The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2019-62-AC1, 2019
© Author(s) 2019. This work is distributed under
the Creative Commons Attribution 4.0 License.

The Cryosphere
Discussions

Interactive comment on "Broadband albedo of Arctic sea ice from MERIS optical data" *by* Christine Pohl et al.

Christine Pohl et al.

cpohl@iup.physik.uni-bremen.de

Received and published: 2 September 2019

Dear Referee 1,

We thank for the time and efforts you spent reading our manuscript.

Below you can find your comments, our response and our changes in the manuscript point by point.

Best wishes, Christine Pohl

The characterization of the radiative properties of Arctic sea ice is of substantial importance for many aspects of climate modeling and monitoring. Thus the present effort to improve upon the MERIS record is welcomed, although the record's relatively

short length does place some restriction on its use. Also, the manuscript's comparison against ERA5 sea ice albedo is welcomed, although the rather limited scope of the comparison leaves the reader with rather many open questions. This reviewer therefore suggests adding more meat into that section, as the other part of the manuscript (updated NBC) is somewhat light in content for a full Cryosphere paper in itself.

Major comments: a. Please elaborate on the ERA5 comparison. What are the likely causes for the discrepancies? What is the associated uncertainty in the MERIS estimates, how much of the difference is explainable through them? Are there regionally or temporally changing drivers behind the differences?

We expand the comparison of the ERA5 and MERIS derived broadband albedo by introducing temporal differences between both products at ERA5 sea-ice concentration of 100 % and at two different areas (on first-year ice in the Beaufort Sea near Barrow, 75° N, 155° W, and on multiyear ice north of Greenland, 84.5° N, 35° W) in the summer month (May – September) 2007. We highlight systematical offsets for both mentioned areas by averaging these differences between the years 2003 and 2011. By introducing the melt pond fraction from MERIS data and sea-ice concentration from ERA5 data, we can identify several causes for the differences, e.g. undetected leads (open water) in MPD algorithm of MERIS, unconsidered melt ponds in ERA5, and the albedo parameterization in ERA5. The quantitative estimation of MERIS broadband albedo uncertainties is difficult due to their complexity. Instead, we introduce a new section about uncertainties generating with the spectral-to-broadband conversion between the sections "Results" and "Improved melt pond detection validation".

-> We completely revised the Section 6: Comparison between broadband albedo from satellite and atmospheric reanalysis. -> We newly introduced the Section 4: Uncertainties due to differing variables along the spectral-to-broadband conversion.

b. Both training and evaluation of the method appear to be based on early-season ice, May-June. Some discussion is warranted on whether or not this implies

issues in the determination of late-season ice cover, given the surface changes incurred by e.g. melt pond draining or surface refreezing.

Discussion in Section 4 (p. 7 l. 27-30):

The STBC is based on various sea-ice surface types in the early season (April - June) mentioned at the end of Sect. 2.2. Nevertheless, it can be applied to later seasonal (July-September) Arctic surface type as well, as those surface types like snow covered sea-ice, white ice, and refrozen surface types are similar to the surface types included in the training data-set (snow layers and frozen melt ponds). Therefore, the STBC can be used for all Arctic sea-ice surface types.

c. I approve of the airborne measurement comparison, but have you evaluated against full-summer albedo observations, such as those available from the Tara expedition of 2007-2008? If not, why not as that is in your study period?

It is difficult to compare the Tara data to MERIS broadband albedo because of the different spatial resolution. While the resolution of MERIS data is (12.5 km) ^{2}, the TARA data were measured at a local place. Discrepancies between both albedo products will occur due to uncertainties in the representativeness of each in-situ TARA measurement for the corresponding MERIS pixel. In contrast, airborne measurements can average the local surface properties for each MERIS pixel, making the comparison from airborne to MERIS derived broadband albedo more significant. Therefore, we omit the comparison of MERIS broadband albedo to TARA broadband albedo.

d. While I understand the brevity in method description given the authors' past works on the topic, a short summary of a couple of sentences describing the principles behind e.g. the BRDF model for the highly heterogeneous sea ice cover and the choice of melt pond optical properties for the varied types of melt ponds seems in order in section 2.1 to facilitate context for the readers.

We give more details about the MERIS MPD algorithm in Sect. 2.1. (p. 4 l. 14-28):

For each classified sea-ice grid-cell, ice and pond parameters (optical thickness of pond and ice, scattering coefficient of ice, effective ice grain size, and absorption coefficient of yellow pigments) as well as a pond fraction are initialized. From those, the white ice and melt pond BRDF are calculated based on the asymptotic solution for optically thick layers (Zege et al., 1991). In case of the melt pond BRDF calculation, the optically thick layer is referred to the melt pond bottom. The reflection and transmission at air-water interface is determined by Fresnel's law. The surface BRDF is calculated as a linear combination of both BRDF values weighted by the pond fraction. From surface BRDF and the atmospheric reflectance and transmittance calculated by the radiative transfer code RAY (Tynes et al., 2001), the radiances at MERIS channels at top of atmosphere are derived based on the atmospheric correction method by Tanre et al. (1983). In an iterative process based on the Newton-Raphson method (Press and Flannery, 1993), the difference of measured and calculated MERIS radiances is minimized as a function of the ice and pond parameters, and of the melt pond fraction. From resulting ice and pond parameters, the spectral black-sky albedo (directional-hemispherical albedo (Schaepman-Strub et al., 2006)) at wavelengths lambda_i = 400; 500; 600; 700; 800; and 900 nm are calculated. The output of the MPD algorithm are the spectral albedo at mentioned six wavelengths, the melt pond fraction and the estimated retrieval error for each MERIS swath data grid-cell. Daily averages are created by gridding and averaging the output of each MERIS swath on a 12.5 km NSIDC (National Snow and Ice Data Center) polar stereographic projection.

e. Is the updated MERIS sea ice albedo dataset available somewhere? The manuscript implies it, but no access method is given anywhere.

The updated MERIS data set will be published at https://seaice.uni-bremen.de/melt-ponds/. A respective comment will be given in the manuscript.

Minor comments 2, 9-26: For the legacy orbiter datasets, APP-x and GLASS are mentioned but not CMSAF CLARA. Why the omission?

We introduced CLARA-A2 SAF in Table 1 and corresponding text:

p. 2, l. 23-26:

A 34 year time series of black-sky surface albedo (SAL) as part of the second edition of the cloud, albedo, and surface radiation data set (CLARA-A2) has been derived from AVHRR measurements onboard NOAA and Metop (Meteorological Operational) satellites (Riihelä et al., 2013; Karlsson et al., 2017).

p. 31 (table):

Data set name: CLARA-A2 SAL Instrument: AVHRR Platform: NOAA, Metop Spatial resolution: 0.25° Temporal resolution: 5 days / 1 month Temporal coverage: 1982 – 2015 Waveband: 0.25 – 2.5 Retrival method: NTBC, ARC References: Riihelä et al. (2013), Karlsson et al. (2017)

9, 19-22: For clarity, please mention what the Ebert-Curry parameterization is based on (air temperature, or?)

The Ebert-Curry parameterization is based on the solar zenith angle and the spectral dependency of reflection. The latter is only considered in the ERA5 parameterization:

p.11 l. 3-4: The sea-ice albedo is simply prescribed as constants following the albedo values given in Ebert and Curry (1993) and considers the spectral variation.

11, 22: by -> up to, depends on the amount of diffuse radiation in the downwelling flux and the surface BRDF.

The mentioned sentence is improved (p. 16, l. 12):

However, clouds increase the broadband albedo of snow up to 0.06 (Key et al., 2001; . . .)

Please also note the supplement to this comment:
https://www.the-cryosphere-discuss.net/tc-2019-62/tc-2019-62-AC1-supplement.pdf

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2019-62, 2019.