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Identifying dynamic memory effects on vegetation state using recurrent neural networks

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The impact of past environmental conditions on vegetation state is still poorly understood. While data-driven studies to explore these so-called memory effects exist, it is unclear if the statistical models are able to represent the involved processes adequately (e.g. regression with lagged variables). Yet, there are models that can deal with complex temporal interactions: Recurrent Neural Networks (RNNs) have been proven to perform excellently on sequential data in fields like text translation, speech recognition, and recently also prediction of Earth system variables. These models, however, are hard to interpret post-hoc and information about memory effects cannot be gained from the model parameters directly.

Here, we model global Normalized Difference Vegetation Index (NDVI), a proxy for vegetation state, as a function of meteorological time-series and static variables representing soil properties and land cover fractions with a Long Short-Term Memory (LSTM) architecture. Further, we test the effect of temporal context (memory), by successively permuting the time-series while keeping blocks of varying length in original order during training, thus limiting the model's access to past observations. The comparison of the different model predictions reveals the role of memory effects on vegetation state.

The model considering memory effects achieved good overall performance with R2=0.93 and RMSE=0.067. Patterns of memory effects support the hypothesis of strong memory effects in arid and semiarid regions. We further discussed the potential of the method to be applied to other Earth observation data to reveal patterns of memory effects.