Integrated Arctic Observation System

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Risk Assessment System V1

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EXECUTIVE SUMMARY

The motivation for developing an integrated risk assessment system is to provide insights and to simplify the process of integration, analysis and use of INTAROS data within Arctic marine risk assessments. This will support business planning and development in the Arctic region. An overview of information, products and services requested by users representing primarily the private commercial sector has been collected via stakeholder dialog and the INTAROS user survey. Among the most important products identified, are risk assessments associated with safe navigation and hydrocarbon extraction. Other relevant products are operational services harnessing real time observations and/or short-term forecasts and ship routing services.

The risk assessment system will be built upon "The Arctic Risk Map" (https://maps.dnvgl.com/arcticriskmap/), a system designed to present data from the Arctic marine environment in an easily accessible way with focus on clear and transparent communication. Selected use cases include sea ice and anthropogenic noise and they are presented with some requirements towards input data and parameters.

The report describes a first version of the envisioned system. It specifically addresses these use cases in light of their value to the industry and potential for uptake. The outcomes of the final system will be reported in D6.15 (September 2021).

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1. Introduction

The world's need for energy is driving interest in further industrial activity in the Arctic, yet the conditions of the region are highly variable depending on the type of activity, location and time of year. This creates a complex risk picture, and stakeholders therefore need a sound decision basis for understanding the risks associated with Arctic development and transportation.

The motivation for developing an integrated risk assessment system is to provide insights and to simplify the process of integration, analysis and use of INTAROS data within Arctic marine risk assessments. This will support business planning and development in the Arctic region. An overview of information, products and services requested by users representing primarily the private commercial sector has been collected via INTAROS user survey (Buch et. al, 2019), and among the most important products identified are risk assessments associated with safe navigation and hydrocarbon extraction. In addition, operational services with real time observations and/or short-term forecasts and ship routing services are among the most relevant products (Buch et. al, 2019).

DNV GL will build the risk assessment system upon "The Arctic Risk Map" (https://maps.dnvgl.com/arcticriskmap/), a system designed to present data from the Arctic marine environment in an easy accessible way with focus on clear and transparent communication (Figure 1). In addition to data visualization, the risk assessment system will be demonstrated with some analytical capabilities for specific analysis on relevant data like sea ice and ocean acoustics. Sea-ice represents a key risk influencing factor and presenting sea-ice data from a coherent study of past and foreseen future sea-ice conditions allows operators and authorities and other key stakeholders to assess current and emerging risks. Such assessments form a basis for operational and strategic planning. The risk assessment system as such is not about implementing a specific risk analysis methodology, but rather to give access to quantitative data and information concerning important risk shaping factors in the Arctic. Such access enables transparent risk-based discussions targeting various types of marine risk assessments. The current report describes Version 1 of the Risk Assessment system (system architecture and selection of use cases), while the final system will be reported in D6.15 (September 2021). DNV GL's plans for the system, and an overview of relevant use cases, were presented at the INTAROS virtual *Workshop on Ocean and Sea Ice* in late April 2020.

A premise for a successful system implementation is coordination, collaborative effort, and sharing of results from activities undertaken in INTAROS Task 6.3 *Ice-Ocean statistics*. The task includes the following five sub-tasks covered by different parties of INTAROS:

1. Integrative analysis: ice-ocean statistics using remote sensing and in situ measurements.

2. Baseline description of Arctic Acoustic environments.

3. Ice-ocean modelling and assimilation experiments.

4. Risk management system for maritime activities.

5. Formulation of user applications in maritime sector in collaboration with stakeholders.

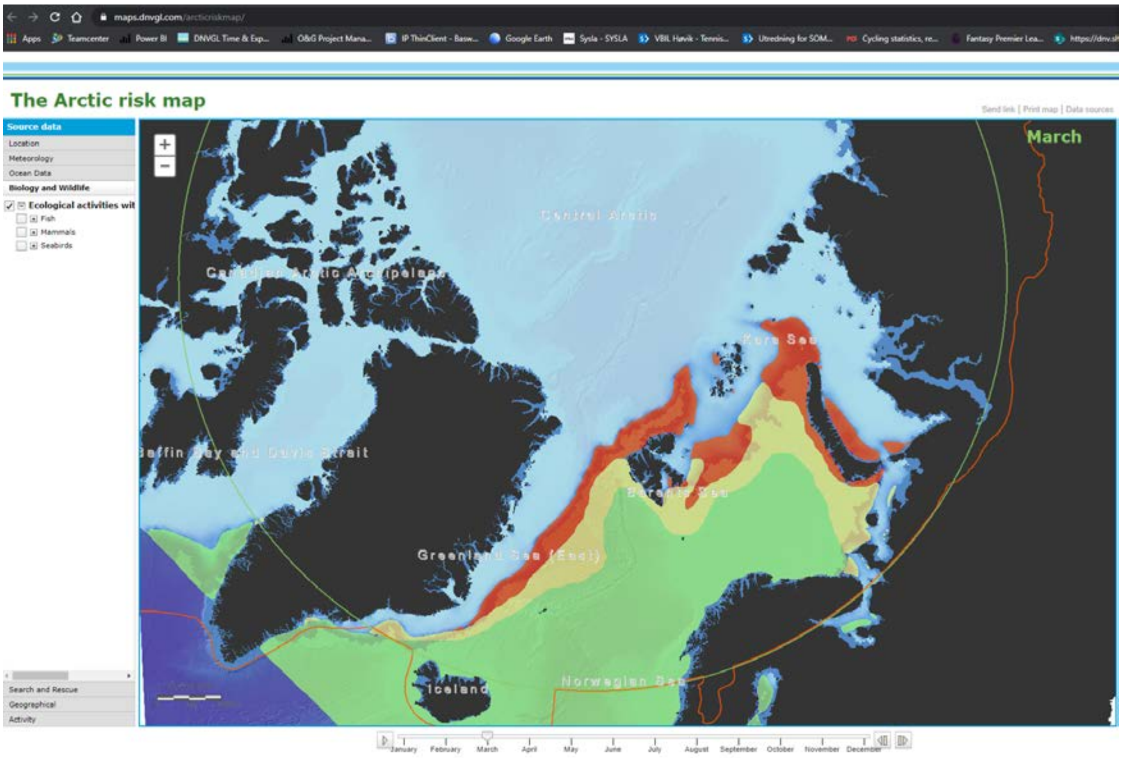
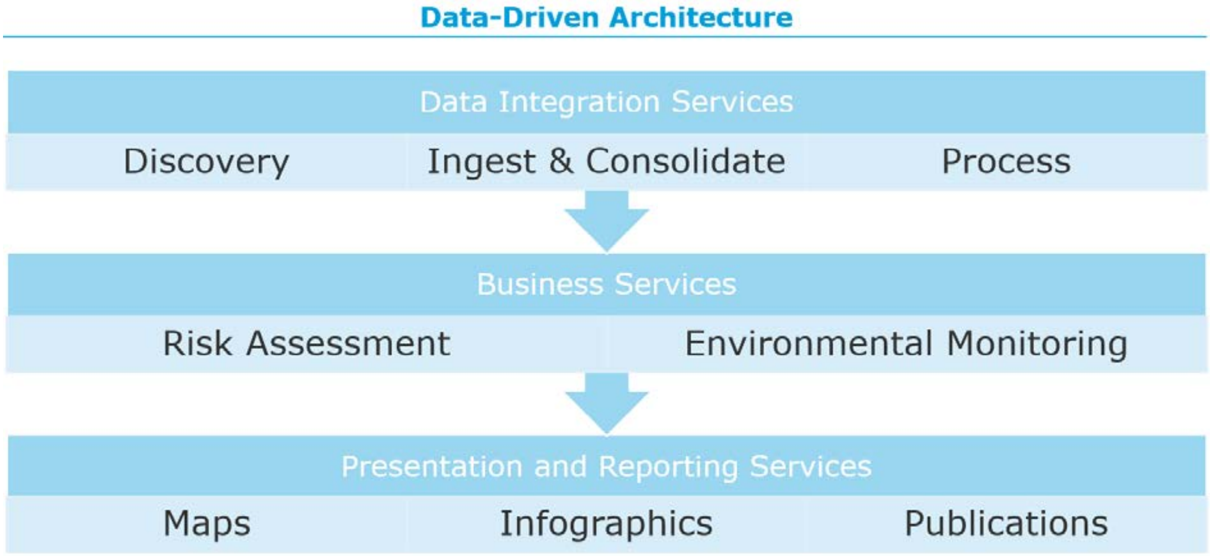


Figure 1. Screenshot from the Arctic Risk map from DNV GL (https://maps.dnvgl.com/arcticriskmap) showing marine icing predictions (high in red, medium in yellow and low in green) in March.

2. The Risk Assessment system

System architecture

A prerequisite to the system is to enable ready integration of sea ice data from disparate sources. Sea ice data are not all coherent in terms of resolution, spatial and temporal coverage, quality, means of acquisition, reliability, and physical properties modelled, so there is a need for harmonization and consolidation of modelled- and in-situ data. The risk assessment system adopts a data-driven architecture to facilitate this (Figure 2). Core to the platform are data ingestion and curation services, a high-resolution met-ocean data archive, and the modelling tier. The modelling tier will comprise algorithms for calculation of sea ice metrics and GIS capacity for spatial analysis and visualization. The system will use a cloud-based infrastructure to serve different components of the service.



Approach to data integration and analysis

1. Determine relevant data sources to the analysis (i.e. the use cases)
2. Qualify data with respect to quality, consistency and reliability
3. Assemble and integrate data in ArcGIS
4. Spatial analysis to derive statistics on phenomena and their co-variation
    a. Capture spatial and temporal variation
    b. Location specific risk analysis

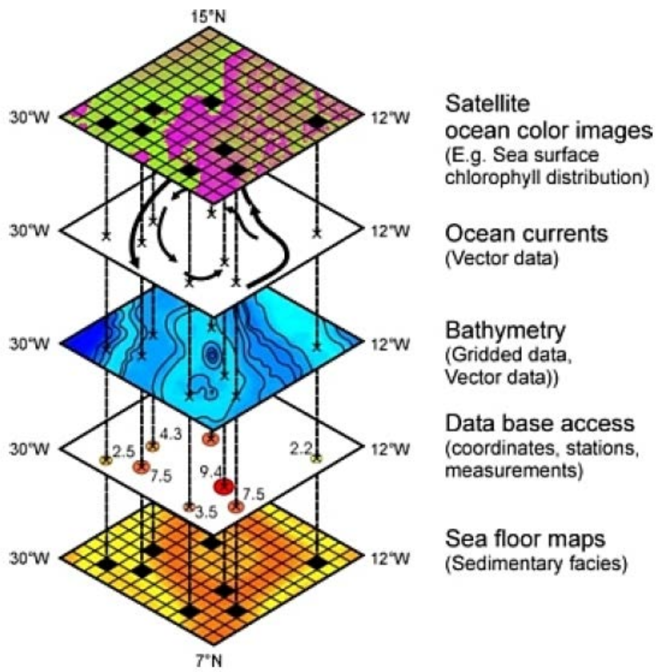


Figure 2. Schematic view of data integration workflow.

Description of Use Cases

Use case: Sea ice

To support design and scoping of viable use cases, a series of interviews with DNV GLs industry partners have been conducted. In addition, the INTAROS user survey (Buch et. al, 2019) has provided input on stakeholder needs. Some apparent use cases were identified. The first, was a use case targeting improved application of sea ice data in general. Sea ice data is used extensively in artic marine risk assessments, such as in:

- Navigation, vessel route planning (ice frequency, icing likelihood and level of icing)
- Vessel design, winterization criteria, ice class, IMO polar code requirements (ice load)
- Field development (downtime due to ice, design of ice management systems)

- Operational support (tactical ice management)
- Ship-to-ship loading operations (operability, weather windows)
- Lifeboat evacuation
- Oil spill contingency (ice conditions, operability)
- Oil trajectory modelling
- Biological resources

A high-resolution historical ice met-ocean archive will contribute to more accurate planning and design basis, as we better resolve eddies and local bathymetric conditions. This will again make planning more precise, shorten waiting times for a suitable weather window, and allow for a design which is optimized with respect to relevant environmental loads. The benefits are reduced capital expenditures related to losses from environmental loads, and cuts in operational expenses due to improved efficiency and resource utilization.

A previous planning tool for visualization and analytics on sea ice data has been made by DNV GL, namely the Ice Mapper tool. The Ice Mapper allows for analysis of historical ice conditions in all regions of the Arctic (Figure 3). Depending on the end-user, sea ice conditions can be visualized by different metrics such as the mean ice concentration (fraction of cell covered by ice) over a period, or the sea ice persistence metric which is a key figure adopted in the Barents Sea management plan (Meld. St. 20 (2019-2020)) and relevant to describe ice edge dynamics.

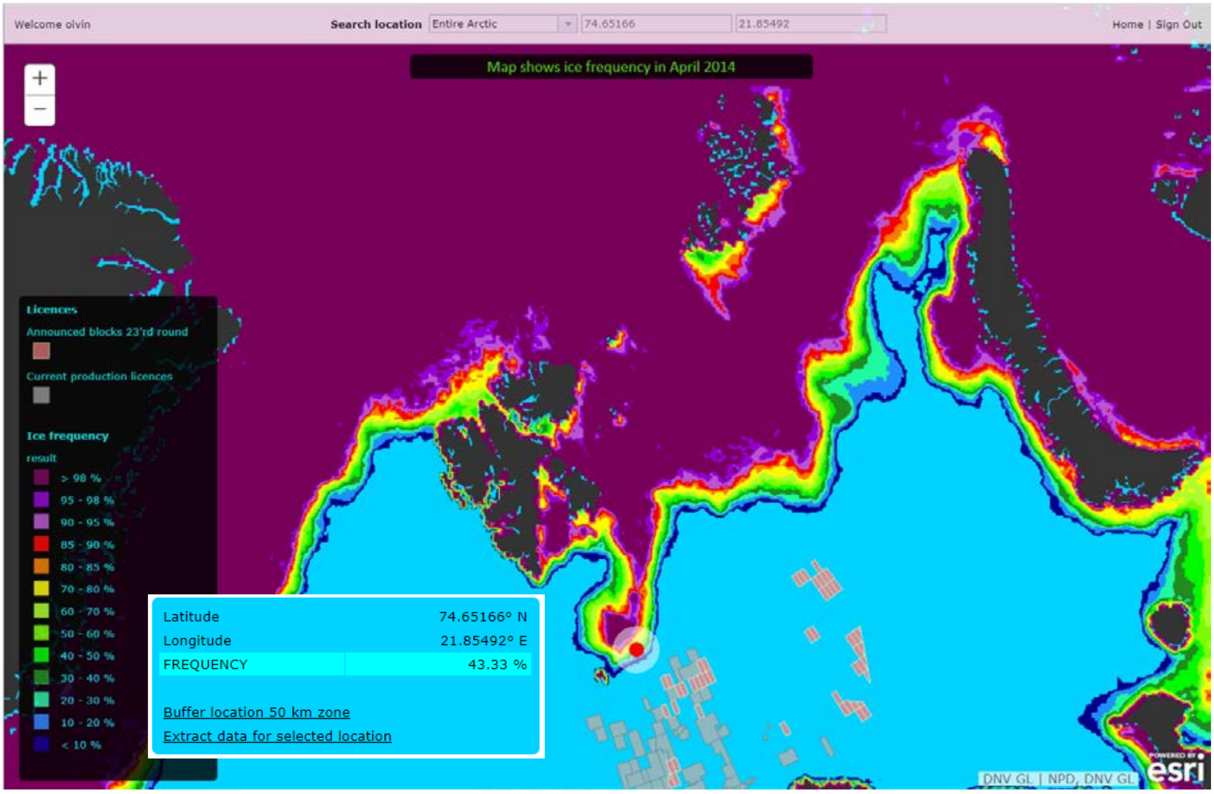


Figure 3. Screenshot from the Ice Mapper tool from DNV GL showing probability for ice frequency >15% for April 2014

For direct applicability to risk assessments, both towards environmental risk and towards shipping risk, the system shall deliver a service to address sea ice frequency and concentration.

10-year reanalysis synthesis

As part of Activity 3, INTAROS Task 6.3, UHAM (University of Hamburg) has provided a 10-year high-resolution synthesis of sea ice data for the circumpolar Arctic (Lyu et. al, 2020). The product includes sea ice thickness and sea ice drift velocity as valued parameters. The product assimilates real observations of sea ice conditions obtained from ships and other platforms and is a valuable contribution to communicating expected sea ice conditions in the area. It should be noted that the synthesis covers past conditions on a daily means basis, and that it would be desirable to extend the synthesis to cover later years post 2016.

Sea ice thickness representations (Figure 4) are valuable to shipping risk assessment as they are used in ship routing schemes. Class requirements, the IMO Polar Code (IMO, 2017), POLARIS (IMO, 2016) and Marine Safety Canada enforces regulation on access to waters under different ice regimes. Under the AIRSS system (Transport Canada, 2018), a decision to enter a given ice regime is based on the quantity of dangerous ice present, and the ability of a vessel to avoid dangerous ice along the route. The inclusion of sea ice thickness, along with other sea ice characteristics, thus helps to classify dangerous ice and tailor a more accurate representation with respect to end-use. For future representations, it is also desirable to consult climate- and sea ice predictions to further refine this view.

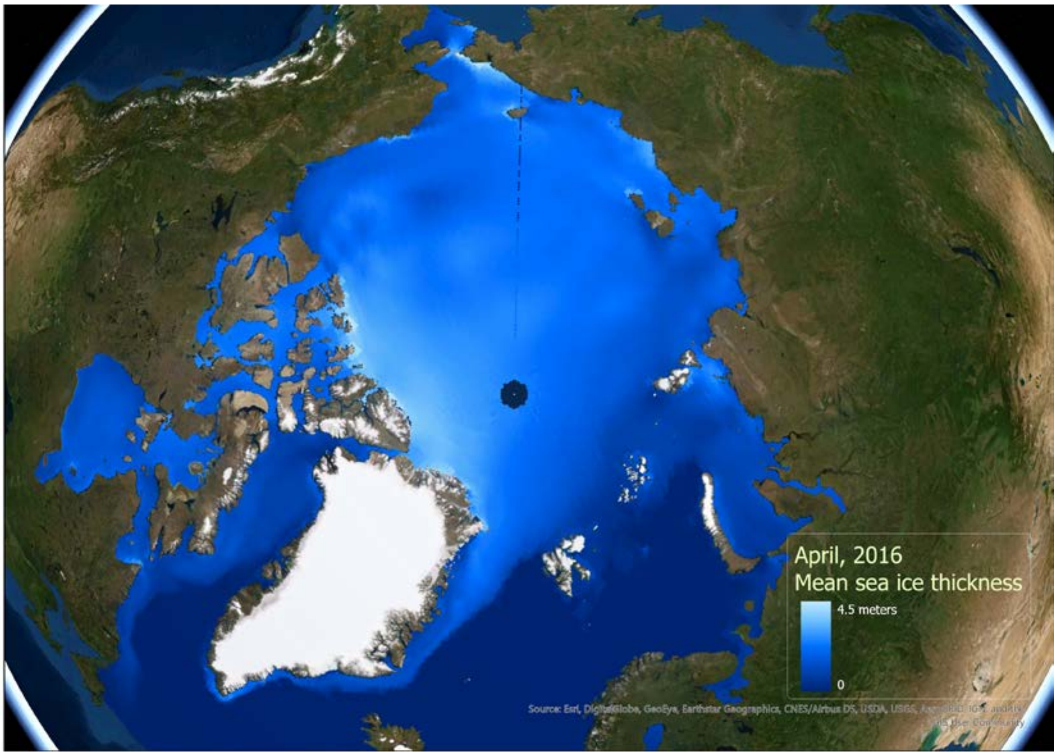


Figure 4. Coherent representations of ice parameters such as sea ice thickness (shown above) and ice type are relevant to shipping risk assessments. Generated from UHAM data for April 2016.

Accurate representation and delineation of the ice edge (and the Marginal Ice Zone) is a critical feature for Arctic environmental management and regulation. A key objective of the risk assessment system is therefore to give a concurrent and realistic view of risk influencing factors, incl. ice metrics. Visualizations will be adapted to fit with the risk assessment process (Figure 5).

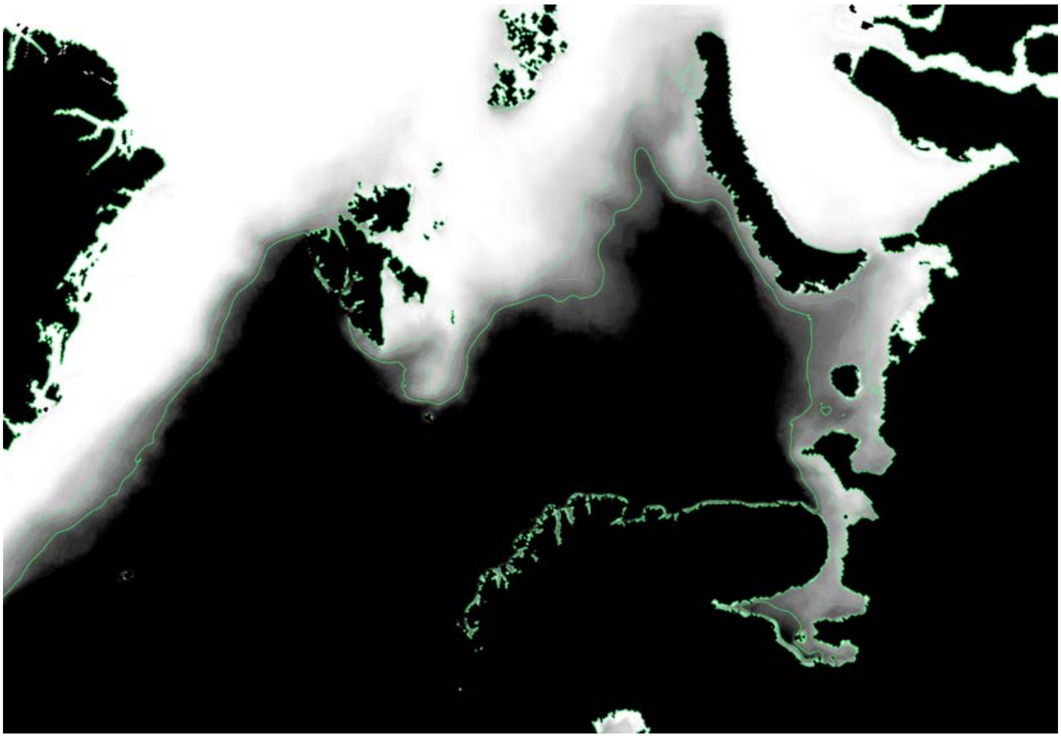


Figure 5. Example on sea ice frequency representation generated from ASI data for April. White is higher frequency.

Sea ice data

Table 1 describes sea ice data parameters in the risk assessment system needed for applications, such as:

1. Ice edge definition.
2. Prognostic speed and direction of the ice edge.
3. Define areas with strong compression of ice (e.g. ridges) and areas with first year ice and multi-year ice.
4. Tracking of icebergs.

Table 1. Parameters requested for Sea Ice use case

Products	Accuracy	Spatial resolution	Resolution in time	Format
Ice concentration	0.5 [%]	Better than 5 km	24 t	NetCDF-CF
Ice thickness	0.1 [m]	Better than 5 km	24 t	NetCDF-CF
Ice edge configuration	10 [degrees]	Better than 5 km	12 t	NetCDF-CF
Ice edge “velocity”	1 [km/t]	Better than 5 km	12 t	NetCDF-CF
Ice age (FYI/MYI)	0/1 -	Better than 5 km	24 t	NetCDF-CF
Ice type	--	Better than 5 km	24 t	NetCDF-CF
Iceberg size category (mean)	10-100 [T]	10 km	12 t	NetCDF-CF
Iceberg drift (direction/speed)	10[degrees]	10 km	12 t	NetCDF-CF
Number of icebergs	-	10 km	12 t	NetCDF-CF

Table 1 above lists parameters relevant to give an accurate account of actual ice conditions. The risk assessment system will build on these and seek to include additional products in the future. With advanced sea ice data products delivered online through well-managed protocols, new sources of knowledge become accessible and contribute to improve assessments targeting different stakeholder groups, use-cases, and operations.

Use case: Anthropogenic noise

The second use case identified was underwater noise in the Arctic. Ocean sound is defined as an Essential Ocean Variable (EOV) by the Global Ocean Observing System (GOOS) program (GOOS, 2019). The sound EOV is being developed and implemented in partnership with International Quiet Ocean Experiment (GOOS, 2019). IQOE under the Special Committee on Oceanic Research (SCOR) has several working groups, including one on Arctic acoustic environments with participants from ten nations (IQOE, 2019). There are some existing and developing management requirements that pertain to ocean noise in Europe, e.g. Marine Strategy Frame Directive - MSFD (EU Commission, 2019) and OSPAR/ICES Impulsive Noise Register (OSPAR, 2018; ICES, 2020). There is still a current need to assess and monitor the potential biological consequences of the anthropogenic noise. What is the background (ambient) noise levels and how does anthropogenic sources contribute? And what are the effects on marine animals; chronic and acute? When trying to answer these questions, there are both technical, logistical and resource constraints of sound measurements, and limitations to modelling.

Appraising biological effects, and consequence are the fundamental unknown parameter in the “risk equation”. Basic research and monitoring campaigns related to the acoustic mapping, species distributions and effects (like INTAROS) would help to monitor and assess current state and trends to inform management and risk assessments. Key elements to address for a risk assessment would be to describe the factors that influences the risk such as (Figure 6):

- Sound source (frequency, content, peak pressure, energy level, duration etc.)
- Ambient noise levels (natural and anthropogenic components)
- Sound propagation (bathymetry, geology of seafloor, hydrography, frequency dependence etc.)
- Biological response (species, hearing ability, behavior, effects, population status etc.)

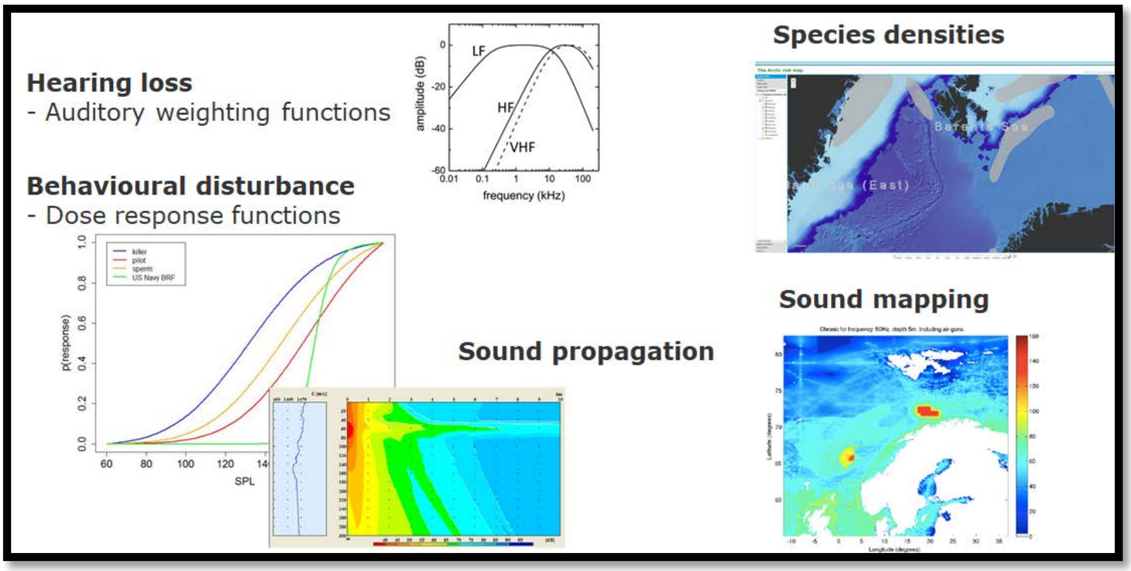


Figure 6. Schematic of key elements to impact and risk assessments related to underwater noise.

An increase in the background noise levels in the ocean has occurred over the last 30-40 years, primarily due to the increasing in global ship traffic (McDonald et al. 2008), and marine organism are more frequently being exposed to intense sound from sources such as seismic airguns, military sonars and underwater detonations (Richardson et al., 1995). Increased background noise levels have the potential to mask biologically meaningful signals and thereby impair animals' ability to communicate, to find and capture food and to navigate (Erbe et al., 2016; Popper and Hawkins, 2019). In addition, exposure to high intensity (pulsatile) sound can cause physical injuries, hearing impairment, or adverse behavioural changes in animals such as fish (Carrol et al., 2017; Popper and Hawkins, 2019) and marine mammals (Southall et al., 2019; Gomez et al., 2016). As the Arctic sea-ice diminishes due to climate change, this opens for human activity in previously in-accessible areas, such as shipping via the Northern Sea Route and Northwest Passage, and the search and exploitation of petroleum further north. Such activities will undoubtedly prompt an increase in the ambient noise levels and alter the character of the Arctic soundscape. Many of the endemic Arctic animals have little, or no, previous experience with the various anthropogenic sounds, and may therefore not be habituated to noise in the same potential way as animals in more noisy parts. This in turn imply that the naïve, Arctic animals may exhibit lower thresholds for disturbance, and thus to a greater extent be affected negatively. In addition, many of these Arctic animals are already directly impacted by dramatic habitat changes, i.e. increased ocean temperatures and decreased sea-ice cover. Introducing an additional stressor to this already strained ecosystem may have therefore have additive negative implications. There is an urgent need to establish a reference ambient noise levels to subsequently monitor the potential changes and appraise the potential biological implications.

Efforts to regulate and monitor underwater noise exist under international agreements such as OSPAR and the EU. The Marine Strategy Framework Directive (2008/56/EC) aims to achieve Good Environmental Status (GES) in all EU marine waters by 2020. The criteria for GES of marine waters address different aspects of marine ecosystems including biological diversity, fish population, eutrophication, contaminants, litter and noise. Measuring underwater energy (descriptor 11 in the directive) is now part of the Environmental Impact Assessment (EIA) that is necessary for new activities to obtain proper licences. Through these EIAs, companies are under the obligation to perform monitoring or to mitigate the effects of the energy input from their activities.
To address concerns of masking and behavioural change the MFSDs Technical Working Subgroup on underwater noise (TG11) has identified measurement of underwater noise as priority and defined two indicators:

- 11.1.1 Distribution in time and place of loud, low and mid-frequency impulsive sounds (i.e. from sources such as seismic surveys, marine piling, sonars, explosions)
- 11.1.2 Continuous low frequency sound (i.e. attributed to commercial shipping and impulse sources at long range in some regions).

In the context of achieving GES, programs to map and monitor the ambient noise have been established or are underway in key regions adhering to the EU: The Baltic Sea Monitoring Program – BIAS (Nikolopoulos et al., 2016), Joint Monitoring Programme for Ambient Noise North Sea (JOMOPANS, 2019), and Joint Framework for Ocean Noise in the Atlantic Seas project (JONAS, 2019) for OSPAR regions III and IV. However, there is not yet any comprehensive program for OSPAR region I, which includes the major part of the NE Atlantic, including the Barents Sea and Arctic waters.
In INTAROS Task 6.3 Activity 4 we propose to develop an integrated management tool, i.e. platform structure, in support of monitoring trends in Arctic ambient noise levels and assessments of potential impacts (risk) on biological species. The fundamental data input to

the tool will be (fixed) soundscape maps (e.g. modelled per month of the year). Separate sets of maps may be included to represent the total ambient noise, the relative contribution of natural and anthropogenic sound sources, and the sound levels above the expected “natural” ambient noise level. Importantly, the analysis tools will allow for extraction of acoustic statistics, e.g. number of days with noise levels above given thresholds in a user-defined area. In addition to the soundscape maps, background layers such as bathymetry, AIS data, sea-ice and biological data (e.g. species densities and spawning areas). An outline of data input to acoustic models and planning tool output is shown in Figure 7. The accomplishment of soundscape modelling and integration into a risked based matrix follows a similar approach as that of the previously mentioned programs (e.g. JOMOPANS). However, one additional key influencer on the ambient noise level and sound propagation will be included for the Arctic acoustic modelling, namely the distribution and properties of sea-ice. Schematics of sound modelling and the GIS tool is presented in Figure 8.

Importance of sea-ice data to model the Arctic soundscape

The Arctic represents a special case with regards to ambient noise level and composition, and sound propagation (reviewed in PAME, 2019). The presence of solid sea-ice isolates the underwater environment from the usual surface-generated noise of wind and rain, which is a dominating soundscape component at lower latitudes. Instead, the fracturing and scouring sounds of ice, generated as sea-ice is forced by the wind and waves. The ambient noise levels are generally held to be lower in the Arctic than in non-polar regions, for two main reasons. Firstly, sea-ice is a strong scatterer of sound, which causes sound (particularly of higher frequencies) to attenuate faster than in open waters. Secondly, there are yet relatively few anthropogenic sources in the Arctic to contribute to the background noise, e.g. shipping. The anthropogenic sounds most frequently identified in the Arctic derive from icebreaker operations, commercial shipping and seismic surveys (Geyer et al., 2016). The influence of anthropogenic activities on the ambient noise levels varies seasonally and among different geographical regions in the Arctic (Ozanich et al., 2017). In the Fram Strait and the Greenland Sea, for example, seismic airgun signals, attributed to distant surveys (e.g. >1400 km away), have been recorded almost daily during the summer months, and shown to dominate the soundscape in the lower end of the frequency spectra (Tollefsen and Sagen, 2014; Ozanich et al., 2017). As diminishing sea-ice and increased anthropogenic noise is likely to alter the Arctic ambient noise levels and composition, potentially radically, there is an imminent need to link the soundscape of for regional efforts to monitoring efforts and integrative tools for management. The coupling of ambient noise levels and soundscapes with sea-ice distribution and concentrations will be central and a key objective in the work towards an integrative monitoring tool.

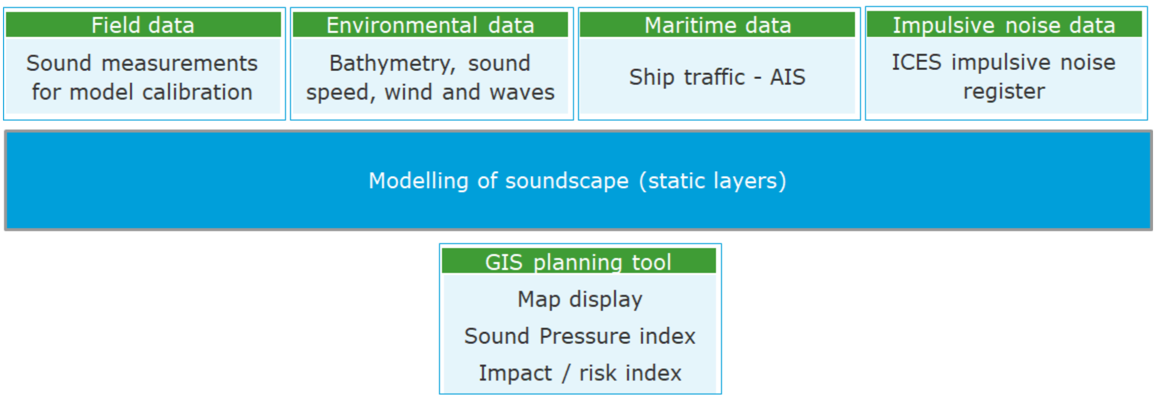


Figure 7 Outline of input data to soundscape modelling and GIS planning tool

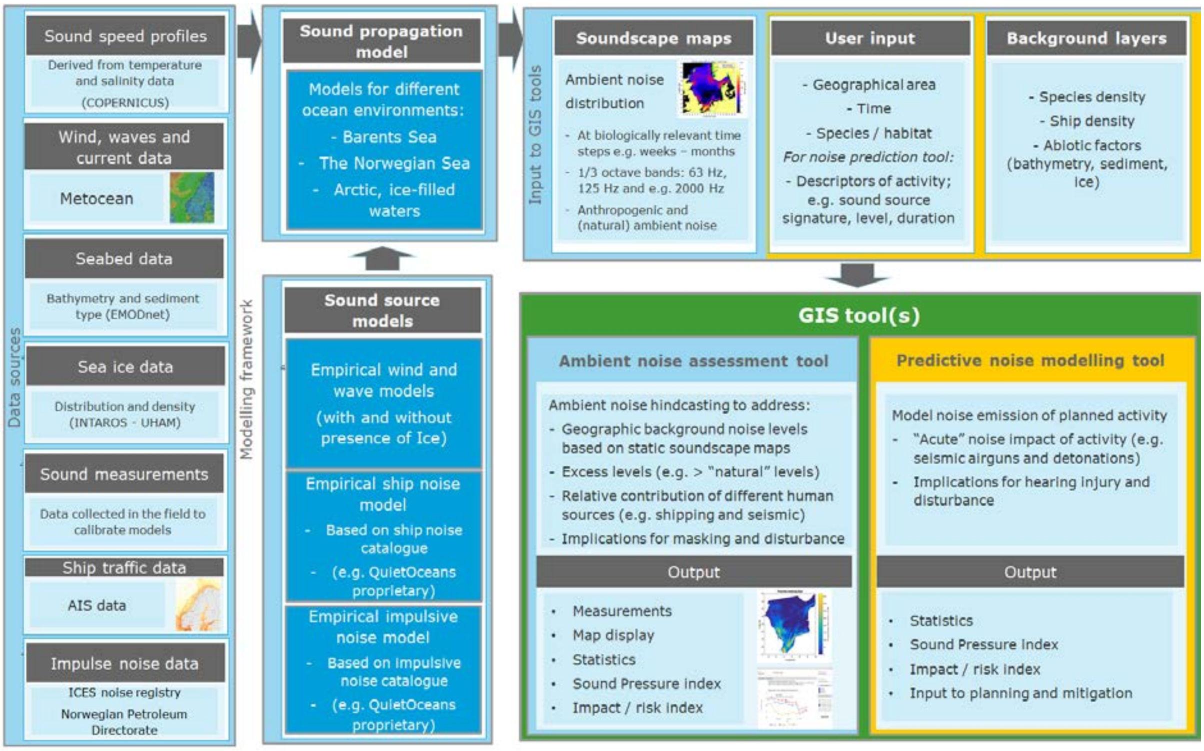


Figure 8. Schematics of ambient and predictive risk assessment tool.

Ocean acoustic data

Table 2 describes use ocean acoustic parameters for the anthropogenic noise use case in the risk assessment system.

Table 2. Parameters requested for Ocean acoustics use case

Variable	Accuracy	Area	Time period	Format
Ocean temperature profiles	0.01 [Celsius]	FS, NS, BS	2008-…	NetCDF-CF
Ocean Salinity profiles	0.1 [psu]	FS, NS, BS	2008-…	NetCDF-CF
Sound Speed profiles	0.5 [m/s]	FS, NS, BS	2008-…	NetCDF-CF
Current	0.1 [cm/s]	FS, NS, BS	2008-…	NetCDF-CF
Sound scape/noise level	+/1 [dB//1 microPa^2 rel 1 Hz]	FS, NS, BS	2008-…	NetCDF-CF
Depth-range averaged ocean temperature	0.07 [Celsius]-	FS, NS, BS	2008-…	NetCDF-CF

FS: Fram Strait, NS: North Sea; BS: Barents Sea

The project will explore opportunities towards using the above listed parameters for visualization of the ocean soundscape, and potential conflict zones with essential ecosystems and marine mammals' distributions.

Conclusion

This report has discussed two use cases for implementation in the Arctic Risk Map system. In the context of environmental risk and shipping risk, both cases are considered highly relevant to Arctic risk assessments. The first case on sea ice statistics is a priority. Implementation of the second case on anthropogenic marine noise and biological effects will rely on access to open and reliable acoustic data products which can be tailored into a viable service. The shaping of such a service must be consistent with objectives of the OSPAR convention and the EU Marine Strategy Framework Directive. With a changing regulatory landscape, and climate change adaptation and mitigation high on the agenda among stakeholders, there is a compelling need to balance risk and societal benefits in future activity in the Arctic region.

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