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Carbon cycling in the epilimnion of Lake Kivu (East Africa): surface net autotrophy and emission of CO_2 to the atmosphere sustained by geogenic inputs

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Lake Kivu [2.50°S 1.59°S 29.37°E 28.83°E] is one of the East African great lakes (2370 km2 surface area, 550 km3 volume). It is a deep (maximum depth of 485 m) meromictic lake, with an oxic mixolimnion down to 70 m maximum, and a deep monolimnion rich in dissolved gases and nutrients. Lake Kivu is permanently stratified (meromictic) and deep layers receive heat, salts, and CO_2 from deep geothermal springs. Seasonality of the physical and chemical vertical structure and biological activity in surface waters of Lake Kivu is driven by the oscillation between the dry season (June-September) and the rainy season (October-May), the former characterized by a deepening of the mixolimnion. This seasonal mixing favours the input of dissolved nutrients and the development of diatoms, while, during the rest of the year, the phytoplankton assemblage is dominated by cyanobacteria, chrysophytes and cryptophytes. Huge amounts of CO_2 and methane (CH4) (300 km3 and 60 km3, respectively, at 0°C and 1 atm] are dissolved in the deep layers of Lake Kivu. The CO_2 is mainly geogenic. Large scale industrial extraction of CH4 from the deep layers of Lake Kivu is planned which could affect the ecology and biogeochemical cycling of C of the lake and change for instance the emission of greenhouse gases such as CH4 and CO_2. Here, we report a data set covering the seasonality of CO_2 dynamics and fluxes, in conjunction with mass balances of C, and process rate measurements (primary production and bacterial production). In order to capture the seasonal variations of the studied quantities, four cruises were carried out in Lake Kivu on 15/03-29/03/2007 (mid rainy season), 28/08-10/09/2007 (late dry season), 21/06-03/07/2008 (early dry season) and 21/04-05/05/2009 (late rainy season). We show that the lake is a modest source of CO_2 to the atmosphere but which is sustained by geogenic inputs from depth rather than net heterotrophy as reported in lakes in general. Indeed we provide several lines of evidence that show that the lake is net autotrophic. This unusual situation is related to the large surface are of the lake and the high ratio of lake surface : watershed surface. As a consequence, the (allochthonous) inputs of inorganic and organic carbon from the watershed are modest compared to the export to depth of autochthonous production. We also show that a large part of the bacterial respiration is sustained by dissolved primary production, consistent with the oligotrophic nature of surface waters of the lake.