The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2017-150-AC1, 2018

The Cryosphere Discussions

Interactive comment on "Reflective properties of melt ponds on sea ice" *by* Aleksey Malinka et al.

Aleksey Malinka et al.

heygster@uni-bremen.de

Received and published: 14 February 2018

We are grateful to the referees for their positive evaluation of our work and particularly for the detailed comments. We made corrections in the manuscript according to the referees' minor comments. In the following we give more detailed answers to their questions. The revised version of the manuscript will be submitted when we will have the answers of the reviewers.

Anonymous Referee #1:

This manuscript details a model simulating shortwave radiative transfer for melt ponds on the surface of Arctic sea ice. The paper is of interest to TC readership and describes a model that appears sound and well tested. The language is a bit awkward in places (see minor comments below), but I do think it is generally readable.

Thank you. As for our English, we did our best and particularly mindfully considered your minor comments and made appropriate corrections in the text. For the final version we will have an additional round of correction by our native speaking coauthors. Besides, there will be English copy-editing by the editorial staff at the final stage.

My only major comment on the presentation is that p. 16 line 16 states that three independent parameters are required for this model: pond depth, ice substrate thickness, and ice transport scattering coefficient. I agree. The results presented in Table 2 show the first two parameters. What is assumed about the third one? There is no information discussed in the manuscript that would suggest what values were inferred for the ice transport scattering coefficient. Almost all of the comparisons between model and observation show remarkable fidelity. It seems so remarkable, that I wonder what range of transport scattering coefficients are used, and whether there is some vertical variability allowed in the ice layer beneath the pond water for that coefficient? If I understand correctly, the model is inferring an optical depth τ so an assumption must be made about the inherent optical properties in order to retrieve the physical depth of the ice? What is that assumption?

You are absolutely right that just the optical depth, rather than the geometrical one, determines the reflectance. They are related by Eqs. (42). We consider all three parameters, z, H, and σt , as independent ones. We vary all of them independently when fitting spectra and don't make any additional assumptions about σt. (Except vertical variability). Of course, we don't have enough information to retrieve the vertical profile of σt , so we assume that we retrieve some constant effective value for a layer). Thus, all these three values are retrieved for every spectrum. In Table 2 we show only two of them just for comparison with the in situ measured values of z and H. This information will also be added to the manuscript. However, nobody measures σt , so we don't show its values. But we added the retrieved values of σt for the light and dark portions of the SHEBA pond (see the last paragraph of Sec. 4.3), where they are important for calculation of the scattering coefficient by bubbles.

Minor comments: p.1 line 9, 19: “large part” and “large fraction” are not very specific

We omit general references and put: “up to 60% on multiyear ice according to Maykut et al. (1992) and up to 80% on landfast ice according to Langleben (1971).”

p.1 line 24: “nowadays” colloquial

Changed: “in light of the environmental changes observed recently”

p.2 line 5 -6: “Makshtas and Podgorny give a formula for pond spectral albedo at direct incidence only; they do not consider the angular distribution of the reflected light.” This sentence is a bit confusing. I understand that M&P give a formula for pond albedo only for direct incidence, but I don’t see why that relates at all to an angularly-resolved description of the reflected field.

We changed the phrase to: “Besides, the question of the angular distribution of light reflected by a melt pond is still open.”

p.2 line 15: “banner of the ice grains presence” makes no sense

Changed to “evidence of the ice grains presence”

p. 2 line 16: “common deficient information” makes no sense

Changed to “when the incident angle is unknown”

p.4 line 1: define ‘AW’ p.5 line 3: define ‘WI’

Definitions are added in p.3, l.27.

p.6 line 6: please supply a reference for the definition of ‘transport scattering coefficient’

We added the references Davison, 1958 and Chandrasekhar, 1960

p. 6 line10: does ‘very elongated’ phase function mean ‘very forward peaked’ phase function? I don’t believe ‘very elongated’ is commonly understood. I think the authors are attempting to convey the idea that a smaller scattering coefficient and lower |g| can

be used to describe the apparent optical properties of a medium with large scattering coefficient and/or high |g|.

Yes, you are absolutely right. Corrected.

p. 6 line 22: mirabilites and hydrohalites. . . should be mirabilite crystals and hydrohalite crystals

Corrected.

p.6 line 26-28: If the highly scattering surface layer isn’t being considered here, then what is being considered?

We tried to specify a little: “We do not consider here the highly scattering surface layer that is formed on top of sea ice during the water drainage process and is commonly referred to as ‘white ice’.” Hope it’s clearer.

p.6 line 28: Statement that air bubbles in sea ice are mostly spherical needs a reference.

We added Gavrilo and Gaitskhoki, 1970; Mobley et al., 1998; Light, 2010.

p.7 line 3: is exponent +1.24 or -1.24?

Corrected to –1.24.

p.8 line 20: sloppy notation, with the ‘t’ used as a subscript on the left hand side of the equation and as a superscript on the right hand side, but both mean the same thing.

We hope this notation will not confuse our readers. After all, these sub- and superscripts are not the tensor indices where their position is principal.

p. 11 line 11: ‘extra-terrestrial solar irradiance’ I think is more commonly called ‘top-of-atmosphere irradiance’?

Both terms are widely used. As for our experience, the term ‘top-of-the-atmosphere’ is more frequent for the Earth reflected radiance, while ‘extra-terrestrial’ for solar light.

eqn 49: it is confusing that both A and alpha are used for albedo

We replaced α by Ablue.

p. 13 line 9 – 10: melt ponds forming during 2 Aug – 8 Oct cruise? Seems unlikely.

These are the dates of the cruise. We added: "The melt ponds were observed in August."

p. 13 line 11-14: The description here lacks detail. I assume the fiber optic probe coupled to the ASD is used to view light reflected by the Spectralon plate, but this isn't adequately described. The phrase "served as a diffuser" doesn't completely describe how the Spectralon plate was employed.

We added: "A sensor measures the light signal supplied by a fiber optical probe, which collects light reflected by a 10x10 cm2 Spectralon white plate."

p. 13 line 31: what does 'open' mean here? No ice skim?

Yes. We put an explanation in the beginning of Sec. 4.1. "The melt ponds were observed in August, being both open (with no ice skim) and frozen over (with a skim of ice), sometimes snow covered."

p. 14 line 31: the spectral albedo was taken every 4 days?

Yes. We put: "The spectra were taken every four days during this period. The spectra processing results are shown in Figs. 12 and 13."

Fig 5 The angle of incidence is stated in the text, but needs to also be stated in the figure caption.

Done.

Fig 6 Where did these spectral curves come from? There needs to be some data attribution.

These spectral curves are modeled for the typical values. We put a phrase "Typical

spectral albedo of melt ponds, snow, and white ice, calculated for the following parameters:

Fig 7 caption should include information (from text) that these all had 2-3 cm layer of ice on top.

Done.

Fig 7 I am surprised at how high the albedo is at blue wavelengths! Could this be due to the frozen surface? If so, then that would contradict the statement p.13 line 21. I would expect the peak albedo at blue wavelengths for unfrozen melt ponds to be somewhere in the range 0.1 to 0.5, at most.

Actually, we cannot be sure that high albedo values do not come from the frozen surface. If an ice skim contains a lot of air bubbles, it can increase the reflectance, but in this case it becomes indistinguishable from the ice substrate. So the optical thickness retrieved is the total thickness (skim + substrate). As we wrote, our model does not consider such cases. The statement p.13 line 21 only states that a layer of transparent ice does not change pond reflection. On the other hand, there is no restriction of 0.5 for open pond albedo. To be objective, we put the phrase in p.13, line 30: "The albedo values are extraordinarily high. This could be related with the fact that the ponds are frozen over with a 2-3 cm layer of ice on top."

Would be useful to show all the panels in each cluster (Figs 7, 8, 9 each a cluster) on the same vertical (albedo) scale.

The plots are quite small, we think it's better when the drawings take all the scale.

Also, captions for Figs 7, 8, 9, 10, 11 need to contain information about the general locations of each series.

We put in the text about the Polarstern cruise: "The stations, where ponds were observed, were located from 84°3N, 31°7E to 82°54N, 129°47E. For more information about the cruise, see Boetius et al. (2012) and Istomina et al. (2016)." For Barrow and

SHEBA the locations are given: Chukchi and Beaufort seas.

Fig 8 If these ponds were heterogeneous, then the exact location of the albedo measurement matters! Can this location be shown?

The exact point of the measurement can be seen in the photograph, where a person is taking observation from the light portion of the pond. Unfortunately, there is no photo for the dark one.

Fig 12 Caption says ‘on June 3’, but I believe was July?

Of course, July. Thank you.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2017-150, 2017.