Allocation of atmospheric CO_2 into labile sub-surface carbon pools: A stable isotope labelling approach in a tundra wetland

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EGU2015-1000, Tuesday, 14 Apr, 8:00-19:30 (15:30-17:00)
Green Posters, board number G67

This conference contribution received **financial support** by **CliSAP** (DFG-EXC177), **School of Integrated Climate System Science** (SICSS).

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Introduction and Objectives

Permafrost-affected soils are likely to released carbon (CO_2, CH_4) into the atmosphere as a result of permafrost degradation. The fraction of methane is important to quantify due to its high radiative forcing [1]. C-storing in increasing biomass in such regions will partly compensate for the released C.

A quantification of the fraction of atmospheric and soil-derived carbon in recently emitted CO_2 and CH_4 allows detailed predictions of the expected emissions and

Previous studies suggest address the problem with combinations of time series analysis (TSA) and pulse-label dynamic analysis. [2]

Calculating the mean residence time of the label in sub-surface carbon pools will help to understand the fluxes among belowground carbon pools and could serve as a calibration method for models describing sub-surface carbon fluxes and stable carbon isotope dynamics in wetlands and other ecosystems.

Research goals:

1. Investigate the interconnections of sub-surface carbon pools
2. To quantify sub-surface carbon fluxes in a tundra wetland

Hypotheses:

1. The labelled atmospheric C can be detected in three belowground carbon pools (DIC, DOC, CH_4) after application of an quick-assembled robust in-situ ^{13}C labeling experiment
2. Sub-surface carbon pool fluxes can be described with this information

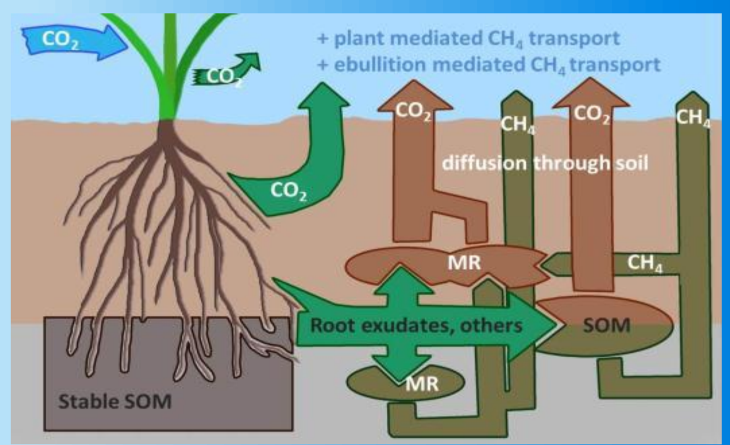


Fig 1: Simplified conceptual model of interconnected sub-surface carbon fluxes and how they are linked to the atmosphere

Methods and Analysis

Fig 3: Experiment site in a low-centred polygon. T-shaped boardwalk for sensitive labelling and sampling.

Fig 2: Polygonal tundra on Samoylov island, Lena river delta, eastern Siberia

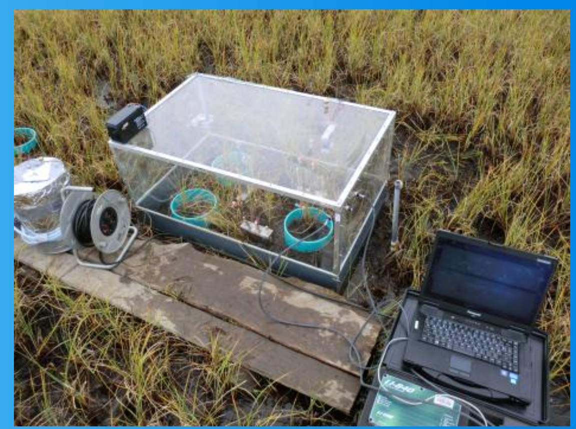


Fig 4: Home-made robust labelling set-up. The chamber and its PVC frame close the label system hydraulically from the environment

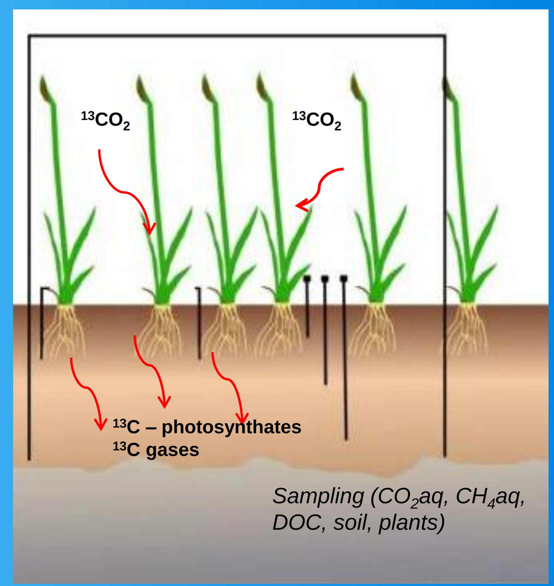


Fig 5: Pathway of labelled atmospheric carbon into belowground carbon pools. It is assumed that the plants are the only way for atmospheric C into soil due to a photosynthetic active layer of mosses directly on the water/soil surface. The site is chosen to have the water level and the soil surface on the same level, in order to avoid creation of variations due to changing water levels.

Labelling: Two pulses (3.2 and 5 hours (August 2013), about 70 and 60 % ^{13}C-CO_2

Sampling: Daily since one day after experiment (DOC, $CO_{2\text{-}aq}$, $CH_{4\text{-}aq}$ (pore water))

Data analysis:

1. The mean residence time (MRT) of CO_2 label is representative for the total CO_2 pool (due to fast turnover rate of the labelled pool).
2. Methane is produced from DOC and DIC. Analysis of fraction of DIC-C and DOC-C in CH_4 with stable isotope-mixing models

The assumed C pool dynamics:

CO_2: stationary flow through the pool (with daily variations) DOC, old DOC (SOM) and CH_4, and root respiration are sources

CH_4: affected by CO_2 and DOC (CO_2 prior calculated by Stable Isotope Mixing Model)

DOC: affected by root exudates, dead root cells and old soil carbon

Results

Prelimanry results:

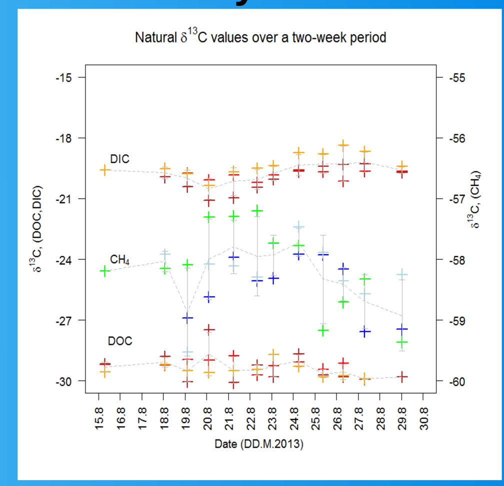


Fig 6: Natural background $\delta^{13}C$ values of DIC, DOC and methane

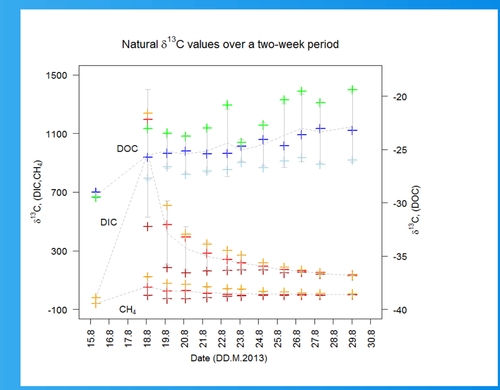


Fig 7: $\delta^{13}C$ of labelled DIC, DOC and methane

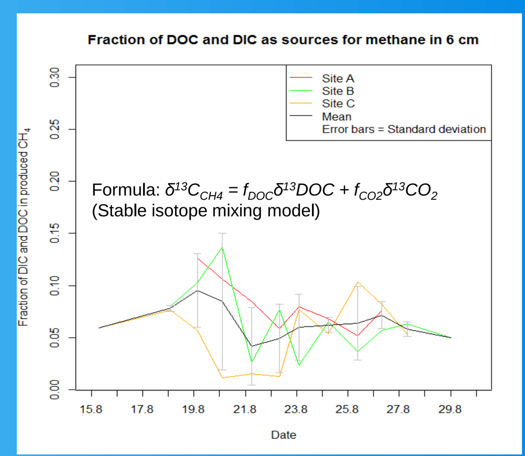
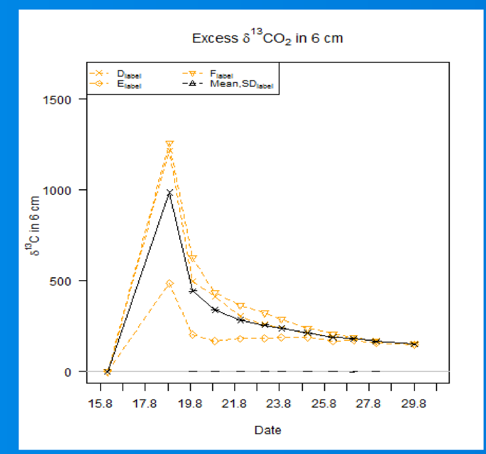
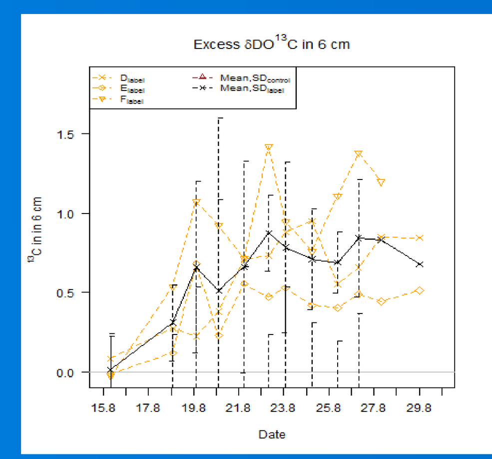
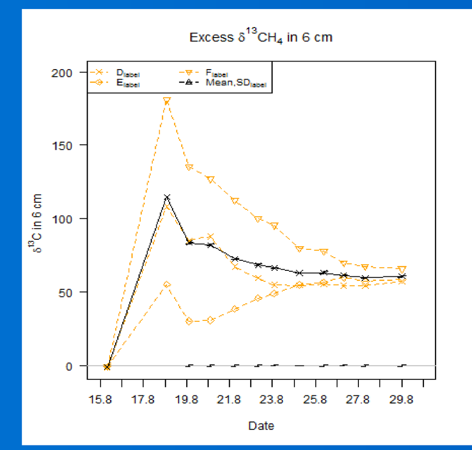


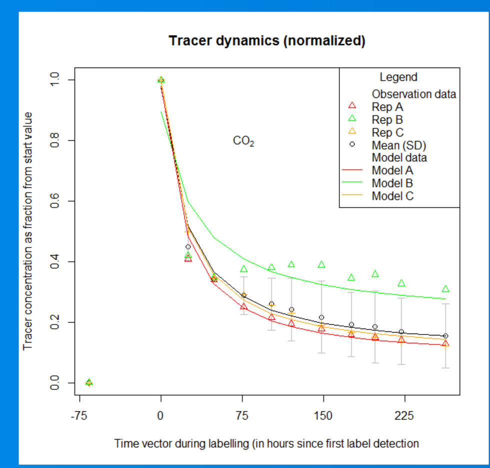
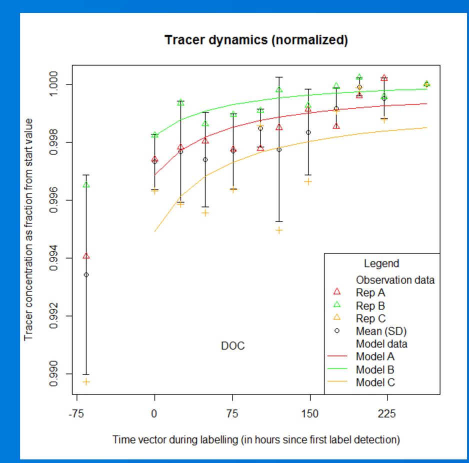
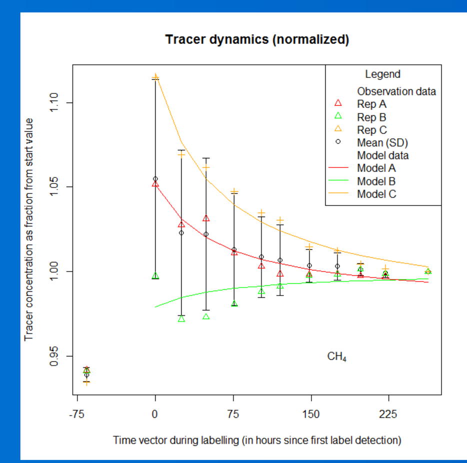
Fig 8: Fraction of CH_4-C that is produced by CO_2 reduction (~6 %). Based on natural $\delta^{13}C$ values.

DIC and DOC carbon pools (directly affected)

CH_4 carbon pool (indirectly affected)

Tracer dynamics in subs-surface carbon pool after pulse-labelling

Tracer dynamics normalized to first encountered tracer amount.
(Fitted model: $C_{tracer} = a\ exp(b/t)$)

MRT of CO_2 : 20.6 ± 2.6 hours
remaining pool: 17.3 ± 4 %
Mean residence time formula:

$$MRT = \frac{1}{tend - t0}\int f(t) * dt$$

How to quantify the exchange fluxes?

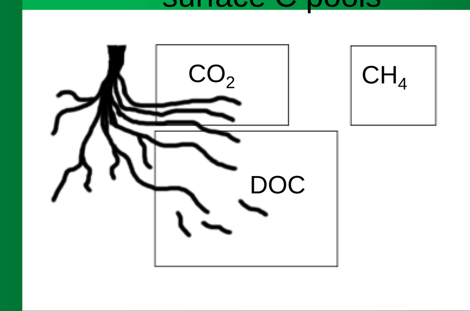
Flux estimation with a model approach

Model parametrization:

$$CO_2 = f(PAR, SoilTemp, CH_4, DOC)$$
$$CH_4 = f(DOC, CO_2, SoilTemp)$$
$$DOC = f(PAR, SoilTemp)$$

$PAR = photosynth.active\ radiation,$
$SoilTemp = Soil\ Temperature\ (Q_{10})$

Interconnections of sub-surface C pools



Summary of preliminary results:

- The tracer is found in all pools
- The tracer is found in carbon dioxide also in 36 cm depth
- In CO_2 and CH_4 the tracer overprints the small daily variations of $\delta^{13}C$ ratio, in DOC the $\delta^{13}C$ value is slightly increased by tracer
- After normalizing tracer concentrations of CO_2 and DOC the replicas show a similar pattern over time, CH_4 does not
- Estimation of exchange fluxes with a model approach
- Parameters as the MRT of CO_2 and the fraction of CO_2-C in CH_4 are valuable information for the model approach

Take Home:

^{13}C labels belowground C-pools

Flux estimation needs a model approach

Outlook

- Setting up a model that describes the sub-surface carbon fluxes and which will be calibrated using this experiment`s data

Literature: **[1]** Schuur et al. 2013, *Expert assessment of vulnerability of permafrost carbon to climate change*, Climate Change, 19, 359-378). **[2]** Kuzyakov & Gavrichkova 2010, *REVIEW: Time lag between photosynthesis and carbon dioxide efflux from soil: a review of mechanisms and controls*, Global Change Biology, 16, 3386-3406.