Svalbard seawaters as a significant source of CH_4 to the atmosphere during summer 2024

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1 VLIZ 2 LIÈGE université GREEN FEEDBACK ICOS INTEGRATED CARBON OBSERVATION SYSTEM

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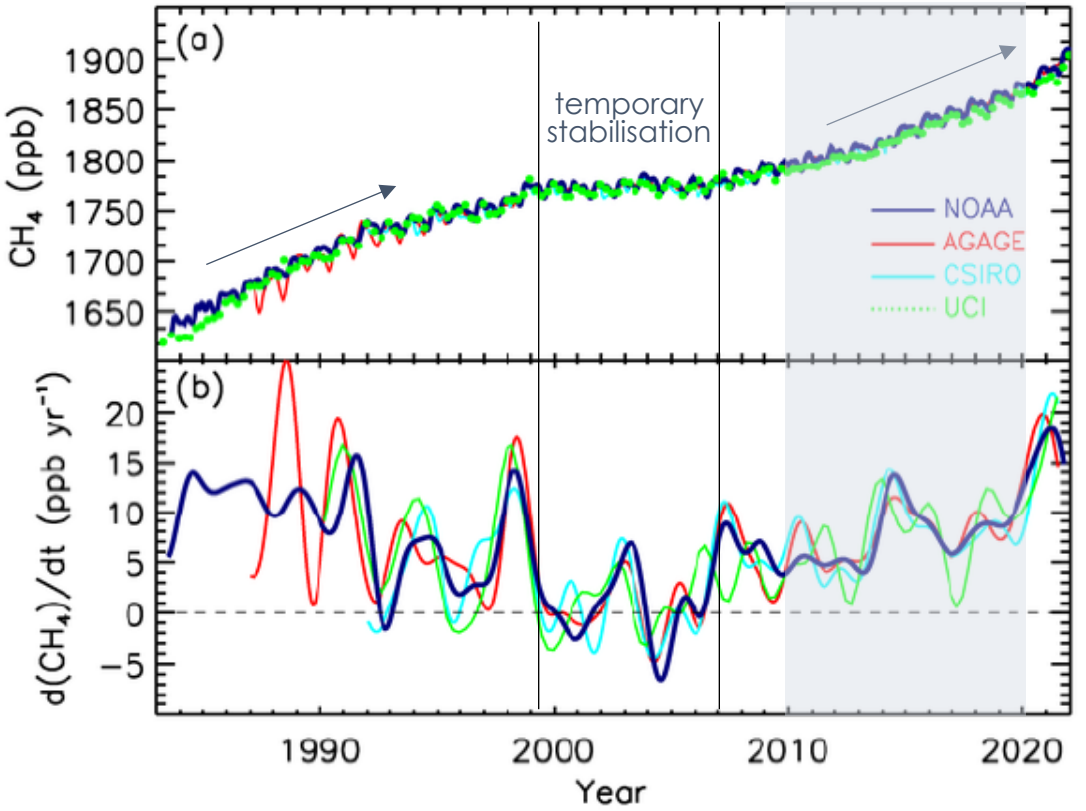
Background: atmospheric CH_4 budget

Saunois et al. 2024; Weber et al. 2019

- **2nd most significant GHG**, with **global warming** potential **~30 times** higher than CO_2
- **CH_4^{atm} ↗ 2.5 times** since the beginning of the industrial era



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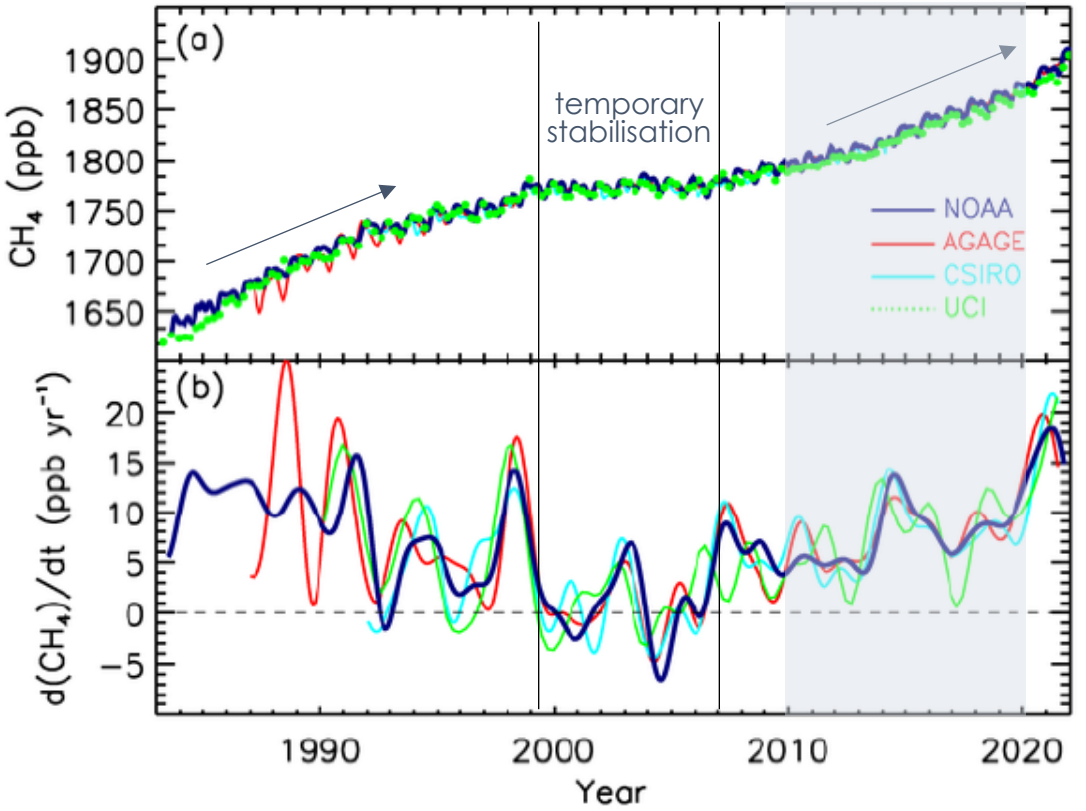
  - direct and/or climate-induced natural sources: e.g., **wetlands**, **freshwaters, shallow coastal seawaters**



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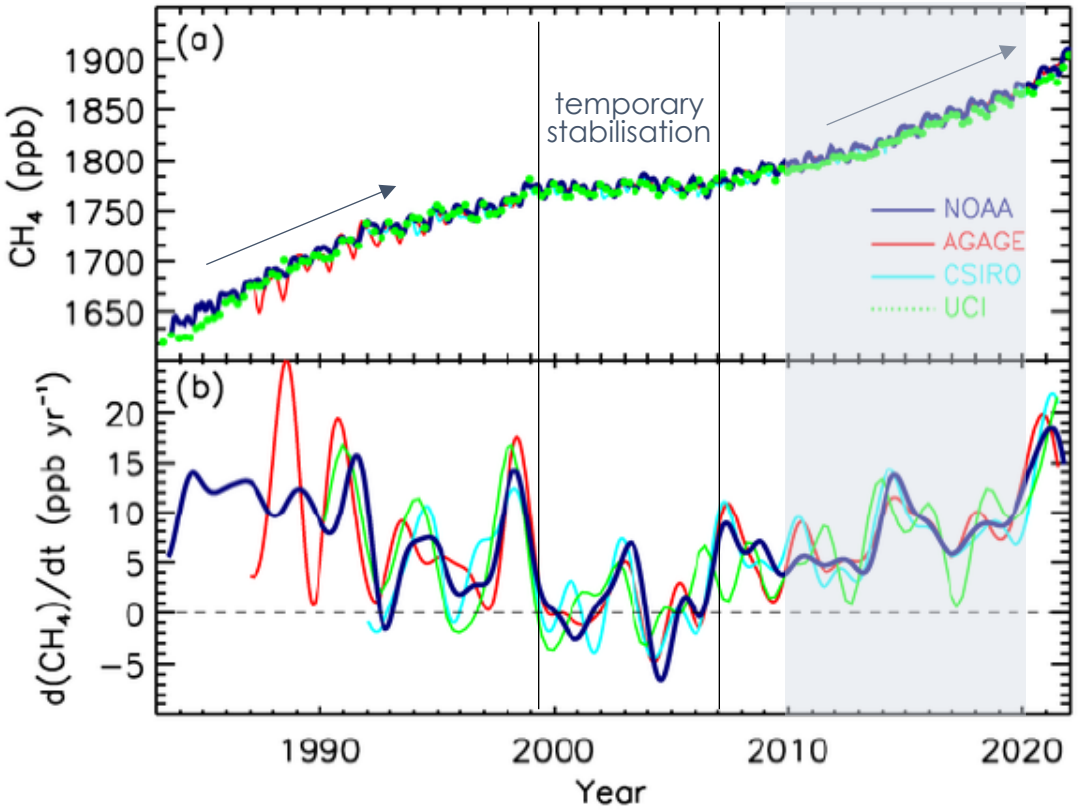


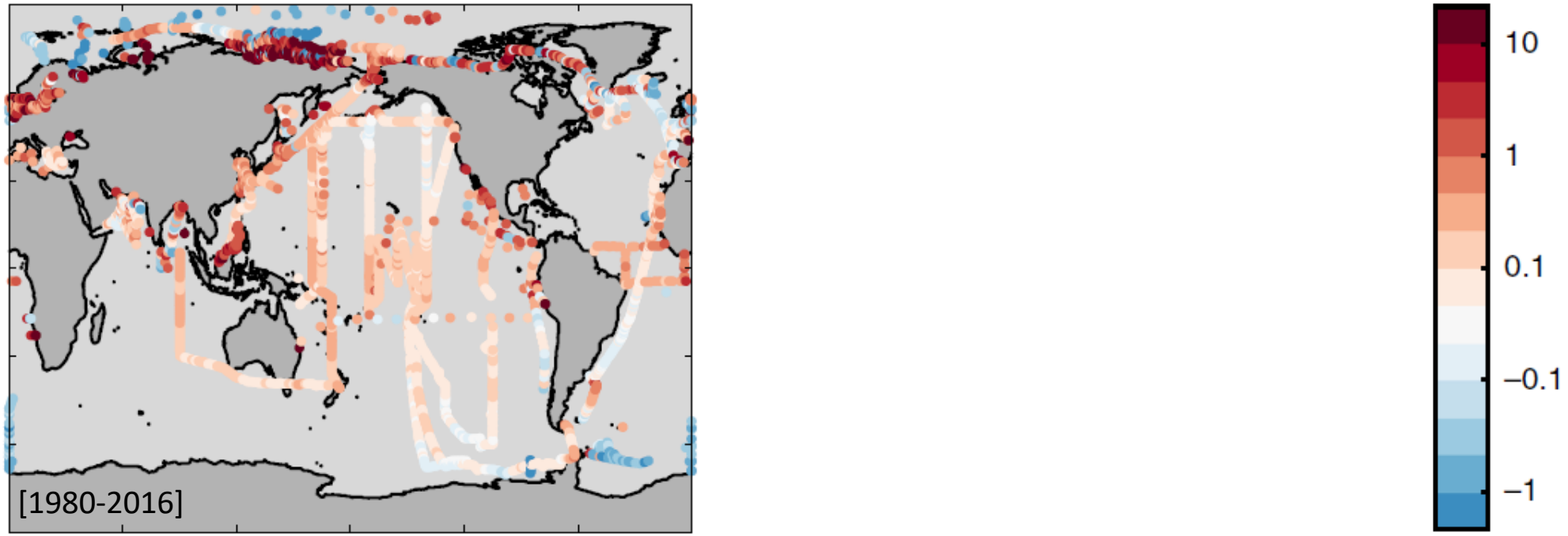
- Ocean → **significant and uncertain component**
  - sparce sampling of dissolved CH_4 in marine environments
  - crude extrapolation methods

→ Limited our understanding of the ocean's leverage over the atmospheric CH_4

Background: oceanic CH_4

Weber et al. 2019

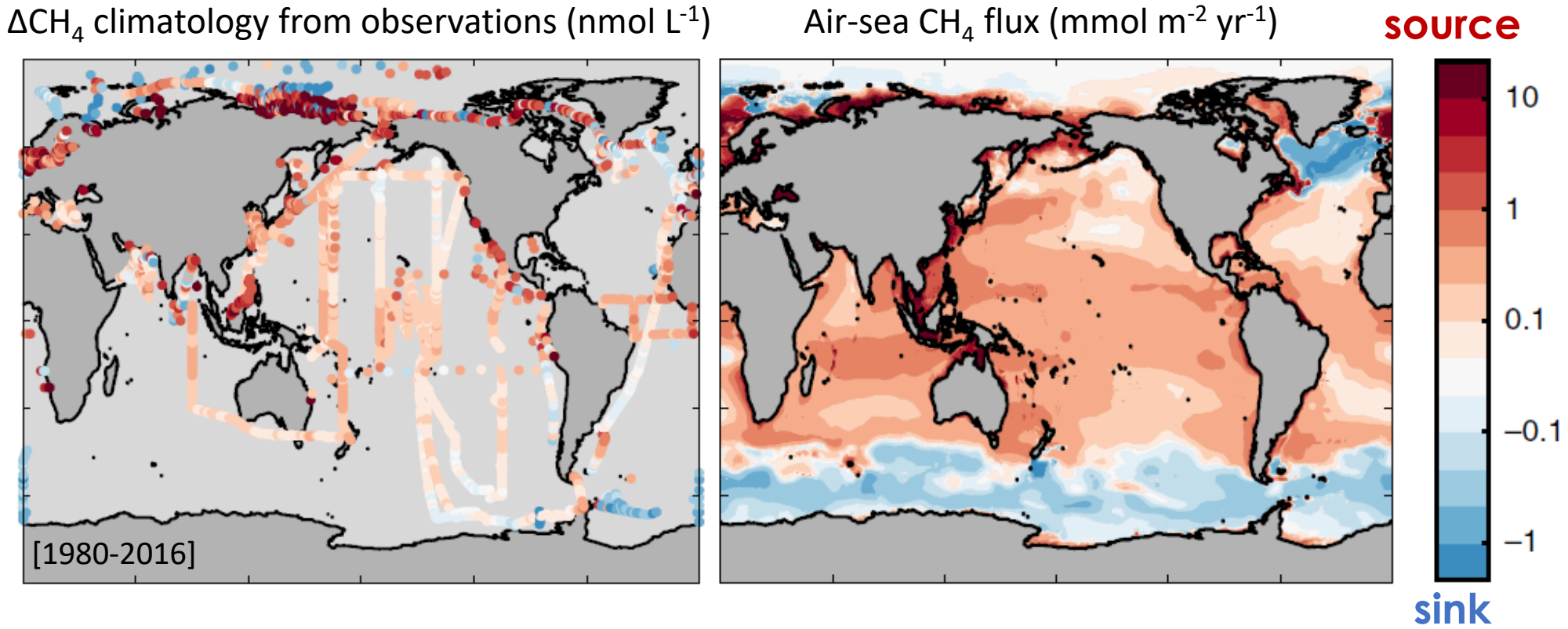
ΔCH_4 climatology from observations (nmol L^{-1})



- **Sparse sampling** of dissolved CH_4 especially in **polar oceans** and marginal seas
- Weber et al. (2019) map:

Background: oceanic CH_4

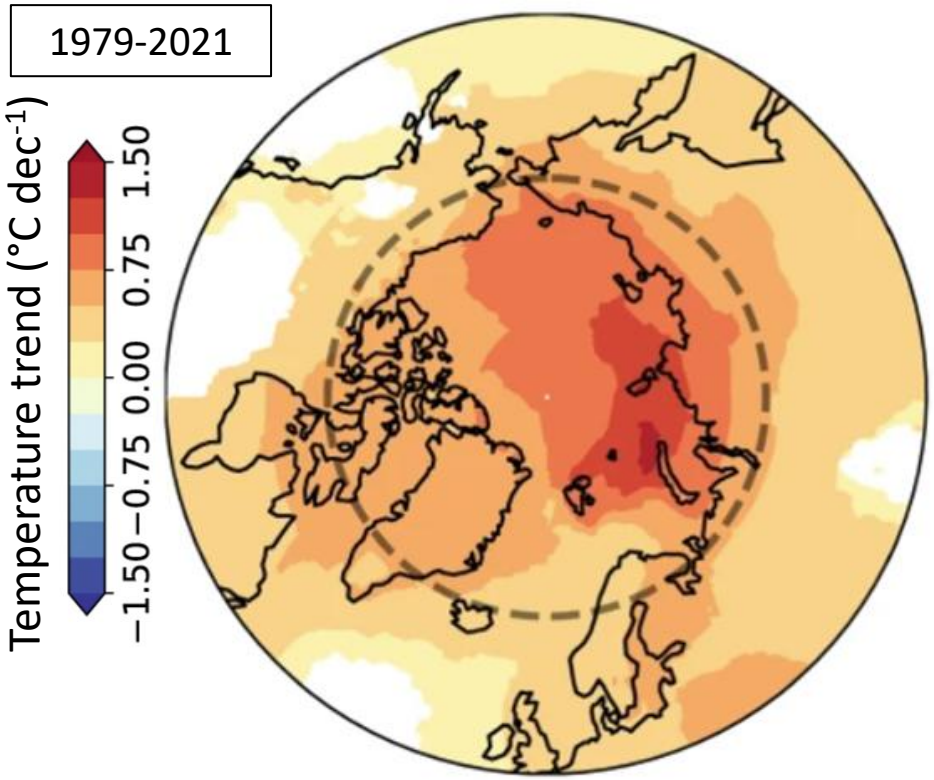
Weber et al. 2019



- **Sparse sampling** of dissolved CH_4 especially in **polar oceans** and marginal seas
- Weber et al. (2019) map: air-sea disequilibrium climatology using machine-learning models
  → Total oceanic emissions at 6 – 12 Tg CH_4 yr^{-1} [1980-2016]
  → Dominated by shallow coastal waters

Background: importance of the Arctic region

Rantanen et al. 2022; Weber et al. 2019
Damm et al. 2015;



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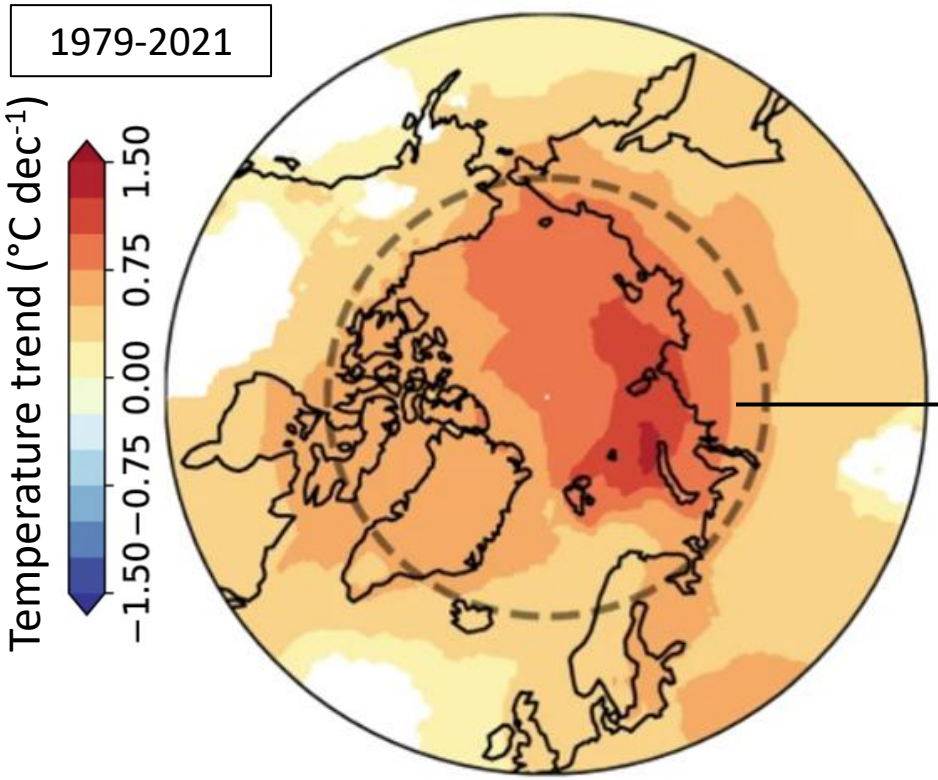
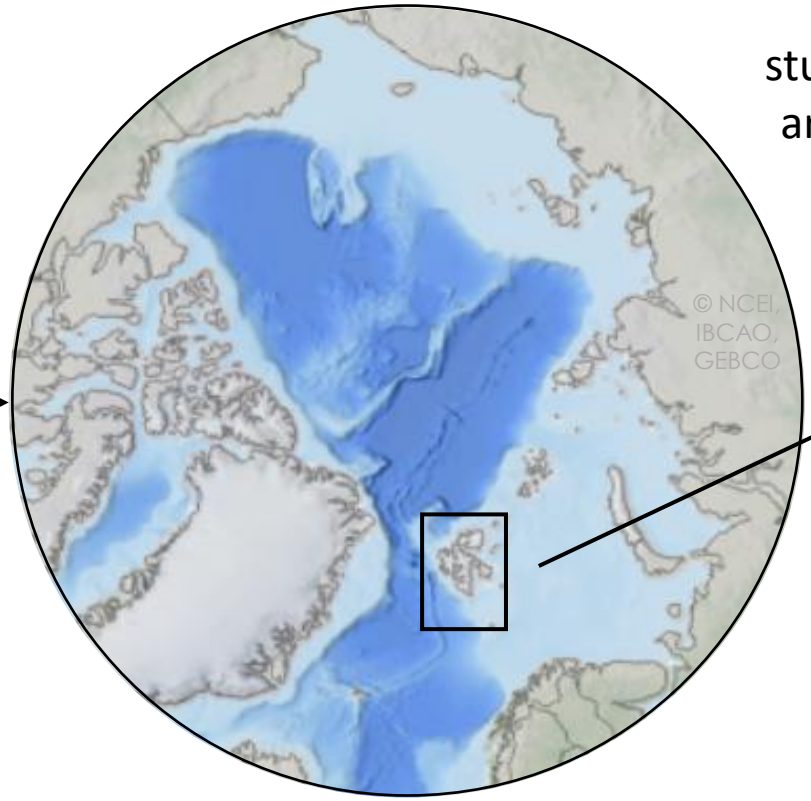
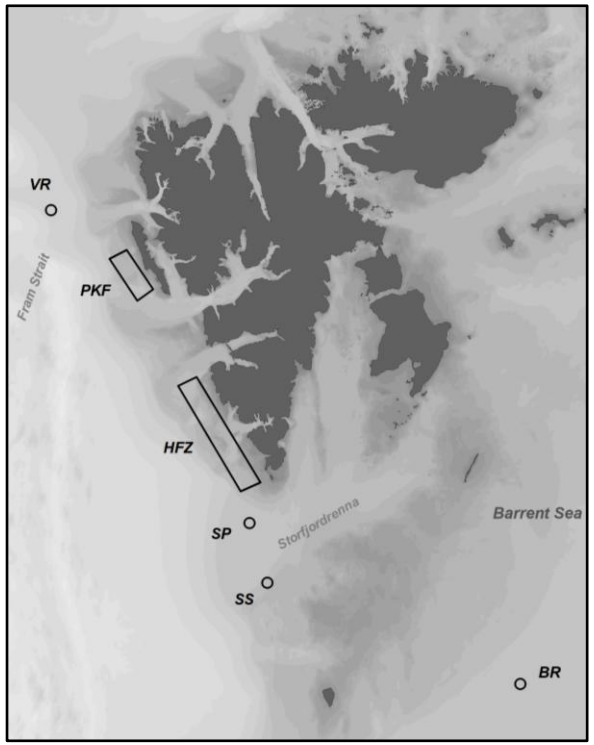




study area



hydrocarbon seeps position

Arctic Ocean waters receive CH_4 from:

the <u>seabed</u>:

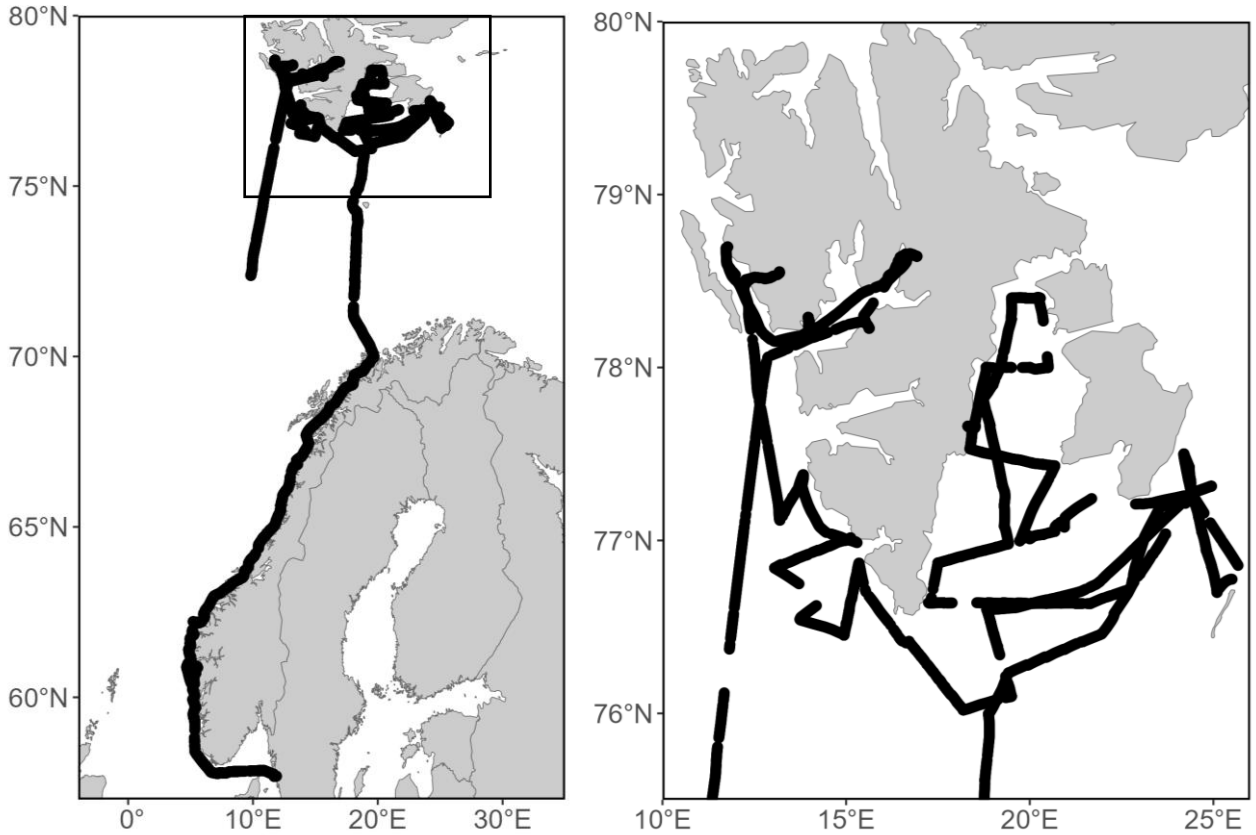
- geological sources (**gas hydrates** dissociation)
- gas reservoirs (**hydrocarbon seeps**)
- submarine **permafrost** degradation

the <u>surface waters</u>:

- **biological production**
- **riverine inputs**
- **brine rejection** (sea ice growth)

→ could reaches the surface water and the atm. (**HIGH rate of CH_4** + **shallow water columns**)

Objectives: study area and measurements



- 26 days at sea (2-27 August 2024) – **R/V Skagerak** IV (Gothenburg University)
- Between Sweden, along the Norwegian coast and through the **<u>southern and west Svalbard</u>**

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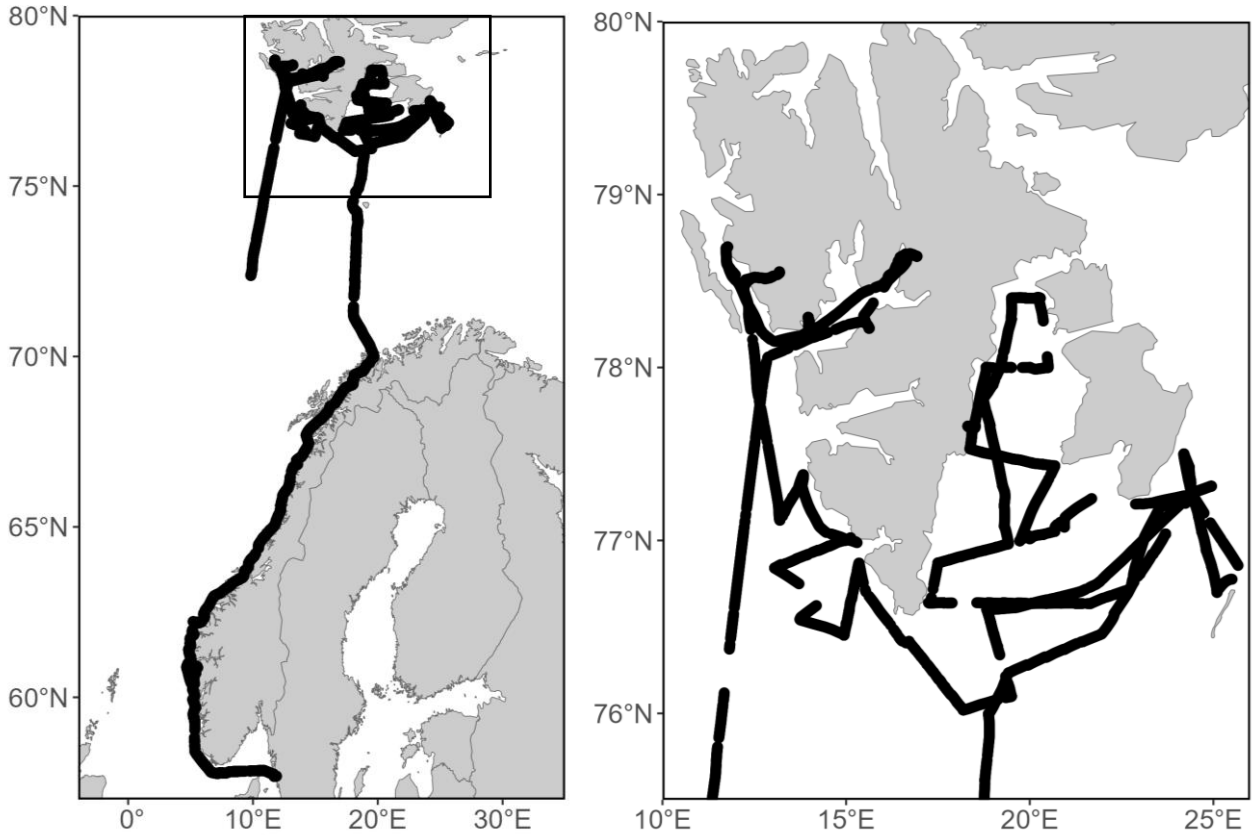

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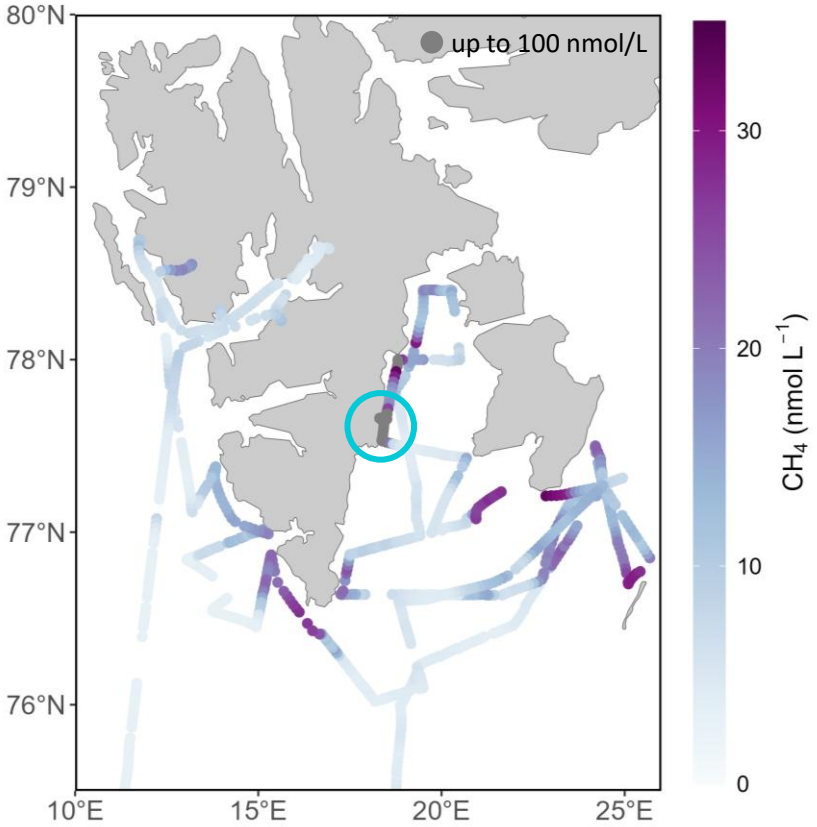
Continuous surface water measurement of CH_4 + Water column sampling

→ estimate **sea-air CH_4 fluxes** → identify seawater sources of **CH_4**

Results: Dissolved CH_4 in Svalbard seawater



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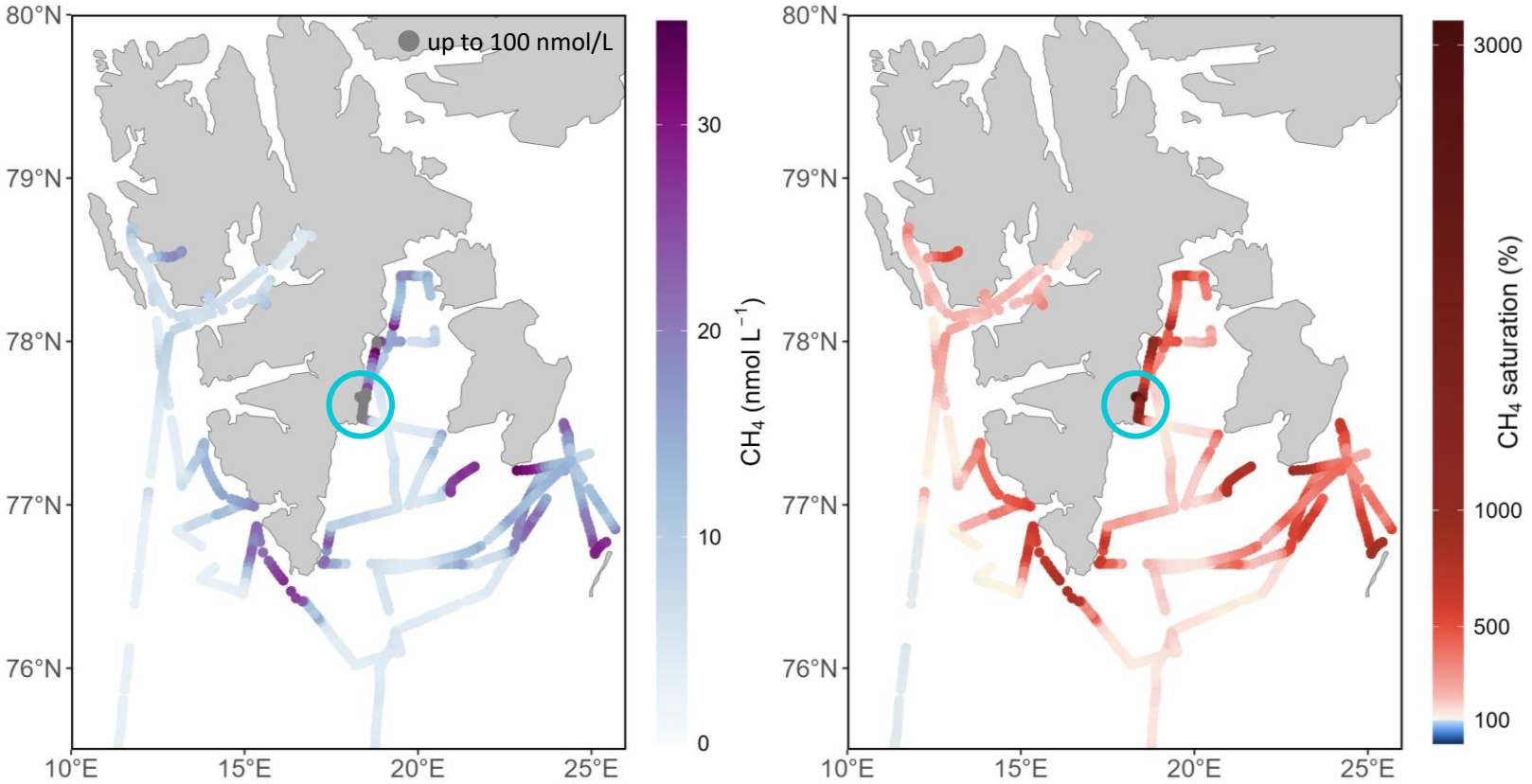

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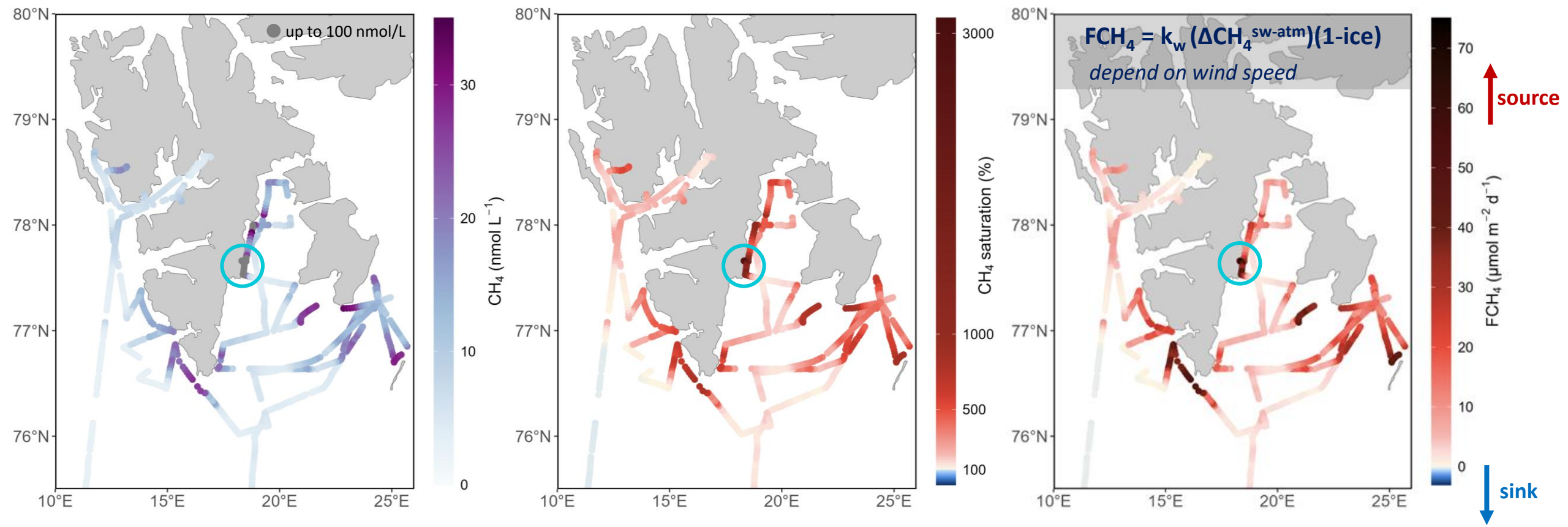

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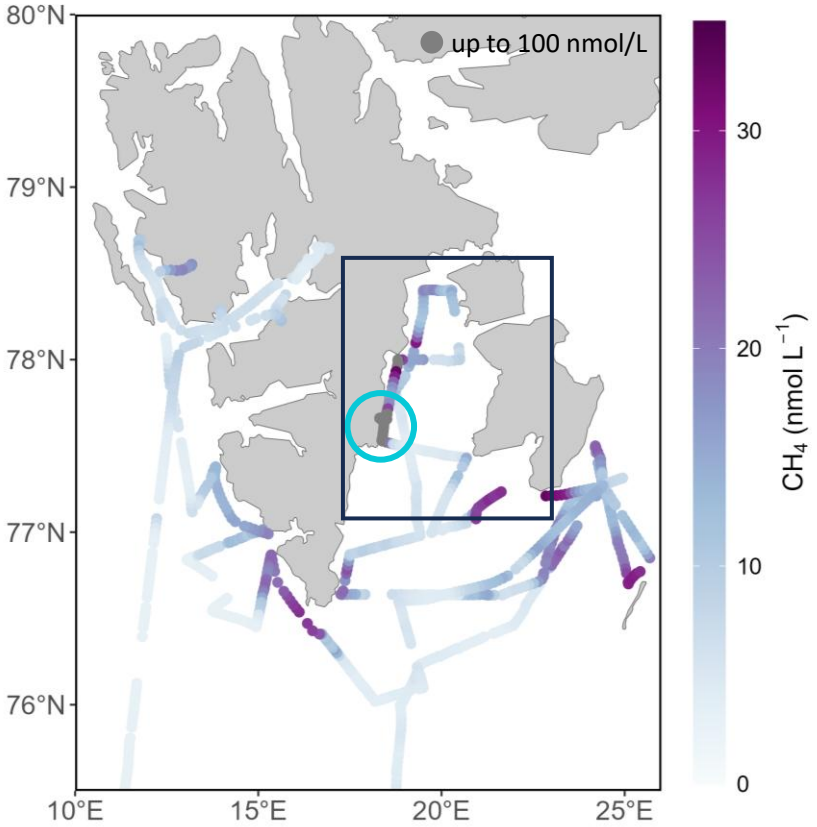
→ exceptionally **high CH_4 supersaturations** (**up to 3000 %**)

→ Important **source of CH_4 to the atm.** up to **70** µmol m^{-2} d^{-1} (global ocean close to equilibrium)

Results: Dissolved CH_4 in front of marine terminated glacier



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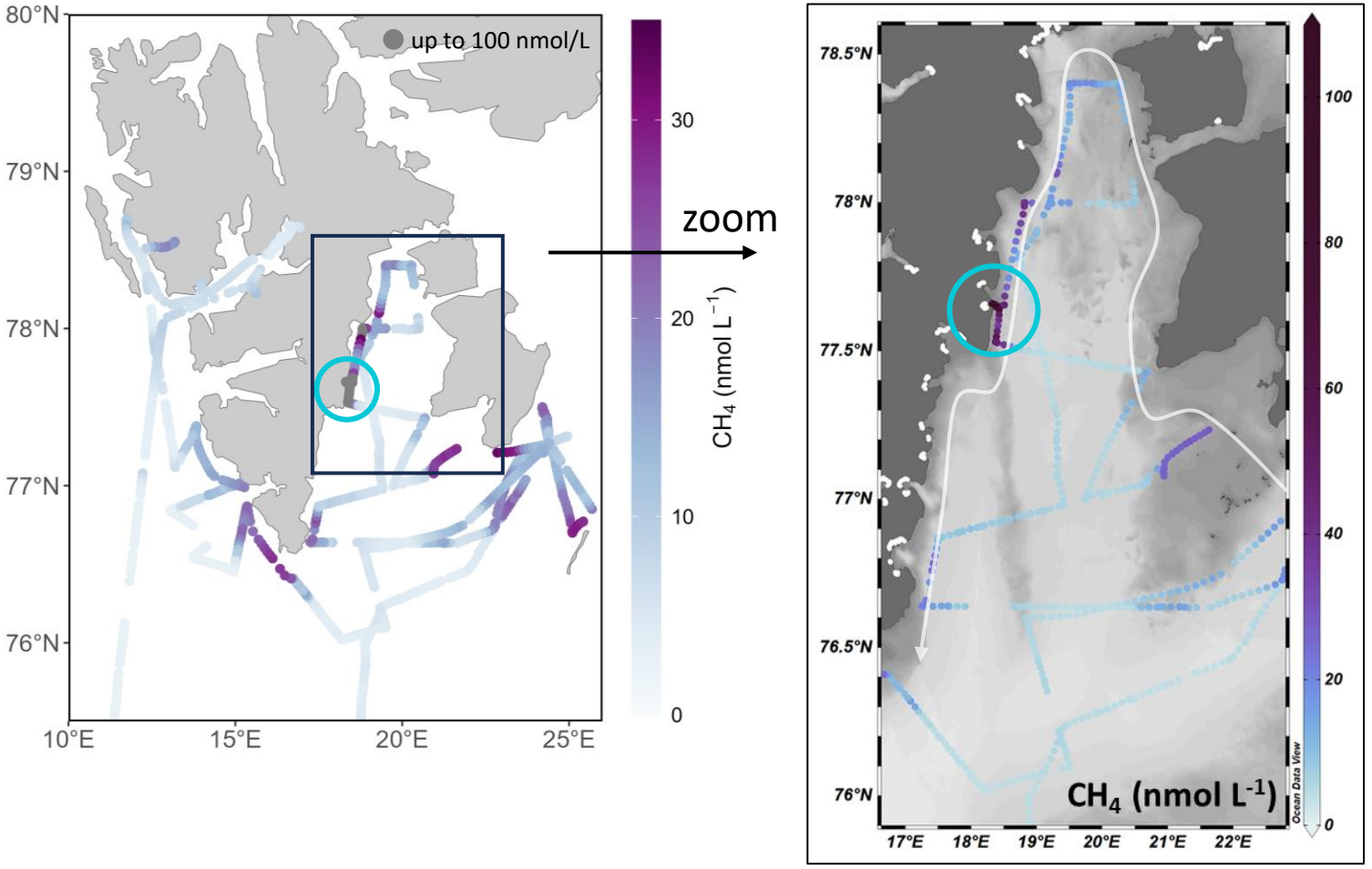

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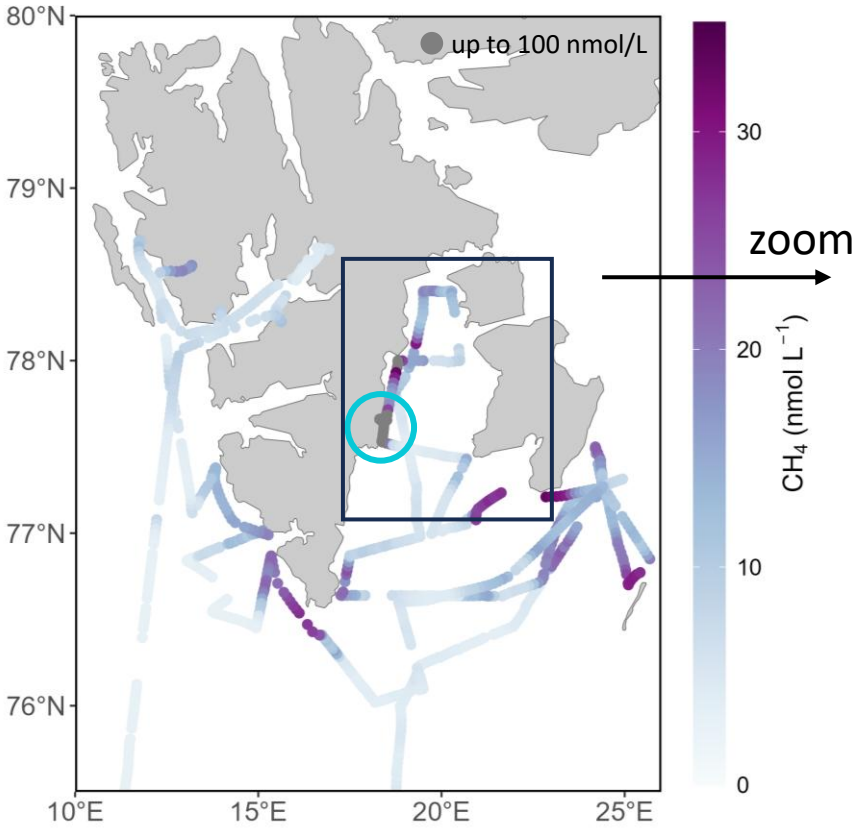

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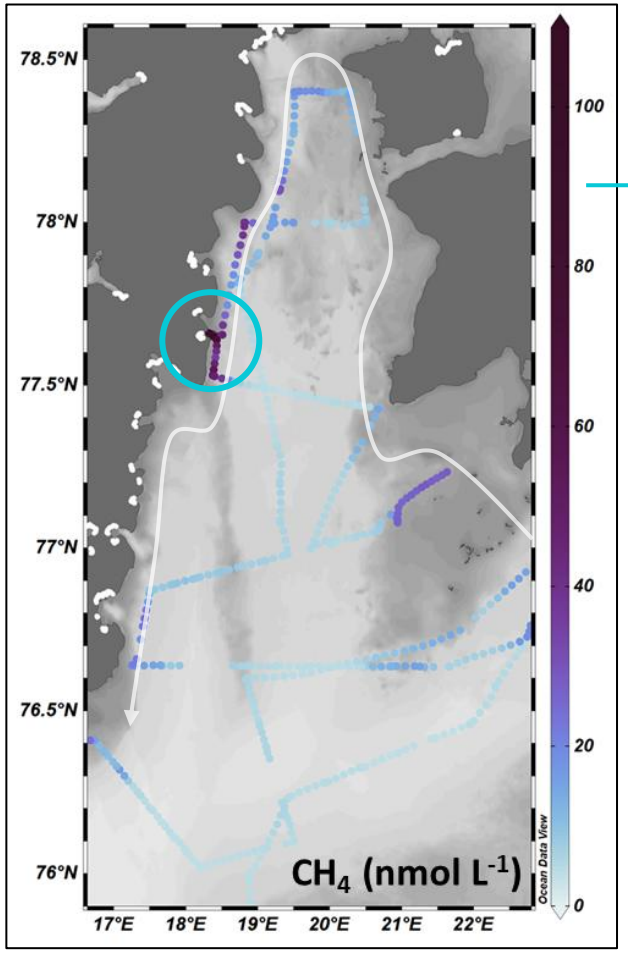

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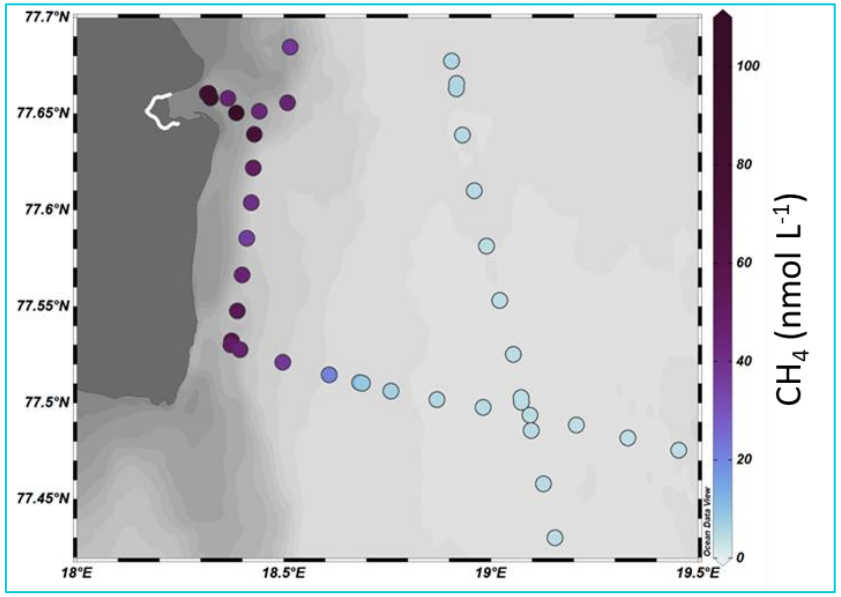

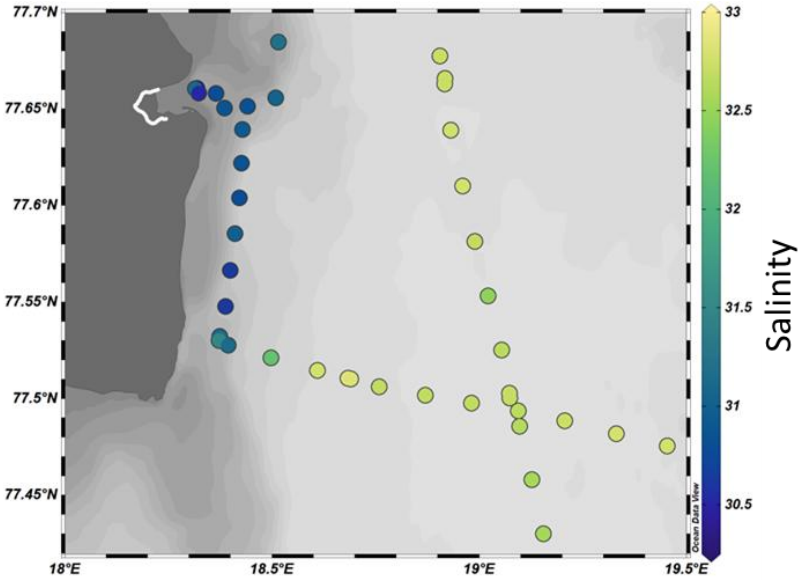

- High [CH_4] ⇝ the western Storfjorden cyclonic coastal current
- ⇝ low salinity

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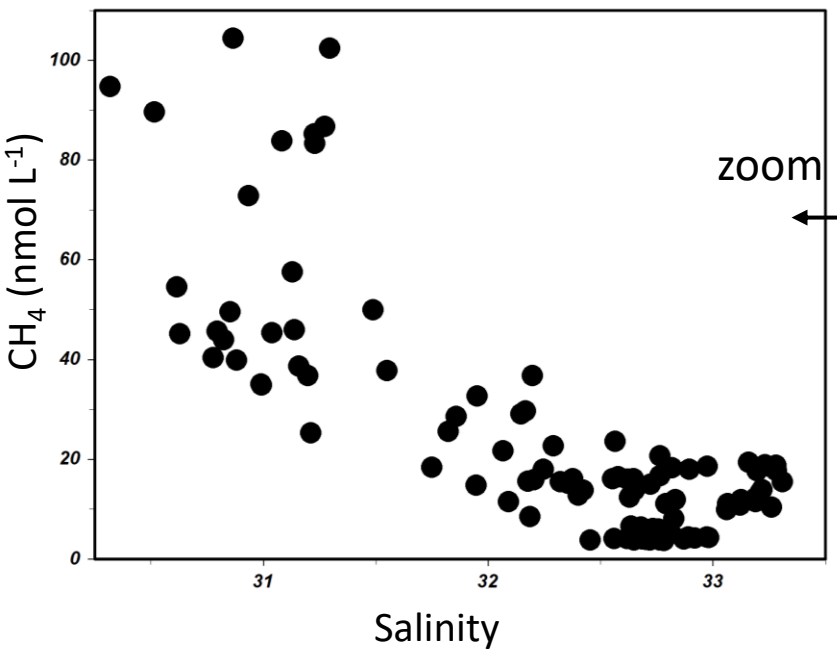

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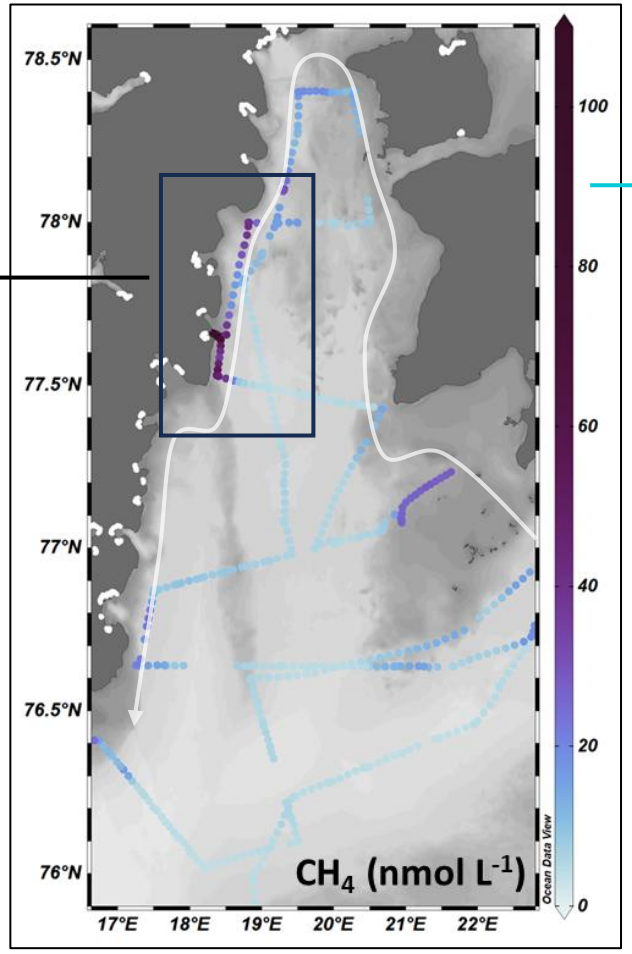

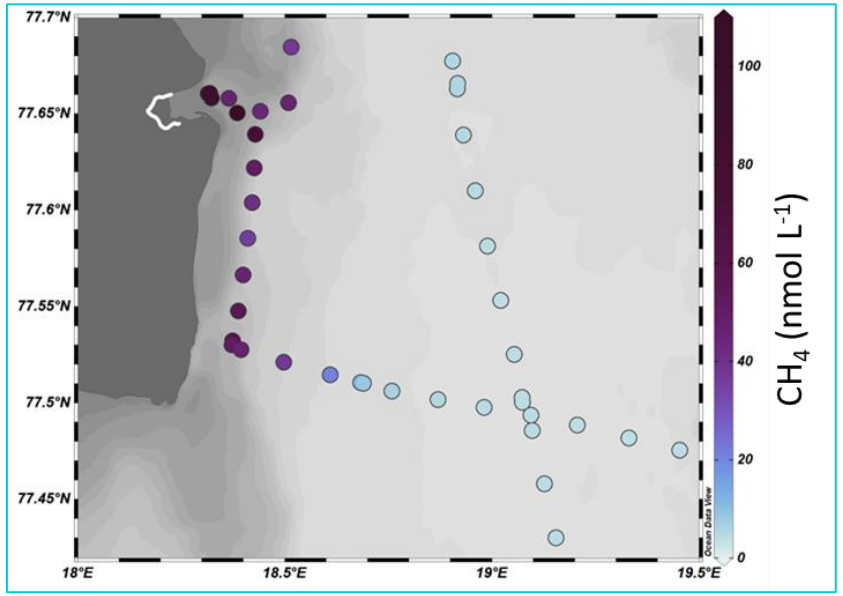

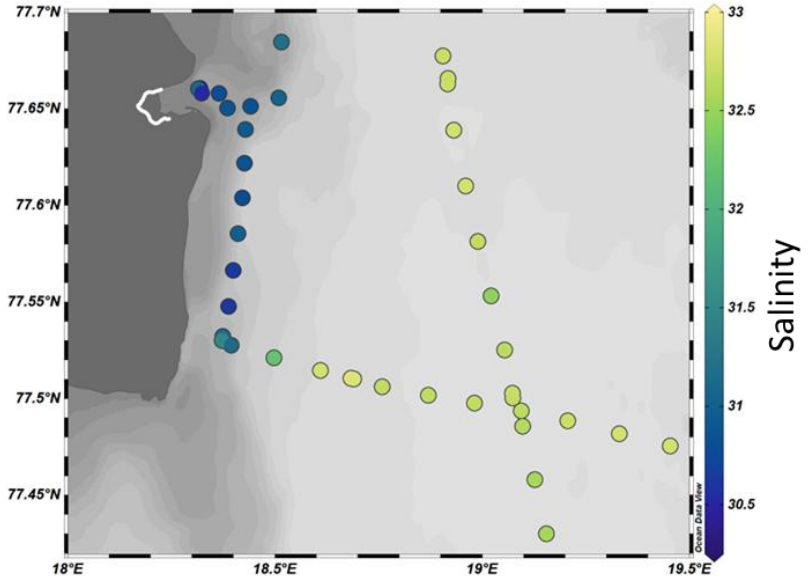

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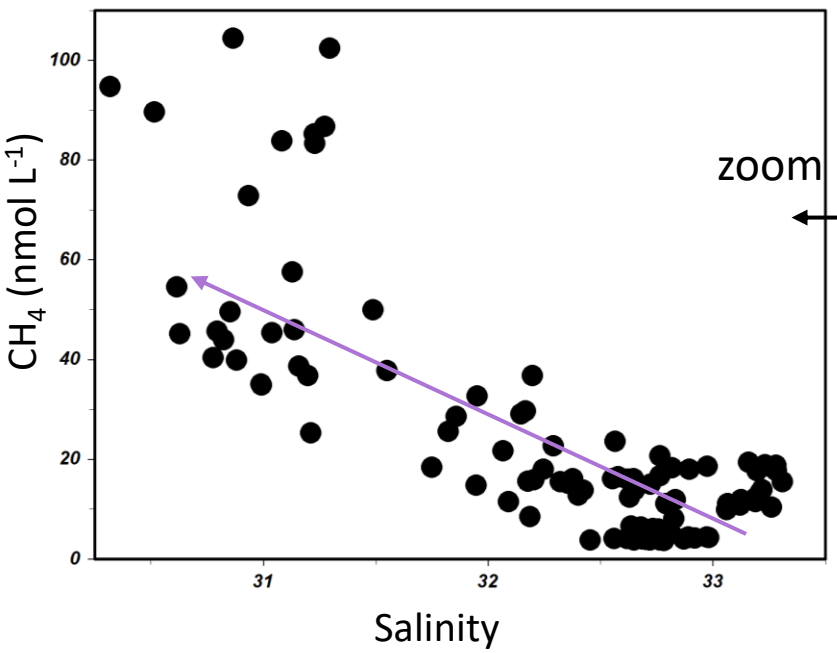

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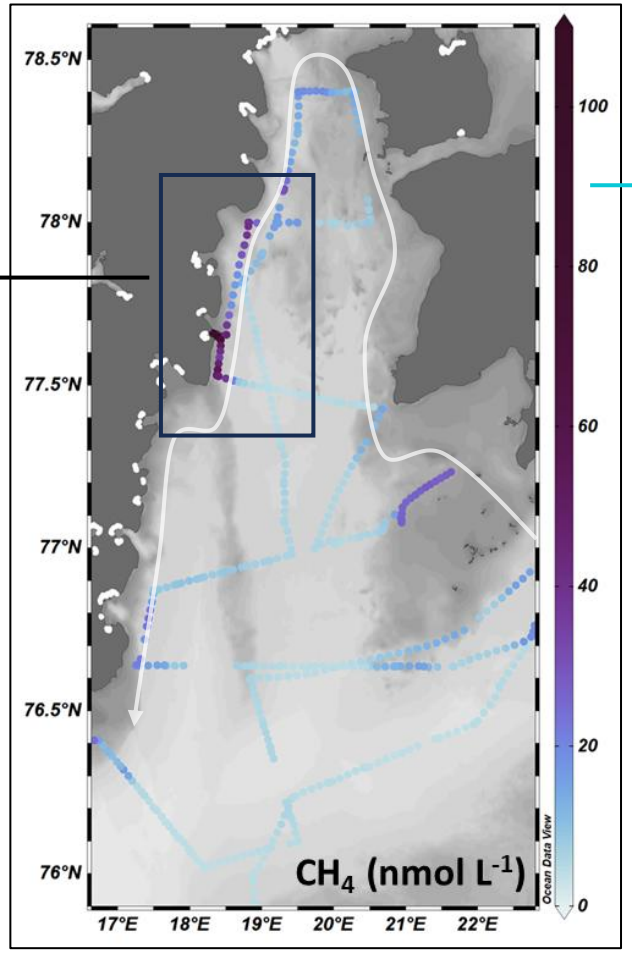

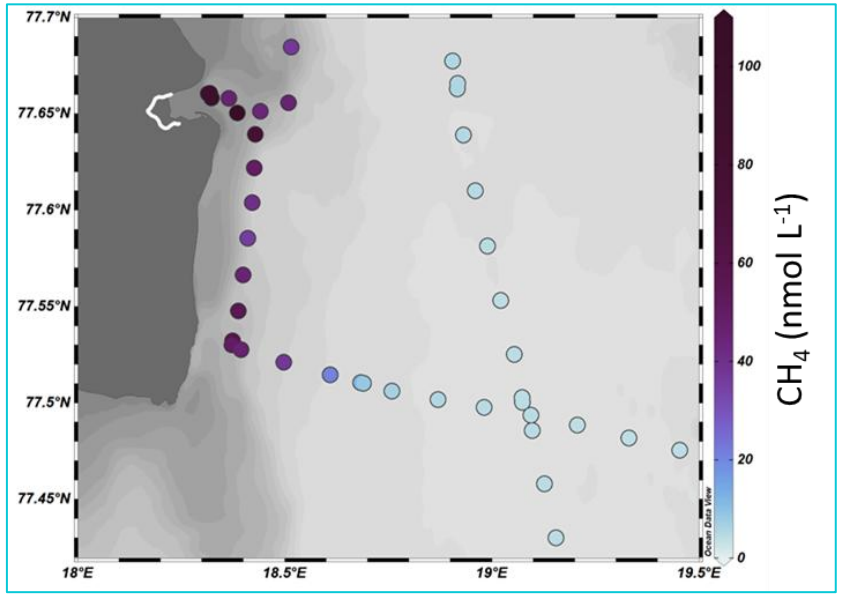

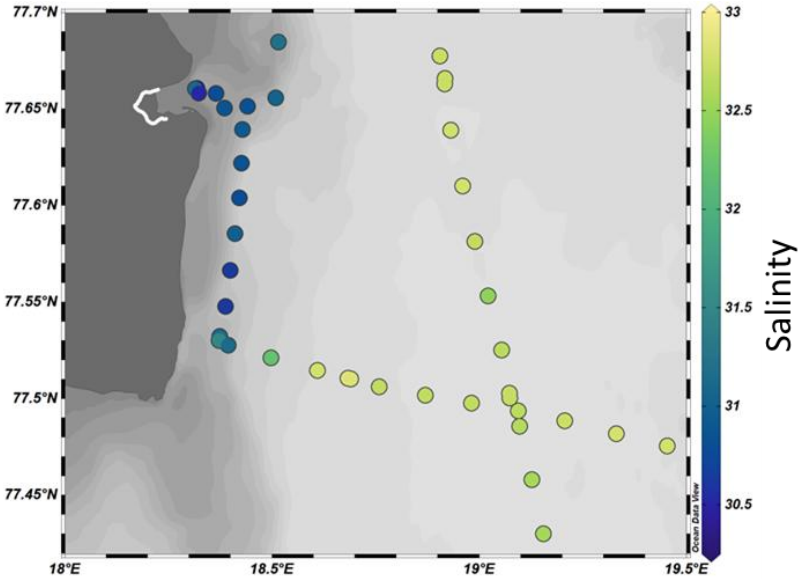

- High [CH_4] ⇝ the western Storfjorden cyclonic coastal current
  → **salinity gradient**

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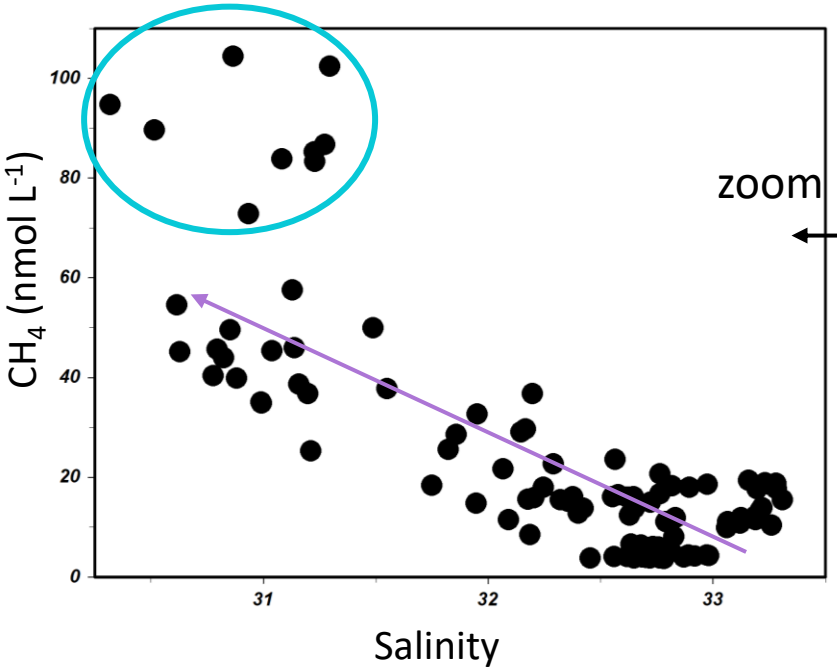
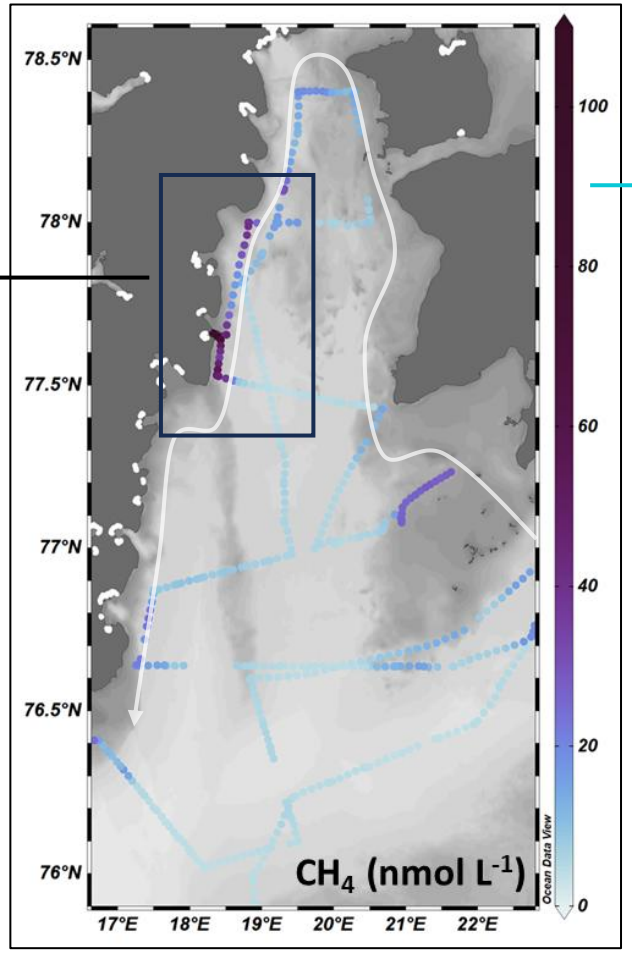
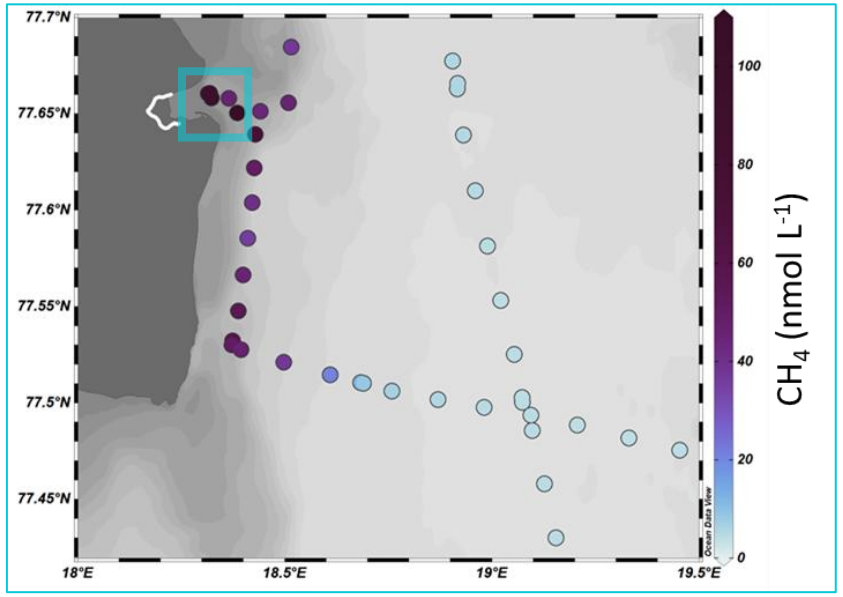
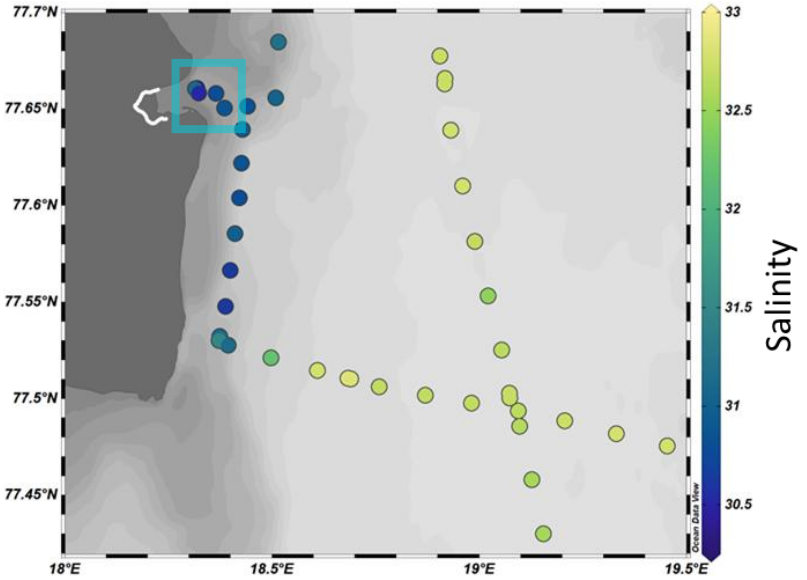




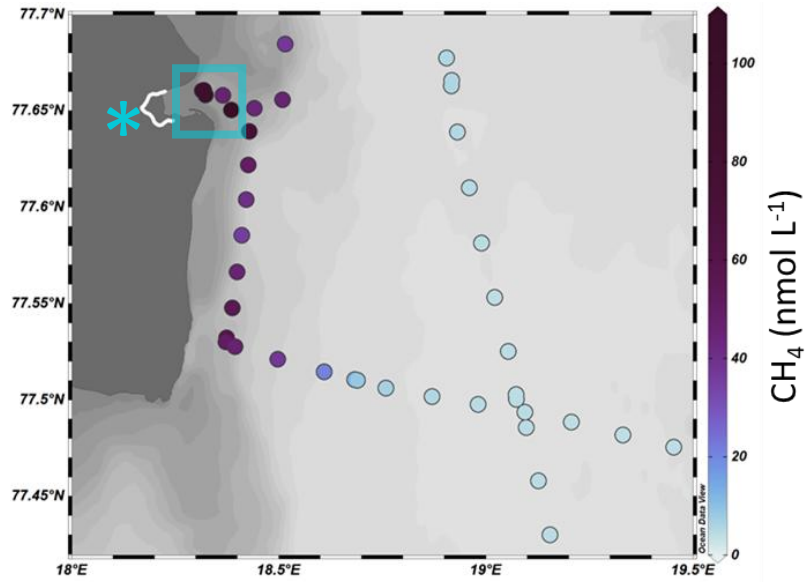


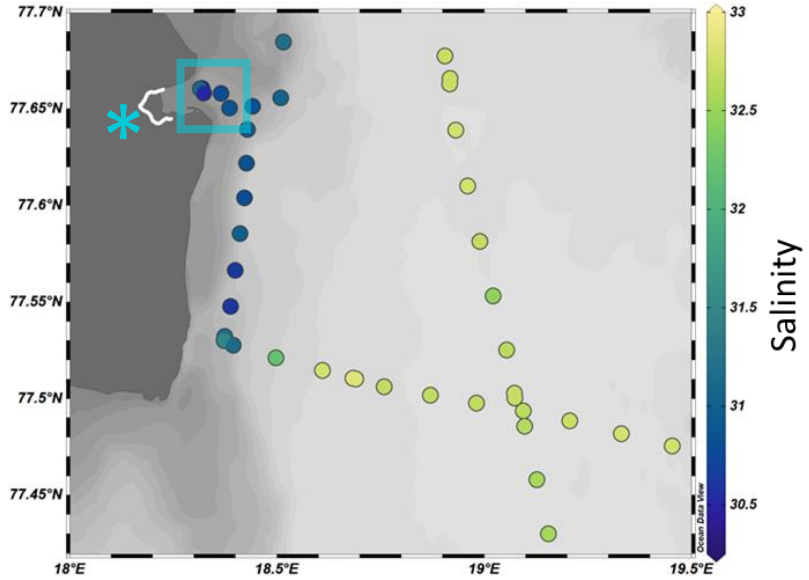


- High [CH_4] ⇝ the western Storfjorden cyclonic coastal current
  → **salinity gradient**
- With maximum **in front of the marine terminated glacier**

Results: Dissolved CH_4 in front of marine terminated glacier

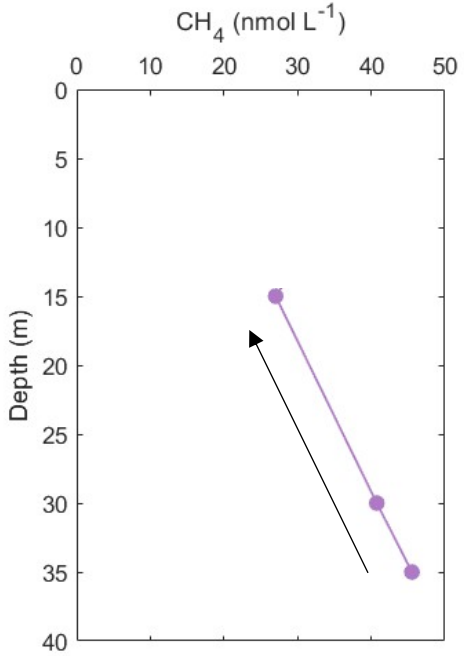
Where come from the CH_4?



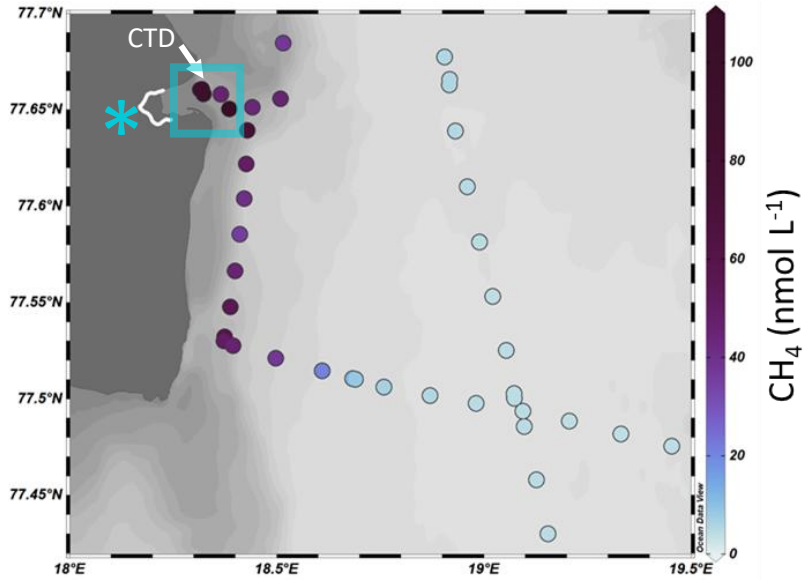


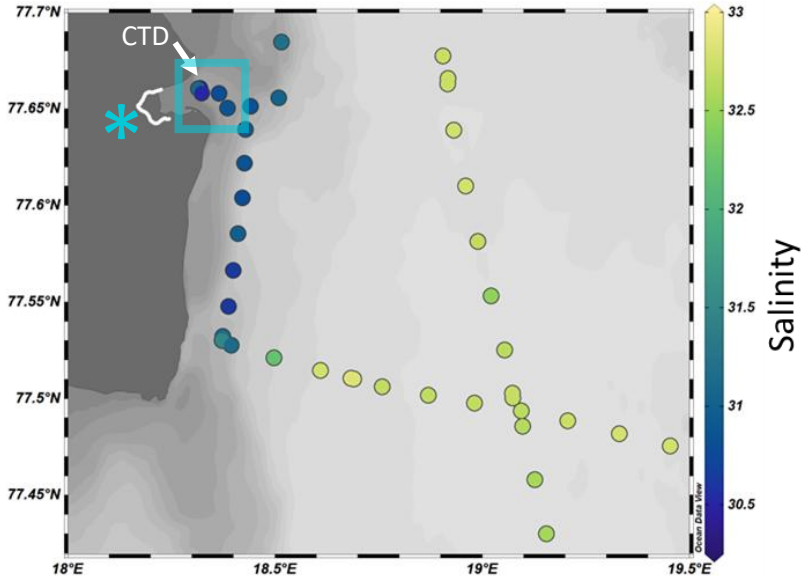
Results: Dissolved CH_4 in front of marine terminated glacier

Where come from the CH_4? **from the water column?**



- [CH_4] decrease "normally" from the bottom through the water column





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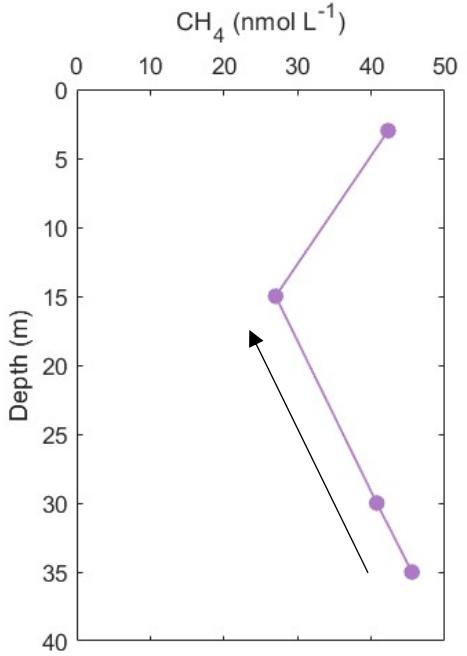

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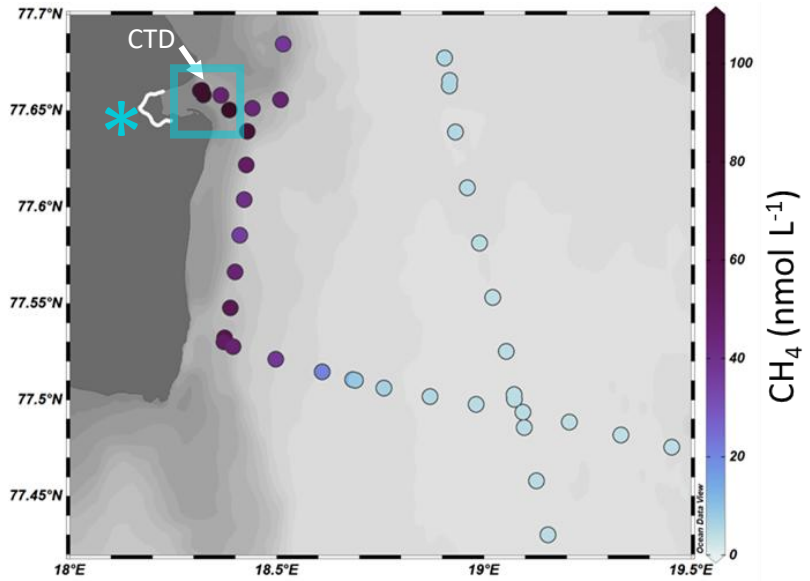

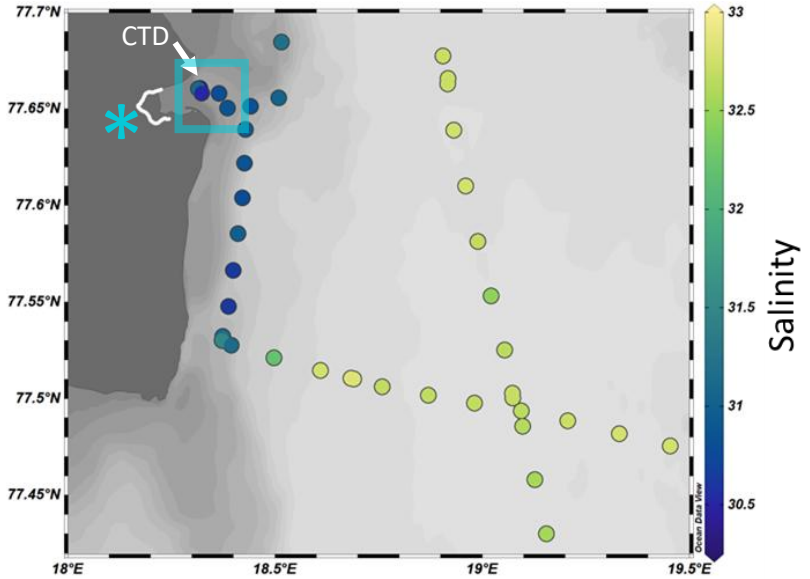

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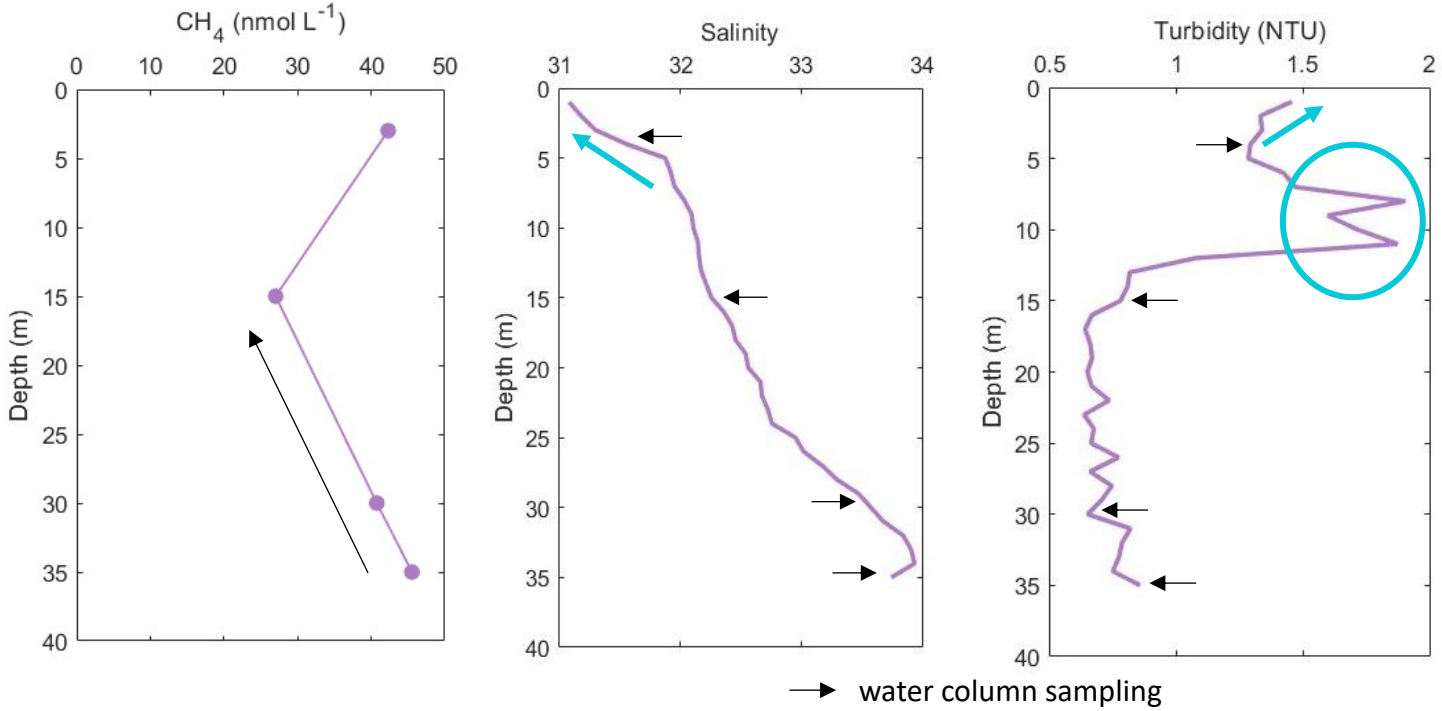

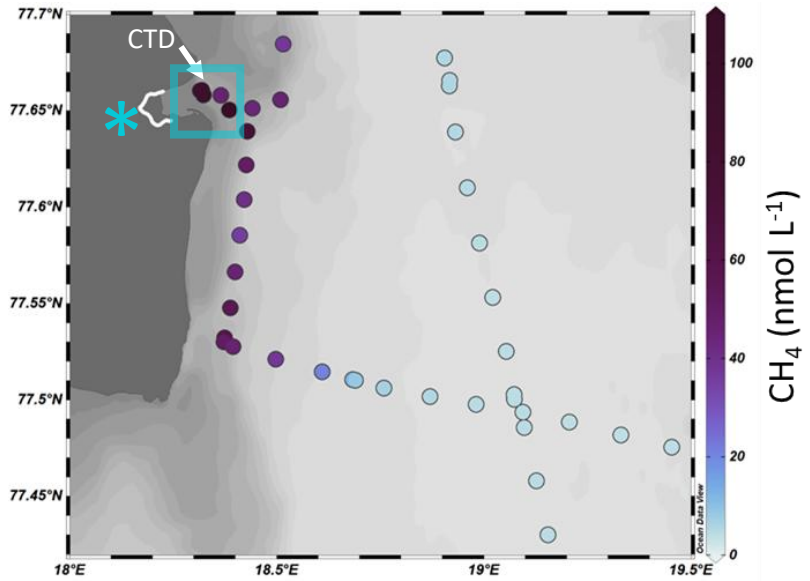

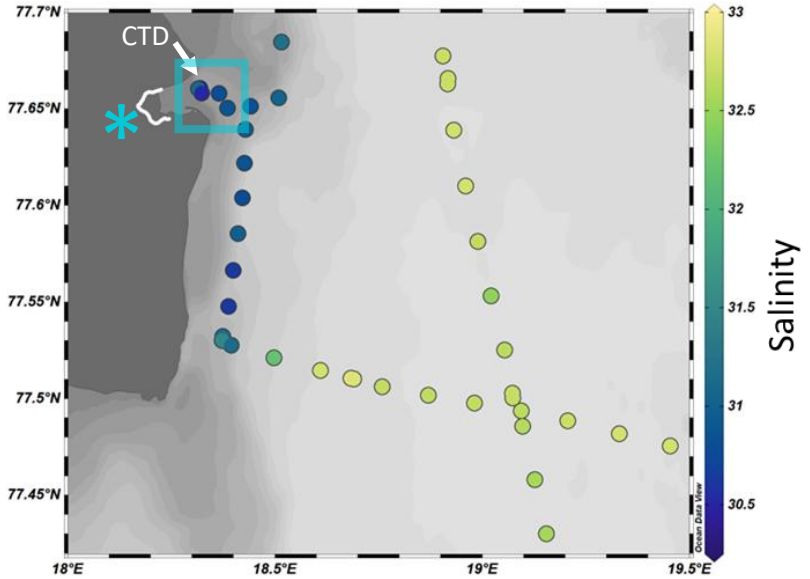

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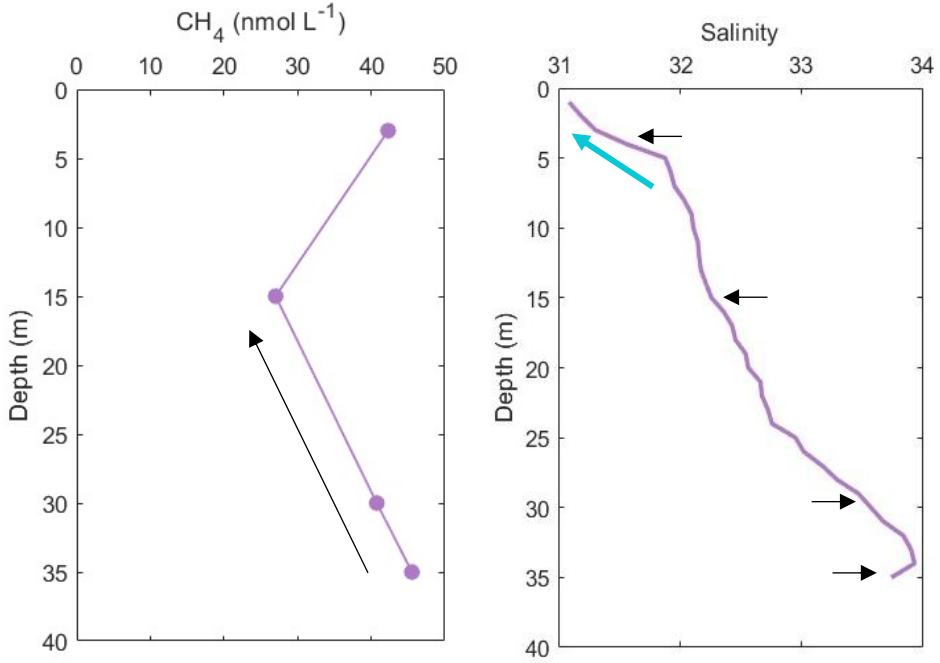
↝ **CH_4 from glacial meltwater?**

↘ salinity + ↗ turbidity

Results: Dissolved CH_4 in front of marine terminated glacier

Rothlisberger and Lang, 1987

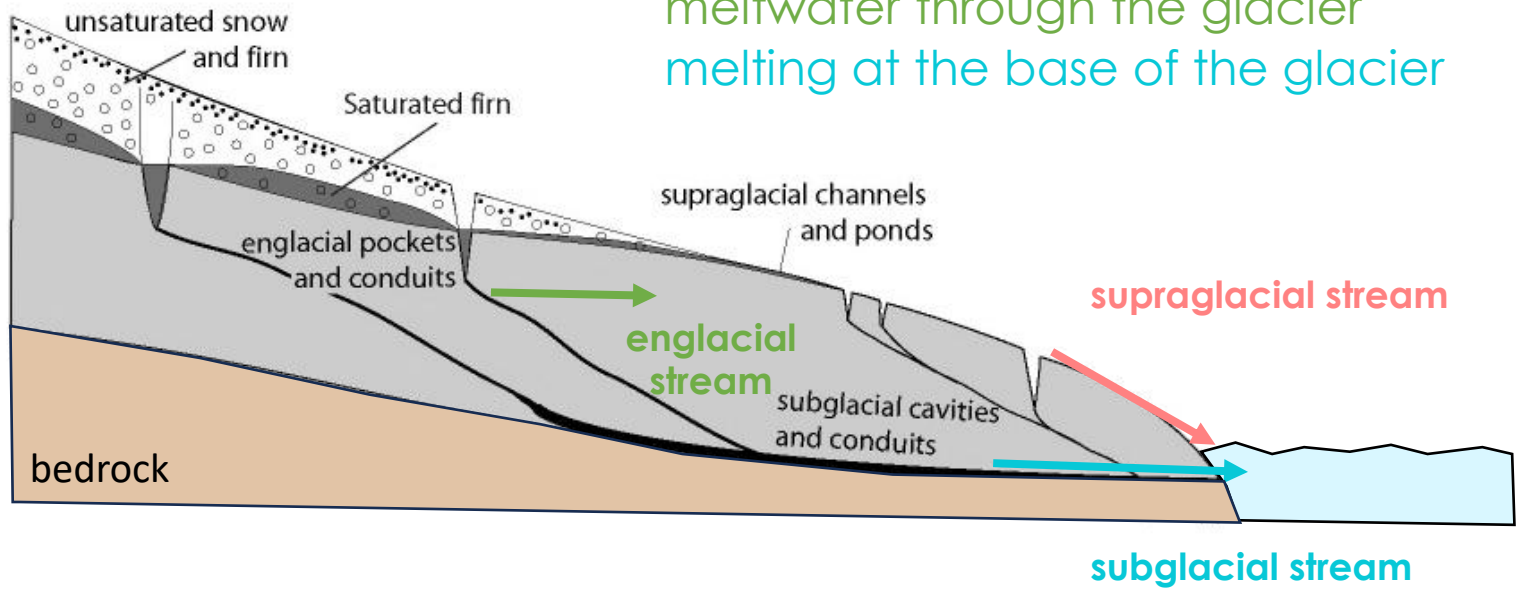
Where come from the CH_4? **from glacial stream?**



melting of the top of the glacier

meltwater through the glacier

melting at the base of the glacier



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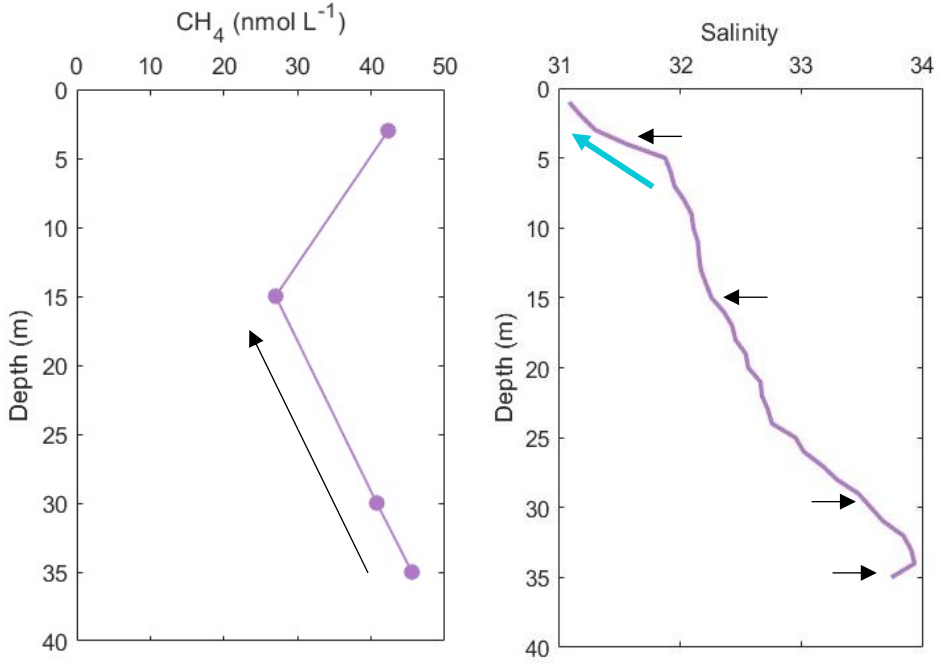

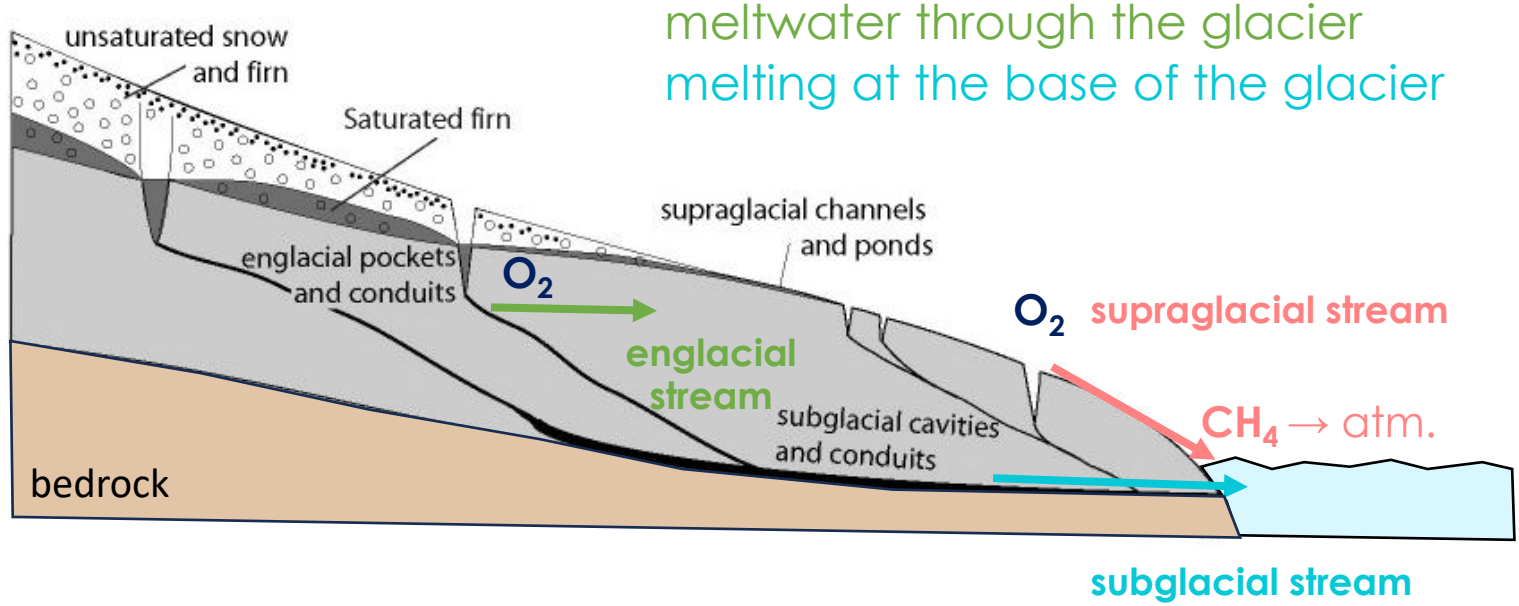

melting of the top of the glacier
meltwater through the glacier
melting at the base of the glacier

Freshwater stream from the glacier:

- **supraglacial** & **englacial** streams are in contact with atmosphere → ~~**CH_4 oversaturation**~~

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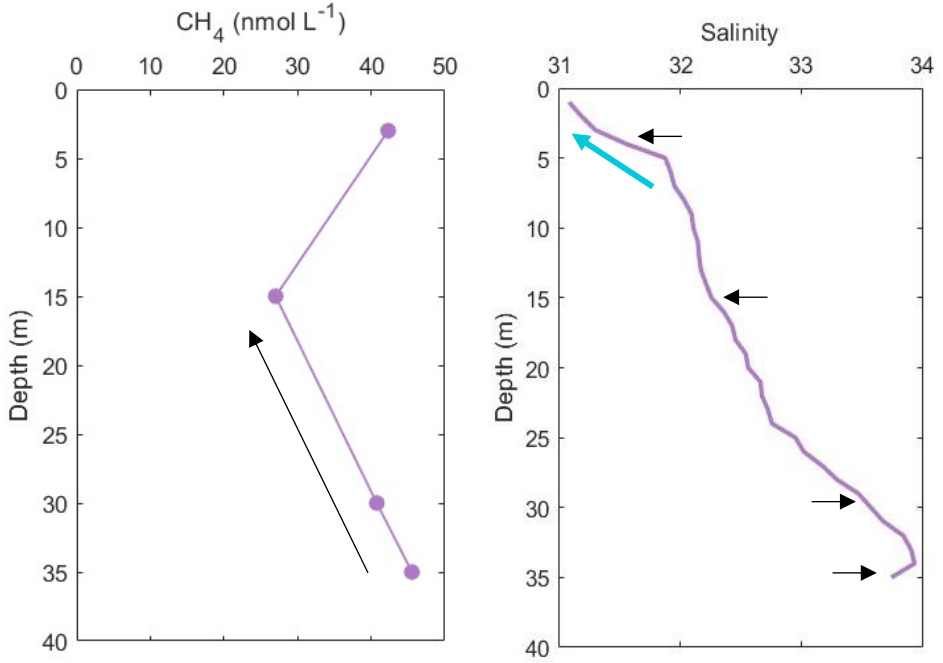
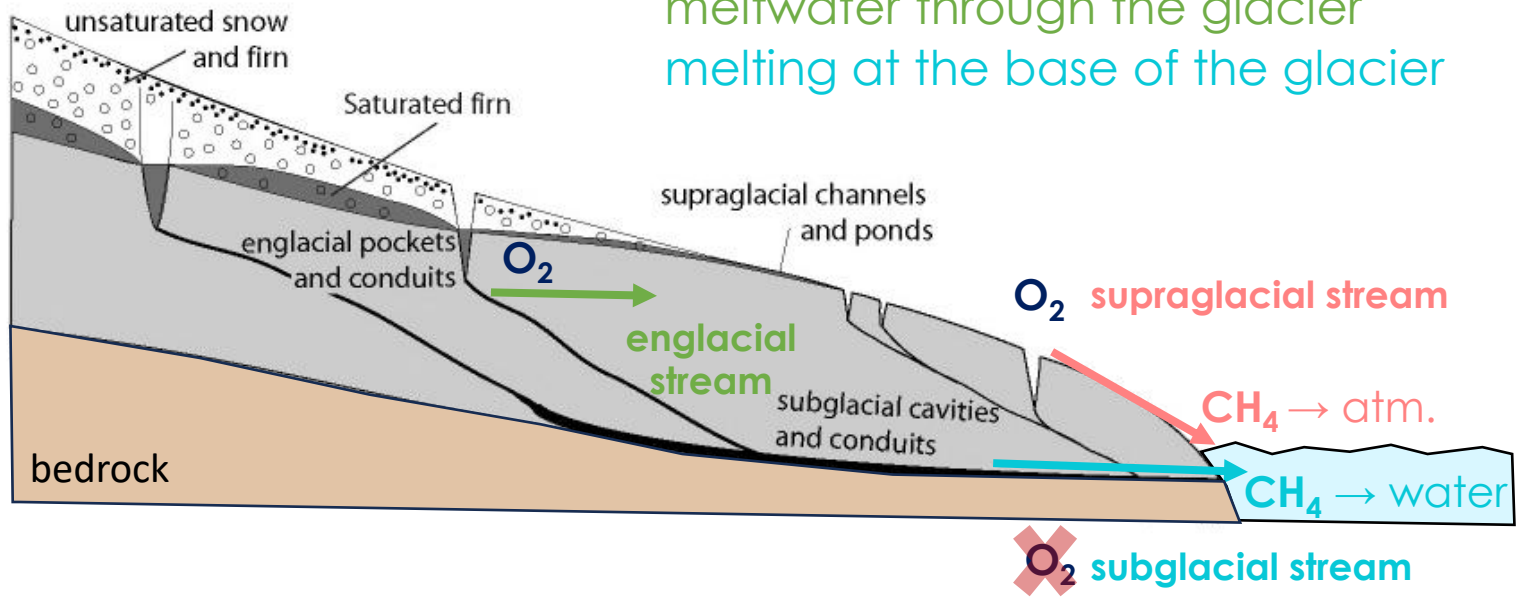
Rothlisberger and Lang, 1987

Where come from the CH_4? **from glacial stream?**



melting of the top of the glacier
meltwater through the glacier
melting at the base of the glacier



Freshwater stream from the glacier:

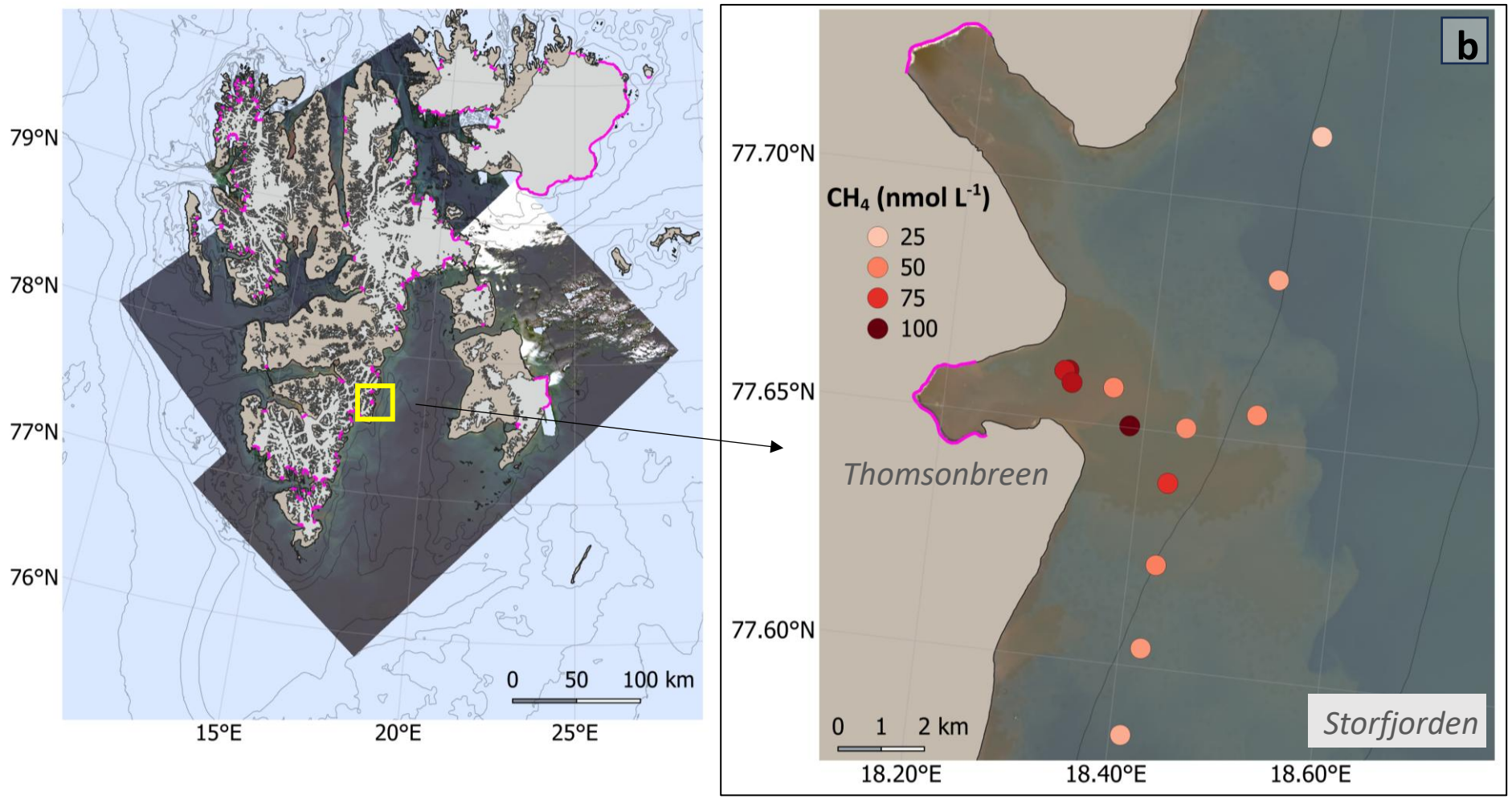
- **supraglacial** & **englacial** streams are in contact with atmosphere → ~~**CH_4 oversaturation**~~
- Only **subglacial stream** (at the base of the glacier – bedrock) → **CH_4 oversaturation**

can receive CH_4 from

- methane hydrate destabilization
- surface microbial process
- volcanic activity

Results: Dissolved CH_4 in front of marine terminated glacier

What is the impact of the **subglacial plume** on larger scales?



data sampling: 18/08/2024 – satellite image: 08/08/2024

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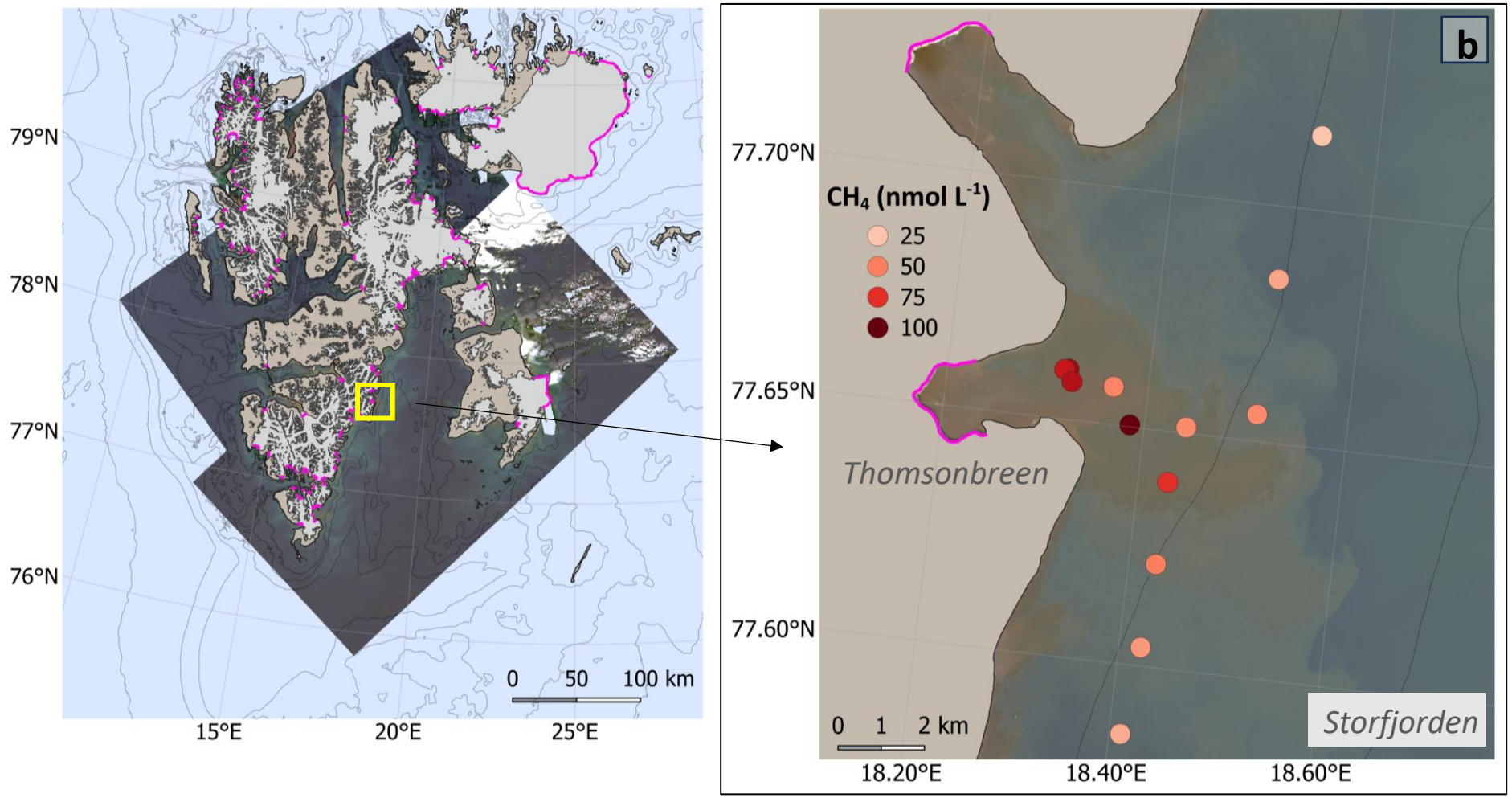
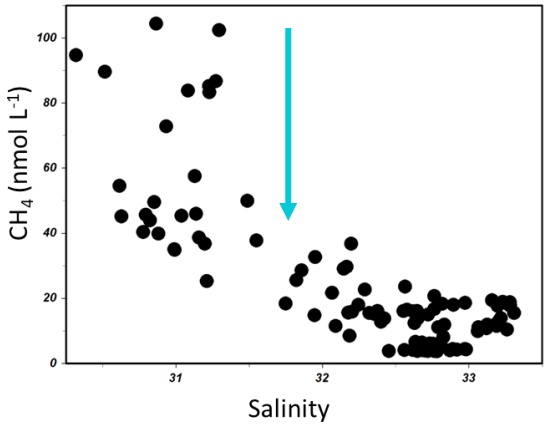


Glacial plume of **7.5 km²**

↓

"rapid" **CH_4 sink**



data sampling: 18/08/2024 – satellite image: 08/08/2024

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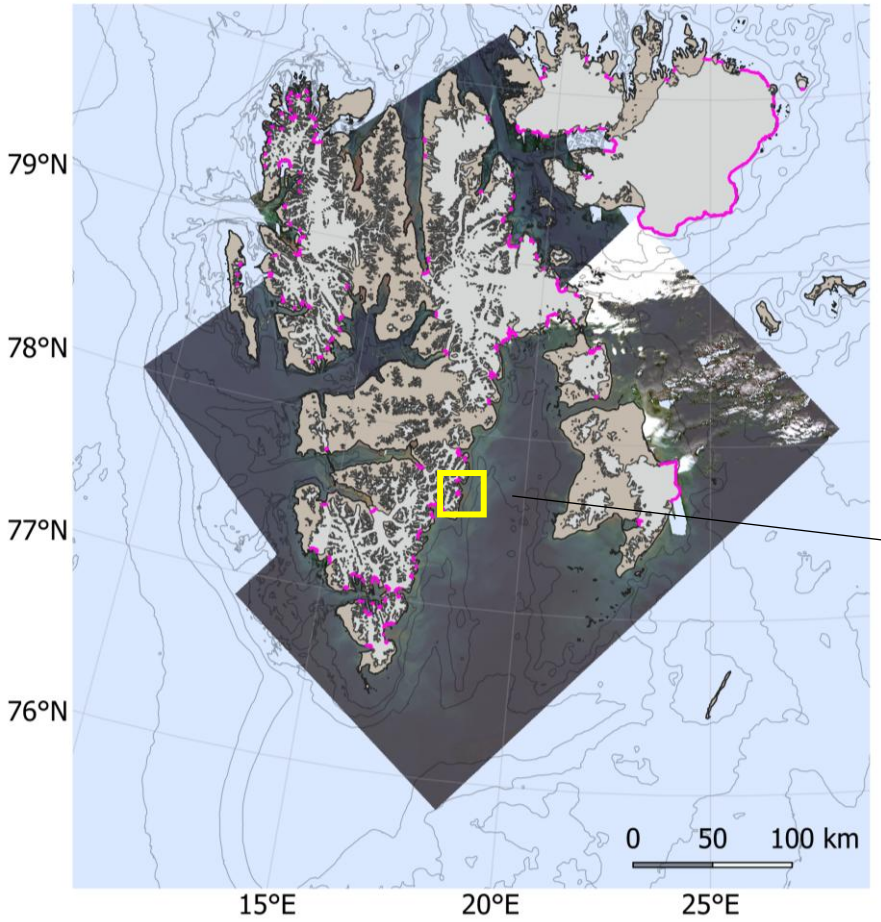
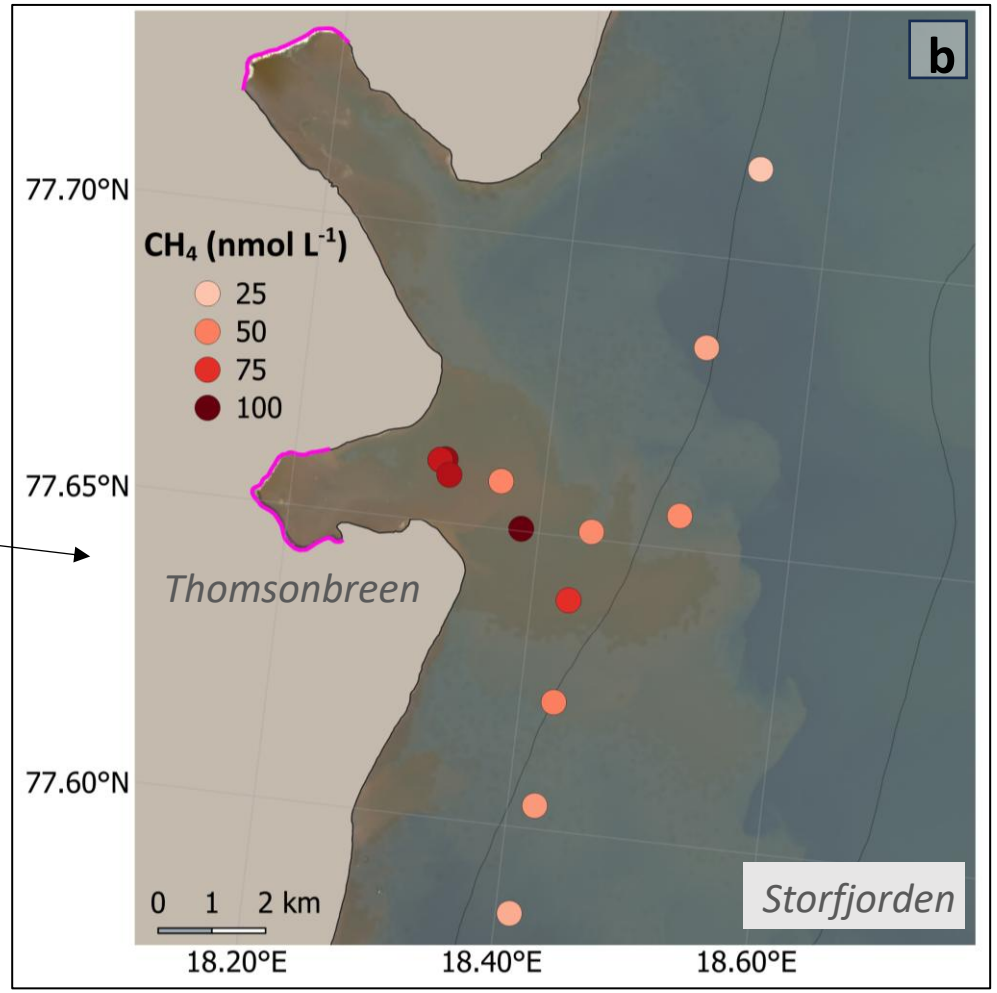




Glacial plume of **7.5 km²**

↓

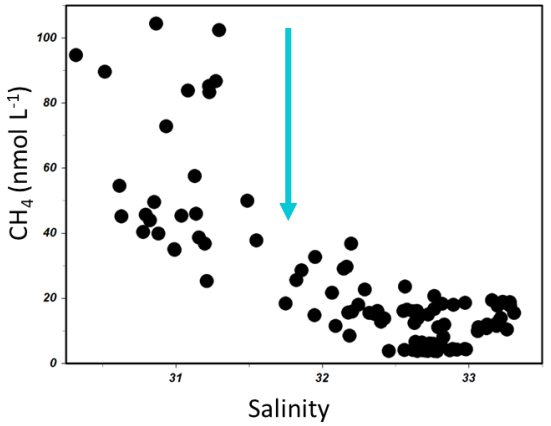
"rapid" **CH_4 sink**

↓

- **Aerobic oxidation** (MOx)

  $CH_4 + 2\ O_2 \rightarrow CO_2 + H_2O$

- **Atmospheric**



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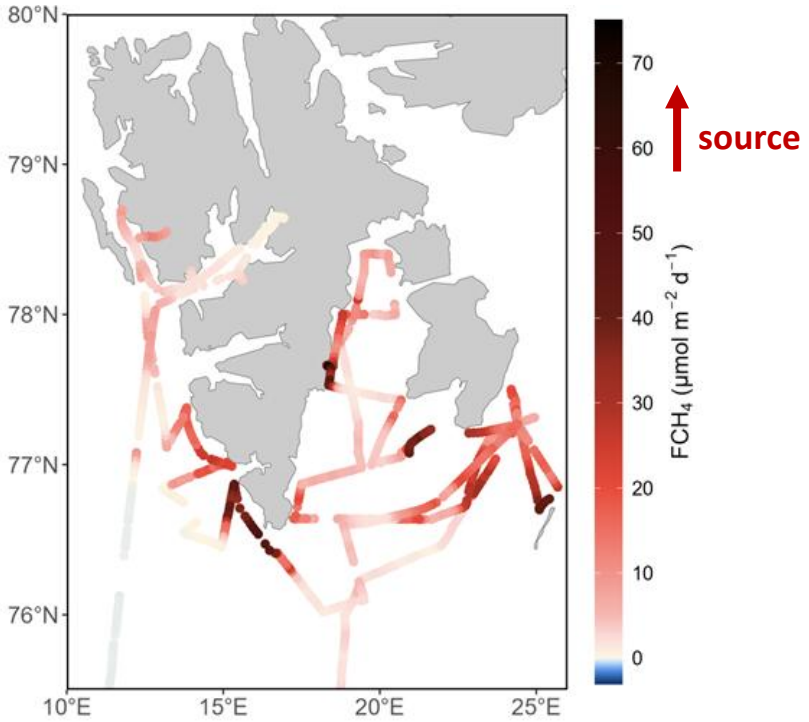
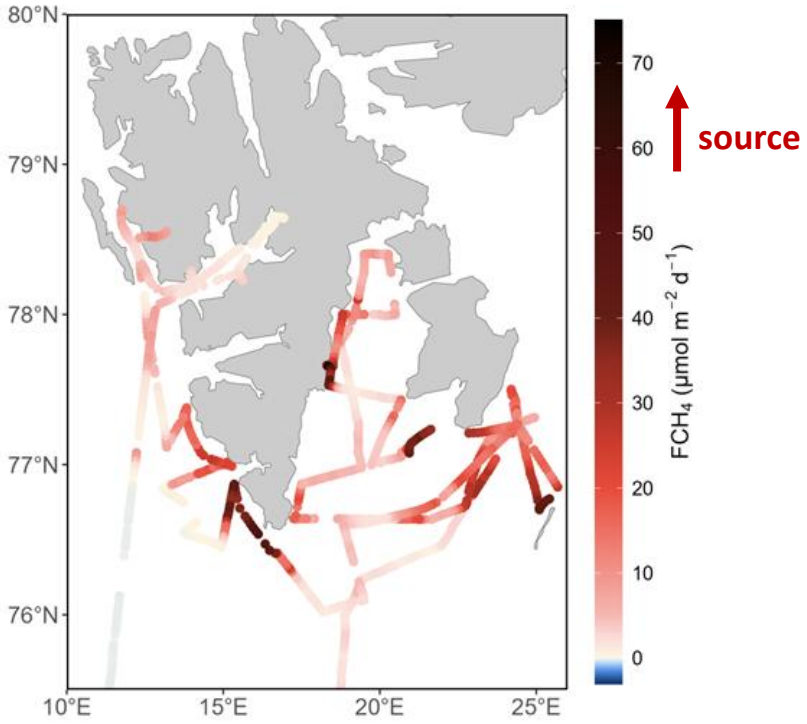
Take Home Message



→ **Svalbard surface waters** are a significant **source of CH_4** to the atmosphere during summer 2024

- **up to 70 µmol m^{-2} d^{-1}** (global ocean: close to equilibrium)

Take Home Message



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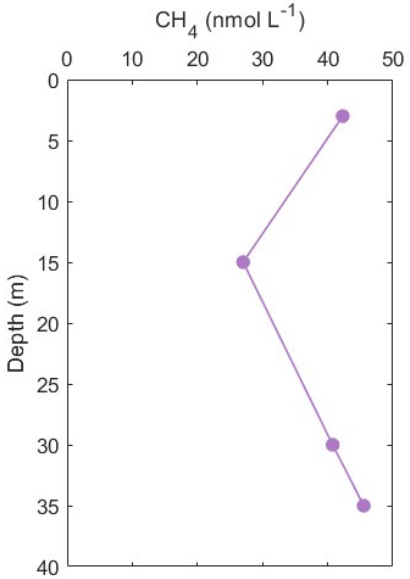
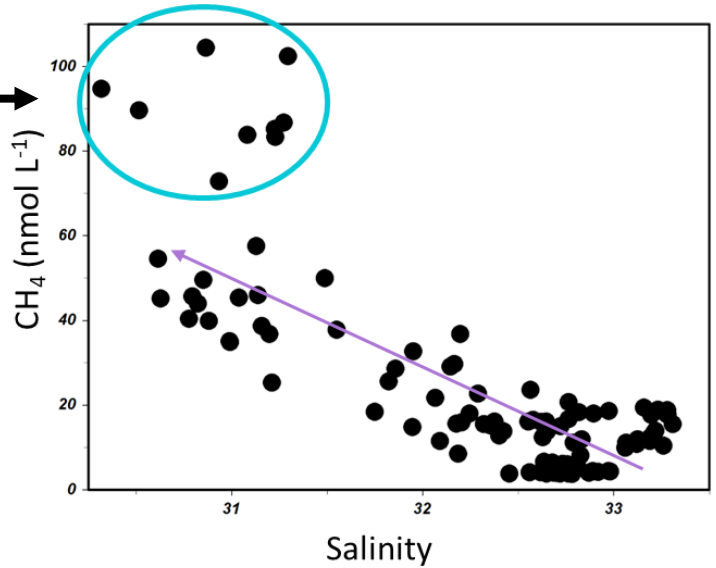
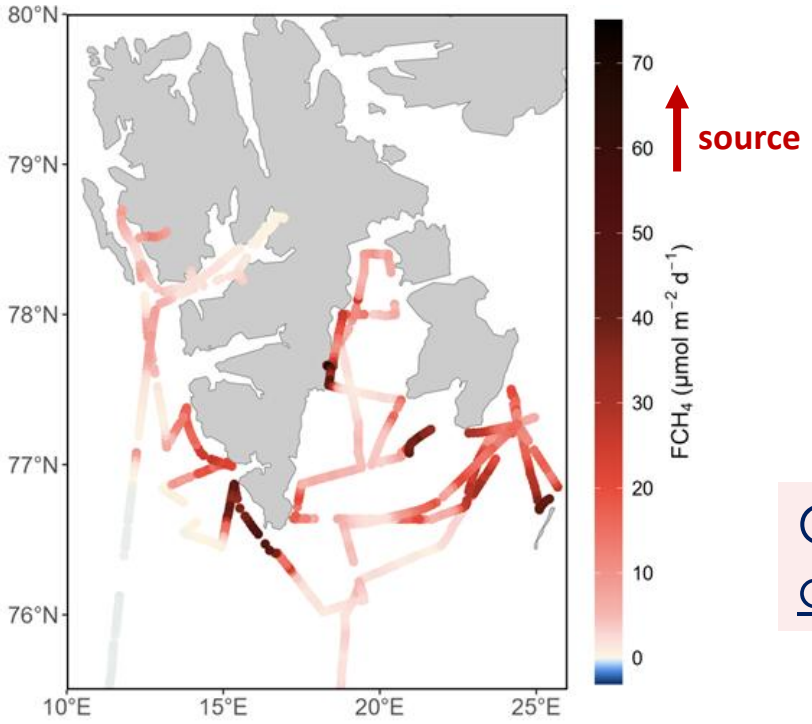
- **subglacial meltwater input?**
- 'rapid' sink of CH_4 after < 10 km





Take Home Message



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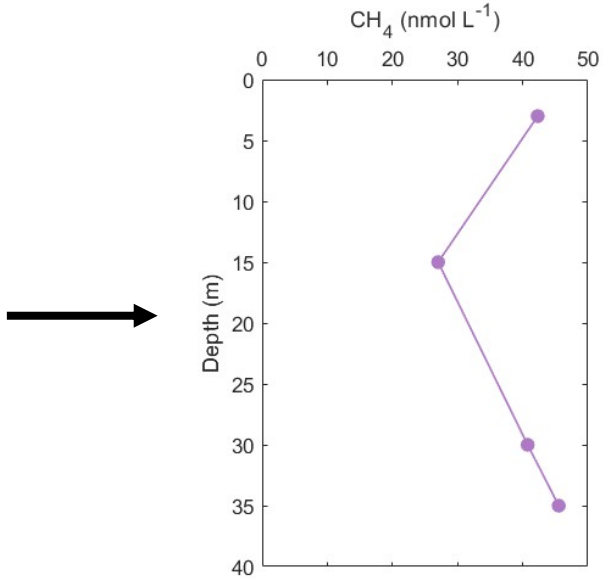
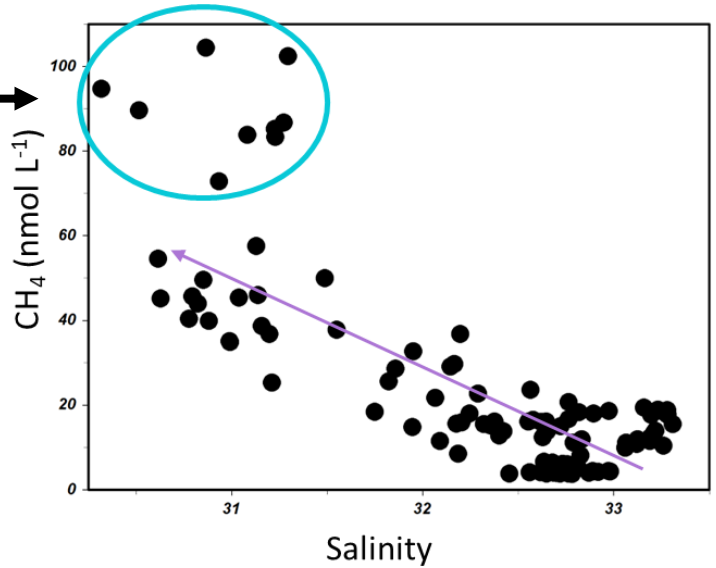
Could the **local source of CH_4** have a long-term effect on climate change?





Svalbard seawaters as a significant source of CH_4 to the atmosphere during summer 2024

Coraline Leseurre[1]

Bruno Delille[2], Hannelore Theetaert[1], Michiel T'Jampens[1], Ozan Efe[2], and Thanos Gkritzalis[1]