

Interactive comment on “Reassessment of the common concept to derive the surface cloud radiative forcing in the Arctic: Consideration of surface albedo – cloud interactions” by Johannes Stapf et al.

Anonymous Referee #1

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Major revisions to this paper are needed prior to publication.

In this paper, cloud radiative forcing (CRF) and the surface radiation energy budget (REB) are calculated for measurements along the Arctic springtime marginal sea ice zone. The authors investigate and quantify the effects on CRF and REB of (A) using incorrect atmospheric thermodynamics (based on geographic mismatch between cloud and clear-sky measurements), (B) using the local surface albedo instead of an areal-averaged albedo, and (C) accounting for the impact of clouds on the albedo.

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This paper includes novel data and is worthy of publication. The application of (A)-(C) above may also have novel elements.

Main criticisms of this paper:

- 1) Additional referencing of the literature is needed to put the paper into context and understand what is novel in this work.
- 2) An uncertainty analysis is needed.
- 3) Some of the writing is confusing and needs to be edited for clarity.
- 4) There are gaps in the descriptions of the measurements and methods that make the work difficult to understand or reproduce.

Details follow.

Title: The title should be reworded. Perhaps something like, “Cloud radiative forcing at the Arctic springtime marginal sea ice zone derived using low-level airborne observations.”

Language (overall): The authors should go through the paper and make sure every paragraph makes a single, clear point. They should also go through each sentence and make sure that it is correct, comprehensible, and stated as simply as possible. I suggest asking a colleague to read the paper and then working with them on how to clarify anything that they do not understand. Here are just a few examples:

- Abstract lines 1 and 2: “warming or cooling effect . . . on the radiative energy budget.” Clouds do not cool the energy budget. Please restate.

- First paragraph of the introduction: This paragraph is difficult to understand, has a lot of unnecessarily detail, and only provides general motivation. I think a few sentences can explain that clouds are important for the Arctic. What is really needed prior to the second paragraph is more specific motivation for this work, including why estimates of CRF and REB are important and how they are used and calculated in the literature

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(discussed more below).

- Page 2 lines 18-22: these sentences are a distraction from the rest of the paragraph, which focuses on SZA and albedo.

- When the words heterogeneous or heterogeneity are used, the authors need to state what is varying – for heterogeneous sea ice is it type of ice? Or ice fraction? What is meant by heterogeneous albedo?

Abstract and Introduction: Is the most important result the application of the parametrization of Gardner and Sharp (2010) to measurements? If this is the case, this should be clear in the abstract and introduction. For example, the authors state in the introduction that, “Both processes have been parametrized, for example by Gardner and Sharp (2010) based on simulations, however, their impact on estimates of the CRF in the Arctic have not yet been evaluated.” They should go on to state in the following paragraph that they apply these parametrizations in this work.

Introduction: Although the paper has a long reference list, missing are examples from the literature of calculations of CRF and radiative fluxes based on observations in the Arctic. Context of the literature is also needed to show what ideas or parametrizations are novel here. For example, if Eqs (7) and (8) are novel, please make that clear in the introduction as well as in Sect. 3, as well as how they relate to calculations of CRF in the literature. The authors should explain how CRF is used in such studies, what are the shortcomings, and how their work addresses these shortcomings. Some possibilities:

Intrieri, J. M., Fairall, C. W., Shupe, M. D., Persson, P. O. G., Andreas, E. L., Guest, P. S., & Moritz, R. E. (2002). An annual cycle of Arctic surface cloud forcing at SHEBA. *Journal of Geophysical Research: Oceans*, 107(C10), SHE-13.

Dong, X., Xi, B., Crosby, K., Long, C. N., Stone, R. S., & Shupe, M. D. (2010). A 10 year climatology of Arctic cloud fraction and radiative forcing at Barrow, Alaska. *Journal of*

Geophysical Research: Atmospheres, 115(D17).

Sedlar, J., Tjernström, M., Mauritsen, T., Shupe, M. D., Brooks, I. M., Persson, P. O. G., ... & Nicolaus, M. (2011). A transitioning Arctic surface energy budget: the impacts of solar zenith angle, surface albedo and cloud radiative forcing. *Climate dynamics*, 37(7-8), 1643-1660.

Hartmann, J. , Kottmeier, C. , Wamser, C. and Augstein, E. (2013). Aircraft Measured Atmospheric Momentum, Heat and Radiation Fluxes Over Arctic Sea Ice. In *The Polar Oceans and Their Role in Shaping the Global Environment* (eds O. M. Johannessen, R. D. Muench and J. E. Overland). doi:10.1029/GM085p0443.

Cox, C. J., Walden, V. P., Rowe, P. M., & Shupe, M. D. (2015). Humidity trends imply increased sensitivity to clouds in a warming Arctic. *Nature communications*, 6, 10117.

Södergren, A.H., McDonald, A.J. & Bodeker, G.E. *Clim Dyn* (2018) An energy balance model exploration of the impacts of interactions between surface albedo, cloud cover and water vapor on polar amplification, 51: 1639. <https://doi.org/10.1007/s00382-017-3974-5>

Measurements: More information is needed about the measurements. What wavelengths are used? (Also, please use “longwave” and “shortwave” instead of “terrestrial” and “solar.” Presumably the aircraft had both up-looking and down-looking pyrgeometer and pyranometers? The text refers to the cloudy ABL, but I think data are only used where the cloud was above the aircraft? (E.g. all upwelling flux measurements were for clear skies). Please clarify this. How did you ensure that there was no cloud around or below the aircraft? Please also provide more detail about measurements of atmospheric thermodynamics, and a table showing the various measurements (with time and location) as context. Finally, Page 2, line 11 implies that this work uses all-sky minus clear-sky (other definitions of CRF use cloudy-sky minus clear sky). Were all downwelling flux measurements of cloudy sky?

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Radiative transfer simulations: Sufficient information is needed here that the results are reproducible. What was the vertical resolution? How were the measurements (dropsonde, radiosonde, and surface) merged? What was used for concentrations of other trace gases (most notably for the longwave calculations, CO₂). It would be helpful to specify which flux and albedo terms were calculated with the various models (longwave, shortwave and 2D vs. 3D). What are the uncertainties for the radiative transfer calculations?

Section 3.2: A lot of work has been done on the longwave CRF that is relevant here. For example, Cox et al 2015 (listed above) examines temperature and humidity.

Uncertainty analysis: A variety of assumptions are made in this work and the calculations and measurements all have associated errors and uncertainties. An uncertainty analysis is needed.

Technical details:

- I_f needs to be defined before the first time it is used.

Interactive comment on Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2019-534>, 2019.

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