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Using the fluctuation-dissipation theorem to examine the atmospheric response to moving tropical heat sources

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In the past, the realization that ENSO events exert a marked influence on midlatitude interannual variability prompted a substantial research effort to characterize how the atmosphere responds to quasi-stationary tropical heat sources. Here, recognizing the presence of prominent moving tropical precipitation anomalies in nature, we are interested in characterizing the response to heat sources that are time dependent. We use the fluctuation-dissipation theorem, as applied to the behavior of an atmospheric GCM, to do this. Comparison of GCM and associated FDT solutions demonstrates the effectiveness of FDT in reproducing GCM behavior, including the reaction of state variables and functionals of state. This makes it possible to systematically investigate how the response is a function of the time-dependent properties of the source while also capturing and analyzing important feedbacks that a conventional linearization approach would not include.

We find that the strength, structure and geographical extent of the response is strongly dependent on the rate and direction of the heat source's movement. To some degree this dependence can be anticipated by conventional linear theory, but feedbacks from the synoptic eddies must also be taken into account for a more complete analysis. Perhaps surprisingly, qualitatively the role of the eddy feedbacks is not strongly dependent on the properties of the source's movement, apparently because these feedbacks take place on such a fast timescale. Implications of the findings for the midlatitude impact of the Madden-Julian Oscillation are highlighted.

Preliminary results raise the possibility of carrying out a similar analysis for nature, though methods for reducing the length of the time series required to construct FDT operators need to be developed.