

# MACSSIMIZE

Measurements of Arctic Clouds, Snow, and Sea Ice nearby the Marginal Ice Zone



## Principal investigator

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## Areas of contribution

Polar atmospheric processes

Oceanic processes

Modelling and forecasting

Polar-lower latitude linkages

Observations

Sea ice processes

Land processes

Data assimilation

Data archiving

## Summary

MACSSIMIZE is a planned measurement campaign to be carried out by the Met Office during Feb/Mar 2018 as part of YOPP. There is an associated plan for data analysis from the campaign including model evaluation and development. In addition, the Met Office hopes to run models throughout the YOPP Core Phase including the operational NWP suite, a regional high resolution model, a seasonal forecasting model with coupled ocean and

atmospheric components, and an experimental coupled ocean-atmospheric NWP system as well as the HadGEM3 coupled climate model. The MACSSIMIZE field campaign is currently planned to take place in two locations: Fairbanks, AK and St. John's or Goose Bay, NL. The Fairbanks campaign will target (1) snow emissivity measurements at IR and mm-wavelengths over collocated ground-based measurements of snow structure on sea ice and nearby land, (2) boundary layer and energy balance measurements in clear and cloudy skies, and (3) orographic flows and their leeside impacts. The Labrador campaign will primarily target cold-air outbreak conditions over the Labrador Sea but opportunities to make the other measurements listed above may arise. The goal of these measurements and modelling efforts is to improve predictability in the Arctic while focussing on (1) assimilation of satellite sounder data into NWP systems, (2) evaluating and developing boundary layer and snow pack parameterizations suitable for Arctic conditions for use in coupled ocean-atmosphere NWP and climate models, and (3) studies of a specific Arctic-mid-latitude exchange mechanism (cold-air outbreaks) that is difficult to model within current weather forecasting models.

## **Description**

Overarching aim: Improving weather and climate forecasting in the polar regions, through a better understanding of key physical processes and an improved representation of those processes within numerical weather and climate prediction systems.

### Background and Motivation

- As sea ice extent and thickness decreases year on year, the use and exploitation of the Arctic for transport, fisheries, hydrocarbons, etc, is bound to increase.
- Predictive skill in the polar regions is significantly lower than for mid-latitudes (see PPP Plans, Bauer et al., 2015 QJRMS; Jung et al. 2016, BAMS). Consequently there is room for improvement via model development and without increasing computational resources.
- There are significant knowledge gaps that prevent the development of existing predictive systems for the polar regions. A programme of research is needed to adapt, tune and develop parameterisations that are polar-focused, and forecasting systems that are optimised for the observations available and required in this region.
- There is a high density of quality satellite observations in the polar regions that are being rejected due to poor prior knowledge of the surface temperature and emissivities at IR and mm-wave frequencies. There is evidence that this mm-wave frequency band contains a wealth of information about the atmosphere as well as the state of the snow pack.
- The community needs to understand where to target computational resources to improve forecasts for the polar regions. For example, on a coupled atmosphere- ocean-sea ice prediction system; on assimilation of new data streams (such as snow temperature or sea ice thickness); on a regional high-resolution model domain; or on ensemble prediction systems?
- A better understanding of the impact of the polar regions on the mid-latitudes and vice versa is needed. Improved skill in the polar regions is known to improve predictions at mid-latitudes too (e.g. Jung et al. 2014, GRL).

### Project Objectives:

- Obtain novel observations from the Arctic of surface emissivity over snow and sea ice, snow microstructure and thermal profiles over snow and sea ice, cloud microphysics and aerosols, boundary layer and energy balance measurements, and orographic flows and their leeside impacts.
- Use these observations to improve the understanding of key processes and develop new or improved parameterizations of these suitable for numerical weather and climate prediction models.
- Test these parameterizations for a range of predictive timescales from hours to seasons.

- Implement new parameterizations and new configurations into operational forecasting systems and subsequently into climate and earth system models.
- Characterize the role of the polar regions in driving mid-latitude weather and climate and vice versa.
- Contribute to the Year of Polar Prediction, making use of the additional observations and model output diagnostics available through YOPP.

Proposed campaign in Feb-Mar. 2018:

- 2+ weeks in Fairbanks, AK – flights over land-fast and pack sea ice and snow-covered land. Work to focus on snow emissivity and thermodynamics, surface fluxes, orographic flows and arctic stratus. We hope to have a ground campaign where measurements of snow properties can be made on sea ice and snow-covered land. Barrow might be an ideal location for such activities.
- 1+ week in St John's, NL – Lagrangian evolution of boundary layer fluxes and cloud processes over marginal ice zone and open water downstream. There will be a particular focus on cold-air outbreaks conditions but flights might sample clear skies conditions as well.

Propose modelling and analysis:

- Model configurations proposed for the YOPP core phase: Regional high-resolution (1-4 km scale) atmospheric model; Global NWP suite; Global coupled ocean-atmospheric NWP system; GloSea Seasonal Forecasting system; and HadGEM3 coupled climate model;
- Evaluation of physical and parameterized snow emissivity models against campaign data;
- Trials of assimilation of satellite sounder data over sea-ice using snow emissivity parameterizations;
- Development of multi-layer snow packs with temperature gradient metamorphism and wind-slab formation necessary for Arctic conditions. Suitable for incorporation within surface schemes such as JULES;
- Modelling of snow on sea ice; evaluation of thermodynamic profiles;
- Coupled ice-snow-atmospheric modeling within coupled NWP system;
- Physical processes within Arctic boundary layer clouds that control formation and breakup in cold-air outbreaks as well as over Arctic ice pack;
- Development of boundary layer parameterizations suitable for Arctic conditions;
- Orographic flows and leeside impacts.

Dependencies on data from collaborators:

- Ground-based snow microphysical (grain-size or correlation lengths) and thermal conditions are necessary for evaluation of models of thermal exchange and microwave emission. These measurements are desired on sea ice as well as over land.
- The snow thermodynamic modeling will be carried out as collaboration with external partners.
- The aircraft measurements over sea ice need to be extended to areas other than those with ground-based measurements. This will be accomplished using ice chart and satellite data as well as thermal IR and microwave emission data acquired over the region nearby the ground measurements with the FAAM aircraft (see Harlow 2011, IEEE TGRS for example methods that might be used).
- Another aircraft for sampling upstream or downstream conditions in cold-air outbreak conditions will be particularly suitable allowing simultaneous measurements of stratocumulus and open cellular regions.

## **Timeline**

2018-02-01 - 2021-03-25

## Regional emphasis

Northern hemisphere: Yes

Southern hemisphere: No

## Key project deliverables

- Obtain novel observations from the Arctic of surface emissivity over snow and sea ice, snow microstructure and thermal profiles over snow and sea ice, cloud microphysics and aerosols, boundary layer and energy balance measurements, and orographic flows and their leeside impacts.
- An advanced multi-layer model for snow on sea ice and its incorporation in coupled models.
- Evaluation of snow microwave emissivity models such as MEMLS and DMRT-ML against collated ground-based and airborne data in 20-200 GHz range.
- Improvements in assimilation of satellite sounder data over sea ice and other snow-covered surfaces.
- Improved parameterisations of significant physical processes governing: The Arctic boundary layer; Development and decay of Arctic stratus; and Orographic and leeside flows.
- Improvements to the NWP models appropriate for more skillful predictions for the polar regions.

## Data management

All FAAM data will be hosted on CEDA (<http://www.ceda.ac.uk/>).

## Is data provided to WMO Global Telecommunication System

Yes

## Real-time provision

All dropsondes from the FAAM aircraft go onto the GTS.

## Other information

Funding for the FAAM campaign and some post-campaign analysis has been secured from the Met Office.

## Timelines

Location	Latitude	Longitude	Start date	End date	Activity
Met Office UK			2016- 09-20	2017- 12-31	Engage snow and sea-ice physicists to collaborate on snow sampling as part of MACSSIMIZE. Partners to apply for funding to participate in analysis of campaign data and

<b>Location</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Start date</b>	<b>End date</b>	<b>Activity</b>
Labrador Sea and Alaska			2018-02-01	2018-03-31	1+ week campaign in Labrador then 2+ week campaign in Alaska (collaborators plan to apply for more funding to extend these campaign periods)
Met Office UK			2018-04-01	2021-12-31	Analysis of airborne and ground-based data; evaluation of emissivity models; testing boundary layer and cloud parameterizations; evaluation of high resolution models with airborne data; intercomparison of Met Office models with each other and with those of other YOPP projects; trials of assimilation of satellite sounder data over sea-ice using snow emissivity parameterizations