ISAPP Symposium

30 and 31 October 2014

Venue:

Faculty of Civil Engineering and Geosciences
Delft University of Technology

Thursday 30 October 2014

09:00	***Registration/coffee/tea***		
09:30	Hegen, Dries	TNO	ISAPP status overview
09:40	Jansen, Jan Dirk	TUD	ISAPP and Recovery Factory technical status overview
10:00	Fonseca, Rahul	TUD	Ensemble-based multi-objective optimization of on-off control devices under geological uncertainty
10:25	Leeuwenburgh, Olwijn	TNO	Constrained life-cycle optimization - implementation and examples
10:55	***Coffee/tea break***		
11:25	Kahrobaei, Siavash	TUD	Identifiability of location and magnitude of flow barriers in slightly compressible flow
11:50	Schutte, Koen	TUD	Numerical simulations of turbulent flow Induced asphaltene deposition in channel and pipe geometries
12:15	Twerda, Aris	TNO	Building blocks of asphaltene modelling: A combination of sub-models to quickly access mitigating strategies
12:45	***Lunch***		
13:30	Popa, Tudor	TUD	Different localization schemes for an ensemble based AHM
13:55	Hanea, Remus	Statoil	Optimization of drilling order under geological uncertainties for a real field case
14:25	Da Silva, Daniel	TUD	Coupling wellbore and reservoir simulators
14:35	***Coffee/tea break***		
15:05	Ashoori, Elham	TUD	Challenges in adjoint-based well-placement optimization when using well models
15:30	Krogstad, Stein	SINTEF	Flow-based proxies and tuned upscaling for efficient optimization of long-term reservoir management problems using MRST
16:00	Leguijt, Jaap	Shell	Using two point geo-statistics reservoir model parameters reduction
16:30	***Move to room D***		
16:45	Lake, Larry	Univ. Texas	Maturing with enhanced oil recovery: The role of a textbook
18:30	***Dinner***		

Friday 31 October 2014

09:00	***Registration/coffee/tea***		
09:30	Siraj, Mohsin	TU/e	Handling uncertainties in balancing short-term and long-term objectives in water-flooding optimization
09:55	Insuasty, Edwin	TU/e	Tensor-based parameterization of flow patterns in oil reservoirs
10:20	Bellout, Mathias	NTNU / IO	Joint well placement and control optimization applied to a case with horizontal wells
10:50	***Coffee/tea break***		
11:20	Szklarz, Slawomir	TUD	POD-DEIM reduced reservoir models
11:45	Hanea, Remus	Statoil	Facies updates in the FMU paradigm for a North Sea Field
12:15	Fatemi, Amin	TUD	Discerning in situ performance of an EOR agent in the midst of geological uncertainty
12:40	***Lunch***		
13:25	Romeu, Régis	Petrobras	Optimal scenario reduction and other approaches for selecting representative reservoir models
13:55	Van der Meer, Jakolien	TUD	Non-physical oscillations in the simulation of Foam Enhanced Oil Recovery
14:20	De Barros, Eduardo	TUD	Value of information in closed-loop reservoir management
14:45	Braal, Richard	TNO	Closing
14:50	***Drinks***		
15:30	***Steering Committee Meeting***		

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Programme Thursday 30 October

09:30 - 09:40 **Dries Hegen (TNO):**
ISAPP status overview

09:40 - 10:00 **Jan Dirk Jansen (TU Delft):**
ISAPP and recovery factory technical status overview

10:00 - 10:25 **Rahul Fonseca (TU Delft), Olwijn Leeuwenburgh (TNO), Ernesto Della Rossa (ENI), Paul Van den Hof (TU Eindhoven) and Jan Dirk Jansen (TU Delft):**
Ensemble-based multi-objective optimization of on-off control devices under geological uncertainty

We consider robust ensemble-based (EnOpt) multi-objective production optimization of on-off inflow control devices (ICDs) for a sector model inspired on a real-field case. The use of on-off valves as optimization variables leads to a discrete control problem. We propose the re-parameterization of such discrete controls in terms of switching times, i.e. we optimize the time at which a particular valve is either open or closed. This transforms the discrete control problem into a continuous control problem which can be efficiently handled with the EnOpt method. Additionally this leads to a significant reduction in the number of controls which is expected to be beneficial for gradient quality when using approximate gradients. We consider an ensemble of sector models where the uncertainty is described by different permeability, porosity, net-to-gross and initial water saturation fields. The controls are the ICD settings over time in the three horizontal injection wells, with approximately 15 ICDs per well. Different optimized strategies resulting from different initial strategies were compared. We achieved a mean 4.2% increase NPV at a 10% discount rate compared to a traditional pressure maintenance strategy. Next, we performed a sequential bi-objective optimization, and a achieved an increase of 7% in the secondary objective (25% discounted NPV to emphasize short-term production gains) for a minimal decrease of 0.5% in the primary objective (0% discounted NPV to emphasize long-term recovery gains), as averaged over the 100 geological realizations. The workflow was repeated for alternative numbers of ICDs showing that having fewer control options lowers the expected value for this particular case. The results demonstrate that ensemble-based optimization workflows are able to produce improved robust recovery strategies for realistic field sector models against acceptable computational cost.

10:25 - 10:55 **Olwijn Leeuwenburgh, Paul Egberts, Alin Chitu (TNO), Frank Wilschut and Dries Hegen (TNO):**
Constrained life-cycle optimization - implementation and examples

In this presentation a simple test case will be used to demonstrate the implications and limitations of the constraint handling capability of typical reservoir simulators.
We will discuss the implementation of a method for efficient output constraint handling in the TNO ensemble-based optimization tool (ELCO). The same simple case will be used to test the implementation, and explore the impact of various choices for the lumping of constraints. The implementation will also be tested on a second test case with realistic complexity. Finally, some implications for output constraint handling in robust optimization (i.e. for non-deterministic cases) will be discussed.

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10:55 - 11:25 ***Coffee/tea break***

11:25 - 11:50 **Siavash Kahrobaei, Mehdi Mansoori (TU Delft), Gerard Joosten (Shell), Paul Van den Hof (TU Eindhoven) and Jan Dirk Jansen (TU Delft):**
Identifiability of location and magnitude of flow barriers in slightly compressible flow

Classic identifiability analysis of flow barriers in incompressible flow reveals that it is not possible to identify the location and permeability of low-permeable barriers from production data, and that only averaged reservoir properties in-between wells can be identified. We extended the classic analysis by including compressibility effects. We used two approaches: 1) a twin-experiment with synthetic production data for use with a time-domain parameter estimation technique, and 2) a transfer function formalism in the form of bilaterally coupled four-ports allowing for an analysis in the frequency domain. We investigated the identifiability, from noisy production data, of the location and the magnitude of a low-permeable barrier to slightly-compressible flow in a one-dimensional configuration. We used an unregularized adjoint-based optimization scheme for the numerical time-domain estimation, using various levels of sensor noise, and confirmed the results using the semi-analytical transfer function approach. Both the numerical and semi-analytical results show that it is possible to identify the location and the magnitude of the permeability in the barrier from noise free data. By introducing increasingly higher noise levels the identifiability gradually deteriorates, but the location of the barrier remains identifiable for much higher noise levels than the permeability. The shape of the objective function surface, in normalized variables, indeed indicates a much higher sensitivity of the well data to the location of the barrier than to its magnitude. These theoretical results appear to support the empirical finding that unregularized gradient-based history matching in large reservoir models, which is well known to be a severely ill-posed problem, occasionally leads to useful results in the form of model parameter updates having unrealistic magnitudes but indicating the correct location of model deficiencies.

11:50 - 12:15 **Koen Schutte (TU Delft), Aris Twerda (TU Delft, TNO) and Ruud Henkes (TU Delft):**
Numerical simulations of turbulent flow induced asphaltene deposition in channel and pipe geometries

Asphaltenes deposition is a major concern in crude oil production, as it obstructs the flow-path of the oil and thereby diminishes the oil production rate. In this project, we aim at acquiring a better understanding of the influence of the turbulent liquid carrier-phase flow on the agglomeration of asphaltenes, as well as on its subsequent deposition. To this end, we use a primary-particle based numerical model that was implemented in an existing channel flow solver. Recently, this model has been extended with a novel approach to account for the deposition of particles at the confinements of the flow domain.
In this presentation, we will focus on how the asphaltene deposition rate, as well as the properties of the deposit layer formed (such as its thickness, and the fraction of the wall-area it covers), depend on the problem parameters. Furthermore, we show to what extent the continuous phase throughput decreases as a result of the asphaltene deposition. Some preliminary results on deposition in pipe geometries will also be included in the presentation.

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12:15 - 12:45 **Aris Twerda (TNO):**
Building blocks of asphaltene modelling: A combination of sub-models to quickly access mitigating strategies

When asphaltenes precipitate from oil and deposit, they give rise to problems by obstructing the flow. Depending on the operating conditions this can either occur in the reservoir or in the well. The loss of production incurred by asphaltenes can have a large economic impact, making the topic of asphaltene control a prime Flow Assurance topic. Because of the physical complexity and the lack of adequate experimental and production field data, it remains difficult to predict where and when asphaltene deposits will form. Furthermore, occurrence of asphaltene deposition is very dependent on the oil properties, or details of the flow path. This makes it difficult to extrapolate learnings from a specific well to other wells, even within the same asset. As a result, it is challenging for field operators to choose between different mitigation strategies, such as solvent jobs, inhibitor injection, pigging, etc. Therefore, a fast and efficient model predicting deposition and the effect of the (to be) applied strategy for a given well or field would be very useful.
The objective of this work is to develop such a comprehensive predictive model. The model consists of several sub models that describe the key phenomena affecting the asphaltene deposition process, i.e. multiphase flow, precipitation, aggregation kinetics, and deposition. All models have been implemented in a MATLAB environment, enabling full flexibility. The MRST platform is used for simulating the multi -phase flow in the near well bore region, while the flow in the well is simulated using a 1D drift flux model developed in-house. In the well the evolution of the particle size distribution, including aggregation and fragmentation, is described by a population balance equation (PBE) model.
The drift-flux model and PBE model are validated using literature data. The combined model is being validated by comparing the results with the few available experimental and field data. The output of the overall model includes deposition rates along the pipe and can be used as a tool to design pipelines as well as to optimize production by giving inside into the need for preventive solvent injection or other mitigation techniques.

12:45 - 13.30 ***Lunch in the Exhibition room***

13:30 - 13:55 **Tudor Popa (TU Delft), Remus Hanea, Lars Hustoft (Statoil) and Marco Verlaan (TU Delft/Deltares):**
Different localization schemes for an ensemble based Assisted History Matching

In reservoir characterization, modern reservoir modelling and history matching aim at delivering integrated models with quantified uncertainty, constrained on all available data. In this paper a variation of the Ensemble Kalman Filter (EnKF) method will be used, namely the Ensemble Smother (ES) (see Evensen et al. (1999)). Ensemble size is critical to the efficiency and performance of the ensemble based methods. A consequence of the finite dimension of the ensemble is sampling errors. A standard recommendation for reducing the spurious correlations and loss of variance due to sampling errors is to use localization. There are two main schemes of localization: covariance localization and local analysis. In the present work we introduce new methodology: region based localization (engineering approach) which will ensure that the dynamics, the physical process and the influence of the structure of the reservoir are not violated. We present initial results of the region based localization approach applied on a realistic synthetic case. The scope of the presentation is not to show an improved AHM for the uncertain parameters against the AHM results without localization, but to validate the soundness and consistency of the new approach.

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13:55 - 14:25 **Remus Hanea, Lars Hustoft and Cassio Pettan (Statoil):**
Optimization of drilling order under geological uncertainties for a real field case

The main objective in any reservoir development plan is to achieve maximum reservoir exploitation or actually maximum estimated net present value (ENPV). Here we present a new approach where the drilling of the wells is optimized and the geological uncertainties are taken into account. We will focus on combining the average permeability and oil volume (in well-penetrated and surroundings cells) across all realizations to estimate the "potential" of each well. Then we open the wells accordingly to their "potential". The final product will supply an optimized order of drilling the wells, with the ability to automatically perform geo-steering or side-tracking of wells in each model realisation under the constraint to match a possible forecasted production profile. We will show results on a realistic synthetic case and preliminary results on a real field case.

14:25 - 14:35 **Daniel Da Silva (TU Delft):**
Coupling wellbore and reservoir simulators

The dynamic interaction between well and reservoir has been object of study for over 3 decades up to now and it has been shown the necessity of such approach to solve a variety of different problems, such as unstable oil production, severe slugging, gas/water coning, development of smart well control systems, shut-in and buildup tests etc. Most of the available commercial dynamic wellbore simulators use a a semi-steady state inflow model to describe the reservoir inflow of gas and oil into the well. Also, most of the commercial reservoir simulators use steady-state lift curves for modeling the wells. The ways these simulators can be coupled also play an important role on the computational effort and stability of the numerical models.
There are different ways of modeling and coupling oilwell and near-wellbore reservoir models, such as explicit, implicit, fully-implicit and hybrid.
The multiphase flow dynamics inside the wellbore is also important in the oil production, as well as surface equipments and are highly affected by the inflow of the reservoir and pressure distribution along the well. Different models and correlations are widely used to describe the multiphase flow, from simple and fast but rather inaccurate homogenous models, to complex and detailed but with high computational effort two/three phase models.

14:35 - 15:05 ***Coffee/tea break***

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15:05 - 15:30 **Elham Ashoori (TU Delft):**
Challenges in adjoint-based well-placement optimization when using well models

There is a general consensus that the adjoint gradient method is the most efficient method in large-scale well-placement optimization. Handels et al. (2007) were the first to use the adjoint method for well placement optimization for which they introduced the concept of 'pseudo wells' surrounding the well to be optimized. Sarma et al. (2008) presented a method to determine the sensitivity of the objective function with respect to the actual well locations directly from the adjoint gradients. The direct dependency of the objective function on the well location comes from weighing the well indices of the pseudo wells by a continuous well-location-dependent function. However, this method is not consistent with the use of the Peaceman well model.
In this work we utilize the Ding well-inflow model (1994), which adjusts the transmissibilities of the adjacent cells of off-centred wells, to enable the direct calculation of the adjoint gradients of the objective function with respect to the well location. Using a simple homogenous 2-D reservoir example, we demonstrate how the non-smoothness of the objective function with the change in the well location, especially around the cell borders, and the simulator time step size can lead to incorrect adjoint gradients. We then show that this problem persists for a smoother objective function in which the Ding method is applied to a bigger neighbourhood of the well cell.
We conclude that irregularities in the objective function can adversely affect any gradient-based optimization method.

15:30 - 16:00 **Stein Krogstad (SENTIF):**
Flow-based proxies and tuned upscaling for efficient optimization of long-term reservoir management problems using MRST

Model-based optimization of long-term reservoir management goals (e.g., NPV) typically involves a large number of reservoir simulations. Regarding the detailed simulation of a complex case (possibly including gradient computations) a black box is likely to result in lengthy computations, and may fail altogether due to robustness issues or inadequate problem formulations. Accordingly, reducing the problem complexity may have several benefits. Besides the obvious (saving time), a reduced model may be more robust with respect to input (reducing the number of failed simulations), and result in a smother response surface (more reliable gradients and possibly fewer local minima).
Based on implementations in MRST (Matlab Reservoir Simulation Toolbox), we present two approaches for reducing the simulation complexity of optimization loops. The first is a simple upscaling approach where coarse-model transmissibilities are tuned to a fine model base-case. The second is a flow diagnostics-based approach involving efficient time-of-flight calculations which produce objective and gradient approximations in the order of seconds. We present results from numerical experiments for two real field models, and discuss pros and cons of the two approaches.

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16:00 - 16:30 **Jaap Leguijt (Shell):**
Using two point geo-statistics reservoir model parameters reduction

An algorithm has been developed to constrain gridded reservoir models that are used with assisted history matching with geo-statistical information and at the same time reduce the number of variables that are needed to describe the model.
Gridded models, as used within most reservoir modelling packages, may consist of 10^5 up to 10^6 grid blocks. A covariance matrix which can be used to constrain the model with a variogram (two point statistics) would consist of 10^10 up to 10^12 coefficients and a direct principal component decomposition of is beyond the capability of current computer systems.
A common way to reduce the number of variables is using the members of an ensemble of models from a geo-statistical simulation as basis vectors for a subspace. When a history match is obtained with a model that is constrained to this subspace, this model will have a decently looking continuity behavior. There is however no guarantee that this subspace contains the directions that correspond with the eigenvectors of the covariance matrix with the largest eigenvalues. This can be demonstrated with a simple simulation and is theoretically described by the Wishart distribution.
It is possible to construct a set of orthonormal basis vectors that contains the directions that correspond with the eigenvectors of the covariance matrix with the significantly large eigenvalues. The number of basis vectors may still be rather large but it is mainly determined by the size of the model and the range of the variogram. From an eigenvector decomposition of this covariance matrix, a very good approximation can be obtained of the eigenvectors with a significant large eigenvalues. As the small eigenvalues can be neglected, the number of eigenvectors needed to describe the model is approximately 10^2, which results in a significant parameter reduction.

16:30 - 16:45 ***Move to room D***

16:45 - 17:30 **Larry Lake (University of Texas):**
Maturing with enhanced oil recovery: The role of a textbook

By the standard of progress in oil production technology, EOR has, with some exceptions, become mature. The first thermal and solvent floods were done in the 1950s; polymer floods in the 1980s. Only in surfactant methods has commercial success been elusive, but there are excellent signs that this is about to change.
Success has come about for many reasons. We cannot, to be sure, negate the benefits of a high oil price. However, other factors play a role. The understanding of process mechanisms, our ability to model (simulate) the processes, the number of field test all contribute to EOR maturity.
The 1989 text Enhanced Oil Recovery is a major contributor to this understanding. Began as a textbook for a graduate course at the University of Texas, the book has become a standard reference, has been used to educate many university students (undergraduate and graduate), has been a manual in short course presentations taught by many beside the original author. The current presentation celebrates the success of 1989 EOR, discusses the basis for its success and outlines the changes done to the 2014 version. 2014 EOR is largely different in there being four, not one, authors. The contribution of all are highlighted as well as are the major learnings from 25+ year of teaching EOR.

18:30 ***Dinner***
't Postkantoor, Hippolytusbuurt 14, 2611 HN Delft, 015-7503243
www.postkantoordelft.nl

Programme Friday 31 October

09:30 - 09:55 **Muhammad Mohsin Siraj, Paul Van den Hof (TU Eindhoven) and Jan Dirk Jansen (TU Delft):**
Handling uncertainties in balancing short-term and long-term objectives in water-flooding optimization

The Net Present Value (NPV) objective in model-based optimization, because of its nature, focuses on long-term gain while short-term production is not explicitly addressed. At the same time the achievable NPV is highly uncertain due to the limited knowledge of reservoir model parameters and varying economic conditions. Different (ad-hoc) methods have been proposed to introduce short-term considerations to balance short-term and long-term objectives in a model-based approach. In this work, we address the question whether through an explicit handling of model and economic uncertainties in NPV (robust) optimization, an appropriate balance between these economic objectives is naturally obtained. A robust optimization framework (which maximizes the average NPV) and the mean-variance approach (which with the maximization of average NPV also reduces the variance of NPV distribution) are formulated with respect to the ensemble of models and the oil price scenarios. It is shown by simulation examples that with RO, the average NPV is increased compared to the reactive strategy, with both forms of uncertainty but a slower NPV build-up over time is obtained. A faster NPV build-up compared to RO, is achieved in MV by choosing different weightings on variance in mean-variance objective, at the price of slightly compromising on the long-term gains. A gradient-based optimization procedure is used where the gradient information is computed by solving adjoint equations.

09:55 - 10:20 **Edwin Insuasty (TU Eindhoven):**
Tensor-based parameterization of flow patterns in oil reservoirs

When using reservoir models as a basis for model-based optimization of Net Present Value (NPV) in water flooding, one would like to decide whether two different realizations lead to essentially different behavior in NPV optimization. In other words: there is a need for an optimization-relevant dissimilarity measure between models. Measures based on parameter fields, NPV or water breakthrough all have their limitations. It is motivated that flow patterns drive the economic performance of oil reservoirs as they drive the ultimate recovery and reserves forecast. This makes the flow patterns a natural dissimilarity measure between models in the context of production optimization. Flow patterns are large-scale structures with spatial-temporal nature. Traditionally, reservoir simulators have vectorized the flow solutions, losing the spatial structure coming from the physical formulation. In this work, we analyze spatial-temporal (tensor) representations of saturation and pressure profiles in reservoir models, as a way to represent the characteristic profiles while keeping spatial structures intact. This allows the construction of low-complexity parameterizations of the essential flow profiles, which subsequently can be used for model characterizations, and evaluation of a control-relevant dissimilarity between models. The resulting tools have potential use in reducing ensemble sizes in robust optimization, as well as in constructing control-relevant reduced order models.
Model-based optimization of oil production over the life-cycle of an oil reservoir has demonstrated better economic performance but at the same time such optimization suffers from high levels of both economic and modeling (geological) uncertainties. In this talk, I will introduce and highlight the main objectives of my PhD research topics. My research aims to investigate the effect of uncertainties on model-based optimization and to develop novel strategies to reduce the negative effect of uncertainty on production strategies. Hence moving towards robust approaches to life-cycle optimization, where the uncertainty is explicitly or implicitly taken into account in optimization. As a secondary objective of my PhD, I will also briefly discuss the possibilities of data-driven modeling and input-output structural identification in a water flooding process with multiple-inputs (injection wells) and multiple-outputs (production wells).

Programme Friday 31 October

10:20 - 10:50 **Mathias Bellout, Bjarne Foss and Jon Kleppe (NTNU):**
Joint well placement and control optimization applied to a case with horizontal wells

In this work, we optimize the location and control settings of four horizontal well trajectories, subject to inter-well distance and well-length constraints, using a joint approach for well placement and control optimization. The joint approach solves the well placement and control problem by nesting the optimization of controls within the well placement search. The master optimization of well placement coordinates is performed using a deterministic, derivative-free, pattern-search algorithm implemented in a distributed environment. The embedded control optimization is solved using a gradient-based method with gradients efficiently computed through an adjoint formulation. The joint approach is compared to a sequential alternative, where well controls are optimized only once the well placement search has ended.
For both the joint and sequential approach, several optimization runs were launched using different formulations of the well-length constraint. The mean field oil production total from well configurations obtained from the joint approach using the different well-length constraint formulations is 7% higher compared to corresponding optimizations using the sequential approach. However, in terms of total number of reservoir simulations, the joint approach is about 7 times more costly than the sequential approach. The overall development of the methodology is part of a pilot in cooperation with an ongoing offshore development project on the Norwegian Continental Shelf.

10:50 - 11:20 ***Coffee/tea break***

11:20 - 11:45 **Slawomir Szklarz (TU Delft):**
POD-DEIM reduced reservoir models

For reservoir models, the number of grid blocks and therefore, the size of the problem can become very large. Therefore the cost of the forward simulation and history matching or production optimization is very high. In recent years, model-order reduction techniques aiming to replace large, complex dynamic systems with lower-dimension models have been successfully applied to reservoir models in order to gain efficiency. In order to integrate the equations in time more efficiently the Proper Orthogonal Decomposition (POD) method and Galerkin projection of the ODEs can be used to approximate high-order models with the low-dimensional models. The key to build accurate POD low-order models is to capture as much dynamics of the ODEs as possible in a low-dimensional vector space. This is accomplished by POD method where the vector from the original space is projected onto the space of the directions of the variabilities in the model. However, the limitation of POD is that the original nonlinear terms are needed for the reduced-order model. This means complexity of the evaluation of the nonlinear functions and the projection is dependent on the high-order. the Discrete Empirical Interpolation Method (DEIM) combines POD-approximation and interpolation techniques to build the reduced-order model. The nonlinear term evaluated at selected points is projected onto the adjusted basis of nonlinear term. The spatial points are chosen to minimize the upper bound of the approximation error. We investigated applicability of POD-DEIM to simple reservoir models and present the results.

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11:45 - 12:15 **Remus Hanea, Torbjørn Ek, Bogdan Sebacher, Daniel Berge Sollien and Benoit Massart (Statoil):**
Facies updates in the FMU paradigm for a North Sea field

This work introduces a parameterization of geological uncertainties, facies distribution in particular. It is based on the idea of parameterizing the facies types (a categorical variable) using probabilities maps in order to able to realistically generate and update (the facies) based on production data, well observations and seismic information. The idea is to treat facies as a hyper-parameter in the geo-model world. This fits perfect into the Fast Model Update (FMU) workflow (the big loop) because it allows us to have a consistent, repeatable and automated way to update facies distributions into a multi-realization world. It is the first attempt to incorporate directly and preserve the information from the seismic probability cube into the Assisted History Matching approach by updating the Random Gaussian Fields (GRFs) which describe the geological concept. The technology applied in this work, Adaptive Plurigaussian Simulation method, is tested on North Sea field and the influences of different truncation/simulation maps tailored to different geological concepts are presented.

12:15 - 12:40 **Amin Fatemi, Jan Dirk Jansen (TU Delft), Cor van Kruijsdijk (Shell) and Bill Rossen (TU Delft):**
Discerning in situ performance of an EOR agent in the midst of geological uncertainty

An enhanced-oil-recovery (EOR) pilot test has multiple goals, among them to demonstrate oil recovery, verify the properties of the EOR agent in situ, and provide the information needed for scale-up to an economic process. Given the complexity of EOR processes and the inherent uncertainty in the reservoir description, it is a challenge to discern the properties of the EOR agent in situ in the midst of geological uncertainty. We propose a simple case study to illustrate this challenge: A polymer EOR process is designed for a 2D layer-cake reservoir. The polymer is designed to have a viscosity of 21 cp in situ. There is uncertainty in the reservoir description, however, represented here in Dykstra Parsons coefficient and spatial arrangement of layers. We allow that the polymer process might fail in situ and viscosity could be half or less of that intended. We test whether the signals of this difference at injection and production wells would be statistically significant in the midst of the geological uncertainty. For a population of reservoirs representing geological uncertainty we compare the deviation caused by loss of polymer viscosity to the scatter caused by the geological uncertainty at the 95% confidence level. Among the signals considered, the rate of rise in injection pressure with polymer injection and maximum injection pressure in the injector give the most reliable indications of whether a polymer viscosity was maintained in situ. Unfortunately, given the likelihood of fracturing of the injection well, injection pressure may be an unreliable indicator of in situ polymer viscosity. Arrival time of the oil bank, minimum oil cut before the oil bank and polymer breakthrough time give a statistically significant indication of loss of polymer viscosity in situ in some cases.

12:40 - 13:25 ***Lunch in the Exhibition room***

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13:25 - 13:55 **Regis Romeu (Petrobras), D.J. Schiozer, A.T.F.S. Gaspar, A.A. Santos (Unicamp), I.T. Ghisi (ESSS), A. Galli and M. Armstrong (Mines Paris-Tech)**
Optimal scenario reduction and other approaches for selecting representative reservoir models

Representing uncertainty for reservoir forecasting and optimization studies has promoted the practice of generating a diversity of alternative models, maybe hundreds or thousands of scenarios and realizations of the same reservoir. But it is not generally feasible to simulate, analyze and optimize them all. A rational solution is then to select a small number (ten, for example) of these scenarios which are to represent the entire set in respect to some statistics. The problem of properly electing these models is known as "representative models selection" or "scenario reduction", and occurs in other field applications too.
This work reviews different approaches of the literature, including previous works from Unicamp [Schiozer et al., 2004], the MUMS approach from Stanford [Scheidt and Caers, 2009], and mainly the method referred as "optimal scenario reduction method" [Heitsch and Römisch, 2003; Armstrong et al., 2012]. Previous to this, we discuss some basic concepts, like the representativeness criteria to select the representative models, and the different kinds of (genotypic and phenotypic) parameters that may used to distinguish the models. Finally we show some application examples. One of these examples, based on real field data, selects ten representative models from 501 initial models, considering seven different production strategies.

13:55 - 14:20 **Jakolien van der Meer (TU Delft):**
Non-physical oscillations in the simulation of Foam Enhanced Oil Recovery

If secondary hydrocarbon recovery methods, like water flooding, fail because of the occurrence of viscous fingering and gravity override one can turn to an enhanced oil recovery method (EOR) like the injection of foam. The generation of foam can be described by a set of partial differential equations with strongly nonlinear functions, which impose challenges for the numerical modeling. Former studies by [Namdar Zanganeh, 2011] and [Ashoori, 2012] show the occurrence of strongly temporally oscillating solutions when using forward simulation models, that are entirely due to discretization artifacts. To analyze these problems, we study the dynamics of a simple foam model based on the Buckley-Leverett equation. Whereas the Buckley-Leverett flux is a smooth function of water saturation, the foam will cause a rapid increase of the flux function over a very small saturation scale. Consequently non-physical oscillations occur in the pressure solution in time. Similar oscillations are observed for the heat equation with a discontinuous thermal conductivity. By applying a change in the discretization scheme we solve this problem. We propose a similar technique for the simple foam model, which we will present here.

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14:20 - 14:45	**Eduardo De Barros, Jan Dirk Jansen (TU Delft) and Paul Van den Hof (TU Eindhoven):** ***Value of information in closed-loop reservoir management*** This presentation introduces a new methodology to perform value of information (VOI) analysis within a closed-loop reservoir management (CLRM) framework. The workflow combines tools such as robust optimization and history matching in an environment of uncertainty characterization. The approach is illustrated with a waterflooding problem in a two-dimensional five-spot reservoir. The results are compared with previous work on other measures of information valuation, and we show that our method is a more complete, although also more computationally intensive, approach to VOI analysis in a CLRM framework. We recommend it to be used as the reference for the development of more practical and less computationally demanding tools for VOI assessment in real fields. The talk also addresses the limitations of the current method and indicates new directions for my PhD research.
14:45 - 14:50	**Richard Braal (TNO):** ***Closing remarks***
14:50	***Drinks in the Exhibition room***
15:30	**Steering Committee Meeting**