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Book of abstracts

Toward a new vegetation map of Svalbard based on Sentinel 2 data

Lead / presenting author: Bernt Johansen, NORCE/Climate and Environment

Co-authors:

Abstract:

The overall objective of this presentation is to announce and put forward to a broader audience the recently developed vegetation map of Svalbard based on Sentinel-2 data. The Multispectral Instrument (MSI) onboard the satellites provide images with a resolution of 10, 20 and 60 meters. In this project S-2 A/B 14 images from the dates 2nd of August 2017, and 31st of July 2017 are used in the map creation process. Images used in this study is resampled to 10 meters. In the map creation process several operational tasks are put together into a fixed and consistent production scheme. This involves pre-processing of land/ocean masks, and a second separation of vegetated land from non-vegetated. Next a “master area” is selected being subject for extensive classification, analysis, and verification of pre-classified images. The classification was performed separately on vegetated and non-vegetated land using the unsupervised k-means algorithm. After stating the optimum class number for the “master area”, the neighboring images were classified, adjusted, and merged into the initially classified master image. The final vegetation map is differentiated into 24 map units: 15 confined to the vegetated areas, the remaining nine to non-vegetated landscape features. At regional scale the inner fjord sone shows the most varied and dense vegetation cover, while glaciers and sparsely vegetated areas dominate in the north-east, north-west, and in southern parts of the archipelago. At local scale the main distinction between habitats is drawn along the dry-wet gradient, where heather tundra communities dominate on the dry side with wetlands, marshes, moss tundra and arctic mires in wet habitats. The vegetation density and fertility are highly reflected in optical satellite images through NDVI values, while moisture conditions are easily extracted by computing moisture indices. In this project the accuracy of the map is evaluated in areas were access to traditional maps have been available. The map product is still under development. The main disadvantage in the map creation process has been the lack of field data from large parts of the archipelago. Here the SIOS project could play an important role in the years to come.

An Embarrassment of Riches; We now have better topography for the ice on Earth than the land

Lead / presenting author: Paul Morin, Polar Geospatial Center

Co-authors:

Abstract:

For years, those of us that made maps of the Poles apologised. We apologised for the blank spaces on the maps, we apologized for mountains being in the wrong place and out-of-date information. Over the past 10 years the situation improved. An image mosaic of Antarctica was built, airborne RADAR produced an improving view under the Antarctic ice sheet and a constellation of satellites started to stream data at ever higher resolution, at an increasing tempo and even during the long Polar winters.

Now a diverse collaboration of US science and intelligence agencies, universities and a geospatial software company has produced REMA - the Reference Elevation Model of Antarctica - and ArcticDEM, using open source software to extract Digital Elevation Models (DEM), or digital topography, from licensed imagery on Blue Waters at a resolution of 2m. The data have an accuracy of a foot and repeat coverage of 90% of the poles an average of 10 times over 6 years. This project was too large for any one agency, university or company. It required a large allocation on Blue Waters, 4 satellites that continuously collected sub-meter optical imagery for 5 years, 100Gbit networking and petabytes of storage.

We never thought that we would ever see a time when the science community has better topography for ice than land and better topography for the Transantarctic Mountains than the Rocky Mountains. Even we, the creators of REMA, are having a difficult time understanding what we have made. The use of it in logistics and facilities management was a surprise. We are as dumbfounded as anyone at the degree to which subsurface topography is expressed in ice sheet surface features. Incredibly, the volume of data and temporal depth of the DEM coverage is causing all of us to reassess how we manage and analyze geospatial in general.
We now apologise to the polar science community for a different reason. They have to keep up. And the current DEMs are only the beginning. We now face an avalanche of imagery and derived products in an increasingly complex landscape of small-sats launched by the dozen. It is a complex, exciting time.

Dynamics of Svalbard glaciers from Sentinel-1 SAR

Lead / presenting author: Adrian Luckman, Swansea University

Co-authors:

Abstract:

The EU Copernicus Programme Sentinel-1 mission has been operationally providing year-round high resolution (10m) synthetic aperture radar (SAR) data from Svalbard every 12 days since 2014 and every 6 days since September 2016. This unprecented availability of repeat-pass, cloud-free data provides a unique opportunity to study the dynamics of Svalbard glaciers in incredible detail through the analysis of changes in ice-front position and the technique of feature/speckle tracking.

Using suitable filtering methods and temporal averaging, the rich database of ice surface velocies provided by Sentinel-1 allows a range of investigations from archipelago-wide velocity maps, changes and trends, to dynamic evolution of individual glaciers through seasonal and surge cycles. This presentation will illustrate the quality of data that is available and highlight the range of dynamic behaviour detected in Svalbard glaciers from contrasting responses to seasonal forcing to variations in surge-type behaviour.

Transfer learning to Svalbard for deep learning-based remote sensing algorithms for damage assessment

Lead / presenting author: Thomas Y. Chen, Academy for Mathematics, Science, and Engineering

Co-authors:

Abstract:

As the frequency and intensity of natural disasters both increase due to the warming earth, automated mechanisms to assess the damage caused become more necessary and effective. Specifically, having machine learning-based methods for assessing the damage incurred by disasters on infrastructure aids in the timely allocation of resources and personnel. In Svalbard, settlements and landscapes are prone to several types of natural hazards, including earthquakes and floods. However, to develop deep learning-based algorithms that remotely sense damage, there is not sufficient data on the islands alone to curate the large-scale datasets that are associated with machine learning and artificial intelligence (“big” data). Therefore, we employ a strategy called transfer learning, which is a research problem that focuses on storing knowledge gained while solving one problem and applying it to a different but closely related problem. We take the approach of training supervised convolutional neural networks (CNNs) on multitemporal satellite imagery around the world, including data from pre-disaster and post-disaster of natural disasters such as earthquakes, hurricanes, wildfires, and floods from North America, Europe, Asia, and Africa. The labeled data includes instances of buildings and other structures such that the output of the model uses change detection to categorize the severity of damage in buildings from 0 to 4. We utilize the ResNet architecture, the cross-entropy loss function as the criterion for optimization. For transfer learning, we harness a Markov logic network framework. The aim of this ongoing work is to develop systems that allow for an efficient and targeted humanitarian assistance and disaster response in extreme weather and seismic events in Svalbard, with the potential to save human lives and minimize economic loss.

Policy Bear: Creating simple arguments from complex data.

Lead / presenting author: Friedrich Röseler, Ludwig Maximilian University of Munich (LMU)

Co-authors: Gregor Wolf, Ludwig Maximilian University of Munich (LMU)

Abstract:

Finding concrete information on specific topics on the internet can be difficult: Facts and figures are poorly researched, taken out of context, manipulated, outdated or just in relation to a completely different time or place. What if there was a way to create arguments in no time by yourself, completely customised but with high scientific standard?

Policy Bear is a simple, yet efficient tool for policymakers to get information on climatic environmental factors in a very compact and plain form. We developed a prototype for a web interface to generate short and relatable sentences from climate data sets. It creates nice looking text graphics with a short sentence about the data and a comparison to a day to day measurement. With our tool, users have the possibility to investigate environmental changes for desired regions and periods without any help or prior knowledge.

Policy Bear began as a contribution to the "Hack the Arctic" hackathon and is now up and running at www.policybear.gregl.it. Up to now it is possible to compare concentrations of greenhouse gases (carbon dioxide and methane) between different dates and observation stations within the ICOS Atmosphere network (Integrated Carbon Observation System). However, in the future it should also be possible to analyse gridded datasets. Our simple structure allows us to easily integrate further parameters, which do not have to be limited to gases only, as long as meaningful comparisons are possible. For example, it is conceivable to compare changes in sea ice concentrations of certain regions with country areas or soccer fields.

Data is directly loaded via Python Api of the ICOS data portal and processed in a flask-powered Python backend that is currently hosted on a Heroku server. The frontend is a Vue.js web app with Bootstrap styling hosted on a netlify server. API-calls are made dynamically so that changes to the generated sentences can be seen instantly. Text graphics can be exported as images or shared via weblink.

Policy Bear is a powerful, versatile and easy-to-use tool to quickly support statements with facts and figures. With high scientific standard, users can easily create custom made arguments for their next conference meeting or the heated evening debate at the bar.

Observing flow dynamics of Svalbard glaciers using Radar remote sensing techniques

Lead / presenting author: Bala Raju Nela, Indian Institute of Technology Bombay

Co-authors: Gulab Singh, Indian Institute of Technology Bombay;

Abstract:

Svalbard is a highly glacierized archipelago and its ice cover an area of approximately 36,600 km2. Svalbard is one of the fastest warming regions on Earth and it is highly sensitive to atmospheric and oceanic influences. So, understanding of Svalbard glacier dynamics is critical to assessing global climate changes. Hence, few satellites like CryoSat, ICESat and GRACE are continuously monitoring glacier/sea ice. But all these missions are specifically for thickness change and mass balance studies. Glacier velocity is another important parameter to understand the glacier dynamics and glacier flow instabilities (enhanced ice discharge) can rapidly increase the sea level. In this study, we observed velocity changes in 25 years (1995 and 2020) for NW and NE parts of Spitsbergen, Svalbard using the Interferometry (InSAR) technique. InSAR is the most accurate radar remote sensing technique to observe the flow velocities. Offset tracking also gives the velocity but it is less accurate than Differential Interferometry (DInSAR). Few studies are also generated velocity maps of the entire Svalbard region using the Offset tracking technique. But the DInSAR is more advantageous since it gives meticulous feature details of a glacier, which cannot be observable in the Offset tracking technique. DInSAR gives LOS (line of sight) velocity as a primary output and later this can be converted into surface velocity using slope and aspect angle. But these parameters may drop the chance of observing minute features on the glacier. Although previous studies already estimated the flow rates, this study mainly concentrated on the glacier dynamic changes in 25 years through its LOS velocity. This study completely analyzed the fast-moving glaciers, glacier frontal changes and glacier surge dynamics through velocity. The glaciers Monacobreen, Kongsbreen, Kronebreen, Sveabreen, located in NW Spitsbergen are identified as fast-moving glaciers. The glaciers in the part of NW Spitsbergen are showing the decrement of velocity at the snout position. The LOS velocity in 1995 is approximately 8-10 times more than the 2020 LOS velocity at this position. The maximum velocity in 2020 was observed at the middle of the glaciers and at this position the velocity is almost doubled from 1995 to 2020. Svalbard archipelago contains a prominent cluster of surge-type glaciers. Kongsbreen glacier is a west side terminating glacier and moving towards the south direction and it is also attached to the Kronebreen glacier, where it changes its flow direction. The separation of these two glaciers is visible in the LOS velocity and it is different in 1995 and 2020 (approximately1 km is advanced in 1995 compared to 2020). A surge could be the main reason for advancing the glacier in 1995. The flow direction (at the meeting point) of these two glaciers is making an angle of 60-70°. Since the Kongsbreen glacier is advanced during 1995 and its main trunk is almost hitting perpendicular to the Kronebreen glacier, it affects the flow of the

Kronebreen glacier. Other interesting unsolved features are also observed in this study. A thin velocity layer, which is surrounded to the glacier main trunk/tributaries of approximately zero movements (varying from 30-60m wide) observed in 1995 LOS velocity for few glaciers like Hinlopenbreen, Oslobreen in the NE Spitsbergen and Kongsbreen, Kronebreen, Konowbreen, Osbornebreen E, Sveabreen glaciers in the NW Spitsbergen. This layer was completely disappeared or shifted in recent years. Supplementary to the remote sensing techniques, field-based measurements adds more information to understand these glacier dynamics.

Retrieving fractional snow-covered area from optical satellites using data assimilation

Lead / presenting author: Kristoffer Aalstad, University of Oslo

Co-authors: Sebastian Westermann, University of Oslo; Laurent Bertino , Nansen Environmental and Remote Sensing Center

Abstract:

Mapping from noisy observations to the hidden states that may have generated them falls under the umbrella of inverse problems. These problems are abundant in Earth system science since our uncertain mechanistic models need to be fully specified while the system is only partially and imperfectly observed. Combined with a steadily growing observing system, this abundance has fueled the development of probabilistic Data Assimilation (DA) schemes that use Bayesian inference to fuse uncertain information from models and observations. Widely used applications of DA include the production of global atmospheric reanalyses and the initialization of numerical weather predictions. At the same time, the added value that DA can bring to remote sensing as a generalized framework for building retrieval algorithms remains largely untapped.

In our contribution, we demonstrate the potential of data assimilation in the task of retrieving fractional snow-covered area (fSCA) from multispectral satellite imagery from moderate (MODIS) and higher (Sentinel-2 MSI, Landsat 8 OLI) optical sensors. In this analysis, we build on our previous work by focusing on the Bayelva catchment near Ny-Ålesund where we have access to independent high-quality validation data obtained from terrestrial photography. We show how the general problem of linear spectral unmixing that is widely used for land cover classification can be recast as a Bayesian inverse problem. This can then be readily solved using ensemble-based data assimilation schemes, where we test both vanilla and sophisticated flavors of the particle filter and the ensemble Kalman filter, as well as Markov chain Monte Carlo benchmarks. By solving the problem in a transformed parameter space, the physical constraints of spectral unmixing are satisfied while reducing the need for ad hocery.

Our Bayesian fSCA retrieval approach lets us deal with ill-posedness, incorporate physical knowledge, and account for uncertainty in the observed reflectances. It performs favorably compared to widely used techniques for fSCA retrieval such as thresholding of the NDSI, regression on the NDSI, and classical (non-negative least squares) spectral unmixing. This method is also much more scalable than classical unmixing since iterations are pre-determined and it can fully exploit vectorization. Furthermore, it does not require any tuning on in-situ observations and it can even be used to solve the endmember selection problem using the concept of model evidence. Crucially, the retrieved fSCA includes dynamic uncertainty estimates that are required for satellite retrievals to be fully exploited by larger data assimilation frameworks. We envisage further validation by leveraging the network of terrestrial cameras operated by our partners in the PASSES consortium (SESS Report 2020). Down the line, our aim is to employ these

satellite retrievals in our ongoing efforts to produce tailored high resolution permafrost and snow reanalyses in cold regions, including Svalbard. At the same time, the approach outlined here could also be modified to retrieve surface albedo and (sub-pixel) land cover globally with even broader implications to Earth system science.

Investigating changes in Svalbards cryosphere by using ICESat, ICESat-2, Sentinel-1 and TanDEM-X remote sensing data

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Abstract:

A decade-long pronounced increase of temperatures in the Arctic and especially in the Barents Sea region resulted in a global warming hotspot over Svalbard. Associated changes in the cryosphere are the consequence and lead to a demand for monitoring of the glacier changes. First, we use spaceborne laser altimetry data from the ICESat and ICESat-2 missions to obtain ice elevation and mass change rates via a orbit-crossover approach between 2003-2008 and 2019. A Svalbard-wide annual elevation change rate of -0.30 ± 0.15 m yr-1 was found, which corresponds to a mass loss rate of -12.40 ± 4.28 Gt yr-1. Compared to the ICESat period (2003-2009), thinning has increased over most regions, including highest negative rates along the west coast and areas bordering the Barents Sea. The overall negative regime is expected to be linked to Arctic warming in the last decades and associated changes in glacier climatic mass balance. Further, observed increased thinning rates and pronounced changes at the eastern side of Svalbard since the ICESat period are found to correlate with atmospheric and oceanic warming in the respective regions. In addition to the ICESat/ICESat-2 investigation, we further present results from current glacier velocity measurements derived through Sentinel-1 data and share first insights in recent elevation change research by using TanDEM-X acquisitions from 2010 and 2017 over the archipelago.

CLIMATE CHANGE DRIVES FLUCTUATIONS OF GLACIAL LAKES IN SVALBARD - CRAMMERBREANE CASE STUDY (BELLSUND FJORD)

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Abstract:

Glacial lakes are common geomorphological forms along the margins of glaciers and ice sheets, and often evolve from ice-contact lakes into ice-distal lakes as a consequence of glacier recession 1. Recent worldwide remote sensing study of glacial lakes estimated that the majority of lakes has expanded (~48%) from 1990 to 2018 2. Climate-driven glacier recession is expected to be the main reason for the rapid growth of glacial lakes. What is also important, glacial lakes store nutrients and hold microbial communities to downstream aquatic systems 3. Recently, we have analysed the Norwegian Polar Institute's collection of aerial images from Svalbard (available at TopoSvalbard) and selected a number of rapid changing glacial lake systems for detailed analyses in geographical information systems. Using this inventory, we have selected the glacier lake system, which has developed in front of Crammerbraene glaciers,Bellsund fjord (SW Spitsbergen, high Arctic). These lakes tend to periodically drain out each summer season. Also, several geomorphological features (such as the network of channels incised in the moraine belt that dams the lakes) suggest that drainage episodes likely occurred in a dramatic manner. This is well in-line with the process-landform associations noted for glacierised landscapes affected by GLOFs (Glacial Lake Outburst Floods) activity 4,5. We plan to use data collected by Dronier mission in 2021 (Airborne remote sensing campaign 2021) to identify changes of size and shape of Crammerbraene lakes and the surrounding geomorphology including potential traces of former GLOF events. Data collected during SIOS (Svalbard Integrated Arctic Earth Observing System) mission, in comparison with remote sensing materials from the last century (aerial photographs, Landsat images and archival maps) will lead to the first multi-decadal study of glacier lake system evolution in Spitsbergen.

1. Fitzsimons, S. & Howarth, J. Glaciolacustrine Processes. Past Glacial Environments: Second Edition (Elsevier Ltd, 2018). doi:10.1016/B978-0-08-100524-8.00009-9.
2. Shugar, D. H. et al. Rapid worldwide growth of glacial lakes since 1990. Nat. Clim. Chang. 10, 939–945 (2020).

3. Modenutti, B., Bastidas Navarro, M., Martyniuk, N. & Balseiro, E. Melting of clean and debris-rich ice differentially affect nutrients, dissolved organic matter and bacteria respiration in the early ontogeny of the newly formed proglacial Ventisquero Negro Lake (Patagonia Argentina). Freshw. Biol. 63, 1341–1351 (2018).
4. Veh, G., Korup, O., von Specht, S., Roessner, S. & Walz, A. Unchanged frequency of moraine-dammed glacial lake outburst floods in the Himalaya. Nat. Clim. Chang. 9, 379–383 (2019).
5. Emmer, A. et al. 70 years of lake evolution and glacial lake outburst floods in the Cordillera Blanca (Peru) and implications for the future. Geomorphology 365, 107178 (2020).

Multi-sensor analysis of snow dynamics and SAR signal sensitivity to vegetation growth in Adventdalen.

Lead / presenting author: Laura Stendardi, Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Italy

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Abstract:

The timing of snowmelt and the first day of snow-free conditions are considered indicators of Arctic climate.
Moreover, snowmelt and the last day of snow cover have a considerable impact on plant phenology in the Svalbard archipelago. The aim of this study is to assess seasonal variations in snow cover using a multi-sensor-based approach and to analyze the sensitivity of Synthetic Aperture Radar (SAR) backscatter to vegetation growth and soil moisture.
We established a multisensor mask using HV backscatter coefficients from Sentinel-1 and the Normalized Difference Snow Index (NDSI) time series from Sentinel-2, monitoring snow dynamics at Adventdalen (Svalbard) for the 2017 and 2018 seasons. Then, a SAR sensitivity analysis was performed using HV polarised channel responses to vegetation growth and soil moisture dynamics.
From our results, C-band radar data were able to monitor seasonal variability in the timing of snowmelt at Adventdalen, revealing an earlier start of about 20 days in 2018 compared to 2017. Sensitivity analyses showed that the HV channel responded more strongly to the vegetation component in areas with drier graminoid-dominated vegetation and not with water-saturated soil ($R = 0.69$). Furthermore, the temperature was significantly correlated with the HV channel ($R = 0.74$) during years with late snowmelt and late soil thaw. Delayed soil thaw, therefore, limits the backscatter's ability to follow the growing season of vegetation.

Observation of cloud base height and precipitation characteristics at a polar site Ny-Ålesund, Svalbard

Lead / presenting author: Asutosh Acharya, National Centre for Polar and Ocean Research, Ministry of Earth Sciences, India

Co-authors: Sourav Chatterjee, National Centre for Polar and Ocean Research, Ministry of Earth Sciences, India; M.P Subeesh , National center for Polar and Ocean Research, Goa, India; Athulya Radhakrishnan , National Centre for Polar and Ocean Research, Ministry of Earth Sciences, India; Nuncio Murukesh , National Centre for Polar and Ocean Research, Ministry of Earth Sciences, India;

Abstract:

Clouds play a significant role in regulating the Arctic climate and water cycle due to their impacts on radiative balance through various complex feedback processes. However, there are still large discrepancies in satellite and numerical model-derived cloud datasets over the Arctic region due to lack of observations. Here, we report observations of cloud base height (CBH) characteristics measured using a Vaisala CL51 ceilometer at Ny-Ålesund, Svalbard. The study highlights the monthly and seasonal CBH characteristics at the location. It is found that almost 40% of the lowest CBHs fall within a height range of 0.5-1 km. The second and third cloud bases that could be detected by the ceilometer are mostly concentrated below 3km during summer but possess more vertical spread during the winter season. Thin and low-level clouds appear to be dominant during the summer. Low-level clouds are found to be dominant and observed in 76 % of cases. The mid and high-level clouds occur in ~16 % and ~7% of cases, respectively. Further, micro rain radar (MRR2) observed enhanced precipitation and snowfall events during the winter and spring which are found to be associated with the lowest CBHs within 2 km from the ground. The frontal process associated with synoptic-scale meteorological conditions explains the variabilities in CBH and precipitation at the observation site when compared for two contrasting winter precipitation events. The findings of the study could be useful for model evaluation of cloud precipitation relationships and satellite data validation in the Arctic environment.

Geomorphological and hydrological studies in the marginal zones of selected glaciers in S Spitsbergen based on AirborneSOS campa

Lead / presenting author: Aleksandra Osika, University of Silesia in Katowice, Poland

Co-authors: Elżbieta Łepkowska, University of Silesia in Katowice, Poland; Małgorzata Błaszczyk, University of Silesia in Katowice, Poland; Michał Laska, University of Silesia in Katowice, Poland;

Abstract:

The ongoing climate warming accounts for rapid changes in the Arctic environment, and new data sources should be used to track them. The data provided by the AirborneSOS campaign in 2020 and 2021 will improve our understanding of paraglacial processes and landscape transformations in Hornsund. The high-resolution images will be used to prepare geomorphological sketch maps of recently exposed marginal zones of selected glaciers, including areas affected by surging in the 20th century. Additionally, hyperspectral data will allow us to analyze the relationship between glacial landforms and vegetation development. GIS-based modelling with DEM extraction from aerial images will also be used for glaciofluvial deposit analysis and an assessment of the paraglacial sediment balance between June 2020 (1st campaign) and August 2021 (expected 2nd campaign) and comparing these results with a 50-years set of in-situ data. Analyzing the magnitude and direction of hydrological and geomorphological changes each year should be an integral part of the monitoring network conducted in the marginal zone of reference glaciers, e.g. Werenskioldbreen.

Svalbard: decadal trends in snow cover and sea-ice area

Lead / presenting author: Mari Anne Killie, The Norwegian Meteorological Institute

Co-authors: Signe Aaboe, The Norwegian Meteorological Institute; Ketil Isaksen, The Norwegian Meteorological Institute; Ward Van Pelt, Department of Earth Sciences, Uppsala University; shild Ø. Pedersen, The Norwegian Polar Institute, FRAM Centre; Bartłomiej Luks, Institute of Geophysics, Polish Academy of Sciences;

Abstract:

Svalbard is covered by snow for large parts of the year, and the seasonal snow melt typically starts by the end of June. The total area that becomes completely snow-free varies from year to year, but snow observations over several decades support the trend of an earlier start of snow melt and a larger total area that becomes snow free during summer. For the 2020 SIOS State of Environmental Science in Svalbard (SESS) report, a 34 years long time series of daily snow cover maps for Svalbard - derived from a climate consistent satellite based dataset - was analyzed in order to study the changes in the terrestrial snow cover over the period 1982 - 2015. This was combined with in situ data and snow modelling data for Svalbard terrestrial snow cover as well as with long-term satellite observations of sea-ice area in the seas surrounding Svalbard - derived from a climate consistent dataset for global sea-ice concentration. The work was a collaboration with researchers from the Norwegian Meteorological Institute, the Norwegian Polar Institute, Uppsala University and the Institute of Geophysics at the Polish Academy of Sciences, and was supported financially by SIOS.
This presentation will give a summary of some of the results from the study published in the SESS report, with focus on the trends in the terrestrial snow cover data and correlations to the sea-ice area data, both derived from remote sensing. We see that the areas with the largest increase in snow-free season are concentrated in regions dominated by low-land valleys and coastal plains. Most noticeable are the changes centred near the large valleys on Nordenskiold Land: Adventdalen, Reindalen and Sassendalen. Also the sea-ice area in the seas surrounding Svalbard shows an overall trend of decreasing ice for all months throughout the year. Negative trends dominate both datasets, with less sea-ice cover and shorter snow season, but is there a correlation between the year-to-year variations? The strongest correlation is found between the detrended datasets for June sea-ice area and June snow cover. The correlation is positive and significant up to 250 meters elevation, but the largest value for the correlation coefficient is found when only including snow cover in the lowlands up to 50 meters.

NoHaze: an app to track the atmospheric pollution and visibility in the arctic

Lead / presenting author: Pramit Kumar Deb Burman, Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, India

Co-authors: Dung Duong Anh, ; Ellen Ilivitzky, Department of Geology and Geography, University of Turku, Turku, Finland;

Abstract:

Our project:
Haze is an atmospheric phenomenon that has impacts on visibility and human health. In recent times, the occurrence of haze events has increased in the arctic regions due to the increased amounts of pollutants such as particulate matters and trace gases in the atmosphere. In the present work, we build an application using in situ measurements and satellite observations to track the arctic haze events in real time. This is aimed at informing travelers about the pollution level at their destinations.

What can NoHaze do?
- Provide easy access to scientific data with a simple interface.
- Allow the user to select the destination and pollutant species of their interest. The app does this by fetching the relevant data from the ground-based measurement stations closest to the user destination.
- Display the trend of selected pollutants for different time windows, by showing a daily, weekly or monthly view of pollution levels.
- At present the user can study sulphur dioxide, carbon monoxide and nitrogen dioxide. by utilizing measurements from SMEAR-ground stations in Finland.
- Use Sentinel-5P data and compare these remote sensing estimates which have larger spatial representativeness with corresponding in-situ measurements at the SMEAR-ground stations, which are more localized in nature and have faster observations available.
- Offer information on haze, its causes and effects and thus spread awareness among app-users.
- Promote citizen/community science through a portal in which the users can submit their observations to the developers and share their opinions, thus enhancing our overall understanding of the arctic haze events.

Backend and our goals for the app:
The app backend is developed in R, which is an open-source programming language. We believe this app will be most useful to tourists but also locals to help avoid illness, reduce fuel consumption and visibility related accidents. Pollution related data can be hard to access and understand. NoHaze gives complicated scientific information a simple interface and easy access from which, users with little to no experience in reading data, can get an understanding of how high levels of certain chemicals are linked to pollution and haze.

Combining data analysis with app development to increase access to remotely sensed and reanalysis data around Svalbard

Lead / presenting author: Robert William Schlegel, Laboratoire d'Ocanographie de Villefranche, Sorbonne Universit, France

Co-authors: Adrien Wehrlé, Institute of Geography, University of Zurich, Zurich, Switzerland;

Abstract:

Thanks to the implementation of FAIR data principles, particularly in the Arctic, the remotely sensed and reanalysis datasets used for research purposes around Svalbard are becoming increasingly open and easier to access. However, the requirement to understand specific terminology, have awareness of data repository locations, and the knowledge of at least one programming language often still prevents potential users from utilising most remotely sensed and reanalysis datasets .
During the 30-hour long 2020 “Hack the Arctic” Hackathon, we formed a team combining skills in data processing/analysis with app development in order to develop and launch an operational interactive web based interface for the visualisation of gridded datasets that fall within a static bounding box of the Svalbard archipelago. The main goal of this project was to bridge the gap between academia and the general public, truly making the datasets we use in research available to anyone with a few clicks and without any prior knowledge required. The backend of the app contains the code involved in the downloading, processing, and analysing of the gridded data. The front end of the app provides an interface that allows a user to look at the long term trends in a number of physical variables at a 0.25° resolution. Monthly and annual means are also available. A demonstration of the utility of the app will be provided.

IcySea: Providing polar navigators with near-real time sea ice information

Lead / presenting author: Alexandra Stocker, Drift+Noise Polar Services

Co-authors: Alexandra Stocker, Drift+Noise Polar Services; Lasse Rabenstein, Drift+Noise Polar Services;

Abstract:

Over the past decades, significant increase in shipping activity has occurred in polar regions, where various challenges related to receiving up-to-date sea ice information are present. Today’s sea-ice information on board ships is lagging behind digital advancements in other fields and does not yet unlock the potential of the today’s availability of satellite observations. Collecting, plotting and analyzing several sources of ice information on-site is a cumbersome job and with a limited internet connection is sometimes impossible. IcySea, a progressive web app (PWA) accessible via https://icysea.app, was developed in cooperation with the Norwegian Meteorological Institute in a Copernicus Marine Service User Uptake Project to address this problem. The PWA makes various near-real time satellite observations available in a user-friendly digital map suited for low-bandwidth connections. IcySea combines and automatically processes operational data such as sea ice concentration, ice drift forecasts and Sentinel-1 radar satellite images around Svalbard. IcySea is in continuous development and new features such as navigational tools, new information layers and new regions are based on user feedback. We hope to see this app as a solution to providing sea ice information directly on board for navigators and field researchers in order to increase planning and safety in polar regions.

Towards a Svalbard Time-Lapse Network: the PASSES experience

Lead / presenting author: Roberto Salzano, National Research Council of Italy

Co-authors: Kristoffer Aalstad, University of Oslo; Enrico Boldrini, National Research Council of Italy; Jean-Charles Gallet, Norwegian Polar Institute; Daniel Kępski, Institute of Geophysics, PAS; Bartłomiej Luks, Institute of Geophysics, PAS; Lennart Nilsen, University of Tromsø; Rosamaria Salvatori, National Research Council of Italy; Sebastian Westermann, University of Oslo;

Abstract:

Ground-based observations are critical requirements for many disciplines that are trying to monitor climate change in a remote environment such as the Svalbard archipelago. We present a recent overview of cameras operating in Svalbard, searching for specific applications that monitor the snow cover and collecting information about images that can be accessed on the internet, including those not solely dedicated to the cryospheric research. This activity has been promoted by SIOS in the framework of the SESS report 2020 and we identified 43 cameras operating in the region that are managed by research institutions and private companies. These cameras include facilities operated by different nationalities and the datasets and we explored the feasibility of using them to determine fractional snow cover. The survey is still open (https://niveos.cnr.it/passes/), and the acquired information are organized to support the different disciplines on selecting those devices that can be useful for revealing problems and filling knowledge gaps. This overview identified therefore some applications that highlighted the opportunities offered by the terrestrial photography in different frameworks (cal/val of satellite data, snow seasonality, vegetation phenology, etc.), but additional effort is required for creating a Svalbard Time-Lapse Network.

Airborne Remote Sensing Platforms on Svalbard, Opportunities and Limitations

Lead / presenting author: Rune Storvold, NORCE Norwegian Research Centre

Co-authors: Agnar Sivertsen, NORCE Norwegian Research Centre; Tom Rune Lauknes, NORCE Norwegian Research Centre; Stian Andre Solbø, NORCE Norwegian Research Centre; Rolf-Ole Rydeng Jensen, NORCE Norwegian Research Centre; Eirik Malnes, NORCE Norwegian Research Centre; Kjell Arild Høgda, NORCE Norwegian Research Centre;

Abstract:

The Covid-19 pandemic and the resulting travel limitations has prevented scientist from travelling and hence conducting their fieldwork as planned, also on Svalbard. This has forced the science community to rethink how to collect field data through increased collaboration and use of new technology. The lessons learned will also have impact in the post-Covid time, reducing need for travel and the environmental footprint of research.

The technological advances over the last 15 years in drone technology and the establishment of the SIOS-NORCE airborne remote sensing pod mounted on the Lufttransport Dornier 228 passenger aircraft based in Longyearbyen allow for efficient collection of remote sensing data at resolution down to mm scale. This do not remove the need for in-situ work but may reduce it.
The Dornier capabilities today consist of high-resolution hyperspectral imagery and aerial camera. NORCE is working on extending this capability with a fully polarimetric, dual frequency Synthetic Aperture Radar (L- and X-band SAR), which will provide unique opportunities for sensor fusion with the hyperspectral data not available on any remote sensing platform today. This will further strengthen Svalbard as the best high arctic site for satellite Cal/Val activities and testing ground for new sensors for future satellite missions, like the Copernicus ROSE-L.

Small drones (<25 kg) are more flexible than larger aircraft, but limited in capacity, when it comes to weight and endurance. Drones are ideal for mapping small areas, testing new sensors and have the flexibility of having it available when you need it. Large drones have great potential but requires more resources to operate and currently limited by regulatory obstacles with regard to access to airspace, in particular when missions are planned above 120 meters above ground and beyond visual line of sight. The European Union Aviation Safety Agency (EASA) has developed a common regulation for drones, adapted into Norwegian Regulation as of January 1st this year. This regulation have three main categories of drones and associated approved types of operations. This opens new opportunities, however there are still unresolved issues with regard to larger drones and beyond line of sight missions.

Collaboration among scientists using drones can help increase access through development of standard operations and safety assessments. The first steps of such a collaboration and what could be achieved will be outlined.

Over the last decade drones have been used to demonstrate their usefulness as a sensor platform for measuring important cryosphere variables useful for process studies, climate modelling and satellite product validation. We will present results from previous NORCE field work on Svalbard. This includes mapping of sea-ice and iceberg properties, snow depth and SWE measurements and glacier dynamic loss.

We will at the end present current drone and sensor capacity available through SIOS and outline future drone based data products that will support the SIOS mission, satellite cal/val activities and earth system science.

Year-round Thermal Infrared measurements of methane emitted by Arctic seas.

Lead / presenting author: Leonid Yurganov, UMBC

Co-authors:

Abstract:

The Svalbard area experiences dramatic climatic changes during last two decades. Methane, as a greenhouse gas, may participate in this changes. Thermal IR sounders (AIRS, IASI, CrIS, and similar) are capable to measure methane concentrations globally, day and night, year-round. Geometry of polar sun-synchronous orbits is favorable for an excellent coverage of the polar areas. Strong summer stratification of seawater prevents sea-to-air flux of this gas; in winter, ice cover plays a role of another barrier. Novel satellite data evidence a significant emission of methane from the ice-free Barents Sea in winter after the breakdown of pycnocline. The winter-time ice barrier in the northern Barents Sea and in Kara Sea decays with years dramatically. Satellite data indicate a significant increase of seasonal methane amplitude due to growing winter concentrations. These satellite data need to be compared with direct in-situ observations.

A comparison of satellite- and model-based snow cover datasets for Svalbard

Lead / presenting author: Hannah Vickers, NORCE

Co-authors: Stein Rune Karlsen, NORCE; Ward van Pelt, Uppsala University; Veijo Pohjola, Uppsala University ; Mari Anne Killie, Meteorologisk Institutt; Toumo Saloranta, NVE; Eirik Malnes, NORCE;

Abstract:

Accurate mapping of snow cover is essential in applications such as water resource management, hazard forecasting, calibration and validation of hydrological models and climate impact assessments. In Svalbard where the climate is warming at twice the rate of the global average it is therefore especially crucial to build up a reliable database of snow cover observations in order to determine the consequences of future climate warming for these applications. Optical remote sensing has been utilised as a tool for snow cover monitoring over the last several decades. However, consistent long-term monitoring of snow cover can be challenging due to differences in spatial resolution and retrieval algorithms of the different generations of satellite-based sensors. Snow models represent a complementary tool to remote sensing for snow cover monitoring, being able to fill in temporal and spatial data gaps where a lack of observations exist. We have utilised three optical remote sensing datasets and two snow models with overlapping periods of data coverage to investigate the similarities and discrepancies in snow cover estimates over Nordenskild Land in central Svalbard. High-resolution Sentinel-2 observations were utilised to calibrate a 20-year MODIS snow cover dataset which was subsequently used to correct snow cover fraction estimates made by the lower resolution AVHRR instrument and snow model datasets, to achieve better agreement between the time series. A consistent overestimation of snow cover fraction by the lower resolution datasets was found, as well as estimates of first snow-free day (FSFD) that were on average 10-15 days later compared with the baseline MODIS estimates. Correction of the AVHRR snow cover fraction time series produced a significantly slower decadal change in the land averaged FSFD, suggesting that caution should be exercised when interpreting climate-related trends from earlier lower resolution observations. Substantial differences in the dynamic characteristics of snow cover in early autumn were also present between the remote sensing and snow model datasets, which indicates a need to investigate the processes driving the snow models during snow onset. The study has demonstrated that the consistency of earlier low spatial resolution snow cover datasets can be improved by using current-day higher resolution datasets as a calibration tool. However, there still remains work to be done to extend this approach to the pixel scale and this should be the focus of future developments to improve not only the consistency, but also the accuracy of lower spatial resolution snow cover datasets.

Geomatics as a site-selection tool for paleo-environmental fieldwork

Lead / presenting author: Benjamin Robson, University of Bergen

Co-authors: Willem van der Bilt, University of Bergen; Jostein Bakke, University of Bergen;

Abstract:

The majority of paleoenvironmental investigations using expert driven knowledge to pin-point suitable locations to lake sediment core extractions. Such an approach can lead to sub-optimal site selection and lakes that do not sufficiently reflect the regional catchments.

Here we present preliminary results looking at Wildefjorden in North-East Svalbard where fieldwork is planned for August to collect data that will be used to reconstruct glacier extent. We use a range of topographic (Arctic DEM) and multispectral data (Sentinel-2 MSI) to investigate the drainage catchment of individual lakes, the relative bathymetry, and the seasonal variation in snowcover and vegetation. We also perform modelling using the opensource "Glabtop2" package to look at estimated subglacial topography to speculate on future stores of meltwater. This allows us to draw conclusions about the spatial-temporal patterns in the landscape and make some preliminary statements on the suitability of different areas for detailed field investigations.

It is hoped that aerial data collected by SIOS in summer 2021 will provide high-resolution data, unaffected by the atmosphere for further calibration and validation of our work.

Towards swath-to-swath and summer season sea-ice drift

Lead / presenting author: Emily Down, Met Norway

Co-authors: Thomas Lavergne, Met Norway;

Abstract:

Sea-ice drift, a vital product for both operational and climatological sea-ice monitoring, is calculated by a cross-correlation algorithm which finds offsets between common features in two passive microwave satellite images. In preparation for the future Copernicus Imaging Microwave Radiometer mission, we have undertaken a study to investigate the possibility of calculating sea-ice drift from two swath images rather than daily gridded maps as is done today. We found that this swath-to-swath technique will improve data availability and timeliness without sacrificing accuracy.

In summer, the cross-correlation technique for measuring ice drift becomes far less accurate due to surface melting of the ice and high atmospheric humidity. We are investigating the usefulness of a computational free-drift model of the ice to provide an ice drift product during the summer season from the early 1990s onwards. This model calculates the ice drift based on wind vectors from the ERA5 reanalysis, under the assumption that the internal stresses of the ice can be neglected.

In this contribution we report on our investigations of the swath-to-swath and summer sea-ice drift, and on upcoming updates of the EUMETSAT OSI SAF sea-ice drift product.

Integration of geomorphological mapping and InSAR kinematics for a comprehensive inventory of rock glaciers in Nordenskiöld Land

Lead / presenting author: Line Rouyet, NORCE Norwegian Research Centre AS

Co-authors: Line Rouyet, NORCE Norwegian Research Centre AS; Hanne H. Christiansen, The University Centre in Svalbard (UNIS); Ole Humlum, ArcticHERO; Ashton B. McDonald, The University Centre in Svalbard (UNIS); Tom Rune Lauknes, NORCE Norwegian Research Centre AS;

Abstract:

Rock glaciers are creeping permafrost landforms consisting of an ice/rock mixture. They are geomorphological indicators of permafrost occurrence and play an important role in the sediment cascade and the hydrological regime of mountain regions. Rock glacier kinematics are considered as an indicator of climate change due to the increasing evidence of relations between creep rate and ground temperature. Rock glacier identification and geomorphological characterization have been done in many cold-climate regions, but these inventories have never been really coordinated, making global comparison challenging. Meanwhile, the development of remote sensing techniques has enabled the documentation of rock glacier kinematics over vast areas.

During past years, the European Space Agency (ESA) Climate Change Initiative (CCI) programme (https://climate.esa.int/en/projects/permafrost/) and the International Permafrost Association (IPA) Action Group on rock glaciers (https://www.unifr.ch/geo/geomorphology/en/research/ipa-action-group-rock-glacier) initiated an international collaboration to design a standardized methodology to map rock glaciers, generate comparable inventories worldwide and exploit Synthetic Aperture Radar Interferometry (InSAR) for documenting rock glacier kinematics. One region included in this project is the Nordenskiöld peninsula in central Svalbard.

In Nordenskiöld Land, we mapped the extent and characterized the type and activity of rock glaciers identified on the most recent orthophoto images. In parallel, we processed and classified InSAR ground velocity based on June-October 2015-2020 Sentinel-1 images. InSAR results were used to assign a kinematic attribute to each identified rock glacier (< cm/yr, cm/yr, cm-dm/yr, dm/yr, dm-m/yr, m/yr). We identified 260 rock glaciers units. Among these, 37 units remain kinematically undefined, 4 are < cm/yr, while 219 have cm/yr to m/yr kinematic attributes. As the first comprehensive inventory of rock glaciers combining geomorphological mapping and remote sensing in Svalbard, our work shows the potential for further research based on a multi-methodological approach to study creeping permafrost and its evolution in a changing climate.

Disturbance Detection and Classification with UAV Images as a Tool in Ecosystem Monitoring –A Case Study from High Arctic Tundra

Lead / presenting author: Isabell Eischeid, UiT Arctic University of Norway, Norwegian Polar Institute, Aarhus University

Co-authors: Eeva M. Soininen, UiT Arctic University of Norway; Jakob J. Assmann, Aarhus University; Rolf A. Ims, UiT Arctic University of Norway; Jesper Madsen, Aarhus University; Åshild Ø. Pedersen, Norwegian Polar Institute; Francesco Pirotti, TESAF Department - University of Padova; Nigel G. Yoccoz, UiT Arctic University of Norway; Virve T. Ravolainen, Norwegian Polar Institute;

Abstract:

Unmanned aerial vehicles (UAVs) are increasingly used as a tool in ecology and may be especially valuable in rapidly changing and remote landscapes such as in the Arctic. For effective applications, decisions of both ecological and technical character are needed. Yet, ecologists often lack the knowledge required. We provide a decision-making workflow for the use of UAVs in developing vegetation maps that can also include disturbance classes as a tool in ecological monitoring. We implement this workflow in a case study of the Arctic tundra in Svalbard, and generated a high-resolution map of tundra vegetation, using a random forest (RF) classifier with four spectral bands, a vegetation index (NDVI) and terrain. To obtain ground-cover classes that can describe vegetation state changes we included classes describing vegetation disturbances by herbivory and winter weather events. We detected goose grubbing, winter damaged areas, and distinguished twelve selected ground-cover classes. Areas affected by grubbing or winter damage had lower NDVI values than their undisturbed associated ground-cover classes. However, we registered an overestimation of the grubbing class in parts of moss tundra terrain, which needs to be refined in future studies. The predictive ability of site-specific models was good (macro-F1 scores between 83-85%), but classifier transfer between the study sites was not possible (F1 macro scores under 50%) without applying algorithm transfer functions which was outside the scope of our study. We show that UAV image analysis can be a valuable asset in studying vegetation state changes in Arctic tundra ecosystems, given a tailored workflow for this purpose, and encourage ecologist to integrate UAV work into their monitoring programs.

Sounding rocket studies above Svalbard: the grand challenge initiative cusp

Lead / presenting author: Andres Spicher, Department of Physics and Technology, The Arctic University of Norway, Tromsø, NO / part of work while at UiO

Co-authors: Jøran I. Moen, University Centre in Svalbard/Department of Physics, the University of Oslo, NO; Douglas E. Rowland, Goddard Space Flight Center, NASA, Greenbelt, MD, USA; James LaBelle, Department of Physics and Astronomy, Dartmouth College, Hanover, NH, USA; Craig A. Kletzing, University of Iowa, Iowa City, IA, USA; Kolbjørn Blix, Andøya Space Center, Andøya, NO; Wojciech J. Miloch, Department of Physics, the University of Oslo, NO;

Abstract:

Every morning, Svalbard passes just below the ionospheric cusp, a region known to be the footprint of the coupling between the Solar wind, the magnetosphere and the ionosphere. This ideal location combined with an excellent research infrastructure make Svalbard an incomparable site to study this coupling and the wide range of phenomena it may cause.

In this presentation, we introduce the Grand Challenge Initiative (GCI) Cusp, an international collaboration coordinating twelve sounding rockets and ground-based experiments designed to investigate diverse cusp phenomena such as ion heating and up-flows, electromagnetic waves, reconnection, and turbulence. Both taken separately and combined, the observations from the different missions provide a unique data set for studying the cusp under different geophysical conditions, allowing to address outstanding questions of Space physics. Here, we present a few selected observations and results focusing on turbulence, and the measurements made using the multi-needle Langmuir probe system, the contribution from the University of Oslo to the project. The fundamental science relevance for planetary atmosphere studies, and the societal relevance for space weather forecasts will be exemplified.

Finally, we also briefly introduce the next large-scale sounding rocket project, the GCI Mesosphere / Lower Thermosphere (M/LT), which has for goal to investigate the M/LT region in detail by combining observation from different platforms, as well as theoretical and modelling work.

SIOS's valuable contribution to operational sea ice monitoring around Svalbard and the Arctic

Lead / presenting author: Penelope Wagner, Norwegian Meteorological Institute, Norwegian Ice Service

Co-authors:

Abstract:

The Norwegian Ice Service (NIS), part of the Norwegian Meteorological Institute (MET) located in Tromsø, is mandated to monitor sea ice in the European Arctic, with a special focus on Svalbard. The NIS plays an important role in supporting users working in maritime activities in this region from shipping, polar tourism, and those living and working in communities in Svalbard and neighbouring locations. From the perspective of monitoring environmental conditions for navigational safety and assessing the impact of climate change, sea ice remains a challenge in being able to fully utilize the large and increasing volumes of in situ and satellite data available, particularly in near-real time. Currently the combination of European Copernicus Sentinel-1 and Canadian RADARSAT-2 satellites provides almost full coverage of synthetic aperture radar (SAR) satellite coverage over our area on a near daily basis. SAR is essential to be able to detect sea ice features necessary for safe navigation through cloud cover and winter darkness. These features include drift ice in the marginal ice zone, the ice edge, ice along the fjords and coastlines and icebergs. The application of multi-frequency SAR is expected to significantly improve ice information retrieval and our capacity to provide relevant information in support of our users. However, there remain geophysical constraints on the ability of algorithms using microwave sensors to accurately interpret sea ice during the Spring and Summer seasons, due to surface melt. Unfortunately this is when we have the highest amount of maritime activity. Therefore there is a critical need for more in situ observations to be integrated into validation procedures to be able to fully assess the impact of melting conditions, and to calibrate new techniques integrating multiple sensors, particularly cloud-free optical, and forecast model data. All operational ice services continue to require expert ice analysts to provide accurate manual analysis for our routine products, and maintain the continuity of their climatological records that started before the satellite era, because there are no sea ice mapping based on automatic algorithms that have been able to demonstrate sufficient accuracy and robustness to account regional and seasonal variability. The ice analysts make use of webcams located around Svalbard to verify where ice is located and sometimes can integrate ship-based sea ice observations. However, to be able to monitor the sometimes very dynamic changes in and around Svalbard, it is necessary to improve how we coordinate these observation systems and metadata standards. This will facilitate the increased use of observing networks to feed into more meaningful applications that will add value to products directly developed to benefit the community. In the near future, we envision that the synthesis of near-real time ingestion of in situ measurements into sea ice products, in combination with data from relevant satellite sensors at the spatial resolution < 0.5 km, will allow for initialization of the new generation of forecast models with greatly improved spatial resolution.

This will provide for a higher frequency of accurate routine sea ice products from the NIS that will be able to support the long-desired user requirements for the new Arctic.

Evaluation of iceberg detection limits from remote sensing data - An investigation around Negribreen

Lead / presenting author: Laust Færch, UiT - The Arctic University of Norway

Co-authors: Thomas Kræmer, UiT - The Arctic University of Norway; Wolfgang Dierking, The Alfred Wegener Institute; Anthony P. Doulgeris, UiT - The Arctic University of Norway; Nick Hughes, The Norwegian Meteorological Institute;

Abstract:

Icebergs pose a serious hazard to marine traffic and offshore installations, especially in areas with a significant human presence, such as the waters around Svalbard. The expected increase in maritime traffic in the High North necessitates improved and reliable methods for the detection of icebergs over vast areas. In an operational context, icebergs are often mapped using Synthetic Aperture Radar (SAR) images, such as those delivered by the European Sentinel-1 satellites.
SAR sensors can operate independently of sunlight and weather conditions, and thus provide an excellent data source for the Arctic regions. Icebergs that are small relative to the resolution of the sensor are assumed to behave like point targets. The challenge is hence to separate targets with a distinct difference in brightness relative to the background clutter. Several methods based on this principle have been developed and tested in the past.
However, there is a serious lack in our understanding of the limits of using SAR data for iceberg detection. SAR brightness variations are often difficult to interpret due to different scattering mechanisms, sensor and speckle noise, and effects of radar frequency, polarization, and imaging geometry. Additionally, the limits of iceberg detectability are also greatly influenced by the imaging mode and processing level.
A better understanding of the limits of iceberg detection methods is of high importance, as even growlers and bergy bits can pose a danger to marine vessels. However, identifying the limits of current iceberg detection methods requires good reference data. In 2020, we were able to obtain high-resolution optical data from the Dornier aircraft through the SIOS-InfraNor call. Using those data, we have manually identified icebergs near Negribreen and investigated whether a set of icebergs can be identified in Sentinel-1 IW and EW SAR images at various processing levels, as well as Sentinel 2 optical images. In addition, we used Google Earth Engine and Sentinel-2 optical data to identify grounded icebergs, which could be reliably identified over a time series of Sentinel-1 images. These detections will be used as validation data when comparing common iceberg detection methods.
Very few training datasets for iceberg detection are publicly available. We plan to publish the detections as an open dataset, which can then be used in support of e.g., machine learning activities by the wider research community.

Prospects for collaboration with SIOS RS/EO to promote research in the Arctic

Lead / presenting author: Hiroyuki Enomoto, National Institute of Polar Research

Co-authors: Nuerasimuguli Alimasi, National Institute of Polar Research; Noriaki Kimura, AORI/University of Tokyo; Tomonori Tanikawa, Meteorological Research Institute; Misato Kachi, EORC/JAXA;

Abstract:

International research cooperation, inclusions of new technologies, data exchange, and capacity building of researchers will provide more efficient ways for grasping rapid environmental changes in the Arctic and researching their unique processes. Svalbard can realize this as a place of international cooperation, and SIOS has made challenges and implemented many practical actions. There have been outstanding ESA contributions for the satellite data, and JAXA can provide valuable satellite data.

We have been building the Arctic Data archiving System (ADS) at NIPR for satellite and field data sharing, which enhances data collecting and visualization capabilities.

We have also introduced ground-based observation equipment to Ny-Ålesund. Furthermore, we introduced opportunities for Arctic research at Svalbard for Japanese researchers. NIPR has activities as a research institute and has the task of inviting domestic researchers to polar research as an Inter-university Research Institute. Through this function, we support sending many researchers to Svalbard. In addition, as a SIOS member organization, we aim to realize broader international exchanges and joint research.

In this presentation, data and utilization systems that can cooperate with SIOS activities from Japan, ongoing and plans for field observations, enhancing the uniqueness of Svalbard in the Arctic region revealed from the research of sea ice, snow conditions around and on Svalbard.

Time-series of cloud-free Sentinel-2 NDVI data used in mapping the onset of growth of central Spitsbergen, Svalbard

Lead / presenting author: Stein Rune Karlsen, NORCE - Norwegian Research Centre

Co-authors: Laura Stendardi, Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Italy; Hans Tømmervik, Norwegian Institute for Nature Research (NINA), FRAM - High North Research Centre for Climate and the Environment, Tromsø; Lennart Nilsen, Department of Arctic and Marine Biology, UiT–The Arctic University of Norway, Tromsø; Ingar Arntzen, NORCE - Norwegian Research Centre; Elisabeth Cooper, Department of Arctic and Marine Biology, UiT–The Arctic University of Norway, Tromsø;

Abstract:

The main aim of this study is to prepare, analyze and present a cloud-free time-series of Sentinel-2 NDVI data for the 2016 to 2019 seasons covering central parts of Spitsbergen on Svalbard, and then to use the dataset in mapping the onset of vegetation growth. Due to a short and intense period with greening-up and frequent cloud cover, all the cloud free Sentinel-2 data were used. Cloud detection includes several different algorithms and visual inspection of every images. Normalized Difference Vegetation Index (NDVI) values were calculated for the cloud-free pixels, and interpolated to daily data. Pixels with more than 10 days since last cloud-free observation were removed from the dataset. The resulting dataset is clear-sky NDVI-maps with 10 x 10 m2 resolution for the 2016 to 2019 seasons. For the 2019 season we used Sentinel-2 data from 30 April to 15 August. For these 107 days we got cloud free data on average 18.8 days. Parts of Reindalen had up to 29 days with cloud free data, which mad gap filling to daily data easy. However, for the 2016, 2017 and 2018 seasons less cloud-free data is available, and the time-series these years have several gaps. The onset of growth was then mapped by a NDVI threshold method, which showed significant correlation ($r2 = 0.47$, $n = 38$, $p < 0.0001$) with ground based phenocam observation of onset of growth in seven vegetation types. However, large bias was found between the Sentinel-2 NDVI-based mapped onset of growth and phenocam based onset of growth in a moss tundra, which indicates that the results in these parts must be interpreted with care. The Sentinel-2 NDVI-based mapping of onset of growth reveals large differences between the years. In 2018 the onset of growth was more than 10 days earlier compared with 2017, except at higher altitudes.

Mapping of Surface Soil Moisture with the Integration of the Optical & Microwave Remote Sensing

Lead / presenting author: Jeenu John, University of Madras

Co-authors: R.Jaganathan, University of Madras; Dharshan Shylesh D S, University of Madras;

Abstract:

Soil Moisture has a significant influence on the exchange of energy between land and atmosphere and plays a significant role in controlling the infiltration, runoff, and evapotranspiration of a region. Mapping of Soil Moisture is very important in monitoring as well as predicting the occurrence of disasters such as flood, drought and also for agricultural planning. In a country like India, where in-situ soil moisture measurement sites are limited the remote sensing technique provides a unique opportunity for the estimation of soil moisture at a high spatial and temporal accuracy. Since SAR data has high temporal resolution and the ability to penetrate all weather conditions it has made used in different researches. In this study, surface soil moisture is estimated with Sentinel 1 A, C-band SAR remote sensing data with VV polarization, and Sentinel 2-A data in the study area okkiyam Maduvu watershed where clayey soil is predominant, situated inside Chennai Basin, India. The proposed methodology is based on the water cloud model in estimating surface soil moisture over vegetated regions and the ability of Sentinel 1 in estimating soil moisture over bare earth regions. The backscattering from the the vegetated region is estimated by vegetation such as Dual polarized SAR Vegetation Index, Radar veegation Index and Normalized Difference vegetation Index. The backscattering from the soil is estimated by inverting the model . The results were validated with in-situ soil moisture measurements and with the Normalized Difference Vegetation Index of the region. This study shows the integration of Sentinel 1 and Sentinel 2 data in mapping soil moisture at a high spatial resolution over bare and vegetated regions.

50 years of tidewater glaciers on the east coast of Svalbard: surface elevation and retreat dynamics

Lead / presenting author: Jan Kavan, Faculty of Science, Masaryk University

Co-authors:

Abstract:

Tidewater glaciers on the east coast of Svalbard were examined for their surface elevation changes and retreat rate. The archival DEM from 1970 (generated from the aerial images by NPI) in combination with recent ArcticDEM were used to compare the surface elevation changes of the glaciers. This approach was complemented by the retreat rate estimation based on the analysis of Landsat and Sentinel-2 images. Four out of eleven examined tidewater glaciers turned into land-based glaciers due to the retreat of the glacier front. The remaining tidewater glaciers retreated with the average annual retreat rate of 48 m/year ranging from 30 to 150 m/year. All the glaciers studied experienced rather important surface thinning in their frontal zones with maximum elevation loss exceeding 100 m in certain parts. In contrast to the massive retreat and thinning of the frontal parts, minor increase in ice thickness was recorded in some highly elevated parts of the glaciers. This change in the glacier geometry suggests an important shift in the glacier dynamics over the last 50 years very likely reflecting the overall trend of increasing air temperature.

Progress of Cryosphere Virtual Laboratory (CVL

Lead / presenting author: Eirik Malnes, NORCE

Co-authors: Daniel Stødle, NORCE; Øystein Godøy, The Norwegian Meteorological Institute, ; Anton Korosov, Nansen Environmental and Remote Sensing Center, ; Robin Skahjelm-Eriksen , S&T; Mikhail Itkin , The Norwegian Polar Institute; Ola Grabak, European Space Agency, ESRIN;

Abstract:

Cryosphere Virtual Lab is a project funded by the European Space Agency and will build of a system that will use recent information and communication technologies to facilitate the exploitation analysis, sharing, mining and visualization of the massive amounts of earth observation data available. The system will utilize available satellite, in-situ and model data from ESA/EU, Svalbard Observatory (SIOS) and other sources. CVL will foster collaboration between cryosphere scientists and allow to reduce the time and effort spent searching for data, and to develop their own tools for processing and analysis.
CVL is currently developing the landing page cvl.eo.esa.int/ and the backbone data source services related to CVL (data search and access). Parts of the system is already functional. We are also working jointly with ESA PTEP (Polar Thematic Exploitation Platform) to provide cloud computing reseources. The vision behind CVL is in the long run to provide a platform where Cryosphere science can be carried out easily, and where used can be inspired by readily access to data , computing resources and a library of processing tools (Jupyter scripts) for EO data. We demonstrate the feasibility of the system in 5 use cases on a wide field of applications including snow, sea ice and glaciers, but also fund 20 PhD/Master students that shall explore the system for their own applications.
The system will be built upon open scientific standards, and data as well as code will be published openly to allow users to adapt the system to their interests. The system will also provide tools for visualization in 2D and 3D. CVL will continue to live after the 3 year project has been finalized, and aims at providing free-of-charge services for the users that are interested in delivering new information about the rapid changing Arctic Cryosphere.

Snow measurement surveys using a drone-borne ultrawideband radar

Lead / presenting author: Markus Eckerstorfer, NORCE

Co-authors: Rolf Ole Rydeng Jenssen, NORCE; Eirik Malnes, NORCE; Hannah Vickers, NORCE; Tore Riise, NORCE;

Abstract:

Snow is an important factor of the Earth's cryosphere and hydrological cycle and a critical component of the Earth's ecosystem. Due to its physical state, snow is highly sensitive to climate change, resulting in strong feedback mechanisms that affect e.g. freshwater management, hydropower applications, flood and avalanche risk and the winter tourism industry.
In situ observations of important snowpack parameters such as spatiotemporal extent, depth and snow water equivalent are sparse, at a point-scale, and focused on accessible areas. To monitor these snowpack parameters, remote sensing platforms, carrying different sensor systems have recently become popular.
We have developed a high resolution, ultrawideband, nadir-looking radar that can perform snow depth, snow density, and snow stratigraphy measurements in a variety of different snow conditions. To access large, remote, or high-risk areas, we developed the radar to be carried by a multirotor drone that can autonomously carry out snow surveys. Our system can effectively collect data with an airspeed of 10 m/s, flying 7 m above ground for up to 25 min in light wind and -20 deg C.
We present the design choices for both the radar and the drone and how the system is operated in the field. We furthermore validate the drone measurements of snow depths with in situ field measurements that resulted in a spatial correlation coefficient of 0.97. Finally, we reflect on future developments of our drone-borne radar system and potential further applications.

Multiscale mapping of plant functional groups and plant traits using field spectroscopy, UAV imagery and Sentinel-2A data

Lead / presenting author: Eleanor Thomson, University of Oxford

Co-authors: Marcus Spiegel , University of Oxford ; Brian Enquist , University of Arizona; Vigdis Vandvik, University of Bergen; Marc Macias-Fauria, University of Oxford ; Yadvinder Malhi, University of Oxford ;

Abstract:

The Arctic is warming twice as fast as the rest of the planet, leading to rapid changes in species composition and plant functional trait variation. Landscape-level maps of vegetation composition and trait distributions are required to expand spatially-limited plot studies, overcome sampling biases associated with the most accessible research areas, and create baselines from which to monitor environmental change. Unmanned aerial vehicles (UAVs) have emerged as a low-cost method to generate high-resolution imagery and bridge the gap between fine-scale field studies and lower resolution satellite analyses. Here we used field spectroscopy data (400–2500 nm) and UAV multispectral imagery to test spectral methods of species identification and plant water and chemistry retrieval near Longyearbyen, Svalbard. Using the field spectroscopy data and Random Forest analysis, we were able to distinguish eight common High Arctic plant tundra species with 74% accuracy. At the UAV level, we were able to map three plant functional groups (mosses, graminoids and dwarf shrubs) at 72% accuracy and generate maps of plant chemistry across a 450 m long nutrient gradient located underneath a seabird colony. Our maps show a clear marine-derived fertility gradient, mediated by geomorphology. We used the UAV results to explore two methods of upscaling plant water content to the wider landscape using Sentinel-2A imagery. Our results are pertinent for high resolution, low-cost mapping of the Arctic.

CIRFA: Remote Sensing in Arctic operations

Lead / presenting author: Torbjorn Eltoft, CIRFA - UiT the Arctic University of Norway

Co-authors: Torbjørn Eltoft, CIRFA - UiT the Arctic University of Norway;

Abstract:

Remote sensing from space is a key technology for observing the physical environment in the Arctic. In this regard, integrated remote sensing, which is to be understood as the process of combining data from multiple platforms and sensors and assimilating the derived information into numerical models, offers unprecedented opportunities to monitor and predict oceanic phenomena like ocean surface slicks, icebergs or sea ice conditions.
Currently, an enormous amount of data is being collected by a suite of remote sensing satellites carrying a multitude of specialized sensors. Among these, the Sentinels, which are the foundation of EU's ambitious Earth observation program Copernicus, are providing new opportunities due to the program's free and open data policy. The Sentinels have high importance for operational monitoring of the Arctic.
For High North monitoring from space synthetic aperture radar (SAR) sensors, operating at microwave frequencies, will be of particular interest due to their relatively high resolution, and their all-weather and light-independent capabilities. However, SAR signals are dependent on imaging geometry and surface properties, and the interpretation of a SAR scene over ocean or sea ice is often ambiguous and extremely complicated. Hence, in many cases multi-sensor integration is needed to resolve ambiguities. Multi-sensor integration also has its own technical challenges, as different sensors have their own underlying physical principles, and they offer information at different spatial resolution, ranging from point measurements (in-situ) to synoptic images with pixel-sizes at kilometer levels (micro-wave radiometers).
Integrated remote sensing and forecasting is the research topic of CIRFA (Centre for Integrated Remote Sensing and Forecasting for Arctic Operations), a Centre for Research-based Innovation hosted by UiT the Arctic University of Norway. The Centre has been operating for 5 years and has in this period made significant scientific and technical contributions. In this presentation, we give a brief review of the research in CIRFA and we provide an update on some of the Centre's main achievements.

Scientific Applications of Unmanned Vehicles in Svalbard

Lead / presenting author: Richard Hann, NTNU / UNIS

Co-authors:

Abstract:

This presentation is based on the chapter "Scientific Applications of Unmanned Vehicles in Svalbard" in the 3rd SESS report.

Unmanned vehicles are important tools for conducting research in the Arctic, especially in the field of climate change. This
emerging technology allows obtaining complementary datasets to established observation methods such as satellite-based remote sensing and ground observations. Therefore, the use of unmanned vehicles in Svalbard is an important component to develop and enhance the knowledge of current changes in the Arctic and on a global scale.

Surge-Related Changes in Negribreen, Svalbard, Observed with ICESat-2

Lead / presenting author: Ute Herzfeld, Geomathematics, Remote Sensing and Cryopsheric Sciences Lab, ECEE, University of Colorado Boulder

Co-authors: Matthew Lawson, Geomathematics, Remote Sensing and Cryopsheric Sciences Lab, ECEE, University of Colorado Boulder; Thomas Trantow, Geomathematics, Remote Sensing and Cryopsheric Sciences Lab, ECEE, University of Colorado Boulder; Jack Hessburg, Geomathematics, Remote Sensing and Cryopsheric Sciences Lab, ECEE, University of Colorado Boulder; Adam Hayes, Geomathematics, Remote Sensing and Cryopsheric Sciences Lab, ECEE, University of Colorado Boulder;

Abstract:

The objective of this talk is to demonstrate the capabilities of ICESat-2 satellite altimeter observations to provide geophysical information on surface signatures of the ongoing surge in Negribreen and to apply resultant measurements and parameters to investigate the evolution of the surge process. ICESat-2 data are complemented by airborne geophysical field observations, conducted by our group in 2018 and 2019, and other satellite data, including Planet SkySat and WorldView data from Maxar, formerly DigitalGlobe, and Sentinel data from ESA's Copernicus Mission.

Initiating from a small region in lower Negribreen in 2016, the surge has spread through most of Negribreen by 2021, resulting in 200-fold acceleration, pervasive crevassing, mass transfer evident in elevation changes and significant mass loss through calving.

In analysis and observation of the surge, we take a mathematical approach centered on crevassing. The characteristic properties of different types of crevasses are indicators of the progression of the surge process. Using the density-dimension algorithm for ice surfaces, the DDA-ice, a method specifically developed for analysis of ICESat-2 ATLAS data, we retrieve surface heights and surface morphologies of the crevassed ice surface at 0.7m along-track resolution of the sensor. Airborne altimeter and image data serve as validation of ICESat-2 measurement capabilities.

Analysis of the entire record of ATLAS data collected from launch in 2018 to date (May 2021) yields information on (1) elevation change, (2) ice-surface roughness, (3) occurrence of different crevasse types, (4) changes in hydrological system of the glacier system, (5) calving, (6) mass loss and (7) contribution to sea-level rise.

The Arctic Amplification over Svalbard: A remote sensing perspective

Lead / presenting author: Igor Esau, Nansen Environmental and Remote Sensing Center

Co-authors: Victoria Miles, Nansen Environmental and Remote Sensing Center;

Abstract:

Climate change in the Arctic is amplified and accelerated. Climate models reveal that Svalbard is situated in the core area of this Arctic Amplification. Century long observations at the Svalbard Airport show the surface air temperature increase by almost 10oC (Nordli et al., 2020). Most of this increase has occurred since 1990 during the era of intensive satellite observations. In this sense, satellite remote sensing is a key to reveal the full extent and complexity of the Arctic Amplification over Svalbard. A credible climatic study however requires long-term synthetic remote sensing data products to characterize the changes. In this study, we consider the Arctic Amplification over Svalbard from a remote sensing perspective. We quantify the changes in the Arctic atmosphere and cloud cover as well as on the land and ocean surface using a diverse set of recently developed products covering at least two decades. We review usability of the remote sensing products for climate modeling and practical applications climate change adaptation applications.