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Using Explainable AI and Transfer Learning to understand and predict the maintenance of Atlantic blocking with limited observational data

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Blocking events are an important cause of extreme weather, especially long-lasting blocking events that trap weather systems in place. The duration of blocking events is, however, underestimated in climate models. Explainable Artificial Intelligence are a class of data analysis methods that can help identify physical causes of prolonged blocking events and diagnose model deficiencies. We demonstrate this approach on an idealized quasigeostrophic model developed by Marshall and Molteni (1993). We train a convolutional neural network (CNN), and subsequently, build a sparse predictive model for the persistence of Atlantic blocking, conditioned on an initial high-pressure anomaly. Shapley Additive ExPlanation (SHAP) analysis reveals that high-pressure anomalies in the American Southeast and North Atlantic, separated by a trough over Atlantic Canada, contribute significantly to prediction of sustained blocking events in the Atlantic region. This agrees with previous work that identified precursors in the same regions via wave train analysis. When we apply the same CNN to blockings in the ERA5 atmospheric reanalysis, there is insufficient data to accurately predict persistent blocks. We partially overcome this limitation by pre-training the CNN on the plentiful data of the Marshall-Molteni model, and then using Transfer Learning to achieve better predictions than direct training. SHAP analysis before and after transfer learning allows a comparison between the predictive features in the reanalysis and the quasigeostrophic model, quantifying dynamical biases in the idealized model. This work demonstrates the potential for machine learning methods to extract meaningful precursors of extreme weather events and achieve better prediction using limited observational data.

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