Microbial to landscape perspectives on large N_2O emissions from bare peat soils in Arctic tundra

Christina Biasi[1], Jenie Gil[1], Maija Marushchak[1], Tibisay Perez[2], Katharina Palmer[3,4], Marcus Horn[3], Dima Kaverin[5], Katarina Diakova[6], Hana Santruchkova[6], Tatiana Trubnikova[1], Henri Siljanen[1], Ricardo Alves[7], Christa Schleper[7], Andreas Richter[7] and Pertti Martikainen[1]

1) University of Eastern Finland, Finland 2) Laboratorio de Química Atmosférica., Venezuela 3) University of Bayreuth, Germany 4) University of Oulu, Finland 5) Institute of Biology, Komi Science Center, Russia 6) Faculty of Science, Czech Republic 7) University of Vienna, Austria

Introduction

Nitrous oxide (N_2O) is a strong greenhouse gas responsible for global warming. The soil contributes with about 70% to the global annual emissions of N_2O, with tropical and agricultural soils accounting for the largest part. Previously, it was believed that arctic soils are negligible within the global N_2O budget due to the nitrogen limited nature of this ecosystem. It was thus surprising, when recently **exceptionally large N_2O hotspots were discovered from tundra[1]**. The emissions derive from patches of bare peat (peat circles) on permafrost peatlands which develop through frost action, and are among the highest ever found from any natural soil.

Fig 1. a. Map of Komi Republic, with approximated location of the field research site, source: http://www.veche.net/eng/komi.html **b.** satellite image (Google Earth) of tundra landscape in northern Russia (Komi Republic). **c.** Picture of the tundra peat circle from the actual field research site.

Research Questions

1) Which microbial/chemical processes contribute to the N_2O production in the peat circles?
2) Which are the key environmental factors controlling the high N_2O emissions from the peat circles?
3) Does the microbial community structure control the N_2O emissions?
4) What is the spatial variability of N_2O hotspots in tundra?
5) How important is N_2O for Arctic systems?

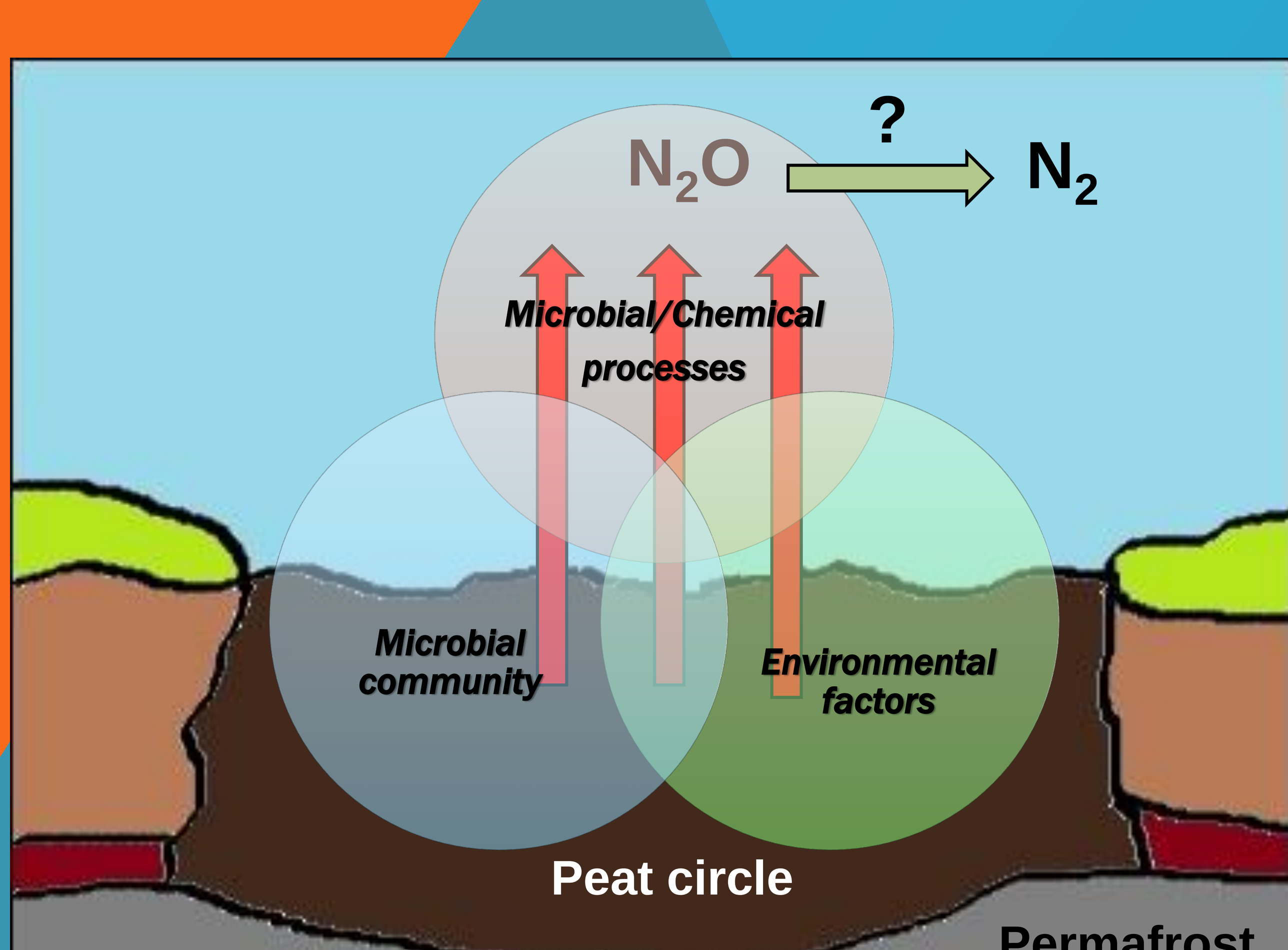

Fig 2. Hypothesized processes and factors responsible for the N_2O emission in tundra peat soils, the basis for the research questions in this project.

Results and Discussion

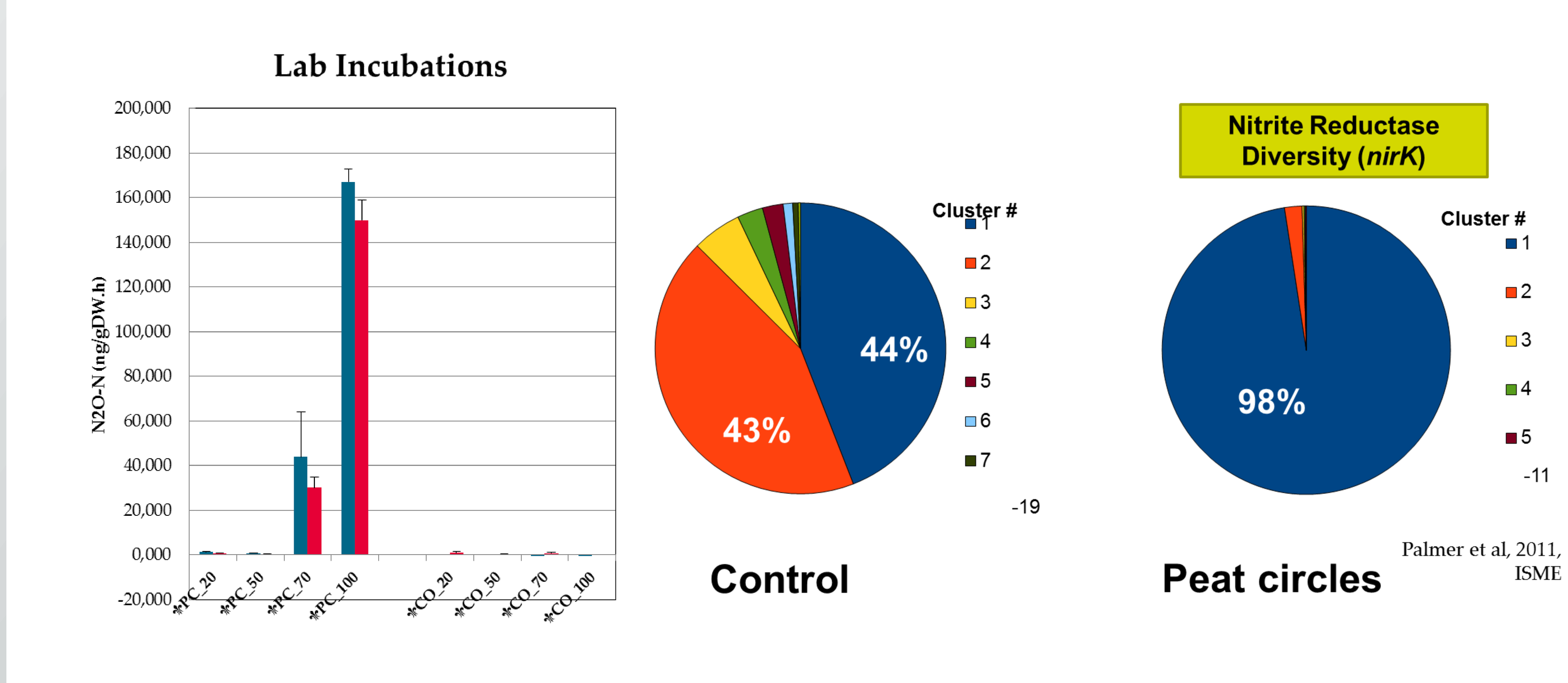

Fig. 3 A (left): Results from laboratory incubations with bare peat soil (peat circles; PC) and soil from vegetated surrounding peat (Control, CO). Red bars indicate + acetylene treatment (at low pressure), blue bars – acetylene. 3B (right): Composition of structural gene *nirK* in peat circles and controls (Palmer et al., 2011).

- Laboratory incubation experiments reveal that N_2O emissions increase significantly with increasing soil water content, indicating that denitrification is the main process responsible for the emissions. This is supported by the finding that acetylene (given at low pressure) does not inhibit the emissions (Fig. 3A).
- The $\delta^{15}N$ values of N_2O in the soil profile (bulk and site-preference values) are indicative for denitrification, however, interpretation of the isotope signature of surface emissions is less straightforward (data not shown)
- The bare peat surfaces are characterized by a distinct, highly specialized denitrifier community (Fig. 3B; Palmer et al., 2011)
- Rough upscaling reveals that the emissions from these hot spots could amount to 0.1 Tg N_2O yr^{-1} (or +31 Tg CO_2-e yr^{-1}; Fig. 4), corresponding to ~5% of warming potential of CH_4 and ~7% of cooling potential of CO_2 (Repo et al. 2009; McGuire, 2012) . **Thus, the N_2O emissions from the bare peat potentially constitute significant sources of greenhouse gases in the Arctic.**

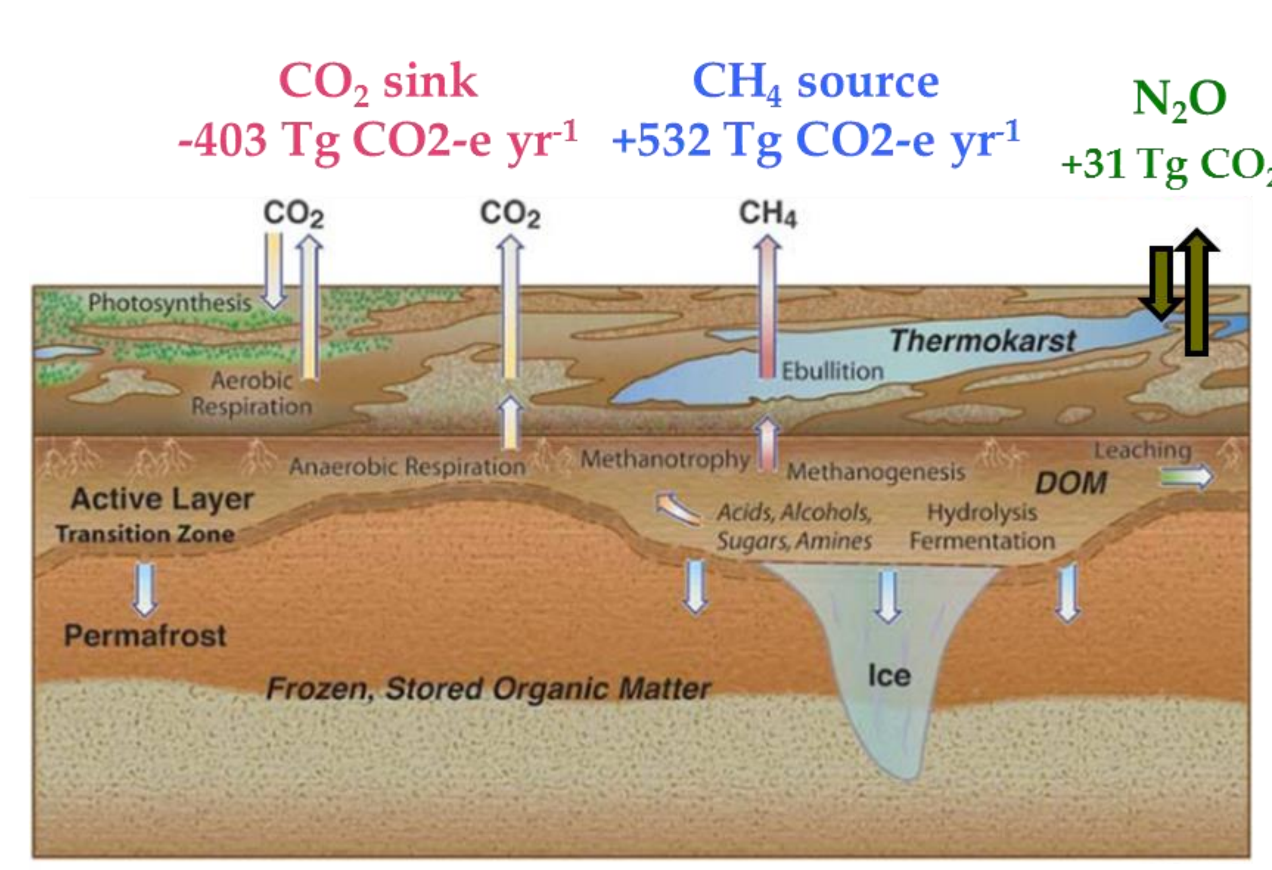

Fig.4. First estimates on source strength of the N_2O hotspots for whole Arctic (calculated as CO_2-equivalents). Data are summarized from McGuire et al. (2012) and Repo et al. (2009).

Acknowledgments

The study was supported by Academy of Finland. General research grants (decision Nr. 132045 and 287469) and Call for joint projects in Arctic research (Nr. 314630).

References

1. Maija E. Repo, Sanna Susiluoto, Saara E. Lind, Simo Jokinen, Vladimir Elsakov, Christina Biasi, Tarmo Virtanen and Pertti J. Martikainen (2009). Large N_2O emissions from cryoturbated peat soil in tundra. Nature Geoscience (2), 189-192.
2. Palmer, K., C. Biasi, and M. A. Horn (2011), Contrastingdenitrifier communities relate to contrasting N2O emission patterns from acidic peat soils in arctic tundra, *Isme Journal*, *6*(5), 1058-1077.
3. **McGuire, A.D.**, T. Christensen, D. Hayes, A. Heroult, E. Euskirchen, J.S. Kimball, C. Koven, P. Lefleur, P. Miller, P. Peylin, W. Oechel, M. Williams, and Y. Yi. 2012. An assessment of the carbon balance of arctic tundra: Comparisons among observations, process models, and atmospheric inversions. *Biogeosciences* 9: 3185-3204, doi:10.5194/bg-9-3185-2012.