Year 11, Number 11
107th edition
November, 2016

UNISIM ON-LINE

Methodology to Compare Probabilistic data from 4D Seismic and Reservoir Simulation Models

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Introduction

Many methodologies that uses 4D seismic (4DS) information for reservoir calibration, consider 4DS data as deterministic dynamic observed data. However, 4DS data also have uncertainties due to, for instance, noise, acquisition problems, processing algorithms, upscaling. Probabilistic approaches can incorporate the variability in the 4DS but it is necessary to develop methodologies to compare 4DS data with reservoir simulation results. This work introduces a methodology to integrate maps of pressure changes (or any other 4DS attribute) obtained from a probabilistic 4DS inversion and from multiple simulation models (SIM). The proposal of the study is to create a methodology to correlate data sets from seismic and simulation considering their uncertainties, to measure the misfit between them and to identify the most precise[1] information (4DS or SIM) in each reservoir location.

Methodology

Figure 1 illustrates a very simplified reservoir model, with 12 blocks. The information used in the methodology is Δp maps.

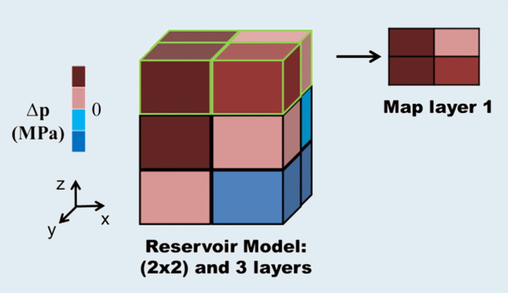

Figure 1: Illustration of the "map" used in the proposed methodology.

As we have multiple simulation models, for each position of each reservoir layer we can obtain a vector of dynamic changes, as Figure 2 shows for layer *i*, i.e.:

$SIM\Delta p\_i = \{ \Delta p\_i_{SIM1}; \Delta p\_i_{SIM2}; \ldots \Delta p\_i_{SIMm} \}$

In the same way, we can build a similar vector using probabilistic 4DS data:

$SEIS\Delta p\_i = \{ \Delta p\_i_{SEIS1}; \Delta p\_i_{SEIS2}; \ldots \Delta p\_i_{SEISm} \}$

As we are comparing both vectors in every reservoir position, it is important to have seismic and simulation data at the same scale. In this work we selected the simulation scale.

Using the kernel density estimator (KDE) we can calculate the probability density function of every vector. The KDE is a nonparametric method to calculate the probability of a certain vector (Assunção, 2016). From the SIMΔp_i shown above, we obtain the PDF_{SIM} and from SEISΔp_i we generate the PDF_{SEIS}.

Using these PDFs, we can compare them calculating the overlapping interval (OVLC), Figure 3a. After identifying the OVLC, we can calculate the proportion of each PDF within the OVLC (Figure 3b and 3c). The parameters that measure these proportions were called OVL_{SIM} (proportion of PDF_{SIM} within OVLC) and OVL_{SEIS} (proportion of PDF_{SEIS} within OVLC). As an example, in Figure 3, we could say that the OVL_{SIM} is approximately 30% (Figure 3b) and the OVL_{SEIS} 100% (Figure 3c).

We can define four possible regions when PDF_{SIM} and PDF_{4DS} are compared. Those regions are shown in Figure 4:

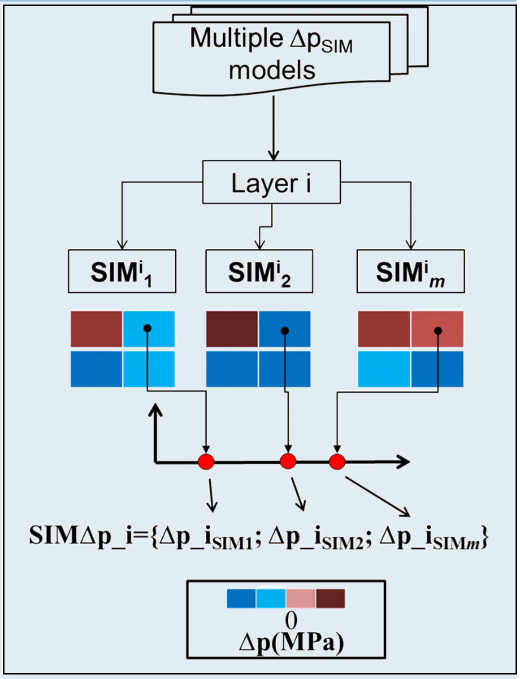

Figure 2: Illustration of the probabilistic data from reservoir simulation models.

(1) PDF_{SIM} and PDF_{SEIS} in agreement (OVL_{SIM}>80% and OVL_{SEIS}>80%);
(2) PDF_{SIM} more precise than PDF_{SEIS}, (OVL_{SIM}>80% and OVL_{SEIS}<80%);
(3) PDF_{SIM} and PDF_{SEIS} in disagreement (OVL_{SIM}<80% and OVL_{SEIS}>80%);
(4) PDF_{SEIS} more precise than PDF_{SIM} (OVL_{SIM}<80% and OVL_{SEIS}>80%).

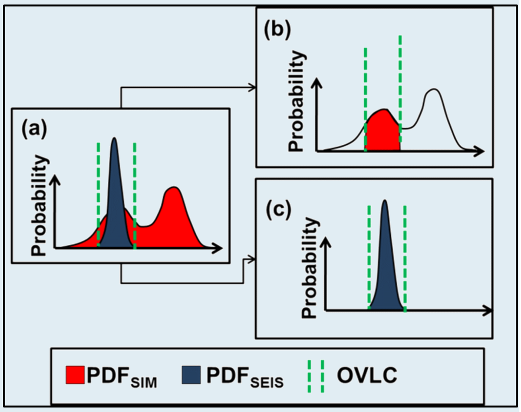

Figure 3: Calculating the OVLC, OVL_{SIM} and OVL_{SEIS}.

The procedure must be performed for each reservoir position (in our case, each grid block). Thus, we will have a map showing one out of the four possible combinations of the PDF_{SIM} and PDF_{SEIS} in each reservoir position.

Note that, instead of Δp maps, the proposed methodology can be performed using ΔS_w maps or any other 4DS attribute, such as impedances. The choice of which attribute to use depends on the data available.

Application

We used a synthetic reservoir with moderate complexity, 7 predominant uncertainties (including distribution of facies, permeability and porosity) and 11 producers and 8 water injectors. Figure 5 illustrates the distribution of facies of the reservoir.

500 Δp_{SIM} maps generated at an intermediate iteration of a probabilistic history-matching procedure using

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[1] *Precision is the closeness of two or more measurements to each other. In other words, it refers to the data variability: high precision means low variability and vice-versa.*

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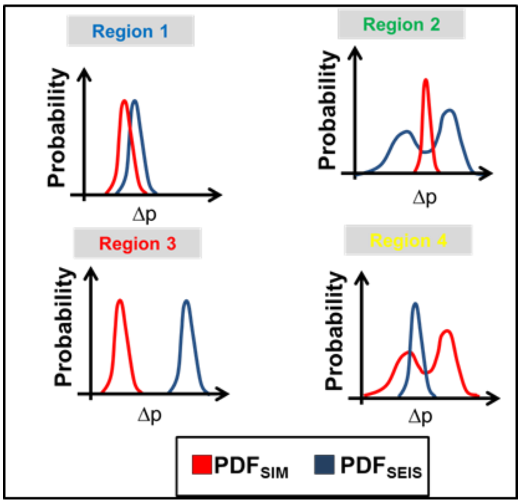

Figure 4: *Possible combinations of PDF_{SIM} and PDF_{SEIS}.*

only wells are the probabilistic reservoir simulation data used in the present work. The 4DS data were obtained from a probabilistic seismic inversion, which generated 500 Δp_{SEIS} maps. Assunção (2016) showed more details of the data and methodology.

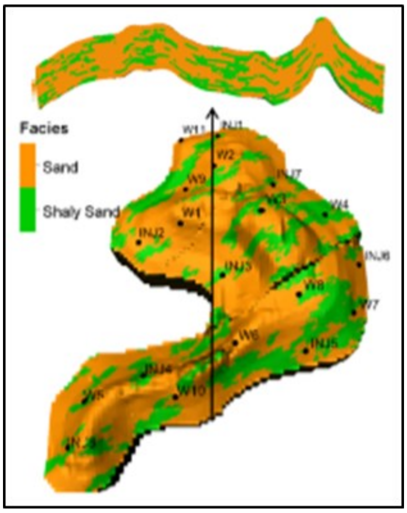

Figure 5: *Distribution of facies of the studied reservoir*

Results

The resulting maps can be used to compare the seismic and simulation information in each reservoir position. As shows Figure 6, we have some locations classified as region (1), indicating that 4DS and SIM are properly calibrated, once they are presenting similar behavior. There are several grid blocks in region (4), that is, reservoir locations where 4DS could bring some information to calibrate the reservoir simulation models, because 4DS data are more precise than SIM in this region. Note that instead of using 4DS in the entire reservoir, we are using only where it could bring some additional information, which can save time in integration analysis.

Moreover, we can also identify critical reservoir zones for reevaluation (region 3), since the high disagreement between simulation and seismic data can be an indication of the presence of "unknown unknowns".

In this specific case, Region 2 appeared only in a few reservoir positions, showing that quality of the 4DS data is better than simulation data. However, in other study cases, it may appear in more positions.

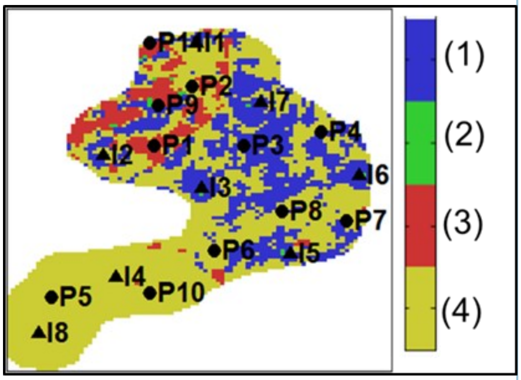

Figure 6: *Map generated by the methodology*

Conclusions

This work proposed a methodology to compare probabilistic dynamic change maps from 4DS and reservoir simulation models. The methodology generates as diagnostic tool a map, indicating the quality of the matching between seismic and simulation data in every reservoir position. This tool is a new way to evaluate the information from 4DS and simulation data and can be useful to understand the reservoir properties in the parameterization phase of the history matching procedure (a complex process) and to reinterpret seismic data considering the engineering information.

Acknowledgments

We would like to thank UNISIM, DE-FEM, CEPETRO, BG Brazil, ANP and CAPES for supporting this work. We also thank CMG and Schlumberger for software licenses.

Reference

ASSUNÇÃO, G.S.C. (2016). A METHODOLOGY TO COMPARE PROBABILISTIC DATA FROM 4D SEISMIC AND RESERVOIR SIMULATION MODELS. Master's dissertation, University of Campinas (UNICAMP). Campinas, Brazil.

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