Two media bathymetric mapping for shallow waters

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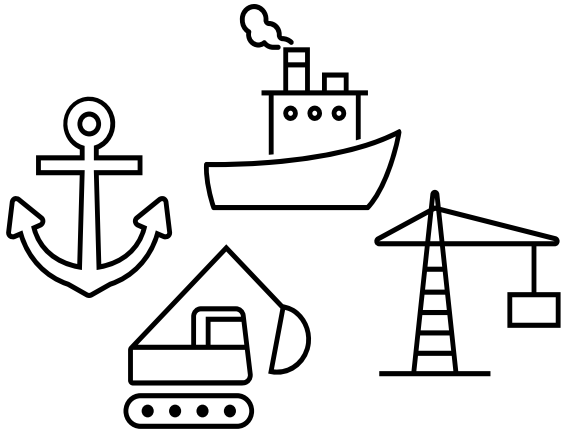
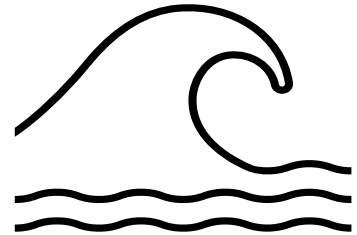
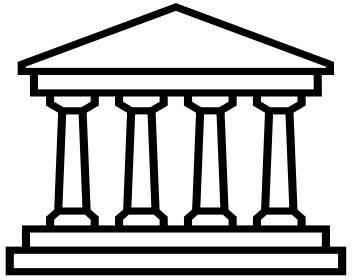
NTUA PH[O]TO GRAMMETRIC COMPUTER VISION

Seabed mapping for shallow waters







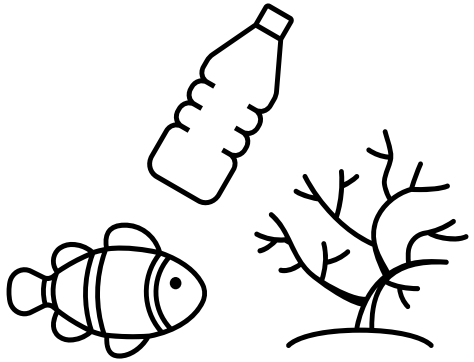
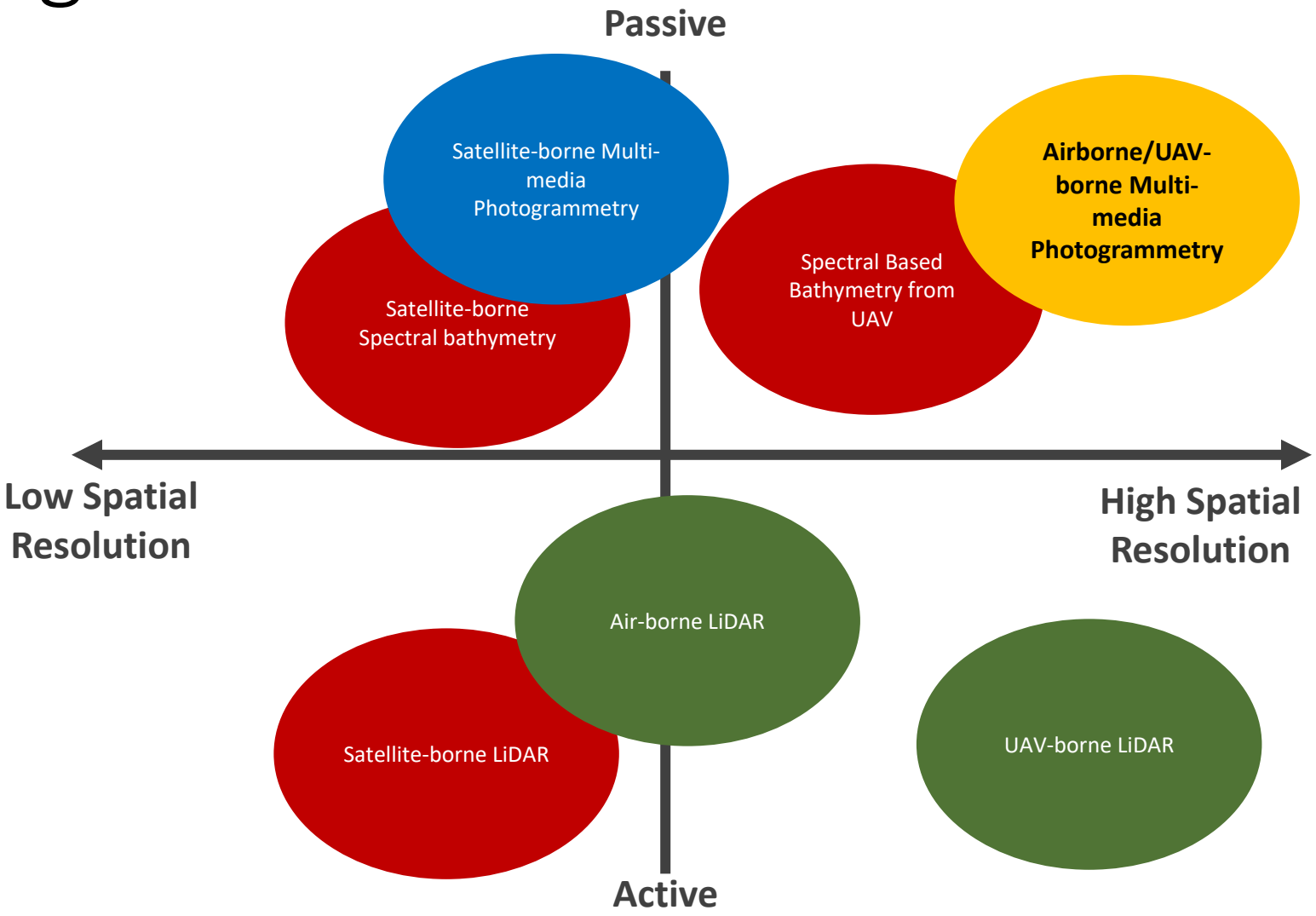


Figure: Photogrammetric Vision Lab, Cyprrus University of Technology

Shallow water bathymetry using remote sensing methods



Airborne Multi-media Photogrammetry

- **Can provide a cheap alternative to traditional (LiDAR-SONAR etc.) and expensive shallow seabed mapping techniques**
- **Offers important visual information and high detail**
- **Offers high density 3D point clouds and meshes**
- **Covers large areas in reduced time and cost**
- **Useful for mapping and reconnaissance of submerged CH in high resolution and extended coverage**
- **However, it is a special case of photogrammetry, requiring specific knowledge and expertise in order to deliver accurate results!**

Where is needed? [1]

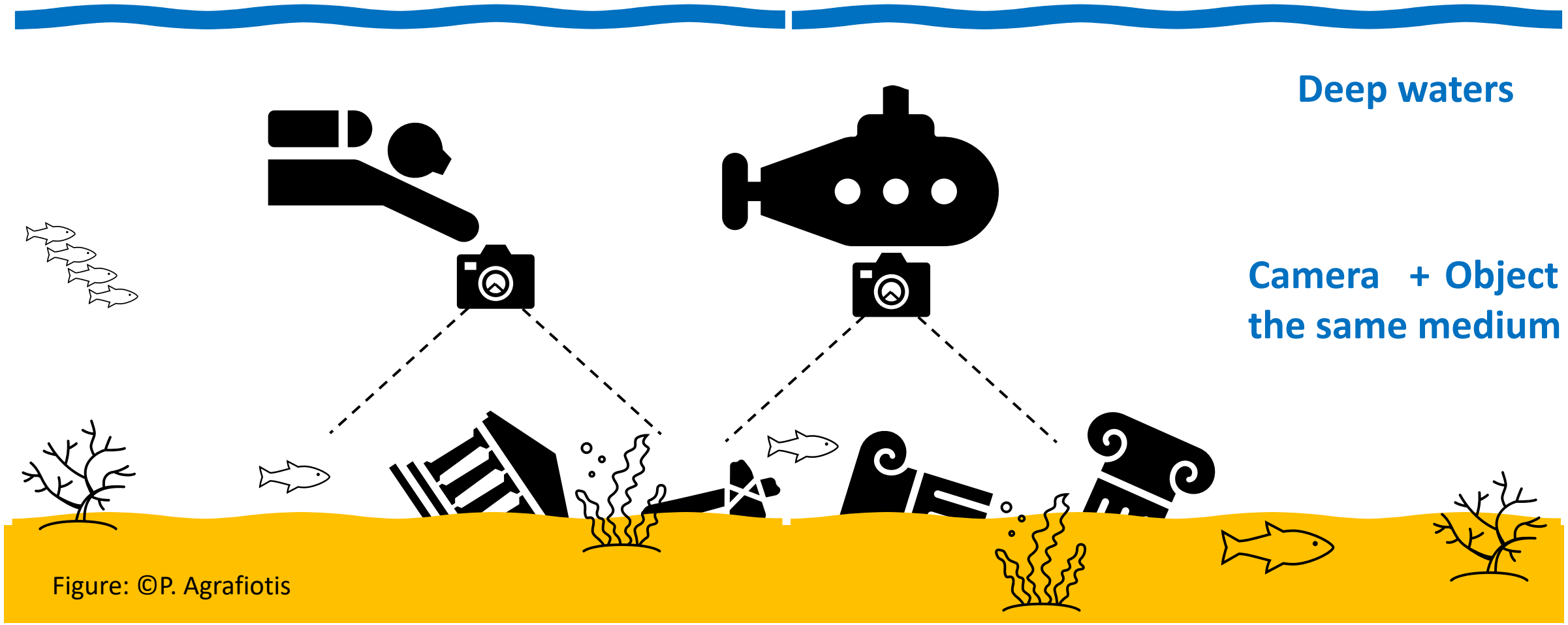


Figure: ©P. Agrafiotis

Where is needed? [2]

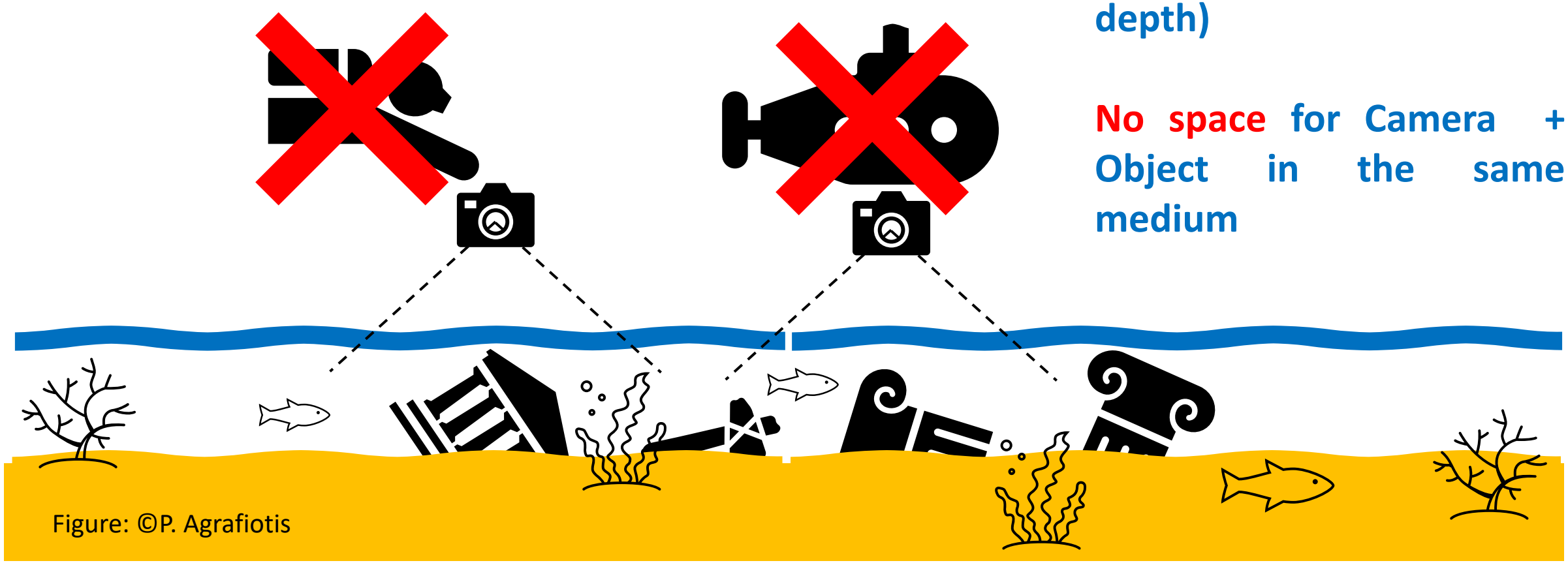


Figure: ©P. Agrafiotis

Very shallow waters (<1m depth)

No space for Camera + Object in the same medium

Where is needed? [3 - 1]

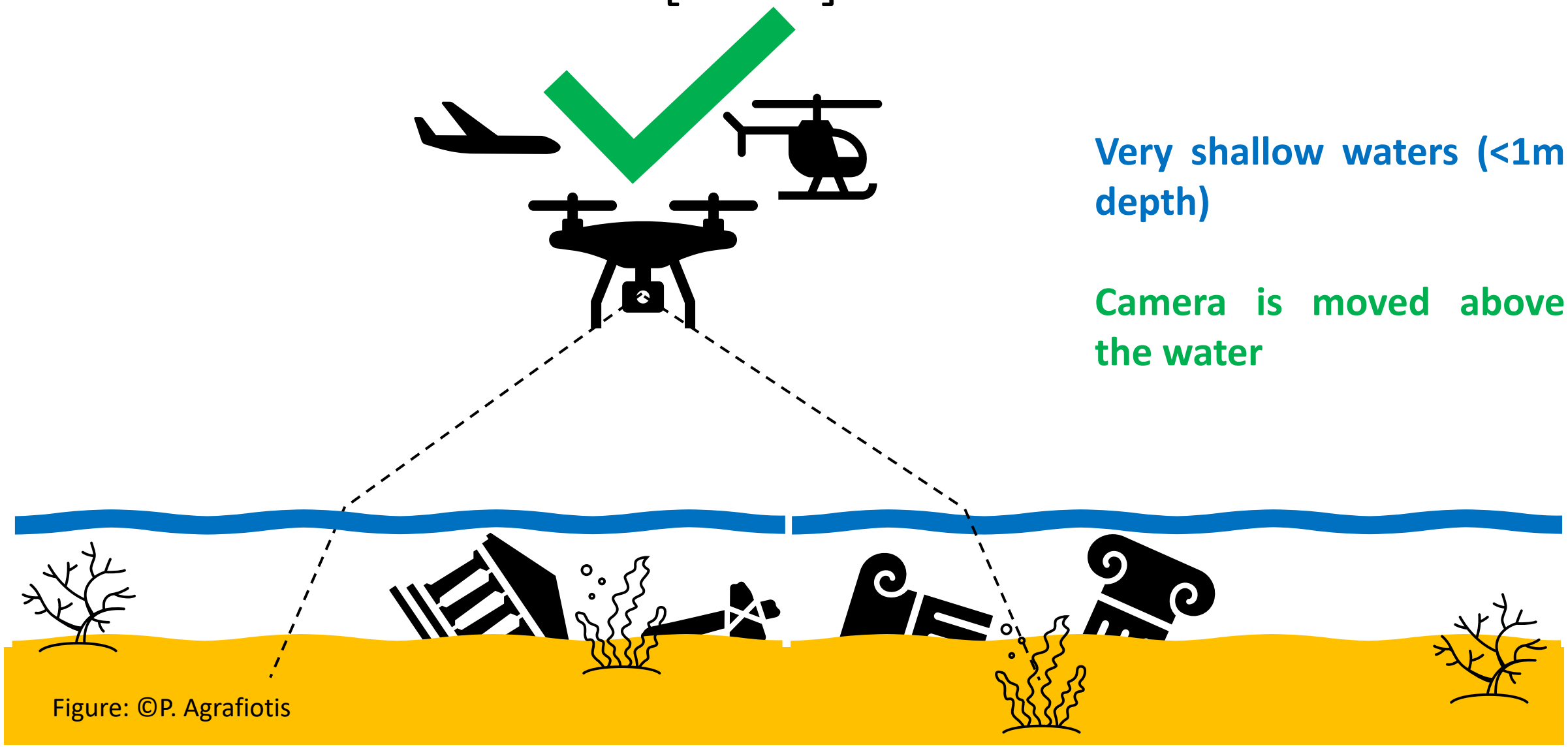


Figure: ©P. Agrafiotis

Very shallow waters (<1m depth)

Camera is moved above the water

Where is needed? [3 - 2]

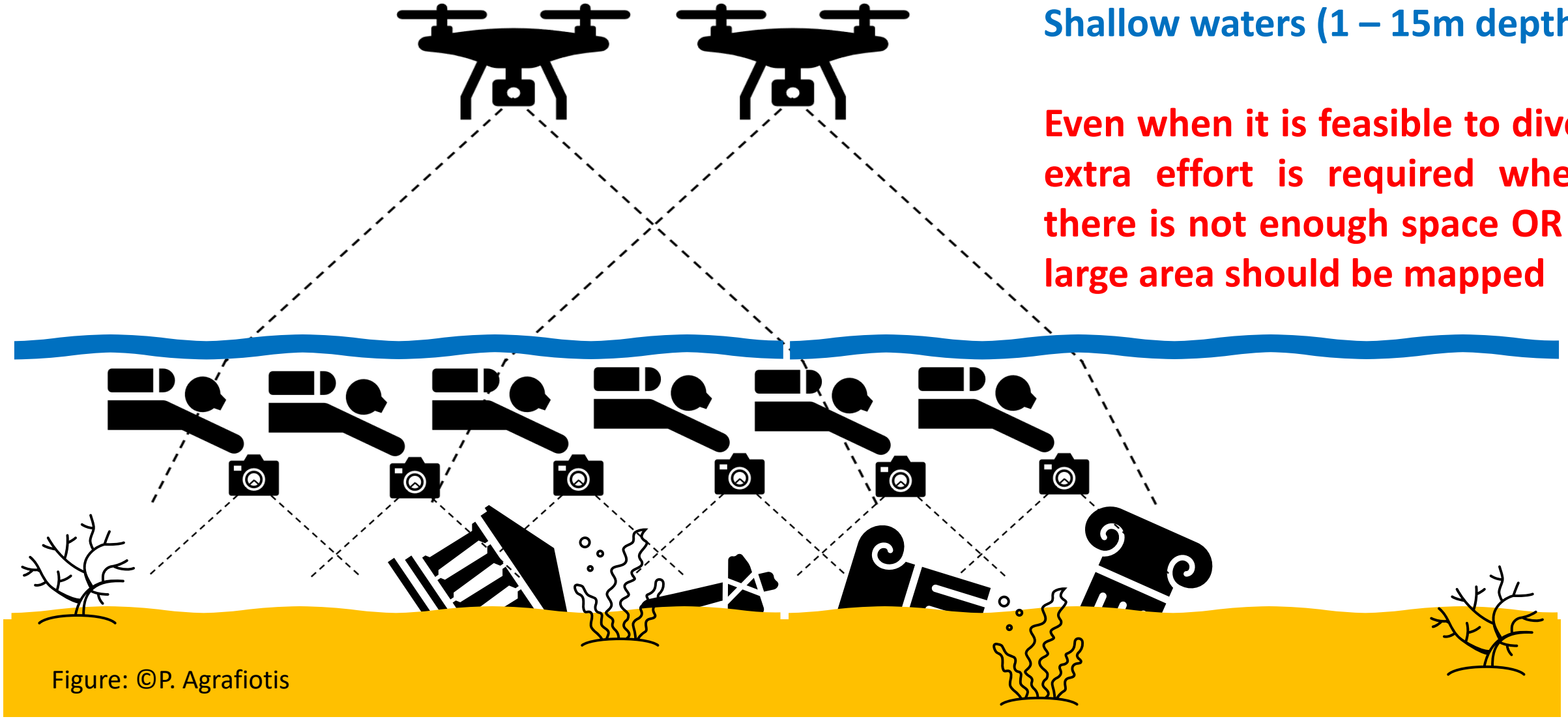
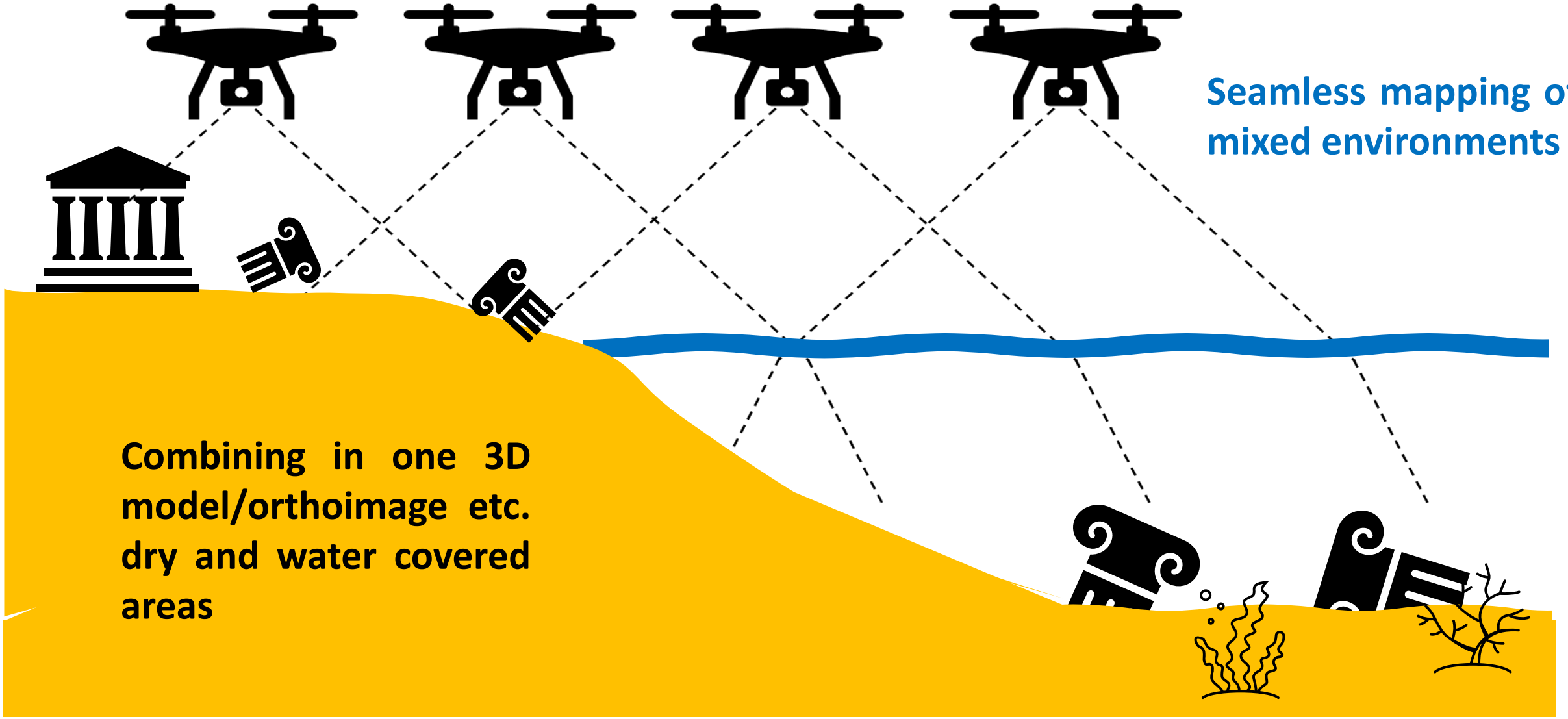


Figure: ©P. Agrafiotis

Shallow waters (1 – 15m depth)

Even when it is feasible to dive, extra effort is required when there is not enough space OR a large area should be mapped

Where is needed? [3 - 3]



Seamless mapping of mixed environments

Combining in one 3D model/orthoimage etc. dry and water covered areas

Why it is a special case ? [1]

Refraction!

Camera + Object in a different medium (air/water)

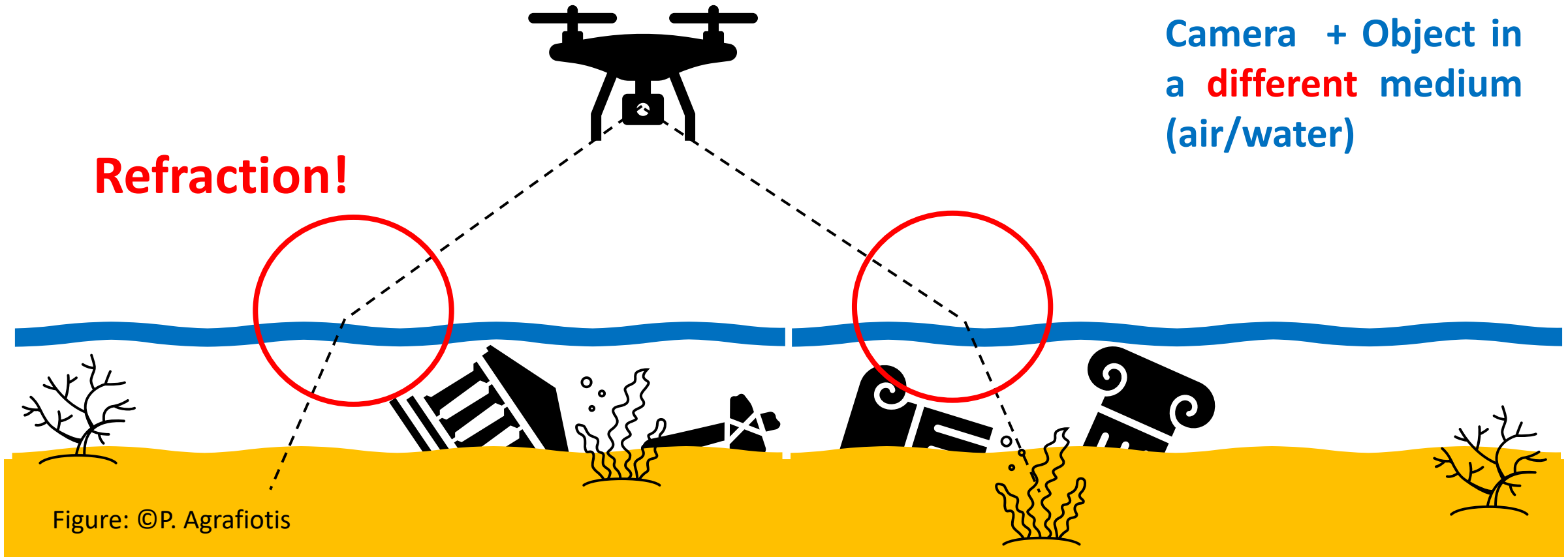
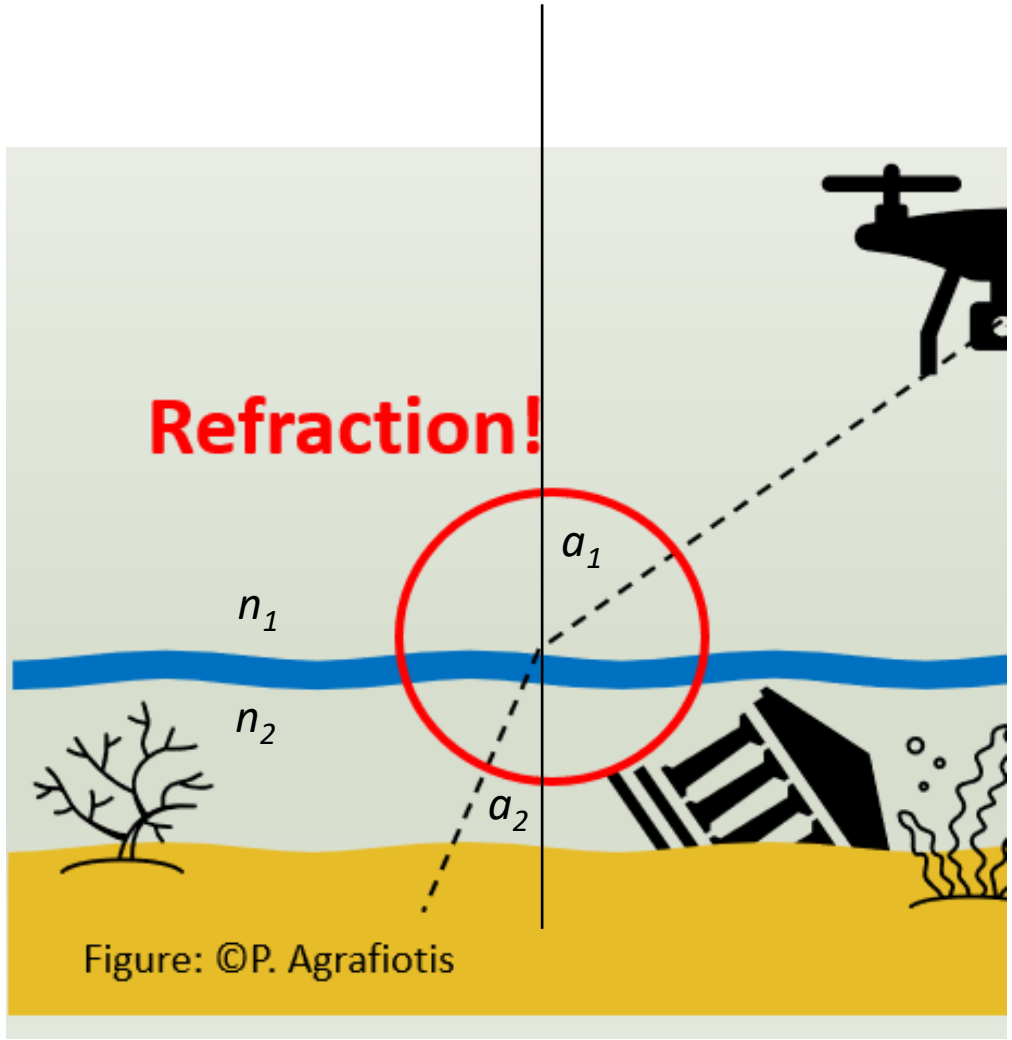


Figure: ©P. Agrafiotis

What's the problem with refraction?



Snell's law

Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media, or equivalent to the reciprocal of the ratio of the indices of refraction.

$$\sin\alpha_2 \times n_2 = \sin\alpha_1 \times n_1$$

- **Violates the Collinearity Equation**
- Generate **apparent depths**
- Roughly, acts like a non uniform radial distortion, depending on the incidence angles and the depth
- In SfM-MVS **adds noise** in the **de-facto erroneous generated depths**

Multi-media Photogrammetry – Single View Geometry VS Multiple View Geometry

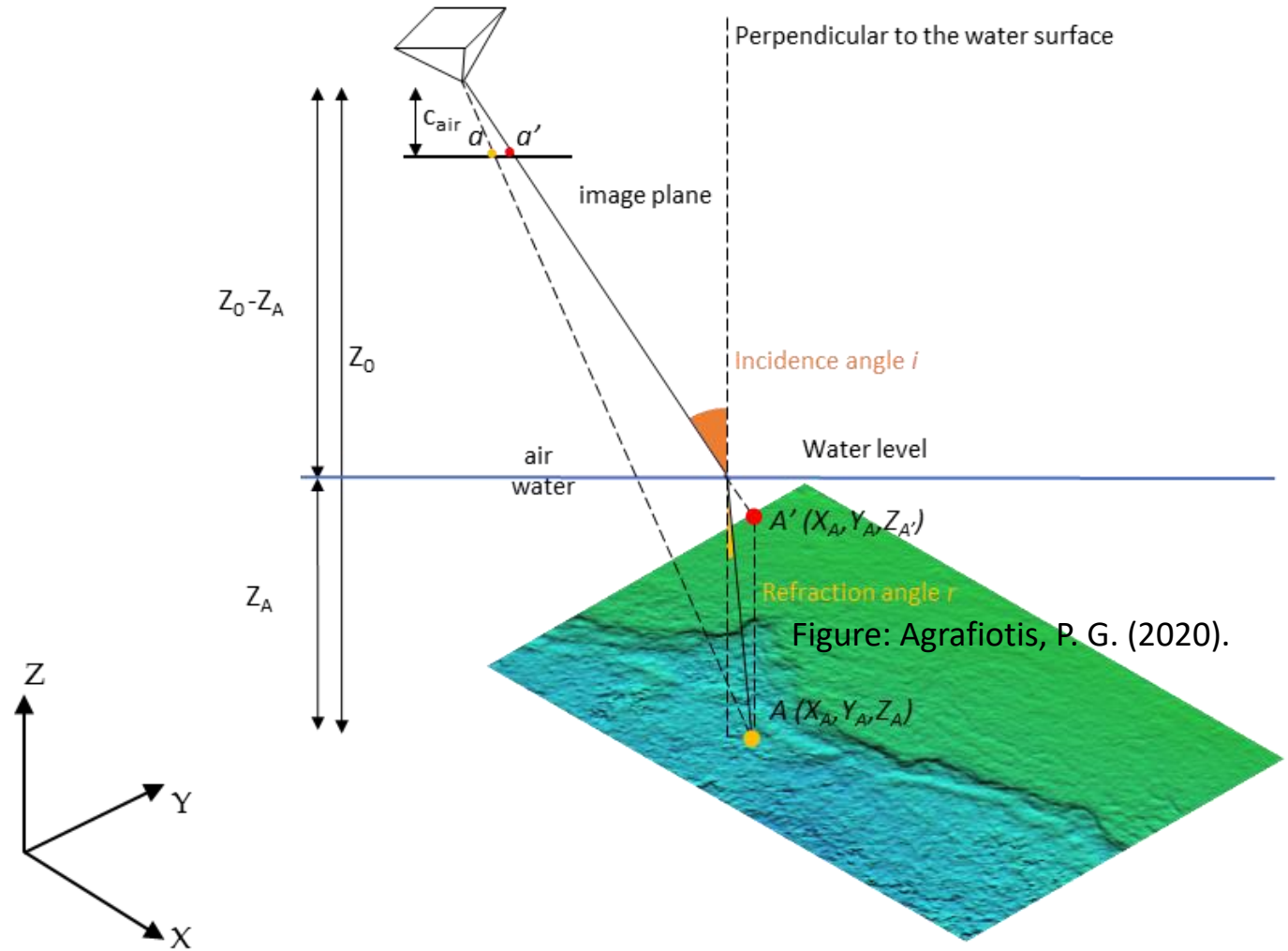


Figure: Agrafiotis, P. G. (2020).

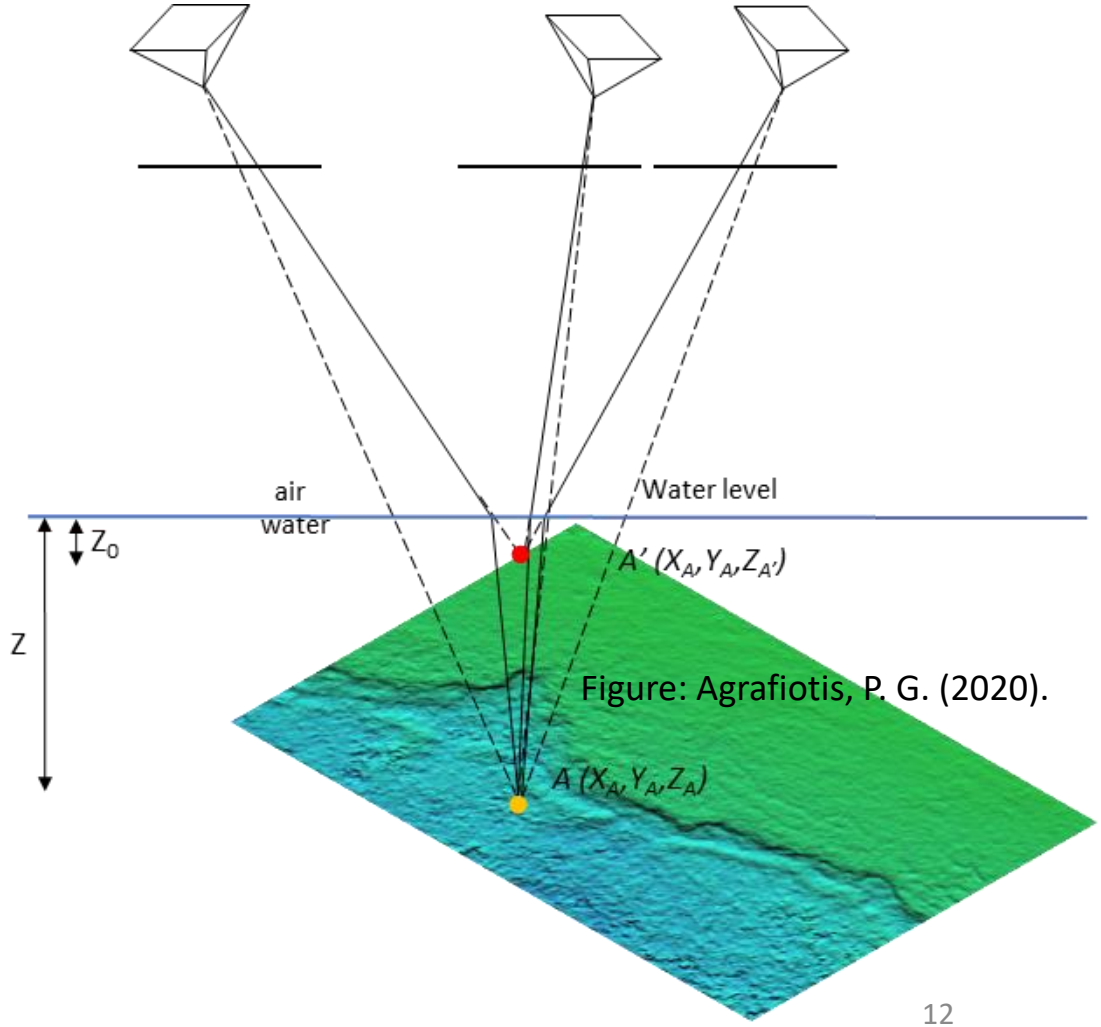


Figure: Agrafiotis, P. G. (2020).

Figures' reference: Agrafiotis, P. G. (2020). Image-based bathymetry mapping for shallow waters., PhD Thesis, National Technical University of Athens

Multi-media Photogrammetry – Correction Basics

Since software is delivering 3D point clouds even when refraction is ignored, can we skip it? – NO, it's physics!

To deliver accurate SfM-MVS results, orthoimages, Digital Elevation Models etc., the correction of refraction effects is necessary!

HOW?

- **Analytical correction:** modification of the collinearity equation. (1950…)
- **Image-space correction**: re-projection of the original photo to correct the water refraction. (2018…)
- **Machine learning-based**: depends on machine learning models that learn the underestimation of depths and predict the correct depth knowing only the apparent one. (2019…)

Multi-media Photogrammetry – Image Space Correction (Skarlatos, D., & Agrafiotis, P., 2018, Agrafiotis et al., 2020)

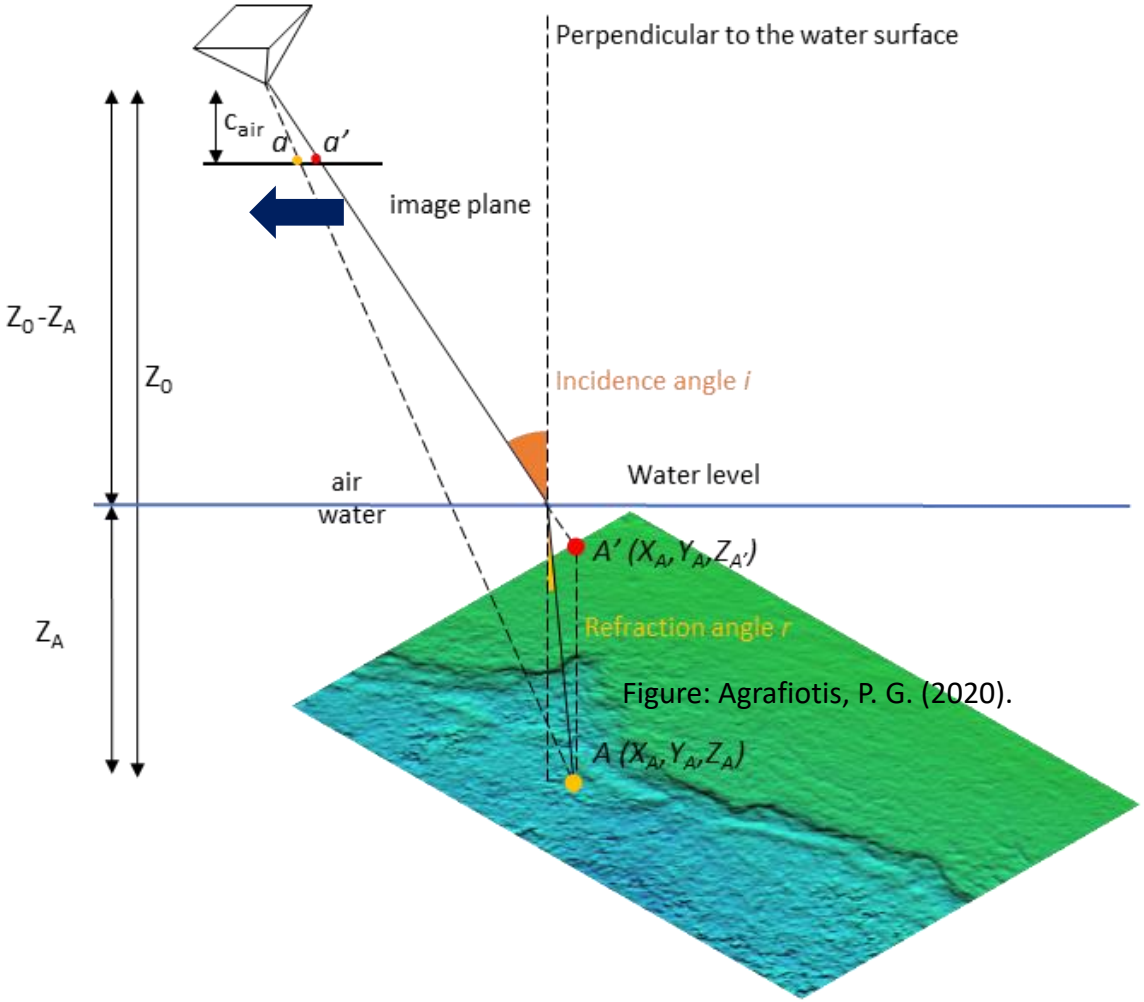


Figure: Agrafiotis, P. G. (2020).

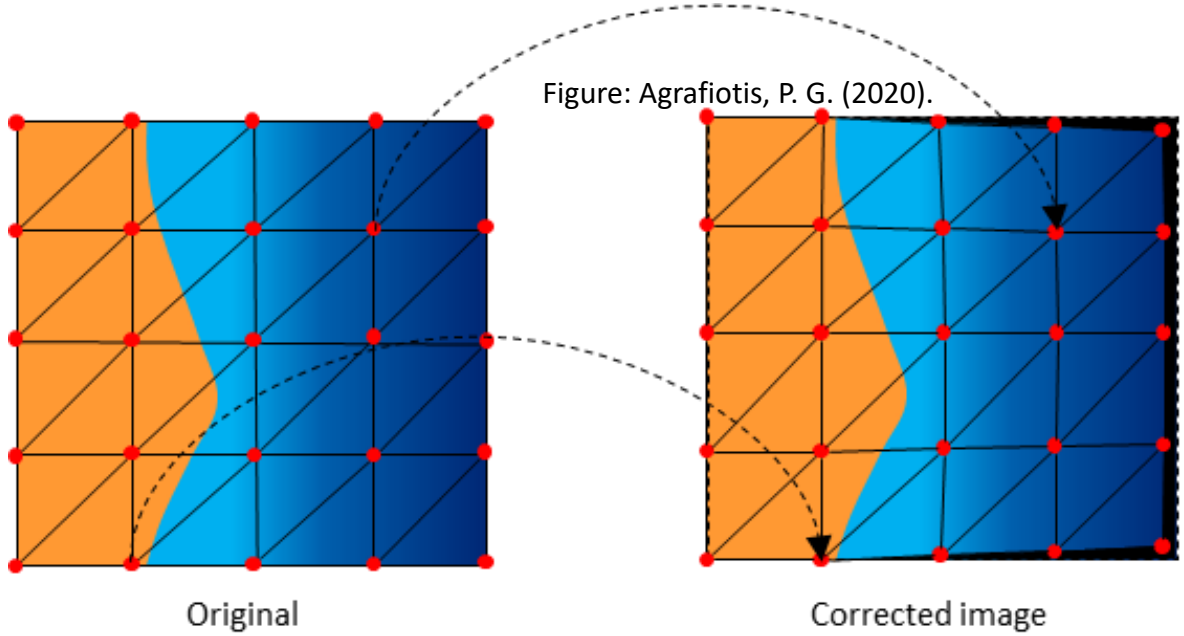


Figure: Agrafiotis, P. G. (2020).

References: Skarlatos, D., & Agrafiotis, P. (2018). A novel iterative water refraction correction algorithm for use in structure from motion photogrammetric pipeline. *Journal of Marine Science and Engineering*, *6*(3), 77.

Agrafiotis, P., Karantzalos, K., Georgopoulos, A., & Skarlatos, D. (2020). Correcting image refraction: Towards accurate aerial image-based bathymetry mapping in shallow waters. *Remote Sensing*, *12*(2), 322.

Agrafiotis, P. G. (2020). Image-based bathymetry mapping for shallow waters., PhD Thesis, National Technical University of Athens

Multi-media Photogrammetry – ML-based Correction (Agrafiotis et al., 2019, 2020, 2021)

1st Prize by the European GNSS Agency*

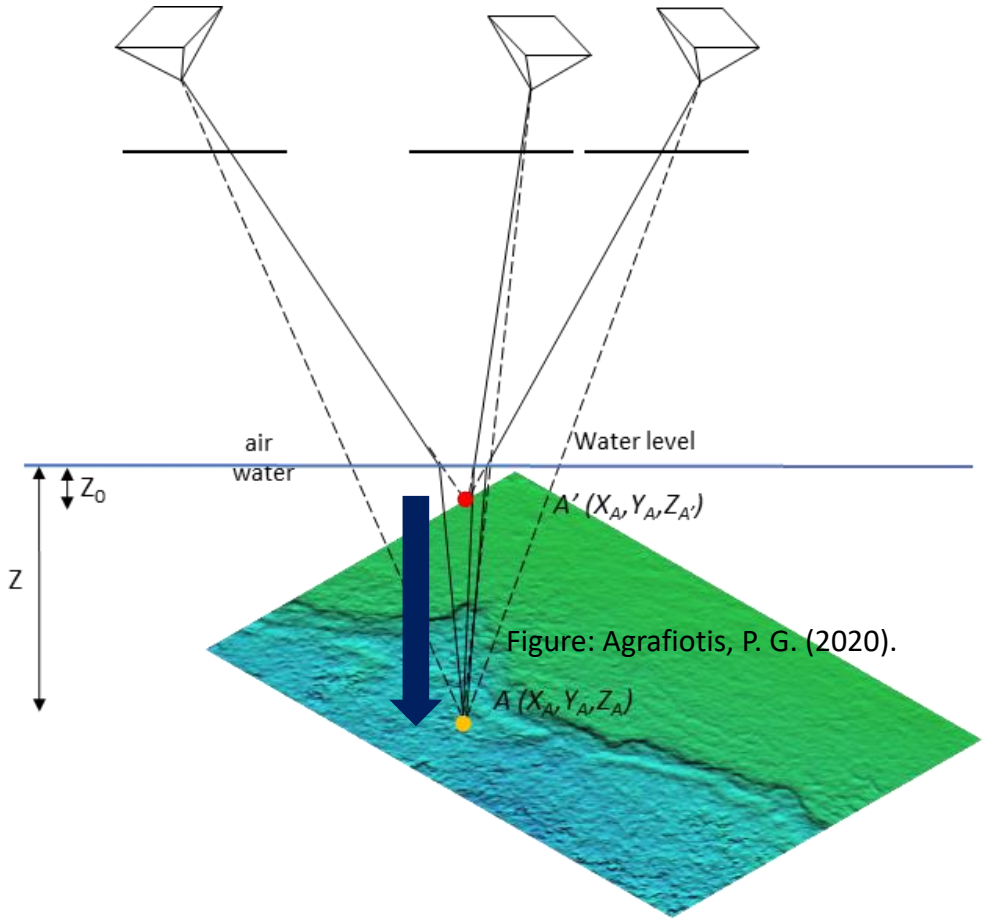


Figure: Agrafiotis, P. G. (2020).

Agrafiotis et al., 2019: $$f(Z_0) = \sum_{n=1}^{N} (a_n + \hat{a}_n)\, k(Z_0,\, Z_{0n}) + b$$

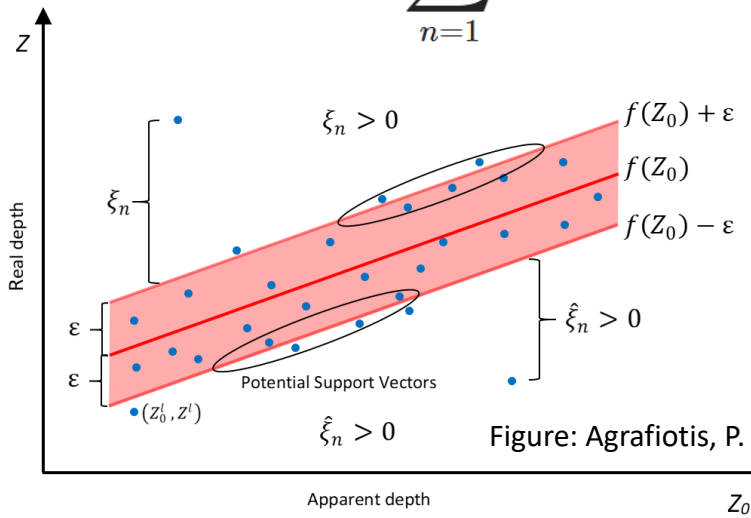


Figure: Agrafiotis, P. G. (2020).

References: Agrafiotis, P., Skarlatos, D., Georgopoulos, A., & Karantzalos, K. (2019). DepthLearn: learning to correct the refraction on point clouds derived from aerial imagery for accurate dense shallow water bathymetry based on SVMs-fusion with LiDAR point clouds. *Remote Sensing*, *11*(19), 2225.

Agrafiotis, P. G. (2020). Image-based bathymetry mapping for shallow waters., PhD Thesis, National Technical University of Athens

Agrafiotis, P., Karantzalos, K., Georgopoulos, A., & Skarlatos, D. (2021). Learning from Synthetic Data: Enhancing Refraction Correction Accuracy for Airborne Image-Based Bathymetric Mapping of Shallow Coastal Waters, *PFG–Journal of Photogrammetry, Remote Sensing and Geoinformation Science, 144, doi:* 10.1007/s41064-021-00144-1

*1st Prize in the GeomaticsOnTheMove contest 2020 Awarded by the European GNSS Agency (GSA) - Europa EU

Vertical (depth) Errors [1]

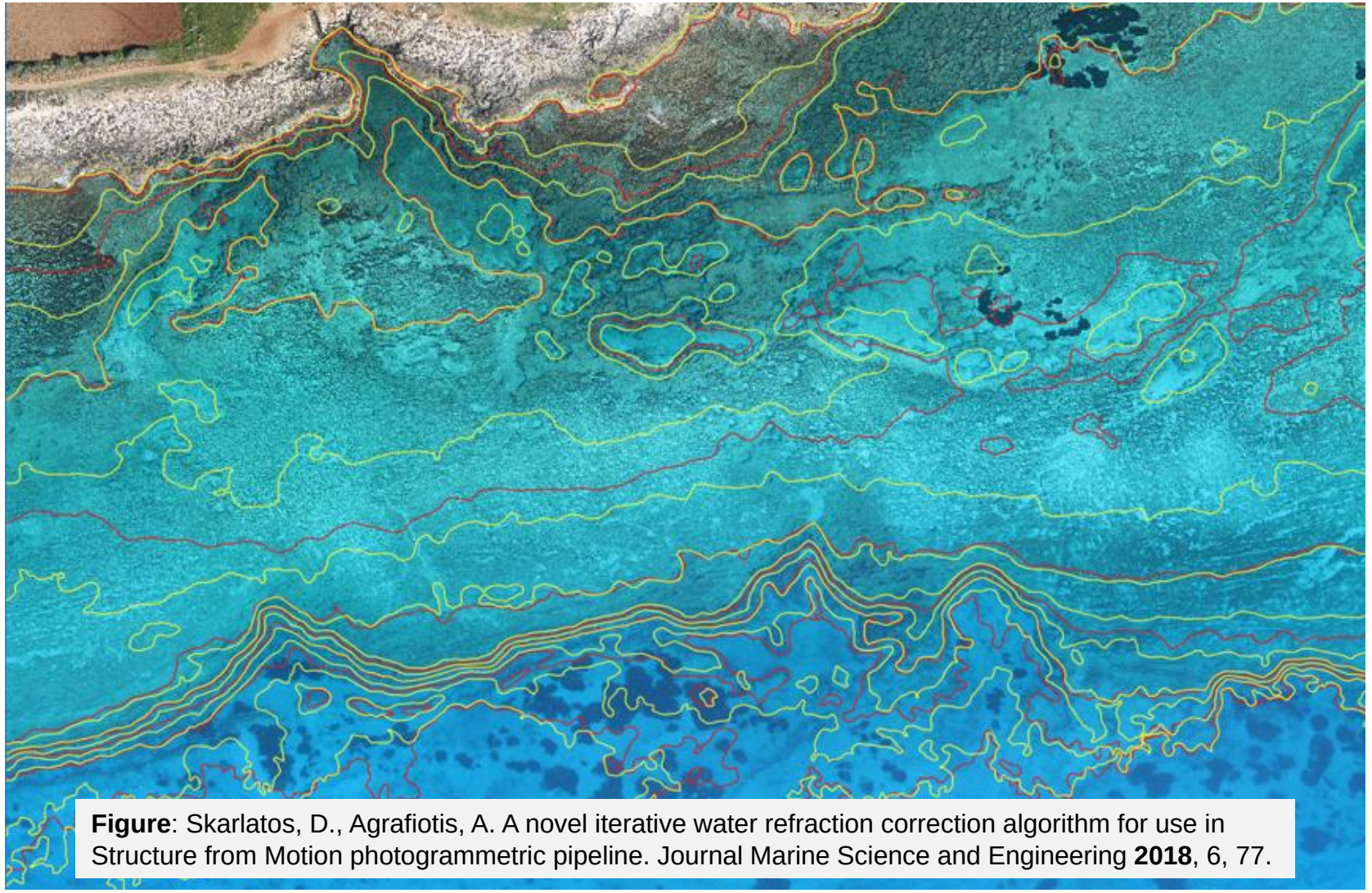
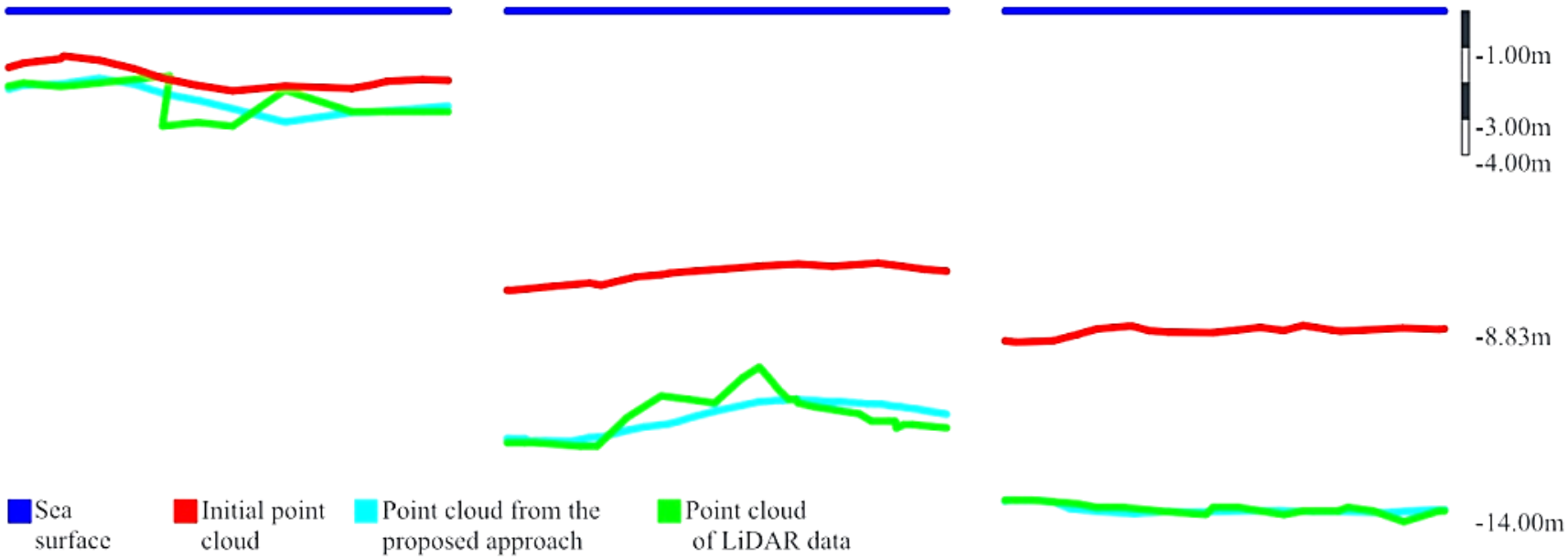


Figure: Skarlatos, D., Agrafiotis, A. A novel iterative water refraction correction algorithm for use in Structure from Motion photogrammetric pipeline. Journal Marine Science and Engineering **2018**, 6, 77.

Red
Erroneous
No correction applied

Yellow
Correction applied

Vertical (depth) Errors [2]



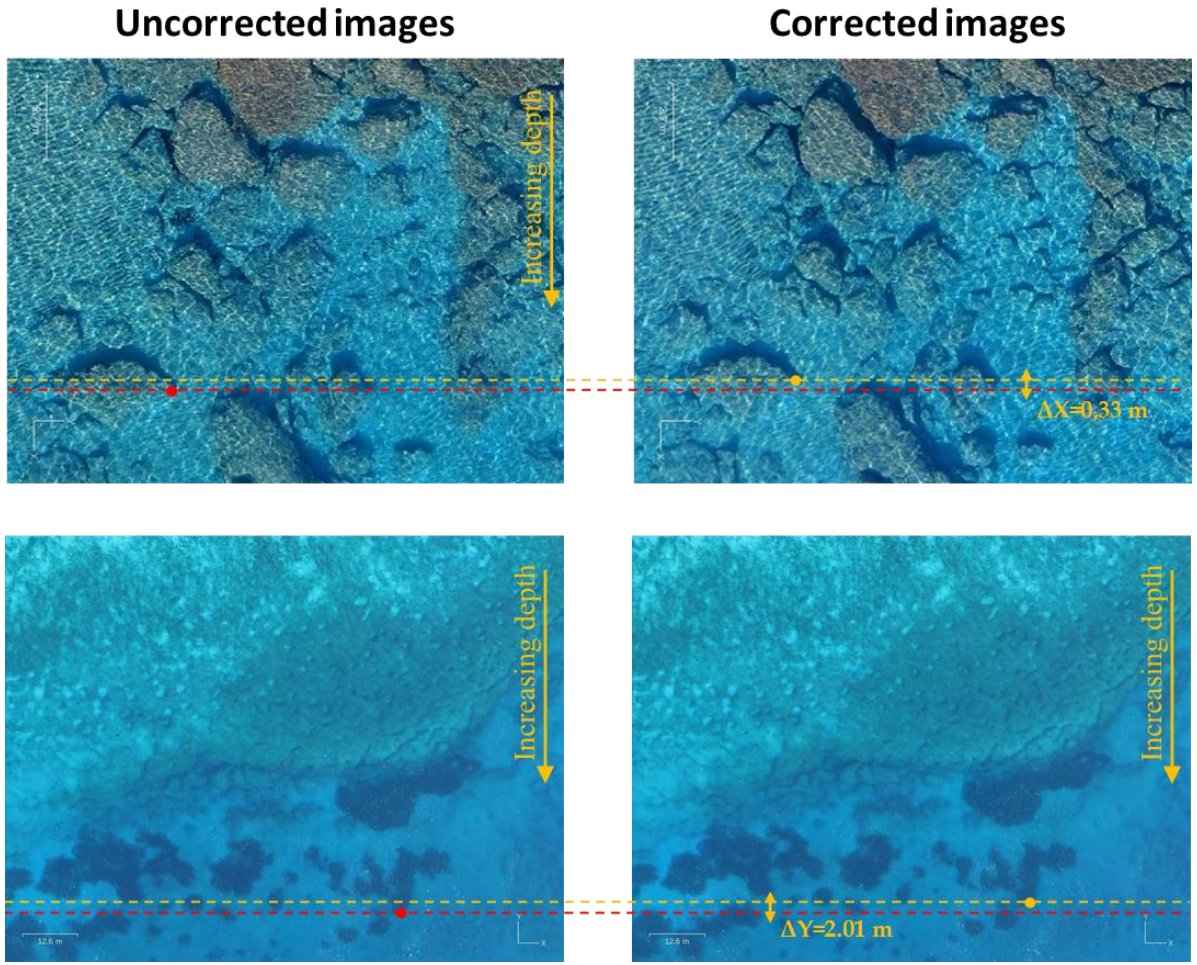
Red
Erroneous
No correction applied

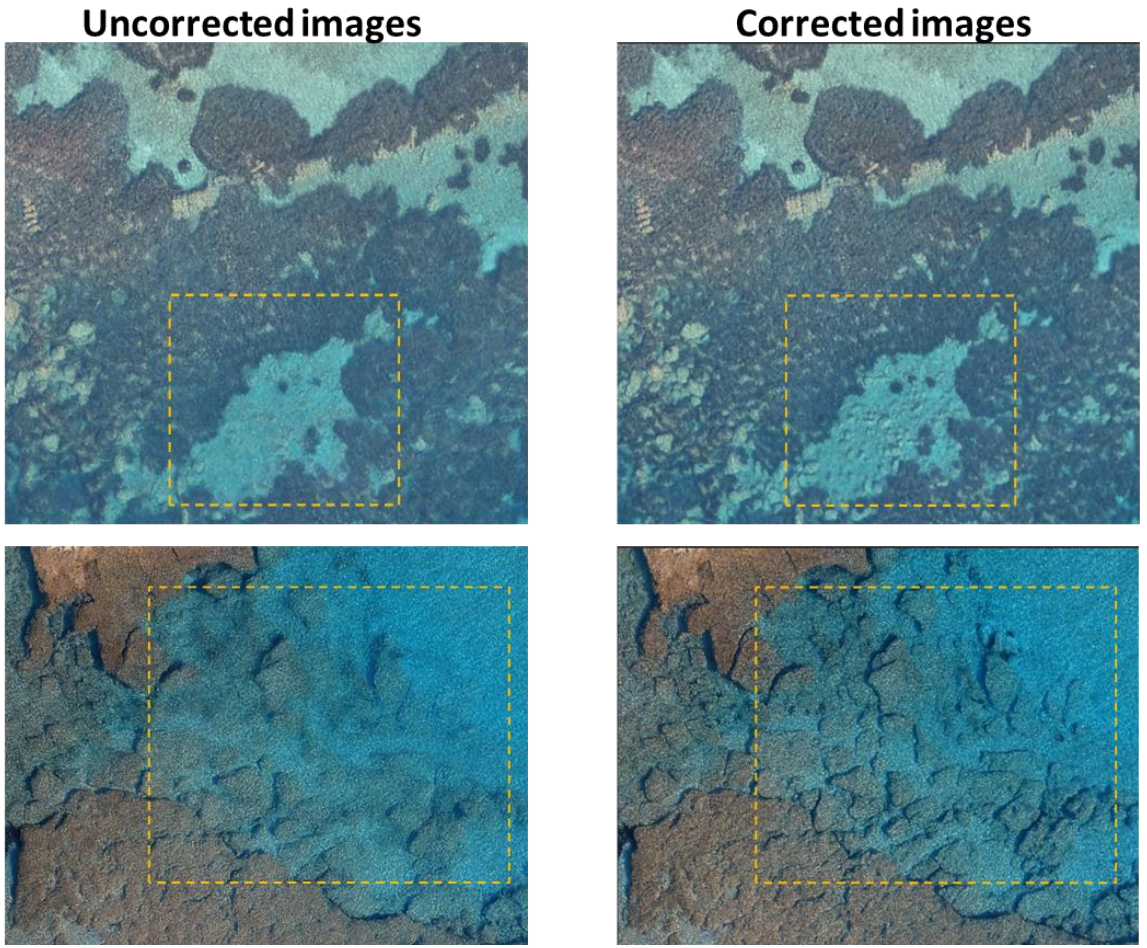
Cyan
correction applied

Green
LiDAR

Figure: Agrafiotis, P., Skarlatos, D., Georgopoulos, A., & Karantzalos, K. (2019). Shallow Water Bathymetry Mapping from UAV Imagery Based on Machine Learning. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *4210*, 9-16.

Horizontal errors/Quality issues





Figures: Agrafiotis, P., Karantzalos, K., Georgopoulos, A., & Skarlatos, D. (2020). Correcting image refraction: Towards accurate aerial image-based bathymetry mapping in shallow waters. *Remote Sensing*, *12*(2), 322.

Examples – Real world applications [1]

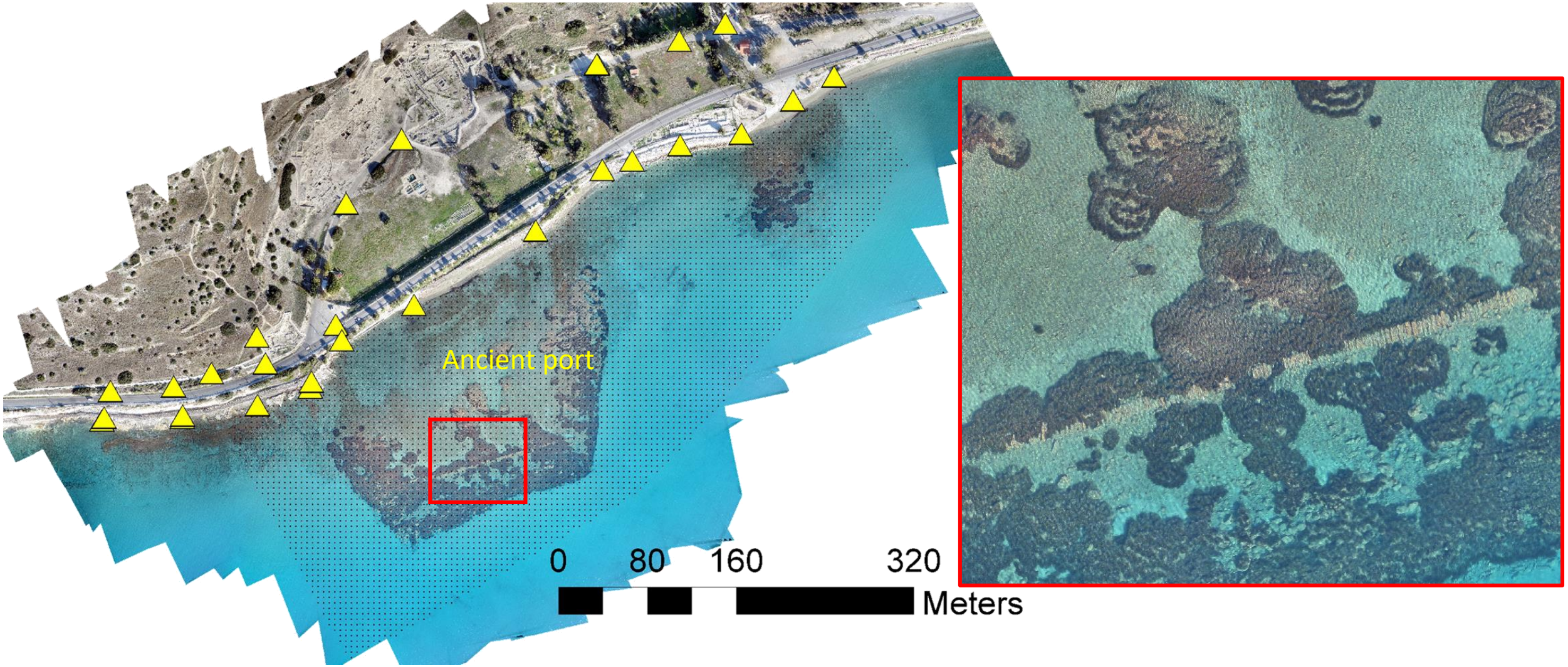


Figure: Photogrammetric Vision Lab, Cyprus University of Technology

Examples – Real world applications [2]

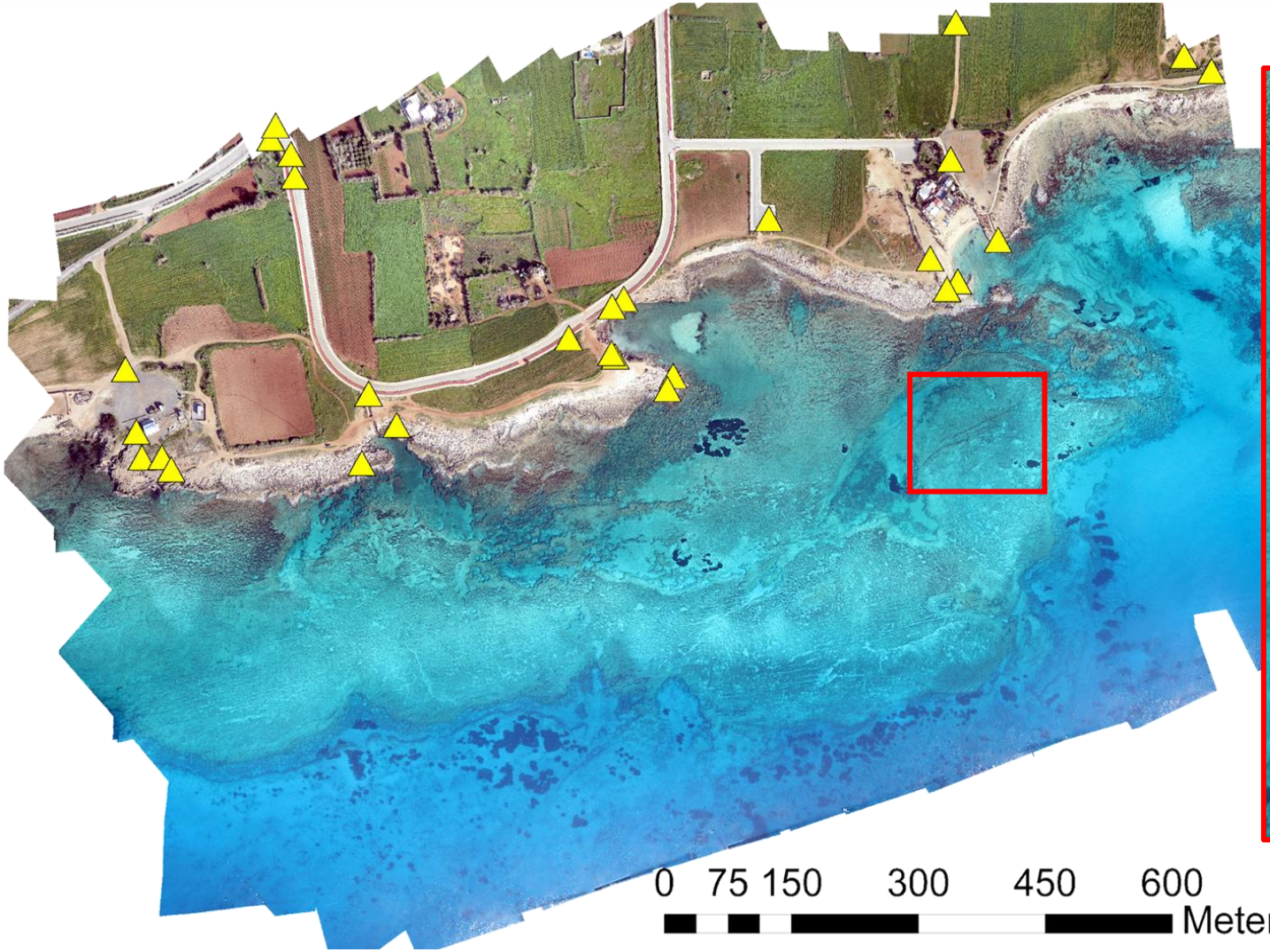


Figure: Photogrammetric Vision Lab, Cyprus University of Technology

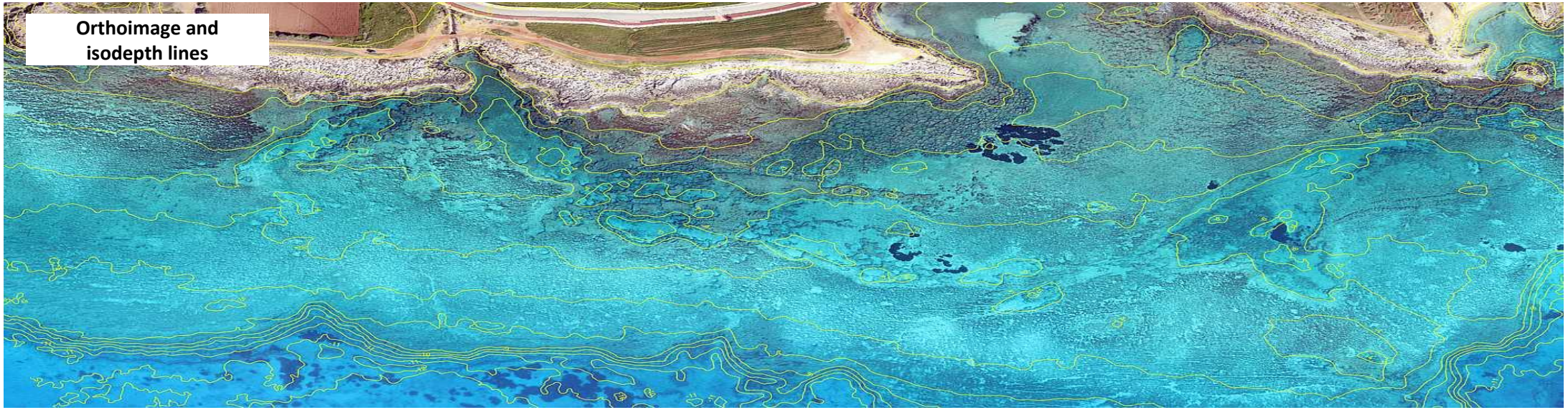
Examples – Real world applications [3]

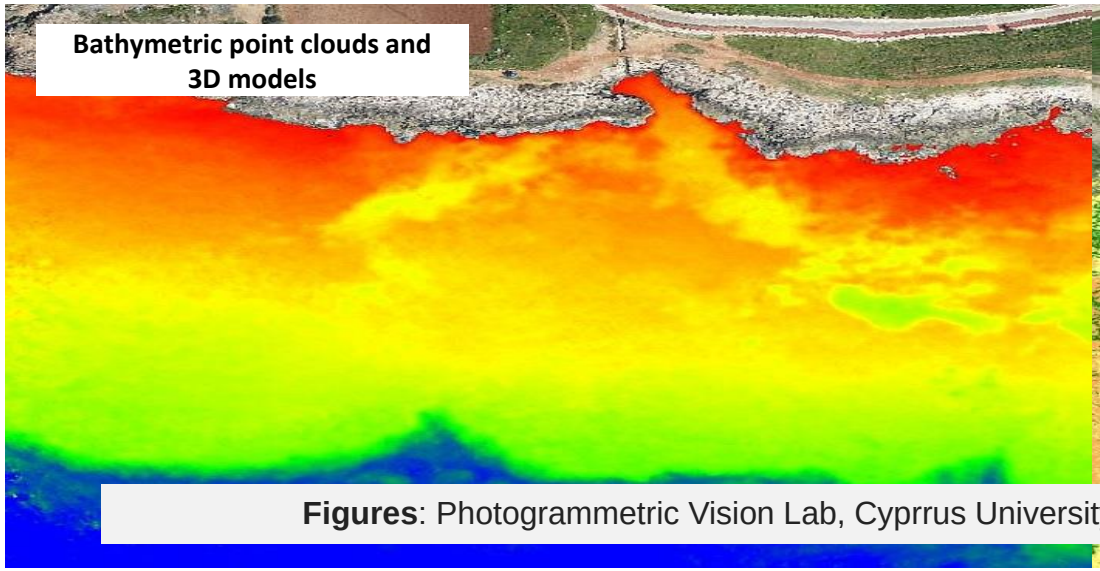
Figure: Photogrammetric Vision Lab, Cyprus University of Technology

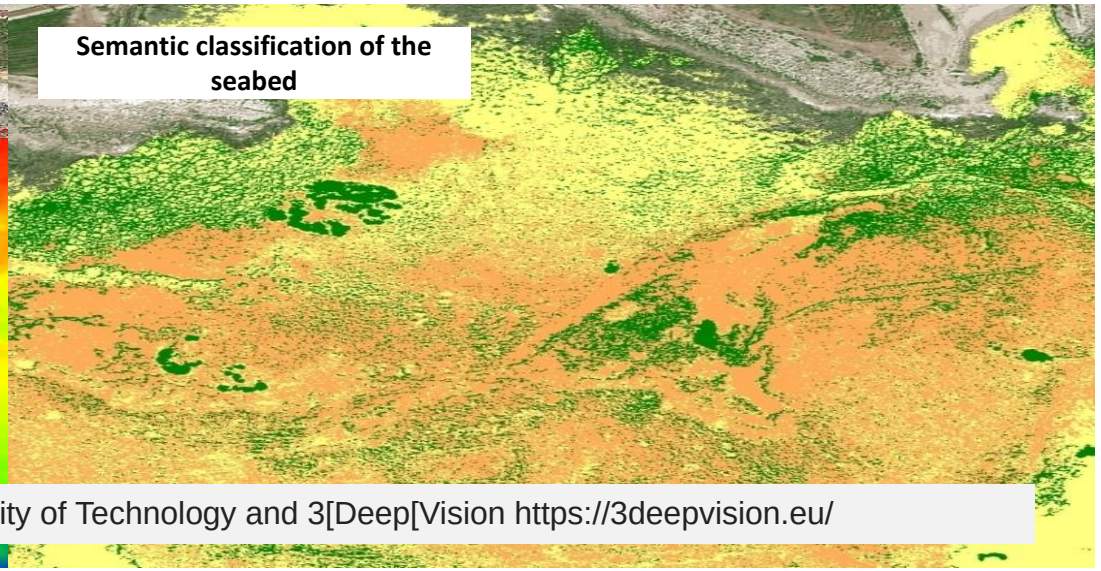
Examples – Real world applications [4]

Figure: Photogrammetric Vision Lab, Cyprus University of Technology

Examples – Real world applications [5]







Figures: Photogrammetric Vision Lab, Cyprrus University of Technology and 3[Deep[Vision https://3deepvision.eu/

Two media bathymetric mapping - Sum up

Multi-media photogrammetry - refraction correction is necessary!

- **Passive method exploiting the geometry of the scenes**
- **Requires texture to perform SfM-MVS**
- **Measured depth through triangulation & Delivers colour information**
- **Delivers high point density in shallow water areas**
- **Deliver seamless DEMs, 3D models and orthoimages with texture**
- **Max depth ~ 1 Secchi**