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Predicting weather regime transitions in Northern Hemisphere data sets

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A statistical learning method called "random forests" generalizes classification and regression trees (CART). In this method, a set ("forest") of CARTs is grown on random subsets of the data and the classification is carried out using subsets of the full "predictor" (i.e., classifier) set. This method is applied here for the first time to actual prediction in time, rather than to classification, by "classifying" outcomes of a time-dependent process.

We apply random forests to the prediction of transitions between weather regimes of wintertime Northern Hemisphere (NH) atmospheric low-frequency variability (LFV). First, we analyzed the output of a long simulation of a global quasi-geostrophic, three-level (QG3) model with topography. This model exhibits realistic regimes and the transitions between them often follow preferred directions. Random forests makes surprisingly accurate predictions of whether, yes or no, a given point within a regime will initiate an exit of the trajectory from that regime and subsequent transition to another, prescribed regime. Sensitivity studies of the predictions to the choice of predictors showed that the angle between a preferred exit direction and the radius vector from the regime centroid to the point in question, as well as the projection of the velocity along the trajectory onto this direction, were particularly successful predictors.

We applied random forests next to the dataset composed of 55 winters of NH 700-hPa geopotential height anomalies. We forecast the break of a regime and subsequent onset of another regime, for three robust transitions in a Markov chain of NH LFV.

The study is carried out in a phase space spanned by a few leading empirical orthogonal functions of the dataset's variability. Taking the relative cost of false positives and false negatives into account, the random forest method shows useful forecasting skill. Plots of estimated response functions underscore the crucial role of the exit angle and velocity as key predictors of regime breaks and subsequent transitions. This result confirms the 20-year old hypothesis of the connection between NH regimes and unstable fixed points of the leading-order, nonlinear dynamics, and between their breaks and preferred modes of instability.