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Mega-heatwave temperatures driven by local and upwind soil desiccation

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Droughts and heatwaves cause agricultural loss, forest mortality, and drinking water scarcity, especially when they occur simultaneously as combined events. Their predicted increase in recurrence and intensity poses serious threats to future food security. Both events have been suggested to reinforce each other. In fact, local land–atmosphere feedbacks — resulting from the dry-out of the heatwave region itself — have been intensively studied in recent years. However, the role of heat advection, and its dependency on water shortages upwind, may have been overlooked. At least intuitively, the sensible heat originated upwind and advected into the heatwave region can decisively impact the intensity of an extreme hot event. Novel observational and modelling tools are becoming suited to dissect the pathways through which heat accumulates in the atmospheric boundary layer, allowing us to explore the impact of local and upwind soil desiccation on the escalation of mega-heatwave temperatures.

Here, we explore these upwind land–atmosphere feedbacks, and disentangle their role in the evolution of heatwaves using a Lagrangian modelling approach constrained by satellite observations. We concentrate on the exceptional incident of 2010 in Eastern Europe, whose unprecedented and persistent heat made it the costliest and deadliest heatwave documented in human history. Our results indicate that during the peak of the event, the heatwave region received anomalously high contributions of heat from east and southeast, while westerly contributions were limited due to the persistent anticyclonic circulation. As the soils in upwind areas were anomalously dry, evaporation was heavily constrained and sensible heat was unusually high. This hot and dry air was continuously advected into the heatwave region, altering the atmospheric boundary layer and further accelerating soil desiccation there. Our findings highlight the dependency of heatwaves on upstream land surface conditions via heat advection, and help understand the simultaneous occurrence of hot and dry extreme events.