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SALIENSEAS

CO-PRODUCING MARINE CLIMATE SERVICES

Enhancing the Saliency of climate services for marine mobility Sectors in European Arctic Seas

Workshop Report

Stakeholder Advisory Group Perspectives and Project Recommendations

Enhancing the Saliency of climate services for marine mobility Sectors in European Arctic Seas (SALIENSEAS)

Stakeholder Advisory Group Workshop Report

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This report provides an overview of the activities and discussions that took place during the first SALIENSEAS Stakeholder Advisory Group workshop, held on 25 January at UiT The Arctic University of Norway in Tromsø, Norway.

The workshop was inspired by a participatory approach, in order to give prominence to the perspectives and needs of the various stakeholders involved in maritime activities in the European Arctic. The core purpose of the workshop was twofold: 1) to identify the most pressing issues around metocean information availability and access, in terms of sector-specific needs to increase safety and efficiency of operations; and 2) to formulate a plan for efficient and relevant data collection from end-users.

Invited stakeholder representatives have extensive expertise in Arctic marine operations, and their knowledge will be considered in the assessment of service needs throughout the project. Each participant brought a unique perspective to the workshop, which contributed to gaining a comprehensive view of marine mobile sectors' metocean information needs in the European Arctic. Though two stakeholder representatives were not able to join workshop activities, they were consulted separately. Their insights are also included in this report.

The structure of the report follows the agenda of the workshop. Each section of the report covers one agenda point and ends with a short summary of key insights. The final section connects these insights in an overall reflection and summarizes potential avenues for further collaboration.

We thank all workshop attendees for their time, ideas, and expertise.

The Project Team

Wageningen University and Research
UiT The Arctic University of Norway
Umeå University
Danish Meteorological Institute
Norwegian Meteorological Institute

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Tromsø waterfront - Photo by Berill Blair

1. Executive Summary

Introduction

SALIENSEAS brings together a team of social and natural scientists, metocean service personnel, and end-users, with the aim to 1). Better understand the mobility patterns, constraints, challenges, decision-making contexts and information needs of end-users in different European Arctic marine sectors; 2). Develop and apply participatory tools for co-producing salient weather and sea ice services with Arctic marine end-users, and 3). Co-develop user-relevant and sector specific weather and sea ice services and dissemination systems dedicated to Arctic marine end-users tailored to key social, environmental and economic needs.

This report provides an overview of the activities and discussions that took place during the first SALIENSEAS Stakeholder Advisory Group (SAG) workshop, held on 25 January 2018 at UiT The Arctic University of Norway in Tromsø, Norway. Participants of the SAG represented a wide variety of perspectives and needs related to maritime activities in the European Arctic, including expedition cruising, ice pilotage, ice breaking, fishing and hunting, and shipping. During this participatory workshop participants reflected on important information needs pertinent to planning and operations in their sectors. The core purpose of the workshop was twofold: 1) to identify the most pressing issues around metocean information availability and access, in terms of sector-specific needs to increase safety and efficiency of operations; and 2) to formulate a plan for efficient and relevant data collection from end-users.

SAG perspectives: State of forecast services in a changing Arctic

Overall, participants noted that they, and the stakeholders they represent, look at and compare notifications from multiple sources, for reasons of assessing reliability and accurateness, and gaining confidence in using information in decisions and actions. Further, the participants emphasized the importance of improving monitoring and short-term forecast products across the different areas that were discussed. A round of initial reflections resulted in some notable observations:

- Wind along the ice edge, katabatic wind, and storm events are relevant to many stakeholders.
- Polar Low events are also of interest, although the degree to which forecast lows impact operations depends on the type of activity planned.
- Experienced navigators prefer annotated satellite images to colored ice charts.
- Colored charts are valuable only for the egg codes they contain, as these communicate information regarding the inhomogeneity of the sea ice, and are obligatory products to meet the requirements of the Polar Code.
- Many users are unaware of the suite of metocean services offered; a centralized depository for information, or comprehensive guide would be very helpful.
- Navigators on large-scale operations subscribe to a vast array of services and receive large amounts of information, much of which could be better automated to aid in planning.
- Increasingly, there is a need for a dedicated ice advisor whose role is to distill and interpret information into operational planning.

Scoping Activities

During the participatory scoping activities, SAG and MET-services participants engaged in discussions about important geographic areas where met-services are especially impactful on operations. For the cruise tourism sector, northern and eastern Svalbard, and eastern and southern Greenland are areas in need of improved forecast services. Katabatic winds and drift ice pose significant hazards to operations. A recurring theme in these discussions, especially in the Greenlandic context, emphasized the importance of appropriately scaled products produced at high enough resolutions to be salient for local users, such as fishing vessel operators. Another issue for end-users is the interoperability of satellite images across platforms so as to facilitate the use of multiple images in tandem. In fact, a central hub for satellite images would be welcome by users to eliminate the time-consuming nature of searching across multiple platforms. While some products need to have a short lead time in order to fit the decision processes of end-users, other forecasts are needed on extended time scales.

Next steps

SALIENSEAS plans to engage with end-users in a variety of ways throughout the different phases of the project. A number of key next steps are envisaged that allow for a close and comprehensive aligning of the project activities with end-user needs.

1. *Explore for each SAG represented sector, opportunities for collecting data that facilitate the mapping of mobility patterns and dominant temporal and spatial dimensions of forecast services use.*
2. *Integrate the insights of the SAG workshop into a tentative framework of behavioral and environmental parameters, to be considered as input for simulation products using Agent-Based Modeling.*
3. *Evaluate the suitability of existing metocean products for further development based on one-to-one user needs.*

The Norwegian and Danish meteorological institutes each have specific geographical regions under their jurisdiction for the provision of metocean monitoring and forecast products. For SALIENSEAS this means that co-production activities, aimed at improving user-provider interaction, are likely to focus on different geographical contexts, communication challenges and user needs. Two phases are envisioned in the development of demonstration services for SALIENSEAS:

Phase 1: Near real-time monitoring products and short term forecasting (1-7 days)

- MET.no will build upon existing forecasting capabilities, by introducing improvements in service products for ice-charting, short-term ice prediction and metocean forecasting, by combining monitoring and forecasting products, or by developing and testing a warning system.
- DMI will focus on improving one-to-one services, in a low bandwidth context.

Phase 2: Sub-seasonal to seasonal prediction

- MET.no will explore and evaluate operational subseasonal to seasonal forecasting systems for the use in the Arctic region, such as climate outlooks and climate watch advisories.
- DMI is particularly concerned with monitoring and forecasting sea-ice conditions. For example, currently fast ice is not included in state of the art models. The cause forcing mechanism for fast ice near Greenland is grounded icebergs, which are not included in these products. Based on observation of icebergs, DMI will develop a parameterization of grounded iceberg and forecast fast ice near Greenland that are expected to improve sea ice prediction significantly.

2. Project Background

Introduction

The rapid warming in the Arctic has profound socio-economic consequences. Current and expected climatic changes in the Arctic are propelling growth in marine mobile activities, such as shipping, tourism and fisheries. This triggers a demand for more accurate and salient Arctic weather and climate predictions, which puts great expectations on our current global and regional forecasting systems. Improving access to, and quality of, climate relevant information is particularly pertinent to those operating in remote and dynamic polar marine environments. Better services might reduce the risks and vulnerabilities associated with activities in ice-infested and dynamic Arctic marine environments. It is, however, unclear what climate services are needed and what constitutes this salience for different ship-based end-users operating in different parts of the European Arctic. In this regard, there is a need for research that considers the situated context of Arctic marine activities, in which various climate services are used. Particularly, given the different interests, challenges, abilities, routines and decision-making contexts of end-users across different spatial and temporal scales, a better understanding is needed of what this means for the saliency of the variety of available –and to be developed– weather and climate services.

While large public and private sector investments are currently made in the development of observations, modelling, forecasting and integrating weather and climate information in, and for, the Arctic region, the potential of these efforts for enhancing services for Arctic marine end-users is currently not yet fully realized. The Norwegian and Danish meteorological institutes are both represented as partners in the SALIENSEAS project. Each hold national and international responsibilities for large parts of the Arctic to provide weather, ocean, and sea-ice services on time scales from days to seasons. The mandate of these institutions are based on developing services for the interest of the end users, thus they have large experience in communication with their users.

Aims

The SALIENSEAS project aims to:

- Understand the mobility patterns, constraints, challenges, decision-making contexts and information needs of end-users in different European Arctic marine sectors;
- Develop and apply participatory tools for co-producing salient weather and sea ice services with Arctic marine end-users;
- Co-develop user-relevant and sector-specific weather and sea ice services and dissemination systems dedicated to Arctic marine end-users tailored to key social, environmental and economic needs.

Approach

SALIENSEAS brings together a team of social and natural scientists, metocean service personnel, and end-users in an iterative research and co-production process. Stakeholders and end-users will be

directly involved in the project, both as advisors in the project management and as respondents and participants in end-user workshops. We will adopt cutting edge and partly in-house developed concepts and methodologies for effectively co-producing knowledge and knowledge systems as an overall approach to the project and as part of the work packages.

SALIENSEAS is organized in three work packages.

- Work package 1, led by Prof. D. Muller (Umeå University, Sweden), studies mobility patterns and constraints of different Arctic marine sectors. The work relies on observation, interviewing, and on an innovative public participatory GIS approach to map Arctic marine mobility patterns and the challenges and risks faced by end-users. It will lead to an agenda for the development of climate services for the European Arctic. It feeds into the simulation model developed in WP2, and informs the scope and content of the demonstration services developed in work package 3.
- Work package 2, led by Dr. M. Lamers (Wageningen University, the Netherlands) aims to understand the role of climate services in decision-making contexts (e.g. planning, operations). It formulates design principles, simulates the use of tailor-made services and develops a support-tool for co-producing and testing climate services. State-of-the art methods will be used such as companion modelling, a role-playing game and agent-based modelling. The end-user workshops function as setting for testing out demonstration services developed in WP3. WP2 thereby forms the bridge between the climate service needs identified in WP1 and the demonstration projects developed in WP3.
- Work package 3, led by Dr. M. Muller (MET Norway, Norway) will develop new services tailored to meet the requirements of the end-users. The development will follow two directions. The first is statistical downscaling, which will utilize available databases of metocean conditions for multi-model forecasting by using advanced statistical downscaling methods to evaluate the predictive skill of key parameters. The second approach will be to add skill to the current state of the art sea ice forecasting and through this improve the description of ice break up in near coastal areas of Greenland. Both approaches will do this, by co-developing a series of demonstration services, based on end-user needs as expressed in the activities of WP1 and WP2, and by utilizing state-of-the art statistical methods, improved descriptions of the physics of sea ice and the IT and forecasting infrastructure from Met Norway and DMI. Importantly, the demonstration services developed will be merged into MET Norway’s and DMI’s forecasting infrastructure and maintained and developed beyond the lifetime of this project.

A workshop participant is engaged in a mapping exercise - Photo by Berill Blair

3. Workshop Proceedings

January 25, 2018 Tromsø, Norway

In the course of the workshop activities the SALIENSEAS Stakeholder Advisory Group reflected on important information needs (sections 3.1 and 3.3), pertinent to planning and operations in their sectors. Relevant in these discussions were planning routines, uncertainties that may arise due to weather and ocean conditions and services needed when considering alternate courses of action. The perspectives relayed through expert testimony at our workshop as outlined below, aim to reflect the collective experiences of stakeholders in distinct maritime sectors. It should be noted however that the perspectives are not assumed to be collective in a way that end-users within each sector have some sort of unified perspective. Rather, we acknowledge the potential existence of a wide variety of perspectives and needs within each represented sector. As such, it is first and foremost the in-depth expertise of each SAG participant that allows for tangible entrance points to scope the project objectives toward relevant needs for each sector. The perspectives are summarized according to the stakeholder groups they aim to represent. The geographic range of expertise (if not Pan-Arctic) is reflected in the naming of stakeholder groups, and the affiliations of representatives who were present at the workshop from each sector are noted below. The following stakeholder representatives have shared their expertise:

Fishers and Hunters: Greenland
Tønnes Berthelsen, *Kalaallit Nunaanni Aalisartut Piniartullu Kattuffiat (KNAPK), Association of Fishers and Hunters in Greenland*

Arctic expedition cruise operators: Norway, Greenland, Canada
Edda Falk, *Association for Arctic Expedition Cruise Operators (AECO)*

Ice pilots: Greenland
Thomas Bøggild, *Greenland Pilot Service (GPS)*

Icebreaking services
Sampo Viheriälehto, *Arctia Oy (Arctia)*

Intermediary operational support: Greenland
Klaus Harnvig, *Harnvig Arctic & Maritime**

Arctic search and rescue & maritime navigation: Norway
Tor Husjord, *Maritimt Forum Nord**

**Klaus Harnvig and Tor Husjord were interviewed outside of the workshop activities due to conflicting schedules. Their input is integrated under relevant headings in section 3.1.*

3.1 Stakeholder Advisory Group perspectives: state of forecast services in a changing Arctic

Operational context and use of metocean services

Fishers and Hunters: Greenland (KNAPK)

KNAPK has more than 2.000 members. Many of its members are fishers fishing on vessels with a length between 14 and 21 feet. About 1.000 KNAPK members fish from open boats. In the Disko Bay fishing is carried out mostly from open dinghies. The number of days that fishers are out at sea varies from one day for smaller boats up to two weeks for larger vessels.

The planning of activities varies according to vessel size. Fishers on small boats check forecasts before they go out - from a few days up to a week ahead - to evaluate ice and weather conditions and forecasts. Importantly, the coastal ice information is decisive in terms of *if* and *where* they go. Next to forecasts transmitted via radio, a main source for metocean information is the website of DMI, but Yr.no is also used. Larger vessels, such as shrimp vessels, are connected to the internet and in that respect the Greenland situation is very similar to other countries in the North Atlantic. For example, larger vessels in the south of Greenland have access to up-to-date metocean information.

Arctic expedition cruise operators (AECO): Norway, Greenland, Canada

Cruises of AECO members are organized all over the Arctic. However, voyage and activity planning differs for expedition cruises and regular cruises. Importantly, for all activity planning and decision making, safety and passenger comfort are the highest priority. Vessels are often operating in both the Arctic and Antarctic summer seasons. For activities in the Arctic this means that they are taking place between May and September, sometimes until October. Vessels used by AECO members vary widely in size and passenger capacity. AECO discerns between vessels up to 12 passengers, and vessels between 12 and 500 passengers. Some of these have a particular ice class. The smaller, open vessels are mainly used for day trips.

The itineraries of vessels are often planned up to 2 years in advance, relying on long-term forecast and historical data of environmental conditions. Still, expedition cruising is relatively flexible in terms of routing. Some operators use a ship performance optimization system, in order to improve efficiency of their activities. The circumnavigation of Svalbard is popular among tourists, but Greenland's popularity is also increasing. Both the Greenland coast and Svalbard coast (circumnavigation of the latter) are relevant from the perspective of AECO members. Being close the ice is an objective, since tourists want to see ice. Also, vessels have regular landings in their itineraries.

AECO members rely on multiple sources of weather and sea ice information. Most used resources are the products of DMI, and the websites Yr.no and Windy.com. There is a difference in sources used when ships are close to land versus at open sea. Also, information is shared between ships (e.g., on ice conditions).

Ice pilots: Greenland (Greenland Pilot Service)

According to the Greenland Pilot Act (2015), it is mandatory for all passenger ships with more than 250 passengers onboard to use a pilot when sailing within the Greenlandic National waters. The Greenland Pilot Service mainly assists the cruise tourism sector. Other vessels (e.g. cabling, tankers, supply vessels) who are not obliged to have a pilot on board are also assisted on occasion. These other operations do not have tight itineraries like those of the cruise sector. The season of operation is May through September with different types of vessels. Transit speeds are high, coupled with tight itineraries.

Ice pilots use free satellite data from the Copernicus system, aligning the updates with vessel itineraries. The Greenlandic ice pilots collaborate closely with DMI to obtain specific products, which are received through mail or via Dropbox. These are subscription-based services that are shared with the customers. Furthermore, ArcticWeb is currently viewed as the best one-click solution, however it was stated that there are not many vessels that are actively using it.

Icebreaking services (ARCTIA)

In Baltic icebreaking, Arctia operates for 3-6 months per vessel annually. This means that some icebreakers are out for 6 months, while some may stay at port if the winter turns out mild. In other regions for offshore and other chartering, the Arctia icebreakers are available for 8 months of the year. Three multipurpose vessels (Nordica, Fennica and IB Otso) can operate between 7-8 months annually. The rest of the fleet operates in the Baltics.

Strategic planning for the icebreaking services takes place days in advance of any mission. Authorities must be notified where and when the vessels are going. The colored ice charts are only used in the strategic planning phase – e.g. to see if the ice class of a vessel fits the criteria. Otherwise these are not used, and annotated satellite images are preferred.

Icebreakers use advanced dedicated technology and may have a dedicated iridium phone open for each function that is needed. At high latitudes, the minimum elevation requirement of satellite antennas may be pushed beyond their documented operational limits to get the data that is needed. Navigators use a broad suite of metocean services and compare information from many sources. This may include Danish, Canadian, Swedish, Finnish systems that are being used side by side. There is a propensity to use satellite images for tactical decisions by comparing several images each day. Importantly, good images show individual tracks of ships that are left as traces in the ice. Based on these openings, coordinates can be used for safe navigation.

Intermediary operational support (HARNVIG Arctic & Maritime)

Building on sixteen years of experience as Master Mariner, HARNVIG Arctic & Maritime provides tailored ice advice, monitoring and management services for maritime transport in the Arctic. Its position as intermediary between metservices and end-users provides an additional perspective on the value chain of metocean information.

For the operational support project activities, as much information as possible is gathered from multiple sources. This ranges from satellite images and ice charts to monitoring products for various meteorological parameters, obtained from various metservices. Optimal operational advice is provided to officers or the captain on board. In other words, ice advisors make the wealth of information easier to

interpret for the end-user, by adding another person in the operation that can handle all the data. HARNVIG Arctic & Maritime provided the following observations based on experience:

- The images produced by the Sentinel missions provide vital products. Sentinel provides excellent coverage, based on at least two dailysatellite passages. Based on manual interpretation of these images users will know where the ice edge is. Such images can be sent to the navigator and the ice pilots on the ship, who are able to interpret the information;
- Long-range ice modeling (1-2 weeks ahead) is seen as less useful, because such models will never be accurate enough for end-users who sail close to the ice edge;
- There is sometimes a large gap between what is scientifically interesting and practically relevant. This is for example the case with drones, which have major limitations in operational contexts (e.g., due to icing);
- Improving the knowledge of dynamics of icebergs is seen as useful, but mostly for scientific purposes rather than for economic or social benefits.

Information needs, environmental conditions and communication challenges

Fishers and Hunters: Greenland (KNAPK)

Weather forecasts on the radio are important in Greenland. However, fishers have traditionally used their own direct observations as an important resource, for exampl, by looking at the clouds or snow conditions. In many cases, various expert resources have replaced or complemented such observations.

The availability of information viaradio poses some challenges, however, especially since shortwave services were discontinued seven years ago. This was a difficult development for many fishers and hunters, especially in East Greenland where there are some issues with reception. Many fishers have also started to use the internet to get access to metocean information.

While the bandwidth for internet connections is not a problem for big vessels, smaller-sized operations with less advanced equipment might have issues. Communication via Iridium satellite can be used in case of emergency or as an alternative in areas with long fjords, and high mountains. In these so-called “dead areas” other communication equipment may have no reception.

Ice cover is decisive in the location of fishers’ activities in Greenland. The ice situation can change rapidly and is the main environmental condition that fishers are really concerned about. Although polar lows and other extreme weather events are good to know some days in advance, and may alter plans to some extent, ultimately fishers go out when they really need to, despite bad weather. For this reason, it is also important to focus on building/using ships that meet the challenges of such conditions.

> *Good satellite images are priceless for tactical decisions.*

Arctic expedition cruise operators (AECO): Norway, Greenland, Canada

Various needs for optimizing metocean content and communication facilities exist. Overall, connectivity is an issue in many areas. Therefore, product formats should take into account the limited bandwidth. For example, there is a preference for getting services by e-mail, over accessing websites and downloading information. Improvements in forecast services that operators would like to see pertain to both content and communication of services. Various weather conditions are relevant for cruises. Visibility (e.g. fog with respect to visibility of wildlife), wind (katabatic winds in Greenland) and wave conditions are specifically mentioned. Some vessels use drones, some even helicopters to check local ice situations.

Suggestions for content improvement include information on visibility, current and wave height, increased resolution of forecasts (both ice and weather, and area modelling for local effects and microclimates), cloud free satellite images of ice, and temperature differences related to katabatic winds. Integrating weather information from the Icelandic Meteorological Office is also needed, since AECO members often sail in Icelandic waters too.

Services available free of charge, and ice prediction communicated in a format such as windy.com would improve services. A dream scenario would be when metocean services are tailored to a vessel's particular needs, based on its characteristics, itinerary and speed. Similarly, direct access to a forecaster (e.g., by phone) for decision support would be valuable. Such services should be integrated with a detailed performance optimization system. In relations to the sharing of metocean information between ships, there is still a potential to improve the level of information sharing. In that context, a dedicated platform for sharing metocean conditions would be very useful for AECO members. Finally, AECO noted that there is a lack of knowledge of the variety of information that is available. SALIENSEAS could contribute by improving knowledge and awareness among AECO members of available information and resources.

Ice pilots: Greenland (Greenland Pilot Service)

The bandwidth for internet on high-end cruise ships is excellent, while smaller vessels deal with connectivity challenges. Each ship has the possibility to access internet at port, and update to latest charts. Colored ice charts are still useful in risk assessments, but in tactical decisions, satellite images are often preferred. The temporal rhythm of information becoming available is crucial in planning and can provide some challenges. For example, many satellite passages happen in the late evening when no one is in the offices, which is delaying the communication process and the usability of information.

Regarding geographical areas of concern, the southern tip of Greenland poses significant challenges for the ice pilots, and there is a need for improved short-term forecasts for this area. The approach used is one of risk management: if information is not current and updated, and risk is hereby increased, this can force the cancellation of scenic cruises such as those in the Prince William Sound.

> *The ability to ensure regularity of services is now especially important for the industries society is developing in Greenland*

Icebreaking services (ARCTIA)

An important challenge is that coordination between different information sources is lacking. It is also noted that intergovernmental agreements are important to coordinate activities across economic zones. Finding as many sources as possible takes a lot of time, and it can take hours to get the best satellite images. There is a need for a website that provides a "one stop shop" for satellite images, where users can check boxes to obtain different layers of images, and easily compare multiple sources of uncertainty information. In that sense, Arctic Web is considered to be a good existing service.

In icebreaking operations, ice-infested waters are a given environmental parameter. The emergence of risks stems from inaccurate information or a lack of access to information due to connectivity issues. When it becomes challenging to maneuver within the ice, various adaptive actions can be taken, most importantly by adjusting the vessel's speed. Swells as risk to icebreakers were also mentioned.

Intermediary operational support (HARNVIG Arctic & Maritime)

From the perspective of intermediary operational support, challenges for metocean communication were provided for various sectors. For fishers, information about the ice edge is particularly important. In the Arctic cruise sector, the whole suite of metocean services are useful for planning purposes including long-range forecasts. Other sectors on the other hand find forecasts more than a week ahead too uncertain and less useful. The major 'new' shipping routes (e.g., NE-passage) demand regular forecast and routing services along the entire route.

An important challenge for end-users aboard vessels is not to a lack of information, but the potential for information overload. In some operations there is so much information coming from so many sources, that navigators do not have time to interpret it all. There is a need for improved automation of advice for planning purposes. Dedicated ice advisors onboard were suggested as intermediaries who can support in reducing the complexity of interpretation. As such, trust in the expertise of intermediary expertise plays an essential role in successful operations.

The mid-Greenland ports around Ilulissat and in the Disko Bay pose a challenge in terms of providing reliable information about sea-ice conditions. Due to the disappearance of thick fast ice, year-round access is expected. Therefore, regularity of reliable ice information is important in these areas. In an ideal world, a 2-3 week ice forecast would ensure and support regular operations and supplies (shipping, transport). However, due to the infeasibility of such a long outlook, improving on the current 7-day models would be sufficient. Especially in the Disko Bay there are huge, annual variations in the ice cover. This has opened, for example, the opportunity for further industrial development, for which the employment of icebreaking services has to be considered. For coastal areas with planned industrial development (e.g. Citronen Fjord) ice modeling is crucial. It is stated that no matter how well the vessels

are ice-strengthened and assisted by icebreakers, various significant hazards remain. Therefore, a 4-5 day advance warning for the closure of the ice lead is necessary to reduce risks.

The southern tip of Greenland has a history of problematic navigation. Due to frequent bad weather (e.g. high winds), weather and drift ice warning (especially going up into fjords) are needed. In addition, katabatic wind forecasting in the various fjords along the Greenlandic coast is lacking. A particular hazard pertains to areas where crystal clear icebergs calf from refrozen glacier water. Such icebergs (e.g., growlers) are extremely difficult to see. The only way to prepare for such conditions is learning from near-miss events. When such conditions occur, advanced engineering (stronger vessels and ice belts) provide protection, beyond the adaptive actions taken by the crew such as sailing at reduced speeds.

Ideally shipping lanes would be monitored at least twice a day and be very accurate. On the other hand, the navigators onboard must be very experienced; no tracking system replaces experience and precaution. Indeed, currently the best approach to iceberg avoidance is education of crew to have good visuals because it is the smaller, dense icebergs that do not show up in satellite imagery that pose the greatest hazards.

Arctic search and rescue & maritime navigation (Maritimt Forum Nord): Norway

The Polar Code is considered an important framework for the management of risks. Maritimt Forum Nord has been involved in the SARiNOR project, developed to improve search and rescue systems in the High North. The follow-up project SAREX will start at the end of February 2018. It involves a 3-year collaboration with the Norwegian Coast Guard in the testing of equipment and human behavior in Longyearbyen. The projected outcome is a database of knowledge on how to increase safety in Arctic shipping. As such, an important parameter for any kind of safety measure is the 5-day survival threshold, implemented by the IMO and integrated in the Polar Code. In case of an emergency, equipment and communication structure, including metocean information, should allow for people to survive for a minimum of five days. The functional requirement of a minimum of 5 days survival period is an important step toward improving safety in Arctic shipping. In terms of preventive measures, educational collaboration is important. In this context a communication structure between MET Norway and Maritimt Forum is important to assist end-users in learning to access and interpret available resources to support decision making. A final and obvious communication challenge that remains in the High North is insufficient bandwidth for internet communication.

Summary

Participants noted that they themselves, and the stakeholders they represent, looked at and compared notifications from multiple sources. This may indicate that they, in order to assess how reliable and accurate various information products are, engage in a verification process before they translate any information into various decisions and actions. This verification is especially pertinent during a 24-hour timeframe ahead of voyages. Generally, the stakeholder representatives emphasized the importance of improving monitoring and short-term forecast products across the different areas that were discussed. Notable observations made during the initial reflections:

Word cloud depicting emphases from SAG participant discussion about important areas and services for operations

- Wind along the ice edge, katabatic wind, and storm events are relevant to many stakeholders.
- Polar Low events are also of interest, although the degree to which forecast lows impact operations depends on the type of activity planned.
- Experienced navigators prefer annotated satellite images to colored ice charts.
- The colored ice charts are valuable for the egg codes they contain, as these communicate information regarding the inhomogeneity of the sea ice, and are obligatory products to meet the requirements of the Polar Code.
- Many users are unaware of the suite of metocean services offered; a centralized depository for information, or comprehensive guide would be very helpful.
- Navigators on large-scale operations subscribe to a vast array of services and receive large amounts of information, much of which could be better automated to aid in planning.
- Increasingly, there is a need for a dedicated ice advisor whose role is to distill and interpret information into operational planning.

3.2 The Norwegian and Danish Meteorological Institutes: plans for demonstration services

Seven representatives from MET Norway and DMI attended the SALIENSEAS workshop in Tromsø. In a dedicated session, both institutes presented their visions for potential areas for collaboration. Summary highlights are presented here.

Norwegian Meteorological Institute (MET Norway)

Two phases are envisioned in the development of demonstration services for SALIENSEAS, based on two temporal levels along which the products will be considered:

- Phase1: Near real-time monitoring products and short term forecasting (1-7 days)
- Phase 2: Sub-seasonal to seasonal prediction

In general, MET Norway is committed to supporting the WMO Arctic PRCC web portal, utilizing the infrastructure, and exploring the potential to visualize (possibly animate) products on sea-ice forecasts combined with sea-ice charts/SAR. These services would demand high speed connectivity, however.

In phase 1 the aim will be to build upon existing forecasting capabilities and, together with end-users, define products which are potentially useful (e.g., tailored content and dissemination). Specifically, this can mean a visual combination of monitoring and forecasting products, or the development and testing of a warning system. Phase 1 will mainly focus on improvements in service products for ice-charting, short-term ice prediction and metocean forecasting. By consulting with end-users, various use cases can be developed about sea-ice/ocean forecasts tailored to end-user needs relative to their spatial and temporal positions.

For Phase 2, MET Norway will explore and evaluate operational subseasonal to seasonal forecasting systems for the use in Arctic areas. The results of this assessment and knowledge gained in phase 1 will provide for a testing platform of sub-seasonal forecasts, such as climate outlooks and climate watch advisories.

Danish Meteorological Institute (DMI)

A key aspect of the SALIENSEAS activities of DMI is their focus on improving one-to-one services, in low bandwidth contexts. An initial focus on short-term forecasts will be extended to seasonal periods. DMI is working to upgrade systems that enable higher resolution models. This improves forecast in near-coastal zones.

DMI is particularly concerned with monitoring and forecasting sea-ice conditions. However, there is also the aim to couple such information with ocean conditions. Currently fast ice is not included in state of the art models. Fast ice parameterizations are beginning to be incorporated in sea ice forecasts that cover shallow waters, however the mechanisms that form fast ice near Greenland are different. In many cases the cause forcing mechanism for fast ice near Greenland is grounded icebergs, which are not included in these products. Based on observation of icebergs, DMI will develop a parameterization of grounded iceberg and forecast fast ice near Greenland. Based on this, DMI plans the following activities

under SALIENSEAS:

- Add icebergs to models and use them as anchor points;
- Tune these insights in order to provide info on fast ice conditions at the right time and location. This implies a close consultation with end-users as to develop such products toward meeting their needs;
- Build a service that can forecast fast ice from short to medium range (days to months);
- By lining up with other concurrent projects, sea ice models will be upgraded in terms of content (e.g., including standard fast ice), but also have a higher resolution which will benefit users in near coastal areas and in the area of Cape Farewell.

Summary

The Norwegian and Danish meteorological institutes each have specific geographical regions under their jurisdiction for the provision of metocean monitoring and forecast products. For SALIENSEAS this means that co-production activities, aimed at improving user-provider interaction, are likely to focus on different geographical contexts, communication challenges and user needs. In consultation with stakeholder representatives of the Stakeholder Advisory Group and their end-users, activities will be tailored further, in order to strengthen the co-production process. See also the Next Steps section below.

3.3 Scoping Activities

Geographical areas of operation & services used to support decisions

In this activity, participants described the geographical areas and routes that saw the most activity among their stakeholder groups, challenges specific to these areas, and relevant information needed to support decision making. The stakeholder representatives and metservice participants were divided in two groups, with one group focusing on the Greenland context and the other on the Norwegian context. Each group was provided with various printed maps of the particular geographic regions. These maps allowed for participants to annotate important zones for operational activity and areas of uncertainty regarding any metocean conditions. The sections below summarize the insights provided and, through their often specific character, add an additional layer to the information provided in section 3.1.

Fishers and hunters: Greenland

In South Greenland drift ice can come earlier than normal and disturb lumpfish fisheries. In Disko Bay fog is an issue. However, fog forecasts are currently not available. The combination of a lot of icebergs in spring and summer with fog is very tricky. Further up north if winter ice is absent, fishing will be hit hard. For snow crab fishing, ice maps are important although recently fishers have not seen much drift ice. Furthermore, maps to capture ocean salinity would be great. Fishers observe that stock of cod are moving north, possibly due to the melting of the South Greenland ice caps, freshwater going down rivers changing ocean salinity. Overall, ice edge mapping is vital to ensuring the safety of fishing operations.

Arctic expedition cruise operators: Norway, Greenland, Canada

Main areas of operation for which decision support is most in need of improvement are Northern and Eastern Svalbard, Eastern Greenland and the Northwest Passage. Ice and ice in combination with weather conditions can affect the planned itineraries. Basically anything that can improve predictions is appreciated. Short term forecasts are more relevant for tactical decisions, while historical data (e.g. climatology-based data) are of interests for long-term strategic planning of cruises. In vessel tracking, AECO uses Long Range Identification and Tracking *BlueTraker*, and *AIS Live*.

AECO works with a booking system to avoid overcrowding of various areas and landing sites. Before the season all members submit their landing plans and receive time slots. Ships can contact each other in case of deviations. At the end of the season, AECO receives the actual itinerary as carried out. Deviations can be the result of weather conditions, the presence of polar bears, ice conditions, or special requests from local authorities regarding important habitat events (nesting of a particular species).

Ice pilots: Greenland

Reliable, consistent forecast products in the southern tip of Greenland such as Prins Christians Sund are extremely important in the cruise sector. When forecast products come in late, it is difficult to make decisions on whether to enter or not. Due to different itineraries, tight schedules and expectations of passengers there is a real need for accurate, timely information. In Eastern Greenland the management of sea ice is extremely important. For navigational safety, information on growlers is most important. Two days in advance it would be helpful to know if and where there is a large concentration of icebergs coming in. This is valuable for the shipping sector as well, as they need to know when they have to stop

service to certain areas. In terms of services used, there are several sources, but Yr.no is frequently mentioned for the ease of use of their applications.

Icebreaking services

The Northwest Passage is of interest in some sectors. Forecasts of ice concentration, thickness and multiyear ice determine the ability to go. Off the west coast of Greenland there are several seismic activities underway, extending from the ice edge into open sea. Off the east coast of Greenland geophysical exploration brings increased activity. Seismic operations require a great deal from ice management, but not many seismic companies want to engage with such logistics. However, information on iceberg conditions are very relevant for seismic operations in east Greenland and require constant ice reconnaissance, as they can force operations out of the area. Icebreakers employ dynamic route planning methods and are not driven by itineraries with dates and ports of call.

Example of a participant's annotated map

Uncertainties & the ideal service model to support decisions

In this activity, participants were first asked to envision ways in which unavailable or inaccurate metocean information may impact safety of operations in their sectors. Next, they were prompted to envision the best possible service model that would eliminate such uncertainties.

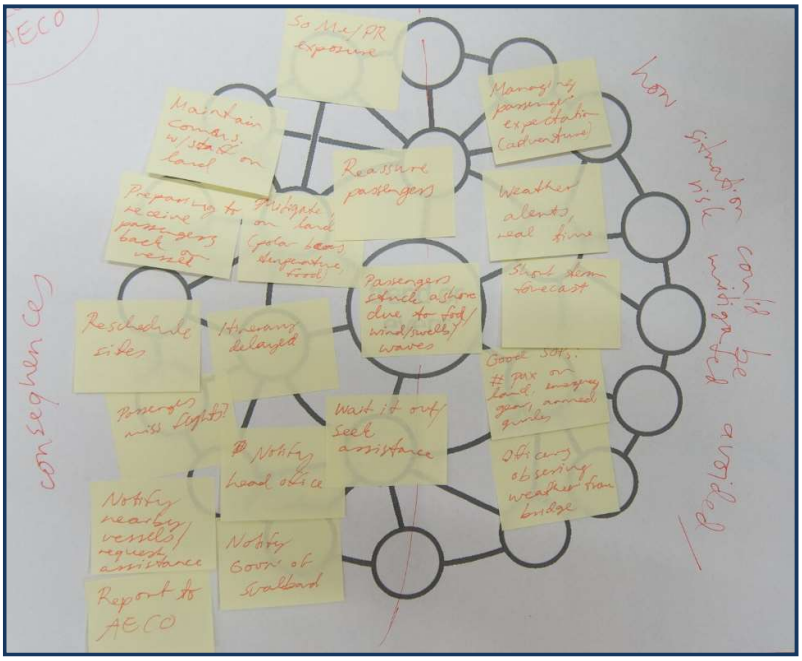
Uncertainties

Each participant was offered a *futures wheel* template to help them brainstorm in this exercise. Futures wheel is a brainstorming technique much used in foresight methodologies. It is intended as a visual aid that contains a circle (focus point) in the middle connected to other circles like a spider web. Participants choose a focus point (in this case an event), and think about possible consequences that may occur as

a result. This exercise allows participants to think through complex relationships between events and their impacts.

Participants outlined cascading physical, financial and human costs stemming from absent or inaccurate metocean information. For example, in the case of the cruise industry even minor deviations to the itinerary impact passenger satisfaction and travel logistics. It is important that weather alerts come with a reported level of (un)certainty to facilitate informed decisions to keep operations safe, while avoiding false alarms as much as possible. Serious events such as vessel-ice incidents or grounding, beyond the obvious risks of physical injuries to passengers and damage to the ship, impact the operator and (potentially) the local economy as well: the operators' reputation may be damaged, while local communities may experience a decrease in the volume of visitors if the destination is viewed risky or less attractive. Other entities such as fishing operations are not bound by the pressures of cruise itineraries, and will continue to operate in less than ideal conditions. On the other hand, they too experience pressures such as, for example, deterioration of cargo and loss of profits in case of adverse events. Accurate short-term forecasts and weather alerts are key to regular and profitable operations.

Participants from metservices expressed concern over predicting high-impact weather events that turn out to be false alarms. A particularly concerning outcome may be that future warnings may be ignored by end-users due to the loss of trust that may result. Or, in the event of forecasting ice-free conditions, predictions may inspire a false sense of safety in users and may contribute to a major emergency event. Education in interpreting forecasts and their potential impact on operations is very important.



Example of a participant's futures wheel

The ideal service model

As a final exercise, a discussion was initiated around the question of what an ideal service model would look like. Participants expressed a need for information that takes into account the variability of microclimates such as those inside fjords and areas with high orography. Overall, high resolution seemed more important than lead time of forecasts. Other notable suggestions and observations include:

- Alerts, warnings and outlooks should be provided pro-actively, instead of end-users having to seek for such information themselves;
- There is a strong preference for communication products in an email format instead of download. This is related to the bandwidth constraints mentioned earlier;
- A 'one-stop information hub' is suggested. ArcticWeb is a much-appreciated service among users of all sectors and can be seen as a promising example;
- Compatibility of formatting between products is to be considered, so that multiple sources can be superimposed and combined;
- Katabatic wind forecast products should be developed and become part of the metservice portfolio. Related to this, wind forecast along the sea ice edge is currently not sufficiently available or accurate.

Highlights

- Short-term forecast products were deemed most influential in all sectors
- Sub-seasonal products can be impactful for shipping sector in terms of knowing when to stop services (e.g. Disko Bay area)
- Confidence level for predictions would be useful information to have when evaluating alternate courses of action

Summary

During the scoping activities at the workshop SAG and MET-services participants engaged in discussions about important geographic areas where metservices are especially impactful on operations. For the cruise tourism sector, northern and eastern Svalbard, and eastern and southern Greenland are areas in need of improved forecast services. Katabatic winds and drift ice pose significant hazards to operations. A recurring theme in these discussions, especially in the Greenlandic context, emphasized the importance of appropriately scaled products produced at high enough resolutions to be salient for local users such as fishing vessel operators. Another issue for end-users is the interoperability of satellite images across platforms so as to facilitate the use of multiple images in tandem. In fact, a central hub for satellite images would be welcome by users to eliminate the time-consuming nature of searching across multiple platforms. While some products need to have a short lead time in order to fit the decision processes of end-users, other forecasts are needed on extended time scales.

4. Next Steps

Regular consultations with end-users are necessary in order to improve both the development and evaluation of forecast products and to strengthen the overall value chain of metocean communication for the European Arctic. To this end, SALIENSEAS plans to engage with end-users in a variety of ways throughout the different phases of the project. Importantly, and directly building on the workshop insights as described above, a number of key next steps are envisaged that allow for a close and comprehensive aligning of the project activities with end-user needs.

1. *Explore for each SAG represented sector, opportunities for collecting data that facilitate the mapping of mobility patterns and dominant temporal and spatial dimensions of forecast services use.*

   Activities that feed into this objective will be led by work package 1 partners and include:
   a. Exploring ways to couple routing information with parameters of observed weather/sea ice conditions and, in close collaboration with relevant metservice partners, with spatio-temporal parameters of issued monitoring and forecast products.
   b. Consulting with SAG partners how to engage with individual end-users within their sectors, in order to get insight in the temporal dynamics of metocean information use in their strategic and operational decision making.
   c. Developing an online survey to get insight in the spatio-temporal characteristics of sector specific end-user needs for metocean information, with particular attention for end-users' awareness of existing resources and their evaluations.

2. *Integrate the insights of the SAG workshop into a tentative framework of behavioral and environmental parameters, to be considered as input for simulation products using Agent-Based Modeling.*

   These activities fall under work package 2. The purpose of the modelling activities is to facilitate in-depth analysis of decision making contexts, uncertainties and areas for improvement in supporting services. Planned activities include:
   a. Data mining of suitable databases/parameters of historical routing information (e.g., AIS data), narrowed down to specific geographic contexts. Initially the geographic contexts will be based on the insights as expressed by SAG representatives during the workshop. However, on the longer term, insights gained in work package 1 will facilitate more detailed geographical contexts.
   b. Stakeholder interviews to gain insights about important sector-specific decision points in navigation routines.
   c. Development of computerized agent-based models to simulate the mobility patterns and

information use of stakeholders, and any sector-level pattern that may emerge as a result.

3. *Evaluate the suitability of existing metocean products for further development based on one-to-one user needs.*

   This objective is led by the metservices involved with work package 3. Based on the insights derived during the workshop, there will be an initial focus on real-time monitoring and short-term forecast products.

   Furthermore, and in close collaboration with project members involved in work package 1 & 2, sector specific end-user needs will be considered in the context of different areas of responsibility (i.e., for the Norwegian Meteorological Institute and for the Danish Meteorological Institute, respectively). Based on the planned follow-up consultation with SAG representatives (as part of work package 1 objectives), tailored and context specific collaborations between metservice partners and end-users will be facilitated. The form of these collaborations depends on both the sector specific needs and the availability of individual end-users. Potential formats include select focus groups and participatory workshop settings. Furthermore, such activities can be implemented both in the earlier phases of the project (focus on evaluation of existing real-time monitoring and short-term forecast products) and in later phases in order to facilitate testing and validation of any newly developed products. See also section 3.2 for details on product development.

Appendix

Contact details of stakeholder representatives and project team members.

Name	Organization	Contact details	Notes
Stakeholder representatives			
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Jan Roger Lerbukt	Hermes AS	www.hermesas.no	Not present at workshop
Klaus Harnvig	Harnvig Arctic & Maritime	www.harnvig-ice.dk	Interviewed, not present at workshop
Sampo Viheriälehto	Arctia	www.arctia.fi	
Thomas Bøggild	Greenland Pilot Service	www.gps.gl	
Tønnes Berthelsen	Association of Fishers and Hunters in Greenland (KNAPK)	www.knapk.gl	
Tor Husjord	Maritimt Forum Nord	www.maritimt-forum.no	Interviewed, not present at workshop
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