Bridging Worlds in Bedform Research with an Open Access, Universal Toolbox: the Bedform Analysis Toolbox

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Abstract

Bedforms (ripples, dunes, sandwaves) are ubiquitous features in many sandy subaqueous settings. They have been observed in a wide variety of flows, including rivers, the surf zone, estuaries, tidal inlets, shallow seas, and deep waters. Bedforms exert a major influence on a range of processes, from small-scale turbulence and sediment transport to large-scale coastal geomorphology. Therefore, knowledge on the dimensions, morphological characteristics and dynamics of large bedforms is relevant for a range of fundamental and applied research. Several methods have been developed over the years to characterise bedform dimensions from bathymetric data. Each method has been created for a specific purpose (e.g. discriminate bedform scale, calculate bedform size and/or shape, detect crestlines) and environment (unidirectional, constrained tidal or open marine) and with a certain accuracy (precise time-consuming detection or coarse rapid detection). Although some of these methods are freely available, it may be difficult for scientists to use them due to the specificity of their design. A unique toolbox which combines the available methods into one easy-to-use software would help the bedform community advance knowledge on bedform research by facilitating the analysis of bedform characteristics. This should also include recommendations of which method should be used for which purpose. The present project aims at creating a Bedform Analysis Toolbox which combines several methods already available. The toolbox will be made open source and freely available. Feedback on the need of the community or required design and specificity would help us create a toolbox which is useful to many scientists.

Bridging Worlds in Bedform Research with an Open Access, Universal Toolbox: the Bedform Analysis Toolbox

Alice Lefebvre, Leon Scheiber, Julia Cisneros,
Li Wang, Judith Zomer, Ronald R. Gutierrez

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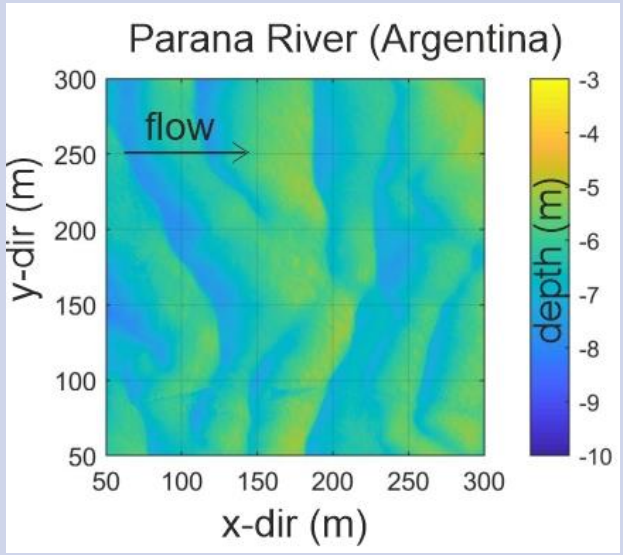
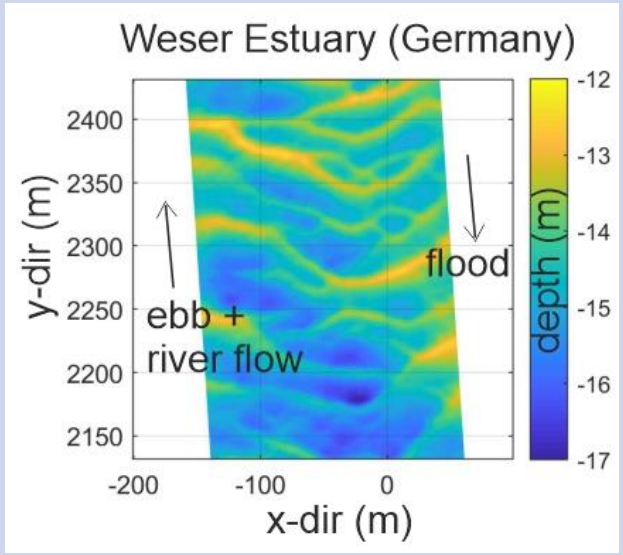
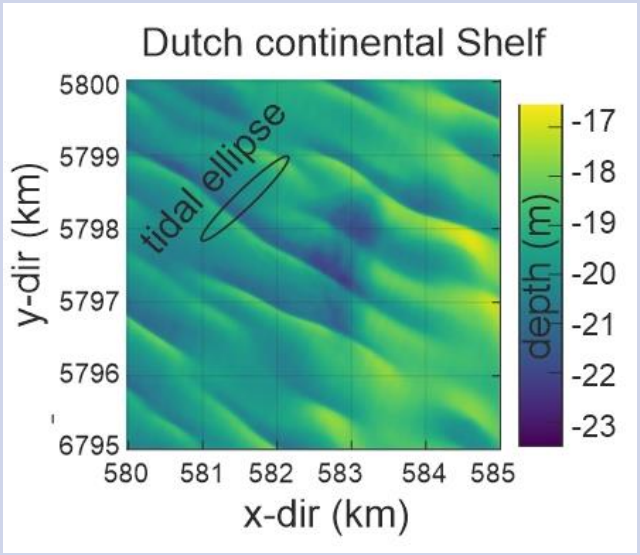
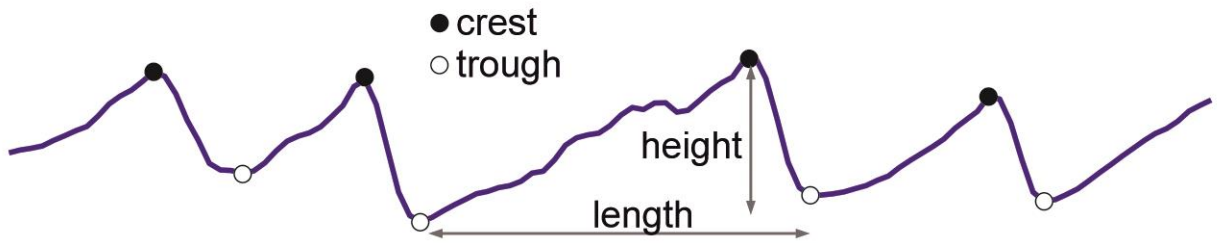
Bedform types

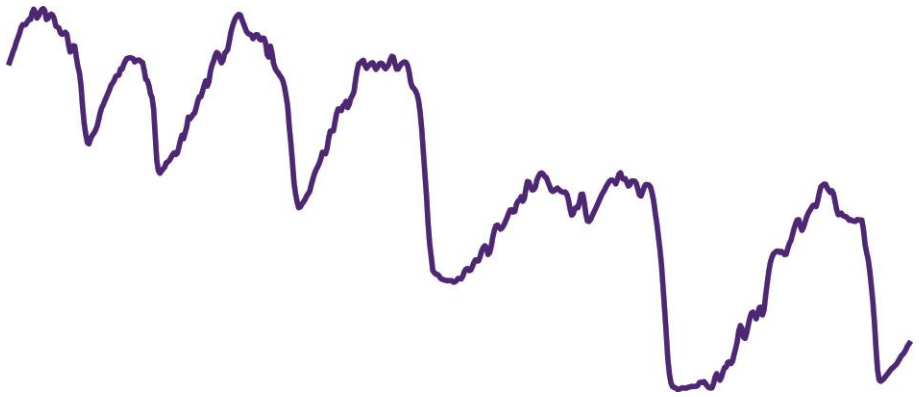
			
Bedform type	River and flume dunes	Estuarine and tidal dunes	Marine dunes
Environment	Unidirectional & constrained	Bidirectional & constrained	Open
Forcing	River flow	Tidal currents, River flow Other currents	Tidal currents Waves Other currents

Bedforms - some definitions

Bed Elevation Profile (BEP)

➔ **BEP bedform size**





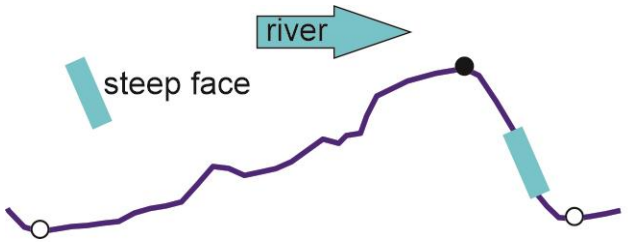
➔ **Scale separation**

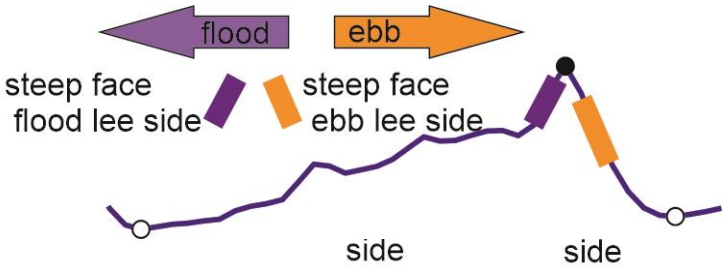
Underlying bathymetry

Large primary bedforms

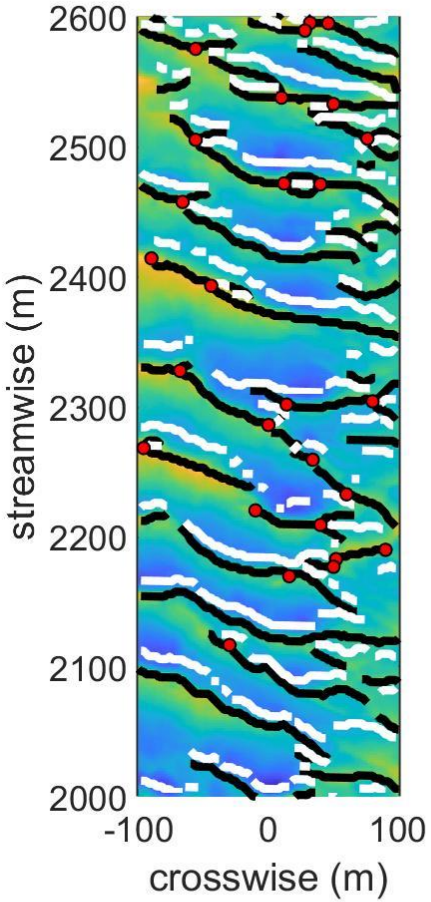
Superimposed secondary bedforms

➔ **BEP bedform shape**





➔ 3D **bedform properties**



Crestline

Troughline

Bifurcation

Lefebvre et al., AGU2021
alefebvre@marum.de

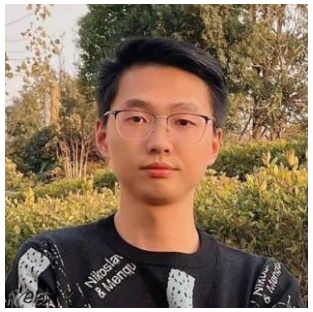
Bedform analysis methods

BAMBI - Julia Cisneros et al, 2020. Dunes in the world's big rivers are characterized by low-angle lee-side slopes and a complex shape.

Bedforms-ATM - Ronald Gutierrez et al., 2018. Bedforms-ATM, an open source software to analyze the scale-based hierarchies and dimensionality of natural bed forms.

Weser bedform analysis - Alice Lefebvre et al., 2021. Morphology of estuarine bed-forms, Weser Estuary, Germany.

BIA - Leon Scheiber et al., 2021. Robust methods for the decomposition and interpretation of compound dunes applied to a complex hydromorphological setting.



Bedform analysis - Li Wang et al., 2020. An automated procedure to calculate the morphological parameters of superimposed rhythmic bedforms

Loess filter - Judith Zomer et al., 2021. Rapidly migrating secondary bedforms can persist on the lee of slowly migrating primary river dunes

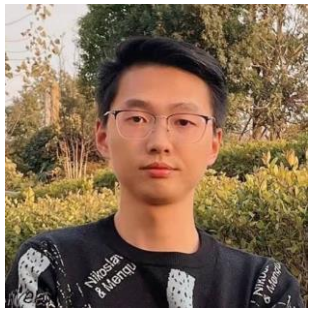
Bedform analysis methods

BAMBI - Julia Cisneros
River bedform size and shape

Bedforms-ATM - Ronald Gutierrez
River bedform scale separation

Weser bedform Analysis - Alice Lefebvre
Estuarine bedform size and shape (2D+3D)

BIA - Leon Scheiber
Tidal bedform size



Bedform analysis - Li Wang
Marine bedforms crestline direction, scale separation, size

Loess filter - Judith Zomer
River bedform scale separation

Aim

➔ Each method is designed for a specific environment, dataset, purpose

We all calculate bedform size – how much difference depending on method?

Spoilt for Choice – When to Use Which Bedform Identification Tool for What Purpose?
Leon Scheiber, Judith Zomer, Li Wang, Julia Cisneros, Ronald R. Gutierrez, Alice Lefebvre
EP55F - Understanding Bedforms Across a Range of Scales and Environments II Poster
Friday 17 December 16:00 - 18:00 CST

➔ Each method has specific strength

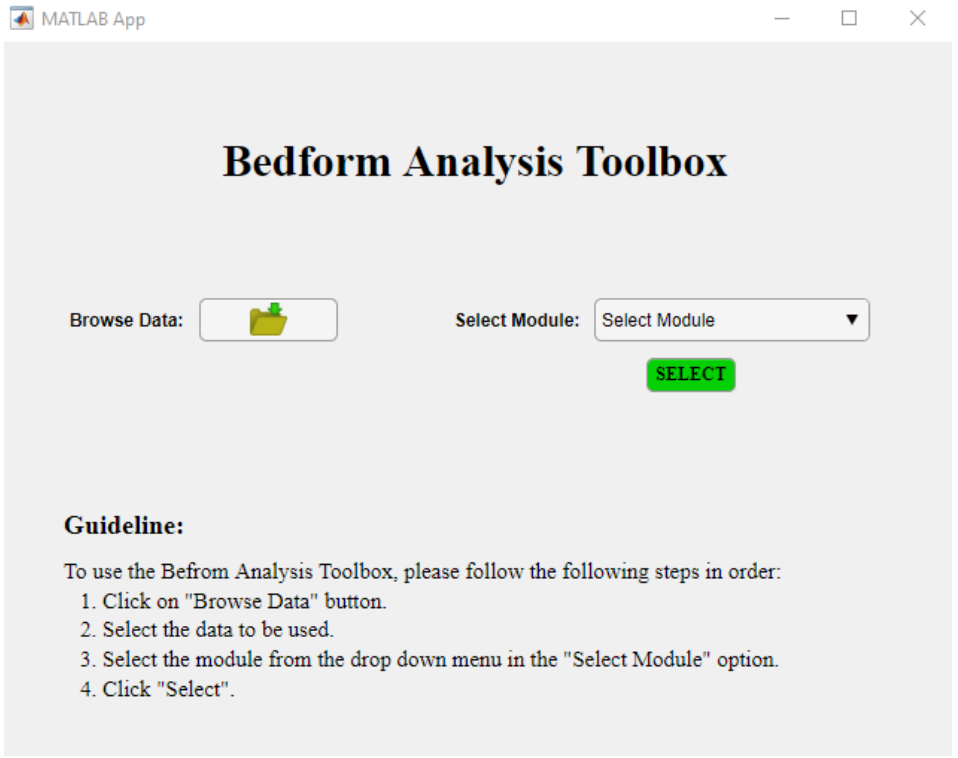
➔ Combine the available methods into one easy-to-use software

➔ Facilitating the analysis of bedform characteristics in a uniform and standardised way

BAT - Bedform Analysis Toolbox

Bedform Analysis Toolbox

Abdul Moeez Qureshi
Data Scientist

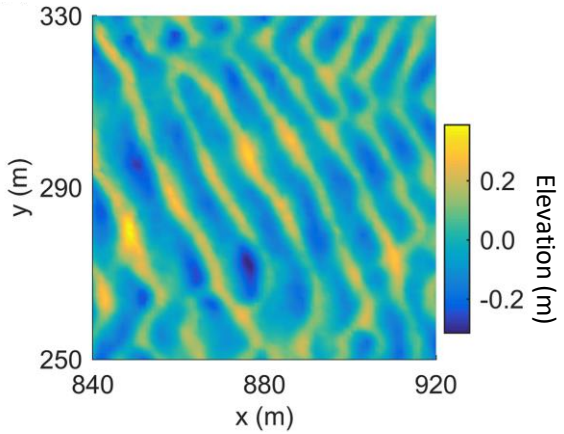


5 modules

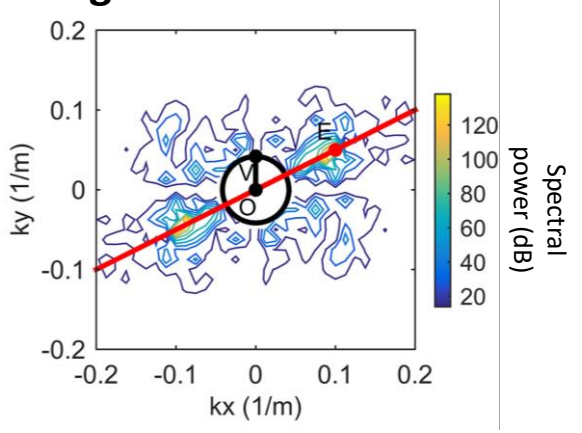
Module 1: data import, crestline direction, rotation

Input (matrices or vectors)

x = longitude
y = latitude
z = depth / elevation



Finding main crestline direction



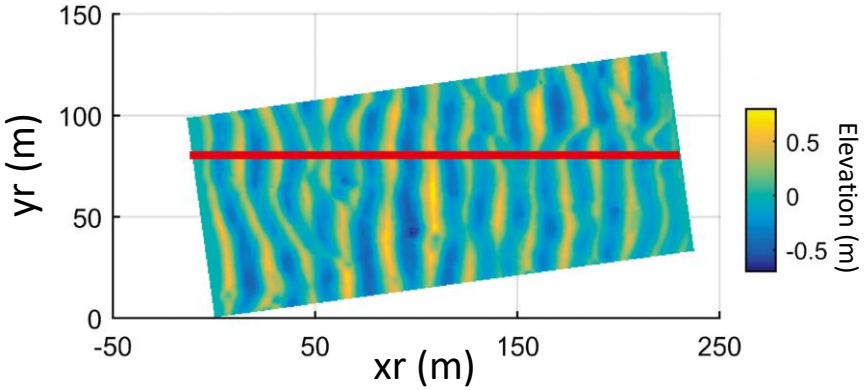
Determination of wavelength(s) of interest using a modified Differential Fourier Transform

Output: xr,yr,zr (r = rotated) as gridded matrices

xr = streamwise direction
yr = crosswise direction
zr = depth / elevation

Wavelengths of interest

Data rotation

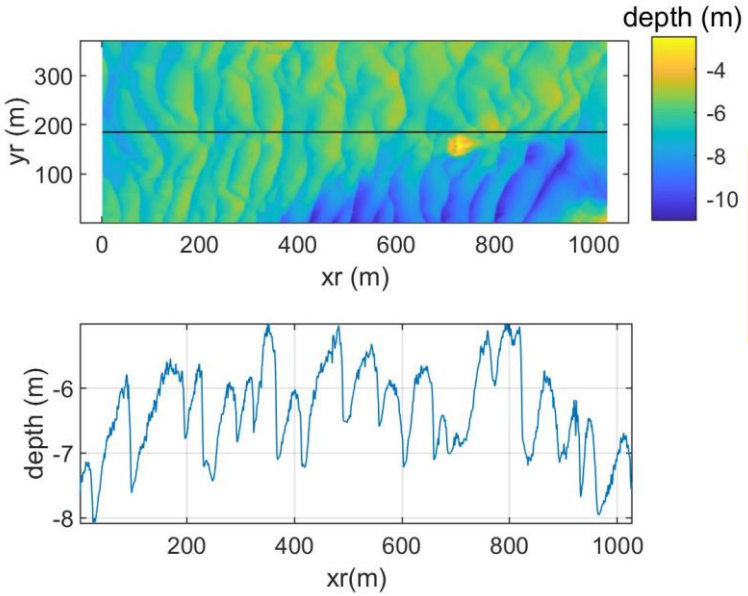


After Lefebvre et al., 2011, Cazenave et al., 2013, Wang et al., 2020

Module 2: scale separation

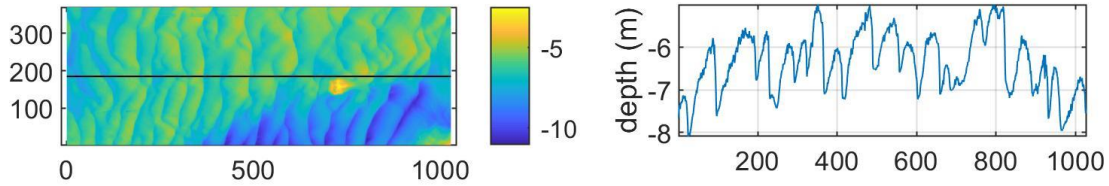
Input: xr,yr,zr as gridded matrices

(wavelengths of interest)

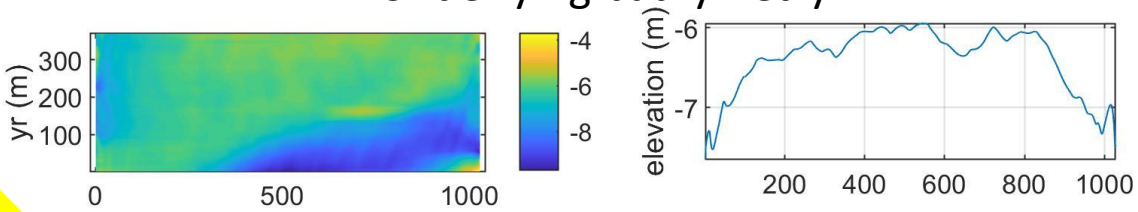


Method 1: moving average
Method 2: loess
Method 3: wavelet analysis

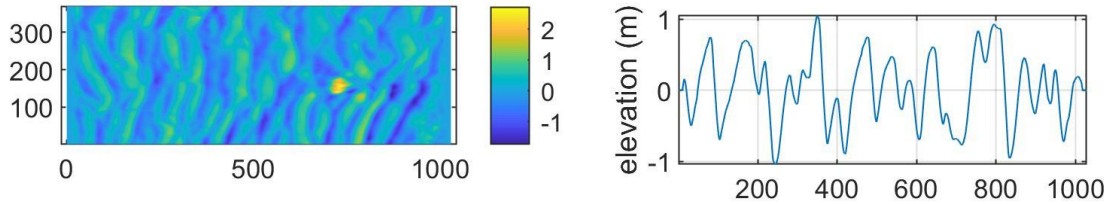
Original bathymetry



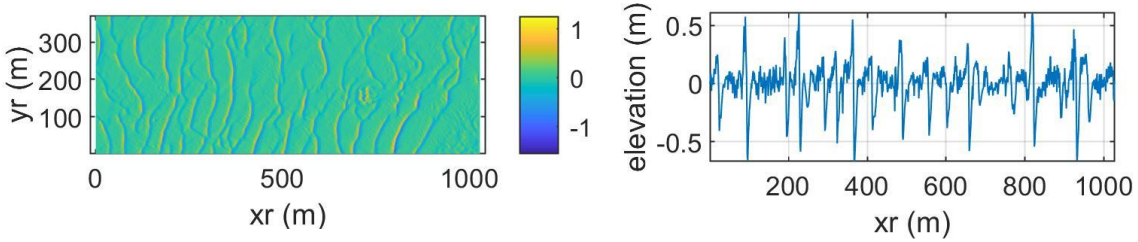
Underlying bathymetry



Primary bedforms



Secondary bedforms



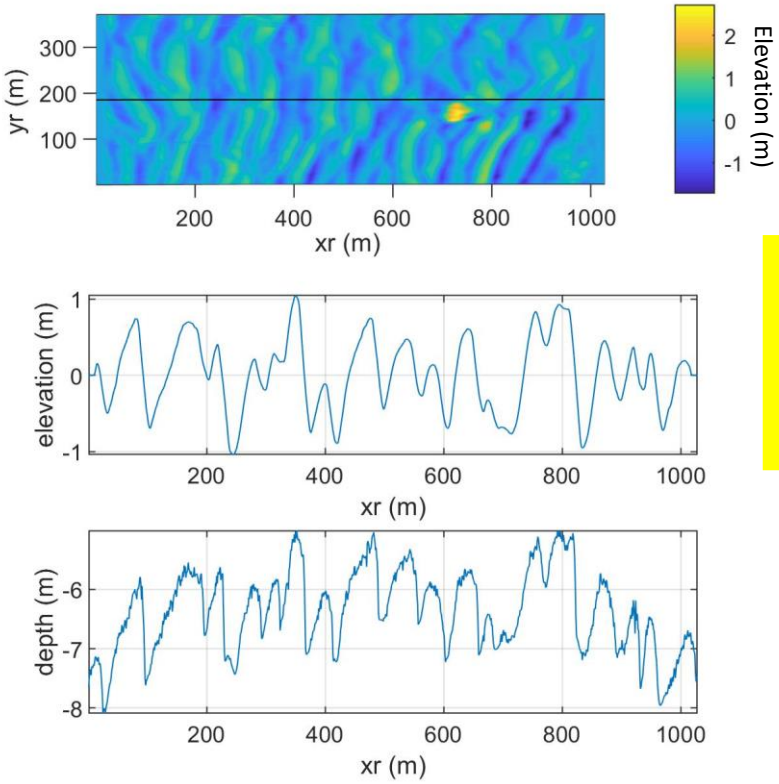
Output: xr,yr,zr,zr1,zr2,zr3

After Gutierrez et al., 2018, Zomer et al., 2021

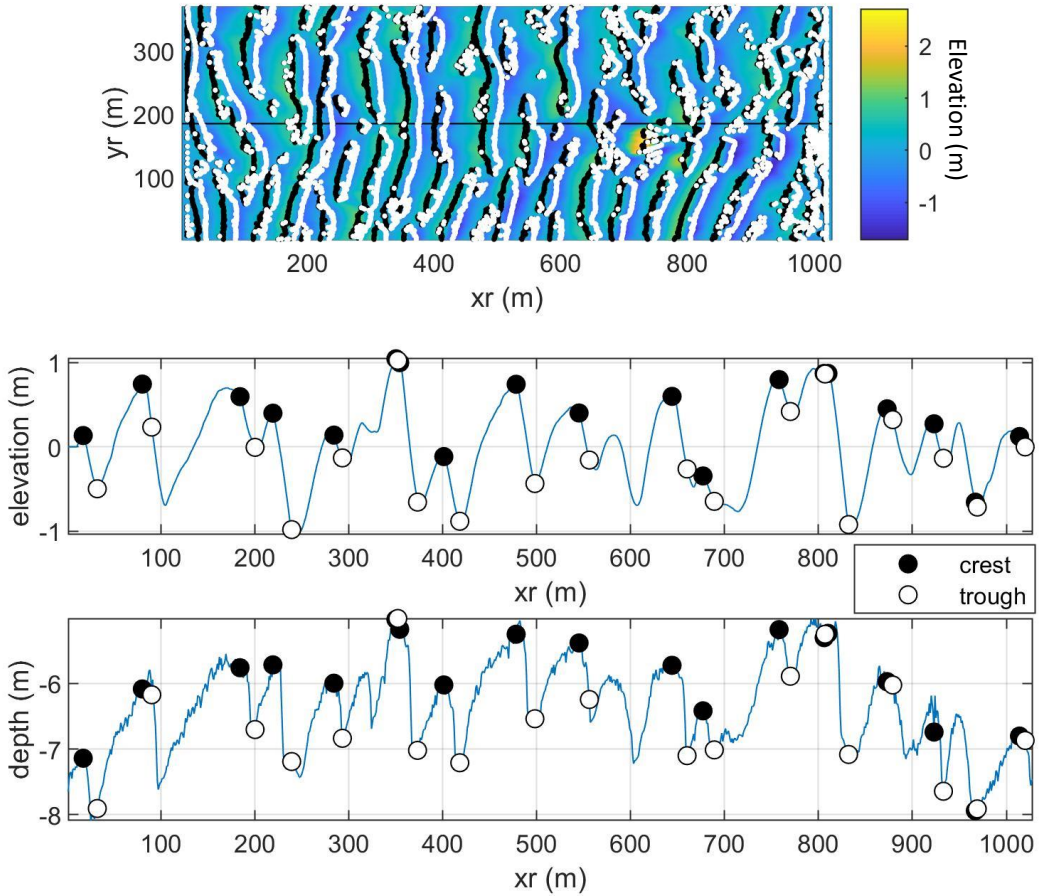
Lefebvre et al., AGU2021
alefebvre@marum.de

Module 3: crest and trough points detection

Input: xr,yr,zr,zrS
(zrS one of the scale from module 2)



Method 1: zero-crossing
Method 2: slope splitting
Method 3: minimum curvature
Method 4: peak detection

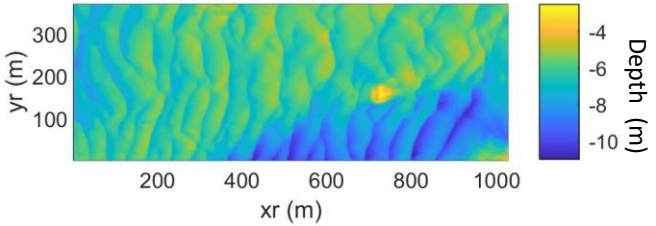


Output: position of crest and trough points

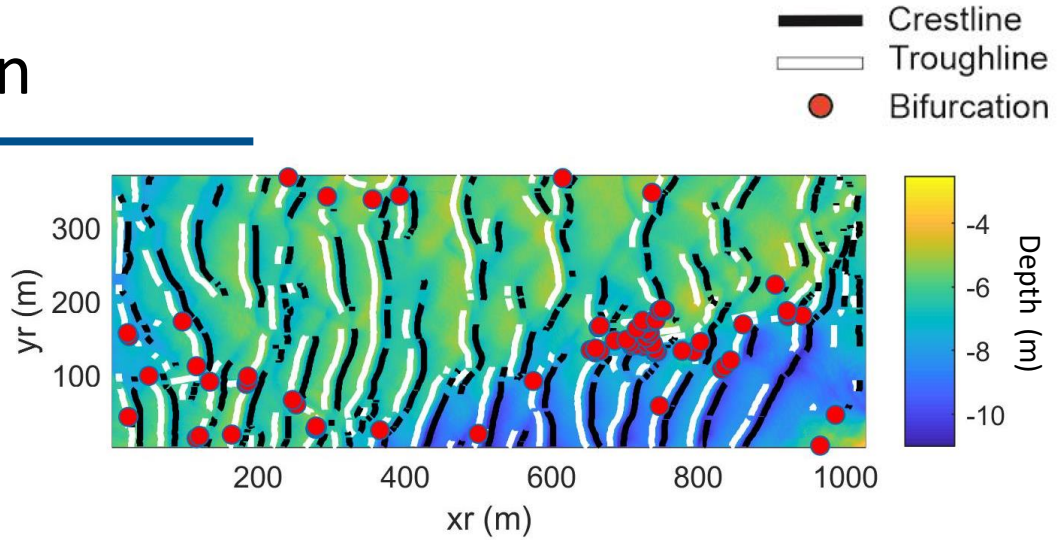
After van der Mark et al., 2008, Cisneros et al., 2020, Lefebvre et al., 2021, Scheiber et al., 2021

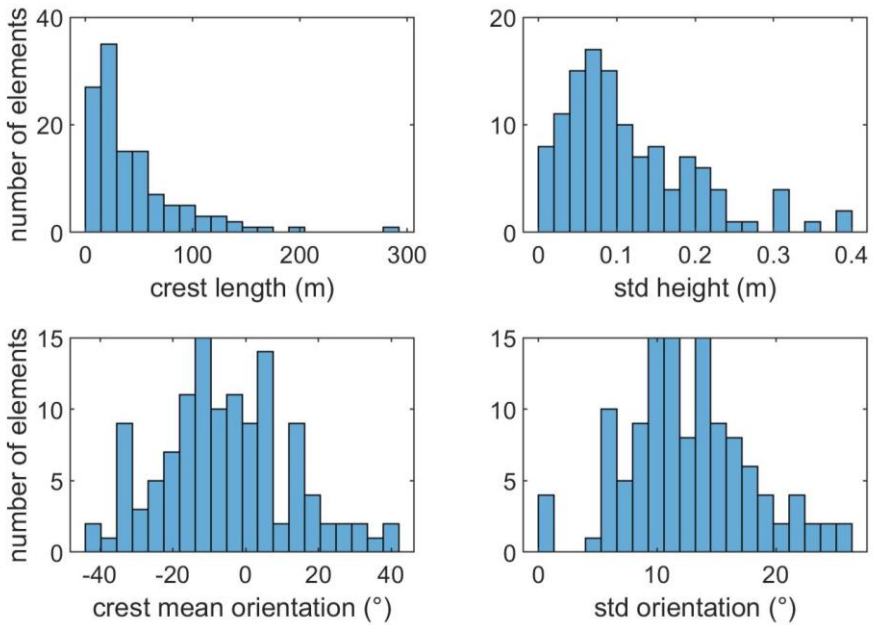
Module 4: crest and trough lines detection

Input: xr,yr,zr
(crest and trough points from module 3)



Method 1: minimum curvature
Method 2: crest-trough points





After Ogor, 2018, Lefebvre et al., 2021

Output: position and properties of crestlines and troughlines

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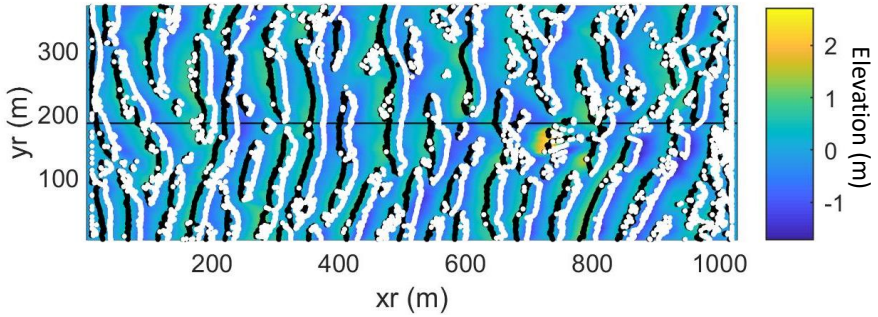
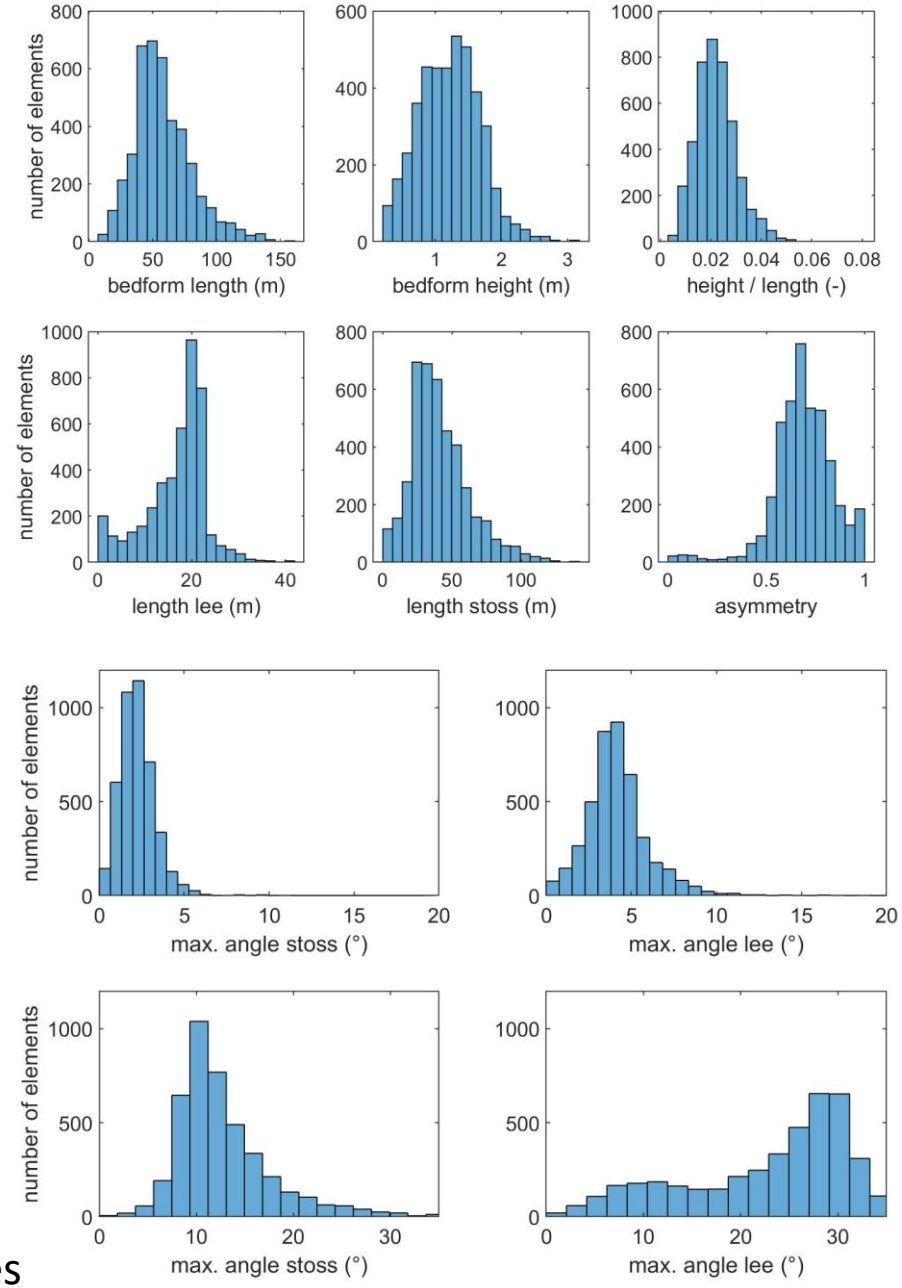
alefebvre@marum.de

Module 5: BEP bedform characteristics

Input: xr,yr,zr,
position of crest and trough points



Unidirectional or tidal?
Cleaning?



Output: BEP bedform properties

After Cisneros et al., 2020, Lefebvre et al., 2021

Lefebvre et al., AGU2021
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Bedform Analysis Toolbox

➔ For non-bedform researchers: GUI, easy to use, first impression of bedform properties

➔ For bedform researchers: functions which can be used individually

➔ Standardised, tested on different datasets, with recommendation

Currently a lot of problems with Matlab…
Still a lot of work to do to standardise and test the functions

Feedback welcome!
➔ What do you need?
➔ Get in touch
email, Twitter (@DrAliceLefebvre), QR code

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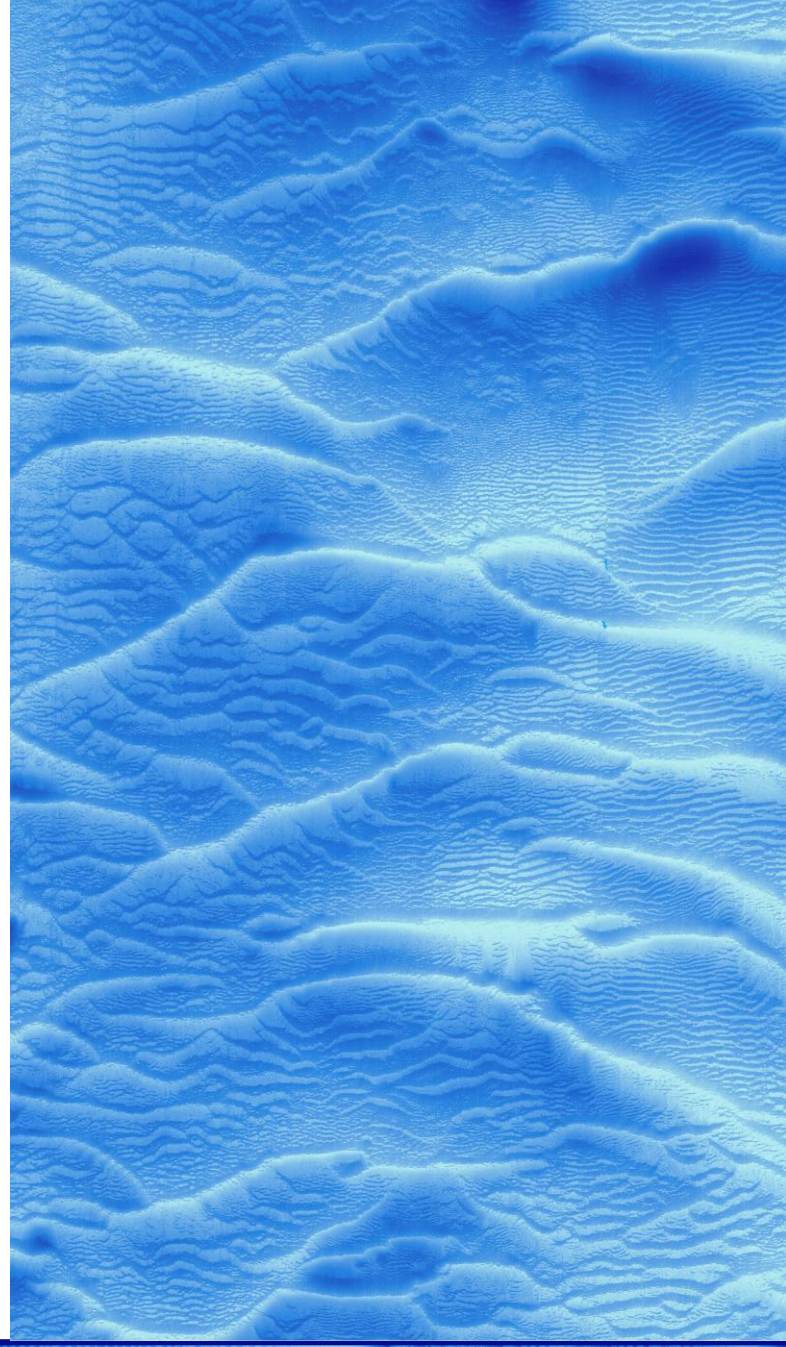
Conclusions

BAT - Bedform Analysis Toolbox

Bridging Worlds in Bedform Research with an Open Access, Universal Toolbox

- ➔ Combine some of the available methods to analyse bedforms into one easy-to-use software
- ➔ Facilitating the analysis of bedform characteristics in a uniform and standardise way
- ➔ For bedform specialists and everyone else



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