Super-Resolved Canopy Map Estimation from Multisource Satellite Time Series

Laboratory: IMAGINE/LIGM, ENPC & LSCE (CEA–CNRS–UVSQ)

Location: Marne-la-Vallée, Champs-sur-Marne / Gif-sur-Yvette

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Remuneration: 1500 euros gross

Starting Date: 1st semester of 2026, 5 or 6 months duration

Keywords: Forest Monitoring, Canopy Height Models, Super-Resolution, Earth Observation, Climate Change

Development Environment: Linux, Python, PyTorch.

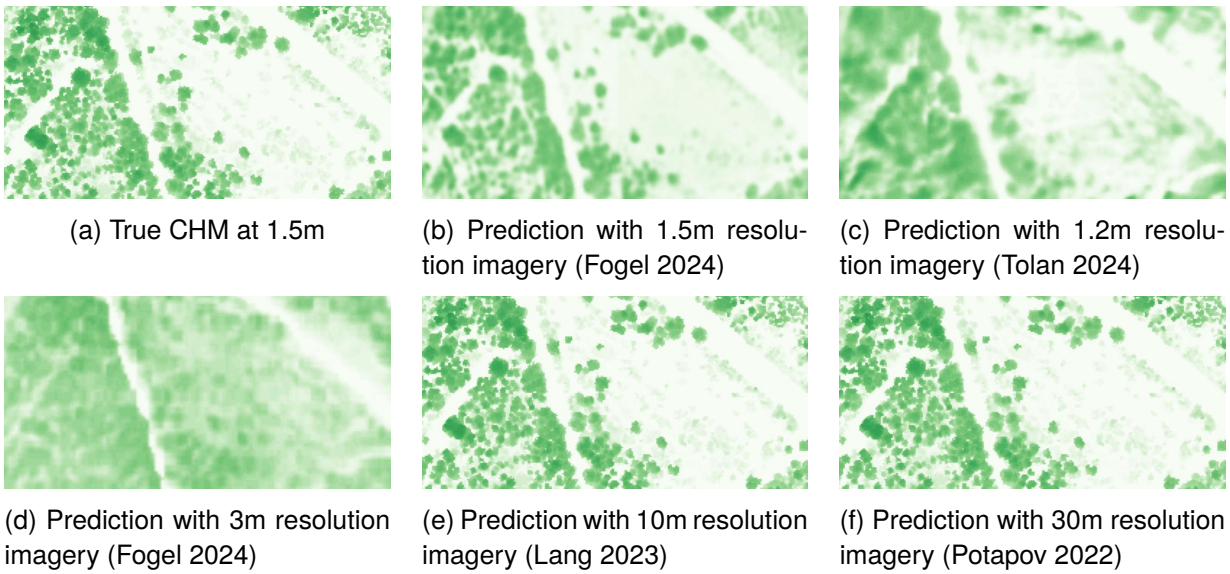
Context: Forest Monitoring and Canopy Height Mapping

Monitoring forest structure is a critical component of climate science, with direct implications for understanding the carbon cycle, biodiversity, and the long-term impact of climate change and deforestation. Among forest structural variables, the *Canopy Height Model* (CHM) plays a central role, as it is strongly correlated with above-ground biomass and carbon stocks [2].

Airborne Laser Scanning (ALS) provides accurate and high-resolution canopy height measurements, and recent initiatives such as OpenCanopy [1] have enabled the creation of large-scale reference CHM datasets. However, ALS acquisitions remain spatially sparse, temporally limited, and costly, which severely constrains their use for long-term and global forest monitoring.

At the same time, optical satellite imagery offers long-term, global, and systematic observations. Very-High-Resolution (VHR) imagery can be used to predict CHMs with good accuracy, but such data are not globally available and lack temporal coverage. In contrast, High-Resolution (HR, e.g. Sentinel-2 at 10 m) and Medium-Resolution (MR, e.g. Landsat at 30 m) imagery provide decades of global coverage, but at resolutions seemingly incompatible with fine-scale canopy structure estimation.

Can canopy height maps be predicted at a resolution finer than the native resolution of satellite imagery? Can long satellite time series compensate for spatial coarseness?



(a) True CHM at 1.5m

(b) Prediction with 1.5m resolution imagery (Fogel 2024)

(c) Prediction with 1.2m resolution imagery (Tolan 2024)

(d) Prediction with 3m resolution imagery (Fogel 2024)

(e) Prediction with 10m resolution imagery (Lang 2023)

(f) Prediction with 30m resolution imagery (Potapov 2022)

Figure 1: **Impact of Spatial Resolution on CHM Prediction.** When relying on a single acquisition, the quality of canopy height map predictions degrades as the spatial resolution becomes coarser. In this internship, we propose to leverage the temporal dimension of coarse-resolution satellite imagery to mitigate this limitation.

Recent work from our team and others suggests that this limitation can be overcome. By exploiting *sub-pixel information embedded in temporal dynamics*, it is possible to predict canopy height maps at a higher spatial resolution than the input imagery itself [3]. If confirmed and extended to long-term archives such as Landsat, this approach would unlock the possibility of producing consistent canopy height maps over **more than 40 years**, enabling unprecedented analyses of forest dynamics and climate-driven change.

Objective

The goal of this internship is to investigate and validate super-resolved canopy height estimation from multisource satellite time series. The work will be conducted jointly between ENPC and LSCE, combining expertise in deep learning, Earth observation, and climate-oriented forest analysis.

The main research objectives are:

- **Augmenting canopy height datasets with multisensor satellite imagery.** Enrich existing ALS-derived CHM datasets (e.g. OpenCanopy) with co-registered Sentinel-2 and Landsat 7/8 time series.
- **Designing deep learning models for super-resolved CHM prediction.** Develop architectures capable of predicting high-resolution canopy height maps from HR and MR imagery by leveraging temporal redundancy and sub-pixel cues.
- **Comparing direct super-resolved prediction with two-stage approaches.** Quantitatively compare end-to-end super-resolved CHM prediction against pipelines that first perform image super-resolution followed by canopy height estimation.
- **Analyzing performance degradation with coarser inputs.** Evaluate to what extent precision is lost when moving from Sentinel-2 to Landsat imagery, and identify regimes where long time series compensate for reduced spatial resolution.

- **Scaling in time and space.** Assess the feasibility of extending the approach to multi-decadal time spans (up to 40 years) and to large-scale or global forest monitoring.

Beyond methodological contributions, this internship aims to provide concrete insights into the limits and opportunities of satellite-based forest monitoring in a climate-change context. **A successful internship may lead to the opportunity to start a PhD on Massively Multimodal Monitoring.**

Requested Profile

- Student in Master 2 in computer science, applied mathematics, remote sensing, or related fields;
- **Strong background in deep learning**;
- Solid experience with Python and PyTorch;
- Ability to design, run, and analyze large-scale experiments;
- Scientific curiosity, rigor, and critical thinking;
- (Optional) Experience with Earth observation data (Sentinel, Landsat, LiDAR);
- (Optional) Background or interest in forestry, ecology, or climate science;
- (Optional) Experience with large-scale training or GPU clusters.

Contact

Send a CV, a link to the project you are most proud of (PDF of a report and, if possible, a link to a Github), your latest grade reports, and a short statement of purpose ($\sim$10 lines) explaining your interest for this internship to the following address: `loic.landrieu@enpc.fr`.

References

[1] Fajwel Fogel, Yohann Perron, Nikola Besic, Laurent Saint-André, Agnès Pellissier-Tanon, Martin Schwartz, Thomas Boudras, Ibrahim Fayad, Alexandre d'Aspremont, Loic Landrieu, et al. Open-canopy: Towards very high resolution forest monitoring. In *CVPR*, 2025.

[2] Sassan S. Saatchi, Nancy L. Harris, Sandra Brown, Michael Lefsky, Edward T. A. Mitchard, William Salas, Brian R. Zutta, Wolfgang Buermann, Simon L. Lewis, Stephen Hagen, et al. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the National Academy of Sciences*, 2011.

[3] Riisøen Sander Jyhne, Christian Igel, Morten Goodwin, Per-Arne Andersen, Serge Belongie, and Nico Lang. SuperF: Neural implicit fields for multi-image super-resolution. *https://sjyhne.github.io/superf/SuperF.pdf*, 2025.