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How did soil dryness intensify recent European heatwaves?

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In August 2010 a *mega-heatwave* hit large parts of Eastern Europe and Russia, breaking the historical records from the 2003 event in Western Europe. While such heatwaves are predicted to become common by the end of this century, our understanding of the physics behind these phenomena is still imperfect, and so is their representation in climate models. In this presentation we will provide new evidence of how land-atmosphere feedbacks contribute to the development of the extreme temperatures based on satellite observations, climate model reanalyses data (ERA Interim), balloon sounding measurements, soil moisture-temperature coupling diagnostics and mechanistic modelling of the lower atmosphere.

Results of our analyses show that in both European mega-heatwaves, persistent synoptic conditions favored evaporation and intensified soil desiccation. As a consequence of soil dryness, a deep residual atmospheric boundary layer (ABL) developed, which allowed the multi-day storage of heat coming from: **(a)** large-scale horizontal advection, **(b)** intense warming from the land surface associated to the increasingly dry soils, and **(c)** enhanced warm air entrainment from the top of the ABL (which counteracted the dilution effect of the gradually deeper layer). This progressive storage of heat in the residual ABL played a crucial role in the escalation of temperatures, and therefore in the regulation and intensification of land feedbacks.

Soil moisture deficits have both direct and indirect effects in all these processes, effects that have not been scrutinized separately in previous model studies. This suggests the need of revisiting the traditional view of the soil moisture-temperature coupling during mega-heatwaves, in which only the direct impact of dry soils on the surface energy balance is explicitly considered. Reinforced by our findings, a more complete conceptualization can be provided, with dry soils enhancing diurnal warm air entrainment and leading to the formation of persistent residual layers that favor the progressive storage of atmospheric heat. These positive feedbacks provide a plausible answer to why temperatures become increasingly higher as heatwaves evolve, and why they reach values so far outside the expected range of variability. We suggest therefore, that both land-surface memory and multi-day ABL development need to be simultaneously considered for timely prediction of future mega-heatwaves.