THE IMPACT OF CO2 FERTILIZATION ON THE GLOBAL TERRESTRIAL CARBON CYCLE AND INTERANNUAL CHANGES IN CO2 STUDIED THROUGH A CARBON CYCLE DATA ASSIMILATION SYSTEM

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ABSTRACT

Based on precise ground measurement of atmospheric CO_2 concentration and satellite remote sensing, it is claimed that terrestrial vegetation has increased their activities gradually, and their significance is becoming larger in interannual and seasonal changes of atmospheric CO_2 during the last several decades. Among many possible causes, the fertilization effect of CO_2 rising on photosynthesis is known to be one of the most possible factors, which could be induced by enhanced terrestrial ecosystem productivity, affecting those atmospheric CO_2 changes. This study compares two different model simulations, which are calculated by the Carbon Cycle Data Assimilation System (CCDAS) using constant CO_2 concentration and transient CO_2 concentration respectively. The result of the CO_2 fertilization is a large enhancement of net ecosystem productivity in forests and large decrease of that in tundra and savanna. Difference in global averaged net ecosystem productivity among the two results fluctuate largely. However, there is only little difference in the long-term trend of the growth rate and the amplitude of CO_2 seasonality among them. These indicate that CO_2 fertilization has affected ecosystem carbon fluxes largely, but did not impact interannual changes in the atmospheric CO_2 concentration seasonality.

INTRODUCTION

The terrestrial carbon cycle has the potential to provide major feedbacks on climate change, but major uncertainties in the spatial and temporal pattern of these feedbacks lasts. To probe the behavior of the current carbon cycle and clarify those uncertainties, CCDAS has been developed (Rayner et al. 2005; Scholze et al., 2007).

Several previous modelling studies of terrestrial ecosystems and atmospheric CO_2 observations have come to the conclusion that there has been an increased terrestrial carbon uptake from the 1980s to the 1990s, and this has been at least partially caused by the terrestrial carbon cycle's response to external forcing (e.g. Keeling et al., 1996; Nemani et al., 2003; Myneni et al., 1997). Possible causes that have been cited are enhanced photosynthesis through rising atmospheric CO_2 or extended growing season through increasing temperatures, although their effects might not necessarily be positive all the time. For this study, the CCDAS is modified to incorporate the effect of CO_2 fertilization and by allowing interannual changes of CO_2 concentration to impact on the photosynthesis scheme of the terrestrial biosphere model. With the optimized parameters, the optimized terrestrial carbon fluxes and the remaining uncertainties diagnosed by the CCDAS, this study discusses the sensitivity of terrestrial carbon cycle to increases in atmospheric CO_2 and attempts to assess the relative significance of climate fluctuations and the fertilization effect on the enhanced terrestrial carbon uptake during those two decades.

METHODS

CCDAS combines the terrestrial biosphere model BETHY (Biosphere Energy Transfer Hydrology Scheme) and the atmospheric transport model TM2, and is capable of both forward and inverse modeling of terrestrial carbon fluxes. Optimal parameters of BETHY are obtained by fitting against atmospheric CO_2 observation at ground stations. The terrestrial CO_2 fluxes are calculated by BETHY using satellite-derived fAPAR and prescribed climate data on a 2^o x 2^o gridded cells, and are then transported to the remote monitoring sites by TM2 on a 7.8^o x 10^o grid resulting in simulated atmospheric CO_2 concentrations. The differences in atmospheric CO_2 concentration between simulation and observations are minimized by iterative calculations of terrestrial fluxes with newly assigned parameters, based on the derivative of a cost function with respect to the model parameters.

In this study, constant CO_2 concentration and transient CO_2 concentration over the optimization period are given to CCDAS as forcing to the photosynthesis process in BETHY respectively. Results are compared to investigate the CO_2 fertilization effect on the fluctuation of atmospheric CO_2 concentration.

RESULTS AND DISCUSSION

Spatial distribution of the difference in NEPs shows that the fertilization effects on terrestrial carbon sequestration is largely positive in forest ecosystems, such as Tropical, Temperate and Boreal forests, and largely negative in non-forest dominated ecosystem, such as Boreal tundra and Tropical savanna. Difference in global averaged NEP varies within a range of -0.8 to 0.8 Pg C yr^{-1}.

Growth rates in global averaged CO_2 concentration show that both simulated values move along with observation moderately, and those increase slightly with time series (Figure 1). On the other hand, the difference between two simulations is small. The amplitude of seasonality in atmospheric CO_2 concentration, calculated as the difference between maximum and minimum CO_2 concentration for each year at five observational sites (Point Barrow, Cold Bay, Mauna Loa, Samoa, and South Pole), does not show large differences in that long-term trends among the two simulations. Thus these two facts suggest smaller significance of fertilization effect on seasonality of CO_2 concentration.

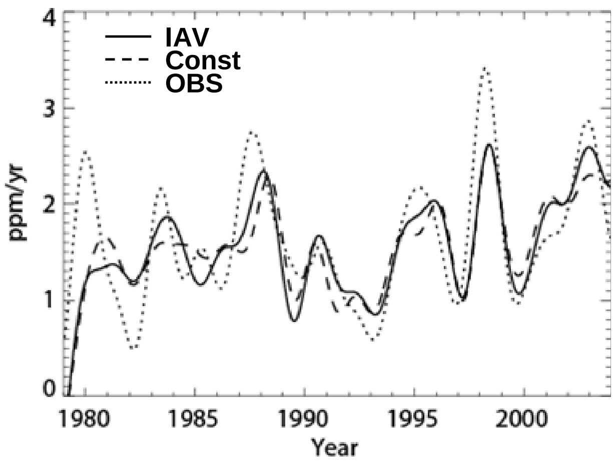

Figure 1. Growth rates in global averaged CO_2 concentration from observation (OBS) and the runs with interannually variated CO_2 conc. (IAV) and constant CO_2 conc. (Const). Data are calculated as averaged with Mauna Loa and South Pole sites' data.

Cost function value against CO_2 concentration was larger in IAV-CO_2 run than that in Const-CO_2 run, and this indicates that CO_2 fertilization effect did not work to reduce the gap between observational CO_2 and simulated CO_2 effectively. Thus, this might show that those fluctuations in amplitude of atmospheric CO_2 have not been conducted mainly by fertilization effect. In this study, however, identical atmospheric CO_2 concentration was assigned for global terrestrial ecosystems during a year, although there should be seasonality and latitudinal trends in that. Further research with more precise forcing settings in seasonal and spatial changes of CO_2 forcing, could give more solid information.

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