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Which future emission pathway is required to limit the global warming to no more than 2°C above pre-industrial levels? New model simulations performed at MPI-M

This question is investigated by Erich Roeckner and co-authors at the Max Planck Institute for Meteorology (MPI-M) in a study entitled ”Historical and future anthropogenic emission pathways derived from coupled climate-carbon cycle simulations“, recently published in the scientific journal ”Climatic Change”.

The results are based on a pilot study performed within the EU-funded ENSEMBLES project. Using the MPI-M coupled climate-carbon cycle model the authors estimate the ”allowable” CO2 emissions in a greenhouse gas stabilization scenario aimed at limiting global warming below the EU target of 2°C above pre-industrial levels. To this end an inverse method is applied allowing to reconstruct the future CO2 emissions from a prescribed pathway of atmospheric CO2 concentrations.

Results: Significant and early policy actions are required in mitigating greenhouse gas emissions to limit global warming to no more than 2°C above pre-industrial levels. In the greenhouse gas stabilization scenario the allowable CO2 emissions increase from 7 GtC in year 2000 to a maximum of about 10 GtC in 2015. Thereafter, the emissions have to be steadily reduced resulting in a decrease of 56 % in year 2050 and almost 100 % in year 2100. The global annual mean surface air temperature increases unabatedly within the next decades, until about year 2040, but more moderately thereafter. At the end of this century the global warming remains below the 2°C target but warming beyond this target cannot be ruled out if the simulations were extended further into the 22nd century.

Methodology

The aim of this study is to simulate future climate changes and anthropogenic CO2 emissions in a scenario that peaks at 530 ppm CO2(equiv) around 2050 and then decreases to approach 450 ppm during the 22nd century. This so-called E1 scenario was designed for attempting to match the European Union target of keeping global anthropogenic warming below 2°C above pre-industrial levels. The E1 scenario was derived within the ENSEMBLES project by using an ”Integrated Assessment Model” which includes the energy system, land use, carbon cycle and also a simple climate model. It provided the concentrations of greenhouse gases and aerosols as input for the MPI-M simulations.

The experimental design employed at MPI-M follows the one proposed for the benchmark simulations of the Fifth IPCC Assessment Report (AR5): Earth System Models (ESMs) including the carbon cycle are used to estimate the anthropogenic CO2 emissions that comply with a prescribed concentration pathway of greenhouse gases and aerosols. The calculated emissions depend crucially on the model simulated uptake of anthropogenic carbon by both the oceans and land (vegetation and soil). In the current study an ensemble approach is used, that is, the simulations were repeated several times starting from different pre-industrial climate states. This method allows to separate anthropogenic climate change and internal climate variability.

The model

The model used in this study is a low-resolution version (about 400 km grid size) of the Max Planck Institute for Meteorology ESM, consisting of sub-models for the atmosphere including land surface, the ocean including sea ice, and the marine and terrestrial carbon cycles. At higher spatial resolution (200 km grid), but excluding the carbon cycle, this model was used for the MPI-M scenario simulations contributing to the Fourth Assessment Report (AR4) of the IPCC.

Results

Figure 1a shows the temporal evolution of the model simulated CO2 emissions in the stabilization scenario E1. After having reached a maximum value of about 10 GtC in year 2015, the emissions decrease to 4.5 GtC in year 2050, corresponding to a reduction of 56 % within 35 years, and approach almost zero by the end of this century.

Figure 1b shows the temporal evolution of the global, annual mean temperature anomaly in the stabilization scenario E1. Until year 2040 the global warming continues unabatedly. Thereafter, the trend becomes weaker and the warming gradually approaches the 2°C target. Obviously, however, an equilibrium state has not yet been achieved so that further warming beyond the 2°C target should be expected if the simulations were extended into the 22nd century.

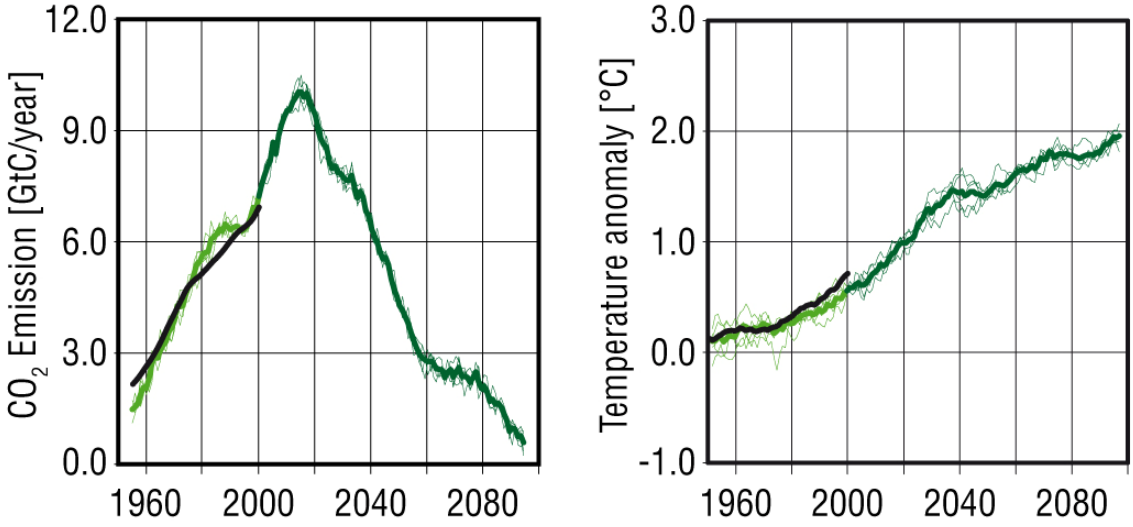

Fig. 1a (left): Observed and model simulated CO2 emissions in GtC/year. Shown are 11-year running means for 5 model realizations (thin) together with the ensemble mean (bold). Light green: historical period (1950-2000); dark green: stabilization scenario E1 (2001-2100); black: observations. Fig. 1b (right): Same as Fig. 1a except for the anomalies of global, annual mean surface air temperature with respect to the reference period 1860-1880.

Within the ENSEMBLES project, several European climate centres have used their respective models for simulating the E1 stabilization scenario. An analysis of this multi-model effort has been submitted for publication in ”Climate Dynamics” by T.C. Johns from the British Hadley Centre.

Reference

E. Roeckner, M.A. Giorgetta, T. Crüger, M. Esch, and J. Pongratz: Historical and future anthropogenic emission pathways derived from coupled climate-carbon cycle simulations. Climatic Change, DOI 10.1007/s10584-010-9886-6, (2010). www.springerlink.com

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