EGU21-1828
https://doi.org/10.5194/egusphere-egu21-1828
EGU General Assembly 2021

A New Mathematical Framework for Atmospheric Blocking Events

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We use a simple yet Earth-like atmospheric model to propose a new framework for understanding the mathematics of blocking events, which are associated with low frequency, large scale waves in the atmosphere. Analysing error growth rates along a very long model trajectory, we show that blockings are associated with conditions of anomalously high instability of the atmosphere. Additionally, the lifetime of a blocking is positively correlated with the intensity of such an anomaly, against intuition. In the case of Atlantic blockings, predictability is especially reduced at the onset and decay of the blocking, while a relative increase of predictability is found in the mature phase, while the opposite holds for Pacific blockings, for which predictability is lowest in the mature phase. We associate blockings to a specific class of unstable periodic orbits (UPOs), natural modes of variability that cover the attractor of the system. The UPOs differ substantially in terms of instability, which explains the diversity of the atmosphere in terms predictability. The UPOs associated to blockings are indeed anomalously unstable, which leads to them being rarely visited. The onset of a blocking takes place when the trajectory of the system hops into the neighbourhood of one of these special UPOs. The decay takes place when the trajectory hops back to the neighbourhood of usual, less unstable UPOs associated with zonal flow. This justifies the classical Markov chains-based analysis of transitions between weather regimes. The existence of UPOs differing in the dimensionality of their unstable manifold indicates a very strong violation of hyperbolicity in the model, which leads to a lack of structural stability. We propose that this is could be a generic feature of atmospheric models and might be a fundamental cause behind difficulties in representing blockings for the current climate and uncertainties in predicting how their statistics will change as a result of climate change.

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