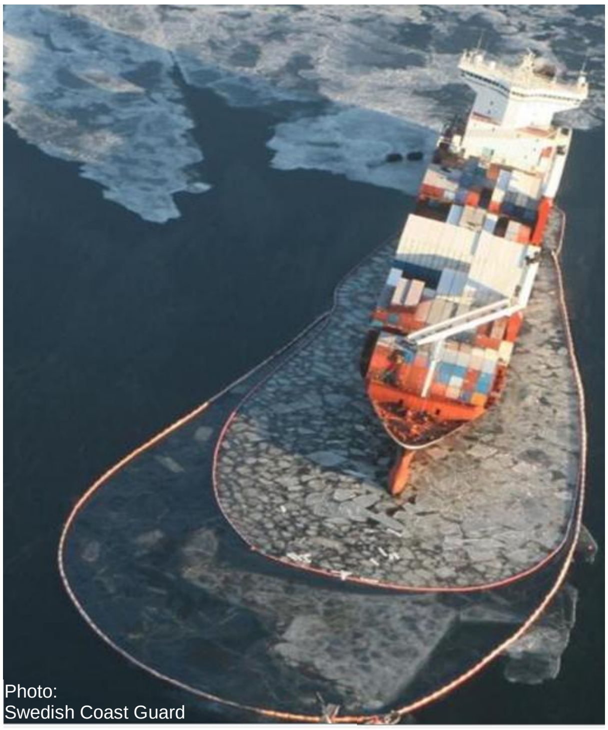
GRACE grant no 679266

# Oil spill risk assessment

D5.6

WP5: Strategic Net Environmental Benefit Analysis (sNEBA)



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Swedish Coast Guard

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# Contents

## Executive Summary

The presented spill risk assessment tool is designed to provide input data for the sNEBA on characteristic oil spill risks in terms of probability, oil quantity, and oil type in Arctic waters. The document describes the background data on spill risk modelling and the design of the designated spill risk assessment model for application in GRACE. Two sites are selected for trial application of the model and for demonstration of the sNEBA tool.

The design of the spill risk assessment model incorporate a number of selected components from other presented models and combine state-of-the-art analysis technique for streaming high resolution AIS information. This ensures reliable and transparent modelling of oil spill risk in Arctic areas and the model is expected to provide a valuable complement to the sNEBA tool.

# 1. Introduction

## 1.1 Grace

The project focuses on developing, comparing and evaluating the effectiveness and environmental effects of different oil spill response methods in a cold climate. In addition to this, a system for the real-time observation of underwater oil spills and a strategic tool for choosing oil spill response methods are developed.

The results of the project will be made available for use to international organizations that plan and carry out cross-border oil spill response cooperation in Arctic sea areas. The full name of the project is: ”Integrated oil spill response actions and environmental effects – GRACE".

## 1.2 Background

Work package 5 will develop and launch a strategic Net Environmental Benefit Analysis (sNEBA) tool for decision-making, to design an appropriate and fast national oil spill response strategy combining the right mix of interventions (e.g., mechanical recovery, in situ burning, chemical dispersants and/or bioremediation).

The work package also includes development of matrices for knowledge/data collection to serve as input to the strategic analysis. Environmental matrices are outlined in deliverable D5.5 and are supposed to answer the question “Shall we?” with regard to usage of different response techniques. The operational requirements matrices are supposed to answer the question “Can we?”, and are described in deliverable D5.4 Operational requirements matrix.

The sNEBA tool structure and information flow is illustrated by Figure 1. The blue oil spill specification boxes represent important initial information for the process and the presented oil spill risk assessment model aims at providing this input into the sNEBA tool. The sNEBA tool will be demonstrated for two different trial application sites, and the spill risk assessment model presented in this document is also illustrated by application for these two sites.

| Assessment sea area / region | | | |
|---|---|---|---|
| I. Components of Strategic Net Environmental Benefit Analysis | | | |
| Environmental sensitivity | Oil spill specifications | | |
| ↓ Key / sensitive organisms<br>• Spatial compartments<br>• Seasons<br>(MATRIX X1) | ↓ High risk area and/or sensitive environment | ↓ Area at lower risk/ large area | ← Oil spill risk assessment |
| ↓ Response methods - pros and cons<br>• Spatial compartments<br>• Seasons<br>(MATRIX X2) | ↓ Oil spill<br>Model simulations<br>Distribution and fate<br>(MATRIX Y1) | ↓ Oil spill<br>Estimates<br>Distribution and fate | |
| ↓<br>• MATRIX X2-SS: Sea surface<br>• MATRIX X2-WC: Water column<br>• MATRIX X2-SB: Seabed<br>• MATRIX X2-C: Coast | ↓ Ecotox profiles:<br>• MATRIX Y2-SS: Sea surface<br>• MATRIX Y2-WC: Water column<br>• MATRIX Y2-SB: Seabed<br>• MATRIX Y2-C: Coast | | |
| ↓ Environmental sensitivity<br>Compiled<br>(MATRIX X3) | ↓ Oil spill<br>Fate and response efficiency<br>(MATRIX Y3) | | |
| ↓ ↓<br>II. Assessment - Strategic Net Environmental Benefit Analysis<br>(DECISION TOOL) | | | |
| ↓<br>III. Results<br>Strategic Net Environmental Benefit Analysis<br>- ranking of response methods with seasons<br>(TRAFFIC LIGHT) | | | |
| ↓<br>IV. Operational requirements<br>(MATRIX Z) | | | ← Oil-in-Ice code |

*Figure 1. Main components of the sNEBA tool and schematic information flow from various add-on applications and knowledge databases.*

# 2 Literature review - Oil spill risk assessment and Arctic applications

## 2.1 Existing tools and projects

In order to design and implement an efficient and cost-effective oil spill Pollution Preparedness and Response (PPR) organisation, it is essential to identify; where, when, by what, and to what extent our oceans and coast lines are exposed to oil spill risks. The probability of an oil spill in an area depends on the type and intensity of activities conducted, but the term risk normally also includes considerations on the severity of the consequences of a potential spill. To assess spill consequences, the resources at threat must also identified, e.g. by environmental sensitivity mapping, and be included in the overall risk assessment. The spill itself but also the response efforts influence the severity of the consequences and the total societal costs. The sNEBA tool aims at facilitate the identification of the optimum response strategy, and if the available response resources and operational requirements are considered sufficient, the tool can assist decision makers on how to proceed with emergency preparedness and contingency planning.

The probability component of the spill risk assessment also provides important input for application of the sNEBA tool, by defining credible oil spill scenarios of relevance for the addressed area and season. Depending on the potential source of spill, offshore activities, spill from tankers due to collision accidents, or spill of bunker oil from other ships, the type of oil vary significantly and potential spill quantities may also vary in a wide range.

A number of different spill risk assessment methods, addressing spill probability as well as consequences, have been presented in the literature over the past decades. They are primarily designed for identification and prioritization of response needs and development of adequate preparedness organisations. The spill risk assessment also provides important input for identification of preventive measures reducing the probability of spills, e.g. by implementation on regulative ship design requirements, aids to navigation, ship routeing measures, vessel traffic services (VTS) and monitoring, training and other efforts for enhancement of safety awareness and policy compliance.

Some methods are specifically addressing the likelihood/probability of spills whilst others focus on the consequence side. Some methods encompass both aspects of the traditional risk assessment structure as outlined by the ISO 31 000 standard or the FSA of IMO, but only a few are designed for application in all/any sea areas in the world and none is specifically designed to take into account the specific risk contribution imposed by the presence of sea ice.

The section below review some recently presented methods and tools to serve as brief background to the development of the GRACE spill risk assessment model and its application for the two test sites; the Disko bay and the Gulf of Finland.

### 2.1.1 Europe

Major oil spills at sea often cause environmental impact and beach pollution in more than one country and response efforts require bi-lateral or international coordination. Prioritization of response strategies and protection of resources at risk are complicated because of national differences in response organisations, priorities, and policies. The EU has therefore initiated and financially supported a number of international cooperation projects on research and development of methods and tools to provide common platforms and facilitate international coordination and cooperation. The examples described below focus on spill risk assessment and show that significant progress has been made over the past decade.

**BRISK**

The BRISK project, conducted 2009-2012 was partly financed by EU´s Baltic Sea Regional Programme. One key topic of the study was a Baltic-wide risk assessment addressing oil and chemical pollution, and its impacts, using a common methodology. AIS-data on ship traffic density and route pattern was used to identify locations of high collision and grounding probability. This information was then combined with estimations of the type and size of oil spill, expected drift and weathering as well as the anticipated effectiveness of available response resources recovery efforts.

Figure 2 shows an example of quantitative estimation of oil spill in the Baltic area extracted from BRISK (Norden, 2013).

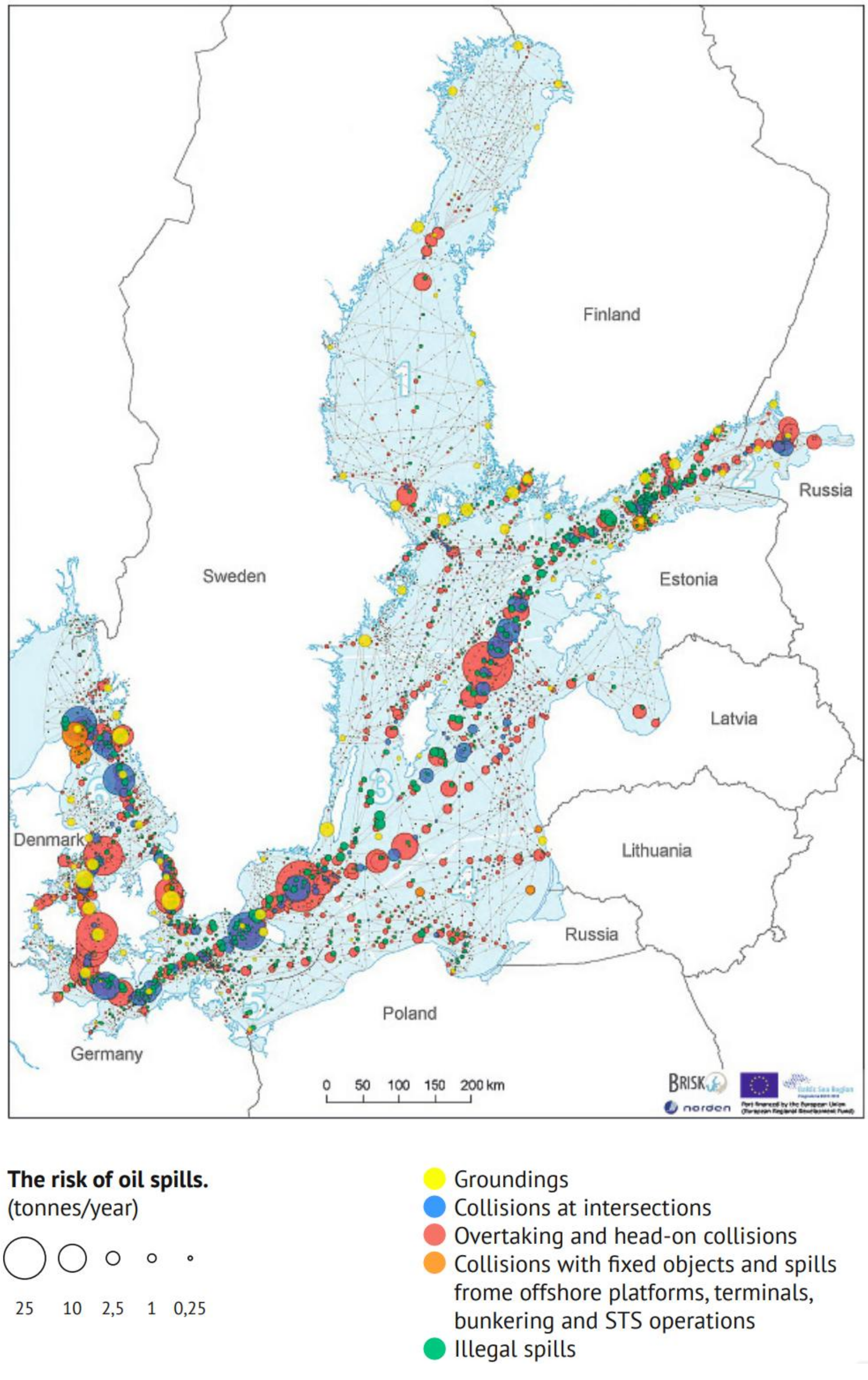



*Figure 2. Oil spill risk expressed in tonnes per year in the Baltic Sea, extracted from the BRISK project.*

BRISK also included a Baltic Sea wide vulnerability mapping with respect to oil pollution. The vulnerability mapping was separated for different seasonal variations and the compiled vulnerability for the summer season is shown in Figure 3.

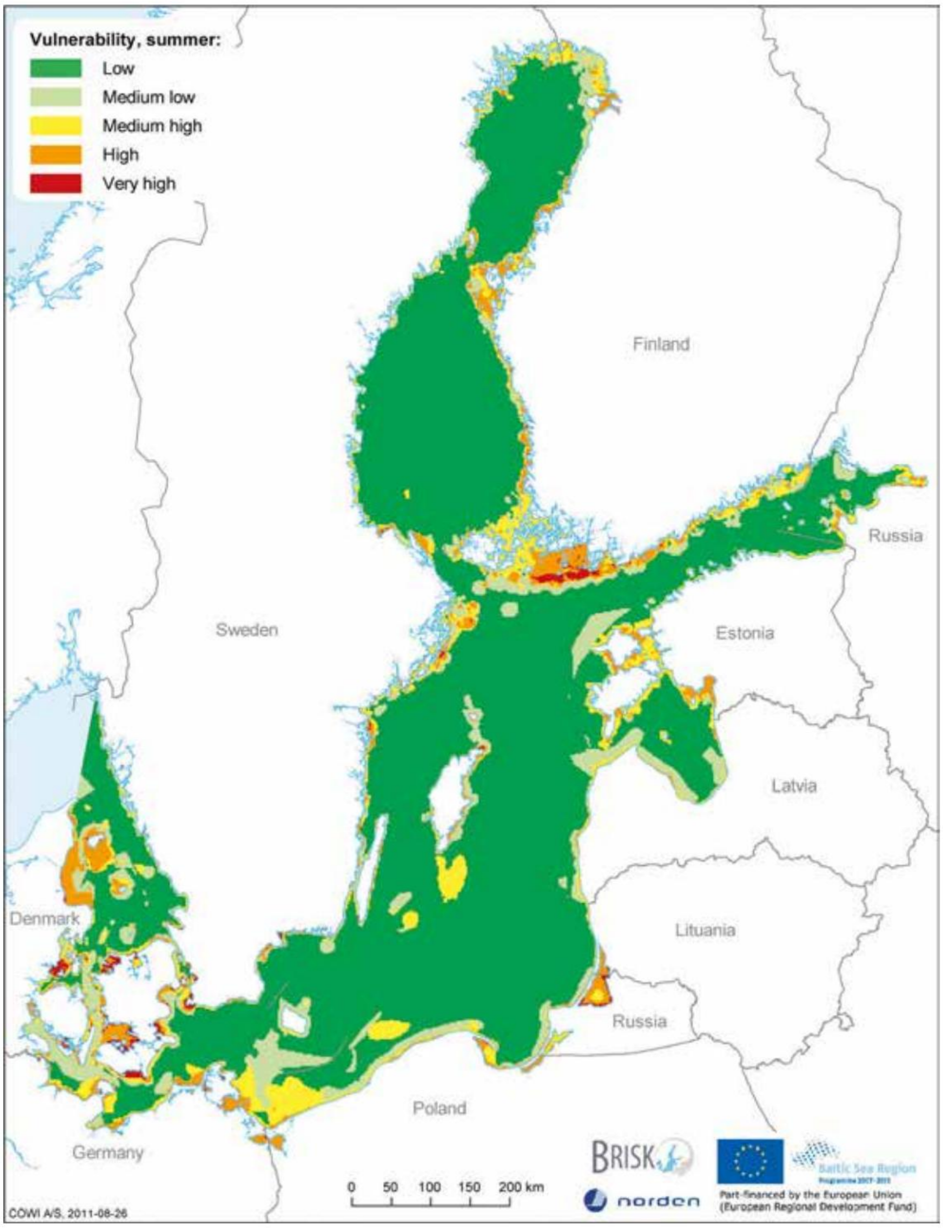



*Figure 3. Baltic Sea vulnerability map for oil spill during summer season, (MSB, 2016)*

The probability maps of expected oil spill quantities are combined with the seasonal vulnerability maps, to provide a map of expected relative distribution of environmental damage risk for the respective season. The risk are generally found to be concentrated along the main shipping routes but coastal areas along the northern side of the Gulf of Finland and in the Danish straits are also exposed to high environmental risk imposed by potential oil spills from ship accidents.

**BRISK-RU**

The Russian part of the Gulf of Finland and its large seaports and oil terminals has a most important role with respect to the overall spill risk in the Baltic Sea. Therefore an extension of the BRISK project, BRISK-RU was launched including Russian partners, and specifically addressing risk issues related to ship traffic to/from Russia. The BRISK-RU project was financed by the Nordic Council of Ministers Aquatic Ecosystems working group and added valuable information on Russian shipping activities and resources to the database developed within the BRISK framework.

**BE-AWARE**

The BE-AWARE project, 2012-2014 was conducted with similar methods and goal as the BRISK project, but was specifically addressing the North Sea area. It was accomplished within the Bonn-agreement framework and co-financed by the EU. Compared with the BRISK, the BE-AWARE model included additional components related to:

- Ecological and socioeconomic features
- Inclusion of vulnerability and impact modelling on water column
- Inclusion of offshore installations (oil platforms and wind farms)
- Tidal effects on oil spill drift
- Potential use of dispersants as a response measure
- Absence of sea ice (sea ice is taken into account as an aggravating response factor in BRISK)

3D modelling of the drift and behaviour of 10 000 $m^3$ crude spills was conducted by the use of the software OSERIT, by the Royal Belgian Inst. of Natural Sciences (RBINS-MUMM).

Similar to BRISK, the output of BE-AWARE is presented in maps. Figure 4 below shows an example of statistically predicted oil spill impact for a base scenario 2020 expressed in terms of $g/km^2$.

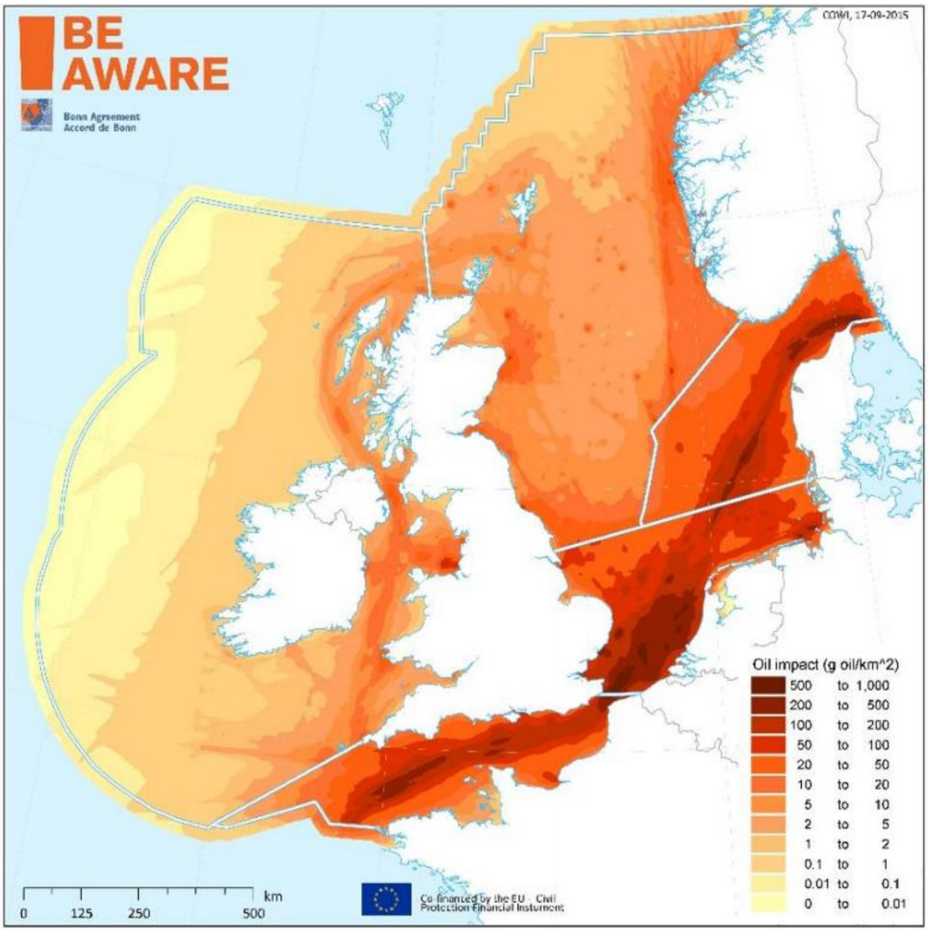



*Figure 4. Predicted oil spill impact for year 2020 for the Bonn Agreement area.*

In analogy with the BRISK project, BE-AWARE also compiled seasonal vulnerability maps to be combined with the oil spill probability maps to provide an overall risk mapping. Figure 5 shows an example of relative spill vulnerability ranked in a scale from 1-5.

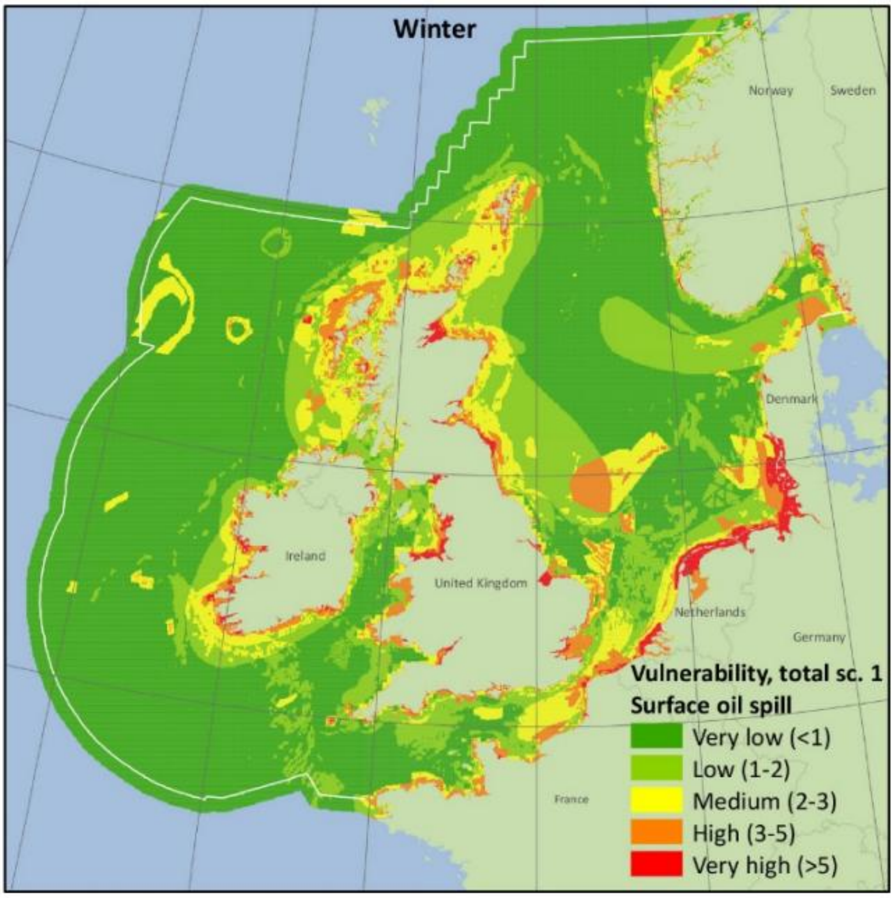



*Figure 5. Combined seasonal vulnerability to undispersed oil spill, wintertime.*

**OpenRisk**

The OpenRisk project is a two year project, 2017-2018, co-financed by EU and with HELCOM acting as the lead partner. SYKE, Finnish Environment Institute, is also partner and thereby forming a linkage to the GRACE project.

The project is based on the same trend as the BRISK and BE-AWARE projects, where development of spill risk assessment methodology becomes increasingly important and more widely applied in the PPR process for identification of needs, gaps, and prioritisation. OpenRisk specifically addresses remaining issues identified in the previously presented projects related to:

- Risk assessment output normally represents an instantaneous view – Open Risk seeks methods reflecting dynamically changing risk characteristics.
- Previously presented methods are complex and too expensive for being regularly updated – OpenRisk will facilitate risk-informed PPR decisions and investments by ensuring more accurate and updated risk figures and cost-benefit considerations.
- Presented national and regional risk assessment are often one-off projects, implemented with heterogeneous, partly undisclosed methodologies – OpenRisk will encourage the use of common jointly agreed methods for coherent application in national, regional, and international level.

The ongoing OpenRisk aims to provide two output components:

- A guideline, based on the ISO 31 000:2018 international standard for risk management.
- An open access toolbox with methods for joint use in national and regional risk analyses, supporting the execution of the risk management process.

The project work includes a number of open workshops identifying various available risk assessment methods and outlining a guideline document. A final version of the guideline will be presented and discussed at a fourth workshop at WMU in Malmö on October 30, 2018.

The draft guideline (OpenRisk, 2018) identifies three categories, of different complexity levels, of risk management processes in which various types of risk assessment methodologies may be applied. The three levels of risk management processes are:

- Basic screening risk management process
- Intermittent risk management process
- Strategic risk management process

In the strategic risk management process, all relevant marine risks are considered in a holistic manner, facilitating decision-making related to major long-term investments in the maritime transportation and the pollution response system. This level is the one of primary relevance with respect to the sNEBA process and its identification of credible design oil spill scenarios. The draft guideline (OpenRisk, 2018) includes 20 different tools, models, or methods in support of the PPR risk management processes. These are described as “freely available to PPR authorities” and some are characterised as more generic models widely used in other industrial activities and recommended in the ISO 31 010:2009 standard on risk assessment techniques. Three of the included tools are specifically developed within the OpenRisk project to bridge identified gaps: MarinRisk tool, the Maritime event risk classification method, and the Accidental damage and spill assessment model for collision and grounding.

The 20 different tools have been evaluated and ranked with respect to their applicability for the various steps in the risk management process as outlined by the ISO 31 000. The evaluation is ranked in three levels and graphically illustrated by figures exemplified in Figure 6.

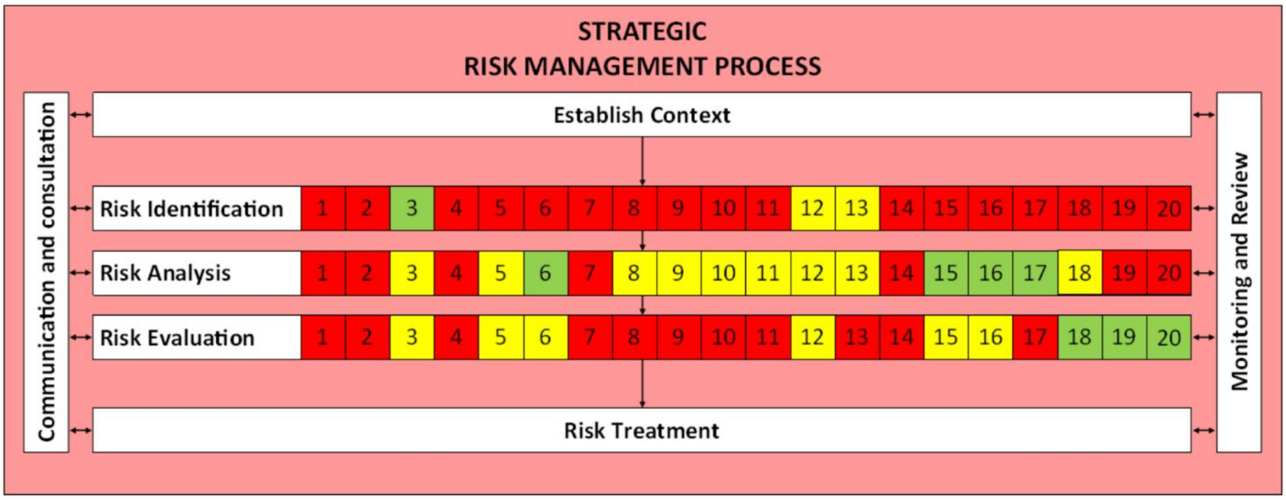



*Figure 6. Applicability of tools/methods numbered 1-20 of the OpenRisk Toolbox for strategic risk management process. Strongly applicable = Green, Applicable = Yellow, Not applicable = Red*

A number of the listed tools or models are particularly interesting with respect to the tasks conducted within GRACE.

The AISyRISK (No 1 in Figure 6) is a new tool under development of the Norwegian Coastal Administration, based on experience from the IWRAP model and the BE-AWARE and BRISK projects and makes use of streaming high-resolution AIS-data to provide a dynamic overall risk assessment for a grid of geographical areas. Probabilities for five different types of ship accidents are calculated and expected consequences are quantified in terms of type/quantity of outflow and loss of lives. The AISyRISK is not yet publicly available on the web but it is expected to be presented as an integrated part of the Administration’s WMS (Web Map Service) Havbase (Havbase, 2018) or Kystinfo (Kystrisk, 2018). Today’s version of Havbase includes a sub site called Arctic Havbase (https://havbase.no/havbase_arktis) with AIS information from the Arctic and Kystrisk includes a thematic map on maritime safety showing the accident probability and spill risk per cell in a 10 x 10 km grid of Norwegian waters based on AIS from 2014.

In order to become applicable for the spill risk assessment outlined in GRACE D5.6, the AISyRISK needs to be complemented by models defining the probability that the accident occur at a location and time where sea ice is present and if and how the ice influences the causation of accident. Presence of sea ice and extreme temperatures may also influence the oil outflow. Potential oil spill accidents from offshore operations as well as operational spill from bunkering and cargo transfer of oil products may also be an important additional component for the GRACE spill risk assessment.

Sea ice or ice conditions are only mentioned in 3 of the 20 listed tools in the OpenRisk guideline (OpenRisk, 2018). The established spill drift and advection forecasting model SeaTrack Web (No 9 in Figure 6) (STW, 2018) have been established as a common tool within the HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission) member states and among recent development steps, improved modelling of oil drift in ice conditions, have been introduced in SeaTrack Web. Trial applications of the new oil-in-ice parameterisation have been presented for the Runner 4 spill accident in the Gulf of Finland 2006 and show that the model describes drift and advection reasonably well but it is highly sensitive to ice flow size, (Arneborg, 2017).

Another interesting tool developed within the OpenRisk project is the ADSAM-C and ADSAM-G (No 8 in Figure 6) (Accidental Damage and Spill Assessment Model for Collision and Grounding) focussing the consequences of collision and grounding accidents and associated oil spills. Both models are probabilistic models designed as Bayesian network models and based on input data on the striking and struck tanker vessels in collision or a grounding event, and by introduction of a number of probabilistic distributions for various conditional parameters, credible or worst-case spill scenarios can be estimated for specific sea areas. Bayesian network models have also been applied for comparative spill risk studies in the Gulf of Finland. A series of successive network models were used for estimation of expected future accident frequency and associated oil spill quantities and included a comparison of two different risk control measures (Lehikoinen, 2015). The result indicated that obligatory pilotage was expected to be about twice as efficient as an automatic VTS alarm function. For the ADSAM-G model, the scenario parameters listed includes ice cover thickness as one of the consequence influencing factors. The ADSAM-G web application can be accessed online at http://www.sea.ee./adsam. The ADSAM-GP and ADSAM-C tools are available on the HELCOM website in xdsl format, to be used directly in the Bayesian network freeware GeNIe available from https://www.bayesfusion.com.

The next generation SmartResponse Web (No10 in Figure 6) is also described as a set of tools including the ADSAM- subroutines for spill consequences and thereby including the ice properties.

MARINRISK (No 2 in Figure 6) is used to calculate specific Nautical Risk Index figures for individual ships. By combining the risk indices figures from all ships in an area and the actual AIS traffic data, the overall nautical risk situation in the area may be described in quantitative terms. The Nautical Risk Index has successively been developed in various EU-funded projects like the MarNIS (SSPA was also participating) and later also within the OpenRisk and include a wide range of semi-empirical multiplication factors for tuning of causation factors with respect to specific ship characteristics, environmental condition, and navigational obstacles. Winter and ice specific risk factors like visibility darkness are included in the list of multiplier factors influencing the local causation factors used in MarinRisk.

### 2.1.2 North America

**US**

The two main US authorities responsible for PPR are the US Coast Guard and the National Oceanic and Atmospheric Administration, NOAA. NOAA’s Office of Response and Restoration has developed a large number of tools and models for contingency planning and emergency response and are continuously engaged in scientific research in the area. The most well established modelling tool developed by NOAA is probably the GNOME suite including spill trajectory and advection software available as Pyhton code or web client. One tool specifically addressing the oil spill probability and its consequences in Arctic conditions is the Oil Spill Risk Analysis Calculator. The Alaska Regional Office of NOAA Fisheries published an Alaska/Arctic Spill Risk Assessment in 2014 presenting the environmental vulnerability for spill scenarios based on i) past and projected future incident rates (average most-probable discharge, AMPD), ii) potential maximum most probable discharge (MMPD), and iii) worst-case discharge (WCD) (NOAA, 2014). The risks are presented for different regions and seasons as well as for different categories of oil (crude, distillate, heavy, and light).

The Oil Spill Risk Analysis Calculator applied for the study is available from the web on: https://alaskafisheries.noaa.gov/habitat/oil-spill-risk

NOAA is also engaged in the Arctic Council cooperation and has presented the Environmental Response Management Application, Arctic EMRA – an online mapping tool for responders to deal with environmental disasters in the Arctic region and Alaska. The Arctic ERMA supports the efforts of the Arctic Council's Emergency Prevention, Preparedness, and Response Working Group, EPPR, as a platform for data sharing, and is used during international response training, as required under the Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic (MOSPA).

**Canada**

In 2013 Transport Canada commissioned an independent assessment to determine the risk of spills, and to compare the risks among regions of Canada. Phase 2 of this Risk assessment for marine spills in Canadian waters specifically addressed the risks north of Lat 60$^{o}$N including the Canadian Arctic areas (TC, 2014). Data on spill probability are derived from Canadian spill statistics for small spills and for large spills, statistical frequencies are derived from Lloyd’s casualty database and from ITOPF and combined with actual recorded AIS traffic statistics from the Canadian Arctic, (Marty, 2016).

The Canadian Coastguard is responsible for PPR in Canadian waters and is also active in the Arctic Council cooperation. The national spill contingency plan (CCG, 2018) is based on a number of legislative mandates and acts – one of these is a specific Arctic Waters Pollution Act (CCG, 1985).

### 2.1.3 Arctic Council

The Arctic Council is an intergovernmental forum with representatives from eight countries and the indigenous people of the Arctic. The EPPR working group has recently initiated a project for preparation of a Guideline and tool for Arctic marine risk assessment, (DNVGL, 2017). The Norwegian Coastal Administration is coordinating the project and DNV GL and Arctic University of Norway (UIT) are assigned to facilitate the project, which is planned to be completed by the end of 2019. The current spill risk assessment component of GRACE has many tasks and issues in common with the EPPR project and will aim at beneficial synergy and cooperation.

## 2.2 Ice and its influence on accident probability

Several of the spill risk assessment tools and models described in previous section, can be applied or modified for application for Arctic areas and some references to Arctic applications are made. In order to be able to utilise established models and tools based on AIS statistics, blind navigation approaches, and empirical accident causation factors, the models need to be refined so that actual ice and operational conditions are taken into account for the accident probability calculations, e.g. by adaptation of the causation factors. Some studies, specifically addressing how much and in what way the presence of sea ice and other Arctic features influences the probability of collision and grounding accidents, are briefly described below.

### Arctic risk map

An interactive map tool specifically focussing the Arctic area has been developed by DNV GL and is available at https://maps.dnvgl.com/arcticriskmap/. The WMS tool includes information from several data sources and allows a range of graphical illustrations of risk drivers related to environmental vulnerability and safety of shipping and offshore activities. The data is presented in qualitative terms and illustrated by colour scales and maps showing geographical and seasonal variations. A relative safety and operability risk index (SOI), reflecting a number of Arctic specific hazards, can be visualized with the risk level of the Norwegian Sea as a benchmark reference (Figure 7).

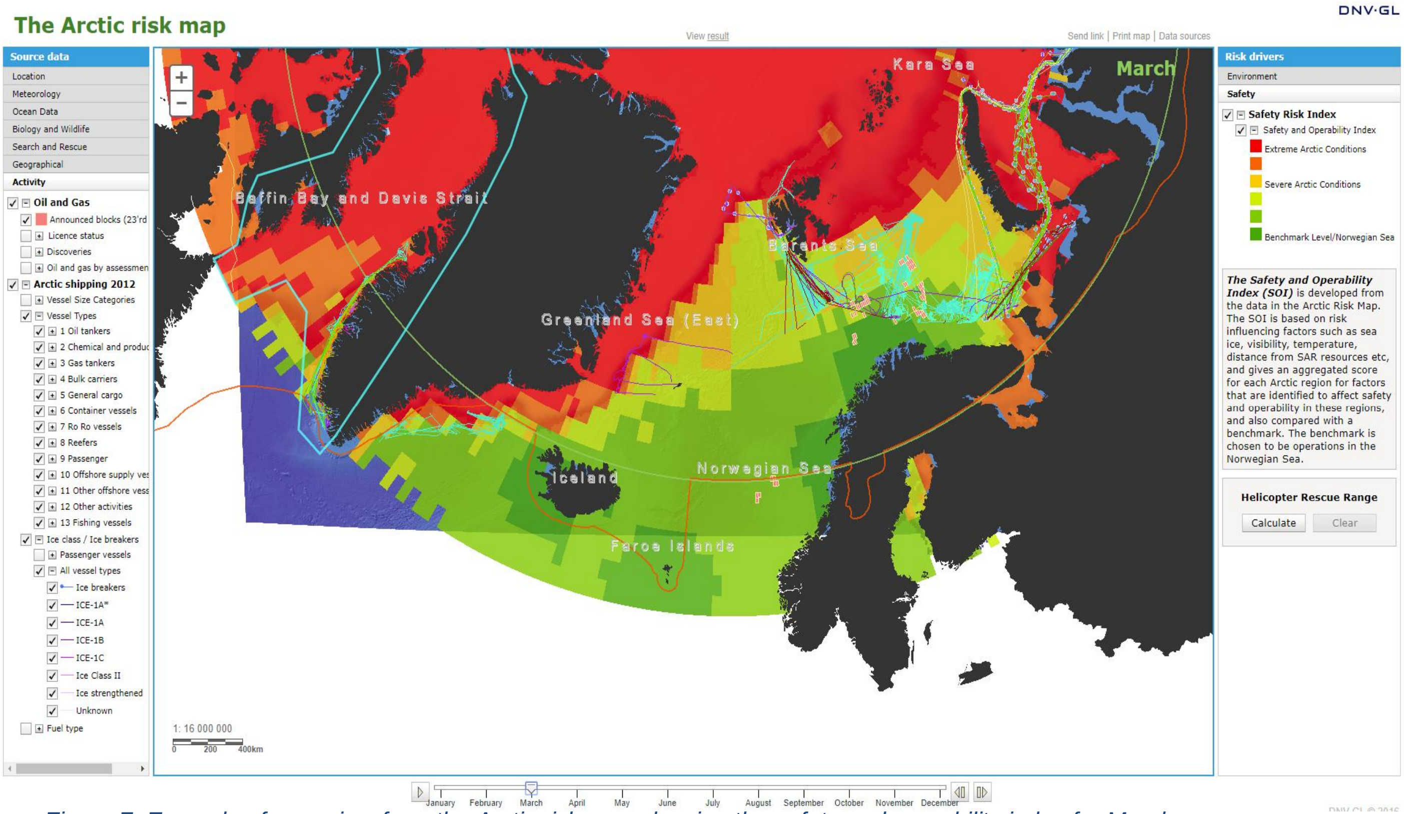



*Figure 7. Example of map view from the Arctic risk map showing the safety and operability index for March.*

### Research projects

The research group on maritime risk and safety of Aalto University in Finland has published a large number of scientific papers and studies specifically addressing issues related to winter navigation and ice induced hazards. Comparative collision risk studies for icebreaker assisted operation and independent operations based on Bayesian network models have been presented and combined with oil spill probability models for various collision events, (Kujula, 2016).

Detailed studies on differences between accidents during winter and ice free periods have also been presented, however, emphasizing that correlation does not necessarily imply causation (Goerlandt, 2017).

# 3 Oil spill risk assessment model for application in the sNEBA

## 3.1 Objective of the spill risk assessment component

The probability component of the GRACE spill risk assessment model provides important input for application of the sNEBA tool, by defining credible oil spill scenarios of relevance for the addressed area and season. For the selected trial application sites, the present potential sources of oil spill are primarily considered to be related to shipping activities. In terms of expected spill frequency, spills of bunker fuel oil caused by grounding or collisions represent the main source. In terms of spill quantity, spills associated with discharge of crude or oil products loaded as cargo in tankers will, however, be associated with the potentially largest spill and worst-case scenarios. Other potential sources may be more relevant in other Arctic areas, and the spill risk assessment methodology will be further elaborated to include other relevant spill sources. Figure 8 illustrate different potential spill scenarios from various potential sources in Arctic areas.

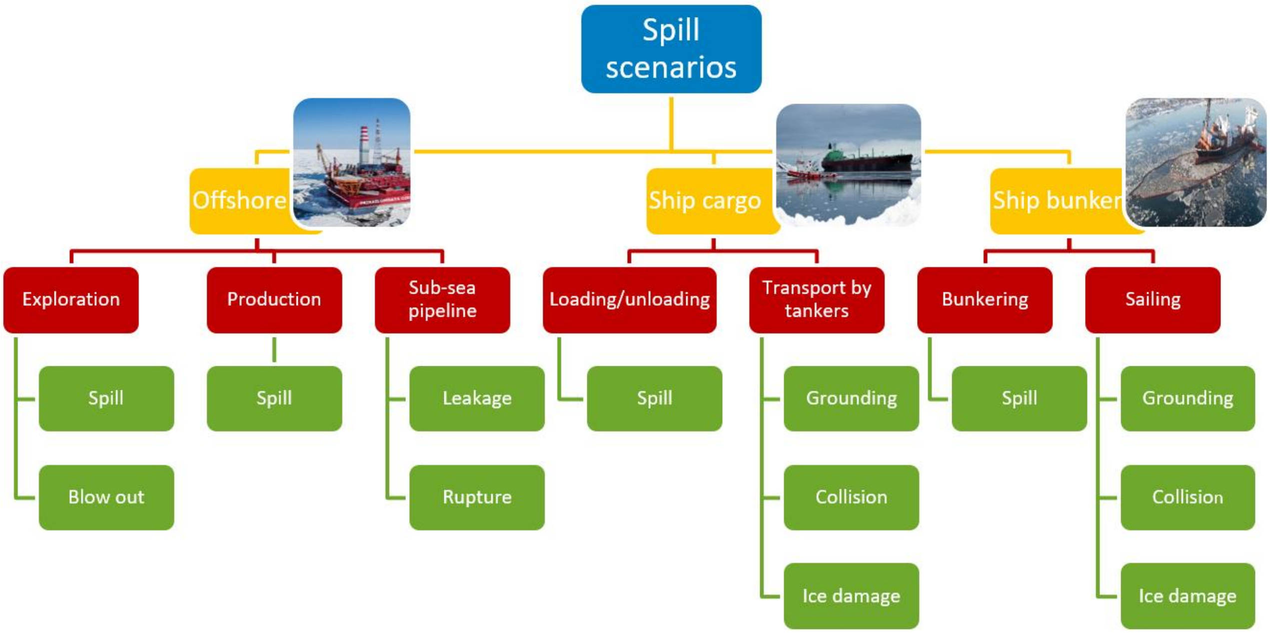



*Figure 8. Various sources of potential oil spill and discharges in Arctic areas.*

## 3.2 Outline of the GRACE spill risk assessment model

The spill risk assessment model is outlined in accordance with established risk assessment methodologies, and in applicable parts, its structure is similar to the FSA, Formal Safety Assessment elaborated by IMO and the ISO 31000 standard.

The spill probability estimations related to ship accidents are primarily based on recorded AIS statistics combined with ice statistics and empirical causation probability factors for different accident types and ice conditions. Quantitative figures on expected accident frequencies for collisions (head-on, crossing, merging, overtaking, and icebreaker contacts), for groundings (powered, drifting open water, drifting in ice) and for other types of ice damage/loads (collision with hard ice features multi-year ice, bergy bits, consolidated ridges, or icing) will be estimated quantitatively per area and specific time period (annual or seasonal). The basic model is a conventional “blind navigation” approach where causation factors describe the probabilities of collision/grounding candidates not making evasive manoeuvres in due time. Specific causation factors for Arctic conditions are partly derived by comparison of accident statistics from ice infested areas and general statistics from EMCIP (The European Marine Casualty Information Platform) and global accident statistics. Adaptation of causation factors and considerations reflecting specific risks associated with icebreaking operations, convoy operations, and towing operations are introduced with reference to findings from the Baltic Sea presented in the literature.

A number of guidelines and codes for safe ship operation in ice and Arctic conditions have been published and identify a wide range of factors and conditions to be considered. If not adequately considered, these factors also represent potential causes of failure and may thereby also contribute to and motivate that accident causation factors for ice navigation should differ from those derived for general, normally, ice free conditions. The bullet list below presented at The Polar Code Hazard Identification Workshop (IMO, 2011), extracted from (DNV, 2013) includes the following contributing factors to the risk of Arctic shipping:

- Ice bergs as collision hazard
- Ship pushed aground by moving ice
- Ice bergs as ship crush hazard (structural failure)
- Ice on ship superstructure (loss of stability, foundering)
- Extreme cold leading to brittleness of metal (structural failure)
- Extreme cold or icing leading to technical failure of equipment, including emergency or backup equipment that might fail on demand due to extreme cold or icing
- Long response times and limited emergency response capability
- Weak or non-existent conventional navigational aids (lights, distinguishable features forbearings, etc.)
- Poor navigational charts
- High latitude effects on navigation systems (lack of GPS, cosmic radiation effects)
- Variations of magnetic north/ south
- Long days or long nights resulting in interrupted sleep patterns, loss of alertness, poor decision making
- Weak primary radar returns from icy shorelines
- Difficulty of distinguishing sea ice from wave clutter with primary radar
- Extremely low visibility or low visibility for long periods of time
- Extreme sea state (wave height)
- Extreme wind speed
- Darkness
- Extreme brightness due to low sun, 24 hours per day.

The consequences are estimated in terms of credible oil discharge, distributed in different spill volume and oil type intervals with different associated probabilities. The computations will use the MMSI (Maritime Mobile Service Identity) ship identifier for crosschecking of characteristic bunker and cargo tank capacity with other ship databases and different assumptions on loading rates (fully loaded or average load/bunker) can be used for derivation of statistically credible spill volumes or for worst-case considerations. Collision types crossing and head-on, with high relative velocities are more prone to generate large spills from the struck vessel than overtaking and merging collisions.

The ship database crosscheck also provides information on the design/location of bunker tanks (for ships built 2010 or later and if bunker tanks > 600 tonnes, requirement on protected location inside hull plating apply).

The type of fuel used and potentially spilled will be influenced by the MARPOL sulphur cap of 0.5% entering into force 2020 (note that Greenland is exempted from this regulation). The potential introduction of a ban of the use and carriage of HFO in Arctic waters may also generate major implications on the quality and weathering properties of potential oil spills in the Arctic.

Figure 9 illustrates schematically the different components of the GRACE spill risk assessment model and its basic structure of established risk assessment steps.

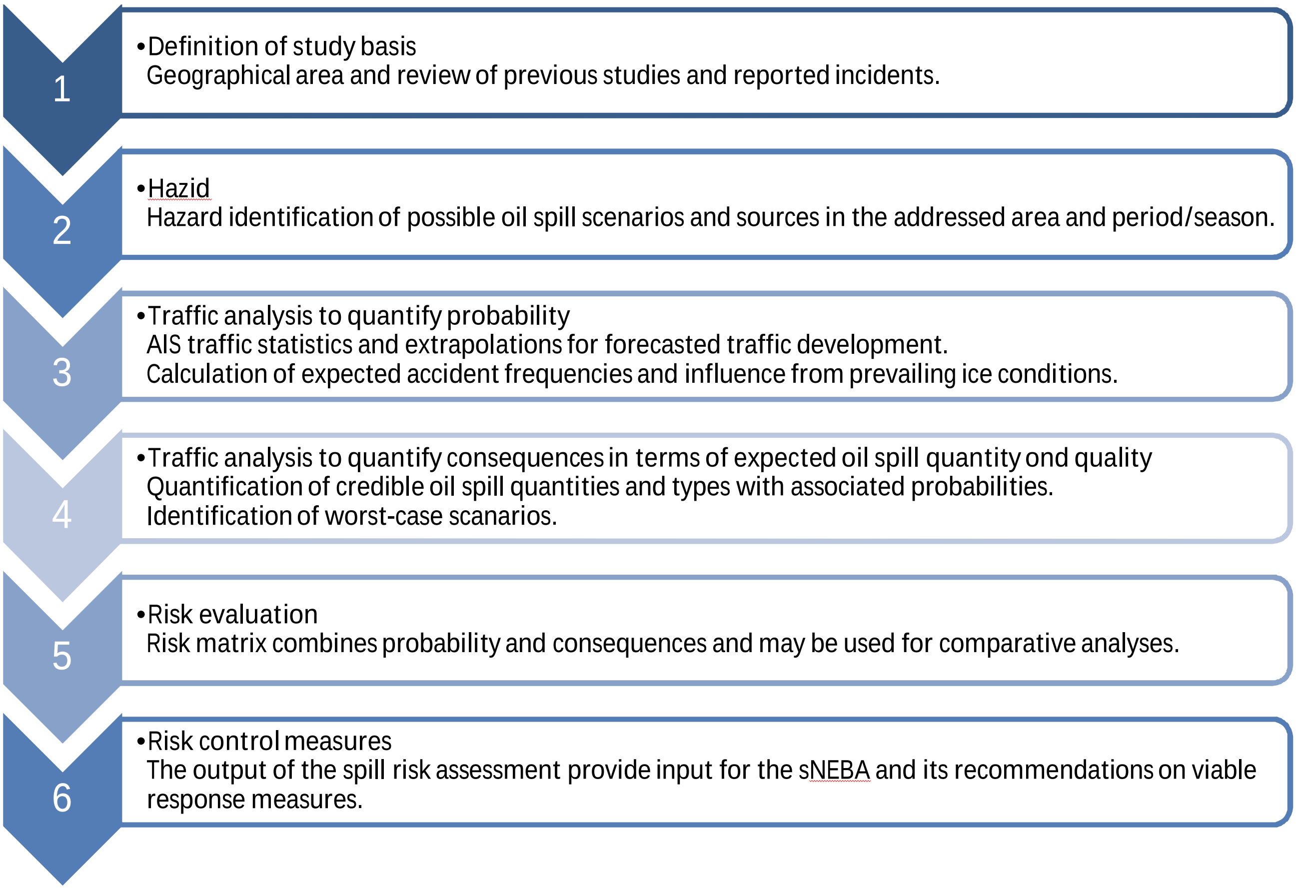



*Figure 9. Schematic structure of the GRACE spill risk assessment model.*

Recorded AIS ship tracks from the Arctic region is analysed and compared with ship databases and ice statistics to provide input for the spill probability calculations. Traffic analysis data can be presented as number of passages across specific identified passage lines and as cumulated sailed distance/ship hours in ice conditions and different identified routes. Figure 10 shows example of recorded AIS ship tracks for statistical calculations.

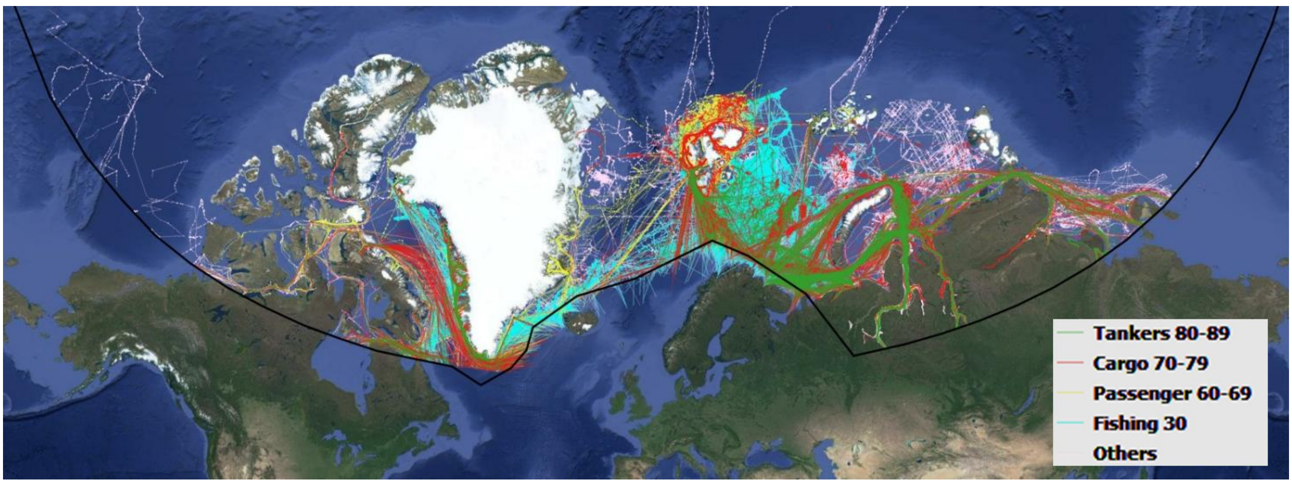



*Figure 10. Example of recorded ship tracks from Arctic waters in 2016 plotted from AIS-data from The Norweigan Coastal Administration.*

Even though the ship traffic intensity still is relatively low in Arctic waters, ship accident databases have recorded a relatively high number of accidents and incidents as shown in Figure 11 .

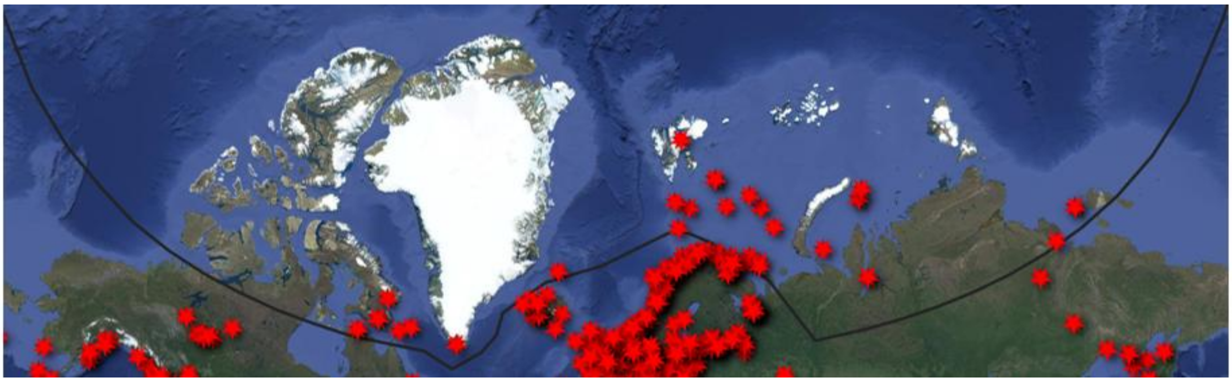


*Figure 11. Example of plotted spots of registered ship casualties and accidents extracted from EMSA's EMCIP database and SeaWeb.*

# 4 Trial applications of the GRACE spill risk model

The GRACE spill risk model is primarily designed for the Arctic area as defined by IMO (Figure 12). The Grace project is, however, also addressing other areas where sea ice is present and two sites for trial applications of the sNEBA tool and for the spill risk assessment model have been selected (Figure 11).

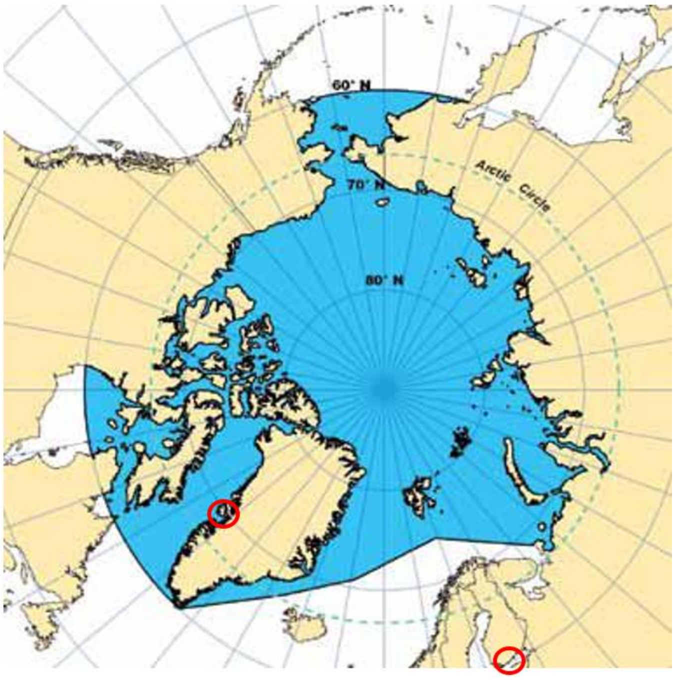
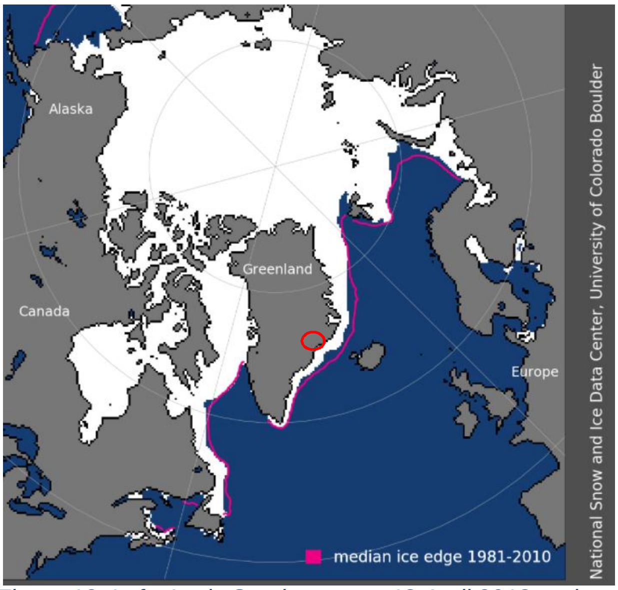



*Figure 12. Arctic area as defined by IMO. The two selected sites for trial applications of the presented spill risk assessment models are encircled in red.*

## 4.1 Trial application site – Disko Bay

The area in Disko Bay is well known with respect to available information on environmental resources and vulnerability. Previous initial studies outlining the sNEBA approach has been conducted for the Store Hellefiskebanke, located on the south-west side of the Disko Bay in Greenland, (Wegeberg, 2016). Disko Bay is practically ice free in summertime, as shown in Figure 13.



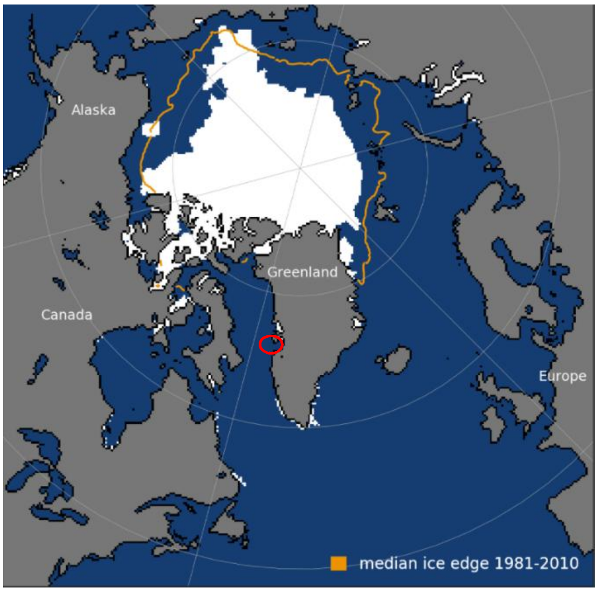



*Figure 13. Left: Arctic Sea ice extent 18 April 2018 and median April ice edge. Right: Ice extent 30 August 2018.*

## 4.2 Trial application site – Gulf of Finland

The trial application site in the Gulf of Finland in the Baltic Sea is very different from the Disko Bay in terms of resources at risk but also with regard to expected oil spill probabilities. The selected area south of Helsinki is characterised by intensive ship cargo and tank ship traffic in and out of the Gulf of Finland, combined with frequent route crossings by ropax ferries between Helsinki and Tallinn in Estonia (Figure 14). A number of different safety assessment and spill risk analyses have been presented for the area during the past decades, and experience from real oil spill in ice conditions provides valuable information for validation of model output from the trial application.


*Figure 14. The Baltic Sea trial site for the sNEBA tool and spill risk assessment model.*

# 5 Conclusions

The spill risk assessment model is still under development and will be described more in detail in the deliverable D1.10 Spill risk assessment methodology for extreme conditions, including Arctic. Deliverable D1.10 is due for delivery in February 2019.

The design of the spill risk assessment model incorporates a number of selected components from other presented models and combines state-of-the-art analysis technique for streaming high resolution AIS information. This ensures reliable and transparent modelling of oil spill risk in Arctic areas and the model is expected to provide a valuable complement to the sNEBA tool.

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