SWISS FOREST LAB

WSL

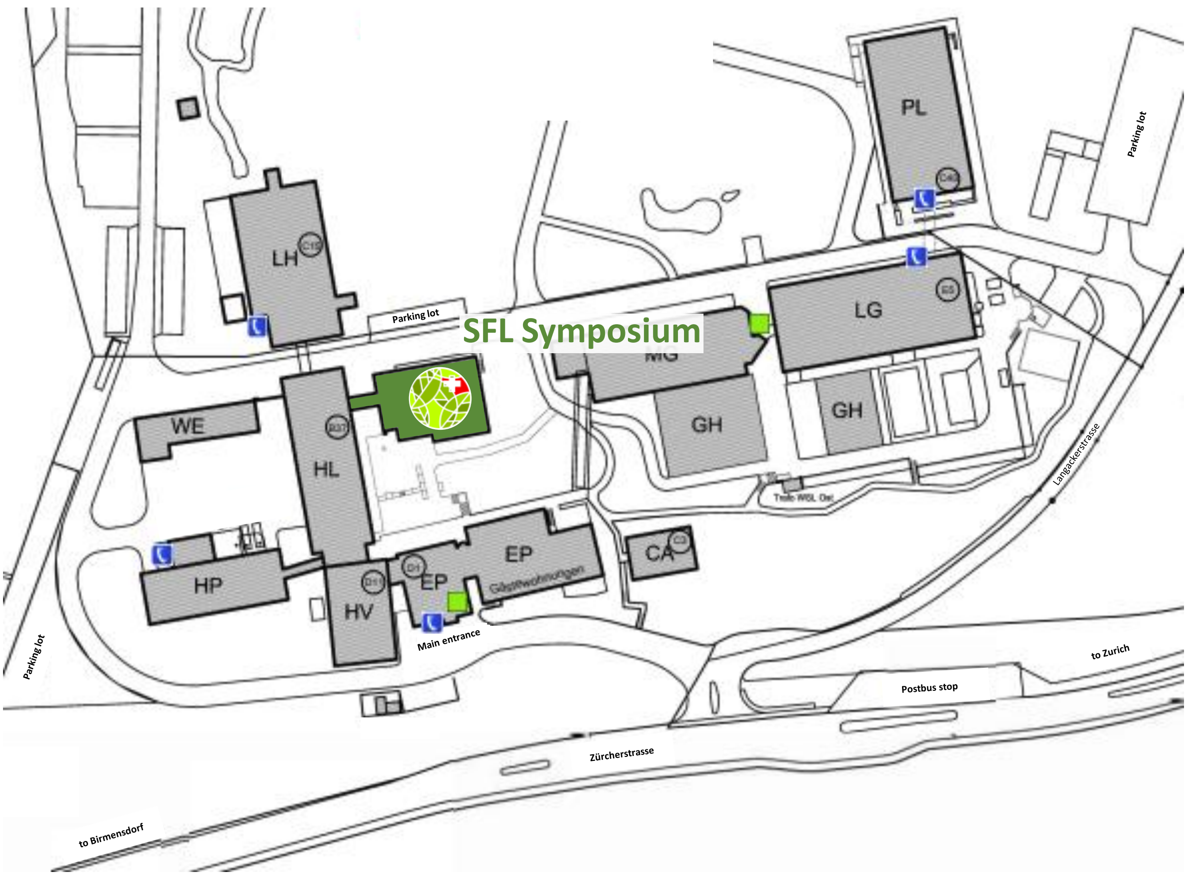
Biosphere – Atmosphere Interactions

Thursday, 18th August 2022

Program Booklet

SFL Symposium

Welcome to WSL Birmensdorf



Swiss Federal Institute for Forest, Snow and Landscape Research WSL
Engler Saal
Zürcherstrasse 111
8903 Birmensdorf

Conveners

Dr. Simone M. Pieber

Dr. Simone M. Pieber holds a Ph.D. in environmental science from ETH Zurich. Her research interest is in gas and particle emissions and their atmospheric transformation. Currently, she focuses on understanding how anthropogenic factors impact ecosystems' emissions into the atmosphere and their consequences on air quality and climate.

Dr. *Ugo Molteni*

Dr. Ugo Molteni is an environmental scientist. His research interest is in biogenic volatile organic compounds emissions and atmospheric oxidation. He is currently investigating the effect of abiotic stressors on European temperate forest tree species.

Keynote Speakers

Prof. Dr. Arthur Gessler

Prof. Arthur Gessler is Director of the Long-term Forest Ecosystem Research (LWF), Group Leader at the Swiss Federal Institute for Forest, Snow and Landscape Research WSL, and Adjunct Professor at ETH Zurich. His research is geared towards understanding the processes that drive and regulate biogeochemical cycles, biotic interactions and biodiversity-ecosystem functioning at different scales is of central importance to our work.

Prof. Dr. Celia Faiola

Prof. Celia Faiola is Associate Professor in Ecology and Evolutionary Biology at the School of Biological Sciences and Associate Professor in Chemistry at the School of Physical Sciences at the University of California in Irvine. Her research broadly explores topics related to plant volatile emissions and production of secondary organic aerosol (SOA) in a changing climate, and how changes to plant emissions alter atmospheric chemistry processes.

Prof. Dr. Markus Kalberer

Prof. Markus Kalberer is Full Professor of Atmospheric Science at the University of Basel, Switzerland, in the Department of Environmental Sciences since 2018. Previously, he also held a Full Professor position of Atmospheric Science at the University of Cambridge, UK in the Department of Chemistry. His research focus is in chemical characterisation of organic aerosol, aerosol toxicity and reactive oxygen species, with custom developed online instrumentation.

Dr. Philipp Sulzer

Dr. Philipp Sulzer is science managerIONICON Analytik. Dr. Philipp Sulzer holds a PhD in Ion Physics and Applied Physics from the University of Innsbruck. Since 15 years he works for IONICON Analytik and currently heads the applied science team and is responsible for analytical services for customers, exploring new PTR-MS applications and IP management.

Session Program

09:05 – 09:10	**Ugo Molteni** **Simone Pieber**	**Introduction**
09:15 – 09:30	**Arthur Gessler**	**New approaches for monitoring forest functioning - crossing scales from the cellular metabolome to the stand wide photochemical reflectance index**
09:35 – 09:55	**Celia Faiola**	**Atmospheric Chemistry of Biogenic Volatile Organic Compound Emissions Associated with Plant Stress**
10:00 – 10:20	Coffee Break	
10:25 – 10:40	**Markus Kalberer**	**How toxic are aerosol particles formed in the atmosphere from biogenic volatile organic compound emissions?**
10:45 – 11:00	**Philipp Sulzer**	**PTR-MS: Fundamentals and Recent Developments**

11:05 Poster Session and Lab Tour

Oral Presentations

New approaches for monitoring forest functioning - crossing scales from the cellular metabolome to the stand wide photochemical reflectance index

Arthur Gessler[1), 2)]

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Long-term forest monitoring has a long tradition and provides important information for science-based decisions in forest management and policy. Until recently, mainly "classical" measurements of e.g., radial growth increment, defoliation and mortality have been performed and they are and in future will be core tools for describing forest vitality and functioning. However, new tools are now available that might provide additional information on mechanisms and environmental cause-effect relationships, and I will here give examples spanning from metabolomics via close-to-real-time assessments of growth and water relations to drone-based proximal sensing.

We linked assessments of the leaf and root metabolic profile in Scots pine to defoliation and observed homoeostatic levels across a wide range of defoliation classes. Only at very strong defoliation, levels of metabolites related to defense, oxidative stress, osmoregulation and energy supply strongly decreased in the roots but where upregulated in needles indicating a negligence of root functioning at the expense of aboveground tissues.

Close-to-real-time assessments with point dendrometers allow to dynamically monitor growth and tree water deficit responses to atmospheric and soil drought complementing annual stem diameter measurements. Species-specific risk assessments can be made and the seasonality of specific environmental factors impairing functioning can be quantified. In combination with xylem flow sensors and in situ water isotopologue monitoring systems, the origin of water taken up by trees can be quantified. With such methods it is possible to assess if trees can switch to deeper soil water resources during drought and how fast they recover their water use after a drought event.

In ground-based monitoring it is sometimes not easy to see the forest for the trees. Drone based proximate sensing allows to receive overhead imagery of the crowns and with wavelength-specific sensors reflectance indices can be determined that show stress signals before any classical visual assessment. Drone-based imagery can thus provide early warning signals as well as a link to satellite remote sensing.

Atmospheric Chemistry of Biogenic Volatile Organic Compound Emissions Associated with Plant Stress

Celia Faiola[1)]

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Climate change is increasing the frequency and severity of environmental conditions that lead to plant stress, including heatwaves, drought, and pest/pathogen outbreaks. Plants often respond to stressors by up-regulating biosynthesis and emission of biogenic volatile organic compounds, particularly terpenes. Terpenes play an important role in atmospheric chemistry processes, influencing atmospheric oxidation capacity and production of atmospheric particles called secondary organic aerosol (SOA). Atmospheric particles play a critical role in Earth's radiation budget through aerosol-radiation and aerosol-cloud interactions, but predictive understanding of the chemistry of many of these plant stress compounds (including complex mixtures of these compounds) has not been achieved. This presentation will summarize laboratory studies investigating SOA formation from complex mixtures of real plant emissions representing healthy and stressed plant emission types. Unexpected effects on aerosol chemistry, composition, and properties attributed to the presence of acyclic terpenes in the BVOC mixture were observed. In particular, beta-ocimene, beta-myrcene and alpha-farnesene, reduced SOA yields and promoted fragmentation reactions while increasing the viscosity of the resulting SOA. The chemistry of these compounds is ignored in global climate models, but could become increasingly important as the Earth's climate changes.

How toxic are aerosol particles formed in the atmosphere from biogenic volatile organic compound emissions?

Markus Kalberer[1)]

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Aerosol particles, from biogenic and anthropogenic origin, are the most toxic components in polluted air. Overall, epidemiological studies suggest that air pollution particles are the most pressing public health issue causing an estimated 4 million premature deaths worldwide per year. There is a large number of natural and anthropogenic sources contributing to the overall particles mass found in the atmosphere with biogenic volatile organic compound emissions from trees being one of the most important sources. The particle sources components in the particles which are most toxic is currently unknown, because the particle composition is highly complex with tens of thousands of mostly organic compounds present in atmospheric particles.

I will discuss some of our recent studies where we compared the toxicity of particles derived from biogenic volatile organic compound from trees with anthropogenic particles. We developed new instrumentation for chemical particle toxicity characterization and to investigate the biological effects of aerosol particles on human cell cultures.

PTR-MS: Fundamentals and Recent Developments

Philipp Sulzer[1)]

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Proton-Transfer-Reaction – Mass Spectrometry (PTR-MS) is a well-established technology in environmental chemistry and atmospheric sciences, which is reflected by hundreds of peer-reviewed publications per year. This is not surprising as the ample advantages perfectly match the needs in this field: direct sample injection, real-time quantification, LoDs in the low pptv range, response times in the 100 ms region, etc.

However, there is always room for improvement. After an introduction to PTR-MS in general, some of the latest technical advances will be presented. This includes various ion focusing techniques which boost the instrument's sensitivity by several orders of magnitude without impairing the well-defined ion chemistry.

We will further discuss a novel method of creating ammonium reagent ions, which requires no ammonia at all and a dedicated aerosol inlet system, which enables the analysis of particles between 70 nm and 2.5 µm in size in addition to VOCs with a common PTR-MS instrument.

Finally, very recent data from a novel instrumental concept will be presented. This so-called FUSION PTR-MS has the potential to become the new gold standard for VOC and aerosol analysis in environmental chemistry.

Poster Presentations

The UCI-WSL plant chamber for biogenic volatile organic compound emissions studies

Ugo Molteni[1), 2)], Jonas Gisler[2)], Simone Pieber[1), 2)], Na Luo[2), 5)], Matthias Saurer[2)], Markus Kalberer[3)], Arthur Gessler[2), 4)], Celia Faiola[1)]

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The study of plant biogenic volatile organic compounds (BVOCs) emissions requires a laboratory setup that guarantees well-controlled physical and chemical conditions. Further, the setup needs to minimize measurement artifacts arising from the stress caused by the experimental handling of the plant. Here, we present a novel plant chamber setup for BVOC emissions sampling which is currently deployed during the AccliMemo 2022 campaign to study juvenile broadleaf and coniferous trees. The setup focuses on reducing the plant mechanical stress and optimizes the sampling time. Finally, a custom hardware/software solution controls and logs gas flows, temperature, humidity, carbon dioxide (CO_2), and total solar radiation.

Memory of environmental conditions across generations affects the acclimation of offspring of scots pine up to 3 years?

Na Luo[1),2)], Arun Bose[1)3)], Arthur Gessler[1)4)]

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We examined that if environmental memory of maternal scots pine (*Pinus sylvestris* L.) drives the acclimation potential of offspring to drought and heat conditions.

We exposed 3-year-old seedlings that grow in ambient conditions from the seeds generated by trees growing under naturally dry ("control"), irrigated ("irrigation"), and formerly irrigated conditions ("irrigation stop") to two temperature (ambient; ambient+4°C) and two water conditions (well-watered vs. drought) to detect the memory effect inherited from mother trees on acclimation potential of offspring. We determined seed carbon and nitrogen content, isotope composition of ^{13}C and ^{15}N. We will also measure seedling growth, gas exchange, carbon allocation, metabolites and DNA methylation of both before and after exposing to drought and hot conditions.

Seeds from irrigated mother trees exhibited lowest $\delta^{13}C$. After exposing to ambient conditions for up to 2 years, above-ground biomass and needle area of first 2-year growth, stem biomass and specific leaf area (SLA) of current-year growth showed the same patterns that seedlings from "irrigation" mother trees showed the highest values and seedlings from "irrigation stop" mother trees showed the lowest values. No difference was observed among the root shoot ratio, total above-ground biomass, below-ground biomass. After exposing to hot and drought conditions for about 2 weeks, assimilation (A) decreased under drought conditions, regardless of the seedling types. Seedlings of "control" mother trees showed the higher iWUE under heat conditions compared to ambient temperature conditions.

This difference in seedling size and iWUE among seedling types, may point to the important role of transgenerational memory for the long-term acclimation of trees. We will further detect whether carbon allocation and metabolites are changed among seedling types and whether DNA methylation conveys the transgenerational memory signals.

How trees can recover from late-spring frost and summer drought?

Na Luo[1),2)], Manuel Walde[1)3)], Yann Vitasse[1)3)], Arthur Gessler[1)4)]

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Climate warming leads to earlier leaf-out which may put trees at higher risks of late frost in Spring (e.g., Zohner et al., 2020). Extreme droughts in summer are increasing in frequency and magnitude. The probability that a late frost and an extreme summer drought occurs in the same year will increase. How trees respond to and recover from the double stress will be important to forest health.

We exposed 2-year-old seedlings of four species (*Quercus petraea*, *Quercus robur*, *Fagus sylvatica*, *Acer campestre*) to an artificially late frost event (keep trees under -5.5℃ for 3 hours) when the leaves were fully leaf-out (at the beginning of May). Then we applied 2-month summer drought treatments during early July to end of August (well-watered vs. drought, 50% reduction of water). We will measure seedling growth, gas exchange and nonstructural carbohydrates (NSC) to detect how trees respond to and recovery from double stress.

Late frost killed 80% of new leaves in about 90% of *Quercus robur*, 70% of *Fagus sylvatica*, 40% of *Quercus petraea* and 20% of *Acer campestre*. After 1.5 months later, biomass and specific leaf area (SLA) of late-frost treated trees did not recover to control in *Quercus petraea*, *Fagus sylvatica*, *Acer campestre*. Assimilation (A) kept lower in late-frost treated trees for 4 species.

Late-spring frost strongly damaged leaves and tree growth. The damage did not recover after 1.5 months. The lag effect of frost damage may interact with the following summer drought damage. We will further detect the lag effect of late-spring frosts on the resilience of trees to drought.

Acclimation of Beech and Pine to Abiotic Stress on Intra-annual, Inter-annual and Inter-generational Time Scales

Tatiana Nazarova[1),2)]

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Forest decline due to climate change has been observed on all continents. Current climate models predict that global temperatures will continue to rise, while extreme events such as droughts and heat waves will increase in frequency, intensity and duration. Whereas typical droughts are characterized by a water deficit in the soil, warmer droughts induce a combination of soil water stress and increased evaporative demand, and are therefore assumed to have an exacerbated impact on forests. Because trees are long-lived organisms, the time scales on which their genetic adaptation takes place is too long to compensate for the detrimental effects of climate change. Unlike genetic evolution, acclimation, that is, reversible shifts in the phenotype, allows individual trees to acclimate to the specific conditions in which they grow. Acclimation occurs not only as a response to continuous growth conditions but also to periodic stress – a process that is referred to as environmental memory. Environmental memory and tree acclimation could play an important role in the response of forests to changing environmental conditions. Although the understanding of these processes is growing, many uncertainties remain, especially concerning the physiological and metabolomic mechanisms of acclimation on various time scales, including intergenerational transmission, as well as the respective contributions of water restriction and increased temperature on tree stress responses.