Markov chain Monte Carlo and high-dimensional, nonlinear inverse problems in Earth Science

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Earth science nearly always requires estimating models, or model parameters, from data. This could mean to infer the state of the southern ocean from ARGO floats, to compute the state of our atmosphere based on atmospheric observations of the past six hours, or to construct a resistivity model of the Earth's subsurface from electromagnetic data. All these problems have in common that the number of unknowns is large (millions to hundreds of millions) and that the underlying processes are nonlinear. The problems also all have in common that they can be formulated as the problem of drawing samples from a high-dimensional Bayesian posterior distribution.

Due to the nonlinearity, Markov chain Monte Carlo (MCMC) is a good candidate for the numerical solution of geophysical inverse problems. But MCMC is known to be slow when the number of unknowns is large. In this talk, I will argue that an unbiased solution of nonlinear, high-dimensional problems remains difficult, but one can construct efficient and accurate biased estimators that are feasible to apply to high-dimensional problems. I will show examples of biased estimators in action and invert electromagnetic data using an approximate MCMC sampling algorithm called the RTO-TKO (randomize-then-optimize – technical-knock-out).

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