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

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EGU Share Geoscience online // CL2.1 Earth radiation budget, radiative forcing and climate change // 6.5.2020

Paper in discussion in Earth System Dynamics

https://doi.org/10.5194/esd-2019-94
Preprint. Discussion started: 2 April 2020

Earth System Dynamics Discussions
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Biases in the albedo sensitivity to deforestation in CMIP5 models and their impacts on the associated historical Radiative Forcing

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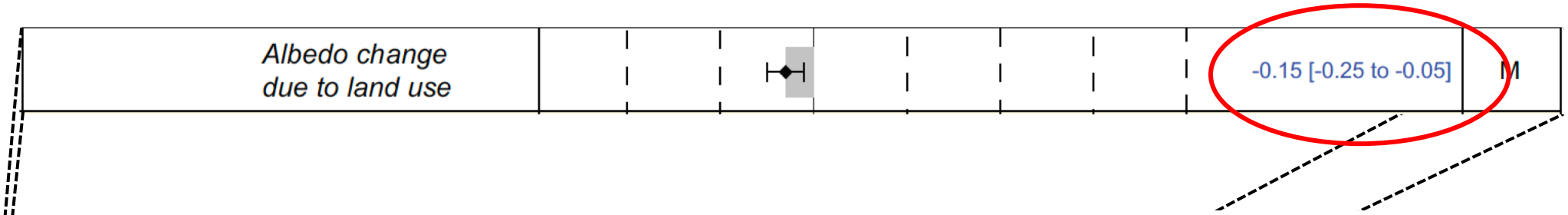
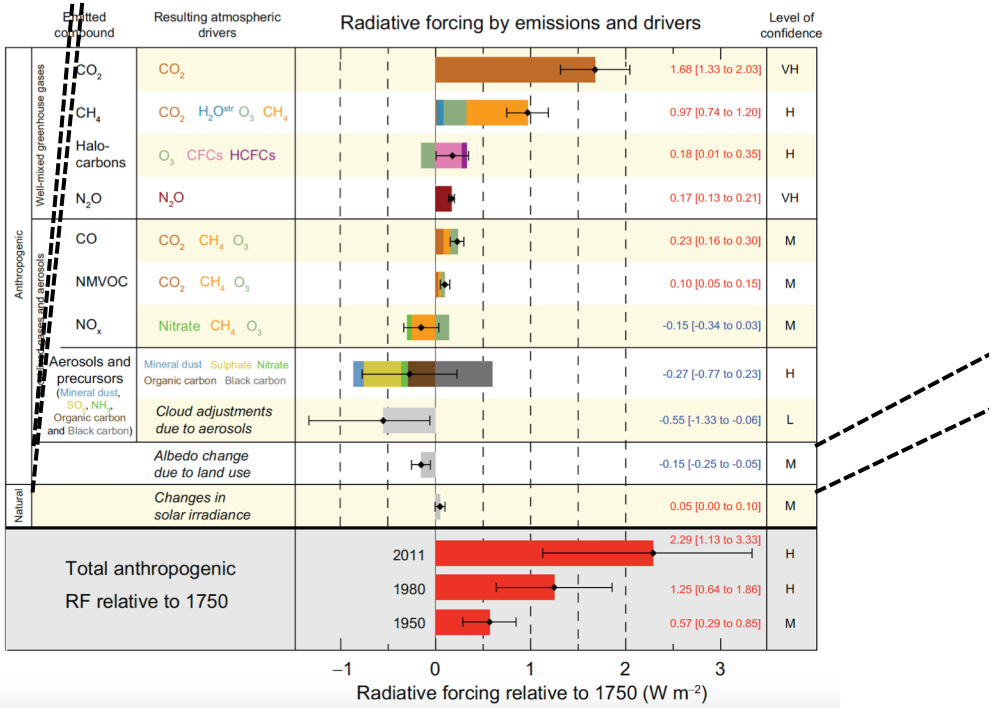
Current knowledge about the Radiative Forcing from land-cover changes since pre-industrial times





However:

- the albedo change between natural vegetation and croplands is usually overestimated in climate simulations compared to satellite-derived observational evidence
- there is a substantial spread in the model parametrizations for the albedo response to land-cover perturbations
- this estimate has not been revisited with a multi-model estimate derived from CMIP5 yet

Myhre et al., 2013

A new method to extract the albedo of trees and crops/grasses in standard (CMIP5) climate simulations

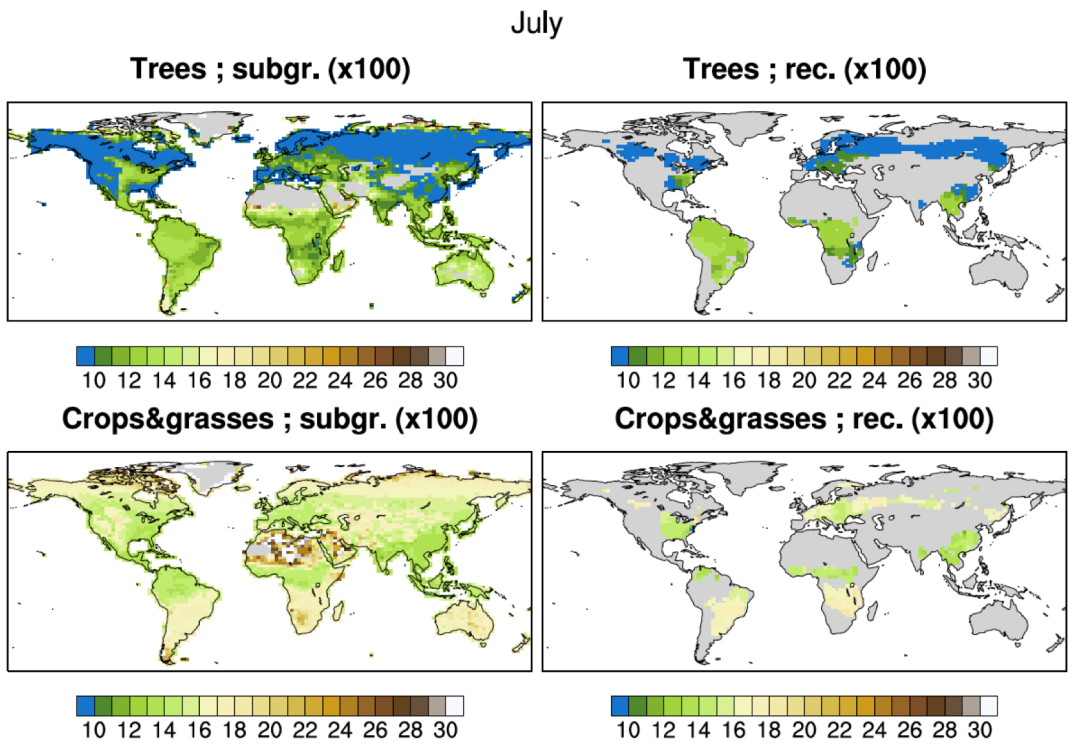


Figure 1: Subgrid (left) and reconstructed (right) estimates of the albedo of trees (upper row) and crops/grasses (lower row) in the CLM4.5 simulations, for the month of July. Note that absolute differences have been multiplied by 100 to facilitate readability.

- based on a multiple linear regression between the present-day land cover fractions (predictors) and albedo (predictand) within a moving window encompassing 5X5 grid cells
- we differentiate between snow-free and snow-covered pixels and different local regressions are calculated among each of these two categories
- validation by applying the method to CLM4.5 simulations that also provide the albedo of these land-cover types (contrary to CMIP5 simulations)

Derivation of the albedo change associated to a conversion from trees to crops/grasses

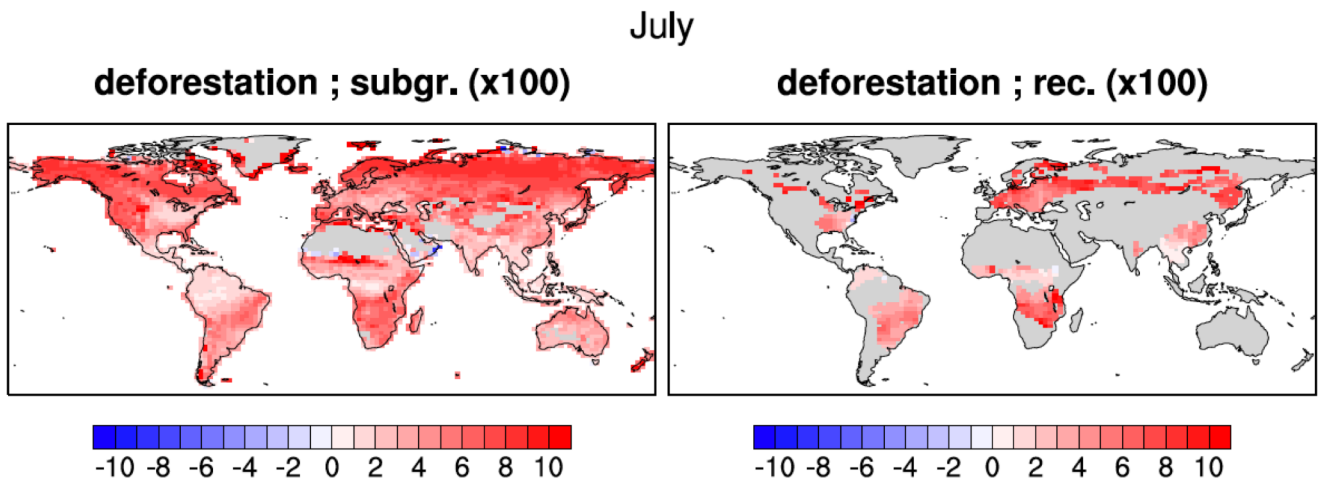


Figure 3: Subgrid (left) and reconstructed (right) estimates of the albedo change associated to a transition from trees to crops/grasses in the CLM4.5 simulations, for the month of July. Note that absolute differences have been multiplied by 100 to facilitate reading.

Identification of biases in the albedo of trees and crops/grasses among CMIP5 models

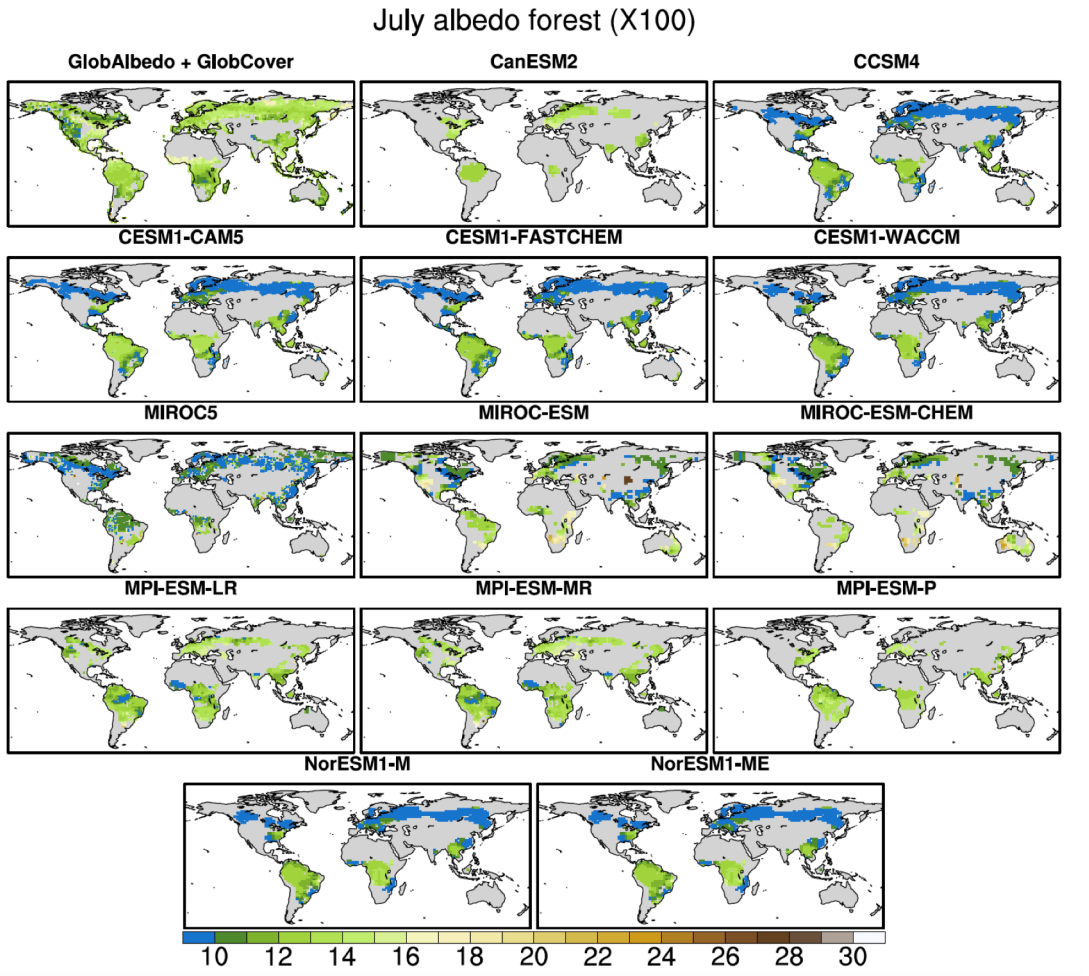


Figure 5: July albedo of trees retrieved from the combination of the observational data GlobAlbedo and GlobCover (top-left corner) and in the analysed CMIP5 models. Note that the albedo values have been multiplied by 100 to facilitate readability.

- observational reference data derived from GlobAlbedo and GlobCover v2.3

Identification of biases in the albedo change associated to conversions from trees to crops/grasses

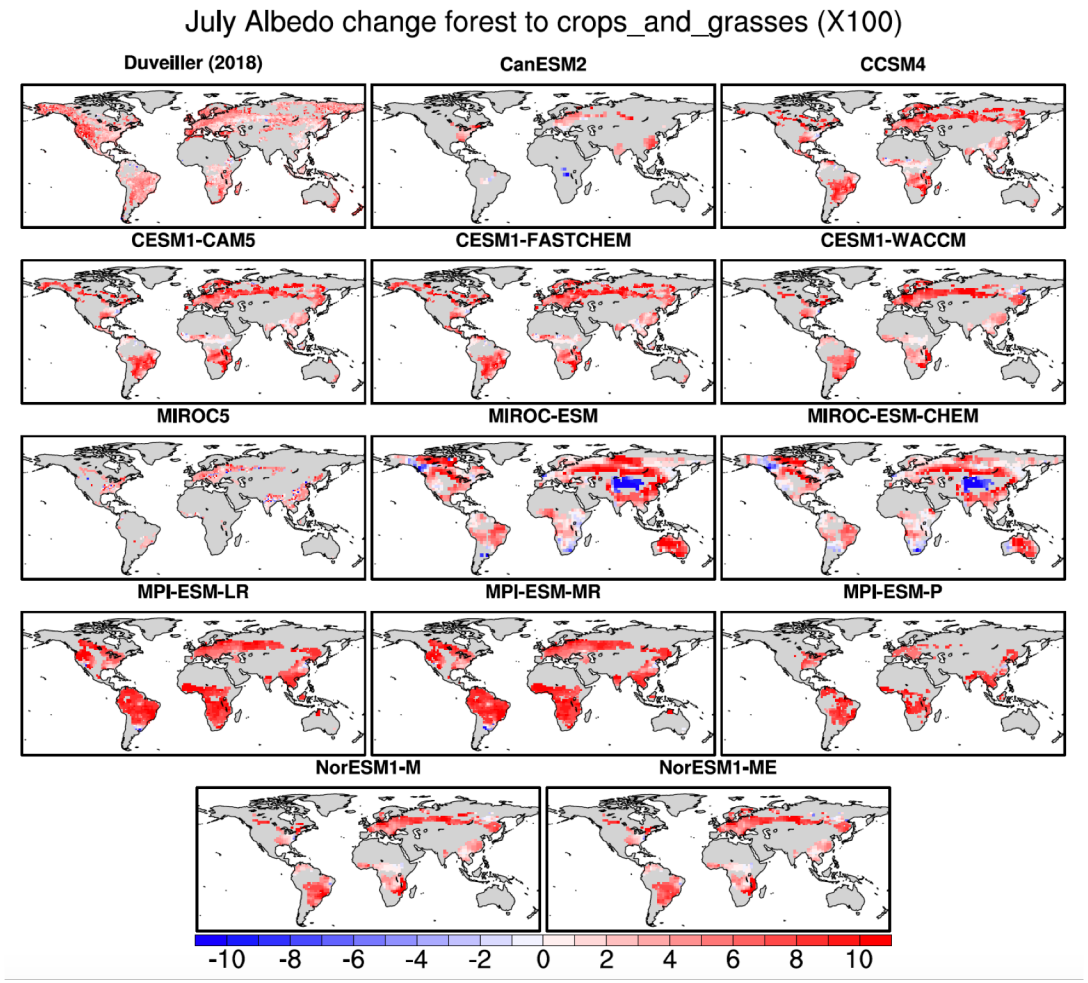


Figure 9: July albedo change associated to a transition from trees to crops/grasses according to the observational dataset of (Duveiller, Hooker and Cescatti, 2018) **(top-left corner) and in the analysed CMIP5 models.**

- observational reference data from Duveiller et al. (2018)

Derivation of the Radiative Forcing associated to albedo changes from historical de/reforestation in CMIP5

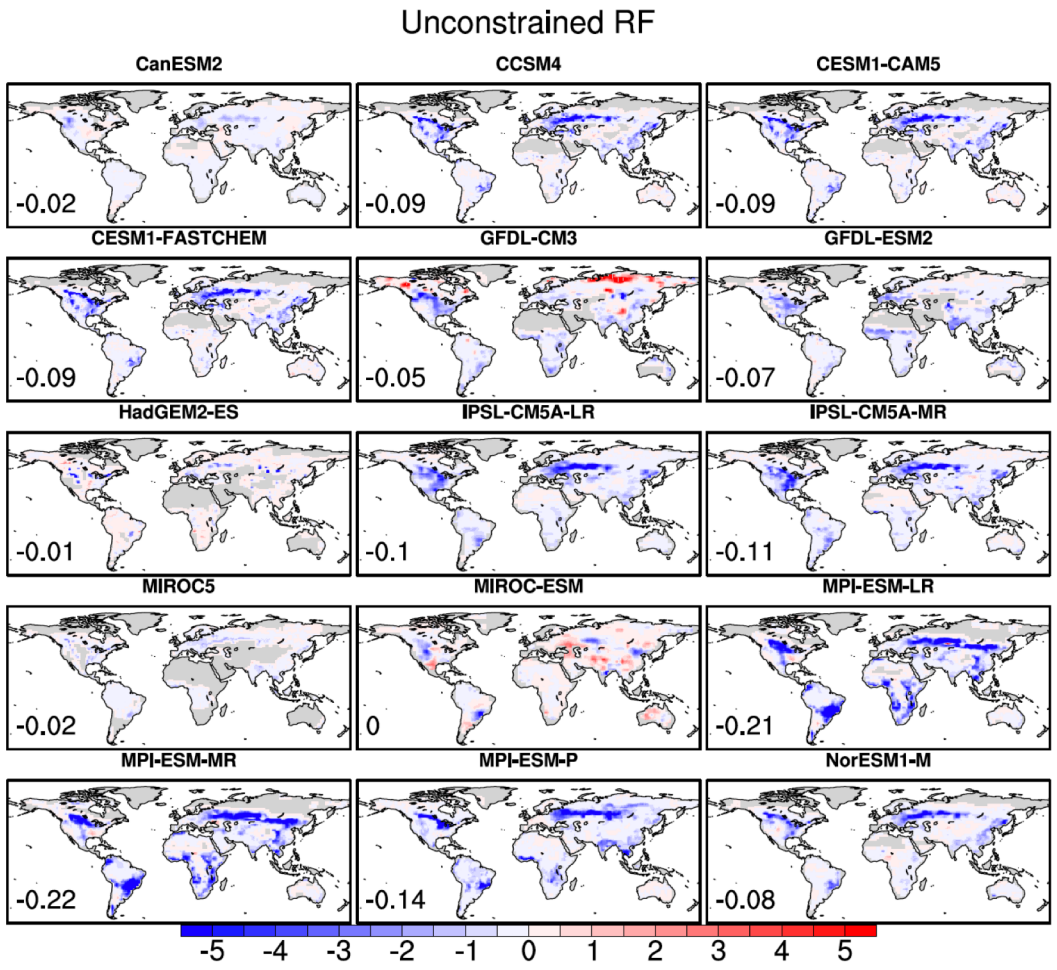


Figure 11: Radiative Forcing from historical deforestation in the analysed CMIP5 models (in W/m²), obtained by applying the reconstruction method. The numbers in the bottom-left corner of each map indicate the global mean Radiative Forcing from historical deforestation.

trees

crops/grasses

downwelling shortwave radiation

albedo change due to transitions from trees to crops/grasses

$$RF_{tr \to cg} = 0.854 \times SW_s^{\downarrow} \times \delta\alpha_{tr \to cg}$$

- parameterisation based on Cherubini et al. (2012)
- downwelling SW radiation from CERES-SYN1deg
- albedo change associated to conversions from trees to crops/grasses extracted from CMIP5 models (see previous slides)

Constraining the Radiative Forcing associated to albedo changes from historical de/reforestation in CMIP5

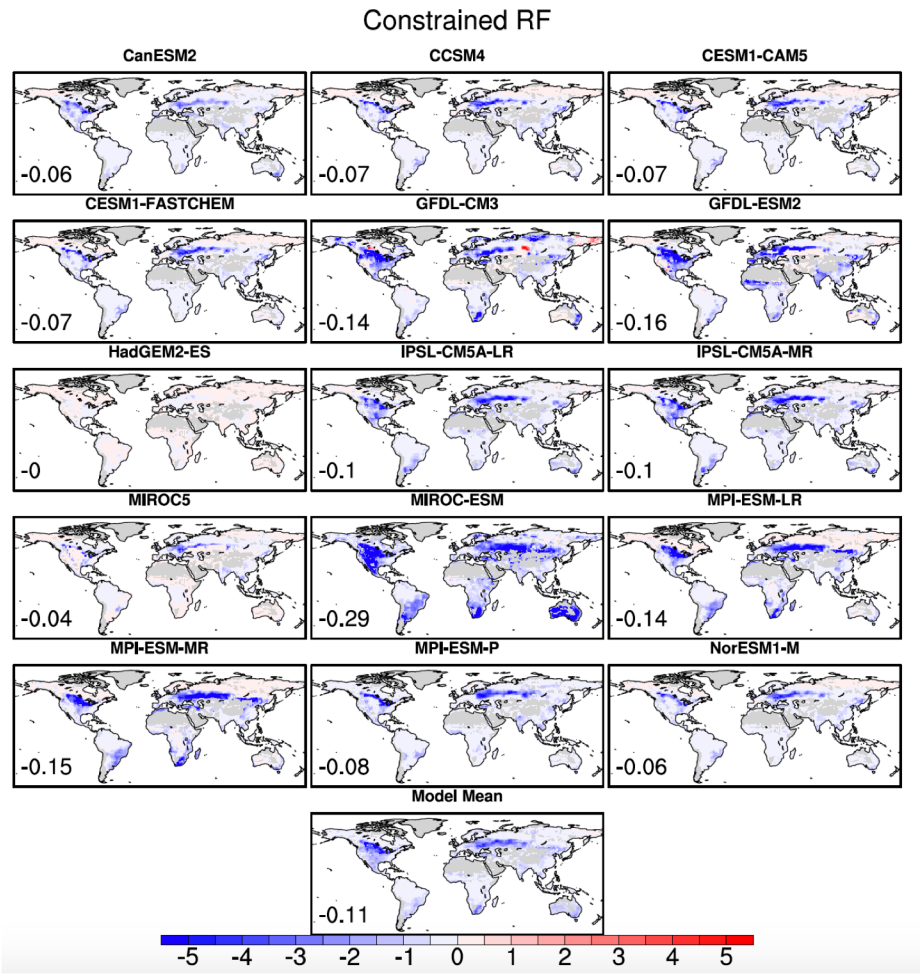


Figure 12: Observation-constrained Radiative Forcing from historical deforestation in the analysed CMIP5 models (in W/m^2). The numbers in the bottom-left corner of each map indicate the global mean Radiative Forcing. To compute the Model Mean, if several CMIP5 models contain the same Land Surface Model they were attributed a lower weight so that the sum of these weights equal 1.

trees

crops/grasses

downwelling shortwave radiation

albedo change due to transitions from trees to crops/grasses

$$RF_{tr\rightarrow cg} = 0.854 \times SW_s^{\downarrow} \times \delta\alpha_{tr\rightarrow cg}$$

- albedo change associated to conversions from trees to crops/grasses from observational reference data (Duveiller et al., 2018)

Best estimate of the Radiative Forcing associated to albedo changes from historical LCC in CMIP5: -0.11W/m^2

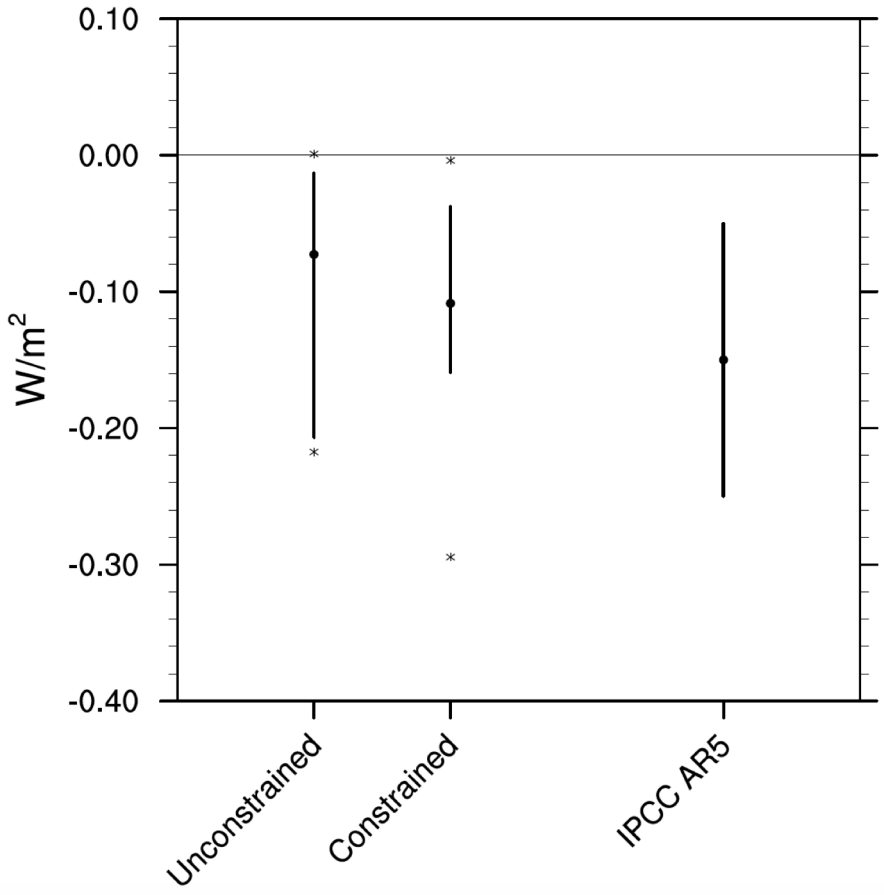


Figure 13: Spread in the unconstrained (left bar) and observation-constrained (middle bar) estimates of the global Radiative Forcing from historical deforestation for the CMIP5 models shown in Figures 11 and 12 (in W/m^2), as well as the IPCC AR5 estimate of the global Radiative Forcing from historical land-use changes (mean estimate and spread as in (Myhre *et al.*, 2013)**). The dots on the left and middle bars show the model mean results for the unconstrained and observation-constrained estimates, respectively, the asterisks mark the lowest and highest value for each category, while the lengths of the bars indicate the spread between the first and ninth deciles.**

- two outliers from the „constrained“ range of estimates have unrealistic changes in tree or crop/grass cover
- constraining the biases in the representation of albedo from specific land cover types with observational data reduces the spread among the other models
- as deforestation/reforestation represents the dominant land cover change in CMIP5 models, this can be considered as an estimate of the RF associated to albedo changes from historical LCC

References

- Cherubini, F., Bright, R. M. and Strømman, A. H. (2012) ‘Site-specific global warming potentials of biogenic CO2 for bioenergy: contributions from carbon fluxes and albedo dynamics’, Environ. Res. Lett, 7, p. 45902. doi: 10.1088/1748-9326/7/4/045902.

- Duveiller, G., Hooker, J. and Cescatti, A. (2018a) ‘A dataset mapping the potential biophysical effects of vegetation cover change’, Scientific Data. Nature Publishing Groups, 5. doi: 10.1038/sdata.2018.14.

- Myhre, G. et al. (2013) ‘Anthropogenic and Natural Radiative Forcing’, in Stocker, T. F. et al. (eds) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, US: Cambridge University Press