TEMPORAL VARIATIONS OF THE ATMOSPHERIC CO_2 CONCENTRATION IN THE SOUTHERNMOST PART OF JAPAN

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ABSTRACT

To examine concentration variations of atmospheric CO_2 in the sub-tropical region of East Asia, systematic air sampling with subsequent laboratory analysis has been made in the southernmost part of Japan since June 1993. A time series of measured CO_2 concentrations was analyzed for long-term trend, seasonal cycle and interannual variability, and the temporal CO_2 variations deduced were interpreted in terms of atmospheric transport and CO_2 flux regions.

INTRODUCTION

The data from precise measurements of the atmospheric CO_2 concentration over a wide geographical area have been used to constrain the global carbon budget. However, the present measurement stations of atmospheric CO_2 are unevenly distributed on the globe, and only a limited number of stations exist on the continents and in the equatorial region. East Asia is a region of rapid economic development, with a consequential increase in greenhouse gas emissions over the coming decades. In order to monitor changes in the CO_2 emission in East Asia, we initiated a regular flask air sampling program in the southernmost part of Japan in June 1993. In this paper, we show temporal variations of atmospheric CO_2 observed in the sub-tropical region of East Asia and interpret them with the aid of backward trajectory analysis and a 3-dimensional atmospheric transport model.

OBSERVATIONS AND DATA

Air sampling was made once a week aboard a ferry plying between Ishigaki Island and Hateruma Island located at the southern end of the Japanese Archipelago, as shown in Fig. 1. The CO_2 concentrations of the air samples were determined against our CO_2 standard gases using a NDIR analyzer. The overall precision of our concentration analyses was estimated to be 0.1 ppmv. The CO_2 concentration values of the two samples collected on the same day were simply averaged to obtain a daily value. After outliers were removed from the data set, a digital filtering technique [*Nakazawa et al*., 1997] was applied to the remaining CO_2 values to obtain long-term trend, average seasonal cycle and their interannual variability. Our data were also compared to the continuous CO_2 measurements taken by the National Institute for Environment Studies on Hateruma Island (HTR) for 1993-2001 and by the Japan Meteorological Agency on Yonaguni Island (YGN) for 1997-2004. In addition to these two sites, we made references to the weekly flask data obtained by the National Oceanic and Atmospheric Administration/Climate Monitoring and Diagnostic Laboratory on Guam Island (GAM: 144º47'E, 13º26'N) for 1993-2002.

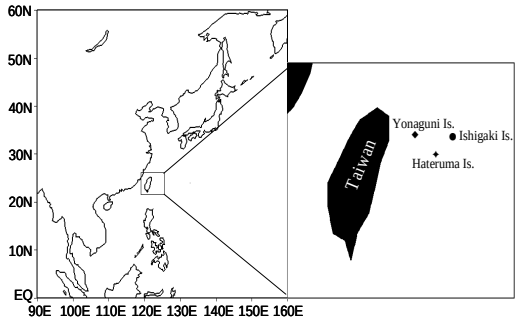

Fig. 1. Map showing our sampling site and its surroundings.

RESULTS AND DISCUSSION

The measured CO_2 concentrations are shown in Fig. 2, together with the best-fit curve of the data and the long-term trend. Also shown are the curves fitted to the data at HTR, YGN and GAM. Our results show that the CO_2 concentration has increased secularly, being accompanied by prominent seasonal cycle and interannual variations. Similar variations are also seen in the results from the other 3 sites. Lower and higher concentration values are clearly found in the spring and summer of 1998, respectively, compared with those in contiguous years. This feature is also seen in the records at HTR and YGN, but not so appreciable in CO_2 variations at GAM.

The average seasonal CO_2 cycle observed at our site reached the maximum and the minimum in early April and mid-September, respectively, with peak-to-peak amplitude of. 8.5 ppmv. This seasonal cycle agrees fairly well with those at HTR and YGN. Compared with the seasonal CO_2 cycles at these 3 sites, the amplitude was smaller by 2 ppmv and the phase was delayed by 1 month at GAM, due to the difference between air masses covering the two areas. The 3-dimensional atmospheric transport model (Fujita et al., 2003) calculated the average seasonal CO_2 cycle that the amplitude is larger by 2 ppmv and the seasonal maximum appears earlier by 1 month than our observed cycle. Causes of the difference may be ascribed to terrestrial biospheric CO_2 fluxes given by the Biome-BGC model for the atmospheric transport model and/or the atmospheric transport field of the model driven by the NCEP/NCAR reanalysis data.

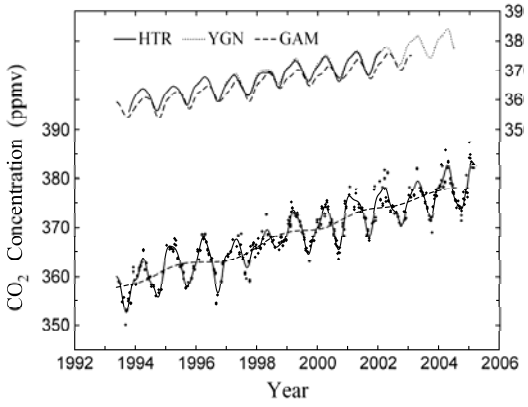

Fig. 2. CO_2 concentrations measured in this study, the smoothed curve and the long-term trend derived by fitting to the data (lower plot), and best-fit curves to the data at HTR, YGN and GAM (upper plot).

The growth rates of the CO_2 concentration are shown in Fig. 3. The average CO_2 growth rate for the period covered by our measurements was calculated to be 1.8 ppmv/yr, which is comparable with those from other measurements. Interannual variations of the growth rate were found to closely correlate with ENSO events, reflecting changes in the terrestrial biospheric CO_2 flux and the atmospheric transport associated with the ENSO event. The temporal behavior of our observed growth rate is similar to those at other sites, except for the beginning of the record where our result varies in opposite phase with those at HTR and GAM. The CO_2 growth rate calculated using the atmospheric transport model showed the temporal variation that is similar to the observed results, but the appreciable difference is also found especially for the period earlier than 1996.

The 3-dimensional backward trajectory analysis suggested that the low CO_2 concentration values found in the spring of 1998 resulted from the alternation of prevailing air mass; our sampling site is usually covered by continental air masses in spring, but in the spring of 1998, the maritime air mass dominated over the continental air mass at the site. The significantly high CO_2 concentrations observed in the summer of 1998 are thought to be caused by the transport of CO_2 originated in forest fires occurred in Southeast Asia in association with the 1997/98 ENSO event.

We also found that very high and low CO_2 concentrations were occasionally observed at our site in winter and late in summer, respectively. By inspecting the results of the backward trajectory analysis and the CO_2 concentration field calculated using the atmospheric transport model, it was found that CO_2 emitted by anthropogenic and terrestrial biospheric activities in East China was mainly responsible for such high CO_2 events, while the low CO_2 concentration appearance was closely related to photosynthetic CO_2 uptake by the terrestrial biosphere in the Eurasian Continent.

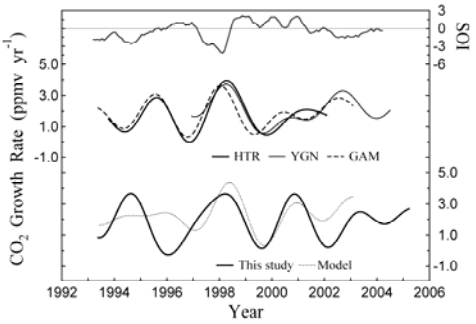

Fig. 3. Growth rates of the CO_2 concentration observed in this study and at HTR, YGN and GAM, and 5-month running mean of the monthly SOI values. The CO_2 growth rate calculated using the 3-dimensional transport model is also shown (Model).

REFERENCES

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