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Identifying oceanic-atmospheric controls on hydrology using a machine learning approach

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A thorough understanding of the biogeochemical, water, and energy cycles and their interactions is needed to assess the potential implications of global warming on our future climate. Oceanic-atmospheric oscillation patterns have a strong impact on the variability in the water cycle and, hence on vegetation dynamics. However, the relation between ocean-atmospheric oscillations and hydrology is not yet fully understood. To accurately predict the impact of climate change on hydrology and ecosystem response, a better knowledge about these connections is indispensable.

The objective of this study is to identify oceanic-atmospheric controls on hydrology and disentangle the impact of individual climate modes. The approach used in this study is called LASSO (least absolute shrinkage and selection operator) regression, which is a data-driven method that uses automatic feature selection and regularization. In our study, we use LASSO to quantify the impact of 17 major ocean-atmospheric oscillations (e.g., El Niño Southern Oscillation, Northern Atlantic Oscillation) on hydrologic variables, such as precipitation. The methodology allows accounting for cross-correlations in the features, i.e. climate oscillation indices, which can therefore be treated as independent variables. For validation of the LASSO models a nested cross-validation and a significance test using the Benjamini-Hochberg procedure is applied. Additionally, every feature incorporates a possible time lag between zero and five months to account for a potential lagged response of hydrology to ocean-atmospheric oscillations. Both experiments to disentangle the overall effect and the seasonal effect are performed.

Looking at the Mediterranean region and using precipitation from CRU (Climatic Research Unit) as response variable, up to 40% of the variability can be explained by ocean-atmospheric oscillations in the winter season model, using data only of December, January and February. We show that the Northern Annular Mode, the East Atlantic Oscillation, the East Atlantic Western Russia Pattern and the North Atlantic Oscillation have a significant impact. These results help us to get a better understanding of how the individual climate modes affect different regions of the world and to gain new insights in the interactions between ocean, atmosphere, land, and ultimately the biosphere.