CASE STUDY · BR-KALMAN FOR PETREL

DEEPSOFT

0

01/09

500

1000

2000

2500

3000

COVER

Hundreds of reservoir models, calibrated without leaving Petrel

BR-Kalman brings ensemble based data assimilation into Petrel, so that production, 4D seismic and well profile data are honored in a single history matching loop.

CLIENT

Petrobras · CENPES

PLATFORM

Petrel · Ocean Framework

STACK

C# · .NET · C++ · CUDA

THE SITUATION

DEEPSOFT

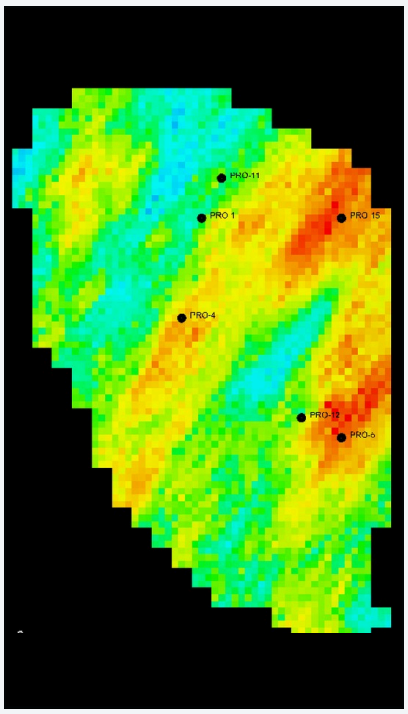
History matching decides what a forecast is worth

Calibrating numerical models until they reproduce observed field data, meaning production, 4D seismic and well profile data, is what reduces uncertainty in reservoir behavior forecasts.

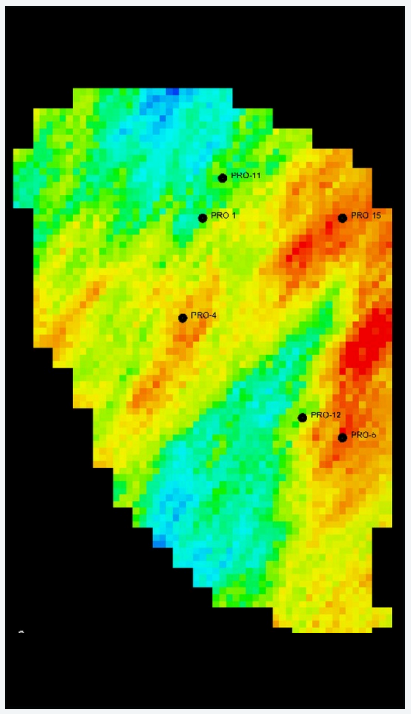
Petrobras needed modern probabilistic methods based on the Kalman Filter, applied at industrial scale.

And it had to stay inside Petrel, the central platform for its geoscience and reservoir engineering workflows. BR-Kalman is the plug in built to do exactly that.

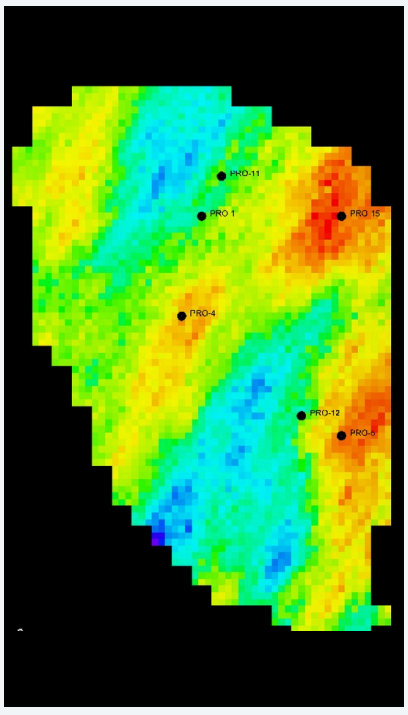
REALIZATION 60



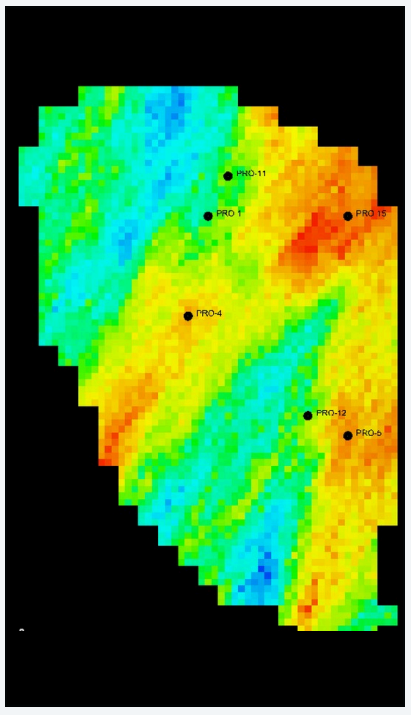
REALIZATION 70

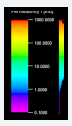


REALIZATION 80



REALIZATION 90





Permeability, mD
0.1 to 1000, logarithmic

Fig. 01 · Permeability in four realizations of the same ensemble. Same wells, same grid, different geology.

DEEPSOFT

Five constraints, none of them negotiable

Hundreds of realizations

Every iteration handles hundreds of reservoir model realizations, with parameter sets that stay consistent across the ensemble.

Data of different natures

Production, 4D seismic and well profile data assimilated at the same time, each with its own scale and its own uncertainty.

HPC execution

Simulations run in parallel on HPC clusters, across different reservoir simulation engines.

Native workflow

No intermediate exports. Data traceability and team productivity depend on never leaving Petrel.

DELFI integration

The same plug in has to serve the local Petrel installation and the SLB DELFI environment, so that hybrid workflows between the desk and the cloud use one tool, not two.

Any one of these is manageable in isolation. Together they rule out scripting your way around the platform.

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ES-MDA: one ensemble, several assimilations

Each model realization is updated based on covariances estimated by the ensemble, taking into account uncertainties in the model and data. At every step the observation error covariance is inflated by a factor, and the data perturbation is scaled by its square root, so the ensemble is not collapsed by the data all at once.

04/09

ES-MDA UPDATE · ENSEMBLE SMOOTHER WITH MULTIPLE DATA ASSIMILATION

$$\mathbf{m}_j^{k+1} = \mathbf{m}_j^k + \mathbf{K}^k \left(\mathbf{d}_{\text{obs}} + \sqrt{\alpha_k}\, \boldsymbol{\varepsilon}_j^k - \mathbf{d}_j^k \right)$$

$$\mathbf{K}^k = \mathbf{C}_{\text{MD}}^k \left(\mathbf{C}_{\text{DD}}^k + \alpha_k\, \mathbf{C}_{\text{D}} \right)^{-1}$$

$$\sum_{k=1}^{N_a} \frac{1}{\alpha_k} = 1, \qquad \boldsymbol{\varepsilon}_j^k \sim \mathcal{N}(\mathbf{0},\, \mathbf{C}_{\text{D}})$$

$$j = 1, \ldots, N_e, \qquad k = 1, \ldots, N_a$$

$\mathbf{m}_j^k$ parameter vector of realization j at step k

$\mathbf{d}_j^k$ predicted data, simulator output for the parameters above

$\mathbf{C}_{\text{MD}}^k$ sample cross covariance between parameters and predicted data at step k

$\mathbf{C}_{\text{D}}$ observation error covariance

α_k inflation factor applied to the observation error covariance at step k

$\mathbf{d}_{\text{obs}}$ observed data vector

$\mathbf{K}^k$ ensemble gain at step k, defined by the second line

$\mathbf{C}_{\text{DD}}^k$ sample auto covariance of the predicted data at step k

$\boldsymbol{\varepsilon}_j^k$ perturbation drawn independently for each j and k

N_e, N_a ensemble size and number of assimilation steps

> The output is the calibrated ensemble, not a single tuned model.

DEEPSOFT

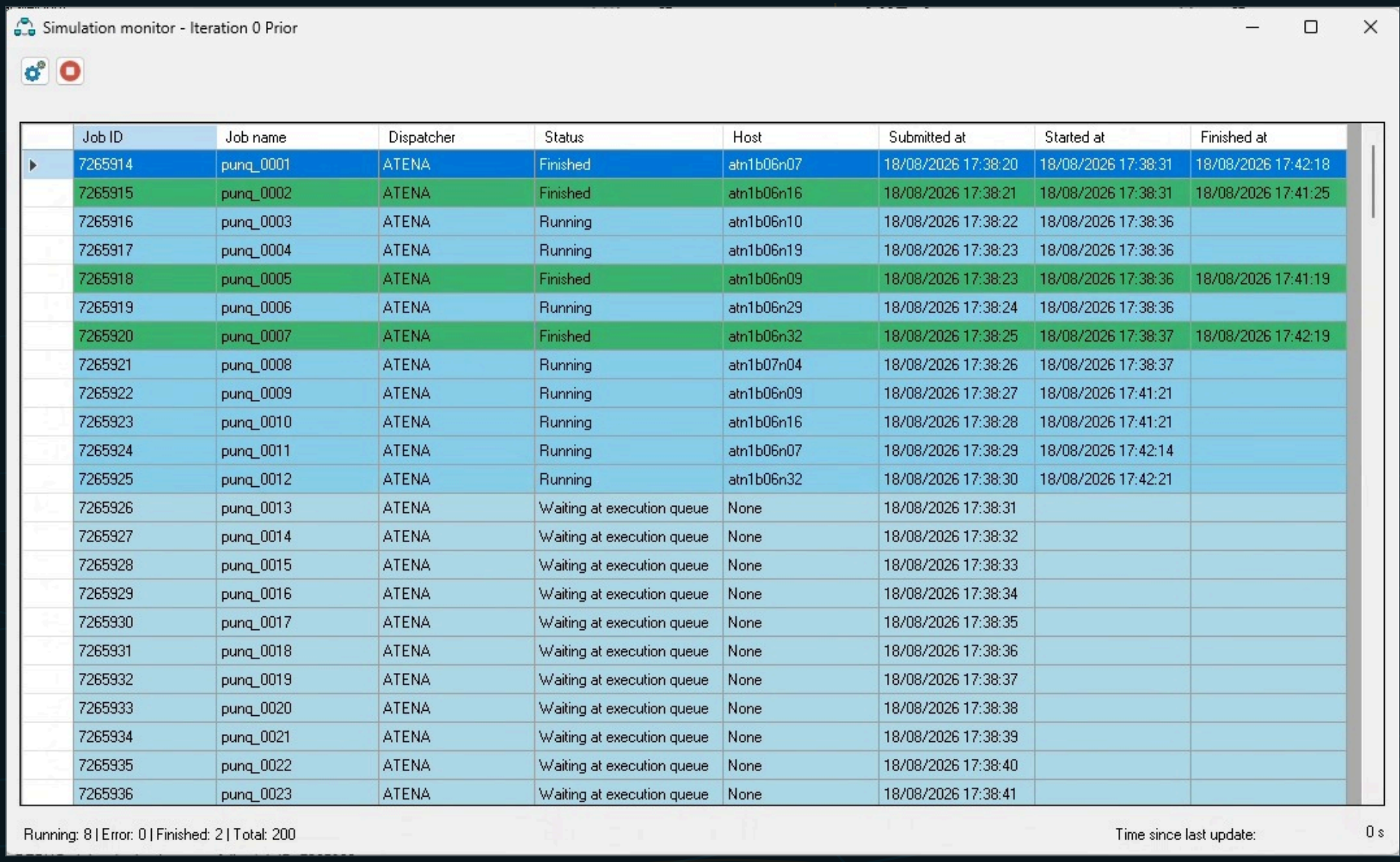


Fig. 02 · Parallel ensemble execution orchestrated from Petrel.

Built for the cluster, not the laptop.

BR-Kalman runs realizations in parallel on HPC clusters, drives the CMG simulator family, and already runs in the SLB DELFI environment, which enables hybrid workflows between the local Petrel installation and the cloud.

OCEAN FRAMEWORK | CMG IMEX · GEM · STARS | HPC CLUSTERS | DELFI READY | CUDA

DEEPSOFT

What changed for the reservoir team

Probabilistic calibration

Multiple calibrated models honoring different data types at once, giving a statistical basis for uncertainty quantification instead of a single best fit.

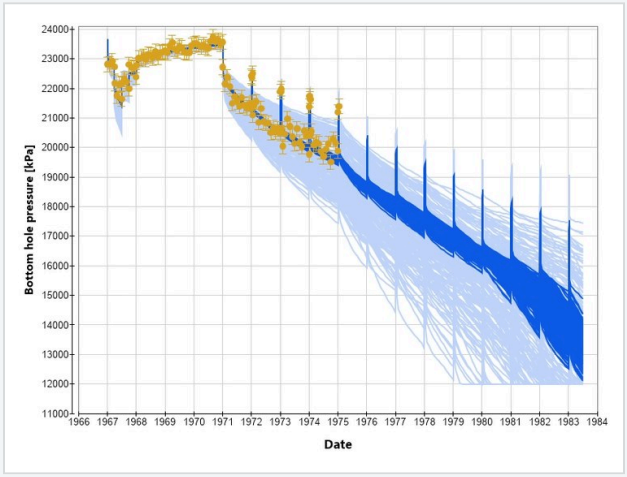
Native integration

The whole cycle, from parameterization to results analysis, runs inside Petrel and stays coherent with the project's geological and simulation models.

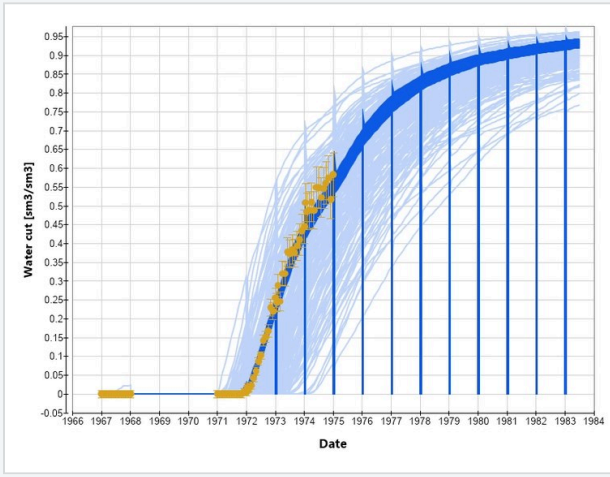
Scalability

Parallel ensemble execution on HPC clusters with CMG support, for complex reservoirs carrying large numbers of uncertain parameters.

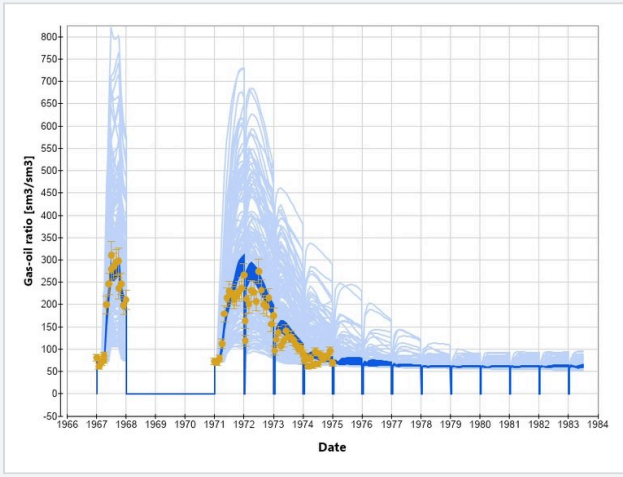
BOTTOM HOLE PRESSURE · PRO-5



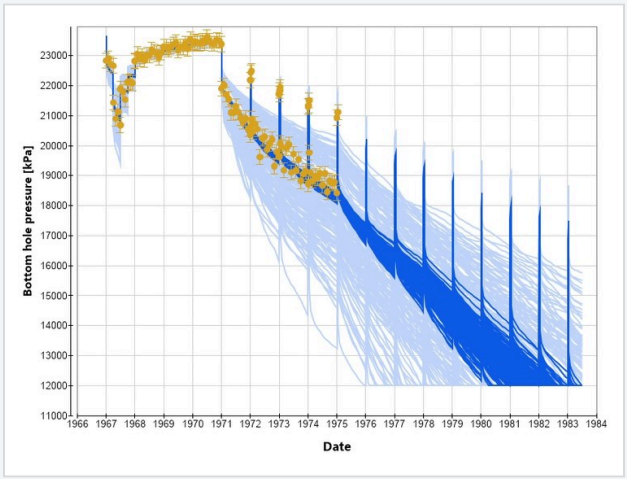
WATER CUT · PRO-11



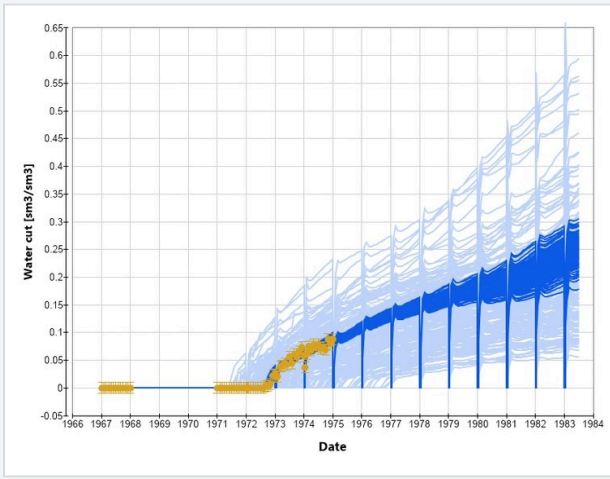
GAS OIL RATIO · PRO-4



BOTTOM HOLE PRESSURE · PRO-12



WATER CUT · PRO-15



GAS OIL RATIO · PRO-15

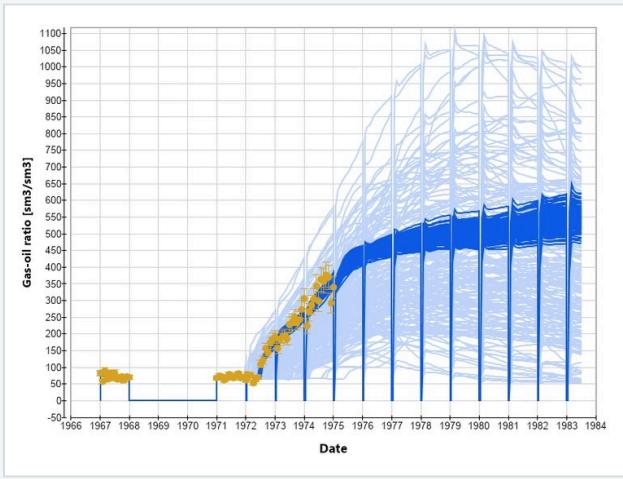


Fig. 03 · Observed data in orange, prior ensemble in light blue, updated ensemble in dark blue. Selected wells of the PUNQ model.

LONG-TERM PARTNERSHIP

DEEPSOFT

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500
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1500
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3 + 5 years

Three years of development, renewed as a five year Technological Order contract

Continued support, evolutionary maintenance and new BR-Kalman features, with the plug in already running in the SLB DELFI ecosystem. Eight years of uninterrupted work on the same tool. The agreement consolidates the collaboration with CENPES on a project of high relevance to the Oil & Gas industry.

07/09

PARTNERSHIP

DEEPSOFT

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“BR-Kalman has made it feasible to apply advanced data assimilation methods directly within Petrel's workflows, integrating production, 4D seismic and well profile data in a single tool.”

It allows us to calibrate our models with greater agility and quantify uncertainties with the statistical rigor that decisions in complex reservoirs demand.

Dr. Alexandre Emerick

Research Leader, BR-Kalman project · CENPES / Petrobras

The research is theirs. Turning it into software is our part.

BR-Kalman is being developed in partnership with Petrobras. The data assimilation methods come from the CENPES research team, and DeepSoft engineers the software that turns them into a tool running inside Petrel, on the cluster, every day. The work continues.

BR-Kalman itself is Petrobras software. What DeepSoft offers is the engineering: Petrel plug ins for teams that already own the science and need it to become production software.

SERVICES

Petrel plug in development

CONTACT

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LINKEDIN

/company/deepsoft

DEEPSOFT

Ocean Framework · C# · .NET · C++ · CUDA