MULTIYEAR CO_2 CHANGES FROM AIRCRAFT, SURFACE AND OPTICAL MEASUREMENTS.

N.M. Gavrilov[1], V.K. Semyonov[2], V.P. Sinyakov, P. Tans[3], D. Guenther[4], and F.V. Kashin[5]

[1]*Saint-Petersburg State University, Atmospheric Physics Dept., Petrodvorets,198504, Russia; gavrilov@pobox.spbu.ru*
[2]*Kyrgyz National University, Institute of Fundamental Research, Bishkek, Kyrgyzstan; svk@elcat.kg*
[3]*Climate Monitoring and Diagnostics Laboratory, NOAA, 325 Broadway, Boulder, CO 80305-3328;Pieter.Tans@noaa.gov*
[4]*Cooperative Institute for Research in Environmental Sciences, University of Colorado, UCB 216, Boulder, CO 80309-0216;*
[5]*Institute of Experimental Meteroiogy, SPA"Typhoon", Obninsk, Kaluga reg., Russia;kashin@typhoon.obninsk.ru*

ABSTRACT
We present a statistical analysis of aircraft and surface measurements of the CO_2 mixing ratio over the US Rocky Mountains during 1993 – 2002 at latitudes close to that of the Issyk-Kul station in Kyrgyzstan. Average characteristics of the CO_2 mixing ratio and its annual variations show only small height variability in the troposphere over well mixed mountain regions. Comparison of Issyk-Kul optical data with US aircraft and surface measurements shows satisfactory agreement. Also some differences at low altitudes were obtained owing to possible regional differences between mountain regions of Central Asia and USA.

INTRODUCTION
Spectroscopic measurements of the CO_2 mixing ratio are important for validating existing and future satellite observations. Therefore, validating and improvement of the main assumptions used in spectroscopic CO_2 studies are of interest. Spectroscopic measurements of CO_2 contained in the atmospheric column have been made since 1980 at the Issyk-Kul station (42ºN, 77ºE). One of the main assumptions of the method is a constant CO_2 mixing ratio at all altitudes in the atmosphere [see *Kashin et al.*, 2000].

In this study we analyze vertical changes of the CO_2 mixing ratio and its seasonal variations in the troposphere from the data of flask aircraft measurements at Carr (41ºN, 105ºW) during years 1993 – 2002. These measurements are made just downwind, at the prevailing wind direction, of the Rocky Mountains at approximately the same latitude as Issyk-Kul station. The results are compared with optical CO_2 measurements and surface data for sites close to Carr and Issyk-Kul station.

AVERAGE CO2 PROFILES AND INTERANNUAL VARIATIONS.
Aircraft measurements of the CO_2 mixing ratio over Carr (Colorado, USA) are made at altitudes 2 – 8 km using chemical analysis of discrete flask samples [*Conway et al.*, 2003]. We used more than 300 vertical profiles obtained during 1992 – 2002. Individual aircraft vertical profiles of the CO_2 mixing ratio may be variable or near constant depending on weather conditions and transport of different air masses to the observation site. For estimating the mean characteristics of 10 years of non-equidistant airplane measurements at 1.5-km thick layers we first calculate and subtract least-square fits to a linear polynomial. Then average 2-year, annual, semiannual, 8- and 6-month harmonics are calculated and subtracted from the data for each altitude layer. Then average values and linear trend are corrected using this filtered data. The mean characteristics are shown in Fig. 1, where altitude variations are much smaller than that for individual flights.

A comparison of GLOBALVIEW curve fits of airplane measurements over Carr and Poker Flats and from ground flask measurements at their respective nearby sites Niwot Ridge and Barrow reveals larger vertical changes of amplitudes and phases of the seasonal variations over the region of Poker Flats than over the region of Carr below an altitude of 2.5 km and their similarity above this altitude. This may reflect larger influence of local CO_2 sources and sinks in the boundary layer than in the free troposphere above. To analyze interannual variations of CO_2 mixing ratio, the trend was calculated as low-frequency part of the spectrum of CO_2 variations using the method developed in CMDL by *Thoning et al*. (1989).

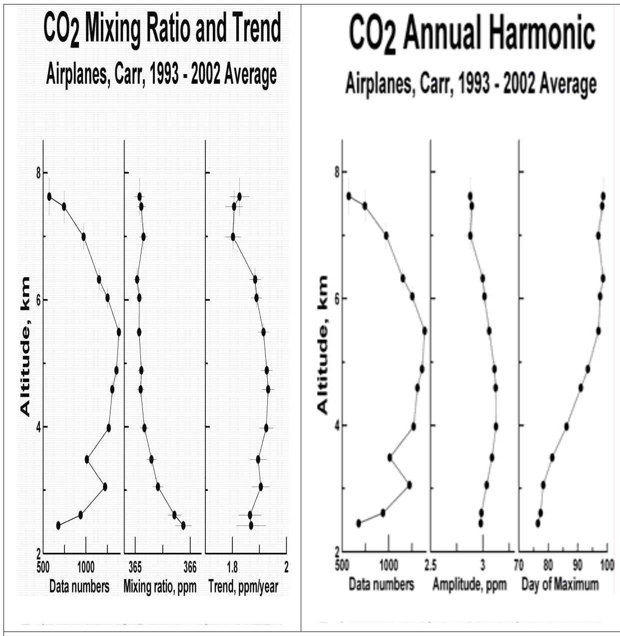

Fig. 1. Numbers of airplane measurements at Carr and average CO_2 mixing ratio and trends (left plot), also amplitude and day of maxima of annual harmonic (right plots) for years 1993 – 2002.

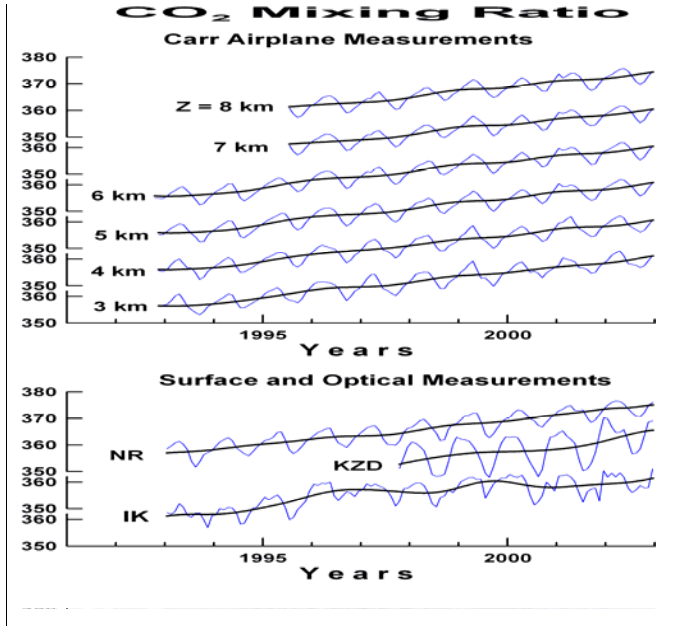

Fig. 2. CO_2 mixing ratio (thin lines) and low-frequency trend (thicker lines) from airplane observations over Carr (top) and at the surface at Niwot Ridge and Kazakhstan, also from optical measurements at Issyk-Kul station (bottom).

Fig.2 shows the measured CO_2 mixing ratio and its trend components obtained from Carr airplane data and from surface and optical CO_2 measurements. One can see similarity of variations at different altitudes. Seasonal variations observed at Issyk-Kul station generally correspond to those over Carr in Fig. 2. This shows that optical measurements reflect mainly CO_2 variations in the free troposphere. Amplitudes of surface CO_2 variations at Kazakh stations are substantially larger than those over Issyk-Kul and over Carr (see Fig. 2). This is likely caused by larger dependences of surface data on local CO_2 sources. Optical measurements at the Issyk-Kul station give information about column CO_2 contents including a contribution from low altitudes. This may explain some discrepancies between Issyk-Kul and Carr seasonal variations. But generally amplitudes of seasonal variations at Issyk-Kul station are closer to those in the free troposphere over Carr.

CONCLUSION

A statistical analysis of airplane, surface and optical CO_2 measurements over USA and Middle Asia during 1992 – 2002 shows that general trends and seasonal CO_2 variations are almost the same at all altitudes 3 – 8 km in a well mixed region close to the Rocky Mountains. Surface and low-altitude CO_2 variations show larger dependence on local conditions. Optical measurements give information about CO_2 variations mainly in free troposphere, which are more homogeneous over the globe.

Acknowledgements. This study was partly supported by the International Science and Technology Center under the grant KR-763.

REFERENCES

Kashin F.V., V.N. Aref'ev, K.N. Visheratin, N.Ye. Kamenogradsky, , V.K. Semenov, and V.P. Sinyakov: Results of Experimental Studies of Radiatively Active Atmospheric Constituents in the Center of Eurasia. Izvestia, Atmospheric and Oceanic Physics, v. 36, No.4, p 425-453. (Engl. transl.). 2000.

Conway, T.J., A. E. Andrews, L. Bruhwiler, et al. Carbon cycle greenhouse gases, *CMDL Report, 27*, 32-57, 2003.

Thoning, K. W., P. P. Tans, and W. D. Komhyr, Atmospheric Carbon Dioxide at Mauna Loa Observatory 2. Analysis of the NOAA GMCC Data, 1974-1985, J. Geophys. Res., v.94, 8549-8565, 1989.