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# MATHEMATICAL METHODS

FLUID DYNAMICS AND  
SIMULATION OF GIANT  
OIL AND GAS RESERVOIRS

3-5 SEPTEMBER 2012  
SWISSOTEL, ISTANBUL, TURKEY



# CONFERENCE PREVIEW

# SCHEDULE OF EVENTS

## WHO SHOULD ATTEND

Monday, 3 September 2012	
0730–0845 hours	Registration, Welcome Refreshments, Collection of Badges and Delegate Packs
0845–0900 hours	Safety Moments and Opening Remarks from the Conference Chairman
0900–1030 hours	<b>Session 1: HPC Trends and Fast Solution Methods (Linear and Nonlinear)</b>
1030–1100 hours	Coffee Break
1100–1230 hours	<b>Session 1 Continued</b>
1230–1400 hours	Luncheon
1400–1530 hours	<b>Session 2: Multiphysics and Complex Model Challenges</b>
1530–1600 hours	Coffee Break
1600–1700 hours	<b>Panel Session: Spatial and Temporal Discretisation for Coupled Non-Linear PDEs</b>
Tuesday, 4 September 2012	
0900–1030 hours	<b>Session 3: Multiscale Modelling</b>
1030–1100 hours	Coffee Break
1100–1230 hours	<b>Session 3 Continued</b>
1230–1400 hours	Luncheon
1400–1530 hours	<b>Session 4: Reservoir Management, Optimisation, Inverse Problems, and Uncertainty Quantifications</b>
1530–1600 hours	Coffee Break
1600–1700 hours	<b>Panel Session: Challenges in Reservoir Simulation</b>
Wednesday, 5 September 2012	
0900–1030 hours	<b>Session 5: Large Scale Data Reduction/Compression, Mining, and Visualisation</b>
1030–1100 hours	Coffee Break
0900–1030 hours	<b>Session 5 Continued</b>
1230–1400 hours	Luncheon
1400–1530 hours	<b>Session 6: Lessons in Large Scale Computing in E&amp;P and Other Application Areas</b>
1530–1600 hours	Coffee Break
1600–1700 hours	<b>Panel Session: Exploitation of Nonhomogeneous Processing: Extreme Computing Hardware and Software</b>
1700–1730 hours	Conference Summary and Close

Scientists from academia and industry, mathematicians, engineers, computational scientists, computer hardware specialists, and others interested in contributing to this subject.

Energy is a vital substance required throughout the world to maintain our current civilisation and advance further. A significant portion of our energy needs come from oil and gas. Giant oil and gas reservoirs of the Middle East and other regions contribute to a major portion of the world's hydrocarbon supply. Mathematical models in fluid dynamics and flow through porous media play a critical role in developing and managing these reservoirs.

Today, oil companies and universities work on highly sophisticated mathematical and computational methods describing multi-phase, multi-component fluid flow in reservoirs, pipe line networks, and surface separators. Numerical solutions of these highly nonlinear coupled partial differential equations require moderate to sophisticated computing platforms.

As giant fields mature, being able to utilise the vast amount of measured data with higher accuracy in simulators paves the road to recover more hydrocarbons and thus respond to the world's energy needs. This conference will gather mathematicians and engineers to address challenges in mathematical modelling of compressible multi-phase flow in porous media with reactions, fractured media, flow in pipes and pipe networks, coupled numerical solution of porous and non-porous media, geomechanics, diffusion, dispersion problems, unstructured grid generation, linear and nonlinear solvers, multi-grid methods, new discretisation methods, parallel computing, hybrid computing involving multicore CPUs and GPUs, scientific visualisation of large data, real field studies for giant oil and gas reservoirs using simulators.

### INTERESTED IN SPONSORING OR EXHIBITING AT THIS EVENT?

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**Ali Dogru**, Saudi Aramco  
(Conference Chairman)

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(Co-Chairperson)

**Mary Wheeler**, University of Texas at Austin  
(Co-Chairperson)

**Serdar Celebi**, Istanbul Technical University  
(Co-Chairperson)

**Andrey Gladkov**, Modeling Technologies Center

**Bret Beckner**, ExxonMobil

**Carol Woodward**, Lawrence Livermore National Laboratory

**Garfield Bowen**, Schlumberger

**Gregory King**, Chevron

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**Philippe Thierry**, Intel

**Ruben Juanes**, MIT

**Shuang Wu**, PetroChina

**Ulisses Mello**, IBM

**Vasilii Shelkov**, Rock Flow Dynamics

## Session 1: HPC Trends and Fast Solution Methods (Linear and Nonlinear)

Session Chairs: **David Keyes**, SIAM and KAUST; **Kees Vuik**, Delft University of Technology

A primary challenge for reservoir simulation is the accurate description of multiphase flow in porous, highly heterogeneous, and fractured media with very complex geometries. The lack of robust and efficient solvers for fully implicit formulations is still one of the main bottlenecks that most simulator developers face in the oil and gas industry. Generally, the underlying systems of partial differential equations are nonlinear, highly non-symmetric, and indefinite. The condition number and degree of coupling of these systems may be subject to dramatic changes due to abrupt flow variations induced by the high-heterogeneity and complex well operations during the simulation process.

In addition, over recent years, reservoir models have been growing in complexity (regarding geometry, discretisation and physical models including, for instance, thermal and chemical influences, geomechanics), heterogeneity, and size, causing these systems to get increasingly large and difficult to solve. In fact, the computational time required to solve these systems of equations is today's major bottleneck in the practicability of numerical simulation. Hence, advanced reservoir simulators need to combine the *numerical* scalability (optimality) of efficient solvers with the *parallel* scalability of modern hardware. This session addresses the efficient use of parallel architectures (including both, large scale clusters of conventional x86 multi-core CPUs as well as heterogeneous systems equipped with hardware accelerators, e.g. GPUs), and all relevant numerical aspects such as the treatment of linear and nonlinear problems, treatment of fully coupled systems (either the Jacobian directly or by CPR-type approaches), efficient preconditioning techniques, and fast linear solvers (hierarchical solvers such as multigrid or multilevel ILU).

## Session 2: Multiphysics and Complex Model Challenges

Session Chairs: **Bret Beckner**, ExxonMobil; **Michel Kern**, INRIA

This session seeks to present challenges and solutions to problems associated with

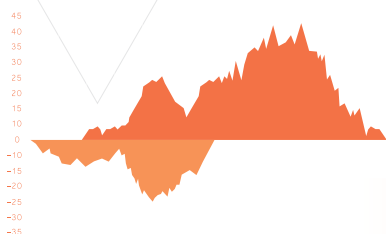
reacting and non-traditional fluid flows in porous media with particular emphasis on application in computational large models. Topics of interest include:

- Challenges and solution methods for modelling reactive transport in porous media. Examples include models for porous media dissolution and/or deposition, induced wettability alteration, salinity effects on EOR and water flooding.
- Modelling of localised, small scale phenomena within reservoir simulation grid blocks. Many important processes occur over length and time scales below that of a typical reservoir simulation. Modelling of combustion and solvent fronts, coupled wellbore flow and near well-bore flows such as fine migration and hydraulic fractures are examples.
- Integrated and efficient modelling of coupled geomechanics and porous media flows
- Advanced methods in compositional reservoir simulation including aggregation methods for large multi-field, multi-fluid systems, fast and robust algorithms for multi-phase, non-isothermal flash calculations, and new methods for phase equilibrium calculations for hydrocarbon/water/CO<sub>2</sub> systems.
- Modelling flows in large unconventional gas and oil deposits including modelling multi-phase dispersion and diffusion effects as well as models for CO<sub>2</sub> sequestration.
- The simulation of coupled models presents specific challenges in addition to those already found in the individual models. The session will also discuss coupling algorithms, their robustness, as well as how they can be adapted for high performance computing.
- Field examples of the need for these complex, multi-physics models in large scale reservoir simulations will also be discussed.

## Session 3: Multiscale Modelling

Session Chairs: **Ruben Juanes**, MIT; **Carol Woodward**, Lawrence Livermore National Laboratory

Hydrocarbon recovery processes act at many scales in a reservoir including the pore/capillary scale (for single-, dual-, or triple-porosity systems), the geologic laminae scale, the core scale, the geologic bed scale, the imposed numerical grid scale, and the reservoir scale. The storage and transport mechanisms associated with



# SESSIONS CONTINUED...

these hydrocarbon recovery processes may be dominated by different physical phenomena at each of these scales. The objective of this session is to discuss methods to model hydrocarbon systems at multiple scales. Topics to be considered include numerical multiscale techniques, characterisation of reservoirs at multiple scales for model input, unconventional (shale gas/oil) reservoirs, upscaling, and uncertainty analysis at multiple scales.

## **Session 4: Reservoir Management, Optimisation, Inverse Problems, and Uncertainty Quantifications**

Session Chairs: **Hector Klie**, ConocoPhillips; **Gregory King**, Chevron

This session will deal with the problem of estimating the distributions of porosity, permeability, and geological shapes (like reservoir boundary position) in heterogeneous and multiphase oil and gas reservoirs, by matching their dynamic behaviour. The dynamic data is in the form of field measurements from well testing, production history, interpreted 4-D seismic information. This process, called history matching by reservoir engineers, is an inverse or parameter estimation problem: inferring reservoir parameters from the indirect measurements. During the session we will discuss on parameterisation techniques, objective function, and inverse problem formulation for devising effective optimisation strategies. Strategies avoiding expansive gradient evaluations and solving adjoint problems will be in the scope of this session. Finding the optimal location of wells may increase significantly a field development project Net Present Value (NPV). This problem is nowadays one of the most challenging ones in oil and gas field development. Because of the very large number of wells involved in the production of giant reservoirs, global optimisation may be a precious help to select the best well patterns, well spacing in patterns, order of drilling different zones. The Session will also address global optimisation techniques and computational effort necessary for their implementation (in terms of number of reservoir simulations and associated computing time).

Model parameters being highly uncertain in the field of geosciences, managing uncertainties is also a major stake in the process of decision-making at every stage of reservoir production from field exploration to production. We will also discuss the

development of statistical methods allowing for the evaluation of uncertainties impact and realisation of sensibility analysis on model parameters, with the aim of weighting uncertainties on reservoir production forecast.

## **Session 5: Large Scale Data Reduction/Compression, Mining, and Visualisation**

Session Chairs: **Klaus Stuben**, Fraunhofer Institute; **Knut Andreas Lie**, SINTEF

Data generated by observation and numerical simulation are the key to understand, explore, and optimise oil and gas reservoirs. Results of many simulation runs are stored, archived, analysed, and compared among each other. This puts very demanding requirements on storage systems, networks, and visualisation systems. Approaches to overcome these issues are application specific data compression of single or multiple simulation results, data reduction methods, and sensitivity analysis. These technologies are enabler to support data mining of simulation results, for example, to find all simulation results with a similar behaviour of a reservoir. This session aims at presenting technologies for data compression of CFD applications as well as data reduction methods, which allow identifying major trends in sets of simulation results and allow for (non-linear) interpolation replacing computation with a new set of parameters. Human interaction with complex systems, e.g. for seismic interpretation or for reservoir modelling, relies on a good visualisation, helping users to explore and understand data, and also communicate that understanding to others. Visualisation is a central tool in carrying out analysis, enabling researchers, and other users to explore datasets to identify patterns, associations, trends, and more. A particular challenge again in terms of data volume and decision support is the analysis of several simulation results representing different loads or uncertain geologic formations. A good data visualisation of sets of results can help users to make robust decisions based on the data being presented. It should provide an effective representation of the underlying data, to help answer a particular question at hand. Communicating data in this way can support senior decision-makers engaged in strategic planning, service managers needing to understand where delivery could be improved, and managers wanting

to monitor performance. This session shall provide answers to related challenges in major areas: Information display and decision aiding, progress in human-system interaction, data reduction, and data compression.

## **Session 6: Lessons in Large Scale Computing in E&P and Other Application Areas**

Session Chairs: **Patrick Demichel**, Hewlett Packard; **Ulisses Mello**, IBM

As we progress towards Exascale computing at the end of the decade, we can observe that numerically intensive large-scale applications in several domains of science and business face numerous challenges to achieve three orders of magnitude performance improvement within 10 years. This will enable unprecedented application capabilities for a 21st century and will open up new frontiers of fundamental research spanning exploration and production, energy, life sciences, engineering, climate, environment, finance, and materials science. To achieve this ambitious goal, massive improvement in current state-of-the-art of power efficiency, scalability, and reliability of computing systems is required, along with exploitation of new technologies like non-volatile memory, silicon photonics, and three-dimensional packaging. Lots of progress has been achieved, unfortunately Exascale will be radically different in many aspects to what we have learnt in the race to Petascale, in particular because we have reached the economical, power, complexity limits of all data centers/institutions. Some emerging problems could become rapidly critical inhibitors, like the data explosion. It is important to understand how new technologies will affect our architectures and how to adapt current and new emerging applications to obtain the greatest benefit of the potential at the lowest effort of transformation and minimise the pressure on the developers. For the designers it is very critical to understand how the code loads and data sets will evolve in the next generation of problems we expect to solve. Then a co-design effort hard/soft is a fundamental dimension of the success of the Exascale effort. In this session, we will discuss technologies and algorithmic transformations to make some fundamental breakthroughs that are necessary to reach the next frontiers.



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