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Methane ebullition and fate in the Rhone River delta (Lake Geneva) and its subaquatic canyons

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There is increasing knowledge of the importance of inland waters as sources of atmospheric methane, but widespread variability of total and individual emission pathway estimates remain in the literature. Ebullition (bubbling) is potentially the most efficient transport mechanism from water bodies, particularly shallow water bodies or regions thereof where bubbles have the greatest chance of reaching the atmosphere. However, ebullition is one of the least monitored of the pathways, mostly due to its stochastic nature making it difficult to constrain spatially and temporally. Recent studies on a large tropical reservoir and a large European lake have shown that river deltas (i.e. localized regions of high allochthonous organic matter sedimentation) can be methane ebullition hot spots emitting disproportionate amounts of methane. Therefore, in this study the Rhone River delta (one Europe's most important rivers) of the Alp's largest lake, Lake Geneva, was surveyed for methane ebullition using a bubble size-calibrated 120 kHz split-beam echosounder (Simrad EK60, Kongsberg Maritime). Extensive ebullition was found in the current river delta complex in proximity to the river inflow, which is the major source of atmospheric methane emission in the entire 100 km2 deltaic region. As water depths approach 100 m, ebullition is constrained to only the top levees of the 10 – 40 m high walls of the subaquatic canyon formed by the plunging Rhone River. Ebullition occurs to depths over 200 m on the levee of the active canyon, where CTD profiles suggest that Rhone River water does extend that far along the canyon. As bubble dissolution depends on release depth and bubble size, which was estimated from the rise velocity of deep bubbles, it was discovered that bubbles emitted from 100 m or deeper would not reach the surface; thus the proximal delta remains the prominent methane source. Eight other canyons exist in the delta complex, of which two non-active canyons formed by previous river inputs were also surveyed for ebullition. Ebullition occurs much less frequently in these older canyons but is also found on bathymetric highs, such as former canyon walls. Ebullition flux rates in the older canyons are much lower than those from the active canyon and are thus not a significant atmospheric methane source. Overall, the Rhone River delta of Lake Geneva is an ebullition hot spot emitting significant amounts of methane to the atmosphere and further highlights the need for more spatially-conscious surveying of inland waters, which an echosounder can efficiently provide.