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Geoscientific Model Development Discussions
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Interactive comment on "Representation of vegetation effects on the snow-covered albedo in the Noah land surface model with multiple physics options" *by* S. Park and S. K. Park

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General comments: Park and Park discuss simulations of albedo for vegetation with snow cover in the Noah-MP model. I have speculated (Essery 2013) that some current models use unrealistic parameter values in their representations of masking of snow albedo by forests, so I am interested to see a specific demonstration of this problem. However, I think that the manuscript requires some clarifications. The English is good for non-native writers, but will need editing for correct usage.

⇒ *The authors appreciate the positive comments by the referee. We agree with the referee's speculation that some current models use unrealistic parameter values*

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in representing the forest-masking effect of the snow albedo. We have included Essery (2013) in the References and cited appropriately in the text, along with other references suggested by the referee. Some parts of the manuscript are explained more clearly following the referee's suggestions. The revised manuscript went through a language editing check. In the following, we made an item-by-item response to the specific comments by the referee. We believe that the referee's comments helped us improve the quality of the manuscript.

Specific comments and technical corrections:

It needs to be pointed out that the minimum leaf and stem area indices quoted are only used by the dynamic vegetation option in Noah-MP. Otherwise, monthly indices are read from tables which could contain more realistic values.

⇒ *We agree with the referee and have added a sentence to page 3200, line 19: "··· Yang et al. (2011).* ***The dynamic vegetation option is employed to assess the minimum leaf and stem area indices.*** *For this study, ···"*

Page 3198, line 5: "Snow albedo of forest is typically lower than that of short vegetation" – that, indeed, can be the case due to litter in snow beneath trees (Hardy et al. 2000), but what is meant here is that the albedo of forests with snow cover is typically lower than that of short vegetation with snow cover.

⇒ *We have rewritten this part as "****Albedo of forests with snow cover is typically lower than that of short vegetation with snow cover.****"*

Page 3200, line 23: The CLASS albedo option in Noah-MP may compute an overall snow albedo, but CLASS itself computes albedos for direct and diffuse radiation in visible and nearinfrared bands (Verseghy et al. 1993).

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⇒ *We have rewritten this part as "**In terms of the albedo options in the Noah-MP, the CLASS simply computes** · · · **and snow age while the BATS calculates** . . ."*

Page 3202, line 24: Why not show Noah-MP snow-covered albedos in Fig. 2? The difference between these and observations is the main point being made.

⇒ *It is impossible to compare directly the observations with the model results because the snow cover fraction is not verified. Thus, we have just confirmed the difference of albedo over short vegetations and over forests with the same snow depth in the Noah-MP, as shown in Table 1 below. Albedo over all vegetation types are overestimated and the differences of albedo over all types are comparable.*

Page 3203: A brief discussion of how Noah-MP predicts leaf and stem indices would be useful. A large seasonal cycle in forest stem area does not seem like an intended behaviour.

⇒ *Figure 1 below shows a monthly averaged LAI during the past 10 years (2001-2010) for deciduous broadleaf forest (Fig. 1a), deciduous needleleaf forest (Fig. 1b), and evergreen needleleaf forest and mixed forest (Fig. 1c). Red lines represent minimum, mean and maximum LAI of the reference values from Asner et al. (2003) for each vegetation type. In Fig. 1c, there are the reference LAI values for only evergreen needleleaf forest. In the original Noah-MP, forest stem area index (SAI) has a seasonal cycle, but quantity is small (see Fig. 2 below). We have assumed that trees matured and focused on winter albedo, thus new stem index (SI) only have the value when the growing season is over and SI does not have seasonal cycle.*

Page 3205, line 7: How were the four radiation components weighted to calculate the total albedo in Figure 3?

⇒ *First, the downward solar radiation (SWDOWN; W/m^2) is divided into four parts, direct visible (SOLAD(1)) and diffuse visible (SOLAI(1)) radiation and direct near-infrared (SOLAD(2)) and diffuse near-infrared (SOLAI(2)) radiation, through equations below:*

*SOLAD(1) = SWDOWN*0.7*0.5 ! direct vis*
*SOLAD(2) = SWDOWN*0.7*0.5 ! direct nir*
*SOLAI(1) = SWDOWN*0.3*0.5 ! diffuse vis*
*SOLAI(2) = SWDOWN*0.3*0.5 ! diffuse nir*

Second, four albedo components are weighted to calculate the total radiaton as follows:

*RVIS = ALBD(1)*SOLAD(1) + ALBI(1)*SOLAI(1)*
*RNIR = ALBD(2)*SOLAD(2) + ALBI(2)*SOLAI(2)*
FSR = RVIS + RNIR

where ALBD(1) and ALBD(2) are albedos from direct visible bands and direct near-infrared bands, respectively. ALBI(1) and ALBI(2) are albedos from diffuse visible bands and diffuse near-infrared bands, respectively. RVIS and RNIR are reflected radiative fluxes from visible bands and near-infrared bands, respectively. FSR is total reflected radiative flux. Finally, you can get the albedo value through the formula below,

ALBEDO = FSR/SWDOWN.

Page 3205, line 12: Why is K_open set to 0.05? It should also vary with vegetation cover. If the comparison is with MODIS white-sky albedo, only the model diffuse albedo should be used.

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⇒ *In the Noah-MP, K_{open} is considered as a constant and set to 0.05. For the accurate comparison, we should have the same condition between the model and the observation, but in the model each part of albedo, such as direct or diffuse albedo and visible or near-infrared albedo is much simply calculated, as shown above. In addition, the difference between the black-sky albedo and the white-sky albedo of MODIS is small, thus the weighted average albedo using the aerosol optical depth may have similar value to each of the MODIS albedo. Therefore, we compared the total albedo of the Noah-MP with the MODIS white-sky albedo and thought that such comparison is within the observation error range.*

Page 3205, line 16: Please consider doi:10.1029/2010EO450004.

⇒ *We thank the referee for recommending this reference. We have rewritten the sentence as: "**At a fixed SI, albedo represents different patterns for different SZA – with increasing SZA, albedo decreases at relatively low SI while it increases at relatively high SI.**"*

Page 3206, line 20: Because the influence of the SI in Figure 4 saturates at positive bias values, it is not just possible but in fact clear that snow cover fraction is too high, forest fraction is too low or snow-covered forest albedos are too high to match the observations.

⇒ *Please note that the bias errors in Fig. 4 are represented in the absolute values (i.e., absolute values of model minus observation), as we clearly mentioned in the text. So the argument made by the referee is partly true, but not always.*

Page 3206, line 27: If showing results from the other radiative transfer options, brief descriptions of them are required.

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⇒ *We have added the description of the radiation options: "Albedo with other radiation options is also overestimated due to underestimated LAI and SAI.* ***There are three radiation options in the Noah-MP for calculating energy fluxes: The first is MTSA, used for parameterization in this study, that calculates canopy gaps from three-dimensional structure and solar zenith angle. The second is two-stream radiation option with no canopy gap, i.e., the leaves are evenly distributed within the grid-cell with a 100 % vegetation fraction. The last is the tile approach that computes energy fluxes separately for the vegetated fraction and the bare fraction, and then sum them up weighted by a fraction. It turned out that the optimal LI and SI with the MTSA had similar improving effect on albedo compared to those calculated with other options.*** *The RMSEs with the original ···"*

Page 3213: Please comment on why the optimized LI turns out larger for deciduous than evergreen forest.

⇒ *We believe that the deciduous broadleaf forest has a higher minimum value of LAI than the evergreen needleleaf forest due to the larger leaf area. Actually, in winter, deciduous forest does not have any leaf and LAI might be 0 theoretically. However, field measurements of LAI of deciduous forests have some value in winter, especially when the grid box size is as large as 25 km × 25 km. In this coarse grid box, vegetation is not fully homogeneous. Therefore, we have regarded that deciduous broadleaf forest has the minimum LAI with low spatial resolution due to heterogeneous vegetation types.*

Page 3215: Figure 2 caption should state that these are from observations.

⇒ *We have rewritten the caption as "**Figure 2. The MODIS white-sky albedo for total shortwave broadband averaged for winter time in 2001-2010 (dots) and***

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corresponding SD (bars) when SCF equals 100 %. Description on areas is in Fig. 1 and Table 2."

Page 3218: Note that OPT_RAD1 in Figure 5 is MTSA in the text. Explain why OPT_RAD3 (new) differs from the other options much more with the BATS snow albedo than with CLASS.

⇒ *Compared to other options, OPT_RAD3 simply calculates the vegetation fraction. OPT_RAD1 calculates the vegetation fraction by considering 3-D structures and solar zenith angle; thus it specifically considers the vegetation effects. Because OPT_RAD2 calculates the grid cell with a 100 % vegetation fraction, the vegetation effects is maximized. Therefore, albedo with OPT_RAD3 is relatively less sensitive to vegetation parameters. In fact, while we examined Fig. 5 to reply to the referee's comment, we found a minor error in producing the results in Fig. 5. We have recalculated and redrawn Fig. 5 with new results in the revised manuscript. With this new calculation, we found that the improvement in the RMSE was approximately 69 % rather than 73 %. We have corrected in the abstract and main text accordingly.*

Essery, R (2013). Large-scale simulations of snow albedo masking by forests. Geophysical Research Letters, 40, 5521-5525, doi:10.1002/grl.51008.

Hardy, JP, R Melloh, P Robinson and R Jordan (2000). Incorporating effects of forest litter in a snow process model. Hydrological Processes, 14, 3227–3237.

Verseghy, D, NA McFarlane and M Lazare (1993). CLASS: A Canadian Land Surface Scheme for GCMs. II. Vegetation model and coupled runs. International Journal of Climatology, 13, 347–370.

⇒ *We thank the referee for suggesting these articles. We have added them to the References section and cited appropriately in the text.*

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Table 1. The values of mean and standard deviation (STDEV) of snow albedo, evaluated by the Noah-MP, for the broadbands of visible, near-infrared and shortwave for different categories of the MODIS land cover. The data are averaged for winter time in 2001-2010 over each vegetation type within $40° - 60°$N with corresponding SD when SCF equals 100 % and other snow conditions are the same.

MODIS land cover	Visible		Near-infrared		Shortwave	
	Mean	STDEV	Mean	STDEV	Mean	STDEV
Dryland Cropland and Pasture	**0.958**	0.003	**0.703**	0.021	**0.831**	0.012
Grassland	**0.958**	0.003	**0.703**	0.021	**0.830**	0.012
Shrubland	**0.956**	0.003	**0.694**	0.023	**0.825**	0.013
Mixed Shrubland/Grassland	**0.956**	0.003	**0.690**	0.022	**0.823**	0.013
Deciduous Broadleaf Forest	**0.933**	0.006	**0.652**	0.006	**0.792**	0.006
Deciduous Needleleaf Forest	**0.932**	0.021	**0.647**	0.039	**0.790**	0.030
Evergreen Needleleaf Forest	**0.919**	0.033	**0.621**	0.063	**0.770**	0.048
Mixed Forest	**0.924**	0.023	**0.632**	0.042	**0.778**	0.032

Interactive comment on Geosci. Model Dev. Discuss., 8, 3197, 2015.

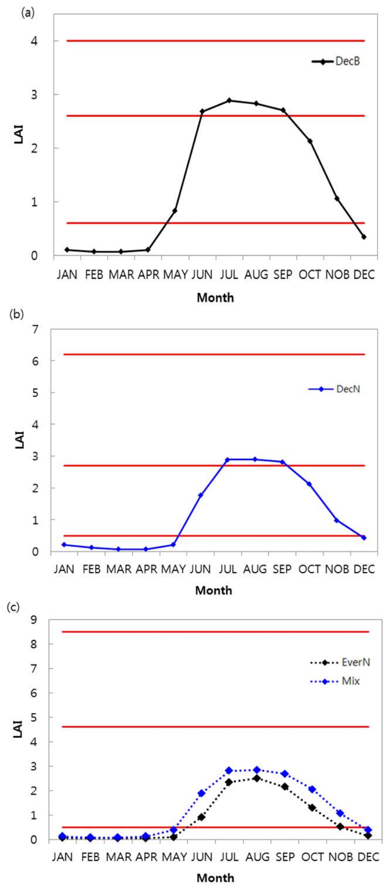

Fig. 1. Monthly averaged LAI in the Noah-MP during the past 10 years for (a) deciduous broadleaf forest, (b) deciduous needleleaf forest, (c) evergreen needleleaf forest and mixed forest.

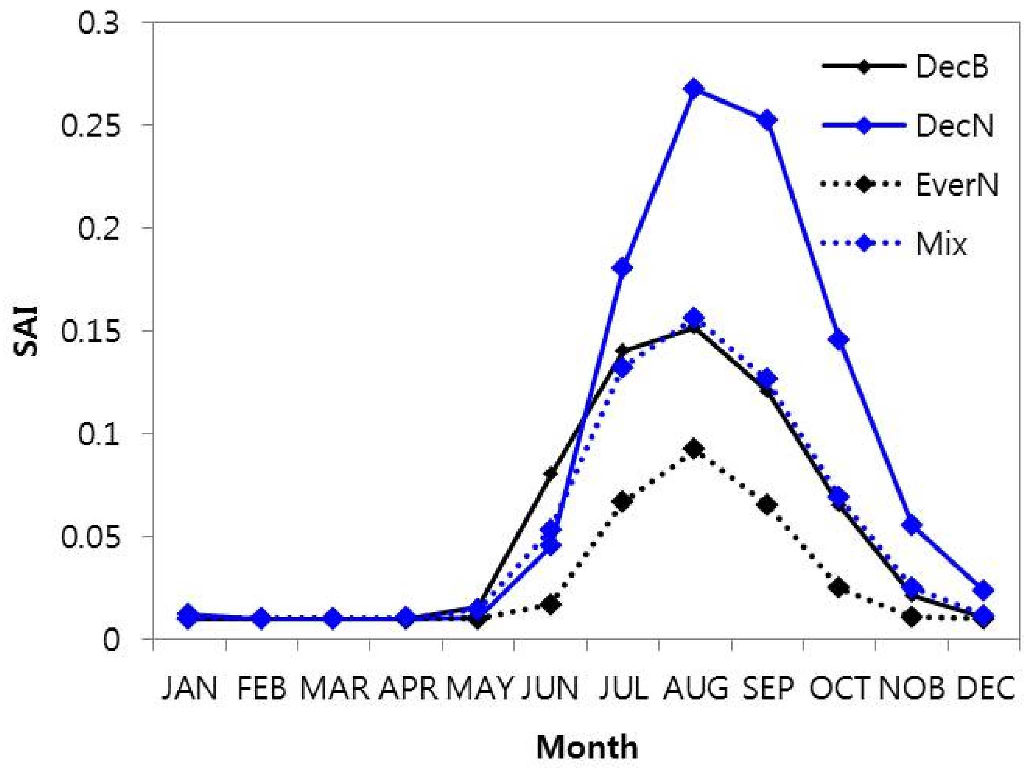

Fig. 2. Monthly averaged SAI in the Noah-MP during the past 10 years for deciduous broadleaf forest (DecB), deciduous needleleaf forest (DecN), evergreen needleleaf (EverN) and mixed (Mix) forest.

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