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Arctic Research Trends

Bibliometrics 2016–2022

Dag W. Aksnes | Christopher Blöcker
Cristian Colliander | Lena Maria Nilsson

Contributions by scite_

UArctic Thematic Network:
Research Analytics and Bibliometrics

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Content

Preface

This work was conducted by the UArctic Thematic Network on Research Analytics and Bibliometrics. It was supported by Global Affairs Canada through the Global Arctic Leadership Initiative.
The aim of this work is to follow up on previous analyses already presented by the UArctic Science & Research Analytics Task Force, i.e. the report *"Arctic Research Publication Trends: A Pilot Study"* published in August 2016 and covering the time period 2001–2015. One of the authors of this report and two of the contributors were involved in writing the first report. The rest of the author and contributor team was recruited in autumn 2022, with the aim to expand the field of Arctic research analytics further. Authors and contributors are listed below:

Authors

- Dag W. Aksnes, Nordic Institute for Studies in Innovation, Research & Education (NIFU), Norway
- Christopher Blöcker, Integrated Science Lab, Department of Physics, Umeå University, Sweden
- Cristian Colliander, Department of Sociology, Inforsk & University Library, Umeå University, Sweden
- Lena Maria Nilsson, Arctic Centre, Epidemiology and Global Health, Umeå University, Sweden

Contributors

- Rickard Danell, Department of Sociology, Inforsk, Umeå University, Sweden
- Lars Kullerud, UArctic
- Keith Larson, Arctic Centre and Climate Impacts Research Centre at Department of Ecology and Environmental Sciences, Umeå University, Sweden
- SCITE team

1. Introduction – Arctic Research Cooperation

International scientific collaboration in the Arctic has existed for more than 150 years, as exemplified by the International Polar Year collaboration arranging its first manifest in 1882–83 and the International Union on Circumpolar Health, arranging its first international symposium in 1967. After the end of the Cold War, a number of initiatives for Arctic research collaborations arose, such as The Arctic environmental protection strategy (AEPS, 1991–96), the International Arctic Science Committee (IASC, 1990), the International Arctic Social Sciences Association (IASSA, 1990), and several other entities.

The Arctic Council, est. 1996, functions as a policy-shaping collaboration between the eight countries surrounding the Arctic: Canada, the Kingdom of Denmark (including Greenland and Faroe Islands), Finland, Iceland, Norway, Russia, Sweden, and the United States (US). The Arctic Council is a unique international organisation, welcoming the indigenous peoples of the Arctic as permanent participants in this collaboration. The Arctic Council also has several observers that include non-Arctic states, inter-governmental and inter-parliamentary organisations, both global and regional, and non-governmental organisations. UArctic, IASC, and IASSA are former observer organisations that represent the scientific community in the Arctic Council.

With an increasing interest in the Arctic across the globe, along with the long history of scientific collaboration within the region and the engagement in Arctic science by the Arctic Council, the first documentation of the state of scientific collaboration in and about the Arctic was carried out in 2016, resulting in four reports covering the period 2001–2015.

Today the world's attention to the Arctic region is even more extensive, not least due to increased impacts on the region due to global warming and so-called green industrialisation. The report aims to continue the previous work on mapping Arctic research with a follow-up report covering the period 2016–2022 (the previous covered 1996–2015). The report includes both figures based on aggregated data for the entire six-year period, and figures limited to more recent years (such as 2020–2022).

1.1 University of the Arctic

The University of the Arctic (UArctic) was established through an initiative by the Arctic Council, expressed in the Iqaluit Declaration (1998). For close to twenty years, the collaboration has been carried out as a network. In November 2019, the University of the Arctic was reorganised and officially registered as a non-profit association under Finnish law to “enhance human capacity in the North, promote viable communities and sustainable economies, and forge global partnerships”.

Due to the war in Ukraine, all UArctic collaborations with Russian Institutions have been paused. Despite this, the UArctic continues to grow as a vital network of over 170 universities and higher education institutions, including northern academic institutions, as well as the majority of all institutions conducting research and education in and about the Arctic in the former eight Arctic Council member states except Russia. UArctic also welcomes members from non-Arctic states, which today constitute close to 25 per cent of all member institutions.

Today, UArctic members are pooling and sharing resources to build cooperation based on the strengths each member organisation brings. UArctic has become the supporting network that enables much of the international academic collaboration across the circumpolar North, and myriads of collaborative efforts have come to reality as a consequence of more than twenty-five years of partnership and cooperation.

1.2 UArctic Thematic Network on Arctic Research Analytics and Bibliometrics

The UArctic Thematic Network on Arctic Research Analytics and Bibliometrics, hosted by Umeå University, was established in 2022 as a continuation of the previous UArctic Science & Research Analytics Task Force. The latter was established in 2015 following the UArctic Rector’s meeting in Umeå, Sweden.

The Thematic Network members include a small, but diverse international group of subject-matter experts who are willing to participate and contribute to this unique and challenging endeavour.

The main goal of the Thematic Network is to identify challenges and gaps in knowledge about the Arctic by using big-data analytics tools and bibliometric/scientometric approaches and methods, and to inform research-based solutions that are possible through the efforts of the UArctic Network. The Thematic Network will continue the work partnering and liaising with global data and information providers to improve the representation and visibility of Arctic research in the global indexed research output.

Given the increasing volume of research data in general, one of the long-term objectives is to monitor the state of Arctic research efforts across institutions and countries, and to provide fact-based insights for the Arctic research community, the general public, and policymakers from Arctic Council member[1] and observer[2] states about Arctic education, collaboration, researcher mobility, science & technology trends and collaboration gaps, challenges, and opportunities.

[1] Finland, Russia, USA, Canada, Kingdom of Denmark, Iceland, Norway, Sweden
[2] Germany, Netherlands, Poland, United Kingdom, France, Spain, China, India, Italy, Japan, South Korea, Singapore, Switzerland.

2. Data & methodology

2.1 Data sources

This study builds on bibliographic records relating to the Arctic, which are retrieved from the Scopus database using several search queries based on a large set of Arctic-related search terms. In addition, the bibliometric analytic platform SciVal was used to complement the records with information about standardised affiliations and citation impact indicators. Both Scopus and SciVal are developed and owned by Elsevier, a publisher and international provider of data solutions (www.elsevier.com). The Scopus data contains a variety of indicators and statistics on scientific and scholarly publishing (Baas et al., 2020). SciVal uses Scopus content from 1996 on. Scopus is the largest abstract and citation database of peer-reviewed research literature in the world.

The report utilised data from 2016–2022, but data for the year 2022 was incomplete at the time of analysis. This means that the final annual figures for 2022 will be somewhat higher than those presented in the report.

2.2 Definition of the Arctic

As part of the work conducted for the previous report by the UArctic Science & Research Analytics Task Force (Aksnes et al., 2016), various definitions of the Arctic were discussed, as well as how the region could be identified geographically and operationalised for use in bibliometric analyses. An international group of subject-matter experts contributed to this process. However, it should be noted that the report was considered a pilot study, and the Task Force group acknowledged that the search methodology and list of keywords were not yet comprehensive and required further methodological improvements.

In the research conducted for this report, we reconsidered and revised the previous search methodology. We added new search terms and excluded some that were previously included. These changes are not very large, and the overall definition of the Arctic has been retained. However, as a consequence, the results of the two reports are not directly comparable.

Below, we have reproduced the main elaborations on how the Arctic was defined in the previous report, as they are still valid for the present report.

2.2.1 Previous definitions of the Arctic

Previous definitions of the Arctic include self-perception by Arctic communities and people, cultural and historical considerations, latitude (Arctic Circle), political definitions (which are often driven by national economic or political goals), as well as natural science-based definitions that incorporate climate, ecosystems, eco-regions, animals, vegetation, sea ice, permafrost, and more. Additionally, there are historical and partially mythological definitions of the North.[3]

A practical definition of “the Arctic” should distinguish the North and the Arctic as regions with distinct ecological and natural systems that are distinguishable from those further south. Ideally, it should also reflect the “northern” human realities and activities, as opposed to those that are “not so northern” human realities and activities.

Moreover, the definition should ideally align with the “common understandings” of the North and/or the Arctic, while taking into account the different perspectives of various audiences. It should also be consistent with national (sometimes policy-driven) definitions, but not be influenced by national borders. Finally, the definition must be practical and easy to use. Achieving these objectives would enable the use of easily recognisable concepts to differentiate the Arctic from non-Arctic regions.

2.2.2 Our definition of the Arctic

The definition used as the basis for this report follows the general trend of Arctic Council-related definitions of the Arctic. This choice is pragmatic, as it acknowledges the Arctic Council's widely recognised authority as the global representative body for the Arctic.

More specifically, the definition adheres to the Arctic Human Development Report (AHDR) boundaries, administrative boundaries on land areas when addressing socio-economic and human-related issues, while following the southernmost of either the Arctic Monitoring and Assessment Program (AMAP) or Conservation of Arctic Flora and Fauna (CAFF) boundaries for natural phenomena on land. Additionally, it uses the AMAP border for marine areas, but allows for flexibility by using the Search and Rescue Agreement when more appropriate for specific marine areas.[4] This means that this study uses the combined definitions of the Arctic Council (AHDR+EPPR+CAFF+AMAP) to define the Arctic.

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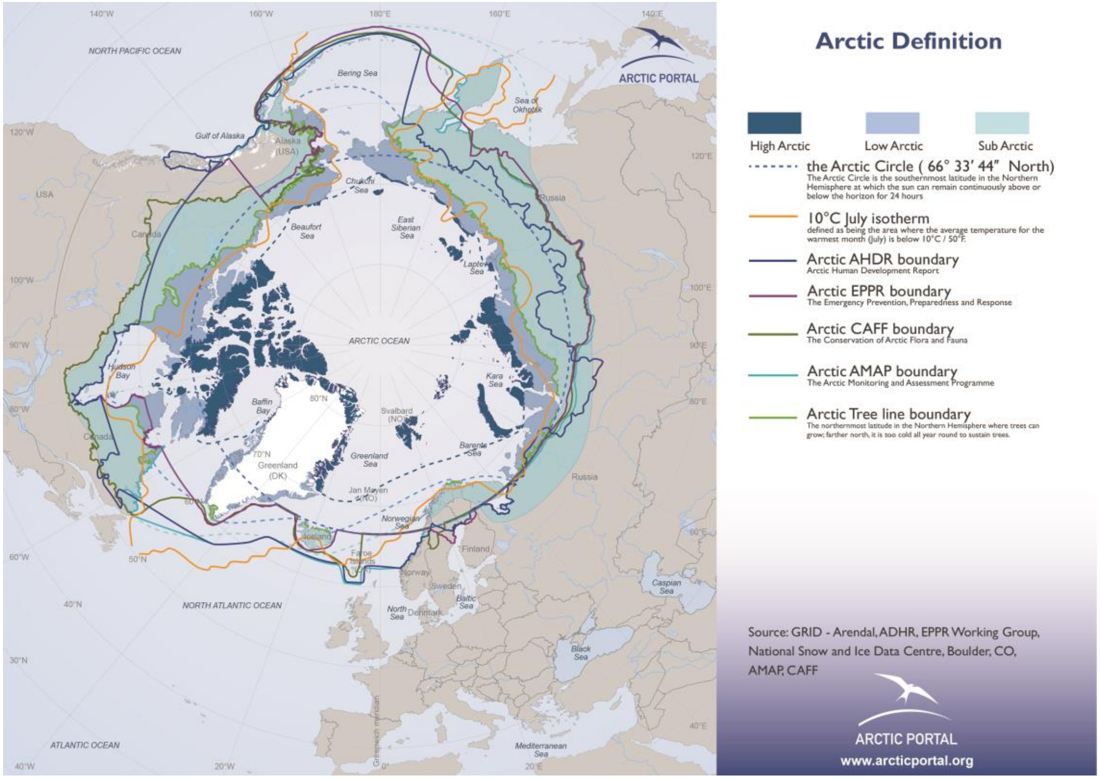
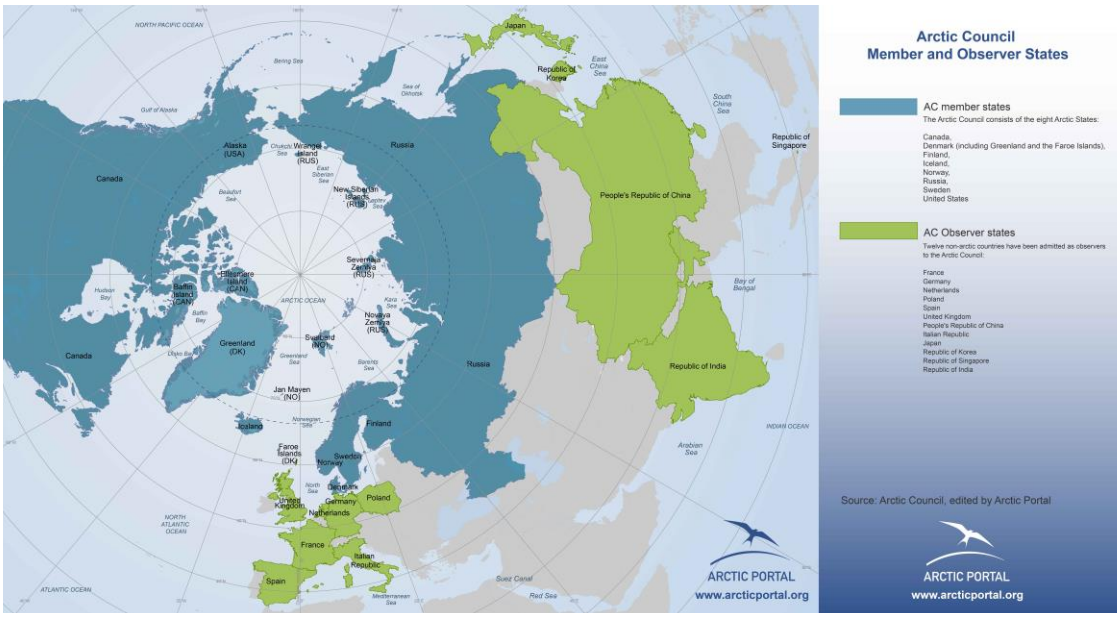
[3] Examples include https://www.arcticcentre.org/EN/arcticregion/Maps/historical-map
[4] For AHDR, CAFF, AMAP lines, see http://arcticportal.org/images/maps/small/1.9.jpg and for the Arctic Search and Rescue Agreement see https://en.wikipedia.org/wiki/Arctic_Search_and_Rescue_Agreement.


Arctic Definition
High Arctic
Low Arctic
Sub Arctic
the Arctic Circle (66° 33′ 44″ North)
The Arctic Circle is the southernmost latitude in the Northern Hemisphere at which the sun can remain continuously above or below the horizon for 24 hours
10°C July isotherm
defined as being the area where the average temperature for the warmest month (July) is below 10°C / 50°F.
Arctic AHDR boundary
Arctic Human Development Report
Arctic EPPR boundary
The Emergency Prevention, Preparedness and Response
Arctic CAFF boundary
The Conservation of Arctic Flora and Fauna
Arctic AMAP boundary
The Arctic Monitoring and Assessment Programme
Arctic Tree line boundary
The northernmost latitude in the Northern Hemisphere where trees can grow; farther north, it is too cold all year round to sustain trees.
Source: GRID - Arendal, ADHR, EPPR Working Group, National Snow and Ice Data Centre, Boulder, CO, AMAP, CAFF
ARCTIC PORTAL
www.arcticportal.org
ARCTIC OCEAN
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
ATLANTIC OCEAN


Arctic Council
Member and Observer States
AC member states
The Arctic Council consists of the eight Arctic States:
Canada,
Denmark (including Greenland and the Faroe Islands),
Finland,
Iceland,
Norway,
Russia,
Sweden
United States
AC Observer states
Twelve non-arctic countries have been admitted as observers to the Arctic Council:
France
Germany
Netherlands
Poland
Spain
United Kingdom
People's Republic of China
Italian Republic
Japan
Republic of Korea
Republic of Singapore
Republic of India
Source: Arctic Council, edited by Arctic Portal
ARCTIC PORTAL
www.arcticportal.org

2.3 Methodology

In this chapter, we describe the methodology used in the study, which is largely based on the approach developed and outlined in the previous report by Aksnes et al. (2016).

2.3.1 Challenges

The need to develop a specific methodology for this study arises from the fact that only a small portion of the research on the Arctic is published in specialised Arctic research journals (such as the journal *Arctic*). The majority of publications are found in more general scientific and scholarly journals, as well as thematic journals, books, and monographs. Due to the challenges associated with defining the Arctic, a keyword search query approach has been utilised to identify publications related to the region.

The main challenge lies in identifying research that pertains to the Arctic, as per the definition described above, and excluding research on topics and objects outside of the defined region. To overcome this challenge, we have decided to focus on two types of terms: geographical names, the names of indigenous peoples and some specific disciplinary terms. Additionally, we have used a few general terms that are assumed to be unique to the Arctic, such as "Arctic" and "tundra". By utilising place identifiers while avoiding the excessive use of specific disciplinary terms, we aim to eliminate any disciplinary bias in the selection of research publications.

2.3.2 Methodology development

To identify relevant publications, we have employed geographical search terms. We have followed the principles applied in the pilot study, and searched through the titles, abstracts and author keywords of all publications in the database. Similar methods were also applied in previous bibliometric analyses of polar and Arctic research (Augustsson et al., 2014; Dastidar, 2007; Aksnes & Hessen, 2009; Côté & Picard-Atiken, 2009). It was assumed that the geographical location of the research would generally appear in either the title, abstract, or as keywords of the publication. Therefore, we used names of geographical areas in the Arctic as an indication of Arctic research content. These names included mainland areas, islands, oceans, seas, lakes, rivers, and key cities and settlements, based on the geographical delimitation of the Arctic as defined previously. While the number of potential geographical search terms is almost infinite, we have limited the terms used to the main geographical localities for practical reasons. In total, we applied 426 terms covering the key geographical regions in all eight Arctic Council member states.

In addition to using geographical terms that directly connect to areas considered "Arctic" by their respective countries, names of indigenous nations, peoples, bands, and languages (e.g. Inuit, Saami, Nenets, etc.) are incorporated as search terms to further refine the search results. Anthropological, ethnographical, and historical studies (such as those conducted by Mousalimas in 1997, Ingold in 1992, and Cruikshank in 1992) suggest that indigenous people and their placenames are intricately linked to the land and space, adding an extra dimension to our geographic search. Furthermore, including these names aligns with the Arctic Council's focus on Arctic peoples as a key constituency for its work. Various such search terms, covering official names and variations in spelling, are included in the search query to ensure that the study would capture relevant research within social sciences, history, arts, humanities, and life sciences. These terms (in total 87) covered all eight Arctic Council member states.

The number of search terms used in this study has been reduced compared to the previous report, particularly for the latter type of search terms. In the previous report, we included all names of indigenous groups that were related to the Arctic borders, taken in the widest sense of the word. However, when we validated this approach, we found that it identified too many irrelevant articles, resulting in false positives (see below). As a consequence, the present study has adopted a stricter approach, requiring only terms for indigenous people living mainly within the geographical definition of the Arctic to be included.

In addition, about 20 expressions were used as excluding (not) terms (e.g. ”Arctic mutation”, causing Alzheimer’s disease).

2.3.3 Validity issues

Although the list of search terms and keywords is not exhaustive, we believe that the method we have applied is adequate for analysing global Arctic research as reflected in the Scopus database. We also find that the new method has increased the precision of the analysis as compared to the pilot study. However, there are still several potential sources of error.

First, it is possible that certain relevant publications were not identified because they did not specify where the research was carried out or because they mentioned names of geographical regions that were not included in the study. To mitigate this problem, additional field-specific search terms could have been used.

Second, the method used in this study may potentially have identified publications that were not relevant to Arctic research. This could be because certain words had multiple meanings or were used in contexts that were unrelated to the Arctic.

To mitigate this issue, we took measures to exclude words with multiple meanings and tested the dataset output using various scenarios to identify any instances of double meaning, or words that produced a significant number of false positive references with no relevance to Arctic research. We also applied exclusion terms as described above. However, in a macro study like this, it is infeasible to prevent including some irrelevant publications. Additionally, there may be cases where certain geographical names, such as Greenland, are mentioned in the abstract, but the research was conducted in, or primarily related to, other regions.

To further assess the gravity of this issue, precision and recall with respect to selecting publications related to the Arctic were estimated. From the set of identified records, 300 articles were randomly selected for validation to serve as the basis for a precision test. The articles were assessed by three domain experts in Arctic research. Of the sample, 87% were assessed to have Arctic content by at least two experts, and 94% by at least one expert. This difference is because there are borderline cases, and the distinction between Arctic versus non-Arctic content is not always clear-cut and is difficult to assess.

We also tested the recall of the search methodology. For this test, we selected four journals with presumably purely Arctic content: Arctic, Arctic Anthropology, Arctic Science, and Arctic Review on Law and Politics, and one journal which predominantly features Arctic content: International Journal of Circumpolar Health (IJCH). Of the 979 articles published in these journals during the period analysed, 85% were identified by our search methodology, somewhat higher at 90% if the non-Arctic-specific journal IJCH is excluded from the calculations.

From these estimations of precision and recall, we conclude that the search methodology is adequate and has quite high validity. However, this test clearly shows that some Arctic publications are not identified by our search methodology, and conversely, some non-Arctic publications are selected. There is always the possibility of errors in the identification of Arctic and non-Arctic publications. This is especially true in large-scale analyses where there is a high volume of articles to sift through. To reduce the false positive records, we post-filtered the data: we embedded the records into 2D space based on the vector of words occurring in their titles, keywords, and abstracts. Then, we used unsupervised clustering to segment the records into groups and examined whether each group related to the Arctic. For groups not related to the Arctic, we identified common terms and used them for exclusion. Moreover, we removed records that were selected because they matched the name of a place, such as Umeå, if that match only occurred as a substring of a university name, such as Umeå University, as well as records that were selected solely due to search term normalisation, that is after replacing special characters with their regular counterparts. In total, the post-filtering removed 852 records.

It is also worth mentioning that the understanding of what constitutes "Arctic content" may vary depending on the researchers and experts involved in the assessment. This could potentially lead to discrepancies in the identification of relevant articles. Thus, one should approach the results of this report with some caution and acknowledge the limitations of the methodology. This is particularly relevant when assessing the publication output of individual institutions. It may be useful to conduct further assessments or to refine the search methodology to improve its accuracy.

Another validity issue concerns the use of the SciVal/Scopus database. This database does not cover all scientific and scholarly publications, and some journals, books, and proceedings relevant to Arctic research are missing. For example, the database covers Russian and Swedish language sources only to a limited extent.

The problem of language and types of publications creates a remaining concern as it produces a systematic bias in the dataset, potentially for specific research areas. However, we believe that the value of the information from such a large dataset far outweighs the limitations as long as this problem is recognised. Most error sources, such as the double meaning of search terms, create random errors that are not specific to one discipline, institution, or country. In this case, the value of the large underlying dataset far outweighs these errors.

In conclusion, there are limitations to this approach. Still, for most questions, this is of less importance given the large number of publications involved, and the fact that our aim is to provide a general overview of Arctic research.

2.4 The dataset

Our query selected a total of 75,503 records from Scopus, which we restricted to the categories of articles, reviews, conference papers, books, and book chapters, reducing the number of records to 73,592. Post-processing the record based on further exclusion terms removed 852 records, leaving 72,740 records. Of those, 72,723 were available in SciVal, and 72,593 were annotated with the relevant time range between 2016 and 2022.

The Arctic dataset of 72,593 records used in our analyses contains 58,551 records published as articles (80.7%), 2,841 as reviews (3.9%), 7,120 as conference papers (9.8%), 479 as books (0.7%), and 3,602 as book chapters (5%).

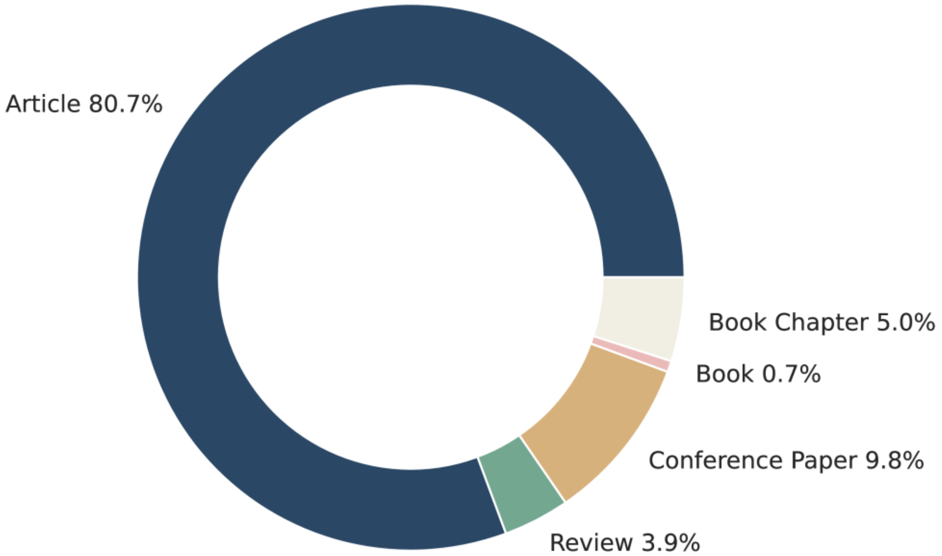


Figure 1. Distribution of Arctic scientific publications by publication type (2016–2022).

2.5 Analyses and indicators

Publications

The indicator "publications" measures research output. The indicator is defined as the fractionalised number of records affiliated with the respective institution or country (further explained below).

Publication share

Publication share is the global share of publications for a specific subject area or groups of countries expressed as a percentage of the total output. Using a global share in addition to absolute numbers of publications provides insight by normalising for increases in world publication growth and expansion of the field in question or the whole Scopus database (Pan, 2014).

Fractionalisation

Different from the pilot study, where whole counting was employed, we use fractional counting in this study (Gauffriau, 2021). The difference between whole counting and fractional counting lies in how much each record contributes to the publication counts of the affiliated entities (e.g., countries or institutions). Under whole counting, each affiliated entity receives a count of one such that a record's total contribution is defined by the number of affiliated entities. Fractional counting defines that each record's total contribution is one, which is equally divided amongst the affiliated entities. When multiple countries are affiliated with a record, its contribution to each country's publications is one divided by the number of affiliated countries. Similarly, when multiple institutions are affiliated with a record, its contribution towards each institution's publications is one, divided by the number of institutions.

Fractional counting prevents publications with many affiliated countries or institutions from dominating the counts and, thus, the patterns that can be identified in the data.

Field-Weighted Citation Impact

The Field-Weighted Citation Impact in SciVal indicates how the number of citations received by an entity's publications compares with the average number of citations received by all other similar publications in the data universe. How do the citations received by this entity's publications compare with the world average? Similar publications are those publications in the database that have the same publication year, publication type, and discipline.

A Field-Weighted Citation Impact of 1.0 indicates that the entity's publications have been cited exactly as would be expected based on the global average for similar publications. Thus, the Field-Weighted Citation Impact of "World", or the entire Scopus database, is 1.0. A value of more (less) than 1.0 indicates that the entity's publications have been cited more (less) than would be expected based on the global average for similar publications. For example, 2.11 means 111% more cited than the world average while 0.87 means 13% less cited than the world average.

We calculate average Field-Weighted Citation Impacts for countries and institutions by fractionalising the affiliated records' Field-Weighted Citation Impact scores according to the number of involved countries or institutions, respectively, normalised by the sum of fractionalisation factors.

International Collaboration

International Collaboration is indicated by articles with at least two different countries listed in the authorship list.

Institutions in SciVal

Institutions are groupings of related Scopus Affiliation Profiles which have been created from standardising author-provided affiliation information in the original publications. More than 20,000 institutions have been predefined and are available in SciVal. It should be noted that this process of connecting heterogeneous – and sometimes vague and ambiguous – author affiliations to known research institutions is a very difficult problem. The specific institution name disambiguation system in Scopus/SciVal has shown to have high precision (when a publication is attributed to an institution, this tends to be correct). Still, in some cases, the recall can be moderate (not all publications from a given institution are identified (Baas, Schotten, Plume, Côté, & Karimi, 2020; Donner, Rimmert, & van Eck, 2020). Statistics on the institutional level should therefore be viewed with this in mind.

Subject areas

In Scopus and SciVal, serial titles are classified using the All Science Journal Classification (ASJC) scheme. Classification is done by in-house experts at Elsevier, and classification is based on the aims and scope of the title and on the content it publishes. The bottom level has 304 categories, and the top level includes 27 categories (Scopus, 2023).

When we refer to subject areas in this report, it is based on the top level of ASJC, except for when macro categories according to the classification scheme Fields of Research and Development classification (FORD) is used. In the latter case, we use a pre-defined mapping between ASJC and FORD available in SciVal.

3. Analyses of Arctic research

3.1 Publication output: total and by country

The analysis reveals that the annual global scientific production of Arctic publications has been in the range of 10,500 to 11,500 in recent years, with an increasing trend from 9,500 publications in 2016 to 11,500 in 2021 (see Figure 2). This corresponds to a relative growth of 22% during the period, or a compound annual growth rate of 4.0%. As noted in Chapter 3, the figures for 2022 are still incomplete, which might explain the slight drop in that year.

The previous report showed that the number of Arctic publications increased from 5,000 at the end of the 1990s to almost 11,000 in 2015, corresponding to a compound annual growth rate of 4.8%. This report applies a somewhat stricter definition of Arctic research, which explains why our figures for 2016 are lower than those previously found for 2015. We observe a less strong growth rate in recent years.

The trend figures indicate that research activities related to the Arctic have continued to expand in recent years. One reason for this is likely the Arctic's key role in understanding the effects of climate change. Previously, the arrangement of the Fourth International Polar Year (2007–2008) led to a boosting effect, an internationally coordinated campaign representing a major initiative to strengthen research activities in the polar regions.

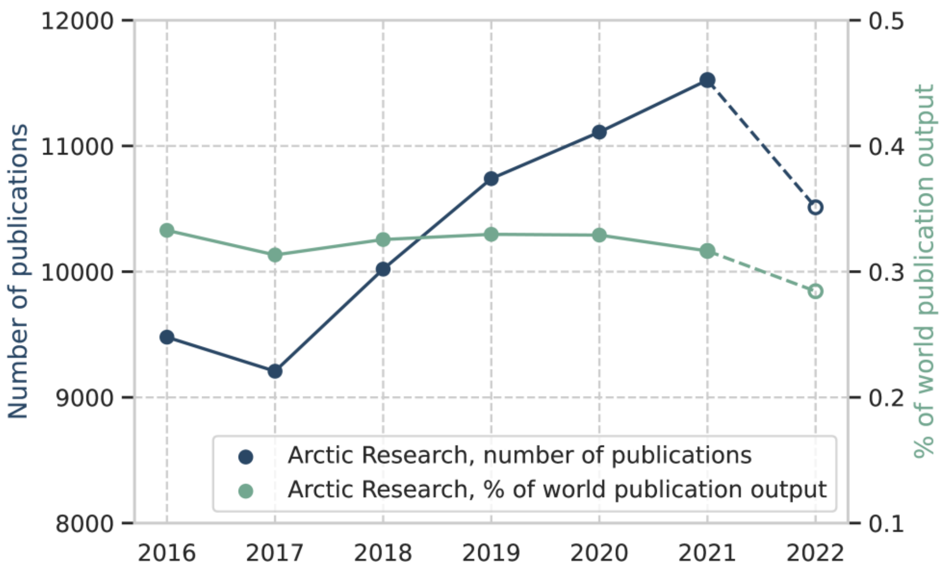


*Figure 2. The development of the global output of Arctic scientific publications, 2016–2022.**

*) The figures for 2022 were still incomplete at the time of analysis.

In 2021, Arctic research represented 0.32% of the total number of publications in Scopus. This proportion remained relatively stable between 2016 and 2021, ranging from 0.31% to 0.33%. However, in 2022, this proportion decreased to 0.28%.

Despite the increase in the volume of Arctic publications, the proportion of the total in the database did not increase. This is because the total number of scientific publications indexed in Scopus has also considerably increased during this period. One might have expected that Arctic research would have shown stronger relative growth compared to the global average, but the empirical results do not support this. Although the figures for 2022 are not yet complete, there appears to be a large decrease in the volume of Arctic publications this year. This is likely due to the decline in Russian publication volume, which will be further explained below.

Figure 3a depicts the countries that make the largest contributions to Arctic research in terms of publication output. It is important to note that the contributions are counted based on the location of the institution where the researchers are based, and not on the researchers' country of origin or the location studied. Here the figures for each country are fractional according to the number of countries on the publications (see Chapter 3). In the analysis, figures for Denmark do not include Greenland or the Faroe Islands. Instead, each part of the realm has been analysed separately. However, due to low publication numbers, Greenland and the Faroe Islands do not show up in most graphs.

In 2022, the United States had the largest number of fractionalised publications among all nations, with more than 2,200 such publications. Russia followed with over 1,700 publications. These two countries rank far above the others in terms of publication volume. Canada and China are almost equal in size, with 915 and 860 fractionalised publications in 2022, making them the third and fourth largest contributors. Norway takes fifth place. Although a large number of countries contribute to Arctic research, many have only a small publication output.

Figure 3a also shows the publication numbers in previous years, indicating that most countries experienced an increase during the 6-year period from 2016 to 2021. However, for most nations, the numbers in 2022 are lower than those in 2021. Nevertheless, some countries exhibited a stronger relative growth than others. Notably, China had the highest relative growth (132%) and moved from the 8th to the 4th largest country in terms of Arctic publication output. As shown in the previous report, China was a very small contributor to Arctic research at the beginning of the 2000s. This remarkable growth is not limited to Arctic research, as China is now the largest country in the world in terms of publication output.

Among the other larger Arctic research nations, Russia exhibited the strongest relative growth during the period, with a 38% increase. China and Russia had the largest increase in absolute terms. However, the figure for Russia drops significantly from 2021 to 2022.

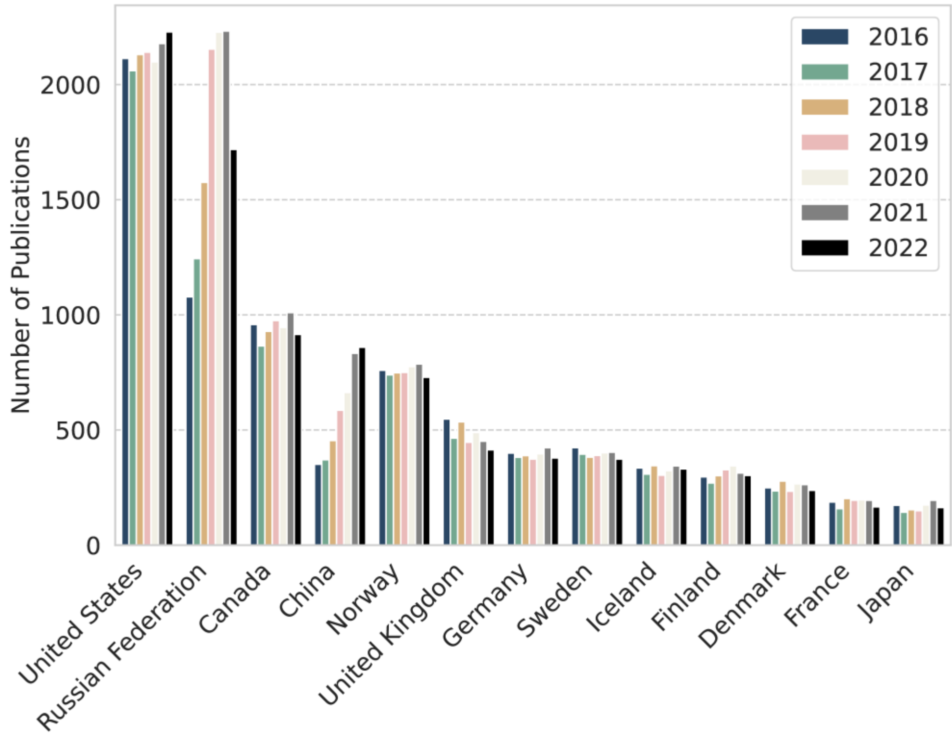


Figure 3a. Total number of Arctic scientific publications by country, 2016–2022 (fractionalised counts).*

*) Limited to countries with at least 150 fractionalised publications in 2016. The figures for 2022 were still incomplete at the time of analysis.

Upon further analysis, it became apparent that there are important differences in the publication channel types utilized by different countries. Notably, Russia has a distinct profile, with a greater emphasis on conference proceedings compared to other nations (particular in IOP Publishing conference series). Figure 3b displays publication numbers with conference proceedings excluded, revealing a less marked decrease in Russia's publication counts from 2021 to 2022. The reason for this trend is unclear.

It is also worth noting that Russian institutions have had their membership in UArctic paused, and several countries have imposed sanctions on research collaboration with Russia (Nazarovets & da Silva, 2022). These factors could potentially contribute to a further decrease in publication volume in the future.

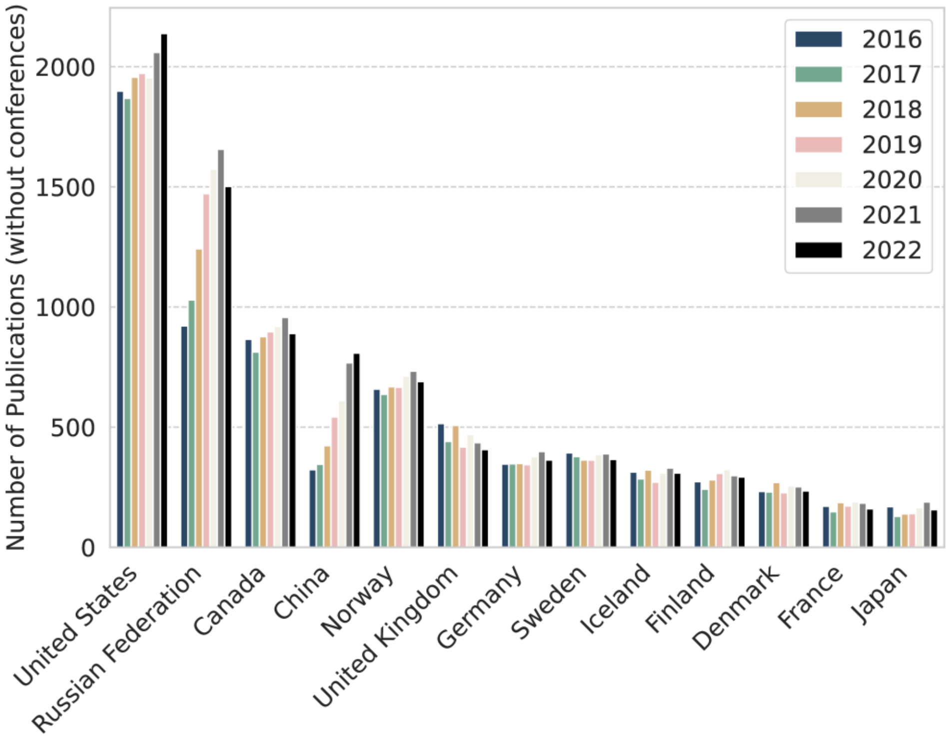


Figure 3b. Number of Arctic scientific publications by country, 2016–2022 (fractionalised counts), without conference proceedings papers.*

*) The figures for 2022 were still incomplete at the time of analysis.

In Figure 4, the countries have been classified into different groups: Arctic Council members, Arctic Council observers, and other countries. Researchers from Arctic Council member states (Canada, the Kingdom of Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States) have contributed to two-thirds of the total Arctic publications produced. The observer countries (China, France, Germany, India, Italy, Netherlands, Poland, Spain, Japan, South Korea, Singapore, Switzerland, and the United Kingdom) have contributed 26 per cent, while other countries have contributed 7 per cent.

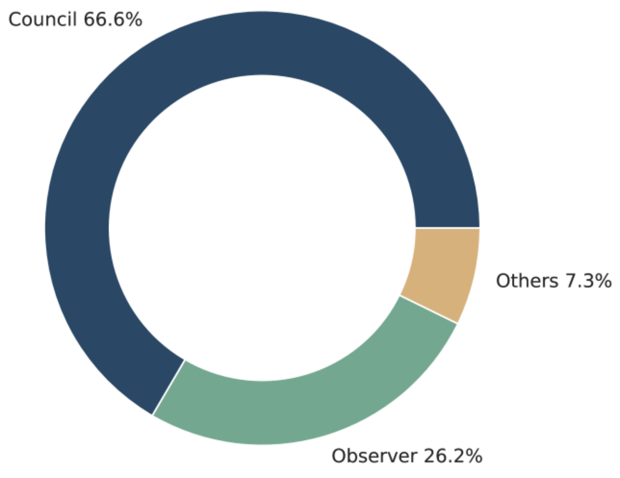


Figure 4. Distribution of Arctic scientific publications by groups of countries, 2022.

The proportions by type of country have remained relatively stable throughout the time period analysed. The number of Arctic publications by type of country is shown in Figure 5. This figure also includes combined counts for the Nordic countries. The contributions by the Nordic countries have been fairly stable, meaning that their relative position as contributors to Arctic research has been somewhat reduced in the period analysed.

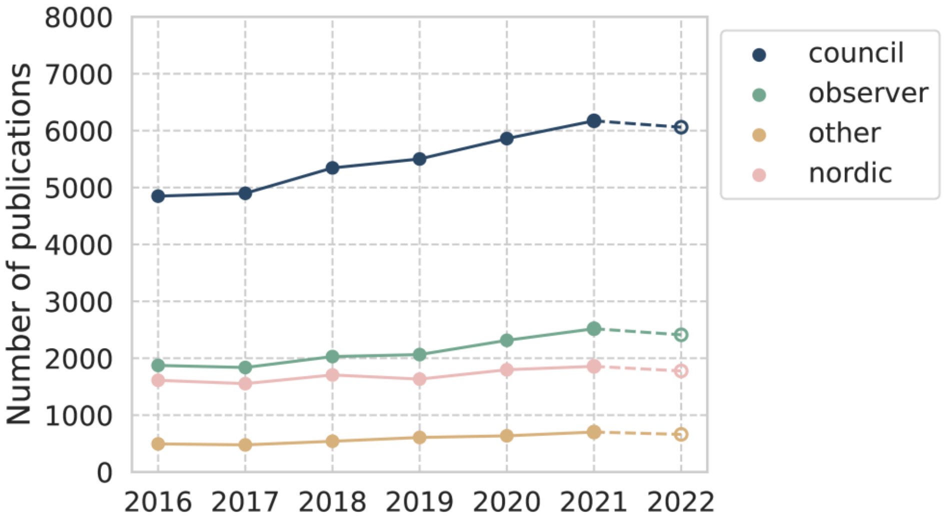


*Figure 5. Number of Arctic scientific publications by groups of countries, 2016–2022.**

*) The figures for 2022 were still incomplete at the time of analysis.

3.2 Publication output by publication channels

The vast majority of Arctic research is published in scientific journals, although publications in books and conference proceedings are also prevalent. Figure 6 presents the top 25 journals based on the number of published papers on Arctic research between 2016 and 2022. At the top of the list is *Geophysical Research Letters* with nearly 1,000 publications, followed by *Remote Sensing* and *Cryosphere*. None of the journals on the list are solely dedicated to Arctic research but a few have a predominantly Arctic or polar research profile. Two journals, *Scientific Reports* and *PloS One*, are mega-journals that cover all areas of science.

Most of the journals cover research within Earth and planetary sciences, but there are also journals in other fields represented, such as biology. In contrast, the ranking list of conference proceedings is dominated by publishers within the fields of engineering and energy.

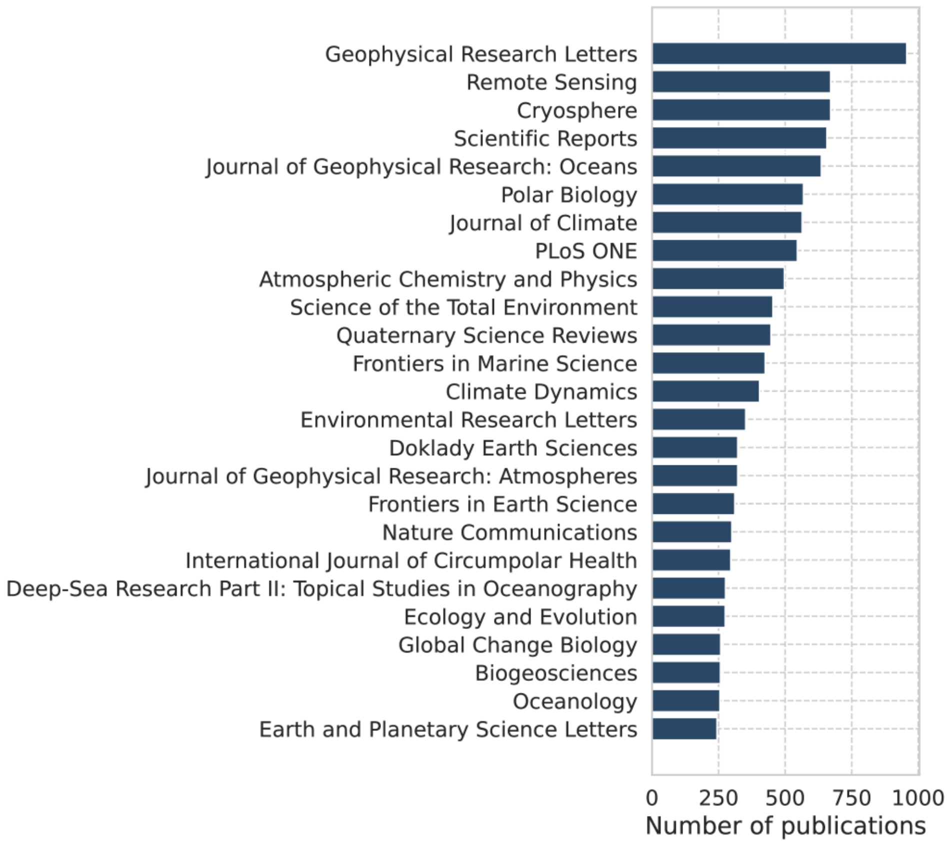


Figure 6. Top 25 journals by number of publications in Arctic Research (2016–2022).

3.3 Publication output by subject area

Arctic research comprises many disciplines, with Earth sciences and biology being the two largest fields. Figure 7 illustrates the distribution of research areas based on the global total of Arctic publications from 2016 to 2022. Earth and planetary sciences, which include geology, geophysics, oceanography, and cryosphere studies, account for 31% of the publications. Then follow two fields which are equal in size measured by publication volume: agriculture and biological sciences and environmental science (13%). Other natural sciences, medicine, biomedicine, technology, social sciences, and arts and humanities make up the remaining publications. Social sciences and arts and humanities are accounting for 9% and 3% of the total, respectively.

It is worth noting that the Scopus database primarily covers articles published in scientific and scholarly journals, and book publications are not as extensively covered. As books are a significant publication channel for social sciences and arts and humanities, and many are published in local languages, the actual contribution of these fields to Arctic research may be underestimated.

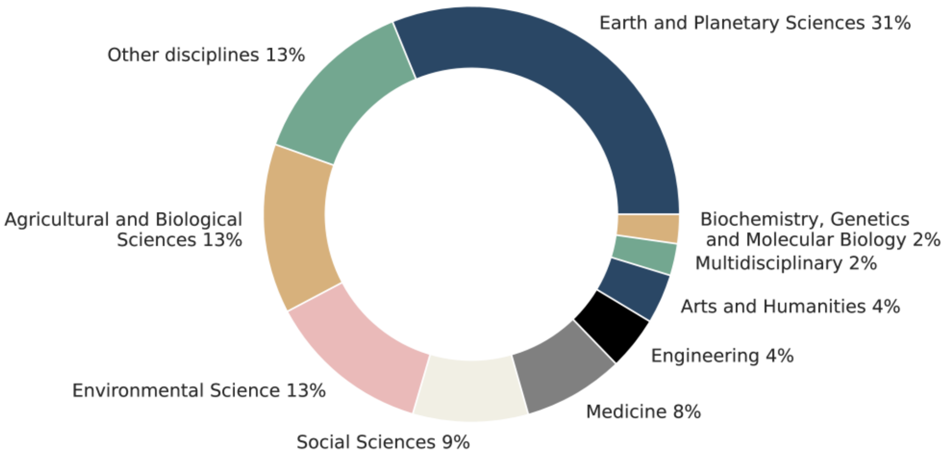


Figure 7. Distribution of Arctic scientific publications by field, 2016–2022.

Between 2016 and 2021, research output increased across all subject areas, although not to the same degree (see Figure 8). Notably, the fields of environmental science and medicine experienced particularly rapid growth in relative terms, leading to an increase in their share of total Arctic publication output. In absolute counts, environmental sciences also showed the strongest increase, followed by Earth and planetary sciences. However, in all fields shown in Figure 6, the publication numbers drop in 2022 due to incomplete Scopus data.

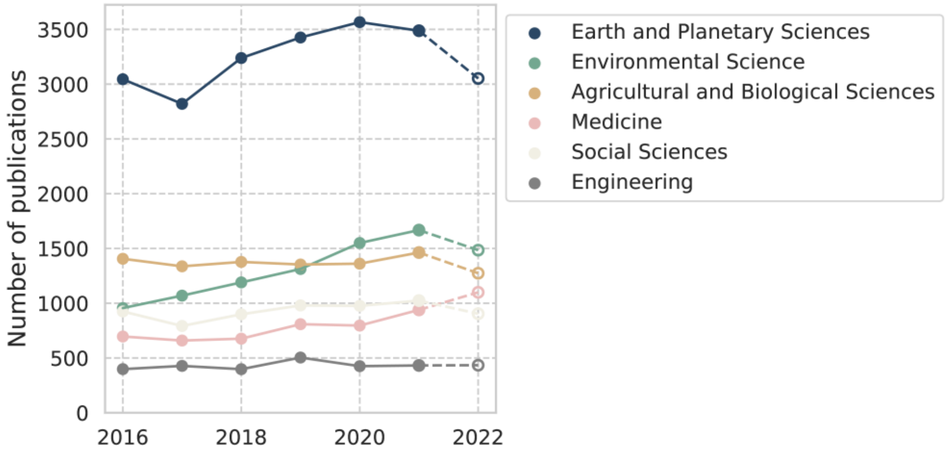


*Figure 8. Number of Arctic scientific publications by Scopus Subject Area, (top 6) 2016–2022.**

*) The figures for 2022 were still incomplete at the time of analysis.

While the Arctic makes up only about 0.3% of all publications in Scopus, this figure varies considerably by subject area. The highest proportion of Arctic-related publications is found in the Earth and planetary sciences (as depicted in Figure 9), although the figures for 2021 and 2022 show a declining pattern.

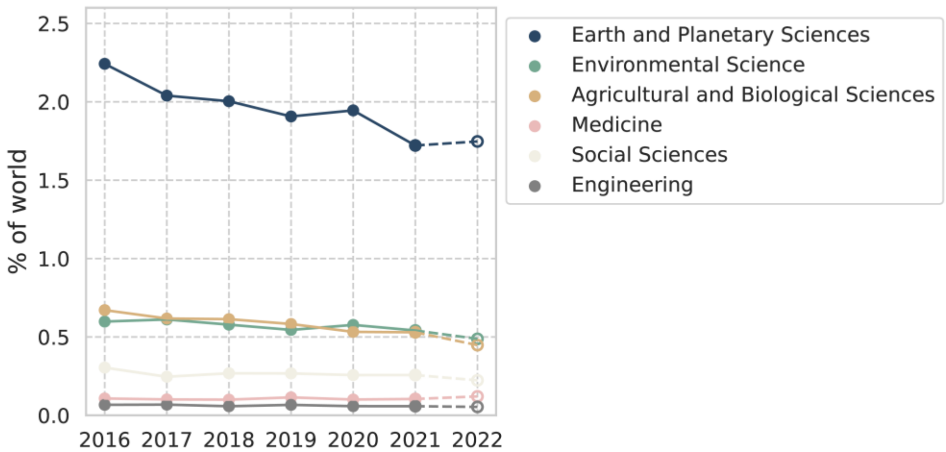


Figure 9. Proportion of the world total of publications that relates to the Arctic by Scopus Subject Area (top 6), 2016–2022.

When analysing Arctic research using the macro categories of the Fields of Research and Development classification (FORD) in the Frascati Manual (OECD), a corresponding picture emerges. While the proportion of Arctic research is increasing in medical and health sciences, it is decreasing in social sciences and agricultural sciences, and remaining relatively stable in the other areas (see Figure 10).

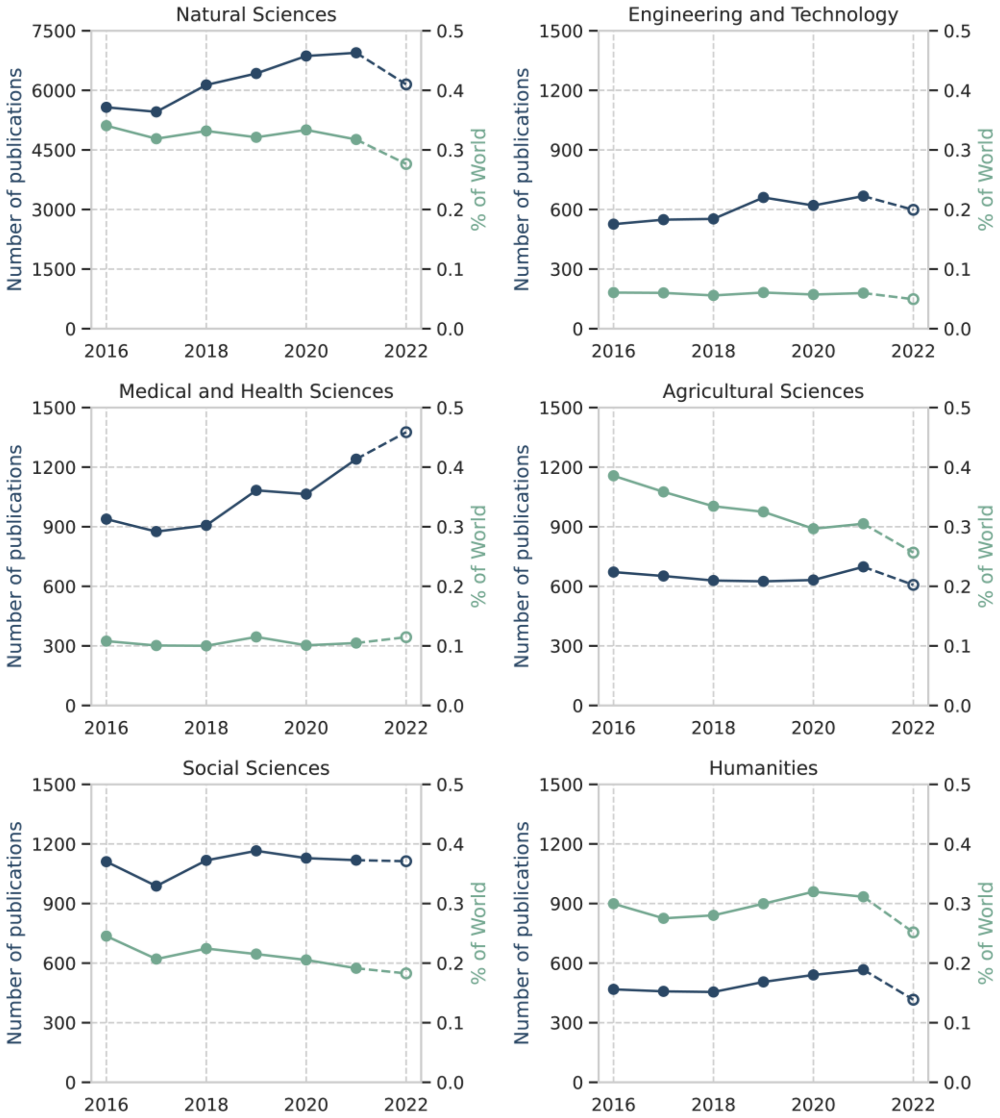


Figure 10. The number and proportion of the world total of publications that relates to the Arctic by FORD categories, 2016–2022.

3.4 Citation impact

The number of citations scientific publications receive in subsequent scientific literature is the basis for calculating citation indicators, a common way to measure the impact of research. In absolute counts, the countries with the highest number of publications also receive the most citations.

However, to determine whether a country's articles are highly or poorly cited, it is common to use size-independent measures. One such measure is the field-weighted citation impact, which expresses the average number of citations per publication compared to the field average. The global average for this measure is normalised to 1.0.

Overall, Arctic research publications tend to be cited slightly above the field average for all publications in Scopus. However, annual citation counts show a declining trend but have remained above 1 every year, expect 2021 (see Figure 11). The reason for this has not been further investigated. Nevertheless, it is worth noting that since the indicator is normalised based on publication year, it is unlikely to be influenced by a shorter citation window.

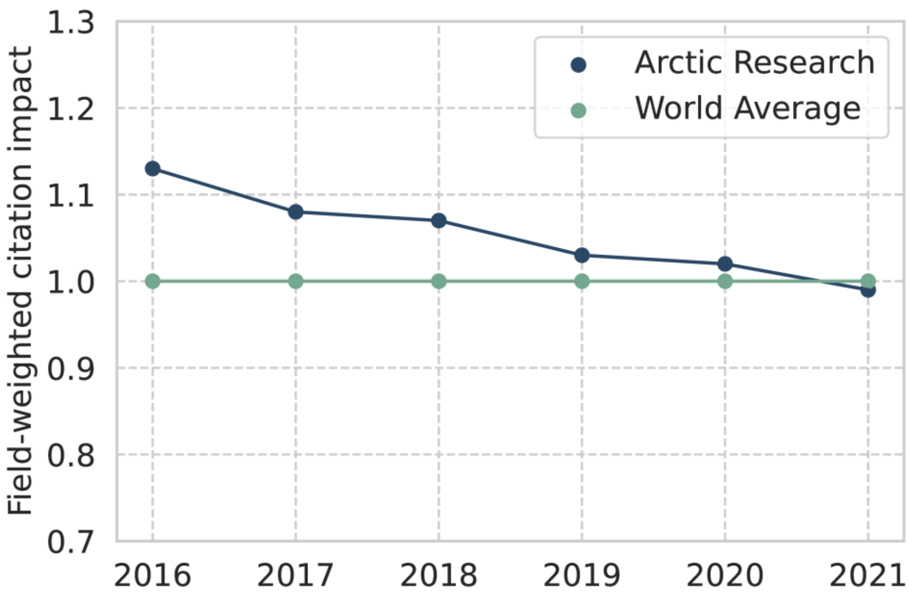


Figure 11. Field-Weighted Citation Impact for Arctic research, 2016–2021.

Figure 12 displays the Field-Weighted Citation Impact for the major contributors to Arctic research, based on their publications from 2016 to 2022. Notably, the citation impact does not necessarily correlate with the overall volume of publications. Netherlands and Australia, for example, are small contributors but have the highest scientific impact as measured by citations. On average, their publications have been cited 60% and 37%, more than the global average (Field-Weighted Citation Impact of 1.60 and 1.37, respectively). The United Kingdom follows closely with a citation impact of 1.34. In contrast, Russia has an index of 0.61, the lowest among the listed countries.

Russia's performance is considerably lower than that of other countries, and one possible explanation for this could be that Russian scientists frequently publish in Russian or non-English-language scientific journals. Since the research results published in these journals may not be accessible to a global scientific audience, they may get fewer citations and consequently have less international impact.

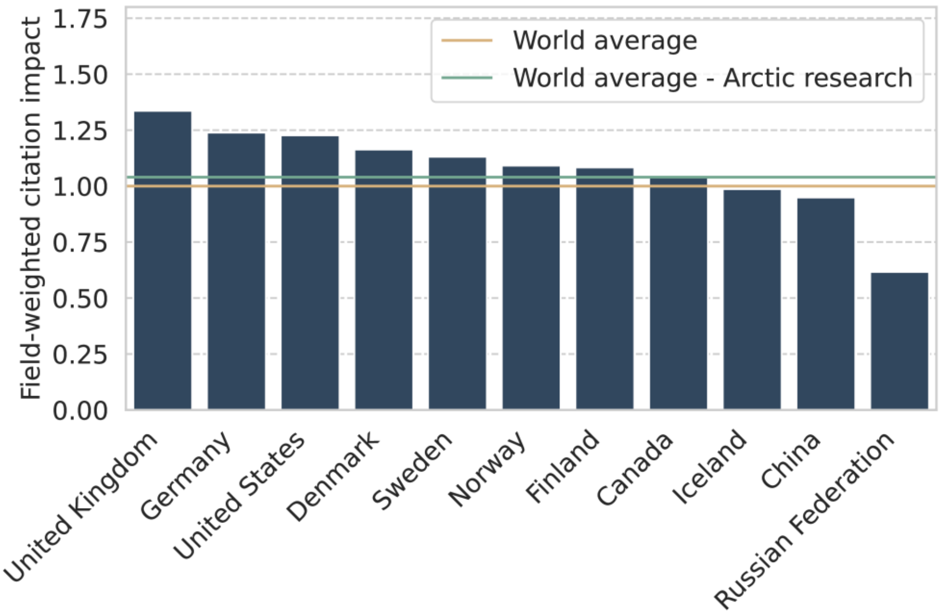


Figure 12. Field-Weighted Citation Impact for the largest Arctic research nations, based on fractionalised publications published during the period 2016–2021.

3.5 Publication output by institutions

Figure 13 presents the number of Arctic publications per institution, considering the 25 largest institutions based on Arctic publications from 2020 to 2022, where each institution has been credited a publication share according to the number of contributing institutions. A comprehensive overview featuring similar indicators for the 140 largest institutions (in terms of Arctic publications) can be found in the Appendix. Here, figures for the entire 2016–2022 period have been shown.

The Russian Academy of Sciences (RAS) stands out as the top institutional contributor with 1,100 fractionalised Arctic publications. RAS is a network of research institutes from across Russia. However, it is worth noting that there are sub-departments within RAS with separate publication numbers (e.g. RAS Siberian branch).

The second largest contributor to Arctic research is the University of Iceland, followed by UiT – the Arctic University of Norway, and the University of Alaska Fairbanks. The University of Oulu is the largest Finnish institution for Arctic research according to publication output, while Umeå University holds a similar position in Sweden. Despite being the third largest nation overall, no Canadian institution rank in the top 10, the largest being Université Laval placed 17th. Of the Danish institutions, Aarhus University has the largest number of Arctic publications.

On the top of the list, we also find a few institutions from countries which are not Arctic states: the Chinese Academy of Sciences, Alfred Wegener Institute – Helmholtz Centre for Polar and Marine Research (Germany), and the French National Centre for Scientific Research (CNRS).

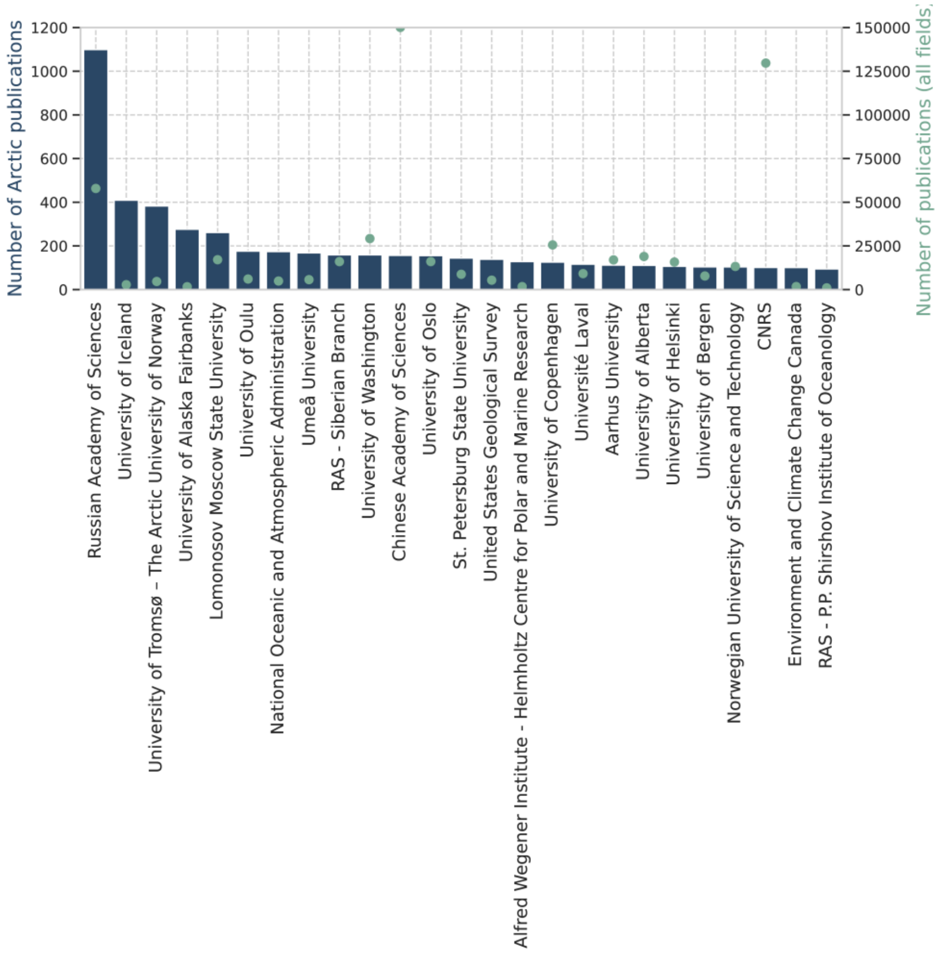


Figure 13. Number of Arctic publications per institution (fractionalised counts) and number of total publications all fields (whole counts), 2020–2022.*

*) Limited to the 25 largest institutions in terms of number of Arctic fractionalised publications.

Figure 13 includes an additional indicator on the total number of publications (all fields), but here the publication numbers have not been fractionalised. As can be seen, there are significant variations among institutions in terms of their overall research output. Some are very large, such as the Chinese Academy of Sciences and CNRS, while others are rather small, such as the University of Iceland. In the case of the latter, Arctic research constitutes a major portion of the institution's research activities.

Furthermore, there are notable differences among institutions in terms of the citation impact of their Arctic publications, as illustrated in Figure 14. This figure includes the 25 largest institutions based on Arctic publication numbers (fractionalised). Among the included institutions, the Alfred Wegener Institute has the highest citation impact of 1.5, followed by the University of Washington and CNRS. As observed from the country figures mentioned above, several Russian institutions perform relatively poorly in citation impact.

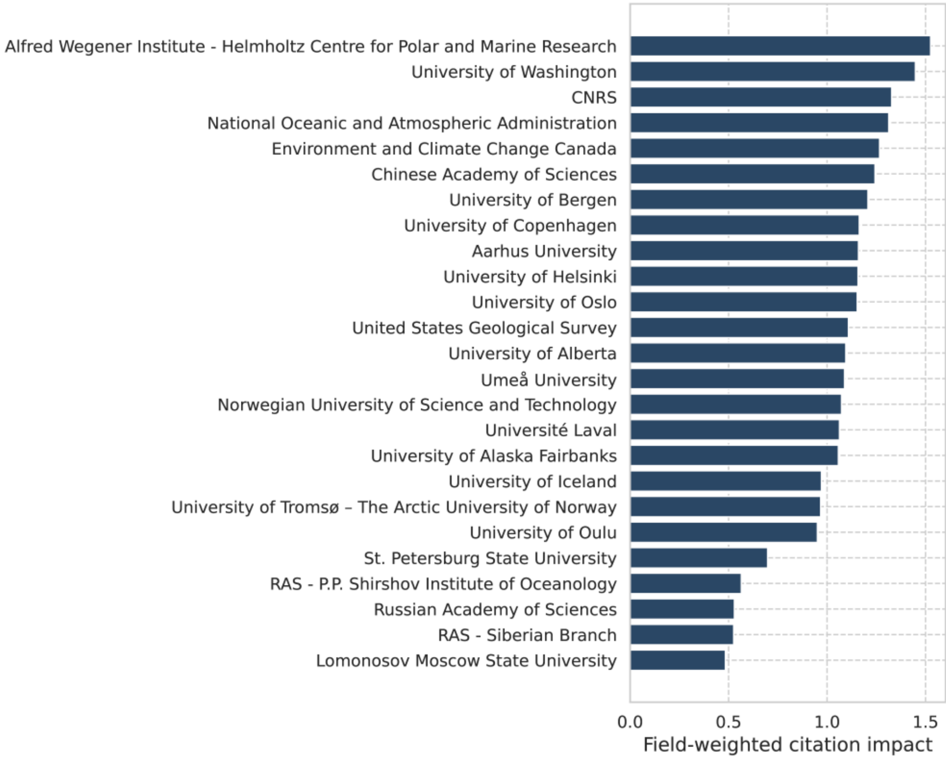


Figure 14. Field-weighted citation impact for the largest Arctic research institutions, based on fractionalised publications published during the period 2016–2021.*

*) Limited to the 25 largest institutions in terms of number of Arctic fractionalised publications.

3.6 International and national collaboration

International co-authorship is a widely recognised indicator of international collaboration. When researchers from different countries co-author a publication, it indicates that the research has involved collaboration. Therefore, international co-authorship can be used to assess the extent of international scientific collaboration.

In recent decades, the degree of international scientific collaboration has increased, both generally and in Arctic research. As of 2022, more than 36% of Arctic publications involved international co-authorship, whereas the average across all fields was 22%, as shown in Figure 15. This indicates that Arctic research is characterised by a high level of international cooperation.

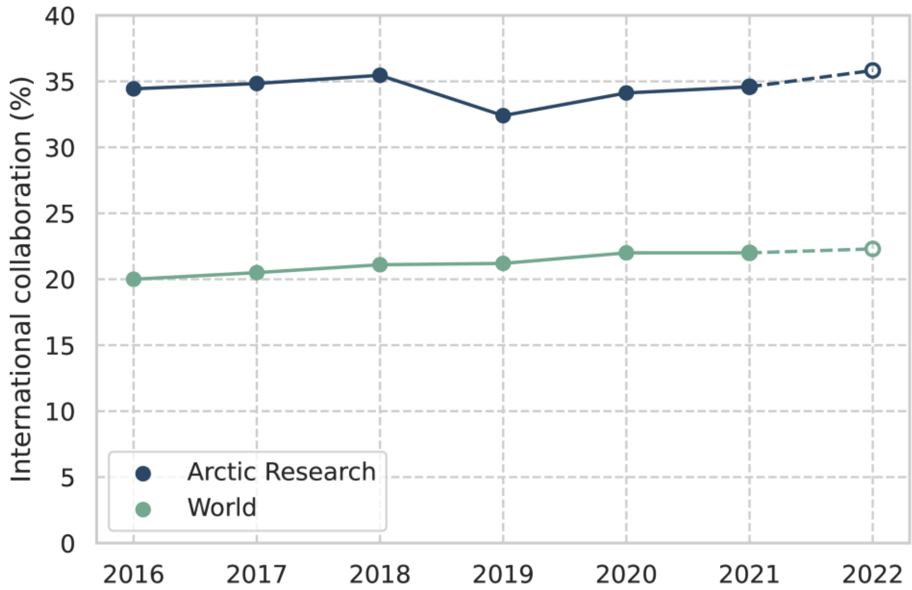


Figure 15. The proportion of international co-authorship, 2016–2022.

Nonetheless, there are significant variations among countries concerning the level of international collaboration. Larger scientific nations within Arctic research produce a greater number of collaborative publications than smaller countries. However, the latter tend to have a significantly higher percentage of collaborative articles. As such, international collaboration holds a relatively more important role in smaller countries. This phenomenon is generalisable and can also be observed in Arctic research, as depicted in Figure 16. In numerous countries, most scientific publications are co-authored internationally. One explanation for this is that researchers in smaller countries more frequently seek out colleagues and partners from abroad who specialise in their field. However, size is not the sole factor influencing the level of international collaboration; access to funding, geographic location, and cultural, linguistic, and political barriers are other critical factors (Luukkonen et al., 1992; Melin and Persson, 1996).

Observing Figure 16, it is evident that Greenland and Switzerland exhibit the highest proportion of international collaboration in their publications, with 83% of their works co-authored with researchers abroad. Thus, the extent of international collaboration is very high. It is noteworthy that in the case of Greenland, collaboration with researchers from Denmark is considered international collaboration based on the design of this analysis. On the other end of the spectrum, Russian scientists exhibit comparatively lower levels of collaboration with foreign scientists, with only 11% of their publications involving such collaboration.

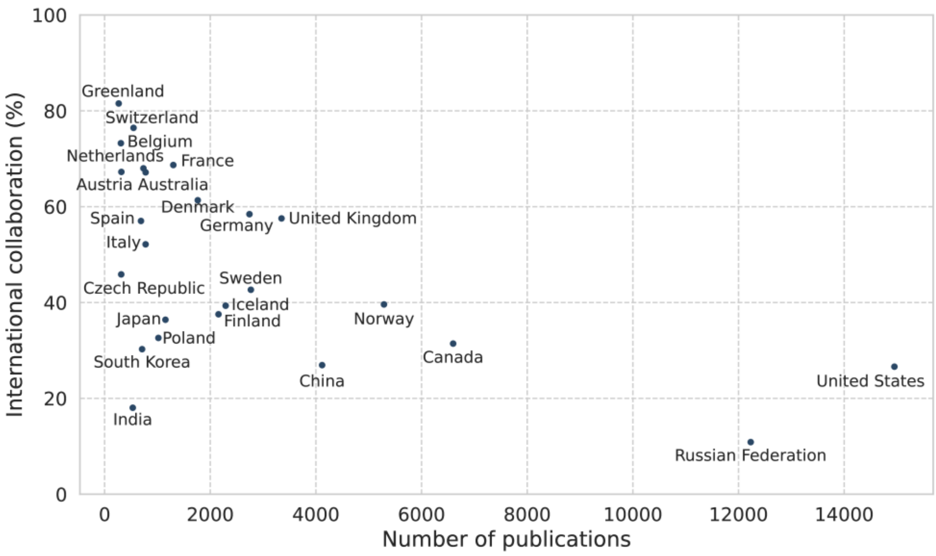


Figure 16. Proportion of international co-authorship and number of Arctic publications by country (2016–2022).

Apart from collaborating with colleagues abroad, there is also extensive national collaboration that can be measured bibliometrically by identifying publications with co-authors from multiple institutions within a country. Figure 17 illustrates the proportion of such co-authorship, which is significantly lower than the proportions for international co-authorship. Furthermore, the ranking list deviates considerably, with China and the United States being among the countries with the highest proportions of national co-authorship. This can be explained by the size of these countries as research nations with a large number of institutions.

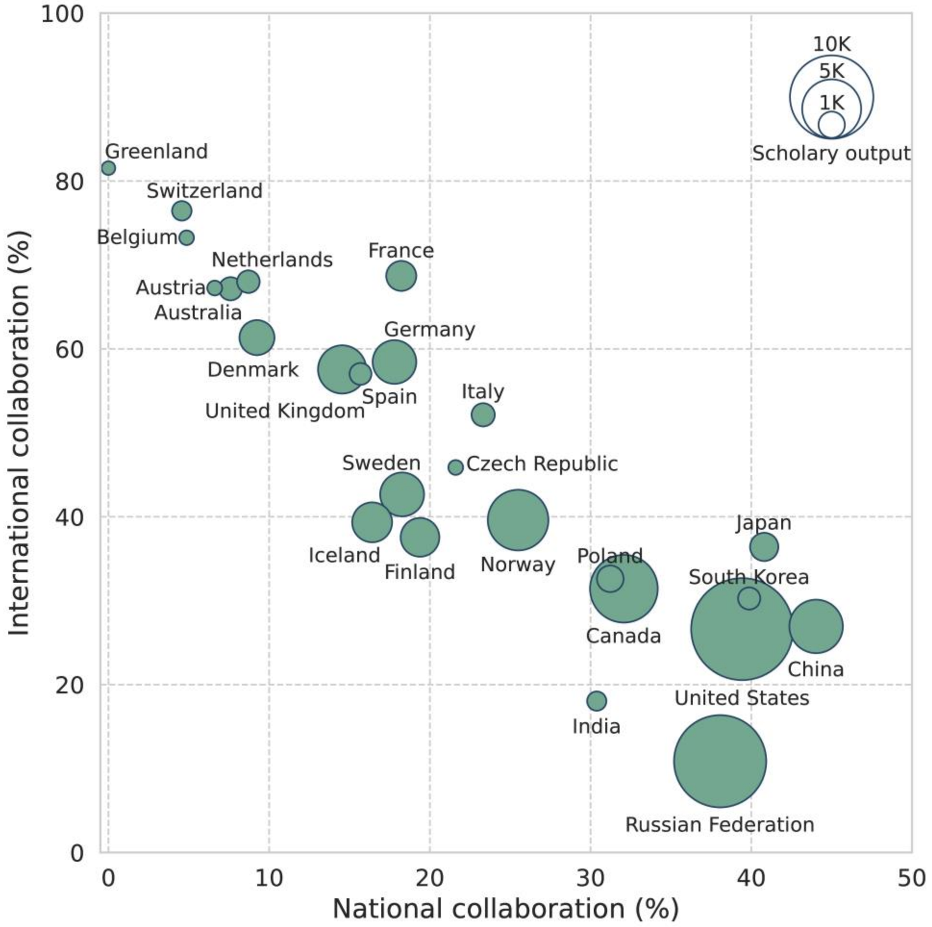


Figure 17. Proportion of national and international collaboration, and number of Arctic publications by country (2016–2022).

3.7 Cross-country collaboration

In this section, we analyse the ways in which various countries involved in Arctic research collaborate with one another. International collaboration can take many forms, ranging from one-to-one collaboration between two researchers to multinational collaborative efforts involving numerous institutions and researchers from around the globe. The latter type of project typically results in articles with long lists of contributing authors and countries.

The analyses in this section are restricted to publications that involve bilateral or trilateral international collaboration, which means that they have authors affiliated with institutions in two or three different countries. These publications account for most of the internationally co-authored papers. By excluding multilateral publications, we obtain a more precise understanding of the unique characteristics of individual countries' collaboration profiles and how these patterns differ across nations.

Figure 18 presents a map of the international collaboration profile. This graphic is created using VOSviewer, a computer program that generates maps based on network data (van Eck & Waltman, 2011). The map illustrates the degree of international collaboration among different countries and how countries are clustered together. The distance between countries indicates the number of co-authored publications. At the same time, the size of the squares represents the total number of co-authored publications in the analysed set of publications.

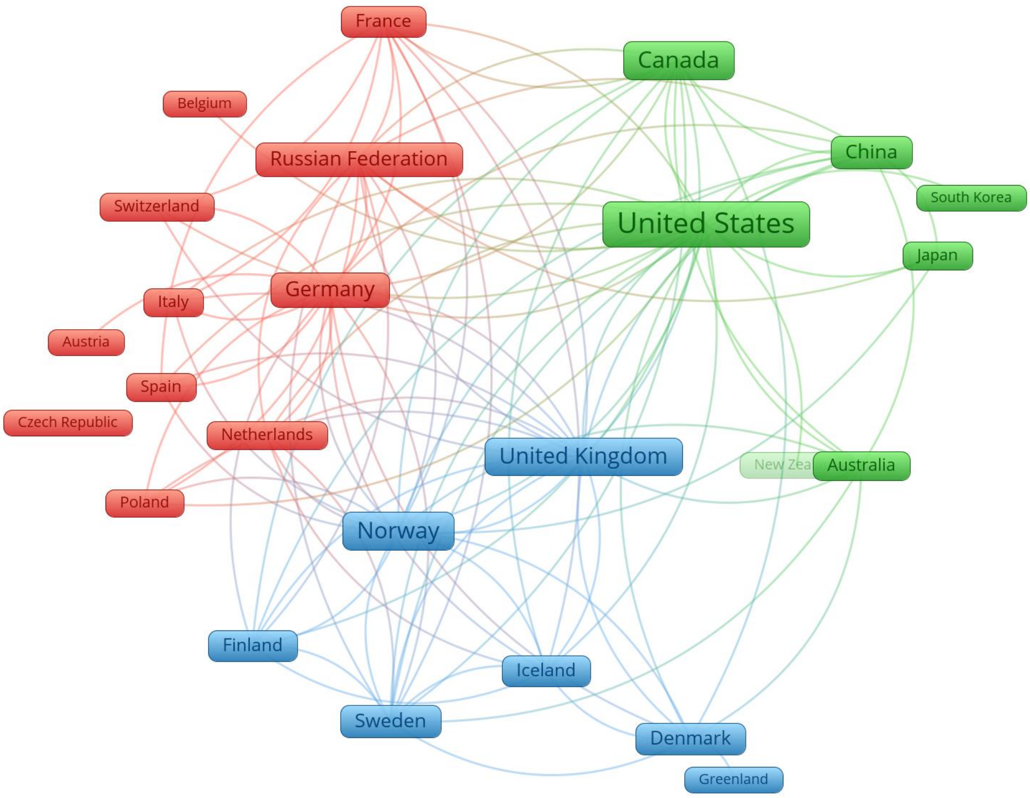


Figure 18. Top 25 countries with respect to the number of fractionalised publications 2016–2022 (based on bi- and triliteral collaborative publications only).

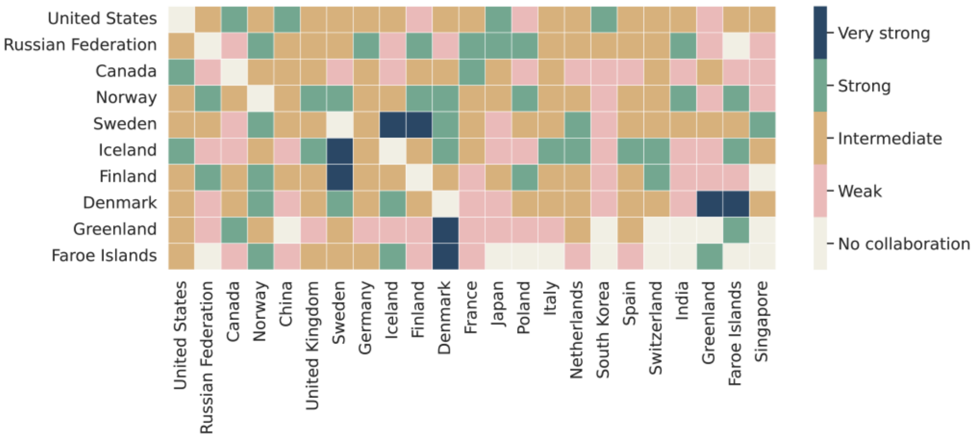
On the map, we can see three clusters that represent closely related countries. The first cluster, shown in blue, consists of the Nordic countries and the UK. The second cluster, shown in green, includes the USA and Canada as the main contributors. It also features China, Japan, South Korea Australia, and New Zealand. The third cluster, shown in red, represents some central European countries and Russia.

Generally, most countries tend to have more collaborative articles with the largest Arctic research nations and fewer with the smaller ones. This is simply due to size effects. As a result, the USA ranks high as a collaborative partner for many countries.

To provide an alternative perspective on the collaboration patterns of Arctic research, we have analysed the relative collaboration intensity of each country-to-country relationship. This is calculated by comparing the observed collaboration with the expected collaboration, taking into account the size of each country and its tendency to collaborate internationally. This indicator was first introduced by Luukkonen, Persson & Sivertsen (1992) and has been further developed by Rousseau (2021).

Table 1 presents the results of an analysis of Arctic research based on the publication set for 2016–2022, illustrated as a heat map. Only Arctic Council members and Arctic Council observers have been selected. As shown, there are strong collaborative links between the USA and Canada, and naturally between Denmark, Greenland, and the Faroe Islands. Additionally, there is significant intra-Nordic collaboration. These patterns reflect linguistic and cultural proximity as well as geographical closeness. With some exceptions, there tends to be low collaborative intensity between countries from different continents, which can be explained by inverse factors. It is, however, important to note that the map reflects relative rather than absolute collaboration intensity. As an example, Iceland has very strong collaborative links with Sweden, but the USA is still the largest collaborative partner.

Table 1. Heat map matrix showing country-to-country relative collaboration intensity. Arctic Council members and Arctic Council observers, 2016–2022.*



*) Legends: Dark blue: Very strong collaborative links (95-100 percentile). Green: Strong collaborative links (75-95 percentile). Orange: Intermediate links (25-75 percentile). Light red: Weak collaborative links (1-25 percentile). White: No collaborative links.

For the Arctic nations, we also analysed their cross-national collaborations over time, counting only their bilateral and trilateral collaborative articles. Figure 19 shows the results. The United States and Canada have by far the largest number of joint Arctic articles with an average of 200 to 250 per year. Russia, Norway, and Iceland have the highest number of collaborative articles with the United States, while Norway holds a similar position to Sweden and Denmark.

The annual figures show some fluctuations and for most country pairs there are no clear trends. However, there is a marked decrease in joint articles between the USA and Russia and between Norway and Russia in 2022. Although we do not have complete data for 2022, the preliminary results indicate a large reduction in the volume of collaborative research activities. This decrease is likely due to the sanctions imposed on Russia, which also encompass scientific collaboration (Nazarovets & da Silva, 2022). We do not observe a similar trend for the other countries. However, it should be noted that the research underlying the 2022 articles was conducted mostly before the Russian invasion (due to publication lag). As a result, it is probable that we will see a much more significant decline in collaborative research activities with Russia among all the other Arctic nations in the coming year.

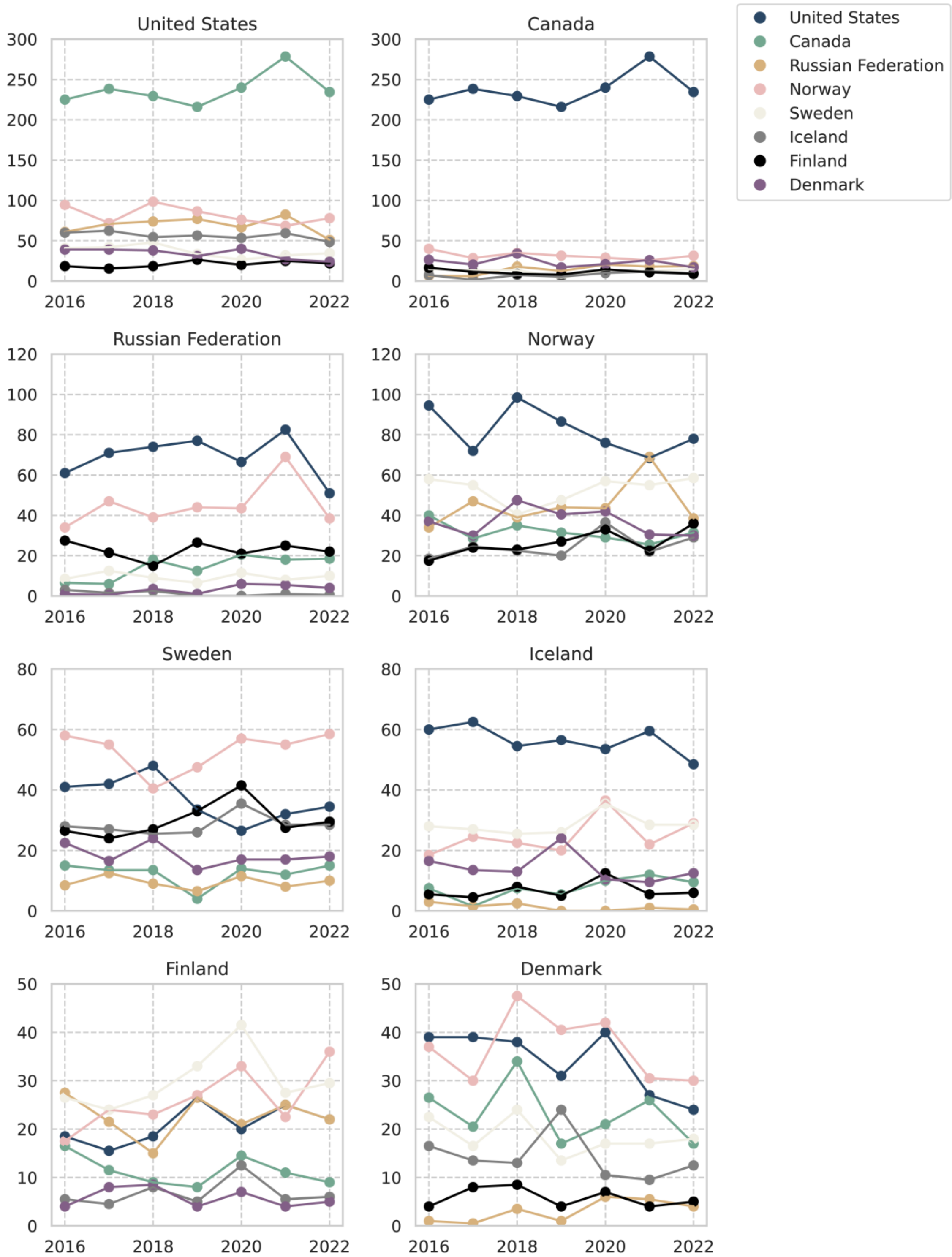


Figure 19. Cross-country collaboration among Arctic nations, 2016–2022. Number of bilateral and trilateral collaborative articles.*

*) The figures for 2022 were still incomplete at the time of analysis.

3.8 Cross-institutional collaboration

Instead of focusing on countries as the unit of analysis, we provide an overview of the 'top' institutions, their collaborative patterns, and citation impact in this section. Some of the analyses below have also been made available in an interactive format on the Thematic Networks and Institutes web page of UArctic*. Here further details are presented, and users can zoom in and out and click on specific locations for more information.

We define 'top' institutions in two different ways and provide separate overviews for these two definitions. Firstly, we identify institutions based on the estimated *intensity* of Arctic research, i.e., the share of an institution's total output in Scopus for the years 2016 to 2022 that are considered Arctic-related. Given at least 10 Arctic-related publications per year (on average) and stipulating a minimum of 5% Arctic intensity, a total of 140 institutions meet these thresholds. The distribution of intensity estimates over institutions is highly skewed and ranges from more than 90% for the Alaska Native healthcare organisation *Southcentral Foundation* (SCF) down to 5% for *I.M. Gubkin Russian State University of Oil and Gas*.

Secondly, we also define 'top' institutions based on the total number of Arctic-related publication fractions from 2016 to 2022. Choosing the top 140 institutions based on this criterion corresponds to a threshold of roughly 100 publication fractions. The publication output for the institutions in this second selection is highly variable, ranging from more than a thousand publication fractions for institutions like the *Russian Academy of Sciences*, the *University of Iceland*, the *University of Tromsø – The Arctic University of Norway*, and the *University of Alaska Fairbanks*, to institutions with publication fractions close to the threshold like, e.g., *NASA Goddard Space Flight Center, Norwegian Institute for Water Research* and *Greenland Institute of Natural Resources*.

We now invite the reader to interactively explore the collaborative patterns online, where maps are provided for the selection of institutions based on Arctic intensity and raw publication volume. Each node in these maps corresponds to an institution whose size is proportional to its publication volume. For each pair of nodes, the number of co-authored publications was calculated (the number of publications with at least one author from the respective institution). To take the large variation in publication volume into consideration, these numbers were normalised with (enhanced) association strength (Steijn, 2021). Clustering and layout were done by modularity optimisation and force-based layout, respectively (Noack, 2009), and VOSviewer was utilised for visualisation (van Eck & Waltman, 2011). Further, information on the number of publications (and fractions), normalised citation impact, and Arctic intensity is provided for each of the 140 largest institutions, and is available in the Appendix.

While studying this data interactively by following the links above is preferable, an overview of the main patterns is now presented. First, for the

* www.uarctic.org/activities/thematic-networks/research-analytics-and-bibliometics/institutional-collaboration-2016-2022/

set of institutions selected based on pure size (number of publication fractions), Figure 20 and Table 2 show a collaborative pattern and grouping of institutions that largely follow geographical location and linguistic areas. Cluster 1 (red, to the left in Figure 20) comprises institutions from the USA. This is the largest cluster concerning the number of institutions. However, cluster 3 (blue, lower part in Figure 20), which encompasses the Nordic countries (except Norway) is the largest cluster with respect to fractionalised publication output. Institutions from Norway are instead the bulk of cluster 5 (purple, lower-right in Figure 20). With respect to citation impact, the USA-oriented cluster and cluster 2, which have institutions from several countries but mainly from the United Kingdom and Germany (yellow, left in Figure 20), have the highest citation impact. Except for cluster 6 (cyan, to the right in Figure 20), which is made up of Russian institutions, the average citation impact for the publications produced by this selection of institutions has a normalised citation impact that is higher or matches the expectation.

Table 2. Summary information for the partition of institutions selected based on size.

Cluster	*Number of institutions*	*Publication fractions*	*Normalised* citation impact	Institutions primarily from
1	31	6474.3	1.30	USA
2	23	3431.8	1.33	GBR / DEU
3	22	6612.8	1.07	SWE/FIN/DNK/ISL
4	20	4520.8	1.08	CAN
5	20	4943.4	1.10	NOR
6	16	7258.9	0.64	RUS
7	8	1445.8	0.99	CHN
Total	***140***	***34687.8***	***1.05***	

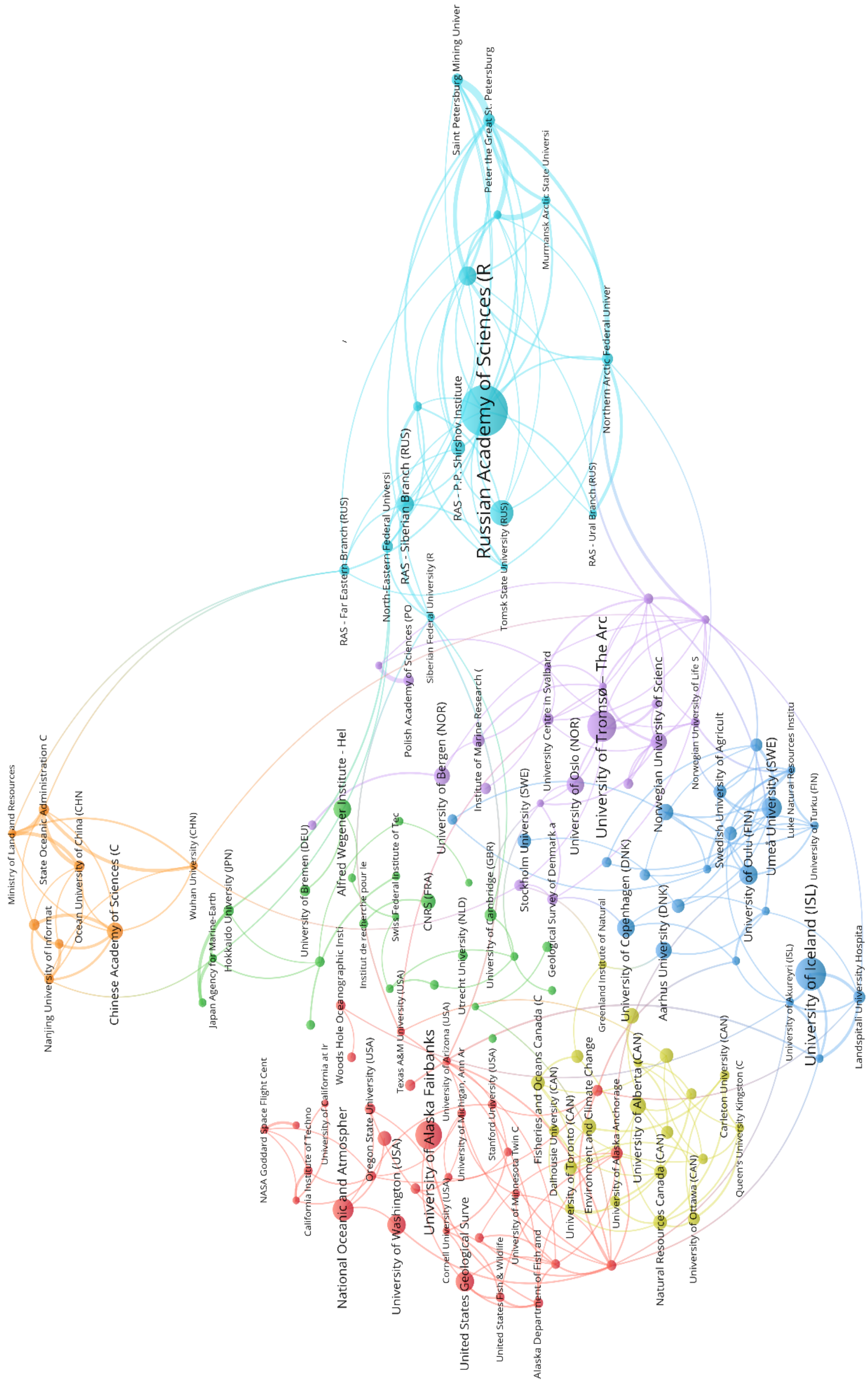


Figure 20. Top 140 institutions (based on size) and their groupings based on collaborative patterns. The interactive version is available here. The size of the nodes is proportional to publication output, colours indicate cluster, and the 300 strongest links are shown. The distance between nodes indicates similarity with respect to the (normalised) number of collaborative papers.

Table 3 and Figure 21 showcase the top 140 institutions based on Arctic intensity rather than pure publication volume. Again, one can observe a collaborative pattern and grouping of institutions that correlate with geographical location and linguistic areas. However, it is less pronounced within this selection of institutions, indicating that we are observing additional driving forces for collaboration, e.g., different orientations and focus regarding the research questions being addressed. Along the horizontal axis in Figure 21, Russian institutions are located to the right, separated from the three largest clusters located to the left that contain institutions from different countries. The underlying publications for the three largest clusters, 1, 2, and 3 (indicated with colours red, green, and blue, respectively), have a somewhat different distribution over the subject areas (see section 3.3). Specifically, when controlling for the size of the subject areas and the size of the institutions, cluster 1 has a higher-than-expected probability of containing publications from *Earth and Planetary Sciences*. In contrast, cluster 2 contains more publications from *Medicine* and *Social Sciences*. Publications from cluster 3, on the other hand, have a higher probability of stemming from *Environmental Science* and *Agricultural and Biological Sciences*. Publications in clusters 4 to 8, i.e., the clusters containing Russian institutions, have, in addition to a higher-than-expected probability of containing publications from *Earth and Planetary Sciences*, more publications stemming from the subject areas *Biochemistry*, *Energy,* and *Engineering*. While the Russian institutions tend to have a low average citation impact, the *Energy*-oriented cluster 7 with institutions such as *A.P. Karpinsky Russian Geological Research Institute*, *Gazprom,* and *Rosneft Oil* is an exception.

Table 3. Summary information for the partition of institutions selected based on Arctic intensity.

Cluster	*Number of Institutions*	*Publication fractions*	*Normalised citation impact*	*Institutions primarily from*
1	43	4515.7	1.30	NOR/USA/GBR/DEU
2	33	6291.4	1.01	ISL/NOR/FIN/SWE
3	26	3771.6	1.04	CAN/USA
4	14	925.9	0.52	RUS
5	8	395.2	0.93	RUS
6	7	917.2	0.64	RUS
7	5	445.6	1.10	RUS
8	4	251.1	0.46	RUS
Total	***140***	***17513.6***	***1.04***	

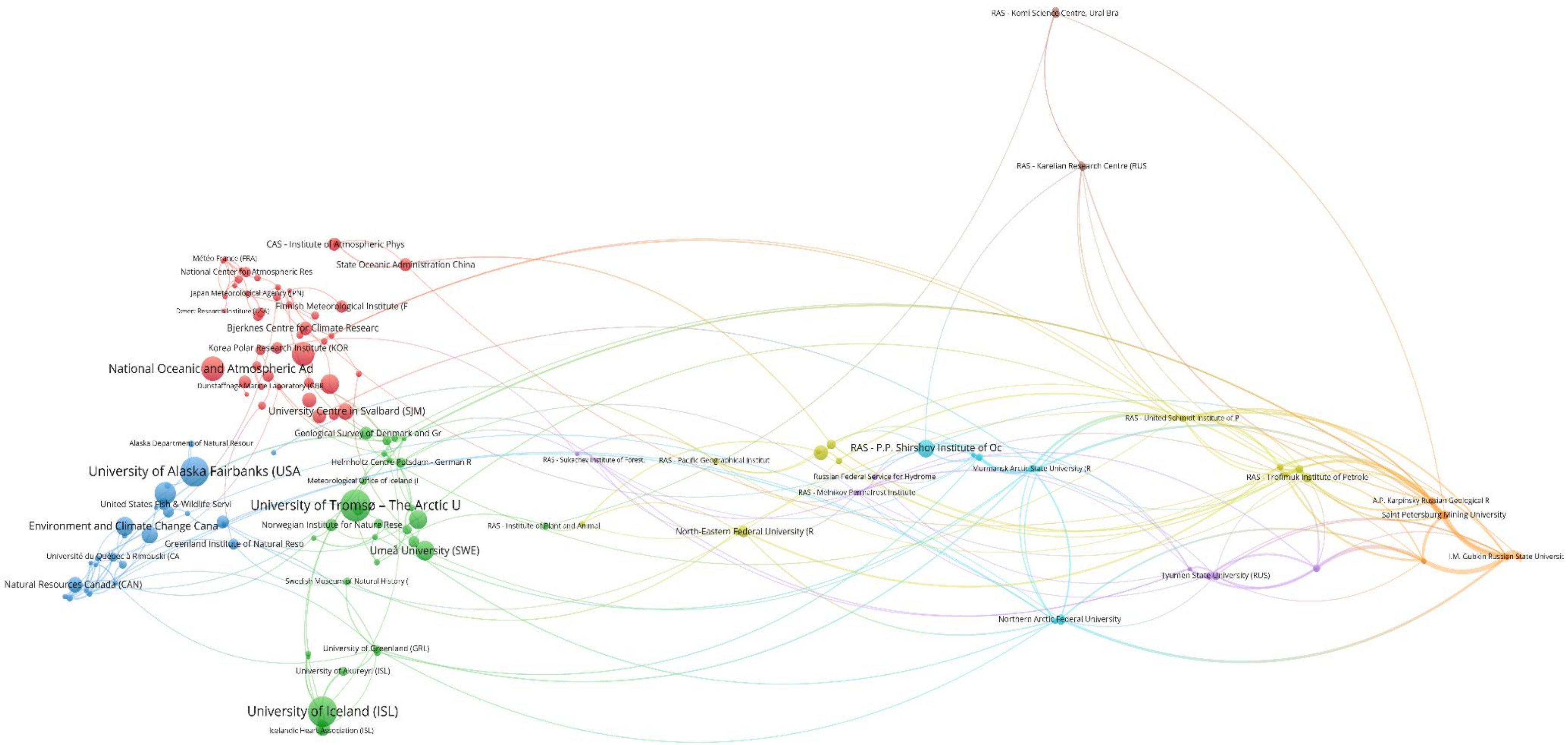


Figure 21. Top 140 institutions (based on Arctic intensity) and their groupings based on collaborative patterns. The interactive version is available here. The size of the nodes is proportional to publication output, colours indicate cluster, and the 300 strongest links are shown. The distance between nodes indicates similarity with respect to the (normalised) number of collaborative papers.

*Table 4. The intersection of institutions from the set with the most publication fractions and highest Arctic intensity, respectively.**

Norway	**Finland**
University of Tromsø – The Arctic University of Norway	University of Oulu
University of Bergen	Finnish Meteorological Institute
Norwegian Polar Institute	University of Lapland
Institute of Marine Research	Luke Natural Resources Institute Finland
Bjerknes Centre for Climate Research	**Island**
Norwegian Institute for Nature Research	University of Iceland
University Hospital of North Norway	Landspitali University Hospital
Norwegian Institute for Water Research	Reykjavík University
Nord University	University of Akureyri
Geological Survey of Norway	**Canada**
Russia	Environment and Climate Change Canada
RAS - P.P. Shirshov Institute of Oceanology	Fisheries and Oceans Canada
RAS - Far Eastern Branch	Natural Resources Canada
North-Eastern Federal University	**China**
Northern Arctic Federal University	CAS - Institute of Atmospheric Physics
Saint Petersburg Mining University	State Oceanic Administration China
Murmansk Arctic State University	**Germany**
Industrial University of Tyumen	Alfred Wegener Institute - Helmholtz Centre for Polar and Marine Research
Russian State Hydrometeorological University	Helmholtz Centre for Ocean Research Kiel
USA	**Denmark**
University of Alaska Fairbanks	Geological Survey of Denmark and Greenland
National Oceanic and Atmospheric Administration	**Greenland**
United States Geological Survey	Greenland Institute of Natural Resources
Woods Hole Oceanographic Institution	**Japan**
University of Alaska Anchorage	Japan Agency for Marine-Earth Science and Technology
Alaska Department of Fish and Game	**Korea**
United States Fish & Wildlife Service	Korea Polar Research Institute
	Poland
	Institute of Oceanology of the Polish Academy of Sciences
	Svalbard and Jan Mayen
	University Centre in Svalbard
	Sweden
	Umeå University

*) We refer the reader to the Appendix for the complete list of institutions and information on publication output, citation impact, and Arctic intensity.

Finally, note that there is a moderate overlap of institutions between the two selections. In total, 47 institutions meet both the required publication volume and Arctic intensity thresholds. As these institutions could be regarded as having a special position in the Arctic research landscape, they are listed in Table 4**,** where Norway has the most institutions of this kind (10), followed by Russia (8) and the USA (7). Additional 12 countries are represented with at least one institution.

4. Conclusions and main findings

In this report, we have analysed Arctic research by publication indicators using the databases Scopus and SciVal. The report builds upon and extends the previous similar report by UArctic Science & Research Analytics Taskforce. We have been able to identify several interesting patterns characterising Arctic research.

The growth identified previously for the period 1996–2015 has continued during the years 2016–2021. The volume of Arctic research measured by publication volume has increased by 22% during the period. While Arctic research continues to increase, the growth rate is not greater than the global average across all fields. As of 2022, the United States remains the largest contributor to Arctic research in terms of publication output, followed by Russia, Canada, China, and Norway. China is the largest contributor among non-Arctic states and has shown the highest relative growth, moving from the 8th to the 4th largest country. Russian publication volume has increased significantly as well, but there is a sudden drop in 2022. Taking a long-term view, the most notable change is the growing role of China and Russia as large contributors to Arctic research.

The analysis reveals that the largest subject area in Arctic research is Earth and planetary sciences, which encompasses disciplines such as geophysics, oceanography, geology, as well as studies of the cryosphere. Research is conducted in various other disciplines as well, where biology is the second largest.

On the whole, Arctic research publications have received slightly more citations than the average for all Scopus publications, indicating a reasonably high scientific impact overall. However, there are large differences in citation impact across countries. Of the largest nations, the United Kingdom has the highest scientific impact as measured by citations.

Arctic research is characterised by a high degree of international cooperation. This is reflected in the proportion of the publications having co-authors from different countries. In 2022, over 36 per cent of Arctic publications involved international co-authorship, compared to the Scopus average of 22 per cent for all fields. However, there are notable variations in the extent of international co-authorship across countries. In several countries, the large majority of Arctic scientific publications are produced through international collaborations. Russia is an exception as only 11% of its publications involve collaboration with foreign institutions.

The report contains indicators on two sets of institutions selected based on pure size and Arctic intensity, respectively. For the first set, there is a correlation between geographical location and linguistic areas in terms of collaboration and grouping of institutions. For the second set, the collaboration pattern and grouping of institutions are less pronounced and indicate additional driving forces for collaboration.

This report presents an analysis of some of the overarching trends in Arctic research. There are various aspects of Arctic research that can be examined through bibliometric analysis, wherein the present study focuses on only a few. For instance, detailed analyses of research topics, institutional patterns, and collaboration among individual countries and institutions could be conducted as part of a broader monitoring program for Arctic research.

We hope that this report sparks further discussions and generates ideas for expanding future analyses. We believe that it is worthwhile to continue to apply and utilise the sources of data that inform our understanding of Arctic research. We recognise the significance of documenting this research for the future.

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Appendix – figures for individual institutions

The table below (A.1) shows selected indicators for the 140 institutions with the largest Arctic publication output (measured by publication fractions) during the period 2016-2022. Please note that when it comes to institutional data, figures may be subject to limitations based on the method used for identifying Arctic research. For the institutions selected by Arctic intensity, a similar table is available on the Thematic Networks and Institutes web page of UArctic*.

Table A.1. Number of Arctic publications per institution, number of publication fractions, field-weighted citation impact (FWCI) and Arctic intensity (the share of an institution's total output in Scopus that is considered Arctic-related) 2016-2022.

Cluster	Institution	No publications	No publication fractions	FWCI	Arctic intensity
6	Russian Academy of Sciences (RUS)	6645	3452.0	0.53	3.7%
3	University of Iceland (ISL)	2812	1416.1	0.97	32.6%
5	University of Tromsø – The Arctic University of Norway (NOR)	2956	1320.7	0.97	22.1%
1	University of Alaska Fairbanks (USA)	2649	1057.3	1.06	49.2%
6	Lomonosov Moscow State University (RUS)	1709	863.1	0.48	3.0%
1	National Oceanic and Atmospheric Administration (USA)	1745	658.2	1.32	10.5%
3	Umeå University (SWE)	1174	650.7	1.08	6.7%
1	University of Washington (USA)	1491	553.6	1.45	1.7%
1	United States Geological Survey (USA)	1456	529.5	1.11	7.9%
3	University of Oulu (FIN)	1095	514.6	0.95	6.2%
3	University of Copenhagen (DNK)	1470	506.0	1.16	1.9%
5	University of Oslo (NOR)	1432	505.7	1.15	3.0%
6	St. Petersburg State University (RUS)	1008	487.2	0.70	3.3%
2	Alfred Wegener Institute - Helmholtz Centre for Polar and Marine Research (DEU)	1665	473.5	1.53	29.6%
6	RAS - Siberian Branch (RUS)	1517	440.7	0.53	3.8%
7	Chinese Academy of Sciences (CHN)	1713	421.0	1.25	0.4%
3	Aarhus University (DNK)	1377	413.6	1.16	2.8%
5	Norwegian University of Science and Technology (NOR)	988	409.3	1.07	2.5%
5	University of Bergen (NOR)	1199	394.6	1.20	5.1%
4	University of Alberta (CAN)	976	387.5	1.09	1.7%
3	University of Helsinki (FIN)	1004	356.0	1.16	2.1%
4	Université Laval (CAN)	973	348.6	1.06	3.6%
2	CNRS (FRA)	2350	342.9	1.33	0.5%
4	Environment and Climate Change Canada (CAN)	1070	335.6	1.27	18.6%
6	RAS - P.P. Shirshov Institute of Oceanology (RUS)	909	334.1	0.56	28.9%
3	Stockholm University (SWE)	999	313.0	1.37	3.1%

* www.uarctic.org/activities/thematic-networks/research-analytics-and-bibliometics/institutional-collaboration-2016-2022/

4	Memorial University of Newfoundland (CAN)	593	299.8	1.14	4.6%
1	University of Colorado Boulder (USA)	1043	289.7	1.47	2.8%
4	Natural Resources Canada (CAN)	716	289.7	1.10	11.9%
4	Fisheries and Oceans Canada (CAN)	836	282.6	1.08	20.4%
4	University of British Columbia (CAN)	706	275.5	1.14	0.9%
4	University of Toronto (CAN)	674	269.7	1.39	0.5%
3	Swedish University of Agricultural Sciences (SWE)	660	263.2	1.20	4.7%
3	University of Lapland (FIN)	419	256.4	1.04	31.4%
3	Uppsala University (SWE)	686	248.8	1.09	1.5%
4	McGill University (CAN)	613	245.3	1.00	1.0%
4	University of Manitoba (CAN)	683	244.8	0.98	2.9%
6	Peter the Great St. Petersburg Polytechnic University (RUS)	356	244.2	1.92	2.3%
1	University of Alaska Anchorage (USA)	513	233.8	0.74	31.0%
2	University of Cambridge (GBR)	677	230.2	1.19	0.8%
5	Institute of Marine Research (NOR)	610	226.5	1.34	23.5%
3	Landspitali University Hospital (ISL)	673	220.7	1.01	32.6%
3	Luleå University of Technology (SWE)	356	219.5	0.74	4.2%
4	University of Ottawa (CAN)	498	218.2	1.01	1.2%
6	Northern Arctic Federal University (RUS)	337	217.6	0.47	20.0%
5	University Centre in Svalbard (SJM)	777	208.4	1.19	70.9%
6	North-Eastern Federal University (RUS)	416	200.8	0.52	13.6%
6	Saint Petersburg Mining University (RUS)	247	199.6	1.60	5.5%
7	State Oceanic Administration China (CHN)	495	188.8	0.68	6.0%
3	Lund University (SWE)	567	186.7	1.08	1.3%
5	Geological Survey of Denmark and Greenland (DNK)	528	185.7	1.04	38.7%
1	Oregon State University (USA)	547	184.3	1.16	2.4%
4	University of Calgary (CAN)	443	184.2	0.86	1.0%
5	Technical University of Denmark (DNK)	502	181.1	1.18	1.5%
4	University of Saskatchewan (CAN)	450	180.7	0.98	2.1%
2	University of Bremen (DEU)	619	173.6	1.24	4.0%
6	RAS - Far Eastern Branch (RUS)	669	172.7	0.45	8.4%
7	Ocean University of China (CHN)	341	171.2	0.74	1.5%
5	Polish Academy of Sciences (POL)	633	170.4	0.96	1.3%
5	Norwegian Polar Institute (NOR)	682	170.2	1.45	70.1%
2	Hokkaido University (JPN)	454	169.8	0.88	1.4%
1	Columbia University (USA)	654	168.1	1.59	0.8%
1	Harvard University (USA)	571	165.8	1.65	0.3%
7	University of Chinese Academy of Sciences (CHN)	683	165.1	1.06	0.4%
4	Dalhousie University (CAN)	434	164.4	1.07	1.9%
1	Centers for Disease Control and Prevention (USA)	287	162.9	2.21	1.3%
1	Woods Hole Oceanographic Institution (USA)	519	160.0	1.52	11.3%
7	Nanjing University of Information Science & Technology (CHN)	432	156.6	0.97	2.0%
2	Korea Polar Research Institute (KOR)	430	156.4	0.67	23.9%
4	University of Waterloo (CAN)	355	155.7	0.94	1.0%
4	University of Victoria BC (CAN)	390	155.6	1.05	2.6%
1	Alaska Department of Fish and Game (USA)	406	153.0	0.78	73.0%
3	University of Gothenburg (SWE)	528	152.5	1.21	1.6%
5	Nord University (NOR)	290	149.7	1.16	9.7%
1	University of Wisconsin-Madison (USA)	396	146.1	1.18	0.6%
2	University of Oxford (GBR)	454	144.3	1.53	0.4%
3	Finnish Meteorological Institute (FIN)	456	143.7	1.41	16.8%
4	Carleton University (CAN)	393	143.3	1.14	2.5%
5	Norwegian Institute for Nature Research (NOR)	459	142.6	1.17	24.9%

2	Utrecht University (NLD)	567	142.0	1.69	1.0%
1	Stanford University (USA)	381	136.9	1.44	0.4%
5	Bjerknes Centre for Climate Research (NOR)	560	134.4	1.72	36.9%
5	University Hospital of North Norway (NOR)	389	134.1	1.02	16.0%
4	Queen's University Kingston (CAN)	305	133.4	1.02	1.4%
1	University of California at San Diego (USA)	416	133.3	1.70	0.6%
1	University of Michigan, Ann Arbor (USA)	375	131.3	1.28	0.4%
7	CAS - Institute of Atmospheric Physics (CHN)	531	130.4	1.39	7.5%
1	United States Fish & Wildlife Service (USA)	389	129.3	0.81	23.0%
1	Colorado State University (USA)	424	125.5	1.18	1.6%
2	Institut de recherche pour le développement (BFA)	1249	123.1	1.62	2.5%
2	University of Leeds (GBR)	435	121.0	1.42	1.1%
1	United States Department of Agriculture (USA)	330	120.7	0.95	0.7%
5	Norwegian University of Life Sciences (NOR)	332	120.6	1.06	4.7%
6	Murmansk Arctic State University (RUS)	181	119.6	0.59	49.5%
1	California Institute of Technology (USA)	545	119.5	1.67	1.7%
6	Industrial University of Tyumen (RUS)	180	119.5	1.16	5.7%
1	University of California at Los Angeles (USA)	385	118.8	1.42	0.4%
2	German Aerospace Center (DEU)	299	117.8	1.34	1.7%
2	Swiss Federal Institute of Technology Zurich (CHE)	439	114.7	1.60	0.7%
5	University of Stavanger (NOR)	198	114.0	0.67	2.5%
2	National Research Council of Italy (ITA)	395	113.4	0.96	0.5%
2	University of Edinburgh (GBR)	407	112.8	1.40	0.7%
7	Wuhan University (CHN)	225	112.8	0.75	0.3%
3	Reykjavík University (ISL)	245	112.3	0.98	11.0%
6	RAS - Ural Branch (RUS)	360	112.3	0.45	4.3%
3	Luke Natural Resources Institute Finland (FIN)	283	111.3	0.91	7.4%
2	Durham University (GBR)	317	110.3	1.37	1.5%
3	University of Eastern Finland (FIN)	307	108.9	1.14	2.1%
1	Texas A&M University (USA)	275	108.3	1.15	0.4%
1	University of Arizona (USA)	289	107.8	1.21	0.7%
2	University College London (GBR)	375	107.1	1.59	0.3%
4	University of Montreal (CAN)	303	106.7	0.90	0.6%
3	University of Southern Denmark (DNK)	324	106.5	0.92	1.2%
3	University of Turku (FIN)	282	106.1	0.94	1.4%
3	University of Akureyri (ISL)	229	105.8	1.08	50.8%
2	Japan Agency for Marine-Earth Science and Technology (JPN)	363	104.4	0.93	6.9%
1	University of Minnesota Twin Cities (USA)	318	103.8	1.25	0.4%
1	Pennsylvania State University (USA)	267	103.4	1.16	0.4%
6	Siberian Federal University (RUS)	195	103.3	0.92	2.6%
1	NASA Goddard Space Flight Center (USA)	449	103.0	1.76	3.2%
1	University of California at Davis (USA)	301	102.4	1.15	0.5%
3	Aalborg University (DNK)	204	100.4	0.90	0.7%
7	Ministry of Land and Resources P.R.C. (CHN)	278	99.9	0.56	2.0%
4	Greenland Institute of Natural Resources (GRL)	385	99.4	1.05	78.4%
2	Helmholtz Centre for Ocean Research Kiel (DEU)	389	98.9	1.35	10.2%
6	Russian State Hydrometeorological University (RUS)	179	98.8	1.52	24.9%
2	The University of Tokyo (JPN)	319	98.5	0.98	0.4%
2	University of Bristol (GBR)	363	97.7	1.37	0.9%
2	University of Exeter (GBR)	301	95.8	1.60	1.1%
5	SINTEF (NOR)	202	95.3	1.08	2.6%

5	Norwegian Institute for Water Research (NOR)	381	95.0	1.17	25.3%
5	Institute of Oceanology of the Polish Academy of Sciences (POL)	331	93.8	1.02	40.6%
2	University of Southampton (GBR)	402	93.4	1.44	1.0%
6	Tomsk State University (RUS)	316	93.4	0.78	2.2%
1	University of Maryland, College Park (USA)	333	92.9	1.64	0.7%
1	University of California at Irvine (USA)	308	92.0	1.80	0.8%
1	Jet Propulsion Laboratory, California Institute of Technology (USA)	475	92.0	1.73	3.3%
1	Cornell University (USA)	246	91.4	1.78	0.3%
5	Geological Survey of Norway (NOR)	253	91.1	1.00	30.8%
2	CSIC (ESP)	516	90.3	1.33	0.5%

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