Полвека Лаборатории математической экологии: биологический круговорот, «ядерная зима», климат мегаполиса

Гинзбург А.С., ***Логофет Д.О., Александров Г.А., Белова И.Н., Голубятников Л.Л., Докукин С.А., Завалишин Н.Н., Казанцев В.С., Помелова М.А., Александров Г.Г., Кривенок Л.А., Фалалеева В.А.***

Half Century of the Laboratory of Mathematical Ecology: biological cycles, "nuclear winter", urban climate

Ginzburg A.S., ***Logofet D.O., Alexandrov G.A., Belova I.N., Golubyatnikov L.L., Dokukin S.A., Zavalishin N.N., Kazantsev V.S., Pomelova M.A., Alexandrov G.G., Krivenok L.A., Falaleeva V.A.***

Kislovodsk, April 7, 2026

Abstract

In 1976, at the Computing Center of the USSR Academy of Sciences, on the initiative of Academician N.N. Moiseev, the Laboratory of Mathematical Ecology (LME) was established under the direction of Yu.M. Svirezhev. In the early 90s of the XX century, by the decision of academicians A.A. Dorodnitsyn and G.S. Golitsyn, the laboratory became part of the A.M. Obukhov Institute of Atmospheric Physics.

The LME scientists obtained general equations for the dynamics of evolving populations, developed a theory of the stability of biological communities, created a new type of Markov models for describing and predicting changes in vegetation cover under the influence of climate change, developed a model for estimating carbon flux in natural terrestrial ecosystems, performed work on the construction and calibration of mathematical models of the biological cycle, developed a nonlinear model of the joint cycle of organic substances and nitrogen in the swamp ecosystem.

Abstract

In the 80s of the XX century, the staff of the LME of the Central Research Center of the USSR Academy of Sciences, together with the scientists of the Institute of Atmospheric Physics, carried out pioneering work to assess the possible long-term climatic and environmental consequences of a large–scale nuclear conflict - "nuclear winter".

During the first quarter of the XXI century, the LME staff members along with traditional studies of the interaction of terrestrial ecosystems and climatic processes, carried out research on the urban climate, the role of anthropogenic heat fluxes in the formation of urban heat island, statistical models of gas and aerosol pollution of urban air, variability of oxygen and methane content in the urban atmosphere, climate continentality, the effects of heat waves on the stability of urban energy systems, criteria for preventive adaptation to climate change, the impact of the decline in economic activity during the COVID-19 pandemic on air quality in megacities, trends in the period of thermal comfort in the context of global warming.

Юрий Михайлович Свирежев

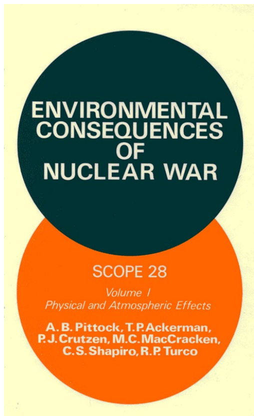
22.09.1938 - 22.02.2007

Ю.М. Свирежев и
Н.В. Тимофеев-Ресовский,
1960е годы

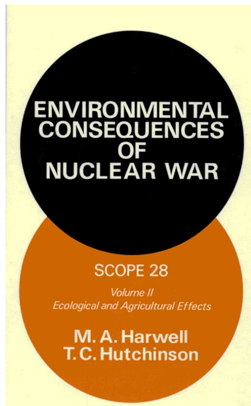
Ю.М. Свирежев в своем рабочем
кабинете
ПИК, Потсдам, осень 2005

Лаборатория математической экологии
(первые полвека, 2076-2026)

80-е годы XX века



Physical and Atmospheric Effects
(1986)

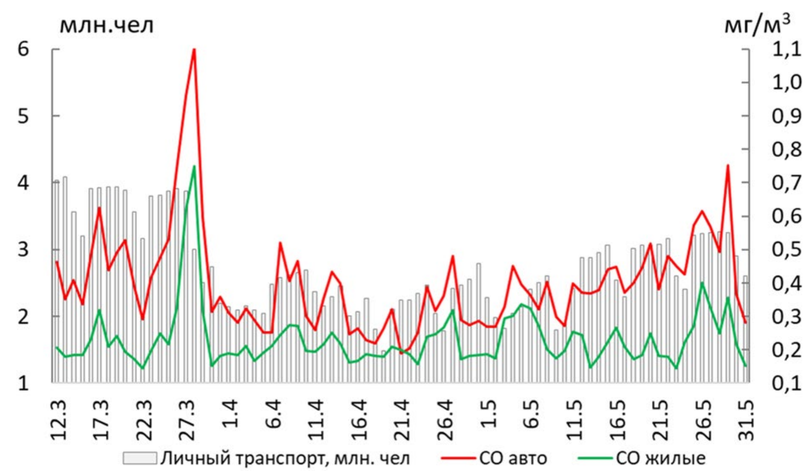


Ecological and Agricultural Effects
(1985)

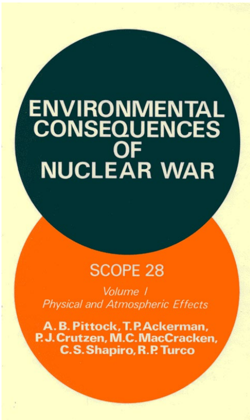
Участие сотрудников ЛМЭ (в составе ВЦ АН СССР) совместно с учеными ИФА в международном проекте исследования физических, атмосферных, экологических и сельскохозяйственных последствий гипотетической ядерной войны.

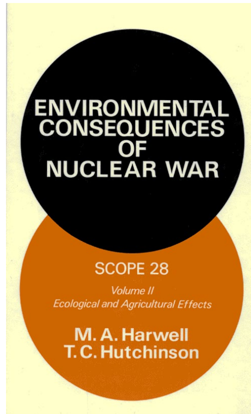
20-е годы XXI века

Исследование воздействия снижения экономической и транспортной активности во время карантина, вызванного пандемией COVID-19, на качество воздуха в Москве в сравнении с другими мегаполисами мира. Снижение концентрации CO вблизи автомагистралей (красная линия) и в жилых районах (зеленая линия), серым показана динамика пассажиропотока личного транспорта (млн. чел/сут). Результаты опубликованы журналах; Доклады РАН, Environmental International и Метеорология и гидрология.



The 80s of the XX century



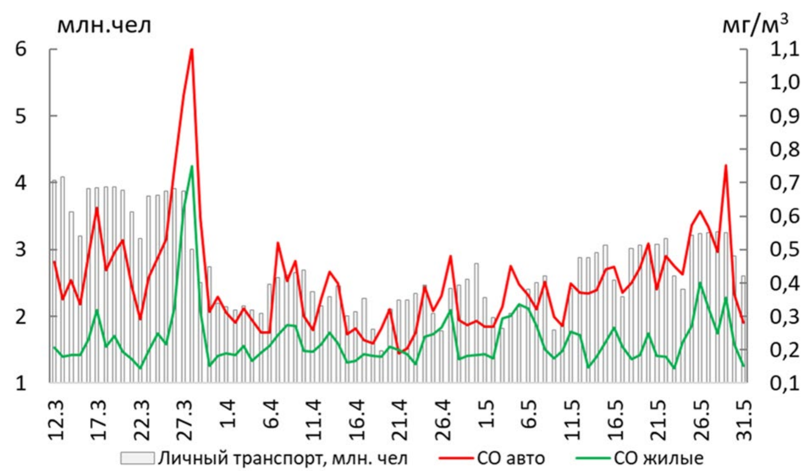


Physical and Atmospheric Effects (1986)	Ecological and Agricultural Effects (1985)

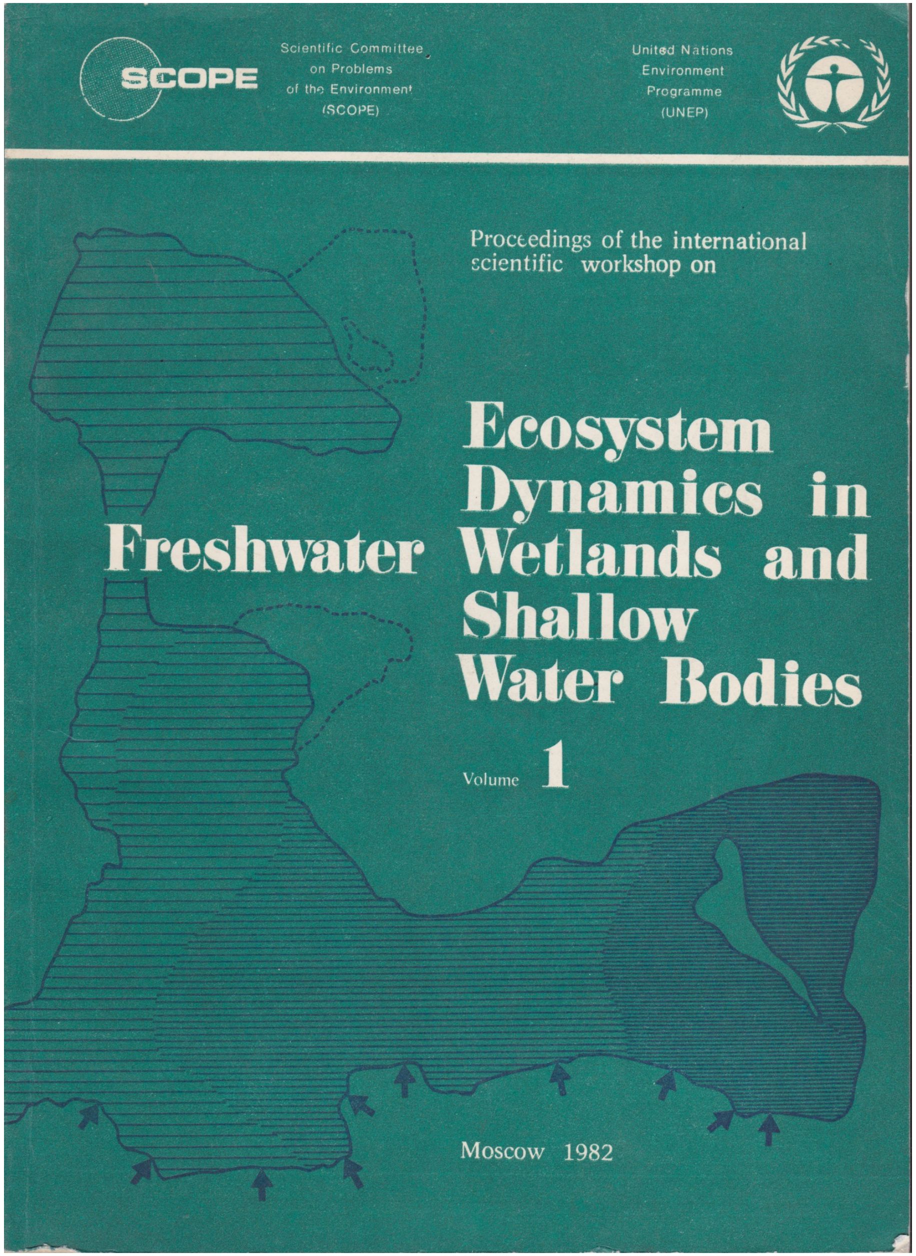
The participation of LME staff members (All-Russian Computing Center) together with IAPh scientists in an international project to study the physical, atmospheric, environmental and agricultural consequences of a hypothetical nuclear war.

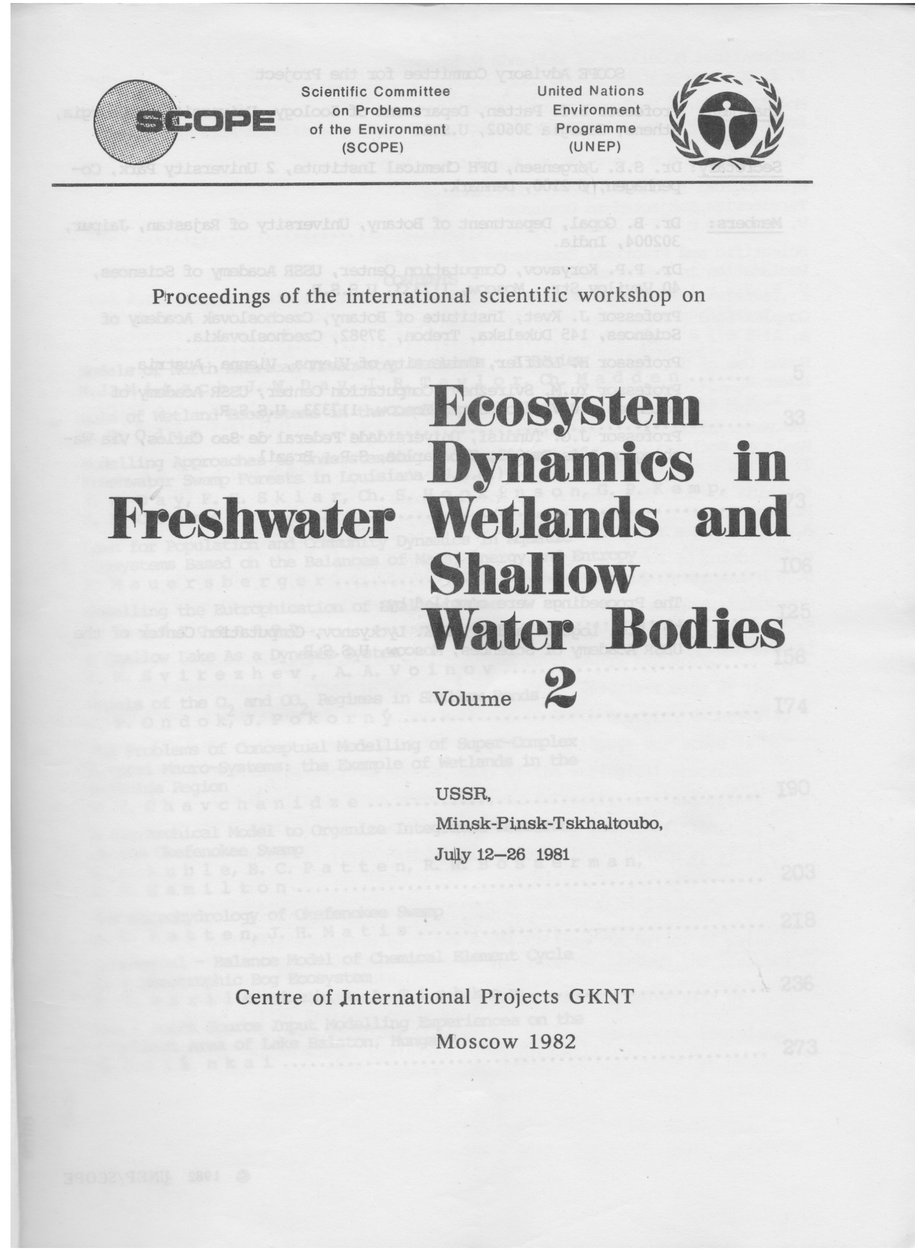
The 20s of the XXI century

Impact of the decline in economic and transport activity during quarantine caused by the COVID-19 pandemic on air quality in Moscow in comparison with other megacities of the world. A decrease in the concentration of CO near motorways (red line) and in residential areas (green line), gray shows the dynamics of passenger traffic of personal transport (million people/day).



LME International Activity, 80s




SCOPE

Scientific Committee on Problems of the Environment (SCOPE)

United Nations Environment Programme (UNEP)

Proceedings of the international scientific workshop on

Ecosystem Dynamics in Freshwater Wetlands and Shallow Water Bodies

Volume 2

USSR,
Minsk-Pinsk-Tskhaltoubo,
July 12–26 1981

Centre of International Projects GKNT
Moscow 1982

https://newyorkessays.com/essay-nuclear-winter-model-made-by-n-moiseev/

Ioannes Paulus II & Vladimir Alexandrov

Yu. Svirezhev & A. Ginzburg, Stockholm, 1988

A M B I O

A JOURNAL OF THE HUMAN ENVIRONMENT

Volume XI, Number 2-3, 1982. Special issue

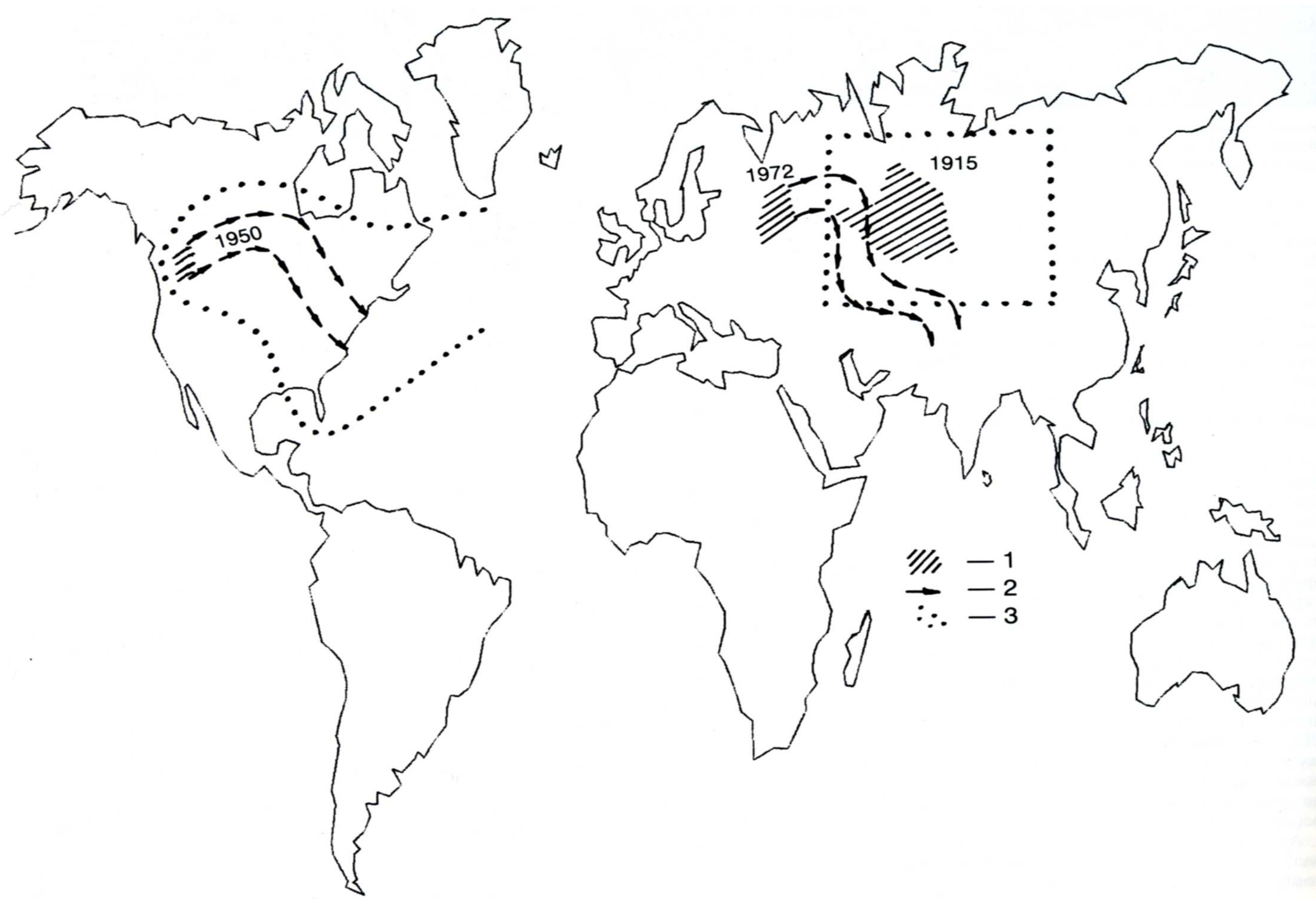
NUCLEAR WAR: THE AFTERMATH

Volume XVIII, Number 7, 1989

NUCLEAR WAR AND THE ENVIRONMENT

Ginzburg A. Ambio, 1989, v. XVIII, № 7, p. 384

Some greatest forest and peat fires in XX century



1 – fire areas, 2 - smoke paths, 3 – smoke clouds boundaries

Lord Byron "DREAM"

I had a dream, which was not all a dream.
The bright Sun was extinguished, and the stars
Did wander darkling in the eternal space,
Rayless, and pathless, and the icy earth
Swung blind and blackening in the moonless air;
Morn came and went--and came, and brought no day...

The habitations of all things which dwell,
Were burnt for beacons; cities were consumed,
And men were gathered round their blazing homes
To look once more into each other's face;
Happy were those who dwelt within the eye
Of the volcanoes, and their mountain-torch...

The winds were withered in the stagnant air,
And the clouds perish'd; Darkness had no need
Of aid from them--She was the Universe.

the night after…

Climatic
and biological
consequences of a
nuclear war

Moscow
Mir Publishers, 1985

Georgi Golitsyn
Corresponding Member of the USSR Academy of Sciences
Aleksandr Ginsburg
Candidate of Physical and Mathematical Sciences

Natural analogs of a nuclear catastrophe

Georgi Golitsyn. Born 1935. Graduated from Moscow State University in 1957. Doctor of Physics and Mathematics. Corresponding Member of the USSR Academy of Sciences. Head of the Department of Climate Theory, Institute of Physics of the Atmosphere, USSR Academy of Sciences. Specializes in oceanology and physics of the atmosphere. Member of the Soviet Scientists' Committee for the Defence of Peace Against Nuclear Threat

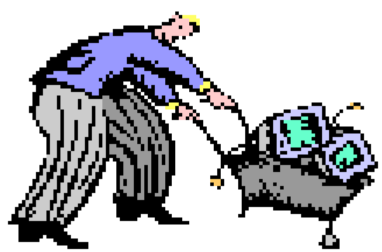
Aleksandr Ginsburg. Born 1944. Graduated from Moscow State University in 1966. Candidate of Physics and Mathematics. Deputy Head of the Laboratory of Climate Theory of the Institute of Physics of the Atmosphere, USSR Academy of Sciences. Specialist in physics of the atmosphere. Consultant to the Soviet Scientists' Committee for the Defence of Peace Against Nuclear Threat

Today mankind has reached such a level of development that it can modify natural situation on the Earth more than all catastrophes, known or conceivable, except perhaps for collision with a large celestial body. Beyond the direct material destruction and the immediate loss of human life by the hundreds of millions, a nuclear war causes radioactive contamination over vast land spaces, depletion of the protective stratospheric ozone layer, multiple urban and forest fires, and firestorms.

There are more or less relevant physical analogs in nature for some of the effects that might be expected as a result of a nuclear war. On the Earth, such catastrophic natural phenomena include earthquakes, floods, droughts, falls of large meteorites, volcanic eruptions, and massive wildfires. On Mars, there are global dust storms. Investigation of these phenomena provides a better understanding and more accurate conception of the possible consequences of a nuclear war.

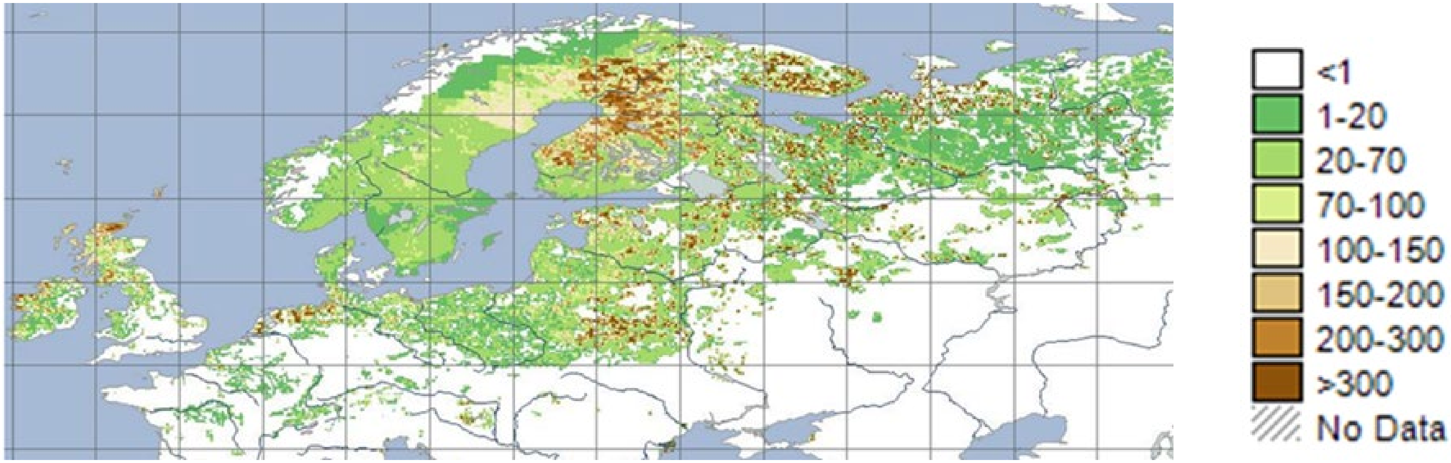
The nuclear war would be unlike any war or natural disaster known to us from past history due to the massive and unpredictable secondary long-term effects. They are consequences which, in the case of a nuclear war, would be critical for the immediate survivors of nuclear blasts. Far from all of the likely global consequences—human and ecological—of a nuclear war are clearly understood today. But it is quite obvious that certain aftermaths leave no room for illusions about a favourable 'post-war' future, even for a few remote regions of the Earth. A nuclear war would spell catastrophe for everyone without exception.

1989–1990



Natural Ecosystems: Observations and Modeling

During the current interglacial period, wetland ecosystems of the northern latitudes remove carbon dioxide from the atmosphere at a rate of 160-400 billion tons per 1,000 years. Since the maximum carbon stock (PCD) in these ecosystems can reach 875±125 billion tons, and the current carbon stocks in them already amount to 547±74 billion tons of carbon, they can accumulate an additional 328±200 billion tons of carbon, thereby removing 1,200±730 billion tons of carbon dioxide from the atmosphere.



Potential carbon stocks in northern peatlands per area of a gridcell in Europe (GtC per square kilometer), https://doi.org/10.5194/bg-17-47-2020

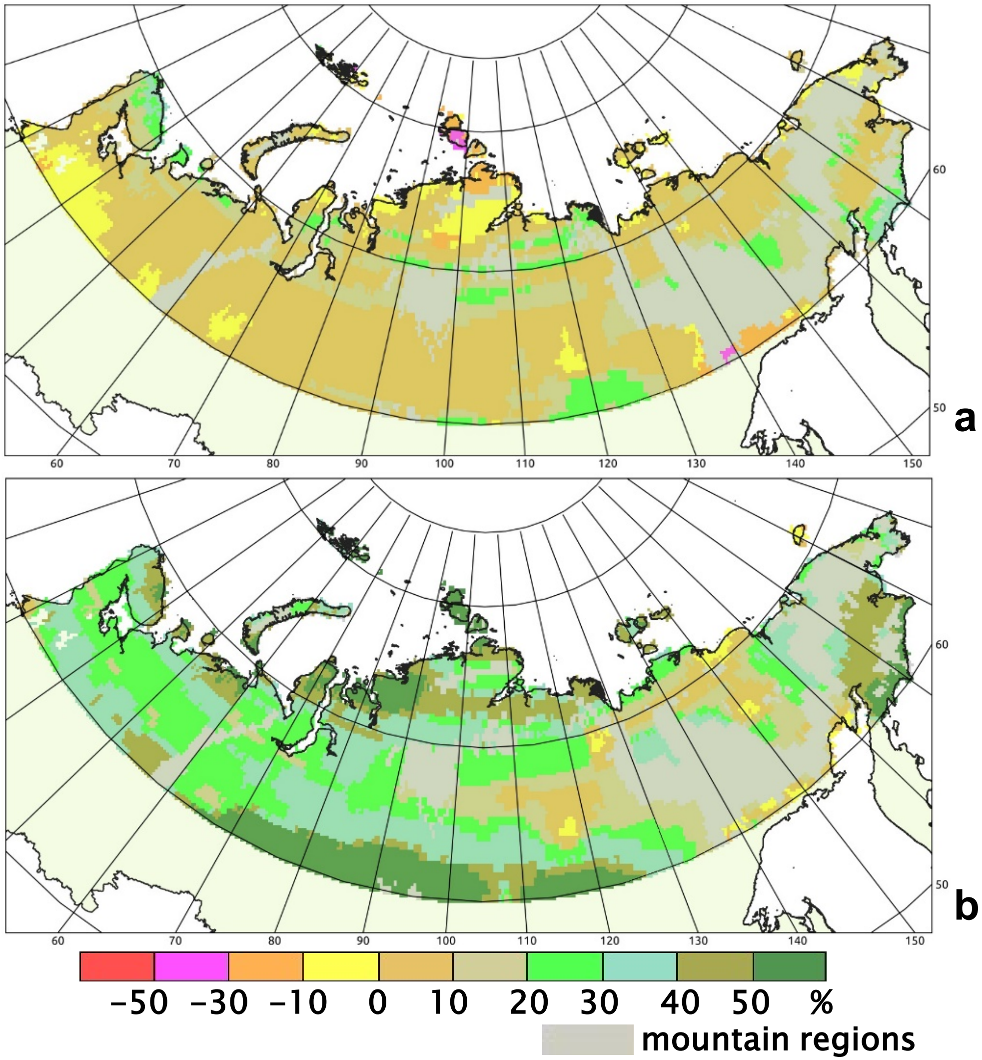
Methane Emissions from Tundra Ecosystems in Western Siberia and Northern Lakes in Karelia

Methane exchange between the atmosphere and ecosystems were investigated in the southern tundra (Western Siberia) and at taiga lakes in the Paanajärvi National Park (Karelia).

Over the warm season, the medians of methane fluxes have the values ($mgCH_4/m^2/h$):
0.02 for peat bog uplands, 2.8 in waterlogged hollows, -0.02 for dry land, and 1.2 for inside wetland lakes (tundra, Western Siberia);
4.5 for deep water and 14.9 for coastal shallow water (taiga lakes, Karelia).

Dry land tundra serves as a sink for atmospheric methane during the warm period.

Climate Change Impact on NPP Dynamics in Russia's Northern Ecosystems

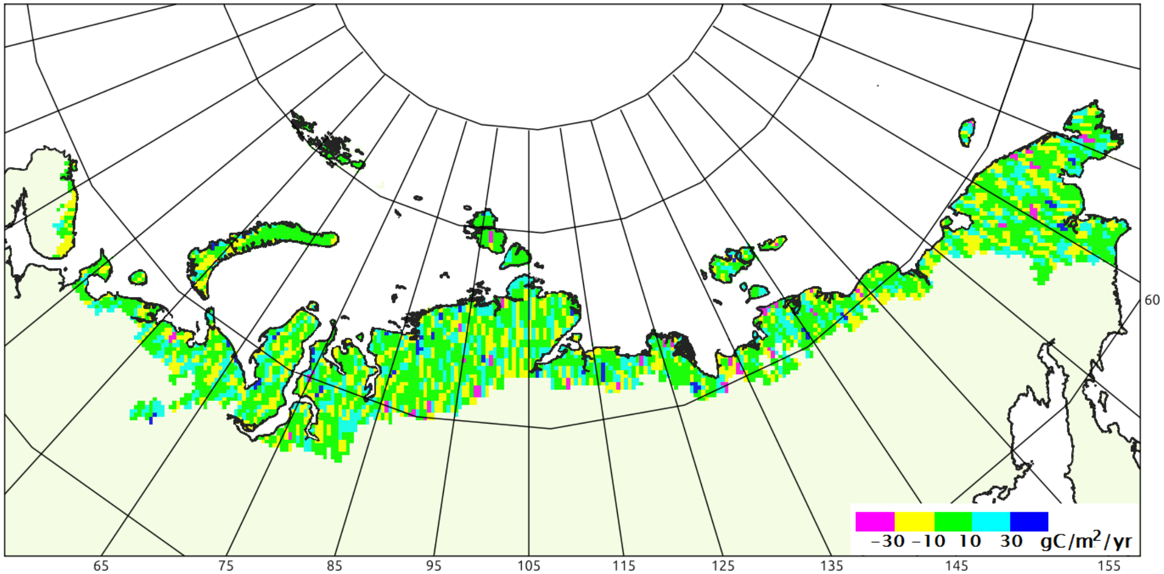


NPP changes by the end of the 21st century
for climate scenarios
SSP1-2.6 (a) and SSP5-8.5 (b)

Using the bioclimatic vegetation productivity model (NPP-model), we estimated NPP changes in Russia's northern ecosystems under climate change by the end of the current century. The obtained results suggest that the annual carbon sequestration by tundra and boreal vegetation in Russia would increase by 6-45% compared to data for the late 20th century.

Tundra Ecosystems in Russia: Carbon Balance Change for 1980–2020

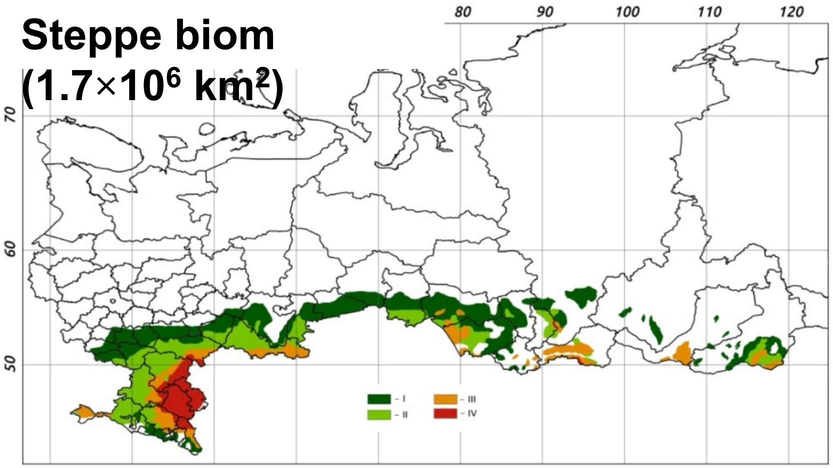
Within the framework of the project “Russian System of Climate Monitoring" we analyzed the dynamics of carbon pools and fluxes in tundra and forest-tundra ecosystems of Russia. It is shown that, between 1980 and 2020 the carbon balance of the studied ecosystems decreased by 9% under climate change.



Changes in the carbon balance of tundra ecosystems in Russia for 1980–2020

Natural Steppe Ecosystems in Russia: Carbon Fluxes & Balance

Steppe biom (1.7×10^6 km^2)

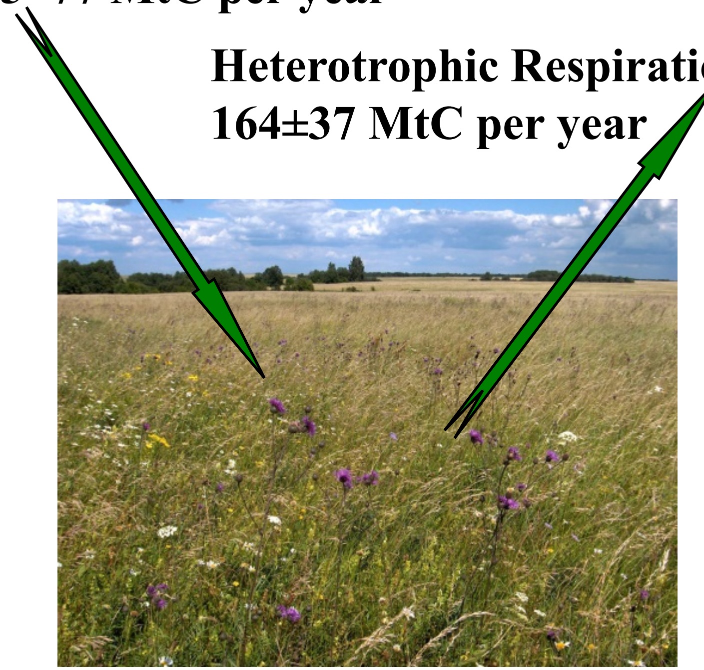


Types of steppes: I - meadow; II - true; III - dry; IV – desert.

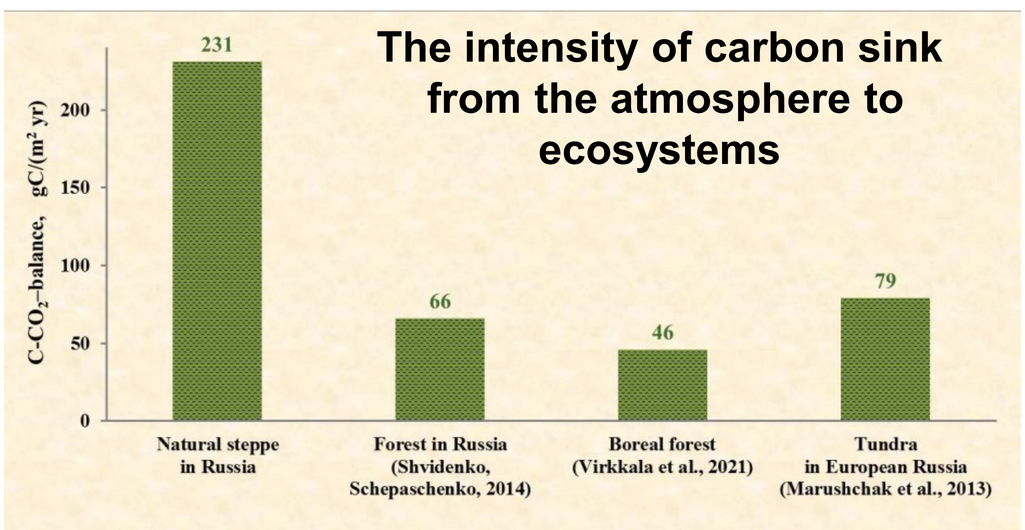
Natural steppes occupy 0.5×10^6 km^2

Net Primary Production 275±77 MtC per year

Heterotrophic Respiration 164±37 MtC per year



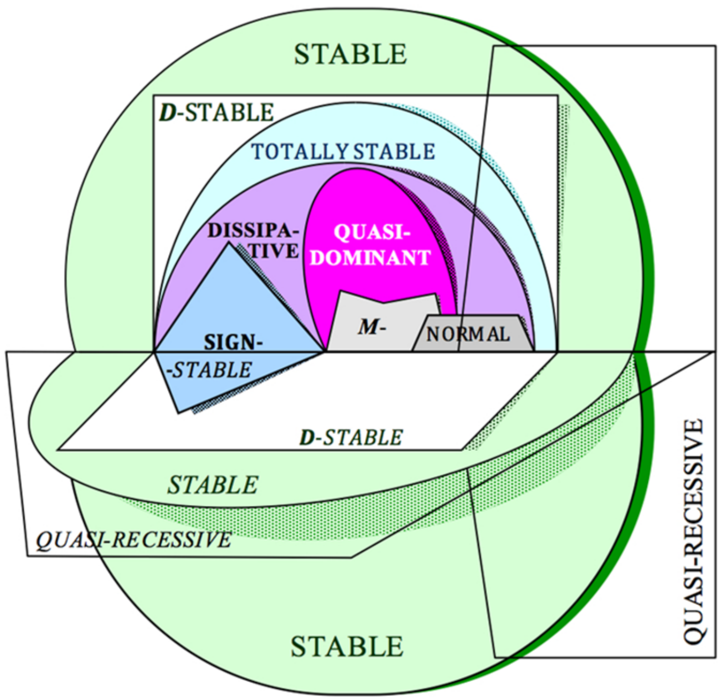
The intensity of carbon sink from the atmosphere to ecosystems



The annual accumulation of carbon dioxide in the natural steppe ecosystems of Russia is evaluated as 111±97 MtC.

Natural Ecosystems: Observations and Modeling Theory Development

“Matrix Flower" is a diagram of logical relationships among specialized stability concepts, more restrictive ones than the standard Lyapunov notion. Those concepts arose in applications, such as mathematical ecology, mathematical economy, etc. Flat inclusion/intersection diagrams common in set theory are given here a 3rd dimension by the signs of matrix diagonal entries, the signs being of crucial importance in stability analysis. To form the Flower, a number of new problems were solved in matrix theory .



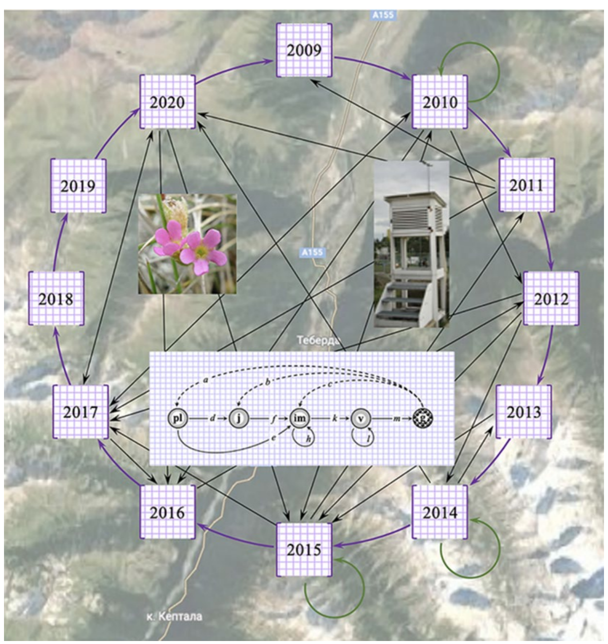
Today, only 10 persons in the world do comprehend the mathematical essence of the Matrix Flower and how it is really constructed.

Far more people accept the theory of non-adaptive, non-Darwinian selection, i.e., selection at the level of biological communities, and the Matrix Flower is a key tool in this theory.

Matrix Flower (Logofet, 2005, Fig. 4)

Natural Ecosystems: Observations and Modelling

Matrix models of population dynamics for alpine short-lived perennial plant species have been developed. The Life Cycle Graph for the species organisms has been constructed as a condensed representation of ontogenetic stages from seedling to death. This graph defines the pattern of the population projection matrix up to its entries' quantitative values. Those entries are uniquely calibrated from the annual long-term (13 years) observations at permanent plots in the Northwest Caucasus. Recovered from those data, a Markov chain has drastically improved the estimates of the population stochastic growth rate in the random environment by the Monte Carlo technique. The picture background represents a relief map of the mountain area where the observations have been carried out.

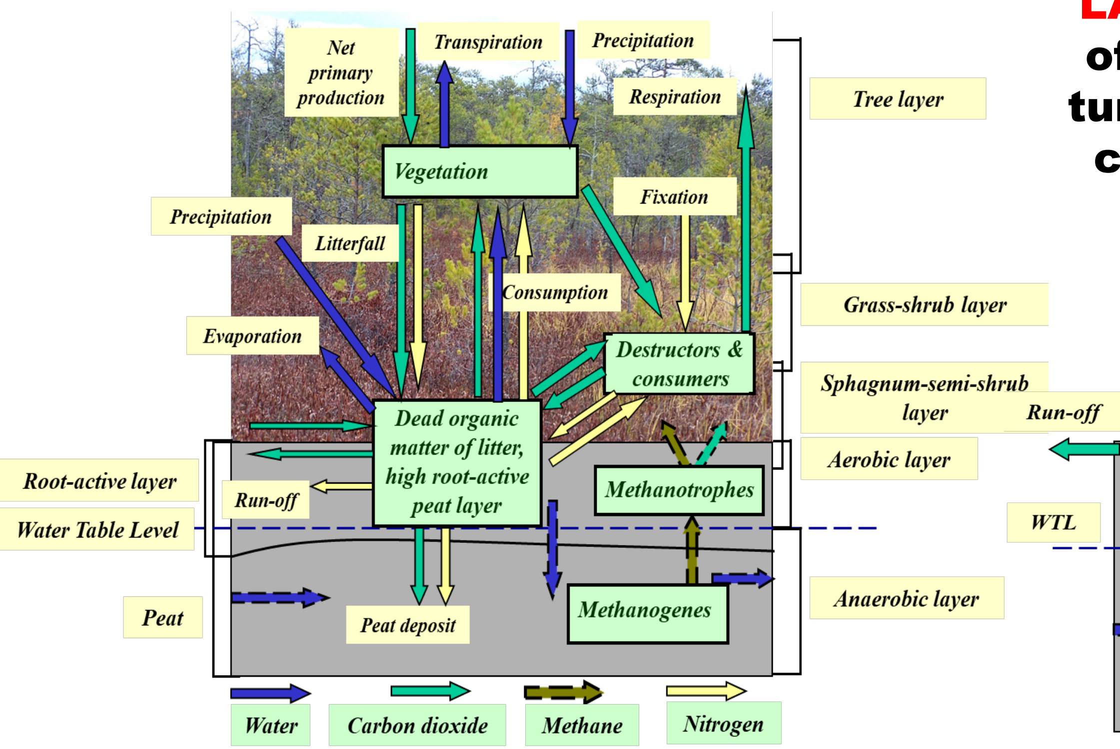


Graphical Abstract, Logofet et al., 2023

Natural ecosystems: observations and modelling

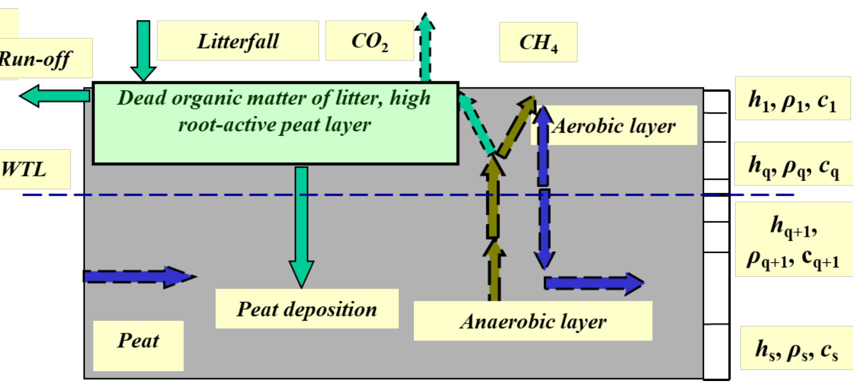
Exergy as the maximal work for transforming an ecosystem into thermodynamic equilibrium with its environment is useful for ecosystem dynamics analysis. Variational principle of maximizing the velocity of exergy change allows one to create and calibrate the set of biologically well-posed mathematical models of biological turnover in terrestrial ecosystems. Peatlands of the Northern Euroasian boreal zone are subjects of this modelling approach under climate change scenarios.

Peatland ecosystem structure



COmplex MOdel of BOg LAndscapes (COMBOLA) is a set of dynamic models of biological turnover in a peatland ecosystem combined with processes in its peat deposit.

Peat deposit layers



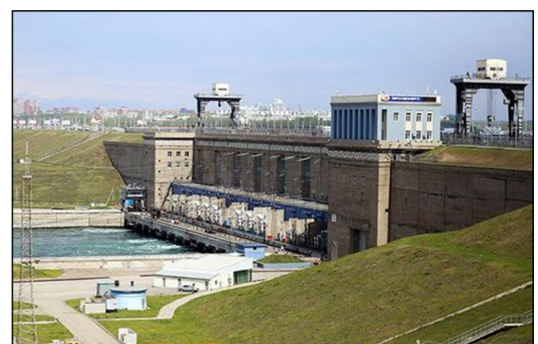
Natural ecosystems: observations and modelling

Angarsk cascade of hydroelectric power plants (HPP)

13 field campaigns since 2020

Ust'-Ilimsk HPP Reservoir 1922 km^2

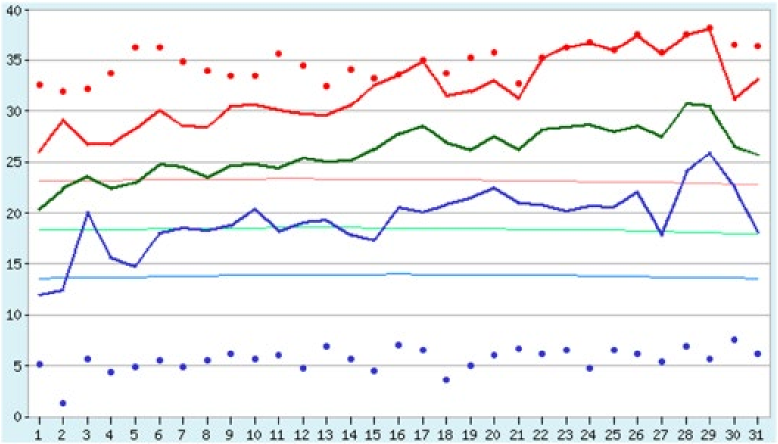
Bratsk HPP Reservoir 5480 km^2

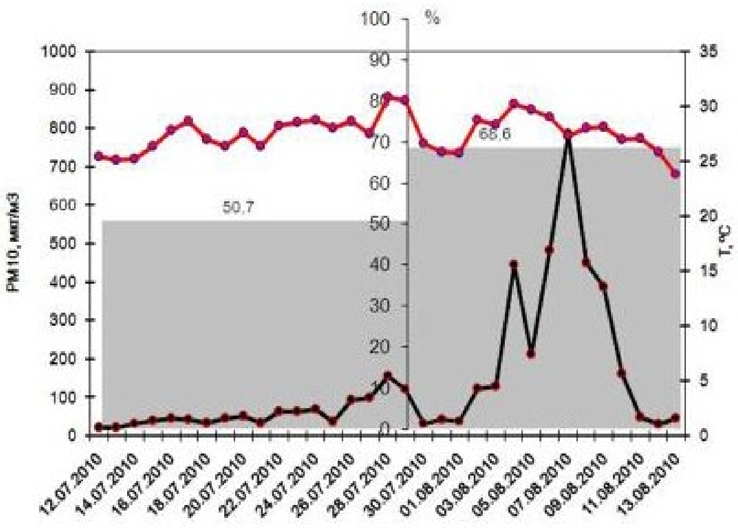


Irkutsk HPP Reservoir 154 km^2

Megapolis ecology and climate

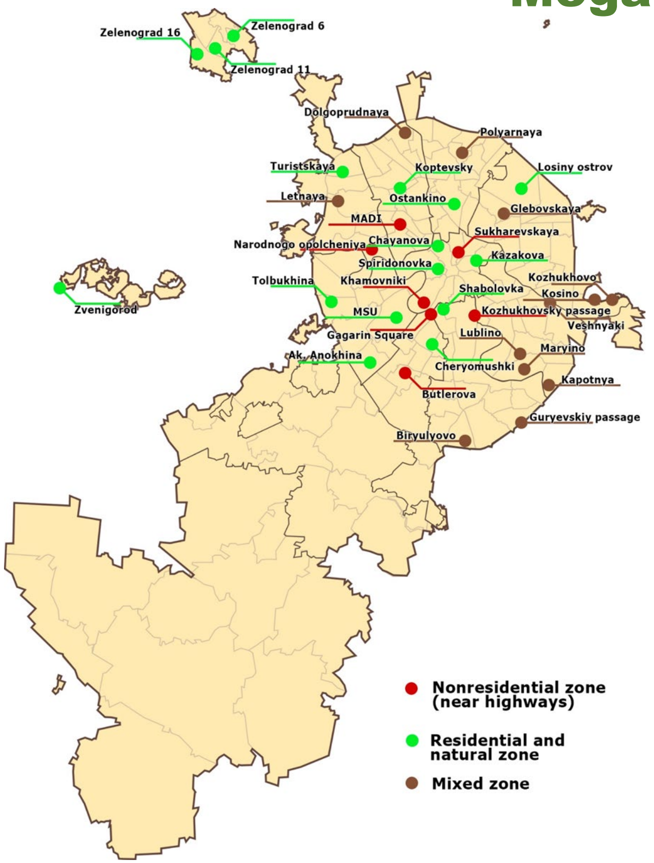
The estimate of the maximum possible air temperature in the Moscow region under conditions of a stable anticyclone turned out to be close to the temperatures observed in the summer of 2010.

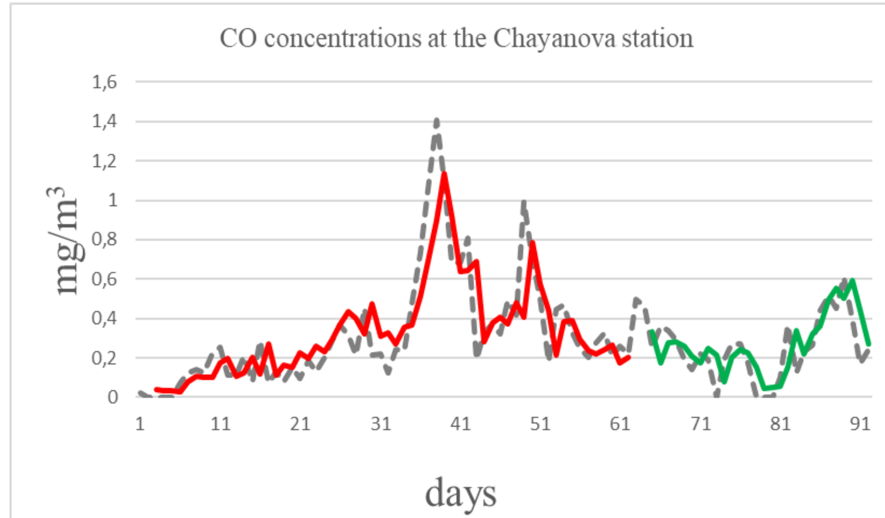




The extremelly hot summer of 2010 in Moscow is a prolonged heat wave with an average daily temperature of over 25° C and smoke from wildfires led to an increase in deaths in July and August by more than one and a half times compared with the average values.

Megapolis ecology and climate



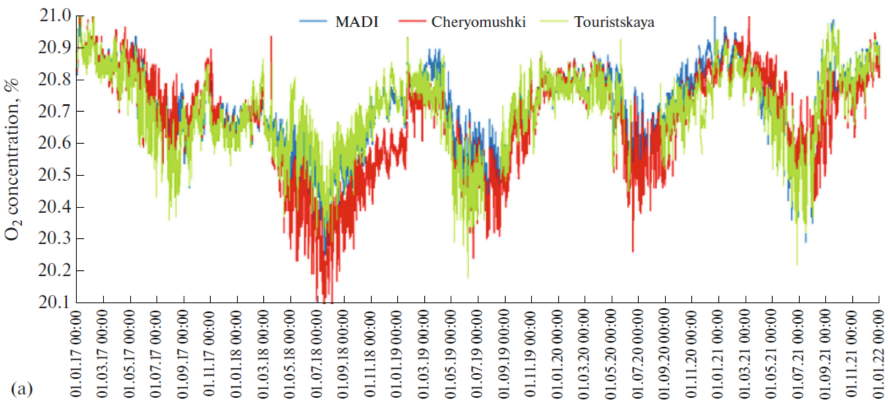


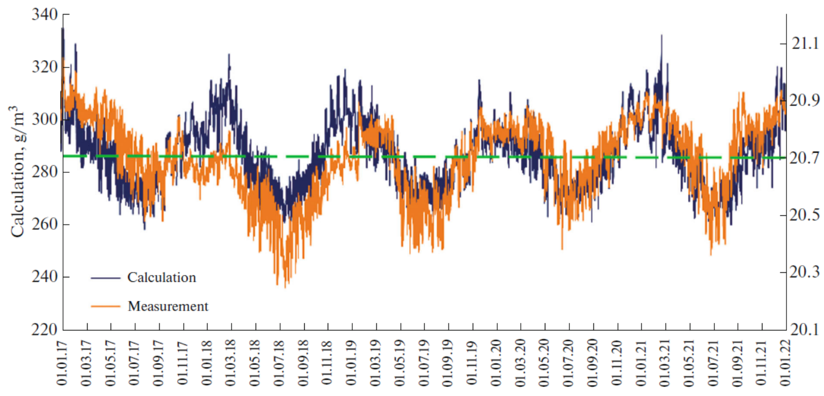
CO concentrations in the period from May to July 2020: the gray dotted line is the observed values, the red line is the simulated values for the period from May to June, the green line is the values predicted for July

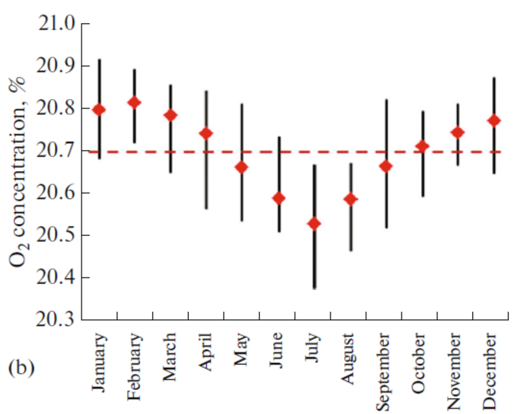
$$Y_i = a_1 y_{i-1} + a_2 y_{i-2} + a_3(v_i + a$$

Y_i is predicted concentration, y_{i-1} and y_{i-2} are measured concentrations on the two previous days, v_i is the average daily wind speed, T_i – the daily mean air temperature, a_1, a_2, a_3,a_4, a_5 and a_6 are the coefficients that provide the best approximation.

Megapolis ecology and climate



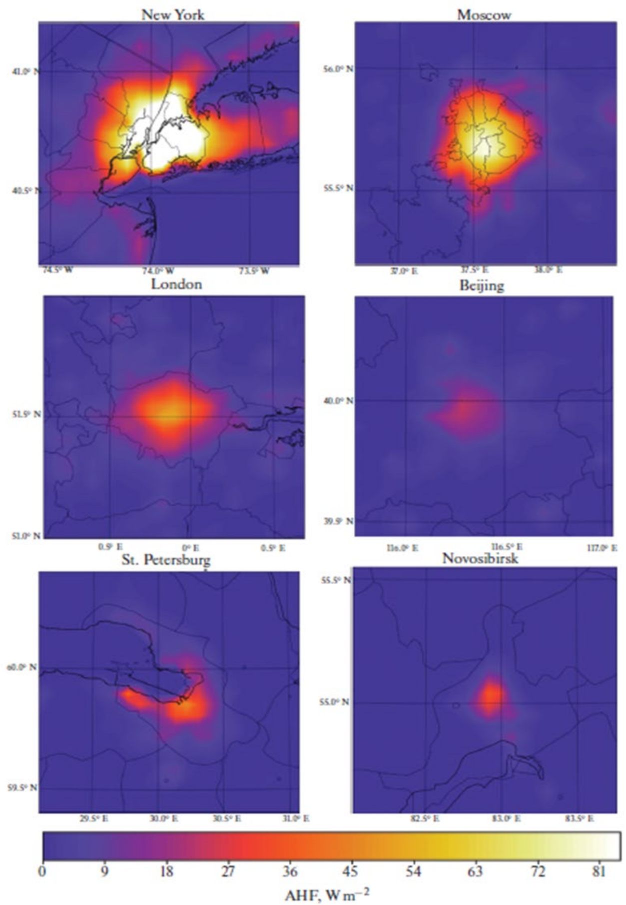


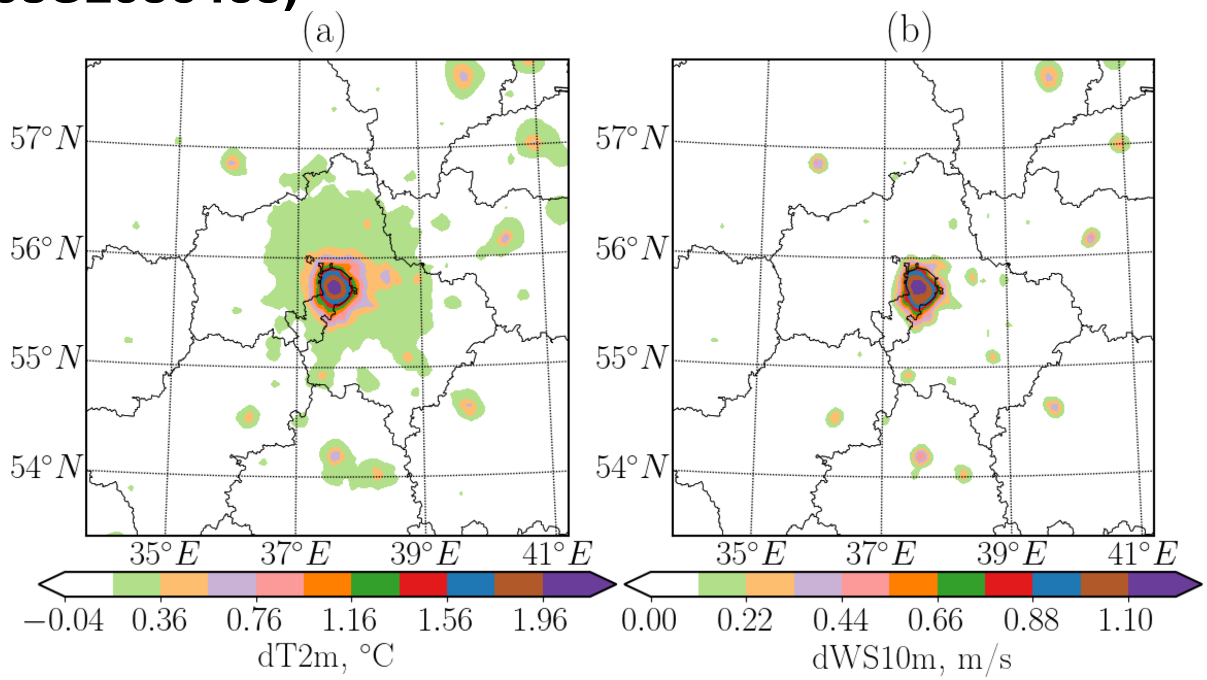


The average measured value of oxygen content in the surface air in Moscow over 5 years (2017-2021) of observations is 20.70 ± 0.12%, calculated from weather data 285 ± 13 g/m^3. The content of O_2 in the surface air of the city during the year is maximal in the cold months and minimal in the warm months reflecting the seasonal course of air temperature.

Megapolis ecology and climate

Urban agglomerations largely shape their own climate through anthropogenic heat fluxes (AHF). Left figure shows AHF fields in large cities in Russia and around the world — New York, Moscow, London, Beijing, St. Petersburg, and Novosibirsk. Data obtained from the TERRA-URB urban parameterization in 2018 (based on data from Flanner «Integrating anthropogenic heat flux with global climate models» (2009) http://dx.doi.org/10.1029/2008GL036465)

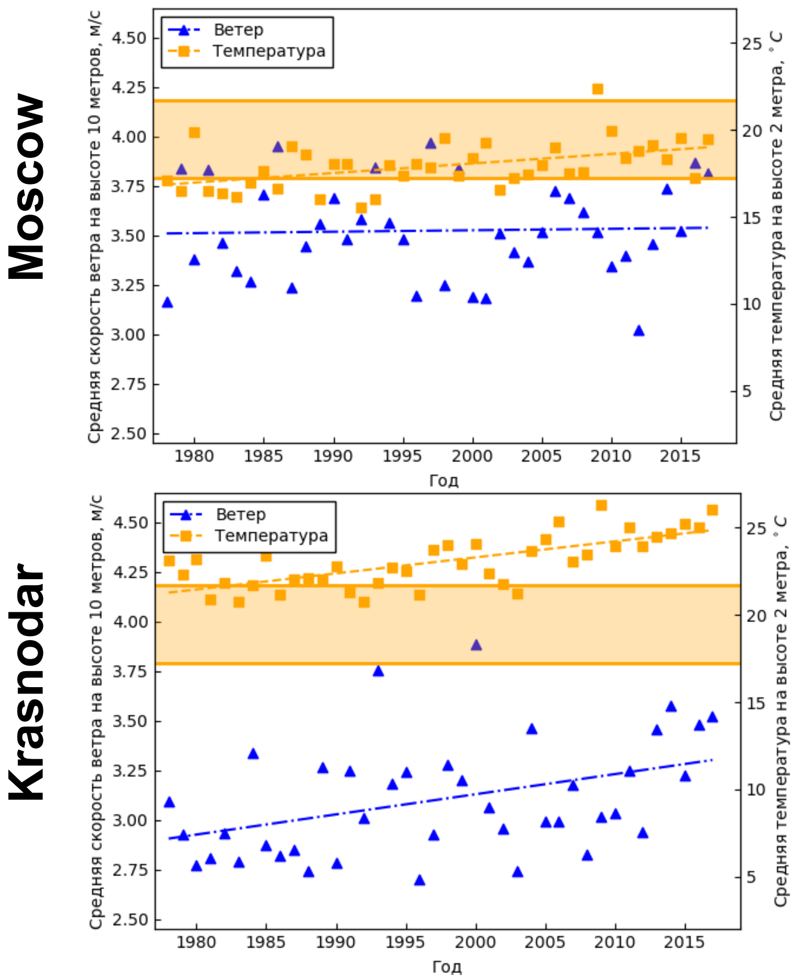




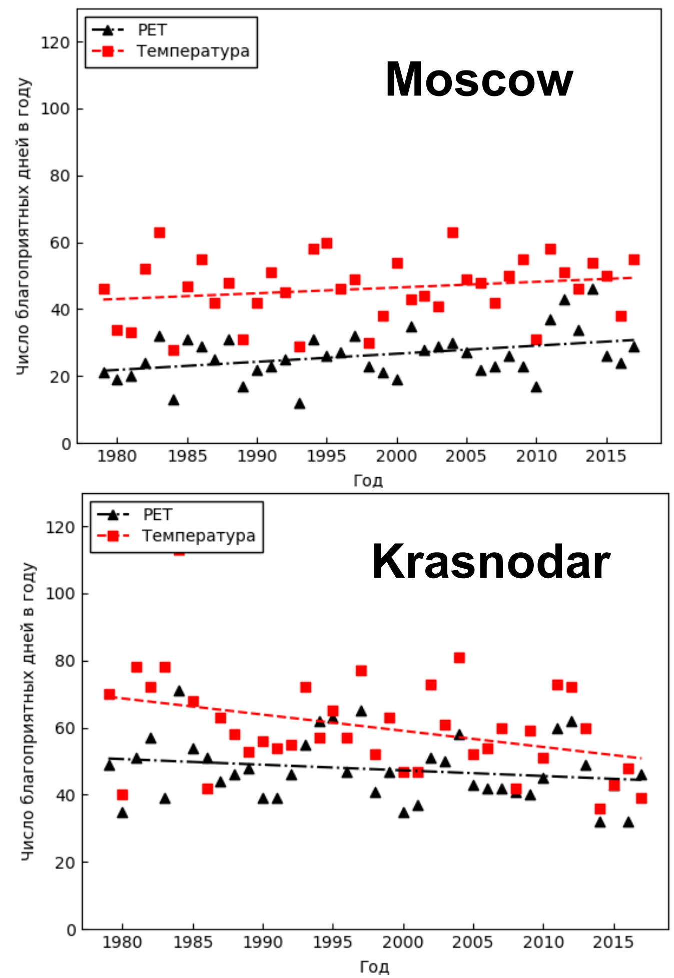
Temperature and wind changes under the influence of anthropogenic heat fluxes. Simulations using the COSMO-CLM model with TERRA-URB urban parameterization.

Megapolis ecology and climate

Surface and physiologically effective temperature (PET) trends study revealed a significant impact of wind speed changes in various climatic zones on the duration of thermal comfort. The combination of positive trends in air temperature and wind speed leads to a negative trend in the number of thermal comfort days in the south of European Russia.



Trends in average summer values of surface air temperature (squares) and surface wind (triangles)



Trends in the number of thermal comfort days calculated based on measured air temperature (squares) and PET (triangles)

Thematic issue “Russian Meteorology and Hydrology” 2024 No. 2

“Weather and climate change: impact on public health"

S. N. Kulichkov, G. A. Bush, A. I. Alekhine, V. G. Perepelkin, A. S. Ginzburg, F. T. Ageev, M. D. Smirnova

On the issue of the influence of atmospheric pressure fluctuations on the hospitalization of patients with cardiovascular diseases

A.S. Ginzburg, I. N. Belova, S. A. Dokukin, V. A. Falaleeva

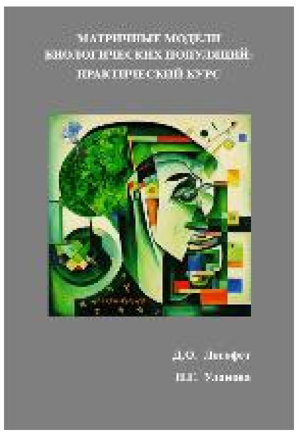
The influence of the wind speed trend on the duration of the thermal comfort period in the European part of Russia in recent decades

Y. O. Shuvalova, A. S. Ginzburg

Air quality in Moscow during the COVID-19 lockdown in comparison with other regions of the world

**Как рассказывать о климате?
Рекомендации и ориентиры для научных журналистов и коммуникаторов.**

**А.В. Чернокульский, А.С. Гинзбург, А.В. Давыдова, О.Г. Добровидова, Т.А. Нестик, А.А. Скворцов.
ГЕОС, 2021. 58 с.**



**Матричные модели биологических популяций: практический курс
(учебное пособие)**

**Д.О. Логофет, Н.Г. Уланова
«МАКС Пресс», 2024**

**Доклад Российского экологического общества
«Адаптация к изменению климата: риски и возможности»**

**Научный руководитель проекта – А.С. Гинзбург
2025**

Volume 95, Number 4
August 2025

ISSN 1019-3316

HERALD OF THE RUSSIAN ACADEMY OF SCIENCES

Herald of the Russian Academy of Sciences

Vol. 95, No. 4, August 2025

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Volume 95, No. 4, 2025

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Спасибо за внимание!

До встречи на следующем юбилее

Thanks for your attention!

See you on the next anniversary