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Identifying causes of short-range forecast errors in maximum temperatures during recent Central European heatwaves using the ECMWF-IFS ensemble

Alexander Lemburg and Andreas H. Fink
Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Karlsruhe, Germany
(alexander.lemburg@kit.edu)

In the last few years, Central Europe faced a number of severe, record-breaking heatwaves. Several previous studies focused on the predictability of such heatwaves on medium-range to subseasonal time scales (5 – 30 days). However, also short-term forecasts with up to 3 days lead time can exhibit substantial errors in the prediction of maximum temperatures (Tmax), even on larger spatial scales. This study investigates the causes of such short-term forecast errors in Tmax over Central Europe for the summers of 2015–2020, with an emphasis on heatwaves. For this purpose, 3-day forecasts of the 50-member ensemble of the operational ECMWF-IFS (ECMWF-EPS) are systematically compared against 0-18h control forecasts for the respective days of interest.

In general, ECMWF-EPS shows a tendency for too cold forecasts during heatwaves, particularly in situations with stagnant air masses under clear skies and weak synoptic forcing. A pattern correlation method and a multi-variate linear regression model are used to study the relative importance of different physical processes for 72h forecast errors in Tmax. It is found that errors in downwelling short-wave radiation (SWDS), mainly due to erroneous low cloud cover, are the dominant error source, particularly in a large-scale perspective and outside of heatwaves. Moreover, Tmax forecasts errors are more strongly linked to SWDS errors on days with too warm forecasts than on days with too cold forecasts.

Within heatwaves, other error sources gain importance; averaged over all summers 2015–2020, the second most important error source is over- or underestimation of nocturnal temperatures in the residual layer. An additional Lagrangian trajectory analysis for the summers 2018–2020 (limited availability of necessary ECMWF-EPS input data) suggests that these errors may be linked to accumulating errors in previous days' diabatic heating of near-surface air masses, much more so in heatwaves than on regular summer days. Such errors in diabatic heating history, which are substantially more important in northern and western parts of Central Europe, are on average consistent with prediction errors in air mass residence time over land and cloud cover traced along trajectories. On regional scales, other physical processes can be of dominant importance, but only during heatwaves. The coastal regions are most influenced by errors in near-surface wind (ventilation by cooler maritime air) whereas errors in soil moisture are most important in some regions of southeastern Central Europe.

In summary, short-range forecasts errors of summertime maximum temperatures over Central Europe are predominantly caused by over- or underestimation of short-wave irradiance. However, the dominance of this error source diminishes substantially during heatwaves, particularly on days where ECMWF-EPS underestimates Tmax. Such days are often stable and cloud-free and a decreased importance of SWDS is therefore not unexpected due to overall lower probability for substantial misprediction. Moreover, especially in heatwaves, Tmax forecasts may suffer from accumulated errors in diabatic heating of near-surface air. Their causes may partly be attributable to errors in air mass residence time over land and/or cloud cover along the trajectory path but further research is needed.