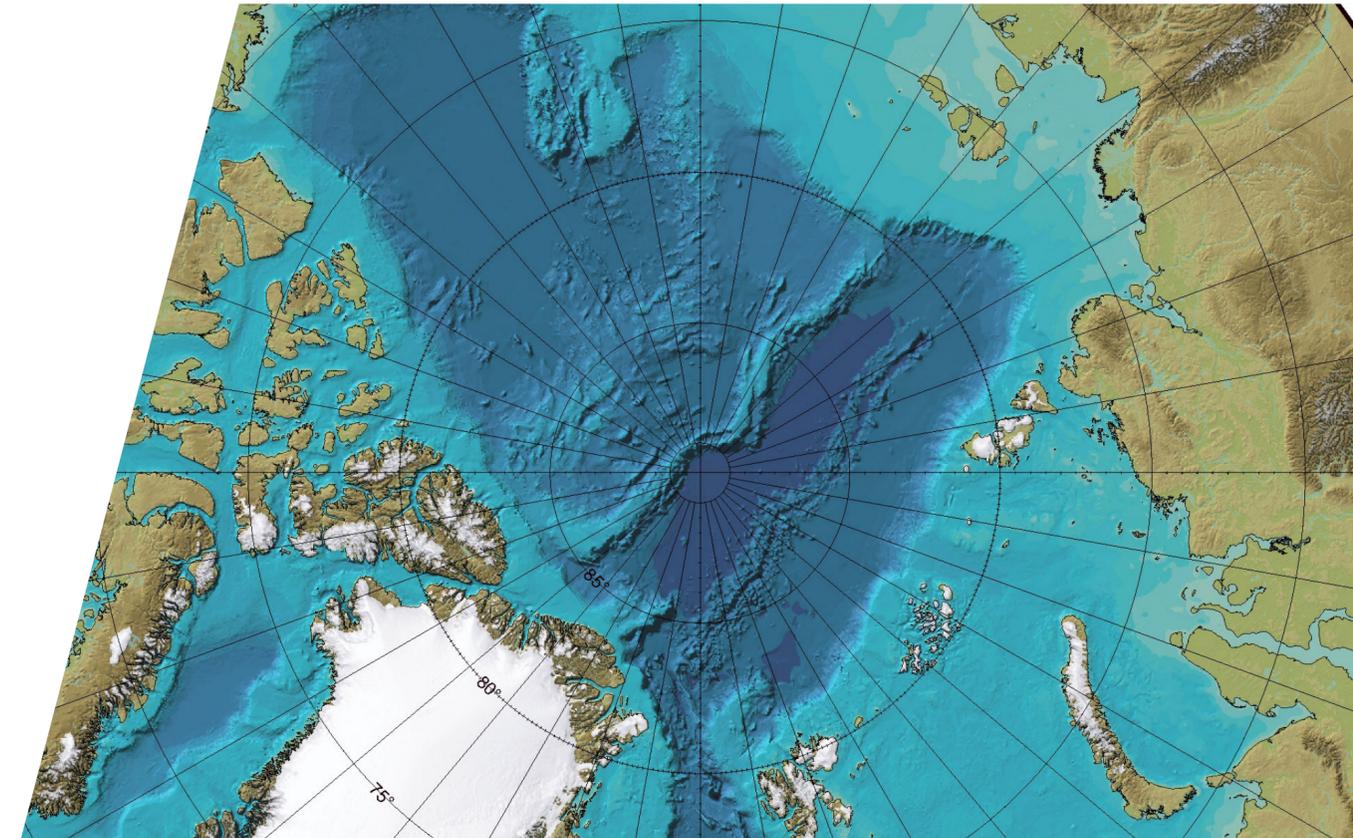




An integrated system of climate-ecological monitoring, development and production of new technique and multiscale modelling of Russian Arctic



Strategic Academic Units

School of Natural Sciences and Mathematics

Engineering school of information technologies, telecommunications and control systems

Research direction

Climate and ecosystems monitoring and modelling, computational methods and algorithms for ecological problems solutions

Development of mathematical methods and cognitive radio-electronic technology for new generation telecommunication and high-precision navigation systems, for processing and recognition of hyperspectral images for advanced satellite and aerospace systems and intelligent robotic technique systems



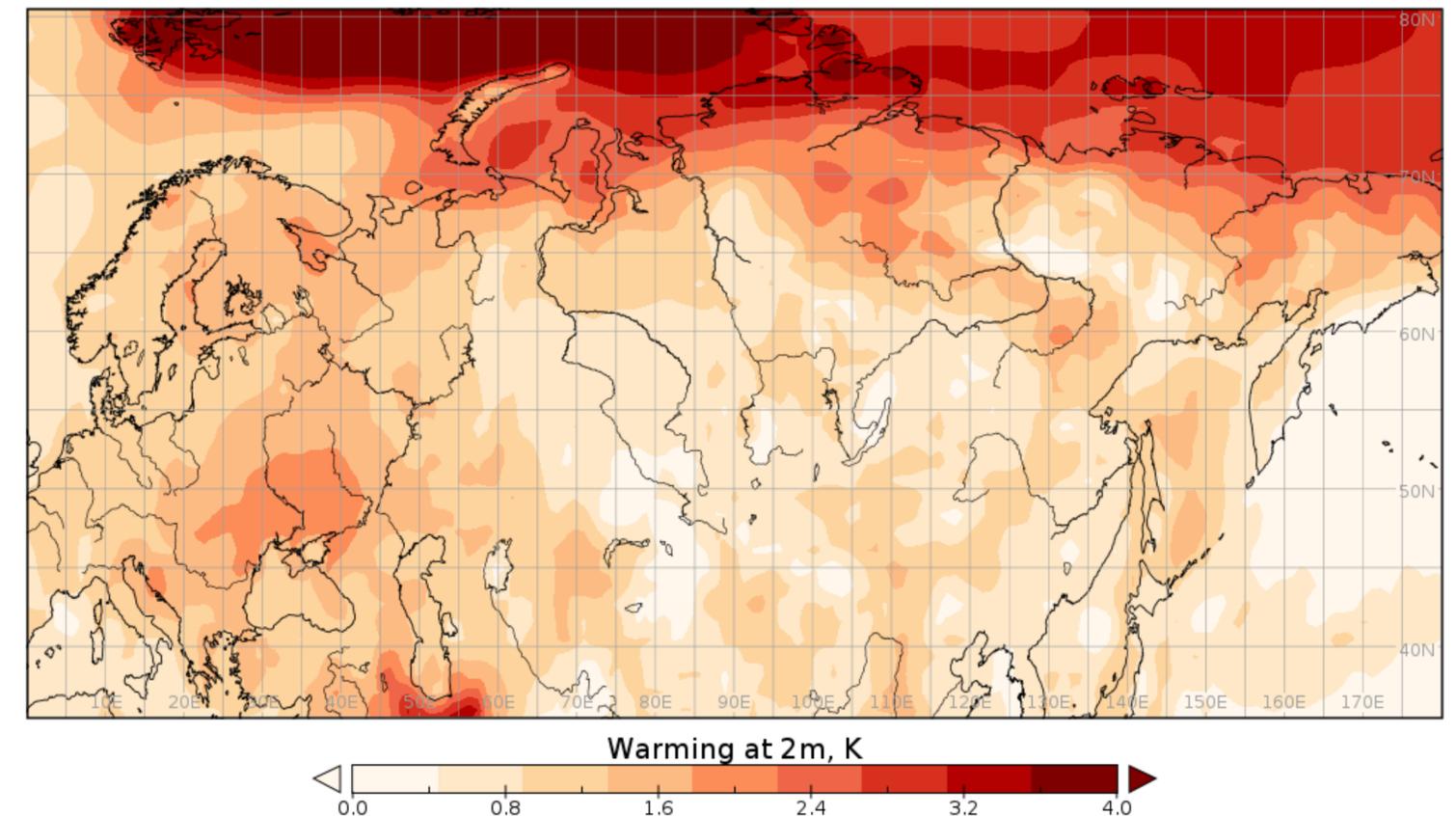
Creating a system of monitoring, climate and permafrost state modeling in the Arctic — the scientific basis for strategic decision making in its development

General task of the project: development and creature of technology of monitoring, multiscale climate and dynamic of Arctic cryo-system simulations.

Quantitative information about the climate change and permafrost melting in a future is necessary to plan social-economic development in Arctic.

As a result of the project the unique actual data (isotopic tracers of water cycle, permafrost vertical temperature profiles on key sites) will be obtained for purpose of verification/validation of modern climate models. A prediction of climate change, sea ice and permafrost dynamic in Arctic will be done for a future nearest decades using the verified climate models.

Air temperature increasing in last decade compared to 80s





Academic coordinator of the project

Dr. Jean Jouzel, France

Ex-director of IPSL (Institut Pierre Simon Laplace), world famous scientist in field of paleoclimate and climate change, author of the methodology of “isotopic paleothermometer”. Co-recipient of Nobel Peace Prize 2007 as IPCC member, the prestigious Vetlesen Prize 2012 with a citation focusing on contribution to the reconstruction past climate for the last 800,000 years using ice core data from Antarctica.

H-Index – 78, citation index (Web of Science) exceed 30 thousand citations.

Jean Jouzel is author or co-author more than 500 scientific papers, about 50 of them are published in most prestigious international journals such as Nature and Science.

Since begin of 1980-th Jean Jouzel was involved into EU projects as general director of two first grants of European Program (EPICA) regarding Antarctic ice core investigation during 1990-th with total budget of the project about 30 mln euro. Between 2009 and 2015 he was coordinator of French part of European consortium regarding creation a KIC (Knowledge and Innovation Community) in the field of mitigation of and adaptation to climate change (total budget of the program 100 mln euro). Jean Jouzel was involved into this program as a member of the Governing Board.

From 2011 to 2013 Jean Jouzel was leading scientist of WSibIsso project of Ural Federal University (in frame of megagrant of Government of RF, act 220) «Impact of climate change on water and carbon cycle of melting permafrost zone in Western Siberia», the Climate and Environmental Physics Laboratory of Institute of Natural Sciences of Ural Federal University was organized due to the WSibIsso project. At present Jean Jouzel is academic supervisor of the laboratory and Chair of Academician Council of the Ural Federal University. Jean Jouzel is foreign member of the US Academy of Sciences.





Co-director of the project from UrFU

Prof. Vyacheslav Zakharov, Head of Climate and Environmental Physics Laboratory, professor of Department of Astronomy, Geodesy and Environmental Monitoring of Institute Natural Sciences and Mathematics of the Ural Federal University.

Key scientific results

Author of the model of threshold runaway greenhouse effect on the Earth: Zakharov V.I. (2009): Regarding Greenhouse Explosion, Chapter 6. pp. 107-132, in book: Global Climatology and Ecodynamics — Anthropogenic changes to Planet Earth. Eds: Cracknell A., Krapivin V., Varotsos C. // Springer/PRAXIS, Chichester, UK; doctoral dissertation «Research of Stability of Global Thermal Regime of the Earth's Surface and Remote Sensing of the Atmosphere Using High Resolution Spectroscopy in Infrared», Ural State University, 2009.

Co-author of the pioneer method for retrieval of relative content of heavy water in the atmosphere using satellite sounding of the atmosphere in thermal infrared: Zakharov, V. I., K. G. Gribanov, G. Hoffmann, and J. Jouzel (2004): Latitudinal distribution of the deuterium to hydrogen ratio in the atmospheric water vapor retrieved from IMG/ADEOS data // Geophys. Res. Lett., 31, L12104.

The method is actively using now for global monitoring of isotopic tracers of atmospheric water cycle.

Co-author of the pioneer method for remote sensing of the atmosphere to retrieve H₂(180) to H₂(160) ratio in the atmospheric water vapor using ground-based FTIR high resolution spectrometers: N. V. Rokotyan, V. I. Zakharov, K. G. Gribanov, M. Schneider, F.-M. Bréon, J. Jouzel, R. Imasu, M. Werner, M. Butzin, C. Petri, T. Warneke, and J. Notholt "A posteriori calculation of $\delta^{18}O$ and δD in atmospheric water vapour from ground-based near-infrared FTIR retrievals of H₂160, H₂180, and HD160" // Atmos. Meas. Tech., 7, 2567-2580, 2014.

Experience of managing of research projects

International projects:

IMG/ADEOS Interferometric Monitor for Greenhouse Gases on Advanced Earth Observing Satellite, NASDA, Japan, project №1117 (1994-1998 г.г. — PI of Russian team);

INTAS CASUS project №03-51-6294 «The effect of climate change on the pristine peatland ecosystem and (sub)actual carbon balance of the permafrost boundary zone in Subarctic Western Siberia" (2004-2007 г.г. — PI of the Ural State University team);

PI of the projects supported by Russian Fund for Basic Research: № 03-07-96836 (2003-2004); № 09-01-00474-a (2009-2011); № 12-01-00801-a (2012-2014); № 15-01-05984-a (2016-2017).

Megagrant of Government of RF, WSibIsso project: «Influence of climate change on water and carbon cycles in zone of melting permafrost of Western Siberia, contract № 11.G34.31.0064, (2011-2013 г.г. — PI of the Ural Federal University team).

Total budget of the projects exceed 200 mln rubles.





Our achievements



The UrFU team developed methods and software for direct and inverse problems of infrared radiative transfer in the cloudless atmosphere for the retrieval of temperature and greenhouse gases vertical profiles in the atmosphere from infrared spectra measured by satellite and ground-based spectrometers with high spectral resolution. All methods are implemented in the software package FIRE-ARMS for Linux that meets the highest international standards. This software package is used in AORI of University of Tokyo, Institute of Space Research RAS, and others.

The project team has successful application experience for the methods and algorithms developed in the frames of international projects for the retrieval of methane, carbon dioxide, and water isotopic composition from satellite data (IMG, AIRS, TANSO-FTS, IASI). Atmospheric Fourier Station in Kourovka is the only station among three Russian stations which is located in forest area with background atmosphere and performing validation experiments for greenhouse and contaminating the atmosphere gases as they retrieved from the data of Japanese satellite GOSAT.

Two team members together with project head Jean Jouzel suggested in 2004 the pioneer method for satellite remote sensing of heavy water in the atmosphere that is currently developing new direction in the field of global monitoring of atmospheric water cycle tracers.

Project team members developed the original methods for multiscale mathematical modeling, for instance the method of stochastic sensitivity function. The methods of mathematical description for new stochastically induced climate modes, transitions and states (including catastrophic scenarios) with the account

of influence of additive and parametric random processes modeling fluctuations of various geophysical parameters, natural processes and human activity are developed.

New project is the further development of the project “Impact of climate change on water and carbon cycles of melting permafrost of Western Siberia” realized in 2011–2013 under supervision of Jean Jouzel (according to Decree 220 of the Russian Federation Government contract No. 11.G34.31.0064 of 27 October 2011).

The project team from UrFU has extensive experience in the practical implementation of R&D related to the project theme. For example, the agreements with the Center for Exploitation of Space Ground-Based Infrastructure: 764.210.017/13 «Creation of providing facilities, equipment and systems of ground-based space infrastructure of Vostochny Cosmodrome (Russia), in terms of creating a system of air sounding of the atmosphere» (99 million rubles), 764.210.015/14 on the implementation of part of the R & D: «Assembling the means of measurement of meteorological parameters, the modernization of the exchange, processing and presentation of upper-air sounding data. Delivery of the Baikonur Cosmodrome. Participation in the tests. «(Director of the works is co-investigator of the project, Doctor of Engineering Science, Honored Inventor of RF, Ivanov V.E).

The team of authors of the project from UrFU for the last five years has more than 200 research papers indexed in Scopus and Web of Science, carried out 46 research projects and contracts, registered 17 computer programs, has more than 20 patents.



Key R&D projects performed at UrFU in last 6 years

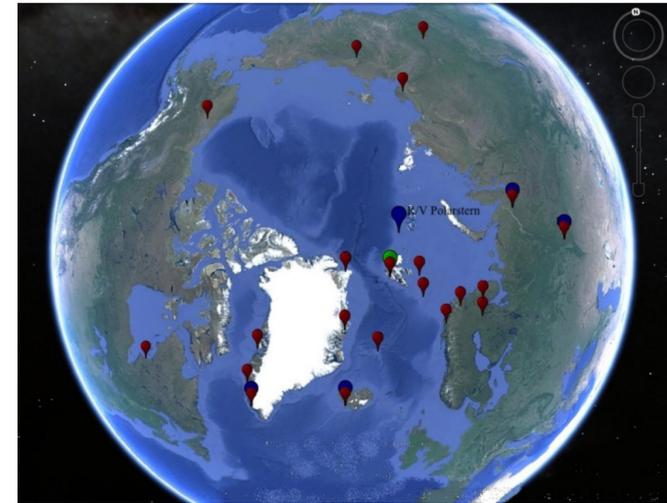
- «Creation and manufacturing of technical means of radio sounding of the atmosphere on the base of satellite navigation systems GPS/GLONASS for the modernization of technological base of ROSGIDROMET upper-air network» (Decree 218 grant of Ministry of Education, 2010–2012, 50 millions rubles)
- The development of upper-air sounding system for Space Centre “Vostochny” (The customer is Center for Exploitation of Space Ground-Based Infrastructure, 2013-2016, approx. 90 millions rubles)
- «Assembling the means of measurement of meteorological parameters, the modernization of the exchange, processing and presentation of upper-air sounding data. Delivery of the Baikonur Cosmodrome. Participation in the tests». (The customer is Center for Exploitation of Space Ground-Based Infrastructure 2014, ~1,5 millions rubles)
- Meteorological Service of preparation and the first (on the SC “Vostochny”) launch of “Soyuz-2-1A” and BV “Volga”, conducting commissioning work (The customer is Center for Exploitation of Space Ground-Based Infrastructure 2016 ~1 millions rubles)





Scientific novelty

- The creation of Russian segment of international pan Arctic network for atmospheric water cycle isotopic tracers monitoring;
- The creation of innovative mobile technologies for precise atmospheric measurements (temperature, humidity, greenhouse gases and their isotopologues contents) on the base of UAVs and radiosondes, organization of their industrial manufacturing;
- Verification/validation of modern supercomputer global climate models for multiscale climate forecasting in Arctic regions of the globe;
- Forecasting of climate and permafrost dynamics in Arctic.





Academic partners

International:

- Atmosphere and Ocean Research Institute, University of Tokyo, Japan — ARWU, World Rank: 9 (Natural Sciences and Mathematics);
- Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
- Laboratoire des Sciences du Climat et de l'Environnement/ Institut Pierre Simon Laplace, France
- Friedrich-Schiller-Universität-Jena, Germany;
- DLR — German Aerospace Center, Germany;
- Swiss Federal Institute of Technology Lausanne (École Polytechnique Fédérale de Lausanne), Switzerland - ARWU, World Rank: 49 (Physics), ARWU, World Rank: 35 (Computer), ARWU, World Rank: 23 (Chemistry);
- Autonomous University of Barcelona, Spain - QS Rank: 51-100 (Physics and Astronomy).

Russian:

- Institute of the Earth Cryosphere of the Siberian Branch of the RAS, Tumen;
- Melnikov Permafrost Institute of the Siberian Branch of the RAS, Yakutsk;
- Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow;
- Institute of Mathematics and Mechanics of the Ural Branch of the RAS, Ekaterinburg;
- Institute of Industrial Ecology of the Ural Branch of the RAS, Ekaterinburg;
- National Research Tomsk State University (participant of the Russian Academic Excellence Project).





Practical Significance

The present project corresponds to the strategy of research and technological development of the Russian Federation (Russian President's Executive Order on the Scientific and Technological Development Strategy, 01.12.2016 No. 642) in parts:

- Item II.15. the necessity of effective reclamation and usage of areas including the overcoming of imbalances of territorial social and economic development as well as a consolidation of Russian interests in the economic, scientific and military exploration of outer and air space, World ocean, Arctic and Antarctic;
- Item II.20. the linkedness of the Russian Federation territory through the creation of intellectual transport and telecommunication system as well as stationing and clear-cut leader ascendancy in developing the international transport and logistic systems, exploring and using the outer and air space, World ocean, Arctic and Antarctic.

The project results (data on climate change and permafrost melting) are required for the state and international institutes, economic entities of the Russian Federation in order to minimize their social and economic expenses while exploring the Arctic regions.

Technological novelty

- A method of application of the standard upper air atmospheric sensing data for precision sensing of trace gases and their isotopologues in the atmosphere;
- A technology of precision sensing of trace gases and their isotopologues in the atmosphere, as well as the temperature, humidity and air pressure using unmanned aerial vehicles and balloon radiosondes for measurements of atmospheric parameters in Arctic conditions;
- The Arctic expeditionary portable navigation system for atmospheric sensing;
- The development of technical facilities as well as technologies for operational measurements and control of the permafrost temperature containing the regular three-dimensional network of sensing detectors.





Industrial partners

JSC «RADIY» develops the manufacture of

- New lightened versions of radiosondes,
- The unmanned aerial vehicle for precision measurements of atmospheric parameters,
- The Arctic expeditionary portable navigation system for atmospheric sensing,
- The technical facilities of automatically operating ground measuring network analyzing the permafrost temperature profiles with a regular three-dimensional matrix of sensing detectors.

JSC Ural manufacturing company VECTOR develops the manufacture of

- The modified digital radiosonde locator Vektor-M,
- The wateractivated battery for radiosonde,
- The compact hydrogen generator for filling the balloons in cold conditions.

Federal State Unitary Enterprise «Center for exploitation of space groundbased infrastructure» provides

- The implementation of hardware and software complex for collecting, storing, processing and analyzing the multiyear meteorological data for the forecasting and missile launching purposes.



Project co-funding

- Estimated project start date (quarter.year) 1.2017;
- Estimated project completion date (quarter.year) 4.2021;
- Overall period of implementation of the project (months) 60;
- Subsidy of the Project of Competitiveness Enhancement of Universities (for the duration of the project) (millions rubles) 500.

Co-funding by partners (full project time) (millions rubles) 200

- Joint Stock Company Kaslinskii radio manufacturer (JSC «RADIY», Kasli, Chelyabinsk Region);
- Joint Stock Company Ural manufacturing company «VECTOR», Ekaterinburg ;
- Center for exploitation of space groundbased infrastructure (CESGI, Moscow).

Co-funding by UrFU (full project time) (millions rubles) 60.