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Supervised learning from noisy observations: Combining machine-learning techniques with data assimilation

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Data-driven prediction and physics-agnostic machine-learning methods have attracted increased interest in recent years achieving forecast horizons going well beyond those to be expected for chaotic dynamical systems. In a separate strand of research data-assimilation has been successfully used to optimally combine forecast models and their inherent uncertainty with incoming noisy observations. The key idea in our work here is to achieve increased forecast capabilities by judiciously combining machine-learning algorithms and data assimilation. We combine the physics-agnostic data-driven approach of random feature maps as a forecast model within an ensemble Kalman filter data assimilation procedure. The machine-learning model is learned sequentially by incorporating incoming noisy observations. We show that the obtained forecast model has remarkably good forecast skill while being computationally cheap once trained. Going beyond the task of forecasting, we show that our method can be used to generate reliable ensembles for probabilistic forecasting as well as to learn effective model closure in multi-scale systems.