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## **SOME CONTEMPORARY DIRECTIONS IN THE INTERNATIONAL SCIENTIFIC ACTIVITIES OF THE S. SUBBOTIN INSTITUTE OF GEOPHYSICS OF THE NATIONAL ACADEMY OF SCIENCES OF UKRAINE**

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**Abstract.** The S. Subbotin Institute of Geophysics has considerable experience in successful international cooperation. By the early 2010s, a cycle of geophysical international studies conducted in Central and Eastern Europe had been almost entirely completed. It is crucial to note that these studies investigated various types of tectonic structures and geodynamic regimes of the Earth's continental lithosphere. The primary sources for these studies were the reports on the Institute's activity and scientists' summarizing articles. The Institute's experience in international cooperation in previous years is covered in detail in publications: "Integration of the Institute of Geophysics of the National Academy of Sciences of Ukraine into Global Science" by V. Starostenko and E. Isichenko, and "International Cooperation of the S. Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine in 2010–2020" by V. Starostenko, O. Rusakov, and A. Yakimchik. The purpose of the article is to analyze and summarize some modern directions and forms of international activity of the Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine. The collected material makes it possible to analyze the priority areas of international activity of the Institute's scientists. Based on the analysis of international events, conclusions have been drawn that Ukrainian geophysicists are expanding the Ukrainian seismological network and gradually integrating it into the international one. The article highlights the forms of international cooperation of the Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine over the past decade. A historical and analytical approach was used in the study, allowing for the generalization of certain directions of international cooperation activities. The article points out that an active combination of

various forms of scientific activity can lead to the realization of goals and the resolution of the challenges that the global community faces today. It is shown that with the onset of the military activities on the territory of Ukraine, new factors have emerged that affect the environmental state. This should draw the attention of the entire international community, as these issues concern not only the Ukrainian territory. The article highlights new international projects in which the Institute's scientists are participating and identifies the need for the implementation of modern information technologies and the maintenance of high standards of scientific activity. Based on the analysis of the projects involving Ukrainian scientists, it is clear that the European vector of international cooperation remains one of the key directions of the Institute's activities. It has been determined that international programs are based on a comprehensive approach to solving complex geological and geophysical problems. It has been determined that a special place in geophysical research is now occupied by monitoring seismic activity, climate change, crustal research, and the study of geomagnetic phenomena. The organization of joint publications addressing current geophysical issues, as well as the holding of seminars and conferences, is an important component of international cooperation today.

**Keywords:** Institute of Geophysics, geophysical research, international projects, seismology, international technical cooperation, integration.

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## **ДЕЯКІ СУЧАСНІ НАПРЯМИ МІЖНАРОДНОЇ НАУКОВОЇ ДІЯЛЬНОСТІ ІНСТИТУТУ ГЕОФІЗИКИ ІМ. С. І. СУББОТИНА НАН УКРАЇНИ**

**Аноація.** У статті висвітлено деякі напрями міжнародної діяльності Інституту геофізики ім. С. І. Субботіна НАН України за останнє десятиріччя. У дослідженні використано аналітичний, історичний підходи, які дають змогу проаналізувати сучасні напрями й тенденції розвитку міжнародної діяльності Інституту, спрогнозувати результати міжнародного співробітництва. Зокрема, використано загальнонаукові та спеціально наукові методи, такі як методи аналізу, синтезу та порівняння. Аналіз праць науковців дав змогу стверджувати, що до 90-х рр. ХХ ст. міжнародна діяльність Інституту було практично обмеженою регіональними організаціями, на кшталт Карпато-Балканської геологічної асоціації. На основі узагальнення даних зроблено аналіз різних форм міжнародної співпраці вчених інституту із зарубіжними колегами. Показано необхідність спільної координації наукової діяльності, спрямованої на вирішення проблем у сучасному світі. Висвітлені найбільш актуальні напрями, які вимагають участі міжнародної наукової спільноти. Серед них: сейсмічна активність, глобальні зміни клімату, екологічне забруднення атмосфери, в т.ч. – внаслідок ведення бойових дій тощо. З аналізу міжнародних програм можна зробити висновок, що вони ґрунтуються на комплексному підході до вирішення складних геолого-геофізичних проблем і передбачають розвиток та збагачення новими даними. Аналіз певних міжнародних заходів свідчить про те, що геофізики України розширюють українську сейсмологічну мережу та поступово інтегрують її до міжнародної мережі. Визначено, що одним із ключових напрямів діяльності Інституту залишається європейський вектор міжнародного співробітництва. Висвітлено, що метою певних сучасних міжнародних проєктів є розробка методів підвищення стійкості та надійності роботи гідроелектростанцій та атомних станцій. Проаналізовані найбільш вагомні міжнародні проєкти, в яких брали участь вчені Інституту. Зроблено висновок, що міжнародна діяльність вчених Інституту повинна розвиватися й бути досліджуваною надалі.

**Ключові слова:** Інститут геофізики, геофізичні дослідження, міжнародні проєкти, сейсмологія, міжнародно-технічне співробітництво, інтеграція.

**Introduction.** The S. Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine holds a significant position in conducting fundamental and applied research in the field of geophysics, not only within Ukraine but also on the international stage. The events of the last decade have profoundly altered the surrounding environment,

both ecologically and socially. There is a certain impact on the environment from natural and man-made factors, including magnetic factors related to the contamination of territories, particularly as a result of the war. Therefore, in international cooperation, it is crucial to coordinate research in the areas of geophysical ecology.

Consequently, the Institute's international activities are also adopting new directions that reflect the emerging global challenges facing science. This article examines some forms of the Institute's international activities at the current stage, all of which aim to further develop international cooperation.

**The Purpose of the Article.** The objective of this article is to analyze and summarize some contemporary directions and forms of international activities of the S. Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine.

**Research Methods.** The article employs historical and analytical approaches, specifically utilizing methods of analysis, synthesis, and comparison. The research is grounded in the principles of historicism and objectivity. The application of these methods enabled the generalization and structuring of trends in the development of contemporary scientific activities.

**Research Sources and Historiography.** The sources for this research include reports from the S. Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine, materials from international conferences, events, and projects, as well as publications by scientists. The issue of international scientific cooperation among the Institute's researchers has been covered in publications by domestic scholars since the inception of the Institute's activities<sup>1</sup>.

**Main Material and Results.** Throughout its history, the Institute of Geophysics of the National Academy of Sciences of Ukraine has actively engaged in international cooperation. The peculiarity of the first half of this period (until the 1990s) was that international activity was practically limited to regional organizations such as the Carpathian-Balkan Geological Association, which included Bulgaria, Hungary, Poland, Romania, the USSR, Czechoslovakia, and Yugoslavia, joint research with individual countries, for example, with Hungary, or occasional business trips abroad. The situation changed dramatically in the 1990-s, when the geographic scope of project participants expanded, involving up to 23 countries, and the format of cooperation was transformed. For fieldwork in Ukraine and adjacent regions, Western partners provided, free of charge, highly expensive geophysical equipment for shared use and covered the expenses of their participants' stays in Ukraine. Bilateral projects without expeditionary work that did not require large funding were carried out, as before, on a currency-free exchange basis<sup>4</sup>.

The integration of the Institute of Geophysics of the National Academy of Sciences of Ukraine into the world science was also carried out through participation in complex international programs of UNESCCO, programs of European countries and programs of international unions – the International Geological Union (IUGS) and the International Union of Geodesy and Geophysics (IUGG)<sup>5</sup>.

Since 1992, the Institute has been involved in a number of programs and projects: EUROPROBE, GEORIFT, EUROBRIDGE, PANCAPDI, DOBRE, INTAS, NARS DEEP, IRIS, SCAR (Antarctic research). Notably significant scientific results were obtained during deep seismic studies conducted as part of the DOBRE-2 project in eastern Ukraine, particularly in the Black Sea and Azov Sea regions. An international team of geophysicists from Ukraine, Denmark, the Netherlands, the USA, and Poland, using state-of-the-art equipment, obtained unique seismic data on the deep structure and development dynamics of the most promising

<sup>1</sup> Старостенко В. И., Исиченко Е. П. Малоизвестные страницы истории формирования и развития геофизических исследований на Украине. *Геофизический журнал*. 2003. Т. 25. № 5. С. 3–30.

<sup>2</sup> Старостенко В. И., Исиченко Е. П. Интеграция Института геофизики НАН Украины в мировую науку. *Геофизический журнал* 2010. Т. 32. № 6. С. 3–100 (in Russian).

<sup>3</sup> Старостенко В. И., Русаков О. М., Якимчик А. И. Международное сотрудничество Института геофизики им. С. И. Субботина НАН Украины в 2010–2020 гг. *Геофизический журнал*. 2021. Т. 43. № 3. С. 206. 205–226 (in Russian).

<sup>4</sup> Там само. С. 206

<sup>5</sup> Старостенко В. И., Исиченко Е. П. Интеграция. С. 6.

oil and gas bearing areas of the Black and Azov Seas, the Donbas lithosphere, and their articulation with the Ukrainian shield<sup>6</sup>.

At the current stage, the forms of international activities of the Institute include participation in international research projects, scientific cooperation, hosting international conferences, exchanging scientific information, and publishing in international journals etc.

Particular attention in geophysical research is currently being paid to the monitoring of seismic activity, issues of climate change, the study of the Earth's crust, and the investigation of geomagnetic phenomena. These issues have become highly relevant in the past decade. The study and implementation of research findings in these areas are of critical importance for the safety and proper functioning of humanity. Therefore, Ukrainian scientists, in particular those of the Institute of Geophysics of the National Academy of Sciences of Ukraine, support global international initiatives aimed at researching and solving these problems.

One of these initiatives is the “GEMMA” project. The Institute of Geophysics participated in this project from 2016 to 2021. Within the framework of this project, Ukrainian scientists, in collaboration with colleagues from Europe and North America, developed models for monitoring changes in the Earth's atmosphere. The goal was to investigate and analyze the consequences of global climate change and to develop methods for mitigating the negative impacts of these changes on the environment.

In recent years, with the participation of leading experts from the Institute and scientists from Europe (Netherlands, Denmark, Germany, Poland, Finland, France, Austria, Hungary, the United Kingdom) and the USA (University of El Paso), work has been carried out on projects such as Eurobridge, Dobre, Georift, RomUkrSeis, Pancake, TESZ, and SHIELD-21. The profiles of these projects intersect the East European and West European platforms, the Scythian Plate, the Pannonian Basin, the Dnipro-Donetsk and the Pripjat Trough. The primary goal of these studies is to investigate the productive thickness of sedimentary rocks that may contain oil and gas fields, to establish the presence of transition zones with deep faults that migrate hydrocarbons into traps and form deposits of other minerals. This program is a comprehensive approach to solving complex geological and geophysical problems and provides for the development and enrichment of fundamental and applied areas of Earth sciences with new data<sup>7</sup>.

Ukrainian geophysicists are expanding the Ukrainian seismological network and gradually integrating it into the international system. In June-July 2023, as part of the “Expansion and Modernization of the Seismic Network in Ukraine” (SNEMU) project, scientists from the Institute underwent comprehensive training in Georgia. With the support and in cooperation with the US Department of Energy (DOE), Livermore National Laboratory (LLNL), Michigan State University (MSU) and the EarthScope consortium, plans are underway to expand the national seismological network by installing permanent broadband seismic stations to record earthquakes across Ukraine. Expert researchers from LLNL, MSU, and the EarthScope consortium gave lectures, conducted training sessions, shared their experience and the latest methods in the field of seismological research<sup>8</sup>.

Since 1995, the Institute of Geophysics of the National Academy of Sciences of Ukraine has been cooperating with United States Geological Survey, jointly maintaining the Kyiv-IRIS digital seismic station in Malyn. The station has enhanced the capabilities of seismological observations in Ukraine, which are especially important for studying the Vrancea seismic zone, as well as the Carpathian and Crimean regions. In September 2017, the US side upgraded the equipment at the “Kyiv-IRIS” station. Regular observations began in February 2018 and continue to this day<sup>9</sup>.

<sup>6</sup> Національна академія наук України. 1918–2008: до 90-річчя від дня заснування. Київ: Вид-во КММ, 2008. С. 289–290.

<sup>7</sup> Легостаєва О. В. Наукові школи та сучасні наукові напрями Інституту геофізики ім. С. І. Субботіна НАН України. *Вісник НАН України*. 2024. № 4. С. 83.

<sup>8</sup> URL: <https://www.nas.gov.ua/UA/Messages/Pages/View.aspx?MessageID=10344>

<sup>9</sup> Легостаєва О. В. Наукові школи. С. 86.

Ukraine has also become a member of the IRIS (Incorporated Research Institutions for Seismology) consortium, gaining access to the global seismic data bank. On September 17, 1998, the U. S. Geological Survey and the Institute of Geophysics signed a protocol on scientific and technical cooperation in the study of Earth physics, the installation and maintenance of seismological equipment, and the exchange of seismological data and related scientific results<sup>10</sup>.

The European vector of international cooperation remains one of the key activities of the Institute.

The Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine participates in the European seismological project AdriaArray. AdriaArray is a European initiative aimed at enhancing our understanding of the deep structure of Central Europe, orogeny, and its connection with mantle dynamics, plate deformation, surface processes, and seismic hazards in the actively deforming orogenic system of the Alps–Apennines–Carpathians–Dinarides. The research will combine modern Earth observation data with high-resolution geophysical images of the three-dimensional geological structure and the physical properties of the lithosphere and upper mantle. Preparation for the implementation of this ambitious project began in 2018, building on the experience gained from two previous European projects, PACASE and AlpArray. Almost 50 institutions from 27 countries will now participate in the long-term experiment. It is planned to create a dense broadband seismic network to cover the Adriatic plate and its surroundings. A total of 1380 broadband seismological stations will be used, of which 971 are stationary. In addition to the existing stations in the region, 409 temporary stations from 18 mobile pools will be deployed to achieve coverage with an average station spacing of approximately 50–55 km. The experiment will be based on intensive cooperation between network operators, ORFEUS and interested research groups. In 2022, 18 MOBNET broadband stations were installed in Romania and Bulgaria. Before the start of Russia’s large-scale war against Ukraine, the Institute of Geophysics of the Polish Academy of Sciences planned to install 14 stations in the Ukrainian seismological network, which could simultaneously use European and Ukrainian equipment. Unfortunately, the war made certain adjustments to the plans of European partners. Today, together with its Polish colleagues, the Institute is working to adapt some seismic stations to work in this project<sup>11</sup>.

The results of the Institute’s geophysicists’ research have been presented in numerous publications. These scientific findings are widely applied in the exploration of deep-seated mineral resources and in assessing seismic hazards in Ukraine. The works of Ukrainian geophysicists are well known abroad, with their findings prominently featured in special issues of journals such as “Tectonophysics”, “Earth Physics”, “Reports RAS”, “Geophysical Journal International”, “EOS, Transactions, American Geophysical Union”, “Global and Planetary Change”, “Pure and Applied Geophysics”, “International Journal of Differential Equations and Applications”<sup>12</sup>.

In 2023, a memorandum of collaboration was signed with the AdriaArray Initiative regarding cooperation in the exchange of seismological information.

The Institute’s staff are also participating in the international NATO Science for Peace Multi-Year Project G5907, titled “Prevention of Geothreats to Azerbaijan’s Energy Independence.” The aim of this project is to develop methods to enhance the resilience and reliability of critical infrastructure, such as hydroelectric power plants and nuclear power stations. The developed approaches and methods are being tested on the Shamkir and Mingachevir hydroelectric power plants in Azerbaijan, which are the largest in the country and are associated with the two largest reservoirs in the Caucasus.

In 2022–23, the Institute carried out work within the framework of projects with foreign institutions:

– Joint Polish-Ukrainian Project: “Development of a Methodology for Calculating Local Geomagnetic Activity Indices Using Data from Magnetic Observatories and Permanent

<sup>10</sup> URL: <http://www.igph.kiev.ua/ukr/about.html>

<sup>11</sup> Гринь Д. М. Сейсмічна небезпека території України. *Вісник НАН України*. 2023. № 6. С. 31–32.

<sup>12</sup> Національна академія наук України. С. 290.

Stations in Ukraine and Poland” (2022–2024), implemented under the Cooperation Agreement between the National Academy of Sciences of Ukraine and the Polish Academy of Sciences. The project involved comparative measurements using Ukrainian and Polish instruments at the Belsk Geomagnetic Observatory. The project also involved the exchange of new geomagnetic observatory data from Poland and Ukraine for the calculation of geomagnetic activity indices.

Joint Polish-Ukrainian Project: “Geophysical Studies of the Lithospheric Structure of the East European Craton” (2022–2024), also under the Cooperation Agreement between the National Academy of Sciences of Ukraine and the Polish Academy of Sciences. This project involved computer modeling and the construction of a preliminary velocity model along the SHIELD21 profile under study.

– Joint Polish-Ukrainian Project: “Paleogeography and Tectonic Evolution of the Ukrainian Shield Based on Paleomagnetic Studies of the Korosten Pluton” (2022–2024), is being implemented within the framework of the Cooperation Agreement between the National Academy of Sciences of Ukraine and the Polish Academy of Sciences. The project included paleomagnetic studies of the Korosten Pluton of the Ukrainian Shield.

In 2023, the Institute had 5 international agreements. The cooperation was carried out within the framework of multilateral projects (INTERMAGNET and others) and under bilateral agreements between the Institute and scientific institutions of foreign countries (Poland, the USA, France, etc.)<sup>13</sup>.

Within the framework of the international project BLACK SEA HAZNET, the possibility of predicting regional seismic activity based on geomagnetic monitoring and information on water levels in wells obtained as a result of the functioning of a specially created data collection network for their archiving, visualization and analysis was statistically confirmed. New data on geophysical influences that can affect the environment, in particular on the relationship between variations in the geomagnetic field and climate change, have been obtained, and differences in this mechanism have been established for the Northern and Southern hemispheres<sup>14</sup>.

Within the framework of the Ukrainian-Japanese SATREPS WG-2 project, new data were obtained regarding radionuclide runoff formation on experimental sites in the Chernobyl Exclusion Zone and the vertical distribution of Chernobyl-origin radionuclides in the sediments of lakes and adjacent areas. This allowed for a comparative analysis of the processes occurring in the water bodies of the Chernobyl zone and in the areas around the Fukushima Daiichi NPP. Work continued under the joint Ukrainian-Japanese scientific and technical project SATREPS “Science and Technology Research Partnership for Sustainable Development”, the main purpose of which is to strengthen the technical level of radiation monitoring and the legislative framework in Ukraine for ecological remediation of radioactively contaminated areas, monitoring and modelling for the purpose of implementing a new zoning of the Exclusion Zone<sup>15</sup>.

**Conclusions.** Over the past decade, the international activities of the Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine have contributed to the integration of Ukrainian science into the global scientific community. New and existing areas of international activity in the research of the scientists are emerging and developing. The Institute’s scientists are actively involved in international research, programs, projects, and scientific conferences. All this contributes to the development of the potential for solving many problems that humanity is currently facing in all corners of the Earth.

It is essential to be aware of the problems that scientists may encounter in their future activities. Primarily, this includes insufficient state funding, which can limit the organization

<sup>13</sup> Міжнародне наукове та науково-технічне співробітництво (2023). *Інститут геофізики ім. С. І. Субботіна НАН України*. URL: <http://www.igph.kiev.ua/International%20Activity/ukr/index.html>

<sup>14</sup> Старостенко В. І., Русаков О. М., Якимчик А. І. *Міжнародне співробітництво*. С. 215.

<sup>15</sup> Про підсумки наукової діяльності установ Відділення наук про Землю НАН України у 2015–2019 рр. *Звіт Академіка-секретаря Відділення наук про Землю НАН України академіка НАН України О. М. Пономаренка*. URL: <https://www.nas.gov.ua/UA/Messages/Pages/View.aspx?MessageID=6402>.

of international scientific events and participation in international projects. Despite the difficult political situation, it is crucial to maintain high standards of scientific activity, seek opportunities to participate in international programs, and improve the qualifications of scientific personnel.

The quality of scientific research can be enhanced by implementing advanced information technologies and the “digitalization” of scientific processes, which will facilitate the peer review of research before submission to international journals.

Key steps in developing international cooperation may include organizing joint publications, participating in world-class scientific seminars, etc. . Joint research, exchange of scientific data, and the creation of international laboratories will also contribute to the advancement of scientific research. These areas should be developed, monitored, and analyzed to address the global challenges of today.

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