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ABSTRACT

In this paper, we use a coupled climate and carbon cycle model to investigate the global climate and carbon cycle changes out to year 2300 that would occur if CO_2 emissions from all the currently estimated fossil fuel resources were released to the atmosphere. By year 2300, the global climate warms by about 8 K and atmospheric CO_2 reaches 1423 ppmv. In our simulation, the prescribed cumulative emission since pre-industrial period is about 5400 Gt-C by the end of 23rd century. At year 2300, nearly 45% of cumulative emissions remain in the atmosphere. In our simulations both soils and living biomass are net carbon sinks throughout the simulation. Despite having relatively low climate sensitivity and strong carbon uptake by the land biosphere, our model projections suggest severe long-term consequences for global climate if all the fossil-fuel carbon is ultimately released to the atmosphere.

INTRODUCTION

The recent coupled climate and carbon cycle models *(,l., Govindasamy et al., 2005; Zeng et al.*, 2004; *Mathews et al*., 2005) have investigated the feedback between climate and carbon cycle, and have focused on projection of climate change and the carbon cycle feedback over the 21st century. These models have not been used to study the multi-century impact of large-scale fossil fuel emissions on climate and the carbon cycle. In this study, we address the impact of releasing CO_2 to the atmosphere by anthropogenic emissions from currently estimated all fossil fuel resources by year 2300 on global climate and carbon dynamics.

MODEL

To investigate the long-term impacts of climate change due to anthropogenic emissions, we use INCCA (INtegrated Climate and CArbon), the coupled climate and carbon cycle model developed at the Lawrence Livermore National Laboratory (*Thompson et al.* 2004; *Govindasamy et al*. 2005).

EXPERIMENTS

We perform two model simulations starting from pre-industrial initial conditions: a “Control” case with no change in forcing for the period 1870-2300, and an “A2 Scenario” case. In the A2 case, CO_2 emissions are specified at historical levels for the period 1870-2000 and at SRES A2 levels for the period 2000-2100 (*IPCC*, 2001). For the period 2100-2300, emissions follow a logistic function for the burning of the remaining fossil-fuel resources (assuming 5270 Giga tones of carbon (Gt-C) in 1750).

RESULTS

The global- and annual-mean temperature change is about 8 K at year 2300. The atmospheric CO_2 increases from the pre-industrial value of 289 ppmv to 1423 ppmv in the same period. Because the largest emissions occur in the 22nd century (Table 1), the largest warming and increase in CO_2 happen in that century. Neither soil carbon nor biomass shows any decline during the entire simulation, and the land remains a sink for carbon throughout our A2 simulation. Of the total cumulative emission of 5400 Gt-C, 38% and 17% are taken up by land and ocean respectively, and 45% remains in the atmosphere (Table 1). We find that the effective climate sensitivity increases from the model’s previously known equilibrium value of about 2 K to 3 K, an increase of about 50%. The carbon cycle feedback factor (*Friedlingstein et al.*, 2003) increases from our previously known value of 1.13 to 1.29. We believe that this increase is due to the reduction in the turnover time scale of the soil carbon pool with time, and because of an increase in climate sensitivity with time. However, the increase in the feedback factor is small and it suggests near-linear behavior of the carbon cycle feedback factor over the 430-year period.

DISCUSSION

Our model has weak climate-carbon cycle feedback and the predicted atmospheric CO_2 is relatively lower in comparison to other coupled climate-carbon cycle models for the 21st century. Our physical climate model has relatively lower climate sensitivity among the climate models (*IPCC*, 2001). Given these facts, our model results represent a conservative estimate of how the specified emissions could affect climate in the future. However, it shows that both climate sensitivity to radiative forcing and carbon cycle feedback with climate increase with time, and our projections indicate the potential for severe long-term consequences for global climate if all the fossil-fuel carbon is ultimately released to the atmosphere.

Table 1: Total emissions (Gt-C) and its partitioning between various reservoirs for each century. Numbers in brackets represent the percent of the partitioning.

Reservoir	20th Century	21st Century	22nd Century	23rd Century	Total since 1870
Emissions	385.1	1790.6	2557.6	644.7	5404
Land	160.7 (41.7)	746.8 (41.7)	906.4 (35.4)	243.9 (37.8)	2067 (38.3)
Ocean	71.7 (18.6)	269.2 (15.0)	350.0 (13.7)	224.4 (34.8)	921 (17.0)
Atmosphere	153.0 (39.7)	777.2 (43.3)	1289.0 (50.9)	174.0 (27.4)	2416 (44.7)

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