A methodology for the quantitative comparison of subsurface structures using geometrical parameters

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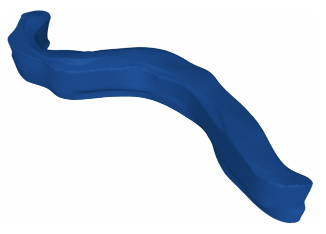
Introduction

- Quantification and comparison of 3D bodies is relevant in many scientific fields and crucial when developing a geomodelling method: Comparing multiple model realizations quantitavely is valuable to assess the dimensional range of geological features, possibly adjust parameters/settings of the chosen modelling method or generally assess the plausibility of modelling results
- Quantification is achieved using geometrical/statistical parameters: lateral & vertical measurements of dimensions on cross sections along and across the horizontal main axis and gradient and curvature measurements on these cross sections are conducted
- Data analysis can reproduce main geometrical characteristics of input data
- Algorithm was tested on 240 intrusive salt structures from the North German Basin

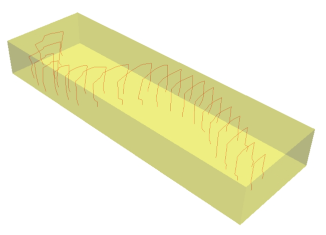
Measurements

Step 1: Cross sections of 1st direction

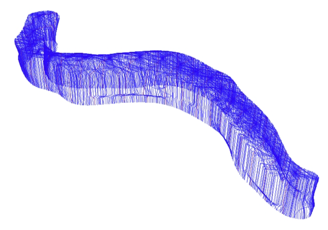
1) Input structure



2) sections ⊥ to axis of bounding box

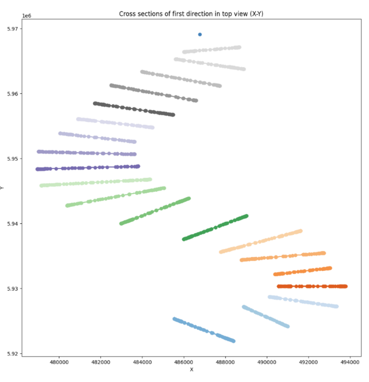


3) incremental rotation of sections by 5° and area calculation



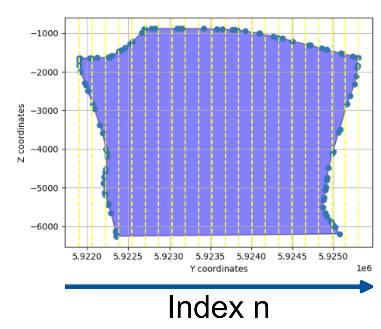
!sections have lowest area when ⊥ to main axis!

4) sections ⊥ to longer horizontal main axis



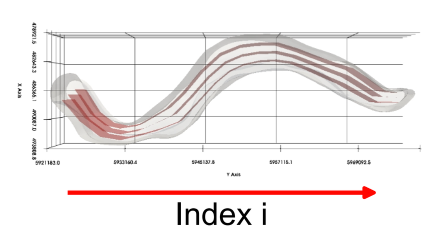
Step 2: Orthogonal cross sections

1) Divide sections of 1st direction (index=i) into n=22 vertical lines
Extract X, Y and Zmin +Zmax from each line → 2 points

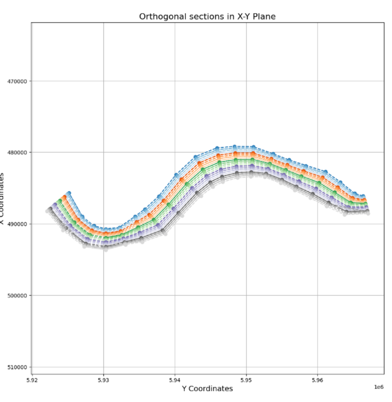


2) Create trapezoidal segments (one from overall 4 points of 2 consecutive sections)

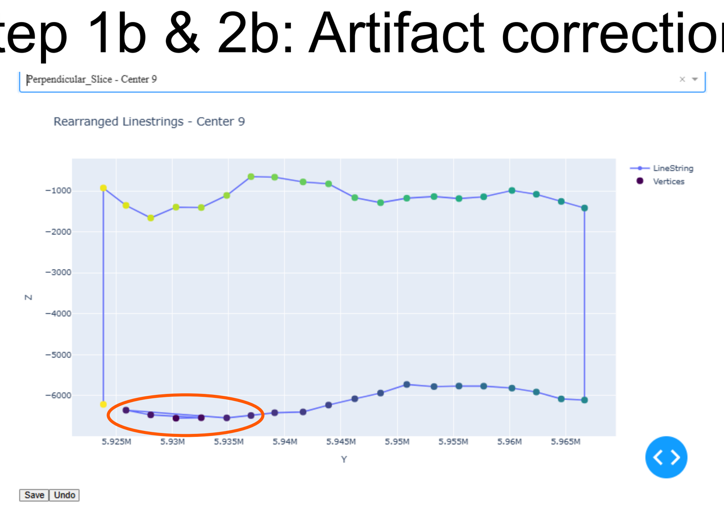
3) Combine trapezoidal segments of given line index=n to form orthogonal section



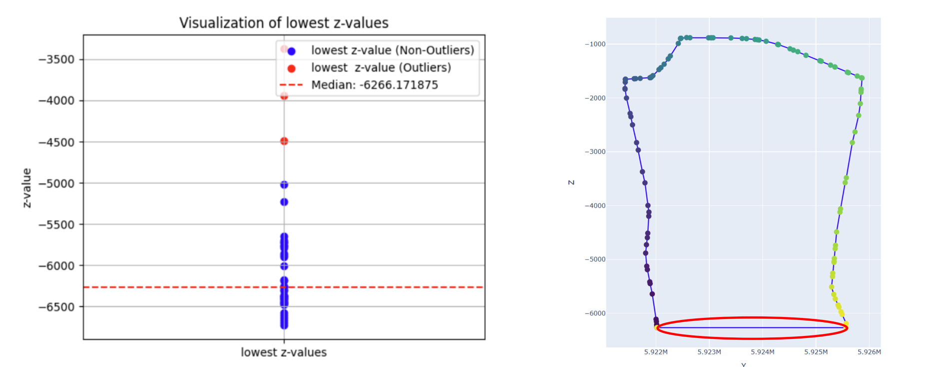
Position of orthogonal sections & overall coverage of input mesh



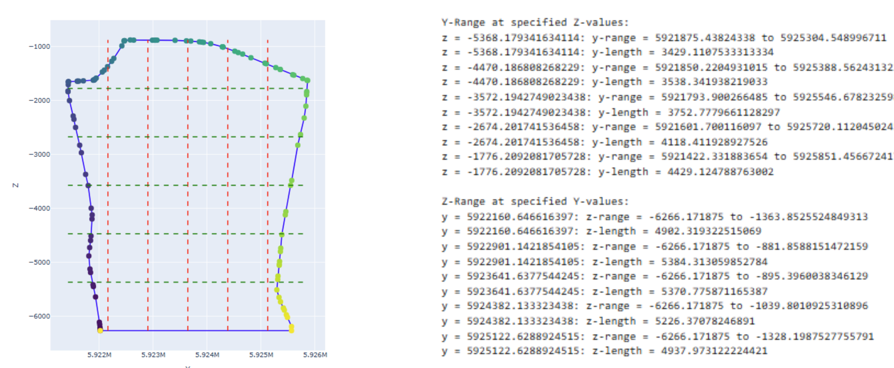
Step 1b & 2b: Artifact correction



Step 3: Constant base level for vertical measurements



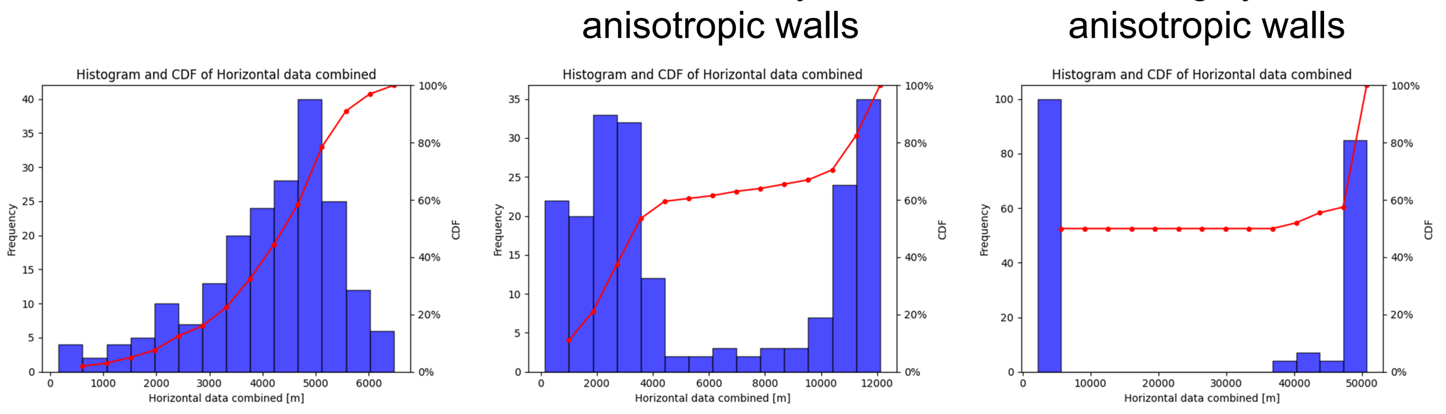
Step 4: Dimensional measurements



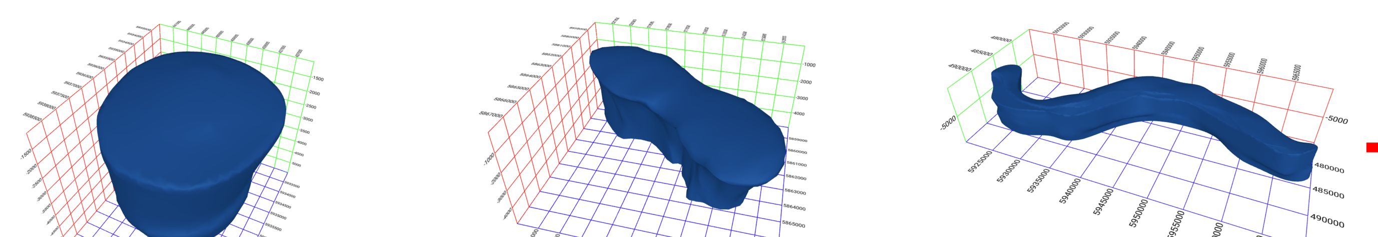
Data analysis

Combined horizontal data

	Stocks	Moderately anisotropic walls	Highly anisotropic walls
Combined distrubutions from X & Y			



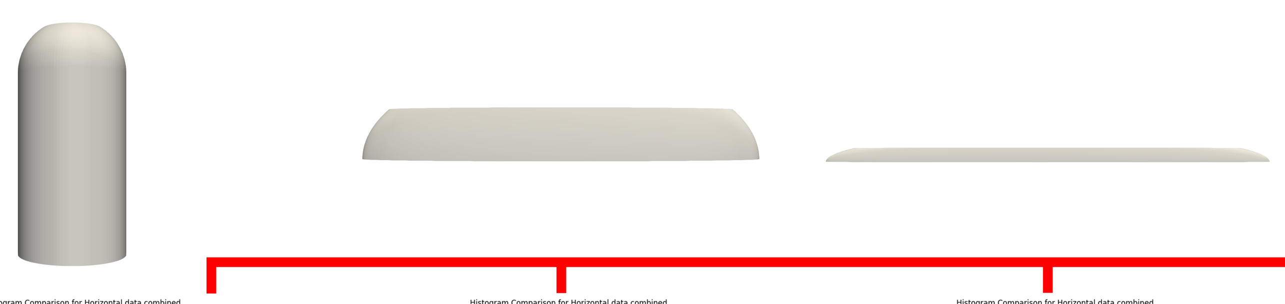
Structural model



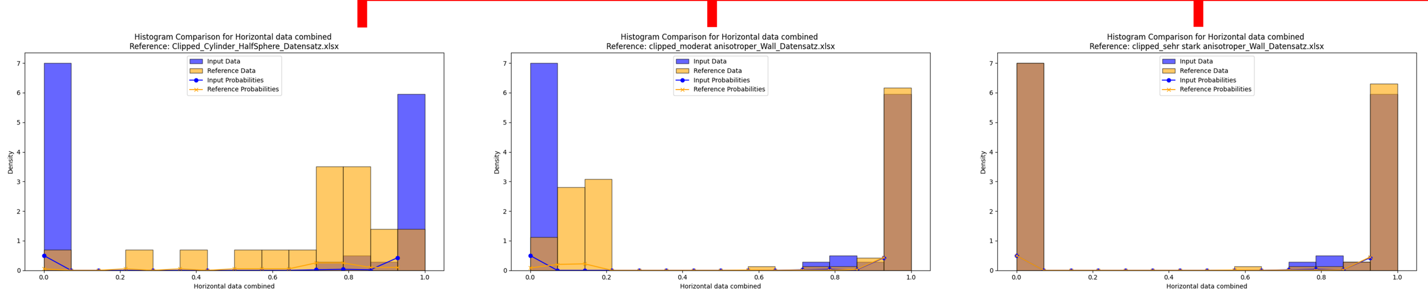
BGR et al. (2022)

Averaged ainsotropy	<2	2-6	>6

Regular comparative model

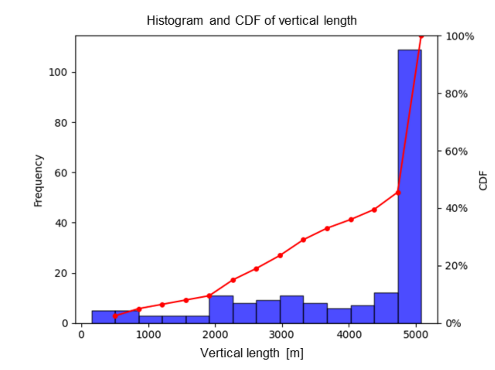


Visualized Kullback-Leibler divergence

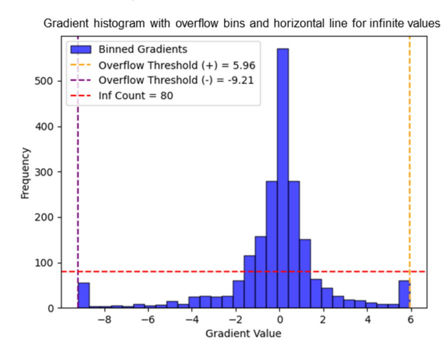


Vertical data, gradients & curvature

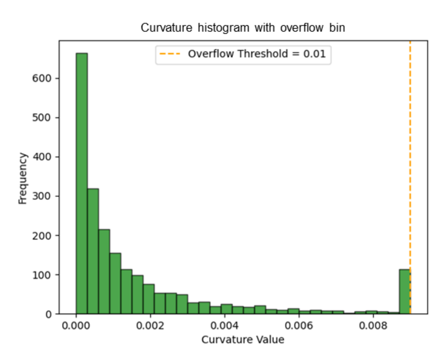
Typical vertical dataset



Example of gradient data

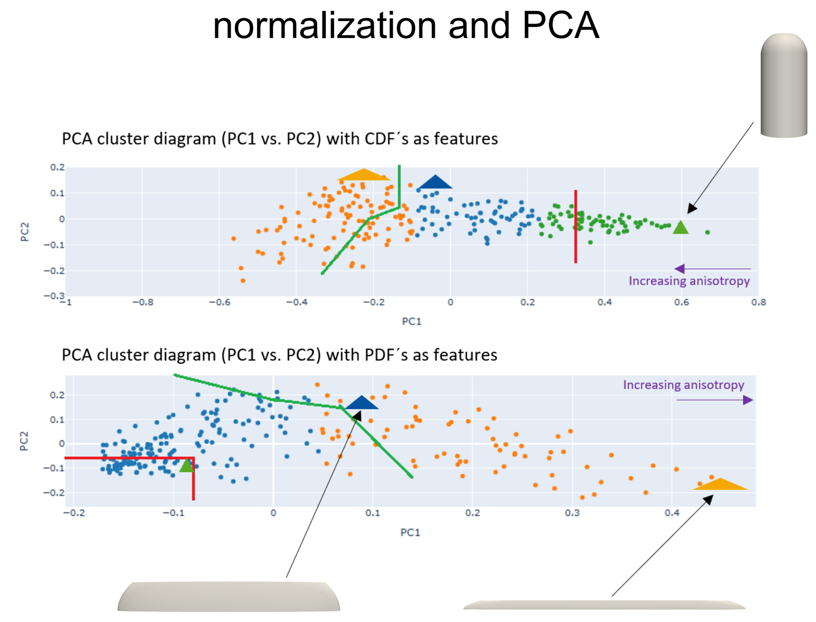


Example of curvature data

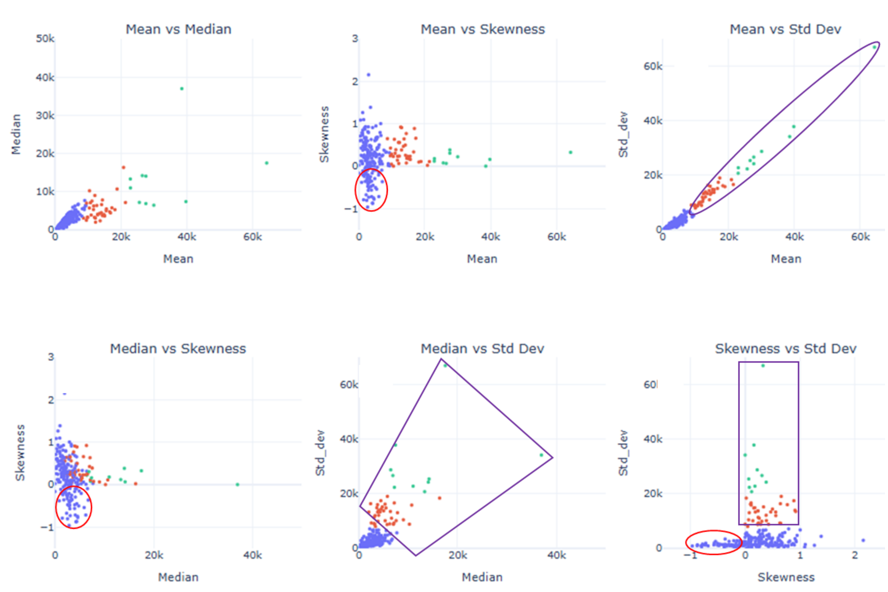


Cluster analysis

Cluster results after normalization and PCA



Cluster results without normalization and PCA



Discussion

Interpretation of histogram data & cluster analyses can reproduce main characteristics of input meshes & differences between datasets:

- Histograms of combined horizontal data can provide insight into (1) anisotropy of datasets and (2) potential existence of overhangs
- Histograms of vertical extent can indicate (1) character of top surface of structures and (2) support or falsify presence of overhangs
- Histograms of gradient and curvature data can indicate (1) prevailing slope of walls of structures, (2) further emphasize potentially present flat top surfaces, (3) give general indicator of sphericity of structure, (4) reflect the amount of input data available ("blocky" appearance)
- Cluster analyses of normalized, dimensionally reduced data can (1) group and systematize input structures based on measured dimensional datasets (2) and can be used to further refine geometrical systematizations for locally restricted case studies
- Cluster analyses of unnormalized data without PCA can support findings of first clustering approach by adding additional comparative measures → especially skewness and standard deviations of datasets provide informational value for geometrical systematization

References

BGR, LBGR, LLUR, & LUNG. (2022). 3D-Modell des geologischen Untergrundes des Norddeutschen Beckens (Projekt TUNB). https://numis.niedersachsen.de/trefferanzeige?docuuid=8b70fe0f-0b03-477b-a3cd-c0f13a2c41b2

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