Probabilistic quantification of allowable carbon emissions for meeting multiple climate targets

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SUMMARY POINTS

1) Probabilistic projections of future climate change that quantify uncertainties are essential to inform society and policy makers.

2) A global mean temperature target such as 2°C is not sufficient to limit the risks from greenhouse gas emissions as required by article 2 of the UNFCCC.

3) We show that multiple climate targets that include ocean acidification, sea level rise, and agricultural productivity (Fig. 1) require considerable lower CO_2 emissions than a temperature target alone (Fig 2).

4) Multiple climate targets must be taken into account simultaneously because allowable emissions for a multi-target are even lower than for the most stringent single target.

More information:

M. Steinacher, F. Joos, T. F. Stocker: Allowable carbon emissions lowered by multiple climate targets. *Nature* 499, 197-201, doi:10.1038/nature12269, 2013.

http://www.climate.unibe.ch/~steinach/climate_targets/

Figure 1: Global change targets to limit multiple anthropogenic impacts on the climate system and ecosystem services. The allowable emissions compatible with these targets are shown in Fig. 2 for two target sets of different stringency (**A** and **B**).

Target definitions: ΔSAT: global mean surface temperature increase since year 1800; SSLR: steric sea level rise since 1800; OA_{SO}: aragonite undersaturation ($\Omega_{arag}<1$) of the Southern Ocean surface (south of 50°S); $OA_{\Omega>3}$: global loss of surface waters with $\Omega_{arag}>3$ since 1800; A_{cNPP}: cropland areas with NPP reductions of 10% or more relative to year 2005; C_{cSoil}: global soil carbon loss on croplands since 2005.

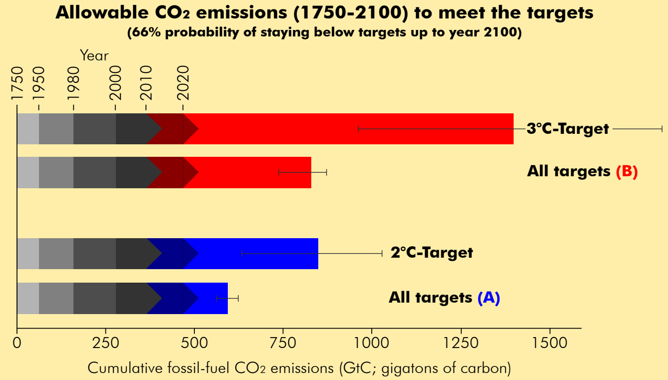
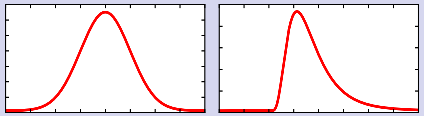


Figure 2: Allowable fossil-fuel emissions for the 2°C and 3°C temperature targets and for the multi-target sets **(A)** and **(B)**. Error bars indicate the uncertainty given by the range of plausible scenarios for the emission of non-CO_2 greenhouse gases and aerosols. Historical emissions are shown in grey with the corresponding years given at the top. Emissions by 2020 are given under the assumption of 1.8%/year increase after 2011.

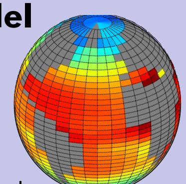
1. Model parameter sampling



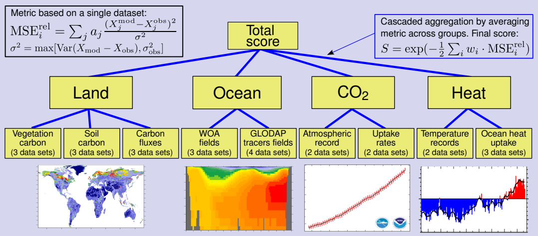
We apply the Bern3D-LPJ model in a Bayesian approach. First, uncertainties in physical and carbon-cycle model parameters, radiative efficiencies, climate sensitivity, and carbon-cycle feedbacks are taken into account by varying 19 key model parameters to generate a model ensemble.

5000-member ensemble of Bern3D-LPJ model

- 3D-dynamic ocean
- 2D-atmosphere
- Interactive global carbon cycle
- Comprehensive terrestrial biosphere with dynamic vegetation, permafrost, peatland, and land-use



2. Observational constraints

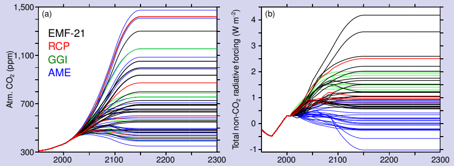


The uncertainty is then reduced by constraining the model ensemble to realizations that are compatible with observations. The observational data set combines information from satellite, ship-based, ice-core, and in-situ measurements to probe both the mean state and transient responses in space and time.

Constrained model ensemble

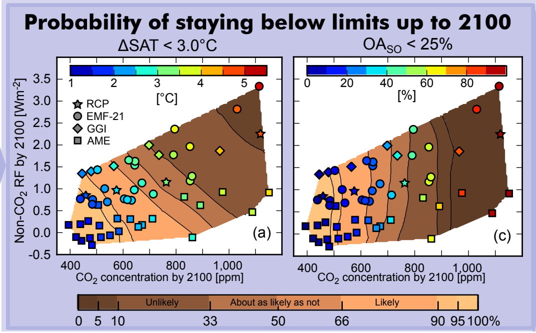
1069 members with associated scores S_m that quantify how well a model configuration is able to reproduce the observations over the historical period (1800-2010).

3. Projections 2010-2300 AD



The constrained model ensemble is run for 55 greenhouse gas scenarios spanning from high business-as-usual to low mitigation pathways.

Simulation results are then interpolated in the two-dimensional scenario space given by pCO_2 and the non-CO_2 radiative forcing by 2100, and probabilities to meet a specific target are derived from the 55×1069 simulations.



4. Allowable carbon emissions

From the contour lines in the scenario space that correspond to the defined target values, the range of allowable emissions to meet those targets can be obtained for each ensemble member. Finally, probability distributions of emissions for meeting one or multiple targets are calculated.