PhD proposal: Modelling leaf area dynamics in tropical canopies from high density UAV lidar

The stakes

Covering just 7% of the Earth's land surface, tropical forests play a disproportionate role in the biosphere: they store about 25% of the terrestrial carbon and contribute to over a third of the global terrestrial productivity. They also recycle about a third of the precipitations through evapotranspiration and thus contribute to generate and maintain a humid climate regionally with positive effects also extending well beyond the tropics. However, the seasonal variability in fluxes between tropical rainforests and atmosphere is still poorly understood. In particular, dynamic global vegetation models (DGVMs) typically simulate a decrease in productivity with a decline in precipitation and soil water availability, while observations in light-limited rainforests, including those in French Guiana, point to a dry-season increase in gross primary productivity. Better understanding the processes underlying flux seasonality in tropical forests is thus critical to improve our predictive ability on global biogeochemical cycles. Leaf area, one key variable controlling water efflux and carbon influx, is poorly characterized. In fact, estimating leaf area index and monitoring its change over time at a meaningful spatial scale is a daunting challenge in dense hyper-diverse aseasonal tropical forest. Airborne lidar has been flagged as a promising way of addressing this challenge (Vincent et al., 2017).

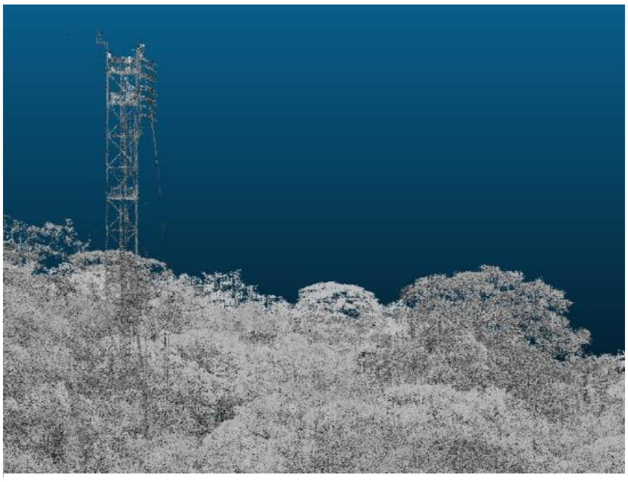

Figure 1 : Flux tower above the forest canopy (UAV laser scanning, Paracou 2019)

The problem

Two separate issues however need to be addressed in order to improve lidar-based estimates of leaf area in forest canopies: how to deal with vegetation clumping and how to separate leaf from wood interception of laser pulses.

Clumping – Vegetation clumping occurs at multiple scales (crown, branch, twig,…). This inhomogeneous distribution of scatterers contradicts the turbid medium assumption required to derive vegetation density from light extinction (Beer-Lambert law). This is partly taken care of by voxelizing the scene (typically with 1 m3 voxels) and solving the equation per voxel. However some level of clumping at the infra-voxel scale remains. Voxel size cannot be reduced *ad libitum* due in particular to sampling issues (related to lidar pulse density and penetration). The proposed work-around is to voxelize at fine resolution, cluster voxels which are similar in terms of likely transmittance value, and then estimate the vegetation density per voxel cluster. To this end, Bayesian clustering and spatial dependency modelling combined into hidden Markov random fields (Lü et al., 2020) seems appealing. Including spatial dependency should allow poorly sampled voxels to benefit from information available in their neighbourhood.

Leaf-wood segmentation – Separating the contribution to the observed absorbance of the leaves and the wood is required since the geometric characteristics of both types of scatterers differ in many respects (size, shape, orientation). It is therefore expected that their specific extinction coefficient (per unit area per volume m2/m3) will also differ.

Leaf vs wood separation may rely on geometric information extracted from the point cloud (Morel et al., 2020; Wang et al., 2018) but can also make use of radiometric information such as individual returns intensity (Wu et al., 2020). Recent algorithms often harness the power of Convolutional Neural Networks but have so far been applied mostly to point clouds (fig. 2) derived from terrestrial lidar scanning, which are an order of magnitude denser. It remains to be seen if existing approaches can be successfully applied to UAV Laser Scanner point clouds.

Figure 2 Automatic leaf wood segmentation based on a CNN classifier (WU 2020) applied to terrestrial laser scanning of a tropical forest stand

Expected outputs

Accurate times series maps of Leaf Area Index from airborne lidar scanning will be used to re-analyse co-located gas exchange measurements between forest and atmosphere.

Working environment :

You will be based in Montpellier AMAP lab (amap.cirad.fr). Short stays in Grenoble are foreseen (lab of co-supervisor). This program will be conducted as part of the PhenOBS project funded by the labex CEBA. It brings together a multidisciplinary and international team that combines different approaches (remote sensing, modelling, ecophysiology, citizen science, plant architecture) to document the phenological diversity in tropical forests within a collaborative project.

Lead supervisor: Dr. G. Vincent (Tropical ecologist and modeller, expertise in lidar applied to vegetation) gregoire.vicent@ird.fr
Co-supervisor Dr. JB Durand (Statistician) Jean-Baptiste.Durand@univ-grenoble-alpes.fr

Tentative PhD comity: Florence Forbes (Bayesian expert), Mélaine Aubry-Kientz (ecological modelling), François Pimont (lidar expert), Tiangang Yin (physical modelling), Philippe Verley (computer scientist), Alexis Joly (CNN expert)

The candidate

Highly motivated student holding an MSc degree in statistics, applied statistics, data analysis, or modelling.
Genuine interest in ecology and environmental sciences
Good level of written and spoken English or French
Occasional sojourn in forest (helping with data collection campaigns) to be considered

Lü, H., Arbel, J., Forbes, F., 2020. Bayesian nonparametric priors for hidden Markov random fields. Stat Comput 30, 1015–1035. https://doi.org/10.1007/s11222-020-09935-9

Morel, J., Bac, A., Kanai, T., 2020. Segmentation of unbalanced and in-homogeneous point clouds and its application to 3D scanned trees. Vis Comput 36, 2419–2431. https://doi.org/10.1007/s00371-020-01966-7

Vincent, G., Antin, C., Laurans, M., Heurtebize, J., Grau, E., Durrieu, S., Dauzat, J., 2017. Mapping plant area index of tropical evergreen forest by ALS. A cross-validation study using LAI2200 optical sensor. Remote Sens. Environ.

Wang, D., Brunner, J., Ma, Z., Lu, H., Hollaus, M., Pang, Y., Pfeifer, N., Wang, D., Brunner, J., Ma, Z., Lu, H., Hollaus, M., Pang, Y., Pfeifer, N., 2018. Separating Tree Photosynthetic and Non-Photosynthetic Components from Point Cloud Data Using Dynamic Segment Merging. Forests 9, 252. https://doi.org/10.3390/f9050252

Wu, B., Zheng, G., Chen, Y., 2020. An Improved Convolution Neural Network-Based Model for Classifying Foliage and Woody Components from Terrestrial Laser Scanning Data. Remote Sensing 12, 1010. https://doi.org/10.3390/rs12061010