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c-u-curve: A method to analyze, classify and compare dynamical systems by uncertainty and complexity

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We propose a method to analyse, classify and compare dynamical systems of arbitrary dimension by the two key features uncertainty and complexity. It starts by subdividing the system's time-trajectory into a number of time slices. For all values in a time slice, the Shannon information entropy is calculated, measuring within-slice variability. System *uncertainty* is then expressed by the mean entropy of all time slices. We define system *complexity* as "uncertainty about uncertainty", and express it by the entropy of the entropies of all time slices. Calculating and plotting uncertainty *u* and complexity *c* for many different numbers of time slices yields the *c-u-curve*. Systems can be analysed, compared and classified by the c-u-curve in terms of i) its overall shape, ii) mean and maximum uncertainty, iii) mean and maximum complexity, and iv) its characteristic time scale expressed by the width of the time slice for which maximum complexity occurs. We demonstrate the method at the example of both synthetic and real-world time series (constant, random noise, Lorenz attractor, precipitation and streamflow) and show that conclusions drawn from the c-u-curve are in accordance with expectations. The method is based on unit-free probabilities and therefore permits application to and comparison of arbitrary data. It naturally expands from single- to multivariate systems, and from deterministic to probabilistic value representations, allowing e.g. application to ensemble model predictions.