

Groundwater springs formed during glacial retreat are a large source of methane in the high Arctic

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Supplementary Notes

Methane concentration calculations

Headspace methane concentrations (ppm) were converted to partial pressures and then converted to moles (n) of methane using the Ideal Gas Law (Supplementary Equation 1):

$$n = \frac{PV}{RT}$$

where P is the partial pressure of the gas in the headspace, V is the headspace volume, R is the ideal gas constant and T is room temperature. The quantity of dissolved methane remaining in the sample water ($CH_{4(aq)}$, mL) was calculated using the Bunsen solubility coefficient (β) for 0% salinity and room temperature (Supplementary Equation 2)⁴⁶:

$$CH_{4(aq)}[mL] = V_w \cdot P_{CH_4} \cdot \frac{V_h}{V_w} \cdot \beta$$

where V_w is the total water volume in the vial during equilibrium, P_{CH_4} is the partial pressure of methane in the vial headspace and V_h is the volume of the vial headspace. The quantity of dissolved methane ($CH_{4(aq)}$, mL) was converted to moles using the Ideal Gas Law (Supplementary Equation 3):

$$CH_{4(aq)}[mol] = \frac{\frac{CH_{4(aq)}[mL]}{1000}}{R \cdot T}$$

The total quantity of methane in each sample was determined by summing the amount of moles of gaseous methane in the headspace with the number of moles remaining dissolved in the

sample water. This was converted to a concentration in nM using the sample volume (after removal of volume for headspace addition) and adjusted to account for the addition of NaOH.

Supplementary Tables

Statistical Analysis

	Early Cretaceous	Middle to Late Jurassic	Palaeogene and Neogene	Triassic to Middle Jurassic
Middle to Late Jurassic	$P = 0.071$			
Palaeogene and Neogene	$P = 0.500$	$P = 0.781$		
Triassic to Middle Jurassic	$P = 0.0000355$	$P = 0.679$	$P = 0.0433746$	
Carboniferous and Permian	$P = 0.235$	$P = 0.002904$	$P = 0.0258225$	$P = 0.0000098$

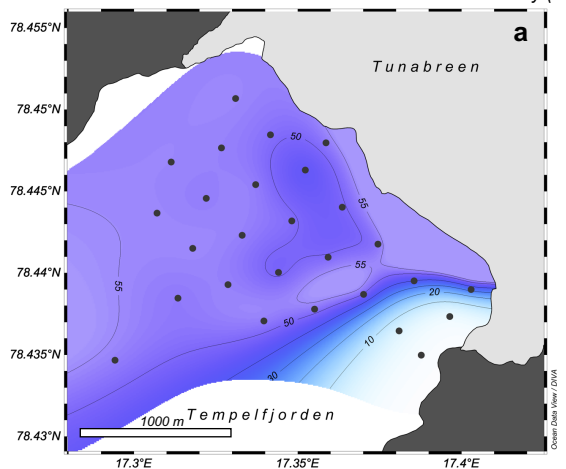
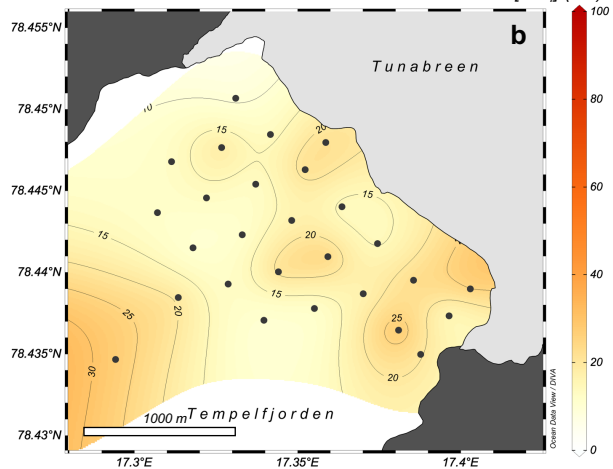
Supplementary Table 1. *P*-values of two-tailed pairwise comparisons made with Tukey's HSD post-hoc test. White indicates $P > 0.05$, light green indicates $0.05 > P > 0.001$ and dark green indicates $P < 0.001$.

Supplementary Figures

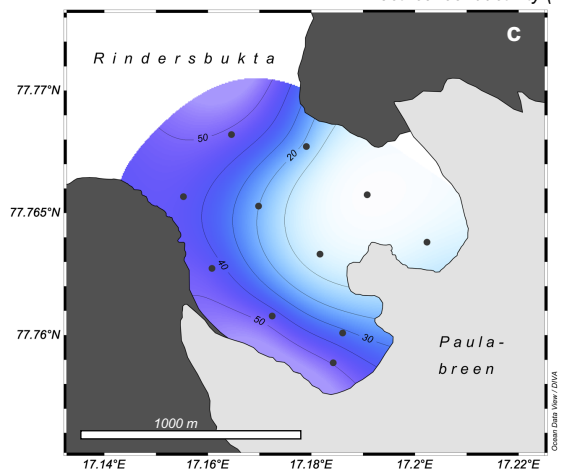
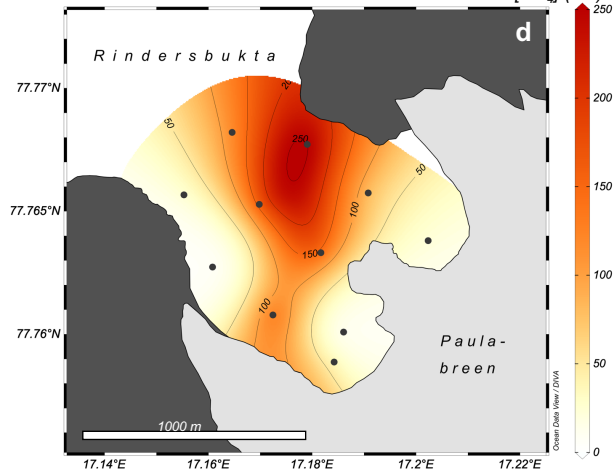
Methane and Salinity in Marine-Terminating Glacier Samples

Supplementary Fig. 1. Comparison of salinity (**a**, **c**, **e**; using electrical conductivity as a proxy) to methane concentrations (**b**, **d**, **f**) in fjord surface waters in front of three marine-terminating glaciers (glaciers are light grey, land is dark grey): (**a-b**) Tunabreen, (**c-d**) Paulabreen, and (**e-f**) Fridtjovbreen. Methane concentrations (nM) and electrical conductivity (mS/cm) are denoted by colored shading on the maps and are interpolated from the sampling points (grey dots) using Data-Interpolating Variational Analysis (DIVA) (created with Ocean Data View, odv.awi.de). The land and glacier shapefiles were digitalized manually by tracing Sentinel-2 satellite images.

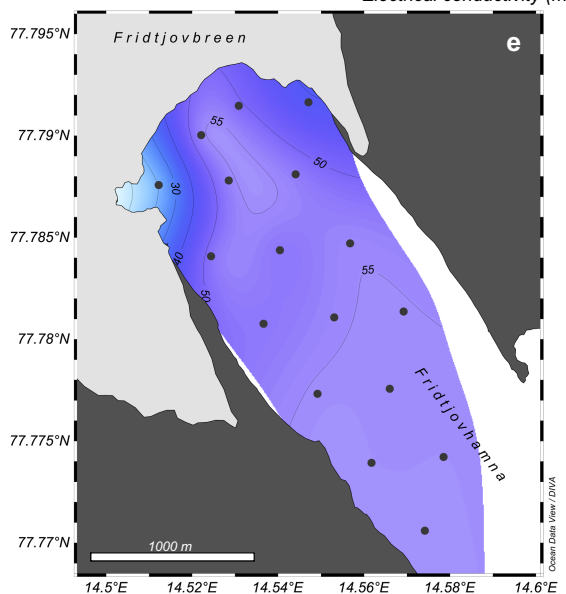
Electrical conductivity (mS/cm)

[CH₄] (nM)

Electrical conductivity (mS/cm)

[CH₄] (nM)

Electrical conductivity (mS/cm)

[CH₄] (nM)