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Interactive comment on "Biases in the albedo sensitivity to deforestation in CMIP5 models and their impacts on the associated historical Radiative Forcing" *by* Quentin Lejeune et al.

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Many thanks to the reviewer for taking the time to go through the manuscript and submitting such detailed comments. This is very helpful to improve the manuscript. We are providing answers to the reviewer's comments below.

- In response to the first main comment: We indeed introduce two different reconstruction methods in the manuscript. We aim at clarifying the methodology section in a revised version of the manuscript, and especially at explaining better what these two methods intend to do and how. We also hope that a newly included figure (see below) will provide visual help in that respect. In this study we reconstruct two different quanti-

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ties in CMIP5 models: 1) the simulated present-day albedo of trees and crops/grasses, to evaluate the albedo change arising from a potential transition between these two classes against observational data, and 2) the historical surface albedo changes associated with transitions between trees and crops/grasses, followed by an assessment of their consequence in terms of Radiative Forcing. Based on Table 1 and Figures 1-4, Section 3 focuses on the evaluation of the ability of the first employed reconstruction method to extract the first quantity (simulated present-day albedo of trees and crops/grasses) in CMIP5 all-forcings simulations. In Section 4, based on Figures 5-10 we evaluate the albedo change arising from a potential transition between trees and crops/grasses in CMIP5 models against observational data. This quantity has been extracted using the first reconstruction method, which has previously been evaluated in Section 3. In Section 5, based on Figures 11-13 we discuss the historical surface albedo changes associated with transitions between trees and crops/grasses between the pre-industrial and 1981-2000 periods, and which have been reconstructed in CMIP5 models using the second reconstruction method.

- In response to the second main comment: We will pay attention at including the spatial and temporal resolutions as well as the temporal coverages where appropriate in the legends of the figures and tables, as suggested by the Referee. Moreover, the revised methodology section as well as the new figure (see below) should make clearer that within one big box, we reconstruct the albedo values (or albedo changes) for the grid cell in the center of the big box, i.e. the reconstructed albedo values and albedo changes have the original model resolution (about 2°).

- In response to the third main comment: All reviewers have suggested to use a different kernel to convert the reconstructed historical albedo changes due to conversions between trees and crops/grasses into RF estimates. Following Ryan Bright's comment, we have decided to use the version 1.0 of the CERES-based albedo change kernel (CACK) from Bright and O'Halloran (2019) for the Radiative Forcing calculations. This kernel is based on a novel, simplified parameterisation of shortwave radiative transfer and driven with downwelling shortwave radiation values at the surface and the top of the atmosphere obtained from the Clouds and the Earth's Radiant Energy System (CERES) Energy Balance and Filled (EBAF) 1°-resolution products. CACK was evaluated by Bright and O'Halloran (2019): While being more easily understandable and easier to apply than kernels derived from climate models, it is able to mimick them more faithfully than five previously employed analytical, semi-empirical and empirical kernels. CACK provides a monthly climatology, it is thus possible to compute a change in top-of-the-atmosphere net radiation amounts due to surface albedo changes that vary from month to month by summing up the contributions from each month. This is summarized in the equation for which a screenshot is attached to this reply (see below).

Detailed comments,

1. As asked by the reviewer, we have included an explicit translation from GlobCover's land cover classification into the two broad classes that we used (trees and crops/grasses) in a new Table S1, and added a reference to this Table in Section 2.1.1.

2. We understand that the GlobAlbedo product makes use of an optimal estimation approach including angular integrals and a gap-filling technique based on the MODIS surface anisotropy dataset in order to integrate data derived from the Advanced Along-Track Scanning Radiometer (AATSR), SPOT4-VEGETATION, SPOT5-VEGETATION2, and MERIS instruments, which exhibit different spectral and angular sampling. We have included this information in Section 2.1.1.

3. The resolution of the dataset from Duveiller et al. (1°) was missing and has now been specified in Section 2.1.2.

4. As specified in Section 2.1.2, we have used the version of the D18 dataset that provides albedo changes for only six land cover transitions between four broad land cover classes (forests, shrubs, crops/grasses and savannas). This classification scheme is referred to as IGBPgen in the paper describing the dataset. Consistently with this

scheme, when represented in the CMIP5 models we have considered grasses, crops and pasture as belonging to one single class: crops/grasses.

5. We will take the comments concerning the language into account before submitting the revised manuscript.

6. The sentence containing “land cover classes are represented in a grid cell” will be reformulated as such: “Therefore, each predictor (*lcftr*, *lcfsh*, *lcfcg*) is only included in the regression (i.e., its corresponding term is included in Equation (1) or (2)) if its value is greater than 0 in at least two snow-free (if *i* is snow-free) or snow-covered grid cells (if *i* is snow-covered).” If for example *lcfsh* is not included in a regression, that one grid cell with *lcfsh* $>$ 0 (if there is one) may still be considered in the regression if over that grid cell *lcftr* + *lcfcg* $>$ 90%. This would effectively mean that *lcfsh* $\leq$ 10%, therefore that the albedo of shrubs only accounts for a small portion of the mean surface albedo over that grid cell, which thus justifies the consideration of that grid cell in the regression.

7. The referee is correct that if a grid cell is snow-free (respectively, snow-covered) in a given month, we only estimate albedo for snow-free (respectively, snow-covered) conditions. We have reformulated parts of Section 2.3.1 to clarify this point, and the new figure should also help in that respect.

8. We suggest to reformulate the sentence originally present line 187 as such: “Moreover, the regressions are only conducted in the big boxes with a at least 15 grid cells (either snow-free or snow-covered) in which the sum of all the included predictors exceeds 90%.” We hope that the inclusion of a new figure will also help to make this methodological point clearer.

9. There was indeed a mistake, there should have been no subscript on the term on the left side of Eq. (9).

10. The description of the jackknife resampling has been reformulated.

11. We indeed estimate the instantaneous RF resulting from historical conversions

from trees to crops/grasses for each month, then compute the annual mean value. We hope that the revised methodology description and in particular the equation for which a screenshot is attached to this reply (see below).

12. In an attempt to clarify the text lines 250-251, we will now differentiate between the potential surface albedo change associated with a transition from trees to crops/grasses ($\delta\alpha_{tr \rightarrow cg}$, reconstructed using the method described in Section 2.3.1) and historical surface albedo changes due to conversions between trees and crops/grasses between the pre-industrial and 1981-2000 periods ($\Delta\alpha_{tr \rightarrow cg}$, reconstructed using the method described in Section 2.3.2). New Equations will also be introduced, which should help for this clarification.

13. We have tried to formulate a clearer explanation of how the subgrid estimates of the present-day albedo of trees and crops/grasses are extracted from the CLM4.5 simulations. Especially, the following sentences should help to understand this point: "Surface albedo values were output for each tile in these simulations, enabling to extract a subgrid albedo value for each land cover class (trees or crops/grasses, similarly as in Malyshev et al., 2015; Meier et al., 2018). For each grid cell and each month, the albedo values for these two land cover classes are computed as the area weighted mean albedo across each PFT pertaining to the respective class over the analysis period. This reference value, later referred to as "subgrid" estimate, can then be compared to the reconstructed albedo values."

Malyshev, S. et al. (2015) 'Contrasting Local versus Regional Effects of Land-Use-Change-Induced Heterogeneity on Historical Climate: Analysis with the GFDL Earth System Model', Journal of Climate, 28, pp. 5448–5469. doi: 10.1175/JCLI-D-14-00586.1. Meier, R. et al. (2018) 'Evaluating and improving the Community Land Model's sensitivity to land cover', Biogeosciences, 15, pp. 4731–4757. doi: 10.5194/bg-15-4731-2018.

14. "Pixel" will be changed to "grid cell" to ensure consistency across the manuscript

and more clarity for the reader.

15. We don't differentiate between snow-covered and snow-free grid cells when looking at the subgrid albedo values for trees and crops/grasses, but extract the subgrid albedo values for any snow cover fraction.

16. In Section 3 we focus on the evaluation of the ability of the first employed reconstruction method (presented in Section 2.3.1) to extract the simulated present-day albedo of trees and crops/grasses in CMIP5 all-forcings simulations.

17. As the Referee found the phrase "for which this information is available" line 464 redundant, we can reformulate the whole sentence.

18. As hinted by the Referee's comment, there was a mistake in the legend of Figure 1 and "absolute differences" should read "albedo values".

19. We have prepared scatter plots over common grid cells between subgrid and reconstructed estimates of albedo values and albedo differences between trees and crops/grasses in the CLM4.5 simulations. These plots will support the discussion in Section 3 of the performance of the first reconstruction method (described in Section 2.3.1).

20. The first reconstruction method (described in Section 2.3.1) requires information on the snow cover fraction (*snc*), which therefore limits the set of CMIP5 models that can be analysed compared to the second one (described in Section 2.3.2). Moreover, for the RF analysis we consider only the CMIP5 models for which at least two ensemble members are available in an attempt to limit the uncertainties of the method. These criteria overall explain that the Figures 5-10 and 11-13 are based on two different sets of models.

21. We had originally chosen not to present a model mean for Figure 12 because it would have required regridding the results from the individual models to a common grid, but this can be done for the revised manuscript.

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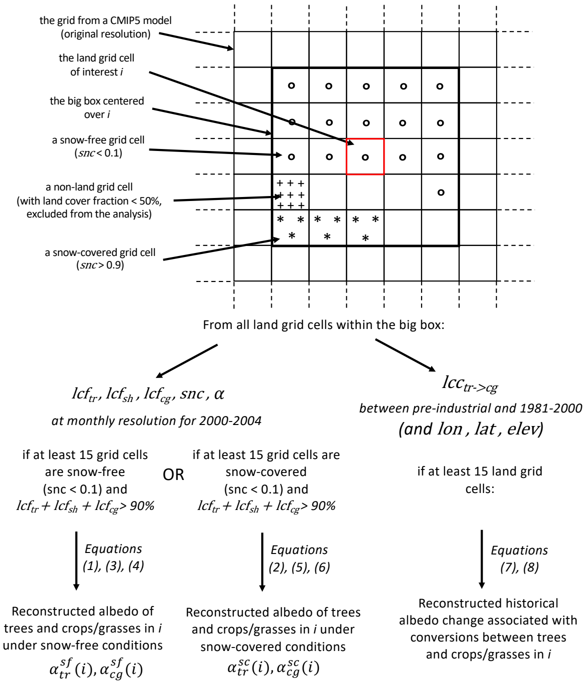

Figure 1: Description of the two employed reconstruction methodologies. *snc* stands for snow cover fraction, α for albedo, *lcf* for land cover fraction, *lcc* for land cover conversion, the suffixes *tr*, *sh* and *cg* for trees, shrubs and crops/grasses, respectively, *lon* for longitude, *lat* for latitude, and *elev* for elevation.

Fig. 1. new Figure detailing aspects of the methodology

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$$RF_{tr\leftrightarrow cg} = -\frac{1}{12}\sum_{m=1}^{12} K_{\alpha_s,m}^{CACK} \times \Delta\alpha_{tr\leftrightarrow cg,m}$$

Fig. 2. Equation describing the calculation of the Radiative Forcing (see point 11 above)