SIMULATIONS OF VARIATIONS OF TROPOSPHERIC CO_2 CONCENTRATION OVER JAPAN

M. Ishizawa[1], S. Maksyutov[2], T. Nakazawa[3], and S. Aoki[3]

[1]*University of Toronto, AQRB/MSC, 4905 Dufferin Street, Toronto, M3H 5T4 Canada; Misa.Ishizawa@ec.gc.ca*

[2] *Center for Global Environmental Research National Institute for Environmental Studies, Tsukuba, 305-8506, Japan; shamil@nies.go.jp*

3Center for Atmospheric and Oceanic Studies, Graduate School of Science, Tohoku University Sendai 980-8578, Japan; nakazawa@mail.tains.tohoku.ac.jp, aoki@mail.tains.tohoku.ac.jp

ABSTRACT

In order to investigate the long-term and inter-annual variations in the atmospheric CO_2 concentration record obtained by aircraft measurements over Japan, we have conducted numerical experiments using a transport model with a process-based ecosystem model. The climate-induced anomalies of net biospheric flux account for a significant part of the inter-annual variations in the CO_2 growth rate. The results indicate that year-to-year change in observed vertical CO_2 gradient is mainly caused by the inter-annual variability in atmospheric transport, likely related to El Niño events.

INTRODUCTION

Since 1979 aircraft measurements for tropospheric CO_2 concentration over Japan have been continued by Tohoku University approximately at a rate of once a month [*Nakazawa et al.*, 2001]. This long CO_2 record provides valuable information on the global carbon cycle, showing spatial and temporal variability in tropospheric CO_2 concentration at northern mid-latitude. Here we examine the long-term and inter-annual variations of CO_2 concentration.

Many previous studies reported that much of the inter-annual variability in atmospheric CO_2 could be accounted for by an imbalance of CO_2 exchange between the atmosphere and the biosphere [e.g., *Fujita et al*., 2003]. Recently, *Murayama et al.* [2004] suggested that variability in the atmospheric circulation pattern is needed to be taken into account to understand the year-to-year change in the observed CO_2 growth rate in mid- and high-latitudes in the Northern Hemisphere. In this study, we have attempted to examine the climate perturbations on the observed inter-annual CO_2 variations through the changes in ecosystem activities and atmospheric transport, using a transport model and process-based ecosystem model. The impact of the recent rapid increase of anthropogenic CO_2 emission by East Asian countries on the long-term trend of atmospheric CO_2 concentration over Japan is also studied.

METHODS

We use the NIES (National Institute of Environmental Studies) global atmospheric transport model [*Maksyutov and Inoue*, 2000] and the Biome BioGeochemical Cycle model (Biome-BGC) [*Thornton et al*., 2002]. The two models are offline-coupled and both are run at a horizontal resolution of $1^o \times 1^o$, driven by the meteorology based on the 6-hourly NCEP (National Centers for Environmental Prediction) reanalysis data [*Fujita et al*., 2003]. For the model experiments, a set of annually-balanced net biospheric CO_2 fluxes is produced by adjusting the imbalance of Biome-BGC-simulated CO_2 fluxes for each year. Fossil fuel-CO_2 fluxes are varied from year-to-year according to the statistical estimates of emission rate and its global distribution. For comparison of the simulated and observed atmospheric CO_2 concentrations, they are first vertically grouped by 2 km-intervals, and then seasonal cycles are subtracted.

RESULTS AND DISCUSSIONS

The simulation results indicate that the inter-annual variations of the CO_2 growth rate are mainly caused by the climate-induced anomalies of net biospheric CO_2 flux (Fig.1). The inter-annual changes in atmospheric transport are identified to make some contribution for the observed CO_2 growth rates in 1980s, but less correlation is found in 1990s.

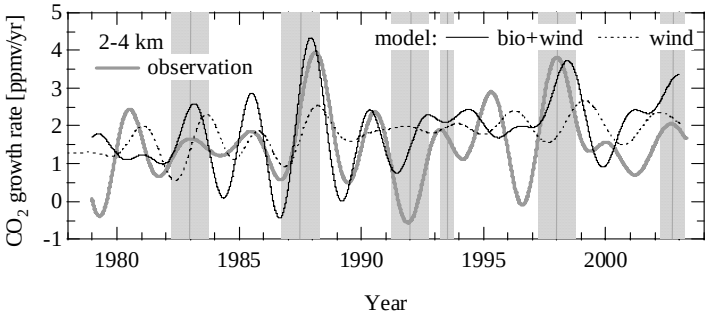

Fig.1. Simulated and observed CO_2 growth rates at altitude of 2-4 km over Japan. For model results, "bio+wind" denotes that both of biospheric CO_2 fluxes and wind fields are inter-annually changing, and "wind" means that only wind fields are changing year to year. The shaded area indicates El Niño periods.

Simulated vertical gradients of CO_2 concentration are relatively similar to, but somewhat smaller in magnitude then the observation (Fig. 2). The model results show that the changes of atmospheric transport contribute significantly to the inter-annual variability in CO_2 vertical gradient. It is interesting to note that the CO_2 vertical gradient tends to be smaller when El Niño event occurs. This pattern suggests that atmospheric mixing is enhanced by such a climate event. Furthermore, over the last two decades, the CO_2 vertical gradient over Japan has been increasing slightly but steadily (about 0.02ppmv/yr), which might be attributed to increasing fossil fuel CO_2 emission rates in East Asian countries due to their rapid industrialization.

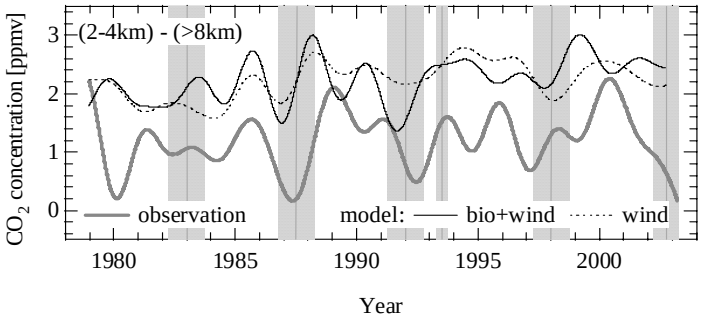

Fig.2. Simulated and observed vertical difference of CO_2 concentration between the altitude of 2-4 km and tropopause (above altitude of 8km).

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