EMODnet Sea-basin Checkpoints
Tender no MARE/2014/09 (lot 1 Arctic)

EMODNET Oil Platform Leak Bulletin

Date: 13/05/2016

The European Marine Observation and Data Network (EMODnet) is financed by the European Union under Regulation (EU) No. 1255/2011 of the European Parliament and of the Council of 30 November 2011 establishing a Programme to support the further development of an Integrated Maritime Policy.

European Commission

Executive Summary

At 10:27 (BST) on 10/05/2016, OSRL and SINTEF were alerted to the fact that an explosion had occured at 08:15 (CET) on the Prirazlomnaya Platform, 60km off the coast in the Pechora Sea (figure 1). Currently, oil is leaking subsurface, at a rate of 800 m^3/day: this is expected to be reduced to 500 m^3/day following emergency repairs with 24 hours, with the leak being stopped completly within 72 hours.

The Pechora sea area is characterised by extremely low temperatures; annual average is -4˚C, and being ice-free for only 110 days a year. Wind strength reaches up to 40m/s and wave heights can be as much as 12 m. The weather and ice forecast for 10/05/2016 are shown below:

Variable	10-May	10-May	10-May	10-May	10-May	10-May	10-May	11-May	11-May	11-May	11-May	12-May	12-May	13-May	13-May
	06:00	09:00	12:00	15:00	18:00	21:00	00:00	06:00	12:00	18:00	00:00	12:00	00:00	12:00	00:00
Wind Speed, knots	16	14	14	12	10	10	10	10	11	12	13	15	16	11	5
Wind From Direction, °	63	55	47	50	54	50	50	55	54	72	77	66	60	58	152
Wind Gust, knots	17	15	14	13	11	10	11	10	11	13	14	16	17	12	6
Sig. Wave Height, m	1.2	1	0.9	0.8	0.8	0.7	0.7	0.6	0.5	0.6	0.7	1.1	1.2	1.1	0.7
Cloud Cover, %	95	95	97	97	98	100	100	98	95	92	98	93	95	86	50
Air Temperature, °C	-4	-4	-4	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
Precipitation, mm/h	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0

The Prirazlomnaya Platform is the main pre-development facility of the Prirazlomnoye oil field. It is used for all production operations, and has been designed so that it can still operate in the extreme conditions.

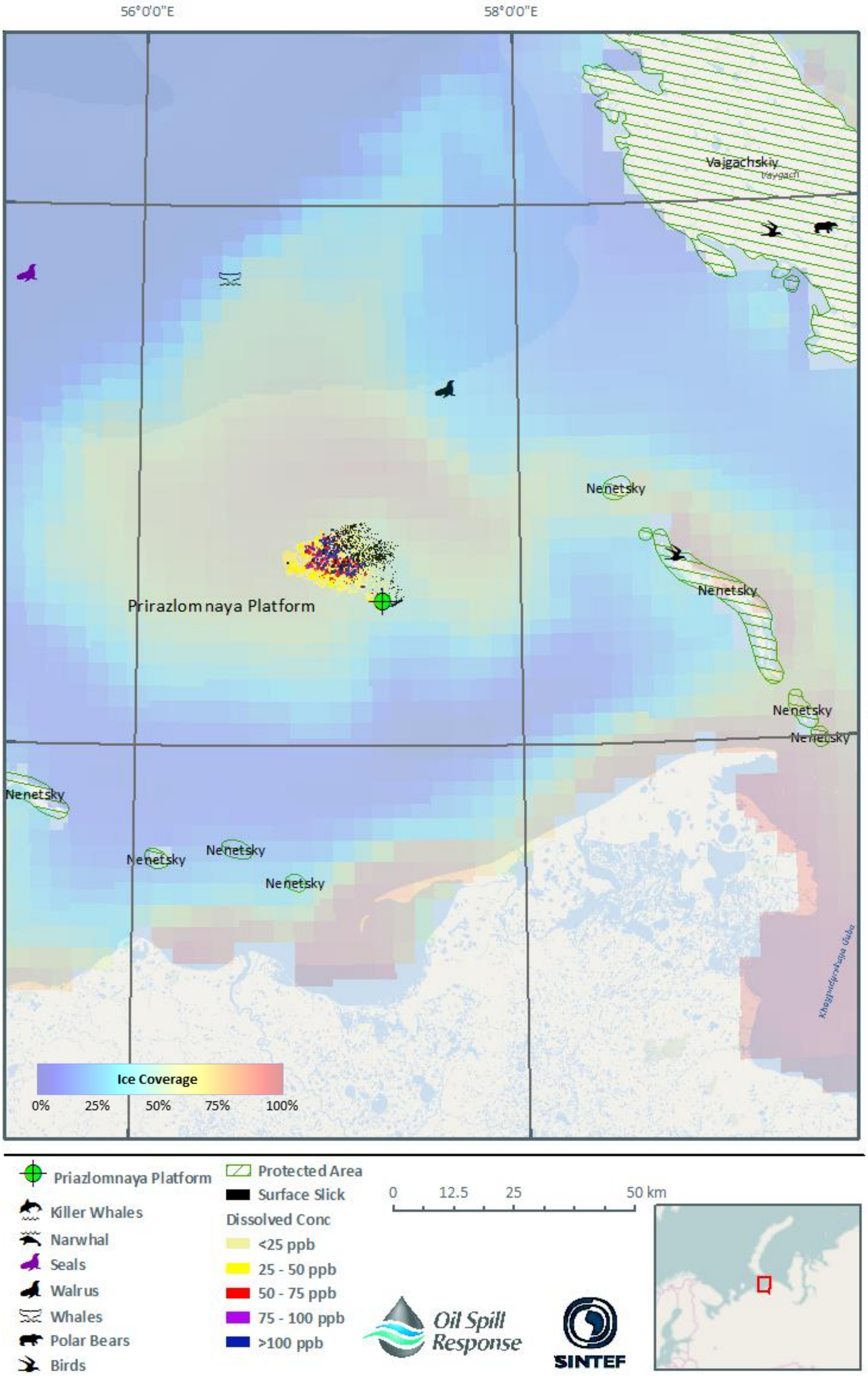


Figure 1: The current location of the leaking oil slick and the ice pack in the 60km off the coast in the Pechora Sea. (13-May-2016 08:15 CET)

Approach and method(s) used

The models used to create this report are:

- SINTEF's OSCAR Model
- RPS ASA OILMAP™ (2D Surface Version Only)
- NOCS, Lagrangian particle-tracking software package, Ariane
- SINTEF Oil Weathering Model

The oil spill forecast was done using SINTEF's OSCAR model. The information provided in the initial email was used for the setup:

Model Setup	
Release Date	11-May-2016
Release Time	08:15 (GMT+1)
Latitude	69° 16' 04.44" N
Longitude	057° 16' 50.48" E
Release Rate	800 m^3/day (0 – 24 hrs) 500 m^3/day (24 – 72 hrs)
Total Volume Spilt	1800 m^3
Model Duration	4 days

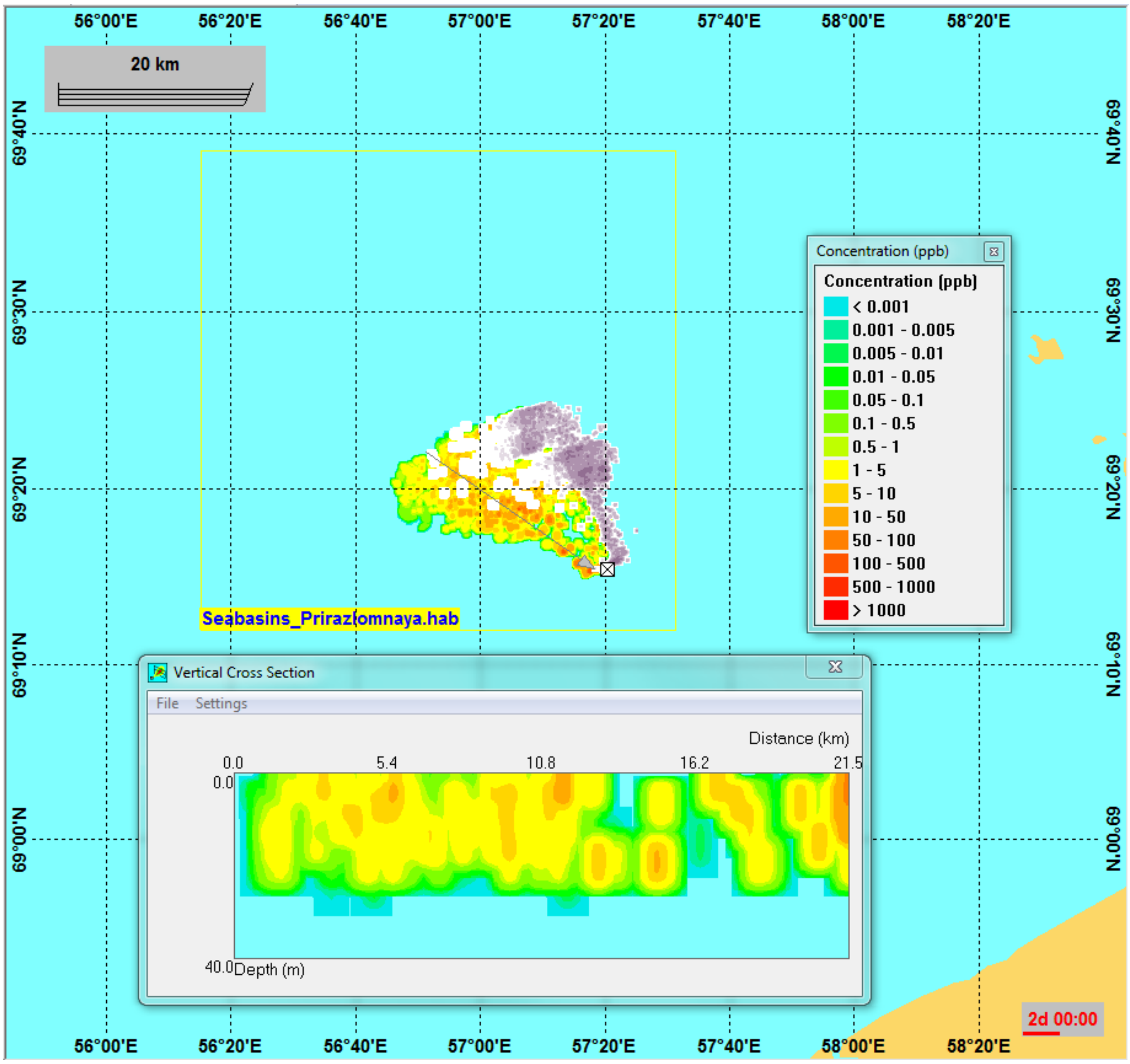
Assumption

The following assumptions were made in order to create a oil spill forecast:

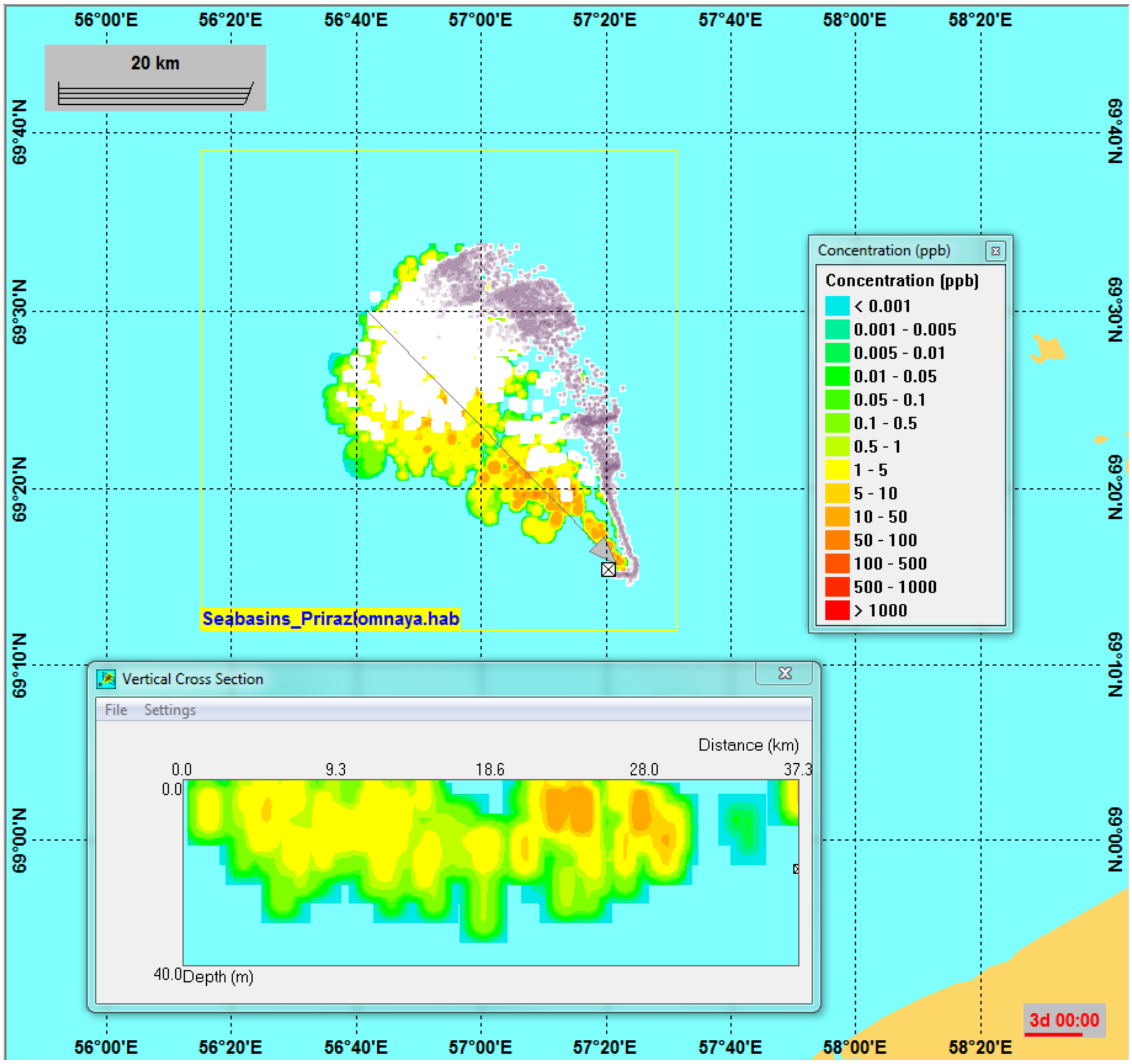
- The oil type is a heavy Group 3 Oil (0.910 kg/m^3) with increased concentration of sulfur and low paraffin content. Information about oil groups can be found here http://www.itopf.com/fileadmin/data/Documents/TIPS%20TAPS/TIP2FateofMarineOilSpills.pdf

- The exact location of the platform is 69°16'4.44"N, 057°16'50.48"E in 19 m to 20 m of water.

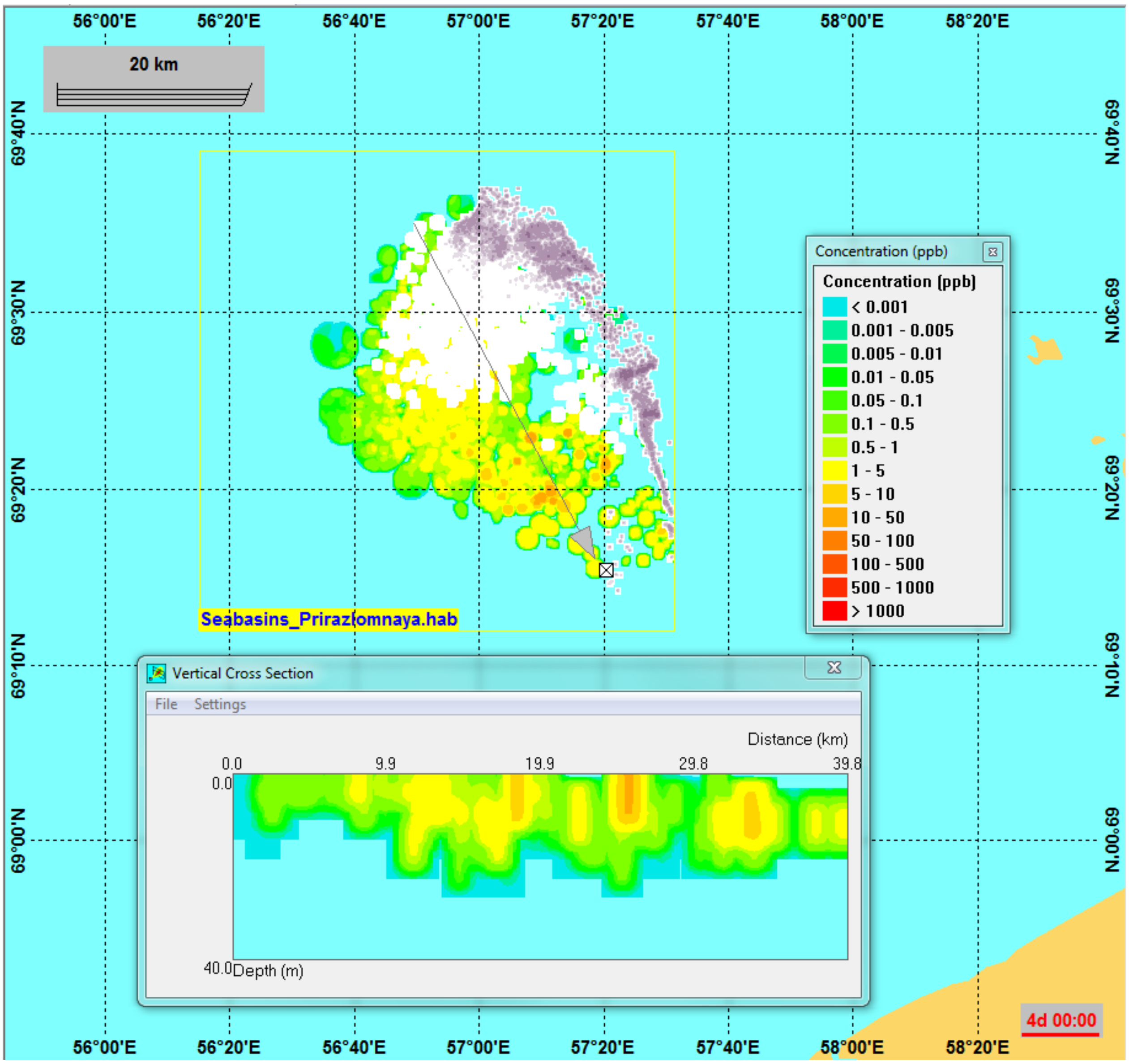
Fate and transport of Leaked Oil



Day 2 (12-May-2016 08:15 CET). Surface oil shown overlaid with a plot of maximum subsurface concentrations and a cross section of subsurface oil concentration at end of Day 2, oil release rate decreasing. (SINTEF OSCAR model, output updated 12 May 2016 1100)

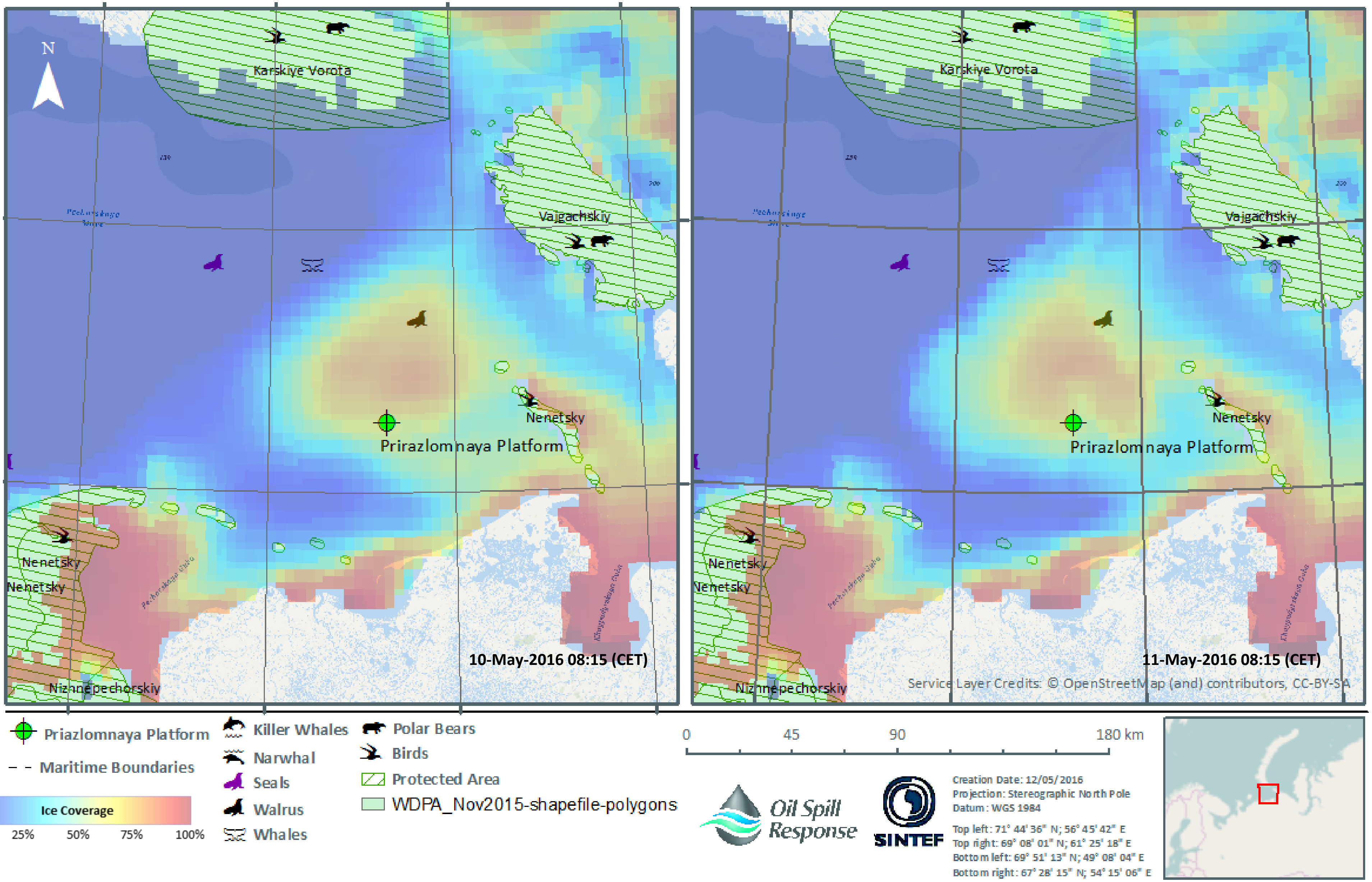


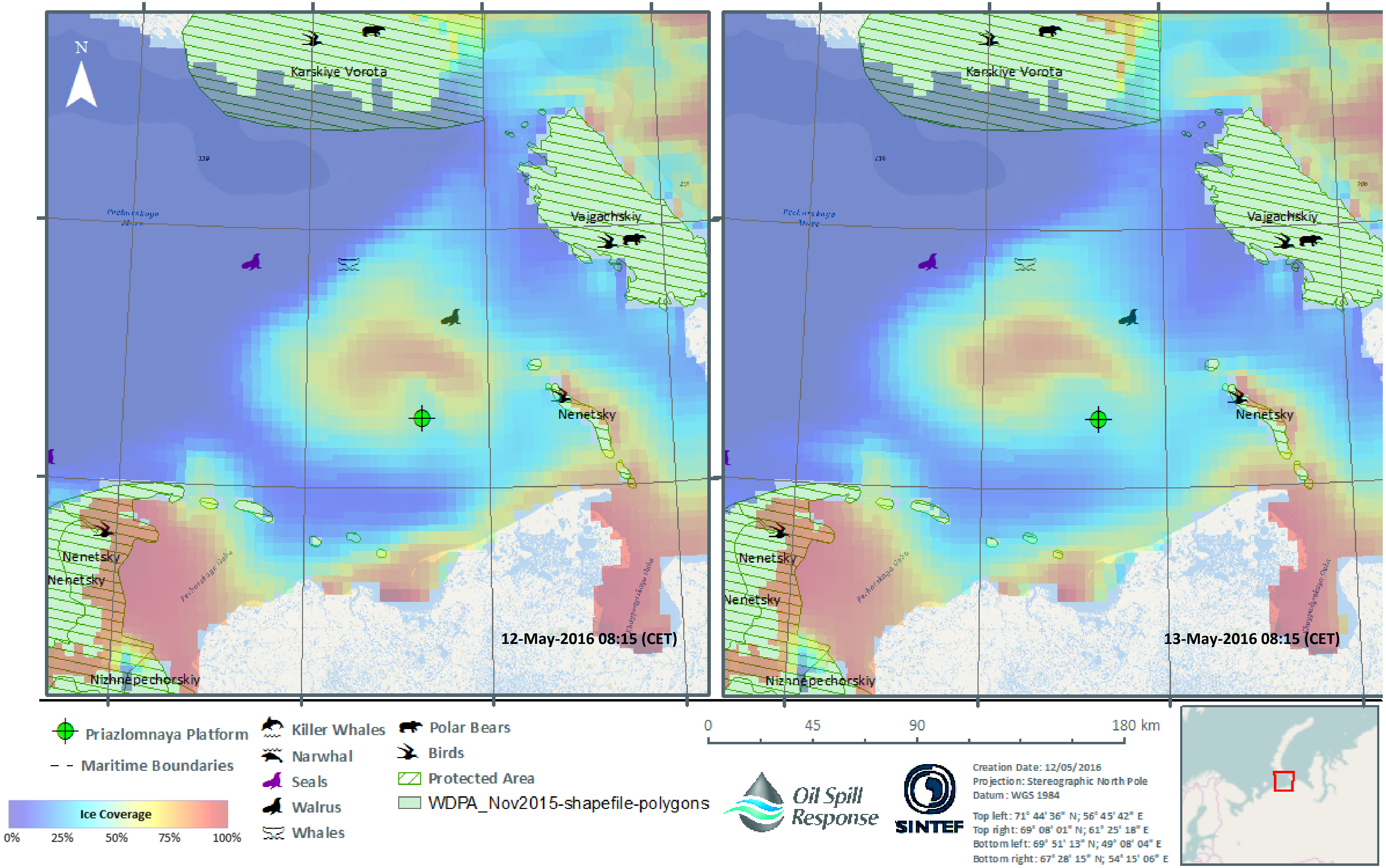
Day 3 (13-May-2016 08:15 CET). Surface oil shown overlaid with a plot of maximum subsurface concentrations and a cross section of subsurface oil concentration at end of f Day 3. Cross section is for arrow shown on map. (SINTEF OSCAR model, output updated 1100 12 May2016)



Day 4 (14-May-2016 08:15 CET). Surface oil shown overlaid with a plot of maximum subsurface concentrations and a cross section of subsurface oil concentration at end of Day 4. Cross section is for arrow shown on map. (SINTEF OSCAR model, output updated 1100 12 May2016)

The following Pages show the ice forecast for the region.


N
Karskiye Vorota
Vajgachskiy
Nenetsky
Prirazlomnaya Platform
Nenetsky
Nenetsky
Nizhnepechorskiy
10-May-2016 08:15 (CET)
11-May-2016 08:15 (CET)
Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA
Priazlomnaya Platform
Maritime Boundaries
Ice Coverage
0%
25%
50%
75%
100%
Killer Whales
Narwhal
Seals
Walrus
Whales
Polar Bears
Birds
Protected Area
WDPA_Nov2015-shapefile-polygons
0
45
90
180 km
Oil Spill Response
SINTEF
Creation Date: 12/05/2016
Projection: Stereographic North Pole
Datum: WGS 1984
Top left: 71° 44' 36" N; 56° 45' 42" E
Top right: 69° 08' 01" N; 61° 25' 18" E
Bottom left: 69° 51' 13" N; 49° 08' 04" E
Bottom right: 67° 28' 15" N; 54° 15' 06" E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13-May-2016 08:15 (CET)
Priazlomnaya Platform
Maritime Boundaries
Ice Coverage
0%
25%
50%
75%
100%
Killer Whales
Narwhal
Seals
Walrus
Whales
Polar Bears
Birds
Protected Area
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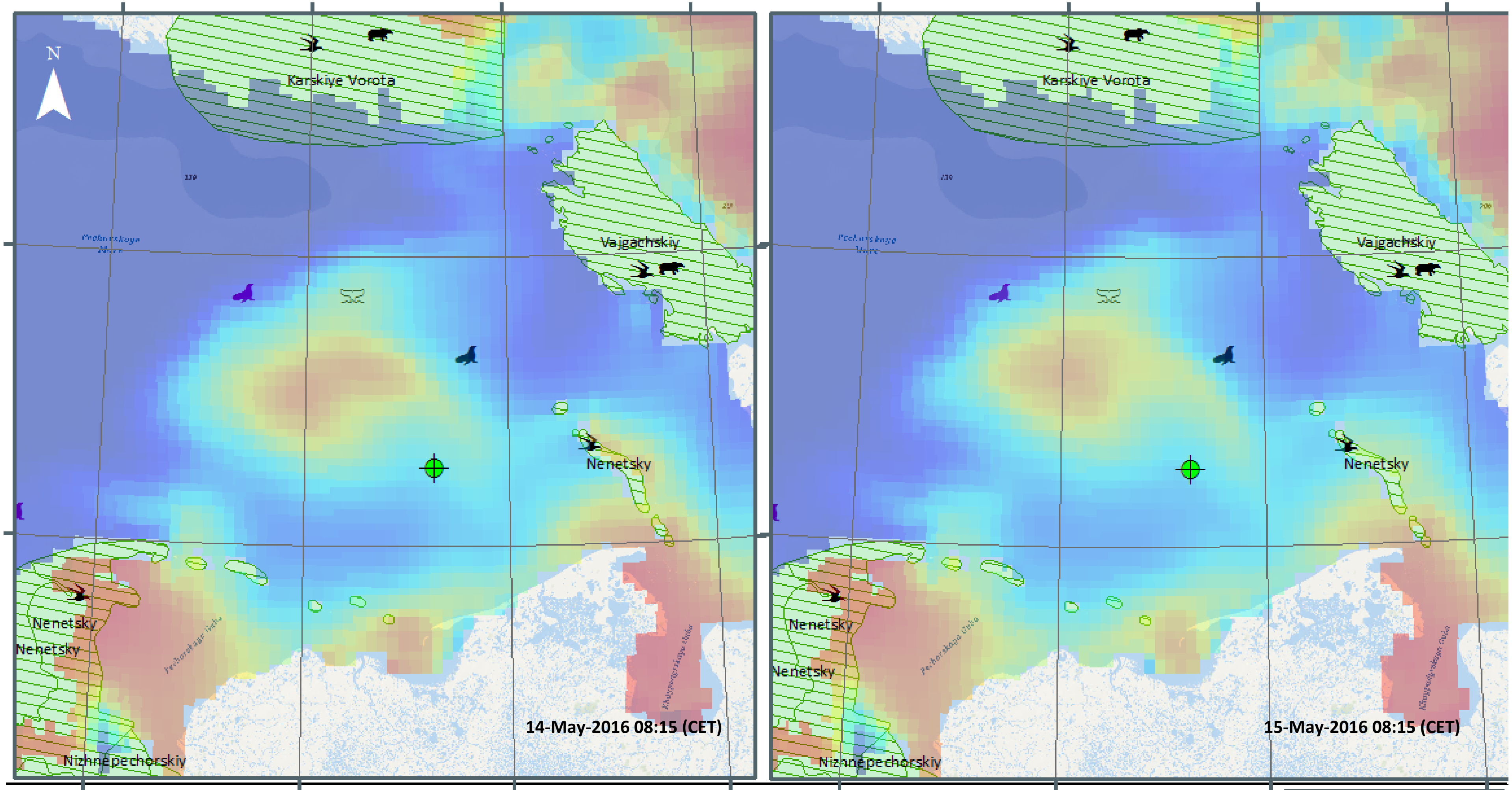

Priazlomnaya Platform
Maritime Boundaries
Ice Coverage
0% 25% 50% 75% 100%

Killer Whales
Narwhal
Seals
Walrus
Whales

Polar Bears
Birds
Protected Area
WDPA_Nov2015-shapefile-polygons

0 45 90 180 km

Creation Date: 12/05/2016
Projection: Stereographic North Pole
Datum: WGS 1984

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Expected Impact on Environmental and Human Activity

Biological Sensitivities

A number of protected areas surround the Pechora Sea: Nenetsky, Karskiye Vorota and Vajgachskiy. Oil is predicted to travel west towards the Barents Sea over the next few days, but if it travels eastwards through the Kara Gate, as looks most likely from the stochastic modelling completed for previous years, then it could also impact the Kara Sea.

The oil slick is not predicted to impact protected areas within the next 6 days, but could affect local wildlife including seabirds, fish and marine mammals. Oiled wildlife response in the Arctic is particularly difficult due to a number a factors:

- Difficult working conditions;
- Safety issues concerned with dangerous animals, such as polar bears and walruses;
- Remote locations and difficulty in transporting heavy, dangerous animals;
- Use of marine animals for subsistence by indigenous people.

An oil spill in the Barents Sea has the potential to affect a diverse range of organisms in and around the sea, some of which are protected. Some organisms at risk are listed below.

	Family	Species
Fish	**Gadidae**	Atlantic cod, polar cod
	Pleuronectidae	Atlantic halibut
	Clupeidae	Atlantic herring
	Salmonidae	Atlantic salmon, Arctic char, sardine cisco
	Osmeridae	Arctic rainbow smelt
Birds	**Gaviidae**	Arctic loon, red-throated loon*
	Sternidae	Arctic tern*
	Laridae	Black legged kittiwake*, glaucous gull*, great black-backed gull*, mew gull*
	Anatidae	Brant goose*, common eider*^{NT}, greater scaup*, green-winged teal, king eider*, long-tailed duck*^{VU}, northern pintail*, red-breasted merganser*
	Scolopacidae	Dunlin*, red phalarope*, red-necked phalarope*
	Stercorariidae	Parasitic jaeger
	Alcidae	Thick-billed murre*
Mammals	**Balaenidae**	Bowhead whale
	Balaenopteridae	Humpback whale, minke whale**
	Monodontidae	Beluga whale^{NT}, narwhal^{NT}
	Delphinidae	Killer whale**
	Phocidae	Bearded sea, harp seal, ringed seal
	Odobenidae	Walrus
	Ursidae	Polar bear^{VU}

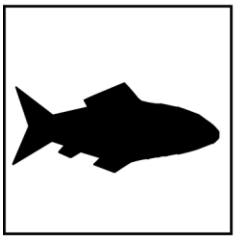
*migratory birds to which the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) applies.

**mammals protected by the EU Habitats Directive.
NT – near threatened; **VU** – vulnerable, according to The World Conservation Union (IUCN) Red List of Threatened Species.

Effects of Oil on Marine Species

Plankton

- Includes juvenile fish and shellfish.
- Toxic, leading to death of plankton.
- Reduced future populations of fish and shellfish.

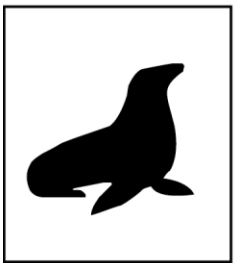


Fish and Shellfish

- Smothering: loss of habitat, irritation and damage to the respiratory system, suffocation, damage to fins and scales, shell closure.
- Ingestion: enlarged liver, fish tainting, reduced growth, heart failure.
- Reduced egg hatching and larval survival.

Birds

- Smothering: loss of habitat, reduced mobility (increased vulnerability), loss of buoyancy, hypothermia, death.
- Ingestion: organ damage, gastrointestinal irritation and ulceration.
- Inhalation: pneumonia and death.
- Development deformities, decreased reproduction/irregular breeding.



Mammals

- Smothering (haired species): irritation, inflammation, infection, suffocation, hypothermia, reduced buoyancy and swimming ability.
- Ingestion: digestive complications, decreased chance of survival.
- Inhalation: respiratory system damage, disorientation, unconsciousness, paralysis, pneumonia, death.
- Loss of habitat (seals, walruses and polar bears).

Socio-Economic Sensitivities

Oil spills are notoriously detrimental to local communities. In this instance there may be some impact to the local Nenets indigenous people. The Nenets undertake great migrations and data on their whereabouts at this time is not readily available.

Longer term there could be an impact on nearby communities that have been set up to support the local oil industry, such as Varandey. The oil export terminal at Varandey is likely to be affected.

Once the ice has melted, shipping that would normally pass through the region may need to be redirected. The Prirazlomnaya Platform lies within close proximity to the Northern Sea Route (NSR). The NSR connects trade between Asia and Northern Europe. The NSR is NOT currently open, but is typically navigable between July and November.

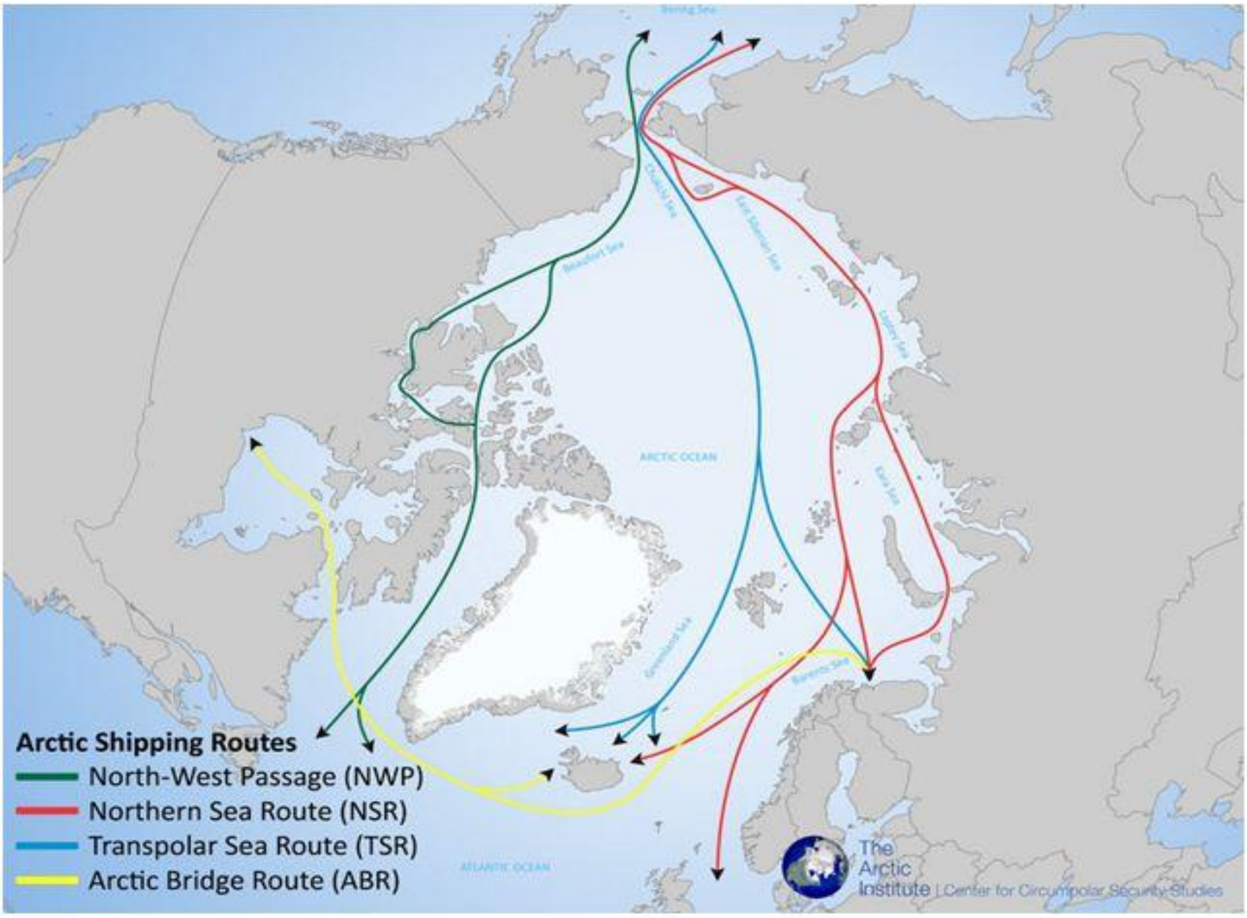


Figure 2: Arctic Shipping Routes

Human Health

The effects of spilled oil on human health vary depending on the chemical composition of the oil and the level of exposure. Those involved in the clean-up have the most potential for exposure. The effects of spilled oil on human health are summarised below.

Acute Toxic Effects	Psychological Effects	Genotoxic Effects
• Headaches • Throat irritation • Respiratory problems • Sore/itchy eyes • Dermatitis • Nausea/vomiting • Dizziness	• Depression • Chronic stress • Anxiety • Post-traumatic stress disorder (PTSD) • Desire to emigrate • Social disruption • Perceived poor health	• Skin tumours following long contact time with oil • DNA damage leading to cancers

The Main Factors which have Strong Influence on the Outcomes of the Fate and Expected Impact

The semi-enclosed Pechora Sea is ice-covered for a considerable portion of the year. Floating ice usually blocks the sea from marine traffic between November and June.

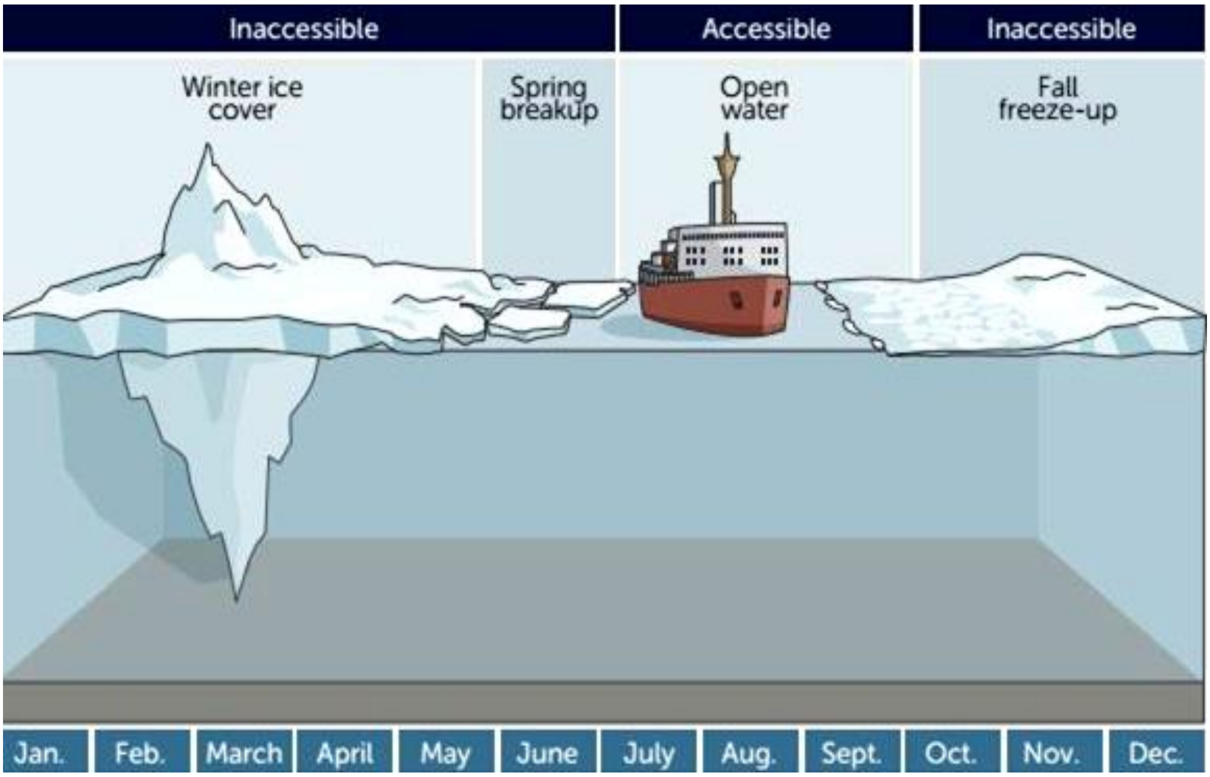


Figure 3: Seasonal Ice in the Arctic

There has been extensive research related to oil in ice. See for example the current JIP (http://www.arcticresponsetechnology.org/)

Surface oil drifts at the speed of the surface currents plus a percentage of the wind speed. This "windage" factor varies from 0-6% depending on the oil type and how fresh the oil is (evaporation causes the oil to become more dense, etc.), so this drift slows down as the oil ages. This is well known.

Oil under ice moves with the currents with some drag from the ice. This implementation in a trajectory model is state-of-the-art. Experimental oil releases in Canadian waters have informed response to oil under ice, and bench and mesoscale studies as well. There are some published models.

Oil-ice interaction is complex. The modelling forecasts have suggested oil will pool under ice. The under-ice topography is fundamental in determining the volume of oil that can be held as oil will pool to fill depressions under the ice. Most of the oil will be contained locally, but it depends on under-ice currents and ice roughness. . Pressure ridges can potentially block oil flow under the ice, leading to changes in direction of the oil's movement under the ice.

Despite being state of the art, the ice modules within oil spill models are a simplified versions of what can be expected in real life. Oil spill models capture the fact that spreading, evaporation, surface dispersion and emulsification is reduced in the presence of ice, but they neglect the transport of oil under ice and the trapping of oil between ice blocks. Modules to better understand oil-ice movement are currently being developed by SINTEF.

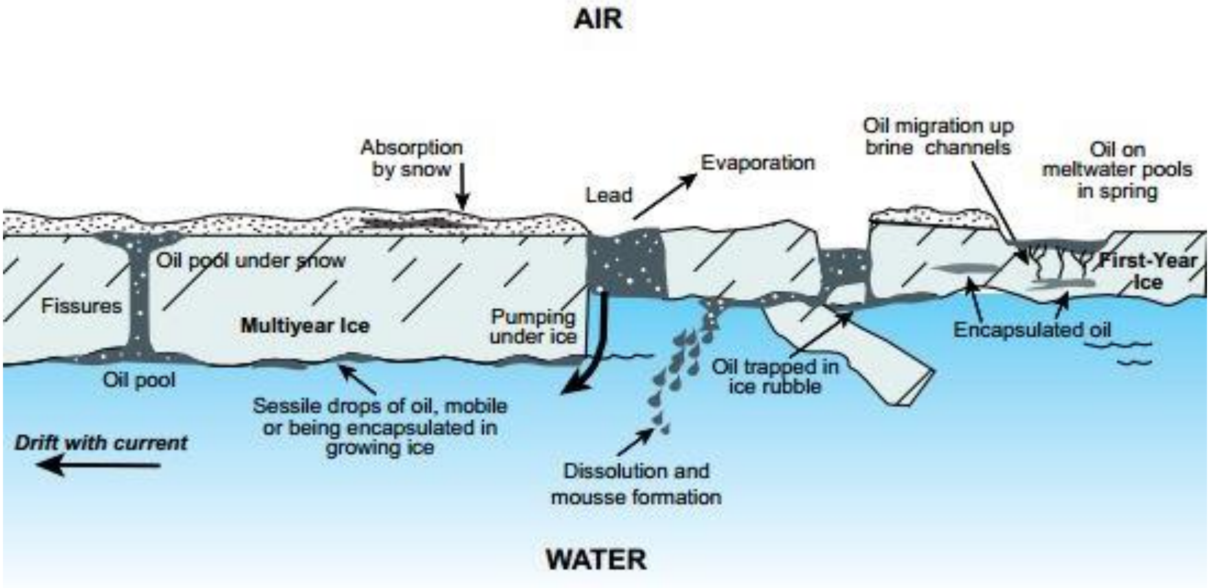
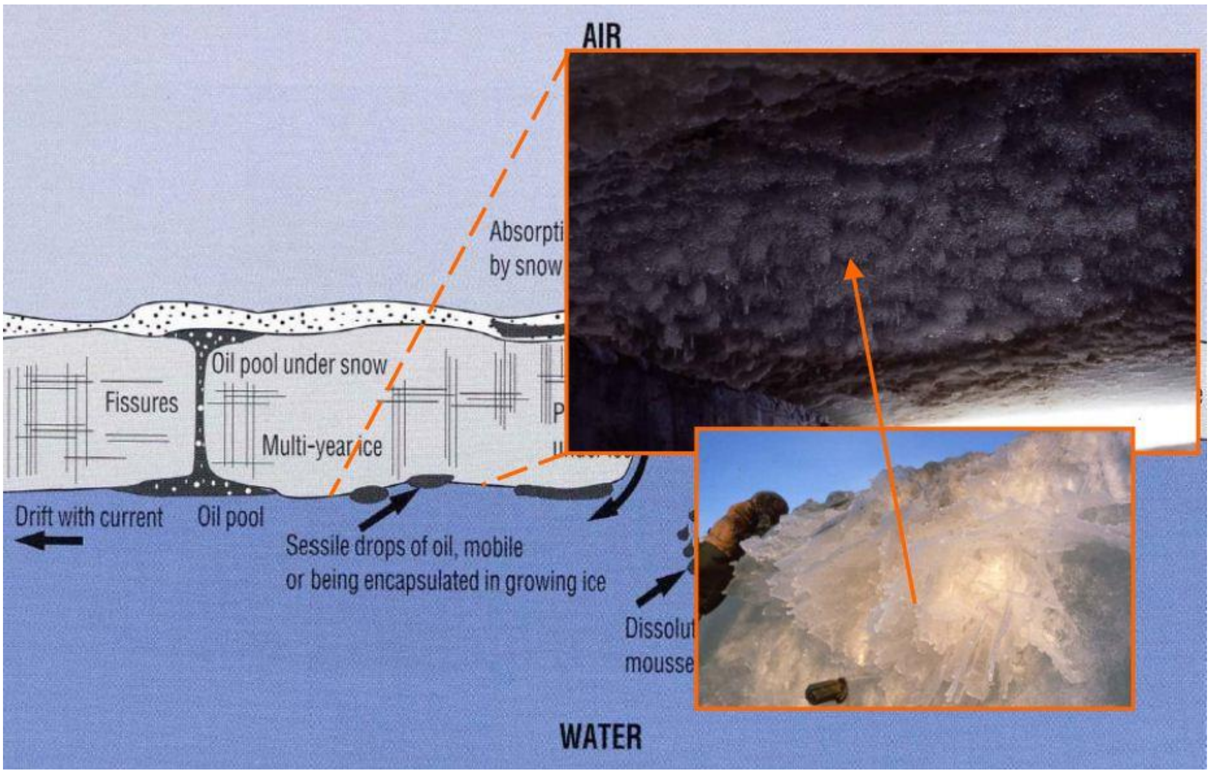


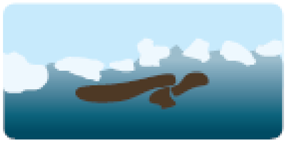
Figure 4: Oil-ice interactions



Response Options

Taking into consideration the thickness of the ice sheet, and the current location of the spill, it would be difficult for OSRL to man a traditional response. The ideal option would be to monitor and evaluate the situation, using forecast modelling, preferably stochastic, to predict the movement and weathering effects on the oil. This would help us to be prepared to act once the ice has started to melt making the oil accessible. Some attempts to locate the oil under the ice and cut trenches for skimmers could be made, but this would depend on the availability of response vessels, and their ability to get through the ice, meaning containment options would be limited. In situ burning could be considered, although accelerants would have to be used.

Feasibility of oil spill response techniques at different stages of ice melt:

Response Technique	Location of Oil		
	Beneath ice 	Beneath broken ice 	Sea surface mixed with ice 
Natural recovery	Low	Medium	Medium
Mechanical recovery	Low	Low	Low
Dispersant application	Low	Low	Medium
In-situ burning	Low	Low	Medium
Airborne surveillance	Low	Medium	Medium
Remote sensing	Low	Low	Medium
Surface surveillance	Low	Medium	Medium
Tracking	Low	Low	Low

Detection strategy

Determine spill extent and thickness with Ground Penetrating Radar (GPR). Cut holes in ice and deploy SONAR. Trained dogs may also be used to detect oil under ice.

Mechanical Recovery

During a field exercise in Alaska it was demonstrated that the actual operating limits for mechanical recovery systems—which are typically defined in the literature as being operable in up to 30 % ice coverage—were closer to 10 % ice coverage.

In icy conditions ice might tear or lift containment boom, and clog skimmers and pumps. It is important to winterise equipment and stored it correctly to prevent it freezing up due to the extreme temperatures. It is also important to make sure that any openings that have been created as enhanced collection points are maintain, and the ice is not able to reform.

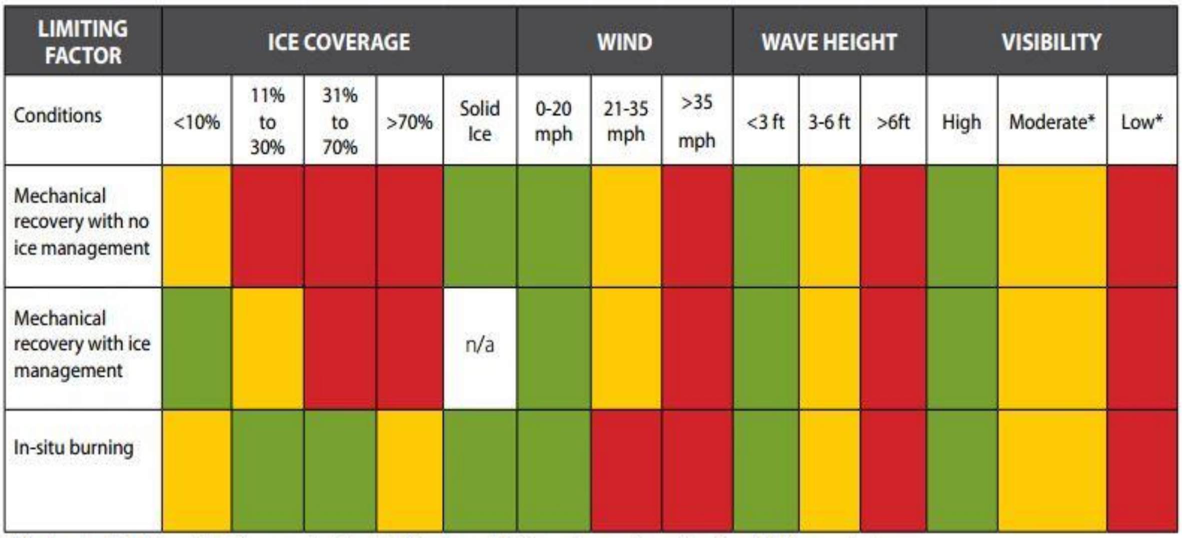
Consider the storage of recovered waste product. Restrictions on vessel access mean that waste may have to be stored in tanks on the ice sheet, but the weight bearing capacity of the ice would have to be monitored.

In-situ Controlled Burning

When ice coverage is above 60 or 70 %, in-situ burning may be viable as the ice acts as natural containment. Slow emulsification rates in the cold waters increase the time window for responders to instigate a burning operation. The strong winds, cold temperatures, fog and high waves can make it difficult to ignite oil, so accelerants may have to be used. It is also very difficult to recover burn residue. Between 30-60 % ice coverage makes in-situ burning more difficult as ice does not contain the oil and boom deployment is not usually possible.

Dispersants

Dispersants are difficult to accurately spray in strong winds. During ice cover >70 % mixing energy will be severely reduced leaving dispersants ineffective.



*Moderate visibility = light fog or <1 mile visibility; low visibility = heavy fog, <¼ mile visibility, or darkness

Bottlenecks and Weaknesses of the Assessment Methodology and Available Tools, the Data as well as the Services Required to Perform the Assessment

For an initial oil spill forecast assessment, dedicated emergency oil spill response organisations can provide a forecast within a few hours. For example, NOAA is the US has a response time requirement of 30 minutes for a weather forecast and written description of the oil spill evolution, and 2 hours for the a model run (4 hours in new areas, usually outside the U.S.). Oil Spill Response Ltd., providing global response coverage, has a response time requirement of less than 2 hours for anywhere in the world.

Recommendations to improve existing data collection and provision services, including the content they offer and the way the service is delivered.

The Copernicus Marine Services data is much coarser resolution than what is available through Met.no and NERSC directly. For responders, high quality high resolution forecasts are key to mobilising response equipment and personnel rapidly to needed areas.

Rapid acquisition and inspection of ocean current and wind data is important in order to evaluate and use data sources for oil spill simulations. The ocean current data must be of a high temporal and spatial resolution to capture tidal effects that greatly affects the transport of oil. MyOcean data sets for this region are given on a coarse spatial resolution using daily mean. This is too coarse for accurate predictions of oil spill trajectories with OSCAR. Met.no produces data sets that are on a 1h temporal resolution and 4k spatial resolution. This will give significantly more accurate simulations, however the acquisition, inspection and usage of this data demonstrates that it does not conform to netCDF CF 1.6, which introduces difficulties to use the data without performing significant adaptations. This introduces a risk regarding whether the adaptations are correct and whether the data sets are fully self-describing which must be checked.

In order to perform this operation rapidly and fail-safe, we recommend that high resolution data sets with the purpose accurately modelling oil spills are collected on a data server, including sufficient meta-data to unambiguously describe the data sets and the projections/grids used. We further recommend that data sets conform to the netCDF format and CF 1.6 (or newer) convention. Furthermore, to reduce the risk of data being interpreted wrongly in the oil spill model, vector maps of the ocean current directions and magnitude should be provided for some time intervals. This makes it easy to rapidly check that the data is being used correctly.

The Met.no website has 4 km and 800 m forecast data for ocean winds and currents and runs the TOPAZ sea ice model at coarse resolution. The English language version of the website has links to download daily average currents, but the Norwegian language version of the website includes hourly data for download. Thus connections to data need to be made early.

The NOAA Office of Response and Restoration has started GOODS (GNOME Online Oceanographic Data Server) (http://response.restoration.noaa.gov/goods). This data server specializes in high resolution high quality data that has been reviewed for use in oil spill response.

The International Oil and Gas Producers has funded a project to add capability to major oil spill models, such as the SINTEF Oil Spill Contingency And Response (OSCAR) model, to use the Nansen Environmental and Remote Sensing Center (NERSC) neXtSIM-F model, which is a high resolution elasto-brittle rheology to improve sea ice dynamics.

The NERSC neXtSIM-F 3 km coupled ice ocean model forecast model is available here:

https://www.nersc.no/data/nextsim-f

Images of the NERSC neXtSIM-F can be found here:

ftp://ftp.nersc.no/pub/Philipp/forecasts/plots_20160510_lowres.png

Annex A: Long Term Impact

Probabilistic analysis of the circulation pathways for an Arctic Oil spill at the Prirazlomnaya Platform in the Pechora Sea

In order to assess the impact of an oil spill from the Prirazlomnaya Platform in the Pechora Sea, we utilise an offline Lagrangian particle-tracking software package, Ariane [Blanke and Raynaud, 1997], in conjunction with output from the leading-edge 1/12th degree resolution NEMO ocean model coupled to LIM2 ice model [Aumont et al., 2015; Madec, 2014; Vancoppenolle et al., 2009]. Ariane is used to determine Lagrangian pathways (Jacobs et al., 2016) from an initial release location in the vicinity of the platform. Probabilistic analysis of the pathways followed was performed at the date of the spill in previous years, and significant interannual variability was observed in our experiments. Regions at risk of contamination within 6 months of a spill occurring have been identified, including IUCN class I-IV protected areas in the Kara Gate.

NEMO Ocean Model & Lagrangian Particle Tracking

NEMO's horizontal resolution in the Arctic is 3-5km, making it eddy-permitting but, due to the small Rossby radius of deformation in this basin [*Nurser and Bacon*, 2014], not fully eddy-resolving. The model has 75 levels in the vertical direction, with the spacing between levels varying from near 1m at the surface to 250m at the abyssal ocean floor. The simulation is driven at the surface using atmospheric reanalysis DRAKKAR Forcing Set (DFS), comprised of 6-hourly atmospheric temperature, humidity and winds, and from daily radiative fluxes and monthly mean precipitation. NEMO has undergone extensive validation and is widely used by the research community [*Duchez et al.*, 2014; *Marzocchi et al.*, 2015; *Srokosz et al.*, 2015].

For this experiment, we track point particles released into the flow field [*Popova et al.*, 2013; Jacobs et al., 2016] and track their progress as they undergo advection due to the ocean currents. It is important to note that these particles are treated as passive – they are neutrally buoyant point particles used to illustrate Lagrangian pathways from the initial release location. This can provide useful information which can be applied to considering the fate of an oil spill, but as these particles do not emulate the physical characteristics of oil, it is important to make the distinction between modelling the Lagrangian pathways that the current follows and modelling actual pollutants.

Experiment

100 Lagrangian particles were released at the ocean surface over a 10x10km area, located at 69°16'4.4"N, 57°16'50.48" - the site of the Prirazlomnaya Platform. 100 particles in a 10x10 grid were released every 3 hours over the course of 3 days from the 10th of May, and their progress was followed for 6 months. In order to build a probabilistic forecast of Lagrangian pathways from this location at this time of year, this experiment was repeated for every year between 1990 and 2010.

The trajectories of these particles were then plotted to highlight the areas most likely to be affected and the timescales involved in reaching these locations. Figures 1 and 2 show the trajectories of all particles in our experiment, and the Appendix shows a year-by year breakdown to demonstrate the high interannual variability in routes taken.

A large number of particles were found to flow through the Kara gate, providing a potential risk to the IUCN class I-IV protected area there. Regions home to various seabirds, marine mammals and fish are all reached by Lagrangian particles in our simulation, so these habitats are all potentially at risk of contamination.

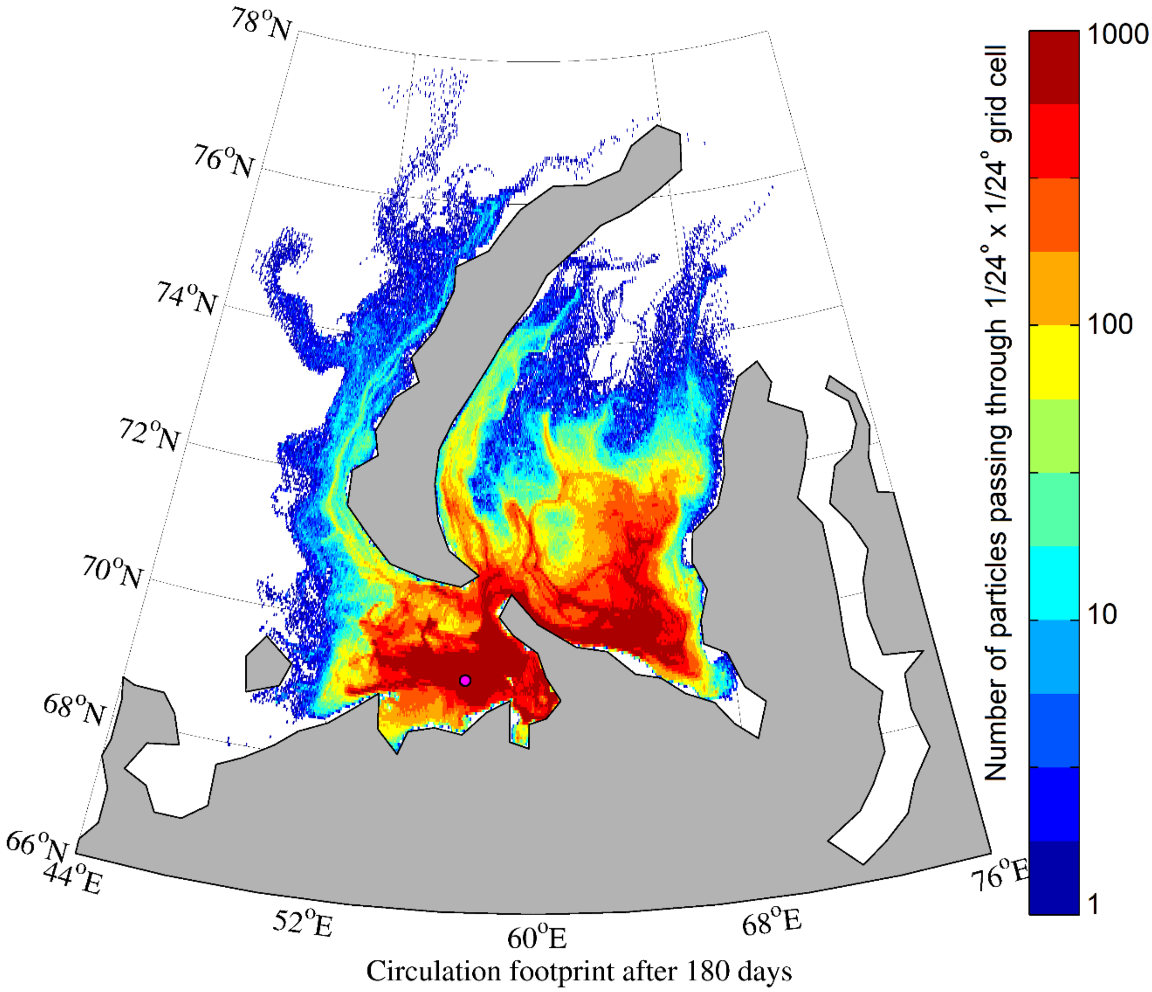


Figure 5: Probabilistic circulation footprint of Lagrangian particles released from Prirazlomnaya Platform (magenta dot.) The footprint is calculated using time period of 1990-2009. Note the large number of particles flowing through the Kara Gate, a marine protected area. Note also that considerable numbers of particles reach both the east and west sides of Novaya Zemlya; while particles flowed into the Kara Sea in every year that we simulated, the western side of Novaya Zemlya is significantly affected in some years and completely untouched in others. See appendix for a full year-by-year breakdown of which regions were affected and when.

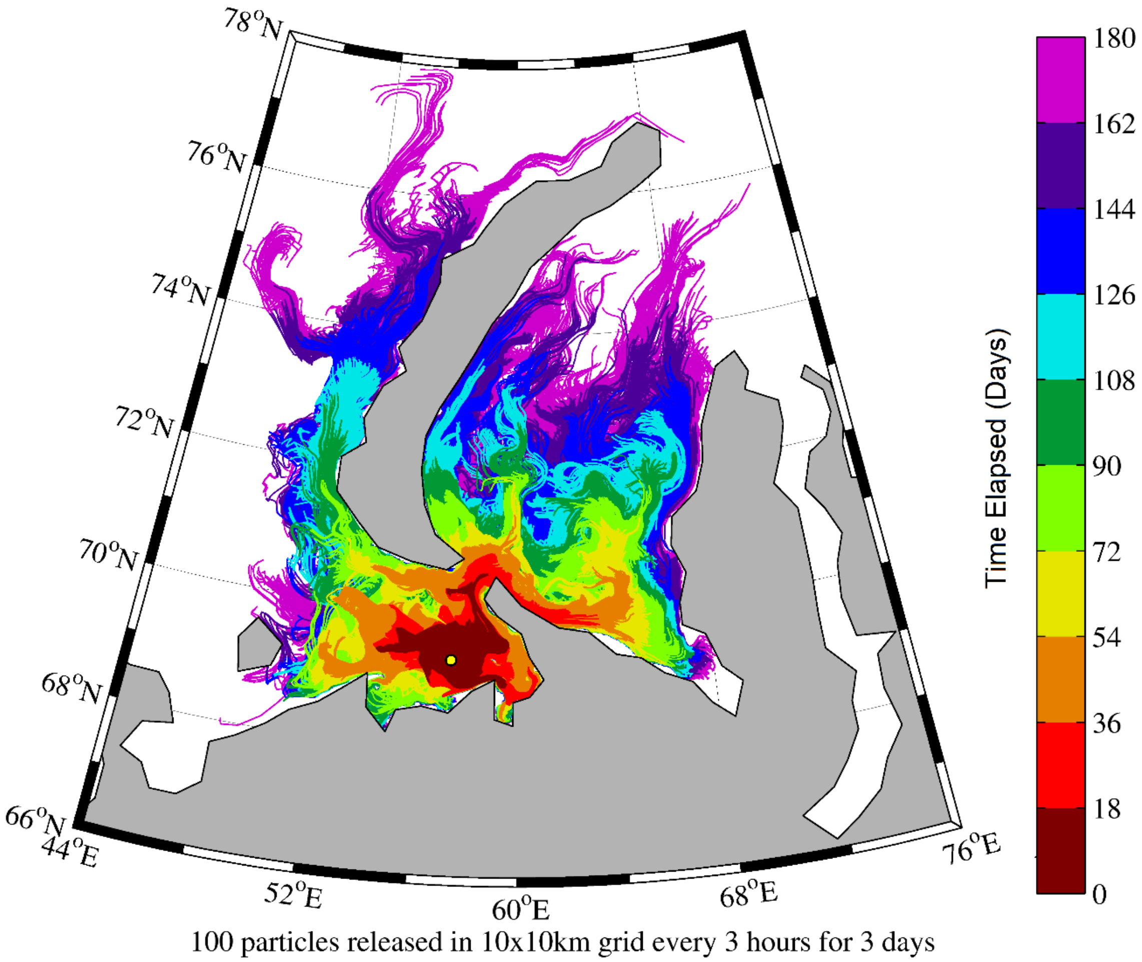
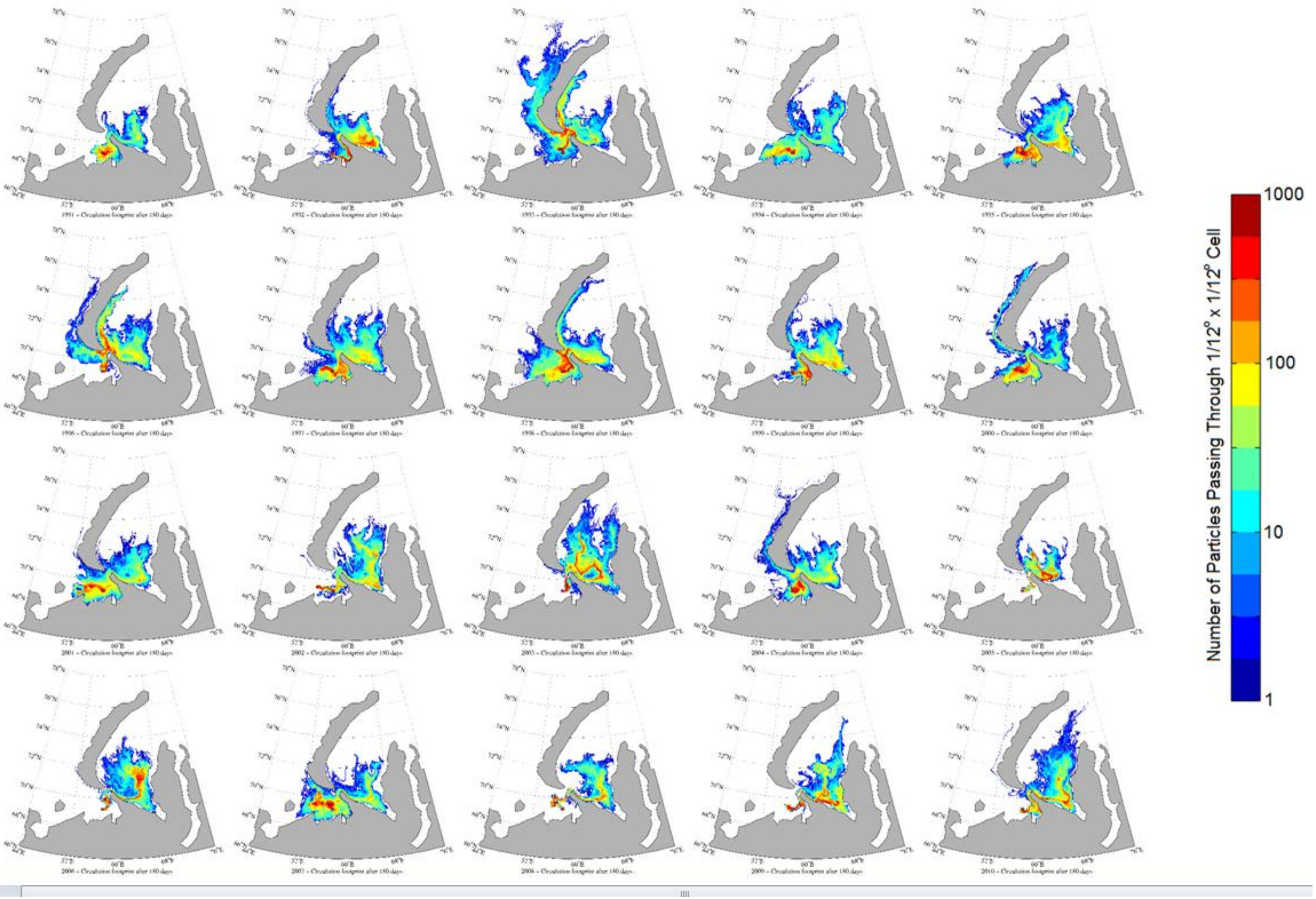
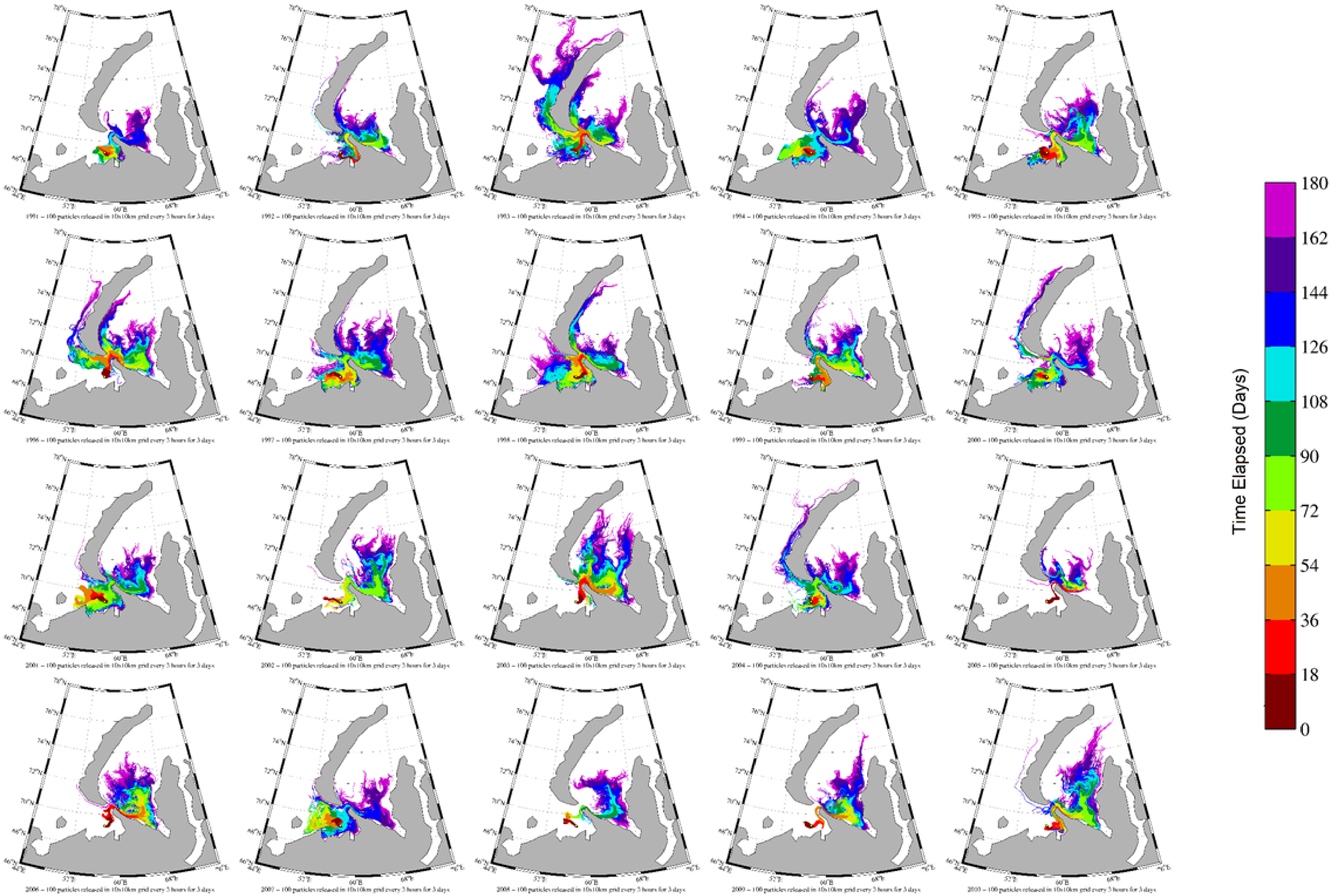


Figure 6: Map showing the timescales required to reach different areas after an initial spill. Note that less only a few weeks are required for marine protected areas including the Kara Gate to be reached. For a full year-by-year breakdown of these experiments, please see the appendix. The footprint is calculated using time period of 1990-2009.


1000
100
10
1
Number of Particles Passing Through 1/12° x 1/12° Cell


1991 – 100 particles released in 10x10km grid every 3 hours for 3 days
1992 – 100 particles released in 10x10km grid every 3 hours for 3 days
1993 – 100 particles released in 10x10km grid every 3 hours for 3 days
1994 – 100 particles released in 10x10km grid every 3 hours for 3 days
1995 – 100 particles released in 10x10km grid every 3 hours for 3 days
1996 – 100 particles released in 10x10km grid every 3 hours for 3 days
1997 – 100 particles released in 10x10km grid every 3 hours for 3 days
1998 – 100 particles released in 10x10km grid every 3 hours for 3 days
1999 – 100 particles released in 10x10km grid every 3 hours for 3 days
2000 – 100 particles released in 10x10km grid every 3 hours for 3 days
2001 – 100 particles released in 10x10km grid every 3 hours for 3 days
2002 – 100 particles released in 10x10km grid every 3 hours for 3 days
2003 – 100 particles released in 10x10km grid every 3 hours for 3 days
2004 – 100 particles released in 10x10km grid every 3 hours for 3 days
2005 – 100 particles released in 10x10km grid every 3 hours for 3 days
2006 – 100 particles released in 10x10km grid every 3 hours for 3 days
2007 – 100 particles released in 10x10km grid every 3 hours for 3 days
2008 – 100 particles released in 10x10km grid every 3 hours for 3 days
2009 – 100 particles released in 10x10km grid every 3 hours for 3 days
2010 – 100 particles released in 10x10km grid every 3 hours for 3 days
Time Elapsed (Days)
180
162
144
126
108
90
72
54
36
18
0

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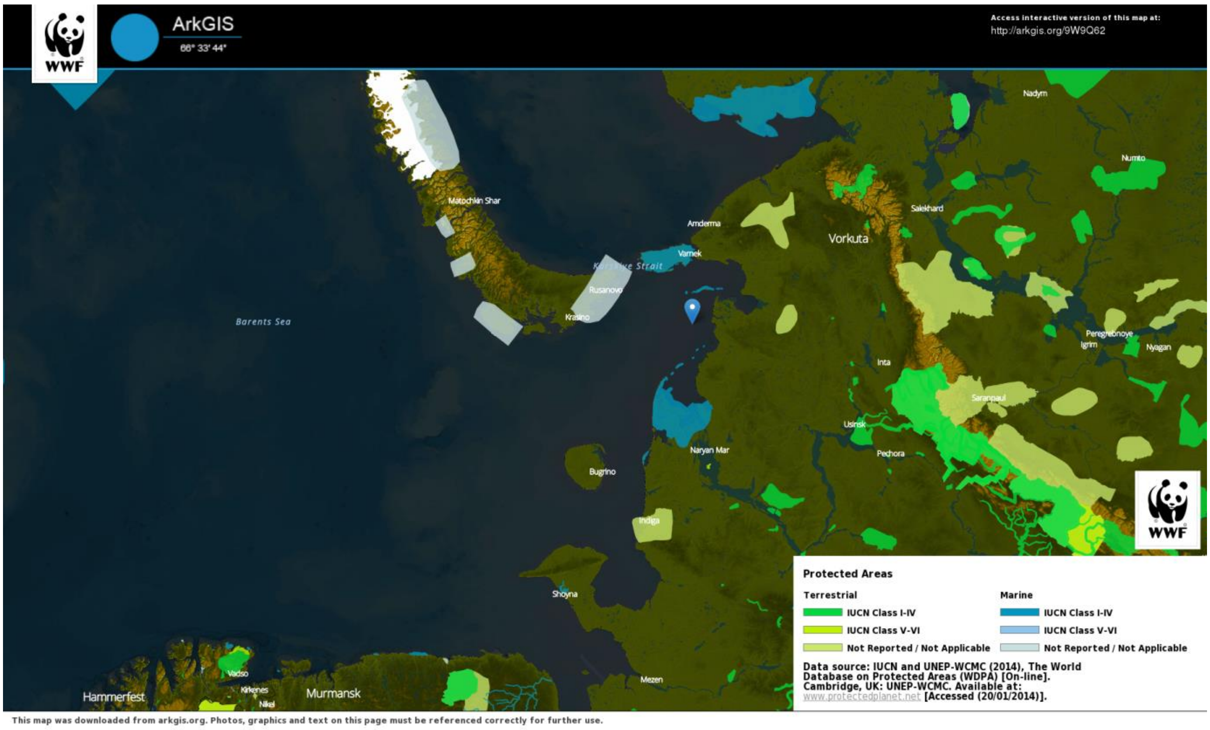
Annex B: Environmental Sensitivities

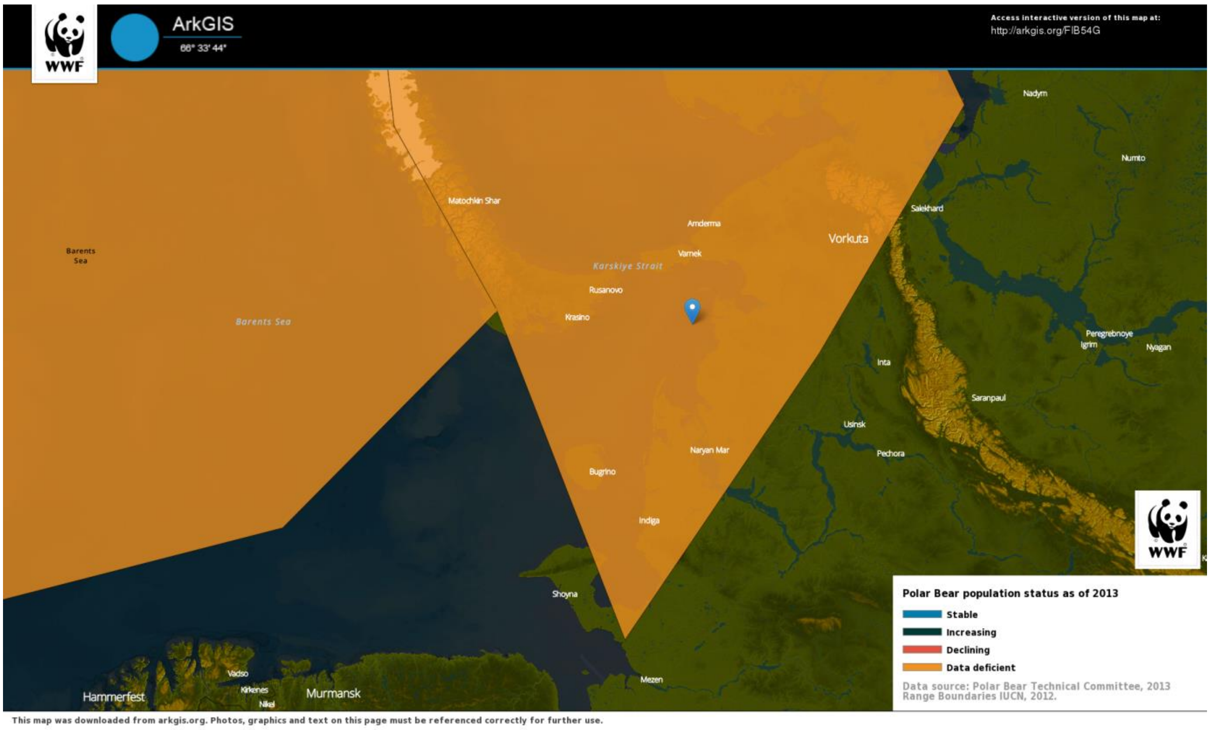
Important ecological areas in the Arctic:

Protected areas

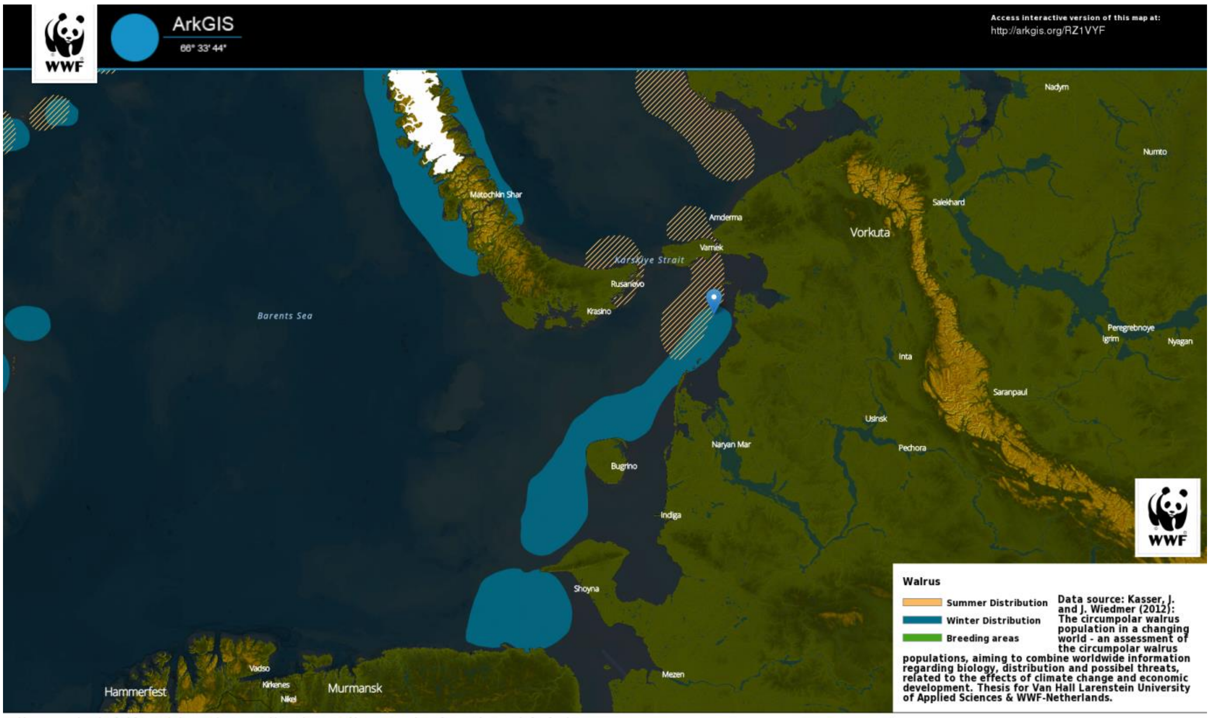


Beluga whale distribution

Polar bear distribution (data deficient)



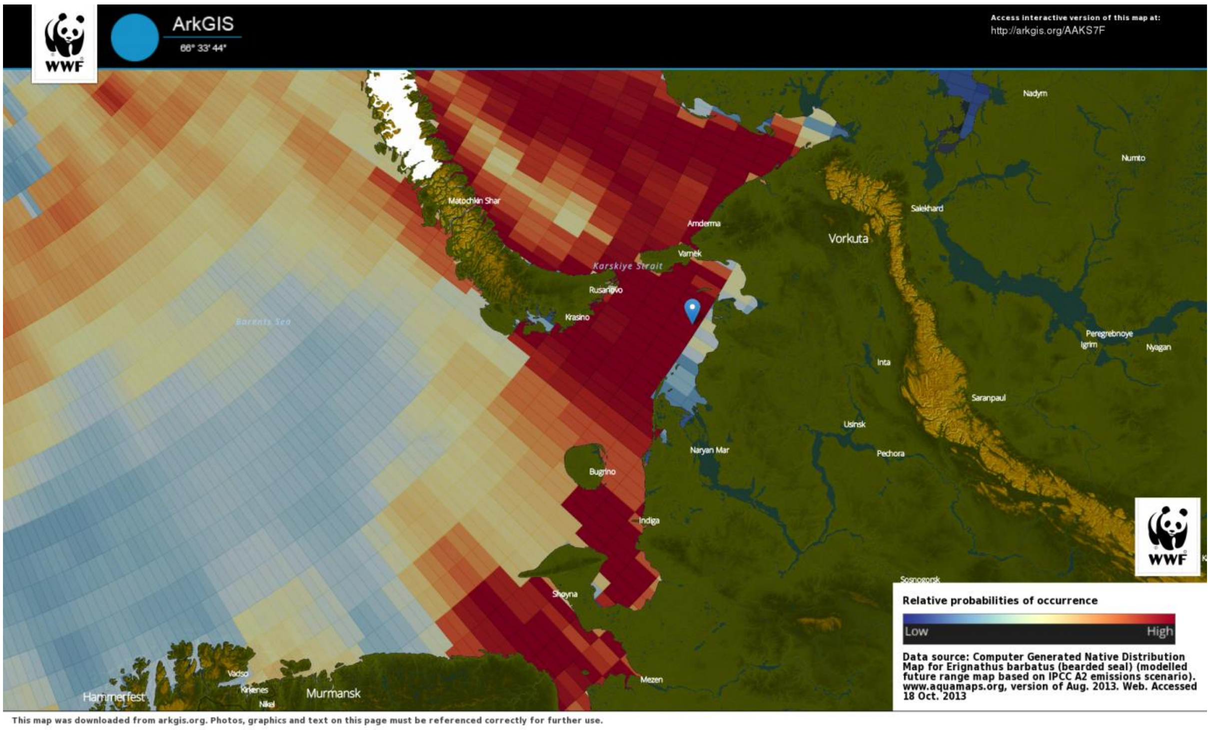
Walrus distribution



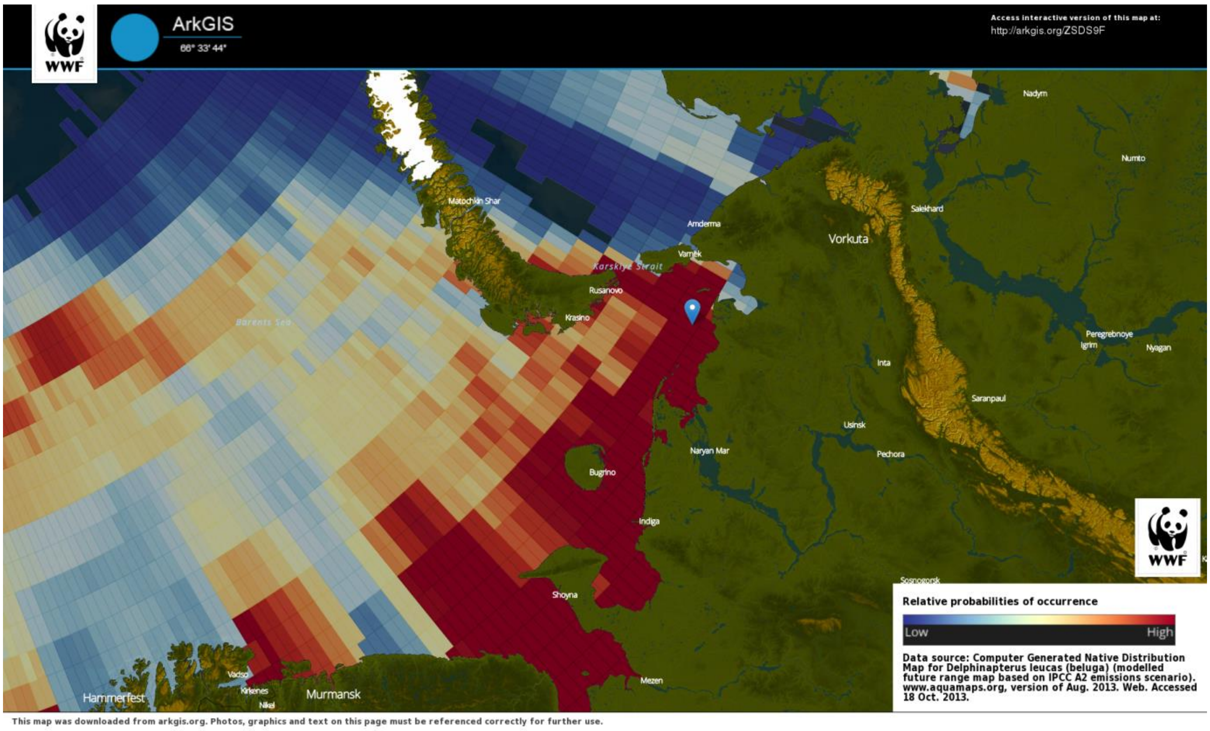
This map was downloaded from arkgis.org. Photos, graphics and text on this page must be referenced correctly for further use.

Relative probability of occurrence of marine mammals in the region

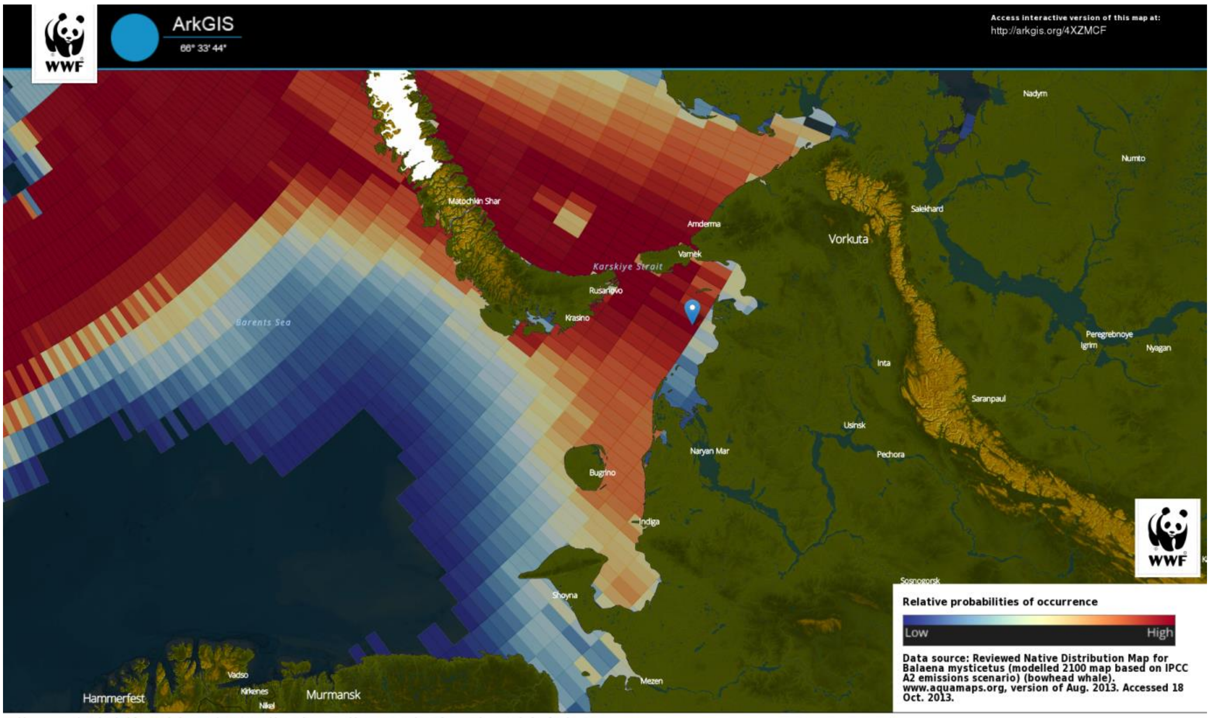
Bearded seal



Beluga whale



Bowhead whale



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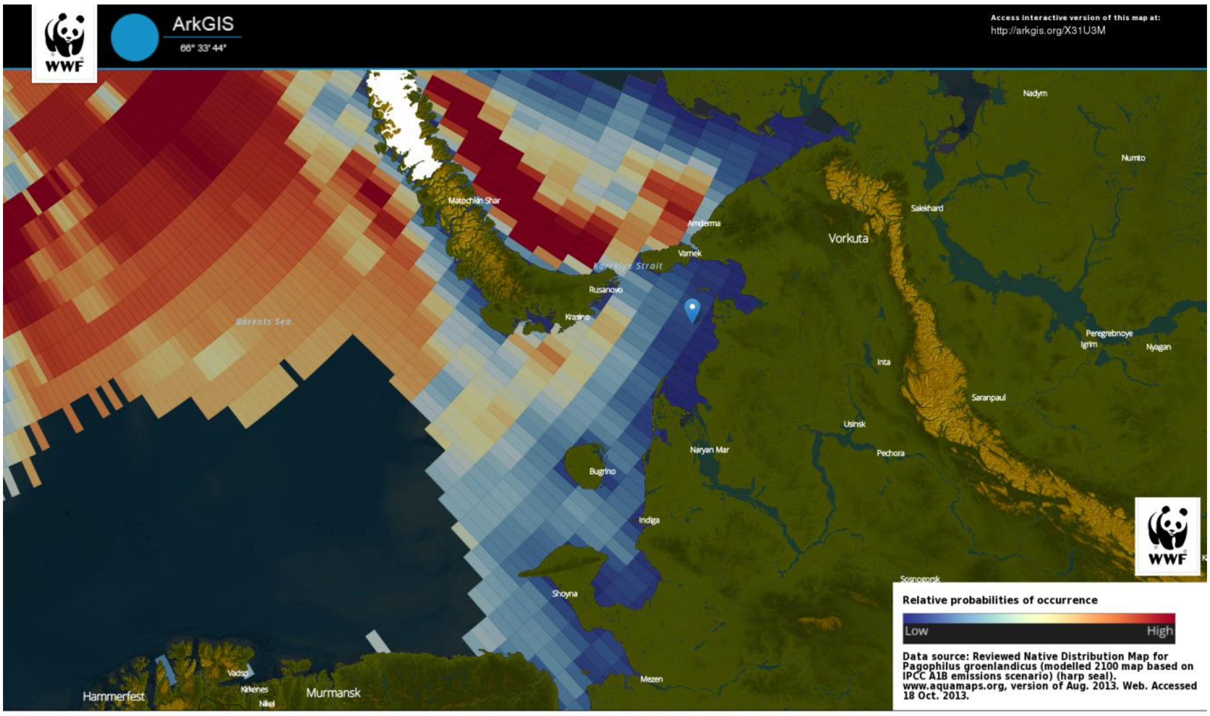
Harp seal



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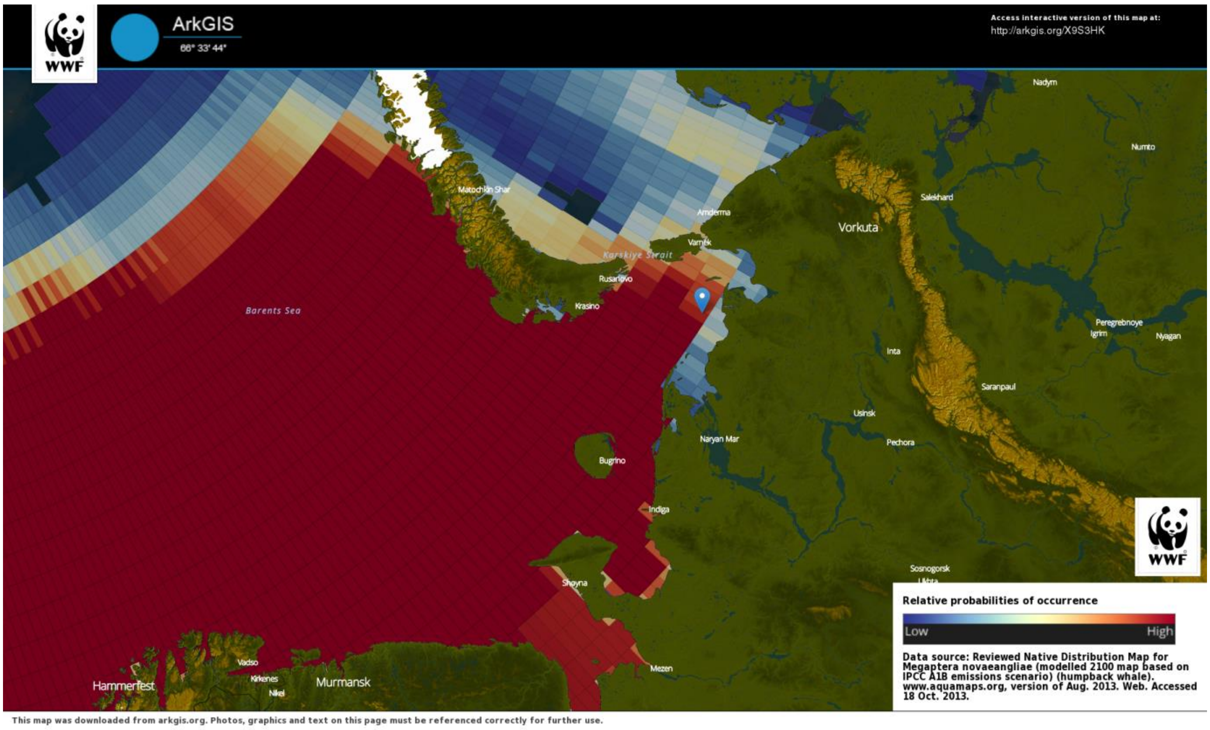
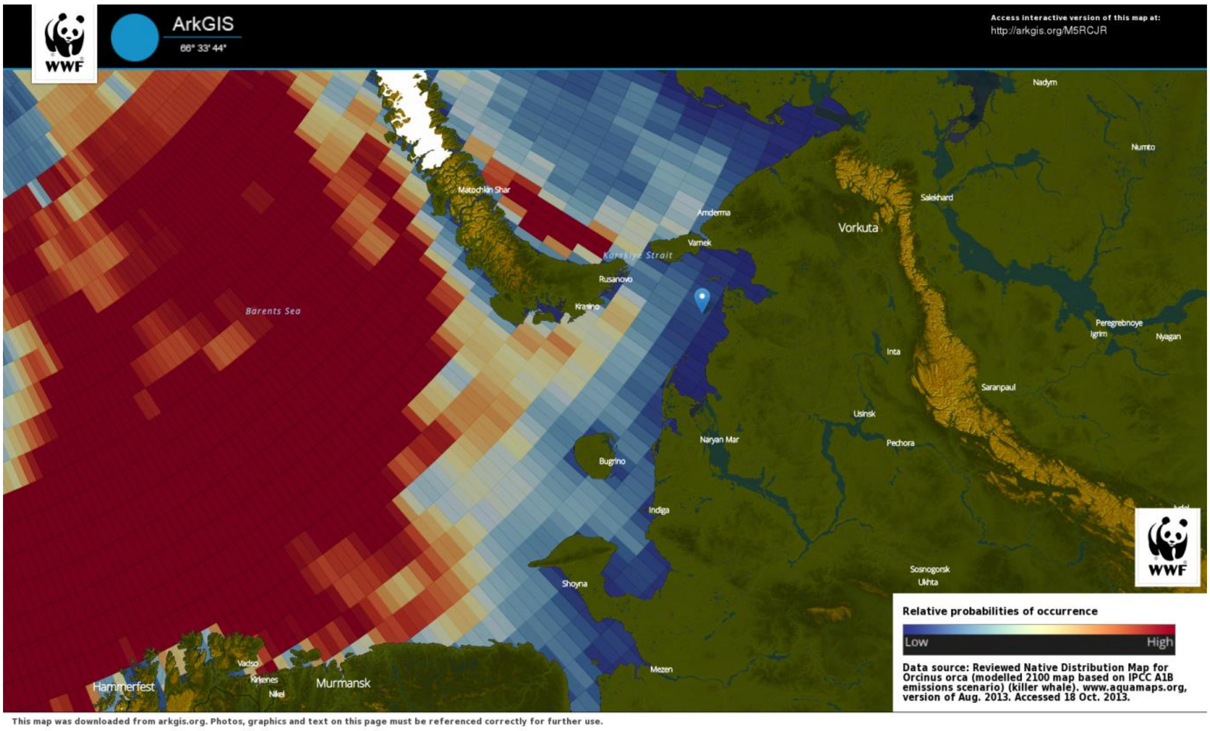
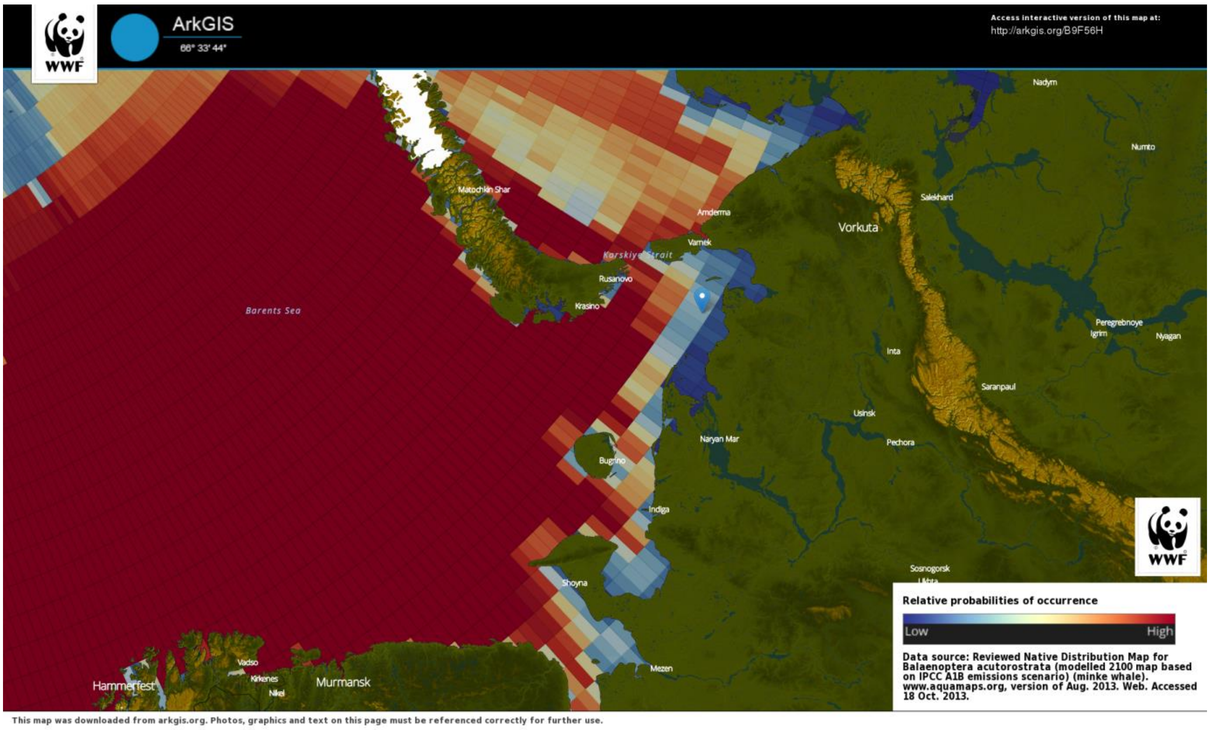
Humpback whale



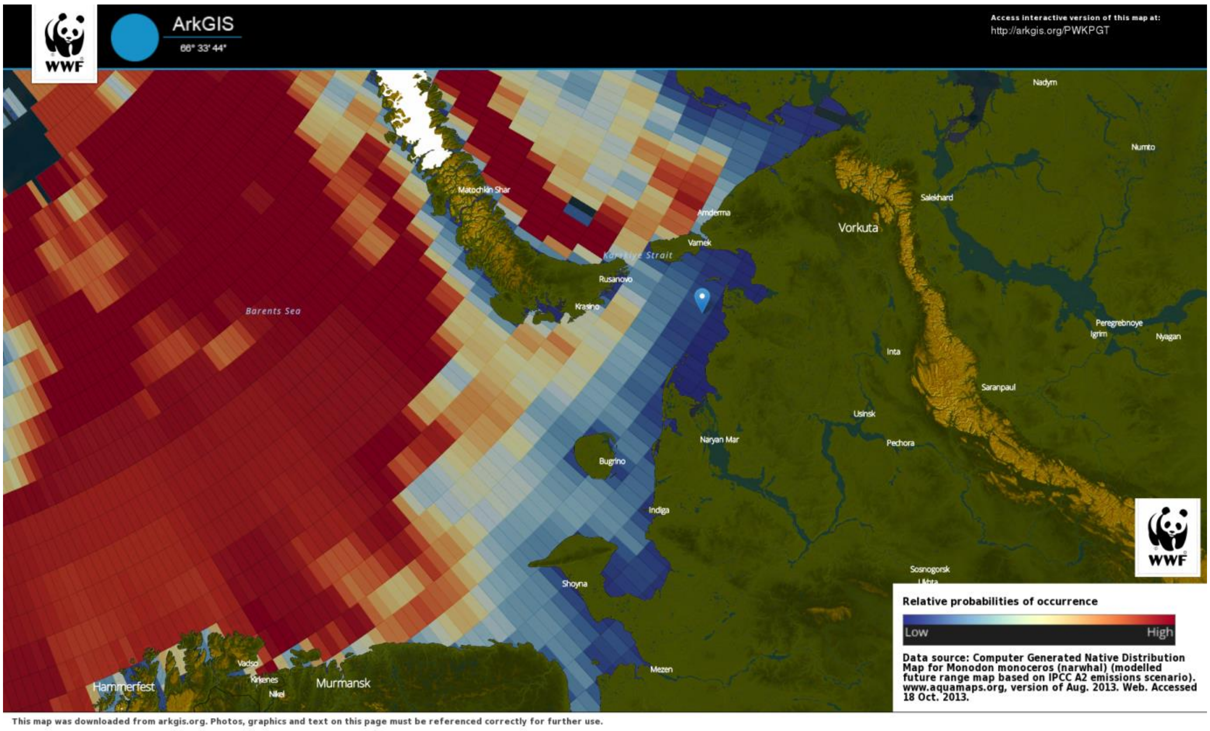
Killer whale



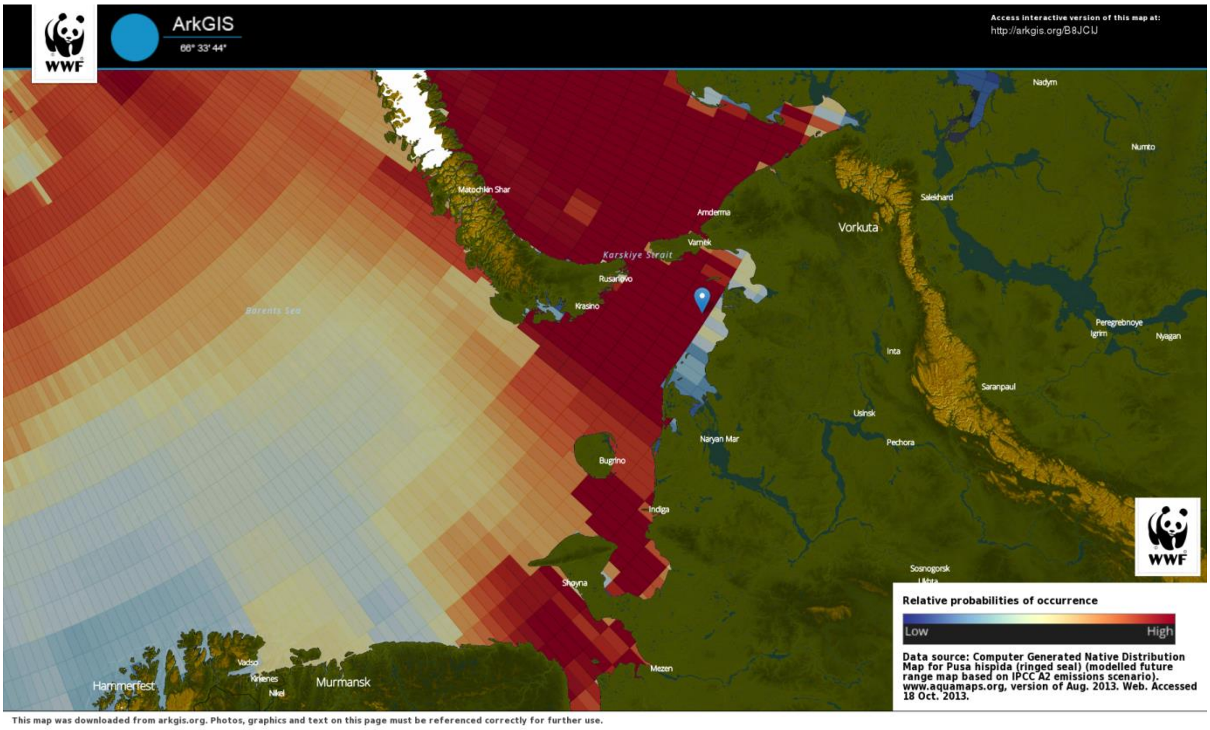
Minke whale



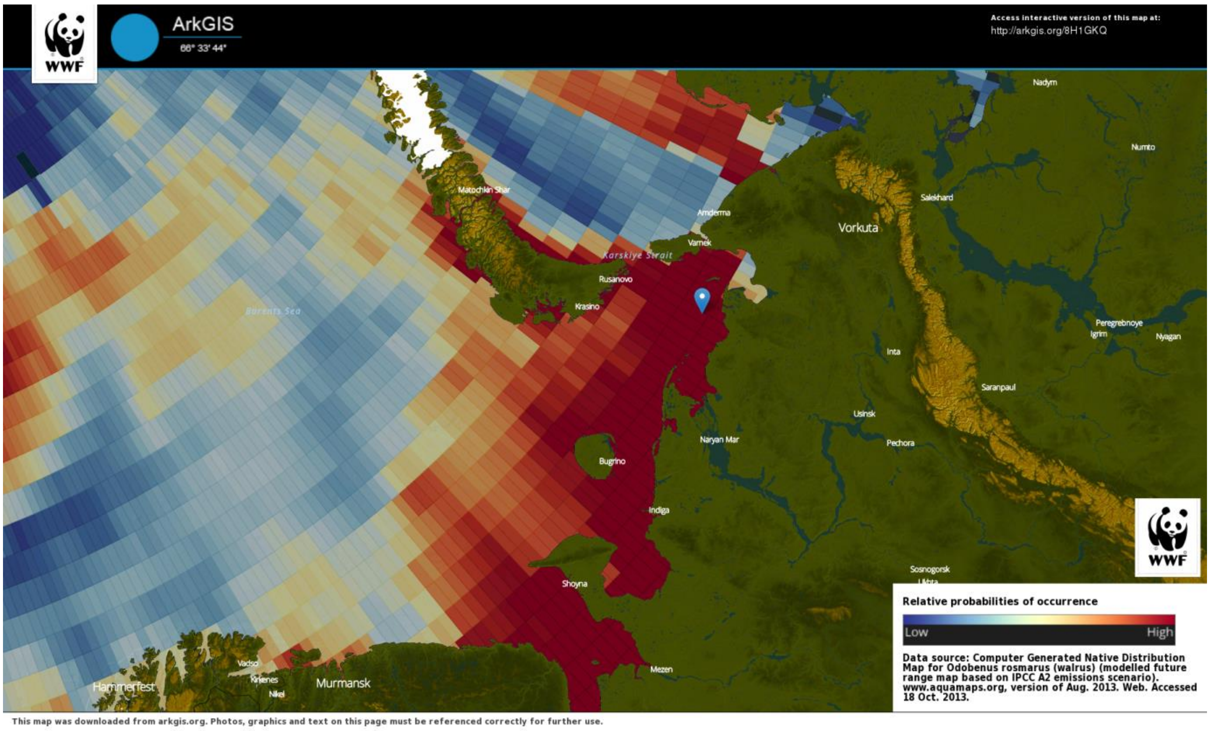
Narwhal



Ringed seal

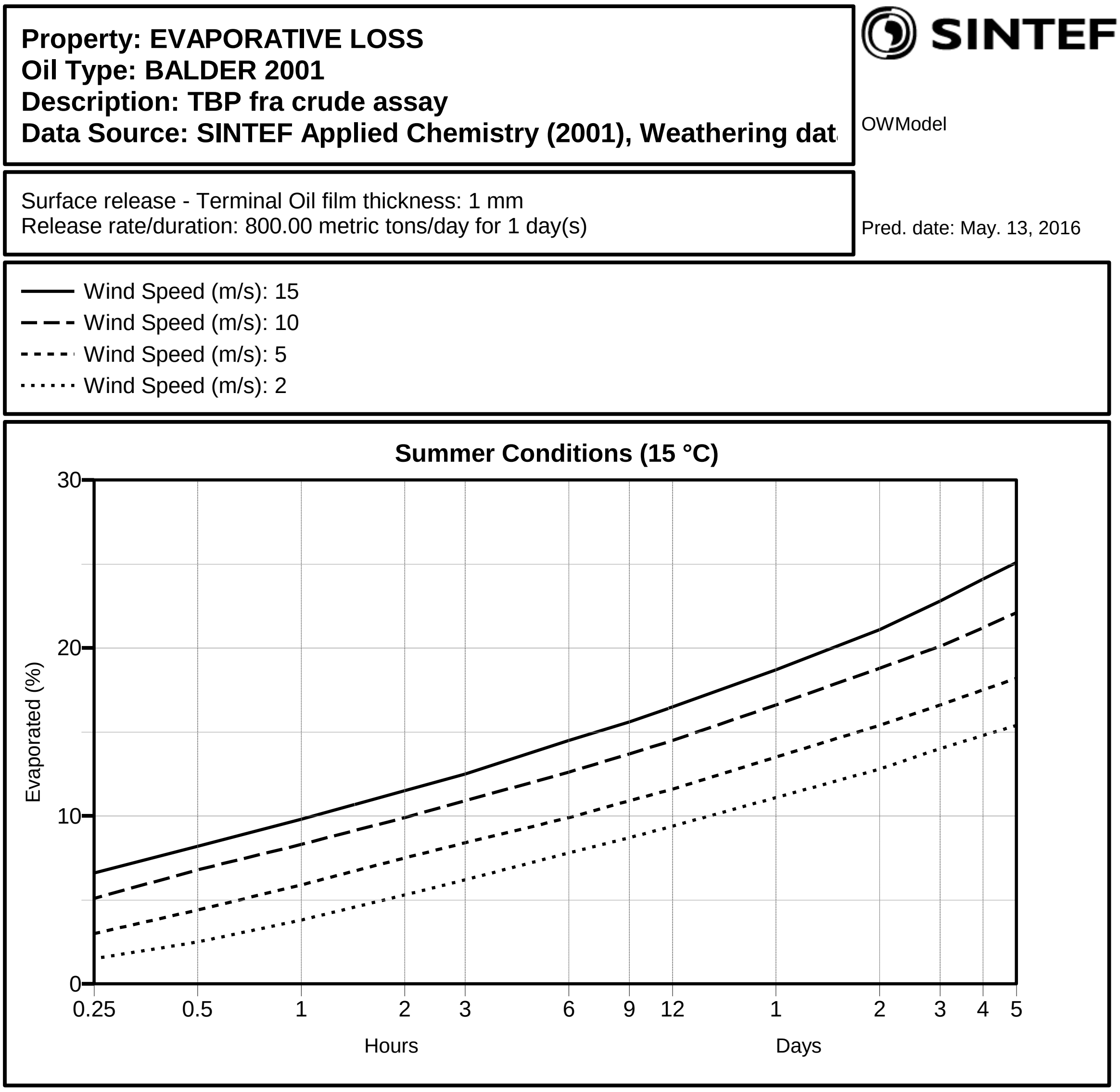

ArkGIS
66° 33' 44"
Access interactive version of this map at:
http://arkgis.org/B8JCIJ
Nadym
Numto
Matochkin Shar
Amderma
Varnek
Karskiye Strait
Rusanovo
Krasino
Vorkuta
Salekhard
Barents Sea
Inta
Peregrebnoye
Igrim
Nyagan
Saranpaul
Usinsk
Naryan Mar
Pechora
Bugrino
Indiga
Shoyna
Sosnogorsk
Mezen
Hammerfest
Vadsø
Kirkenes
Nikel
Murmansk
Relative probabilities of occurrence
Low
High
Data source: Computer Generated Native Distribution Map for Pusa hispida (ringed seal) (modelled future range map based on IPCC A2 emissions scenario). www.aquamaps.org, version of Aug. 2013. Web. Accessed 18 Oct. 2013.
This map was downloaded from arkgis.org. Photos, graphics and text on this page must be referenced correctly for further use.

Walrus


ArkGIS
66° 33' 44"
Access interactive version of this map at:
http://arkgis.org/8H1GKQ
Nadym
Numto
Matochkin Shar
Amderma
Varnek
Karskiye Strait
Rusanovo
Krasino
Vorkuta
Salekhard
Barents Sea
Inta
Peregrebnoye
Igrim
Nyagan
Saranpaul
Usinsk
Naryan Mar
Pechora
Bugrino
Indiga
Shoyna
Sosnogorsk
Mezen
Hammerfest
Vadsø
Kirkenes
Nikel
Murmansk
Relative probabilities of occurrence
Low
High
Data source: Computer Generated Native Distribution Map for Odobenus rosmarus (walrus) (modelled future range map based on IPCC A2 emissions scenario). www.aquamaps.org, version of Aug. 2013. Web. Accessed 18 Oct. 2013.
This map was downloaded from arkgis.org. Photos, graphics and text on this page must be referenced correctly for further use.

Annex C: Weathering Properties of the crude oil

Evaporative loss:



Pour point with no ice coverage

Property: POUR POINT FOR WATER-FREE OIL
Oil Type: BALDER 2001
Description: TBP fra crude assay
Data Source: SINTEF Applied Chemistry (2001), Weathering dat

SINTEF

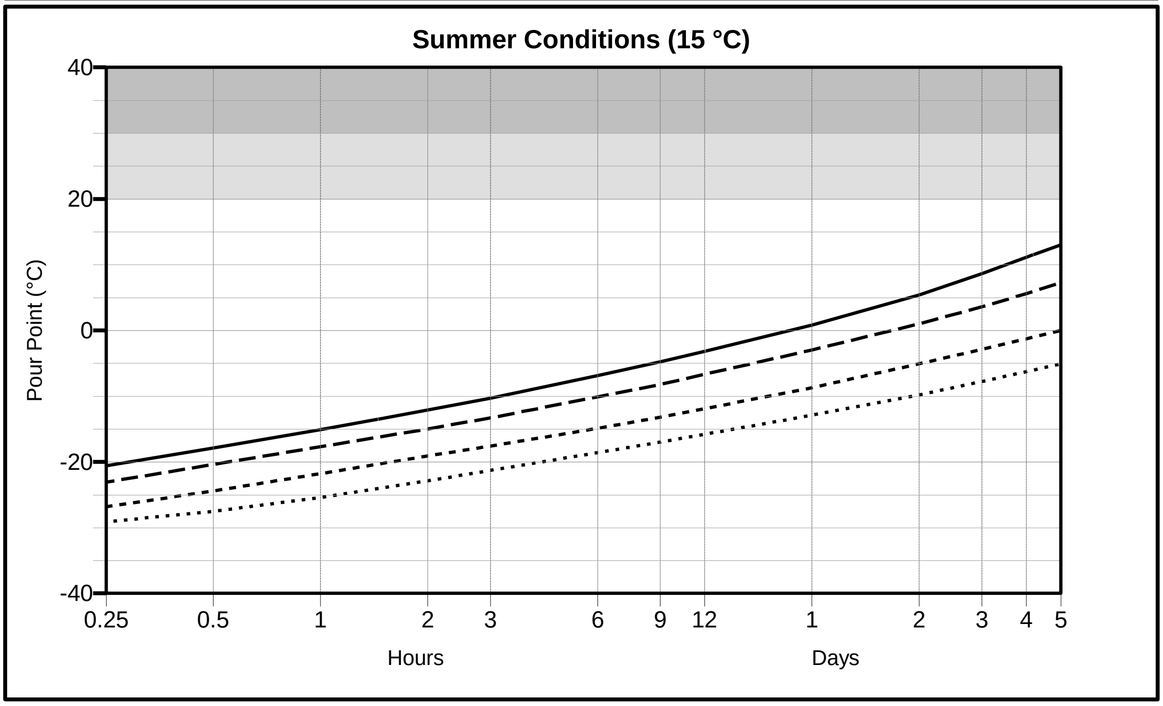
OWModel

Surface release - Terminal Oil film thickness: 1 mm
Release rate/duration: 800.00 metric tons/day for 1 day(s)

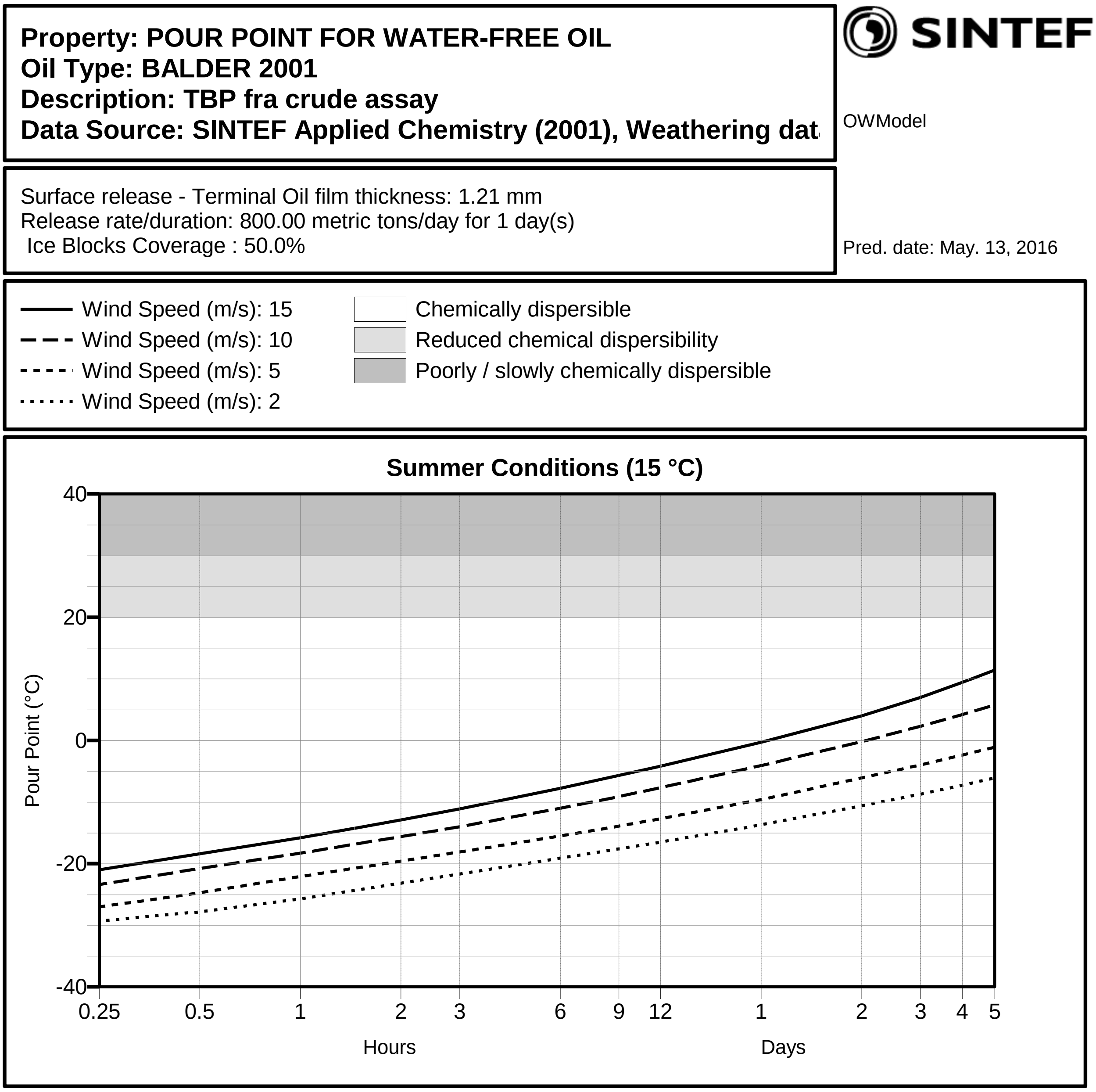
Pred. date: May. 13, 2016

Wind Speed (m/s): 15
Wind Speed (m/s): 10
Wind Speed (m/s): 5
Wind Speed (m/s): 2

Chemically dispersible
Reduced chemical dispersibility
Poorly / slowly chemically dispersible



Pour point with 50 % ice coverage



Water uptake

Property: WATER CONTENT
Oil Type: BALDER 2001
Description: TBP fra crude assay
Data Source: SINTEF Applied Chemistry (2001), Weathering dat

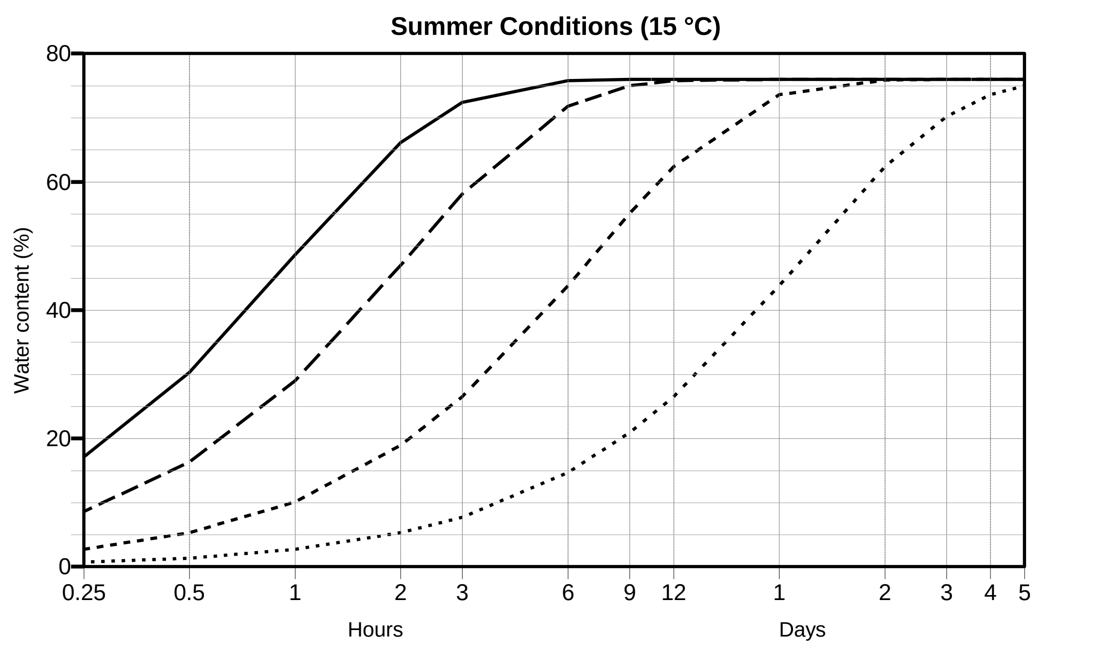
SINTEF

OWModel

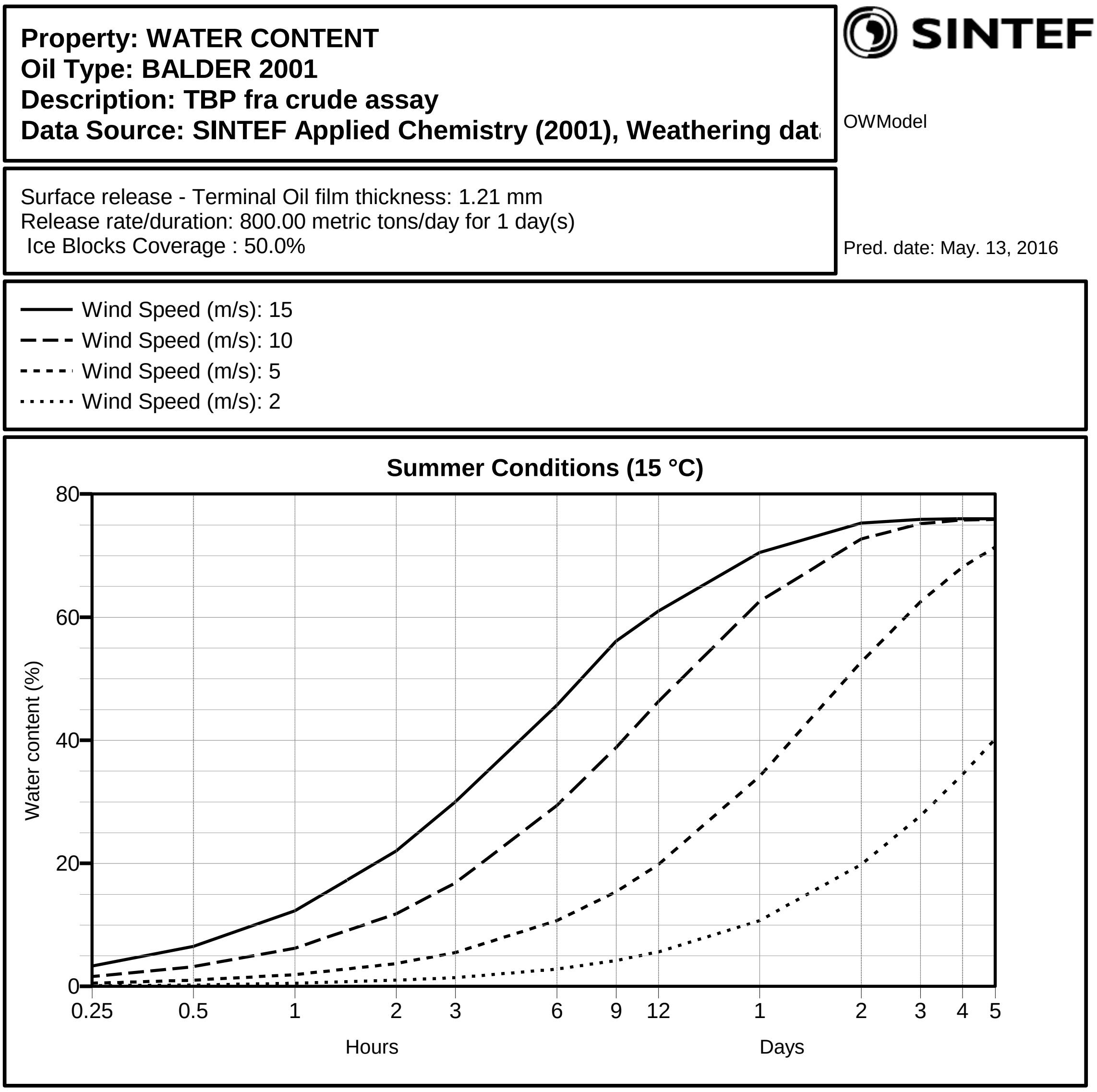
Surface release - Terminal Oil film thickness: 1 mm
Release rate/duration: 800.00 metric tons/day for 1 day(s)

Pred. date: May. 13, 2016

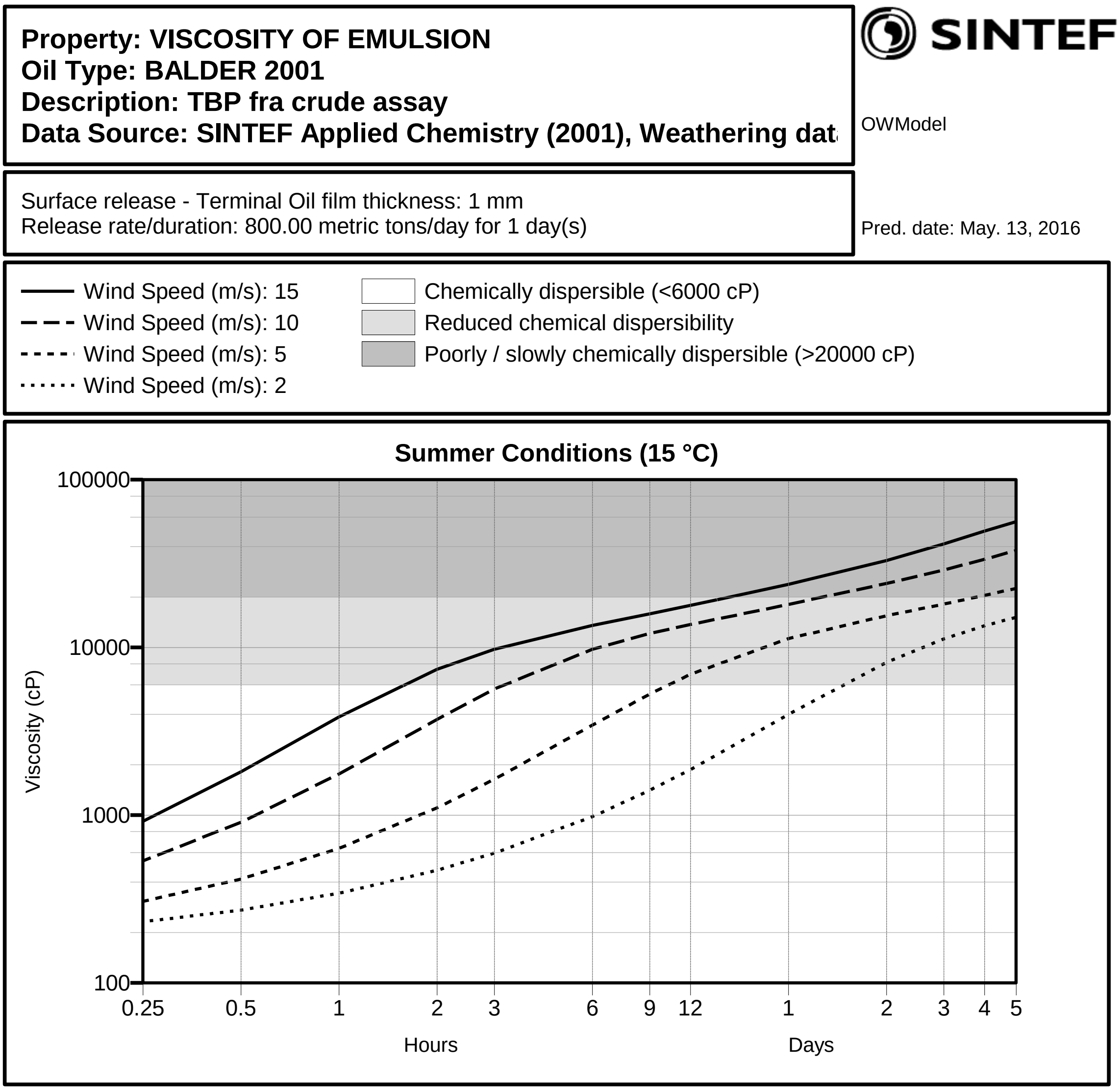
Wind Speed (m/s): 15
Wind Speed (m/s): 10
Wind Speed (m/s): 5
Wind Speed (m/s): 2



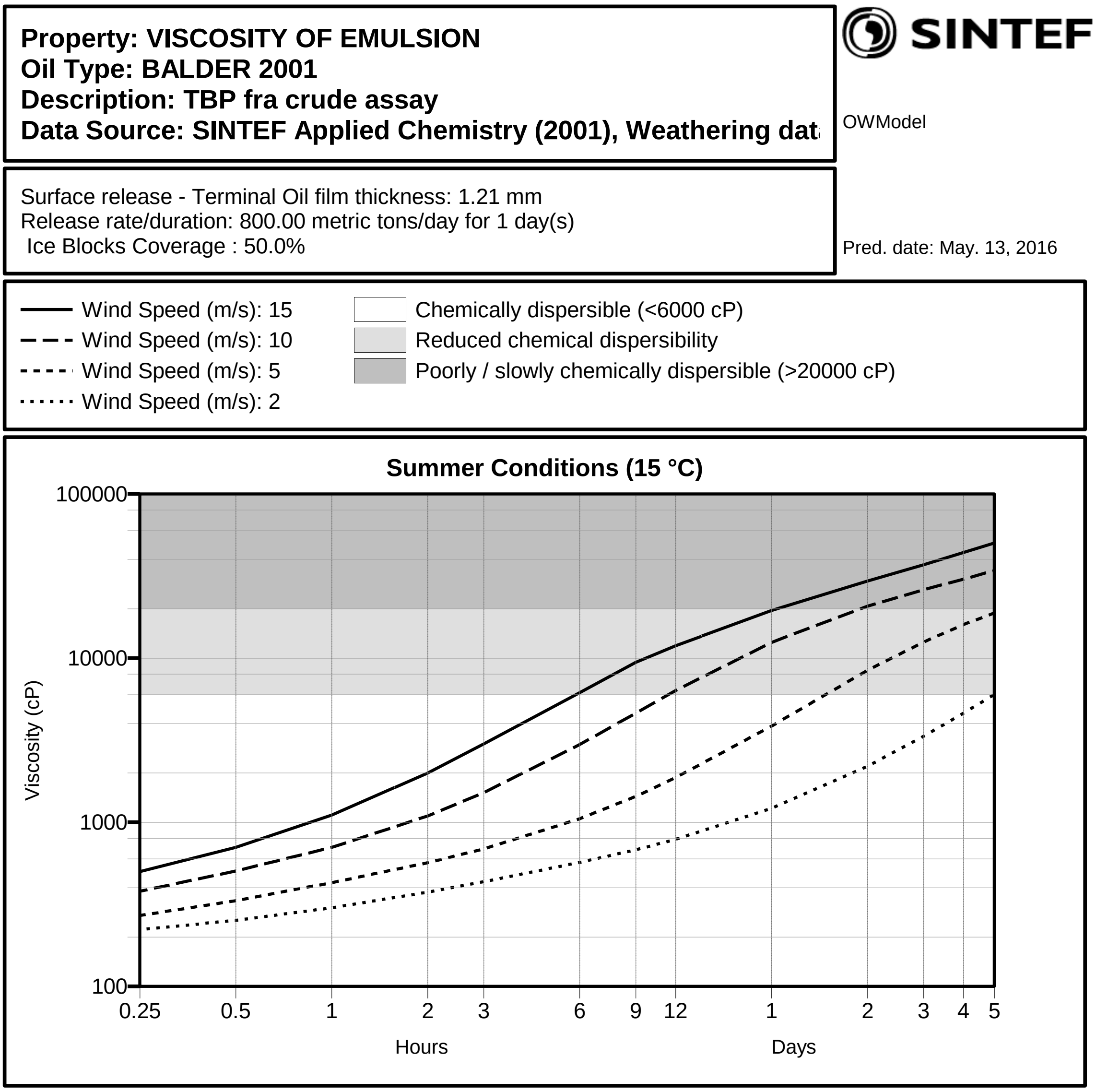
Water uptake with 50 %ice coverage



Emulsion viscosities



Emulsion viscosities with 50 %ice coverage



Massbalance

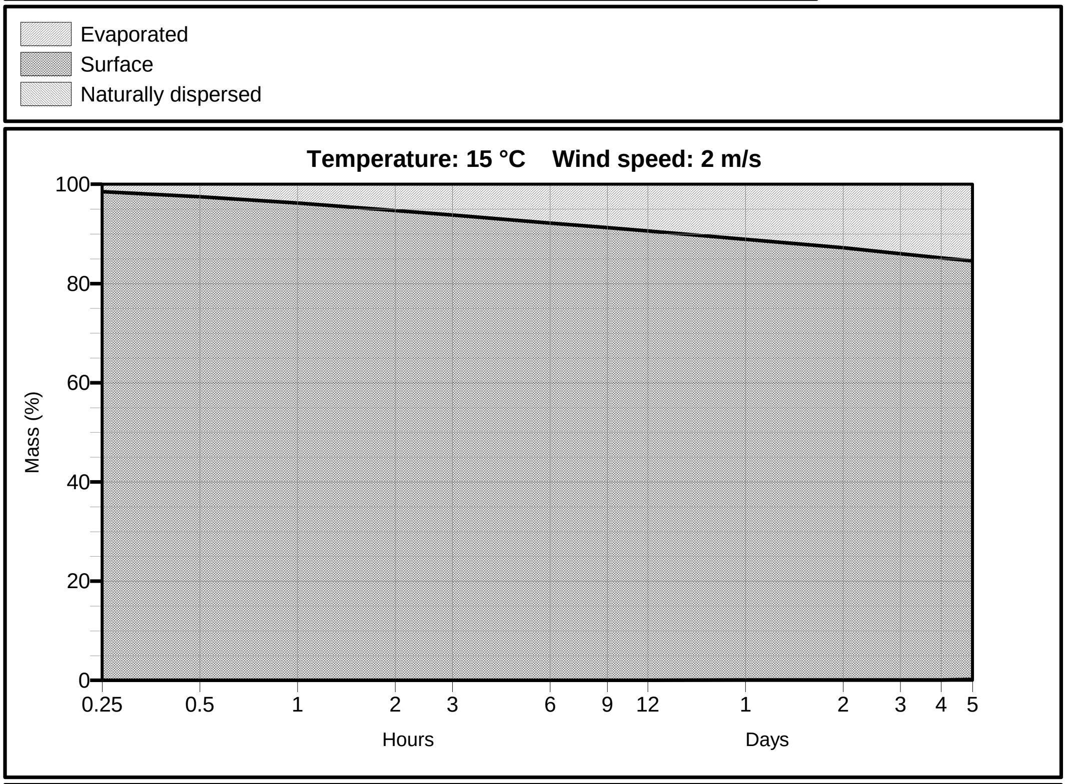
Property: MASS BALANCE
Oil Type: BALDER 2001
Description: TBP fra crude assay
Data Source: SINTEF Applied Chemistry (2001), Weathering dat

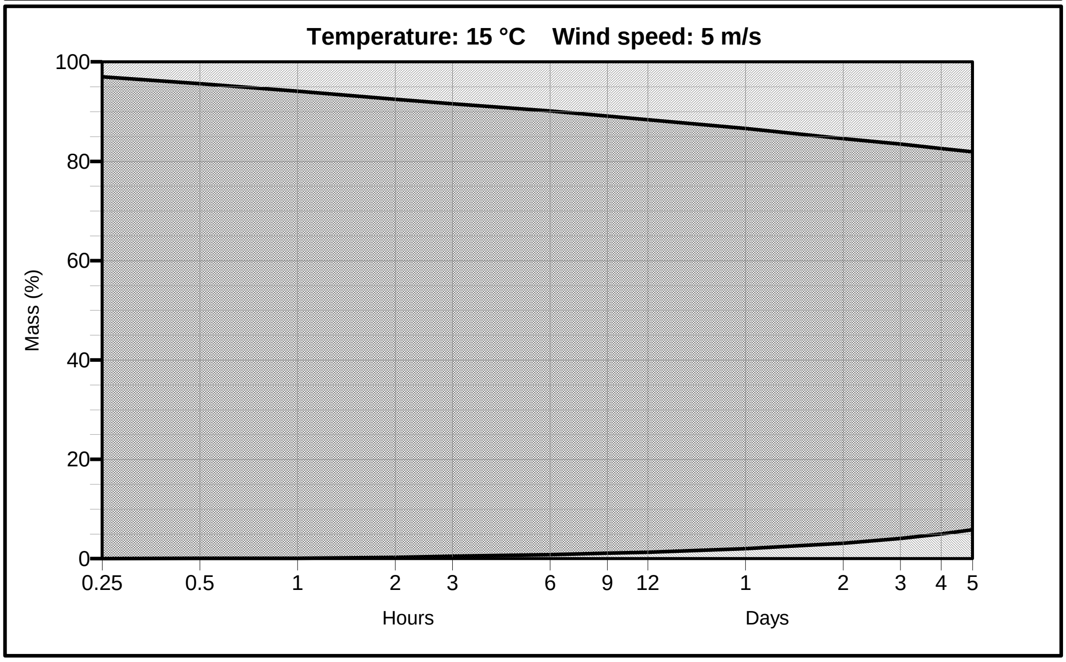
SINTEF

OWModel

Surface release - Terminal Oil film thickness: 1 mm
Release rate/duration: 800.00 metric tons/day for 1 day(s)

Pred. date: May. 13, 2016





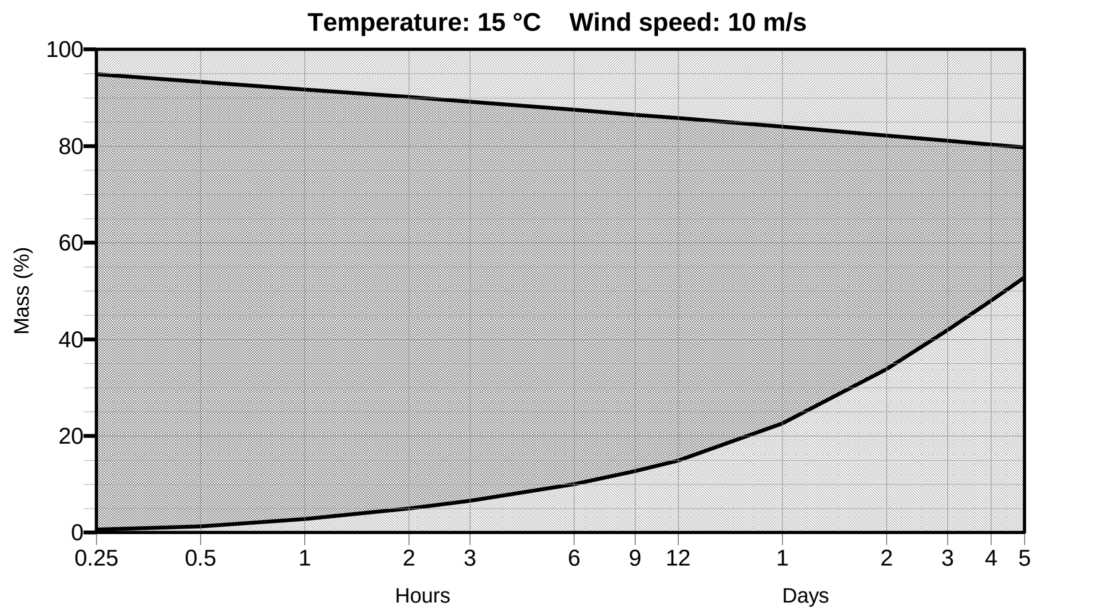
Property: MASS BALANCE
Oil Type: BALDER 2001
Description: TBP fra crude assay
Data Source: SINTEF Applied Chemistry (2001), Weathering dat

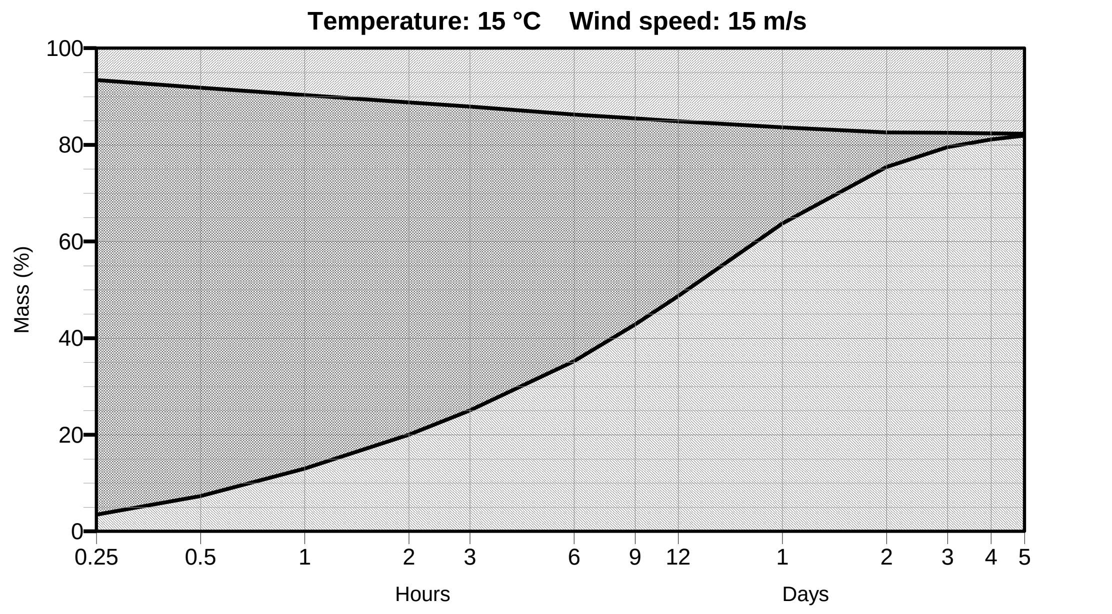
OWModel

Surface release - Terminal Oil film thickness: 1 mm
Release rate/duration: 800.00 metric tons/day for 1 day(s)

Pred. date: May. 13, 2016

Evaporated
Surface
Naturally dispersed





The algorithm for prediction of natural dispersion is preliminary and is currently under improvement.Model predictions have been field-verified up to 4-5 days.

Massbalance with 50 % ice coverage

Property: MASS BALANCE
Oil Type: BALDER 2001
Description: TBP fra crude assay
Data Source: SINTEF Applied Chemistry (2001), Weathering dat

SINTEF

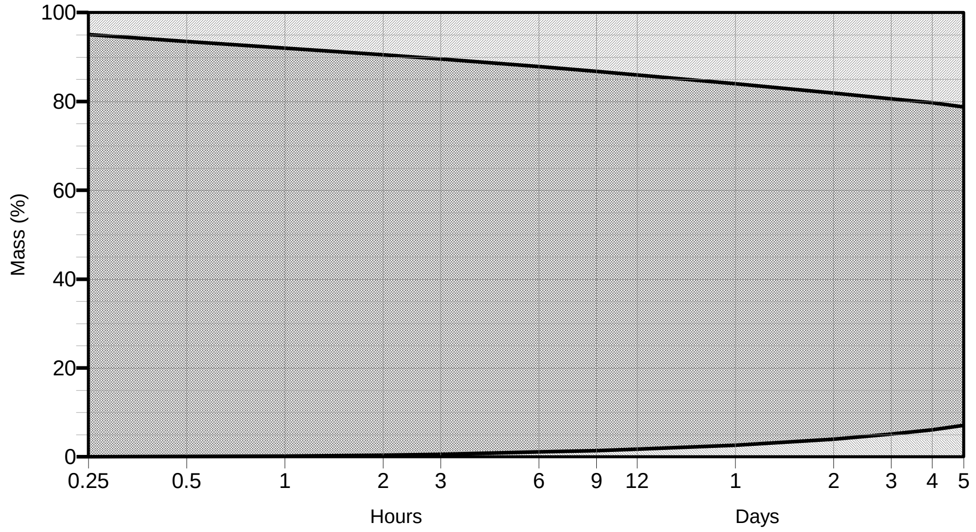
OWModel

Surface release - Terminal Oil film thickness: 1.21 mm
Release rate/duration: 800.00 metric tons/day for 1 day(s)
Ice Blocks Coverage : 50.0%

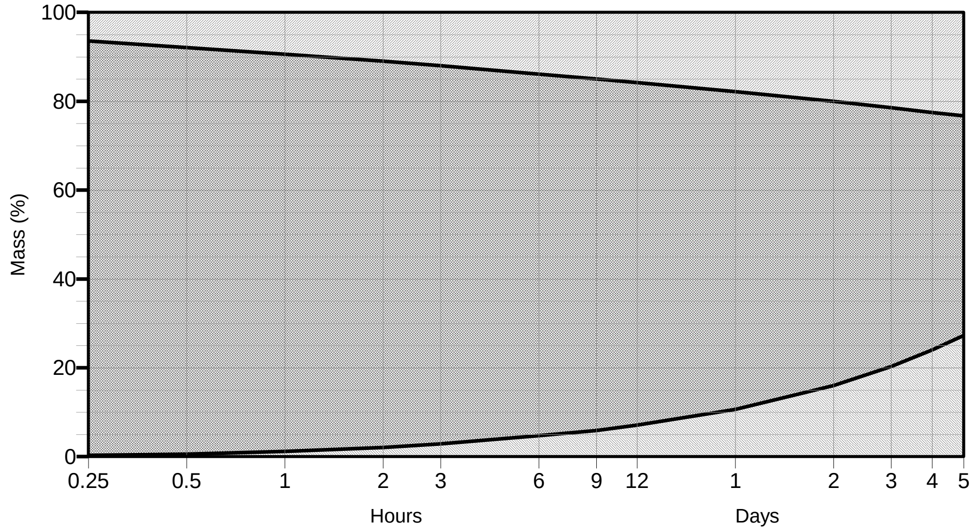
Pred. date: May. 13, 2016

Evaporated
Surface
Naturally dispersed

Temperature: 15 °C Wind speed: 10 m/s



Temperature: 15 °C Wind speed: 15 m/s



The algorithm for prediction of natural dispersion is preliminary and is currently under improvement.Model predictions have been field-verified up to 4-5 days.