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A simple linear response closure approximation for slow dynamics of a multiscale system with linear coupling

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Many applications of contemporary science involve multiscale dynamics, which are typically characterized by the time and space scale separation of patterns of motion, with fewer slowly evolving variables and much larger set of faster evolving variables. This time-space scale separation causes direct numerical simulation of the evolution of the dynamics to be computationally expensive, due both to the large number of variables and the necessity to choose a small discretization time step in order to resolve the fast components of dynamics. In this work we propose a simple method of determining the closed model for slow variables alone, which requires only a single computation of appropriate statistics for the fast dynamics with a certain fixed state of the slow variables. The method is based on the first-order Taylor expansion of the averaged coupling term with respect to the slow variables, which can be computed using the linear fluctuation-dissipation theorem. We show that, with simple linear coupling in both slow and fast variables, this method produces quite comparable statistics to what is exhibited by a complete two-scale model. The main advantage of the method is that it applies even when the statistics of the full multiscale model cannot be simulated due to computational complexity, which makes it practical for real-world large scale applications.

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