

Transport and Transformation of Sub-ice Methane in the Yukon River

JOSHUA SOMTOCHUKWU ANADU¹, JOHN S. MAGYAR¹, HANNAH DION-KIRSCHNER¹, YUTIAN KE¹, MICHAEL P. LAMB¹, A. JOSHUA WEST² AND WOODWARD W. FISCHER¹

¹California Institute of Technology

²University of Southern California

Rivers are significant sources of methane (CH₄) and carbon dioxide (CO₂) to the atmosphere [1]. Methane emissions from high-latitude lakes have also been estimated to be greater than two times global ocean emissions [2]. We present new data pertinent to the sources and fate of carbon in the Yukon River watershed. We performed both concentration and flux measurements of both gases, the former via headspace equilibration and the latter directly with a floating flux chamber. Notably, wintertime greenhouse gas concentrations under the ice are several orders of magnitude higher than summertime concentrations, consistent with our simultaneous flux observations that revealed inhibition of degassing due to the presence of thick river ice. Similar seasonal dynamics occur in high-latitude lakes. Unlike high-latitude lakes, which commonly become hypoxic during the winter months [3], the Yukon remains oxygenated throughout the season, suggesting a significant role for aerobic methanotrophs in consuming methane during its lateral transport. Carbon-rich waters are advected from the interior out to the ocean wherein additional methanotrophy can occur with limited atmospheric connection under the Bering Sea Ice. The kinetics of sub-ice methanotrophy present key uncertainty in determining the magnitude of CH₄ drawdown [4]. In addition, our measurements of dissolved inorganic carbon radiocarbon ages indicate that wintertime respiration has a significant source from ancient carbon in the system. As Arctic time-integrated ice cover declines with amplified warming, understanding these wintertime processes is critical for predicting future CH₄ and CO₂ emissions.

[1] Rocher-Ros, Gerard, et al. "Global methane emissions from rivers and streams." *Nature* 621.7979 (2023): 530-535.

[2] Saunio, Marielle, et al. "The global methane budget 2000–2017." *Earth System Science Data Discussions* 2019 (2019): 1-136.

[3] Phelps, Allan R., Kim M. Peterson, and Martin O. Jeffries. "Methane efflux from high-latitude lakes during spring ice melt." *Journal of Geophysical Research: Atmospheres* 103.D22 (1998): 29029-29036.

[4] Dion-Kirschner, Hannah, et al. "Evaluating the contribution of methanotrophy kinetics to uncertainty in the soil methane sink." *Environmental Research Letters* 19.6 (2024): 064059.