METRICS TO ASSESS THE MITIGATION OF GLOBAL WARMING BY CARBON CAPTURE AND STORAGE

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ABSTRACT

Different metrics to assess mitigation of global warming by carbon capture and storage are discussed. The climatic impact of capturing 30% of the anthropogenic carbon emission and its storage in the ocean or in a geological reservoir are evaluated for different stabilization scenarios using a reduced-form carbon cycle-climate model. The accumulated Global Warming Avoided (GWA) remains, after a ramp-up during the first ~50 years, in the range of 15 to 30% over the next millennium for deep ocean injection and for geological storage with annual leakage rates of up to about 0.001. For longer time scales, the GWA may approach zero or become negative for storage in a reservoir with even small leakage rates, accounting for the CO_2 associated with the energy penalty for carbon capture. For an annual leakage rate of 0.01, surface air temperature becomes higher than in the absence of storage after three centuries only.

INTRODUCTION

Among the options considered for carbon management, geological formations and the deep ocean are considered to have sufficiently large storage capacity to make deep cuts in the emissions if carbon taxes are introduced. In the case of dissolution of CO_2 at depths of around 3000m in the ocean, climate and near surface impacts of elevated CO_2 are then reduced at the expense of a local environmental impact in the water column near the injection site. In this study we make a first step at systematic comparison over a time scale of a millennium, using a simple model that is first validated against more complex models. We introduce a simple metric called Global Warming Avoided (GWA), and briefly discuss how different the same results may appear when evaluated in different ways and over different time horizons.

MODEL AND SETUP

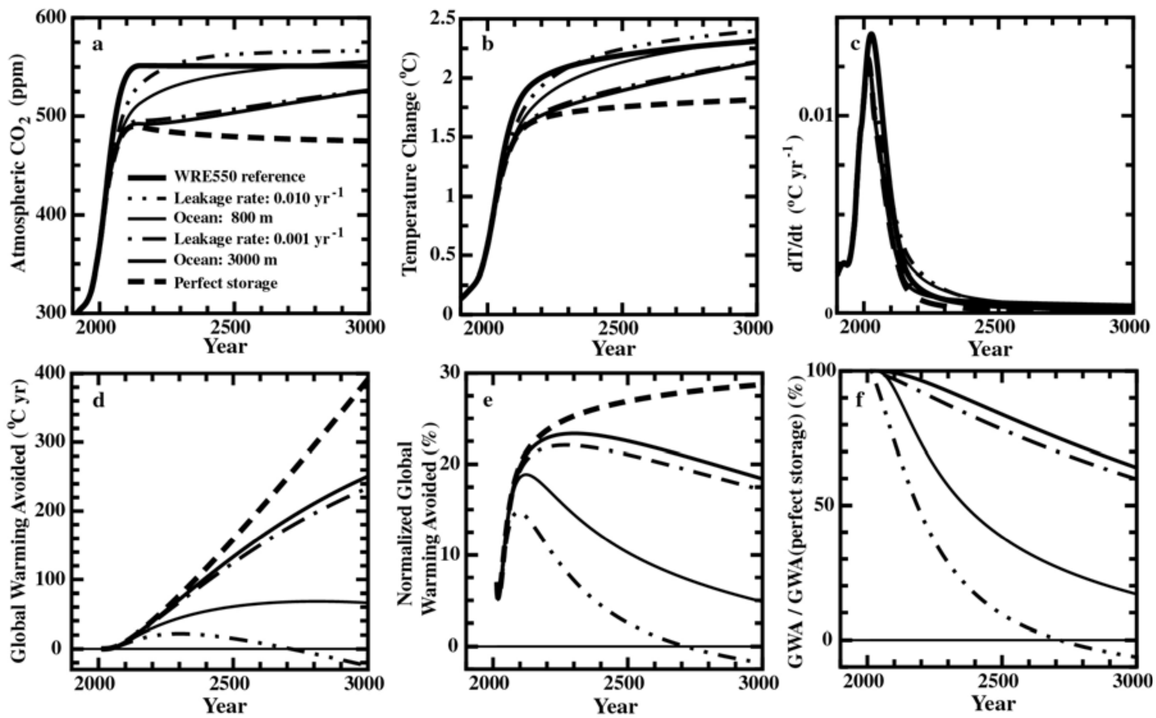
The model consists of the HIgh Latitude Diffusion-Advection (HILDA) model coupled to a 4-box biosphere model and an energy balance model. The ocean component has a vertical diffusivity for heat and tracers varying with the vertical coordinate. The climate sensitivity for a nominal doubling of atmospheric CO_2 is set to 2.5^{o}C. First, by comparison with previously published results, we find that CO_2 ocean injection efficiencies are within the range of the more comprehensive model results for injection at 800 and 3000 m. Next, we perform case studies with different ocean and geological storage scenarios. More details as well as additional case studies are given in *Haugan and Joos* [2004].

As reference we use anthropogenic emissions derived with the model from scenarios which stabilize atmospheric CO_2 at a given level if no sequestration is applied. In sequestration scenarios, 30% of the annual emissions are captured from year 2035 onward. In order to simulate build-up of sequestration capability, we assume no sequestration before 2010 and a linear increase in the percentage captured over the 25 years from 2010 to 2035. Since capture requires energy, we assume that for the captured CO_2, there is more CO_2 produced. This added CO_2 is also sequestered. So for example if the reference case annual emission is 10 PgCyr^{-1}, and the energy penalty is set at 20%, the sequestration scenarios would emit 7 PgC yr^{-1} and store 3.6 PgC yr^{-1}. For geological storage, we include a “perfect” storage case in which all the sequestered CO_2 is assumed to be isolated from the atmosphere indefinitely, and cases with annual leakage rates of 0.001 and 0.01, respectively, of the cumulative amount of CO_2 stored at any point in time.

RESULTS AND DISCUSSION

The figure below displays projected (a) atmospheric CO_2, (b) global average surface temperature change, (c) rate of global average surface temperature change, and Global Warming Avoided (d) in ^oC year, (e) in percent of the cumulative warming of the reference case, and (f) relative to the perfect storage case for WRE550 emissions. No carbon is captured and stored in the WRE550 reference case. The Global Warming Avoided (GWA) in units of ^oC year is defined by:

$GWA(t) = \int_{t_0}^{t} (T_{ref} - T_s)dt$, where T_s is the surface air temperature of any given (sequestration) scenario, T_{ref} is that of the reference scenario, t_0 is the starting time, here year 2010, and t is the time at which cumulative effects are compared.



None of the sequestration scenarios give significant reduction of the maximum rate of change of air temperature. Perfect storage of 30% of emissions gives a GWA approaching 30% of the reference case warming over the millennium. Deep ocean storage behaves similarly to 0.001 annual leakage rate. Shallow ocean storage is slightly better than 0.01 annual leakage, but still gives increased air temperature before the end of the millennium because of the energy penalty. GWA relative to that of perfect storage may interpreted as a measure of storage effectiveness incorporating not only carbon reservoir accounting, but also climate effects.

REFERENCES

Peter M. Haugan and Fortunat Joos 2004. Metrics to assess the mitigation of global warming by carbon capture and storage in the ocean and in geological reservoirs. *Geophysical Research Letters* 31, L18202, doi:10.1029/2004GL020295.