B-4.4 Development of Airborne Instruments for the Greenhouse Gases Flux Measurements

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Abstract

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1.Introduction

In order to scale up the ground base data of methane and carbondioxide fluxes to global scale, satellite data to classify the vegetation and other parameters such as surface temperature or water level are used. The validation of this scale up should be done by some intermediate scale measurement. The three dimensional distribution measurements of greenhouse gases, together with other trace gases and meteorological elements, are important validation experiment.

The periodical measurement of vertical distribution of GHG's is desirable to compare with the model calculation based on the emission/sink inventory and the wind data base. This type of monitoring will be effective especially to understand the interaction between the terrestrial ecosystem and the atmosphere. The boundary layer atmosphere is directly influenced by the surface process and the turbulent mixing and transportation process. The upper free tropospheric air is sometimes contains the air transported directly by strong thermal convex or the air intruded from stratosphere, but mainly the background air common at the same latitude. These process can be separated by obtaining a set of data; the concentration of GHG's(CO_2, CH_4, N_2O, CFCs), Ozone, CO, H_2, VOC, stable isotopes in CO_2 and CH_4, aerosol (black carbon), etc.

Another approach is to measure the fluxes over a typical ecosystem by use of aircraft. The relation between the flux and the vegetation type and the physiological condition of plants can be obtained in a scale of several kilometers.

2.Periodical air sampling on an aircraft

As a part of joint research with National Aerospace Laboratory, the air at 8 levels up to 7000m is sampled in glass bottles semi-automatically at a rate of twice per month followed by a laboratory analysis of several gases components; CO_2, CH_4, N_2O, CO, H_2, $^{13}CO_2$. The flight area is over Sagami Gulf, which is in the south west of Kanto Plateau about 80km from Tokyo. The results are shown in Fig.1. The high concentration of CO_2 on February 2 and March 4, 1997, at lower altitudes are due to the anthropogenic activities as the wind direction is NW at that time. The concentration of CH_4 and CO were high, too, supporting the above explanation. The CO_2 concentration in summer is lower as a whole than the background, and it should be attributed to the photosynthesis of plants. The concentrations of CH_4 and CO are low only below 2000m. It would be due to the photochemical reaction with OH radical produced by the photolysis of O_3 followed by the reaction with H_2O, and the photochemical chain reaction catalyzed by NOx, both of which are dominant at lower altitude. Long period observation will lead to a better understanding of such processes.

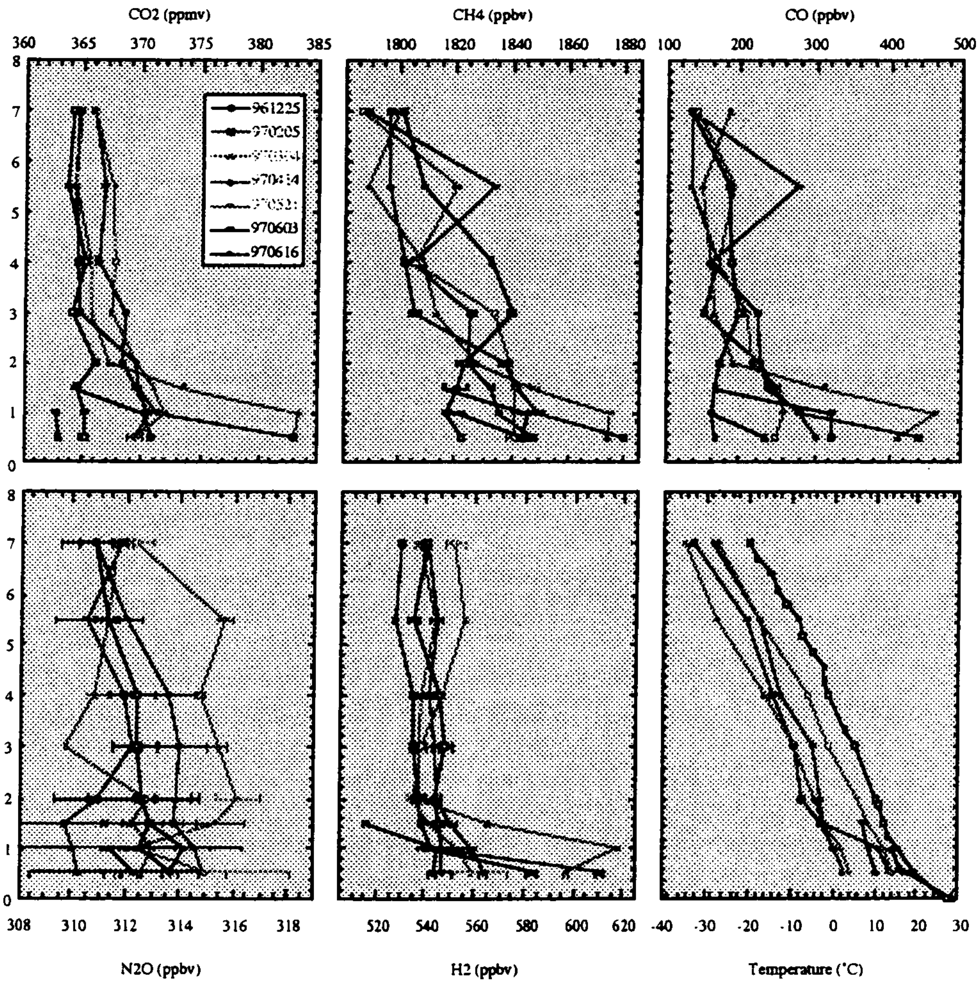

Fig.1. Vertical profile of CO_2, CH_4, N_2O, CO, H_2 and temperature over Sagami Gulf in the period from December, 1996, to June, 1997.

3.Continuous measurement of CO_2 on aircraft

Beside the air-sampling experiment, a continuous measurement of trace gases continuously on board is desirable, even if the precision of the concentration is worse. The concentrations of trace gases are very variable in altitude and the sampling may made at a peak or at a bottom, which is afraid not to be a typical sample at the altitude. So, the combination of bottle sampling to determine the concentration precisely and to measure all the components, and the continuous measurement to obtain a detail structure is desirable.

The concentration of CO_2 is measured by non-dispersive infrared meter in general, but it is pressure dependent. The automatic pressure controller was put at the exit of sample and reference gas, and the stability of 100ppb / 100m was achieved.

We have already developed continuous CH_4 measurement instrument combining a selective oxidation of non-CH_4 hydrocarbons and flame ionization detector. At this moment, the weight and power consumption is not suitable for a small aircraft, but improvement will be possible. The sensor of O_3 commercially available has a function to make the pressure correction. So, the next target will be CO. Some additional instruments such as particle and black carbon will prepare a full set of data to assign the source and sink process and the transportation processes.

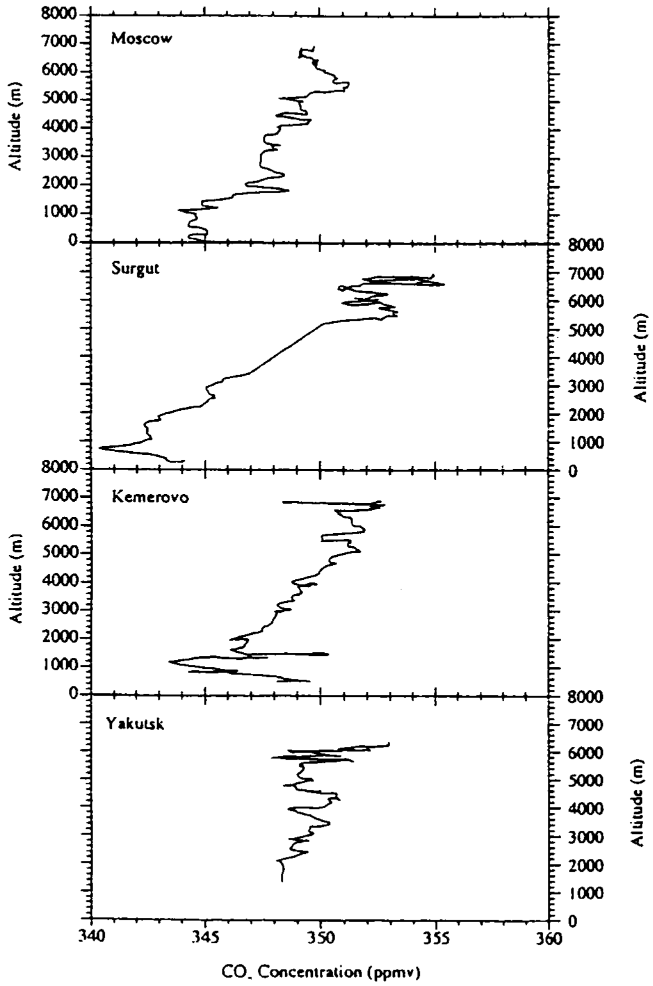

Fig.2. Vertical distribution of CO2 in Siberia.

City	; latitude	longitude (°)
Moscow	; 55.45	37.42
Surgut	; 61.10	73.20
Kemerovo	; 55.25	86.05
Yakutsk	; 62.10	129.50

4.Eddy correlation flux measurement of CO_2 and H_2O on an aircraft

Eddy correlation flux measurement of CO_2 and H_2O on an aircraft has been performed successfully over East Hokkaido, in 1995, flying at the altitude of 200m above surface.

The experimental setup is as follows: Air is sampled from the top of Dornie and lined to the cabin by a copper tube, 1/4", and introduced to Lyman alpha hygrometer. This hygrometer can be installed outside of the cabin, but it was installed on the sampling line for the comparison with CO_2 sensor. The air is compressed to 2.5 atmosphere and water vapor was removed by a drain trap and a denuder tube down to -17℃. CO_2 concentration is measured by a NDIR spectrometer, LiCor 6262, in fast response mode. The wind velocity measurement was done by National Aerospace Laboratory, and the detail is described on a separate paper.

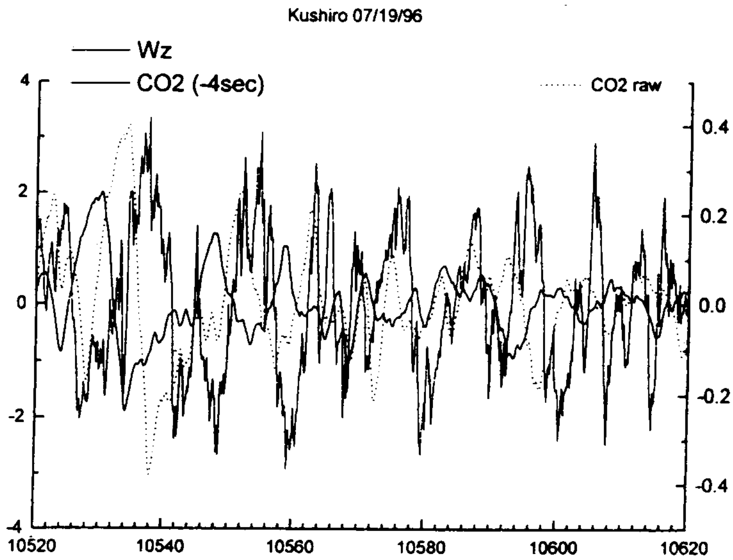

Fig.3. Short term variation of CO2 concentration (smooth line) and vertical wind velosity (noisy line).

The delay of CO_2 signal caused by a long line before the sensor was 4 seconds judging from the co-variance analysis of vertical wind velocity variation and CO_2 signal, which is in good agreement with the estimation from the line volume and flow speed. Fig.3 shows a typical result where the noisy line is vertical wind velocity and smooth one is CO_2.

The positive peak of vertical wind velocity and the negative peak of CO_2 coincide well. The delay of water vapor was negligible. From the time-shifted covariance, the fluxes of CO_2 and H2O were obtained. The data were divided by 3 minutes intervals and the fluxes at different places were obtained; the fluxes at 10km intervals were obtained. As the number of eddies is only about 20, and the data thus obtained is noisy. On July 19, nine flights were repeated on the same line of 110° . All the flux data are plotted on Fig.4 together with a map; negative flux of CO_2, ●, and heat,□. The horizontal axis of the figure, the line of -20 W m^{-2} of heat, -0.02 mgC m^{-2} s^{-1}, is fitted to the flight course on the map. So, the location of peak of flux can be assigned on the map at this axis. Although the flux obtained is noisy, the agreement among the data point of different flight leg is very good. The peaks of negativeflux, downward flux, of CO_2 coincide with the heat flux. The peaks appear when the aircraft crosses with a big road, route # 391, #33 and #44, but no peak was observed when crossing with route 272. The route 272 here is a channel road, and the surface is not heated by solar radiation. A large flux of

CO_2 is accompanied by a large heat flux, and it occurs where the surface is open widely and heated by sun, and the thermal convex carries the low CO_2 concentration air from the nearby forest upward. Other area is forest mainly, and both ends are wetland, and relatively larger negative flux is observed over forest than wetland area.

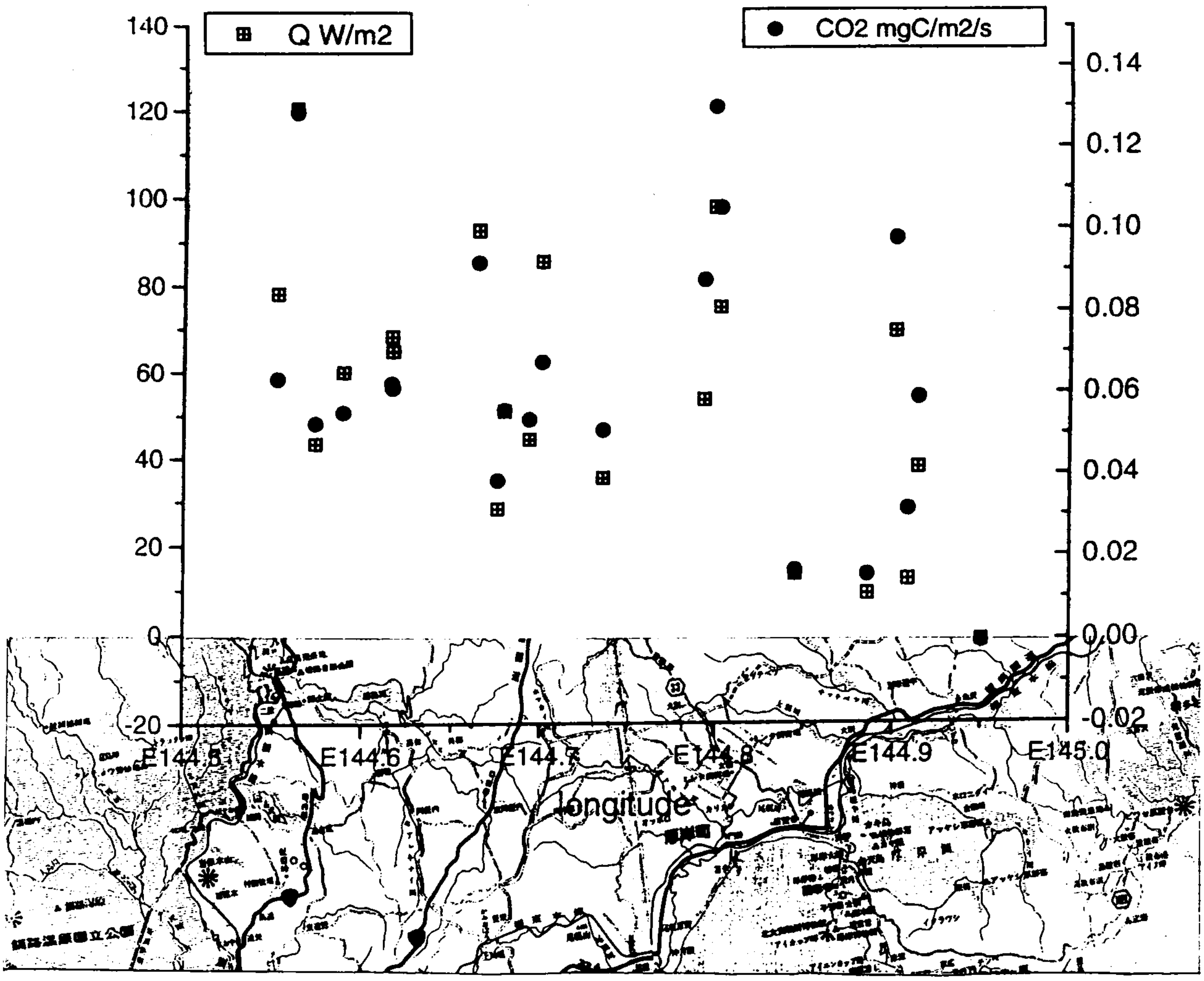

Fig.4. Downward flux of CO2 and upward flux of heat are potted against the longitude, overlapping the horizontal axis on the flight rout on a map. Data of July 19, 1995.

5. Conclusion

Periodical measurement of vertical profile of trace gases, especially greenhouse gases, combining the air sampling method for the precise measurement and high level analysis such as stable isotope ratio, and the continuous measurement on board to obtain the detail structure of the atmosphere, has been prepared in this study. It will provide us a very important data to study the source, sink and transportation processes.

The eddy correlation flux measurement of CO_2, H_2O and heat has been done successfully, and very interesting data was obtained. Further measurements under different season and meteorological condition are necessary.

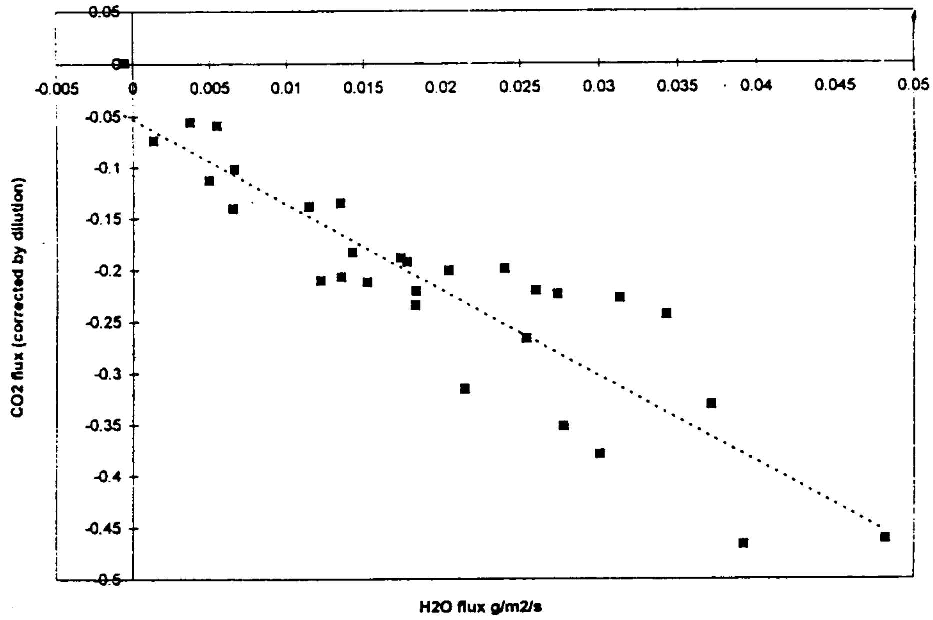

Fig.5. H_2O flux vs CO_2 flux observed on July 19, 1995, at the altitude of 200m over Hokkaido.