Hyperspectral Remote Sensing of Coastal Morphodynamics

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- BA in Physical Geography @ University of Lausanne (Switzerland)
- MA in Coastal Management and Planning @ University of Wollongong (Australia)
- Geospatial sciences and Remote Sensing fanatic
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Methods and Tools</th>
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</table>
| I       | Sediment Facies Radiometrics | • ASD Field Spectroscopy of supra/intertidal sandy sediments + Lab analysis  
• Endmembers extraction  
• Open Source Spectral Library (Specchio) |
| II      | UAS-based Sediment Facies Mapping | • Multitemporal UAS SfM and Hyperspectral beach surveys  
• Segmentation and supervised classification with spectral library  
• Sand sampling for ground-truth  
• SfM volumetrics + classification maps = sediment transportation maps |
| III     | Satellite-based hyper/multispectral monitoring | • Depending on imagery availability (Satellogic, Reaktor Space Lab)  
• Pixel unmixing analysis to study the sand classes present in every pixel  
• Mineral abundance maps, if UAS spectroscopy and lab radiometry is done prior to image acquisition |
| IV      | Satellite-based shoreline monitoring | • Python scripting for shoreline extraction from Sentinel-2 and Planet imagery  
• DEA ARD data + NCI cloud computing via Jupyter NB for Sentinel-2 imagery  
• Planet API + Google Earth Engine and Citizen Science UAS data for Planet imagery |
| Ongoing | Citizen Science data analysis scripting | • Python scripting for automatic analysis (transects analysis)  
• Creation of Jupyter Notebook for open source analysis tools  
• Basic spatial database structure for storing profiles and volumetrics (future work) |
Hyperspectral + Coasts
From DoDs to Sediment Facies Maps

SfM allows to calculate volumes loss/fill in a spatially explicit way along sandy beaches, answering the question «how much sediment has been cut/fill here?». However, it doesn’t provide a clear sediment directionality dimension and sediment exchanges between depositional environments or even coastal compartments can only be inferred by geomorphological observations or expensive and time consuming sediment tracking methods.

This study aims to deliver a method for answering the question «how much of that specific type of sand accumulated/eroded from here?», with the type of sand being an indicator of the geographic and geomorphic sediment origin.
Previous Study

The Belgium Coastline (Deronde et al. 2008)

Sediment facies Map

**PROs**

- **Direction** of sediments can be qualitatively derived
- **Nourishment sand** is detected and monitored

**CONs**

- High operational **costs** (aerial)
- Detect only **surficial sand**, not absolute classes volumetrics

Coastal compartment cross-shore transects

- Multiple Coastal Compartments Field Surveys
- Classes to be defined
- Biogenic stranded material

My Approach

Spectral Response

- Function of Grain size
- Mineralogy
- Organic matter
- Water content

Sand Facies Endmembers
are site specific

Specchio library

Get ready for the future!

Aerial/Satellite Spectroscopy
Satellite Hyperspec is evolving rapidly ...

### Government

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<th>(Year)</th>
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<th>Multi-spectral</th>
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### Commercial, nano and small satellites

- **Satellogic**, microsat, 29MIO
- **Zhuhai Orbita Control**, smallsat, $?
- **Orbital Sidekick**, 4.7MIO
- **Reaktor Space**, 6U, $?
- **HyperSat**, smallsat, 85 MIO
- **NorStar NorthStar**, microsat
- **Hypersat**
- **Cosine**
- **Siwei Star Co.Ltd.**

Source: Transon et al., 2018

Source: www.newsspace.im
Citizens Science + UAV data
Data Quality and Validation

Hardware

Software

Planning

Professional Support
Data Quality and Validation

- 58 Smart GCPs
- 2-3 hours acquisition time
- 7.4 and 8 mm XYZ variance during GCP acquisition time

- Lady Bay, 1.6 km² (161.6 ha)
- 2.4 cm RMSE 3D absolute accuracy
- 2.56 cm GSD → 1 pixel of error
Data Quality and Validation

7 cross-shore transects of varying lengths with RTK-GPS location surveyed every meter

- Independent set of 208 RTK-GPS checkpoints used to validate DSM Z values
- Point to Raster (PR) method
  - Low quality points discarded
    - lateral error < GSD
Data Quality and Validation

**Mean Error (ME)** = -0.04m (4cm)

→ DSM values are slightly overestimated, but accurate.

**Root Mean Squared Error (RMSE)** = 0.09m (9cm)

→ RMSE over PR method are known to overestimate the error estimations (Carrivick et.al, 2016).

→ 9 cm RMSE in Z is a common value in the scientific UAV literature and also aerial LiDAR surveys.
By the end of the 3 years time Citizen Scientists will have produced more than 200 datasets ...

... there will be 1 Tb of DSM and orthophotos to analyse ...

... 14 locations with differences in wind, wave and sediment regimes. Good research possibilities!

How to analyse such an amount of geospatial data in an efficient way?

pgAdmin 4 + jupyter

PostgreSQL + PostGIS Python Geospatial Scripting
Analysis and Communication

- **Automatic** extraction of all elevation profiles along the multitemporal DSMs
- **2 main inputs**: the DSM and the transects (vector lines)
- **1 big data table**, text format, full of information
- **Python** geospatial processing is fast and efficient
- **Interactive plotting** inside Jupyter Notebooks
- **Powerful** geostatistical analysis with Geopandas
- **Big Data** table feeds directly into PostgreSQL to be manipulated and queried with PostGIS
- Fits perfectly with **Qgis** and ArcGIS
Virtual Network of Elevation Profiles

Several hundreds virtual profiles will be monitoring the UAV sites at unprecedented accuracy.

- Convenience (data format and size)
- Cut/Fill observations \(\rightarrow\) seasonal? Storm-dependent?
- Dynamic equilibrium?
- Lack of wave data \(\rightarrow\) wind+profiles=wave conditions?

Why elevation profiles?
Virtual Network of Elevation Profiles

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Port Fairy Beach

Beach length: 5800 m
Surveyed section: 2200m
Orientation: SE
Waves: avg 1.5m
Thanks!
Questions?

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