

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



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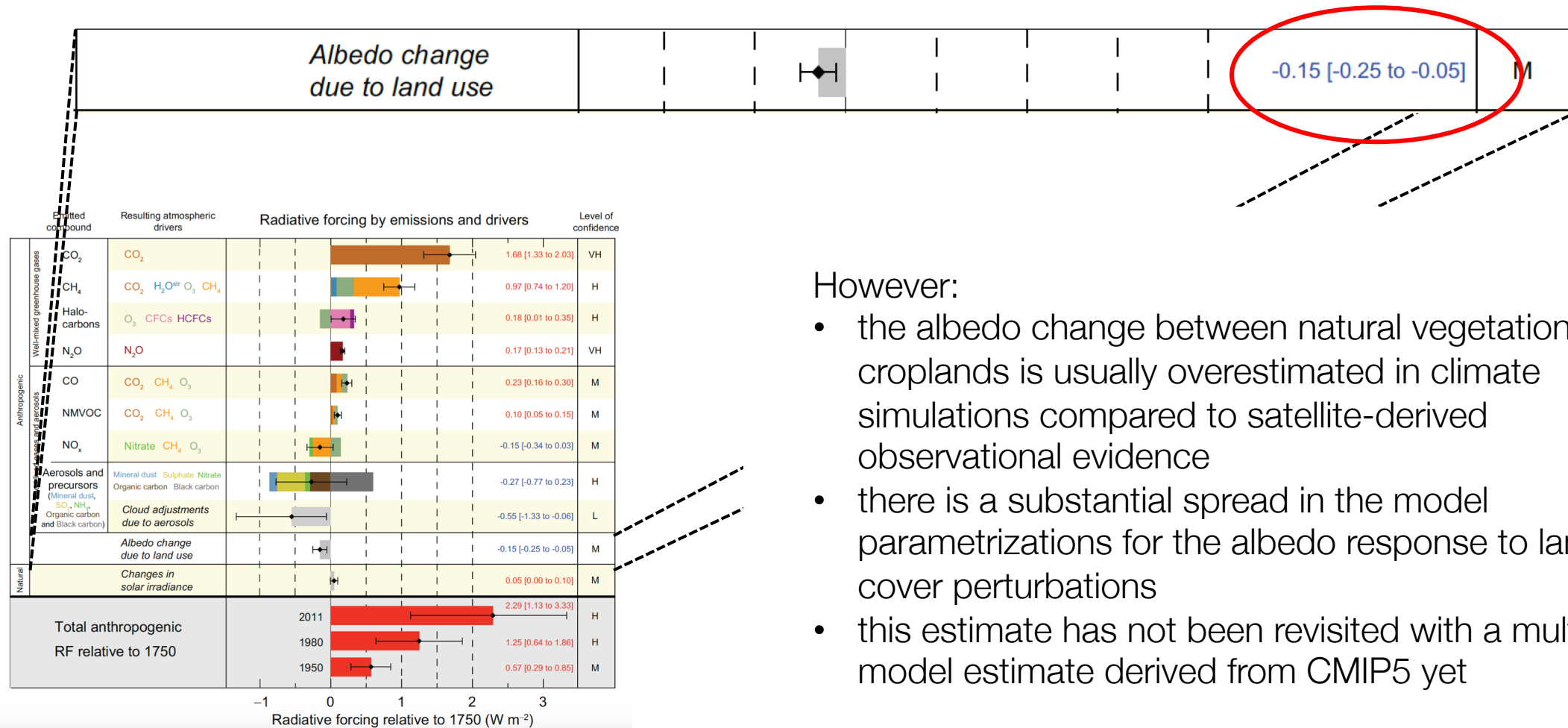
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# Current knowledge about the Radiative Forcing from land-cover changes since pre-industrial times



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

# New method: albedo changes from historical conversions between trees and crops/grasses in CMIP5 simulations

within a moving window (5X5 model grid cells),  
local multi-linear regression:

$$\delta\alpha_{tr \rightarrow cg} = \delta_0 + lcc_{tr \rightarrow cg} \times \delta_1 + lat \times \delta_2 + lon \times \delta_3 + elev \times \delta_4$$

albedo changes

conversion rates between  
trees and crops/grasses

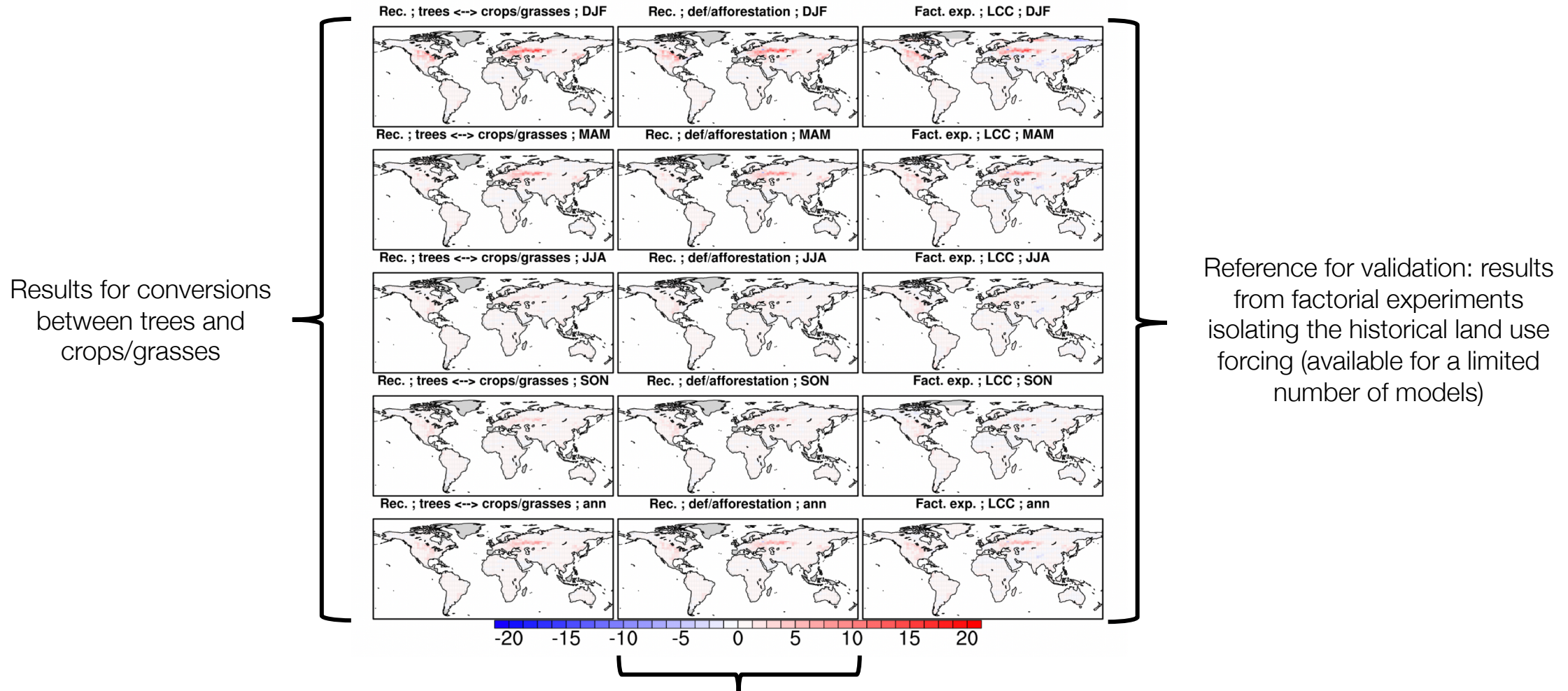
latitude longitude elevation

for the grid cell  $i$  in the center of the  
moving window:

$$\delta\alpha_{tr \rightarrow cg}(i) = lcc_{tr \rightarrow cg}(i) \times \delta_1$$

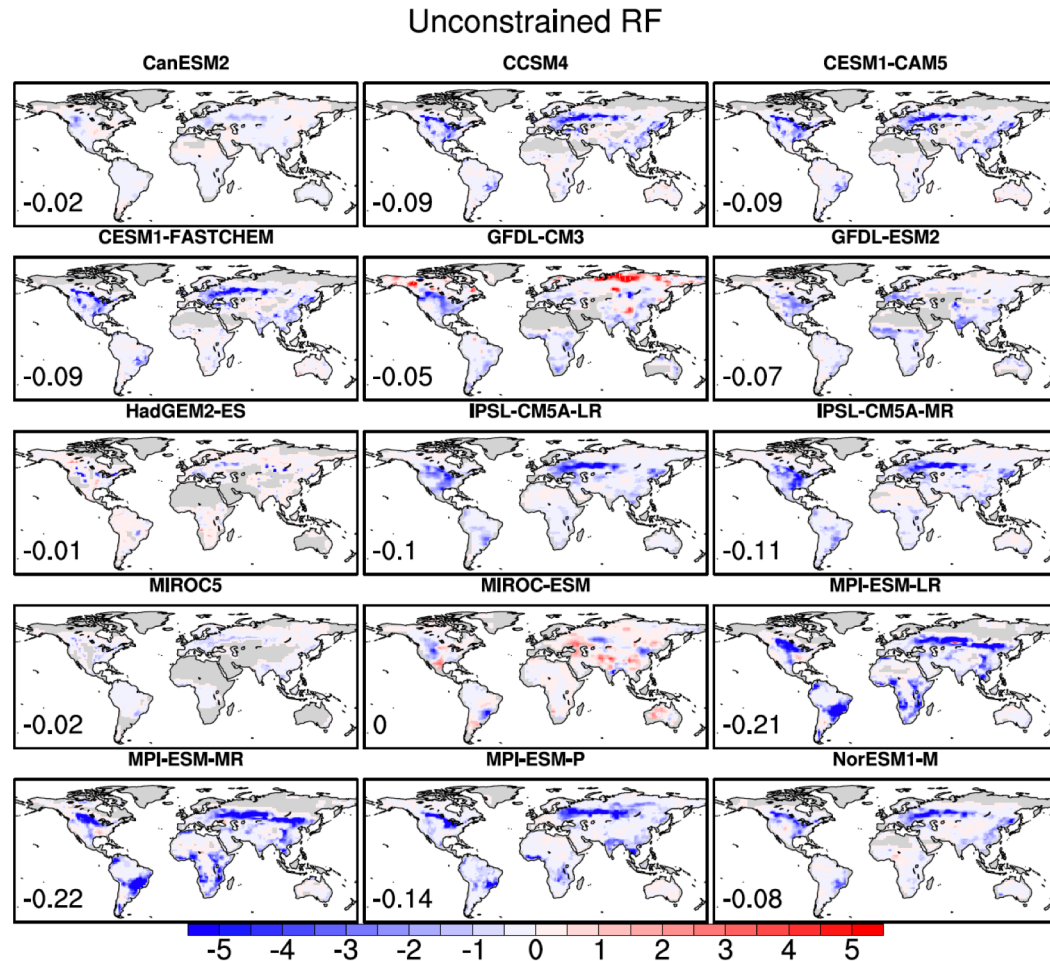
# New method: albedo changes from historical conversions between trees and crops/grasses in CMIP5 simulations

Results for IPSL-CM5A-LR





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



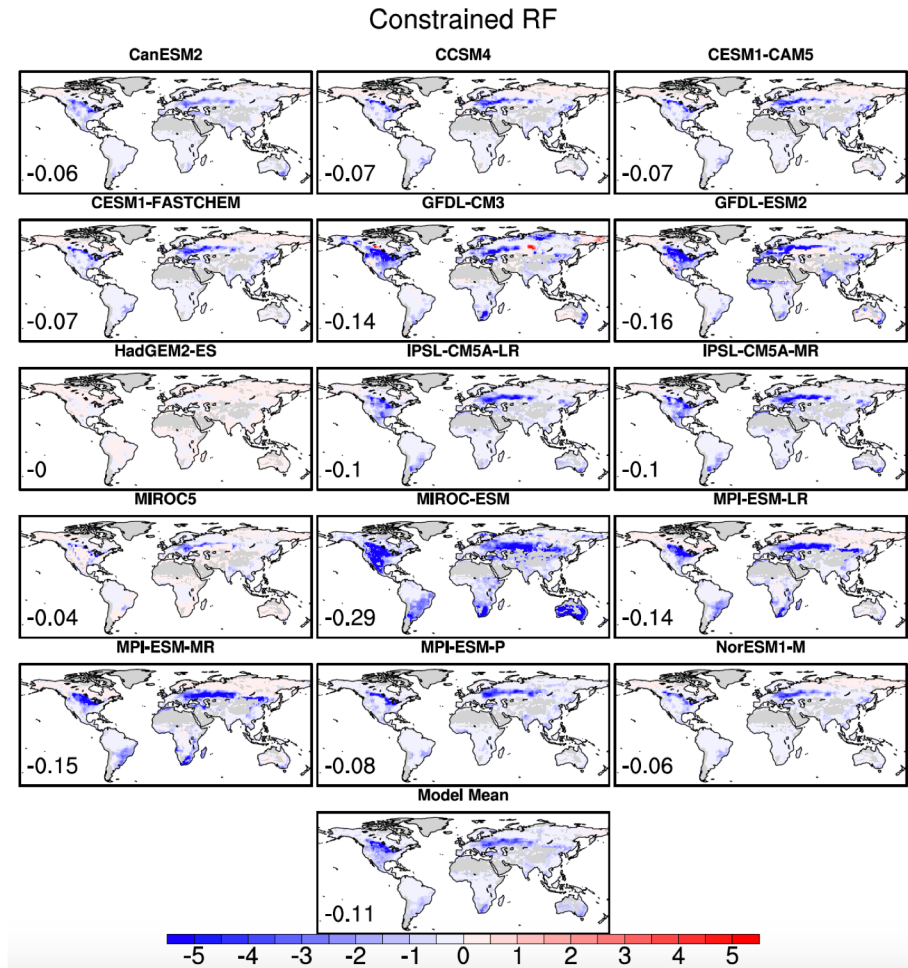
crops/grasses  
 trees  
 downwelling shortwave radiation  
 albedo change due to transitions from trees to crops/grasses

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

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

Figure 11: Radiative Forcing from historical deforestation in the analysed CMIP5 models (in W/m<sup>2</sup>), 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.

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



crops/grasses

trees

downwelling shortwave radiation

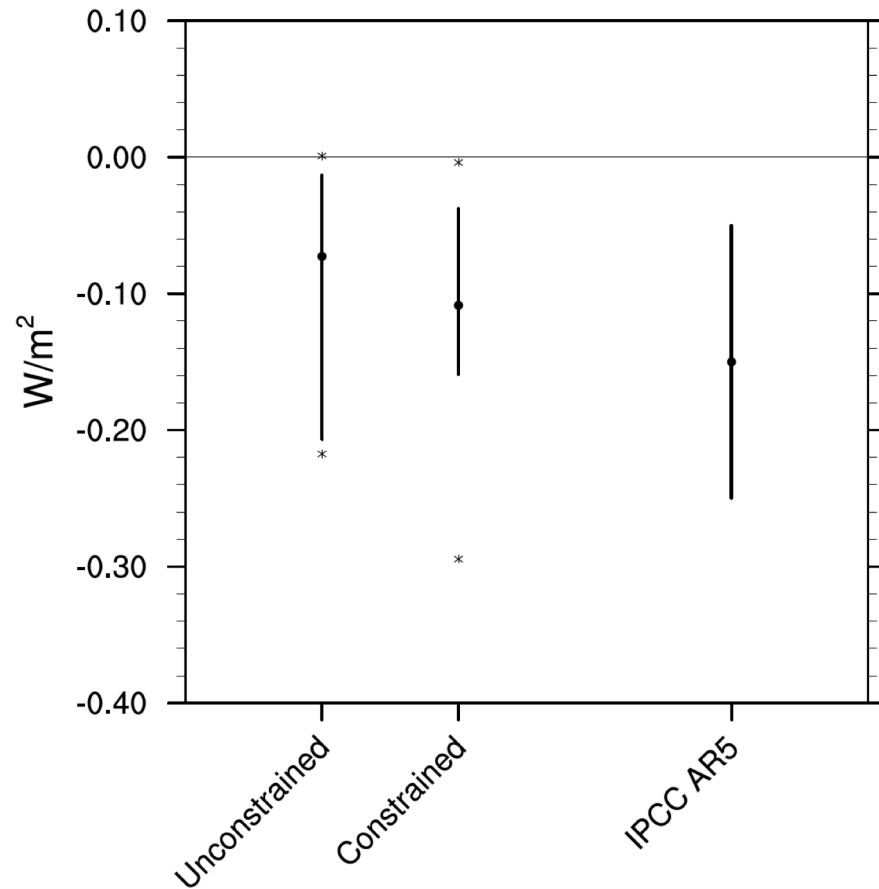
albedo change due to transitions from trees to crops/grasses

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

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

Figure 12: Observation-constrained Radiative Forcing from historical deforestation in the analysed CMIP5 models (in W/m<sup>2</sup>). 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.

# Best estimate of the Radiative Forcing associated to albedo changes from historical LCC in CMIP5: $-0.11\text{W/m}^2$



- 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

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  $\text{W/m}^2$ ), 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.



# Summary

- We have developed a method to derive the global Radiative Forcing from albedo changes associated to historical land-cover changes in standard simulations from 13 CMIP5 models
- The RF estimates have also been constrained using the albedo changes associated to land cover conversions from observational data
- After excluding two models with unrealistic historical land-cover changes:
  - Unconstrained estimates:  $-0.07 \text{ W/m}^2$  (model mean), from  $-0.01$  to  $-0.22 \text{ W/m}^2$  (spread)
  - Constrained estimates:  $-0.11 \text{ W/m}^2$  (model mean), from  $-0.04$  to  $-0.16 \text{ W/m}^2$  (spread)
  - compared to IPCC AR5:  $-0.15 \text{ W/m}^2$  [ $-0.25$  to  $-0.05$ ]
- In our paper, we also discuss the individual model results in relation to identified biases in the representation of the albedo of trees and crops/grasses. Check out <https://www.earth-syst-dynam-discuss.net/esd-2019-94/#discussion>

# References

- Cherubini, F., Bright, R. M. and Strømman, A. H. (2012) 'Site-specific global warming potentials of biogenic CO<sub>2</sub> for bioenergy: contributions from carbon fluxes and albedo dynamics', *Environ. Res. Lett.*, 7, p. 45902. doi: 10.1088/1748-9326/7/4/045902.
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