Analysis of teleconnection patterns during extreme warm summers and heatwaves over Europe with a rare event algorithm

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Several studies in recent years have highlighted the role of quasi stationary planetary and synoptic scale waves in the occurrence of extreme events such as heatwaves and cold spells. The advancement of our understanding of the dynamical properties and predictability of these events is however hindered by the poor statistics of extreme events in observations and numerical simulations. Recently we have shown how the problem of sampling extreme events in climate models can be tackled using rare event algorithms, numerical tools developed in statistical physics to reduce the computational effort required to sample rare events in dynamical systems. Here we study extreme warm summers and heatwaves over France and Scandinavia in present-day climate conditions, applying a rare event algorithm to ensemble simulations with the CESM1.2 general circulation model. The application of the rare event algorithm concentrates the ensemble members on dynamical trajectories leading to extreme seasonal and subseasonal temperatures for the target regions. In this way we generate samples of extreme heatwaves orders of magnitude larger than what is feasible with direct sampling, and we perform with high degree of precision composite and spectral analysis of dynamical quantities conditional on the occurrence of the extremes. We show how extreme warm summers and heatwaves are associated to low wavenumber hemispheric teleconnection patterns, and how the most extreme summers are related to the succession of rare subseasonal heatwaves. We then discuss the application of these methods to the detection, prediction and analysis of the dynamics of atmospheric Rossby waves related to the formation of extreme heatwaves and other time persistent extreme events.