Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., referee comment RC2
https://doi.org/10.5194/gmd-2020-442-RC2, 2021

Comment on gmd-2020-442

Christiaan van Dalum (Referee)

Referee comment on "A versatile method for computing optimized snow albedo from spectrally fixed radiative variables: VALHALLA v1.0" by Florent Veillon et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-442-RC2, 2021

This study presents a new and numerically fast way to determine the snow albedo for use in climate models. The spectral albedo model TARTES together with SBDART are used to determine the energy absorbed for various snowpacks. By using kernel functions, the absorbed energy can be interpolated between tie points, which allows the absorbed energy to be calculated for a wide range of wavelengths. The authors also investigate the impact of various processes and find that the optical depth and LAP content are the most important variables.

The algorithm that the authors present is a clever way to determine the absorption of energy in snow and is also within the scope of this journal. However, I had to read the manuscript several times to properly understand the method and there are still several parts not entirely clear to me. Although VALHALLA is potentially a useful model for the community, the manuscript does not provide an adequate description on how to implement it, hindering the actual implementation in climate models that may be done by others. Consequently, I think that some parts of the manuscript should be reformulated and/or expanded on. The following comments should help with solving most issues, with, for example, P1 L1 meaning page 1, line 1.

General comments

- The most pressing concern is that the method section is hard to follow and misses some information in my opinion. As this is a vital part of the manuscript, it is hard to interpret the results if the methods are not clearly defined. For example, it took a while before I realized that VALHALLA models absorption and not albedo. I especially miss a part about how the implementation would look like in a climate model. I would suggest to rewrite or restructure most of the method section to take away the confusion. The authors may use the following structure, breaking Sect. 2 in 3 parts:
  2.1) Existing models

2.1.1) TARTES, 2.1.2) SBDART
2.2) VALHALLA description
2.2.1) Theoretical considerations (currently 2.3). Inlcuding a) a discussion why a tie-point method is a clever way to go. b) Explain why the authors choose to model the absorption curve and not the spectral albedo curve.
2.2.2) Interpolation method (currently 2.4). Furthermore, some steps, choices and variables in Sect 2.3 and 2.4 are poorly explained and could be expanded upon. More details can be found in the specific comments.
2.2.4) Reference situation selection (current 2.5.2 – 2.5.4)
2.3) Implementation considerations. It is unclear how VALHALLA can be embedded in a climate model. VALHALLA has a list of insolation situations and a list of snow states, but how do you connect the VALHALLA snow states to the actual snow state in a model? Concerning the incoming radiation, one could simply feed broadband downwelling radiation to VALHALLA, but that is ignoring the spectral radiation available from radiation modules within atmospheric modules? Why should you do that? Furthermore, what input parameters are required, which parameters are then calculated using what equations, are there lookup tables involved, what input parameters are required, what do you do for cases with a SZA larger than 80 degrees, etc. This would be in my opinion a vital subsection and should take away the confusion.

- The comparison with Van Dalum et al. (2019), mentioned in the introduction and discussion, is inadequate. The authors have to realize that SNOWBAL and VALHALLA fulfil a different niche. SNOWBAL is a coupling scheme, which is built to couple a spectral albedo model like TARTES with a narrowband radiation scheme as is available in RACMO2. This does not only allow for the physics of TARTES to be directly implemented in a climate model, but also allows for an absorption profile on every timestep for each (sub)surface snow layer and for each narrowband, hence allowing internal heating. VALHALLA, on the other hand, as far as I could tell, does not directly couple TARTES, but is an albedo parameterization, as it approximates the total amount of energy absorbed in the snowpack. It reduces the computational time and applies the physics of TARTES indirectly into a climate model, but loses the information of internal absorption of energy. Hence, it is comparing apples with oranges.
  Comparing the number of *tps* used with the number of RWs is also not a valid comparison, as RWs are not used to determine a kernel function. Also, the number of RWs that are used in SNOWBAL are determined by the number of narrowbands available in the climate model to couple. The uncertainty of SNOWBAL would lower if more narrowbands are available, as the sub-band variability is then reduced. At the contrary, the computational costs of SNOWBAL-TARTES would increase, while it remains the same for VALHALLA. In conclusion, I would suggest to revise or (partly) remove the comparison with SNOWBAL.
- In my opinion, the manuscript would benefit if some analysis is done by comparing VALHALLA with existing albedo parameterizations (like the parameterization of Gardner & Sharp (2010)). It would allow the authors to illustrate the importance of VALHALLA with respect to previous work and validate its necessity. This could also be used to further highlight what processes are now captured properly and could answer some questions. For example, how well does VALHALLA perform on real cases, or alternatively, on snow layers as produced by climate models. Such models typically have many thin but distinctive layers, so how well does it perform then? How would VALHALLA treat ice lenses close to the surface? Adding a short comparison would improve the manuscript.
- Can the authors say something about or show why they do not deem it necessary to make a distinction between liquid and ice water clouds and why they keep the water vapour content constant?
- The authors state that VALHALLA could also be used to determine narrowband albedos. However, I am not convinced yet. How well does the method do for small narrowbands, in which, for example, only one or two *tps* are located? Can the authors say more about applying VALHALLA to a narrowband scheme?

- Some parts of the manuscript would benefit from more interpretation. See specific comments for more details.

I also have some specific comments that I would like to see addressed.

Specific comments

P1 L16: Please add a reference to this statement.

P1 L17: Shortly define the albedo here.

P2 L35-37: "This is usually … and ice surfaces." Climate models are also often limited to narrowbands, so spectral fluxes are not available and consequently the albedo has to be determined for narrowbands or broadband.

P2 L38: This might be a bit confusing, as the narrowband albedo is usually defined as the albedo of a spectral band, not over several spectral bands.

P2 L47: Van Dalum et al. 2019 calculate RWs for the first 12 of the 14 bands of RRTMsw.

P2 L48: It is also important to note that with using the RWs computed with SNOWBAL, Van Dalum et al. 2019 actually couple TARTES with RACMO2. This does not only allow for the calculation of a narrowband albedo, but also provides the absorption of solar radiation in every modeled snow layer for each narrowband.

P2 L53-L56: Although SNOWBAL has been used for RACMO2, it is not true that it is not applicable for other models. RWs can be determined for models with a different set of narrowbands just as easily, as long as the SZA, cloud content and water vapour content are available.

P3 L69-73: For me it is not clear why Crocus is introduced here. It is not mentioned in the introduction and as far as I could tell also not used in the remainder of the manuscript. So it might be better to remove this part.

P3 L79: Please be aware that SSA is usually the abbreviation of specific surface area. Also add a space between m^2 and kg^{-1} and also apply this to all other units in the manuscript.

Eq 1: 'SSA' and 'ice' should not be in italics.

All Equations: As an equation is part of a sentence, punctuation is often required at the end of the equation.

P3. L83-84: Please introduce grain shape and 'g' and 'B' a bit more.

P4, Sect 2.2: SBDART should be described in more detail in my opinion. Also, why did you use specifically this version of DISORT?

P4 Sect 2.3: A few introductory sentences are necessary in my opinion to illustrate that you will introduce the physical concepts of VALHALLA.

P4 L97: The use of the letter 'r' for the spectral albedo is unconventional and may cause confusion, as it is often used for grain radius.

P4 L97: "… or an homogeneous, …" --> "… or a homogeneous, …"

P4 L101-104: On L104 you define Lambda-tilde as λ/λ0. This should be moved to L101. Also, where do you use the absorption coefficient of Eq. 3 and explain the Angstrom coefficient. Furthermore, what does 'pol' in Eq. 3 mean, pollution?

P4 L101: Can you describe the parameter 'I' in more detail? It is a bit vague, as it apparently represents both the size and shape of a grain.

P4 L104 and elsewhere: Units should not be in italics.

P4 L105: “… can be approximate as” --> “… can be approximated as”

Eq 4: Why can Eq 2 be approximated as Eq 4? Please explain.

P4 L107: Please use one symbol for the imaginary part of the ice refractive index, as a different symbol is used at L100.

P4 L107 and Eq 4: Is the parameter 'J' a tuning parameter of some sort? Please explain in more detail.

P4 L109: “The fraction of absorbed energy in the snowpack …” --> “The fraction of absorbed energy with respect to the incoming energy…”, or something similar.

P4 L112: “… through a given media…” --> “… through a given medium” .

Eq. 7: Similar to Eq 4, what did you assume to rewrite Eq. 6 to Eq. 7? Also similar to the parameter ‘J’ of Eq 4, what is parameter 'D’ here?

P5 L125 – 126: “(varying between 10 and 80)”, missing units.

P5 L129: What do you mean with ‘experience’ irradiance?

Eq. 9: It is not clear over what you are integrating, I suppose wavelength? If so, add ‘dy’. Also, why do you want to calculate ‘C’, what does it represent? Furthermore, what is ‘i’, please specify.

Eq 13: I think there is an error in this equation. The ‘G’ term should be in the denominator. I quickly checked the VALHALLA code and it seems that it is correct there, but please verify this.

P6 L147: This is a strange sentence, please rewrite and also explain in more detail what happens in Eq. 14. Do you do this optimization for all cases? Please also define the Delta term.

Sect. 2.5.1: It might be beneficial if this is told earlier, i.e. in Sect. 2.4.

P6 L150-151: “30 tps is selected” à “30 tps are selected”.

Fig 1: Can you explain why there is no tp at the major minima of the spectrum, like around 1200 and 1400 nm? Furthermore, the units should not be in italics.

Sec. 2.5.2 and 2.5.3: These sections should be merged. Could you also specify for cloudy conditions if you use a liquid water or ice cloud and what its droplet radius is.

P7 L161-163: “These parameters … on model outputs”. I do not fully understand this.

Table 2: “one fore full-overcast” à “one for full-overcast”. I also suppose that the Mid-latitude winter atmospheric profile is one of the AFGL standards, please specify.

Table 3: Not all units are correct in this table and the last sentence of the header should be reformulated.

Sect. 2.5.4: This section is hard to follow and some information is missing; it would be beneficial if it is rewritten. Furthermore, can you say why you consider these impurity concentrations? They seem very high to me. Similarly, the SSA of 155 m^2 kg^{-1} for fresh snow looks very high.

Also, what grain shape did you assume (so what g and B in TARTES) and which refractive index data set did you use (e.g., Warren and Brandt (2008))? Please elaborate on this.

Fig 2: The wrong section numbers are shown here: “… in Section 5.c) and 5.d) using …”

P8 L185-186. “Overall, the median error on the broadband absorbed energy calculated for all simulations decreases with increasing SZA”. Can you explain why?

P11 L203: There is a redundant dot here: “Figure 3a,b. show the…”

Fig 3: Not all units are correct and change “for all the simulations described 2.5.3 and 2.5.4 …” into “for all the simulations described in Sect. 2.5.3 and 2.5.4…”. Please define ‘BB error’.

P11 L207: “More than 75% of the errors are positive”. Please add one time what you mean with ‘positive’ or ‘negative’ errors, to take away any possible confusion, i.e., that VALHALLA overestimates the absorption of energy for a positive error.

P11 L217: ‘”the majority of the errors are positive and…”, I think ‘positive’ should be ‘negative’ here.

P14 L250: What do you mean with “the most important errors”?

P14 L258: Typo

Fig 6: Can you be a bit more specific about what you mean with ‘Method’ in the right panel? Can you also state the meaning of the boxes, whiskers etc. or refer to a previous figure where you explained it.

Sect. 3.5: This part is hard to follow. For example, what do you mean with “the broadband albedo is calculated between 320 and 4000 nm and then between 327 and 4000 nm”? Furthermore, can you interpret Fig. 6 a bit more. For example, why does a higher resolution generally result in a negative bias? Why is the bias at a 72 nm resolution so much more negative than the bias of a bit lower and higher resolution? Please rewrite this section.

P16 L278-L280: “The irradiance provided by the method must, therefore, be as close as possible to the irradiance of the exact calculation to obtain a good representation of the absorbed energy.”. What does this mean if you apply your method into a climate model, as the irradiance is often not as close to the exact calculation in such model.

P17 L288-290: It is maybe also good to mention that although the absolute error decreases with SZA, the relative error generally increases for high SZA, as can be seen in Figures 3-5. Furthermore, for very high SZA (>85 degrees), what do you use then?

P17 L308-310: “The method presented … in van Dalum et al. (2019)”. SNOWBAL is not only adapted to RACMO2, but can be applied to any narrowband climate model. Furthermore, SNOWBAL is also based on spectral albedo calculations. For P17 L305-314:

As is stated in the general comments, comparing SNOWBAL and VALHALLA is like comparing apples with oranges in my opinion.

P18 L329-330: “For the other … profile is inadequate.” This sentence is confusing, please reformulate.