MSc- and BSc-projects at the DMI

2022-2023

Danmarks Meteorologiske Institut

DMI, October 2022

Student Research Projects

This catalogue is the result of an effort to collectively present the ideas that researchers at the National Center for Climate Research (NCKF) and Weather Research (VF) at DMI) have for MSc and BSc projects.

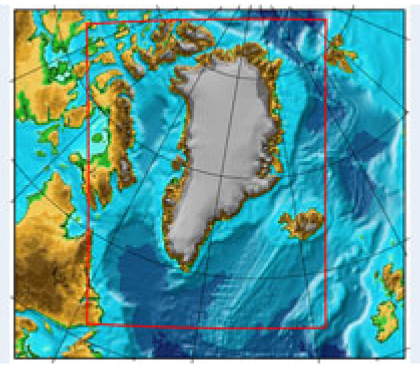
Some descriptions are in English and some are in Danish. This means nothing neither for the working language during the project nor for the language of the final report.

Best wishes,

Secretariat for NCKF and VF departments
Danmarks Meteorologiske Institut/Danish Meteorological Institute

Danmarks
Meteorologiske
Institut

Klimaændringer i havet omkring Grønland og i Arktis



DMI er ved at lave en analyse af de fysiske forhold i havet omkring Grønland og i Arktis for perioden 2003-nu. De oceanografiske felter kan f.eks. bruges til at studere de store ændringer i udbredelsen af den arktiske havis der er sket de sidste 10-20 år eller til at studere de store hydrografiske ændringer observeret i de sydøst- og vestlige grønlandske farvande i samme periode. De oceanografiske felter kan også danne baggrund for studier af det grønlandske marine miljø. Felterne kan således bruges til at drive f.eks. marine biologiske, kemiske eller andre modeller, som afhænger af de fysiske parametre.

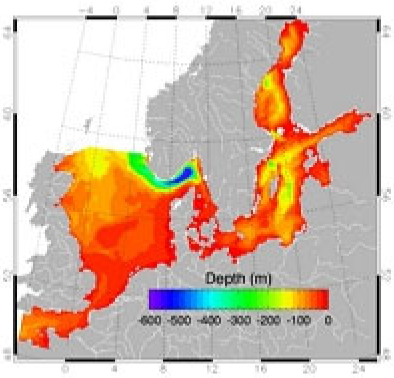
Kontakt: Kristine S. Madsen (kma@dmi.dk)

Sea Ice Thickness

En komparativanalyse af havis tykkelser i det Arktiske Ocean baseret på model data udviklet af Danmarks Meteorologiske Institut, satellit data (f.eks. CryoSat-2), samt supplerende observations data indsamlet fra fly og bøjer. (In English: A comparative analysis of sea ice thicknesses in the Arctic Ocean based on models developed by the Danish Meteorological Institute, satellite data (e.g. CryoSat-2) and supplementary observations collected from aircraft and buoys).

Kontakt: Till A. Rasmussen (tar@dmi.dk)

Simulering af vandmasserne omkring Danmark



DMI's operationelle havmodel HBM beregner strøm, salinitet og temperatur i Nordsø – Østersøområdet. Ved hjælp af en kunstig tracer er det muligt at følge vandmasser med forskellig oprindelse, fx hvordan vand fra Tyske Bugt bevæger sig langs den jyske vestkyst og ind i Skagerrak og Kattegat.

Kontakt: Jacob Woge Nielsen (jw@dmi.dk)

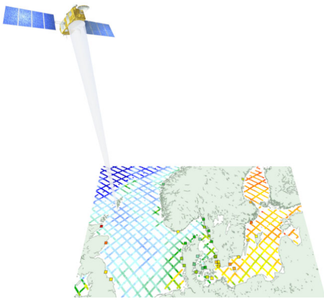
Hav- og istemperaturer i Arktis, observeret fra satellit

Arktis er et af de områder på jorden, hvor klimaændringerne har den største effekt. Vil du være med til at fastlægge hvor og hvordan temperaturændringerne har fundet sted, så er der her et spændende projekt for dig. Satellitobservationer af havoverfladetemperatur er en veludviklet videnskab og bliver i dag benyttet både i oceanografiske og meteorologiske modeller på DMI. DMI har foretaget en reprocessering af satellit SST tilbage fra 1982 of frem til nu. Dette datasæt er det bedste der findes for Arktis og kan bruges til at fastlægge klimaforandringer i de sidste 30 år for det åbne ocean.

Som noget helt nyt har DMI også udviklet metoder og algoritmer, der bestemmer temperaturen af overfladen af hav-isen, og sammen med havets overfladetemperatur kender man dermed overfladetemperaturen overalt i Arktis. Disse nye og eksperimentelle produkter skal først valideres mod in situ observationer, hvorefter de kan bruges til at fastlægge temperaturforandringer i Arktis for både hav- og istemperatur med meget større detaljegrad end hidtil.

Kontakt: Jacob Høyer (jlh@dmi.dk)

Havets overfladehøjde målt fra satellit



Over det åbne ocean kan havets overfladehøjde måles med få centimeters nøjagtighed. Hvis vi kan opnå samme præcision i de Indre Danske Farvande og andre kystnære områder, vil det give mulighed for en række vigtige studier, f.eks. af vandudvekslingen mellem Østersøen og Nordsøen, og af den lokale geoide. Kystnær satellitaltimetri kan også blive vigtig for stormflodsvarslingen. Danmark er førende inden for kystnær satellitaltimetri i vores havområde, og du kan få glæde af det velfungerende samarbejde mellem DMI og DTU Space.

Kontakt: Jacob Høyer og Kristine S. Madsen (jlh@dmi.dk og kma@dmi.dk)

Human Influence on the Variability of Climate (in Europe/NH) and Circulation Patterns

A possible consequence of global warming is the change of the distribution of the climate variability, hence the return of the extreme events. This study is to investigate whether the anthropogenic warming can lead to changes in the variability of (1) surface climate (i.e., patterns and frequencies in extremes); (2) atmospheric circulation patterns such as North Atlantic Oscillation (NAO) and the multi-decadal Atlantic Oscillation (MAO); and (3) the deep ocean circulation, i.e., Atlantic meridional overturning circulation (AMOC). The interconnections between the climate and these circulation patterns under different forcing conditions will also be investigated.

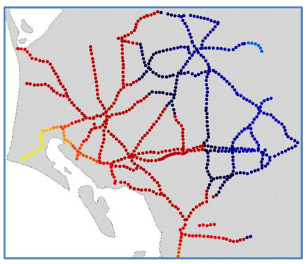
Contact: Shuting Yang (shuting@dmi.dk)

The Role of Greenland Ice Sheet on the Climate System

Recent observation and model studies have shown that Greenland and Antarctic ice sheets can respond to atmospheric and ocean warming on relatively short time scales of a decade or less. Understanding and quantifying the response of the ice sheets to climate change and the ice sheet feedbacks to the climate system requires a climate model system that are dynamically coupled with an ice sheet model. One of such a model, the EC-EARTH – PISM coupled model, has recently been developed which incorporate the dynamical interaction of the Greenland ice sheets (GrIS). A number of control and $4xCO_2$ simulations of more than 350 years have already performed using the coupled (EC-EARTH – PISM) and uncoupled (EC-EARTH) model.

Contacts: Shuting Yang (shuting@dmi.dk), Marianne S. Madsen (msm@dmi.dk)

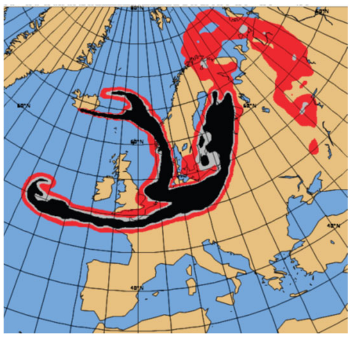
Processing and Quality Control System for Thermal Mapping Measurements



The road weather forecasts with a focus on prediction of the slippery road conditions are performed by the Road Weather Modelling System (RWMS), and it is an important operational product produced by DMI in collaboration with the Danish Road Directorate (DRD). Recently the RWMS extended its applicability with focus on detailed road stretch forecasting at distances of 1 km and even down to 250 meters along the driving lanes, and hence, information about spatial variability of observed icing conditions on roads or situations leading to such danger became needed. Ice on road surfaces is one of the most serious and dangerous meteorological hazardous phenomenon, and it is well known that annually it causes serious injuries and even deaths in road accidents.

Contact: Claus Petersen (cp@dmi.dk)

Comparing Different Remote Sensing Estimates Of Earth's Albedo



The shortwave reflectivity of Earth (its 'Albedo') is a factor in the radiative energy balance of Earth. Changes in Albedo can be important indicators of changes in the **climate** system. Usually satellite data (images) are used to map the evolution of Earth's Albedo, since the start of the satellite era. Satellite instrument sensitivities drift with time and the systems must be calibrated. This can be done on terrestrial targets (such as salt deserts or ice sheets) from space, but accuracies better than 1% are difficult to attain, and therefore unacceptable drifts in satellite-based Albedo products probably occur. This makes satellite based Albedo data difficult to use for climate change studies. And alternative means of finding Albedo is to use observations of the Moon's dark side (the side only illuminated by Earth's own light) relative to its bright side. Hemispheric-average Albedo can thereby be determined, on the basis of Earth-surface modelling and knowledge of the Moon's surface properties from lunar-orbiting satellites such as the Lunar Reconnaissance Orbiter.

Meteorological uncertainty of the Prediction of the Atmospheric Dispersion of Hazardous Substances from an Accidental Release

In the event of a large accidental release of radioactivity or other harmful substance to the atmosphere, DMI predicts the dispersion of the released gasses and particles with the Danish Emergency Response Model of the Atmosphere (DERMA) using in-house Numerical Weather Prediction (NWP) model data.

As a result of the two recent Nordic research projects MUD and FAUNA, a methodology has been developed to assess the potentially large associated uncertainties stemming from meteorology by using data of the DMI NWP ensemble model system.

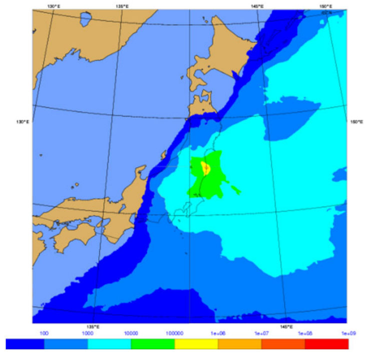
Contact: Jens Havskov Sørensen (jhs@dmi.dk)

Meteorological Uncertainty of The Prediction of The Dispersion of Volcanic Ash

In the event of a volcanic eruption, DMI predicts the atmospheric dispersion of volcanic ash that affects air traffic, and the deposited ash that may affect grazing ruminants. The Danish Emergency Response Model of the Atmosphere (DERMA) is used by an operational system at DMI to predict the dispersion and deposition of volcanic ash from eruptions. However, the uncertainties of the resulting plume predictions, and consequences for air traffic management, have not been estimated before.

Contact: Jens Havskov Sørensen, jhs@dmi.dk

Advanced Albedo Modelling with the HARMONIE Greenland Weather Model

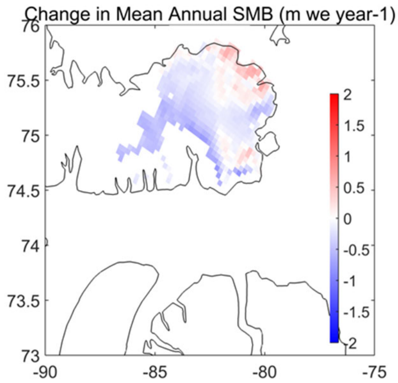


The albedos of snow and ice are of great importance for the surface energy balance in the Arctic. They are often considered to be a number ranging from 0 to 1 that gives the reflectance of shortwave (solar) irradiances. A more elaborate description of albedos includes their dependences on the angular distribution of spectral radiances. This description can be used in the framework of the HARMONIE Greenland weather model.

Contact: Kristian Pagh Nilsen (kpn@dmi.dk)

Assessing the Health of Small Glaciers and Ice Caps in the Arctic

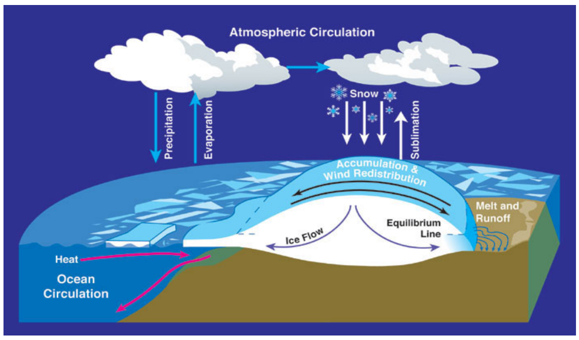
Small glaciers and ice caps are disproportionally important in Greenland as they receive large amounts of snow and experience large amount of melting. Around the Arctic, some of the best mass balance records are found on the smaller glaciers and ice caps, giving good possibilities to validate records. However, the small size of these ice caps makes them tricky to resolve in most regional climate models and innovative techniques to statistically compare modelled and observed meteorological and glaciological variables are required. In this project, the output from very high resolution (~5km) simulations by the RCM HIRHAM5 covering Greenland, Svalbard and Eastern Arctic Canada will be made available to the student to analyse and compare with observations for key ice caps and glaciers including for example, but not limited to: Devon Ice cap, Renland Ice cap (Greenland), Mittivakat ice cap (Greenland), Midre Lovenbreen (Svalbard).



Contact: Ruth Mottram (rum@dmi.dk)

Attributing Changes in Surface Mass Balance in Greenland to Climate Change

The Arctic as a whole has warmed much more than other parts of the globe in the last decade and at the same time increasing surface melt in Greenland has led to ever higher losses of mass from the ice sheet. This melt is due in part to higher temperatures and also clear skies in summer that enhance melt through an albedo feedback. In addition, precipitation variability may also play a role in reducing the amount of snow cover on the ice sheet in spring.



Surface mass balance (SMB) is defined as the sum of snowfall (positive) and ablation (negative) where ablation includes melt water that runs off the ice sheet and evaporative fluxes from the surface. These processes are modelled successfully at very high resolution in the HIRHAM5 Regional Climate Model (RCM) run at DMI. In Greenland, variability in SMB correlates with regional and hemispheric scale climate variability, for example the North Atlantic Oscillation, the Arctic Oscillation and the Atlantic Multi-Decadal oscillation. Recent analysis has shown that the total mass balance of the ice sheet is dominated by the surface mass balance and it is therefore crucial to understand what the controls on SMB are in order to both make accurate projections of sea level rise and to be able to attribute recent changes in SMB trends to natural or anthropogenic changes.

Contacts: Ruth Mottram (rum@dmi.dk), Peter Thejll (pth@dmi.dk)

Resolution Effects in Ice Sheet Modeling

When running an ice sheet model, a set of input data is needed to drive the model. These corresponding records of temperature and surface mass balance or precipitation are usually taken from a climate model. The resolution of the climate model is much coarser than the resolution of the ice sheet model and various interpolation schemes transform the data from one grid to another. But how dependent is the response of the ice sheet on the resolution of the initial climate model? When increasing the climate model's resolution, more features caused by e.g. local topography become apparent, but how will the ice sheet model respond to this? As an example, a better representation of the coastal orography of Greenland may shift precipitation patterns, thereby affecting the forcing fields for the ice sheet. This study will be comprised of running the ice sheet model PISM over Greenland forced by a number of climate model (HIRHAM) runs at various resolutions and comparing the various outcomes in order to identify any effects of resolution of the driving model.

Contact: Ruth Mottram (rum@dmi.dk)

Ice Drift Model Forecast Skill

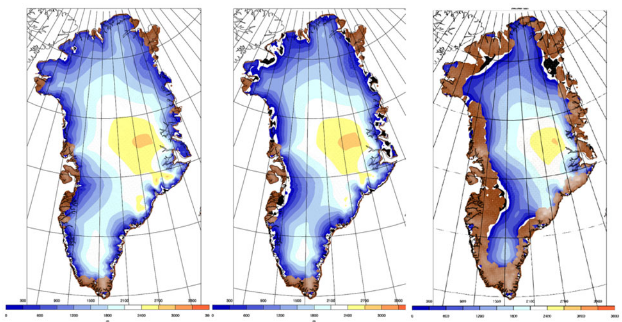
Sea ice in the arctic ocean is constantly moving, driven by wind and ocean forcing. We observe ice drift by gps equipped buoys and by tracking the ice using daily satellite radar images. In addition, we try to estimate the ice drift by applying ice drift prediction models. Buoy locations are transmitted via satellite communication link (typically iridium) every 1-2 hours while satellite observations are typically available ever 1-2 days. From the satellite observations, it is thus possible to determine ice drift over a period of 24-48 hrs.

We have ice drift predictions from DMI's own ice/ocean models as well as from the Copernicus marine core service global and regional operational forecast models. The DMI model delivers ice drift forecasts for every hour, whereas only daily average ice drift is available from the Copernicus models. Predictions typically reach 5-10 days into the future and are periodiced 1-2 times per day.

Contact: Till Rasmussen (tar@Dmi.Dk)

Sea Ice Surface Emissivity at Millimeter Frequencies (183 – 664 Ghz)

The next generation of European operational meteorological satellites the EUMETSAT polar system – second generation (ESP-SG launch in 2022) will carry the ice cloud imager (ICI) instrument measuring the top-of-the atmosphere microwave emission at 11 channels between 183 and 664 GHz. This will expand the current capabilities for weather prediction, especially under cloudy conditions, but this is challenging as the radiative transfer models have not been fully developed and evaluated yet up to these frequencies. In fact no effort has been made yet towards the development of the surface emissivity models at these high frequencies. At low latitudes the atmosphere is virtually opaque at ICI frequencies due to water vapor absorption. However, for the dry atmosphere, it is expected that a portion of the signal received by the satellite will come from the surface and in these cases a reliable estimate of the surface emissivity will be necessary to account for this surface contribution and perform an accurate retrieval of the atmospheric properties which is the aim of the mission. The large transmission will likely occur around the poles and at mid-latitudes during winter, i.e. regions covered by snow and sea ice.



Contact: Fabrizio Baordo (fab@dmi.dk) and Johanne Øelund (joe@dmi.dk)

Assimilation of GPS Radio Occultation Profiles in the HARMONIE Model

Radio Occultation (RO) measurements utilizing the Global Positioning System (GPS) is an emerging technique which probes the atmosphere horizontally, as opposed to conventional satellites that views the atmosphere from above.

GPS RO measurements complement conventional satellite retrievals have proven very valuable for initializing global numerical weather prediction (NWP) models. The assimilation of GPS-RO data in NWP can be done without bias correction as opposed to all other assimilated data, and therefore they serve as a unique tool for anchoring the models.

Contacts: Stig Syndergaard (ssy@dmi.dk og Johannes K. Nielsen (jkn@dmi.dk)

Study of Nonhydrostatic Effects with HARMONIE Model

Hydrostatic balance is an approximation used extensively in meteorology. Under this assumption, pressure gradient in the vertical is balanced by gravity and vertical acceleration can be neglected in the vertical component of the momentum equation, resulting in great convenience in numerical weather prediction and in observation technique for measuring atmospheric profiles. Hydrostatic balance, however, breaks down when aspect ratio of meteorological phenomena, i.e., the ratio between vertical and horizontal scales of the motion, approaches 1. This corresponds to situation with significant vertical acceleration, often seen in strong convection, and orographic induced flow associated with steep orography.

Contact: Xiaohua Yang (xiaohua@dmi.dk)

Neighborhood Forecast in Post-Processing of HARMONIE Forecast

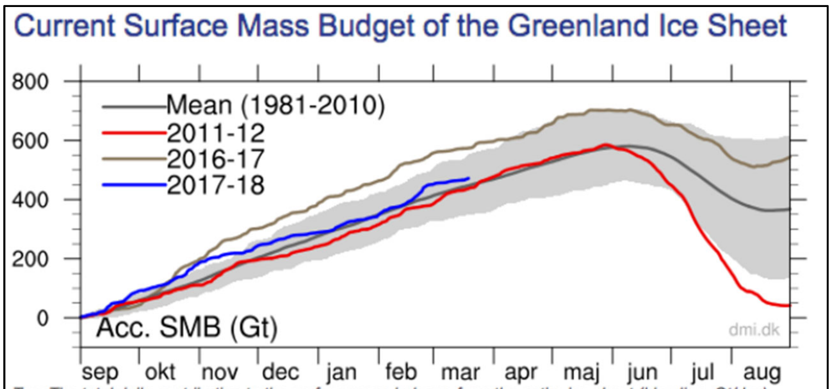
HARMONIE is the mesoscale Numerical Weather Forecast (NWP) model used at the Danish Meteorological Institute for routine short range weather prediction, which has shown great potential in prediction of high impact weather. As a convection-permitting model, HARMONIE resolves directly deep convection, resulting in more realistic description for small scale, strongly convective weather situation. On the other hand, it is a major challenge to base on fine scale model output for prediction of individual points.

In this study, we explore and evaluate use of neighborhood method to post-process HARMONIE model output for individual points to provide forecast with additional probabilistic information. Such forecast takes into account spatial scales with predictive skills, the uncertainty in model prediction on temporal and spatial phases. The proposed work is inspired by the research at UK Met Office on verification of mesoscale model with in-situ measurement (Mittermaier, 2014).

Contact: Xiaohua Yang (xiaohua@dmi.dk

How much of the surface of the Greenland ice sheet is melting?

The Arctic is one of the regions of the world, where the climate changes are most pronounced. The changes in the Arctic affect the global climate, for example by increasing global sea level through the reductions in the volume of the Greenland ice sheet.



Top: The total daily contribution to the surface mass balance from the entire ice sheet (blue line, Gt/day). Bottom: The accumulated surface mass balance from September 1st to now (blue line, Gt) and the season 2011-12 (red) which had very high summer melt in Greenland. For comparison, the mean curve from the period 1981-2010 is shown (dark grey). The same calendar day in each of the 30 years (in the period 1981-2010) will have its own value. These differences from year to year are illustrated by the light grey band. For each calendar day, however, the lowest and highest values of the 30 years have been left out.

Contact: Jacob L. Høyer (jlh@dmi.dk)

Integration of remote sensing data into ocean and sea ice models

Integration of remote sensing data into ocean and sea ice models is used for both validation and assimilation. With the right combination of supervisor from DTU and DMI a wide range of studies can be setup.

One example of the more challenging fields is to measure sea ice thickness based on altimetry. The satellite measures the freeboard, which includes some assumptions about the snow cover. The ocean and sea ice model has knowledge about both sea ice thickness and snow thickness, therefore a study of how the freeboard is represented in the remotely sensed observations and the coupled model system is interesting.

Contact: Till Rasmussen (tar@dmi.dk)

Using AI in retrieval of humidity and temperature from GNSS radio occultation

Global Navigation Satellite Systems (GNSS), such as GPS are being used in weather forecasting and climate research in many ways. One of the more exotic ways, the Radio Occultation (RO) technique, exploits the signals emitted from navigation satellites by observing the atmospheric refraction of the emitted radio waves, passing horizontally through the atmosphere. The receiver is mounted on another satellite, traveling in a low orbit (see illustration). Due to vertical density and humidity gradients the path of the radio signal is bended by the atmosphere.

Contact: Johannes K. Nielsen (jkn@dmi.dk)

MSc projects at the DMI Research Department, Climate Section

Topic: Global and Regional Climate Modelling

1. The Atlantic Multidecadal Variability and its representation in the global climate model ECEarth3
Contact person: Annika Drews andr@dmi.dk

2. Assessing the change of annual cycle observed in the recent years and the discrepancy in global climate models
Contact person: Shuting Yang (shuting@dmi.dk)

3. Forced and internal variability of atmospheric circulation modes over the North Atlantic – Eurasian region (and impacts to European climate)
Contact person: Shuting Yang (shuting@dmi.dk)

4. Assessment of the changes in jet streams under climate warming as simulated by CMIP6 models
Contact person: Shuting Yang (shuting@dmi.dk)

5. How much ice will melt on the Greenland ice sheet out to 2100? Application of a new SMB model to a range of CMIP6 global climate models under different emissions pathways
Contact persons: Ruth Mottram and Christian Rodehacke (rum@dmi.dk , cr@dmi.dk)

Topic: Greenland Ice Sheet

1. Modeling the response of the Greenland Ice Sheet to Extreme precipitation.
Contacts: Nanna B. Karlsson (nbk@geus.dk) or Marianne S. Madsen (msm@dmi.dk)

2. Iceberg calving Processes in Inglefield Bredning: A tale of two glaciers
Contacts: Ruth Mottram (rum@dmi.dk), Christian Rodehacke (cr@dmi.dk), Marianne S. Madsen

3. Compatible Surface Mass Balance (SMB) calculation at weather stations on the Greenland ice sheet via genetic optimization techniques.
This masters project aims to find a consistent set of parameters controlling the SMB model CISSEMBLE (Copenhagen Ice Snow Surface Energy and Mass Balance modEL). Accordingly, optimization techniques are applied at an AWS (automatic weather station) location where parallel measurements of the snow properties are available, such as the PROMICE stations around the Greenland ice sheet. The candidate will simulate the surface mass balance with CISSEMBLE, for instance, and work with standard python modules to perform the task. The final product is an optimal calibrated CISSEMBLE model that reproduces the observed snow state. In addition, the machinery shall be made available as a toolbox for DMI's SMB model CISSEMBLE.
Christian (CISSEMBLE) cr@dmi.dk , Mark Payne (genetic algorithm optimization technique) mapa@dmi.dk

4. Effect of topographic evolution in modulating Greenland ice sheet loss.
Contact person: Ruth Mottram (rum@dmi.dk)

Topic: Machine Learning Techniques

1. Using Machine Learning techniques to correct the trajectories of freshwater from Greenland in a low resolution model
Subject: Computational time of very high resolution model is expensive. Therefore, global climate model usually run with a resolution of one degree in the ocean, 1/4 of a degree for the new generation to come. At these resolutions, the trajectories of the freshwater coming from the coast are not well resolved and we propose here to use deep learning-based super resolution approaches trained on a 1/24 of a degree resolution simulation of the model NEMO forced by a realistic set of freshwater fluxes coming from Greenland Ice Sheet (GrIS) Melting. The trained CNN will then be used for simulation at one and 1/4 of a degree with the EC-Earth3 climate model to properly account for the acceleration of the melting of GrIS in the last decades by correcting the fate of the additional freshwater input in the ocean.
Contact: Marion Devilliers (mde@dmi.dk)

5. Mapping sea ice leads with machine learning tools Master thesis topic: Sea ice lead-width mapping with machine learning
Contact: Tian Tian (tian@dmi.dk)

In recent decades, sea ice in the Arctic Ocean has been melting faster than it re-freezes in winters. The accurate seasonal forecast of Arctic sea ice on regional spatial scales is a pressing need for maritime transport, oil and fishery industries and tourism. Sea-ice leads, namely narrow (meters to kilometers) openings in the Arctic sea ice cover, in winter are potential predictors for summer Arctic sea ice extent forecasts. In the central Arctic, where leads only cover 1.2% of the ocean during winter, they contribute to more than 70% of the upward heat fluxes. Furthermore, heat transport over narrow leads is more efficient than over larger ones. However, sea ice forecast systems with coupled atmosphere-ice-ocean model components generally have too coarse a resolution (~100 km) to simulate leads explicitly. Therefore, there is an increasing interest in parametrization and modeling the effect of lead width on winter turbulent exchange over the Pan-Arctic region. In this project, verification datasets for lead parametrization are needed and the work is aimed at:

1) integrating* and improving the existing sea ice lead database by processing SAR images with machine learning image classification technique.
2) parameterizing (e.g., empirical formula) leadwidth distribution based on sea ice thickness thresholds for the marginal ice zone (thin ice) and the central Arctic (thick ice), respectively.
3) producing Pan-Arctic leads-width mapping (e.g. flag information of narrow lead (<5km) area fraction) at model resolution (0.25~1 degree). * The student is expected to employ transfer learning techniques in multi-satellite products to overcome the limitations in spatial and temporal coverage, and the inconsistency in different algorithms applied to different data sources at different resolutions.