University of Zurich[UZH]
Department of Geography

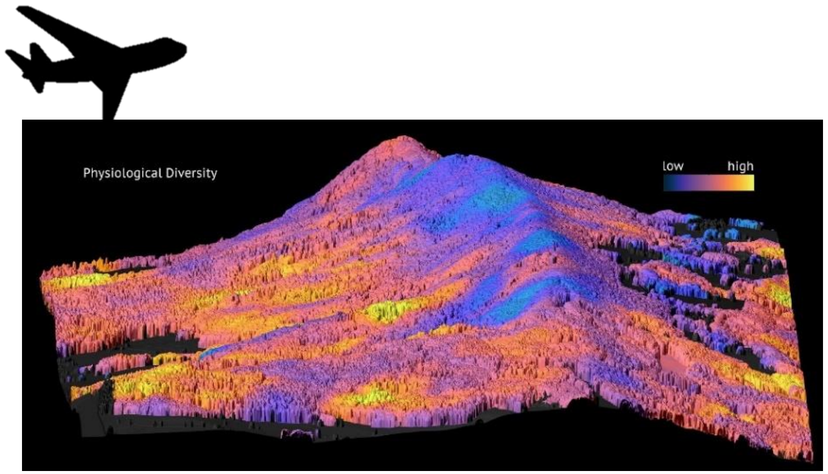
RSL

URPP Global Change and Biodiversity

Disentangling the biological information and measurement uncertainties from field spectral reflectance of beech leaves

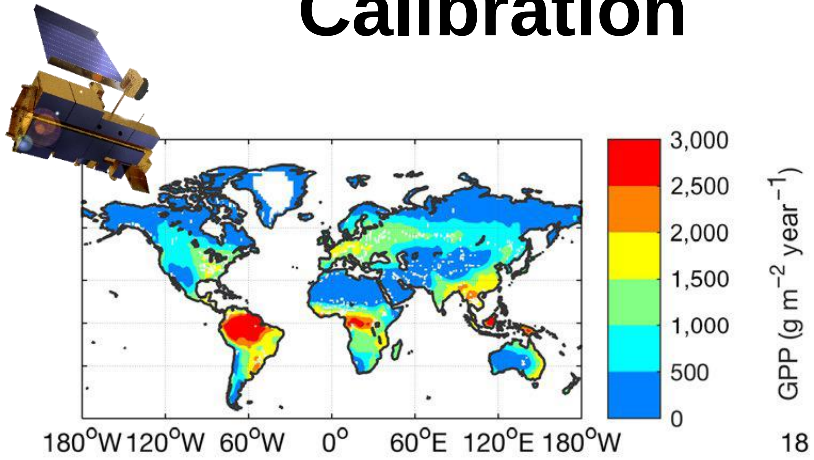
Fanny Petibon, Ewa A. Czyż, Giulia Ghielmetti, Andreas Hueni, Mathias Kneubühler, Michael E. Schaepman, Meredith C. Schuman

28.04.2021

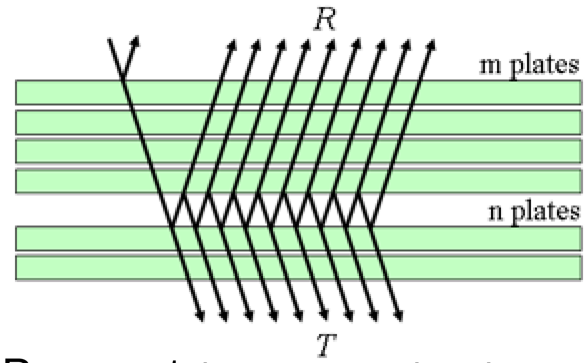


(Schneider et al., 2017)

Calibration



(Luo et al., 2019)

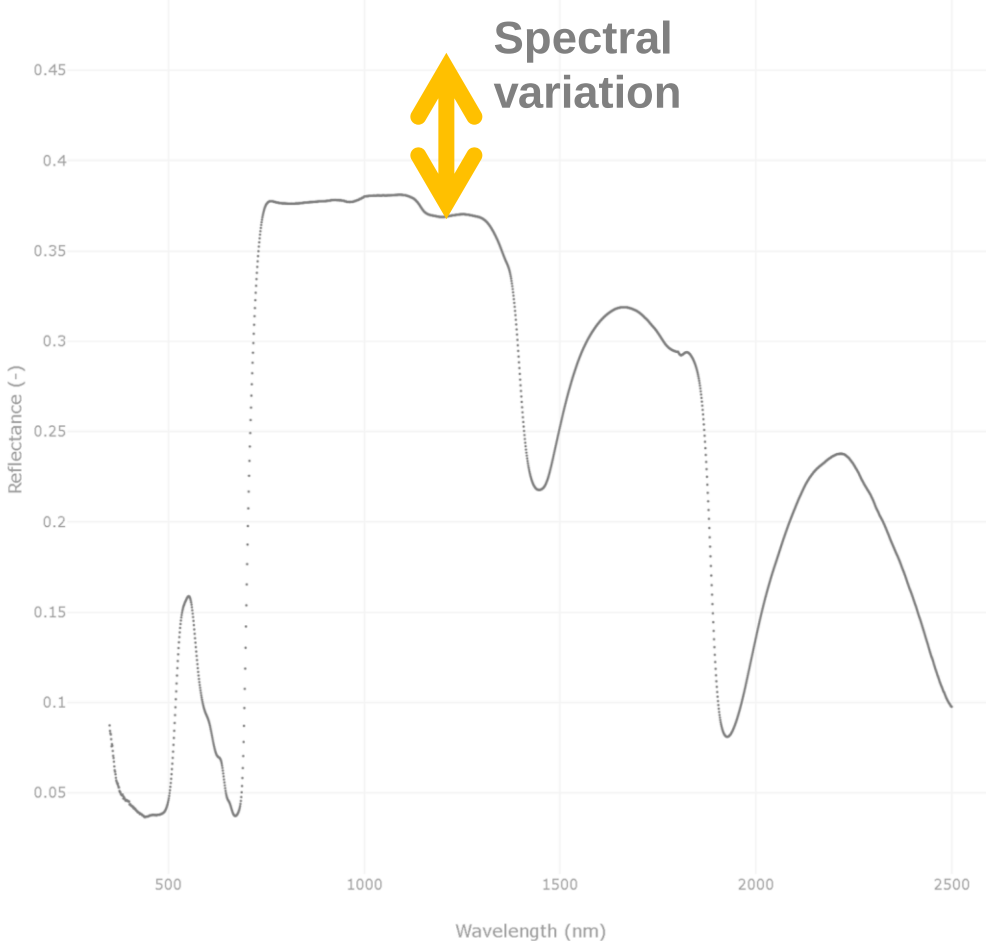


Prospect *(Jacquemoud and Baret, 1990)*

Direct application

(Santiso et al. 2015)

Spectral variation =
Biological variation + uncertainty of measurement



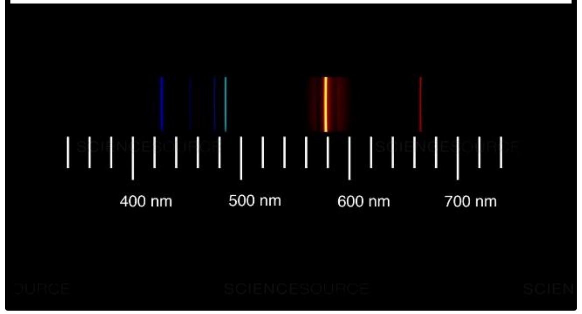
Spectral variation

Uncertainty of measurement

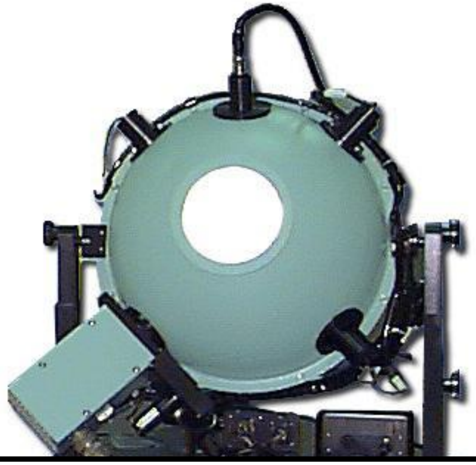
Biological variation

Spectral data calibration

Spectral calibration



System calibration



Data calibration

Data calibration

Digital Number → **Radiance** $Wm^{-2}sr^{-2}nm^{-1}$ → **Reflectance**

f(sensor,
light source,
surface material)

f(light source,
surface material)

f(surface material)

Uncertainty?

(Petibon et al., 2021)

Research questions

1. What are the **sources of uncertainty** in LOP measurements?

2. To which extent does **uncertainty** of measurement **contribute to the spectral variation**?

3. Do LOP measurements permit the **detection of biological variation** *(e.g. species traits)*?

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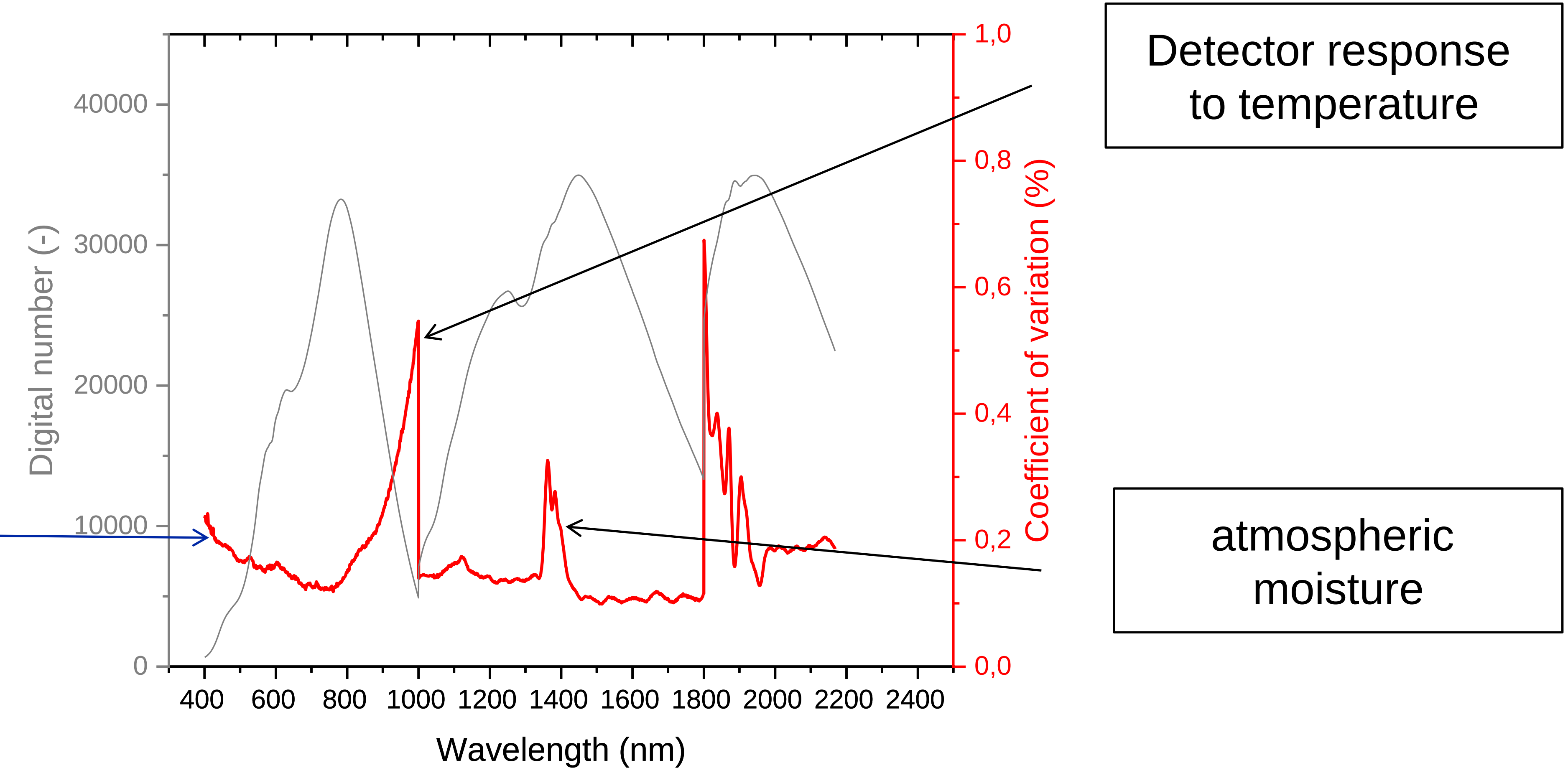
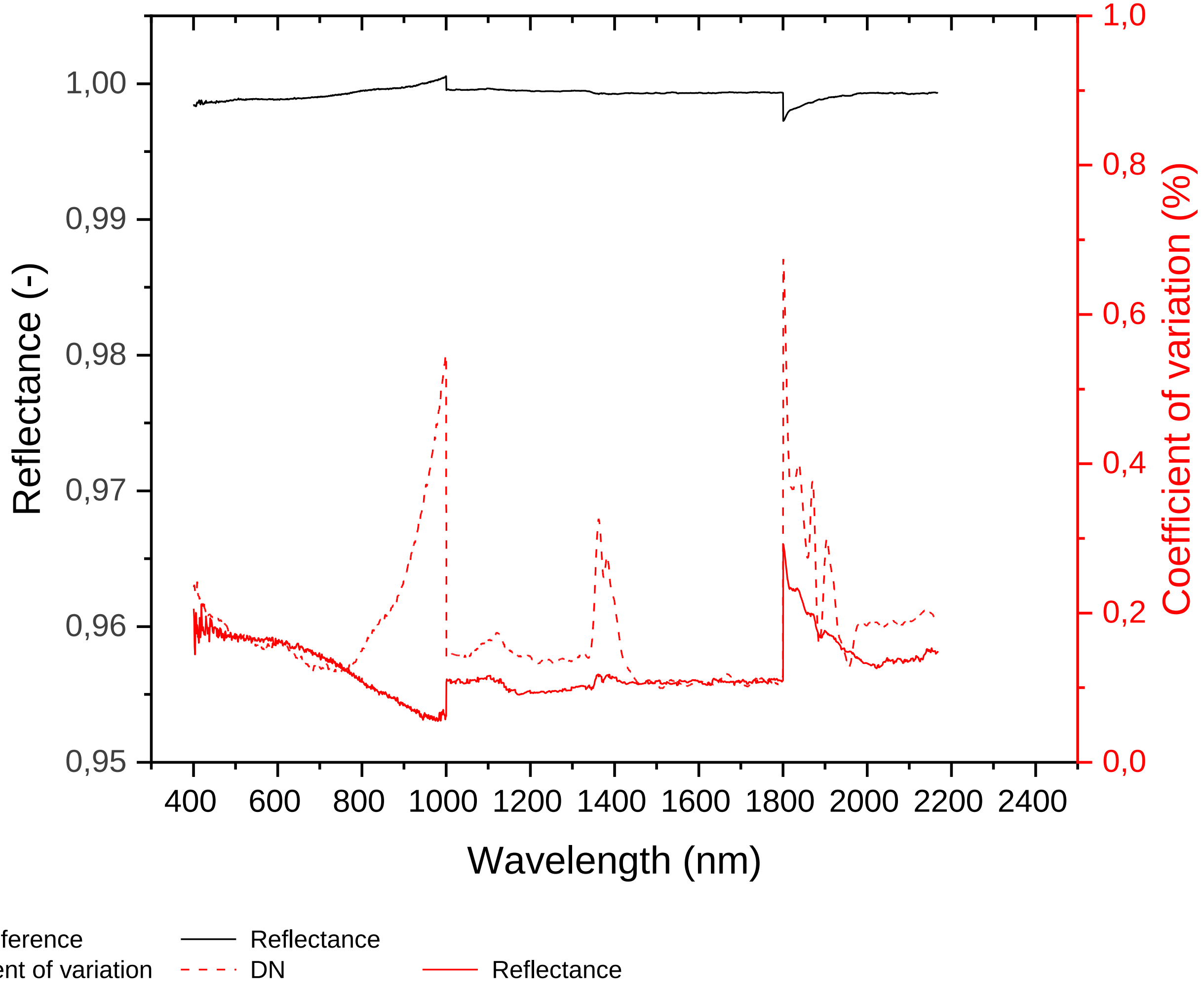
1. What are the sources of uncertainty in LOP measurements?

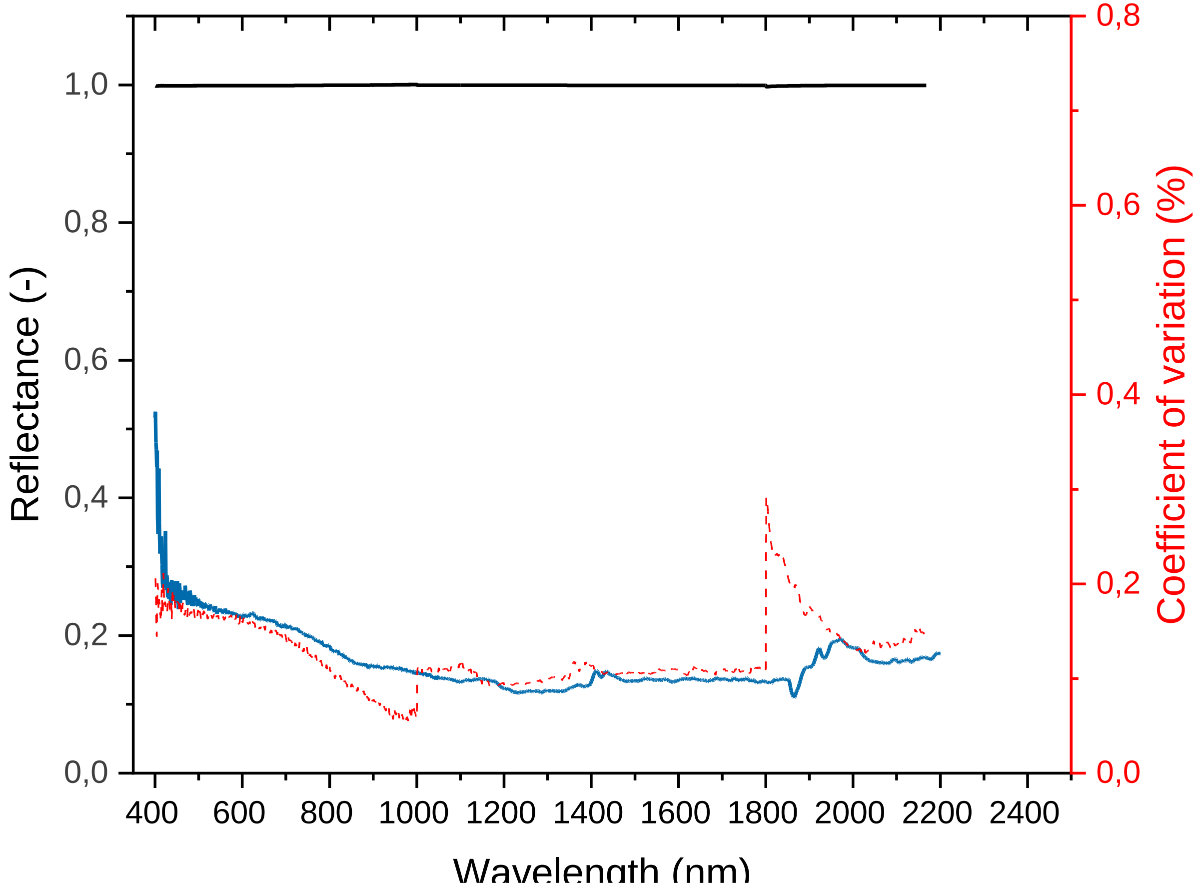
The **uncertainty of measurement** depends on the characteristics of **optical sensor** and **experimental conditions**



The **uncertainty of measurement** depends on the characteristics of **optical sensor** and **experimental conditions**

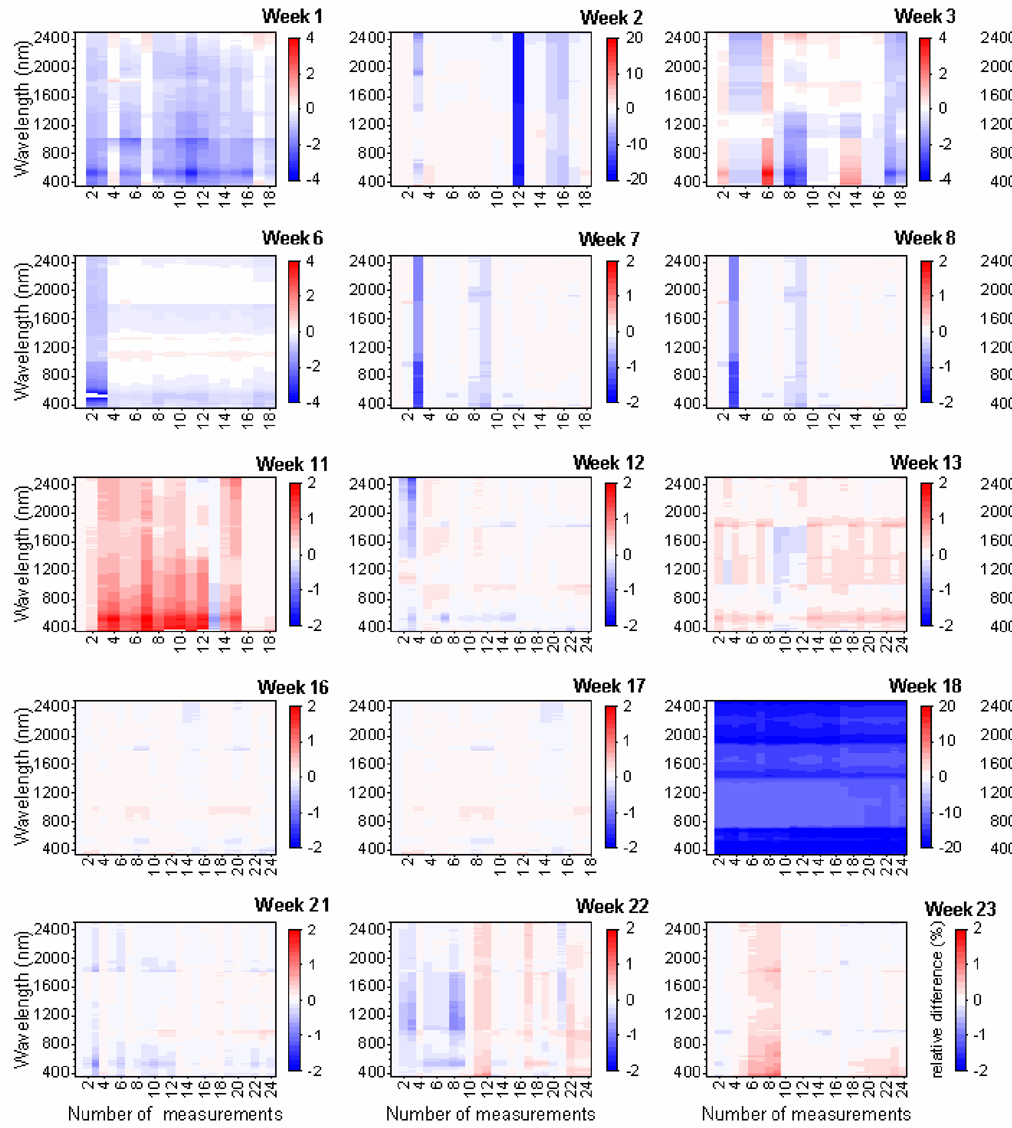


The **uncertainty of measurement** depends on the characteristics of **optical sensor** and **experimental conditions**



+ temperature correction
(Hueni, 2021)

The **uncertainty of measurement** depends on the characteristics of **optical sensor** and **experimental conditions**

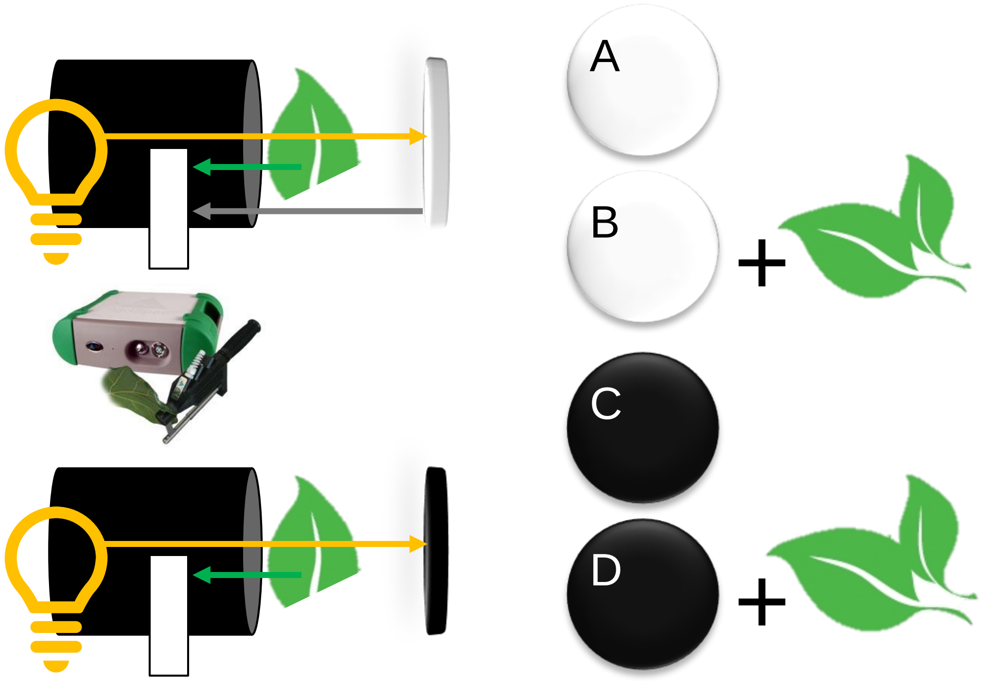


Time stability

1. Estimating the measurement uncertainty

Method

Uncertainty of measurement was estimated by **uncertainty budget**



Reflectance *(eq.1)*

$$R = \frac{A * D - C * B}{A - C}$$

Absolute uncertainty: Law of propagation *(eq.3)*

$$U_{R,abs}{}^2 = \sum_{i=1}^{n} \left(\frac{\partial R}{\partial x_i}\right)^2 * U_{x_i}{}^2, \text{with } U_{x_i} = \frac{STD_{x_i}}{\sqrt{N}}$$

Relative uncertainty *(eq.2)*

$$U_{R,rel} = 100 * \frac{U_{R,abs}}{R_{MEAN}} \ (\%)$$

Spectral variation was approximated by the **coefficient of variation**

(eq.3) $$\mathrm{CV} = 100 * \frac{R_{STD}}{R_{MEAN}} \ (\%)$$

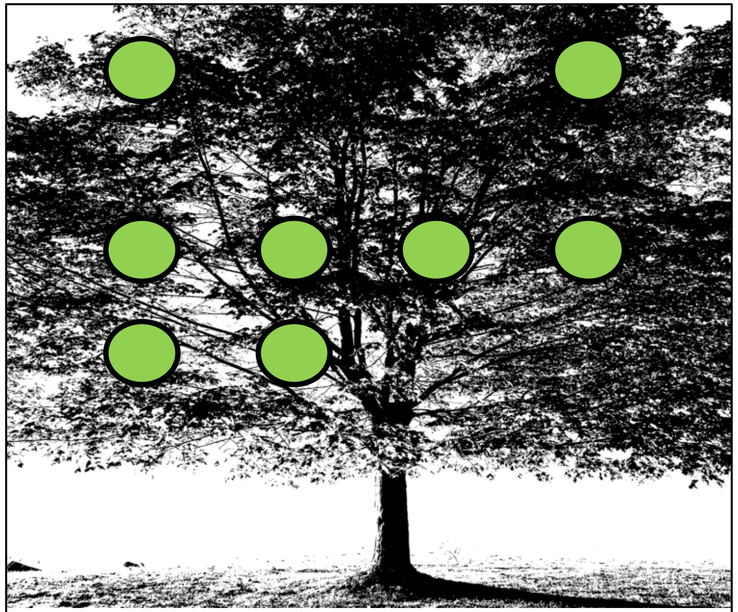
Biological variation was approximated by *(eq. 4)* $\mathrm{BV} = \mathrm{CV} - U_{R,rel}$

Datasets

DATASET 1:
Standard materials

- Sources of uncertainty

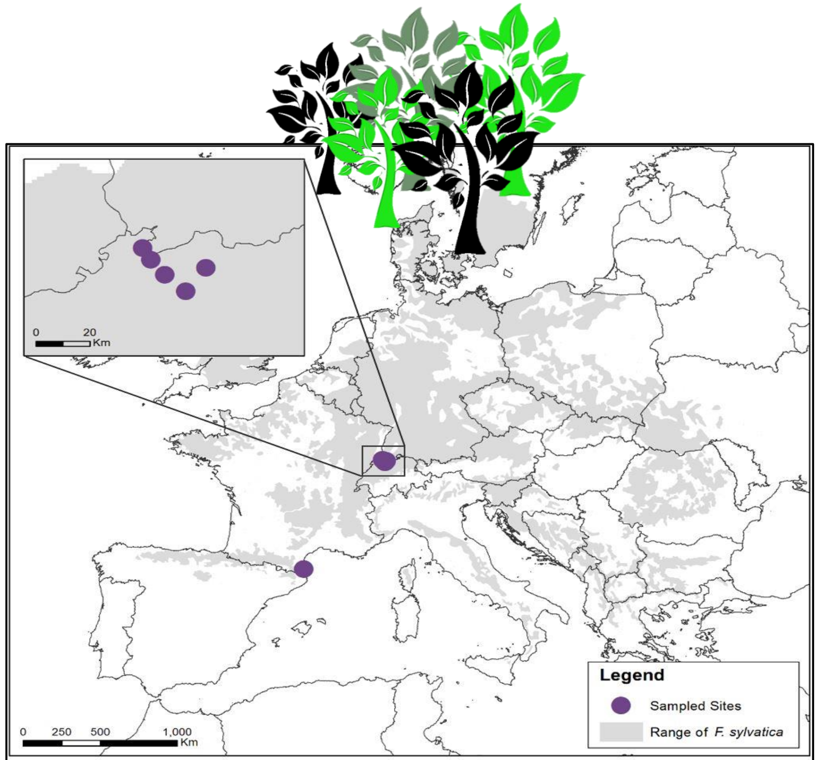
4 materials with diverse optical properties



DATASET 2:
***Fagus sylvatica* individual**

- Variation within an individual

28 sampling weeks

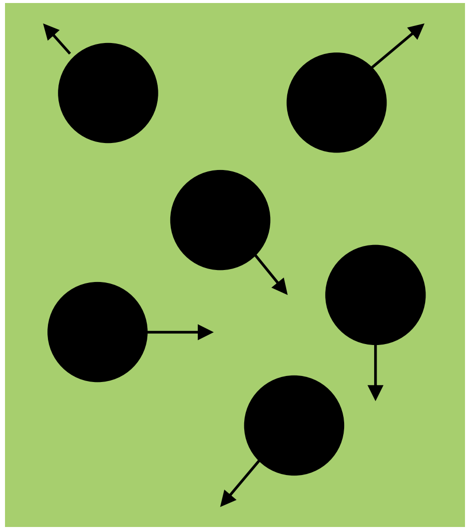


DATASET 3:
***Fagus sylvatica* forest**

- Variation between individuals

6 forest sites

Measurement protocol



Uncertainty 1
n = 1 measurement

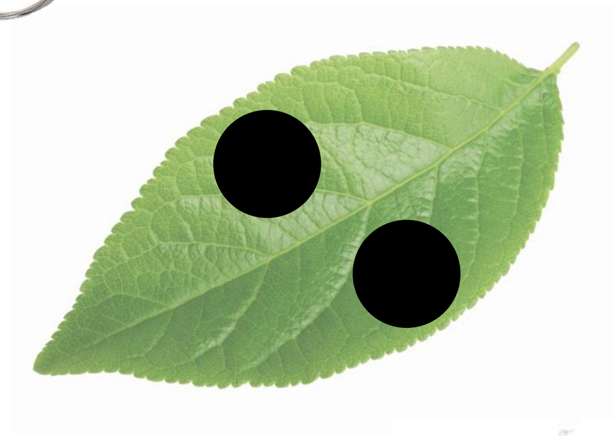
→ 10 readings
→ 30 scans

Uncertainty 2
n = 6 measurements

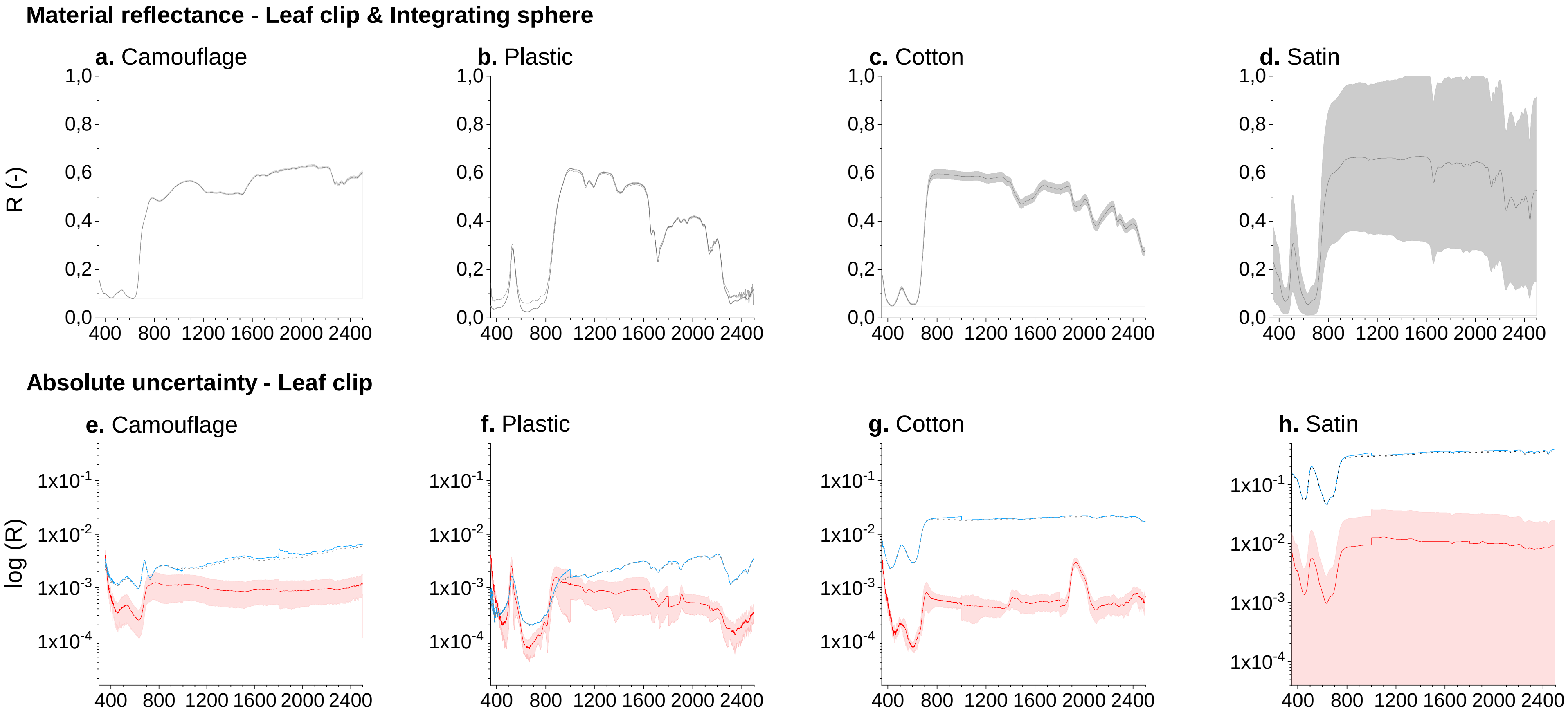
Non-biological variation = 0

Uncertainty 1
n = 1 measurement

→ 10 readings
→ 30 scans



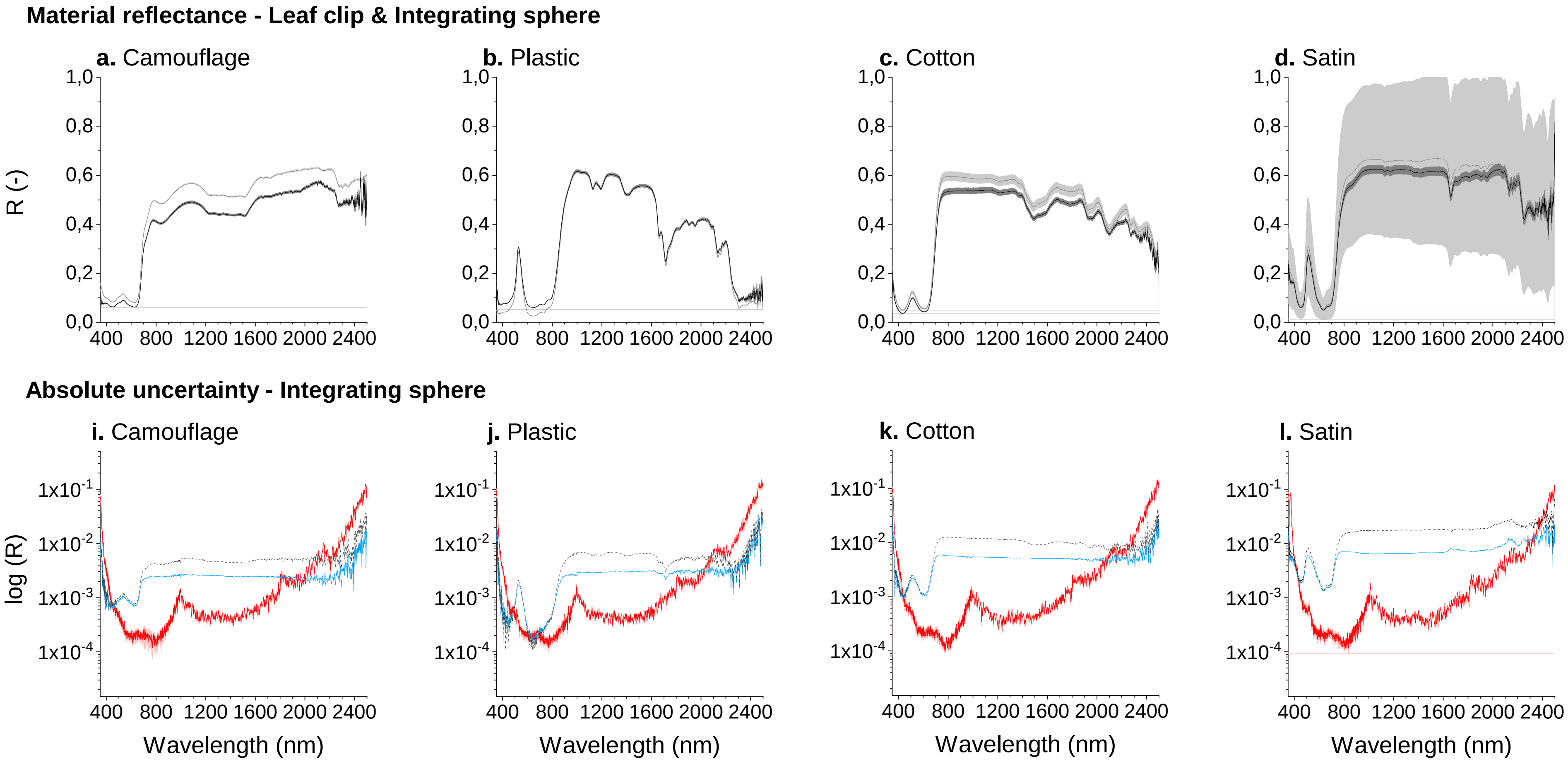
The **uncertainty** depends on the **optical properties of the target**.



Single measurements

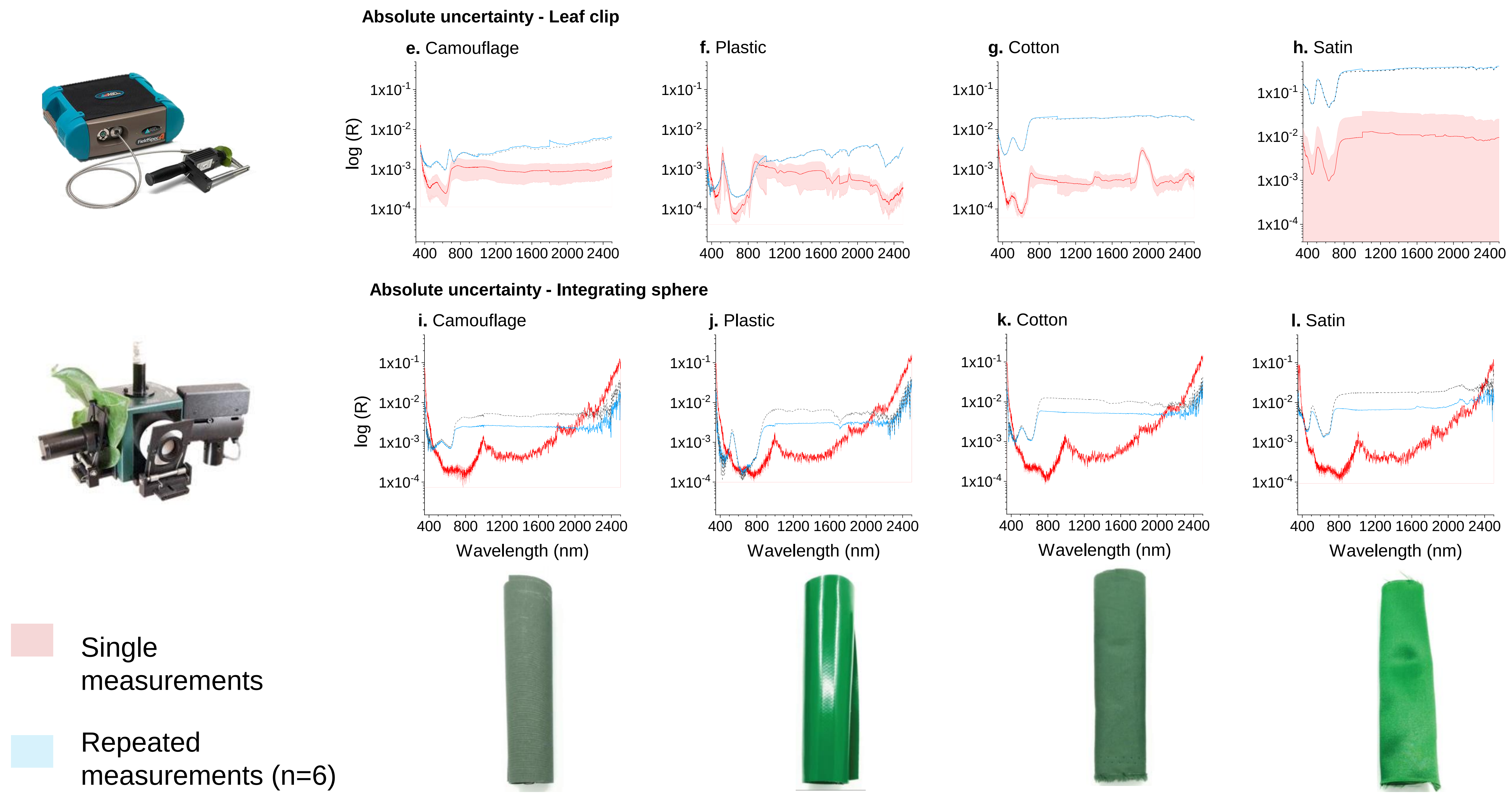
Repeated measurements (n=6)

The **uncertainty** depends on the **sampling probes**.

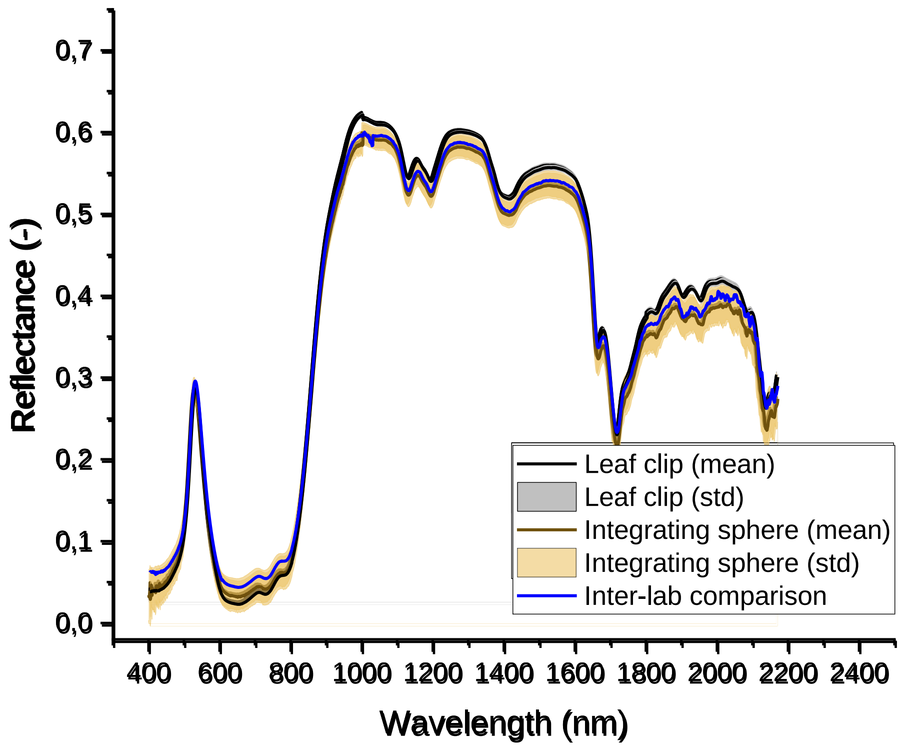


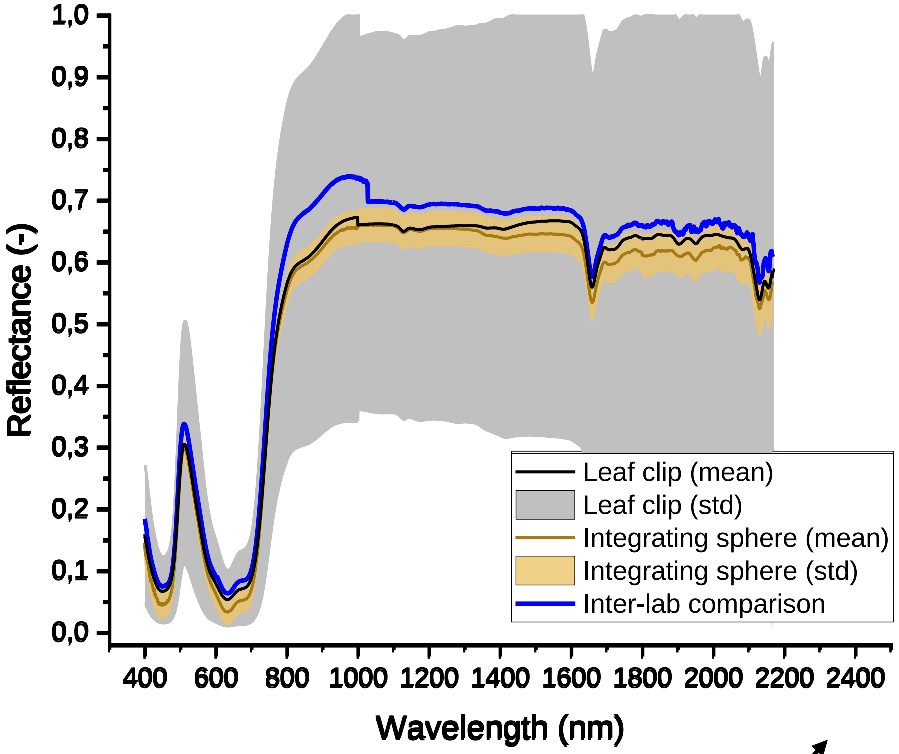
Single measurements

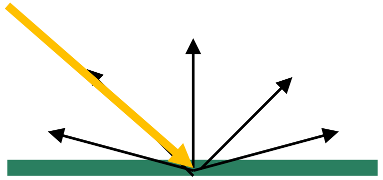
Repeated measurements (n=6)


Absolute uncertainty - Leaf clip
e. Camouflage
f. Plastic
g. Cotton
h. Satin
log (R)
1x10-1
1x10-2
1x10-3
1x10-4
400 800 1200 1600 2000 2400
Absolute uncertainty - Integrating sphere
i. Camouflage
j. Plastic
k. Cotton
l. Satin
Wavelength (nm)
Single measurements
Repeated measurements (n=6)

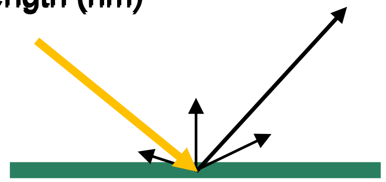
The **uncertainty** is specific to one spectroradiometer and measurement protocol.







Isotropic

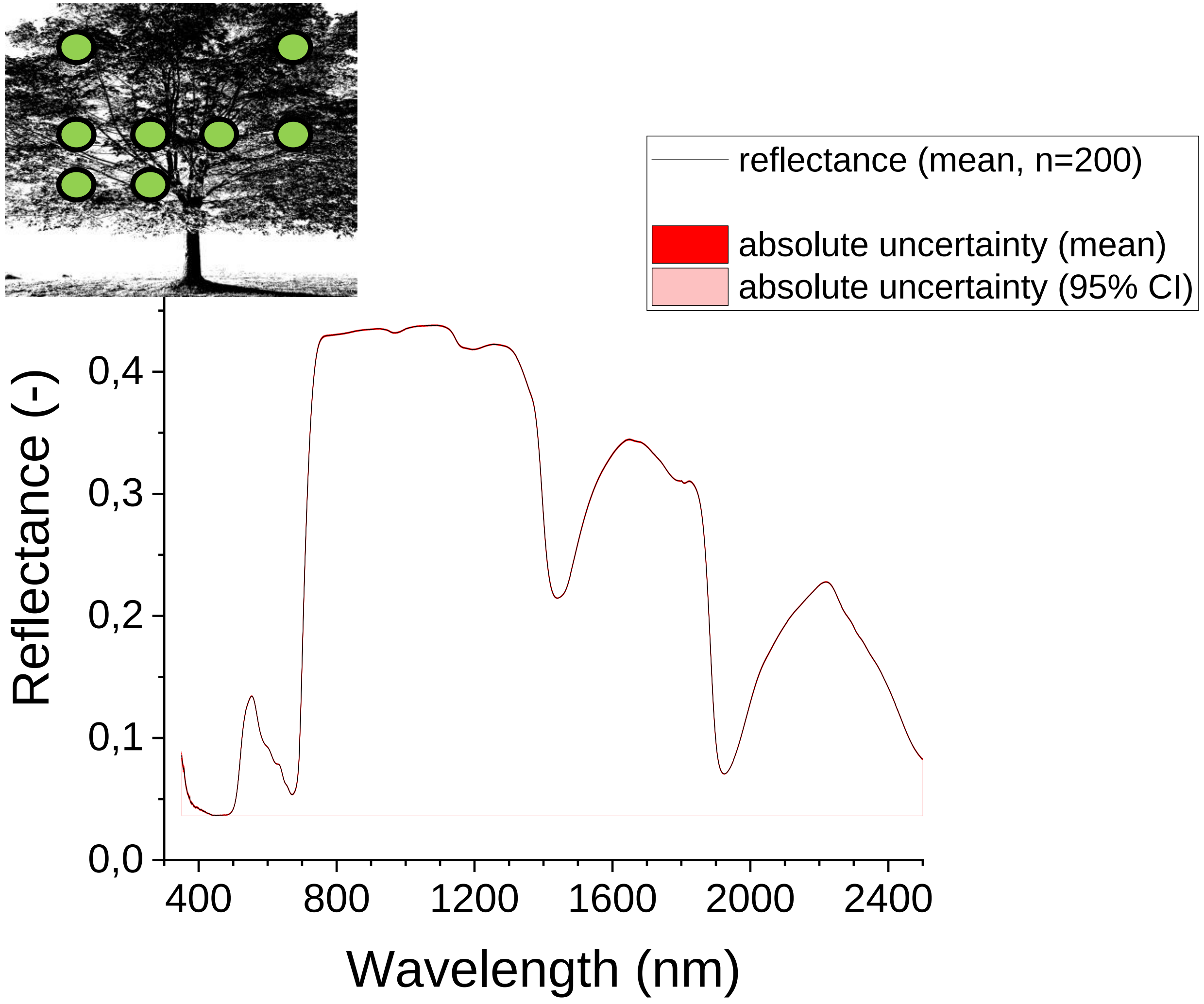


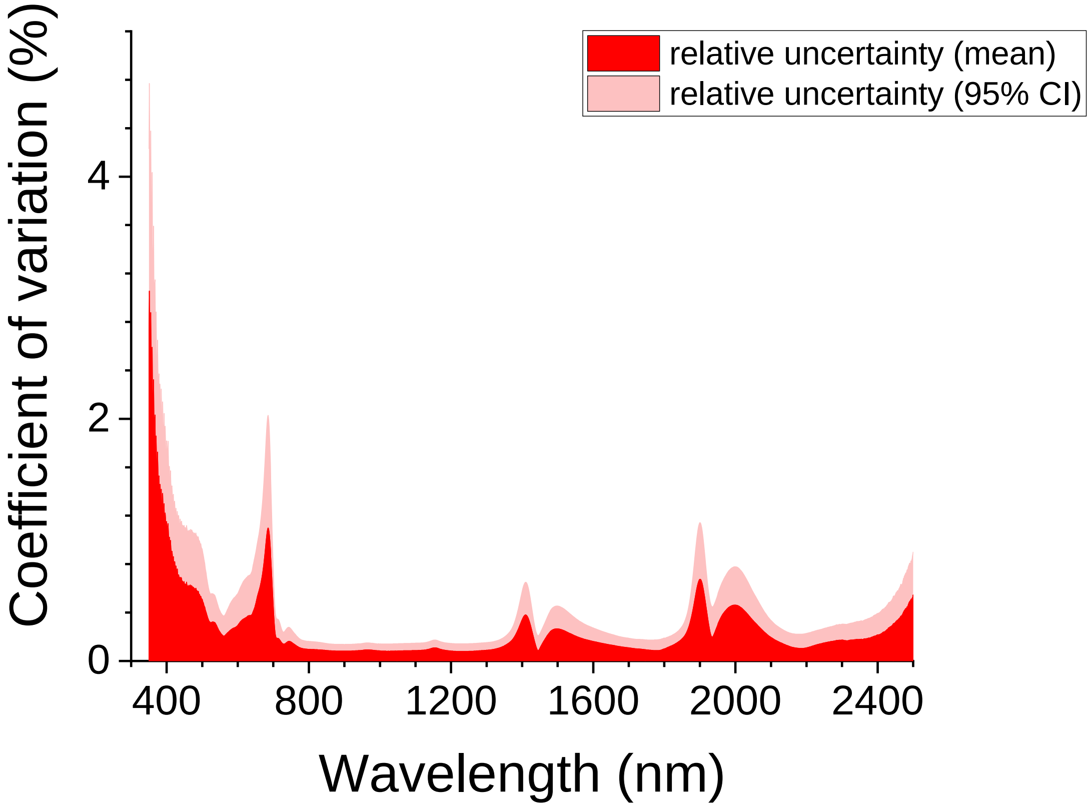
Anisotropic

n=15 laboratories

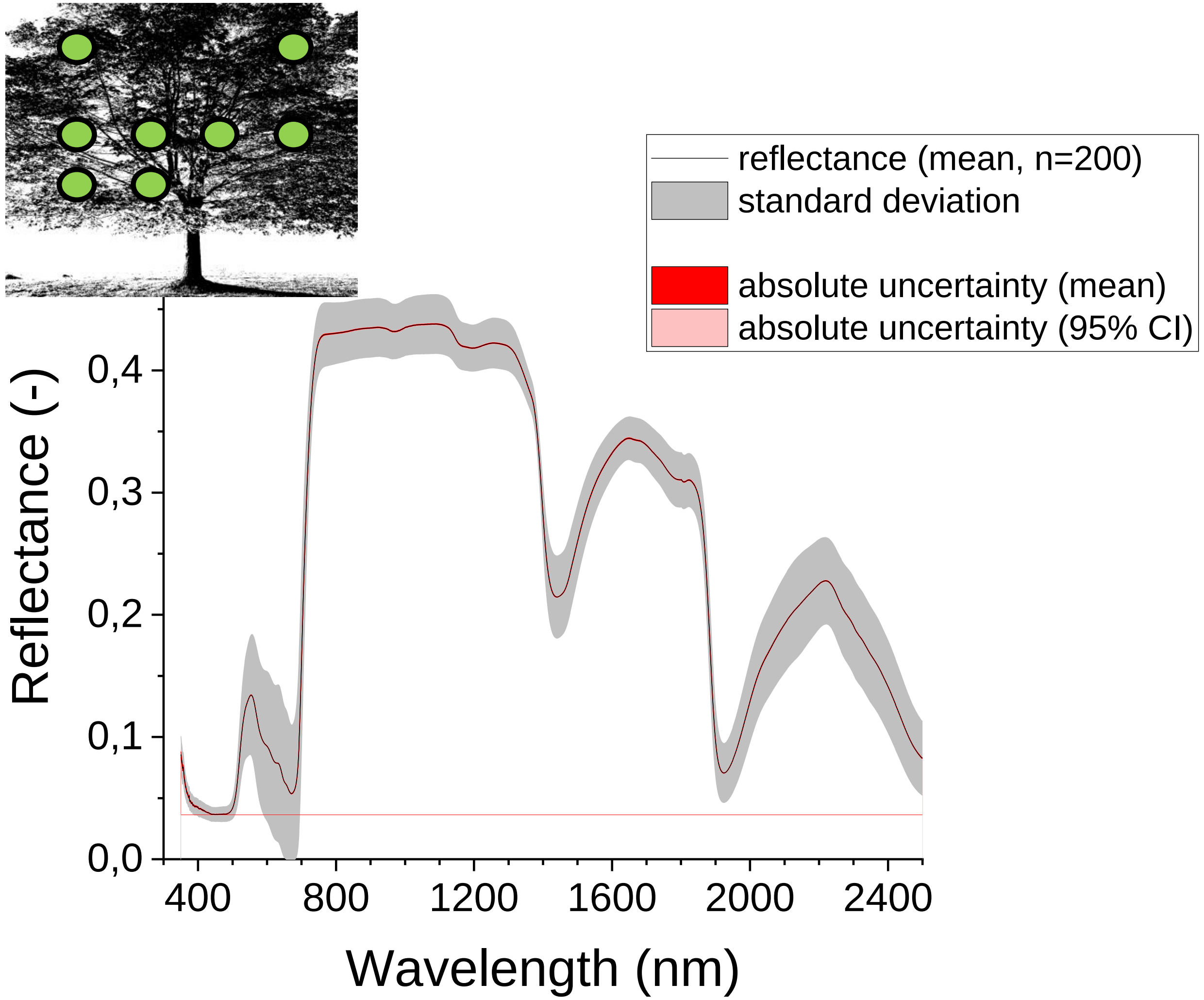
2. To which extent does uncertainty of measurement contribute to the spectral variation?

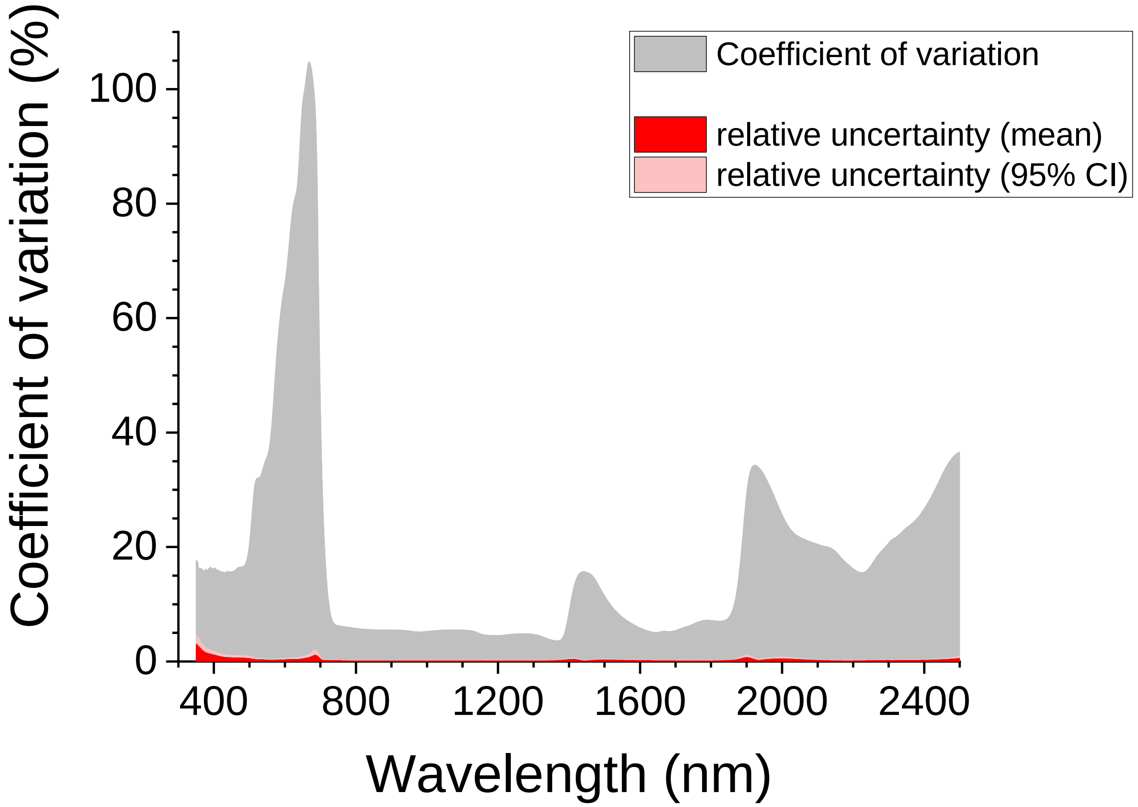
The **uncertainty** associated with **LOP** represents **0.3 - 4 %** of reflectance





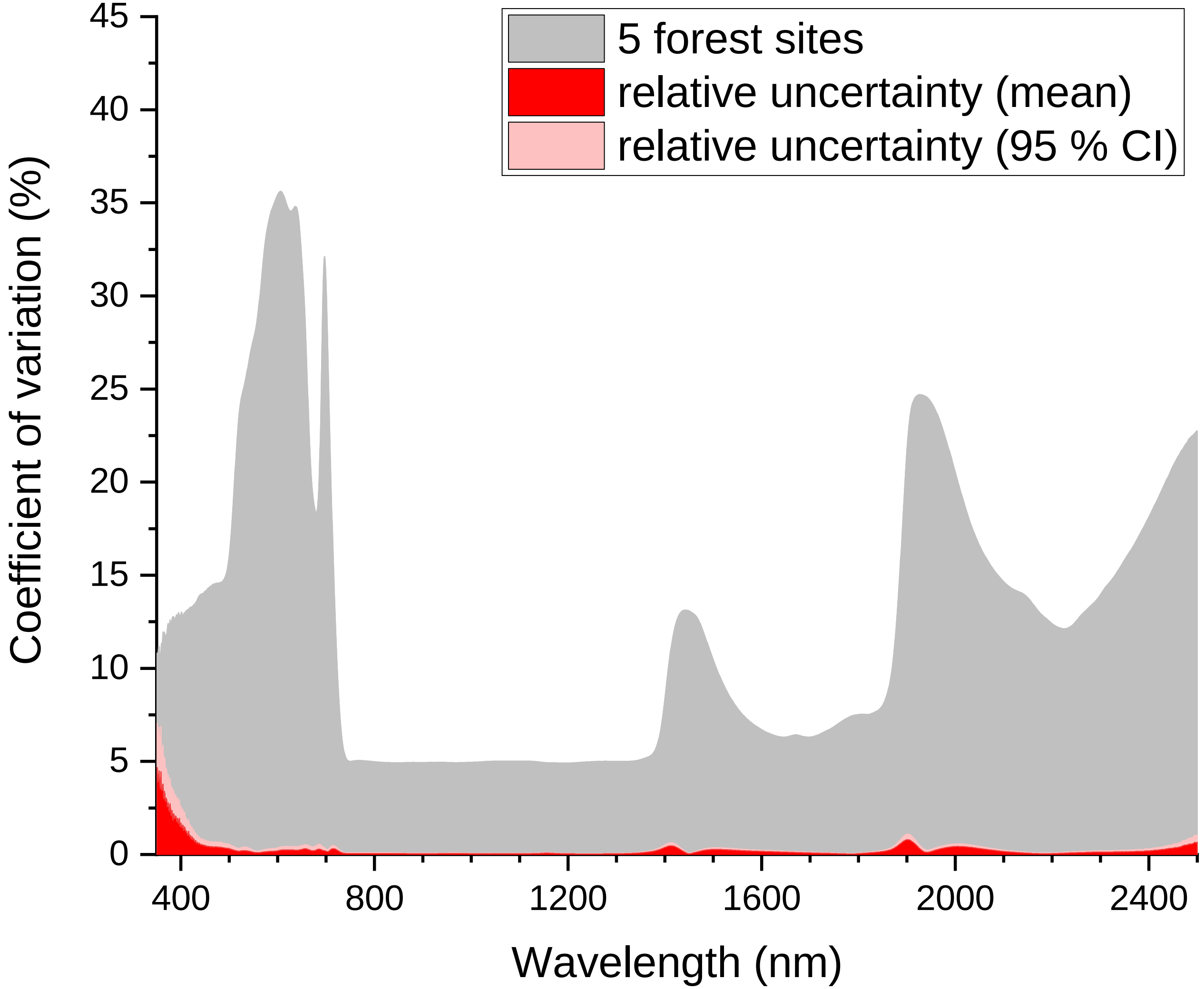
The **uncertainty** associated with **LOP** represents **2 - 25 %** of spectral variation

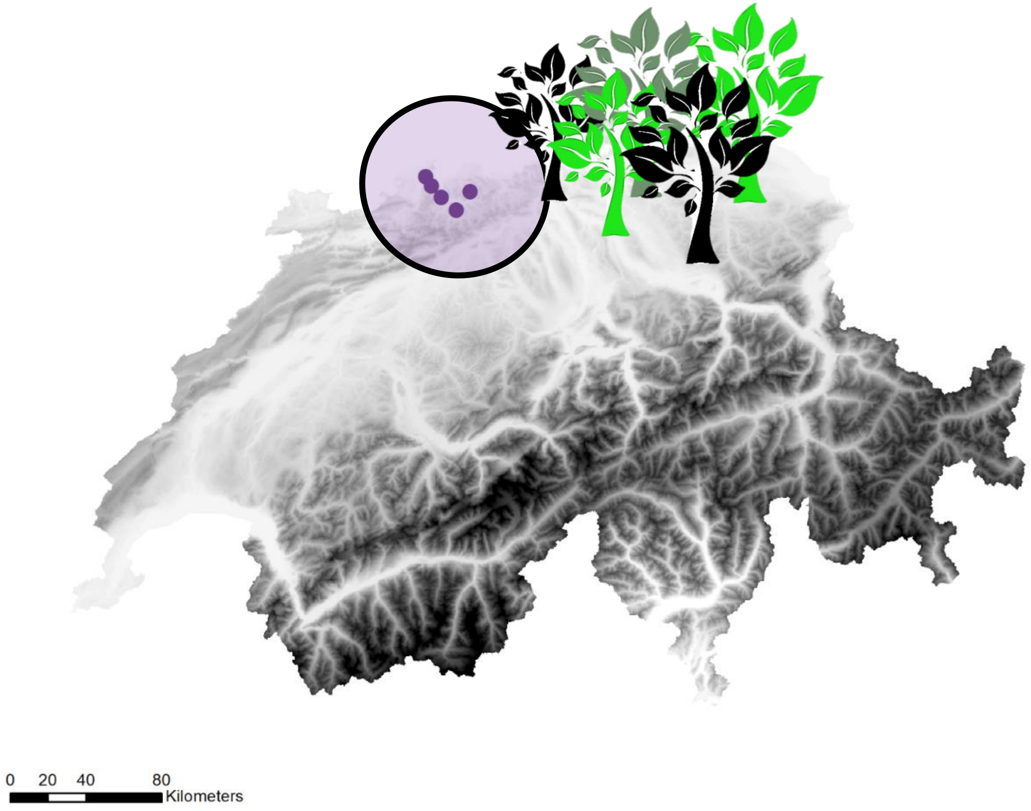




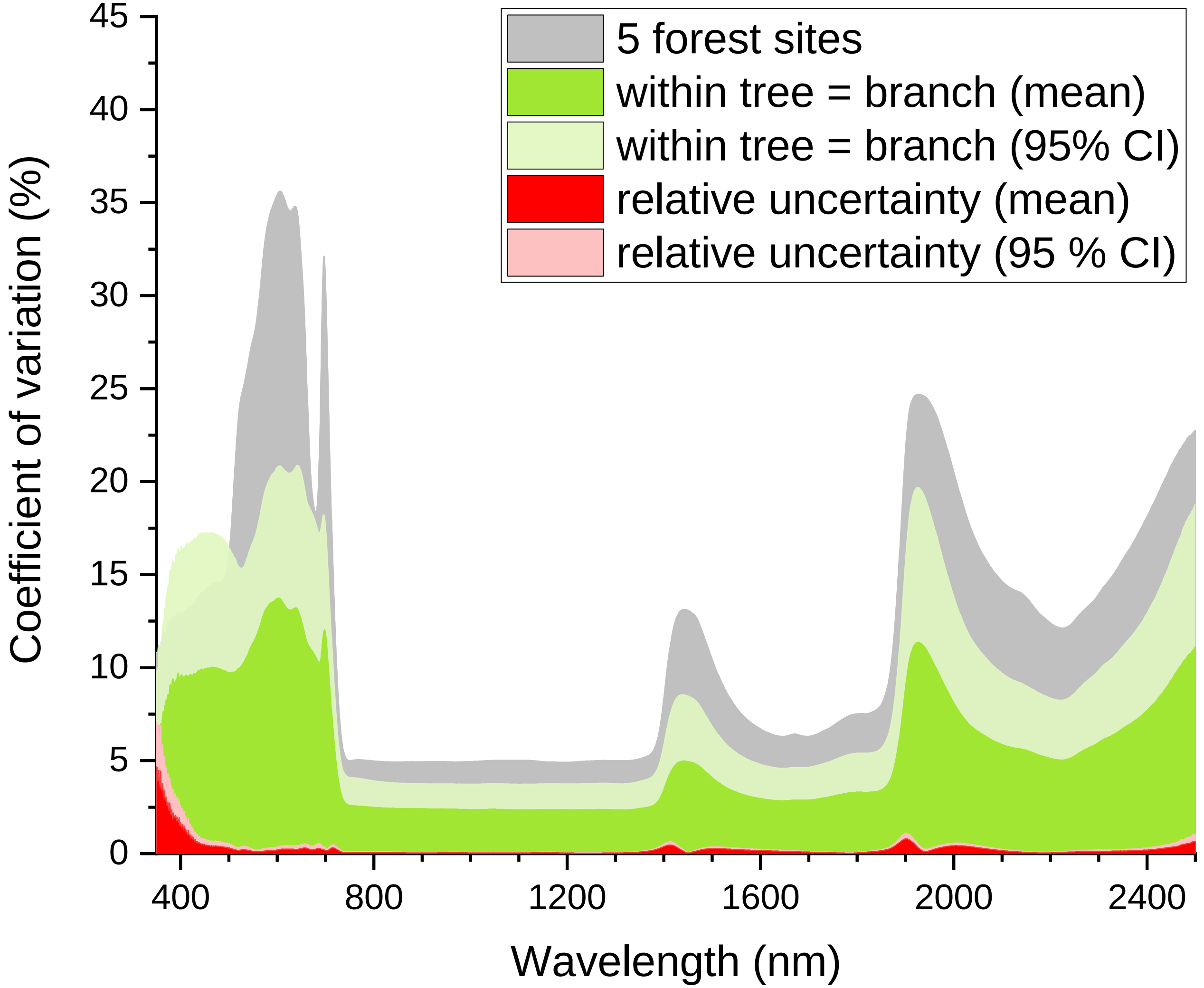
3. Do LOP measurements permit the detection of biological variation?

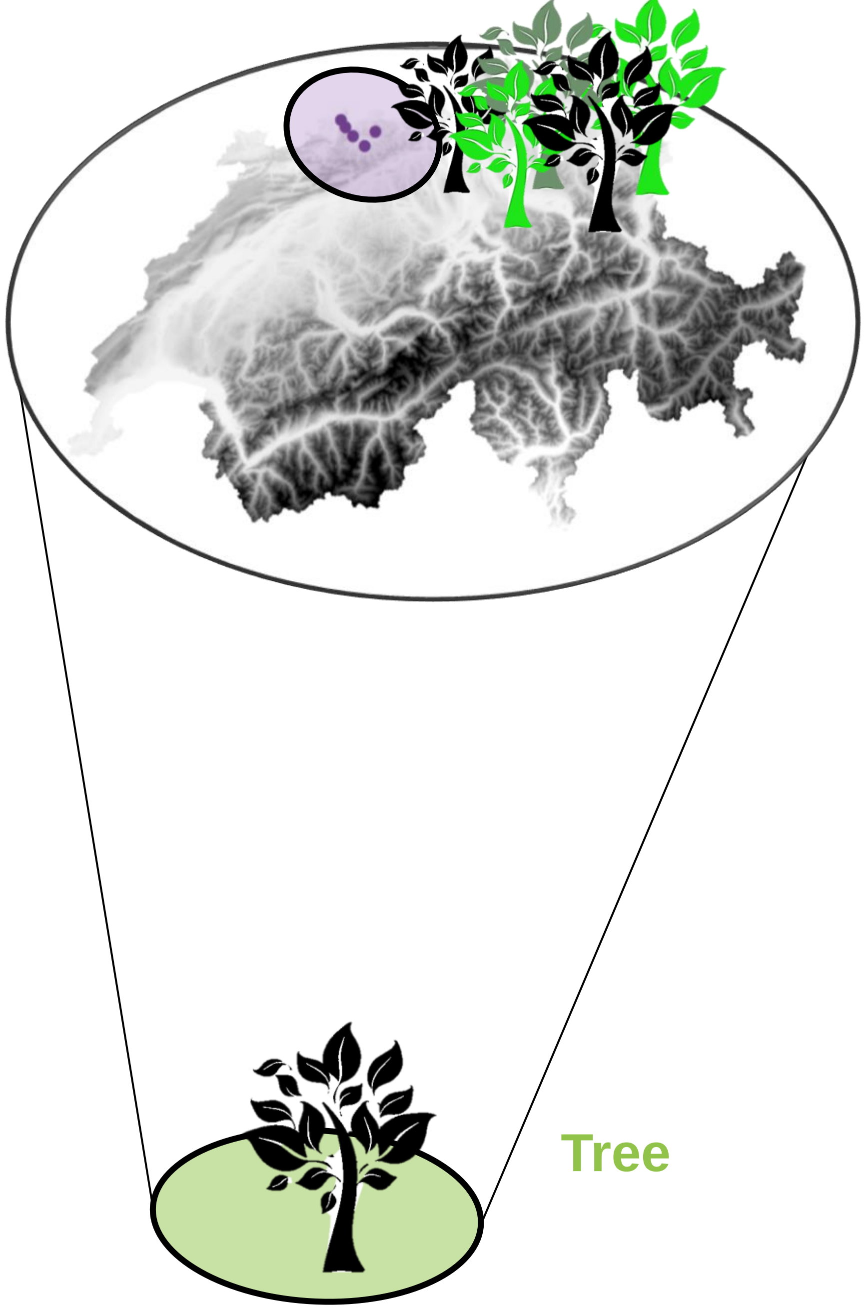
The **biological variation in Swiss forest sites**



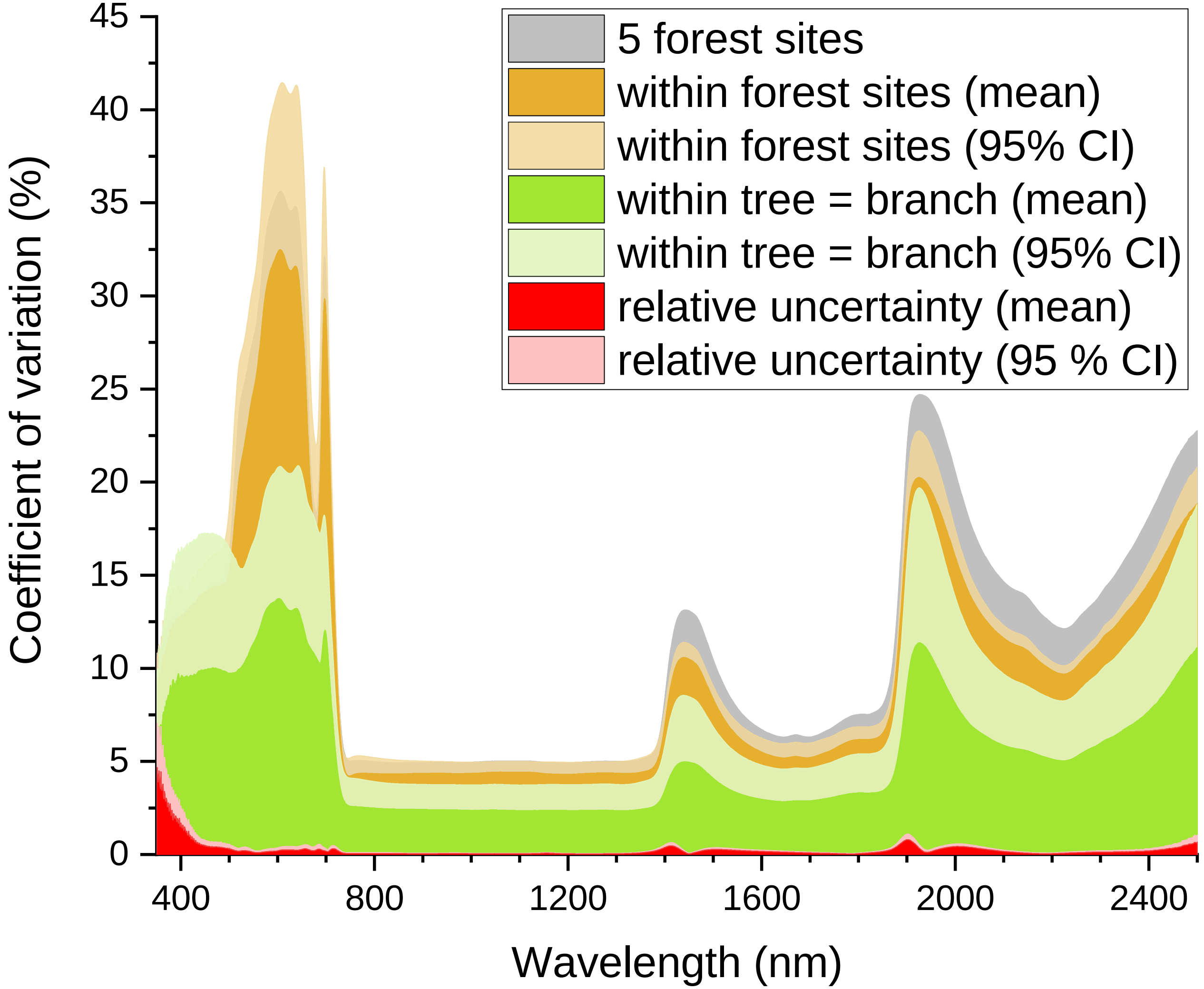


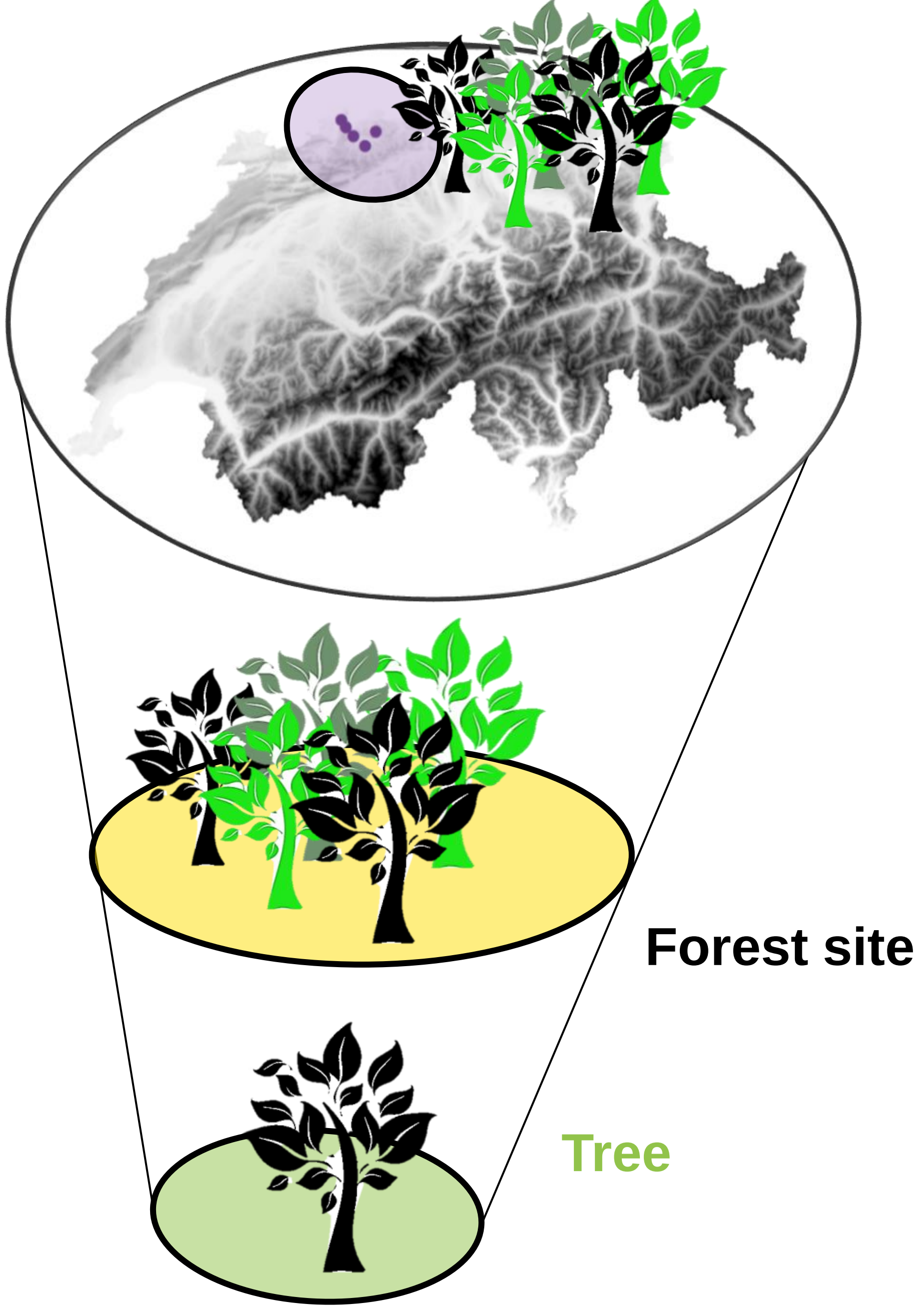
The **biological variation in Swiss forest**



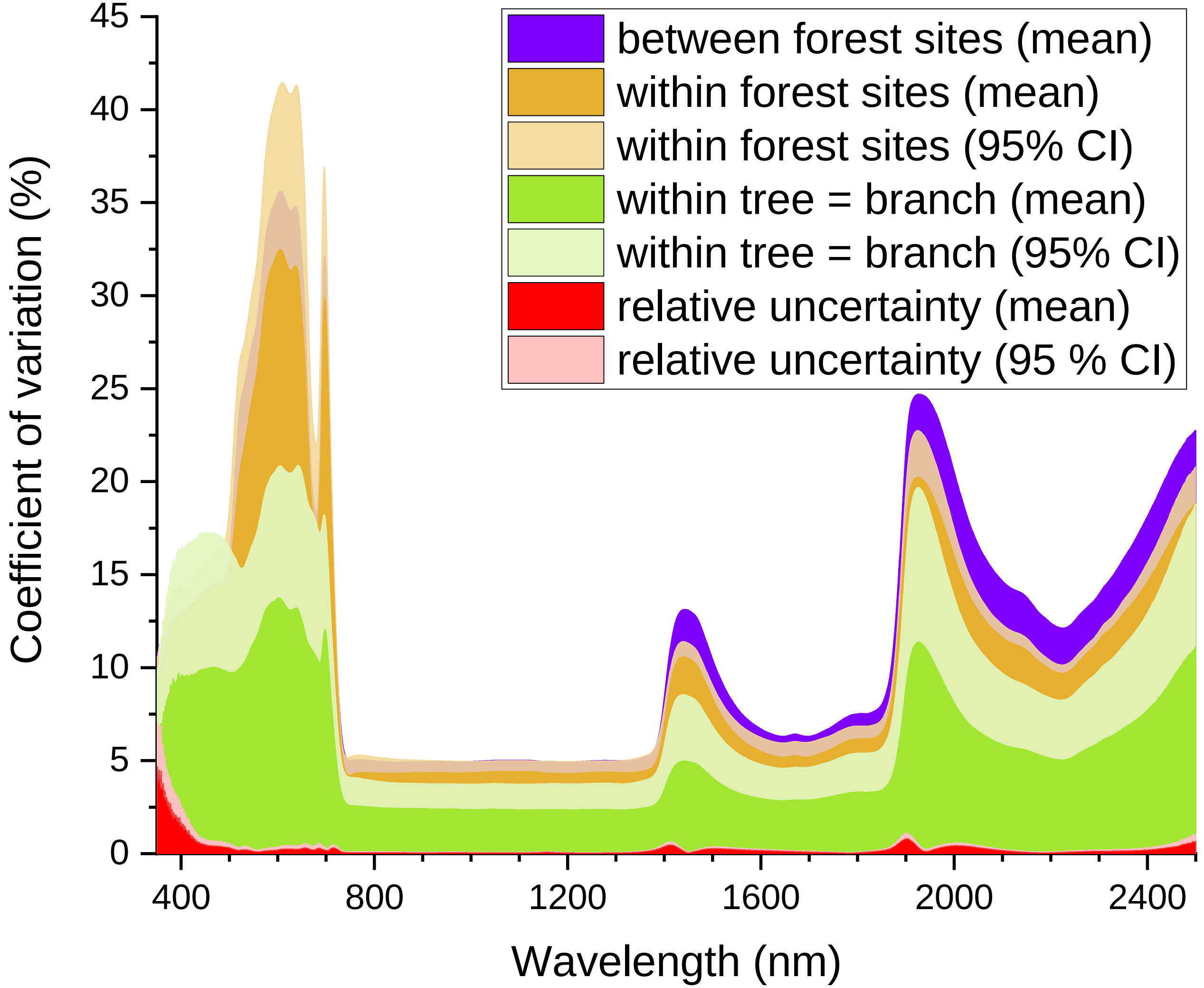


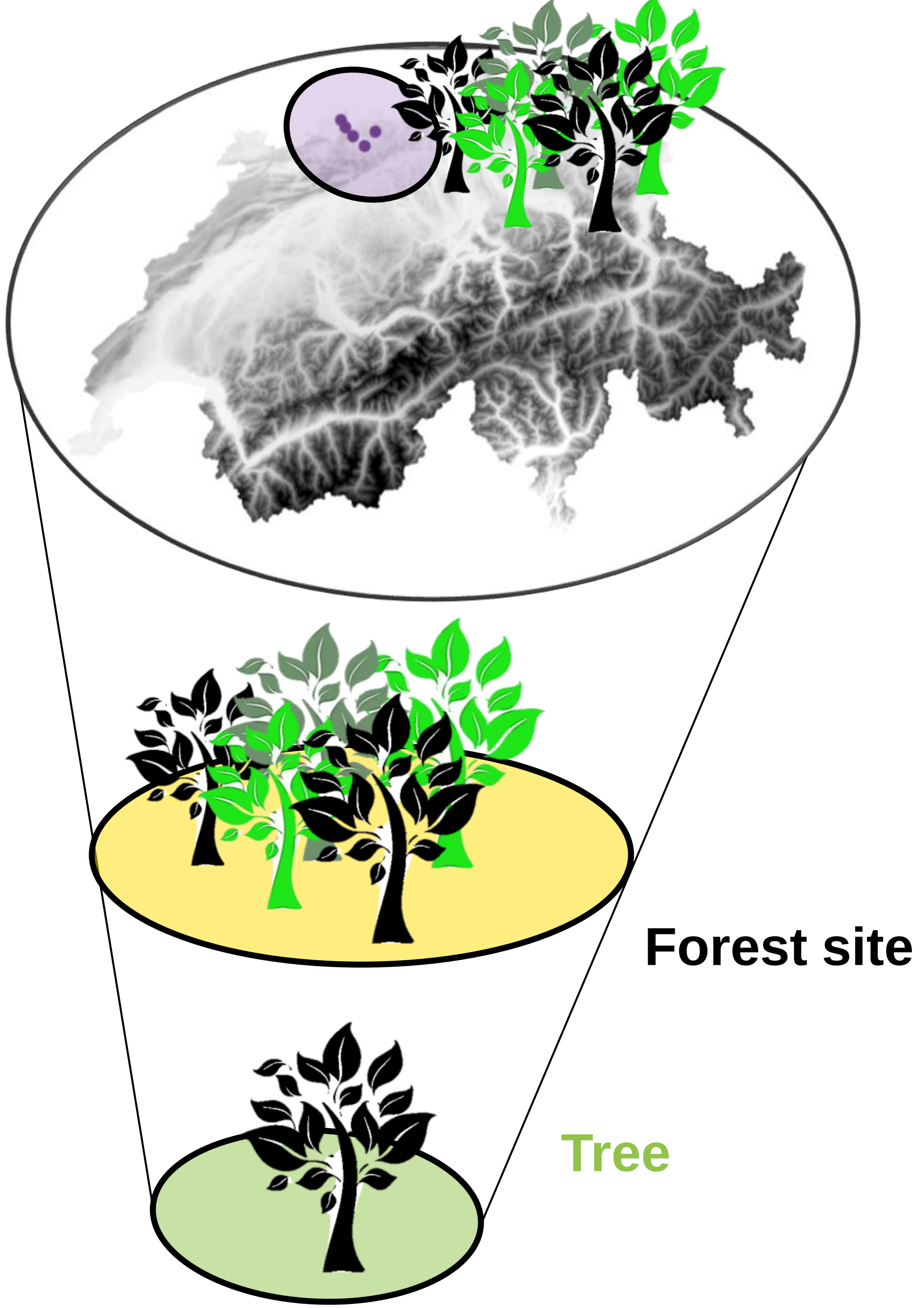
The **biological variation in Swiss forest**





The **biological variation in Swiss forest**





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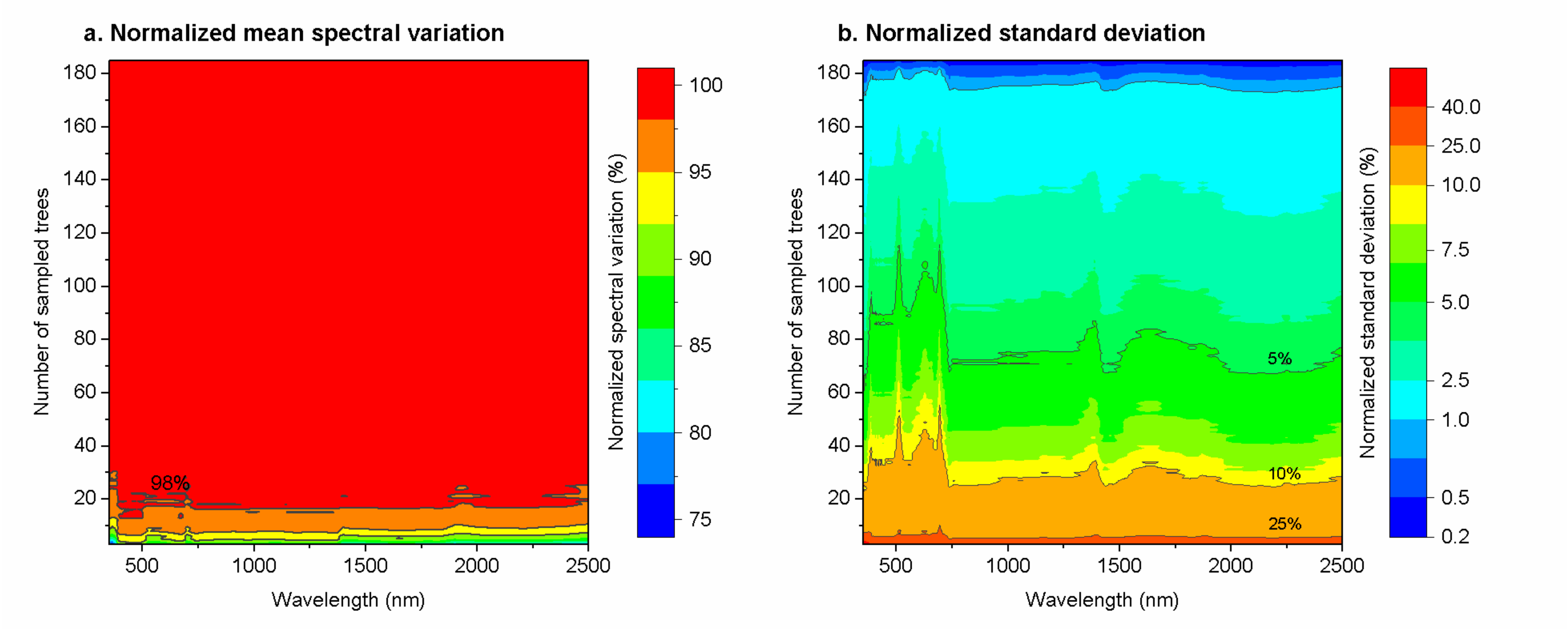
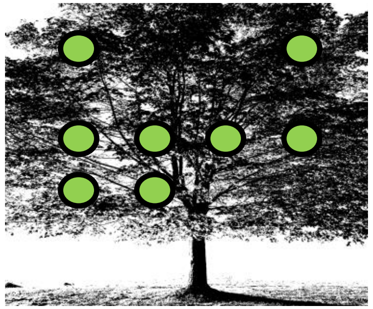
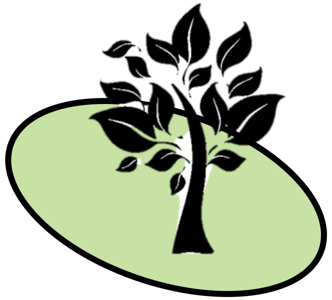
4. Standardized sampling and uncertainties

Sample size matters

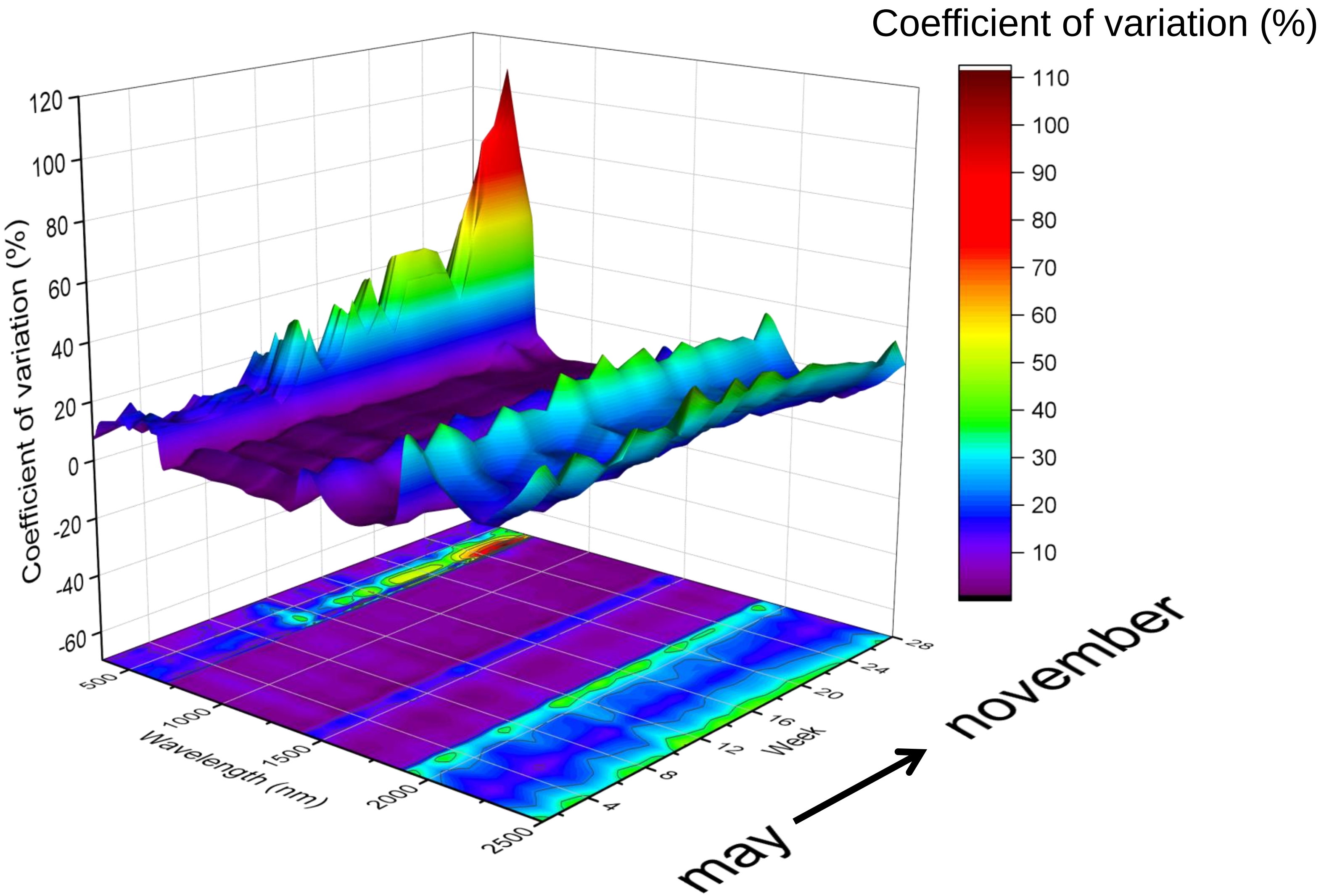


Temporal scale matters

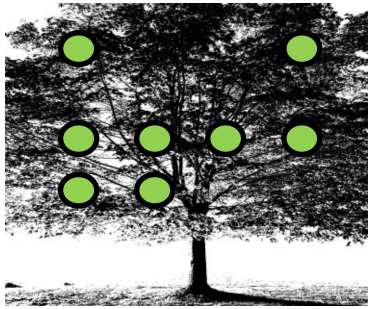


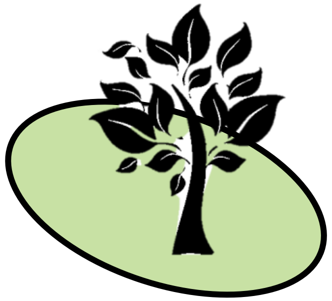


Tree



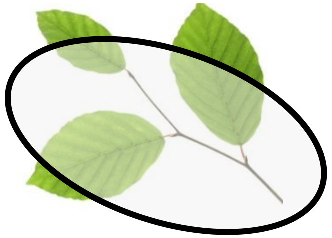
Measurement unit matters





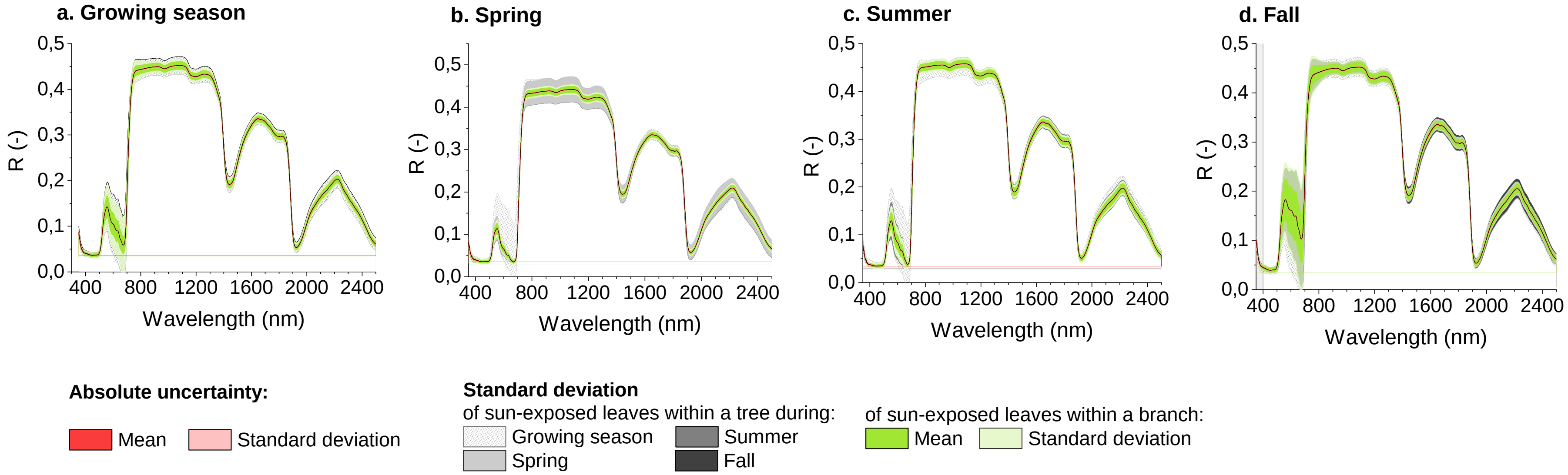
Tree

≠

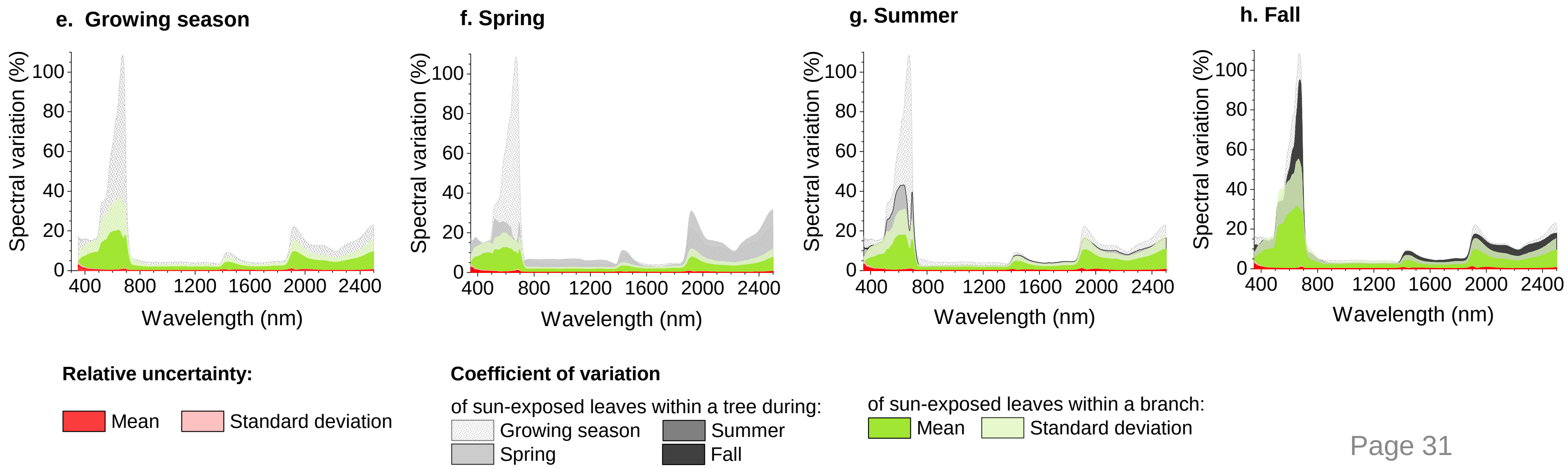


Branch

Spectral variation



Relative spectral variation



Take-home message

OUTLOOK:
Data calibration

Digital Number

Radiance
$Wm^{-2}sr^{-2}nm^{-1}$

Reflectance

f(sensor,
light source,
surface material)

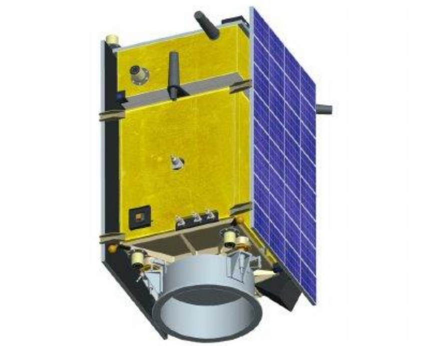
f(light source,
surface material)

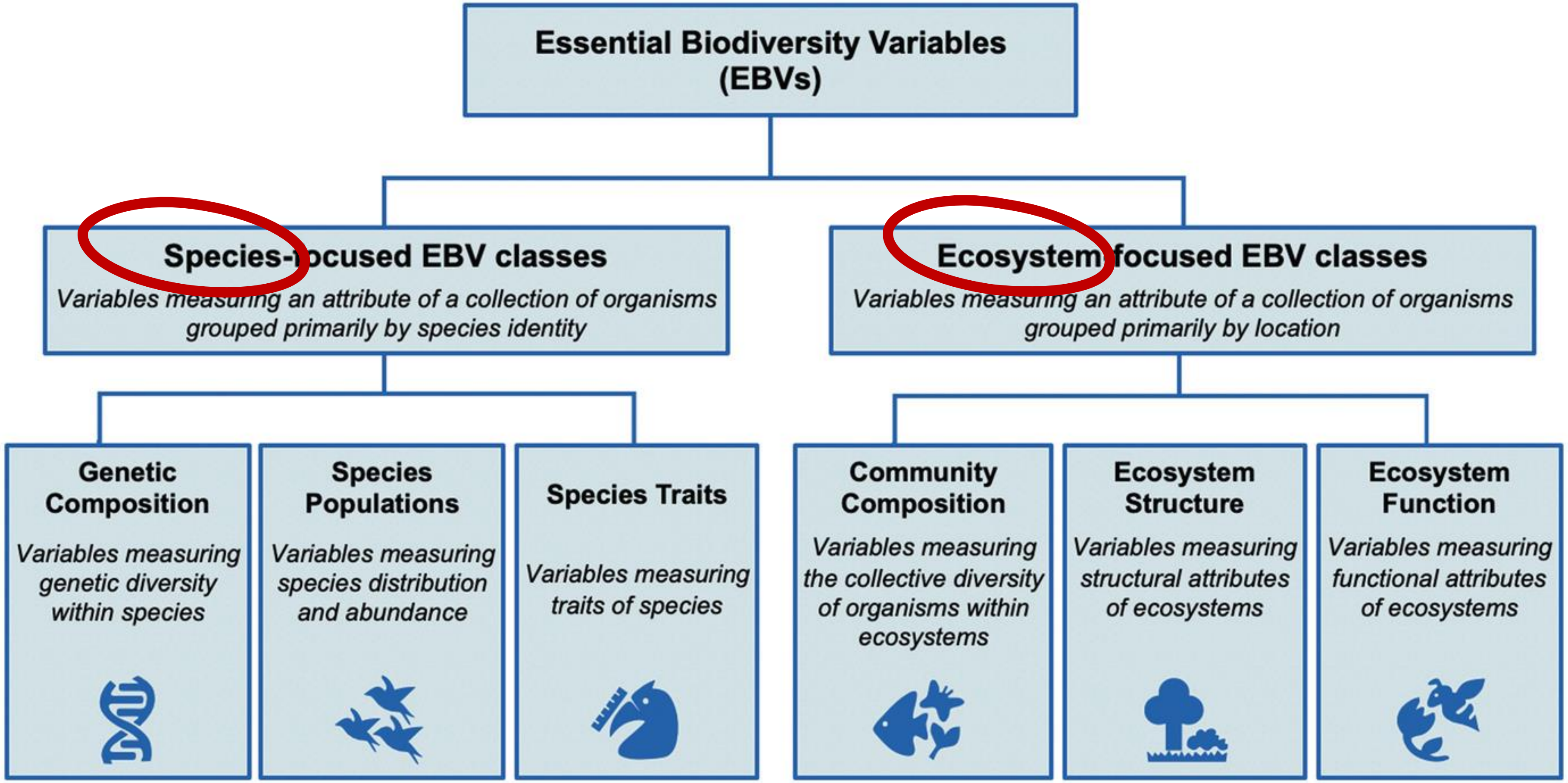
f(surface material)

Sensitive to species trait variation

Estimated measurement uncertainty

OUTLOOK:
Data calibration





Current SRS-EBV						
Future SRS-EBV						

Fernández et al. (2020), Pereira et al. (2013), Kissling et al. (2018), [Petorrelli et al. (2016)]

OUTLOOK:
Data calibration

Digital Number → **Radiance** *$Wm^{-2}sr^{-2}nm^{-1}$* → **Reflectance** → **Biological Information**

f(sensor,
light source,
surface material)

f(light source,
surface material)

f(surface material)

- Plant traits
- Biodiversity metrics
- …

Sensitive to species trait variation

Estimated measurement uncertainty

=

Uncertainty?

(Petibon et al., 2021)

(Petibon et al., in prep)

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New Results

Comment on this paper

Variation in reflectance spectroscopy of European beech leaves captures phenology and biological hierarchies despite measurement uncertainties

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THANKS FOR YOUR ATTENTION

Any question?

don’t hesitate to contact us

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Take-home message

- **Measurement uncertainty** is specific to ***ASD-Sampling probe-Target***
  → 0.0001 – 0.01 reflectance unit [0-1]
  → 0.3 – 4% leaf reflectance

- **Leaf Optical Properties (LOP) permit the detection of diverse scales of biological variation**

- Take into account the **variation over biological, spatial and temporal scales** when designing a research project.