Extending the BE-Vie ecosystem station characterization with NMVOCs and Ozone

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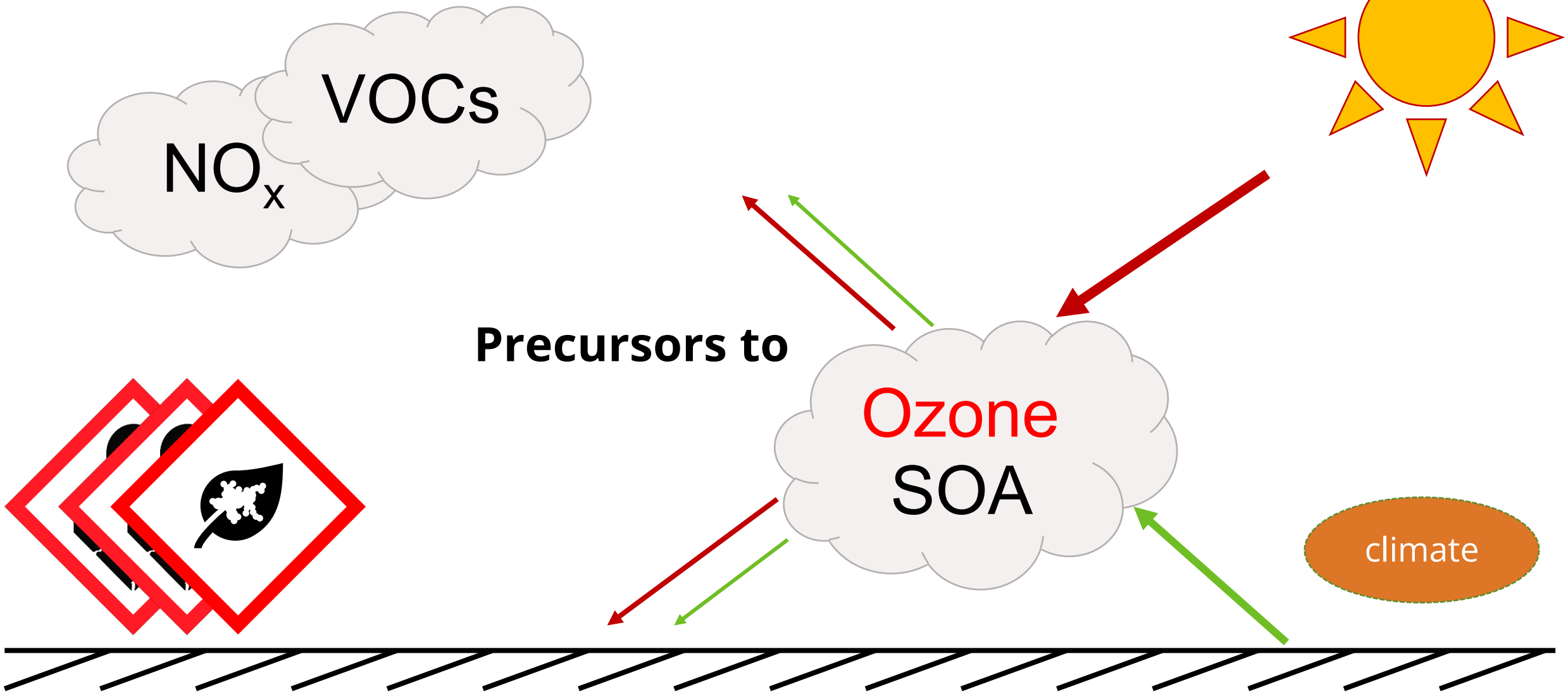
01

Reactive trace gases in the atmosphere

What reactive trace gases are we studying and why do we care?

RELEVANCE



BVOCs in ecosystems

Light

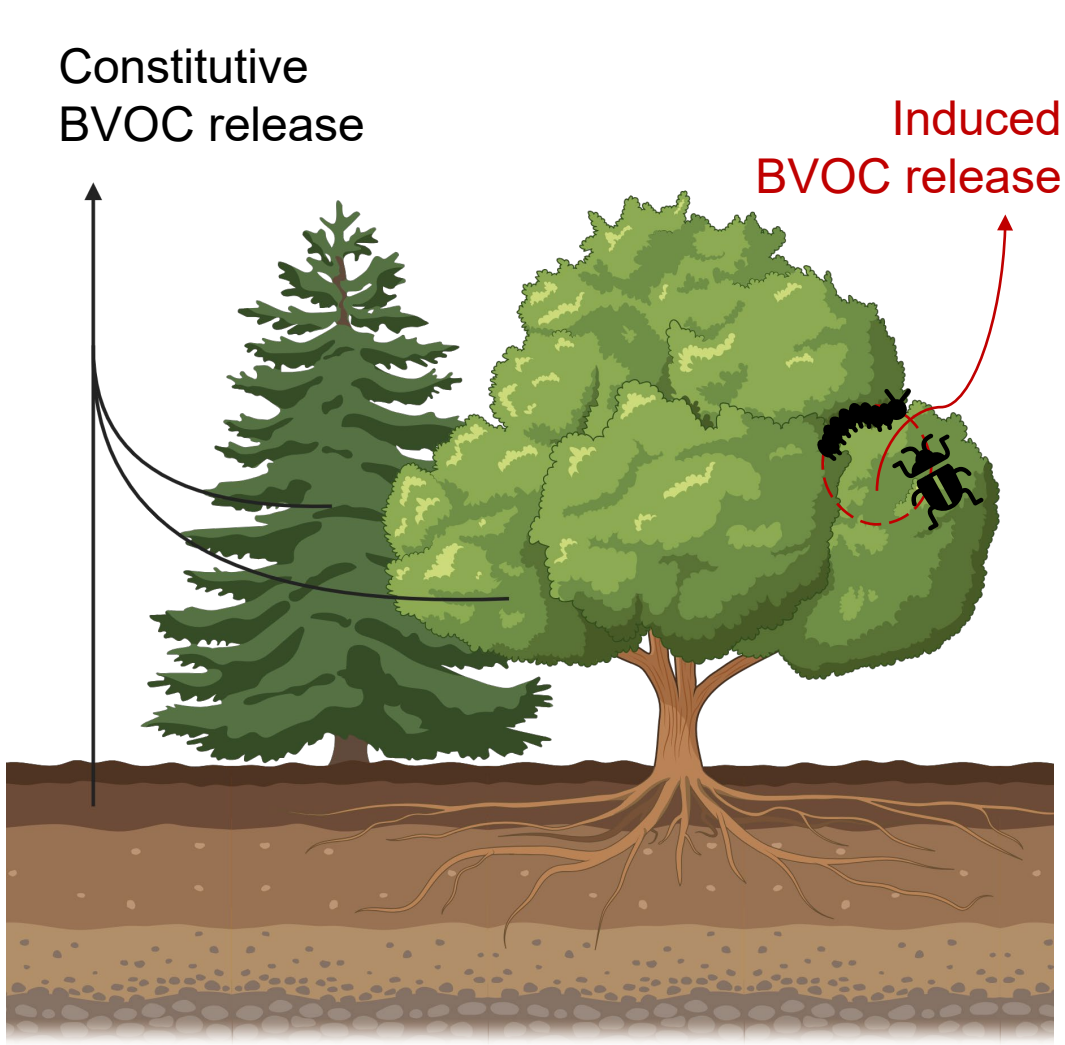
Temp.

Leaf age

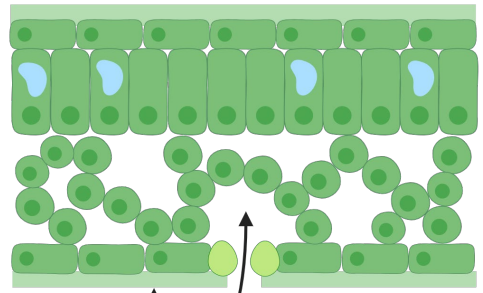
Soil moisture

Leaf area

CO_2



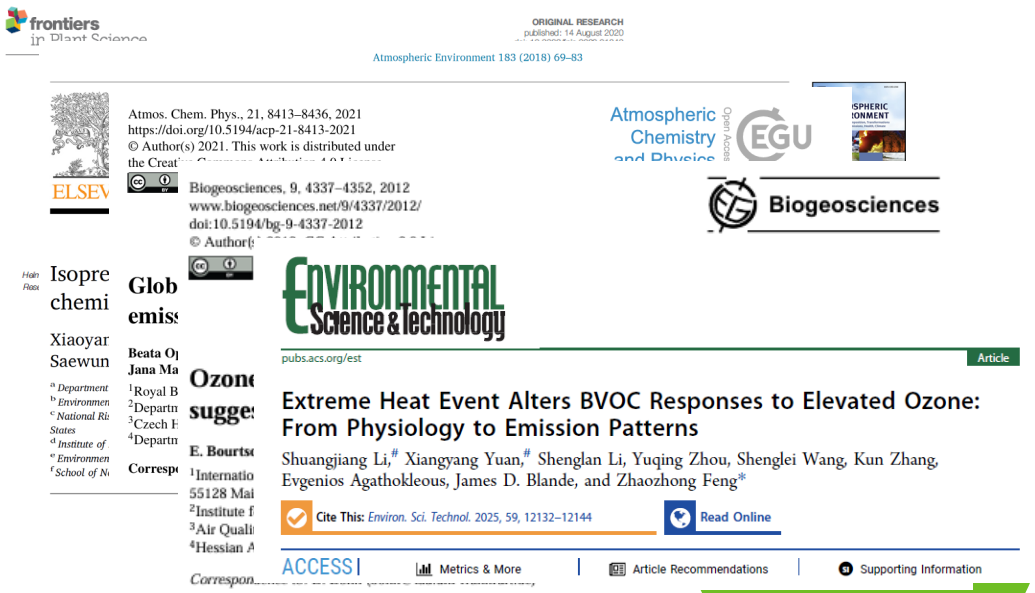
Created in https://BioRender.com



BVOC Deposition
- → To cuticles
- → Stomatal uptake

Bi-directionally exchanged!

FEEDBACKS



Increased GHGs

Increased sources OH

Response OH sources still uncertain

Higher global Temperature

Global change

- Heat waves?
- Droughts?
- Land-use change?
- Ozone damage?
- Combined stresses?

(B)VOC exchanges

Increased SOA, CCN

Effect on radiative forcing still uncertain

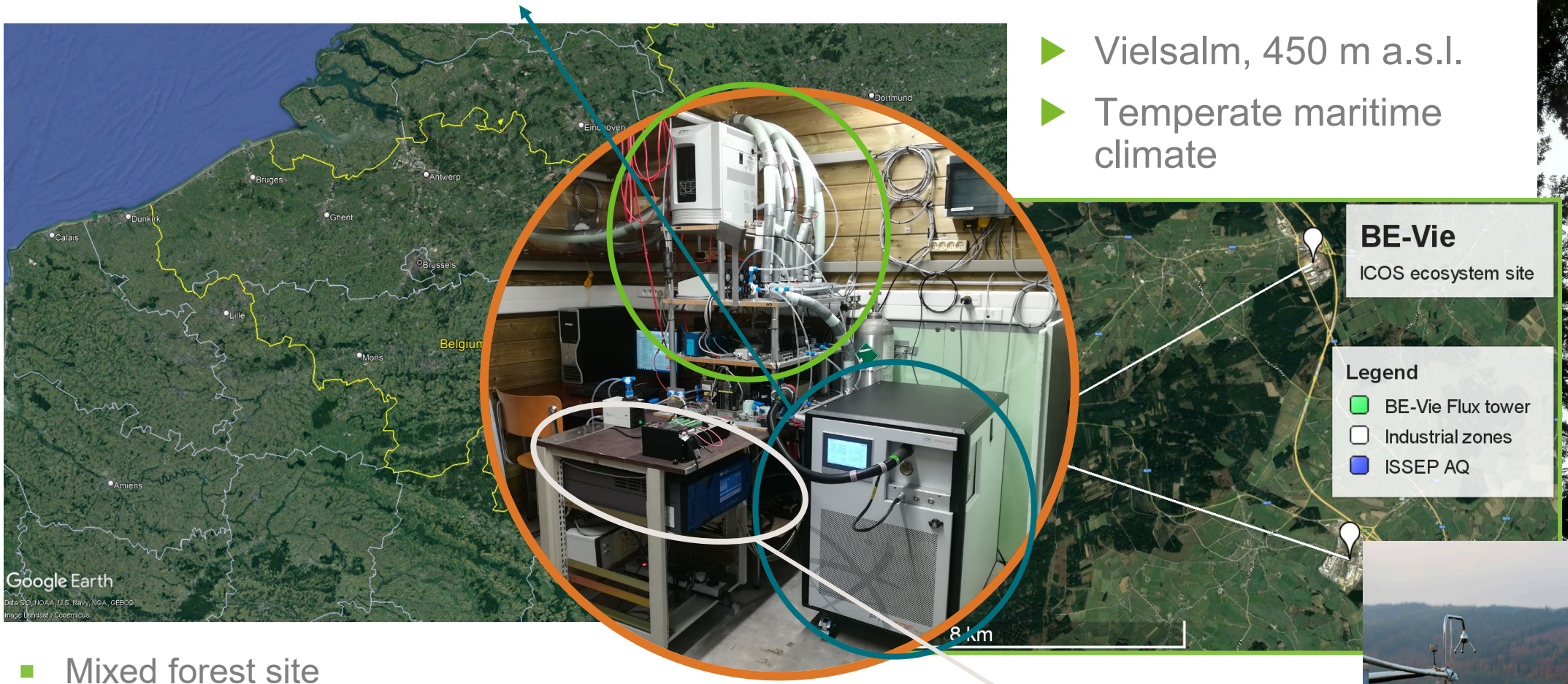
02

Measurement setup BE-Vie

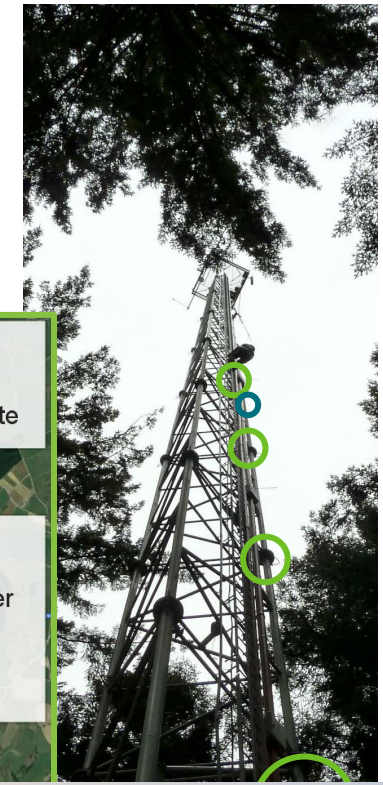
Embedding chemical measurements (ACTRIS) into ecosystem flux towers (ICOS) to connect local biology with atmospheric chemistry

PTR-TOF-MS

- High time resolution (10 Hz)
- Selective to a suite of (O)VOCs
- Sensitive to sub-ppbv concentrations



- Vielsalm, 450 m a.s.l.
- Temperate maritime climate



- Mixed forest site
- Nearby industrial anthropogenic emissions

Ozone analyzer

03

Our dataset and analysis

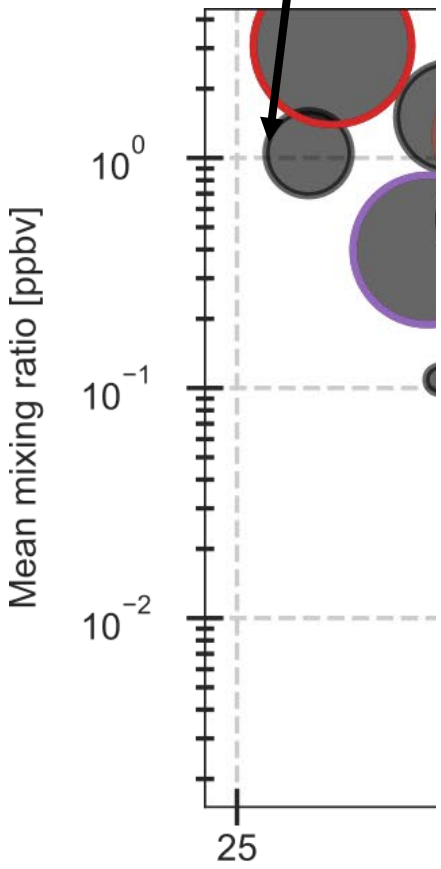
Plant life cycles don’t just affect carbon exchange, they change atmospheric chemistry

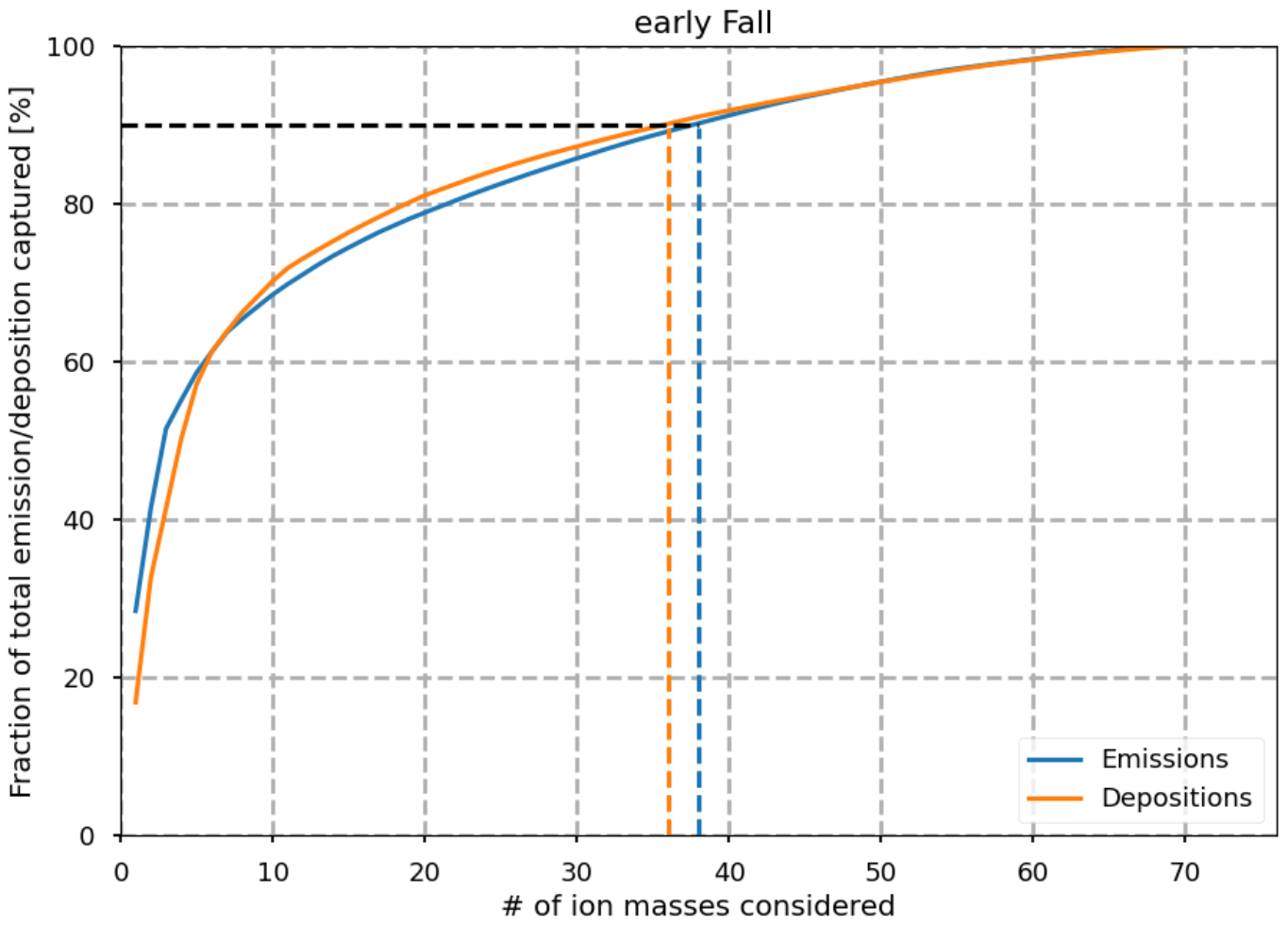
6 Formaldehyde

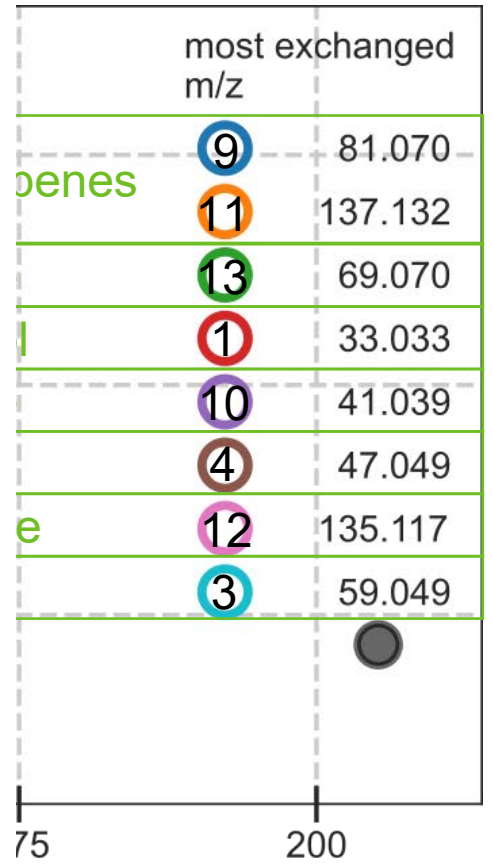
2&5 Acetic Acid

7 Acetaldehyde

8 Formic Acid

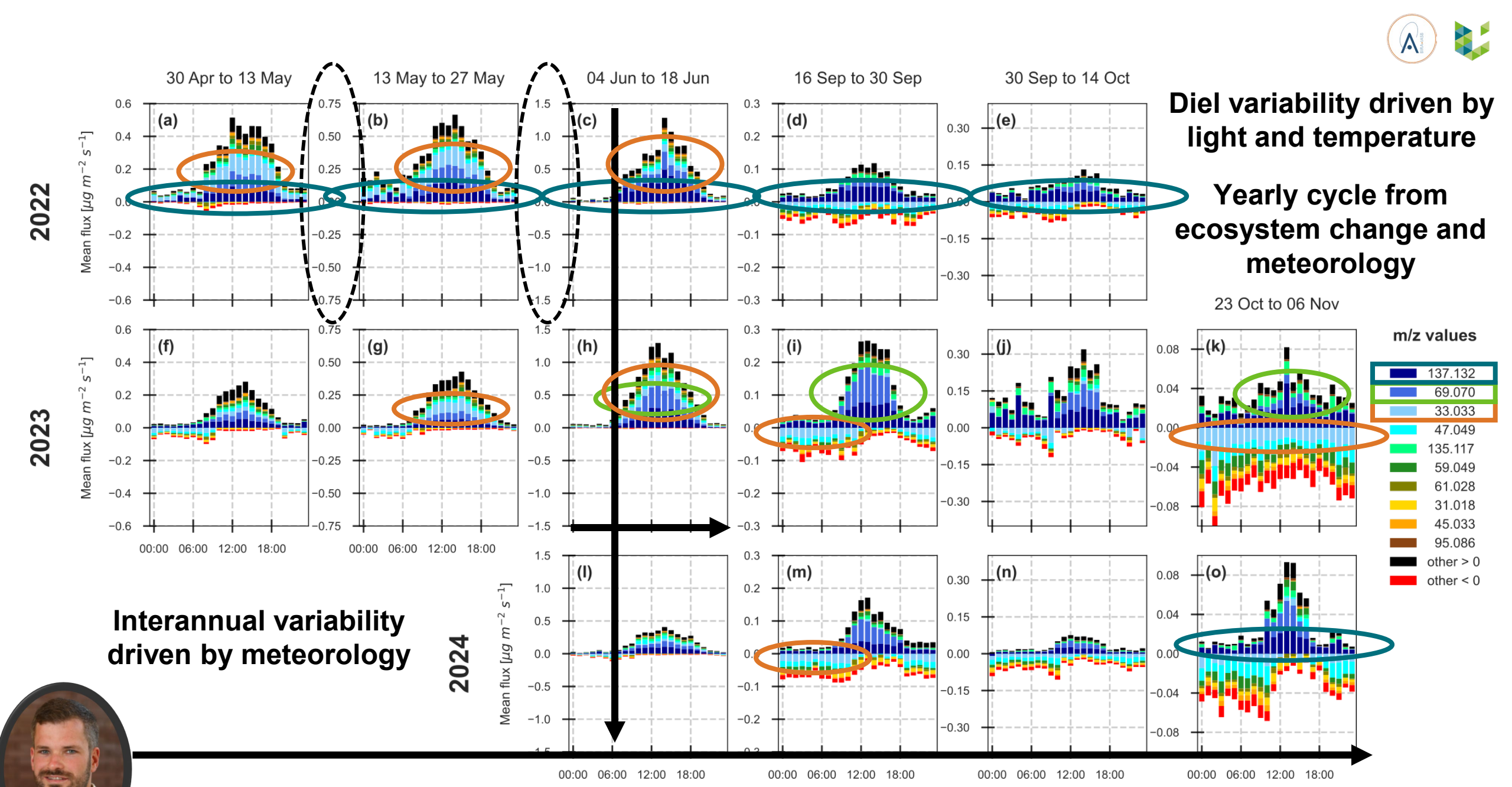






Mean absolut [µg m^{-2} s^{-1}]

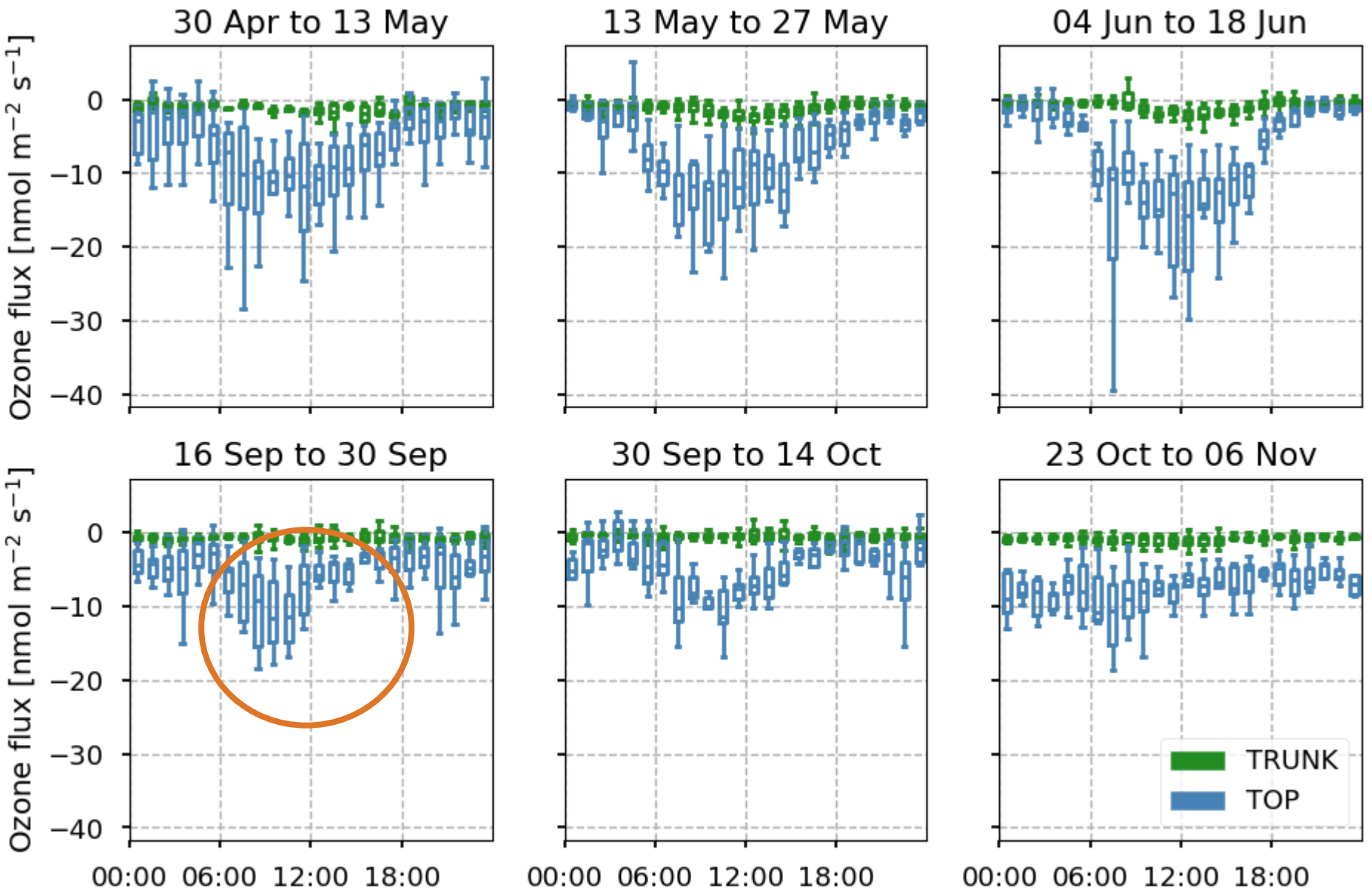
5e-05 5e-04 5e-03 5e-02


30 Apr to 13 May
13 May to 27 May
04 Jun to 18 Jun
16 Sep to 30 Sep
30 Sep to 14 Oct
23 Oct to 06 Nov
2022
2023
2024
Mean flux [µg m⁻² s⁻¹]
00:00 06:00 12:00 18:00
m/z values
137.132
69.070
33.033
47.049
135.117
59.049
61.028
31.018
45.033
95.086
other > 0
other < 0
Diel variability driven by light and temperature
Yearly cycle from ecosystem change and meteorology
Interannual variability driven by meteorology

- Ozone fluxes

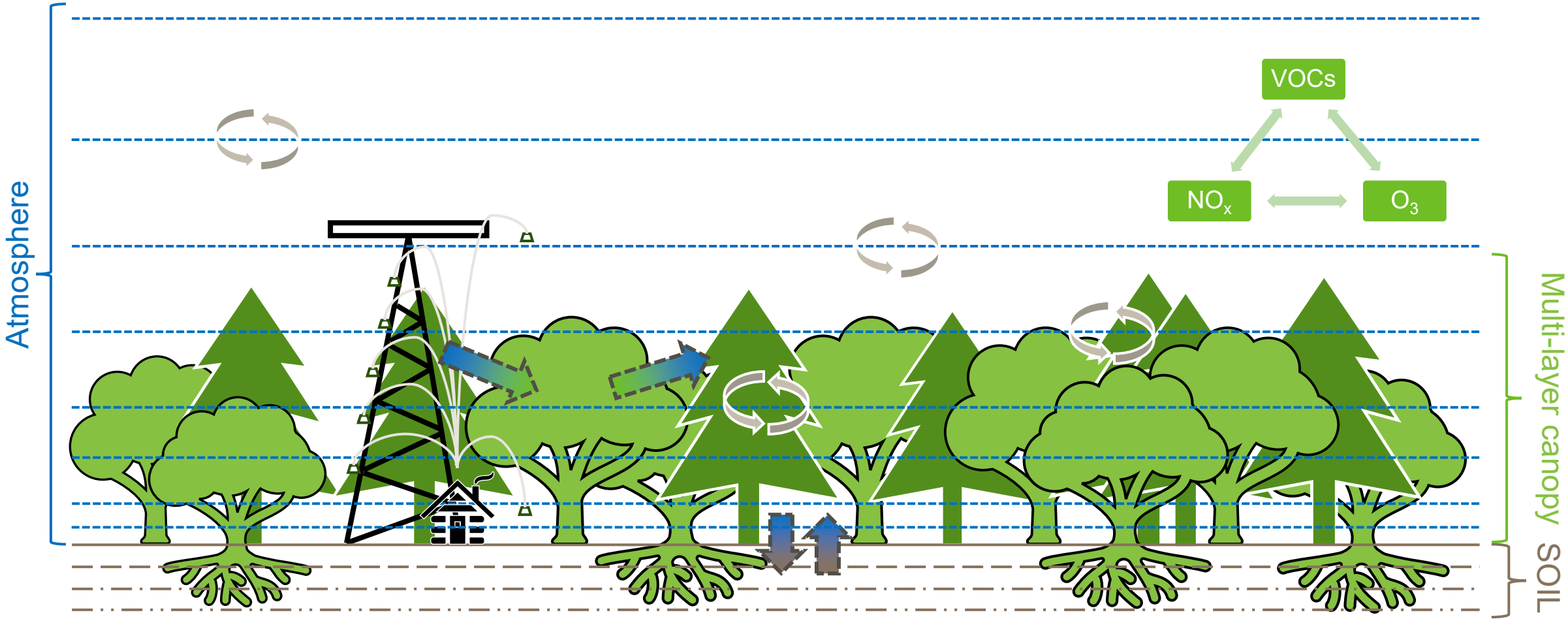
2023

Diel profile from stomatal conductance!



1-D Canopy Exchange Modelling: FORCAsTv2.0

- Emission
- Deposition
- Chemistry
- Turbulence



ACTRIS | Exploring the Atmosphere

Short-lived atmospheric cons

- Aerosol, Clouds, **Trace Ga**

Key scientific themes:

- Monitoring reactive gases sources at high precision
- Studying chemical transform the atmosphere
- Assessing their role in air pollutio climate forcing, and **ecosystem interactions**

https://actris.eu/about/what-we-do/key-scientific-themes

Long-lived GHG vs short-lived climate forcers

Ecosystem follow up from ICOS to perform driver analysis with ACTRIS data

Photosynthesis and impact of Ozone/VOCs

ICOS | Integrated Carbon Observation System

Greenhouse gas budget

- ere, **Ecosystem**, Ocean

ndardized, high-precision
m observations
esearch to understand the
ycle and provide necessary
tion on greenhouse gases

https://www.icos-cp.eu/about/icos-in-nutshell/mission

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Questions?

Preprint under review for
Earth System Science Data

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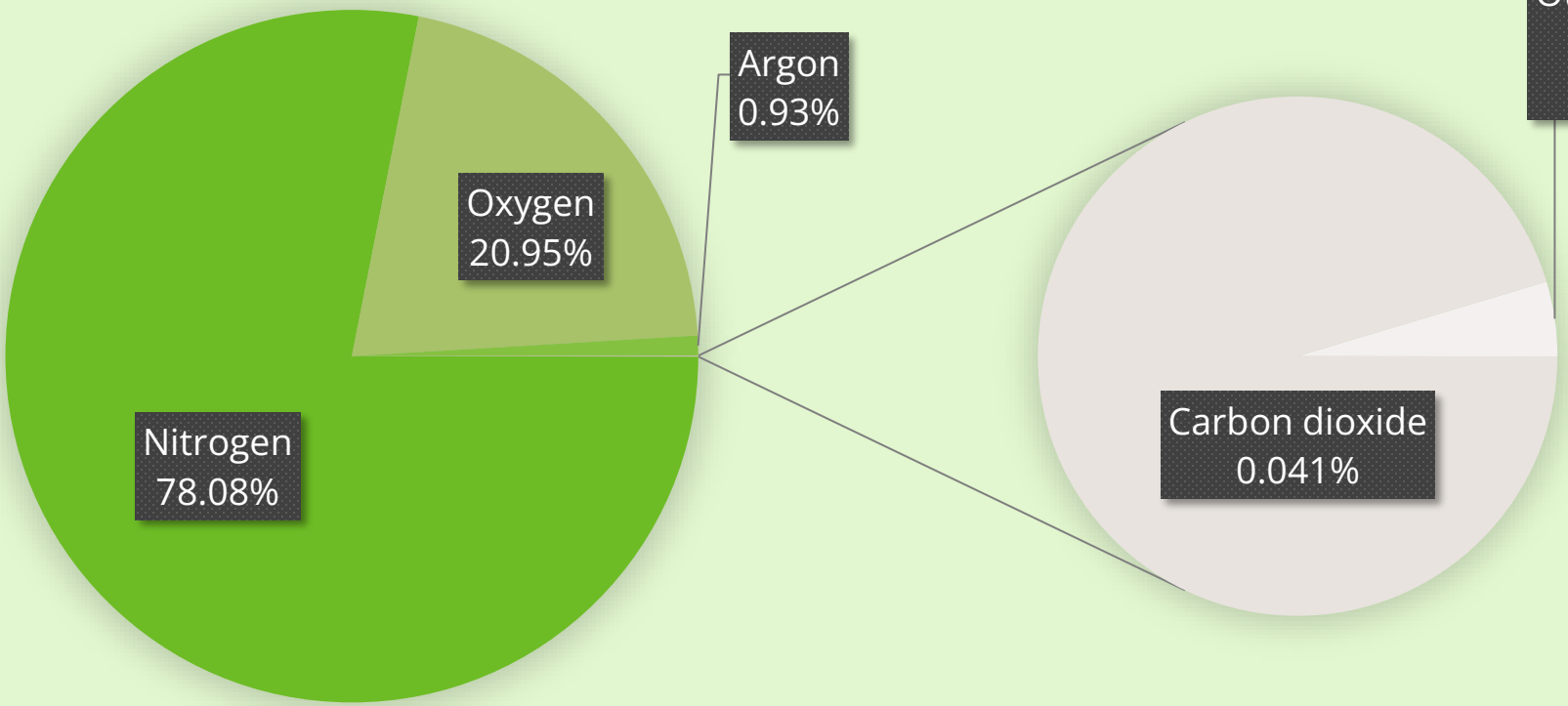
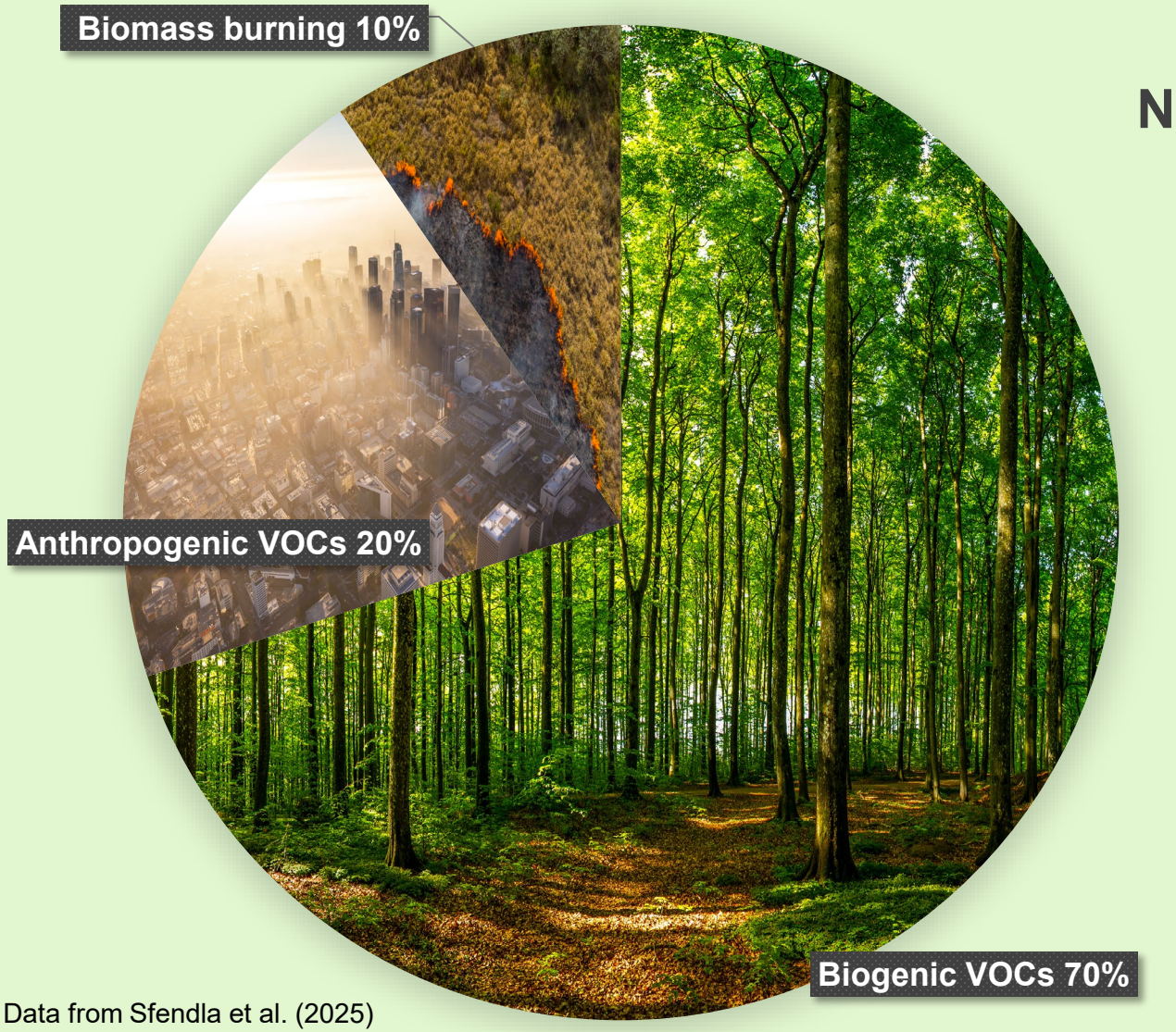


- Neon
- Helium
- Methane
- Krypton
- Hydrogen
- Nitrous oxide
- Ozone
- Non-methane VOCs
  5 – 20 ppbv



Data from Sfendla et al. (2025)
Top-down inversion from satellite measurements HCHO and glyoxal

NMVOCs emitted in 2021 (~ 1170 Tg)

- Ocean source highly uncertain
- Biomass burning source highly variable
- AVOCs highly relevant for air quality in cities
- BVOCs largest source globally

RELEVANCE

AGU ADVANCING EARTH AND SPACE SCIENCES

Geophysical Research Letters

RESEARCH LETTER

10.1029/2025GL114712

Impacts of Interannual Isoprene Variations on Methane Lifetimes and Trends

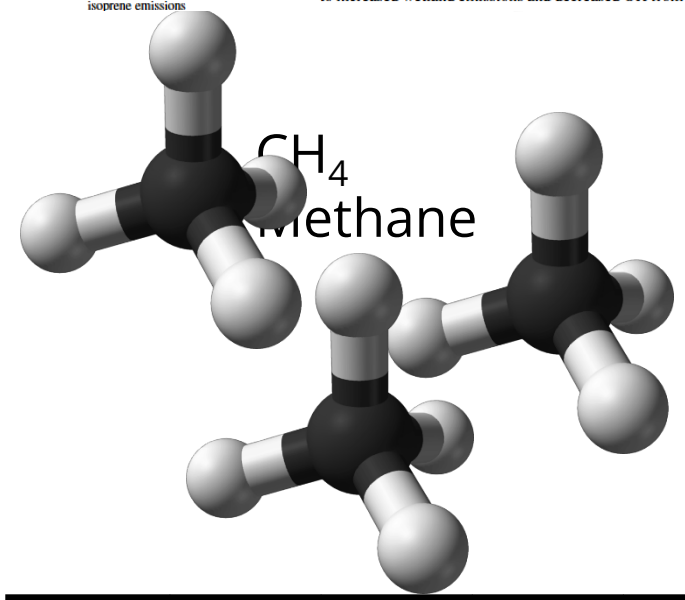
Key Points:

- The Cross-track infrared sounder (CrIS) instrument detected high tropical isoprene anomalies in 2020
- Increasing isoprene emissions to match CrIS results in better agreement with MOPITT CO and interhemispheric OH parity
- This isoprene anomaly could have contributed to 13% (10%–28%) of 2020's methane growth if driven by isoprene emissions

James (Young Suk) Yoon[1], Kelley C. Wells[2], Dylan B. Millet[2], Abigail L. S. Swann[1,3], Joel Thornton[1], and Alexander J. Turner[1]

[1]Department of Atmospheric and Climate Science, University of Washington, Seattle, WA, USA, [2]Department of Soil, Water and Climate, University of Minnesota, Falcon Heights, MN, USA, [3]Department of Biology, University of Washington, Seattle, WA, USA

Abstract Recent observations show anomalously high methane growth in 2020, which has been attributed to increased wetland emissions and decreased OH from lower COVID-19 nitrogen oxide (NO_x) emissions. NO_x



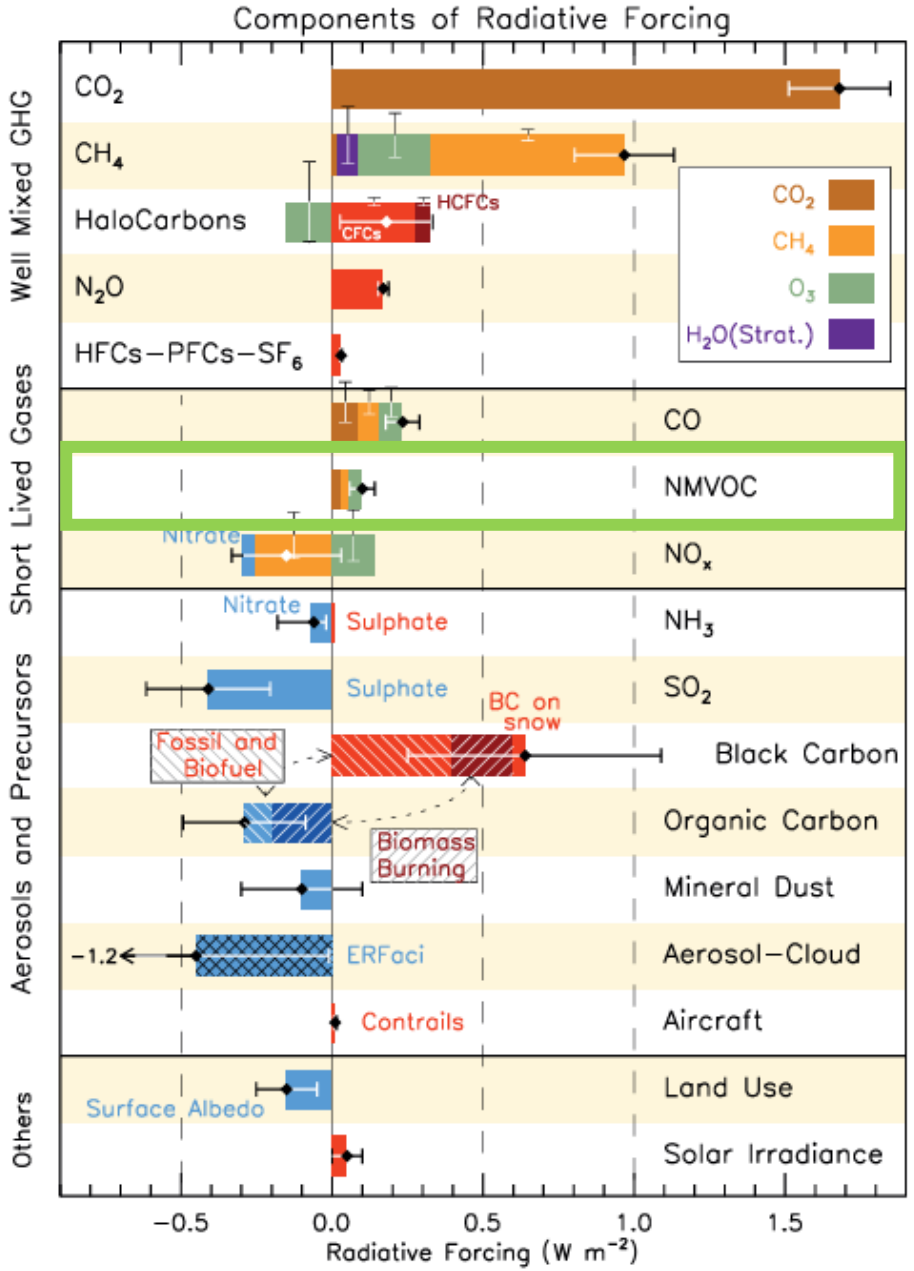
CH_4
Methane

SLOW

OH

Oxidation products

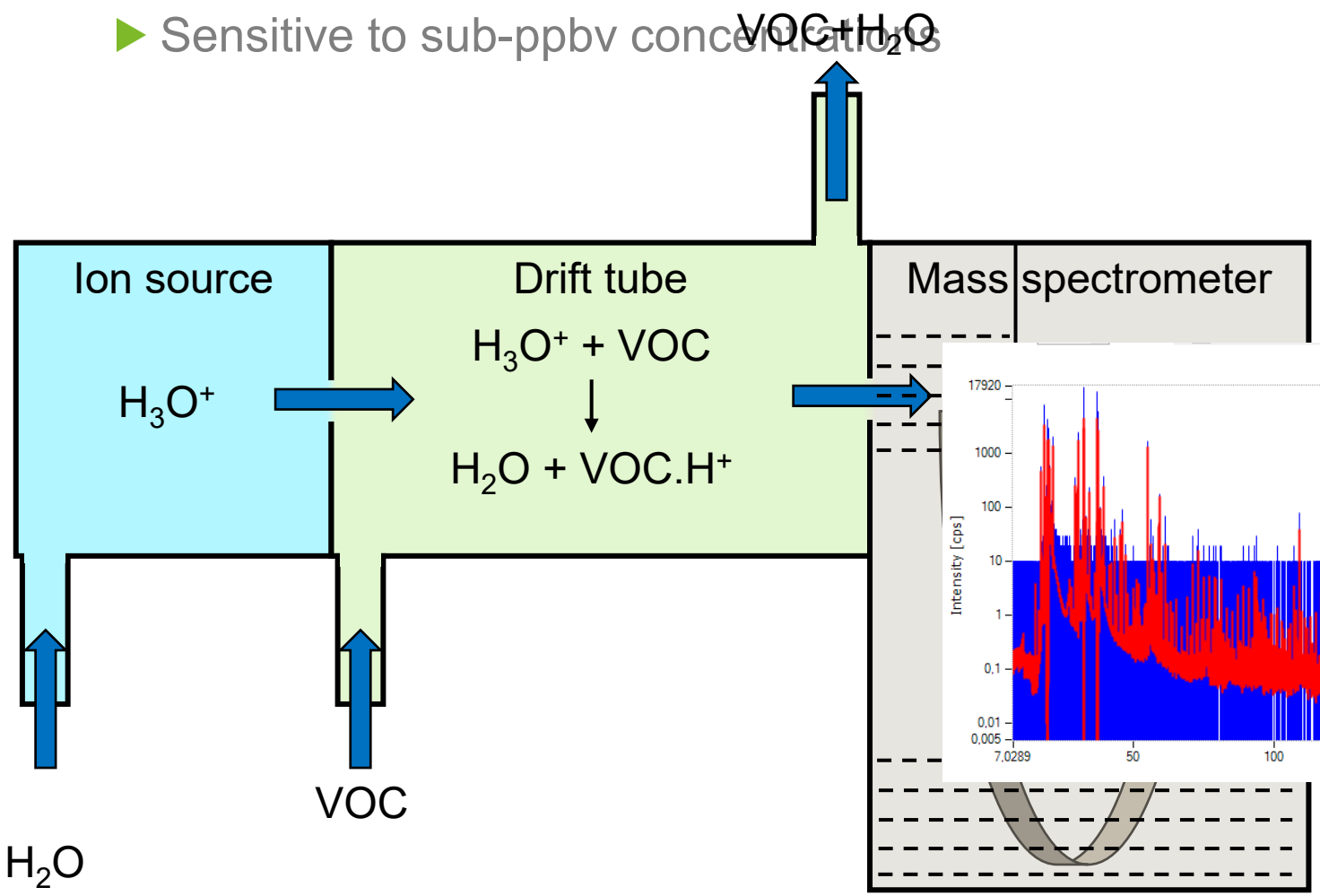
climate

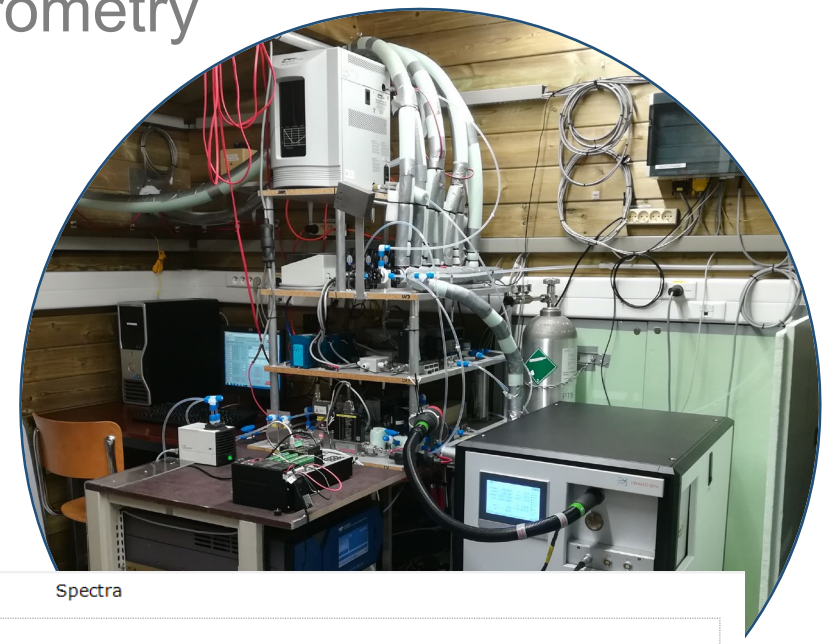


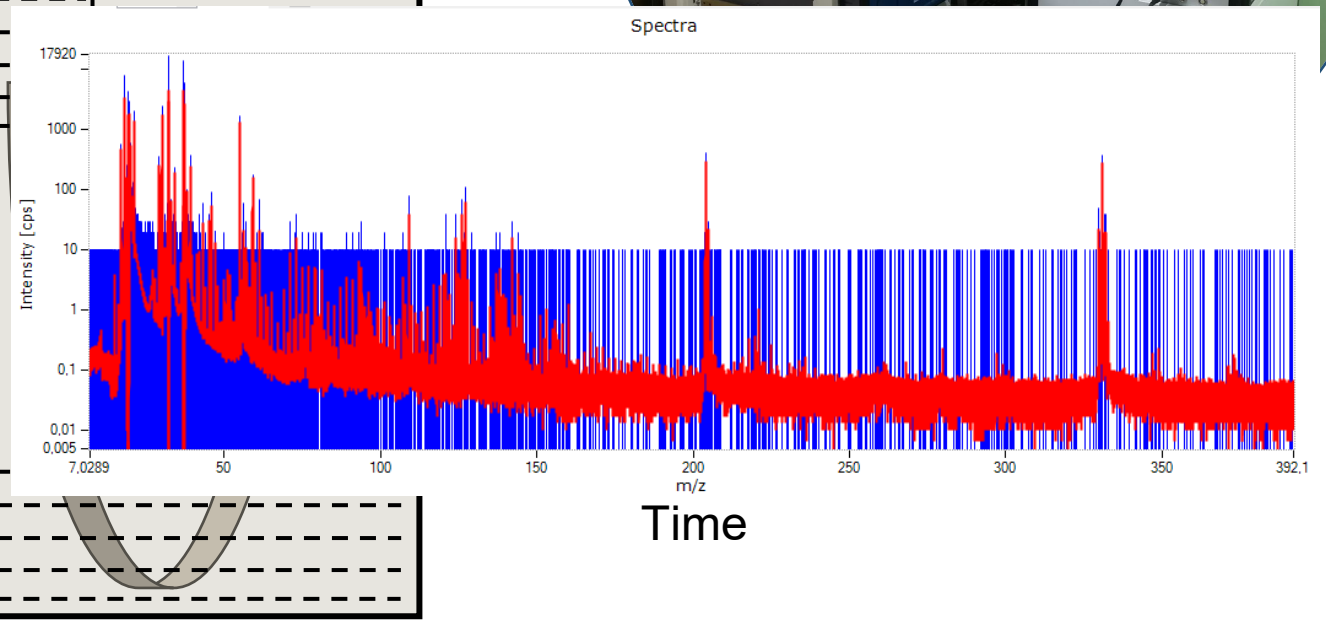
- IPPC Ch8 (2018)
- Components of radiative forcing from 1750 to 2011
- Only includes Anthropogenically emitted VOCs
- Global emission of isoprene is about 2 times higher than all AVOC emissions
- Isoprene only about 70% of all BVOC emissions
- Global isoprene emission estimates differ largely between estimates (factor of 2)
- Important to correctly characterize natural VOC emissions and their responses to changing climate

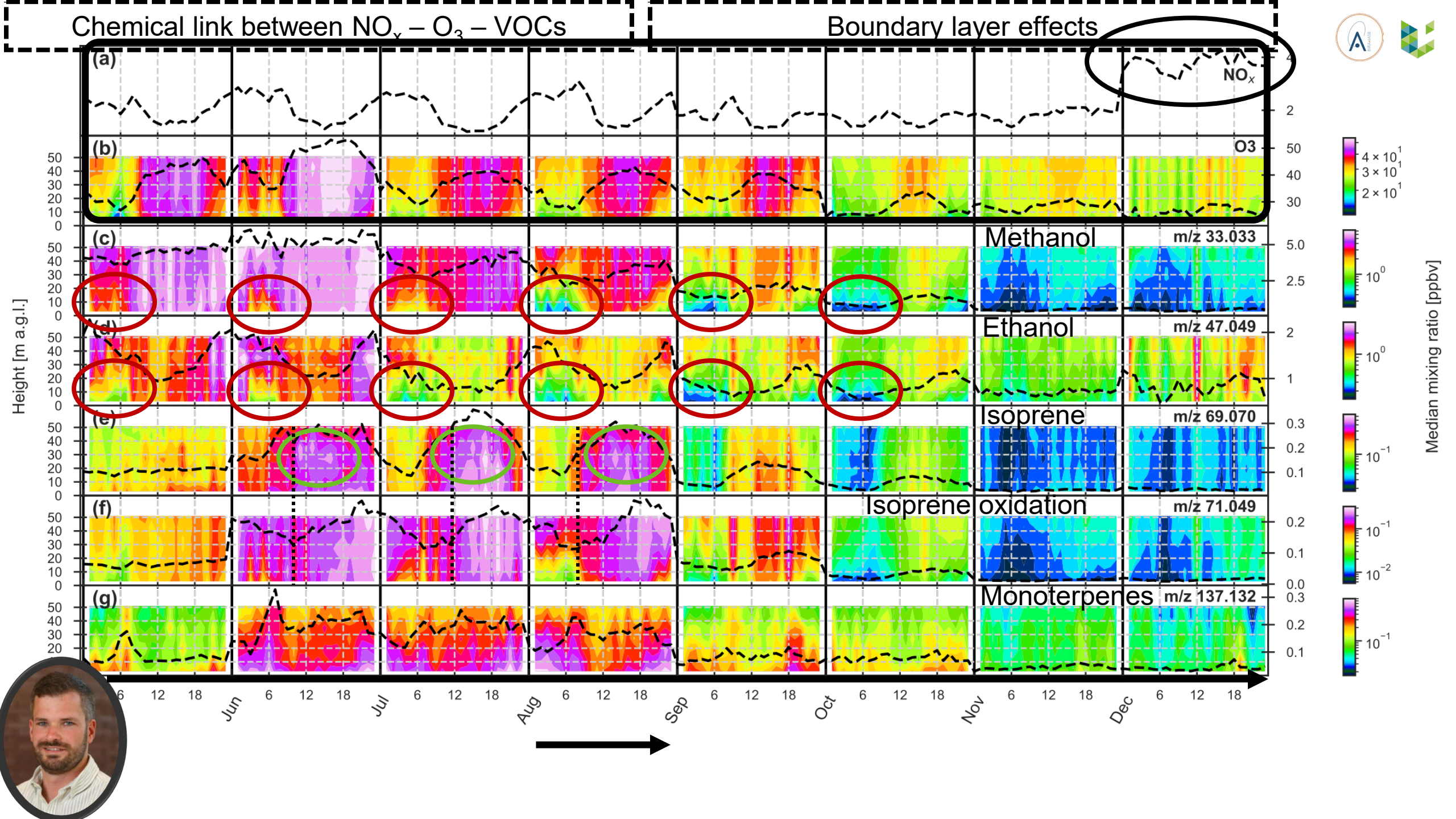
Proton-Transfer-Reaction Time-of-Flight Mass-Spectrometry

- High time resolution (10 Hz)
- Selective to a suite of (O)VOCs
- Sensitive to sub-ppbv concentrations

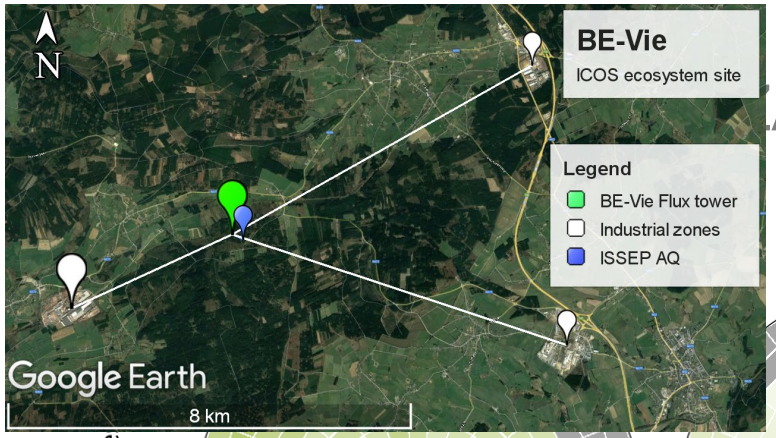


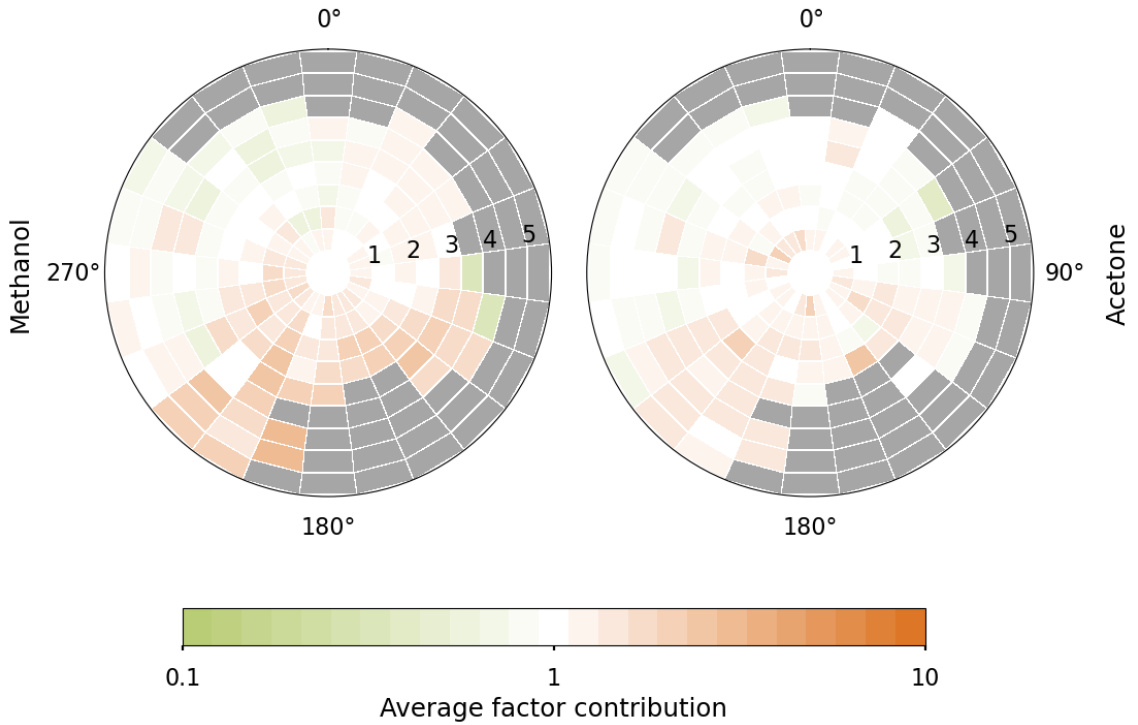





Chemical link between NO_x – O_3 – VOCs
Boundary layer effects
(a)
NO_x
(b)
O3
(c)
Methanol
m/z 33.033
(d)
Ethanol
m/z 47.049
(e)
Isoprene
m/z 69.070
(f)
Isoprene oxidation
m/z 71.049
(g)
Monoterpenes
m/z 137.132
Height [m a.g.l.]
Median mixing ratio [ppbv]
Jun
Jul
Aug
Sep
Oct
Nov
Dec

ZATION PRELIMINARY RESULT (data 2022)





Summary

- Importance VOCs and ozone
- VOC exchanges
  - Large variety of VOCs exchanged
  - Diel, seasonal, interannual variability
  - Most emitted ≠ most abundant
- Ozone depositions
  - Predominantly to the canopy
- 1-D modelling
  - Sub-canopy processes and VOC/O_3 interactions
- Complementarity ICOS and ACTRIS
  - Exchanges between surface and atmosphere
  - Ecosystem feedbacks