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Summers full of extreme heat: using ensemble boosting storylines to quantify the drivers of heatwave clusters

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We investigate the most extreme but physically plausible heat-loaded European summers in current and near future climate conditions using ensemble boosting. With this approach, we identify the most extreme summers in an initial-condition large ensemble with the model CESM2 and *boost* them, creating a large ensemble of re-initialized simulations with slightly perturbed atmospheric initial conditions. This allows us to efficiently generate storylines for summers that are even more extreme than the original simulations, either due to a higher number of days or grid cells exceeding extreme heat thresholds, or original heatwave clusters exceeding such thresholds by larger margins.

We compare these storylines of summer heat clusters to the most extreme European summers in the observational record, and determine the necessary and exacerbating mechanisms behind these clusters of extreme heat. We quantify how factors such as the intensity and persistence of atmospheric patterns as well as sea surface temperatures and terrestrial water budgets contribute to the most extreme simulated summers. Furthermore, we disentangle the effects of extreme early heat in May-June acting as a preconditioning factor in driving more extreme conditions during the rest of the summer, due to it causing more heat-prone conditions such as warmer oceanic basins and dryer soils, versus the effects of large-scale preconditioning factors that may lead to more persistent and intense heat through the summer, regardless of if it starts early in the season or not.

Ensemble boosting is a computationally efficient approach that allows us to sample extreme rare events, now over time scales of several months, while preserving physical consistency both in time, space and across variables. This is an ideal setup for disentangling contributions from different driving factors, and the generated boosting storylines can be used in impact studies that require physical consistency, a prolonged simulation time, and successive or compounding hazard exposure.