

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

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The logo for CEA (Commissariat à l'énergie atomique et aux énergies alternatives) features the lowercase letters 'cea' in white, with a green horizontal bar underneath.

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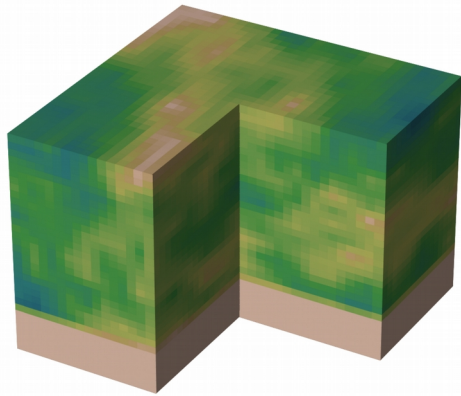


CentraleSupélec

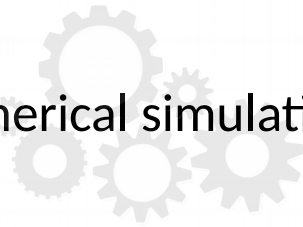
université
PARIS-SACLAY

école
normale
supérieure
paris-saclay

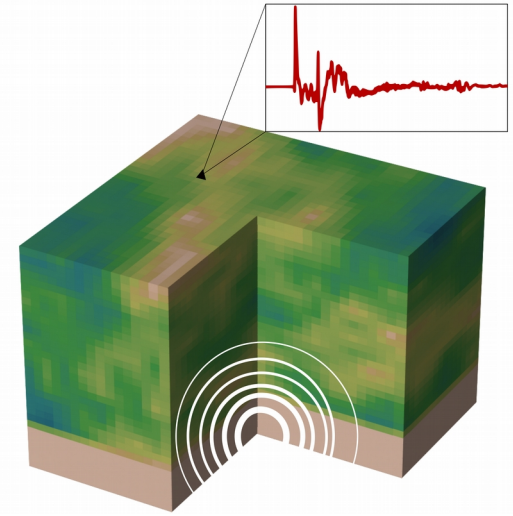
complex 3D
geophysical medium
with uncertainties



numerical simulation



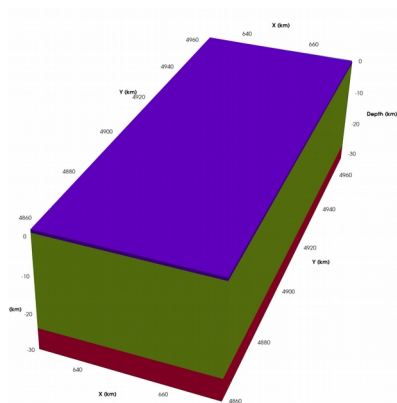
physical output



Example: seismic wave propagation.

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

Simplest description of a
geophysical medium



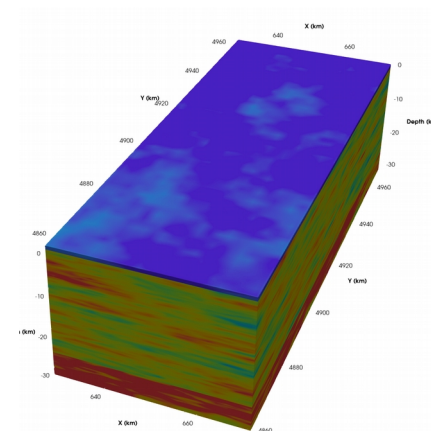
+

Uncertainties model

Random fields
Correlation lengths on x, y and z
Coefficient of variation



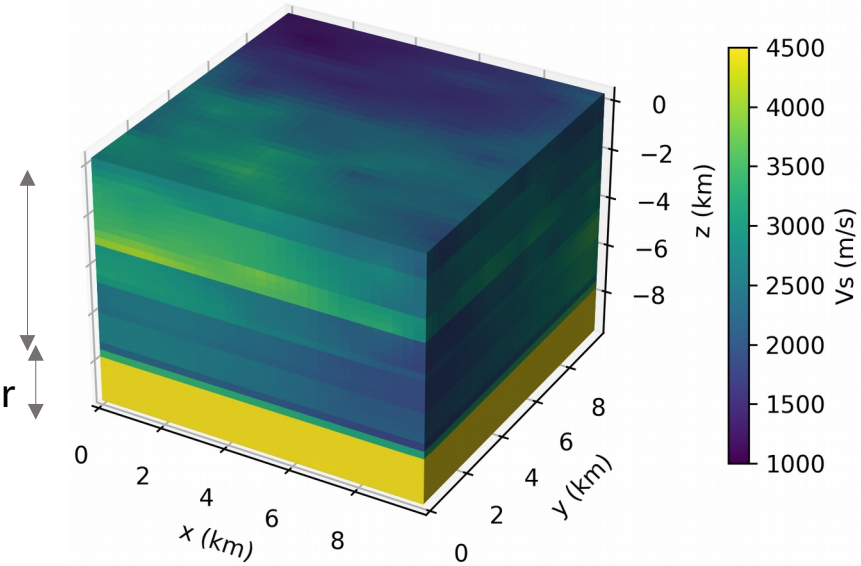
Heterogeneous model



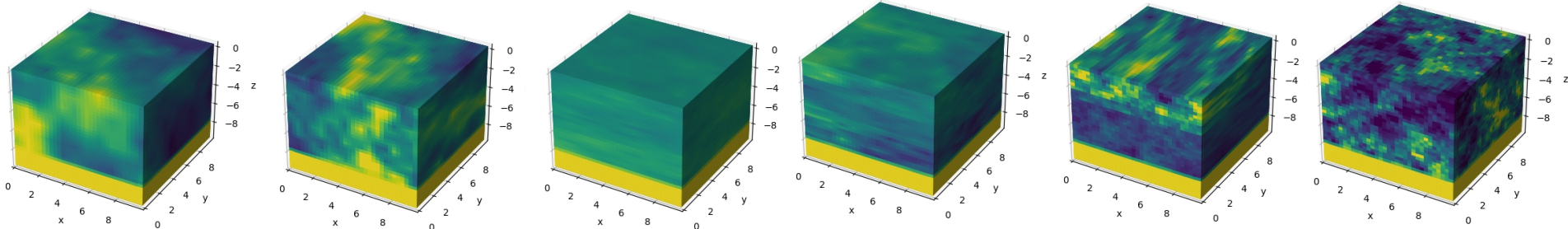
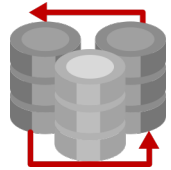
We built a database of 100,000 heterogeneous geophysical media.

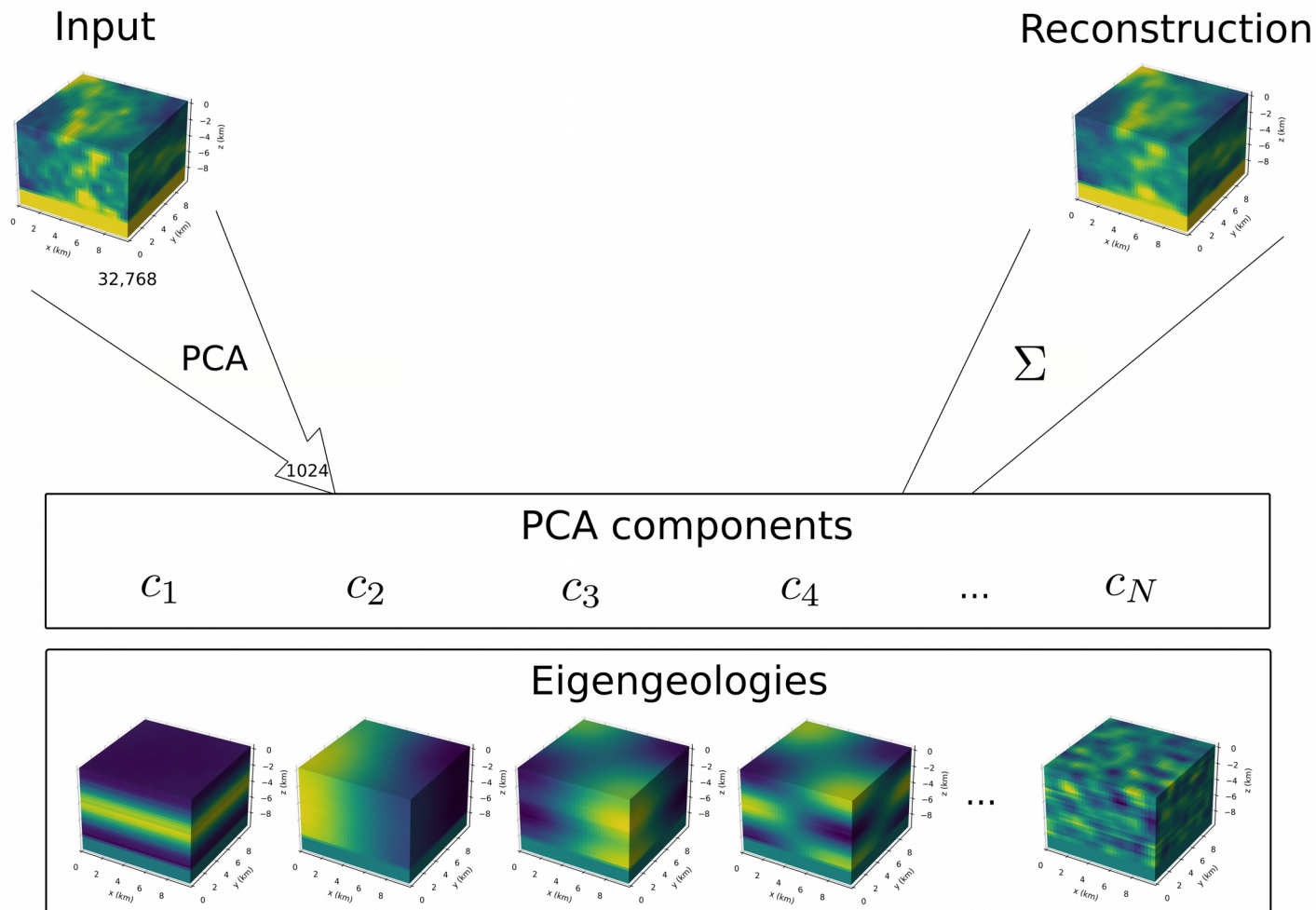
Several layers with varying thickness
+ random fields with different parameters

constant velocity layer



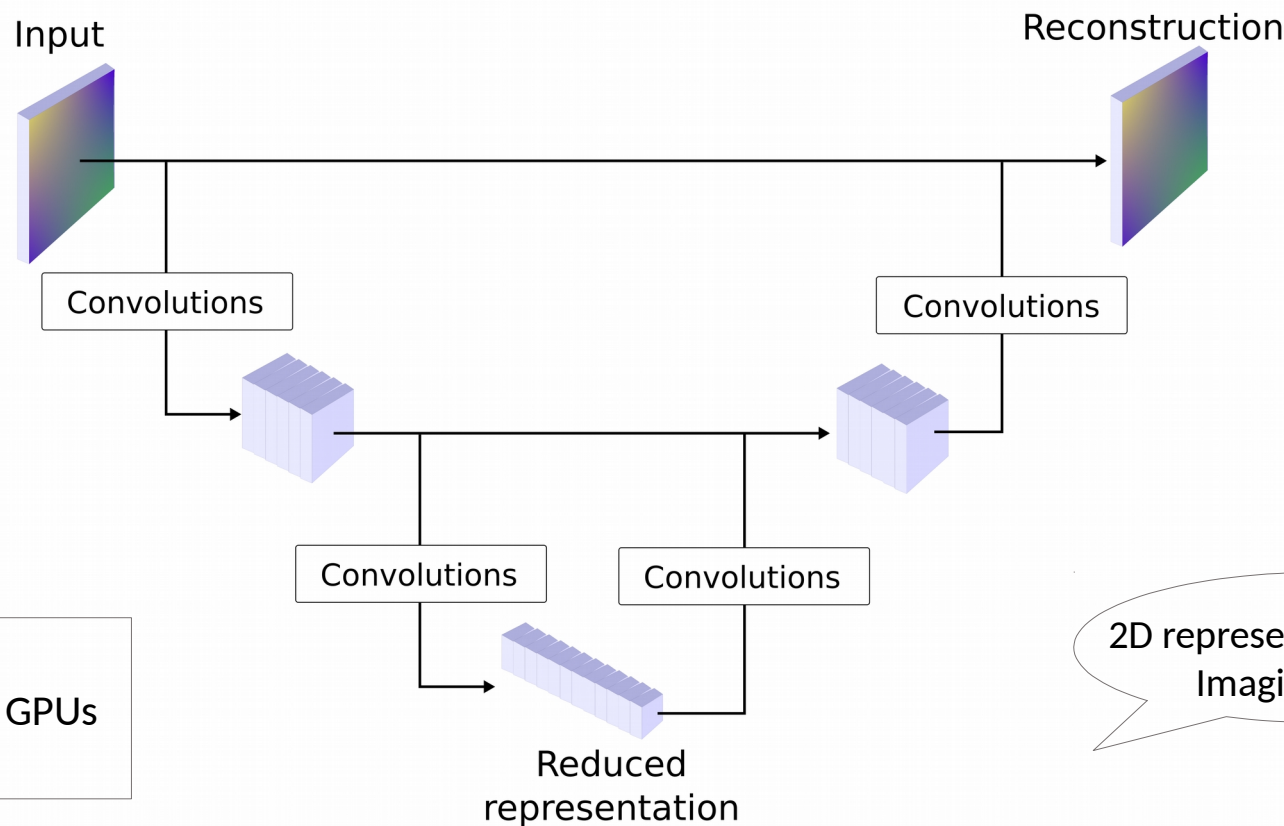
Publicly available! (14Go)
[10.5281/zenodo.6983054](https://doi.org/10.5281/zenodo.6983054)





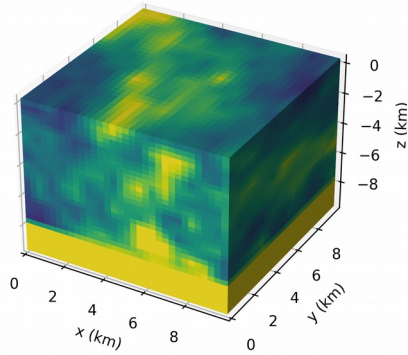
Auto-encoder ~ non-linear extension of the PCA

3D UNet [Çiçek et al. 2016], [Wolny et al. 2020]

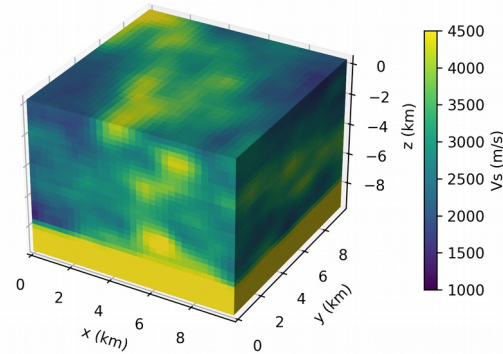


4 million parameters
Training time: 9.5h on 4 GPUs
for 1000 epochs

Input

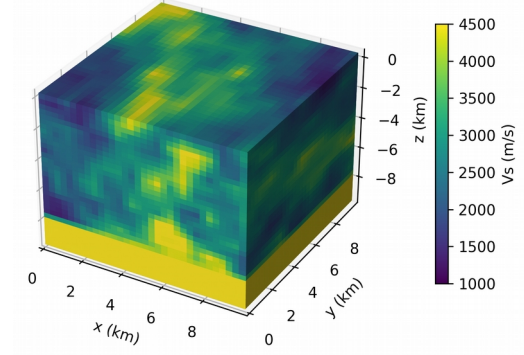


PCA



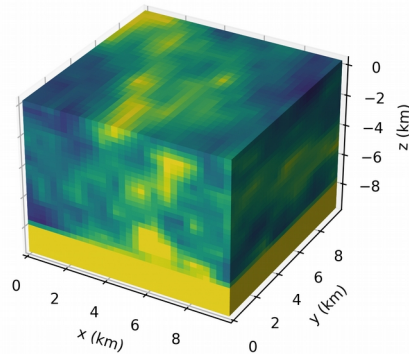
« Smoothed » reconstruction

3D UNet

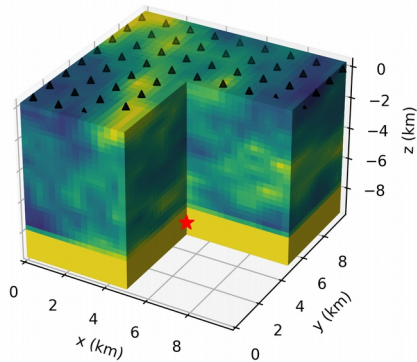


Biased reconstruction (mean value)

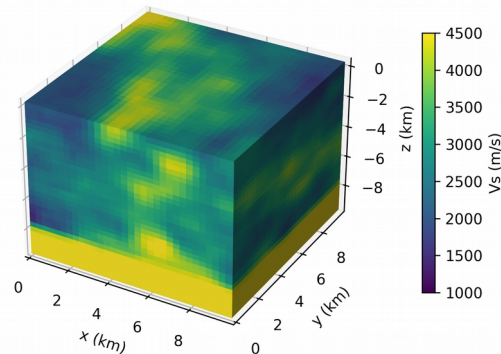
Input



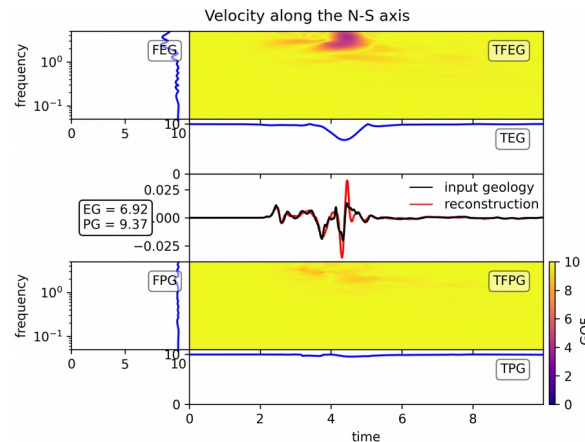
Input



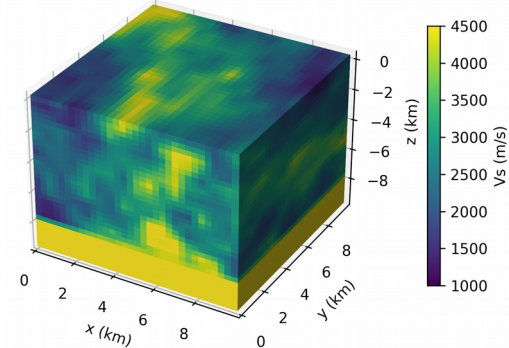
PCA



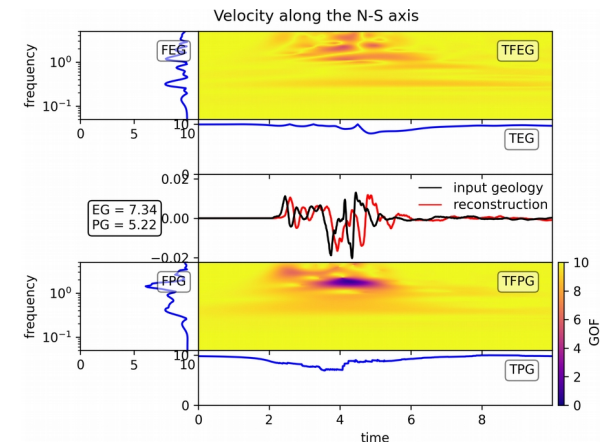
« Smoothed » reconstruction



3D UNet



Biased reconstruction (mean value)



QUESTION

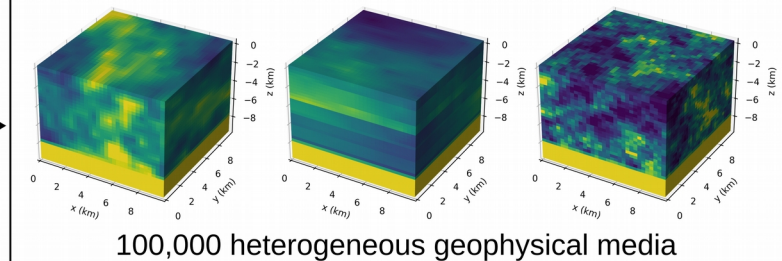


Quantify the variability of the problem's output due to geophysical media uncertainties.



[Lehmann et al. 2022]

DATABASE



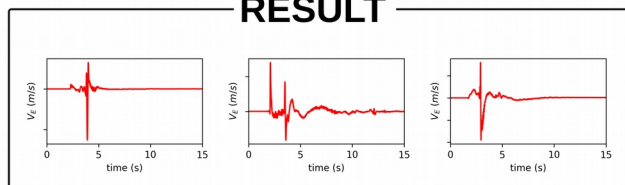
Principal
Component
Analysis

Auto-encoder
3D UNet

REDUCED REPRESENTATION



RESULT



physics-based simulation

REFERENCE

