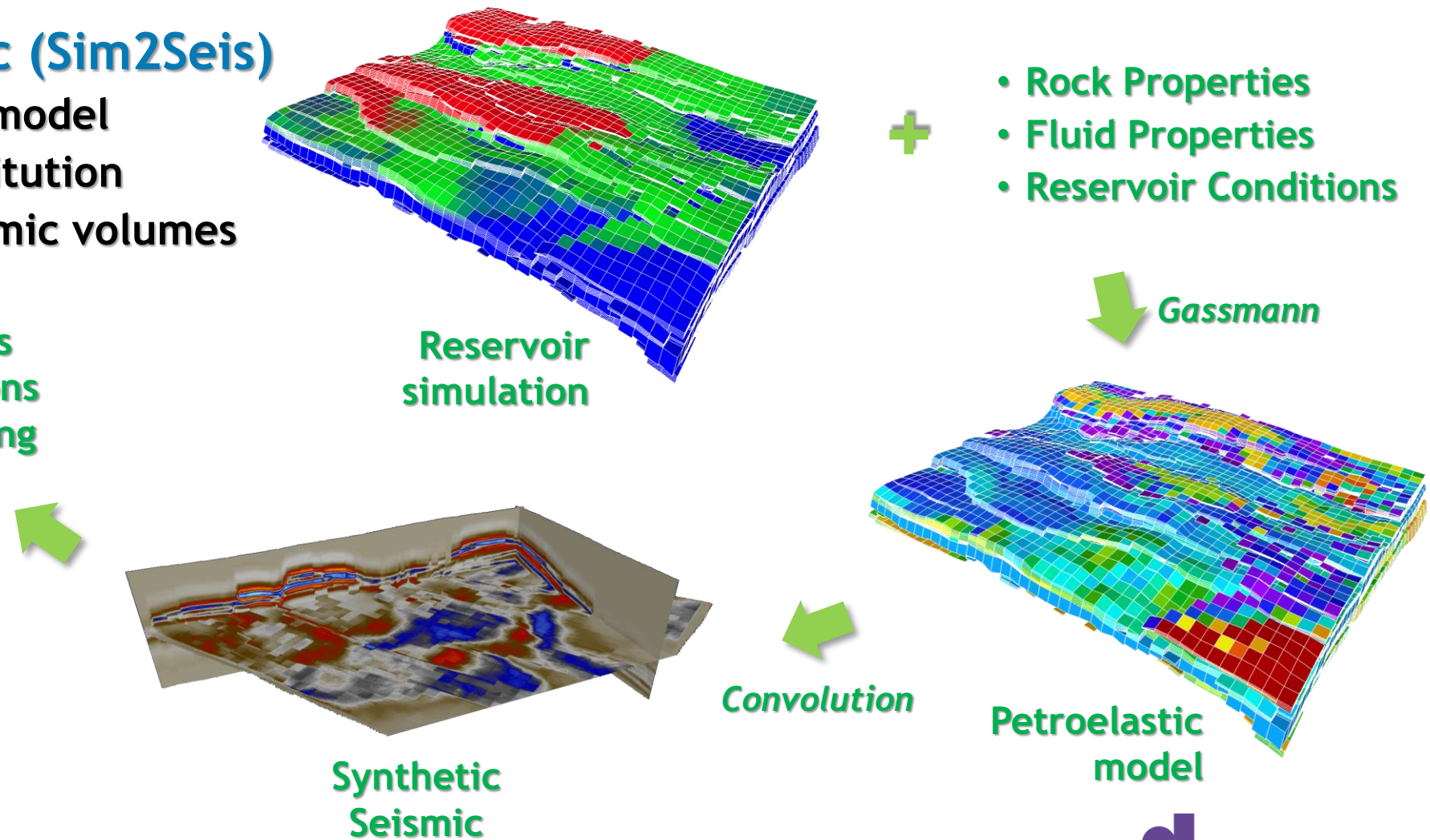


Simulation to Seismic. An Integrated Approach with CoViz 4D

- **Simulation → Seismic (Sim2Seis)**

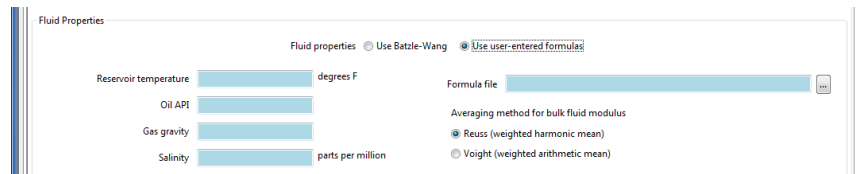
- Input reservoir fluid model
- Gassmann fluid substitution
- Create synthetic seismic volumes

- Qualitative comparisons
- Quantitative comparisons
- Assisted History Matching
- Feasibility studies



Advanced / Custom Sim2Seis Options

- Multiple options for stress sensitivity
 - Stress Hysteresis
- Custom, user-entered fluid formulas



Fluid Properties

Fluid properties ☐ Use Batzle-Wang ☒ Use user-entered formulas

Reservoir temperature degrees F

Oil API

Gas gravity

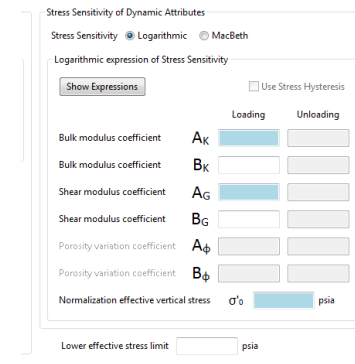
Salinity parts per million

Formula file

Averaging method for bulk fluid modulus

☒ Reuss (weighted harmonic mean)

☐ Voigt (weighted arithmetic mean)



Stress Sensitivity of Dynamic Attributes

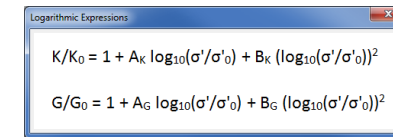
Stress Sensitivity ☒ Logarithmic ☐ MacBeth

Logarithmic expression of Stress Sensitivity

☐ Use Stress Hysteresis

	Loading	Unloading
Bulk modulus coefficient	<input type="text"/> A _K	<input type="text"/>
Bulk modulus coefficient	<input type="text"/> B _K	<input type="text"/>
Shear modulus coefficient	<input type="text"/> A _G	<input type="text"/>
Shear modulus coefficient	<input type="text"/> B _G	<input type="text"/>
Porosity variation coefficient	<input type="text"/> A _φ	<input type="text"/>
Porosity variation coefficient	<input type="text"/> B _φ	<input type="text"/>
Normalization effective vertical stress	<input type="text"/> σ' ₀	<input type="text"/> psia

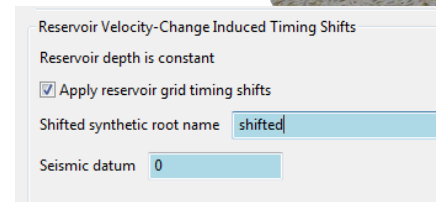
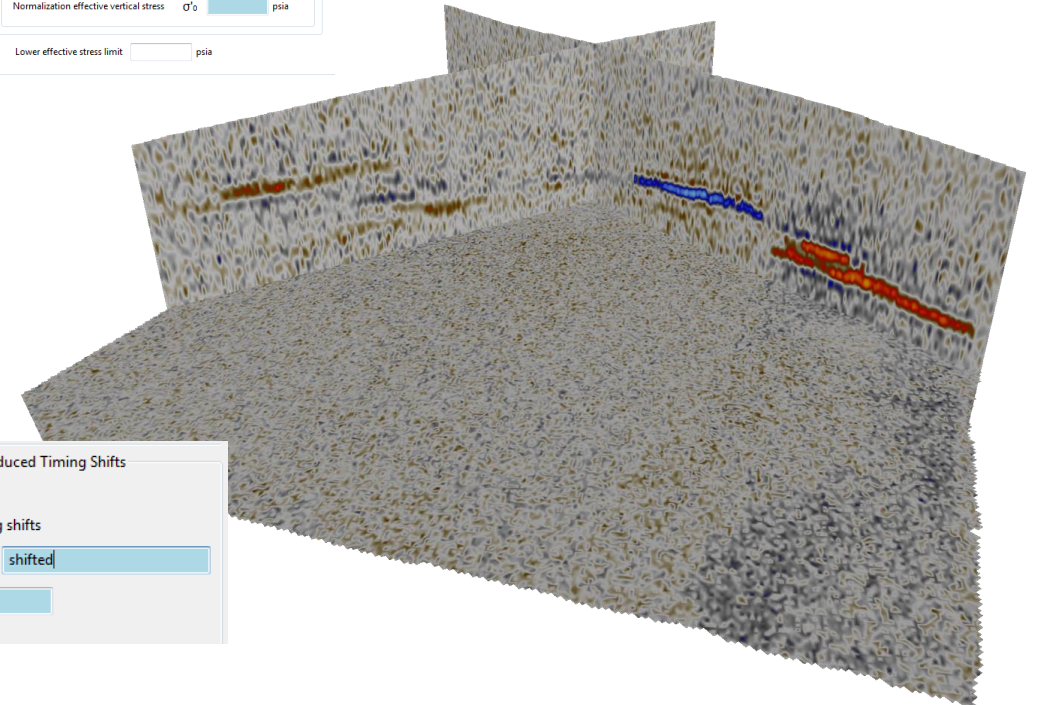
Lower effective stress limit psia



Logarithmic Expressions

$$K/K_0 = 1 + A_K \log_{10}(\sigma'/\sigma'_0) + B_K (\log_{10}(\sigma'/\sigma'_0))^2$$
$$G/G_0 = 1 + A_G \log_{10}(\sigma'/\sigma'_0) + B_G (\log_{10}(\sigma'/\sigma'_0))^2$$

- Dynamic porosity specifications
- P wave to Shear wave - OBN
- Background “shale” models
- Velocity-induced timing shifts
- Add 4D noise to synthetics



Reservoir Velocity-Change Induced Timing Shifts

Reservoir depth is constant

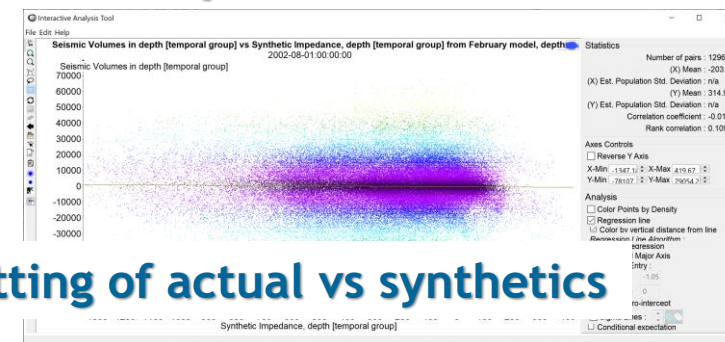
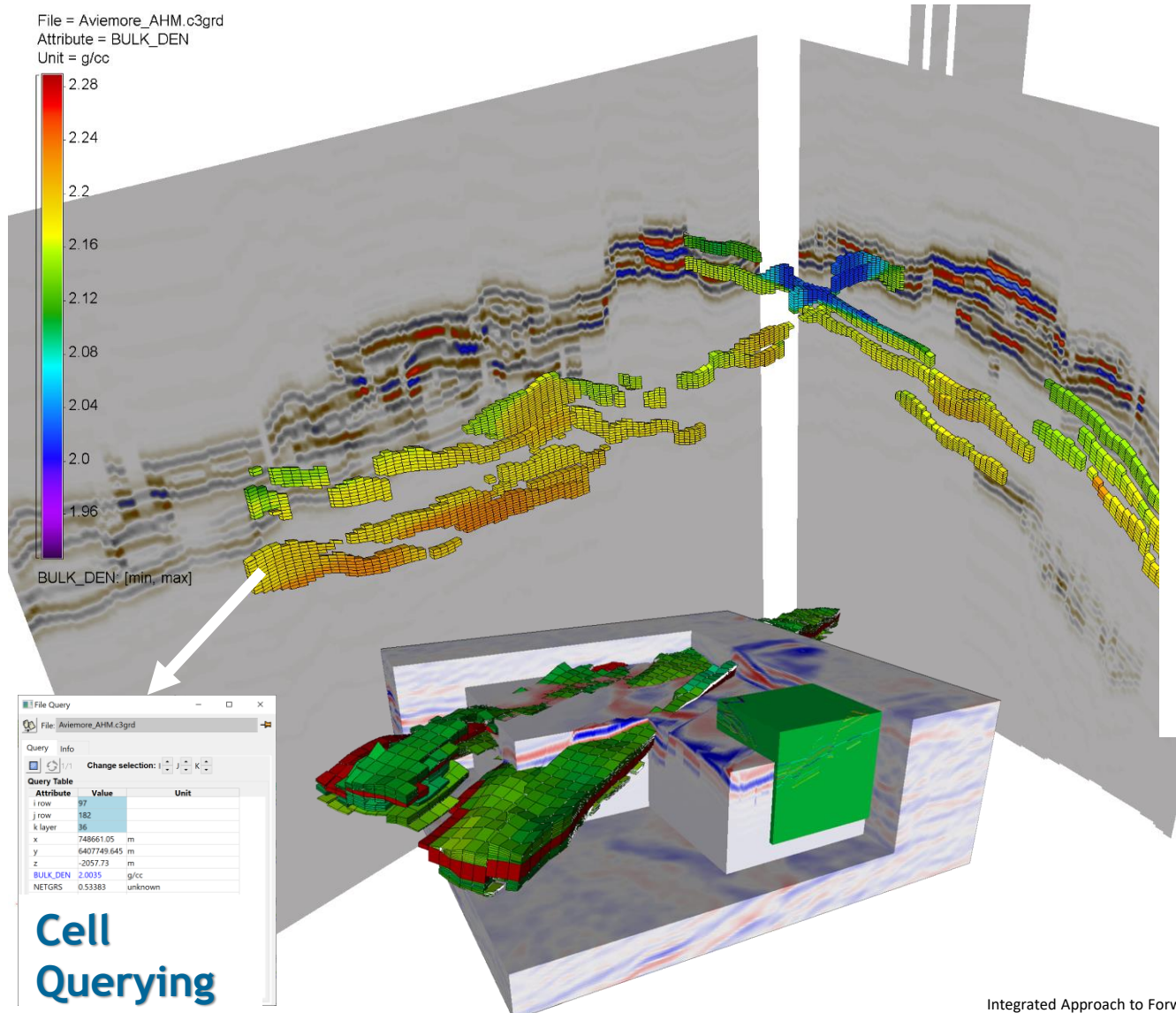
☒ Apply reservoir grid timing shifts

Shifted synthetic root name shifted

Seismic datum 0

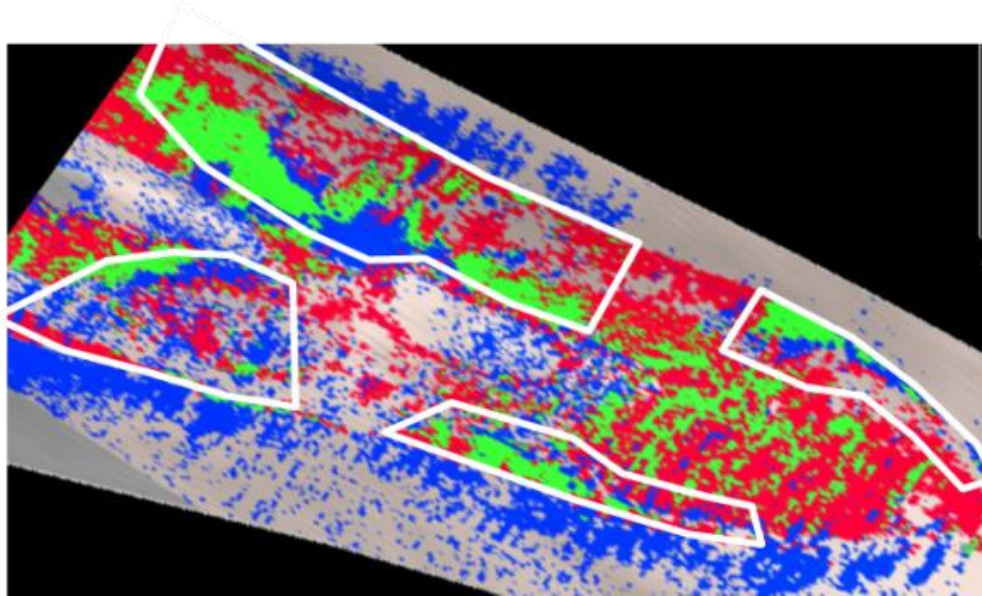
Quantitative Analysis of Sim2Seis Results

- Analysis can be in time or depth
- Spatially / temporally overlapping data quantitatively compared
- Tools for statistical comparisons
- Regions of interest can be flagged for attention in the simulator
- Interactive, or scripted...



Cross plotting of actual vs synthetics

How good is your model? AHM Match Quality Calculations



Match quality is calculated as a misfit ratio within certain AOI polygons from a composite attribute map produced by the AHM workflow (example shown to the left).

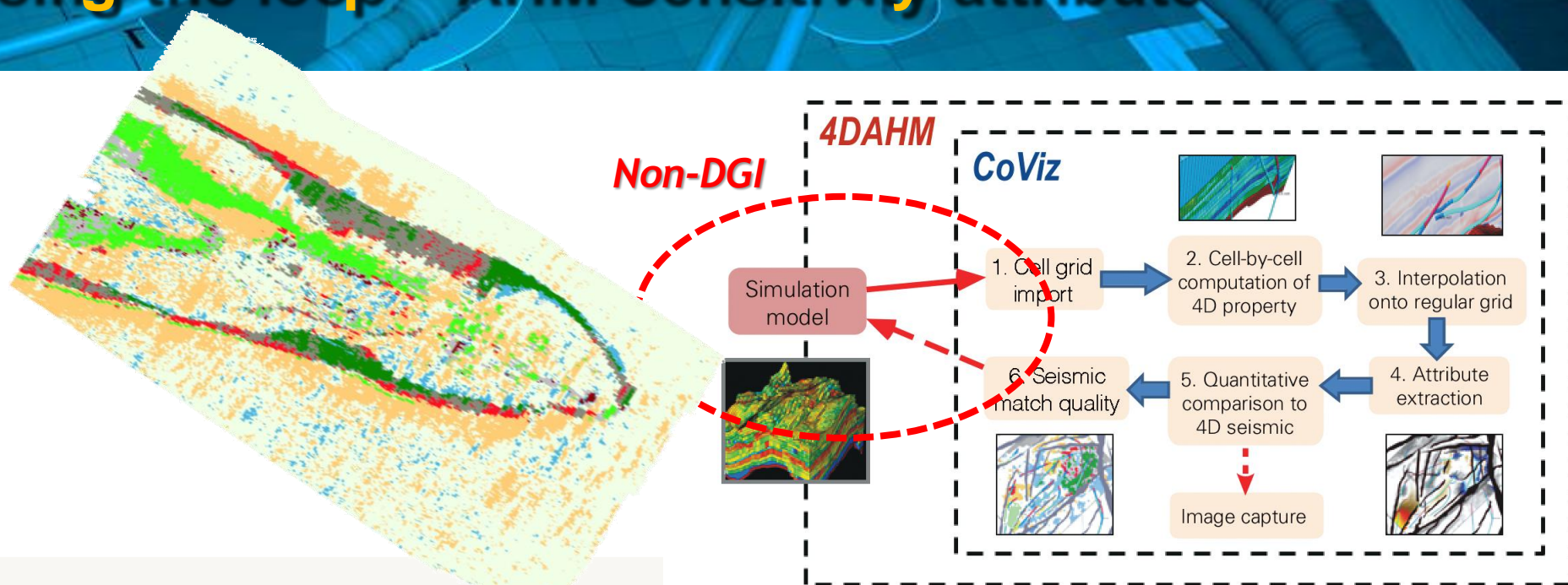
$$\text{match quality} = \frac{\text{misfit (blue + red)}}{\text{Area of polygon}}$$

Green	4D signal	Seismic and model agree
Grey	No 4D signal	Seismic and model agree
Blue	4D signal	Seismic and model disagree
Red	No 4D signal	Seismic and model disagree

MQArea		Observed		
Model		+ ve	0	- ve
	+ ve			
	0			
	- ve			

Closing the loop – AHM Sensitivity attribute

The sensitivity attribute visualises the individual components of MQArea match quality, enabling detailed QC



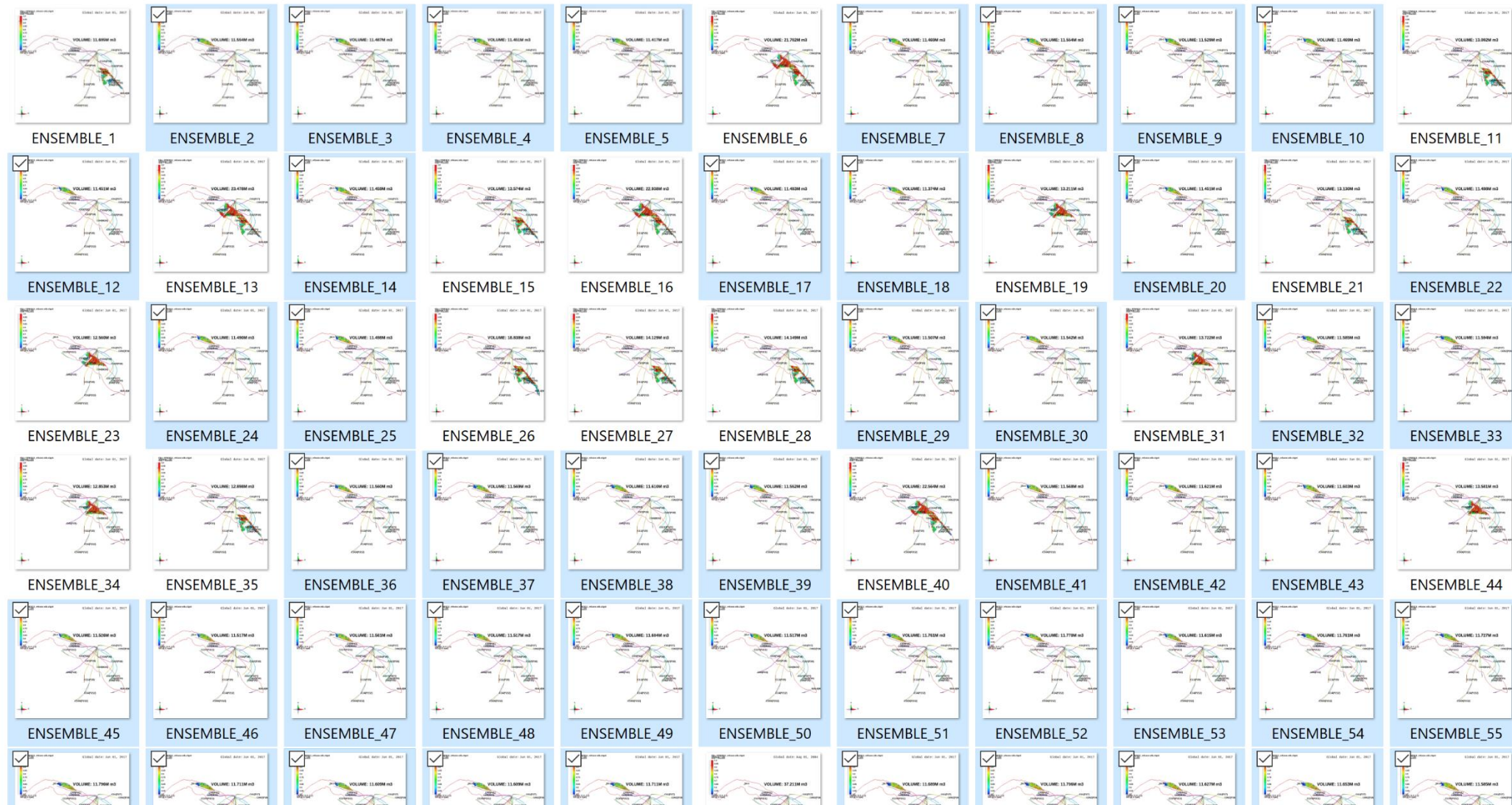
Legend for Match Quality Sensitivity Maps

MQArea		Observed		
Model		+ ve	0	- ve
	+ ve			
	0			
	- ve			

Green	Seismic and Model Agree	hardening	Below threshold	softening
Blue/Orange	4D Signal in Seismic but not in model	Seismic hardening		Seismic softening
Grey	4D Signal in model but not in seismic	Model hardening		Model softening
Red	Seismic and Model Disagree	Seismic hardening		Seismic softening

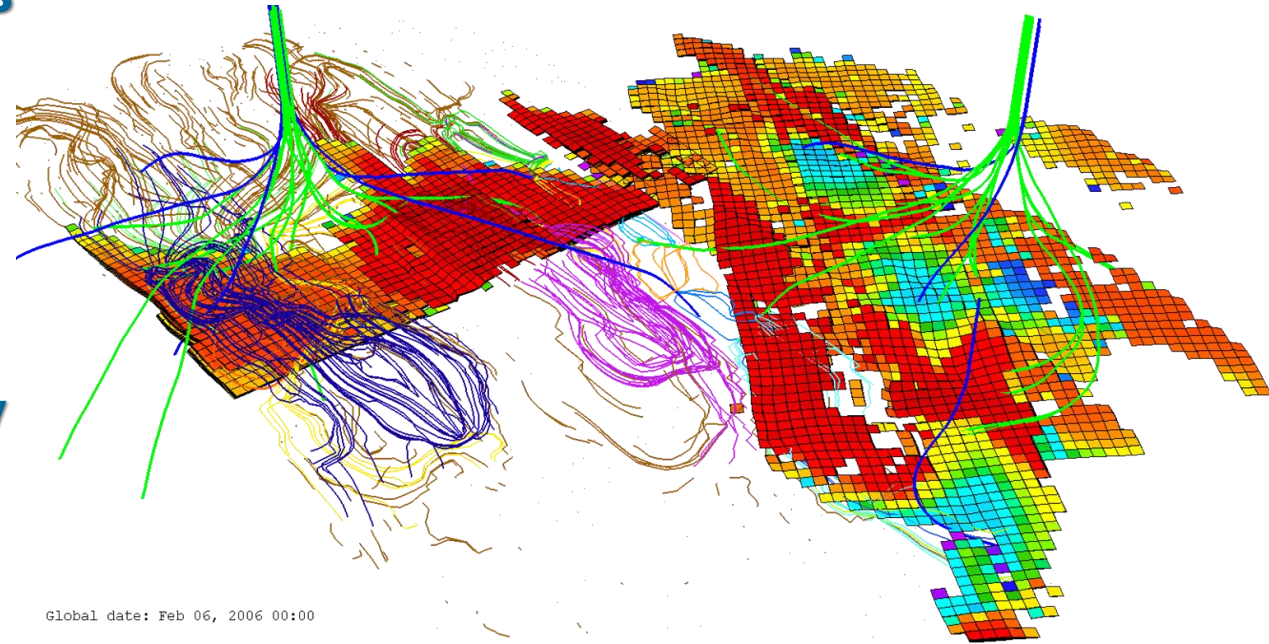
You have one solution, now repeat – 100 times, 1000 times

- Ensembles
- Repeatability
- Automation
- Capture results



Summary

- Wide variety of 4D reservoir data types
- Integrated quantitative analysis
- Assisted History Matching
- Customizable workflows / functionality
- Accessible, fast decision-making



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