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# Flow2Seis

Transforming Reservoir Simulations into 4D Seismic Insights

**Dozens of hours per  
model,  
or one run for the whole  
ensemble**

DEVELOPED WITH

Repsol Sinopec Brasil ·  
Unicamp

ORIGIN

ANP Project 23095-3 ·  
RESSIM-FORM.CO2

PLATFORM

Petrel · ECLIPSE · CMG  
simulators



**anp**  
Agência Nacional  
do Petróleo,  
Gás Natural e Biocombustíveis

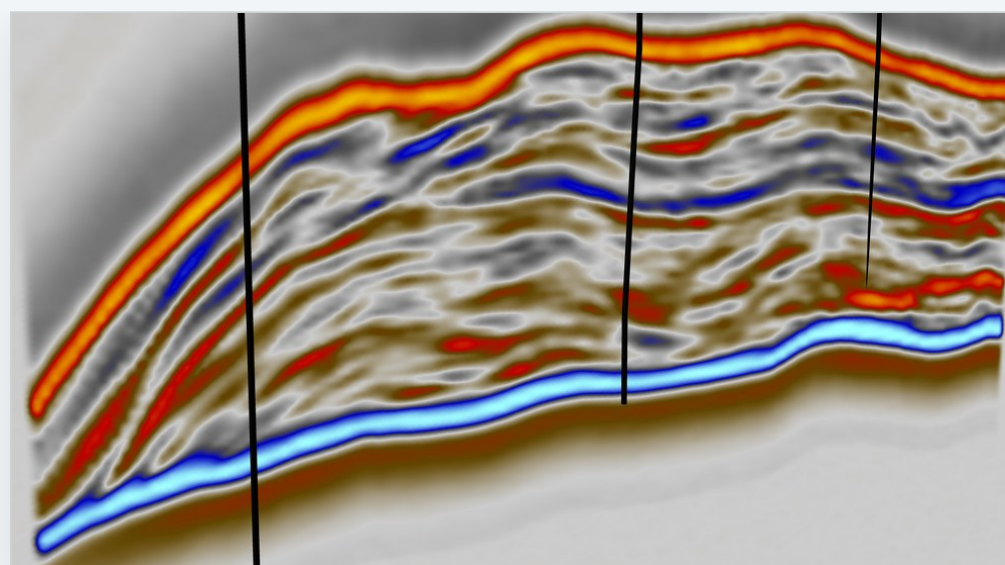
Technology developed within the scope of ANP Project 23095-3, RESSIM-FORM.CO2, supported with resources from the ANP research, development and innovation clause.

# Synthetic seismic, one model at a time

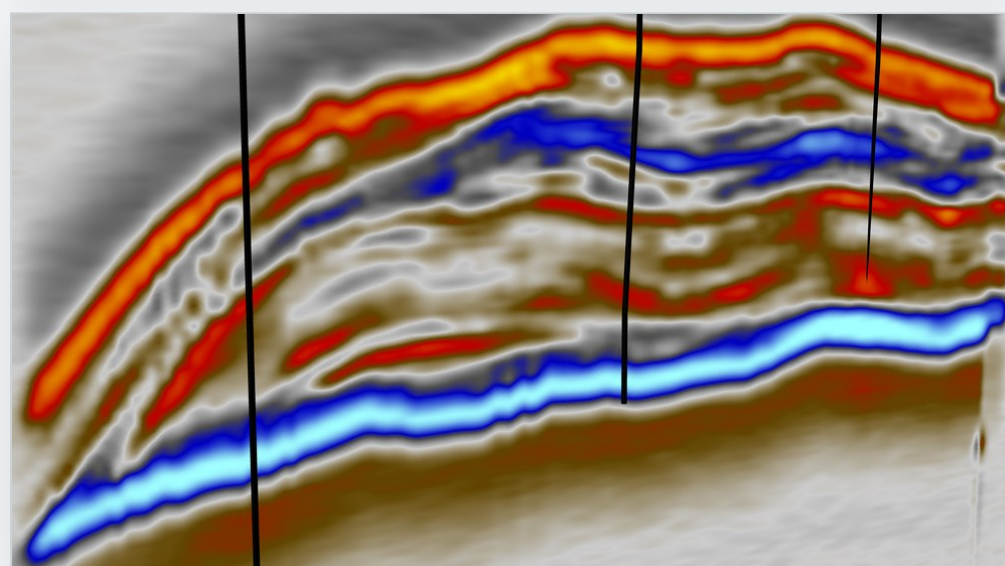
The traditional forward modeling chain runs model by model, with files moving by hand between the flow simulator, the rock physics routines and the seismic environment. Each realization costs dozens of hours, and at that price studies based on ensembles are simply not attempted.

Which is exactly the approach modern reservoir management needs in order to quantify uncertainty and mitigate risk.

EXPECTED  
MONITOR



SYNTHETIC



**Fig. 01** · Synthetic amplitude compared with the expected monitor survey, same section, wells P14, P15 and I16.

# From flow simulation to synthetic amplitude, without leaving Petrel

Flow2Seis is a native Petrel plugin that reads the results produced by the flow simulator and automates the whole 4D seismic forward modeling chain from there, in batch, over hundreds of simulation models in a single execution.



- 01

Simulator results read directly from ECLIPSE and CMG simulators, including .sr3 files
- 02

Petroelastic modeling with one rock physics model per facies
- 03

Scale transfer from the stratigraphic grid to the seismic grid
- 04

Conversion from depth to time across the modeled volume
- 05

Reflectivity in post stack or angle stack, up to five incidence intervals
- 06

1D convolution with the wavelet given for each angle interval
- 07

Noise with frequency filtering and structural smoothing, calibrated to a target NRMS by numerical optimization
- 08

Difference cubes and 4D maps, seven extraction methods and optional time shifts

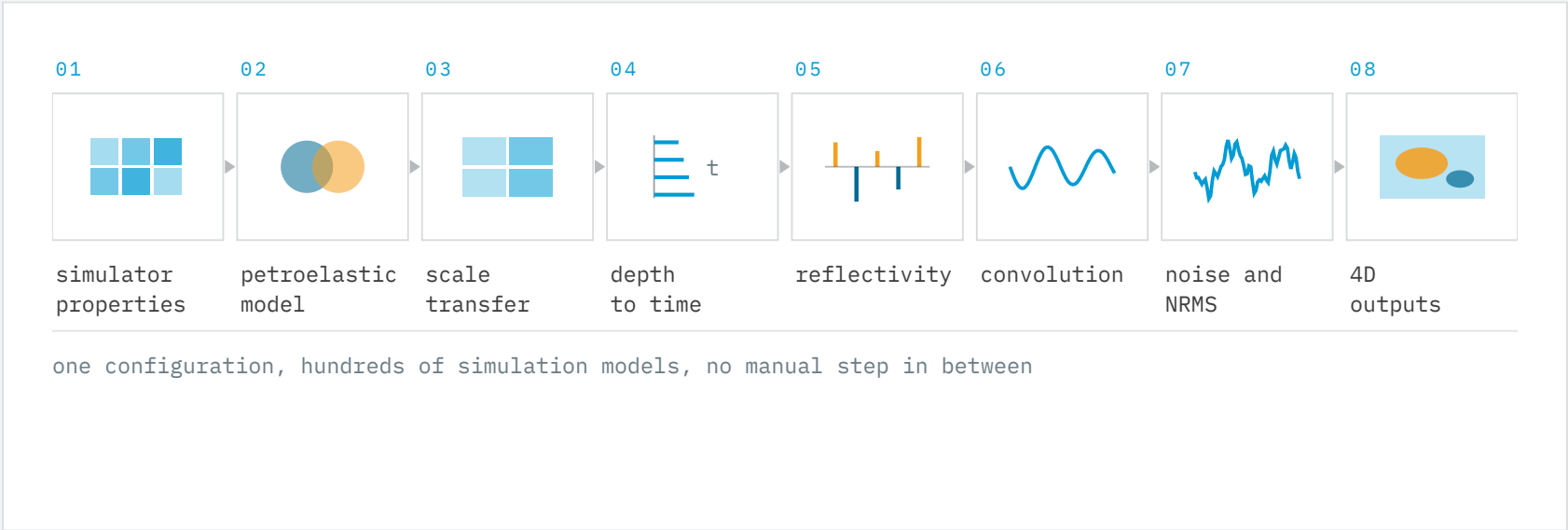


Fig. 02 • Schematic. What the chain does to the data at each stage.

# Four things the batch workflow unlocks



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## Forward modeling at ensemble scale

Hundreds of realizations processed in batch, so generating synthetic seismic for each scenario stops being the bottleneck.

## Less uncertainty in the models

Synthetic and acquired seismic compared at statistical scale, which surfaces the realizations that reproduce the observed data and discards the ones that diverge.

## Oil and CO<sub>2</sub> in the same tool

The same workflow serves mature oil field management and geological CO<sub>2</sub> storage monitoring projects.

## Workflow ready

Each stage is available as a task in the Petrel workflow editor, so the petroelastic model can run inside uncertainty and sensitivity studies, or inside any routine the team already maintains.

One project setup processes dozens or hundreds of models with no manual intervention.

# Reflectivity in, amplitude out

The petroelastic model provides the elastic properties required to derive seismic reflectivity per incidence angle. Amplitude comes from convolution with the wavelet of each angle interval, and the noise term is calibrated by numerical optimization until it matches the NRMS of the reference survey.

ANGLE STACK SYNTHETIC · SHUEY WITH TWO TERMS

$$s_{\theta}(t) = w_{\theta}(t) * R_{\theta}(t) + n(t)$$

$$R_{\theta} \approx R_0 + G \sin^2 \theta$$

$w_{\theta}$  wavelet provided for each angle interval

$R_0, G$  intercept and gradient

$R_{\theta}$  reflectivity from the petroelastic model

$n(t)$  noise calibrated to a target NRMS

Zoeppritz, Aki-Richards PP, Aki-Richards PS and Fatti are also available when the two term approximation is not enough.

# One petroelastic model per facies

## Dry rock

- Xu-Payne, fractured carbonates
- Extended Cemented Sand
- Extended Unconsolidated Sand
- User defined, with polynomial or exponential porosity correction

## Fluids

- Batzle-Wang
- Batzle-Wang modified for oils with high CO<sub>2</sub> content
- Simulation proxy for compositional models
- Three phases, with homogeneous or patchy saturation, mixed using Wood or Voigt averaging

## Minerals

- Up to three minerals
- Voigt-Reuss
- Hashin-Shtrikman
- Configurable interpolation weight

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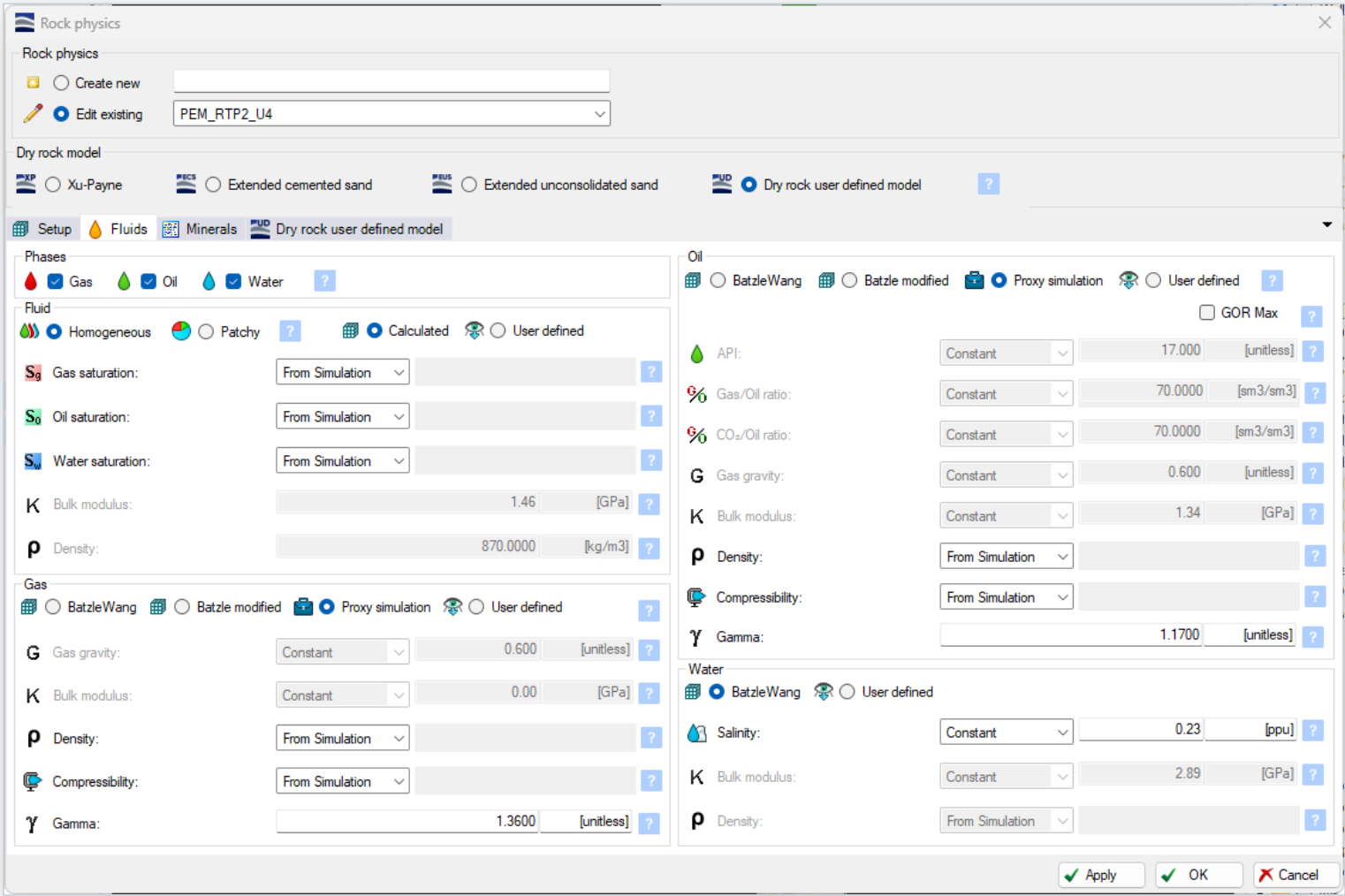
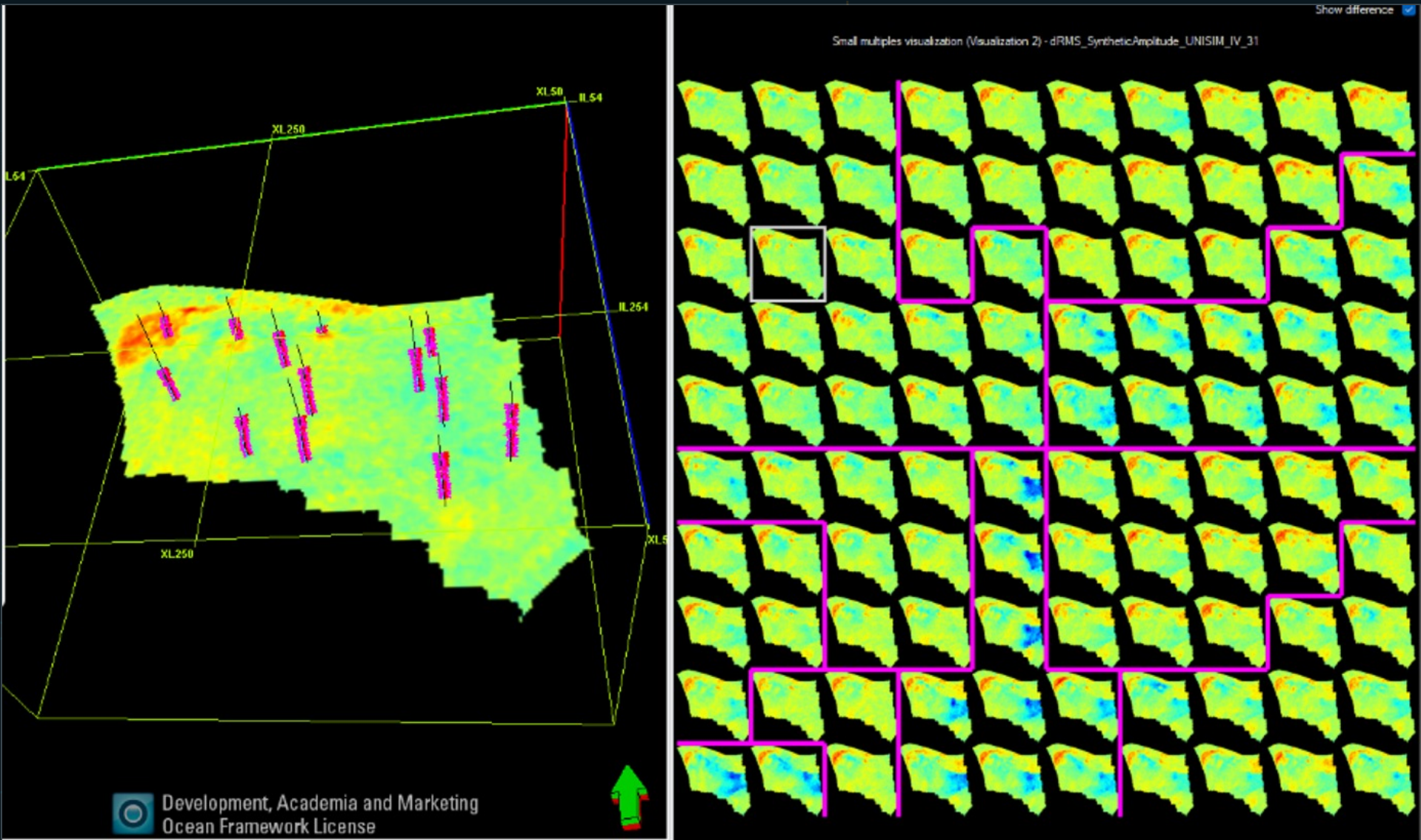


Fig. 03 · Rock physics setup, one independent model per facies, with dry rock, fluid and mineral blocks.



07/11 Fig. 04 · Right, small multiples of the synthetic amplitude difference across the ensemble, clustered by similarity. Left, the realization under the cursor, drawn in the 3D window.

# Hundreds of realizations on a single screen.

Dedicated Pixelization and Small Multiples windows cluster realizations by similarity and rank them against the expected response. Hovering a tile draws that realization in the 3D window beside it, which is how undrained zones and disagreements between model and seismic become visible.

- PIXELIZATION
- CROSS CORRELATION
- SMALL MULTIPLES
- K-MEANS CLUSTERING
- RMSE RANKING

# Tested where the rock actually differs

## UNISIM-IV

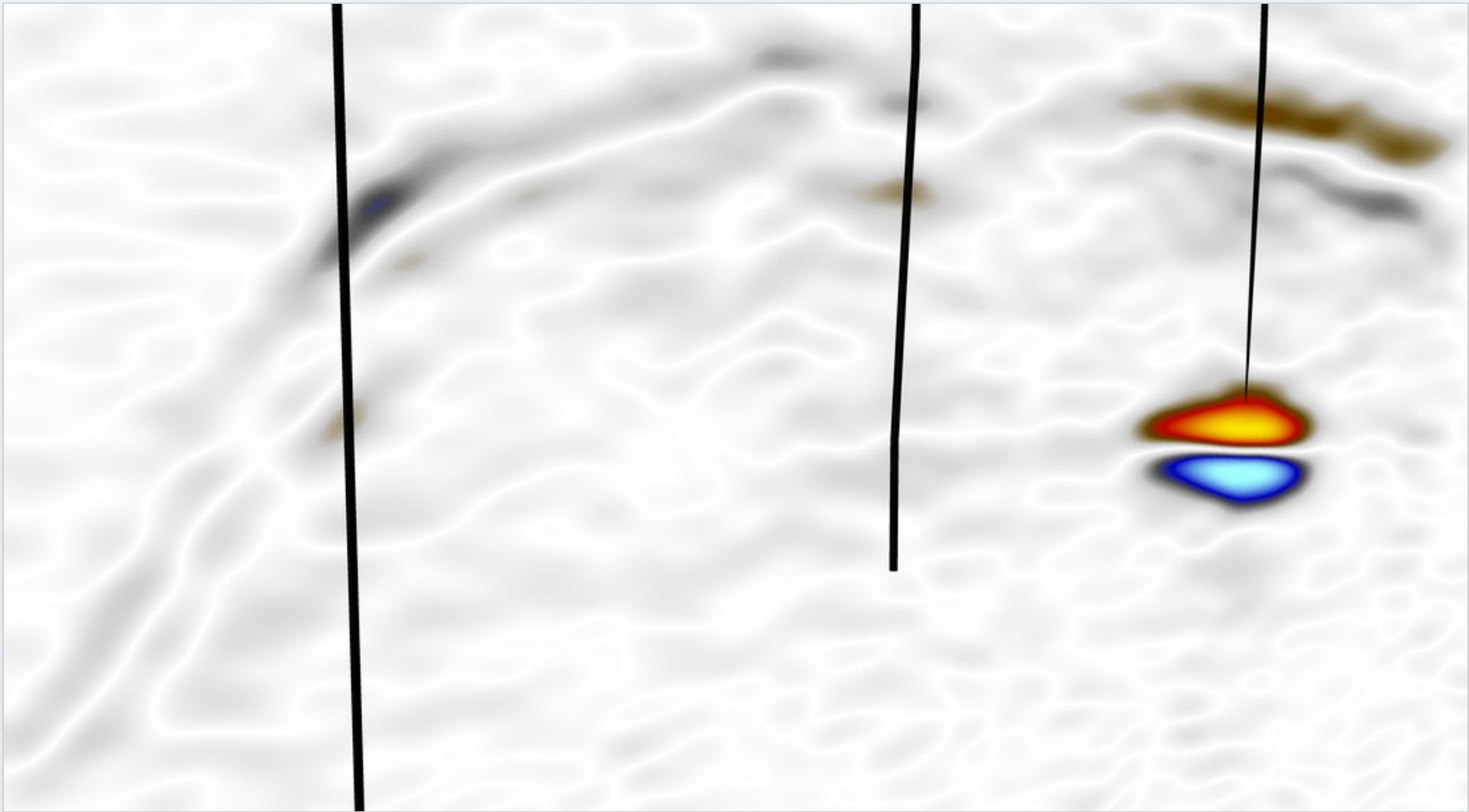
Synthetic benchmark on a pre-salt carbonate, used to check the full chain against a known answer.

## Campos Basin

Real deepwater turbidite case, with acquired monitor surveys and production history.

## Sleipner

CO<sub>2</sub> injection monitoring in the North Sea, covering the storage side of 4D interpretation.



**Fig. 05** · Synthetic 4D difference, monitor minus baseline, with noise added, showing the injection response at well I16.

# The people who funded it, coordinated it and built the method

**Flow2Seis is a relevant technological result of the collaboration among Repsol Sinopec Brasil, Unicamp and DeepSoft. The tool contributes to making 4D seismic forward modeling workflows more efficient and supports studies related to reservoir management and geological CO<sub>2</sub> storage monitoring.**

Leonildes Soares

Geosciences Research Manager · Repsol Sinopec Brasil

**Our tool automates processes that used to be manual and slow. It is now possible to compare hundreds of models quickly, which speeds up calibration and allows more efficient reservoir management.**

Alessandra Davólio Gomes

Director of CEPETRO, Unicamp · coordinator of the project

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**The tool brings together reservoir engineering, geophysics, rock physics, and computing in an efficient and accurate multidisciplinary framework.**

Daiane Rossi Rosa

Researcher · UNISIM, CEPETRO

# Presented and discussed in industry and academic forums

- SBGF 2023
- EAGE 2024
- SEG 4D FORUM 2024
- SBGF 2025
- UNICAMP MSC

2023

## Optimizing the 4D QI process: a Brazilian turbidite case study

Dillon, L., Schwedersky, G., Nunes, C., de Melo Filho, L., Roisenberg, H. & Davolio, A.

Expanded abstract · 18th International Congress of the Brazilian Geophysical Society and Expogef, Rio de Janeiro

2023

## Validating dynamic reservoir model with 4D seismic data: a deep water Brazilian turbidite case

Olusegun, A., Rosa, D.R., dos Santos, M.S., Pilato, M., Dillon, L., Schwedersky, G., Munerato, F.P., Pinheiro, C., de Melo Filho, L.S. & Davolio, A.

Short abstract · 18th International Congress of the Brazilian Geophysical Society and Expogef, Rio de Janeiro

2023

## Calculating acoustic fluid properties for 4D seismic studies for an oil with significant CO<sub>2</sub> content: a proxy approach

Rosa, D.R., dos Santos, M.S., Dillon, L., Schwedersky, G., Pilato, M., Pinheiro, C., de Melo Filho, L.S. & Davolio, A.

Expanded abstract · 18th International Congress of the Brazilian Geophysical Society and Expogef, Rio de Janeiro

2024

## Best practices on forward 4D seismic modelling from dynamic reservoir models

Rosa, D.R., dos Santos, M.S., Schwedersky, G., Pilato, M., Pinheiro, C., de Melo Filho, L.S., Schiozer, D.J. & Davolio, A.

Expanded abstract · 85th EAGE Annual Conference and Exhibition, Vol. 2024, No. 1, pp. 1 to 5 · European Association of Geoscientists and Engineers

2024

## A visual tool to analyze the matching quality between simulation models and 4D seismic data

Rosa, D.R., da Silva, C.G., da Silva Siqueira, K.R., de Andrade Miyazato, M.L., dos Santos, M.S., Pilato, M., Dragone, I., de Melo Filho, L.S., Schiozer, D.J. & Davolio, A.

4D Forum, Insight to Actions: a Global Forum, Galveston, Texas, November 2024, pp. 127 to 130 · Society of Exploration Geophysicists

2025

## A novel routine for generating and calibrating random noise in 4D seismic data

Dragone, I., Rosa, D.R., Pilato, M., Pinto, T., Mesquita, P.V., dos Santos, M.S., Melo Filho, L.S. & Davolio, A.

Expanded abstract · 19th International Congress of the Brazilian Geophysical Society

2025

## Implementation of advanced visualization techniques for evaluating modeled seismic properties from ensembles of reservoir models

Mesquita, P.V., Miyazato, M.L.A., da Silva, C.G., Rosa, D.R., Pilato, M., Dragone, I., Pinto, T., Melo Filho, L.S. & Davolio, A.

Expanded abstract · 19th International Congress of the Brazilian Geophysical Society

2025

## Forward time lapse seismic modeling from numerical simulation models

Akinmuda Olusegun Benard

Master's dissertation · Universidade Estadual de Campinas, Unicamp, 2020 to 2025

# How long does one synthetic survey take on your desk today?

Whatever the answer is, Flow2Seis exists to shorten it. The whole forward modeling chain, from simulator properties to synthetic amplitude, running in batch inside the Petrel project your team already works in.

Bring one simulation model and one monitor survey. We run the chain end to end on your data and show you what the same configuration does with the rest of the ensemble.

## COMMERCIAL AVAILABILITY

Licensing subject to the applicable intellectual property arrangements and to formal agreement among the rights holders

## DEMONSTRATIONS

Coordinated by DeepSoft, subject to confidentiality, data protection and software licensing requirements

## CONTACT

[contact@deepsoft.com.br](mailto:contact@deepsoft.com.br)

Flow2Seis is a jointly developed technological result of the RESSIM-FORM.C02 project, involving Repsol Sinopec Brasil, Unicamp and DeepSoft. Any demonstration involving customer or partner data is subject to prior confidentiality, information security, data licensing and third party software requirements. Petrel and ECLIPSE are trademarks of their respective owner. CMG product names and trademarks belong to Computer Modelling Group Ltd. Their mention does not imply sponsorship or endorsement.



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