# Model-Reduced Gradient-Based History Matching

**Małgorzata Kaleta**
T.U. Delft

In typical simulation models for subsurface flow in oil and gas reservoirs, many geological parameters are uncertain. Their estimated values can sometimes be improved by using surface and downhole production data in a process called history matching. History matching can be performed very efficiently by gradient-based algorithms. However, those methods require the implementation of an adjoint method which in turns requires computation of Jacobians with respect to the state variables and to the system parameters. Although in reservoir models, the Jacobians with respect to state variables are usually available, the Jacobians with respect to the parameters need to be computed. The derivation and implementation of the latter make the computation of the adjoint an immense programming effort.

We propose a gradient-based history matching algorithm based on model reduction, where the original (nonlinear and high-order) forward model is replaced by a linear reduced-order forward model. Consequently, the adjoint of the tangent linear model is replaced by the adjoint of a linear reduced-order forward model. Due to the linearity of the reduced-order model, the corresponding adjoint model can be easily computed. The gradient of the objective function is approximated and the minimization problem is solved in the reduced space; the procedure is iterated with the updated estimate of the parameters if necessary. The reduced-order model is constructed with the aid of the conventional Proper Orthogonal Decomposition (POD) method and the balanced POD method. The conventional POD-based approach is adjoint-free and can be used with any reservoir simulator. The balanced POD-based method requires the adjoint states but does not required the Jacobians with respect to the parameters.

The methods were evaluated for a water-flooded reservoir with uncertain permeability field. A comparison with an adjoint-based approach shows that the model-reduced approaches give comparable quality of history matches and predictions. The required computational effort is higher than of an adjoint-based approach but lower than of an approach where the gradients are obtained with simple finite differences.

In this talk, we will present the formulation of the history matching problem, and we will briefly describe the classical gradient-based method and the model-reduced approach. The talk will finish with results and conclusions.