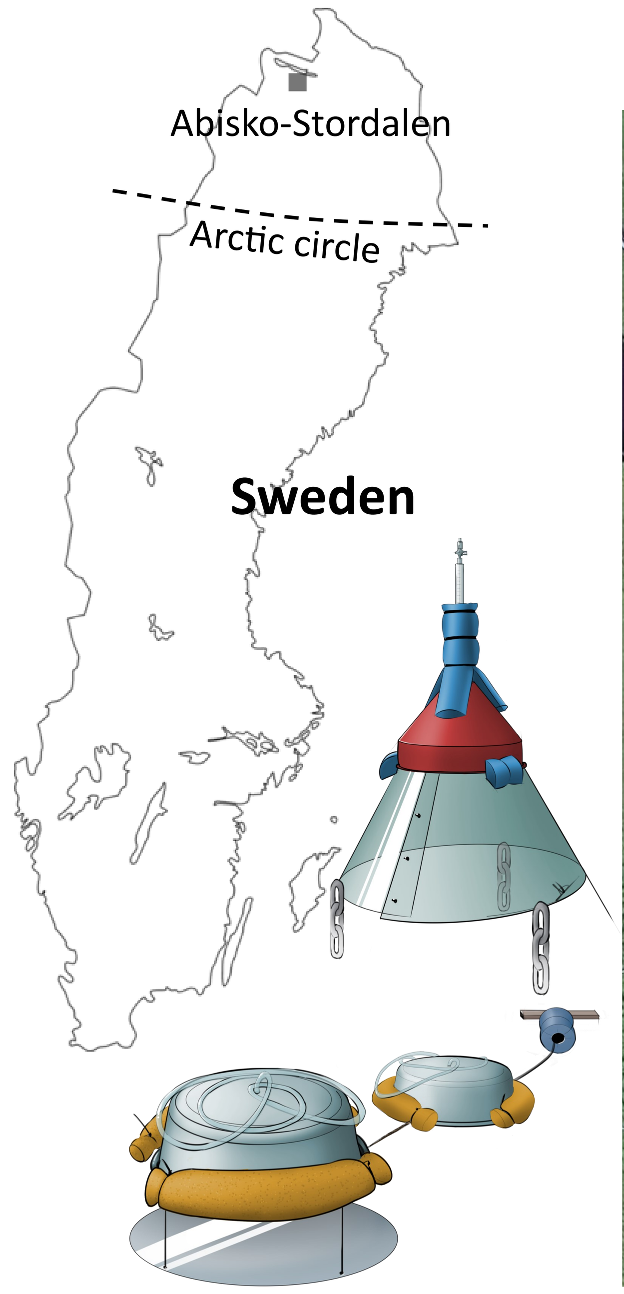
Drivers of carbon gas emissions from seasonally ice-covered lakes

Joachim Jansen[1], Mathilde Jammet[2], Brett Thornton[1], Martin Wik[1], Alicia Cortés[3], Sally MacIntyre[3], Thomas Friborg[2], Patrick Crill[1]
[1]Department of Geological Sciences & Bolin Centre for Climate Research, Stockholm University, Sweden
[2]Department for Geosciences and Natural Resource Management, Copenhagen University, Denmark
[3]Marine Science Institute, University of California at Santa Barbara, Santa Barbara, CA, United States

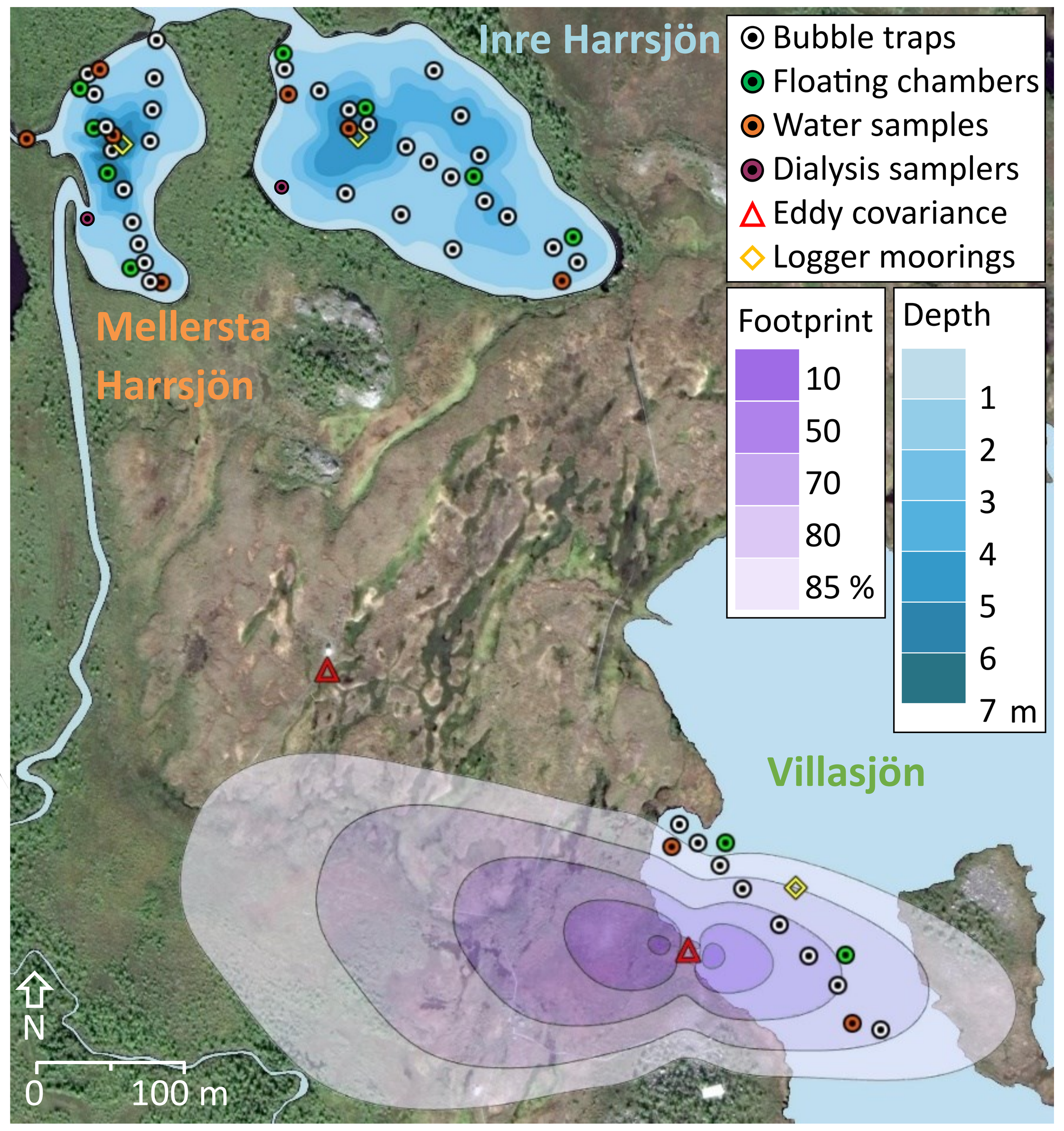
Bolin Centre for Climate Research

Stockholm University

Quantifying climate forcing trace gas emissions from subarctic lakes



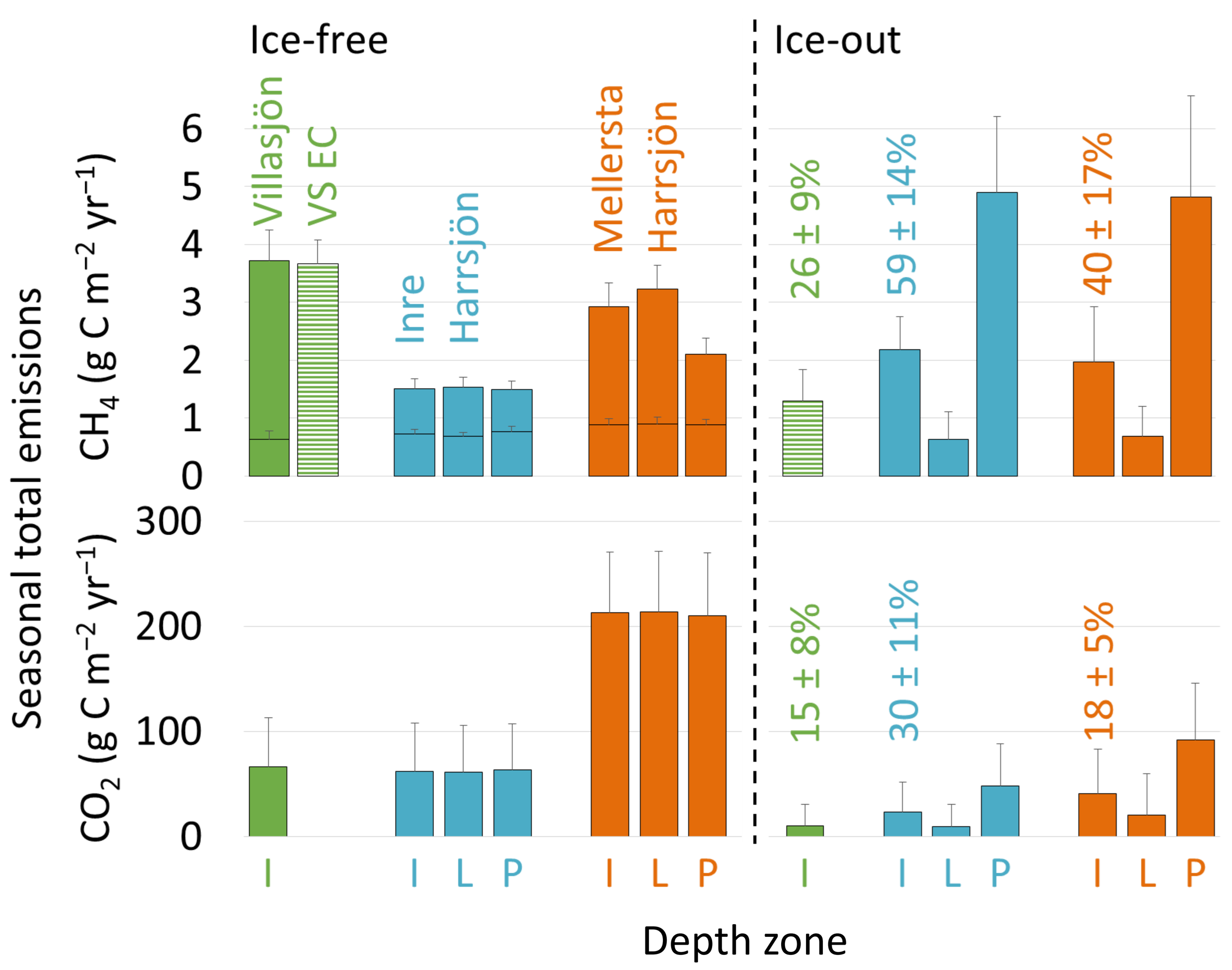
Field site: the Stordalen Mire complex



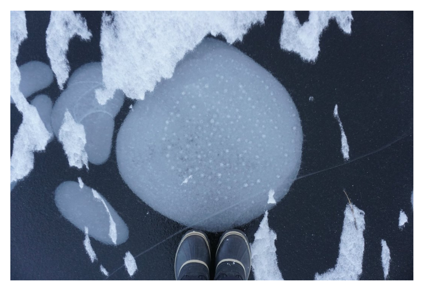
Long-term study (2009-2018) of three subarctic lakes (<0.2 km²) in a permafrost peatland:

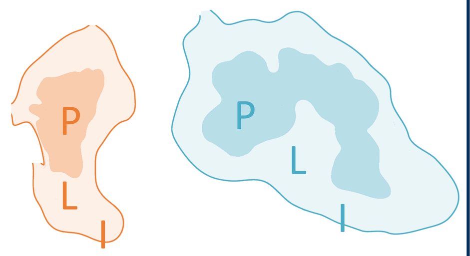
- Summer sampling: 10 surface flux chamber pairs, 38 bubble traps (CH_4 fluxes)
- Year-round: eddy covariance (CH_4), water sampling (CH_4, CO_2); loggers for temperature, DO
- Lab: concentrations of CH_4 (GC-FID), CO_2 (IRGA); stable isotopes of CH_4 (GC-IRMS)
- Models: surface renewal model (CO_2 flux), open system isotope fractionation model

The spring efflux contributes significantly to annual C emissions



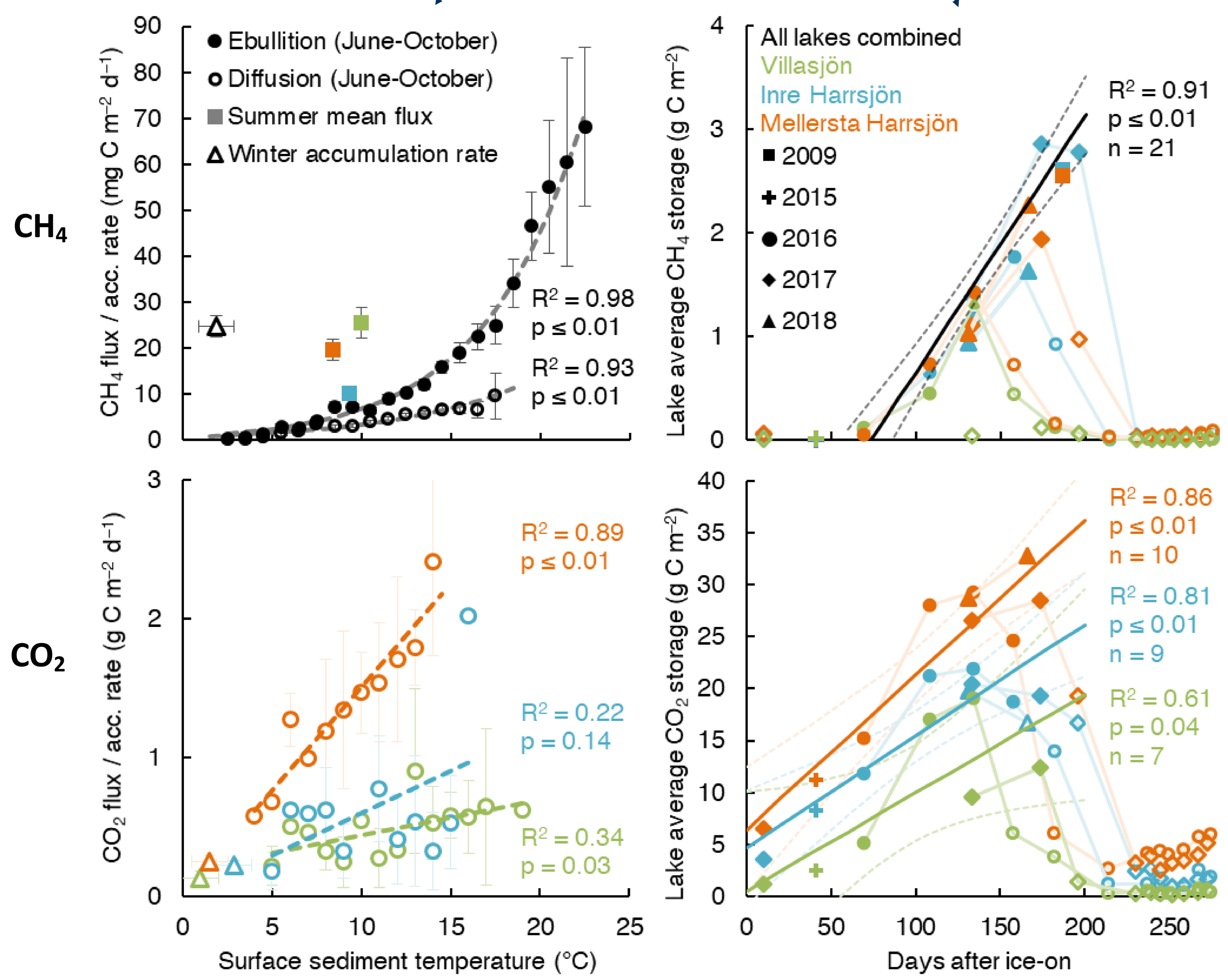
Spring contribution from water column CH_4 storage in deeper lakes **40-59%**: up to **71%** if we also include ice-trapped CH_4 bubbles





- Greater under-ice buildup of CO_2 and CH_4 in pelagic (P) than in littoral (L) zones
- Downslope gravity currents may redistribute carbon gas under ice

Energy input controls summer C fluxes, but not winter accumulation



- Under-ice carbon gas storage scales predictably with ice-cover season length

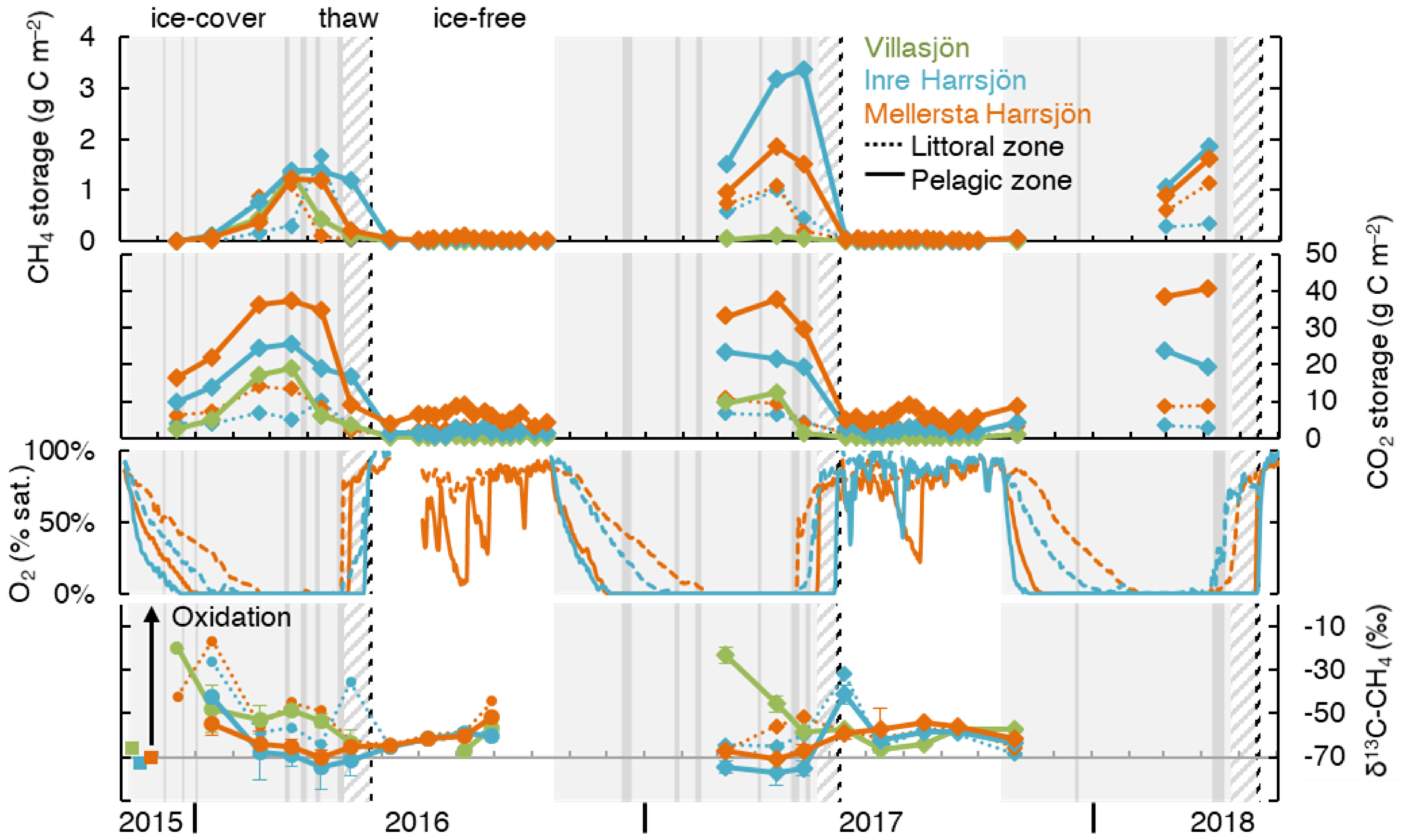
? How can under-ice CH_4 accumulation rates exceed summer fluxes?

H1 Low CH_4 production rates offset by minimal oxidation

H2 Anoxia enables water column methanogenesis

H3 Fresh C from senescing plants enhances production

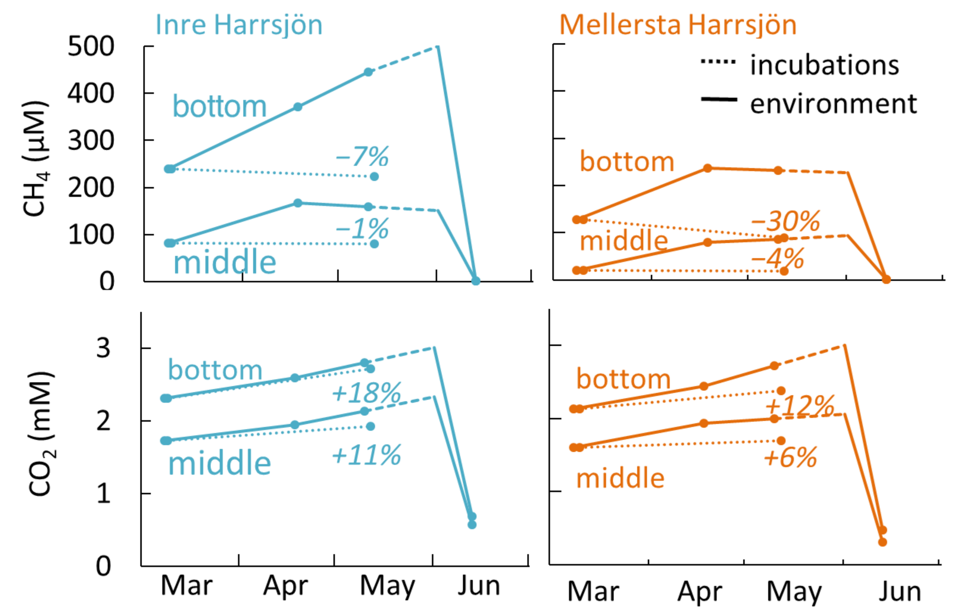
Redox regime regulates carbon gas accumulation in winter



- ΔDIC/ΔDO mass balance: ~70% of under-ice DIC accumulation due to anaerobic respiration

~~H1~~ ~50% of CH_4 is oxidized in summer, but minimal ox. under ice cannot explain CH_4 acc. rates

Respiration, but no methanogenesis in anoxic water under ice



- Hanging bottle incubations at two depths in the deeper lakes (March-April 2017)

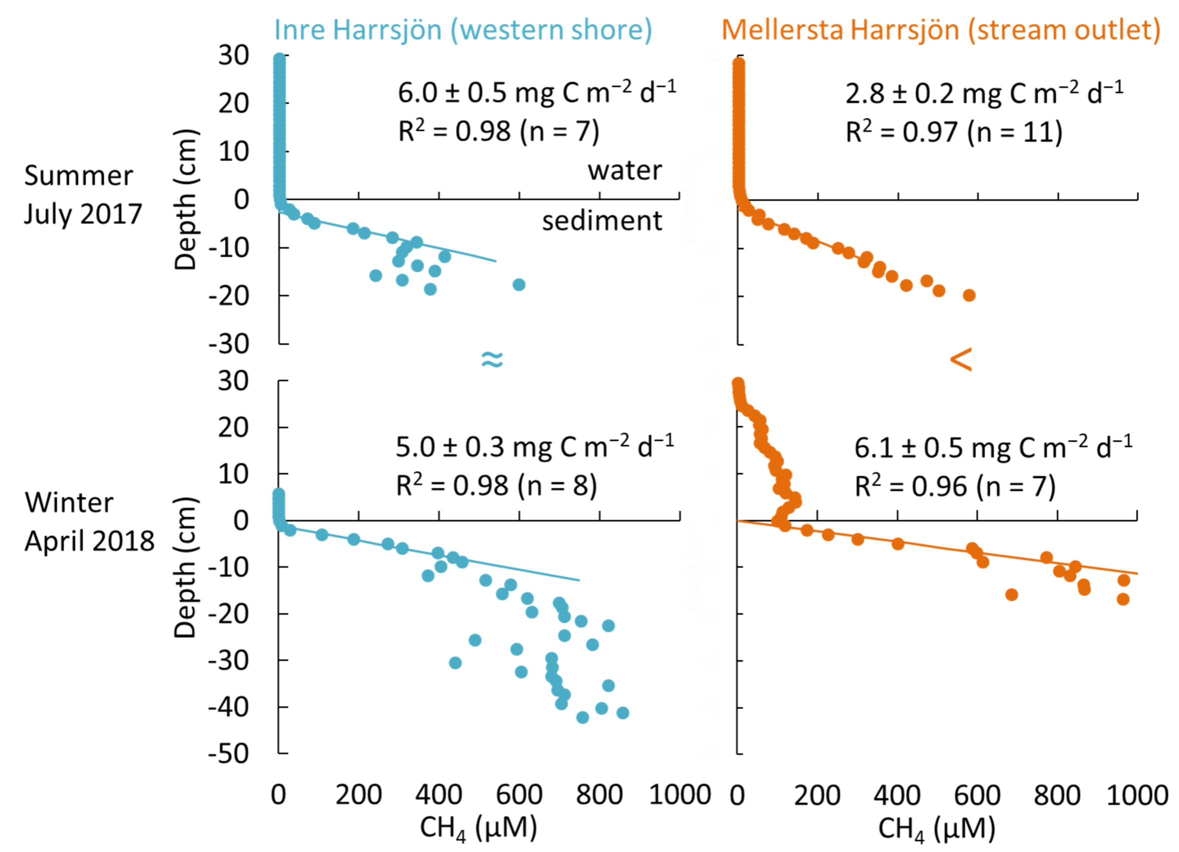
~~H1~~ Anaerobic methanotrophy and respiration active under ice

~~H2~~ No evidence of water column methanogenesis

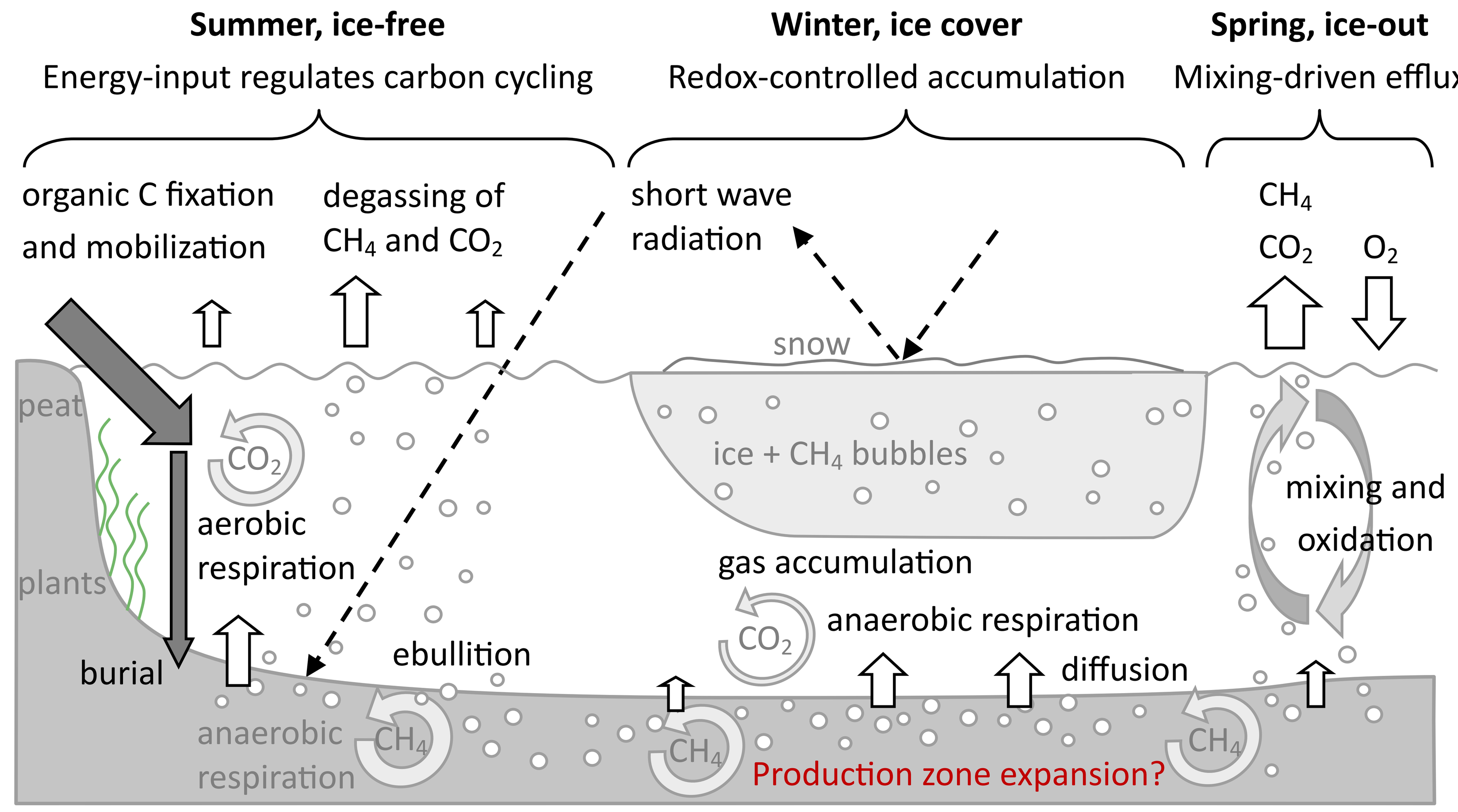
Sediment efflux of CH_4 similar or higher in winter than in summer

- Dialysis samplers deployed in shallows
- Sediment flux from Fick's first law

H3 Anoxia may enable CH_4 production zone expansion toward the sediment surface where more labile C is available



Synopsis



References

Jansen J, Thornton B, Jammet M, Wik M, Cortés A, Friborg T, MacIntyre S, Crill P (2019) Climate-sensitive controls on large spring emissions of CH_4 and CO_2 from northern lakes. *J. Geophys. Res. Biogeosc.*, 2019JG005094.

Acknowledgements

This research is supported by grants from the Swedish Research Council to P. Crill, from the US National Science Foundation to S. MacIntyre and from the EU programme PAGE21 to T. Friborg. We thank our field assistants and staff at the Swedish Polar Research Secretariat for their support, which enabled this work.