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An imprecise probability estimate for climate sensitivity

E Kriegler
Potsdam Institute for Climate Impact Research, Potsdam, Germany (kriegler@pik-potsdam.de)

Constructing a probability distribution for climate sensitivity usually requires three steps: the estimation of a likelihood that a set of model hypotheses reproduces the observations, the assumption of a prior probability for the model hypotheses, and the updating of the prior with the likelihood information via Bayes' rule. The application of this framework to climate simulations is hampered by the multi-faceted uncertainty about the historical radiative forcing and the unforced natural variability in the climate signal. As a consequence, the estimated likelihood function will vary with the assumption about these factors giving rise to an entire set of plausible likelihood estimates. Likewise, the assumption of a prior probability carries a subjective flavour which can be reduced if entire sets of plausible prior probabilities are subjected to the updating process.

Sets of likelihood functions and prior probabilities can be treated with methods of imprecise probability theory. We present an application to the problem of updating an imprecise prior probability for key determinants of climate change with a precise likelihood function for reproducing the 20th century global mean temperature change. We use a simple energy balance box model with a 1-D diffusive ocean to simulate the dependence of SST and land surface temperature on climate sensitivity and effective ocean heat diffusivity. The model is forced with the historical radiative forcing of natural and anthropogenic origin to generate a large ensemble of hypotheses about 20th century climate change. We estimate a likelihood for the model hypotheses by assuming that the residual between model response and instrumental SST record constitutes an AR(1) process after removal of the ENSO signal. In addition, we test the decorrelated residuals for white noise with a Portmanteau statistics. On the basis of this test, we can only reject small values of climate sensitivity and a very large cooling from sulfate aerosols.

Imprecise prior probabilities for climate sensitivity and sulfate aerosol forcing are con-

structed from lower and upper distribution functions as well as lower density functions that can be distilled from recent probability estimates in the literature. The imprecise prior probability for ocean heat diffusivity is derived directly from observations of ocean heat uptake in the second half of the 20th century. We represent the imprecise prior probabilities for the three parameters by a joint belief function that constitutes the lower envelope of the set of plausible prior probabilities. The belief function is updated with the likelihood information by means of two updating rules: a generalised version of Bayes' rule and Dempster's rule of conditioning. As a result, we will present lower and upper posterior distribution functions for climate sensitivity, and deduce lower and upper probabilities for the event that climate sensitivity lies within the IPCC range of 1.5 to 4.5 Kelvin.