

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

The logo for CEA (Commissariat à l'énergie atomique et aux énergies alternatives) features the lowercase letters 'cea' in a white, stylized font. A thick green horizontal line is positioned below the letters. The logo is set against a dark red background that has a faint, repeating pattern of small white dots.

Fanny Lehmann^{1,2}

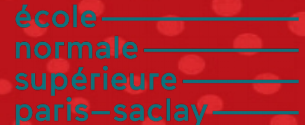
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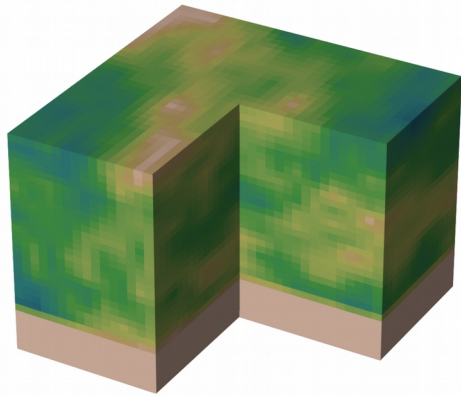
² Université Paris-Saclay, ENS Paris-Saclay, CentraleSupélec, CNRS, LMPS - Laboratoire de Mécanique Paris-Saclay, 91190 Gif-sur-Yvette, France



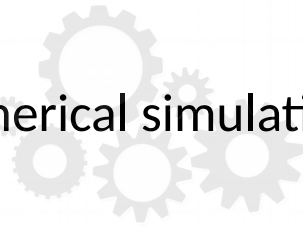
CentraleSupélec

The logo for Université Paris-Saclay features the word 'université' in a large, blue, serif font, with 'PARIS-SACLAY' in a smaller, blue, sans-serif font below it. A small blue dot is positioned to the right of the word 'université'. The logo is set against a dark red background with a faint dot pattern.The logo for École Normale Supérieure Paris-Saclay features the words 'école', 'normale', 'supérieure', and 'paris-saclay' stacked vertically in a blue, sans-serif font. Each word is followed by a horizontal line. The logo is set against a dark red background with a faint dot pattern.

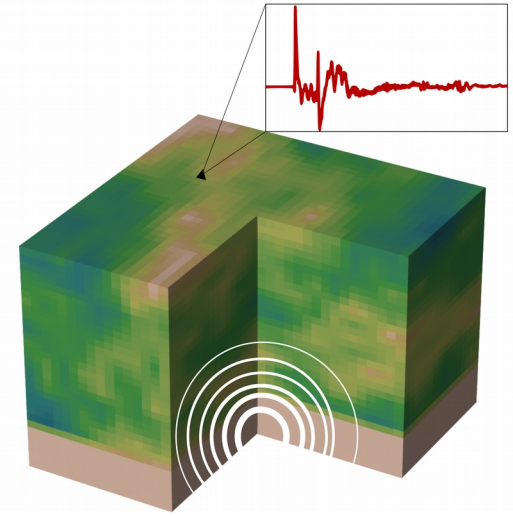
complex 3D
geophysical medium
with uncertainties



numerical simulation



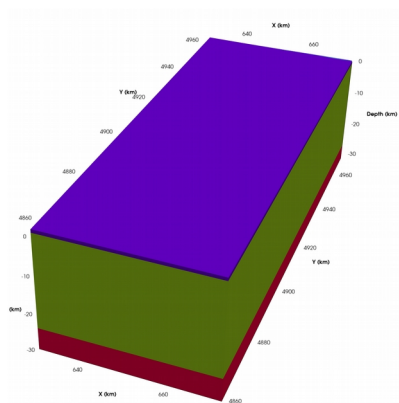
physical output



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



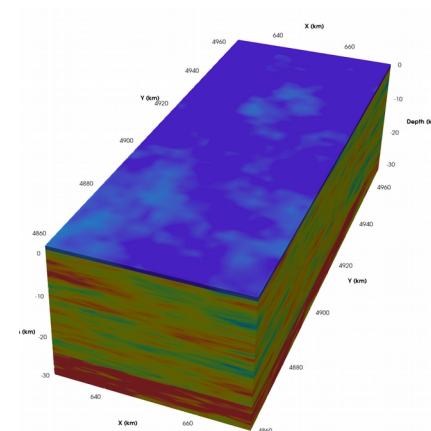
+

Uncertainties model

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



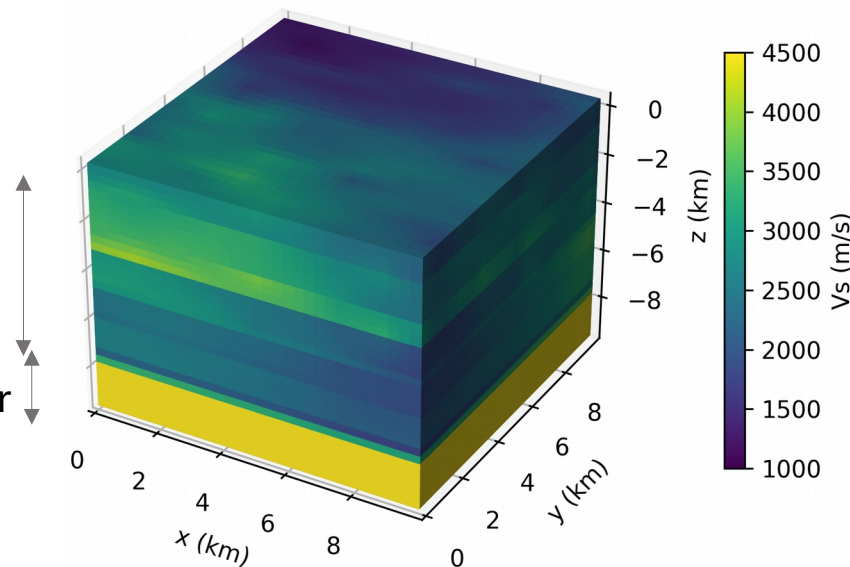
Heterogeneous model



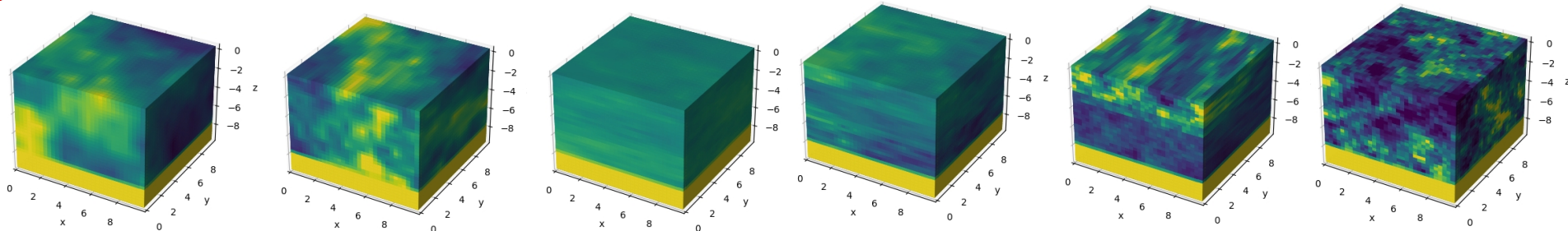
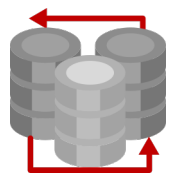
We built a database of 100,000 heterogeneous geophysical media.

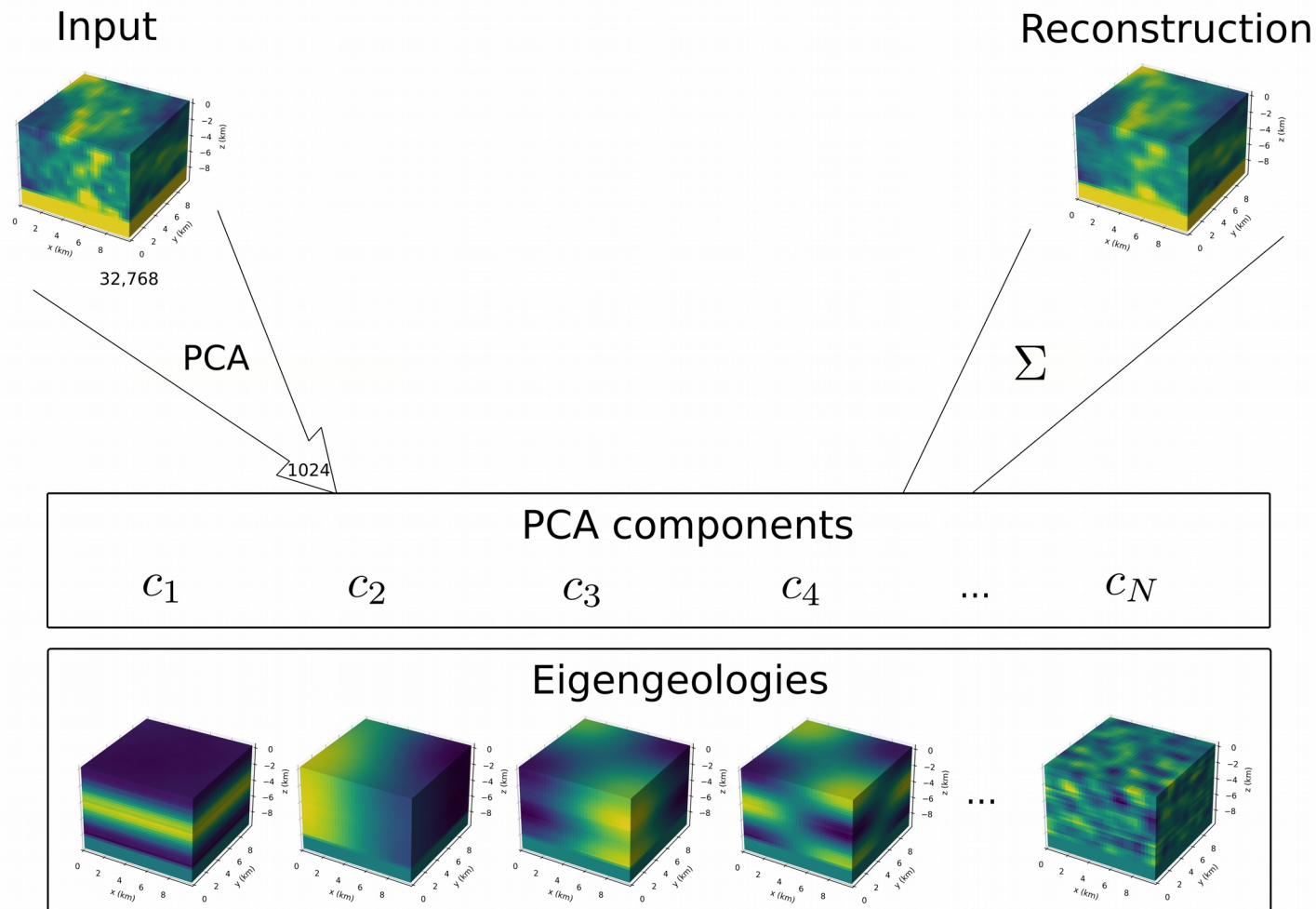
Several layers with varying thickness
+ random fields with different parameters

constant velocity layer



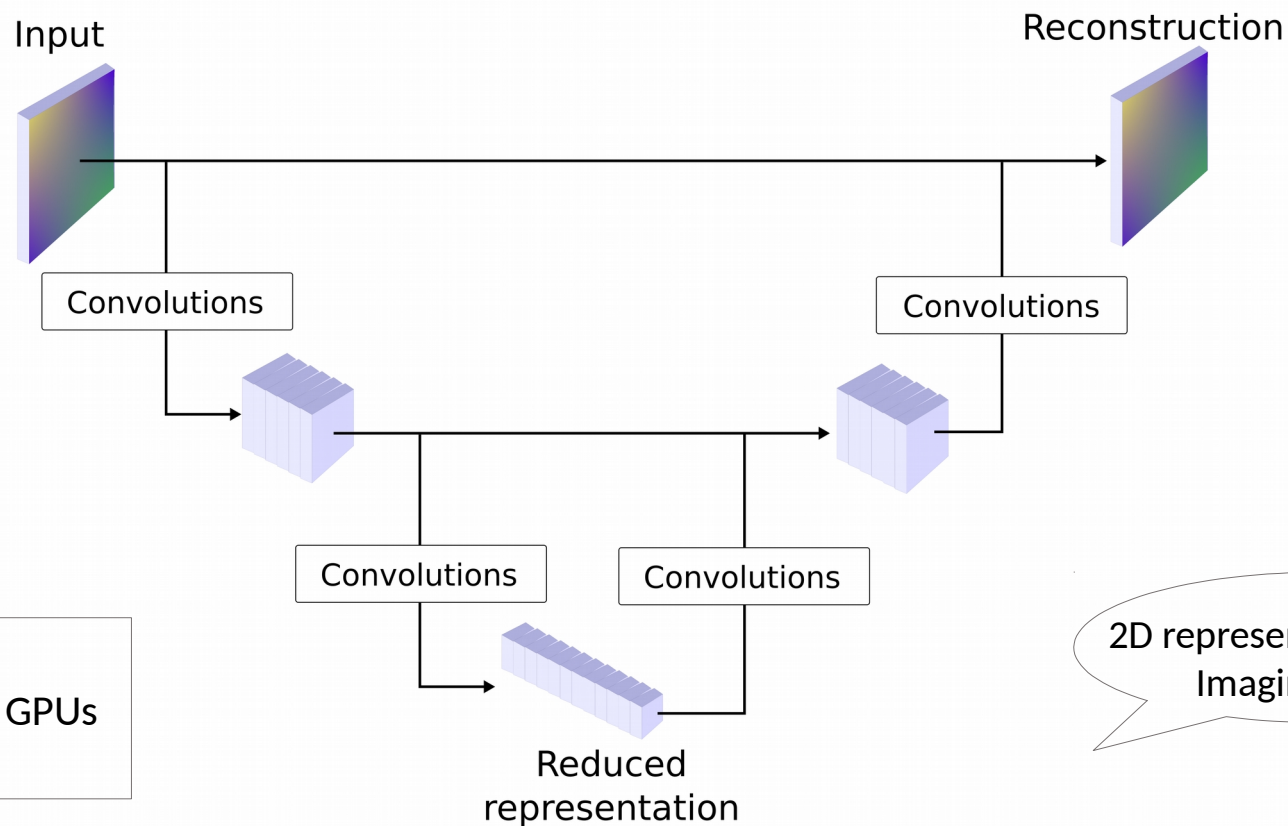
Publicly available! (14Go)
[10.5281/zenodo.6983054](https://doi.org/10.5281/zenodo.6983054)





Auto-encoder ~ non-linear extension of the PCA

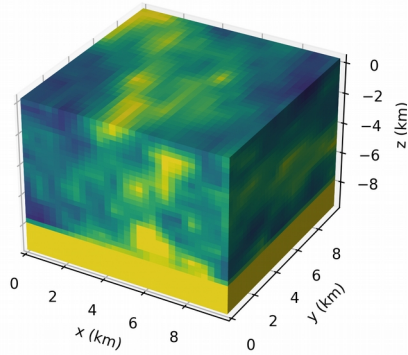
3D UNet [Çiçek et al. 2016], [Wolny et al. 2020]



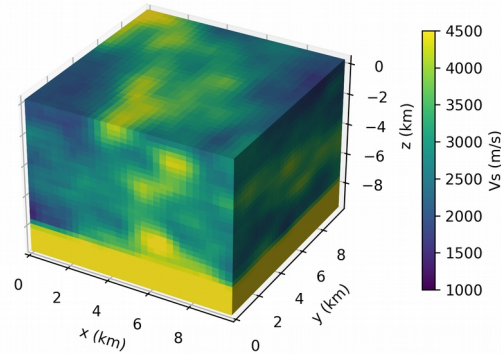
4 million parameters
Training time: 9.5h on 4 GPUs
for 1000 epochs

2D representation of UNet
Imagine it in 3D

Input

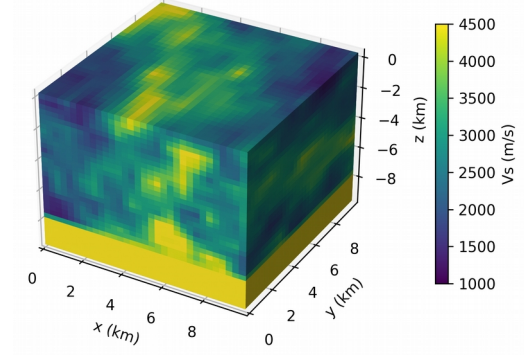


PCA



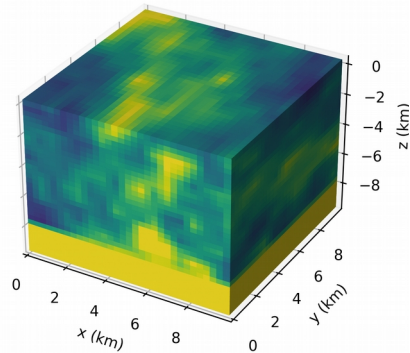
« Smoothed » reconstruction

3D UNet

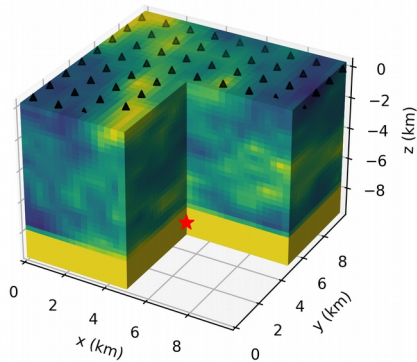


Biased reconstruction (mean value)

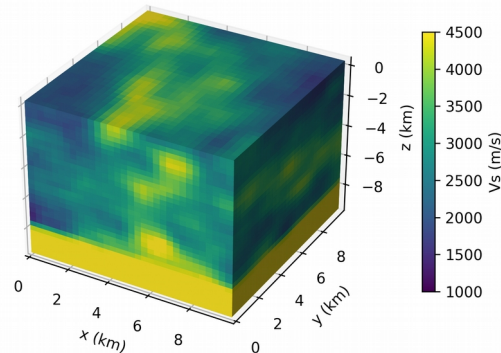
Input



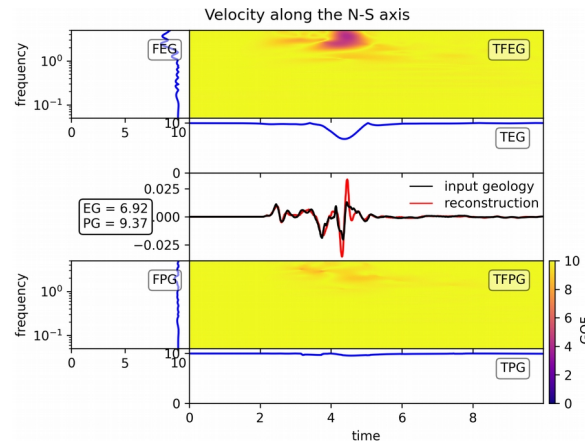
Input



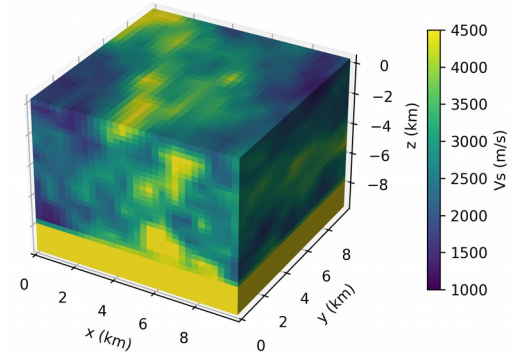
PCA



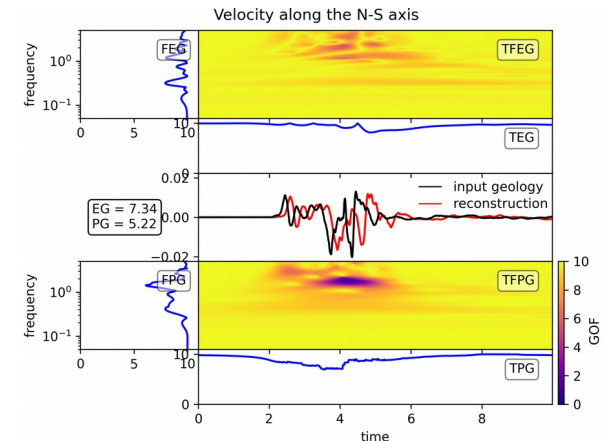
« Smoothed » reconstruction



3D UNet



Biased reconstruction (mean value)



QUESTION

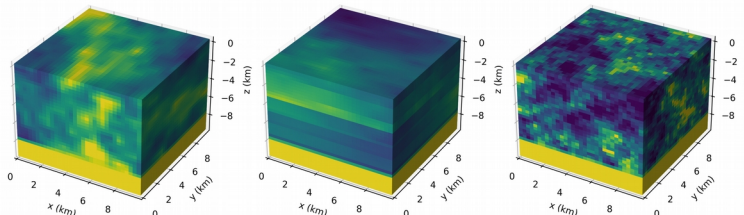


Quantify the variability of the problem's output due to geophysical media uncertainties.



[Lehmann et al. 2022]

DATABASE



100,000 heterogeneous geophysical media

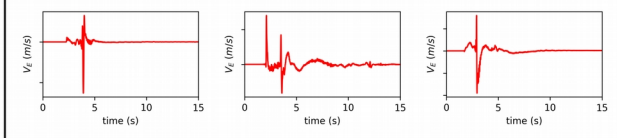
Principal
Component
Analysis

Auto-encoder
3D UNet

REDUCED REPRESENTATION



RESULT



physics-based simulation

REFERENCE

