Spatial mapping of daily temperature extremes in Europe and the Middle East *

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Introduction

In the course of climate change monitor of high resolution temperature Tmin/Tmax (2 m height) 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 map daily extreme temperatures on a spatially high resolution. It should be operationally applicable to produce daily 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 background 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 Simple Kriging.

Predictors

- **Elevation (z)** data is taken from a DEM (SRTM, and gtopo30) with a spatial resolution of 1 km²
- **Zonal mean temperature (b)** 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
- A **distance-to-coast parameter (c)** is introduced, as temperature is strongly modified by large water bodies. For fitting the regression function this parameter is only applied for stations within 250 km of the coast
- An **inversion index (i)** is chosen to account for cold pools in every season, which especially applies for Tmin. The inversion value is calculated as follows: (a) Assign to each grid cell the elevation of the lowest grid cell within a 100 km radius; (b) low-pass filter the result of (a) with a Gaussian filter of radius 100 km (base); and (c) add an inversion height of 300 m to the base. Grid cells below the inversion height are assigned an inversion index 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. The results are given as averages over all climate regions.

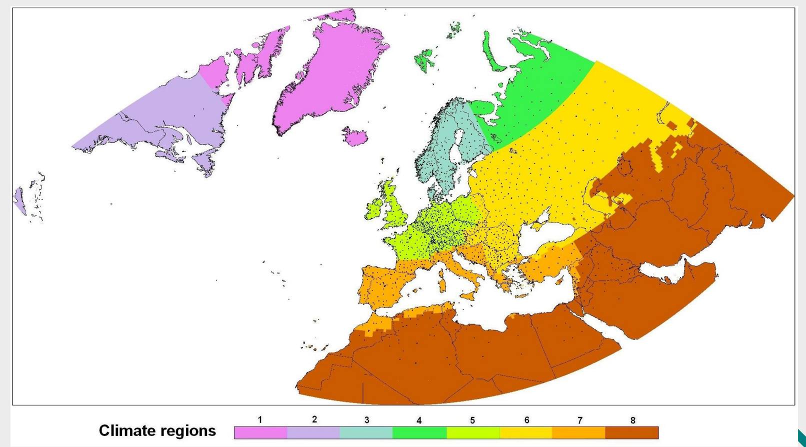

Fig. 1: Climate regions (colors) and station locations (black dots).

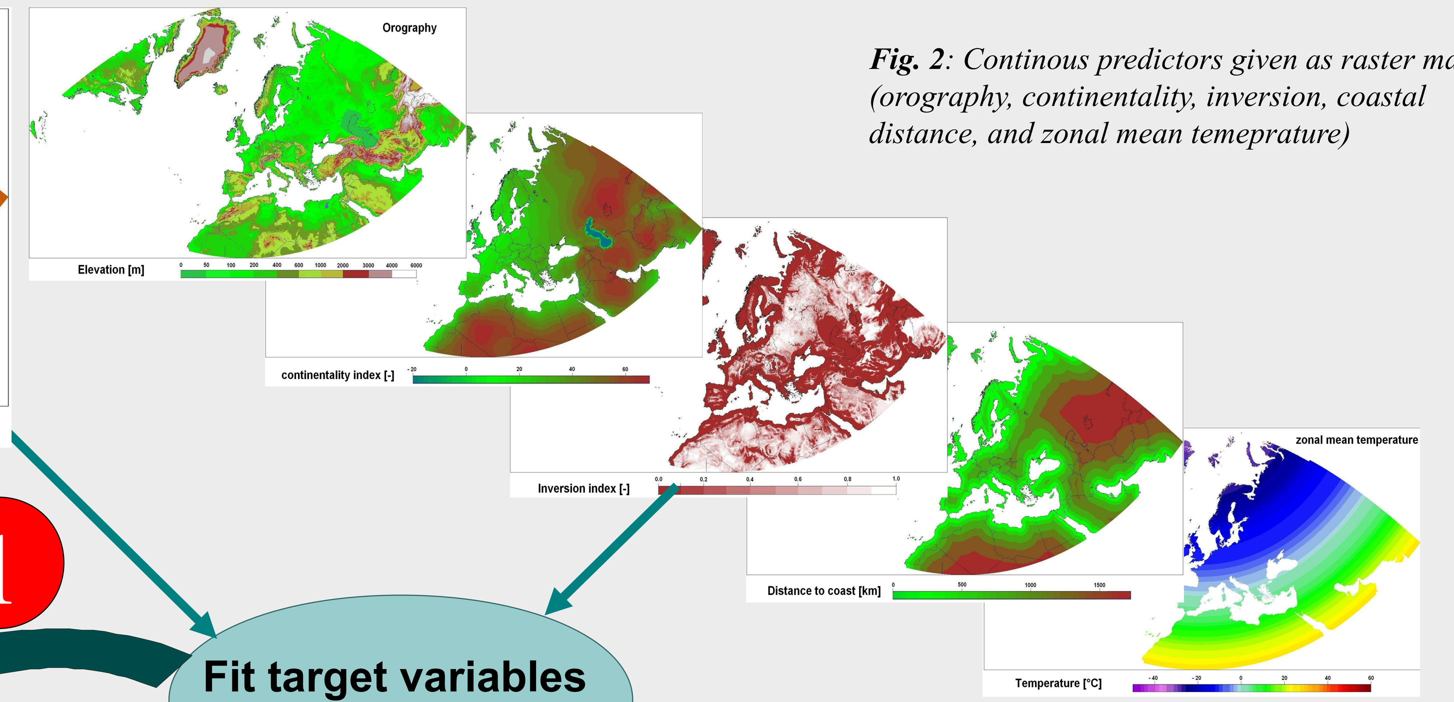

Fig. 2: Continous predictors given as raster maps (orography, continentality, inversion, coastal distance, and zonal mean temeprature)

1

Fit target variables using predictors

Points denote regression residuals

2

Interpolate residuals (Ordinary Kriging)

Add interpolated residuals to fitted trend

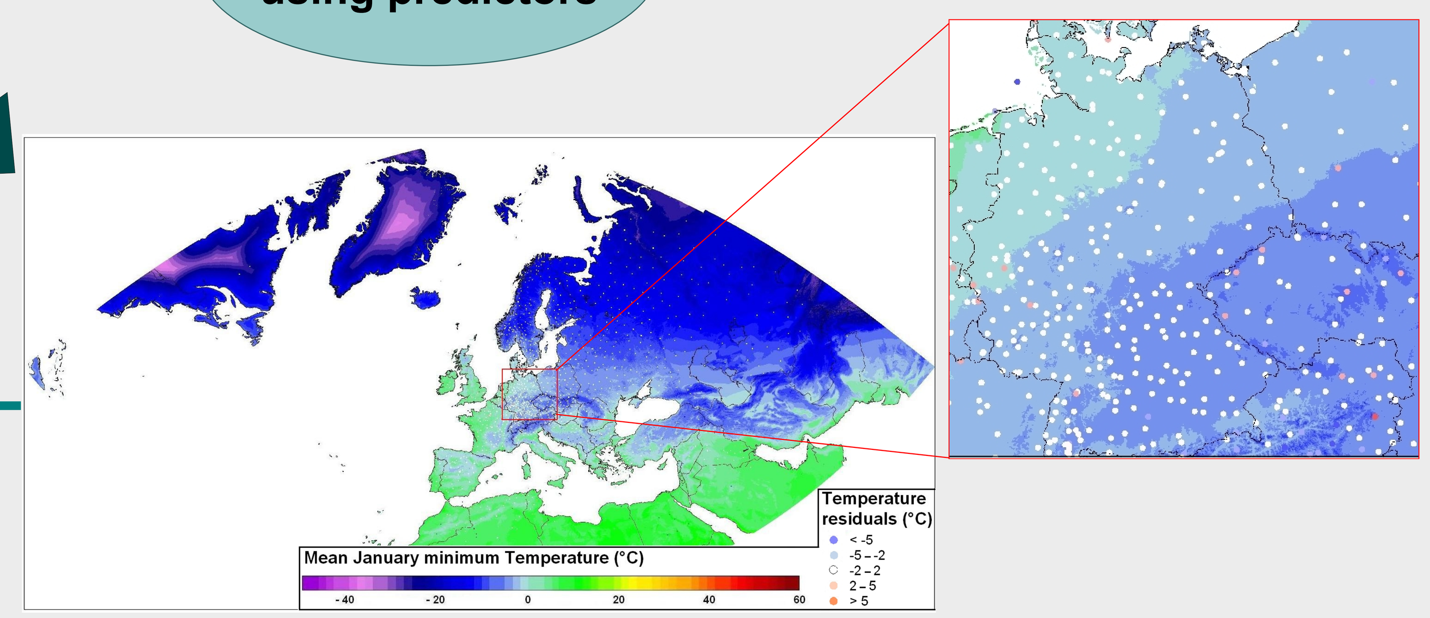

Fig. 3: Mean January Tmin as trend-estimate, resolution 5 km x 5 km (above), red square enhanced resolution 1 km²(right). Regression residuals given as colored dots.

Points denote daily residuals

3

Interpolate Daily residuals (Ordinary Kriging)

Add interpolated residuals to fitted trend

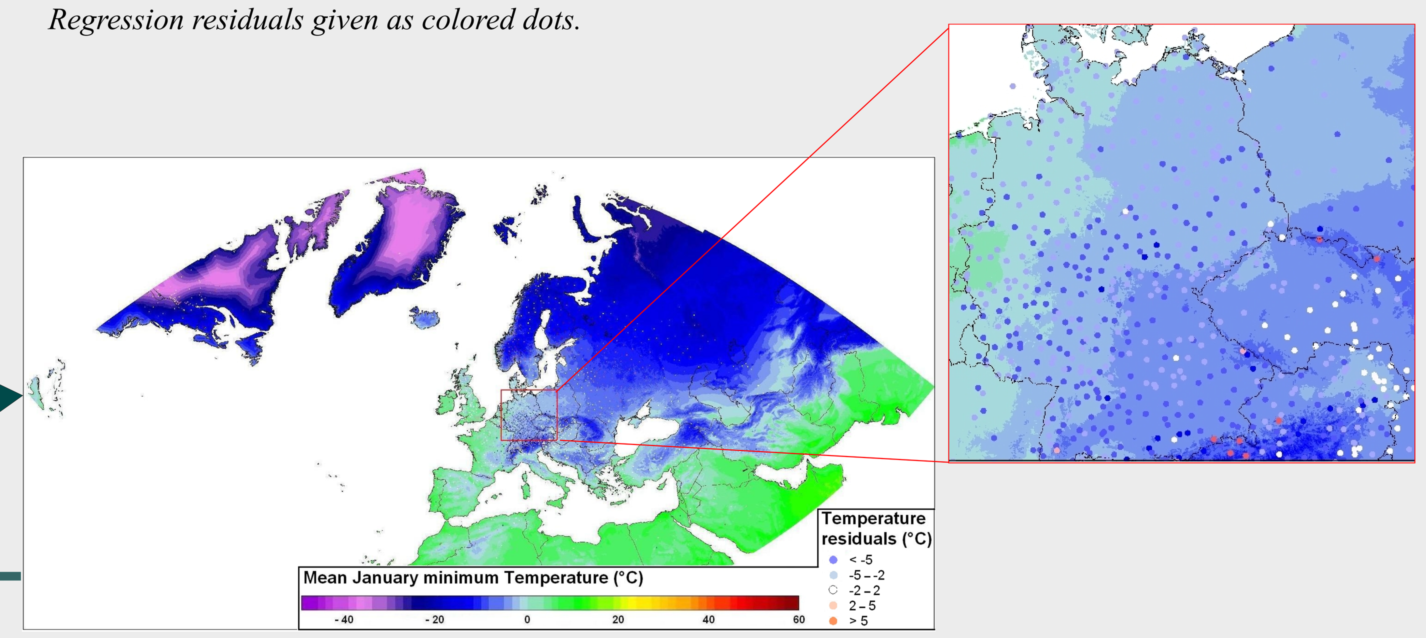

Fig. 4: Mean January Tmin as monthly climate prediction map, resolution 5 km x 5 km (above), red square enhanced resolution 1 km² (right). Daily residuals given as colored dots.

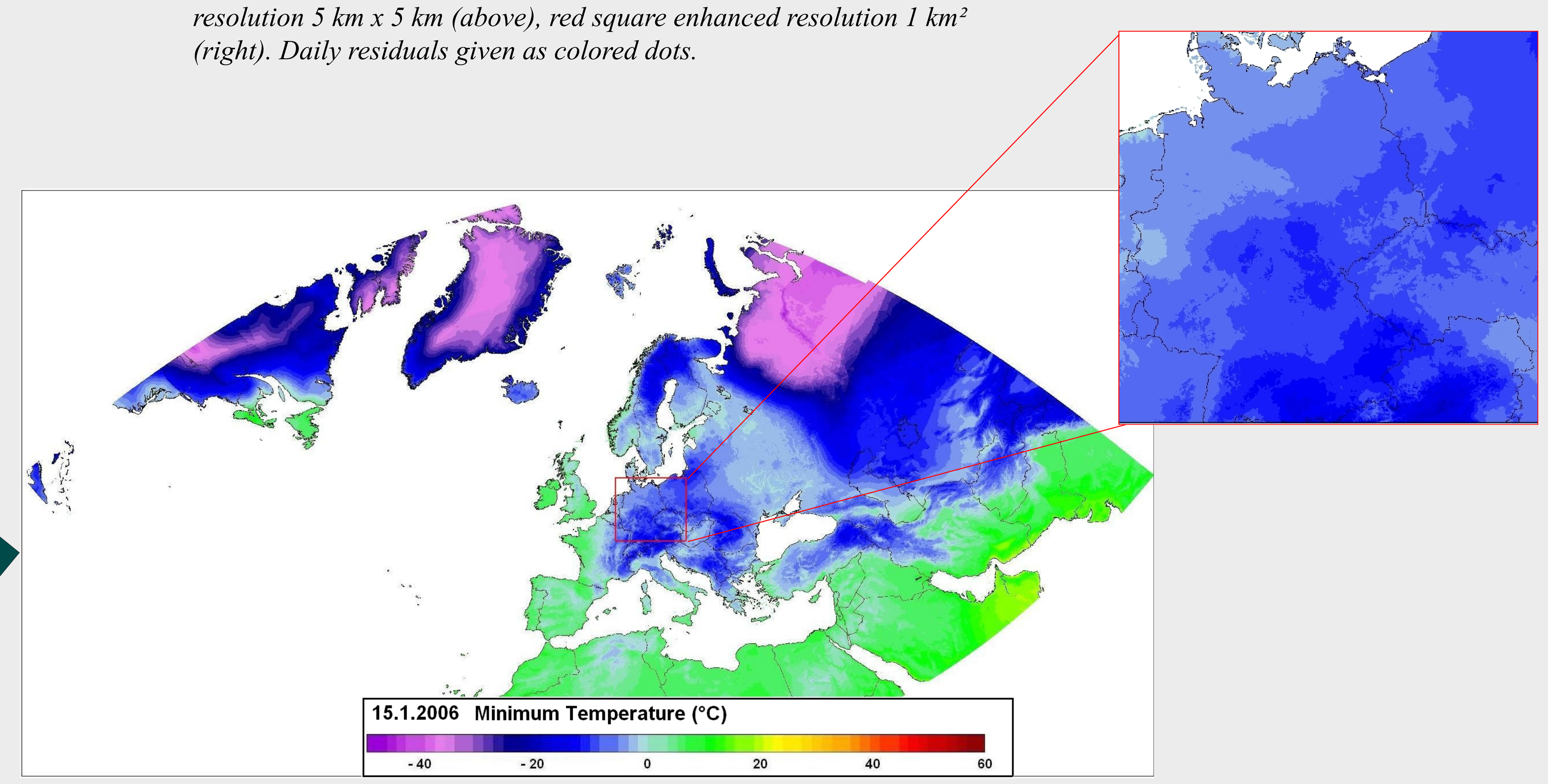

Fig. 5: Tmin on the 15.1.2006 as daily extreme value map, resolution 5 km x 5 km (above), red square enhanced resolution 1 km² (right).

Regression function

- "b" 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 of the chosen regression function is smallest for Tmin in summer

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

Formula/ RMSE	Jan		Jul		Average (all)
	Tmin	Tmax	Tmin	Tmax	
t~z	6.11	5.81	3.28	4.40	4.90
t~K	4.97	5.05	3.29	3.86	4.29
t~b	5.56	4.77	2.52	3.20	4.01
t~K+b+z	3.14	2.95	2.28	2.66	2.76
t~K+b+z+c+i	3.04	2.87	2.22	2.61	2.69

Mean monthly map

The evaluation criteria are the RMSE of the prediction error, and VARI (the ratio between estimated variance and observed variance). For Regression Kriging (RK) the prediction error is the sum of trend prediction and Simple Kriging of the residual. For Ordinary Kriging (OK) the observed climate extreme values are directly interpolated.

- OK generally outperforms RK in terms of RMSE
- RK clearly outperforms OK in terms VARI, which is not surprising as OK is a data-fitting method which is known to underestimate the spatial variability.

Table 2: Comparison of the prediction error for the generation of mean monthly extreme value maps using Regression Kriging, and Ordinary Kriging.

Interpolation Method		Jan		Jul		Average (all)
		Tmin	Tmax	Tmin	Tmax	
RK mt.	RMSE	2.98	2.89	3.23	2.67	2.94
	VARI	1.14	1.03	1.33	0.89	1.1
OK mt.	RMSE	2.91	2.64	2.02	2.46	2.51
	VARI	0.71	0.71	0.59	0.62	0.66

Daily map

For RK the daily residuals to the monthly climate values are re-estimated. OK re-estimates the daily observations.

- RK outperforms OK in terms of RMSE. The reason is that RK only interpolates daily residuals, which are smaller than the daily observed values and more normally distributed.
- RK also outperforms OK in terms of VARI. The benefit is smaller than for monthly data, because daily residuals are considerably larger and the OK part of the process which smoothes the temperature field has more weight.

Table 3 Comparison of the prediction error for the generation of daily extreme value maps using Regression Kriging, and Ordinary Kriging.

Interpolation Method		Jan		Jul		Average (all)
		Tmin	Tmax	Tmin	Tmax	
RK daily	RMSE	3.47	2.89	2.27	2.39	2.76
	VARI	0.93	0.94	0.74	0.78	0.85
OK daily	RMSE	3.51	3.04	2.57	2.99	3.03
	VARI	0.80	0.81	0.64	0.66	0.73

Acknowledgements

Monthly climate temperatures based upon various station networks, daily observations are SYNOP-data, data delivered through Deutscher Wetterdienst, Offenbach.

References

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