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Stochastic Data Integration to model Quaternary Aquifers: Application on the Aare Valley, Switzerland

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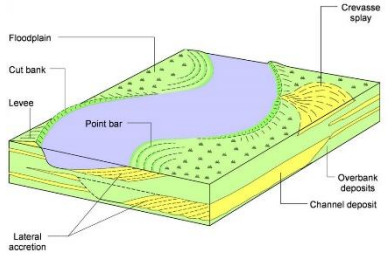
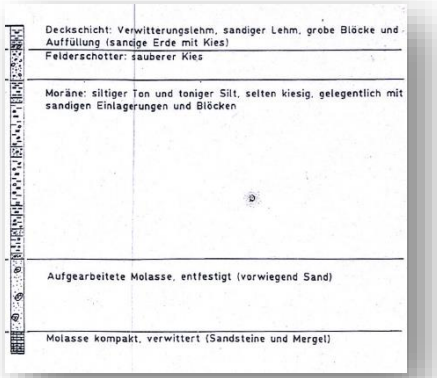
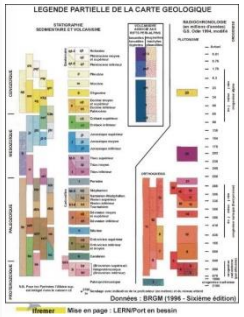
AGU FALL MEETING
New Orleans, LA & Online Everywhere
13–17 December 2021

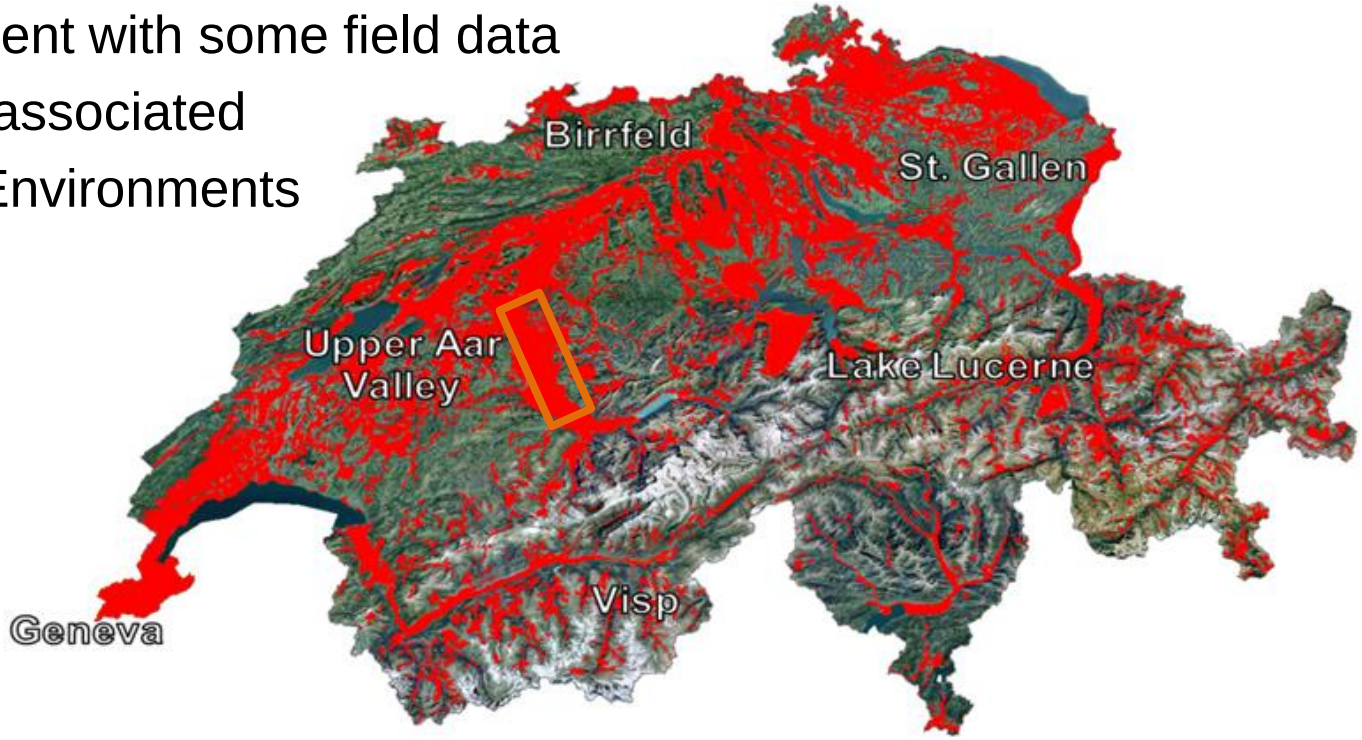
DATA

- In most countries, digitalization of data is growing.
  (mandatory to send new boreholes data)
- Too much data to manually interpret them
  - No uncertainty analysis
  - The final model might be in disagreement with some field data
  - Only boreholes based models can be associated with high uncertainties in Quaternary Environments





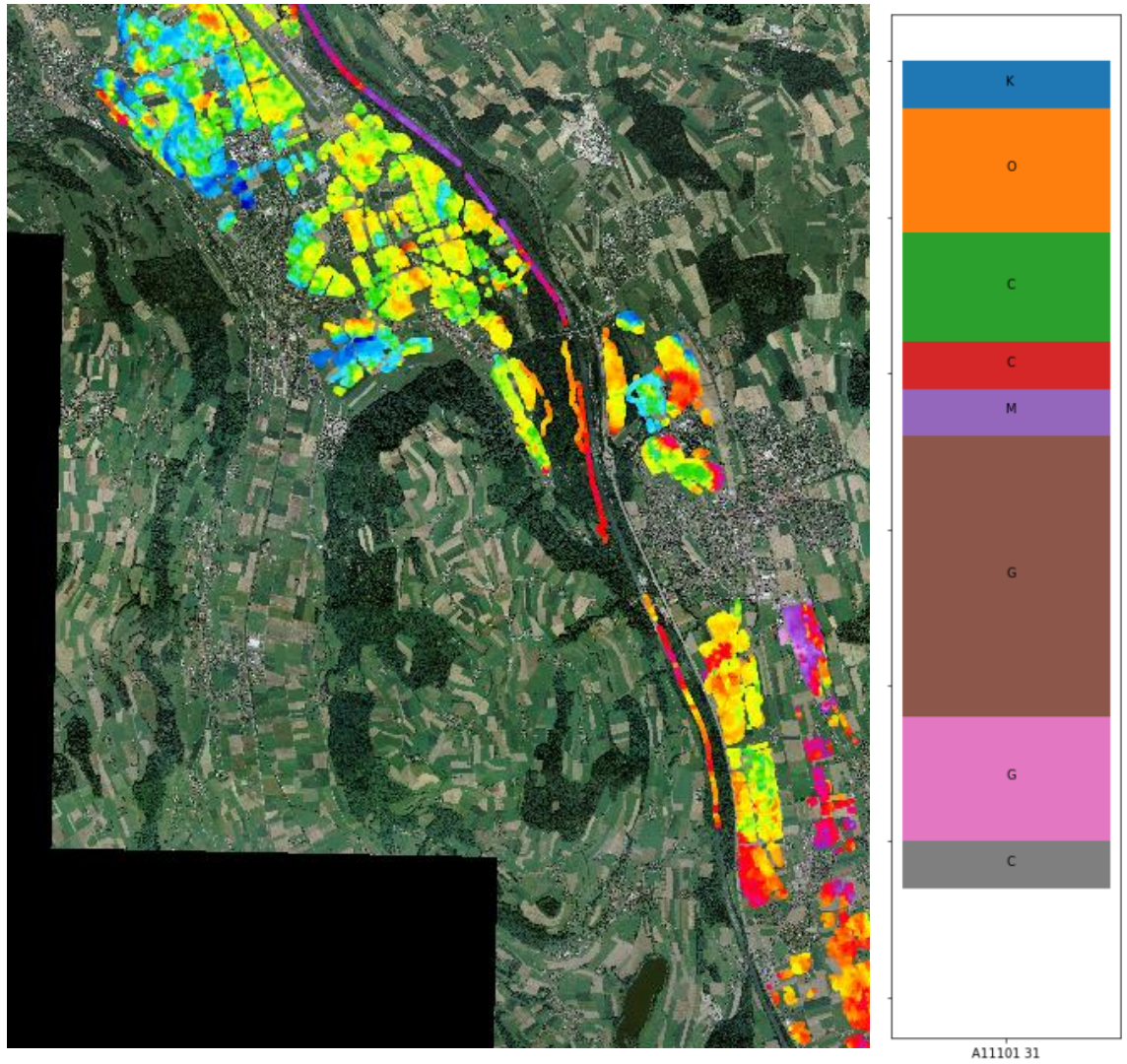




DATA

- What data do we usually have on site ?
  - Described boreholes (usually lithological)
  - Pumping test, or groundwater heads monitoring
  - Geophysical data (seismic, DC, EM, …)

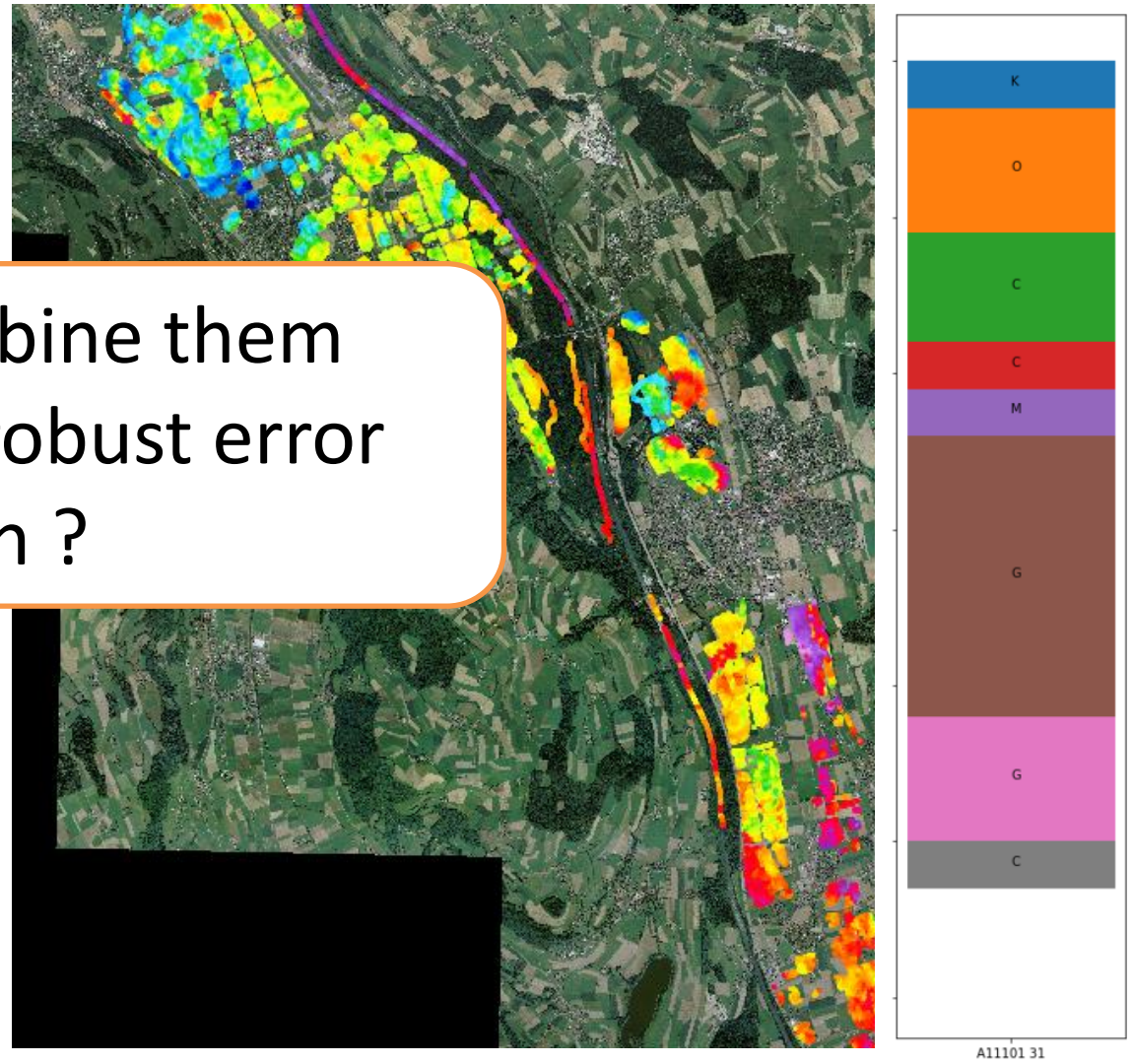
  - Conceptual idea



DATA

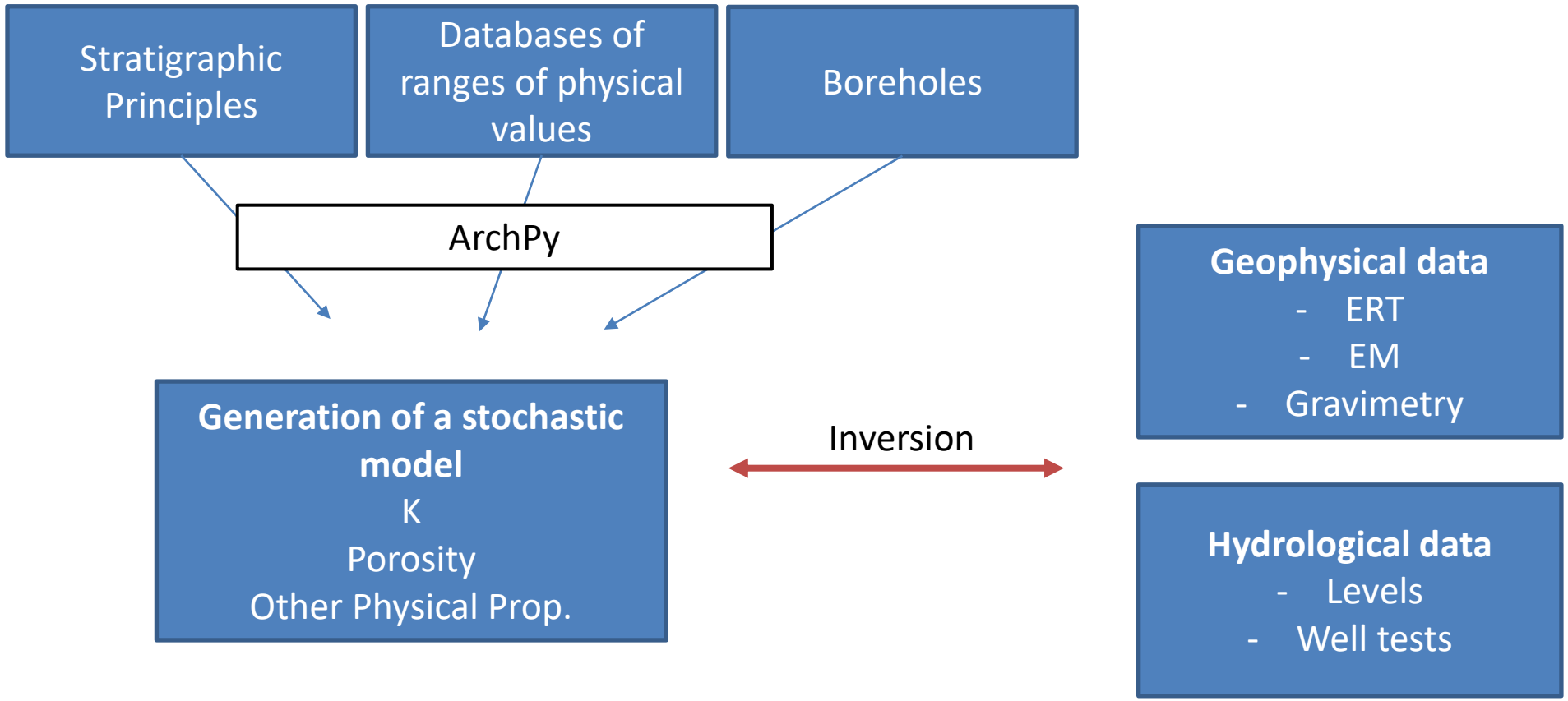
- What data do we usually have on site ?
  - Described boreholes (usually lithological)
  - Pumping te
    heads mon
  - Geophysica
    EM, …)
  - Conceptual idea

How can we combine them efficiently, with a robust error estimation ?



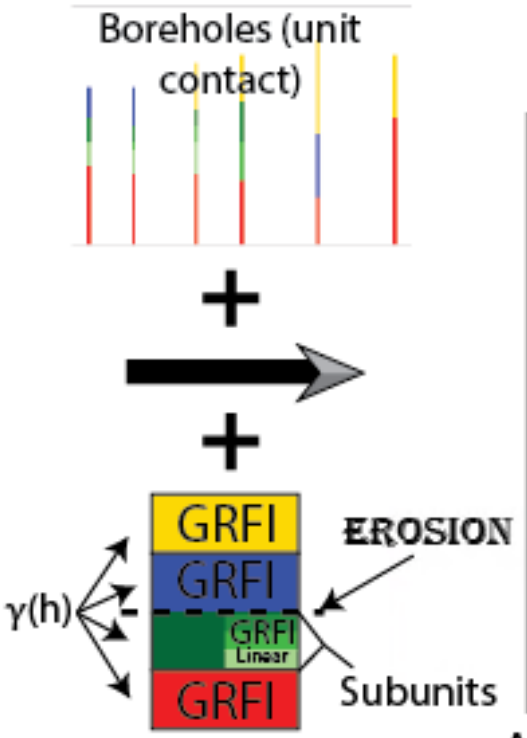
WHAT NEXT ?

– We need to be able to give some kind of geological principles !



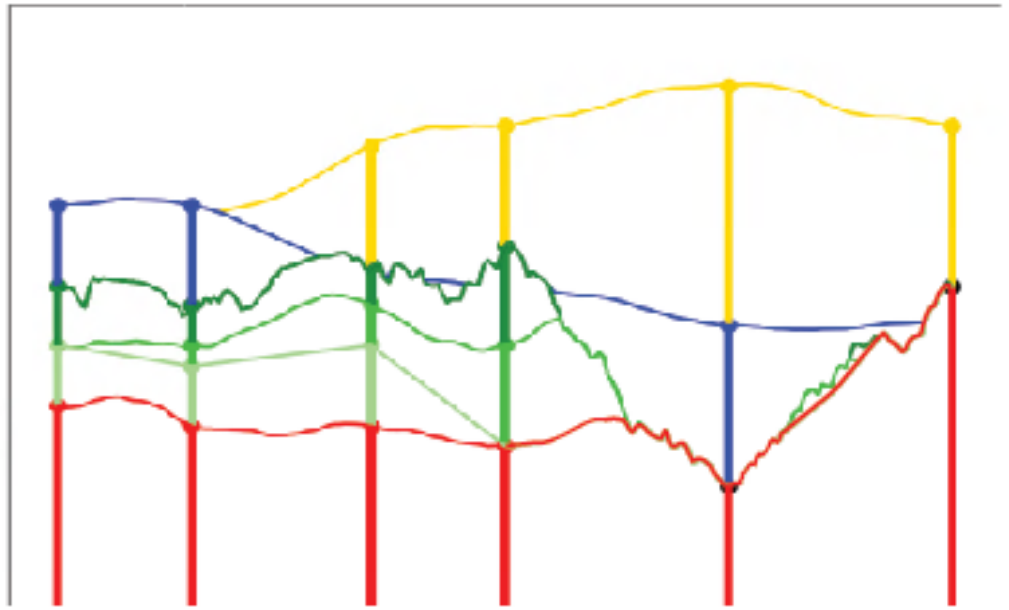
WHAT NEXT ?

Stratigraphic Principles



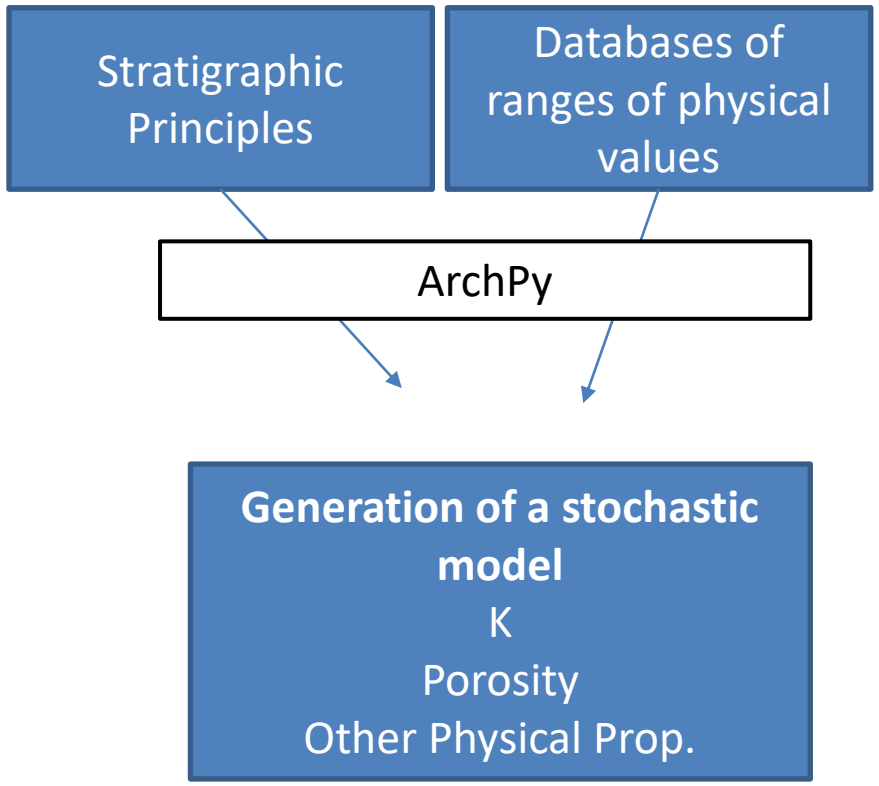
Stratigraphic pile and interpolation method/parameters (variograms (γ(h))

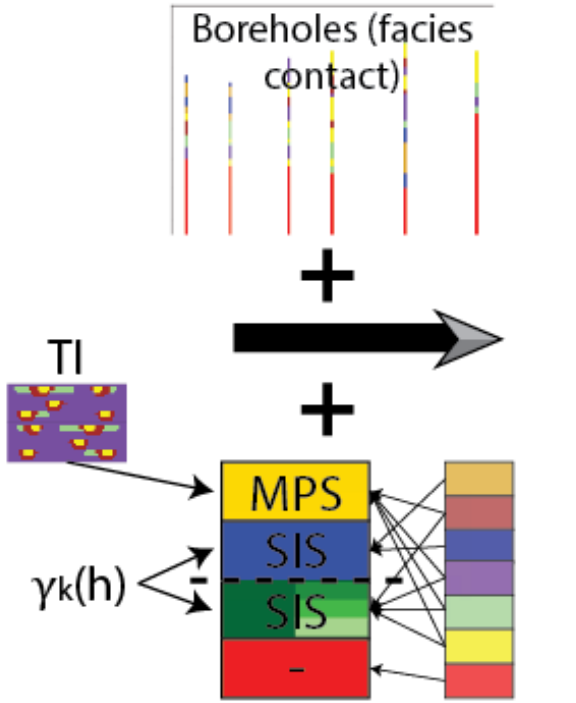
1. Computing units surface elevation



Available interpolation methods are : Kriging (OK, SK), Gaussian Random, function with (GRFI)/without (GRF) inequalities , basic splines and nearest neighbour and soon Multiple Point Statistics (MPS).

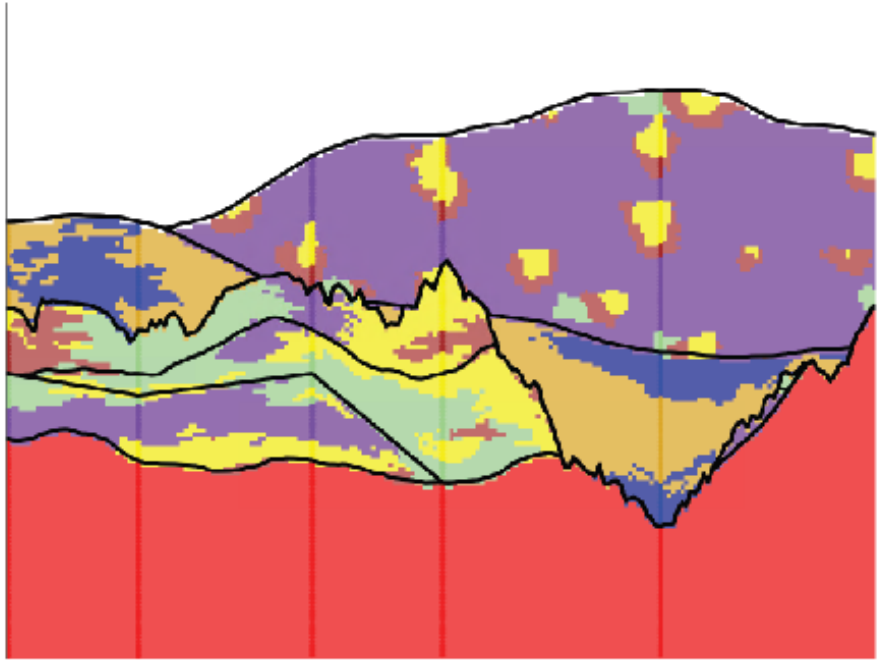
WHAT NEXT ?





Facies relation to units and filling method/parameters (Training images, indicator variograms ($\gamma_k(h)$, etc.)

2. Filling units with associated lithologies/facies (sand, clay, ...)



Filling operates only inside unit given the method used. The available ones are : MPS, Sequential Indicator Simulations (SIS), Truncated PluriGaussians (TPGs) and homogenous (-).

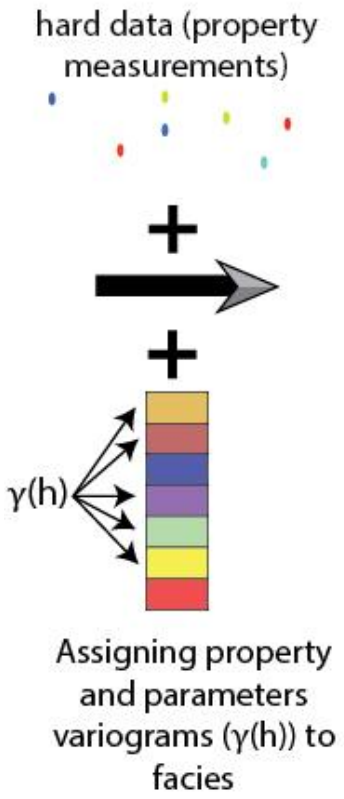
WHAT NEXT ?

Stratigraphic Principles

Databases of ranges of physical values

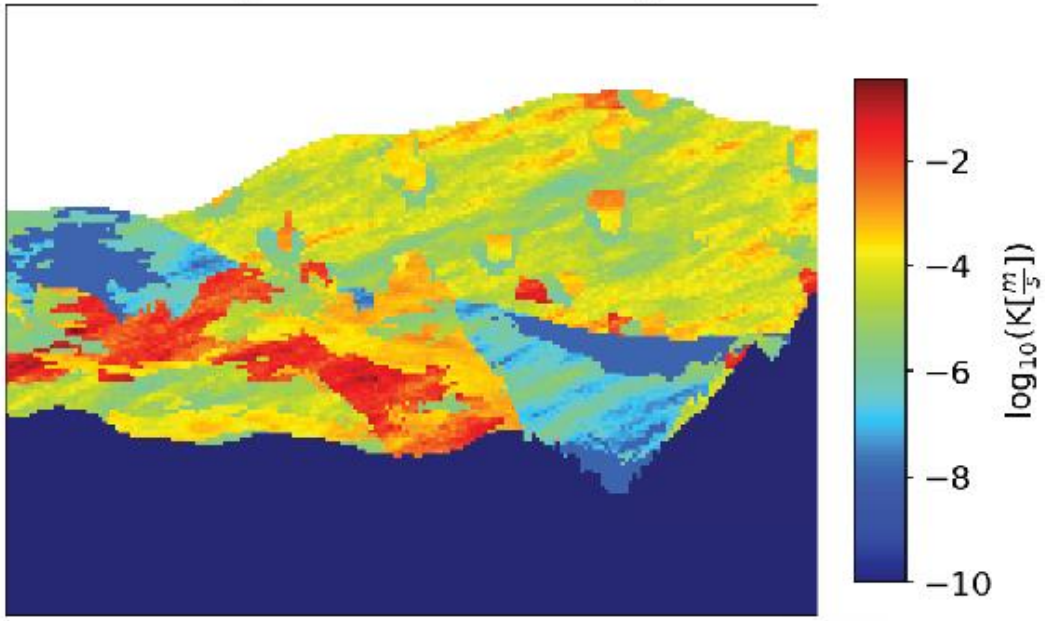
ArchPy

Generation of a stochastic model
K
Porosity
Other Physical Prop.



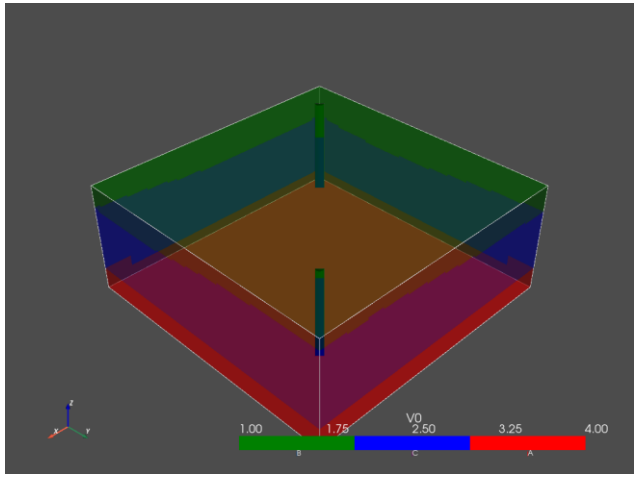
Assigning property and parameters variograms (γ(h)) to facies

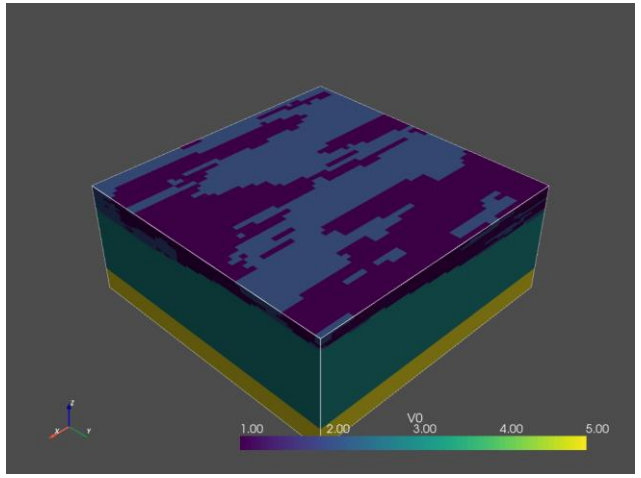
3. Computing physical models (e.g. hydraulic conductivity)

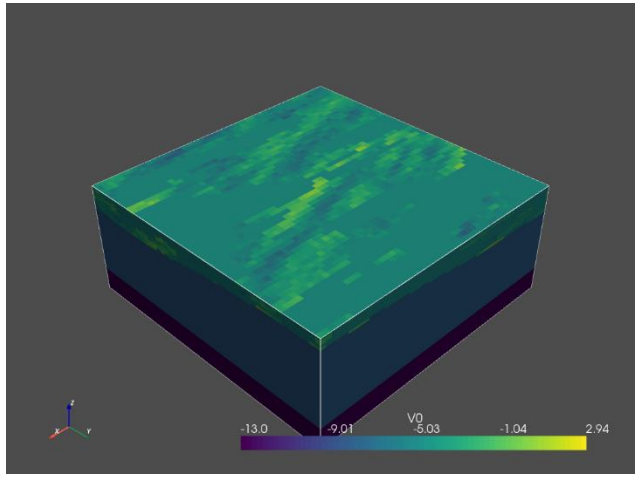


The desired properties are simulated inside each facies using GRFs or are simply set homogenous. Any number of properties can be assigned.

SUMMARY

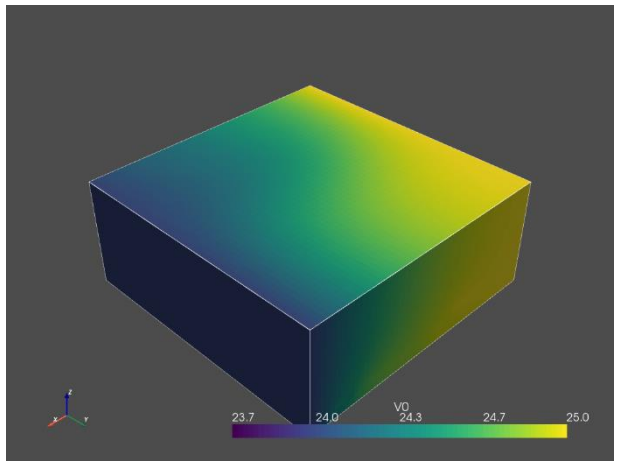


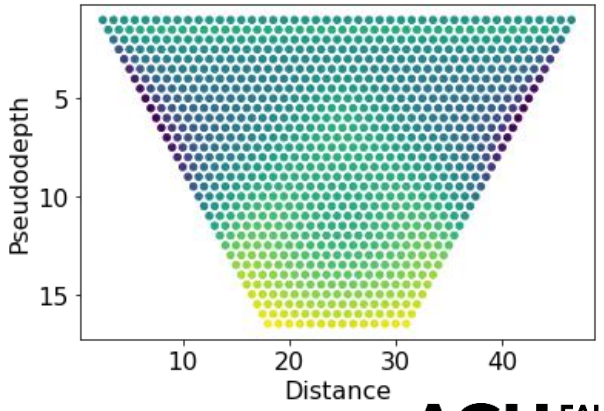


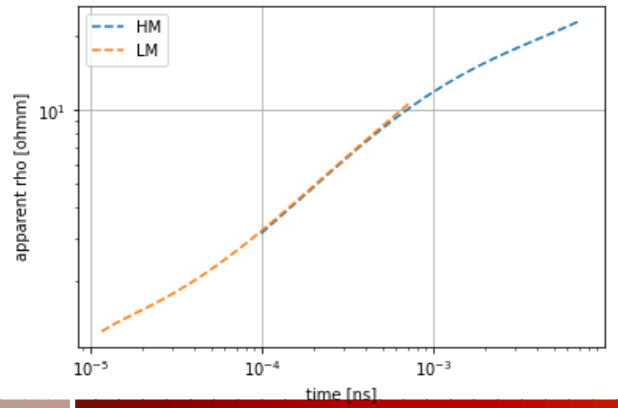


Units → Facies → Parameters

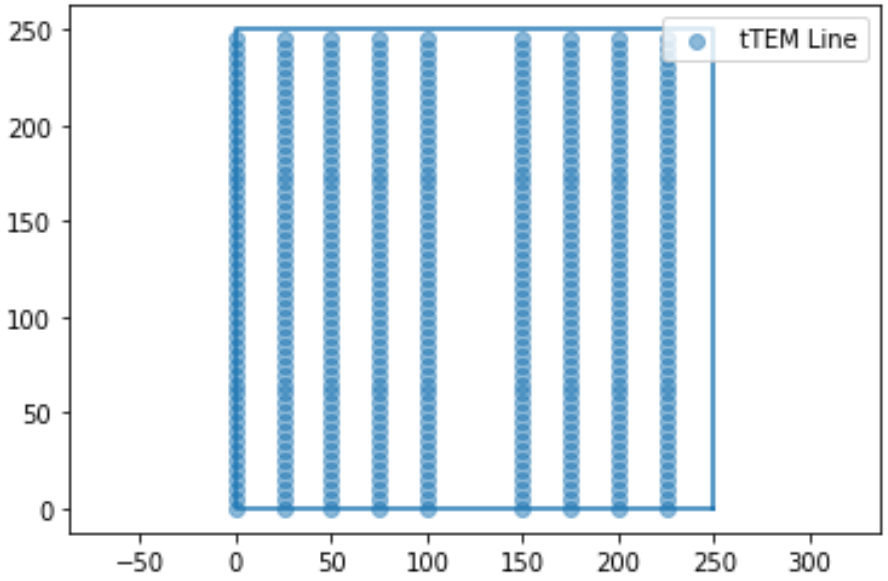
Any Physical Forward

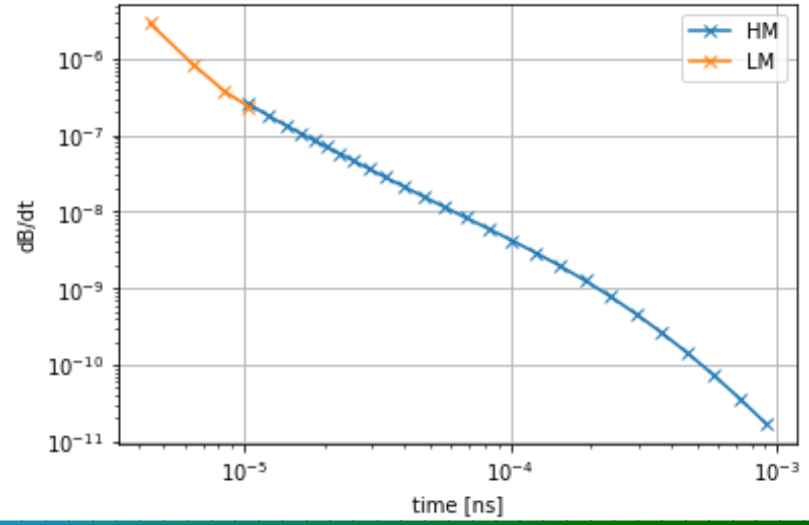






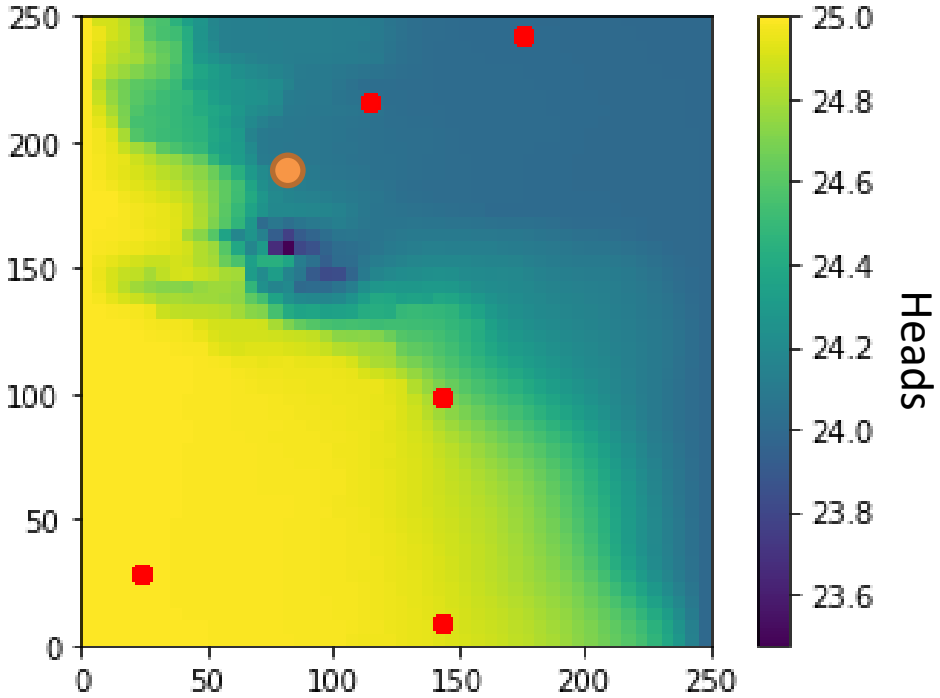
SYNTHETIC EXAMPLE - DATA





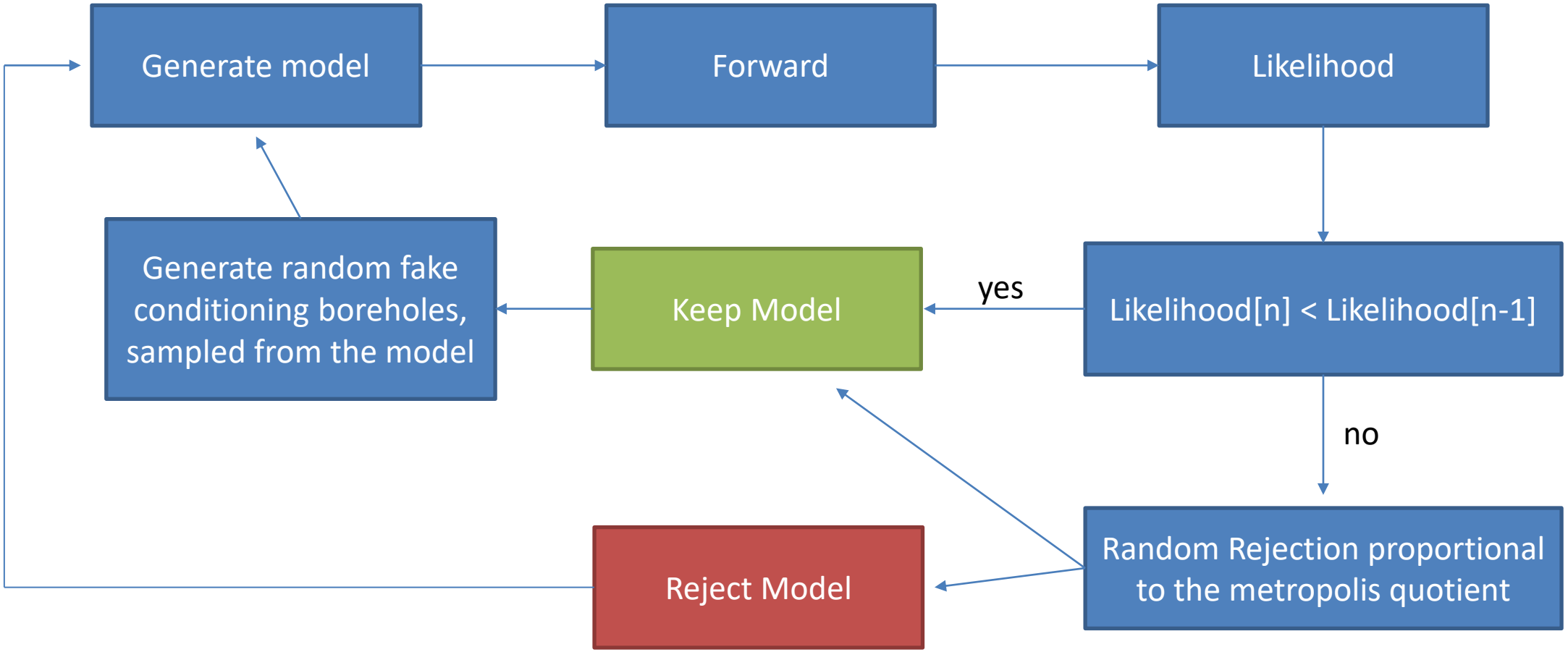
Geophysical data – random noise added
Towed TEM measurements

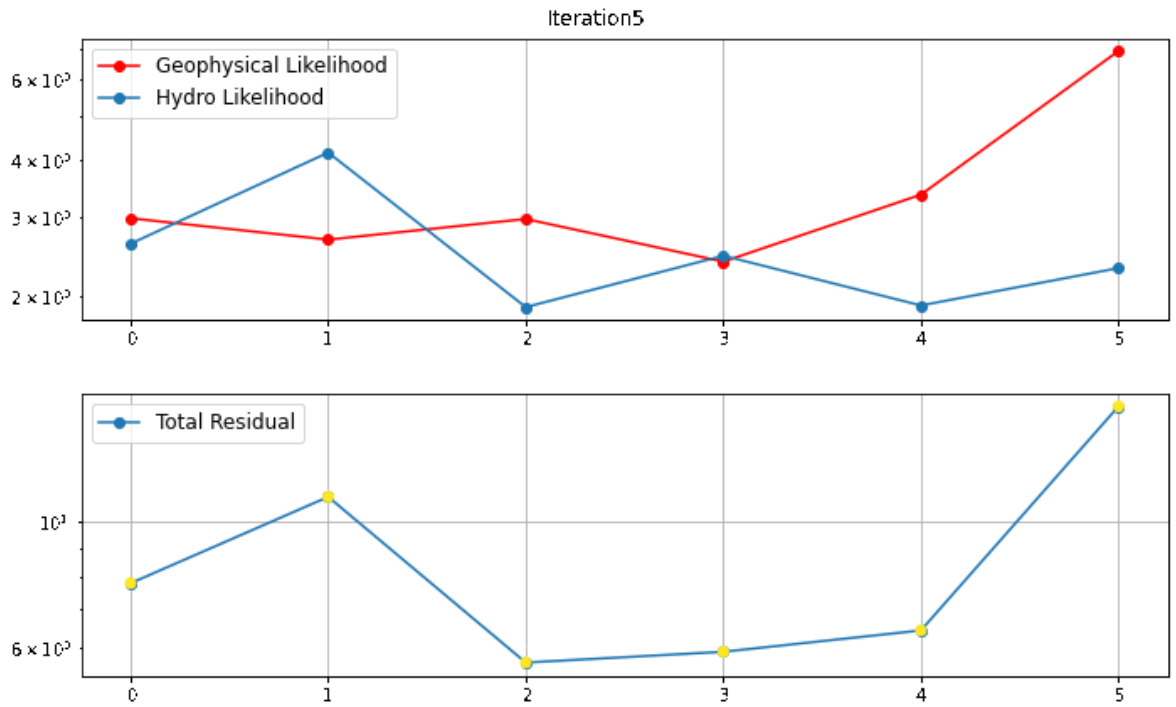
1 pumping well – constant rate
5 monitoring wells
2 wells are lithologically described

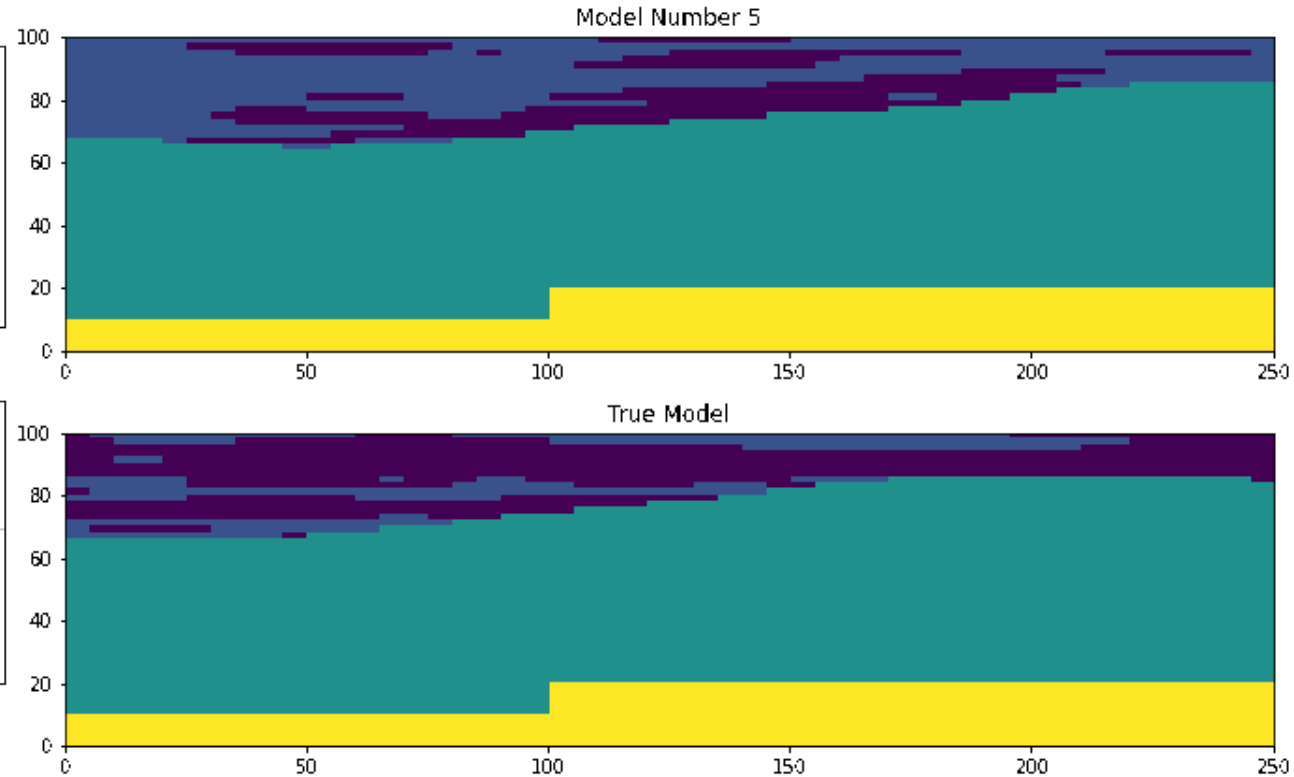


METROPOLIS HASTINGS

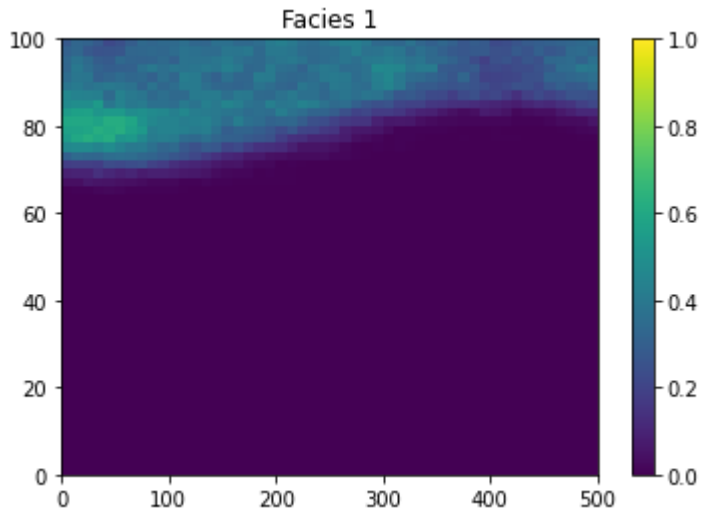
– Simplest stochastic inversion



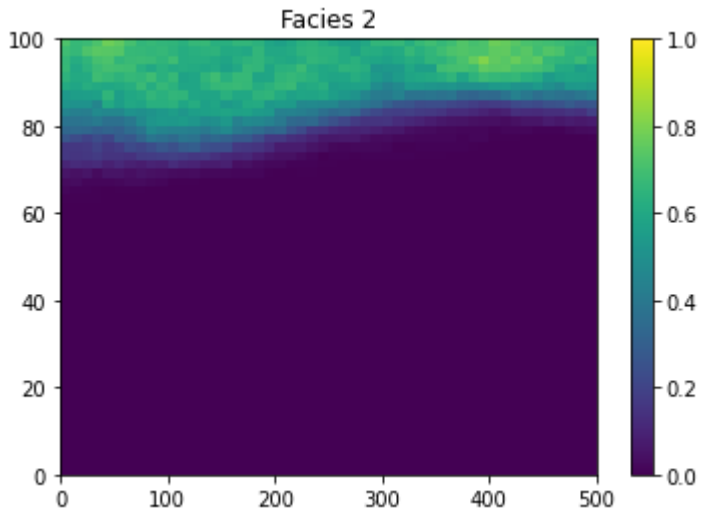

Iteration5
Geophysical Likelihood
Hydro Likelihood
Total Residual


Model Number 5
True Model

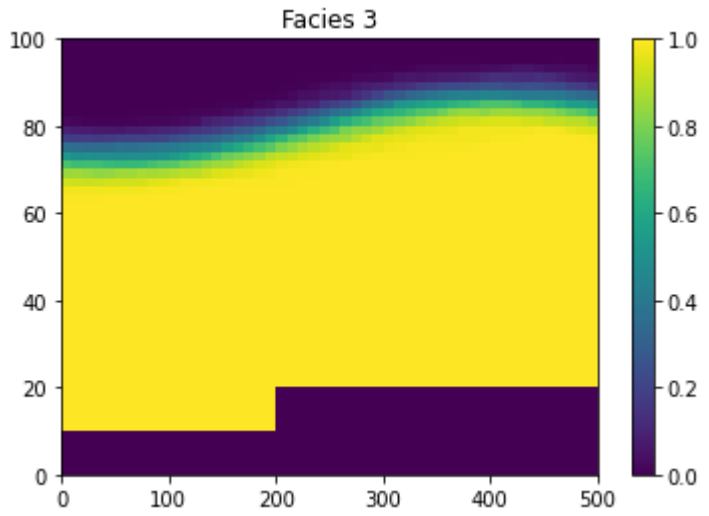
RESULTS OF THE SYNTHETIC



P(gravel)

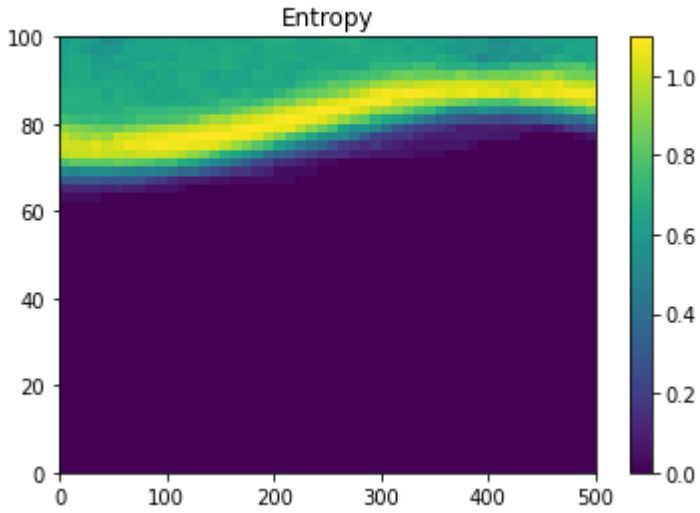


P(sand)

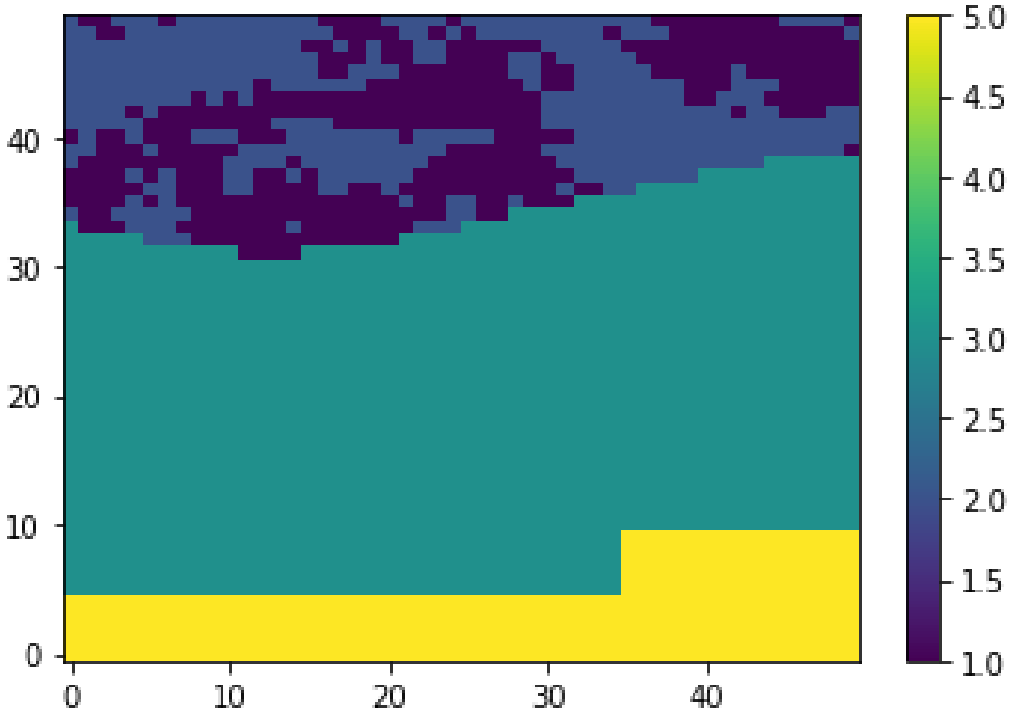


P(clay)

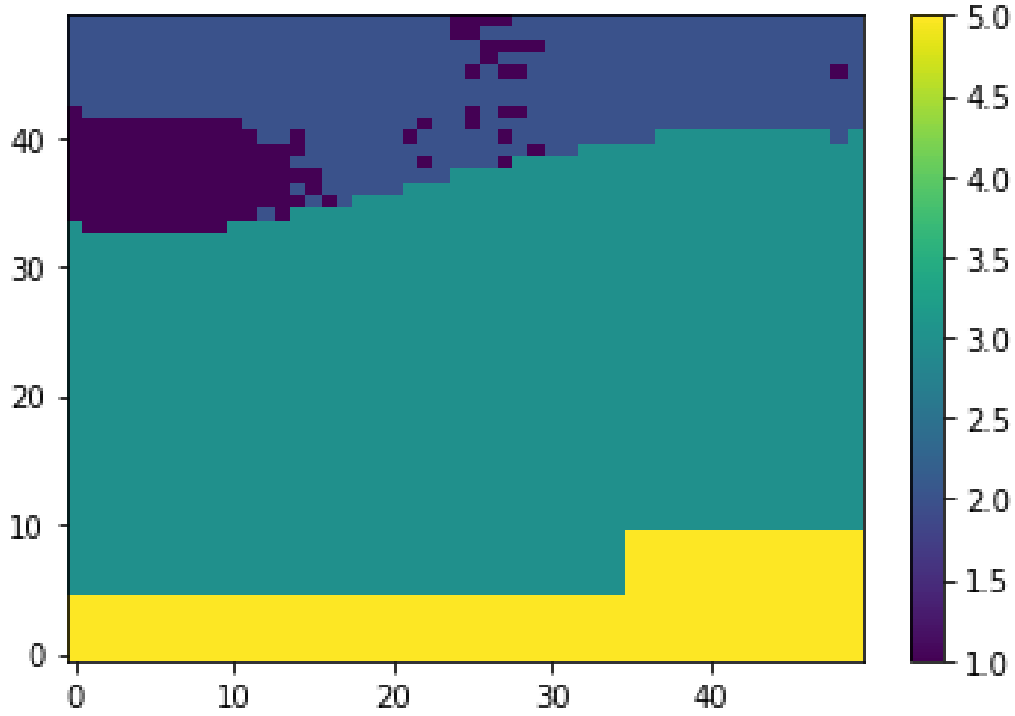
Based on 3000 iterations



True Model



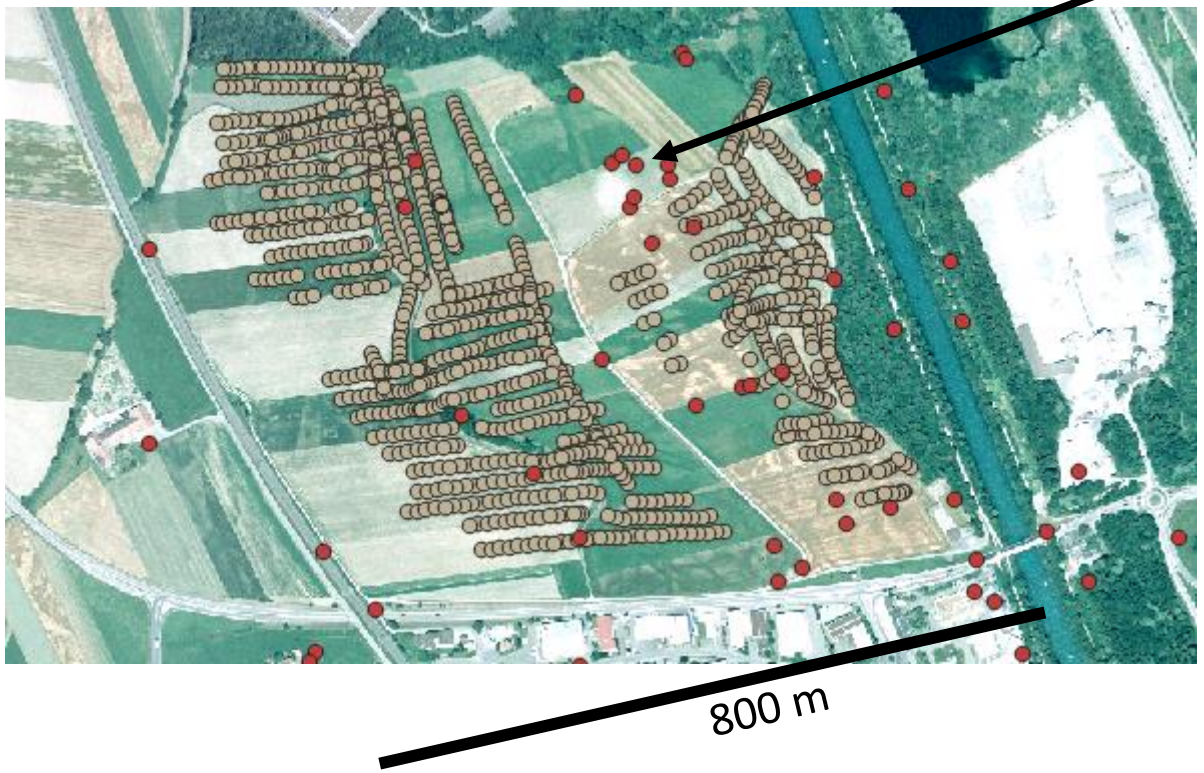
Most probable model



It works ? Yes but…

The real statistical models are known
The TEM data are in their “best scenario”

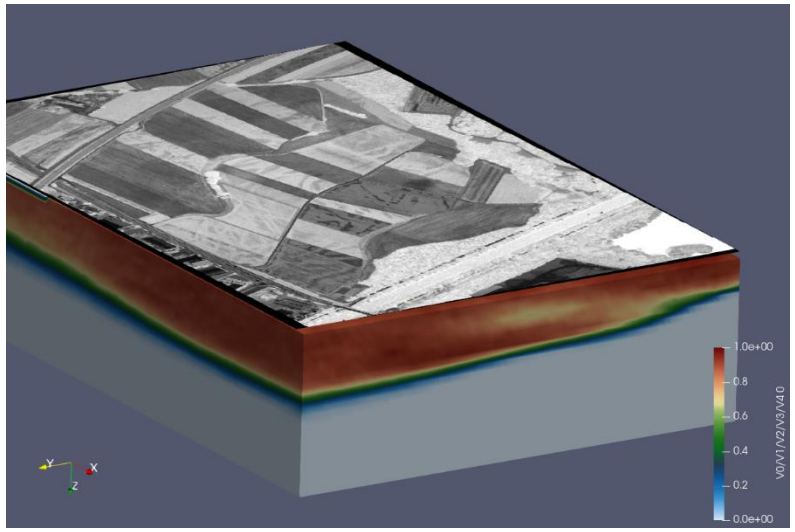
AMERIKAEGGE TEST SITE



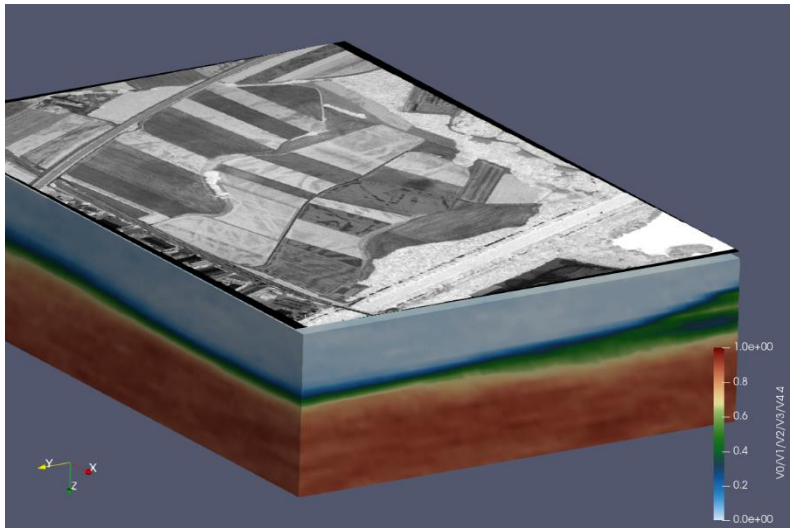
4000 iterations
5 Boreholes considered
No flow model (yet)

Let’s have a look with some real field data

AMERIKAEGGE TEST SITE

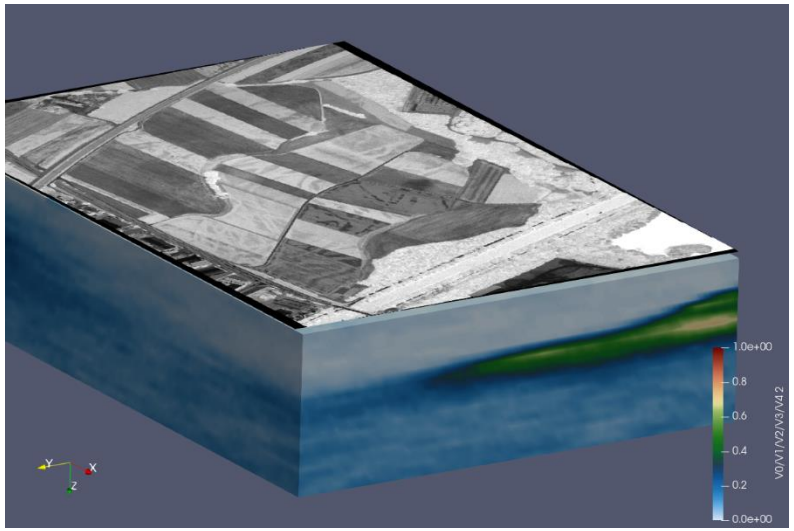


P(gravel)

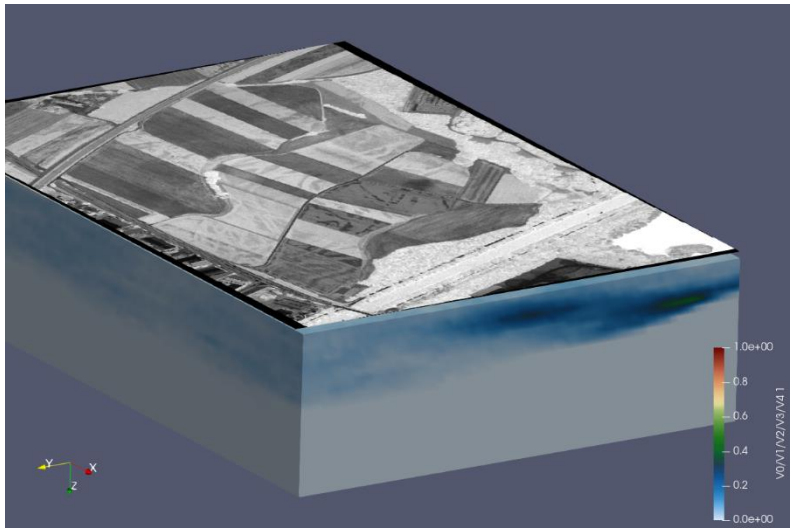


P(clay)

Based on 3000 iterations

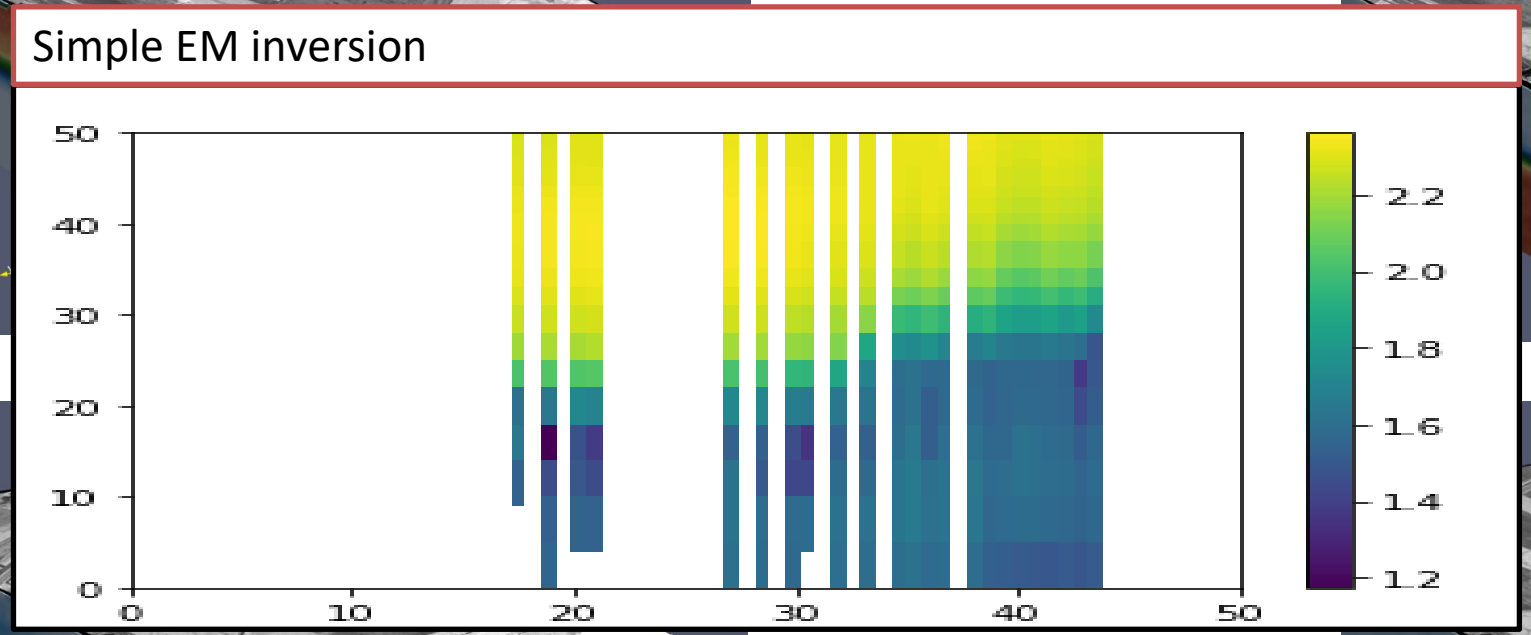


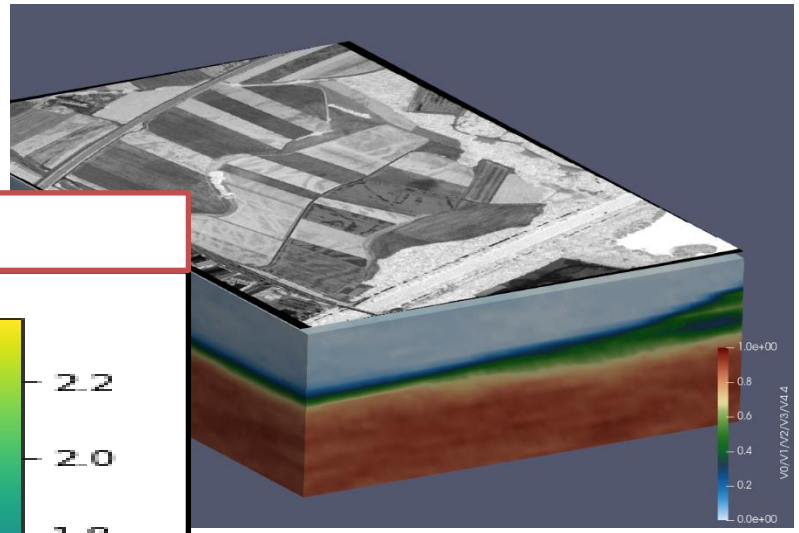
P(sandy clay)

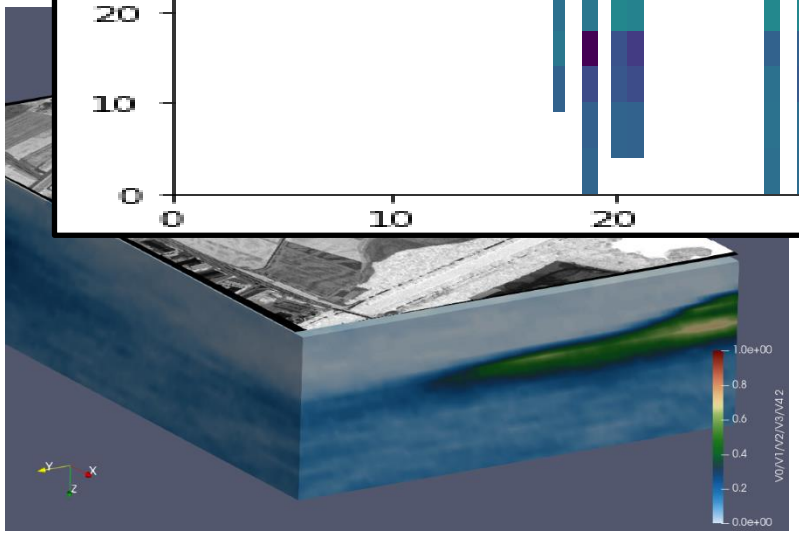


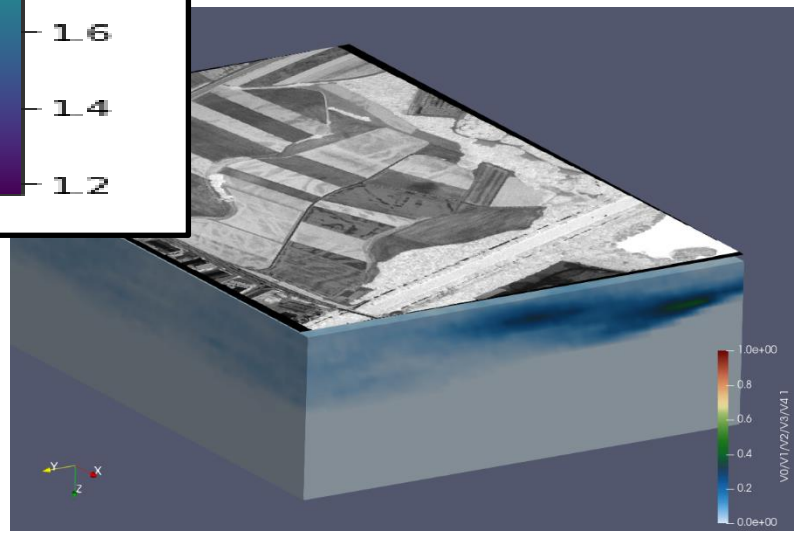
P(sand)

Simple EM inversion









CONCLUSION

- Promising approach
- This methodology :
  - Directly integrates multiple data types, and generates models in agreement with all of them
  - Is agile and easy to update

- Publish them open source
- Complete benchmark
- Other stochastic inversion strategies

THANKS FOR YOUR ATTENTION

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