Winter CO_2 and CH_4 fluxes through the snowpack

Alex Mavrovic[1-2-3], Juha Lemmetyinen[4], Carolina Voigt[1-5-6], Oliver Sonnentag[1-5] and Alexandre Roy[1-2]

Contact: alex.mavrovic@uqtr.ca

Introduction

In arctic and boreal regions, the winter carbon exchanges between the soil and the atmosphere in the form of carbon dioxide (CO_2) and methane (CH_4) are highly uncertain. The insulating properties of snow allow the ground to maintain soil temperatures high enough to allow soil respiration (CO_2 emissions) and CH_4 metabolization. The winter contribution to the annual carbon balance for these large environments cannot be neglected in order to determine whether these regions are net carbon sources or sinks.

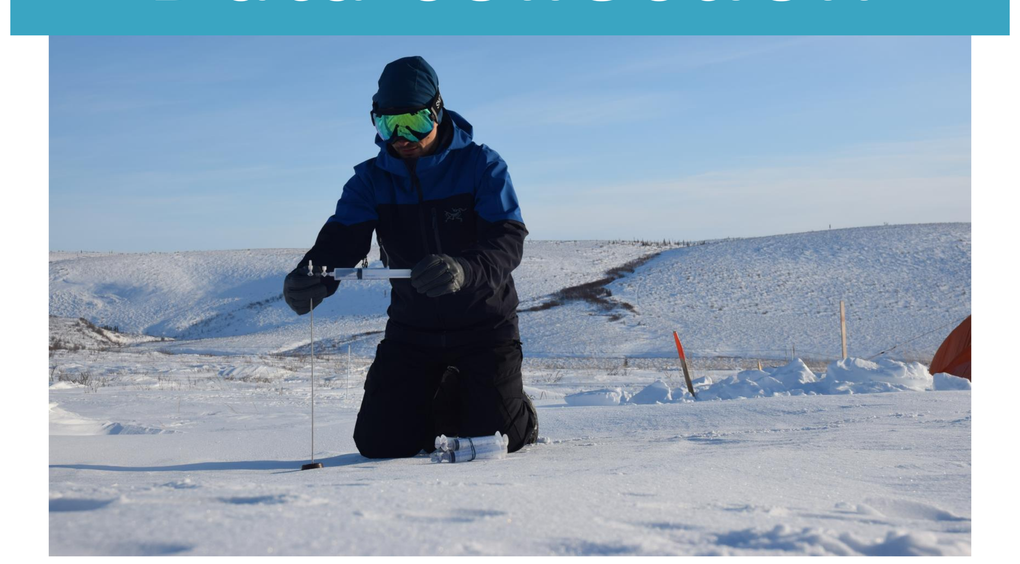
Study sites

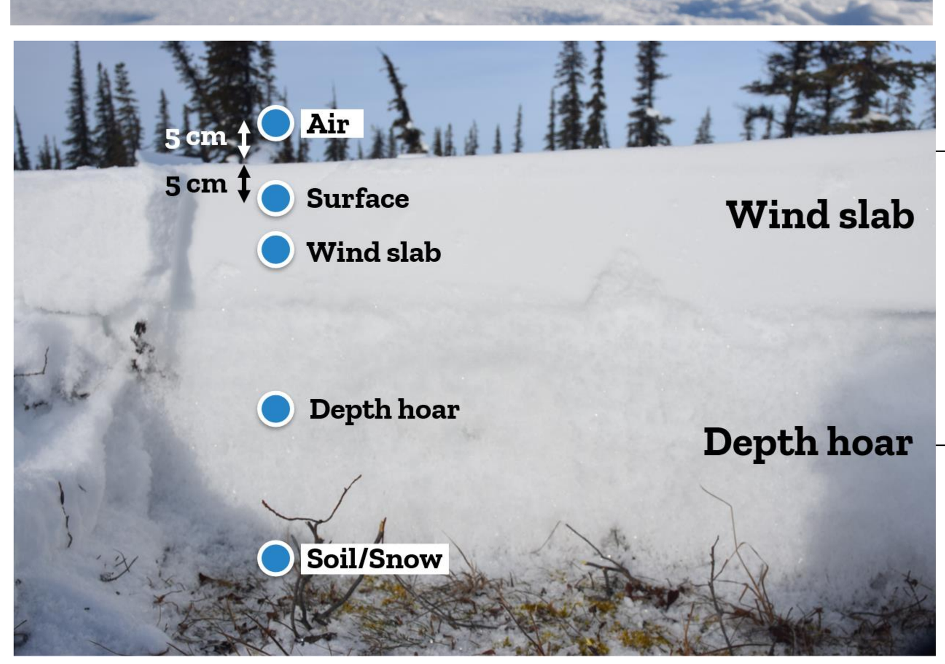
Montmorency Forest, Quebec
Boreal forest - Momo

Trail Valley Creek, Northwest Territories
Arctic tundra - TVC

Cambridge Bay, Nunavut
Arctic tundra - CamBay

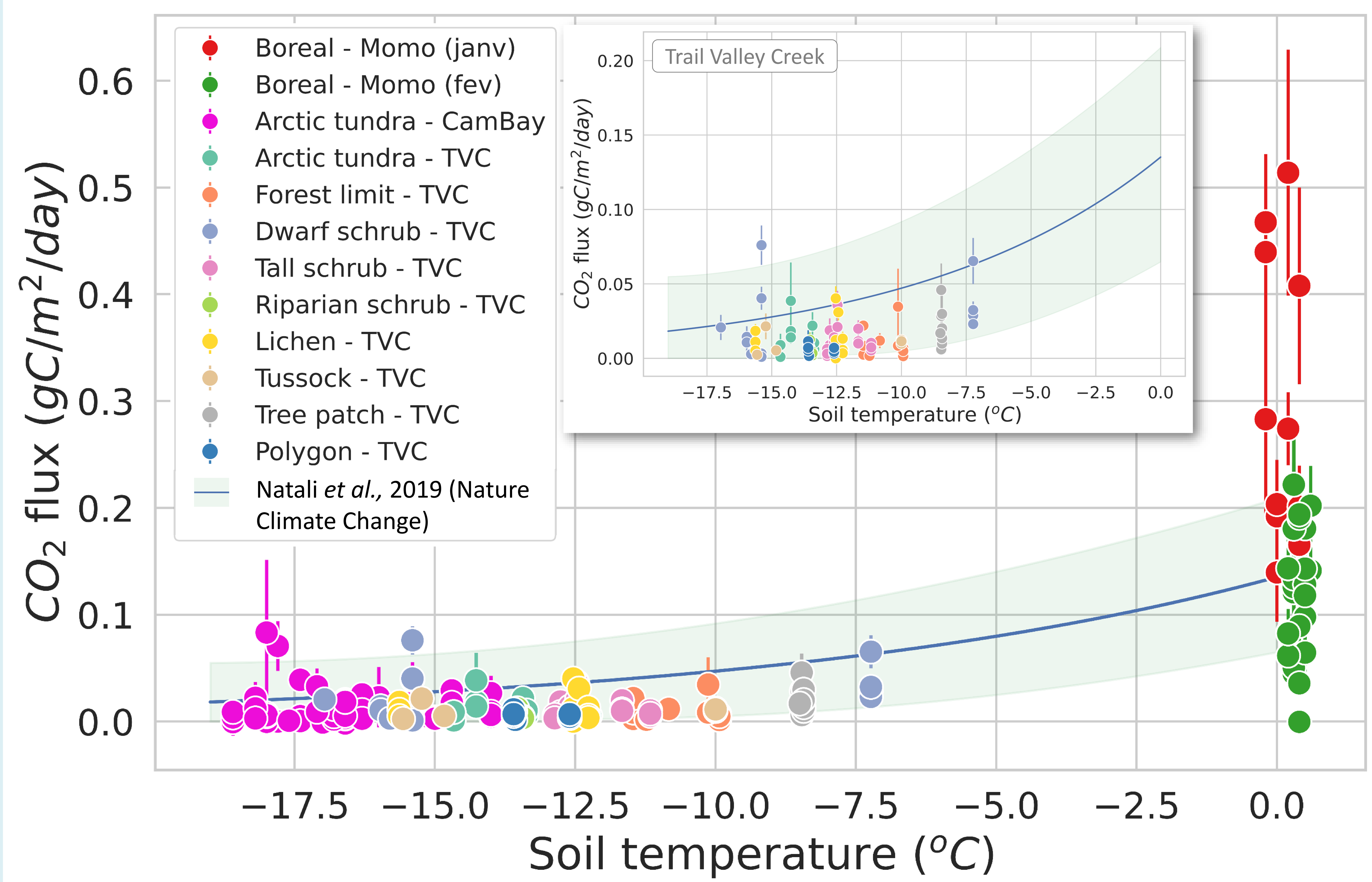
Data collection



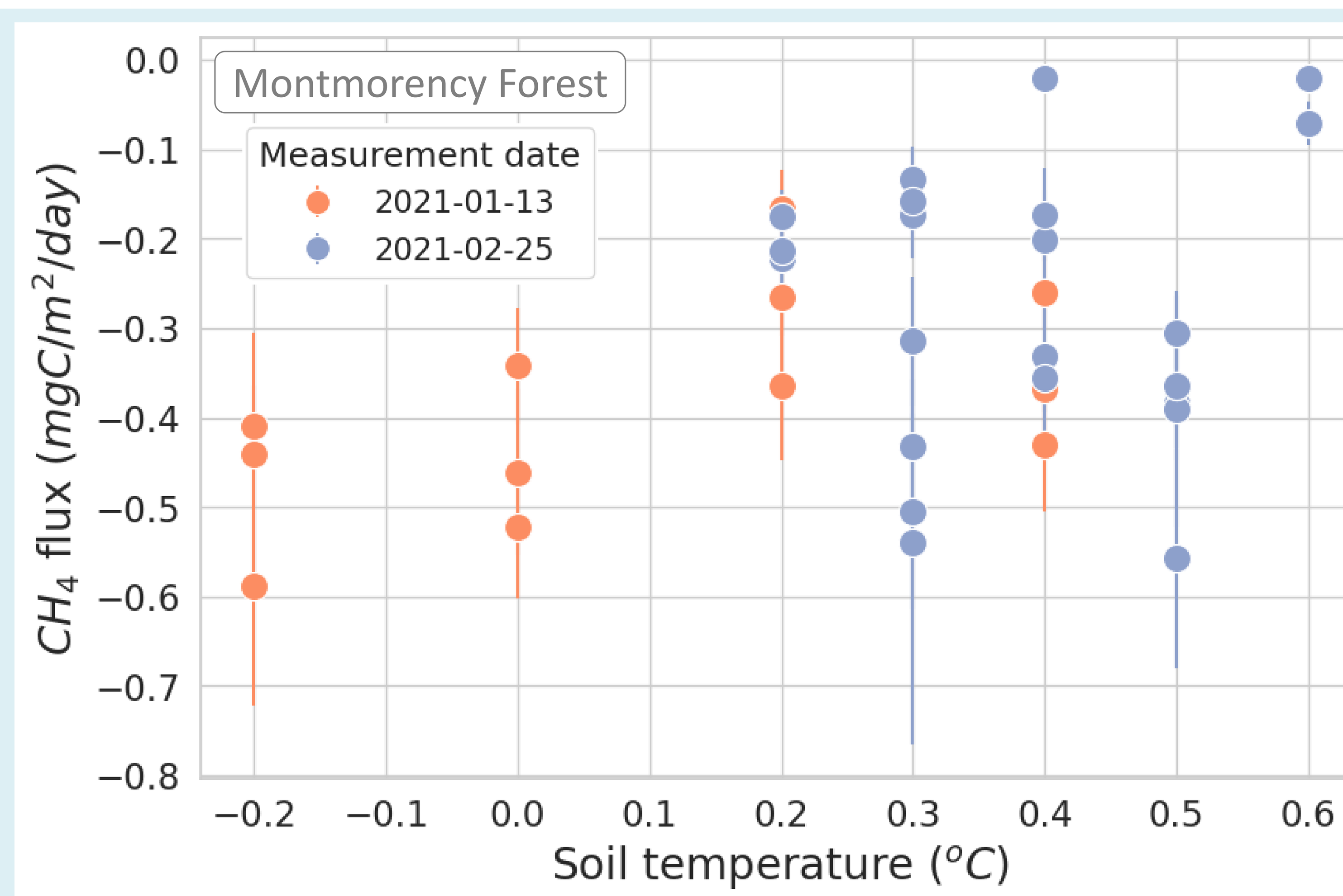


Gas sample collection was conducted using a thin rod limiting snow disturbance. 5 samples from different snow depths were collected at each site along with snow measurements (density, temperature, grain size and stratigraphy).

Results



The top graph displays CO_2 flux estimates from the three study sites. All TVC and CamBay data were collected in March-April. The blue curve is taken from Natali *et al.* (2019) and represent an exponential fitting of winter CO_2 flux data from a wide variety of sites and flux estimation methods. The embedded graph is a magnification of the TVC arctic tundra CO_2 flux estimates. The bottom right graph display CH_4 flux estimates from the Montmorency boreal forest. The negative CH_4 fluxes indicate uptake from the soil.



Flux estimates

Fluxes ($F_{CO2/CH4}$) were estimated from the concentration gradient (∇) in the snowpack (CO_2 or CH_4 alike):

$$F_{CO2} = \varphi t D \nabla CO_2$$

The ∇CO_2 is estimated using a linear regression between $[CO_2]$ and snow depth. Snow tortuosity (t) is estimated from snow porosity (p) which is calculated from snow density (ρ_{snow}). D represents the diffusion coefficient of CO_2 in air.

$$t = 1 - (1 - \varphi)^{2/3}$$
$$\varphi = 1 - \rho_{snow}/\rho_{ice}$$

The coefficient of determination of the ∇CO_2 is the strongest in the Momo deep snowpack (R^2 = [0.75-0.96]) and a bit lower for the TVC/CamBay arctic tundra (R^2 = [0.50-0.96]) possibly because of the arctic snowpack wind slab/depth hoar stratification and more important wind pumping of the exposed shallower snowpack.

What's next?

During the 20-21 winter, the focus was on developing the measurement methodology and surveying the spatial flux variability of our study sites. The 21-22 winter will target monitoring the temporal flux variability of our current study sites with an additional site in the Finnish Arctic. Important $[CO_2]$ peaks just below the snow/atmosphere interface were observed in 11-20% of the arctic tundra profiles. We will investigate their potential causes including production from within the snowpack, wind pumping and diffusion constraints.

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