B-1.1 Study on the Environmental Behavior of Greenhouse Gases of Industrial Origin

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Abstract

In this study, the sources and sinks of CO_2 and CFCS are investigated and field observations to study the behavior of CO_2 were carried out over and around Japan.

According to observational results, we get the value of 2 to 4 g/(m^2hr) for intake rate of CO_2 due to the activity of vegetation under the daytime condition of Iriomote Island of Okinawa and the value 1.5 to 2.5 g/(m^2hr) under the daytime condition of Tsukuba in Ibaraki. The values are roughly proportional to the amount of insolation. From the product of this value by whole area of the Iriomote (20,000 ha), we can calculate that the total intake of CO_2 due to the vegetation in the Iriomote is between 400 to 600 tons/hr. These values become about 1 g/(m^2hr) under cloudy condition or in the evening. Emission rates of CO2 in night are 0.3 to 0.4 g/(m^2hr). However,we need to measure the net-intake of CO2 during whole year for clarification of the role of vegetation.

Key Words CO_2, Sources and Sinks, Exchange Process, Airplane, Vegetation, Field Measurement

1.Introduction

The assessments of CO_2 concentration in future and its impact on environment have large ambiguity due to the uncertain behavior of CO_2 in the environment and uncertainty of the fossil-fuel consumption.

In this study, the sources and sinks of CO_2 and CFCS are investigated and field observations to study the behavior of CO_2 were carried out over and around Japan.

2.Research Objectives

Main objectives of this study are as follows;

(1) Investigation of the sources and sinks of CO_2 and CFCS.

(2) Development of sensors of these gases and field measurement method.

(3) Field observations using the airplane and tower to study the exchange rates of CO_2 among the atmosphere,vegetation and sea.

We carried out field experiments to estimate the exchange rates of CO_2 between atmosphere and sea or vegetation at Iriomote Island of Okinawa in March & November, 1991 and in July, 1992, at Moshiri of Hokkaido in October, 1992 ,and at Tsukuba of Ibaraki in July & September,1991 and January,1992.Using these data, time variations of CO_2 intake rates and the relations between intake-rate and meteorological conditions were investigated.

3.Research Method

3.1 Airplane measurements

Spatial observations of CO_2 concentration, temperature and humidity were made by the light airplane, Cessna-404. Total number of flights was 8 runs in March 1991, 7 runs in November 1991 and 9 runs in July 1992. The flight path covered two or three heights between 200m and 1000m and the time for one run was approximately one and half hours. The flight speed was about 150 knots. The flight courses were chosen by the purpose of measurement from rectangular flight (20km x 4 legs), crossing flight(20-30km) over the Iriomote or long distance flight (30-40km) in the down-wind side of the island ((1) in detail).

The infrared CO_2 sensor with open sensing path was installed in the cabin (refer(2)). Outside air was introduced to the sensor through a pipe. Thermister dry & wet bulb thermometer was used to measure the mean-temperature and mean-humidity, and mixing ratio of water vapor was measured by a Lyman-alpha hygrometer.The height of flight was estimated from output of barometer. Two or three air samples were taken at the each flight level and the concentration of CO_2 was analyzed by the non-dispersive infrared analyzer in the laboratory.

3.2 Air sampling and its analysis

The air samples of surface were taken at the three points including two points of ships and one point at the inner site of the Iriomote. And, the upper airs around and over the Iriomote were sampled by the airplane. The frequency of sampling by airplane was 2 or 3 times at each flight level and 6 to 9 samples were taken during one run.

Air sample container is cylindrical stainless-steel flask of one liter capacity. Before sampling, the flasks are evacuated to remove the contaminants. The air samples are pressurized up to about 3 atm using an electric diaphragm pump.

These air samples were analyzed by a non-dispersive infrared CO_2 analyzer manufactured by Hitachi - Horiba Co.,Japan. Since the NDIR gas analyzer is for relative measurement, it requires standard gases defined by the CO_2 absolute calibration system. System of CO_2 analysis and calibration follow after the method developed by Tanaka et al.(3). We used four standard gases between 321 ppm and 411 ppm of CO_2 based pure air for calibration. The precision of better than 0.2 ppm was attained.

3.3 Measurements of meteorological conditions by a tower

At the same time of CO_2 measurements, we observed the meteorological conditions such as wind speed, wind direction and temperature and insolation.

4. Observational results

4.1 Observational results of an airplane

Fig.1 shows two examples of CO_2 concentration measured by the crossing flights over the Iriomote. The upper graph of Fig.1 is a case of the crossing flight from A' to B' at the height, 600 m (10:14-18, March 24). The wind direction in this case is around E and depression of CO_2 concentration is about 3 ppm over the center of the island. The lower graph of Fig.1 is a case of the crossing flight from A to B at 400 m (13:08-14, March 24). The wind direction in this case is SE and CO_2 depression is about 2 ppm over the center of the island (refer(4)).

Fig.2 shows the vertical profiles of CO_2 on the windward and leeward sides of the island measured by airplane. We can estimate the amount of CO_2 absorbed by the biosphere of Iriomote Island according to the difference of CO_2 concentration between the two locations.

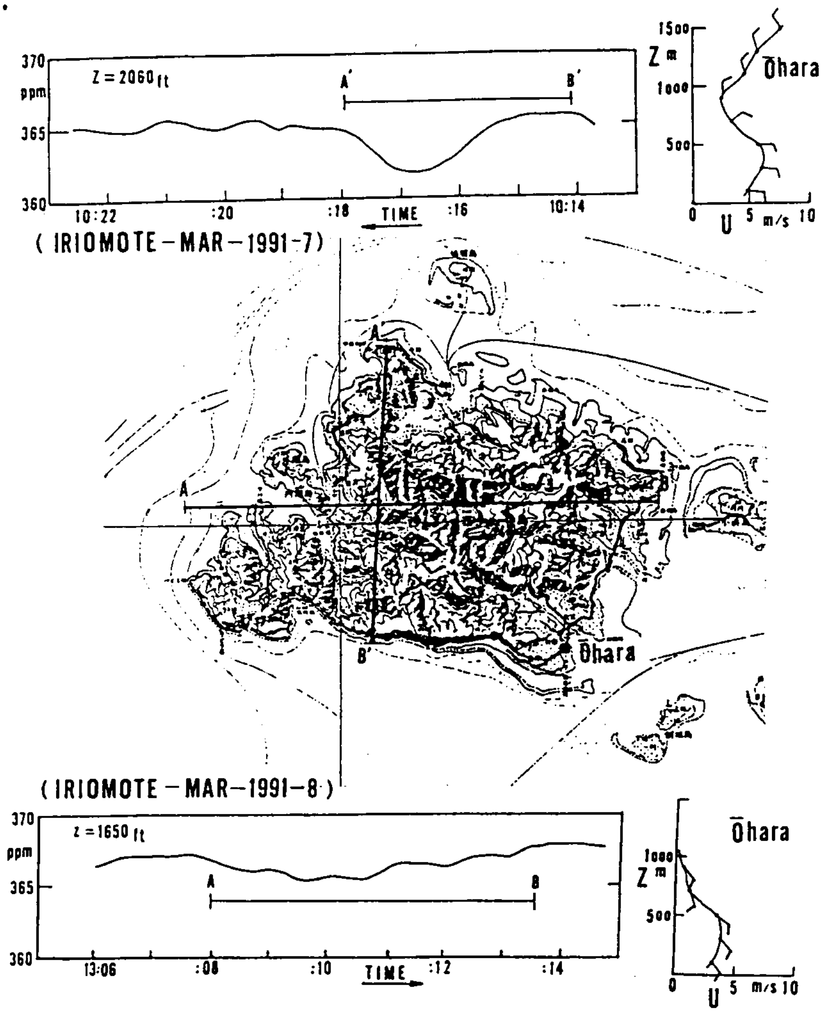

FIGURE 1 Airplane measurements of CO_2 concentration over the Iriomote (IRIOMOTE-MAR-1991-7,3/24 10:14-10:18,height;2060ft (600m),A'-B' and IRIOMOTE-MAR-1991-8,3/24 13:08-13:14,height; 1650ft(500m), A-B).

The relationship between the amount of CO_2 absorbed by the vegetation and solar radiation measured at Iriomote Island and Tsukuba is shown in Fig.2. According to these results, net-intake rate of CO_2 due to the activity of vegetation takes a value of 2 to 4 g/(m^2hr) at Iriomote and a value of 1.5 to 2.5 g/(m^2 hr) at Tsukuba under daytime condition, and the value is roughly proportional to the amount of insolation.

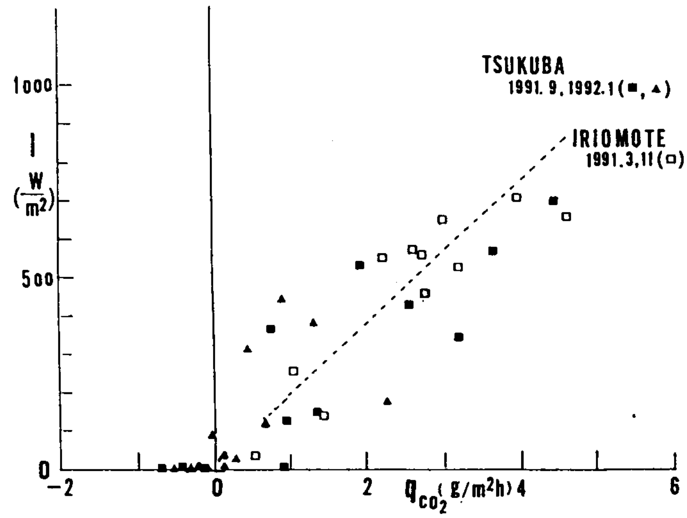

FIGURE 2. Relation between insolation and CO_2 absorption.

5.Discussion of the results

We chose the Iriomote for the experiment site from the reasons that the sub-tropical forests distributed uniformly in the island and the artificial emission of CO_2 was small. However, the area is too large to clear the CO_2 distribution all over the island only by the experiment. Then, decrease of CO_2 due to activity of vegetation was calculated using the plume diffusion model with Pasquill diffusion parameters.

In the diffusion model, the negative sources (intake of CO_2 by vegetation) were given at the every mesh (1km x 1km, area sources) over the island, and the source height was 2m above the ground surface. The ground level above sea surface was taken from the topographical data, but the mechanical effects of topography were not considered. The source intensity,-2 g/(m^2hr) was assumed for the value of net-intake rate of CO_2 as the result of vegetation activities including photosynthesis, respiration and decay of organic matter. In actual condition, intake value of CO_2 by vegetation depend on the species of plants, meteorological condition and CO_2 concentration, but we use this value for mean and representative one of net-intake of CO_2 due to the activity of sub-tropical vegetation during clear daytime.

Fig.3 shows the result of diffusion calculation using the diffusion condition at the time of the measurement of Fig.4; U=3 m/s, wind direction=SE, stability=C. The decrease due to the CO_2 intake of vegetation is more than 2 ppm at the center of the island according to this result.

Fig.4 is a comparison between horizontal distribution of decrease of CO_2 according to the calculation (Fig.4) and the horizontal variation of CO_2 concentration observed by airplane (lower graph of Fig.1). In this calculation, the value, 2 g/(m^2hr) was used for the net-intake rate of CO_2, but the value, 2.5 g/(m^2hr) is more agreeable to the observed result.

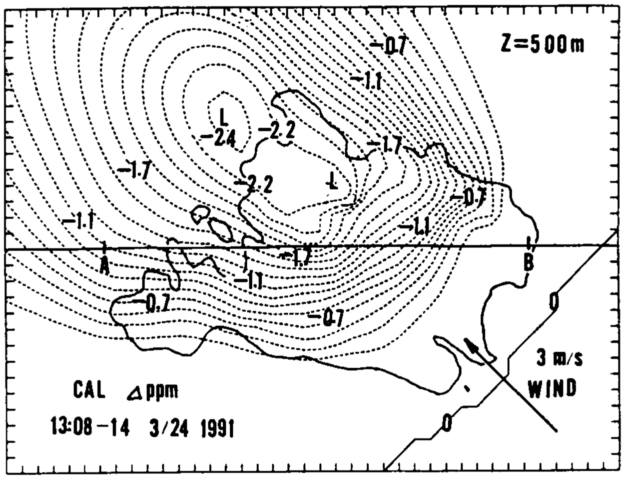

FIGURE 3.Horizontal distribution of CO_2 concentration decrease calculated by Pasquill diffusion model (height=500m, wind=3m/s, SE, stability=C).

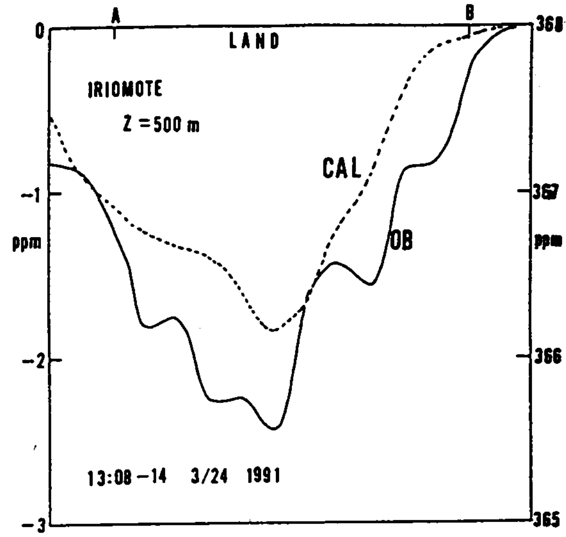

FIGURE 4.Comparison of the horizontal distribution of CO2 concentration decrease according to the diffusion calculation (Fig.3) with airplane measurement of CO_2 concentration (Fig.1).

6.Conclusions

Above discussion, we can get the value of 2 to 4 g/(m^2hr) for intake rate of CO_2 due to the activity of vegetation under the daytime condition of the Iriomote of Okinawa ,and the value 1.5 to 2.5 g/(m^2hr) under the daytime condition of Tsukuba in Ibaraki. The values are roughly proportional to the amount of insolation. From the product of this value by whole area of the Iriomote (20,000 ha), we can calculate that the total intake of CO_2 due to the vegetation in the Iriomote is between 400 to 600 tons/hr. These values become about 1g/(m^2hr) under cloudy condition or in the evening. Emission rates of CO_2 in night are 0.3 to 0.4 g/(m^2hr). However, we need to measure the net-intake of CO_2 during whole year for clarification of the role of vegetation. Calculation of the CO_2 flux using the eddy correlation method should be necessary to clarify fine mechanism of CO_2 exchange between the atmosphere and vegetation or sea. This problem has to be investigated as a next step.

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