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“Reservoir and production facilities models are characterized by uncertain properties and behavior. Therefore, it may be necessary to reduce uncertainty in both reservoir and production system models to improve short- and medium-term production forecast.”

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Methodology for Data Assimilation in Reservoir and Production System to Improve Short- and medium-Term Forecast

Célio Maschio

Introduction

In a context of integrated production systems involving the reservoir, wells, and production facilities, the quality of production forecast depends not only on the quality of reservoir models and well productivity/injectivity but also on the boundary condition for the future extrapolation which, in turn, depends on the production system characteristics. Reservoir and production facilities models are characterized by uncertain properties and behavior, such as porosity and permeability, among others, for reservoir; pipeline roughness, multiphase flow behavior in pipes, among others, for the production system. Therefore, it may be necessary to reduce uncertainty in both reservoir and production system models to improve short- and medium-term production forecast.

This text presents a summary of the work published by Maschio et al. (2021) which proposes a methodology for dynamic data assimilation to reduce uncertainty in both reservoir and production system models to improve short- and medium-term production forecast.

The motivation of the work is the lack of a methodology that treats uncertainties in both reservoir and production systems in an integrated manner, dealing with multiple solutions for both systems and assessing the impact of the integration in short-term production forecast.

In this context, the main objective is to propose a methodology to deal with the data assimilation process comprising reservoir model and production system while reducing uncertainties in both systems to improve short-term production forecast. One of the main contributions of this work is an approach that considers the inclusion of Vertical Lift Performance (VLP) tables (resulting from the production system data assimilation) in the reservoir data assimilation process.

Methodology

The methodology proposed in this work is composed of four main steps, described as follows:

- Step 1: the first step consists of the production system data assimilation process, using observed data to reduce the uncertainty of the production system variables (uncertain attributes). The premise of our methodology is that, as the production system calibration process is an inverse problem, multiple solutions can be obtained. Thus, our objective is to apply a probabilistic approach to assimilate the observed data and find multiple solutions. The main reason of using a probabilistic approach is that there are uncertainties associated to the production system parameters.
- Step 2: the second step consists of using the best solutions obtained in Step 1 to generate Vertical Lift Performance (VLP) tables. Each solution is submitted to the tubing pressure calculator and for each solution a VLP table is generated.
- Step 3: the third step consists of the reservoir data assimilation process. In this Step, two approaches are compared. In the approach A1, one VLP table (per each well) is imposed in the production forecast. This VLP table comes from the best solution for the production system data assimilation after applying the NQDS (Normalized Quadratic Deviation with Sign) filter. For the approach A2, which is the main innovative contribution of this work, first we select a set of VLP tables (one set per producer well) generated in Step 2. Thus, the set of VLP tables are used as an uncertain attribute during the reservoir data assimilation process.
- Step 4: the fourth step comprises the analysis of the overall results, focusing on short- and medium-term production forecast. After Step 3, we apply a NQDS filter to select the best reservoir models from the posterior or set of models to analyze the quality of the production forecast. These models are extrapolated from the end of history to the forecast period imposing the VLP tables generated in Step 2.

It is worth mentioning that, since we are fixing a boundary condition (in this work measured liquid rate is being imposed to the wells during the history period), both system (reservoir and production system) can be solved separately, that is, the data assimilation process for the reservoir and production system can be performed independently of each other.

Application and results

The methodology proposed in this work was applied to the UNISIM-I-MI benchmark, which is derived from a case study for optimization of management variables of an oil production strategy. UNISIM-I-MI, derived from UNISIM-I-M, is a field management case in which the production system simulation model is integrated with the reservoir simulation model.

Firstly, a comparative analysis showing the influence of the production system and the reservoir in the production forecast is presented. Figure 1 (a) shows the NQDS for two sets with 20 models each before data assimilation (prior). The first set (RES) is composed of 20 reservoir models with one fixed VLP table and the second set (PS) is composed of one reservoir model with 20 different VLP tables.

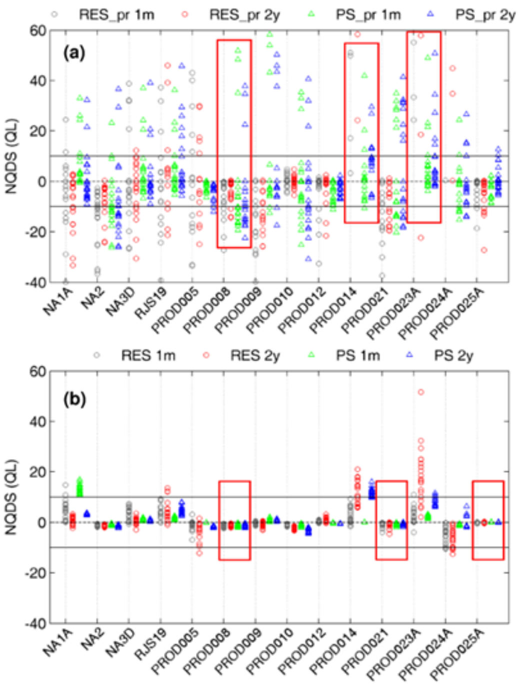

***Figure 1**: Influence of the production system and reservoir in the forecast period.*

Figure 1 (b) also shows two sets with 20 models each, however, after data assimilation (post). In these plots, the NQDS is computed after 1 month (short-term) and 2 years (medium-term) of forecast. In both cases (prior and post) it is possible to note that the variability in the forecast due to the VLP variation, that is, fixing the reservoir model (PS) is similar to the variability due to the reservoir properties variation, fixing the VLP table (RES), in both short- and medium-term forecast.

Figure 2 shows the quality of the production forecast (short -term) as a function of the production system’s matching quality. Each ensemble is formed using five matched reser-

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voir models filtered from the posterior ensemble (resulting from the data assimilation process, approach A2) combined with 20 VLP tables selected according to five different cut-off values of NQDS (1, 3, 5, 10, 20, and 50). Each ensemble is labeled using the letters PS (Production System) followed by the respective NQDS cut-off value. Clearly, the forecast quality worsens as the production system's matching quality get worse.

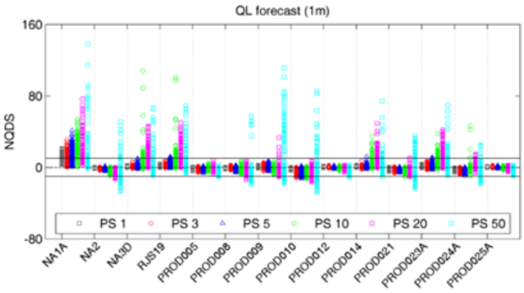

Figure 2*: Influence of the production system's matching quality in the forecast quality.*

Figure 3 shows the forecast (liquid rate) of one of the producer wells (NA3D) comparing Approaches A1 and A2. It is possible to observe that the models related to the Approach A2 (filtered models) properly encompass the reference case and, more important, the strong discontinuities observed in Approach A1, which jeopardize the short-term forecast, do not appear in Approach A2, in which the forecast is more coherent.

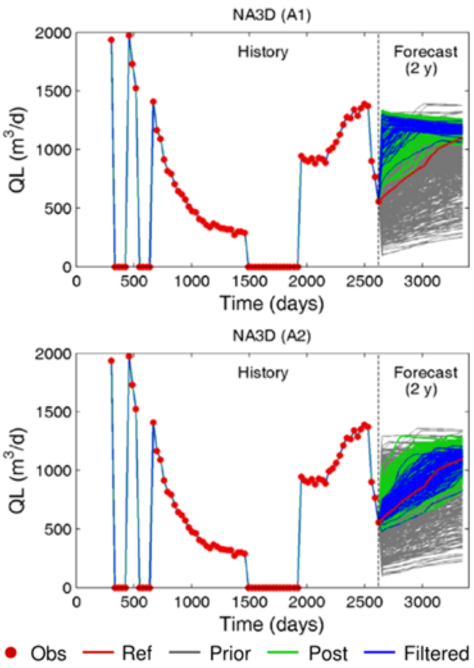

Figure 3*: Comparison of Approaches A1 and A2 (forecast results).*

Figure 4 shows NQDS for all producer wells related to all four forecast periods analyzed (1 month, 6 months, 1 year and 2 years). In general, the NQDS for the Approach A2 is smaller and more uniformly distributed inside the shown rage when compared to the Approach A1.

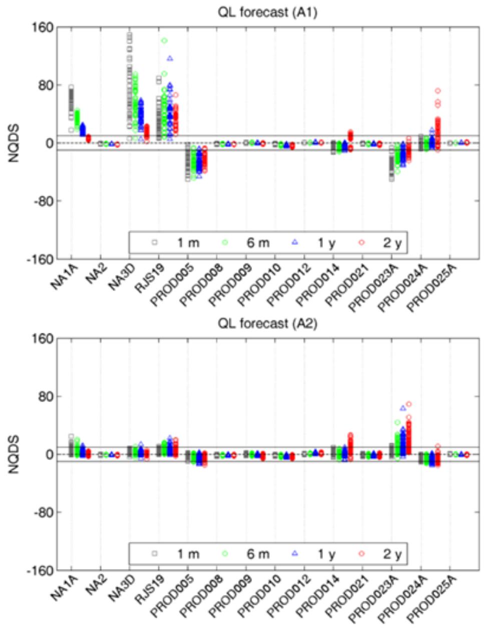

Figure 4*: NQDS for all producer wells related to the four forecast periods analyzed.*

Conclusions

A methodology to integrate the data assimilation process comprising reservoir and production system models' uncertainties was presented in this work. The main focus of the work is on the uncertainty reduction for both reservoir and production systems, improving short- and medium-term production forecasts. The specific conclusions and remarks are:

- Overall, approach A2 provided better results than approach A1, meaning that the inclusion of VLP tables (resulting from the production system data assimilation) during the reservoir data assimilation was beneficial to the process;
- We showed that by focusing on the short- and medium-term production forecast, the production system uncertainties and the reservoir uncertainties cause variability in production forecast in the same order or magnitude. Based on this, it is recommended to consider multiple solutions of the production system in the production forecast;
- This work showed that it is important to perform data assimilation process in both reservoir and production systems to obtain more reliable short- and medium-term production forecasts.

More details and results can be found in the full version of the paper.

Reference

Maschio, C.; Hohendorff Filho, J. C. V.; Schiozer, D. J. 2021. "Methodology for Data Assimilation in Reservoir and Production System to Improve Short- and Medium-Term Forecast", Journal of Petroleum Science and Engineering, v. 207, 109083 (pp. 1-21)
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