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Swedish University of Agricultural Sciences (SLU), Faculty of Forest Sciences

Bubbles as gateways for gas exchange between inland waters and the atmosphere

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Abstract

Terrestrial ecosystems and inland waters are closely connected through the cycling of carbon, nutrients, and energy. While terrestrial ecosystems typically capture and store atmospheric carbon, the lakes and rivers that drain landscapes generally return part of that carbon back to the atmosphere as greenhouse gases such as carbon dioxide and methane. Yet, the processes that control how these gases move between water and air remain surprisingly uncertain. One of the largest sources of uncertainty lies in the gas exchange velocity, which determines how fast gases move across the air–water interface.

Inland waters have traditionally been described as systems where gas exchange is governed by turbulence. However, my research has shown that this picture is incomplete. Together with colleagues, I have demonstrated that bubbles can act as powerful additional pathways for gas exchange, accelerating the transfer of gases far beyond what turbulence alone can explain. These findings reveal that bubbles may account for a large fraction of total gas exchange in running waters, providing a new perspective on carbon dynamics in these systems and their surrounding landscapes.

In this lecture, I will outline the development of this research field and present results from mesocosm experiments and field observations that connect bubble abundance, size, and dynamics to carbon dioxide and methane exchange rates in lakes and rivers. I will show how bubble size distributions can serve as a “master variable” linking hydraulic conditions and gas exchange and discuss how these insights help refine existing models of air–water fluxes. I will also address the long-standing microbubble hypothesis, which proposes that invisible, microscopic bubbles could enhance gas exchange even in the absence of visible bubbling. Using advanced acoustic measurements, I will present new results that test this hypothesis directly.

Finally, I will discuss how these findings contribute to a broader understanding of land–water–atmosphere connectivity. Quantifying the role of bubbles improves our ability to assess the greenhouse gas balance of inland waters and to better represent these processes in global carbon cycling models. However, I will also pitch the idea that beyond gases, bubbles may also influence other forms of mass exchange in inland waters.

By highlighting how subtle and short-lived physical processes such as bubbles shape greenhouse gas fluxes, the lecture seeks to stimulate dialogue across disciplines about the interactions between terrestrial and aquatic systems and the atmosphere, and their shared significance for the Earth’s material cycles.