UNISIM ON-LINE
Year 19, Number 3 | 157th edition | May, 2024

“The seismic data provides spatially rich information related to the reservoir fluid distribution and this allows the assimilation method to better detect the influence between a given attribute and the fluid movement.”

Specials interests:

- UNISIM
- UNISIM Publications
- Reservoir Simulation and Management Portal
- Previous Issues

Links:

- UNICAMP
- Cepetro
- Petroleum Engineering Division
- School of Mechanical Engineering
- Petroleum Sciences and Engineering

Graduate:

Petroleum Sciences and Engineering: interested in Masters and PhD in the Simulation and Oil Reservoir Management area click here.

Performance Assessment of an Iterative Ensemble Smoother with Local Analysis to Assimilate Big 4D Seismic Datasets Applied to a Complex Pre-Salt-Like Benchmark Case

Célio Maschio

Introduction

Data assimilation (DA) uses dynamic data, such as production, pressure, and 4D seismic (4DS), to reduce uncertainties and improve the quality reservoir models and production forecast. Well data is more detailed in time and 4DS is more detailed in space, so both types of data are important and play complementary roles. Incorporating 4D seismic (or time-lapse seismic, TLS) in the data assimilation makes the process more complex due to the higher amount of data to be assimilated, requiring more robust methods and better computational resources (processing capacity and memory). The development and application of permanent seismic monitoring technologies have increased in the last years, with two outcomes. On one side, these technologies improve the overall seismic quality, in terms of signal resolution and repeatability. On the other hand, a massive amount of data is generated from the multiple monitors, making the incorporation of 4DS data in the DA process even more complex. Therefore, it is necessary to seek robust DA methods capable of dealing with such a huge amount of data effectively and efficiently.

This text summarizes the paper published by Maschio et al. (2024), which aims to assess the performance of an iterative ensemble smoother method, named Subspace Ensemble Randomized Maximum Likelihood with a local analysis scheme (SEnRML-LA) implemented by Silva Neto et al. (2021) to assimilate a big datasets. The main advantage of the method SEnRML-LA is its efficiency in terms of memory consumption, which makes it very suitable to assimilate huge volumes of observed data. A detailed analysis of the computational requirements with increasing data-set size was performed by Silva Neto et al. (2021). The authors made it clear the advantages of the SEnRML-LA method compared to other ensemble-based methods. Details about the method can be found in Silva Neto et al. (2021).

Application

The case studied in this work is the UNISIM-IV, a reservoir model based on the UNISIM-III benchmark case representing a giant field composed of fractured carbonate karst reservoir from the pre-salt province. The production strategy consists of 17 vertical wells, eight producers and nine injectors. The recovery strategy in this benchmark case assumes that the injectors reinject all the produced gas in the reservoir. Furthermore, each injection well operates in WAG cycles of 6 months, except for well I16, which only injects gas.

The observed data assimilated in this work was generated from the UNISIM-IV-R and is composed of well and 4D seismic data for seven pairs of monitors. The 4DS data are the impedance ratios (between two consecutive monitors) in 15 seismic horizons, totaling 105 maps to be assimilated. To our best knowledge, this is state of the art in terms of practical applications in data assimilation. There are a total of 86004 data points to be assimilated: 69426 related to TLS data plus 16578 related to well data. It is worth mentioning that this amount of data is very challenging for most ensemble-based assimilation methods.

The case related to the simultaneous assimilations of 4DS and production data is named ”TLS-Well” and the case assimilating only well data (used for comparison purposes) is named ”Well”.

Results

Figure 1 shows the NQDS for 3 producers (P14, P15, and P16), indicating that TLS data improved the well data match. Figure 1 also shows the water rate curves for P16 comparing the prior ensemble (gray) and the posterior ensemble for the cases TLS-Well (blue) and Well (green). Analyzing the posterior simulation curves, one can see that there is a trend of underestimation of water production for the Well case, as also depicted in the NQDS plot. On the other hand, the inclusion of the seismic data improved the well data match. The seismic data provides spatially rich information related to the reservoir fluid distribution and this allows the assimilation method to better detect the influence between a given attribute (relative permeability, for example) and the fluid movement, improving as a consequence the well data match.

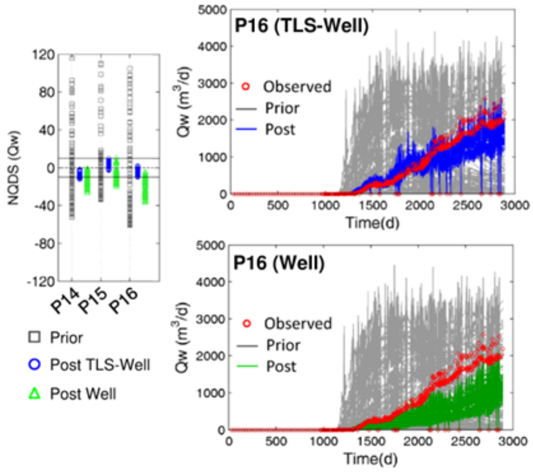

Figure 1: *NQDS and water rate (P16).*

Figure 2 shows the time-lapse maps (acoustic impedance ratios) comparing the observed map with the prior mean, and the posterior mean for the cases TLS-Well and Well. For the Well case, we run the reservoir simulations again for the models of the last iteration to generate the data necessary to compute the impedance ratios, since during the data assimilation for this case only well data were generated. The TLS-Well posterior mean is more similar to the observed map compared the Well posterior mean.

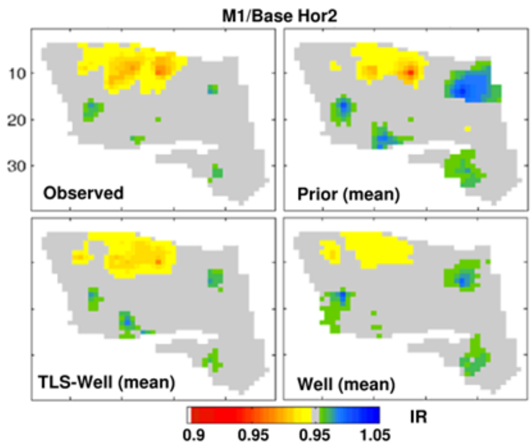

Figure 2: *Impedance ratio for the map “M1 H2” (Monitor1 divided by the Baseline, Horizon 2).*

Figure 3 shows the NQD (|NQDS|) for six pairs of monitors, including M1 H2. Notably, the NQD for the case TLS-Well is lower that the NQD for the case Well, showing that the case assimilating TLS and wells together provides better results comparing to the case assimilating only well data.

Figure 4 shows faults transmissibility multiplier (TM), indicating that the Well case practically maintained the prior distribution for the Fault 1, meaning that the wells data was not enough to constrain this fault transmissibility and the method (SEnRML-LA) correctly maintained

"The problem solved in this work with the SEnRML-LA is the state of the art in data assimilation process. It was possible to assimilate all the data simultaneously, including the 105 horizons for the TLS and the wells' production and pressure data."

UNISIM opportunities:

If you are interested in working or developing research in the UNISIM Group, please contact us.
For further information, [click here](#).

Research in Reservoir Simulation and Management Group

Petroleum Engineering Division - Energy Department
School Of Mechanical Engineering
Center for Energy and Petroleum Studies
University of Campinas
Campinas - SP

Phone.: 55-19-3521-1220

unisim@cepetro.unicamp.br

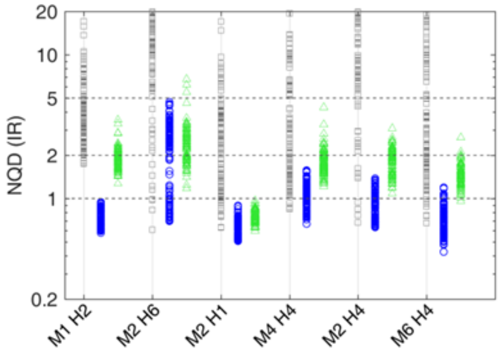

***Figure 3**: NQD (|NQDS|) for six pairs of monitors.*

the uncertainty for this attribute. On the other hand, the spatial information from the TLS enabled the uncertainty reduction of this fault (TLS-Well case). Fault 2 is located in a region of the reservoir close to the wells' locations. This explains why both cases reduced the uncertainty in the transmissibility multipliers of this fault similarly.

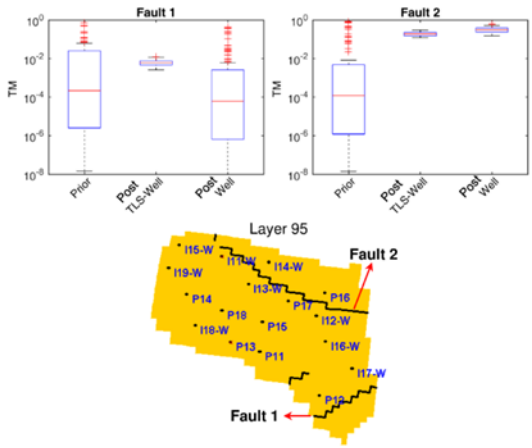

***Figure 4**: Faults transmissibility multiplier (TM).*

Figure 5 shows a forecast example of a well opened after the end of the history period, showing how the models can predict a new well performance (without history).

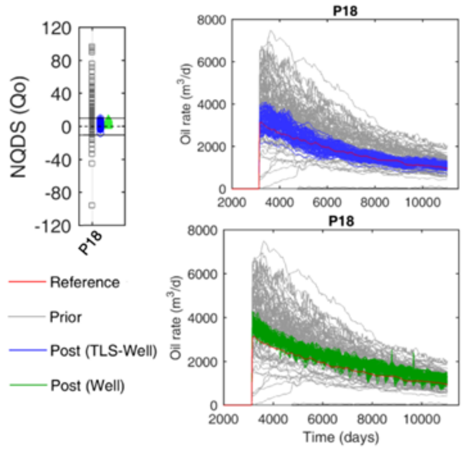

***Figure 5**: Example of forecast result.*

Note, in Figure 5, that the TLS-Well posterior curves are more symmetrically distributed around the reference. Another observation is that the oscillations in the P18 posterior curves for the case Well do not appear in the TLS-Well case, in which the behavior of the models is very similar to the reference solution.
More details and results can be found in the full version of the paper ([Maschio et al., 2024](#)).

Conclusions and Final Remarks

In this work, we performed well and time-lapse seismic data assimilation in a realistic case that represents challenges similar to a Brazilian pre-salt reservoir. We employed the SEnRML method with local analysis to assimilate seven pairs of seismic monitors together with the well data. The specific conclusions are:

- The method SEnRML with local analysis (SEnRML-LA), proposed by Silva Neto et al. (2021), is able to handle big data sets originated from multiple monitor acquisitions, being an alternative to solve practical problems involving permanent seismic monitoring technologies.
- The problem solved in this work with the SEnRML-LA is the state of the art in data assimilation process. It was possible to assimilate all the data simultaneously, including the 105 horizons for the TLS and the wells' production and pressure data.
- The data assimilation was successful, in terms of the quality of the results and method performance. Good convergence was verified for both objective functions (seismic and wells) for the TLS-Well case. For the Well case, good convergence was also verified for the well objective functions.
- Finally, this work showed the benefit the TLS data gathered from multiple monitors using permanent monitoring technologies and proved the robustness of the SEnRML-LA method in assimilating all seismic monitors simultaneously.

Acknowledgments

We conducted this work with the support of Libra Consortium (Petrobras, Shell Brasil, TotalEnergies, CNOOC, CNPC, and PPSA) within the ANP R&D levy as "commitment to research and development investments" (5850.0105307.17.9) and Energi Simulation. The authors are grateful for the support of the Center of Petroleum Studies (CEPETRO-UNICAMP/Brazil), the Department of Energy (DE-FEM-UNICAMP/Brazil), and the Research Group in Reservoir Simulation and Management (UNISIM-UNICAMP/Brazil). Also, a special thanks to CMG and Schlumberger for software licenses.

References

Maschio, C.; Silva Neto, G. M.; Davolio, A.; Rios, V. S.; Schiozer, D. J. 2024. Performance assessment of an iterative ensemble smoother with local analysis to assimilate big 4D seismic datasets applied to a complex pre-salt-like benchmark case. Journal of Geophysics and Engineering, 21 (1), 68–97. https://doi.org/10.1093/jge/gxad099

Silva Neto, G. M.; Soares, R. V.; Evensen, G.; Davolio, A.; Schiozer, D. J., 2021. Subspace Ensemble Randomized Maximum Likelihood with Local Analysis for Time-Lapse-Seismic-Data Assimilation. SPE J. 1–21. https://doi.org/10.2118/205029-PA

About the author:

Célio Maschio is graduated in Mechanical Engineering from UNESP, holds a MS and a PhD degree in Mechanical Engineering from UNICAMP. He is a researcher at UNISIM/CEPETRO/UNICAMP since 2001 developing research and leading projects focused on data assimilation for uncertainty reduction.