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# Greenhouse gas ($CO_2$ and CH4) emissions from a high altitude hydroelectric reservoir in the tropics (Riogrande II, Colombia)

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Tropical hydroelectric reservoirs are considered as very significant source of methane (CH4) and carbon dioxide ($CO_2$), especially when flooding dense forest. We report emissions from the Rio Grande II Reservoir located at 2000 m.a.s.l. in the Colombian Andes. The dam was built at the confluence of the Rio Grande and Rio Chico in 1990. The reservoir has a surface of 12 km2, a maximum depth of 40m and a residence time of 2.5 month. Water quality (temperature, oxygen, pH, conductivity), nitrate, ammonium, dissolved and particulate organic carbon (DOC and POC), $CO_2$ and CH4 were monitored bi-monthly during 1.5 year at 9 stations in the reservoir. Diffusive fluxes of $CO_2$ and CH4 and CH4 ebullition were measured at 5 stations.

The Rio grande II Reservoir is weakly stratified thermally with surface temperature ranging from 20 to 24°C and a constant bottom temperature of 18°C. The reservoir water column is well oxygenated at the surface and usually anoxic below 10m depth. At the stations close to the tributaries water inputs, the water column is well mixed and oxygenated from the surface to the bottom. As reported for other reservoirs located in "clear water" watersheds, the concentrations of nutrients are low ($NO_3$-<0.1ppm, NH4+<0.2ppm), the concentrations of DOC are high (2-8 mg L-1) and POC concentrations are low (< 3 mg L-1). Surface CH4 concentrations at the central stations of the reservoirs are 0.5 $\mu$mol L-1 (0.07-2.14 $\mu$mol L-1) and 3 times higher at the stations close to the tributaries inputs (up to 7 $\mu$mol L-1). In the hypolimnion, CH4 concentration is <100 $\mu$mol L-1 in the wet season and can reach up to 400 $\mu$mol L-1 in the dry season. The spatial and temporal variability are lower for $CO_2$. Surface $CO_2$ concentration was on average 72 $\mu$mol L-1 (up to 300) and hypolimnic concentration ranged between 250 and 1000 $\mu$mol L-1.

The $CO_2$ diffusive flux is 517$\pm$331 mmol m-2 d-1 with little seasonal and spatial variations. At the center of the reservoir, the median diffusive flux of CH4 is 1.75 mmol m-2 d-1 and sporadic high fluxes (>10 mmol m-2 d-1) were observed during the dry season. Close to the tributaries water inputs where the water column is well mixed, the average diffusive flux is 8 mmol m-2 d-1. CH4 ebullition was 3.5 mmol m-2 d-1 and no ebullition was observed for a water depth higher than 5m.

The zone under the influence of the water inputs from tributaries represents 25% of the surface of the reservoir but contributed half of total CH4 emissions from the reservoir (29MgC month-1). Ebullition contributed only to 12% of total CH4 emissions over a year but it contributed up to 60% during the dry season. CH4 emissions from the Rio Grande Reservoir contributed 30% of the total GHG emissions (38Gg$CO_2$eq y-1). Overall, this study show that the majority of CH4 emissions from this reservoir occur through hotspot and hot moments and that mountainous reservoir located in the tropics could have emission factors as high as Amazonian reservoirs.