Responses to Mark Flanner, reviewer RC2

This manuscript provides a comprehensive technical description of the TARTES v2.0 radiative transfer model for snowpack. TARTES is widely used by the community and is embedded in the CROCUS snow thermodynamic model. A unique and valuable feature of TARTES is the representation of ice particle asphericity via two parameters that can vary continuously and are not tied to any particular shapes, thus enabling the representation of the "optical shape" of snow via a continuum. The manuscript is well-written and appropriately includes both technical descriptions and comparisons against other snowpack radiative transfer models. The introduction is well-referenced and provides useful background to the topic. I have only minor comments and am happy to recommend publication of the manuscript in GMD.

We thank Mark Flanner for this main comment and the following comments, all of which we have thoroughly considered.

Minor comments:

line 30: "understand" -> "understanding"

done

lines 34-36: "SSA ... advantageously replaces the grain size as it can be rigorously defined and calculated for any porous medium" - While I agree about the advantages of SSA, "calculating" the surface area of complex shapes and porous media is often non-trivial. To me, the main advantage of SSA is simply that it is a well-defined physical quantity, whereas the meaning of effective radius can be unclear for complex shapes and porous media.

Our intent in this sentence was to stress that SSA can be defined (and calculated) even when the medium is not made of grain (and so grain size is not well defined). We propose to amend the sentence by adding “even when distinct grains are not apparent”.

line 107: "an" -> "a"

done

line 123: The latter part of the sentence also refers to diffuse illumination, so perhaps change the first party to "... illuminated by a beam source and diffuse light…"

done

line 163: "into" -> "in"

done

line 244: The appearance and application of these exponential terms is not immediately clear to me. Could you please clarify or elaborate on this point?

The reviewer RC1 made a similar comment, and we decided to remove this sentence as the equations are self-sufficient.

line 373: "When impurities are added in realistic low quantities, we assume the extinction coefficient of snow is unchanged..." - Although this is certainly a valid approximation for most realistic impurity mixing ratios, there may be situations where high impurity loads appreciably affect the total extinction coefficient, particularly in the near-IR spectrum. For example, very high dust loads can flatten out the 1.03um ice absorption feature (e.g., Fair et al, 2022, https://tc.copernicus.org/articles/16/3801/2022/) . Hence, it might be useful to provide a rough upper limit to the "low quantity" that applies for this assumption to hold, or in general to define the limits of applicability for model users.

It is difficult to provide rigorous limits without proper Mie-based numerical calculations, which TARTES does not do. Based on the reference suggested by the reviewer, showing results of such numerical calculations, we propose the following amendment:

“This supposes that impurity scattering is negligible. According to simulations at 1030\,\unit{nm} \citep{fair_2022}, this applies to BC in any case, as well as to dust except for fine particles (<1\unit{mum}) in high concentration (e.g. >500\,\unit{ppm}). When this approximation is valid, it follows that the single scattering co-albedo is:”

line 466: Briefly, what are the user-controlled inputs to this "atmospheric_incident_spectrum" function?

There are two parameters:

“The function takes the solar zenith angle and cloud optical depth as input and uses the default cloud properties of SBDART \citep{ricchiazzi_1998}.

line 492: The accuracy of the delta-Eddington technique in handling diffuse incident light was also assessed more recently by Dang et al (2019, https://doi.org/10.5194/tc-13-2325-2019)

We propose to add the reference:

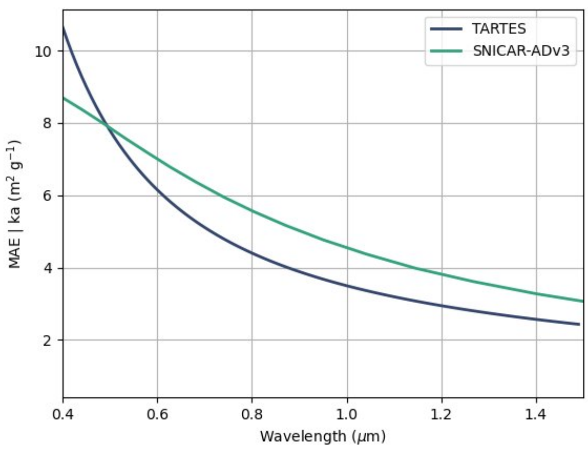
“\cite{wiscombe_1977} has shown that in the case of diffuse radiation the performances of the δ-Eddington approximation were limited, sometimes leading to negative values of albedo. This is why \cite{warren_1980, **dang_2019**} computed the diffuse albedo as an angular average of direct albedos.”

line 576: "benefice" -> "benefit"

done

p.29 and Fig. 11: The comparison provided is useful because it shows how the default representations of BC in each model affect the simulated albedo. Because the BC optical properties are slightly different in each model, one could further explore the sources of differences between TARTES and SNICAR by imposing identical BC properties. This could be accomplished, e.g., by directly importing the BC MAE values from the SNICAR optics library into TARTES, similar to how dust MAE is used in TARTES. I am not requesting this for manuscript revisions, but merely highlighting it as an informative sensitivity study for the future.

The MAE obtained with TARTES assumption (monodispersed, Rayleigh approximation) is close to SNICAR MAE reported in Fig 3a in Flanner et al. 2021 (see Figure below). The refractive index is exactly the same in both, so that the only difference is coming from the fact that SNICAR considers a distribution of size with Mie calculation, which leads to a slightly lower MAE in the short wavelength range (<500 nm), and higher in the longer range. This corresponds to the difference shown in our albedo comparison.



We propose the following addition in the text:

“Comparing MAE predicted by TARTES and reported for SNICAR-ADv3 in figure 3a in \citet{flanner_2021}, we observe (not shown) a slightly higher MAE with TARTES at 400\,\unit{nm} (+20\%), an agreement at 490\,\unit{nm}, and a slightly lower MAE at 1000\,\unit{nm} (-23\%), which explains the lower TARTES albedo at wavelengths <500\,\unit{nm} and higher at longer wavelengths observed in Fig. ~\ref{fig_model_comparison_soot}.”

line 605: "67um": Typo, should be "67nm"

done

line 605: 67nm appears to be close to the monodisperse radius of maximum MAE. Because the SNICAR BC properties are mass-weighted from a lognormal distribution, the MAE value at the effective radius corresponding to the maximum MAE for a monodisperse distribution (i.e., the trough in Fig. 12) will always be less than the monodisperse MAE at that radius, since the weighted average incorporates lower MAE values from both sides of that radius. This could explain the phenomenon described in this part of the text. But other model factors could also contribute to differences in the absolute simulated albedos shown in Fig 12. For example, are identical ice refractive indices used in each model simulation?

We indeed use the same ice refractive index database for TARTES, SNICAR and DISORT. Only TARTES.F has its own database and was not updated for this work but it is not used here for the comparison with impurities.

We propose to add a more explicit statement about the use of the ice refractive index at the beginning of the section 4.3 on the comparison between models.

“The conditions of simulations are as similar as possible among the model. For instance the same ice refractive index \citep{picard_2016c} is used for the three models. TARTES.F is also included in this comparison, but with a different ice refractive index \citep{warren_2008} as discussed below.”

We also propose to add an explanation why SNICAR gives a larger albedo than DISORT-Mie: “This results from the fact that SNICAR simulations with BC mean radius of 67 μm includes actual impurities with radii smaller and larger than 67 μm (it assumes a lognormal size distribution) for which the absorption is larger than at 67 μm, as 67 μm appears to be very close to the minimum absorption.”

line 624: "This rates" -> "This rate"

done

line 638: "model as TARTES" -> "model such as TARTES"

done

line 654: For which wavelength or wavelength range does g=0.82 apply?

This applies to g0 at n=1.3 and any non absorbed wavelength (the input parameter of TARTES). In the discussion we decided not to distinguish g and g0 for simplicity.

line 655: "These values are the defaults in TARTES v2.0" - Actually, it might be helpful to include a table of all of the default parameter settings in TARTES v2.0, but I leave this to the authors to decide.

We added a table with the symbols in the revised paper, including the default values.

Finally, I agree with a comment from the other referee that it would be useful to highlight differences and improvements between versions 2.0 and 1.0 of TARTES.

We now detail the main differences between versions 1.0 and 2.0 of TARTES in section 3.1.