

Estimation de la hauteur de canopée à partir d'images satellites et de lidar par intelligence artificielle.

Martin Schwartz, Fajwel Fogel



LSCE

1/4 of French forests



Office National des Forêts

Valérie Metrich-Hecquet
Director of the ONF



CO₂ Absorption

~ 25 % of fossil fuel emissions



Wood production

+ 20 % harvest
- 10 % growth



Bark beetle attacks



Fires, Storms

+ 54 % Mortality

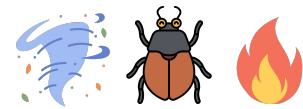
How to monitor French forests ?



Laifour, Ardennes



Forest resources ?

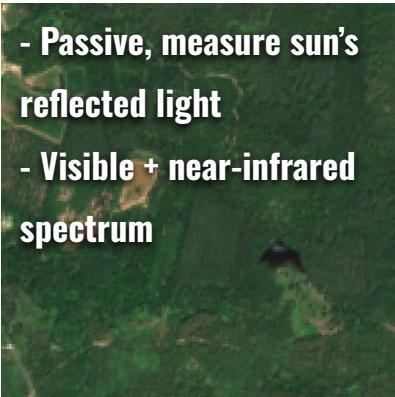


Damages ?

Remote sensing (RS) imagery

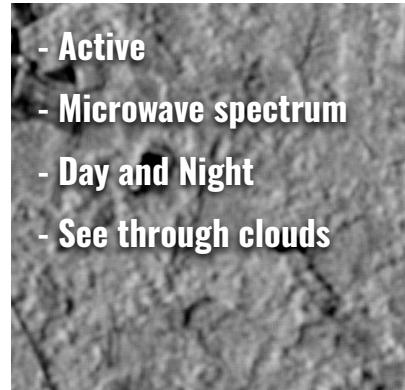


Optical sensors



Sentinel-2

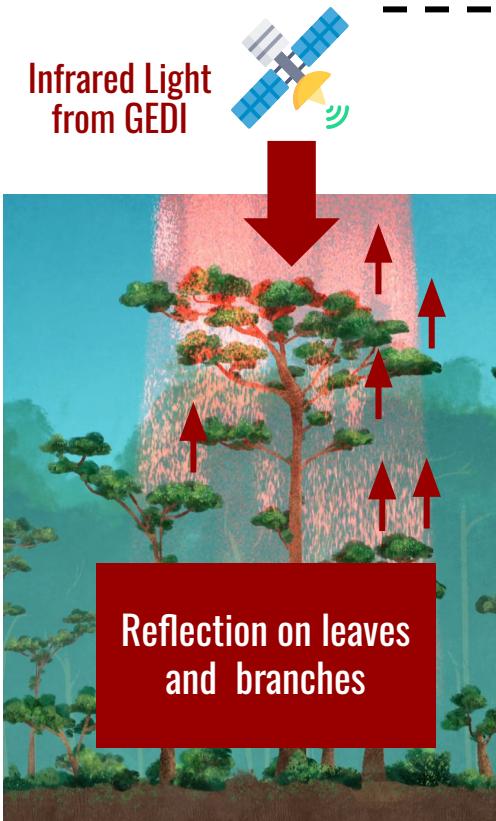
SAR (Synthetic Aperture Radars)



Sentinel-1



Global Ecosystem Dynamics Investigation



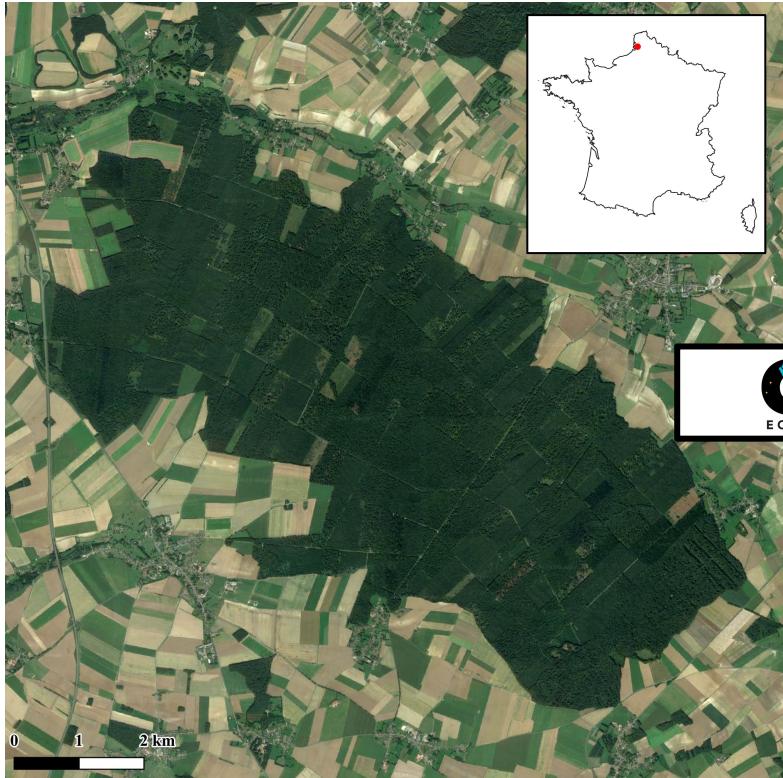
Waveform that gives information on forest vertical structure



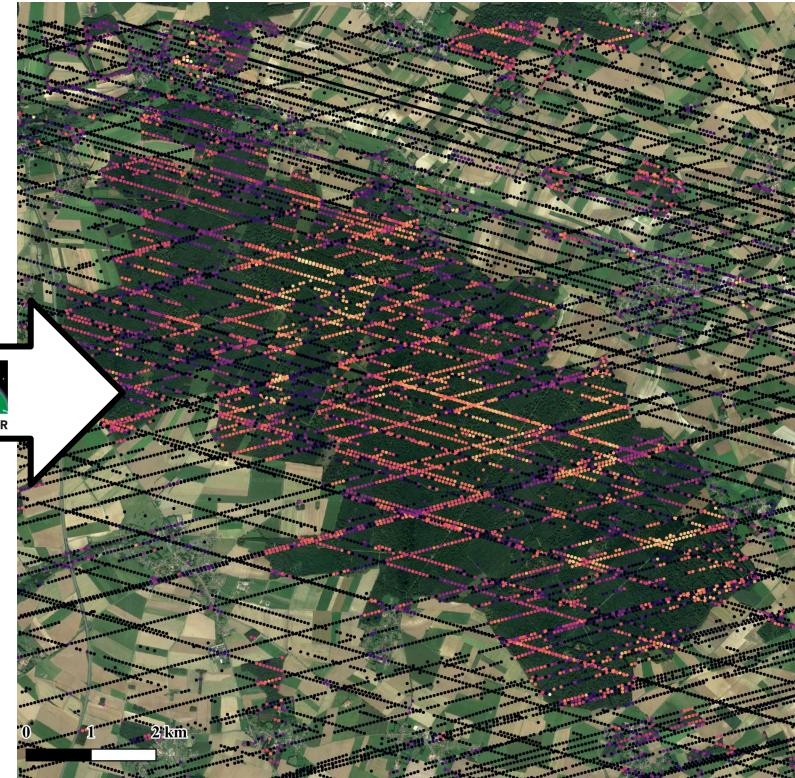


Global Ecosystem Dynamics Investigation

Crecy Forest, Somme, © Google Maps

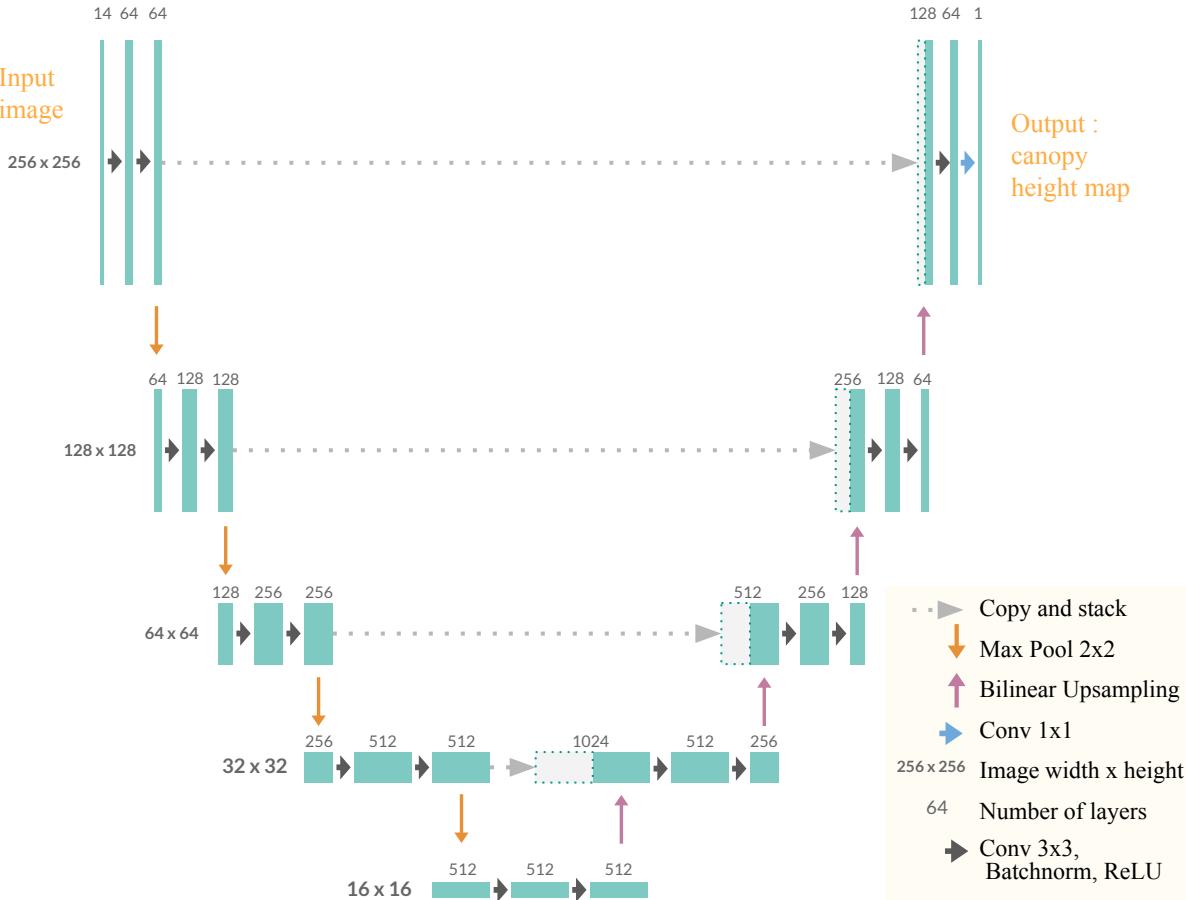


GEDI height measurements



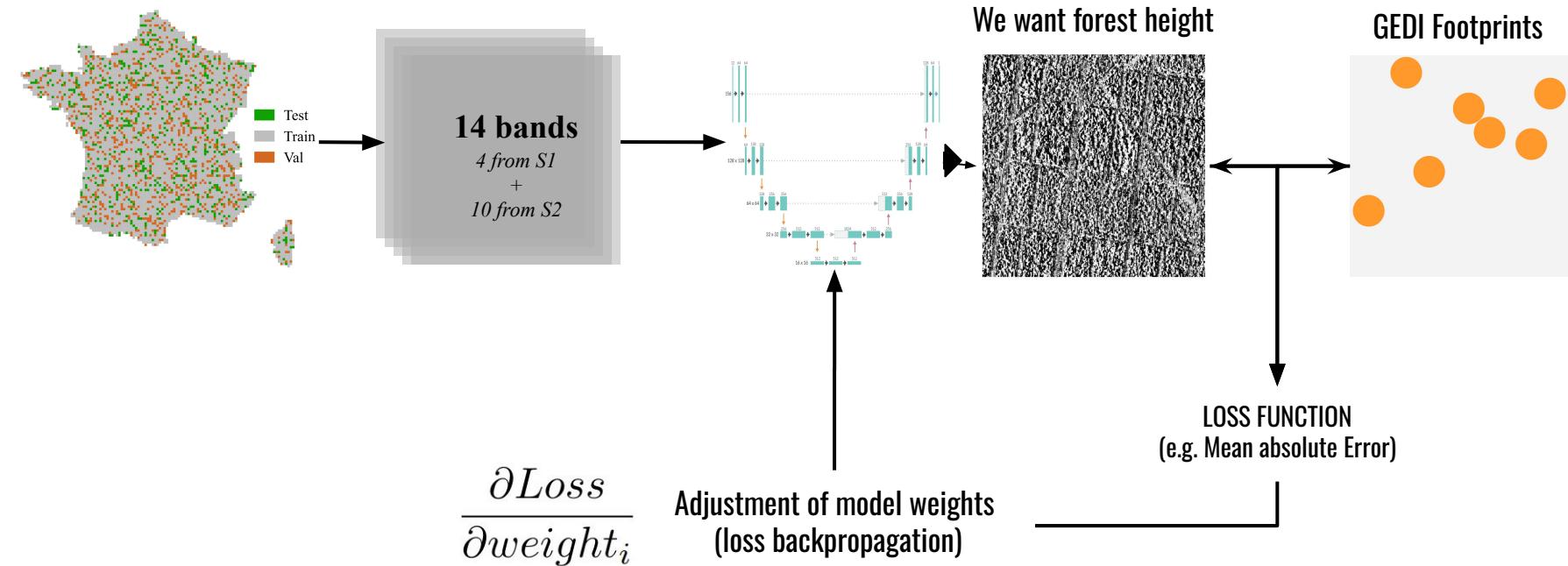
U-NET

- Designed in 2015 for medical image segmentation
- Outperforms classical ML algorithms
- Learn from multi-scale image texture and context
- ~ 17 Million of weights



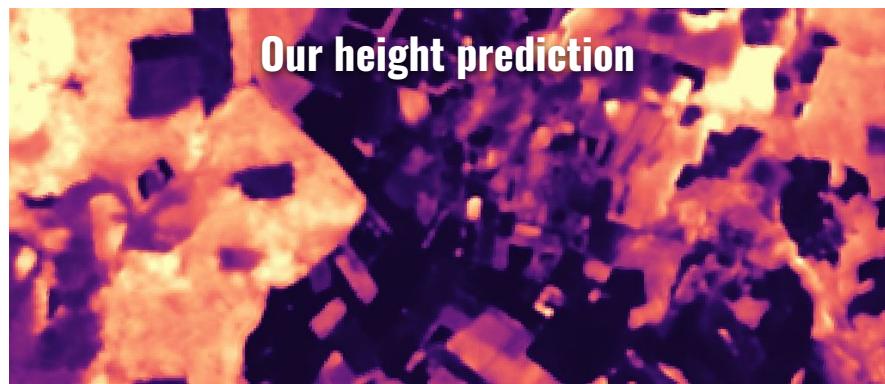
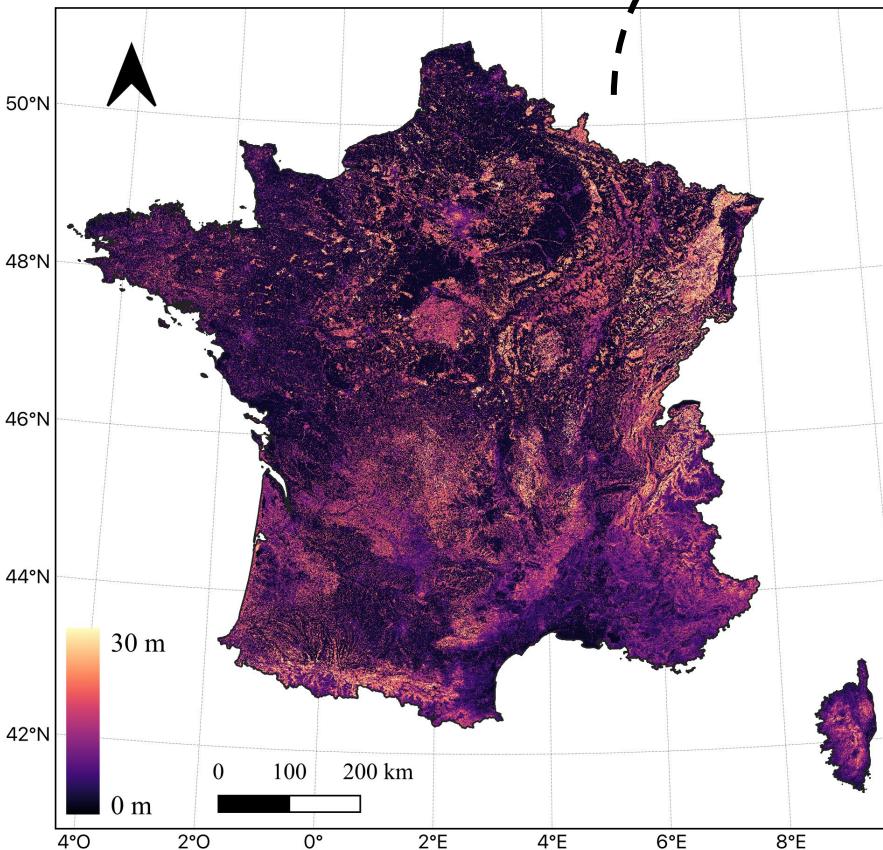
Methods: Training process

Repeat $\sim 10^5$ times to minimize the loss



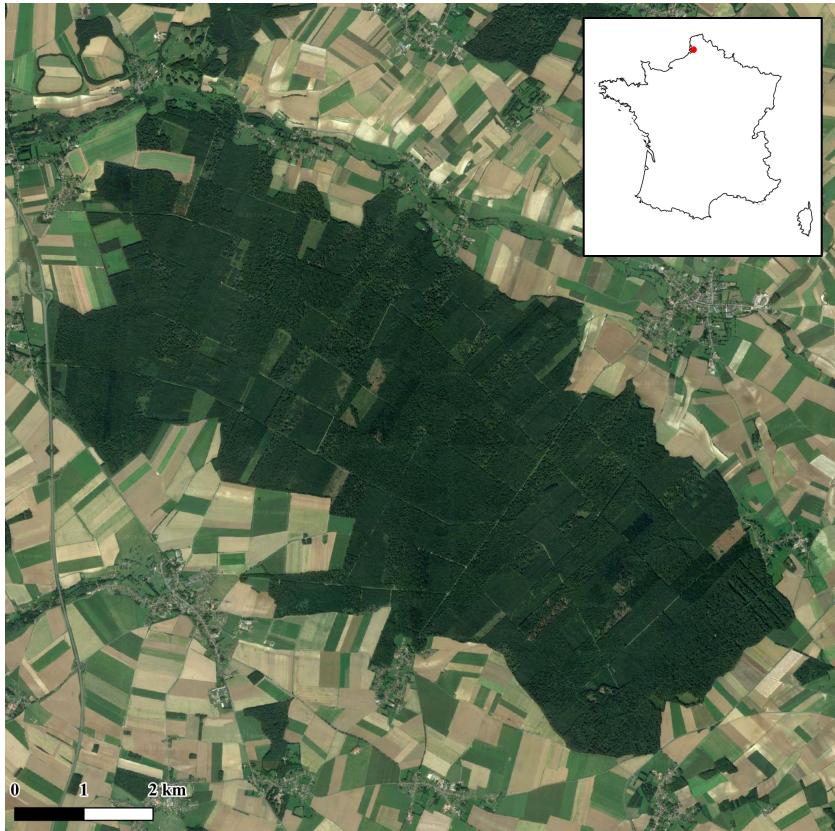
Canopy height map

FORMS-H: FORest Multiple Satellite - Height

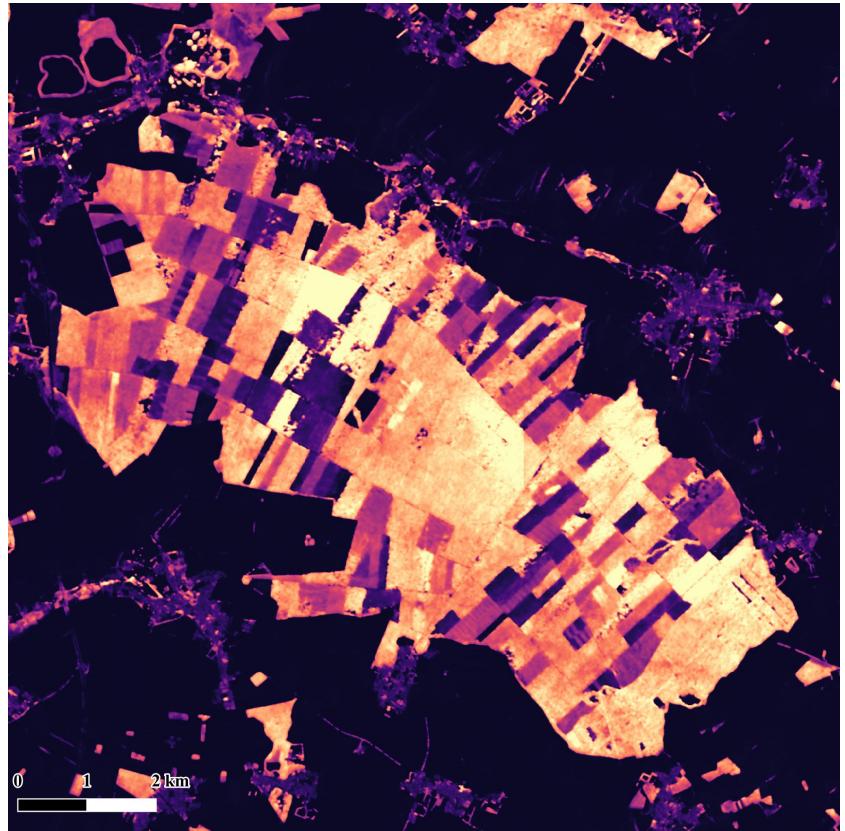


FORMS-H: Canopy height map

Google Maps, Forêt de Crécy (France)

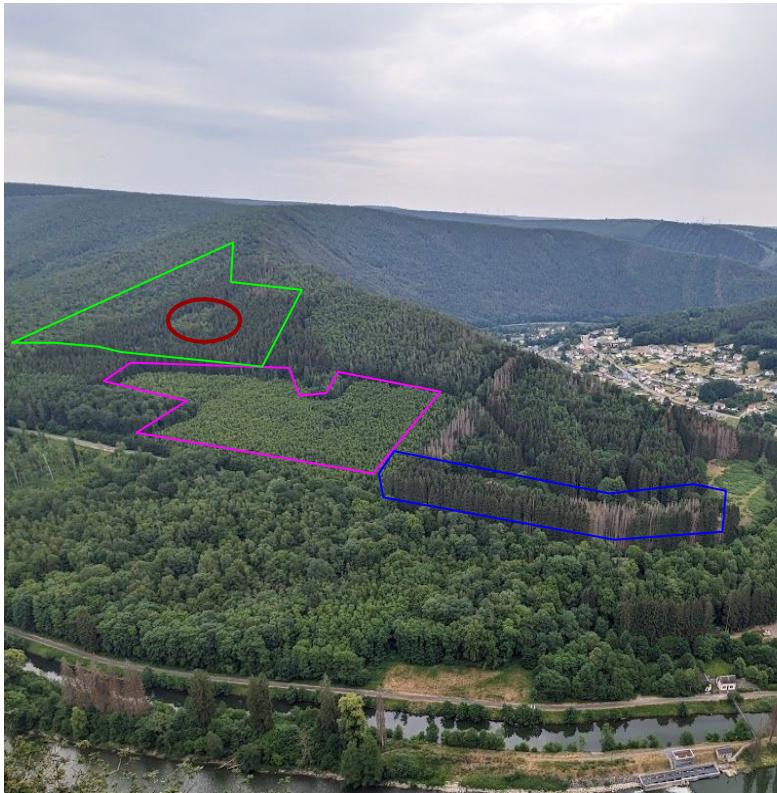


GEPI
FORMS-H (our model)
ECOSYSTEM LIDAR

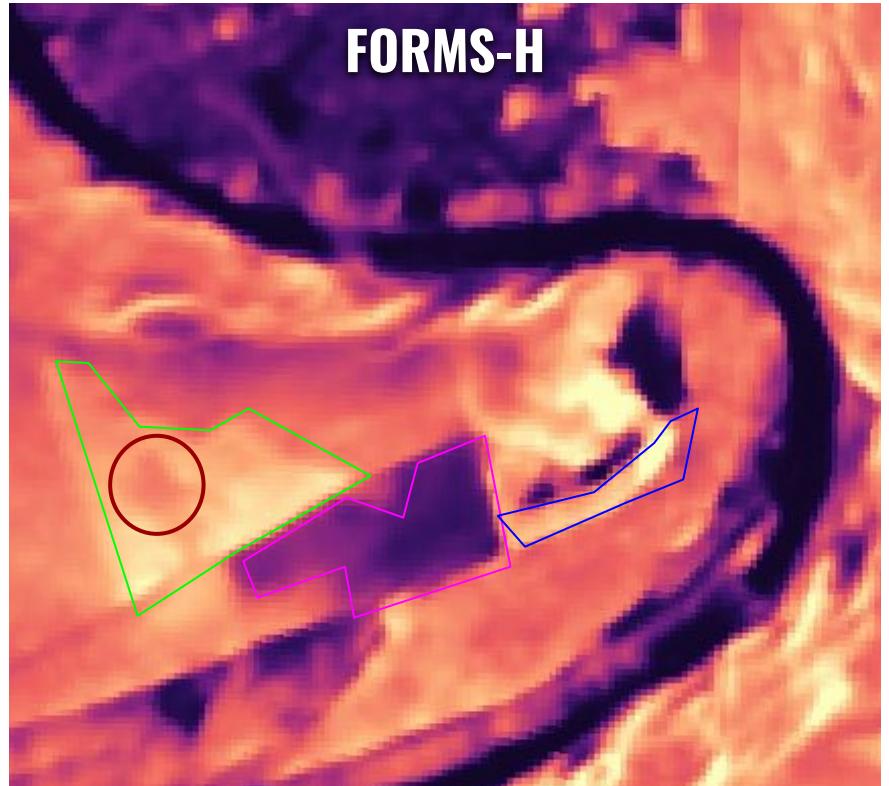


— FORMS-H: Canopy height map

How to validate ?



Laifour, Ardennes

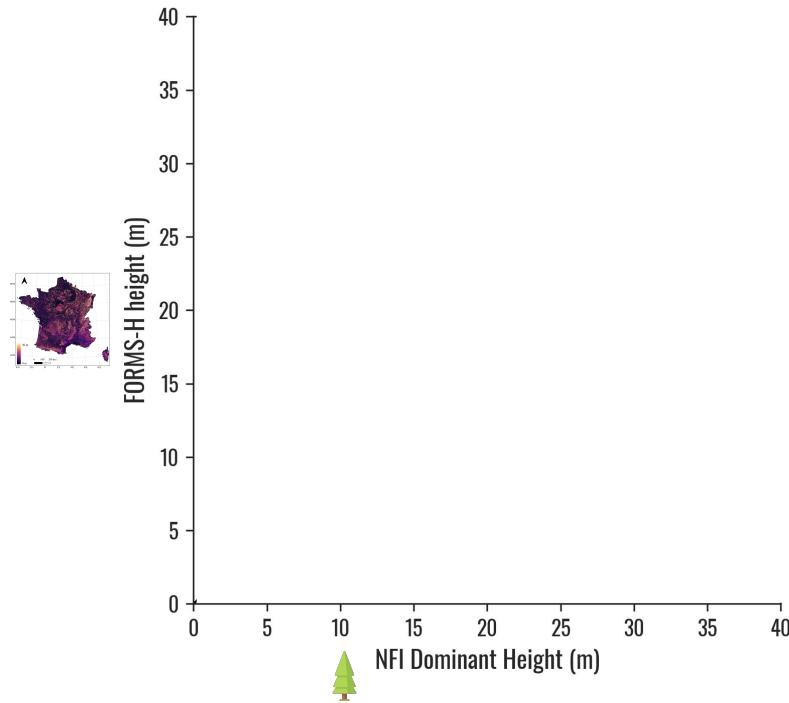


Validation with independent data



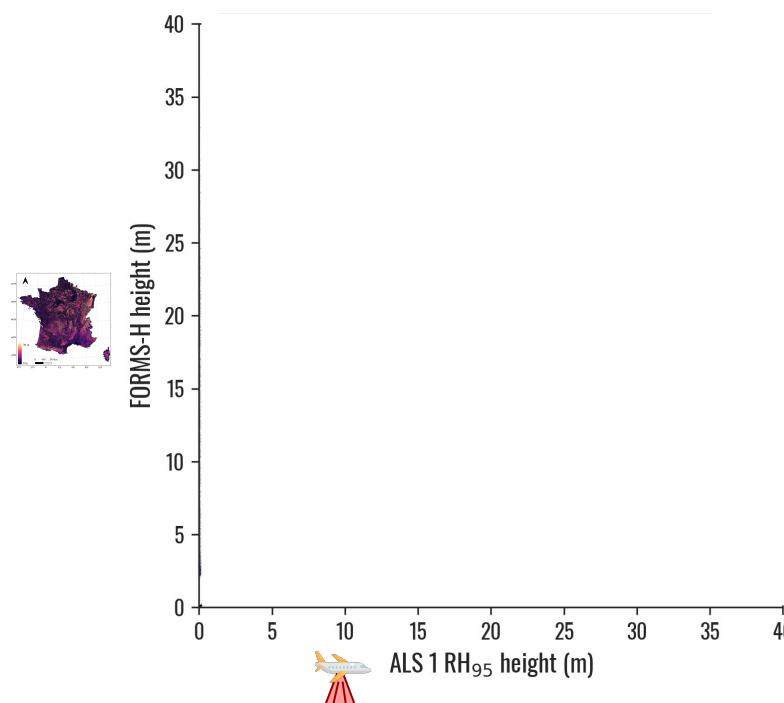
Comparison to Forest Plot data (5 475 plots)

French National Forest Inventory 2020, IGN

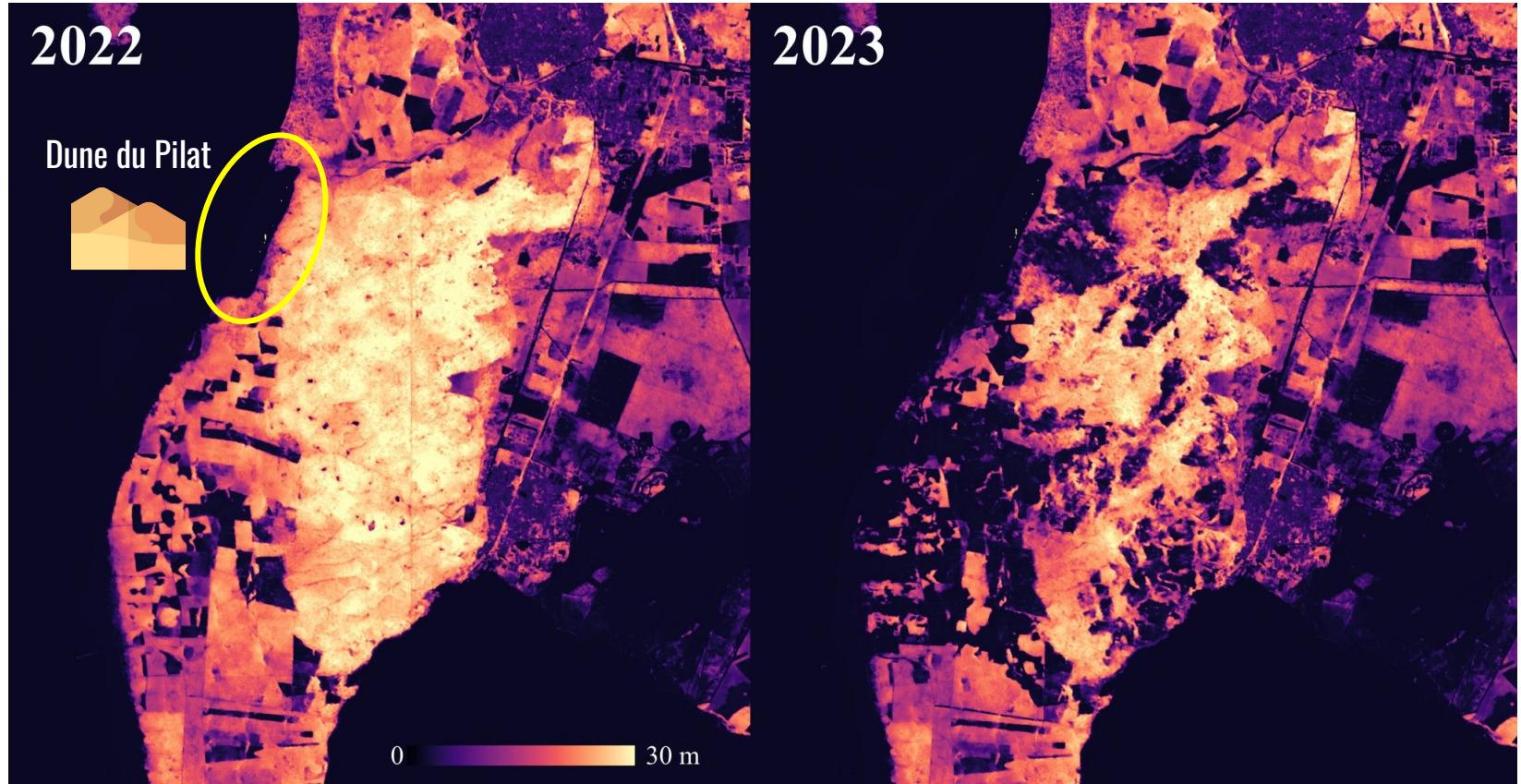


Comparison to Airborne Lidar

LIDAR HD, IGN, 2022



Height change: Application to detect perturbations



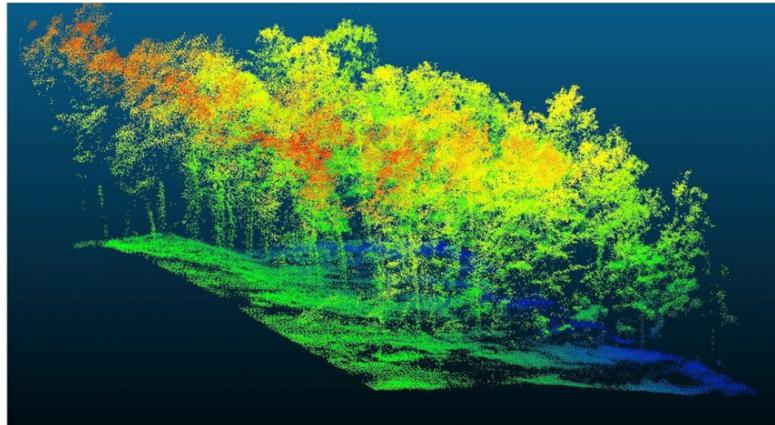
Teste de Buch forest, before and after the 2022 wildfires

Towards higher-resolution (Fajwel Fogel)

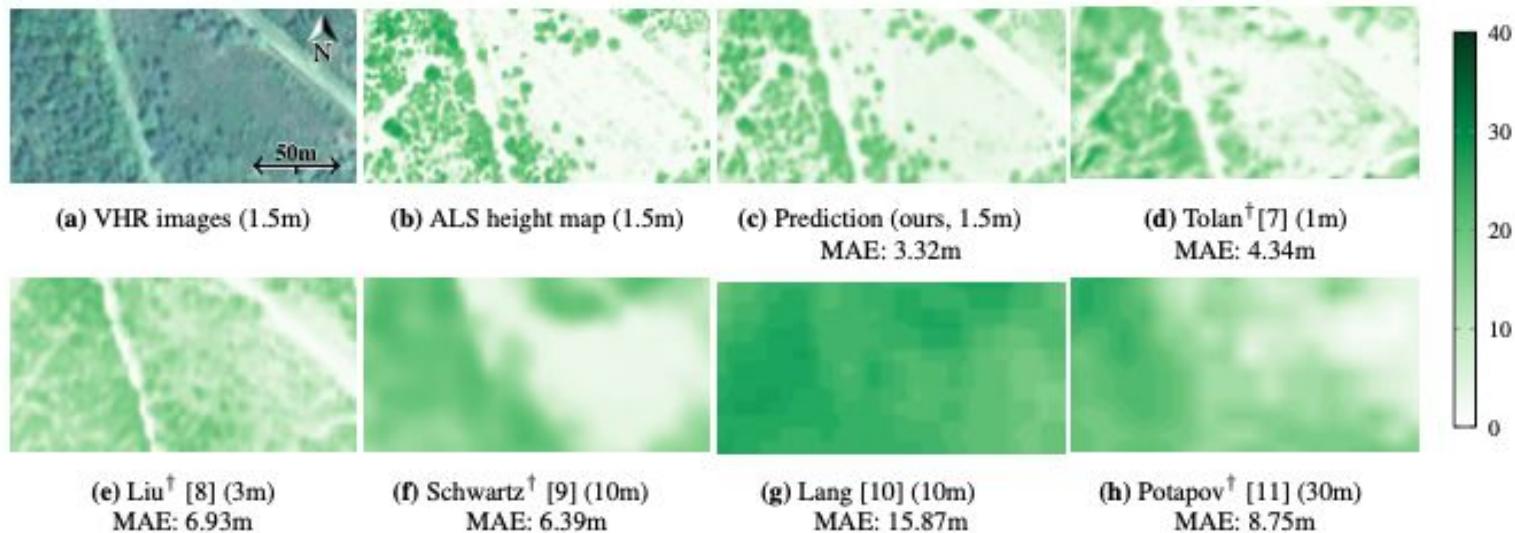
SPOT images (DINAMIS) : 1.5m



ALS data (LiDAR HD IGN)

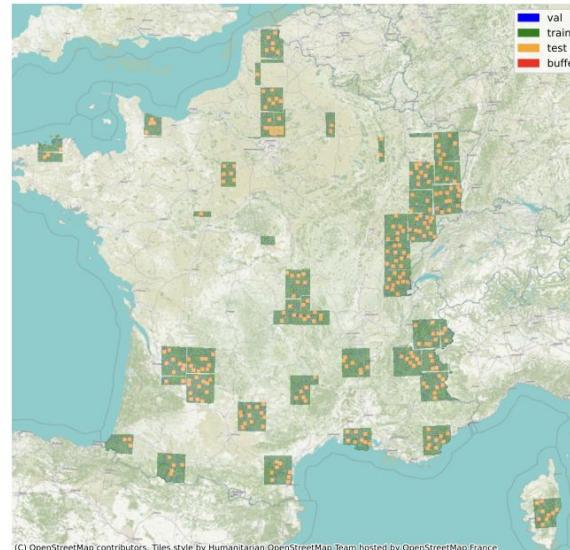


Towards higher-resolution : SPOT images (DINAMIS) + ALS data (LiDAR HD IGN)

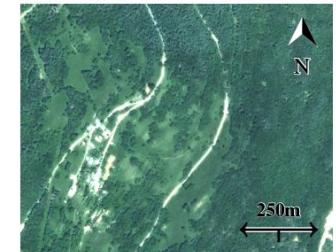


OPEN-CANOPY:

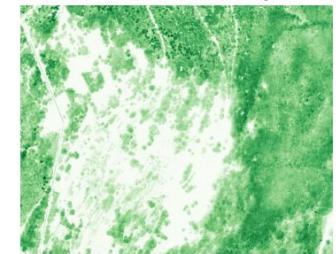
An open access dataset with preprocessed data and fixed train/val/test splits for the ML community



(a) Splits



(b) VHR satellite image



(c) ALS-based height map

Evaluation on
forests + high vegetation



(a) ALS Vegetation Mask



(b) Forest Outline



(c) Combined Mask



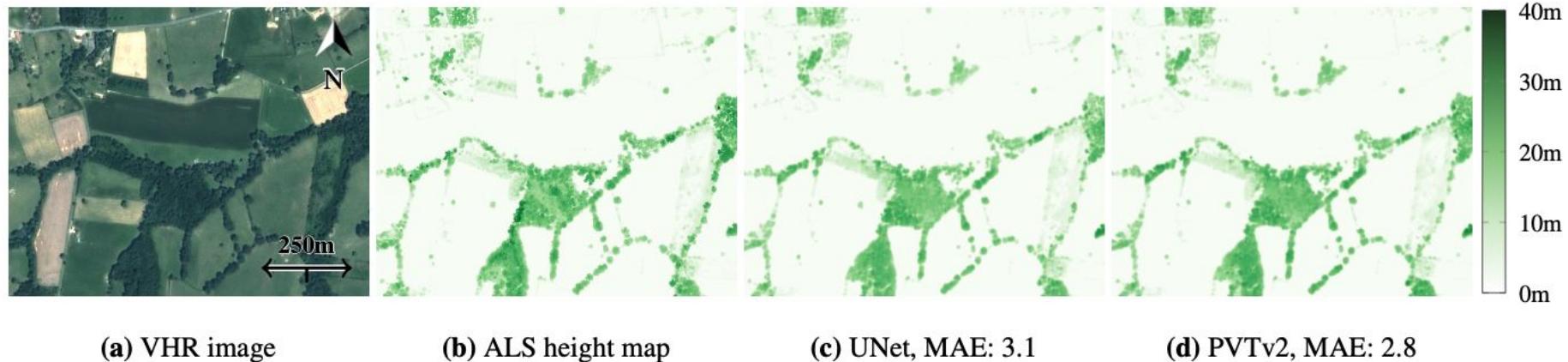
(d) VHR image

Towards higher-resolution : SPOT images + ALS data

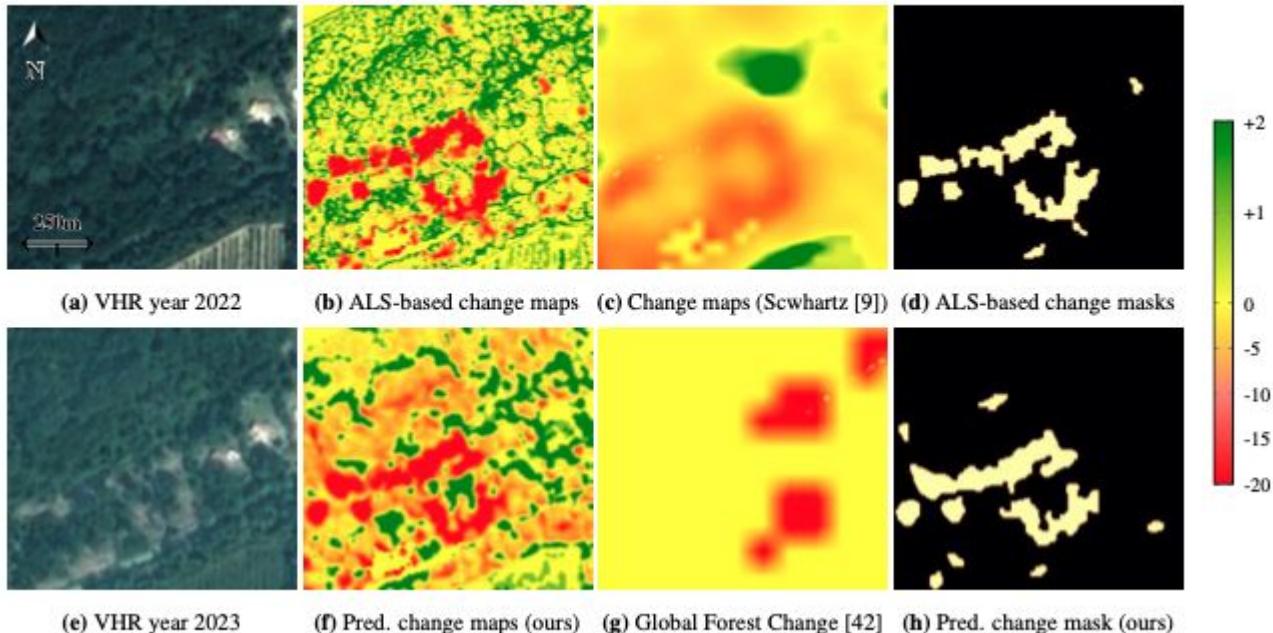
An extensive benchmark of deep learning models

Model	pretraining	MAE in m	nMAE in %	RMSE in m	Bias in m	Tree cov. IoU in %
UNet ⁴ [33]	ImageNet1k [68]	2.67	23.8	4.18	-0.30	90.4
DeepLabv3 ¹ [62]	ImageNet1k [68]	3.18	28.4	4.83	-0.26	88.0
ViT-B ³ [34]	ImageNet21k [62]	4.26	37.8	6.06	-0.84	86.0
HViT ³ [34]	ImageNet21k [62]	2.65	24.0	4.18	-0.13	90.2
PCPVT ³ [41]	ImageNet1k [62]	2.57	23.1	4.06	-0.17	90.4
SWIN ³ [40]	ImageNet21k [62]	2.54	22.8	4.00	-0.11	90.5
PVTv2 ³ [12]	ImageNet1k [62]	2.52	22.9	4.02	0.00	90.5
ScaleMAE ⁵ [65]	FotM [69]	3.45	31.2	5.13	-0.48	88.2
ViT-B ³ [34]	DINOv2[39]	4.84	43.2	6.68	-0.48	84.8
ViT-B ² [34]	CLIP_OPENAI [64]	2.87	25.9	4.43	-0.07	89.7
ViT-L ⁶ [34]	Tolan[7]	4.46	38.9	6.27	-1.03	85.6

Towards higher-resolution : SPOT images + ALS data
Best models are hierarchical ViT and Unet



Towards higher-resolution : SPOT images + ALS data
Height change detection (when it works)
min height change 10m, min area of change 100m²



Towards higher-resolution : SPOT images + ALS data Height change detection: a very challenging task

Table 4: Forest Change Mask Evaluation.

	Precision (%)	Recall (%)	F1 score (%)	IoU (%)
Schwartz [9]	32.7	4.6	8.0	4.2
Global Forest Change [42]	0.6	5.4	1.0	0.5
Open-Canopy (ours)	29.5	48.8	36.8	22.5

Some limitations are due to the data itself
e.g., LiDAR acquisition date not matching exactly SPOT acquisition date

Thank you for your attention

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