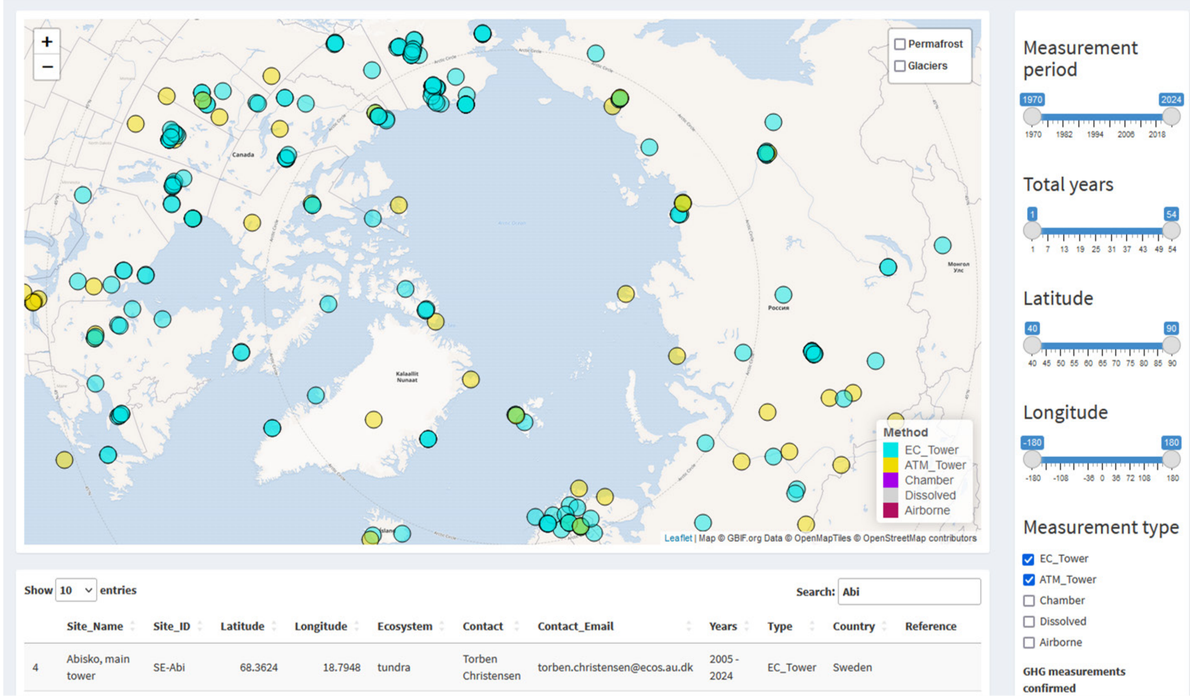
Monitoring and modelling the Arctic carbon cycle: present status and future strategies

Martijn Pallandt et al.[1]

1. Where are we measuring?

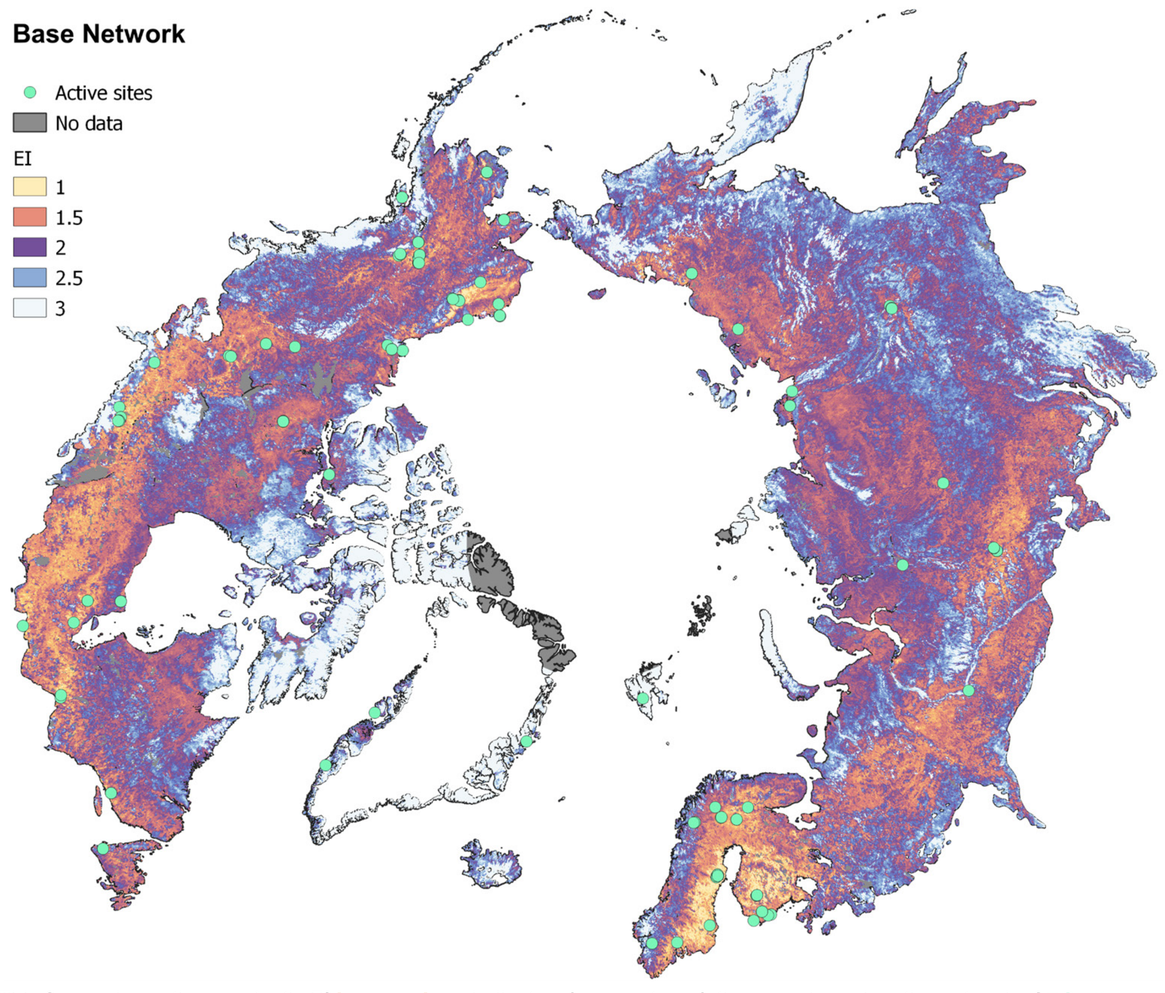


- Chambers, Eddy covariance, Dissolved, Atmospheric, and Airborne.
- Available on https://cosima.nceas.ucsb.edu/carbon-flux-sites.
- Paper on the way.

2. How well do these sites represent the domain?

Representativeness of the eddy covariance network (to measure ghg fluxes). Two methods were employed:

- Distanced based metric between bioclimatic variables (Pallandt et al. 2022).
- Extrapolation error characterization (EI) based on flux prediction (Pallandt et al 2024).



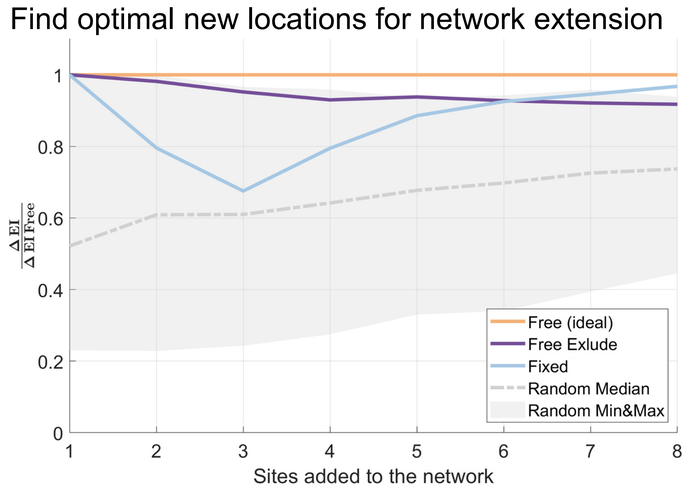
This figure shows the pan Arctic EI **lower values** indicate a lower extrapolation error based on the network of **EC sites**.

3. Key findings from experiments

- Methane and Wintertime measurements lag considerable behind summertime CO_2
- Especially the High Arctic, Siberia and mountainous regions lack representation
- Continued measurements are required, even more so in a changing environment
- Support and upgrades for existing sites is the most cost effective course of action.
- We must expand towards harder to reach regions, possibly with mobile platforms.

4. Optimization of the network

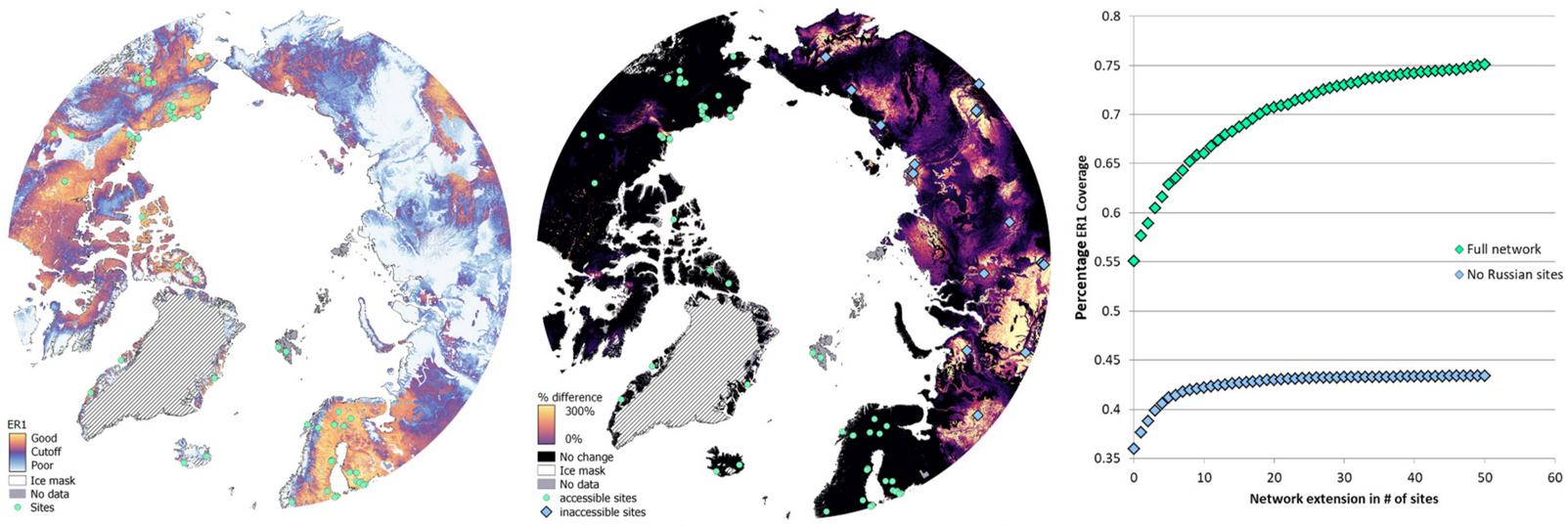
Find optimal new locations for network extension



Relative optimization results compared to the ideal case

- **Free** automated optimization.
- **Free Exclude** les practical options where excluded.
- **Fixed** 3 sites were predetermined, 2 of which inferior choices.
- **Grey** random allocation among reasonable sites.

5. No access to Russian Sites

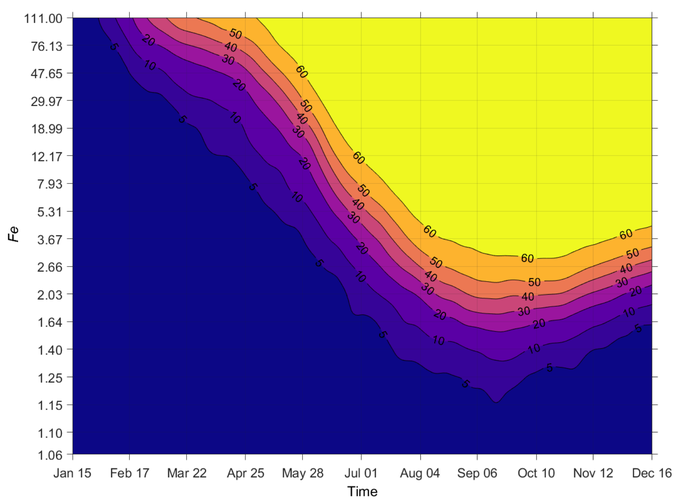


Left: EC network in pre-war conditions (distance based method). Centre: difference without access to Russia. Right: Mean representativeness with optimization, green network in pre war state, blue without Russian sites.
New sites outside of Russia can't compensate for the loss of access to data within Russia (Schuur et al. 2024).

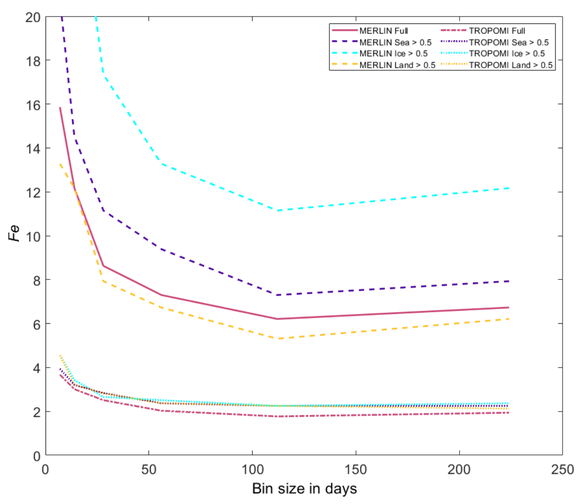
6. Top down systems: Tall towers and Satellites

An observing system simulation experiment on the detection limits of methane release from thawing Yedoma

- Tall towers: continuous long term GHG monitoring,
  - Can detect small changes if wel position but suffers from high transport modeling errors
- TROPOMI: passive satellite sensor
  - Large number of samples with low random error results in low detection limits, can't measure in the dark
- MERLIN: active satellite sensor
  - Relative high random error in Arctic conditions but low bias, active during dark conditions



Flux enhancement *Fe* at which a significant difference is found between baseline and enhancement scenario for the tall tower network with one month bins. Isolines indicate number of sites that detect this change.

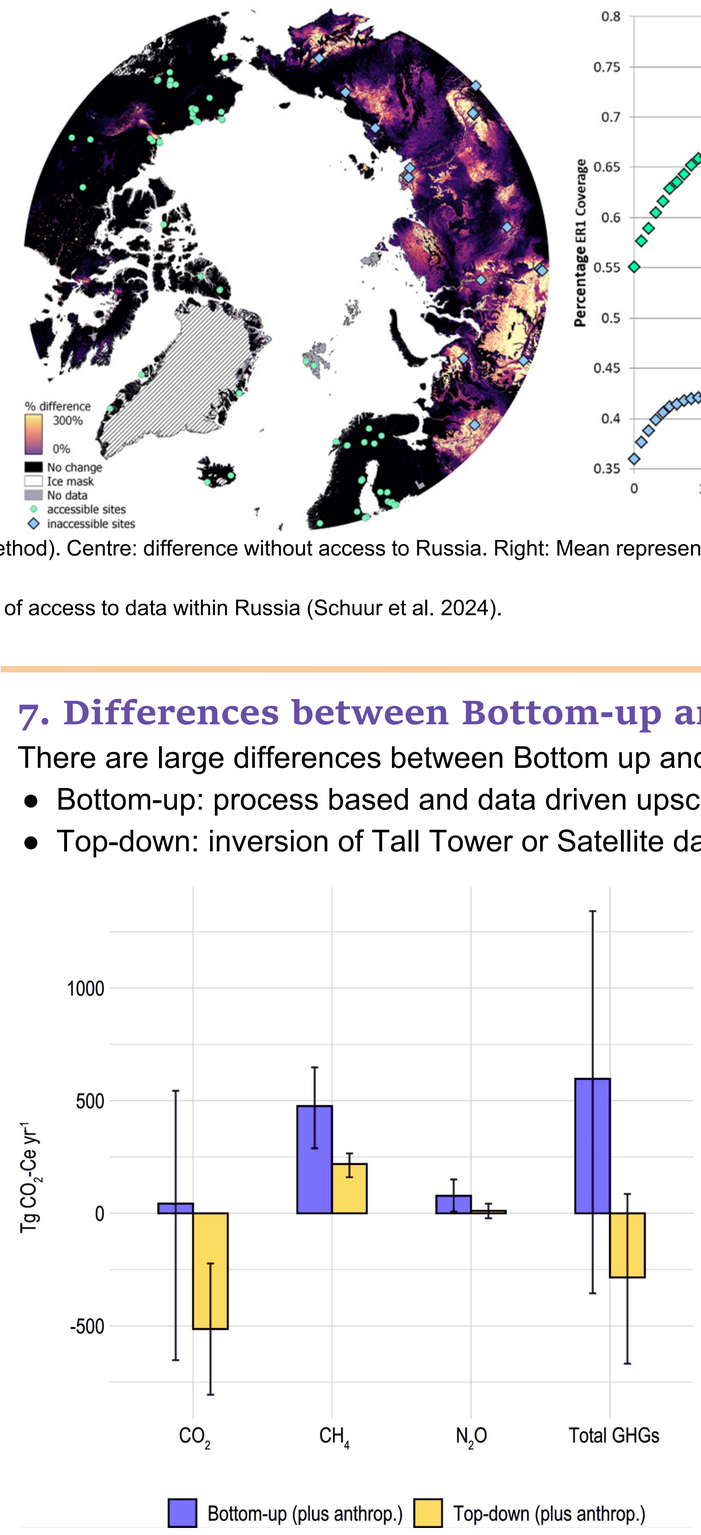


Flux enhancement *Fe* at which a significant difference is found between baseline and enhancement scenario for MERLIN and TROPOMI, per temporal bin.

7. Differences between Bottom-up and Top-down budgets

There are large differences between Bottom up and Top down estimates.

- Bottom-up: process based and data driven upscaling models.
- Top-down: inversion of Tall Tower or Satellite data.



Adapted from Hugelius et al. 2024. Bottom-up budgets indicate a small CO_2 source, while Top-down a large sink. CH_4 differences are the same sign,Top-down expect roughly half the source compared to Bottom-up

Potential causes

- Limited priors in Inversions
- Limited data for Inversions
- Double counting
  - Different definitions
  - Different resolutions
- Eddy covariance
  - Footprint heterogeneity
- Domain extend definitions

Planned approach

1. Inventory of flux vs input sources and configuration.
2. Workshop with involved parties.
3. Inversions based on updated best practices.

[1]**Authors**: Pallandt M. M. T., Arndt K., Celis G., Chatterjee A., Hoffman F. M., Hugelius G., Jung M., Kumar J., Marshall J., Mauritz M., Natali S., Ott L., Rogers B., Schuur E. A. G., Virkkala A.-M., and Göckede, M.

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Pallandt, M. M. T. A., Jung, M., Arndt, K., Natali, S. M., Rogers, B. M., Virkkala, A.-M., & Göckede, M. (2024). High-latitude eddy covariance temporal network design and optimization. *Journal of Geophysical Research: Biogeosciences*, 129, e2024JG008406. https://doi.org/10.1029/2024JG008406

Hugelius, G., Ramage, J., Burke, E., Chatterjee, A., Smallman, T. L., Aalto, T., et al. (2024). Permafrost region greenhouse gas budgets suggest a weak CO2 sink and CH4 and N2O sources, but magnitudes differ between top-down and bottom-up methods. Global Biogeochemical Cycles, 38, e2023GB007969. https://doi.org/10.1029/2023GB007969