

**ACAS**

**Arctic Climate Across Scales**



**Principal investigator**

Michael Tjernström

michaelt@misu.su.se

Stockholm University

**Areas of contribution**

Polar atmospheric processes

Modelling and forecasting

Polar-lower latitude linkages

Education

Observations

Sea ice processes

Data archiving

Outreach

**Summary**

The project seeks to improve our understanding of physical processes in the Arctic and specifically to explore what it would take to reduce the risk of summer sea-ice completely disappearing within this century. The tools to achieve this will be improved modeling across the scales from hemispheric to local and especially for the surface energy balance and clouds, and improved process-level research-grade observations by building a semipermanent atmospheric observatory on the Swedish icebreaker Oden.

## **Description**

Understanding the Arctic climate system is one of the most difficult scientific challenges, perhaps even overwhelming. This project focuses both on the large scale atmospheric dynamics and on regional and local processes of cloud formation or turbulent exchange at the surface, and integrates across scales, and also across the observational and modeling domains. The project hence crosses several artificial and detrimental boundaries in climate and weather prediction science. Hence, the project needs leading hypotheses, priorities and well-defined boundaries to other research; it also needs to be well integrated with international efforts. We believe that the most critical uncertainties needing to be reduced for an adequate understanding of the Arctic climate system, Arctic climate change and its links to the global climate are found in the atmosphere. Sea-ice accumulates energy from above and below but is also dynamic; transported and deformed by the stress exerted by the wind. Changes in sea-ice feeds back to atmosphere and the upper ocean. It therefore makes sense to consider atmosphere, sea ice and ocean mixed layer as a coupled system. Hence, without ignoring the deeper ocean, we focus on atmospheric processes that affect the energy fluxes at the surface of the Arctic Ocean and feedbacks associated with the sea ice and the upper ocean.

The most uncertain aspect of the surface energy balance is the presence of clouds, affected by many processes. Clouds reflect solar radiation but also trap thermal radiation. In the Arctic, where solar radiation is weak and surface albedo is high, longwave surface warming by clouds dominates. The relative magnitude of short- and longwave radiation effects depends on cloud micro-physics and the thermodynamic structure of the lower atmosphere. Low-level clouds, often consisting of a mixture of super-cooled water and ice crystals known as mixed-phase clouds, dominate; clear conditions are more rare, especially in summer. Current numerical models of the atmosphere have problems representing clouds and thus the Arctic surface energy balance. Observations in the Arctic indicate two preferred quasi-steady states: clear and cold, or cloudy and warm, alternatively persisting for several days. Changes in large-scale advection of moisture and heat cause rapid transitions between these two states but within each the system evolves more slowly. Cloud formation is hence also critically sensitive to the large-scale circulation of the atmosphere, bringing heat, moisture and other constituents into the Arctic. But the large-scale circulation is also sensitive to changes in the Arctic. Enhanced sea-ice melt may affect the mid-latitude hemispherical circulation, while clouds can affect melting and vice versa; both are obviously affected by large scale advection. Hence understanding of Arctic climate requires an approach across the scales, from the hemispheric scale, over regional cloud formation to local processes determining the energy transfer by radiation and turbulent fluxes and back on the large-scale effects of Arctic change in the hemispheric circulation.

This project is built around three interlinked scientific Work Packages (WPs) that will utilize tools provided by two Infrastructure Organizations (IOs):

- WP1 will identify the main linkages between the Arctic and global climate systems and the changes in large-scale atmospheric circulation due to Arctic climate change.
- WP2 will identify and quantify the main processes governing the formation and life cycle of Arctic clouds, and quantify the role of local and remote aerosol sources.

- WP3 will assess the integrated effects of global climate change on the Arctic surface energy balance and ultimately on the sea ice demise.
- IO1 will apply and develop a hierarchy of numerical models, ranging from small-scale process models to ESMs.
- IO2 will build a new research observatory on the Swedish icebreaker Oden. The idea is to instrument an icebreaker with advanced instruments in such a manner that it will always run regardless of expedition aims and targets.

The three WPs and the two IOs build a perpendicular structure, that will ensure that new knowledge is generated in an integrating and synthesizing process, where modeling and observations are two branches on the same trunk. The common but detrimental division of “observations” and “modeling” as separate activities is avoided, and larger-scale dynamics and small-scale processes are considered parts of the same problem. For several aspects we will also rely on international collaborations. For modeling we are part of several modeling consortia (EC-Earth and NorESM to mention two) and for observations we will integrate closely with the Swedish Polar Research Secretariat as well as with MOSAiC.

## **Timeline**

2016-01-01 - 2020-12-25

## **Regional emphasis**

Northern hemisphere: Yes

Southern hemisphere: No

## **Key project deliverables**

\* Improved process understanding, focusing on cloud processes and surface energy exchange, including sea-ice processes and feedbacks to the atmosphere.

\* Improved modeling across all scales, from process modeling over regional modeling to global modeling. The improvements will be integrated in existing models within established consortia, but we will also develop a single-column fully coupled modeling tool that integrates across the ocean/sea-ice/atmosphere boundaries.

\* A proof of concept for permanent advanced observations on research icebreakers, that will help advance atmospheric observations in the Arctic Ocean.

\* A database with detailed observations of the vertical structure of the atmosphere, including clouds, from ship-borne remote sensing instruments and soundings, as well as surface energy-balance and other in-situ observations from the icebreaker Oden.

**Data management**

The Bolin Center for Climate Research database ([www.bolin.su.se](http://www.bolin.su.se))

**Is data provided to WMO Global Telecommunication System**

No

**Real-time provision**

The suggested atmospheric observatory on the icebreaker Oden will provide some data in real time, e.g. soundings and regular weather observations.

**Other information**

Item 11 above is only very roughly outlined. The project runs for five years, but involves hiring substantial amounts of PhD students and postdocs, and also procuring of instruments. As this is gradually accomplished, everything will run through the entire project time.