Responses to Editor and Referee's comments

First of all, we would like to thank the Editor and Referee for their comments and suggestions, which improved greatly the presentations and interpretations in our revised manuscript. In the revised article, we have addressed all comments and suggestions from the Editor and Referee. Our point-by-point responses to the Referee's comments are outlined below. The Referee's original comments are shown in italics and our responses are given in normal fonts.

Referee #1

Comments:

Land use change has been demonstrated to show large impacts on regional or even global climate change. This study quantified the LUC-induced albedo change and its radiative forcing based on high-resolution remote sensing-derived LUC dataset. Thank the authors carefully resolved my comments in the previous round of review. Please see below for my further comments.

Response: We thank the Referee's positive and encouraging comments which help us to improve this article considerably.

Major concerns:

1. Line 102-103: The authors stated that they assigned a 5% uncertainty in OSCAR modeled ARF based on LUC data uncertainty. However, what is the LUC data uncertainty? How did the authors derive this 5% threshold? Please provide more details.

Response: The uncertainty of the LUC data is subject to its accuracy (82.81%, Liu et al., 2020). We examined the response of modeled ARF to the 5% uncertainty by increasing the uncertainty to 10% and 15%. The differences of simulated mean ARF between 5% and 10% and 15% were only 0.23% and 0.47%, respectively.

Corresponding text has been added to revised section 2.1.

Liu, H. et al. Annual dynamics of global land cover and its long-term changes from 1982 to 2015. *Earth Syst. Sci. Data* **12**, 1217–1243 (2020).

2. Line 152: The authors mentioned that they conducted extensive sensitivity experiments by reducing each LU transition area by 20% within five major LU types. However, why did the authors select this 20% threshold? Please clearly clarify it.

Response: For many satellite-derived land-use classification products, overall classification accuracies range between 70% and 90%. This implies that misclassifications can lead to an uncertainty of 10% to 30% in land-use area estimates.

So, we took 20% in our sensitivity experiments.

We have added corresponding text and a reference (Gong et al., 2013) in the first paragraph of section 2.3.

Gong, P. et al. Finer resolution observation and monitoring of global land cover: first mapping results with Landsat TM and ETM+ data. *Int. J. Remote Sens.* **34**, 2607–2654 (2013).

3. Line 142: The authors mentioned that they neglected the LUC-induced surface roughness change. Please discuss the potential uncertainty from this.

Response: Following the Reviewer's comment, we have rephrased the last paragraph in revised section 2.2, we wrote:

"The OSCAR model does not take the surface roughness length into account. The surface roughness affects primarily on turbulent exchange of heat and air mass between the underlying surface and air, which may indirectly alter surface radiation fluxes via changing sensible and latent fluxes under a heat balance status (Andrews, 2012). This characteristic can significantly influence RF largely via its association with surface albedo. Given that the OSCAR introduces directly the surface albedo, it is expected that excluding the roughness length would not perturbate RF prediction significantly."

4. The latest LUH2 dataset is available. There are some improvements in LUH2 compared to LUH1. Please use the latest version of LUH2 rather than the out-of-date LUH1.

Response: We thank the Reviewer's suggestion! The LUH2 dataset collectively categorizes grass, shrub, and other surface types into Non-forest types, and the purpose of this study is demonstrate that highly-resolved LUC data might yield significant difference of RF from previous investigations, and to comprehensively assess the effects of transformation among the major LU types on RF. Molded RFs induced by land-use changes using LUH2 and GLASS-GLC might not be consistent and, therefore, LUH2 results are not straightforward to compare with GLASS-GLC derived RF. In fact, the LUC-derived global RF reported in IPCC AR6 used LUH2 dataset (Fig. 1b).

5. Although the GLASS-LUC has a higher spatial resolution, the authors upscaled them to national and regional levels. Please clearly clarify this point.

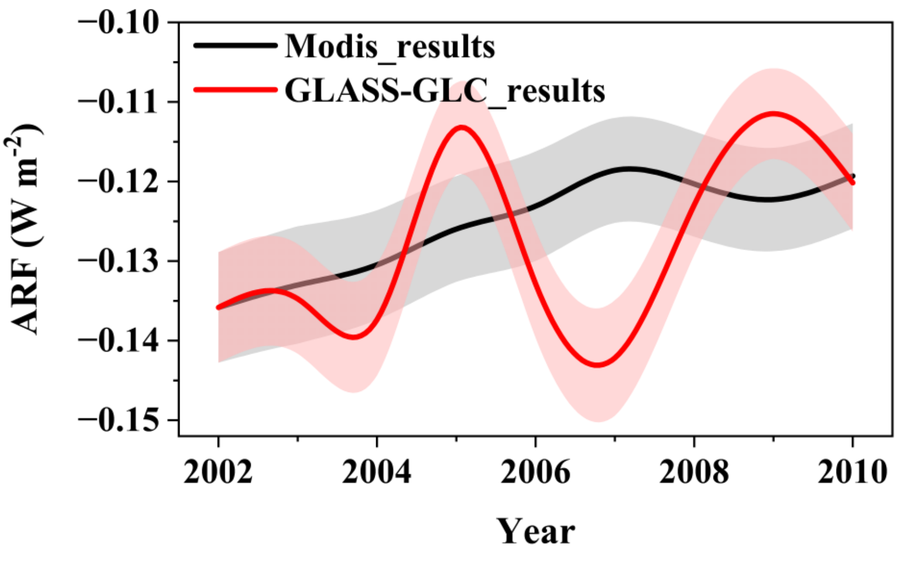
Response: Because the OSCAR is not a grid-resolved model, the highly-resolved LUC data cannot be implemented directly into the model. However, the highly-resolved GLASS-GLC data provides more detailed LU type transition in each country, which plays a crucial role in estimating albedo-induced RF.

6. However, GLASS-LUC also include uncertainties, and is not necessarily more accurate than LUH2 data. I suggest the authors include more remote sensing datasets e.g., MODIS data to increase the robustness of the results.

Response: Following Reviewer's comment, we compared GLASS-GLC and MODIS LUC data, of which, the GLASS-GLC used satellite multi-source fusion approach and MODIS used direct MODIS sensor to derived their respective LUC inventories. The GLASS-GLC dataset spanning 1982-2015 but MODIS data is only available from 2000 onward. So, we replaced the GLASS-GLC by MODIS LULC data from 2002 to 2010 in the OSCAR model. The figure below shows annual fluctuations of the OSCAR simulated annual RF under global forestland changes using GLASS-GLS and MODIS from 2002 to 2010, respectively. Both RF results show annual fluctuations, though the RFs from the CLASS-GLC illustrate somewhat stronger oscillations. However, during this period, accumulated RFs subject to the global forestland changes driven by GLASS-GLC and MODIS LUC are 0.0165 Wm^{-2} and 0.0157 W m^{-2}, respectively, indicating only a 5% difference between the two satellite remote sensing derived LUC datasets.

Sun et al. (2022) compared the applications of six LULC products in the identification of LUCs in Northwestern China. Their results indicated, while the GLASS-GLC and MODIS (MCD-12Q1) were not superior to other four products (developed only for China), these two datasets were of most temporal and spatial consistency. This paper has been cited in the revised paper.

These discussions have been summarized in a new paragraph in section 2.2 (third paragraph).



The GLASS-GLC dataset was further compared temporally and spatially with the LUH1 dataset in Supplementary Figures S1 and S2. While the GLASS-GLC is superior to the LUH1, the magnitude of GLASS-GLC is comparable to LUH1 dataset. Eq. S1 defines the principle of the OSCAR model to predict ARF, which is closely related to the area of LUC, and therefore, the fluctuation of the ARF results is also reflected by the land use conversion data of the dataset, which is well reflected by Figure 3 and Figs. S3-S13 of this paper.

The result has been added to the revised Supplementary Text 2 (the last paragraph).

Sun, W. et al. Land use and cover changes on the Loess Plateau: A comparison of six global or national land use and cover datasets. Land Use Policy 119, 106165 (2022).

7. The authors mentioned that OSCAR does not estimate surface albedos itself. Instead, it collected surface albedos in different countries and regions from literature and other climate models. However, as I know, surface albedo shows large spatial variation even for the same land types. Please provide a direct evaluation of the OSCAR surface albedo using the available remote sensing data, e.g., MODIS. Without such evaluation, the results from this study can be unreliable.

Response: We thank the Reviewer' s suggestion. We agree with the Reviewer that surface albedo vary spatially and temporarily. Albedo can change significantly over time due to seasonal effects, such as snow cover, vegetation growth, and land use changes. This temporal variability makes it challenging to obtain consistent albedo measurements. Surface albedo can also vary greatly over small spatial scales due to changes in land cover, vegetation type, soil moisture, and surface roughness. This spatial complexity complicates the estimation process, particularly in a global scale and a long-term perspective. As a result, it is difficult to obtain an "accurate albedo dataset". In fact, the albedo data from most widely used MODIS and GLASS is only available from 2000 onward, whereas our model simulations extend from 1982 to 2010. Some satellite instruments lunched in the 1980s could provide albedo data in the early stage but these data seemed not consistent with MODIS data.

This study aims to demonstrate the responses of RF to the tempo-spatial resolution of LUC. Following the Reviewer's main comment 4, we compared modeled RF using MODIS LUC and GLASS-GLC datasets from 2002 to 2010, the results revealed minor differences. However, we do recognized uncertainties in OSCAR albedo data in the revised section 2.1.

Nevertheless, efforts will be made in future to replace OSCAR albedo data by satellite remote sensing albedo data, but this will be a time-consuming and heavy task.

Minor concerns:

1. L136-137: Please provide the citation.

Response: Done, thanks!

2. Data availability: Please also share the model output in the study.

Response: Done, thanks! We provide a repository to access relevant output data (https://doi.org/10.5281/zenodo.14586249).

Below are my comments from the previous round of review.

Response: Thanks! These comments have been addressed before the discussion stage.

Land use change has a large impact on global climate change. This study quantified the LUC-induced albedo change and its radiative forcing based on remote sensing-derived LUC dataset. The study is interesting and the results and conclusions are meaningful. However, some issues are needed to be carefully revised: 1) The authors set a lot of thresholds when calculating RFs and carrying out the sensitivity analysis, without accounting the corresponding reasons. 2) The urban change is not accounted for, which can induce large uncertainty. Please see below for my specific comments.

Major concerns:

1. *Line 15-18: Land use change has complex impacts on climate change. Whether it is cooling or warming effect depends on the specific conversions from one land use to another land use. Land use change can emit GHG, change surface albedo and ET, and further affect climate. However, which factor dominates depends on the specific conditions.*
2. *L103: The authors assigned a 5% uncertainty in modeled ARF induced by LUC uncertainty. However, why the authors set this value is unclear. How did the authors use this in the model?*
3. *L131: Some studies (e.g., Ouyang et al., 2022) have shown that urbanization has an albedo-induced warming effect. However, this study neglected the urban change, which may induce large uncertainties.*

Ouyang, Z., Sciusco, P., Jiao, T. et al. Albedo changes caused by future urbanization contribute to global warming. Nat Commun ***13****, 3800 (2022). https://doi.org/10.1038/s41467-022-31558-z*

1. *L139: In the sensitivity experiments, why did the authors set this threshold of 20%?*
2. *GLASS LC data cover 1982-2015. Why did the authors just analyze the data from 1983-2010?*
3. *Section 2.1: Please clarify how OSCAR model uses the land use data, considering it is not spatially resolved.*
4. *3: why did the authors select 1% as the threshold?*
5. *Figure 1 & 2: Please explain why the simulations in S1 and S2 show very different trends in the global average and regional values. Please add the corresponding LUC analysis and clearly explain it in the main text.*
6. *Line 157: Considering that there is a big difference between LUH1 and GLASS, replacing LUH1 with GLASS in 1982 can induce some uncertainties. Please discuss it. How did the authors harmonize these two LUC datasets?*

7. *The work neglected the impacts of LUC on surface roughness, which deserves some discussion.*
8. *In the methods section, the authors mainly introduced the sensitivity analysis. Also need to introduce how to use two LUC datasets for the analysis of albedo-induced RFs. Please also introduce the objective of the sensitivity analysis. In the sensitivity analysis, the authors define multiple new variables. However, some of them are not easy to understand. Please make them easier to follow.*
9. *There is a large spatial variation of surface albedo. Surface albedo is dependent on the vegetation structure, leaf/soil albedo and surface topography. I am curious how OSCAR considers the spatial variation of surface albedo.*

Minor concerns:

1. *L67: Please provide the citation.*
2. *L163: to2010 -> to 2010.*
3. *L267: This equation can be moved to methods section.*
4. *Figure 3: Effective area and RF have different units. Why did the authors put them together?*