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Parameter inference and uncertainty quantification for an intermediate complexity climate model

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Well-adapted parameters in climate models are essential to make accurate predictions for future projections. In climate science, the record of precise and comprehensive observational data is rather short and parameters of climate models are often hand-tuned or learned from artificially generated data. Due to limited and noisy data, one wants to use Bayesian models to have access to uncertainties of the inferred parameters. Most popular algorithms for learning parameters from observational data like the Kalman inversion approach only provide point estimates of parameters.
In this work, we compare two Bayesian parameter inference approaches applied to the intermediate complexity model for the El Niño-Southern Oscillation by Zebiak & Cane. i) The "Calibrate, Emulate, Sample" (CES) approach, an extension of the ensemble Kalman inversion which allows posterior inference by emulating the model via Gaussian Processes and thereby enables efficient sampling. ii) The simulation-based inference (SBI) approach where the approximate posterior distribution is learned from simulated model data and observational data using neural networks.
We evaluate the performance of both approaches by comparing their run times and the number of required model evaluations, assess the scalability with respect to the number of inference parameters, and examine their posterior distributions.