

# Combining drone and underwater photogrammetry to map coral reef complexity at centimeter resolution over large extents

*Urbina-Barreto Isabel ‡\*, Poulain Sylvain ‡, Chauvin Anne, Lelabousse Clément,  
Barde Julien, Tribollet Aline, Guilhaumon François*

*\*speaker*

*Postdoctoral researcher*

*Isabel Urbina-Barreto*

*UMR Entropie – IRD*

*[isabel.urbina-barreto@ird.fr](mailto:isabel.urbina-barreto@ird.fr)*

# Thanks to all collaborators, funding and partners



Financé par  
l'Union européenne  
NextGenerationEU



RÉPUBLIQUE  
FRANÇAISE  
Liberté  
Égalité  
Fraternité



**PI Aline Tribollet (LOCEAN) ; PI François Guilhaumon (UMR ENTROPIE)**

Clément Lelabousse (PNMM - OFB) ; Georgeta Stoica, Philippe Charpentier (CUFR) ;

Isabel Urbina-Barreto (IRD) ; Anne Chauvin (IRD) ; Marta Gentilucci (CUFR) ; Thomas Claverie (CUFR) ; Swanne Gonthare (Sorbonne Univ) ; Pascale Cuet (Univ. Réunion) ; Eric Douville (CEA – LSCE) ; Lionel Bigot (Univ. Réunion) ; Sophie Bureau (Univ. Réunion) ; Justine Daudon (IRD) ; Sylvain Poulain (IRD) ; Julien Barde (IRD) ; Diego Alaguarda (Sorbonne Univ) ; Joelle Robbe Sorbonne (Univ–MCAM) ; Orlane Velin (Univ. Réunion) ;

Antoine Ringard (Sorbonne Univ) ; Ariane Fô (l'Ecole M3 - Lyon) ; Julie Closse-independent ; Florinah Razafimandimby (Univ. Réunion) ; Matéo Moreau (ENSC, Bordeaux

INP)

**PI Julien Barde  
(UMR MARBEC )**

Sylvain Poulain  
(IRD)

# Photogrammetry surveys spread up worldwide

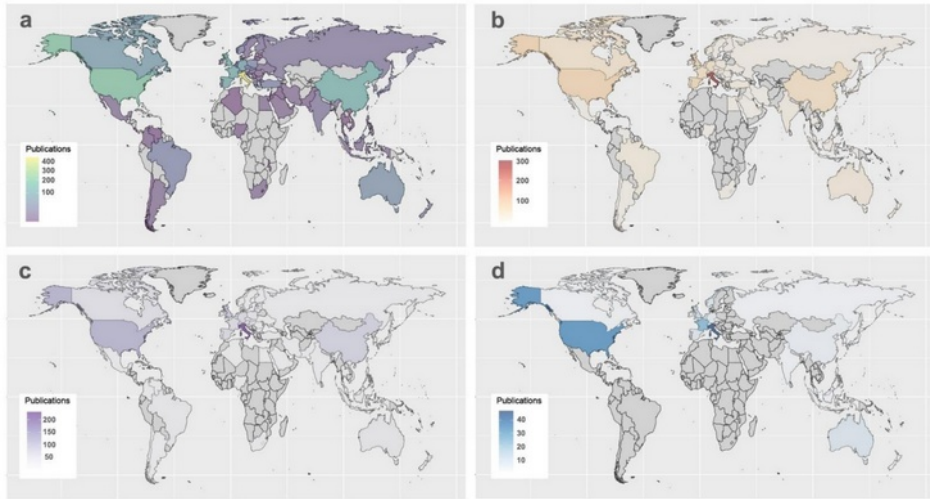


Figure 3. Geographical distribution of the countries who funded the study in the analysed publications: (a) total number of publications, (b) ground-based applications, (c) airborne-photogrammetry applications, and (d) underwater applications.

Relevance and versatility of SfM Photogrammetry

Rapid assesment monitoring

Multiscale integrative perspective

Tailored conservation measures

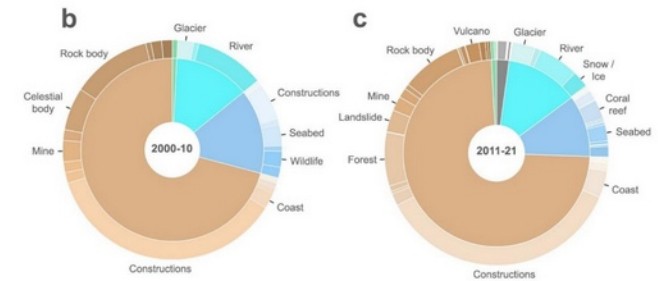
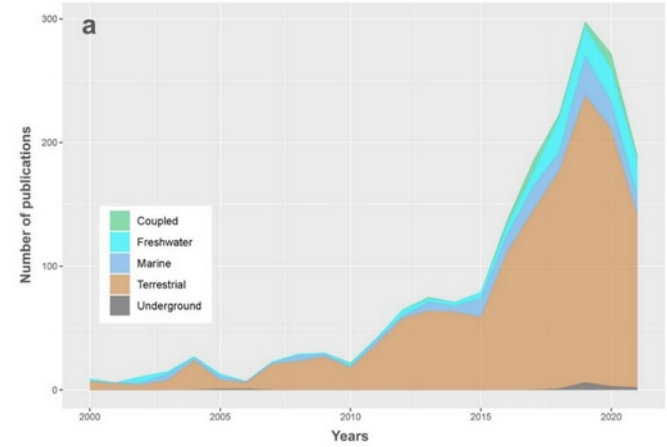


Figure 5. Type of environments addressed during the surveys over the past two decades: (a) temporal trend; (b) ring chart representing the percentage of surveys performed per environment from 2000 to 2010; (c) ring chart representing the percentage of surveys performed per environment from 2011 to 2021.

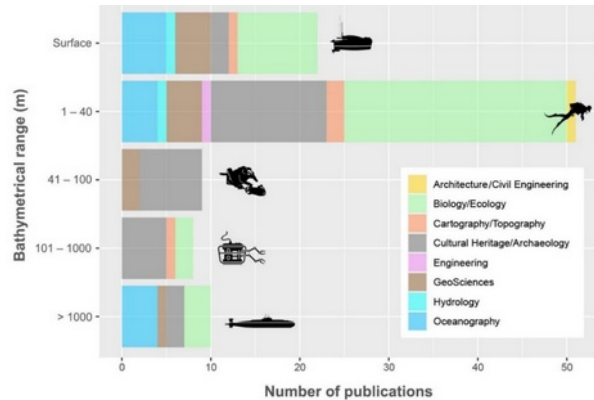
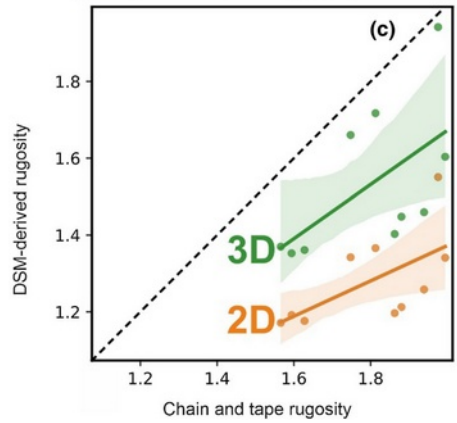
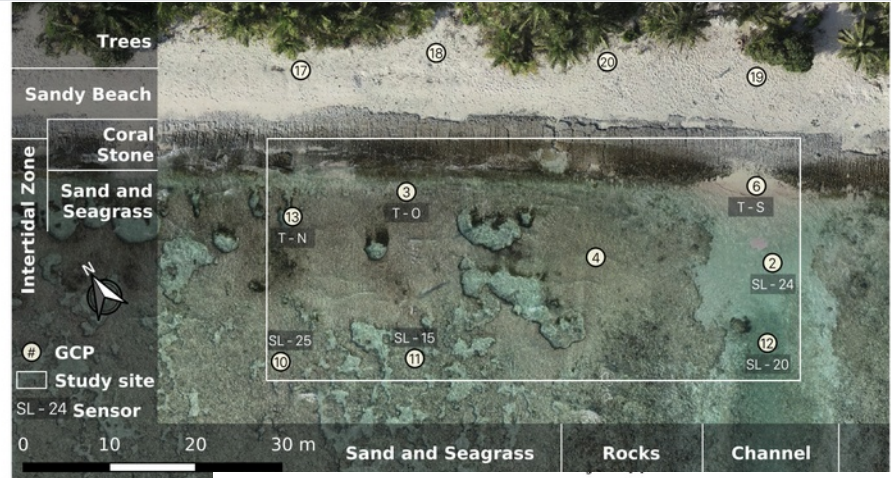
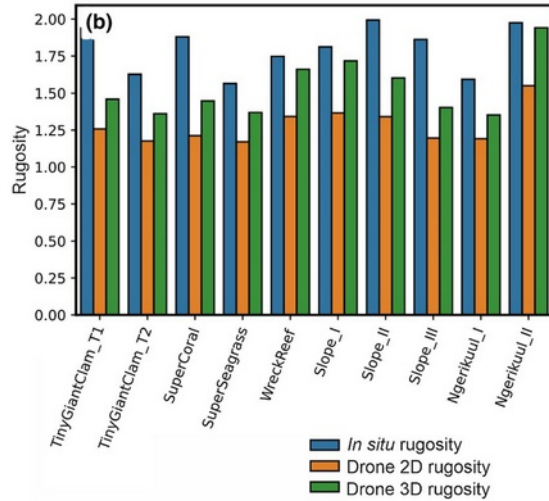
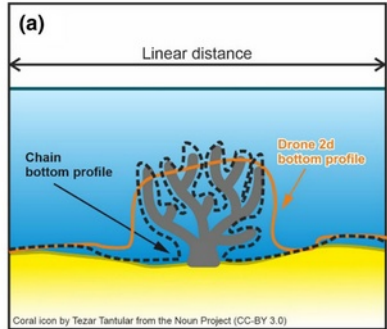


Figure 6. Bathymetric distribution of underwater photogrammetric approaches with the relative disciplines of implementation. Icons indicate the main but not exclusive tools applied at each depth range.

Mantas *et al.* 2023  
Since 2010...

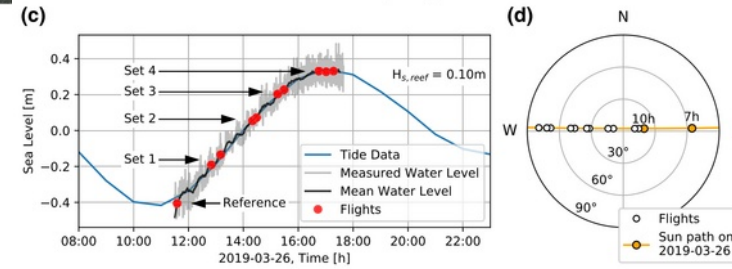
# Underwater photogrammetry by Structure-from-Motion (UWP) & Aerial surveys using Unmanned Aerial Vehicles (UAVs - *drones*)



Casella et al. 2022

! Physical descriptors → complexity surface is underestimated vs *in situ* traditional methods

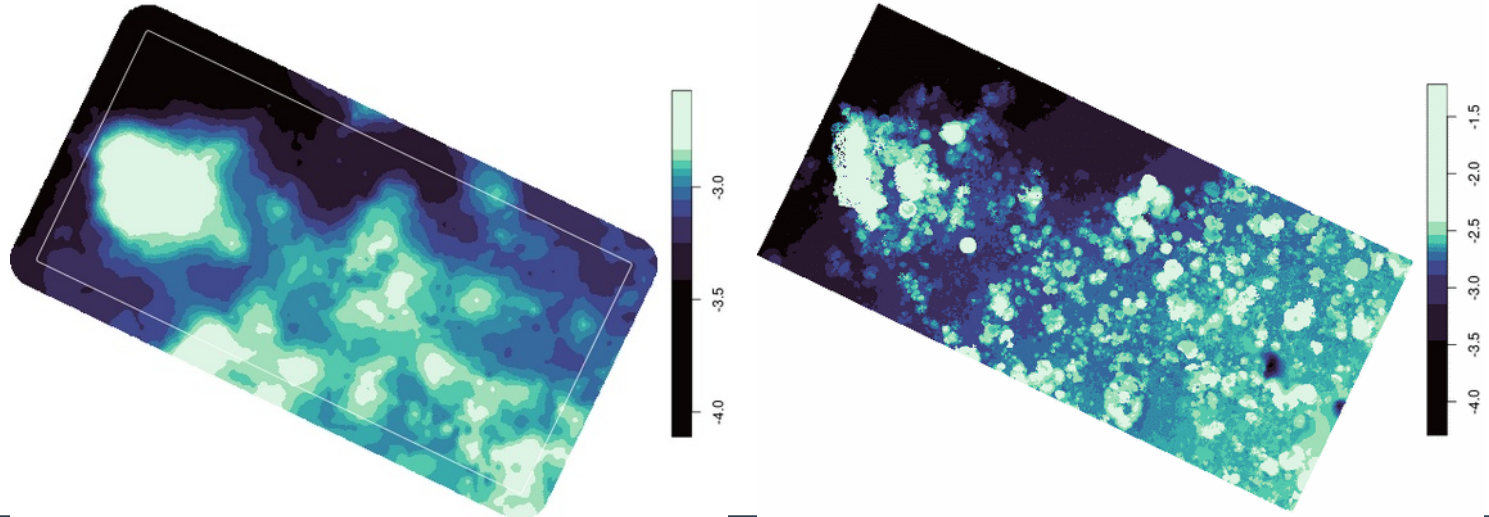
David et al. 2021



! Corrected imagery did not improve the overall accuracy of reconstruction

# Major goal, relationships between habitat descriptors:

*Fractal dimension (fd), surface complexity (sc) and slope (sl) derived from Underwater Photogrammetry (UWP) and Drones (UAV) Digital Elevation Models at two sites around Mayotte island - Western Indian Ocean*



# Study sites

Well-developed reefs with strong environmental contrasts and a range of anthropogenic pressures

## Comoro archipelago



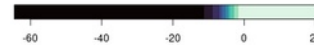
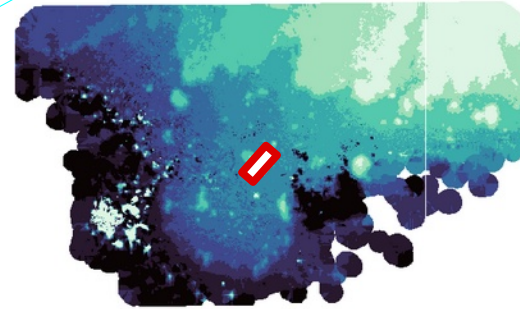
## Mayotte



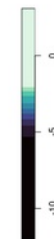
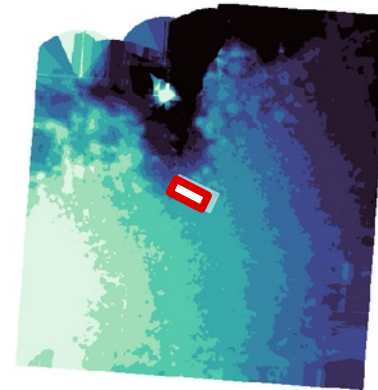
Surprise  
Île blanche

image\_Sentinel2

## inner barrier reef



## fringing reef



Total survey area/site:

UWP  
area ~ **180m<sup>2</sup>**  
Time ~ **60min**  
**SCUBA or Free diving**

UAV  
Area ~ **10ha**  
Time ~ **25min**  
**drone flight**

depth range ~ 6 m

# Photogrammetry SfM sampling and 3D reconstructions

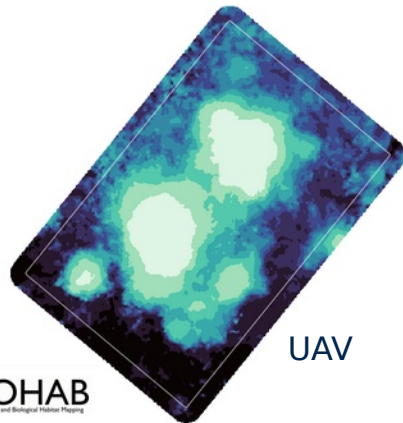
UWP - small scale & HR: sonny RX100M5, 70 % overlap, GSD < 1cm/pixel (*sampling resolution*) ;

UAV - large scale & LR: DJI-Mavic2-Pro, 70 % f 60 % s overlap, GSD ~ 1-3cm/pixel

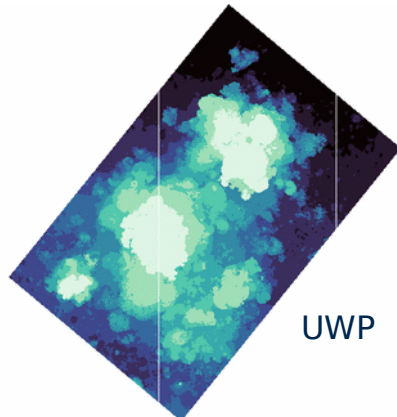
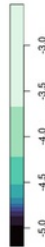


3D reconstructions  
Metashape and  
Open Drone Map

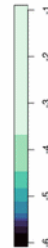
Digital Elevation Models



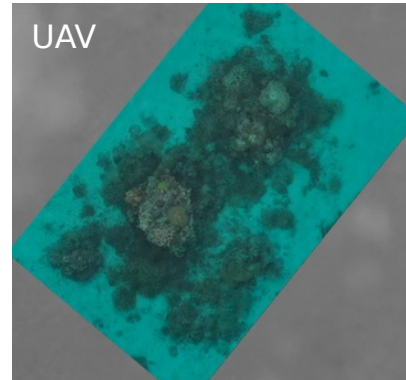
UAV



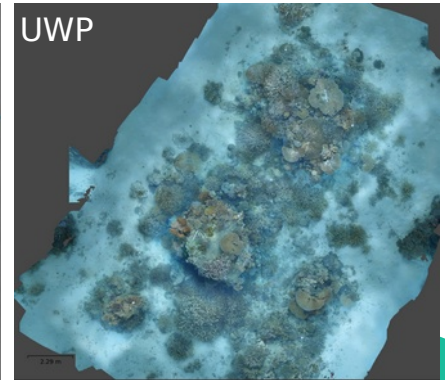
UWP



Orthomosaics



UAV

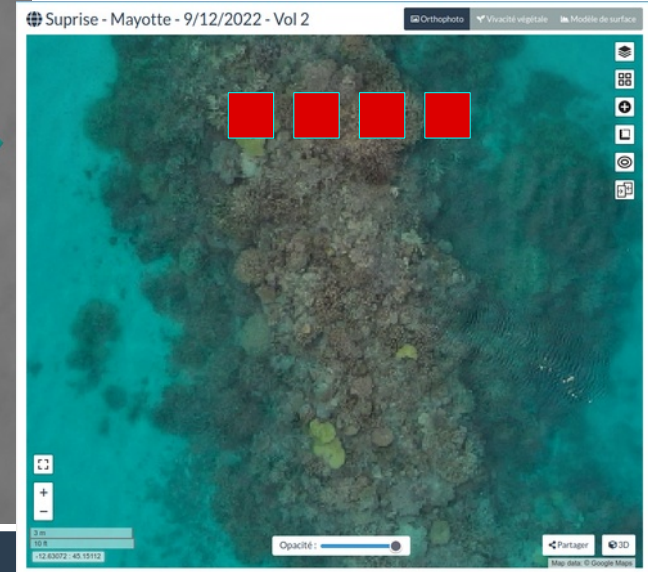
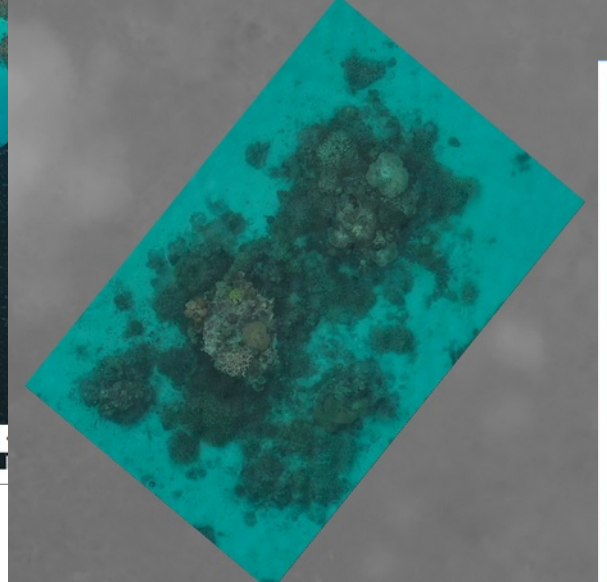


UWP

# Warped and tiling DEMs process:

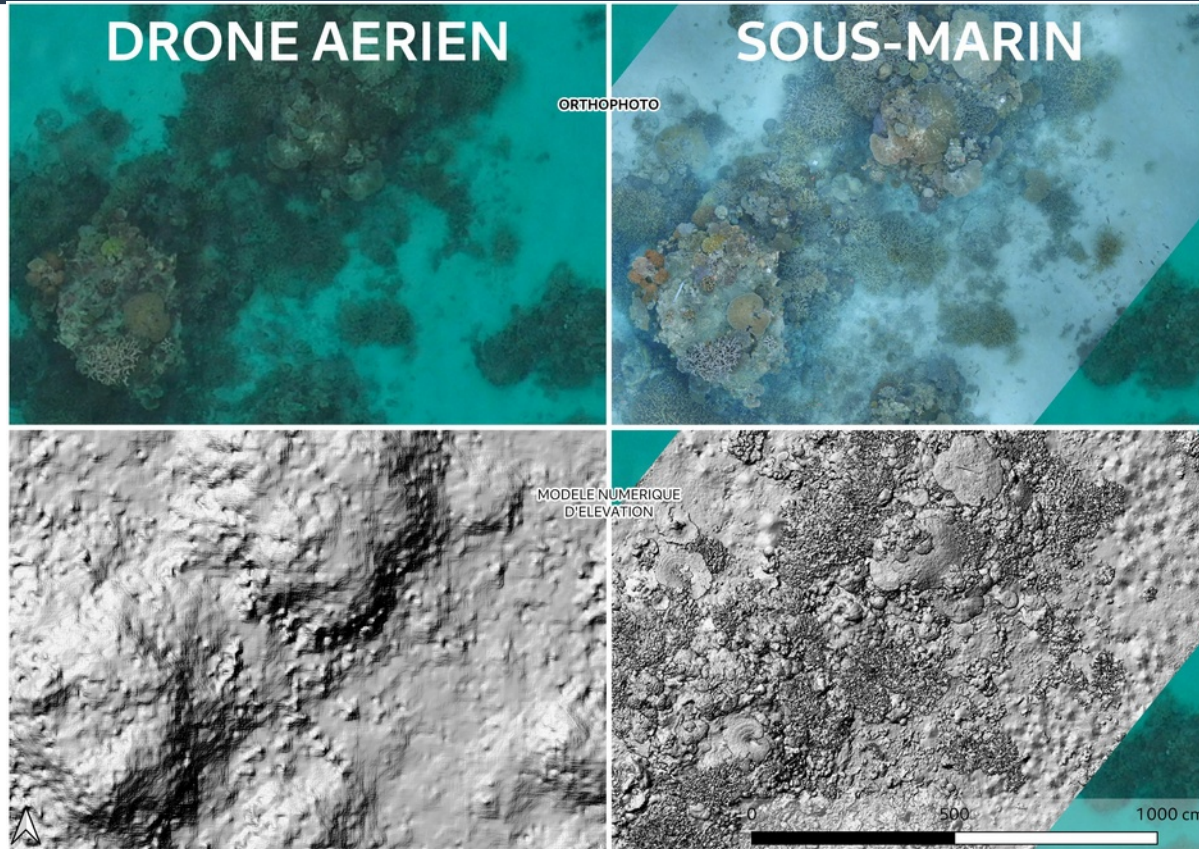
UWP-DEMs and UAVs-DEMs have been warped using the UWP sampling extent and UAV sampling resolution (GSD~1-3cm/pixel)

- Tiles  $1\text{m}^2 \rightarrow fd, sc, sl$



# Analyses and results

comparison of Orthomosaic (top) Digital elevation models (bottom) UWP (right) and UAV (left)



Relationships UAV & UWP :

- linear models
- non parametric ANOVAs

1<sup>st</sup> « *tile by tile* »

2<sup>nd</sup> Wilconxon-test

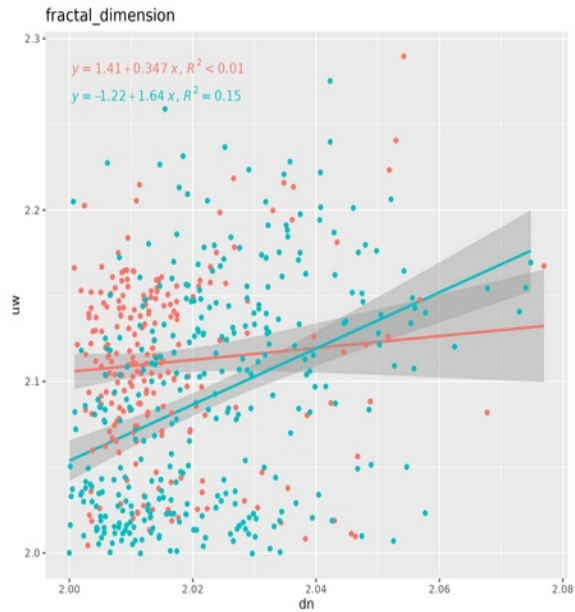
3<sup>rd</sup> Polynomial regressions with **ranked descriptors values** →

to investigate spread UAV & UWP descriptors values

# Statistical results & discussions

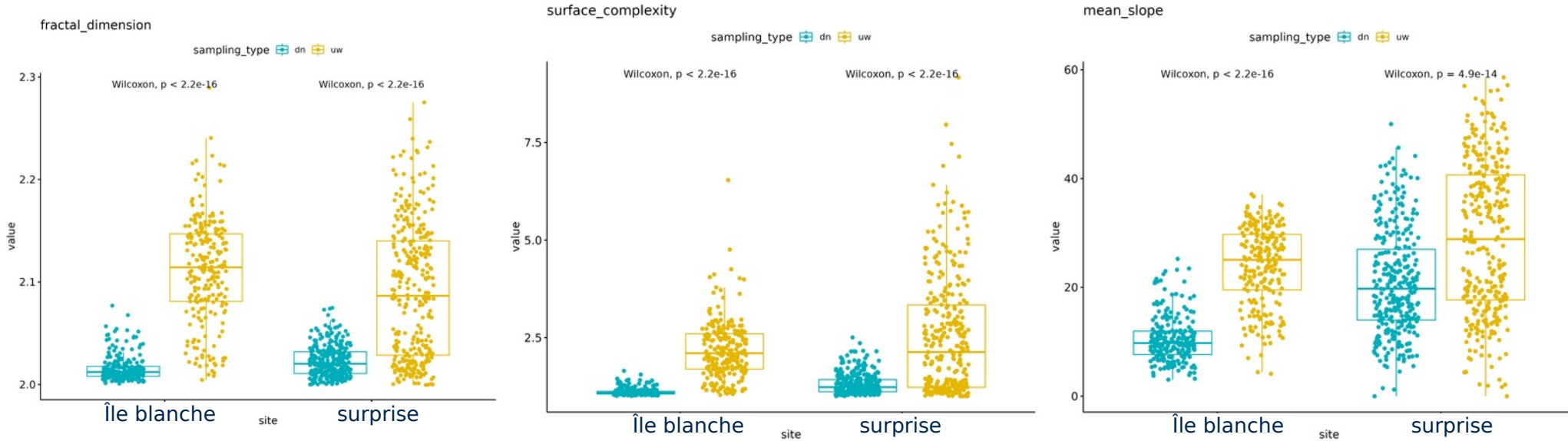
1<sup>st</sup> « tile by tile » →  $R^2 < 0.2$

Île blanche  
surprise



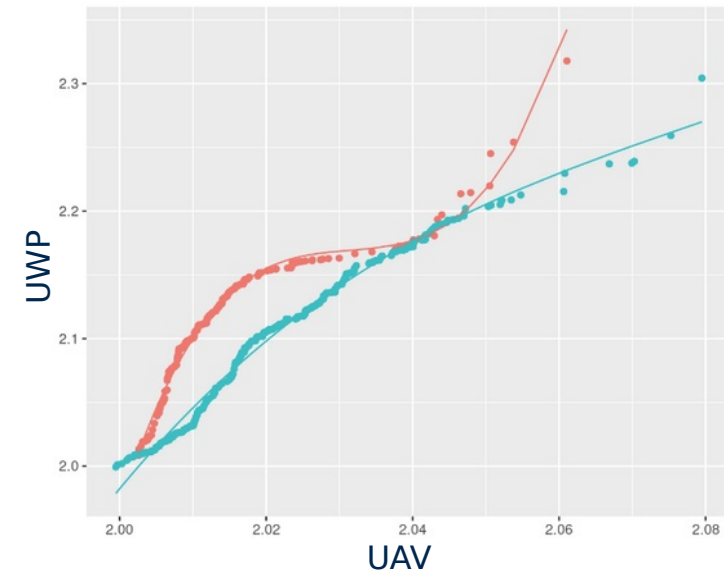
# Statistical results & discussions

2<sup>nd</sup> Wilconxon-test → UAV always underestimate significantly the descriptor values (as showed by Casella et al. 2022)

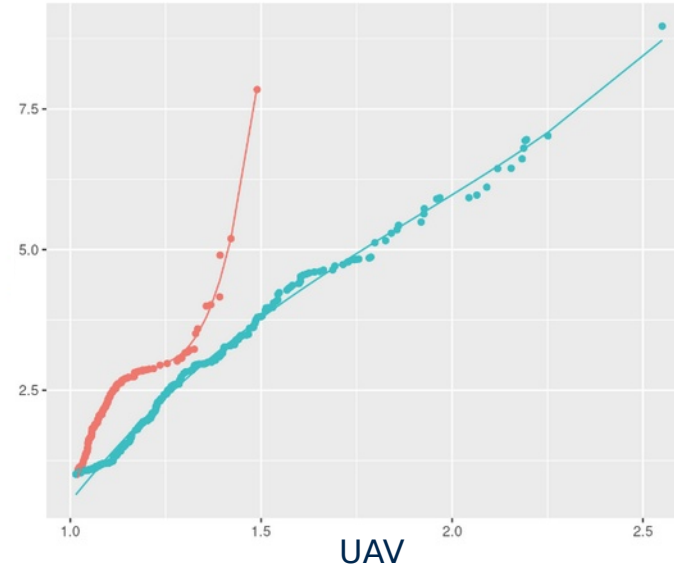


# Statistical results & discussions

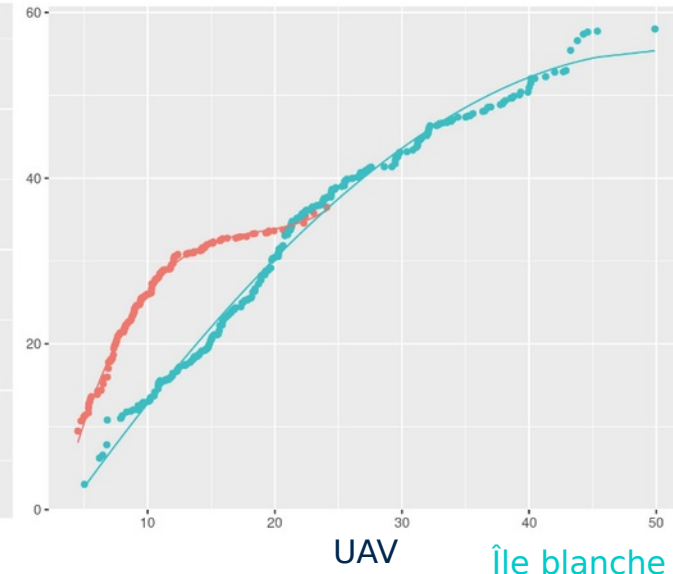
3<sup>rd</sup> ranked descriptors values → across all sites the relationship between ranked descriptor values is strong and provide substantial predictability (all  $R^2 > 0.9$ ) ; but site dependency...



(a) fractal dimension



(b) surface complexity



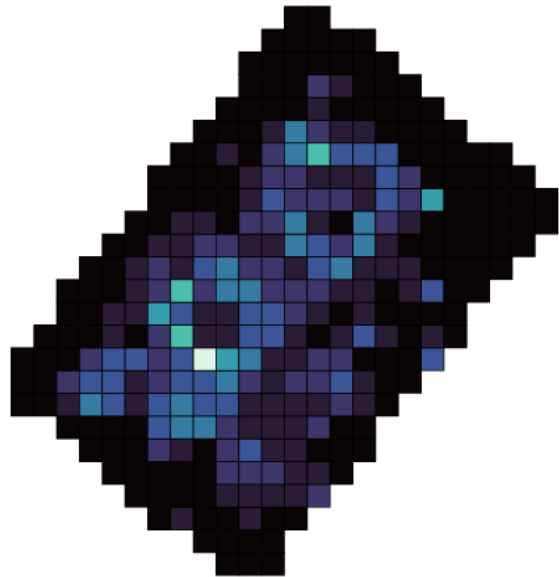
(c) mean slope surprise

île blanche

# Comparison

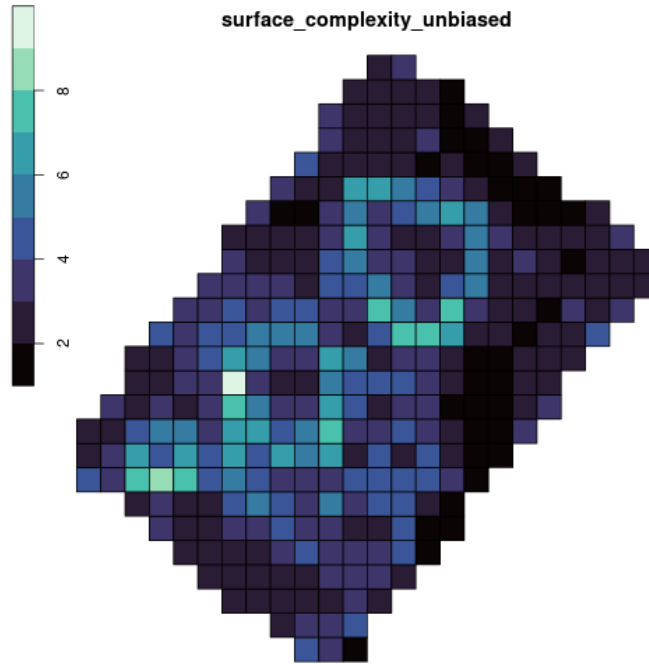
UWP values → unbiased drone values → original drone values

**UWP** surface\_complexity



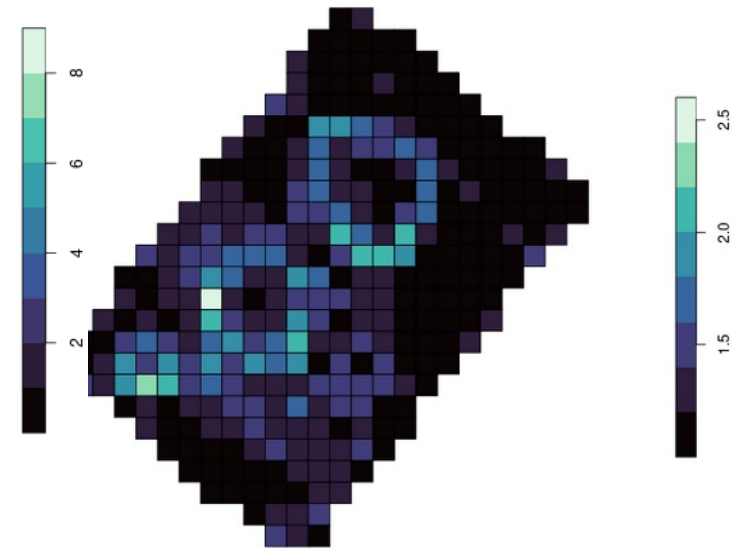
**UAV- unbiased**

surface\_complexity\_unbiased



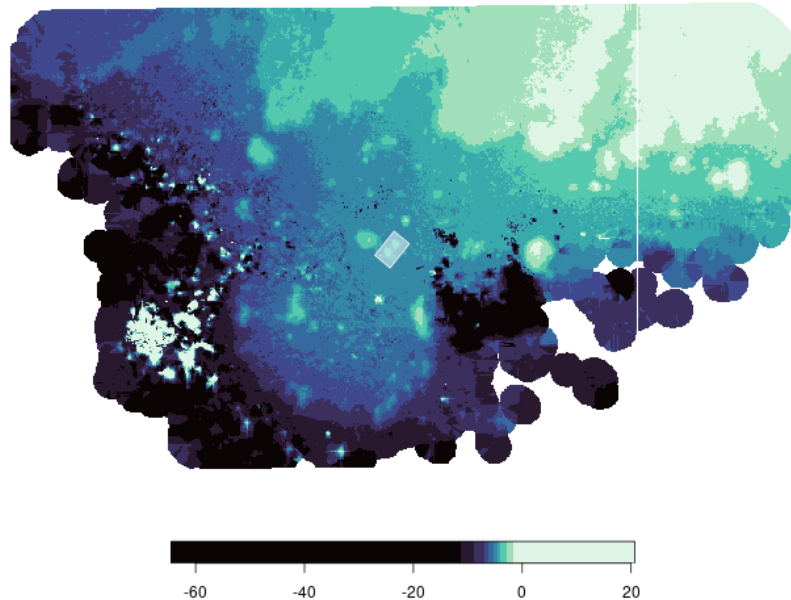
**UAV original**

surface\_complexity

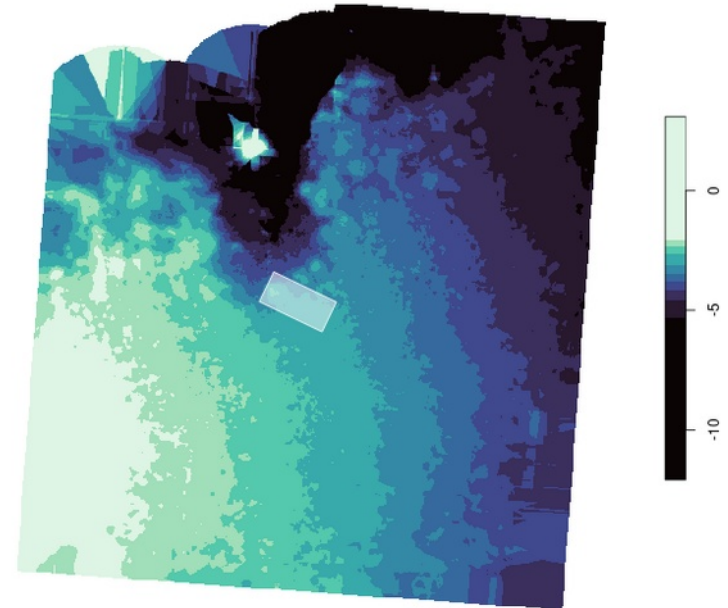


# Perspectives

- *Cross validation to quality evaluation of unbiased values ... (but ... tile to tiles no good correlation)*
- *Replaces the linear models with machine learning → e.g. Xgboost, extreme gradient boosting to prediction improvements*



DEMs



**Questions ?**