Arctic Safety Conference 2021

Book of Abstracts

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Handling uncertainty - a way to improve risk management in local avalanche warning systems

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Abstract

The settlement of Longyearbyen is exposed to avalanches due to the close proximity to steep mountain sides. Residential areas have been hit by avalanches twice since 2015. The avalanches have had tragic outcomes with loss of human life and major structural damage.

As a measure to be able to evacuate residents in danger zones, Longyearbyen has a daily local avalanche warning. There are many sources of uncertainty that can affect the risk assessments behind an avalanche warning. The quality of the alert is crucial in order to make the right decisions to evacuate in time. One challenge is that it is difficult to assess the overall quality of a warning because there are so many sources of uncertainty.

How uncertainty is identified and assessed is therefore an important factor in increasing the quality both in the process of preparing a warning and for the result itself. The focus of this paper is how uncertainty management can provide better risk management in this process.

Through a case study consisting of a document study of the local avalanche warning system and interviews with actors participating in different parts of the forecasting organization, sources of uncertainty and factors related to the risk assessment are identified and classified. Theory basis in the paper is based on a risk perspective with a focus on the fact that uncertainty can be understood as a lack of knowledge.

The key findings from the case study are: 1) how uncertainty factors associated with an avalanche problem are identified, 2) how the level of knowledge about uncertainty is described, and 3) how this level of knowledge is considered weak, medium or strong knowledge. By using background knowledge as a measure of uncertainty, a qualitatively better picture of the risk in the warnings should be possible to achieved.

This approach can form the basis for developing a more systematic and dynamic approach to uncertainty in avalanche risk assessments. The approach also has transfer value for risk assessment of other types of natural hazards, as many of the sources of uncertainty will be the same.

Flying against the clock – risk management and resilience in Arctic search and rescue and casualty evacuation flights

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Abstract

Despite the successful conclusion of the 2011 Arctic Search and Rescue Agreement, the resources available for search and rescue operations in the high north remain very limited. Rescue flights are time critical. Survival times – especially in the Arctic – are severely curtailed by the environment. At the same time, clinical evidence supports the need to provide critical casualty care within the first, or 'golden' hour following injury. These factors, plus the extreme weather of the Northern Regions, may limit flight operations and place severe moral pressure on crews. Climate change is predicted to bring additional impediments to the safe conduct of rescue and ambulance flight operations. The selection and training of personnel lies at the heart of addressing the risks attendant upon both flying and rendering appropriate casualty care under such circumstances. Despite technological advances, and sometimes because of them, human decisions, and how they are made, remain pivotal. This paper examines recent advances in decision enhancement techniques and their application in improving the safety and resilience of future Arctic rescue flight operations.

Rescue of grounded vessel at 80o North in mid-winter 2018/2019 and wreck removal in 2020

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Abstract

On December 28, 2018, one of the most difficult rescue operations at sea was successfully carried out. It took place in the northern-most waters of Norway, more than 1200 km from the Norwegian mainland. Rescuers were confronted with a worst-case scenario: A trawler grounded at 80o N, in the darkest of winter, and at extremely low temperatures. The conditions were harsh with both an on-going snowstorm and drift ice up to 2 meters thick In addition to the 14 trawler crew, the ship carried 332,000 liters of marine gas oil, substantial amount of hydraulic oil, different chemicals, electronic and fishing equipment. The accident happened in a nature reserve with a unique and highly fragile ecosystem. Everything could have gone wrong: but it didn't. The rescue operation was successful in every way. The crew were rescued. There was no oil spillage or other pollution from the wreck. The wreck was secured pending summer conditions.

The wreck removal was a very challenging operation. The chosen method in 2019 did not succeed due to the worst ice condition recorded in the last 30 years. A more simple method was chosen in 2020. With less time to mobilize and stop the e operation to severe ice- and weather conditions. The lack of local knowledge to ice- and weather conditions is challenging for salvage crews working in these remote areas.

The influence of complex and changing Arctic conditions on historic waste disposal sites - a multi-criteria risk assessment

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Abstract

Management of waste from both human settlements and mining activities has been a major challenge in the Arctic region. Historic practice has relied on permafrost conditions in the soil to stabilize waste and prevent contaminants from being released into the environment. Now that the climate is warming, especially in the Arctic region, this might result in mobilization of contaminants from historic waste. In addition, the traditional approaches to handling of mine waste are no long valid and new solutions should be developed.

To address these challenges a multi criteria risk assessment approach has been developed taking into account the various processes that can pose pressure or act as a driver on a waste site system:

- Future climate and change in precipitation patterns triggers erosion.
- Permafrost is expected to lose its role as a geological barrier for the containment of contaminants.
- Landslides and avalanches impact stability and safety at the site.
- Geotechnical stability will govern mass movement of the stored waste and release of contaminants.
- Hydrological conditions guide the functioning of barriers between waste and the environment and are being corrupted.
- Waste properties are the drivers for the release of contaminants and their potential impact on the ecosystem, requiring a clear classification.

These factors are interrelated, and the risk posed can be addressed by combining their probability of occurrence and the consequences in a risk matrix. This integration allows both a qualitative as well as a quantitative approach of the involved risks to both human and the environment. Thereby it is possible to find solutions which will be sustainable under the future scenario we are expecting in the Arctic. In our presentation we show how this approach can be applied to historic and future waste sites in the Longyearbyen region.

Climate Change Impact on Rock Fall Risk – preliminary results from large-scale modelling in Switzerland

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Abstract

Various reports of IPCC suggest that changes in the climate system, such as temperature rise and more frequent extreme precipitation events, will likely influence the dynamics of gravity driven hazards, such as snow avalanches, rock fall, debris flow and shallow landslides. Within the WSL research program "Climate Change Impacts on Alpine Mass Movements", we are developing a framework to model hazard and risk caused by mass movements considering climate and socio-economic changes. In this contribution, we focus on the modelling of rock fall risk for current and future climate scenarios and its impact on the national railway network in Switzerland.

In a first step, we model rockfall risks in Switzerland for the current climate situation. The potential release areas are automatically defined by slope angle, soil class and a flow accumulation parameter. Soil characteristics as input for the numerical modelling are based on 11 soil classes, the influence of forest is considered with various forest layers. The spatial distribution of the rock fall hazard for 30y, 100y and 300y scenarios is simulated using the large-scale module of RAMMS::ROCKFALL taking various block sizes and block forms into account. The so-derived hazard indication maps are taken as input for different risk models such as CLIMADA and the risk tool of the Swiss Federal Railway Company SBB. In these risk models, we use high resolution building and infrastructure layers to identify exposed objects and impact functions based on the – in Switzerland – widely used risk assessment method "EconoMe" to calculate the risk potential. In a second step, we model rockfall risks for the future climate situation by taking into account the effects of climate change on hazard disposition.

These so-derived risk indication maps provide a basis for identifying risk hot spots, changes of risk due to various climate scenarios and therefore to adapt to climate change impacts with appropriate adaptation measures.

Synergies between a Safe Arctic Ocean and a Safe Southern Ocean: Hazard Mitigation and Adaptation and the U.N. Southern Ocean Decade

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Abstract

In the framework of the United Nations Decade of Ocean Science for Sustainable Development, the Southern Ocean Community engaged in a stakeholder-oriented process to develop the Southern Ocean Action Plan to provide a framework for Southern Ocean stakeholders to formulate and develop concrete activities that support the Decade vision. The outcome is the Southern Ocean United Nations Task Force (https://www.sodecade.org/), which includes 8 working groups on topics such as ocean safety, resiliency, sustainability, and cross-cutting themes. In the Southern Ocean, the combined effects of various forms of pollution, transport, tourism, migration, infrastructure, and the pursuit of natural resources, as well as accelerated climate change at high latitudes, are exerting increasing pressures on the environment. These climate- and human-induced changes have the potential to alter the role the polar regions play in regulating global climate and other systems, as well as impacting a host of other important ecosystem services. Since the Southern Ocean Community of stakeholders is globally unique in its operation within the Antarctic Treaty System, which is entirely based on scientific understanding and environmental protection, it is imperative to strengthen international collaborations to improve scientific and political understanding of this remote region.

The fifth working group of the Southern Ocean Decade Task Force, “A Safe Ocean,” focuses on mitigating, understanding, and adapting to natural and human-induced hazards. The working group contributes to the final U.N. report defining priorities for the next decade. Priorities identified include improving forecasting capabilities, understanding the impact of changing environmental conditions, improving emergency response capabilities, and engaging effectively with policymakers. In this presentation, we discuss how synergies can be fostered between a safe Southern Ocean and a safe Arctic Ocean. We focus on how the uniqueness of both polar oceans within the larger global ocean system relates to particular aspects of strengthening hazard response efforts in the Arctic and Antarctic. Addressing the prevalence of hydro-meteorological, geophysical, biological and human induced hazards, especially those amplified by a rapidly changing climate, requires coherent collaboration between academic, government, and industry across both the Arctic and Antarctic communities. We issue a call for action and encourage the formation of collaboration along these lines, under the broader guidance of the U.N. Ocean Decade.

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Developing a permafrost and meteorological climate change response system to build resilience in Arctic communities (PermaMeteoCommunity)

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Abstract

The interdisciplinary scientific PermaMeteoCommunity project develops resilience in Arctic communities by developing and testing a geoscientifically developed coupled permafrost and meteorological climate change response system. This system will assist decision making by providing real-time key geoscientific observations affected by the increasing climatic changes that especially the high Arctic environment such as Svalbard experiences. Longyearbyen is an excellent test site for developing such forward-looking technology to provide safer and better living conditions for the inhabitants. The developed response system shall be exportable to other polar or cold climatic areas, with permafrost or seasonal frost, which are most affected by climate change.

We investigate permafrost in the different landforms that the Longyearbyen area is built upon by 1) using different geophysical and geotechnical measurements and 2) performing permafrost drillings collecting cores from the active layer and permafrost analyzing the ground ice content and type, thermal properties, age and grain-size. These studies allow interpretation of the types of sediment infilling the Longyeardalen valley, and to produce ground ice content and saline sediment maps. This will enable selecting the most critical sites to be equipped with observation instrumentation for observing in real-time changes in key parameters affecting slope and building stability (content of water in the active layer, the ground permafrost temperature, air temperature, amount of precipitation and wind). Permafrost model output and all observations will be transferred in real time to 'the climate change response system', which will be excellently suited for use in preparedness. The growing amount of data in the system will encompass a broad range of extreme climatic situations (such as warm seasons, wet seasons, long lasting summers which means late ground refreezing in autumn). In the future, we see the potential for using novel machine learning and artificial intelligence technology to statistically forecast future extreme events based on its comprehensive database, thereby given authorities early warnings.

Local IoT-based landslide early warning system

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Abstract

This paper examines the implementation of a local landslide early warning system supported by Internet of Things (IoT) technology. IoT technology supports a monitoring system for water-induced landslides on a catchment scale. The monitoring system is investigated as a landslide risk management strategy for a catchment in central Norway that is prone to landslides induced by rainfall and snow melting. The monitoring system aims to reduce landslide risks by providing timely alerts that can be used to reduce consequences by evacuating people and mobile property from areas subjected to landslides. The implementation of the monitoring system is focused on deploying sensors that collect information on the landslide triggering parameters related to changes in groundwater conditions in response to rainfall or snowmelt. Details of the system architecture will be provided together with the interpretation of the data collected by the sensors. The collected data are used in combination with a physical-based landslide prediction model and weather predictions to provide estimates of landslide susceptibility for the area. Details of the implementation of the early warning system and the interpretation of predictions will be presented.

Sea spray icing estimation dependence on spray flux in Arctic-Norwegian waters

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Abstract

Sea spray ice accretion is considered one of the significant obstacles to safe ship operation in the Arctic. An accurate model to estimate ice accumulation can make marine operations in the region safer and assist in designing efficient winterization techniques. The accuracy of the estimated ice accretion by the present ship-icing models is primarily dependent on the incoming spray flux generated by wave-ship interaction. The icing models use spray-flux estimations based on past empirical observations from mostly fishing trawlers. The incoming spray flux consists of the amount of liquid water (LWC), the duration and the distribution of the spray associated with surface impingement, and the spray generation frequency. This study aims to analyze the dependency of spray icing estimation models on LWC, which is one of the key parameters of spray flux. To achieve this, we consider a fishing vessel named ONEGA, which capsized and sank after experiencing heavy icing in the Barents Sea west of Yuzhny Island, Novaya Zemlya Archipelago, on 28 December 2020, claiming 17 lives. By assuming minimum vessel stability criteria prior to ice accretion, assuming the dimension of the vessel ONEGA, we identify the probable locations of accreted ice and estimate the likely amount of ice accumulation that destabilized the vessel. Then this is compared against the amount of ice accretion estimated by the MINCOG model. In order to highlight the dependency of MINCOG output on the LWC, an analysis is carried out using different liquid water content calculations proposed by researchers. In conclusion, a more realistic spray-flux formulation and considerations such as wind-generated spray flux may improve the icing estimations, ultimately emphasizing on real-time spray-flux measurements.

Atmospheric icing as a hazard to unmanned aircraft applications

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Abstract

Unmanned aircraft systems (UAS) are an emerging technology with a wide range of applications. In particular, UAS can offer valuable contributions to emergency services and become a key element for safety and rescue missions. For example, UAS can provide real-time information from a birds-eye perspective with visual or infrared sensors during emergency situations.

The Arctic is a harsh and remote environment which is a challenge for safety-related missions. In this setting, UAVs are proving to be especially valuable. Because UAS are operated remotely, they can be quick to deploy and fly in hazardous conditions without endangering the life of pilots. UAS can cover large distances and be a cheap alternative for manned aircraft applications. UAS thereby offer the potential for a significant contribution to Arctic safety challenges in the future.

A key barrier to unlocking this potential is atmospheric in-flight icing. Icing occurs when aircraft encounter supercooled liquid water droplets in clouds. When these droplets hit the airframe, they form ice on the surface. Icing is a severe hazard to all aircraft but is, in particular, a high risk for UAS due to their smaller size and lower payload capacity. In fact, the hazard of icing to UAS is so substantial, that unmanned aircraft today can effectively not operated in conditions where icing can be expected. This limitation of the operational envelope of UAS is a major barrier for unlocking their benefit. This “icing barrier” is especially relevant in high-latitude areas like Norway and Svalbard.

This presentation will discuss safety-relevant applications for UAS in the Arctic and describe the hazards of atmospheric in-flight icing. Furthermore, the technical and operational solutions to overcoming the icing barrier are presented.

Uncertainty in risk-informed decision-making processes in snow avalanche risk management in the Arctic

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Abstract

Recent climate research indicate that the Arctic is experiencing climate changes at a higher intensity than the rest of the world. The climate changes also impact natural hazards such as snow avalanches in Arctic settlements which create rippling effects for critical infrastructure and societal functions. Climate change can in several contexts be described as an contributing factor to uncertainty in different sectors. In risk management, uncertainty can be defined as an expression of the strength of knowledge judgements. The uncertainty is high when the knowledge is judged as weak.

The purpose of the paper is to demonstrate how uncertainty is related to and handled in decision-making processes for snow avalanche risk management. The paper is based on 14 interviews with informants who is associated with various avalanche warning systems in Svalbard and mainland Norway. Sources of uncertainty and uncertainty management were covered in the interviews. The paper is mainly paying attention to uncertainty in decision-making and risk-reducing measures, and to a less extent on uncertainty in the assessment of risk.

The interviews show that uncertainty is dealt with in two ways: 1) by the precautionary principle when there is little or no knowledge available and 2) by continuously knowledge transfer. The informants state that uncertainty is something that is assessed and handled through tacit knowledge of the involved persons. The interview study indicates that transitions between tacit and explicit knowledge is a key mechanism for handling uncertainty, similar to organizational learning. Parameter uncertainty and model uncertainty from the risk assessment also influence decisions-making. However, it is mainly competency uncertainty that impact decision-making. A key challenge is how to communicate uncertainty, from risk analysts to decision-makers as well as from decision-makers to different stakeholders. Benefits of digital solutions for improved data collection and analysis for reduced uncertainty is discussed.

The role of experiential learning in safety awareness development among guides working in polar adventures tourism- case study on Arctic Nature Guides program on Svalbard

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Abstract

Adventure and extreme environment are emphasized factors of growing tourism in the Arctic. Risks associated with adventure tourism take course at different levels; it is a source of entertainment for guests, work environment for guides and fundamental part of existence for tour operators. Arctic adventure guides are expected to facilitate guest's safety, while dealing with challenges such as remoteness and rapidly changing weather. There is scarce research on Arctic guide's safety practices, following lack of studies on guide's risk perception and safety training. The purpose of this study is to critically evaluate the use of experiential learning, adventure experience paradigm and arctic safety theories in developing safety competence among future Arctic guides. The research is based on Arctic Nature Guide program, including the views of students and instructors on the learning experience process. The data collection is based on field research and includes participant observation and interviews with students and instructors taking part in guiding program. The research aims to explore the realities and possibilities of experiential learning approach in context of improving safety training related to guiding in the Arctic. The study hopes to introduce findings that might be relevant to stakeholders working in the Arctic: safety educators, adventure guides and tour companies

Natural hazards in Svalbard settlements: a historical overview

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Abstract

The establishment of the settlements in Svalbard during the early 20th century was governed by the prospect of industry and economic gain. The idea of extracting the hidden resources in the Arctic mountains led to many adventurous initiatives and investments. The mines and living quarters were established where prospectors located promising deposits of coal, marble, ore or other resources. This led to rather challenging location of settlements and infrastructure during the early investments in Svalbard. Furthermore, development during this first period was less regulated compared to today's planned settlements. Through the course of the last century, many of the early settlements have been impacted by natural processes like avalanches, floods, debris flows, landslides, rockfalls and slushflows – processes which are extremely challenging to avoid completely in complex, high-relief Arctic terrain. Settlers and miners learned fast and the early installations were soon adjusted to the most frequent natural hazard events. However, given the relatively short experience with these landscapes, less frequent events were difficult to comprehend and mitigate against. Several severe accidents and damages have occurred through the years. This presentation gives a brief overview of significant hazard events, the involved processes and the mitigation that was implemented in the aftermath of these events. Recent trends during the past decades have showcased a shift towards a warmer climate. More precipitation may increase the likelihood of hydrometrological hazards such as slush flows and debris flows. Permafrost change will impact rock fall hazards and is predicted to result in larger and more frequent landslides. Emerging trends in winter precipitation will likely have implications for snow avalanches. These recently observed changes will likely require climate-adaptive approaches to hazard and risk, calibrated to uniquely complex Arctic landscapes.

SIOS's airborne remote sensing platforms for identifying surface crevasses in Svalbard for field safety

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Abstract

Svalbard Integrated Arctic Earth Observing System (SIOS) is an international collaboration of 26 research institutions from 9 countries studying the environment and climate in and around Svalbard. SIOS actively supports usage of airborne remote sensing platforms for research purposes in Svalbard. SIOS member institution NORCE has installed and tested a suite of optical imaging sensors on the Lufttransport Dornier passenger aircraft stationed in Longyearbyen, as part of the SIOS-InfraNor project. The aircraft is configured to acquire aerial imagery and hyperspectral remote sensing data in addition to its normal transport operation. SIOS supports usage of Dornier aircraft-based data acquisition in Svalbard. In addition, SIOS provides opportunity to use uncrewed aerial vehicles (UAVs) funded by the SIOS-InfraNor project, and other drones available with the UNIS drone group and NORCE.

Many scientists conduct field campaigns in Svalbard that includes glaciated areas. Glaciers in Svalbard are characterized by surface crevasses. Surface crevasses are linear cracks on the surface of glacier. These cracks can be very dangerous while conducting field campaigns both by foot and snow mobiles. Therefore, identifying and mapping of crevasses on the glacier surface before the field campaign is highly recommended for safe venturing on the glacier surface. Furthermore, glacier crevasses form an important scientific topic within glaciology as they can have severe effects on glacier melt. Traditionally, scientists make use of satellite images for crevasse detection. However, satellite-based crevasse detection has a limitation of spatial resolution and cloud cover. On the other hand, aerial imagery one can get better resolution and detect crevasses that would not been seen in most satellite imagery but would be wide enough to cause harm for surface transports.

SIOS airborne platforms can be used to map glacier crevasses from a safe distance. Data acquired by UAVs and aircraft images can be used to generate precise crevasses maps, understand their distribution, size and depth using high resolution digital elevation models (DEMs). This talk will present a few case studies showing the potential of UAV and Dornier aircraft-based images for mapping crevasses in Svalbard. Drone-based crevasse maps were generated for Tunabreen, Fridtjovbreen, Nordenskiöldbreen, Mohnbukta, and Wahlenbergbreen. Aircraft-based data was collected in 2020 for Holtedahlfonna to better map crevasses. Eventually, these maps will be very useful for field scientists visiting glaciers sites annually to avoid accidents.

Future Risk Pictures of the Northern Sea Route

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Abstract

The Northern Sea Route (NSR) is the North-Eastern Passage going from the Barents Sea to the Bering Strait. Because of global climate change, the ice sheet of the Arctic is melting, which has caused numerous stakeholders to gain interest in its prospects. Not only can the route serve as a viable alternative to the Malacca Strait, and the Panama and Suez Canals to support global trade infrastructure, but it also holds prospects within petroleum and liquefied natural gas, and tourism industries. Consequently, this spur of interest has given rise to new challenges within polar maritime and environmental safety, as well as the development of its corresponding international and national legal frameworks. The purpose of this paper is therefore to uncover the possible futures of the Northern Sea Route and their corresponding risks, by taking into consideration the involved stakeholders, and the development of technologies, legislature, regulation, and the global geopolitics that shape it. Future Risk Vectors of the Northern Sea Route revolves around the operationalization of wicked problems into analyzable scenarios. Wicked problems are problems that are not predefined, nor do they have a single solution. They are problems that exist due to the opinions and wants of the stakeholders involved in the formation of a problems in the future. The main issue of analyzing wicked problem is that they are subjective, non-quantifiable, non-linear, and non-delineated. In other terms they are the products of different forms of analytic and heuristic thinking of different individuals in different networks that occur across a timespan. As a cumulative effect, one cannot objectively assign them ontic quantities such as risk or uncertainty. Thus, one cannot make a form of casual deterministic inference about the possible manifestation of futures, but one can use discrete models to fix futures. In this paper the general morphological analysis framework was employed to create an interactive inference model that allowed for the investigation of future risk scenarios. Through the interactive inference model, it was deduced that the dimensions: East/West Relations, Global Environmental Politics, and Technical and Navigational Requirements, were the most pivotal for the formation of different futures. The interplay between the connections of these dimensions as parameters clearly formed distinct opposing scenario clusters for possible futures. Effectively identifying relations, technology, and environmental politics as the strategic areas to target to shape the future of the Northern Sea Route.

Near miss incident (it's development and consequences) on a student free time trip to backcountry in Greenland

Martin Kotol[1]

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Abstract

In February, an incident occurred in Sisimiut, Greenland where students and a staff member of DTU took on the multi day hiking trip in the backcountry. The group underestimated the weather conditions, their physical and orientation skills as well as knowledge of the local conditions and terrain, which led to a series of incidents. The group chose inappropriate and non-uniform means of transportation. Some had snowshoes, some XC skis and some AT skis. The lack of experience with the skis combined with frequent detours resulted in significantly slower progress than planned. The day was getting shorter and the weather stared to change rapidly and storm with 20 m/s winds was coming. Some members started having concerns about the safety but kept hiding them. The group was determined to continue according to the original plan all the way to the cabin where they should spend the night. Along the way, the terrain became too difficult for the XC skiers with pulks. Therefore, the group decided to abandon the pulks and skis and proceed on foot. In deep snow without snowshoes, the progress was now even slower. When the group finally made it to the cabin, the moral was quite low and they decided to use the inReach and request a rescue for the next day. Unfortunately, the position of the cabin and the weather situation did not allow a low risk rescue from either land, air or water within the next 24 hours. Therefore, after considering all the factors the group was advised to stay an extra day in the cabin where they were safe. Meanwhile, the DTU personnel arranged a snowmobile rescue for when the weather allows. After the storm calmed down the group started heading towards the meeting point and neglected indicators of possible avalanche risks. Consequently they triggered an avalanche which luckily did not burry anyone. However, made further progress impossible. In the end the local police had to be informed and SAR boat was sent to pick the group up from the shore. The students had been through the safety course, avalanche course and were warned by several staff members about the predicted weather changes and difficulty of the chosen trip. Yet still, they left and did not turn back when they could. On multiple occasions this trip could have ended fatally. This incident raised discussions about safety procedures, their enforcement and applicability on various situations.

Maritime Mass Rescue Operations in the Arctic

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Abstract

A large increase in maritime activity in the Arctic oceans has taken place the last few years, from merchant vessels, fishing vessels, research and tourism. However, climate conditions, remoteness, communication challenges and limited crisis response actors, are challenging both for safe ship traffic and for emergency response operations in Arctic waters. A large ship accident resulting in a mass rescue operation would be challenging for all involved parties. The aim of this paper is to study how a mass rescue operation could be conducted using a temporary camp on a deserted beach to give crew and passengers a temporary shelter while waiting for a transport to a main settlement.

The empirical findings stem from a review of the requirements specified in the International Code for Ships Operating in Polar Waters (IMO, 2014) and on the special challenges of operating in these waters, on many years of experiences with SAR operations in the Arctic, on participant observation during the SARex2 and SARex3 exercises in Svalbard in 2017 and 2018, and on a recent project on Arctic Mass Rescue Operations exercises. The theoretical lenses are preparedness, crisis response, exercises and resilience. The article starts with a presentation of the challenges of operating in polar waters and some relevant parts of the Polar Code. Then the conceptual framework of the study is presented, followed by methodology. Then follows a discussion of a promising strategy for SAR and evacuation of passengers and crew following a ship accident in Arctic waters. Finally, some concluding remarks are presented, on how a temporary camp may contribute to a resilient crisis response.

The risk-based approach to dimensioning of Arctic rescue services – real and perceived emergency response in Greenland and Svalbard

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Abstract

There are specific hazards in the Arctic that challenge both everyday activities as well as emergency response operations and rescue operations. Thus, both Greenland and Svalbard face challenges when it comes to emergency preparedness. While the Arctic hazards they face are mostly similar, there are significant differences in their responses to these hazards.

Creating robust emergency preparedness in Greenland and Svalbard are difficult. Greenland is a large island of 2 million km^2, around 410'000km^2 of ice-free areas, 56'000 inhabitants and around 70 towns and villages. Svalbard is a remote archipelago of 61,022 km^2, 3000 inhabitants in three larger settlements, located some 830 km from Greenland and 950 km from the Norwegian mainland.

From a normative standpoint, we would like to see a risk-based approach to dimensioning of emergency preparedness. Risk-based dimensioning aims to create consistency between available resources and the need for response capacities that matches identified hazards. However, there are many factors influencing stakeholders decision-making on the level of preparedness, such as available resources, experiences from rescue operations, overall activity in the area, and the need to prioritize between different public goods. The paper aims to study the specific Arctic hazards in Greenland and in Svalbard, the emergency preparedness structures established in Greenland and in Svalbard to handle these hazards, and the degree to which we can describe the approach at Greenland and Svalbard as risk-based approaches to emergency preparedness. The findings in this study stem from literature studies, discussions with key stakeholders within emergency preparedness in the two regions and own observation.

We start with an introduction to Greenland and Svalbard, followed by presenting the most relevant Arctic hazards, the two regions experiences with rescue operations and maritime activity. We then continue with a short presentation of available rescue resources in the two regions, followed by our conceptional framework of risk and emergency response. Our methodology for data collection is then presented, followed by our findings and discussions before we present our conclusions and recommendations.

Windtech - A novel sensory device for cold climate regions risk management

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Abstract

The Windtech team has developed a novel (submitted for patent) portable/wearable device that gives a more realistic feeling of the 'cold' to prevent cold-related accidents/injuries. The device gathers the related parameters utilizing several built-in sensors and calibration algorithm. The device output is the sensation of heat loss and reflect upon the true feeling of cold. It is found to be primarily dependent on four atmospheric variables: ambient temperature, wind velocity, irradiance and humidity, however output indication is not limited to these. The output values can be utilized for classifying the risks according to standards, for example, ISO 11079:2007. The Windtech device can be used to gather the local atmospheric data for short-term weather prediction. This can help individuals and corporations with planning and management of outdoor activities in the cold climate regions. Furthermore, output from Windtech device may be utilized for proposing appropriate actions and recommendations such as de-icing or anti-icing operations, appropriate clothing suggestions, work limitations, and other HSE-relevant actions.

Arctic Heritage at Risk 2021: Safety, Analysis, Preparation and Response

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Abstract

Climate change in the Arctic impacts human heritage on a devastating scale, ranging from coastal erosion, damaging or destroying coastal archaeological sites, to accelerating biological and chemical processes causing decay, disturbance and obliteration of objects and structures. Climate change has resulted in the pillaging of woolly mammoth tusks from thawing ground, many from archaeological sites, and general tourist 'souveniring' of material culture. The cultural safety of local communities is at risk through the theft, damage or destruction of cultural objects, and places of spiritual, cultural and historical significance. The human risks associated with responding include the regular challenges of Arctic field operations, potential exposure to hazardous materials from past industrial and military activity and, in some instances, encountering criminal activity. This is a challenge for governments and industry, including tourism. In addition, it concerns NGOs such as the International Council on Monuments and Sites' International Polar Heritage Committee, academia and local communities.

Remote sensing and robotics are increasingly integrated into the data collection necessary for computational and human assessment to inform heritage at risk policy, analysis, planning, preparation and response in a safe manner. Changes to the environmental setting, such as coastal erosion, permafrost thawing, and boreal advances, can be routinely and effectively monitored using spaceborne remote sensing to better understand cumulative changes and monitor extreme events. Higher spatial resolutions, down to the centimetre scale, can be achieved using remote sensing systems carried by UAVs and are well-matched to the scale of sites, structures and artefacts. Integrating local communities' expert knowledge with remote sensing and robotics resources is a culturally appropriate effect multiplier that will improve safety and resilience in the Arctic heritage domain. The technical tools required to analyse spatial and temporal data collected in these ways are increasingly available in the public domain, and often through open-source platforms. Analysis in the field can be enhanced utilising larger computational resources, and with additional human analysis. In extreme events, ranging from major storms and fires to criminality or civil conflict, remote sensing has an important overwatch role of heritage sites and heritage personnel.

Remote sensing, robotics, analytical and cultural resources can enhance heritage fieldwork, inform broader situational awareness, and contribute to further research. This will allow the limited number of archaeologists, other heritage professionals and support members to be deployed more efficiently, effectively and safely.

Can expedition cruise vessels be utilized in Arctic oil Spill Preparedness and Response?

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Abstract

Given the increase in the Artic expedition cruise operations in recent years, ships may cover a relatively wide area during the main cruising season and their presence in many areas could represent a valuable resource. In the event of an incident at sea, or on land, expedition cruise vessels may be the first on site and potentially able to act as first responders before larger professional or government resources can reach the site.

The Emergency Prevention, Preparedness and Response (EPPR) working group under the Arctic Council, conducted project NEPTUNE. The project partners were the Association of Arctic Expedition Cruise Operators (AECO), U.S. Coast Guard Office of Marine Environmental Response Policy and Norwegian Coastal Administration. The project aims at looking into the possibility of expedition cruise vessels and operators becoming part of oil spill preparedness and response in the Arctic.

The project conducted a survey of opportunities and obstacles for expedition cruise vessels to become part of the Arctic Oil Spill Preparedness and Response community. The survey included issues such as equipment, space, storage, responsibilities, competence, costs, organization, etc. Both Industry and the Arctic States competent oil Spill Authorities participated in the survey.

The project conducted two table top exercises (TTX) with Hurtigruten and the vessel *Roald Amundsen* and Lindblad Expeditions, with the vessels *National Geographic Explorer* and *National Geographic Endurance*, to help answer many questions about the industry and guide future discussions and exercises.

The surveys and exercises results show that the expedition cruise industry can be an excellent partner that is willing and capable of providing valuable first responder services during oil spills in the Arctic. These small, specialized cruise operators are committed to sustainability and their self-reliance. Due to the rugged environments in which they operate, they are prepared to respond to emergencies for themselves as well as other vessels. They are not often considered as a spill response asset, but in the Arctic, they could very likely be the first and only asset on-scene for up to a few days depending on location.

Learnings from the most ambitious environmental project in Norway

Ole Kristian Madsen[1], Pernille Meyer[2] , Ove Haugen[1] , Sverre Kvalheim[3] , Gudmund Løvli [3]

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Abstract

After almost 100 years of coal production, the mining community in Svea and Lunckefjell is under decommissioning. The mine is the largest coal mine ever in Norway, and at its peak there were over 400 employed miners. Svea is now under deconstruction, and the area is to be restored to its original condition in accordance with the Svalbard Environmental Act. Upon project completion, the glaciers and mountain sides should appear virtually unaffected by the industrial activity, and only a few cultural heritage items will be left. In addition to the mines, the project includes removing the settlement in Svea. This encompasses more than 100 buildings, 27 km of roads, several tank farms, power stations, tunnels, two quay facilities and an airport. It is one of the largest and most ambitious ecological restoration projects globally to date. Further complexity is added by the fact that Store Norske still operates the Svea settlement in parallel with the deconstruction process. The nature of potential hazards and risk of unwanted occurrences changes continuously as the project progresses and infrastructure of the settlement is reduced. Additionally, years of industrial activity has also left a potentially hazardous environmental footprint to be handled.

Store Norske has defined ambitious HSE and quality targets, and Safetec has contributed with advisory services in the project since 2019. The results so far are in line with the expectations from the authorities. This presentation will outline how the ambitions was developed and operationalized from idea, through planning, contract development, purchase, execution, and finalization. To manage risk in this complex project, executed at a remote-site in harsh environment, with a range of unique hazards and threats, specific risk reducing activities and procedures has been adapted.

The systematic approach to risks involves working both proactively and reactively to control onsite hazards, including identifying hazardous operations through task analysis and safe job analysis, careful planning, carrying out environmental sampling, communicating with onsite workers, going through registered unwanted occurrences on a regular basis, and more. Despite the identification of hazardous operations and implementation of risk reducing measures, unwanted occurrences have resulted in dangerous situations, serious injuries, and environmental damage. To handle these occurrences in a suited manor is key to avoid reoccurrences.

The close collaboration between all key stakeholders is essential to ensure continuous success of this ambitious environmental project, and as we enter the final phase, we are confident that the project will end successfully.

Improve safety by learning from previous cases. Arctic accident GIS and story map

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Abstract

Safe navigation is unthinkable without an analysis of previous experience and mistakes. Marine Accidents in the Arctic should be investigated for the successful development of the Polar regions. There were many accidents during the long history of navigation in ice infested waters. Some of them became legends and changed attitude and safety regulation. For example, the Titanic tragedy provoked public awareness, which led to SOLAS Convention (1914-1974). Several accidents initiated the development and adaptation IMO Polar Code (2014-2017). But casualties continue to happen even in 2021, and its analyses are not performed in the proper way.

Presented work aims to make accident data accessible and useful; create an online resource, show the events on the map and explain how the situation developed; prepare information for the best perception to ensure the proper social and scientific awareness.

Using created cloud-based Geographical Information System (GIS), one can find and visualize information about accidents and natural conditions, dive into details via hyperlinks. The typical cases such as grounding, collision, ice bounding/drift and icing are shown. “Case study story maps” reveal the most remarcable and instructive events combining maps with narrative text, images, and multimedia content. GIS layers and performance tools will be discussed in the presentation.

Possible inclusion of the GIS into the existing web-mapping services, like “BarentsWatch”, “The Arctic risk map”, or other dedicated portals will make the data even more accessible and requested. It will improve emergency management competence and increase response capacities via innovative training and knowledge dissemination.

Navigational problems and dangerous ice phenomena in Spitsbergen Fjords

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Abstract

High speeds of water currents in narrow straits and shallow regions influence safe navigation, transportation, and field works. Several examples are given in the present paper. Island Akseloya crosses the entrance in the Van-Mijen Fjord fjord from Bellsund and leaves two narrow straits for water exchange. Navigational activity is organized in the northern strait Akselsundet since the southern strait Mariasundet is very shallow. Total width of Akselsundet is 1 km, but navigational part of the strait is narrower. Minimal depth is the navigational channel is 40 m. Maximal speed of tidal current reaches 2.5 m/s (7 knots), while the slack water period acceptable for the navigation of big boats is associated with water speeds less 0.5 m/s. According to the request of Port captain from Svea the Acoustic Doppler Profiler was deployed to measure vertical profiles of the water velocities over 45 m of the water column in the strait with sampling interval 5 min from November 4, 2015, to March 18, 2016. We discovered that slack water period depends on the tidal phase and changes from several hours to 15 min in syzygy tide. The table of slack water periods versus tide heights was delivered to the customer. Strong currents in the strait influence drift of sea ice near the strait in the Van Mijen Fjord that may create dangerous situation during the field works on the ice. In March 2021 small plastic boat Polarcirkel was trapped in the ice during the field works of AT-211 course. Drift floe locked open water space between Polarsyssel and Polarcirkel during 15 min, and ice ridge started to form near Polarcirkel. Fast ice dynamics was not visible from sea ice and was not recognized from Polarsyssel preliminary. For 15 minutes Polarsyssle managed to destroy ice and rescue Polarcirkel. There are several fjords in Spitsbergen where even stronger currents were registered. For example, Norwegian pilot (2016) reports about high water speed and no slack water period in Heleysundet between Spitsbergen and Edgoya. Drifting buoys measured ice drift speed up to 5 m/s in the strait. Strong currents below the ice in combination with weather conditions can influence fast decrease of ice thickness over a short time. We observed changes of ice thickness from 5 cm to 30 cm over several hours in the strait between Vallunded lagoon and Svea Bay in 2019.

Equality or health? A forced choice for many women

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Abstract

Physical requirements and environments of many jobs have evolved at a time when few women occupied those jobs. Training and equipment have been designed for a single model of an ideal (male) employee rather than for complementary teams. The effect has sometimes been to put extra burdens on women workers. For example, tool belts can be designed for people with hip-waist ratios typical of male workers, small size outfits can be available only in male body proportions, training methods can be inappropriate for strength types most common among women. Women workers have been reluctant to point out these problems, fearing they will be accused of asking for "special" treatment. They often feel torn between a need to protect their health, and a desire for workplace equality. But adapting the workplace to a wider range of potential employees is not the same as giving special treatment to a few. Employers need to foster more efficient teamwork by insisting on respect for different talents and complementary abilities, think about how their workplaces need to modernise, and devise specific programs to facilitate entry of new workers.

Building resilient Arctic communities with mobility infrastructure: Sitka, Alaska and northern Finland

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Abstract

Connectivity is one aspect touted as supporting resilient communities, with remote communications being important, but without neglecting physical links, especially for transportation. This mobility infrastructure can be harbours, airports, roads, railways, and overland routes for skiddoos or animal-based transport such as dogs and reindeer. Ways into a location for people and supplies can also mean more resource extraction and increased quick-trip tourism while providing emigration incentives. Key questions for Arctic resilience and mobility infrastructure then become:

(i) How to determine the advantages and disadvantages of changing mobility infrastructure.

(ii) How to measure or calculate the influxes and outfluxes.

(iii) How to ascribe causation or non-causation from changed mobility infrastructure to changed mobilities.

To link these questions to resilience, analyses are provided here for two Arctic locations: Sitka, Alaska and northern Finland. Specific examples from these locations demonstrate the interplay of mobility infrastructure, mobility, and resilience:

(i) Cutting roads for forestry.

Some state that these roads disrupt the ecosystem and are temporary for resource extraction only. The forestry sector highlights that the roads can also be used for accessing cottages and recreational areas, except some of the roads are suitable for driving mainly when they are frozen over, in winter. Who gains and loses resilience from forestry roads?

(ii) Less use today of waterways than in the past.

Sitka's sounds see mainly cargo and cruise ships while the river bordering Sweden and Finland is rarely a transportation mode. Has resilience been lost or gained through less day-to-day dependence on water mobility infrastructure?

(iii) Opposition to improved mobility infrastructure, e.g. bridges, tunnels, and causeways or larger airports.

Expectations, right or wrong, can be that an inevitable consequence of more mobility infrastructure is detrimental social change. Is isolation seen to increase resilience?

As such, for Arctic communities, it might be that immobility infrastructure--transportation systems designed to discourage movement--has as much relevance for resilience as mobility infrastructure.

Women in polar fieldwork - how small details make a big difference and why we should talk about it

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Abstract

When planning or conducting fieldwork in polar regions, women have to face certain obstacles that men don't. Clothing and PPE designed for men and the male body can lead to situations ranging from minor discomfort but also to serious safety issues like reduced water intake, leaving women at risk of dehydration and urinary tract infections (Greene et al, 2020). Bringing these issues up during preparation and planning is important to inform and prepare inexperienced women for the challenges they have to face as well as to allow expedition leaders and coordinators to understand the needs of all participants. An open discussion about this topic also helps to raise awareness and may eventually lead to the establishment of useful and safe routines and PPE for everyone. Very often only minor changes are necessary remove obstacles and discomfort. Using the example of PPE during the MOSAiC expedition, common problems and potential solutions will be addressed.

Criteria-Based Risk Analysis of Wind Farms in Cold Climate Regions

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Abstract

Wind energy industry is flourishing in cold climate regions, due to the fact that those regions are windy and sparsely inhabited, which provide ideal conditions for the establishment of wind farms. Cold climate regions, by definition, are locations that experience temperatures below the operational limits of standard wind turbines and may experience incidents of icing conditions. Wind farms in cold climate regions are subjected to different types of risks. These risks can emerge from the harsh weather conditions, which can affect the performance of wind farms, their surrounding environment and society. In this paper, 6 types of risks arising in cold climate regions are identified, which are the increased failure rates of wind turbines' components, ice shedding from wind turbines, cold stress to workers at wind farms, limited accessibility to wind farms due to snow cover on pathways, environmental and societal risks caused by the wind farm. Furthermore, two criteria for the probability and consequences of each risk are defined in this paper. In order to demonstrate the use of those criteria, a wind farm in Arctic Norway was selected as a case study. A risk matrix was built, specific to the selected wind farm, to rank the risks according to their level of probability of occurrence and severity of consequences. The risk matrix revealed that the two highest-ranked risks were the limited accessibility to the wind farm due to snow cover on pathways and the increased failure rates of wind turbines' components due to reasons relevant to weather conditions such as cold temperatures and icing. The other risks were not rated as highly risky. Counter measures to mitigate the two highest-ranked risks are proposed to improve the availability of wind farms in cold climate regions

Resilience of Wind Farms in The Arctic: A Probabilistic Approach Using Bayesian Networks

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Abstract

Wind farms in the Arctic are prone to different types of disruptions emerging from harsh weather conditions that degrade their resilience. There is a growing interest among decision makers, in resilience-building strategies, in order to improve the ability of wind farms, to withstand and recover from disruptions. For this purpose, it is very important to devise methods for accurate calculation of resilience of wind turbines in the Arctic as a tool to assist decision makers. In this work, a probabilistic approach, using Bayesian networks, is followed to calculate the resilience of wind farms in the Arctic. In the context of this work, resilience is defined in terms of the reliability, maintainability, supportability, and the organizational resilience of the wind farms. As a study case, the proposed method is implemented to a wind farm in Arctic Norway to demonstrate the effects of disruptive weather conditions on wind farm resilience, through three different scenarios, using the proposed Bayesian network. The first scenario is the baseline scenario, which calculates the resilience of the wind farm under normal operating conditions. The second scenario is the Arctic operating conditions scenario, which calculates wind farm resilience in the light of Arctic conditions. While the third scenario is an extreme scenario in which the operation of the wind farm is extremely disrupted due to extreme Arctic weather conditions. According to the analysis of the three scenarios, the resilience of the wind farm is high during the baseline scenario, slightly degraded under Arctic weather conditions scenario, and significantly reduced under the third scenario, which is the mostly disruptive scenario. Backward propagation of Bayesian networks allows for determining the percentage of improvement needed to attain an acceptable value of resilience. This is applied to the third scenario to determine which resilience factor needs more improvement and the magnitude of that improvement to reach an acceptable level of resilience for the wind farm case study. It is proposed that the reliability of the wind farm should be improved in order to significantly increase the resilience of the wind farm to an acceptable level, which can be also attained by installing anti or de-icing systems, that will reduce the stoppage events of wind turbines caused by ice accretion on their blades during the disruptive Arctic conditions.

Tailored probabilistic weather and sea-ice forecasting services for Arctic marine operators

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Abstract

Due to the Arctic's extreme environmental conditions and remoteness, maritime operators are strongly demanding user-specified weather and sea-ice predictions. Because of the chaotic nature of the coupled atmosphere-ocean-sea-ice system and systematic errors inherent in our model systems, careful and accurate estimation of the forecast accuracy is needed to provide the end-user with high-quality, actionable information for decision-making. Probabilistic forecasts based on ensemble prediction systems can provide the necessary information. The potential value of probabilistic forecasts for maritime decisions in the Arctic is currently not fully realized, and requires in-depth collaborations between providers and users of forecast services.

In the FOCUS project (2020-2023) an interdisciplinary team of researchers and intermediate users are collaborating in order to understand the relevance of improved forecasting services around Svalbard, as well as to disseminate and communicate forecast uncertainties to specific end-user groups. On the one hand, new probabilistic forecast products are being developed in a close dialogue with maritime stakeholders. On the other hand, new services will be integrated into navigational platforms. These platforms are used by a large number of ships worldwide, including several which sail around Svalbard. We will present an overview and first results of the FOCUS project, and will discuss the challenges in developing and providing useful Arctic probabilistic forecast information

Making remote polar fieldwork more inclusive for women: Lessons from the Australian Antarctic Program

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Abstract

Antarctica is a remote, historically masculine place. However, it is also a workplace, and the human interactions there are connected to power structures and gendered expectations. The pervasiveness of heroic white masculine leadership and exploration in Antarctica has meant that women and other underrepresented groups have had less access to Antarctic research and remote fieldwork opportunities. For instance, although women are becoming more visible in the Australian National Antarctic Program, they still comprise less than 25% of Antarctic expeditioners. Even when they do make it down South, women face several physical, social, and psychological barriers that compromise their safety because the 'typical' expeditioner is still presumed to be male. For example, women have difficulty managing basic hygiene/toileting in the field and often find that polar field gear is rarely available in women's sizes. Women are also 3.5 times more likely than men to experience sexual harassment during fieldwork. Most women do not report their harassment for fear of backlash or loss of opportunities. The lack of attention paid to issues of gender and sexuality in polar fieldwork specifically contributes to the invisibility and exclusion of women and other underrepresented groups more broadly. This paper examines how we might rethink equity and inclusion in remote polar fieldwork based on work currently being undertaken in the Australian Antarctic Program.

Computer-assisted management training for professionals in High Arctic SAR -operations.

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Abstract

This paper takes as a starting point the competence needs of managers responsible for the complex crisis response operations in a High Arctic setting. We elaborate on the need for competence on multi-organizational cooperation and coordination at tactical and operational management levels in maritime mass rescue operations (MRO). We look into the special context of High Arctic environments with remoteness, cold climate and a vulnerable environment. Even though the risk of severe accidents in this region is low the consequences may be severe with the loss of life and health when large vessels with a lot of passengers and crew are involved.

In this paper we focus on the relation between competence needs and adequate training schemes for key personnel responsible for coordinating a mass rescue operation in this environment. We illuminate how simulator training may increase the competence related to the managerial roles and especially the coordination of a large number of units and agencies. We in particular emphasize training for management at tactical level (on-scene coordination) involving both the vessel in distress and samaritan vessels, and operational level coordination involving SAR mission controllers and crises response agencies such as the police. We illuminate the contributions that simulator-based training may have with data from the Exercise Isfjord run annually at NORDLAB for students from Norwegian crisis response agencies.

Data from qualitative semi-structured interviews with students, mentors and academic staff revealed the importance of proper preparations of the participant group and the process of building trust among the participants to build a temporary shared situational awareness. Further, increased context-realism and simulator-assisted exercise was found to have a positive effect on the safety training outcome. The simulator created realism and the mentors could add knowledge on the system and best practices. Previous knowledge and trust among the actors were found important as well as adapting the exercise to previous knowledge on both operational context and the emergency response system. This underlines the need for meeting arenas and tailor-made training schemes, including the right composition of the groups training together.

The results reveal that simulation-based exercises with high degree of context-reality as well as realism in the sense of human actions and interactions may provide advanced safety training outcomes. This could meet a broad range of crises as it promotes efficient collaboration between the involved parties, including both public and private.

Gridded snow maps for Svalbard

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Abstract

The simulated snow and weather maps displayed in web-portals Varsom Xgeo and Varsom SeNorge give the natural hazard warning services and the public valuable information about the snow and weather conditions. Varsom Xgeo is one of the most important tools in the natural hazard assessment and does not only include gridded maps, but also data from different measurement stations, observations from the field (from Varsom Regobs) and events such as road closures. In addition, satellite images and post-processed products from Sentinel 2 and 3 satellites are available through the Xgeo portal.

The gridded maps for Svalbard consist of maps that shows precipitation, air temperature, new snow, new snow depth, rain and snow melt, snow water equivalent and snow melt. The temporal resolution is 3 or 24 hours, and the spatial resolution is 1 km^2. The maps cover both the main island Spitsbergen and the more remote islands of Svalbard, such as Nordaustlandet, Kong Karls Land, Egdeøya, Hopen and Kvitøya.

While the snow maps on mainland Norway are based on gridded observation-based precipitation and temperature maps since 1957 as input data, the Svalbard maps use the hourly meteorological forcing data obtained and downscaled from the AROME Arctic numerical weather prediction model. The model data archives go back to autumn 2012. The AROME data is aggregated from hourly to 3-hourly values and precipitation is adjusted based on initial evaluation of the snow maps against satellite images of snow-covered area. To maintain focus on the seasonal snow cover, snow or firn older than 1 year is removed from the model's snow store on September 1 each year.

The snow maps for Svalbard in Varsom Xgeo give the natural hazard warning services a unique opportunity to combine both simulated weather and snow maps, and observed data from measurement stations and events in their natural hazard assessments for Svalbard. Since the available number of observations, such as observations done by the public through the Varsom Regobs app, varies in time and has a rather sparse spatial coverage, the snow maps for Svalbard can provide valuable additional source of information about the snow conditions, especially in more remote areas of Svalbard (B-regions, not covered by the daily, regional avalanche bulletins).

Slushflow early warning in Arctic areas

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Abstract

Slushflows pose a significant hazard in the Artic. They cause great danger and damage to both infrastructure and people, and have resulted in several fatalities in Svalbard. Slushflows are rapid mass movements of water saturated snow. Due to permafrost, Arctic areas are especially prone. The number of slushflows is expected to increase in future climate in the next decades.

As opposed to snow and rock avalances, slushflows release in low to moderate slopes (<30^{o}). Slushflows therefore entail some additional challenges as the path and runout may affect other areas. Due to their high liquid content, they can flow around and across obstacles and thus appear unexpectedly.

Slushflows are typically released as a result of rapid air temperature increases throughout the snow season. Like during warm spells in winter with rain on snow and snowmelt, and following rapid transitions to high pressures in spring causing intense snowmelt. They might be triggered in sunny, late spring conditions, when snow avalanche danger is generally low.

Some terrain features are known to be especially prone to slushflow development. Vannledningsdalen in Longyearbyen is such an example. Slushflows are frequently triggered and can destroy buildings and infrastructure downstream. The hazard has until now been managed by making a channel in the valley in springtime to drain the meltwater from the plateau. However, warm spells in winter are still a challenge.

Hazard prediction and early warning is crucial to prevent damage caused by slushflows. A new operational early warning service for slushflows has been established in Norway during the last years. The method is based on assessment of snow and hydrometeorological conditions. Four variables are central: ground conditions, snow properties, air temperature and water supply. The method is relatively novel, and still under development.

A benefit is that combined with local knowledge, the slushflow early warning method may be implemented in all Polar regions where the necessary input data are available. Physical measures are generally expensive. They are usually difficult to implement due to the nature of slushflows. Thus, a slushflow early warning system is an asset both to protect buildings and infrastructure and as an incentive to take safety measures for tourism, other organized trips and during fieldwork.

A resource perspective on Arctic field safety management

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Abstract

Many hazards face field operations of small teams of researchers and students working out of research stations in the Arctic. Teams in Greenland frequently visit and work in this environment characterised by its remoteness, extreme weather, challenging navigation and temperature events. Some of these stations have a core of competent staff that can support fieldwork, but most are primarily staffed with one or two people or have no regular presence. This paper explores how smaller research stations in Greenland can maintain and improve their risk analysis given limited resources, level of experience and rudimentary governance structures. A model for cognitive network risk analysis is used to evaluate the capability of staff at these stations to assess Arctic hazards. The cognitive network risk analysis model comprises four elements: Activities, Sensory, Individual and Coordination, all relating to a specific Context. Using the Danish Technical University (DTU) research station Artek in Sisimiut, Greenland, the paper explores how a small but staffed station works to engage in a continuous virtuous circle of risk mitigation improvements despite limited resources. Findings show that it is difficult for station staff to monitor individual tasks as they are either absent or lack knowledge of risks associated with specific scientific methods or exercises. There are also fewer activities that transcend the organisation and require coordination with other research institutions or local organisations. The station deploys both passive and active sensors to monitor safety but lacks formalised pre-risk assessment and a logbook for fieldwork, enabling the virtuous circle of continuous improvements. Many teachers and researchers visit the station during the year, some have experience working in the Arctic, but a significant proportion has little or no specific updated emergency response training. Coordination is possible because of the limited complexity of field operations and the size of the research groups. A resource perspective on field safety management shows that the station can only support operational safety in a limited way, relying on the knowledge base of visiting researchers and teachers. The small formal governance structure and partial use of standards limit the scope of safe activities that the station can perform, but the boundary remains fluid. The resource-based perspective provides an approach to risk analysis of fieldwork focused on optimising limited resource as an alternative to a standards-based approach that can be difficult to manage.

Civic Organizing for Environmental Stewardship: A Program from the Institute for Civic Organizing Piloting in Three Arctic Communities

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Abstract

Civic Organizing for Environmental Change is a program of The Institute for Civic Organizing (TICO). TICO functions as a hub for the political process, bringing together different voices and expertises to both assess the social economy of an area, and then design solutions to bring people and public institutions closer together. The purpose of Civic Organizing for Environmental Change is to combine climate efficacy with the political process to guide arctic communities to be safely conservationist-organizers of their own land. This program takes a three pronged approach: (a) Environmental Stewardship (your knowledge of your land), (b) the political process as is relevant to your environment, and (c) using the political process to support and protect your community's land. We take a broad definition of "your," holding that anyone can make an impact in their home. The ultimate goal is to create ecological and political systems in line with what a community not only needs but also will participate in. Using Bristol Bay, Alaska, Kautokeino, Norway, and Nuuk, Greenland as case studies in civic organizing for environmental stewardship, this presentation will present a methodology for adapting the political process to support conservation efforts in climate vulnerable areas. A methodology that can serve as a blueprint for other communities across the arctic to increase environmental efficacy amongst its population.

Resilience-based monitoring of climate adaptation

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Abstract

Understanding and adapting to climate change is one of the greatest ongoing societal challenges. The primary objective of the ARCT-RISK project (Risk governance of climate-related systemic risk in the Arctic) is to develop knowledge and tools to make sense of and deal with effects of climate change on society's ability to protect the life and health of its citizens and to maintain critical infrastructure and function.

The response to the threat of climate change include two main pillars, the reduction of greenhouse gas emissions and climate adaptation, the latter related to the fostering of climate resilience. The focus of ARCT-RISK is climate adaptation, both short-term and long-term. An understandable priority for decisions-makers in Longyearbyen is short-term measures especially related to the most prominent risks such as risk related to avalanches. However, the municipalities, having the main responsibility for climate adaptation in Norway, need to adapt to both short-term and long-term effects of climate change, and potential interactions between short-term and long-term measures. Initiatives have been introduced to measure the status of municipalities' work on climate adaptation using indicators. In this paper, the focus is on a resilience-based approach for monitoring of municipalities' work on climate adaptation (climate resilience), using Longyearbyen as a case.

The result is a method for monitoring of municipalities' work on climate change both on short-term and long-term, whereas it provides mainly medium- and longer-term decision support. It is based on a method termed Critical Infrastructure Resilience Assessment Method (CIRAM) but adapted for the follow-up of work on climate adaptation. It will provide ideas for long-term governance of climate adaptation as part of the ARCT-RISK project. Further work is needed to provide a link between this resilience-based approach and a risk-informed approach for risk governance of systemic risks related to the effects of climate change.