Determination of sediment transport mode based on grain size and shape data from dynamic image analysis:

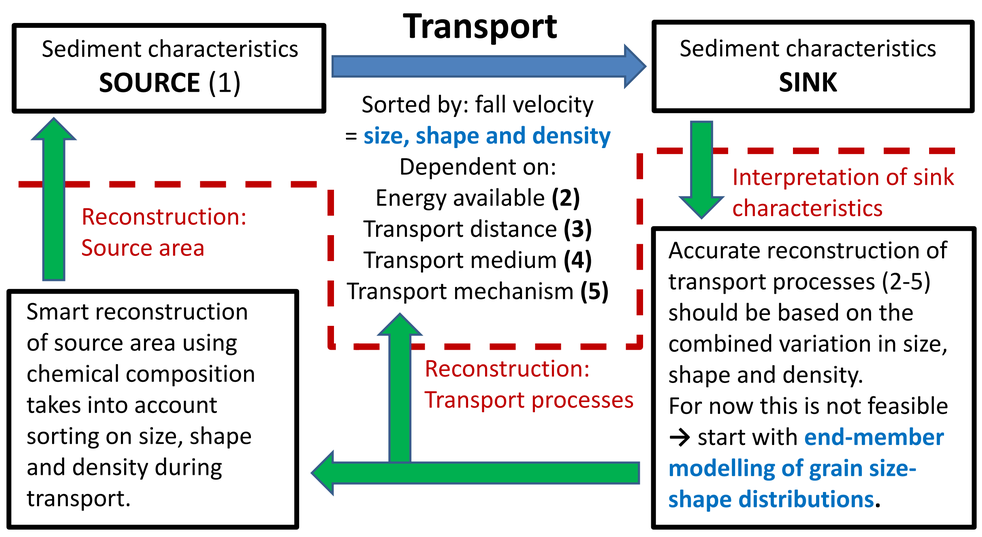
application to a secondary tidal inlet system

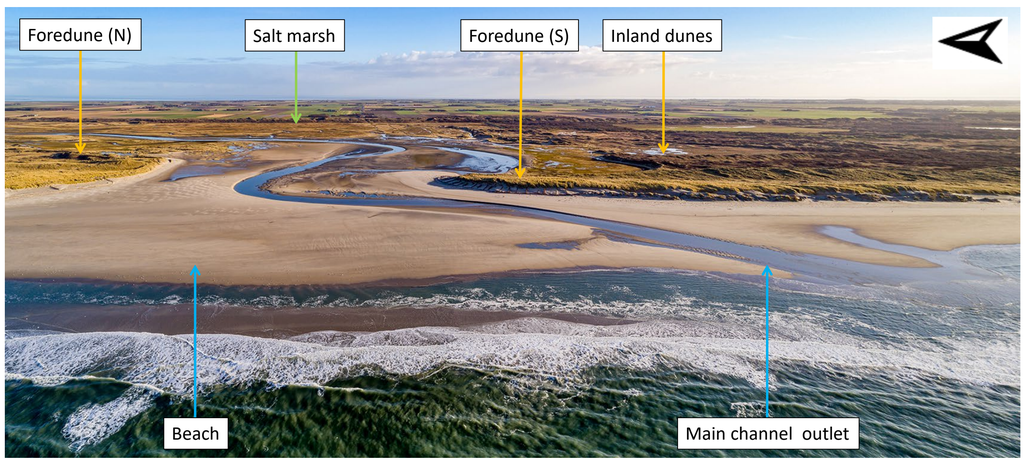
M.A. Prins[1], Y. Cuijpers[1], J.A. van Hateren[1], J.B.W. Stuut[1,2], S.R. Troelstra[1]

[1]*Department of Earth Sciences, Faculty of Science, Vrije Universiteit Amsterdam, The Netherlands.*

[2]*Department of Ocean Systems, Netherlands Institute for Sea Research (Royal NIOZ), The Netherlands.*

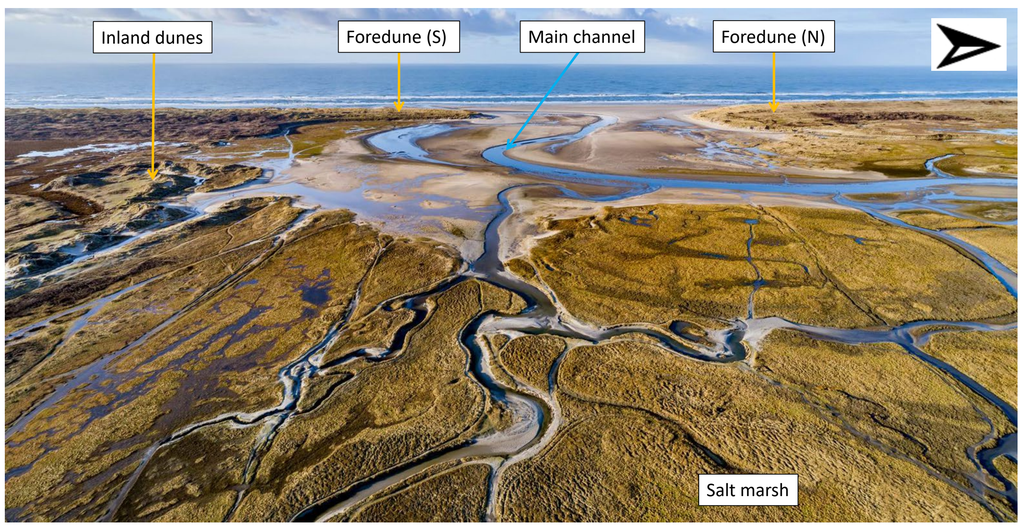
Introduction



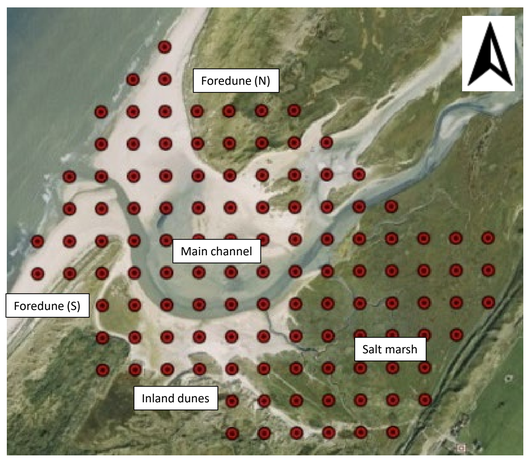


Aim of this study

Here we present an application of a novel methodology for determination of sediment transport modes based on end-member modelling of grain size-shape distributions from dynamic image analysis [1]. Surface sediment samples from an active secondary tidal inlet system along the Dutch coast – the Slufter nature reserve on the island of Texel – are used to assess the physical meaning of the method's output in a complex sedimentary system where sediment is transported by waves, tides and wind.



Methodology



Surface sediment samples (n=118) have been obtained on a fixed grid (resolution 125 m) in April 2019.

Two types of sedimentological analyses have been performed:

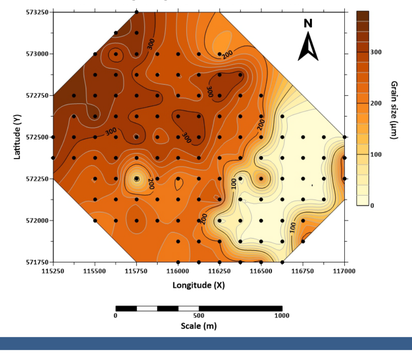
- Laser-diffraction particle size analysis (Sympatec HELOS KR) → grain-size distribution.
- Dynamic image analysis (Sympatec QICPIC)→ size-shape distribution.

The size (HELOS) and size-shape distributions (QICPIC) of all samples are decomposed using AnalySize [2] resulting in two end-member mixing models.

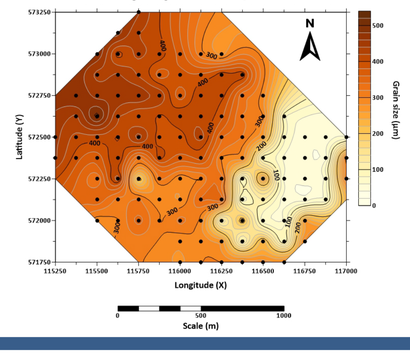
Results

The median grain size shows a clear spatial distribution pattern which is best described as an overall west-east fining trend. Important to note is that the two instruments produce very similar grain size results.

Sympatec HELOS



Sympatec QICPIC



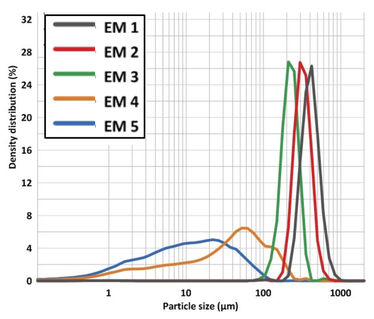
Results

Mixing models - HELOS (left) & QICPIC (right)

Mixing model 1

'Size only'

Sympatec HELOS

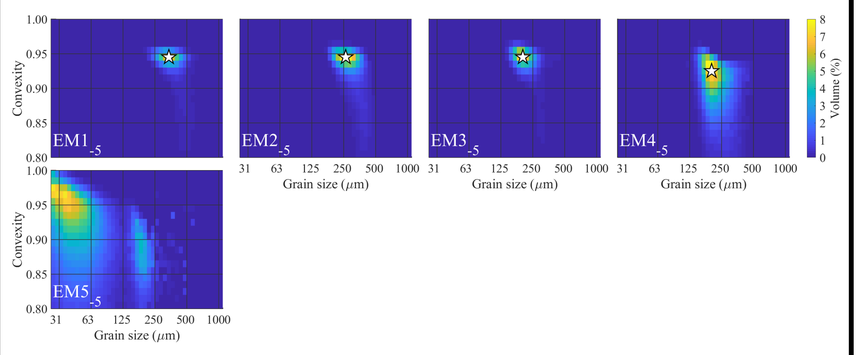


End member size distributions: EM1 (mode 400 µm), EM2 (300 µm), EM3 (210 µm) are well-sorted. EM4 (55 µm, 2nd mode 150 µm) and EM5 (25 µm) are poorly-sorted.

Mixing model 2

'Size and Shape'

Sympatec QICPIC



End member grain size-shape distributions: EM1 (mode 350 µm), EM2 (260 µm) and EM3 (180 µm) are highly convex, and well-sorted with respect to size and shape. EM4 and EM5 are poorly-sorted with respect to size and shape. EM4 (180 µm) overlaps with EM3 in terms of size but shows a strong decrease in convexity towards coarser grain size. EM5 is significantly finer-grained (40 µm, 2nd mode ~180 µm) and also shows a strong decrease in convexity with increasing grain size.

Spatial end member distributions

Mixing model 1

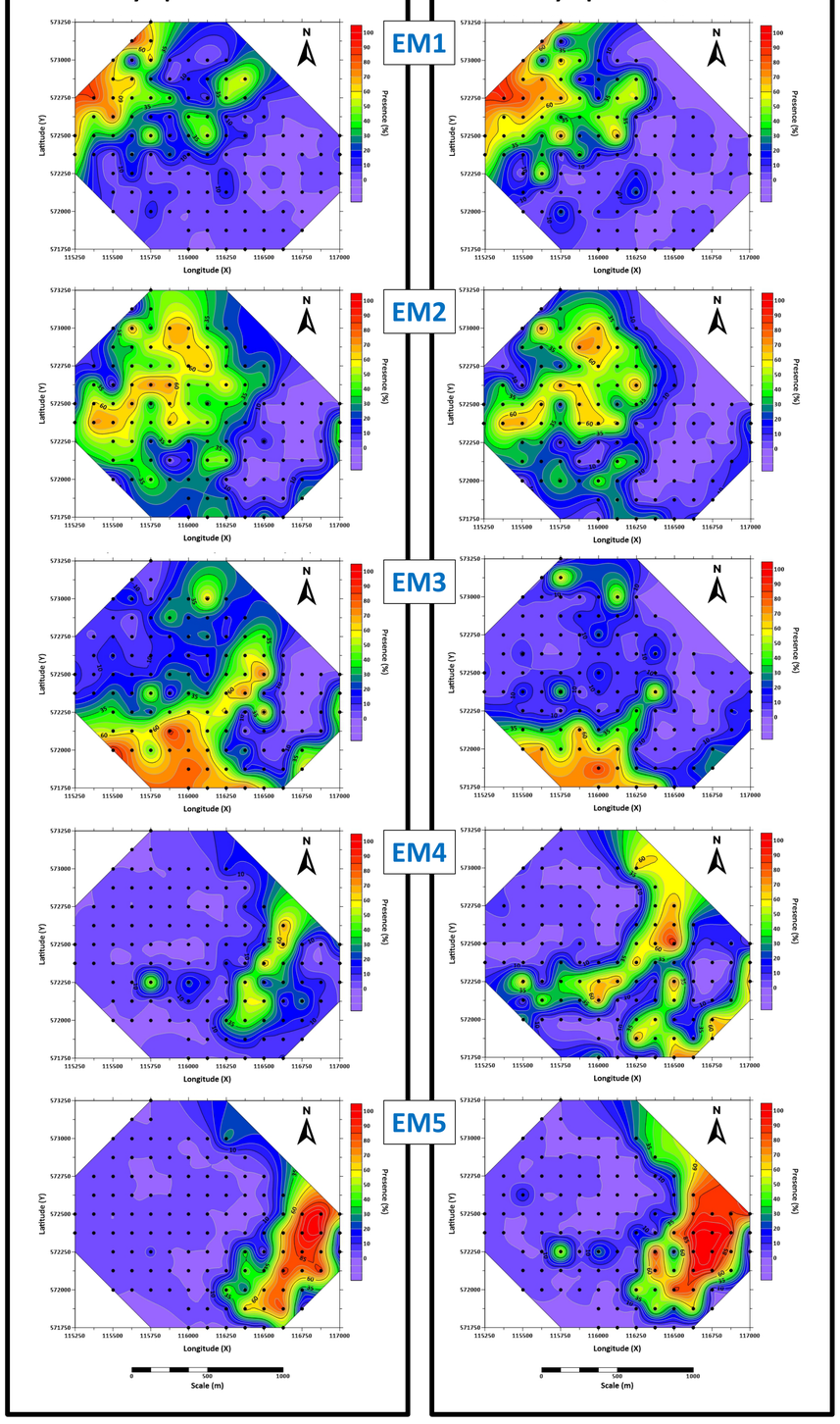
'Size only'

Sympatec HELOS

Mixing model 2

'Size and Shape'

Sympatec QICPIC



Discussion

EM compositions:

- Size distributions of **EM1**, **EM2** and **EM3** are very similar for both mixing models. The shapes of the size-shape distribution of EM1-EM3 (QICPIC) indicate that these components have been transported as **bed load**.
- Size distributions of **EM4** and **EM5** are very different for both mixing models: the HELOS model distinguishes two silty components, whereas the QICPIC models shows one sandy and one silty component. The shapes of the size-shape distributions of EM4 and EM5 (QICPIC) indicate that these components have been transported as **suspended load**.

Spatial EM distributions:

- **EM1** is dominant on the beach and in the main channel outlet → **wave- and tide-dominated bedload transport**.
- **EM2** is dominant in the main channel and foredune regions → **tide- and aeolian dominated bedload transport**.
- **EM3** is dominant in the sheltered inland dunes south of the main channel → **aeolian-dominated bedload transport**.
- **EM4** is dominant in the main channel and close to tidal creeks on the salt marsh → **tide-dominated suspended load transport**.
- **EM5** is dominant in the salt marsh region → **tide-dominated suspended load transport**.

References

[1] Van Hateren, J.A., van Buuren, U., Arens, S.M., van Balen, R.T., Prins, M.A., 2020, Identifying sediment transport mechanisms from grain size-shape distributions. Earth Surface Dynamics, 8, 527–553.

[2] Paterson, G. A., & Heslop, D. (2015). New methods for unmixing sediment grain size data. Geochemistry, Geophysics, Geosystems, 16: 4494-4506.

Conclusions

Laser-diffraction particle size analysis and dynamic image particle size and shape analysis result in very similar results for highly convex ('well-rounded') sediment particles but strongly divergent results for low convex ('angular') sediment particles clearly highlighting the often neglected particle-shape effects on size analysis.

Using combined end-member modelling of grain size-shape distributions, different modes of sediment transport can be readily identified in a present-day tidal inlet system:

(1) the shape of the size-shape distributions allows the distinction of bedload versus suspended-load transported sedimentary components,

(2) the modelled size-shape end members show clear spatial distribution patterns reflecting sedimentary (sub-) environments which are different in terms of geomorphology, the dominant transporting agent and overall energy conditions (W to E: high energy → low energy).