Well-posed Bayesian geometric inverse problems arising in subsurface flow

Marco Iglesias
School of Mathematical Sciences,
University of Nottingham
{marco.iglesias@nottingham.ac.uk}
Joint work with Kui Lin (Fudan), Yulong Lu (Warwick) and Andrew Stuart (Warwick)

Optimal management in subsurface applications involves decision-making under uncertainty that arises from the lack of direct information concerning geologic properties of the subsurface. A common strategy to reduce this uncertainty and obtain a better characterization of the subsurface is to solve the inverse problem of finding estimates of the geologic properties given observational flow data. In this talk we discuss a theoretical and computational Bayesian framework for the characterization of the permeability of the subsurface from pressure measurements, within the framework of an incompressible single-phase Darcy flow [2, 3] .

Our application of the Bayesian framework incorporates prior knowledge in terms of geometric features relevant to the characterization of geologic properties such as the permeability of the subsurface. We first consider parameterizations that have been previously used to characterize multiple geologic facies including the potential locations of faults as well as geometric features such as channels typical of fluvial environments [4, 1]. These prior models of the permeability lead to the estimation of a finite number of unknown parameters determining the geometry, together with a finite number of functions representing the permeability on each one of the geologic facies defined by the geometry [2]. We then incorporate more general complex geometric features with a level set formulation of the Bayesian inverse problem [3].

In this talk we discuss key aspects of the application of the Bayesian framework, namely the proof of the existence of the posterior and its continuity in the Hellinger and total variation metrics, with respect to observational data. In addition, we discuss novel MCMC methods in which prior-reversible proposals are defined, leading to an acceptance probability determined purely by the likelihood (or model-data mismatch) hence having clear physical interpretation. Finally some numerical examples are presented demonstrating the feasibility of the methodology.

References

[1] J. N. Carter and D. A. White. History matching on the Imperial College fault model using parallel tempering. *Computational Geosciences*, Vol. **17**, 43-65, 2013.

[2] M. Iglesias, K. Lin and A.M. Stuart. Well-posed Bayesian geometric inverse problems arising in subsurface flow. *to appear in inverse problems*, 2014.

[3] M. Iglesias, Y. Lu and A.M. Stuart. A level-set approach to Bayesian geometric inverse problems. *In preparation*, 2014.

[4] Landa, J. L., Horne, R. N. A Procedure to Integrate Well Test Data, Reservoir Performance History and 4-D Seismic Information into a Reservoir Description. *in Proceedings of the SPE Annual Technical Conference and Exhibition, 5-8 October 1997, San Antonio, Texas, U.S.A.*