YEAR-ROUND FOREST-FLOOR GREENHOUSE GAS FLUXES IN A SUBALPINE CONIFEROUS FOREST

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1 INTRODUCTION

- **Forests** play an important role in the global carbon (C) budget by **sequestering about 30% of global anthropogenic CO_2 emissions** and by acting as an important **CH_4 sink.**
- **Forest-floor greenhouse gas (GHG) fluxes** are one of the major components to consider when determining the C budgets of forests.
- Although **winter fluxes** are essential to determine the annual C budget of forests, there have been very few studies that have examined **long-term, year-round forest-floor GHG fluxes** in high elevation forests.
- Especially during **snowy periods**, forest-floor GHG fluxes are difficult to measure and are therefore **often missing from studies**.

2 OBJECTIVES

A. Investigate the seasonal and annual variations in climate variables and forest-floor CO_2, CH_4 and N_2O fluxes

B. Evaluate the climate drivers of the forest-floor GHG fluxes

C. Calculate annual budgets of the forest-floor GHG fluxes

3 METHODS

Study site: Subalpine Norway spruce (*Picea abies*) forest located in Davos in the Swiss Alps (at 1640 m a.s.l.); certified as ICOS Class 1 Ecosystem station; annual precipitation sum: 1020 mm; mean annual temperature: 4.3 °C (1997-2021); understory vegetation: blueberry (*Vaccinium myrtillus* and *Vaccinium gaulterioides*) and mosses (*Sphagnum* sp.).

Automatic chamber measurements: CO_2, CH_4 and N_2O fluxes for the years 2017 and 2020-2022 (N_2O only 2017, 2020); year-round measurements (every 3 hours) at four custom-made automatic chambers, aggregated to daily averages for analysis.

Random forest (RF) analysis: To assess importance of environmental drivers for CO_2, CH_4 fluxes and to gap-fill CO_2, CH_4 fluxes for budget calculation.

Environmental predictor set:

- air temperature (T_{air})
- soil temperature (T_{soil} at ~5 cm depth)
- water-filled pore space (WFPS at ~5 cm depth)
- photosynthetic photon flux density (PPFD)
- 1 and 4 day leads of WFPS, T_{soil}, T_{air}, PPFD
- snow height
- leaf area index (LAI)
- total C and N stock
- bare soil fraction inside chambers

4 RESULTS & DISCUSSION

A

- The forest-floor is a continuous **source of CO_2** with very high flux rates in summer. The magnitude of the CO_2 fluxes is particularly high in 2022.
- The forest-floor is a consistent **sink for CH_4**. Periodically, we find short peaks of CH_4 emissions connected to snowmelt and snow fall.
- **N_2O fluxes are very low** (not shown), which is why we consider them negligible for the overall forest-floor GHG budget at our site.
- **2022** was by far the warmest year ever recorded at the Davos research site (annual mean T_{air} was 5.6 °C).

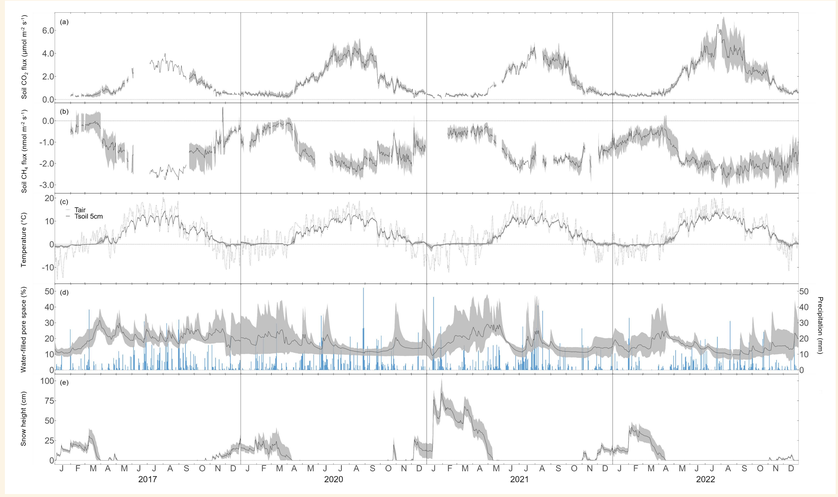

Fig. 1: *Daily mean forest-floor a) CO_2 fluxes, b) CH_4 fluxes, c) soil temperature at 5 cm depth and air temperature, d) water-filled pore space at 5 cm depth and precipitation, and e) snow height for 2017, 2020,2021, and 2022. Black lines show mean over four chambers, gray ribbons show min and max among the chambers.*

B

- Modeling the forest-floor CO_2 and CH_4 fluxes using the RF yielded **R^2 of 0.95 and 0.92**, respectively (on test data).
- Most important drivers of CO_2 and CH_4 fluxes are **T_{soil}** and **4d-lead of T_{soil}**, respectively.
- Winter fluxes are mainly driven by **snow height**.

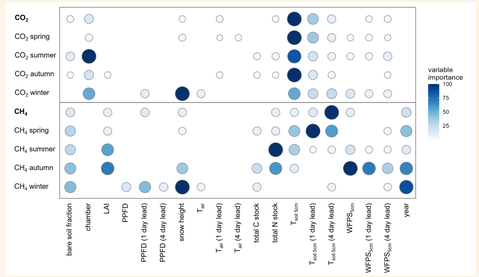

Fig. 2: *Relative variable importance (normalized to 0-100) according to the random forest driver analysis for CO_2 and CH_4 fluxes for the years 2017, 2020-2022.*

C

- Mean annual forest-floor CO_2 budget: **2.34±0.39 kg CO_2 m^{-2} yr^{-1}**
- Mean annual forest-floor CH_4 budget: **-0.70±0.13 g CH_4 m^{-2} yr^{-1}**
- **The total annual GHG budget** is mainly determined by the CO_2 emissions.
- Estimates agree well with previous studies.

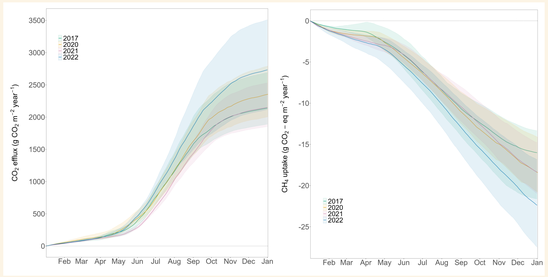

Fig. 3: *Annual cumulative CO_2 (g CO_2 m^{-2} yr^{-1}) and CH_4 (g CO_2-eq m^{-2} yr^{-1}) fluxes per year. Ribbons show min and max among the chambers, the lines show the annual means over all chambers.*

5 SUMMARY

- The forest-floor CO_2 and CH_4 fluxes show **strong short-term, seasonal and inter-annual variability**, driven by different environmental parameters.
- On the annual basis, the forest-floor is a **CO_2 source** and **CH_4 sink**, with CH_4 fluxes only offsetting **0.8 %** of the CO_2 emissions.
- The length of the active period largely determines the annual forest-floor GHG budget, which can only be captured with **year-round measurements**.

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