Regular Monitoring of Lakes Nyos and Monoun
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CTD measurement

It is imperative to monitor the chemical structures of Lakes Nyos and Monoun from time to time, because degassing and recharge of CO_2 are going on at both lakes. Following the regular monitoring program of the lakes, we made CTD casts, measurement of CO_2 profiles, and collection of water and gas samples for determination of chemical and isotopic compositions in March 2012. Figure 1 shows the conductivity profile at Lake Nyos measured on 6th March 2012 (a) and at Lake Monoun measured on 12th March 2012 (b). The electric conductivity profile at Lake Nyos shows a shallow chemocline at about 80 m and a sharp increase toward the bottom below 202 m. The whole profile subsided slightly compared to the 2011 profile (not shown). Note that conductivity at the surface increased noticeably due to addition of deep water from the degassing pipes. At Lake Monoun the conductivity profile shifted slightly *upward* but the general pattern remains the same compared to the 2011 profile. Slight upward shift of the conductivity profile in deep water indicates that recharge of deep fluid from the sub-lacustrine system resumed and that the change in the CTD profile became noticeable after degassing pipes stopped working in 2010-2011.

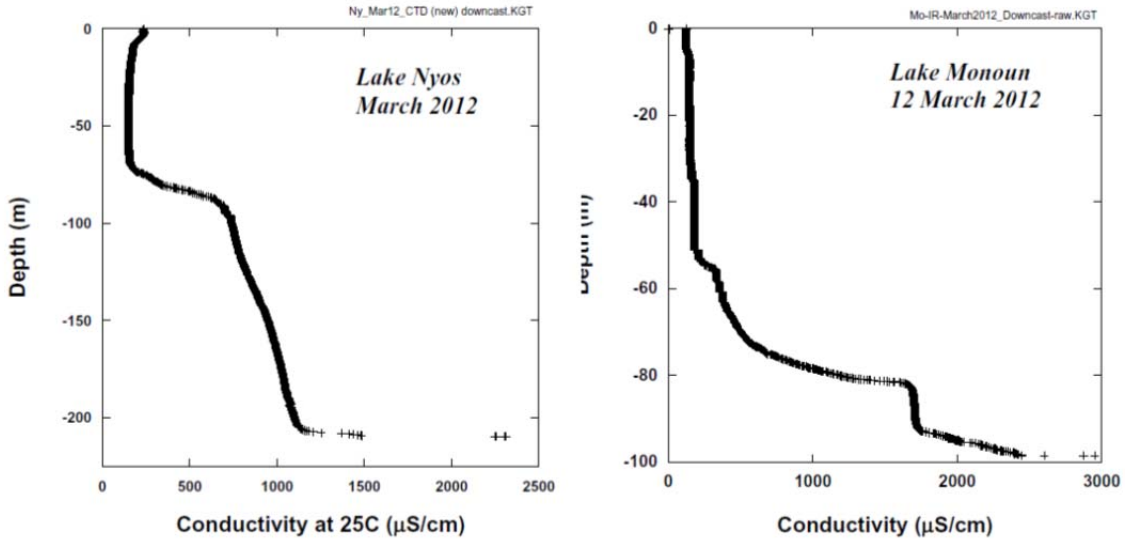

Fig. 1. Conductivity profiles at Lake Nyos (a) and Lake Monoun (b) in March 2012.

CO_2 measurement

Closely spaced CO_2 profiles have been obtained at Lakes Nyos below 180 m using the Flute de Pan method or YY method (Yoshida et al., 2010) as shown in Fig. 2. Since gas self-lifting ceased at the depth of 110 m, CO_2 concentrations were measured between the depths of 120 m to bottom. Obviously the March 2012 profile shows the lowest CO_2 concentration at all depths, indicating that

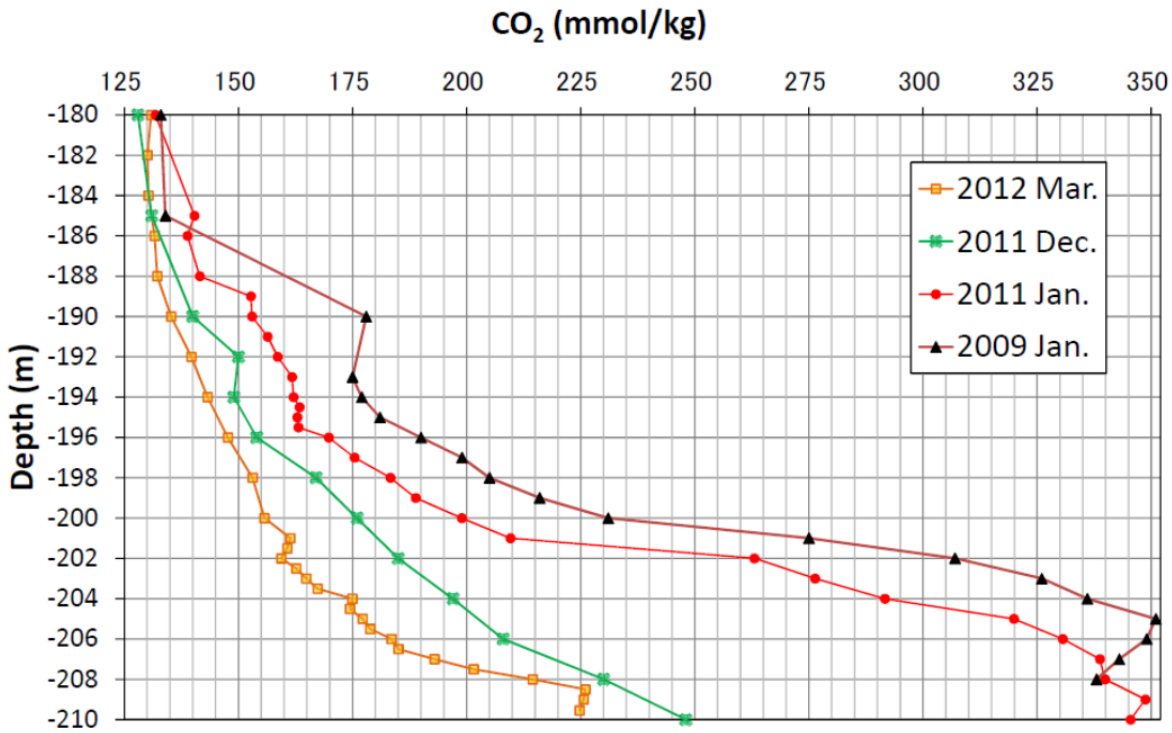

Figure 2. Comparison of the CO_2 profiles measured with the Flute de Pan method or YY method in 2009, 2011 and 2012 at Lake Nyos.

degassing has been going on steadily. The CO_2 concentration at the deepest water was about 225 mmol/kg, approximately 1/3 of the earlier steady CO_2 concentration of ~350 mmol/kg. This profile, coupled with the results from the syringe method and pH method (Kusakabe et al., 2000) was used to calculate the whole lake CO_2 profile in March 2012 together with the earlier data as shown in Fig. 3. Figure 3a show progressive subsidence of the CO_2 profile during the degassing operation. The rate of recent gas removal, with 3 pipes, calculated from the 2011 and 2012 CO_2 profiles is ~1.9 Gmol/yr. If this rate continues, CO_2 dissolved in the lake will be mostly removed in about 4 years from now. However, the rate will be lowered as degassing proceeds, and some fraction of the gas would remain undegassed when the degassing system has lost its gas self-lift capability as we experienced at Lake Monoun. Figure 3b shows the change in CO_2 profiles at Lake Monoun since 2003 when degassing started. Degassing practically stopped in 2011. Naturally the 2011 profile shows the lowest CO_2 concentration at all depths. It is important to note that the March 2012 profile significantly sifted upward compared to the 2011 profile, indicating that (1) recharge of CO_2-rich fluid from the bottom still continues, and (2) the rate of CO_2 recharge is estimated to be ~21 Mmol/yr calculated from integration of the difference between the 2012 and 2011 profiles. This rate is approximately 3 times greater than the early estimate of ~8 Mmol/yr (Kling et al., 2005, Kusakabe et al., 2008).

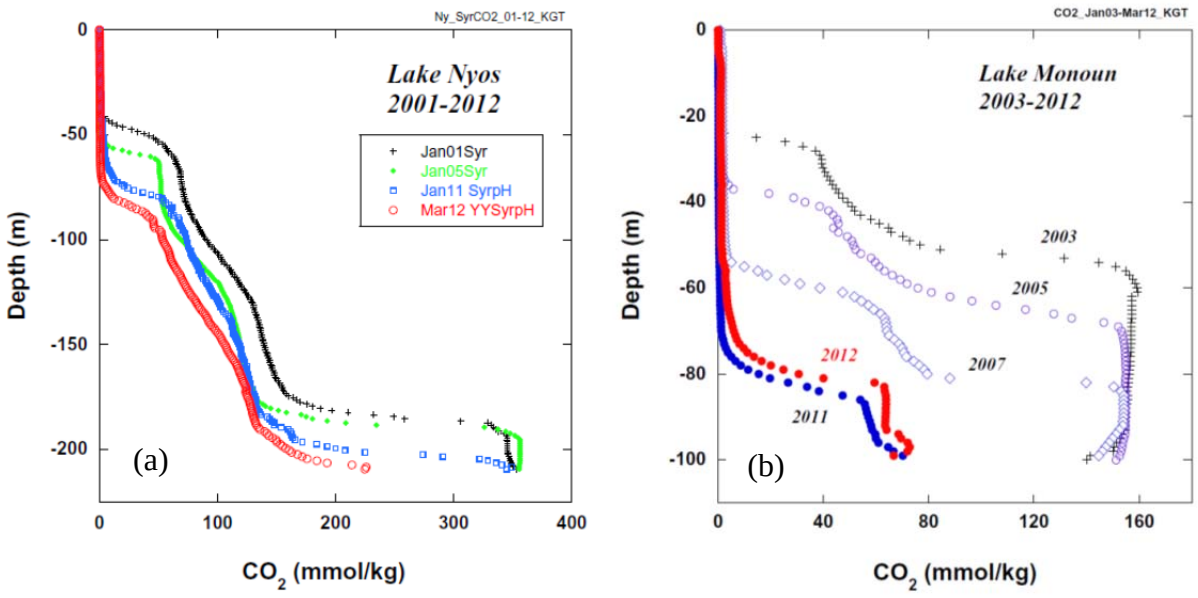

Figure 3. CO2 profiles during the controlled degassing at Lake Nyos (a) and Lake Monoun (b). The pre-degassing profile is indicated by small black crosses in both figures. Note that a significant upward shift of the 2012 profile at Lake Monoun.

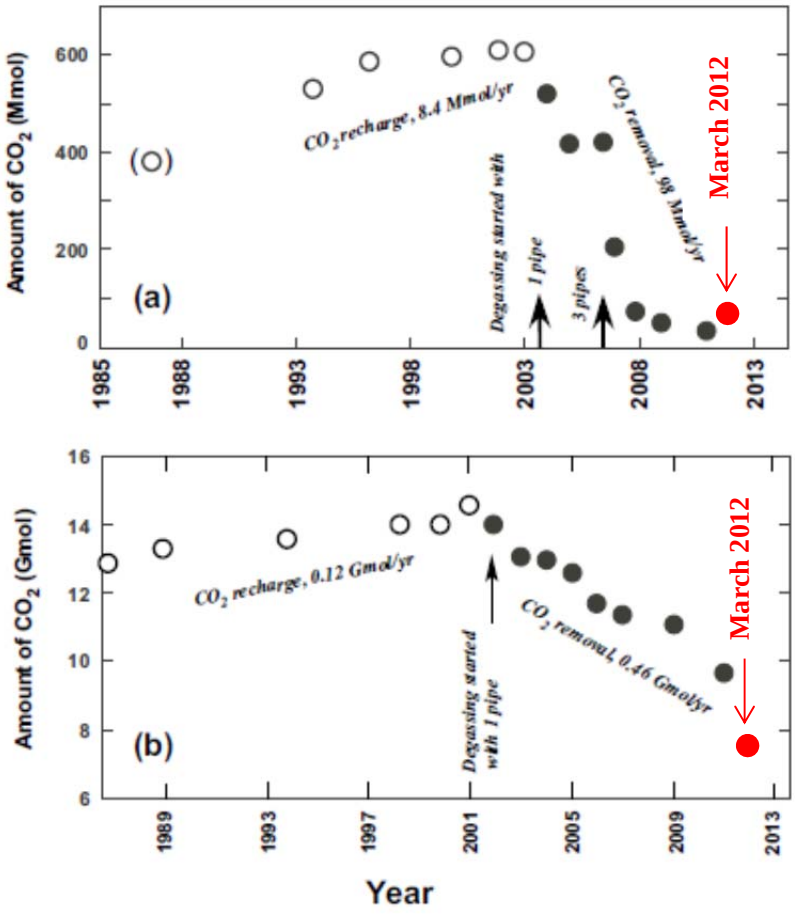

Fig. 4 Change with time in CO_2 content at Lakes Monoun (a) and Nyos (b) during controlled degassing.

Change with time in CO_2 content in Lakes Monoun and Nyos is shown in Fig. 4. At Lake Monoun (Fig. 4a) the CO_2 content restarted to rise. Since the degassing system at the lake has lost its gas self-lift capability, it is anticipated that the rise will continue in the future. This finding gives a strong justification of our proposal that deep water of Lake Monoun should be pumped out during our SATREPS period. Implementation of the pumping system is scheduled sometime in 2013-2014, hoping that the Lake Monoun would be completely safe after the implementation.

Other work

(i) During the March 2012 expedition to Lake Monoun, we inspected the existing degassing pipes to evaluate the possibility that one of the pipes can be utilized for installation of the water pump (Fig. 5).

Fig. 5. Checking the diameter of an existing degassing pipe at Lake Monoun.

(ii) Two rafts were newly constructed at Lake Nyos in June 2012. One is for installation of the climate station (Fig. 6a), and another for stationary observation of the lake (Fig. 6b). Equipment of the climate station was successfully set up on the new raft by Kling and Evans. Sensors were attached to the station to measure the conductivity, temperature, total gas pressure of the lake water and climatic parameters. Data acquisition is going on.

(iii) Two rafts were newly constructed at Lake Monoun in January 2013. One is for installation of the climate station (Fig. 7a), and another for stationary observation of the lake (Fig. 7b). Equipment of the climate station is the same as that installed at Lake Nyos.

(iv) A small depository to store the SATREPS materials was set up inside a magazine at lakeside of Lake Nyos in June 2012.

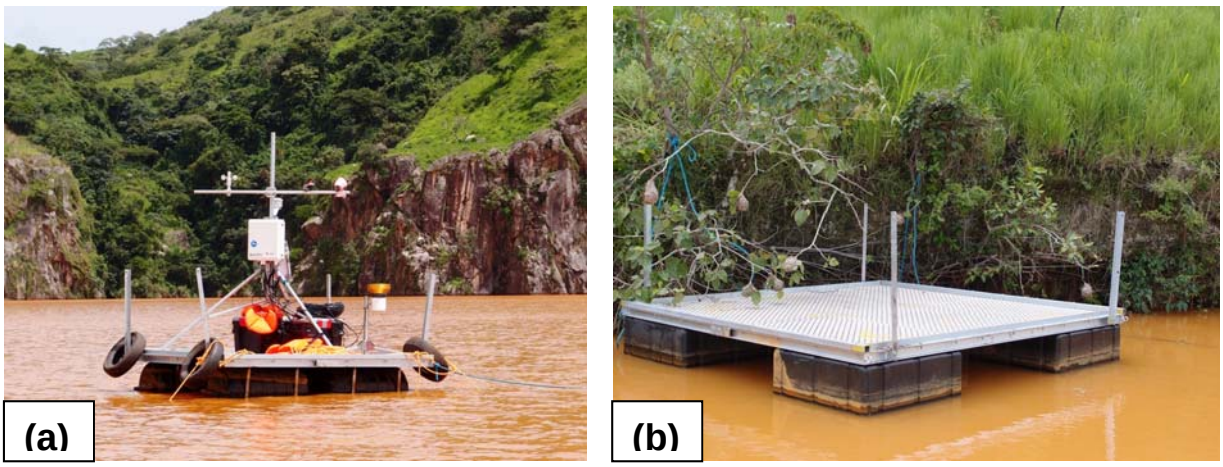

Figure 6. (a) Climate station (2.5m×2.5m) and (b) work raft (3.2m×3.2m) at Lake Nyos, June 2012.

Figure 7. (a) Climate station (2.5m×2.5m) and (b) work raft (2.5m×2.5m) at Lake Monoun, January 2013.

Presentations

Y. Yoshida, M. Kusakabe, Issa, T. Ohba and A. Ueda. Evaluation of the degassing effect through detailed monitoring of CO_2 concentration at Lake Nyos, Cameroon. The Annual Meeting of the Geochemical Society of Japan (September 2012, Fukuoka, Univ. Kyushu, Japan)

M. Kusakabe. Tragedy of Lake Nyos (Cameroon) – Efforts for 25 years to solve the problems. Invited lecture at the University of Shizuoka, Japan. December 2012.