Institute of Geophysics
Polish Academy of Sciences

PUBLICATIONS
OF THE INSTITUTE OF GEOPHYSICS
POLISH ACADEMY OF SCIENCES

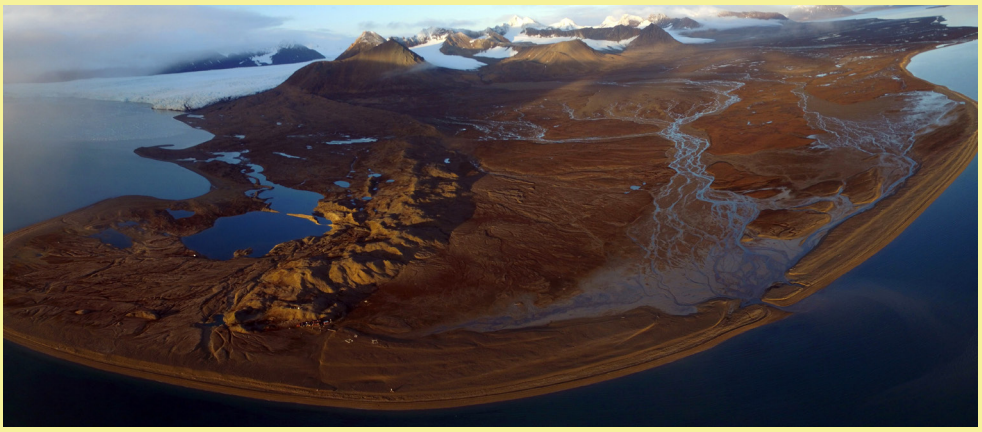
Geophysical Data Bases, Processing and Instrumentation

431 (P-2)

MONOGRAPHIC VOLUME

Polish Polar Research:
Green-and-White Paper

under the aegis of the Polish Polar Consortium (PPC)



Warsaw 2020 (Issue 5)

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Photo “Svalbard (Spitsbergen, Kaffiøyra region)” on the front cover by Ireneusz Sobota

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CONTENTS

Editorial note 7
Acknowledgements 7
Acronyms/Abbreviations 8
Abstract 10
Streszczenie 11
INTRODUCTION 13
1. Aims of the book 14
2. Historical outline 15
3. The legal and organizational framework of polish polar research 16
3.1 Poland's polar policy and research 17
4. Outline of research potential 18
4.1 Collaboration at national level 19
4.2 International collaboration 19
POTENTIAL OF POLAR RESEARCH IN POLAND 21
5. Manpower 22
6. Research centers in poland dealing with polar areas 24
7. Polar infrastructure 39
7.1 Land infrastructure 39
7.2 Maritime infrastructure 45
7.3 Condition of polar infrastructure 46
POLAR RESEARCH ISSUES 49
8. Scientific fields in polar research 50
8.1 Biology and ecology 50
8.2 Environmental chemistry, hydrochemistry 51
8.3 Physics of the ionosphere and atmosphere 52
8.4 Physical geography, study of perennial permafrost, geomorphology, soil science and landscape research 53
8.5 Geology and geophysics 54
8.6 Hydrology, glaciology, snow research 54
8.7 Meteorology and climatology 55
8.8 Environmental microbiology 56
8.9 Social sciences and humanities 56

8.10 Oceanography 57
8.11 Paleobiology 57
9. Implemented research projects 58
THE FUTURE OF POLAR RESEARCH 61
10. The vision for future research, infrastructure and polar missions in Poland: proposals 62
10.1 Research which should be done in Poland in order to expand the knowledge on polar issues 64
10.2 Polar missions – proposals for structural solutions 65
11. Promotion and popularization of knowledge and education – forge of future polar researchers 66
12. Scientific papers published in the years 2007–2018 (in journals covered by JCR) 69

Editorial note

The White Paper[1] is a document containing officially developed conceptual proposals relating to specific EU policies and usually presents a catalog of specific proposals and measures to be implemented in order to achieve the EU treaty tasks.

The Green Paper[2] is a report gathering information on a specific topic, and usually provides a starting point for a White Paper.

The present book combines the qualities of both the White Paper and the Green Paper. It is published in two language versions: Polish and English.

Acknowledgments

Thanks are due to Ms. Anna Ostrowska for her help in editing the first version of the text, Mr. Mariusz Pasik for sharing the archival materials, and the editorial staff of the Institute of Geophysics PAS for preparing the final version for publication.

The text was translated into English by Anna Dziembowska.

[1] https://en.wikipedia.org/wiki/White_paper
[2] https://en.wikipedia.org/wiki/Green_paper

Acronyms/Abbreviations[3]

AMU = Adam Mickiewicz University in Poznań
- **AMU:FGGS** = Faculty of Geographical and Geological Sciences, AMU
- **AMU:DAET** = Department of Animal Ecology and Taxonomy, AMU
- **AMU:PS =** Polar Station of the AMU

Arctowski Station = Henryk Arctowski Polish Antarctic Station on King George Island, South Shetlands

DAB PAS = Department of Antarctic Biology, PAS (now the Department of Antarctic Biology, IBB PAS)

CPS = Center for Polar Studies (KNOW status)

Dobrowolski Station = Antoni B. Dobrowolski Polish Antarctic Station

GMU = Gdynia Maritime University

GUT = Gdańsk University of Technology
- **GUT:DWWT** = Faculty of Civil and Environmental Engineering, Department of Water and Wastewater Technology, GUT
- **GUT:FCh =** Faculty of Chemistry, GUT
- **GUT:DACh** = Faculty of Chemistry, Department of Analytical Chemistry, GUT

IBB = IBB PAS = Institute of Biochemistry and Biophysics, Polish Academy of Sciences
- **IBB:DAB** = Department of Antarctic Biology, Institute of Biochemistry and Biophysics, PAS

IGF = IGF PAS = Institute of Geophysics, Polish Academy of Sciences
- **IGF:DPMR = DPMR** = Department of Polar and Marine Research IGF PAS

IGS PAS = Institute of Geological Sciences, Polish Academy of Sciences

IO PAS = Institute of Oceanology, Polish Academy of Sciences

IPal PAS = Institute of Paleobiology, Polish Academy of Science**s**

JKU = Jan Kochanowski University in Kielce

JU = Jagiellonian University in Cracow
- **JU:DPRD** = Department of Polar Research and Documentation of the Institute of Botany at the Faculty of Biology, JU
- **JU:IGSM** = Institute of Geography and Spatial Management of the Jagiellonian University at the Faculty of Geography and Geology, JU

KNOW = Polish acronym for National Scientific Leadership Centre

MCSU = Maria Curie-Skłodowska University in Lublin
- **MCSU:PS** = Polar Station of the MSCU
- **MSCU:FES** = Faculty of Earth Sciences and Spatial Management of the MSCU

MES = Ministry of Education and Science
MSHE = Ministry of Science and Higher Education

MSI = Ministry of Science and Informatization

NCRD = National Centre for Research and Development (NCBR in Polish)

[3] The abbreviations added by the translator in order to make the text more compact and readable

NCU = Nicolaus Copernicus University in Toruń
- **NCU:PS =** Polar Station in Spitsbergen of the Nicolaus Copernicus University
- **NCU:FESSM =** Faculty of Earth Sciences and Spatial Management
- **NCU:PRC** = Polar Research Center

NSC = National Science Center

PAS = Polish Academy of Sciences

PGI-NRI = Polish Geological Institute-National Research Institute

PNRP = Polish–Norwegian Research Program

PPC = Polish Polar Consortium

PPSH = PPS Hornsund = Hornsund Station = Stanisław Siedlecki Polish Polar Station Hornsund

PRMRI = Polish Road Map of Research Infrastructure

SCSR = State Committee for Scientific Research (KBN in Polish)

SIOS = Svalbard Integrated Earth Observing System

SPUB = Polish acronym for MSHE funds allocated for Special Research Equipment

SRC PAS = Space Research Center PAS

UG = University of Gdańsk

UŁ = University of Łódź
- **UŁ:DPBO =** University of Łódź, Institute of Ecology and Environmental Protection, Chair of Invertebrate Zoology and Hydrobiology, Dept. of Polar Biology and Oceanobiology, UŁ

US = University of Silesia
- **US:FES** = Faculty of Earth Sciences, US
- **US:IES** = Institute of Earth Sciences, US

UWM = University of Warmia and Mazury
- **UWM:FBB** = Faculty of Biology and Biotechnology, UWM
- **UWM:CMM** = Chair of Microbiology and Mycology, UWM

UW = University of Warsaw
- **UW:FG** = Faculty of Geology, UW
- **UW:CeNT=** Centre of New Technologies UW
- **UW:CeNT:LPCG** = **CeNT:LPCG** = Laboratory of Paleogenetics and Conservation Genetics at UW:CeNT

UWr = University of Wrocław
- **UWr:FESEM** = Deptartment of Applied Hydrogeology, Faculty of Earth Sciences and Environmental Management, UWr
- **UWr:FBS=** Faculty of Biological Sciences, UWr
- **Baranowski Station** = Stanislaw Baranowski Polar Station of UWr

WUT = Warsaw University of Technology
- **WUT:FGC** = Faculty of Geodesy and Cartography, WUT

Abstract

Polar research is a colloquial term for cross-area, cross-domain and interdisciplinary research in the Arctic and Antarctic. Polar research is mainly the domain of natural sciences, but technical sciences and humanities also grow in importance. Being vulnerable to climate change, polar regions are commonly considered as a kind of litmus paper of changes in geosystems, hence the importance of research done there. It aims at a better understanding of the processes taking place in the polar environment and the search for links between the bio-, litho-, atmo- and hydrosphere on the one hand, and the anthroposphere on the other, which would provide a better knowledge on the genesis of the present glaciation and then a reliable forecast of future global changes.

The document is composed of three main parts. The "Introduction" and presentation of the legal and organizational framework is followed by Part I, describing the potential of the polar scientific community in Poland along with the infrastructure and logistical means (on land and sea). Part II presents the research topics implemented in Polish scientific entities. In Part III we outline the future of polar research in Poland, trying to specify the most important directions, feasible with a view to the existing research potential.

At the end of the document, the achievements of polar community are displayed collectively in the form of a bibliography of over 800 scientific publications through the years 2007–2018, covered by the Journal Citation Reports. Keeping in mind that it is an output of about 300 scientists and technicians managing just two active polar stations (in the Arctic and Antarctic) and operating two small (though brave) research vessels, this is a respectable achievement. Worth emphasizing is also an additional yet not minor aspect of our polar activities, namely, the daily effort put into organization, logistics and maintenance of the material research base in the extreme natural environment.

To sum up, the general message of this document is a strong argument for promoting polar research in Poland, because the ratio of expenditures to cognitive and social effects seems to be very attractive from the point of view of the Polish Polar Policy and general scientific policy of the country.

Keywords: Polish polar research, Arctic, Antarctic, Polish polar infrastructure, Polish polar research potential, Polish polar scientific publications.

ZIELONO-BIAŁA KSIĘGAPOLSKICH BADAŃ POLARNYCH POD EGIDĄ POLSKIEGO KONSORCJUM POLARNEGO (PKPol)

Streszczenie

Badania polarne to kolokwialne określenie międzyobszarowych, międzydziedzinowych i interdyscyplinarnych badań naukowych, prowadzonych w Arktyce i Antarktyce. Badania polarne są domeną głównie nauk przyrodniczych, jednak coraz większą rolę odgrywają także badania z zakresu nauk technicznych i humanistycznych. Ze względu na wrażliwość na zmiany klimatyczne, rejony polarne uważane są powszechnie za swoisty papierek lakmusowy zmian w geosystemie, stąd waga badań przyrodniczych prowadzonych na tych obszarach. Zmierzają one do lepszego poznania procesów zachodzących w środowisku polarnym oraz poszukiwania sprzężeń pomiędzy bio-, lito-, atmo- i hydrosferą oraz antroposferą, co pozwoliłoby zrozumieć genezę obecnego zlodowacenia, a następnie wiarygodnie prognozować zmiany globalne w przyszłości.

Przedstawione opracowanie ma trójdzielną strukturę. Po „Wprowadzeniu" oraz naświetleniu ram prawnych i organizacyjnych, w części I dokument przedstawia potencjał środowiska naukowego w Polsce oraz infrastrukturę i środki logistyczne (lądowe i morskie), znajdujące się w jego dyspozycji. W części II przedstawiono uprawiane w Polsce tematyki badawcze w podziale na krajowe jednostki naukowe. Część III szkicuje przyszłość badań polarnych w Polsce, starając się zidentyfikować najważniejsze kierunki działań naukowych, które znajdują oparcie w aktualnej bazie badawczej.

Na końcu opracowania, przedstawiono zbiorczo osiągnięcia środowiska polarnego, w postaci bibliografii ponad 800 publikacji naukowych z okresu 2007–2018, przygotowanej na podstawie analizy Journal Citation Reports. W zestawieniu z liczbą ok. 300 pracowników naukowo-badawczych i technicznych zaangażowanych w badania polarne, dwóch czynnych stacji polarnych w Arktyce i na Antarktydzie oraz dwóch niewielkich, choć dzielnych jednostkek pływających, to jest to dorobek budzący szacunek. Dodatkowym i wcale nie najmniej ważnym aspektem działań środowiska polarnego w Polsce na rzecz badań w rejonach podbiegunowych jest codzienny wysiłek, wkładany w organizację, logistykę i utrzymanie materialnej bazy badawczej w ekstremalnym środowisku przyrodniczym.

Podsumowując, ogólne przesłanie niniejszego dokumentu stanowi mocny argument dla wpierania badań polarnych w Polsce, albowiem stosunek nakładów do efektów poznawczych i społecznych wydaje się bardzo atrakcyjny z punktu widzenia Polskiej Polityki Polarnej oraz generalnej polityki naukowej Państwa.

Słowa kluczowe: polskie badania polarne, Arktyka, Antarktyda, polska infrastruktura polarna, polski potencjał badawczy badań polarnych, polskie polarne publikacje naukowe.

INTRODUCTION

1. AIMS OF THE BOOK

Polar research is a colloquial term for cross-area, cross-domain and interdisciplinary research in the Arctic and Antarctic. Polar research is mainly the domain of natural sciences, but the role of technical sciences and humanities is also growing. The most important aim of this research is to deepen the understanding of the processes taking place in the polar environment and to find the links between the bio-, litho-, atmo- and hydrosphere on the one hand and the anthroposphere on the other.

The polar zones – the Arctic around the North Pole and the Antarctic around the South Pole – are the areas of the globe that most dynamically respond to climate change. This is because the increase in temperature leads to the disappearance of the light ice cap and exposes an ever-increasing surface of the dark ocean, which heats up faster, reinforcing the effect of temperature rise (the so-called polar reinforcement or amplification). In the global energy exchange system, therefore, an increased share of greenhouse gases intensifies the temperature rise in the Polar Regions, leading to a reduction in the air temperature difference between polar and tropical zones. Geological data indicate that at the beginning of Cenozoic, about 60 million years ago, the temperature at the poles was by about 50°C higher, while at the Equator it was only a few degrees higher than today, so that the temperature distribution on Earth was more even and the climate zones were much less diversified than today. For millions of years the Earth was a warm planet, with several short (on a geological scale) glacial episodes. The global cooling process over the last 55 million years has dramatically changed the pattern of climate zone layout. The current glaciation, covering both hemispheres, has a global dimension and is sometimes considered to be the largest glaciation on Earth in the last 500 million years. However, it seems to be coming to an end and it is possible that the anthropogenic process of retreating from global cold and returning to a warm climate on Earth has begun.

Due to their vulnerability to climate change, the Polar Regions are commonly considered to be a kind of litmus paper of changes in geosystems, hence the importance of natural research conducted in these areas. It aims at a better understanding of both the origins of the present and the forecasting of global changes in the future.

The scientific research in the Polar Regions has also become a strong argument in politics, and the scientists involved in this research have become scientific ambassadors of their countries, especially in the extraterritorial area of the Antarctic continent. Several dozen countries, with thousands of researchers, participate in the research, permanent and temporary stations and ships are being built, and scientific publications resulting from polar studies have a significant share in the global scientific legacy. Based on the results of this research, political decisions have been made at the international level (e.g. Kyoto Protocol 2005), as well as UN resolutions and conventions, such as the United Nations Framework Convention on Climate Change (1994), have been enacted.

Polish Arctic and Antarctic researchers engage in polar research as far as financial and infrastructural capabilities allow. Their main objective is to get a better knowledge of trends in climate change and their consequences for the natural environment, including rising ocean levels, changes in water relations on continents and the evolution of the biosphere by adapting it to changing environmental conditions. An important aspect of Polish involvement in polar research, along with its cognitive value, is the possibility of expert, based on own observations, support for the country's public administration and the economy in planning activities necessary for survival in the new natural environment.

The aim of this document is to present the current state of Polish research in the polar areas, as well as to suggest the main directions for further development of this research, taking into account its educational and cognitive importance and its social and economic utility. The book is addressed to the state administration and the scientific communities in Poland, those already engaged in polar studies as well as those seeking new openings in their current research. The book should also be a starting point for updating the current Polar Research Strategy[4].

The document is composed of three main parts. Having presented the legal and organizational framework, the document highlights the scientific potential, research topics practiced in Poland and outlines the future of polar research in our country, keeping in mind the condition of the national budget.

2. HISTORICAL OUTLINE

The tradition of exploring the Polar Regions by Polish researchers dates back to the end of the 19th century, as concerns both the Arctic and the Antarctic. In 1897, a Belgian expedition, in which two Poles, Henryk Arctowski (1871–1958) and Antoni B. Dobrowolski (1872–1954) took part, went from Antwerp to the Antarctic region. Currently, two Polish polar stations in Antarctica bear the names of those researchers, whose contribution to the development of cryosphere research cannot be overestimated. Although at the beginning of the twentieth century Polish polar scientists were few in number, their experience made it possible for the researchers from reborn Poland to participate in the Second International Polar Year and organize a year-long expedition to Bear Island (1932/1933), belonging to the Svalbard archipelago and located on the Barents Sea, between Scandinavia and Spitsbergen. The importance of this expedition, both scientific as well as organizational, social and political, was enormous. A series of consecutive expeditions in the 1930s, to Spitsbergen and Greenland, strengthened the position of Poland in polar research. The collected experience created an opportunity for Poland to participate in the work of the Third International Polar Year, also known as the International Geophysical Year (1957/1958), as well as to establish the Polish Polar Station over the Hornsund Fjord in Spitsbergen and carry out year-round research there, and to acquire (from the USSR) the A. B. Dobrowolski Station in the Bunger Oasis in Eastern Antarctica (Fig. 1).

Another opening in Polish polar research took place in the 1970s, when a series of scientific expeditions to Spitsbergen began. The decision to build the H. Arctowski Polish Antarctic Station in the South Shetland archipelago (1977) and the thorough reconstruction of the Hornsund station in Spitsbergen (1978) gave grounds for the development of multidisciplinary research in both polar zones, based on the output of the year-round scientific expeditions to these stations and their usability in the logistics of summer expeditions to more remote areas.

Of particular importance is the great experience and high competence gained by several hundred Polish participants in polar research over four decades. Permanent stations with laboratories – polar research platforms – have enabled extensive cooperation with many centers around the world. Its manifestation was the involvement of Polish scientific teams in the work

[4] http://www.kbp.pan.pl/index.php?option=com_content&view=article&id=304&Itemid=128&lang=en

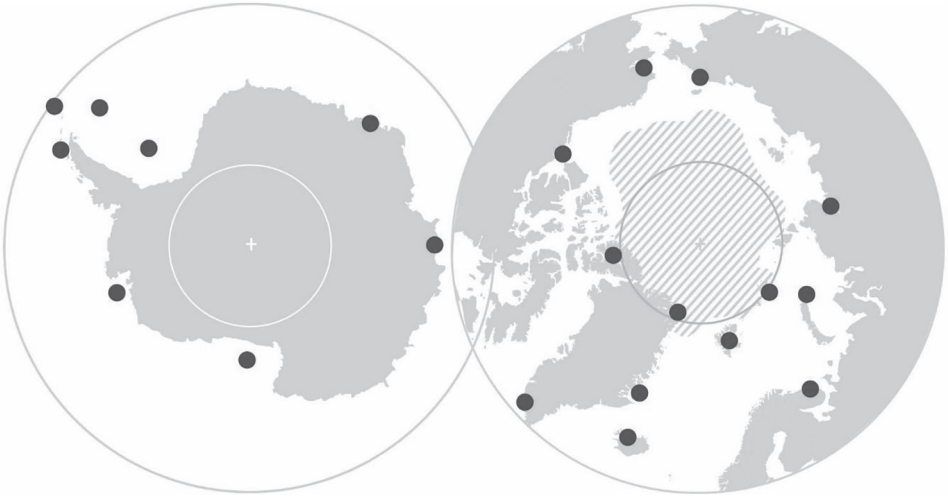

Fig. 1. The regions of Polish polar research in the Arctic and the Antarctic from the end of the 19th century until today.

of the Fourth International Polar Year (2007–2009). It was visible on a European scale, despite the extremely modest condition of our polar fleet, represented by two vessels, r/v OCEANIA and r/v HORIZONT II, whose low ice class limits the area of operation to the waters of the European part of the Arctic. At this point it should be noted that the basic barrier against further development of Polish polar research is the lack of a research vessel that would be able to operate in both the Arctic and the Antarctic. In particular, the exploration of the Antarctic is currently totally dependent on the possibility of chartering a suitable vessel on the international market.

The growth of interest in polar areas, both in Poland and around the world, has significant scientific, economic and political consequences. The polar race, which started at the end of the 19th century, is still going on and motivates many countries, geographically distant from the polar circles, to explore the polar areas both for cognitive reasons and for foreseeable economic activity in these regions. This situation should encourage the consolidation of the activities of Polish polar centers and create a vision for the development of polar research in the next decade. Without our active and effective polar policy, we will be passive observers of the events taking place in these crucial geosystemic areas of the planet in the future.

3. THE LEGAL AND ORGANIZATIONAL FRAMEWORK OF POLISH POLAR RESEARCH

In the framework of the Antarctic Treaty, Poland is one of the 29 countries managing the part of the world south of the 60oS parallel and is fulfilling its treaty obligations, e.g., by carrying out scientific investigations there with the use of the infrastructure of a research station built in 1977. It should be stressed that, according to Article IX (2) of the Treaty, Poland's presence in the Antarctic is possible only due to the fact that it "carries out substantial scien-

tific research and has established a scientific station". Thus, maintaining our research capacity in the Antarctic is of vital importance for Poland's further full participation in the Antarctic Treaty System and translates into the international position of our country. The key role in this respect is played by the Polish Antarctic Station named after Henryk Arctowski[5].

In the Arctic, Poland is present mainly in Svalbard. Under the 1920 Paris Treaty[6], the Svalbard archipelago (in original language: Spitsberg archipelago) was placed under the administration of the Kingdom of Norway, while ensuring equal access to this territory for the countries that are parties to the Treaty. Poland ratified the Treaty in 1931. A Polish research station on the Hornsund Fjord[7] has been operating on Spitsbergen, the archipelago's largest island, since 1957.

3.1 Poland's polar policy and research

Polish polar research was financed by virtue of decisions and commissioned programs of the government. Preparations for Poland's participation in the 4th International Polar Year 2005–2007 were financed in this way. Recently, Polish polar infrastructure has been maintained owing to the Ministry of Science and Higher Education (MSHE) funds allocated for Special Research Equipment (SPUB). Scientific teams and individual researchers gain funds under the general rules of scientific competitions in research funding agencies, within the Framework Programmes of the European Union, by the National Science Centre, National Centre for Research and Development, Norwegian Financial Mechanism and other.

Polar research has been part of our national culture for nearly a hundred years, and now it is building the image and prestige of Poland in the international dimension, allowing us to meet the international treaties and obligations that the countries responsible for recognizing the state of the Earth's natural environment should fulfill. We have great traditions and scientific achievements, great experience, excellent staff and our own research platforms in the Arctic and Antarctic. It should be stressed, however, that so far the driving force behind the progress of polar research in Poland has been the persistence of the scientific community in permanent search for funds for infrastructure and research. While other countries are rapidly developing the infrastructure of their bases and polar stations and building new research vessels, on our side it is only the Stanisław Siedlecki Polish Polar Station Hornsund (PPSH) that maintains its world-class level as a complex research facility. The Arctowski Station is struggling with financial and organizational problems in connection with the relocation of the infrastructure to a less environmentally sensitive site, and the r/v OCEANIA is lagging behind on account of the inevitably running time. Financing limited to measures for securing the operation provided by the SPUB and gained in research grant competitions will not establish a stable position of Polish polar research and services in the international market. It is to be decided: should we take a step backwards, stay in the current state, or develop. Only the first eventuality does not require an increase in funding for polar research.

[5] http://www.arctowski.pl/?p=2
[6] https://hornsund.igf.edu.pl/hornsund.old/traktat.html
[7] https://hornsund.igf.edu.pl

4. OUTLINE OF RESEARCH POTENTIAL

A permanent sign of Poland's scientific presence in both polar areas is the two Polish research stations: Stanisław Siedlecki Polish Polar Station Hornsund (PPSH) on the Hornsund Fjord in Svalbard and the Arctowski Station on King George Island in South Shetlands.

Moreover, Poland is in possession of the OCEANIA research vessel that has been active in Arctic waters for 28 years and the HORIZONT II training and research vessel in operation since 2000. Each year, OCEANIA carries out, during 40 days, research in the Greenland Sea and Spitsbergen coastal waters under the AREX multidisciplinary program. The vessel HORIZONT II combines transporting (transporting people and equipment to the PPSH) and research functions. It should be emphasized that none of these ships fully meets the needs of polar research, as their area of operation is limited to the Arctic, excluding the Antarctic.

An important part of the infrastructure and scientific activity in Svalbard are also the field stations of the University of Wrocław, Nicolaus Copernicus University in Toruń, Maria Curie-Skłodowska University in Lublin and Adam Mickiewicz University in Poznań, which are used by both Polish and foreign scientists.

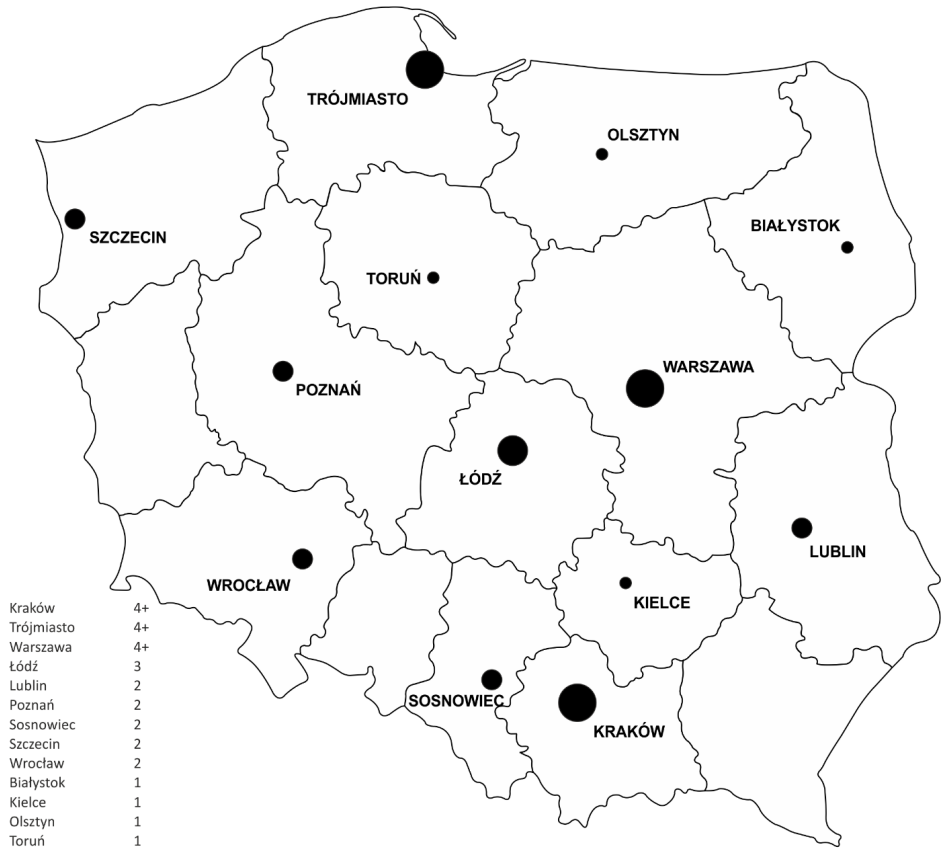

Fig. 2. Centers where polar research is conducted in Poland; the size of the black circles is proportional to the number of institutions involved, without assessing the quality of the substantive contribution to the polar research.

The scientific community dealing with polar research in Poland consists of about 300 people affiliated to universities and polytechnics (mainly Warsaw and Gdańsk) and institutes of the Polish Academy of Sciences and, in a smaller number, research institutes (Fig. 2). Its scientific representation is the Polar Research Committee at the Presidium of the Polish Academy of Sciences, established in 1977, supported by the Polish Polar Consortium, established in 2012, which currently comprises 15 scientific institutions. In addition, in 2013 there was established the Centre for Polar Studies (CPS) convened by the Faculty of Earth Sciences of the University of Silesia (leading entity), the Institute of Geophysics, Polish Academy of Sciences, and the Institute of Oceanology, Polish Academy of Sciences; in the years 2014–2018 it had a status of National Scientific Leadership Centre KNOW in Earth Sciences. CPS promotes and carries out interdisciplinary research and teaches the young academic staff.

4.1 Collaboration at national level

Integration of polar research in Poland is an undoubted success of the national polar community. Within the framework of the activity of the Polar Research Committee of the Polish Academy of Sciences, Polish Polar Consortium or Centre for Polar Studies, there are regular consultations and joint actions. These organizations gather information about the infrastructure and access to it, and, more importantly, they execute multidisciplinary research projects, including those which constitute Poland's participation in international polar projects. Integration on the social level has been supported for over 40 years by the Polar Club at the Polish Geographic Society, which organizes cyclic symposia for scientists, explorers, sportsmen and polar tourists. Implementation of many Polish polar research projects is based on cooperation between national centers, thus leading to comprehensive studies and exchange of experience.

4.2 International collaboration

Poland is an active member of the following polar organizations and international cooperation structures:

- Arctic Council – a high-level intergovernmental cooperation forum in which Poland has a status of observer;
- The Antarctic Treaty – an intergovernmental cooperation structure in which Poland has a status of consultant member;
- The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR);
- Scientific Committee on Antarctic Research (SCAR);
- International Arctic Science Committee (IASC);
- European Polar Board (ERA);
- International Permafrost Association (IPA);
- Forum of Arctic Research Operators (FARO);
- The Council of Managers of National Antarctic Program (COMNAP);
- The Association of Polar Early Career Scientists (APECS).

The international scientific cooperation in polar areas was initiated in the 1880s, when the First International Polar Year was announced. Today, modern research would not have been possible without international cooperation – mutual support in logistics and infrastructure. Polish institutions actively cooperate at the level of research teams and institutes with the most important research centers abroad. International cooperation facilitates the promotion of Poland as a dynamic country, with aspirations to play a significant role in polar research, and enables us to participate in large scientific projects.

POTENTIAL OF POLAR RESEARCH IN POLAND

5. MANPOWER

Polish polar scientific community gathers specialists from various fields of science, at all levels of their career, scattered in numerous centers. In the years 2007–2017, research related to the Polar Regions was conducted in Poland by about 370 people from 27 institutions (universities and research institutes). This group includes the researchers who have devoted their entire scientific careers to polar areas, as well as those who have been involved in polar projects only episodically.

Figure 3 presents the number of scientists involved in polar research, taking into account their career stages, measured by the highest degree/title awarded in the years 2007–2017.

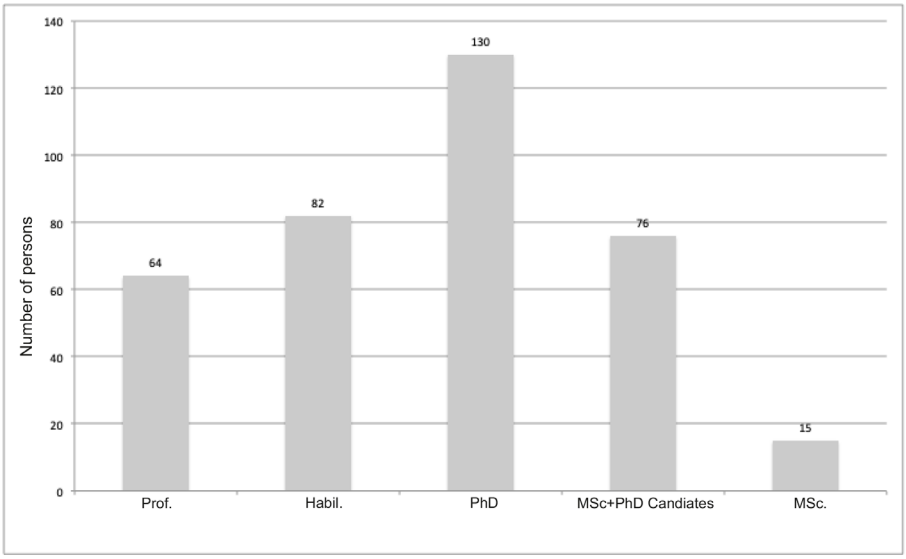

Fig. 3. Number of scientists involved in polar research in 2007–2017, grouped according to the stages of their professional career. Compilation of data: Piotr Głowacki.

Currently (2019), the number of people (scientific and technical staff) dealing with polar issues in Poland reaches about 300, some 1/3 of them being employed by the Institute of Oceanology, Polish Academy of Sciences.

In the years 2001–2017, there were 220 diploma theses related to the Polar Regions, 73 people defended their doctoral dissertations on polar subjects, 28 persons obtained the degree of doctor habilitatus, and five persons obtained the title of professor.

The intense research conducted in the past decade gave grounds for obtaining a number of grants, financed from both the domestic and foreign sources, as well as for issuing numerous publications. There were 124 grants financed from the funds of the National Science Center and earlier the State Committee for Scientific Research: in the analyzed period, Polish scientists also participated in 109 grants financed or co-financed with foreign funds.

Over the years 2007–2017, the number of publications on polar issues in the best international journals, authored or co-authored by scientists from Polish institutions, has been systematically growing: from 85 in 2007 to 268 in 2017 (Fig. 4).

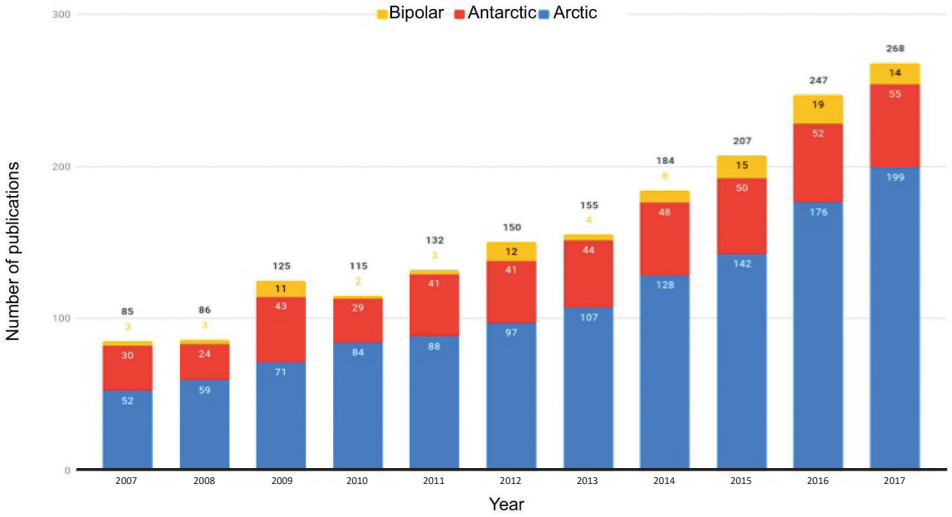

Fig. 4. Number of publications on the Arctic, Antarctic and bipolar, authored or co-authored by scholars from Polish institutions, in the years 2007–2017, source: Web of Science. Compilation of data: Piotr Głowacki.

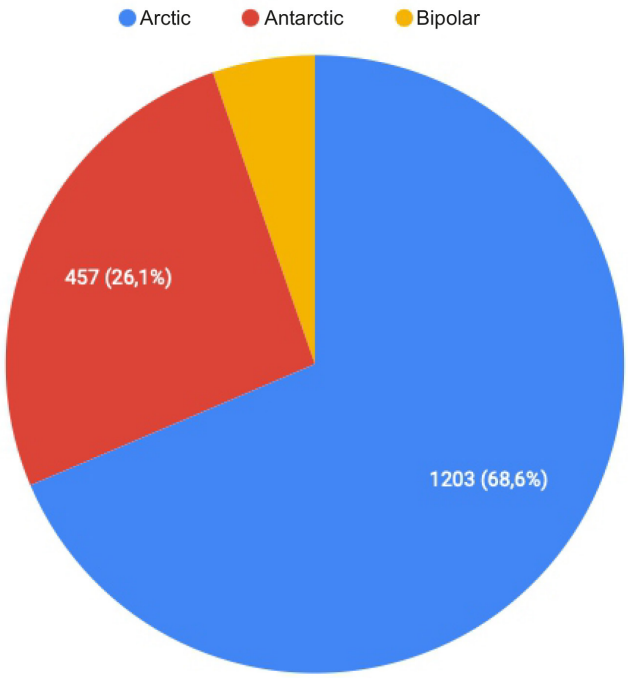

Fig. 5. Share of publications on Arctic, Antarctic and bipolar topics authored or co-authored by scholars from Polish institutions in 2007–2017, source: Web of Science. Compilation of data: Piotr Głowacki.

Regarding the share of Arctic, Antarctic and bipolar publications in the total number of publications, about two-thirds (68.6%) were those dealing with the Arctic, about a quarter (26.1%) with the Antarctic, and the rest were the bipolar ones (Fig. 5). These proportions have been rather stable throughout the analyzed period. A special area, well established in the tradition of Polish polaristics, is the Svalbard Archipelago.

The achievements of Polish scholars, expressed in publications, academic degrees or presentations at scientific conferences (Fig. 6) are highly valued by our partners and are a strong argument in the applications of our researchers for Polish and foreign funds.

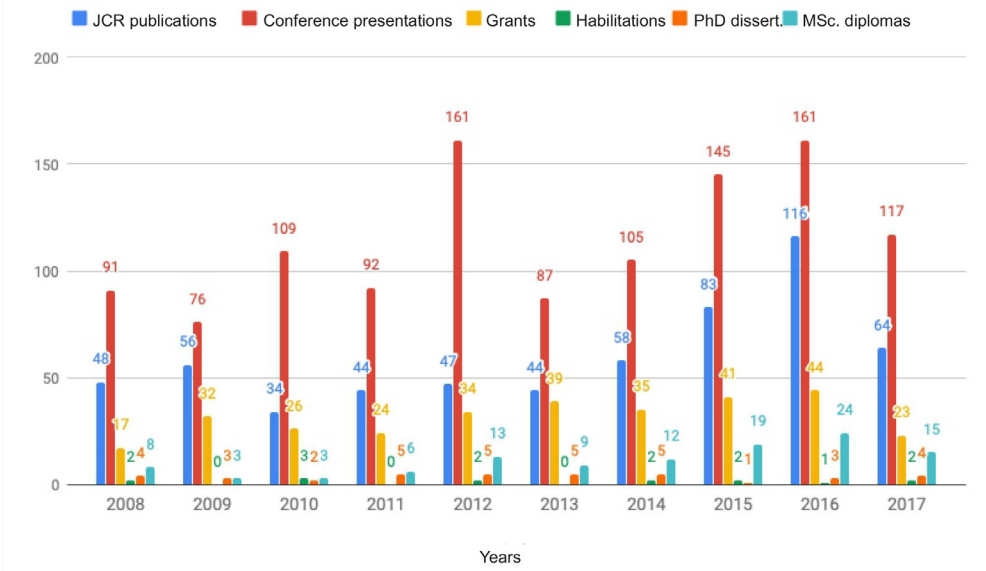

Fig. 6. Output of Polish scientific activity in Svalbard in the years 2008–2017, source: JCR – Journal Citation Index. Compilation of data: Piotr Głowacki.

6. RESEARCH CENTERS IN POLAND DEALING WITH POLAR AREAS

This chapter presents the potential of scientific centers (presented in alphabetical order according to the parallel Polish edition), as illustrated, by some of their achievements. The institutions listed below cooperate with other research centers, that are not explicitly described here (e.g. Space Research Center, Polish Academy of Sciences; Institute of Geophysics, University of Warsaw; J. Kochanowski University in Kielce; Faculty of Biology of the University of Bialystok; Gdynia Maritime University; and Faculty of Oceanography and Geography, University of Gdańsk), which effectively, although sporadically or in a narrow range, are involved (or have been involved in past decades, such as the now-defunct Institute of Biology of the University of Bialystok) in the study of the polar areas.

Institute of Biochemistry and Biophysics PAS (IBB PAS), Department of Antarctic Biology (IBB:DAB)

IBB PAS is a scientific institution which carries out a wide range of research in areas such as molecular genetics of bacteria and yeasts, mutagenesis and DNA repair, plant molecular biology, structural biology and bioinformatics. The Institute maintains one of the world's larg-

est banks of polar psychrophilic microorganism strains, including those with the potential of being biotechnologicaly useful.

Since 2012, the Institute manages the Arctowski Station on King George Island in Antarctica. Based on the Station, the IBB PAS, together with the Ministry of Foreign Affairs, represents Poland in Antarctic management organizations: ATCM (Antarctic Treaty Consultative Meeting) and CEP (Committee for Environmental Protection), and its employees act as scientific advisors to the Ministry of Foreign Affairs on all matters related to the Poland's presence in the Antarctic (e.g., they participate, among other representatives from research institutes, in the annual Polar Task Force meetings).

The IBB PAS, together with the relevant international institutions, takes care of two Antarctic Specially Protected Areas (ASPA 128 Western Shore of Admiralty Bay and ASPA 151 Lions Rump), taking all necessary environmental management measures and preparing appropriate management plans. The research and monitoring carried out on the basis of the Arctowski Station is therefore an effective tool to support and enable the proper fulfillment of Poland's international obligations.

In the years 2014–2017, a series of abiotic environment monitorings was launched in Antarctica, including: the calving process of the Lange Glacier, hydrology of the Baranowski Glacier, atmospheric pollution in water bodies, environmental geochemistry, which was carried out in cooperation with the Gdańsk University of Technology and the University of Gdańsk. In addition, the Arctowski Station has been equipped with a second automatic meteorological station, and is the first station on King George Island to continuously monitor the balance of solar radiation in a wide spectrum range.

The IBB PAS also provides, on the basis of the Station's materials, a scientific advisory service to the Ministry of Maritime Economy and Inland Navigation concerning the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) in a broad spectrum of deep-sea fisheries issues (in the Southern Ocean area), in order to formulate the standpoint of Poland and to build substantive arguments to implement it for deep-sea areas.

Institute of Geophysics PAS (IGF PAS), Department of Polar and Marine Research (DPMR)

IGF PAS manages and is responsible for the infrastructure of the Polish Polar Station Hornsund (PPSH). Using the PPSH infrastructure, DPMR conducts (in cooperation with other IGF PAS units and other scientific institutions in Poland and abroad) observations of processes occurring within the Earth, the hydrosphere and the atmosphere, submitting the results to world data centers (see https: / /hornsund.igf.edu.pl/). The main goal of DPMR's research is to get a better understanding of the phenomena and dynamics of physical and chemical processes in the polar climate occurring in the abiotic part of the geosystem. The information collected is unique, since the observatories recording physical and chemical parameters of the abiotic environment in the extreme polar conditions are scanty. Thanks to the many-year monitoring, the IGF PAS is in possession of the long time series of meteorological and magnetic data that are unique in the Arctic research practice. Also, the monitoring of UV radiation has been carried out at Hornsund Station since 1996 up to now, with the use of annually calibrated wide-band biometers.

DPMR actively participates in the implementation of international scientific programs and projects, such as the Svalbard Integrated Arctic Earth Observing System (SIOS), INTERACT, INTAROS, EU-POLARNET, or educational projects such as EDU-ARCTIC, ERIS, ODDYSEY, or BRITEC. These projects are financed from European Commission sources and the contributions of consortium members participating in the projects. In addition, the em-

ployees of the Department participate in eight projects financed by NSC, SIOS, US NSF and the Research Council of Norway (as at the end of 2018). The full list of projects is available at https://www.igf.edu.pl/projekty-w-igf-pan.php.

DPMR currently employs seven researchers and supervises one PhD student (as of June 2019). In total, about 20 people are involved in polar research. Scientific publications cover a wide thematic scope, including geophysical research into solid Earth, hydrosphere and atmosphere, geochemistry and geology of the Arctic and Antarctic, and even teaching in natural science subjects. In addition to the PPSH infrastructure, IGF PAS is in charge of the scientific instrumentation for polar investigations financed under the first stage of the program named Polish Multidisciplinary Polar Research Laboratory PolarPol (see https://www.polarknow.us.edu.pl/bazy-danych/igf-bazy/). PolarPol is a project placed on the Polish Road Map of Research Infrastructure (PRMRI). Alongside, IGF PAS uses its own paleomagnetic laboratory of international standard, and also cooperates with the most modern geochemical laboratories in Poland and other countries. Recently, IGF PAS obtained financial resources from the Ministry of Science and Higher Education, intended for the reactivation of the Polish Antarctic Station named after Antoni B. Dobrowolski in the Bunger Oasis (East Antarctica), inoperative for many years. Its organizational and scientific goal is to conduct natural observations (seismic, geomagnetic, meteorological) using autonomous and automatic geophysical stations capable of continuous operation for one year at least. Ultimately, data should be submited online to world data centers.

In seismic studies, IGF PAS has been closely cooperating with the Institute of Geophysics of the University of Warsaw for years. The combined potential of both institutes gave grounds for scientific activities of international importance. In the last decade, materials collected during four Geophysical Expeditions to West Antarctica in 1979–1991 were reinterpreted. The data collected from 20 seismic refractive profiles and 12 reflective seismic profiles allowed us to present models of the structure of the Earth's crust and upper mantle northwest of the Antarctic Peninsula – from the island of Adelaide in the south to the island of Elephant in the north. The output of this work has been presented in a number of publications, including the concept of the geodynamic model, the map of the Moho boundary depth in the study area, and joint results of modeling of gravity and magnetic anomalies along seismic profiles crossing the Bransfield Strait, South Shetland Islands and the South Shetland Trench. Using modern data processing methods it became possible to accomplish, for the first time, a comprehensive interpretation of seismic sections, with a total length of about 1000 km, acquired during the first, 1979/1980 expedition. Data from reflection profiles have been submitted to the international Antarctic Data Center ANTOSTRAT.

Institute of Geological Sciences PAS (IGS PAS)

In the last decade, the IGS PAS' polar research concerned the Cenozoic geological systems in West Antarctica, focusing on the reconstruction of the history of the origin and stages of development of the Antarctic ice cover. Field research covered the area of the James Ross basin (geological outcrops of the Seymour, James Ross and Vega islands in the Weddell Sea) and the volcanic arc area of the northern Antarctic Peninsula, in particular the geological outcrops of King George Island. Research in Antarctica was made possible by cooperation with the Department of Antarctic Biology, PAS (now the Department of Antarctic Biology, IBB PAS) and the Instituto Antártico Argentino (Dirección Nacional del Antártico) in Buenos Aires. A detailed recognition of rock formations containing the geological record of the preglacial period (Eocene), the initial stage of ice cover spread (early Oligocene), the late Oligo-

cene interglacial and glacial Miocene periods was made. The reconstruction of paleoclimatic phenomena associated with the development of ice cover required combined research from many fields in broad domestic and foreign cooperation. As a result, a new stratigraphic diagram of the stages of the West Antarctic glaciation was presented for the age range between 50 and 20 million years ago, and the age of ice cover reaching the top of the Antarctic Peninsula was determined at 32 million years ago. IGS PAS has also performed geochemical survey on the oldest rocks in the areas of Enderby Land (Antarctica), Greenland and Labrador.

In 2018, IGS PAS, due to objective circumstances (personneal changes), decided to suspend polar research and withdrew from the Polish Polar Consortium.

Institute of Oceanology PAS (IO PAS)

The core of the Institute's arctic activity is the AREX long-term multidisciplinary observation program. An important part of it are the annual scientific expeditions of the research vessel r/v OCEANIA conducted since 1988 as part of the Institute's statutory activities. Up to now, there have been 30 research expeditions over summer seasons. The main research areas are the Norwegian, Barents and Greenland seas as well as the coastal waters and fjords of the Svalbard Archipelago. In recent years, when the summer ice cover withdraws, the research of r/v OCEANIA is more and more often conducted in the Arctic Ocean, north of the Strait of Fram and Svalbard. R/v OCEANIA is the only Polish scientific vessel conducting systematic research on open ocean. AREX expeditions are the largest and most comprehensive Polish polar expeditions, during which interdisciplinary research of the marine abiotic and biotic environment is done. Their additional value lies in the fact that data is collected each year on the same measuring grid and in the same period of the year. This made grounds for creating many unique data series. Each year, measurements from the board of r/v OCEANIA are performed by several dozen scientists from Poland and other countries; during the 60 days of stay in the Arctic this makes up more than 700 man-days of research.

At the IO PAS, arctic research is conducted in the following departments: Marine Dynamics, Marine Physics, Marine Chemistry and Biochemistry, Marine Ecology, Genetics and Marine Biotechnology, and in the following laboratories: Marine Pollution and Paleoceanography. Over 100 out of a total of 150 employees are involved.

The IO PAS has developed comprehensive strategic directions in which statutory research of the Arctic is conducted. These are:

- the role of the ocean in shaping the climate and the effects of climate change in European seas;
- contemporary changes in ecosystems along the shelf sea shores;
- genetic and physiological mechanisms of the functioning of marine organisms. These directions cover a wide spectrum of research related to the causes, dynamics and effects of environmental changes in the Arctic. The most important long-term observation programs include:
- monitoring of changes in the physical properties and dynamics of Atlantic masses flowing into the Arctic Ocean and the Svalbard fjords;
- monitoring of selected elements of the biological environment (taxonomic composition, biodiversity and biomass of plankton and benthic complexes) in the Fram Strait and fjords of West Spitsbergen;
- optical, acoustic, chemical, genetic, paleoceanographic research and research on the sea-atmosphere exchange processes in the Arctic regions.

In addition to statutory research, the IO PAS, participates in a number of programs and national and international grants. The scientists of the IO PAS are involved in the study of many Polar Regions conducted from foreign ships and research stations in the Arctic and

Antarctic. IO PAS participates in many comparative studies of the Southern Ocean and Arctic Ocean, including ecological research on marine benthos or water masses.

Institute of Paleobiology PAS (IPal PAS)

The Institute's research in both polar areas has been conducted practically incessantly since the 1970s. Out of the approximately 20 scientists currently employed at the Institute, more than half were involved in polar research to a greater or lesser extent. Specimens of fossils and rocks, primarily from King George Island in South Shetlands and the ones obtained in cooperation with the Argentinean side (Instituto Antartico Argentino) from Seymour Island (West Antarctica), as well as from Spitsbergen and Greenland, constitute a significant part of the Institute's collection, which in recent years has obtained independent financing in the framework of SPUB. Some specimens are also presented as part of the permanent exhibition of the IPal PAS's Museum of Evolution at the Palace of Culture and Science in Warsaw, as well as loaned to other institutions. The Institute is consistently upgrading and enlarging its research equipment. The Institute was a member of the NanoFun consortium, which created a unique center focused on the development of functional materials, while working on the most current problems in nanotechnology, microfluidics, biotechnology, medical sciences and environmental protection. Two laboratories have been created at the Institute, equipped with – the first in Poland – cathodoluminescent microscope with a hot cathode containing a spectroscopic system and an x-ray microtomograph with submicrometer resolution. In the near future, a high-resolution scanning electron microscope with rich equipment will be purchased from the MSHE targeted grant. A modern research platform will be created based on mutually complementary high-resolution electron microscopy and computer microtomography techniques, enabling ambitious interdisciplinary research in geology, chemistry, physics and biomedicine.

In the last decade, IPal PAS continued research on fossils from Cenozoic marine and sea-glacial sediments of the Antarctic Peninsula region accumulated in 1976–2007. A number of publications describe various biotic complexes inhabiting the Antarctic coastal seas during the last 50 million years. This broadened the knowledge about changes in the living world during the progress of biogeographic isolation and cooling of the Antarctic climate. Comprehensive actuarial and paleontological research is also carried out based on Antarctic microfossils, mainly hole saws. They are a rich source of information when reconstructing the conditions of the natural environment, as well as the chronology of deglaciation processes after the maximum of the last glaciation (last 20,000 years). These studies are conducted using foreign research platforms, in cooperation with centers from the USA (Rice University, Louisiana State University), primarily in the Antarctic Peninsula, Pine Island Bay, as well as in the Ross Sea. In cooperation with the University of Geneva, as well as the Laboratory of Paleogenetics and Conservation Genetics at UW:CeNT, biogeographic and paleoenvironmental research is in progress, first restricted to hole saws, and ultimately embracing other groups of organisms.

IPal PAS employees are also involved in Arctic research. The study of Precambrian-Paleozoic sequences of sedimentary rocks of northern Russia and Spitsbergen was continued. A team of paleontologists from IPal PAS, in cooperation with foreign scientists, has been reconstructing groups of invertebrates from fossil chemosynthetic environments from the Arctic. These studies included Jurassic, Cretaceous and Paleocene sites from the Arctic Archipelago, Spitsbergen and New Earth. In July 2014, IPal PAS organized an international research expedition to East Greenland, to search for remains of Late Triassic vertebrates in the Carlber Fjord (Jamson Land). Systematic exploration has resulted in a rich collection of petrified bones and tracks. Finding the remains of late Triassic mammals that are subject to further testing should be considered a greatest success.

Polish Geological Institute–National Research Institute (PGI–NRI)

Research in King George Island concerning the stratigraphy of volcanic sequences and also paleomagnetic research have been conducted by the PGI–NRI since 2007. The results obtained and expected in the future are the following: precise location in time of Cenozoic glaciations of this island; precise location in time of mineralization phenomena, especially polymetallic sulphide mineralization; precise placement in time of the Bransfield Rift; reconstructions of the geodynamics of individual terranes of King George Island; reconstructions of the directions of magma migration (magnetic susceptibility anisotropy). The work was carried out as part of a project financed by the Ministry of Science and Informatization, MSI (2007–2009) and the international project: Antarctic Circumnavigation Expedition ACE (2009–2011). Current work is carried out as part of the state geological service duty. The polar research planned to be performed by PGI–NRI in the near future includes the following:

- studies on the age and genesis of polymetallic mineralization from King George Island;
- research on the origin of glacial material from the period of the first Cenozoic glaciation of King George Island in the context of defining the centers of former glaciations;
- pilot study of feasibility of aerogeophysical research (detailed magnetic survey) with a drone in the ice area of King George Island for developing a comprehensive geological and structural map of this island;
- chronostratigraphic studies of the Creto-Cenozoic sequences from Livingston Island (cooperation with the Chilean Antarctic Institute INACH).

PGI–NRI uses its own analytical laboratories: an isotope geochemistry laboratory equipped with a SHRIMP spectrometer (world class) and a European-class paleomagnetic laboratory.

Currently, four people are engaged in polar research at PGI–NRI.

Gdańsk University of Technology: Faculty of Civil and Environmental Engineering, Department of Water and Wastewater Technology (GUT:DWWT); Faculty of Chemistry, Department of Analytical Chemistry (GUT:DACh)

GUT:DWWT is engaged in the microbiological studies of environments, conducting research on Spitsbergen, in collaboration, e.g., with the Department of Ecology, IO PAS in Sopot and the Faculty of Biology and Biotechnology, UWM in Olsztyn. Research was carried out in the framework of the Ministry of Science and Higher Education (MSHE) projects (including the National Polar Program 2005–2007 "Biosphere"). In 2007, the testing area was expanded to include the Kongsfiorden Fjord thanks to funding from the Norwegian research center called the European Center for Arctic Environmental Research (ARCFAC V). As part of another MSHE project, research was also continued in the Antarctica during the XXXIII (2008/2009) Polar Expedition to the Arctowski Station. In the research conducted in the years 2009–2010 in the Admiralty Bay, three regions, differing from each other in microbiological terms, were distinguished. In cooperation with the University of Warmia and Mazury (UWM), in a special project implemented at the Department of Antarctic Biology, Polish Academy of Sciences, in Warsaw, and as part of the 4th International Polar Year and the ClicOPEN program, research was conducted in the bay area under the head of the Ecology Glacier. Analyzes included microbial communities inhabiting the stony lagoon bottom, periodically free of water. Molecular studies have shown significant diversity in the taxonomic structure of the Ecology Lagoon bacteriocenosis, which is crucial for stimulating and regulating the rate at which processes occur in the lagoon ecosystem. In the years 2010–2014, research on Spitsbergen was continued as part of cooperation with UWM and the University of Wrocław. At that time, biological processes occurring during periods of total darkness (po-

lar night) were studied, and bacterioplankton structure of shallow lakes in the PPS Hornsund region was analyzed. Microbiological tests were also carried out as part of the GAME project. At present, in cooperation with the GUT:DACh, analyzed was the impact of chemical parameters modifying the environment on bacteriocenosis diversity in the arctic river catchment areas. The GUT:DWWT team dealing with polar areas consists of 5 people.

Polar research at GUT:DACh is carried out by a group of 5 researchers, their PhD students and students completing their master's and engineering courses. The first polar project funded by the National Science Center (2013) was dealing with research on the release of persistent organic pollutants from melting snow cover in the Arctic, finding a dangerous tendency to concentrate some compounds as a result of re-freezing of water from melting snow. In the next project (2014), which was implemented in the Revelva river basin (Wedel–Jarlsberg Land), a number of chemical compounds were determined, such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls, formaldehyde and total phenols as well as the sum parameter: total organic carbon. In 2018, research was expanded to better explain the impact of environmental stress on the biodiversity of microorganisms, including the verification of the phosphorus hypothesis as a factor limiting microbial activity. Since 2015, as part of cooperation with the Faculty of Earth Sciences and Spatial Management of the Maria Curie-Skłodowska University in Lublin, interdisciplinary research is being conducted in the fields of chemistry, glaciology, hydrology and meteorology. The research, funded by another NSC grant, provided information on the transport of a wide range of pollutants (including PCB, PAHs, metals) within the glaciated catchment of the Scott River, modification of ablative waters of the Scott Glacier by rainwater, and the load of chemical compounds eventually reaching the waters of Bellsund Fjord. The implemented project provided unique hydrochemical information about one of the 17 Svalbard glaciers covered by the mass balance test in the framework of the World Glacier Monitoring System (WGMS). Another NSC project (2018) is an expansion of the existing research on the movement of pollutants from the group of persistent organic pollutants (POPs) in the Arctic environment. The significance of the project lies in indicating the possible effects of climate change (and changes in the Arctic environment resulting from it) on pollution concentrations, which can be a dangerous mechanism that worsens the living conditions of the local ecosystem. As part of this project, one doctoral dissertation is under way.

The GUT:DACh also conducts research on biological materials from sea birds and the Svalbard reindeer, which are a source of information about pollution of the polar environment. The analyzes performed searched for the presence of metals and for the presence of polychlorinated biphenyls, polycyclic aromatic hydrocarbons and organochlorine pesticides accumulated in tissues and animal products. Research, which is a topic of one doctoral thesis, provides evidence that non-destructive biological materials are a valuable source of information in ecotoxicological studies and may be particularly useful for protected polar species.

Another research initiated by the GUT:DACh concerns the area of Antarctica. The project, carried out in cooperation with IBB PAS, deals with measurements of the levels of concentrations and translocations of atmospheric pollutants. Based on this research, one doctoral thesis has already been completed and another is under way. One of the areas covered by the study is King George Island (South Shetland Islands). The results will give grounds for assessing the degree of pollution of surface waters, sediments and soils in the area of the west coast of the Admiralty Bay, i.e., the Antarctic Specially Protected Area 128 (ASPA 128). The Department's employees, students and Phd students participated in 7 grants/projects implemented in the Polar Regions. The scientific infrastructure includes the gas chromatographs with FID, ECD,

NPD, MS detectors, high performance liquid chromatographs with MS, DAD, fluorescence, IR and UV detectors and a tandem mass spectrometer, ion chromatographs, atomic absorption spectrophotometers, isotachophoregraph, capillary electrophoresis apparatus, TOC/OWO analyzers, injection-flow analysis kit, inversion voltammetry kit (electrochemical trace metal analyzer), flame photometers, mercury analyzer, atomic absorption spectrometer with atomization in a graphite cuvette and flame atomization. The Department is equipped with a two-dimensional gas chromatograph, unique in Poland and Europe, coupled with mass spectrometry. In the domain of polar topics there were defended four doctoral dissertations, 43 master's theses and 8 engineer diploma theses.

Warsaw University of Technology, Faculty of Geodesy and Cartography (WUT:FGC)

The Faculty of Geodesy and Cartography has been participating in scientific expeditions to Polar Regions on both hemispheres for over 60 years. Although polar research is not the leading scientific research topic of WUT:FGC, its employees have already participated in the first post-war expeditions to Spitsbergen (1957) and Antarctica (1958/59). Both during these expeditions and later on, in the 1970s, 1980s and 1990s, researchers from WUT:FGC were mainly involved in the study of acceleration of the Earth in the Antarctica (Dobrowolski Station) and the study of glacier dynamics using ground photogrammetry, as well as geodynamic studies around the Hornsund Fjord in the Arctic (S. Siedlecki Polish Polar Station on Spitsbergen). In the last two decades, the Faculty has organized several scientific expeditions to Hornsund, during which the current research was continued using GPS satellite methods and laser scanning. The main research directions were the studies of surface runoff speeds and changes in the range of the Hansbreen (Hans Glacier) forehead. In the last decade, scientific activity related to King George Island in Antarctica has been intensified. In 2014, works were undertaken on reactivating the geographical information system for the island, called KGIS, which, until 2011, was carried out as part of SCAR's activities. Within the reactivated system, now named KGIS.PL, the existing national cartographic studies were integrated and a portal for their presentation was prepared. It is assumed that the system's functionality will be extended by including the possibility of collecting and analyzing data in the fields of biology and botany, as well as other natural sciences. In addition to conducting its own research, the Faculty often provides geodetic support for research and scientific activities carried out by other units. In 2015, cooperation was started with the Faculty of Botany of the University of Warsaw and the IBB PAS in the research on invasive flora on King George Island. WUT:FGC, under the cooperation agreement, supported the IBB PAS by developing large-scale cartographic materials for desiging a reconstructed and modernized the Arctowski Station. In recent years, in cooperation with the Faculty of Earth Sciences of the Nicolaus Copernicus University in Toruń, research has been undertaken to examine changes in the thickness and extent of glaciers on the western shore of the Admiralty Bay on King George Island, using multi-source geodetic and satellite data. Initial actions were also taken to create a spatial information infrastructure for polar areas and to join the global Polar SDI (Spatial Data Infrastructure) initiative. Several people participate in polar research.

Jagiellonian University (JU): Department of Polar Research and Documentation of the Institute of Botany (JU:DPRD) at the Faculty of Biology; Institute of Geography and Spatial Management (JU:IGSM) at the Faculty of Geography and Geology

Polar studies at the Jagiellonian University have been performed by Professors Józef Morozewicz (since 1904), Mieczysław Klimaszewski (since 1938) and Zdzisław Czeppe (since

1957) – the authors of pioneering scientific monographs. Professor Z. Czeppe has initiated the modern research, leading a series of interdisciplinary summer expeditions of the Jagiellonian University to Sørkapp Land in the years 1980–1990. They embraced geological, geographical, biological, archeological and historical investigations. Consequently, in 1979, there was established the Polar Research Documentation Institute, later transformed into the Department of Polar Research and Documentation of the Institute of Botany (JU:DPRD), named after Professor Z. Czeppe. In this Department, Prof. Maria Olech has developed the botanical and ecological research of King George Island.

Of great importance in polar activity of JU:IGSM and JU:DPRD was the continuation of Sørkapp Land's research, which focused on two problems: (1) changes in the natural environment and landscape due to global warming: in the northwest peninsula in the years 1982–2008 and in the northeast peninsula in the years 2005–2016; (2) comparison of landscape functioning and transformation between the east and west coasts.

Since 2001, every 5–7 years (in 2001, 2006, 2012, 2019), a team from the Department of Physical Geography of the JU:IGSM has been conducting studies of landscape changes due to the warming and recession of glaciers in the Lindströmfjellet-Håbergnuten mountain range (Nordenskiölda Land). Since 1989, the team from the Department of Soil Science and Geography of the JU:IGSM has carried out detailed studies on the genesis, properties and spatial diversity of cryogenic soils on the west coast of the Sørkapp Land and the Fuglebergsletta plain, near the Polish Polar Station. In recent years, research has focused on the quantity and quality of organic matter in cryogenic soils on the north coast of Hornsund in the context of its susceptibility to microbial degradation and the release of organic carbon in the form of CO2 into the atmosphere. Examined were also the development, differentiation and contamination with trace elements of cryogenic soils in the Longyearbyen region

In JU:IGSM, the polar research is done by several people, two having permanent positions (one from each of the above-mentioned units) , and others (employees, doctoral students and graduate students) working temporarily.

Research of JU:DPRD is done in both the Arctic and Antarctic areas (1986–2018). In the Arctic, it covers the Svalbard archipelago, Iceland, northern Canada, Alaska, Newfoundland, Labrador and Greenland, and concerns: (1) the ecology of land areas, including mature communities of the Arctic tundra, as well as initial communities in the foreland of glaciers; (2) cryptogamic organisms as bioindicators of anthropogenic pollution of Polar Regions; (3) interaction between vegetation and herbivores in the context of climate change; (4) taxonomic issues. In the southern hemisphere, the research covers the South Shetland, the Antarctic Peninsula and the Antarctic continent, and its topics focus on: (1) taxonomic issues; (2) the impact of anthropogenic factors on the Antarctic terrestrial ecosystems; (3) the presence of alien species in Antarctica.

At JU:DPRD, polar research has been conducted in recent years by 8 people, including employees, doctoral students and students.

Adam Mickiewicz University: Faculty of Geographical and Geological Sciences (AMU:FGGS)

Employees and students of the University of Adam Mickiewicz in Poznań have been engaged in polar research since the early 1970s. In 1984, continuing the work in the Hornsund area, the Faculty of Geographical and Geological Sciences of the Adam Mickiewicz University organized the first expedition to Petunia bay (Billefjorden, central Spitsbergen), choosing as its basis the wooden house Skottehytt built in the 1920s. The refusal to use Skottehytt from 2010 on forced the organizers of the UAM polar expeditions to try to put their own station,

which was accomplished after nearly two years of negotiations in July 2011. In subsequent years, the station underwent modifications and in its current form is already fully functional. Throughout the 35 years elapsed since the first expedition to the bay of Petunia, teams from Poznań have worked there during 24 seasons, mainly in summer (June–September), but several spring trips were organized too.

The station is a site of long-term observations of the cryosphere response to climate change, as well as modern geomorphological processes. Other studies include: geological, paleogeographic and paleontological, geochemical, oceanographic, meteorological and climatological research, as well as research on the diversity and succession of vegetation and human impact on the Arctic environment. In 2013, basing on the previous experience and discussions, observations were initiated in the vicinity of Petuniabukta regarding subsystems of Integrated Monitoring of the Natural Environment, preparing statesments that could be a reference for areas of medium latitude with a more pronounced anthropopressure.

Currently, about 25 people deal with polar research in the AMU:FGGS.

University of Łódź, Institute of Ecology and Environmental Protection, Chair of Invertebrate Zoology and Hydrobiology, Department of Polar Biology and Oceanobiology (UŁ:DPBO)

The analyzes conducted in the last decade summarized almost 40 years of research on zoobenthos of the Admiralty Bay in the area of the Arctowski Station. On the basis of data collected in the 1980s and 1990s and as part of the 4th IPY (2007–2009), works on documentation of ecological gradients were carried out, factors determining the diversity of sea floor complexes of shallow glacial bays were analyzed, and the biodiversity of the Antarctic and Arctic fjords was being compared. Studies also concerned the taxonomy of some arthropods and unicellular algae (diatoms) of the Southern Ocean. As part of international cooperation, studies have been developed on the diversity of selected groups of invertebrates of the Ross Sea, Scotia Sea and Amundsen Sea, as well as the waters surrounding Iceland. The employees of the Department were also co-authors of Biogeographic Atlas of the Southern Ocean, editors of the Polish Polar Research journal, and editors of the international SCAR-MarBIN database. Currently, 8 people and 3 doctoral students work at the UŁ:DPBO.

Maria Curie-Skłodowska University (MCSU) in Lublin, Faculty of Earth Sciences and Spatial Management (MSCU:FES)

The MCSU employees have been gaining polar experience since the early 1970s. Professor Kazimierz Pękala participated in the expeditions of the University of Wrocław and worked in the Hansbreen area (habilitation thesis). Jan Rodzik, MCSU professor, participated several times in year-round expeditions to the Hornsund Station.

Studies of polar areas initiated by MCSU in 1986 were interdisciplinary from the very beginning. They involved representatives of various fields of science, namely: geomorphologists, geologists, soil scientists, meteorologists, hydrolologists and hydrochemists, biochemists, botanists and archaeologists. Currently, polar research is one of the leading issues implemented at the MSCU:FES. They concern both the biotic and abiotic sphere, yet also the socio-political one. They concentrate, e.g., on the following:

- the functioning of glaciated and non-glaciated catchments in the context of climate change;
- modern morphogenetic processes in paraglacial and periglacial areas (monitoring);
- dynamics of shoreline changes in the context of the impact of glacial, marine, fluvial and periglacial processes;

- thermics and dynamics of the permafrost layer, in the context of specific thermal conditions (meteorological monitoring);
- development of physico-chemical characteristics of arctic soils;
- hydrological and hydrochemical characteristics of waters from glaciated and non-glaciated basins;
- quantitative and qualitative determination of slurry and rubble transport in glaciated catchments;
- glacological studies of glaciers in the vicinity of the station and geomorphological and hydrological mapping of their foregrounds;
- the use of modern measuring systems – laser scanning, hydrochemical laboratories;
- studies of polar areas in the political and economic aspects, including the objectives and tools of Polish arctic policy.

In the years 2010–2018, five research projects funded by the National Science Center were implemented, mainly dealing with issues of geomorphology and hydrology of southwestern Spitsbergen, as well as social issues.

Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management (NCU:FESSM)

The scientific activity of the employees of NCU:FESSM includes the organization of scientific expeditions to Spitsbergen in the Arctic and to the Antarctic (Prince George Island) and conducting field research, mainly geomorphological, glacological, hydrological and meteorological. Moreover, climatic research has been done for the entire Arctic and Antarctic, with particular attention to climate change. The study spans over the last several hundred years.

Systematic research in the Polar Regions is done by 10–15 employees currently supported by students and PhD students. The most important advantage of field research activity is the fact that the University has its own station on Spitsbergen (NCU:PS), as well as the existence of Polar Research Center (NCU:PRC), which aims at doing scientific research in Polar Regions (Arctic and Antarctic) and contemporarily glaciated areas, enhancing cooperation with domestic and foreign research centers in science and education in the Polar Regions, creating conditions favorable for getting access to interdisciplinary research projects related to Polar Regions, as well as promoting knowledge about Polar Regions.

During scientific expeditions to Svalbard, research is conducted in the following fields: (1) hydrology (e.g. outflow from glaciers; glacial river regime; suspended, solute and dragged transport in glacial rivers), (2) cryology (modern changes in cryosphere, long-term permafrost and periglacial processes), (3) meteorology and climatology (e.g. topoclimatic differentiation, soil thermics, the impact of atmospheric circulation on weather conditions, climate changes) and (4) geomorphology (shape and genesis of glacial foregrounds, glacial and periglacial processes). In the scope of hydrology and cryology, the most important are glaciological studies on glaciers of the Kaffiøyry region, with particular emphasis on their mass balance in the light of contemporary climate changes, changes and dynamics of glaciers, surging glaciers of the Aavatsmark Glacier, hydrothermal structure of glaciers, glacial ablation (melting), accumulation and properties of snow cover, runoff from glaciers and the glacial river regime, transport of suspended, solute and dragged material in the glacial rivers. An important supplement to the research is the analysis of the outflow variability from the contemporarily glaciated catchment, as a result of transformations taking place on glaciers and the catchment's area. In the scope of meteorology and climatology, the most popular are studies on the recognition of weather conditions and topoclimatic diversity. Of great interest to the NCU

climatologists are also the problems of thermics and dynamics of the permafrost active layer and the impact of atmospheric circulation on weather and climate. Geomorphological studies concern, e.g., reconstruction of geomorphological changes in the last several hundred years, determination of the shape, internal structure and genesis of forms occurring on the glacial foregrounds, determination of the type and rate of deglaciation for various types of glaciers, and specification of sea coast types.

In the southern polar zone, field research was begun in 1978 at the Dobrowolski Station, and then, since 1995, continued in several expeditions to the Arctowski Station. In Antarctica, pronounced warming is particularly evident in the Antarctic Peninsula. On King George Island, research was carried out on the differences in local climatic conditions between the glaciated and non-glaciated areas, and the variability of soil temperature in an annual cycle. The causes of increasing warming in the Antarctic Peninsula were searched by examining the role of ocean surface thermics and the extent of sea ice. Studies concerned also the glacier mass balance in the area of Arctowski Station, including accumulation and ablation of nearby glaciers. The rate of glacier's withdrawal and its relationship with climate change in the region were determined. The unique data on glacier thermics have been obtained.

The aforementioned climatological studies throughout the Arctic and Antarctic focus mainly on examining the contemporary climate change and its causes. Moreover, in the Arctic, extensive studies on climate reconstructions have been made , covering its entire area and individual regions, for the early-instrumental period (from the beginning of the 19th century to the mid-20th century). A detailed summary of the scientific activity of Toruń climatologists in polar research in the period 1975–2018 is contained in the publications: Przybylak et al. (2015) and Przybylak et al. (2019; http://ptgeof.imgw.pl/?strona=5,27,1).

As a result of research, several hundred scientific publications in the field of Earth and environmental sciences were created (including many for awarding academic degrees). They have been published in high-score and prestigious journals, indexed in international databases (including Journal Citation Reports) and listed in Part A of the list of scored journals established by the Ministry of Science and Higher Education, as well as in the form of monographs issued by well-known foreign publishers. A list of all publications is presented in the paper Polar regions bibliography of the Faculty of Earth Sciences, Nicolaus Copernicus University (ed. Sobota 2017). High research activity in the polar areas was possible, among other things, owing to international cooperation and raising funds under 19 research projects from SCSR MES, MSHE, NSC, NCRD(AWAKE and AWAKE-2).

University of Silesia, Faculty of Earth Sciences (US:FES)

The faculty conducts comprehensive research of the polar environment, focusing its activities primarily on Svalbard and northern Scandinavia. Their goal is to explain the interactions between the atmosphere, hydrosphere, lithosphere and the Arctic cryosphere in the context of contemporary environmental changes. The glaciological issues are focused on the evolution of Svalbard glacial systems, manifested by changes in their geometry, reduction of range, weight loss, changes in thermal regime and dynamics. Studies of the head zones of glaciers discharging into the sea provide valuable information on the amount of fresh water delivered to the ocean, affecting both global sea levels and regional changes in the marine environment of Svalbard's surroundings. In glaciological studies, remote sensing and photogrammetric methods as well as geophysical tools are used. Other studies concern the interaction of glaciated areas with the periglacial zone, as well as analyzes of the extent and geophysical properties of permafrost. Previous geomorphological studies of marginal glacier zones by means of

geophysical methods have been continued. Observed are also changes in snow cover in glaciated and non-glaciated areas of Svalbard, including spatial distribution of snow, its evolution, internal structure and physical properties.

The US:FES specializes in on-site meteorological monitoring (also on glaciers) using automatic meteorological stations as well as in studies in meteorology and polar climatology. Extensive studies are conducted in the domains of hydrology, hydrochemistry, chemistry and analysis of polar environment pollution (with particular emphasis on glaciated drainage basins), as well as environmental and ecological research using dendrochronological methods. The efficient functioning of research in Polar Regions is supported by the so-called Polar Laboratory of the University of Silesia, which consists of a complex of instruments (e.g. glacier-sounding radar sets, automatic meteorological stations, geodetic satellite sets), software (e.g. for remote sensing and geophysical data processing), and logistic and transport means (snowmobiles, boat with outboard engine).

The research described above is conducted through the implementation of scientific projects, including those under the European Union Framework Program "Horizon 2020" (INTAROS), the 7th EU Framework Program (ice2sea), the European Science Foundation (SvalGlac), the Polish–Norwegian Research Cooperation Program (AWAKE, AWAKE2), or financed by the Ministry of Science and Higher Education and the National Science Center.

Currently, about 15 employees of the US:FES are involved in polar research. Nine PhD students affiliated to the University of Silesia, implementing projects related to polar areas, study at doctoral courses (including Interdisciplinary Polar Studies) and at the International Environmental Doctoral School at the Center for Polar Studies. The University of Silesia has also courses for students at the master's degree program, majoring in Exploration of Polar and Mountainous Areas.

University of Warmia and Mazury in Olsztyn (UWM), Faculty of Biology and Biotechnology (UWM:FBB), Chair of Microbiology and Mycology (UWM:CMM)

Polar research has been conducted at the UWM:FBB since 2000. It focuses on the issues of Antarctic botany, in particular on the embryonic development of Antarctic plants, the specific properties of sugar contained in them and the response of these plants to cold stress. In the Chair of Microbiology and Mycology (UWM:CMM) studies of Polar Regions concern the ecology and ecophysiology of microorganisms. The basic scientific goal is to acquire knowledge about the structural and functional characteristics of microbiocenoses of polar ecosystems, both of glaciers as well as new proglational environments created on their foreground. This knowledge allows one to determine the role of glacial microbiomes in shaping the dynamics of the biosphere. Research on Spitsbergen is conducted in the area of the Werenskiold Glacier in the Wedel Jarlsberg Land (Baranowski Station – the summer station of the University of Wrocław, hus in Hyttevice, and the PPS Hornsund). Research in Antarctica is done on King George Island, using the facilities of the Arctowski Station.

The choice of the first area, showcase from the point of view of research, is associated with its unique properties, and, in particular due to the junction, as a "continuum", of the three areas: the Werenskiold glacier, the adjacent area of "young" soils and the proglational river and lake system of the Brattegg valley fed with snowmelt . A dozen or so research sites were established in the studied area, whose location enabled tracking the changes within individual environments (glaciers, glacial reservoirs and soils), as well as throughout the entire system. At Spitsbergen, these studies were conducted as part of three NSC projects, regarding: (1) processes shaping the formation of microbiocenoses of freshwater reservoirs in the foreground of the glacier under ac-

celerated deglaciation, (2) mechanisms and dynamics of mineral changes in young polar Spitsbergen soils, and (3) metagenomic, structural and functional characteristics of microbiocenoses glacial environments (Hans and Werenskiold glaciers on Spitsbergen and Ecology glacier on King George Island in Antarctica). Research is conducted in cooperation with many institutions and based on a very wide set of physico-chemical, biological and microbiological analyzes. The physico-chemical analyzes of water were made by means of isotope analysis and atomic absorption spectrometry (AAP), rarely used in field studies. Microbiological tests were carried out using a number of classic and molecular techniques, including advanced fluorescence and confocal microscopy techniques. Analysis of the data collected in this way allowed describing the phenomena and mechanisms related to the formation of microbiota in various types of environments under study. This study is one of the very few, in a world scale, comprehensive analyzes of microbiocenoses of a river-lake system in Polar Regions. The collected results constitute a unique database, the analysis of which made it possible to explain important processes occurring during deglaciation and the impact of this process on polar microbiocenoses. The main research collaborators are IBB PAS, UWr:FESEM, and GUT:DWWT. The main scientific achievements are: (1) evidencing differences in microbiocenoses under different environmental influences of two polythermal glaciers of southwestern Spitsbergen (Werenskioldbreen and Hansbreen), (2) demonstrating that succession in the Arctic flight-lenitic system of the Brattegg valley (South–West Spitsbergen) is done by simplifying the structure of microbial communities with a simultaneous increase in the number and activity of prokaryotes, (3) explanation of changes in water chemistry along the newly created Arctic river and lake system of the Brattegg valley (South–West Spitsbergen), (4) description of successive changes in bacterial biodiversity in postglacial soils in the foreground of the Werenskiold Glacier (South–West Spitsbergen) in a time and space gradient; description of the direction and mechanism of these changes. Polar research conducted at the UWM:CMM follows the latest global trends in microbiological scientific research and, despite many logistic difficulties, it aims at expanding the knowledge about the functioning, biodiversity and the possibilities of utilizing the potential of microorganisms occurring there. Two employees of the Chair participated in 11 grants implemented in the Polar Regions, including ClicOpen (IPY-34).

University of Warsaw, Faculty of Geology (UW:FG)

In the last decade, there was implemented the EU IMCOST program, coordinated by the Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research (AWI, Bremerhaven, Germany). Analyzed were also the materials collected during Russian–Polish cooperation in West Antarctica (King George Island and Seymour Island) and Eastern Antarctica (Schirmacher, Larsemann Oasis and Price Charles Mountains). Research topics included hydrobiological and hydrogeological issues in the Admiralty Bay area, onshore Quaternary research on the Fildes Peninsula, paleolimnological analysis (Penguin Island, King George Island, Schirmacher and Larsemann oases) and reconstruction of climate changes in the last millennium based on geochemical and biochemical record taken from the shallow branches of the Admiralty Bay. Studies carried out jointly with IGS PAS concerned also the geochemical, petrographic and paleoecological exploration of Eocene rock formations on the islands of King George and Seymour. As part of the IPY ACE research project carried out in cooperation with IGS PAS, the geological records of the oldest Cenozoic glaciation in Antarctica (oligocene, lower miocene, King George Island) and the beginning of the permanent Upper Miocene glaciation of the continent (Prince Charles Mountains) were explored. Currently, several people (variable number) deal with polar research.

University of Wrocław, Faculty of Earth Sciences and Environmental Management (UWr:FESEM), Faculty of Biological Sciences (UWr:FBS)

The Wrocław Center belongs to the precursors of polar research in post-war Poland, owing to the achievements of outstanding polar explorers, Professors Alfred Jahn, Aleksander Kosiba, and Dr Stanisław Baranowski. A university research station (named after Stanisław Baranowski) has been operating in Spitsbergen since 1971, located in the vicinity of the Polish Polar Station Hornsund.

The present-day scientific activity in the field of polar research is carried out at the Faculty of Earth Sciences and Environmental Management (UWr:FESEM) and the Faculty of Biological Sciences (UWr:FBS). The research works are aided by modern, specialized instruments for geophysical, geochemical and meteorological measurements, two servers with high computing power as well as departmental laboratories and workshops (including the Land and Hydrochemical Laboratory, Dendrochronological Laboratory, Laboratory of Spatial Modeling Methods, Laboratory of Microscopic Techniques, and Electronic Workshop).

Taking advantage of the rich tradition, new research directions have been developed, in which geomorphological and permafrost research in Spitsbergen, Greenland, Iceland, the Canadian Arctic and the Antarctic, are leading the way. Parallel to research in the field of periglacial, littoral and fluvial geomorphology, dendro-climatological and dendro-geomorphological studies have been initiated, and the unique and multi-faceted application of dendrochronological methods is internationally recognized. Based on test areas in Spitsbergen, northern Scandinavia, Iceland and the Canadian Arctic, debris flow activity and fluvial systems' development have been monitored, and the reconstructions of climate and extreme events have been carried out.

Techniques for spatial analysis and modeling of Svalbard climate conditions are being successfully developed with the use of the mesoscale WRF synoptic model. The leading theme in botanical and ecological research is the biogeochemistry of trace elements, chemical plant ecology and bioindication of chemical contamination of the environment.

The research currently done at the Stanisław Baranowski Spitsbergen Polar Station of UWr (Baranowski Station) includes the following: studies of spatial and temporal conditions of permafrost dynamics in a mountain valley, the impact of climate change on the development of river valleys and processes of glacial landscape transformation.

The leading bipolar issue is research on the development of rocky coasts in polar climates conducted along the coasts of the Hornsund Fjord (Svalbard) and the Admiralty Bay (South Shetland Islands). Since 2013, Wrocław geomorphologists have been analyzing the importance of littoral processes in the development of paraglacial sedimentary cascades operating since the end of the Small Ice Age on Spitsbergen. The Wrocław center also specializes in research into the impact of changes in the Arctic coast zones on the security and development of settlement infrastructure in Spitsbergen and Greenland.

Together with the University of Silesia (US) and the Center for Polar Studies (CPS), the Polish Svalbard Snow Program was initiated, which, under the auspices of the Polish Polar Consortium, is a platform for multidisciplinary national and international cooperation. A permanent element of activity are the "Workshops on Snow and Winter Safety", regularly co-organized with the Mountain Volunteer Rescue Service and members of the Polish Polar Consortium; they constitute a platform for the exchange of current knowledge and experience, especially dedicated to young staff and students.

In polar research, there are permanently engaged 5 independent academics, two PhD holders and one technician.

7. POLAR INFRASTRUCTURE

7.1 Land infrastructure

Thanks to the funds allocated by the Ministry of Science and Higher Education, there are two Polish polar stations with the status of Special Research Equipment (SPUB) – in Antarctica and the Arctic. These are year-round stations that have the capability of accomodating for a team in excess of ten people, and in the summer season 30–40 people can stay there at the same time.

University stations generally work seasonally, although there are some exceptions; the NCU station, for instance, is prepared for year-round operation (Fig. 7).

Fig. 7. NCU Polar Station in summer 2018 (left) and spring 2019 (right). Photo Ireneusz Sobota.

Year-round stations and larger university stations have technical facilities, as well as power generators, photocells, automatic weather stations and motor boats, and appropriate safety equipment, providing protection on water and glaciers. It also includes mandatory radio and telephone (satellite) communication equipment, and satellite rescue equipment.

While searching through the Web of Science for the term "Polish Polar Station" we get information about the number of references to Polish stations in the world literature (Fig. 8).

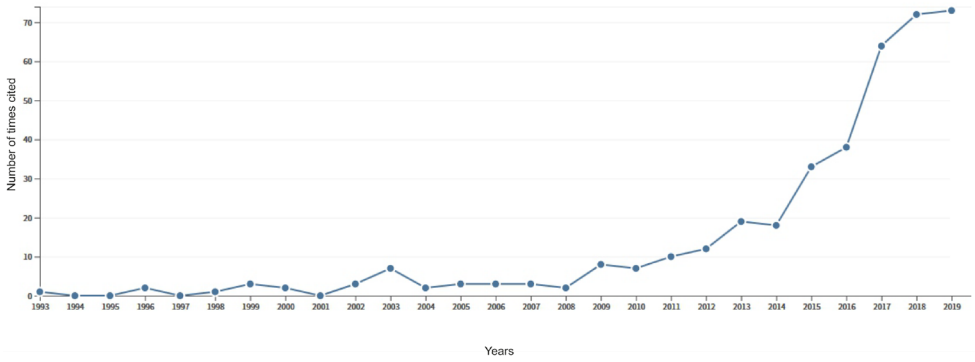

Fig. 8. Number of references to Polish polar stations in scientific literature according to WoS since 1993. Compilation of data: Marek Lewandowski.

Leaving aside the incomplete range of input data (not all Polish polar stations were cited in the publications with the same keywords), the graph in Fig. 8 shows an indisputable increase in the rank of Polish polar stations in the world's scientific literature, expressed by a 10-fold increase in station's quotations over the last ten years.

Henryk Arctowski Polish Antarctic Station (Arctowski Station)

Antarctica and the surrounding South Ocean is an area where unique research can be done on, e.g., the role of the Polar Regions in current and future changes in the global environment, evolution and biological adaptation of organisms to life in extreme environments, tectonic evolution of the Earth lithosphere and the Sun–Earth interaction. The research of Polar Regions, their scientific, geopolitical and economic importance is the subject of active interest of many countries, as manifested by special scientific governmental programs. The Arctowski Station is located on Admiralty Bay on King George Island in the South Shetland archipelago in Antarctica (Fig. 9a). It started operating on 26 February 1977, and has since then been incessantly used as a year-round station. Since 2012, by virtue of the resolution of the Presidium of the Polish Academy of Sciences of 29 November 2011, the station was incorporated into the IBB PAS. Poland is one of only 20 countries possessing year-round scientific-research stations in Antarctica.

Fig. 9a. The Arctowski Station. Photo: Marek Figielski.

The Arctowski Station's infrastructure consists of 16 objects with equipment (year-round residential building, seasonal residential buildings, laboratories, halls, warehouses, power plant) covering a total area of 1,980 m^2, petrol stations with tanks and two field bases – at Demay and Lions Rump Cape. Due to the fact that the station is isolated from the world throughout major part of the year, it has its own logistic facilities: heavy equipment (amphibians, bulldozer, tractor, excavator, crane, KH 200 vessels, reloading barges, etc.) necessary for the unloading and loading of the ship and during renovation works, means of land and sea transport (snowmobiles and inflatable boats) needed for scientific work and enabling contact with field bases, other stations on King George Island, and ships.

Thanks to establishing the Arctowski Station and the research programs based on it, Poland obtained the status of a consultative state of the Antarctic Agreement, and consequently the equivalent right to vote in decisions concerning the management of the Antarctic (all decisions concerning this area are taken by the group of 29 consultative states).

Based on the Arctowski Station and the two field bases, at Cape Lions Rump and Demay (Fig. 9b), research has been done in the following areas: oceanography, geology, glaciology, geomorphology, climatology, microbiology, botany, ecology, ornithology, genetics, marine biology and chemistry, cartography, and permanent environmental monitoring, to name just

Fig. 9b. Field base on Cape Demay in Paradise Bay. Photo: Marek Figielski.

the major ones. This research is structured in the framework of interdisciplinary programs addressing issues such as the variability of polar ecosystems, evolution, structure and dynamics of biodiversity or the impact of climate change in the Antarctic on the functioning of marine and terrestrial ecosystems.

Scientific materials and data collected since 1977 on the basis of the infrastructure of the Arctowski Station are permanently used by over 20 scientific institutions in Poland and numerous institutions from 22 countries.

Currently, due to the progressing coastal abrasion, as well as the needs of ongoing research projects, a thorough reconstruction of the Station's infrastructure and erection of a new main building, which will be located in a more convenient and safe place, has started. The design of the new main building of the Arctowski Station, prepared by the Kuryłowicz & Associates architectural studio, was awarded a silver medal in the Future Education Projects category in the prestigious World Architecture News (WAN) Awards 2019.

The Stanisław Siedlecki Polish Polar Station Hornsund (PPSH, Hornsund Station), built in 1957 over the Hornsund Fjord on Spitsbergen Island (Svalbard; Fig. 10), is managed by the Institute of Geophysics PAS in Warsaw. PPSH carries out the following monitoring: hydrological, hydrochemical, meteorological (rain and snowfall, pressure, temperature), of permafrost condition, snow cover, glaciological, oceanographic (temperature and salinity structure, amount of suspended matter in water and rate of its subsidence, icing of bays), geomagnetic, ionospheric, seismological, as well as the monitoring of atmospheric electricity and radiation processes in the atmosphere.

The Hornsund **meteorological station** works within a network of Norwegian stations and is registered with the World Meteorological Organization (WMO) under number 01003. Systematic, round-the-clock measurements and observations of basic meteorological parameters according to WMO standards are carried out there.

Fig. 10. PPSH in summer and winter (left photo: Barbara Barzycka, right photo: Dariusz Ignatiuk). PPSH is a modern facility, part of the international Svalbard Integrated Earth Observing System (SIOS).

The **seismological station** belongs to the international network of seismological observatories. It is the only station belonging to the Polish seismological network located outside the country. The main task of the seismological laboratory over the Hornsund Fjord is a continuous recording of local earthquakes of tectonic and glacial origin.

The **natural Earth's magnetic field** variations are recorded incessantly. Due to its geographical location, the PPSH observatory records some of the largest changes in the Earth's magnetic field. They are about 5 times larger than those registered, e.g., in Poland, and that is why the results are valuable for scientists from the whole world. Since 2002, the magnetic observatory belongs to the world research network INTERMAGNET.

PPSH conducts long-term research on ionosphere structure. This research belongs to the autonomous scientific activity of the Space Research Centre PAS. The research's aim is to measure how the plasma particles after explosions on the Sun affect our planet, **Glaciological research** in the Hornsund area is conducted in nearby glacier Hansbreen. Measurements are carried out to determine the mass balance and dynamics of glacial changes. These data are transmitted to the World Glacier Monitoring System (WGMS).

The **research of phenomena in the atmosphere** is focused on monitoring the Earth's electric field, UV radiation and aerosol content. These data are transmitted to the international AERONET network established by NASA.

In the chemical laboratory, the main research is directed towards the chemical composition of surface and precipitation water. Its aim is to specify the biogeochemical processes involved and determine the amount of pollutants that reach the site and remain there, also as a result of human activity.

PPSH is in possession of measurement series of different time spans. Some of them have recordings over several decades, which is a unique collection of information on an Arctic scale. The data from monitoring are made available, upon request, to interested institutions as well as Polish and foreign researchers. Monitoring activities and the costs of maintaining the research infrastructure, as well as the costs of employment and maintenance of the station's staff, are covered by the SPUB funds, currently allocated by the Ministry of Science and Higher Education every three years. PPSH is kept ready to accommodate for research by members

of consecutive Spitsbergen expeditions. In recent years, PPSH's crew consisted of 8–10 people employed by IGF PAS.

In addition to the studies performed as part of the year-round plan of the Station, there are biological, geological, geodetic, geomorphological, glaciological and oceanological researches done in the Hornsund area in the spring and summer seasons by various groups of scientists implementing their own projects. They then share the logistic and scientific facilities of the Station. The PPSH infrastructure is used in numerous scientific projects, both domestic and foreign.

In addition to the two year-round polar national stations, the list of land-based infrastructure units dedicated to polar research includes the following:

Antoni B. Dobrowolski Polar Station (Dobrowolski Station), located in the Bungera Oasis in Eastern Antarctica (https://dobrowolski.igf.edu.pl/), has been inactive for forty years. There is now a plan to revitalize it as an automatic geophysical observatory. The infrastructure of the revitalized station will consist of autonomous (in the sense of power supply), automatic measuring devices, to record natural seismic waves, as well as geomagnetic field components and meteorological parameters.

The core of the revitalization project in the part concerning scientific infrastructure is to design and construct a power station for supplying measuring instruments with electricity generated by renewable energy sources (wind, solar) or fuel cells. In this respect, in May 2019, the IGF PAS and the Institute of Power Engineering, with the substantive support of the Polish Energy Group PGE, signed an agreement on scientific and technical cooperation aimed at creating a project, and then a prototype, of a universal unit to supply the measuring instruments.

The predictable time horizon for the start of observations in Bunger Oasis can be reliably estimated for the years 2022–23. These estimates are based on consultations with Australian (Australian Antarctic Division) and Russian (Arctic and Antarctic Research Institute) partners as well as on scientific cooperation agreements signed with both Geoscience Australia (2018) and WNII Okeangeologia Russia (2019).

The Polar Station in Spitsbergen of the Nicolaus Copernicus University in Toruń (NCU:PS) is located in the western part of Oscar II Land, the northern part of the Kaffiøyra coastal plain, bordering the Forlandsudet Strait to the west.

Since the beginning of the Station's activity, 49 scientific expeditions have been organized, and over 300 people participated in them. The expeditions included mainly scientists, doctoral students and students, but also mountaineers, speleologists and divers. Many of them were attended not only by the employees of the Nicolaus Copernicus University, but also scientists from other Polish and foreign centres.

The research based on NCU:PS covered almost all aspects of the geographical environment. In the scientific programmes, the greatest emphasis was placed, among other things, on research into contemporary changes in the cryosphere, glaciology, glacial geomorphology, perennial permafrost and periglacial processes as well as climatological and botanical research. The monitoring of glacier mass changes has been a permanent component of the World Glacier Monitoring Service (WGMS) in Zurich for many years, and the glaciers of the Kaffiøyra region are among the most important benchmark glaciers in this programme. Research on the changes and dynamics of glaciers has also been continued, e.g. within the framework of the Dynamics and Mass Balance of Arctic Glaciers and Ice Sheets – GLACIODYN project, research on the hydrothermal structure of glaciers, research on ablation (melting) of glaciers and hydrological research on glacial runoff and the Waldemar River regime,

as well as research on perennial permafrost, especially the active layer, which is part of the international Circumarctic Active Layer Monitoring (CALM) program. Studies of thickness and temperature of the active layer have been conducted since 1975. The station has one of the longer series of air temperature measurements on Spitsbergen and a perfectly developed network of topoclimatic measurements.

Glaciological research based on NCU:PS is part of the Glaciology Flagship project developed by the Norwegian Ny-Ålesund Science Managers Committee (NySMAC), whose main objective is to integrate joint activities in the field of glaciology.

The **NCU:PS** base is an important part of the Svalbard Science Forum as a formal and permanent research centre. The station can accommodate fifteen people at a time. It consists of a main room, a workshop, a room and two sleeping mezzanines, a bedroom, a fully equipped kitchen and a laboratory. There are also additional storage areas, laboratory, bath, toilet and garages for boats, scooters and engines.

The Polar Station of the Adam Mickiewicz University in Poznań (AMU:PS) is located in the central part of Spitsbergen, in Petuniabukta Bay. It is a seasonal station. It consists of three container buildings and provides a working space for 14 people in cottages with a total area of forty square meters, connected during the summer by a tent hall doubling the building area. The station conducts long-term research on the cryosphere response to climate change, as well as on contemporary geomorphological processes. Other research includes: geological, palaeogeographic, palaeontological, meteorological and climatological studies, as well as studies on vegetation diversity and succession and human impact on the Arctic environment.

Polar Station of the Maria Curie-Skłodowska University of Lublin (MCSU:PS). The First Polar Expedition of the Maria Curie-Skłodowska University of Lublin, organized at the initiative of Professor Kazimierz Penkala, jointly with the Institute of Basic Geology of the University of Warsaw, left Lublin on 24 June 1986. The home of the MCSU Polar Expeditions was the buildings of the old mining settlement Calypsobyen, located on the south-eastern bank of Bellsund. Twenty-eight expeditions were organized by 2016. The number of participants in the expeditions and the duration of their stay in Spitsbergen varied, depending on the research aims and logistic feasibility. Altogether, there were 85 participants, representing both the MCSU and other institutions from Poland and abroad.

The aim of the research of the MCSU Polar Expeditions was to explore the natural environment of the Bellsund region. Research programs and scientific projects were interdisciplinary in nature, although the earth sciences predominated. The research concerned such scientific fields as: geology, geomorphology, climatology and meteorology, hydrography, soil sciences, environmental protection, botany, plant physiology, biochemistry, radiochemistry and archaeology. A variety of research methods were applied. Technical progress made it possible to use more and more modern equipment, for which new specific research procedures were developed, e.g. the use of GPS (Global Positioning System) resistors or laser scanning (Leica Geosystems Polska, TPI Poland). In recent years, comprehensive studies of the coastline of the north–western part of the Wedel Land and the bottom of the Recherche Fjord have been conducted. These studies included: determination of the variability of the coastline – the use of GPS technology and laser scanning; determination of factors affecting the coast and description of the condition and transformation of old coasts (raised sea terraces from late Vistulian). Cooperation with the Institute of Geophysics PAS in Warsaw and the University of Gdańsk lead to the recognition of facial differentiation of sediments at the bottom of Recherche, Vestervågen (Chamberlindaen) and Josephbukta Fjords. Modern measurement systems (laser scanning, hydrochemical laboratories) were also used in complex studies of

glaciated and non-glaciated catchments, including the quantitative and qualitative determination of slurry and debris transport.

The Stanisław Baranowski Polar Station of the University of Wroclaw (Baranowski Station) is located on the foreground of the Werenskioldbreen Glacier on the south–western coast of Spitsbergen. The research conducted there includes the influence of climate change on glacial processes, as well as geomorphological and hydrological problems and various environmental studies, including phytosociological and dendrochronological ones.

7.2 Maritime infrastructure

The maritime infrastructure applicable to polar research comprises an r/v OCEANIA research vessel built in 1985, belonging to the Institute of Oceanology PAS in Sopot (Fig. 11).

The research done from the deck of r/v OCEANIA, concerns the fields of physical oceanography, optics, acoustics, chemistry, marine ecology and meteorology. It is the only Polish research vessel adapted to conduct oceanographic research in a wide range of physics, chemistry, ecology and marine biology on unlimited waters and equipped with modern laboratories (chemical, spectroscopic, computer), unique scientific equipment (CTD probes for temperature measurement, salinity and other properties of sea water, acoustic current meters, bottom sediment samplers, optical and acoustic sensors, seawater intake devices, meteorological stations, laser particle counters) and on-board installations enabling oceanographic measurements down to a depth of 5,000 m. The equipment meets modern world standards.

Fig. 11. R/v OCEANIA under sails. The ship was built in 1985 and since then it has served the Institute of Oceanology PAS in Sopot as the main research platform in the Baltic Sea and the Arctic. It is a well-equipped oceanographic vessel, but it will be necessary to replace it with a more modern one in the nearest years. Photo from IO PAS resources.

R/v OCEANIA spends 230–270 days at sea each year, including about 80 days (June–August) in the Nordic Seas, Spitsbergen and the Arctic Ocean. Most of these expeditions are related to IO PAS's own research activities or to international programs in which IO PAS participates. In recent years, research on board r/v OCEANIA has been carried out under 6 projects of the "Polish–Norwegian Research Cooperation" Program and European projects Horizon2020. On-board training was provided to students and PhD students of the IO PAS doctoral school and the Center for Polar Studies (National Scientific Leadership Centre KNOW).

The polar research is also done onboard the research-training vessel r/v HORIZONT II (Fig. 12), belonging to the Maritime Academy in Gdynia (Ministry of Maritime Economy). Since 2000, this vessel was a site of teaching classes as well as scientific investigations into deep structures of the Earth and marine acoustics. The vessel is also providing supplies to polar stations in Svalbard.

Fig. 12. Horyzont II. Photo: Paulina Zych, Shipowner Department, GMU.

7.3 Condition of polar infrastructure

The condition of infrastructure used in polar research is not fully satisfactory. The Antarctic station needs to be promptly renovated, and r/v OCEANIA, working 30 years in the Arctic, should be replaced with a newer ship. The polar infrastructure of Poland clearly reflects the financial capacities of the country. We do not postulate to construct an icebreaker, large oceanic vessels, research oil platforms or new research stations. Such large investments are made by international consortia or countries with economic and territorial interests in the polar zones. Polish researchers have access to them through international cooperation. However, the national polar infrastructure, in spite of the limitations mentioned above, should meet modern standards and be a showcase for Poland. This also applies to the Dobrowolski Station in the Bunger Oasis (Eastern Antarctica, Fig. 13), which can be revitalized with relatively little re-

sources as an automatic, unmanned geophysical station, whose construction and equipment could be made using Polish advanced technologies. According to the information provided by Russian researchers from WNII Okeangeologia in St. Petersburg who visited the Dobrowolski Station in 2018, its condition is quite good as for 60 years elapsed after its construction.

Fig. 13: Bunger Oasis (left) and the Dobrowolski Station (right), established in 1957 and handed over to Poland in 1959; state of 2010. Photographs from the Australian Antarctic Division (AAD) resources.

POLAR RESEARCH ISSUES

8. SCIENTIFIC FIELDS IN POLAR RESEARCH

The motivation of Polish polar studies performed thus far has been the following:

- A pursuit for getting knowledge on the phenomena in the Polar Regions of the globe in order to identify the laws and regularities of geosystemic functioning (i.e. the system on a global scale), in relation to both the inanimate nature systems and ecosystems;
- The desire to elucidate the processes currently shaping the Polar Regions in order to unreveal the geological past of our country, once covered with ice sheet, which is connected, among other things, with recognition of mineral resources and groundwater;
- The need to elucidate the mechanisms governing environmental changes through research carried out in the areas that are most vulnerable to these changes;
- The willingness to obtain practical knowledge about the technical and material aspects of human activity in the Polar Regions, as well as the functioning of human body in extreme environmental conditions;
- The need for a better understanding of the socio-political dimension of the Polar Regions, which is essential for a responsible and effective international policy in these areas;
- Discovering the geological history of the Polar Regions in the course of retreating ice caps and uncovering new, hitherto unavailable rocks.

All these objectives translate directly or indirectly into the general development of civilization, primarily in science and technology.

The Polish research activity in particular disciplines is presented below (in alphabetical order according to Polish edition). The research areas in which Polish scientists are experts or hold a significant independent position are emphasized.

8.1 Biology and ecology

Participating entities: IO PAS, NCU, JU:IGSM, JU:DPRD, AMU:FGGS

- The systematics and taxonomy of polar organisms; in view of the phenomenon called taxonomic impediment (i.e. the lack of specialists able to identify species) in world science on the one hand and the pressure to recognize the diversity of the living world on the other hand – it is of great value that several Polish scientific institutes have experienced staff who are able to identify and describe biological species (e.g., at the Jagiellonian University – cryptogamous organisms: fungi, lichens, aphids, cyanobacteria, algae; at the University of Łódź and at the Institute of Oceanology PAS – marine invertebrates); this creates a significant position for Polish researchers in international cooperation (Polish teams are invited to carry out global projects such as the Cenzus of Ocean Marine Life and the Encyclopedia of Life);
- Research on the succession of primary vegetation, including cryptogamic organisms and soil development in the forefields of Arctic and subarctic glaciers;
- Analysis of initial and mature tundra regions in the Arctic;
- The use of cryptogamic species as bioindicators of polar environmental pollution;
- Interaction between vegetation and herbivores in the context of climate change;
- Monitoring of bioindicator species (mammals and birds) of King George Island – ecological recognition and observation of changes in key elements of the Antarctic ecosystem, as well as explanation of interactions between animal life cycles, food availability and predation density; the monitoring is carried out on the west coast of the Gulf of Admiralty; part of the data obtained is used in the international CCAMLR Ecosystem Monitoring Program, which aims at controlling safe exploitation of commercial species of the South Ocean (krill, fish);
- Research of deep-water Arctic and Antarctic fauna and ocean processes during the polar

night, carried out in international cooperation with r/v James Clark Ross, r/v Polarstern, r/v Helmer Hansen and at the Ny Ålesund Research Station;
- Research on ornithogenic ecosystems and the impact of land-based fertilisation by nesting birds on soil-forming processes and on the formation of terrestrial and marine ecosystems in the Antarctic;
- Research on the influence of seabird colonies with different diets on the structure and functioning of ornithogenic tundra on Spitsbergen, using, among other things, the method of stable nitrogen and carbon isotopes;
- Studies on the influence of different tundra types on the content and quality of organic matter accumulated in cryogenic soils on Spitsbergen;
- Study of differences in proportions of carbon and nitrogen isotopes in tissues of marine and terrestrial organisms in order to quantify the rate of removal, accumulation and use of organic matter of marine origin;
- Work on the ATBI (All Taxa Biodiversity Inventory) project, which included analyses of environmental conditions (biotic and abiotic) of Spitsbergen, ontogenesis of selected Spitsbergen freshwater crustacean species and the ability to adapt to changing environmental conditions and tolerance limits to various physical and chemical factors of selected Spitsbergen crustacean species;
- Hydrobiological studies in water bodies and watercourses in the area between Hansbreen and Werenskiöldbreen;
- Monitoring the contamination status of terrestrial habitats;
- Research into changes in the Sørkapp Land's natural environment, especially the landscape and vegetation, since the early 1980s;
- Research on the biology, ecology and behavior in one of the largest breeding communities of the Alle alle in Spitsbergen (Hornsund), which is crucial for the functioning of the species' ecosystem in the context of observed and predicted changes in oceanographic and climatic conditions;
- Studies of the location and degree of use of the feeding grounds by the three-toed gulls from the Gnålberget colony;
- Studies of the food composition of three-toed gulls;
- Counting of sea birds and mammals feeding in Spitsbergen areas;
- Recognition of the influence of glaciers on the concentration of marine animals;
- Recognition of the effect of temperature changes on the growth and size of sea animals;
- Verification of the hypothesis that the degree of complexity of the marine ecosystems is increasing;
- Ecological role of nitrogen sources in diversification of terrestrial ecosystems of the Arctic tundra;
- Research on terrestrial ecosystems biodiversity in the Hornsund Fjord and preparation of an up-to-date vegetation map.

8.2 Environmental chemistry, hydrochemistry

Participating entities: IGF PAS, GUT:DACh, AMU:FGGS

- Recognition of the routes of pollution movement (including those identified as AMAP priorities) in the Arctic;
- The study of adaptability of catchments (with glaciers), to receiving and storing atmospheric-borne pollutants over long periods of time and the existence of factors and mechanisms

conditioning the migration of pollutants deposited in the snow cover, catchments and glaciers of the Arctic;
- Recognition what individual morphometric characteristics of glaciers have a key role in the accumulation of contaminants/constituents or their further transport to lower parts of glacial catchments;
- Studies on the degradation of perennial permafrost and recession of glaciers (in the era of climate change) as factors modifying the chemical composition of surface waters in areas of negligible anthropogenic activity selected for research (e.g. west coast of the Admiralty Bay, King George Island);
- Studies to determine the anthropogenic influence of the city of Longyearbyen on Adventfiorden;
- Recognition of the role of precipitation in the migration process of pollutants present in surface water samples taken from Arctic catchment areas (Polish Polar Station Hornsund);
- Studies on the intensified release of pollutants from a melting glacier in response to the occurrence of extreme weather events characterized by a simultaneous significant increase in air temperature and the occurrence of heavy rainfall (glacial catchment area): Spitsbergen, Svalbard;
- Study of the decisive influence of meteorological conditions on the thawing of a multi-year permafrost and the shaping of hydrochemistry of two creeks with snow-rain-permafrost feeding (non-glaciated catchments): Bellsund Fjord, Spitsbergen;
- Recognition of the "retention" role of the tundra lakes in the Arctic, as elements of the abiotic environment where chemicals from dry and wet deposition (non-glaciated catchments) accumulate: Bellsund Fjord (Svalbard);
- Study of the differentiation of anthropogenic pollution loads transported in the waters feeding the periglacial Scott river (Bellsund, Spitsbergen) when modified by rainwater;
- Study of bacteria in peri-circular areas modified by chemicals (including pollutants) present in these environments (Spitsbergen);
- Determination of nutrients as the primary growth factors for bacteriocenoses in the Arctic catchments of south–western Spitsbergen;
- Biological materials from animals and birds as a source of information on polar environmental pollution.

8.3 Physics of the ionosphere and atmosphere

Participating entities: IGF PAS, SRC PAS

- In the domain of ionospheric physics: pursuit for early warning procedures for the risks posed by violent solar plasma ejections;
- In the domain of atmospheric physics: study of aerosol using the infrastructure of the international polar station in Ny Ålesund;
- Monitoring of the ionosphere at large geomagnetic latitudes;
- Measurements of atmospheric electricity in the area of the Polish Polar Station Hornsund; measurements of the electric field strength of the Earth;
- Measurements of radionuclide concentration in the air and total dust using the AZA 1000 station – cooperation with the National Centre for Nuclear Research in Świerk;
- Measurements of atmospheric aerosol parameters in the framework of the world network AERONET – NASA;
- Lidar measurements of aerosol and water vapor concentration profiles;

- Measurements of solar radiation reaching the Earth's surface, carried out in cooperation with NASA;
- Monitoring of troposphere and ionosphere parameters based on GNSS observations.

8.4 Physical geography, perennial permafrost, geomorphology, soil science and landscape research

Participating entities: IGF PAS, NCU, JU:IGSM, JU:DPRD, UWr:FESEM; AMU:FGGS

- Research on the evolution of polar landscapes – interdisciplinary studies based on long-term field studies on landscape ecology, soil science and botany in the Svalbard region;
- Geomorphological research on typology and transformation of glacial and post-glacial formations;
- Study of mechanisms controlling the evolution and geomorphology of rocky coasts in the polar climate;
- Studies on the interaction of coastal and periglacial processes in the coastal zone and their impact on the development of littoral relief in the Arctic;
- Interaction of glaciers and perennial permafrost as an environmental continuum between the glacial and periglacial area in Scandinavia and Spitsbergen;
- Studies on perennial permafrost, especially its active layer, as part of the international CALM program; standard studies on thickness and temperature of the active layer in the Kaffiøyra (since 1975), Belsund (since 1986) and Petuniabukta (since 1985);
- Research into the development and properties of cryogenic soils in Sørkapp Land, the Hornsund area, and the Longyearbyen area;
- Research into the processes and sediments of the periglacial zone of the Kaffiøyra Plain, the coasts of Belsund and Billefjorden;
- Studies of the influence of the glacial environment on the mechanical treatment of the gravel fraction clusters building the head moraines – case study of the Waldemarbreen glacier (north–west Spitsbergen);
- Basic studies of all elements and current (since 1991) changes in the natural environment and landscape of the SE coast of Spitsbergen.

Within this category of research, of particular cognitive value are considered to be the following: the long-term measurement series of key parameters of the natural environment in the Arctic, e.g. the continuous research on the dynamics and mass balance of Spitsbergen glaciers (e.g. Hansbreen, Waldemarbreen) conducted since 1982; regular studies on the dynamics of waters, plankton and benthos of the Spitsbergen shelf and the Kongsfjord and Hornsund Fjords (since 1986); monitoring of the atmosphere, waters and permafrost in the surroundings of the Polish Polar Station Hornsund (since 1988), as well as in the polar stations of Polish universities. The importance of this research lies in the fact that, in spite of international appeals, it is very difficult to maintain multi-annual measurement series, because the world system of science is based on short-term grants, which in practice makes long-term planning impossible. The Polish measurement series are among the longest and most complete and that is why they are highly appreciated by the Norwegian administration in Svalbard and the international scientific community, to name just a few.

8.5 Geology and geophysics

Participating entities: IGF PAS, US:IES, AMU, WUT:FGC, AMU:FGGS

- The paleoclimatic and palaeoenvironmental evolution of the Western Antarctic and, in later prospect, the Eastern Antarctic in the Bunger Oasis, with regard to the formation and development stages of the Antarctic ice cap on the basis of the geological records; research in this area is of great importance for explaining the causes of the current glaciation and for better understanding of contemporary climate change;
- Seismic surveys of deep ocean floor structures, made in cooperation with international research platforms, e.g. the German ship r/v Polarstern;
- Observations of changes in geomagnetic field elements carried out at the Polish Polar Station Hornsund, transmitted in real time to the International Real-time Magnetic Observatory Network (INTERMAGNET), as well as the interpretation of these data, leading to a better understanding of the Earth's geodynamic mechanism; analogous observations at the Dobrowolski Station are recommended, using its unique location in the immediate vicinity of the Earth's southern magnetic pole;
- Detection and interpretation of seismic phenomena, carried out jointly with NORSAR in Norway;
- Research on tectonic activity of the rock mass in the Hornsund region;
- Geological research on structures and geologic history of consolidated basement rocks;
- Research on contemporary sedimentation processes in lakes and fjords carried out in the area of Polish Polar Station Hornsund (cooperation with Czech Academy of Sciences) and in the area of the Arctowski Station (cooperation with Argentina);
- The research, conducted since the Arctowski Station was established, on the climatic and environmental variability of the Antarctic past on the basis of the evidences recorded in sedimentary rocks;
- Palaeomagnetic research on the Triassic, magma and meta-magma rocks of the Svalbard Archipelago;
- Seismological monitoring in Polish polar stations;
- Schumann's resonance research – in cooperation with foreign partners;
- Research on the ionospheric and magnetospheric processes within the International Monitor for Auroral Geomagnetic Effects (IMAGE) research program;
- Continuous recording of horizontal magnetic field components and vertical electric field components – cooperation with the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences;
- Research on magnetic pulsations – cooperation with the University of New Hampshire in the United States.

8.6 Hydrology, glaciology, snow research

Participating entities: US:IES, IGF PAS, NCU, JU:IGSM, WUT:FGC, GUT:DACh, AMU:FGGS

- Monitoring and studies on the mass balance, dynamics and evolution of glaciers in the reference areas of Svalbard: Hornsund Fjord (Hansbreen, Werenskioldbreen) and Kaffiøyra region (Waldemarbreen, Irenebreen, Elisebreen); results are reported in the international World Glacier Monitoring Service database;
- Analysis of changes in geometry of the Spitsbergen and King George Glacier Glacier, including the fluctuation of glacier faces when they enter the sea and end on land and changes in their volume and mass (e.g. studies of changes in the range and thickness of the Sørkapp

Land and Nordenskiölda Glaciers on Spitsbergen and the Ecology, Sphinx and Baranovsky Glaciers on King George Island);
- Studies on the reconstruction of changes in the range of glaciers ending up in the sea on the basis of subaqueous moraines: case study of the Forlandsundet region with special emphasis to St. Jonsfijorden;
- Determination of sub-glacial topography and estimation of the volume of Svalbard glaciers;
- Monitoring of the dynamics of the front zones of glaciers entering the sea and estimating the calving rate of the glaciers;
- Estimating the fresh water supply to the ocean from the melting of glaciers' surfaces and their calving;
- Studies of the water drainage system within the Svalbard glaciers and the properties of waters of glacial origin;
- Determination of the spatial distribution, evolution and physical properties of snow on the Spitsbergen glaciers;
- Studies on variability of movement dynamics, hydrothermal structure and ablation of glaciers and hydrological studies on outflow and regime of glacial rivers (e.g. Waldemarbreen and Werenskioldbreen outflows);
- Monitoring of snow cover distribution in the area of Polish Polar Station Hornsund;
- Hydrochemical monitoring in the non-glaciated catchment area of Fuglebekken and in the glaciated catchment area of Ariedalen;
- Hydrochemical monitoring of proglacial watercourses in order to identify differences in chemical denudation by measuring radon isotope 222Rn concentration in the forefields of selected glaciers (Werenskioldbreen, Gåsbreen, Sofiebreen, Bautabreen and Lorchbreen);
- Research on the Arctic climate, ocean, ice and glacial interactions in the Svalbard area in cooperation with a team from NORUT (Northern Research Institute Tromsø AS).

8.7 Meteorology and climatology

Participating entities: IGF PAS, NCU, JU:IGSM, GUT:DACh, AMU:FGGS

- Research on the Arctic climate and its changes in the historical outlook – notably the reconstruction of the Arctic climate – carried out in international cooperation (AWI, AARI, Norwegian Meteorological Institute, and some other institutions); the results were used in the 20th Century Reanalysis Project;
- Investigation of a number of parameters, such as: air temperature and humidity, atmospheric pressure, wind speed and direction, ground temperature, precipitation, horizontal visibility, cloud cover, sunshine, height of snow cover, water equivalent of snow, meteorological phenomena and their duration; meteorological data are an important element of all projects carried out in the polar station and provide a background for research in hydrology, geomorphology, glaciology, biology and environmental chemistry;
- Monitoring of topoclimatic conditions of glaciated and non-glaciated areas by creating a network of automatic instruments recording selected meteorological parameters (thermorecorders and automatic meteorological stations);
- Monitoring of the winter ice cover of the Hornsund Fjord;
- Studies of climate change in the whole Arctic or parts of it and the mechanisms of such a change, including the role of ocean processes in shaping the Arctic climate;
- Cataloguing types of circulation (since December 1950) for Spitsbergen and atmospheric circulation indicators;

- Summer meteorological observations on the SE Spitsbergen coast.

More details on this subject can be found in a review publication by Przybylak et al. (2019).

8.8 Environmental microbiology

Participating entities: AMU:DAET, IBB, UWM:FBB, UWM:CMM, GUT:DACh, GUT:DWWT

- Study of organisms inhabiting newly formed fresh water reservoirs in the foreglacier fields;
- Studies of the dynamic transformation of abiotic and biotic environmental components when glacier watercourses have been joining the reservoirs;
- Studies on the impact of birds on the Arctic's summer habitat, mainly geese, whose faeces provide easily assimilable organic matter and nutrients;
- Assessment of the degree of water pollution in the European Arctic and its impact on the occurrence of selected groups of micro-organisms;
- Decomposition of bird guano and marine macroalgae in the Arctic and Antarctic;
- The impact of global warming and glacier retreat on the composition of microbiocenoses of post-glacial soils;
- Changes in microbial communities on the glacial surface of both hemispheres;
- Spare materials of cold-liking bacteria from the Polar Regions and their role in adaptation to the environment;
- Bacterial microbiota associated with vascular plants and lichens found in the Maritime Antarctic;
- Research on the structure and function of polar ecosystem microbiocenoses;
- Study of succession mechanisms and their impact on the biodiversity of polar ecosystems;
- Changes of polar myrcobiocenoses against the background of climate change;
- Bioprospection and search for bacterial strains with biotechnological properties;
- Structure, biodiversity and factors shaping the microbial mats;
- Research on the glacial microbiome;
- The importance of Arctic and Antarctic hypertrophic reservoirs as "hot spots" in oligotrophic ecosystems;
- Sub-glacial lagoons, new polar environments, selection and adaptation of microorganisms.

8.9 Social sciences and humanities

Participating entities: MCSU, JU, US, UG, JKU, UWr.

- Poland's presence in Polar Regions (research on the history of Polish polaristics, analysis of Polish foreign policy towards Polar Regions, polar literature in Poland);
- Arctic and Antarctic as areas of threat to multidimensional international security (research on international relations, security studies, social and economic geography in connection with natural sciences, especially research on environmental protection and tourism development);
- The Arctic and its inhabitants in the era of globalization and climate and environmental change (studies in anthropology, ethnography, health sciences, sociology, political science, economics and law, as well as psychological research on participants in polar expeditions).

8.10 Oceanography

Participating entities: IO PAS, IGF PAS

- Large-scale studies on changes in the inter-annual characteristics and dynamics of Atlantic water in the Nordic Sea and Arctic Ocean under the AREX multi-annual observation program and international projects;
- Oceanographic studies of the western Spitsbergen fjords and water exchange processes between the deep basin, shelf and fjords;
- Year-round observations of water properties and dynamics in the Arctic regions using ARGO profiling floats in the European EuroArgo program;
- Year-round continuous observations of the properties and transport of Atlantic waters into the Arctic Ocean using anchored measuring verticals;
- Studies of the ocean's impact on climate, sea ice and glaciers in the European Arctic sector;
- Studies on sea water circulation in the Hornsund Fjord, particularly in the glacier foreland, in cooperation with the SCRIPPS Institution of Oceanography from the United States;
- Studies of underwater acoustic noise propagation patterns and determination of amplitude-frequency characteristics of dynamic ice phenomena occurring in the glacier gulf, carried out jointly with SCRIPPS Institution of Oceanography from the United States;
- Studies of the effect of ice on the waving and coastal erosion in polar conditions, performed jointly with the SCRIPPS Institution of Oceanography from the United States;
- Acoustic observations of the behavior of marine organisms;
- Acoustic detection and classification of seabed habitats of marine fauna;
- Studies on the ecology and functioning of marine organisms, the dynamics of their populations on a seasonal and perennial basis in the Arctic Ocean;
- Assessment of the impact of factors depending on climatic conditions (duration of ice cover, fresh water inflow, suspended snowmelt water, direction of wind induced surface movements of water layers, water mixing depth) on physical and chemical properties of the water column and biomass, spatial distribution and taxonomic composition of phytoplankton communities in the Gulf of Admiralty (Antarctic);
- Studies of changes in environmental and climatic conditions on the basis of their biogeochemical recording in the lake bottom sediments of the Finnish Arctic (under the EU LAPBIAT Project) and the Antarctic.

8.11 Paleobiology

Participating entity: IPal PAS

- Research on the Cenozoic history of evolution of Antarctic marine organism complexes, important palaeontological discoveries in the region of Southern Shetlands, Seymour Island (Western Antarctic) and Fisher Massif (Eastern Antarctic);
- Taxonomy and research on the evolutionary history of penguins (also in cooperation with the Faculty of Biology of the University of Bialystok);
- The evolution of Antarctic shallow-water foraminifera assemblies of the last 55 million years;
- Study of Palaeozoic marine Spitsbergen complexes;
- Reconstruction of late Triassic vertebrate communities (mammals and reptiles) of eastern Greenland;
- Research on invertebrate assemblies from fossil Arctic chemosynthesis environments in the Arctic Archipelago, Spitsbergen and New Earth (Jurassic–Paleocene);

- Research on Precambrian and early-Paleozoic fossils from northern Russia;
- Palaeo-environmental reconstructions, in particular the history of fjord and shelf deglaciation in the Western Antarctic, with the use of microfossils after the maximum of the last glaciation, about 20,000 years ago;
- Molecular biogeography of Antarctic and sub-Antarctic foraminifera, fossil DNA analysis (sedaDNA).

9. IMPLEMENTED RESEARCH PROJECTS

In the years 2011–2018, Polish scientists won 80 different polar research grants awarded by the National Science Centre (NSC). Many units also allocate funds and other resources from their own means to carry out research in Polar Regions. The numbers of grants awarded and the amount of funds designated by the Ministry of Science and Higher Education and the NSC for polar research are presented in Figs. 14–17.

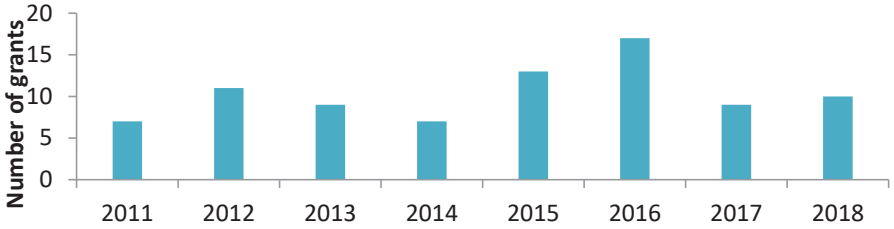

Fig. 14 Grants allocated by the NSC over the period 2011–2018.

The largest group of grants awarded are OPUS and PRELUDIUM projects.

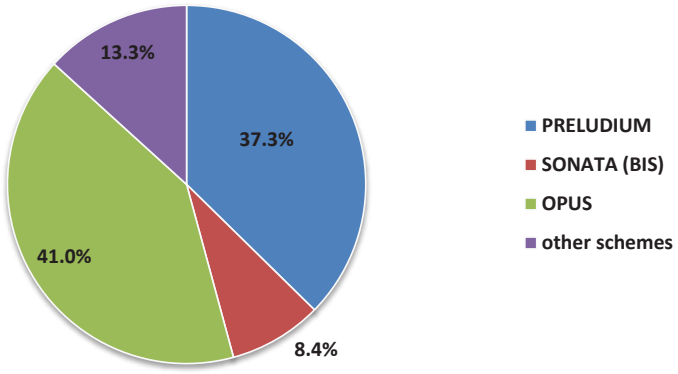

Fig. 15. Grants allocated by the NSC in the years 2011–2018 (in %). The received grant projects totaled PLN 35,043,92.

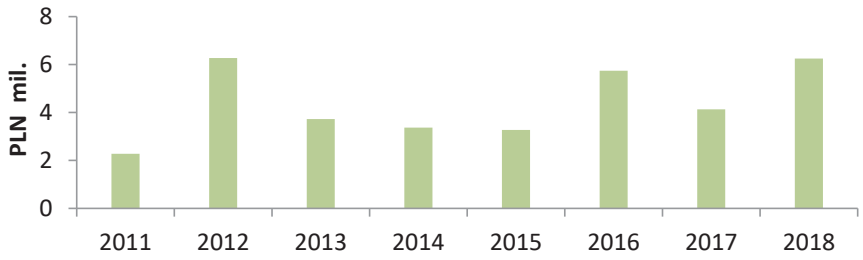

Fig. 16. Annual amounts of grants allocated by NSC.

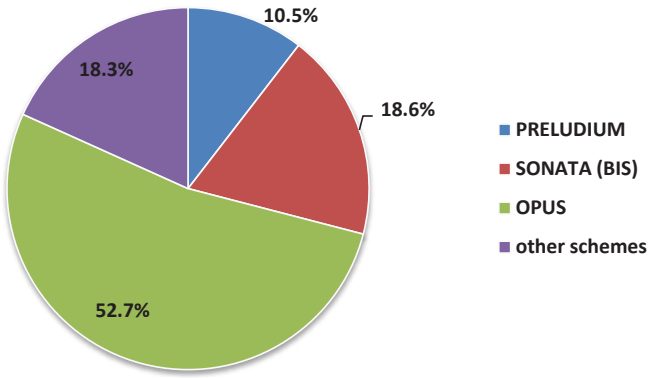

Fig. 17. Financial means (in %) allocated to polar research under different types of grant contests.

As for the end of 2019, Polish researchers have also awarded fourteen projects co-financed under the Polish–Norwegian Research Cooperation Program for the sum of PLN 54,304,068, thirteen of which being in the field of climate change and one in environmental studies. Titles of the most important projects have been presented in the text of the Book; the Reader is also referred to the relevant websites.

THE FUTURE OF POLAR RESEARCH

10. THE VISION FOR FUTURE RESEARCH, INFRASTRUCTURE AND POLAR MISSIONS IN POLAND: PROPOSALS

The strategy of Polish polar research aims at defining the directions of development of Polish research in the Arctic and Antarctic in terms of cognitive, economic and social utility and strengthening Poland's international position.

Research in the Arctic and Antarctic land areas makes a major contribution to the polar zone research programs, enabling comparative studies of environmental changes caused by climate and human activity. Numerous Polish universities and scientific institutes are involved. Recommendations for research are provided by international organizations such as IASC, SCAR, ATCM/CEP, COMNAP, SCALOP, as well as the European Polar Program, currently under preparation, developed by EU-PolarNet, in which Poland participates.

The most important features of Polish research on polar landscapes and terrestrial ecosystems are: interdisciplinarity, bipolar character, and international cooperation. The largest research programs are focused on global climate change and increasing human activity in Polar Regions. Of importance is the applicability of basic research and biotechnological implementation of the potential of polar environmental organisms, as well as integrated monitoring of terrestrial ecosystems.

The following main directions of research development are proposed, taking into account their complementarity and interdisciplinarity:

1) Further in-depth recognition of the abiotic components of the environment of the polar areas and the laws governing them, in particular concerning the following:

- the cryosphere (glaciers, perennial permafrost, sea ice and snow cover) and land waters;
- the oceans (physical and chemical phenomena and processes in the polar oceans, shelf waters and fjords);
- the atmosphere (the weather conditions against the background of atmospheric circulation, recognition of their trends in time, the occurrence of extreme phenomena, the state and chemical composition of the atmosphere, including aerosols and anthropogenic pollutants);
- the lithosphere (structure of the Earth's interior, including the Earth's crust, as well as reconstruction of geological history at different time scales);
- the geomorphological processes and their effects;
- the evolution of landscapes (as an expression of the interaction of abiotic and biotic factors), including the use of remote sensing to observe the state of ice caps, in order to get a better knowledge on the dynamics of their changes.

2) Wider recognition of the response of terrestrial ecosystems to global climate change:

- landscape changes as a result of climate change, analysis of created geomorphological structures, geomorphological mapping;
- soil-forming processes;
- dynamics of terrestrial biocenoses;
- colonization and biological succession;
- evolution of landscapes and ecosystems on the basis of field and remote sensing studies (comparative analysis from different periods) as well as palaeolimnological and palaeobotanical studies;
- biological resources, biodiversity and adaptation to life in extreme conditions of the Antarctic environment;
- the modifying role of animals in creating specific habitats (e.g. ornithogenic habitats);
- protection of polar land ecosystems in view of increasing human activity.

3) Advanced recognition of the state and changes of biotic components of the polar en-

vironment and the rules that govern them in a systemic approach, with the use of computer modelling techniques of natural processes, especially in relation to:

- marine ecosystems – response of the marine biosphere to climate change;
- land ecosystems – changes taking place in land ecosystems under the influence of global climate change;
- cryosphere ecosystems – consequences of its contraction for the organisms that inhabit it.

4) Getting a wider knowledge on the functioning of polar marine biocoenoses, forecasting and observation of changes resulting from altered environmental conditions in view of climate warming:

- the response of polar species, complexes and ecosystems to changes in the extent of perennial sea ice, rising water temperatures, changes in productivity and ocean acidification;
- changes in the range of occurrence of cold and thermophilic species, the impact of changes in species composition on biodiversity and functioning of polar complexes;
- impact of increased anthropogenic pressure on the functioning and productivity of Polar Regions.

5) Better recognition of conditions, progress and consequences of processes related to human activity in polar environment and the social component of Polar Region studies as an element of development of Polish social sciences and humanities.

6) Initiation of broader application-oriented research on the use of advanced technical solutions in extreme polar conditions (also treated as analogous to Martian environments), testing of materials, devices and technical systems, as well as the use of Polish polar platforms in space research and astronomical observations.

7) The use of modern measurement technologies, in particular photogrammetric, remote sensing, gravimetric, satellite (GNSS) and information/geoinformation ones, for spatial monitoring and integrated imaging in multidisciplinary polar surveys aimed at coherent, multidimensional analyses.

The proposed directions of research differ in terms of previous achievements, human resources and infrastructure. In some of them, Polish scientific teams are strong and well-recognized international partners, in others, long and systematic observation series are an advantage, and in still others, there are new, innovative ideas and research proposals that emerge, arousing great interest. Polar research is an excellent platform for the progress of technology and techniques, both in the domain of measuring instruments and data transmission technology using satellite techniques. It would be possible and desirable to build Polish measurement equipment dedicated to space research, which could be tested in areas with terrain-climatic characteristics similar to the potential targets of space expeditions. Such areas can be found on land and ice sheets of polar areas.

Irrespective of what was said above, further dynamic development of Polish polar research will be based on realization of its essential tasks, which are:

- strengthening the presence of Polish research in Polar Regions;
- engagement in scientific research in Polar Regions;
- participation in enhancing the Poland's image in the international scientific arena;
- involvement in expert activities in support of industry and politics;
- building the synergy between polar research and innovativeness;
- schooling and shaping new generations of polar scientists;
- active participation in activities aimed at Polar Region protection;
- social involvement (educational and popularization activities);
- improvement of logistic activities in Polar Regions.

10.1 Research which should be done in Poland in order to expand the knowledge on polar issues

Areas of research that should be conducted in order to expand knowledge and gain experience in Polish research institutes, implement modern didactics, undertake new international cooperation, build the necessary scientific competence in the country and develop new technologies:

- microbiology and biotechnology of polar environment;
- mechanisms of interconnections in the processes shaping the weather and climate (teleconnections);
- identification of factors governing the evolution of polar environments, including anthropogenic ones;
- micro-paleontology with the use of genetic methods to better understand the paths of biological evolution;
- dynamics of changes in the landscape (including sediments, sculpture, water network, vegetation and soils) of polar areas in the context of forecasts of environmental changes;
- polar social sciences and humanities, especially in the field of research on Poland's polar policy, multidimensional security in the Arctic and the Antarctic, as well as the social aspects of the Arctic transformation in the context of climate change and globalization, reflected in the growing polar tourism (Fig. 18);
- modelling of the expected climate change in Polar Regions;
- applying new measurement and analytical technologies and testing new technical and technological solutions under extreme conditions, including the implementation of a specific technological challenge: the installation of autonomous geophysical stations in Bunger Oasis (at Dobrowolski Station).

Fig. 18. The rapidly growing interest in the tourism in Polar Regions (see the Polish research vessel r/v OCEANIA in front of a Spitsbergen cruise ship) causes that not only natural sciences but also social and humanistic ones (sociology, political science, cultural studies, history) gain in importance in polar research. Photo: J. M. Węsławski.

Automated geophysical units to be located in areas of the globe that are difficult to reach, notably in Polar Regions, could be Poland's speciality. Such units, as well as manipulation devices for various purposes, equipped with modern energy sources and on-line data transmission, would be a testing ground for equipment designed for space missions. At the same time, they could be our material contribution (in-kind) to international scientific collaboration.

Polish polar research, however, will not attain a higher level of development as long as Polish science does not acquire a vessel that would be not only capable of year-round oceanic research but also able to deliver cargo to polar stations in both hemispheres. The idea to build such a ship should be put forward by the state authorities, since, by doing so, they would not only fulfill the demands of scientific circles, but also increase the prestige of the country in the international arena. Conceptual works are not expensive and can be started immediately, in anticipation of a better economic situation for the design and construction phase. One can also consider the purchasing of the needed vessel on the aftermarket, rich in vessels with appropriate maritime bravery and often dedicated to scientific research.

10.2 Polar missions – proposals for structural solutions

Recognizing that the financing of science must be competition-based and follow from the quality of the proposed research, we are making a petition to allocate special funds to the **National Polar Research Program**, the implementation of which will bring four basic results:

- **It will strengthen Polish scientific activity and the position of Polish researchers in the international** arena by intensifying publications in important journals, creating an open database on polar research, and promoting valuable scientific achievements on the scientific market;
- **It will stabilize the position of the young polar researchers** – many young, talented and effective polar researchers remain in the "post doc" status on short-term contracts, which prevents stabilization and further academic development. There is an urgent need to prepare for the replacement of the present-day research staff dominated by 60-year-olds by a new generation, which would be able to obtain stable employment in competitions;
- **It will make it possible to modernize the Polish research infrastructure in polar areas** – especially the renovation of the Arctowski Station in Western Antarctica, the replacement of the 30-year-old research vessel r/v OCEANIA with a new one, the creation of Polish logistics centre in Longyearbyen, Spitsbergen, and the development of autonomous measuring stations that could replace humans in an extreme natural environment;
- **It will enable the revitalization of the Dobrowolski Station** in Eastern Antarctica, in order to create an automated laboratory recording geophysical field parameters and making data available on-line.

Achieving these objectives will be possible thanks to the activity of such organizational structures created in recent years as the Polish Polar Consortium and the Centre for Polar Studies, cooperating with the Polar Research Committee of the Polish Academy of Sciences. Thanks to these structures, the Polish polar environment has created, on its own initiative, effective tools for managing public funds, facing today a great chance to raise scientific activities to a higher level, in cooperation with the state administration, industry and the sphere of education, for the benefit of society and the political significance of our country. High hopes are associated with the Polish Polar Policy, the governmental document which is currently in its final stage of preparation[8].

[8] As of 1/08/2020.

11. PROMOTION AND POPULARIZATION OF KNOWLEDGE AND EDUCATION – FORGE OF FUTURE POLAR RESEARCHERS

The debate on human adaptation to climate change has recently gone beyond the field of science and has become part of social discourse. However, this is often based on rashly formulated views, which may entail inappropriate management or political decisions. There is therefore an urgent need for easy access to reliable scientific information describing the current state of the natural environment and its development for the next decades. Polar areas, the most vulnerable to climate change, are the natural litmus test of global change. For the scientific world they are a basic laboratory for tracking processes in geosystems. The transfer of knowledge to the society requires modern and well-organized educational techniques, which not only provide objective knowledge, but also allow to distinguish the knowledge based on facts from the so-called "fake news", permeating the circulation of public information and obscuring the image of reality. A special way of their dissemination is through social media, providing quick access to many recipients, without any control over the content. A conscious and educated society can defend itself against false information. Therefore, educational projects, e.g. EDUSCIENCE or EDU-ARCTIC, promoting knowledge at school level are very valuable. Popularization of knowledge about polar areas, including illustrations, showing the realities of life and work in extreme polar conditions, which require sacrifice and courage, is also very much needed. Polar areas are an extraordinary space, associated by most Poles with something very distant, almost unattainable. This makes transmissions from the Arctic or the Antarctic to be more interesting and attractive, and a scientific trip "to the far north" may encourage students to consider choosing a scientific career path.

The first major educational initiative in the field of polar research was the EDUSCIENCE project, coordinated by the Institute of Geophysics PAS. The project involved online lessons, including those conducted by the employees of PSP Hornsund, and competitions for schoolchildren, where the prize was a two-week stay in the polar station. The project concerned the broadly understood natural sciences, but, according to evaluations at the schools testing the project, it was the polar topic that has aroused the greatest interest of young people. As the initiative worked out so well, it was decided to transfer it to the European level. In 2016–2019, the Institute coordinated the EDU-ARCTIC project (Horizon 2020), which offered courses about the fascinating world of the Arctic and polar research to high schools across the whole of Europe.

Of great importance are also teaching projects offered to students of the second and third level of university education, such as Interdisciplinary Polar Studies for PhD candidates and the MSc majoring: Exploration of Polar and Mountainous Areas, offered by the Centre for Polar Studies (CPS). The Centre was established in 2013 by three entities involved in polar research: the Faculty of Earth Sciences, University of Silesia (leading), the Institute of Geophysics PAS and the Institute of Oceanology PAS; in the years 2014–2018, the Centre had a status of National Scientific Leadership Centre KNOW in Earth Sciences. One of the most important objectives of the CPS's activity is to educate young scientists through a wide opening to national and international cooperation with leading research-teaching centers in the field of interdisciplinary and dedicated polar studies.

Polar matters arouse interest and, at the same time, due to their specific character, provide a good opportunity to consolidate a positive perception of science in the public opinion. Therefore, it is worthwhile to present polar research to the general public. An example of such very useful initiatives with a social aspect is the organization of the Museum of Polar Research in Puławy, as well as films, articles or internet materials. Various forms of popularization of

polar research among the general public are also proposed by the EDU-ARCTIC.PL project (e.g. open lectures, lectures for Universities of the Third Age and workshops for children's universities, Polar Festival or 3d mapping on polar subjects).

It would also be desirable to maintain the high position of the quarterly Polish Polar Research, well perceived on the international scientific forum, by encouraging the scientific community to publish the best scientific articles in the only Polish scientific periodical dedicated entirely to polar research. It is worth supporting the initiative of civic science, i.e. the involvement of the public at large in the collection of scientifically useful information. In polar areas, the natural partners of such activities are tourists – sport yacht crews, climbers, scuba divers. In Poland it is a rapidly growing group of hobbyists interested in the polar countries (Fig. 19). Another group that can be helpful in obtaining information are the native inhabitants of the Arctic. Due to the fact that many researches of Polish scientists are conducted in Svalbard, cooperation with this group is nowadays quite rare.

From the solutions of the **EDUSCIENCE project "Improving the pupils' competences in the field of mathematical, natural and technical sciences using innovative methods and technologies – EDUSCIENCE"** (2011–2015, Human Capital Operational Program) have so far benefited over 3.5 thousand schools and 15 thousand teachers. The aim of the project was to increase the interest of children and young people in mathematical and natural sciences through innovative teaching methods and contact with scientists, including employees of the Polish Polar Station Hornsund in Spitsbergen. Within the project, there were created an e-learning platform, a nature portal (www.eduscience.pl), methodological materials, a program of 9 didactic trips and a nature monitoring program.

The **EDU-ARCTIC "Innovative educational program, attracting young people to natural sciences and polar research**" (2016–2019, Horizon 2020) was implemented by 6 institutions from 5 countries. Scientists made the research in Polar Regions accessible to youngsters,

Fig. 19. Presentation of polar meiofauna (marine microorganisms up to 1 mm in size) at one of the scientific picnics. Photo: J. M. Węsławski.

thus evoking their interest in natural sciences and encouraging to pursue scientific careers. School-children from 60 countries learned about the work of scientists and the specificity of polar areas, by participating in online lessons from the Arctic, and even attending polar expeditions. The project offered webinars with the participation of polar researchers, an environmental monitoring programme, Polarpeda, workshops for teachers and Arctic competitions (Fig. 20).

Fig. 20. Group of winners of the EDU-ARCTIC polar competition (2018 edition) in the vicinity of the Polish Polar Station Hornsund. Photo: Tomasz Wawrzyniak.

The project **EDU-ARCTIC.PL: "Promoting scientific research in the polar areas as a tool for internationalization and developing a positive public perception of Polish science"** (2019–2021, DIALOG) uses proven tools (webinars, polar contests), extending the target participants to include additional age groups (students, school-children, senior citizens) and complementing it with additional activities designed for a broad society (open lectures, lectures for Third Age Universities and workshops for children's universities, Polar Festival or three-dimensional mapping on polar themes).

The experience of polar educators is reflected in the articles devoted to the didactics and methodology of teaching about nature in Polar Regions, the most important ones being listed below):

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