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Towards the automation of sand dune detection in the bathymetry

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Introduction

The advances in echo sounder (MultiBeam EchoSounder) and positioning (GPS) technologies of the past two decades enabled us to survey larger areas, faster and more accurately. The collected data show how diverse underwater sand dunes are in terms of shape, spatial organization, dimensions, dynamics, etc. To deal with this large amount of bathymetric data, manual processing appears outdated. By consequent, tools allowing to quantitatively describe their morphology and dynamics have been developed [1,2,3]. It mainly enables to objectively characterize the sand dunes and banks. Unlike the existing tools, we aim at describing each dune independently with a set of morphometric parameters. With this goal of dune characterization, the first step consists in detecting the dunes in the bathymetry. As a preliminary approach, we propose a detection technique inspired from geomorphometry.

Datasets

To conduct this research, SHOM (French Navy Hydrographic Office) and the FPS (Federal Public Service) Economy gave us access to their dune databases. These two datasets are complementary as they were not collected in the same prospect.

SHOM Dataset

- Long lines run to explore the continental shelf (Brittany, straits of Dover) or boxes surveyed over interesting structures
- Depth ranging from 30 to 200 m
- Large to giant dunes (below 1m high to over 20 m high)
- Data acquired during annual campaign

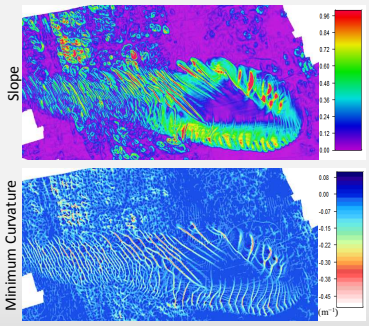
FPS Economy Dataset

- 11 small areas spread around the Belgian continental shelf surveyed to monitor the impact of aggregate extraction
- Depth ranging from 5 to 40 m
- Few meter-high dunes with sand waves superimposed.
- Surveys completed several times every year since 1999.

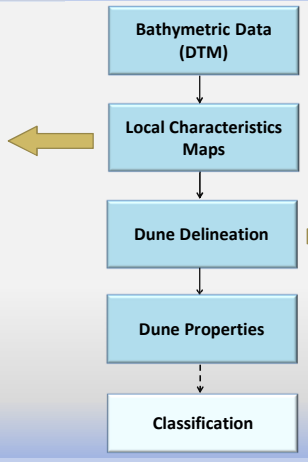
These datasets are perfect to appreciate the wide variety of dunes in terms of morphology and dynamics.

Geomorphometric approach

Local Characteristics Selection



Among the large number of local characteristics commonly used in geomorphometry to detect features at the Earth's surface (e.g. volcanoes [4], mountains [5], drumlins [6]), the slope and minimum curvature seem the most appropriate to our case : dunes.



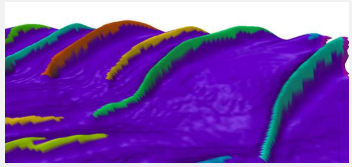
Dune Delineation

The region growing algorithm is divided into two phases:

1. Define the seed regions (Crest Regions)

Minimum Curvature Threshold

Threshold = −0.08 m⁻¹



2. Find a criterion to stop the region growth

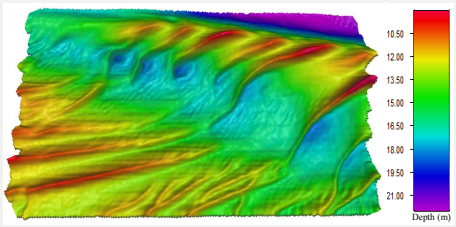
Slope Threshold

Threshold = 0.2



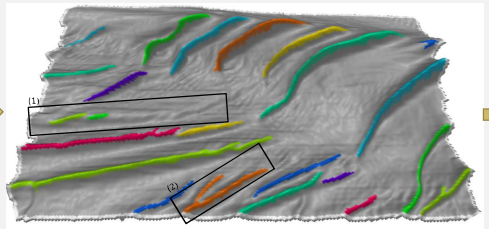
Results

Bathymetry



DTM of the KBMA area surveyed in 2013.

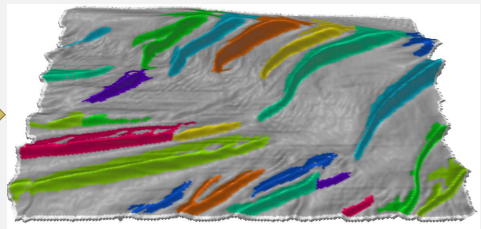
Crest Regions



Observations:

- ❑ Most dune crests are correctly detected
- ❑ Some crests are partly detected or/and split into few regions (Frame 1)
- ❑ A crest region can gather several dune crests (Frame 2)

Dunes



Observations:

- ❑ Slope varies from a dune to another or even from a flank to the other:
  - Holes in some dunes
  - Under/overgrown dunes
  - Abnormally distorted dune limits
- ❑ Flanks can wrongly be extended to sloping areas near the dunes

Conclusion

The preliminary results are promising and confirm that the choice of designing a geomorphometric approach to automatically detect dunes is realistic. Indeed, the algorithm was tried out on a dataset for which we also have manually-drawn crest lines. 248 dunes are detected by the algorithm against 252 with the classical, manual approach.

The minimum curvature is very effective to highlight the crest locations. To base the growth stage on the slope is too simple as such. Another metrics, criterion inspired from the slope is to be found.

It is essential that the crest regions are perfectly extracted prior to the region growth. Furthermore, the region growth is very challenging as the dune limits are sometimes not obvious to a human expert.

In addition, the dune diversity of shapes makes impossible the use of crisp thresholds appropriate to all the dunes.

Perspectives

Things to be considered in order to design a fully-automated dune detection algorithm:

- ➢ Consider other data structures (TINs ,point clouds)
- ➢ Keep low the number of heuristics and adjust it automatically if possible
- ➢ Let the user set intuitive heuristics only
- ➢ Be clear on the definition of a dune (where it starts and ends) -> user expectations
- ➢ Take into account the data uncertainty

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