AN EARLY WARNING INDICATOR FOR TIPPING POINTS IN STRONGLY FORCED SYSTEMS

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Classical critical slowing down early warning signals (observing increasing trends in the autocorrelation and variance) have been developed to try and detect when a system is approaching a tipping point, typically represented mathematically by a bifurcation. However, these signals often fail for strongly forced slow systems. Here we propose a new method that reconstructs the quasi-equilibrium state and therefore produces a robust indication of where the critical threshold may lie in a system.

We show that the standard deviation of this reconstructed quasi-equilibrium state increases exponentially ahead of its critical threshold, at time t_crit, for both strongly forced fast and slow systems. Furthermore, we show that the standard deviation of the quasi-equilibrium state varies proportionally to 1/(t_crit - t)^alpha, where the exponent alpha can be derived analytically based on the type of bifurcation being crossed. Using both the reconstructed quasi-equilibrium state and fitting the above form to its standard deviation allows us to diagnose the location of the critical threshold without needing to have any further knowledge of the system's parameter values.