

Geosci. Model Dev. Discuss., referee comment RC2  
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## Referee report on gmd-2022-67

Anonymous Referee #2

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Referee comment on "Improving snow albedo modeling in the E3SM land model (version 2.0) and assessing its impacts on snow and surface fluxes over the Tibetan Plateau" by Dalei Hao et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2022-67-RC2>, 2022

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This study presents an overview of the impact of several grain shapes, the mixing state of light absorbing impurities and sub-grid topographic effects on the surface energy and water cycles in the Tibetan Plateau using ELM. The authors illustrate that non-spherical shapes and sub-grid topographic effects impact the surface energy and water balance considerably during spring, while the impact of the mixing state of light absorbing impurities is smaller. The manuscript is well written and the topic is relevant. The impact of the mixing state of light absorbing impurities and topographic effects, and to a lesser degree also grain shape, is often overlooked in ESMs and climate models. This manuscript thus provides a necessary overview of the importance of these processes for such models.

The following comments should help with solving the remaining issues, with, for example, P1 L1 meaning page 1, line 1.

### General comments

- The comparison with satellite observations is limited to the control run only and could be expanded to some of the other experiments as well. It would be especially interesting to see how well ELM performs for the 'combined effect' experiment. Also, if the authors could make a figure showing the difference between model and observations could help visualizing the results.
- It is not clear to me what grain size is chosen in this study and why. Furthermore, it is also good to notice that a homogeneous snow grain size that does not vary in time, as is employed in ELM if I am not mistaken, could have a significant impact on the results. Wet and dry snow metamorphism, refreezing and the presence of slush or ice can all impact the grain size and albedo. This may explain for a large part the differences observed with remote sensing observations. Similarly, it is not clear to me what

concentrations of LAPs are chosen.

- This study investigates several grain shapes. It is not clear to me, however, why these grain shapes are chosen in particular. Are these grain shapes often occurring on the Tibetan Plateau? If the authors could show that these shapes are relevant, it would strengthen the results of this study. Also, what grain shape will you assume in the final ELM version?
- In the manuscript, the authors show that the impact of TOP on the results is quite large and larger than the impact of the mixing state. This is in my opinion an important result of this work and should get more attention. It should get mentioned in the abstract and the conclusions as one of the main results. The impact of the mixing state of LAPs should not be overexaggerated in the abstract and conclusions as well.

### **Specific comments**

P1 L18: "The mixing state of LAPs in snow also has large impacts...". In the manuscript you show that the impact of the mixing state is considerably smaller than compared to grain shape and TOP. So please rephrase.

P1 L27: Please format units like  $W/m^2$  with negative exponents, i.e.,  $W m^{-2}$ , throughout the manuscript.

P3 L42: Please provide the definition of albedo here as well.

P3 L44: 'Sky conditions' is unclear

P3 L67: Define the asymmetry factor.

P3 L69: Define the single-scattering albedo.

P4 L75: In my opinion, more should be said about the physical processes that make the albedo drop because of dry and wet deposition. So why is there a difference between the impact of dry deposition and wet deposition. Also, do you expect dry or wet deposition to be most relevant for the Tibetan Plateau?

P4 L102: haven't --> have not

P6 L140-141: " 1) SZA dependence of surface irradiance". This is a bit confusing, it suggests that you have implemented a new routine for SZA dependency, but if I understand it correctly, it is part of the SNICAR-AD model. Please clarify.

P6 L144: There are six types of atmospheric profiles now included, but are clouds considered as well or is it only for clear-sky conditions? As clouds alter the spectral distribution of irradiance and limit direct radiation, it often has quite a large impact on the broadband albedo.

P6 L147: Assuming that you will introduce the single-scattering albedo and asymmetry factor earlier, please also define the extinction cross section.

P6 L160: Why do you choose to investigate these three non-spherical grain shapes?

P7 L171: "... and  $R_s$  is the specific-projected-area-equivalent radius." This has already been said and can be removed here.

P7 L181: "...where  $\omega_{\text{dust}}$  and  $\omega_p$  are single-scattering albedo of pure snow and dirty snow...". I suppose it is vice versa? i.e.,  $\omega_p$  is for pure snow?

P9 L228: A dot is missing after the citation.

Table 1: What impurity concentration do you assume?

P10 L237:  $\mu\text{m}$  -->  $\mu\text{m}$

P10 L44: Why do you choose this simulation to be the control simulation? Is this the most realistic one? Please explain.

P10 L257-260: Could you elaborate a bit more on ANOVA? Also, what do you mean with 'maximum absolute relative difference' and 'mean absolute relative difference'?

Fig. 2: For areas in the east, it is hard to see if there is a low snow cover or no snow at all. This can be solved by providing a separate color for no snow cover. Furthermore, The

figure might be easier to read if discrete colors are used.

Fig 3 and all other boxplots. Please also state that what is on the x axis; i.e., that fsno and SAR as a function of elevation are shown.

Fig. 4: Same as Fig 2. Also, 'Same as Figure 3' is written, while it is the same as Fig. 2

P11 L277: "... although their spatial patterns are similar." This is somewhat hard to see in the figures. A figure with the difference between ELM and the observations could help with that.

P12 L290: "The difference may be due to the overestimation of snow grain size...". Can you explain a bit more why this may be the case? As grain size has a strong impact on the albedo, modelling this incorrectly could lead to large differences with observations, potentially overshadowing any grain shape or mixing state effects. It seems to me like it may have a large impact on the results here and should be mentioned.

P14 L316: "Western regions show larger RFs induced by all LAPs than the eastern regions". Looking at Fig. 2 there is almost no snow cover in the east, so logically barely any RF changes are visible there.

P14 L324: I assume you mean Table 3, not Table 1?

P14 L328: "... which is identical to" --> which is similar to.

P15 L341: Are all shown changes in Fig. 6 significant? If not, please also illustrate significance on the maps.

Caption of Fig. S4 and S5: I suppose you mean  $a_{sno}$  instead of  $A_{sno}$ ?

Fig. 7: A bit confusing that the color scale is now inverted compared to Fig. 6. To help solve this confusion, please explicitly state in the manuscript that the differences are now negative.

P19 L389: "... has larger effects on  $F_{lat}$  than  $F_{sen}$ ". Why?

P19 L391 - 392: "The differences in ... than those for Koch snowflake shape". Can you explain why?. Similarly on P19 L395 - 396, please explain why you would expect a sign change.

P21 L417 - 418: One of the figure references can be omitted.

P23 L455 - 456: "... to the reported values in the existing study". What do you mean? It is not clear to me what the authors want to say here.

P23 L459 - P24 L466: "However, different studies ... or annual scales". I am not sure if I understand what you want to say with this part.

P24 L470: "Mixing state of LAP-snow also has large impacts on SAR". Looking at the results of this manuscript, it looks like the impact is considerably smaller than the impact of grain shape and TOP. Please rephrase.