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Climate Sensitivity via a Nonparametric Fluctuation–Dissipation Theorem

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The fluctuation–dissipation theorem (FDT) has been suggested as a method of calculating the response of the climate system to a small change in an external parameter. The simplest form of the FDT assumes that the probability density function of the unforced system is Gaussian and most applications of the FDT have made a quasi-Gaussian assumption. However, whether or not the climate system is close to Gaussian remains open to debate, and non-Gaussianity may limit the usefulness of predictions of quasi-Gaussian forms of the FDT. We describe an implementation of the full non-Gaussian form of the FDT. The principle of the quasi-Gaussian FDT is retained in that the response to forcing is predicted using only information available from observations of the unforced system, but in the non-Gaussian case this information must be used to estimate aspects of the probability density function of the unforced system. Since this estimate is implemented using the methods of nonparametric statistics, the new form is referred to as a “nonparametric FDT.” Application is demonstrated to a sequence of simple models including a stochastic version of the three component Lorenz model. The authors show that the nonparametric FDT gives accurate predictions in cases where the quasi-Gaussian FDT fails. Finally we consider practical application of the nonparametric FDT to higher-dimensional systems.