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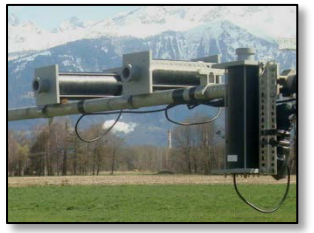
Experimental investigation of birch pollen emissions (MicroPoem) and the influence of sensor orientation and meteorological factors on the inlet sampling characteristics of volumetric bioaerosol samplers



COST Action ES0603 Project MicroPoem

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Outline

- **Introduction**
- **Pollen emission experiment**
  - Site and set-up
  - Relative performance of vertically oriented bioaerosol samplers
- **Calibration experiment**
  - Site and set-up
  - Relative performance of vertically and horizontally oriented bioaerosol samplers
  - Description of the calibration procedure
- **Summary and conclusions**
- **Outlook**

Introduction

- Investigation of pollen production and emission as function of meteorological factors
- ‘Natural tracer’ field experiment and modeling work
- Dispersion characteristics around a well-defined source
- Evaluation of sampling efficiency of different sampler types

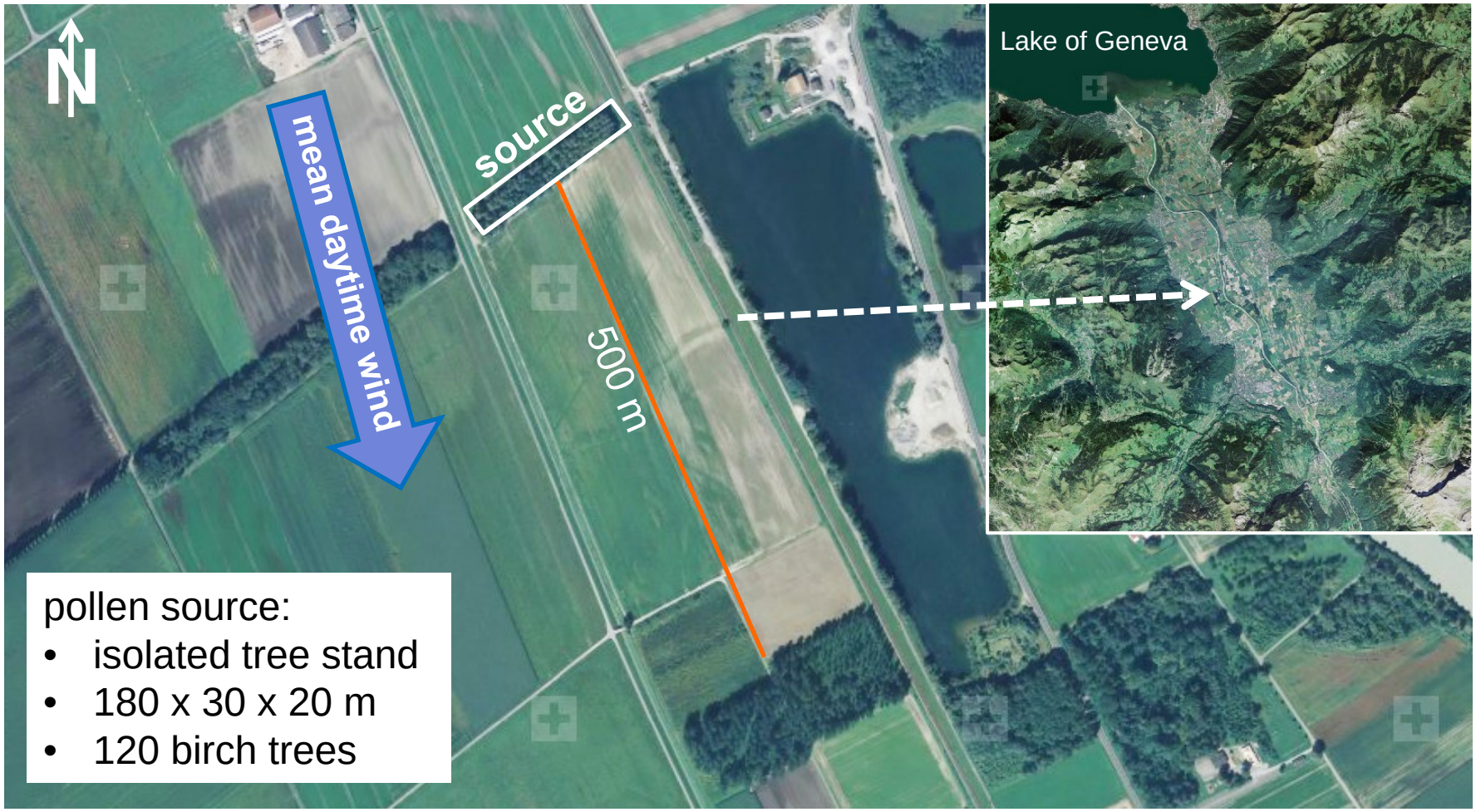
Motivation

- Diseases due to aeroallergens increased in Europe over the last decades
- Need for assessment of production and release of various pollen species and forecasting of their atmospheric dispersion
- Description of the emissions is the most important shortcoming in existing pollen dispersion systems
- Missing knowledge in the physical and biological processes that determine emission

Pollen emission experiment

Site and set-up

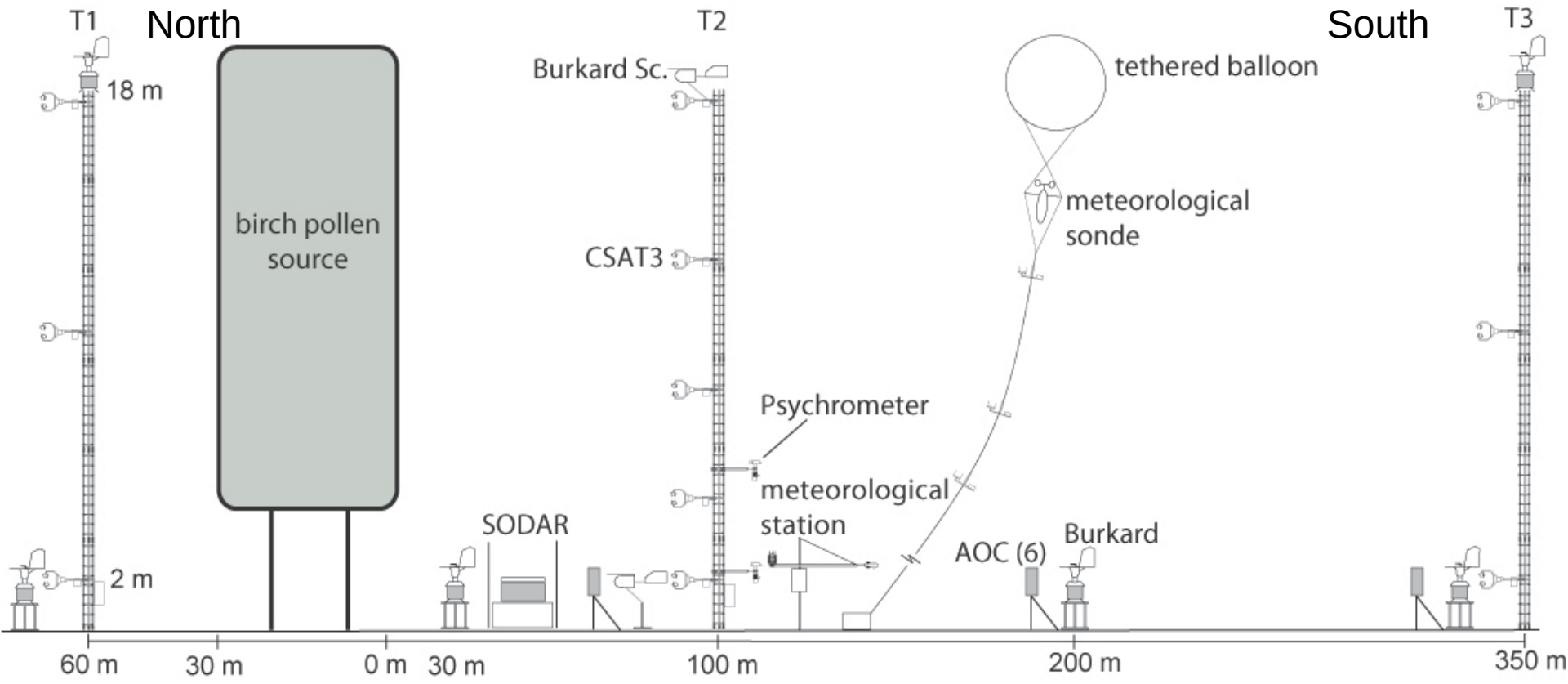
- April 2 – 24 2009 in Illarsaz, Switzerland
- Birch pollen season
- Valley location with persistent plains-mountain wind system



Satellite images of the experimental site (Federal Office of Topography swisstopo, 2011)

Pollen emission experiment

Site and set-up



- 3 sonic anemometer profiles (CSAT3)
- Scintec SODAR wind profile
- Tethered balloon system
- WXT weather transmitter
- CNR1 net radiometer
- Psychrometer profile
- Soil temperature probes and heat flux plates
- 29 pollen samplers (vertical and horizontal profiles), 3 different types

Pollen emission experiment

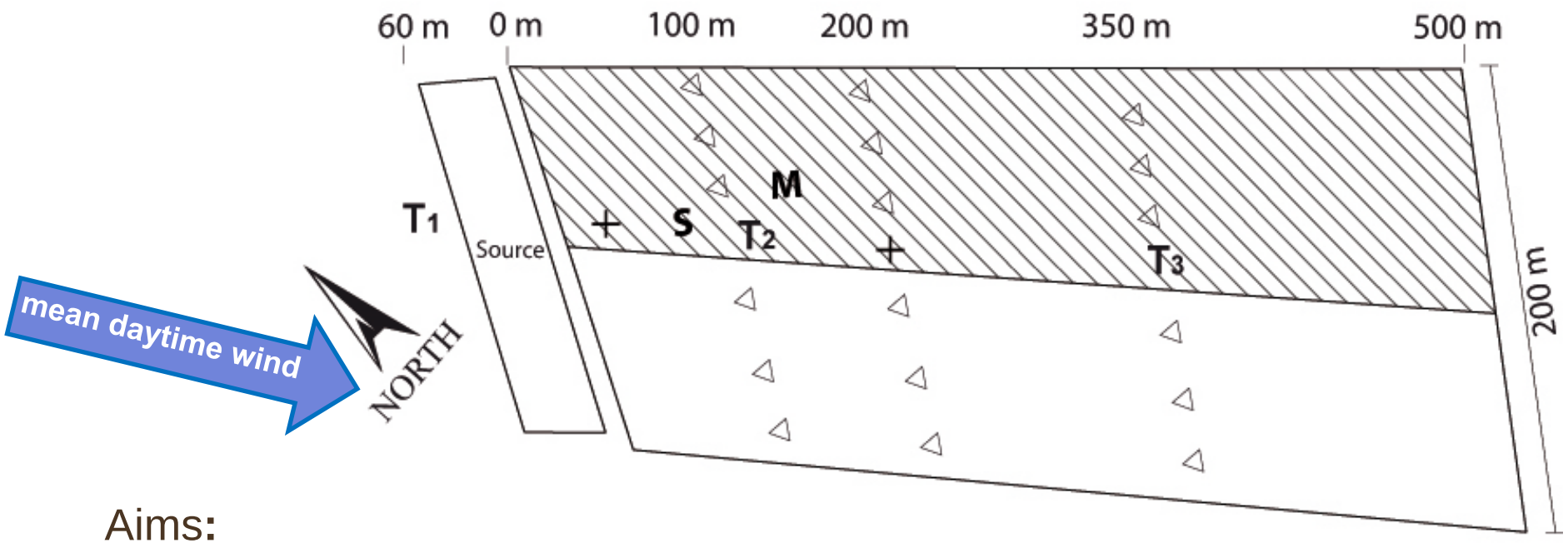
Site and set-up

Air-O-Cell pollen sampler
(vertically oriented orifice)
air throughput 18 l/min

Burkard pollen sampler (reference)
(horizontally oriented orifice)
air throughput 10 l/min

Emission experiment

Site and set-up



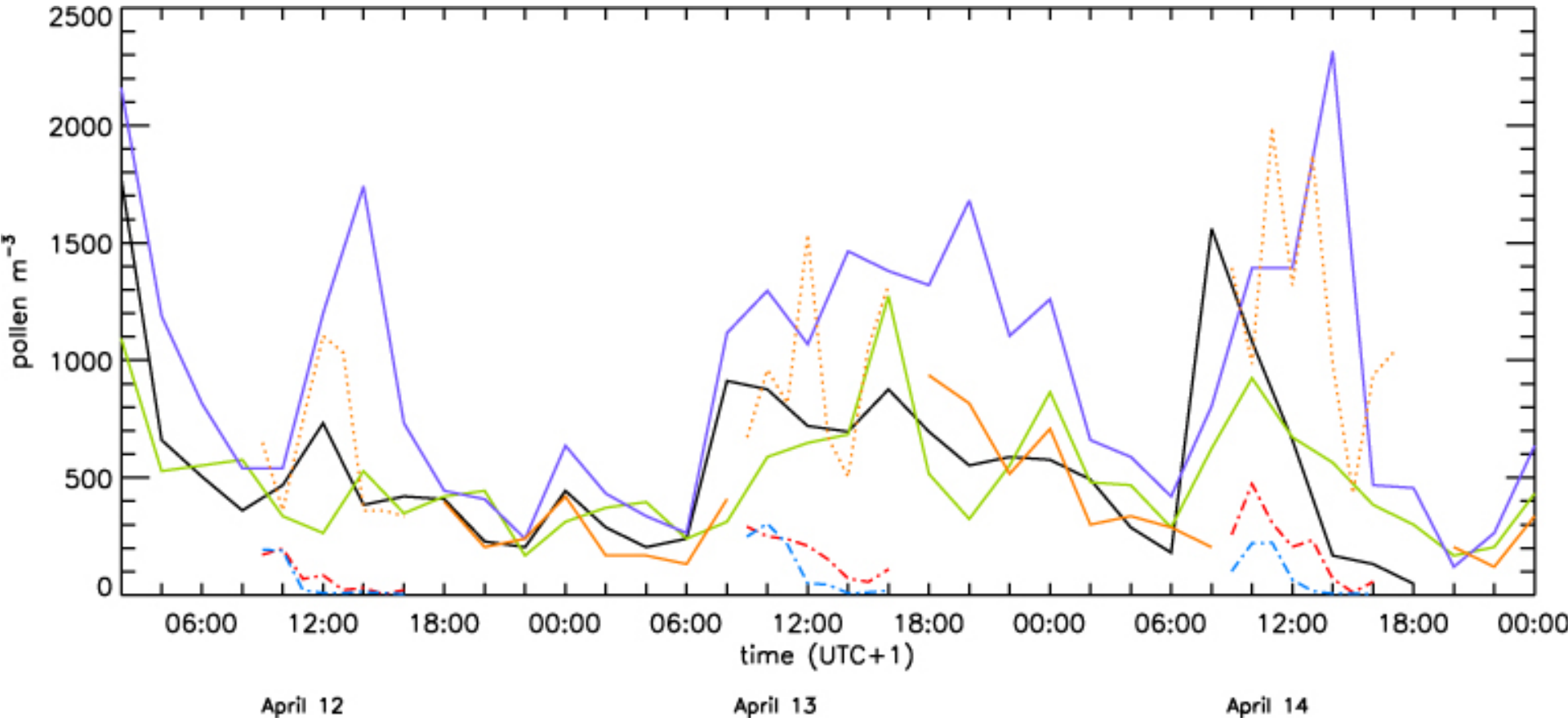
Aims:

- Quantification of released pollen as function of meteorological factors
- Characterization of local pollen dispersal downwind of a pollen source

T towers
S SODAR
M meteorological station
\+ singular Burkards
△ Air-O-Cell pollen samplers

Emission experiment

Relative performance of vertically oriented bioaerosol samplers

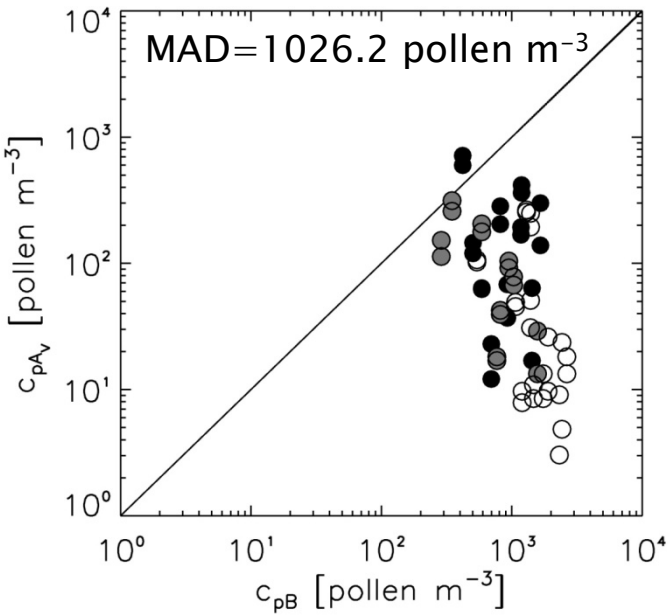


Course of 2-hour pollen concentrations during IOPs 3 to 5 measured using different pollen sampler types

- Burkard 30 m background
- Burkard 30 m
- Burkard 100 m
- Burkard 350 m
- AOC 100 m
- AOC 200 m
- Burkard Scientific 100 m

Emission experiment

- Burkard samplers yield plausible information on longitudinal downwind pollen dispersal
- Dramatic underestimation of pollen concentration with vertical Air-O-Cell samplers compared to Burkard measurements
- Diurnal course of differences
- Hypothesis: influence of meteorological conditions on sampling efficiency, above all wind velocity due to inertial effects

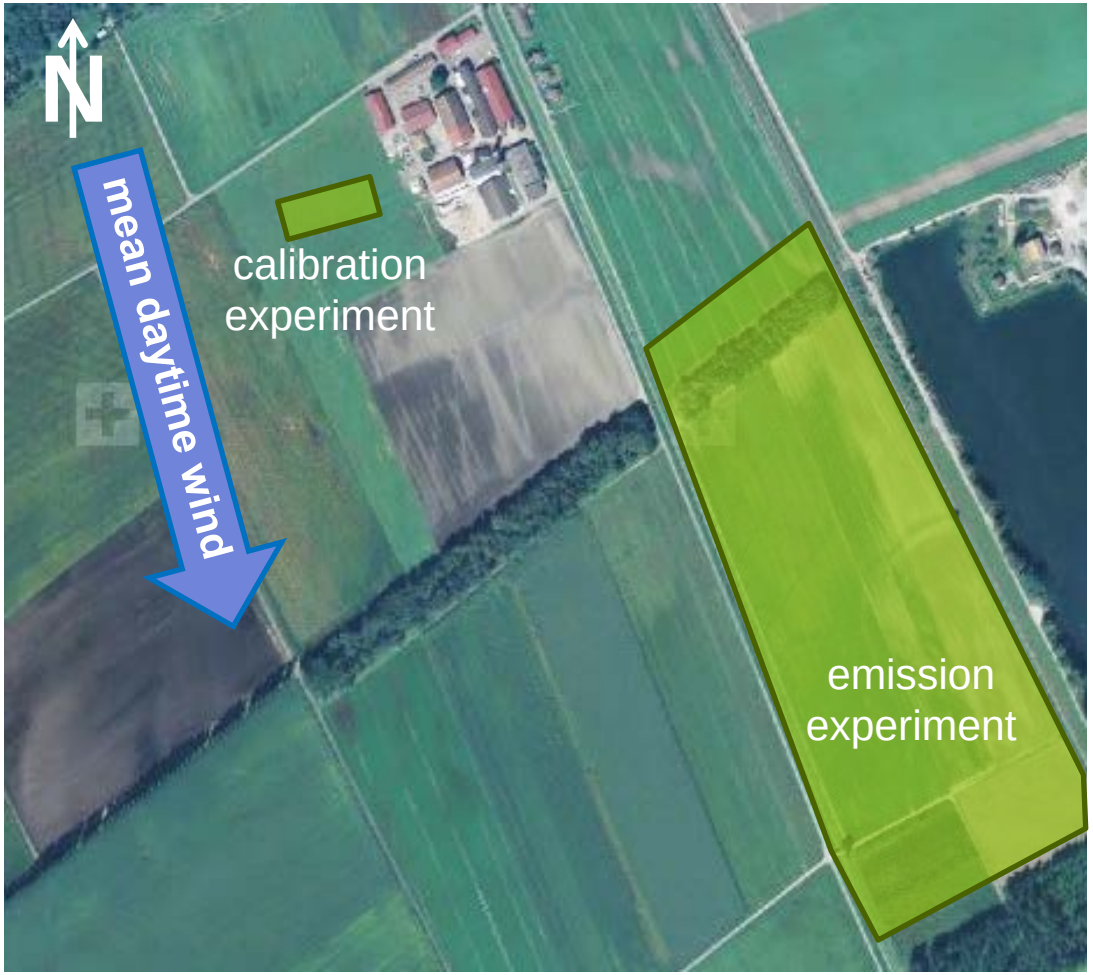


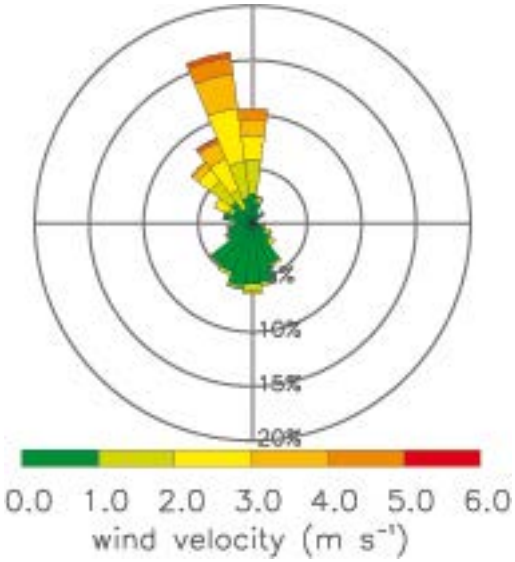
Burkard vs. Air-O-Cell 2-hour data

Calibration of vertically oriented pollen samplers is required, based on meteorological factors

Calibration experiment

Site and set-up



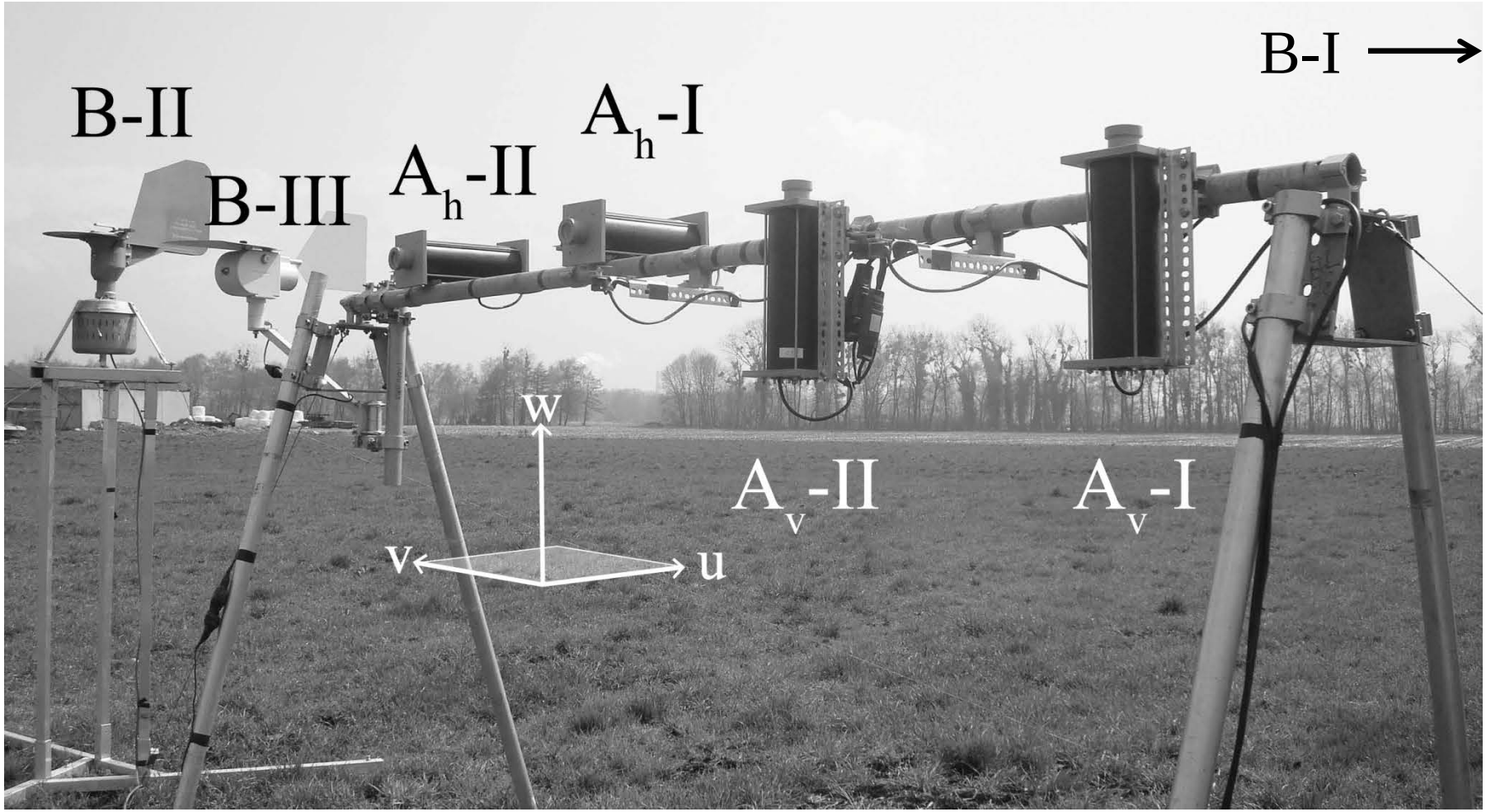


- April 5 – 22 2010 in Illarsaz, Switzerland
- Birch pollen
- Pollen source not defined

Satellite images of the experimental site
(Federal Office of Topography swisstopo, 2011)

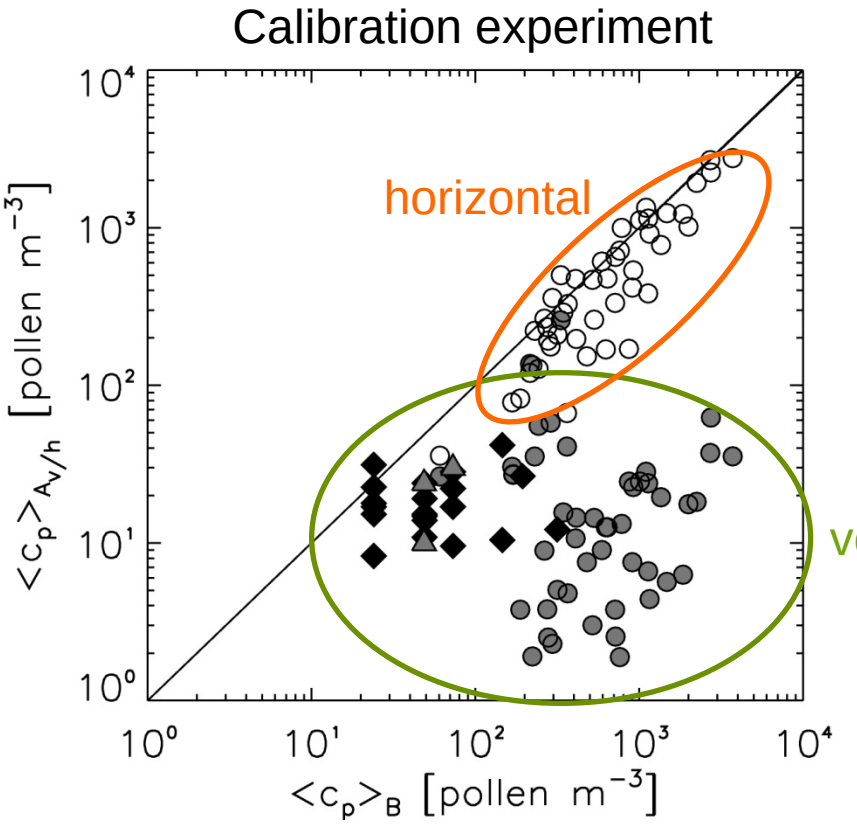
Calibration experiment

Site and set-up

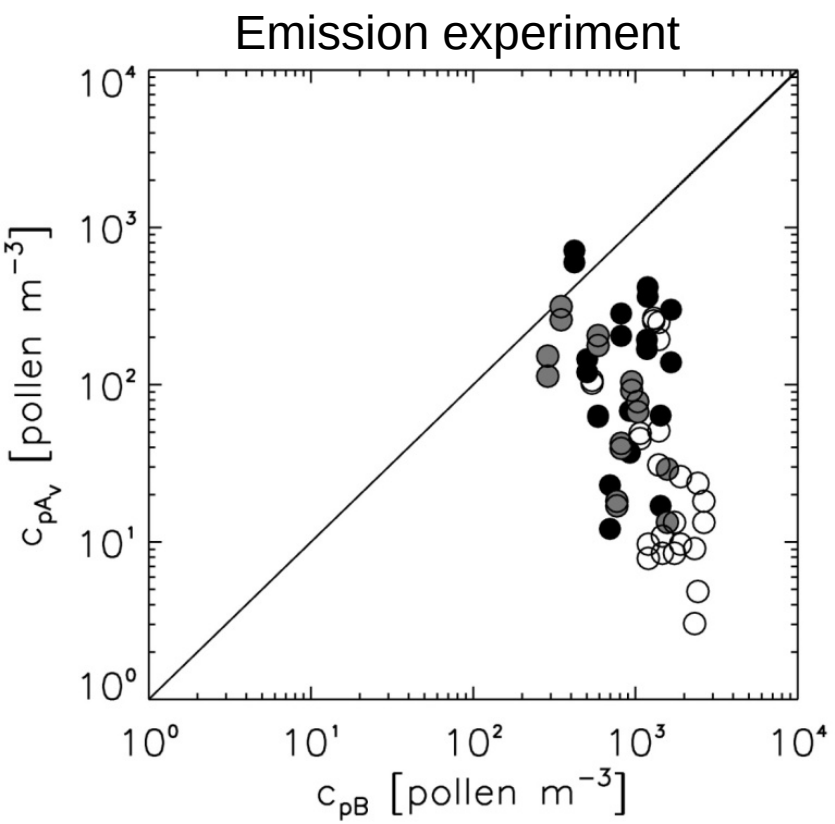


- Redundant pollen measurements (3 sampler types)
- Wind and turbulence characteristics (METEK USA-1 anemometer)
- Different orientation of AOC systems (horizontally and vertically)
- Instrument orientation according to daytime main wind direction (350 °)

Calibration experiment



Burkard vs. horizontal and vertical Air-O-Cell 1-hour data



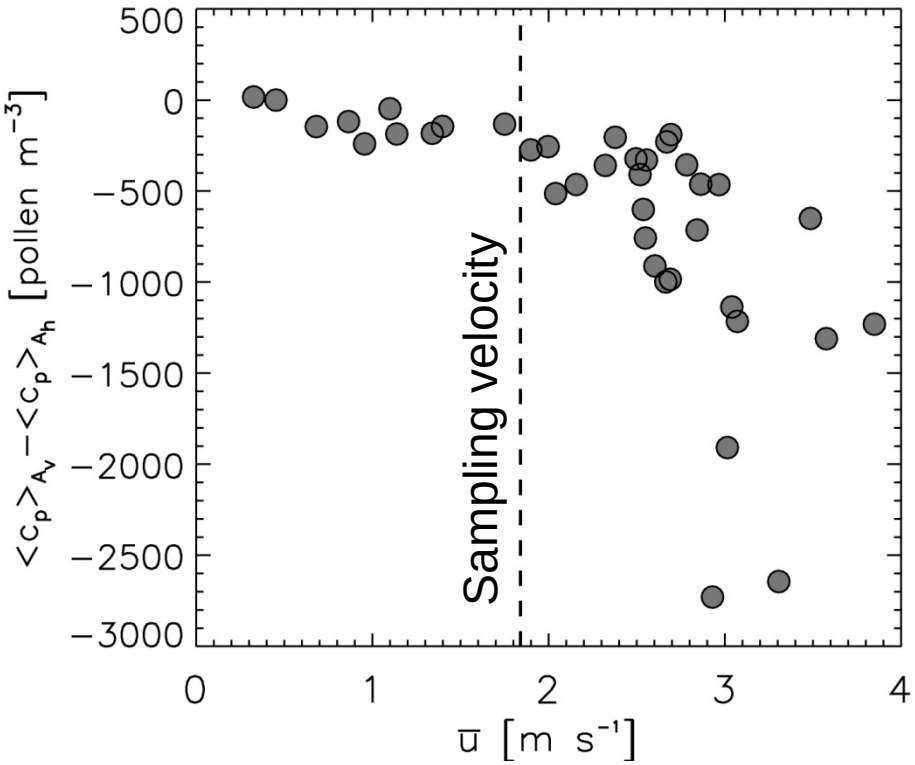
Burkard vs. Air-O-Cell 2-hour data

horizontal orientation of Air-O-Cell pollen samplers significantly improves the agreement to Burkard samplers, yet with a slight underestimation

Calibration experiment

Description of the calibration procedure

Find meteorological factors, wich influence the sampling efficiency of vertically oriented pollen samplers



Differences AOC-Burkard vs. longitudinal wind velocity

- Strong influence of wind velocity on sampling efficiency
- Linear dependence on wind velocity *u,* if *u* < sampling velocity
- Linear dependence on *u* and *rh*, if *u* > sampling velocity

The influence of humidity on the sampling efficiency can be explained by an impact on the inertial state of the moving pollen. The specific weight of pollen grains is variable, due to their ability to hydrate and dehydrate

Pohl, F. (1937), 'Die Pollenkorngewichte einiger wildbluetiger Pflanzen und ihre oekologische Bedeutung', Beih. Bot. Cbl. 57, 112–172.

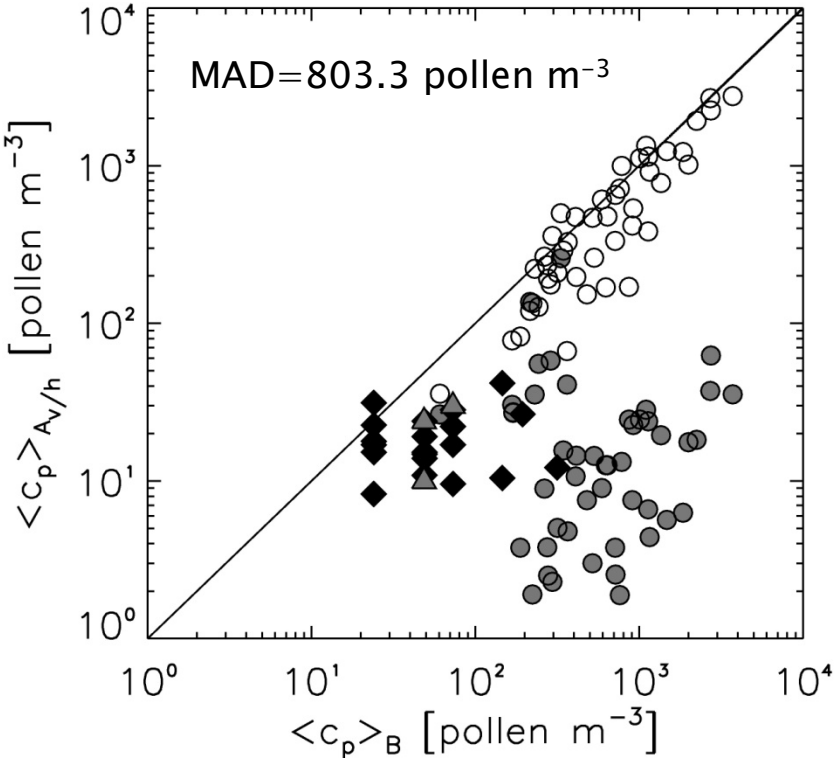
Calibration experiment

Description of the calibration procedure

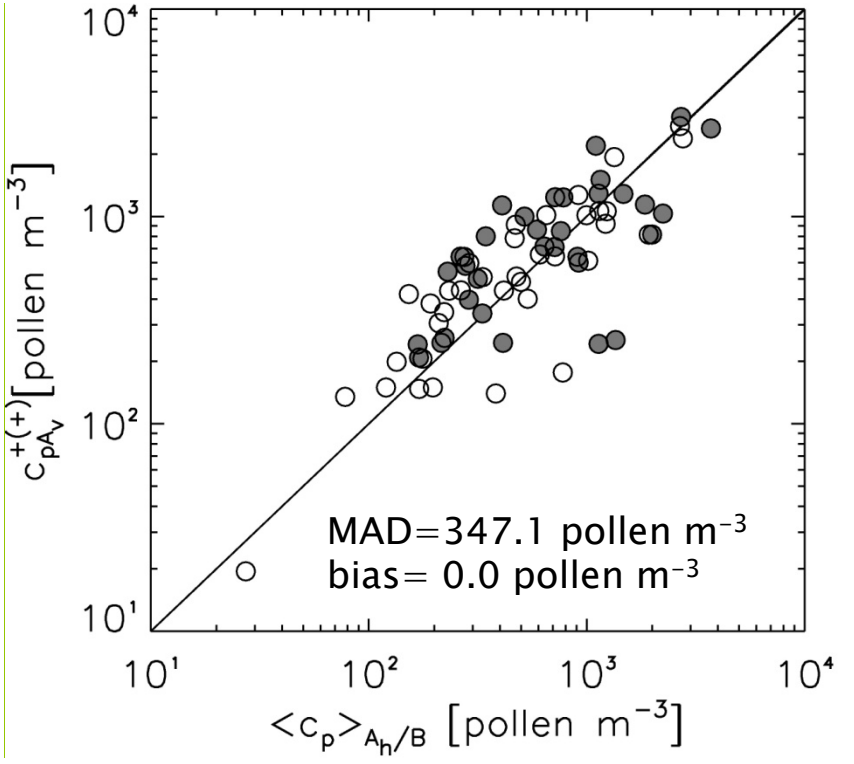
orientation correction = $\alpha_0 + \alpha_2\, cp_v + \alpha_2\, \bar{u}$ if $\bar{u} \leq$ sampling velocity

orientation correction = $\alpha_3 + \alpha_4\, cp_v + \alpha_5\, \bar{u} + \alpha_6\, rh$ if $\bar{u} >$ sampling velocity

offset correction = $\beta_1 + \beta_2$ orientation correction



Burkard vs. uncorrected Air-O-Cell 1-hour data



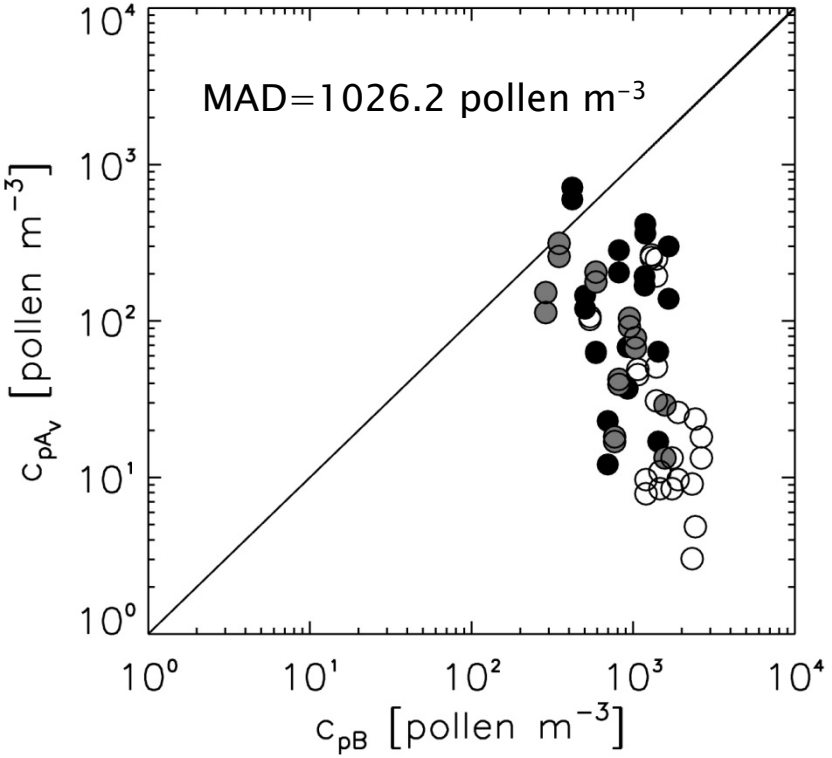
Burkard vs. orient. corrected Air-O-Cell 1-hour data

Burkard vs. offset corrected Air-O-Cell 1-hour data

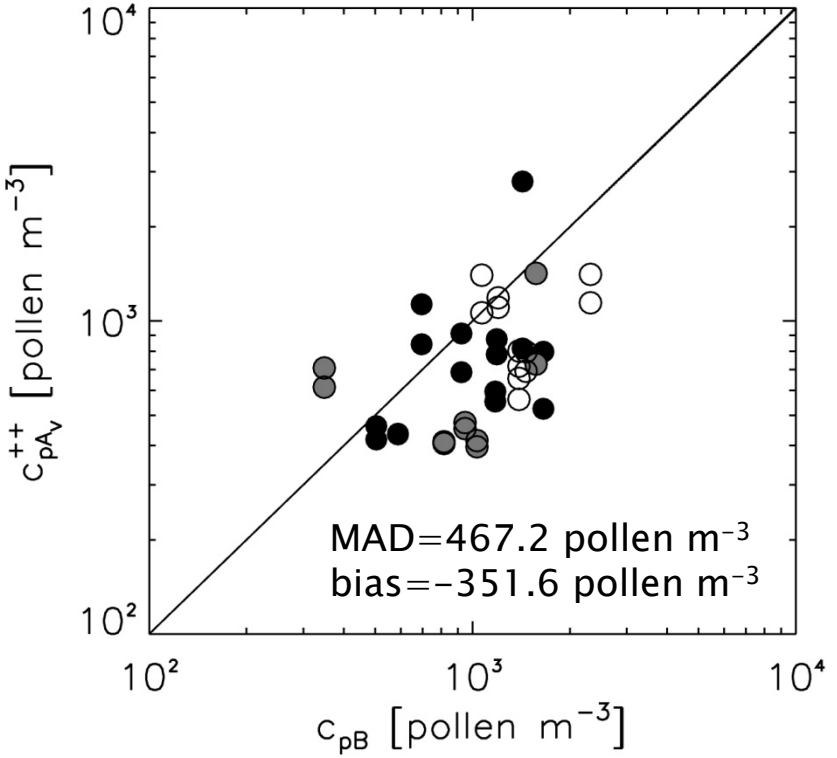
Calibration experiment

Description of the calibration procedure

Application of the calibration models to the emission experiment dataset



Burkard vs. uncorrected Air-O-Cell 2-hour data



Burkard vs. corrected Air-O-Cell 2-hour data

- Absolute mean precision error of the Burkard samplers = 218.2 pollen m^{-3}
- Error includes local spatial variability of pollen concentration

Summary and Conclusions

- Horizontal wind velocity and relative humidity have a large influcence on vertically oriented pollen samplers
- Horizontal orientation of pollen samplers significantly improves the sampling performance compared to vertical orientation
- Applying linear calibration models based on measured wind velocity and relative humidity can be used to significantly reduce the uncertainty of vertically oriented pollen samplers
- Bioaerosol sampling systems without wind-vane work best in calm-air environments (e.g. indoor), where no influence of the orifice orientation is expected
- If operated in natural conditions with moving air, the sampler orifice should (whenever possible) be oriented horizontally, facing the wind

Outlook

- CFD modeling of the wind flow around the birch stand
- Reproduction of observed downwind pollen distribution by using a local dispersion model*
- Description of the pollen dispersion characteristics around the pollen source as function of (micro-) meteorological data
- Emission parameterization based on meteorological variables

* De Haan, P. and Rotach, M.W. (1998): A novel approach to atmospheric dispersion modelling: The Puff-Particle-Model, *Quart. J. Roy. Meteor. Soc.* 124, pp. 2771-2792

Acknowledgments

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  - Federal Office of Meteorology and Climatology MeteoSwiss