MSc- and BSc-projects

at

DMI

Primo 2017

Danmarks
Meteorologiske
Institut

DMI, May 2017

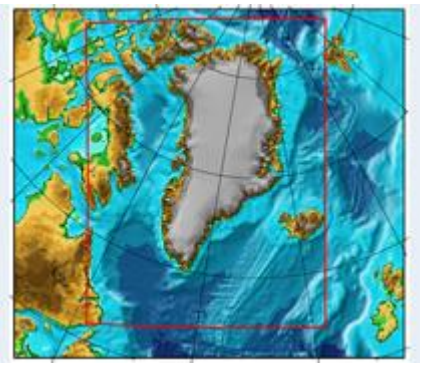
The following catalogue is the result of an effort to collectively present the ideas that researchers at FU (Forskning og Udvikling, DMI) have for MSc and BSc projects.

Some descriptions are in English and some are in Danish. This means nothing for the working language during the project or the language of the final report.

Best wishes.

FU team

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

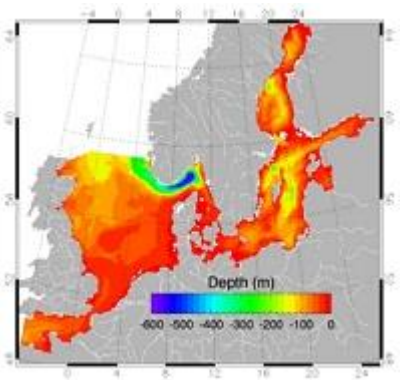
En komparativanalyse af havis tykkelser i det Arktiske Ocean baseret på model data udviklet af Danmarks Meteorologiske Institut, satellit data (f.eks. CryoSat-2), samt supplerende observations data indsamlet fra fly og bøjer. (In English: A comparative analysis of sea ice thicknesses in the Arctic Ocean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

Udbydende beskrivelse

Havisen har en stor påvirkning på det globale klima, og når Jordens temperaturer ændrer sig er havisen, det første der bliver påvirket. For at bestemme havis volumen i det Arktiske ocean, skal havis tykkelsen bestemmes. Havistykkelser i det Arktiske Ocean bestemmes i dag fra modeller (se Polar Portalen) og fra satellit altimetri (CryoSat-2). Desværre er valideringen af diverse Arktiske havis tykkelser sparsom, men ekstrem vigtig for at kunne forstå de tilhørende fejlkilder. Dette projekt vil netop involvere en sammenligning af model og satellit data, samt validering af disse ved at inkludere uafhængige data sæt af havistykkelsen fra observationer foretaget fra fly og/eller bøjer. (In English: Sea ice is strongly affecting the global climate. To estimate the Arctic Sea ice volume the sea ice thickness must be determined. Today sea ice thicknesses are obtained either by models (see Polar Portalen), or by satellite altimetry (CryoSat-2). Unfortunately, validation of the Arctic Ocean sea ice thickness products are sparse, but extreme important in order to understand the associated error sources. The aim of this project is an inter-comparison study of model and satellite data, together with validation of the related error sources by including independent observations obtained by aircraft and/or buoys).

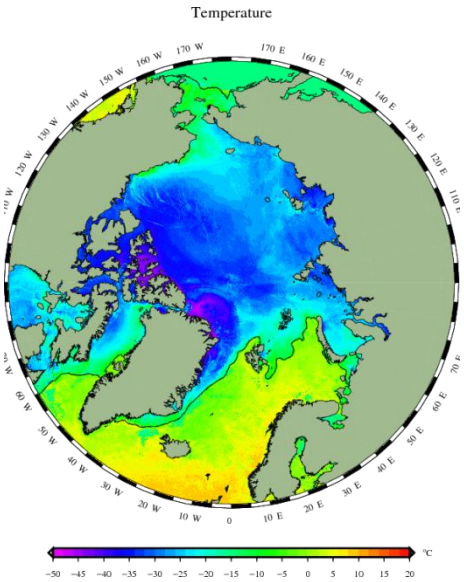
Kontaktperson: Till A. Rasmussen (tar@dmi.dk)

Simulering af vandmasserne omkring Danmark



DMIs operatinelle 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

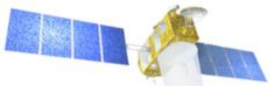


Arktis er et af de områder på jorden, hvor klimaændringerne har den største effekt. Vil du være med til at fastlægge hvor og hvordan temperaturændringerne har fundet sted, så er der her et spændende projekt for dig.

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 satellite 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.

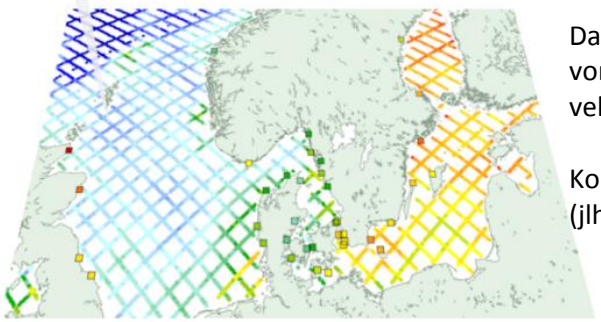
Som noget helt nyt har DMI også udviklet metoder og algoritmer, der bestemmer temperaturen af overfladen af hav-isen, og sammen med havets overfladetemperatur kender man dermed overfladetemperaturen overalt i Arktis. Disse nye og eksperimentelle produkter skal først valideres mod in situ observationer,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

Kunne du tænke dig at være med til at lave noget af det spædende arbejde, så kontakt Jacob Høyer (email: 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 stromflodsvarslingen.



Danmark er førende indenfor 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

Contacts: Shuting Yang (shuting@dmi.dk)

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 (ie., 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.

The work will take the advantage of the existing 450+ year EC-EARTH simulations under 4xCO2 (abrupt and 1% per year increase) and pre-industrial control, and carry out analyses of variability and extremes of temperature and precipitation, Arctic sea ice, variability of NAO and MAO, etc. One of the focuses will be on the connection between the NAO, the MOC and the Arctic.

The role of Greenland ice sheet on the climate system

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

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 4xCO2 simulations of more than 350 years have already performed using the coupled (EC-EARTH – PISM) and uncoupled (EC-EARTH) model.

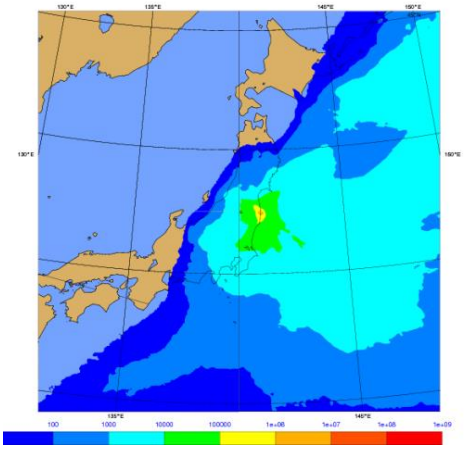
The suggested study aims at exploring the role of GrIS and its feedback on the climate system. The work will carry out the following analyses in the exiting simulations of the EC-EARTH – PISM model under the 4xCO2 forcing (abrupt and 1% per year increase):

1. Quantify the fresh water flux into the ocean from GrIS melt and its impact to the North Atlantic and the Arctic ocean;
2. Quantify the difference in radiative forcing with and without the GrIS feedback;
3. Investigate the difference of the Arctic sea ice formation/exportation with an interactive GrIS in the system.

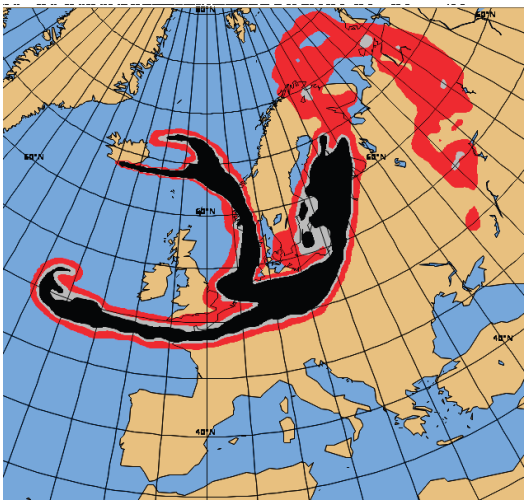
Student research project

Project title:	**Comparing different remote sensing estimates of Earth's albedo**
Level:	Masters
Contact:	Peter Thejll (pth@dmi.dk) and Hans Gleisner (hgl@dmi.dk)
Background:	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. An automatic telescope to observe the earthshine on the Moon was designed and built, and the system operated on Mauna Loa in Hawaii for two years. Data from this observation sequence must be compared to satellite-based Albedo estimates. The purpose is to verify that the two methods measure average Albedo comparably and to estimate the level of precision and accuracy that can be reached in both methods given natural Albedo variability.
Tasks:	Satellite-data (images from geostationary satellites – e.g. GEOS West or Japan's MTSAT) must be downloaded for dates on which lunar observations were performed. Low-Earth Orbit albedo data, in the form of cloud products and surface albedo products (e.g. from the CM-SAF project, or similar), can also be acquired, also for relevant dates. Depending on student's level and interests data from earthshine observations and satellites are then compared in various ways. First a simple correlation study must be performed to see level of co-variability in the datasets. Second, Earth models, using surface property products, geometry, and reflectance functions, can be built so that 'scene' pictures of the way Earth looked at the moment of lunar observations can be generated. Third, if the Earth model is correctly parametrized it becomes possible to 'fit' earthshine observations by varying the Earth model Albedo-parametrization, so that best fitting properties of Earth are determined. Assessment of expected levels of natural variability and the impacts of this on the required length of observing periods is to be performed. An understanding of the expected levels in long-term albedo-change, given simple climate physics and observed, or future estimates, of climate change, is to be developed.
Partners:	DMIs Climate and Arctic Research Division
Prerequisites:	Experience with programming in e.g. Python, matlab or Fortran.
Links:	

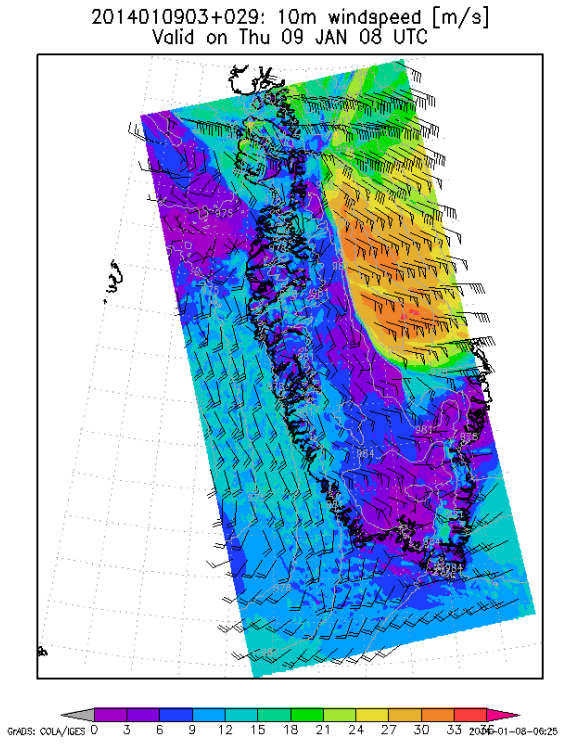
Student research project

Project title:	**Meteorological uncertainty of the prediction of the atmospheric dispersion of hazardous substances from an accidental release**
Level:	Master
Contact:	Jens Havskov Sørensen (jhs@dmi.dk), DMI, Research and Development department, Model Development
Background:	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.  
Tasks:	The student(s) will develop the methodology further and apply it to selected scenarios, e.g. the accident in 2011 at the Fukushima Daiichi nuclear power plant, and thereby address associated consequences for emergency management.
Partners:	
Prerequisites:	Fortran Linux (Unix)
Links:	http://www.nks.org/en/nks_reports/view_document.htm?id=111010212220490 http://www.nks.org/en/nks_reports/view_document.htm?id=111010212977216

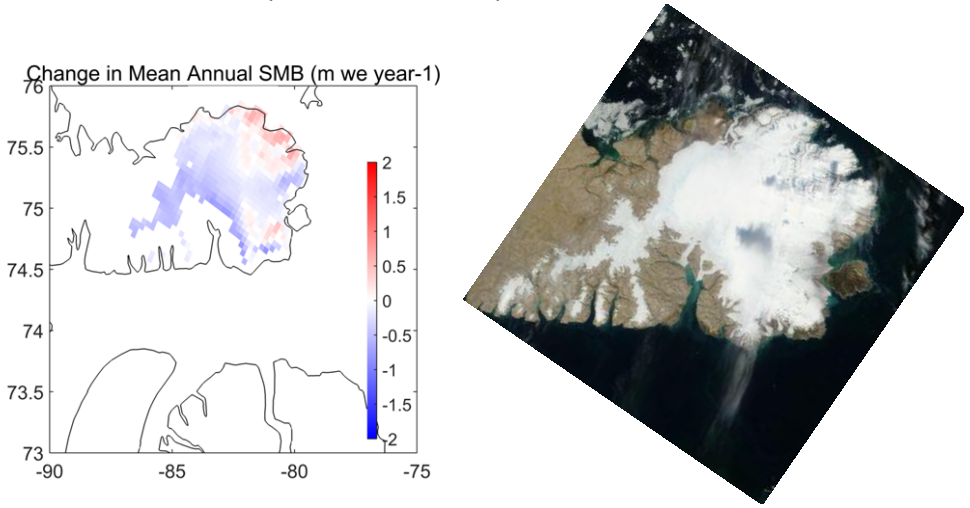
Student research project

Project title:	**Meteorological uncertainty of the prediction of the dispersion of volcanic ash**
Level:	Master
Contact:	Jens Havskov Sørensen (jhs@dmi.dk), DMI, Research and Development department, Model Development
Background:	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. 
Tasks:	In this project the student(s) will use DERMA to simulate eruptions of Icelandic volcanoes (possibly hypothetic eruptions) using ensemble data from a Numerical Weather Prediction (NWP) model system, e.g. from the European Centre for Medium Range Weather Forecasts. The dispersion ensemble will be used to study the effects of meteorological uncertainties on ash dispersion, and risk maps indicating the probability for exceeding threshold concentration levels (indicating air-space closure) will be produced. Both deposition to the surface of the Earth and air concentration levels at various heights above the surface will be considered.
Partners:	
Prerequisites:	Fortran Linux (Unix)
Links:	http://dams.dk/vejret/arkiv/vejret-126.html

Student research project

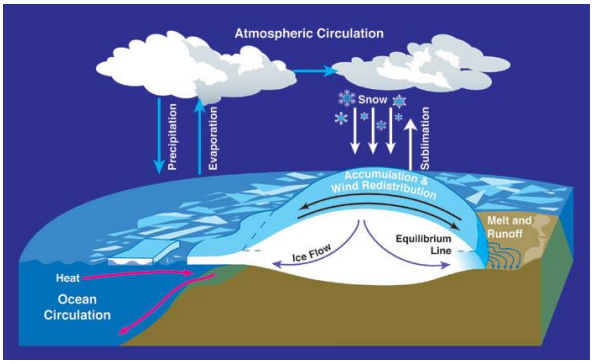
Project title:	**Advanced albedo modelling with the HARMONIE Greenland weather model**
Level:	Master student
Contact:	Kristian Pagh Nielsen (kpn@dmi.dk) , DMI, Research and Development Department
Background:	The albedos of snow and ice are of great importance for the surface energy balance in the Arctic. 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. The HARMONIE model is run for South Western Greenland with a resolution of 2 km. It is a state-of-the-art weather model for forecasting and re-analysis. It includes the advanced SURFEX surface physics module that can be run with snow models such as 3-L and Crocus. With the HARMONIE model is it possible to run with either 2, 4, 6 or14 shortwave spectral bands. The model can be run both as a 1-dimensional atmospherice model and a full 3-dimensional atmospheric model that is run in real time. With the 1-dimensional model the sensitivity of various albedo schemes can be tested. The issue of spectral resolution is generally interesting for both weather and climate models. 
Tasks:	Data analysis, Numerical weather prediction model runs.
Partners:	DMI, the ALADIN-HIRLAM consortium
Prerequisites:	Optics or general electro- magnetic theory at an adequate level and have experience with basic programming languages as for instance Matlab or Fortran
Links:	http://research.dmi.dk/research/research-topics/numerical-weather-prediction/ http://www.cnrm.meteo.fr/aladin/

Student research project

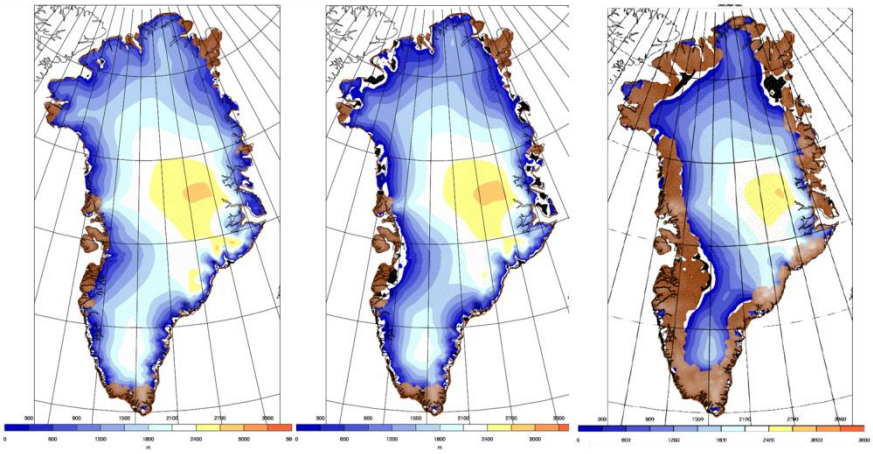
Project title:	**Assessing the health of small glaciers and ice caps in the Arctic**
Level:	MSc or BSc
Contact:	Ruth Mottram (rum@dmi.dk), DMI, Research and Development Department
Background:	Small glaciers and ice caps are disproportionally important in Greenland as they receive large amounts of snow 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). This is a broad and flexible project with scope for the student to branch into several different areas according to what they find interesting. There is a possibility for the student to travel to one or more of the glaciers in question on fieldwork and there will also be scope for the student to run sensitivity studies with the HIRHAM5 model to improve parameterization schemes. Numerical competence with for example, Matlab or Python (MATplotlib) is an essential pre-requisite for this project, though some instruction will be given. Some insight into glacier surface processes and/or the meteorology of the Arctic is an advantage and knowledge of Fortran90 would be helpful but is not a requirement.  *Fig.1 shows the changing surface mass budget (left) of the Devon ice cap (right from Google Earth) in recent decades as calculated with the HIRHAM5 regional climate model.*

Tasks:	Analyse model output and compare with observational datasets for small glaciers and ice caps around the Arctic. Statistical downscaling to refine estimates of accumulation, melt and surface mass balance Modelling using simple offline model to improve projections
Partners:	UNIS (University Centre on Svalbard)
Prerequisites:	Numerical competence with a plotting and analysis tool, for example, Matlab or Python (MATplotlib) is an essential pre-requisite for this project
Links:	

Student research project

Project title:	**Attributing Changes in Surface Mass Balance in Greenland to Climate Change**
Level:	MSc
Contact:	Ruth Mottram (rum@dmi.dk), Peter Thejll (pth@dmi.dk), DMI, Research and Development Department
Background:	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.  In this project we seek an MSc student, comfortable with standard mathematical tools, to conduct a statistical analysis of a simulation of surface mass balance, based on results from the HIRHAM5 regional climate model but possibly also extending to other models. The model output will be compared to observations of large scale circulation indices, in order to understand the relative importance of local and global phenomena.
Tasks:	Statistical analysis of model output compared with standard climatic datasets
Partners:	
Prerequisites:	Some experience with standard mathematical analysis and plotting tools. Insight into statistical techniques for climate.
Links:	

Student research project

Project title:	**Resolution effects in ice sheet modeling**
Level:	MSc
Contact:	Ruth Mottram (rum@dmi.dk), DMI, Research and Development Department
Background:	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.  Ice sheet model topography for present day and future projections using the PISM model
Tasks:	Setting up and running experiments with the PISM ice sheet model Data analysis and plotting results
Partners:	
Prerequisites:	Experience with programming and using plotting and data analysis tools such as Matlab or Python
Links:	

Student research project

Project title:	**Mapping global climate using satellite-based GPS Radio Occultation data**
Level:	Master project
Contact:	Hans Gleisner (hgl@dmi.dk), Danish Meteorological Institute
Background:	Radio Occultation (RO) is a satellite-based technique for measuring the refractive index of the Earth's atmosphere, through the detection of phase shifts of GPS radio signals traversing the atmosphere on a limb sounding path. The refractive index is a simple function of pressure, temperature, and humidity. Hence, the RO technique provides globally distributed data that can be used to generate accurate climate data records. RO instruments are currently flown onboard several satellites – both for operational and research purposes – and the number of RO missions will most likely increase in the future. DMI is the host institute for one of EUMETSAT's Satellite Application Facilities, the ROM SAF. An important task for the ROM SAF is to generate and disseminate global climate data records based on RO data. This is currently done by relatively simple binning and averaging techniques. Studies of alternative climate data generation methods may provide insights into error characteristics and limitations of the methods and data, and may provide opportunities for a more efficient use of the intrinsic spatial and temporal resolution of the globally distributed RO data sets.
Tasks:	The method of fitting global spherical harmonics, or other basis functions, to irregularly distributed RO data will be investigated. The optimal number of basis functions (order and degree of the spherical harmonics), sampling errors of the resulting climate maps, and the useful temporal and spatial resolution obtainable from the present and future constellation of RO satellites can be studied by sampling a global atmospheric model, e.g., a global climate model or the weather prediction model from the European Centre for Medium-Range Weather Forecast. Depending on the time available, and the mathematical background of the student, Bayesian methods can be used to constrain the models to avoid overfitting. The potential of alternative basis functions (e.g., spherical wavelets or splines) can also be studied.
Partners:	The project is associated with EUMETSAT's Satellite Application Facility for RO Meteorology (ROM SAF).
Prerequisites:	Programming experience, good mathematical skills
Links:	http://www.romsaf.org/climate_monitoring

Student research projects

Project title:	**Ice drift model forecast skill**
Level:	Master project (or with reduced scope Bachelor project)
Contact:	Till Rasmussen (tar@dmi.dk)
Background:	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 hours. 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.
Tasks:	The purpose of the project is to compare the different datasets (in-situ, satellite and model) taking into account their spatial and temporal properties. The observations (in-situ and satellite) shall be used to validate and compare the forecasts, including validation of the forecast skills etc. The observation dataset in addition can be used to investigate empirically the relationship between wind and icedrift (how large a fraction of the variability in ice drift can be explained by variability in wind, and do we see trends in observed ice drift over the last 10-20 years that cannot be explained by trends in wind?) A potential extension (depending on the scope of the project) is to use the DMI ice drift model to experiment with changing drag coefficients to try to improve the ice drift prediction skills.
Prerequisites:	Python or Matlab. Understanding of ocean models
Links:	

Student research project

Project title:	**Sea ice surface emissivity at millimeter frequencies (183 – 664 GHz).**
Level:	Master
Contact:	Rasmus Tonboe, DMI, rtt@dmi.dk
Background:	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.
Tasks:	The task of this project is to simulate the snow and sea ice emissivity and effective temperature at ICI frequencies using existing and possibly new combinations of model modules. In particular: 1) literature review of the ice permittivity and emission models at ICI frequencies 2) estimate the penetration depth in snow at ICI frequencies 3) use simple surface scattering models to simulate the reflectivity 4) use existing snow emissivity models to simulate the emissivity and compare 5) compare volume and surface scattering contributions to the emission
Partners:	The ESA MWI-ICI science advisory group.
Prerequisites:	Basic programming skills in matlab, python or similar.
Links:	https://directory.eoportal.org/web/eoportal/satellite-missions/m/metop-sg

Student research project

Project title:	**Mapping ionospheric scintillations in GNSS radio occultation measurements**
Level:	Master's project
Contact:	Stig Syndergaard (ssy@dmi.dk)
Background:	Measured amplitude fluctuations generated by small-scale irregularities in the ionospheric electron density affect the derivation of stratospheric temperature and other atmospheric parameters using the GNSS (Global Navigation Satellite System) radio occultation technique (www.romsaf.org/radio_occultation.php). This is because the GPS signals, which are measured by a receiver onboard a low earth orbit satellite, pass through the ionosphere. The effect of the ionospheric electron density on the measurements is sought eliminated by using a dual-frequency combination of the GPS signals, but ionospheric scintillations are not generally removed in this process. In some cases the ionospheric scintillations result in large errors in the derived temperature, or even prevent sensible temperature retrievals. A better understanding of the characteristics and global morphology of the scintillations might help efforts in reducing these errors.
Tasks:	To study the signature of ionospheric scintillations in GNSS radio occultation data using already available data from a satellite mission called COSMIC (www.cosmic.ucar.edu). To learn and understand the reason for the scintillations in GNSS radio occultation measurements and the physical processes in the ionosphere that generate them. Depending on the geomagnetic latitude, local time, solar activity, and perhaps also season, it is expected that the ionospheric scintillations have different characteristics and strength. Part of the project would be to develop software that can identify these characteristics automatically. Some scintillations originate from sporadic E-layers, others from the ionospheric F-layer. Another part of the project would be to describe the global morphology of both E-layer and F-layer scintillations and generate global maps of the strength of the scintillations as seen in the COSMIC data. Depending on the scope of the project, there would also be the possibility to apply data processing techniques to try to mitigate the effect of the ionospheric scintillations on the retrieval of atmospheric parameters. The project would include development of software to handle of a large amount of GNSS radio occultation data from the COSMIC mission.
Partners:	The project would be associated with the Radio Occultation Meteorology Satellite Application Facility (ROM SAF) at the Danish Meteorological institute (DMI).
Prerequisites:	Programming experience; knowledge about the ionosphere and space weather effects on GNSS signals; knowledge about measurement techniques.
Links:	www.romsaf.org/radio_occultation.php; www.cosmic.ucar.edu

Student research project

Project title:	**Assimilation of GPS Radio Occultation Profiles in the HARMONIE model**
Level:	Master's project
Contact:	Stig Syndergaard (ssy@dmi.dk), Mats Dahlbom (mda@dmi.dk) and Johannes K. Nielsen (jkn@dmi.dk)
Background:	Radio Occultation (RO) measurements utilising 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 basically all other assimilated data, and therefore they serve as a unique tool for anchoring the models.
Tasks:	At the DMI we wish to investigate the possible benefits from assimilation of GPS-RO in the non- hydrostatic local area model, HARMONIE. The assimilation algorithm for this purpose has been implemented. We propose a pilot study, to be performed by a master student, which investigates the effect of including GPS-RO in HARMONIE. One problem is the currently sparse spatial coverage of GPS-RO that may dampen the effect of assimilating the data. In meteorology such obstacles are overcome by producing artificial realistic data and investigate the effect of assimilation of such data in the model. On that background it may be possible to assess the feasibility of GPS-RO assimilation in local area models in a future scenario with better RO satellite coverage.
Partners:	The project would be associated with the Radio Occultation Meteorology Satellite Application Facility (ROM SAF) and the FU-model development section at the Danish Meteorological institute (DMI).
Prerequisites:	Programming experience; good math skills.
Links:	www.romsaf.org/radio_occultation.php; http://www.romsaf.org/Publications/reports/ecmwf_111_sean.pdf

Student research project

Project title:	**Study of nonhydrostatic effects with HARMONIE model**
Level:	Master degree
Contact:	Xiaohua Yang (xiaohua@dmi.dk), DMI, Forskning og Udvikling Afdeling
Background:	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. HARMONIE is the state of art short range, mesoscale numerical weather prediction model used at Danish Meteorological Institute for routine weather prediction, with focus on high impact weather. HARMONIE forecast has been found to be particularly useful in prediction of summer time heavy convection and storm weather over Greenland. While HARMONIE model is formulated with nonhydrostatic dynamics, it features hydrostatic option as well. This brings convenience in conducting scientific research to understand the scales and conditions for which nonhydrostatic effects become significant.
Tasks:	Perform comparative numerical experiment to examine nonhydrostatic effects for weather situation in Denmark and/or Greenland with emphasis on sensitivity to model grid resolution, as well as on various high impact weather.
Partners:	DMI Research Department, Model development
Prerequisites:	Master students with basic research skills and interest
Links:	http://Hirlam.org (about HARMONIE)

Student research project

Project title:	**Neighborhood forecast in post-processing of HARMONIE forecast**
Level:	Master degree
Contact:	Xiaohua Yang (xiaohua@dmi.dk), DMI, Forskning og Udvikling Afdeling
Background:	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 postprocess 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). Reference: Mittermaier M. 2014, A strategy for verifying near convection resolving model forecast at observing sites. JAS vol 29.
Tasks:	1. Implement neighborhood method as described in Mittermaier (2014) to post-process HARMONIE forecast for selected cases. 2. Compare and evaluate the resulted neighborhood forecast to the reference point forecast which is based on bi-linear interpolation.
Partners:	DMI research department, model development
Prerequisites:	Master student with basic science skills and interests
Links:	http://Hirlam.org

Processing and Quality Control System for Thermal Mapping Measurements

Contact: Claus Petersen (cp@dmi.dk)

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. The data/measurements of road surface temperature (Ts) and air temperature (Ta) (i.e. a set of so-called the thermal mapping data, ThMD) are obtained from special instrumentally equipped vehicles. These measurements are mostly done during days when salt is spread along the roads to prevent icing conditions. Such kind of data provides more details of the road conditions along road sections/stretches, and can be used to improve the forecasts by providing more local information. This allow optimizing of the amount of salt spreaded over the road surface to prevent the icing/freezing as well as better planning and timing of the schedule for such operations by the road authorities, and hence, this improves the safety of road traffic. The road conditions depend strongly on the cloud cover, shadows, precipitation, wind speed, air temperature, and humidity. However, some of these quantities have a large local variability and the road conditions can be affected by changes in these parameters on very short temporal and spatial scales. Since existing model systems do not provide sufficient accuracy for these parameters, it is expected that ThMD can give more detailed information and improve existing forecasts of road conditions at selected points along the Danish road station network.

The aim is to develop and test a processing and quality control system for thermal mapping data measurements taken along roads of the Danish road network. The specific objectives of this study are: (i) Extract and analyze available ThMD measurements (provided by DRD); (ii) Estimate accuracy of measurements, instrumental errors and in-time calibration issues of ThMD sensors mounted at vehicles; (iii) Develop/or refine procedure for processing, treatment and quality control of ThMD measurements into the RWMS; (iv) Evaluate Ts forecasts at selected road stations/stretches as a function of different road and surrounding road land-use/environmental characteristics; (v) Explore possibilities (considering limited spatial and temporal distribution and irregular measurements) for ThMD assimilation into operational forecasts.

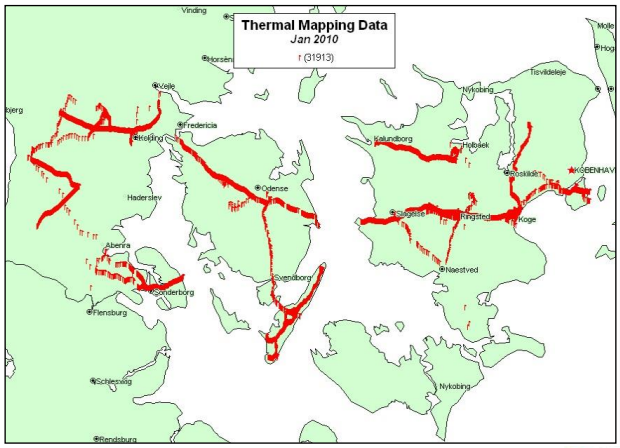


Fig. 1: *Example of spatial distribution of the thermal mapping data assigned to road stretches positions.*

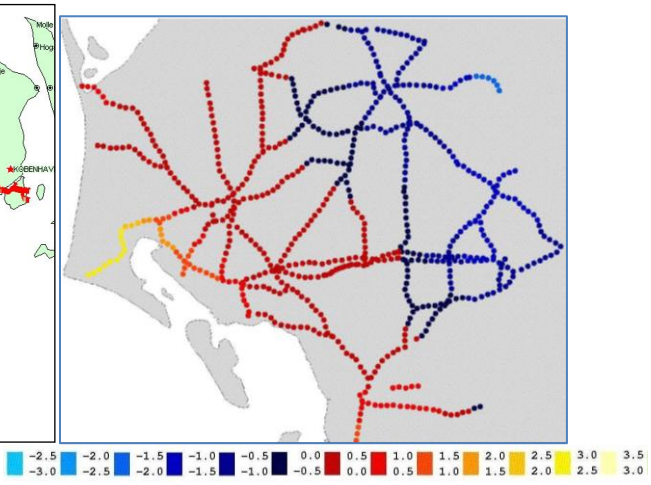


Fig. 2: *Example of 3 hour forecasts of the road surface temperature at road stretches in North Jutland.*