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D1.21 The MOSAiC Example: How to develop and fund
a large-scale international initiative from a national
bottom-up idea

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D1.21. The MOSAiC Example: How to develop and fund a large-scale international initiative from a national bottom-up idea

Introduction:

Effective international cooperation in Polar research and operations is necessary to understand and mitigate the rapid changes occurring in the Polar Regions and their global effects. Polar research is therefore a scientific area in which international cooperation is well developed also due to safety, environmental, logistical and budgetary reasons. The international Polar community is showing an impressive willingness to work together in large-scale programmes, sharing facilities, results, and data. However, these large international activities require a significant investment of human and financial resources to implement and coordinate them. Thus, large scale international initiatives in the Polar Regions are generally one-off, and the extensive cooperation generated tends to fade relatively soon after they and their associated funding end.

Good examples for large-scale international research projects¹ in the Polar Regions are [MOSAIC](#) and [T-MOSAIC](#), [SAS](#), [YOPP](#), [East GRIP](#), [BE-OI](#) or multi-national infrastructure consortia², such as [SIOS](#) or [EISCAT](#), which also include Asian partners.

The Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition is the largest Arctic research project in history and an immense effort to understand how the changing Arctic will affect the rest of the planet. It is built upon a truly bottom-up idea by a German and a Russian atmospheric scientist and developed into one of the largest international campaigns to investigate the Polar regions. The following chapters describe how it has been implemented and what lessons the Polar research community can learn from this process.

MOSAiC background and challenges

Scientific background

The Arctic is generally considered to be an early warning system for climate change. The dark water absorbs more energy than the ice, which reflects solar radiation, and thanks to the thinner ice, more heat is making its way from the comparatively warm ocean to the surface and into the atmosphere. In this way, feedback effects are significantly amplifying the warming of the Arctic. The Arctic scientific community still lacks the observations needed to understand complex coupled system processes in the ocean, sea ice and atmosphere, as well as their interconnections with biogeochemical and ecological cycles, and to quantify them in state-of-the-art climate models. The dramatic scale of Arctic warming is not adequately reflected in today's climate models, and the uncertainties in climate projections for the Arctic are large. There is thus an urgent need to comprehensively study the local and regional processes involved in the Arctic climate system, especially during the winter.

In addition, the effects of a changing Arctic can already be felt in Europe, Asia and North America: the weaker temperature differences between the Arctic and the Tropics are destabilising the typical atmospheric pressure patterns; as a result, cold polar air is finding its way to the moderate latitudes, while warm, moist air pushing into the Central Arctic is increasingly accelerating the warming.

¹ MOSAiC: Multidisciplinary drifting Observatory for the Study of Arctic Climate, T-MOSAiC: Terrestrial Multidisciplinary Observatories for the Study of Arctic Connections, SAS: Synoptic Arctic Survey, YOPP: Year of Polar Prediction, East GRIP: East Greenland Ice-core Project, BE-OI: Beyond EPICA - Oldest Ice

² SIOS: Svalbard Integrated Arctic Earth Observing System, EISCAT: European Incoherent Scatter Scientific Association

The understanding of Arctic climate processes is limited by a dramatic lack of observations in the central Arctic, especially in winter and spring. During these seasons' sea ice is so thick that even the best research icebreakers cannot penetrate the Arctic and researchers have always been locked out.

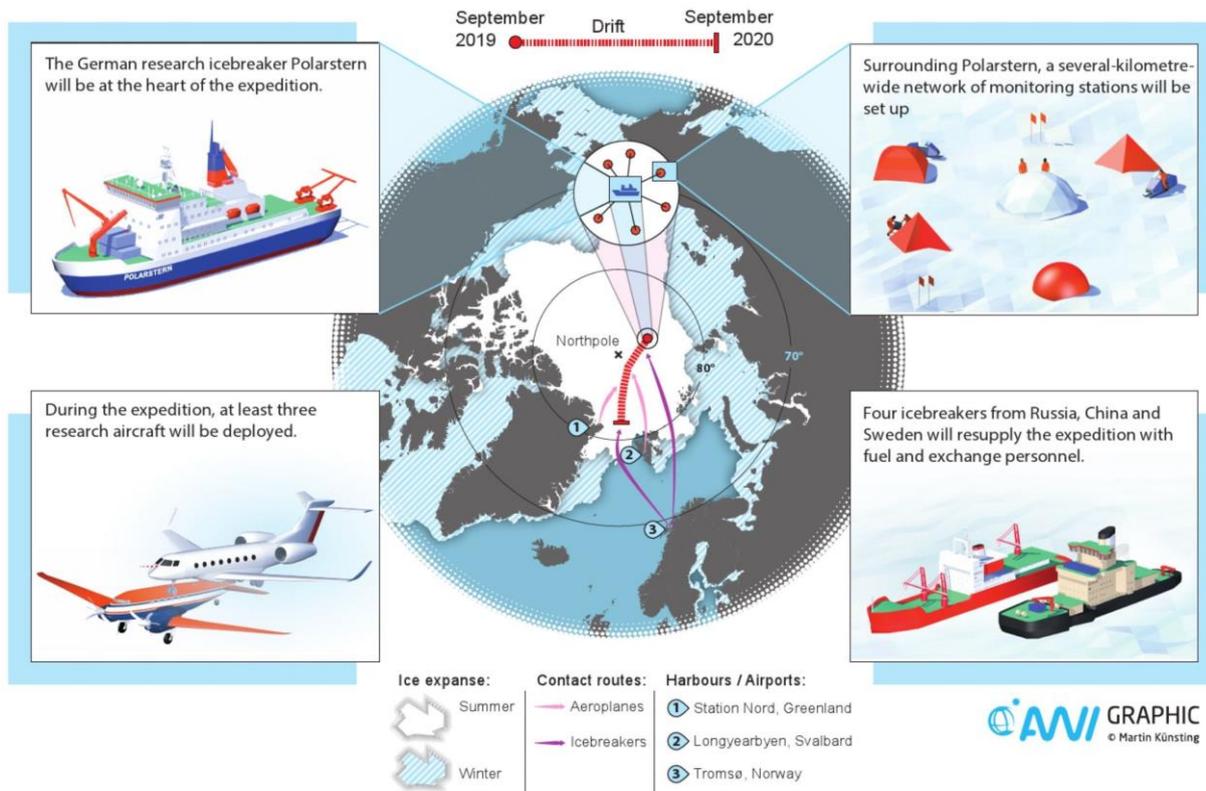


Fig. 1: The transpolar drift of *Polarstern* within MOSAiC during 2019 – 2020.

The goal of the MOSAiC expedition is to gain fundamental insights into the Arctic climate system that are key to better understand global climate change. Following the footsteps of Fridtjof Nansen's ground-breaking expedition with his wooden sailing ship *Fram* in 1893-1896, the MOSAiC expedition brings a modern research icebreaker close to the North Pole for a full year including for the first time in polar winter. The data gathered will be used by scientists around the globe to bring climate research to a completely new level. The main scientific goals for the initiative can be found in the MOSAiC science plan and were based on a series of workshops held in Potsdam and Boulder between 2011 and 2014.

Operational challenges

MOSAiC took the German icebreaker *Polarstern*, accompanied by the Russian icebreaker *Akademik Fedorov* near the North Pole in late autumn 2019 to start the drift. Four additional icebreakers from Russia and China are involved in the expedition and need to be coordinated. These icebreakers will provide logistical support during the expedition. In addition, a dedicated landing strip will be created, to be used for resupply flights and two research aircrafts. Helicopters, snowcats and snowmobiles are also used. *Polarstern* has been equipped with cutting-edge scientific instrumentation and acts as a central observatory. A complex research camp has been set up on a suitable ice floe. The expedition participants connected the research camp with a network of measuring stations set up over a radius of 50 kilometres around the vessel.

During the course of the year, circa 300 researchers from 16 countries will be on board, from Belgium, Canada, China, Denmark, Finland, France, Germany, Great Britain, Japan, the Netherlands, Norway, Russia, Spain, Sweden, Switzerland and the USA. They will be supported on land by researchers from Austria, Italy, Poland and South Korea. The questions that the researchers will be investigating during the expedition are intricately linked. They will gather data on five subsystems: atmosphere, sea ice, ocean, ecosystems and biogeochemistry, in order to gain insights into the interactions that shape the Arctic climate and life in the Arctic Ocean.

Financial challenges

The budget for the expedition, which is roughly 140 million euros, needed to be covered by the international Polar research community. About 70% of the budget is covered by Germany (BMBF) which provides the platform and significant parts of logistical support free of charge.

The Chinese State Administration offered their new icebreaker *Xue Long II* to resupply *Polarstern* without charge and thereby contributed significantly to the expedition. Chinese scientists can therefore participate in MOSAiC without daily fee. All other participants pay a daily fee of 1.500 Euro to contribute to the costs of the expedition as e.g. the charter of the Russian icebreakers *Kapitan Dranitsyn* and *Akademik Fedorov*.

Implementation of MOSAiC:

MOSAiC builds on a successful and long-term cooperation between AWI and the Arctic Antarctic Research Institute (AARI), St. Petersburg in atmospheric research. The ideas for MOSAiC were developed from the outset together with AARI colleagues, in particular with V. Sokolov and I. Frolov. One of the highlights of this bilateral cooperation was the participation of an AWI researcher in the NP-35 Russian drift station within the IPY (2007/08). The preparation of the NP-35 joint expedition started in 2006 supported by AARI director Prof. I. Frolov. Within a joint project entitled "*Atmospheric investigations on a drifting station in the Arctic Sea (AIDA)*" studies on the coupling between the Arctic boundary layer and the free troposphere as well as stratospheric ozone soundings and tropo-stratosphere coupling have been performed on the NP-35 expedition.

Following the successful completion of this IPY project, AWI and AARI scientists organised a joint workshop in Potsdam to discuss the scientific results of the NP-35 expedition. In addition, an application for funding within the bilateral Helmholtz-Russian Joint Research Groups funding scheme was prepared, which was unfortunately unsuccessful.

The best solution to continue with Arctic climate investigations over a full annual cycle was to include the international community into the activities and raise the project from a bi-lateral cooperation to a multi-lateral one. In December 2008, an international team submitted the FP7 proposal "*TORUS - Toward the reduction of uncertainties in Arctic and global climate projections*" to the EC to implement the idea of atmospheric, oceanic and sea ice measurements from an international Arctic drift station. The proposal was, unfortunately, not granted.

In January 2009, the International Arctic Science Committee (IASC) council and working group meetings took place in Potsdam. Klaus Dethloff, the German PI of the project and German member of the atmospheric working group of IASC, proposed to plan and prepare an international ice drifting station over the Arctic Ocean to study the processes of Arctic sea ice decline based on data and model simulations.

In September 2011, AWI organised the first ice drift workshop at AWI Potsdam with 50 international participants supported by IASC. The workshop was titled: *Atmospheric investigations on a drifting Observatory on the Arctic Sea and regional and global climate model simulations (AIDA-RCM)*.

On August 7, 2012, the AWI team applied for the implementation of this scientific idea and requested ship's time on the research icebreaker *Polarstern* together with the international MOSAiC Consortium (e.g. V. Sokolov from AARI St. Petersburg, M. Shupe from CIRES Boulder and H. Yang from PRIC Shanghai). The *Polarstern* application with the project no. N-2014-H-060_Dethloff was successfully reviewed and approved on May 12, 2015.



Fig. 2: Participants of the first drift ice workshop at AWI Potsdam in 2011. At that time, the project was still called AIDA (Atmospheric Investigations on a Drifting observatory over the Arctic Ocean).

Two additional workshops to develop a science plan for MOSAiC took place in June 2012 at CIRES in Boulder, Colorado (2nd MOSAiC workshop) and in May 2013 in Potsdam (3rd MOSAiC workshop). New research topics, like biogeochemistry and ecosystem processes have been added to the project. A white paper titled "*Multidisciplinary drifting Observatory for the Study of Arctic Climate: A drifting research station to study atmosphere-ocean-sea-ice processes in the central Arctic icepack (MOSAIC)*" has been written based on the workshop results. In addition, the team agreed on an outreach plan to improve the visibility of the project and approved MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) as its final name.

Lectures given by the AWI director, MOSAiC PIs and IASC representatives at various Arctic conferences and workshops improved the international visibility of the MOSAiC significantly. The main breakthrough for the implementation of the MOSAiC expedition was achieved on a workshop during the Arctic Science Summit Week (ASSW) in Toyama, Japan 2015. The AWI director announced that Germany will provide *Polarstern* for the MOSAiC expedition and thereby support MOSAiC with a significant financial contribution. Soon after this announcement, in June 2015, the MOSAiC team organised an international implementation workshop for MOSAiC in Potsdam with more than 70 participants. This workshop focused further on the scientific priorities of the expedition but discussed also possible models of co-funding MOSAiC to close the financial gaps.

In between summer 2015 and spring 2017 the scientific and logistic plan for the MOSAiC expedition developed further. Germany decided to cover the full costs for *Polarstern* for the entire MOSAiC drift and asked for financial support from the international partners to finance the service icebreakers and air links needed to re-supply and re-fuel *Polarstern* during the drift. The Chinese State Administration offered support to MOSAiC by sending their research icebreaker *Xue Long II* (Snow Dragon) to refuel *Polarstern* and exchange scientists and crew. In return service Chinese scientists can join the MOSAiC

expedition. In addition, negotiations with Russia to charter some of their icebreakers and possibly helicopters to supply the drifting vessel have been initiated.

Table 1: Series of workshops to implement MOSAiC

<u>MOSAiC Workshops</u>	City	Country
Kick off Workshop September 2011	Potsdam	Germany
Science Planning Workshop June 2012	Boulder	USA
Science Plan Writing Workshop May 2013	Potsdam	Germany
Implementation Planning Workshop July 2015	Potsdam	Germany
MOSAiC workshop during ASSW, April 2017	Prague	Czech Republic
Implementation Workshop November 2017	St. Petersburg	Russia
Science Workshop May/June 2018	Potsdam	Germany
Science and Implementation Workshop March 2019	Potsdam	Germany

After evaluating several ways on how international partners could financially contribute to MOSAiC, the steering committee agreed to raise a daily fee for all participants from countries without significant in-kind contribution (as e.g. Russia and China). The daily fee was fixed to 1.500, - Euro per day per participant. By this method, most of the international participants were able to apply for the daily fee within their national funding systems. This decision was a breakthrough for the implementation of the project.

In April 2017, a MOSAiC workshop was held during the ASSW in Prague and in November 2017 another implementation workshop took place at the AARI in St. Petersburg. Both have further specified the scientific and logistical details.

Initially, the MOSAiC drift was planned for the period 2018-2019. For internal AWI reasons and in coordination with the involved international partners, this period had to be postponed by one year to 2019-2020. To date MOSAiC is successfully taking place.



Fig. 3: AWI Sea ice physicists working on the ice during MOSAiC (Photo. S. Hendricks, AWI)
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Lessons learnt and recommendations:

MOSAiC is an excellent example of how an improved international cooperation enables the Polar research community to focus jointly on a big and complex science question which a single nation would not be able to address alone. It took 13 years to implement MOSAiC from the original scientific idea developed in 2006 to the start of the MOSAiC drift in September 2019. This shows that the PIs of such ideas need a great deal of perseverance but also sustained institutional support to pursue such an idea over a long period of time and cope with the throwbacks. In addition, the implementation of MOSAiC allows to draw the following recommendations for future large-scale initiatives:

1. At least one institute is needed which commits to move the idea forward and is willing to contribute significantly with human and financial resources to the initiation and implementation process. The preparatory work including proposals, workshops, reports, outreach, and networking is costly and time consuming. One of the main breakthroughs for the realisation of MOSAiC was certainly the commitment by Germany (AWI) to provide *Polarstern* as platform for the drift and contribute with a significant percentage to the costs of MOSAiC.
2. Another important step during the development of MOSAiC was to seek the support of an international scientific organisation such as IASC and to invite the international science community to contribute and to complement the project with several new scientific topics. The international visibility of the project increased significantly and the number of partners and thus also options to support and finance the expeditions rose.
3. Another important step towards MOSAiC was the agreement of an easy to implement and transparent financing structure by implementing a daily berth fee for all expedition participants whose countries do not provide significant in-kind contribution, such as e.g. China, Russia and Germany. This daily berth fee allowed several scientists to get a grant for MOSAiC from their national funding agencies. In addition, it also allowed participants from countries with smaller Arctic programmes to participate as well.
4. Finally, persistent, and intensive outreach is of particular importance. On a scientific level, various presentations and lectures during workshops and conferences as well as workshops dedicated to developing internationally agreed science and implementation plans have proven to be necessary and successful. Active information and cooperation with decision makers and involvement of the public supports the implementation significantly.