From forest to atmosphere: towards a more comprehensive assessment of BVOC exchanges in a mixed temperate forest

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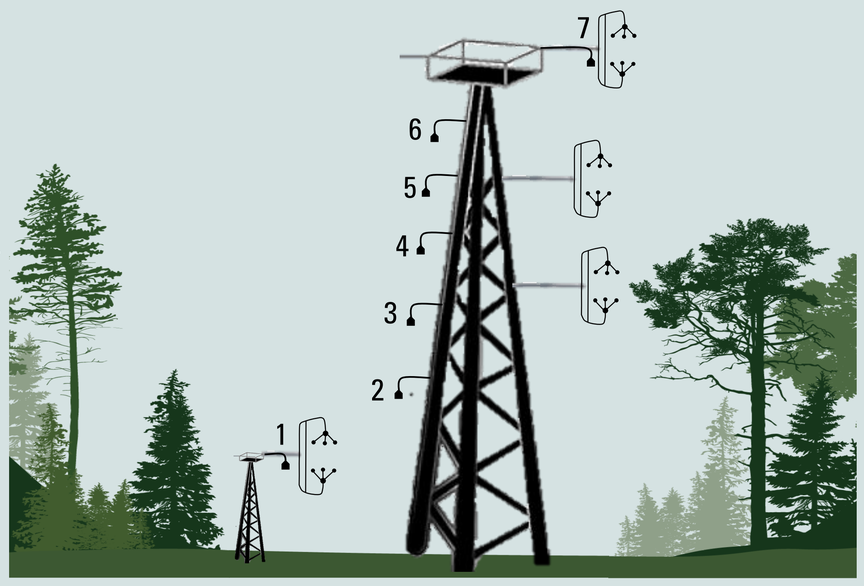
CONTEXT & OBJECTIVES

- **Forests** are **major sources** of **biogenic VOCs** (BVOCs), precursors of air quality and climate related substances (O_3, SOA).
- Forest/atmosphere BVOC **exchange** is often **bidirectional**; above canopy fluxes result from a **variety of processes** along the soil-canopy-atmosphere continuum.
- **Uncertainties** remain regarding the diversity, magnitude, and temporal variability of BVOC exchanges. A **better characterization** is needed for improved BVOC emission, air quality and climate modelling.

MEASUREMENTS AND DATA PROCESSING



Set-up

- **Site**: Vielsalm station, Belgium – mixed temperate forest with a flux tower (ICOS site BE-Vie)
- **Period:** 3-years, from Spring to Autumn
- **Fluxes:** BVOC fluxes at 51 m and 3 m above ground, measured by PTR-TOF-MS (PTR-TOF-4000) + eddy covariance
- **Profiles:** BVOC conc. (7 levels) + turbulence (4 sonic anemo.)

Processing

- Development of a new **open-source pipeline** for quantifying VOC mixing ratios and fluxes
- Identification of **51 BVOCs** with significant fluxes: low-mass oxygenated compounds, terpenoids (isoprene, monoterpenes) and oxidation products, from **m/z 31.018 – m/z 205.195**

RESULTS

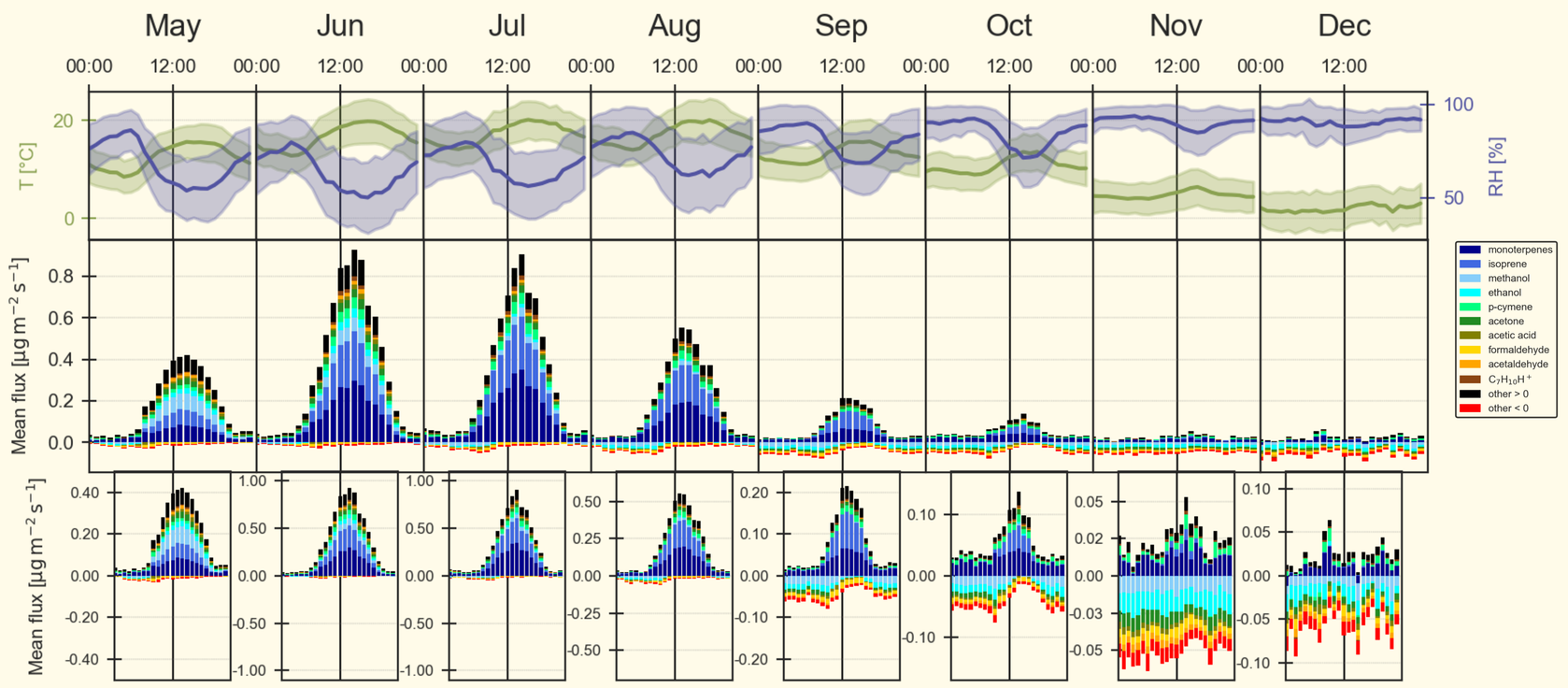


Fig1. Monthly evolution of BVOC fluxes together with two meteorological variables in 2022 – 2024. **Top panel**: mean diel profiles of air temperature and relative humidity. **Middle panel**: mean diel above-canopy fluxes of the 10 most exchanged BVOCs; remaining compounds grouped into emission (other > 0) and deposition (other < 0) categories. **Lower panel**: same as middle panel, but with a variable y-axis highlighting depositions.

A balance between emissions and depositions

Seasonal evolution

- The forest acts as a **net source of BVOCs** into the atmosphere (total BVOC emission ≈ 0.37% of CO_2 uptake)
- **Isoprenoid** emissions peaking in **summer**, **low-mass BVOC** emissions highest in **spring**
- From **autumn** onwards, emissions decline and are outweighed by **non-negligible depositions**

Diurnal evolution

- **Deposition** mainly at **night** for low-mass bidirectional BVOCs (e.g. methanol, ethanol,…) and partly enhanced by relative humidity
- Around **sunrise**: **shift from** net **sink** to net **source** for bidirectional compounds
- Different sensitivities to environmental conditions (light **(in)dependent emissions**)

Source localization : below-canopy fluxes ≈ **10%** of above-canopy fluxes (not shown)

Complex in-canopy processes

- Observed concentrations = combined effects of **emission**, **uptake**, **photochemistry**, and **atmospheric transport**
- Coupled **O_3 - NO_x** evolution: daytime NO_2 photolysis produces O_3, which is later consumed by NO
- **Ozone vertical gradient**: lowest concentrations at ground level due to **continuous deposition**
- **Isoprene profiles**: driven by daytime production, with maximum concentrations near the **canopy**
- **MVK+MACR**: markers of isoprene **oxidation**, with delayed maxima observed at higher altitudes
- Similar observations available for **dozens of BVOCs**

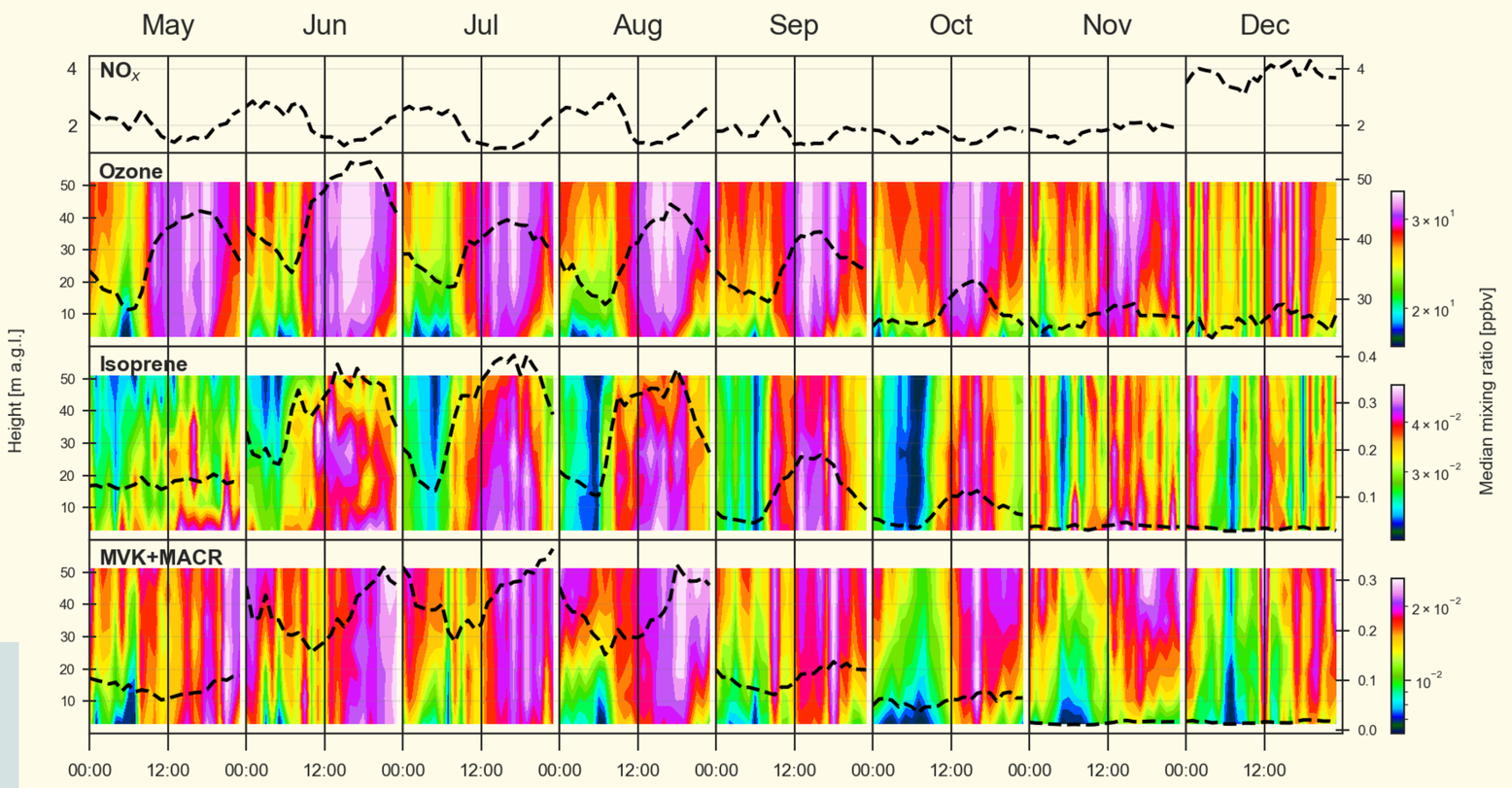


Fig2. Monthly median diel evolution of trace gas concentrations at the top of the canopy (shaded lines) and vertical profiles (contour plots) for years 2022 – 2024.

Perspectives

- Additional **vertical profiles of NO_x** concentrations: improved characterization BVOCs-O_3-NO_x interactions
- BVOC **dry deposition**: partitioning stomatal, cuticular and soil contributions using above- vs. below-canopy and daytime vs. nighttime fluxes combined with resistance analogies
- **In-canopy processes**: improved understanding of complex interactions through 1-D modelling (FORCAST)
- Vertical **localization** of **sources** and **sinks** by integration of concentration profiles and turbulence data into Lagrangian inverse modelling

Code and Data availability

These results are part of a recently submitted data paper. Open-source access is provided to the flux processing tool and to the flux and profile datasets.

PREPRINT · FLUXES · PROFILES · FLUX COMPUTATION

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