Disentangling Uncertainty and Error: On the Predictability of Nonlinear Systems

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Abstract

Chaos places no a priori restrictions on predictability: any uncertainty in the initial condition can be evolved and then quantified as a function of forecast time. If a specified accuracy at a given future time is desired, a perfect model can specify the initial accuracy required to obtain it, and accountable ensemble forecasts can be obtained for each unknown initial condition. Statistics which reflect the global properties of infinitesimals, such as Lyapunov exponents which define "chaos", limit predictability only in the simplest mathematical examples. Model error, on the other hand, makes forecasting a dubious endeavor. Forecasting with uncertain initial conditions in the perfect model scenario is contrasted with the case where a perfect model is unavailable, perhaps nonexistent. Applications to both low (2 to 400) dimensional models and high (10^7) dimensional models are discussed. For real physical systems no perfect model exists; the limitations of near-perfect models are considered, as is the relevance of the recurrence time of the system in terms of the likely duration of observations. It is argued that in the absence of a perfect model, a perfect ensemble does not exist and hence no accountable forecast scheme exists: accurate probabilistic forecasts cannot be made even when the statistics of the observational uncertainty are known exactly. Nevertheless, ensemble forecasts are required to maintain the uncertainty in initial condition; returning to single best guess forecasts is not an option. Both the relevance of these observations to operational forecasts and alternatives to aiming for an accurate probabilistic forecasts are discussed.