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Processes determining heat waves across different European climates

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Heat waves have various impacts on human health, environment and economics and are expected to increase in the future over Europe. It is therefore a pivotal issue to correctly identify and forecast the processes leading to heat waves.

Here, we present a comprehensive analysis of processes determining heat waves across different climates in Europe for the period 1979 – 2016. Heat waves are defined using the percentile-based Heat Wave Magnitude Index daily (HWMId). Backward trajectories initialised in the lower troposphere in the affected heat wave area are used to quantify adiabatic compression by subsidence and local and remote diabatic heating in the upper- and lower troposphere. This Lagrangian analysis is complemented by an Eulerian calculation of horizontal temperature advection.

During typical summers in Europe, one or two heat waves occur with an average duration of four to five days. Whereas high, near-surface temperatures over Scandinavia are accompanied by omega-like blocking structures at 500 hPa, heat waves over the Mediterranean are connected to comparably flat ridges. Tracing air masses backwards from the heat waves, we identify three trajectory clusters with coherent thermodynamic characteristics, vertical motions, and geographic origins. In all investigated regions, horizontal advection of warm air is rather negligible. In two of the three clusters, subsidence in the free atmosphere is of first order importance in establishing high temperatures near the surface, while the air masses in the third cluster are warmed primarily due to diabatic heating near the surface.

Large interregional differences occur between the British Isles and western Russia. Over the latter region, near surface transport and diabatic heating appear to be very important in determining the intensity of the heat waves, whereas subsidence and adiabatic warming are of first order importance for the British Isles. Although the large-scale pattern is quasi-stationary during heat wave days, new air masses are steadily entrained into the lower troposphere during the life cycle of a heat wave. Our results therefore suggest that stagnant air masses at the lower troposphere are not a general feature of European heat waves.

Overall, the results of the present study provide a guideline as to which processes and diagnostics weather and climate studies shall focus on to understand the severity of heat waves.