ARCTICFIRE

Long term effects of fire on carbon and nitrogen pools and fluxes in the arctic permafrost and subarctic forests

Academy of Finland ARKTIKO Research Programme
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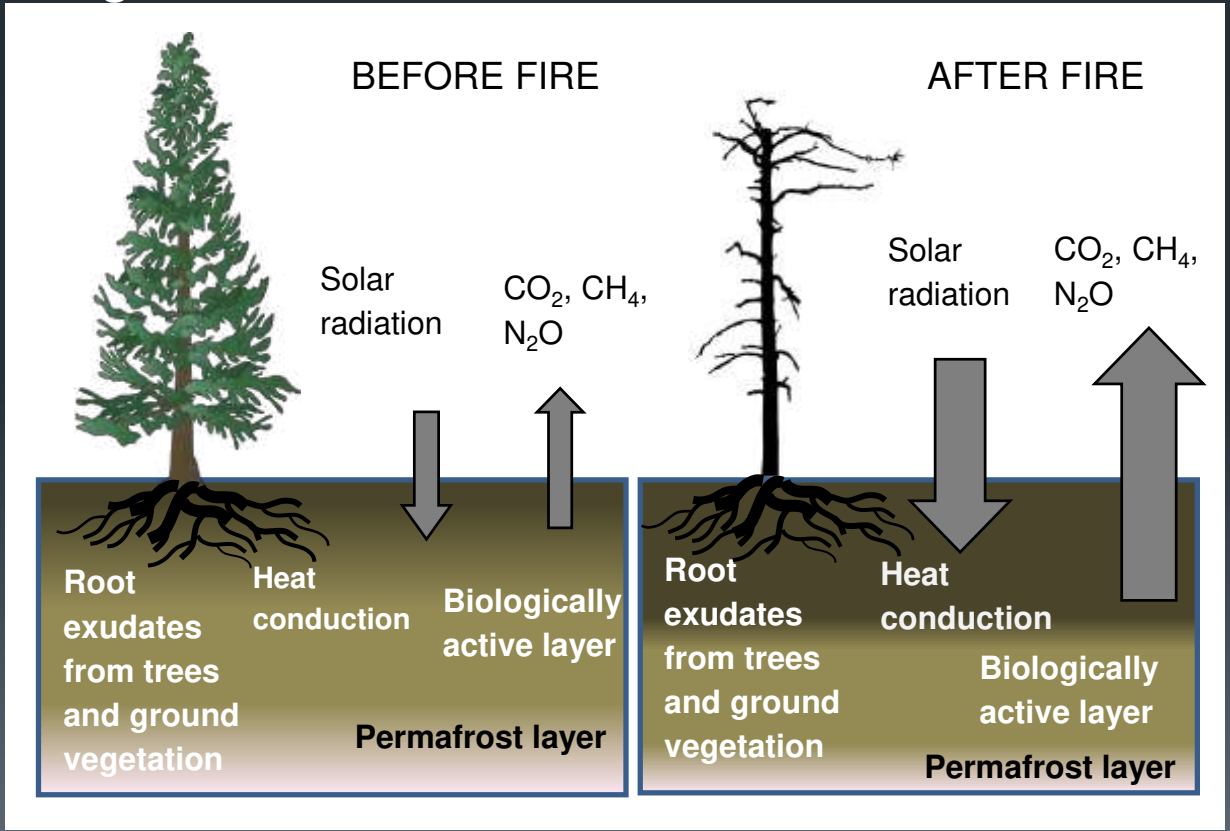
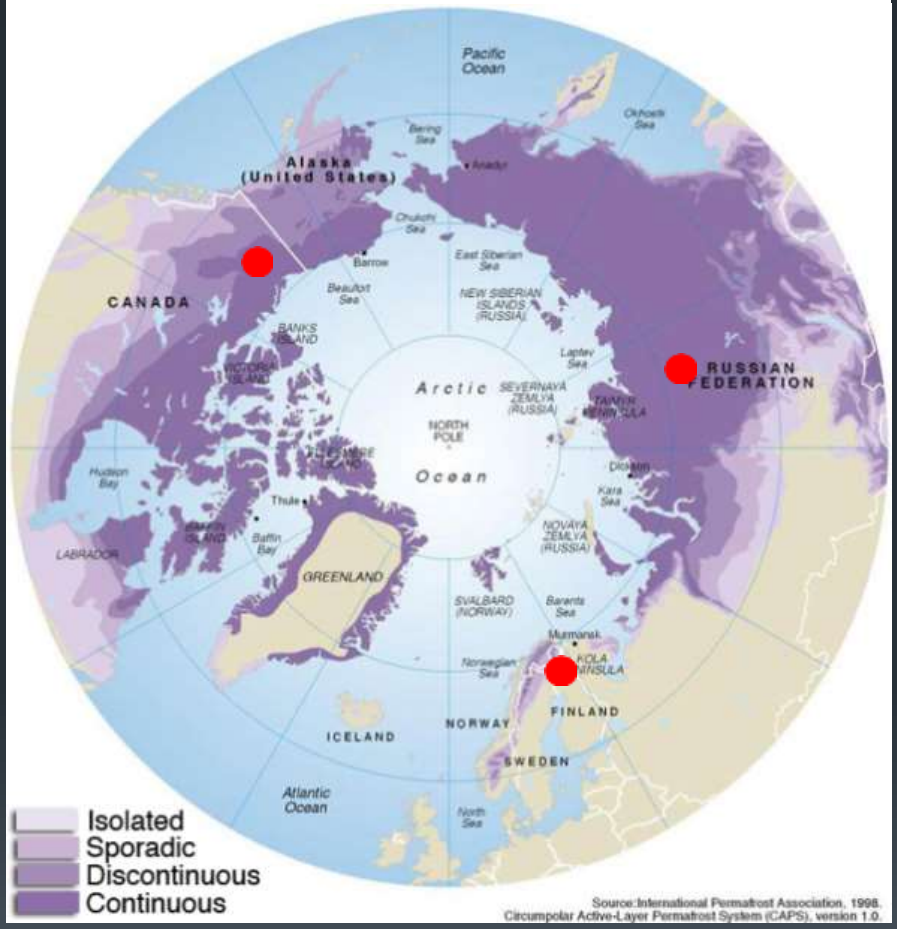
MAIN HYPOTHESES

- Forest fire changes the energy balance of soil
- Depth of biologically active layer increases
- Microbial activity increases
- Increasing greenhouse gas fluxes



Boreal forest biome

Permafrost area



● Study areas

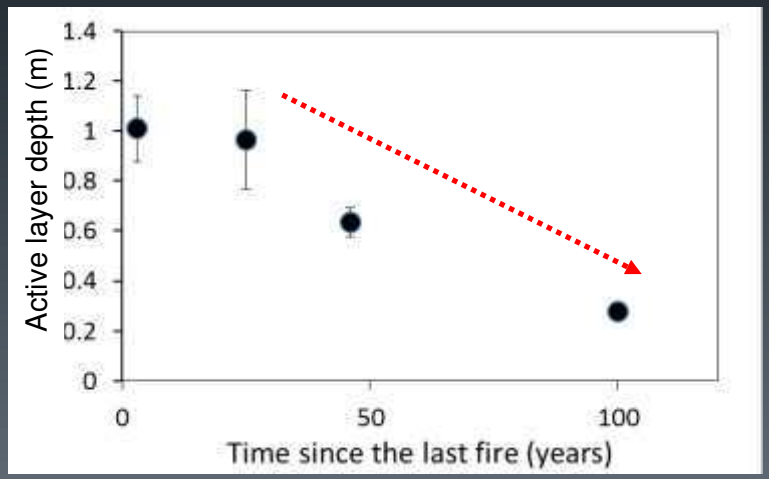
Fire chronosequence in Yukon and Northwest territories

- 2 fire chronosequences;

  Permafrost soil

  Non-permafrost soil

- Fire ages: 3 years, 25 years, 50 years and ~100 years since the last fire



Fire chronosequence in Siberia, Tura

Fire chronosequence

Russia,
Tura

Couple of years after fire

More than 40 years after fire

More than 120 years after fire

Canada,
Dempster HW

METHODS

Field

- Greenhouse gas fluxes
- Carbon and nitrogen stocks
- Tree + vegetation biomass
- Permafrost depth + T + SWC profile

Laboratory

- Soil organic matter (SOM) was separated to easily decomposale and recalcitrant fractions by using water (H_2O), ethanol (EtOH) and sulphuric acid (H_2SO_4).
- ^{13}C, ^{15}N and FTIR
- Microbial biomass (chloroform fumigation extraction)
- Fungal species composition (next generation pyrosequencing)
- Functional gene arrays (GeoChip) -> information on the activity of genes encoding decomposing enzymes and nitrogen uptake

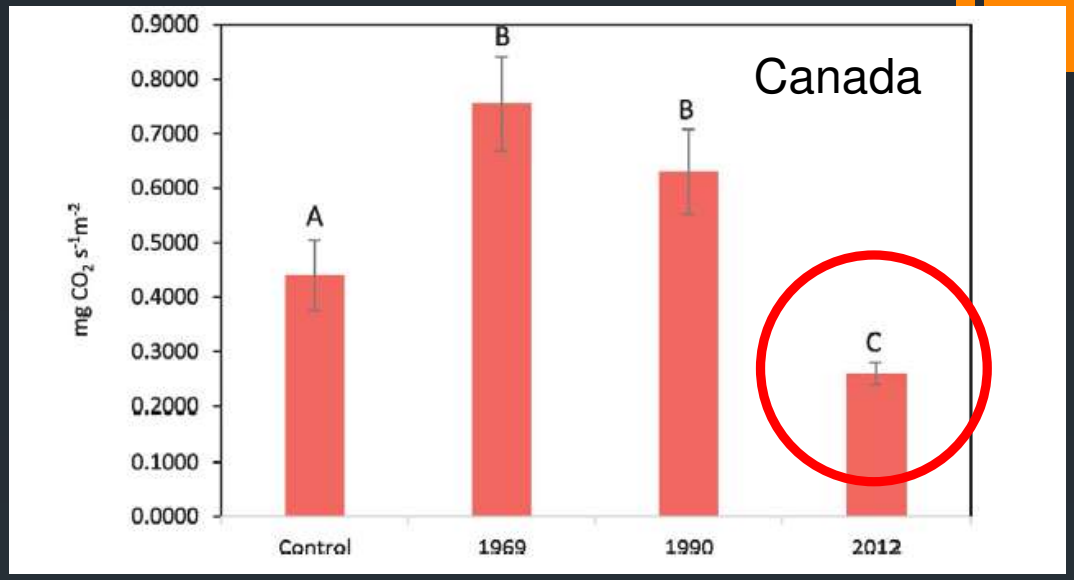
Modeling

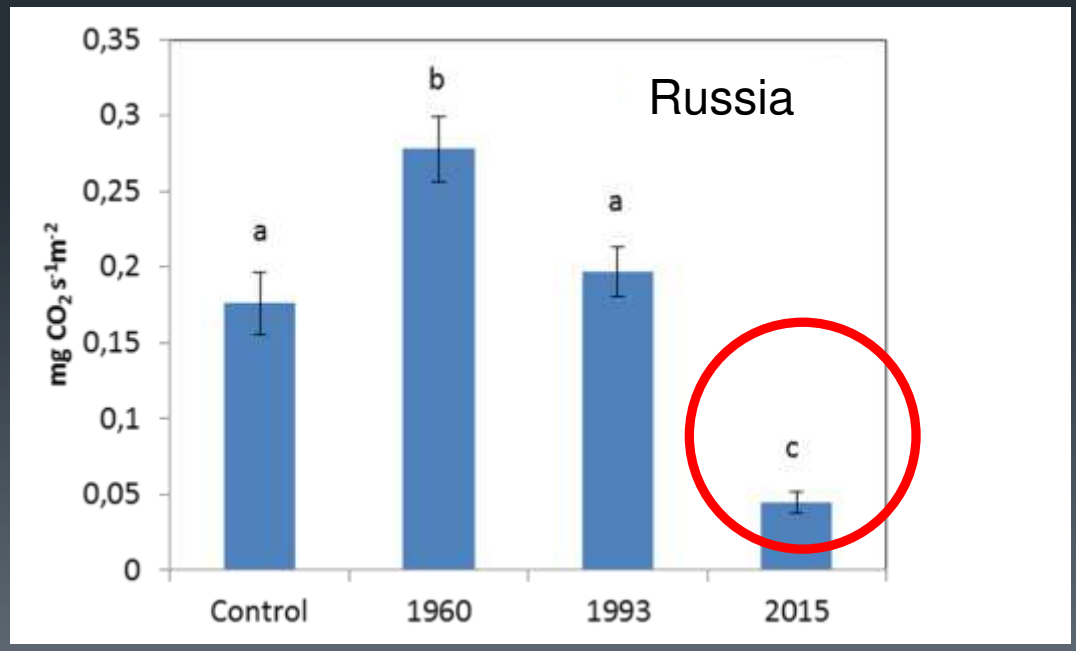
- Process based model for for predicting the effects of increasing fire frequency on soil carbon stocks and greenhouse gas fluxes

Methods

Fire effects on soil CO_2 and CH_4 efflux on permafrost soil

- Fire decreased soil CO_2 efflux both in Canada and in Russia.



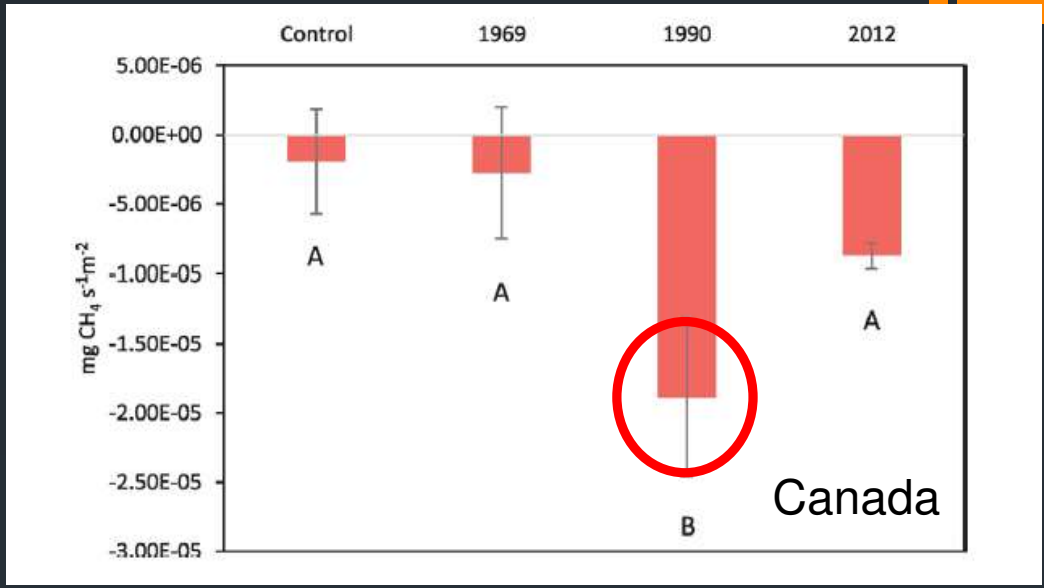


Köster E., Köster K., Berninger F., Aaltonen H., Zhou X. and Pumpanen J. 2016. Carbon dioxide, methane and nitrous oxide fluxes from a fire chronosequence in subarctic boreal forests of Canada. Science of the Total Environment 601-602: 895-905.

Köster E. et al. Changes in greenhouse gas fluxes caused by fire in Siberian boreal forest with continuous permafrost. Journal of Environmental Management. Accepted.

Fire effects on soil CH_4 efflux in permafrost soil

- In Canada, the CH_4 uptake was significantly higher in the area burnt in 1990.



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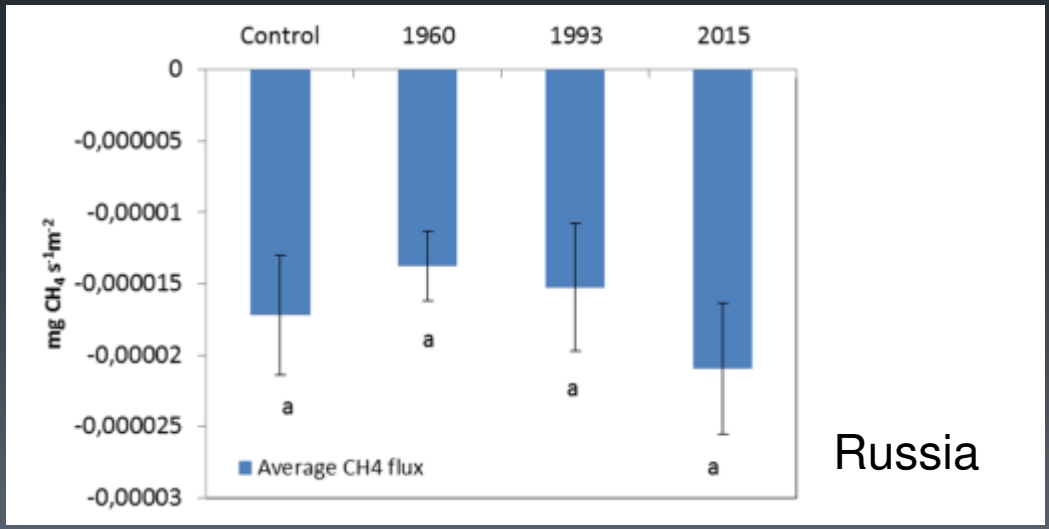
- In Russia, all areas were sinks of CH_4. No significant difference between the sites.



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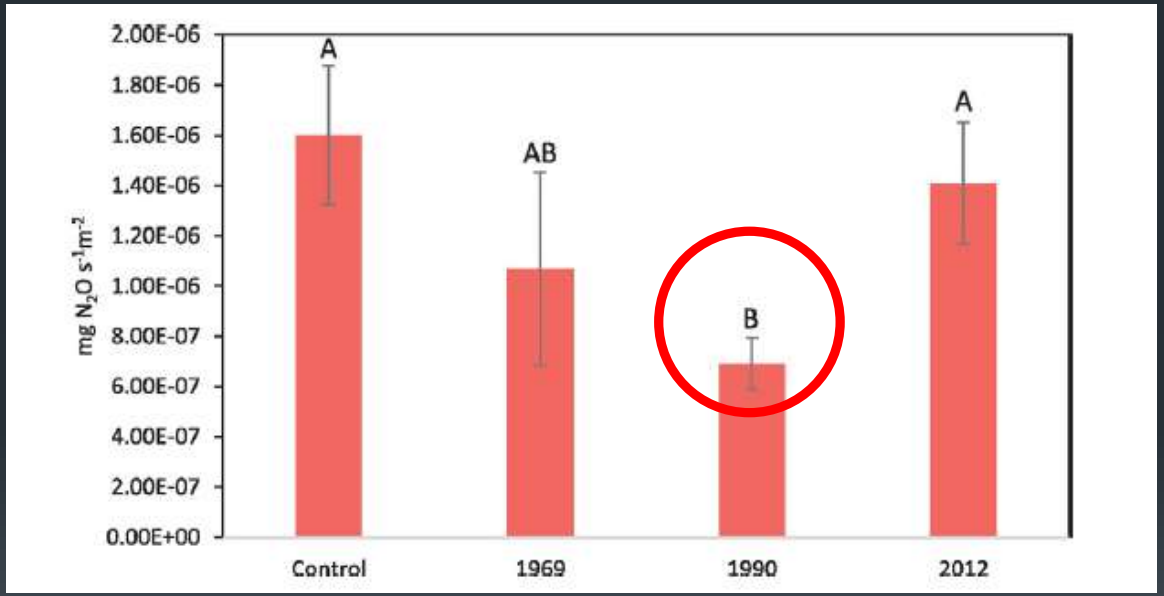
Fire effects on soil N_2O efflux on permafrost soil

- N_2O flux was significantly lower in the 1990 burnt area.



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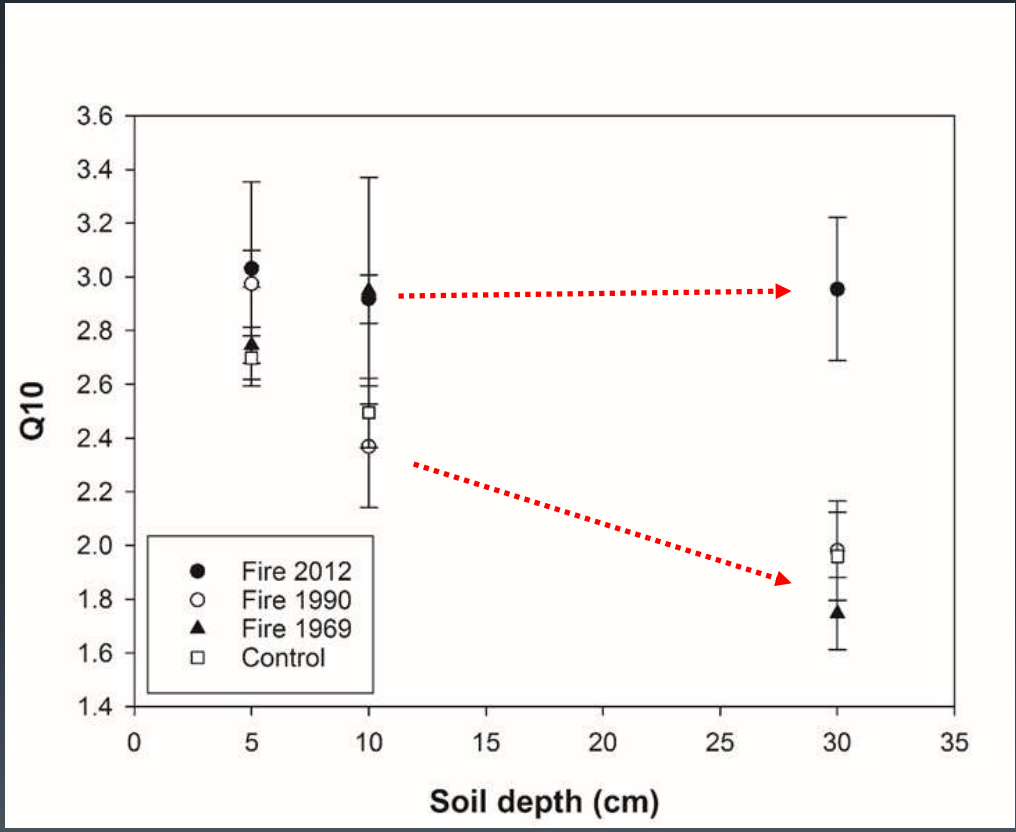
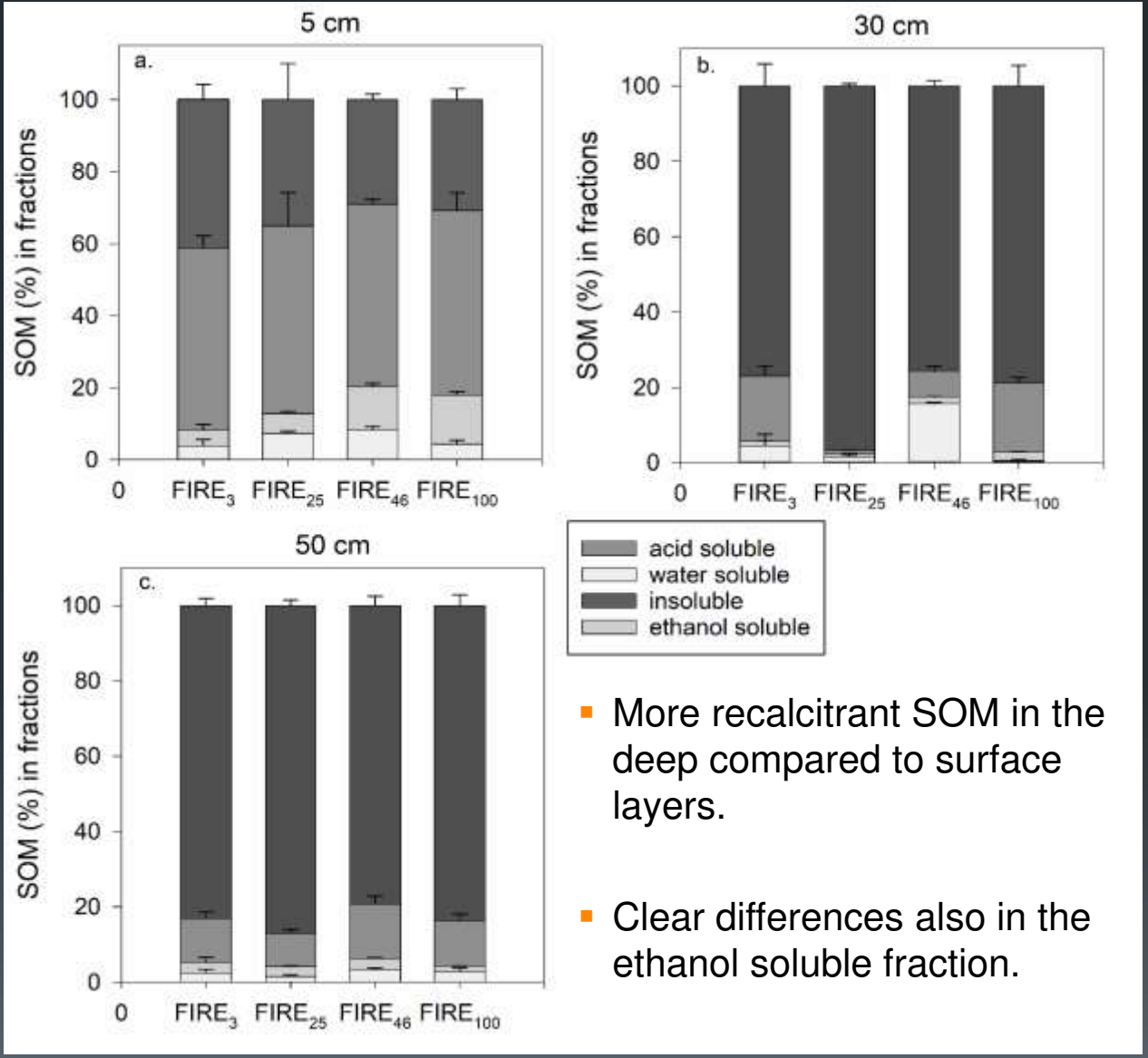
Effect of permafrost thawing on temperature response of decomposition, Aaltonen et al.

- Fire increased the temperature sensitivity of decomposition (Q_{10}) at 30 cm the 3 years ago burned.
- At 5 and 10 cm depth the Q_{10} values were similar in all fire ages



Aaltonen H., Palviainen M., Köster K., Köster E., Berninger F. and Pumpanen J. 2017. Temperature sensitivity and decomposition of soil organic matter over a forest fire chronosequence in Canadian permafrost region. Journal of Environmental Management. Submitted.

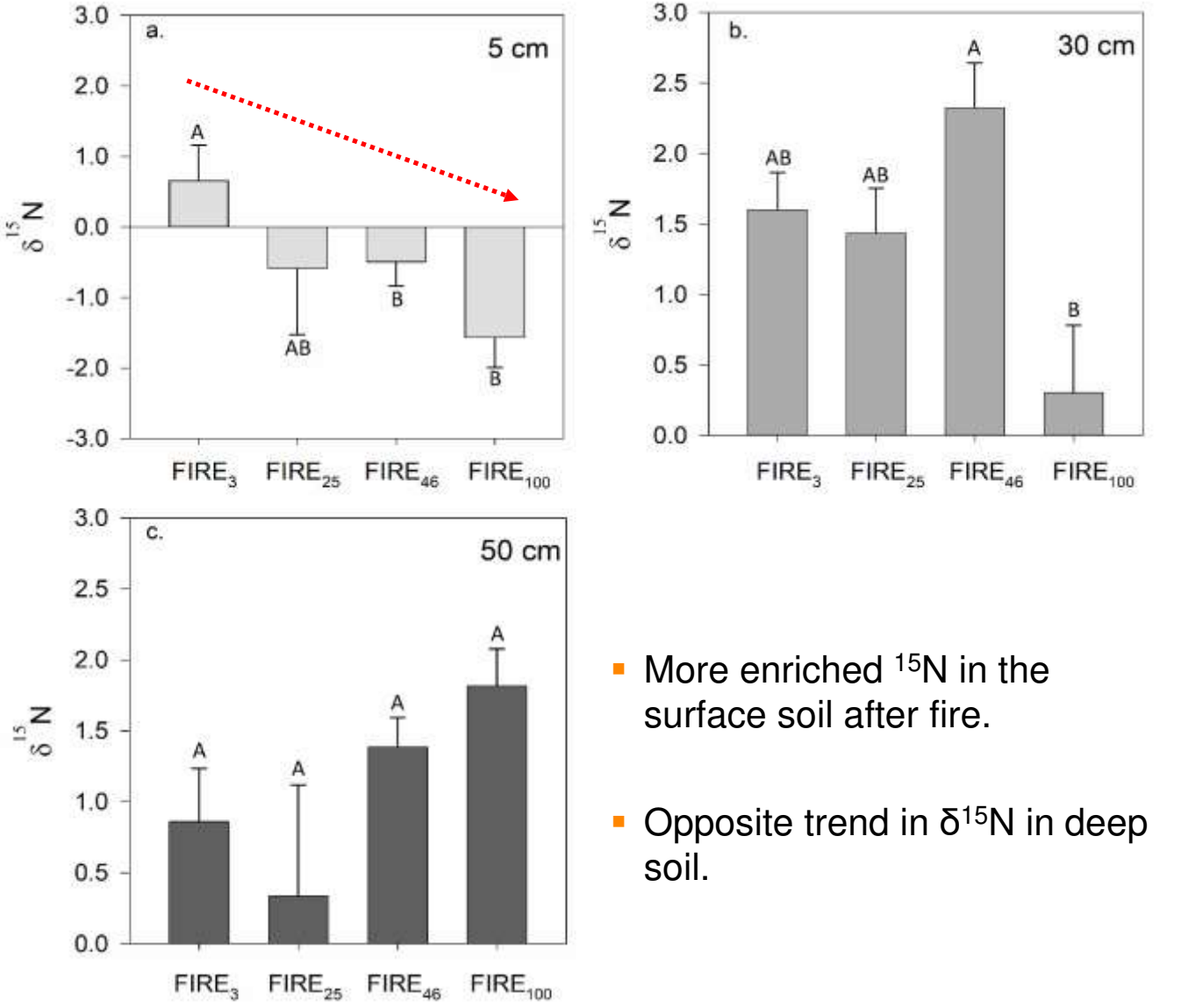
SOM fractionation, Aaltonen et al.



- More recalcitrant SOM in the deep compared to surface layers.
- Clear differences also in the ethanol soluble fraction.

Biogeochemistry. Submitted.

^{15}N isotopes in soil

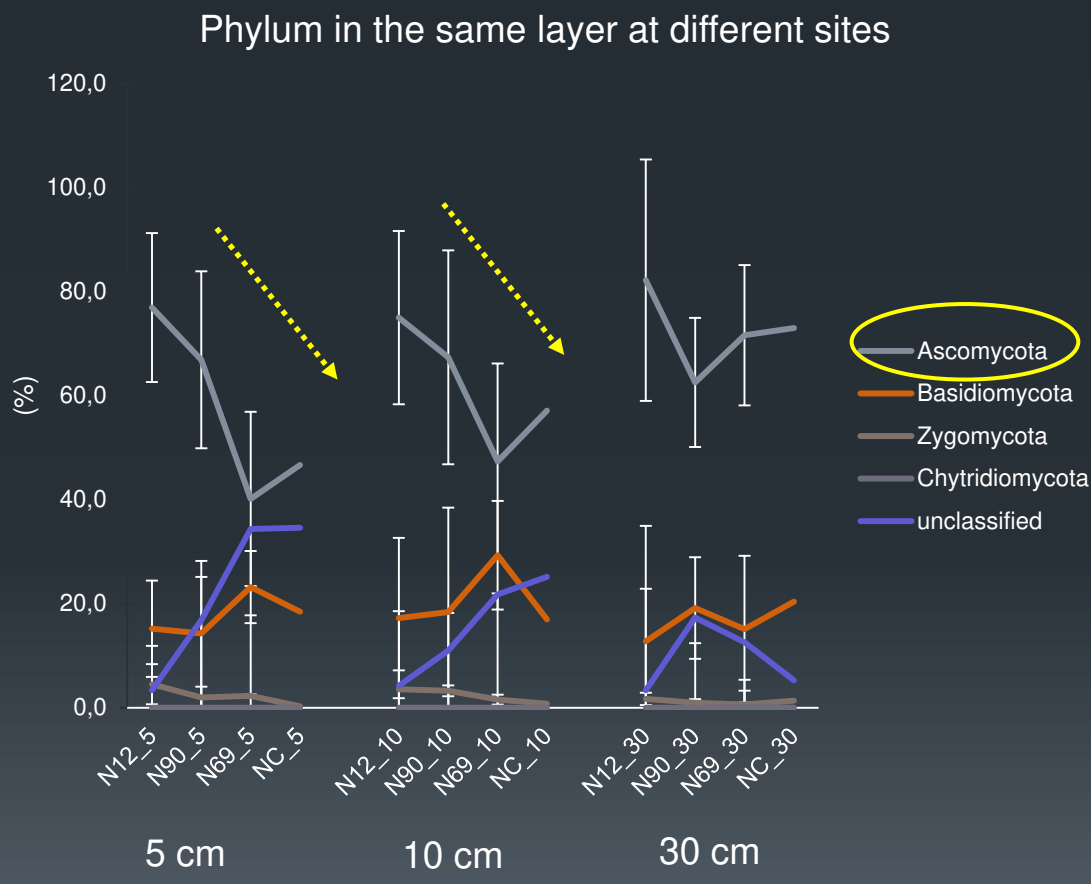


- More enriched ^{15}N in the surface soil after fire.
- Opposite trend in $\delta^{15}N$ in deep soil.

Biogeochemistry. Submitted.

Fungal diversity and community structure

- Ascomycota were the most abundant group (64%) followed by Basidiomycota (18%), Zygomycota(1.6%) and rare Chytridiomycota (< 0.01%).
- Unclassified fungi accounted for 15.9% of the sequences.
- Ascomycota was the most abundant in the recently burned site (burnt in 2012) in each layer.



Summary

- Permafrost mineral soils were sources of CO_2 and N_2O. Soil CO_2 emissions decreased after fire.
- Permafrost mineral soils were generally CH_4 sinks.
- Fire seemed to increase the CH_4 sink.
- Fire increased the temperature sensitivity of decomposition of soil organic matter in deep soil layers.
- Fire decreased the amount of labile carbon in soil surface.
- SOM in permafrost soils in this area seems to be very recalcitrant.
- Even if permafrost thaws, the scale and rate of C emissions might be smaller than thought in the upland mineral soils on permafrost.
- Fire results in large changes in soil microbial species composition and isotopic signature of the soil surface.

Thank you !