Understanding the quality of field measurements used to validate EO-derived biophysical parameters: A 3D Radiative Transfer modelling approach

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Introduction

In order to interpret biophysical E0-derived products such as land surface albedo, Leaf Area Index (LAI) and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) correctly, they must be validated. To ensure a proper validation of satellite-based retrievals, uncertainties should be provided at each step in the verification procedure. There is currently no consensus among the scientific community in a standard protocol for the definition of uncertainties associated with field measurements, due to varying definitions of the quantity in question, the fact they may not measure the true value of the biophysical quantity per se, but rather it may infer its value, and also due to a lack of the 'true' value of the target quantity.

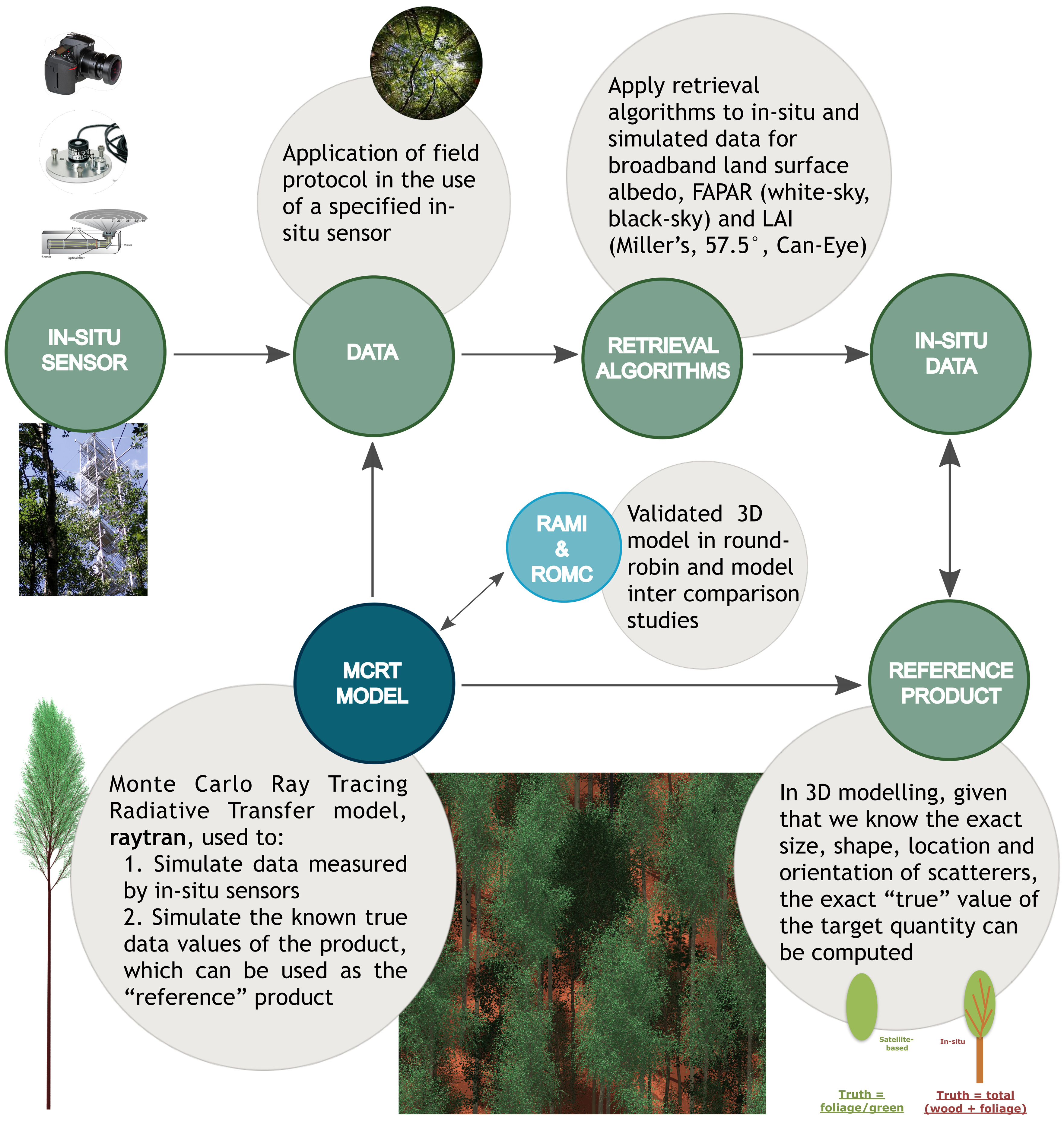
3D modeling can provide an alternative means of uncertainty quantification. A model-based approach for quality assessment of field measurements and their protocols is capable of benchmarking canopy biophysical parameters against a precisely known true value, benefitting both validation and traceability communities for Earth Observation (EO). Such an approach is non-destructive and highly flexible, and is beneficial since it avoids comparing the field measurement validation products against a independent estimates that in reality cannot reflect the true value.

Study aims

This study aims to address the following questions:

1. What are the quality assurance requirements for biophysical EO-derived products for climate observations?
2. What are the requirements for field measurements and how can we determine if these accuracy requirements are met?
3. What can validated 3D models can tell us about current accuracy requirements and the capability of EO products to meet them?
4. How well do 3D models represent the truth?
5. What can 3D models tell us about uncertainty in observation?

Method: Building a model-based Quality Assurance (QA) Framework



Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)

Contributions to uncertainty in measuring FAPAR from Digital Hemispherical Photography (DHP):

- Definition of FAPAR; white-sky, black-sky, blue-sky and algorithms used to compute them (Fig. 1)
- Solar Zenith Angles (SZA)
- Height of the DHP camera
- Sampling designs
- Plot size
- Number of samples
- Minimum separation distance from tree trunks (Fig. 3)
- Canopy type and heterogeneity (Fig. 2)

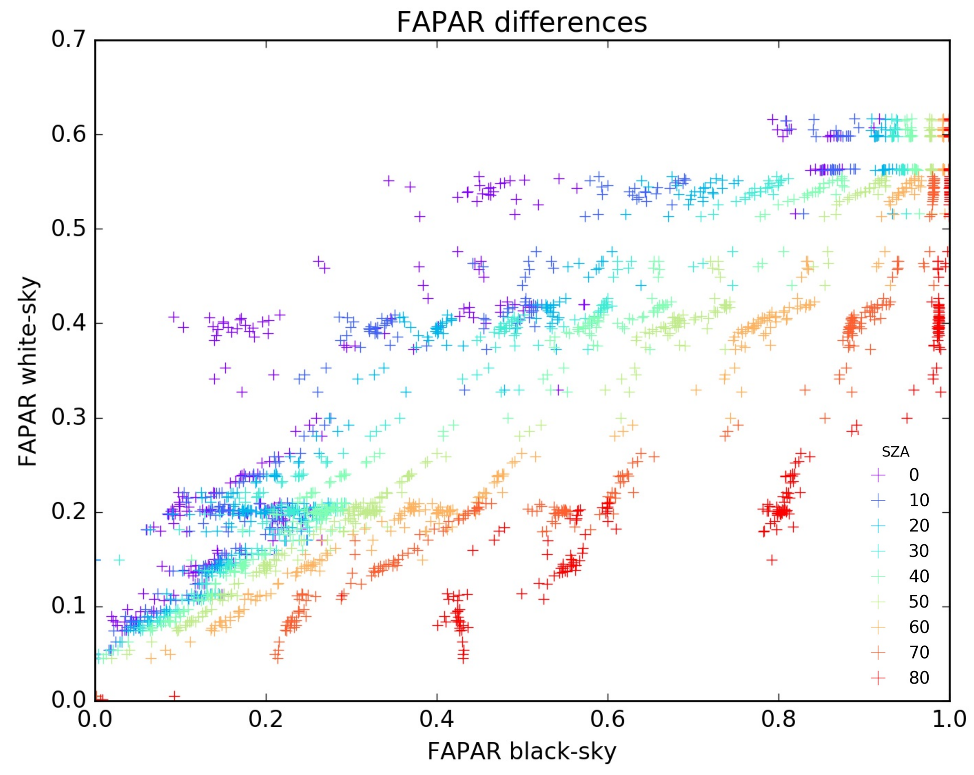


Fig. 1. Black-sky vs white-sky FAPAR for varying SZAs (0-80°)

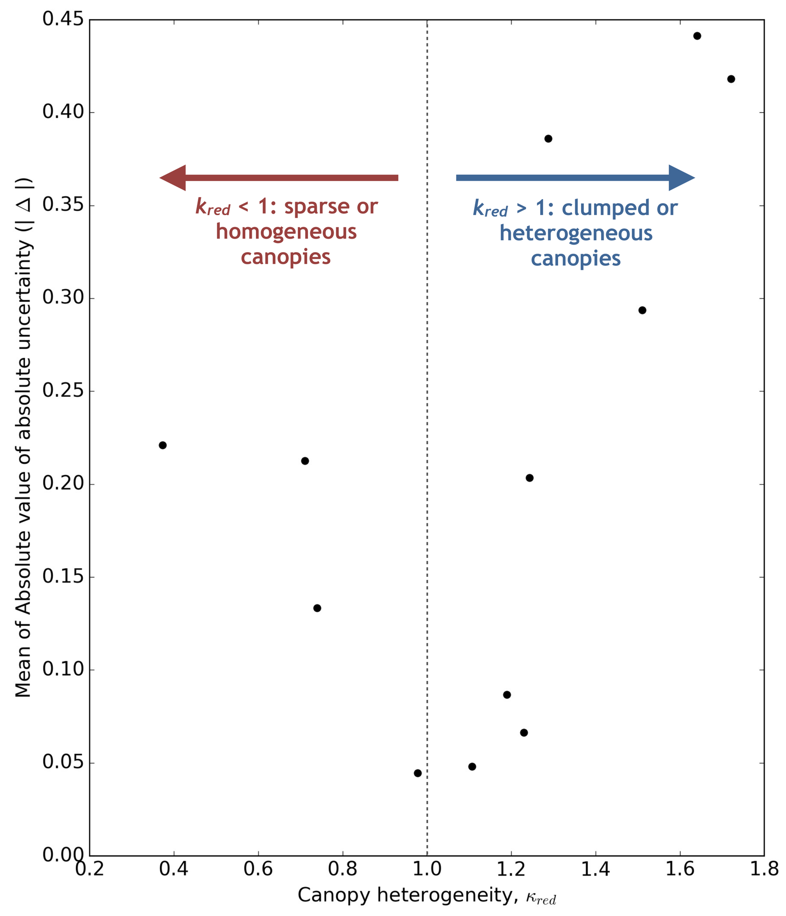


Fig. 2. Mean absolute uncertainty values for canopy heterogeneity index, k_{red}. A k_{red}<1 indicates homogeneous or sparse canopies, and k_{red}>1 indicates heterogeneous or clumped canopies. Uncertainties appear to be lowest when k_{red}≈1, i.e. neither too sparse nor too clumped.

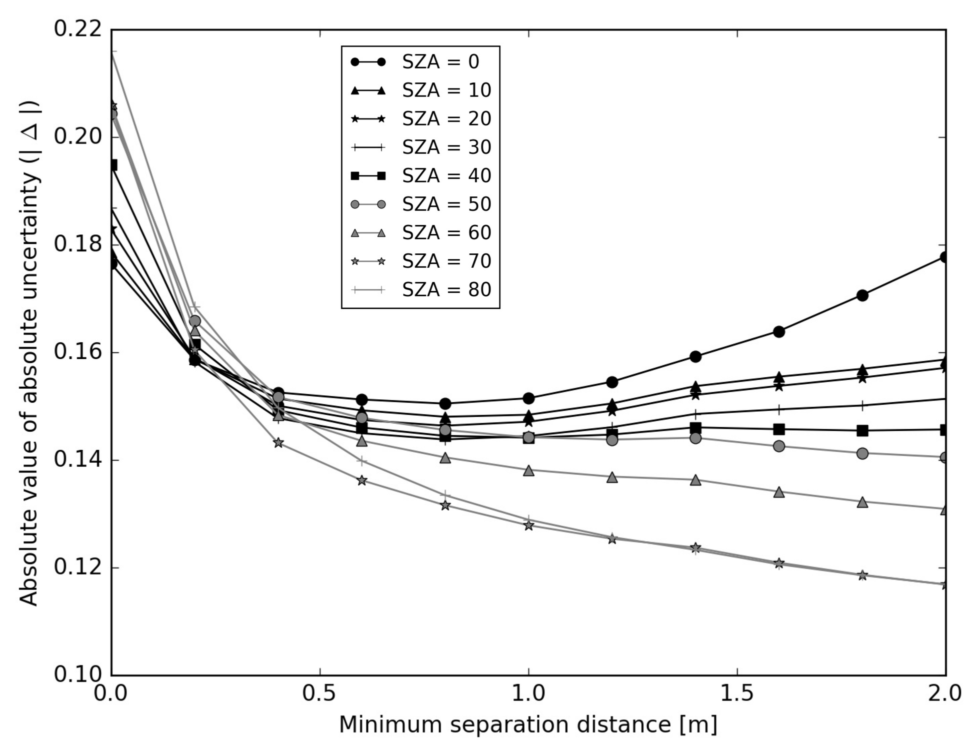


Fig. 3. Absolute uncertainty (| reference-measured |) values for instantaneous black-sky FAPAR for all canopies and sampling designs for SZAs (0-80°) at varying minimum separation distances from tree trunks. Across all SZAs, initially moving the camera away from underneath tree trunks up to 0.6-0.8m reduces uncertainties. For SZAs 50-80°, uncertainties reduce with increasing minimum separation distances. At angle 40° uncertainties stay constant from 0.6-0.8m with increasing minimum separation distance and for angles 0-30° uncertainties increase slightly past separation distances of 0.8m.

Land surface albedo

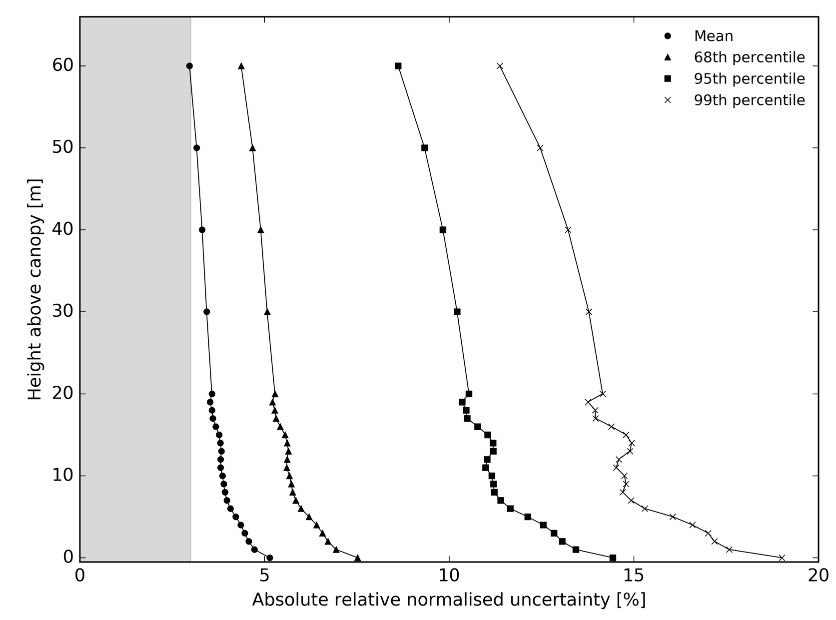


Fig. 4. Absolute relative normalised uncertainty [%] values for Jarvselja summer birchstand canopy for height of albedometer above the canopy. Grey area represents the WMO 3% accuracy requirements

3D models used to:

A. Assess conformity of in-situ albedo measurements to WMO 3% accuracy requirements at specified confidence levels, and the height that the albedometer should be placed above the canopy to reach requirement (Fig. 4).
B. Provide information on the utility of multiple albedometers: in all canopies, the use of 2 albedometers can significantly reduce uncertainties, and improve conformity to WMO accuracy requirements (Fig. 5).

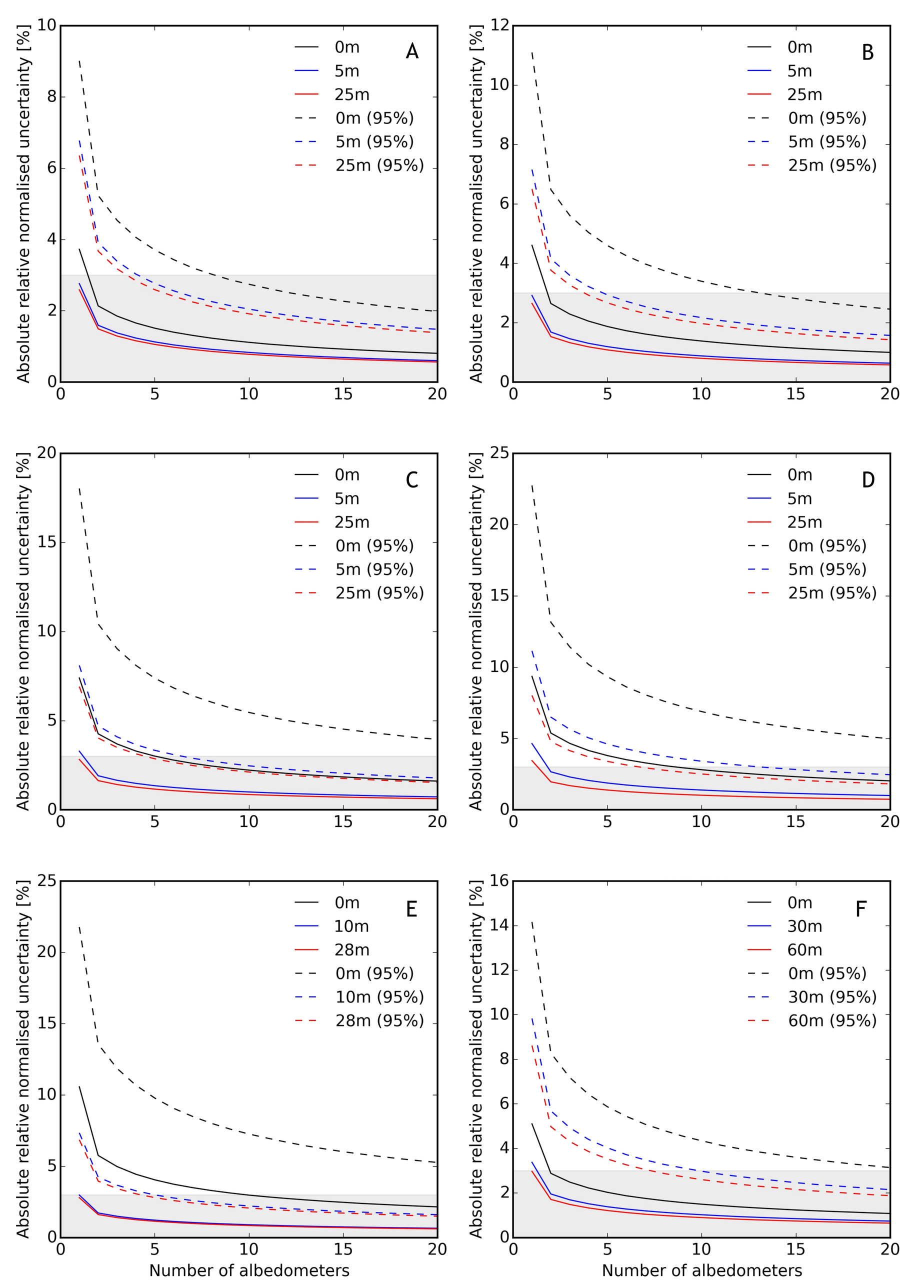


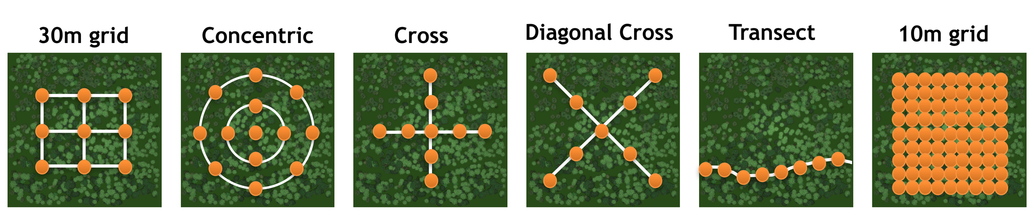
Fig. 5. Mean and 95th percentile absolute relative normalised uncertainty [%] values at albedometer heights (minimum, maximum and height at which WMO accuracy requirement is reached) for canopy scenarios A) citrus SZA/SAA 0° , B) citrus SZA 20° SAA 0°, C) citrus SZA 50° SAA 0°, D) modified citrus 20% trees removed, E) Jarvselja summer birchstand and F) winter birchstand.

Adams *et al* (2016) "A model-based framework for the quality assessment of surface albedo in-situ measurements protocols" *JQSRT*

Leaf Area Index (LAI)

Digital Hemispherical Photography (DHP) is one method of measuring in-situ LAI and FAPAR. The 3D MCRT model can be used to simulate fisheye images and then apply algorithms commonly applied in softwares such as Can-Eye, GLA, Hemiview, Hemisfer, WinSCANOPY, Winphot.

Table. 1. Absolute relative normalised uncertainty [%] for Jarvselja summer birchstand canopy using different sampling designs. Values indicate effective and true LAI for 57.5° and Can-Eye 6.1 LUT algorithms



		30m grid	Concentric	Cross	Diagonal Cross	Transect	10m grid
EFF	57.5	24.65%	23.86%	17.97%	23.11%	12.62%	23.41%
	LUT	56.12%	53.46%	52.08%	50.71%	47.40%	51.10%
TRUE	57.5	**9.74%**	**8.80%**	**1.75%**	**7.91%**	**4.66%**	**8.30%**
	LUT	**1.97%**	**5.75%**	**13.33%**	**0.05%**	**5.12%**	**1.24%**

Conclusions

3D modeling can be used in the context of validating EO-derived biophysical products to 1) to provide uncertainty information, 2) to benchmark the algorithms and methods used, 3) to test conformity against accuracy requirements for field measurement protocols of land surface albedo, FAPAR and LAI and 4) to identify specific contributions to uncertainty.

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