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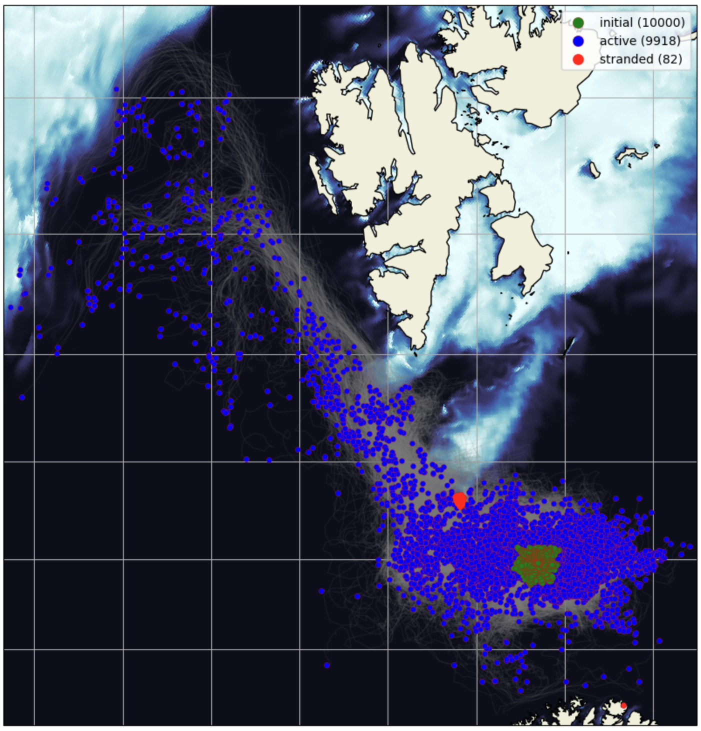
Simulations of hypothetical oil spills from the Wisting oil field in the Barents Sea

-Application of the OpenOil/OpenDrift model

Lars Robert Hole & Knut-Frode Dagestad



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Abstract

On request from Naturvernforbundet and Greenpeace, the Norwegian Meteorological Institute has carried out a series of oil drift simulations for the Wisting Oil field (73.44ºN, 23.40ºE) in the Barents Sea. Simulations have been carried out using the OpenDrift/OpenOil ocean trajectory model forced by the Barents2.5km ocean model and the AROME arctic 2.5km atmospheric model. Hypothetical oil spills from 1 to 98 days at the sea surface and the seafloor have been simulated. Simulation durations are the same as spill durations. Both summer and winter conditions (2021) have been studied. It appears that about 50% of the oil evaporates or is biodegraded, while the other half of the oil mass is either at the surface or submerged. Almost none of the oil is present at the surface during windy conditions (10-15 m/s), which is rather common in winter. Some oil hits the ice edge, but hardly any oil hits the shoreline in these simulations.

Keywords

Oil spill simulations Barents Sea Wisting

Disiplinary signature

Responsible signature

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1 Introduction and method

On request from Greenpeace and Naturvernforbundet, the Norwegian Meteorological Institute (MET Norway) has carried out a series of simulations of hypothetical oil spills from the Wisting Oil field in the Barents Sea (73.44ºN, 23.40ºE). The simulations are meant to resemble some of the hypothetical oil spill cases in DNV report 2021-0737, Rev. 2 (listed in Table 2-8). In addition, a 98-day simulation is carried out. The winter cases start on 1 January 2021, whilst the summer cases start on 1 June 2021.

Table 1: Hypothetical oil spill cases included in the report. Simulations are carried out for winter (Starting 1 January 2021) and summer (starting 1 June 2021). For all simulations, the oil type *Wisting Central 2017* (density 838 kgm^{-3}) from the NOAA oil database is used and 10000 oil elements are seeded. See DNV report 2021-0737 Table 2-8.

Case#	**Surface(S)/ Seafloor(F)**	**Duration (days)**	**Volume (m^3)**	**Comment**
1	S	1	1000	Unloading operation accident
2	S	48	5500	Collision
3	S	48	12000	Ship collision
4	S	24	1000	Leakage
5	F	24	1000	Seafloor leak
6	F	48	200	Seafloor leak
7	S	98	12000	Ship collision (winter only)

The simulations are carried out using MET Norway's oil drift model OpenOil which is part of the OpenDrift framework (https://opendrift.github.io/). OpenDrift is a software package for modelling trajectories and fate of objects or substances drifting in the ocean, or even in the atmosphere. OpenDrift is open source, and is programmed in Python. As the software is very generic, it is rather a "framework" than a "trajectory model" in the traditional sense. Trajectory models for specific purposes (e.g. oil drift, search and rescue, ship drift, larvae, marine plastic, marine chemical pollution) may reuse all common functionality from the core model and need only implement a Python Class describing the purpose-specific processes (physics/biology etc). See https://opendrift.github.io/, Dagestad et al., (2018), Röhrs et al. (2018) and Fig. 1 for more details.

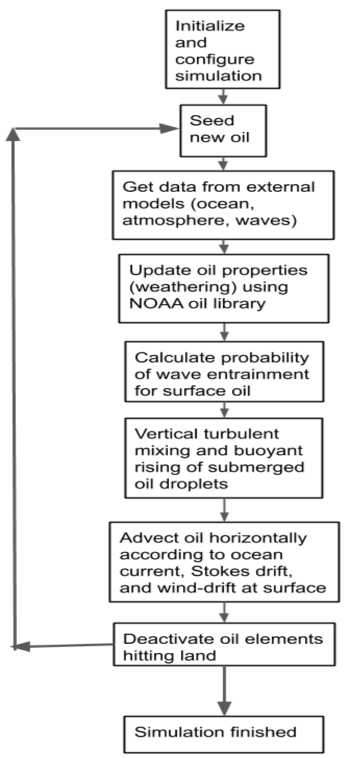

Figure 1: Flow chart of OpenOil.

OpenDrift/OpenOil is a Lagrangian model system which represents an oil slick as a number of oil elements with individual properties (density, water content, viscosity etc.) that changes with time. All important processes for oil weathering such as evaporation, emulsification, vertical mixing and biodegradation are included in the simulations.

OpenOil has been shown to provide accurate simulations of a massive oil spill such as the Macondo spill in the Gulf of Mexico in 2010 (Hole et al., 2019) and also controlled minor spills released during the Norwegian Oil-on-Water exercise (Brekke et al, 2021). Recently, the capability for oil/ice interaction has been implemented in OpenOil by Aguiar et al., (2022), so that the oil drift will be influenced by ice drift at ice concentrations larger than 30%.

One of the most important factors in ocean trajectory modelling is the choice of forcing data. While OpenDrift itself can be run on a laptop computer, forcing data for ocean and atmosphere depend on larger model systems. Here we use our own operational Barents Sea 2.5km model system (Fig. 2) which we believe is the best available ocean model for the region.

Our operational ocean models are built on the Regional Ocean Modelling System (https://www.myroms.org). ROMS solves the Reynolds averaged, hydrostatic primitive equations using a bottom-following coordinate system with free surface.

The Barents-2.5 model is a coupled ocean and sea ice model covering the Barents Sea and areas around Svalbard (https://ocean.met.no/models). It is MET Norway's main forecasting model for sea ice in the Barents Sea. The model is based on the METROMS framework which implements the coupling between the ocean component (ROMS) and the sea ice component (CICE). The model employs a curvilinear grid in the horizontal with 2.5km resolution, and an irregular topography-following vertical coordinate system for the ocean consisting of 42 layers, while the ice is modelled in 5 thickness categories, each with 7 vertical layers and a single snow layer on top. The ocean and sea ice is forced by atmospheric fields from MET Norway's in-house operational 2.5km AROME-Arctic model. Furthermore, boundary conditions comes from TOPAZ4, tides from TPXO tidal model, river runoff climatology from NVE data (mainland Norway) and AHYPE hydrological model (Svalbard+Russia) and the bottom topography is taken from the IBCAO v3 dataset. The model runs a 24 hours analysis for assimilating AMSR2 sea ice concentration from the University of Bremen and then runs a subsequent 66 hours forecast from the produced analysis. Daily updated validation results for the sea ice forecast are available at https://cryo.met.no/en/sea-ice. The operational archive of the model is available on https://thredds.met.no/thredds/fou-hi/barents25.html. All analysis runs (to create a continuous time series) as well as the latest forecast are included. Details on the model setup are provided in Röhrs et al, in prep and Duarte et al. (2022). A discussion on the assimilation of sea ice concentration data is provided in Fritzner et. al. (2019).

Central to the Lagrangian particle tracking in this work are the ocean surface currents provided by Barents-2.5. While the mesoscale ocean circulation has large uncertainty in forecast models in general, the model system exhibits statistical skill on resembling realistic ocean currents (Idzanovic et al, in prep). This skill owes mostly to a realistic resemblance of wind forcing and ocean turbulence in the model, in the fact that the mesoscale circulation relevant for short-term particle transport is resolved by the model's resolution. Statistical skill in the hydrodynamic model is essential for reliant risk analysis studies on particle transport (Röhrs et al. 2018, 2021).

Atmospheric forcing for the oil drift simulations presented here, was taken from the operational 2.5km AROME-Arctic model, providing consistency with the ocean model. Atmospheric forcing is important for evaporation, Stokes drift (wave drift) and vertical mixing. Details on the configuration of Arome-Arctic are provided in Müller et al. (2017).

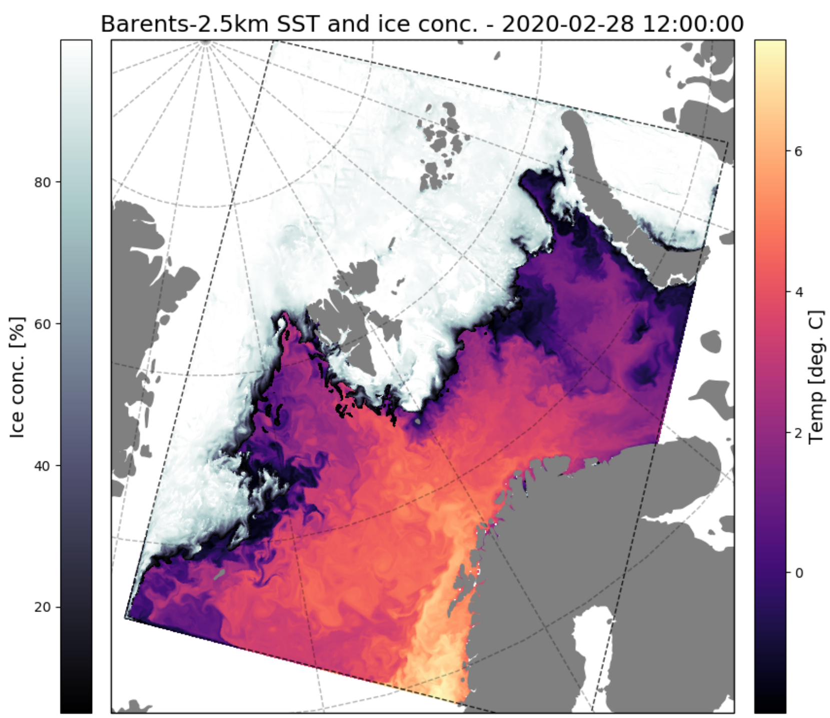

Figure 2: Domain of the Barents Sea 2.5km operational ocean model.

2 Results

In the following, the 12 simulations are presented as surface plots (Figs. 3-9). For the winter simulations, the sea ice fraction is shown as background, whilst for summer simulations, the Sea Surface Temperature (SST) is shown. Only the last time step in the simulation is shown.

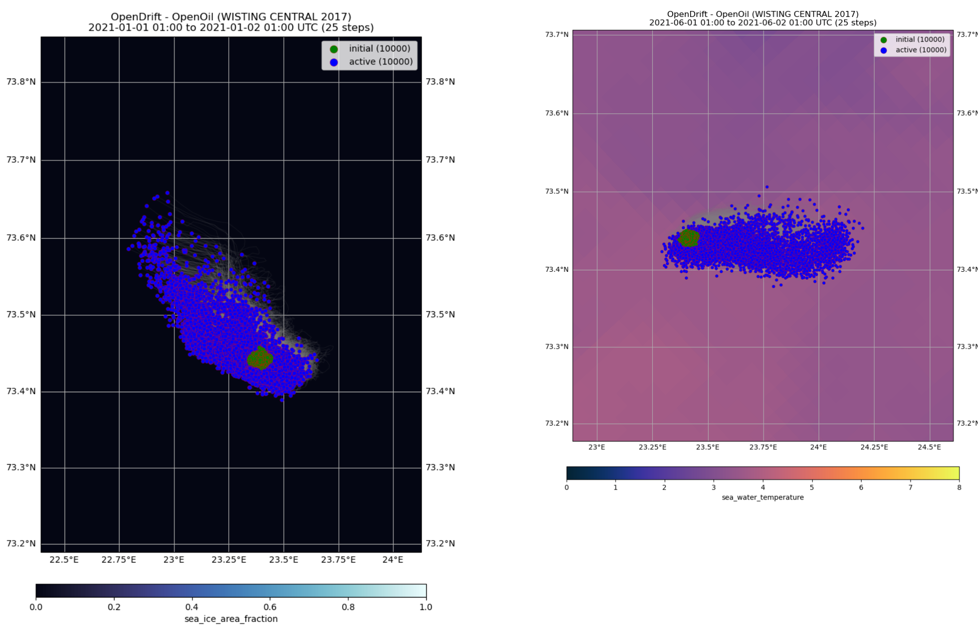

Figure 3. Simulation of Case 1 (1 day / 1000m^3) for winter and summer 2021. For winter, the sea ice area fraction is shown, whilst for summer, the sea surface temperature is used as background. Green particles indicate the seeding location, and blue particles indicate the distribution of oil at the end of the simulation. The trajectories between are indicated with grey lines.

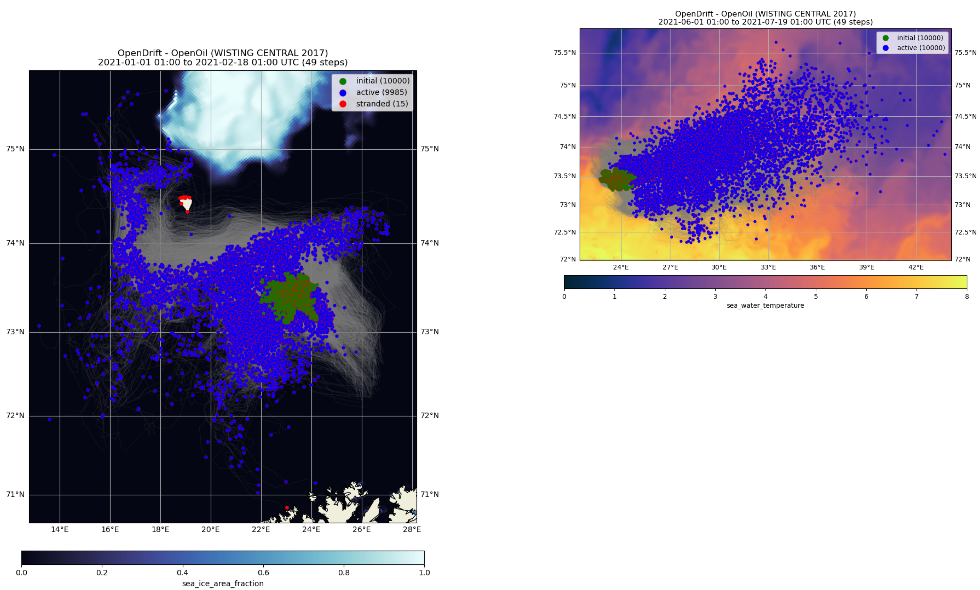

Figure 4: Same as Fig. 2, but for Case 2 (48 days / 5500 m^3).

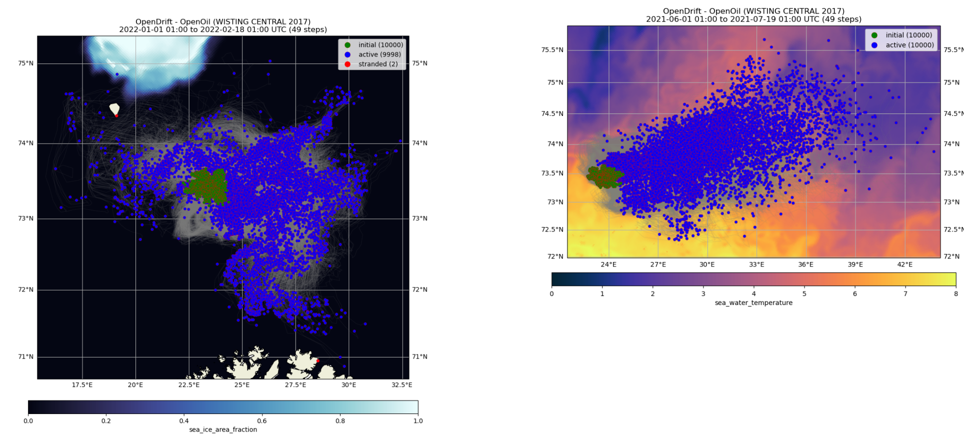

Figure 5: Same as Fig. 4, but for Case 3 (48 days / 12000 m^3).

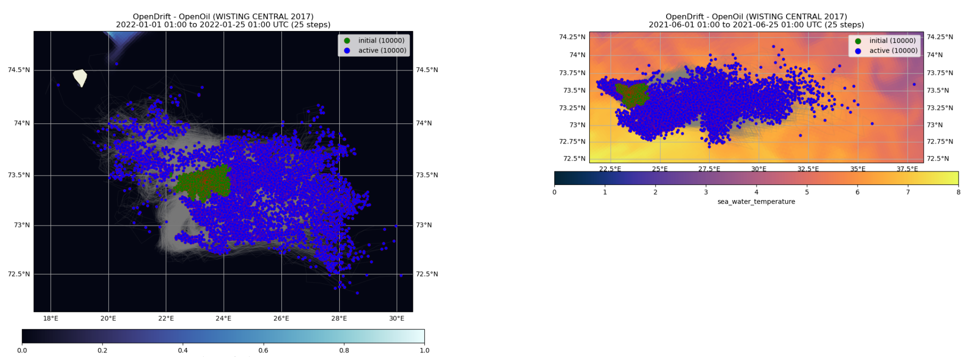

Figure 6: Same as Fig. 5, but for Case 4 (24 days / 1000 m^3).

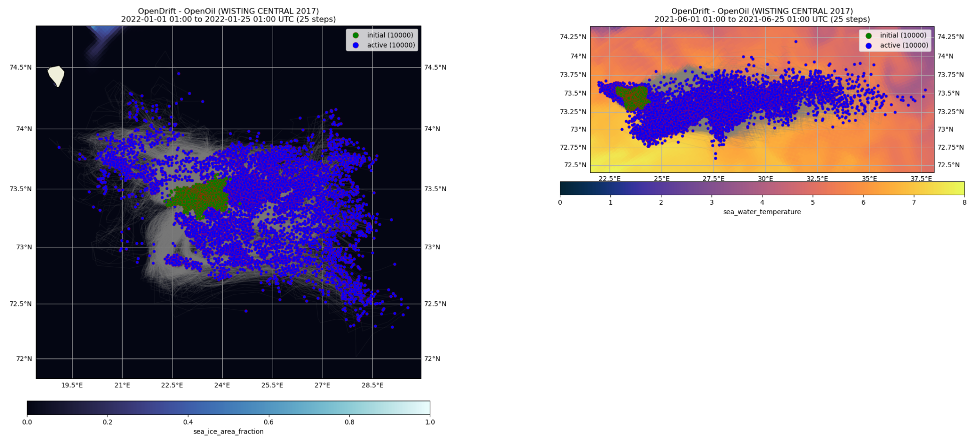

Figure 7: Same as Fig. 6, but for Case 5 (24 days / 1000 m^3).

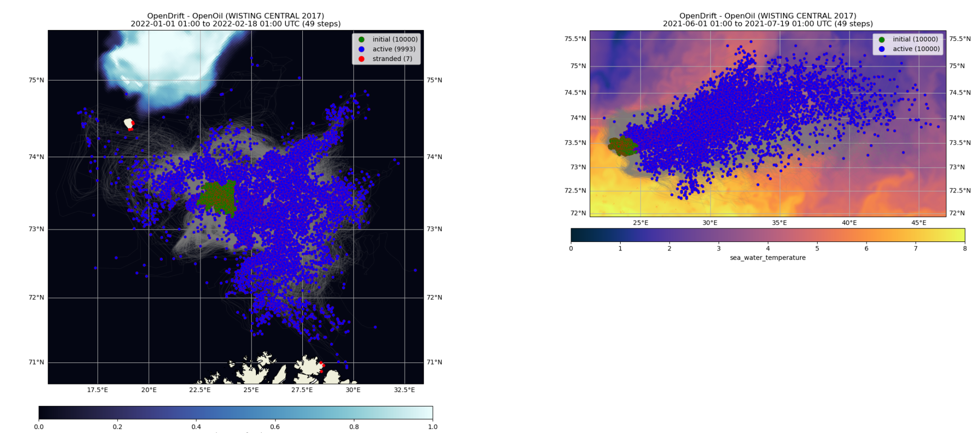

Figure 8: Same as Fig. 7, but for Case 6 (48 days / 200 m^3).

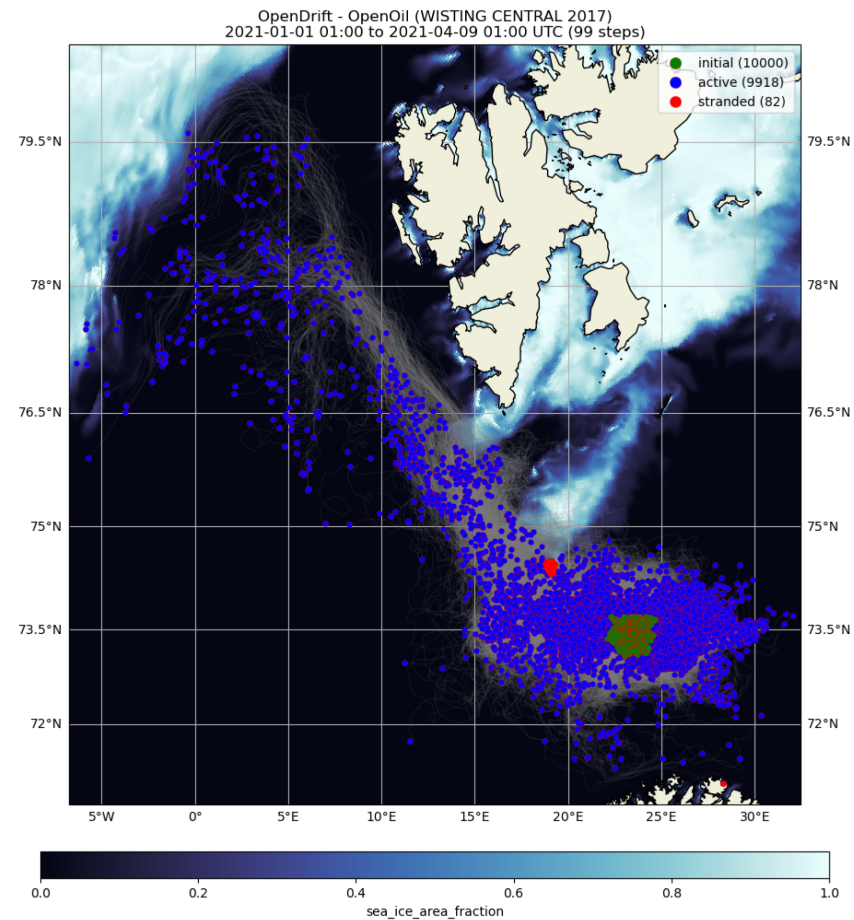

Figure 9: Same as Fig. 8, but for Case 9 (98 days / 12000 m^3).

3 Discussion and conclusion

A series of simulations are presented here to illustrate the fate of hypothetical oil spills from the Wisting field in the Barents Sea, for summer and winter conditions. It should be stressed that the simulation dates are randomly selected, and that simulations at other dates may look different. Also, the probability of such spills is not discussed.
The long winter simulations (24 and 48 days) tend to show drift towards NW (towards Bear Island and even Spitsbergen), whilst the summer simulations tend to show drift towards E. In addition, a 98-day simulation is included.

- About 50% of the oil is evaporated or biodegraded (see oil budgets in Appendix).
- In periods with strong wind during the winter simulations (10-15 m/s), the rest of the oil is submerged and close to zero oil is present at the sea surface. This means that oil film thickness is not a relevant parameter to present in these cases.
- More oil tends to stay on the surface in summer due to less wind and wave activity.
- In general, more oil is present at the surface in summer when wind speed is lower, but a large fraction of the oil is submerged at any time and may reappear at the surface when the wind calms down.
- Only a few percent of the oil mass actually reaches shore in the simulations presented here (see Case 3).

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5 Appendix1: Mass budget plots

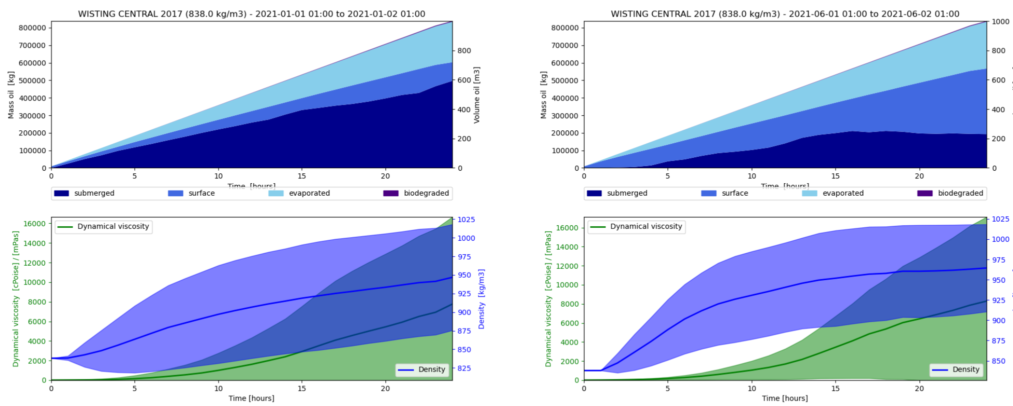

Figure A1: Oil mass budget for Case 1, winter (left) and summer (right).

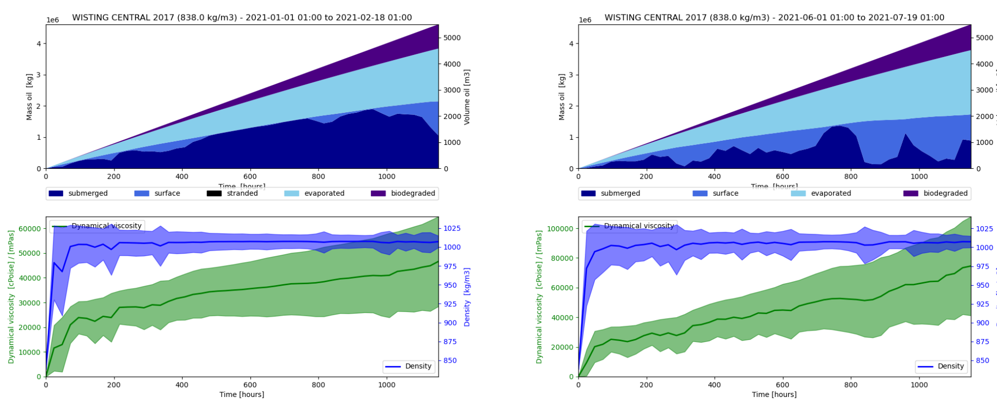

Figure A2: Oil mass budget for Case 2, winter (left) and summer (right).

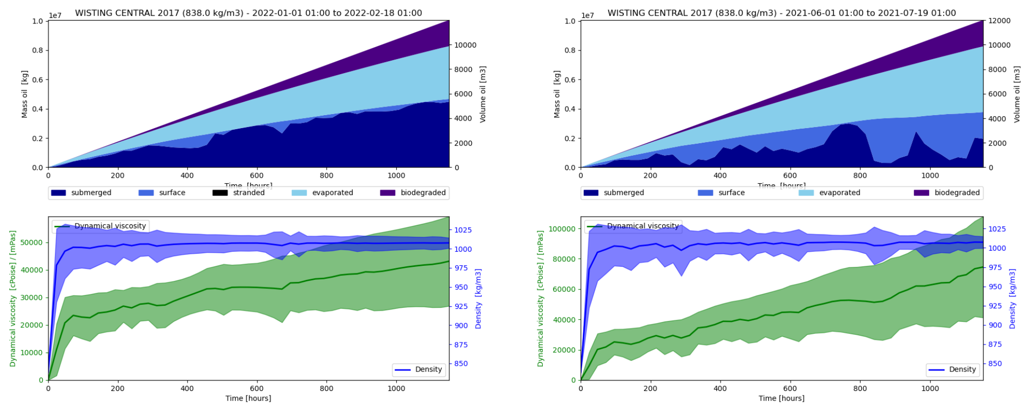

Figure A3: Oil mass budget for Case 3, winter (left) and summer (right).

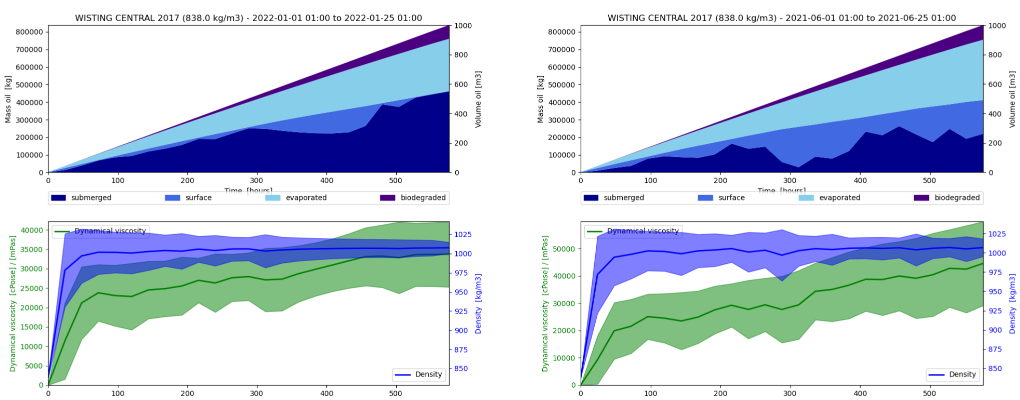

Figure A4: Oil mass budget for Case 4, winter (left) and summer (right).

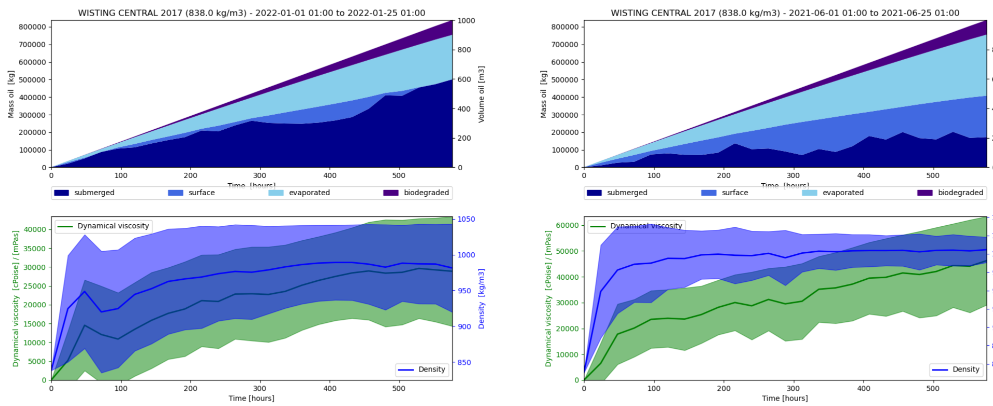

Figure A5: Oil mass budget for Case 5, winter (left) and summer (right).

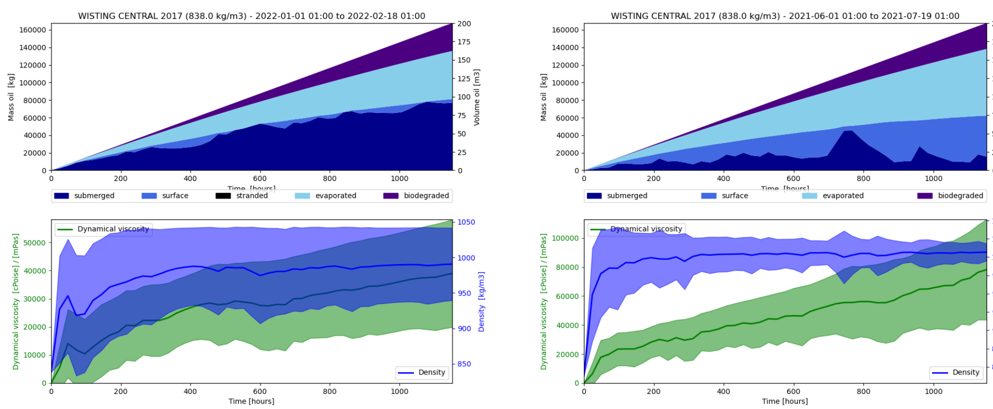

Figure A6: Oil mass budget for Case 6, winter (left) and summer (right).

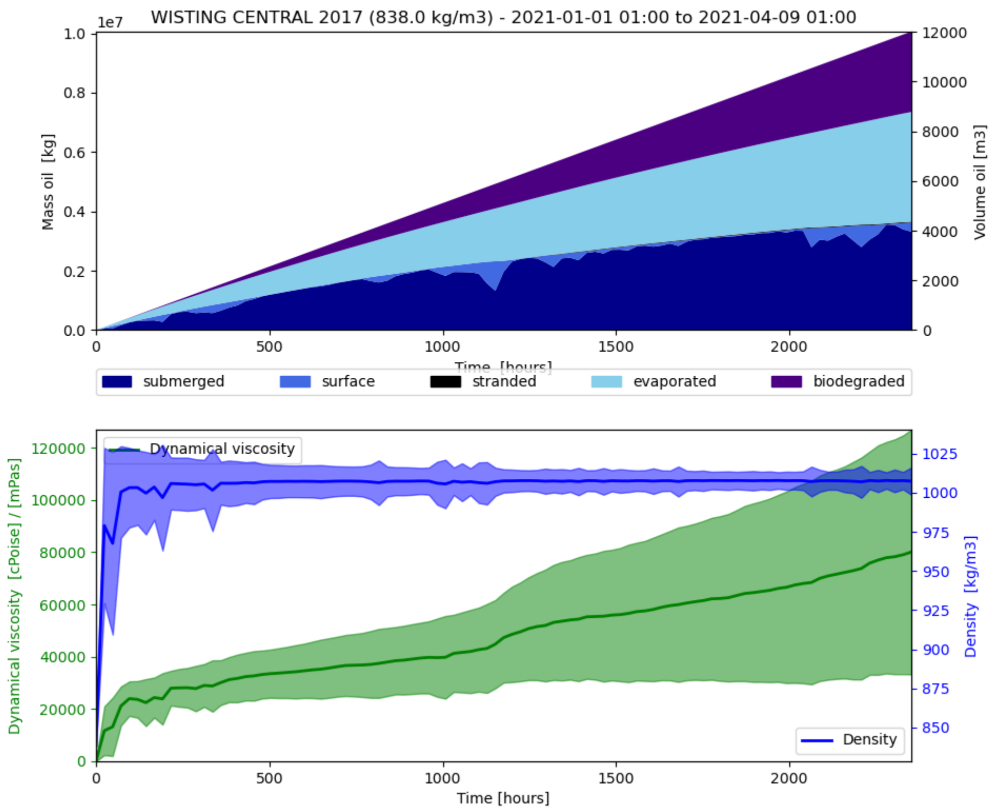

Figure A7: Oil mass budget for Case 7.