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Global distributions and transport of CO2 in upper troposphere obtained by commercial aircraft observations

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The upper atmosphere plays an important roll for global carbon cycle because it contains a large portion of atmospheric carbon as carbon dioxide (CO2) and it serves as a pathway for long-range transport. However, our knowledge about vertical structure of CO2 is still limited because CO2 observations are conducted generally near the surface. Measurement by using commercial airliner is very powerful tool to provide precise and global CO2 distributions. Now Japan Airlines aircraft in regular service measure CO2 in flight by using the Continuous CO2 Measuring Equipment (CME), covering a substantial geographical area in the Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL) project.

This study focuses on the seasonal CO2 distributions observed in the upper troposphere. We used more than 2 million in-situ CO2 data from 4248 flights from November 2005 to December 2009. In order to give a climatological overview of the CO2 distributions in the upper atmosphere, we presented CO2 for a reference year of 2008 assuming the annual trend of 1.9 ppm/year observed in recent years.

In the northern high latitudes, monthly CO2 distribution in April in the upper troposphere shows larger values more than 387 ppm and values are gradually decreased to the 382 ppm in southern mid-latitude. The large decreases in CO2 in the upper troposphere are detected in the northern high latitudes in boreal summer. The mixing ratios over the Eurasian continent begin to decrease in May, and it reaches minimum values of about 380 ppm in July. On the other hand, the mixing ratios over the Northern Pacific begin to decrease after one month delay and it has minimum values of 382 ppm in August. The longitudinal differences in CO2 mixing ratios are largest in mid summer ($\sim$4 ppm) in July, although they are reduced to 2 ppm in August. The differences are not significant in winter season from October to April. These suggest that very low mixing ratios by strong sink for CO2 in the terrestrial biosphere are efficiently transported to the upper troposphere over the Eurasian continent creating significant longitudinal differences in summer.

Next, we studied the meridional cross sections for CO2 observed over the western Pacific regions in equivalent latitude-pressure coordinate. Cross sections in boreal winter to spring show clear boundaries near the equator; higher CO2 mixing ratios in the Northern Hemisphere compared to lower values in the Southern Hemisphere. However, higher CO2 more than 384 ppm in the Northern Hemisphere begin to get over this tropical barrier in April at higher altitudes (200-400hPa). Above 300 hPa in the Southern Hemisphere a rapid increase of about 2 ppm are found from March to June, suggesting the inter-hemispheric transport of high CO2 from the Northern Hemisphere. This distribution pattern corresponds to the unique autumn maximum in the upper troposphere in the Southern Hemisphere.

CONTRAIL CO2 data show the unique and clear seasonal cycles in the upper atmosphere. The longitudinal or latitudinal differences in CO2 distributions are found in this frequent and wide coverage aircraft observation project. Distributions of CO2 based on frequent observations delineate how CO2 in the upper troposphere spreads from land to ocean or Northern Hemisphere to Southern Hemisphere.