Empirical acquisition of bidirectional reflectance of tropical forest ecosystems using unmanned aerial vehicles

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Both the sensor viewing angle and the solar angle influence the remote sensing signal of terrestrial ecosystems. This influence is characterized by the bidirectional reflectance distribution function (BRDF). Knowledge of this BRDF is needed to correctly interpret the signal, but can also provide information on vegetation characteristics and structure. Obtaining the BRDF is far from straightforward: at leaf scale, laboratory goniometers can measure reflected radiation over a range of sensor-solar angle; for very homogeneous ecosystems, such as grassland or agricultural cropland, unmanned aerial vehicles (UAVs) can be programmed as giant goniometer, scanning the BRDF of an area of up to a few m\textsuperscript{2}. For heterogeneous ecosystems such as forests, this is not feasible. In this case, BRDF could so far only be derived from theoretical radiation transfer models or semi-empirical models; yet these models do not always agree.

We here propose a new method for measuring BRDF of forest ecosystems with UAVs, by measuring a star-shaped area of the ecosystem, covering in total about 3600m\textsuperscript{2} and capturing 6 different sensor-solar azimuth angle and three different zenith angles. This approach was applied over two sites of tropical rainforests in Queensland, Australia, with measurements with a RGB camera and a spectrometer. By repeating the flights several times during the day, we were able to test the Helmholtz reciprocity principle – that states the BRDF function of ecosystems remains the same, regardless of the solar angle – and are able to increase the range of sensor-solar angles. Our results present the first strictly empirical BRDF of tropical rainforests and confirm the importance of accurate BRDF correction of remote sensing products from forest ecosystems.