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Global assessment of atmospheric and land surface drivers of heatwaves

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Heatwaves are extreme weather events characterized by exceptionally high temperatures that have severe impacts on society and ecosystems. Their magnitude and frequency are increasing with climate change in many regions. They are driven by both atmospheric and land surface processes such as advection or reduced evaporative cooling. The contributions of these individual drivers to the formation of heatwaves have been analyzed in case studies for major past events with model experiments. At the same time, the global relevance of heatwave drivers remains unclear.

We perform a global analysis with reanalysis data to determine the relation of heatwave temperatures to (i) atmospheric variables such as wind, pressure, and pressure differences, each at different geopotential heights, as well as (ii) land surface variables such as evaporative fraction, enhanced vegetation index, and surface net radiation. First, we identify the hottest day in each grid cell during the period 2001-2020. We also determine the values of the driver variables on this day. Then, for each driver variable, we select five days from the entire study period where the variables' value most closely matched the hottest day value (=analogues). Next, we compare the averaged temperature anomalies of these analogues to those of the hottest day. The more similar the analogue temperature anomalies are (=hotter), the more relevant the driver variable is deemed. This is done for the three hottest days in each grid cell, ensuring that they are at least 15 days apart from each other to belong to separate heatwave events.

The results show that pressure at the 500 hPa level is the most relevant driver of heatwaves in the mid-latitudes, while in the tropics a combination of variables plays a more important role than individual variables. Radiation is the second most relevant driver in many regions, particularly in tropical areas. In most cases, several drivers seem to contribute to the heatwave events such that only their aggregated analogue temperature anomalies can match the observed anomalies. These findings confirm previous case studies which highlighted the relevance of atmospheric circulation patterns such as blocking as well as reduced evaporation related to vegetation water stress. For the first time we identify the relevance of these processes across the globe, and with observation-based data. This can contribute to a better management and potential mitigation of heatwave

temperatures and their impacts.