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Observation-constrained Radiative Forcing from historical land-cover changes in CMIP5 models

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The albedo of trees is lower than the one of crops and grasses, especially in the presence of snow. It is therefore understood that the replacement of forests by croplands and grasslands used for agricultural purposes that has occurred since pre-industrial times led to large-scale albedo increases. This is reflected by the estimate of the Radiative Forcing (RF) from historical Land-Cover Changes (LCC) of the Fifth Assessment Report (AR5) of the IPCC, which amounts to -0.15 +/- 0.10 W/m^2. However, this expert judgment was intended to both account for a few studies using single climate models which put forward values close to 0.2W/m^2, and the finding that climate models usually overestimate the albedo difference between natural vegetation and croplands in comparison to satellite-derived observational evidence. Further uncertainties around this number have also been suggested by studies revealing a substantial model spread in the albedo response to historical LCC. This points at the need to revisit the IPCC AR5 conclusions in light of recent model intercomparison efforts and observational data.

In this study, we reconstructed the local albedo changes induced by conversions between trees and crops/grasses since 1860 for 15 CMIP5 models. We evaluated the employed methodology using factorial experiments isolating the historical LCC forcing in four models for which the required simulations are available, and obtained very similar results. Using an empirical parameterisation of the radiative kernel, we then derived estimates of the associated RF ranging between 0 and -0.22 W/m^2, with a multi-model mean value of -0.07 W/m^2.

Furthermore, we constrained the RF estimates with observations by replacing the albedo response to the transition between trees and crops/grasses from the models by that provided by satellite-derived data. This led to an unexpected increase in the range between the models, due to two models having unrealistic conversion rates from trees to crops/grasses. Excluding these two models, we obtain a revised multi-model mean estimate of -0.11 W/m^2 (with individual model results between -0.04 and -0.16 W/m^2). We were also able to link the differences between the unconstrained and constrained RF estimates to some of the model biases in the albedo sensitivity to deforestation.

Since the conversions between trees and crops/grasses are responsible for almost the totality of

historical albedo changes in CMIP5 models, our findings are comparable to previous estimates of the RF from all LCC. They point at values that are at the lower end of the range provided by the IPCC AR5. The approach described in this study can be applied on other model simulations, such as those from CMIP6.