Combining data assimilation and machine learning to predict chaotic dynamics with imperfect observations and models

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Prediction of spatio-temporal chaotic systems is important in various fields. While data assimilation has been widely used to predict chaotic systems in geoscience, machine learning algorithms, such as Reservoir Computing (RC), have recently been recognized as a promising tool for the model-free prediction of chaotic systems. However, most of the previous studies on the machine learning based prediction neglected observation errors or sparsity although they are inevitable in real-world problems. In this study, we evaluate the skill of RC with noisy and sparsely distributed observations. We intensively compare the performances of RC and Local Ensemble Transform Kalman Filter (LETKF) by applying them to the prediction of the Lorenz 96 system. Although RC can successfully predict the Lorenz 96 system if the system is perfectly observed, we find that RC is vulnerable to observation errors and sparsity compared with LETKF. To overcome this limitation of RC, we propose to combine LETKF and RC. In our proposed method, the system is predicted by RC that learned the analysis time series estimated by LETKF. Our proposed combination method can successfully predict the Lorenz 96 system using noisy and sparsely distributed observations. Most importantly, our proposed combination method can predict better than LETKF when the model is imperfect.

Keywords: Data Assimilation, Machine Learning, Reservoir Computing, Chaos, Local Ensemble Transform Kalman Filter

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