INTERANNUAL VARIATIONS OF CARBON DIOXIDE IN THE UPPER TROPOSPHERE OBSERVED OVER THE WESTERN PACIFIC FROM 1993 TO 2005

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ABSTRACT
The spatial and temporal variations of atmospheric CO_2 at 8-13 km from April 1993 to March 2005 were observed by measuring CO_2 concentrations in samples collected biweekly from a commercial airliner between Australia and Japan. The 12-year record between 30N and 30S revealed several characteristics for CO_2 interannual variabilities in the upper troposphere. The most significant year-to-year change was found in a large increase in the growth rate during 1997/98 and 2002/03 that were associated with the ENSO events. During these years, changes in north-to-south gradient of latitudinal distribution and seasonal cycle were observed compared to data during the normal years.

INTRODUCTION
Atmospheric CO_2 concentrations have been measured by a large number of ground-based stations and cruise ships in the world, but CO_2 measurements in the free troposphere are sparse due to the limited number of high-mountain monitoring stations and aircraft campaigns. Thus, more systematic and long-term observations of CO_2 in the middle and upper troposphere are necessary for a better evaluation of a global carbon cycle model.

A commercial airliner is useful for collecting CO_2 data in the upper troposphere for a long period of time [*Matsueda et al.,* 2002a,b]. Thus, we developed a new automatic flask sampling system as airborne equipment for a commercial airliner (Boeing 747) under a co-operative program with the Meteorological Research Institute (MRI), the JAL Foundation, Japan Airlines (JAL), the Japan Meteorological Agency, and the Japanese Ministry of Land, Infrastructure and Transport. The operation of the sampling system started in April 1993 to measure the concentrations of CO_2, and other trace gases such as carbon monoxide and methane. In this study, we present a 12-year record of the CO_2 from 1993 to 2005 to clarify the CO_2 interannual variation focusing on the large anomaly during the ENSO events.

SAMPLING AND ANALYSIS
Details of our automated sampling system with 12 titanium flasks have been reported elsewhere [*Matsueda and Inoue*, 1996; *Matsueda et al.,* 1999]. Between April 1993 and March 2005, more than 250 northbound sampling flights from Australia to Japan were made using the passenger aircraft of JAL. The first 12 flights before June 1994 were made from Cairns, Australia to Narita, Japan. After July 1994, the flight route changed from Cairns to Sydney or Brisbane to expand the latitudinal coverage of the sampling points in the Southern Hemisphere. The air samples were collected at the cruising altitudes of 8-13 km.

The analysis of CO_2 concentration was conducted using an automated measuring system with a NDIR. The overall precision of CO_2 measurement was estimated to be less than 0.1 ppm. The CO_2 concentrations in all sampled air were reported here on the basis of the WMO CO_2 mole fraction scale.

RESULTS
Data analysis for the measurements was conducted to make time-series data sets of mean CO_2 for 12 latitudinal bands at intervals of 5 degrees latitude between 30N and 30S, and their results are shown in Fig. 1. Each piece of data represents the mean CO_2 mixing ratio for 5 degrees latitude calculated from

the 12 flask measurements for each flight. The solid and dashed curves represent the smoothed-fit curve and long-term trend, respectively.

Using this CO_2 data set, we could analyze interannual variabilites of long-term trends, seasonal cycles in the both Hemispheres as well as latitudinal distributions over the western Pacific. The CO_2 trend showed continuos increases in all latitudinal bands, but their growth rates largely varied from about 1 ppm/yr to more than 3 ppm/yr during the past 12 years. The growth rate was enhanced around 1997/98 and 2002/03 associated with the ENSO events. During these ENSO events, seasonal cycles in the upper troposphere largely increased compared to those in the normal years. In addition, a change of north-to-south gradient in the CO_2 latitudinal distributions was also related to the ENSO events. To examine these year-to-year variations in the upper troposphere, we compared with the data of other trace gases from the same aircraft observations as well as the surface CO_2 data from the ground-based stations. These comparison results suggest that not only yearly changes of CO_2 fluxes from the land biosphere and ocean but also modulation of transport processes are responsible for the interannual variations of CO_2 in the upper troposphere.

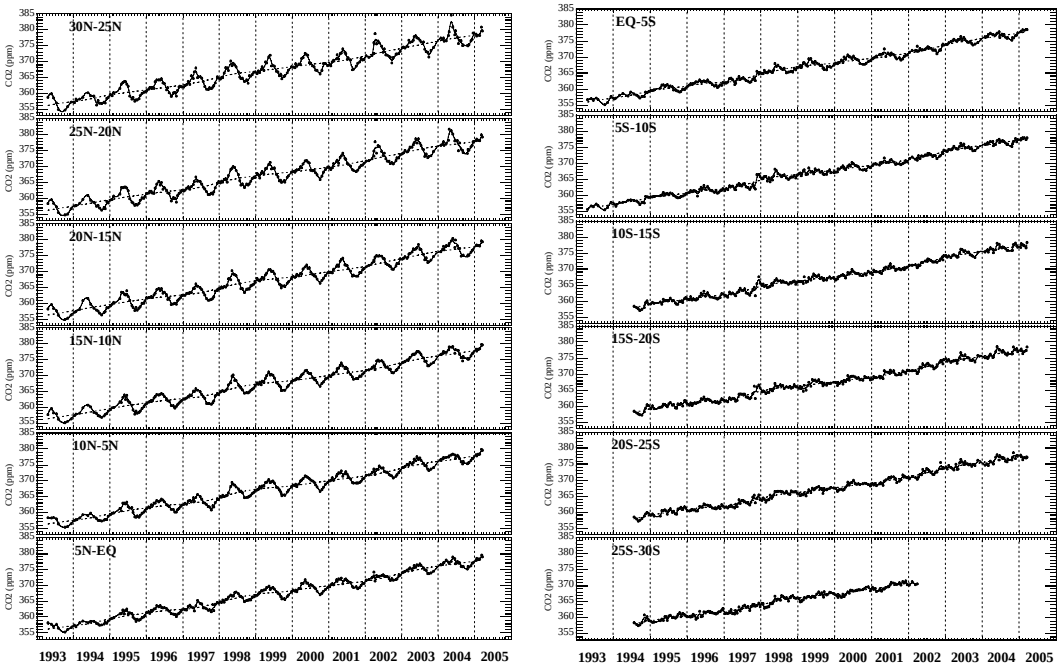

Fig. 1. The time variations of CO_2 for 12 latitudinal bands from 30°N to 30°S over the western Pacific from April 1993 to March 2005.

REFERENCES

Matsueda, H., and H. Y. Inoue (1996), Measurements of atmospheric CO_2 and CH_4 using a commercial airliner from 1993 to 1994, *Atmos. Environ.*, *30*, 1647-1655.

Matsueda, H., H. Y. Inoue, M. Ishii, and Y. Tsutsumi (1999), Large injection of carbon monoxide into the upper troposphere due to intense biomass burning in 1997, *J. Geophys. Res.*, *104*, 26867-26879.

Matsueda, H., H. Y. Inoue, and M. Ishii (2002a), Aircraft observation of carbon dioxide at 8-13 km altitude over the western Pacific from 1993 to 1999, *Tellus*, *54B*, 1-21.

Matsueda, H., S. Taguchi, H. Y. Inoue, and M. Ishii (2002b), A large impact of tropical biomass burning on CO and CO_2 in the upper troposphere, *Science in China* (Series C), *45*, 116-125.