Climate Response to Severe Forestation: A Regional Climate Intercomparison Study
Author Response to Anonymous Review #1

Legend:
Reviewer Comment
Author response
Manuscript edits suggested by author

General Comment

This study uses three regional climate models, albeit two of them are very similar (CRCM5 and CRCM6), to assess the biogeophysical impacts of forestation in North America (NA). The methodology follows the protocol designed in the first phase of the CORDEX flagship pilot study Land Use and Climate Across Scales (LUCAS) and described in Davin et al. (2020). The study also contextualises its results for North America with those already published for Europe, and explores the transferability of results between the two continents. The work is well within the scope of the journal and provides a substantial contribution to the field.

Major Comments

1. The title and abstract are a little misleading. This study does not present new results for Europe, nor is Europe its focus. This study focuses primarily on North American and contextualises these results in the framework of the CORDEX LUCAS work for Europe. The results for Europe have been presented previously in Davin et al (2020) and elsewhere, which is correctly referenced throughout the manuscript. In this regard, it is strongly recommended to (a) include North America in the manuscript's title, and (b) revise some of the sentences in the abstract and introduction to show that the focus is North America.

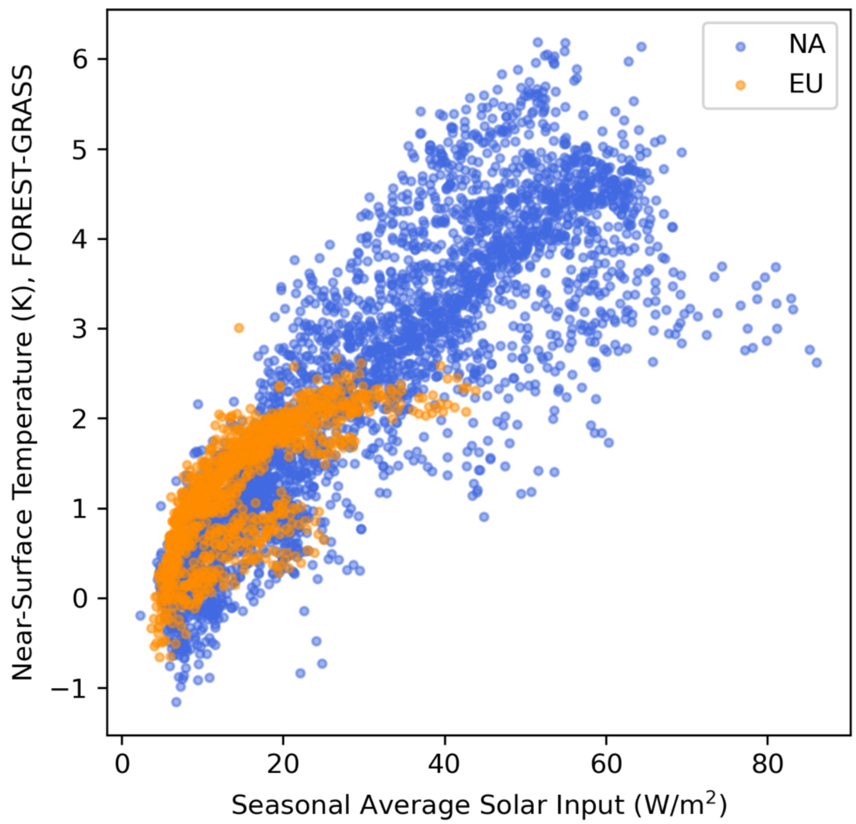
We agree with the reviewer's comment that the original title of the manuscript — ***Climate Response to Severe Forestation: A Regional Climate Intercomparison Study*** *— did not clearly convey the manuscript's main point. However, we do not see this study as focusing primarily on North America. Instead, we think that the main contribution of this paper is to show the intercontinental transferability of the response to forestation, which is made possible by the production of the new CRCM5 simulations over both North America (NA) and Europe (EU). The NA runs of CRCM6 and WRF (section 4) should rather be seen as a robustness test of the CRCM5 NA run used in the intercontinental comparison. To reflect this, we suggest the following new title:*

On the Intercontinental Transferability of Regional Climate Model Response to Severe Forestation

We believe that with this reframing of the paper's title, the abstract makes sense as it currently is.

2. It would be beneficial to see a confirmation of the authors hypothesis that the difference between NA and Europe in winter is due to the presence of Evergreen Needleleaf forests and snow cover at lower latitudes in NA compared to Europe.

We produced a new figure showing the strong fit between the temperature delta from forestation in relation to insolation for snow covered regions, and adjusted the text of section 3.1 accordingly:



Caption of new figure 3: Wintertime near-surface temperature response to forestation (CRCM5-CLASS) as a function of the incoming shortwave radiation flux (taken from the FOREST simulation). Only grid points within snow-covered (covered by snow more than 90% of winter in the FOREST simulation) northern needleleaf forests are included.

Section 3.1:

Figure 3 shows the relation between warming and insolation over snow-covered needleleaf forests in wintertime. Each dot represents a grid point within the northern needleleaf forests of North America (blue) or Europe (orange) with snow cover during at least 90% of winter. In these regions, the warming response to forestation is dominated by snow masking, and the magnitude of this warming is proportional to incoming shortwave, here mostly a function of latitude. Since snow-covered needleleaf forests extend to much lower latitudes in North America, the scatter reaches higher warming and incoming solar input on this continent. The Europe scatter is instead confined to weak warming because needleleaf forests occupy high latitudes with little insolation. It is noteworthy that the scatter and trend of the two continents overlap strongly, suggesting that the mechanisms at work are similar.

3. It is important to compare the biogeophysical impacts in NA and Europe during spring in addition to the winter. In Europe, the snow albedo effect is strongest in spring when the colder regions of Northern Europe have snow and sufficient solar radiation to observe the snow-albedo effect. It would be reasonable to expect that NA and Europe would have similar results during this season.

The reviewer is right that the snow-albedo effect is even stronger in spring than winter, because snow cover is almost as important and insolation is much greater. We initially stuck to only winter and summer in Section 3 because that is also what Davin et al. (2020) focuses on, and these two seasons illustrate all the relevant physical mechanisms at work. We nevertheless added a paragraph on spring in section 3.1 following the reviewer comment. But to keep the paper concise, we kept the discussion short and left figures for spring (and fall for symmetry) in the supplementary material.

Section 3.1:

Insolation also changes with the time of the year. In springtime, snow cover remains important and incoming shortwave radiation increases both in magnitude and latitudinal reach (figure S3). Therefore, the warming effect of snow masking is stronger and affects higher latitudes in the springtime for both continents.

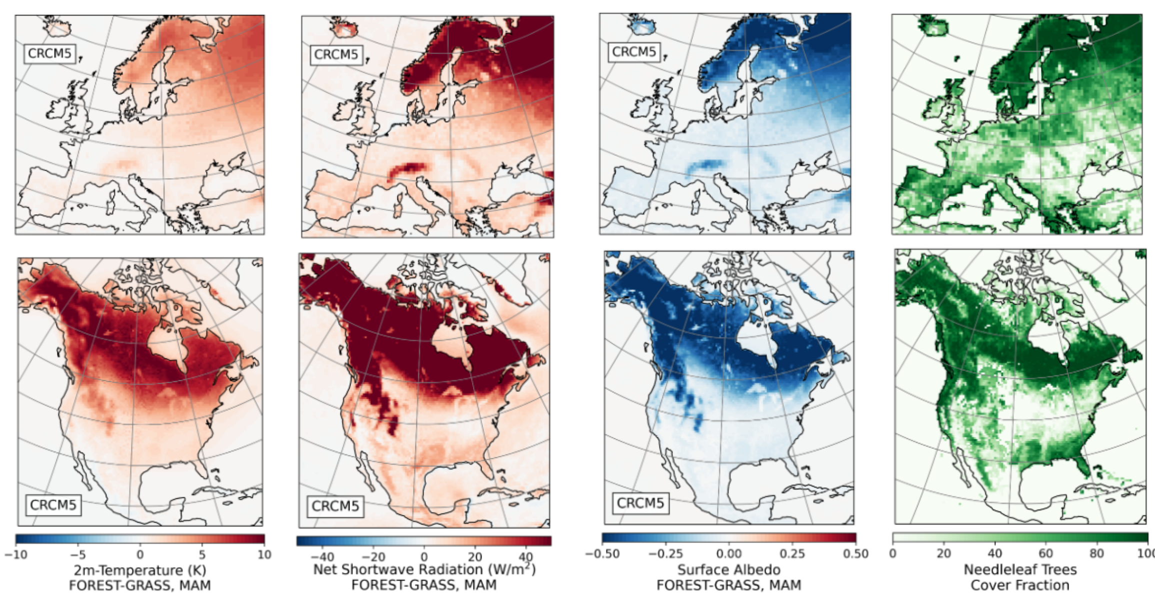


Figure S3. CRCM5-CLASS springtime response to forestation (FOREST-GRASS) averaged over 1986-2015, MAM. From left to right: near-surface temperature, shortwave radiation excess, surface shortwave albedo and needleleaf tree distribution.

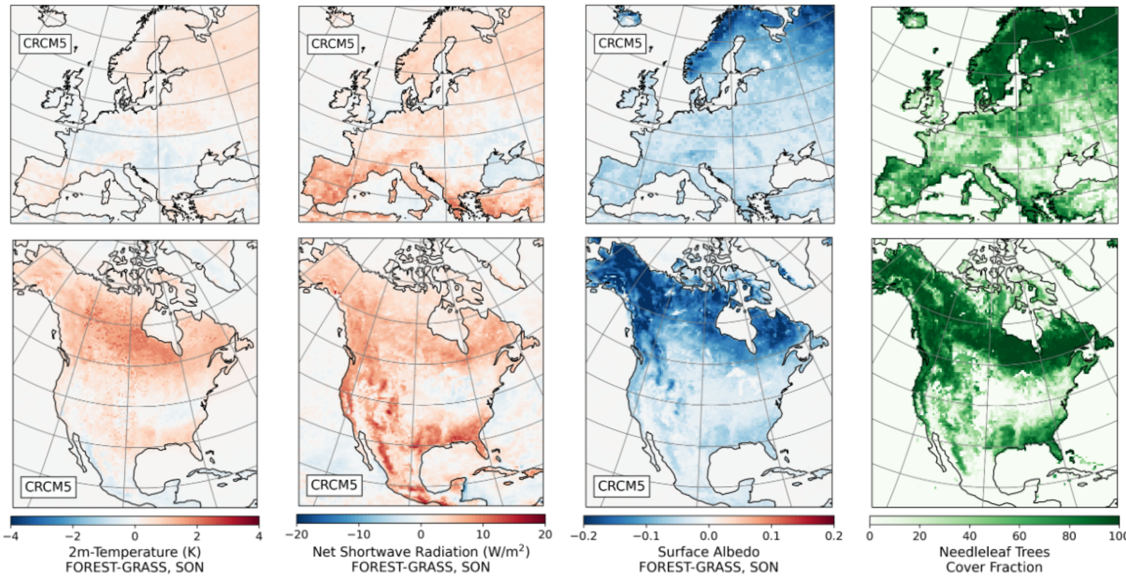


Figure S4. CRCM5-CLASS fall response to forestation (FOREST-GRASS) averaged over 1986-2015, SON. From left to right: near-surface temperature, shortwave radiation excess, surface shortwave albedo and needleleaf tree distribution.

4. The paper would benefit from being restructured. It would be clearer if the results focused first on the biogeophysical impacts of forestation in NA and finish by contextualizing these results with the previous work in Europe i.e., section 3 should be just before the conclusions and discussions.

We are unsure why the paper would be clearer with this major restructuration. Current section 3 presents the main results of this manuscript, i.e. the inter-continental similarities/differences in the forestation response. We believe that it makes sense to begin the results part of the paper with the main message so that it does not get diluted in the thorough technical analysis of the later sections. Current section 4, which the reviewer would move before section 3, is better thought of as a thorough robustness test of the CRCM5 response over NA.

The suggested edit would require rewriting current sections 3, 4 and 5, because sections 4 and 5 use concepts that were introduced in the summer-winter overview of section 3. Given the significant work required by such an edit and the unclear benefits, we prefer leaving the structure as is.

5. Section 3 focuses more on comparing the results from NA with Europe. This is good but given the large intermodel variability and the availability of an ensemble for each region, it is recommended that the ensemble for each region is used to improve the robustness of the results in this section.

We agree with the reviewer that the inter-model variability is quite substantial (both in EU, as revealed by Davin et al. (2020) and in NA, as revealed by this study's section 4). To emphasize this (and address comment 6 at the same time), we added a new paragraph to the last section:

Section 6:

More generally, it is crucial to recall that this study is based on a very small ensemble of new simulations, i.e three members over North America and only one new member over Europe (although it is complemented by the nine other model combinations from the original LUCAS study). Of the three models used, WRF produced a response that is significantly different from the two versions of the CRCM, whose responses were comparably close. This skewed response distribution with few members, as well as the important structural similarities between the CRCM versions, should be kept in mind when assessing the robustness of the results.

However, we think that this inter-model variability actually makes the ensemble average not very meaningful, especially for North America where the ensemble is quite small (N=3), and where 2/3 of the models (CRCM5 and CRCM6) are very similar and WRF is an outlier, as remarked by the reviewer. It is thus not clear what an average of these three members would mean. For instance, during winter WRF shows no snow-masking, which was deemed unrealistic. It would seem inappropriate to average in this effect in an ensemble response. Similarly, it is not clear what it would mean to take an ensemble mean of the strongly divergent LUCAS-EU summertime responses.

Since we have simulations on both continents with CRCM5, it seems best to first explore the inter-continental comparison with this model only (section 3), then test the robustness of these results with an analysis of the full NA ensemble (section 4).

6. It is important to recognize in the conclusions, and perhaps the paper more broadly, that the ensemble size for NA is quite small.

We agree with the reviewer that this is an important point that was not sufficiently emphasized. We modified the manuscript accordingly (see comment 5 above).