Specification of Understory Reflectance for SL2P-D over Canadian Boreal Forests

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SL2P-D is an algorithm for mapping vegetation canopy biophysical variables using multispectral satellite data. SL2P-D relies on a database of simulations of reflectance that would be measured from a specified satellite given canopy information and acquisition geometry. A library of understory reflectance spectra spanning 400nm to 2500nm is sampled to produce this database. The library should be representative of possible local conditions in terms of the shape of the spectrum (it is later scaled to represent natural variability and variability due to illumination and view conditions).

The default SL2P-D library is the library used in SL2P (Figure 1) (Weiss and Baret, 2016). This library is not representative of Canadian boreal forests as it does not include open water, mosses, lichens and surface litter typical of such forest understories. We hypothesize that a version of SL2P-D calibrated using such representative spectra, with or without the default spectra, will have lower uncertainty in estimated variables than using the SL2P understory reflectance library. Open water spectra will not be included since flooding is ephemeral for forests while the targeted application of the algorithm it typical seasonal conditions.

The goal of this report is to document the production of the specification of a representative Understory Reflectance library for SL2P-D over Canadian Boreal Forests. There are few publically available understory reflectance spectra for Canadian Boreal Forests; especially spanning a typical growing season. We use the BOREAS RSS-19 1994 Seasonal Understory Reflectance Data (Miller et al., 1994) as the basis as it includes a range of species, site conditions and seasons and is collected in a systematic manner with uncertainty information. A major limitation of this data is that it only spans 400nm to 900nm. The region between 900nm and 2500nm in includes important water absorption features that often scale independently of reflectance between 400nm and 900nm as understory moisture content varies. A systematic approach for extrapolating the measured spectra between 901nm and 2500nm is required. Here, a physical model for foliage reflectance (PROSPECT5D) is used to perform this extrapolation by first matching reflectance between 800nm and 900nm and then simulating a range of foliage moisture content for longer wavelengths; with the range being a function of understory cover type.

Section 2 documents the BOREAS RSS-19 spectra used. Section 3 describes the extrapolation algorithm. Section 4 provides results based on the extrapolation. Code and input spectra are found at <https://github.com/rfernand387/SL2PD>.

Section 2 BOREAS RSS-19 Spectra

The RSS-19 Spectra were filtered in Excel to include only May to September data (Table 1). The Spectra corresponded to measurements spanning 402nm to 1000nm. The average of all spectra for a plot (typically 3) was used to represent each plot. Plot spectra were interpolated using a piecewise cubic hermite polynomial (MATLAB interp1). Spectra were extrapolated between 350nm and 401nm using the measured reflectance at 402nm. This will likely overestimate reflectance in this region but most algorithms do not make use of spectral bands including this region. Spectra were extrapolated between 100nm and 2500nm by simulation using PROSPECT5D. The dry matter concentration (Cm) required to match the measured plot reflectance between 825nm and 875nm (using fixed values of N=1.5, Cab=40ug.cm-2,Car=10ug.cm-2,zero anthocyanin and brown pigments and Cw=0.02g.cm-2). The fitted value of Cm was then used to simulate reflectance 825nm and 875nm for four different values of Cw (0.01g.cm-2,0.02g.cm-2,0.03g.cm-3 and 0.04g.cm-2). A different extrapolated plot mean reflectance spectrum was estimated using each value of Cw.

Table 1. Summary of spectra by plot. OJP=Old jack pine, YJP=young jack pine, OBS=old black spruce.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Plot# | Site | Date | GMT HHMM | INSTRUMENT | SOLAR\_ZEN\_ANG (deg) | Dry Matter  g.cm-2 |
| 1 | NSA-YJP | 01-Sep-94 | 1542 | 'SE590' | 54.15 | 0.106 |
| 2 | 'NSA-FEN-FLXTR' | 03-Sep-94 | 1602 | 'SE590' | 55.312 | 0.104 |
| 3 | 'NSA-OJP-FLXTR' | 06-Sep-94 | 1617 | 'SE590' | 54.388 | 0.048 |
| 4 | 'NSA-OBS-FLXTR' | 16-Jul-94 | 1624 | 'SE590' | 35.377 | 0.039 |
| 5 | 'NSA-OJP-FLXTR' | 11-Jun-94 | 1703 | 'SE590' | 36.091 | 0.037 |
| 6 | 'SSA-YJP-FLXTR' | 26-May-94 | 1709 | 'SE590' | 35.459 | 0.082 |
| 7 | 'SSA-FEN-FLXTR' | 12-Sep-94 | 1734 | 'SE590' | 52.113 | 0.173 |
| 8 | 'SSA-OJP-FLXTR' | 21-Jul-94 | 1741 | 'SE590' | 35.008 | 0.03 |
| 9 | 'SSA-OBS-FLXTR' | 31-May-94 | 1752 | 'SE590' | 33.354 | 0.045 |
| 10 | 'SSA-OBS-FLXTR' | 23-Jul-94 | 1800 | 'SE590' | 34.475 | 0.043 |
| 11 | 'SSA-YJP-FLXTR' | 20-Jul-94 | 1814 | 'SE590' | 33.913 | 0.086 |
| 12 | 'SSA-YJP-FLXTR' | 12-Sep-94 | 1906 | 'SE590' | 50.178 | 0.106 |
| 13 | 'NSA-OBS-FLXTR' | 02-Sep-94 | 1921 | 'SE590' | 51.076 | 0.051 |
| 14 | 'SSA-OJP-FLXTR' | 26-May-94 | 2015 | 'SE590' | 39.182 | 0.037 |
| 15 | 'SSA-OJP-FLXTR' | 12-Sep-94 | 2137 | 'SE590' | 61.791 | 0.059 |

Results

The calibrated Cm values (Table 1) ranged from 0.03g.cm-2 (a mature pine forest) to 0.173g.cm-2 (a fen). Typical values for foliage dry matter range from 0.001g.cm-2 to 0.01g.cm-2. We hypothesize the calibrated values are much higher as i) they include all the accumulated dry matter on the surface and not the dry matter per unit leaf area ii) brown pigments are not included while much of the dry matter will be brown and hence have higher scattering iii) the surface is equivalent to a scattered of infinite depth rather than foliage that has a small (N) number of scattering layers.

While the Cm values are effective values they provide reasonable fits to NIR reflectance between 825nm and 875nm and extrapolated reflectance in the shortwave infrared region (Figure xx). One caution in using some of these measurements is that they will include low lying (<50cm tall) forbs and mosses that technically may be considered as part of the overstory LAI. The spectra do indicate some level of red absorptance typical of live foliage. Nevertheless, this absorption feature is weak and less dominant that the large green and NIR scattering typical of senescent matter. Even so, it is recommended that these spectra be used without increasing their magnitude as is typically done when integrating mineral soil spectra within radiative transfer model simulations (Weiss and Baret, 2016).



Figure 1. Understory spectra.

References

Miller, J.R., D.R. Peddle, and J.R. Freemantle. 1998. BOREAS RSS-19 1994 Seasonal Understory Reflectance Data. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/304>

Weiss and Baret, 2016, **S2ToolBox level 2 products. Version 1.1** , Available online [step.esa.int/docs/extra/ATBD\_S2ToolBox\_L2B\_V1.1.pdf](http://step.esa.int/docs/extra/ATBD_S2ToolBox_L2B_V1.1.pdf)