The Cryosphere Discussions

The Cryosphere Discuss., referee comment RC2
https://doi.org/10.5194/tc-2021-372-RC2, 2022

Comment on tc-2021-372

Anonymous Referee #2

Referee comment on "Quantifying the effects of background concentrations of crude oil pollution on sea ice albedo" by Benjamin Heikki Redmond Roche and Martin D. King, The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-372-RC2, 2022

This manuscript provides a theoretical / modelling study of the impact of crude oil droplets on sea ice albedo. The authors use a coupled atmosphere-snow/sea ice radiative transfer model to simulate the wavelength-dependent albedo of three common types of sea ice in response to increasing mass ratios of two different types of crude oil, whilst accounting for different optical and physical parameters. The main findings of the article are that: 1) sea ice properties play an important role when considering the impact of oil pollution, 2) the thickness of sea ice is an important factor to be considered, 3) the type of crude oil dispersed in the sea ice also significantly affects the response of sea ice albedo, and 4) the size of the oil droplets polluting the oil only plays a small role in albedo response.

The manuscript appears to be a "logical" continuation of the previous works of the research group who used a similar modelling approach to characterise the effects of black carbon [Marks et al. 2014] and mineral dust deposits [Lamare et al., 2016] on the albedo of sea ice. The article is clearly written, well structured and the results shown in the figures are easy to understand. Although the findings are not ground-breaking, the authors provide valuable insights into the impacts of increased pollution on the albedo of sea ice, which is a timely subject to be addressed in the current Arctic context. Moreover, the parametrisations used in this study are of value to the scientific community, for further modelling studies. For these reasons, I recommend this manuscript for publication, after the authors have address a few minor comments stated below.

General comments

There is a misalignment between the title of the article and certain statements (see detailed comments below) and the actual purpose of the proposed work. Indeed, the climatic impact of crude oil pollution is not addressed in this sensitivity study. I would recommend that the authors rephrase the title of the manuscript and correct the statement line 641.

The impacts of crude oil droplets dispersed in sea ice are investigated in the visible wavelengths (400-700 nm). Could the authors please expand on the reasons for this wavelength range? Is it a limitation of the model or a deliberate choice? Most observation tools (ground-based instruments, drone or aircraft mounted sensors, Earth Observation satellite) cover a larger spectrum, generally from the visible to the shortwave infra-red. Furthermore, climate models (e.g. CMIP models) consider the longwave radiative balance to monitor the Earth's energy balance. Although longwave radiation is most likely out of scope for this study, it is surprising that such a small range of wavelengths is being considered here. Extending the range to 2500 nm would allow direct comparisons with observations.

The authors state that "*the effects that oil pollution has upon sea ice albedo have not previously been considered in literature*". Although this statement holds, the authors disregard the existing corpus of works that investigate the effects of oil pollution on sea ice reflectance (e.g. 1-5 in the reference section below). Despite the quantities being different, albedo can be derived from reflectance using a BRDF model, and it is widely accepted that reflectance may be used as an approximation for albedo. A short review of the existing studies would be desirable in the introduction.

In this study the authors have chosen to distribute the oil evenly throughout the sea ice. While this may be realistic in certain conditions (particularly for low oil concentrations), how plausible is this to occur at higher loadings (1000 ng g-1)? In the discussion (line 496) the authors describe the different scenarios of how oil entrains itself into sea ice. From these comments, it is clear that layering of the oil is a common situation encountered in sea ice. The model used allows the definition of layers throughout the ice pack: rather than address the relationship between black carbon and oil loadings, would it not have been of value to consider the effects of oil located in specific (e.g. surface, or sub-surface) layers?

In link to the paragraph above, the concentrations of the oil would deserve more clarifications. Indeed, the article focusses on "*microscopic sized background concentrations of oil*" (line 509) but in the introduction it is mentioned that after the Deepwater Horizon incident, mass ratios of 100 ng g-1 were found. Can mass ratios of 1000 ng g-1 still be considered as "background"?

More information about the relationship between the oil droplet size and the mass ratios would be important to better understand which scenarios in the paper are most plausible. Have the authors investigated if there is a relationship between droplet size and mass ratios between 1 and 1000 ng g-1 or is it likely to find all sizes within the loading range?

Section 4.6 on the implications of the study is quite light and could be fleshed out more. It would be insightful to read the authors thoughts on the implications in terms of how the sea ice melting rates and extent in summer will be affected by oil pollution. How does the increased oil pollution impact the energy balance of the Arctic, and are the effects sufficient to be considered in General Climate Models?

Lastly, as a side note, I would suggest that the authors make the input data available through an open repository, which would benefit the modelling community greatly (e.g. use of the parametrisations of crude oil in climate models) and allow for further inter-comparisons of modelling approaches.

Detailed comments

l46: What do the authors mean by: "*The wavelength integrated and spectral albedos for different types of sea ice have previously been considered [...]: this study focuses on three types of sea ice: melting, first-year, and multi-year sea ice.*" It is not clear if the authors are referring to the literature or if they are stating that they have considered a wide variety of sea ice types before settling for the three mentioned.

Table 1: One would expect the density of first-year, multi-year and melting sea ice to be different owing to differences in structure (brine channels, air bubbles...). The reference cited by the authors [Marks and King, 2014] states that the density of sea ice ranges 700–950 kg m^{-3}. How do the authors justify the same fixed value for all sea ice types?

Table 2: On what basis were the number of layers (201) and the increments chosen for the model?

l236: In this paragraph the authors describe the optical properties of the two types of crude oil used in the study. Although it is stated that "*Whilst both crude oils have a variety of uses, including as marine engine fuels, Romashkino can be considered a typical marine engine Heavy Fuel Oil*", the reasons for selecting Romashkino and Petrobaltic oil is not sufficiently clear to the reader, who has to wait until line 578 to understand that "*both Romashkino and Petrobaltic can be regarded as the upper and lower respective brackets of the effect that oil pollution can have on sea ice albedo*". Furthermore, it would be useful to understand if these oil types are only representative of pollution that may occur from shipping activities, or can also be used to understand the impacts of oil spills from drilling activities.

l275: There seems to be a repetition in the first and second sentences. In the second sentence, the author state the same elements as in the first sentence but with melting and multi-year sea ice in addition. Please fix or clarify.

l279: In the sentence concerning the effect of oil droplet size, it would be useful to explicitly state the sea ice type considered.

Figure 1: I suggest using a Y axis ranging from 0.3 to 0.9, and putting the legend outside

the figure for more clarity, if this is allowed by editing rules.

Section 3.3 Could the authors specify why melting sea ice was chosen for the analysis of the effects of oil droplet size on albedo? Are the implications similar for other types of sea ice?

Section 3.4: A reference to ΔA/Δm used in Figure 5 is expected in the text.

l627: "*Arctic multi-year and first-year sea ice are declining at 17.5% and 13.5% respectively...*" is not clear. Please rephrase.

l641: "*[...] this is the first instance that the climatic effect of oil pollution on sea ice has been considered.*" This sentence is misleading and implies the use of a climate model or conclusions on the large scale impact of oil pollution in the Arctic which is not the case here. Please rephrase.

l659: "*[...] the findings of this study may only be valid during the ablation season when snow cover has melted or been removed by wind.*" In this case why consider different types of sea ice? I believe the value of this paper lies in the sensitivity study considering a variety of optical and physical parameters. I suggest to add that this may be the case in practise and that the authors restate the main purpose of the study..

References

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