Uncertainty Quantification for Retrieving BRDFs from UAV-based radiometers for Fiducial Reference Measurement Generation

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Abstract

The acquisition and elaboration of Fiducial Reference Measurements is a key aspect of Cal/Val activities. FRMs provide independent validation data with a well-characterized uncertainty budget. The determination of surface reflectance following FRM principles contributes to this current Cal/Val effort. Surface reflectance is however a loose concept that needs first to be defined following metrological standards (Nicodemus, 1977).¹ This requires selecting a measurand that depends only on the state of the surface.

Among all reflectance quantities defined by Nicodemus (1977), only the BRDF, DHR (black-sky albedo) and BHR (white-sky albedo) are intrinsic to the surface—the DHR and BHR being easily recoverable from the BRDF. However, using the BRDF as the measurand is impracticable. Instead, experimentally accessible reflectance quantities are integrated over illumination directions, i.e. the HDRF and BHR. One can however use the DHR as a proxy for the BRDF when the surface is illuminated by a perfectly directional source. Getting near these measurement conditions in a laboratory is possible; in the field, where the surface is illuminated by both unscattered (direct) and scattered (by the atmosphere) radiation from the Sun, this is impossible. Consequently, field measurements can only yield the HDRF, which characterizes both the surface and the illumination.

Using the HDRF when applying FRM to land surfaces leads to contradictions. This study focuses on the uncertainty resulting from the use of HDRF as a proxy for in situ BRDF measurements. Specifically, this presentation demonstrates our contribution to quality control and best practices for the acquisition of surface reflectance distributions by measuring hemispherical radiances with UAV-borne radiometers. We identify which parameters, among those defining observation conditions, drive the difference between the targeted surface BRDF and the actual measured HDRF. We identify four parameters: (i) atmospheric scattering, (ii) the radiometer’s field-of-view, (iii) the UAV flight duration and (iv) the departure from the Lambertian assumption of a calibration reference panel.

We simulate UAV observations over a 3D canopy under realistic atmospheric conditions using Eradiate. Eradiate¹ is a 3D radiative transfer model (RTM) developed by Rayference to support Cal/Val activities. It supports simulations of flat surfaces, digital elevation models (DEM) and explicit vegetation models (abstract or mesh-based). Eradiate also simulates atmospheric scattering and supports an arbitrary number of aerosol layers with pre-defined and custom particle scattering properties. Eradiate can notably simulate ground-based and space-based observations.

In this presentation, we will introduce the problem and its relevance to FRM generation, followed by the design and parametrisation of our study. Results of this sensitivity analysis will be presented and discussed. Finally, recommendations concerning possible uncertainty minimization of HDRF acquisitions will be provided.

2. Eradiate is open-source software available at: www.eradiate.eu