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On the numerical properties of empirical master equations

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Master equations are used in the in atmospheric sciences mainly in a discrete time approximation for providing probability density forecasts in a discretized phase space spanned by a few climate variables. The coefficients of an empirical master equation (EME) are estimated from the relative frequencies of transitions observed in time series of the variables. The EME is formally equivalent to an (empirical) first-order Markov chain description. The quality of the EME depends inter alia on the length and time resolution of the available time series. These dependences are studied on the basis of data from the three-component Lorenz model with additional white noise forcing. Thus, time series of almost any length and time resolution can be generated easily, and probability density forecasts can be compared directly with the evolution of an ensemble of points. Useful results are obtained by partitioning the phase space into several hundred cells of equal grid size. We find that there exists a threshold length of the time series beyond which the performance of the EME hardly improves. It is even more surprising that the performance deteriorates with reduction of the time step. This is due to an increase in numerical diffusion. The choice of the dimensionality and the selection of the variables are crucial to the quality of the EME. These results provide useful guidelines for any application of the EME in the atmospheric sciences and elsewhere. An application to stratospheric climate variability is briefly presented.