Moving towards traceable fAPAR product validation using radiative transfer models with realistic 3D forest structure

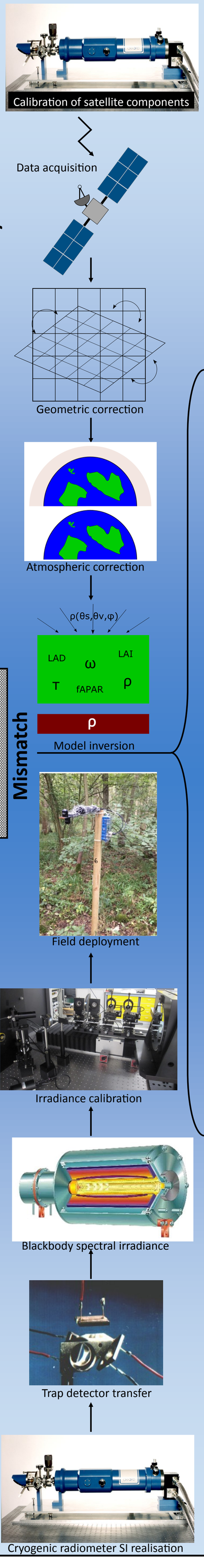
Niall Origo (NPL/UCL), Joanne Nightingale (NPL), Mat Disney (UCL) & Kim Calders (NPL/UCL)

Introduction

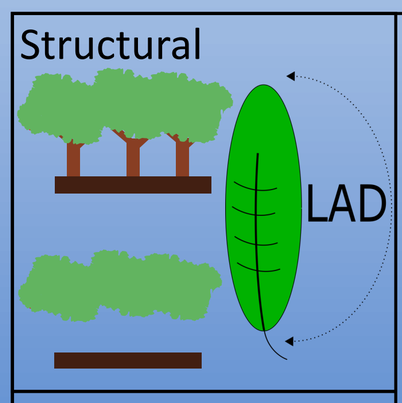
Assessing the quality of a satellite product in a metrologically traceable manner requires propagation of uncertainties through the satellite and validation processing chains from all input data sources. Conformity analysis will subsequently determine whether the product agrees with the validation data under the specified conditions. Using the fraction of absorbed photosynthetically active radiation (fAPAR) as an example, this poster describes the types of mismatches that exist and a potential solution to reconciling them using radiative transfer (RT) modelling. The aim is to produce a series of conversion factors (with uncertainty metrics) tailored to specific products so that direct validation can be facilitated.

Satellite fAPAR products are wide ranging in their pre-processing and quantity retrieval techniques. Retrieval of fAPAR from satellite data requires an RT model to interpret the reflectance signal. The chosen model utilises assumptions about the surface and illumination conditions in order to constrain the solution space. This is in contrast to the retrieval of in situ fAPAR from PAR networks (in particular four-flux networks) where natural illumination conditions and the exact scene structure influence the measurement. Direct validation of fAPAR products using in situ data from PAR networks is insufficient, even when accurate information about the network uncertainty is present.

Satellite traceability chain



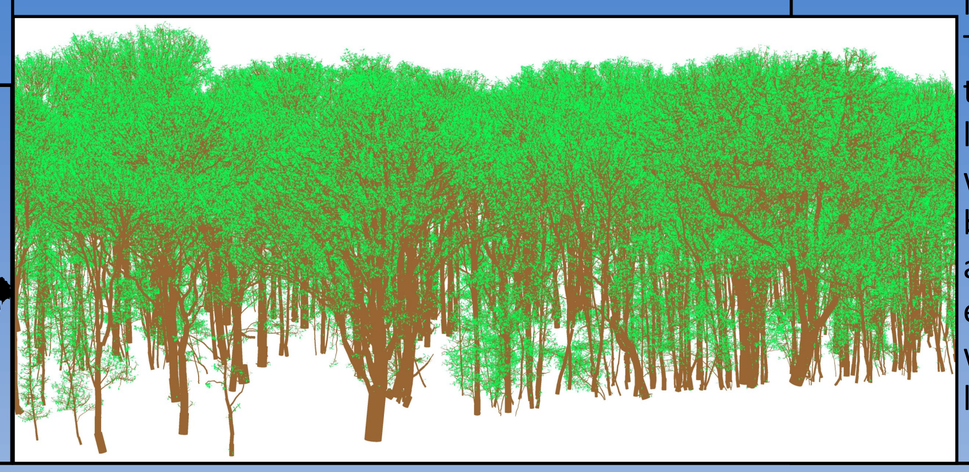
In situ traceability chain



TLS-derived 3D model

A tool to translate between the conditions employed by the retrieval algorithm and the conditions experienced by the network is required. Monte Carlo (MC) RT models equipped with realistic 3D descriptions of the forest canopy can provide the necessary flexibility to assess the expected differences under different scenarios. This becomes more powerful when accurate representations of real sites are possible, as is emerging with the continued development of terrestrial laser scanning (TLS) derived tree reconstruction techniques.

The Wytham model has been built using TLS data collected in summer and winter over the 6 ha field site. The tree skeletons were produced using the technique described in Raumonen et al. (2013) from tree point clouds extracted from the wider registered point cloud. Leaves were added using a simple LAI profile derived directly from the point cloud data.



Example application

Satellite fAPAR products commonly retrieve fAPAR from green leaves while in situ estimates consider the whole canopy volume. Through modification of a 3D model the former can be converted into the latter and tested to determine the effect on the in situ estimates. Given that the Wytham model is still under development, this was tested using a pre-existing 3D model (Järvselja birch stand). The example results are shown in figure 1.

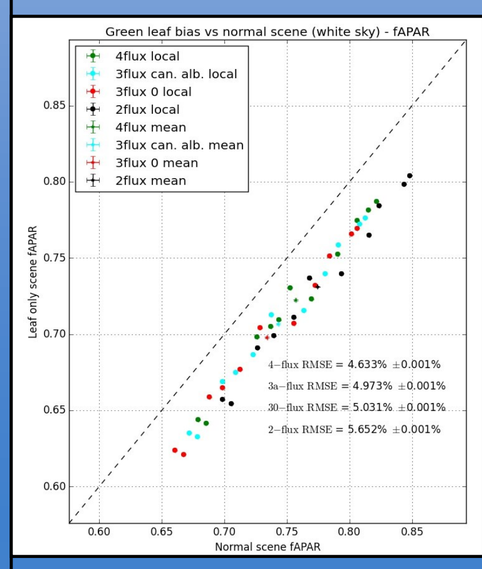
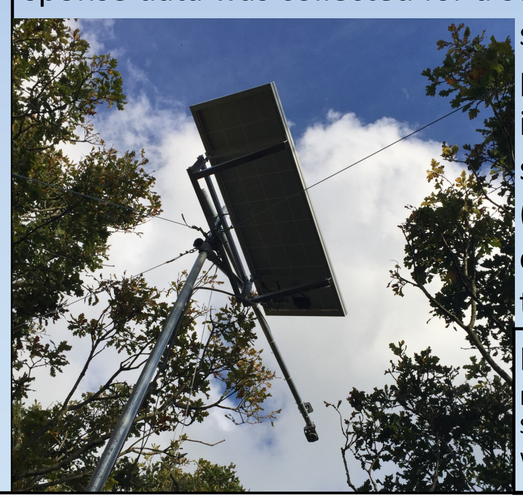


Figure 1. Direct comparison between leaves-only and full scene 3D model for fAPAR.

It is clear that ~4.5% - 5.5% bias exists for this site, as shown by the RMSE, depending on the number of fluxes considered. The stability of these estimates relative to the number of rays used in the simulation is very high. This is one example where the bias and stability metrics can be used to inform the network values and be included in its uncertainty budget when assessing satellite products whose fAPAR definition refers solely to leaf-only scene conditions.

In situ: Wytham Woods PAR network

The network consists of 64 PAR sensors at 32 locations covering approximately 150 m^2 and is set-up to record four-flux fAPAR. Each sensor has been calibrated in the laboratory against an FEL lamp which is traceable to the cryogenic radiometer and subsequently to the SI realisation of optical power. Supplementary spectral and angular response data was collected for a selection of the sensors in order to inform the uncertainty derivation and provide accurate sensor characteristics in the RT simulations. The size of the network relative to the satellite footprint is the major prohibiting factor for direct comparison, however the level of detail in which it has been characterised should provide new insights that have not been addressed by larger sites and validation activities. The network also lacks the ability to determine the 'true' fAPAR (green or otherwise) since the estimation techniques employed infer the absorption from the closure of the energy balance (Widlowski 2010). As such simulation work is needed to ascertain the expected difference between the in-situ techniques and the 'true' fAPAR at this site.



References

Raumonen, P., Kaasalainen, M., Åkerblom, M., Kaasalainen, S., Kaartinen, H. et al. (2013). Fast Automatic Precision Tree Models from Terrestrial Laser Scanner Data. Remote Sensing, 5, 491–520.

Widlowski, J,-L. (2010) On the bias of instantaneous FAPAR estimates in open-canopy forests. *Agricultural and Forest Meteorology* **150**:1501-1522