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Mathematical Modeling of Climate, Dynamics Atmosphere and Ocean: to the 95th Anniversary of G. I. Marchuk and the 40th Anniversary of the INM RAS

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Abstract—Introductory article on the issue of the journal Izvestiya RAN, Atmospheric and Oceanic Physics, 2020, vol. 56, no. 3 dedicated to the 40th anniversary of the Marchuk Institute of Numerical Mathematics of the Russian Academy of Sciences (INM RAS) and the 95th anniversary of the birth of its founder—Academician G.I. Marchuk. The main features of the scientific-organizational and pedagogical activities of G.I. Marchuk, who had a significant impact on the development of modern geophysical fluid dynamics, physics of the atmosphere and ocean, and their reflection in the INM RAS research and development activities over a 40-year period.

Keywords: atmosphere and ocean physics, mathematical modeling, numerical mathematics, algorithms

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Remember now your Creator in the days of your youth...
While the sun, or the light, or the moon, or the stars,
be not darkened, nor the clouds return after rain...
Or ever the silver cord be loosed, or the golden bowl be broken, or
the pitcher be broken at the fountain, or the wheel broken at the cistern...
The words of the wise are as goads, and as nails fastened
by the masters of assemblies, which are given from one shepherd.
(Ecclesiastes, XII:1-6, 11)

The issue of the journal is dedicated to the 40th anniversary of the Marchuk Institute of Numerical Mathematics of the Russian Academy of Sciences and the 95th anniversary of the birth of its founder—Academician Gury Ivanovich Marchuk.

The eminent scientist and organizer, teacher and public figure, Guri Ivanovich Marchuk left a bright mark in the development of several areas of modern science, the organization of scientific institutes and educational departments of Soviet and Russian Universities. We will single out the five keystones of his scientific, organizational, and pedagogical activity—two Institutes and three university Chairs. In the Novosibirsk Academgorodok, these are the Computing Center of the Siberian Branch of the USSR Academy of Sciences and the Chair of Mathematical Methods in Dynamic Meteorology at the Mechanics and Mathematics Department of Novosibirsk State University, with a major in Computational Mathematics, organized in 1964 (it was included in the Chair of Computational Mathematics in 1972); in Moscow—the Department (in 1991, the Institute) of Numerical Mathematics of the Academy of Sciences of the USSR (later the Russian Academy of Sciences) and the Chair of Mathematical Modeling of Physical Processes at the Department of Problems of Physics and Energetics of the Moscow Institute of Physics and Technology (MIPT), and also organized in 2004, the Chair of Computational Technologies and Modeling at the Faculty of Computational Mathematics and Cybernetics of Lomonosov Moscow State University (MSU).

Works by G.I. Marchuk in the field of computational mathematics [1–3] and mathematical modeling of climate, atmospheric and ocean dynamics [3, 4], developing of national scientific traditions [5–7], had a significant impact on modern science. First of all,

this refers to the central direction of atmospheric and ocean physics –mathematical modeling and numerical solution of weather prediction and climate change problems. The deep connection of numerical mathematics and geophysical fluid dynamics is the main feature of the work of his scientific school and the Institute of Numerical Mathematics (INM) of the Russian Academy of Sciences founded by him.

Among the scientific studies of G.I. Marchuk and his scientific school in the field of geophysical fluid dynamics, the atmospheric and oceanic physics can distinguish several main directions. This is a simulation of the Earth's climate system; mathematical problems of climate theory; adjoint equations and methods of the control theory in geophysical fluid dynamics problems; mathematical simulation and numerical algorithms of atmospheric and oceanic dynamics.

It should be noted an important feature of the organizational activities of G.I. Marchuk, to this day manifesting itself in the traditions of the scientific teams founded by him. It is expressed in the creation of a key science group, which is taken to solve extremely large, multidisciplinary problems [8–10]. The group, as a rule, small and mobile, brings together both experienced researchers, graduate students, and students. The solution of extremely large problems requires, in addition to the key group, the involvement of specialists of various scientific profiles from other research institutes and universities, and the creation of external scientific teams. On this basis, the scientific directions, structure and modern research staff of the Marchuk Institute of Numerical Mathematics are formed.

Guri Ivanovich said that in its activities, the INM RAS should follow the following principles: be aimed at solving important urgent problems; consist of three almost equal parts uniting researchers, graduate students and students; instead of traditional laboratories and departments, have a more flexible structure—creative research teams, the composition and subjects of which can change over time, following the challenges of modern science [11, 12].

The main research directions of the INM RAS are related to the scientific interests of its creator. In 1980 there were four of them: numerical mathematics; simulation of atmospheric and oceanic dynamics; mathematical immunology and medicine; parallel computing. Currently, the research areas of the Institute has changed somewhat. Now it is computational mathematics, tensors and optimization methods [13–19]; methods and technologies of numerical mathematics and problems of biology and medicine [20, 21]; modeling the Earth system dynamics and environmental problems [22–25]; mathematical modeling of the atmosphere and ocean dynamics; and the variational data assimilation problems [10, 12, 17, 26–29].

Celebrating its 40th anniversary in 2020, the Marchuk Institute of Numerical Mathematics RAS is currently in consortium with Lomonosov Moscow State University, Keldysh Institute of Applied Mathematics RAS is part of the Moscow Center for Fundamental and Applied Mathematics.

The research directions of the INM RAS correspond to the Program of Fundamental Studies of the State Academies of Sciences for 2013–2020. In addition to 16 basic research topics, the Institute over the past 5 years has completed more than 100 various projects under the Programs of the Presidium and Departments of the Russian Academy of Sciences, Federal Target Programs, Programs of Ministries and Departments, Russian Foundation for Basic Research, Russian Science Foundation, and International Programs (https://www.inm.ras.ru).

In the field of geophysical fluid dynamics, climate theory and environmental problems, the Institute actively cooperates with leading scientific teams of the Obukhov Institute of Atmospheric Physics RAS, Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Institute of Monitoring of Climate and Ecological Systems SB RAS, Shirshov Institute of Oceanology RAS, Moscow State University, Hydrometeorological Center of Russia, Marine Hydrophysical Institute RAS, Nuclear Safety Institute RAS, Zubov's State Oceanographic Institute and other organizations.

Along with scientific research, the Institute pays more attention to scientific and pedagogical activities in the framework of the graduate school of the INM RAS and its two basic Chairs: Computing Technologies and Modeling in Geophysics and Mathematics—at the Department of Control and Applied Mathematics of the Moscow Institute of Physics and Technology and Computing Technologies and Modeling—at the

Faculty of Computational Mathematics and Cybernetics of Moscow State University [16, 30]. Of the 55 scientific staff at present, 29 graduates of the Moscow Institute of Physics and Technology and 11 at Moscow State University work at the INM RAS.

The joint efforts of researchers, graduate students and students at the INM RAS develop ideas that were laid down by the founder of the Institute, Academician Gury Ivanovich Marchuk.

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