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Early-warning signals (potentially) reduce uncertainty in forecasted timing of critical shifts

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Despite the identification of early-warning signals precluding critical shifts or state transitions in ecosystems, limited evidence exists that they can be used to forecast the actual timing of a critical shift. Here, we propose a probabilistic Bayesian approach to forecast the timing of a shift by combining uncertain prior information about the ecosystem dynamics (parameters and drivers) and sampled spatial and temporal correlation and variance of ecosystem states, which are well known early-warning signals. For an ecosystem of logistically growing vegetation under linear increase in an external driver (grazing pressure), we show that the use of sampled early-warning signals results in lower prediction uncertainty in forecasted timing of shifts compared to forecasts made with sampled mean state variables. In addition, we show that uncertainty in ecosystem parameters decreases well ahead of a shift. An important conclusion of our study is that the use of early-warning signals in forecasting of shifts is promising, provided that a large number of samples are collected (n $\approx$10000 in our study) and that random sampling error is small. With a smaller number of samples the advantage of using early-warning signals disappears and the use of sampled mean state variables outperforms the use of sampled early-warning signals. This is due to the large uncertainty in sampled early-warning signals when the number of samples becomes small. This is because the spatial or temporal correlation values used as early-warnings are higher order statistics. Uncertainty in higher order statistics calculated from sparse sampling data is notably large compared to uncertainty in mean values.