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From surface deformation to pressure fields: contribution of machine learning to cost-effective CO2 injection monitoring

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From surface deformation to pressure fields: contribution of machine learning to cost-effective CO2 injection monitoring

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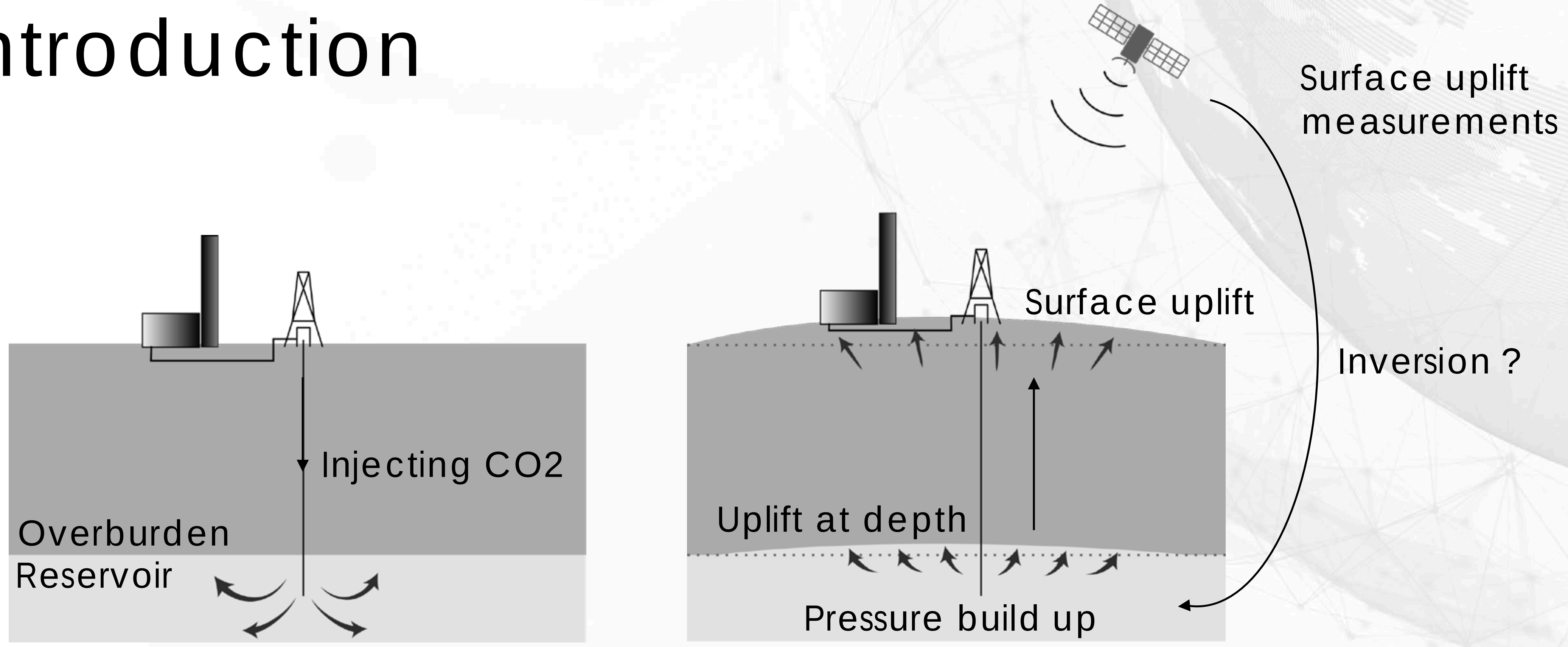
Introduction

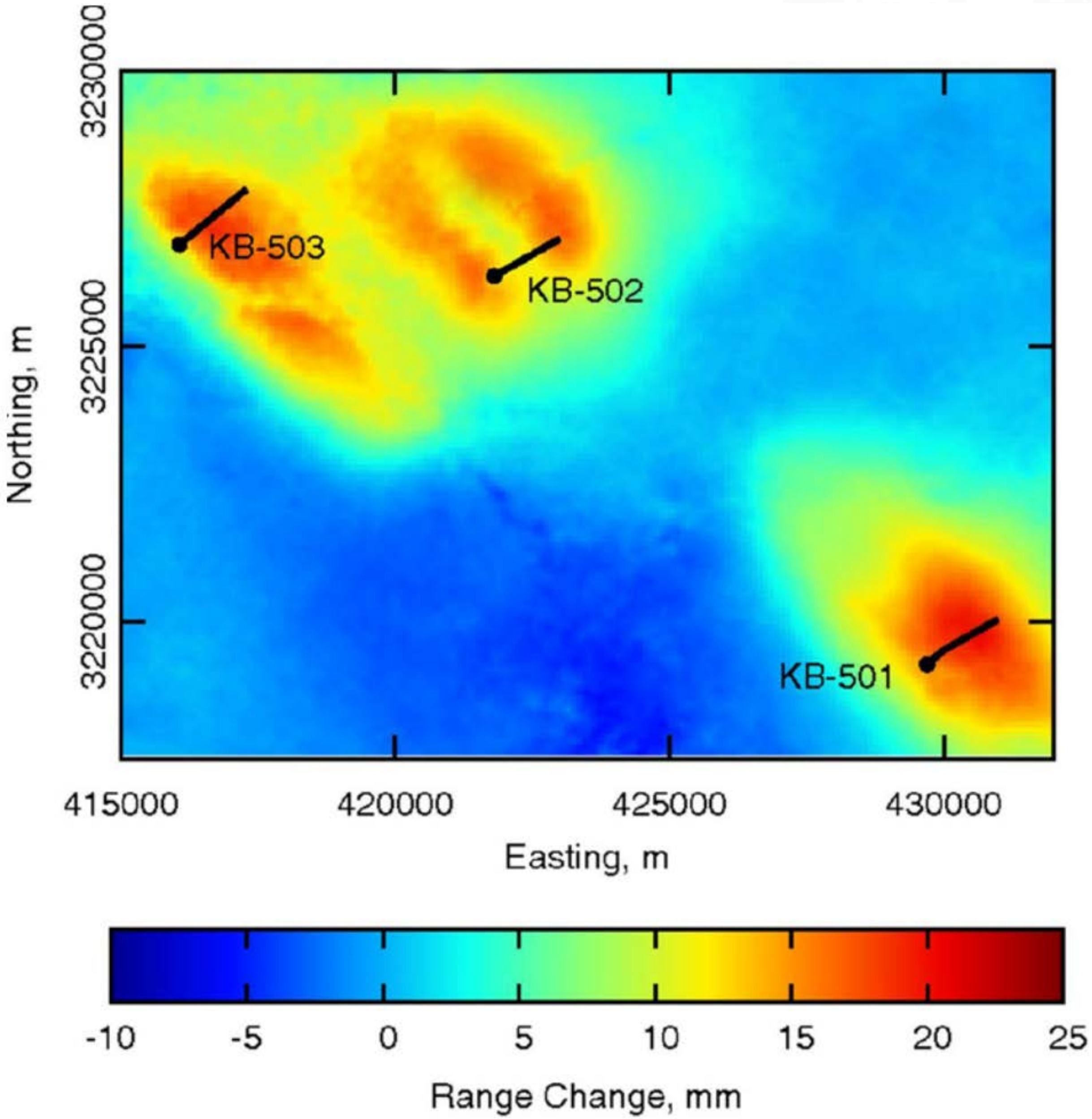


- Injecting CO2 –> Pressure build up –> Surface uplift
- Surface uplift -> Estimation of pressure distribution ?

Headlines

- Context on the In Salah injection site
- Measured InSAR data
- Synthetic dataset -> reference data
- Machine Learning ? Requirements, training set ...
- Results
- Conclusions

In Salah injection site



- Production site for natural gas
- CO_2 injection between 2004 and 2011
- 3 injection wells
- More than 3.8 million tonnes of CO_2 stored
- Surface deformation used in this study measured in 2011 with InSAR data

Review of the injection history - Bohloli et al., 2018

Surface uplift from InSAR data
Figure from White et al. 2014

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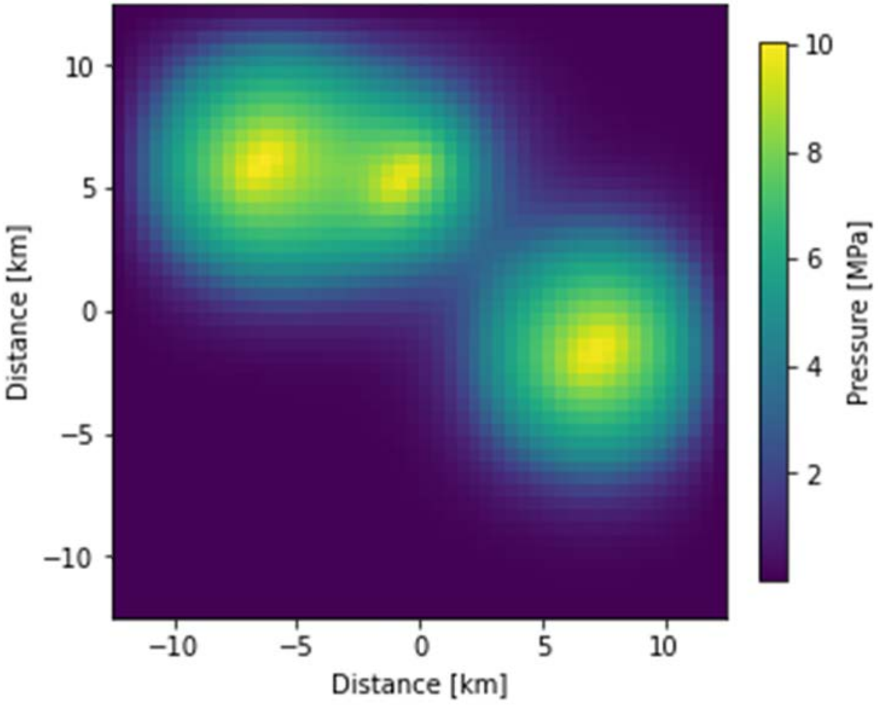
The synthetic dataset

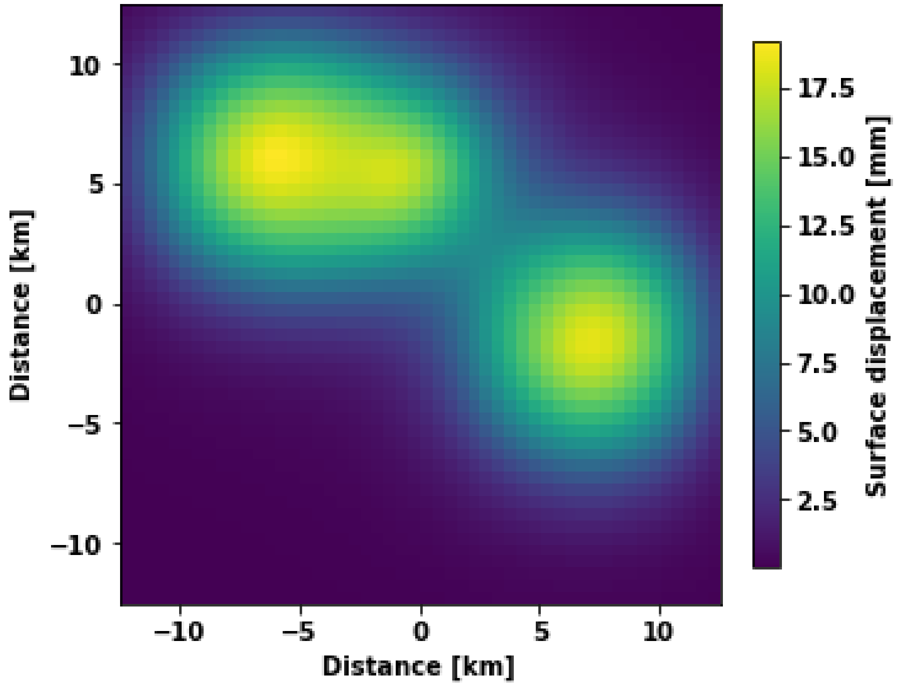
Layer	Thickness[m]	Young's modulus[GPa]	Poisson's ratio [-]	Remark
1	900	3	0.25	Shallow aquifer (Cretaceous)
2	750	5	0.30	Cap rock (Visean mudstone)
3	130	2	0.30	Lower cap rock
4	20	20	0.25	Tight sandstone
5	20	9	0.15	Reservoir
6	∞	15	0.30	Devonian (underburden)

Layering and material properties for In Salah inspired synthetic model (after Bjørnarå et al., 2018)

Pressure distribution



Surface Displacement



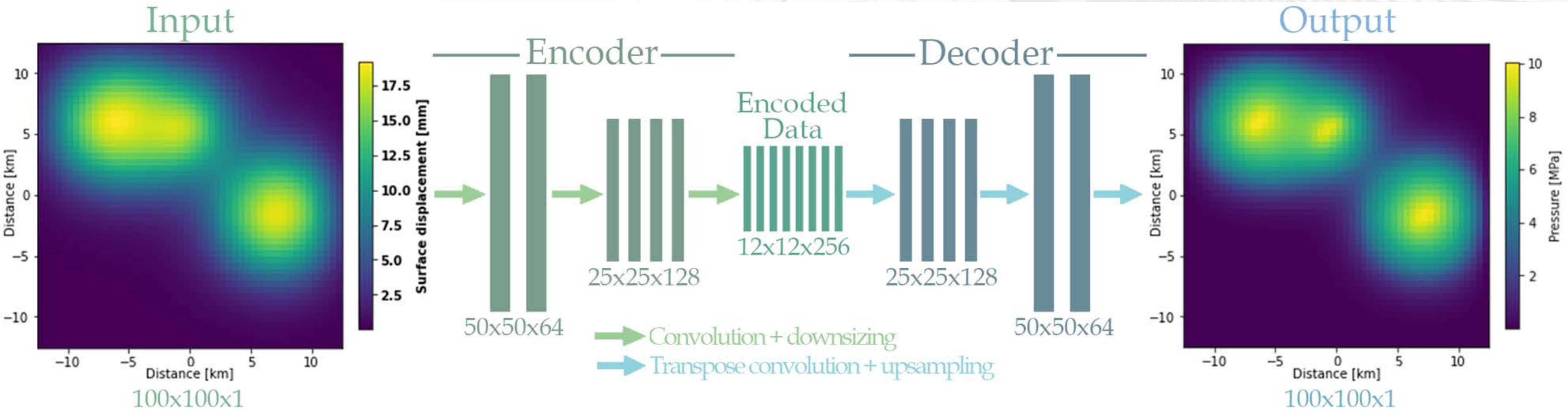
Extension : 25km
Bin size : 250 m

After Park et al., 2021
Inspired after Bjørnarå et al., 2018

Machine Learning requirements

- Validation set – previous slide
- Training set
- ML network/architecture

Machine Learning network



- “Translate” an Image to an image -> encoder-decoder
- Images -> convolutional layers

Technical information
Activation functions : ReLU
For last layer: Linear

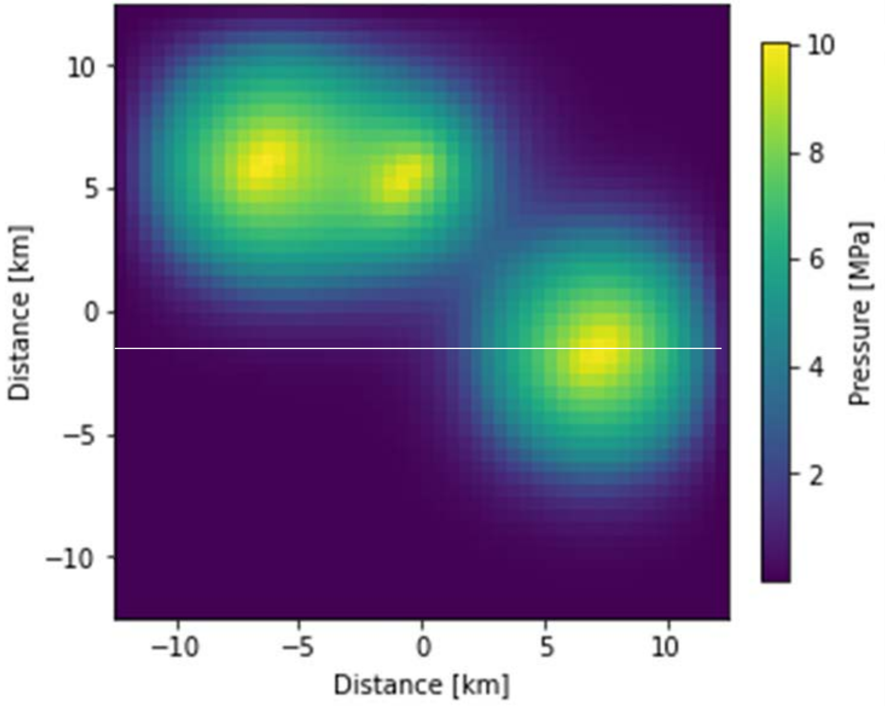
Loss function : mse

Training set

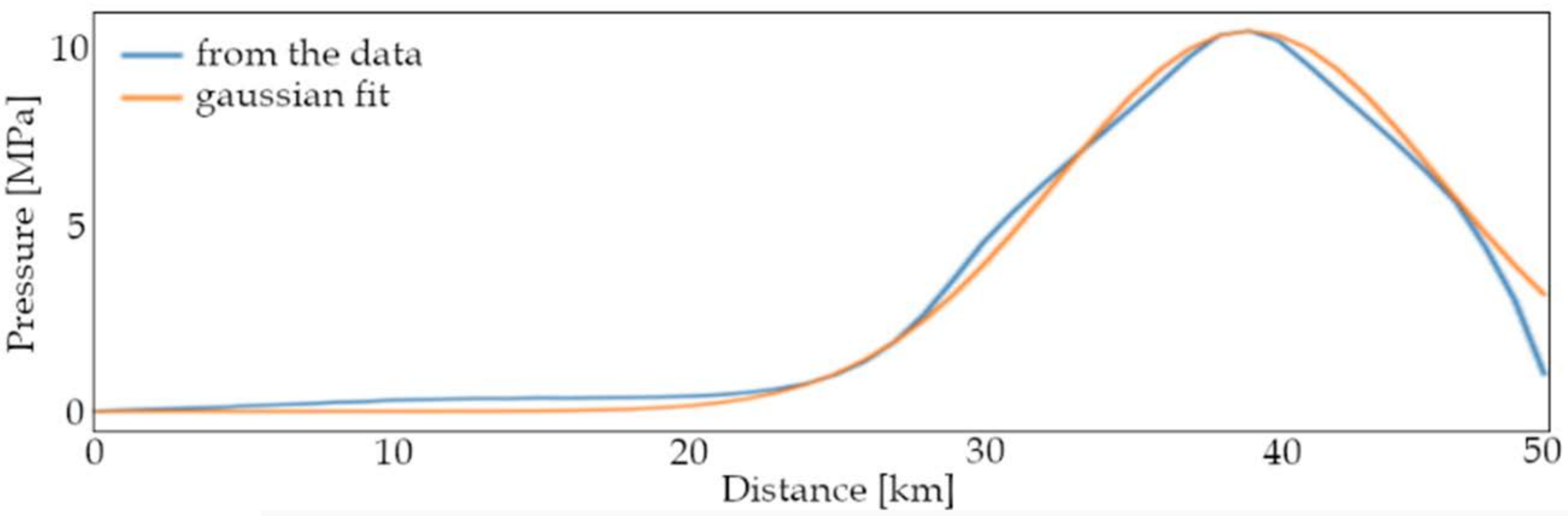
- Pressure distribution
  - Randomness

- Corresponding surface displacement (forward modelling)
  - Generalized Geertsma solution – Park et al., 2021
  - Considered a tabular model – needs the thickness, Young's modulus and Poisson's ratio of each layer

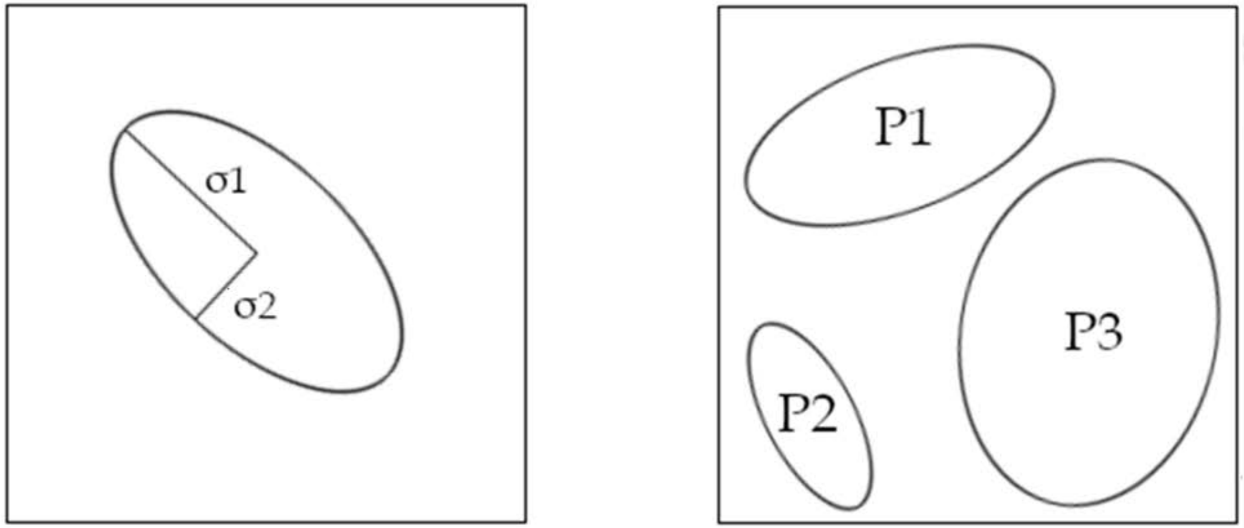
Training set – pressure maps

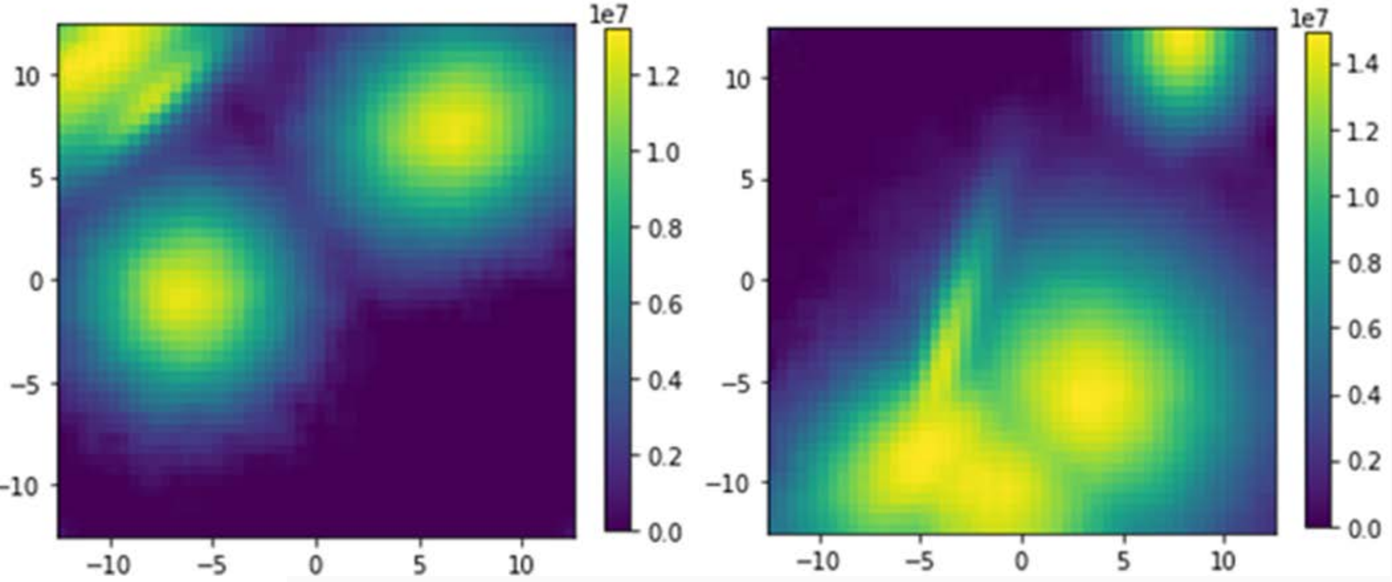


- Criterion – randomness and “realistic”



Training set – pressure maps

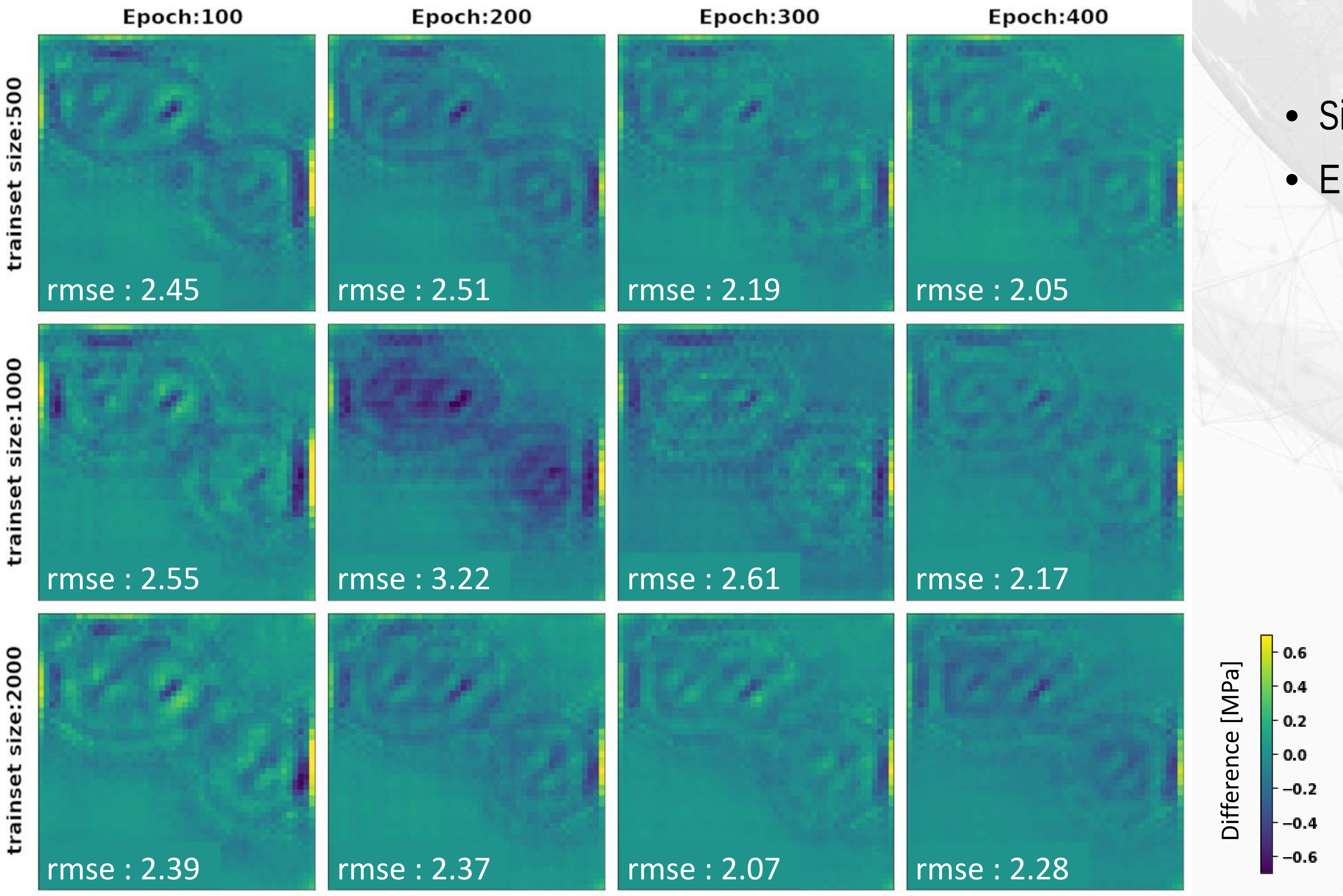




- 1 Patch defined by :
  - pressure patch width along 2 directions (σ1 and σ2)
  - center
  - rotation angle

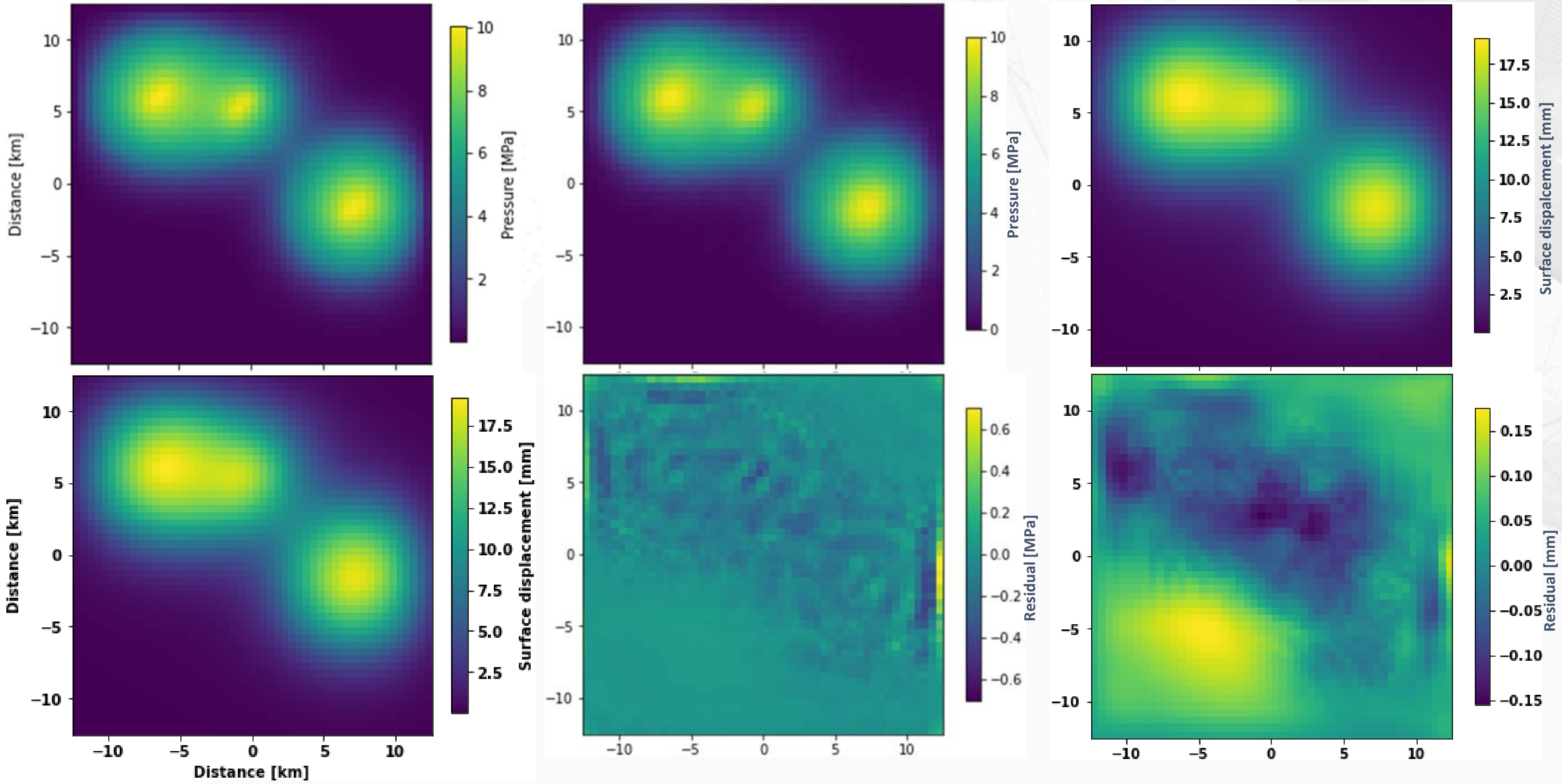
- Multiple patches (2 to 5) creates a pressure distribution

Training the model and results



- Size of training set
- Epoch number

Training the model and results



Proof

Predicted P

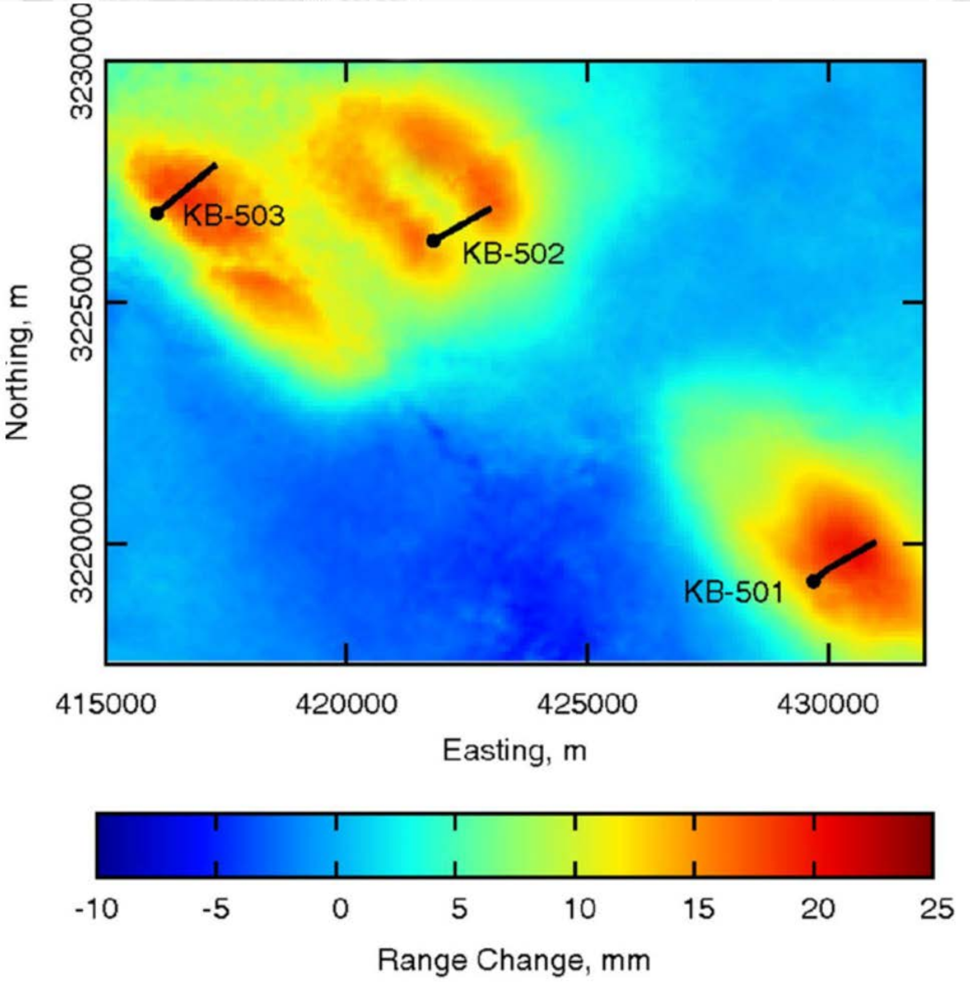
Surface uplift from prediction

Epoch 300
training size 2000

Conclusions

Pressure distribution throughout a reservoir can be obtained based on ground displacement at surface using Machine Learning, with some conditions:

- Simplified surface uplift measurements
- Tabular geological model
- Good geological model is required (Poisson's ratio, Young's modulus)



- How to do better ?
  - What accuracy do we want to obtain ?
  - Improving the generation of random pressure distribution
- Application ?
  - Time lapse monitoring

Thank you

Aknowledgement

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