KEPLER Deliverable Report

Report on Deliverable D1.1

Deliverable name	Stakeholder Needs: Maritime Sector Needs			
Scheduled delivery	**month:**	6	**date:**	June 2019
Actual delivery	**month:**	6	**date:**	June 2019
Report type	Internal report			
Lead author	Penelope Wagner, Norwegian Meteorological Institute - Norwegian Ice Service			

Contributing authors

Ole Jakob Hegelund, Norwegian Meteorological Institute - Norwegian Ice Service
Nick Hughes, Norwegian Meteorological Institute - Norwegian Ice Service
Keld Qvistgaard, Danish Meteorological Institute, Greenland Ice Service
Jaakko Seppänen, Finnish Meteorological Institute, Finnish Ice Service
Patrick Eriksson, Finnish Meteorological Institute, Finnish Ice Service
Antti Kangas, Finnish Meteorological Institute, Finnish Ice Service
Isabella Grönfeldt, Swedish Meteorological and Hydrological Institute, Swedish Ice Service

Context of deliverable within Work Package

This deliverable represents stakeholder and end-user needs from the Maritime sector and will address specific feedback related to what the operational marine community would like to have for specific sea ice parameters, focusing on general scales (spatial and temporal) based on their activities. This report will not cover meteorological and oceanographic parameters because they have been covered for ice-free areas and are out of the scope of the user needs requested in this work package. The European Ice Services (EIS) are responsible for leading this subtask because as operational ice services, they act as a conduit between stakeholder and end-user needs for this community and research and development groups who develop value-added products to support this sector of users. Ice services directly interact with users and have an intrinsic knowledge of different scales users work and how they use sea ice information and their challenges (i.e. bandwidth, data format, information systems, data needs...etc.). Additionally, these services evaluate derived products and forecasts that are normally developed from research institutes to determine what is appropriate for operational users.

This work package collated previous and current feedback collected from stakeholders and end-users who operate in ice-encumbered areas and provide a concise and comprehensive summary

Co-funded by the Horizon 2020 programme of the European Union

of relevant user requirements expressed over approximately the last 15 years. This subtask will investigate commonalities between user needs, scales, recommendations, determine if they have changed and seek out what has already been done so far to address these needs from the research community and space agencies.

Feedback from stakeholders and end-users will be grouped in subsections summarizing pertinent 1) EC and ESA reports from 2004 - 2018, 2) workshops focusing on user needs for this community from 2018 and 3) Internal and unpublished surveys conducted by the ice services from 2017 - 2019. The recommendations from this subtask and subtask 1.2 and 13. from KEPLER work package 1 will be provided to subsequent KEPLER work packages 2-4 which will evaluate these needs regarding the current state of Copernicus services, research and satellite capabilities and develop an end-to-end roadmap based on this feedback from the operational maritime community. The following work packages will also present the possibilities with addressing some of the user needs through Copernicus and provide additional recommendations if necessary.

To clarify, Copernicus services include the Marine Environmental Service (CMEMS) and the Maritime Surveillance Service (CMS). As there is no dedicated service for the polar regions, needs for operators travelling in these extreme areas can apply to both services depending on the activity. However, to clarify from the EMSA Workshop report (Part 4: *Copernicus Maritime Surveillance Service (EMSA) Workshop*) "*CMEMS provides services which are open and available online to the general public, based on satellite, in-situ or model data, with a spatial resolution of kilometres and a range of temporal resolutions (from average daily sea ice thickness to weekly). CMS provides services to authorised users on a restricted interface based on satellite image, value added and fusion products, with a spatial resolution of 1 to 100 m, in NRT (from 30 min after satellite acquisition)*"[9].

Overview

This deliverable will provide a comprehensive summary of marine sector needs in the Antarctic, Arctic and the Baltic that have been compiled from multiple European Commission (EC) and European Space Agency (ESA) projects, internal and unpublished surveys, and stakeholder and end-user workshops. There have been parallel efforts to understand user needs in this community for approximately the last 15 years, and this report will present a consolidation of general requirements and recommendations from previous reports, relevant workshops and surveys specific to operational marine user needs. User feedback consisted of a wide range of different marine users relevant to the KEPLER project, such as marine safety, ship operators (representing various economic sectors), coastal and environment operators, fishing activities, Arctic planning and logistics, and passenger vessels. As the World Meteorological Organization (WMO) regulatory body of ice information provision services, the European Ice Services (EIS) (consisting of national ice services from Norway, Sweden, Finland, and Denmark) are in direct contact with end-users, marine and industry operators in the Arctic and Baltic who rely on varying levels of ice provision services and products to safely and efficiently operate in ice-encumbered areas. The EIS collated stakeholder and

Co-funded by the Horizon 2020 programme
of the European Union

end-user responses from the following previous EC and ESA projects: Sea Ice Downstream Services for Arctic and Antarctic Users (SIDARUS)[1]; Arctic Climate Change Economy and Society (ACCESS); Ice Services for Marine Operations (ICEMAR)[3] ; Improvement of Maritime Safety in the Baltic Sea through Enhanced Situation Awareness (ISABELIA); Sea ice monitoring for marine operation safety, climate research, environmental management and resource exploitation in Polar Regions (ICEMON); Polaris; the Joint Research Centre (JRC) User requirements for a Copernicus Polar Mission; and the EU PolarNet Gap Analysis Report for Technical and Operational Requirements of the European Polar Research Programme. Additional feedback from stakeholder workshop reports and previous internal surveys from the Norwegian Ice Service (NIS) survey results from the Association of Expedition Cruise Operators (AECO) and Space-borne observations for detecting and forecasting sea ice cover extremes (SPICES) survey results from the Arctic Shipping Forum meeting in Helsinki, April 2018. Current stakeholder and user responses were collected during the KEPLER project (2019) from the Swedish Meteorological and Hydrological Institute (SMHI). Additionally, a questionnaire was developed and provided by the Greenland Ice Service (GIS) and the International Ice Charting Working Group (IICWG) in conjunction with Nautical Institute and three marine training centers in April, 2019. Surveys in this report have not been published elsewhere.

It is important to bear in mind that responses compiled in this report are specific to the respondents. Perspectives among operational users vary due to the nature of different activities that are often performed during different times within the season and require several types of information at several different spatial and temporal scales, depending on the phase within the activity (Figure 25)[39]. Each of these sources of information detailed in this report (i.e. reports, surveys, and workshop outcomes) are collective responses from stakeholders and end-users based on targeted inquiries, thematic workshops and projects that sought out specific information depending on the aim of the information requested. Therefore, there is a bias introduced in the summary which is limited to the respondents who were willing to provide feedback, their understanding of the questions being asked and specific companies who were selected to represent operational marine industries (i.e. shipping, fishing, planning..etc.). Additionally, stakeholders and end-users can work in several different industries or economic sectors simultaneously, thus their information needs will vary depending upon their requisite roles.

The majority of this report will focus on feedback on ice information needs from the Arctic and Baltic marine user community. Ice information needs for these areas differ from those in the Antarctic for the following reasons:

- The Antarctic is more remote and although visitor numbers are increasing, these are a magnitude less than those for the Arctic.
- It has less infrastructure, that is more sparsely situated except for the region around the Antarctic Peninsula.

Co-funded by the Horizon 2020 programme of the European Union

For these reasons, the Antarctic is seen as a lower priority for satellite coverage. As its coastline lies mostly at higher latitudes than the Antarctic it is therefore a much larger area that is less easy to cover on repeat orbits.

Part 1. Areas of Interest

The Arctic environment has been showing an increase in changes with trends in weather and sea ice interannual variability [28 & 33] and is projected to open up new routes in areas that were once ice-covered year around. The advent of more economic opportunities in these regions and further instability will require a need for more accurate and comprehensive environmental monitoring information to help provide guidance to end-users as they're navigating areas that may become more unpredictable. It is critical to understand the following: how all users apply different types of data; the temporal and spatial scales they work; identify when they're required; and overall preferred data (i.e. geophysical parameters) in order to develop appropriate products. The peak time for activities in the Arctic, the Baltic and Antarctic vary greatly depending on the type of industry, location of ice covered areas surrounding coastal zones inhabited by communities, and interests in exploration and tourism.

Regional differences in activity specific for marine operations in the Arctic can be separated into the following sections:

1. *European Arctic:* East coast of Greenland to Cape Chelyuskin
2. *Canadian Arctic:* Canadian Archipelago, including the Northwest Passage
3. *Alaska:* Coast of Alaska, including the Aleutian Archipelago and the Bering Strait
4. *Russian Arctic:* Chukchi Sea to the Eastern Barents Sea, including Northern Sea Route

For the sake of brevity, this report will focus on the European Arctic and the Baltic because this is the focus for the ice service partners in KEPLER and these areas are showing the highest level of activity in the Arctic and are expected to significantly increase [28 & 35].

The European Arctic sees the greatest activity with operational vessels during the Spring and Summer seasons when the sea ice is receding and ice tends to be more dynamic. It makes it easier for non-ice reinforced vessels to travel along the marginal ice zone and ice edges because the ice can be dispersed and many ships are able to travel to areas (i.e. fjords and narrow channels) that are normally inaccessible during the freeze-up and winter seasons. Polar tourism is a prominent industry during this time due to the increased interest from the general public in climate change. Wildlife is also most active along the ice edges boundaries between stable and unstable ice conditions which naturally encourages more travel to polar regions, thus an increase in the amount of passenger vessels that will travel in ice-encumbered areas. Additionally, resource extraction and planning has been active in the Barents Sea and north-east Greenland coast in recent years, with a strong focus on reducing operational risks and safeguarding the environment. This has increased the

Co-funded by the Horizon 2020 programme
of the European Union

requirements for metocean and ice information products that exceed those currently routinely available.

Travelling through sea ice in the Baltic has been strictly regulated by national authorities for many decades, due to the smaller regional area, very busy winter navigation and need for international cooperation between many states. Environmental protection measures have been in place since 1974 under the auspices of HELCOM (Baltic Marine Environment Protection Commission, also known as the Helsinki Commission). Whilst ice conditions are forecast to become gradually less severe, the enclosed nature of the sea can lead to high interannual variability. The Baltic is characterized by a more seasonal and smaller ice area compared to the Arctic, but surrounded by established ice services. The produced ice charts are of a comparatively good quality, but due to wind and currents, the ice conditions may change rapidly and the drift ice becomes compacted against the coasts and against the fast-ice edge.

One of the main challenges in the Baltic sea is maintaining transportation routes of ice open to vessels as there is a large number of port calls to the Baltic region during the winter. This secures a demand of assistance from icebreakers depending on the vessel's power and size. The detailed sea ice information is currently based on synthetic aperture radar (SAR) imaging in order to maintain and improve the safety of Baltic sea transportation. There is a requirement from the maritime sector for more detailed ice charts or other products or other products based on SAR data, especially in the areas of deformed ice. Ice thickness data is being obtained through either from in situ observations from along the routes of the vessels, or from a small number of coastal stations.

In the Antarctic, the operational activity is mainly in part due to polar tourism along the western part in the Antarctic Peninsula, Amundsen and Bellingshausen Seas, however, is beginning to move eastward through Antarctic Sound and to the Weddell Sea and south towards the Ross Sea. Other areas for small volume, but significant traffic, are the eastern side of the Weddell Sea and the western side of the Ross Sea, into the McMurdo Sound. These two areas have a concentration of national research stations that necessitate annual resupply. User needs have been outlined by the Council of Managers of National Antarctic Program (COMNAP) in a White Paper [40] and satellite needs paper [30]. Further out, in the areas of the ice edge around the Antarctic there is fisheries activities which occasionally encourages vessels to venture into hazardous areas. PMW sea ice concentration products are used for navigation, not because of user preference, but in the lack of anything else. Users have indicated that they would prefer more SAR coverage, and the Argentinian SAOCOM mission is seeking to address this issue [Argentine Navy, pers. comm.].

Part 2. Stakeholder and End-user Resources for Feedback

The European Union (EU) Framework Program 6 and 7 (FP6 and FP7, respectively) ran from 2002-2013 and focused on various projects focusing on addressing the needs of society by connecting research and applied sciences. The FP7 (2007-2013) specifically incorporated research

Co-funded by the Horizon 2020 programme
of the European Union

with industry partners (from private and public sectors) and policy makers to facilitate formal collaborations and identify user needs from stakeholders and end-users working in the Polar and Subpolar regions, particularly those operating in cryospheric conditions. The onset of the Sentinel satellite missions in 2014 increased the Synthetic Aperture Radar (SAR) coverage, thus improved Earth Observation (EO) capabilities for operational monitoring. This created new opportunities for product developers and information providers (government and commercial) to improve the development of value-added weather and sea ice products and forecasts for the public sector. Additionally, stakeholders and end-users had access to more high spatial resolution imagery, normally reserved for government and private use, due to the considerable expense for one image. This helped to open a new era of increased potential for economic activity for operators and information providers, as well as the onset of challenges with "Big Data." In 2017 the International Maritime Organization (IMO) adopted an international set of requirements for ships travelling in sea ice encumbered areas [21 & 22]. As a result, ship operators are required to have a certain competence in using various environmental data, depending on the activity, and it is mandatory that a ships' design is suitable to travel in specified ice conditions, based on the ship's class. Therefore, the new requirements, changing environmental conditions in the Polar and Subpolar regions combined with the evolution of technology and EO computing power, has defined a userscape where the flow of data between stakeholders, end-users and intermediate users are not always successive and data needs vary depending on the type of user, the activity and the phase in which the activity is being performed (early planning stage vs. late phase) [39].

Stakeholders and end-user definitions are often used interchangeably because both groups have common interests and may work in many roles depending on the required activity. For example, stakeholders can be end-users. However, they will be separated accordingly in this project and simply defined as the following:

- ***Stakeholder:*** A person or a group interested in a product or service which may be used to develop value-added products or services to end-users.
- ***Intermediate users:*** Product developers and information providers that generate value-added products to end-users. Intermediate users normally work in research, commercial and governmental institutes, but often private and commercial operators include internal personnel. Intermediate users develop products for, but not limited to, research, operations, planning and logistics purposes.
- ***End-users:*** A person or group that uses a product or service.

From the EU FP7 and the current Horizon2020 projects, identifying stakeholder needs has been at the forefront of the EC and ESA interest, particularly with EO missions. Previous and current EC and ESA projects have clearly identified data, satellite gaps and needs for the marine community based on surveys and workshops more than the past ~10 years. For this reason, it is necessary to acknowledge the current state of user fatigue from participating in multiple surveys, meetings, workshops and other dialogue over the course of this time. This has been expressed by the

Co-funded by the Horizon 2020 programme of the European Union

stakeholder and end-user community over the last few years, particularly within ongoing projects (EU-Polarnet, Salienseas and KEPLER) when trying to inquire about user needs. The stakeholder and end-user community also stated that they were unclear about the long-term goals of these projects, how their feedback has been communicated to the EC, ESA and research community to improve products and overall plan for dissemination to the general public.

To address these concerns, in this deliverable we will take advantage of the work, regarding user feedback, that has already been undertaken in previous projects and combine them with updated information on stakeholder and end-user needs. Information will be collated from relevant EC and ESA reports (deliverables) and internal surveys (unpublished) over the past decade and user feedback from previous workshops to find commonalities between different user needs pertaining to the operational marine community. Additionally, this will include current feedback from surveys conducted within the timeframe of KEPLER.

The following sections will provide further detail on each of these resources and summarized to provide guidance on user needs and gaps in knowledge for subsequent work packages in KEPLER.

Part 3. EC and ESA Reports Assessments

This section will provide a concise summary of outcomes from EC and ESA projects specifically focused on evaluating stakeholder and user-needs from ICEMON (2004) to current ongoing projects, such as, EU-PolarNet. From this we highlight commonalities between user responses in order to present a correlation of user needs from different sectors and how they have either evolved or stayed the same over time given the improvements of new technologies and satellite sensors. Many projects were active simultaneously and collaborated with one another in order to assess needs by relying on the same survey or mechanisms to obtain user feedback, however, targeted different user groups. Some challenges in evaluating all user reports to the same standard were that results from each project may have been weighed differently due to the project criteria. Additionally, while some projects expressed the use of existing data, others may have only included information on desired parameters. However, there are prevailing user-needs that we have been found and not yet been addressed or resolved with the current state of satellite coverage. The following sections will review previous reports in chronological order and provide a brief synopsis according to the targeted user group, existing and desired parameters and main recommendations from each project and are illustrated in Tables 6, 7 & 13.

ICEMON and Northern View Portfolio (2004)

The Northern View and ICEMON projects were polar environment services that specialized in These two projects specifically focused on defining and evaluating user needs on EO for climate/weather, environmental monitoring and marine transport and safety for the polar regions. This project was commissioned by ESA (ESA ESRIN, ICEMON [Contract No. 17060/03/I-IW] and Northern View [Contract no. R-04-059-281])[16 - 19] and were of interest from the international, regional, and

Co-funded by the Horizon 2020 programme
of the European Union

national policy organizations. The current state of satellites used for operations during this time were primarily visible and Near Infrared (VNIR), scatterometer (Quikscat), sparse coverage and limited availability of SAR and passive microwave (PMW), to be used to augment areas lacking the aforementioned coverage.

ICEMON:

Icemon targeted the marine community for the Arctic and Baltic for the following sectors:

- Ice Navigation and transport, maritime authority
- Ship design
- Environmental monitoring
- Weather and ice services
- Climate monitoring and research

ICEMON Desired parameters:

A priority ranking was established from high(1) to low(3) for all users on how they view the importance of specific sea ice parameters and features for their activities. Despite a wide range of users surveyed in this project, an overall consensus deemed the following to be the most important: Ice concentration (100m - 5km); sea ice edge (100m - 1km); sea Ice type (50m - 5km); sea Ice drift (1km); floe size (10- 100m); deformation information (10m - 1km); and first-year ice thickness and multi-year ridges (10m - 5km). The spatial and temporal resolution range for all parameters was broad because the survey combined all user needs. From the outcome of this survey, it was not clear how different users require various scales of information, however, it did provide an insight to what types of satellite information they relied upon to obtain the desired sea ice parameters. Additionally, it was useful to get a glimpse of the changes these individual sectors were preparing for in the subsequent years.

From the outcome of this project , the greatest challenge stated for users during this time as the following:

- Interpreting satellite images and the ability to receive high-res images to ships
- Information from optical that is operational due to clouds and illumination
- SAR ability to detect important features such as ice concentration, leads/polynyas, ice type, ice drift, and ice deformation and ridging in temperatures above 0°C due to snow melt
- Current ice charts that combine PMW and Advanced Very High Resolution Radiometer (AVHRR) are too coarse to be useful for navigation.
- PMW cannot detect features important for maritime operations such as ice edge, ice concentration, ice drift and polynyas
- For climate research, there is a need better reference data, products and statistics.

Co-funded by the Horizon 2020 programme
of the European Union

Northern View Service

Northern View, currently PolarView, is a service provision agency in monitoring glacier, snow, icebergs detection and risk analysis, ice edge monitoring, and oil spill detection. Northern View assessed overall needs from:

- Local communities working in the Arctic
- Operational marine community for ship and iceberg detection
- Indigenous communities that work along the ice edge and on the fast ice

The users were not familiar with the satellite data prior to this project, thus their feedback did not specify parameters in satellites that users relied upon but provided the following assessments:

- *For icebergs:* SAR satellites compliment iceberg detection reconnaissance between flights because they can provide iceberg distribution and location.
- *For ice edge monitoring:* SAR provides hunters and operators more information about the ice and is a complementary source to AVHRR. The following responses state:
    - Provides a higher frequency of products during peak periods
    - Assists in determining conditions such as wind direction, ice thickness, areas of ridging and where floes are breaking up
    - Potential areas of leads and ice conditions in the last 12 hours to assist where and how they should plan to go in order to get to the floe edge.
    - Canadian park wardens can effectively use this information for safety in navigation
    - Opinion that SAR assists in coastal erosion models

The outcomes from both reports presented an overwhelming demand for high-resolution imagery spatial resolution of meter scale that is provided with the use of radar altimetry, SAR, and visible satellite sensors, with the added desire for more frequent coverage.

ACCESS, SIDARUS and ICEMAR (2010-2012)

ACCESS[1], SIDARUS[34] and Copernicus pilot program for ice service for maritime operations (ICEMAR) were part of the EU FP7 Program and addressed how impacts from climate change affected operations and communities working in the Arctic and the Baltic. SIDARUS and ICEMAR were responsible for developing sea ice downstream services for polar users and stakeholders, based on user feedback, that will improve marine safety and environmental monitoring for operations and climate research. ICEMAR was specifically focused on developing a service for the Global Monitoring for Environment and Security (GMES) maritime operations that included a specific sea ice information delivery system that transmits ice information from ice services to ships operating in ice-encumbered waters in the Arctic and the Baltic. The ACCESS project was tasked to evaluate the current state of monitoring and examine how sectors such as transportation, fisheries,

Co-funded by the Horizon 2020 programme of the European Union

aquaculture, livelihood, energy extraction and development and governance was affected by the changing climate. In 2011 a questionnaire was developed for the three parallel-running EC projects, SIDARUS, ACCESS, and ICEMAR. Each project contributed a set of questions relative to its perceived user requirements. The questionnaire was sent out initially through SIDARUS, and several months later through ACCESS. As a result the number of users accessed for ACCESS was slightly higher than that for SIDARUS. The SIDARUS project survey results also included a summarized feedback from the previous ESA project for reference (not included in their results), Sea Ice Monitoring in the Polar Regions (ICEMON) and Northern View. Results for ACCESS and SIDARUS were released in July 2011 and February 2012, respectively [1 & 34].

Subsequent to these activities, the questionnaire was further used by the Australian Bureau of Meteorology (BOM) to assess Antarctic logistical user requirements and reported at the Scientific Committee for Antarctic Research (SCAR) Council of Managers of National Antarctic Program (COMNAP) *Sea Ice Challenges Workshop* meeting in Hobart, Tasmania in 12-13 May 2015 and 16th IICWG meeting [2, 3 & 32].

EC ACCESS, SIDARUS and ICEMAR:

The SIDARUS, ACCESS, and ICEMAR report summary for sea ice, weather, and oceanographic parameters had questions aimed at different data provision needs and user sectors (Table 1).

Table 1. EC projects SIDARUS, ACCESS and ICEMAR distinction between user sectors and project focus

Project	User sectors	Focus
SIDARUS	Marine Safety, Marine and Coastal Environment Research, and Climate and Seasonal Forecasting,	Current and New products for situational awareness, marine safety and climate and forecasting
ACCESS	Fishing, Tourism, Air Logistics, Shipping, Research and Oil and Gas	Long-range forecasting and planning requirements
ICEMAR	Atmosphere and Marine GMES Pilot services	Demonstration on how data format and transmission for information retrieval at high latitudes influences downstream services

Co-funded by the Horizon 2020 programme of the European Union

In all cases the users were a combination of researchers, information providers and end-users. In some cases multiple responses from the same organisation were received, providing an insight into the requirements at different levels of that organisation. Results from ACCESS and SIDARUS were combined for this report to show the most important sea ice parameters, information requirements, and data format requirements (Figures 1-3).

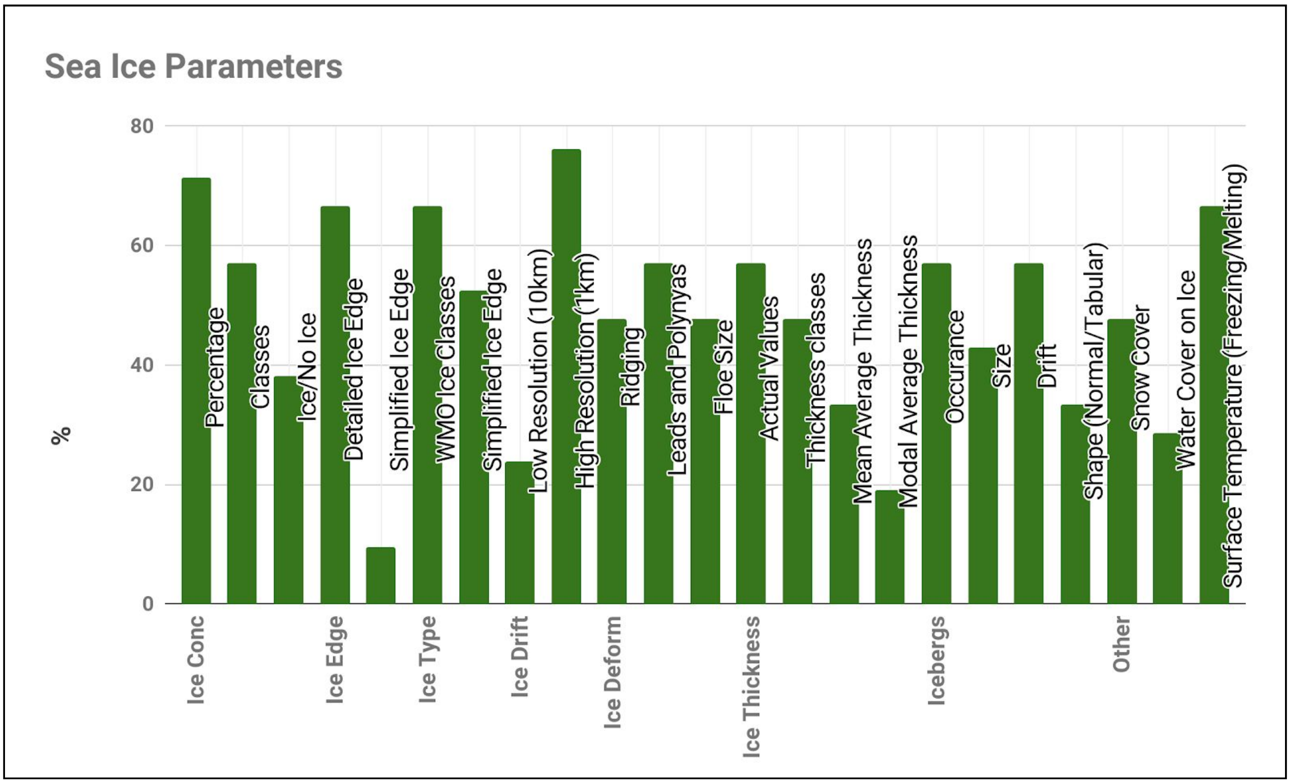


Figure 1. Requirement for sea ice parameters from ACCESS and SIDARUS

Co-funded by the Horizon 2020 programme
of the European Union

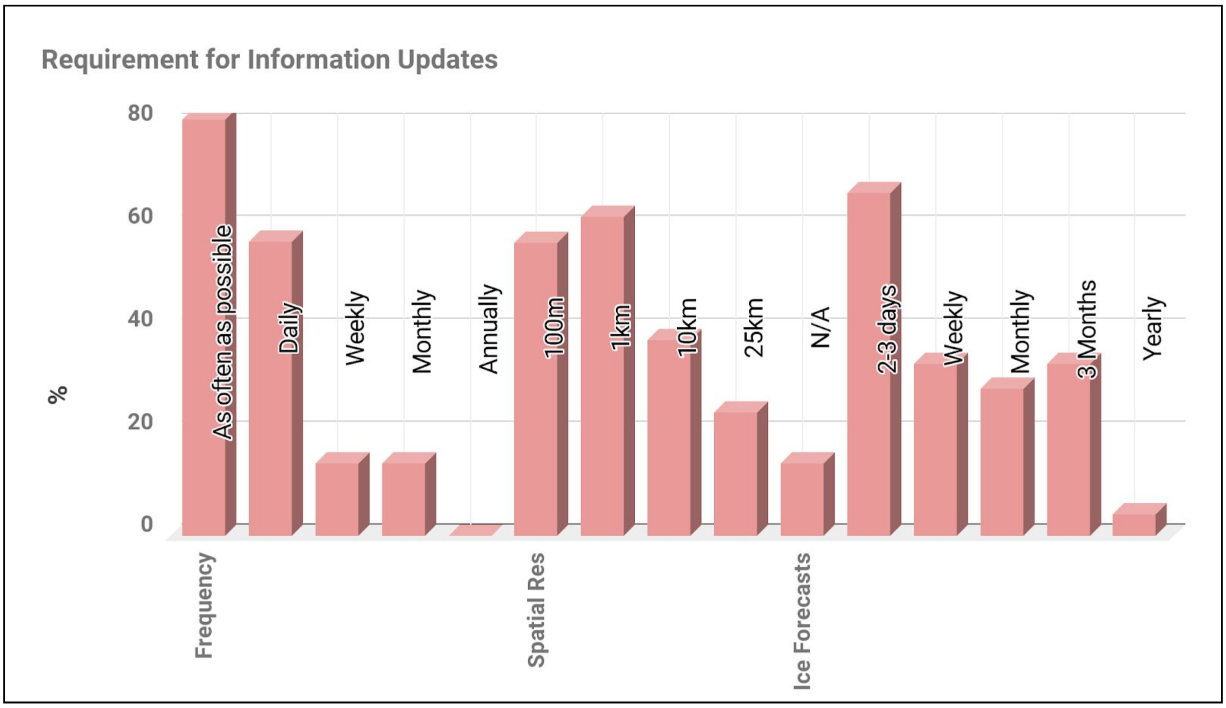


Figure 2. Requirement for information updates from ACCESS and SIDARUS

Updates for information provision were preferred to be as often as possible, followed by daily information as a secondary choice. The responses for spatial scale information was at sub-kilometer scale.

Co-funded by the Horizon 2020 programme of the European Union

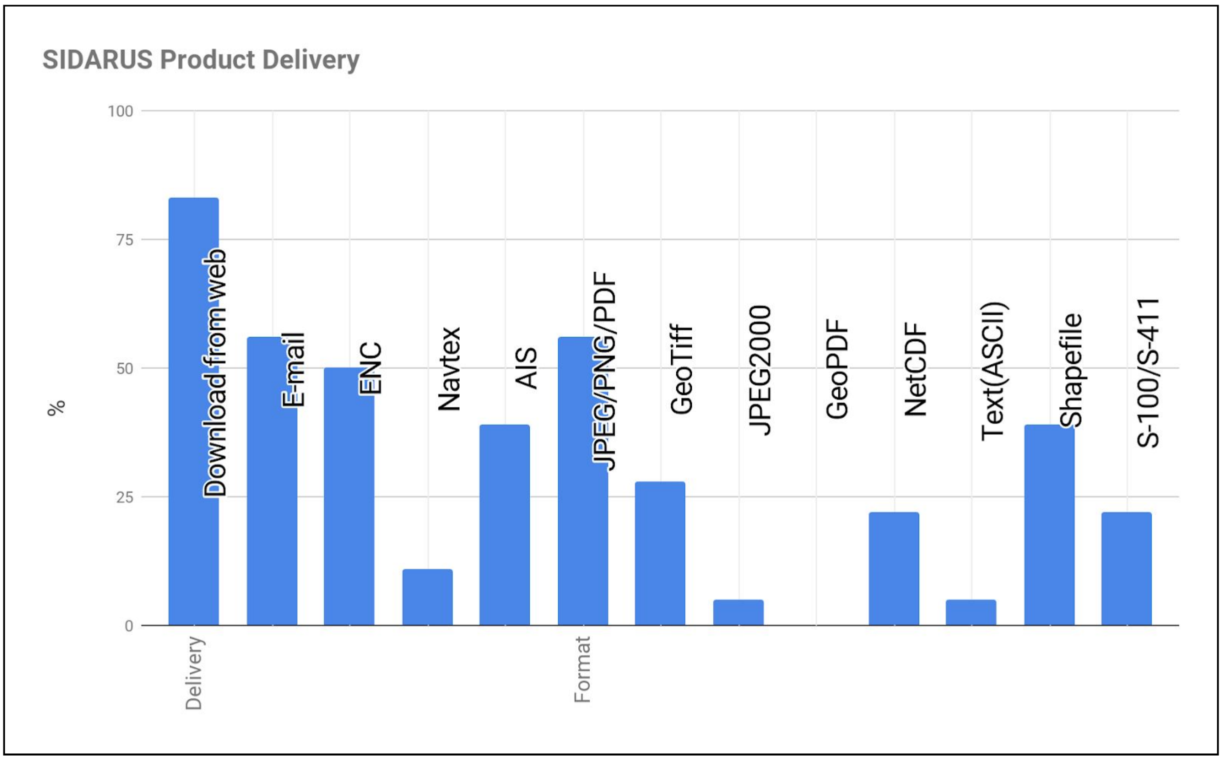


Figure 3. Data format requirements responses from SIDARUS

The overall sea ice parameters required for the Arctic and Baltic were specified to be SAR-based products for habitat studies (environmental monitoring and research). Main sea ice parameter requirements for marine operators are ice concentration, a detailed and simplified ice edge, information included about the WMO ice classes [42], high spatial resolution (<1km) information and information on surface temperature in order to assess whether the ice is undergoing a freeze or melt stage (also in Table 6). Desired parameters needed for the Baltic area were focused more on drift ice in order to keep transportation routes through ice open to merchant vessels, more detailed ice information and ice charts and ice thickness data at similar requirements to that of the Arctic.

Main recommendations for ACCESS, SIDARUS and ICEMAR:

A list of the main recommendations from these projects can be found in Table 7. To summarize, for both the Arctic and the Baltic, mutual recommendations highlight the need for high spatial and temporal resolution sea ice information and for forecasts (approx. 2-3 days) which includes data assimilation from SAR, optical and other high-resolution instruments to optimize transit routes through the ice field. These models should also be made more frequently where users can plot ice information based on a combination of assimilated sea ice monitoring information and model forecasts for a particular time. The transmission of data in a standard format that users can easily ingest were considered to be electronic navigational chart (ENC's), email, automatic identification systems (AIS), and navigational telex (Navtex).

Co-funded by the Horizon 2020 programme
of the European Union

ISABELIA (2013)

The Improvement of Maritime Safety in the Baltic Sea through Enhanced Situational Awareness (ISABELIA) project was an ESA Advanced Research in Telecommunications Systems (ARTES) project aimed to evaluate user requirements for maritime safety specific to the operators in Baltic [23 & 24]. This project focused on situational awareness scenarios that incorporated multiple seasonal case studies, environmental conditions and types of end-users specific to the Baltic (Table 2):

- National Maritime Authority
- Ship operators for Search and Rescue (SaR), Icebreakers, and Marine Service
- Ice Services
- International Organizations

Table 2: Scenarios for Maritime Shipping in the Baltic (*from ISABELIA, 2013*)

Scenarios		
Number	Name	Season
Scenario 1	Rough Sea	Open Water Season
Scenario 2	Collision risk	Open Water Season/Ice Season
Scenario 3	Travel time	Ice Season
Scenario 4	Ship stuck in ice	Ice Season
Scenario 5	Accident in ice	Ice Season
Scenario 6	Route Planning	Ice Season
Scenario 7	Vessel travelling from A to B through the Baltic Sea	Open Water Season/Ice Season

Based on the needs of the target groups, four concepts were created: the Dynamic ice risk map service, the Met/Ocean risk map service for water conditions, the Collision risk service and the Grounding risk service.

Desired parameters for ISABELIA:

All ships, shipping operators and national maritime authorities deemed information on ice drift and ice compression to be critical due to the potential damage to the ship and risk of getting stuck in the

Co-funded by the Horizon 2020 programme of the European Union

ice. Additionally, up-to-date trafficability information (i.e. estimated ship speed) was considered important by these users/stakeholders (Table 6).

Main Recommendations for ISABELIA:

It was mentioned that although ship operators have knowledge of their ships' behaviour in open water, they sometimes do not have a good understanding of their capabilities when travelling through ice-encumbered areas. For areas travelling in open water, the most important needs were related to having better ocean state forecasts (waves, wave directions, effects in own ship) to be able to predict and avoid possible dangerous situations. This includes improved grounding warning and collision warning information that was preferred among ship operators and International organizations. Additionally, the high activity of operating ships in the Baltic (over the Arctic) also increases their need to have improved information on the advection of oil in sea ice covered and open water areas. From ship and logistics operators, the need for improved information to be used for stationary vessels risk analysis was not considered to be of high importance (Table 7).

ESA POLARIS Report (2016):

The ESA Polaris report was led by PolarView and consists of a comprehensive compilation of reports, consultations and workshops from the user community highlighting environmental information requirements for the polar regions which included 50 organizations that were consulted and consisted of the following industries [10 and 11]:

Table 3. ESA Polaris Report user groups and company names

User Groups	Name
Scientific research groups (Earth science and climate research) and Data Centers	AWI, AAD, BAS, DTU, Finnish Geospatial Research Institute, NASA Carbon Cycle and Ecosystems Office/SSAI, NSIDC, NPI, Polar Geospatial Center, Research Data Alliance, Stockholm University
Polar Tourism	AECO, IAATO
Local Communities	ArcticNet, Inuit Circumpolar Council-Alaska, Asiaq Greenland Survey
Meteorological Institutes	UK Met Office, DMI, MET Norway, ZAMG

Co-funded by the Horizon 2020 programme of the European Union

Ice Operations and Ice Services	Canadian Coast Guard, AARI, DMI, IICWG, NIS
International Programs	AMAP, CAFF, CCAMLR, CCU, ARCUS, ASP, Antarctic and Southern Ocean Coalition, SCAR, SOOS, SAON, WCRP, APECS, CCIN
Energy, Oil and Gas	Chevron Arctic Centre, Danish Energy Agency, Shell Global
Governmental organizations, marine safety and military	Finnish Ministry of Defence, EMSA
Shipping, Logistics and Arctic Planning	Canadian Shipping Company, Aker Arctic Technology Inc., The Nautical Institute
Fishing and Biological monitoring	Coalition of Legal Toothfish Operators, European Fisheries Control Agency, Polar Bears International
Terrestrial monitoring	INTERACT
Commercial and Third-Party Sea Ice Monitoring Services	C-CORE

User community environmental information requirements were identified, consolidated and linked with ESA EO high-level mission requirements systems covering the Polar Regions. Additionally, this report provided gaps in satellite monitoring needs for specific parameters and evaluated new integrated information services

Desired parameters for the ESA POLARIS Report

Needs specific to the operational marine community primarily focused on specific sea ice parameters and the spatial and temporal resolutions required that are summarized in comparison with other previous needs described in other reports in this KEPLER report D1.1. However, the Polaris report also provided detailed descriptions on the significance of requested parameters for ship operators (Table 4).

Co-funded by the Horizon 2020 programme of the European Union

Table 4. ESA Polaris Report description on the importance of sea ice parameters for marine domain awareness

KEPLER Report similarities	Parameters	Description
Similar Parameters	Sea Ice Extent	Inadequate discrimination between first year and multi-year ice; integration with ice concentration information required; lack of product quality information
	Sea Ice Drift	Need near real-time service delivery; lack of product quality information
	Snow Depth	Require near real-time service delivery; insufficient quality with current sensor and algorithm combinations; integration with ice thickness information needed
	Structure/Age	Require near real-time service delivery; lack of nested products to satisfy large to small scale applications; lack of product quality information
	Thickness	Require near real-time service delivery; lack of product quality information
	Icebergs	• Lack of frequent image acquisitions for Calving and Drift • Need NRT service delivery • Lack of product quality information • Detailed sea ice and iceberg classification at higher temporal resolution than

Co-funded by the Horizon 2020 programme of the European Union

		currently available
Additional Parameters	Freeze/Thaw	Lack of necessary sensor frequencies
	Surface State/Albedo	Inadequate resolution and ability to detect surface detail and subsurface layers
	Rheology	Lack of product quality information

Main Recommendations for ESA Polaris Report:

From the summary report [10] a description of typical uses of sea ice information for science and operations stated the following:

Operational users require information to support their activities in weather forecasting, engineering design, operational planning, navigation, emergency response, and environmental impact analyses. A statement regarding resolution and validation stated "*In general, operational users require higher spatial and temporal resolution compared to science users. While they may user historical data for strategic planning and design, and forecasts for tactical planning, they often require current information as soon as possible after it is required.*"

Science users require information to understand and model natural processes. This specifically states "*They require data over larger areas and longer-time scales than operational users, although data requirements vary considerably depending on the subject of enquiry and the requirements of some science users are similar to operational users.* "

The main recommendations focused on information system gaps and sensor needs. Regarding information system gaps, the primary suggestions were summarized with improved data integration, information products (i.e. standard format), information discovery (i.e. accessibility and dissemination and information on data quality), information access (i.e. low cost and not bandwidth intensive), training (i.e. provision of training on new sources of information for users), and data platforms (i.e. available tools for integration, access and training for users).

Regarding product quality, the ESA Polaris report D2.1: Gaps and Impact Analysis ([11] *pg. 20*) highlighted the need from both the research and operations communities for improved product quality. The ESA Polaris report acknowledged the various available sources of EO-based products and

Co-funded by the Horizon 2020 programme of the European Union

services for and that users can work both in research and operations, simultaneously. However, for the marine operations community and cited from the , it stated that "*the current state of environmental monitoring capabilities are not yet adequate for many of the operational requirements, which are often related to NRT, high-resolution information (i.e. High resolution ice concentration and thickness data that are vital for tactical risk assessment and decision-making).*" Additionally, regarding the lack of product quality it also stated that "*it is relatively easy to generate automated products from satellite data that a majority of users will accept at face value, but they may never have been validated, their accuracy may be unknown, and it is unclear what extent the services are offered to a larger community or are targeted towards only a smaller group of users.*" This means that it is unclear if current automated products are developed for marine operational users or downstream services. An example using passive microwave ice concentration products were used and stated "*They do not identify ice in concentrations less than 15-20%, which are the locations in ice where most of the ships are operating.*"

Regarding sensor needs for marine operations, an overall consensus of the use of SAR instrumentation (Dual and Tri-Band SAR [2+ SAR frequencies]) was preferred to fulfill large parts of the requirements in terms of ice sheets, iceberg, river/lake ice and snow and had the highest impact factor across categories related to economy, safety, environment, society and knowledge, while optical was considered best for atmospheric and land parameters ([9] *pg. 23*). The use of SAR and active microwave sensors were specifically stated to help with the ice and snow boundary conditions. However, the use of historical data and forecasts were considered useful for strategic planning and design. Additionally, SAR interferometry combined with passive companion for Sentinel-1 was suggested to provide a good measurement of surface elevation and motion. Alternatively, for iceberg and ship detection using SAR an overall need to combine AIS data with SAR, as well as stereo optical sensors and radar altimetry were considered to be useful ([11]*pg. 20-21*).

EU JRC Technical Reports: User Requirements for a Copernicus Polar Mission: Polar Expert Group Report(2017)

The JRC Technical Report for User Requirements for a Copernicus Polar Mission: Polar Expert Group (CPEG) Report was initiated by the Joint Communication by the European Commission and the High Representative of the Union for Foreign Affairs and Security Policy issued in April 2016. Under the integrated European Union policy for the Arctic three priority areas focusing on 'Climate Change and Safeguarding the Arctic Environment,' 'Sustainable Development in and around the Arctic,' and 'the Blue economy' and 'International cooperation on Arctic Issues,' were featured. Thus, the CPEG group was selected to act as the basis of core user requirements for future Polar and Snow monitoring missions to include a focus on the needs for future EO, navigation and communication satellites in the Arctic and Sub-Polar Seas. This group was to assess the already existing Copernicus thematic services for monitoring the atmosphere, marine environment (research and operations), terrestrial, climate, emergency management and security, and identify new requirements from key Arctic user communities. These requirements were reviewed at a polar and snow workshop held in June 2016

Co-funded by the Horizon 2020 programme
of the European Union

and subsequent reports, Phase 1 Report -User Requirements [7] and Priorities and Phase 2 Report -High-level mission requirements [8] were created to form the basis of this section on user requirements submitted to the EC for Copernicus. Existing requirements for user feedback were submitted by the CPEG members as well as, ice services, meteorology and hydrology agencies and the following reports:

- ESA Polaris study reports from Polar View project (April 2016)[10]
- The Integrated Global Observing Strategy (IGOS) cryosphere 2007 report[25]
- Copernicus maritime surveillance service user workshop report by European Maritime Safety Agency (EMSA) (December 2016)[9]
- Polar Space Task Group (PSTG) on 'Strategic plan: 2015-2018' (November 2015)[29]
- DG Research and Innovation/ESA Climate Task Force report (November 2016) [6]
- Copernicus Marine Environment Monitoring Service (CMEMS) 2016 Position Paper on polar and snow cover applications [5]

Desired parameters and requirements for the Copernicus Polar Expert Group report:

Desired parameters from the Phase 1 CPEG report on user requirements presented the highest priority to be floating-ice parameters including sea ice extent, concentration, thickness, type, drift velocity, thin sea-ice distribution, iceberg detection and volume change because they are key to operational services (navigation, marine operations) as well as to climate modelling. The operational component of the user feedback was considered to be of great importance when evaluating the mission concept. The desired parameters and parameters based on spatial scale requirements in comparison to other reports in this KEPLER report D1.1 can be found in Table 6.

Main Recommendations for the CPEG report :

Parameter performance requirements were separated in themes and domains Figure 4 [7].

Co-funded by the Horizon 2020 programme of the European Union

Themes (THM)		Domains (DOM)	
AT	atmosphere	ME	meteorology
OC	ocean	CL	climatology
FW	surface water (freshwater)	HY	hydrology
SN	snow (seasonal)	OC	oceanography
GL	glaciers, caps	EC	ecology
IS	ice sheets	HZ	natural and technical hazards
SI	sea ice/iceberg	EM	emergency response (incl. search and
LA	land surface and vegetation	EN	energy
PF	permafrost and soils	TR	transport/navigation
		OI	other infrastructure
		SE	security
		GEN	general — all domains

Figure 4. JRC Technical Reports: User Requirements for a Copernicus Polar Mission, Phase 1 report, themes and domains from Table 7 [7].

The following themes specific for sea ice/iceberg parameters are assembled in Table 5 and focusing on needs for the maritime operational (i.e. navigation, transportation, security, emergency response) and research (i.e. meteorology, climatology, hydrology, and oceanography) domains. This table includes only selected relevant information and specifications (i.e. spatial and temporal resolution, lead time, and accuracy) for the KEPLER project in order to provide insight into recommendations for work packages 2-5. The full table can be found in: [7] *Tables 9 and 11-15*.

Table 5. Specification table for sea ice parameters from the Copernicus PEG Report listing spatial and temporal resolution where T= minimum and G= optimum goal.

Domain	Parameter	Spatial Resolution	Temporal Resolution	Lead time	Accuracy
OC	Sea ice Fraction	T: 5 km	6hr	--	5%
CL		T: 10 km G: 1 km	1dy	--	1%
TR		T: 20 m G: 2 m	T:1 dy G: 12 hr	24hr	5%
OC	Sea ice thickness (think and thick) and freeboard	< 5km	1dy	--	0.1
ME		T: 3km G: 1km	T: 1dy G: 6hr	--	horizontal: T: 10 %, G: 5 %

Co-funded by the Horizon 2020 programme of the European Union

					vertical: T: 0.5 m G: for thickness > 0.5 m: 0.5 for thickness < 0.5 m: 0.1 m
TR		T: 20m G: 2m	T: 2 dy G: 1 dy	24 hr	T: 0.1 0.02
TR		25 m	T: 24 hr G: 12 hr	--	vertical: T: 0.5 m, G: 0.1 m
CL	Thin Sea ice	T: 10km G: 1km	1dy	--	5%
OC		T: 5km	T: 6 hr	--	5%
TR		T:20m G:20m	T: 2 dy G: 1 dy	24 hr	T: 0.03 G:0.01
TR	Ice Type	T: 20m G: 2m	T: 2 dy G: 1 dy	24 hr	T: 85%, G: 95%
TR		T: 40m G: 25m	T: 1 dy G: 6 hr	--	T: 85%, G: 95%
ME,OC		T: 3km G: 1km	T: 1 dy G: 12 hr	1	T: 85%, G: 95%
CL,ME	Iceberg Detection	T: 10km G: 5km	T: 24hr G: 12hr	--	1%
OC		T: 25m G: 10m	T: 2dy G: 1dy	--	T: 85%, G: 95%
TR		T: 20m G: 2m	T: 2dy G: 1dy	24 hr	T: 85%, G: 95%
TR		G: 25m, marginal ice zone G: 50m, inner ice zone	T: 24hr G: 6hr to capture diurnal and tide effects	--	T: 85%, G: 95%
OC	Iceberg Drift	10km	3hr	--	--
OC	Snow depth and density	< 5km	1 dy	--	
CL		1-0km	1dy	--	0,01m
TR		25m	T: 1 dy	--	0,1m

Co-funded by the Horizon 2020 programme of the European Union

			G: 12 hr		
OC, ME		T: 3km G: 1km	T: 12 hr G: 6 hr	--	horizontal: T: 10 %, G: 5 % vertical: T: 0.1 m
OC		T: 10km G: 1km	30 dy	--	T: 0.05 m G: 0.02 m
OC	Ice Surface Temperature	T: 5km	6 hr	--	0.5 K
TR		T: 150m G: 50m	T: 2dy G: 1 dy	24hr	T: 1k G: 0.25K

Additionally, desired parameters, parameters based on spatial scale requirements and main recommendations in comparison to other reports in this KEPLER report D1.1 can be found in Table 7.

Clear observations should be highlighted:

- **Need for improved spatial and temporal scales:** User feedback clearly shows that all domains have a desire and need for improved spatial and temporal resolutions within their product performance. However, the difference of resolution needs between the operational and research domains vary where operational needs are all on the sub-kilometer scale and research, climatology, oceanography and meteorology, greater than 1 kilometer scale is required for models and forecasts.
- ***For research:*** A clear recommendation from the report [7] states "*There is a real worry about the long-term continuity of space observations from European and non-European satellite missions (e.g. AMSR-2). Strong and close coordination between space agencies (through different existing mechanisms e.g. the Committee on Earth Observation Satellites (CEOS), the Group on Earth Observations and its Global Earth Observation System of Systems (GEO/GEOSS) and the WMO are to tackle these issues and ensure that at least an optimum number of dedicated space missions are firmly planned (concept of virtual constellations discussed within CEOS/GEO partners).*"

This statement is correct from the feedback reflected in the research community

- ***For Operations:*** However, from [8] the first priority satellite recommendations it states "*The expert group recommends retaining as first priority the proposed imaging passive microwave solution which complies with the following:*
  - *Meets the joint EU communication high priorities,* ***in particular the provision of operational sea-ice services which are of prime importance for navigation safety in the Arctic and adjacent seas with at least daily revisits in polar regions.***

Co-funded by the Horizon 2020 programme of the European Union

- *Offers the best solution from technical, scientific and operational viewpoints (operational daily observations of polar regions in almost all weather conditions, day and night)."*

From the feedback in Table 5 of this report and Tables 9 and 11-15 in the original report [7], these recommendations for the use of PMW for navigation DO NOT agree with feedback from the navigation and marine operations community and is highly misrepresenting the needs of this sector and their use of satellite need.

  - **Need for provision of uncertainty estimates**
  - **Development of new product development:** The need for new products derived from new/improved space observations should be analysed, taking into account the experience gained since operational Copernicus services have been delivered to users (importance of regular users feedback, User Forum).

EU PolarNet Gap Analysis for Technical and Operational Requirements and Recommendations fro Improved Coordination (2018)

The EU-PolarNet is a EU Horizon2020 project established to coordinate activities between EU member polar research organizations focusing on developing networks to share knowledge and resources for stakeholder and scientific needs in the polar regions. Additionally, they aim to identify short and long-term needs in order to facilitate trans-disciplinary collaboration and sustaining co-operation between various relevant groups. Where the EU-Polarnet focuses on the general science and end-user needs in scientific developments from H2020 projects, KEPLER aims to identify end-user needs for Copernicus program recommendations. Additionally, there are projects to support Copernicus in H2020 but on a greater scale, Copernicus also includes satellite missions needed for a global monitoring programs. The EU-PolarNet completed a gap analysis [11] that focused on the technical, operational and future monitoring requirements based on several recent publications and reference documents [4, 7, 8, 10 & 31]. Similar to the KEPLER aim, this project agreed that there was no need to repeat efforts to conduct additional user surveys involving direct consultation with users for user satellite requirements and polar parameter needs because recent studies are sufficient. User needs from this report for the marine navigation community referenced the needs stated in the ESA Polaris report [10 & 11] also in this report (See Part 1: *ESA Polaris Report* in this report) we will not repeat the description of parameters needed in this section but were included in Tables 6. Also, though evaluations from EU-Polarnet were more focused on technical requirements and specific satellite applications which is out of the scope of the KEPLER work package 1 (i.e. focusing on user needs), they did provide an insight into the challenges and recommendations that will affect the quality of information provided to address end-user needs and also presented in Table 7.

Co-funded by the Horizon 2020 programme of the European Union

Existing Requirements from the EU-PolarNet:

The overall outcome for end-users working specifically in operational navigation clearly established the need for up-to-date information on current sea ice and weather conditions, primarily derived from satellite data. Regarding sea ice and iceberg parameters, SAR was stated as being especially effective for monitoring features on the required scale and also due to prevailing cloud cover and lack of illumination during the winter. Additionally, the analysis of historical data are useful for route planning for ship navigation. Alternatively, users working with emergency response (i.e. joint rescue coordination centers, maritime rescue coordination centers and aeronautical rescue) required additional information such as wind speed and direction, sea state including wave height, near-real time (NRT) surface conditions and routes for responding assets, and information on advection of oil in the case of an oil spill or any other environmental hazard.

Main Recommendations from the EU-PolarNet:

General recommendations specified some fundamental challenges which were similar and also expressed by end-users in the Arctic Frontiers Workshop outcomes of this report (See Part 4: *Arctic Frontiers 2018: Stakeholder Sea Ice Forecast Workshop and SALIENSEAS Stakeholder Advisory Group Workshop* of this report*)*

- There is a need for improved and ongoing communication between space agencies and the polar community to develop engagement plans with ESA and EC space and data programs to represent user requirements where possible.
- The polar community needs to coordinate with national space agencies and be integrated into satellite planning efforts.
- Relevant polar operators and scientists should be included in advisory and expert groups for space activities to represent community needs.
- National polar operators should develop engagement plans with representatives to the ESA and EC space programs to represent their requirements where possible
- Regarding risk management, there is a need for tracking and mitigating risks requires good information about likelihood and occurrence and severity, thus needs information on the scales that navigators operate.
- The increasing volume of satellite data and derived products developed for the user community requires:
  - Improved data integration
  - Access to derived and additional products by non-expert users rather than raw satellite data available over multiple sites and organizations
  - Development of products in a standard format useful to end-users
  - Availability of education and training on the use of EO information products
  - Improved high performance computing for better data assimilation of information into products for navigation

Co-funded by the Horizon 2020 programme
of the European Union

A solution to investigate a better use of improved data platforms and cloud-based infrastructures may allow for integrated sources of multiple products that would be easily accessible for users.

Summary of EC and ESA Reports for Stakeholder and User Needs and Requirements

Though outcomes of the reports were weighted differently due to the combination of different user input and the nature of how user feedback was collected, there were some common parameters and recommendations from all the reports that users identified (Tables 6 & 7). The majority of desired or requested improvements with sea ice parameters were focused on sea ice thickness, ice drift information and snow on sea ice and at the sub-kilometer scale. The snow on sea ice greatly affects monitoring by satellites, and also affects icebreaking performance of ships hulls. The reports reflected feedback from both the Arctic and the Baltic which we would expect to have different operational specifications for sea ice information and this is also evident from the ISABELIA project report, that was specific to the Baltic. However, the CPEG summary for the needs regarding satellite spatial needs for the marine navigation community contradicted what was provided from the actual feedback in Table 5 in this report and Tables 9 and 11-15 in the original report [7]. There was not as much information from the IICWG on desired or required sea ice parameters in this section, however, detailed feedback from a recent survey from this group can be found in Part 5: *Internal Survey Feedback: IICWG Survey 2019* of this report.

General recommendations from users were focused requests for technological developments within the scope of satellite capabilities to provide improved products such as higher spatial and temporal resolution products, NRT data assimilation, inclusion of more SAR information in routine products to present sea ice features more accurately for tactical guidance and requests for the provision of better accessibility and understanding of sea ice products (Table 7). Overall, the feedback was consistent from all reports that route and voyage planning were important and the availability of improved sea ice forecasts from high resolution data would provide valuable support to maritime operations. Feedback from sea ice forecast needs from surveys are covered in Part 5 of this report. Based on dialogue with users, the direct experiences from ice services, and feedback contained in all sections of this report, it is still rare for sea ice forecasts to be used for tactical support of operational maritime activities.

A recurring recommendation from users is the need for the development of data that is easily understood and available in familiar and standard data formats. This includes being able to easily access the information from multiple sources without having to encounter bandwidth intensive formats and issues. Standard format usually includes ENC's, ice charts in various standard graphics formats, GIF, PDF and JPEG2000 for raw satellite data when used (See Part 5: *Internal Survey Feedback* of this report). Additionally, the increase of sea ice information provision should also include better dissemination, tools and training of different data products for non-specialists. Issues with end-users understanding of multiple products has been a critical challenge of user uptake with new products. For most marine users it can also be difficult to access large data files due to communication limitations.

Co-funded by the Horizon 2020 programme of the European Union

Table 6. Common desired parameters from EC and ESA project reports (grey) and Surveys (white). **IC** = Ice Concentration, **IT** = Ice Type, **IE** = Ice Edge, **IEX** = Ice Extent, **L/OW** = Lead and Polynyas, **IA** = Ice Age, **SIT** = Ice Thickness, **ID** = Ice Drift, **D** = Deformation, **F/MYI** = Discrimination between FYI and MYI, **IT/RA** = Ice Thickness with Radar Altimetry, **DIC** = Detailed Ice Charts, **W**= Waves at ice edge, **SN** = Snow on Sea ice, **FR** = Sea Ice Freeboard, and **IB** = Icebergs.

	Desired Parameters															
	IC	IT	IE	IEX	L/OW	IA	SIT	ID	D	F/MYI	IT/RA	DIC	W	SN	FR	IB
ACCESS	■	■	■	■	■		■	■	■	■	■	■		■		■
SIDARUS	■	■	■	■	■		■	■	■	■	■	■		■		■
ICEMON	■	■	■	■	■		■	■	■	■				■		
ESA Polaris				■		■	■	■						■		■
PEG	■	■					■	■						■	■	
IICWG							■									
ISABELIA						■	■	■	■			■	■			
EU-PolarNet				■		■	■	■						■		■
FMI	■						■		■			■				
IICWG							■	■	■					■		■

Co-funded by the Horizon 2020 programme of the European Union

Table 7. Common agreement on main recommendations from EC and ESA project reports (grey) and Surveys (white). MS = Multiple Sensors/Complementary data, **AF** = Affordable data, **ACS** = Automatic Classification (SAR), **IS** = In situ observations, **NRT/DA** = NRT Data Assimilation, **DA/S** = Data Assimilation from SAR, **HRSF** = High resolution Sea ice forecasts from SAR, **DSAR** = More details from SAR (i.e mode flexibility, increased coverage and higher resolution of sea ice features, **I/SD** = Iceberg size and drift, **L** = Improved latency on products, **DA** = Data that is easily understood and available, **SF** = Familiar data formats and standards, **DT** = Better dissemination, tools and training of different data products for non-specialists, and **RA**= Risk Analysis.

	Main Recommendation													
	MS	AF	ACS	IS	NRT/DA	DA/S	HRSF	DSAR	I/SD	L	DA	SF	DT	RA
ACCESS			■	■	■	■	■		■					
SIDARUS			■	■	■	■	■		■					
ICEMON	■	■	■	■	■	■	■	■						
ESA Polaris	■		■	■			■		■	■	■	■	■	
PEG				■										
EMSA	■							■		■				
IICWG	■		■	■			■						■	
ISABELIA			■					■						
EU-PolarNet	■				■	■	■			■	■	■	■	
FMI								■			■	■	■	
IICWG	■													■

A general comment of this section regarding the EC and ESA reports is that there were not only overlapping feedback from users requirements and main recommendations, most of the reports referenced one another to show how the feedback had already been collected from users at different stages over approximately the last 15 years. It is clear that repeated surveys and projects focusing on user needs for marine operators has resulted in end-user fatigue in providing additional feedback. The questionnaires are slightly varied but there are more similarities in the overall outcomes rather than differing opinions. Additionally, though these reports are well-known to some who are familiar with these projects, finding archive copies is difficult because these are project-based and there is no standard archiving of documents that are clearly distributed widely to the research and operations community. It is unclear how information from these individual reports are communicated to the policy makers, researchers, funding agencies who can influence the

Co-funded by the Horizon 2020 programme of the European Union

development of sea ice information provision, especially when these groups do not often interact with end-users.

Part 4. Stakeholder and User Workshop Assessments for Sea Ice Monitoring and Sea Ice Forecasts

IICWG Top Research Requirements of the Ice Services (October, 2011)

The IICWG is an international group representing all the ice services of the world and they meet annually at a general assembly to discuss how to resolve current issues and challenges specific to sea ice operations related to the WMO, changing environmental conditions, information, operational and research needs and preparation for future activities.

Main recommendations from the IICWG ASRSC Report XII:

The 12th meeting held in held in Cambridge, U.K. on 17-21 October 2011 at the British Antarctic Survey, presented results from the Applied Science and Research Standing Committee (Action item: SC10-1) survey sent to sent to ice service heads[20]. The most important research requirements are summarized summarized in comparison with other previous needs described in other reports in this KEPLER report D1.1 and described in more detail with the following main points:

- Collecting proper in-situ data with good quality
    - Good quality in-situ observation of ice thickness and icebergs
- Accurate and regular observations (surface and satellite)
- Accurate ice thickness measurements from satellite
- Ice forecasting guidance
    - Incorporation of automatic analysis
- Comfortable interfaces between ice models and ice analysts
- Better use of remote sensing technique
    - High resolution classification of Arctic sea ice types (NRT)
    - Improvements on regional weekly to seasonal ice forecasting
    - SAR ice classification (with ridging, rafting, etc.)

It is important to note that those working in operations do not prioritize publishing peer-reviewed papers because their first mandate is the provision of ice information for monitoring for safety and navigation in their area of responsibility according the WMO meteorological areas (Metarea) and navigational area (Navarea) guidelines [41 & 42]. Therefore, the results from user-needs are normally published in the form of project, internal and international reports, surveys and user consultation included in white papers or in-house documents within the ice services.

Co-funded by the Horizon 2020 programme of the European Union

A follow-up survey from the IICWG was sent out in Spring 2019 and results are in this report (See Part 5, *The International Ice Charting Working Group (IICWG) Survey*).

Arctic Frontiers 2018: Stakeholder Sea Ice Forecast Workshop and SALIENSEAS Stakeholder Advisory Group Workshop

The Arctic Frontiers (AF) 2018 conference theme “Connecting the Arctic” hosted several user workshops specifically focused on community sea ice data, and forecast needs and requirements. This theme appropriately reflected the changing landscape and aimed to bring together researchers, data producers and information providers with the public and policy makers to address current and future needs of operators working in the Arctic. This section focuses on the two workshops that were organized during this 2018 AF intended to specifically facilitate and document user feedback for researchers and intermediate users.

The “Arctic Sea Ice Prediction Stakeholders Workshop” (ASIPSW) was organized by the EU-PolarNet, the Norwegian Ice Service - Norwegian Meteorological Institute (MET), University College London (UCL), Sea Ice Prediction Network (SIPN2) project, Arctic Research Consortium of the U.S. (ARCUS), Bjerknes Centre for Climate Research (UiB), Research Council of Norway, and WMO WRCP Climate and Cryosphere (CliC) Project [12]. The goal of this workshop was to assess the economic value of sea ice forecasts and information for stakeholders and end-users, and determine how these products were utilised in making decisions. The workshop opened a dialogue for stakeholders and end-users to communicate relevant metrics that are required for their operations, as well as provide recommendations on how they could use different types of products based on their activities at varying spatial and temporal resolutions.

The Enhancing the “Saliency of climate services for marine mobility Sectors in European Arctic Seas” (SALIENSEAS) project, part of the European Research Area Network (ERA-NET) program [26] under the EU Horizon 2020 programme, aims to understand how environmental information is currently being used and what will be required in the future for those making operational and strategic decisions in the European Arctic marine sectors. This project is coming from a perspective of social and natural scientists, together with applied personnel from meteorological institutes who directly work with end-users. The goal of the project is to develop improved Arctic seasonal forecast products that are relevant for operations. SALIENSEAS organized a “Stakeholder Advisory Group” workshop on January 25 to identify critical issues with metocean information and develop better mechanisms to procure user feedback that would be valuable for guiding future product developments.

These workshops were designed as interactive forums, that included researchers, ice information producers, and several types of end-users working with Arctic sea ice forecasts and information. This allowed the end-users to provide constructive feedback on what types of data they deem important for their activities. The stakeholders and end-users comprised of industry

Co-funded by the Horizon 2020 programme of the European Union

representatives (shipping, resource extraction, fishing, etc.), ship operators, ice pilots, polar tourism representatives, search and rescue (SaR) and local/national planners and policy makers. Both workshops comprised of presentations from stakeholders and end-users and breakout groups in order to yield a good representation of perspectives from various sectors.

The ASIPSW included 54 participants of which 9 were end-users, 18 were ice information providers (intermediate users), and 27 researchers. Of the end-users, 5 presented summaries of the requirements for their sector. SALIENSEAS was more selective, with 20 participants of which 7 were end-users, 8 were ice information providers (intermediate users), and 5 researchers connected to the project. The ratio of end-users to information providers and researchers was therefore higher in this workshop, allowing greater in-depth discussion of the issues.

Table 8 provides a summary of the types of end-user participating in the 2 workshops. There was only a partial overlap of industries that attended both workshops, however, most of the commonality in participants was with the researchers and ice information providers involved. ASIPSW had a greater focus on Arctic tourism, and SALIENSEAS on Greenlandic users.

Table 8: Summary of end-users participating in AF 2018 workshops.

Sector	ASIPSW	SALIENSEAS
Indigenous peoples		Fishers and Hunters: Greenland
Polar Tourism, Cruise Operators	AECO, EYOS, G-Marine	AECO
Specialised navigation providers		Ice pilots: Greenland
Icebreaker management		Arctia Oy
Commercial ice information provider	Drift & Noise	Harnvig Arctic & Maritime
Search and Rescue	U.S. Coast Guard - Alaska	Maritimt Forum Nord
Climate Monitoring	GRID-Arendal	
Energy	Equinor	
Insurance	DNV-GL	
Fisheries	Fiskbåt	

Summary of Stakeholder and User Workshop Assessments for Arctic Frontiers

The key findings of the ASIPSW were as follows:

- Need for more co-production of decision-making systems to educate both sides on potential new products and services, and tailor solutions to industry needs.
- Create an iterative process to product development that allows for synergies and better understanding of respective skills, limitations, and promotion of better tools.
- Establish a common language between stakeholders and ice information providers.

Co-funded by the Horizon 2020 programme of the European Union

- Encourage industry to employ and engage with more sea ice scientists
- Create better visualisation tools, taking into account low bandwidth limitations.
- Better communication by forecasters of the assumptions, limitations and expectations.
- Build in understandable confidence and uncertainty estimates into forecasts. Accuracy is a key requirement.
- Link to complementary programmes and initiatives focusing on the links between industry needs and forecasts.

In contrast, the SALIENSEAS workshop made more specific recommendations for the types and level of information required, including:

- Winds along the ice edge, katabatic and storm events
- Polar Low forecasts
- Annotated satellite images, in preference to ice charts, for experienced navigators.
- WMO Egg Codes to portray inhomogeneity of the ice and comply with the Polar Code.
- Many users were unaware of the range of metocean services available.
- More automated compilation and filtering of the large number of available services, with the use of common format standards.
- Need of a dedicated ice advisor to distil and interpret information.

To some extent these SALIENSEAS conclusions reflect the communications issues between end-users and ice forecast providers identified by the ASIPSW. Both workshops highlighted the lack of awareness of ice information product availability, due to poor provider communication. This confusing situation seems to be exacerbated by multiple types of providers including national ice services, Copernicus services, and commercial providers, all competing for the same end-user base.

Many of the points raised by SALIENSEAS are already a fixture of ice information provision. Annotated satellite images can provide more information, but only if the user is sufficiently experienced to interpret them, and are currently not feasible at higher latitudes due to the satellite communications bandwidth limitations. This, and the use of ice advisors to distil the data and information into knowledge, resulted in the need for the current network of national ice services to adhere to standard recognised formats, SIGRID-3 for ice chart interchange and S-411 for ENCs, based on the Egg Code terminology, to reduce data volume and communications overheads.

Regarding sea ice forecasts, an agreement between both workshops stated that short-term forecast products were deemed most influential in all sectors and most valuable in the early planning phase. Sub-seasonal products are currently useful to provide a broad overview on knowing when to discontinue services for marine operators. However, sea ice forecasts are not necessarily relied upon for operations. They could be more valuable with strategic planning if they included less ambiguity regarding uncertainty estimates, particularly for trajectory forecasts that can provide useful information to plan alternative courses of action, similar to weather forecasts.

Co-funded by the Horizon 2020 programme
of the European Union

Copernicus Maritime Surveillance Service (EMSA) (2018)

The Emergency Maritime Safety Agency(EMSA) Copernicus Maritime Surveillance Service Workshop was organized to facilitate dialogue with users, identify new user needs and assess feedback from users on current issues and services and operational requirements. This workshop included end-users, policy makers and operational staff working in maritime domain awareness. A First User Group Report was produced and the outcome provided feedback relevant to the following sectors [9]:

- Fisheries
- Law Enforcement
- Marine Safety and Military
- Environmental Monitoring

Though EMSA primarily focuses on sub-Arctic and mid-latitude areas, there is a strong overlap with monitoring operations for sea ice-encumbered waters and areas in the subpolar regions regarding spatial and temporal resolution satellite needs, as well as the data access and infrastructure (i.e. data format, information accessibility, provision of understandable and relevant information for specific users...etc.) that are common to all operators working in the maritime domain. Additionally, the breakout sessions during this workshop covered ice monitoring needs related to the Copernicus services but did not provide specific information on desired or required parameters. The following will summarize feedback from the workshop related to maritime requirements in KEPLER WP1.

Desired requirements for monitoring for EMSA

Recommendations were provided to Copernicus Services regarding how improvements in the CMS services would assist this community and increase the uptake of end-user activities. As EMSA is focused on maritime safety feature detection is one of the primary concerns. One of the main suggestions was to improve delivery time for both SAR and optical acquisitions and to increase the number of featured products for activity and feature detection. This includes ships and icebergs and the tools to discern between the two. Regarding the differences between the two Copernicus services, CMEMS and CMS (see Overview section of this report), EMSA expressed that the use of CMS for ice monitoring is limited to support to safety of navigation in ice conditions where it is most helpful to support safe passage through areas that include dynamic ice conditions, and to detect ice sheets and icebergs in NRT.

Regarding future implementation and EO capabilities, users requested improvements with services for data acquisition and latency. The integration of new satellite constellations, preferably with SAR and optical, was considered important for all sectors. Furthermore, with improvements on satellite latency, users wanted more integration with AIS and the development of synergies with Remotely Piloted Aircraft Systems (RPAS) operations, Frontex Maritime Aerial Surveillance (MAS) and the availability of RPAS possibly through Copernicus.

Co-funded by the Horizon 2020 programme of the European Union

Main Recommendations for EMSA

Regarding technological requirements, it was noted that user experience and understanding with different types of data varied and some fundamental recommendations on improvements to Copernicus are described below:

- Size and bandwidth of EO products should be considered in order to enable delivery in remote locations for those users who would like to access the full product; more developed reports (i.e. EMSA provides for oil spills, could be considered for other products if there were sufficient)demand.
- The reliability of services (i.e. availability and priority) was stated as particularly important:
    - Assurance that acquiring images will have the highest priority (from national and commercial agencies)
    - Improved routine monitoring and increase of images over specific areas, could assist to prioritize surveillance areas and increase updates on feature detection and positions of objects in the water.
- SAR and optical and use to combine with other sources of information (i.e. intelligence, transponder data, AIS).
    - Rapid tasking time and quasi near real time delivery time and wide area coverage
    - Video-streaming could potentially add value, whether from satellite or RPAS
- Data integration:
    - Link with on-board AIS receiving capabilities and access to vessel positioning information (i.e. Satellite AIS) in combination with EO data was deemed crucial
    - EO data shall also be used as complementary to existing data sources (e.g. AIS or LRIT) and integrated in Automatic Behaviour Monitoring algorithms.
    - Image data for strategic intelligence: There may also be a benefit in analysing cumulative historical satellite data for pattern analysis, with a view to developing better strategic intelligence.

Co-funded by the Horizon 2020 programme
of the European Union

Table 9. Requirements for new SAR missions identified by Copernicus Maritime Surveillance Service Workshop (taken from [9])

Requirement Type	Description
Operational	All-weather 24/7 monitoring
Revisit Time	● 4 to 6+ acquisitions over the same area per day (requires satellite constellation). ● Ability to monitor the same area at different times of day (i.e. every 4 hours)
Delivery Time	QRT (15 minutes) over European EEZs, both in Europe and outside (e.g. Overseas Territories)
Tasking Time	In-orbit tasking (less than 1 hour before acquisition)
Resolution	1 metre to 15 metre (very high and high resolution)
Coverage	Wide coverage for both very high and high resolution (swath width bigger than 50km) Long swaths for extended area monitoring (high satellite duty cycle enabling coverage of wide areas)
Other Sensors	On board AIS receiver

- For support to ice and iceberg monitoring more detailed requirements were listed:
    - Reduce iceberg risk by augmenting SAR revisit time to include more high-resolution SAR images
        - Baltic Sea:
            - Product: Radarsat-2 images with different polarizations
            - Resolution: 100 to 200m
            - Tasking type: Routine
            - Delivery: 3 hours
            - Period: November-May
            - Revisit: Daily or twice per day
        - Arctic: synthetic aperture radar images; daily coverage;
            - resolutions of 10 to 20m to detect small icebergs which constitute navigation hazards of concern, especially over choke zones

Co-funded by the Horizon 2020 programme of the European Union

- The required spatial resolution spans from medium resolution for overall assessment of a broader area, to high resolution in sensitive ice infested waters

Part 5. Internal Survey Feedback

Internal surveys are often conducted when working with end-users in order for services to update and improve their products for evolving user needs. The range of sea ice information users covering the European Arctic, from Greenland to Russia, interact with all the national ice services for the Arctic and the Baltic (NIS, GIS, FMI, SMHI, and the German Federal Maritime and Hydrographic Agency [BHS]). The following sections summarize surveys that were administered by national ice services over the last three years, as well as during the EC projects, SPICES [36] and KEPLER. There were many different organisations represented, covering a range of different user types which will be described in each section.

Norwegian Ice Service Survey for Arctic Shipping Forum (2018) / AECO - Polar Tourism (2017)

The user organisations that responded from the Arctic Shipping Forum (ASF) 2018 and AECO multiple choice survey were combined and categorised by their primary interest in the Arctic Sea, into different user sectors (Fig. 5)(Appendix c and d). The main user sectors were those involved in the following:

- Polar tourism with (18)
- Logistics (6)
- Shipping (5)
- Information providers (Intermediate users - EO)
- Military, and governmental regulations were under-represented with just one respondent in each of these categories(%)

Sectors such as logistics (air) and polar tourism are known to use ice charts but tend to be smaller scale operations where they utilise publicly available data and do not necessarily have the resources or time to interact with the data or information provider.

Co-funded by the Horizon 2020 programme of the European Union

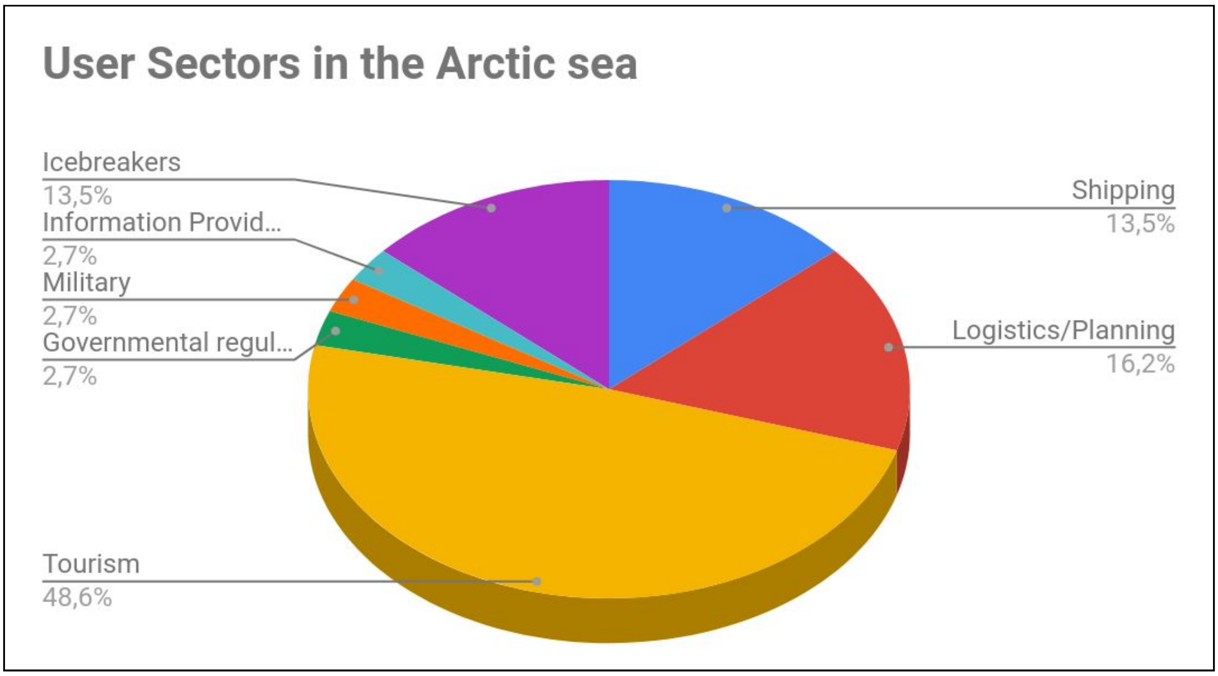


Figure 5: Pie chart showing the user sectors in the Arctic Sea. In total 37 participants from Arctic Shipping Forum 2018 and AECO - Polar tourism who answered with free text and comments.

Respondents were asked about the types of general information users prefer on a daily basis (Figure 6). Daily ice charts were the primary source of information followed by personal experience by the user. This is expected because most operators who frequently travel through ice-encumbered areas, such as those working in polar tourism or shipping industries, require certifications and competencies that qualify them to operate in these environments. This does not necessarily apply to all those operating in the Arctic. The Polar Code [21 & 22] requires all navigators operating through sea-ice to have key competencies of understanding sea ice properties and how to access standard information, but the proficiency in operators who have intrinsic knowledge of understanding ice behavior in specific regions, varies depending on the industry.

Co-funded by the Horizon 2020 programme
of the European Union

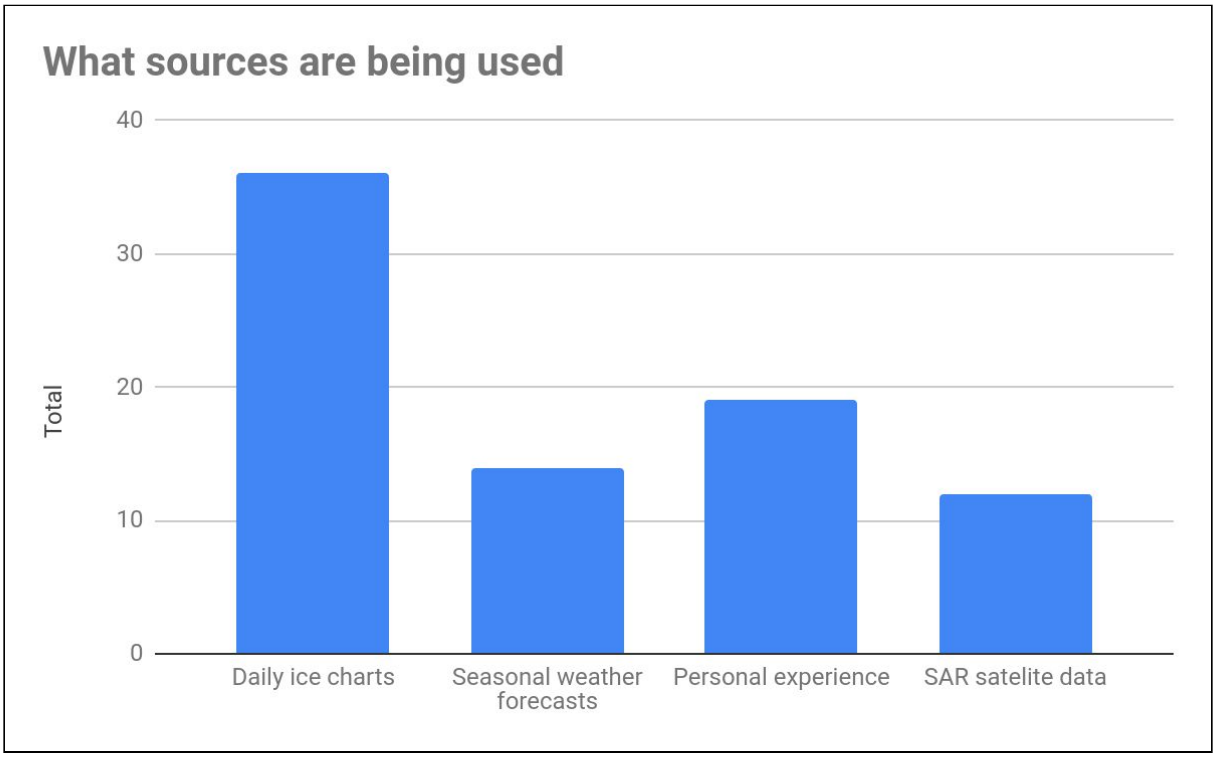


Figure 6: Diagram showing what sea ice information sources are being used on a daily basis, many of the respondents tend to use combinations of these sources.

As the Arctic region is characterized by a year-round ice cover in some areas and partly very rough ice conditions including ice pressures and heavy multi-year floes, particularly around the Northern, Eastern and Eestern part of Greenland and within the pack ice above Svalbard and the Barents Sea. Due to an environment that can impose safety and environmental risks, ice mapping of the Arctic Sea is highly dependant on remote sensing on the meter scale, for operations as the primary source of information. Regarding user needs for ice information, in the Arctic it can be more limited compared to the Baltic Sea due to lack of frequent in situ observation sites and stations, and additional high resolution satellite coverage considered to be "operational" (i.e. commercial satellites are normally used to augment areas of missing high resolution satellite coverage from the ESA Sentinel 1 mission). However, figure 7 and figure 8 reflect the collective need for spatial and temporal resolutions for the Arctic and Baltic operators and show that they coincide with requirements to have more frequent coverage (i.e. As often as possible and daily) with the minium spatial resolution at <1km, depending on the phase in the activity. Overall, new and improved products for the maritime sector were consistently requested in order to provide high resolution ice products based on SAR as well as information on ice thickness and ice type.

Co-funded by the Horizon 2020 programme
of the European Union

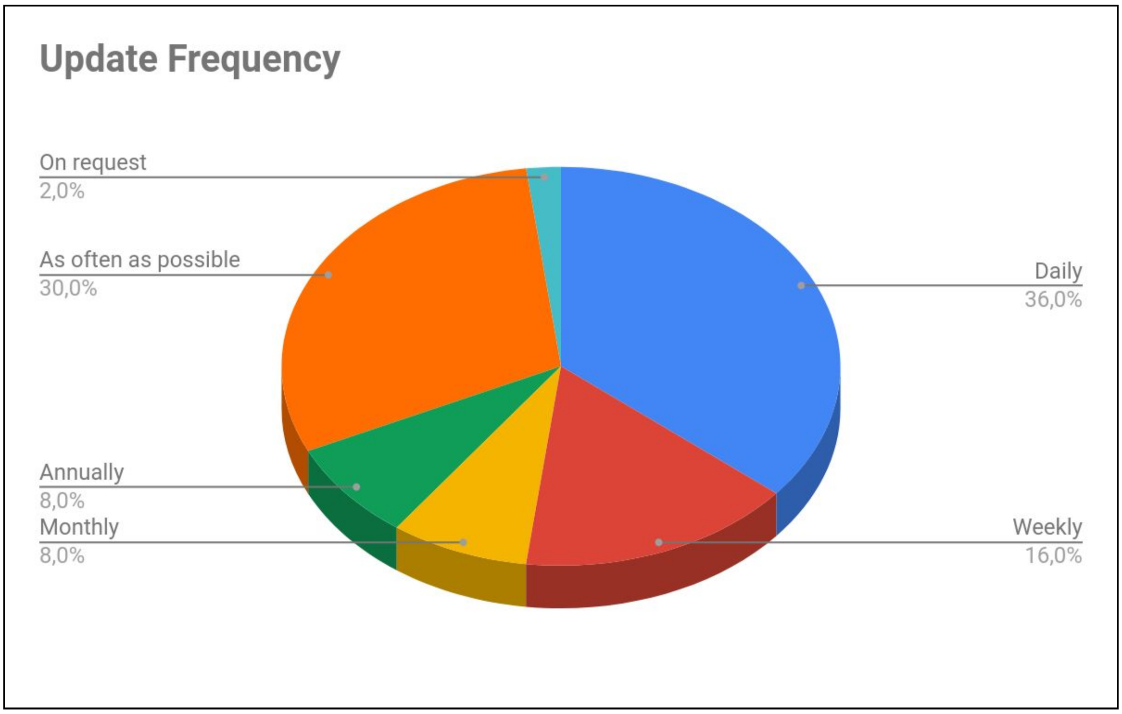


Figure 7: Pie chart showing the update frequency for tactical and operational ice forecasts

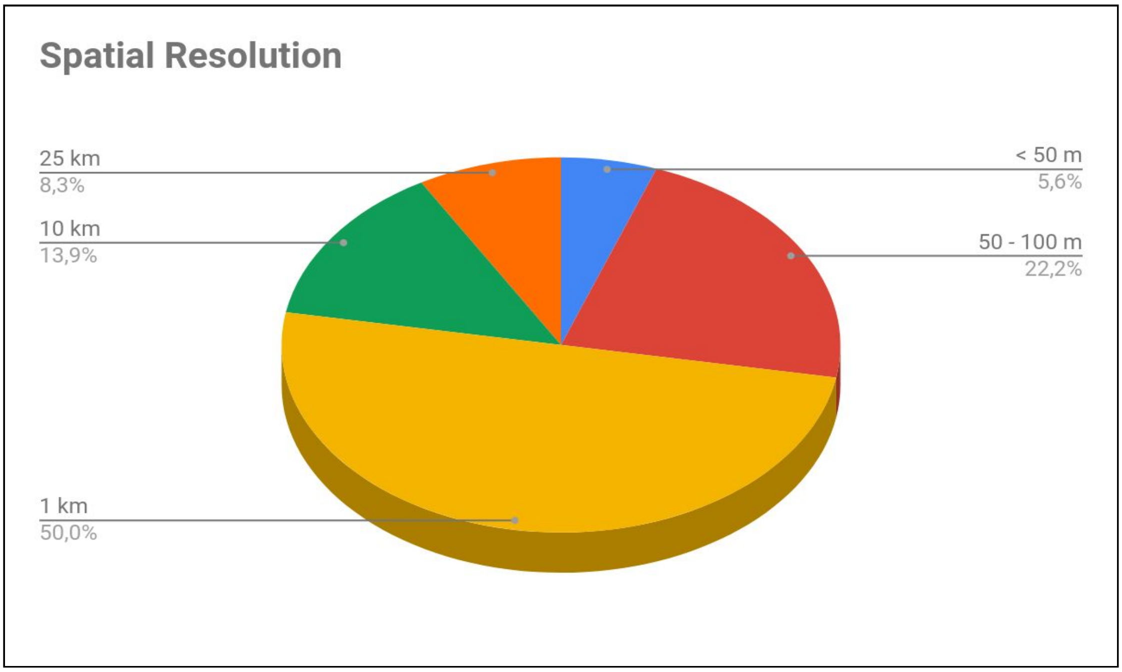


Figure 8: Pie chart showing the demand of minimum spatial resolution

Co-funded by the Horizon 2020 programme of the European Union

NIS Results for Data format and Product Delivery

For ships operating in the Arctic Sea, the communication bandwidth can be limited at high latitudes (over 80N) or when ships are travelling in the interior of fjords or mountainous regions. The NIS survey feedback from ASF 2018 and AECO presents the data format and delivery preferences from users and provides information on how sea ice products to be more user-friendly in the future. The internal feedback clearly show the difference on how the user sector use the data in terms of their operations.

Survey results suggest users depend on receiving easily accessible sea ice information as JPEG/PNG/PDF or a format that is clear and easy to understand for the operator (Figure 9), that is also consistent with preferred data formats desired (Figure 10). Due to potential poor satellite coverage and bandwidth challenges. It is crucial for the information provider to compress and limit the amount of data before transferring out to the ships. From NIS experience with users, preferably at an approximate file size between 1-1000 Kb, depending on the ships capability.

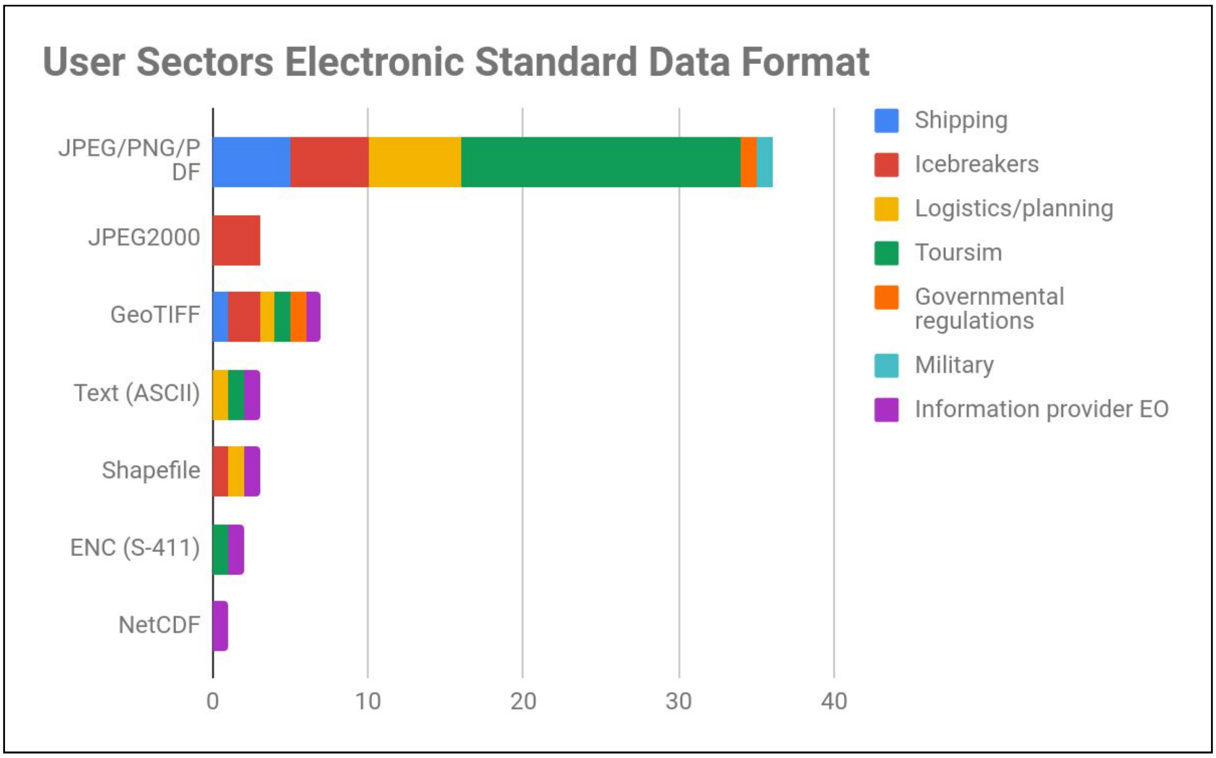


Figure 9: Diagram showing the electronic data the user sector use on a daily basis. Plotted from ASF 2018 and AECO surveys

Co-funded by the Horizon 2020 programme of the European Union

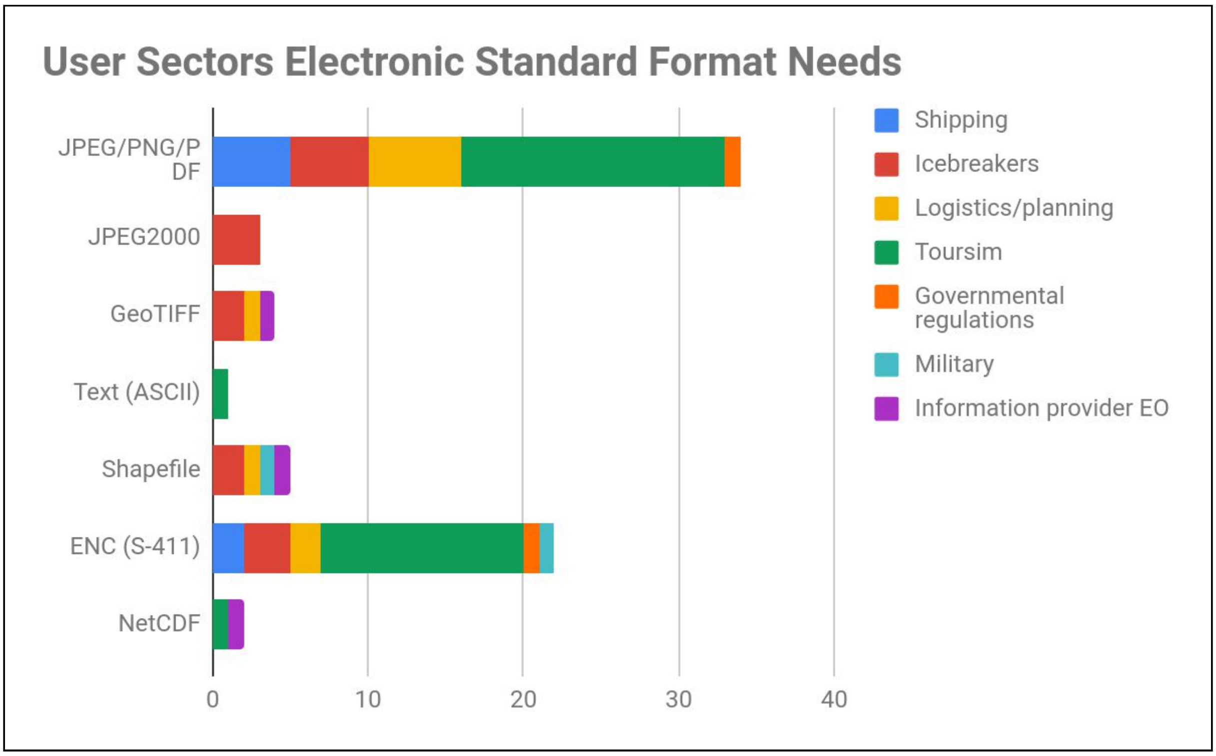


Figure 10: Diagram showing what electronic data format is preferred or what the user sector needs for their specific operations. Plotted from ASF 2018 and AECO surveys

The preference for GeoTIFF, Shapefiles, and NetCDF are primarily useful for information providers (eg. in Earth Observation) and can be government and logistics and planning. These sectors can be end-users and intermediate users, and they are often stationary and located with unlimited internet access at all times. For this reason it makes it easier to work with additional data formats and they are adept at working with other electronic data formats containing sea ice information that may be too large to access from ships or platforms in remote areas or not easy to understand for practical users (Figures 9 and 10).

The AECO survey for polar tourism included additional questions related to NIS ice information provision products and how user-friendly they found the accessibility and data formats to be compared to one another. Figures 11 and 12 show the MET Norway Ice charts are considered to be more user friendly for accessibility and with the data format, with Polarview being secondary, compared to EU Copernicus services. From this suggests there may be a large gap between the expectations and in communications from the end-users and information providers from downstream services, such as the Copernicus Services, on how the sea ice information should be delivered.

Co-funded by the Horizon 2020 programme of the European Union

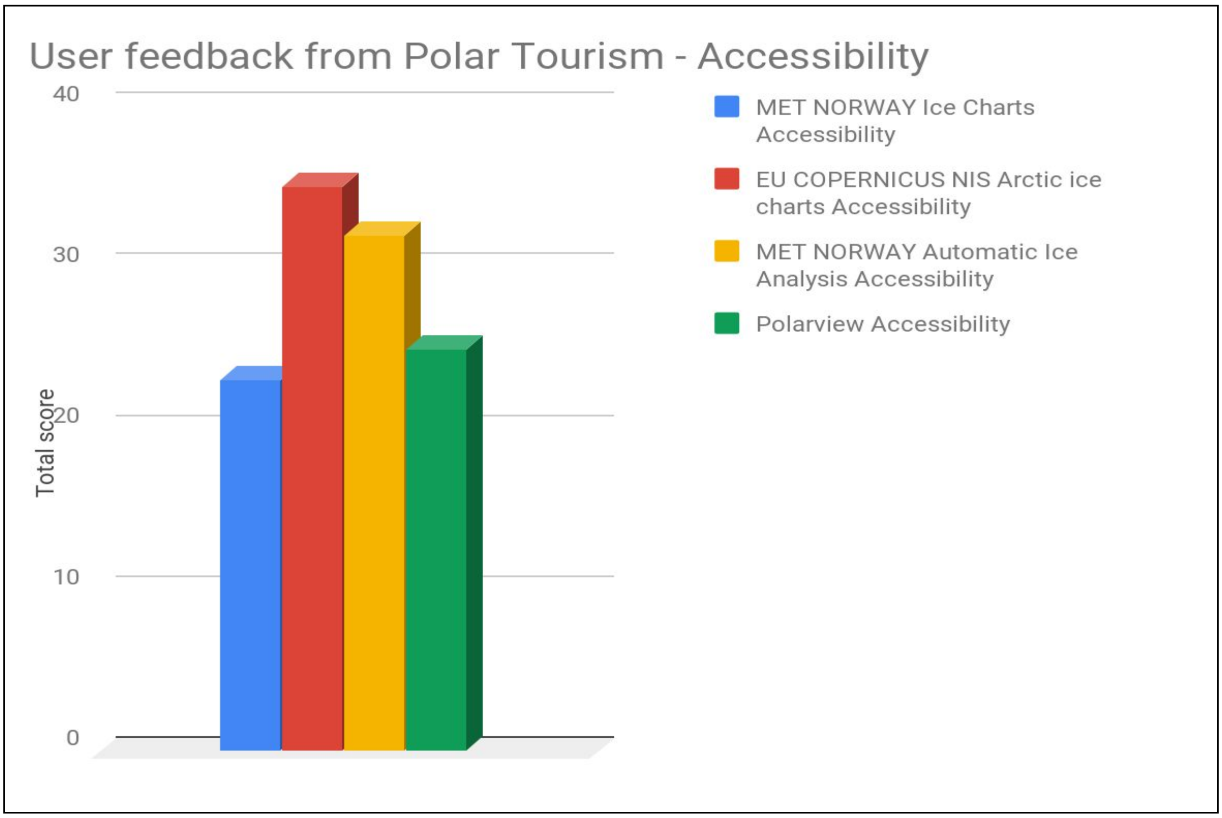


Figure 11: Diagram showing the cumulative feedback from polar tourism of the accessibility from The scale of the user-friendly the accessibility ranges were set from 1 to 5. Grade 1 - Very easy, Grade 5 Very difficult.

Co-funded by the Horizon 2020 programme of the European Union

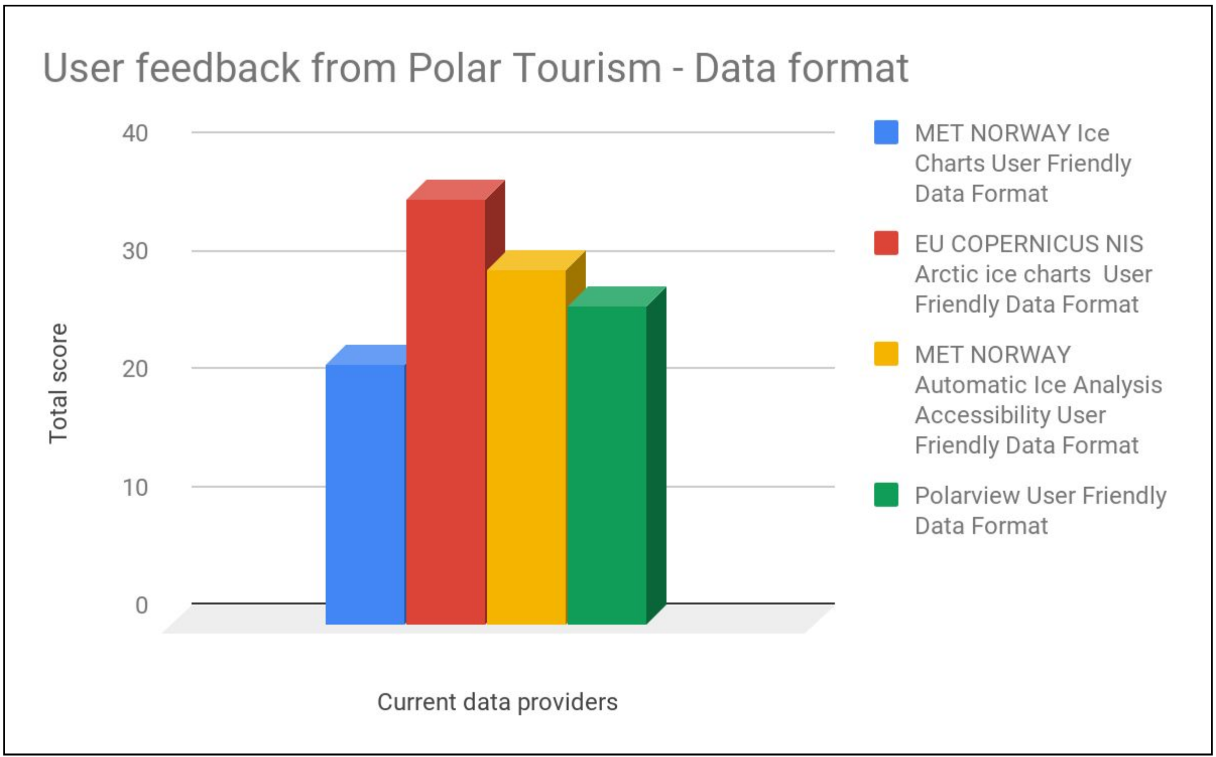


Figure 12: Diagram showing the feedback from polar tourism of the data format from the different data providers. The survey and graded the accessibility and user friendliness in grades from 1 to 5. Grade 1 - Very easy, Grade 5 Very difficult.

NIS Survey Results for Sea Ice Forecasts for Passenger Vessels

There's an overall need from the operational marine community to have reliable, understandable and easily accessible sea ice forecasts available at multiple time-scales. They assist with strategic and route planning (short-term and sub-seasonal), as well as being valuable for long-term planning or logistics (seasonal). Sea ice forecasts typically assimilate passive microwave derived sea ice concentration and, if more advanced, sea ice thickness estimates, both at low resolutions of 5 or more kilometers [27]. Whilst this is felt be some developers to be inadequate, there are few attempts to push for datasets that are more complicated to derive due to the time and resources used in setting up and running these models. Drifting sea ice poses a challenge for sea ice forecasts to accurately assimilate certain parameters such as sea ice type, thickness and concentration, particularly during the late spring and summer seasons due to snow melt. It is especially difficult to convey sea ice in forecasts at the MIZ and along the coastal areas where due to the merging of satellite products from multiple time points and with varying sensor frequency footprints, there is often a smearing of the ice edge and any features of potential interest [37].

Co-funded by the Horizon 2020 programme of the European Union

Feedback from the NIS survey assessed how sea ice forecasts were useful, the level of user-friendly data formats. The results were based on a scale from 1-5, where 1= very easy and 5 = very difficult. The cumulative average for each data format are summarized in Figures 11 & 12. There were 15 responses and the following summarizes plot graphs from PolarTourism use of current data products. Ice charts from NIS and information from Polarview were considered the most accessible, whereas the largest difficulty was found with those from the EU Copernicus website and second was the NIS automatic ice chart.

The FMI Ice Map as a Product, Observation of the Concept Survey (2017)

User/stakeholder views were studied through 12 multiple choice questions and free text comments. The survey was published at the FMI website and ice chart and was open for all users. 306 users participated in total, 272 answering the Finnish and 34 the English version of the survey. Respondents were separated into professional and non-professional users (Figures 13 and 14). However, a larger proportion of responses were from users who were non-professionals.

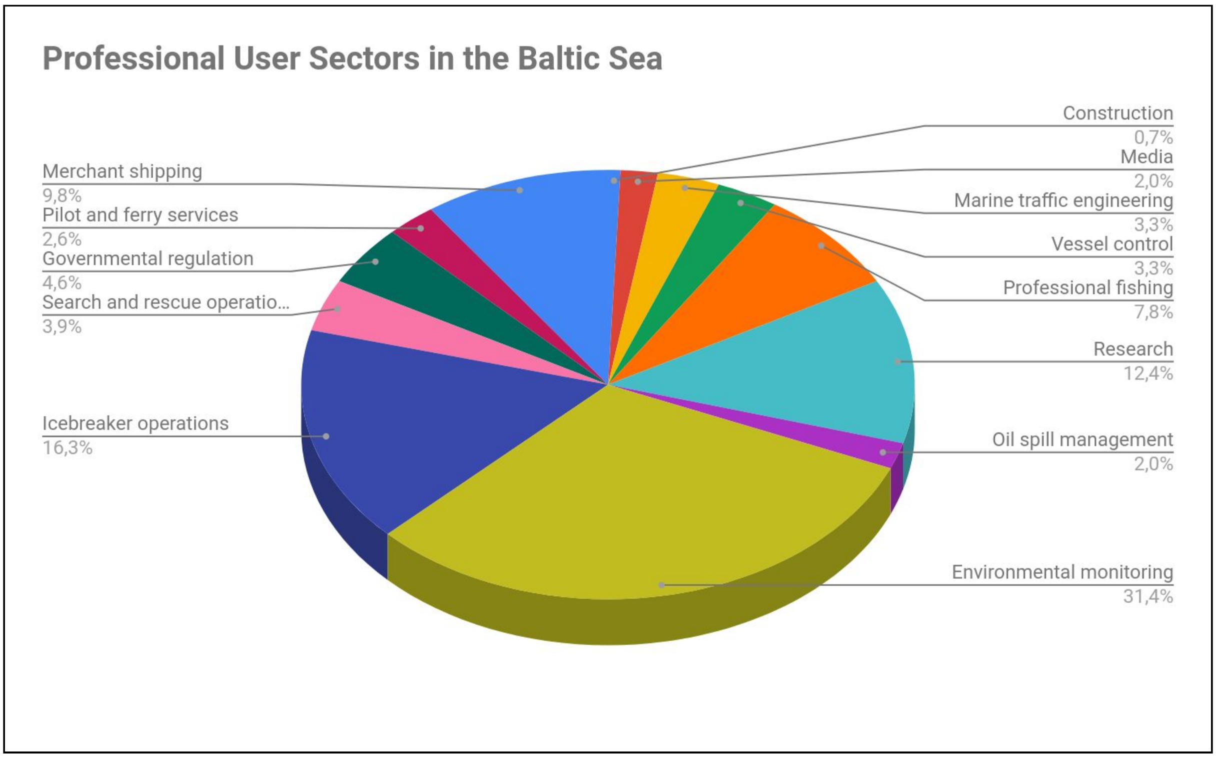


Figure 13: Pie chart showing different professional uses defined by participants in the Baltic Sea

Co-funded by the Horizon 2020 programme
of the European Union

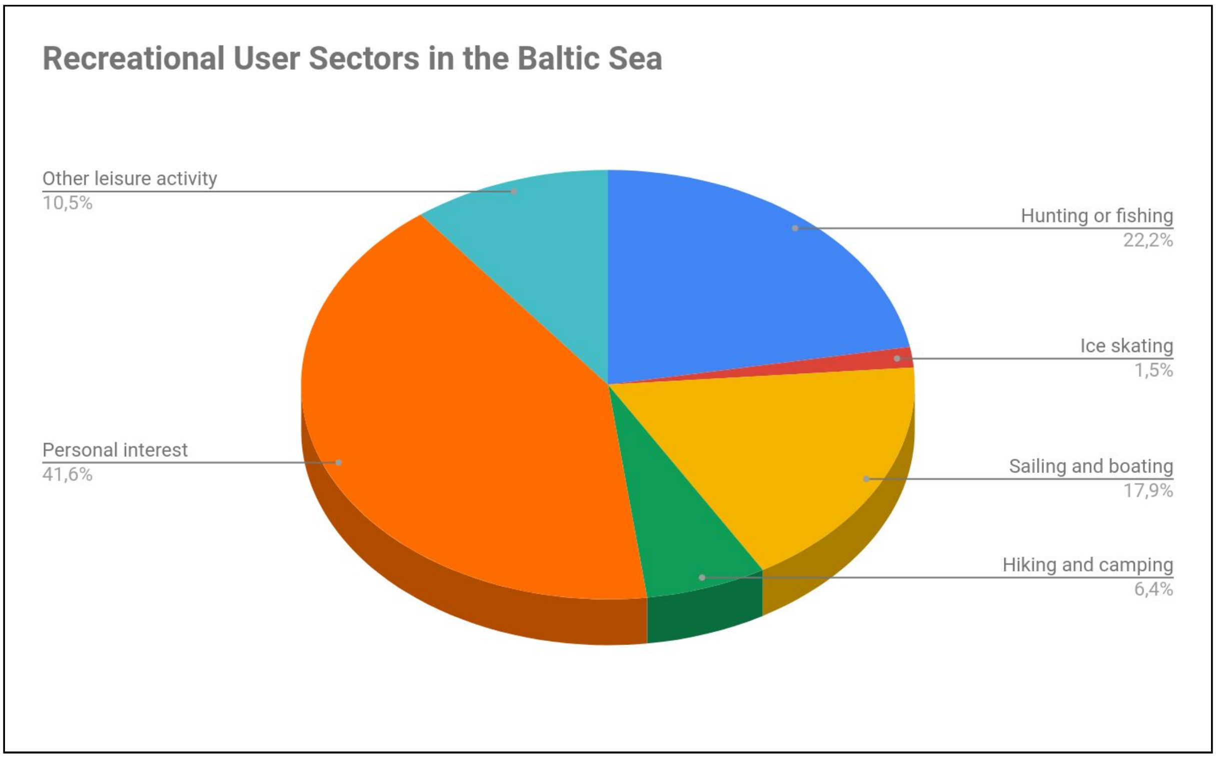


Figure 14: Recreational user sectors in the Baltic Sea

Critical sea ice parameters for users (in order of most desired) were daily ice thickness (73%), ice concentration (56%), sea temperature (45%) and ice deformation (32%). All user groups would benefit of a larger amount of ice thickness observations.

The most used product was the daily colored ice chart delivered as PDF. However, more than 60% of the users used a mobile device for reading the ice chart and many considered the data format to be outdated and clumsy. From the survey, 91% of the users found what they were looking for, and 12 % were not satisfied to information available in the ice charts. Many users could not find such basic products as ice prediction or daily ice map. They had trouble finding the daily chart from the FMI web service despite searching it and used the weekly chart instead. Similarly many users could not find the ice predictions. Information in archipelagos and near coast was considered lacking. Many users desired charts from inland waters with the same resolution as in Sweden.

Additional users relied on the ice chart as a reference for planning their own ice mapping. Information on traffic limitation was considered disturbing in some uses and presenting it in another product could be useful. However, many users requested open access to archived ice charts and requested metadata to be available in producing the ice chart.

Co-funded by the Horizon 2020 programme
of the European Union

FMI Survey on Services and Products (2018)

FMI conducted another survey specifically targeted to known ice service customers that were in the database. This included ship captains, ice breaker companies, journalists and primarily professional users. Though no in-depth analysis was done, preliminary results are summarized as the following:

Regarding FMI Services and Products, the majority of feedback responded positively to the current state of services and products offered (Table 10) (Appendix b).

Table 10. FMI survey for how professional users deem current products and services, where the scale was set from 4 (poor) to 10(excellent).

	4	5	6	7	8	9	10	Total
Extent and versatility of the products and services of the ice service	0	0	0	1	8	17	3	29
Communication of new products and services	0	0	2	9	7	6	1	25
Quality of the products and services	0	0	0	1	9	18	2	30
Price/quality of the products and services	0	0	0	2	11	6	1	20
Suitability of the channels of the products and services	0	0	0	3	5	18	1	27
Delivery times of the products and services	0	0	0	1	9	14	4	28
Technical forwardness of the products and services	0	0	0	3	8	11	3	25
Usability of the products and services	0	0	0	2	12	8	2	24
Speed of tailoring of the products and services	0	0	1	5	9	3	1	19
Success in tailoring of the products and services	0	0	0	3	9	6	1	19
Expediency of the products and services for own needs	0	0	0	3	8	14	2	27
Response time for inquiries to the ice service	0	0	0	3	6	9	3	21
Quality of the responses to the inquiries	0	0	0	2	7	9	4	22
Total	0	0	3	38	108	139	28	316

Regarding the grade of the ice chart, news sheet and forecasts being offered at FMI, respondents seemed overall very satisfied with the quality and accuracy, scoring on the upper range of satisfaction (Table 11).

Co-funded by the Horizon 2020 programme of the European Union

Table 11. FMI survey for the level of satisfaction with the quality and accuracy of FMI ice charts, newssheets, and forecasts, where the scale was set from 4 (poor) to 10(excellent).

	4	5	6	7	8	9	10	Total
Accuracy of the ice charts	0	0	1	1	6	14	4	26
Clarity and understandability of the ice charts	0	0	1	3	5	14	5	28
Accuracy of the ice news	0	0	1	1	7	13	2	24
Jäätiedotteiden selkeys ja ymmärrettävyys	0	0	0	3	7	11	5	26
Quality of the forecasts of the ice service	0	0	0	2	11	11	1	25
Total	0	0	3	10	36	63	17	129

Another section focused on the professionalism of the ice analysts and experts at the Finnish Ice Service and the majority of the responses were highly favorable (Table 12).

Table 12. FMI survey for the level of professionalism of ice analysts and experts at FMI, where the scale was set from 4 (poor) to 10(excellent).

	4	5	6	7	8	9	10	Total
Reachability of the experts (phone, email)	0	0	0	3	2	13	6	24
Ability of the experts to listen you needs and problems	0	0	0	2	3	12	6	23
Ability of the experts to understand your current needs	0	0	0	2	6	10	5	23
Service orientation of the experts, ability to meet your expectations	0	0	0	2	2	11	7	22
Responsibility of the experts	0	0	0	1	6	10	5	22
Reliability of the experts	0	0	0	2	4	10	9	25
Competence and professionalism of the experts	0	0	0	1	3	12	10	26
Total	0	0	0	13	26	78	48	165

Feedback from users also indicate how FMI products and services are critical for marine navigation in the Baltic and reliable quality is important to the majority of their end-users.

Co-funded by the Horizon 2020 programme of the European Union

SMHI Survey (2019)

In order to chart the needs of its users, the Swedish ice service at SMHI has conducted a survey in Spring 2019. The survey, which was in Swedish, was promoted on the ice service web page and on social media. It was also sent out by email to some users, such as the Swedish Maritime Administration, the Swedish ice breakers, the ice skating community, harbours, municipalities and Swedish transport administration.

There were 80 survey respondents. These were divided into four groups. The largest group (60 %) was non-professionals on ice or water. The second largest group was the shipping industry (17.5 %). The two smallest groups were professionals outside shipping (15 %) and other non-professionals (7.5 %). Below, the results from the shipping industry are presented (Figure 15).

The most used product (100 % of the respondents) is the detailed ice chart (http://www.smhi.se/klimatdata/oceanografi/havsis). 63 % use the less detailed chart (https://www.smhi.se/vadret/hav-och-kust/is-till-havs). The Swedish ice report is read by 81 % of the respondents. Respondents from the shipping industry tend to use many of our products, compared to other user groups.

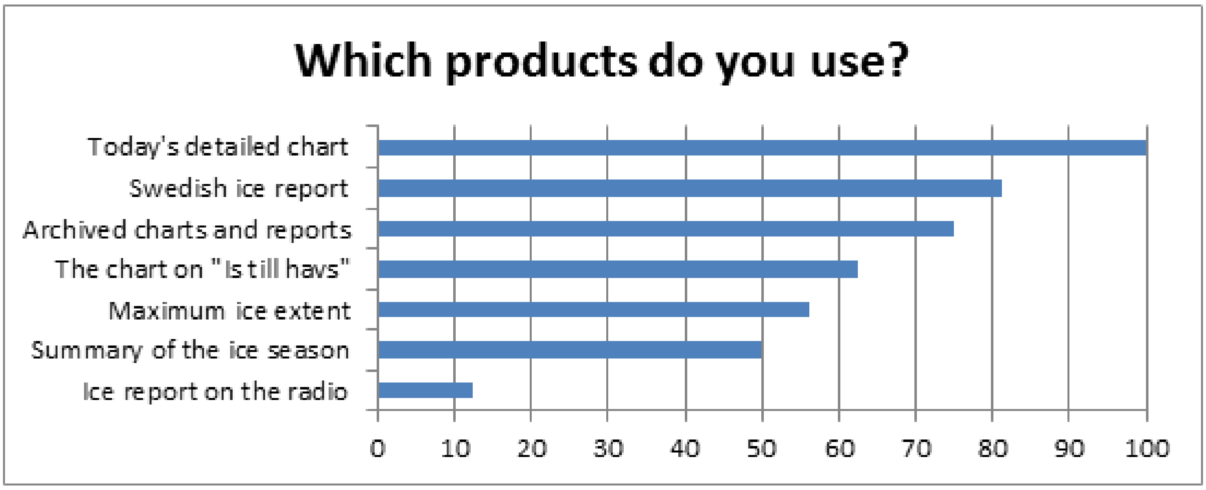


Figure 15. Current products used by respondents (%)

Regarding products that could be useful if made available, the shipping industry uses the products of the Swedish ice service mainly for route planning and 50% for summaries and follow-ups (Figures 15 and 16). Many of the respondents would use satellite images (69 %) and ice measurements (44 %), if available. None would use a dictionary (Figure 16).

Co-funded by the Horizon 2020 programme
of the European Union

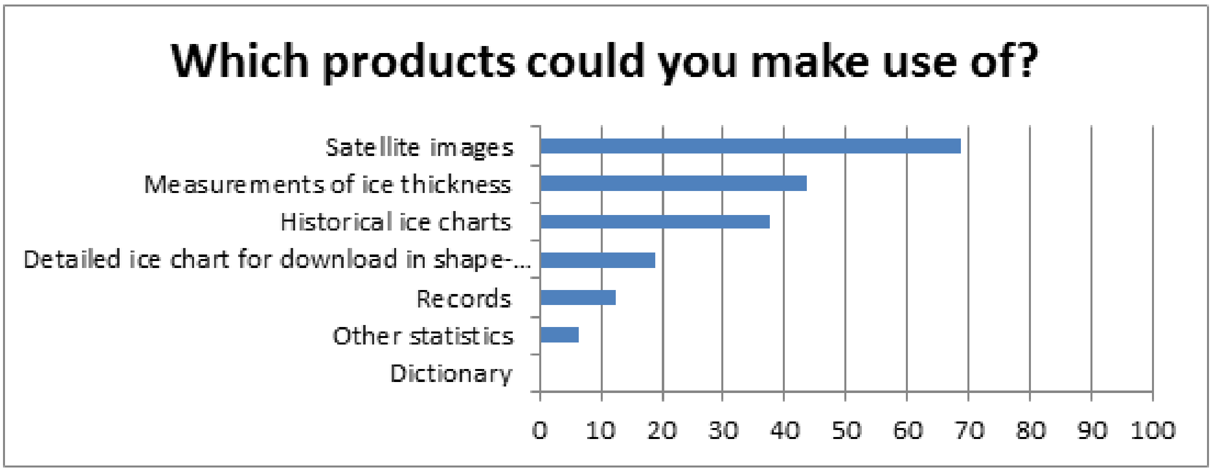


Figure 16. Comparison of products that would be of interest if made available (%)

All of the respondents would like to retrieve information from a web page. Many are also interested in data for download (63 %) and an app (50 %). None want information via social media or reading articles. More respondents prefer to read a chart (69 %) than a text (25 %) (Figure 17).

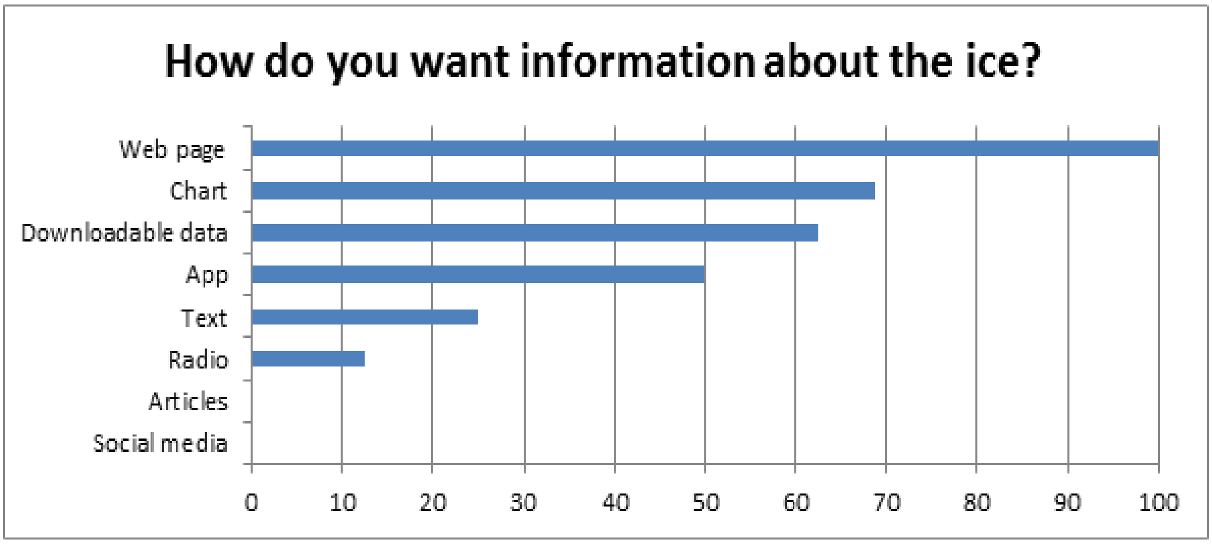


Figure 17. Responses on preferred way of receiving ice information (%)

The shipping industry often needs to know the ice thickness, but also other parameters such as concentration, extent, ice type and character/texture/roughness of the ice surface. Slightly more than half of the respondents would be willing to report their own ice thickness measurements, if possible.

Co-funded by the Horizon 2020 programme
of the European Union

International Ice Charting Working Group (IICWG) Survey (2019)

Through the spring of 2019 a task team under the IICWG conducted a survey on mariners ice information requirements for safe operations in ice-covered waters (Arctic and Antarctic). The questionnaire had 28 multiple choice questions and some questions allowed entering free text text for the participant. 95 mariners responded to the survey. 60 pct were captains, and more than 50 pct of the responders had more than 10 years of navigating experience in Polar waters. The IICWG Survey was initiated due to demands from both policy and regulations, as well as, users who had operational requirements for met-/ice-ocean services. The main drivers were users of sea ice information.

From survey results the most widely used source of information for navigation is regional ice charts (77.9%), followed by local and tailored information (72.6%), visible and IR images (71.6%) and SAR images (61.1%). The use of lower resolution satellite data such as PMR and other sources from radio bulletins and climatology were used with approximately 25% of the respondents (Figure 18).

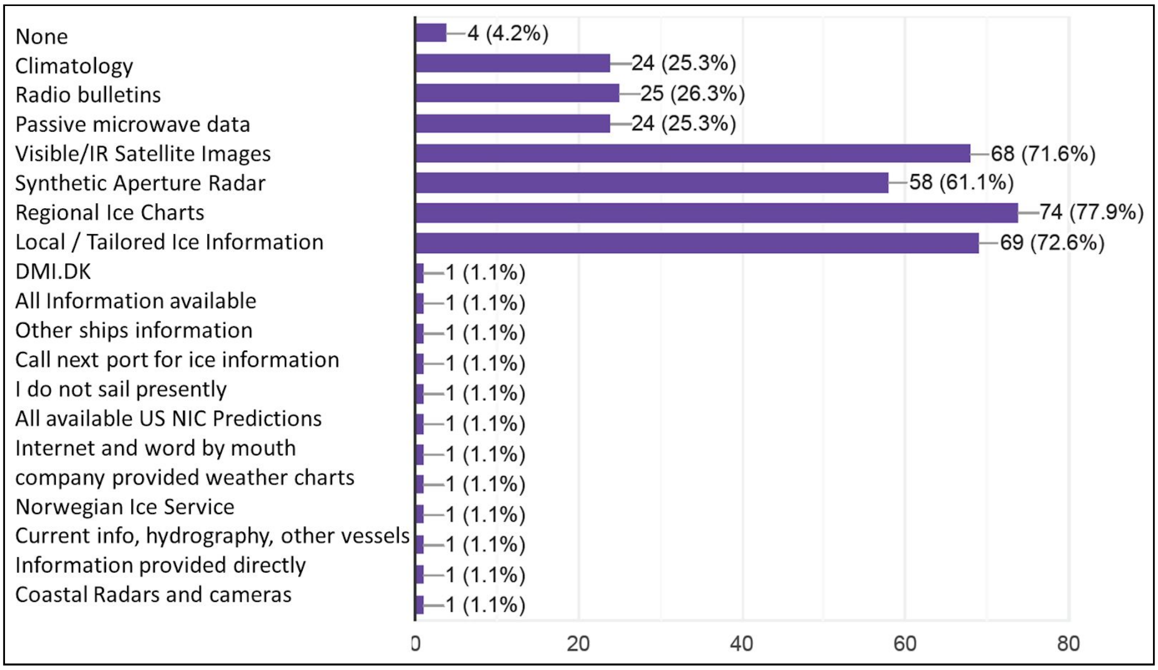
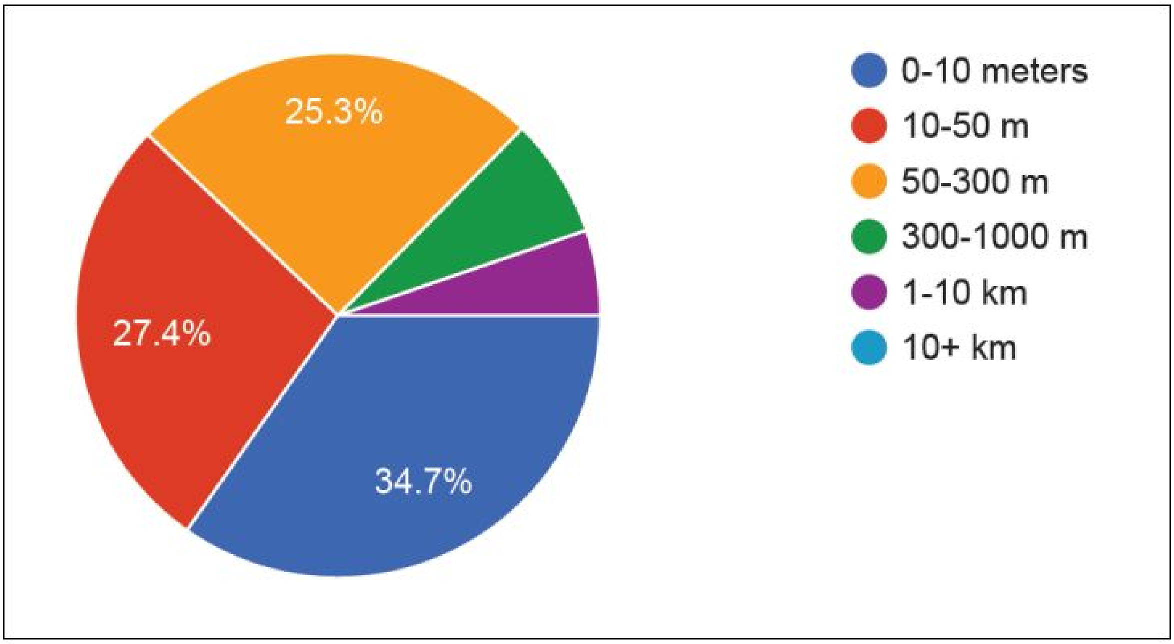


Figure 18. Responders use of ice information sources for navigation

Regarding the spatial scale that users operate, Figure 19 presents that approximately 87% of users require sub-kilometer scale spatial resolution of sea ice information and a greater percentage prefer higher resolution information than is currently offered.

Co-funded by the Horizon 2020 programme of the European Union



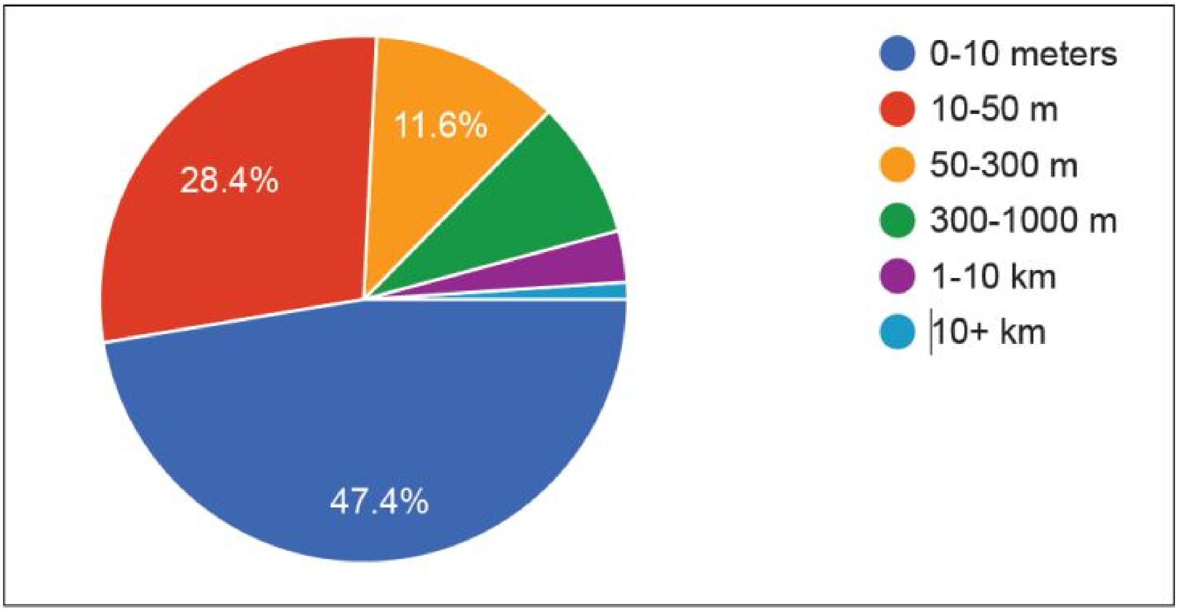


Figure 19. Acceptable minimum spatial resolution of sea ice information size (ie.e. iceberg, ridge, floe, and lead) (top) and optimal level spatial resolution (bottom)

Figure 20 reflects the geophysical challenges and the limitations in the Arctic during spring and summer and there are seasonal, as well as a regional variations to when sea ice begins the freeze-up and melt stages. For example, fast ice (ice attached to land and normally thicker and more stable

Co-funded by the Horizon 2020 programme of the European Union

than drifting ice) can appear different than that of drifting thinner ice types from satellites, depending on the snow loading and the amount of break-up. To reiterate, melting of the snow cover over the ice can result in presenting thicker sea ice types with the same signature as open water when monitoring from satellites. This makes it more time consuming for sea-ice analysts to interpret the satellite images from only one satellite source so they will use multiple sources as a quality control input and assess the situation based on all the latest and greatest satellite, meteorological and oceanographic information available. Additionally ice analysts have an intrinsic knowledge of how ice is changing and behaving in their area of expertise because they consistently follow the patterns, as service-based providers of information. Therefore, their local knowledge allows them to be experts with how the ice conditions are changing in a specific area and more adept at identifying anomalous conditions from the satellite images, rather than another person who is not familiar with local environmental conditions.

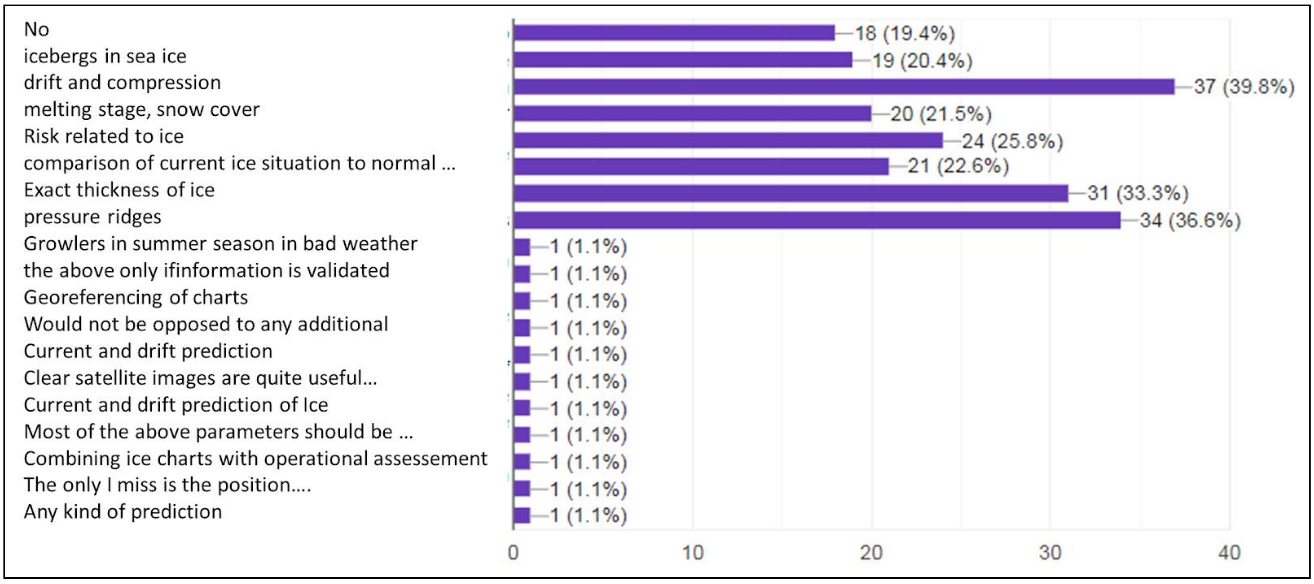
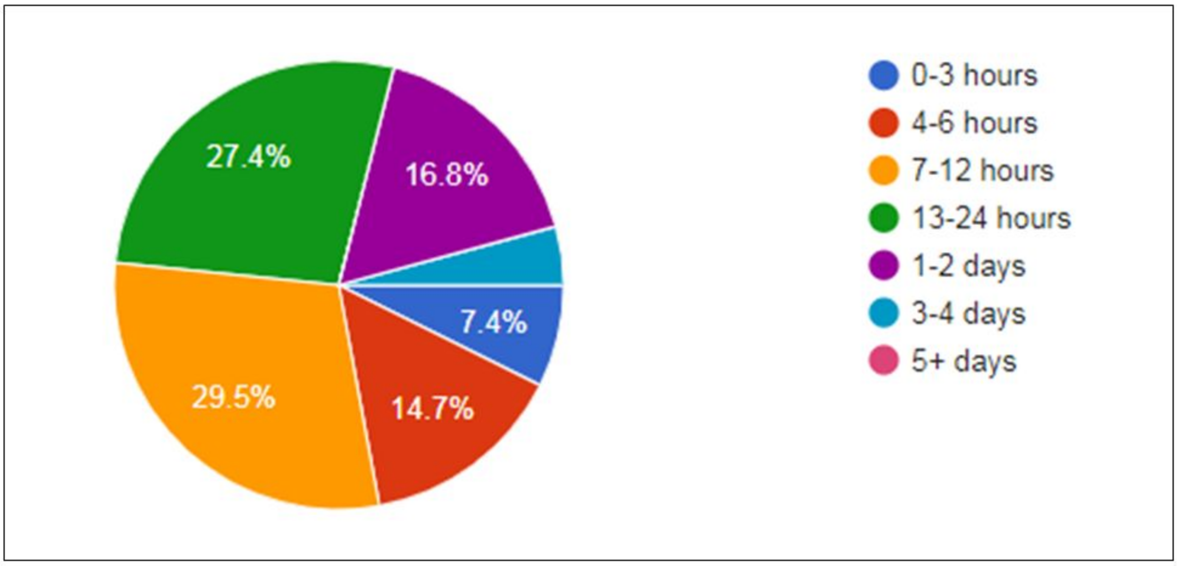


Figure 20. Ice parameters missing in ice products

Figures 21-22 presents the temporal resolution and latency preferred when receiving sea ice information. The acceptable and optimal level of timeliness for navigators are consistently less than one day and varies between the hour ranges. The 7-12 and 13-24 hour ranges appear to be ideal with a preference for improvements to 4-6 hours (Figure 21).

Co-funded by the Horizon 2020 programme of the European Union



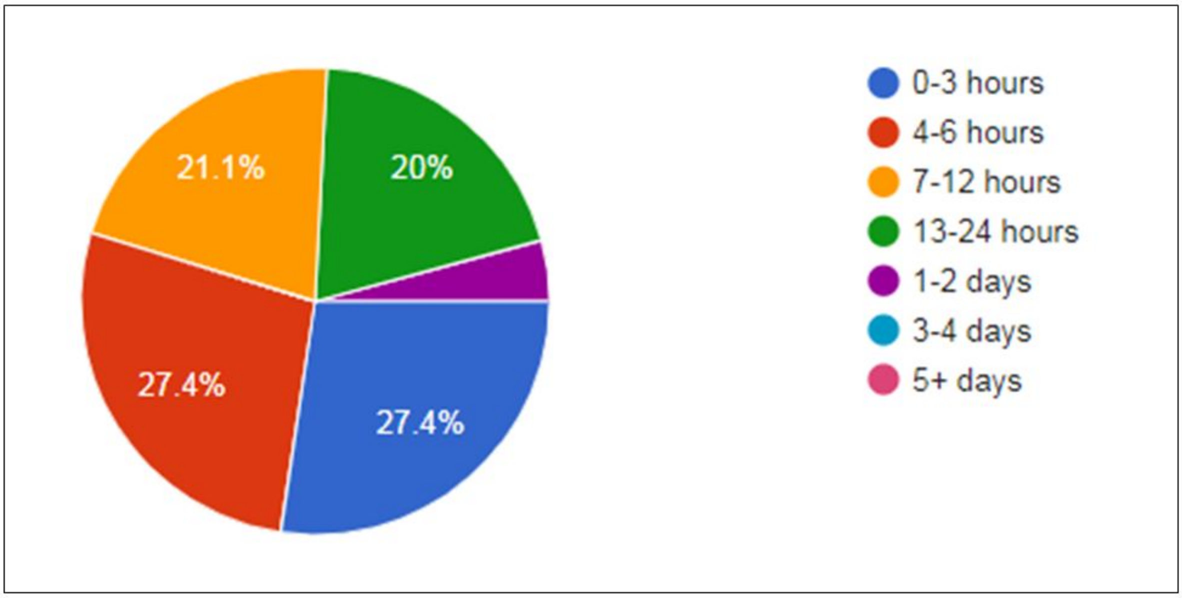
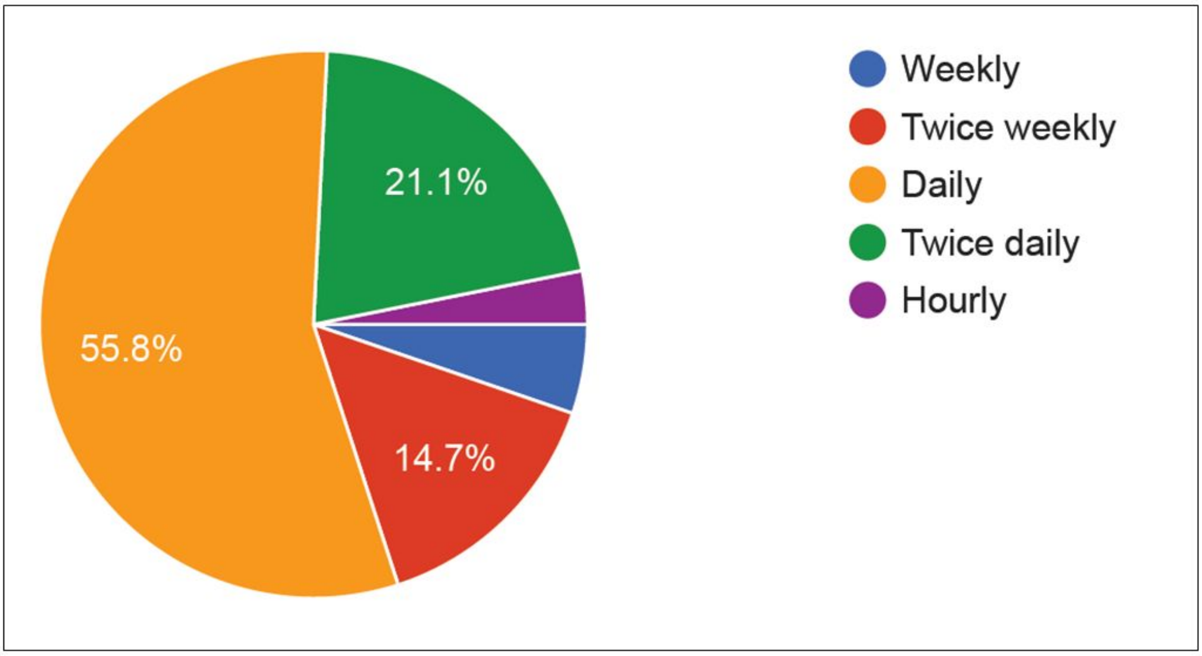


Figure 21. Acceptable level of product timeliness (top) versus optimal level of ice product timeliness (bottom)

Daily to twice daily is considered acceptable for over 75% of respondents but a greater percentage preferred twice daily information (Figure 22).

Co-funded by the Horizon 2020 programme of the European Union



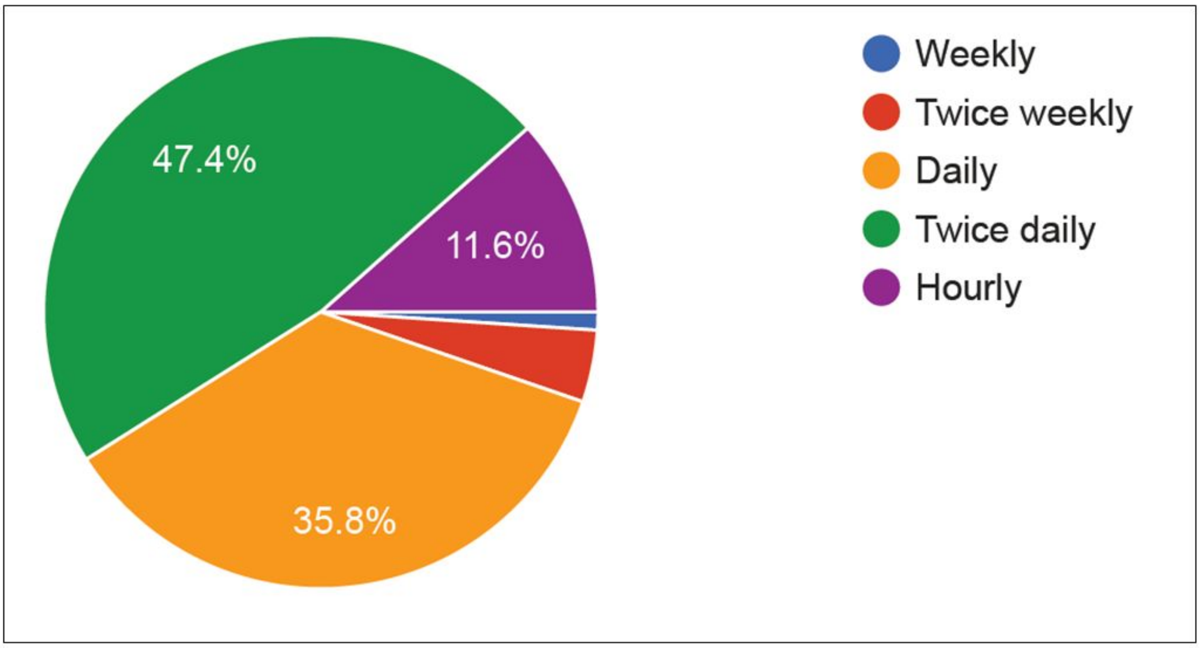
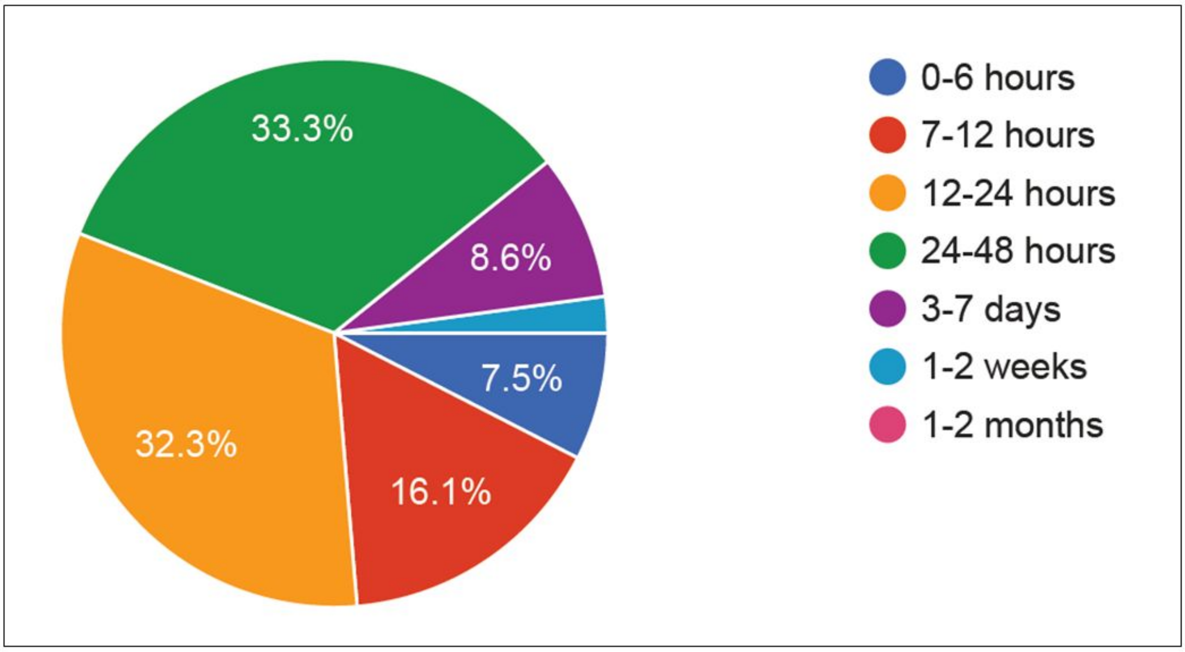


Figure 22. Respondents acceptable ice information update frequency (top) versus optimal update frequency (bottom)

For critical forecasting timescales, 65% of respondents would like to have forecasts on average 12-48 hours but a higher preference is for 12-24 hours (Figure 23).

Co-funded by the Horizon 2020 programme of the European Union



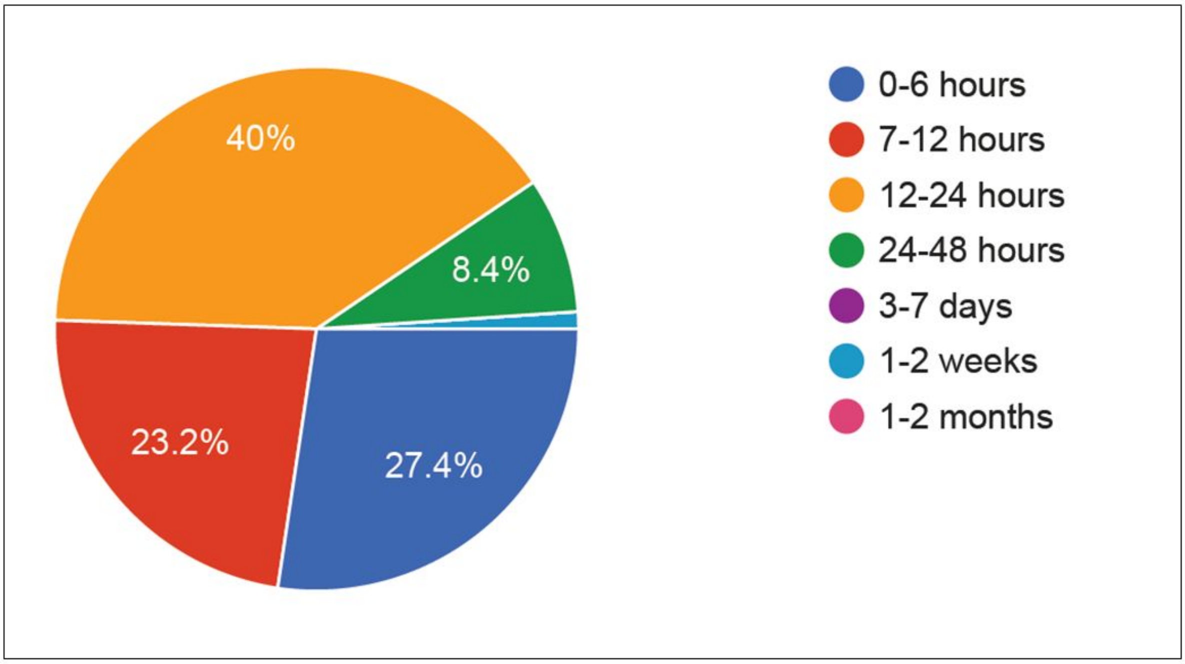


Figure 23. Critical ice forecasting time scale for operations far from ice (top), and in ice, near ice, near shore (bottom)

Co-funded by the Horizon 2020 programme of the European Union

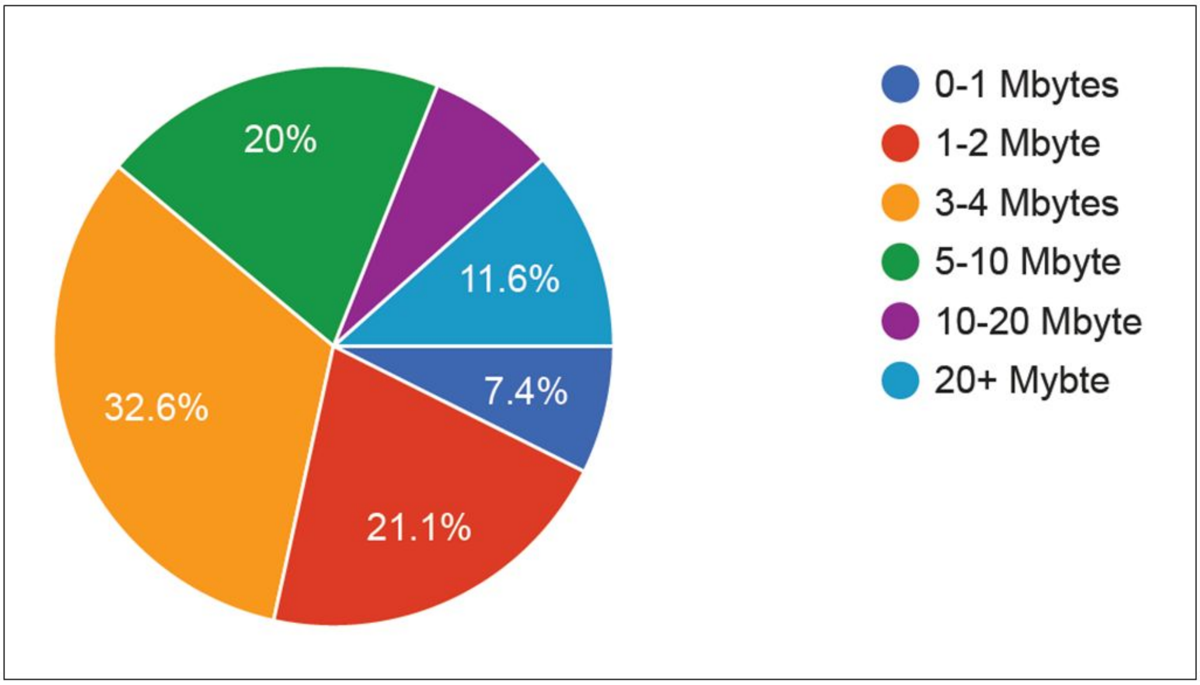


Figure 24. Maximum file size to be received for tactical operational maritime activities

Survey highlights and preliminary conclusions from the IICWG Survey:

- **Operational users** - Operational users use many different vessel types and requires near real time ice information for navigation. All vessel classes are represented in the survey from polar class (PC)1 icebreakers to vessels with no ice class. All polar ocean areas and ice regimes are well represented in this survey and 20% of respondents operate without any ice class in ice covered waters. The need for ice information is to conduct their activities in a safe, more efficient manner and to avoid a potential of an environmental impact. In general operational users require higher spatial and temporal resolution compared to the science users (Figure 19). They may use historical data for strategic planning and design, and forecasts for tactical planning as they often require current information as soon as possible after it is acquired. Very few of these users require low resolution, statistical data; while most of the users in the survey requires high-resolution data in near real-time.
- **Information products** - The majority or mariners use SAR or optical data for local and regional route planning, risk assessment and navigation (Figure 18). Many end users are not in a position/time or have the skills to work directly with raw EO data. They need information products and services that provide processed data in accessible formats. The acceptable ice product timeliness is 12 hours or less for 51,6% of the respondents, while the optimal ice product timeliness is 6 hours or less for 51,8% of the respondents (Figure 21). The acceptable ice product update is daily or more for more than 75% but 94% would like it

Co-funded by the Horizon 2020 programme
of the European Union

from daily to hourly (Figure 22). Additionally, the access to good metadata is an important component, because the information on data quality and uncertainty needs to be a part of the metadata.

- **Data platforms** - The solution to many of the identified gaps could be achieved through good data platforms and formats that would store sea ice information and provide polar integration. Over 93,7% of the respondents received ice products via the internet and 74,7% receive ice products as digital graphics as email briefings. Over half of the respondents (54,7%) would like to receive ice information in scalable formats in the future. These platforms should in the future use open web services that can be easily used by partners in the development of applications and systems (Figure 24).

The results from this survey clearly shows the same issues as the other surveys included in this project; there are multiple preferences for data formats and the different terms of understanding for NRT data among the users. There are some key areas with specific needs for improved operational monitoring with use of SAR such as the NSR (Northern Sea Route), Svalbard and Greenland waters including the Fram Strait. Climate modelling and research requirements are mainly focused on retrieving long reference datasets over periods of 10-100 years with a coarser resolution compared what processed SAR images can provide today.

Summary of Stakeholder and End-user Surveys

From the questionnaires the users were asked for what type of sources of sea ice information, parameters and data format they use on a daily basis. The overall feedback shows the majority of respondents use daily ice charts as a primary source for retrieving sea ice information (Fig X). The ice charts are being updated daily and the ship navigators can use this information for tactical and strategic route-planning within the Arctic. For users who are new to the Arctic area, daily ice charts provide guidance to understand and help to find the best routes through the sea ice. Personal experience is mostly used together with the ice charts, but this is users within shipping, icebreakers and few operators in polar tourism. The use of raw satellite data in conjunction with ice charts are mostly used by intermediate users or mainly with experienced data users, such as those in the scientific community, in order to provide value-added products to end-users. This user sector tends to be more stationary, with unlimited internet access at all times.

The participants were also asked about the level of detail they required in ice information products (eg. update frequency) for tactical and operational setting. Most of the participants answered daily or as often as possible (NRT). However, the definition of NRT sea ice data among the user sectors is a bit vague. For example in an operational setting the understanding of NRT sea ice information can vary from 30 minutes to a few hours, whereas for those working with forecasts can range from one to a couple of days to a week, depending on the use of the product, particularly for those that are designed for long-term planning and a climatological perspective over time. From an operational perspective, end-users can work on various spatial and temporal resolutions at one time or depending on whether or not they're in the early or late planning phase [39]. It is critical to understand the spatial and temporal scales that need to be considered when developing products

Co-funded by the Horizon 2020 programme of the European Union

useful for end-users because often many users have needs that often overlap at any given time or it could be one user that works on multiple scales at one time (Figure 25).

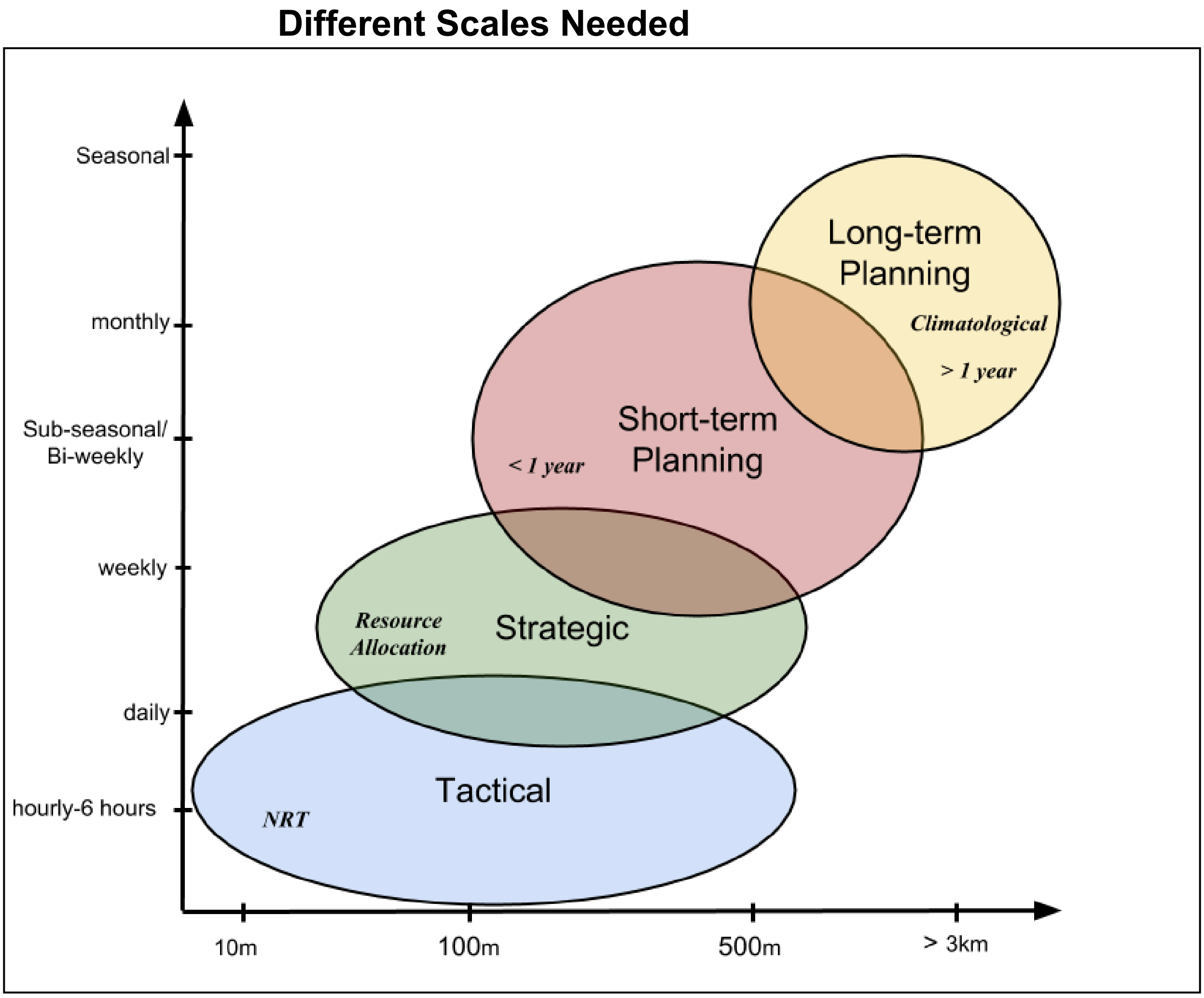


Figure 25: Diagram showing the different situation and the spatial resolution

Figure 25 will be expanded upon within KEPLER to illustrate where different users work on these scales. The KEPLER work package 1, subtask 1. 3 will include a description of NRT and high resolution definitions for different information providers from the tactical, planning and climate scales.

Part 6. Summary

Sections in this work package were separated by the relevant EC/ESA reports, workshop, outcomes and surveys conducted by national ice services in order to provide a comprehensive review of schemes that have been funded to better understand user-needs for the operational marine community. In this report, most end-users worked in tactical marine activities and a smaller percentage with short and long-term planning and logistics. Another smaller sector was represented

Co-funded by the Horizon 2020 programme
of the European Union

by research working with sea ice provision for operations. This sector can be simultaneously end-users, stakeholders and intermediate users and will be more focused in the KEPLER work package 1, subtask, 1.3. As stated in the summaries from Part 3 - 5, operational end-users consistently agreed on what was required regarding sea ice parameters, high spatial and temporal scales in which they operated, a preference for the use of more SAR data, the general need for data to be delivered in a standard and understandable format, and the desire for reliable sea ice forecasts at appropriate resolutions for tactical activities (between approximately 2-3 days). Another component was what types of sea ice information could be beneficial for long-term planning and towards providing information for probability (i.e. for Arctic logistics, resource extraction and regulatory information for ship-building requirements and the Polar Code). The mechanisms to obtain user-feedback varied which greatly impacted the results. This is due to differences in the project, workshop, or survey aim, how the questions/surveys were structured and the distribution and expertise of respondents. With the results collated in this report, the EC and ESA reports were long-term projects (i.e. 2+ years) motivated to provide guidance on future activities, and product and development needs for the general public. Workshops were 1-3 day activities that were targeted to answer specific questions towards a distinct group; and surveys were set-up due to internal interests and needs from applied institutes in order to assess their operations. An underrated and expected challenge is that it is also difficult to get most-end users to provide feedback on surveys and participate in meetings or workshops if it takes them away from their normal activities, especially if there is no additional incentive, such as financial or a direct result in product improvements or data exchange. Therefore, the same end-users may be targeted to provide feedback over multiple projects and activities.

Another challenge is regarding how information on user-needs are disseminated. Extensive survey and questionnaire results for user feedback are normally situated in national or internationally funded project reports that are not always easy to find or available after the life of the project. Though operational and applied research interact with end-users and conduct internal studies of user needs, it is not common practice to publish this information, especially in peer-reviewed articles. Additionally, the research community, understandably, does not include statistics on user-needs in their publications.

With these distinctions in mind, it may be difficult to find commonalities between various activities. As a consequence, in recent years end-users have expressed a great deal of frustration that they've spent the time providing constructive feedback (i.e. through surveys, workshops, meetings, etc.) and they are not clear about how this information is being used to improve services for their activities. Therefore, this work package aimed to evaluate basic information needs from what the operational marine community has expressed over the last approximately 15 years, how these needs have changed, and what has been previously done before to address these needs.

Due to the dynamic sea ice conditions, particularly during the Spring and Summer, when most navigators operate, spatial resolution of sea ice information is of particular concern. Effects of regional weather systems impact how the ice changes, especially when it's less compact and more unstable. The current state of information provision cannot always provide details on sea ice features such as rheology on the scale that would improve support for the operational marine

Co-funded by the Horizon 2020 programme
of the European Union

community; unless it is administered by private or commercial services and those arrangements should be set-up in advance.

From the material collected for this report, some common themes on spatial resolution were combined in a summary table to show the level of interest in spatial scales for different parameters based on whether these were for tactical or planning purposes (Table 13). The level of interest is overwhelming for high resolution products for tactical purposes, where high resolution is understood to be a scale of 1 kilometer or better.

Low resolution, i.e. spatial resolutions worse than 1 kilometer are only of interest at the planning stages for most users, and for the research community because it is deemed too coarse for navigation and tactical use and cannot detect features important for maritime operations such as ice edge, ice concentration, ice drift and polynyas (See Part 3: ICEMON, ESA POLARIS AND CPEG reports). It is therefore difficult for the research community to translate the results of their current focus into sustainable, marketable products and services.

Co-funded by the Horizon 2020 programme of the European Union

Table 13. Summary of user requirements surveys and reports, key parameters assessed, and their conclusions on spatial resolution according to tactical and planning timescales.

		% of users
	No interest	
	Low interest	> 0% < 12.5%
	Medium interest	> 12.5% < 25%
	High interest	>25%

Tactical ⟵⟶ Planning

		SPATIAL SCALES BY USER	High Resolution					Low Resolution
	Name	User Type	0 - 10 m	10 - 50 m	50 - 300 m	300 - 1000 m	1 - 10 km	10+ km
Surveys	IICWG	Navigators						
	NIS	Shipping, Icebreakers, Logistics/Planning and Polar Tourism						
Report	ACCESS	Shipping						
		Oil and Gas						
		Research						
		Other						
	SIDARUS	Marine Safety						
		Marine and Coastal Envir.						
		Climate and Forecs						
Workshop	Copernicus Maritime Survellance (EMSA) - Baltic	Marine safety, security, and marine environment monitoring						
	Copernicus Maritime Survellance (EMSA) - Arctic	Marine safety, security, and marine environment monitoring						
		SPATIAL SCALES BY PARAMETER						
		Parameter	0 - 10 m	10 - 50 m	50 - 300 m	300 - 1000 m	1 - 10 km	10+ km
Report	CPEG	Thin Sea Ice (Research)						
		Thin Sea Ice (Navigation)						
		Sea Ice Type (Research)						
		Sea Ice Type (Navigation)						
		Iceberg Detection (Research)						
		Iceberg Detection (Navigation)						
		Iceberg Drift (Research)						
		Snow depth/Density (Research)						
		Snow depth/Density (Navigation)						
	ESA Polaris	Ice thickness						
		Stage of Development						
		Extent						
		Structure/Age						
		Topography						
		Motion						
		Iceberg						
		Snow on sea ice						
		Drift						
		Sea ice deformation						

Operation ice services focus ⟶ | ⟵ Current CMEMS focus

Co-funded by the Horizon 2020 programme of the European Union

From the amount of time and effort that has been spent on understanding and identifying user-needs for operational marine community, it is clear that this sector is considered to be high-priority for the EC, ESA, operations and research. However, it is also evident that user needs have not changed too much because the same requests are still being reiterated from current feedback in the last few years [7, 8, 10, & 11 and Part 4 and 5 of this report].

The first mandate for ice services is to constantly update their products with the latest satellite information available in order to provide the most accurate routine products, therefore, they will often survey users to assess their needs and implement changes accordingly. Operational services have the flexibility to modify their products while maintaining compliance with the WMO standards defined by a consensus of all ice services [41 & 42]. Since the launch of the ESA Sentinel's beginning in 2014, information provision to the marine operational community has greatly improved due to the increase of higher spatial and temporal resolution from different sensors, as well as third-party services that develop value-added products for users. However, end-users continue to require essential improvements for sea ice information and forecasts that have not been able to be developed. From the interest in the research and ice information provision community to resolve these issues, it is clearly not due to a lack of trying.

Regarding projects and workshops that continue to request information user-needs, this begs the question as to why there is so much overlap and repetition; and why a single user feedback survey has not been considered sufficient. Further questions that need to be addressed by the European Commission and the Copernicus programme are:

- **What has been done from the research and EU community to address these issues?**
- **Do these results suggest some kind of misunderstanding to plan and launch satellites with the right capability because the current state is considered to be adequate?**

Though the researcher community state plans to resolve these issues:

- **Is the satellite or technical capability currently available to address current needs? In what way?**
- **Is the satellite or technical capability going to be available in a timely manner to keep European research competitive on operational monitoring issues, or further than 10 years in the future?**

In going forward, it is necessary to clarify these questions to identify how the operational, information provision and research community can efficiently communicate user-needs to the EC and ESA to address all user needs in a transparent and understandable manner.

Co-funded by the Horizon 2020 programme
of the European Union

Part 7. Appendix

a. ACRONYMS

ACCESS: Arctic Climate Change, Economy and Society

AECO: Association of Expedition Cruise Operators

AF: Arctic Frontiers

AIS: Automatic Identification System

AMSR-2: Advanced Microwave Scanning Radiometer 2

ARCUS: Arctic Research Consortium of the U.S.

ARTES: ESA Advanced Research in Telecommunications

ASF: Arctic Shipping Forum

ASIPSW: Arctic Sea Ice Prediction Stakeholders Workshop

AVHRR: Advanced Very High Resolution Radiometer

BHS: German Federal Maritime and Hydrographic Agency

CEOS: Committee on Earth Observation Satellites

CliC: Climate and Cryosphere Project

CMEMS: Copernicus Marine Environmental Service

CMS: Maritime Surveillance Service

COMNAP : Council of Managers of National Antarctic Program

CPEG: JRC Technical Report for User Requirements for a Copernicus Polar Mission:

EC: European Commission

EIS: European Ice Services

EMSA: European Maritime Safety Agency

ENC: Electronic Navigational chart

EO: Earth Observation

ERA – NET: European Research Area Network

Co-funded by the Horizon 2020 programme of the European Union

ESA: European Space Agency

FMI: Finnish Meteorological Institute

GEOSS: Group on Earth Observations and its Global Earth Observation System of Systems

GIS: Greenland Ice Services

GMES: Global Monitoring for Environment and Security

ICEMAR: Copernicus pilot program ice service for maritime operations

ICEMON: Sea ice monitoring for marine operation safety, climate research, environmental management and resource exploitation in Polar Regions

IICWG: International Ice Charting Working Group

IGOS: The Integrated Global Observing Strategy

IMO: International Maritime Organization

ISABELIA: Improvement of Maritime Safety in the Baltic Sea through Enhanced Situational Awareness

JRC: Joint Research Commission

KEPLER: Key Environmental Monitoring for Polar Latitudes and European Readiness

MET: Norwegian Meteorological Institute

Metarea: Meteorological area

Navarea: Navigational area

Navtex: Navigational telex

NIS: Norwegian Ice Service

NRT: Near-real time

PC: Polar class

PMW: Passive Microwave

PSTG: Polar Space Task Group

SALIENSEAS: Saliency of climate services for marine mobility Sectors in European Arctic Seas

SaR: Search and Rescue

SAR: Synthetic Aperture Radar

Co-funded by the Horizon 2020 programme of the European Union

SCAR: Scientific Committee for Antarctic Research

SIDARUS: Sea ice downstream services for Arctic and Antarctic Users and Stakeholders

SIPN: Sea Ice Prediction Network

SMHI: Swedish Meteorological and Hydrological Institute

SPICES: Space-borne observations for detecting and forecasting sea ice cover extremes

UCL: University College London

UiB: Bjerknes Centre for Climate Research

VNIR: Visible Near Infrared

WRCP: World Research Climate Project

b. FMI Survey

The survey from FMI can be found at:
https://drive.google.com/open?id=1y19WkomoCEpjWfHyVgv_X3ZjcujsbAGU

c. ASF Survey

The survey from the ASF can be found at:
https://drive.google.com/file/d/1pj7ziOswsG5jywKTB3PLEh5Vho9nUVbq/view?usp=sharing

d. AECO Survey

The survey from AECO can be found at:
https://drive.google.com/open?id=1gMc8hKX1XSYAm_936NbH93updwcx3Otz

References

1. Arctic Climate Change, Economy and Society (ACCESS)(2012). D2.14: Assessment of current monitoring and forecasting requirements from users and international providers of services.
2. Carpentier, S., Neal Young & Jan Lieser (2015). 'A case for coordinating Antarctic marine weather services.` SCAR COMNAP Sea Ice Challenges Workshop meeting in Hobart, Tasmania in 12-13 May 2015. Available at: https://www.comnap.aq/Publications/Comnap%20Publications/COMNAP_Sea_Ice_Challenges_BKLT_Web_Final_Dec2015.pdf
3. Carpentier, Scott (2015). 'COMNAP Survey Results and Perspectives:' 16th IiCWG, Rostock, Germany. Available at: ftp://sidads.colorado.edu/pub/projects/noaa/iicwg/IICWG-2015/Carpentier_COMNAP_Survey_Results_and_Perspectives.pdf

Co-funded by the Horizon 2020 programme of the European Union

4. COMNAP Antarctic Roadmap Challenges report: Council of Managers of National Antarctic Programs (COMNAP)ARC report.
5. Copernicus Marine Environment Monitoring Service (CMEMS) 2016 Position Paper on polar and snow cover applications
6. DG Research and Innovation/ESA Climate Task Force report (November 2016)
7. Duchossois, G., Strobl, P. and Toumazou, V. (2018) European Commission Joint Research Commission Technical Reports User Requirements for a Copernicus Mission: Phase 1 Report - User Requirements and Priorities
8. Duchossois, G., Strobl, P. and Toumazou, V. (2018) European Commission Joint Research Commission Technical Reports User Requirements for a Copernicus Mission: Phase 2 Report - High-Level Mission Requirements
9. EMSA Copernicus Maritime Surveillance Service User Requirements Workshop Report, V1.0, 20/12/2016.
10. ESA Polaris (2016) User Needs and High-Level Requirements for Next Generation Observing Systems for the Polar Regions: Summary Report. Prepared by Polar View Earth Observation Ltd.
11. ESA Polaris Gaps and Impact Analysis Report (D2.1) (2016). D2.1: Gaps and Impact Analysis Report. Prepared by Polar View Earth Observation Ltd.
12. EU-PolarNet Deliverable 1.8 Minutes of a workshop with international partners and stakeholders at ASSW
13. EU-PolarNet Deliverable no. D3.3, Survey of existing use of space assets by european polar operators, including recommendations for improved coordination
14. EU-PolarNet Deliverable no. 3.6, Gap Analysis highlighting the technical and operational requirements of the European Polar Research Programme for satellite applications
15. EU-PolarNet Deliverable no. D3.4, Survey of Polar Commercial Infrastructure
16. ICEMON Core User Group Executive Report, Deliverable No. U8 (2004). Core User Group Executive Report. Prepared by Goodwin, H.
17. ICEMON Data Needs and Availability Prospectus, Deliverable No. C12 (2004): Data Needs and Availability Prospectus. Prepared by Goodwin, H.
18. ICEMON Service Utility Report, Deliverable No. U7 (2004): Service Utility Reports. Prepared by Goodwin, H. and Hall, R.
19. ICEMON Core User Needs Dossier, Deliverable No. U5 (2004). Core Users Need Dossier. Prepared by Goodwin, H.
20. IICWG 12th meeting presentation from the Applied Science & Research Standing Committee Report (2011). Available at: ftp://sidads.colorado.edu/pub/projects/noaa/iicwg/post-meeting/2011/meeting_docs/ASRSC_Report.pdf
21. IMO. "GUIDELINES FOR SHIPS OPERATING IN ARCTIC ICE-COVERED WATERS" (PDF). Archived (PDF) from the original on 2012-12-25. Retrieved 2019-06-28.
22. IMO. "GUIDELINES FOR SHIPS OPERATING IN POLAR WATERS" (PDF). Retrieved 2019-06-28.

Co-funded by the Horizon 2020 programme of the European Union

23. ISABELIA: Improvement of Maritime Safety in the Baltic Sea through Enhanced Awareness (2013). D1: User/Stakeholders overview and User Requirements, version 1.1.
24. ISABELIA: Improvement of Maritime Safety in the Baltic Sea through Enhanced Awareness (2013). D1: Results from additional user needs and requirements interviews, version 0.3.
25. Key, J. (2007). Integrated Global Observing Strategy Cryosphere Theme Report (IGOS). Report number: WMO/TD-No. 1405, Affiliation: World Meteorological Organization.
26. Lamers, M., Knol, M., Müller, M., Blair, B., Jeuring, J., Rasmussen, T. & Sivle, A. (2018). Enhancing the saliency of climate services for marine mobility sectors in European Arctic seas (SALIENSEAS): Stakeholder Advisory Group Workshop Report. Wageningen University; 2018. 28 p.
27. Liu, J., Chen,Z., Hu,Y., Zhang,Y., Ding,Y., Cheng,X., Yang,Q., Nerger,L., Spreen,G., Horton,R., Inoue,J., Yang,C., Li, M., & Song,M. (2018), Towards reliable Arctic sea ice prediction using multivariate data assimilation. Sci. Bull., 64, 63-72.
28. Melia, N., Haines, K., & Hawkins, E. (2016). Sea ice decline and 21st century trans-Arctic shipping routes. Geophysical Research Letters, 43(18), 9720-9728. Polar Space Task Group report strategic plan 2015-2018
29. Polar Space Task Group Strategic Plan (2015-2018), Final Version 2015: http://lps16.esa.int/posterfiles/paper2286/PSTG_StrategicPlan_final_Nov15.pdf
30. Pope, A., Wagner, P., Johnson, R., Shutler, J., Baeseman, J., & Newman, L. (2017). Community review of Southern Ocean satellite data needs. Antarctic Science, 29(2), 97-138. doi:10.1017/S0954102016000390
31. Reid, Tyler & Walter, Todd & Blanch, Juan & Enge, Per. (2015). GNSS Integrity in the Arctic
32. SCAR COMNAP Sea Ice Challenges Workshop meeting in Hobart, Tasmania in 12-13 May 2015: https://www.comnap.aq/Publications/Comnap%20Publications/COMNAP_Sea_Ice_Challenges_BKLT_Web_Final_Dec2015.pdf
33. Serreze, M. C., & Stroeve, J. (2015). Arctic sea ice trends, variability and implications for seasonal ice forecasting. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 373(2045), 20140159.
34. SIDARUS (2011): Seventh Framework Programme FP7-SPACE-2010-1 Stimulating the development of downstream GMES services: D1.1 User Requirement review document.
35. Smith, L. C., & Stephenson, S. R. (2013). New Trans-Arctic shipping routes navigable by midcentury. Proceedings of the National Academy of Sciences, 110(13), E1191-E1195.
36. SPICES: https://www.h2020-spices.eu/
37. Tonboe, R. T., Eastwood, S., Lavergne, T., Sørensen, A. M., Rathmann, N., Dybkjær, G., ... & Kern, S. (2016). The EUMETSAT sea ice concentration climate data record. The Cryosphere, 10(5), 2275-2290.
38. US Navy (2014). U.S. Navy Arctic Roadmap 2014 - 2030. Online at: http://www.navy.mil/docs/USN_arctic_roadmap.pdf

Co-funded by the Horizon 2020 programme of the European Union

39. Wagner, P., Hughes, N., Bourbonnais, P., Stroeve, J., Bhatt, U., Wiggins, H., Little, J. and Fleming, A. (2019) Sea-ice Information and Forecast Needs for Industry Maritime Stakeholders. Polar Geography Special Issue (*under review*)
40. Wagner, T. (2015). Future needs of remote sensing science in Antarctica and the Southern Ocean: A report to support the Horizon Scan activity of COMNAP and SCAR. https://www.comnap.aq/Projects/SiteAssets/SitePages/ARC/Satellite%20Studies%20Whitepaper_%2021%20July2015.pdf
41. WMO publication no. 574 (2017) : Sea-Ice Information Services in the World, Edition 2017.
42. WMO No. 259, volume 1 – Terminology and Codes, Volume II – Illustrated Glossary and III – International System of Sea-Ice Symbols) by March 2014 (5th Session of JCOMM Expert Team on Sea Ice)

Related Publications and Dissemination Output

[If applicable – make sure you add it to the portal too].

Co-funded by the Horizon 2020 programme of the European Union