The Geometry of Model Error

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Abstract

This paper investigates the nature of model error in complex deterministic nonlinear systems, such as weather forecasting models. Forecasting systems incorporate two components, a forecast model and a data assimilation method. The latter projects a collection of observations of reality into a model state. Key features of model error can be understood in terms of geometric properties of the data projection and a model's attracting manifold. Model error can be resolved into two components, a projection error, which can be understood as the model's attractor being in the wrong location given the data projection, and direction error, which can be understood as the trajectories of the model moving in the wrong direction compared to the projection of reality into model space. Our investigation introduces some new tools and concepts, including, the shadowing filter, causal and non-causal shadow analyses, and various geometric diagnostics. Various properties of forecast errors and model errors are described with reference to low dimensional systems, like Lorenz's equations, then an operational weather forecasting system is shown to have the same predicted behaviour. The concepts and tools introduced show promise for the diagnosis of model error and the improvement of ensemble forecasting systems.