To the Editor (Yevgeny Aksenov),

Thank you for agreeing to serve as editor and offering your positive comments for these minor edits. Thank you for also agreeing to extend our deadline as Martin and I have been abroad. Please see below our responses to the remaining comments from Editor 1.

In our responses, we have printed the reviewers' comments in black and our responses in blue. The underlined text immediately precedes quotations from the text that has been added or edited; the text that has been added or edited to the manuscript are italicised and between quotation marks.

*I have noticed that the line numbers I have mentioned below are incorrect in the Track Changes file but correct in the submitted final file. Sorry about this, it appears to be a common Track Changes error on Word, however, all of the edits are highlighted in red in the text and in the margin.

Kind regards,

Ben Redmond Roche and Martin King

Response to Anonymous Referee #1 on tc-2021-372

1. Reviewer comment '*If it is the authors' intent that first-, multiyear, and melting ice types be distinct ice types, and if no snow cover is being considered, then it needs to be explicitly stated that the first- and multiyear ice cases represent bare ice (without snow cover) that is not melting*'.

- Author response: We have now made clear that it is bare sea ice in the Abstract, Methodology, and Uncertainties sections.
- line 8 changed in the Abstract to now read: '*In this study, the albedo response of three different types of bare sea ice (melting, first-year, and multi-year sea ice) are calculated at increasing mass ratios (0–1000 ng g-1) of crude oil by using a coupled atmosphere-sea ice radiative-transfer model (TUV-snow) over the optical wavelengths 400–700 nm.'*
- Line 172 changed in Section 2.1 to now read: '*In this study, the albedo response of three different types of bare sea ice (multi-year sea ice, first-year sea ice and, melting sea ice) to increasing amounts of two different crude oils are calculated using the TUV-snow model.'*
- Line 685 changed in Section 4.7 to now read: '*Therefore, similar to the work by Light et al (1998), the findings of this study may only be valid during the ablation season when snow cover has melted or been removed by wind, as the different types of sea ice considered here are bare.'*

2. Reviewer comment '*Statements such as are included in the abstract (line 22 – 24) are thus difficult to justify: "All three types of sea ice are affected, however firstyear sea ice and particularly melting sea ice are very sensitive to oil pollution; thus, the Arctic may become more vulnerable to oil pollution as the ice becomes progressively thinner and younger in response to a changing climate."*

- Additionally, the conclusion (line 764) that "*This may become increasingly important as multi-year sea ice continues to decrease, first-year sea ice becomes more dominant and there is earlier melting of sea ice in the year*." is also not justified, since the first- and multiyear ice types considered in this study are anomalous, not the more common melting variety.

- Author response: We have made the following changes in the Abstract and Conclusion sections.
- Line 22-24 in the Abstract removed, line 20 changed to now read: '*Therefore, the work presented here demonstrates that low background concentrations of small submicron to micron-sized oil droplets have a significant effect on the albedo of bare sea ice. All three types of bare sea ice are sensitive to oil pollution, however first-year sea ice and particularly melting sea ice are very sensitive to oil pollution.'*
- Line 732 in the Conclusion, referred to by the reviewer as line 764, has now been removed.

3. Reviewer comment '*One could argue that since snow covered sea ice is not considered in this study, the only significant ice type to draw climate-relevant conclusions from would be the melting ice. I understand that the properties of these three ice types were adopted from earlier work (Marks and King, 2014), and it is acceptable to run these cases through this sensitivity analysis, but it is an overstep to draw conclusions about the implications of these studies on the climate.'.*
- Author response: Our Abstract, Discussions, and Conclusions sections no longer discuss or mention climate. The world climate only appears in the Abstract and Introduction sections (line 1 and 42) to explain how albedo is an important component of Earths climate.

Minor/technical comments

4. Reviewer comment: '*Title: add 'Arctic' sea ice albedo*'.
- Author response: These results are not specific only to the Arctic, so we decline to add the word Arctic to our title as our findings are applicable to all bare sea ices on Earth.

5. Reviewer comment: '*30-31: "Perennial sea ice cover decline is between 12.2% and 13.5% for first-year sea ice…" Confusing. Usually "perennial" sea ice is considered ice that survives at least one summer melt season. Maybe "Interannual sea ice cover decline…" was intended'*
- Author response: Thank you for highlighting this error, it has now been corrected.
- Line 30 in section 1 changed to now read: '*First-year sea ice cover is declining at between 12.2% and 13.5%, and multi-year sea ice cover is declining at between 15.6% and 17.5% per decade, respectively (Comiso, 2012; Tschudi et al., 2019).'*

6. Reviewer comment: '*41 – 42 "The high latitude, radiative balance, is…" delete commas; also, this applies only in summer.'*
- Author response: Thank you for highlighting this error, it has now been corrected.
- Line 42 in section 1 changed to now read: '*The high-latitude radiative balance is primarily controlled by shortwave solar radiation during the summer which significantly affects both sea ice and snow cover in the region (e.g., Perovich et al., 1998; Flanner et al., 2007).'*

7. Reviewer comment: '*54 - 56: "The albedo of sea ice is wavelength dependent with maximum albedo values occurring at 390 nm in pure ice, where absorption is at a minimum (Warren at al., 2006)." I agree this is the theoretical maximum albedo, but I've never seen an observation that shows this is true for sea ice.'*
- Author response: Sentence unchanged as the reviewer appears to agree with us.

8. Reviewer comment: '*Table 1: If the properties of the ice cover are resolved by multiple vertical layers in the model, why are the properties of the ice uniform? It is well*

established that 3 layers are needed to simulate radiative transfer in sea ice (see e.g., Light et al., 2008)'

- Author response: The three types of ice described in this study are based on previous work (e.g., Marks and King, 2013; 2014; Lamare et al., 2016), which are themselves based on the seminal work by Grenfell and Maykut (1977). We agree that other studies such as Light et al (2008) have established the three layers and have now added reference to this in the text. It is also unknown how oil moves between different types of ice fabric, so we have therefore kept the optical properties of the ice homogeneous.
- Text added to Section 2.1: '*The types of ice have been kept simple and in keeping with previous work (e.g., Marks and King, 2013; 2014; Lamare et al., 2016), further studies with a better understanding of how oil moves between different ice fabrics may wish to consider the three-layer model proposed by Light et al (2008).'*

9. Reviewer comment: '*Eqn(2), fine, but sigma traditionally used for scattering coeff, not absorption coeff. But OK since it's defined.*
- Author response: Different fields use different nomenclature; we are using the same symbols as the original radiative transfer model (Lee Taylor and Madronich, 2002).

10. Reviewer comment: *'"… ice sheet continues to grow underneath the sea ice,…" what does this mean? Maybe it should be " …and the ice continues to grow at its interface with the ocean"?'*
- Author response: Whilst the original text makes sense, it has now been clarified for the reader.
- Line 516 of Section 4.1: '*Oil is known to entrain itself into sea ice in several ways: (1) oil beneath the sea ice is frozen into the sea ice and the ice continues to grow at its interface with the ocean, with the oil being fully encapsulated in the ice matrix within 18–72 hours'*

11. Reviewer comment: '*551: which require more work—what does this mean'*
- Author response: The text has now been edited.
- Line 529 of Section 4.1: '*These studies have focused on macroscopic quantities of oil whereas the work presented here focuses on microscopic-sized background concentrations of oil which are less well characterised.'*

12. Reviewer comment: *663: '"relatively light absorbing" is potentially confusing—does it mean relatively minimally absorbing, or does it mean relatively energy absorbing?'*
- Author response: The text has now been edited.
- Line 717 of Section 5: '*The albedo response is dependent on the type of oil, with the strongly absorbing Romashkino oil (relative to Petrobaltic oil) having the largest effect owing to its large mass absorption coefficient.'*