Machine learning opportunities to reduce the dimension of uncertain complex geophysical media

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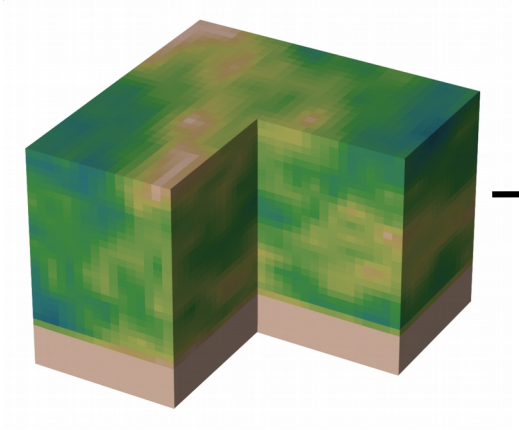
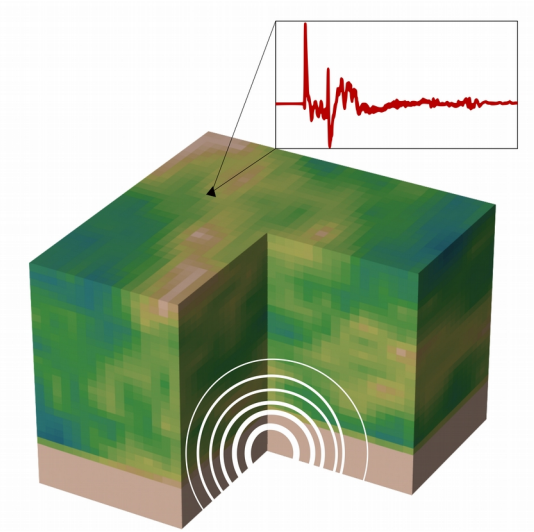
Introduction

complex 3D geophysical medium with uncertainties



numerical simulation

physical output

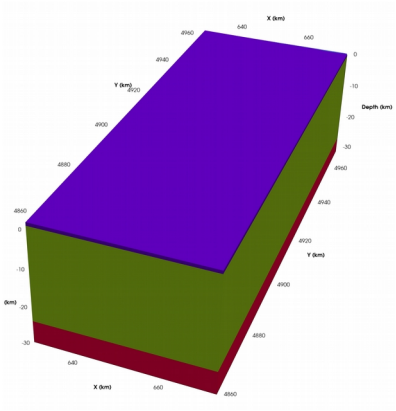


Example: seismic wave propagation.

Goal: Reduce the dimensionality of the media to characterize the relationship between the medium and the problem's output.

Introduction

Simplest description of a geophysical medium



+

Uncertainties model

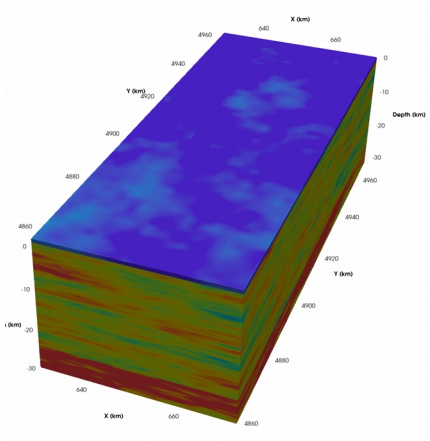
Random fields

Correlation lengths on x, y and z

Coefficient of variation

→

Heterogeneous model

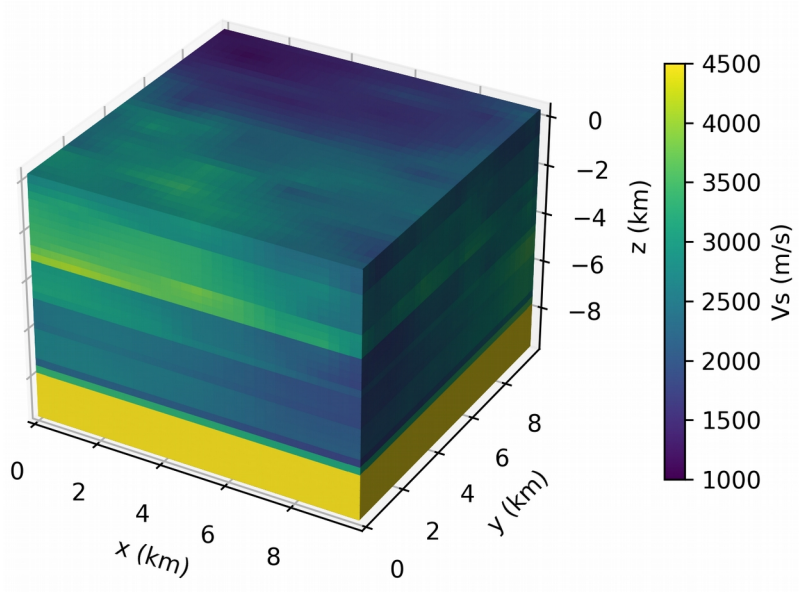


Database

We built a database of 100,000 heterogeneous geophysical media.

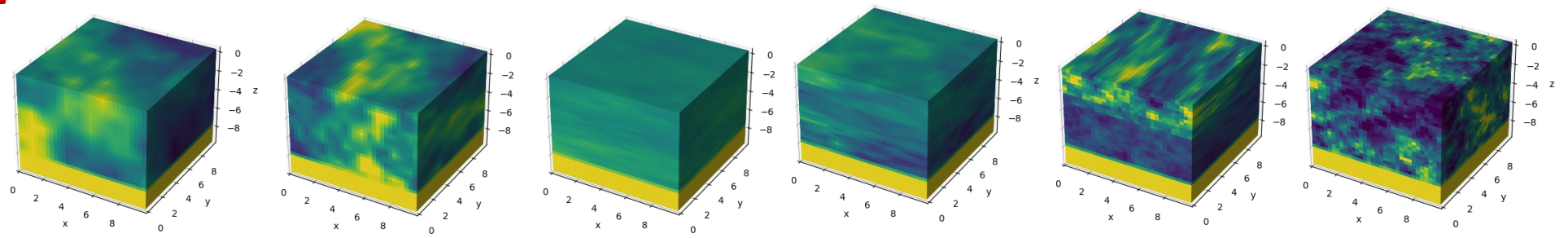
Several layers with varying thickness
+ random fields with different parameters

constant velocity layer

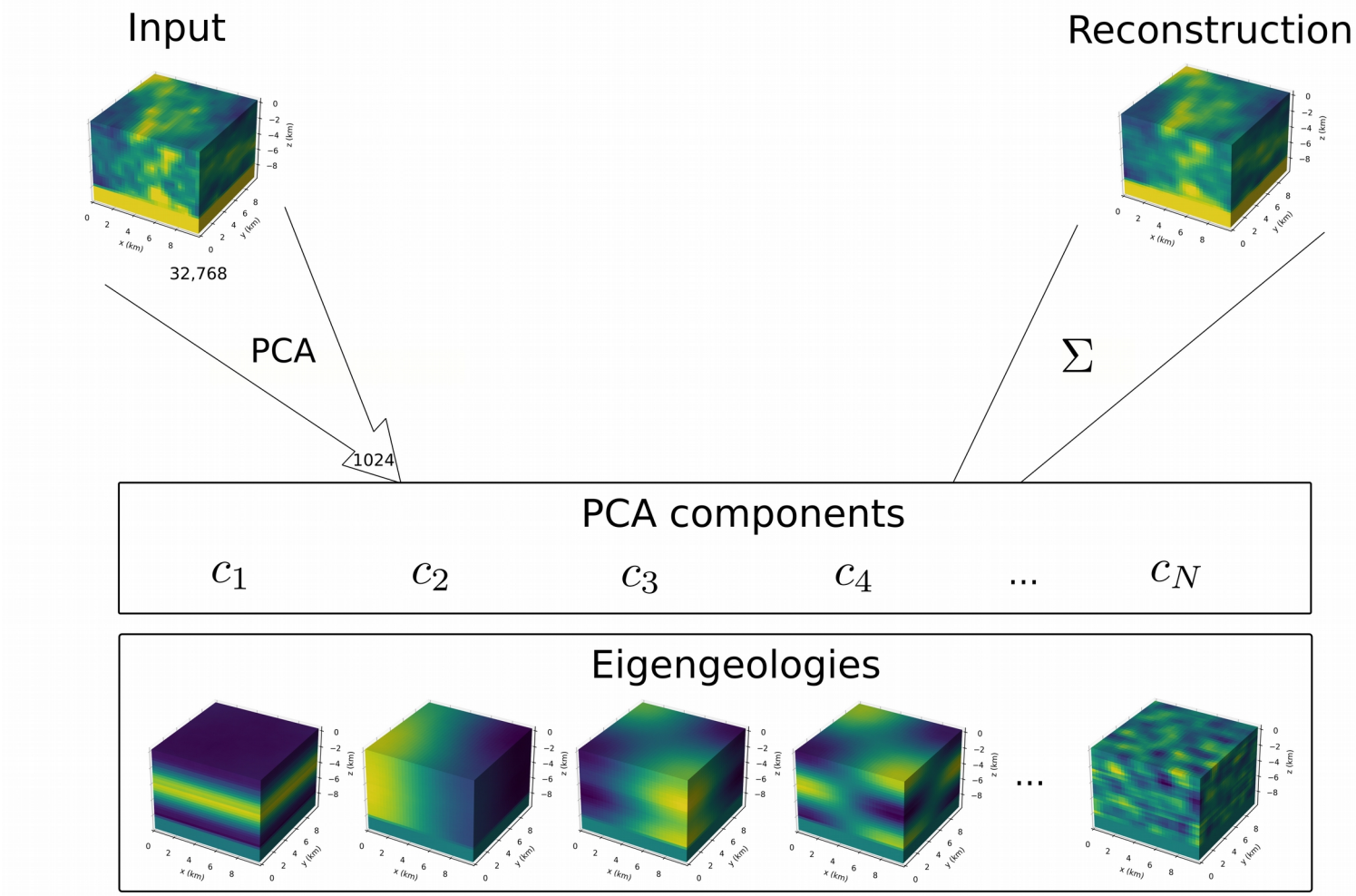


Publicly available! (14Go)

10.5281/zenodo.6983054

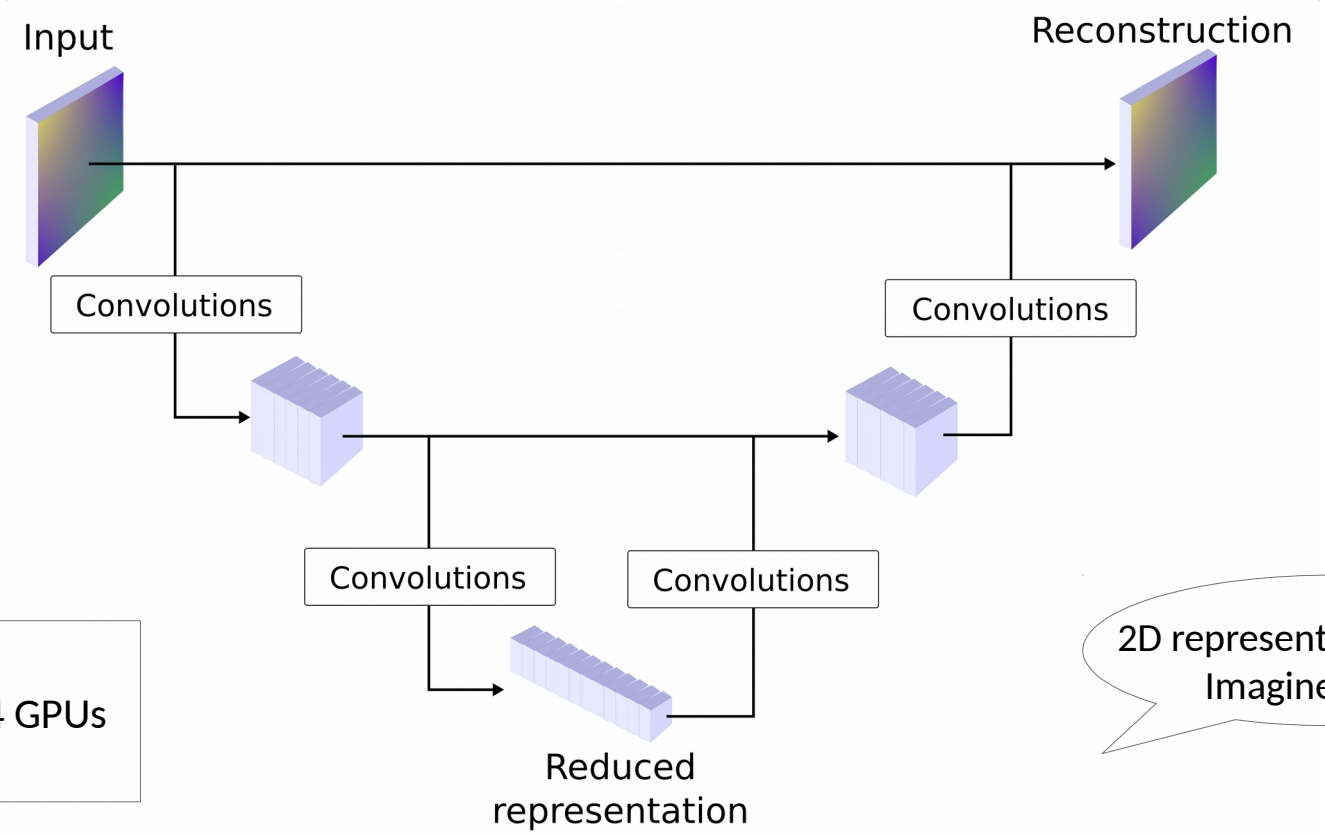


Method 1 – Principal Component Analysis (PCA)



Method 2 – 3D Auto-encoder

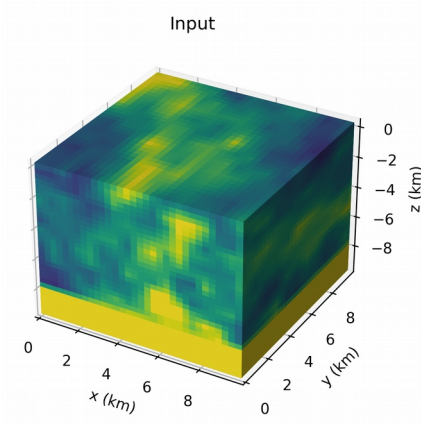
Auto-encoder ~ non-linear extension of the PCA
3D UNet [Çiçek et al. 2016], [Wolny et al. 2020]



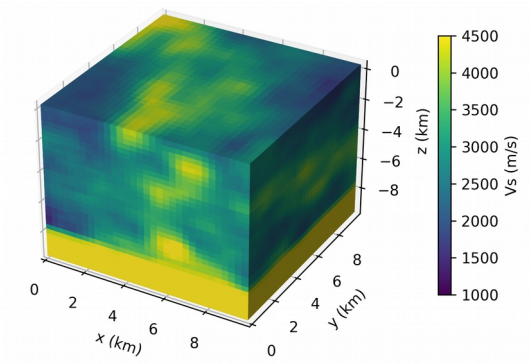
4 million parameters
Training time: 9.5h on 4 GPUs for 1000 epochs

2D representation of UNet
Imagine it in 3D

Results – Reconstruction error

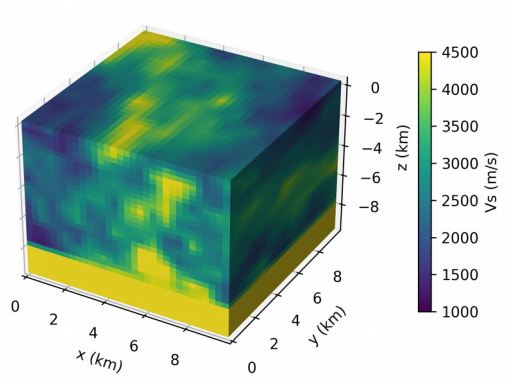


PCA



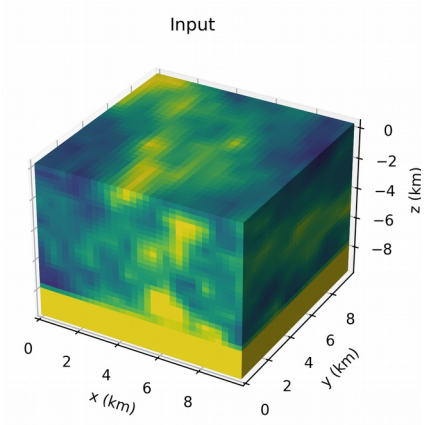
« Smoothed » reconstruction

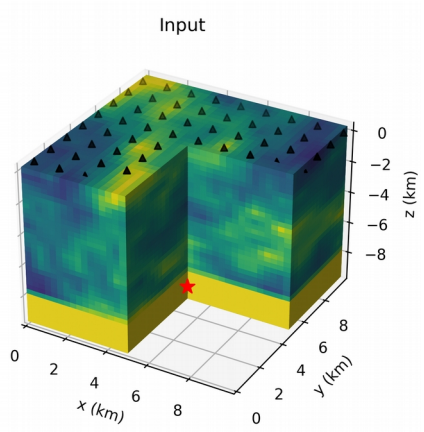
3D UNet



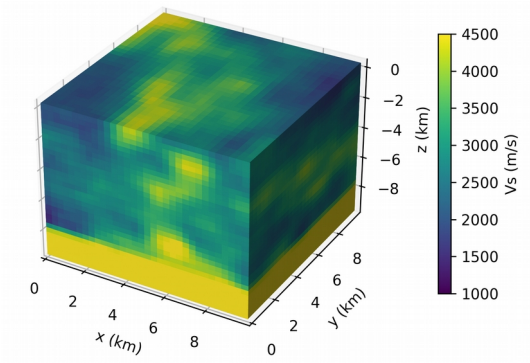
Biased reconstruction (mean value)

Results – Influence of the reconstruction on the output

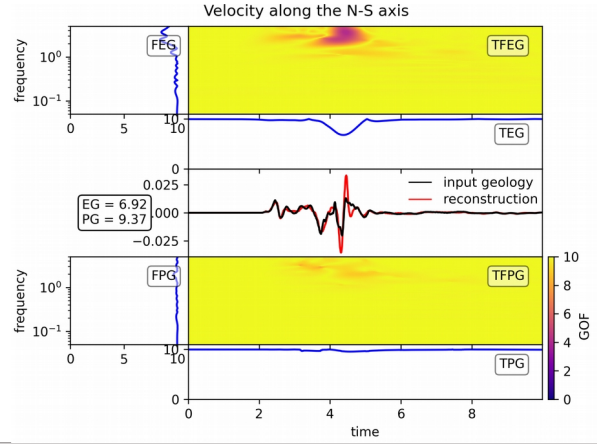




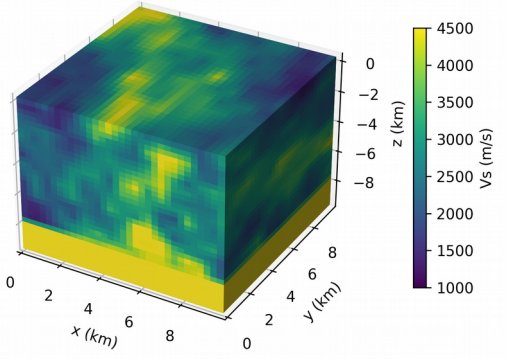
PCA



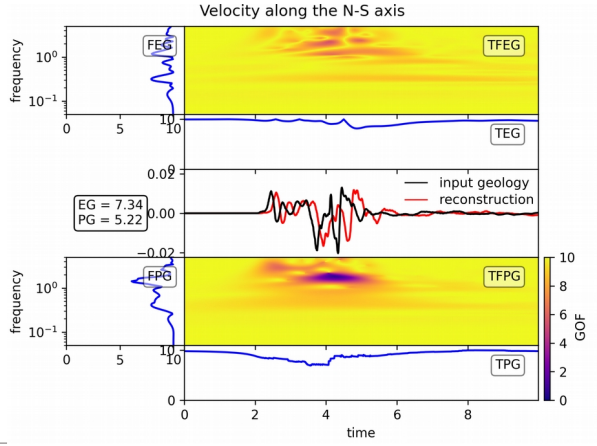
« Smoothed » reconstruction



3D UNet

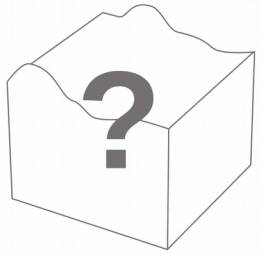


Biased reconstruction (mean value)



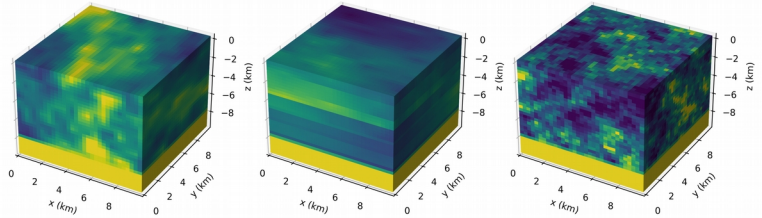
Conclusion

QUESTION



Quantify the variability of the problem's output due to geophysical media uncertainties.

DATABASE



100,000 heterogeneous geophysical media

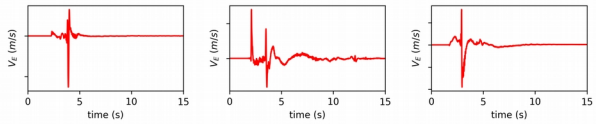
Principal Component Analysis

Auto-encoder 3D UNet

REDUCED REPRESENTATION

physics-based simulation

RESULT



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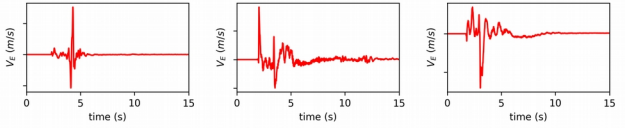

[Lehmann et al. 2022]