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Model Uncertainty Quantification for Data Assimilation in partially observed multi-scale systems

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Model uncertainty quantification is an essential component of effective Data Assimilation (DA). However, it can be a challenging task for realistic applications characterised by complex partially observed non-linear systems with highly non-Gaussian uncertainties. Stochastic Parameterisation methods have been receiving increasing attention for cases where model uncertainty arises due to unresolved sub-grid scale processes. However, these are generally only applicable when knowledge of the true sub-grid scale process or full observations of the coarse scale process is available. Here a methodology is presented for estimating the statistics of sub-grid scale processes using only partial observations of the coarse scale process, and without relying on Gaussian assumptions. Additive errors are estimated over a training period by minimising their conditional variance, constrained by available observations. Special is that these errors are binned conditioned on the previous model state during the minimisation process, allowing for the recovery of complex error structures. We present the theory behind the approach along with numerical experiments using the multi-scale Lorenz 96' model. Various parameterisations of the Lorenz 96' model are considered, along with both small and large time scale separations between slow (coarse scale) and fast (fine scale) variables. Results demonstrate improved analyses and forecasts with the proposed method compared to two existing methods for accounting for model uncertainty in DA.