Mission report of "CO_2 supply-system-study team" on survey at Lakes Nyos and Monoun in March 2015

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The field survey was performed between 7th March and 10th March at Lake Nyos, and 12th and 13th March 2015 at lake Monoun. We performed three kinds of activities as follows.

Activities

1. Measurement of sound velocity profile at Lakes Nyos and Monoun
2. Measurement of the CO_2 flux from the surface of Lakes Nyos and Monoun
3. Photography and colorimetry of the bottom of the lakes by an underwater camera with pressure container

Results

1. Measurement of sound velocity profile at Lakes Nyos and Monoun

Measurement of vertical profiles of sound velocity was performed at 10 points at Lake Nyos and 6 points at Lake Monoun by a sound velocity profiler MinosX (AML Oceanography) in 2015. All points measured by our survey during SATREPS project are summarized in Table 1 and Figure1 for Lake Nyos and Table 2 and Figure 2 for Lake Monoun. We found that there is a good correlation between total CO_2 concentration (= $[CO_{2(aq)}]$ + $[HCO_3^-]$) and the excess of sound velocity (Δv) from the pure water with the same temperature and pressure. Because the correlation coefficient has not been determined for the data of 2015, we read the change of CO_2 concentration roughly here. Representative profiles of the excess sound velocity are shown in Figure 3. The value of Δv can be considered to be proportional to total CO_2 concentration. At Lake Nyos we confirmed that there is no change in the profiles regardless the measuring points. The thickness of high CO_2 concentration layer at the bottom shows a decreasing trend year by year. The results at Lake Monoun indicate that the sound velocity profiles at Lake Monoun are different between Central and East Basins. In Fig 4 the circles are measurements at East Basin and the crosses are measurements at Central Basin. The thickness of high CO_2 concentration layer at the bottom of East Basin (MRaft in Fig 3) increased from 2012 to 2014 but decreased from 2014 to 2015. It must be the effect of the pumping system with a solar panel constructed in 2013. On the other hand, the thickness of high CO_2 concentration layer at the bottom of Central Basin (M03 in Fig 3) looks stable.

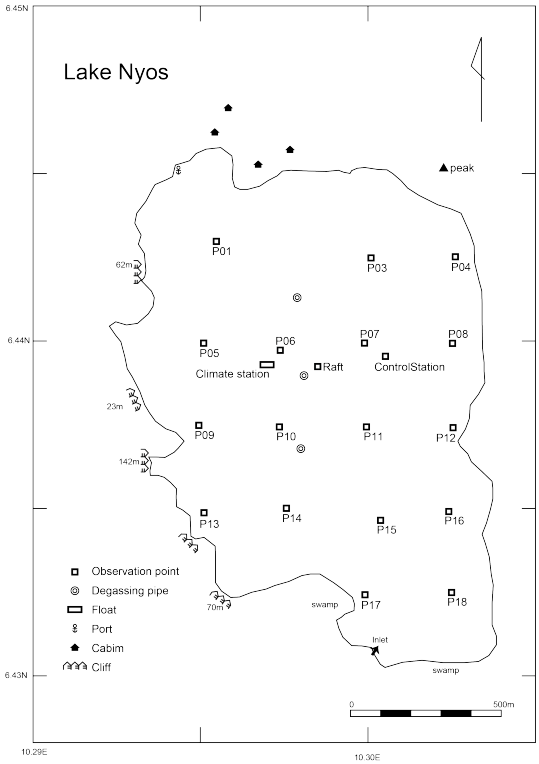

Figure 1.
Observation points of sound velocity profile in 2012, 2014, and 2015 survey at Lake Nyos.

Table 1 Measurment points for sound velocity profile at Lake Nyos

Point name	Lat. (degree)	Lon. (degree)	Date of measurements								
			5-Mar-12	6-Mar-12	7-Mar-12	1-Mar-14	2-Mar-14	7-Mar-15	8-Mar-15	9-Mar-15	10-Mar-15
P01	6.44296	10.29549	✔								
P03	6.44246	10.30011	✔		✔					✔	
P04	6.44250	10.30262	✔								
P05	6.43992	10.29511		✔	✔	✔	✔	✔			✔
P06	6.43970	10.29739		✔	✔	✔			✔		
P07	6.43991	10.29991		✔	✔	✔			✔		
P08	6.43990	10.30253		✔							
P09	6.43746	10.29497		✔							
P10	6.43741	10.29737		✔	✔		✔	✔		✔	✔
P11	6.43742	10.29997		✔	✔					✔	
P12	6.43739	10.30255		✔							
P13	6.43485	10.29512		✔			✔		✔		
P14	6.43499	10.29758		✔					✔		
P15	6.43462	10.30039		✔							
P16	6.43488	10.30243		✔							
P17	6.43240	10.29993		✔							
P18	6.43247	10.30252		✔							
ControlStation	6.43952	10.30053	✔	✔	✔		✔		✔	✔	
Raft	6.43920	10.29842	✔	✔	✔				✔		

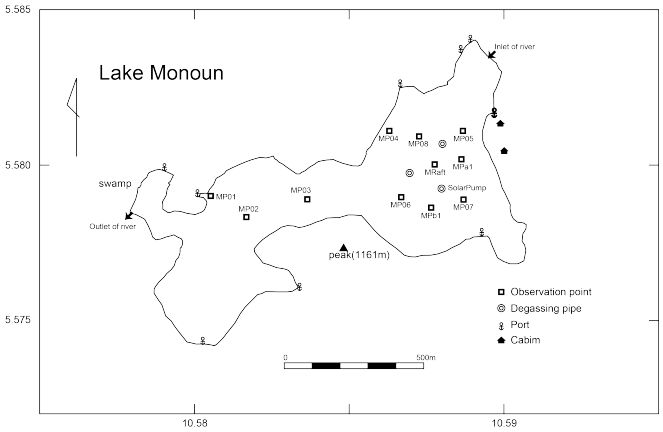

Figure 2.
Observation points of sound velocity profile in 2012, 2014, and 2015 survey at Lake Monoun.

Table 2 Measurment points for sound velocity profile at Lake Monoun

Point name	Lat. (degree)	Lon. (degree)	Date of measurements					
			9-Mar-12	10-Mar-12	4-Mar-14	5-Mar-14	12-Mar-15	13-Mar-15
MP01	5.57901	10.58056	✔					
MP02	5.57833	10.58171	✔	✔	✔		✔	✔
MP03	5.57890	10.58368	✔	✔	✔		✔	✔
MP04	5.58110	10.58632	✔	✔	✔			
MP05	5.58110	10.58869	✔	✔				
MP06	5.57897	10.58670	✔	✔				
MP07	5.57888	10.58871	✔	✔				
MRaft	5.58002	10.58778	✔	✔	✔		✔	
SolarPump	5.57925	10.58800			✔			✔
MP08	5.58093	10.58728				✔		
MPa1	5.58019	10.58864					✔	✔
MPb1	5.57864	10.58767					✔	

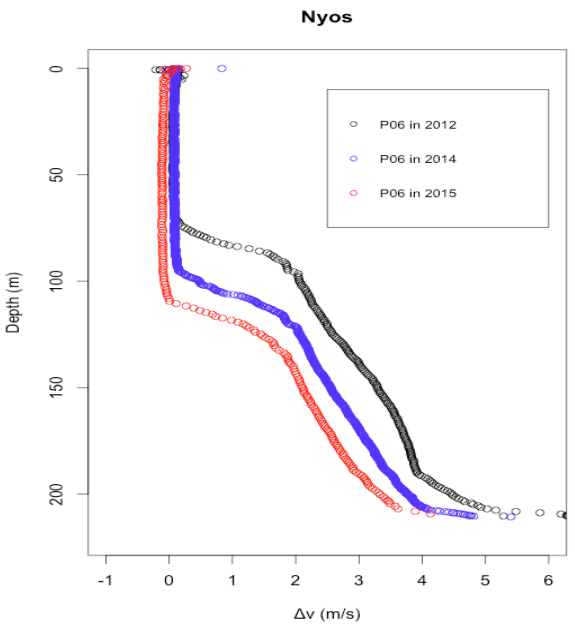

Figure 3. Representative profiles of Δv at Lake Nyos.

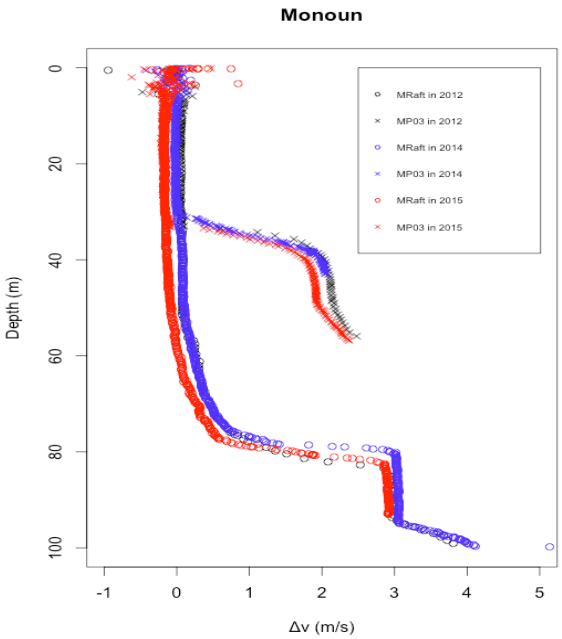

Figure 4. Representative profiles of Δv at Lake Monoun.

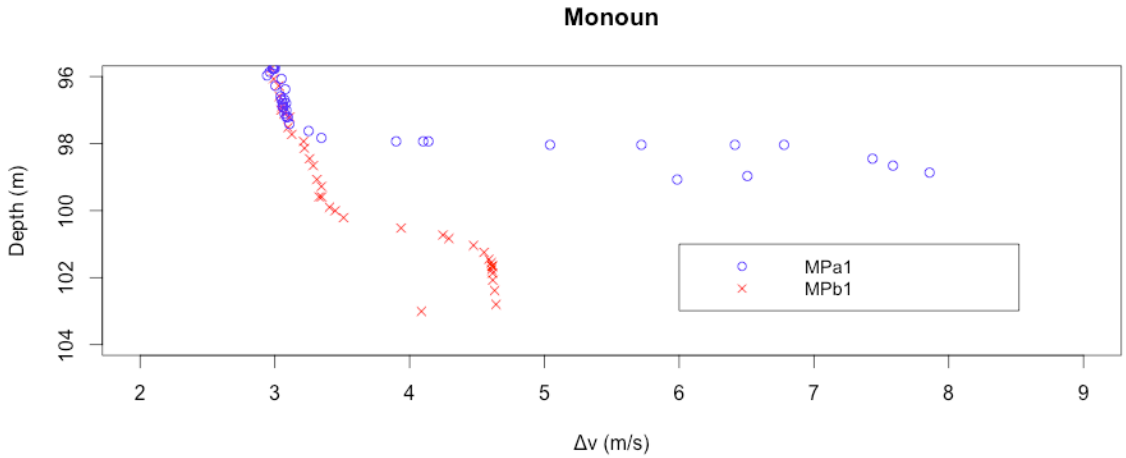

Figure 5. Closeup of profiles of Δv at the bottom of two depressions newly found by multi-beam SONAR operation at Lake Monoun.

Dr. Ohba's team found two depressions on the bottom of East basin by muti-beam SONAR operation. And based on the CTD observation, they concluded that in the region deeper than -97m at D1 (corresponds to Mpa1), a hot fluid significantly enriched in CO_{2aq} and HCO_3^- was detected, and that in the region deeper than -99m at D4 (corresponds to MPb1), a fluid similar to that at Mpa1 was detected although the enrichment relative to the normal lake water is not high (Ohba et al. this activity report). To confirm Dr. Ohba's findings, we also observed the sound velocity at two depressions. The results are shown in Figure 5. Indeed, there is a high Δv layer at the bottom of MPa1. It may suggest the existence of the outlet of fluid containing magmatic component as Dr. Ohba mentioned.

2. Measurements of the CO_2 flux from the surface of Lakes Nyos and Monoun

We measured diffusive CO_2 fluxes from lake surface in order to understand manners of CO_2 emission and transport at Lakes Nyos and Monoun. We used a device consisting of LI-COR LI820 CO_2 Analyzer and plastic vessel (Photo1, Fig. 6). They are connected with plastic tubes and a pump and the air in the device is circulated between the chamber and CO_2 gas analyzer. The CO_2 content of the air in the device increases by CO_2 flux from the surface with time and are measured by the CO_2 gas analyzer. On the basis of this temporal change of the CO_2 content, CO_2 flux value can be estimated.

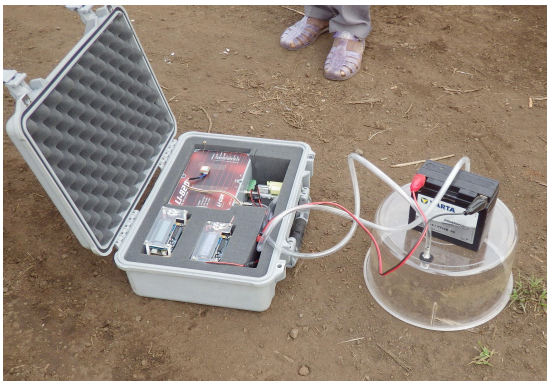

Photo 1. The device of CO_2 flux measurement.

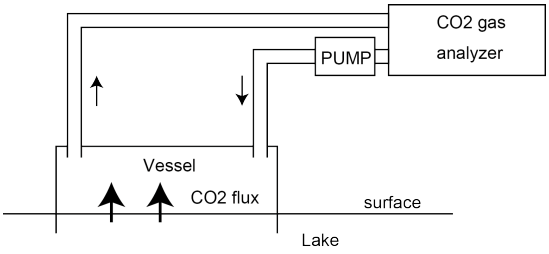

Figure 6. Schematic illustration of the device of CO_2 flux measurement.

Measurement results in Lake Nyos are presented as follows (Fig. 7). Our measurements show that range of diffusive CO_2 flux is between 1.7-18.9 μmol/m^2s. The diffusive CO_2 flux from the lake surface roughly tends to be larger. Total diffusive CO_2 flux from lake of Nyos is the order of magnitude of 1 Gmol/year. This amount is about 10 % of the total amount of CO_2 in Lake Nyos. Although analyses of measurement results in Lake Monoun is ongoing, the diffusive CO_2 flux is smaller than that in Lake Nyos. Processes governing diffusive CO_2 flux and transfer of CO_2 in the lakes will be considered on the basis of our results and vertical profile data in the lakes such as CO_2 concentration and temperature in future work.

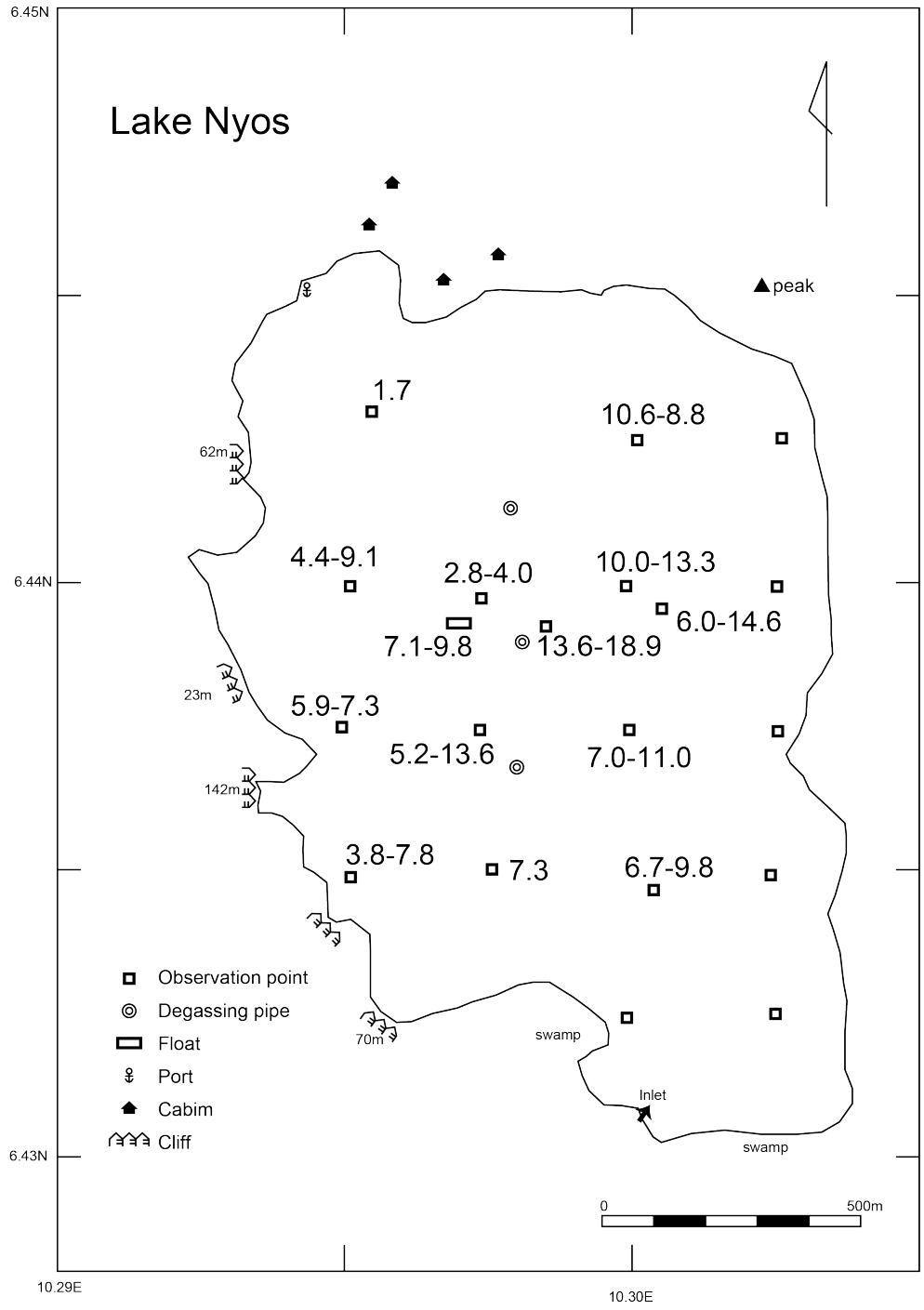

Figure 7. Measurement results of diffusive CO_2 flux in Lake Nyos. Figures are diffusive CO_2 flux (mmol/m^2s).

3. Photography and colorimetry of the bottom of the lakes by an underwater camera with pressure container

In succession from the 2014 survey, also this time we took movies of the under-water and the bottom of the lakes using an underwater camera with a pressure container of 200 m resist (Fig. 8). The vertical change of transparency and color of water was observed by checking the visibility of front and rear reflectors (Fig.8 and Fig.9). A pressure sensor simultaneously monitored the depth. The data analysis is ongoing, but significant change in transparency was found at Lake Monoun. The lake water became more opaque than 2014. A new simple apparatus for the measurement of transparency using LED light and photo transistor had been developed (Fig 10) and operated at Lake Monoun. We obtained quantitative profile of transparency change with depth at four points at Lake Monoun.

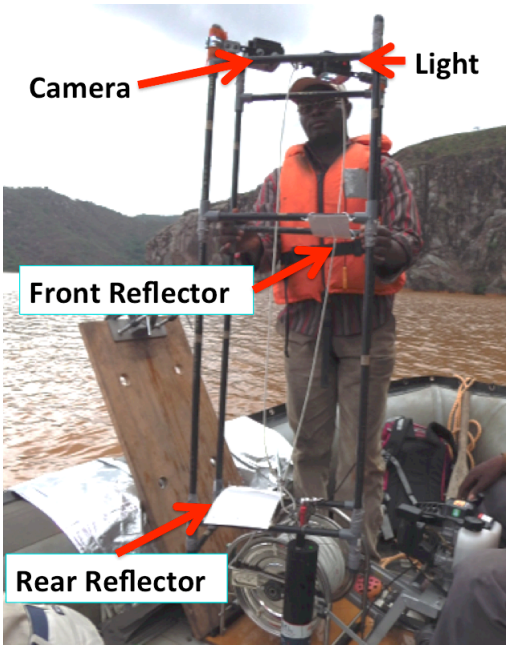

Figure 8. Position of an underwater camera and reflectors.

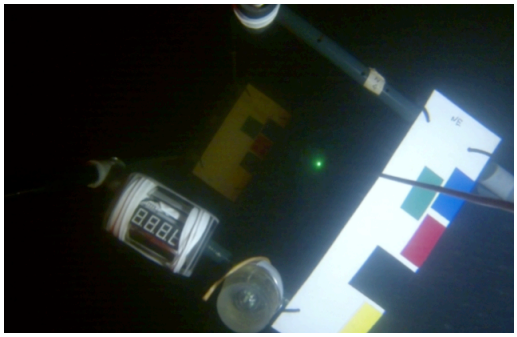

Figure 9. Underwater view at Monoun.

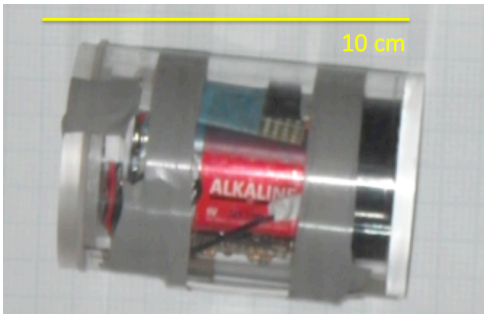

Figure 10. Anew simple transparency sensor.