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# *Interactive comment on* "A module to convert spectral to narrowband snow albedo for use in climate models: SNOWBAL v1.0" *by* Christiaan T. van Dalum et al.

**Anonymous Referee #3**

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This is a very ambitious paper that addresses a very important issue in atmospheric modelling of properly coupling atmospheric radiative transfer computation to the radiative transfer computations of a snowpack. A main issue at present is that these two forms of computations have been developed separately, and the different spectral bands are used in each type of model. The authors aim to combine the RRTM_SW atmospheric radiative transfer model, with 14 shortwave (SW) spectral bands, and the TARTES snowpack radiative transfer model, that includes more than 100 spectral bands. The method is to find representative wavelengths (RWs) from TARTES for each of the 14 spectral bands in RRTM_SW. Thereby, the use of TARTES can be made more efficient. The RWs are chosen based on multi-spectral DISORT/libRadtran simulations combined with TARTES simulations.

The paper is generally well-written and -structured.

Major issues:

The authors claim to have developed their scheme, so that the relative RMSE of this for each spectral band is less than 0.01 (or 1%) relative to the "fully spectral DISORT and TARTES calculations." This can easily be read as if the general error is less than 1%, however, that depends on the accuracy of the performed DISORT/TARTES calculations! Here the DISORT computations are run with the libRadtran script library, which is easy to use but which easily can be used incorrectly. Specifically, I have the following issues:

1a) DISORT is here run with 6 streams. Have you tested if that is enough to get the desired accuracy? If not, you should do so! Quote from Stamnes et al. (2000): "For strongly forward-peaked phase functions it is difficult to get accurate intensities with fewer than 16 streams, and even with 16 streams accuracy can be poor at some angles. Thus, careful users have been forced to use 32 or even 64 streams to be sure of getting 1% accuracy" Stamnes et al. here speak of intensities and not fluxes for which less streams are required, however, I expect that 6 streams are too little also to obtain very accurate fluxes. Tests should be done particularly for high solar zenith angles (SZAs), as these often occur in Greenland.

1b) In the DISORT simulations the surface broadband albedo is set to 0.5. In the supplementary scripts, it can be seen that this is done regardless of wavelength with the "albedo" input option in libRadtran. Here, the "albedo_file" input option should have been used, in which spectral albedos can be specified. In order to make the atmospheric and snowpack radiative transfer computations consistent, the TARTES spectral albedos should be used in this albedo file. As shown by for instance Nielsen et al. (GMD, 2014), the downward fluxes at the surface are not independent of the albedo. Given the complex variations of spectral irradiances and albedos shown in Fig. 1, it seems important to run DISORT with the TARTES albedos. Fig. 1 is a very illustrative figure by the way! An even better representation of the surface reflectance could be obtained by running coupled DISORT simulations for both the snowpack and the atmosphere. This can be done by adding the spectral inherent optical properties of the layers of the snowpack as the lowest model layers in DISORT. In this way the full BRDF of the snow surface will be properly represented and coupled with the atmospheric simulations, which cannot be done with the two-stream TARTES simulations.

1c) The "subartic winter" atmospheric profile is used. The reference describing the details of this is missing and should be added. I assume that this is one of the AFGL standard atmospheres of Anderson et al. (1986). Additionally, the "rural aerosols" of Shettle (1990) are used. How representative are these profiles for Greenland? Could typical atmospheric profile data from the CAMS reanalysis be used in stead? The clear sky spectrum can change quite a lot depending on the gasses and aerosols assumed to be present. You should mention this uncertainty in the method chosen.

1d) When inputting liquid and ice clouds to DISORT you assume these to have effective/equivalent radii of 10 $\mu$m and 20 $\mu$m, respectively. Here the former number is reasonable, but 20 $\mu$m is a very low number for typical ice clouds, where I would suggest using 50 $\mu$m in stead. Also, you make these look-up table values a function of the cloud optical thickness rather than the cloud liquid water path (LWP) and ice water path (IWP). Since the cloud optical thickness is proportional to LWP+IWP and approximately inversely proportional to the effective/equivalent radii, similar relative changes in these cloud properties cause similar changes to the cloud optical thickness.

1e) In the DISORT experiments a range of cloud ice water path of up to 5 kg/m$^2$ is simulated. This is at least 10x more than a realistic maximum value for clouds over Greenland. Cloud liquid water paths of up 40 kg/m$^2$ are also simulated. This is also an order of magnitude higher that cloud water paths that can occur even in the tropics. I suggest that the simulations are done for more realistic ranges. Also, the results shown in Fig. 7 are run for a LWP of 0.5 kg/m$^2$. Is that a typical LWP for clouds over

Greenland? Please update your experiments to more typical values.

1f) In the supplementary scripts it can be seen that the rte_solver disort is used in the libRadtran/DISORT experiments. Here, the rte_solver sdisort (Dahlback & Stamnes 1991) should be used in stead. The regular disort/disort2 solver is designed for a plane-parallel geometry, where the atmosphere curves. sdisort is a pseudo-spherical disort solver, which accounts for the atmospheric curvature. In particular for high SZAs using disort will cause errors. This is also likely to explain the discrepancies seen for high SZAs in Fig. 11.

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2) Page 21, lines 14-15: "However, this version of the IFS code embedded in RACMO2 does not explicitly model any cloud content properties nor includes a parameterization of the optical depth." That is incorrect! Since you have not included the RACMO2 source code in your supplementary material, I cannot tell what "the IFS code embedded in RACMO2" entails, but I am very familiar with the IFS radiation scheme and SRTM as used in cy33r1. In this the cloud optical thickness is parameterized. In fact it is computed for each spectral band in each 3D model grid box.

3) Page 9, line 10: "The broadband albedo, which is for direct radiation close to 0.78 for most SZAs..." The broadband albedo of snow can be quite different from 0.78 depending on atmospheric and snow conditions. Please correct this line to reflect this!

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Minor comments:

- Abstract, line 5: "... Integrated Forecast System atmospheric..." –> "... Integrated Forecast System (IFS) atmospheric..." Also, add the version number 33r1!

- Abstract, line 10: "... 14 spectral bands of the ECMWF shortwave..." –> "... 14 spectral bands of the IFS shortwave..."





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- Page 1, lines 22-23: "... the melt-albedo feedback, e.g. Dumont et al. (2014)." –> "... the melt-albedo feedback (e.g. Dumont et al., 2014)."

- Page 2, line 4: "... solar angle" –> "... solar zenith angle"

- Page 2: You need to add spectral band definitions of what you mean, when you refer to "near-UV" and "near-IR".

- Page 2, lines 13-14: "... the ratio of upwards to downwards shortwave radiative flux integrated over the solar spectrum." –> "... the ratio of upwards to downwards shortwave radiative flux on a horizontal surface integrated over the solar spectrum." Here you should also add explanations of the direct ("black sky") albedo, which varies as a function of the SZA, and the diffuse ("white sky") albedo. Both of these are used as input variables to SRTM in the IFS radiation scheme.

- Page 2, lines 19-20: "For example, a buried dark impurity layer will only significantly affect near-UV albedo." This I disagree with. Water has minimal absorption at the UV/violet spectral boundary, and the absorption is also very low in the UV, blue and green parts of the spectrum. Thus, these parts are also significantly affected by underlying impurities.

- Page 2, line 21: "... the thermal regime" –> "... the snow heating rates"

- Page 2, line 30: The RRTM_SW (also known as SRTM in the IFS code) references are placed after "RACMO2" in this line. They should be moved back to where RRTM_SW is referred to!

- Page 4, lines 1-2: "RRTM_SW computes flux profiles for clear-sky and total-sky conditions on hourly intervals." –> "RRTM_SW computes instantaneous flux profiles for clear-sky and total-sky conditions."

- Page 4, lines 14-15: "... specific surface area (SSA)..." This is the same acronym that is used for single-scattering albedo, an essential radiative transfer variable, which can be confusing. You should consider using something else.

- Page 5: lines 31-32: "The effective droplet radius for ice and water clouds ..., which is a realistic radius for clouds" –> "The effective droplet radius for ice and water clouds ..., which are realistic radii for clouds"

- Page 10, lines 20-21: See my comment 1b above.

- Figure 12: This is a very nice figure, however, it is very difficult to distinguish cloud covers of 0 and 1. Please expand this part of the figure, so that these data are not hidden by the graph axes!

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