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Quantifying the potential of the Greenland ice sheet to produce and release CH_4 into the atmosphere

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Ice sheet beds host extensive, warm-based sedimentary zones isolated by the overlying ice. They contain large amounts of organic matter (OM) overridden during periods of ice advance and become anoxic due to microbial respiration and other oxidation reactions; this creates favourable conditions for biological methane (CH_4) production. CH_4 has been detected at retreating glacier margins globally, including the Greenland Ice Sheet (GrIS). To quantify the potential of the GrIS to produce and release CH_4 we conducted an intensive sampling campaign, complemented by continuous monitoring, to gain a detailed overview of CH_4 export across the western margin of the ice sheet. We found that CH_4 export was not limited to any specific hotspot or region in Greenland but was ubiquitous across the entire western margin. Isotopic analyses demonstrate that this CH_4 originates from the subglacial microbial degradation of OM formed following the Holocene Climatic Optimum (HCO) and overridden by subsequent ice advance. Reaction transport modelling indicates that the GrIS will continue to export CH_4 for the coming centuries. Radiocarbon dating of the CH_4 yields Holocene ages that correspond to geological evidence for minimum ice limits, supporting the hypothesis that the GrIS was significantly smaller during the HCO. Since recent findings of well-preserved OM in basal ice and sediment in GrIS ice cores reveal that even older, and potentially richer, subglacial OM stocks exist deeper within the interior regions, beyond the Holocene-aged substrate, future export of CH_4 is not only likely to be sustained over the coming centuries but could, potentially, be enhanced substantially and well beyond this timescale. Our study provides new insights into subglacial carbon recycling and export processes, their prevalence, and their impact on future GHG concentrations.