

Summary of IASC WG Atmosphere Workshop on
Atmospheric Investigations on a Drifting observatory
over the Arctic Ocean (AIDA)

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Polar regions are important players in the climate system because the widespread surface snow and ice cover in these regions strongly impacts the surface energy budget, which is tightly coupled to global atmosphere and ocean circulation. The observed decrease of Arctic summer sea-ice cover over the last decades is best viewed as a combination of strong natural variability due to large-scale dynamics and regional feedbacks in the coupled atmosphere-ice-ocean-land system with a growing radiative forcing associated with rising atmospheric greenhouse gas concentrations. However, it is yet to be established the degree to which diminishing Arctic sea ice and the occurrence of new atmospheric circulation states are driven by a warm phase of decadal-scale climate variability versus the anthropogenic forcings. Attribution of ongoing Arctic changes is difficult because natural variability may be large enough to partially mask the anthropogenic influences, and because the current understanding of important Arctic system process interactions is limited. The rate of observed sea-ice decline is higher than in IPCC AR4 model simulations, while the causes of these declines and their regional and global impacts are not fully understood. Current regional and global climate models (RCM, GCM) suffer from missing processes and regional feedbacks due to insufficient atmospheric parameterizations; to improve simulations of Arctic processes within the global climate system these parameterizations must be further developed and enhanced.

The Arctic warming and reduction of sea ice cover will result in increasing navigation and exploitation of natural resources. To guarantee the safety of these operations, demands will increase for accurate operational short-term forecasts for weather and sea ice conditions. When applied to the Arctic, numerical weather prediction (NWP) models suffer, however, from basically the same problems as climate models. The general lack of understanding of the complex Arctic climate system is clearly associated with insufficient Arctic observations and the resulting inadequate modeling and forecasting tools. Due to these deficiencies, there is a significant disconnect between public and political expectations (seasonal to decadal predictions) and current deliverables (climate projections). To reduce this critical lack in understanding with the aim of enabling predictions, longer-term observations of the complex atmosphere-sea-ice-ocean system are needed. Such observations must occur year-round to capture the annual variability of important processes and should rely on enhanced observation techniques relative to those implemented in the past. A combination of in-situ observations and satellite measurements should be used to monitor important atmospheric and surface parameters that are needed to improve model parameterizations with a strong focus on atmospheric processes and their

interactions with the snow- and sea-ice-covered surface. Furthermore, since atmospheric processes, such as those related to the stable Arctic planetary boundary layer, are a source of large systematic errors in atmospheric models the measurements must be interfaced with NWP models, regional Arctic climate system models (atmosphere-only RCMs, coupled A-O-I RCMs), and global climate system models in order to study the impact of sub-grid scale parameterizations on atmospheric circulation patterns and decadal climate variability.

1. Science Drivers

A proposed overarching science question around which to motivate and organize Arctic observational and modeling efforts was "Why is the Arctic sea ice disappearing?" Implicit in this question is the recognition that to develop an answer requires modeling and observing the Arctic system as a whole. Thus, this question integrates atmospheric, oceanic and cryospheric processes, thereby involving the cryospheric IASC group. Other overarching questions that were proposed include: "How can we better understand the new Arctic" or "What physical processes are key for understanding the new Arctic." These two questions emphasized the point that the important current Arctic processes or process interactions are likely distinct from those in the past as a result of the recent large areal increase of young first-year ice and decrease of older multi-year ice. There were also suggestions that the overarching question should incorporate the objectives of improving numerical modeling and understanding the effects of a changing Arctic on sub-Arctic regions. A tentative project description title could be "Understanding the changing Arctic climate over the Arctic Ocean", including conceptual understanding and improvement of process models and high-resolution models.

2. Summary of AIDA measurement design discussions

It was established that there is a need for long-term profile measurements of the boundary layer and free tropospheric structure, turbulent and radiative fluxes, cloud properties including cloud-aerosol interactions, surface conditions, ice and snow albedo, ice thickness and distribution, snow depth measurements, and spatial airborne and surface measurements around a central drifting site. It was decided that the primary platform of an AIDA observatory would consist of either an icebreaker-supported ice camp or an ice camp supported by a non-icebreaker floating structure, such as a barge, which could provide lodging and meals, safety, research and laboratory space, and power. Observational platforms tentatively offered include two ice breakers (Finnish Atmosmare Foundation and Russian Akademik Treshnikov) and one non-icebreaker ship (R/V Mirai). Additionally, the German AWI P-5 and P-6 aircraft were offered to serve both scientific and logistical purposes.

.A two-year drifting ice floe trajectory is highly preferable in order to understand the variability of important processes during all seasons in the Arctic. If logistical constraints limit the drift length, a minimum one-year drift is necessary to accomplish the most basic objectives of the program. A 1-2 year long drift requires careful consideration of the set-up locations. It was deemed important to find a drift track that promotes studies of processes in the changing Arctic where first-year ice is a significant ice type but where there is also ice that is sufficiently thick to establish a safe and stable ice camp. Additionally, the track should be designed such that the selected ice flow will remain within the Arctic Basin for longer than one year and provide substantial sampling time within the European Arctic. One suggestion for setup location was in the northern Beaufort Sea, though post-workshop analysis suggests that this location will not

allow for a transpolar drift required to enter the European Arctic. A second suggestion was to set up the ice camp just north of the Canadian Archipelago, though this will also likely not lead to a drift into the European Arctic. The third setting up was an observatory north of Wrangell Island close to the 180° meridian in the northern Chukchi Sea. Post-workshop analysis shown below indicates that this suggestion would meet the requirements listed above. Objections were raised to this suggestion at the workshop, including concerns that the camp would not be within reach for resupply flights and that European funding sources would not be willing to fund establishment of an observatory in the Western Arctic. Responses to the latter concern included that the station would drift into the European side of the Arctic during the latter half of the field program and would be ideally located with respect to supporting European land-based measurements on Svalbard and Greenland (see Fig. 1). Furthermore, the science that would be accomplished during this drift would be equally relevant to the European Arctic nations as it would be to Russia, Canada, and the United States. However, the inability to reach an observatory along this track for resupplying was recognized as a substantial consideration.

Figure 1a shows the sea-ice distribution at the end of the melt season 2011, and the drift tracks of multiple historic ice stations established at about the same time of year. Tracks from two relevant DAMOCLES and NPEO ice buoys (2008C and 2010A) are shown. Figure 1a shows all of the tracks from previous years that lasted at least one year. Near real-time production of ice age maps such as Fig. 1b during the summer and fall before the establishment of the AIDA observatory would be very useful.

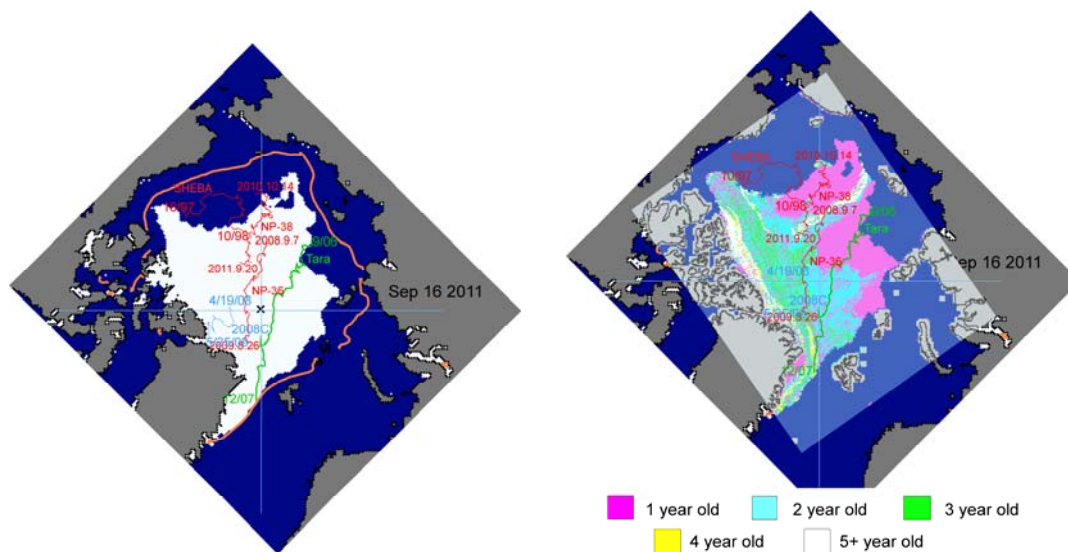


Fig. 1a: (Left) September sea ice extent from NSIDC for 2011. Drift tracks of previous years with at least 1-year longevity are shown to give suggestions of possible put in locations (courtesy NSIDC website).
 Fig. 1b: (Right) Same as for Fig 1a, but showing ice age rather than just ice extent (courtesy J. Maslanik and NSIDC), delivered by O. Persson.

3. Modeling approach

It is impossible to construct, understand, and explain changes in the climate system based on observational data without modeling. Observational data analysis is needed for model

calibration, evaluation, and development. RCMs are limited-area models that are driven at their lateral boundaries by reanalyses or GCM-generated data. The prognostic variables in a RCM are relaxed towards these lateral boundary conditions. Observational field and process studies which lead to improved parameterizations of Arctic specific processes are carried out on a much finer scale than current GCMs can resolve. The adaptation of this meso-scale information to a global-scale parameterization is a complex and difficult topic. RCMs can contribute to this issue by dynamical downscaling with higher horizontal and vertical resolution compared to the driving data. Such models improve the understanding of feedbacks by process studies in close connection with observations and by up-scaling regionally important processes into global models, e. g., connected with sub-grid scale parameterizations and feedbacks in the coupled system. Deficiencies of GCMs in describing the Arctic climate are at least partly due to inadequate parameterizations of important Arctic physical processes. The higher RCM resolution compared to GCMs allows for meso-scale details to be added upon the driving large-scale flow. Despite the fact that RCMs are constrained by lateral boundary conditions (LBCs), recent studies have shown that RCMs also exhibit internal variability. This variability is usually understood as the capacity of the model to produce different solutions for the same set of LBCs and appears to vary as a function of season, domain size, and geographical location.

Careful design of an RCM domain and specification of the LBCs from analysed fields allows an RCM to be constrained to follow the observed large-scale atmospheric evolution, while still permitting local interactions between parameterizations and the model's resolved dynamics. Furthermore, the spatial resolution of the model and therefore the scales classified as unresolved are well defined in an RCM. Careful design of an RCM or Numerical Weather Prediction (NWP) Model can allow simulated variables to be carefully evaluated against localised observations for a time-limited period, as is often the case with intensive observation campaigns.

Some years ago an Arctic Regional Climate Model Intercomparison Project (ARCMIP) was conducted to assess and document the performance of atmospheric RCMs over the Arctic. The first ARCMIP experiment was designed to capitalise on the SHEBA observation campaign, occurring in the western Arctic between September 1997 and October 1998.

4. Summary of model breakout session

Following these ideas a new model intercomparison project in an Arctic subdomain along and around the AIDA ice floe trajectory will be carried out with the aim to test parameterizations with a new generation of RCMs. The main focus will be on processes between the planetary boundary layer (PBL) and baroclinic scales in the free troposphere and the interaction of these with the surface. As in ARCMIP, process-related simulations and improvement of models can be expected. The AIDA-MIP will be carried out with about 8 RCMs from Germany, Sweden, US, Denmark, Norway, Finland, Canada and Russia. NWP models will also be included e.g. Hirlam, Harmonie, and WRF. A relative small domain around the AIDA trajectory for atmosphere-only simulations and a large Pan-Arctic domain for both atmosphere-only and coupled Arctic RCM simulations will be applied including ensemble simulations and process-understanding analysis.

Simulations for the single-year in atmosphere-only models are planned in forecast and climate mode configurations exploiting available data of other campaigns or measurements. The role of

clouds, aerosols, PBL, inversions, precipitation, atmospheric structure, and vertical exchanges of heat, moisture, and momentum can be addressed with appropriate measurements at AIDA. Obtaining a better understanding of Arctic baroclinic cyclones could perhaps be accomplished through case studies with enhanced spatial observations using additional measurement platforms including the use of NWP models for selected time periods.

AIDA can improve our understanding of surface energy budgets governing the regional Arctic climate, whereas assessments of the globally changing climate would need to come from coordinated GCM experiments. AIDA would provide measurements of the surface energy balance, heat, moisture and momentum fluxes, cloud and aerosol properties, water vapor, and ozone concentrations. AIDA could also provide the data to understand forcing of inherent variability of atmospheric processes, including responses to decreases in sea ice and shifts in atmospheric teleconnection patterns.

Some of the above gaps would be addressed by combining the long-term drifting observatory measurements with other observations, either during shorter or longer time periods. These would be provided by episodic aircraft campaigns with both manned and unmanned aircraft, the latter launched from the main observatory. Other ships such as the R/V Mirai, the Russian Akademik Treshnikov, the Finnish ship, the German Polarstern, or the Swedish Oden could provide periods of enhanced, surface-based spatial observations. The Mirai could provide measurements in the open water near the ice edge adjacent to the main observatory during fall freeze up in September and October of the setup-year. It could serve as a platform for open-water atmospheric measurements of clouds, baroclinic systems, and precipitation with radiosondes and radars, and a platform for conducting sea-ice growth and energy flux measurements. Similar measurements could also be carried out at the main observatory, with UAVs obtaining the meteorological and surface measurements necessary for estimating the surface energy fluxes between the two sites and over the open-water or thin-ice portions.

The role of the Arctic as global energy sink, for impacts on mid-latitude circulation, global teleconnection patterns and storm tracks could not be directly answered with AIDA observations alone. Therefore the RCM simulations will be coordinated with sensitivity experiments in GCMs. The effect of Arctic processes and feedbacks on sub-Arctic regions and teleconnection patterns will be studied within the NCAR CCSM4.

Additional data assimilation studies in the ECMWF forecast system during the AIDA study could be carried out and ECMWF will take part in the next upcoming AIDA workshops. In a pilot study the added value of measurements over the Arctic Ocean could be investigated in the ECMWF data assimilation system.

AIDA workshop summary:

The workshop participants recommended the establishment of a manned atmospheric observatory under international leadership to drift for preferably two years in the ice pack of the Arctic Ocean with instrumentation to observe the most important atmospheric, sea ice and oceanic processes. These measurements will be exploited in regional climate model simulations to evaluate and improve sub-grid scale atmospheric parameterizations in Numerical Weather Prediction, Regional and Global Climate Models. There are differing opinions about the target and domain for deployment of the atmospheric observatory over the Arctic Ocean (Beaufort Gyre or North-West region of Greenland) which need further discussions. A rough estimate for

the required instrumentation, ice breaker, overwintering vessel, runway on ice and airplanes for logistics and science flights is around 40-50 Million €. The ultimate AIDA measurement design depends on the science questions to be developed by the scientific community in a follow-up workshop in May 2012 to be organized in coordination with IASC WG Atmosphere leadership. By autumn 2012 it is anticipated that a white paper will be written.