



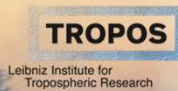
Modelling at Leibniz-Science-Campus „Biosmoke“

Insights to Modelling topics and challenges

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UNIVERSITÄT
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Outline

1. Introduction to Leibniz Science Campus „Biosmoke“
2. Project Objectives and Structure of DBFZ-Subproject
3. From wood to lab: Test Rig, sampling & Experimental Design
4. Modelling concept and challenges

Outline

1. Introduction to Leibnitz Science Campus „Biosmoke“

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Leibniz Association:

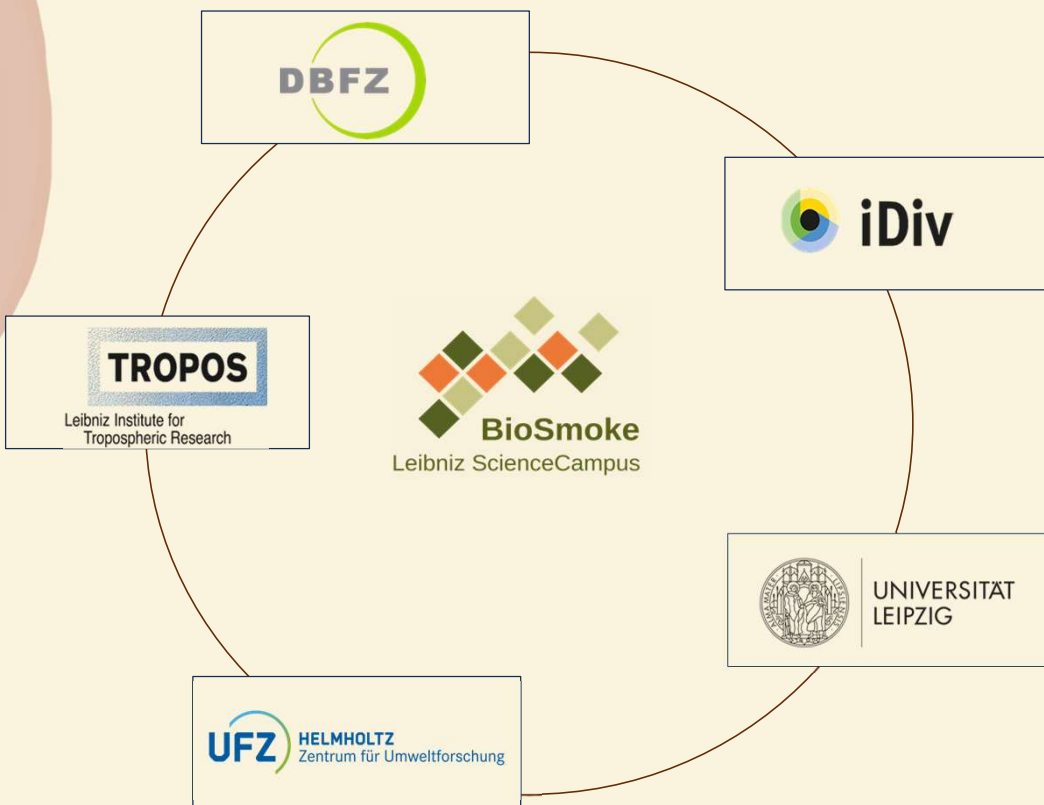
96 independent research institutions focusing on the natural sciences, engineering, environmental sciences, economics and social sciences



Leibniz Science Campus (LSC):

- Regional networking with partner institutes
- Pooling expertise from related departments
- Opening up new research fields in major, socially relevant topics

1. Introduction to Leibniz Science Campus „Biosmoke“



Overview



- **Name:** Leibniz ScienceCampus “Smoke and Bioaerosols in a Changing Climate” (BioSmoke)
- **Start:** Spring 2024; funding period: 4 years (extendable)
- **Coordination & location:** TROPOS (Leibniz Institute for Tropospheric Research), Leipzig

Research Goals



- Investigating the **links between wildfires and climate change**
- **Atmosphere-biosphere interactions** in the context of wildfires
- Impacts of wildfire emissions on **atmospheric chemistry, cloud formation, atmospheric processes and large-scale climate change**, including feedbacks on wildfire occurrence

1. Introduction to Leibniz Science Campus „Biosmoke“

Why is the topic relevant?

Climate change and more frequent, intense droughts are expected to increase wildfire occurrence.

The severity of wildfires increase

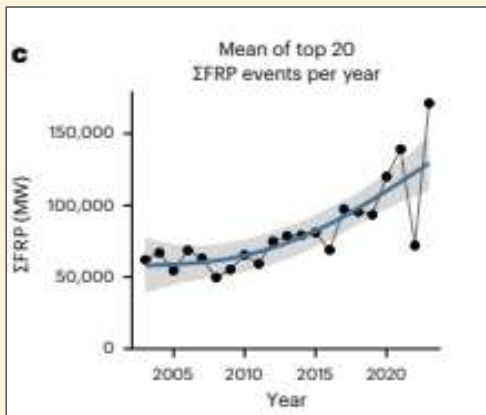


Fig. 1: Increase of Fire Radiative Power of the most severe wildfires (FRP) [4]

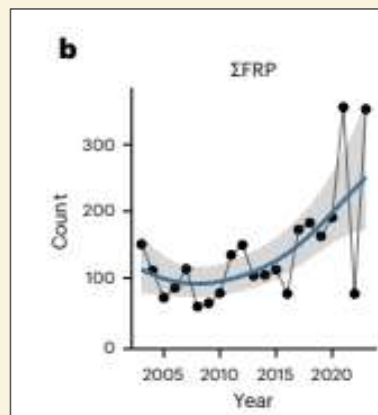


Fig. 2: Increase of burned area of severe Wildfire [4]

This year's wildfire season in unprecedented in Europe's history

- With 1.2 Million ha this year's burned area exceeds the record of the previous year [1]
- The previous two year's burned area exceeds the average of 2006-2024 by factor 3 [2]
- France and Spain affected the most this year [2]
- Displacement of 300k people and estimated costs of 3,1 billion € [3]

1. Introduction to Leibniz Science Campus „Biosmoke“

Structure of the LSC

Linking vegetation, smoke emission and smoke properties (physical, chemical, biological) to transport and atmospheric processing is key to assessing potential changes.



Cluster 1

Emissions and aging of particles and smoke of vegetation fires



Cluster 2

Atmospheric transport and processing of smoke and PBAPs



Cluster 3

Effects of smoke and bioaerosols on the atmosphere

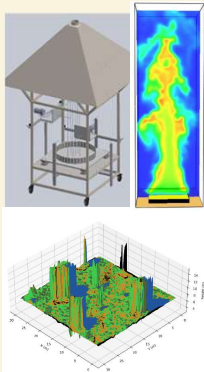
1. Introduction to Leibniz Science Campus „Biosmoke“

Modelling within the LSC



Cluster 1

Modelling of Combustion Experiments and Vegetation-Models



CFD-based modelling of combustion experiments with real wildfire fuels and vegetation modelling in field

Fig. 6: lab test rig model and vegetation model [5]

Smoke composition & thermal parameters and vegetation model



Cluster 2

Transport and Process Modelling of Smoke

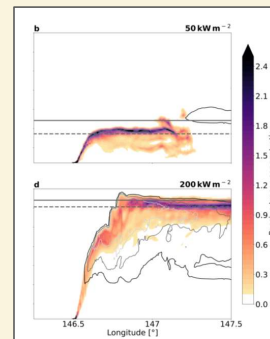


Fig. 7: Plume height dep on heat release rate [6]

Modelling of pyroconvective smoke transport (ICON-LES), smoke chemistry (CAPRAM) and interaction with atmosph. Param.

Smoke Composition and injection heights



Cluster 3

Modelling of Atmospheric Impacts

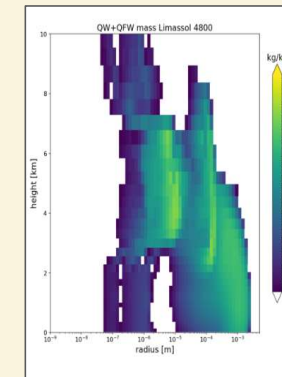


Fig. 8: concentration of particle diameters in diff. Heights [7]

Modelling of precipitation formation and radiation impact (SPECS) & rad. transfer of smoke different in heights (CARES)

Outline

2. Project Objectives and Structure of DBFZ-Subproject

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Project Introduction

Combustion- and Emission- Characterization of European Forrest Fire Fuels

Goal: Investigation and simulation of primary emissions and combustion behaviour from relevant European fuels under wildfire-like laboratory conditions



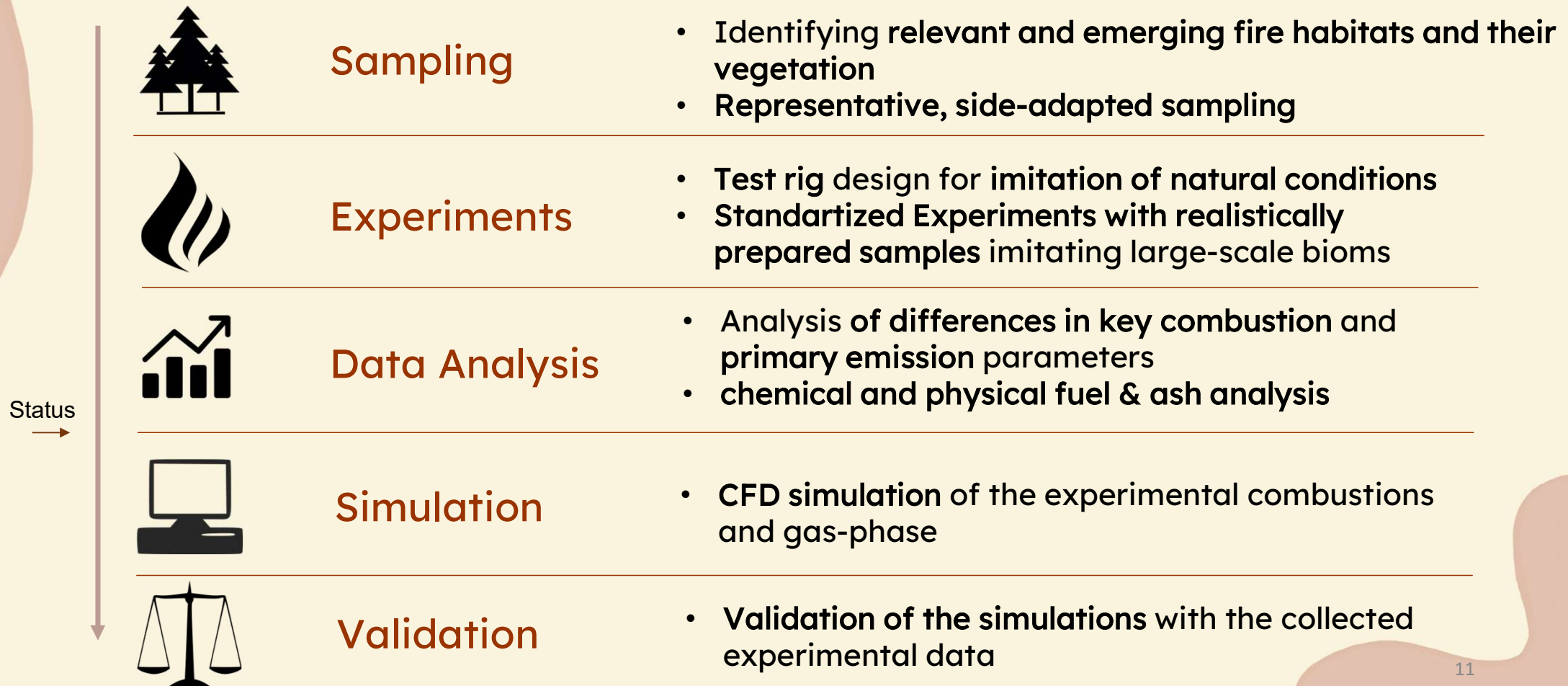
Prof. Dr.
Ingo Hartmann



David Reitmajer
PhD-Candidate



2. Project Objectives and Structure of DBFZ-Subproject



Outline

3 From wood to lab: Test Rig, sampling & Experimental Design

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Sampling

How do we quantify relevant areas?

- Selection of the most relevant European fire regimes based on fire intensity (FRP)
- Mapping of MODIS-derived normed Σ FRP over the last 22 years

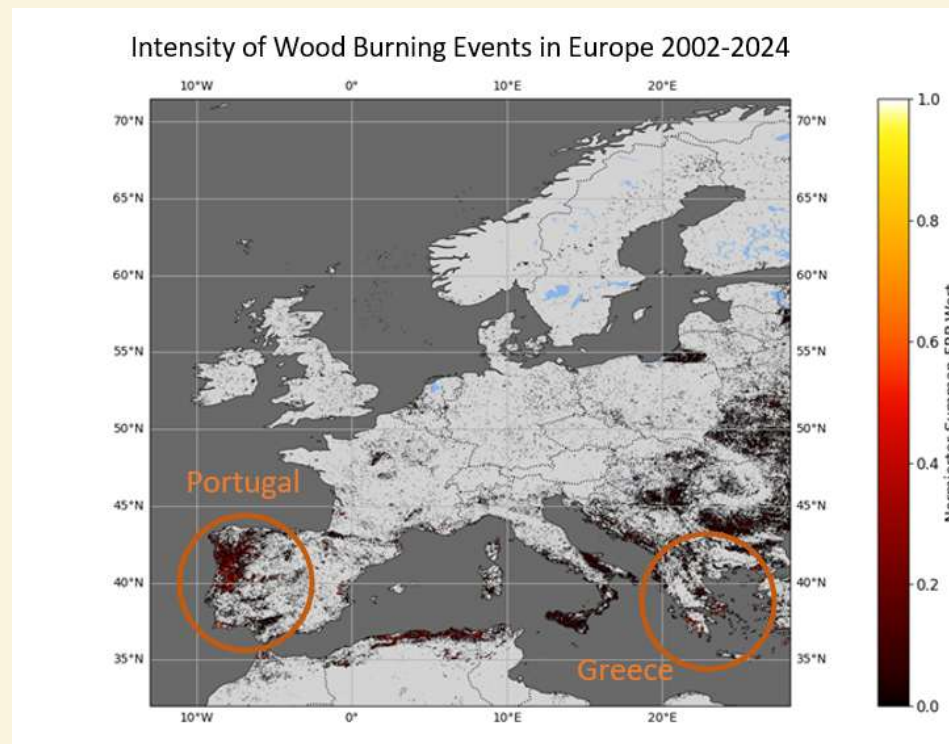


Fig. 9: Summed, normed FRP Value 2002-2024.

3 From wood to lab: Test Rig, sampling & Experimental Design



Sampling

Where are Portugals Hotspots?

- First campaign: **Portugal** in fire season 2025
- To isolate the Hotspot the **99%-Percentile** was mapped resulting in **5 Hot-Spots**
- 3 were visited on site

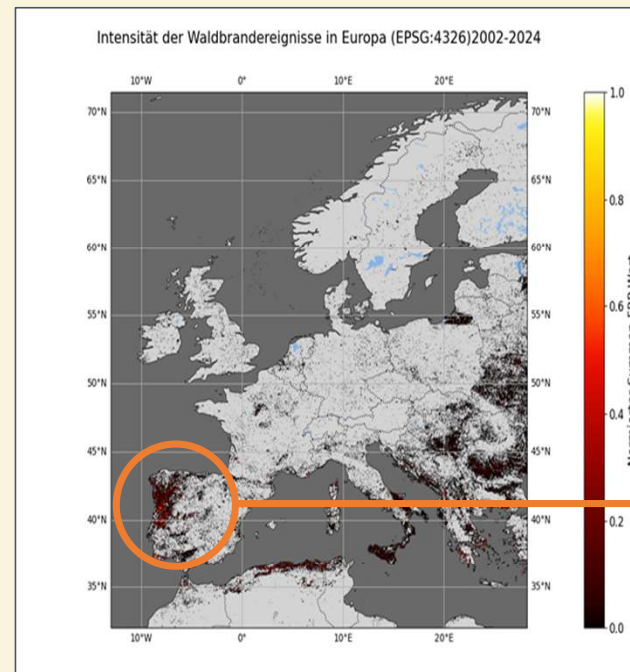


Fig 10: Cumulated FRP-Value in Europe 2002-2024.

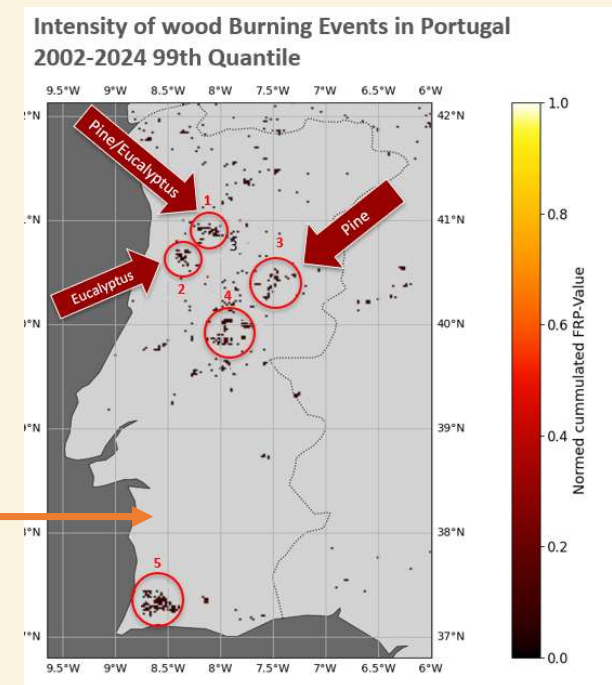


Fig 11: Cumulated FRP –Hotspots. 99%-Percentile in Portugal 2002-2024.

3 From wood to lab: Test Rig, sampling & Experimental Design



Sampling

What is growing there?

- Vegetation analysis with vegetation maps in HotSpot center before and after fire

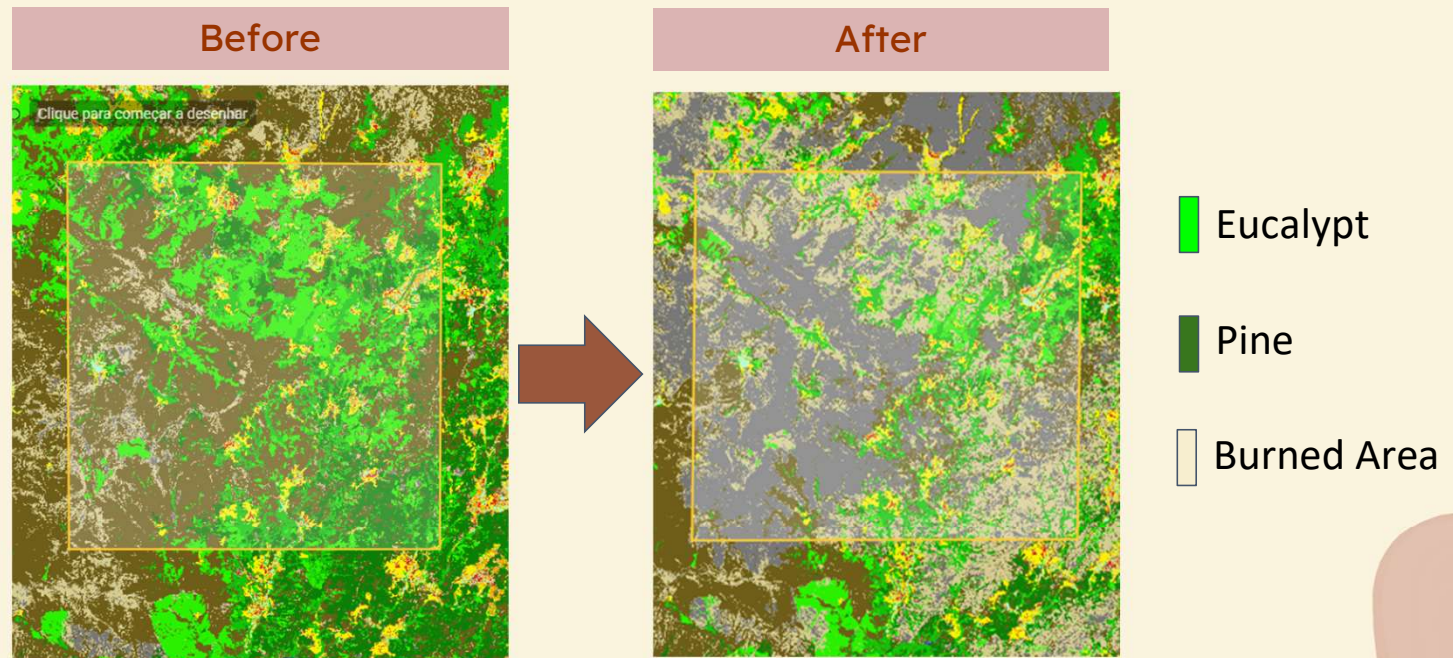


Fig.12 Example of Vegetation Analysis HotSpot Region 1 [8]

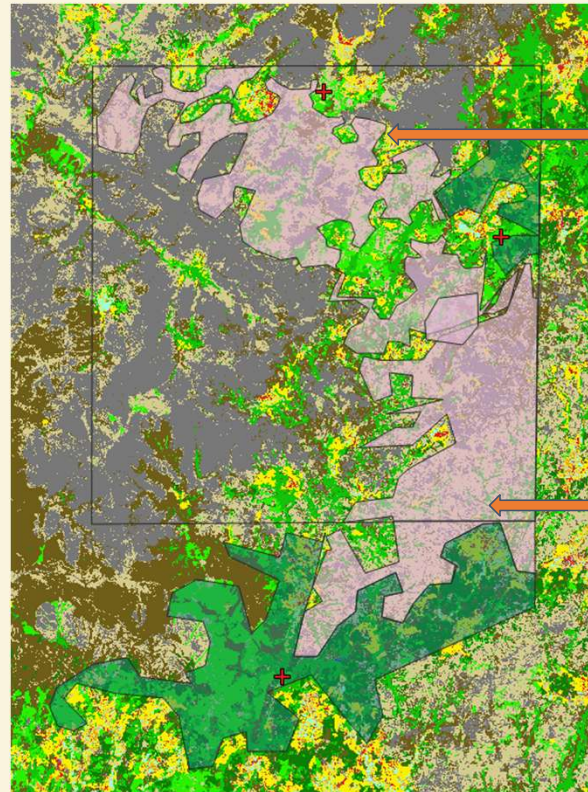
3 From wood to lab: Test Rig, sampling & Experimental Design



Sampling

Where do we sample ?

- Marking of burned area separated by the wood type
- Marking remaining adjacent area of the same wood type as sampling areas



Burned Area
Eucalypt

Burned Area
Pine

Fig 14: Example of Vegetation Analysis. Modified from: [8]

3 From wood to lab: Test Rig, sampling & Experimental Design

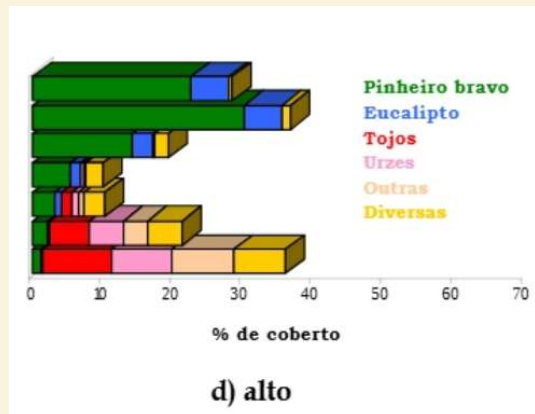


Sampling

The Biotope Problem

- Underneath of the canopy different understory grows
- Dominating understory must be sampled

Dominating Pine understory



Dominating Eucalypt understory

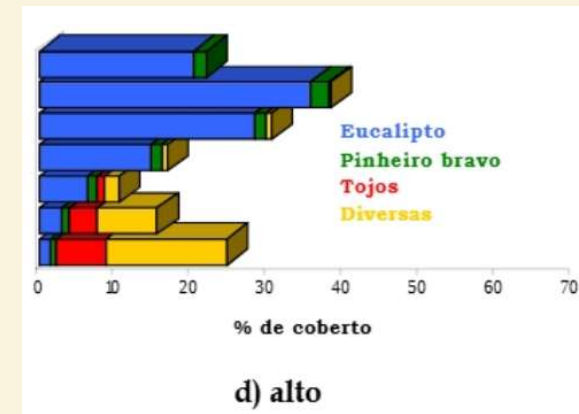


Fig 15: Dominating understory of eucalypt and pine woods in northern portugal [14]

3 From wood to lab: Test Rig, sampling & Experimental Design



Sampling

The Representativity Problem

- Understory does not grow consistently
- The plot dimensions and positioning must be chosen so that the plot reflects the ground cover of the vegetation mosaic.

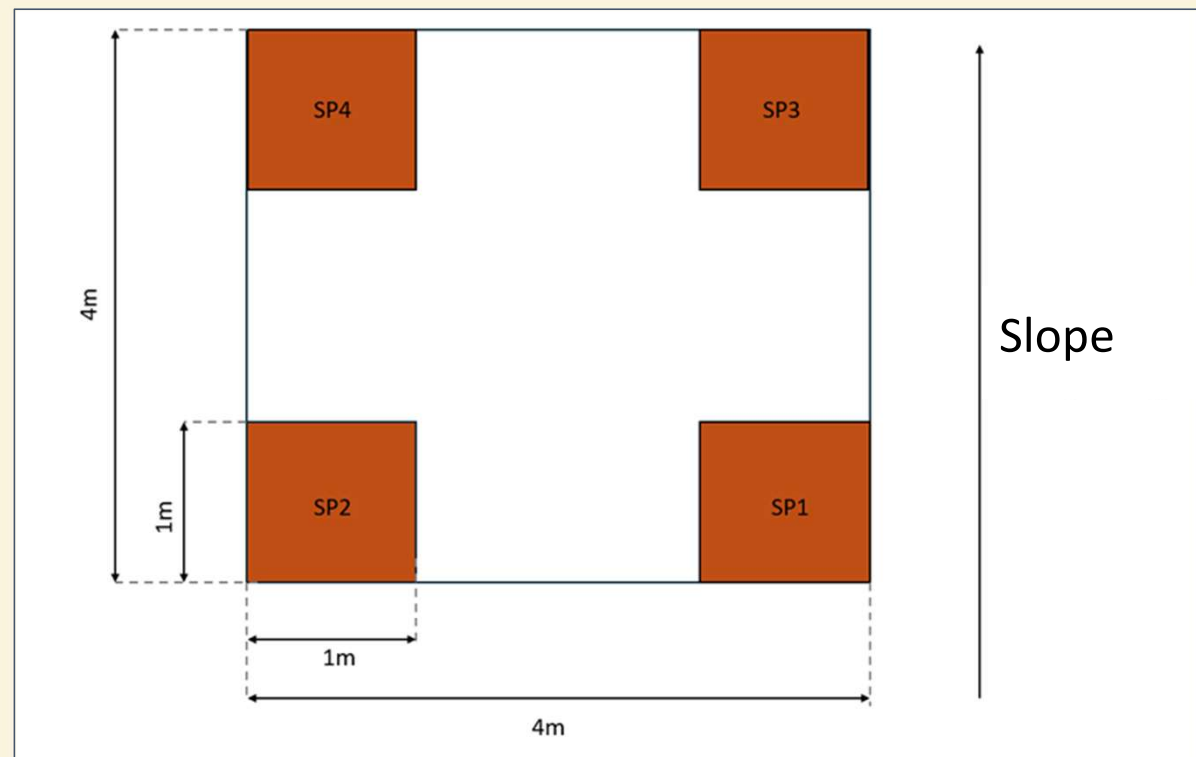


Fig 16: Sampling-Method

3 From wood to lab: Test Rig, sampling & Experimental Design



Sampling

Impressions...

Tile

before



after



Fig 17: Sampling tile before (l.) and after (r.)

Plot



Fig 18: Sampling plot before (l.) and after (r.)

3 From wood to lab: Test Rig, sampling & Experimental Design



Experiment

Measured parameters

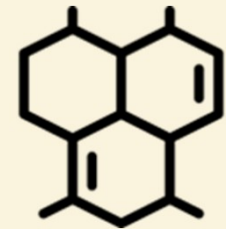
- The focus is on combustion and emission characteristics as well as validation and parameterisation data for models.



Temperature
(-field)



Pressure



Gas-Chemistry



Partikelnumber
+ distribution



Mass-loss



Flow-Speed

3 From wood to lab: Test Rig, sampling & Experimental Design



Experiment

Test rig

- The focus is on combustion and emission characteristics as well as validation and parameterisation data for models.



Fig 19: CAD – Model test rig.

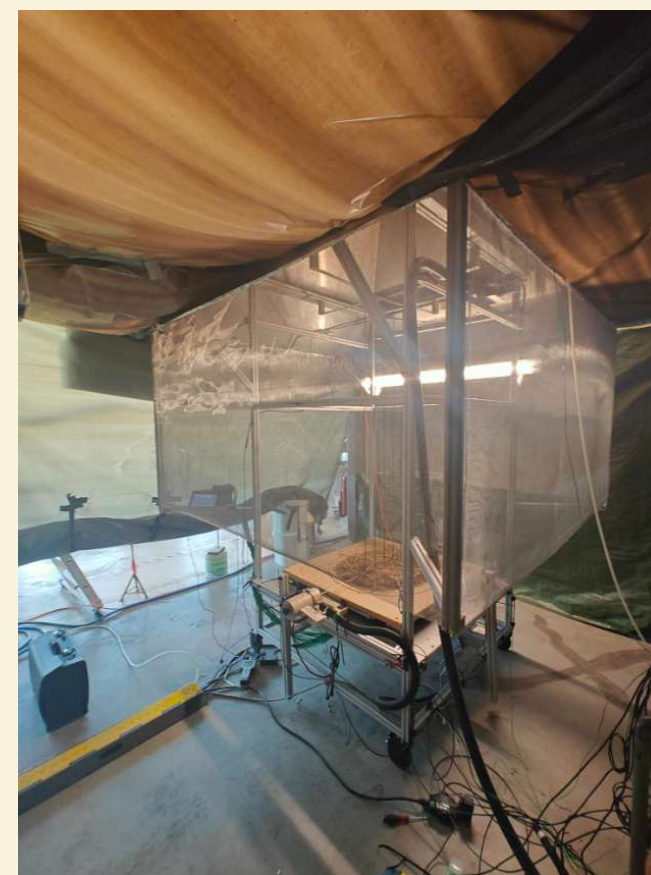


Fig 20: test rig in the lab

3 From wood to lab: Test Rig, sampling & Experimental Design



Experiment

Test rig

- The focus is on combustion and emission characteristics as well as validation and parameterisation data for models.

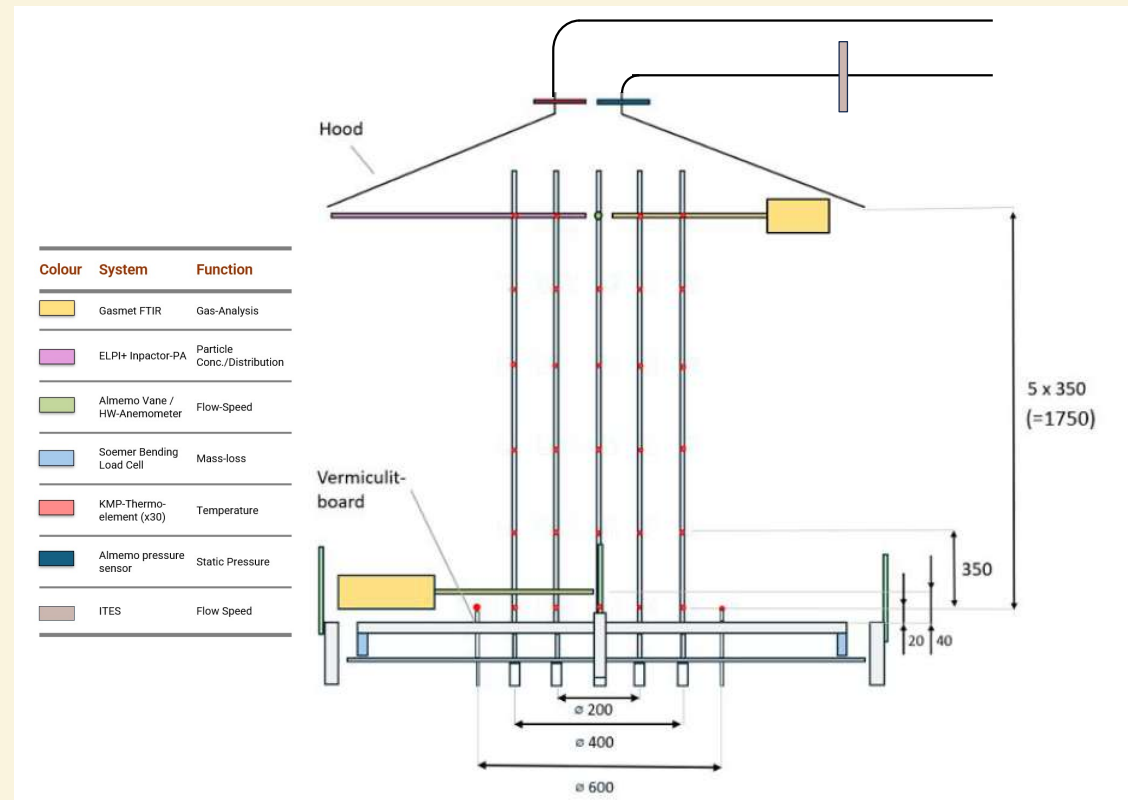


Fig 21: schematic illustration of the test rig

3 From wood to lab: Test Rig, sampling & Experimental Design



Experiment

Sample preparation

- Sample mixing due to volume and shape is a problem
- Samples are separated by components
- Mass fraction is determined

Separation



Fig 22: Sample Separation into components

Composition Analysis

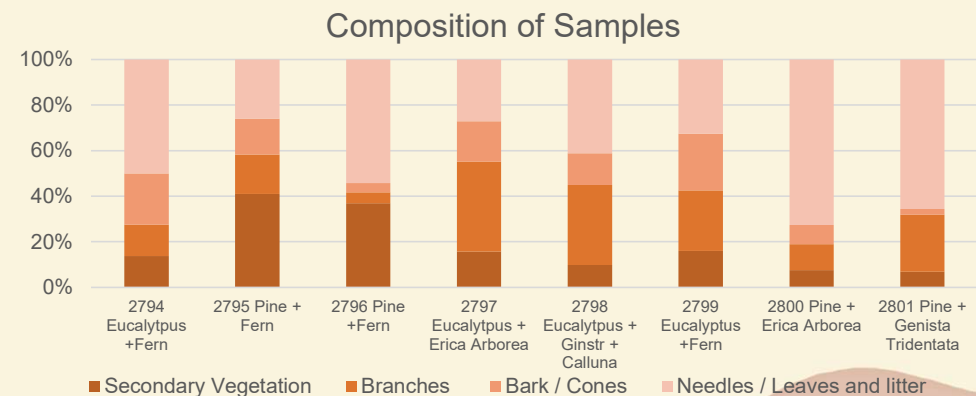


Fig 23: Sample Composition by component groups

3 From wood to lab: Test Rig, sampling & Experimental Design



Experiment

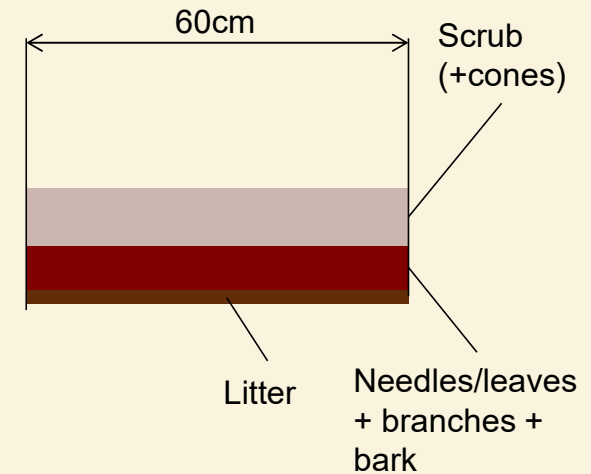
Sample standartization

- 350 g total fuel mass per experiment, composed according to predefined mass fractions
- Layer structure according to natural ground vegetation layer
- 5 Experiments per sample

Fuel bed



Fig 24: Sample preparation



Ignition



Fig 25: Ignition spot



Fig 26: Combustion

Smoke and Bioaerosols in a Changing Climate „BioSmoke“

Leibniz Science-Campus Leipzig



3 From wood to lab: Test Rig, sampling & Experimental Design

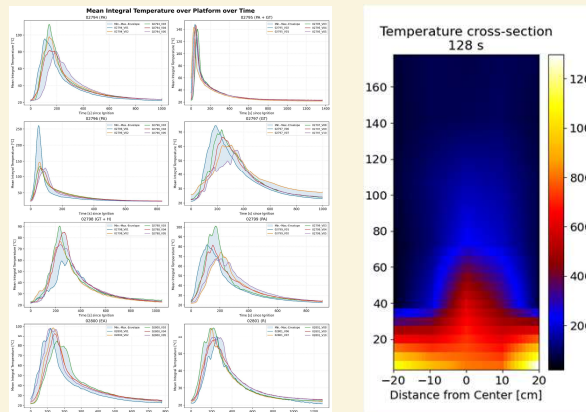


Data Analysis

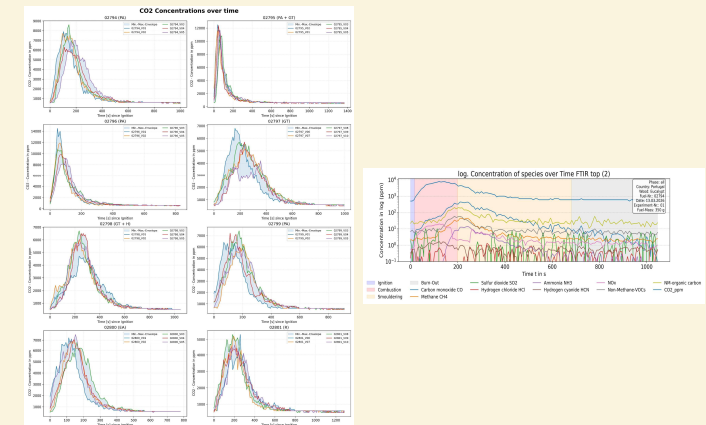
Impression of results

- Experiment-run-averaged time series for each parameter and sample
- single experiment time series or time depended spatial & time resolved distributions

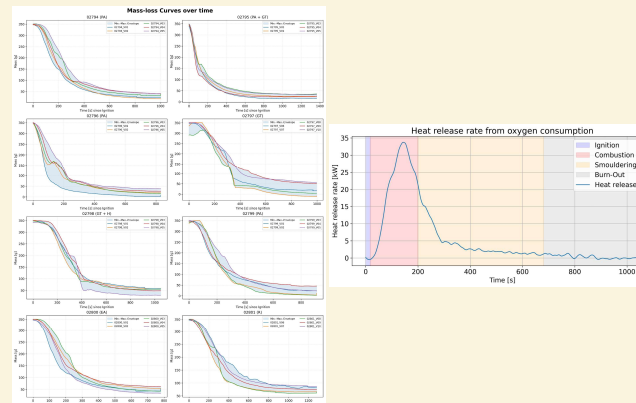
Temperature



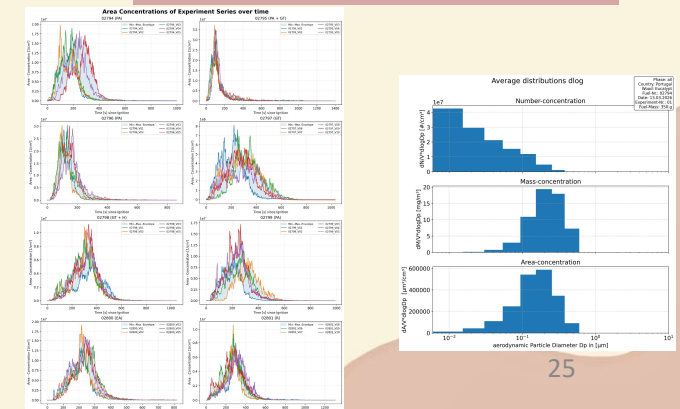
Gas Chemistry



Mass loss / heat release



Particle



Outline

4 Modelling concept and challenges

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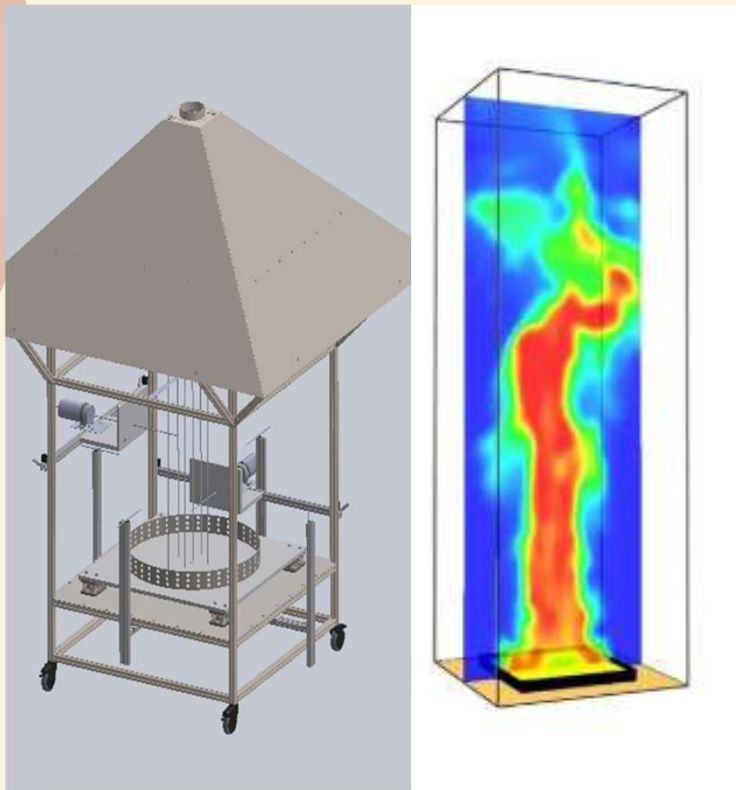


Fig 27: Model Domain

Fig 27: Simulation Example [13]

Model basic principle

- CAD-Model of the test rig serves as the simulation domain
- The volume over the platform is divided in cells by the finite-volume-method
- Conservation equations for each cell is solved and coupled with the adjacent cells for each time step:
 - Mass
 - Impulse (Navier-Stokes-Equation with variable Density and buoyancy)
 - Energy (Enthalpy, Temperature)
 - Chemical species (O_2 , combustibles, CO_2 , H_2O , CO, Sooth...)

Results

- Temperature-, Speed- and concentration Fields
- Heat Release Rate (HRR), Mass-loss, Flame and Plume Height
- Gas Emissions
- Particulate emissions (limited)

Speed- and concentration fields can be validated at one Spot

4 Modelling concept and challenges

How is the model composed? What are the requirements?

Gas-phase Model

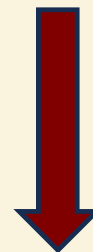
- Reactive multi-phase flow
 - Turbulence Model (compressible, variable Density, buoyancy) → Impulse, Energy, Species, Reaction
 - Reaction Model (complex, multi-stage reaction mechanisms) → Species-, Energy-Equation
 - Radiation model (varying smoke composition, adsorption) → Energy-Equation
 - (Particle Model)

solid-state Bed model

- Solid-phase pyrolysis of fuel:
 - Convection model (Gas-solid, heterogeneous fuel structure)
 - Heat conduction model (Solid heterogeneous matrix)
 - Drying Model
 - Radiation model (Gas-solid)
 - Reaction model (complex multi-stage decomposition into combustibles)



Gas
composition,
Temperature,
Density, mass-
flow...



Radiation,
convection

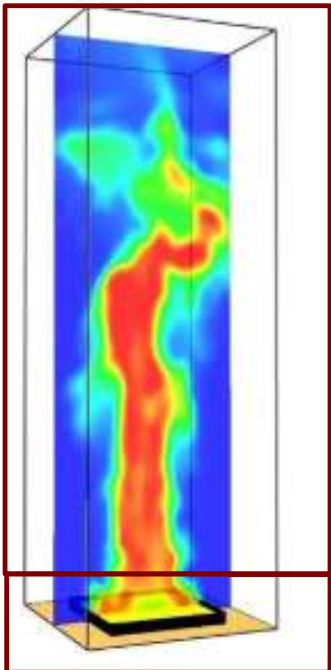


Fig 28: Model Example

4 Modelling concept and challenges

Modelling challenges/Diskussion

- **Bed structure:** irregular shapes, heterogeneous packing, bed collapse during burning
- **Mixture effects:** non-additive burning behaviour, individual kinetic and physical parameters per component
- **Particle size:** coarse components not thermally thin (thermal gradient), some larger than grid cells
- **Material data & kinetics:** uncertain pyrolysis parameters (from TGA with low constant heating rates), parameter change during transition from flaming to smouldering, Nusselt- and radiation-models don't apply for irregular shaped and oriented particles
- **Open combustion:** boundary conditions, air entrainment, drafts
- **Emissions:** CO, soot and organic aerosol strongly dependent on local conditions, aerosols difficult to model due to rapid changes

Quellen

- [1] <https://eu-space.europa.eu/components/earth-observation-copernicus/image-of-the-day/severe-fires-affected-europe-and-north-africa-july-and-august-2026>, 29.09.2026
- [2] <https://eu-space.europa.eu/components/earth-observation-copernicus/image-of-the-day/severe-fires-affected-europe-and-north-africa-july-and-august-2026>,
- [3] <https://www.carbonbrief.org/factcheck-no-europe-is-not-having-its-quietest-year-for-wildfires>, 27.09.2026
- [4] Cunningham et al, 2024, Nature Ecology and Evolution
- [5] IPCC AR5, 2013, Fig. 8.17
- [6] Simoneit et al, 2002, Appl. Geochem.
- [7] Ansmann et al, 2025, ACP
- [8] Presentation Kai Weber, «Vegitation Modelling», 2026 Smoky Days
- [9] Pyroconvective Smoke Modelling, Jason Müller, Presentation Smoky Days, 03/2026
- [10] <https://www.swri.org/markets/chemistry-materials/fire/fire-research-engineering/computational-fluid-dynamics-cfd-fire-modeling>, 29.09.26