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A Statistical Mechanical Approach for the Parametrization of the Coupling in a Fast-Slow System

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Constructing accurate, flexible, and efficient parametrizations is one of the great challenges in the numerical modelling of geophysical fluids. We consider here the simple yet paradigmatic case of a Lorenz 84 model forced by a Lorenz 63 model and derive a parametrization for the effect of the Lorenz 63 model using a recently developed statistical mechanical methodology based on the Ruelle response theory. We derive an expression the deterministic and the stochastic component of the parametrization and we show that the approach allows for dealing seamlessly with the case of the Lorenz 63 being a fast as well as a slow forcing compared to the characteristic time scales of the Lorenz 84 model. We test our results using both standard metrics based on the moments of the variables of interest as well as Wasserstein distance between the projected measure of the original system on the Lorenz 84 model variables and the measure of the parametrized one. By testing our methods by looking at reduced phase spaces obtained by projection, we find support to the idea that comparisons based on the Wasserstein distance might be of relevance in many applications despite the curse of dimensionality.