Two media bathymetric mapping for shallow waters - Learning from synthetic data and beyond

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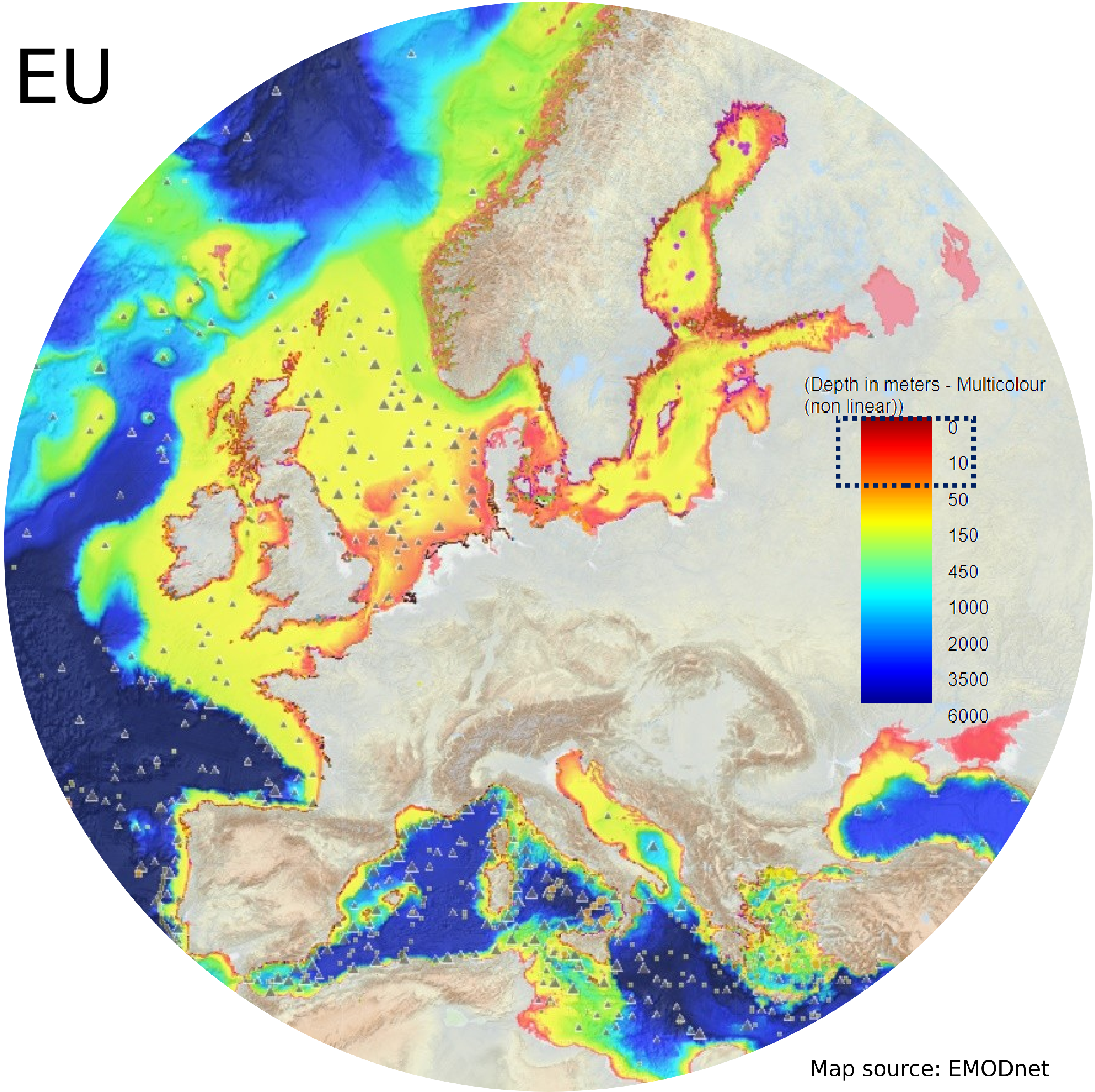
NTUA PHOTOGRAMMETRIC COMPUTER VISION

3[Deep]Vision
Research Group

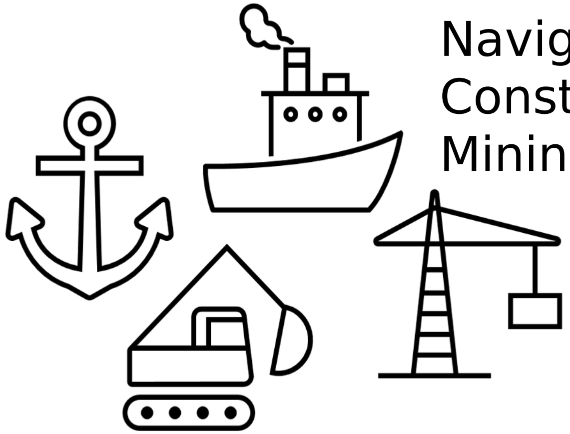
Shallow waters in EU



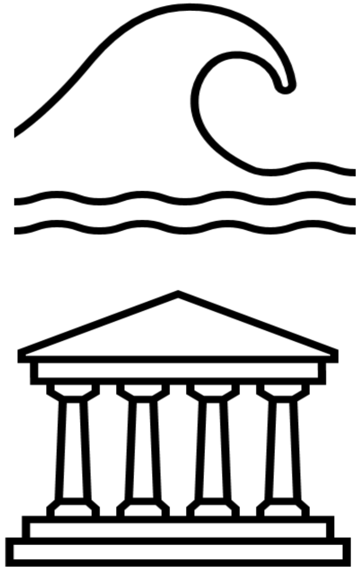
2.5% of the seabed is “shallow”
(<20-25m depth) excluding lakes

Map source: EMODnet

Seabed mapping for shallow waters



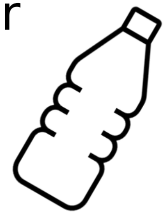
Navigation
Constructions
Mining

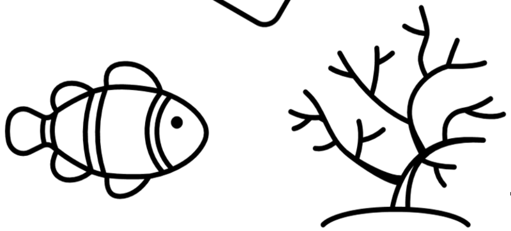


Tourism

Cultural Heritage

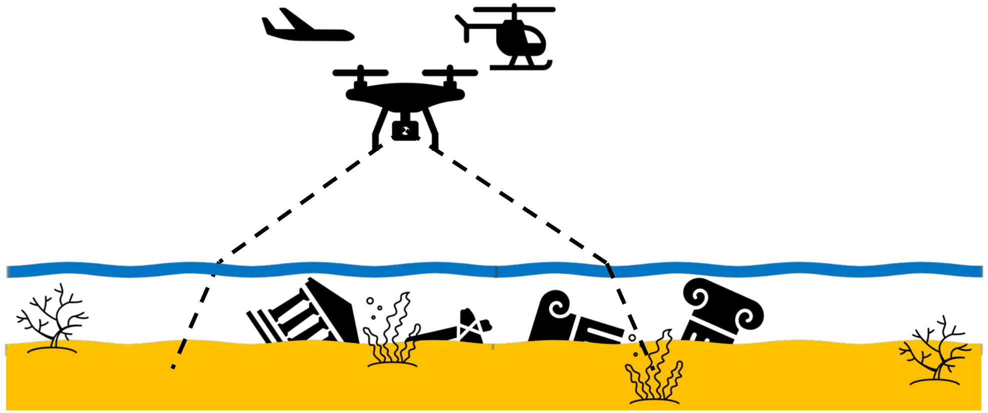
Marine litter detection



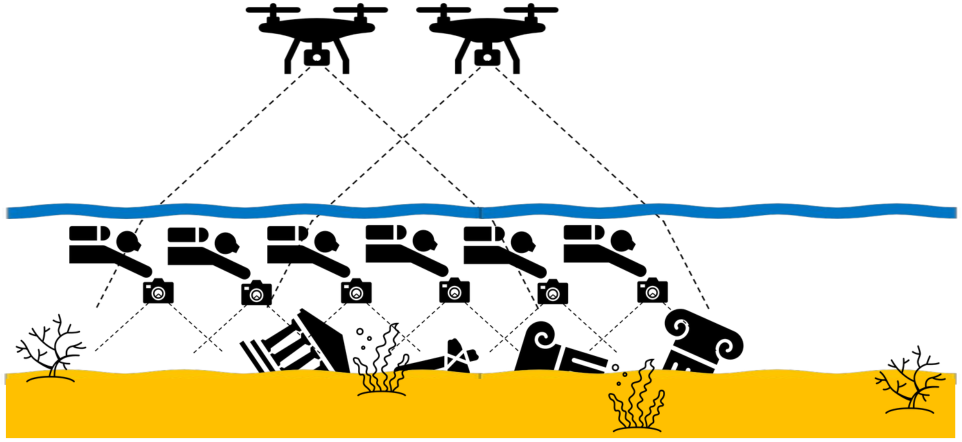


Marine animal forests

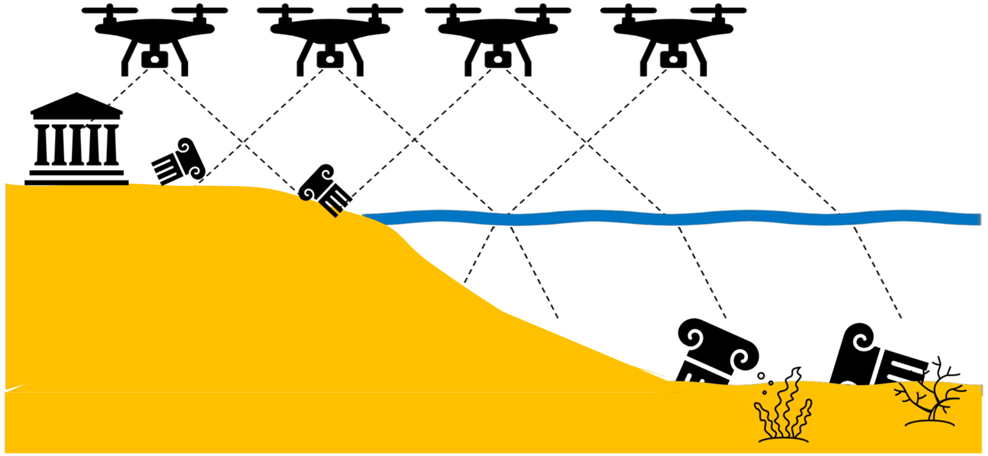
Why airborne multi-media photogrammetry?



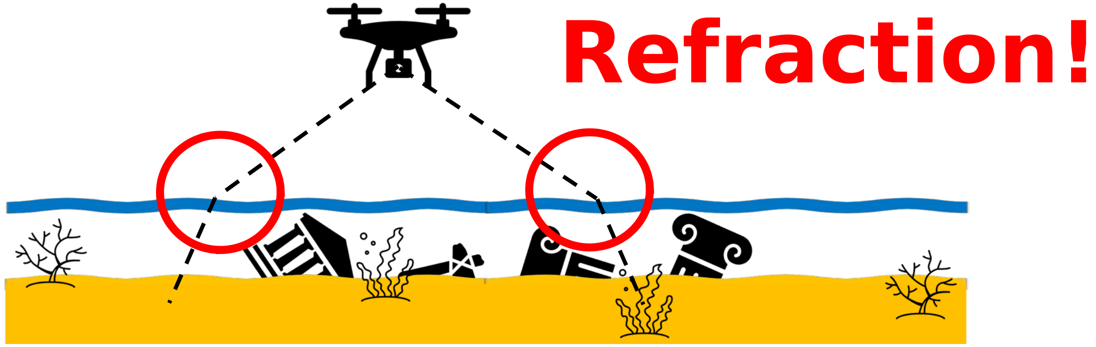
Mapping very shallow waters <1m depth



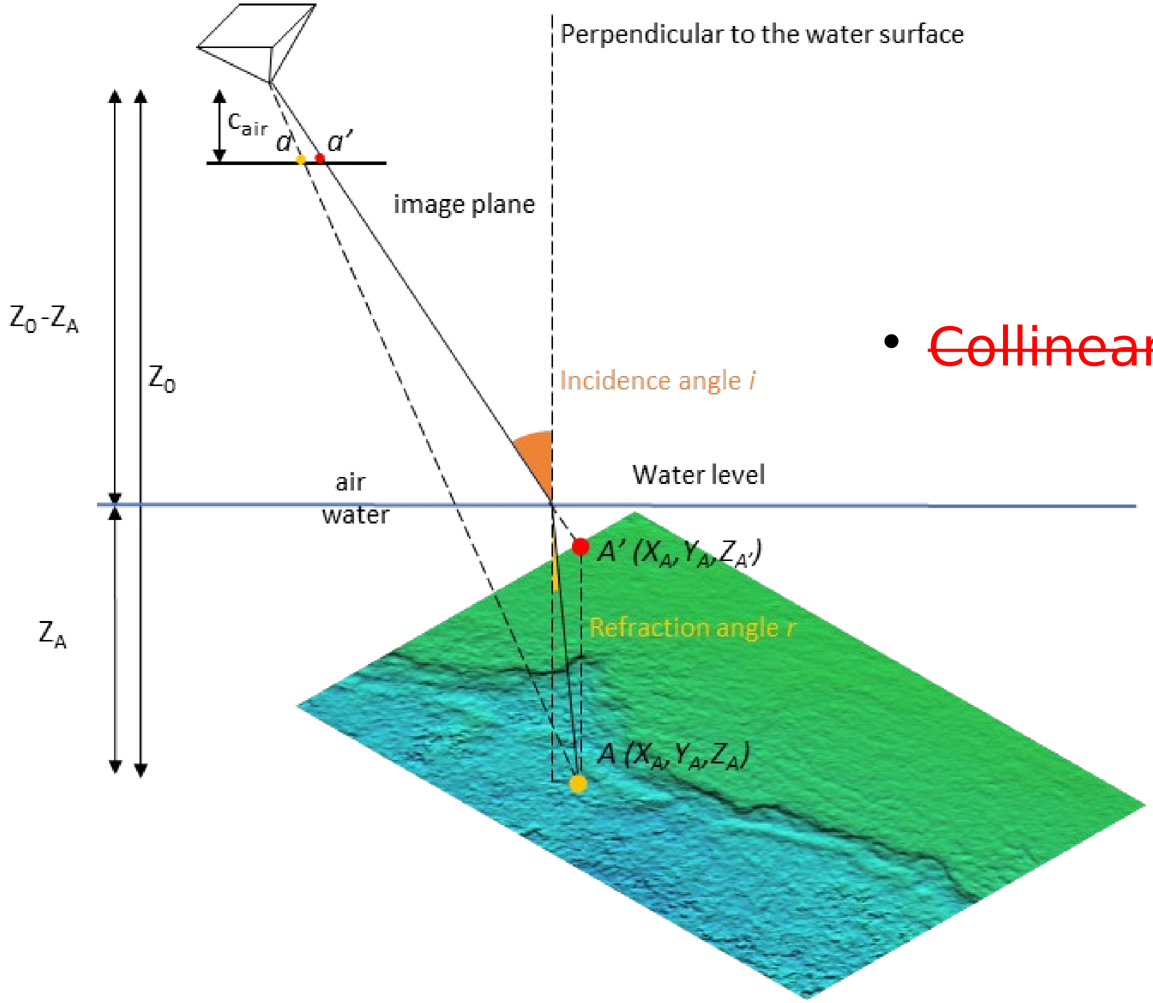
Mapping very shallow waters >1m depth<20m depth with less effort & lower resolution



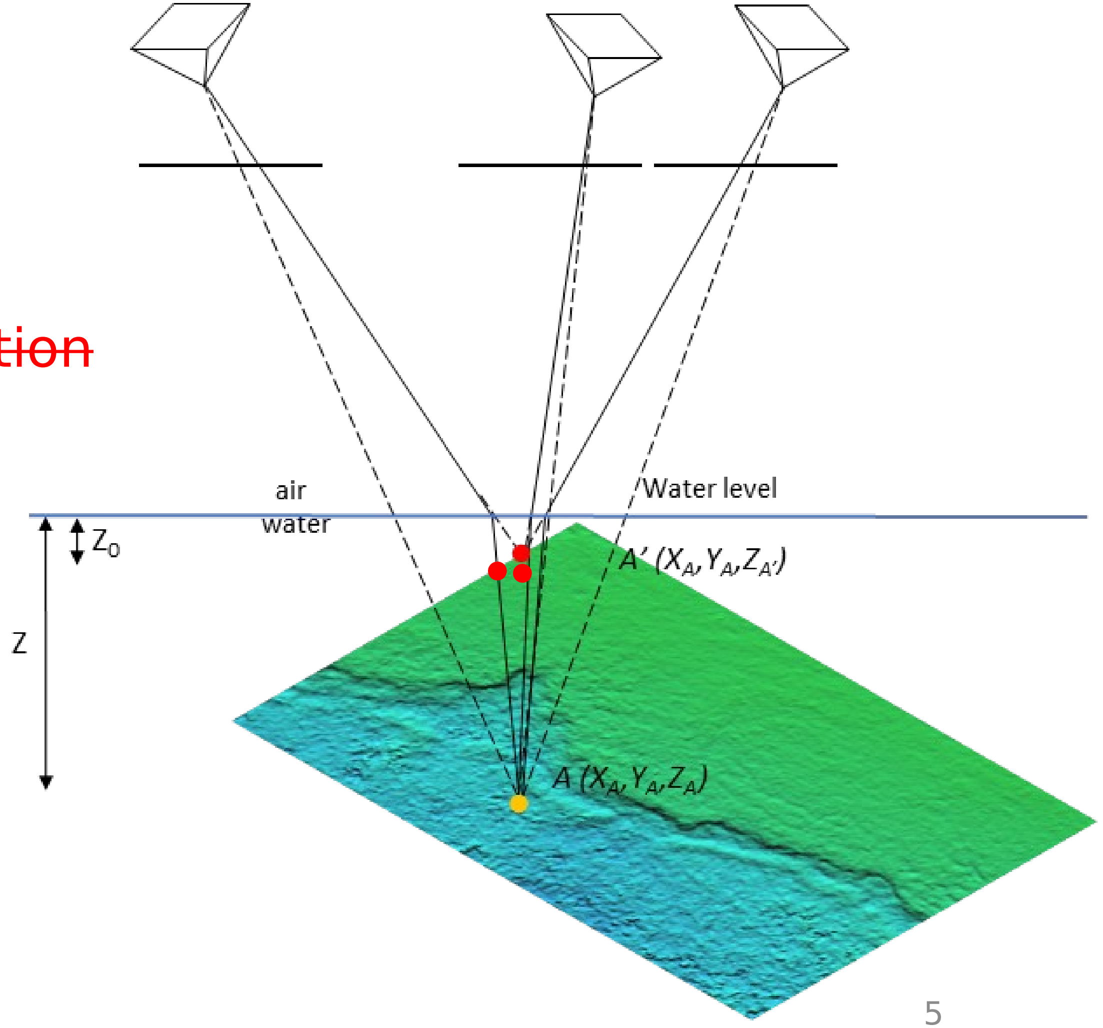
Mapping seamlessly dry and water-covered areas



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



- ~~Collinearity condition~~



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

Multi-media Photogrammetry – Correction Basics

We cannot ignore the effects of refraction! We have to correct those!

Analytical correction:
Modification of the collinearity equation. (1950+)

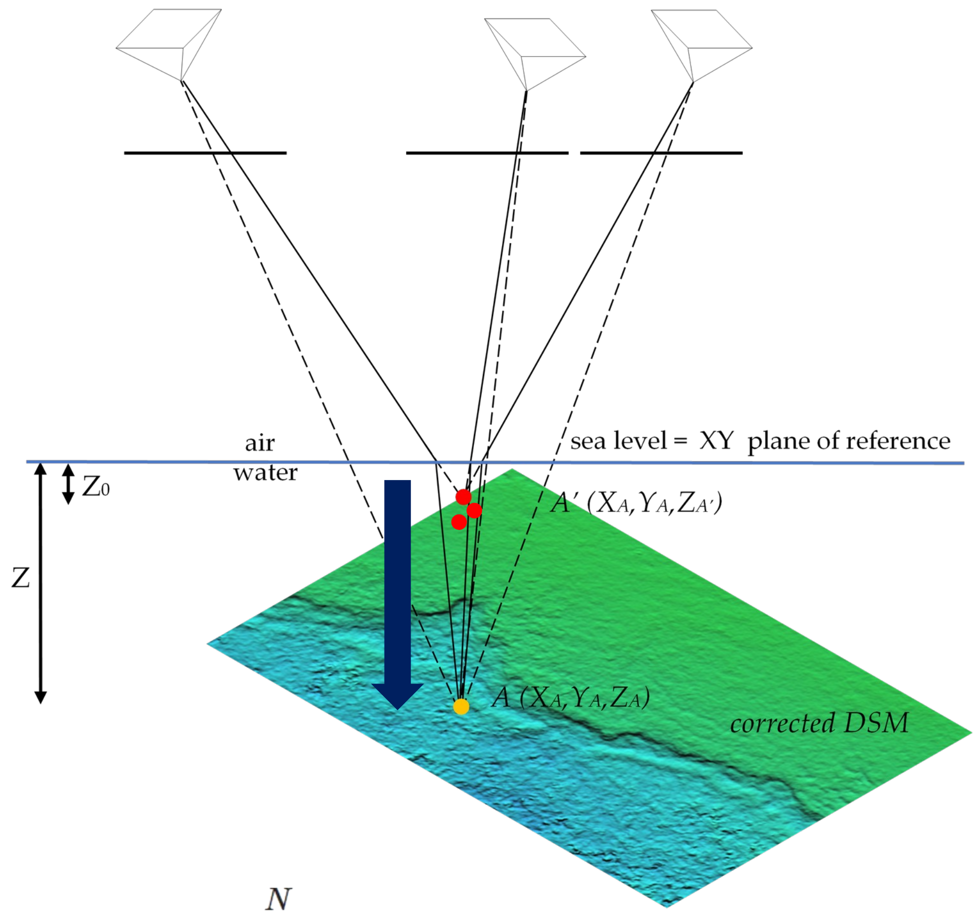
Image-space correction:
Re-projection of the original photo to correct the water refraction. (2018+)

Machine/Deep learning-based:

Depends on shallow or deep learning models that learn the underestimation of depths and predict the correct depth knowing only the apparent one. (2019+)

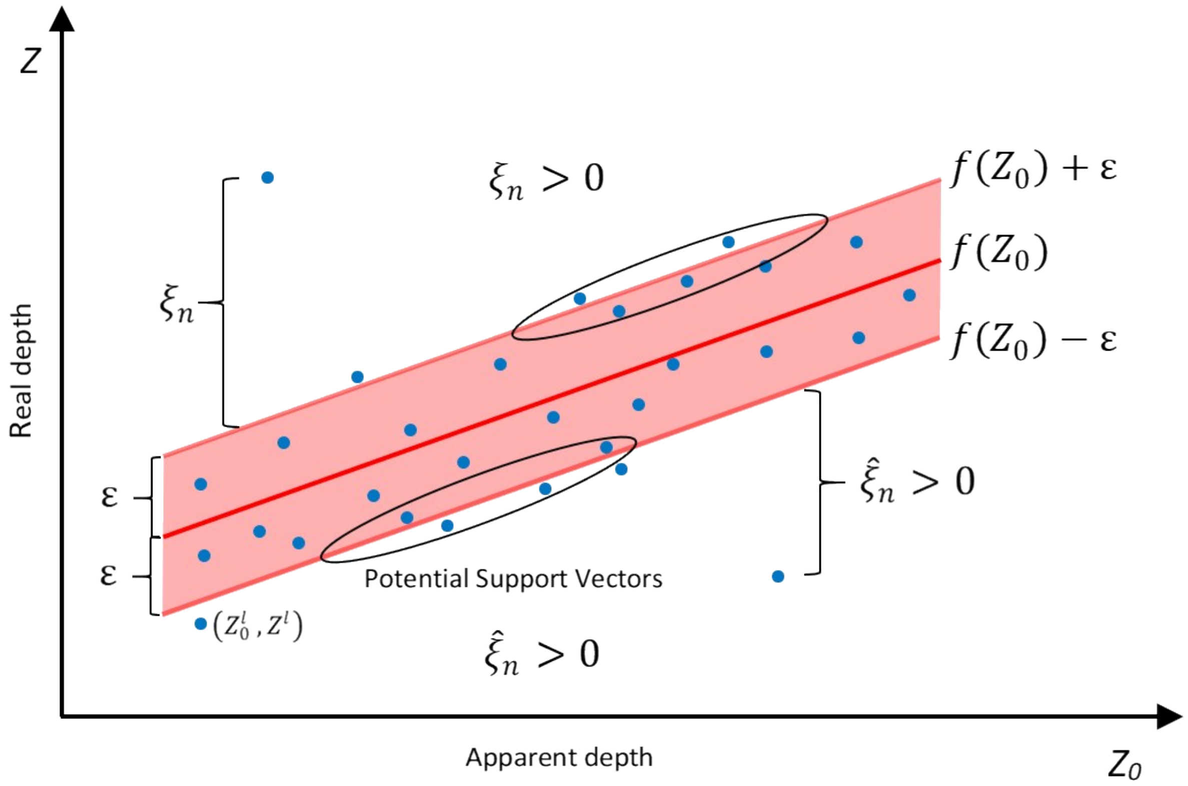
Depends on deep learning models (CNNs, FCNs etc.) that predict the depth based on the RGB+ information of the scene. (2020+)

Developed ML-based Correction (Agrafiotis et al., 2019, 2020, 2021)



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

(Agrafiotis et al., 2019)



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.

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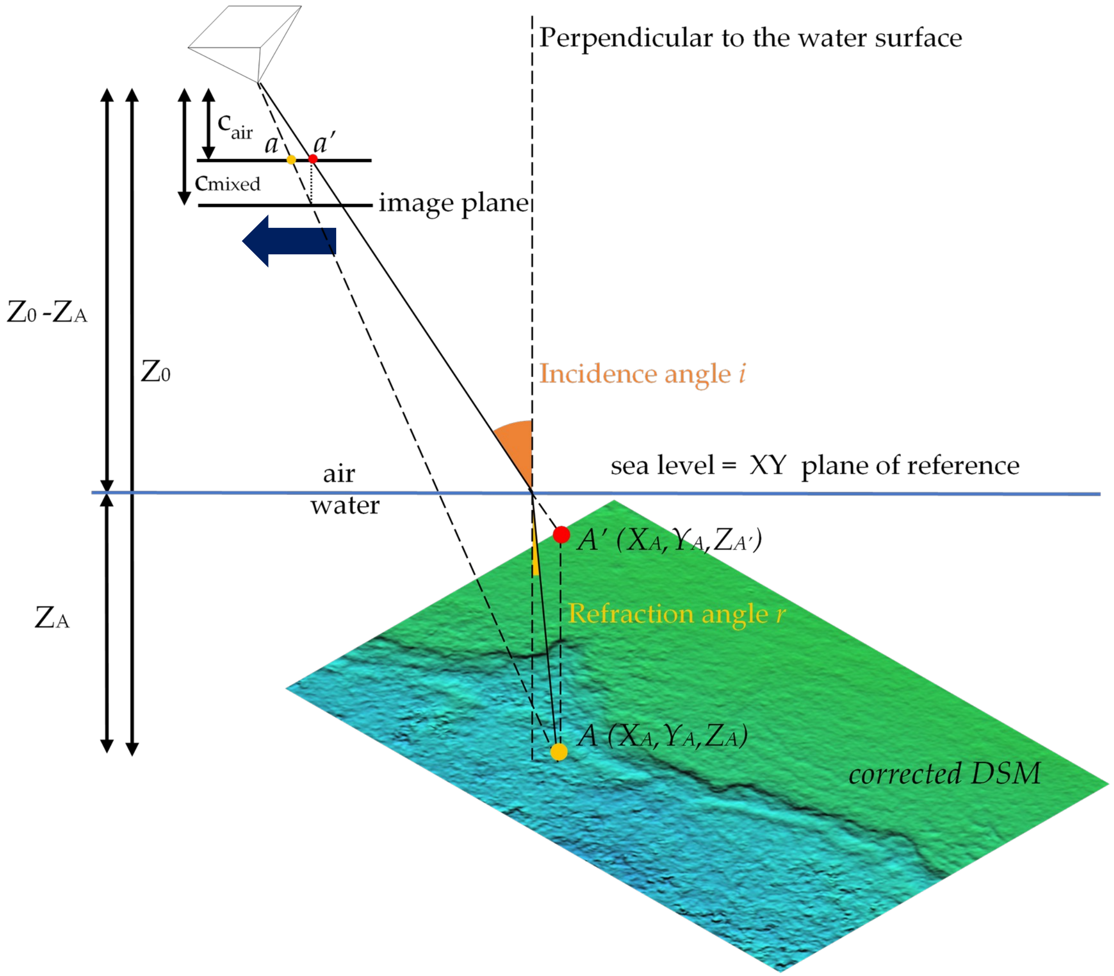
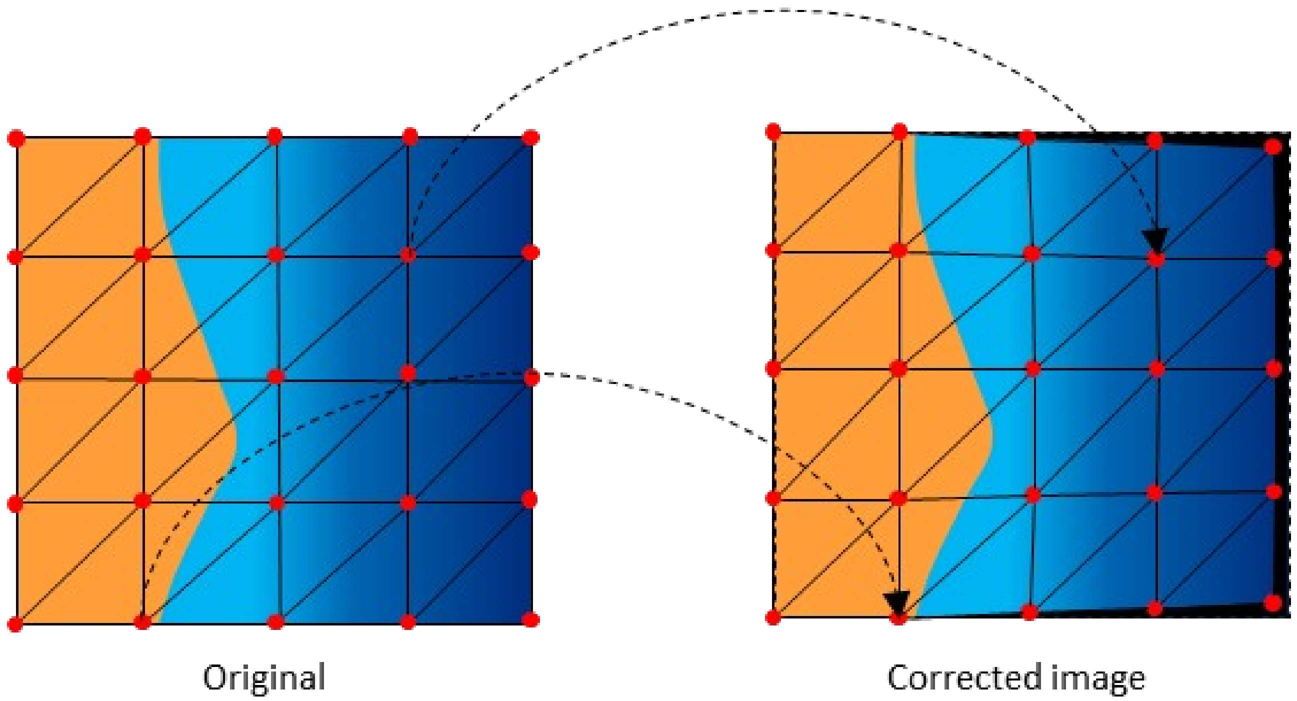
Developed image Correction (Skarlatos and Agrafiotis 2018, Agrafiotis et al., 2020)





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.

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Need for synthetic data

Known:

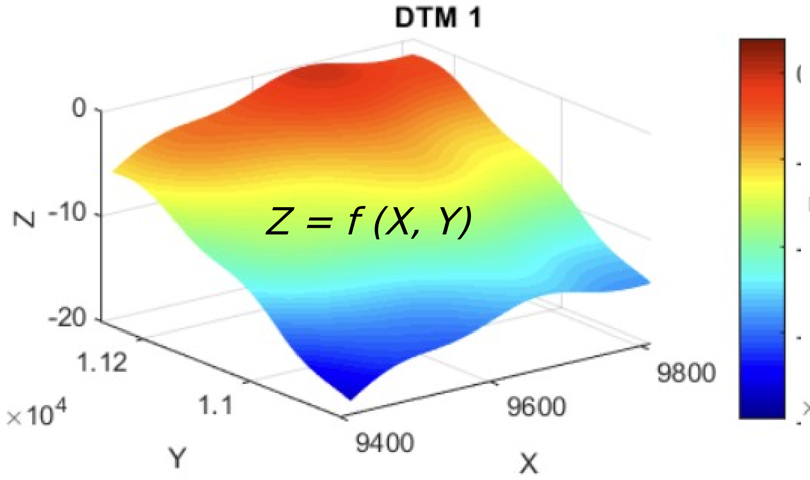
- Accuracy & reliability of depths
- EO & IO
- No errors and limitations in image matching caused by the visibility restrictions (turbidity, caustics, sun glint)
- No errors introduced by the wavy surface

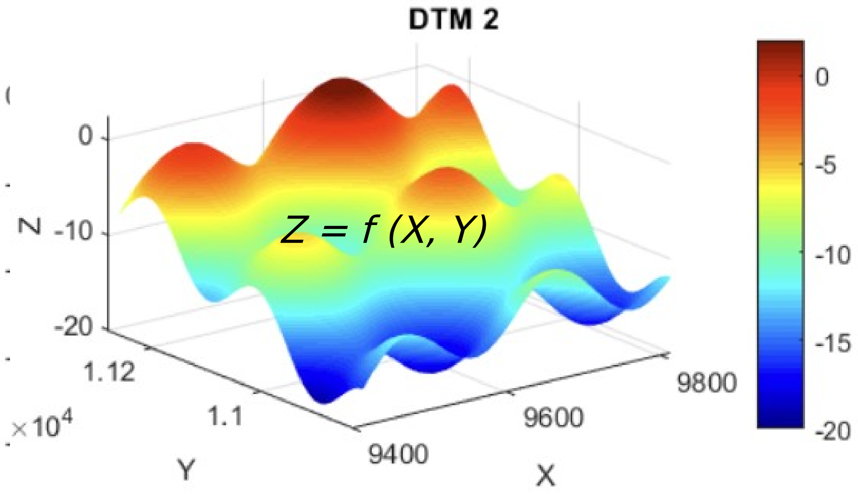
Unknown:

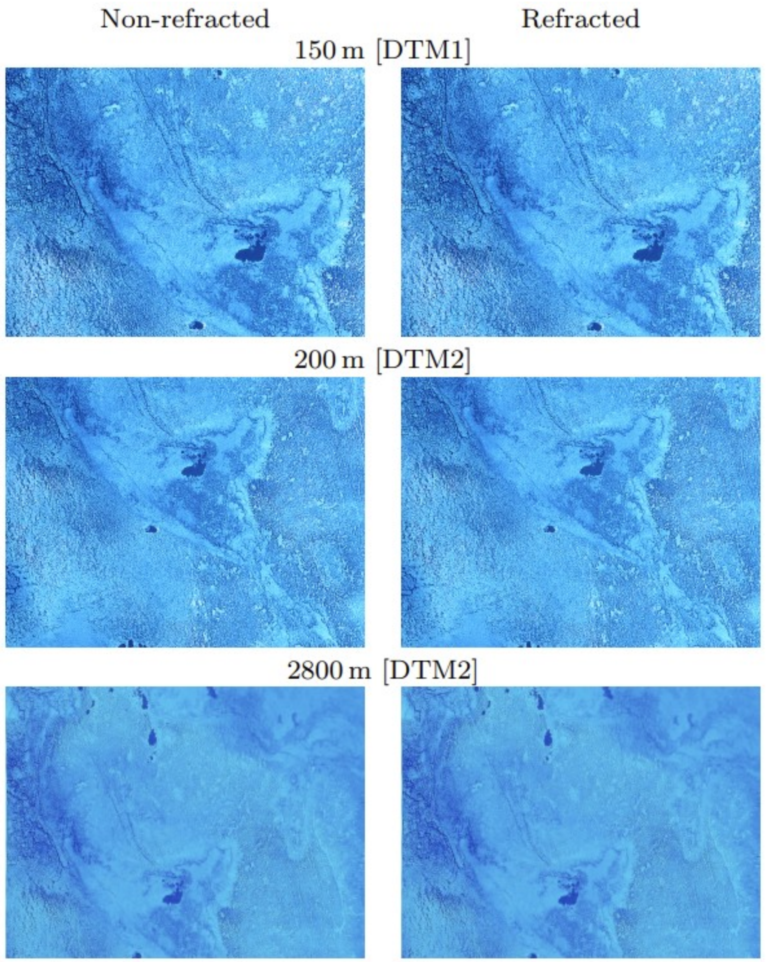
- **Refraction effect**

Generated synthetic data

- 2 DTMs
- 8 datasets
- Flying height from 150m-2800m
- Various sensors/flight patterns
- Camera constant from 3.6mm to 100.5mm
- Image dims 3000x4000 pixels to 26460x17004 pixels
- GSD 0.03 – 0.10m







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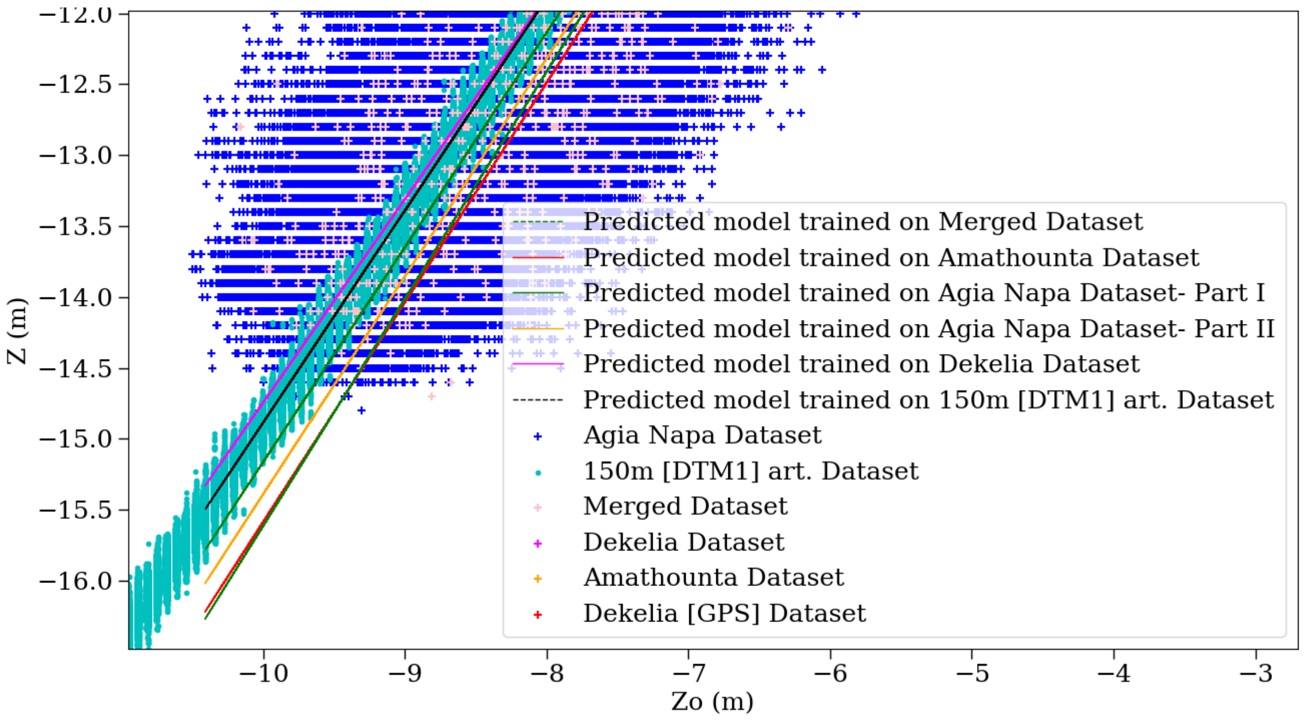
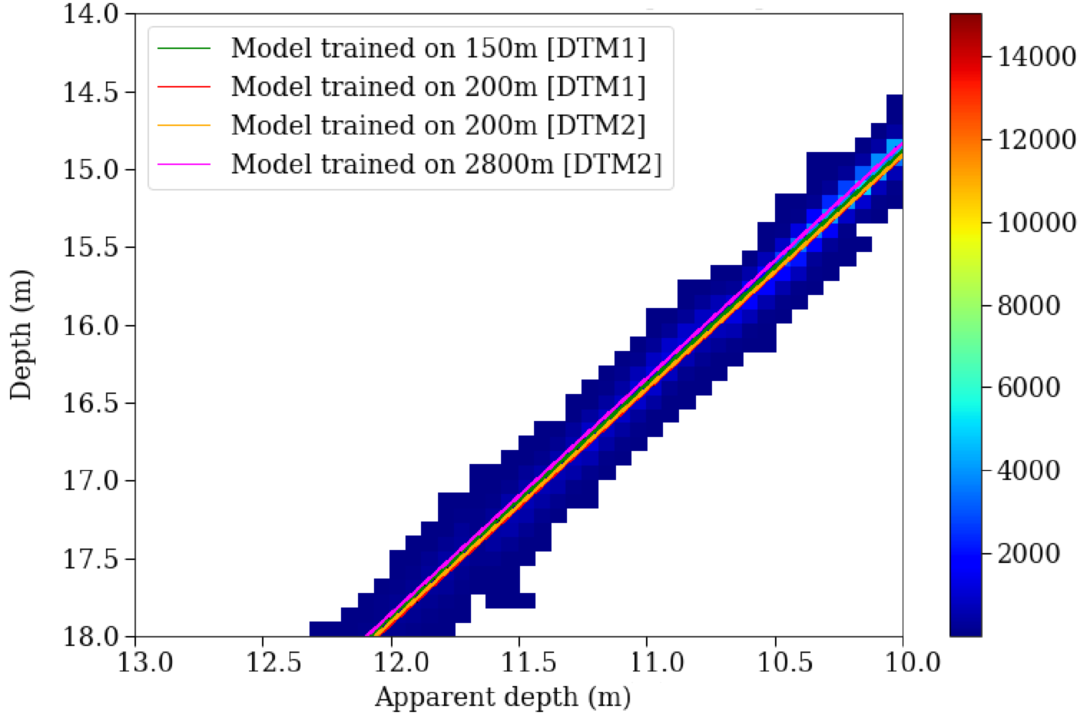
Learning from Synthetic Data

Training the SVR models only on synthetic data



Models trained on **real** data
(Agrafiotis et al., 2019)



Models trained on **synthetic** data
(Agrafiotis et al., 2021)

Increased accuracy

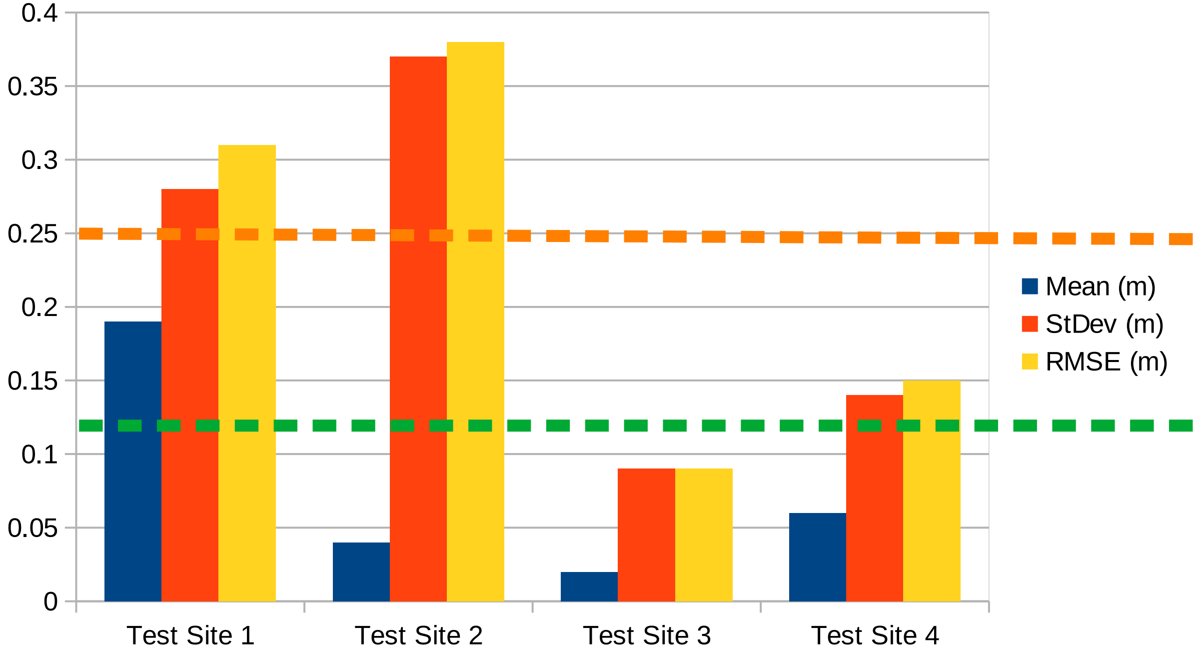
Testing on synthetic data

UAV-borne: RMSE of 3.34m reduced to **0.09m**!
Aircraft-borne: RMSE of 6.38m reduced to **0.20m**!

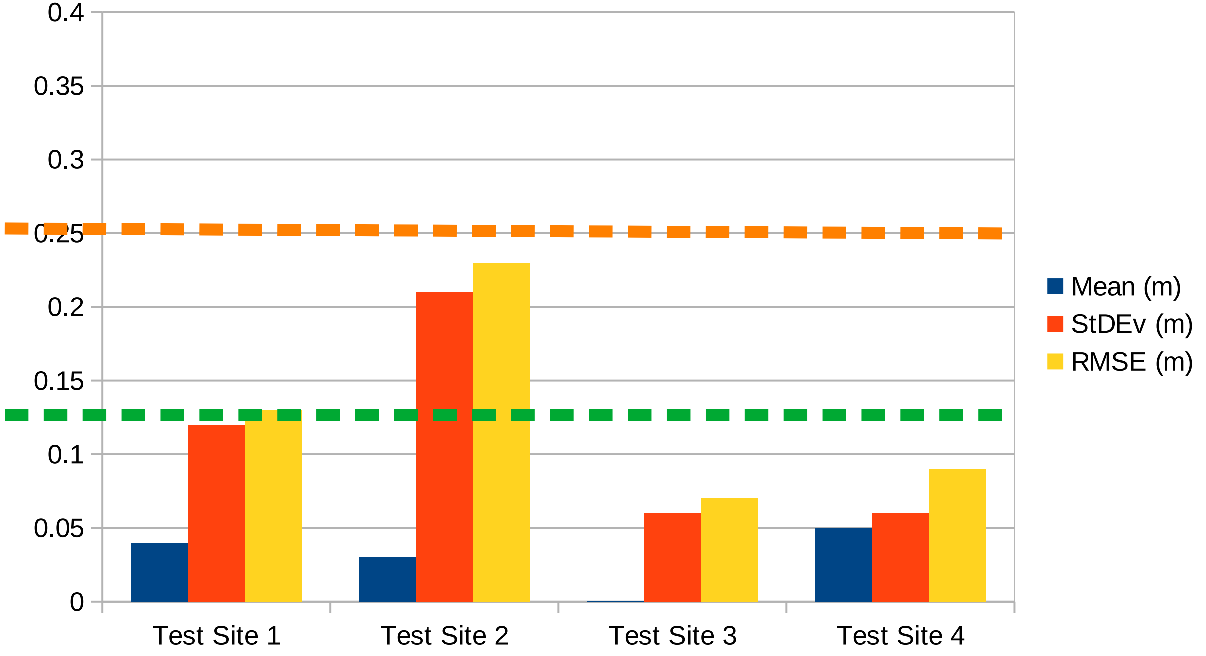
✓**IHO Exclusive Order***
✓**IHO Special Order***

Testing on real data (reduction of the RMSE ~50%)

Model trained on **real** data



Model trained on **synthetic** data



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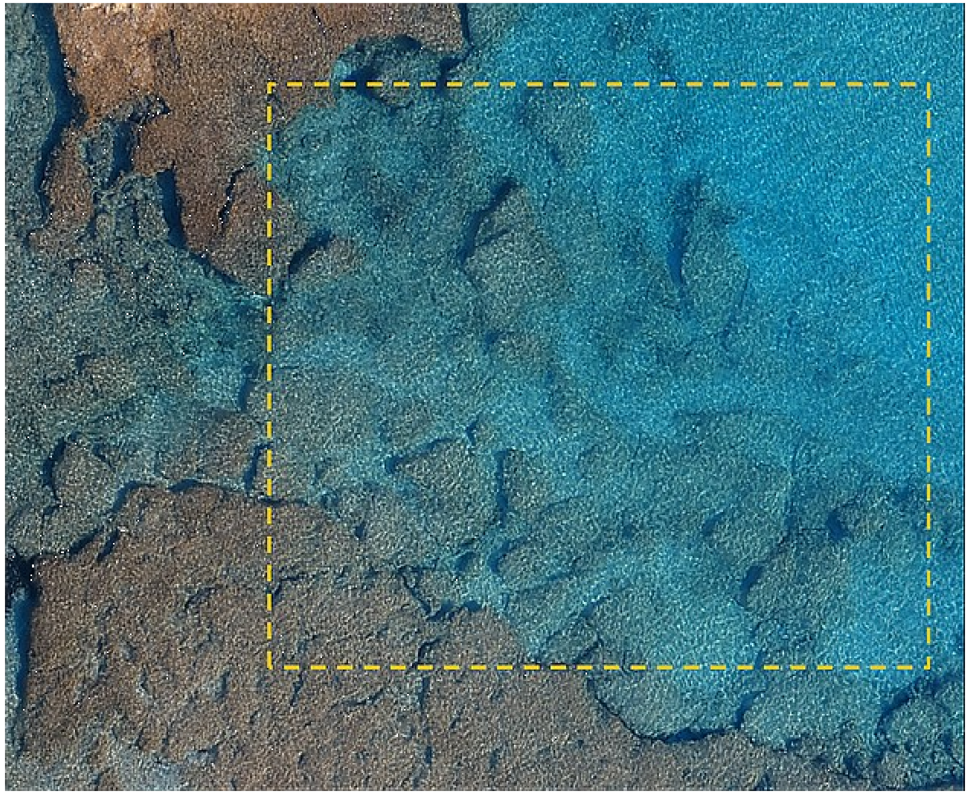
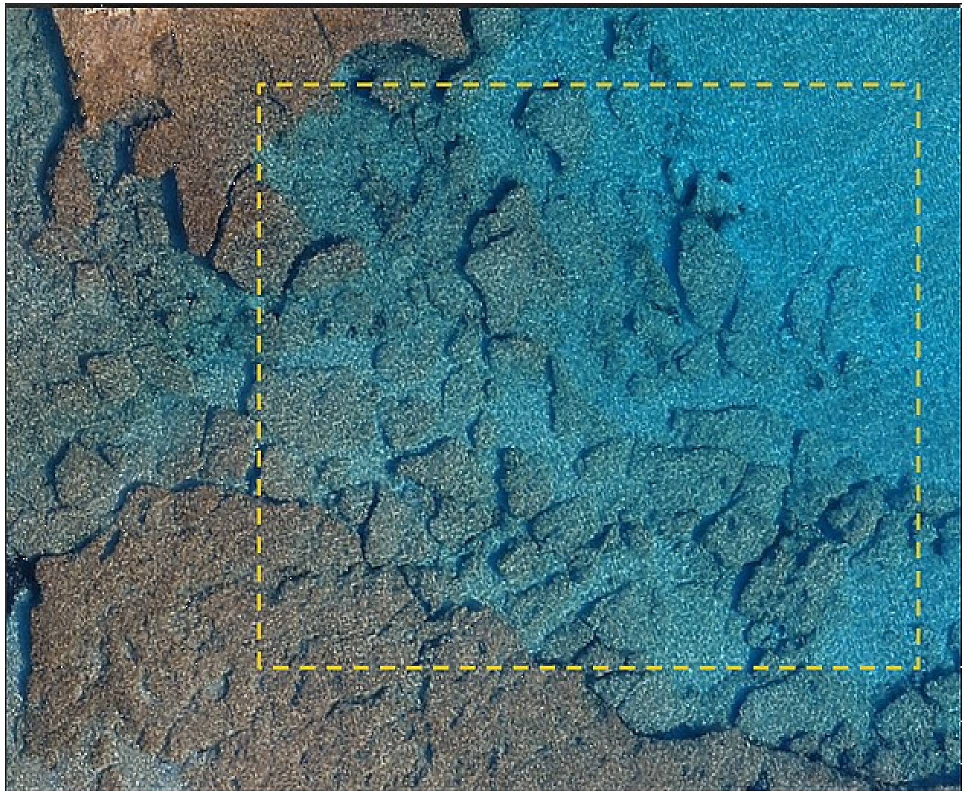
Improvements on the textures and orthoimages

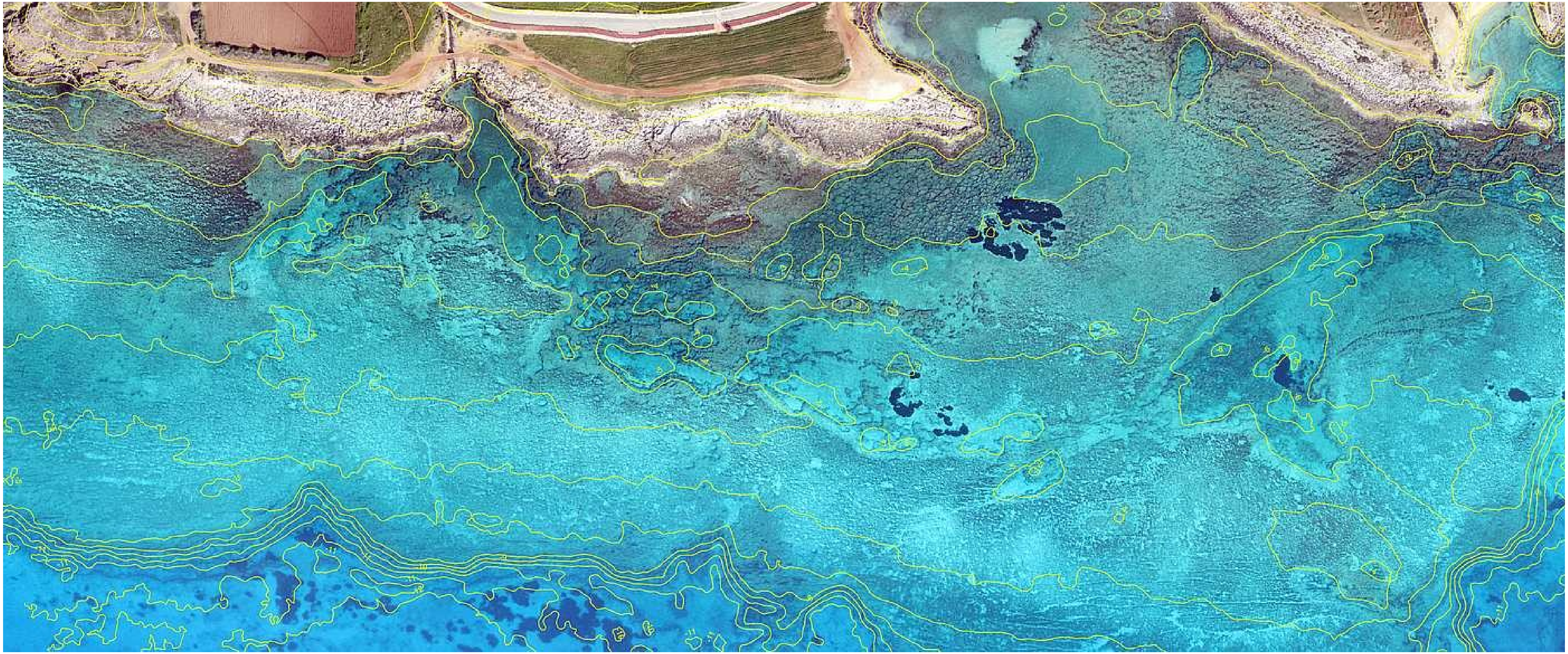
Uncorrected images



Corrected images

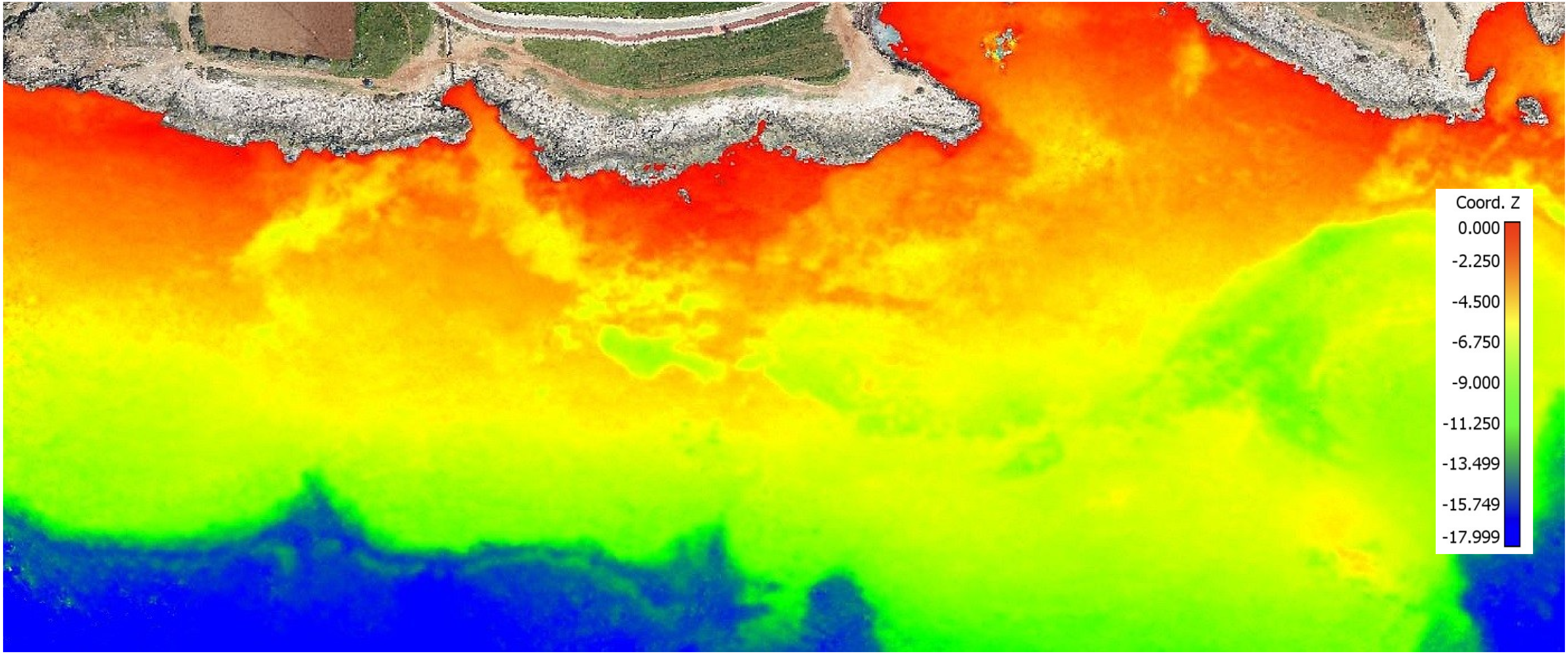


Examples – Real world applications



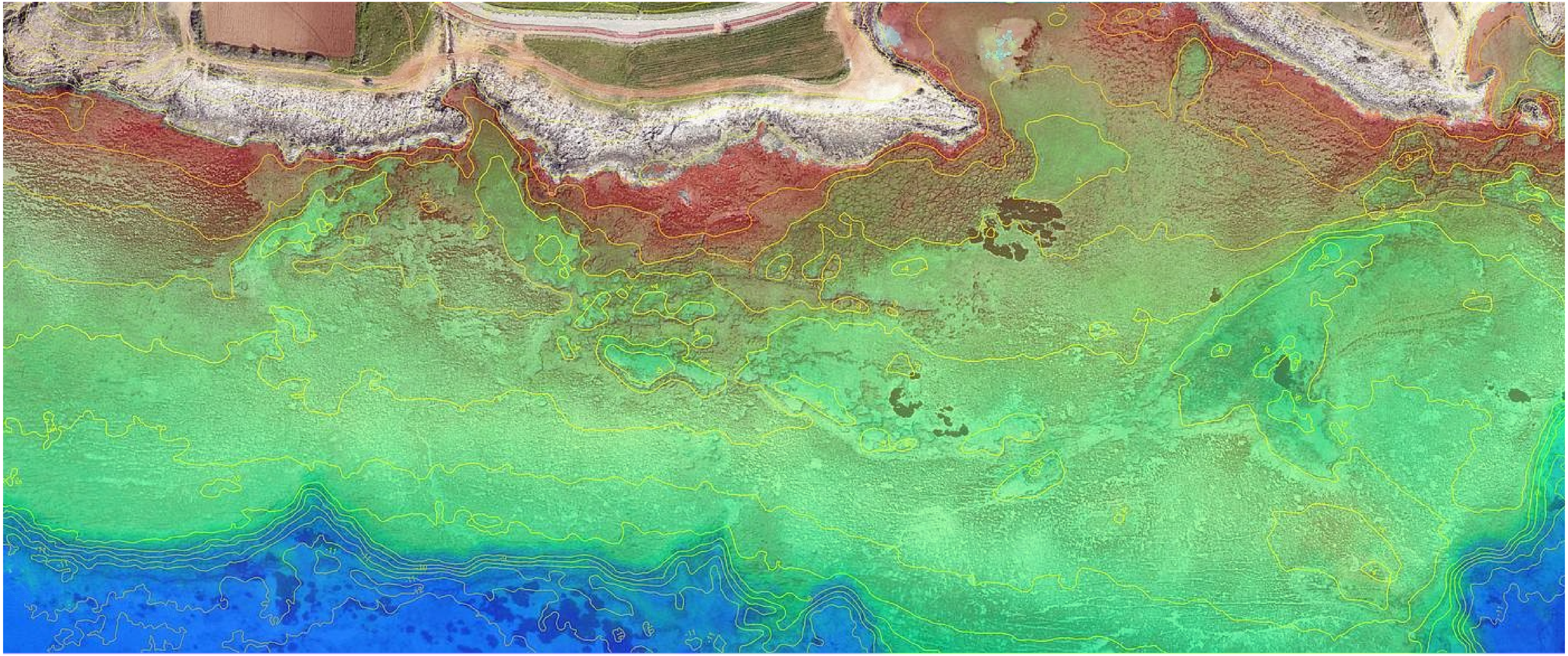
Orthoimage with isodepth lines

Examples – Real world applications



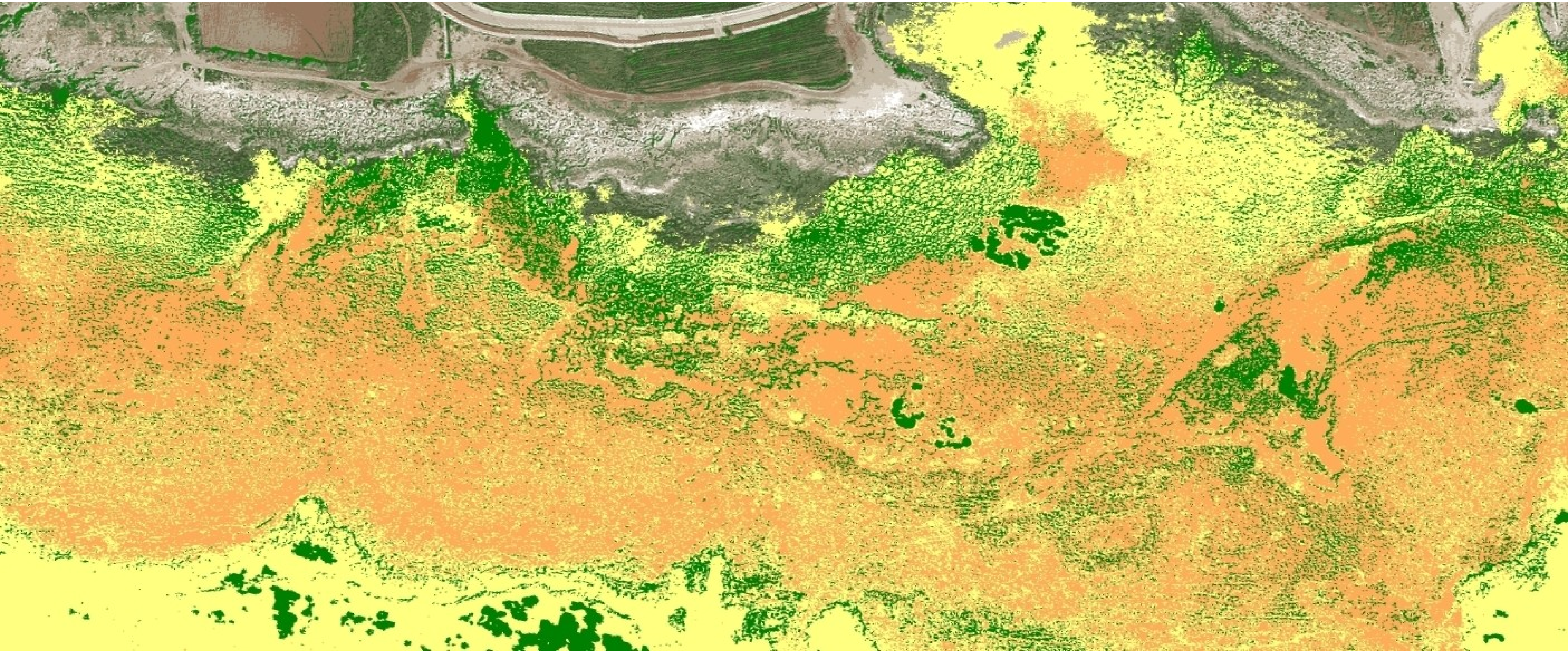
DEM

Examples – Real world applications



Orthoimage with isodepth lines and overlaid DEM

Examples – Real world applications



Semantic segmentation of the orthoimage or the point cloud

Examples – Real world applications

Orthoimage with isodepth lines

References

1. 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

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

3. 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.

4. 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.

5. 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.