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Compound events drowned in climate noise? The benefits of employing a regional SMILE in compound hot and dry summer assessment

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Compound hot and dry extremes like the recent summers of 2015, 2018, and 2022 have an impact on a wide range of sectors in Europe, including health, transport, energy production, ecology, agriculture, and forestry. Current research suggests that climate change will increase the intensity, frequency, and duration of joint hot and dry extreme summers in Europe.

However, how robust and skilful are assessments of these compound events?

Here, we understand compound hot and dry extreme summers as the joint exceedance of temperature and (negative) precipitation thresholds (thresholds: 2001-2020 summer 95th percentiles). Since this definition results in particularly rare events, a robust climatology of these extreme events can hardly be obtained from observational time series alone. To investigate these events and their variability, larger sample sizes are required. Some studies so far focus on temporally limited observational records and regional multi-model ensembles that both do not allow for robust climate variability assessment. Others address internal climate variability by using single-model initial condition large ensembles (SMILEs), but based on global models and thus truncating spatial heterogeneity. In an attempt to meet these limitations, we exploit a 50-member SMILE of the Canadian Regional Climate Model, version 5, at 12 km resolution (CRCM5-LE, RCP 8.5 from 2006 onwards, driven by the Canadian Earth System Model Version 2 large ensemble, CanESM2-LE) in this study. Owing to its large size and high spatial resolution, the CRCM5-LE is a yet unique source for analyzing compound events on a regional scale.

We consider detrended ERA5-Land data during 1955-2023 for evaluation purposes. In general, comparing single observational time series to SMILEs remains challenging due to internal climate variability. By using, among others, a bootstrapping approach, we find a very good agreement of the local compound event frequency distribution in the CRCM5-LE and ERA5-Land. Also, regional hotspots of event frequencies agree in the SMILE and reanalysis data. Going one step further, we also statistically disentangle climate change signals and internal variability in event frequencies at

two global warming levels (+2 °C, + 3°C) by means of, e.g., signal-to-noise ratios.

In general, the regional model (re)produces fine-scale spatial patterns of hot and dry compound events (e.g., mountains, land-sea contrast). These are found in event frequencies and change signals at impact-relevant scales. Furthermore, the application of a SMILE provides an extensive database of events. The latter is crucial for assessing trends and climatologies of highly variable events like compound hot and dry extremes. In combining a regional climate model and the SMILE approach, we thus show the benefits of a regional SMILE for addressing the uncertainty in compound event assessment.