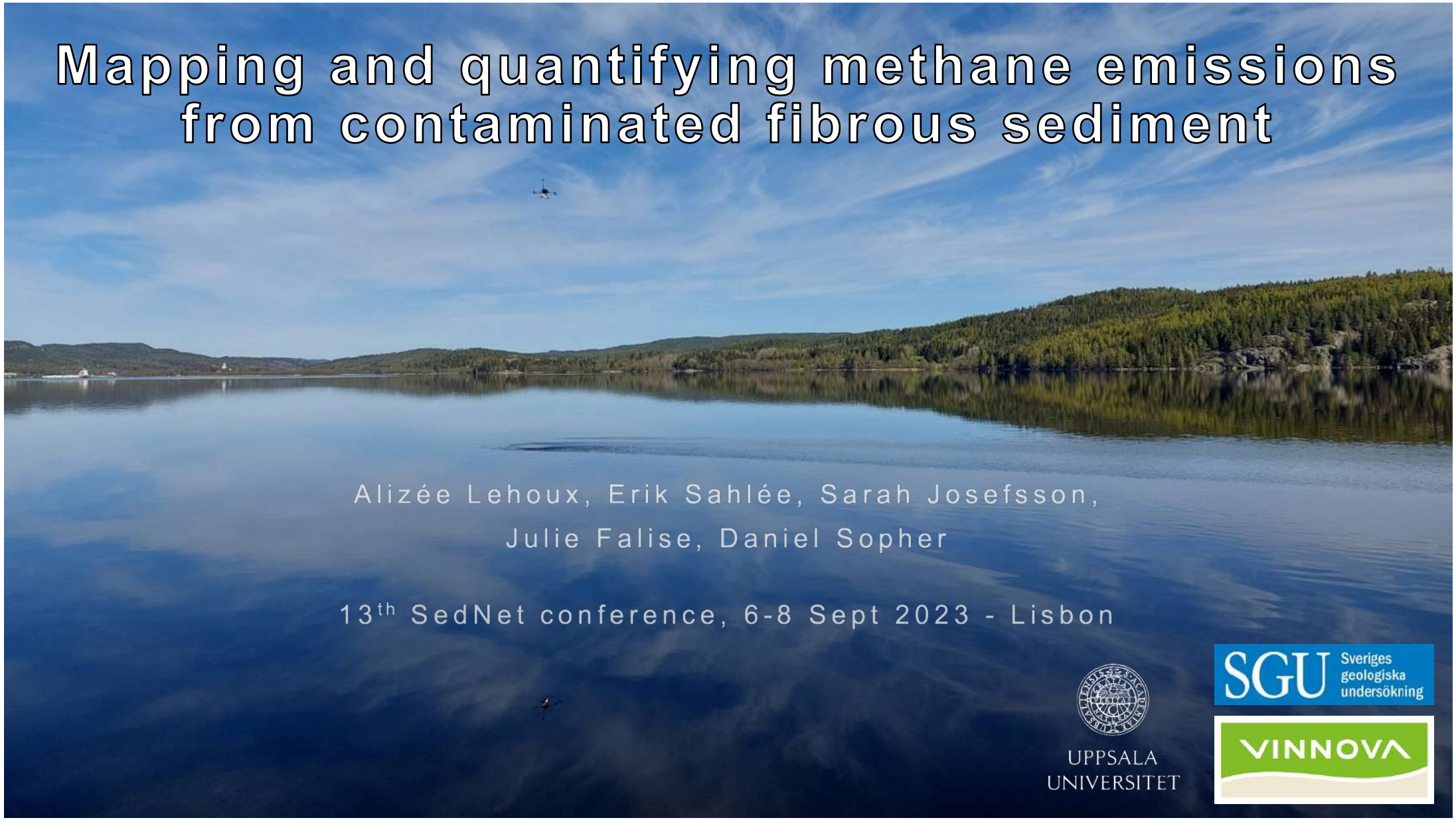
Mapping and quantifying methane emissions from contaminated fibrous sediment



Alizée Lehoux, Erik Sahlée, Sarah Josefsson,
Julie Falise, Daniel Sopher

13th SedNet conference, 6-8 Sept 2023 - Lisbon

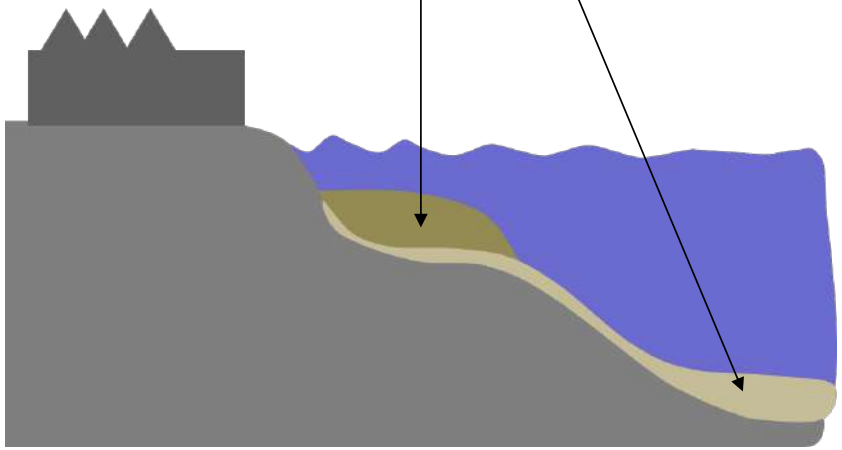
UPPSALA UNIVERSITET

SGU Sveriges geologiska undersökning

VINNOVA

Fibrous sediments in the aquatic environment

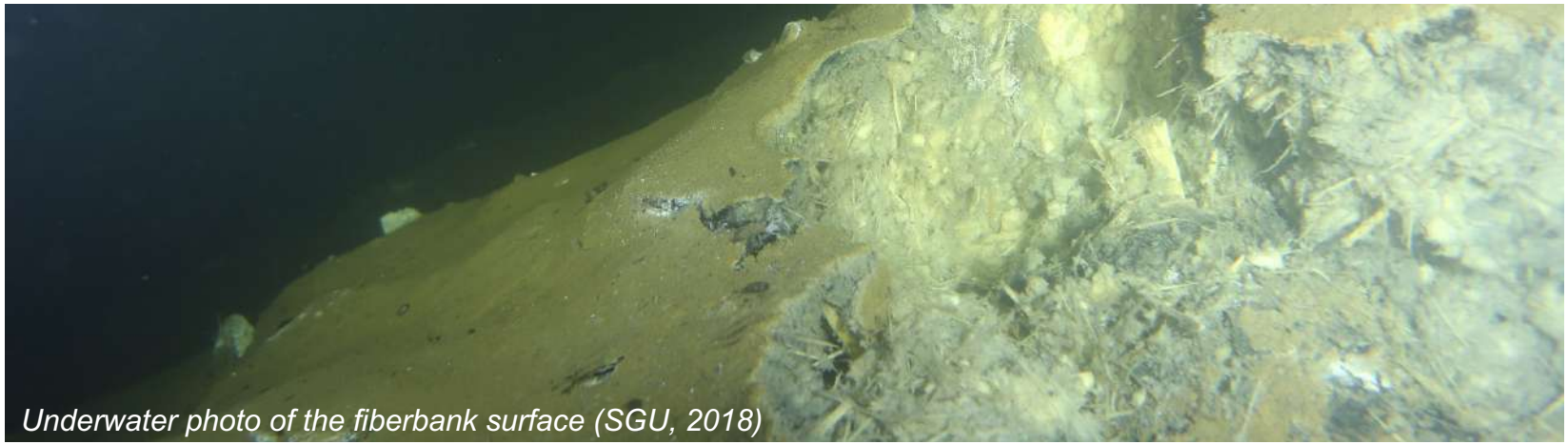
- Waste from pulp & paper industry
- Discharged untreated in the aquatic environment (until 70's in Sweden)
- Formation of 2 types of sediments:
  - **Fiberbank sediment:** Large banks of pure wood chips, cellulose fibers and timber
  - **Fiber-rich sediments:** Natural sediment mixed with fibers, often further away from the factories



A Swedish pulp mill discharge (Lantmäteriet 1958)

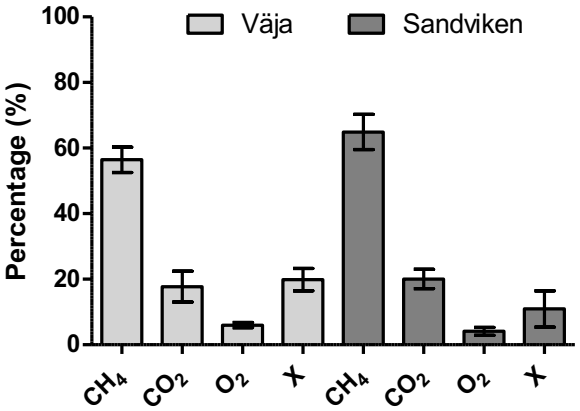
Contaminant levels in fiberbanks

- High amounts of Persistent Organic Pollutants: DDT, PCBs, HCB
- High amounts of metals and metalloids: Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn, As
- High gas production: CH_4, CO_2, H_2S



Underwater photo of the fiberbank surface (SGU, 2018)

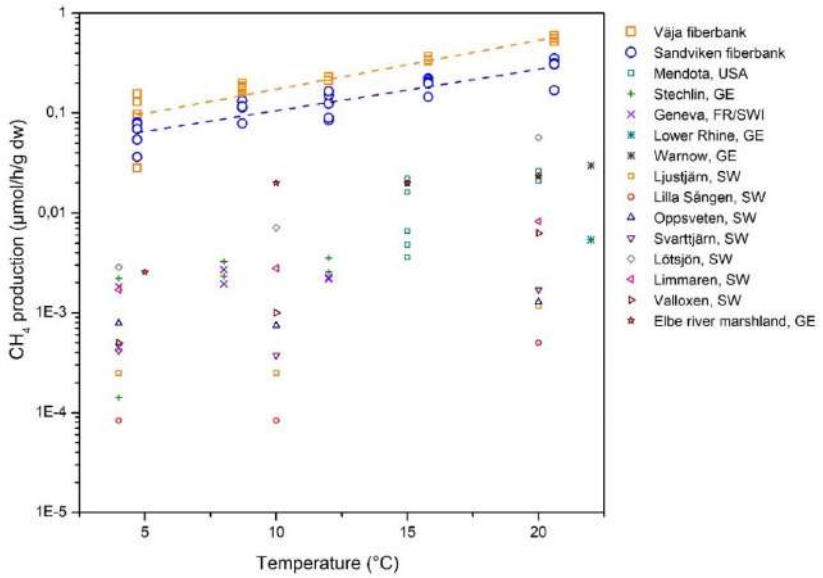
Gas composition



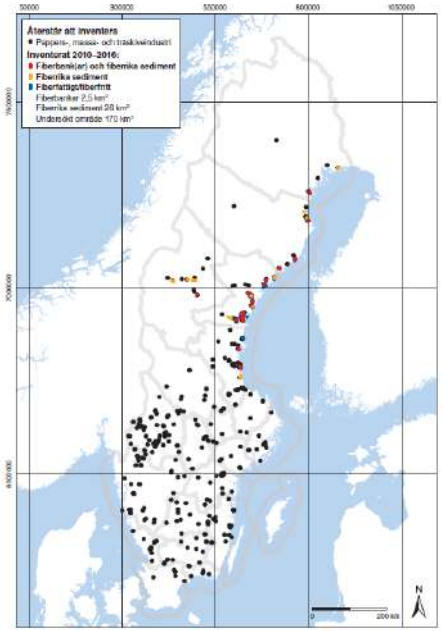
- Released gas mainly composed of CH_4
- A large part of CO_2 and other gases
- Other gases :
  - H_2S between 0 – 400 ppm
  - N-gases

Lehoux et al., 2021

Methane emissions:
Laboratory measurements and upscaling



Lehoux et al., 2021



Norrlin & Josefsson, 2017

GHG emissions from fiberbanks could be as high as 7% of Sweden's GHG release in 2019

Can drones be used to estimate the emissions in the field?

Can they also help identify contaminated sites?

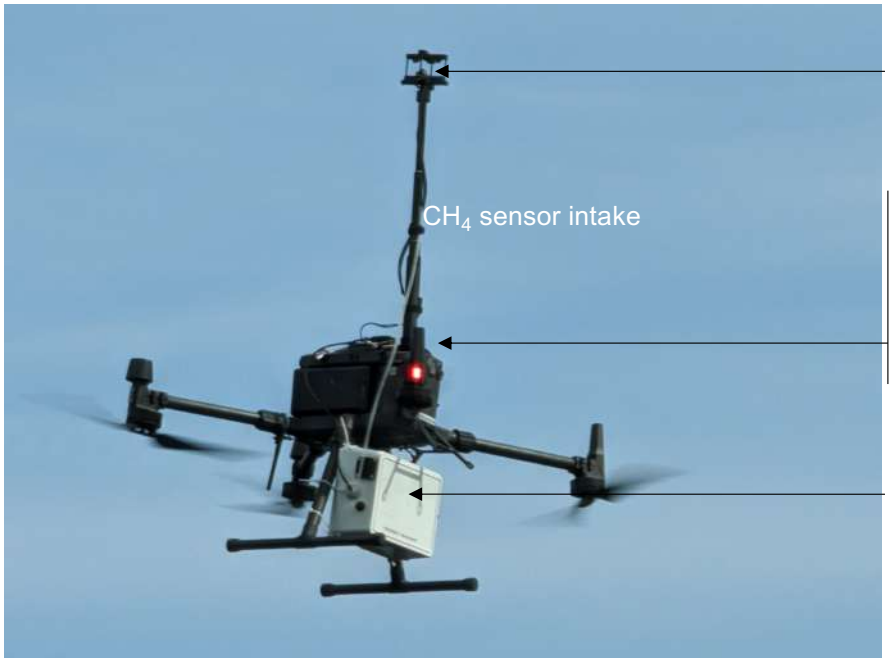
Drone platform

DJI Matrice 300 RTK

Total weight : 8.6 kg

3 pairs of battery

Flight length : ~ 3 x 25 min



Anemometer

Thermometer
Air pressure
Relative humidity
Positioning system

Methane sensor
Aeris Mira Pico
Laser gas sensor
Sensitivity 0.84 ppb/s
Accuracy ~5 ppb

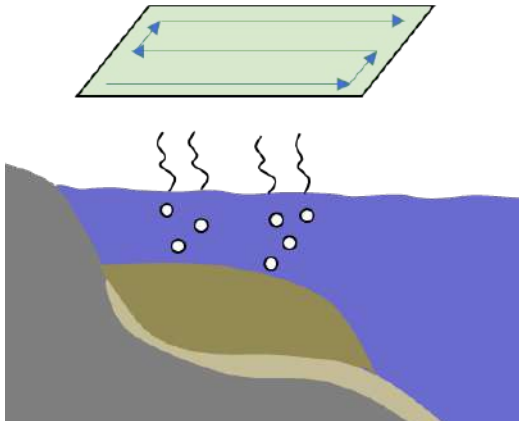
System delivered by Sparv embedded
Similar setup as in Gålfalk et al. 2021

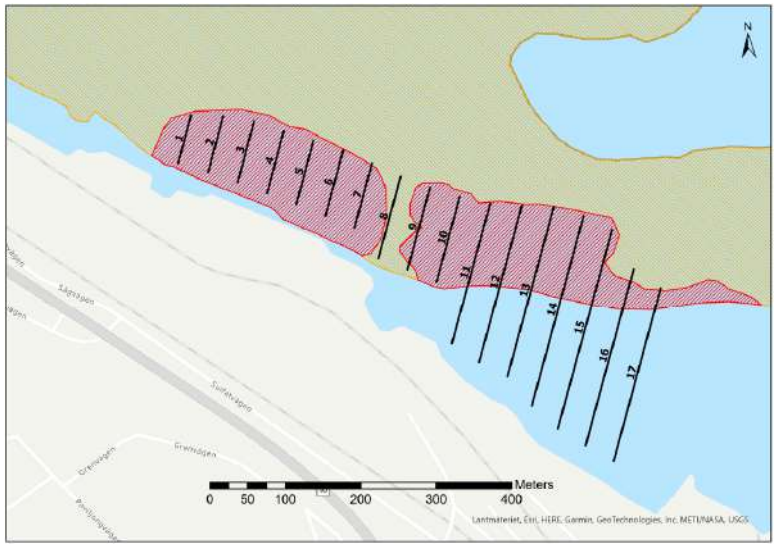
Methodology

Horizontal mapping

Objective: Find hotspots

Conditions: Low wind speed (<1 m/s)

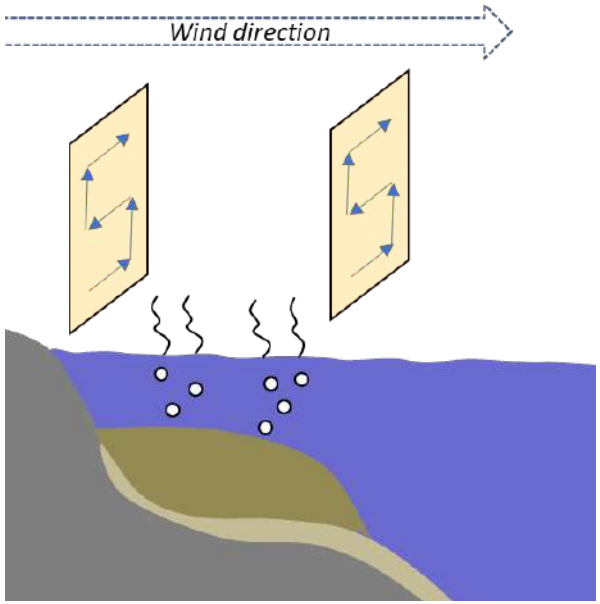




Methodology
Vertical flights

Objective: Observe methane distribution in space and calculate fluxes

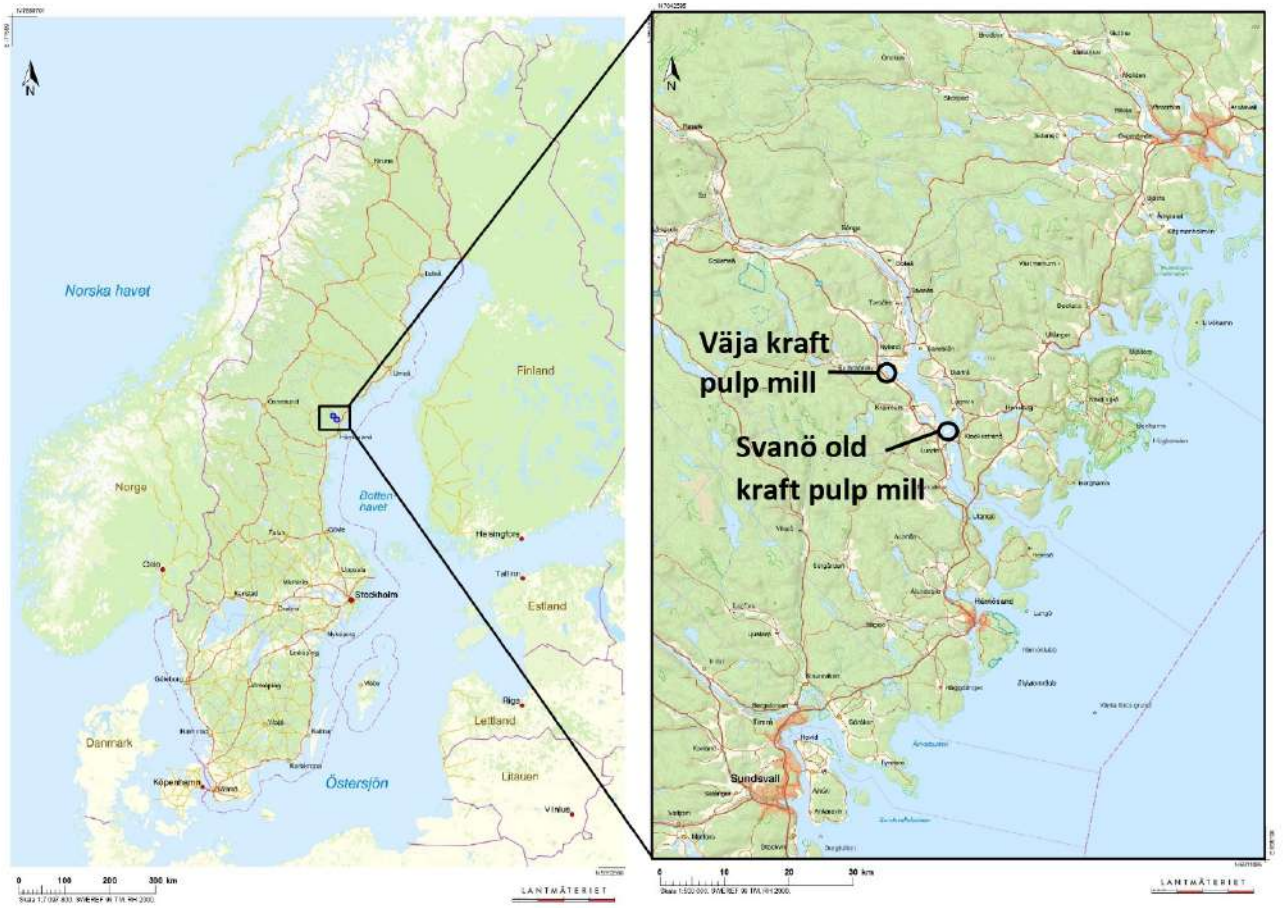
Conditions: wind >2 m/s



$$F(CH_4) = \int_0^z \int_{x_1}^{x_2} (X_{ij} - X_0)\rho_{air} M_{CH4} U_{ij} dx dz$$

X_{ij} : CH_4 mixing ratio,
ρ : Air density,
M_{CH4} : Molar mass of CH_4
U : Wind speed perpendicular to the vertical fence.

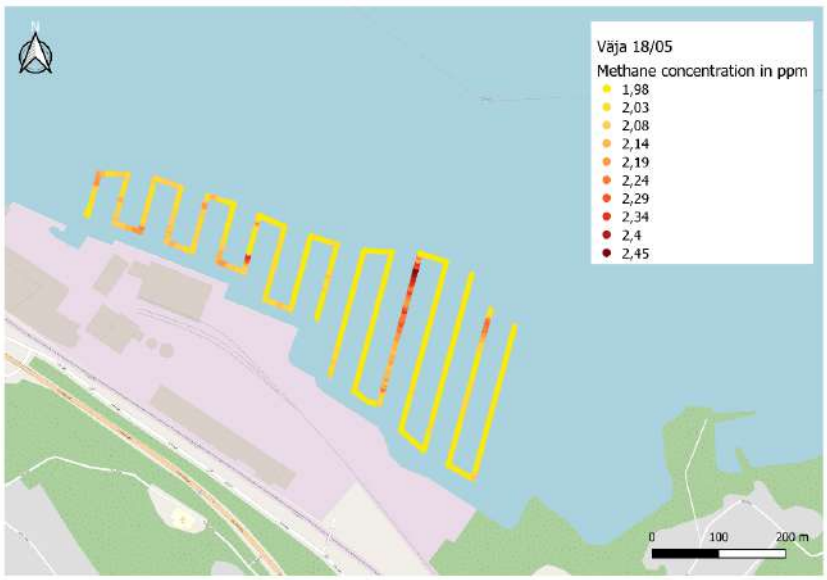
Localisation of the study sites

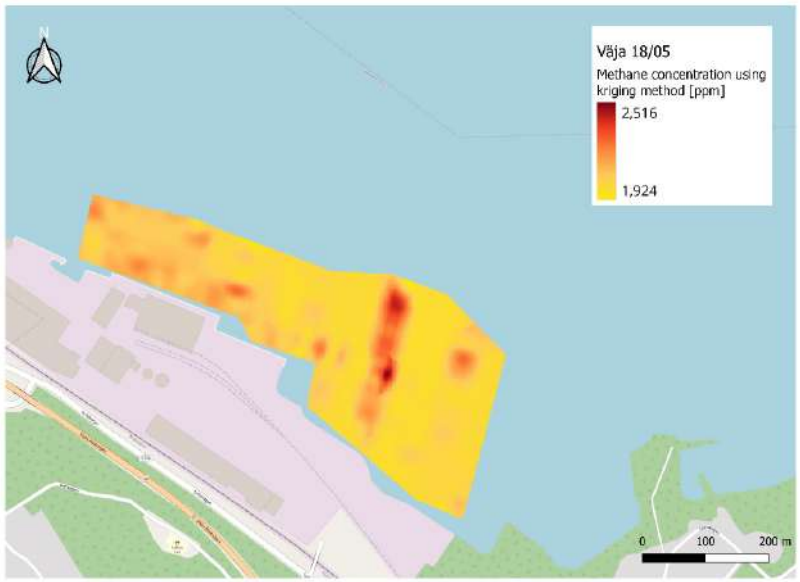


Study site 1: Väja

- Active sulfate paper mill
- Site in activity since 1914
- Fiberbank covering approx. 70 000 m^2
- Fiberbank thickness > 6 m

Horizontal mapping in Väja

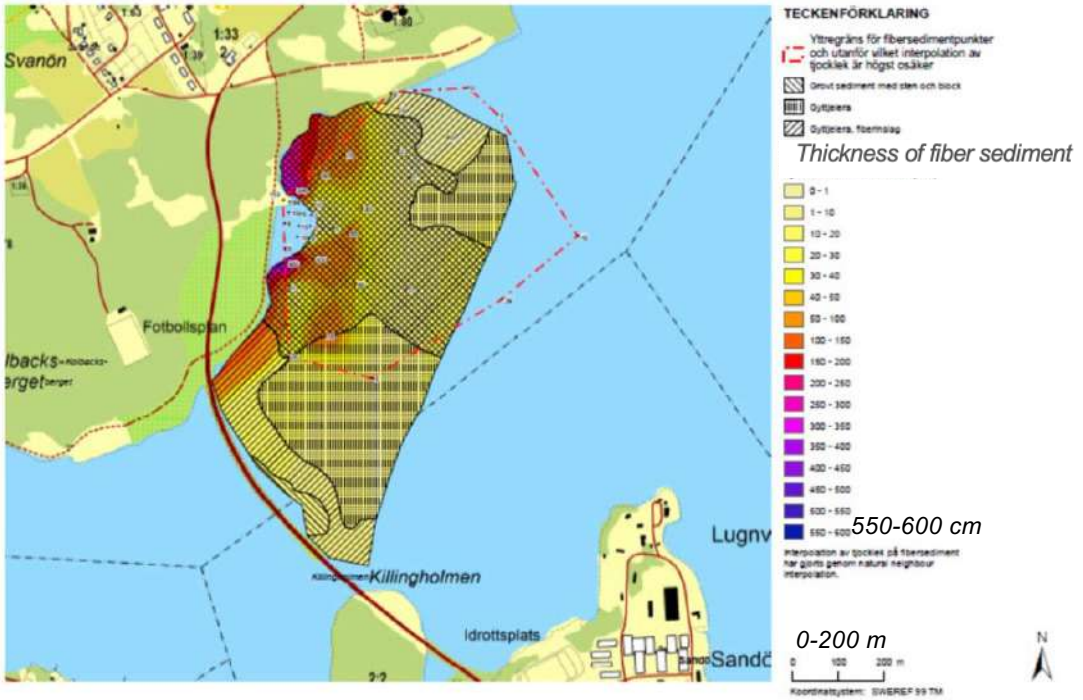




Date : 18 May 2022
Air temperature : 12 ℃
Wind speed : 0-1 m/s

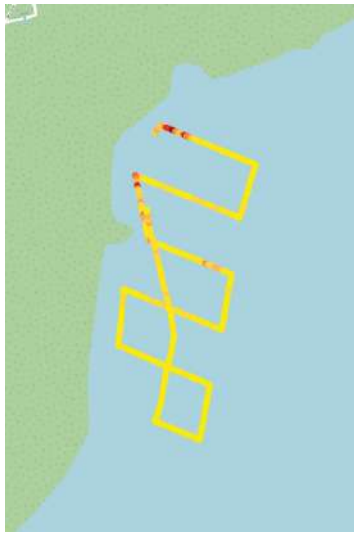
Study site 2: Svanö

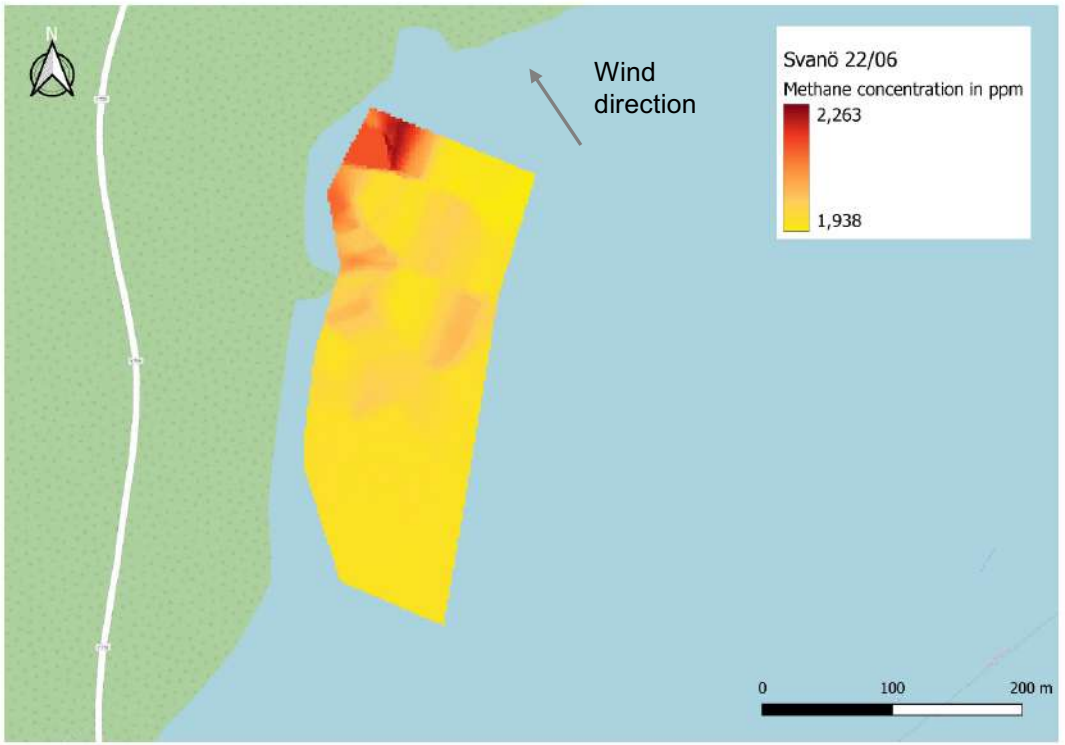
- Sulfite paper mill active between 1906 and 1966
- Extensive remediation on land has been done, but most of the fiberbanks are left in place.
- High concentrations of Hg



Golder Associates report, 2016

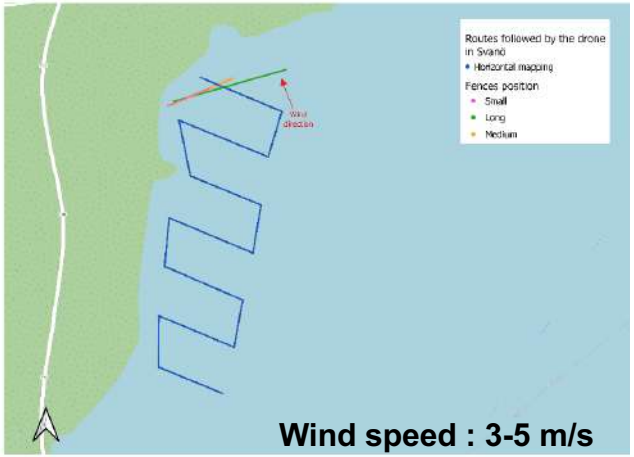
Horizontal mapping in Svanö

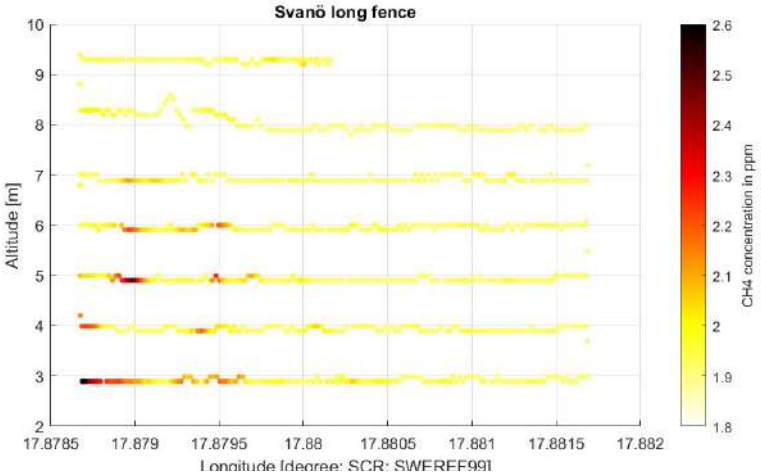


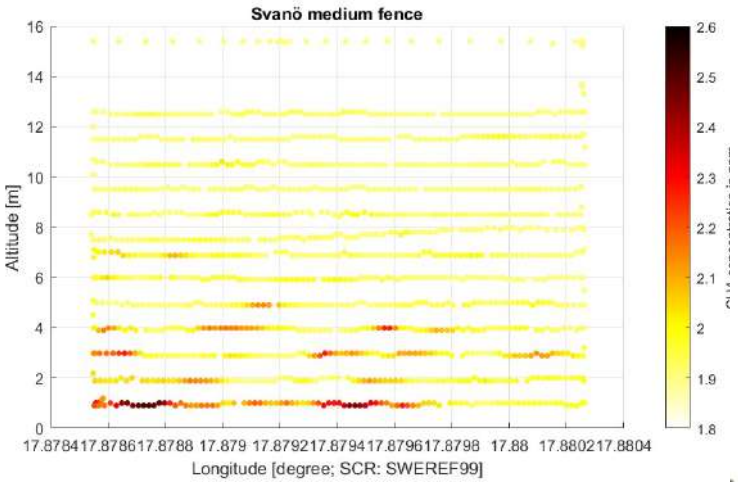


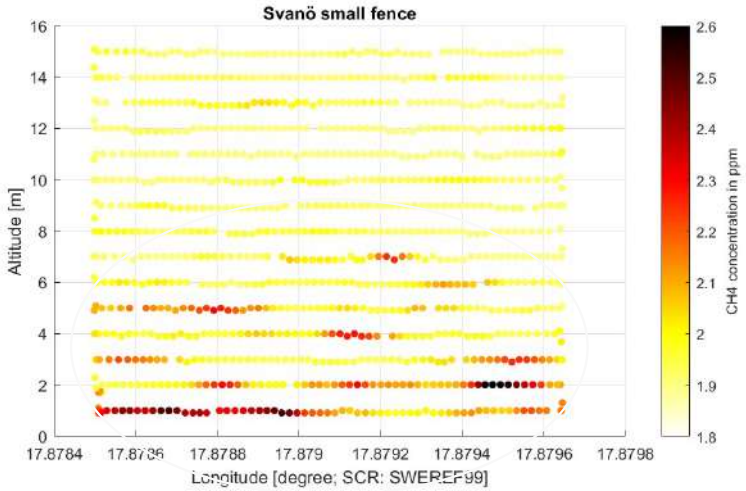
Date : 22 June 2022
Air temperature : 19 ℃
Wind speed : ~ 4 m/s

Fences in Svanö (30 min between each)

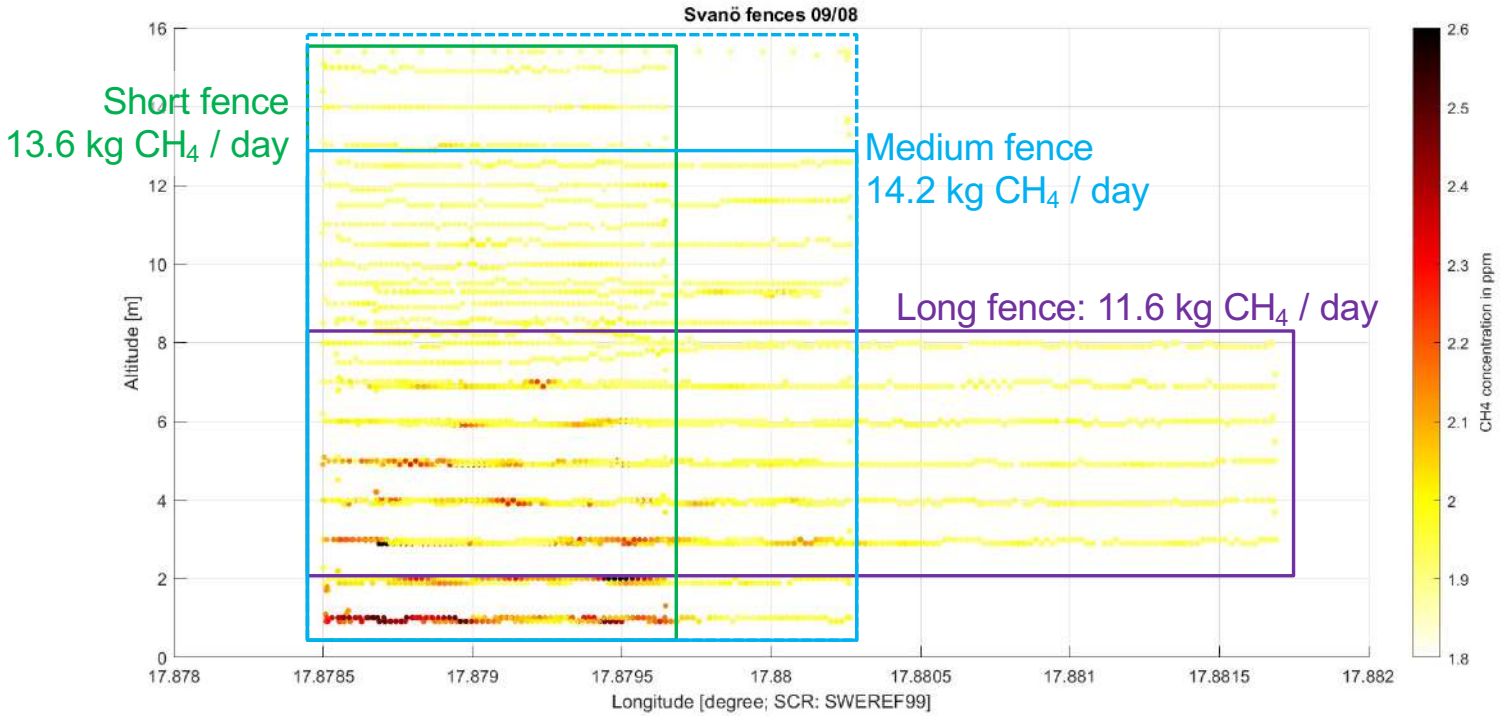








Comparison of three fences

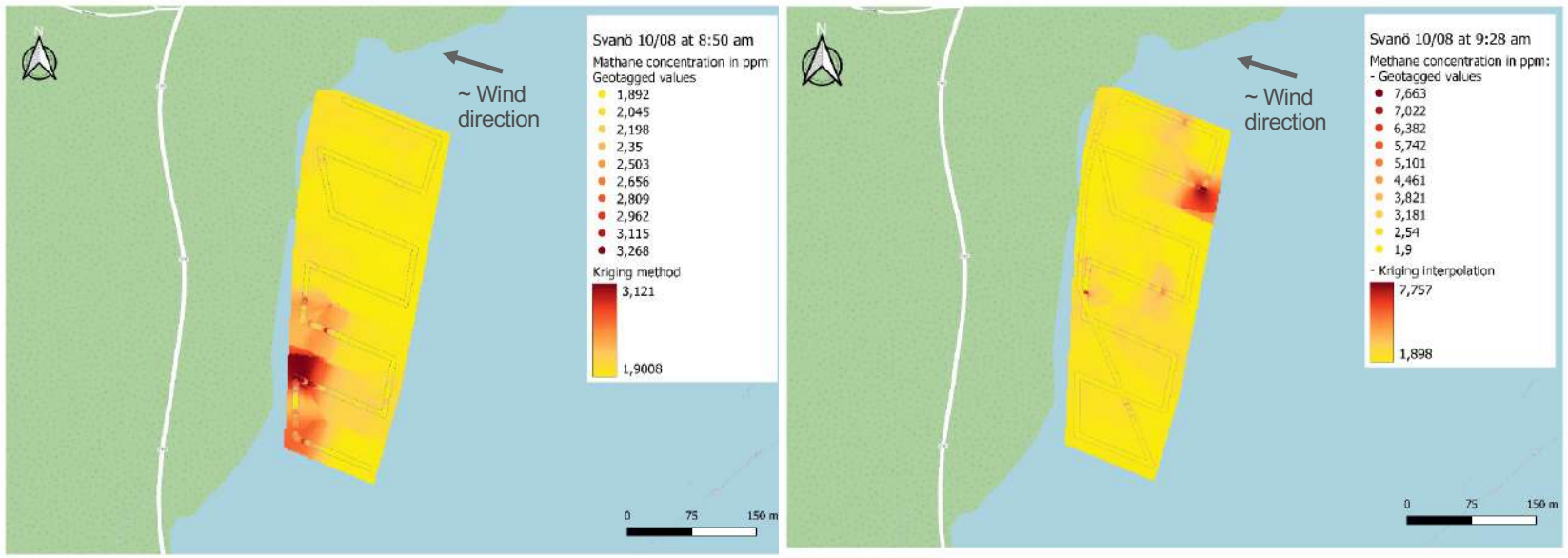


Methane emissions were estimated using the mass balance method.

Emissions from the Svanö fiberbank averaged from the three flights:

13.1 kg CH_4 / day

Two horizontal mappings in Svanö

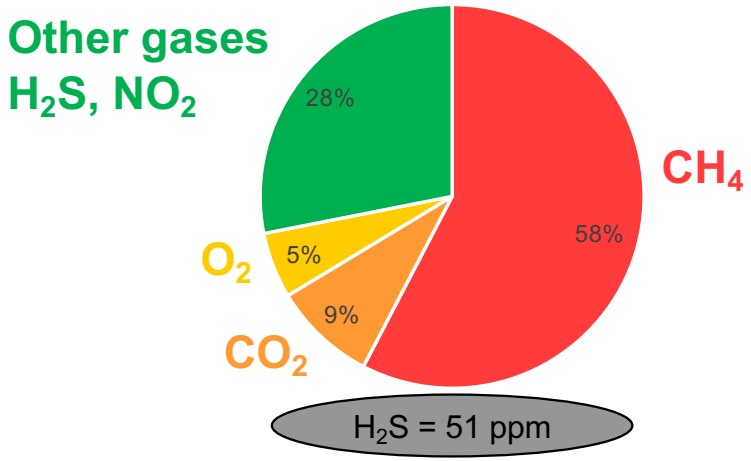


Date : 10 August 2022
Air temperature : 20 ℃
Wind speed : 1-2 m/s

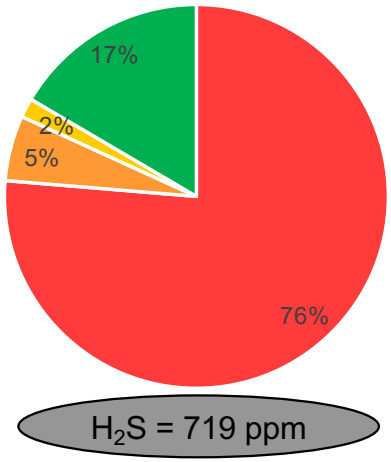
- Measurements performed 9 h after an earthquake <10km away
- Magnitude 2.6

Field measurements of the gas composition from the fiberbank sediments in Väja

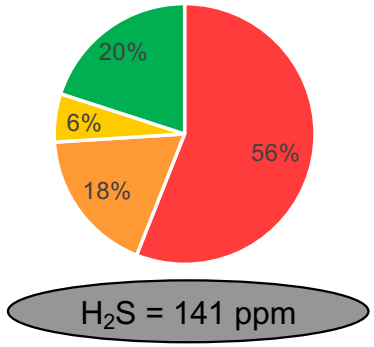
Average passive sampling

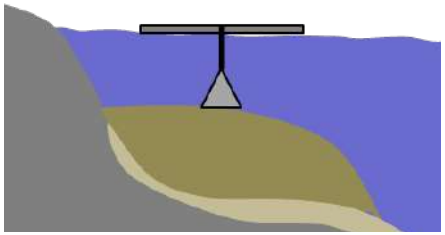


Average forced sampling



Average production in the laboratory
(Lehoux et al. 2021)





STATENS GEOTEKNISKA INSTITUT
NGI SLU

Co-Gas project (2021-2023, Swedish EPA)

Conclusions

- Horizontal mapping at low wind speed conditions allows the detection of

  → ebullition events

  → “hotspots”

- Methane emissions from fiberbanks occur mainly through ebullition

  → challenging to obtain a representative map

  → several horizontal mapping flights are necessary.

- Using the mass balance method enables estimation of the total methane flux.
- Earthquakes and other disturbances may trigger higher methane release from fiberbanks.
- Fiberbanks need to be remediated to limit GHG release to the atmosphere.

UPPSALA
UNIVERSITET


Thank you for your attention !
UPPSALA
UNIVERSITET
SGU
Sveriges
geologiska
undersökning
VINNOVA