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Combining variational mode decomposition and recurrent neural network to predict rainfall time series and evaluating prediction performance by universal multifractals

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Rainfall time series prediction is crucial for geoscientific system monitoring, but it is challenging and complex due to the extreme variability of rainfall. In order to improve prediction accuracy, a hybrid deep learning model (VMD-RNN) was proposed. In this study, variational mode decomposition (VMD) is first applied to decompose the original rainfall time series into several sub-sequences according to the frequency domain. Following that, different recurrent neural network (RNN) models are utilized to predict individual sub-sequences and the final prediction is reconstructed by summing the prediction results of sub-sequences. These RNN models are long short-term memory (LSTM), gated recurrent unit (GRU), bidirectional LSTM (BiLSTM) and bidirectional GRU (BiGRU), which are optimal for sequence prediction. The root mean square error (RMSE) of the predicted performance is then used to select the ideal RNN model for each sub-sequences. In addition to RMSE, the framework of universal multifractal (UM) is also introduced to evaluate prediction performances, which enables to characterize the extreme variability of predicted rainfall time series. The study employed two rainfall datasets from 2001 to 2020 in Paris, with daily and hourly resolutions. The results show that, when compared to directly predicting the original time series, the proposed hybrid VMD-RNN model improves prediction of high or extreme values for the daily dataset, but does not significantly enhance the prediction of zero or low values. Additionally, the VMD-RNN model also outperforms existing deep learning models without decomposition on the hourly dataset when evaluated with the help of RMSE, while universal multifractal analyses point out limitations.