Long-term dynamics of N_2O fluxes from soil, stem and canopy in a hemiboreal forest: Impact of wet and dry periods

Ülo Mander[1], Thomas Schindler[1], Kateřina Macháčová[2], Alisa Krasnova[1,3], Jordi Escuer-Gatius[3], Martin Maddison[1], Jaan Pärn[1], Gert Veber[1], Dmitrii Krasnov[3], and Kaido Soosaar[1]

[1] Dept. Geography, Inst. Ecology and Earth Sciences, University of Tartu, Estonia
[2] Global Change Research Institute CAS, Brno, Czech Republic
[3] Estonian University of Life Sciences, Inst. Agricult. & Environ. Sciences, Tartu, Estonia

Background

- Riparian zones known as hotspots of N_2O emission (Groffman *et al*., 1998; Van den Heuvel *et al*., 2009)
- Grey alder (*Alnus incana* (L.) Moench.) is a fast-growing tree species with a great potential for short-rotation forestry in the Northern and Eastern European countries, typically found in riparian zones (Uri *et al*., 2014).
- The symbiotic dinitrogen (N_2) fixation ability makes alders important for the regulation of nitrogen (N) cycle in forested areas (Huss-Dannell *et al*., 1991).
- There are few studies on N_2O emission from grey alder stands (Soosaar et al., 2011; Mander *et al*., 2014), however, no research on ecosystem-level N_2O budgets (soil and tree stem fluxes with eddy covariance (EC) measurements above the canopy) could be found.


Eddy tower in Agali grey alder forest

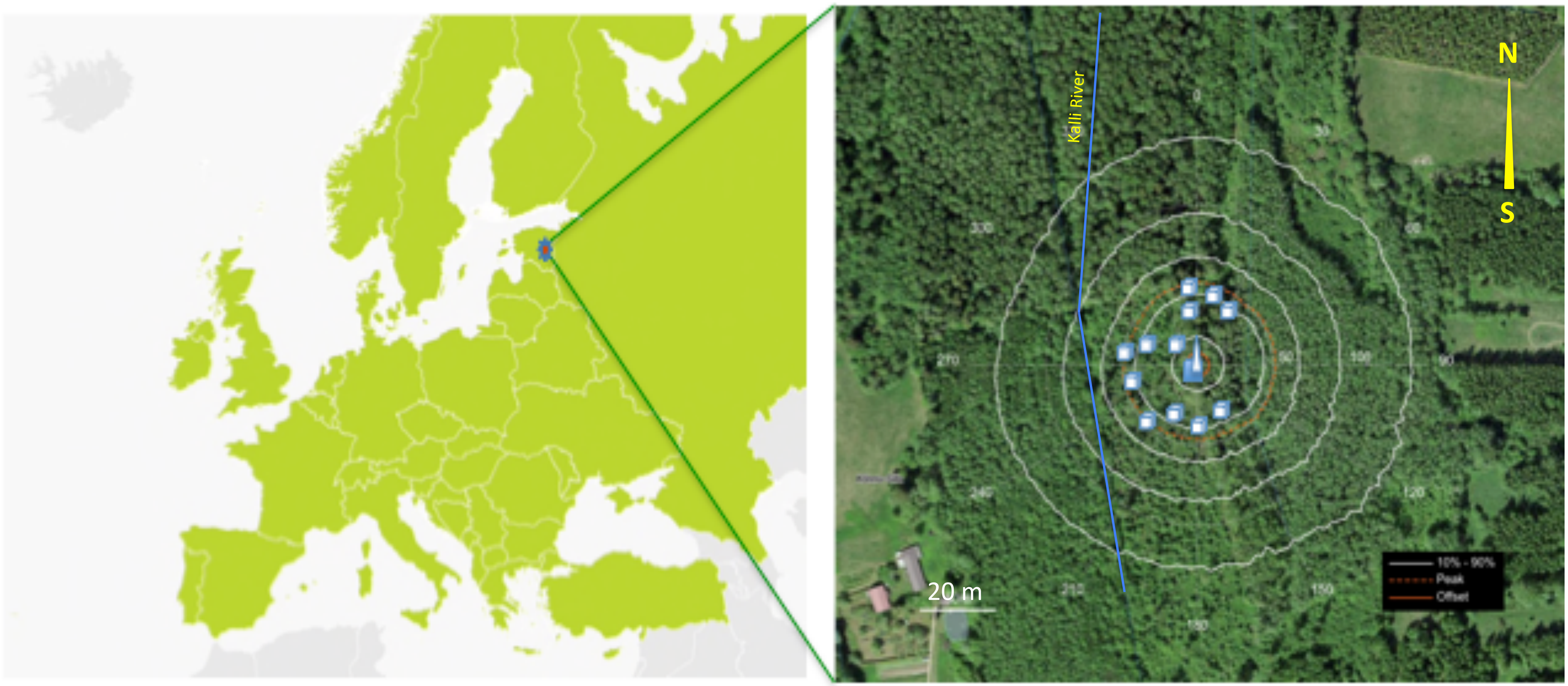

Soil and stem chambers in Agali

Objective: estimating main relationships between N_2O fluxes and key environmental factors in long-term perspective using continuous high-frequency measurements

Research setup

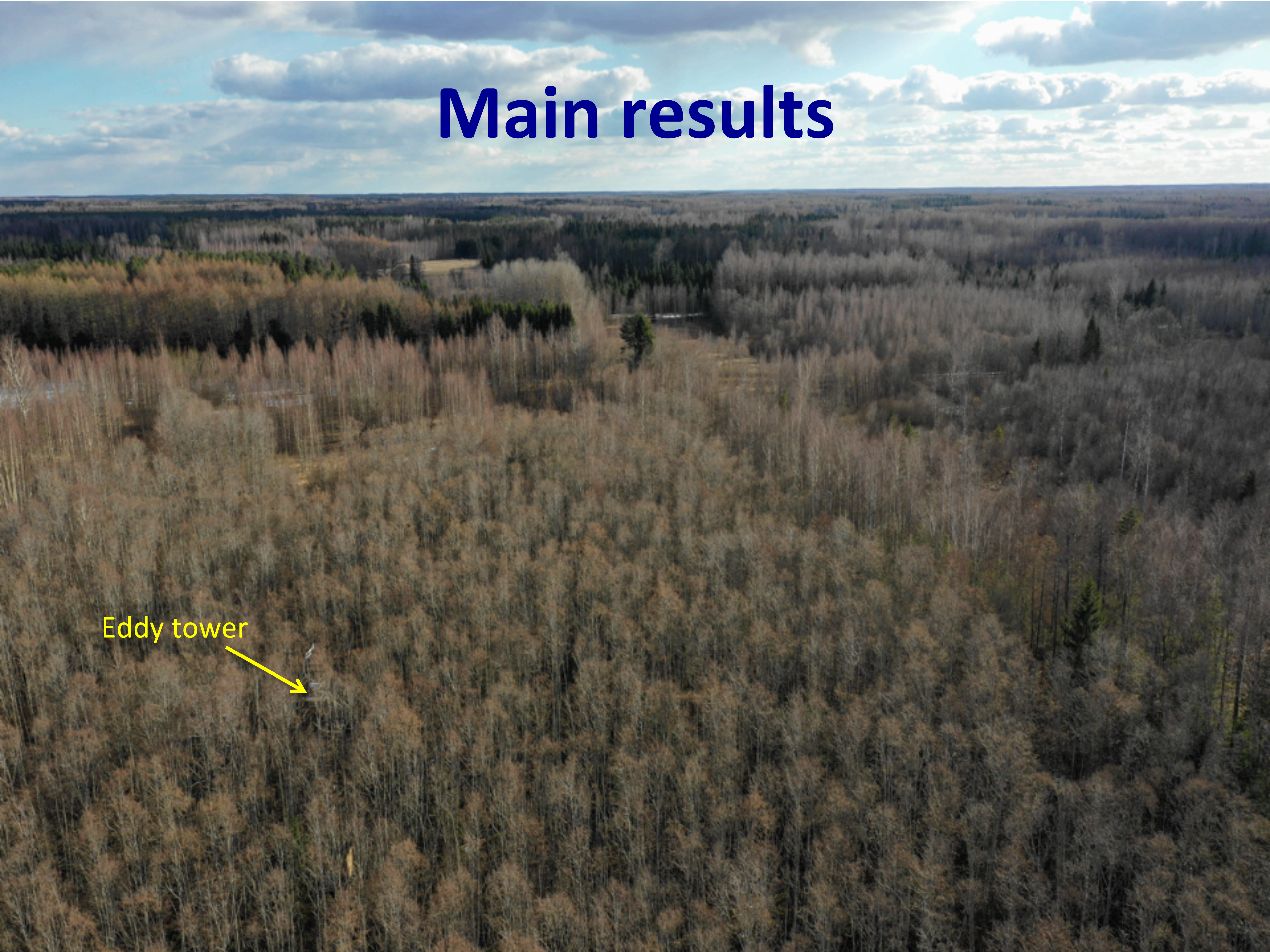
- **Study site**: 40-yrs old riparian grey alder forest stand on former agricultural land (Gleysol , Luvisol) in Agali, Eastern Estonia
- **Measurements**
  - ***Eddy covariance fluxes*** (Gill 3D anemometer on 18m eddy tower, Aerodyne quantum-cascade laser absorption spectrometer (QCLAS), ca 5Hz working frequency)
  - ***Soil fluxes*** with 12 automated soil chambers (8 opaque, 4 transparent; 0.16 m^2, 0,032 m^3) connected with multiplexer and a pump to Picarro 5280 laser spectrometer, (ca 12 measurements per chamber per day)
  - ***Tree stem fluxes*** (12 trees, at heights 0.1, 0.8, and 1.7 m from ground, two chambers per stem interconnected with tubes into one system (volume 0.00119 m^3, covering 0.0108 m^2 of stem surface, gas concentration homogenized by pump, gas sampled of 0/60/120/180 min sequence in12 mL glass vials, concentration and flux measured in lab with Shimadzu GC-2400, 62 manual sampling sessions from August 2017 until July 2018)
  - ***Potential soil N_2 flux*** measurements in lab using He-O_2 method (Butterbach-Bahl *et al.*, 1998), September 2017, August 2019)
  - ***Ancillary measurements*** of key environmental factors (meteo-parameters, groundwater level, soil volumetric water content VWC, soil temperature − continuously with automatic sensors, soil and groundwater physical- chemical parameters 10 sessions)

Location of the Agali riparian grey alder forest in Eastern Estonia and eddy tower footprint area with automated soil chambers

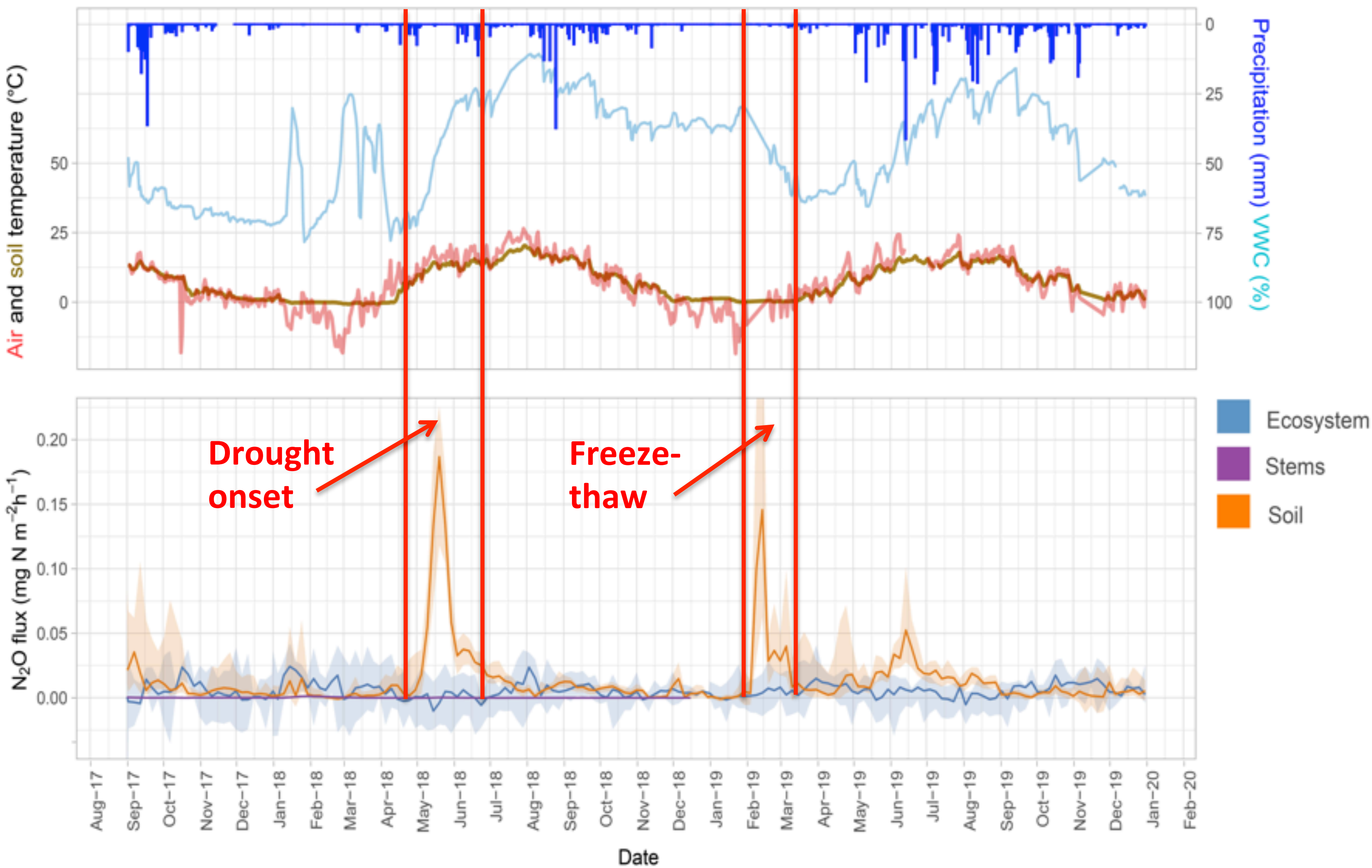


Agali grey alder forest measurement setup
Eddy tower
Eddy covariance measurements (CO_2, CH_4, N_2O)
Gill 3D sonic anemometer
49x40x20cm
Automated soil chamber
CH_4, N_2O with Picarro 2508 (12 times per chamber d^{-1})
PICARRO
Soil & stem study (CO_2, CH_4, N_2O)
Aerodyne QCLAS
Cottage
Stem chambres & a transparent soil chamber

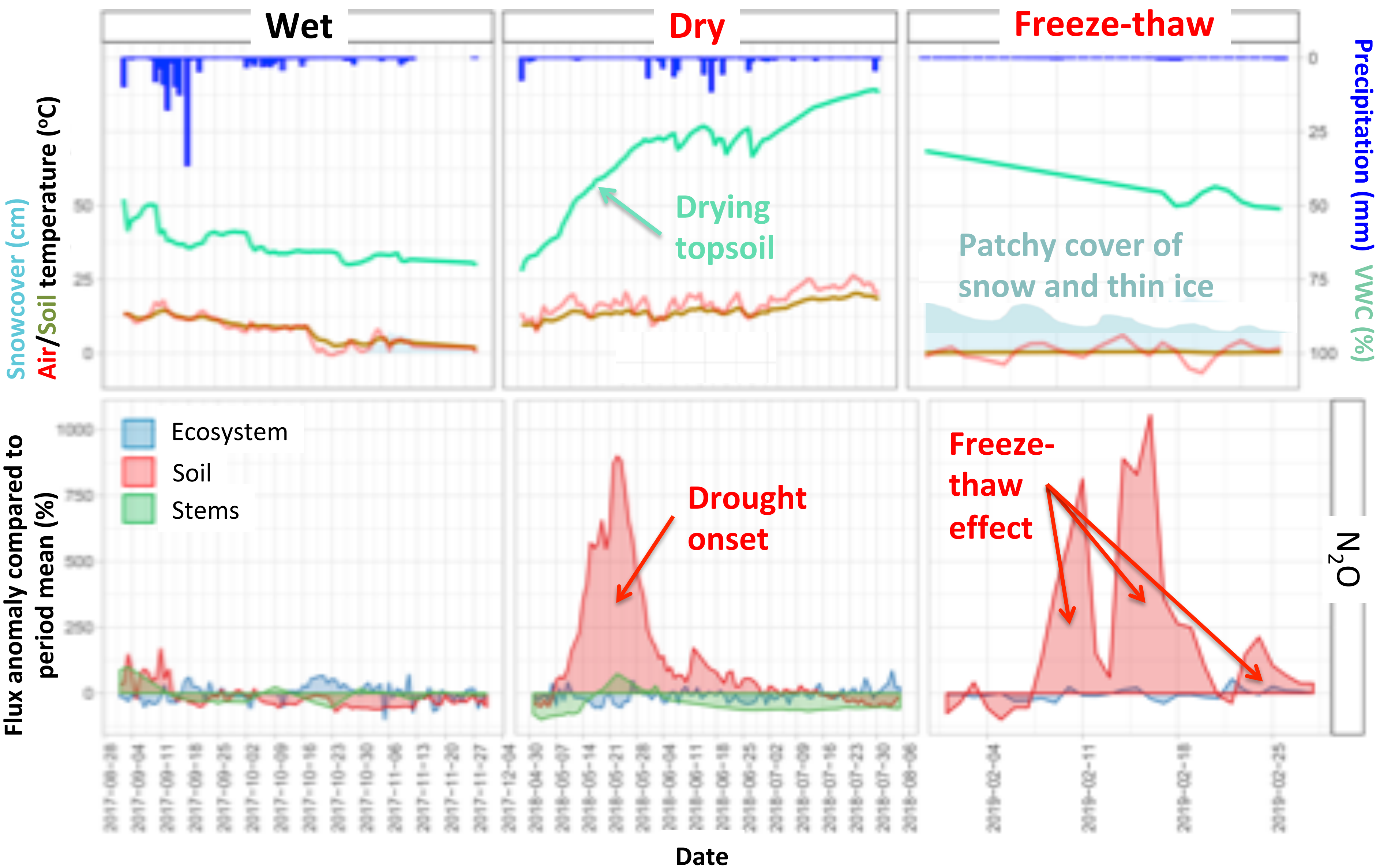
Main results



Dynamics of N_2O fluxes in the Agali riparian grey alder forest from August 2017 to December 2019



Hot moments in N_2O emission: “Dry” (1st May – 5th August 2019) and “Freeze-Thaw” (1st – 28th February 2019)



Most important outcomes

- Mean ± s.e. fluxes of N_2O during the period August 2017 to September 2019 were (kg N_2O-N ha^{-1} yr^{-1}):
  - Ecosystem (eddy covariance) - 0.43 ± 0.01
  - Soil - 1.33 ± 0.03
  - Tree stems - 0.0075 ± 0.001
- The range of N_2O fluxes from the ecosystem, soil and tree stems varied from -0.89 to 1.61, from -0.08 to 3.20 and from -0.0073 to 0.033 kg N_2O-N ha^{-1} yr^{-1}, respectively.
- The ecosystem level N_2O flux was relatively equal during the whole study period showing a slight diurnal pattern
- The maximum soil flux was found at the soil VWC of 50, peaking in two hot moments − drought onset and freezing-thawing periods, surprisingly, no increase in eddy flux was observed this time
- Stem fluxes of N_2O were low showing some increase in wet periods.
- The average annual potential N_2 flux in soil was 140 kg N_2-N ha^{-1} which made the average N_2-N:N_2O-N ratio in the soil about 60.

Acknowledgements

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