B-4.4 Aircraft Observation of Areal Carbon Absorption

Contact person Takashi Tamaru
Director, Aero-engine Division, National Aerospace Laboratory
Ministry of Education, Culture, Sports, Science and Technology
7-44-1, Higashi-machi, Jindaiji, Chofu, Tokyo 182-8522, Japan
Phone: +81-422-40-3450 Fax: +81-422-40-3445
E-mail: tamar@nal.go.jp

Total Budget for FY1999-FY2000 16,979,000 Yen **(FY2000**; 8,490,000 Yen)

Abstract The aim of this research is to establish aircraft measurement technique of trace gases in the atmosphere. The trace gases are carbon dioxide and other gases that influence the activity of forests. The present research consists of obtaining measurement techniques of gas concentration and the local three-dimensional flow at once on an airplane in order to know the flux, or mass transportation, of those chemical species. Comparing with the data obtained by the fixed radar facility, the verification was made to the data by ultrasonic anemometer installed on an aircraft. It demonstrated that the flux measurement by the airplane with an ultrasonic anemometer was made and the absorption of carbon dioxide was observed over the forest in Hokkaido.

Key Words Carbon dioxide, mass transport, aircraft observation, wind measurement, ultrasonic anemometer, trace gas flux

1. Introduction

The aircraft has a great advantage to measure the areal atmospheric phenomena[1, 2]. Especially, it can measure the movement and quality of the air directly by in situ measurement of the atmosphere over the specific area.

In this research, we expected to establish a flux measurement technique by exact measurement of three dimensional air velocity and trace gas concentration on an airplane[3-9]. To calculate the flux of the gas, various compensations have to be made on the measured velocity data on an airplane since it moves and changes its location, altitude and attitude. It needs transpose of coordinates, modulation of the probe movements and compensation of air flow around the airplane. None could ever confirm the values measured by air-borne instruments precisely. We have verified the measured values by comparing with the data obtained at the stationary observation facility, so called an MU radar observing the upper and middle atmosphere, in the Shigaraki MU observatory,

the Radio Atmospheric Science Center, Kyoto University.

As the demonstration of the practical use to get the flux of trace gases, simultaneous measurement of air velocity and the concentration of trace gases were performed over the forest of Tomakomai-area, Hokkaido. This technique could be applied to wide area of measurement to know the quantitative emission, absorption, and the transportation of trace gases in areal atmosphere.

2. Research Objective

The aim of this research is to establish aircraft measurement technique of trace gases in the atmosphere. The trace gases are carbon dioxide and other gases that influence the activity of forests. By simultaneous measurement of gas concentration and the local three-dimensional air flow at once, we could know the local flux of the chemical species in the atmosphere.

3. Research methods and procedure

Flux measurement of trace gases When the concentration of a trace gas and the vertical wind velocity are expressed as C and W, respectively, flux of the gas can be expressed as eq. (1) shown below. In the equation, the time average concentration of the trace gas is expressed as $\overline{C}$, and the deviation is as C'. In the same way, $\overline{W}$ and W' are an averaged wind velocity and the deviation respectively, and the equation can be developed as eq. (2). Since the average of the deviation becomes zero, averaged value of flux in terms of eq. (1) will be reduced to eq. (3).

$$C \cdot W = (C' + \overline{C}) \cdot (W' + \overline{W}) \quad (1)$$

$$= C' \cdot W' + C' \cdot \overline{W} + \overline{C} \cdot W' + \overline{C} \cdot \overline{W} \quad (2)$$

$$\langle C \cdot W \rangle = \langle C' \cdot W' \rangle + \langle \overline{C} \cdot \overline{W} \rangle \quad (3)$$

The average value of vertical wind near the ground becomes generally close to zero because of the effect of boundary, i.e., the ground. Then the flux can be expressed only by an average value of the product of derivatives of the concentration and the velocity, known as "Eddy-correlation". In the case of aircraft measurement, however, the assumption that the average value of the vertical wind being zero cannot be always correct since it flies high enough to avoid the obstacles on the ground. Then eq.(1) is used directly to calculate the flux in our case.

Comparison of the data by U-sonic and MU radar The ultrasonic anemometer (hereafter referred to as U-sonic) was calibrated with wind tunnel test. The wind velocity (Vw) can be calculated from the difference between the ground speed (Vg) and air speed (Va) of the aircraft. The

Va is got by converting U-sonic data into the inertia coordinate using the transformation matrix consisting of airplane attitude. The Vg is got by the Inertial Reference System (IRS) and the GPS.

The MU radar consists of 475 VHF antennas in an area with 100m in diameter. The MU radar can provide the three-dimensional wind velocity data in 150 m vertical step interval above 2km at every 10 minutes. Simultaneously, we obtained the wind velocity data by the U-sonic flying over the MU radar and by the MU radar on ground. Then, the verification of the u-sonic wind data was made by comparing the data obtained by MU radar.

Measurement of flux over the forest For the purpose of establishing an aircraft observation technique to get flux of local atmospheric trace gases, simultaneous measurement was made on the air flow and trace gas concentration over the Tomakomai forests in Hokkaido. The trace gas concentration was measured by CO_2 analyzer (Li-6262). The flow measurement was made by a U-sonic mounted on an airplane. The construction of the measuring instruments on board is shown in Fig. 1.

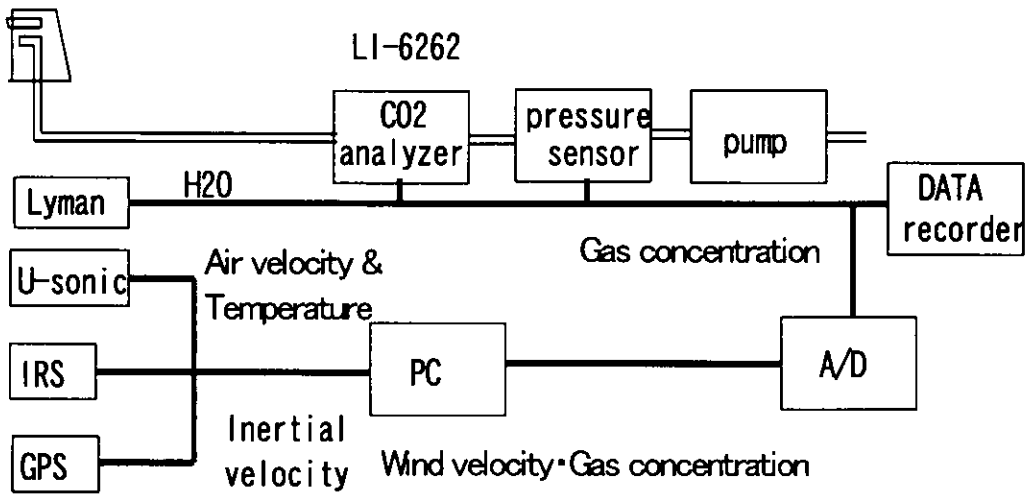


Fig. 1 Block diagram of measurement instruments on the airplane

4. Results

Comparison of the data by U-sonic and MU radar The wind data measured by U-sonic installed on a NAL airplane B-65 was compared with wind data measured by MU radar for quality assurance. It was achieved by simultaneous observation during flight tests (February, 2000) over the Shigaraki MU radar. The MU radar data was interpolated for the aircraft time data and also for the altitude data. Flight test data is averaged every 10 minutes for correspondence of the MU radar. Average values and standard deviations of the difference between data of the MU radar and wind obtained from the aircraft U-sonic are shown as follow.

$\Delta Vwn = -0.9m/s, \quad \sigma wn = 0.8m/s,$

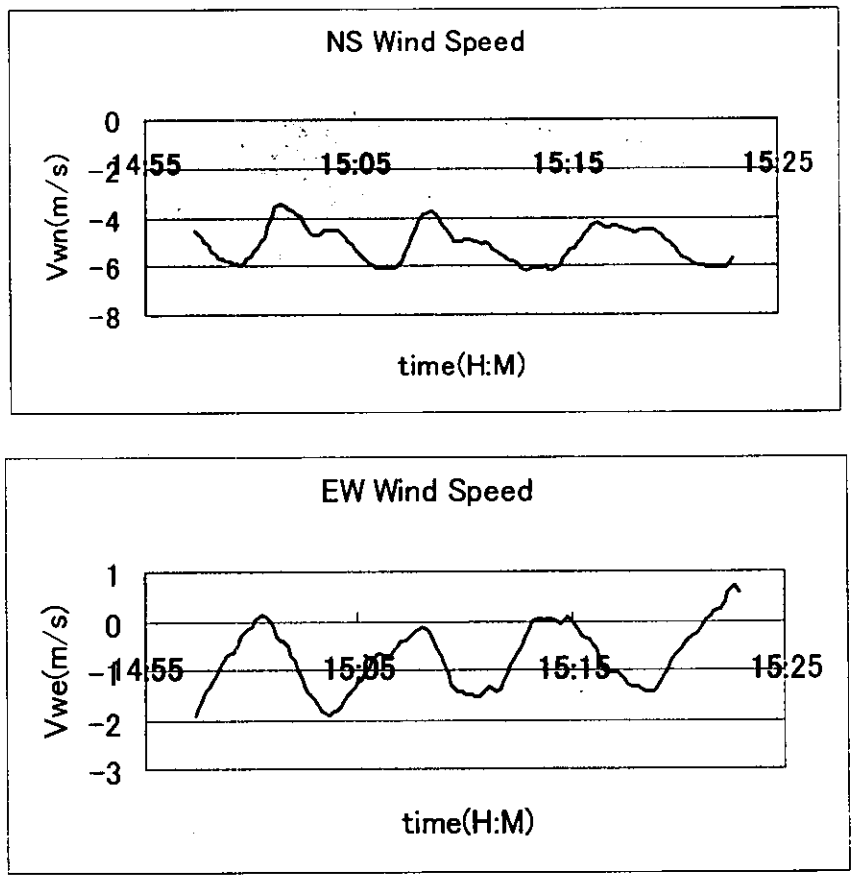
$\Delta Vwe = 0.2m/s, \quad \sigma we = 0.8m/s,$

$\Delta Vwz = 0.005m/s, \quad \sigma wz = 0.06m/s$

Where Vwn, Vwe, and Vwz express north wind, east wind and vertical wind respectively. The comparison proved that both values are in satisfactory agreement.

Measurement of flux over the forest Flux of carbon dioxide was measured by NAL airplane over the forest of Tomakomai, Hokkaido on Aug. 25 &27, 2000. The altitudes were 150, 300, 800 and 1600 m and flight course was 10 km in length and 2 km in width. The weather was cloudy on Aug. 25 and clear on Aug. 27.

Fig. 2 shows one of the results of measured data. It shows periodical nature since the airplane flied around the same course during the 20 minute flights.



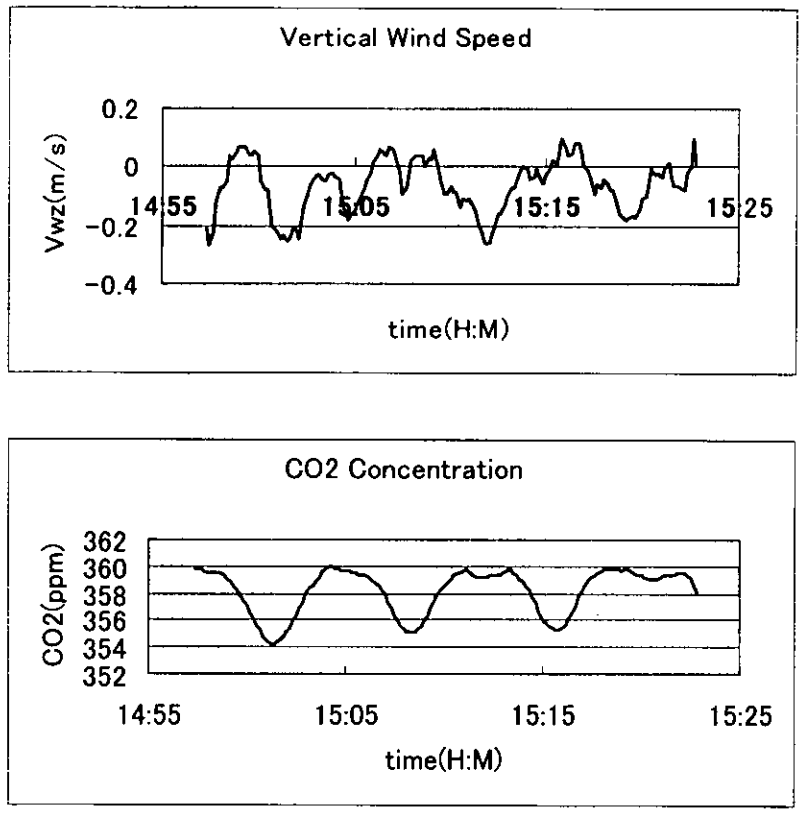


Fig. 2 Results measured on Aug. 27 PM, altitude 150m

Fig. 3 shows the flux obtained from the data above by every 100 second averaging. It shows that the negative fluxes of CO_2 were obtained over the forest and it means absorption or sink of the gas in the area. This result shows that there was absorption of forest or downward transportation of CO_2 in most time of the measurement.

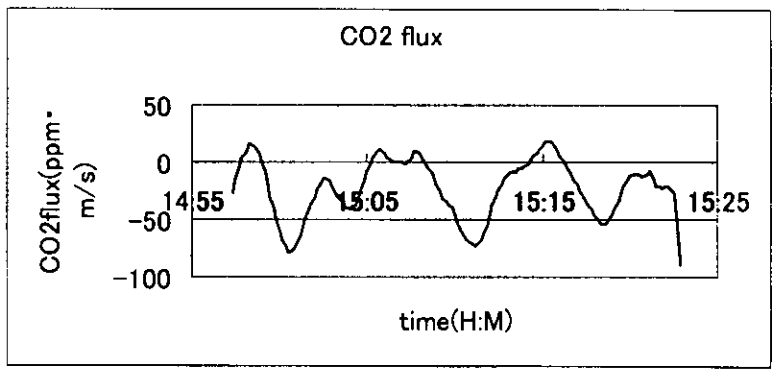


Fig. 3 CO2 flux over the Tomakomai forest

5. Conclusion

1) Comparison of wind measurement data by the MU radar and by the ultrasonic anemometer installed on an airplane showed good agreement with each other.

2) Flux measurement technique to know the areal mas transportation of the trace gases in the atmosphere is established by use of an ultrasonic anemometer on an airplane.

6. References

1) T. Tamaru, K. Yazawa, T. Tagashira, T. Machida and G. Inoue: Vertical Distributions of Greenhouse Gases Measured by Aircraft over Sagami Bay near Tokyo, Technical Memorandum of National Aerospace Laboratory, TM-745 (2000/1) [Japanese]

2) T. Machida, K. Yazawa, T. Tagashira, G. Inoue, T. Tamaru: Ariborne Observation of Atmospheric Carbon Dioxide over Sagami Bay, Japan Technical Report of National Aerospace Laboratory TR-1422 (2001/1) [Japanese]

3) K. Yazawa, T. Tamaru, et al.: Greenhouse effect gas measurement of the Kushiro bog by the aircraft, The 8th Symposium on the Joint Siberian Permafrost Studies between Japan and Russia in 1999 Proceeding, 2000.3

4) K. Yazawa, et al.: Comparison of wind observation between MU radar and an aircraft, Proc. 3rd Mu radar symposium, (2000/3) [Japanese]

5) K. Yazawa, T. Tamaru, Hashiguchi; Comparison of data by MU radar and by airplane, Proc. 11th Taiki Kagaku Symp. (2001/3) [Japanese]

6) K. Yazawa, T. Tamaru, et al.: Greenhouse effect gas measurement of the Kushiro bog by the aircraft, The 8th Symposium on the Joint Siberian Permafrost Studies between Japan and Russia in 1999, (2000/1)

7) K. Yazawa, T. Tamaru, T. Tagashira, T. Sakai, G. Inoue, S. Maksyutov and T. Machida: Flux Measurements of Greenhouse Gases by the Aircraft over the Kushiro Bog, Proceedings of the Eighth Symposium on the Joint Siberian Permafrost Studies between Japan and Russian in 1999, Inoue and Takenaka eds. (2000/3) pp300-305

8) K. Yazawa, et al.: Eddy-correlation technique applied to CO2 and water vapor flux measurements over Hokkaido in July 1996, International Workshop for Advanced Flux Network and Flux Evaluation (Kick off meeting of the Asia Flux Network), Hokkaido University, Sapporo, 2000.9

9) K. Yazawa, et al.: Flux Measurements of Greenhouse Gases by the Aircraft over Tomakomai Experimental Forest Symposium on the Joint Siberian Permafrost Studies between Japan and Russia in 2000, 2001.1.23