

## ***Interactive comment on “Metamorphism of Arctic marine snow during the melt season. Impact on albedo” by Gauthier Verin et al.***

**Anonymous Referee #1**

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General comments: This paper presents results of snow physical properties and spectral albedo measured with high frequency on sea ice in Baffin Bay of Northern Canada during two melt seasons in 2015 and 2016, and result of spectral albedo simulations using radiative transfer model. The authors discuss in detail the evolutions of snow physical and optical properties by dividing the observation period of each year into 4 phases in terms of snow stratigraphy, snow specific surface area (SSA), snow density, and spectral albedos. They also discuss causes of temporal variation of albedos in the visible (500 nm) and near infrared (1000 nm) by comparing the albedos measured with those calculated using radiative transfer model, and by sensitivity tests for effects of SSA and snow layer thickness on albedos.

My overall impression for the manuscript is that the first half part (~Section 3.3) is

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detailed but the latter half part is redundant. Although Chapter 3 is “Results”, causes of temporal variations of albedos are DISCUSSED with sensitivity tests using radiative transfer model in Section 3.4. In “4 Discussion”, similar things as described in “3 Results” are described repeatedly.

Another reason I feel redundant is that each of Sections 3.4, 4.1, 4.2 and 4.3 and Chapter 5 consists of only one paragraph although those paragraphs have a volume more or less one page. These make the findings, discussing points and conclusion of this paper ambiguous. It is needed to explain with a focus on important points and organize the text.

In Section 3.4, it is discussed on uncertainties in measurements of vertical snow physical properties as cause of disagreement in albedo between measurement and calculation in phases I and II. However, it is not discussed on the horizontal heterogeneity. This would be possible cause of the disagreement. Please discuss on this issue.

Bottom figure in Fig.11 are discussed as “total solar energy input in sea ice” in Section 3.4 (p. 11, L19) and “total energy transmitted to the sea ice system” (p. 28, Figure 11 caption). It looks to be calculated by equation,  $(1 - \text{albedo}) \times \text{irradiance}$ , where the irradiance = 784 [Wm<sup>-2</sup>] shown in p.6, L29. If so, this value of the figure is not solar energy input to sea ice, but just solar energy absorbed by media below snowpack. To discuss on the solar energy to sea ice, it should be calculated by  $(\text{snowpack's transmittance}) \times \text{irradiance}$ .

Data set of snow physical and optical properties in-situ measured during 2 seasons in the Arctic is very valuable although the manuscript contains ambiguous points and is still disorganized. To be suitable paper for The Cryosphere, the issues mentioned above should be solved.

Specific comments: p.5, L1: “weighted” is a typo for “weighed”

p.5, L6-8 “The correction concerning the determination of SSA of wet snow introduced

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by Gallet et al. (2014b) was not applied in this study because it did not induce significant changes on albedo simulations at the end.”: Please indicate amount of error in SSA by not applying this correction.

p.5, L26-27 “Unrealistic data, based on qualitative criteria, were rejected.”: Please indicate example(s) of the qualitative criteria.

p.5 L32: “upwelling” is a typo for “downwelling”

p.5 L32-33 “sun zenith angle (SZA)” : The term “solar zenith angle” is used in many other parts. It is better to unify the technical term.

p.6 L4 “Albedo spectra were finally smoothed using a low-pass filter.”: Does this mean the raw spectral albedo varies not smoothly unless a low-pass filter? Please explain the reason.

p.6 L26: This term “SBDART” is first appearance. Please show what does this abbreviation stand for and the reference.

p.7, L2: Please replace “radiation” with “downward radiation”.

p.7, L25: Please replace “the snowpack was” with “all snow layers were”.

p.9, L29: I think it is better to replace “Reflectance” with “Albedo”.

p.10, L4: “Figure 7.b)” is a typo for “Figure 7b).”

p.10, L17 “with a standard deviation (STD) of 0.09.”: The value “0.9” is shown in Table 3.

p.10, L22-25 “If it is the case, . . .”: I don’t understand this discussion on snow impurities. It is described “the impurities may have potentially lowered the albedo by 1% at maximum . . .” which is larger than the values of “reducing the reflected irradiance by 0.4% to 0.7%”. If effects caused by snow thickness variations is larger than the impurities effect (1%), the latter (impurity effect) is not negligible.

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p.10, L25: It would be better to start a new paragraph from the sentence “Occasional errors, are however found. . .”. Please confirm the cause of disagreement in albedo at 500 nm at the end of the previous paragraph.

p.11, L7 “(star and gray dot markers respectively in Figure 8b)” : I suppose the gray dots are measurements. If so, this sentence is “(star and black dot markers . . .”.

p.11. L9: It would be better to start a new paragraph from the sentence “TARTES was also used in order to illustrate how. . .”.

p.11. L11: “bar ice” is a typo for “bare ice”.

p.11. L11 “as soil albedo in TARTES.”: General readers don’t know underlying surface of snow is assured to be soil in TARTES. Please revise to more general description “as underlying surface albedo in TARTES.”

p.11, L14: It would be better to replace “Reflectance” with “Albedo”.

p.11, L18 “The variations observed at 1000 nm . . .”: This discussion is qualitative. More quantitative discussion is needed.

p.11. L19: It would be better to start a new paragraph from the sentence “Figure 11 shows the evolution of broadband albedo. . .”.

p.11. L20 “calculated using albedo simulations”: Please show the value of downward irradiance here again.

p.11. L22-23: Please replace “light conditions” with “light illumination conditions”.

p.11. L23: Please replace “section 2” with “section 2.6”.

p.11, L30: “albedo measures” is a typo for “albedos measured”.

4.1 Snowpack formation: This section describes observation results of snow physical properties qualitatively, some of which were shown in Sections 3.1 and 3.2. Dune formations continues from explanations for phases I – III in the first part, that is confusing.

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At least discussion on dunes should be made in separate paragraph.

4.2 Albedo and surface evolution: This section also describes temporal variations of observed albedos and their potential causes, that is not enough as conclusion. And, some of which were shown in Sections 3.3. Do you really need redundant sentence as, for example, “Our observations of two melt seasons near Baffin Island including numerous spectral albedo measurements and observations of detailed physical properties suggest that a new main relevant phase may be distinguishable: phase III.” (p.12, L9-11).

p.13, L12-13 “which strongly enhanced the light penetration depth especially at lower wavelengths.”: This sentence seems to be observation result of this study. However, there is no measurement data of light penetration depth in the manuscript.”

4.3 Albedo modeling, limitations and suggestions: This section is almost summary of Section 3.4.

Figure 3: Please indicate the terms “I, II III and IV” in the figure for main phases.

Figure 4, caption L3: “Additionally, main snowfalls in 2015 are specified.” Please add “in (B)” at the end of this sentence.

Figure 5, caption: Please indicate the year.

Figure 7, caption: Please indicate the year.

Figure 8, caption: - “Albedo measurements (black) and modeling (gray) at 700 nm (A) and 1000 nm (B)”: I suppose “black” and “gray” are opposite. - “700 nm” is a typo for “500nm”. - “The grey shaded area specifies the melting period.”: Please replace “melting period” with “surface melting” or “phase-II”, which is a defined name for this period in this study.

Figure 9: Isn't the value along the 1 by 1 line zero? The value near an origin is not zero.

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Figure 10: Dashed line is represented as “Simulations over pond” in the figure, but “a slush layers” in the caption. Please unify the term.

Figure 10, caption: - “SSA of 33 m<sup>2</sup>kg<sup>-1</sup>”: The value shown in the text is 3 m<sup>2</sup>kg<sup>-1</sup> (p.11, L12). Which is correct? - “bar ice” is a typo for “bare ice”. - Please replace “the data at respectively” with “the albedo measurements at respectively”

Table 3, caption: - “at 500,700 and 1000 nm” is a typo for “at 500 and 1000 nm”. - “1.3 ± 0.9”: The value “±0.09” is shown in the text. (p.10, L17).

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