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Parametrization of fast subgrid-scale processes using Edgeworth expansions

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A classical approach to the parametrization of subgrid-scale processes is to assume a large time scale separation between slow “climate” and fast “weather” processes. This assumption leads to a reduction of the full system to a set of slow variable that are impacted by a noise that parametrizes the fast processes. This type of reduction method has been called “Hasselman’s program” or the “MTV approach” (after a series of papers by Majda, Timofeyev and Vanden-Eijnden) in the climate community and “homogenization” in the mathematical community.

Homogenization is an extension of the central limit theorem (CLT) to dynamical systems, in that one obtains a weak convergence to a stochastic process with Gaussian noise. A number of theorems are known that give more details on how this convergence unfolds in the case of the CLT, describing the error one makes by taking the Gaussian limiting distribution instead of the actual distribution.

We will discuss how such results, in particular the Edgeworth expansion, can be used in the setting of time-scale-separated dynamical systems to develop extended parametrizations that more accurately describe the statistics of slow-fast systems than the limiting homogenized equations. This we are able to do by developing the first few Edgeworth correction terms and matching them by a time-correlated surrogate process that now parametrizes the fast processes instead of the Gaussian white noise.