

Monitoring underwater cultural heritage sites: the submerged harbours of Hipponion (Italy) and Amathus (Cyprus)

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Wissen für Morgen



Monitoring Submerged Cultural Heritage (CH) Sites with DESIS

Bathymetry (water depth estimation)

Shoreline erosion

Deterioration of the relics

Water Constituents Analysis

- Chlorophyll
- Turbidity
- Colored Dissolved Organic Matter
- Total Suspended Matter
- Brightness of Sand
- Phytoplankton

Eutrophication

Pollution

Illegal discharges

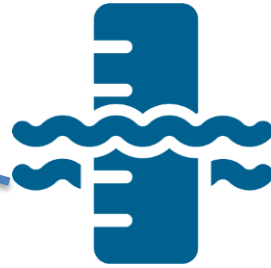


Amathus Harbor, Cyprus

Amathus Archaeological Site in Cyprus



Above water:
Ongoing excavations
Agora, baths and palace open to the public



Below water:
The submerged harbor

Amathus (Ἀμαθοῦς) was one of the ancient royal cities of Cyprus until 300 BC

Amathus Harbor: Variations in Depth

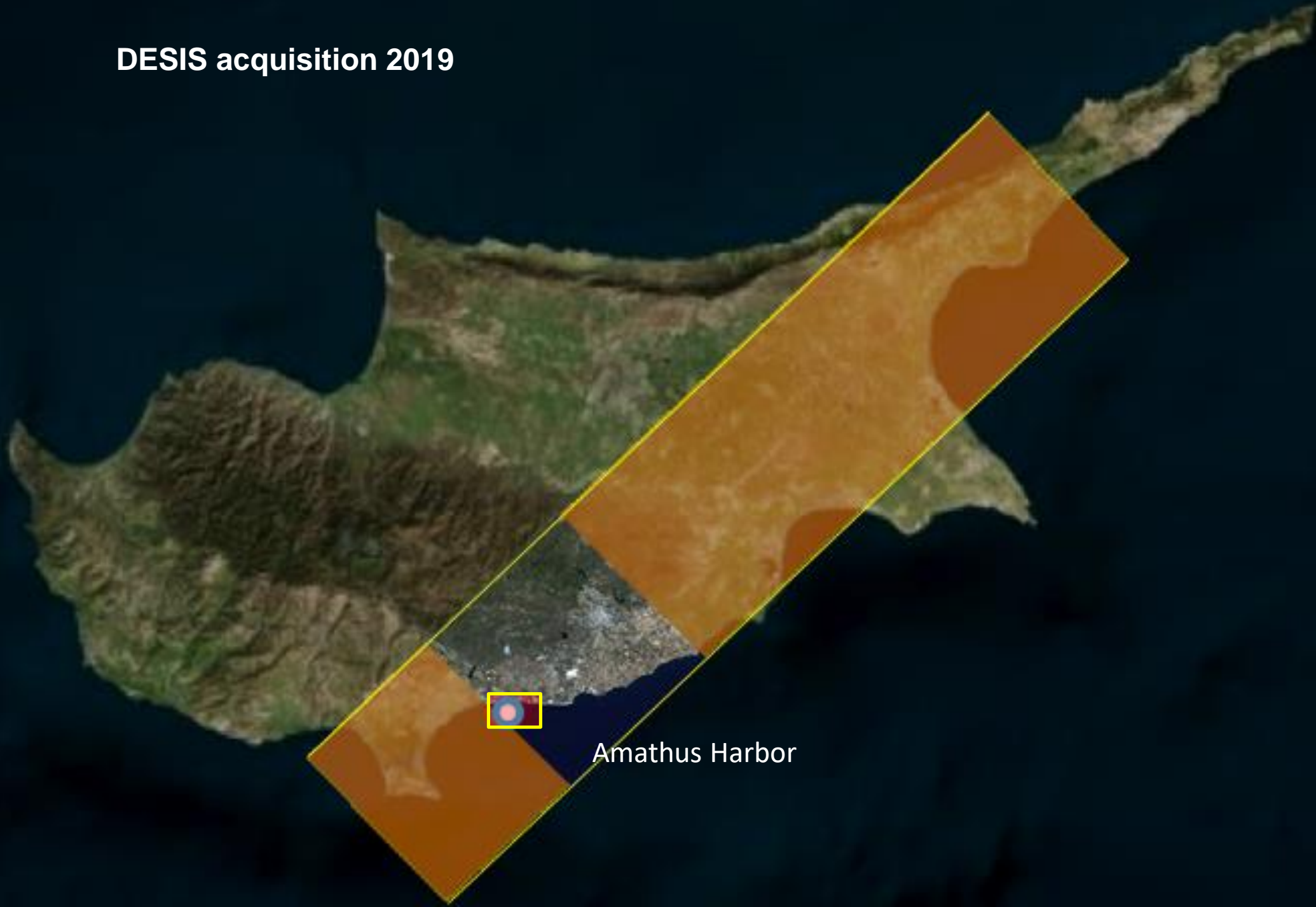


The harbor in 1984
(museum of Nicosia, Photo: Michael Watts)



The harbor in 2010
© cyprushighlights.com

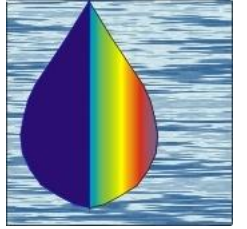
DESIIS acquisition 2019



Amathus Harbor

WASI

Water color simulator



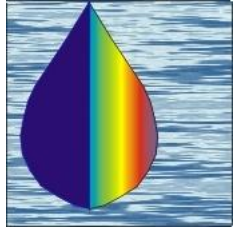
- ✓ Simulation and analysis of spectral measurements in water ($a, R_{rs}, E_d, L_u, \dots$)
- ✓ Bio-optical models for deep water [1] and shallow water [2]
- ✓ Analytical model of downwelling irradiance
- ✓ Elementary data base of SIOPs, bottom substrates, atmospheric absorbers
- ✓ Physically traceable and transparent calculation steps

[1] P. Gege (2004): The water colour simulator WASI: An integrating software tool for analysis and simulation of optical in-situ spectra. *Computers & Geosciences* 30, 523–532.

[2] P. Gege, A. Albert (2006): A tool for inverse modeling of spectral measurements in deep and shallow waters. In: L.L. Richardson and E.F. LeDrew (Eds): "Remote Sensing of Aquatic Coastal Ecosystem Processes: Science and Management Applications", Kluwer book series: Remote Sensing and Digital Image Processing, Springer, ISBN 1-4020-3967-0, pp. 81-109.

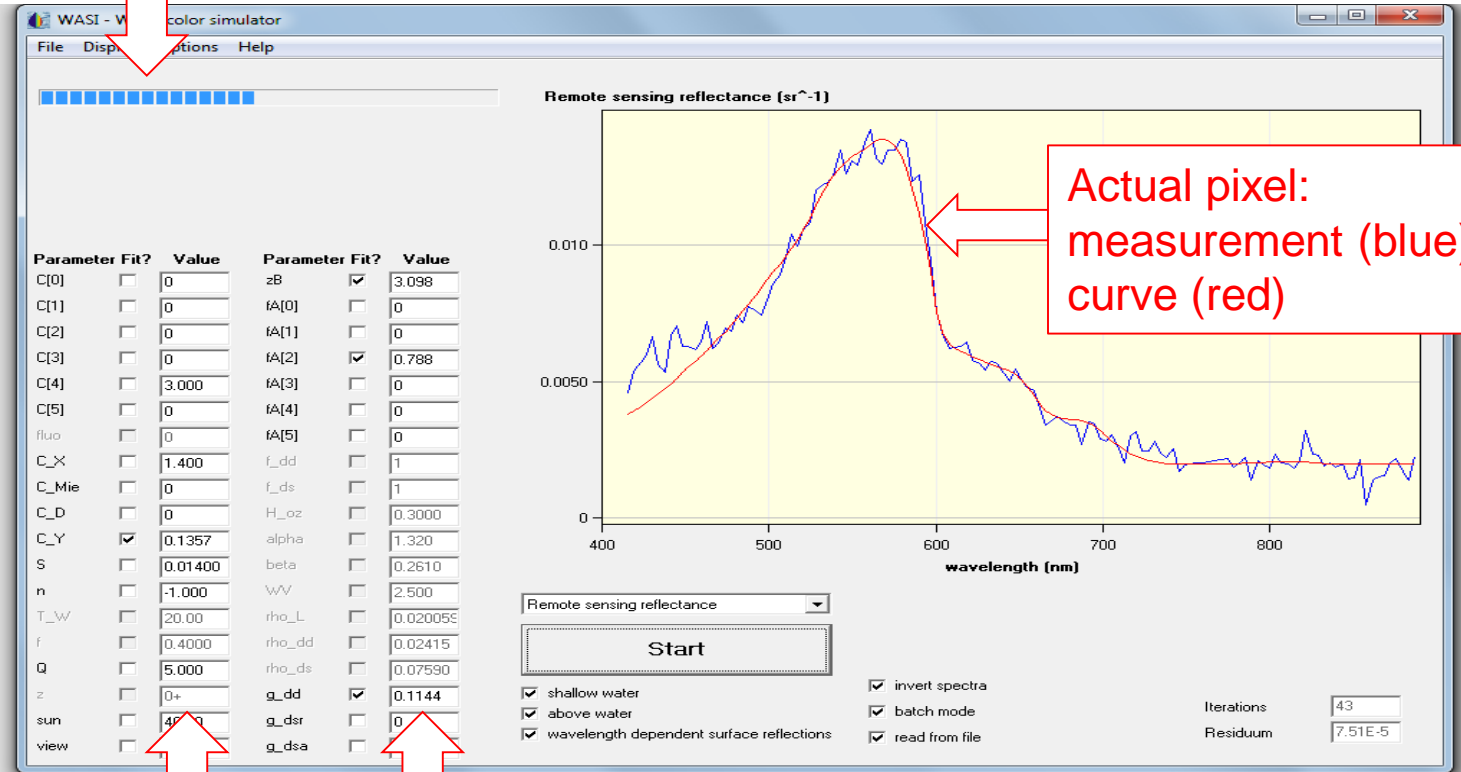
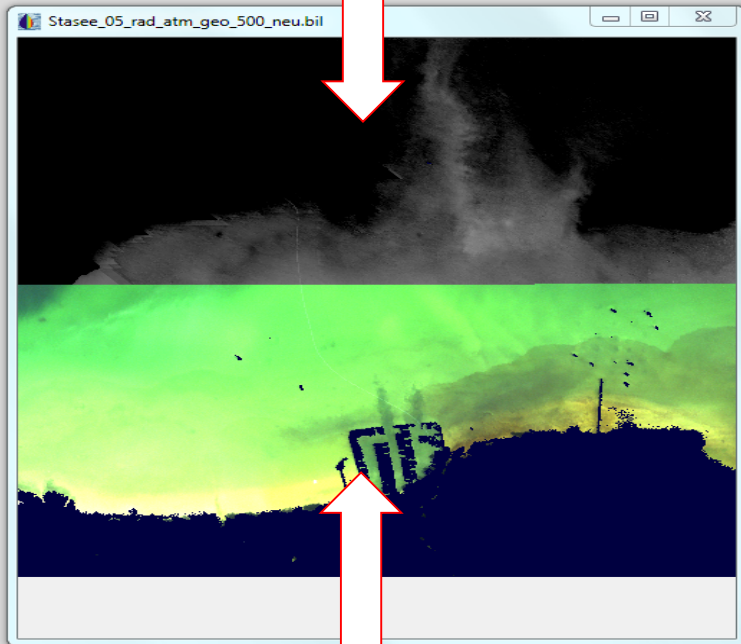
WASI-2D

Module of WASI for local image data processing



Preview of selected fit parameter

Progress bar



Actual pixel: measurement (blue) fit curve (red)

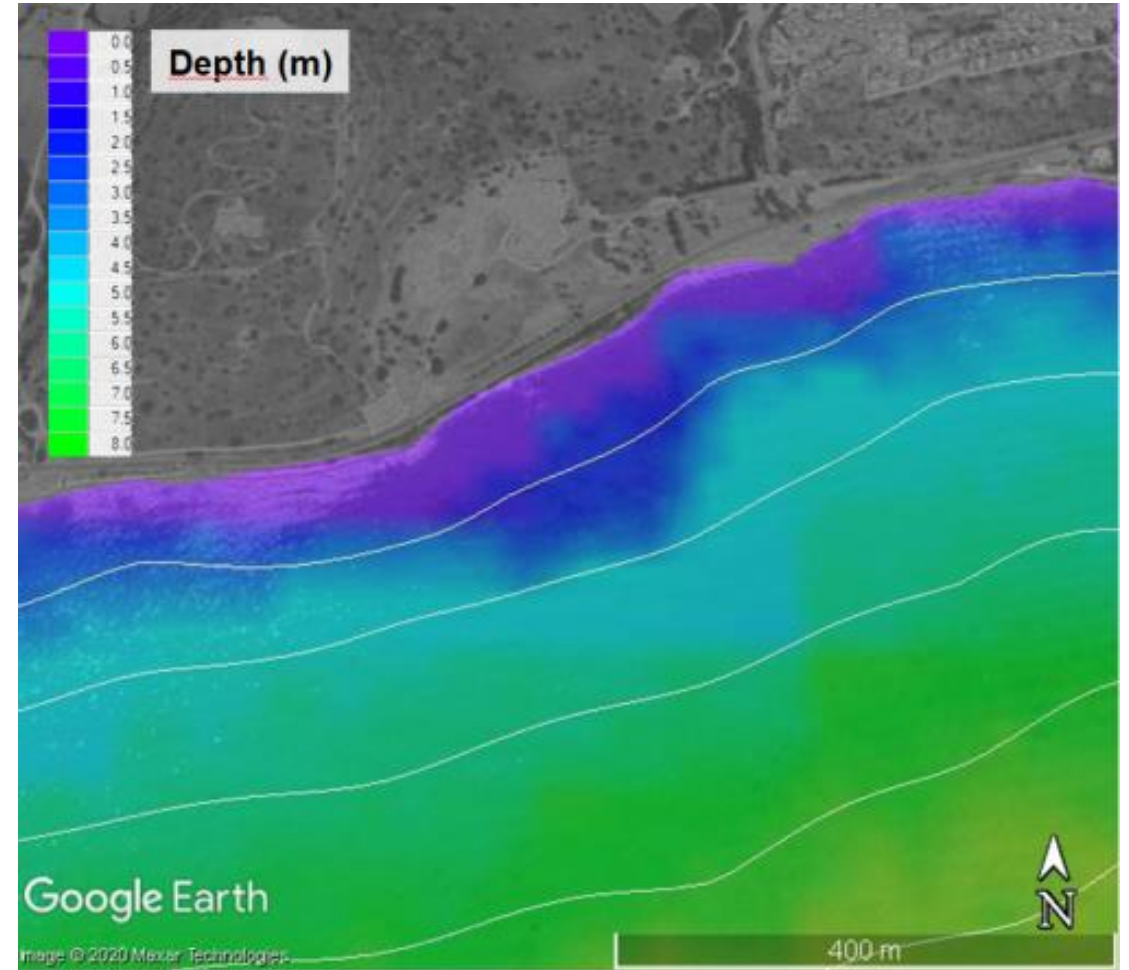
Image preview of 3 selected bands

Actual pixel: (fit) parameters

The Amathus Harbor: DESIS vs. Contour Lines

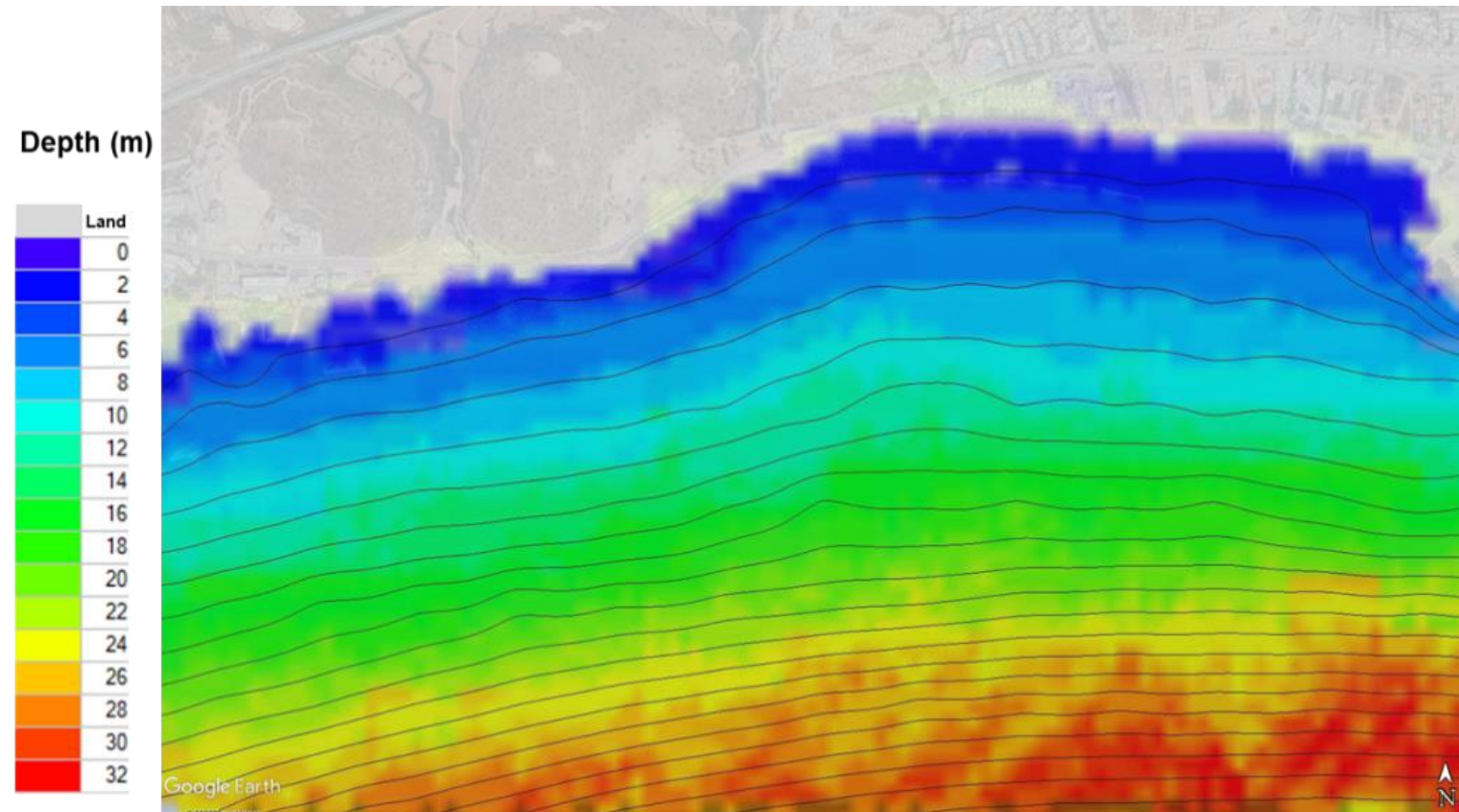


Archive Image © Google



Depth Map

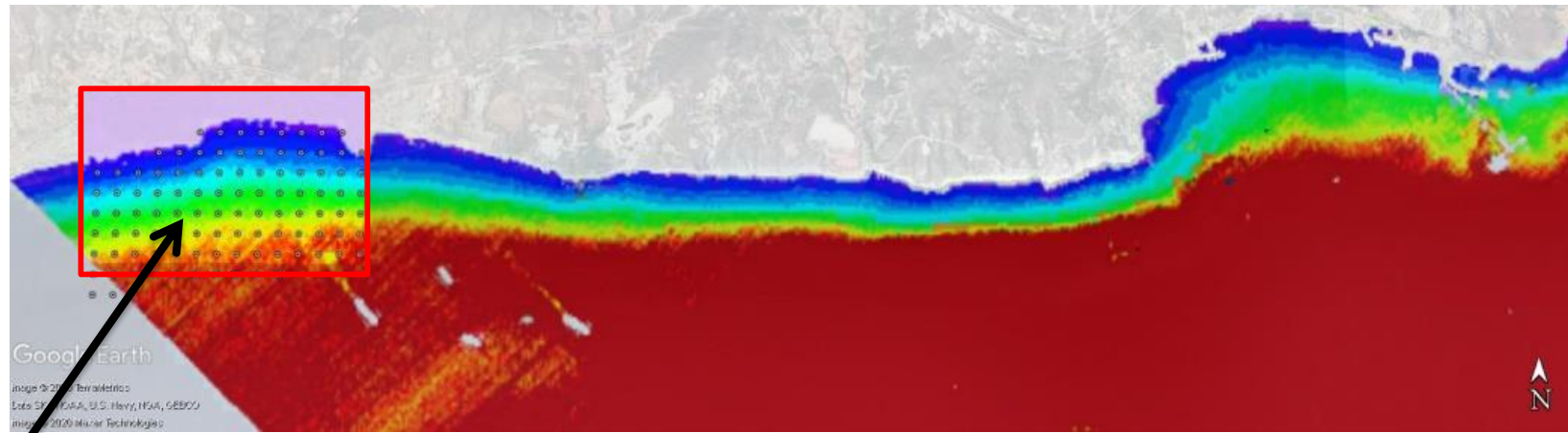
DESIIS-derived Bathymetry overlaid on Google Earth



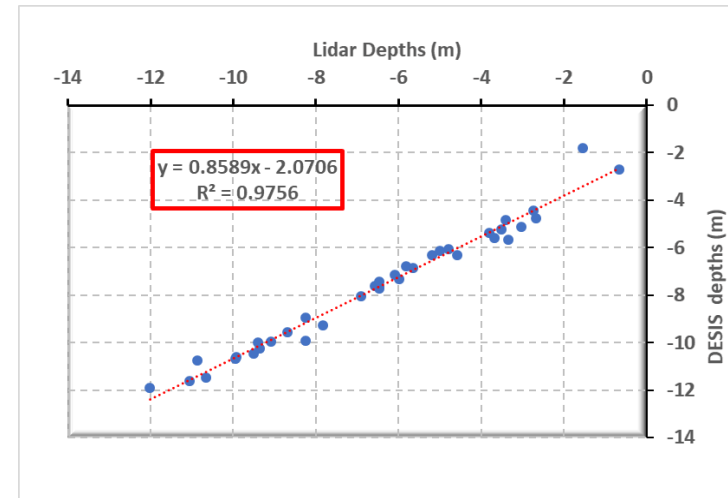
- Contour lines derived by interpolating in situ LiDAR depth measurements
 - Spaced 2 meters
- Bathymetrical map from DESIS image using WASI
 - Pixels with the same color → depth in a range of 2 meters
- High accuracy for depths up to approximately 15 meters

Larger Map and Validation

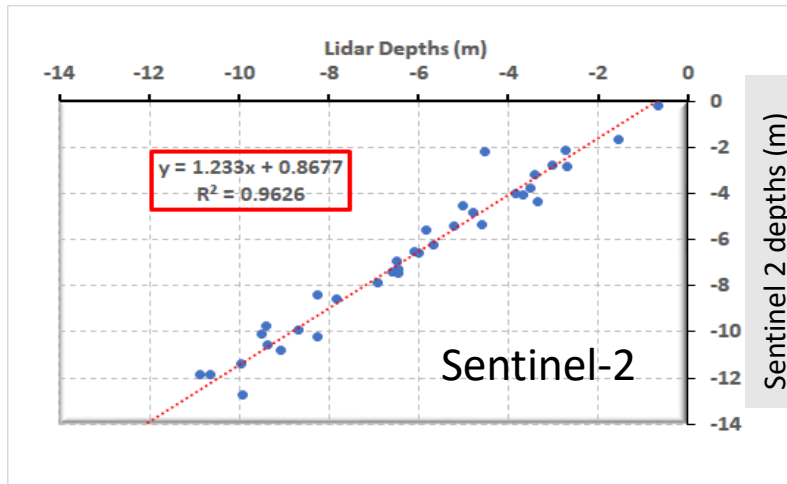
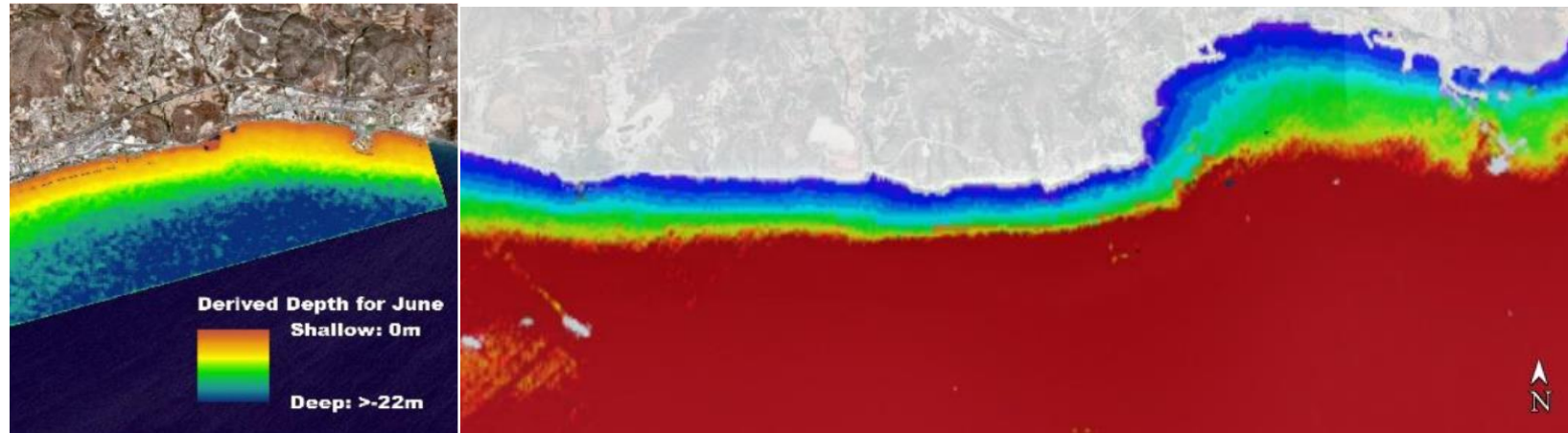
Area in Previous slides



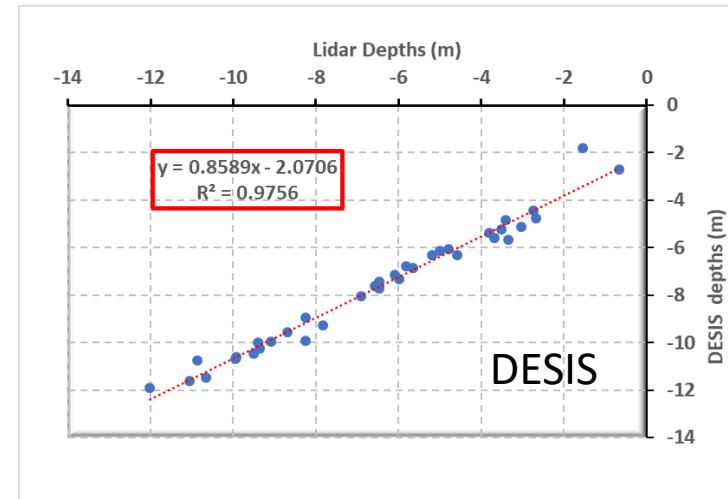
Locations of LiDAR Depth Measurements



Comparison: Copernicus Sentinel-2



RMSE = 0.72 m



RMSE = 0.41 m

Hipponion Submerged Harbour

Renovated in 300 BC

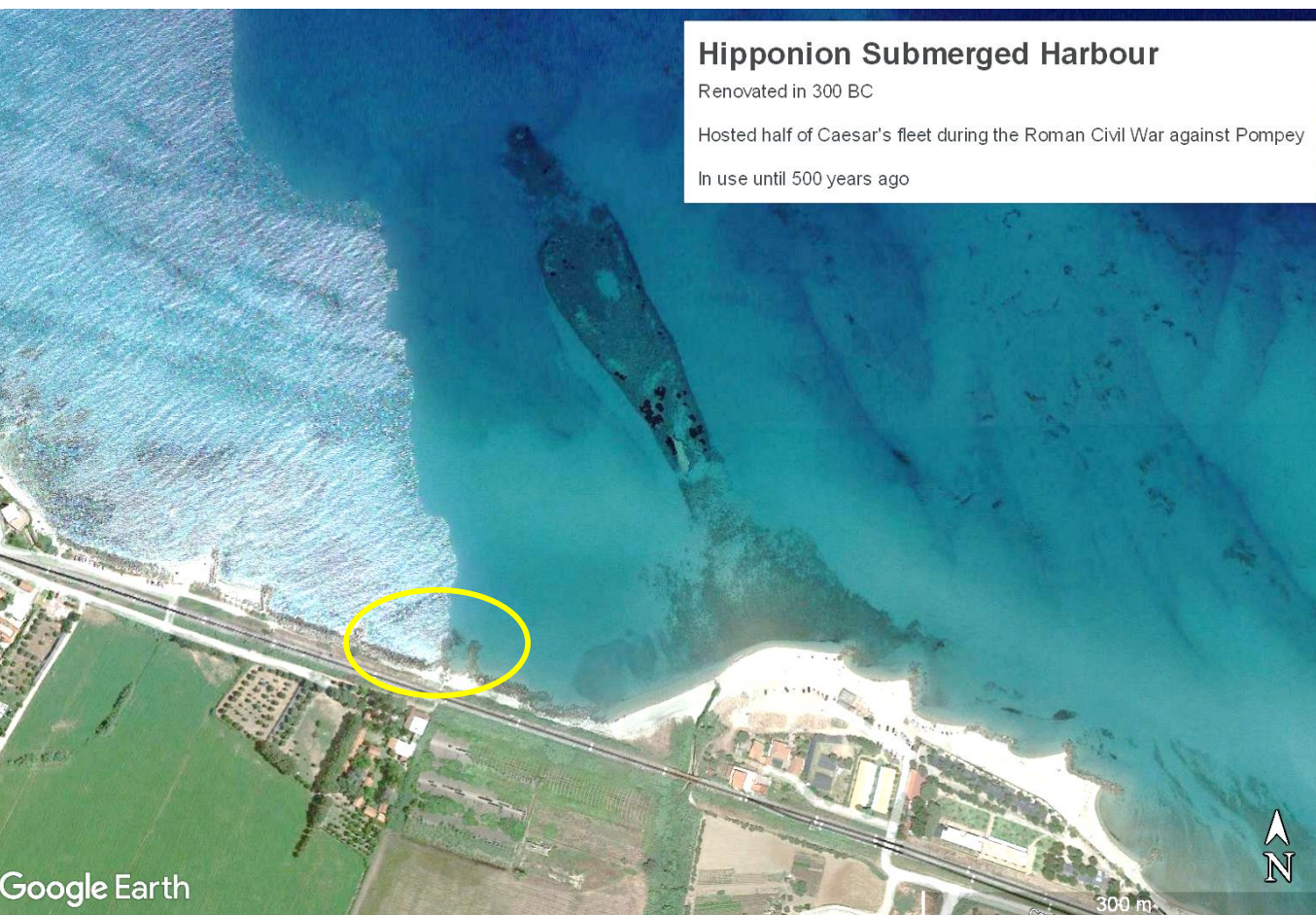
Hosted half of Caesar's fleet during the Roman Civil War against Pompey

In use until 500 years ago



Vibo Marina, Italy





Hipponion harbour 50 years ago (aerial image)



This bulwark disappeared

Gioacchino Lena

**Viaggio geoarcheologico
attraverso la Calabria**

← Reference (2021)

Hipponion Harbour

Acquisition: 2021-06



Vibo Marina, Calabria



Pseudo-truecolor

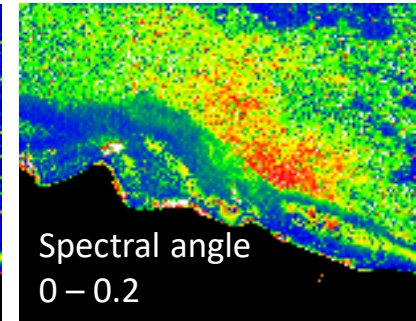
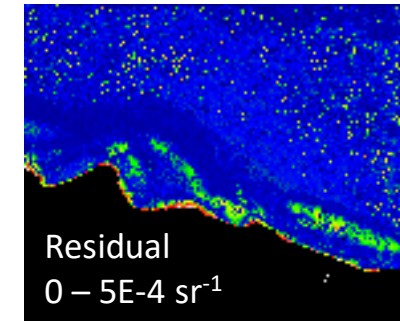
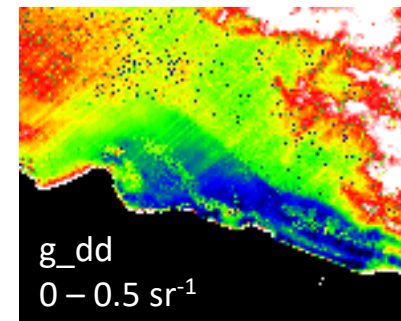
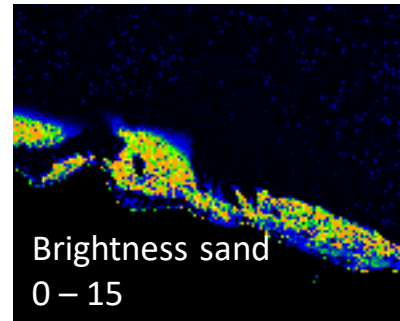
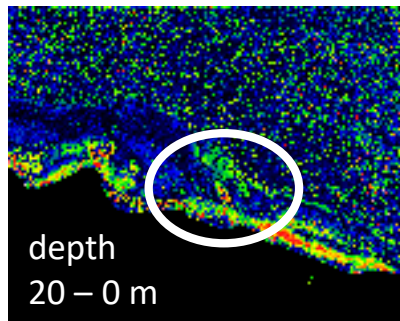
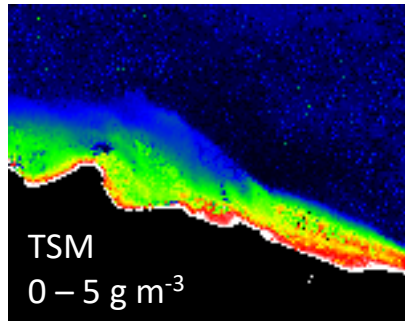
Bands 16, 59, 90
440 nm, 550 nm, 630 nm

Preliminary results on a single image

Bands 16, 59, 90
440 nm, 550 nm, 630 nm



The harbour is visible in DESIS!
40 m wide, likely to have pure pixels



Local depth shallower

WASI: 7 m depth
Harbour actually at 8 m depth

Correct!

Can nearby illegal discharges pose a threat to submerged CH sites? The Mesima river



Pseudo-truecolor

Bands 16, 59, 90
440 nm, 550 nm, 630 nm



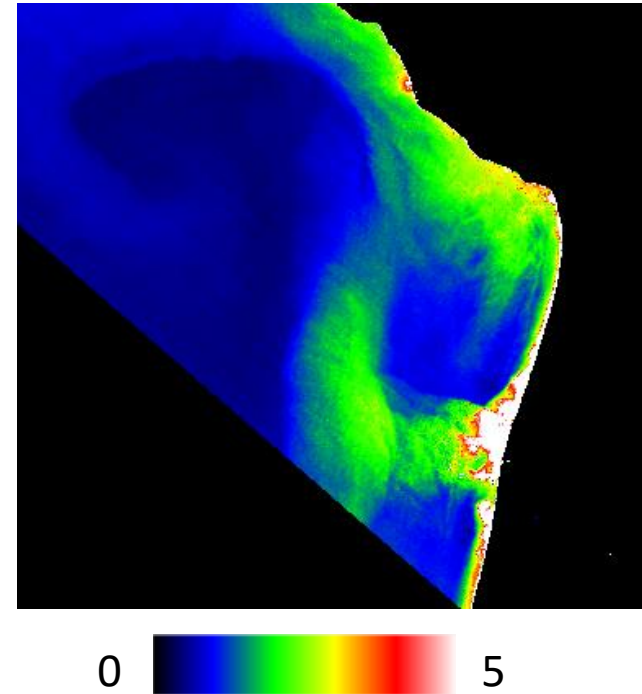
Image acquired by drone showing illegal discharge systems
In Mesima river

Credit: LaC News

the Mesima river

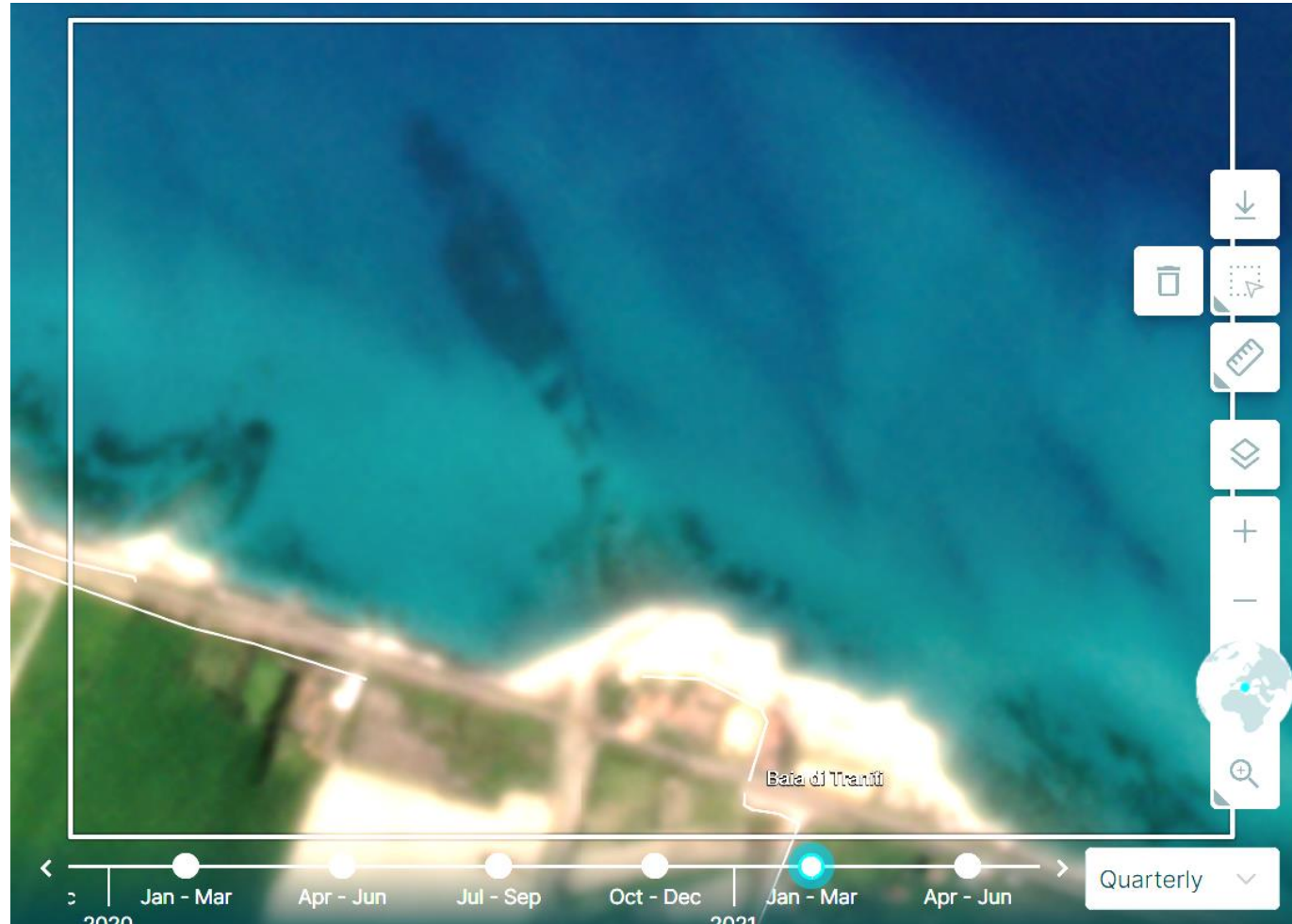


Total suspended matter
shows clear spatial patterns.



Bands around 703 nm (R, band 60), 700 nm (G, band 59)
and 675 nm (B, band 54) show a high concentration of
inorganic compounds in the water.

Additional data: Planet images



Thanks for your attention 😊