Modifications to SL2PD for using FLIGHT Simulations during Calibraton

SL2PD is a MATLAB programme that calibrates non-linear regressions to predict canopy biophysical varables (‘variables’) using multispectral measurements. Calibration is performed using a set of variables and associated simulated top-of-canopy (TOC) or top-of-atmosphere (TOA) bi-directional reflectance ( R ) . A radiative transfer model with known uncertainty is used to simulate TOC R. SL2PD was based on SL2P (Weiss and Baret, 2016) that only used one RT model: sail3, an approximation of PROSAIL. Sail3 and PROSAIL are now implemented in SL2PD. These are homogenous quasi-turbid RT models in that the canopy is described assuming only knowledge of average ratio of the size of foliage elements to their spacing (known in PROSAIL as the hot-spot dimensional factor or HsD).

The RAMI benchmarking experiments (Widlowski et al., xx) indicate that homogenous quasi-turbid RT models can have large errors in R for heterogeneous discrete canopies such as forests; in contrast to RT models based on Monte-Carlo photon tracking and explicit description of the size and location of foliage elements (MC models). The RAMI experiments found that number of MC models lie within a consensus estimate of R for typical conditions corresponding to view angles not coincident with the sun illumination angle. FLIGHT is unique among these consensus models in that it requires only input of canopy average structure parameters (Table 1). The goal of this document is to provide a specification of these canopy parameters that spans the space of allometrically plausible canopies for typical land cover classes within an ecosystem. The specification is optimized to make use of information that may be available over forests but, in principle, can apply to any canopy that follows similar allometric functional forms.

Table 1. FLIGHT Canopy inputs

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | FLIGHT Symbol | Units | Description |
| Plant Area Index | TOTAL\_LAI | m2 /m2 | Half all sided plant area per unit horizontal ground area |
| Fraction green | FRAC\_GREEN | 0-1 | Fraction green leaves in plants by area |
| Fraction senescent | FRAC\_SEN | 0-1 | Fraction of senescent/shoot material in plants |
| Fraction bark | FRAC\_BARK | 0-1 | Fraction of bark in plant |
| Leaf angle distribution | LAD | 0-1 | normal to leaves and vertical as fraction lying within 10 degree bins |
| Soil roughness | SOILROUGH | 0-1 | Lambertian soil 0, rough (mean slope 60deg) given by 1 |
| Leaf size | LF\_SIZE | m | radius |
| Fraction crown cover | FRAC\_COV | 0-1 | vertical projection of opaque crowns |
| Crown shape | CROWN\_SHAPE | ‘e’ or ‘c’ | 'e' for ellipsoid, 'c' for cones |
| Crown radius | Exy | m | Crown radius |
| Crown semi-height | Ez | m | Crown centre to top distance |
| Minimum crown base height | MIN\_HT | m | min height to crown base |
| Maxium crown base height | MAX\_HT | m | max height to crown base |
| Diameter at breast heigh | Dbh | Cm | Diameter at breast height |
| Shoot clumping |  | Dim | Shoot clumping index |

SL2PD currently defines the joint distribution of RT model inputs using 8 canopy variables and a soil brightness variable (Table 2). These variables are insufficient to specify the FLIGHT inputs as only TOTAL\_LAI and FRAC\_COV are specified. Ideally, a minimum set of new input canopy variables should be added to specify the joint distribution of variables in Table 1.

Canopy variables will covary with species and ecosystem and will typically correspond to either even aged monocultures or natural stands with mixes species and cohorts. FLIGHT cannot easily simulate trees with variable crown dimensions (to do so requires construction of tree specific parameter files that would significantly increase computational costs). As such, only a single species will be simulated. The species is selected based on the conditional likelihood of the species given stand age. The conditional likelihood of species is determined by normalizing the probability of age given a species across all species using age pdfs.

Upon selection of a species a number of global parameters are defined by sampling pdfs for the selected species:

1. Leaf radius
2. Needle to shoot area ratio .
3. Site index defined as the dominant and codominant height at 50years age (S)
4. Ratio of crown height to diameter is radius ()
5. Number of cohorts ()

Table 2. SL2P Canopy structure input variables.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | FLIGHT Symbol | Units | Description |
| Leaf Area Index | **LAI** | m2 /m2 | Half all sided green foliage area per unit horizontal ground area |
| Average leaf angle | **ALA (°)** | deg | Average leaf elevation agnle. |
| Fraction crown cover | **Crown\_Cover** | 0-1 | Fraction of area not covered by canopy or crowns. |
| Hotspot Dimension | **HsD** | 0-1 | Ratio of leaf size to mean leaf vertical spacing. |
| Stand age. | **Age** | yrs | Age of dominant cohort. |

Leaf radius () corresponds to the radius of a disk with the same projected area of a leaf or shoot averaged over all directions. As this information is not typically available, flat leaves are approximated as flat ellipses with major axes radius () corresponding to the longest dimension and minor axis radius () as the perpendicular dimension at the bisector of the major axis. In this case, . Shoots are approximated as either spheres or cylinder. In this case the leaf radius corresponds to a disk equal to the average projected area: one quarter of the total surface area area.

The green area fraction is given as:

(1)

SL2P requires a specified . For FLIGHT, the in flight must be adjusted to account for shoot clumping, since shoots are the basic foliage element for FLIGHT simulations here, and to account for since is actually plant area index:

(2)

For each cohort, the age is resampled and stands mean height is estimated using one of a set of equations:

1. the expanded Chapman-Richard Equation is to and with species dependent limits

(3a)

and are then determined by sampling from a normal distribution with mean and standard deviation proportional to the prediction error of Equation (3) (assuming this error is totally due to natural variability). Here a proportionality of is used, corresponding to the ratio of the range of the one standard deviation of uniform to normal distribution.

The stand mean, maximum and minimum heights are then the median, and respectively over all cohorts. Crown radius and clive crown ratio height are assumed a linear function of :

(4)

(5)

Where is related to median height using the Chapman-Richards Equation:

(6)

Equation 5 strictly speaking applies to the dominant and codominant cohort. It is applied to the median age cohort here.

The height to the base of the crown is then given by

(7)

(8)

Where is the standard deviation of height to crown base approximated from field data.