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Robustness in quantification of uncertainty in climate system properties

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Bayesian statistics provides a framework for quantifying uncertainty in climate modelling. However, every statistical analysis is based on specific assumptions that can only partly be corroborated by empirical data. It is thus important to assess the robustness of the derived uncertainty estimates with respect to these assumptions. Robust Bayesian statistics is an attempt to quantify the sensitivity of the results of a Bayesian statistical analysis to the adopted assumptions. Instead of single prior distributions and likelihood functions, classes of prior distributions and likelihood functions are considered, and upper and lower expectations of quantities of interest are calculated.

We present results of the application of robust Bayesian analysis to the quantification of uncertainty in climate system properties using the Bern 2.5D climate model, an earth system model of intermediate complexity.

Focus is on the parameter climate sensitivity. Using the framework of robust Bayesian analysis, we first define a non-parametric set of prior distributions for climate sensitivity S and update the entire set according to Bayes' theorem. The upper and lower probability that S lies above 4.5 degrees Celsius is calculated over the resulting set of posterior distributions.

Furthermore, posterior distributions under different assumptions on the likelihood function are computed. We find that the main characteristics of the marginal posterior distributions of climate sensitivity are quite robust with regard to statistical models of

climate variability and observational error. However, the influence of prior assumptions on the tails of distributions is substantial considering the important political implications. Moreover, we find that ocean heat change data have a considerable potential to constrain climate sensitivity.

To compute posterior probability distributions we use a Metropolis-Hastings Markov Chain Monte Carlo algorithm with blockwise update. The sample size is 150’000. The probability density functions are estimated using a kernel density estimator.

The observations that we use consist of global annual mean surface temperature data and annual mean change in world ocean heat content down to 700 meters depth. The Markov Chain Monte Carlo technique allows for taking advantage of the full data time series.