Towards Understanding the Contribution of Waterbodies to the Methane Emissions of a Permafrost Landscape on a Regional Scale – A Case Study from the Mackenzie Delta, Canada

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B41I-2088

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1. Motivation and Objectives

Waterbodies in the arctic permafrost region are considered a strong source of the greenhouse gas methane (CH_4). However, we do not sufficiently understand their contribution to the circum-arctic CH_4 budget, due to the spatio-temporal variability of the fluxes and methodological constraints. We aim at advancing our understanding by addressing these **research questions:**

1. Are there relations between waterbody types and CH_4 flux that exist independently from the spatial resolution of the CH_4 measurements and from the study area?
2. Are CH_4 emissions larger in areas with a large number of shallow or small waterbodies?
3. Are CH_4 emissions from waterbodies exceeding those from the surrounding land surface?

2. Study areas and setup

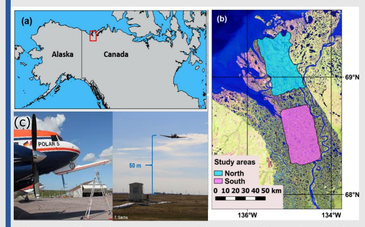
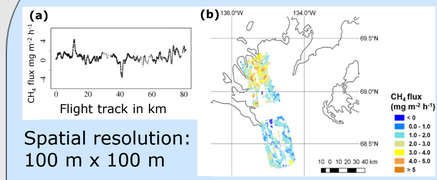


Fig. 1: Study areas in the Mackenzie Delta and flight campaign setup

- Two study areas of 1000 km² each in the Mackenzie Delta (1a,b)
- Aircraft campaign AIRMETH (Airborne Measurements of Methane Fluxes, 1c)
- 12 flight days in July 2012 and 2013

3. Data and Methods

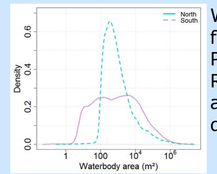
3.1 CH_4 flux data



Spatial resolution: 100 m x 100 m

Fig. 2: (a) CH_4 flux derived from eddy-covariance measurements along one exemplary flight track. (b) CH_4 flux map derived from all flights via flux topographies and cut to extent of waterbody maps.

3.2 TerraSAR-X data



Waterbodies from the Permafrost Region Pond and Lake database PeRL

Fig. 3: Distribution of waterbody sizes within the two study areas.

3.3 Sentinel-1 SAR backscatter data

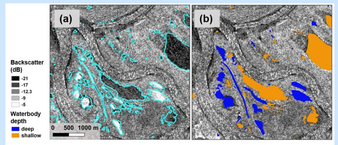


Fig. 4:Classification of waterbodies as „deep" or „shallow" based on Sentinel-1 backscatter signal (see info box). If > 80% of pixels within a waterbody grounded: „shallow", otherwise „deep".

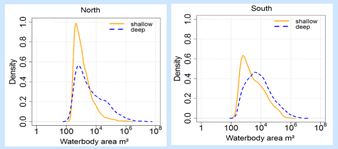


Fig. 5: Size distribution of shallow and deep waterbodies in the two study areas.

Info box: Sentinel-1 backscatter

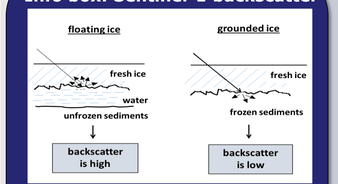


Fig. 6: Schematic of differences in Synthetic Aperture Radar (SAR) backscatter signal from grounded and floating ice in waterbodies.

Waterbody size classes:
Large: > 10,000 m²
Medium: > 500 m², ≤ 10,000 m²
Small: ≤ 500 m²

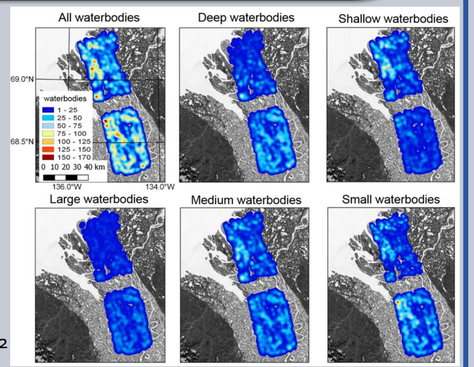


Fig. 7: Spatial distribution of waterbody types in the study areas

4. Results and Discussion

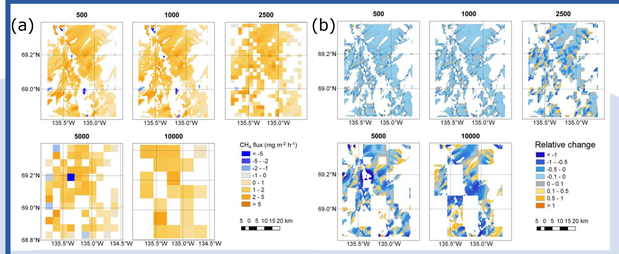


Fig. 8: (a) Stepwise coarsened CH_4 flux map of the northern study area and (b) relative changes between original CH_4 flux map and the resampled maps.

Relative change (x, $x_{original}$) =

$$\frac{x - x_{original}}{|x_{original}|}$$

We coarsened the CH_4 flux map to cut less waterbodies into fragments.
We couldn't detect the „best" resolution for detecting relationships between CH_4 and waterbodies.

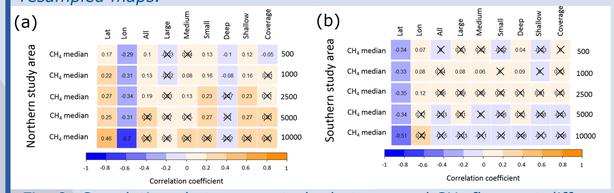


Fig. 9: Correlations between waterbody types and CH_4 fluxes at different spatial resolutions (numbers on y-axis) in the (a) northern and (b) southern study area. Crossed cells: correlations not significant.

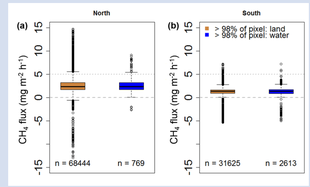


Fig. 10: CH_4 fluxes in cells with mainly water and mainly land (at 100 m x 100 m resolution)

4.1 All correlations between waterbody types and CH_4 flux were small. We did not find correlations that existed independently of study area or spatial resolution.

4.2 Unlike in the southern study area, in the northern study area, a higher number of shallow or small waterbodies was slightly positively correlated with the CH_4 flux.

4.3 CH_4 fluxes from water surface were not significantly larger than from land surface. A higher surface coverage with water was not correlated with higher CH_4 fluxes.

- Potentially too coarse resolution of CH_4 fluxes to detect a significant influence of waterbody emissions on regional scale
- Even if permafrost waterbodies seem to be strong emitters on an individual basis, they do not necessarily translate into significant CH_4 emission hot spots on a regional scale

5. Conclusions

- Airborne CH_4 flux measurements too coarse to assign flux to single waterbodies
- Technical developments in drones might enable regional coverage at high resolution and to detect regional flux patterns from waterbodies

Acknowledgements: Funding through grants of the Helmholtz Association to T.S. and S. Muster (VH-NG-821 and VH-NG 203) and by the National Science Foundation (DBI-0752017) to S. Metzger. The AIRMETH campaigns were mainly funded by Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research.

References: Kohnert et al., 2017, Scientific Reports, 7:5828; Mauder et al., 2008, Boundary-Layer Meteorology, 129:431-450; Metzger et al., 2013, Biogeosciences, 10:2193-2217; Muster et al., 2017, Earth System Science Data, 9:317-348.