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Application of multi drought definitions to forecast streamflow drought across Europe

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Streamflow drought forecasting is a key element of contemporary Drought Early Warning Systems (DEWS). The term streamflow drought forecasting, rather than streamflow forecasting, however, has created confusion within the scientific hydro-meteorological community, as well as in operational weather and water management services. Streamflow drought forecasting requires an additional step, which is the application of a drought identification method to the forecasted streamflow time series. The way, how streamflow drought is defined, is the main reason for this misperception. The purpose of this study, therefore, is to provide a comprehensive overview of the application of different drought identification approaches to forecast streamflow drought, incl. its characteristics, such as drought occurrence, timing, duration, and deficit volume, across the pan-European river network and for the Rhine River in more detail. In this study, the implications of different approaches for forecasting streamflow drought are elaborated using the extreme 2003 drought in Europe, as an example. The forecasted 25 ensemble streamflow data with 7-month lead time (LT) were obtained from the LISFLOOD hydrological model fed with seasonal meteorological forecasts from the European Centre for Medium-range Weather Forecasts system 5 (ECMWF SEAS 5). Streamflow droughts were analyzed using the daily and monthly Variable Threshold methods (VTD and VTM), daily and monthly Fixed Threshold methods (FTD and FTM), and the Standardized Streamflow Index with 1-month accumulation period (SSI-1). Our results clearly show that streamflow drought characteristics derived with different approaches deviate, which are partly associated with different climate regions across Europe. Using the forecasts initiated in July 2003 for LT=7-month, first, the daily drought approaches forecast more drought events than the monthly approaches. Second, the VT droughts (VTD and VTM), incl. SSI-1 forecast a lower number of drought occurrences than the FT droughts (FTD and FTM), which highlights the importance of taking seasonality into account. Overall, the FT approaches predict a longer drought duration, earlier drought timing, and higher drought deficit volume in many European rivers than the VT approaches. The characteristics of SSI-1 drought, in general, are close to what is being identified by the VTM approach. A detailed analysis of the drought forecasts for the Rhine River indicates that the number of drought events derived from the median of ensemble members can be predicted relatively well, but with lower skill for other drought characteristics. The use of monthly-aggregated forecasted flow data (e.g. VTM, FTM, and SSI) seems to be the best practice for seasonal drought forecasts because it will alleviate the drought forecast skill. The monthly drought threshold approaches, however, will forecast higher drought duration and deficit volume

than using daily datasets. The choice of the drought identification method when forecasting streamflow drought, ultimately rests with the end-users and we need to realize that there is no one drought identification approach that fits all needs.