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Discussions

Interactive comment on "Observations and simulations of three-dimensional radiative interactions between Arctic boundary layer clouds and ice floes" *by* M. Schäfer et al.

Anonymous Referee #2

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The manuscript examines 3D radiative interactions occurring in cloudy areas where the sea is partly covered by ice. The manuscript expands our knowledge of this topic in several ways, for example it shows how 3D effects change with the size of ice floes or with cloud properties such as optical thickness. The paper can be of interest to a wide range of readers because it discusses not only theoretical issues, but also the implications for satellite measurements of cloud optical thickness and droplet size. The study relies on appropriate methodology. The presentation is clear and concise, with only a few minor wording issues. Still, the manuscript would benefit from adding more depth and clarity to the discussions of results. As a result, I recommend some

significant revisions. Please find my specific comments below.

Substance:

Page 1424, Lines 20-25: I don't quite agree with this point. The fact that the Zinner et al. (2010) paper found weak 3D effects for stratocumulus clouds does not rule out strong 3D effects for many observations of Arctic stratus clouds. This is because while the Zinner et al. (2010) simulations used a 45° solar zenith angle, numerous studies pointed to much stronger 3D effects for the lower solar elevations that are quite frequent for Arctic clouds (see, for example, Loeb and Davies 1997, Loeb and Coakley 1998, Horvath et al. 2014, Grosvenor and Wood 2014).

Page 1428, Lines 1-5: I recommend adding some qualifying words here, as the results only show that retrievals are not possible using the wavelengths used in this paper. However, using other wavelengths such as 1.2 micron can enable retrievals for some water clouds over frozen surfaces (Platnick et al. 2001) even if the retrieval accuracy is lower.

Page 1435 lines 9-13, and Page 1447 lines 13-15: I recommend mentioning that having stronger 3D effects for larger optical thicknesses is similar to the behaviors discussed earlier in the context of aerosol measurements near bright clouds. For example Marshak et al. (2008) found stronger "bluing" (3D enhancement near clouds) at shorter wavelengths, where the Rayleigh optical thickness is larger.

Page 1435, lines 21-27: I recommend mentioning the additional consideration that, because of the nonlinearity of the optical thickness vs. reflectance curve, the same 5% relative change in reflectance implies a larger relative change in retrieved optical thickness for thicker clouds than for thinner clouds. In other words, it may help to determine Delta_I using a lower threshold for thick clouds than for thin clouds. For example, depending on solar elevation and other conditions, a 5% reflectance-difference threshold could be optimal for cloud optical depths around 1, but a 3.5% reflectance-difference threshold may be optimal for CODs around 5 and a 2% reflectance-difference thresh-

old may work best for CODs around 10. It may even be worth including some results based on such dynamic thresholds into the paper.

Page 1442, lines 5-6: It appears to me that in Figure 12 the spread of radiance distributions over sea and ice are much larger for Scenario 1 than for scenarios 2-4. So I suggest some correction or clarification, for example by describing what is meant by "spread".

Page 1441, lines 17-18: It is a very interesting observation that 3D effects reduce the scene average reflection, and I wonder if the authors could offer an explanation for this. For example, could 3D surface-cloud interactions involving double surface reflection explain the reduction?

Page 1454, Table 1: Either in the table or somewhere in the text it would be important to discuss the level of Monte Carlo simulation uncertainty. Most importantly, how do they compare to the deviations from 100% in Table 1?

Page 1443, lines 21-23: I suggest considering another possible explanation for the Figure 13 frequency distributions being broader in the observations than in the simulations: the possibility that clouds may have been at a higher altitude or were geometrically thicker in reality than in the simulations. In order to support or disqualify this hypothesis, it would help to mention the top height (and/or thickness) of observed clouds, for example by discussing results from the AMALi lidar mentioned in Page 1426. Alternatively, the simulations could be repeated assuming higher cloud altitudes.

Page 1445, lines 26-29: I recommend elaborating a bit more on the suggested technique, mainly to explain why a retrieval far from any sea ice would be needed for applying the correction factors in Figure 15 to pixels near clouds.

Page 1447, lines 10-12: I am not sure if I fully agree with the statement that the enhancement over water is stronger than the reduction over ice. It is true that in Table 1 the total reflectance is enhanced, so in this sense the "winning" effect is indeed the

enhancement over water. However, the table also shows that the enhancements over water have smaller magnitudes than the reductions over ice. I suspect the enhancement of total reflectance occurs only because in the simulated cases ice covers much smaller areas than water does. So in cases of higher ice coverage the overall effect might be a net reduction, not enhancement.

Wording:

Page 1424, lines 25-27: I suggest moving this sentence to the next paragraph, as it discusses the topic of that paragraph.

Page 1425, line 7: I suggest replacing "Here" by "In Section 2".

Page 1428 line 18, page 1429, lines 21 and 22: The word "both" should be replaced by "the two".

Page 1432, lines 2223: The words "in dependence" should be replaced by "as a function".

Page 1434, line 25: I suggest clarifying early which figure contains the grey lines, perhaps by mentioning Figure 7 in or around line 21.

Page 1437, line 3: I believe "geometrical" should be replaced by "optical", as Equation (4) does not include geometrical thickness, but the first sentence after the equation describes the way the equation coefficients change with optical thickness.

Page 1437, line 5: "proofs" should be replaced by "proves".

Page 1438, lines 10-15: I suggest refining the wording to make it clear that curvature affects both large and small ice floes.

Page 1438, line 24: For clarity, I suggest mentioning the pixel size here.

Page 1443, line 24-26: To prevent any confusion, I suggest clarifying that Table 1 shows results for idealized scenarios.

Page 1444, line 8: "roll" should be replaced by "role".