B-4.2 Field Measurement of Seasonal Change of CO2 and its Annual Balance

Contact Person Gen Inoue
Chief, Global Warming Mechanism Research Team
Division of Global Environment Research
National Institute for Environment Studies
2-16 Onogawa, Tsukuba, Ibaraki 305, Japan
Phone +81-298-51-6111 ext. 461 or 352,
Fax +81-298-51-
E-mail inouegen@nies.go.jp

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Abstract: One of the most important subject of research concerning the global climate change is so called "missing sink of CO2". The annual variation of CO2 and its stable isotope concentration suggests that boreal forest may be one of the most important missing sink of CO2.

The long term measurement of CO2 concentration in Taiga area, Yakutsk, in East Siberia has been started. Self-support type CO2 instrument, which consists of Ni-converter FID-GC, nitrogen carrier gas generator, hydrogen generator, hydrocarbon free air generator and some meteorological instruments, has been installed in a container laboratory. The sampling of air from 77, 44, and 11m in height will give us the information about the interaction between the atmosphere and the forest in Siberia.

Some large scale CO2 observations have been performed by an observation aircraft over Siberia. The diurnal variation of vertical distribution of CO2 suggest that the boundary layer is strongly influenced by the vegetation. Measurement of CO2 concentration change in the temperature inversion and in the mixing layer combined with the analysis of mixing dynamics will lead us to a better understanding of this interaction

Key Wards CO2, Global Warming, Taiga, Carbon Cycle

1.Introduction

Among the greenhouse gases, carbon dioxide plays the most important role except water vapor, which acts both as GHG and enhancement of albedo and the net effect is not clear. The contribution of CO2 to the increment of radiation forcing in past twenty years is estimated to be 55%, which exceeds to the other values, 25% of CFC's, 15% of methane, and 5% of N2O. The main anthropogenic source of CO2 is the consumption of fossil fuels (5.4GtC) and the deforestation due to agricultural activities (1.6GtC). The imbalance between the above input and the increase of CO2 in the atmosphere (3.4GtC) and the amount of CO2 absorbed by ocean (2.0GtC) is called as missing sink of CO2 (1.6GtC). It is supposed to be the absorption by terrestrial ecosystems or to the underestimation of oceanic absorption.

Among the terrestrial ecosystems, natural forest or tundra are supposed to be the main sink, because the uptake of carbon dioxide by agriculture activities is equivalent to the consumption as food and agricultural wastes, which are turned over to the atmosphere in a short period. The natural conifer forest over Siberia, which is called Taiga, is the largest natural forest in the world, and the increase of biomass in this boreal or sub-boreal forest is expected due to the fertilizer effect of CO2, the global warming in this area or the increase of nitrogen compound precipitation. Peat moss in boreal and arctic wetland is said to increase the depth of peat at the rate of 1mm/yr. on average. These increase of biomass is one of the possible missing sink.

It is well known that the GCM calculation predicts the most remarkable increase of temperature in arctic area, and it really observed recent years. Under such an elevated temperature condition, the thawing of permafrost which lead to the change of forest to wetland, the desiccation of

wetland, and the change of vegetation. Very large biomass stock in boreal and arctic area will be emitted to the atmosphere as either CO2 or CH4. The northern limit of forest will be shifted to higher latitude because of presence of slowly growing small trees near the limit. Thus, there are a lot of possible change in emission and sink strength of CO2, and the net effect is difficult to estimate. It is important to develop the methodology to detect these changes.

2.Long range observation of atmospheric CO2 concentration in Taiga forest

The net balance of carbon in the forest is difficult because the uptake of CO2 by photosynthesis and the emission by respiration in forest ecosystem. The imbalance is very small compared with the source and sink strength. There are a strong diurnal variation and a seasonal variation, and the lifetime of trees, which corresponds the different turnover times, 1day, 1year and about 60 years, for example.

One of the possible research method is to monitor the CO2 flux continuously. The method to measure the CO2 flux are under development, and no definite method is established for a long term monitoring. As the first step of monitoring, the continuous measurement of CO2 concentration is important. In this research program, the annual change of atmospheric CO2 concentration as well as atmospheric temperature, wind velocity, precipitation and solar radiation.

A monitoring station was established in 1992 at the suburbs of Yakutsk city. Yakutsk is at the center of Eurasian Permafrost area and it is in a typical East Siberian Taiga forest. The station is within a field of radio station, 24km to the west of Yakutsk city. There is a road which is open for four seasons, and the traffic density is about 1 car per 15 min. The station is surrounded by conifer trees, such as larch, pine and birch. There is a dried alert, a lake formed by the melting of permafrost, 1 km from the station. No agricultural activity is present near 10 km, and no industrial activity except the maintenance of the radio station and an underground wheat storage facility.

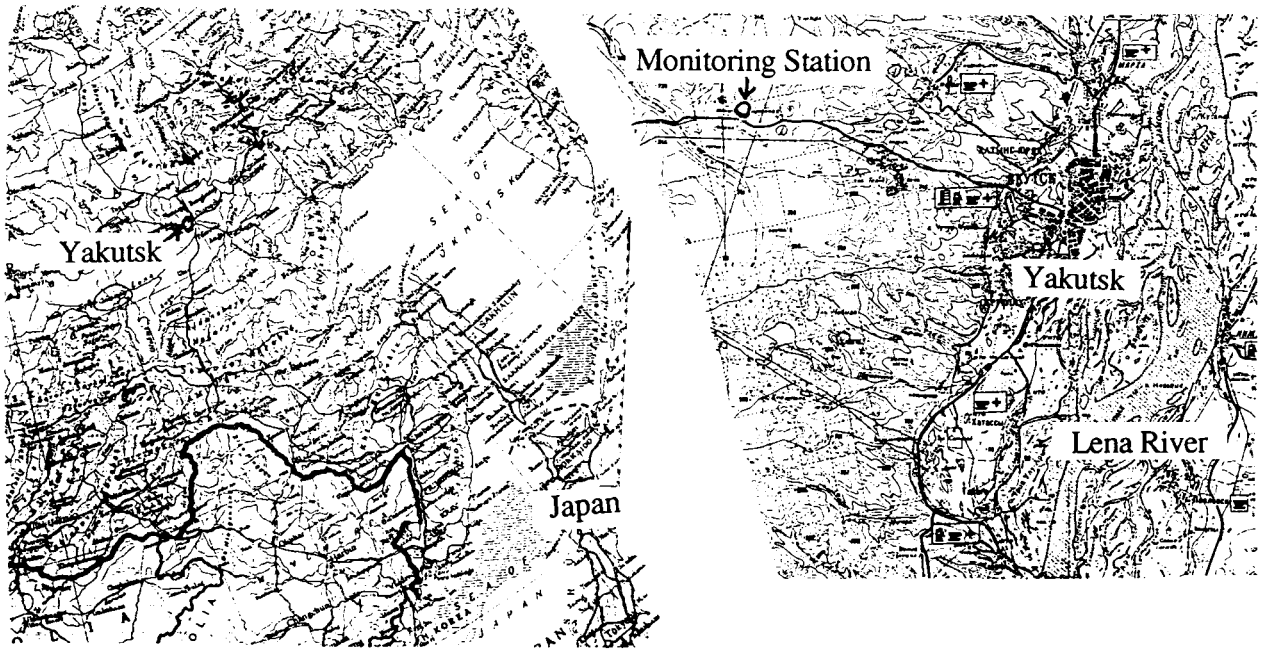


Fig.1 Location of Monitoring Station in Yakutsk

The air is sampled from three points at the altitude of 77, 44 and 11m on the radio transmission tower (120m). The sample inlet is made of stainless steel with a plate with a lot of small holes and a mesh to prevent the insects and big dust to enter. The sample is introduced to a container laboratory 14m away from the tower through three copper tubes (1/4" in diameter). Three sample lines and a standard gas line are switched for the successive analysis by gas chromatograph. Carbon monoxide separated by GC column is converted into CH4 by Ni converter with hydrogen gas and analyzed by FID detector. The raw data are compared with standard gas value to eliminate the effect of pressure and temperature effects of the sensitivity. There are several different points from general

monitoring station. One is that this station locates in a very sever temperature condition; from -55 to 35℃. The container laboratory, which originally is a ship container and modified to a laboratory, is installed on a sand mat of 2m depth to prevent the inclination due to the unstable active layer above the permafrost which acts as the heat insulator, as well. The lower half of the container is surrounded by wooden tips (50cm width) for the heat insulator in winter. Electricity supply cable is lined underground. Signal cables are covered by teflon or some special rubber to prevent the crack at low temperature. Inside is heated by electric heater above 5 ℃. Another different point is that it is designed to stand on its own. Because of the transportation system in Russia, the necessary gases is designed to be produced within the station except standard gas. The carrier gas, N2, is generated from the air the impurity hydrocarbon in which is burned in heated oxidizing catalyzer. Hydrogen gas and air are produced by electrolysis of water and by removing hydrocarbon from compressed air, respectively. Supply of distilled water and electricity is necessary for this station.

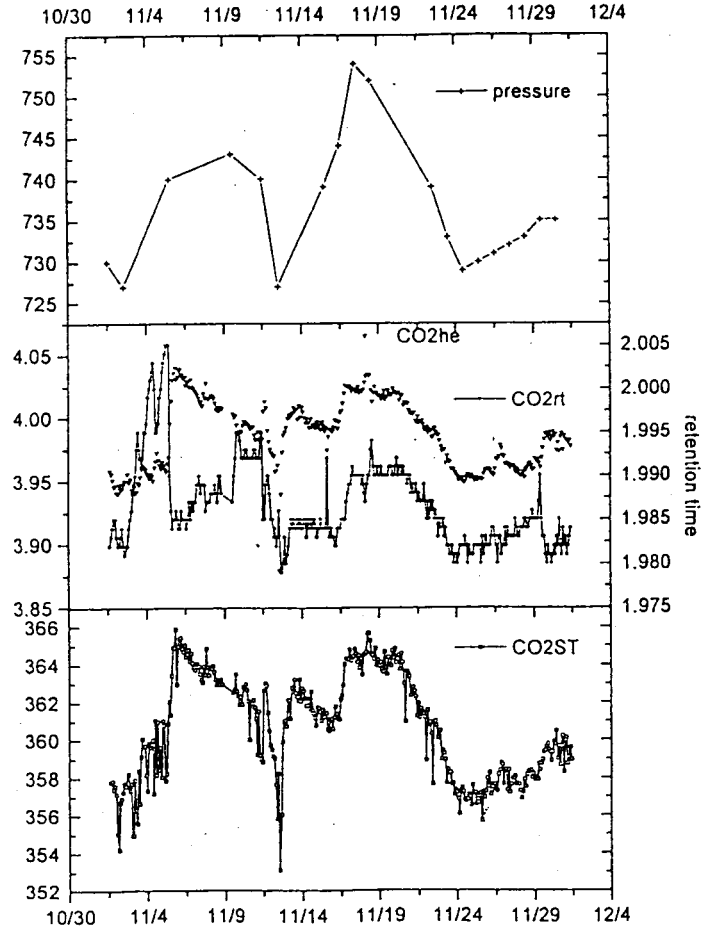


Fig.2 Data obtained at Yakutsk Monitoring Station in November, 1993. (a) Atmospheric pressure in Torr unit. (b) CO2 standard gas GC signal in height (triangle) and retention time of the peak (filled circle). (c) CO2 standard gas GC signal in area (open circle).

This station has come to be operated continuously from September in 1993 after solving a lot of problems. Fig.2 shows the raw data obtained in November in 1993. The upper figure, Fig.2-a, shows the atmospheric pressure, and the standard CO2 signal obtained from GC peak height is shown by triangle in the middle figure, Fig.2-b, together with retention time. In a constant circumstances, both the signal and retention time should be constant, but it is clearly influenced by atmospheric pressure. The amount of sample injected to GC is proportional to the atmospheric pressure because it is let to be in equilibrium in pressure with atmosphere. So, the signal values are corrected to the pressure and shown in Fig.3. The variation of the raw signal in November was 2.5% and it was reduced to be 1.8%.

All the raw concentration values of samples from the three levels are plotted in Fig.3 after the correction of pressure. The corrected values comparing with standard gas data are shown in Fig.4. The values of different altitudes are similar when the concentration is low, around 365ppm, which are observed when the wind is strong, and mixing is strong. This value seems to be the background concentration in this area. When the concentration is higher than this background level, the concentration is lower at higher altitude, and the wind is weak at this time.

In autumn, all the photosynthesis is stopped because of low temperature, and there is no sink of CO2. So, there is no remarkable diurnal cycle of concentration. However, the microbiological activity in soil is still high because the soil temperature is not below zero at this time, and the respiration of forest still is expected not zero. So, it is quite natural that CO2 thus formed under the ground or near the surface is trapped in the strong boundary layer in calm condition. If the data were carefully compared, there exists a diurnal cycle which corresponds to the strength of temperature

inversion in the boundary layer atmosphere.

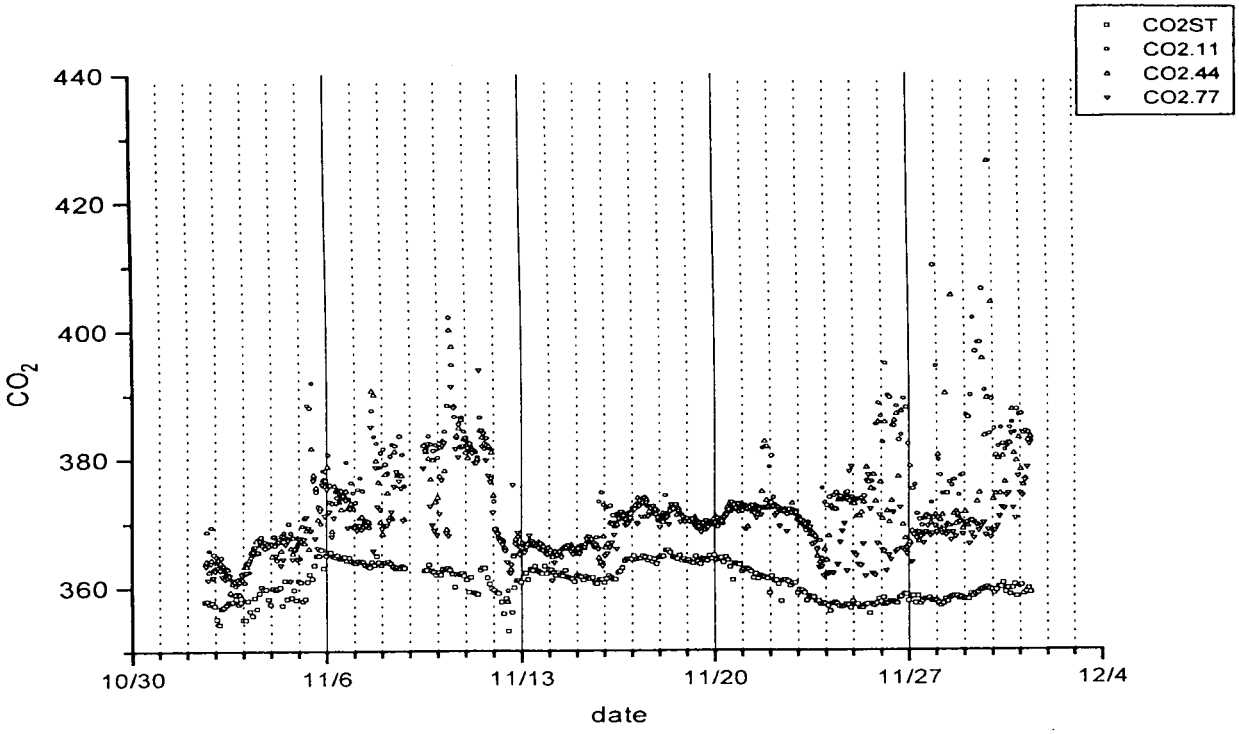


Fig.3 CO2 standard gas (rectangle) and atmospheric sample gas from 11m (circle), from 44m (upper triangle) and from 77m (lower triangle). All the data are corrected for atmospheric pressure.

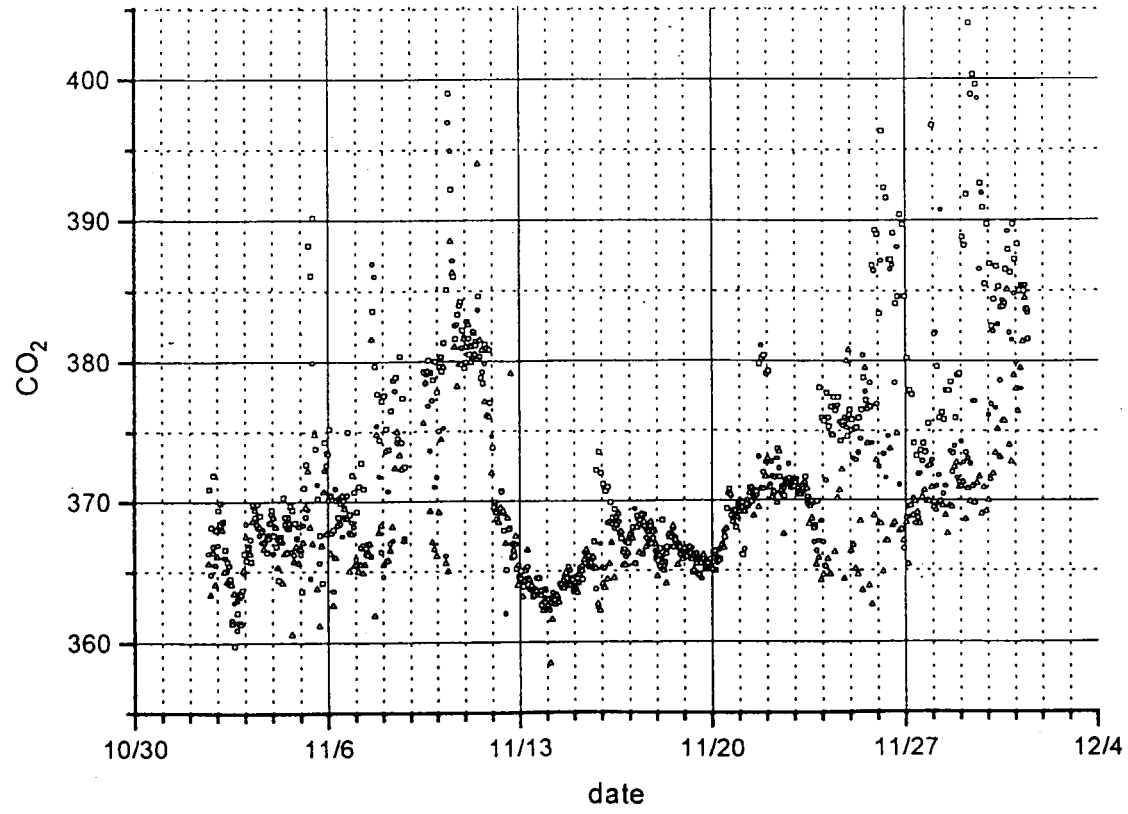


Fig.4 CO2 concentration obtained from different altitude (symbols are the same as Fig.3) after the correction by standard gas. Nearest 5 standard data have been used for the calibration.

3.Large scale CO2 distribution measurement by aircraft

The other approach to the estimation of atmosphere and surface ecosystem is to study a large scale distribution of CO2. The CO2 concentration in boundary layer air is very strongly influenced by the daily activities of surface ecosystem showing a large diurnal variation. But the free tropospheric air or the upper boundary layer air is expected to show an averaged value for several days scale. The mixing by thermal convection within the boundary layer make the concentration of CO2 in daytime uniform, but as the surface is cooled down by thermal radiation, the temperature inversion layer is formed and the concentration near the surface is changes depending on the respiration or photosynthesis. The height of this temperature inversion is less than 500m in general, and the air between the temperature inversion layer and the top of mixing layer is kept constant. As this daily process is repeated, the concentration in this area decreases its concentration if the net balance of CO2 on the surface is on the side of sink. In some cases, there occurs a larger scale convex and sometimes it grows to form a cumulonimbus cloud. In such cases, the airmass in the mixing layer is lifted up into the free troposphere. This occasional mixing changes the CO2 concentration in the background, and it is observed as the seasonal variation at the baseline monitoring station. If this picture is valid, the monitoring at the altitude above the temperature inversion and within the mixing layer would be the most powerful monitoring methodology to estimate the sink and source strength of the surface ecosystems in the area concerned.

Fig.5 shows one of a typical vertical profile of CO2 concentration in early morning, which was observed on July 20,1992 near Tumen. The very large concentration up to 370ppm was observed near the surface and it decreases down to 345ppm at 600m, which is the top of the

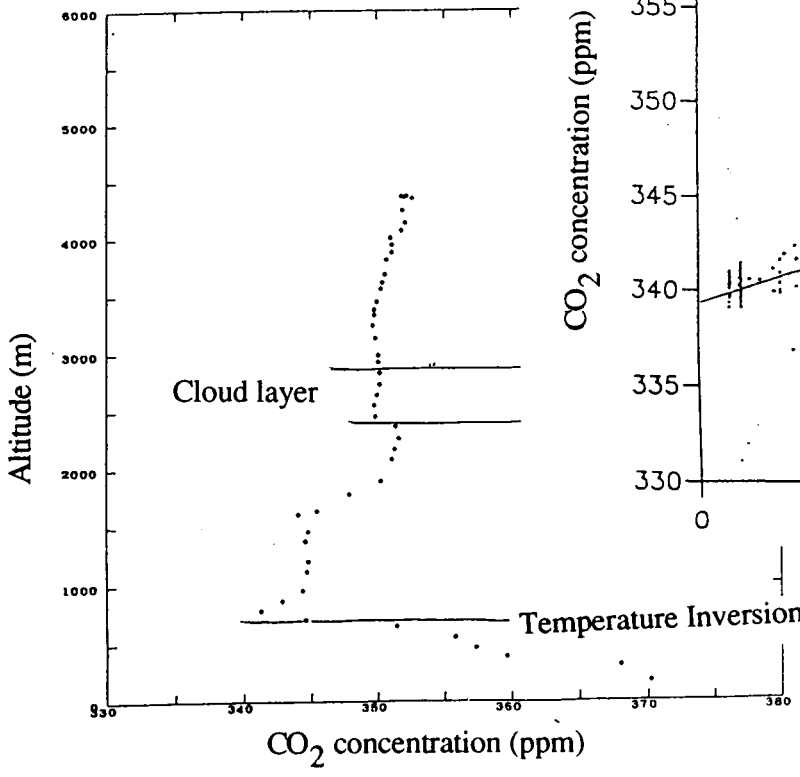


Fig.5. Vertical profile of CO2 observed at 3:44-4:01 local time on July 20, 1992.

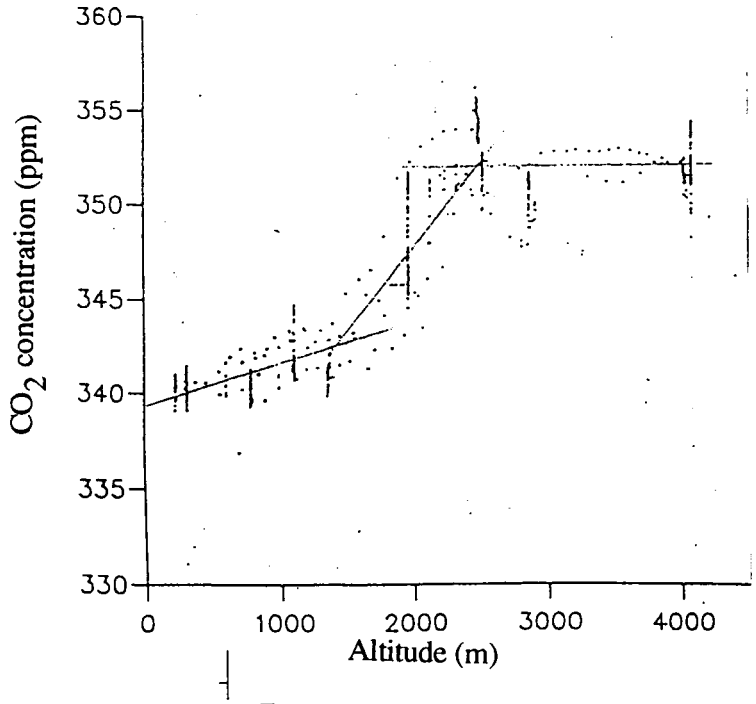


Fig.6. Vertical profile of CO2 observed at 7:58-8:17 local time on July 18, 1992.

temperature inversion. The concentration is small between 600 and 1800m, that above 1500m is the same as the background values. The height CO2 concentration in the temperature inversion is not observed in daytime on July 18, 1992, in the same area (See Fig.6, but the altitude is in horizontal axis). The concentration gap is observed at the same altitude in both days, 1800m. It would be important to repeat such an measurement to obtain a diurnal cycle of the dynamics to judge the ability to estimate the CO2 uptake rate by the ground vegetation in a large scale.