NORMALIZATION OF ILLUMINATION CONDITIONS FOR GROUND BASED HYPERSPECTRAL MEASUREMENTS USING DUAL FIELD OF VIEW SPECTRORADIOMETERS AND BRDF CORRECTIONS

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1 INTRODUCTION

Ground based hyperspectral measurements of earth surfaces and vegetated canopies are intensively used to obtain detailed spectral characteristics and as a substitute for satellite or airborne imagery. Field campaigns rely on spectroradiometers to obtain surface reflectance properties. A critical constraint to obtain meaningful data is the requirement of stable illumination conditions, which can only be guaranteed under clear sky conditions. While for single date measurements this condition may be not too restrictive, the establishment of (vegetation) time series of ground data is severely hampered in many world regions where overcast weather conditions prevail. This research presents an enhancement to an alternative measurement technique, dual field-of-view spectroscopy, which has been occasionally applied to alleviate these restrictions and make measurements largely independent of illumination intensity.

2 THEORY

Reflectance measurements are generally based on ratioing the measured radiance of a target surface by the radiance of a reference whitepanel surface, each illuminated with the same light source (power, geometry). Classical spectroradiometer field campaigns rely on subsequent measurements of target and reference and are therefore restricted to stable illumination conditions. By making use of one dual-beam spectroradiometer or two different instruments, it is possible to simultaneously measure the target and the sky irradiance or whitepanel radiance. This research will focus on the use of two instruments.

Measurements under hazy and (partly) cloudy conditions require consideration of the surface and whitepanel bidirectional reflectance factor (BRDF) since cloud cover not only changes light intensity, but also increases the ratio of direct to diffuse illumination, which causes a different sampling of the target's BRDF. The measured apparent reflectance (ρ_{app}) can be expressed as:

$$\rho_{app} = \left(\gamma_{dir}\rho_{diff} + (1-\gamma_{dir})\rho_{dir}\right)$$

with γ_{dir} the fraction of direct sunlight. The direct and diffuse reflectance components, ρ_{dir} and ρ_{diff}, are defined as:

$$\rho_{dir}(\theta_s,\lambda) = \frac{fr_{TAR}(\theta_{sun},0,\lambda)}{fr_{WP}(\theta_{sun},0,\lambda)}; \quad \rho_{diff}(\theta_s,\lambda) = \frac{\int_0^{2\pi}\int_0^{\pi/2} fr_{TAR}(\theta,0,\varphi,\lambda)\, L_{sky}(\theta,\varphi,\lambda)\sin(\theta)\cos(\theta)\, d\theta\, d\varphi}{\int_0^{2\pi}\int_0^{\pi/2} fr_{WP}(\theta,0,\varphi,\lambda)\, L_{sky}(\theta,\varphi,\lambda)\sin(\theta)\cos(\theta)\, d\theta\, d\varphi}$$

where fr is the BRDF of the target (TAR) or reference (REF) with illumination zenith angle θ, relative azimuth φ and nadir viewing angle. $L(\theta,\varphi,\lambda)$ is the diffuse sky radiance. Since different illuminations will cause different values of L_{sky} and γ_{dir}, also the apparent reflectance will change. In order to normalize the measurements, estimates are required target and whitepanel BRDF, the (relative) distribution of the sky irradiance and the fraction of direct incident light. When a standard whitepanel is being used, empirical expressions of its BRDF have been published for different wavelengths [2]. Sky irradiance distribution can be assumed isotropic or a more detailed formulation can be obtained from analytic expressions or radiative transfer code. The fraction of direct sunlight can be derived from the data if one assumes a direct relationship, for a given solar position, between the total irradiance (which can be estimated from the radiance of the whitepanel) and the fraction of direct radiance. This relationship may either be derived from simulations or from field data if appropriate equipment is available. The last unknown is the target BRDF which is also the surface property being measured. Therefore additional assumptions are required. When multiple measurements are made over different targets of similar structure (e.g. all tree crowns or all grass sods), the BRDF of a specific target j can be approximated by the product of an object specific property with no angular dependence (such as the white sky albedo) and a kernel function κ that is identical for all objects in a series.

3 SENSITIVITY ANALYSIS

Severely decreased light intensity will not only cause a different BRDF sampling, also the signal-to-noise ratio will change. Using known sensor characteristics (noise equivalent radiance or NER), classical error propagation will be used to establish error bounds on the obtained apparent reflectance values.

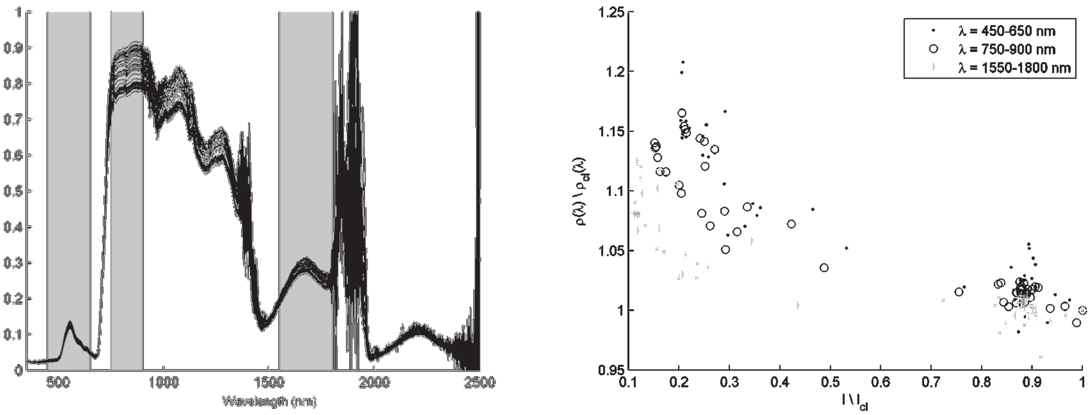

Figure 1: Apparent reflectance of citrus trees with solar zenith of 33° under partly cloudy conditions. Shaded boxes indicate the wavelength regions of the right image (left). Scatterplot of relative irradiance (X-axis) and normalized reflectance (Y-axis) (right).

4 MATERIALS AND METHODS

4.1 Ray-tracing Simulations

Ray-tracing simulations are set up in a physically based ray-tracer, adapted and calibrated for hyperspectral use [3]. Different homogeneous vegetative targets will be constructed with varying leaf area index (LAI) and leaf angle distribution (LAD). Additional targets will be simulated using a soil BRDF model. Per target, nadir reflectance simulations will be generated with varying realistic illumination conditions, making use of skymaps produced by atmospheric radiative transfer code and direct illumination. Varying cloud cover can be simulated by altering cloud optical thickness. These simulations will enable an estimation of the pure algorithmic performance of model based target corrections.

4.2 Field measurements

Five datasets were collected over three surface types (grass, potted *Citrus* tree crowns and gravel) at varying solar elevations. For each dataset, two full-range HR1024 spectroradiometers (Spectra-Vista corp.) were used, one of which was fixed above the target while the other was fixed over a Spectralon (Labsphere inc.) whitepanel. Per dataset between 20 and 40 measurements were made at varying illumination conditions on partly cloudy days, ranging from a fully unobscured to a fully obscured solar disk.

5 BRDF CORRECTION

The easiest correction is empirical. Since the kernel κ of all targets in a series is assumed to be approximately equal, it is possible to generate a calibration set by holding the target sensor in a fixed position over a calibration target (e.g. a tree with average structural characteristics) and making target measurements over a short time span for a wide range of illumination conditions. After proper ratioing, for each wavelength a quadratic regression may be fitted between whitepanel radiance (I/I_{cl}) and the apparent reflectance (ρ/ρ_{cl}) each normalized their values at maximal illumination power. This is illustrated in figure 1.

When an estimate of the surface BRDF can be obtained, model based corrections can be made to convert the apparent reflectance into any desired surface property such as black or white sky albedo. By making initial assumptions on the target's surface BRDF (relative fractions geometric optic, volumetric and Lambertian reflectance), the RossThick-LiSparse kernel correction [1] will be implemented. Kernel correction parameters will first be derived from model fitting on ray-tracing data simulated for comparable targets and illumination conditions. Similar simulations can also be used to obtain the intrinsic performance of the correction procedure under ideal conditions. Final validation will apply these correction parameters on field measurements made over a stable target.

6 REFERENCES

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