Forecasting the monthly severity of widespread flooding in Germany using dilated convolutional neural networks conditioned by large-scale climatic indexes

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Spatially co-occurring floods pose a great threat to the resilience and the recovery potential of the communities. A timely forecasting of such events plays a crucial role for increasing the preparedness of public and private sectors and for limiting the associated losses. In this study we investigated the potential of dilated Convolutional Neural Networks (CNN) conditioned on a set of large-scale climatic indexes and antecedent precipitation for monthly forecast of widespread flooding severity in Germany using 63 years of streamflow observations. The severity of widespread flooding (i.e., spatially co-occurring floods) was estimated as simultaneous (within a given month) exceedance of an at-site two-year return period for streamflow peaks across 172 mesoscale catchments. The model was trained for the whole country and for the three diverse hydroclimatic regions individually to provide insights on spatial heterogeneity of model performance and drivers of flooding. Evaluation of the model skill for floods generated by different processes revealed the largest bias for events generated during dry conditions. The bias for rain-on-snow flood events was the lowest despite their higher severity indicating higher predictability of these events from large scale climatic indexes. Model-based feature attribution and independent wavelet coherence analyses both indicated considerable difference in the major drivers of widespread flooding in different regions. While the flooding in the North-Eastern region is strongly affected by the Baltic Sea (e.g., East Atlantic pattern), the North-Western region is affected more by global patterns associated with the El-Niño activity (e.g., Pacific North American pattern). In the Southern region in addition to the effect of the global patterns we also detect the effect of the Mediterranean Sea (Mediterranean Oscillation Index), while antecedent precipitation seems to play less important role in this region compared to the rest of the country. Our results indicate a considerable potential for forecasting widespread flood severity using dilated CNN especially as the length of the available time series for training increases.