The biogeophysical effects of idealized land cover and land management changes in earth system models

Response to Community comments

30/07/2022

Community comments

Community Comment 1

We understand that there are clear differences in the setup of the FRST simulation between EC-Earth and the other models. The CC3 comment addresses this issue. To make the study consistent between the different models it would demand a new FRST simulation with prescribed forest cover as in the other ESMs. This would be of utmost importance as this simulation will be the basis for additional studies (you mention a LAMACLIMA study performed by Suqi Guo).

Response

we agree that in the current form FRST in EC-EARTH is not exactly comparable to the other ESMs FRST simulations and this is also clearly stated at several stages within the manuscript:

Firstly it is mentioned in section 2.1.2 regarding experimental design when the simulations are introduced. We added a part to the sentence to highlight the low amounts of afforestation in EC-EARTH. Line 193-194 now state the following :

> Note that this difference in implementation of the LCLMC has led to strong differences in the total extent of the LCLMC, most notably regarding the afforestation experiment where EC-EARTH shows little afforestation in contrast to MPI-ESM and CESM (Figure 1f). These low amounts of afforestation modelled in the EC-EARTH FRST simulation make that it is less comparable to the other ESMs for this land cover change.

Next it is mentioned in the results when the temperature response of EC-EARTH as a consequence of afforestation is discussed in section 3.2.2. more specifically Line 379-381 states:

> The lack of local boreal warming in EC-EARTH is probably related to the differences in experimental setup and the resulting low amounts of afforestation in this simulation (Figure 1f).

Finally this issue is brought up in the discussion :Line 518-524 section 4.1

> Although we have harmonised the land cover and management representation across the different models, strong differences remain, most notably in the implementation of irrigation expansion and afforestation (Figure 1). This implies that the comparison of the different simulations across ESMs is not perfect and inconsistencies can be caused by

> disparity in model structure and by spatial differences and differences in extent of the applied LCLMC. As for afforestation, the differences found here were mainly caused by the technical difficulty of implementing this in the dynamic vegetation model LPJ-GUESS used in EC-EARTH.

As we already make this point at 3 distinct locations in the paper, when the simulations are introduced in the methods, when they are presented in results and finally in the discussion. We feel we communicate clearly and openly about this caveat. We tried to increase clarity by adding some extra lines in the first section where the simulations are introduced (section 2.1.2).

We agree that a different FRST simulation for EC-EARTH with a setup where land cover is prescribed and LPJ-GUESS handles the biogeochemistry would be more comparable to the FRST simulation of MPI-ESM and CESM as presented in this study. As the LAMACLIMA project envisions multiple publications which would be based on these simulation data it would indeed be an ideal situation if the EC-EARTH FRST simulation could be repeated.

However, we would like to stress that these simulations performed within the LAMACLIMA project are the fruit of almost 3 years of full time work of 3 researchers in 3 different groups and this is the first paper that would be based on this work. Throughout the setting up of the simulations and preparatory discussions we have tried everything to make sure that the model setup was as sound as possible, among which intense discussions with the respective ESM development communities including the EC-EARTH community. Due to the limited computational resources, time availability of staff and other project milestones it would not be possible to run the simulations again within the LAMACLIMA project. We ask the editor and community for understanding of this situation and to consider the large amounts of work that has gone into this manuscript.

Community Comment 2

Also, your improbable EC-Earth result (that there aren't any differences in albedo effects between the EC-Earth FRST and CROP simulations) which is pointed out in CC4 is something that needs to be examined closer and corrected. Your result is unlikely considering your statement that there are different albedo effects even when comparing the CROP and IRRI simulations. As expressed in CC6, the difference between the albedo effects should be smaller in the CROP-IRRI comparison than in the FRST-CROP simulation comparison, as irrigated crops have the same physical parameters as rainfed crops in HTESSEL.

Response

We take this concern seriously as we also find it strongly unintuitive that EC-EARTH shows no local albedo changes. It should be noted that this does not imply that no albedo changes where apparent in the simulations, as was mentioned clearly within the manuscript in section 3.1 lines 333-336 (added here below) the albedo response is generally a non-local feature in EC-EARTH.

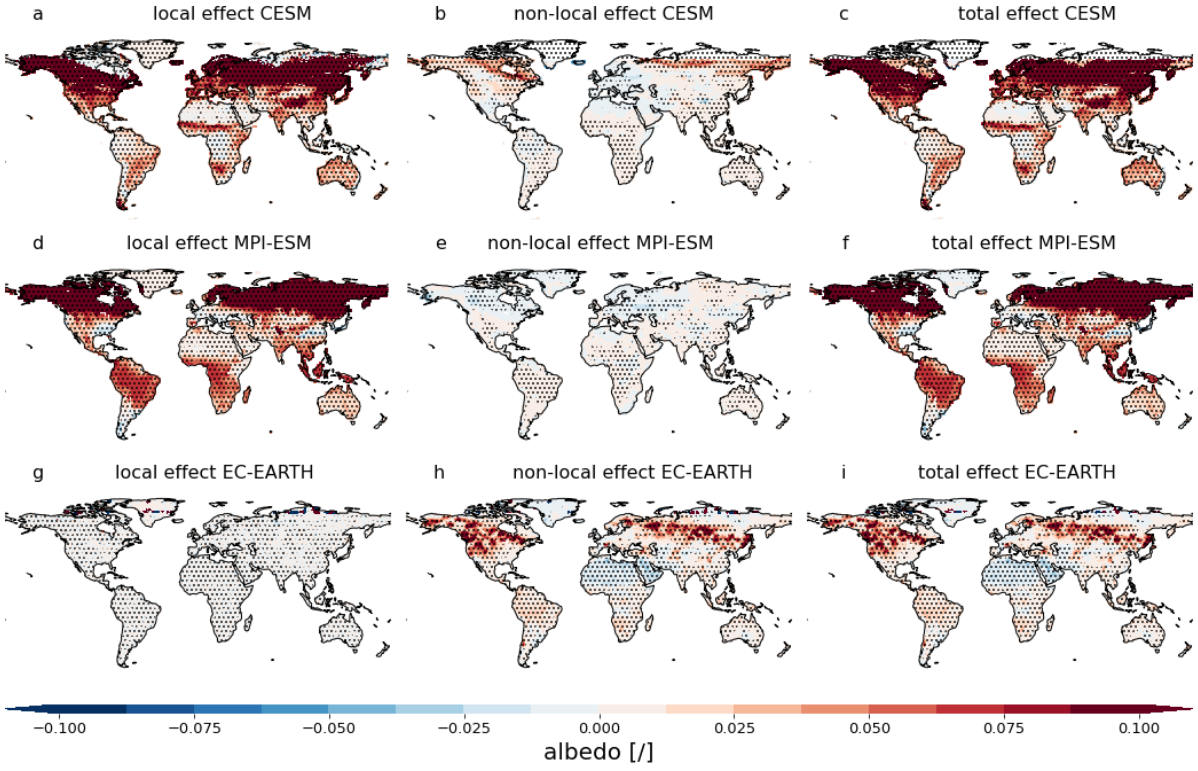
> In EC-EARTH the local albedo change is zero (Figure 4c), however there is a stronger non-local albedo change despite this being almost absent in other ESMs (Figure D1). The non-

local albedo change is near-zero except over boreal latitudes, where it agrees in sign with observations but strongly underestimates the magnitude (Figure D2).

This point was also brought up again in the discussion, more specifically in section 4.4. (limitations and outlook) in line 645-649 (see below). We reworded a bit to acknowledge the anomalous albedo behaviour more explicitly.

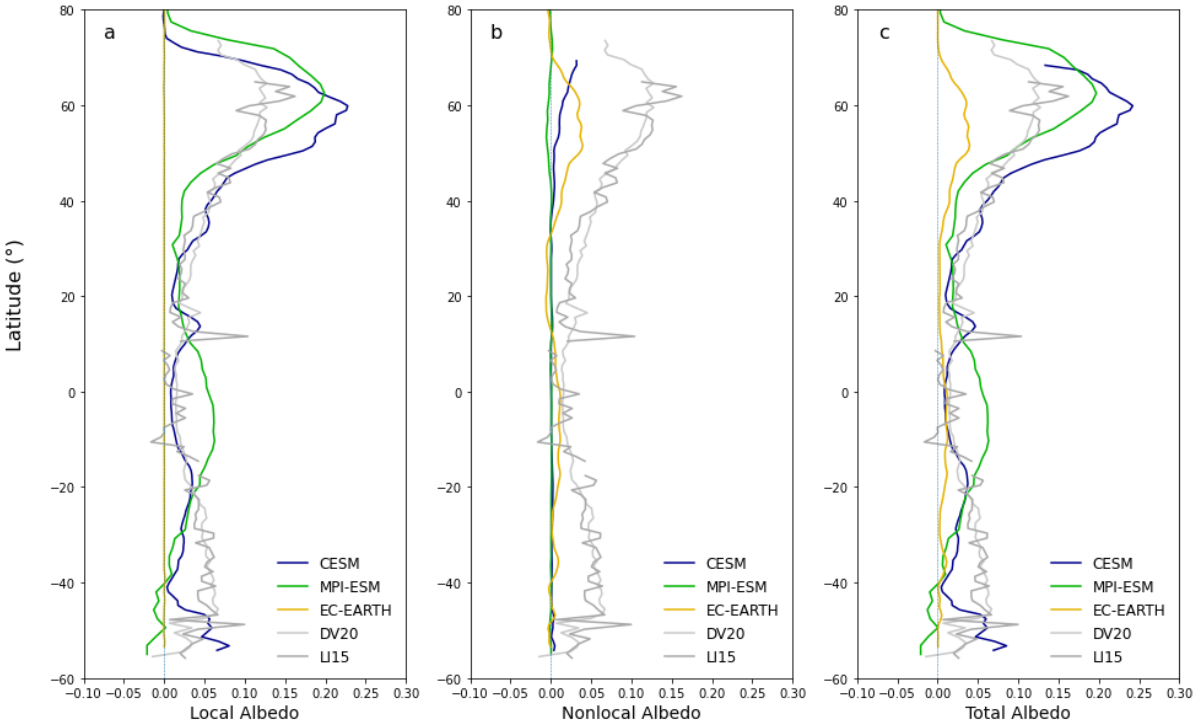
For EC-EARTH, even though it has a highly advanced land model (LPJ-GUESS), the interface with the atmosphere is handled by a more simple submodel (HTESSEL) within the atmosphere model IFS. ~~This leads to some clear biases (e.g., an unrealistic response in the turbulent energy fluxes and albedo).~~ This causes some clear biases such as the unrealistic response in the turbulent energy fluxes and the unrealistic partition of albedo as a non-local feature in EC-EARTH (Figure 4c). Addressing these biases could be a useful strategy when further developing this ESM to make land cover induced climate effects more realistic.

To clarify this we add a figure here below showing the local, non-local and total effects for all ESMs for the CROP-FRST case (which is added to the paper in a separate appendix chapter dedicated to this issue and which summarises this discussion). We have adapted the colorbar range from the one used within the manuscript to clearly illustrate all small changes in albedo. It shows that the albedo change has a dominant local component for CESM and a smaller non-local component, MPI-ESM only shows a local contribution while EC-EARTH only shows a non-local contribution.

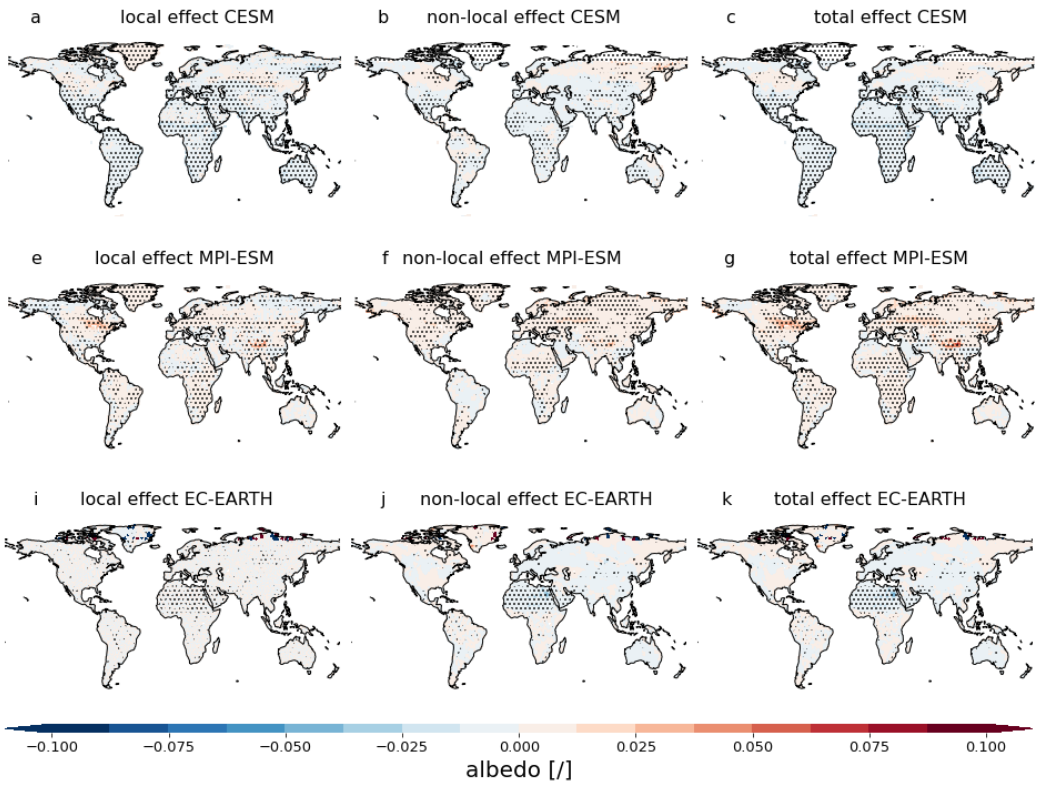


Additionally we add a latitudinal figure with the local, non-local and total effects on the albedo for the 3 ESMs compared to the observational datasets (likewise added to the appendix chapter mentioned above). This figure again illustrates what was mentioned above. However it also clearly

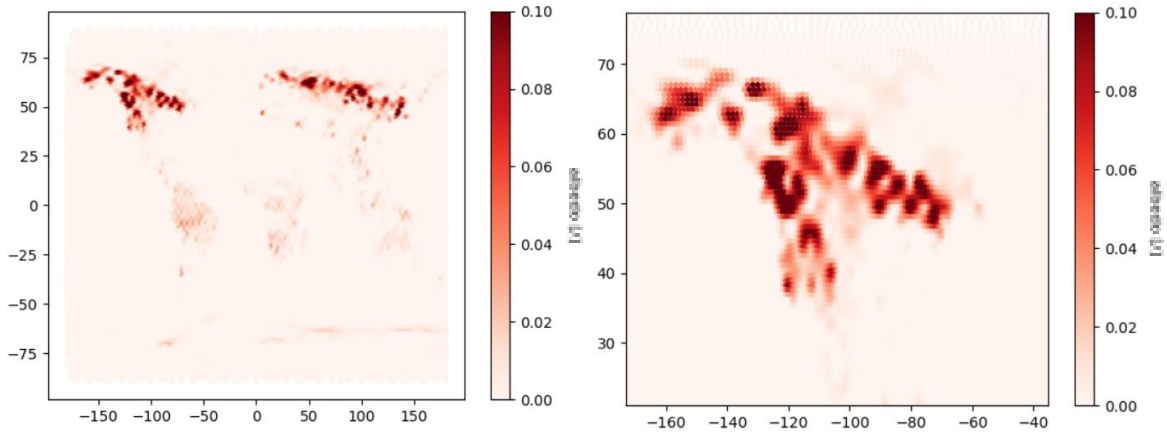
shows that even when total effects are considered EC-EARTH strongly underestimates albedo change compared to the observational datasets used within the paper. This is especially important in the boreal latitudes where EC-EARTH does show a slight increase in the NH, however this effect is still less than half as strong as the observational datasets indicate. It should be noted that EC-EARTH has undergone less land cover change in the CROP-FRST case compared to the other ESMs as the FRST simulation for this ESM showed very little afforestation amounts (see Figure 1 in the paper and the discussion above), which could explain the underestimation of the total albedo effects for this ESM.



A third figure is shown below to illustrate the effects IRR-CROP, these are indeed completely zero in EC-EARTH as was explained within the comment (irrigated crops have the same physical properties as rainfed crops). We apologise for any confusion due to our wording in CC6 and clearly illustrate here that IRR-CROP has a negligible albedo change in EC-EARTH while the albedo change is clear in CROP-FRST albeit a non-local effect. Note that this figure, representing the effects of irrigation on albedo, is the same as Figure D12 in the first submission of the manuscript but with adapted colorbar and Figure E12 in the revised version submitted within this review round.



As a final figure we show the difference of the raw albedo output from the EC-EARTH CROP and FRST simulation, i.e. without any postprocessing performed (signal separation or interpolation). The left panel shows the total albedo change globally and the right panel is a zoom on North America (note that as the EC-EARTH raw data is not in netcdf format these plots are quite rough but they deliver the message). These plots illustrate what was seen previously in the signal separated figure, as in the right side plot even though different grid cells can be distinguished there is no checkerboard visible at all, this indicates that both the grid cells which have undergone land cover change as those with unaltered land cover change have the same albedo effects meaning that the albedo changes are indeed a non-local feature in EC-EARTH. It should be noted that a slight checkerboard pattern is present on the left panel figure over the tropical rain forests (especially clear over Amazon), however it should be noted that these values are very small (only up to 0.02 change in albedo) which has a negligible effect and shows that local albedo change is completely negligible in EC-EARTH.



Hence it is clear that this anomalous albedo result (being a non-local in stead of a local feature) is directly derived from the model output and is not caused within the postprocessing performed in this study. This is something which requires resolving at the EC-EARTH level with HTESSEL and LPJ-GUESS developers, we are happy to contribute to this process but acknowledge that that it is not something we can solve within this present study.