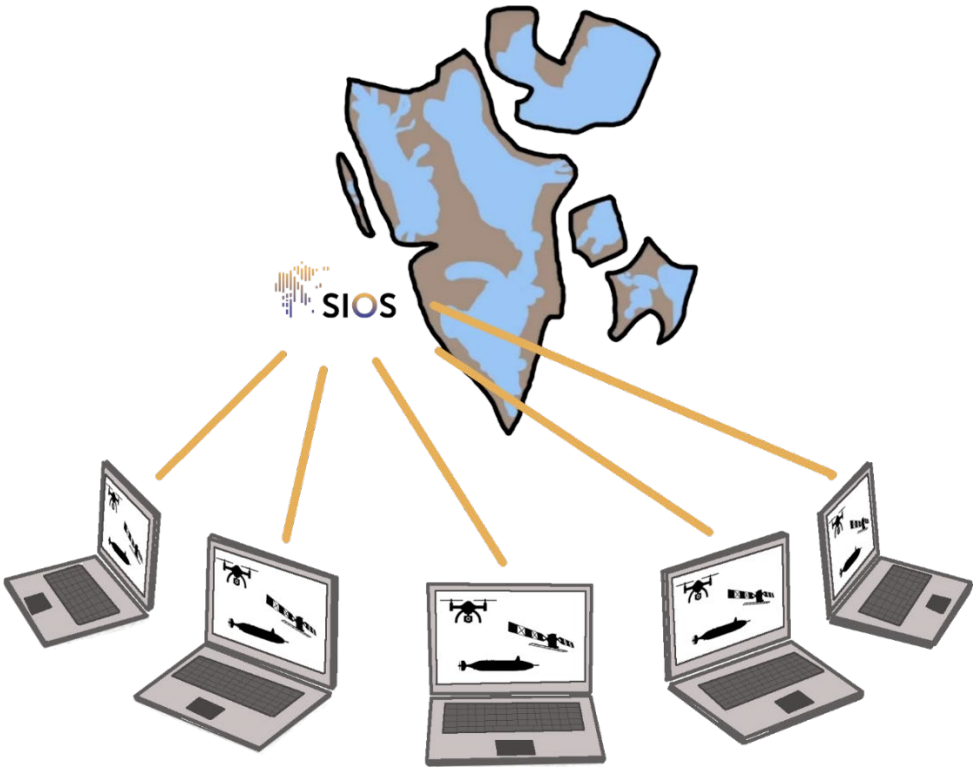
SVALBARD INTEGRATED ARCTIC EARTH OBSERVING SYSTEM

SIOS Online Conference on Remote Sensing (RS) and Geoinformation (GI) applications in Svalbard

4-5 June 2020

Book of abstracts



Keynotes

- **ESA's contribution to Arctic Cal/Val activities and its specific relevance to Svalbard research community.**
  Malcolm Davidson, Tommaso Parinello, Mark Drinkwater, and Tania Casal (Team ESA)
  PDF Video
- **Arctic Amplification $(AC)^3$ Project**
  John Burrows (Team AC^3), University of Bremen
  PDF Video
- **Satellite remote sensing of sea ice - recent advances and remaining challenges**
  Eero Rinne, Finnish Meteorological Institute
  PDF Video

Invited talks

- **Airborne radar system for cal/val activities in Svalbard**
  Tom Rune Lauknes, NORCE

- **MOSAiC: World's largest drift campaign -Remote Sensing activities**
  Suman Singha, German Aerospace Center (DLR); Gunnar Spreen, University of Bremen; Thomas Krumpen, Alfred Wegener Institute (AWI); MOSAiC Remote Sensing and Sea Ice Team
  Video
- **Norwegian Space activities in the Arctic**
  Maria Høegh Berdahl, Norwegian Space Agency
  Video

SIOS's Airborne remote sensing campaigns in Svalbard

- **Veijo Pohjola:** Mapping of perennial firn aquifers and firn characteristics on Svalbard ice fields (PFA) and Mapping surface properties on Lomonosovfonna (SurfPro) Project
  PDF Video
- **Jack Kohler:** Kongsvegen surge: Digital Elevation Model 2020 (KNG_SURGE_DEM2020)
  PDF Video
- **Małgorzata Błaszczyk**: Airborne Remote Sensing in South of Spitsbergen (current evolution of polar environment) (AirborneSOS)
  PDF Video
- **Marta Majerska:** Hindcasting and projections of hydro-climatic conditions of Southern Spitsbergen (HyMote)
  PDF Video
- **Hans Tømmervik:** The Vanishing White (VANWHITE) - Airborne Remote Sensing campaign Svalbard 2020
  PDF Video
- **Lennart Nilsen:** Automatic system for monitoring vegetation and environmental seasonal changes on Svalbard using hyperspectral data (ASMoVEn)
  PDF Video
- **Maarten Loonen:** Long term changes in vegetation and permafrost in Rosenbergdalen (Rosenbergdalen) and Barnacle Goose Ecology: interactions with a changing environment (GOOSE)
  PDF Video

SIOS Data Management System (SDMS) - towards open data in Svalbard research

Lead / presenting author: Dariusz Ignatiuk, SIOS KC

Co-authors: Øystein GODØY, MET.NO; Lara Ferrighi, MET.NO; Heikki Lihavainen, SIOS; Shridhar Jawak, SIOS; Inger Jennings, SIOS; Christiane Hübner, SIOS; Bo Andersen, SIOS

PDF - Video

Abstract:

The Svalbard Integrated Arctic Earth Observing System (SIOS) is establishing a regional observing system for long-term monitoring and research on global environmental change in an Earth System Science perspective. SIOS is, through its 24 international member institutions, monitoring atmospheric, terrestrial, cryospheric, ocean and sea ice composition, conditions and variability. The purpose of the SIOS Data Management System is to establish unified discovery and access to datasets relevant for SIOS regardless of their physical location (host data centre). The SDMS provides users with tools for data validation and transformation as well as services for data submission, discovery and access. Possibilities of sharing data and the principles of SDMS (FAIR data, Data Access Point) will be presented as well as discussion of SDMS activities related to remote sensing.

NextGEOSS data hub and platform - enhancing remote sensing data and analysis in Svalbard

Lead / presenting author: Bente Lilja Bye, BLB

Co-authors: Torill Hamre, NERSC; Markus Fiebig, NILU

Abstract: PDF - Video

Polar regions share common challenges related to access to in-situ data. Remotely sensed data is therefore of great value to research and management of places like Svalbard. Even more critical is our ability to combine the variety of data in an effective manner. It is a great potential in learning from the experiences and knowledge aquired across the various fields. The H2020 project NextGEOSS has built a European data hub and platform to support the Earth observation communities with a set of tools and services through the platform. The suite of tools on the platform alllows scalablitly, interoperability and transparency in a flexible way, well suited to serve a multifaceted interdisciplinary community, NextGEOSS is developed with and for multiple communities, the NextGEOSS pilots. The NextGEOSS Cold Regions pilot liaises with ongoing initiatives such as SIOS, GEO-CRI, WMO GCW, as well as national programs in Antarctica, to contribute to improved access to observations and products for science, public and private sector, within the framework of GEOSS.
We will introduce the NextGEOSS data hub and platform and show how the Cold Regions pilot has made selected Copernicus data and products related to Svalbard discoverable and accessible. The products are made available through the NextGEOSS Data Hub and the Cold Regions Pilot Community Portal, for users and stakeholders in the GEO community, polar research and education. Having a common entry point makes it easier for users to find relevant data and products. NextGEOSS 5 step user experience and step by step onboarding system are made to serve communities like SIOS on Svalbard as well as other polar regions. Capacity building is built in the NextGEOSS activities including for the Cold Regions communities. Ways to benefit from these resources also beyond the project period of NextGEOSS will be explained.

Satellite remote sensing estimation of suspended particulate matter in the coastal waters of Svalbard

Lead / presenting author: Rakesh K. Singh, Université du Québec à Rimouski (UQAR)

Co-authors: Daniela Walch, Universität Potsdam; Simon Bélanger, Université du Québec à Rimouski (UQAR) ; Amanda Poste, Norsk institutt for vannforskning (NIVA); Janne E. Søreide, University Centre in Svalbard (UNIS)

Abstract: PDF - Video

Satellite remote sensing offers a unique opportunity to gain insight into seasonally and spatially dynamic processes in Arctic coastal ecosystems. It can be used to estimate key water quality parameters, including suspended particulate matter (SPM) concentration with a higher temporal resolution and synoptic coverage. The present study aims to link satellite observations from Operational Land Imager (OLI) sensor (on-board Landsat-8) with contemporaneous field observations of SPM concentration in Isfjorden (Svalbard) during 2018 and 2019, including detailed field campaigns with a gridded sampling of the Adventelva river plume in June and August of 2019. These field and remote sensing data are used to validate algorithms for prediction of SPM in Svalbard's coastal waters and construct time series of coastal surface SPM concentration (and spatial extent of freshwater influence) in Isfjorden. The remote sensing estimation can be extended to the estimation of Chlorophyll-a (Chl-a) concentration and chromophoric dissolved organic matter (CDOM) with the inclusion of data from more satellites, such as Sentinel-2 and 3. The improved estimation of optically active constituents (Chl-a, SPM and CDOM) in coastal waters will help us to gain insight into how coastal ecosystems respond to seasonal changes in inputs from land to sea as well as extreme climate events (e.g. high river inputs due to large rainfall events).

An overview of EO activities in the SIOS access programme and SIOS-InfraNor project

Lead / presenting author: Inger Jennings, SIOS

Co-authors: Shridhar Jawak, SIOS

Abstract: PDF - Video

SIOS Knowledge Centre (SIOS-KC) administrates a programme providing access to the research infrastructure owned by SIOS members. The SIOS access programme has had annual calls since 2017 and has supported 15 projects so far (up to and including March 2020). Of these, two projects are strongly linked with EO activities: (1) Validation of a satellite-based Snow Cover Index for Svalbard (SvalSCE), and (2) Negribreen surge. In the SvalSCE project, a team from the Norwegian Meteorological Institute has derived daily snow cover maps for Svalbard from a 34-year (1982 - 2015) long time series of Advanced Very High-Resolution Radiometer (AVHRR) data. In the “Negribreen Surge” project, a team from the University of Colorado Boulder collected geophysical data over the glacier system to investigate the surge phenomenon. One of the objectives of this project was to evaluate satellite laser altimeter data of NASA's ICESat-2 mission, funded by NASA Earth Sciences.
The SIOS-InfraNor project is funded by the Research Council of Norway (RCN) and Norwegian Space Agency (NoSA) and project managed by SIOS-KC. The project includes 41 items, ranging from scientific instruments to satellite data products. We present four examples: 1) SIOS-NORCE Dornier passenger aircraft to acquire high-resolution aerial images and hyperspectral data in Svalbard during September 2019, (2) installation of the Pandora spectrometer (Sept. 2019) in the northernmost part of the planet to support Cal/Val of Sentinel-5P satellite mission,(3) generation of high-resolution Sentinel-1 Synthetic Aperture Radar (SAR) based wind fields over Svalbard and associated waters in October 2019, (4) generation of vegetation maps using Sentinel-2 and WorldView-2 data.
These six examples demonstrate the usefulness of EO technology in Svalbard (1) by providing aerial imagery to field scientists working in Svalbard to complement their research studies, (2) by installing new sensors to support calibration and validation activities for satellite missions, and (3) by using satellite data to provide information about wind, vegetation and snow cover. These coordinated efforts are expected to contribute to address broad scientific questions in Earth system science and assist in integrated monitoring, modelling and decision support in Svalbard in the coming decades.

New possibilities with a dual frequency (X/L-band) SAR onboard Lufttransport's Dornier DO-228

Lead / presenting author: Tom Rune Lauknes, NORCE Norwegian Research Centre

Co-authors: Agnar Sivertsen, NORCE Norwegian Research Centre; Rune Storvold, NORCE Norwegian Research Centre; Kjell Arild Høgda, NORCE Norwegian Research Centre; Charles Werner, Gamma Remote Sensing Research and Consulting AG; Wolfgang Dierking, UiT The Arctic University of Norway/AWI Alfred Wegener Institute for Polar and Marine Research

Abstract: PDF - Video

Lufttransport AS operates a Dornier DO-228 aircraft (LN-LYR) stationed in Longyearbyen, Svalbard. The aircraft is currently equipped with a scientific data package consisting of a hyperspectral imager, medium format camera, high-precision GNSS navigation system, a broadband radio, and an AIS receiver. Future plans include enhancing the operational and scientific capabilities by also adding a L– and an X-band synthetic aperture radar (SAR). In addition to improved scientific and Cal/Val capabilities, the two radar systems will also improve safety and emergency response in the Arctic.

Current climate changes as well as an increased marine activity in the arctic regions impose a growing need for better scientific observations and increased situational awareness. Satellite SAR systems provide all weather observational capacity, and the European Commission's Copernicus Sentinel-1 C-band SAR constellation is a key asset. However, it is well known from the literature that SAR sensors with other wavelengths such as L-band and X-band are highly complementary due to the backscatter frequency dependence of many ground targets. The longer wavelength of L-band allows penetration through snow and vegetation canopy, as well as improved capability of detecting ground motion using SAR interferometry (InSAR) in areas with vegetation or strong motion, while the shorter wavelength of X-band improves spatial resolution and detection capability of smaller targets, which is of particular importance for maritime surveillance applications. By collecting dual-frequency, fully polarized radar backscatter, it is possible to study the frequency dependence of polarized and depolarized backscatter, which is very relevant for cryospheric applications.

An airborne L– and X-band SAR system will fill important observation gaps in arctic regions by contributing to:
● Providing an all-weather sensor for search and rescue and maritime surveillance including detection of vessels and oil spills, sea ice type separation and detection of icebergs critical to safe navigation in Arctic areas;
● Operational monitoring of glaciers and ice caps related to the climate change policy, and addressing the information gaps in Snow Water Equivalent (SWE) retrieval;
• Safety by extending the monitoring of geohazards linked with surface motion such as landslides and subsidence also into vegetated areas providing

complementary service to current Copernicus satellites;
• Providing an airborne platform that can collect essential calibration and validation data for satellite SAR missions such as ROSE-L and NISAR.

The identification of previously unknown surge-type glaciers in Spitsbergen

Lead / presenting author: Osip Kokin, Lomonosov Moscow State University

Co-authors: Aino Kirillova, Zubov State Oceanographic Institute; Nikita Meshcheriakov, Murmansk Marine Biological Institute KSC RAS; Andrey Vashkov, Geological Institute KSC RAS

Abstract:

Surge-type glaciers are widespread in Spitsbergen. Nowadays, about 150 surging glaciers are known here. They were established according to the evidences of sudden terminus advance and special ice-surface features (loop moraines, unusually intense crevassing, etc.). Direct observations, historical records and multi-temporal remote sensing data analysis are sources of these evidences which are short-lived and allow to establish only those glacier surges that occurred recently.
Morphological features of deglaciated areas are the only evidence of surges not recorded by sudden terminus advance and special ice-surface features. There are some attempts to identify previously unknown surge-type glaciers using a specific suite of indicator landforms (a land-system approach). These indicator landforms are thrust moraines, concertina eskers, subglacial crevasse-squeeze ridges, hummocky moraine and flutings.
In this paper, an alternative approach is considered. It is based on the hypothesis that the surging and non-surging behavior of the glaciers leads to the lateral moraine formation of a different configuration outside the mountain valleys with identical longitudinal profile of the lower part of the valley and at the exit from it. In order to test this hypothesis, the deglaciated area of 80 the most largest surge-type glaciers in West Spitsbergen were analyzed using open remote sensing data of the npolar.no portal. Longitudinal profiles of the lower part of the valleys and at the exit from it were evaluated using the ArcticDEM digital elevation model. There are direct and concave longitudinal profiles. Only 50% of glaciers have lateral moraines outside the mountain valleys. 70% of them have direct longitudinal profiles of the lower part of the valleys and at the exit from it. 86% of them have straightforward lateral moraines which continue the sides of the valleys outside them unlike lateral moraines that diverge in different directions when leaving the valley.
Thus, if a non-surging glacier has a direct longitudinal profile of the lower part of the valleys and at the exit from it and straightforward lateral moraines outside the valley, then with a high degree of probability we can speak of the surge behavior of the glacier during the formation of these lateral moraines. These morphological features of lateral moraines can be used as evidences for identification of previously unknown surge-type glaciers in Spitsbergen.
The reported study was funded by MSU, Faculty of Geography (AAAA-A16-116032810055-0).

‘The Svalbard glaciers response to the climate change: an investigation into Hansbreen dynamics.’

Lead / presenting author: Joanna Tuszynska, Institute of Geophysics, Polish Academy of Sciences

Co-authors: Jacek Jania, Institute of Geophysics, Polish Academy of Sciences; Małgorzata Błaszczyk, Institute of Geophysics, Polish Academy of Sciences; Bartłomiej Luks, Institute of Geophysics, Polish Academy of Sciences

Abstract: PDF - Video

Remote sensing data makes an important element of study dedicated to Hansbreen (Southern Spitsbergen) dynamics. Geospatial technologies are constantly developing and thus are providing us with wide range of possibilities. In the field of glaciology, the most important is monitoring of glacial processes - such as ice surface velocity, ice-cliff’s fluctuation and calving intensity.
Satellite, airborne and ground-based images are highly valuable and complementary to constantly growing collection of in-situ measurements. In my research, except for multiyear dGPS measurement I intend to use two kinds of remote sensing data.
Long series of time-lapse images will be used to survey Hansbreen surface velocity and its terminus calving rates
Aerial photography is planned to be used to perform feature tracking analysis which allows for a calculation of Hansbreen surface velocity.
Detailed knowledge and understanding of mentioned processes are essential for correct recognition of the ice-atmosphere-sea interactions.

Long-term monitoring of glaciers in Hornsund (Svalbard) with remote sensing data

Lead / presenting author: Malgorzata Blaszczyk, University of Silesia

Co-authors: Małgorzata Błaszczyk, Faculty of Natural Sciences, University of Silesia in Katowice, Poland; Jacek A. Jania, Faculty of Natural Sciences, University of Silesia in Katowice, Poland; Barbara Barzycka, Faculty of Natural Sciences, University of Silesia in Katowice, Poland; Mariusz Grabiec, Faculty of Natural Sciences, University of Silesia in Katowice, Poland; Dariusz Ignatiuk, SIOS Knowledge Centre, Longyearbyen, Svalbard; Michał Ciepły, Faculty of Natural Sciences, University of Silesia in Katowice, Poland; Mateusz Moskalik, Institute of Geophysics, Polish Academy of Sciences, Warszawa, Poland.; Bartłomiej Luks, Institute of Geophysics, Polish Academy of Sciences, Warszawa, Poland.; Agnieszka Strzelewicz, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland; Waldemar Walczowski, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Abstract:

Glaciers draining to the Hornsund basin (Southern Spitsbergen, Svalbard) have experienced a significant retreat and mass volume loss over the last decades, increasing the input of freshwater into the fjord. Here we present outcomes of the long-term monitoring of glaciers conducted in Hornsund based on remote sensing data. Thanks to the vicinity of Polish Polar Station in Hornsund, results of satellite based research were validated with wide range of in-situ data collected during scientific expeditions. (1) Marine-terminating glacier front fluctuations between 1992 and 2017 were studied with use of wide range of archive multispectral and radar data (Landsat 5, Landsat 7, Landsat 8, Terra ASTER, Alos AVNIR, SPOT 5, ERS-1, ERS-2, ENVISAT, Alos PALSAR, TerraSAR-X, TanDEM-X, Sentinel-1 and Sentinel-2). Results show high correlation of front position changes with air temperature and oceanographic condition, as well as water depth. (2) Geometry changes in the period 2012–2017 over Hansbreen and Hornbreen, two tidewater glaciers in Hornsund were studied based on the DEMs (Digital Elevation Model) generated from high resolution satellite images (WorldView-2 and Pléiades). Accuracy and precision of digital elevation models (DEM) were assessed based on in-situ data. Result show significant lowering of the glaciers surface. (3) Frontal ablation of tidewater glaciers in Hornsund in period 2006-2015 was estimated based on archive satellite data (ERS-2, Envisat, ALOS, TSX and Sentinel-1). Frontal ablation were compared with other sources of freshwater supply to the fjord. Results indicate glaciers as a main source of freshwater in the fjord. (4) Monitoring of glacier zones in Hornsund was based on classification of Synthetic Aperture Radar (SAR) data from both de-commissioned (ENVISAT ASAR) and modern satellite missions (RADARSAT-2, Sentinel-1, ALOS-2 PALSAR). Supervised classification of Landsat 8 images was used for assessing the progress of snow cover melting on Hornsund glaciers during the season.

Unmanned Vehicles for Autonomous Sensing and Sampling near glacier fronts in the Arctic region

Lead / presenting author: Azzaro Maurizio, Institute of Polar Sciences

Co-authors: Caruso Gabriella , Institute of Polar Sciences; La Ferla Rosabruna , Institute of Polar Sciences; Maimone Giovanna , Institute of Polar Sciences; Azzaro Filippo , Institute of Polar Sciences; Cosenza Alessandro, Institute of Polar Sciences; Alessandro Ciro Rappazzo, Institute of Polar Sciences; Zappal Giuseppe, Institute for Biological Resources and Marine Biotechnology ; Ferretti Roberta, Institute of Marine Engineering; Odetti Angelo, Institute of Marine Engineering; Bruzzone Gabriele, Institute of Marine Engineering

Abstract:

Advanced technologies for marine monitoring are needed to understanding the impact of natural and human-induced change on the environment, especially those related to ice melting. Within the UVASS (Unmanned Vehicles for Autonomous Sensing and Sampling) project, an unmanned marine vehicle (PROTEUS, Portable RObotic TEchnology for Unmanned Surveys), equipped with an automatic water multisampler, were applied to study the response of planktonic communities, particularly prokaryotes, in the extreme environment of Kongsfjorden (Svalbard Islands). During June 2017, seawater samples collected by those automatic systems along three transects located from glaciers to the open sea were analyzed for organic matter utilization by microbial activity, using Biolog-Ecoplates and extracellular enzymatic activity rates (leucine aminopeptidase, beta-glucosidase and phosphatase activities). Richness and Shannon-Weaver index and Principal Component Analysis were used to depict differences in the microbial catabolic potential. Variations in the functional diversity of microbial assemblages were observed.

Exploring Relationship between Atmospheric Variables and Sea Ice in Svalbard

Lead / presenting author: Bhasha Harshal Vachharajani, Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India

Co-authors: Ms. Dency V. Panicker, Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India; Bhasha Harshal Vachharajani, Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India; Rohit Srivastava, Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India; D. Ram Rajak, Space Applications Centre,Indian Space Research Organization, Ahmedabad, Gujarat, INDIA

Abstract: PDF - Video

The advent of satellite era and remote sensing provided an immense thrust to progress in knowing the Polar Regions and studying the climatic conditions over there. Scientists have reported large scale changes in the Arctic in terms of sea ice extent and area. Moreover, there exists a unique meteorology over the seas of Arctic Region which is driven by the presence of sea ice and a seasonal oscillation from a large heat loss in winter to a little gain in summer. As summer progresses, air temperature increases causing relative absorption and insolation at the surface. This results in snow and ice melt and ultimately increasing open water area.

Thinning and Reduction of sea ice over north and east of Svalbard in recent years is consistent with global warming and have possibly led to more wind generated upward mixing of warm and saline Atlantic Water from about 200 m depth, preventing formation of sea ice. As this warm and saline water is cooled by the atmosphere, it gets heavier and sinks in a convection process that brings up more Atlantic Water to the surface. In many years (like 2011, 2012 and 2013) such a process likely prevented sea ice formation during autumn and winter in large parts of the western Nansen Basin north of Svalbard. Such huge anomalies in the sea ice create large air-sea fluxes between the relative warm ocean and the cold atmosphere during winter and have together with anomalous weather conditions given many extreme high temperature events during the recent years.

The present study focuses on addressing the sea ice near Svalbard region with land as a focal point. We have chosen the Svalbard region [76.5°N-80.5N, 30°E-10°W] to study the atmospheric factors affecting sea-ice growth and decay. Additionally, the peripheral region of Svalbard, mostly surrounded with morphologically different seas obviously adds on the varied behaviour in cryospheric parameters due the atmospheric variability. We have chosen sea ice concentration (SIC) as a cryospheric variable and air temperature (AT) and Out-going Longwave Radiation (OLR) as atmospheric variables. All the three are extracted from NCEP for the span 2017-2020. Sea ice always being impacted by the season fluctuation, the study aims at bifurcating the time, with one being its growth phase and the other being the decay phases i.e. October-March and April-September respectively. It is found that, over Svalbard, AT and OLR seem to play a role in driving SIC. Both AT and OLR are inversely related to SIC with R2 values

0.79 and 0.31 respectively. It shows that air temperature is one of the most important atmospheric parameters that affect sea ice decay and melt. The reason behind such behaviour of the atmosphere over the sea is its convection process that causes the water bodies at the surrounding to act as a sink and source of heat. Additionally, the tremendous temperature fluctuations caused mainly due to global warming which attributes to the no sea ice condition way before summers.

Keywords: Svalbard, Air Temperature, Out-going Longwave Radiation, Sea Ice Concentration

Evaluation of satellite-derived estimates of lake ice cover timing on Linnévatnet, Kapp Linné, Svalbard using in-situ data

Lead / presenting author: Samuel Tuttle, Mount Holyoke College

Co-authors: Steven Roof, Hampshire College; Jin Cao, Mount Holyoke College; Alan Werner, Mount Holyoke College; Michael Retelle, Bates College; University Center in Svalbard

Abstract: PDF - Video

Arctic lakes are sensitive climate indicators. In recent decades, satellites have greatly expanded the capacity to monitor lake ice timing, especially in remote areas. However, satellite observations of Arctic lake ice are not often ground-truthed with in-situ measurements and direct observations, due to the remoteness of much of the region. In this study of Linnvatnet on Kapp Linn, Svalbard (78°02'N 13°50'E), we use automated photographs from ground-based cameras and continuously monitored lake water temperature profiles to evaluate the ability of satellite platforms to capture lake ice timing and duration. Visible and near infrared surface reflectance data from the Moderate Resolution Imaging Spectroradiometer (MODIS) were used to observe the seasonal change in reflectance of Linnvatnet from fall 2003 - spring 2019, and to determine summer ice-off (also called break-up end, BUE). Microwave backscatter data from Sentinel-1 were similarly used to determine BUE and fall freeze-up (also called freeze-up start, FUS) from fall 2014 - spring 2019. BUE dates were determined from MODIS by applying smoothing splines to the time series of cloud-masked, mean lake reflectance, then determining when the smoothed curve crossed a reflectance magnitude threshold. Similarly, BUE and FUE dates were determined from the time series of Sentinel-1 mean lake backscatter. These estimates were directly compared to twice-daily photographs of Linnvatnet, as well as inferred ice cover from lake water temperatures. The analysis indicates that satellite-based BUE estimates for Linnvatnet compare favorably with in-situ data during the study period, with mean absolute error of 4 days for MODIS and 3 days for Sentinel-1. Additionally, the data show that lake ice duration has decreased significantly from 2003-2019 in this part of Svalbard, with little change in summer break-up but a trend toward later and more variable fall freeze-up.

Interannual variability of sea ice concentration over the Svalbard Archipelago: March 2020, a case study

Lead / presenting author: Dr. Suchithra Sundaram, Independent Researcher, suchithrasundaram@gmail.com

Co-authors:

Abstract:

The Svalbard archipelago lying between 74-82°N, 6–30°E, is one of the most remote places on the Earth, close to the North Pole. The archipelago's coastal region consists of many fjords, narrow inlets, cliffs, and more than half of the region is covered by sea ice. Due to its unique location and topography, the Svalbard archipelago has a polar-maritime climate. The climate of this region is molded by the North Atlantic oceanic and atmospheric circulations and by the Arctic ocean-atmosphere-cryosphere interactions. In this study, the interannual variability of the March sea-ice variability over the Svalbard region during 1979-2020 is investigated. An interesting feature observed in the analysis is that before 2003 there were many years of anomalous increase of sea ice concentration over the west-northern side of the Spitsbergen region. But after consecutive sixteen years of anomalous low, March 2020 witnessed a notable increase in the anomalous sea ice concentration over the west-north side of Spitsbergen and also over the Barents Sea. Hence this study focuses on understanding the ocean-atmosphere-cryosphere interaction processes which contributed to the return of anomalous increase of sea ice concentration particularly, over the West Spitsbergen. The study will be accomplished through the use of satellite, reanalysis, and observational data set. Preliminary results obtained through the analysis of monthly anomalies of NCEP/NCAR sea level pressure, sensible heat, and NOAA Reynolds Sea Surface Temperature indicate that the ocean-atmosphere-cryosphere interaction over the Arctic and North Atlantic region and the associated teleconnections play a crucial role in generating such an event. Further analysis with observational data and model simulations are required to fully understand the phenomenon.
Keywords: Svalbard, cryosphere, Air-sea interaction, sea ice concentration, teleconnection, Sea Surface temperature

Ocean eddies around Svalbard from multi-mission SAR observations

Lead / presenting author: Igor Kozlov, Marine Hydrophysical Institute of RAS

Co-authors: Larisa Petrenko, Marine Hydrophysical Institute of RAS; Evgeny Plotnikov, Marine Hydrophysical Institute of RAS; Oksana Atadzhanova, Shirshov Institute of Oceanology, Russian Academy of Sciences; Alexander Konik, Shirshov Institute of Oceanology, Russian Academy of Sciences

Abstract:

Ocean eddies play important role in transport of heat, salt and pollutants over long distances from their formation sites. Arctic Ocean is a host to major ocean circulation systems many of which generate eddies. However, comprehensive observations of critical eddy characteristics are currently limited to spatially and temporally sparse in situ observations. At the same time, high-resolution model outputs have become available for the study region during recent years. The latter, in turn, need comprehensive validation with observations that are often lacking. Here we use multi-mission high-resolution spaceborne synthetic aperture radar (SAR) measurements to detect eddies over ice-free and marginal ice zone regions around Svalbard and in Fram Strait. We provide the first estimate of eddy properties, including their locations, size, vorticity sign and monthly distribution in 2007 and 2018 using historical Envisat ASAR and current Sentinel-1 A/B images, respectively.
The most prominent feature of the obtained results is that cyclonic eddies strongly dominate over anticyclones. Eddies are frequently observed over continental slope and shelf regions around Svalbard, including many of its fjords, however, a large number of eddies is also identified over the deep Fram Strait. In general, eddies range in size between 1.5 km and 64 km with a mean value of 8 km. Larger eddies of 10-30 km in diameter are usually found over deep water, while smaller eddies of 3-7 km in diameter prevail around Svalbard. As observed, the overall pattern of eddy field in the strait attributes well to the position of West Spitsbergen Current jet and its southern recirculation branch known from literature.
The orbital velocities of eddy movement in the marginal ice zone are also derived from sequential Sentinel-1 images acquired in August-September 2017 using maximum cross-correlation between image sequences. Analysis of sequential Sentinel-1 images allows retrieving high-resolution surface current velocity field that possess distinct signatures of eddies and narrow filaments in the Fram Strait marginal ice zone with associated velocities up to 0.75 m s-1. Presented results clearly demonstrate the potential of spaceborne SAR data to retrieve critical properties of eddies of various scales, and further investigate their role in the Arctic Ocean.
Envisat ASAR images used in this work were available from European Space Agency within CAT-1 Project C1F.29721. Sentinel-1 data used in this study were obtained from the Copernicus Open Access Hub (https://scihub.copernicus.eu). This work was supported by RFBR grant No. 18-35-20078 and state assignment no. 0555-2020-0001.

Characteristics of a surge of Franklinbreen detailed from remote sensing archives

Lead / presenting author: Robert McNabb, School of Geography and Environmental Sciences, Ulster University

Co-authors:

Abstract: PDF - Video

In recent years, a number of glaciers in the Arctic have rapidly surged or destabilized. These events have been characterized by the rapid transfer of land-based ice to the ocean, with speeds in excess of 20 m/d, surface lowering often in excess of 20 m/yr, and front advances of several kilometers. Here, we examine the development of a speed-up and possible surge of Franklinbreen, an outlet glacier of the ice cap Vestfonna in NE Svalbard. Using re-processed Landsat imagery, digital elevation models and surface velocity maps derived from a variety of sources, we map the glacier's front position, surface velocity, and surface elevation between 1976-2019. Preliminary results show that over this period, the northern terminus of the glacier advanced nearly 2 km, with nearly 50 m surface elevation increase. The southern terminus of the glacier remained nearly stationary, with thickening of over 50 m near the terminus, and an increase in surface velocity from near stagnation to over 1 m/d at the terminus in 2019. While a number of the characteristics of this surge development are remarkably similar to other recent surge events, the glacier has not reached the speeds observed in other recent surge events. With further detailed examination of the available satellite record, we hope to provide a more thorough picture of the development of the speed-up and surge, and use these contrasting characteristics to gain further insight into glacier instabilities.

Use of Multiple Information Extraction Techniques for Mapping Facies on Svalbard and Himalayas Glaciers

Lead / presenting author: Sagar Filipe Wankhede, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka 576104, India

Co-authors: Shridhar D. Jawak, Svalbard Integrated Arctic Earth Observing System, SIOS Knowledge Centre, P.O. Box 156, N-9171, Longyearbyen, Svalbard; Alvarinho J. Luis, Earth System Science Organization, National Centre for Polar and Ocean Research, MoES, Headland Sada, Goa 403804, India; Manoj Patley, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora-263 643, Uttarakhand, India; Timothy Warjri, Savitribai Phule Pune University, Pune, Maharashtra- 411007, India

Abstract:

Glacier facies are zones of a glacier that can be distinguished by their structural and spectral characteristics. These zones are formed as a result of the melt and mixing of snow with dust and debris, as well as its maturity and compactness. The facies provide a non-invasive understanding of the melt cycle of the glacier. Furthermore, studies suggest that the quantitative assessment of the distribution of glacier facies is an important input data for distributed mass balance models. However, each glacier is different. While the primary purpose of distinction of facies may be to identify zones of accumulation and ablation, the number and type of facies differ across glaciers world over. In-situ observations to determine facies are not feasible for most glaciers due to the logistic duress and inaccessible terrain. Hence, satellite imageries are of paramount importance to map glacier facies over large regions. However, in such cases, the number and type of facies mapped depends upon the wavelength spectrum of the sensor. Its spatial, spectral and radiometric resolution further adds complexities to the mapping. The information extraction technique employed for identifying facies can also delimit the accuracy of the mapped products. In order to test the effect of different information extraction methods on very high-resolution imagery, the present study focuses on two glacial regions, Ny-lesund, Svalbard and Chandra basin, Himalayas to exploit the regional variations and spectral differentiation of the glacier surface. WorldView-2 and WorldView-3 imagery were used for Chandra basin and Ny-lesund, respectively, and customized spectral index ratios were developed. We used object-based procedure and both conventional and advanced pixel-based classifiers to map facies, after thorough radiometric corrections and image rectification. A total of 24 pixel-based classification methods and two object-based algorithms were tested. The facies identified on the Himalayan glaciers consisted of crevasses, glacier ice, ice mixed debris, shadow, debris and snow, while those identified on the Svalbard glaciers were fresh snow, shadow, low debris, medium debris, high debris, dry snow, semi-dry snow and off glacier. Accuracy assessment for the pixel-based methods reveals that the Mahalanobis Distance algorithm achieved the highest overall accuracy of 93% (κ= 0.91), whereas the Spectral Angle Mapper underperformed with an overall accuracy of 30% (κ= 0.17). The object-based rule sets achieved a high overall accuracy of 93%

(κ= 0.92) and a low overall accuracy of 87% (κ=0.86). The results were further interpreted based upon the atmospheric correction algorithm and the thresholds used to map facies. The findings for the Himalayan region suggest that the spectral indices developed need to be tested for their transferability due to the variable spectral response of ice mixed debris and shadowed ice across multiple, as well as the same glacier. The object-based methods were particularly efficient in mapping crevasses. The findings for the Svalbard glaciers suggest that the use of different atmospheric correction methods can yield different accuracies when using the object-based approach. The pixel-based method may deliver similar results when using finer resolution due to the salt and pepper effect. The above inferences encourage us to undertake regional level mapping of glacier facies in order to test the developed image indices for their transformational capacity.

Svalbox: an interactive digital portal to Svalbard's geoscientific data

Lead / presenting author: Peter Betlem, UNIS/UiO

Co-authors: Kim Senger, UNIS

Abstract: PDF - Video

The Svalbard archipelago is a geological paradise, offering excellent outcrops testifying a complex geological evolution. Fieldwork is, however, highly dependent on the seasons, accessibility and HSE considerations (e.g. harsh weather, polar bears). Available geoscientific data are usually published as maps, publications and subsurface data (well logs, geophysical surveys) that are not adequately integrated or accessible as such. Competitive advantage is granted to those that can efficiently analyze all relevant data sets within a study area. Digital models, amongst other data sets, are key to fieldwork planning and quantitative post-fieldwork data analysis, and enable spatial integration. Structure-from-motion photogrammetry enables the acquisition of cost-effective mm- to seismic-scale georeferenced digital models (e.g. cultural heritage, outcrops, samples). To accommodate the publication of Svalbard's geological data in an interactive geological context and streamline data analysis, we present the Svalbox database. Svalbox integrates existing surface and subsurface data in a 3D environment within an integrative software package, Petrel. It includes geoscientific maps, terrain models, bathymetric data, stratigraphic logs, seismic and electromagnetic data, exploration well data, gravity-magnetic data, cross-sections, and satellite imagery. All data are geo-referenced in space and depth, and the database is continuously updated through addition of new data & types. Relevant web services are streamed directly to the Svalbox.no online portal, which include fully interactive digital models, regional geology (from Norwegian Polar Institute), Longyearbyen CO2 Lab datasets, virtual field trips to key localities, 360° drone footage, and more. With dozens of unique digital models from across Svalbard freely accessible online, Svalbox is routinely used for education and research at UNIS in Longyearbyen, with the ambition for broader usage of the platform in the near future.

Two decades of Climatic and Environmental Monitoring on Lomonosovfonna

Lead / presenting author: Veijo Pohjola, Uppsala University

Co-authors: Tim van den Akker, Utrecht University; Andy Hodson, UNIS; Elisabeth Isaksson, The Norwegian Polar Institute; Sergey Marchenko, Uppsala University; Ward van Pelt, Uppsala University; Rickard Pettersson, Uppsala University; Carleen Reijmer, Utrecht University

Abstract: PDF - Video

The ice field Lomonosovfonna on the east coast of Spitsbergen has been in focus of a more than 20 years of climatic and environmental monitoring. The monitoring started with an ice coring program 1997, and the first decade was focused to understand climatic variability from ice core parameters, and to monitor and reconstruct anthropogenic pollutant flow from snow and ice core records. The second phase started 2006 with an extensive mass balance program along the outlet glacier Nordenskildbreen, including weather parameter and ice speed monitoring. A third phase was initiated 2012 with an extensive program to study the thermodynamics of the firn area in the higher parts of the ice field. From this emanated a firn hydrology phase 2018, focused at the physical development of perennial firn aquifers and the mapping of cryobiology in these aquifers. We will give an overview of our activity on Lomonosovfonna, and in more detail present a few highlights from our results, and the way forward.

Terrestrial photography applications for snow cover monitoring: implementation of a shared approach

Lead / presenting author: Roberto Salzano, CNR - Institute of Atmospheric Pollution Research

Co-authors: Kristoffer Aalstad, University of Oslo; Enrico Boldrini, CNR - Institute of Atmospheric Pollution Research; Jean-Charles Gallet, Norwegian Polar Institute; Daniel Kępski, Polish Academy of Science - Institute of Geophysics; Bartłomiej Luks, Polish Academy of Science - Institute of Geophysics; Lennart Nilsen, University of Tromso; Rosamaria Salvatori, CNR - Institute of Polar Sciences; Sebastian Westerman, University of Oslo

Abstract: PDF - Video

Terrestrial photography consists of extracting information from images acquired by oblique time-lapse cameras. This methodology can be very useful in remote environments such as the Svalbard archipelago, where a description of the seasonal evolution of the surface can be an extremely important ground-truth data source. Several applications are available in the literature and those focused on the snow cover are the most interconnected with different disciplines (glaciology, hydrology, plant and animal ecology, coastal processes, remote sensing cal/val applications). While terrestrial photography can offer data with a high spatiotemporal resolution, the logistics and data processing can be approached in many different ways. The different components that must be considered are: the camera sensor. installation setup, data acquisition, imagery orthorectification, image classification, data archiving, and finally data interoperability. Concerning snow cover applications, different algorithms and tools are available in the literature, but the final output is based on estimating the fractional snow-covered (FSC) area. An overview of this specific application in Svalbard is an important starting point for defining a harmonization platform focused on describing the snow cover. Several sites in Svalbard (Ny-lesund, Hornsund and the Adventdalen area) have existing terrestrial photography-based FSC monitoring programmes. Developement of common FSC data acquisition and processing schemes/protocols could be extremely beneficial for the monitoring operators and the whole SIOS research community, by helping to fill the multi-scale gaps present between different methodologies and disciplines.

Ground-based monitoring of snow spectral reflectance

Lead / presenting author: Rosamaria Salvatori, CNR-Institute of Polar Sciences

Co-authors: Roberto Salzano , CNR - Institute of Atmospheric Pollution Research; Christian Lanconelli , JRC-Joint Research Centre; Giulio Esposito, CNR - Institute of Atmospheric Pollution Research; Marco Giusto, CNR - Institute of Atmospheric Pollution Research; Mauro Montagnoli, CNR - Institute of Atmospheric Pollution Research

Abstract: PDF - Video

The availability of snow spectral reflectance obtained during field surveys is the key for interpreting remotely sensed images, not only for monitoring the snow cover extent but also for assessing the snow cover metamorphism. Unfortunately, field data are collected occasionally and remotely-sensed optical images are available only in absence of cloud cover during the light season. Weather conditions represent from this perspective the major limitation since it is not possible to have regularly and simultaneously all of these data, remotely sensed and ground truth, in complex environment such as the Arctic region. The aim of this contribution is to present an experimental approach, developed at Ny Alesund (Svalbard), which offer the way to minimize the gap between in-situ and remotely observation of snow. A cost-effective device, the Continuous Reflectance Monitor (CReM), was deployed (close to the CCTower) during the field campaign 2015. This device is operating every melting season and it offers an important key for studying the snow spectral behaviour. The device is characterized by different narrow bands, centered in the visible and in the short-wave infrared wavelength ranges that describe the typical spectral behaviour of snow covers. This ground-based sensing device is equipped with cameras for checking the sky conditions, the extent of the snow cover and its outputs have been compared with spectral radiometric measurements performed with Fieldspec spectroradiometer (ASD). The first results assessed the feasibility of continuous monitoring the spectral variations of snowed surfaces during the melting period. This study represents a first attempt to associate snow surface metamorphism to spectral variations.

Development of microwave observation techniques of melting of the snow-covered area and Rain-on-Snow in Polar Regions

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

Co-authors: Nuerasimuguli Alimasi, National Institute of Polar Research

Abstract: PDF

The Arctic is experiencing rapid environmental change due to climate warming, resulting in snow condition changes [1]. Melting of ice sheets has been observed, and recently Rain-on-snow has become a new focus as it indicates evidence of warming and causes disaster in the snow-covered region [2] [3].
Passive microwave observation is a useful tool to monitor these changes [1]. Arctic research projects are sending filed research groups and establishing observation sites in the various places in the Arctic. Satellite observation is available to supporting research planning, evaluation of observation period and place, as satellite observation can cover in time and space. This study used satellite passive microwave observation as this is available even in the polar night when the sunlight is not available, and cloudy or foggy conditions.
We collected microwave data from research sites in North America, Siberia, Svalbard, Scandinavia, and Greenland. Japanese research groups have observed many of those areas [4]. The data was sampled by pixel based on the location data of the observation site and used for monitoring local snow and ice conditions. The present study introduces snow cover and melting durations. Then this study focuses on evidence of intensive melting in the Arctic monitoring points and Rain-on-ice events.

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A new way to derive the sea ice thickness from satellite observation data of AMSR

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

Co-authors: Kimura Noriaki, Atmosphere and Ocean Research Institute, The University of Tokyo; Hasumi Hiroyasu, Atmosphere and Ocean Research Institute, The University of Tokyo

Abstract:

ABSTRACT
As a first step of the ice thickness deriva-tion, present study examines a history of drifting sea ice from the formation in both Northern and South-ern Hemispheres. We first examine the ice trajectory traced back to the ice formation. The ice tracking is carried out using daily ice velocity product for 2003-2019, derived from images by satellite mi-crowave sensors Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) and AMSR2. Based on the derived backward tra-jectory, we focus on parameters of the age in day, traveling distance, and history of ice convergence. There are large regional and interannual variability in these parameters.

KEY WORDS: Sea ice history, Arctic, Ant-arctic, Satellite remote sensing

INTRODUCTION
Sea ice is a vital component of the global climate system. We need to monitor the cur-rent condition of sea ice and to predict the future change of it. Since 1972, observations using satellite microwave sensors have pro-vided continuous images of sea ice. It im-proved our knowledge of sea-ice cover and its temporal and spatial variability. Ice thickness also is the important information of sea ice. There are various ice-thickness products based on satellite observations (radar and laser altimeter, microwave sensor, etc.) and numerical models. These products generally agree in the spatial distribution and ba-sin-scale gradients of the thickness but differ in their absolute value.
This study aims to derive the ice thickness by a new way based on the history from the formation of individual sea ice. We first analyze the ice trajectory traced back to the ice formation. Based on the derived trajectory, we examine the parameters of the age in day, traveling distance, and history of ice convergence.

METHOD OF ICE TRACKING
Daily sea ice velocity was derived from satellite microwave sensor AMSR-E and AMSR2 data. Ice velocity was computed from the gridded brightness temperature of 36 GHz (winter: December–April) and 19 GHz (sum-mer: May–November) horizontal and vertical polarization channels. The calculation of the ice drifting speed was based on a pattern matching method, the maximum cross correla-tion technique (Kimura et al., 2013). This method determined the spatial offset that maximized the cross-correlation coefficient between two brightness temperature arrays in consecutive images separated by 24 hr. After applying filtering and

interpolation processes, we constructed a daily ice-velocity dataset without missing data over the sea-ice area on a 60 × 60 km grid for 2003–2019.
Backward trajectory is calculated using the daily ice motion. First, particles are arranged at an interval of 10 km over the ice area on a certain day. Daily displacement of parti-cles released on the day is calculated from the ice velocity on one-day time steps. Ice velocity at each particle position is derived from neighboring grids weighted by Gaussian func-tion of distance between the particle position and data grid. By this procedure this study tracks the particles up to 2 years. When the particle reaches open ocean (no-ice) area, we assume it to be ice production.

RESULTS
In the Northern Hemisphere, mature sea ice older than 1 year exists the Greenland -Canadian side of the Arctic. The area expands toward the Atlantic side along the north and west coasts of Greenland via the Transpolar Drift Stream and the East Greenland Current, and toward the North American side, moving across the Beaufort Sea to the East Siberian Sea under the influence of the prevailing clockwise Beaufort Gyre. Additionally, narrow branches extending to the New Siberian Island and Severnaya Zemlya (Fig 1). Accumulated ice convergence is generally large in these old ice areas. In these areas, traveling distance of sea ice from the ice formation reaches more than 3000 km.
In the Southern Hemisphere, sea ice moves westward along the coast and eastward in lower latitude regions. Old ice is observed especially in the western Weddell Sea, and Amundsen Sea (Fig 2). The old ice is produced in the coastal region.
Generally ice thickness changes through dynamic deformation (thickening) and ther-modynamic growth and melt. These processes can be related to the derived parameters of the ice convergence and heat budget. We aim to derive the ice thickness through comparisons between the time-integrated sea ice infor-mation from satellite observation and inde-pendent thickness measurements obtained in situ.

Marine robotics for unmanned safe observation of tidewater glacier fronts: the CNR experience

Lead / presenting author: Roberta Ferretti, Italian National Research Council – INstitute of Marine engineering

Co-authors: Gabriele Bruzzone, Italian National Research Council – INstitute of Marine engineering; Angelo Odetti, Italian National Research Council – INstitute of Marine engineering; Massimo Caccia, Italian National Research Council – INstitute of Marine engineering

Abstract: PDF - Video

Svalbard Archipelago, in the Norwegian Arctic sea, with its fjords system particularly vulnerable, is considered by scientists a suitable site for investigating the phenomena related to climate changes. Physical processes occurring in the Svalbard fjords have an influence not only on the local environment but also at large scale, influencing the global environment.
Nevertheless, even if the Arctic ocean is considered a key indicator of climate change, significant gaps in data collection still remain. For example, it is recognised that tidewater glaciers have great influence on the biogeochemical processes that occur in the marine environment but the real extent of this influence is still affected by lack of data from close proximity to glacier fronts, to which, for safety reasons, manned surface vessels cannot get too close. In this context, unmanned marine vehicles can provide effective solutions for collecting high quality data in hazardous environment, mitigating risks.
This contribution describes the field activity performed by CNR-INM in 2015, 2017 and 2018 respectively, when three campaigns were carried out in Ny-Ålesund, Svalbard Islands. Unmanned operations in hardly accessible areas, such as Polar Regions, require specific designs and ad-hoc studied solutions. Each campaign was conceived and implemented to achieve a specific purpose in terms of acquired data. This has led to the design and production of a robotic tool capable of performing an efficient and reliable multi-sensor data acquisition in the whole water/air column (underwater-sea surface-air) in the direct contact with tidewater glaciers front. An overview of the different types of data acquired will also be given.

Sentinel-2 based mapping of the growing season (phenology in central parts of Svalbard

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

Co-authors: Ingar Arntzen, NORCE Norwegian Research Centre; Laura Stendardi, Free Univeristy of Bolzano

Abstract:

A time-series of daily clear-sky Sentinel-2 L1C for central parts of Svalbard has recently been processed. The dataset covers the period from May to August each year, for the years 2016 to 2019. The dataset is in-particular useful to characterize the growing season and it also give an indication of the annual plant production. For cloud detection we combine several methods, where a main part is visual inspection and removal of cloud and shadow of clouds. The frequency of cloud varies across the study area, for the Adventdalen area 20-30 cloud free days were found in the 2019 season, but only 8-15 days in 2016 season with only Sentinel-2A data available. This show cloudy conditions about 80-90% of the time. For gap-filling of NDVI to daily data, a Kernel Ridge Regression machine learning method with a gentle savitzky-golay filtering seems to give good results, except for June 2016. Then, we use this clear-sky time-series to explore which wavebands best identify different phenophases at different vegetation types (shrubby-, grass-, or bryophyte dominated vegetation). The preliminary results indicate that NDVI is good enough to map the onset of the growth. At autumn, different band combinations (indices) have to be used, according to different vegetation types.

The first evaluation of observations by Pandora spectrometer in Svalbard

Lead / presenting author: Ann Mari Fjæraa, NILU

Co-authors: Georg Hanssen, NILU

Abstract: PDF - Video

The Pandora Spectrometer System is a ground based remote sensing instrument designed to specifically look at levels of ozone, nitrogen dioxide and formaldehyde in the atmosphere.

The Svalbard Pandora, currently in operation at the Sverdrup research station in Ny-Ålesund, was installed in September 2019 as the northernmost Pandora in the world. There are around 150 similar instruments installed all over the globe.

Following the instalment of the instrument at this unique location, the first observed NO2 and O3 columns measurements were provided in April 2020.

This talk will provide a summary of the first evaluation of the measurements from April 2020, both individual time series as well as compairsons to other ground based measurements and satellite data at the same locations.

Modelling a Perennial Firn Aquifer using MODFLOW 6

Lead / presenting author: Tim van den Akker, Uppsala University, Utrecht University

Co-authors: Ward van Pelt, Uppsala University; Carleen Reijmer, Utrecht University; Veijo Pohjola, Uppsala University

Abstract: PDF - Video

Perennial Firn Aquifers (PFA's) can contain large bodies of fresh water, slow down sea level rise, affectsliding processes of glaciers and contain microbiological life. There is proof that PFA's are forming inplaces formerly expected to not be suitable for PFA formation. The dynamic characteristics of PFA's,such as flow rates, water table depth variations and the reaction to a changing climate, are poorlyunderstood and remain an uncertainty in existing climate models. A horizontal flow model does not yetexists of a PFA, and might be able to decrease this uncertainty. In this research, a horizontal flow modelof a PFA is created using MODFLOW 6 and FloPy. The area that is modelled is a grid on top of theLomonosovfonna ice field on Svalbard. The hydraulic conductivity of firn snow is used as a tuningparameter. It is found that for a cubic depth-dependent hydraulic conductivity, the RMSE betweenmodel output and observations is lowest (4.8 meters). Given the time average depth density profile, thehydraulic conductivity was transformed to a density dependent hydraulic conductivity. The resultinghydraulic conductivity-density relation is a non-linear decreasing function, that decreases faster forhigher densities. The model was then run from 1957 to 2019, and for two RCP scenarios (RCP 4.5 andRCP 8.5) from 2019 - 2060. Our results suggest that a perennial firn aquifer has likely been present onthe Lomonosovfonna ice cap since at least 1957, and has considerably grown in recent decades. Themodel predicts a rise in the water table in both future scenarios, more pronounced in the RCP 8.5scenario. In all runs there is a very clear seasonal cycle observed. In both RCP scenarios, the modelledwater table reaches the surface around 2050. Further research can use this model as a starting point tomodel more elaborate firn-water interactions, such as the creation of ice lenses. Also, more research canbe done to develop an above-surface routine for the water, such as runoff or lake formation. Furthermore,one could extent this model vertically to the bedrock bottom of the ice cap. The density-dependenthydraulic conductivity can be used on other glaciers or ice caps to perform similar model experiments.

Airborne geophysical evaluation of ICESat-2 altimeter data over the surging Negribreen, Svalbard

Lead / presenting author: Ute Herzfeld, University of Colorado Boulder

Co-authors: Thomas Trantow, University of Colorado Boulder; Matthew Lawson, University of Colorado Boulder; Adam Hayes, University of Colorado Boulder

Abstract:

The ATLAS instrument aboard NASA's ICESat-2, launched 15 Sept 2018, is the first spaceborne multi-beam micro-pulse photon-counting lidar altimeter system and registers measurements at 0.7m along-track from space, an increase of more than a factor of 200 from the previous ICESat GLAS data (2003-2009). This unprecendented type of remote sesning suggests that we can now measure surface heights of heavily crevassed glaciers. The current surge of Negribreen has presented a unique opportunity for a synergy of studying ice dynamics during the surge and validation of ICESat-2 measurement capabilities. In this paper, we report
findings from our 2019 field campaign over Negribreen, addressing geodetical accuracy, airborne data analysis, a new method for data analysis (the density-dimension algorithm for ice surfaces) and glaciological implications about the ongoing surge.
Altimeter data are complemented with airborne and satellite image data.

The new type of sensor reuqires new data processing approaches.

Mapping the timing of seasonal thaw subsidence and frost heave in central western Spitsbergen using InSAR

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

Co-authors: Lin Liu, Chinese University of Hong Kong (CUHK); Tom Rune Lauknes, NORCE Norwegian Research Centre AS; Hanne Hvidtfeldt Christiansen, University Centre in Svalbard (UNIS); Sarah Marie Strand, University Centre in Svalbard (UNIS); Yngvar Larsen, NORCE Norwegian Research Centre AS

Abstract: PDF - Video

In permafrost landscapes, the seasonal ground freeze and thaw induce heave and subsidence due to the phase change of the water within the active layer. Modifications of the ground thermal regime in a changing climate can lead to modification in the distribution, amplitude and timing of displacements. In this context, it is paramount to develop large-scale measurement techniques able to monitor periglacial environments and explore the relationship between ground dynamics and environmental variables.
Synthetic Aperture Radar Interferometry (InSAR) allows for measuring ground displacements at at millimetre to centimetre scales over large areas. Based on Sentinel-1 and TerraSAR-X InSAR results in Adventdalen area, we showed that subsidence/heave can be measured with a 6-day sampling and the temporal patterns of the displacement match the variation of ground temperature measured in boreholes. The time series over flat areas can be well described by the Stefan equation with a composite model that combines thawing and freezing degree-day indices. It shows the potential and value for upscaling the monitoring of the transition from thaw subsidence to frost heave. The spatial variability of the seasonal ground displacements is largely related to topographical and geomorphological factors. Water/ice content in the active layer is highly variable and also controls the amplitude of the seasonal displacements.
The conclusions of the initial study highlight the potential for further developments to exploit InSAR measurements in complex permafrost landscapes. In the follow-up research, we are focusing on mapping the day of maximum displacement, in Adventdalen, Kapp Linné and Ny-Ålesund areas, to detect the timing of the subsidence-to-heave transition at landscape-scale. We identify geographical zonation and inter-annual variability of the ground dynamics, suggesting the potential for designing new large-scale strategies for mapping and monitoring ground freeze-thaw processes over Svalbard.

Aerodynamic Surface Roughness of Crevassed Glaciers from UAV Mapping

Lead / presenting author: Armin Dachauer, UNIS/ ETH Zurich

Co-authors: Richard Hann, NTNU; Andy Hodson, UNIS; Andreas Bauder, ETH Zurich

Abstract:

The surface of crevassed ice, which in Svalbard often is found on the terminus of tidewater glaciers, is rougher than that of glaciers without crevasses. This leads to more turbulence when the wind is blowing over the surface. The aerodynamic roughness of a glacier's surface influences the turbulent heat exchange between the glacier surface and the atmosphere. Both, sensible and latent heat fluxes balance this heat exchange on the surface and therefore have a large impact on the meltwater production of glaciers. These fluxes are expected to have an increasingly important contribution to the overall melt volumes due to warmer air temperatures that are coming along with climate change (Smith et al., 2016). There are intrinsic properties of the crevassed ice that strongly limit our understanding of the turbulent heat transfer from the atmosphere to the ice surface (Colgan et al. 2016). Thus, a good knowledge of the efficiency of energy transfer from the atmosphere to the glacier is crucial.
The aim of this master thesis is the application of unmanned aerial vehicles (UAVs) to take drone-based surveying images as an integrated remote sensing method. Therefore, we operated with the two drones DJI Phantom 4 Pro and Mavic 2 Enterprise to take high-resolution images.
A photogrammetry method can be used to extract data from the aerial images and provide information about the shape of crevasses like depth, size and distribution. The processing runs on a technique called structure-from-motion (SfM) and allows to reconstruct the three-dimensional geometry and camera position of a surface from two-dimensional pictures that are taken from multiple viewpoints. The data output of this processing is a digital elevation model (DEMs) of the mapped glacier. These DEMs will be utilized to estimate the aerodynamic surface roughness length z0 on crevassed glaciers in Svalbard. The aerodynamic surface roughness length z0 is a length scale that is difficult to measure and thus is often only approximated. It represents the height above the surface where the wind speed reaches zero. Its quality is, that it can be used as a control on the rate of turbulent heat exchange between the glacier's surface and the atmosphere (Cuffey and Paterson, 2010). There exist several methods for the estimation of z0 (e.g. Smith et al. 2016; Irvine-Fynn et al., 2014). However, this is the first time that UAV based data is used to estimate the surface roughness length. We assume that drone mapping can help to better represent the heat exchange rates and with it the actual melt rate of glaciers needed in energy balance models. The main advantage of this approach is that drone data, which is increasingly available recently, can be used to determine heat fluxes that usually are difficult to measure in the field.

Further, the chosen DEM approach allows to divide the glaciers into areas of different surface roughness values instead of only one for the whole glacier what leads in a better representation of the heat fluxes on a glacier. The result of the thesis can be used to show the impact of crevasses on the rate of surface melting using local climate data. We expect the crevasses to intensify the heat exchange between glacier and atmosphere. The described master thesis is part of the overall project called "Using UAVs to investigate effects of crevasses upon glacier surface melting" (RiS ID 11148).

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The metadata profile for a snow-ice spectral library

Lead / presenting author: Sabina Di Franco, CNR-Institute of Polar Sciences

Co-authors: Rosamaria Salvatori, CNR-Institute of Polar Sciences; Roberto Salzano, CNR-Institute of Atmospheric Pollution Research

Abstract: PDF - Video

The cal/val activities on satellite products require ground-truth dataset suitable for assessing the quality of retrieved information and for improving the capacity of observing the snow cover in particular environments such as the Svalbard archipelago. From this perspective, the availability of optical, spectrally resolved, field data are an important source of information useful for detecting remotely surface characteristics when field data can not be collected. The first step for preparing a sharable and interoperable spectral library consists of defining the appropriate metadata profile for the description of snowed and iced surface covers.
Different spectral libraries on vegetation, rocks and soils are already available and described in details. In fact, science needs data, but is increasingly difficult to share and search them with accuracy and precision now that every action leaves a digital footprint, creating a huge amount of data, the so-called “Big Data”. The scientific world has decided upon principles to grant “open access” in activities as the ERC guidelines, the FAIR principles, the GEO Data Sharing Principles, and the Research Data Alliance. Metadata are an essential part of these principles but to help data usability they must be well documented and sound.
Having to adopt a set of metadata to describe our spectral library containing snow and ice spectral signatures (SISpec), we searched for a metadata profile, specific to cryosphere properties, but found none. The ISO standards 19115 (Geographic information — Metadata, both part 1 and 2 - Extensions for acquisition and processing) were chosen for profiling general metadata. When the existing metadata were not sufficient or suitable to describe the SISpec data, metadata extensions or new detailed metadata components were created to be compliant with the ISO 19115 standards.
Particularly detailed metadata were created for describing spectral signatures and microphysical snow parameters.

Role of Earth Observation (EO Technologies to Optimise the Sustained Observing System in Svalbard: Recommendations from the State of Environmental Science in Svalbard (SESS) Report

Lead / presenting author: Christiane Hübner, SIOS

Co-authors: Shridhar Jawak, SIOS; Sebastian Gerland, Norwegian Polar Institute; Manuel Bensi, OGS – Istituto Nazionale di Oceanografia e di Geofisica Sperimentale; Øystein Godøy, MET Norway; Inger Jennings, SIOS; Bo Andersen, SIOS; Dariusz Ignatiuk, SIOS; Heikki Lihavainen, SIOS

Abstract: PDF - Video

This talk will introduce the concept of the annual State of Environmental Science in Svalbard (SESS) report published by SIOS. The report summarises the state of current knowledge of key Earth System Science parameters and analyses how these parameters influence one another. It combines the long-term monitoring data that form the core of the observing system with new, innovative monitoring and research and connects in-situ measurements with remote sensing technology. In addition to evaluating the state of current knowledge, the SESS report highlights questions that remain unanswered and recommends solutions in terms of research infrastructure improvements and research priorities. It is an arena for open sharing of ideas and discussions on which measures should be taken to enable scientists to provide observations needed to gain a holistic view of the Earth System of Svalbard and the Arctic in general.
In the two first SESS reports, 2019 and 2020, nine of 18 chapters include Earth Observation (EO) and Remote sensing (RS)-driven activities. We will present highlights from these chapters and show how robust recommendations from the SESS report can contribute to optimising the regional observing system for long-term measurements in and around Svalbard in the coming decades.

Modelling glacier mass balance and seasonal snow conditions in Svalbard

Lead / presenting author: Ward van Pelt, Uppsala University

Co-authors: Veijo Pohjola, Uppsala University

Abstract: PDF - Video

In situ data are essential for calibration and validation of remote sensing products. While remote sensing products may generate spatially distributed and temporally continuous information of glacier surface and snow conditions, in situ observations are typically scarce in space and time. Numerical models, calibrated against in situ data, can help to overcome this issue by generating spatiotemporally continuous information. Here, a short overview will be given of recent glacier mass balance and snow modelling efforts in Svalbard (Van Pelt et al., 2016; 2019). Two different snow models will be presented, and the use of in situ data for calibration and validation is discussed. Thereafter, spatial patterns and long-term evolution of glacier mass balance and seasonal snow parameters are presented, with most focus on variables that can be compared against remote sensing products (e.g. glacier mass change, surface albedo, snow water equivalent, snow season duration).

Automating the surveillance of sea ice using artificial intelligence in the Extreme Earth project

Lead / presenting author: Åshild Kiærbech, Norwegian Meteorological Institute, Norwegian Ice Service

Co-authors: Joakim Lillehaug Pedersen, Norwegian Meteorological Institute, Norwegian Ice Service; Alistair Everett, Norwegian Meteorological Institute, Norwegian Ice Service; Nick Hughes, Norwegian Meteorological Institute, Norwegian Ice Service

Abstract: PDF - Video

The EU H2020-funded Extreme Earth project concentrates on developing techniques and software for extraction of sea ice and iceberg information from big Copernicus data using cloud-based machine learning and deep learning techniques. The Ice Service of the Norwegian Meteorological Institute (NIS) leads the development of the “polar use case” of the project, intending to improve sea ice and iceberg monitoring.

The polar regions including Svalbard play an important role in regulating and driving the global climate, but are experiencing significant change. An associated effect is growing global interest in the polar regions, that comes with increased attention and traffic. It is essential to develop new tools to monitor these changes and ensure the safety of operators involved in a broad range of activities in, or related to, ice-covered waters. Prevention of incidents safeguards the environment.

We are developing deep learning techniques for automated sea ice mapping. The new technologies developed within Extreme Earth for satellite data analysis will be beneficial to the routine ice charts produced at NIS. This will reduce the workload of the expert analysts allowing them more time to assist end-users, and more frequent ice chart updates with additional information and higher precision.

Our neural network-based methods have performed well on well-known machine learning reference datasets and we experiment with applying them to large datasets of sea ice satellite images. The three main product focuses are ice edge, ice type classification, and iceberg detection. The project contributes to the sea ice research community by producing new sea ice datasets for algorithm training and validation purposes.

The combination of the best from the machine learning field with large amounts of satellite data contributes to more information on the daily maritime situation around Svalbard and the surrounding Arctic.

Current activities and development in the Norwegian Ice Service

Lead / presenting author: Ole Jakob Hegelund, Norwegian Meteorological Institute

Co-authors: Ole Jakob Hegelund, Norwegian Meteorological Institute, Norwegian Ice Service, Tromsø Norway; Nick Hughes, Norwegian Meteorological Institute, Norwegian Ice Service, Tromsø Norway; Alistair Everett, Norwegian Meteorological Institute, Norwegian Ice Service, Tromsø Norway; Penelope Wagner, Norwegian Meteorological Institute, Norwegian Ice Service, Tromsø Norway; Marcin Pierechod, Norwegian Meteorological Institute, Norwegian Ice Service, Tromsø Norway; Åshild Kiærbech, Norwegian Meteorological Institute, Norwegian Ice Service, Tromsø Norway; Joakim Lillehaug Pedersen, Norwegian Meteorological Institute, Norwegian Ice Service, Tromsø Norway

Abstract: PDF - Video

The Ice Service of the Norwegian Meteorological Institute (NIS) is responsible for ice monitoring around Svalbard and provides routine (Monday-Friday) high resolution ice charts. These are based primarily on imaging from Synthetic Aperture Radar (SAR) and optical satellites, augmented by observations and forecasts, and show sea ice concentration, fast ice, and sea surface temperature.

NIS main focus is maritime safety. However, the 54-years of archive also allows climatology studies. Analysis of infrared images started in 1970, and their resolution, later supplemented with SAR, provides a record in narrow fjords and straits that is unavailable from other sensors.

With new satellites, such as the Copernicus Sentinels, delivering increasing volumes of data NIS is evaluating new techniques for image analysis and engages in a number of projects including;

The EU H2020 ExtremeEarth project is developing techniques and software for extraction of sea ice and iceberg information from big data using a cloud-based machine and deep learning techniques. NIS leads the “polar use case” of the project.

In Sentinel4ThinIce NIS works with the Norwegian Computing Centre developing algorithms to map thin sea ice thickness using infrared data from Copernicus Sentinel-3.

NIS co-leads the Pilot Services work package in the NFR-funded Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CIRFA) at UiT - The Arctic University of Norway.

NIS coordinates the EU H2020 Key Environmental monitoring for Polar Latitudes and European Readiness (KEPLER) project that is developing a roadmap for the next phase of Copernicus 2021-2027.

In the Arctic and North Atlantic Security and Emergency Preparedness Network (ARCSAR), NIS are the link between the research and Polar search-and-rescue communities.

NIS now runs the Ice Watch ASSIST shipboard observation program, and are making it to contribute observations through development of the IceWatchApp funded by the ESA Citizen Science Earth Observation Lab (CSEOL).

Opportunites and Challenges for Remote Sensing with UAVs in Svalbard

Lead / presenting author: Richard Hann, NTNU / UNIS

Co-authors:

Abstract: PDF - Video

In recent years, there has been a strong development and increased utilization of unmanned aerial vehicles (UAVs). These automated drones are suitable for a wide range of applications and are used in many different industries or science areas today. Fixed-wing UAVs are well suited for remote sensing operations in isolated and harsh areas, such as the Arctic. In particular, UAVs offer significant opportunities for earth observation, remote sensing, and geoinformation applications. UAVs can be used in combination with satellite to close to the gap between space-borne remote sensing and ground-based applications. UAVs offer many opportunities to a wide range of applications on Svalbard, including but not limited to geology, geomorphology, biology, atmospheric research, oceanography, glaciology, natural hazards, archaeology, and technology. Examples of such applications and their integration with other remote sensing methods will be discussed. Furthermore, the challenges to UAV operation in the Arctic will be covered. The cold climate conditions special challenges for UAV operations. This is a topic that has only recently shifted into the focus of research and will be discussed in detail in this contribution. The main challenges are low temperature, wind, atmospheric icing, GPS coverage, legislation, and remoteness.