Spatial mapping of daily temperature in Europe and the Middle East
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Introduction
In the course of climate change the capture of high resolution Temperature extremes (2 m height) for monitoring climate change gains importance. Synoptic weather stations capture daily temperature extremes point-wise. These point extreme temperature observations are mapped for Europe (WMO region IV) using Regression Kriging.

Approach
Development of a method to spatially map daily extreme temperatures on a spatially high resolution. It should be operationally applicable to produce daily spatial extreme temperature maps for Europe (WMO region IV).

Method
Regression Kriging (RK) was chosen which combines a regression of the dependent variable on auxiliary variables with Simple Kriging (SK) of the regression residuals. Regression allows for extrapolation in regions with less elevated observations, and SK is used to fit the residuals, i.e. the unexplained variation. The interpolation process is split into three parts:

1. Monthly trend for Tmin/Tmax: The target area is split into 8 climate sub-regions, to account for local conditions. The target variable is fit by multiple linear regression separately within each climate region using the predictors (elevation, continentality index, zonal mean temperature, inversion index, and distance to coast line), and monthly observations.
2. The monthly climate map for Tmin/Tmax is generated adding the interpolated regression residuals (Simple Kriging) to the monthly trend.
3. The final daily map for Tmin/Tmax is generated interpolating daily residuals (deviation of daily Tmin/Tmax observations to the monthly climate map) using SK.

Predictors
- Elevation (z) data is taken from a DEM (SRTM, and gdpl30) with a spatial resolution of 1 km².
- Zonal mean temperature (t) is calculated from the CRU dataset, and serves as a predictor for the N-S dependency of the surface temperature.
- The continentality index (K) depends on the mean annual temperature amplitude and the latitude (Gonzalez). A distance-to-coast parameter (d) is introduced, as temperature is strongly modified by large water bodies. For fitting the regression function this parameter is only applied for stations with less than 250 km off coast.
- A inversion index (i) is chosen to account for cold pools in every season, which especially applies for minimum temperature. The inversion value is calculated as follows: (a) Subscribe the minimum elevation of grid cells within 100 km radius to each grid cell; (2) low-pass filtering the minimum elevation grid with radius 100 km (base); and (3) adding a climatological inversion height to the base (300m). Stations below the inversion height are assigned an inversion value ranging from 0 to 1.

Results
In the following the quality of the generated temperature maps is evaluated. In the first part the fitting of the regression function is statistically examined. Subsequently Regression Kriging (RK) is compared to Ordinary Kriging (OK), using cross-validation (leave-one-out method), on a monthly and daily basis.

Regression function
- RK performs generally best as a single predictor
- Introduction of further predictors leads to a decreasing RMSE, combining all predictors yields the least RMSE
- The prediction error is smallest for Tmin in summer

Table 1: RMSE for regression-residuals for regression functions of increasing complexity and its seasonal variation

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK</td>
<td>2.99</td>
<td>2.90</td>
<td>2.83</td>
<td>2.67</td>
<td>2.65</td>
<td>2.64</td>
<td>2.62</td>
<td>2.59</td>
<td>2.57</td>
<td>2.53</td>
<td>2.51</td>
<td>2.50</td>
<td>2.55</td>
</tr>
<tr>
<td>RK</td>
<td>2.37</td>
<td>2.30</td>
<td>2.26</td>
<td>2.19</td>
<td>2.17</td>
<td>2.16</td>
<td>2.14</td>
<td>2.11</td>
<td>2.09</td>
<td>2.07</td>
<td>2.05</td>
<td>2.03</td>
<td>2.07</td>
</tr>
<tr>
<td>OK daily</td>
<td>2.76</td>
<td>2.79</td>
<td>2.76</td>
<td>2.73</td>
<td>2.71</td>
<td>2.68</td>
<td>2.65</td>
<td>2.63</td>
<td>2.60</td>
<td>2.58</td>
<td>2.55</td>
<td>2.53</td>
<td>2.56</td>
</tr>
<tr>
<td>RK daily</td>
<td>2.39</td>
<td>2.42</td>
<td>2.39</td>
<td>2.36</td>
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<td>2.31</td>
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<td>2.24</td>
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Mean monthly map (Tmin/Tmax)
The evaluation criteria are the RMSE of the prediction error, and VARI being the ratio between estimated variance and observed variance. For RK the prediction error is the sum of trend prediction and Kriging of the residuum. For Ordinary Kriging the observed climate extreme values are directly interpolated:
- OK generally outperforms RK in terms of RMSE
- RK clearly outperforms OK in terms of VARI, which is not surprising as OK is a data-fitting method which is known to underestimate the spatial variability.

Daily map (Tmin/Tmax)
For RK the daily residuals to the monthly climate values are re-estimated. OK re-estimates the daily observations.
- RK generally outperforms OK in terms of RMSE. The reason is that RK only interpolates daily residuals, which are smaller compared of the daily values and more normally distributed.
- RK also outperforms OK in terms of VARI. The benefit is smaller as for monthly data, because daily residuals are much larger and the OK part of the process which smoothes the temperature field has more weight.

Table 2: Comparison of the prediction error for the generation of daily extreme maps using Regression Kriging, and Ordinary Kriging

<table>
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Acknowledgements
Monthly climate temperatures based upon various station networks, daily observations are SYNOP-data, data obtained through Deutsche Wetterdienst, Offenbach.

References