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Building Response Operators Using Koopman Formalism: the Link between Free and Forced Variability

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Linking free and forced variability is one of the key challenges in climate science. As the climate system is an out of equilibrium one, the standard application of the fluctuation-dissipation theorem is out of scope. It has been shown in the past that it is possible to construct response operators that can be used to perform climate change projections using a more general formulation of response theory for nonequilibrium systems. Nonetheless, such operators lack the key property of interpretability: one cannot separate the contribution to the total response coming from different modes of natural variability of the system. We show here in a few low-dimensional models how this issue can be taken care of by taking advantage of the Koopman formalism. One can then write the response operator as a sum of terms each associated with a specific mode of variability. The obtained results also shed light on previous findings by Hasselmann and colleagues and on recently proposed data-driven methods aimed at deriving response operators from data.