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Multi-Data Reservoir History matching of Crosswell Seismic, Electromagnetics and Gravimetry Data

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SUMMARY

Reservoir engineering has become of prime importance for oil and gas field development projects. With rising complexity, reservoir simulations and history matching have become critical for fine-tuning reservoir production strategies, improved subsurface formation knowledge and forecasting remaining reserves. The sparse spatial sampling of production data has posed a significant challenge for reducing uncertainty of subsurface parameters. Seismic, electromagnetic and gravimetry techniques have found widespread application in enhancing exploration for oil and gas and monitor reservoirs, however these data have been interpreted and analyzed mostly separately rarely utilizing the synergy effects that may be attainable. With the incorporation of multiple data into the reservoir history matching process there has been the request knowing the impact each incorporated observation has on the estimation. We present multi-data ensemble-based history matching framework for the incorporation of multiple data such as seismic, electromagnetics, and gravimetry for improved reservoir history matching and provide an adjoint-free ensemble sensitivity method to compute the impact of each observation on the estimated reservoir parameters. The incorporation of all data sets displays the advantages multiple data may provide for enhancing reservoir understanding and matching, with the impact of each data set on the matching improvement being determined by the ensemble sensitivity method.

Introduction

Reservoir engineering has assumed an unprecedented importance for oil and gas field development projects. Cost increases and production in ever more challenging environments have necessitated optimizing reservoir production and maximizing recovery from reservoirs. With rising complexity, reservoir simulations and history matching have become critical for fine-tuning reservoir production strategies, improving understanding of the subsurface formation and forecasting remaining reserves. Production data have long been incorporated for matching subsurface reservoir parameters, however the sparse spatial sampling has posed a significant challenge for reducing uncertainty of subsurface parameters (Aanonsen, Oliver, Reynolds, & Vallis, 2009). Seismic, electromagnetic and gravimetry techniques have found widespread application in enhancing exploration for oil and gas and monitor reservoirs, however these data have been interpreted and analyzed mostly separately rarely utilizing the synergy effects that may be attainable. With the recent progress in incorporating multiple data into the reservoir history matching process and the consequently significant matching improvements, there has been the focus to determine the impact each incorporated observation has on the forecast step. We present multi-data ensemble-based history matching framework for the incorporation of multiple data such as seismic, electromagnetics, and gravimetry (Katterbauer, Hoteit, & Sun, 2013) for improved reservoir history matching and provide an adjoint-free ensemble sensitivity method to compute the impact of each observation on the estimated reservoir parameters. The incorporation of all data sets displays the advantages multiple data may provide for enhancing reservoir understanding and matching, with the impact of each data set on the matching improvement being determined by the ensemble sensitivity method.

Methodology

The developed framework is presented in Fig. 1 and based upon the template of O. Leeuwenburgh (Leeuwenburgh, 2013) with major modifications been performed. The framework integrates a 2D finite difference black oil reservoir simulator MRST (Lie, Krogstad, Ligaarden, & Others, 2012) together with 4D seismic and electromagnetic survey modules, that are complemented by a time lapse gravity survey module. The reservoir simulator and the survey modules are then interfaced to the EnKF together with a sensitivity analysis module.

Results

We present in Figure 2 the oil production rates for the four producer wells and a regression analysis for determining the relationship between the estimated permeability field versus the true field. Comparing the individual wells, the incorporation of seismic, EM and gravimetry data reduce significantly the ensemble spread, and aligns the individual ensembles closer to the real production curve (red), that subsequently reduces the uncertainty as seen by the reduced ensemble spread. The impact is especially outlined for the individual ensemble production rates for the first well, where some of the ensembles exhibit a steep raise and subsequent drop in the rate for the history matching of only production data, that is not observed in the real production curve. In contrast, this ensemble development is not observed when incorporating Seismic, EM and Gravimetry data. Comparing the Root Mean Squared errors (RMSE) for the two cases indicates that the additional incorporation of Seismic, EM and Gravimetry data leads to a reduction in the RMSE error by 67.82 %. A further aspect is the strong improvement in the estimation of the permeability field that exhibits a stronger relationship between the permeability values of the true field and the estimated ones. The improvement is displayed in the higher R² value of the linear regression curve, implying that estimated permeabilities align closer to the true permeabilities.

Conclusions

Multi-Data incorporation has become essential for the Reservoir Engineers to optimize Reservoir production and understand more profoundly the Reservoir. The presented work displays the

significant benefits an incorporation of multiple data may have on improving Reservoir forecasting and return on investments.

Figure 1 Multi-Data History Matching Framework assimilating production, seismic, electromagnetic and gravimetry data via an Ensemble Kalman Filter and analysis of the sensitivity of the analysed state with respect to each observational data.

Figure 2 Comparison of the oil production levels for the incorporation of Seismic, Electromagnetic and Gravimetry Data (top, left) and without (top, right) and a regression analysis for the permeability estimates. A significant reduction in the Ensemble spread is achieved with improved history matches.

References

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