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Quantifying Limits to Detection of Early Warning for Critical Transitions

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Catastrophic regime shifts in complex natural systems may be averted through advanced detection. Recent work has provided a proof-of-principle that many systems approaching a catastrophic transition may be identified through the lens of early warning indicators such as rising variance or increased return times. Despite widespread appreciation of the difficulties and uncertainty involved in such forecasts, proposed methods hardly ever characterize their expected error rates. Without the benefits of replicates, controls, or hindsight, applications of these approaches must quantify how reliable different indicators are in avoiding false alarms, and how sensitive they are to missing subtle warning signs. We propose a model based approach in order to quantify this trade-off between reliability and sensitivity and allow comparisons between different indicators. We show these error rates can be quite severe for common indicators even under favorable assumptions, and also illustrate how a model-based indicator can improve this performance. We demonstrate how the performance of an early warning indicator varies in different data sets, and suggest that uncertainty quantification become a more central part of early warning predictions.

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