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A new downscaling approach to derive heat episodes on a regional scale from GCM scenarios

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The year 2003 has shown that heat waves can have massive impacts on the public life also in most of Europe. In Austria a new project called Startclim 2004 was carried out to investigate such heat waves in more detail, both the occurence in the past and future as well as the effects on agriculture or water availability. Within this project we investigated how well global circulation models (GCMs) are able to detect such heatwave episodes in northeast Austria. Based on station measurements in the region, an algorithm to find such heat waves was developed and tested with the ERA40 data. Then we applied the new algorithm to GCM scenarios to derive the climatology of future heatwaves in Austria.

As first step, we used ERA40 reanalyses data with a horizontal resolution of 2.5 x 2.5 degrees on four pressure levels (850 hPa, 700 hPa, 500 hPa and 200 hPa) and studied the relationships of some parameters such as temperature, humidity, wind, etc. with temperature measurements. All the investigations were performed for the months April to September, because only the summer half-year is relevant for heat waves. To make the scales better comparable and to eliminate single extreme values in the measurements caused by very local phenomena, we used a hierarchical cluster algorithm to group the measurement stations into three regions of Austria. For the northeast region, four grid points of the large-scale model are representative. With a step-wise multiple regression procedure, we derived a linear relationship between parameters from the large scale model and the mean maximum temperature of the northeast region of Austria. Taking only the temperature in 850 hPa into acount, the regression leads to an R2 of 0.89. The final multiple regression includes the following parameters: T_850 (temperature at 850 hPa) on two grid points, RH_700 (relative humidity at 700 hPa), RelTop_850-700, astronomically available solar energy, Z_850,

U_700, and V_850. This combination leads to an R2 of 0.94. We tried to include also the Showalter index as an indicator for convection, but it was not selected in the stepwise regression procedure. Based on ERA data and the regression as obtained, we calculated heat episodes and compared them with observations (test of performance of the regression with perfect data).

As the second step, we interpolated the GCM data (grid size 2.8 x 2.8 deg) to the grid points of the ERA field used in the regression. These interpolated data on the four grid points were compared to the ERA data set. For each month, we calculated the cumulative frequency distribution of the relevant meteorological parameters of the ERA40 dataset, the GCM control and scenario run. Their shapes are similar, but for example for temperature, some percentiles deviated on the order of 2 K. In the next step, we used the differences between the cumulative frequency distributions of ERA and GCM control run to adjust the GCM data, both control and scenario. With other words, we calculated the changes from GCM control run to the scenario run for each percentile and added this value to the corresponding ERA40 value.

To detect heat waves, it is neccessary to define what you call a heat wave. One option is to count all successive days with temperatures exceeding 30 deg C (heat days). This definition is rather strong, because one single dip to 29.9 deg C splits the episode into two shorter ones. This is the reason why we also used a (slightly modified) definition from Kysely (2000). This definition starts with three successive heat days and continues as long as summer days follow and as the mean temperature over the episode stays over 30 deg C. As a simple indicator for the effect of a changing climate, we calculated also the number of heat days per year. As result, we obtain a strong increase of the number of such days. Today, we observe approximately 5 heat days in the northeast region of Austria per year. For the ECHAM4/OPYC3 (IS92 A) we obtained 25 days (simplified model based only on T_850) or 32 days with the full regression model (8 parameters). Heat episodes with five or more successive heat days in the region occured in 1948-2001 with a return period of 11 years, but twice a year in the scenario (2019-2048).

To compare these results with those obtained by commonly-used, more complex downscaling methods, we compared them to results obtained by an analogue methode. With the analogue technique, the number of heat days in the northeast region of Austria would increase to 25 per summer.

In addition to the statistical downscaling, a regional climate model (from the PRUDENCE project), based on the HadAM3H GCM with scenario SRES A2, was evaluated for two regions of Austria. For the northeast region, the results look reasonable taking into account the statistical results. An increase of the heat day number for the periode 2070-2100 to 43 days per year is predicted. However, in the southeast region, average daily temperature maxima during the summer were approximately 2.5 K warmer in the control run than measured. It seems that a strong underestimation of precipition in the model is the reason for this too high values.