Biomass burning: An atmospheric chemistry perspective

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Motivation

Biomass burning (BB): A major driver of multiphase atmospheric chemistry

- Major global source of primary organic aerosol and reactive precursors (Fig.1)
- Rapid atmospheric oxidation leading to substantial secondary organic aerosol (SOA) formation
- Strong influence on air quality, oxidative potential, cloud processes, and climate forcing

Field observations → Real-world emission and aging conditions

Chamber experiments → Controlled investigation of oxidation pathways

Multiphase modeling → Mechanistic understanding of SOA formation

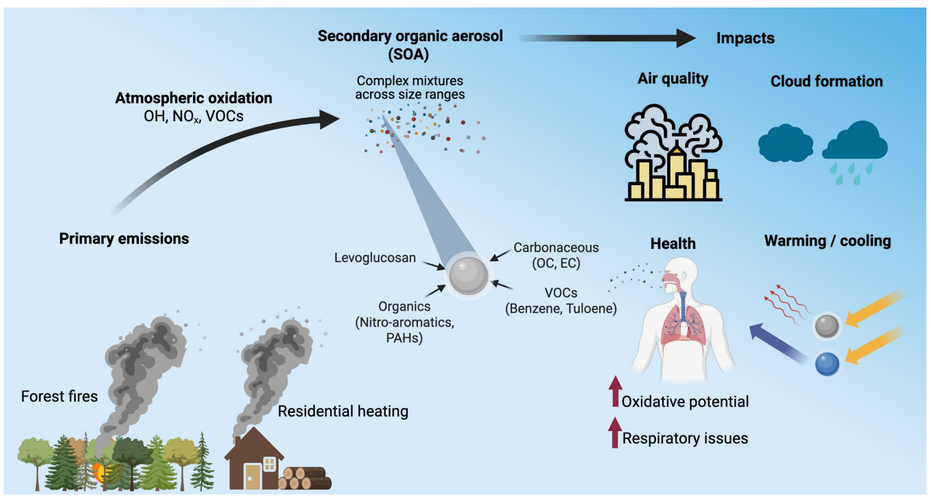

Fig. 1: Conceptual overview of biomass burning emissions, atmospheric chemical processes, and their impacts on climate, air quality, and health.

Field observations

Melpitz: Background site

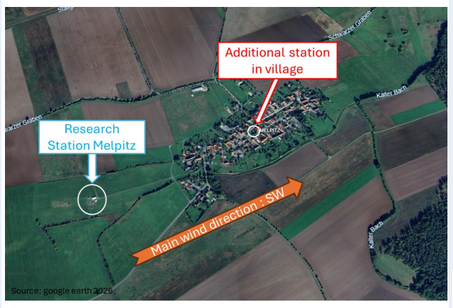

Fig. 2: Concept of the Melpitz twin-site stations

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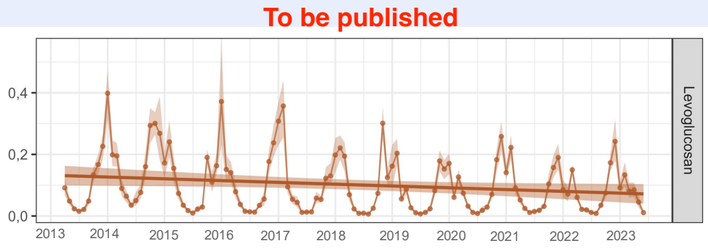

Fig. 3: Levoglucosan trend over the last decade

- **Strong seasonal** variability
- **BB** identified as a **major contributor** to **winter** PM variability
- **Slight decreasing** trend over the past decade (Fig.3)
- Winter heating increases BB-PM by 1–2 µg m^{-3} **(+55–64%)** vs. rural background (Fig.4).

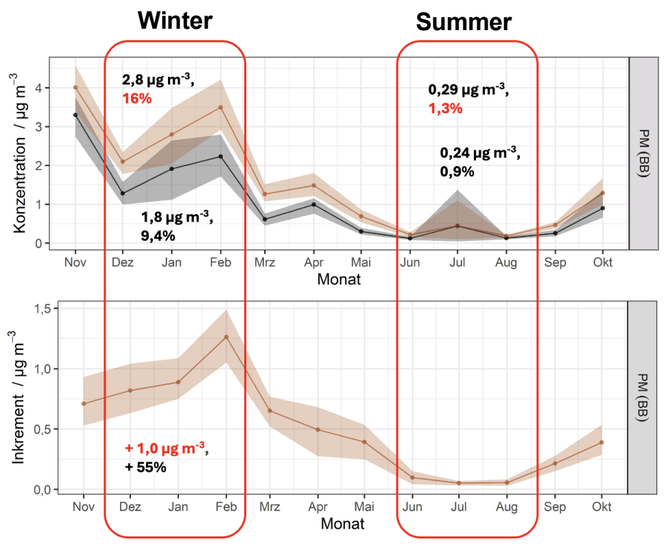

Fig. 4: Seasonal variability and local enhancement of BB aerosol at the Melpitz twin-site stations.

Radeburg: Residential biomass burning

Fig. 5: Overview of residential BB sources and field measurement setup in Radeburg

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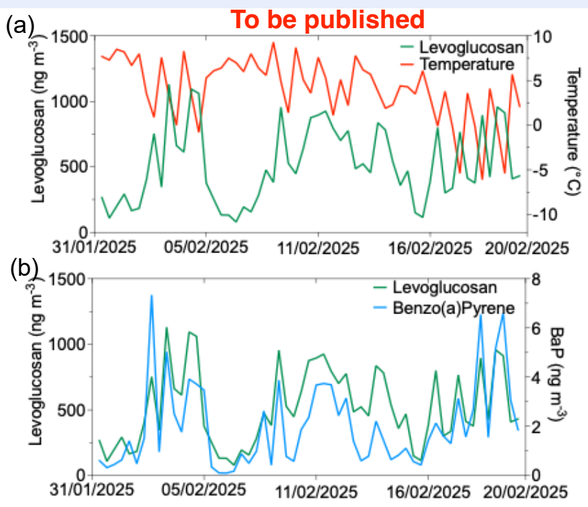

Fig. 6: Wintertime variability of BB-tracers (a) Levoglucosan and (b) Levoglucosan and benzo(a)pyrene (BaP)

- Strong BB episodes indicated by **elevated levoglucosan** (>1000 ng m^{-3})
- Similar trend with **BaP** (~7 ng m^{-3}) (Fig.6)
- Winter **PM$_1$** dominated by **organics (44%)** followed by nitrate (32%) and sulfate (14%) (Fig.7)

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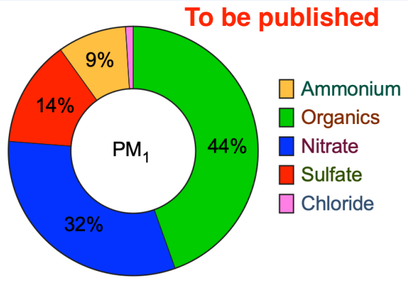

Fig. 7: Chemical composition of winter PM$_1$ at Radeburg

Chamber experiments

Experimental setup

- **Oxidation experiments** of real BB emissions from residential heating, crop burning, and wildfire fuels (Fig.8)
- **Controlled studies** of BB emissions under daytime and nighttime aging to elucidate **SOA** formation pathways

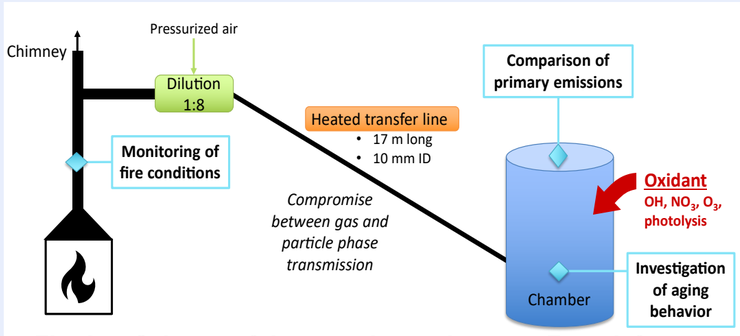

Fig. 8: Scheme of the experimental set-up. From left to right: Leibniz Biomass Burning Facility (LBBF), transfer line, atmospheric chemistry department chamber (ACD-C)

Aging experiments and mechanistic investigation

- **OH aging:** Significant OA mass increase, aged/primary OA ratio of 1.59 ± 0.24 after 4h
- **NO$_3$ aging:** No significant OA mass increase, aged/primary OA ratio of 0.99 ± 0.06 after 4h (Fig.9)

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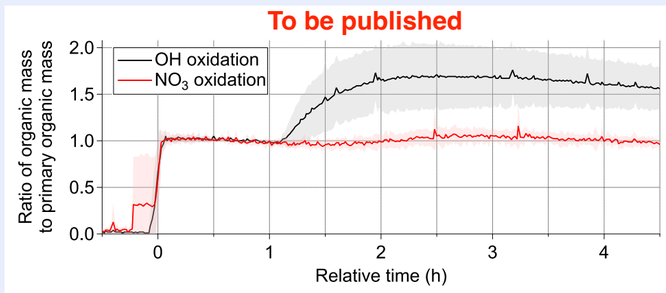

Fig. 9: Timeseries of OA development during aging of wheat burning emissions in comparison to primary OA. Varying levels of relative humidity and NOx.

Multiphase modeling

CAPRAM: Biomass burning module

- **Integration** of BB emission chemistry into CAPRAM **multiphase mechanism**
- Includes detailed aromatic **oxidation chemistry** representation (Fig.10)

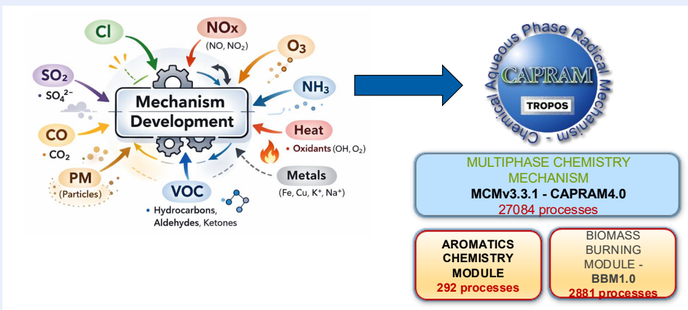

Fig. 10: Overview of biomass burning chemistry development from field observations to mechanism development and modeling frameworks.

Modeling the multiphase chemistry of BB emissions

- **CAPRAM-BB1.0** simulates BB multiphase chemistry
- **Sensitivity simulations** comparing BB/cloud **(BBC)** vs. non-BB/non-cloud **(woBBwoC)** conditions for spring and winter (Fig.11)

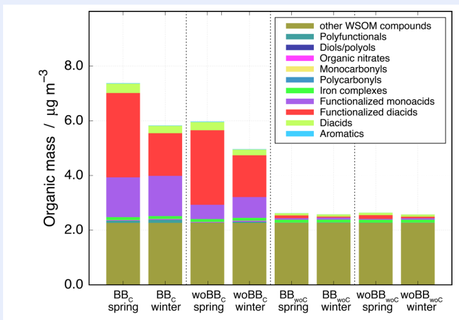

Fig. 11: Comparison of modeled organic mass composition, including BB species and cloud chemistry contributions.

Transfer & societal impact

- Public information event on BB air quality in Radeburg
- Media coverage of residential heating and air pollution research
- Outreach and collaboration activities (Night of Science, CAPRAM workshop)

Scan me!

Publications

Atabakhsh, S., et al., Atmos. Environ., 346, 121075, 2025; **Atabakhsh, S.**, et al., Atmos. Chem. Phys., 25, 8907–8926, 2025; **Deabji, N.**, et al., Environ. Sci. Pollut. Res., 2024; **Deabji, N.**, et al., Atmos. Environ., 355, 121273, 2025; **Fomba, K.W.**, et al., ACS Earth and Space Chemistry, 2025; **Hoffmann, E.H.**, et al., ACS Earth and Space Chemistry, 9(6), pp.1593–1606, 2025; **van Pinxteren, D.**, et al., ACS Environmental Au, 2024.

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