Determination of sediment transport mode based on grain size and shape data from dynamic image analysis:
application to an active coastal dune system

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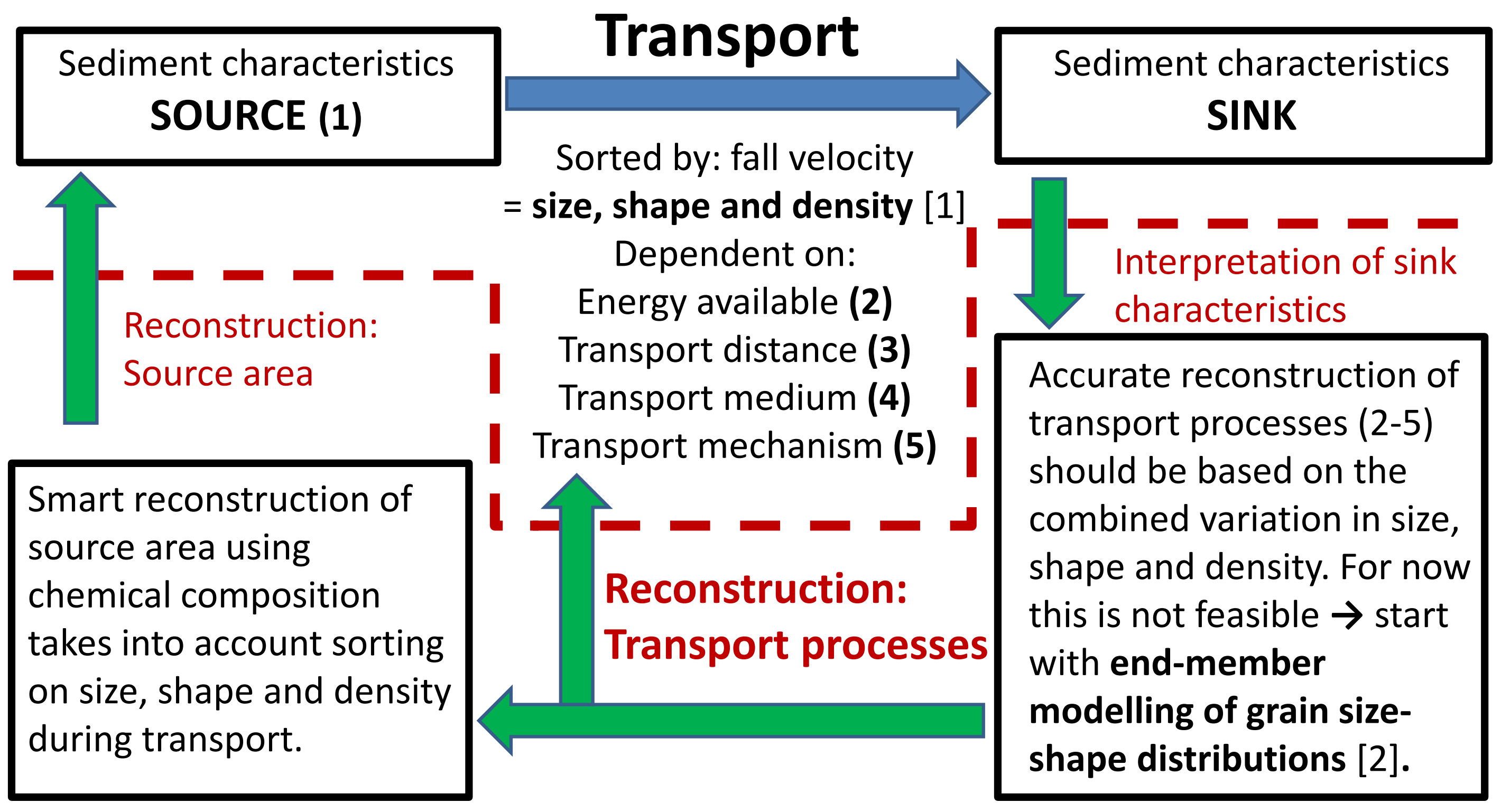
Introduction



Transport

Sediment characteristics
SOURCE (1)

Sediment characteristics
SINK

Sorted by: fall velocity
= **size, shape and density** [1]
Dependent on:
Energy available **(2)**
Transport distance **(3)**
Transport medium **(4)**
Transport mechanism **(5)**

Reconstruction:
Source area

Interpretation of sink characteristics

Smart reconstruction of source area using chemical composition takes into account sorting on size, shape and density during transport.

Reconstruction: Transport processes

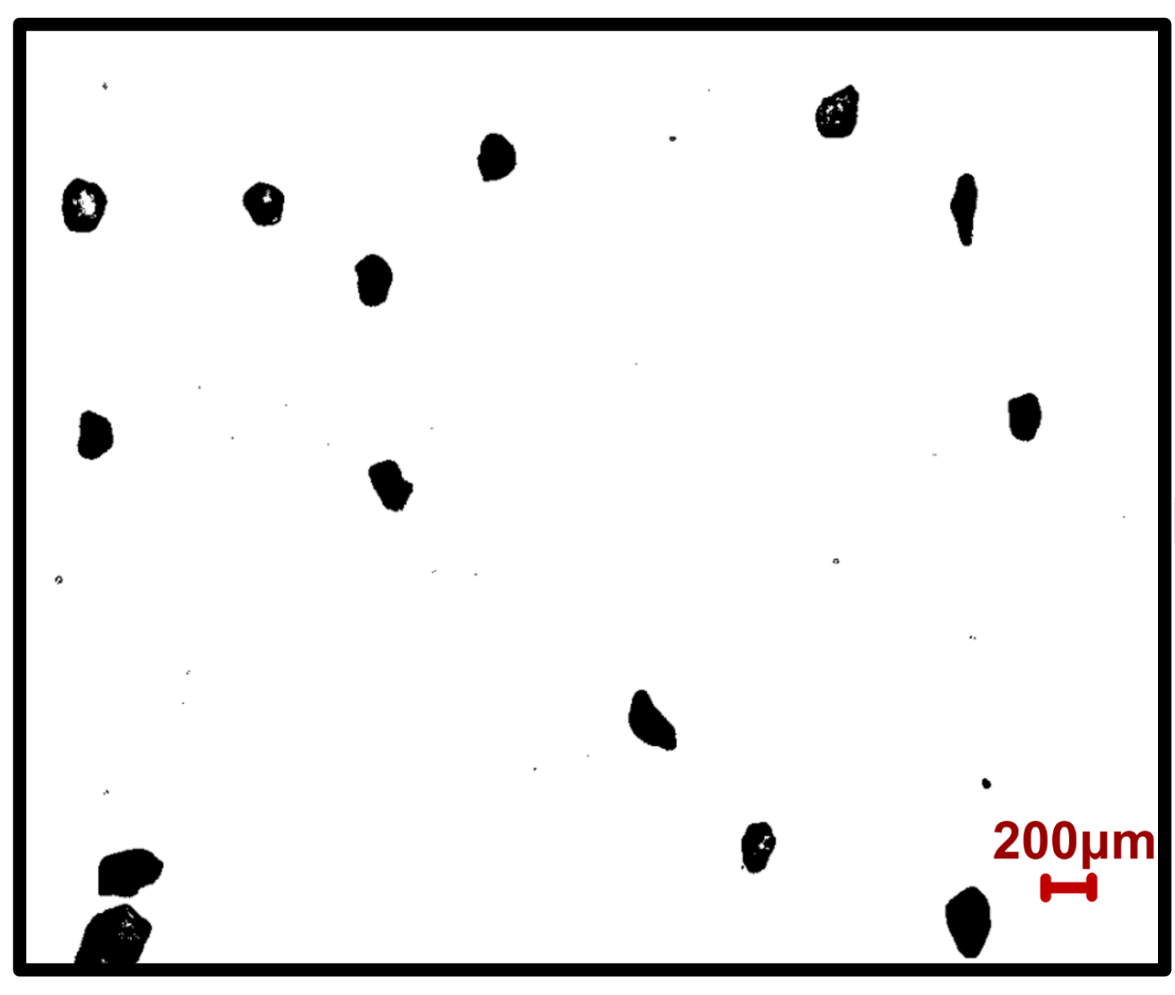
Accurate reconstruction of transport processes (2-5) should be based on the combined variation in size, shape and density. For now this is not feasible → start with **end-member modelling of grain size-shape distributions** [2].

Study area

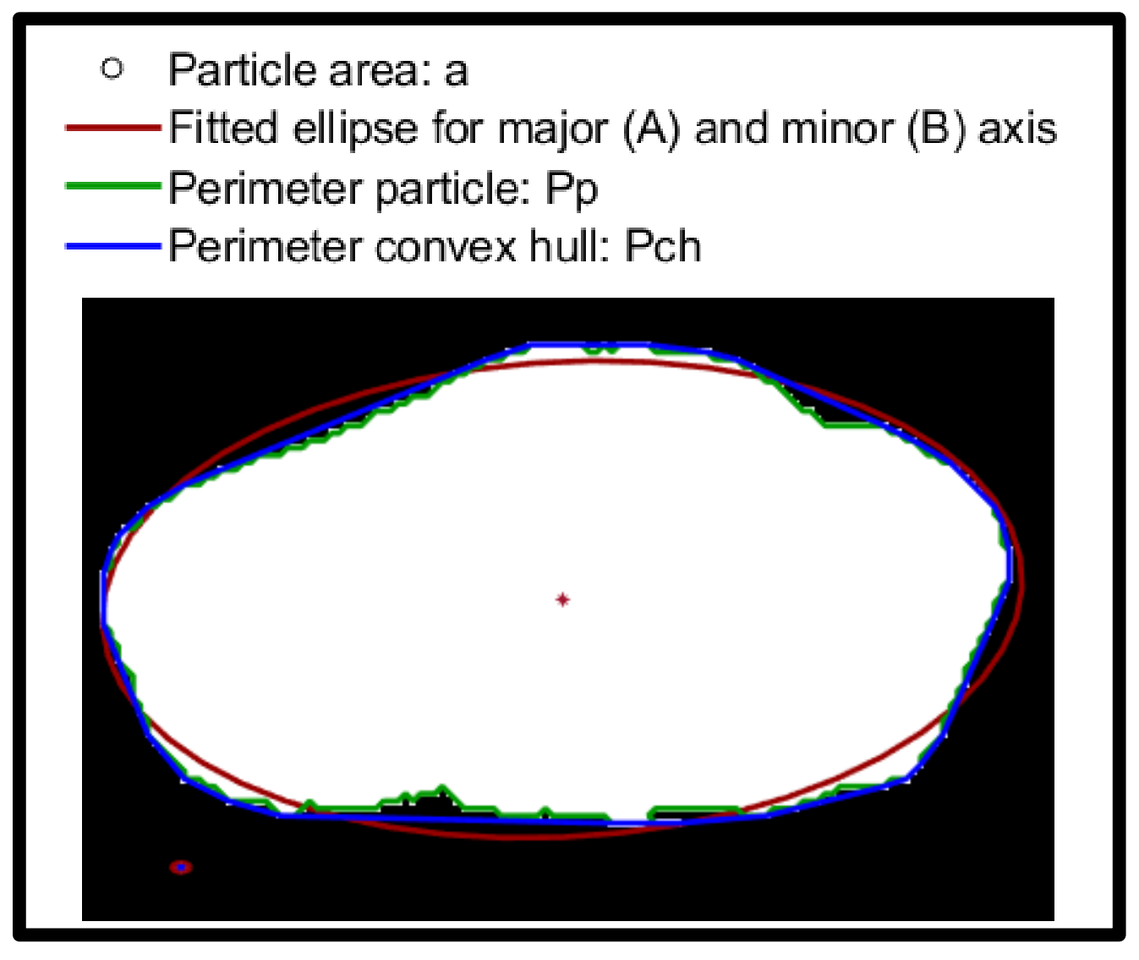
A sand remobilisation project in the Dutch coastal dunes provides the opportunity to study active aeolian bedload and suspension processes on basis of surface sediment samples (beach, notch (red line), foredunes (yellow line)) and suspended-sand trap samples (red triangles). Remobilisation of the dunes in this area is promoted by digging of notches through the first dune-row (1) and removing vegetation from inland dunes (2).

Methodology

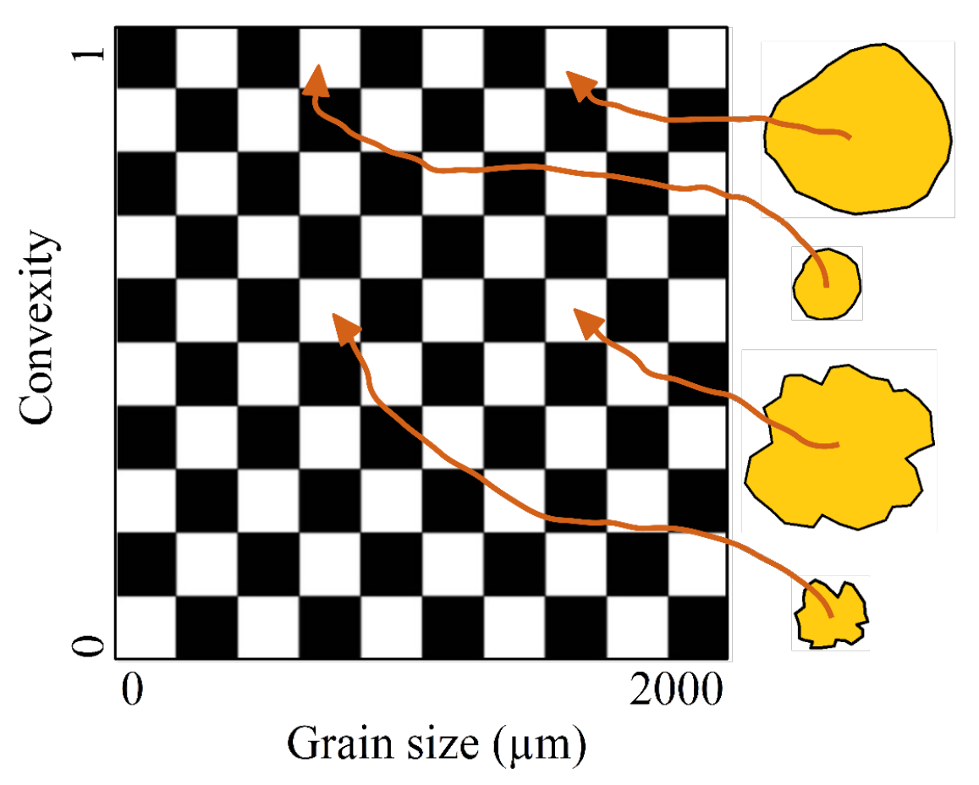
1) **Sympatec Qicpic dynamic image analysis** takes images of the sample in suspension at 25 frames per second → a few 100 thousand particles are analysed per measurement.



2) **Grain properties of individual particles** are computed using Matlab. Basal parameters shown in the figure are used to compute area proportional diameter (D2d), aspect ratio, **convexity** and Cox circularity.



3) Using R, each particle is assigned to a "**size-shape bin**" by its size and its shape (convexity in the example). This gives the x and y value. The volume of all particles in a "square of the chessboard" is summed, giving rise to the z value: volume percentage.

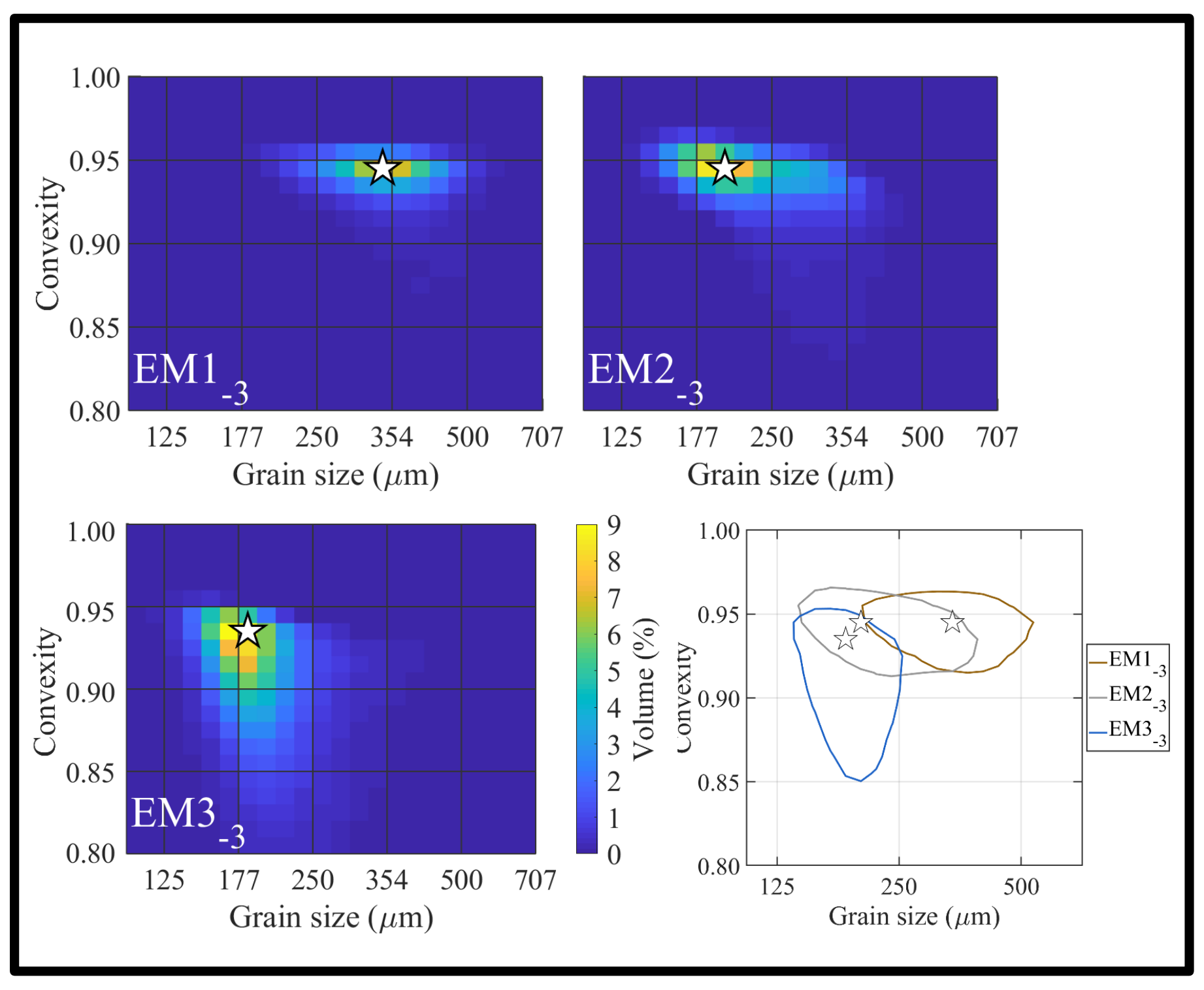


4) In steps 1 to 3 a **size-shape distribution** was created for each sample. The size-shape distributions of all samples are unmixed using AnalySize [3] which was determined to produce the most accurate unmixing results for grain size distribution datasets [4].

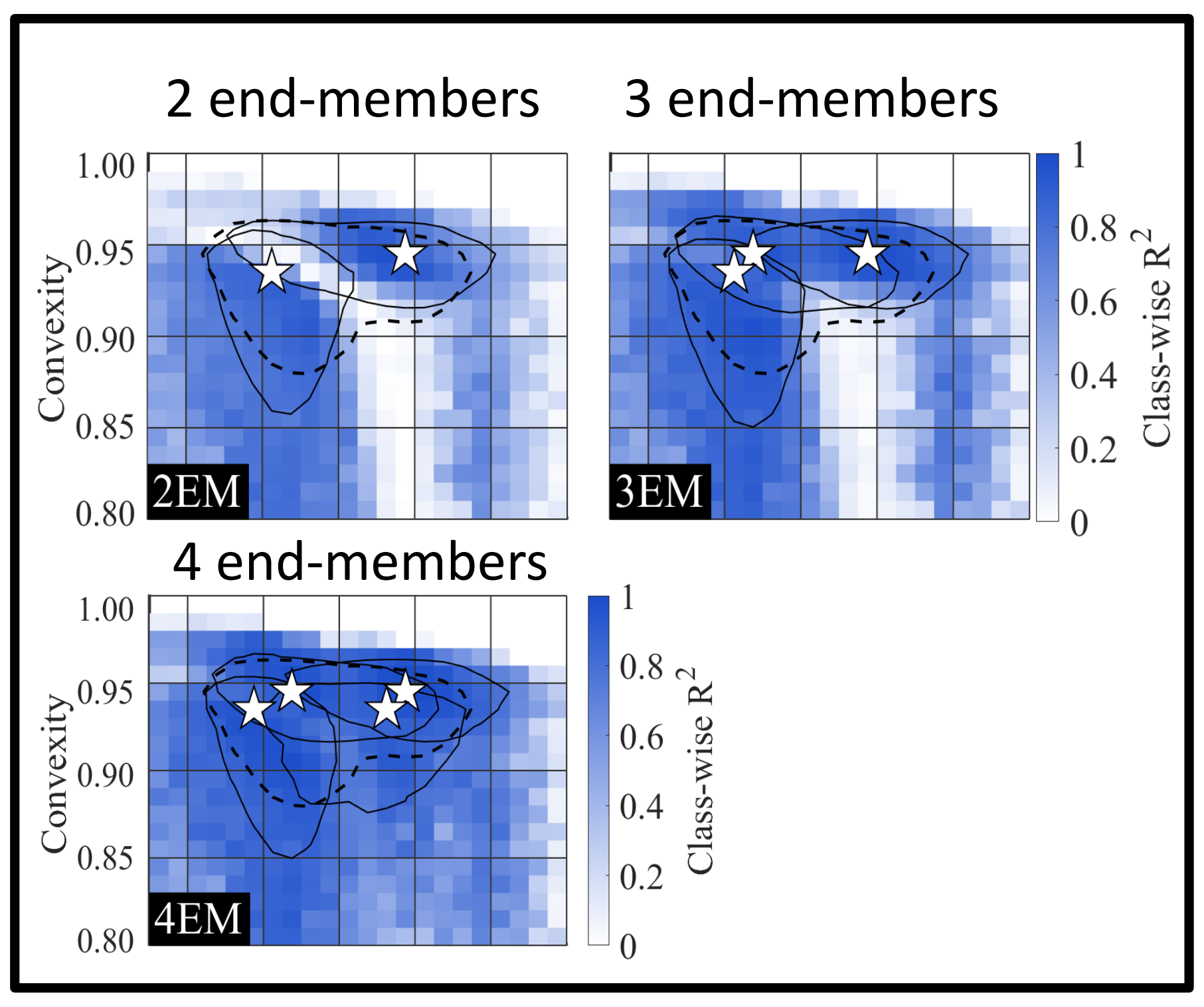
References
[1] Cui, B., Komar, P. D., & Baba, J. (1983). Settling velocities of natural sand grains in air. Journal of Sedimentary Research, 53(4).
[2]] Van Hateren, J.A., van Buuren, U., Arens, S.M., van Balen, R.T., Prins, M.A. (2020). Identifying sediment transport mechanisms from grain size-shape distributions. Earth Surface Dynamics, 8, 527–553.
[3] Paterson, G. A., & Heslop, D. (2015). New methods for unmixing sediment grain size data. Geochemistry, Geophysics, Geosystems, 16(12), 4494-4506.
[4] van Hateren, J. A., Prins, M. A., & van Balen, R. T. (2018). On the genetically meaningful decomposition of grain-size distributions: A comparison of different end-member modelling algorithms. Sedimentary Geology, 375, 49-71.

Results and discussion

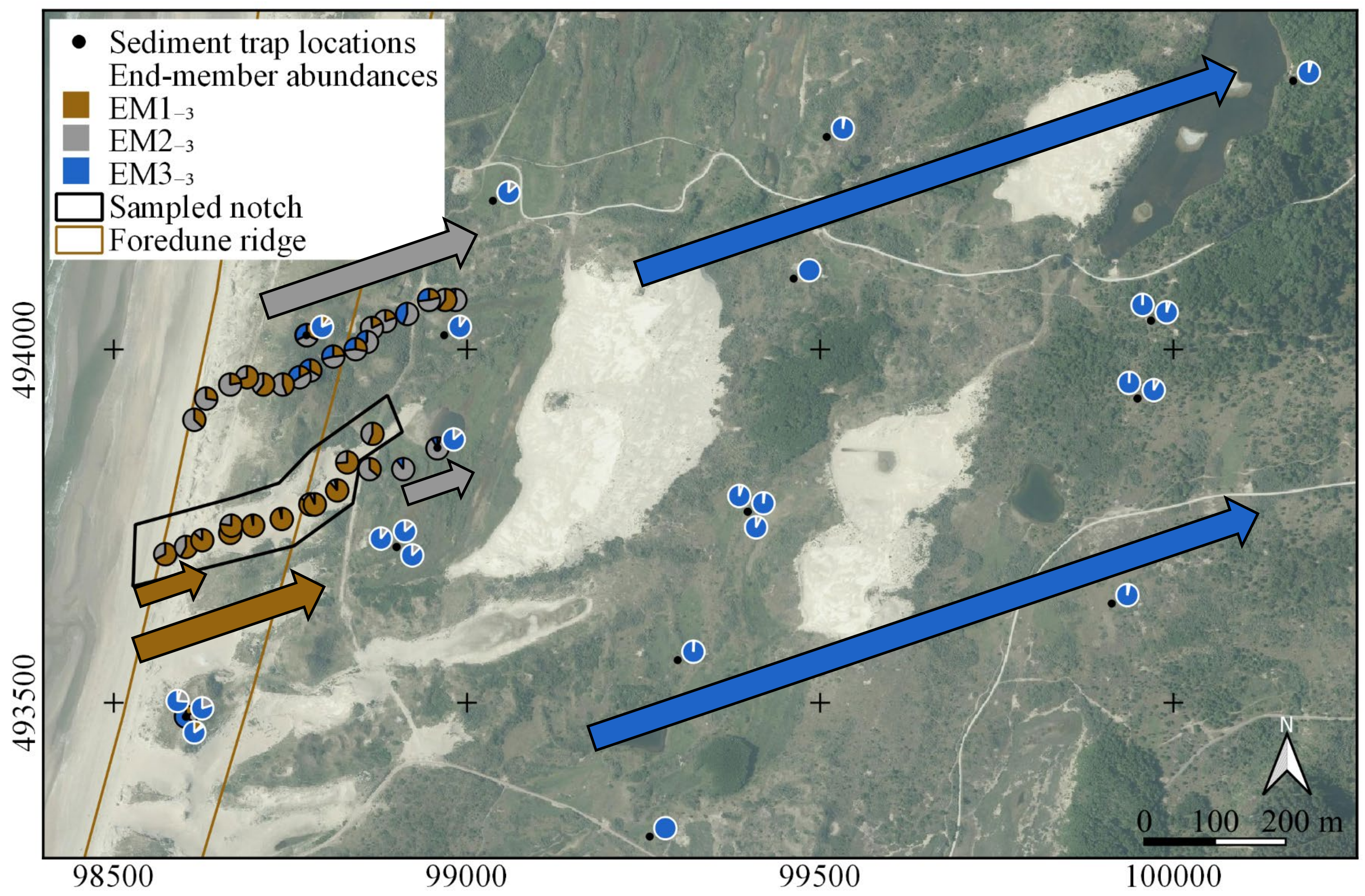
1) **End member grain size-shape distributions** (shape parameter shown here: convexity). From top left: EM1: the coarsest and highly convex end-member. EM2: the intermediate end-member, showing less convex grains in the coarser range. EM3, the finest grained and least convex end-member. The differences between end-members are well displayed by the 2% volume contour plots of the end-members (bottom right).



2) **Explained variance per size-shape bin** (a "square on the chessboard"). A 2% volume contour of the average size-shape distribution of the samples is plotted as reference. Note the low explained variance of the 2 EM model in the middle of the 2% contour. The 3 EM model performs significantly better in this region. The 4EM shows improvement, but this mainly occurs in size-shape bins that contain insignificant amounts of volume in the data.



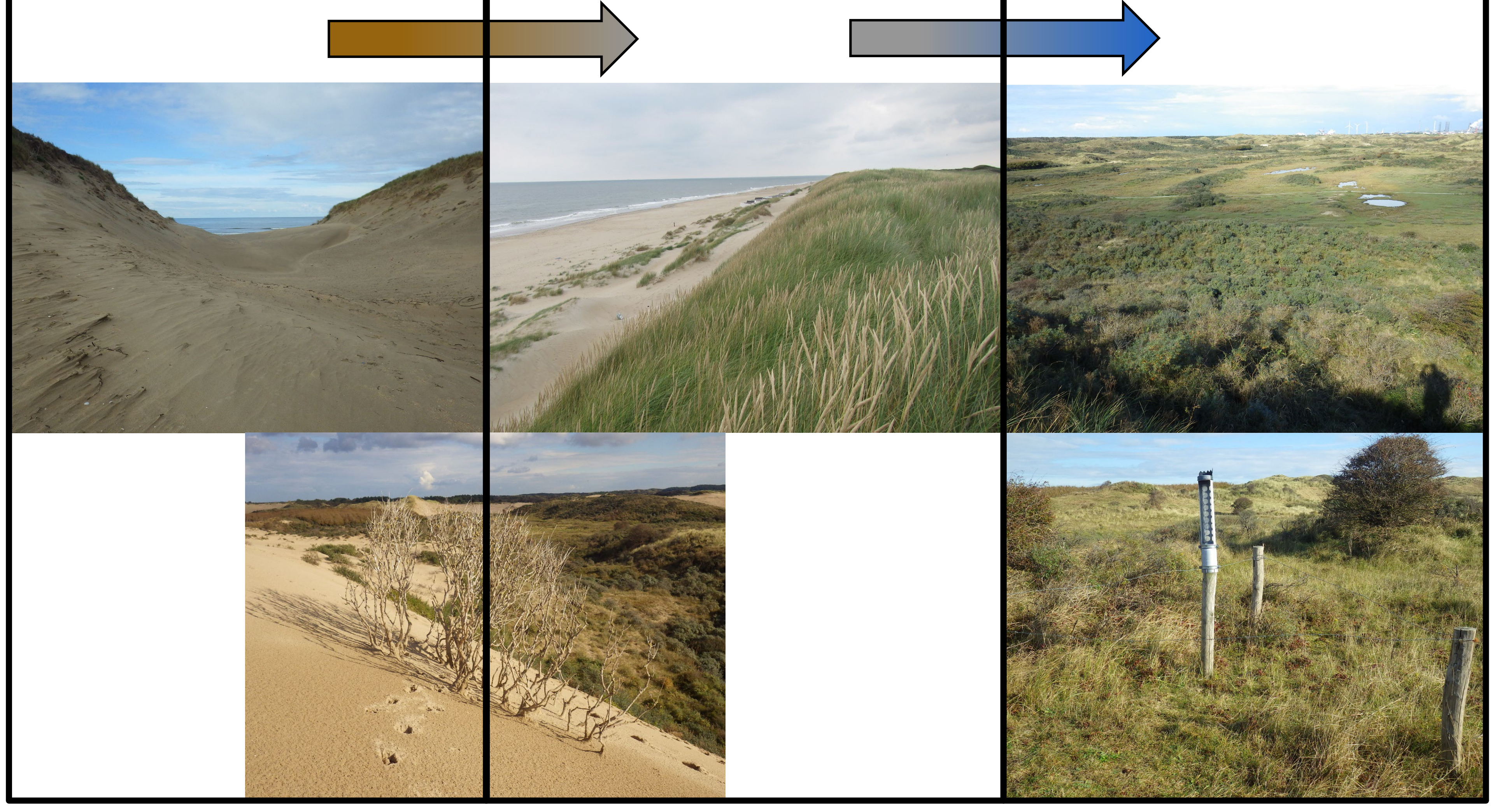
4) **Spatial distribution of end-member abundance** (proportion of the end-members in each sample) in the field. Brown represents the coarsest and highly convex EM1, grey represents the intermediate EM2 and blue the fine-grained and least convex EM3. End-member abundances show a clear spatial pattern that can be interpreted in terms of the dominant transport processes occurring along a beach-dune transect: the bare notches that allow bedload transport directly from the beach (brown arrows) correlate with EM1. The first dune row from the beach, where marram grass partly blocks bedload transport, as well as the vegetated area directly behind the notch, are dominated by EM2 (grey arrows). In these areas, grains may be carried a short distance land inward in modified saltation (very short-term suspension). Further land inward, only transport in suspension is possible due to vegetation, EM3 dominates this area (blue arrows).



Upper beach and bare notches: bedload (EM1)

Initial vegetation: modified saltation (EM2)

Fully vegetated dune area: suspension (EM3)



Conclusions

- The spatial distribution of the three end members is in accordance with the local geomorphology and reflects the three dominant aeolian transport processes known to occur along a beach to dune transect.
- These processes are characterised by distinctly different end-member size-shape distributions, resulting from differential shape sorting with increasing size. Bedload shows a constant grain shape, modified saltation a minor decrease in grain regularity, and suspension a strong decrease in grain regularity.
- The principal advantage of the new method is that the characteristic shapes of the end-member size-shape distributions can be used as a fingerprint of the transport mode. The new method therefore resolves the ambiguity that arises when the transport mode is reconstructed using grain-size distributions.