Individual Intro – Maximilian Ramgraber

I am a PhD student enrolled at the University of Neuchâtel, Switzerland, and currently working at the Swiss Federal Institute of Aquatic Science and Technology (Eawag) near Zürich. My project is focussed on the field of numerical groundwater modelling.

I finished my B.Sc. studies of Geoscience at the University of Kiel, Germany, with specialization in the fields of numerical modelling and aquatic geochemistry. Aspiring to further specialize in these subjects, I continued my studies in the M.Sc. program Applied & Environmental Geoscience at the University of Tübingen, Germany, with special focus on numerical modelling and hydrogeology. A particular interest for novel techniques both in the field and in a simulated environment motivated me to organize my own master thesis topic, investigating the potential ability of tree growth rings to preserve chemical signatures of historical groundwater salinization in Israel (turns out they don't).

As part of the INSPIRATION project, I now tackle another challenge: the online calibration of groundwater models. The need for this kind of research arises from the necessity to understand groundwater flow regimes: without knowledge of the dynamics of subsurface flow, it becomes nigh impossible to delineate groundwater protection zones or implement effective remedial countermeasures. To this end, it is common practice to create numerical models - simulations of physical processes on a spatial grid. Unfortunately, the geological information required to adequately describe the real flow conditions is often just as inaccessible as the sparse groundwater information that motivates the use of models in the first place. This conundrum is addressed with the use of inverse parameter estimation, techniques that search for parameter sets which may reproduce the observations made in the field site.

These methods are of particular importance at the scales at which agricultural contamination becomes relevant: Due to the high cost associated with measuring the true subsurface geology, it is infeasible to investigate the geology of anything larger than a very small plot of land in a rigorous, direct manner (in fact, there are only a handful famous sites in the world where such attempts were made in earnest). The parameter inference techniques employed in lieu of reliable knowledge, however, are mainly offline. This means that they require a long history of observations in order to yield acceptable results, and cannot adequately deal with growing data sets.

When significant groundwater contamination is identified, however, it has usually gone unnoticed precisely because no observations were made in the first place. When immediate action, and the system understanding preceding it, is then required, it may be expedient to have a calibration scheme 'learning' alongside the on-going data collection, so the best possible parameter guess is available at all times. This is where so-called online calibration techniques come into play: these methods procedurally incorporate new data to refine their parameter guess.

Current approaches, however, generally suffer from two drawbacks: they either require highly simplifying assumptions about the system physics that are rarely met in reality, or they have such massive computational effort that it becomes infeasible to use them for anything but the simplest of models.

In the field of statistics, however, recent developments yielded an algorithm called the nested particle filter, which may employ Metropolis-Hastings MCMC kernels. In layman's terms, the advantage of these kernels lies in their ability to allow the user to target the calibration procedure, introducing human system understanding into the process. This flexibility comes at a great cost: in order to compare a given solution and a suggested improvement, it is necessary to re-simulate the entire data history with the proposed parameter set. This computational effort grows exponentially with time, eventually rendering this approach intractable.

In my project, I therefore aim to investigate possible ways to circumvent this restriction. Assuming some degree of ergodicity within the groundwater system (i.e. that the groundwater tables today do not depend on the groundwater table 5 years ago), it might be possible to only retrace the most recent part of the data history, bounding the computational effort, and allowing the use this approach in an online manner. The investigation of this simplifying assumption, the implementation of the algorithm in a groundwater modelling framework, and the evaluating the possibilities arising beyond form the core of my thesis.