Year 10, Number 4
91st edition
March, 2015

UNISIM ON-LINE

UNICAMP
UNISIM

> *"Integration of geostatistical modeling with history matching has been subject of interest in the last years. It allows the creation of multiple scenarios, honoring geologic, petrophysic and geophysic knowledge, using data from well logs and extrapolating it for the entire reservoir."*

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.

Integration of Geostatistical Modeling With History Matching

Gonçalo Soares de Oliveira

Introduction

Decision-making is only possible with a calibrated reservoir model. The calibration, also known as history matching, is an iterative process where different parameters are modified in order to change the behavior of the reservoir model, so that history data and simulated results have an acceptable difference, enabling us to classify the model as representative of reality.

One of the main reservoir uncertainties is the distribution of static rock properties and integration of geostatistical modeling with history matching has been subject of interest in the last years. It allows the creation of multiple scenarios, honoring geologic, petrophysic and geophysic knowledge, using data from well logs and extrapolating it for the entire reservoir. The geostatistical realizations have a great influence in dynamic data and reservoir model behavior. It defines events like barriers and high permeability channels that have a great effect in flux.

The objective of this work is to create a methodology to integrate geostatistical modeling with history matching, allowing the reduction geostatistical properties spatial distribution uncertainty.

Two approaches were tested, one to use when the amount of data is scarce, making a global perturbation and another when that allows perturbation of regional areas of the reservoir improving the match in chosen wells without mismatching other.

Methodology

In history matching process, the treatment of heterogeneity can be done globally or regionally according to the objective intended, the life-time of the field and the amount of available data.

Global perturbation method should be used when data available is scarce. On the other hand, regional perturbation method, has more advantages when the number of wells increase and the life-time of the field difficult the match of history data.

Both methods presented follow the same principle described in **Mata-Lima (2008)**, using Direct Sequential Co-simulation to modify images previously generated.

Sequential Gaussian Co-Simulation was initially developed to characterize a set of attributes that have some correlation between them. To use co-simulation 2 parameters must be defined, a secondary image and a correlation coefficient that varies between 0 and 1. In Global method the procedure should follow:

1) Quantify the quality of each image from the entire set, with the Global Objective Function (Equation 1), it takes into account all parameters and wells;
2) Select the best image (minimum value of OF);
3) Select a correlation coefficient between 0.7 and 0.9, as defended by **Mata-Lima (2008)**;
4) Use the image and the correlation coefficient to generate a new set of reservoir images using co-simulation.

Global Objective Function (Equation 1)

The iterative process continues until an acceptable minimum or a plateau value is reached.

In the regional method, the optimization is done locally which by each well can be matched individually, ensuring solution convergence for an acceptable limit or a plateau value. It is necessary to parameterize the regions so that no region is intersected and that all together represent the entire reservoir. The parameterization of the region is a crucial step in regional method and should be chosen carefully and according to objectives. With the first set of images generated, regional method should follow:

$$GOF = \sum_{We=1}^{k} \sum_{Pa=1}^{n} \sum_{t=1}^{m} \left[\left[\frac{(obs - sim_t)^2}{(obs_t * tol_{Pa} + C_{Pa})^2} \right]_{Pa} \right]_{We}$$

1) Select the best image for each region using Equation 1 (k is the number of wells in the region);
2) Define a correlation coefficient for each region (**Oliveira, 2014**);
3) Joint selected images and correlation coefficient from all regions;
4) Generate a new set of reservoir images using co-simulation.

Application

The methodology proposed is applied in a synthetic case of study named UNISIM-I-H (**Avansi and Schiozer, 2015**) created with real well log data from Namorado Field in Campos Basin (Brazil).

The model has 25 wells, which 14 are production wells and 11 are injector wells (Figure 1).

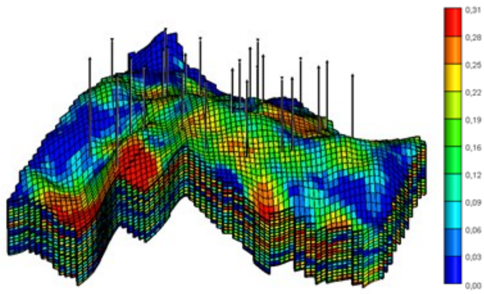

Figure 1: Case of study UNISIM-I-H, porosity distribution

The dynamic data chosen to match were pressure, oil rate and water rate in a total of 11 years of production.

First Set of Reservoir Images

Heterogeneity is responsible for the location of high permeability channels, barriers and other geologic events that affect flux, affecting simulated production data. When the first set of images is created, it is difficult to understand where these events will benefit or not the reservoir behavior. Stochastic simulation only uses information of well logs and seismic (if applicable) in this first set of images, generating different possibilities for spatial distribution with a large range of quality (Figure 2). In order to evaluate this quality, it was quantified the mismatch in each parameter of each well using Normalized Quadratic Deviation with Sign (NQDS) described in **Avansi (2014).**

Global Method Results

Global method is a simple and efficient way to reduce the solutions of the multiples scenarios given by geostatistics (Figure 3). The user must select the image that gave the best match and use it to condi-

"Regional method has proved clear advantages when compared with global method, it is far more stable and it converges twice as fast for a better solution."

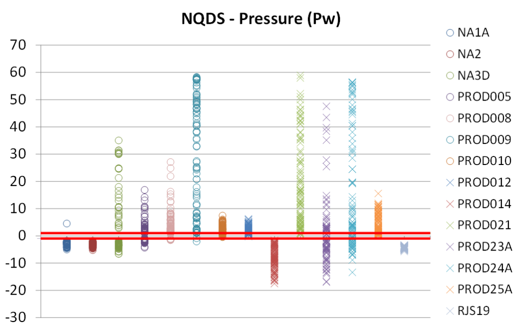

Figure 2: NQDS values of pressure from 1st iteration

tion the spatial distribution on the following iterations. Because we select one image to condition the entire reservoir some wells will never converge for the desired solution, it can reduce the range of values from OF but they will be misfit from the ideal solution. However, it is simpler to do and it can be a valuable step to a iterative history matching procedure (errors are reduced from Figure 2 to Figure 3).

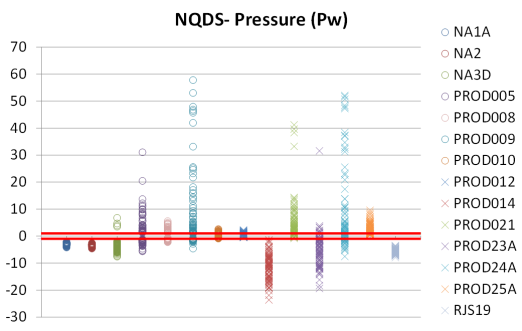

Figure 3: NQDS values for pressure after global method optimization

Regional Method Results

There is a greater effort using this method when compared with global method. It is necessary to parameterize all regions the best way possible to guarantee the effectiveness of the method, the number of regions increase with the number of wells, for each region defined a correlation coefficient and a reservoir image must be chosen.

In this case of study it was used Voronoi polygons to parameterize the regions, however other possibilities should be studied, for example use streamlines, take into account the continuity modelled in the variograms, joint pair producer-injector wells, etc.

Despite the increased effort it has shown clear advantages when compared with the first set of reservoir image or even when applied the global method. The ranges of values of NQDS are smaller and near an acceptable value (errors largely reduced when comparing Figure 2 and 3 with Figure 4).

In the regional method, the behaviour of Global Objective Function along iterations is more stable and a better value is obtained at the end. Once a better reservoir image is achieved the following will ensure the quality obtained in the previous iteration, with a probability of getting even better.

Regional method has proved clear advantages when compared with global method, it is far more stable and it converges twice as fast for a better solution (better value of GOF).

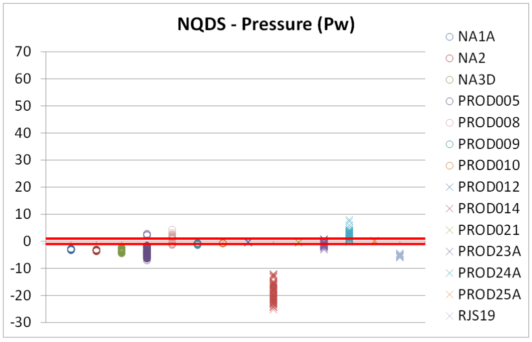

Figure 4: NQDS values for pressure after regional method optimization

Final Considerations

In this work, it was presented a methodology that can be included in history matching process. The correct parameterization, the definition of geologic model and its uncertainty are essential steps to increase reservoir model reliability.

Results show that both methods, global and regional, can be used to improve reservoir behaviour; the choice is dependent of the amount of data in the project, the number of years of history data and the time that you have to calibrate the model.

To apply the methodology proposed some steps must be studied carefully. The choice of the correlation coefficient and the region parameterization are two critical ones.

Bibliography

AVANSI, G., 2014, *Ajuste de Histórico Integrado à Caracterização de Reservatórios de Petróleo e Sísmica*, PhD Thesis, Universidade Estadual de Campinas (Campinas-Brazil).

AVANSI, G., SCHIOZER D., 2015, *UNISIM-I: Synthetic Model for Reservoir Development and Management Applications*.

OLIVEIRA, G. S., 2015, *Integração da modelagem geostatística com o processo de ajuste de histórico*, Mestrado, Instituto Superior Técnico (Lisbon, Portugal)

MATA-LIMA, H., 2008, *Reservoir characterization with iterative direct sequential co-simulation: integrating fluid dynamic data into stochastic model*, Journal of Petroleum Science and Engineering.

About author:

Gonçalo Soares de Oliveira is attending PhD in Science and Petroleum Engineering at UNICAMP. With MSc in Petroleum Engineering and BSc in Civil Engineering by Instituto Superior Técnico (IST-Lisbon). Its PhD research subject is about integration of geostatistical modelling with history matching.

UNISIM opportunities:

If you are interested in working or developing research in the UNISIM Group, please contact us.
Immediate interest in:

- **Researcher in the simulation area, management and reservoir characterization.**

For further information, click here.

Research in Reservoir Simulation and Management Group

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

Phone.: 55-19-3521-1220
Fax: 55-19-3289-4916

unisim@dep.fem.unicamp.br

For further information, please visit
https://www.unisim.cepetro.unicamp.br

The UNISIM Research Group is part of UNICAMP (Petroleum Engineering Division, Energy Department, School of Mechanical Engineering, Center for Petroleum Studies) that aims to develop Works and projects in the simulation and reservoir management area.