BioSpace25 - Biodiversity insight from Space
10 - 14 February 2025 | ESA-ESRIN | Frascati - Italy

An innovative approach for remote sensing methods and sensors benchmarking prior to BCE monitoring at large scale.

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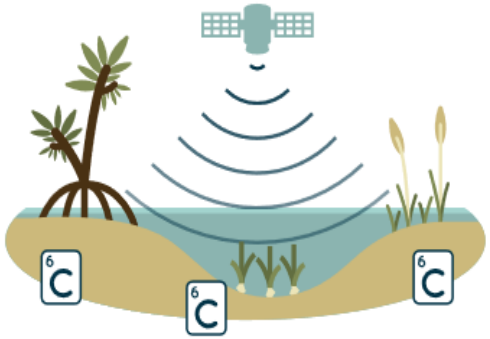
[1]i-Sea, France

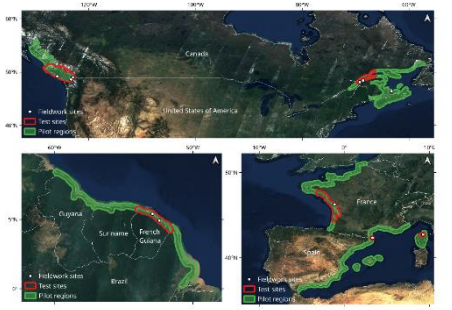
ESA Coastal Blue Carbon

https://esa-coastal-blue-carbon.eu/

- **ESA-CBC : a very challenging remote sensing project !**
- It starts from local knowledge of habitats and carbon ground estimation.
- VHR remote sensing as shown great potential, it is also a resolution that offers a ground expert a direct vision/interpretation of nature as descriptive earth-observation.

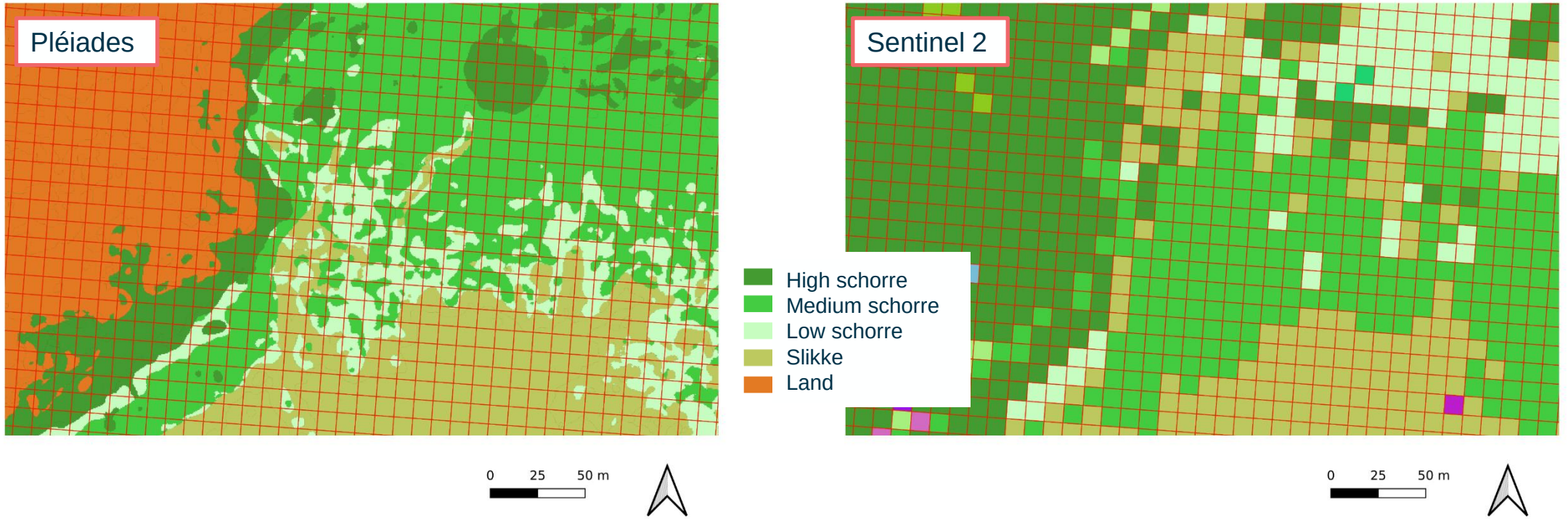
- **We aim to :**
  - 1- Map habitat extends testing the robustness of different precision levels (typologies).
  - 2- Estimate biomass for those habitats (at different precision levels).
  - 3- Derive carbon stock maps, from ground estimated allometric relations.
  - **And all of these should be applied operationally at large scale !**





Main Motivation

HABITAT MAPPING : What happens when using VHR (Pléiades) designed reference data applied to HR (Sentinel-2) images….



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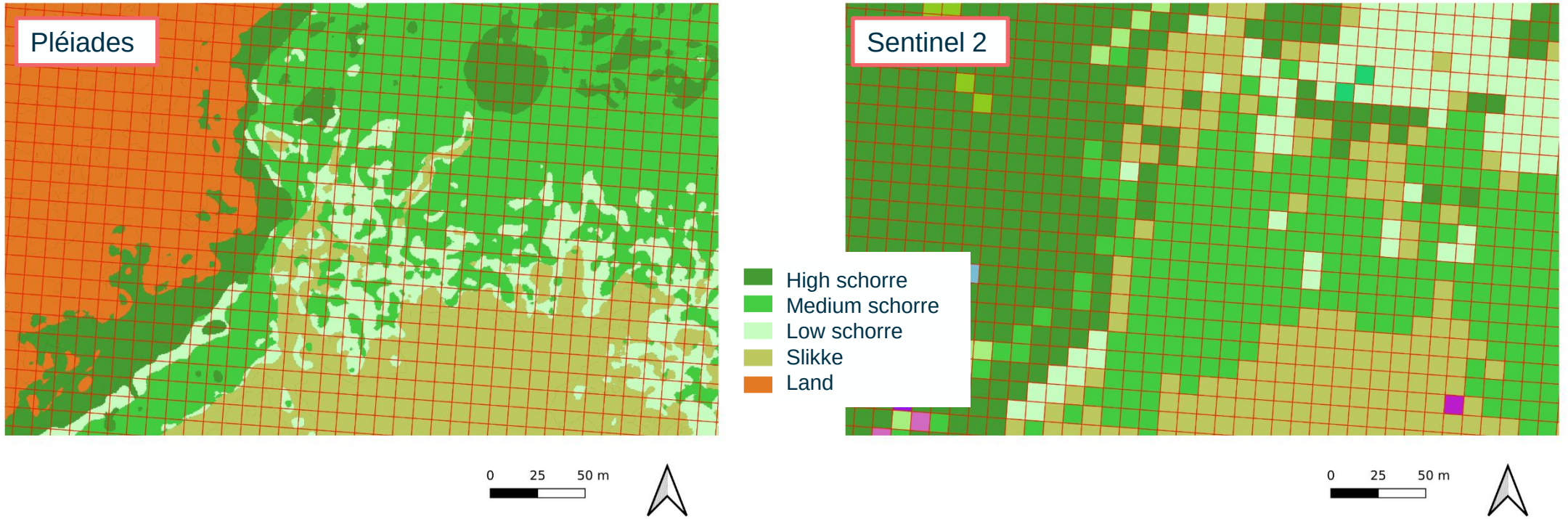


is what we want to avoid !

Main Motivation

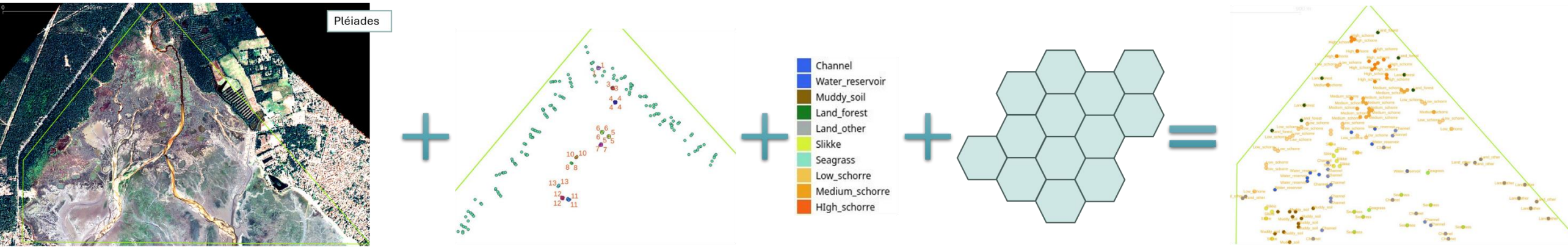
The need of a standardized protocol to harmonize reference data for both Habitat mapping task and Biomass/Carbon modelling task…

- ➔ **Working with various labs with different approaches, different habits, very different "same" habitats, different scales, different levels of precision… (and sometimes different units or metric systems)**
- ➔ **how to integrate field measurements and their spatial ranges for good correspondence with remote sensing data ?**
- ➔ **How to benchmark sensors, features, temporality, machine learning algorithms (for both classification and regression tasks) with consistency ?**

We want to upscale methods… going from VHR and field understanding of the World (locale scale) to large scale… we need to measure and understand the loss of information, control the uncertainties snowball !

A standardized proposition

- A fixed Hat method, based on hexagrid (20m -> ~1000m^2) :
  - Allows harmonization of reference data coming from : ground or photo-interpretation or existing maps.
  - A fixed spatial information integration that will allows to :
    - Compare strictly sensors (Sentinel-2, Planet, Spot, Pléiades…), features, mono VS multi-temporal
    - Work at pixels, objects and patches levels (and so on try/test more advanced ML approaches)
    - Test various machine learning algorithms with a rigorous scheme
    - Measure the information loss between VHR and HR
    - Monitor changes and then understanding the changes drivers



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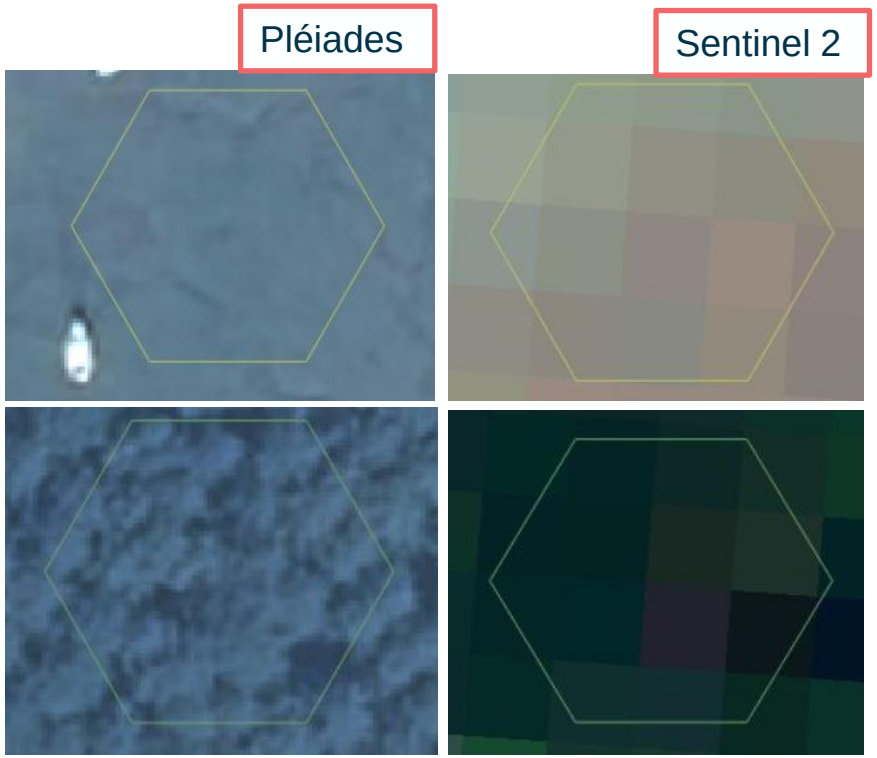

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class_namel_vl2	Text20	class name level2 (automatic from table join)
source_info_lvl2	Text10	"photoint" / "field" / "existing_map"
class-lvl3	uint8	class label to inform/ level3
class_namel_vl3	Text20	class name level3 (automatic from table join)
source_info_lvl3	Text10	"photoint" / "field" / "existing_map"
AGB_mean	Float32	AGB mean measured on the field
AGB_std	Float32	AGB std measured on the field
BGB_mean	Float32	BGB mean measured on the field
BGB_std	Float32	BGB std measured on the field
TotCstock_mean	Float32	TotCstock mean measured on the field
TotCstock_std	Float32	TotCstock std measured on the field
C_source	Text80	comment on ToTCstock origin
Comment	Text200	comment

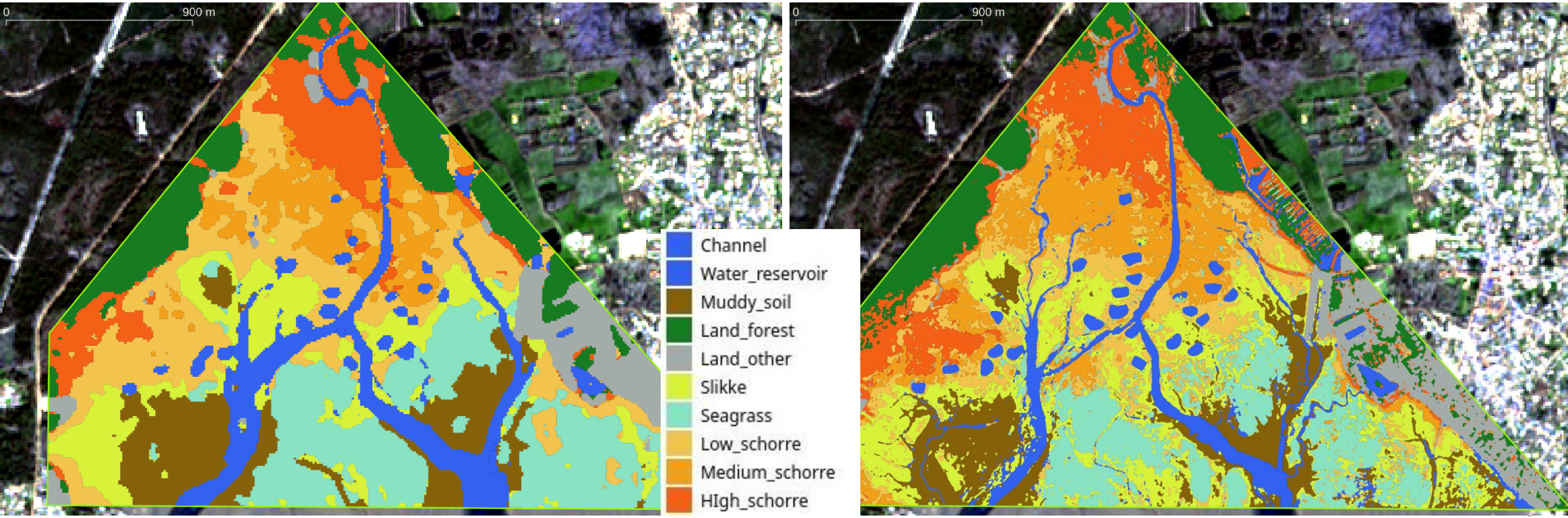
Benchmarking methods

Habitat mapping from Pléiades (50cm) and Sentinel-2 (10m)… very consistent !

Exemple of pixel simplest approach (RF,1image), comparing SegNets, Conv3d, CNNxLSTM Mixture (HR&VHR)…

Sentinel 2

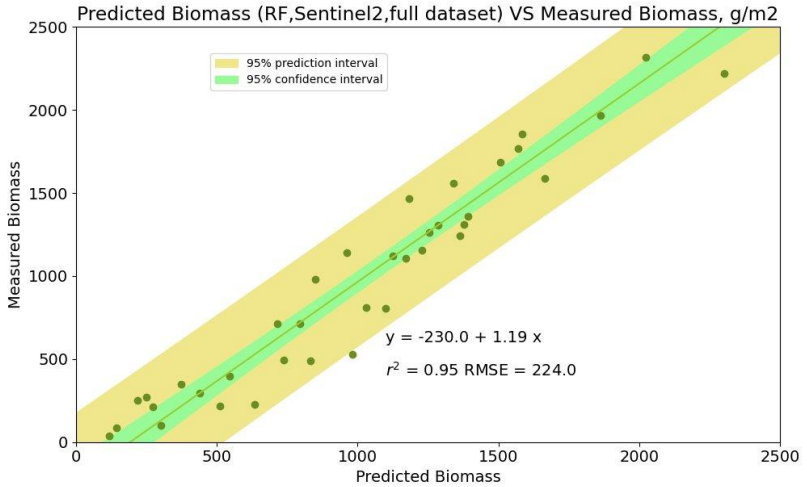
Pléiades



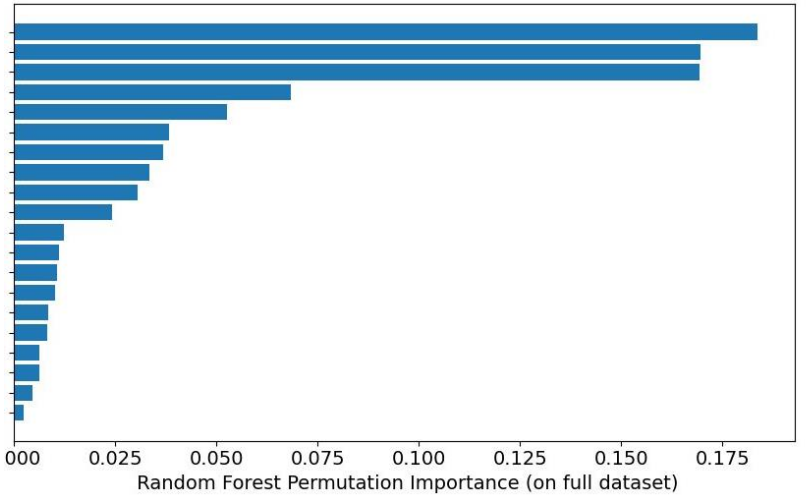
Benchmarking methods

Exemple of a machine learning methods benchmarking for Biomass estimation :

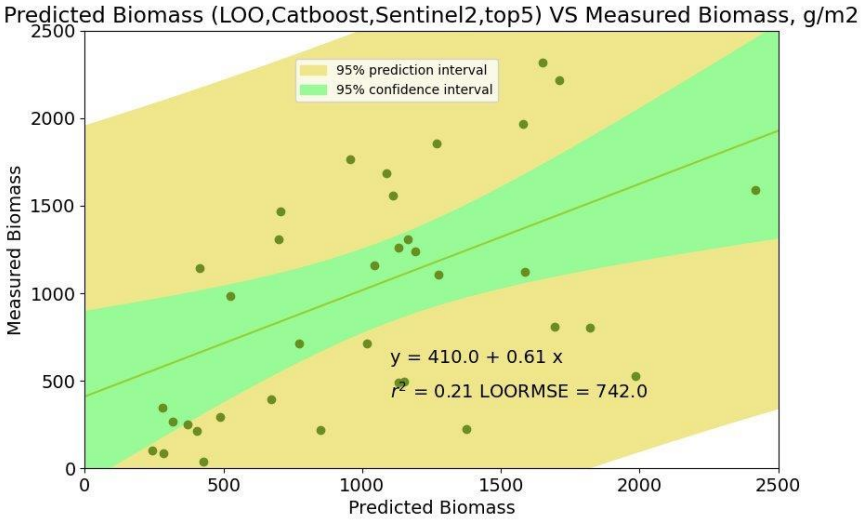
Fitting a Random Forest with all samples and all features :



Working on feature selection, an example of RF permutation importance estimation



- Working on cross validation : LOO (LeaveOneOut), Bootstrap, other..
- Regression methods comparison : RandomForest, XGboost, CatBoost, FNN



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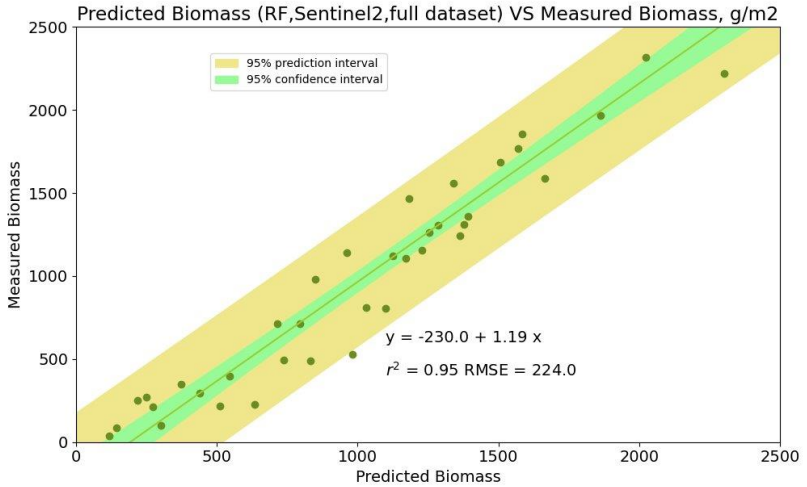

	LOO - RMSE	
Methods	**Sentinel-2**	**Pléiades**
Random Forest	566,72	469,89
XGBoost	604,52	516,62
CatBoost	561,13	465,07
FNN	1067,38	1062,96

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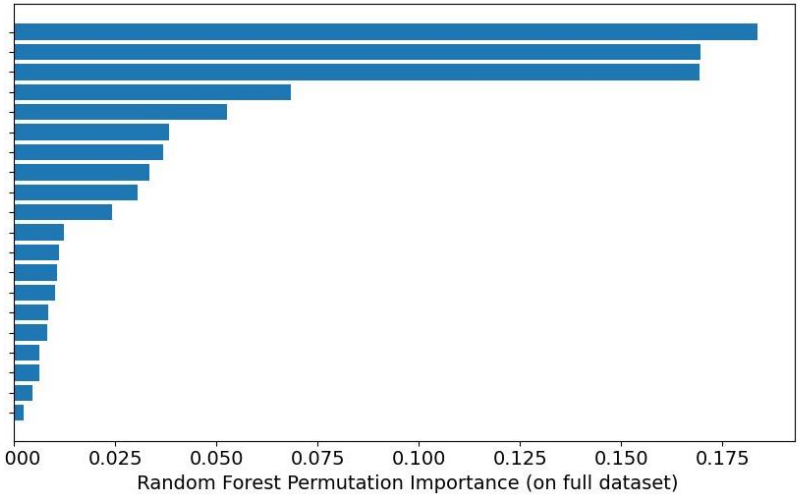

Deep Learning is not always the best solution !

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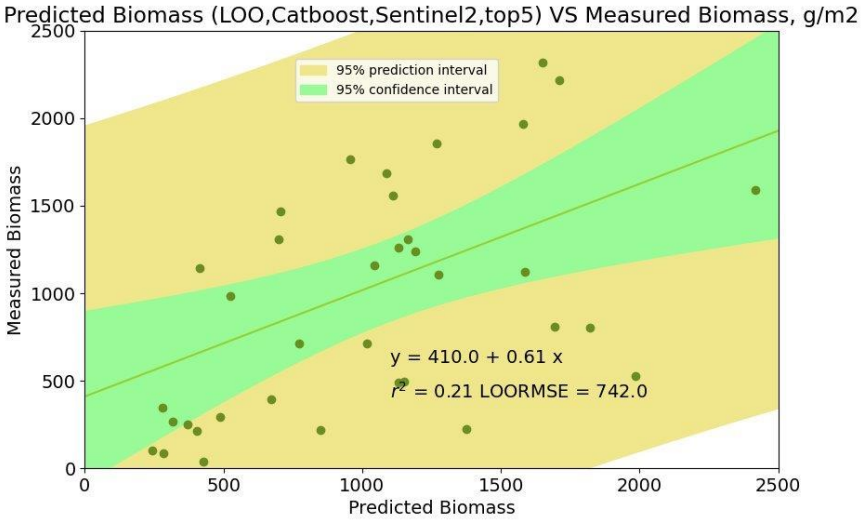
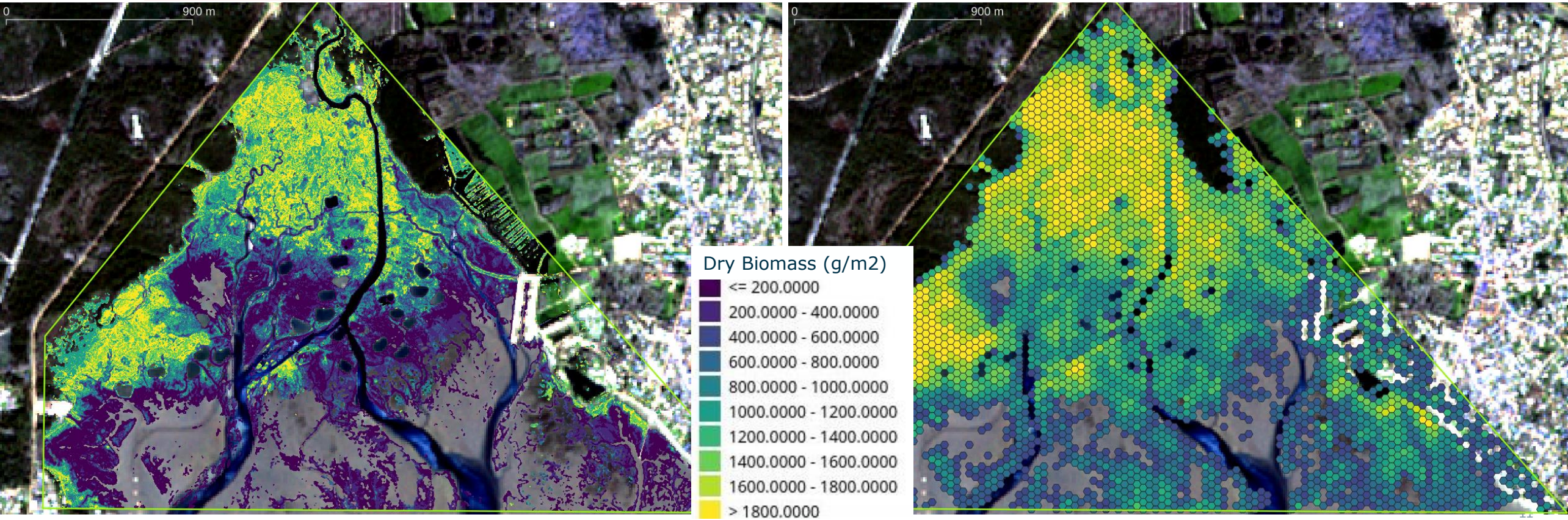


Working around prior to upscaling

Biomass prediction at pixel level and at hexagrid level…

Pléiades Pixel level biomass prediction

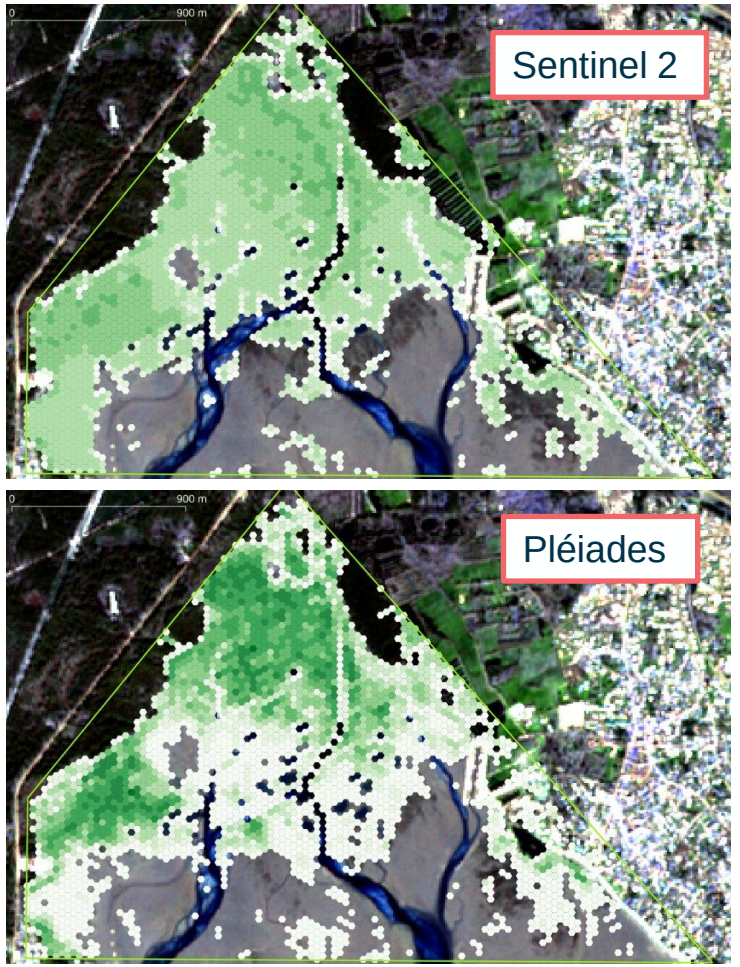
Pléiades hexagrid level biomass prediction

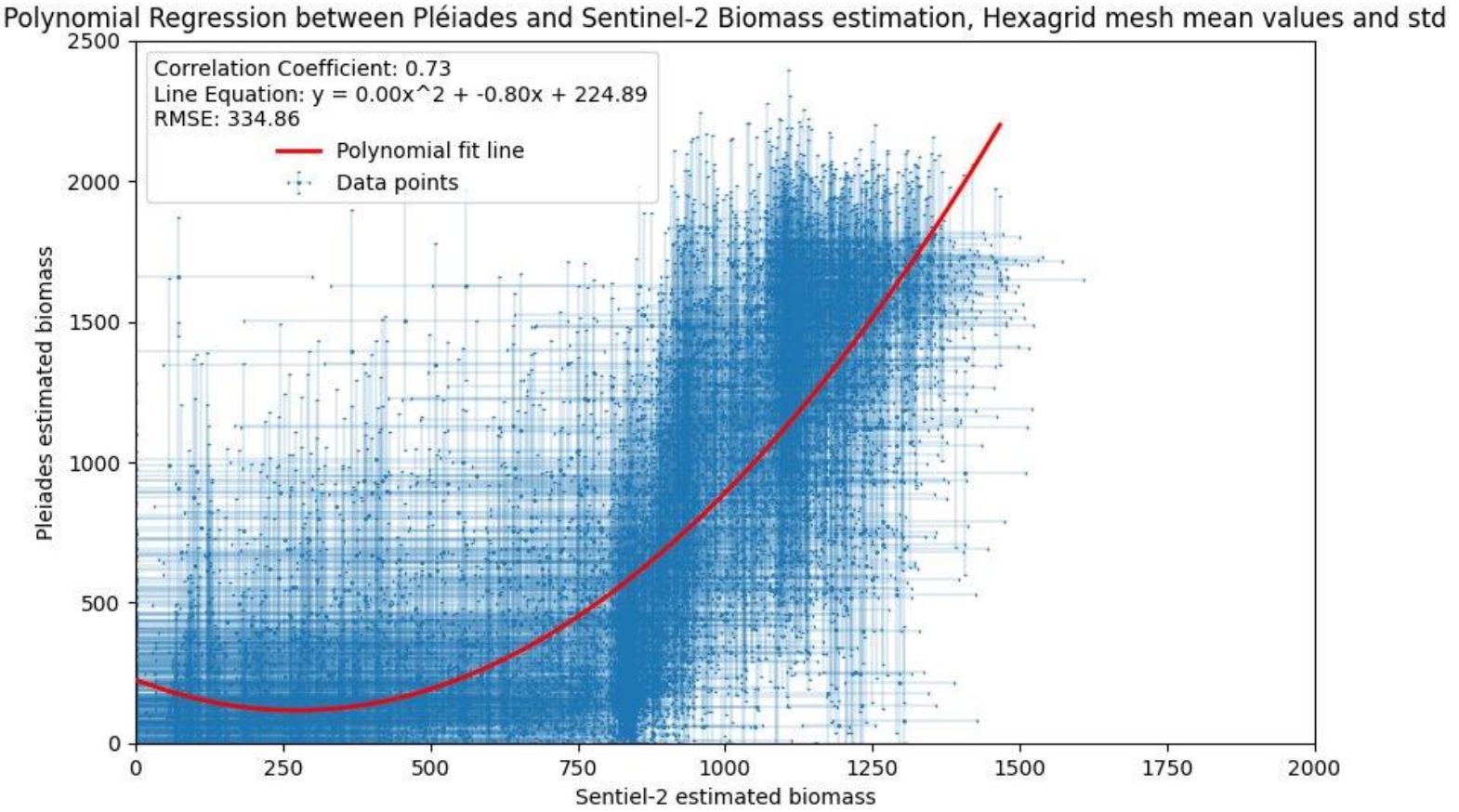


Working around prior to upscaling

i-Sea

… and observing VHR and HR relations, and why not estimate correction factors before going large scale !

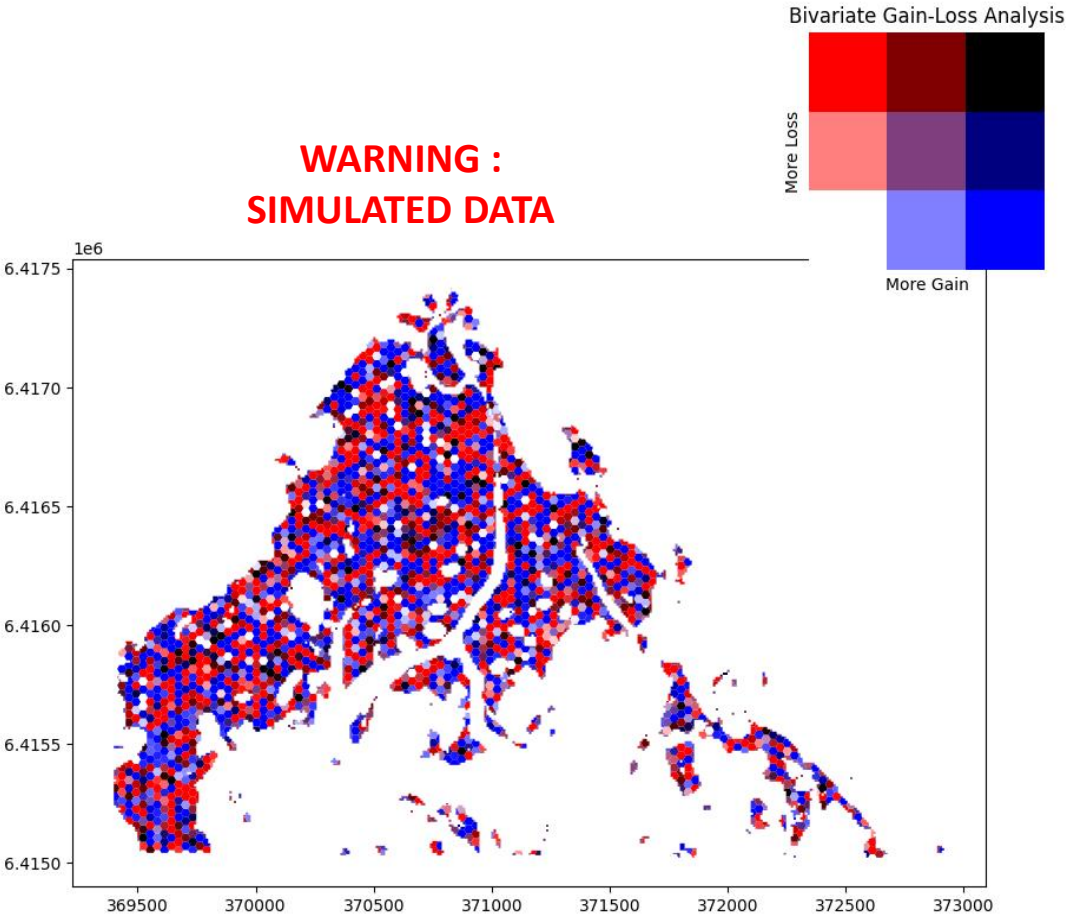




Anticipate monitoring evolutions

The fixed hexagrid allows a stable and consistent change detection !

WARNING :
SIMULATED DATA



Synthesis

- **A standardized approach, based on fixed hexagrids, in order to :**
  - Homogenize the construction of a reference database for Habitat mapping, Biomass estimation and therefore estimation of carbon stocks coming from various labs and working habits.
  - Benchmark remote sensing sensors and features (spectral, temporal, textural).
  - Benchamrk machine learning methods at different levels (pixel, object, patch) with a rigorous experimental scheme.
  - Understand the information loss from VHR to HR and control the uncertainties snowball.
  - Monitor changes with a consistent spatial representativness.

- **On going :**
  - Experimentation at large scale through the ESA Coastal Blue Carbon project :
    - Salt marshes and intertidal seagrasses (France, Canada)
    - Subtidal seagrasses (France, Spain)

ESA Coastal Blue Carbon PROJECT

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THANKS A LOT FOR YOUR ATTENTION !

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