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Automated extraction and fusion of the intertidal and subtidal bathymetry from the Landsat and Sentinel satellite data

Introduction

Monitoring of the intertidal and subtidal bathymetry at large spatiotemporal scales using traditional surveying methods is a challenging and costly task. Well established methods of remote sensing and increasing frequency of freely available satellite data enable automated monitoring of intertidal and subtidal bathymetry. A number of methods exist to extract intertidal bathymetry by combining the observed water masks with the water level data simulated by intertidal numerical models and local water level measurements. At the same time, the light attenuation in a water column, observed by optical satellite sensors, can be used to estimate water depth, providing a way to estimate subtidal bathymetry. In this research, we will discuss how both methods can be combined to generate a consistent intertidal and subtidal bathymetry data. Challenges, such as automated processing at a continental scale (using Google Earth Engine), calibration, and validation of the algorithm will be discussed. This research is used to improve the European Marine Observation and Data Network (EMODnet) bathymetry and is supported by the European Commission and Dutch Ministry of Infrastructure and Water Management.

Method

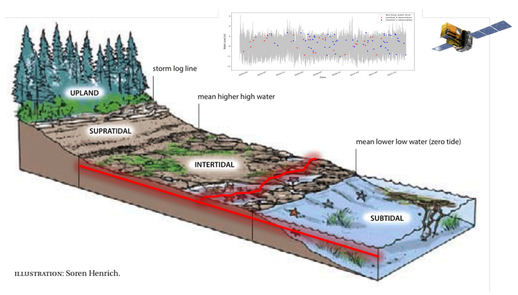
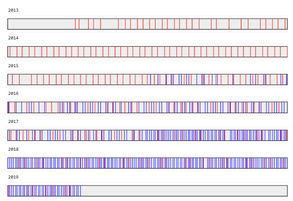
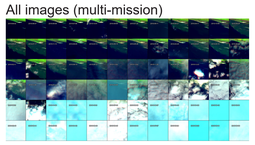


ILLUSTRATION: Soren Henrich.

Revisit frequency (Landsat 8 and Sentinel-2)

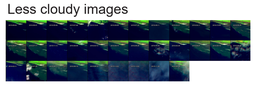


All images (multi-mission)



❶ Filter

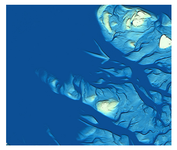
Less cloudy images



❷ Water occurrence (intertidal)

Compute water occurrence as a weighted-average of NDWI (clamped) and using weights computed from spatio-temporal variability of reflectance

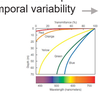
$$P_{water} = E[I_{NDWI}] = \sum I_{NDWI} \cdot w(t_{clouds}, x, y, t)$$

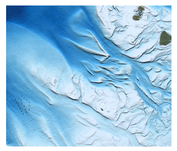


❸ Water depth (intertidal and subtidal)

Compute water depth as weighted-average of inverse-depth and using weights computed from spatio-temporal variability of reflectance

$$D = E[d] = \sum d \cdot w(t_{clouds}, x, y, t)$$
$$d = log(\rho - \rho_{deep})$$





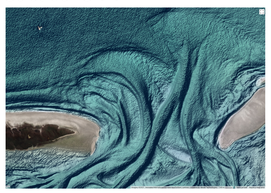
Conclusions

- New algorithm to derive bathymetry
- Tracking bathymetric changes at high frequency
- Intertidal and subtidal
- Automated using Google Earth Engine
- Prototype app: **http://eo-bathymetry.appspot.com**

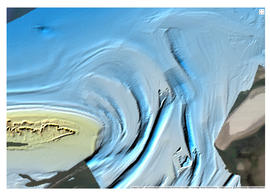
Results

Validation

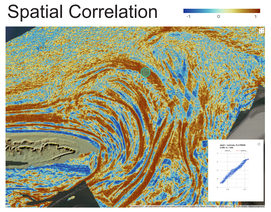
Subtidal SDB



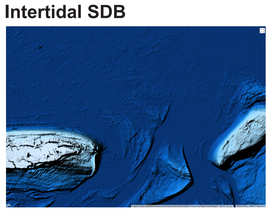
Jarkus Measurements



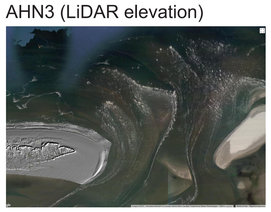
Spatial Correlation



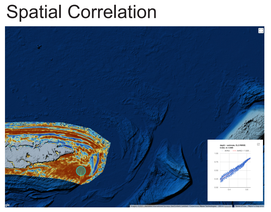
Intertidal SDB



AHN3 (LiDAR elevation)

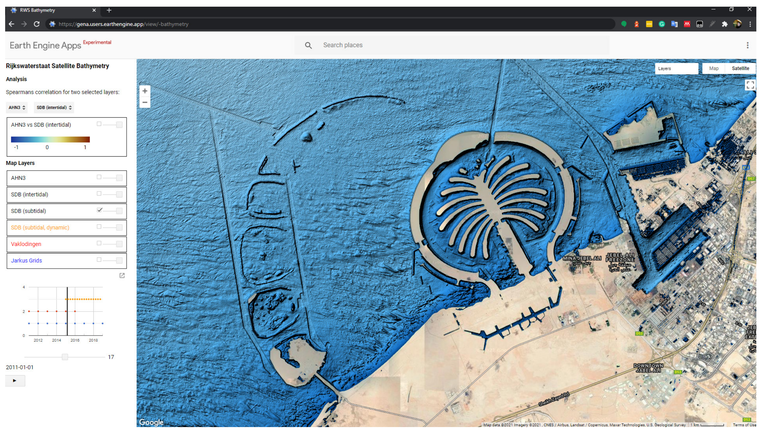


Spatial Correlation



Intraannual and Interannual Dynamics

Exploratory Web Application



Applications

- Automated high frequency bathymetry maps of inter and subtidal morphology to assist operational coastal management (eg. dredging, replacement of navigation buoys). The actual frequency depends on cloud cover and image availability and can vary from days to years.
- Assist monitoring of long term coastal developments. High frequency maps with especially high horizontal accuracy supplement regular low frequency echo-sounding bathymetry surveys.
- Analysis of inter-annual morphodynamics not captured in annual or multi annual regular surveys.
- Co-analysis of morphodynamics along the Dutch coast, based on both traditional survey techniques and remote sensing derived data.
- Estimate effects of dredging, sand nourishments, and land reclamation on natural morphodynamic processes

Next

- Use machine learning to automatically calibrate the algorithm (k-means, CNN, probabilistic NN, GAN)
- Improve calibration by adding a step to classify seabed albedo changes
- Automated estimation of turbidity
- Fusion of intertidal and subtidal bathymetry estimates
- Automated estimation of vertical errors based on the inter-annual and intra-annual variability and in-situ data (if available)
- Validation for multiple locations with varying morphodynamics and depth
- Scale globally and temporally (more than three decades)

References

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