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The carbon footprint of a tropical reservoir: measured versus modeled values highlight the underestimated key role of downstream processes

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Reservoirs are important sources of greenhouse gases (GHGs) to the atmosphere and their number is rapidly increasing, especially in tropical regions. Accurately predicting their current and future emissions is essential but hindered by fragmented data on the subject, which often fail to include all emission pathways (surface diffusion, ebullition, degassing, and downstream emissions) and the high spatial and temporal flux variability. Here we conducted a comprehensive sampling of Batang Ai reservoir (Malaysia), and compared field-based versus modeled estimates of its annual carbon footprint for each emission pathway. We further explored the processes fuelling and regulating emissions downstream of the dam, which are important but commonly overlooked. Carbon dioxide (CO_2) surface diffusion and methane (CH_4) ebullition were lower than predicted, whereas moderate surface CH_4 diffusion was accurately predicted. Most GHGs present in discharged water were degassed at the turbines, and the remainder were gradually emitted along the outflow river, leaving time for CH_4 to be partly oxidized to CO_2. Overall, the reservoir emitted 2475 $gCO_2eq\ m^{-2}\ yr^{-1}$, of which 89 % occurred downstream of the dam, mostly in the form of CH_4. These emissions, largely underestimated by predictions, are mitigated by CH_4 oxidation upstream and downstream of the dam, but could have been drastically reduced by slightly raising the water intake elevation depth. Degassing and downstream emissions are largely due to the accumulation of GHGs under the permanent thermocline. Studying the interplay between the processes regulating CO_2 and CH_4 concentrations in the reservoir deep layer highlighted the key role of physical factors on GHGs dynamics. Overall, our results show that exploring morphometry, soil type, and stratification patterns as predictors can improve modeling of reservoir GHGs emissions at local and global scales.