Analysis of the IPCC AR5 transformation pathways with a new compact Earth system model

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❶ Introduction

The climate impacts of all transformation pathways from IPCC AR5WG3 (AR5 WG3 Ch.6) were estimated with a single model named MAGICC. It was shown to produce consistent climate projections when concentration-driven (AR5 WG1 Ch. 12). However, its carbon-cycle - and therefore its ability to be emission-driven - was shown to be slightly biased (AR5 WG1 Ch. 6). A large fraction of non-CO2 forcings - as expected in low-carbon scenarios- also makes its projections span a narrower range than that of complex models (AR5 WG1 Ch. 12).

Here, we use OSCAR 2.2, a new reduced-form Earth system model to analyze the AR5 WG3 transformation pathways. **Our analysis aims at detecting and understanding the cause of any systematic bias induced by using only one reduced-form model**. Ultimately, the use of two compact Earth system models, instead of a single one, will help the analysis of socio-economic scenarios to gain in reliability, and will therefore improve the next IPCC special report on the 1.5C target.

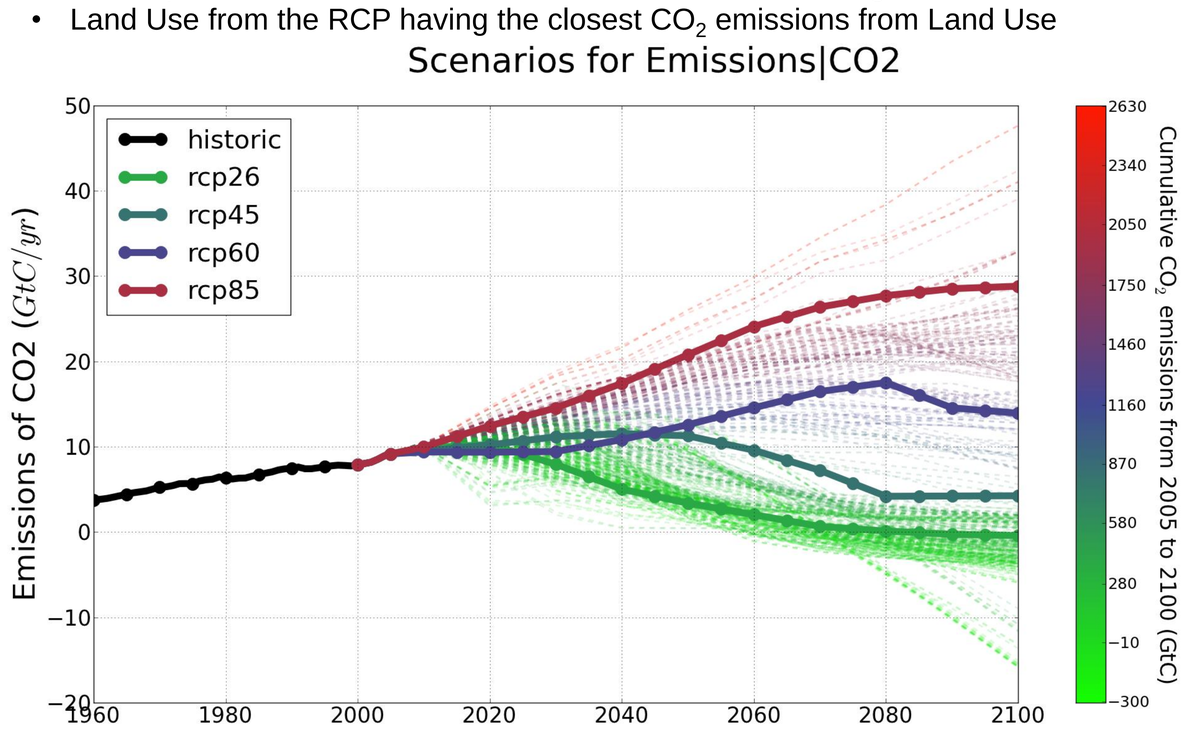
❷ Material: scenarios of emission

We use the database from AR5WG3, starting in 2005. We reproduce the same treatment as described in Annex II.10 AR5WG3 and Schaeffer et al (2015):

- Selection of scenarios: if CO_2 from Fossil Fuels & Industry, CH_4, N_2O are provided
- Completion of missing gases
  - CO_2 from Land Use: mean of RCP used
  - SO_x : relation with the SO_x/CO_2 from the baseline of the scenario
  - Other gas: *"central model"* or interpolation on RCP
- Rescale on RCP emissions, with the factor decreasing to 1 in 2050

Treatment added:

- Estimates are based on the global totals, and not the regional totals
- Decomposition of F-Gases into all HFC,PFC, ODS according to the mean of RCP
- Land Use from the RCP having the closest CO_2 emissions from Land Use

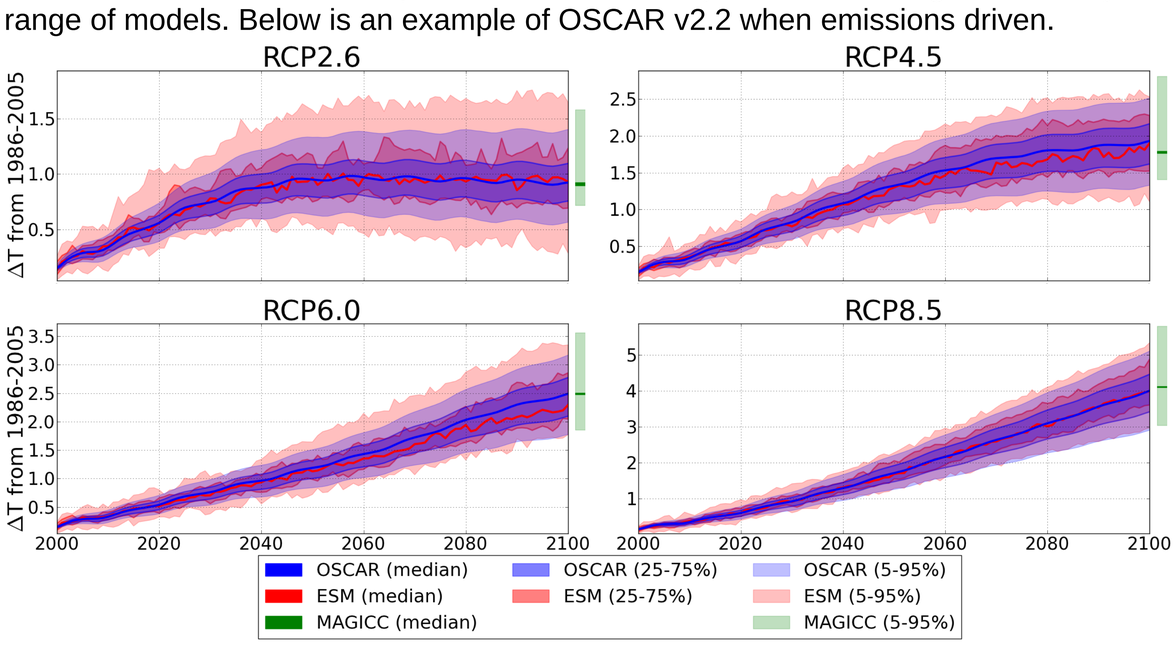


❸ Material: OSCAR v2.2

OSCAR v2.2 is an Earth system model of reduced complexity [Gasser et al., 2016 ; Li et al., 2016]:

- Calibrated on the latest intercomparison exercises (CMIP5, TRENDY, ACCMIP, CCMVal2, WETCHIMP) and on more complex models like ESM.
- Advanced carbon-cycle representation
- Emulates the complete range of results in non-CO_2 modeling by complex models
- Exchanges the spatial & temporal resolution for more interactions and feedbacks

OSCAR v2.2 allows to combine the sensitivities of different more complex models across its modules, thus to reproduce the uncertainty in climate change induced by the range of models. Below is an example of OSCAR v2.2 when emissions driven.



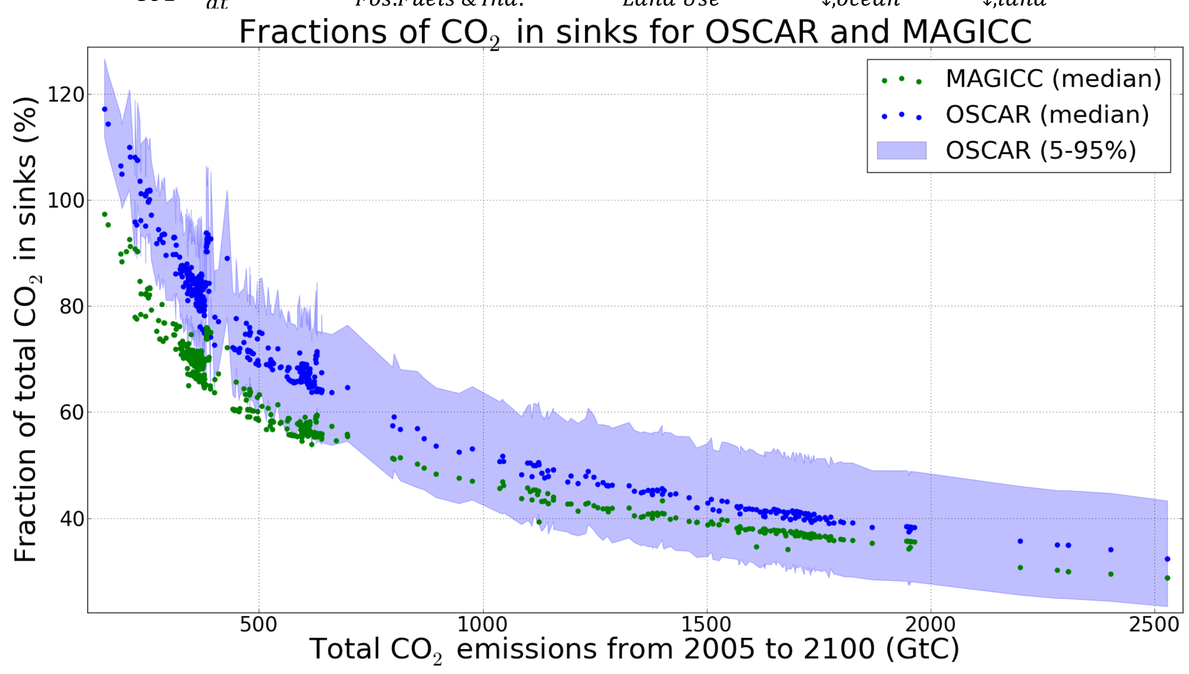
❹ Method

- **1700-2005** → Monte-Carlo analysis with equiprobability for all parameters of OSCAR. Selection of 100 configurations among 3000 under constraints :
  - → ΔCO_2, ΔN_2O, ΔCH_4 from 1990-2000 to 1755-1765
  - → ΔT from 1990-1999 to 1880-1909
- **2005-2100** → For the 523 scenarios with sufficient data, simulation for all constrained configurations
- Comparison of distributions

❺ Different carbon cycles: overview

To evaluate the differences between the carbon cycles of MAGICC and OSCAR, we compute the total CO_2 sink for all scenarios using:

$$\alpha_{CO2}\frac{d[CO_2]}{dt} = E^{CO2}{}_{Fos.Fuels\,\&\,Ind.} + E^{CO2}{}_{Land\ Use} + F^{CO2}{}_{\downarrow,ocean} + F^{CO2}{}_{\downarrow,land}$$

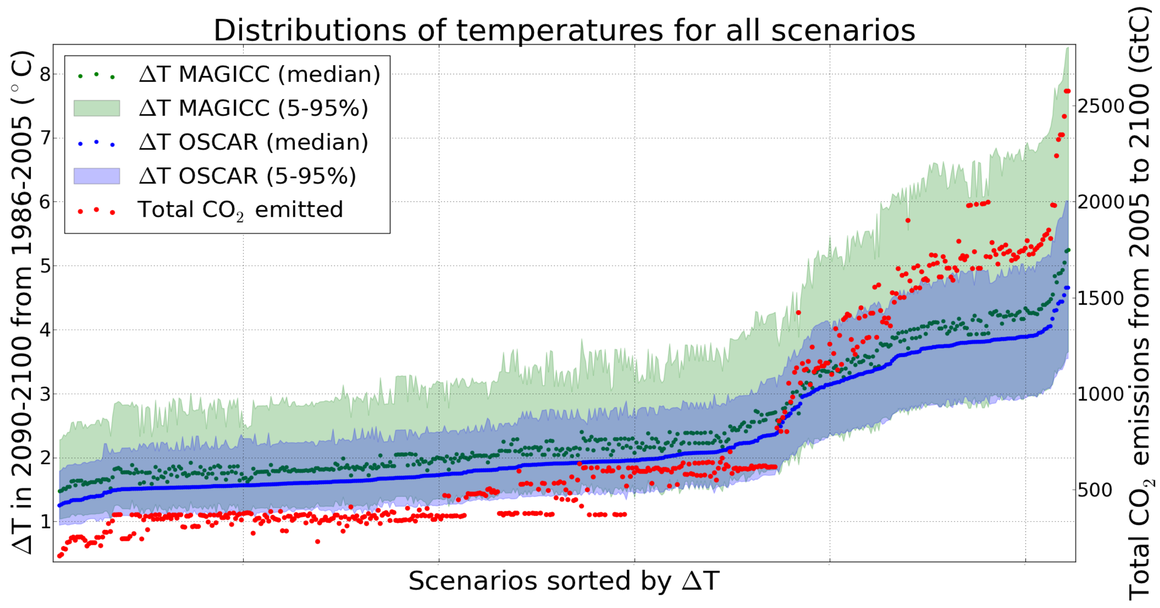


The bias in the carbon cycle seems relatively independent of total CO_2 from scenarios.

❻ Impact on temperatures

The evaluation of the range from non-CO2 forcings require more data on the distribution of forcings of MAGICC. However, the distributions of temperatures in 2090-2100 show :

- in the median: a bias almost independent from CO_2 emissions
- in the upper range: a bias increasing with CO_2 emissions



❼ Conclusion

This is a work in progress. Nevertheless, we have shown that:

- OSCAR v2.2 reproduces the produced uncertainty in climate change by ESM, even when emissions-driven.
- MAGICC CO_2 sinks are not as efficient than those of OSCAR. Further information are required to evaluate which sink and in which conditions.
- MAGICC seems to have non-CO_2 forcings spanning a range wider than OSCAR

The study of the climate impacts of transformation pathways should rely on more than a single reduced-form ESM, especially when considering 1.5°C or 2°C targets.

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