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A Lagrangian analysis of upper-tropospheric anticyclones associated with heat waves in Europe

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Heat waves impose large impacts on various sectors. Meteorologically, these events are co-located to upper-tropospheric anticyclones. In order to elucidate the formation of these anticyclones and the role of diabatic processes, we trace air masses backwards from the upper-tropospheric anticyclones and quantify the diabatic heating in these air parcels. We analyse anticyclones that are connected to summer heat waves at the surface during the period 1979 – 2016 in different European regions. Around 25-45% of the air parcels are diabatically heated during the last three days prior to their arrival in the upper-tropospheric anticyclones and this amount increases to 35-50% for the last seven days. The influence of diabatic heating is larger for heat wave anticyclones in northern Europe and western Russia and smaller in southern Europe. Interestingly, the diabatic heating occurs in two geographically separated air streams. Three days prior to arrival, one heating branch (western branch) is located above the western North Atlantic and the other heating branch (eastern branch) is located to the southwest of the target upper-tropospheric anticyclone. The diabatic heating in the western branch is related to the warm conveyor belt of a North Atlantic cyclone upstream of the evolving upper-level ridge. In contrast, the eastern branch is diabatically heated by convection, as indicated by elevated mixed-layer convective available potential energy along the western side of the matured upper-level ridge. Central Europe is influenced by both branches, whereas western Russia is predominantly affected by the eastern branch. The formation of the upper-tropospheric anticyclone, and therefore of the heat wave, is highly depended on the western branch, whereas its maintenance is more affected by the eastern branch. For long-lasting heat waves, the western branch regenerates. The results from this study show that the dynamical processes leading to heat waves may be sensitive to small-scale microphysical and convective processes, whose accurate representation in models is thus supposed to be crucial for heat wave predictions on weather and climate time scales.