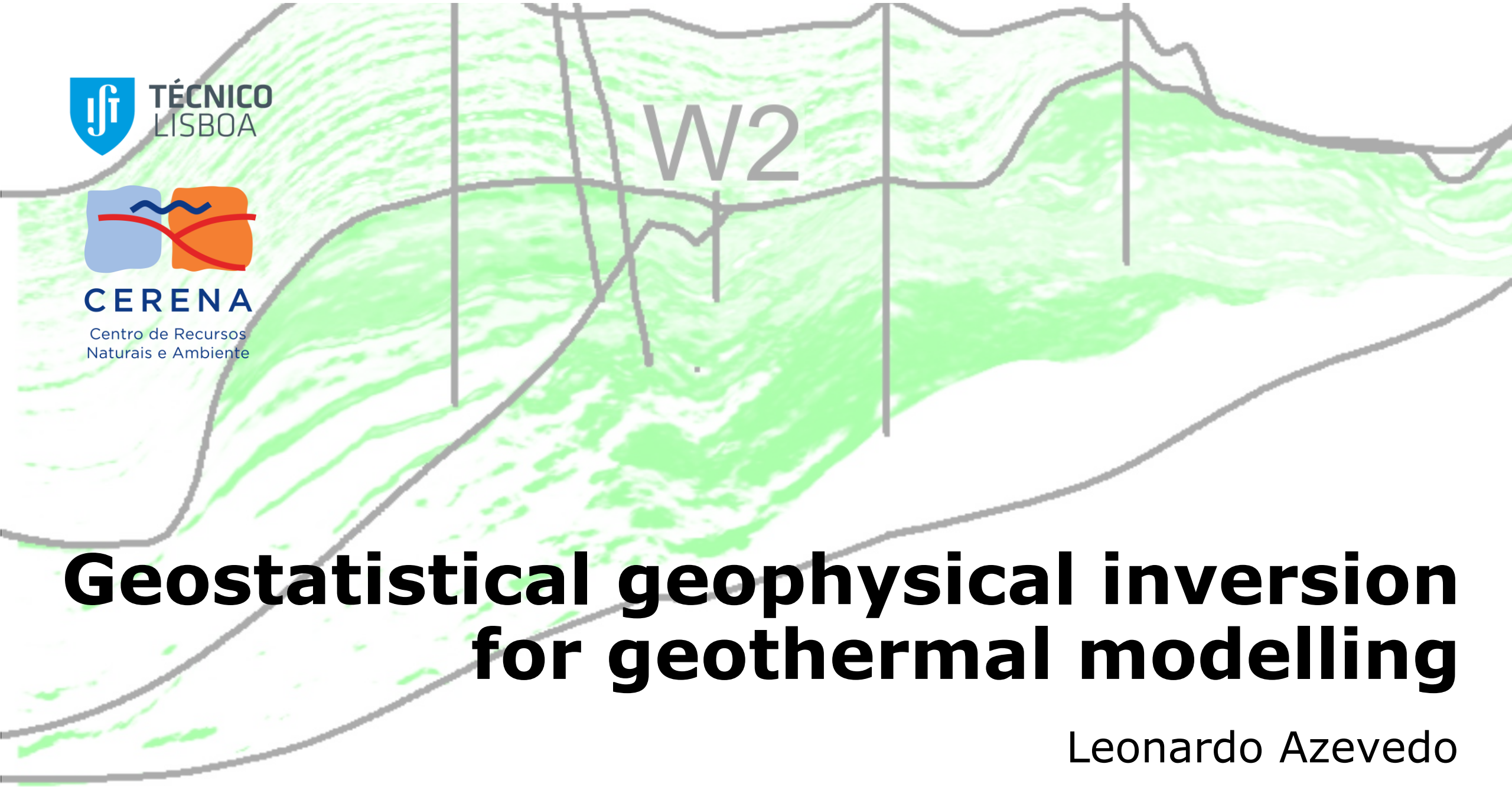


TÉCNICO LISBOA

CERENA
Centro de Recursos Naturais e Ambiente

Geostatistical geophysical inversion for geothermal modelling

Leonardo Azevedo

26 May. 2021

leonardo.azevedo@tecnico.ulisboa.pt

Introduction

- **Why subsurface modeling ?**

Understanding the spatial distribution

Development plans and behavior prediction

Central piece of information: *gateway for expertise and aggregating data*

- **What are critical issues ?**

Diversity of data, geological, geophysical and fluid flow parameters

Data with **different scale of information**, models with different resolution

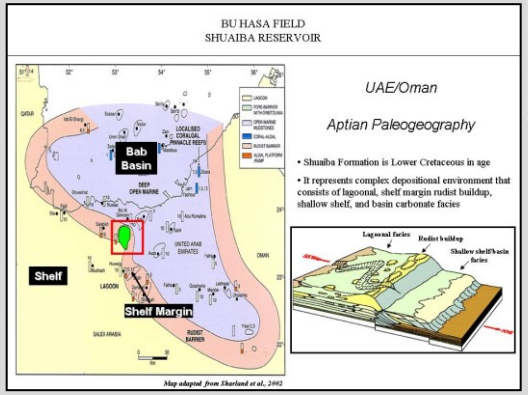
Hierarchy in model building

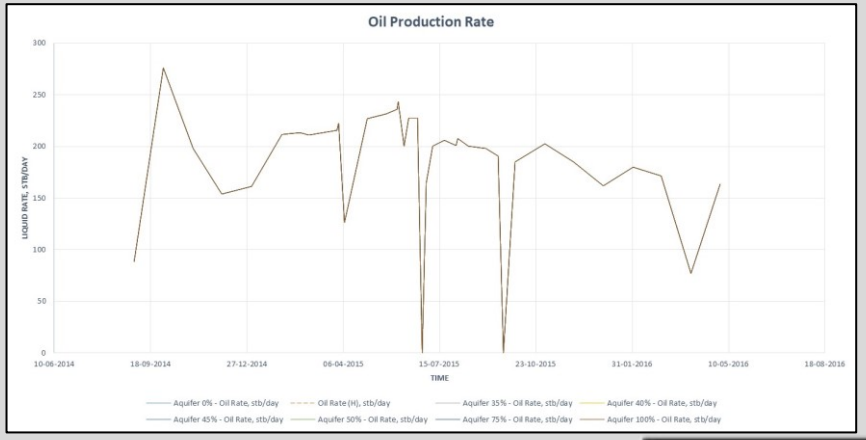
Subjectivity in model building, few ground truths

Uncertainty in all model and data aspects

Pyrcz and Deutsch 2004

Subsurface modelling

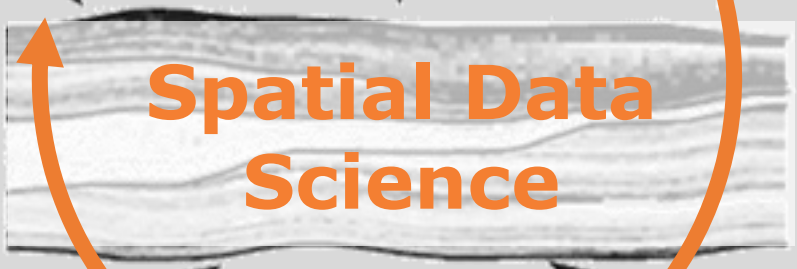




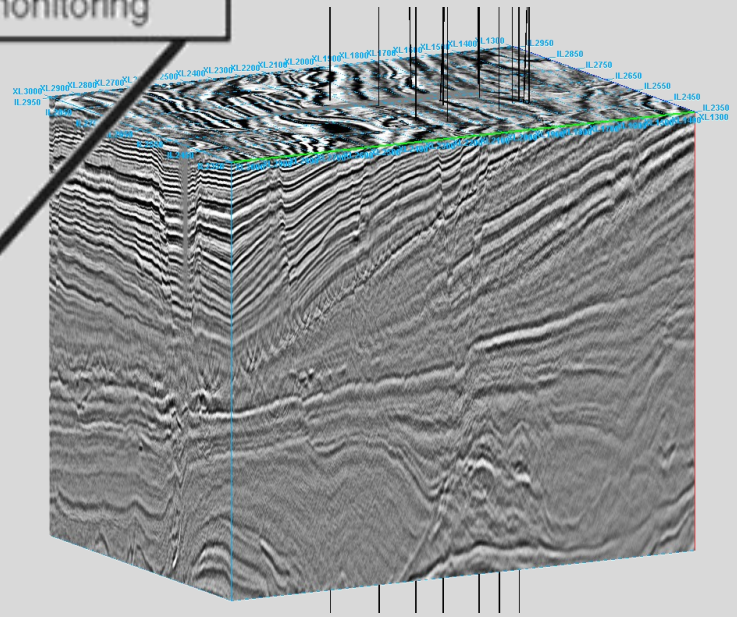
Conceptual Geological
- stratigraphic interpretations
- analogue fields/outcrops

Seismic
- surfaces/stratigraphy/fluids
- attributes for porosity, facies
- 4-D seismic for monitoring

Well Logs and Core
- surface locations
- lithofacies/geologic data
- porosity/permeability



Spatial Data Science



Engineering Data
- DST/RFT data
- pressure transient/tracer
- historical Q,P,C data

Forward Sediment Modeling
- stacking patterns
- geometric data for facies
- spatial information for ϕ/K

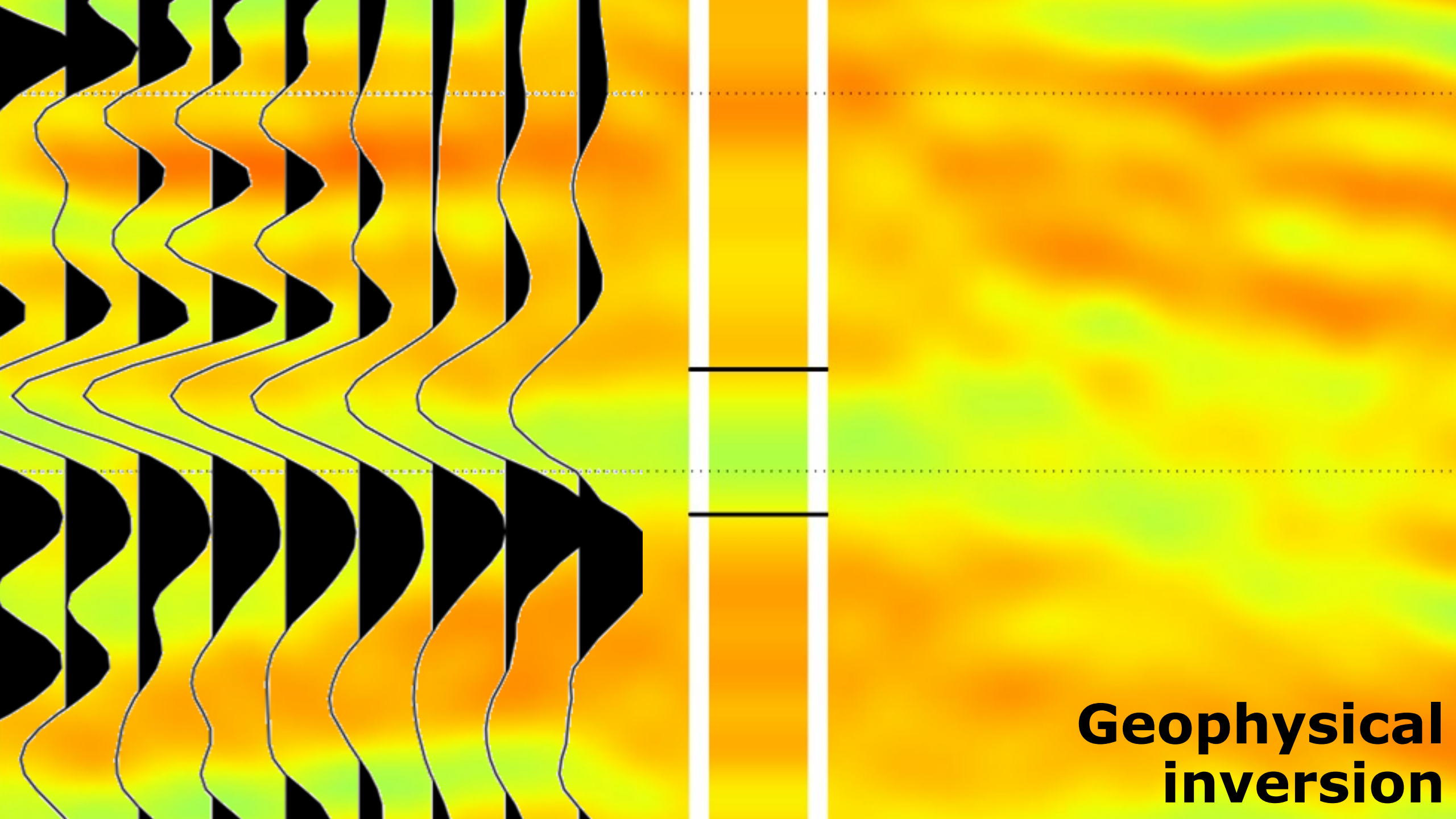
Pyrcz and Deutsch 2004

Geophysical subsurface characterization

- Using **quantitative interpretation** of seismic/geophysical data to characterize the earth's internal properties

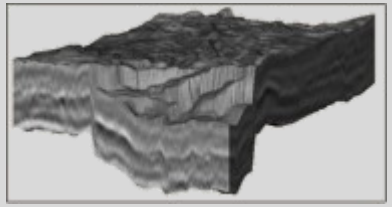
- Create **probability maps** of rock and fluid properties: *facies* + *fluids*

- Build **quantitative earth models** constrained to geophysical interpretation and honoring spatial geologic continuity: ***geological plausibility***

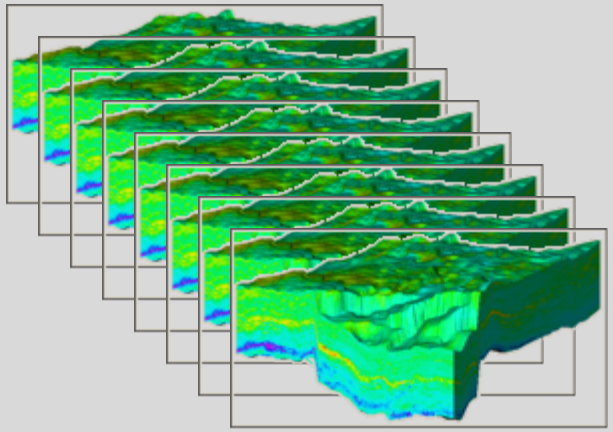


Geophysical inversion

$\boldsymbol{d_{obs}}$ Geophysical data



$\boldsymbol{m}$ Rock properties



$$\boldsymbol{m} = \overset{???}{F^{-1}}(\boldsymbol{d_{obs}}) + \boldsymbol{e}$$

Geostatistical geophysical inversion

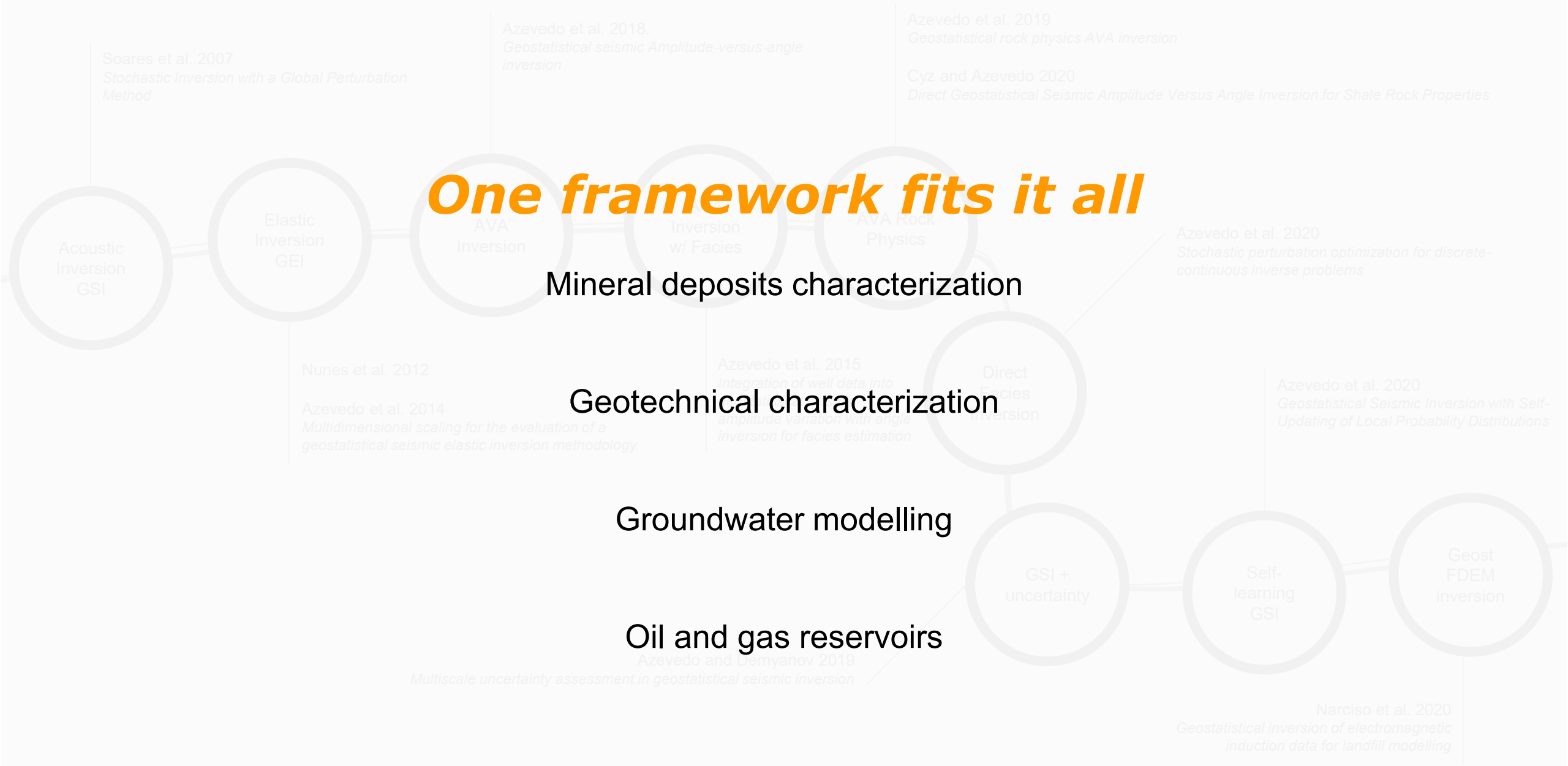
One framework fits it all

1) Consistent framework for acoustic/elastic/rock properties.

2) Global perturbation with *Direct Sequential Simulation* (all flavours)

3) Stochastic global optimizer based on local mismatches between simulated and observed data

Geostatistical geophysical inversion



One framework fits it all

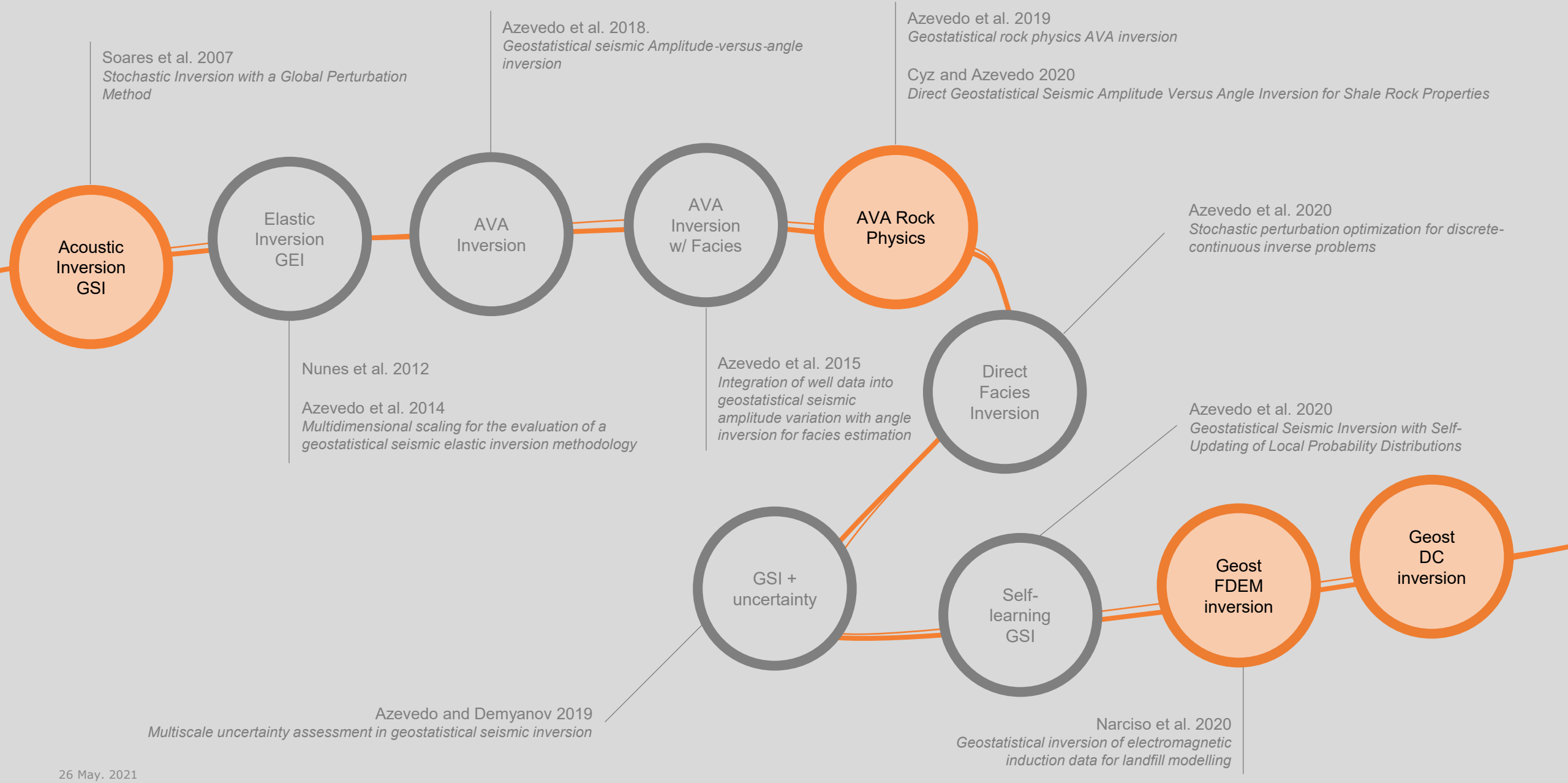
Mineral deposits characterization

Geotechnical characterization

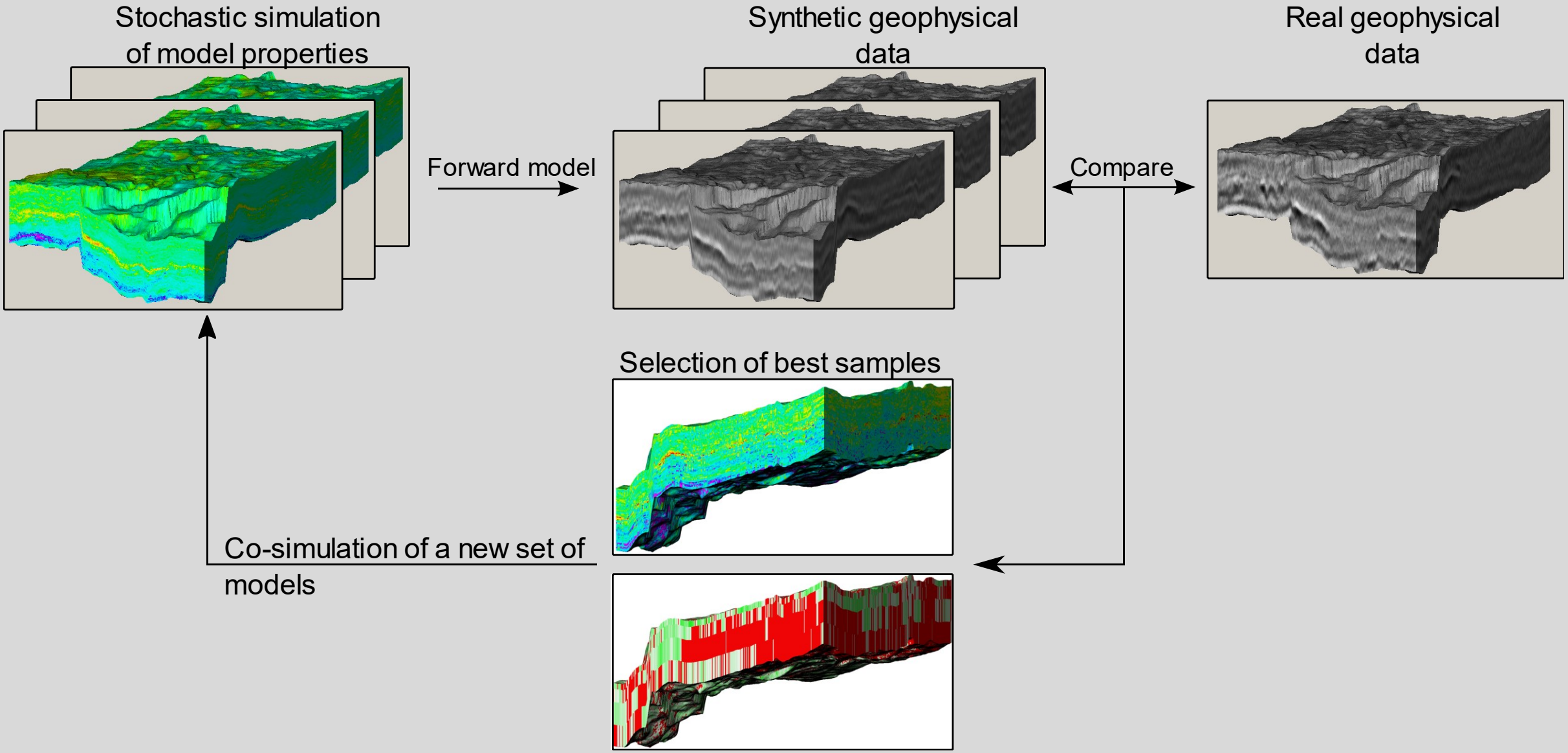
Groundwater modelling

Oil and gas reservoirs

One framework fits it all



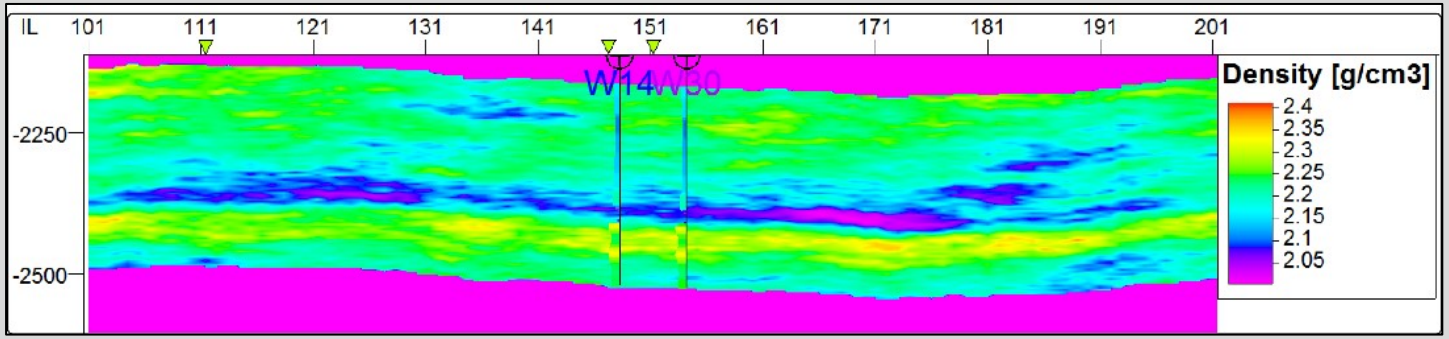
Geostatistical seismic inversion

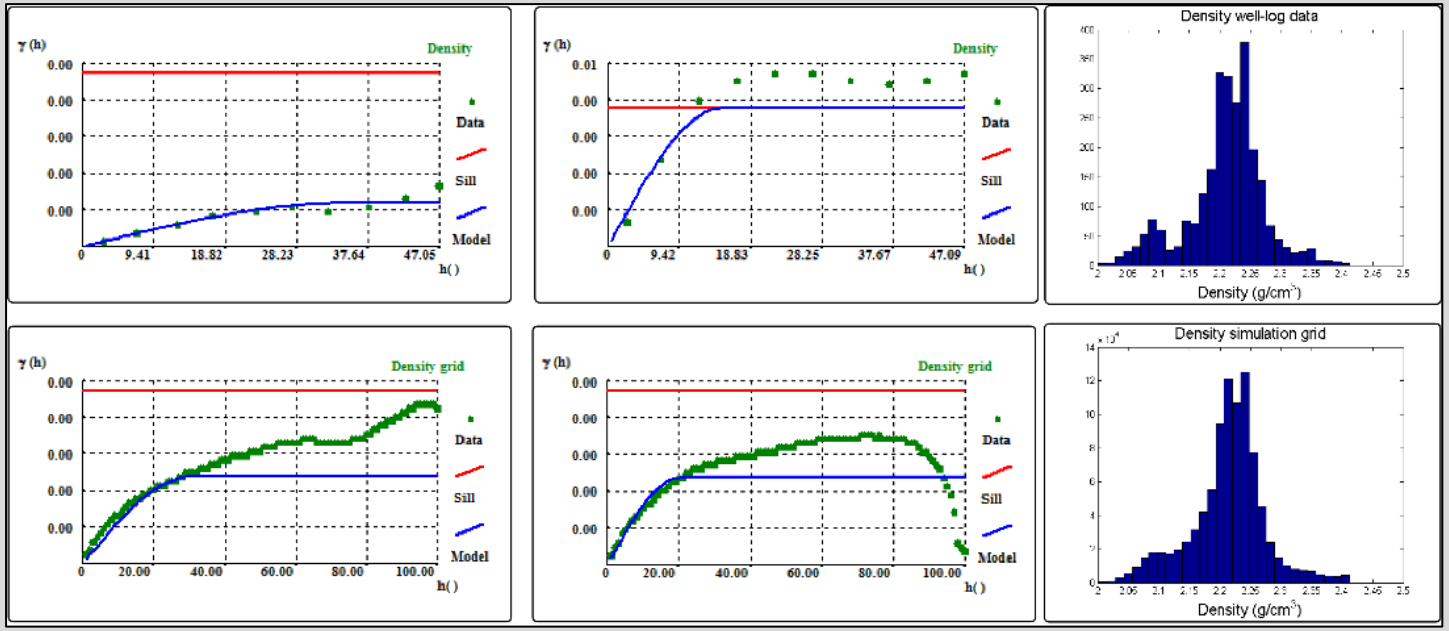


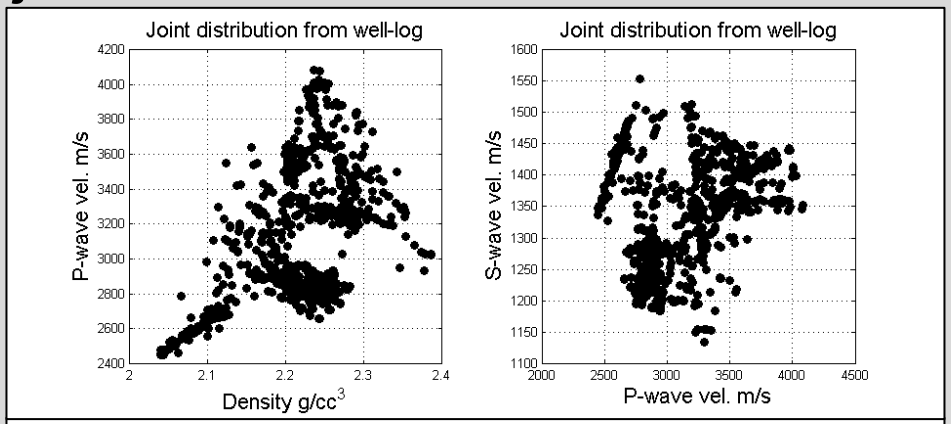
Azevedo & Soares. Geostatistical methods for reservoir geophysics. 2017

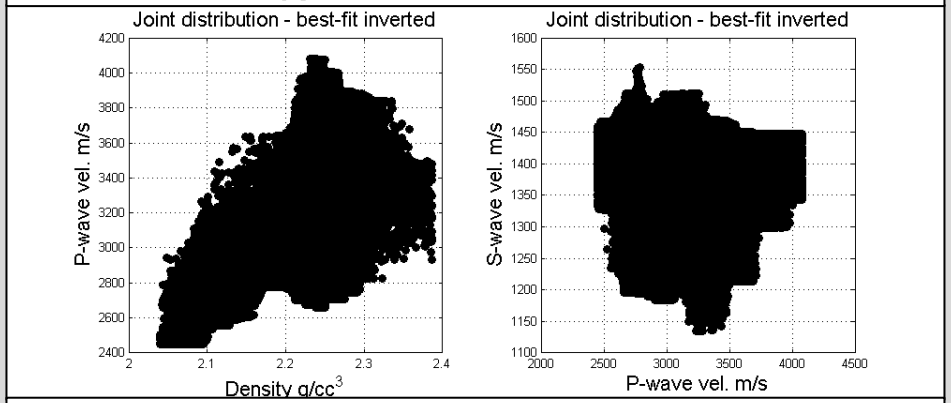
Key features

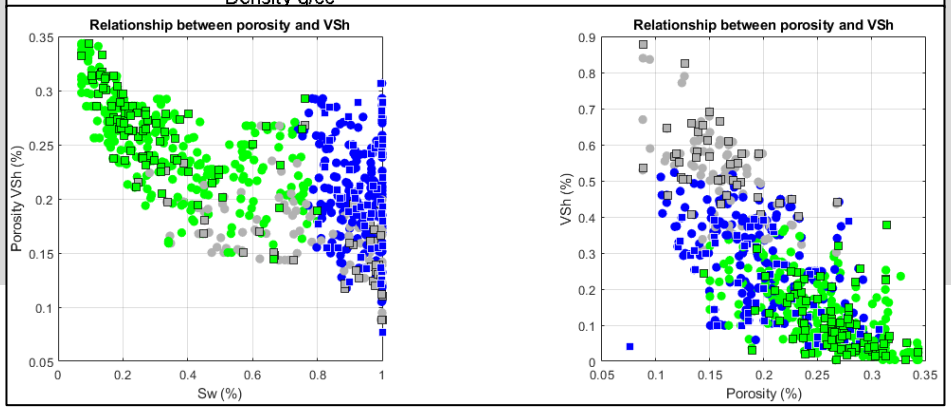
Reproduction of well data, variogram, marginal and joint distributions





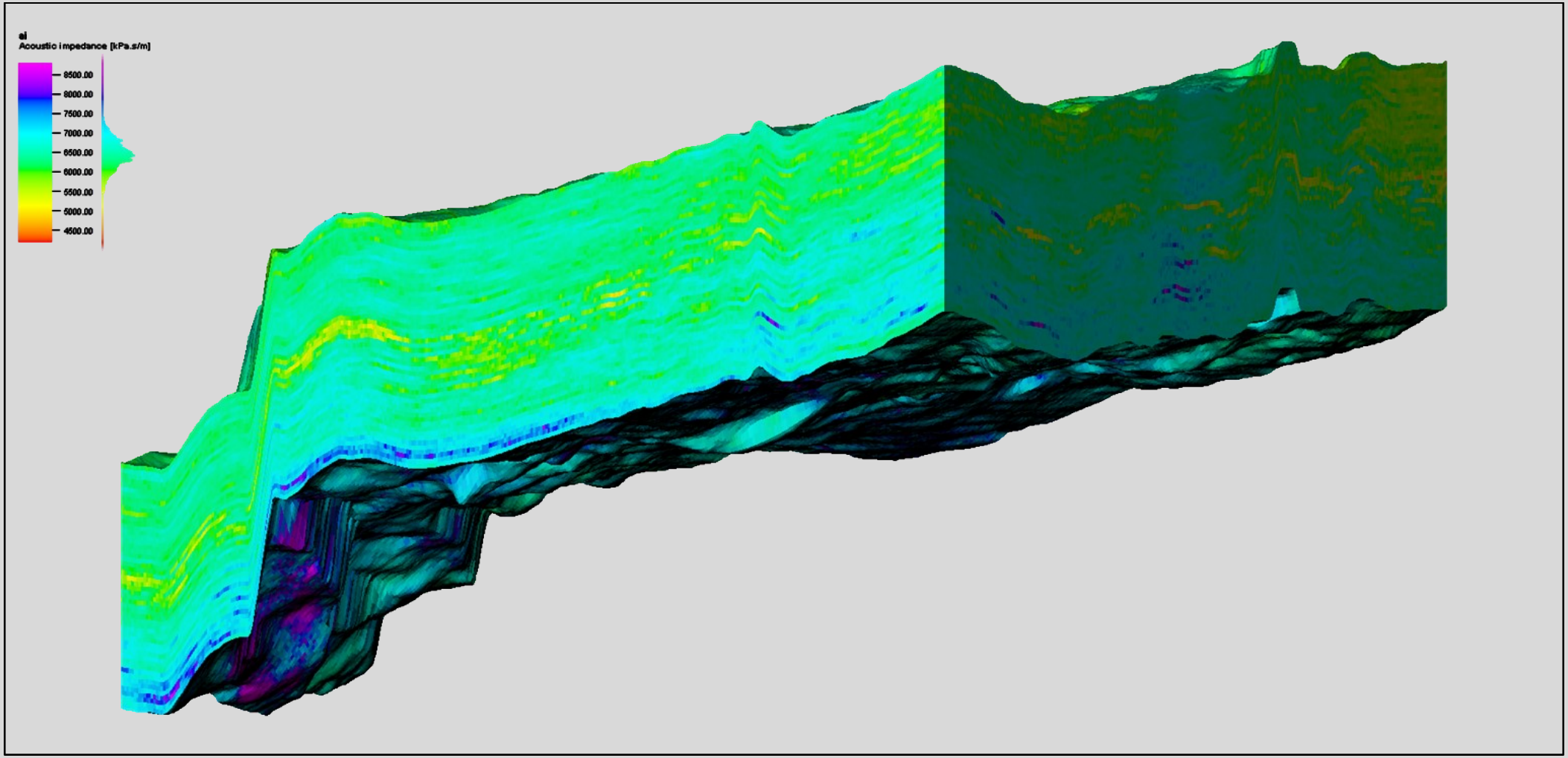






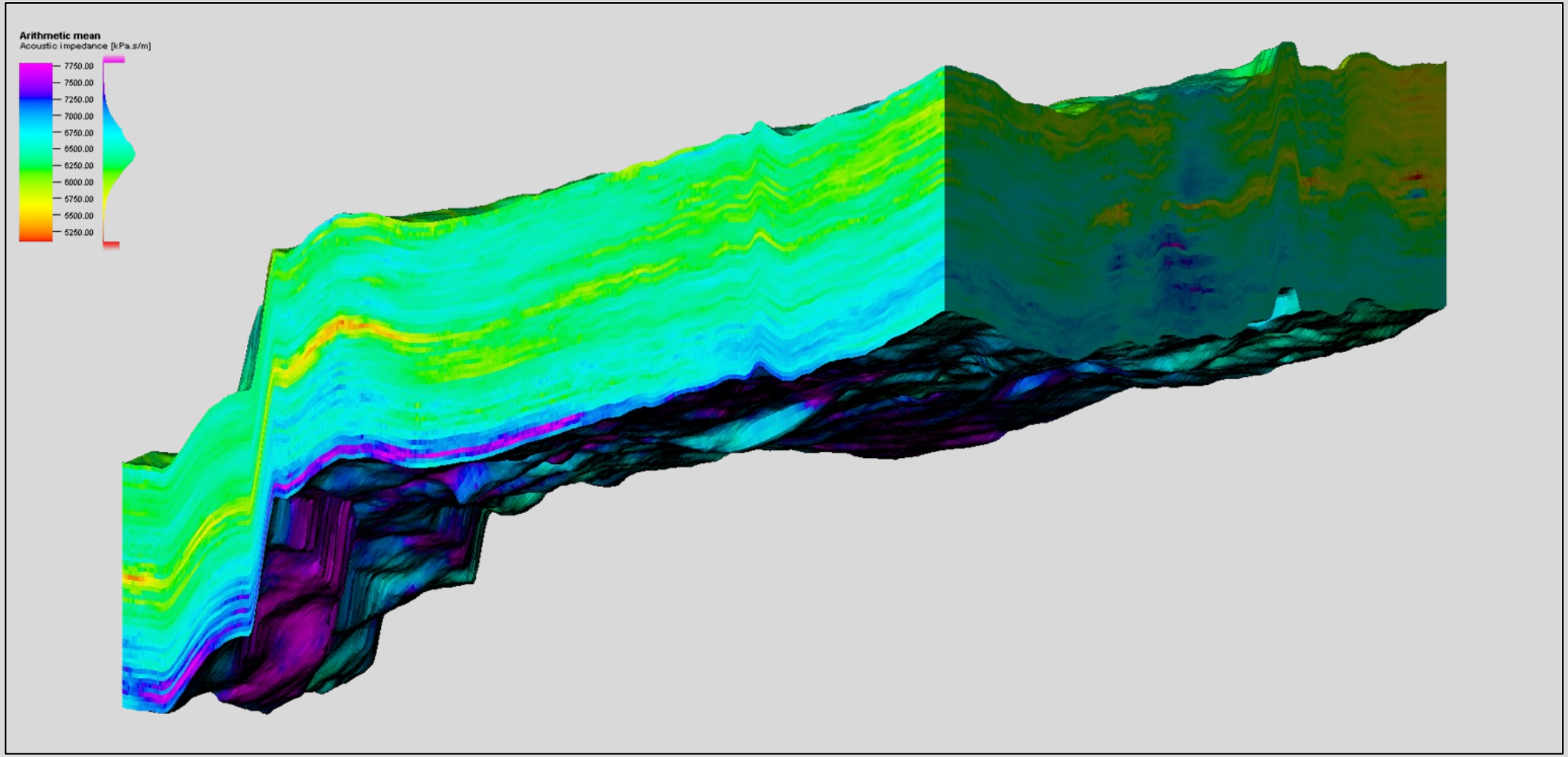
Global Stochastic Inversion (GSI)

- Realizations of Ip from last iteration



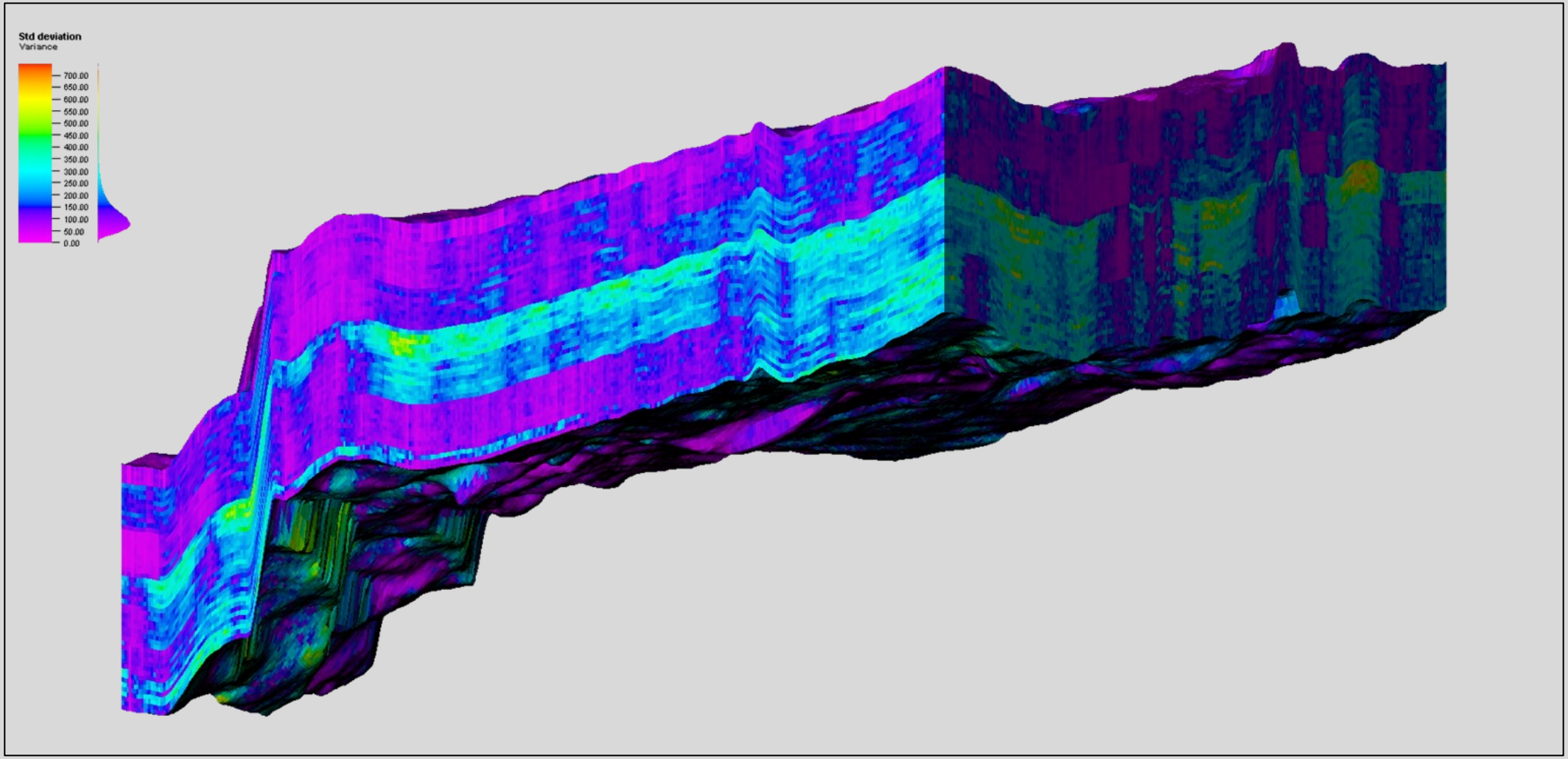
Global Stochastic Inversion (GSI)

- Mean from realizations of last iteration



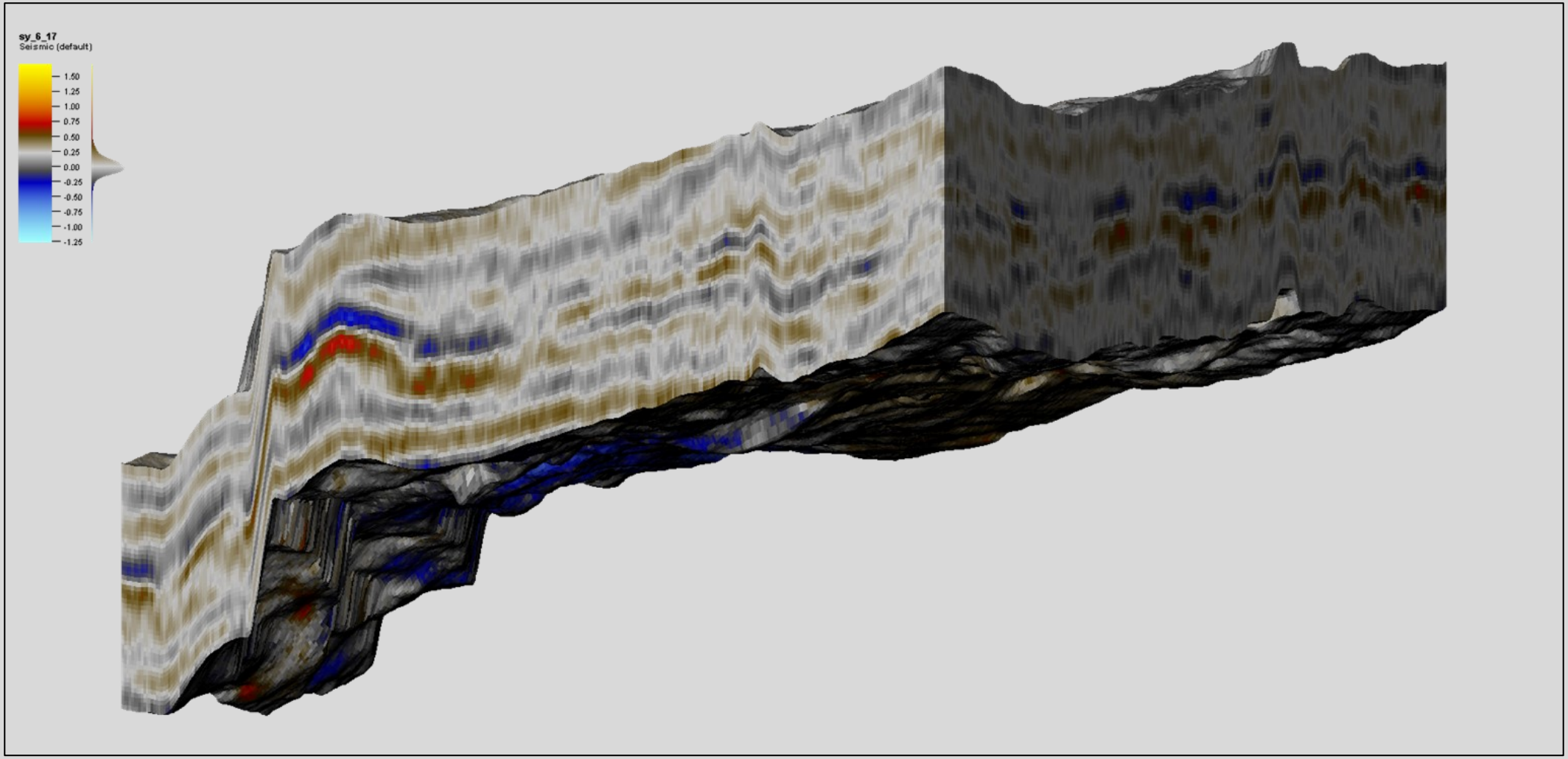
Global Stochastic Inversion (GSI)

- Variance from last iteration seismic

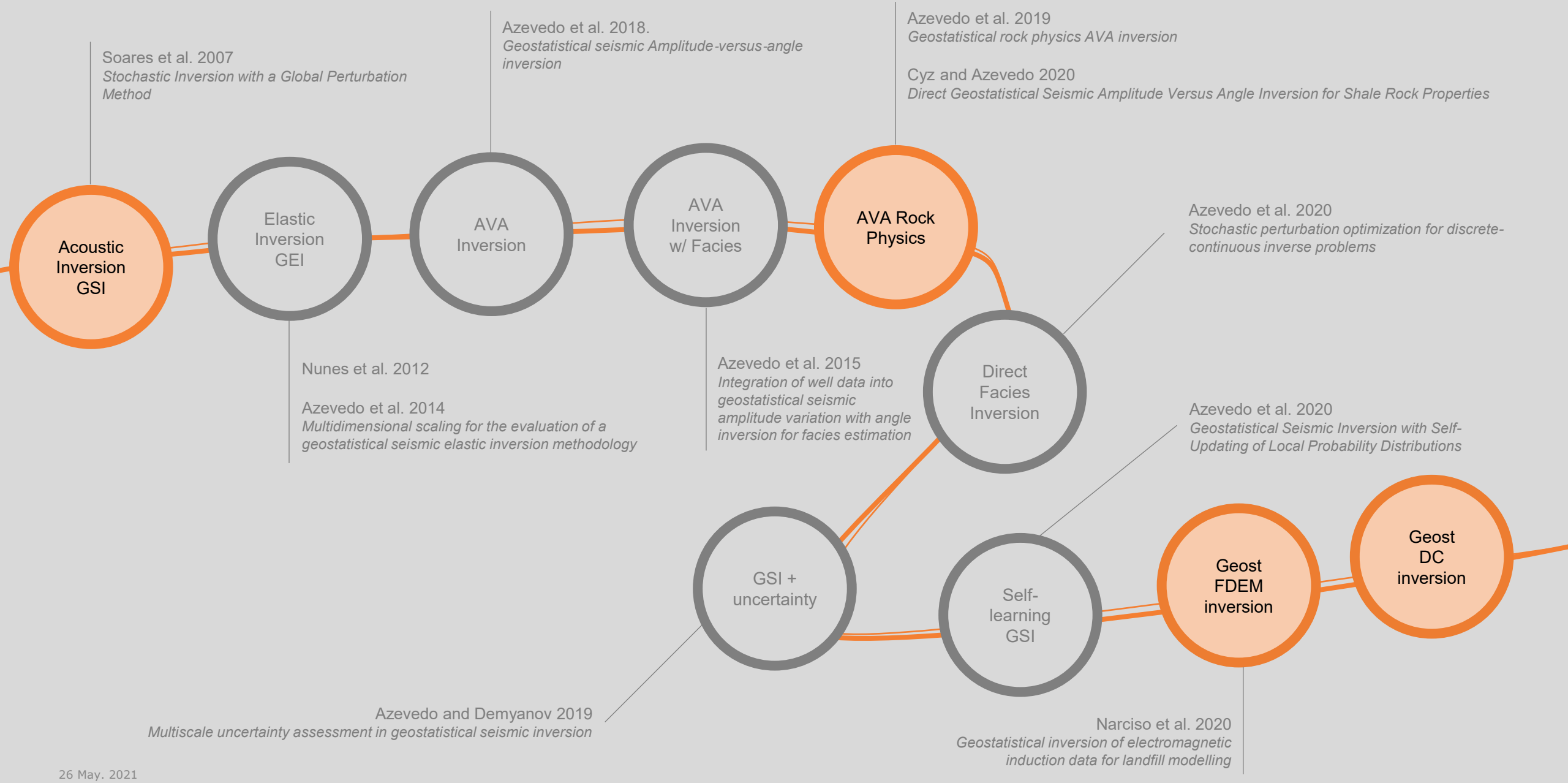


Global Stochastic Inversion (GSI)

- Best-fit synthetic seismic

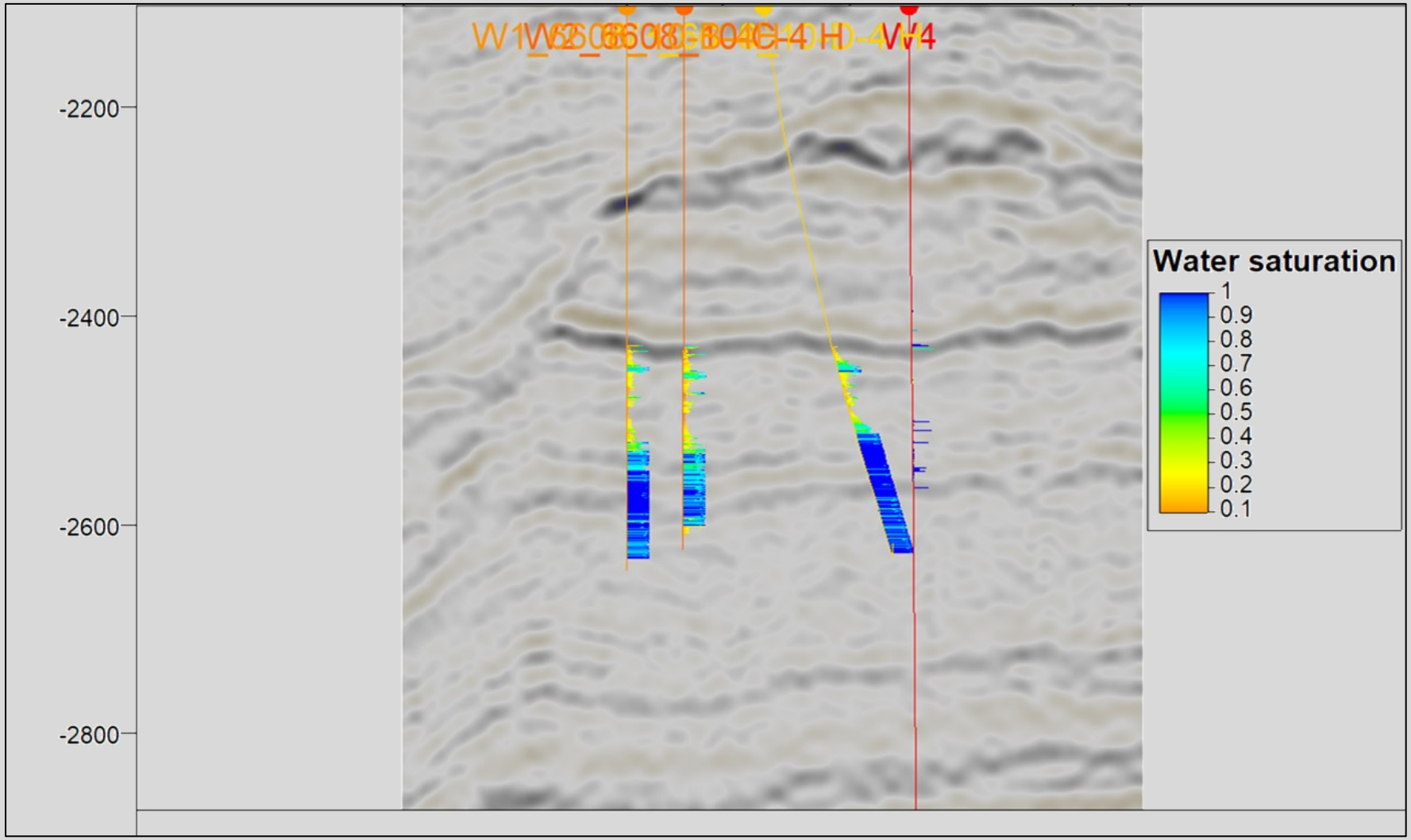


One framework fits it all



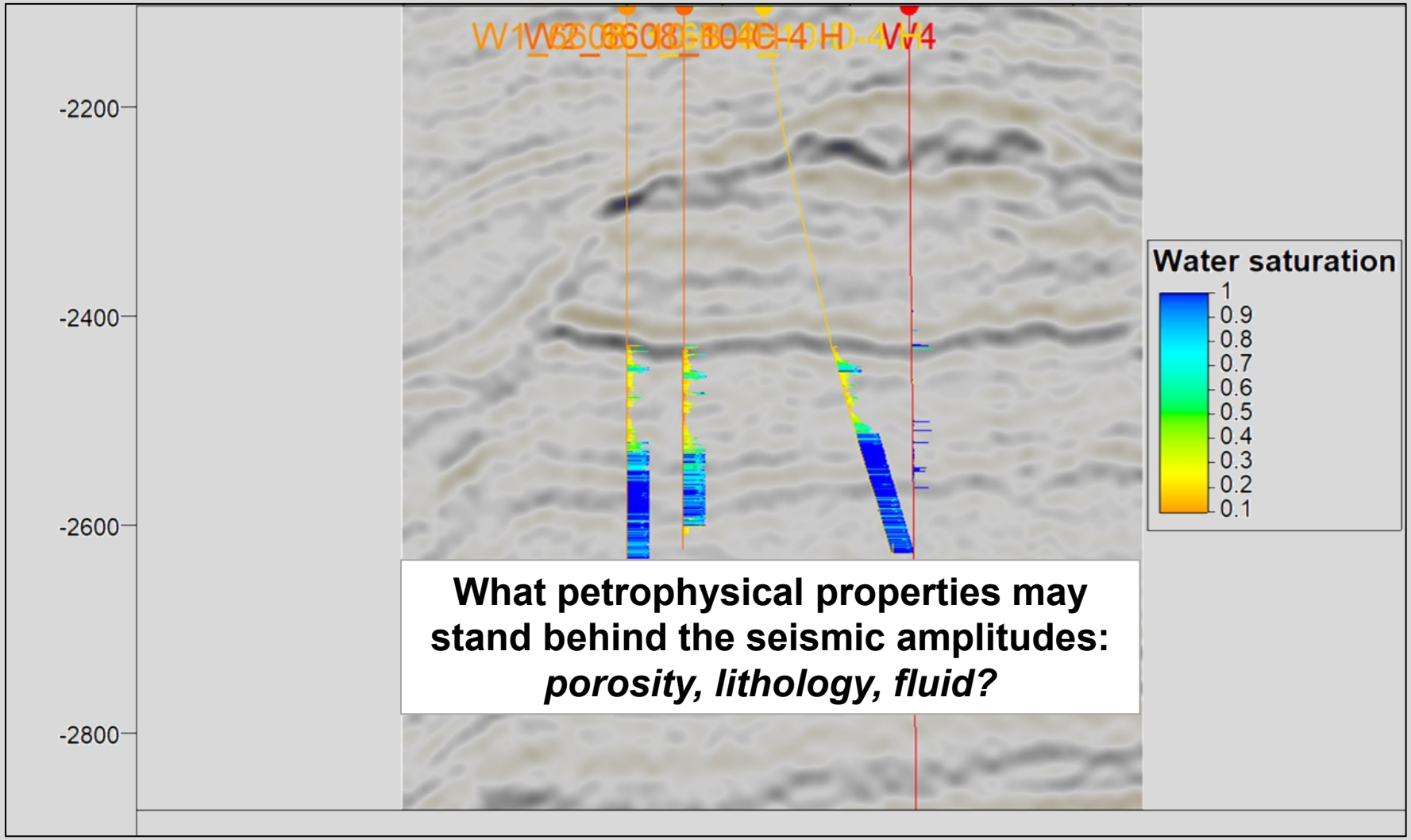
How to model the spatial distribution of rock properties?

Porosity
Fluid saturations
Volume of minerals
Pressure



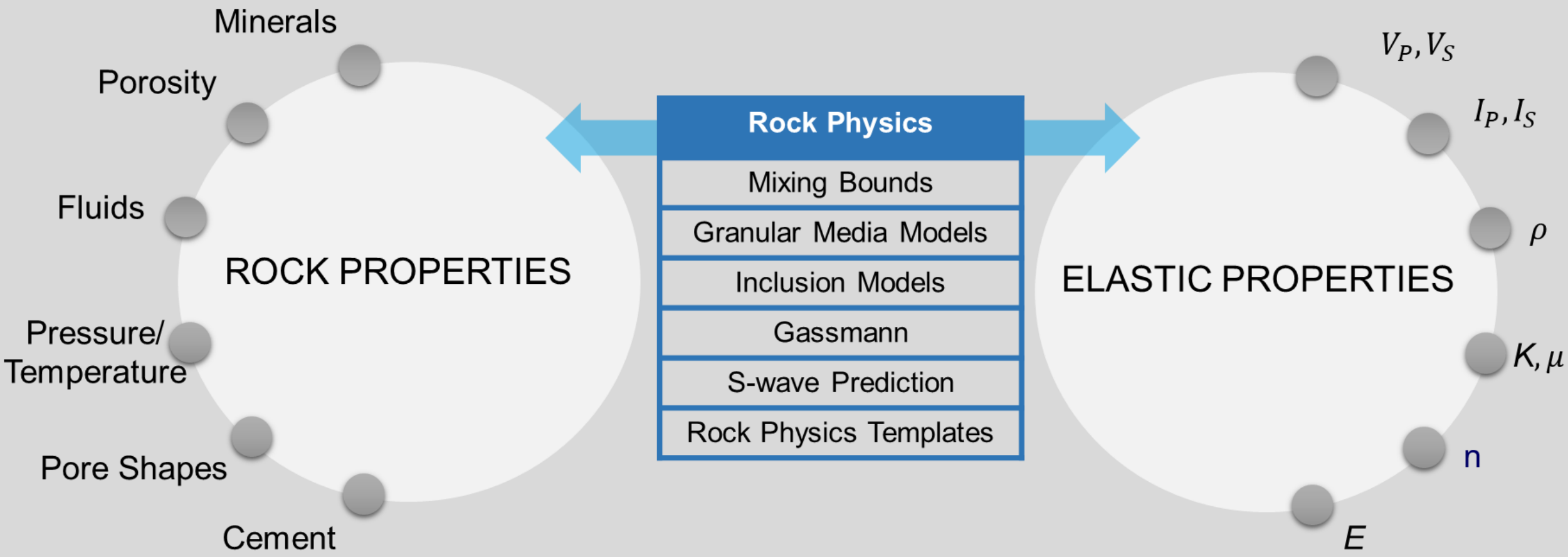
How to model the spatial distribution of rock properties?

Porosity
Fluid saturations
Volume of minerals
Pressure

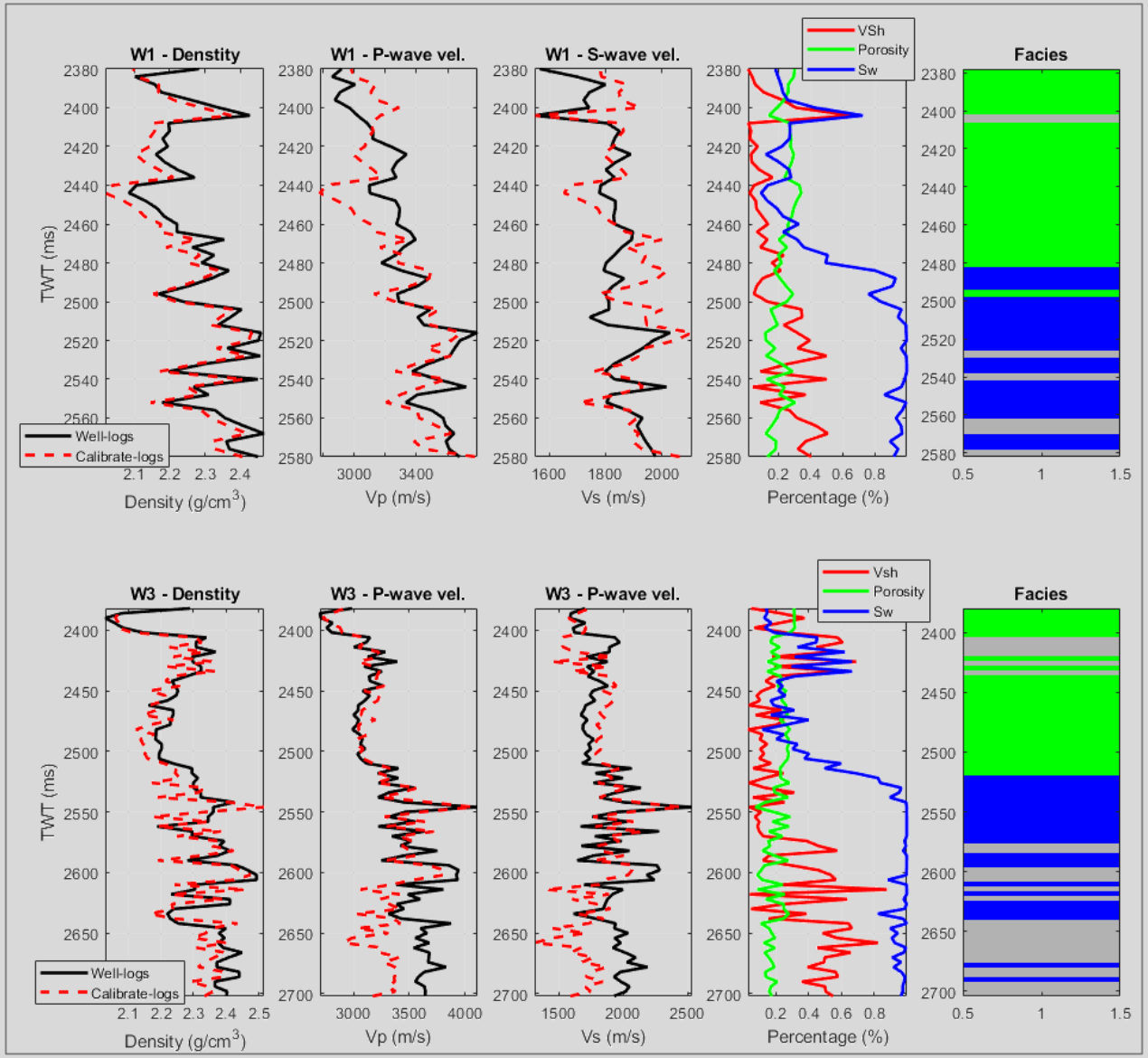


What petrophysical properties may stand behind the seismic amplitudes: *porosity, lithology, fluid?*

Introduction: *rock physics modelling*

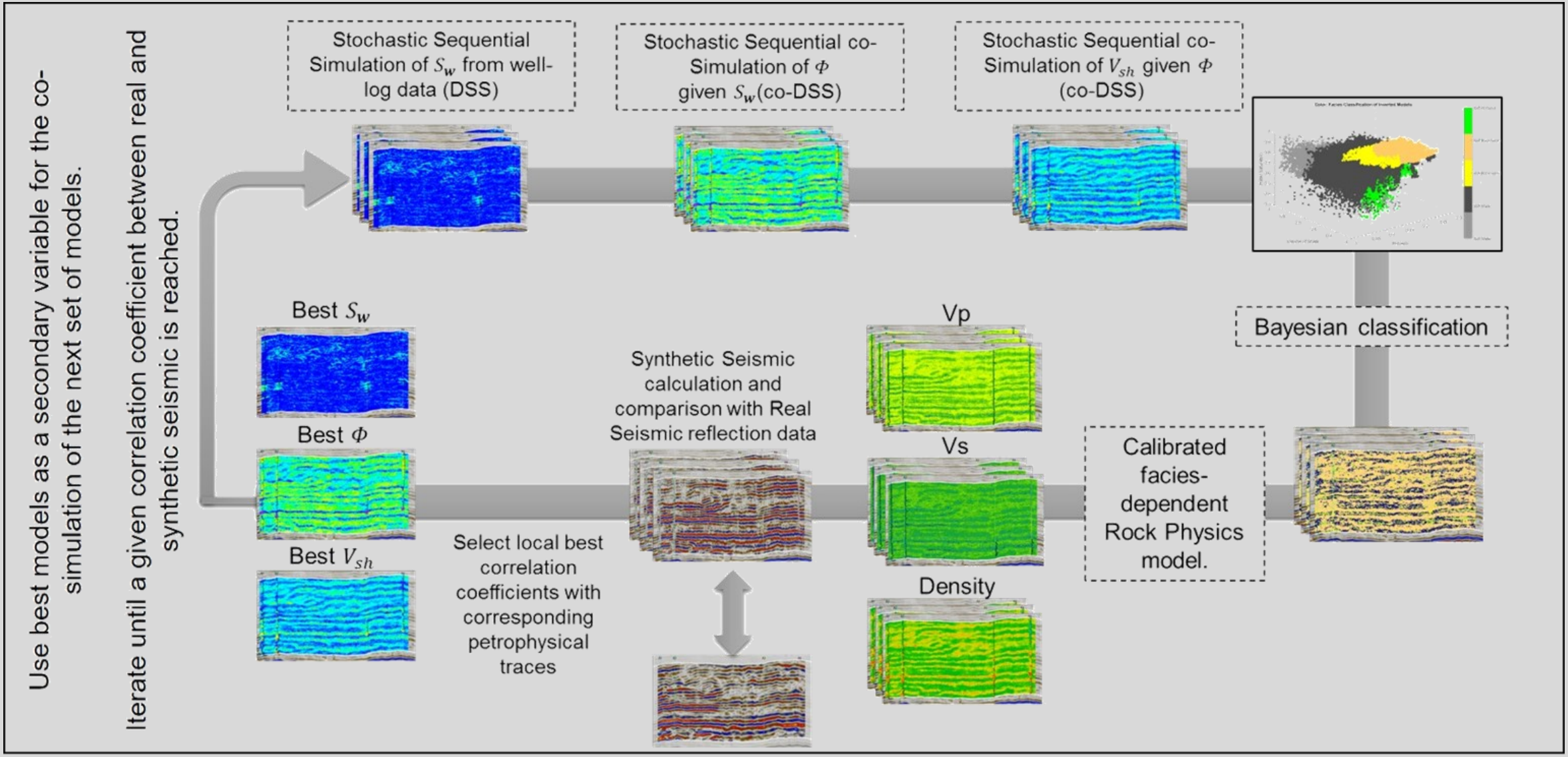


Calibration at the well



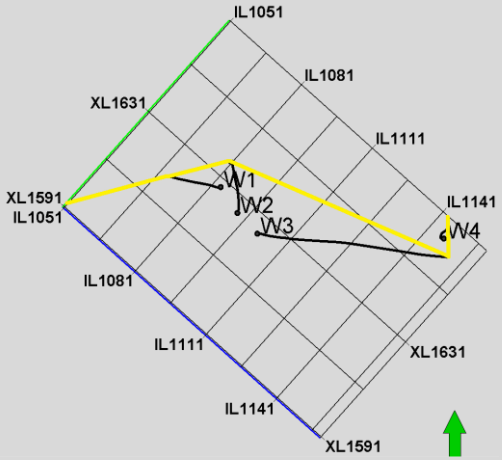
Azevedo, Grana, Amaro. Geostatistical rock physics AVA inversion 2018

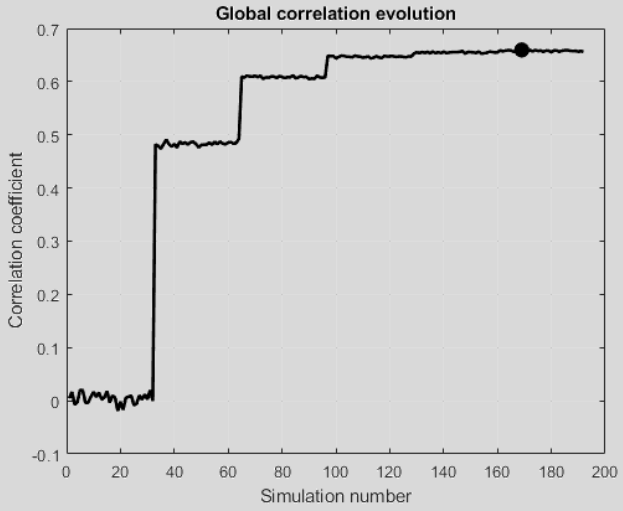
Geostats. seismic rock physics inversion



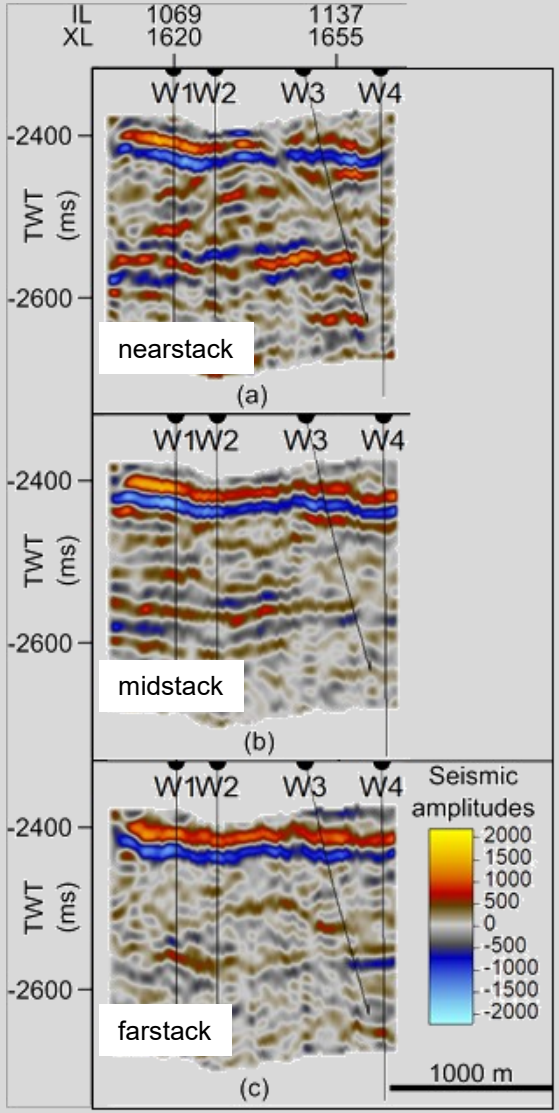
Azevedo, Grana, Amaro. Geostatistical rock physics AVA inversion 2018

Real case application example

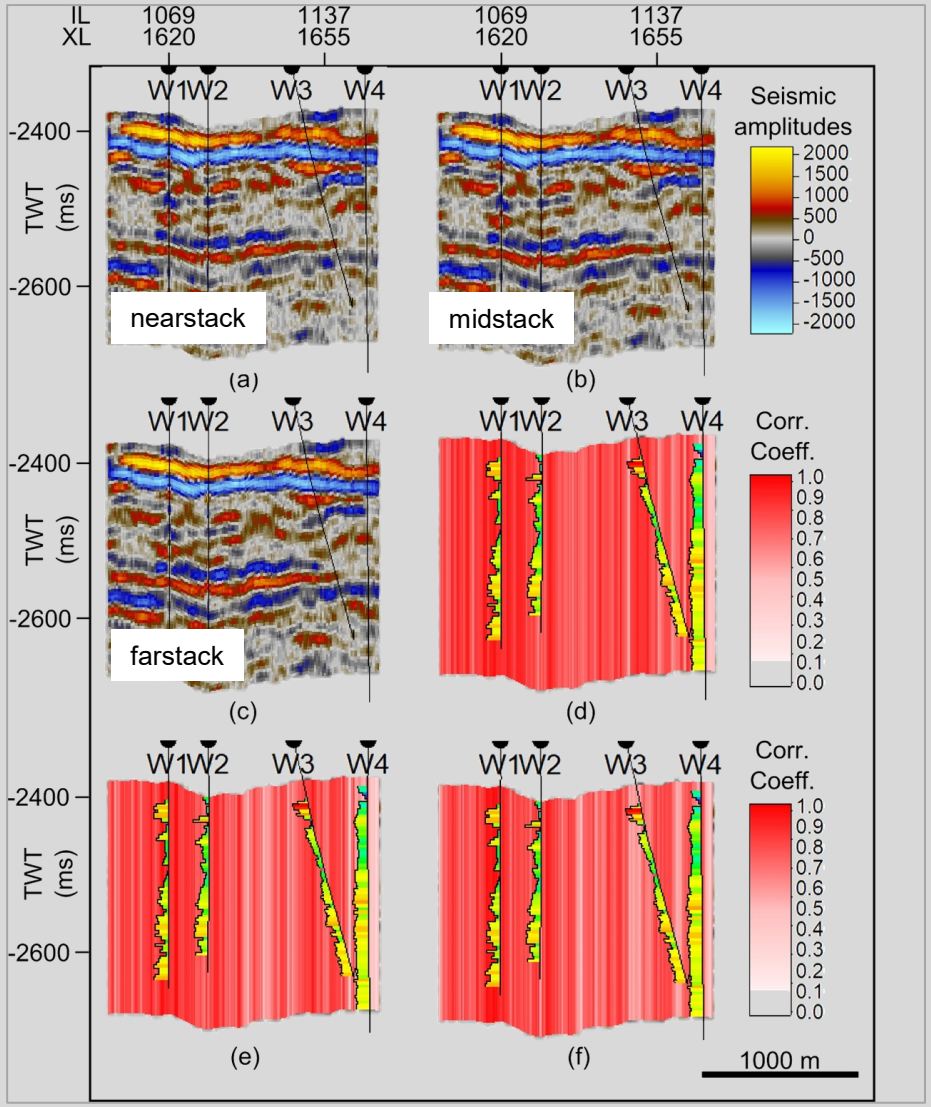




True Data

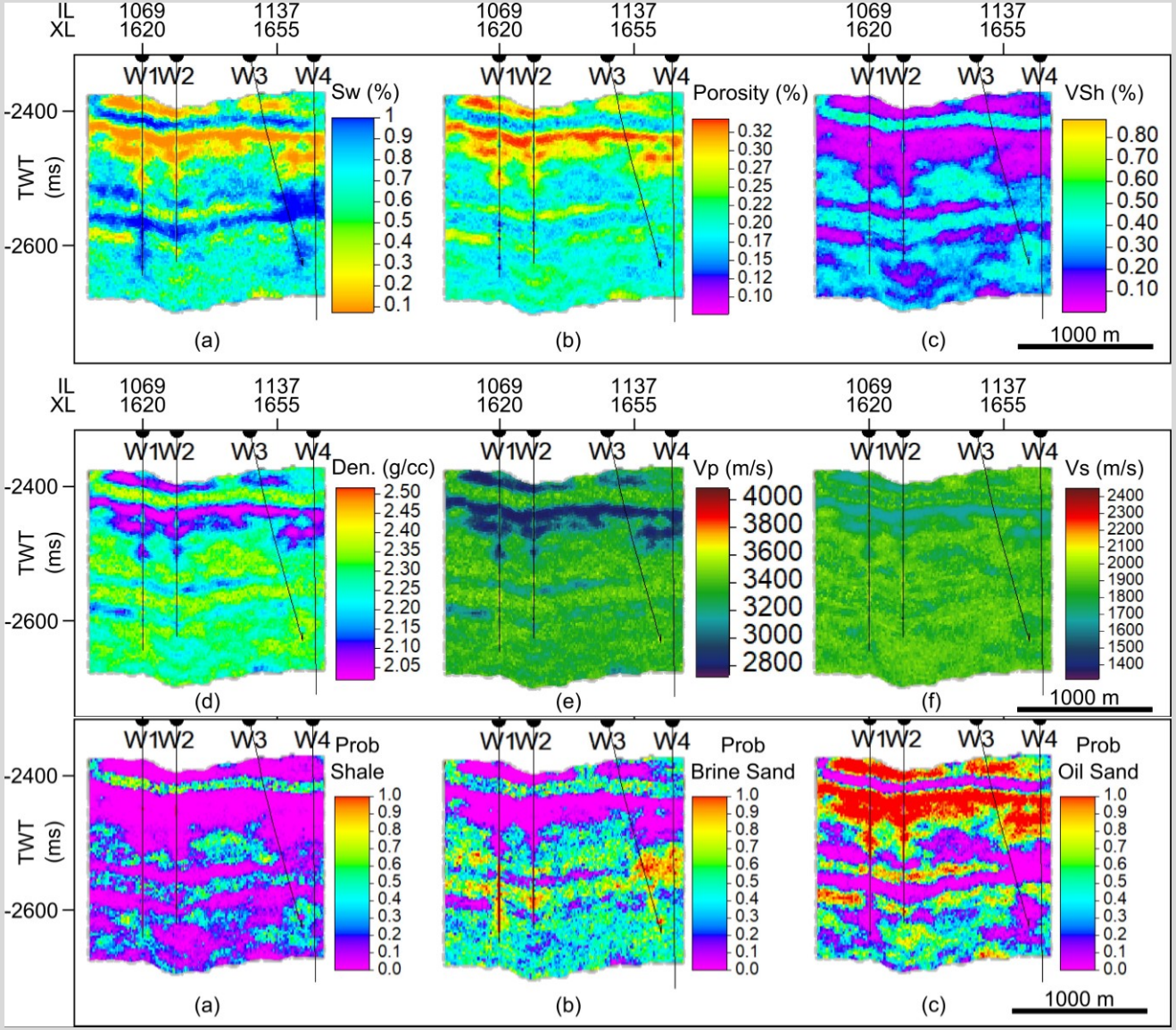


Predicted Data



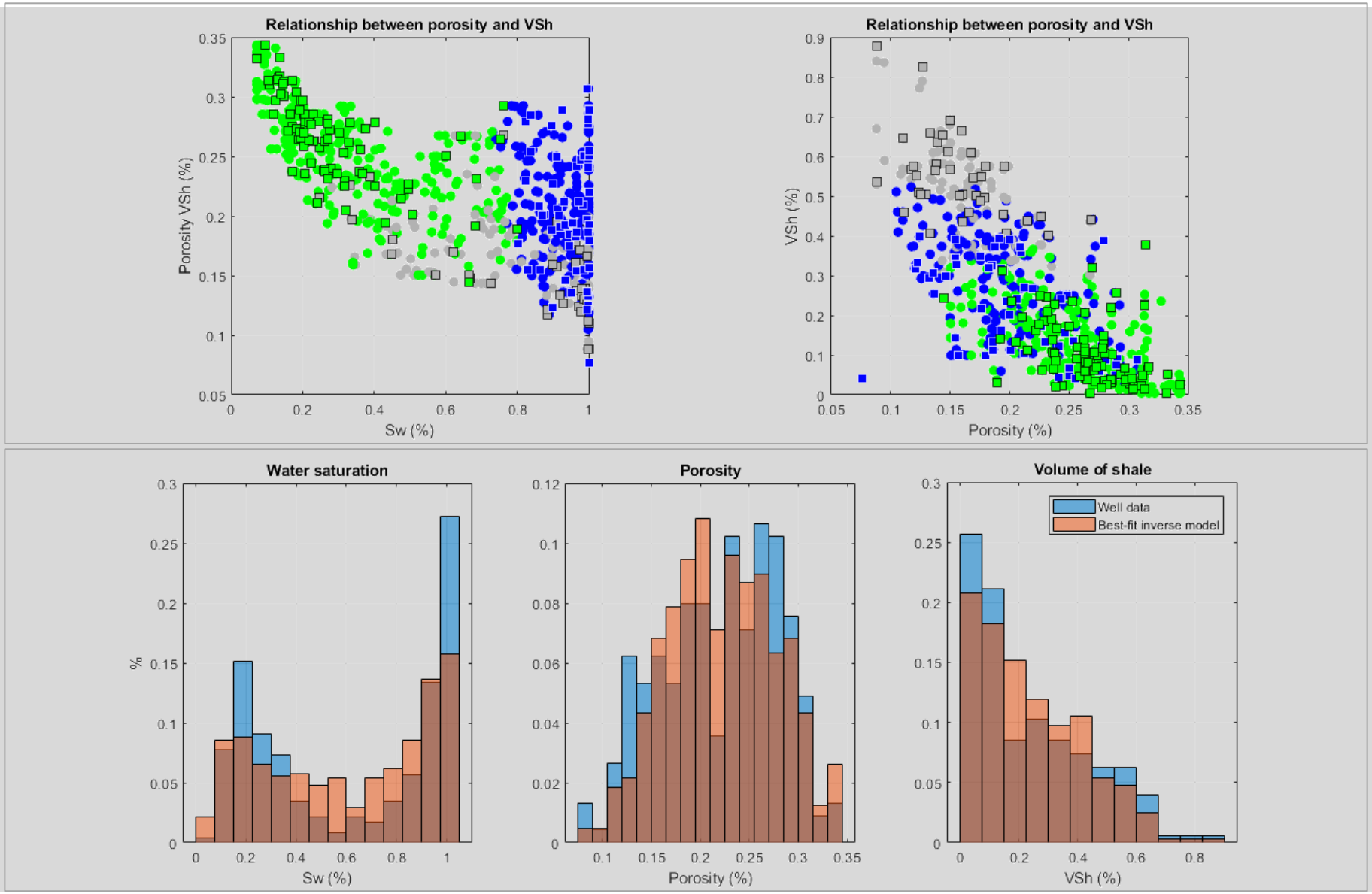
Azevedo, Grana, Amaro. Geostatistical rock physics AVA inversion 2018

Inverted petro-elastic models



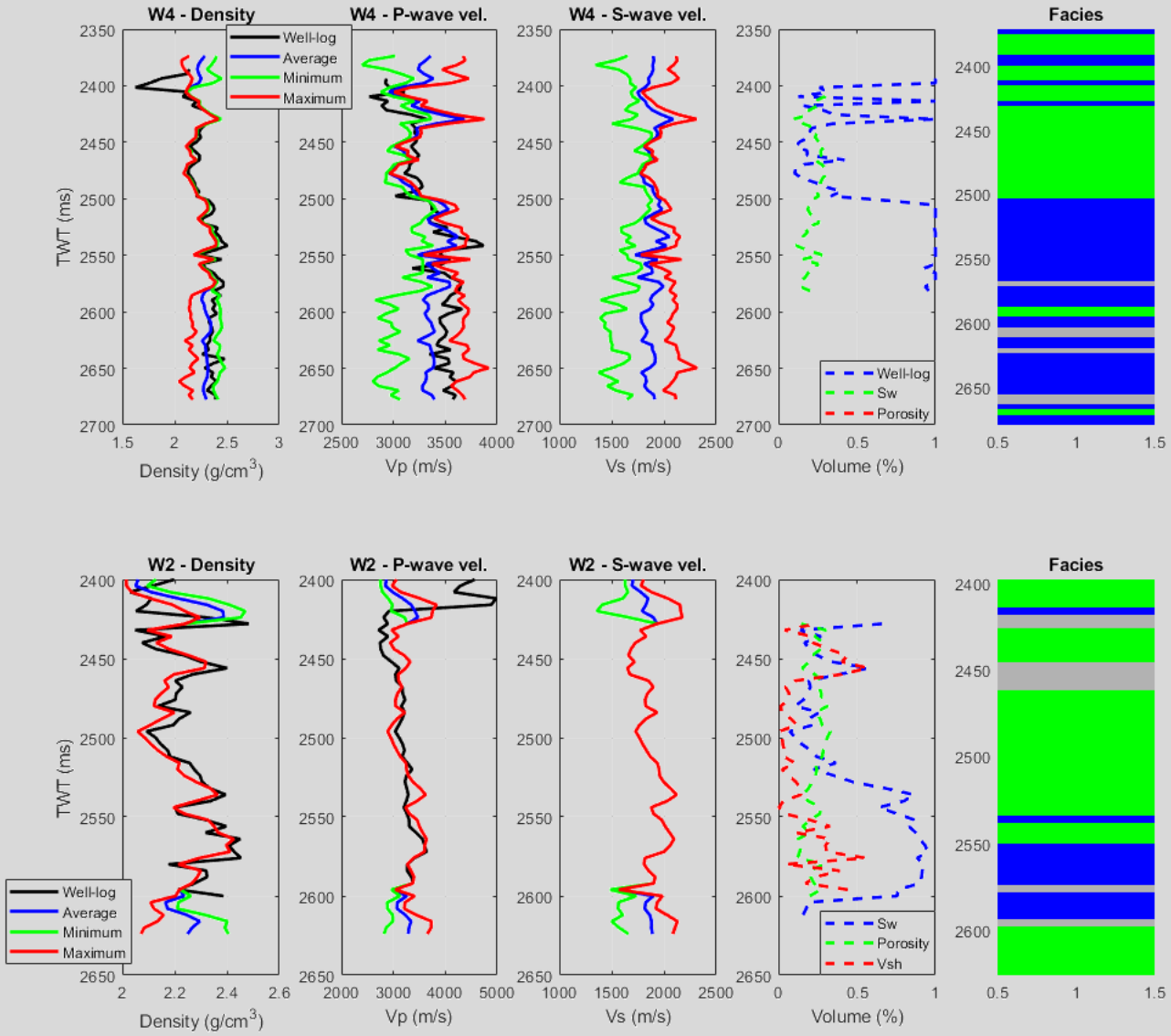
Azevedo, Grana, Amaro. Geostatistical rock physics AVA inversion 2018

Relationship reproduction



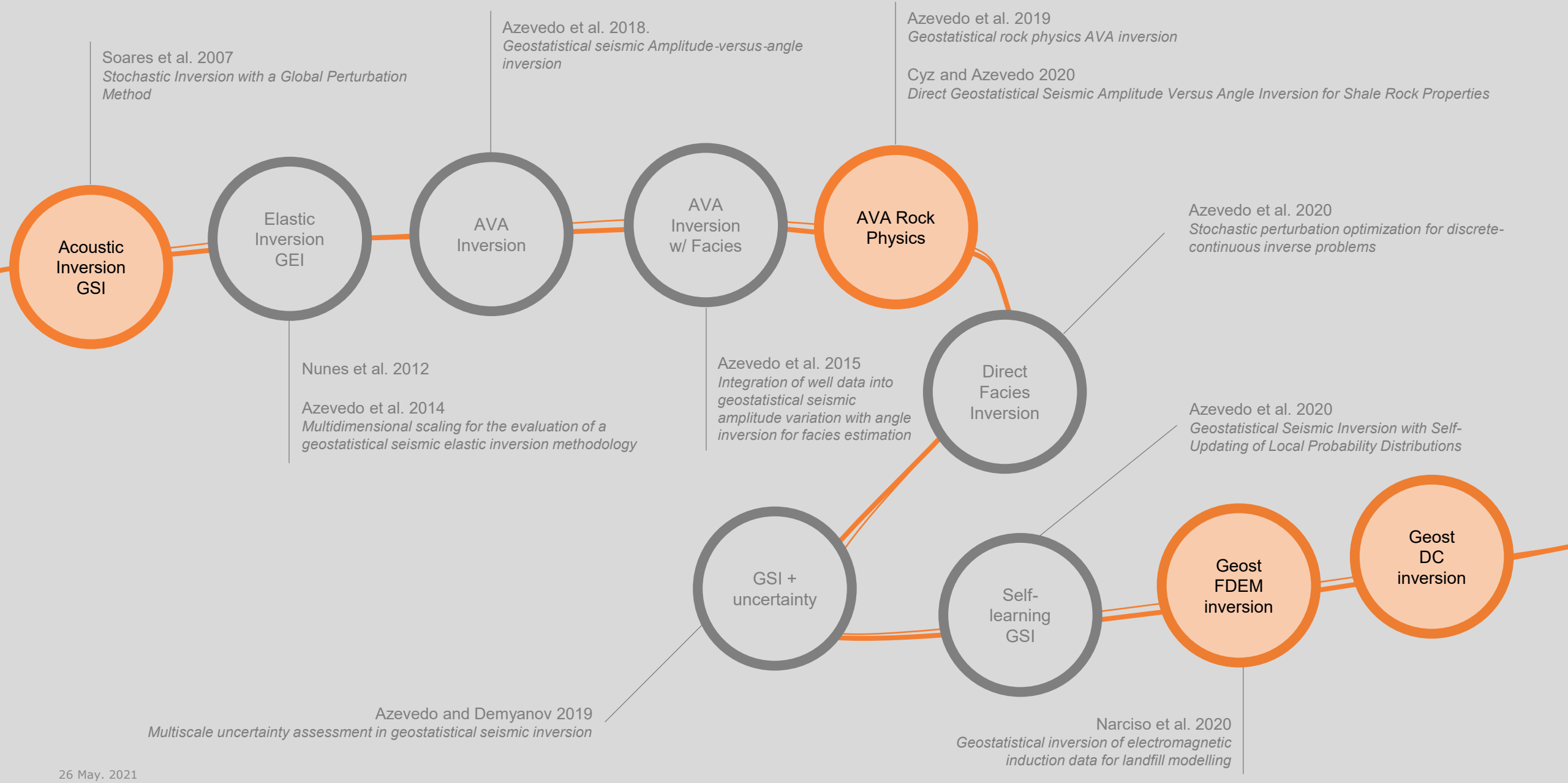
Azevedo, Grana, Amaro. Geostatistical rock physics AVA inversion 2018

Blind well assessment

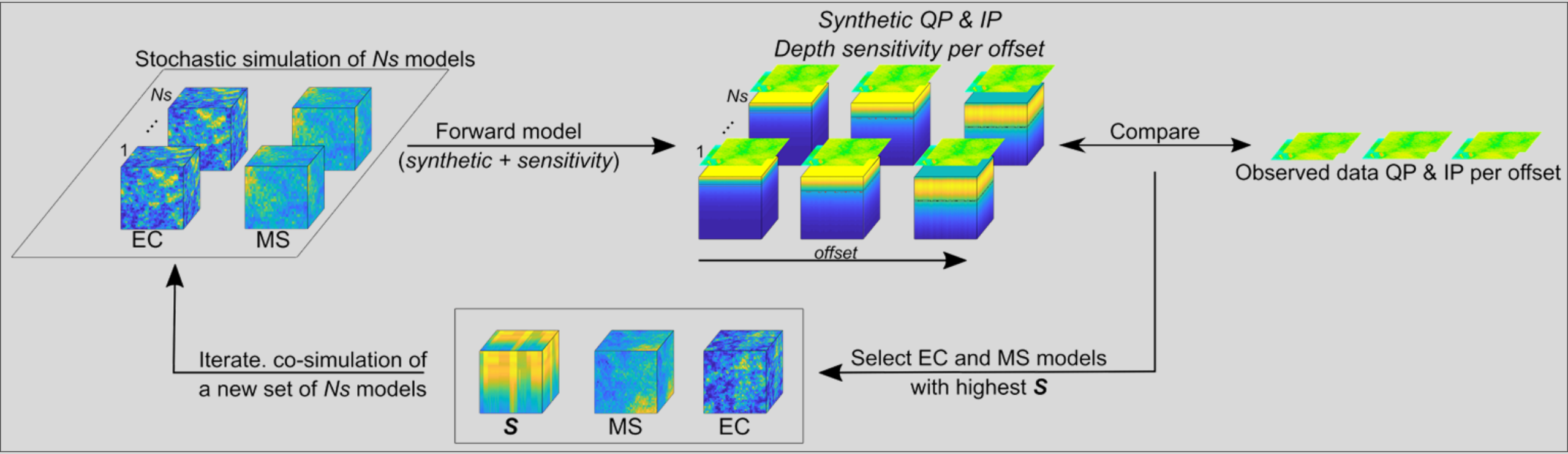


Azevedo, Grana, Amaro. Geostatistical rock physics AVA inversion 2018

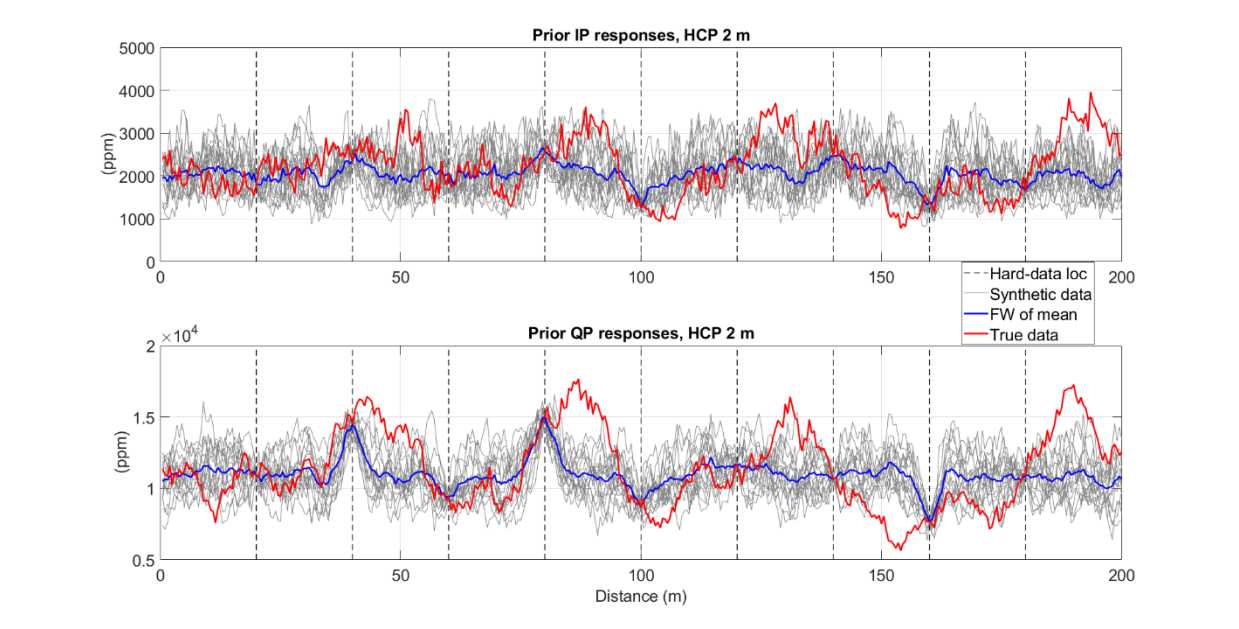
One framework fits it all

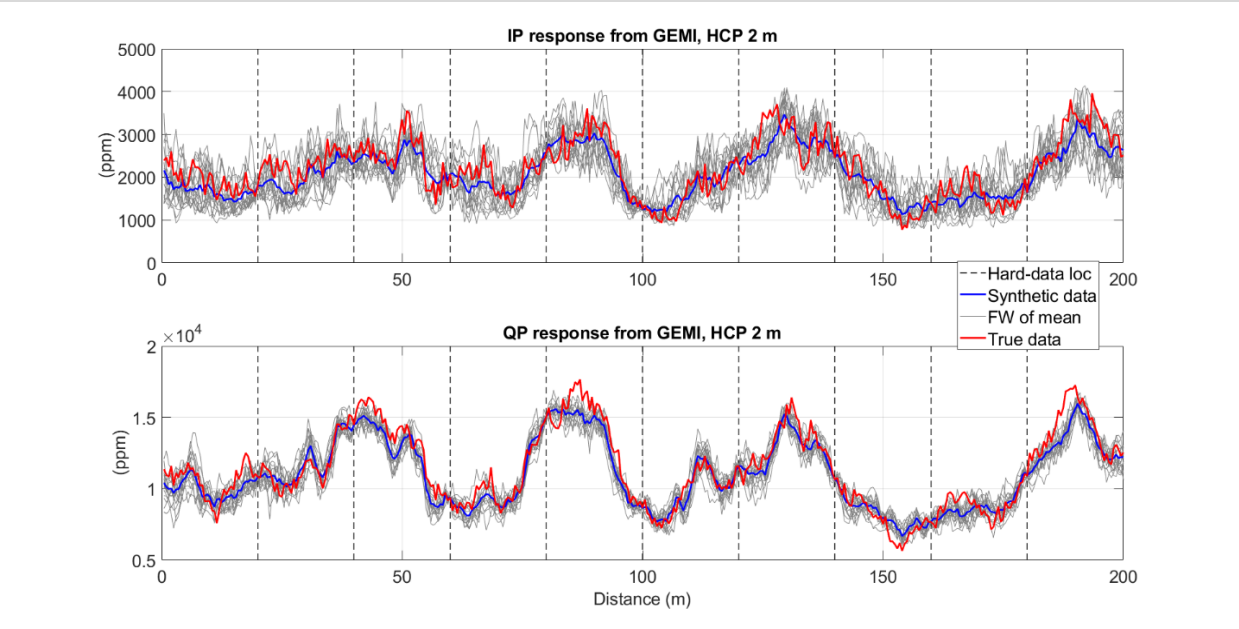


Geostatistical FDEM inversion



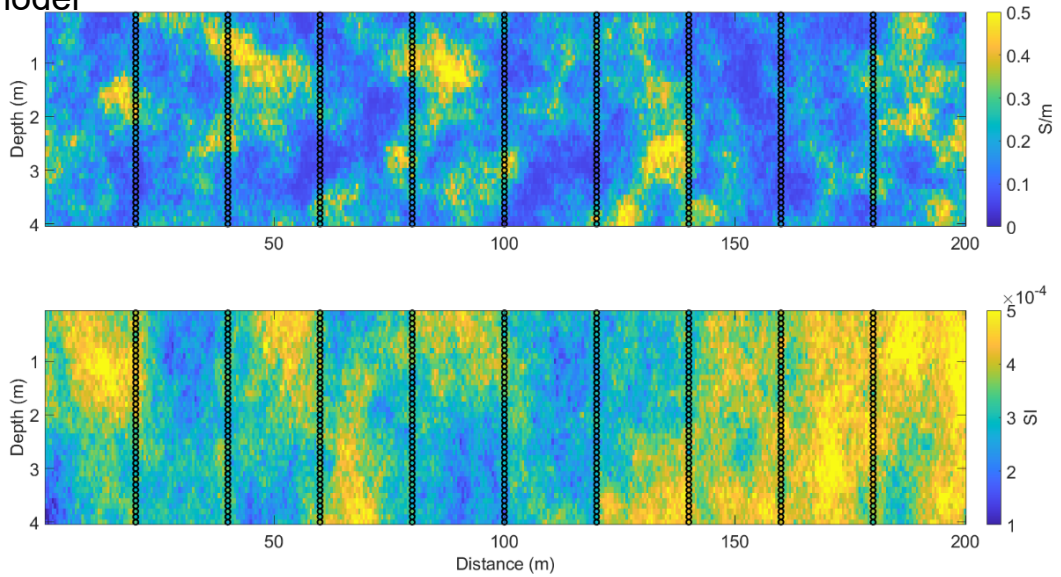
Geostatistical FDEM inversion



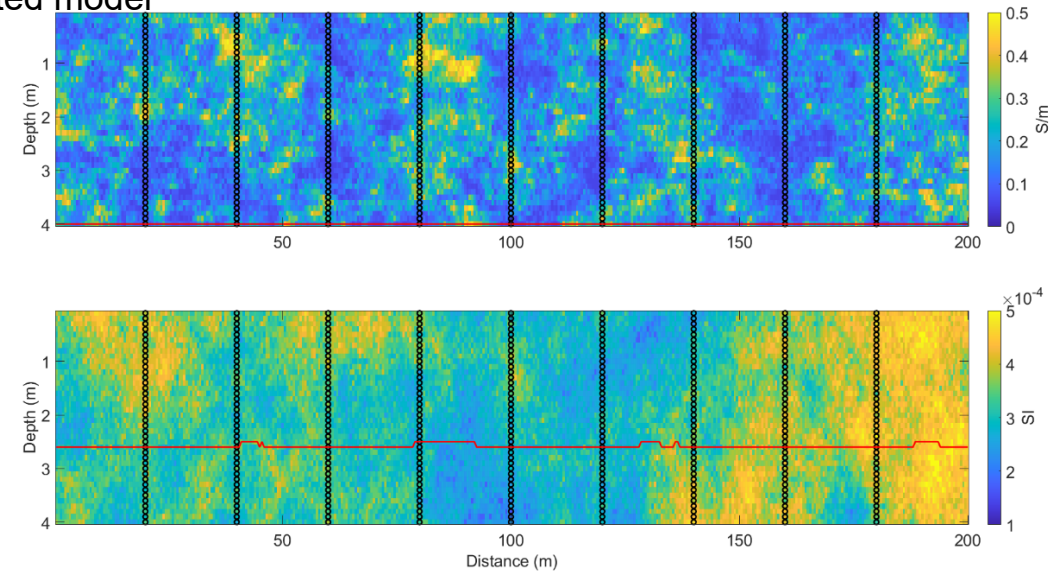


Geostatistical FDEM inversion

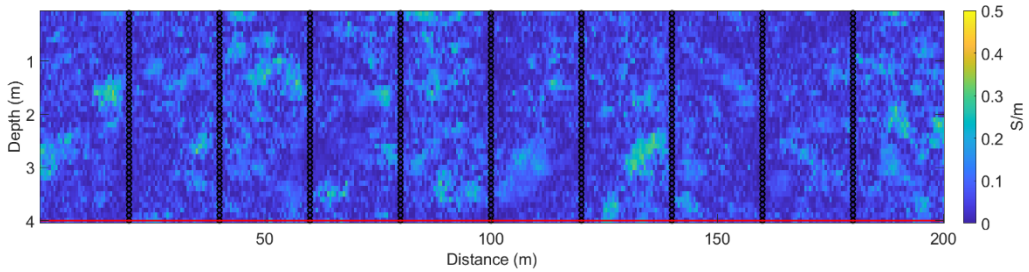
True model

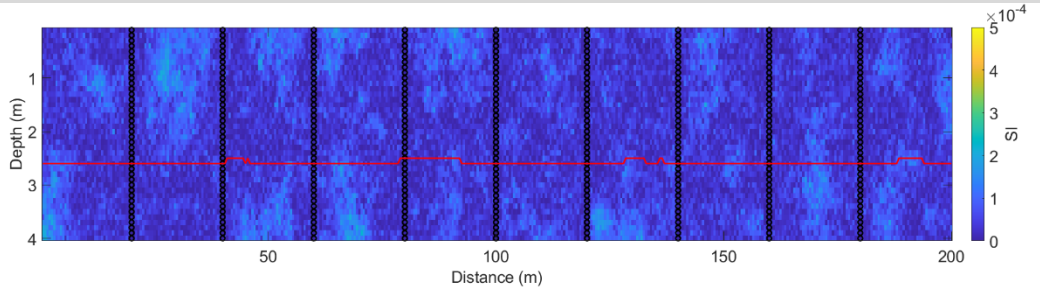


Inverted model

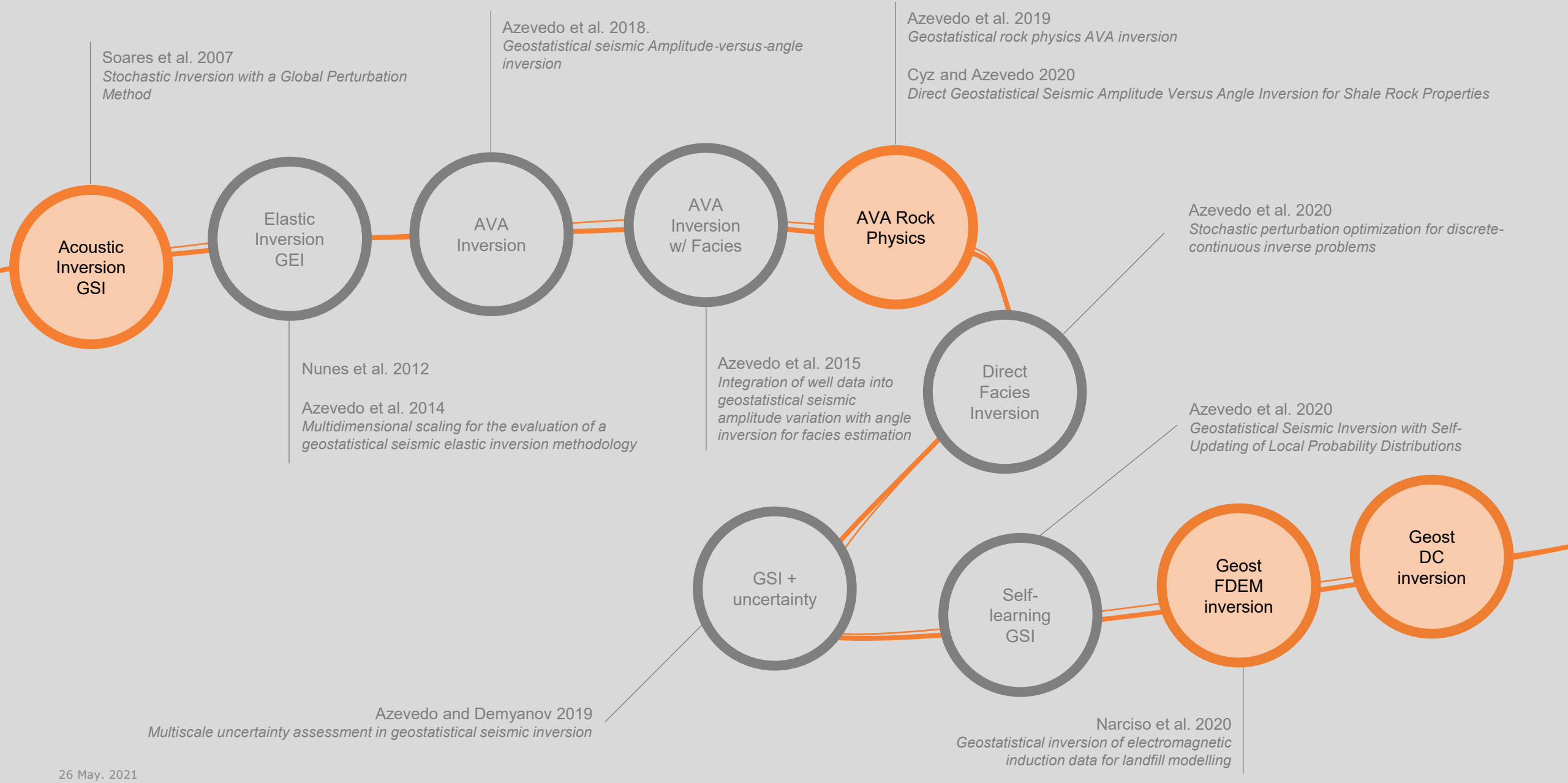


Residuals

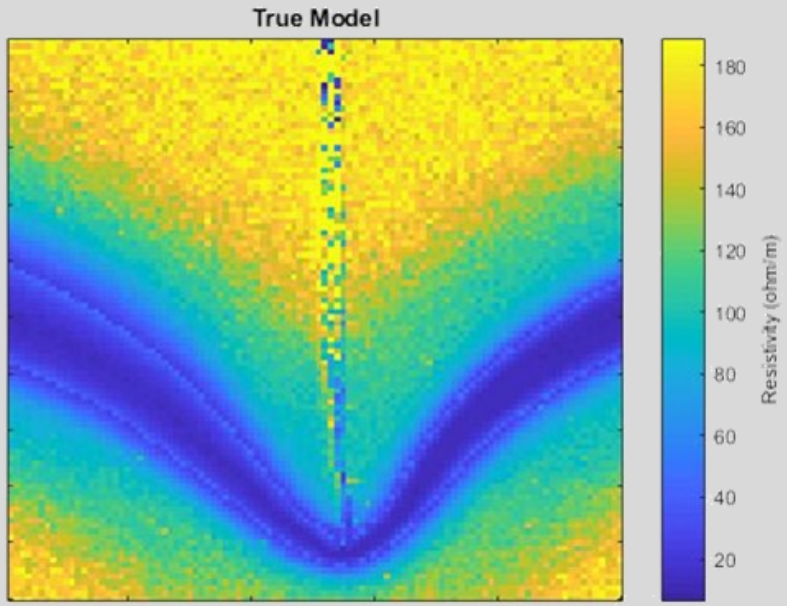


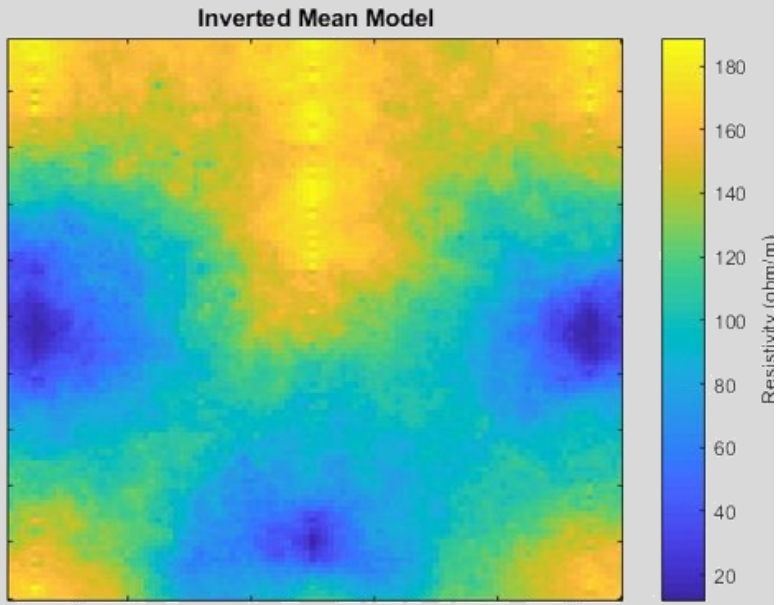


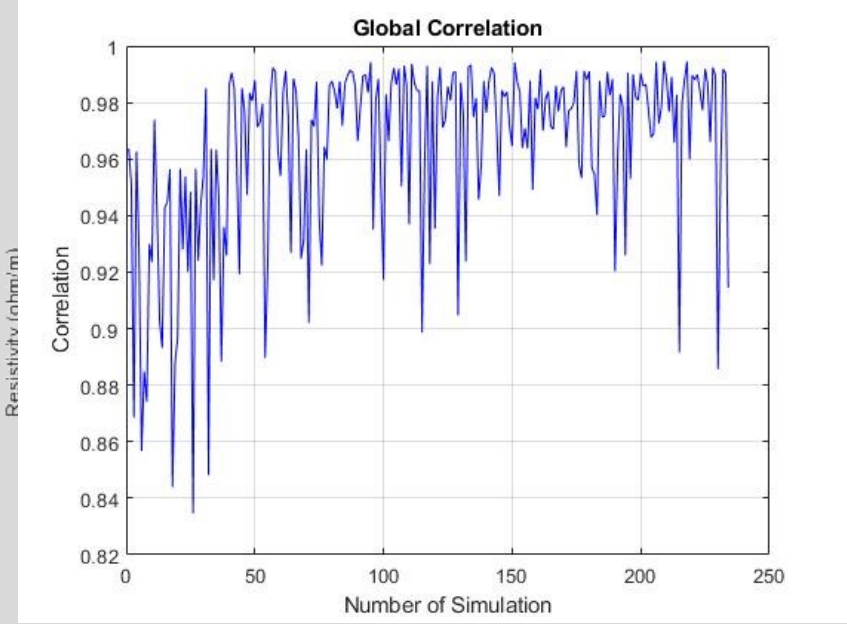
One framework fits it all

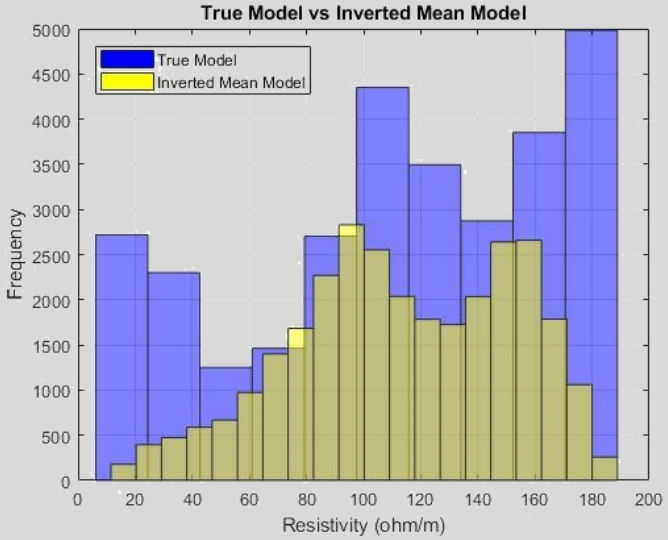


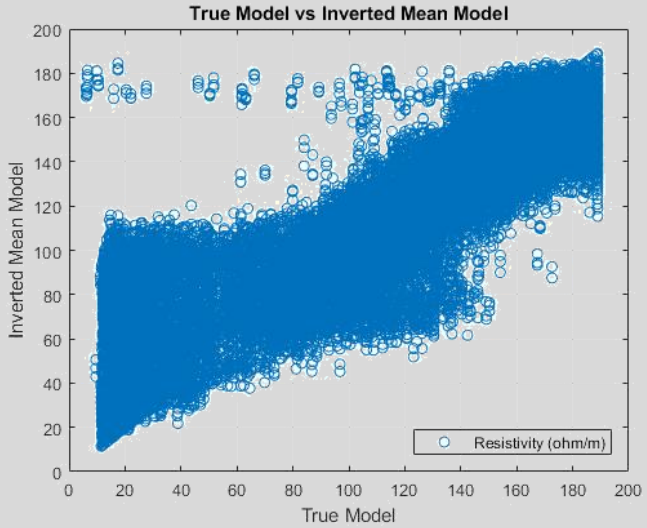
Geostatistical DC inversion

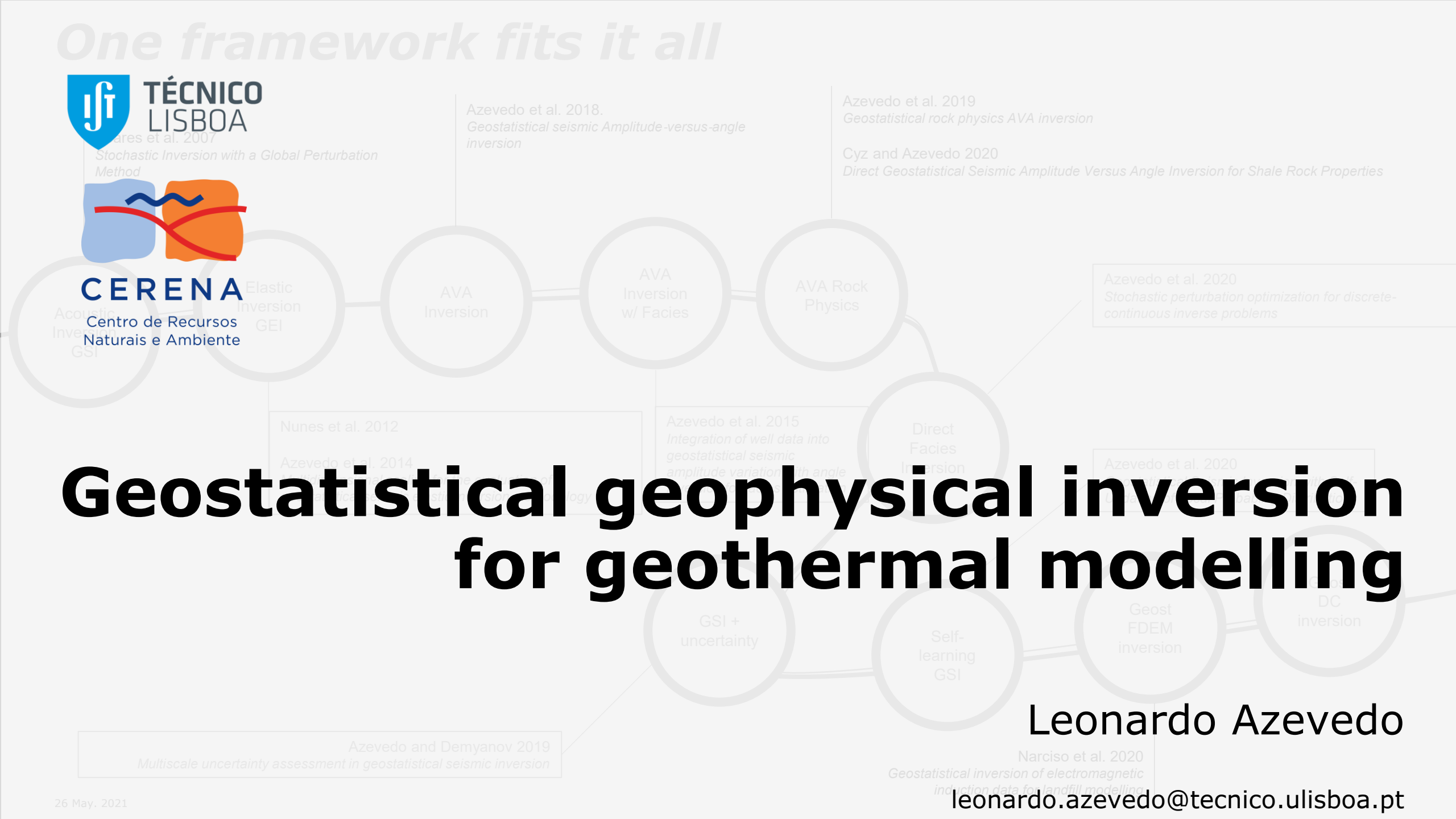












TÉCNICO LISBOA

CERENA
Centro de Recursos Naturais e Ambiente

Geostatistical geophysical inversion for geothermal modelling

Leonardo Azevedo

leonardo.azevedo@tecnico.ulisboa.pt