



Hydroacoustic quantifications of CO₂ bubbles in volcanic lakes

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Echosounding surveys have been performed on Indonesian (Rinjani, Kelud, Kawah Ijen, Galunggung) and Philip-pians (Taal) volcanic lakes with a SIMRAD ES60 single beam, dual frequency (50 and 200 kHz) echosounder since 2007. CO₂ gas bubbles are strong scatterers of incident acoustic waves. Echosounding methods might therefore be helpful for mapping gas emissions at the floor of volcanic lakes and to quantify fluxes of CO₂ emitted through the lake.

Analyses were carried out using 50 kHz data. Echointegration technique has been applied on the 40 log₁₀ R(TVG) echograms using Sonar 4 post processing software (Balk and Lindem, 2007). A lower threshold of 70 dB (corresponding to a spherical bubble radius of 0.1 mm) has been used in order to avoid the backscattered noise. Each water column segment was analyzed ~ 3 m below the surface to avoid near field problems.

Bubble flux were estimated based on methods developed for methane by Ostrovsky et al. (2008) and Greinert et al. (2006) were adapted to carbon dioxide. The volumetric concentration (V_c) of bubbles in the water column is calculated by retrieving the total backscattering volume (S_v) with the target strength (T_s = 10 log₁₀ B_s, B_s: backscattering cross section). Taking into account the rise velocity of bubbles, the molar volume of CO₂ at the bottom and V_C, one can calculate the gaseous carbon dioxide fluxes.

This made a mapping of gaseous emissions possible in each lake. CO₂ (g) floating accumulation chamber measurements performed in Kelud and Taal lakes allowed a comparison of CO₂ flux values retrieved by both methods. Echo sounding method gives systematic lower values which highlight an important CO₂ diffuse flux not resolved by the echo sounding technique. By inspecting vertical trains of ascending bubbles, we found a carbon dioxide dissolution rate fairly constant in the whole lake. A CO₂ flux increase was detected 4 months prior to the 2007 eruption of Kelud volcano, well before any other monitored parameter. As echo sounding lakes/caldera is fast and non invasive, this method could thus provide useful information on degassing processes especially when coupled with complementary methods.