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Automatic parameter estimation in a mesoscale model without ensembles

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In numerical forecasting, unknown model parameters have been estimated from a time series of observations by regarding them as extra state variables, and applying standard data assimilation methods that use ensembles to represent background error. In many situations, however, the use of ensembles is prohibitively expensive and/or impracticable because of the inability to properly account for model error in the initialization scheme. If one is seeking to estimate model parameters as data is assimilated, it is possible to take advantage of the assumed relative constancy of such parameters over large regions of time and space to derive an estimate from a single realization. The approach follows from a general result on synchronously coupled dynamical systems, where one system here represents "truth" and the other "model": If two such systems can be made to synchronize when their corresponding parameters are identical, for any coupling scheme (such as might be used in conventional data assimilation) a parameter estimation law can generally be added that will dynamically reduce a total cost (Lyapunov) function including parameter mismatch terms as well as state mismatch terms.

The approach is used to estimate a parameter that quantifies the effect of soil moisture in a single-column version of the Weather Research and Forecasting (WRF) model. The scheme can be extended to infer a 2D map of soil parameter values for a 3D model, using the fact that the parameter is slowly varying almost everywhere. Discontinuities are represented as additional degrees of freedom, and the Lyapunov function is augmented so as to penalize for horizontal variations in the soil parameter value except at locations of such discontinuities. The constrained optimization approach that is proposed should be useful for a variety of NWP parameter estimation problems, and will extend the power of ensemble methods.