Robustness of critical slowing down indicators to power-law extremes in an Amazon rainforest model

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Critical slowing down has recently been detected as an indicator of reduced resilience in remotely sensed data of the Amazon rainforest [1]. Tropical rainforests are frequently hit by disturbances such as fire, windthrow, deforestation or drought, which are known to follow a heavy-tailed amplitude distribution. Early warning signals based on critical slowing down are theoretically grounded for systems under the influence of weak, Gaussian noise. Hence, it is not imminent that they are applicable also for systems like the Amazon rainforest, which are influenced by heavy-tailed noise. Here, we extended a conceptual model of the Amazon rainforest [2] to study the robustness of critical slowing down indicators to power-law extremes. These indicators are expected to increase before a critical transition.

We find the way by which such an increase is detected is decisive for the recall of the early warning indicator (i.e. the proportion of critical transitions detected by the indicator). If a linear slope is taken, the recall of the early warning signal is reduced under power-law extremes. Instead, the Kendall-Tau rank correlation coefficient should be used because the recall remains high in this case. Other approaches to increase robustness, like a high-pass filter or the interquartile range, are less effective. In [1], reduced resilience of the Amazon rainforest was determined through an increase in the lag-1 autocorrelation measured by the Kendall-tau rank correlation. Hence, if there was a resilience loss, they can correctly detect it even in the presence of relatively strong power-law disturbances. However, we also quantify the false positive rate, that is, how often a resilience loss is measured if the model represents a stable rainforest. At a significance level of 5% (1%, 10%) for the early warning signal detection, the false positive rate is approximately 10% (5%, 15%). For strong heavy-tailed noise, this false positive rate can deteriorate to as high as 25% (15%, 35%). This indicates, that increasing critical slowing down may not always be caused by an approaching critical transition, a false positive detection is possible.
