Three-Dimensional Modeling of Geological Bodies Using Radial Basis Function with External Drift Function

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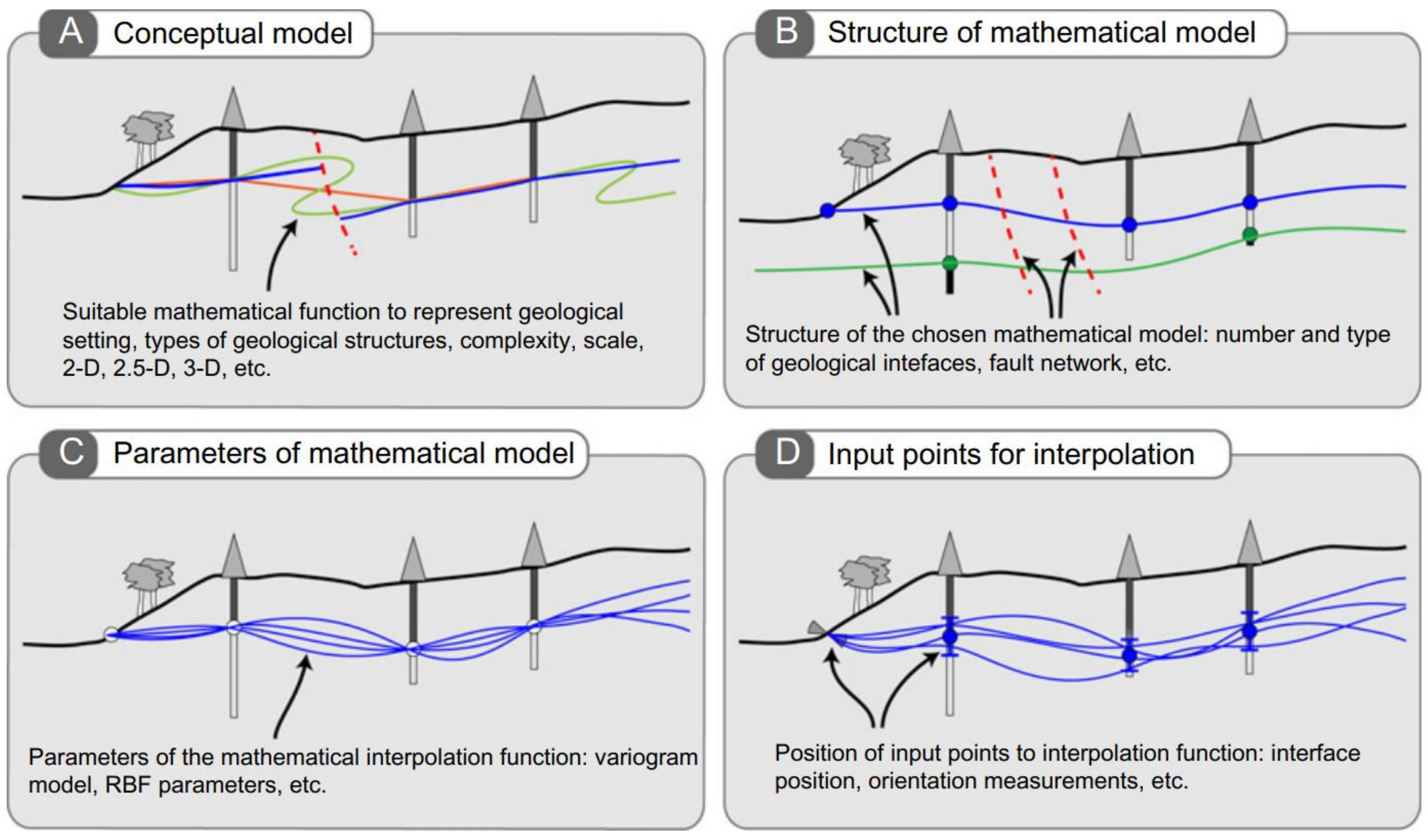
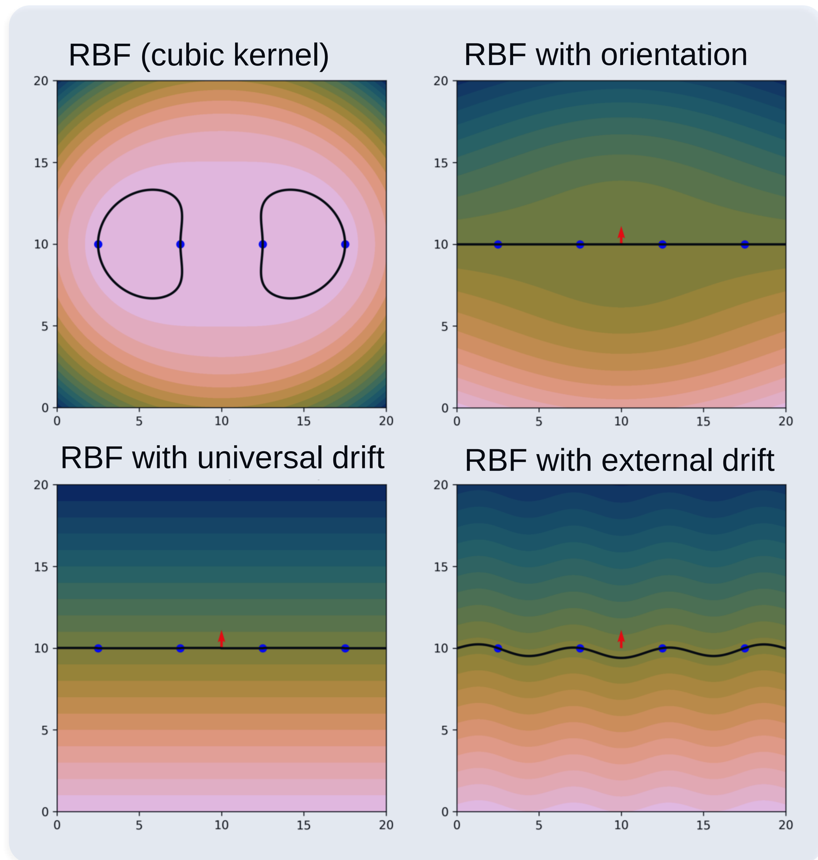
Motivation

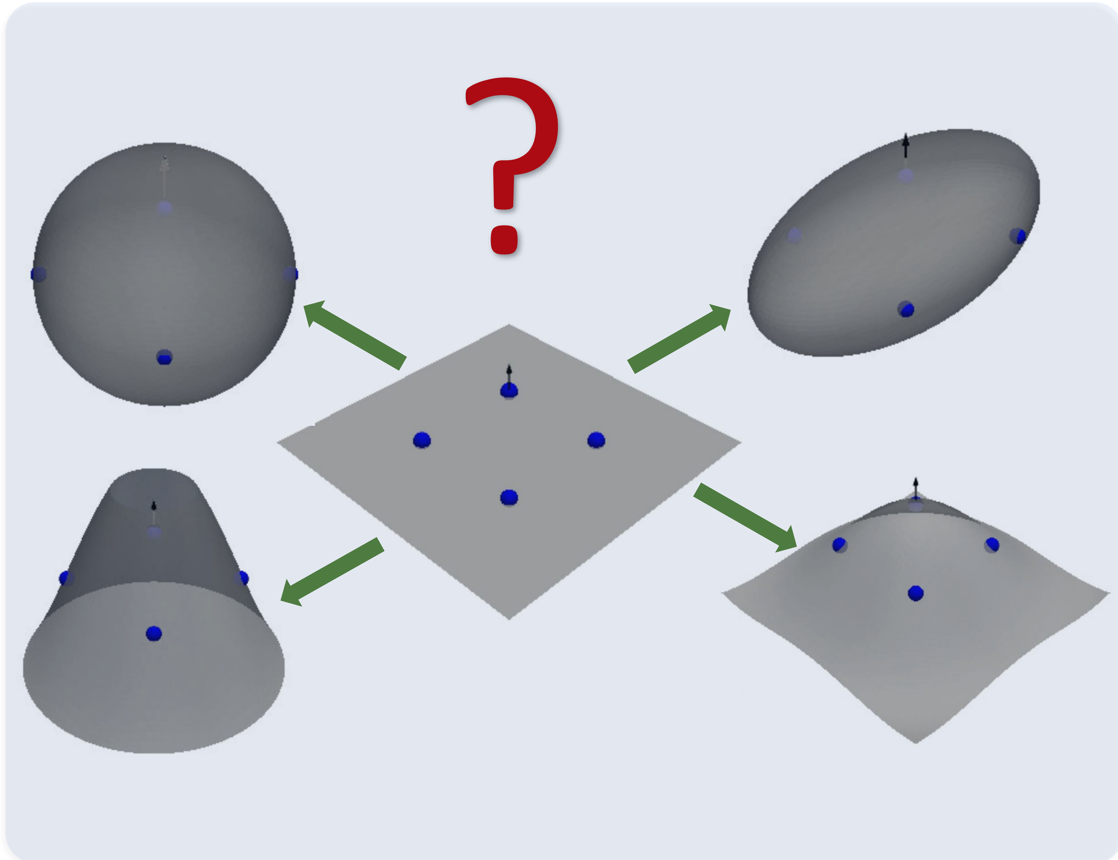
This study addresses the gap by proposing an innovative approach that integrates geometrical **external drift** into the RBF framework. This enhancement allows the RBF models to be purposefully **biased towards** desired **geometric configurations**, significantly improving their ability to accurately model various geological structures such as planar strata, folded formations, and salt domes.



Sources and types of uncertainty related to different modeling steps (Wellmann & Caumon, 2018)

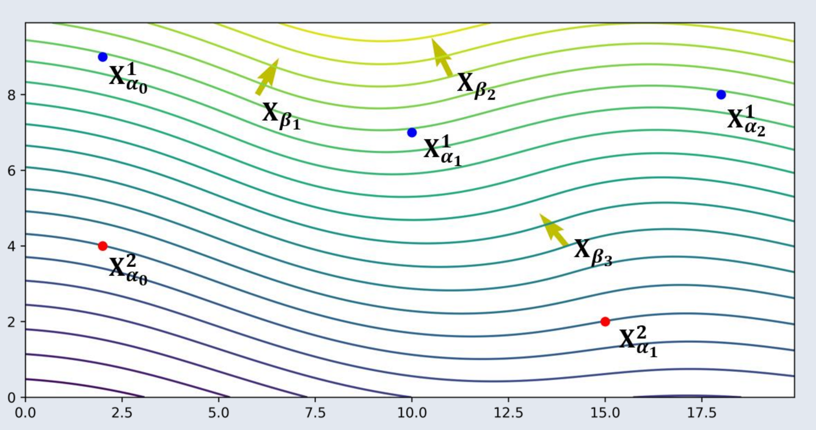
How to find the most suitable interpolation method for different geological geometries?



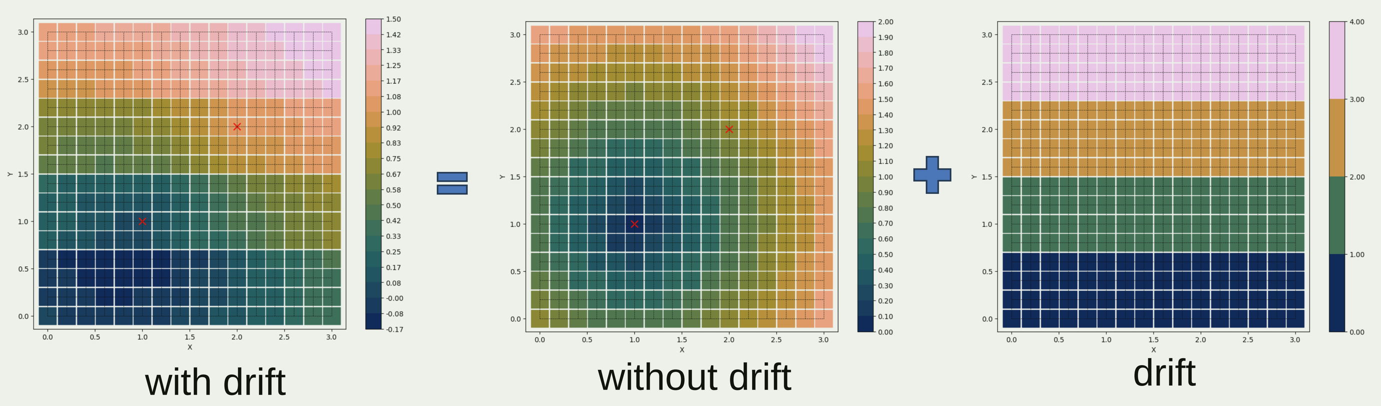


Method and Result

Step 1: Get formatted dataset



Example of geological dataset for implicit modeling: interface points and orientations

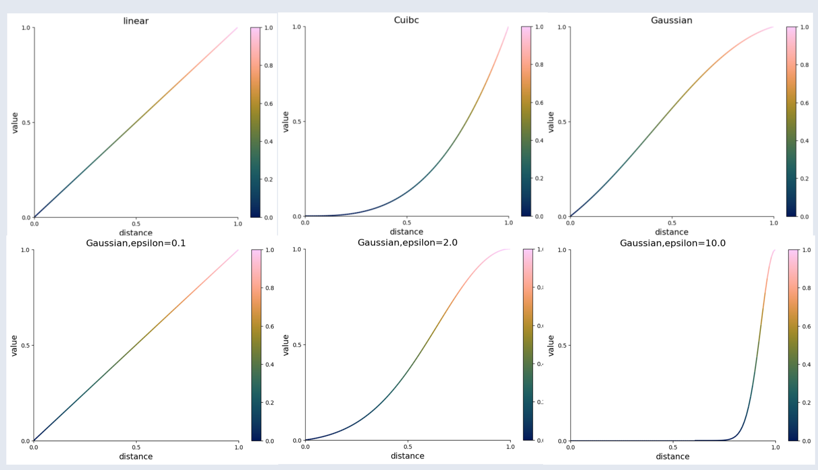


- weighted sum of distance based kernel function

$$f(x) = \sum_{n=1}^{N} \lambda_n \cdot \phi(\|x - x_n\|) + m \cdot q(x)$$

where N represents the total number of data points, $\phi(\|x - x_n\|)$ is either the covariance between a data point x_n and an unknown point x, or a radial basis function such as a thin plate spline, or simply the distance (also known as a biharmonic function), λ_n are the interpolation coefficients that need to be determined, m is a drift coefficient that needs to be estimated and $q(x)$ represents an external predefined drift function, defining the behavior of a predefined general trend.

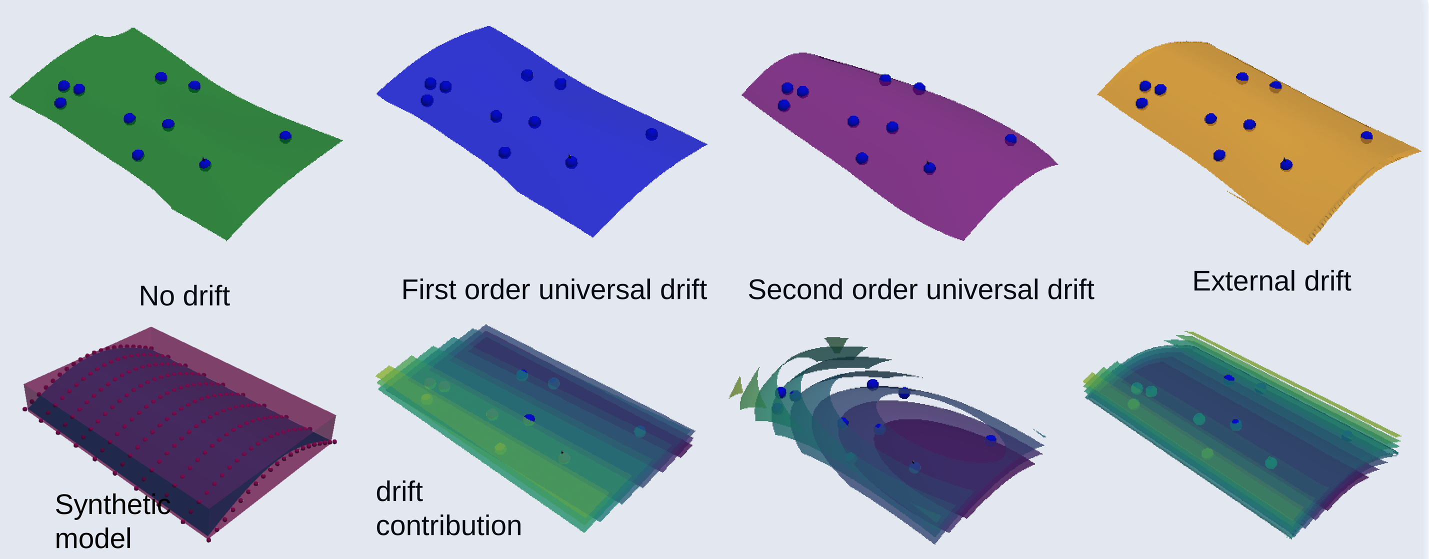
Step 2: Use cross-validation to optimize kernel functions and parameters



Different kernel functions and parameter for kernel functions

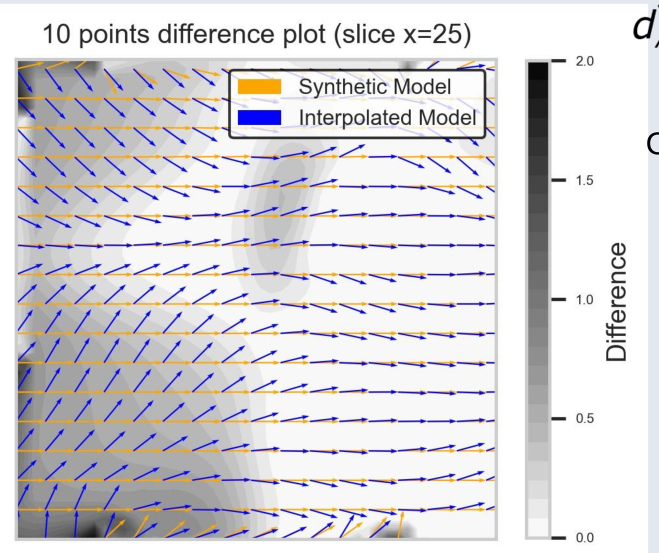
Scan for demo video of workflow with GUI

Step 3: Interpolate with different drift



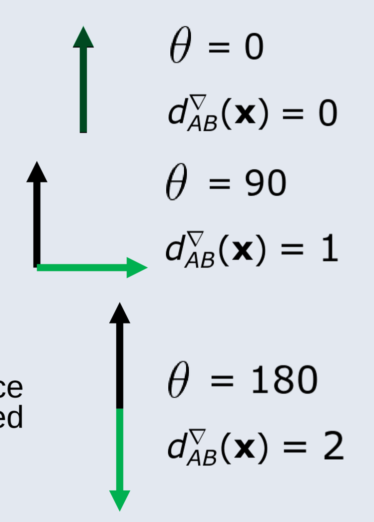
Interpolation results for a synthetic fold model using 10 sampling points and 1 orientation vector, presented as using three different drifts and drift contribution for scalar field in 3D contour plot. Blue points indicate the sampled locations from the synthetic fold model.

Step 4: Model comparison (cosine similarity)

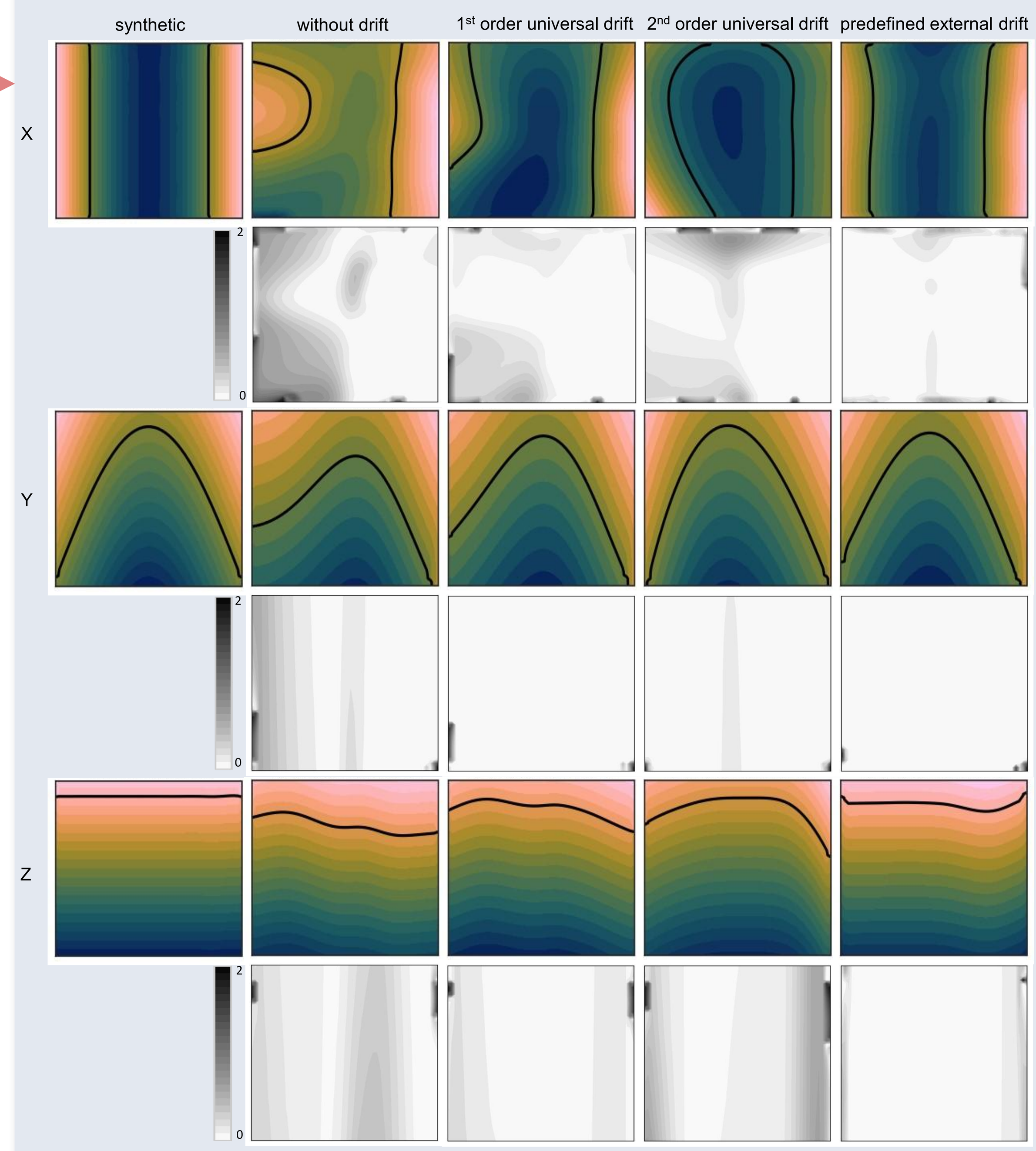


$$d^{\nabla}_{AB}(\mathbf{x}) = 1 - \frac{\nabla f_A \cdot \nabla f_B}{\|\nabla f_A\| \|\nabla f_B\|}$$

Caumon (2022)

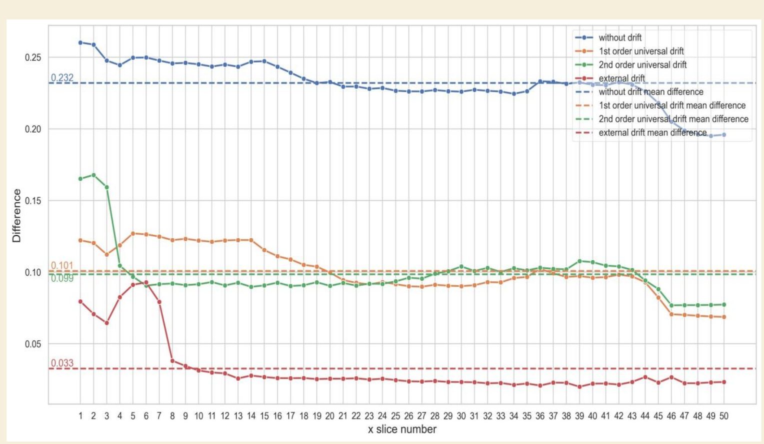


- Visualization of the cosine similarity difference between two interpolated scalar fields derived from 10 sampled points.



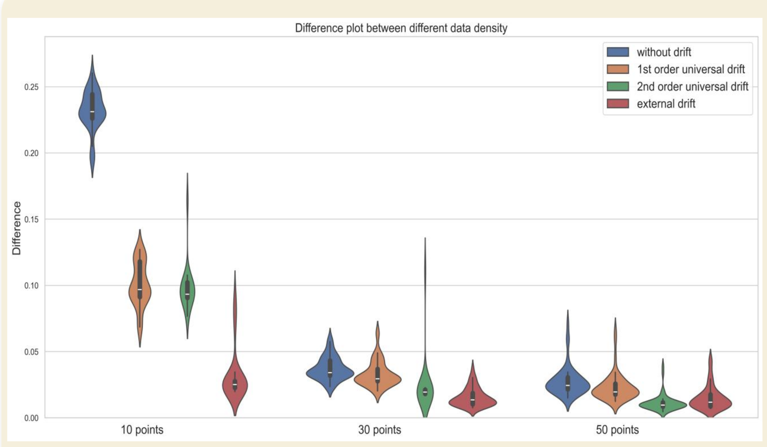
Scalar field plots displaying mid x-, y-, and z-plane cross-sections. Rows correspond to different planes, and columns represent distinct methods: without drift, 1st order universal drift, 2nd order universal drift, and external drift. The black contour lines delineate the surface boundary in each cross-section. The black and white scalar field plots illustrate the cs difference between synthetic mode and interpolated model. The Z axis is stretched to a certain extent to enhance readability.

CS difference



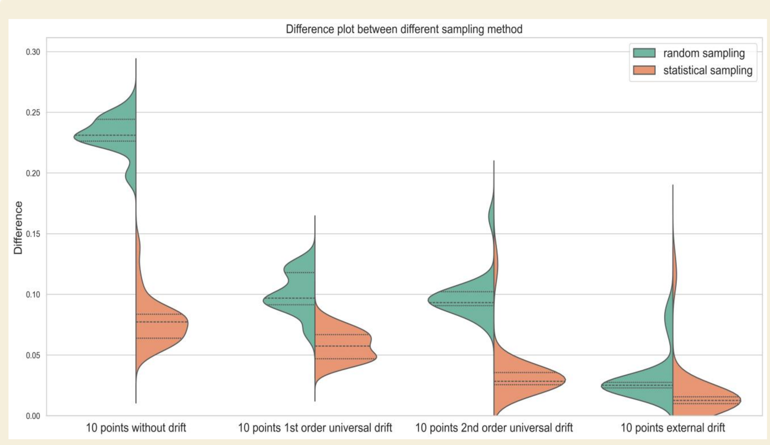
- CS difference plot between synthetic model and interpolated model with different drift functions. The difference is shown in 50 slices on the x-axis.

Data density



- Differences in interpolations across various data densities (10, 30, and 50 points) under different drift models: without drift, 1st order universal drift, 2nd order universal drift, and external drift.

Sampling method



- Differences between random sampling and statistical sampling methods across various drift models (without drift, 1st order universal drift, 2nd order universal drift, and external drift) using 10 data points.

Reference

- Wellmann, F. and Caumon, G. (2018). 3-d structural geological models: concepts, methods, and uncertainties. Advances in Geophysics, 1-121. https://doi.org/10.1016/bs.agph.2018.09.001
- Caumon G (2022) On some comparison metrics between 3D implicit structural models. In IAMG 21st annual conference, Nancy, France

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