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# Decadal variability of drought conditions over the southern part of Europe based on Principal Oscillation Pattern Analysis

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This study introduces a novel method of estimating the decay time, mean period and forcing statistics of drought conditions over large spatial domains, demonstrated here for southern part of Europe (10°E - 40°E, 35°N - 50°N). It uses a two-dimensional stochastically forced damped linear oscillator model with the model parameters estimated from a Principal Oscillation Pattern (POP) analysis and associated observed power spectra. POP is a diagnostic technique that aims to derive the space-time characteristics of a data set objectively. This analysis is performed on an extended observational time series of 114 years (1902 – 2015) of the Standardized Precipitation Evapotranspiration Index for an accumulation period of 12 months (SPEI12), based on the Climate Research Unit (CRU TS v. 3.24) data set. The POP analysis reveals four exceptionally stable modes of variability, which together explain more than 62% of the total explained variance. The most stable POP mode, which explains 16.3% of the total explained variance, is characterized by a period of oscillation of ∼14 years and a decay time of ∼31 years. The real part of POP1 is characterized by a monopole-like structure with the highest loadings over Portugal, western part of Spain and Turkey. The second stable mode, which explains 15.9% of the total explained variance, is characterized by a period of oscillation of ∼20 years and a decay time of ∼26.4 years. The spatial structure of the real part of POP2 has a dipole-like structure with the highest positive loadings over France, southern Germany and Romania and negative loadings over southern part of Spain. The third POP mode, in terms of stability, explains 14.0% of the total variance and is characterized by a period of oscillation of ∼33 years and a decay time of ∼43.5 years. The real part of POP3 is characterized by negative loadings over the eastern part of Europe and positive loadings over Turkey. The fourth stable POP mode, explaining 15.5% of the total variance, is characterized by an oscillation of ∼65 years and a damping time of 54 years. The spatial structure of POP4 is characterized by positive loadings over France and negative loadings over the southern part of the Iberian Peninsula and the eastern part of Europe. The stable POP modes identified could be related to preferred modes of climate variability that are characterized by similar oscillation periods (e.g. the Atlantic Multidecadal Oscillation, which is defined as a coherent pattern of variability in basin-wide North Atlantic sea surface temperatures with a period of 60-80 years). The decadal components identified by the POP analysis can be used operationally by decision makers as early predictors of drought conditions over the southern part of Europe.