Activity Report
"CO_2 supply system at Lakes Nyos and Monoun"
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1. Summary

The purposes of the study of our group are (1) to clarify the CO_2 supply system and the pathway of CO_2 to the lakes, and (2) to establish an automatic device to find forerunners of limnic eruption. In the March 2012 survey, a portable CO_2 analyzer to measure atmospheric CO_2 concentration was tested in the field. Also, basic data to obtain the concentration of dissolved CO_2 in water through sound velocity measurement were collected. The field survey was made between 4th and 7th March at Lake Nyos, and between 9th and 10th March 2012 at lake Monoun.

2. Test of the CO_2 analyzer

A portable CO_2 analyzer (LIR820, Meiwa Fosis Co. Ltd.) was used to measure the atmospheric CO_2 concentration during daytime between 5th and 7th March 2012 about 60 cm above the lake surface. Data obtained from Lake Nyos at total 24,114 points were shown in Fig. 1a. The maximum and minimum CO_2 concentrations observed were 7877.83 and 288.02 ppm, respectively. About 60% of the data was within 400 to 410 ppm, which is similar to the global atmospheric concentration. The highest concentration was observed near the degassing pipes, suggesting that excess CO_2 was derived from the pipes. The CO_2 measurement was performed during daytime on 9th and 10th March at Lake Monoun. Data obtained from Lake Monoun at total 18,733 points were shown in Fig. 1b. The maximum and minimum CO_2 concentrations observed were 958.17 and 248.16 ppm, respectively. About 60% of the data was again within 400 to 410 ppm, similar to the global atmospheric concentration. Since degassing had ceased at Lake Monoun, high CO_2 concentration was not observed near the degassing pipes. High CO_2 concentrations were not reproducible, probably derived from exhaust of the boat engine.

3. Underwater sound velocity measurement for monitoring dissolved CO_2 concentration

It is possible to estimate dissolved CO_2 concentration by measuring the sound velocity of lake water. If a handy sensor to measure the sound velocity is available, CO_2 monitoring of the lakes would become easy especially in a remote place like Lake Nyos where maintenance of scientific instruments is difficult in the field. For this purpose, we have developed a portable device for measuring the underwater sound velocity through

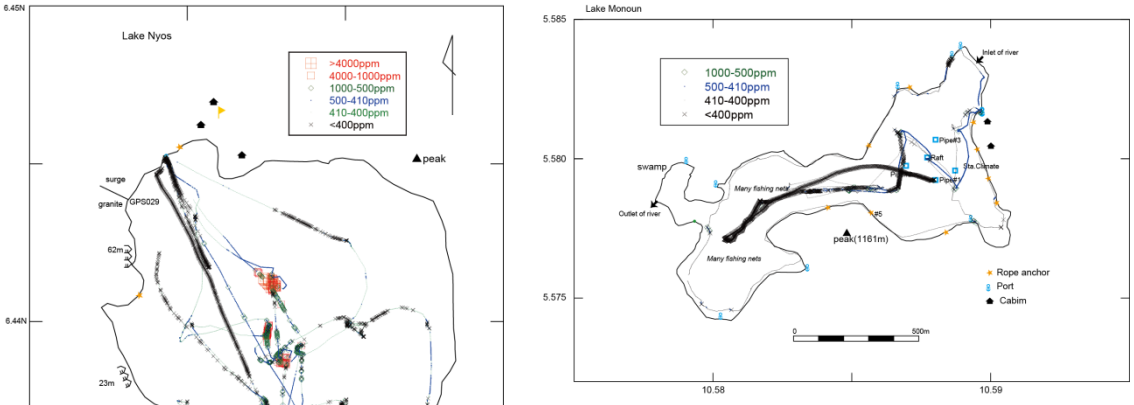

Figure 1. Distribution of atmospheric CO_2 concentration just above the lake surface at Lake Nyos (left, 5-7 March 2012) and Lake Monoun (right, 9-10 March 2012).

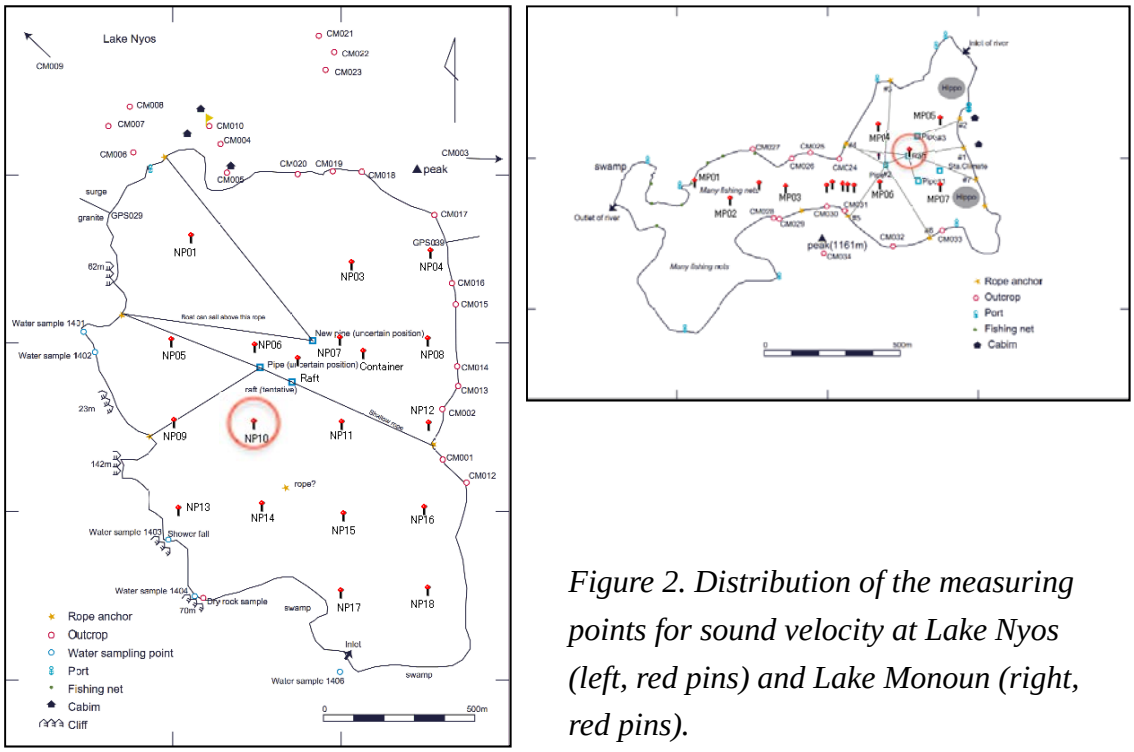

Figure 2. Distribution of the measuring points for sound velocity at Lake Nyos (left, red pins) and Lake Monoun (right, red pins).

modification of a commercially available underwater sound velocity profiler (Minos X, AML Oceanography). We attached temperature and pressure sensors to the profiler. Underwater sound velocity is a function of temperature and concentration of dissolved substances. Sound velocity increases with increasing concentration of ionic species and CO_2 dissolved in water. If we can remove the effect of dissolved ionic species, we can measure the CO_2 concentration using the sound velocity profiler.

Measurement using the modified sound velocity profiler was made at 19 points at Lake Nyos (Fig. 2a) and 14 points at Lake Monoun (Fig. 2b). Preliminary results of the sound velocity measurement shown in Fig. 3 indicate that (1) there was no change in the profiles regardless the measuring points and (2) there was no daily change. It can be said that Lake Nyos is well stratified. The sound velocity profiles at Lake Monoun are different between the east and west basins. The profiles increase significantly in the western basin (Fig. 3b). CO_2 concentration in the eastern basin has been lowered by artificial degassing, whereas high CO_2 concentration is suggested in the western basin.

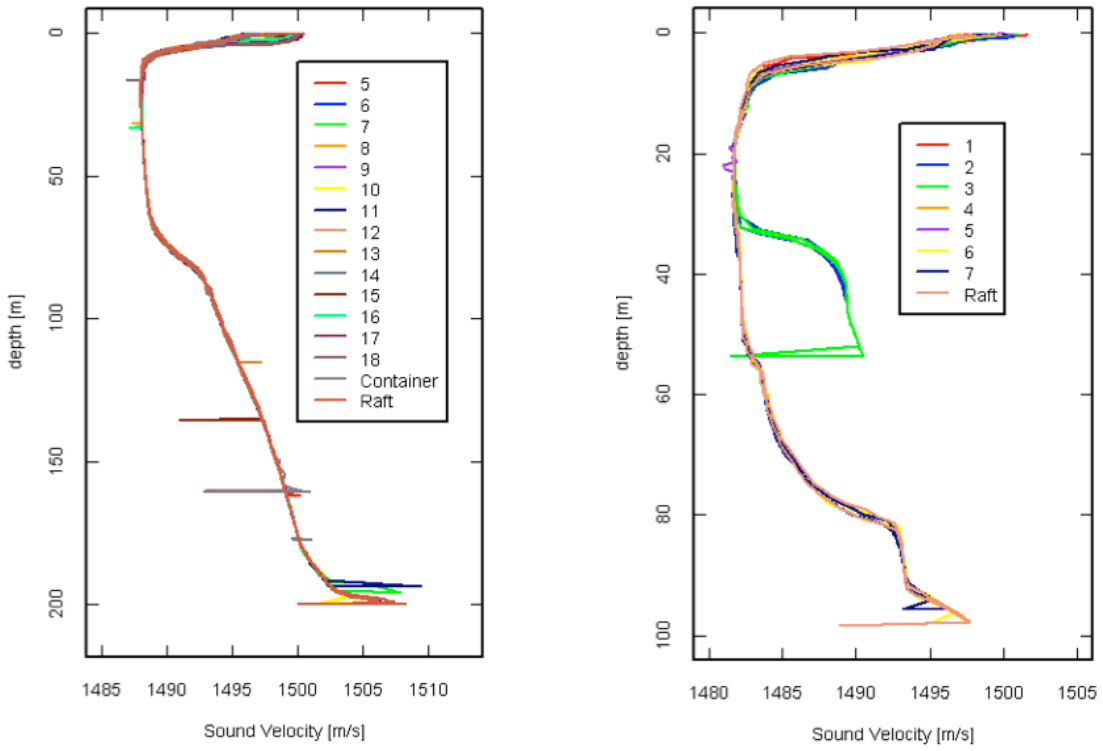

Figure 3. Sound velocity profile at Lake Nyos (left, 6th March 2012) and at Lake Monoun (right, 9th March 2012). Noises are due to bubbles attached to the sensor. The profiles were uniform throughout the lake. High velocity was found in the western basin at Lake Monoun (green plots), suggestive of high CO2 concentration.

Concentration of dissolved CO2 was calculated from the following equation,

$$\Delta v = k_1[CO_{2(aq)}] + k_2[HCO_3^-]$$

where Δv is the difference in the sound velocity between CO_2-containing solution and pure water at a given temperature. k_1 is a factor that represents the effect of dissolved CO_2 concentration, and k_2 is a factor representing the effect of HCO_3^- concentration. k_1 was obtained from the results of laboratory experiments at Osaka University using a pressurized vessel. k_2 was obtained from sound velocity, temperature, pressure, electric conductivity and dissolved CO_2 concentration obtained from the syringe method. It has been shown that the precision of $CO_{2(aq)}$ determination by the present method is less than ±10 mmol/kg unless relative cation composition remains unchanged. The $CO_{2(aq)}$ concentration obtained from the sound velocity measurements is shown in Fig. 4a for Lake Nyos and in Fig. 4b for Lake Monoun.

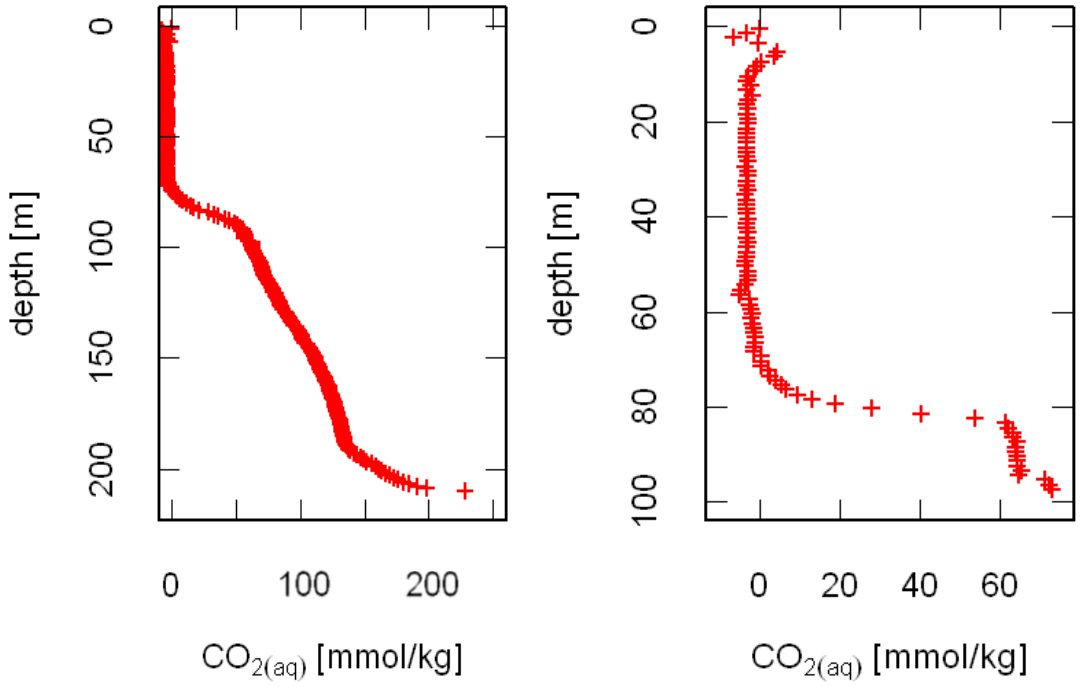

Figure 4. $CO_{2(aq)}$ profile obtained by the sound velocity measurement at Lake Nyos (left) and Lake Monoun (right). Data were taken at the encircled point shown in Fig. 2