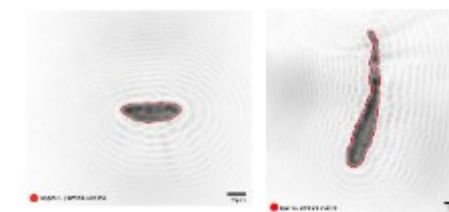
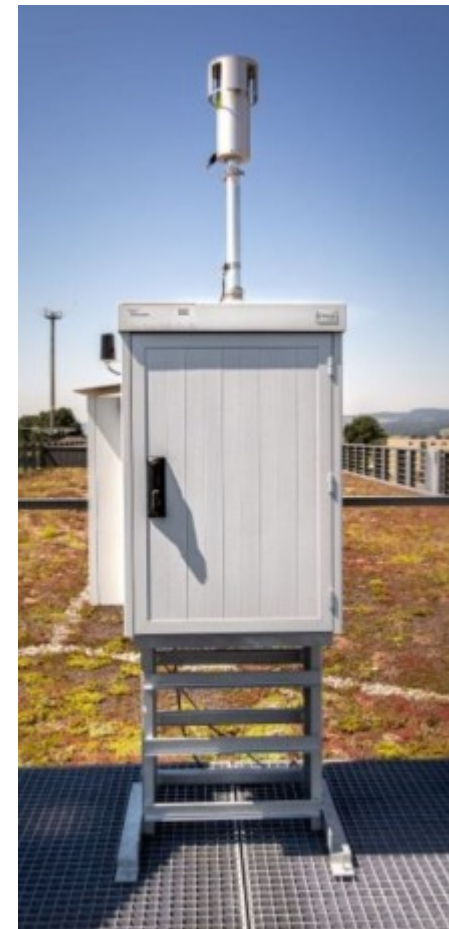


Real-time detection of late and early blight in the field using the SwisensPoleno Jupiter

Tomke Musa, A. Schwendimann, Y. Zeder, E. Graf, H. Gütlin, Ch. Kunz, R. al Naser, F. Mascher, G.-D. Lieberherr, S. Erb, B. Clot, T. Bendinelli, S. Dietler and **Erny Niederberger**

19.05.2026, EuroBlight Workshop, Ourense (ESP)





Content

SwisensPoleno Jupiter

- Improvement of the algorithms/classifier

Field experiments 2023-2025

- Results SwisensPoleno Jupiter measurements on the ground validated against Hirst-type traps
- Comparisons of SwisensPoleno Jupiter on the ground with SwissPollen rooftop

Conclusions and Outlook



SwisensPoleno

Automatic Real-time Monitoring of Bioaerosol

Current method for identifying pollen and spores



Sampling



Visualization

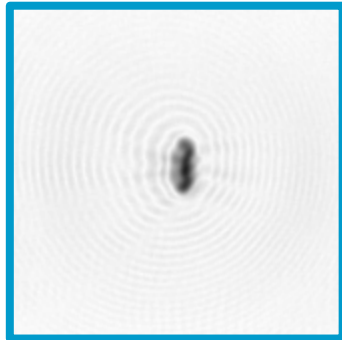
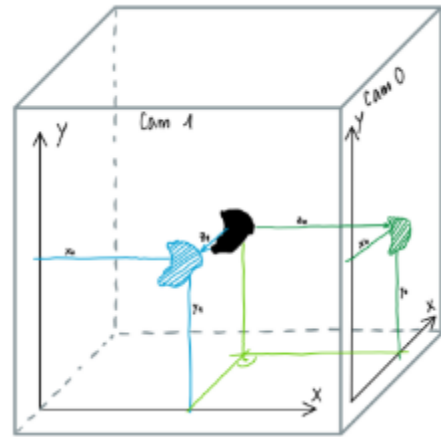
- **Manual identification**
- **Several days delay**

New method:



- **Fully automatic**
- **Continuous monitoring**
- **Real-time classification**

Characteristic Image Features via Post-Processing



Step 1

Shape reconstruction for the 90° displaced holography measurement setups

Result:

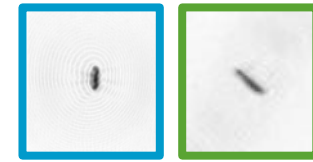
Images showing front and side views of the same particle

Step 2

Image features extraction

Result:

15 standard features for each image are calculated



Property	Value	Value
area	397	512
bbox area	510	1575
convex area	421	574
eccentricity	0.898461	0.979012
equivalent diameter	22.4828	25.5323
feret diameter_max	34.2345	55.2178
major axis_length	34.1256	57.3276
max intensity	0.706567	0.717488
mean intensity	0.458022	0.507221
min intensity	0.12674	0.21994
minor axis_length	14.983	11.6835
orientation	-0.0500055	0.91972
perimeter	83.598	125.539
perimeter crofton	81.9374	121.7
solidity	0.942993	0.891986



Recognizing Spores vs Pollen: key challenges

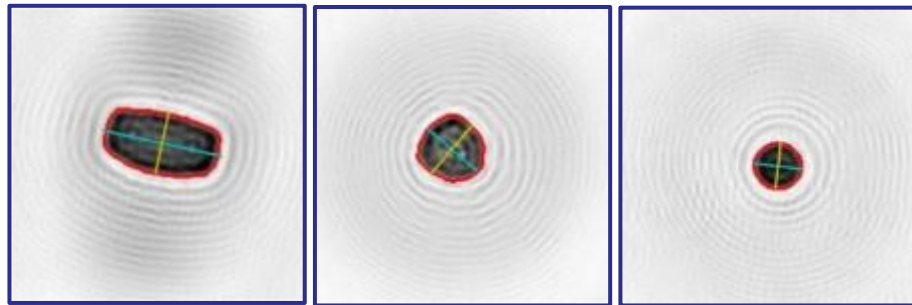
Pollen

- Compact shape; Rigid structure
- Large size (10µm+)

Spores

- Morphology depends on stage of maturity
- isolates of same species differ in shape
- String-Like appearance
- Wide range of sizes (<1µm up to 100µm+)
- particle-chains

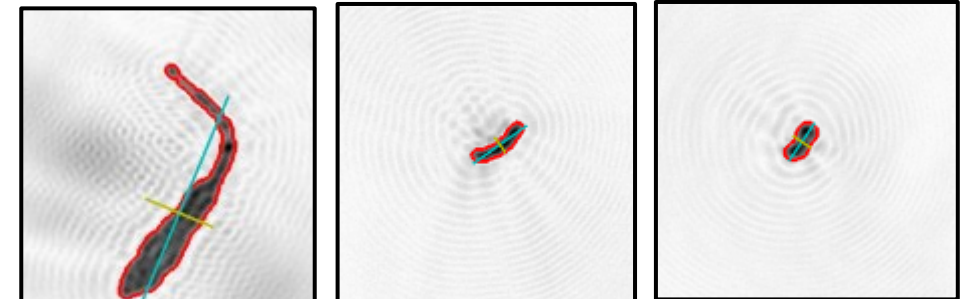
Standard Features: Major Axis, Minor Axis, Size, Compactness (Solidity)



*Quercus
robur*

*Betula
pendula*

*Urtica
dioica*



*Alternaria
solani*

Fusarium

Cladosporium

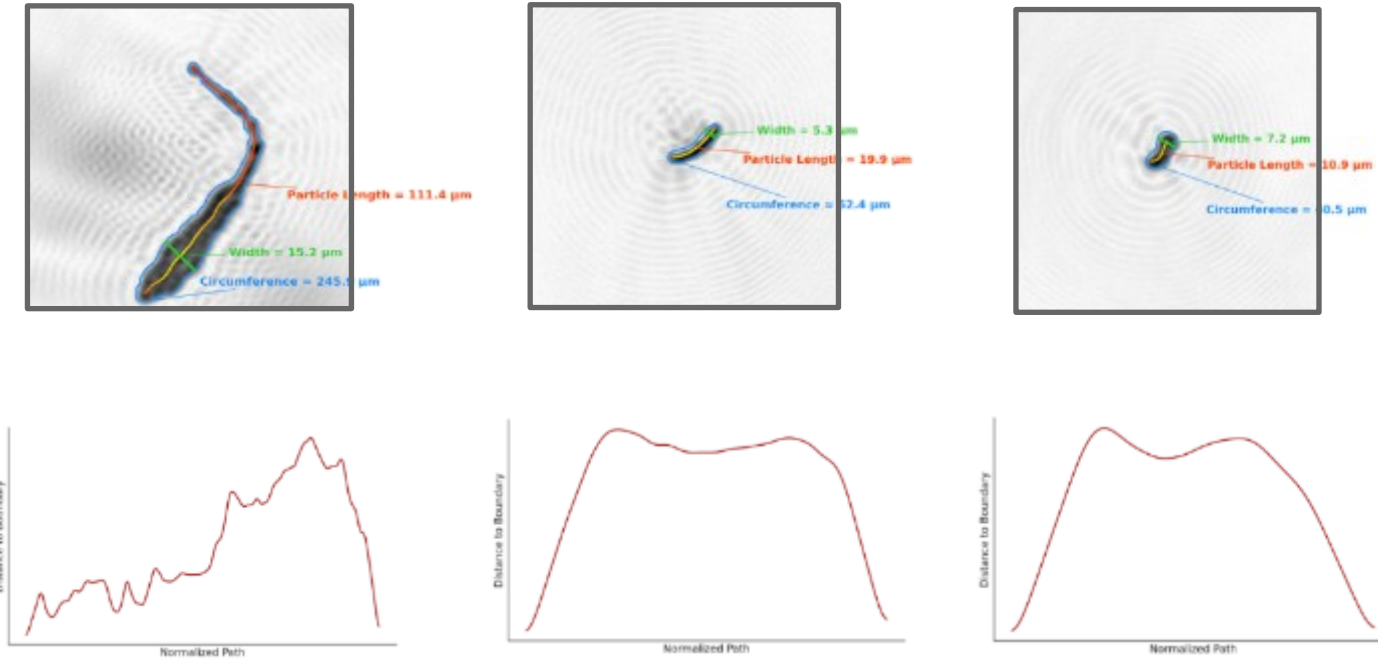
Standard features work well!

Standard features inaccurate or fail!

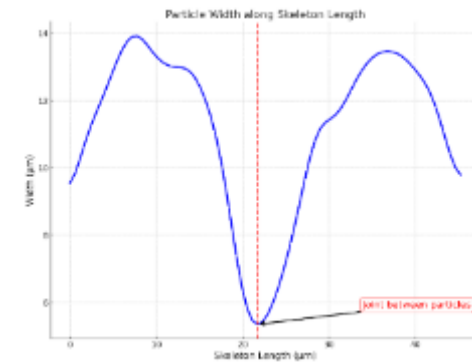
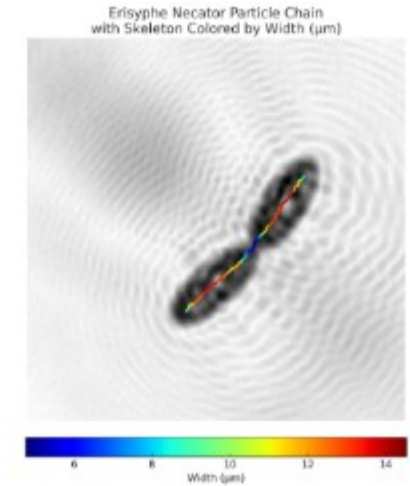


Solution: Advanced Image Feature Extraction

Leveraging Skeleton Extraction + Distance Transform



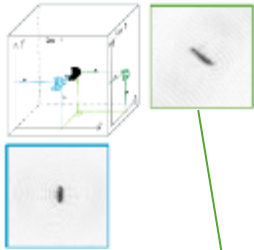
Detecting Particle Chains



Solution: Advanced Image Feature Extraction

Solution: Skeleton merging!

By using knowledge of camera position



Feature	Value	Value
area	397	512
bbox area	510	1575
convex area	421	574
eccentricity	0.898451	0.979012
equivalent diameter	22.4828	25.5323
feret diameter max	34.2345	55.2178
major axis length	34.1256	57.3276
max intensity	0.706567	0.717488
mean intensity	0.458072	0.507221
min intensity	0.12674	0.21994
minor axis length	14.983	11.6835
orientation	-0.0500555	0.91972
perimeter	83.598	125.539
perimeter crofton	81.9074	121.7
solidity	0.942993	0.891986

Problem:

Example

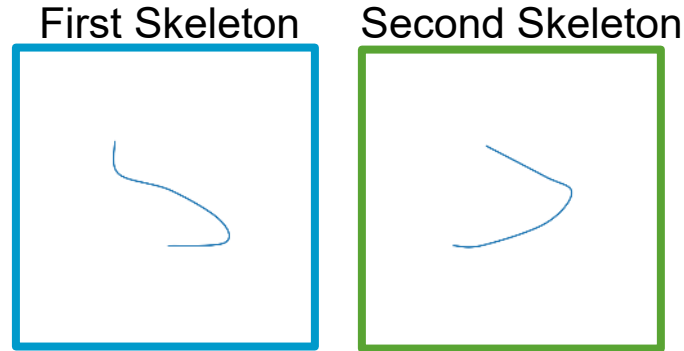
- One “length” value from each image
- Which one shows the true length of the particle?
- What length is it?

Maximum...?

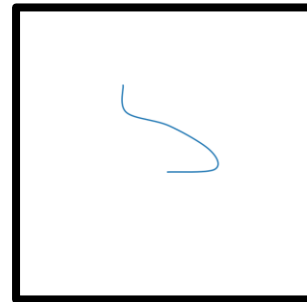
Mean...?

Something else...?

Average...?



Merged Skeleton
(animated image, effect not visible in pdf)



New Features *:

- **Global Particle Length**

*Condition: «Up»-direction in both images should match.
Not always possible, but good approximation!

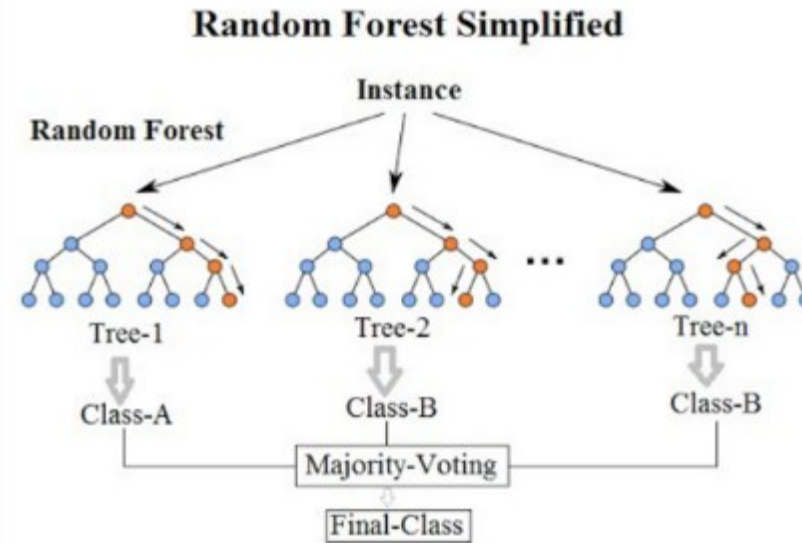


Classifier

- The feature engineering quality improved
- Therefore, a random forest-based classifier is an alternative to a CNN based classifier

Benefits

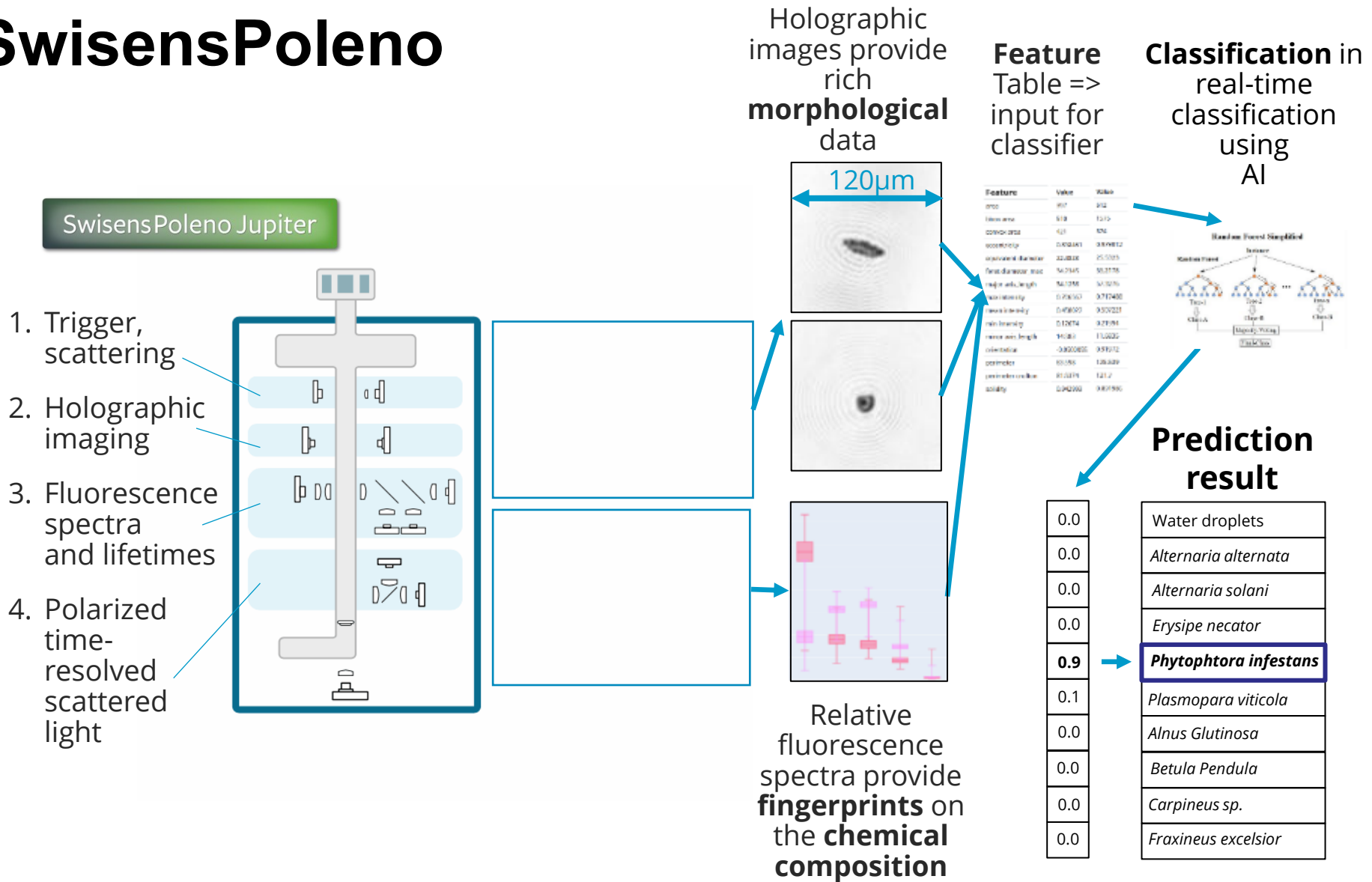
- Less computational requirement
- faster development
- more explainable
- deployment on edge devices



Simplified random forest classifier (source unknown)



SwisensPoleno

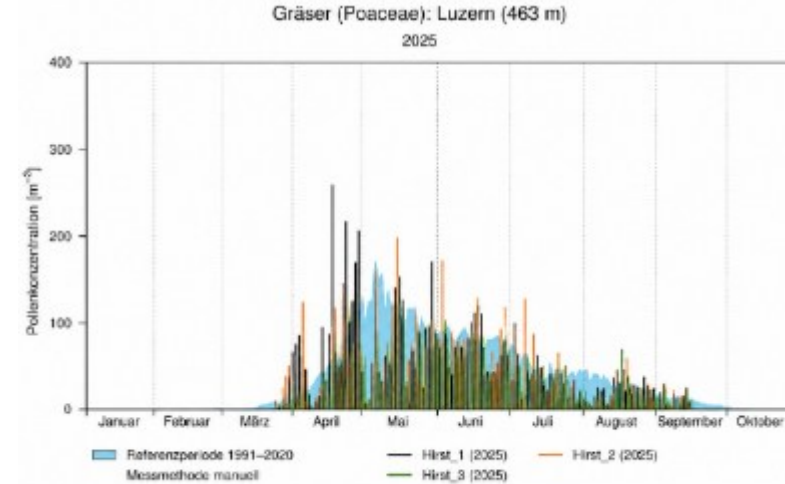




Evaluating classifier performance under real-world conditions



Source: AI generated



Source: AI generated simulation on Kendall's Tau 0.5 based on MeteoSwiss data from Lucerne 2025

Benchmark Kendall's Tau for comparison of pollen concentration time series for different pollen types (Meurville et al)*

	<i>Alnus</i>	<i>Betula</i>	<i>Corylus</i>	<i>Fagus</i>	<i>Fraxinus</i>	<i>Poaceae</i>	<i>Quercus</i>
Kendall's tau	0.48	0.63	0.50	0.66	0.75	0.64	0.66

* Meurville, Marie-Pierre, Bernard Clot, Sophie Erb, et al. 2025. 'A General Framework for Evaluating Real-Time Bioaerosol Classification Algorithms (Preprint)'. *EGUsphere*, November 19, 1–26.
<https://doi.org/10.5194/egusphere-2025-5440>.

➤ **Kendall's Tau > 0.5 is considered as acceptable quality**

Challenge of validation under real-world conditions: Reference Spore Concentration

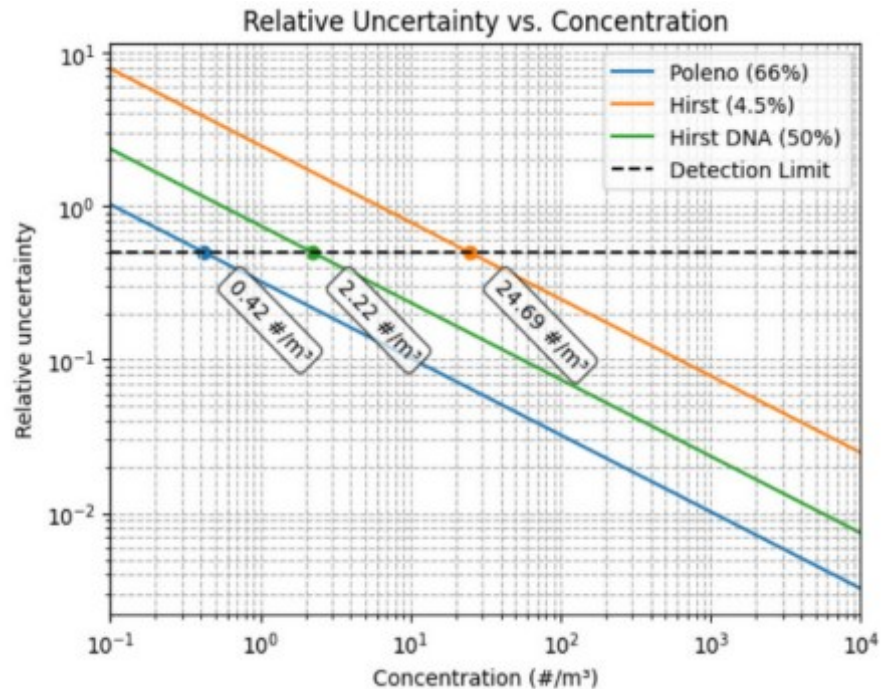


Fig. Calculation of relative uncertainty ($k = 2$) at a given concentration. Only the statistical error due to sampling is considered, representing a best-case scenario. The detection limit is assumed to be at 50% relative uncertainty as defined in Tummon et al. (28).

Limitation

- If concentrations are below 25 spores/m³, the Hirst-based measurement method has a high uncertainty
- The overall measurement efficiency of both methods cannot yet be validated metrologically.
- SwisensPoleno bases its concentration measurements on Hirst (Scaling factor).

Ref figure: Malvessi Cattani, Amanda, Yanick Zeder, Elias Graf, et al. 2026. 'Automated Air-Flow Cytometry Enables Real-Time Monitoring of *Plasmopara Viticola* Sporangia in Vineyards'. *Applied and Environmental Microbiology* 92 (4): e02152-25. <https://doi.org/10.1128/aem.02152-25>.

Field experiments 2023-2025 - local measurement

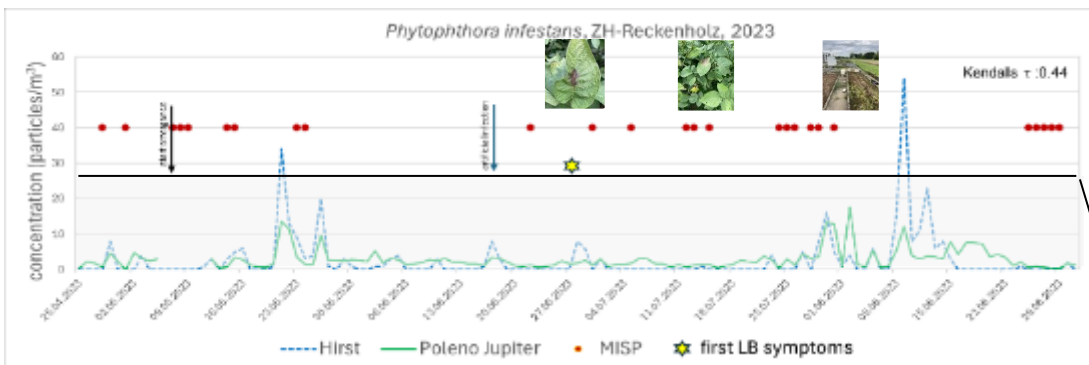
- SwisensPoleno Jupiter (automatic) and traditional Hirst spore trap (manually) positioned on the ground
- untreated potato plots at Zurich-Reckenholz and Zollikofen (BE)
- Late blight assessment (occurrence, spread) as well as registration of Main Infection and Sporulation Periods (MISP PhytoPRE)



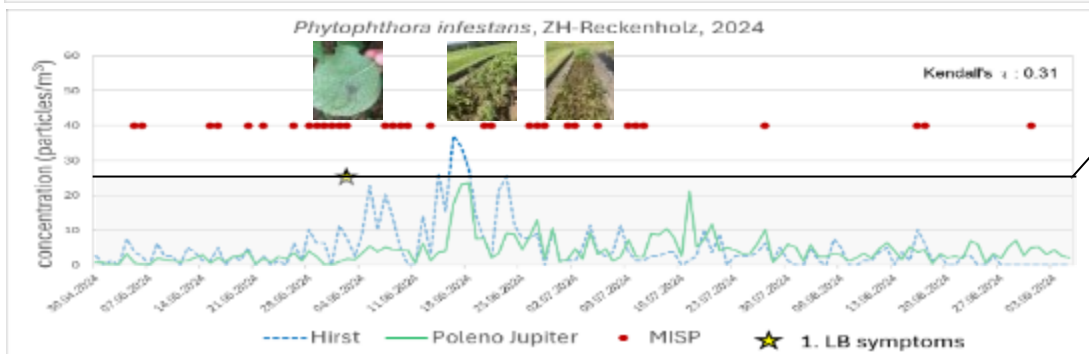


Hirst vs SwisensPoleno on the ground (2023-2025) – *P. infestans* classifier

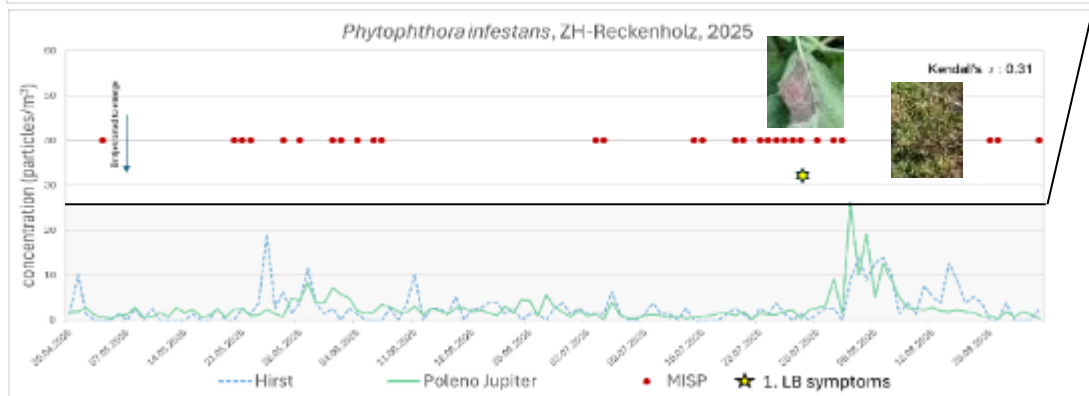
2023



2024



2025



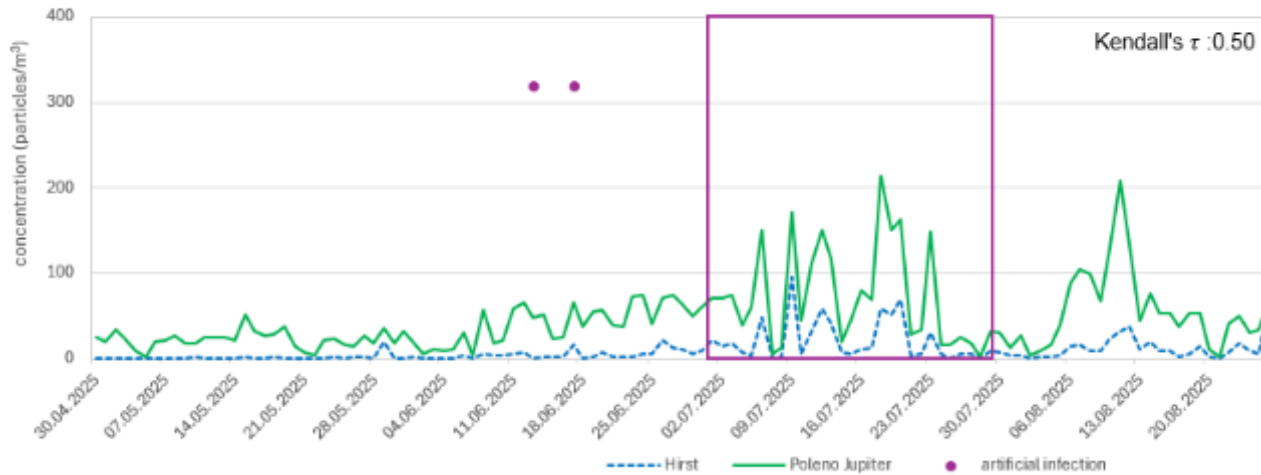
Hirst detection limit

Local measurement:

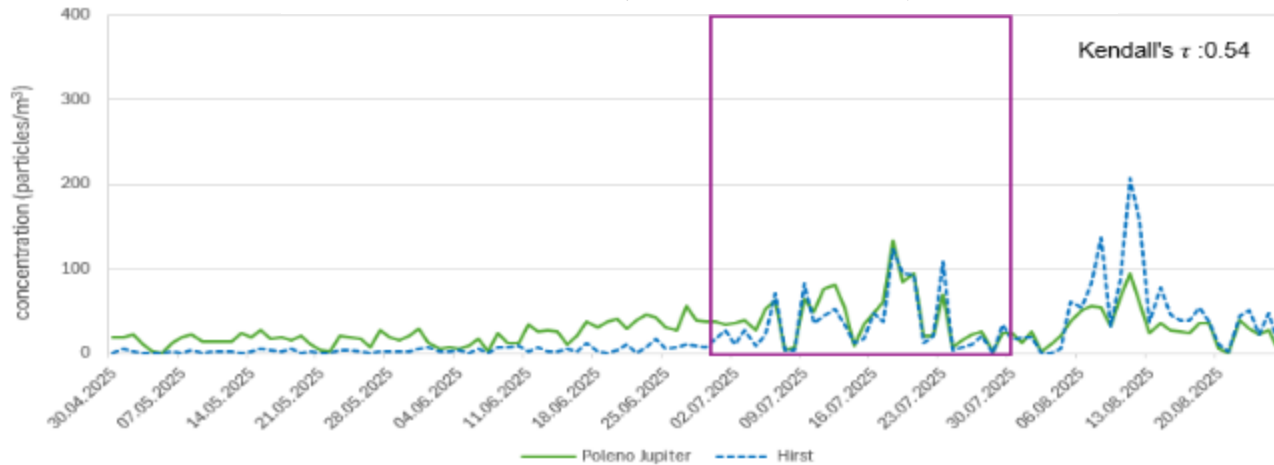
- Sporangia concentration low in all three years, even if late blight pressure quite different
 - After LB symptoms: Increase in sporangia concentration in both systems observed if weather conditions favourable (2024,2025)
 - Before LB symptoms: No clear concentration increase observed to explain the LB attack
 - Positive medium correlation of spore concentration.
- **Limitation:**
High uncertainty regarding low spore concentrations and Hirst detection limit.

Swiss flag icon Hirst vs SwisensPoleno on the ground (2025) – *Alternaria solani*/ *A. alternata* classifier

Alternaria solani, ZH-Reckenholz, 2025



Alternaria alternata, ZH-Reckenholz, 2025



Local measurement:

- Concentrations higher compared to *P. infestans*
- After artificial infection: Increase in spore concentration in both systems observed
- Medium to strong positive correlation of spore concentration for *Alternaria solani* & *A. alternata*

Kendall's τ for Hirst vs SwisensPoleno

	<i>P. infestans</i>	<i>A. solani</i>	<i>A. alternata</i>
2023	0.44	0.41	0.43
2024	0.31	0.43	0.56
2025	0.31	0.50	0.54

SwisensPoleno: ground-level vs. rooftop resp. local vs. boundary layer measurements



Distance between the ground and the roof: 6.6 km



Distance between the ground and the roof: 5.7 km

Spore transported in higher air layers?

SwisensPoleno Jupiter on the ground and on roof tops (height ca. 20m)

Roof tops in more urban environments, operated by MeteoSwiss for pollen measurements

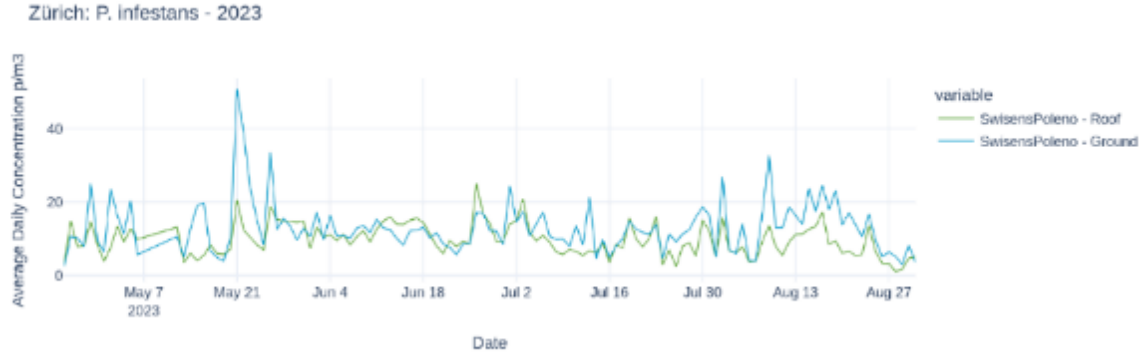


MeteoSwiss SwisensPoleno roof location in Zurich. Source: MeteoSwiss

➤ **Is the existing SwisensPoleno network applicable for spore measurements?**



Validation for *P. infestans*, *Alternaria alternata* and *A. solani* classifier



Data from year 2023

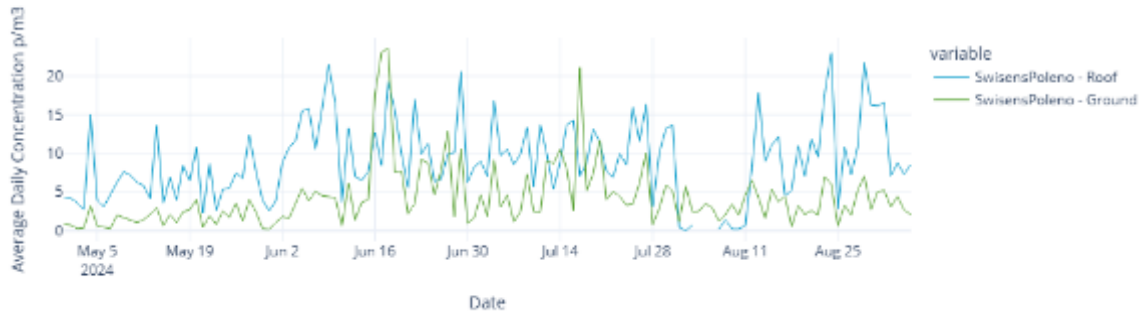
Boundary layer/ roof top measurement:

- Medium to strong correlations (Poleno vs Hirst) for all three types of spores/sporangia
- Roof vs Ground: Simultaneous increase in spore concentrations, especially for *Alternaria solani* & *A. alternata*

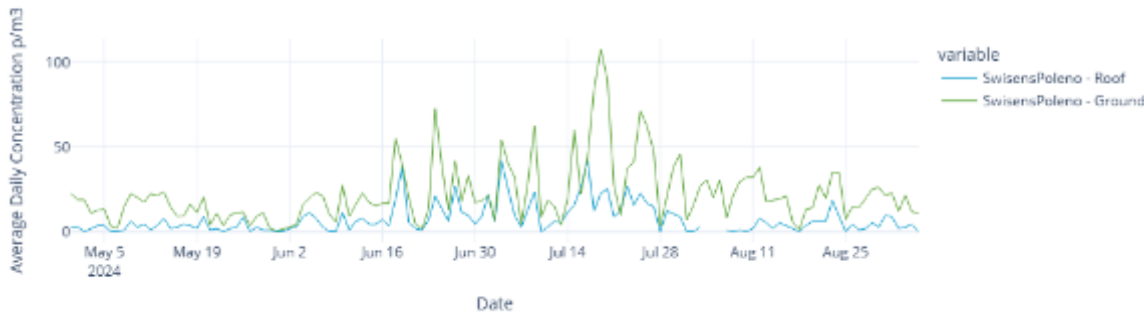


Validation for *P.infestans*, *Alternaria alternata* and *A. solani* classifier

Zürich: *P. infestans* - 2024



Zürich: *A. solani* - 2024



Zürich: *A. alternata* - 2024



Data from year 2024

Boundary layer/ roof top measurement:

- Roof vs Ground: Simultaneous increase in spore concentrations, especially for *Alternaria solani* & *A. alternata*
- Medium to strong correlations (Poleno ground vs Poleno roof) for all three types of spores/sporangia

Kendall's τ correlation coefficient

		<i>P. infestans</i>	<i>A. solani</i>	<i>A. alternata</i>
Zurich	2023	0.38	0.67	0.75
	2024	0.44	0.56	0.65
Zollikofen (BE)	2023	0.36	0.55	0.64
	2024	0.36	0.63	0.68



Conclusions and identified limitations

Evidence provided

- SwisensPoleno, together with the tested classifiers, measured spores with a moderate to strong correlation to Hirst
- Increase in spore concentrations after infection were measured by SwisensPoleno Jupiter

Identified limiting factors in the study

- High uncertainty in reference measurements of spore concentrations at low concentrations
 - Low spore concentrations at ground level
 - Few “biological events” e.g. only one first infection per season
 - Limited number of sensors per site
 - Relatively small potato plots
- Automated real-time pathogen monitoring could become an important tool for infection risk forecasting and precision crop protection

Research Outlook regarding *A. solani*, *A. alternata* and *P. infestans*

Open research questions

- What is the measurement uncertainty of SwisensPoleno Jupiter at low spore concentrations, and how can it be quantified reliably?
 - What is the ideal measurement setup for detecting the onset of an epidemic? (sampling location, number of sampling stations, sampling position above ground, ...)
 - What is the minimum airborne spore concentration required which leads to a successful infection under field conditions?
 - How does airborne spore concentration relate to infection severity?
-
- **Next steps**
 - Develop a simpler approach for validating measurements at low spore concentrations to improve the determination of measurement uncertainties.
 - Conduct studies with improved study designs (more measurement instruments per site, in the most relevant agroclimatic zones,...)

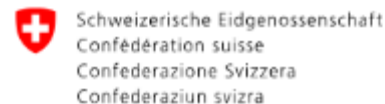
➤ **EuroBlight partners interested in a collaboration?**



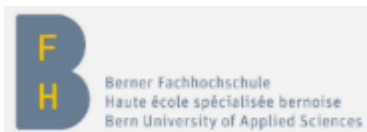
Thank you for your attention



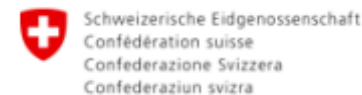
Erny Niederberger
Elias Graf
Yanick Zeder
Andreas Schwendimann



Bundesamt für Meteorologie und
Klimatologie MeteoSchweiz
Gian-Duri Lieberherr
Sophie Erb **EPFL**
Bernard Clot



Christa Kunz
Rafah al Naser
Fabio Mascher



Federal Department of Economic Affairs,
Education and Research EAER
Agroscope



Silas Dietler
Tommaso Bindelli

Tomke Musa
Haruna Gütlin

Sponsored by:

BLW-Project



Bundesamt für Landwirtschaft BLW



Chips Joint

