ICE-ARC

ICE • CLIMATE • ECONOMICS

Ice, Climate, Economics - Arctic Research on Change

Directly assessing the social and economic impact of Arctic sea-ice loss

Highlights 2014 – 2017

SEVENTH FRAMEWORK PROGRAMME

www.ice-arc.eu

Insights from the Arctic on global change

Nowhere on Earth are the effects of climate change more apparent than in the Arctic. Temperatures are rising at more than double the global average rate, causing rapid loss of sea ice along with shifts in atmospheric and oceanic conditions.

These changes are setting off complex chain reactions with far-reaching environmental, social, and economic impacts extending beyond the region. The Arctic is being affected by climate change, but the consequences are global.

Understanding these changes, and predicting and anticipating their effects is a formidable task. It requires the coordinated efforts of a broad range of expertise, as well as the involvement of indigenous and local communities.

The ICE-ARC project is a €12 million EU funded programme uniting researchers and scientists from 24 institutions across 12 countries. ICE-ARC has spent four years rising to this challenge. Chemists, physicists, biologists, and engineers have worked alongside economists, social scientists, and the indigenous population to provide a holistic understanding of the impact of Arctic change, and to quantify the global economic and societal costs of responding to it – or failing to respond.

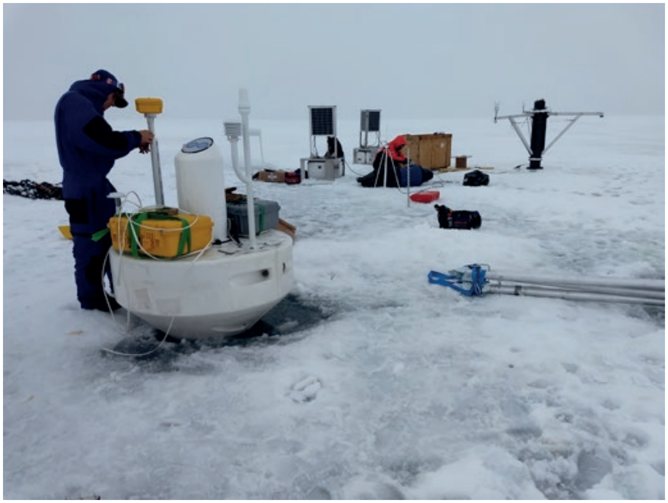
Integrating Arctic research: from observations to models

Understanding the full extent of changes underway in the Arctic requires a great volume of highly diverse information. ICE-ARC is responding to this need with a multidisciplinary research program that blends together technology, observations, and models.

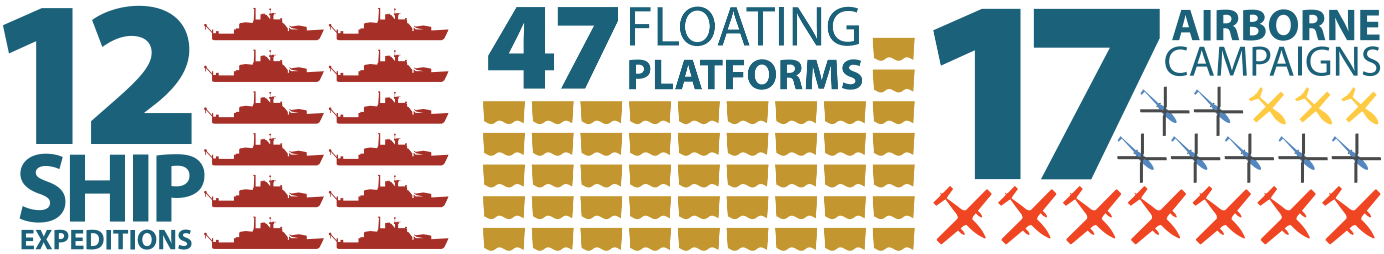
ICE-ARC engineers have developed innovative sensors that advance polar technologies and propel polar research into the future.

ICE-ARC researchers have deployed nearly 50 robotic platforms from numerous expeditions across the Arctic Ocean. We have collected data that encompass the marine environment; from cloud thickness, solar radiation and air temperature through to sea-ice thickness, ocean salinity, zooplankton species and abundance, and beyond.

ICE-ARC collected data from satellite and airborne sensors as well as systems deployed on the ice, on the sea surface, and underwater. These together improve our understanding about the workings of the changing Arctic system.



Remoteness and extreme weather conditions represent significant challenges for carrying out research in the Arctic; hence, datasets are sparse. Partnerships with local communities, as well as advanced autonomous technology and techniques make year-round real-time monitoring and data capture a reality.



Improvements to climate projections

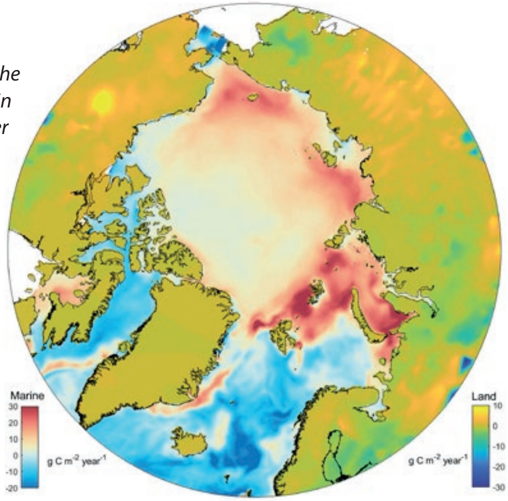
Global climate models are the best tools available to predict the future climate of our planet, a product of a complex series of interactions and feedbacks between the atmosphere, ocean, ice, and land.

ICE-ARC uses regional oceanic and atmospheric model systems to improve our understanding of these interactions. We do this by examining the underlying uncertainties in climate model predictions. Improved understanding leads to refined mathematical algorithms within global climate models which, in turn, contribute to improved climate predictions.

Based on observations, ICE-ARC has improved the model representation of sea-ice thickness. This reduces the uncertainty associated with predictions of how ice conditions will vary throughout this century. We have also identified several sources of uncertainties related to atmospheric forcing, which is important for improved weather prediction in the Arctic.

We investigated the effects of increased Arctic shipping which is expected to rise with the decreasing sea-ice trend. Increases in atmospheric pollutant emissions have potential impacts on biochemical cycles in the Arctic.

This figure shows the projected change in carbon uptake over land and sea from present climate over the next 90 years, based on the IPCC scenario RCP2.6.



Whilst the Arctic will have more light available for harvestable production as ice cover decreases, strong stratification and low levels of mixing will lead to a nutrient-limited primary production.

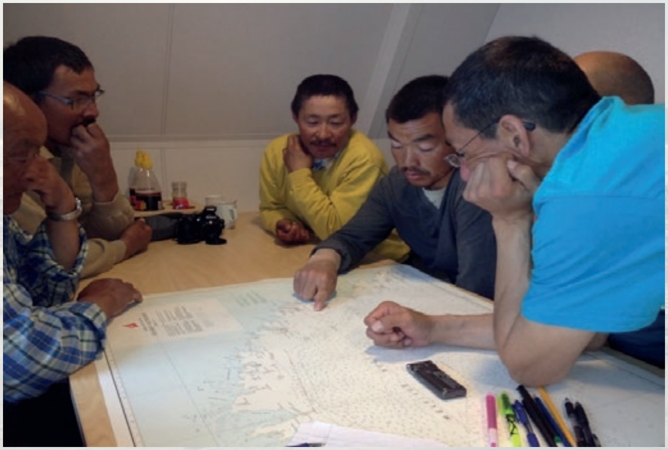
Climate change impacts both terrestrial and marine ecosystems, but the drivers are different. Available light and nutrients control primary productivity in the ocean. However, on land, increasing CO_2 is the current main driver for changes in productivity, whereas changes in air temperature are the dominant driver for changes in growing season length.

Outputs from climate models feed into PAGE-ICE, the project's advanced decision-making tool. This integrates climate predictions, in line with the Paris Agreement, with socio-economic consequences to assess the full impact of a changing Arctic under a range of global emissions and socio-economic scenarios.

Co-production of knowledge with local and indigenous communities

ICE-ARC works with the indigenous people of Northwest Greenland to identify trends and to appreciate the impact Arctic climate change is already having on the region, especially within a context of socio-economic transition. Nobody better understands, or is more sensitive to, changes in the Arctic than the people who live there. We all benefit greatly from this close collaboration.

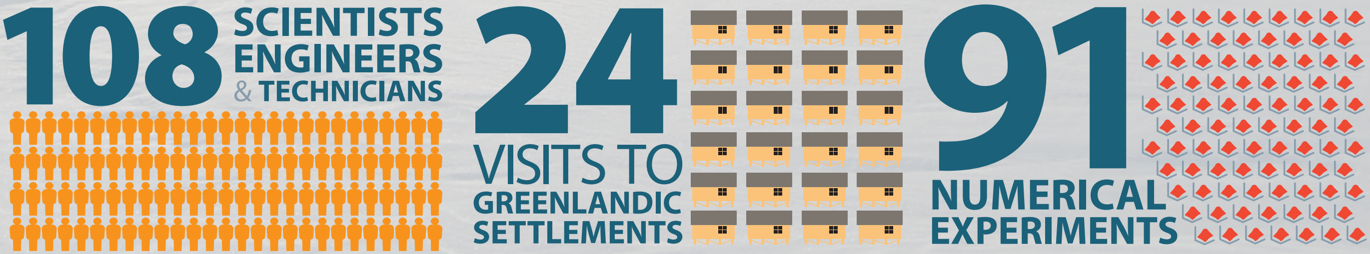
Inuit communities report that reductions in sea-ice levels are affecting seasonal hunting practices and mobility, with fewer months of the year bringing ice that can be safely used for hunting and fishing by dog sledge. Life at the ice-edge and travelling long distances across unpredictable frozen surfaces now carries more risk.



But these changes are also bringing opportunities. In Qaanaaq, on Greenland's Northwest coast, reduced sea-ice thickness has enabled the establishment of a halibut fishery and has led to a new source of income.

ICE-ARC has been studying how Inuit have responded to change in the past, and exploring how they might anticipate and adapt to both climatic and socio-economic shifts in the future. Marine sediment cores, obtained by ICE-ARC, enable us to understand better how past environmental and climatic shifts influenced the movement of people in northwest Greenland.

Hunters in Qaanaaq are working directly with scientists to measure sea-ice thickness in the region by installing instruments on their sleds. The ongoing dialogue between the project team and the local population of Northwest Greenland emphasizes a community-based approach to research and greatly enriches the project.



Selected highlights

To achieve a broad insight into ice, ocean, atmospheric and ecosystem processes, ICE-ARC partners worked from icebreakers, aircraft, helicopters, military vessels, Coast Guard ships, on-ice tractor trains, sailing vessels, drones, and with local hunters and their dog teams. This tremendous spread of logistical support can only be realised through the spirit of international collaboration and trust, which runs deep within polar science.

Observational data improve climate models, and are being used to inform the economic models. The results have, and will continue to be, published in numerous peer-reviewed journals.

- Acceleration of climate change driven by thawing Arctic permafrost and melting sea ice could cause up to $130 trillion worth of extra economic losses globally under current business-as-usual trajectory over the next three centuries. If global warming is limited to 1.5°C, the additional cost will be reduced to under $10 trillion.
- Detailed analysis of historical records, prior to the satellite era, reveal that the last decade stands out as the period with the most reduced sea ice over the past 150 years for North-West Greenland.
- Inuit observations of sea ice in north-west Greenland indicate that it tends to form later and break up earlier than local inhabitants have known during their lifetimes. The period of travel by dog sledge on good, solid sea ice is now only around 3 months.
- We have seen that wide-ranging human movement in and around Northwest Greenland occurs around the same periods as changes in the marine ecosystem, as revealed by marine sediment cores spanning the last 4000 years.

Sea-ice remains: *If we reduce our CO_2 emissions in line with the Paris Agreement (RCP2.6) summer sea-ice will remain in the Arctic. Climate model output for the years 2070-2099 show regions with more than 15% sea-ice cover. Icons represent the location of observational activities performed within ICE-ARC.*

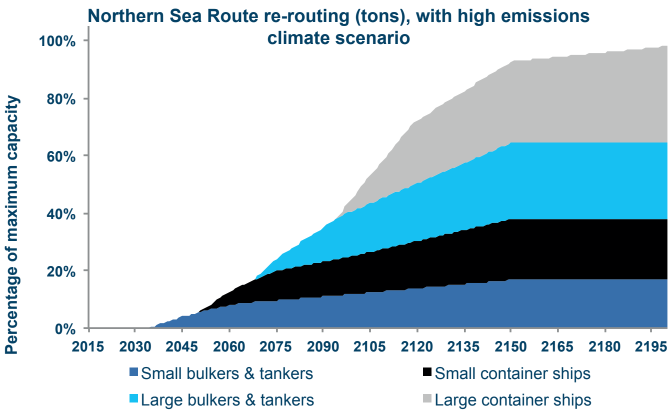
- New observations show that some snow, sea ice, and cloud processes are not accurately accounted for in current climate models. These processes could enhance melt rates, and are potentially significant to climate change.
- A new algorithm has been developed from satellite measurements of the temperature of the sea-ice surface. These calculations are important for improving the accuracy of sea-ice models.
- Coupled climate model simulations indicate that changes in Arctic winds, on decadal timescales, drive a large part of the variability of fresh water in the Arctic Ocean.
- Sea-ice measurements north of Greenland reveal a continued thinning, especially in thick deformed sea ice, as seen in a data set from aircraft over the last 20 years.
- Future Arctic shipping will likely lead to increases in atmospheric pollutant concentrations and the deposition of pollutants to marine ecosystems, in particular as a result of shipping diverted into the Arctic from southerly routes.
- Increased acidification, due to the decay of plant and animal material from the land, was more than five times stronger in ocean areas dominated by coastal erosion (which is enhanced by climate change), than areas dominated by river input.
- High acidity levels have been measured in the East Siberian Sea region, already far exceeding projected levels for the year 2100 for the Arctic Ocean. Ocean acidification affects marine ecosystems and is considered a direct effect of anthropogenic CO_2 uptake from the atmosphere.
- Shipping is anticipated to increase in the Arctic as a result of reduced sea-ice cover and projected favourable economic gains. Current predictions for the resulting changes in climate forcing agents suggest that this will cause net warming globally. The corresponding climate cost could be up to \$2 trillion over the next two centuries, with the biggest losses occurring in Africa and India.

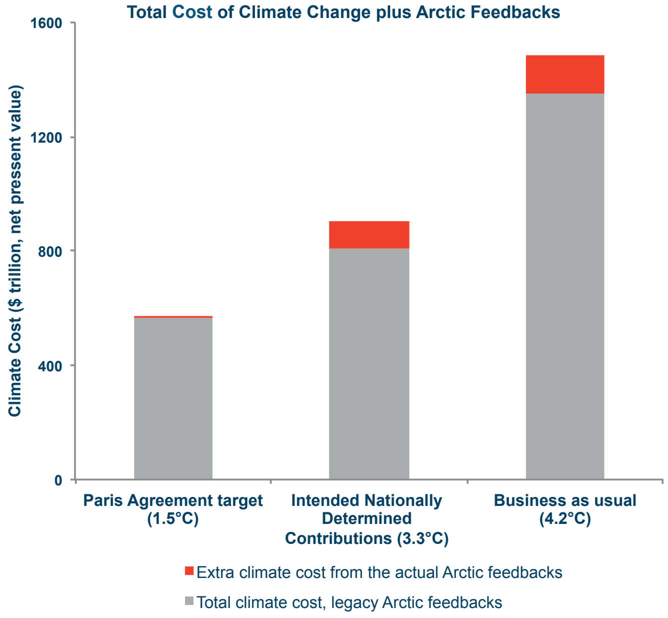
Sea-ice disappears: *If we continue to produce CO_2 as we are today, business as usual (RCP8.5), then summer sea-ice will disappear from the Arctic in September. Climate model output for the years 2070-2099 show regions with more than 15% sea-ice cover, i.e. none.*

Calculating the cost of Arctic change

To assess the global cost of Arctic change, ICE-ARC has combined the latest sea ice and permafrost simulations from state-of-the-art climate models with current environmental and socio-economic information to produce a more accurate integrated assessment model: PAGE-ICE.

Arctic feedbacks associated with the decline in sea ice and land permafrost will accelerate climate change and could jeopardise mitigation efforts. Running PAGE-ICE under a wide range of climate scenarios, including those from the Paris Agreement, revealed how these feedbacks affect the global economy over the next 300 years. The cost of net additional warming from Arctic feedbacks is significant. If climate targets are to be met, adequate financing is needed, for example a carbon tax that covers the additional cost associated with Arctic change, which has been calculated by PAGE-ICE.





The additional warming from the two Arctic feedbacks will increase the cost of climate change. This is illustrated by the red bars in the figure above, which are added to the grey bars representing previous climate change cost estimates. The effect is greatest if we carry on as usual (right), but is much reduced if we achieve the Paris Agreement target of 1.5°C (left).

ICE-ARC also developed a specialised tool for predicting trade volumes along the Northern Sea Route and estimating the resulting economic gains and changes in emissions (figure left). We used simulations from climate models and crop models to investigate correlations between the loss of Arctic sea ice and an increase in global food security risk.

Arctic knowledge without limits

ICE-ARC proactively captured data, worked with local communities, science community, industry, society, and with Arctic policy makers, to address the urgent issue of generating new knowledge and understanding of past, present, and future change. This has been achieved by disseminating the latest findings to Arctic communities through dedicated meetings and workshops, to the science community through high impact scientific papers and educational programmes, to industry through dedicated round-tables, to the public through wide-reaching outreach events including school visits, and to high-end policy makers through high-level sessions and discussions. These are some highlights:

Scientific community

In addition to publishing scientific papers, participating at international workshops and at project meetings, ICE-ARC members have presented their research at major scientific conferences.

Local communities

ICE-ARC has worked directly with Greenlandic communities, for example here discussing sea floor maps from an ICE-ARC cruise with Toku Oshima, a local fisher and hunter.

Policy makers

United Nations Framework Convention on Climate Change (UNFCCC) annual Conference of Parties (COP)

ICE-ARC co-organised a series of Arctic-oriented events at these COP meetings to provide high-level decision-makers with a holistic overview of Arctic change and its multi-sector impacts.

Speakers included: Manuel Pulgar-Vidal (President of COP20), Petteri Taalas (WMO Secretary General), Inia Seruiratu (Fiji's Climate Champion for COP23), Aqqaluk Lynge (former President Inuit Circumpolar Council).

World Economic Forum (WEF)

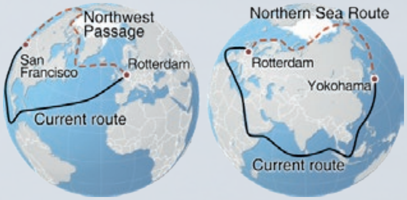
The Arctic Base Camp Davos, a unique event held during the WEF's annual meeting in 2017, brought together civil society leaders, politicians, scientists and policy makers, to discuss the types of advanced information on Arctic change that are needed for effective decision-making. Keynote speakers included Al Gore and Christiana Figueres. @ArcticDavos #ArcticMatters.

General public

In addition to specific stakeholder groups above, our results are available through blogs and news stories on *www.ice-arc.eu*, through social media @*ICEARCEU* and *www.facebook.com/iceclimateeconomics/*, and several science festivals.

Industry

ICE-ARC has held a number of industry-driven round-table discussions which brought together the EC, governmental policymakers, NGOs, academia, and industry representatives.



Challenges and lessons learned

The Arctic environment is changing at an unprecedented rate. The ICE-ARC project has led to a much-improved understanding of the effects and long-term implications of Arctic change, but it has also made clear the scale of the challenges facing our planet.

Even if we are successful in meeting the Paris Agreement's target of limiting global temperature rises this century to 2°C above pre-industrial levels, we can still expect temperatures in the Arctic to increase by 5°C or more. ICE-ARC has shown, in more detail than ever before, what the consequences and cost of this rise would be. But we must continue to develop our understanding of the region and to build the case for a coordinated, international response.

The project's success can be attributed to its focus on cross-discipline collaborations, by uniting economists, social scientists, and natural scientists, and directly involving indigenous communities in the region. ICE-ARC's findings make clear that understanding, assessing and responding to Arctic change requires a multidisciplinary and integrated international response.

Climate change may pose some of the greatest challenges and opportunities humanity has faced.

To adequately address this, we need to continue to strengthen the links between science, policy and society. Holistic programmes like ICE-ARC provide these connections, and enable policy-makers to develop evidence-based policies that address the dual goals of climate change mitigation, as well as to exploit the economic growth opportunities that a low-carbon society offers. The work of ICE-ARC will be followed up by the EU Arctic Cluster - a collaboration of the EU funded Arctic programmes, led by the EU-PolarNet - see #EUArcticCluster.

12 COUNTRIES

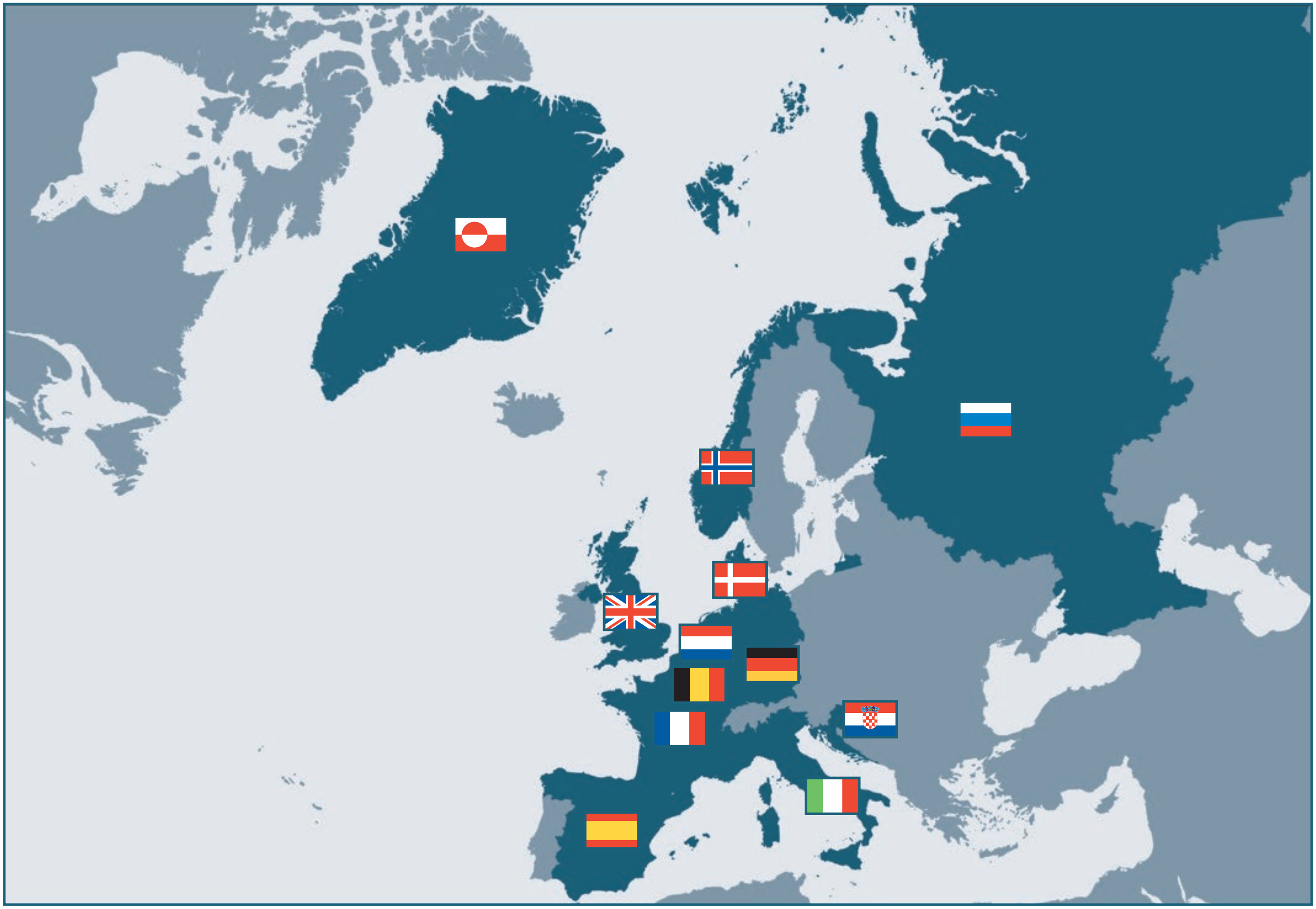
24 INSTITUTES

€12 MILLION

ICE-ARC brings together 24 institutes across 12 countries:

The ICE-ARC community thank our many valued international collaborators for their cooperation, support, and substantial logistical commitment during the past four years. We are extremely grateful for the inspiration, insightful comments, and suggestions made by our Advisory Board, to whom we extend our deepest appreciation:

Peter Bakker	President, World Business Council for Sustainable Development
Tom Brookes	Managing Director of the Energy Strategy Centre at the European Climate Foundation
Eddy C. Carmack	Emeritus, Institute of Ocean Sciences, Victoria, Canada
HRH Prince Jaime de Bourbon de Parme	Dutch Ambassador to the Holy See
Bruce C. Forbes	Leader of the Global Change Research Group, Arctic Centre, Finland
David Hik	University of Alberta, former President, International Arctic Science Committee
Charles Kennel	Former Director of Scripps Institution of Oceanography, now Visiting Research Fellow at the Cambridge Centre for Science and Policy
Pam Pearson	International Cryosphere Climate Initiative
Johan Rockström	Stockholm University
Dominick Waughray	World Economic Forum
Jan-Gunnar Winther	Former Director, Norwegian Polar Institute



Coordinator:
Dr. Jeremy Wilkinson, British Antarctic Survey
jpw28@bas.ac.uk

Programme Manager:
Dr. Elaina Ford, British Antarctic Survey
elaina.ford@bas.ac.uk

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