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Observed land surface temperature evolution during dry spells across Europe

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Soil moisture driven land-atmosphere feedbacks are known to influence the evolution of European summer heat waves. Climate models disagree on where and how strongly the land surface energy budget is limited by soil moisture. Observations of evapotranspiration during rain-free periods provide timescales of response at flux sites, but are too few to ascertain a representative regional response. At the large scale, however, remotely sensed land surface temperature (LST) data provide an instantaneous snapshot of the land surface thermal state, which is related closely to the surface energy partition; a freely-evaporating surface has a lower LST than a water-stressed surface. Here 1 km MODIS-Terra LST are used in combination with gridded air temperature to explore how the surface warms during rain-free periods.

The analysis is performed using the mid-morning overpass data (10:30 local time), aggregated up to 0.5 degree resolution across Europe. Using gridded precipitation, a set of 94350 dry spell events, lasting 10 days or longer, were identified for the period 2000 to 2012, April through to October each year. Across all dry spells, we build up a composite of LST having accounted for variations in air temperature. This provides a measure of how rapidly the surface warms up relative to the atmosphere, and is related to variability in sensible heat flux. By considering dry spells as short as 10 days a warming signal can be observed which is consistent with an increasing soil moisture constraint on evapotranspiration. To better understand the observed response, dry spell events are stratified by antecedent precipitation, land cover type and geographic regions. Stratifying by antecedent precipitation (used as a proxy for soil moisture) reveals that rates of warming are sensitive to soil moisture levels at the onset of a dry spell. Under dry antecedent conditions, rates of warming over 10 days are weak as the surface is already dry, consistent with little change in the partitioning of surface fluxes. For wetter antecedent conditions, rates of warming are stronger, indicating a change in the surface energy balance in response to a drying surface and a shift toward sensible heat production. Under the wettest antecedent conditions, the dry spell warming rate weakens again consistent with high rates of evapotranspiration being maintained ∼5 days into the dry spell. For forests, lower rates of warming are observed than over croplands. Regional variations in the composite LST show different responses in terms of the average rates of warming.

This study provides a unique analysis of large-scale observations of LST, from which the surface energy balance response to levels of soil moisture can be identified. Capturing the temporal evolution of LST during rain-free periods provides a new opportunity to evaluate this critical feedback process in climate models.