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Evaluating stream CO_2 outgassing via Drifting and Anchored flux chambers in a controlled flume experiment

Filippo Vingiani[1], Nicola Durighetto[1], Marcus Klaus[2], Jakob Schelker[3,4], Thierry Labasque[5], and Gianluca Botter[1]
[1]University of Padua, Department of Civil, Environmental and Architectural Engineering, Padova, Italy (filippo.vingiani@phd.unipd.it)
[2]Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, 901 83 Umeå, Sweden
[3]Department of Limnology and Oceanography, University of Vienna, 1090 Vienna, Austria
[4]WasserCluster Lunz GmbH, 3293 Lunz am See, Austria
[5]Géosciences Rennes, Université de Rennes 1, 35042 Rennes, France

Carbon dioxide (CO_2) emissions from running waters represent a key component of the global carbon cycle. However, quantifying CO_2 fluxes across air-water boundaries remains challenging due to practical difficulties in the estimation of reach-scale standardized gas exchange velocities (k_{600}) and water equilibrium concentrations. Whereas craft-made floating chambers supplied by internal CO_2 sensors represent a promising technique to estimate CO_2 fluxes from rivers, the existing literature lacks of rigorous comparisons among differently designed chambers and deployment techniques. Moreover, as of now the uncertainty of k_{600} estimates from chamber data has not been evaluated. Here, these issues were addressed analyzing the results of a flume experiment carried out in the Summer of 2019 in the Lunzer:::Rinnen - Experimental Facility (Austria). During the experiment, 100 runs were performed using two different chamber designs (namely, a Standard Chamber and a Flexible Foil chamber with an external floating system and a flexible sealing) and two different deployment modes (drifting and anchored). The runs were performed using various combinations of discharge and channel slope, leading to variable turbulent kinetic energy dissipation rates ($1.5\ 10^{-3} < \varepsilon < 1\ 10^{-1}\ m^2\ s^{-3}$). Estimates of gas exchange velocities were in line with the existing literature ($4 < k_{600} < 32\ m\ d^{-1}$), with a general increase of k_{600} for larger turbulent kinetic energy dissipation rates. The Flexible Foil chamber gave consistent k_{600} patterns in response to changes in the slope and/or the flow rate. Moreover, Acoustic Doppler Velocimeter measurements indicated a limited increase of the turbulence induced by the Flexible Foil chamber on the flow field (22 % increase in ε, leading to a theoretical 5 % increase in k_{600}).
The uncertainty in the estimate of gas exchange velocities was then estimated using a Generalized Likelihood Uncertainty Estimation (GLUE) procedure. Overall, uncertainty in k_{600} was moderate to high, with enhanced uncertainty in high-energy setups. For the anchored mode, the standard deviations of k_{600} were between 1.6 and 8.2 $m\ d^{-1}$, whereas significantly higher values were obtained in drifting mode. Interestingly, for the Standard Chamber the uncertainty was larger (+ 20 %) as compared to the Flexible Foil chamber. Our study suggests that a Flexible Foil design and the anchored deployment might be useful techniques to enhance the robustness and

the accuracy of CO_2 measurements in low-order streams. Furthermore, the study demonstrates the value of analytical and numerical tools in the identification of accurate estimations for gas exchange velocities.

These findings have important implications for improving estimates of greenhouse gas emissions and reaeration rates in running waters.