Project information

Project title
Oil Spill Modelling in Ice Covered Ocean - and environmental consequences (OSMICO)
Year
2019
Project leader
Lars R. Hole
Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
65-85 N, 0-70 E
Participants

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Flagship
MIKON
Funding Source

597 000 NOK – Fram Centre

50 000 - MET

Summary of Results

It has been demonstrated that output from OpenDrift simulation can be combined with gridded biological data from the Norwegian Directorate of Environment and/or from Russian environmental institutes (MMBI), for example for seabird, fishes or zooplankton distribution, to identify impact area and ecosystem components at risk in case of an accidental oil spill.

We have built scenarios for crude oil (cargo) and marine diesel (fuel) spill from a tanker in the south-eastern part of the Barents Sea – the Pechora Sea in different times of the year, generated maps for selected ecosystem components (valuable species) distribution, ran OpenDrift simulations and looked at possible impacts – species at risk (Figs. 1-3).

Further, OpenDrift combined with ecological data/maps can be used for express net environmental benefit analysis (NEBA) and decision upon oil-spill response and recovery solutions (Fig. 4).

MET has recruited a master student, Victor Aguiar, who will finish his master in summer of 2021. He will work on physical oceanography and develop an oil/ice module for OpenDrift and provide input to APN and MMBI.

APN and MMBI collected metadata and data available for the Barents Sea, focusing on ‘valuable ecological components’ (VEC) and areas of petroleum and shipping pressure. For instance, high-resolution seabird distribution data were recently made available by the Norwegian Institute of Nature Research (Fauchald et al. 2019). Using the common guillemot ( Uria aalge ) as example species and a simulated oil spill in the Kara Gate in September as example spill (Figure 5), we here present snapshots overlap studies of seabird distributions and oil drift patterns (Figure 6).

Figure 5. a) Density distribution of the seabird common guillemot ( Uria aalge ) in september. b) Simulated oil spill in the Kara Gate in September (red star), and resulting oil drift trajectories during the following 10 days (grey lines).

The common guillemot in the Barents Sea in September is mainly found in the southern araes near the northern coasts of Norway and Russia (Figure 5a). The simulated oil spill initially resulted in oil trajectories northwestwards along the western coast of Novaya Zemlya, but after approximately one week the oil started to drift westwards into the Barents Sea (Figure 5b).

Figure 6. Combined visualizations of common guillemot ( Uria aalge ) main distributions (green) and drifting oil (red) following a simulated oil spill in the Kara Gate. Spill site is shown as a yellow triangle. The figures show oil distribution after 96 hours (i.e., 4 days; left panel) and after 240 hours (i.e., 10 days; right panel). In the white area, the likelihood of finding this species in September is low.

We selected a species (i.e., the common guillemot, Uria aalge ) that in September has its main distribution area in the central-south of the Barents Sea, i.e. far to the west from the simulated oil spill site. Therefore, 10 days of simulated would not cause an overlap between drifting oil and the main distribution area of the common guillemot (Figure 6).

Similar figures can be made for 5 other, common seabird species, some of which are found close to the virtual spill site in September (e.g., the Brünnich’s guillemot, Uria lomvia ).

MET, APN and MMBI submitted a joint proposal ‘Oil spill modelling in the Barents Sea and biological consequences (BarBiOil) to the Russian-Norwegian call of the Research Council of Norway and Russian Foundation for Basic Research. –The proposal was highly evaluated by RCN (with a mean score 6 – excellent), but not financed by the joint programme . The project team will work further with the model development within OSMICO and submit the new proposal in 2020.

The oil drift model implemented by the Master student (Victor Aguiar) is based on the relation proposed by Nordam et al. (2019) and is given as follows:

voil = kicevice + (1-kice)( vwater +fw v wind)

where voil, vice, vwater and vwind are the velocity vectors of the oil drift, ice drift, surface water and wind, respectively, and fw is the wind drag coefficient which varies between 0% and 6% with a common value of 2% for ice drifts and 3% for open sea. Moreover, kice is a factor dependent of the the sea ice concentration ( A ) as:

kice={0, if A < 0.3 ; A-0.30.8 - 0.3, if 0.3A< 0.8; 1, if A ≥ 0.8}

in other words, for a region with low sea ice concentration ( A < 0.3) the oil spill will spread as in open water, forced solely by the currents, wind and waves, whereas in regions with high sea ice concentration ( A ≥ 0.8) the horizontal motion of the oil slick will be contained within the ice field and hence follow its displacement. On the other hand, the oil motion is governed by the linear relation when present in areas with 0.3A< 0.8.

Although such an approach was first proposed by El-Tahan et al. (1988), other researchers developed variants of the model (Vefsnmo and Johannesen, 1994; Stanovoy et al. , 2012) and in-situ observations were made in the Barents Sea in May 2009 by Faksness et al . (2011). In this regard, on a six-day experiment done in an area that sea ice concentration varied between 0.7 and 0.9, the latter work indicates that the oil drifted with the sea ice and remained between the sea ice floes despite the presence of a storm. Hence, although simplistically formulated, this model seems to work properly and to be suitable for the project objective.

The figure below presents four theoretical scenarios of oil spilling in the Barents Sea in March 2019 (10.3.2019 - 20.3.2019). We considered two distinct oil types, heavy (IFO-180LS) and light crude oils (Marine Diesel, ESSO), and two versions of oil-in-ice models: the old version of OpenDrift (Dagestad et al ., 2017) and the new one based on the relation presented by Nordam et al. (2019). The background map is the 10 days time-averaged sea ice concentration obtained from the Nordic4km model and the dashed line represents the isoline of sea ice concentration = 0.6, which was used in the old version of OpenDrift as a threshold to deactivate oil particles that reached such value. The location and period for these runs were not randomly chosen: March is the month which sea ice extent reaches its annual maximum and the virtual oil spill location (74.9ºN, 33.43ºE) is close to the Norwegian Continental Shelf boundary next to

Russian waters, northward from the licensed field 859 and within a potential area of oil exploitation, the Storbanken high.

Comparing the old to the new version presented in Fig. 1, we see how the new approach, the one based on Nordam et al. (2019), changes the light crude oil horizontal spreading. On the old version, 98.9% of the particles were deactivated, i.e. , they reached the C = 0.6 threshold, whereas in the new version they follow the same mean trajectory as the heavy crude oil particles. Furthermore, is must be noticed that in the new implemented module Marine Diesel (ESSO) oil slick presents a more diffused pattern than the IFO-180LS, in agreement with the observed behavior.

(figures are missing)

For the Management

Norwegian and Russian environmental metadata and data for the Barents Sea (tables, maps) – harmonization possibilities

Published Results/Planned Publications

Manus submitted to Marine Pollution Bulletin: Simulating offshore oil spill accidents in the Barents Sea: a study of possible environmental and economic consequences (together with a team from the University of Oulu).

- An abstract Modelling oil spill in the ice-covered Barents Sea using an integrated open source tool submitted to the AMEMR (Advanced in Marine Ecosystem Modelling Research) Conference to be held in Plymouth, UK on 13-16 July, 2020.

- An application for OSMICO presentation submitted to the EcoArctic-2020 Forum to be held in Naryan-Mar, Russia on 19-21 of March 2020

Communicated Results

- Presentation at Arctic Frontiers 2019: Oil drift modelling in the Arctic Environment

- Presentation and discussion of the oil drift modelling and environmental consequences assessment tool at the round-table ‘Actual issues of safe exploration of the Arctic and mitigation of industrial impact on the environment’ held in Naryan-Mar, Russia on 22 March 2019

- Presentation of OSMICO status at MIKON Flagship meeting in the Fram Centre on 29 October 2019

Interdisciplinary Cooperation

Marine Biology, Oceanography, Sea ice modelling, GIS

Budget in accordance to results

During our pre-project, we had a workshop in Murmansk in 2018 with much media attention and interest. This motivated the proposal for our ongoing 2-year project. We have submitted a proposal to the research council of Norway for a Russian-Norwegian collaborative project, which was not financed but highly evaluated (score 6/7 - excellent). We plan to develop the project and submit a new research proposal

Could results from the project be subject for any commercial utilization

No

If Yes

Yes, please explain: The OSMICO tool could be of interest to oil and shipping companies and oil-spill response teams for environmental impact analysis and oil-spill response planning (express NEBA).

Conclusions

Oil / ice module for OpenDrift is under development and can be combined with biological data to run express NEBA. The tool can be started from a graphical user interface. To have an open source code for this purpose available is a step forward and a completely new approach.

Next steps, points to improve on the model and questions to further investigation:

1. Validate the model using OpenDrift.

2. What might have been noticed but still worth it to be highlighted is the lack of information regarding mixing and turbulent processes in the vertical plane. It is clear that such approach deals only with horizontal spreading of the particles but vertical movements ( e.g. submerging/resurfacing), entrainment, vertical diffusion, for instance, are also important. Is the vertical motion behavior of oil under sea ice similar to the one observed in ice free areas? If it is different, is it possible to implement a model also based on the sea ice concentration?

3. More than being trapped between ice floes, oil might also be encapsulated within the ice and travel further away from its spill location without being weathered. How does the oil percolates in the ice? What is the role of brine channels?

4. Photooxidation is a weathering process still not considered in OpenDrift. However, in high latitude areas where daylight may span over 20 hours, such process might play a more significant role.

5. Evaporation is considered the main weathering process specially when it regards to light oils. In this sense, considering an oil slick under the sea ice