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Effects of a new land surface parametrization scheme on thermal extremes in a Regional Climate Model

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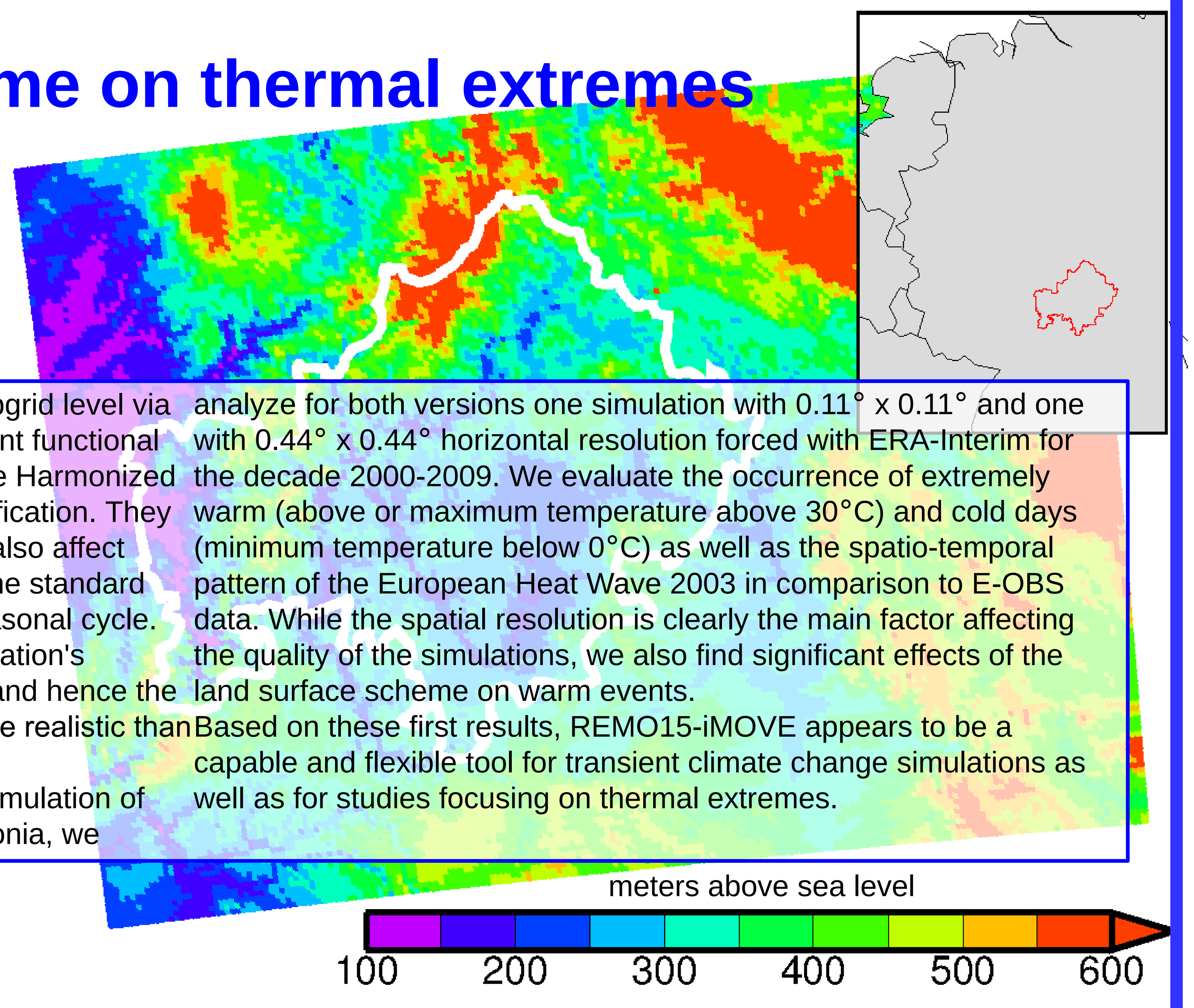
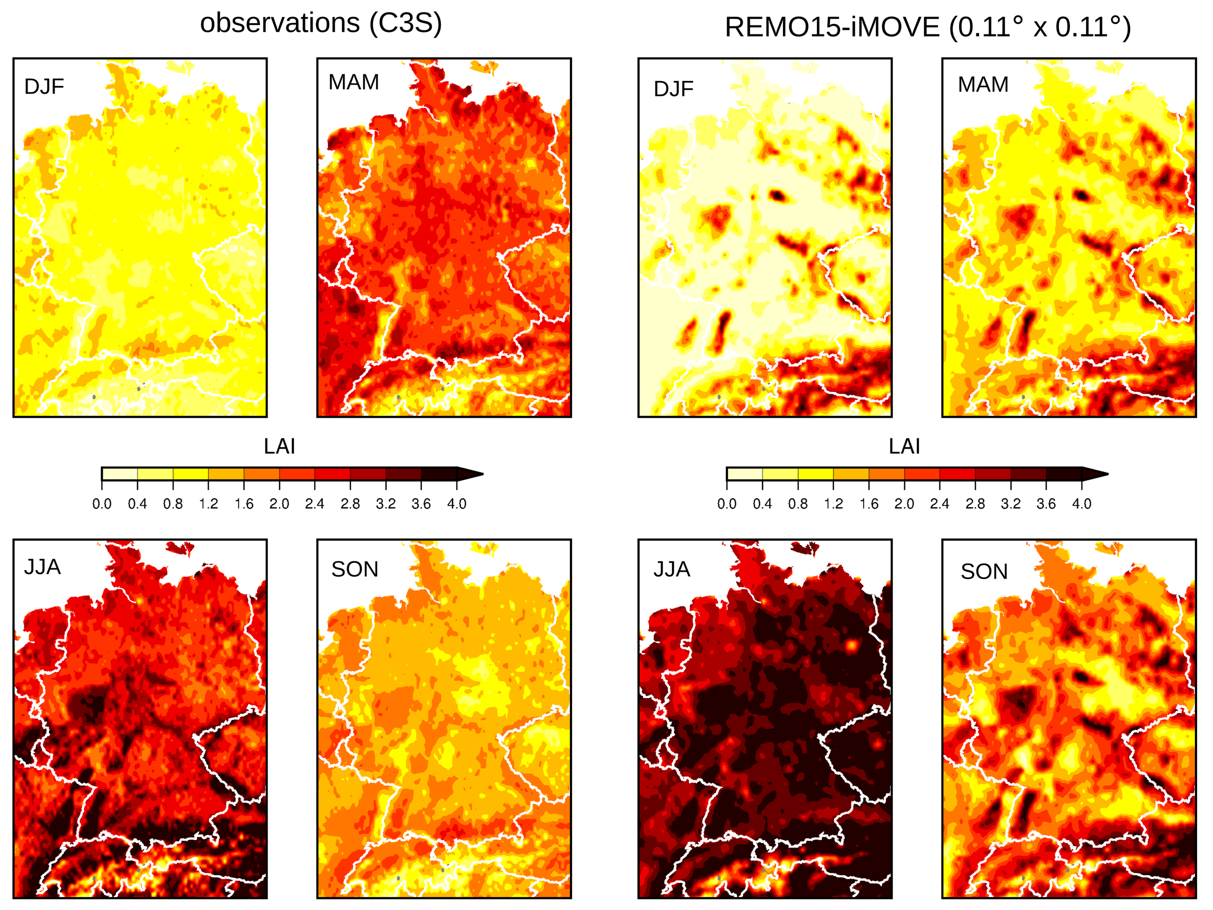


summary

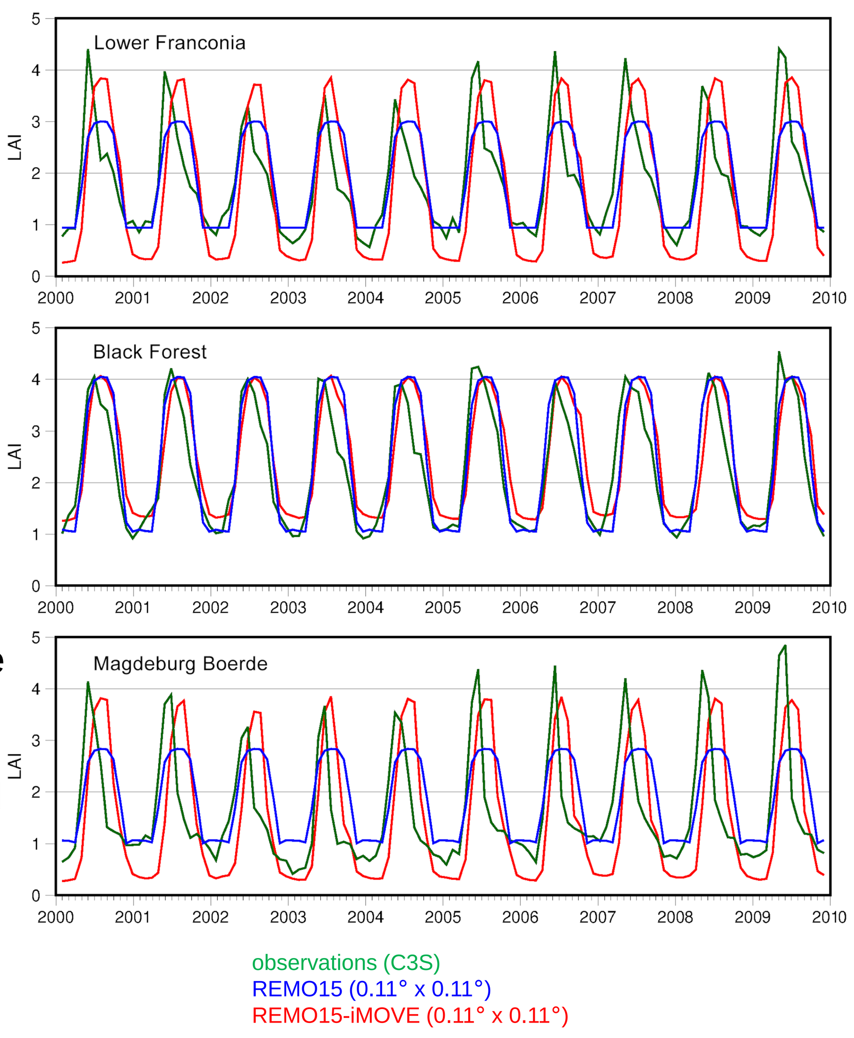
The EFRE project Big Data@Geo aims at providing high resolution environmental information for the Lower Franconian region in Bavaria, Germany, including climate change simulations suitable and relevant for adaptation. Hence, it is a crucial task within this interdisciplinary project to enhance the regional climate model REMO, both by substantially increasing the spatial resolution as well as by including further processes in the model, which must be resolved on this new spatial scale.
For the first time, we successfully coupled REMO's version 2015 (REMO15) with a superior land surface parametrization scheme (iMOVE) based on JSBACH, the land component of the MPI Earth System Models MPI-ESM and ICON-ES. REMO15-iMOVE's core feature is the interactive vegetation, represented on subgrid level via 16 discrete classes. The spatial distribution of these plant functional types (PFTs) is based on the GLOBCOVER dataset, the Harmonized World Soil Database, and the Holdridge life zone classification. They do not only respond to atmospheric forcing, but in turn also affect numerous near-surface climate variables. In contrast, the standard version of REMO15 employs an idealized, constant seasonal cycle. Preliminary results indicate that REMO15-iMOVE vegetation's dynamic is in good agreement with observational data and hence the atmosphere's lower boundary conditions should be more realistic than in REMO15.
To estimate the effects of the enhanced model on the simulation of thermal extreme events typically affecting Lower Franconia, we analyze for both versions one simulation with 0.11° x 0.11° and one with 0.44° x 0.44° horizontal resolution forced with ERA-Interim for the decade 2000-2009. We evaluate the occurrence of extremely warm (above or maximum temperature above 30°C) and cold days (minimum temperature below 0°C) as well as the spatio-temporal pattern of the European Heat Wave 2003 in comparison to E-OBS data. While the spatial resolution is clearly the main factor affecting the quality of the simulations, we also find significant effects of the land surface scheme on warm events.
Based on these first results, REMO15-iMOVE appears to be a capable and flexible tool for transient climate change simulations as well as for studies focusing on thermal extremes.

dynamic vegetation

While the quality of the spatial pattern is largely due to the preprocessing and the resulting spatial distribution of PFTs, the temporal dynamics of their quantities represent the coupling of the REMO model with the vegetation module. As high quality observational data is available, we focus on the LAI. Besides the EFRE-region Lower Franconia we also consider two more homogenous regions in Germany: the Black Forest and the largely treeless Magdeburg Boerde.
The LAI's seasonal spatial pattern differs considerably between observations and model. Note that – as a consequence of the idealized land cover by the plant functional types - REMO-iMOVE's seasonal cycle is even more pronounced than the observed one.

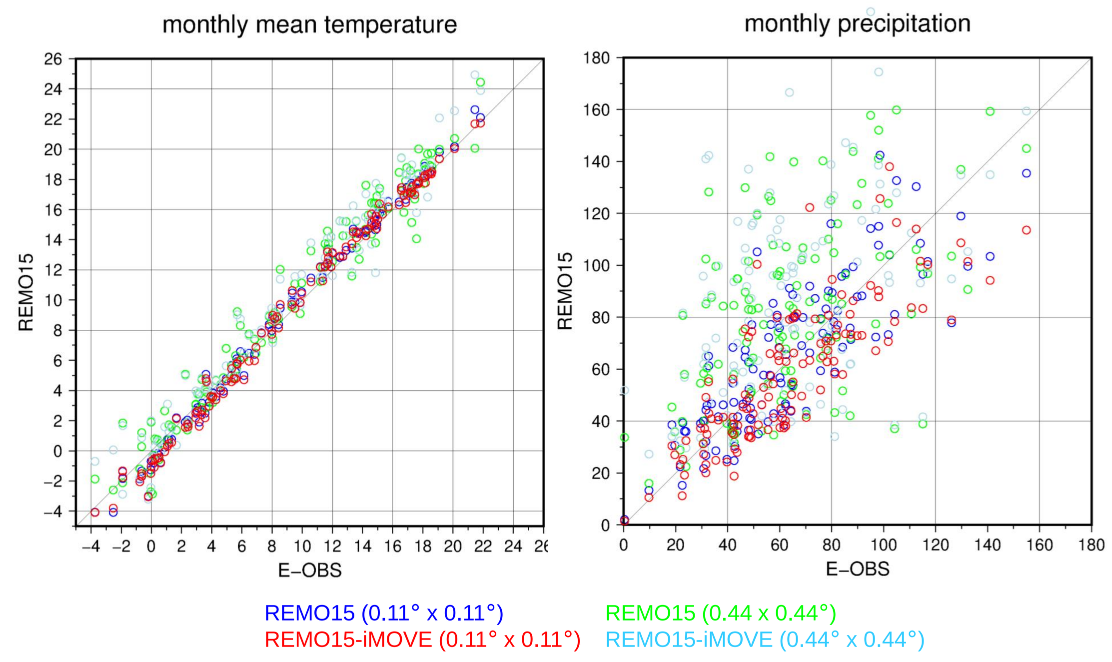


REMO15-iMOVE is capable of reproducing the main features of the vegetations' seasonal cycle. Obviously, the reduction of the LAI during winter is overestimated for Lower Franconia and Magdeburg Boerde.
In comparison to the standard version, the LAI is clearly reproduced more realistically. However, the LAI peaks one to two months later than in the observational data. Note that REMO-iMOVE underestimates the interannual variability of the LAI and the vegetation in general. However, the time series of monthly standardized anomalies correlates well with the observations (r = 0.82 for Lower Franconia).



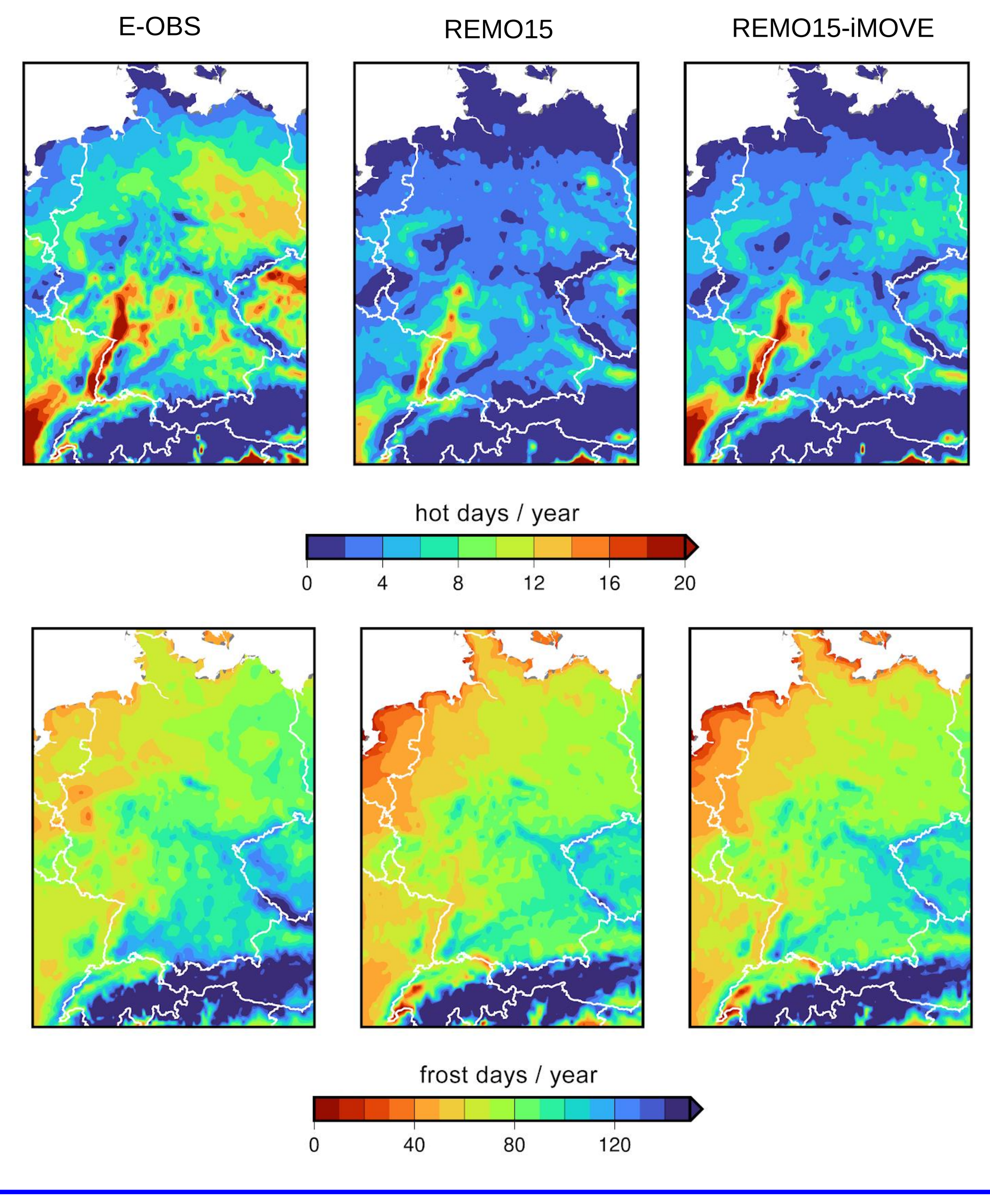
monthly mean data

The figures show monthly mean temperatures and monthly precipitation, for Lower Franconia, scattering REMO against E-OBS. While for temperature all four simulations are in good agreement with the observations, the two high resolution ones nonetheless outperform the 0.44x0.44 runs. REMO15 is slightly closer to E-OBS than REMO15-iMOVE, but the differences are not significant. The benefits of the high resolution are even clearer for precipitation.
Altogether, the monthly mean values of the core climate variables are hardly affected by the inclusion of the iMOVE module, but massively by resolution



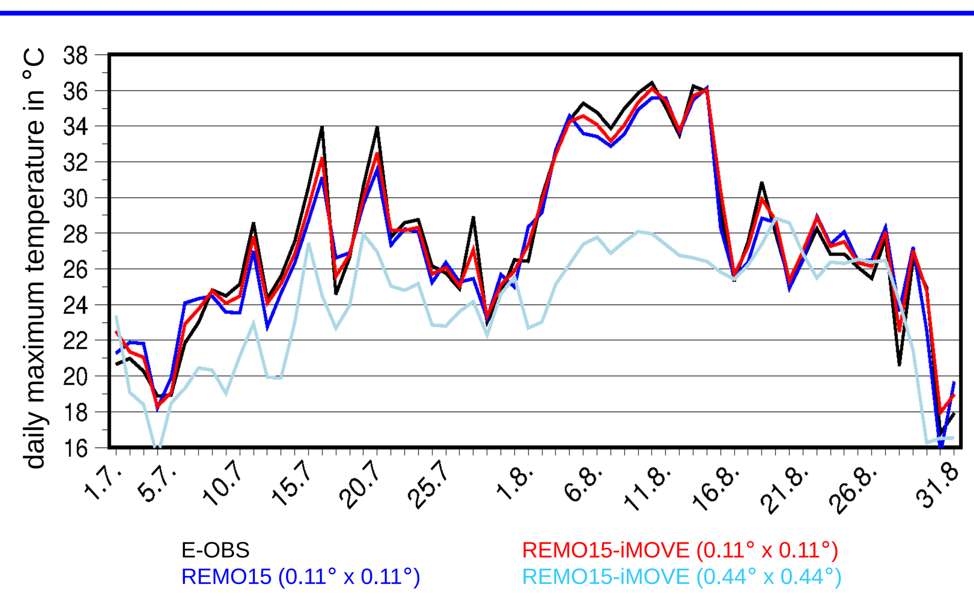
thermal extreme events

As a warm extreme event, we consider the number of hot days, defined as those days with the maximum temperature exceeding 30°C. REMO15 noticeably underestimates this number for the 10 years of simulation. However, the underestimation by REMO15-iMOVE is less pronounced in general . Especially for regions with a large number of hot days, such as the Rhine Rift Valley and most parts of eastern Germany the simulation is improved.
Note that we didn't perform any adjustments to the E-OBS data. Using a simple bias correction effectively removes all effects of REMO15-iMOVE. We found similar, but less pronounced, results for other measures of warm extremes.
For frost days (minimum temperature lower than 0°C) there is no apparent systematic effect of the iMOVE module. This is not unexpected, given the fact that vegetational dynamic is reduced in winter. In general, the model underestimates the number of frost days per year in comparison with E-OBS.



european heat wave 2003

We consider the temporal development of daily maximum temperatures for Lower Franconia. REMO15 in the 0.11°x0.11° resolution is in excellent agreement with the E-OBS time series. While the correlation is nearly perfect for both simulations, the absolute deviation from the observation is slightly, but constantly, smaller for REMO15-iMOVE. Hence, this model version produces higher temperatures. The mean absolute deviation from E-OBS it 0.6°C and 1.1°C, respectively. The difference is significant according to a t-test (p < 0.01). This improvement is solely due to the different representation of the vegetation.
To put this finding into perspective, we further illustrate the effects of a finer resolution. For that, we included the same time series for a simulation using REMO15 in the 0.44°x0.44° resolution. Clearly, its



variability is synchronous with the observations (r = 0.75), but peak temperatures are less extreme. This is especially true for the climax period of the heatwave during the first half of August. Apparently, the improved resolution is a much more important factor in the simulation of heat waves than the dynamic vegetation. However, it is also a much higher computational effort.

REMO15-iMOVE's simulation of the 2003 heatwave's spatial pattern (mean maximum temperature for August 1 to August 13) for southern Germany resembles the pattern in the E-OBS data much more closely than that of REMO15. Especially for the state of Bavaria the simulation appears more realistically. Even the improved model still underestimates the daily maximum temperatures for large parts of the study area.