Towards realistic CDR portfolios for our climate targets

Earth System Modelling with Overshoot, Climate Neutrality and Carbon Dioxide Removal Options

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In Short

- Climate targets of the Paris Agreement are expected to be overshot, and large-scale application of CDR options appears to be required for mitigation
- Knowledge about CDR feasibility and their potentials and dangers is still limited
- As part of the Horizon EU 2021 project RESCUE we will simulate portfolio scenarios for the 21st century and beyond with the Earth system model FOCI-MOPS
- We support an exhaustive analysis of the role of CDR in reducing GHG emissions with its environmental impacts and side effects and the response of the Earth system to global mean temperature stabilization after GHG emissions reduction

By ratifying the Paris Agreement, most nations of the world committed themselves to reduce greenhouse gas (GHG) emissions to levels consistent with a global warming well below $2°$C compared to pre-industrial levels. In order to reach the targeted temperature stabilization, countries should ideally accomplish a climate neutral world by the middle of this century. Currently, the ambitious goals are compromised by delays in climate policy implementation and an overshoot of the Paris Agreement target is expected. The situation might be remedied by long-term net-negative CO_2 emissions, which are achievable by a broad set of carbon dioxide removal (CDR) options. CDR methods either aim at enhancing land and ocean carbon sinks or seek to engineer the direct removal of CO_2 from the atmosphere or from sea water. However, knowledge about CDR feasibility and their potentials and dangers is still limited; possible interactions, feedbacks, trade-offs and synergies have to be evaluated. The experiments of this project are part of the Horizon Europe 2021 funded project RESCUE [1], which develops new CDR portfolio scenarios for the 21st century and beyond in order to assess the potential role of CDR in reducing net GHG emissions with and without overshoot, as well as its environmental threats, side effects and potential co-benefits. Our simulations will use the Earth system model FOCI-MOPS [2,3], which is one out of five contributing ESM's in RESCUE. We plan to simulate composite CDR scenarios that target different global mean temperatures with and without overshoot. Associated base-line scenarios will enable a comprehensive assessment of CDR impacts.

There have been several attempts to represent CDR techniques in ESMs [4–7]. All these studies used different parameterizations and more importantly different experimental designs, making intercomparisons difficult. To overcome this limitation, CDRMIP [8] was initiated as part of the Coupled Model Intercomparison Project, phase 6 (CMIP6). However, ESM studies have relied, so far, on idealized scenarios with very large overshoots, equilibrium carbon cycle and were mostly concentration driven [9]. At the same time, studies using IAMs highlight the importance of varying assumptions on overshoot constraints and availability of CDR alternatives.

One of the main unknowns that hampers the design of informed pathways towards the achievement of the Paris Agreement goals, is how the global carbon cycle components will respond when atmospheric CO_2 will peak and then decrease [8]. For the assessment of emission pathways leading to net zero or net negative emissions, it is crucial to know how fast the natural carbon sinks decline and whether or when they will turn into sources to the atmosphere, since this determines the global effectiveness of CDR methods. To date only limited information on carbon cycle response and reversibility under deployment of realistic scenarios is available. Earlier studies have typically been single model studies using idealized concentration pathways and no explicit representation of CDR methods [9,10] Multi model simulations of overshoot pathways are now emerging from CMIP6 but ESMs typically still do not represent CDR methods explicitly and obstacles related to the consistency of IAMs and ESMs need to be overcome.

Therefore, CDR methods with new parameterizations that are derived with the aid of integrated assessment models (IAMs) will be simulated with FOCI-MOPS. Four core methods are ocean alkalinity enhancement (OAE), direct air carbon capture and storage (DACS), bio-energy with carbon capture and storage (BECCS), and afforestation/reforestation (AR). Moreover, ocean alkalinization will be imposed using estimates of available materials and their geographical availability that will be provided by the newly designed scenarios.

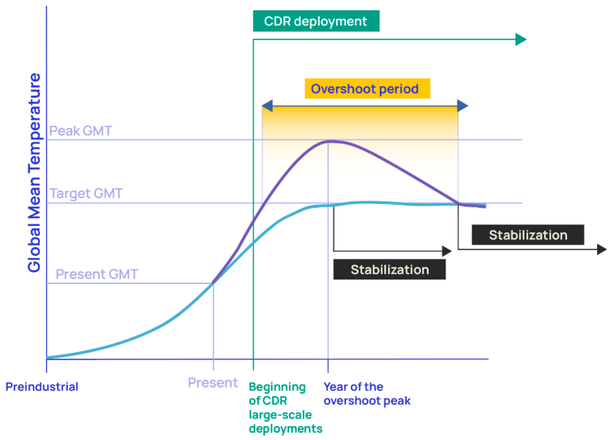

Figure 1: *Conceptualization of the scenario design in RESCUE. For any GMT target there will be pairs of scenarios, designed to have the same carbon budget, with and without overshoot.*

We will simulate pairs of climate neutrality scenarios which include all CDR options for different Global Mean Temperature (GMT) targets. Each pair of scenarios is designed to have the same carbon budget, with and without an overshot of the target GMT. The scenarios will cover the time period until year 2100. Figure 1 sketches the concept of our S simulations. For each CDR scenario two associated baseline simulations are planned in order to facilitate comprehensive conclusions about the impacts of CDR in reaching climate neutrality.

The first baseline simulation will resemble the corresponding scenario but exclude CDR options. The difference between this simulation and the full-CDR scenario allows us to determine the overall removal of carbon by CDR methods including all earth system (carbon cycle, climate, and biophysical) feedbacks.

The second baseline simulation is also excluding all CDRs, but it uses the atmospheric CO_2 trajectory from the full-CDR scenario. It has the same carbon and climate feedbacks as the full-CDR scenario but the land and ocean physical properties are not manipulated by deployment of CDRs. This simulation is useful to estimate the biophysical impacts of CDRs on climate through albedo changes, changes in evapotranspiration and surface roughness changes among others.

The difference between the two baseline simulation can serve to determine the Earth System feedbacks (carbon cycle and climate change, but excluding the biophysical feedbacks of CDR deployment, e.g. albedo changes).

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http://www.geomar.de

More Information

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DFG Subject Area

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