Using analogues to assess uncertainty in urban-area climate relocation

Sebastian Kopf[1], Minh Ha-Duong[2], Stéphane Hallegatte[3]

[1]International University Bremen, [2]CIRED/CNRS , [3]CIRED and ENM, Météo-France

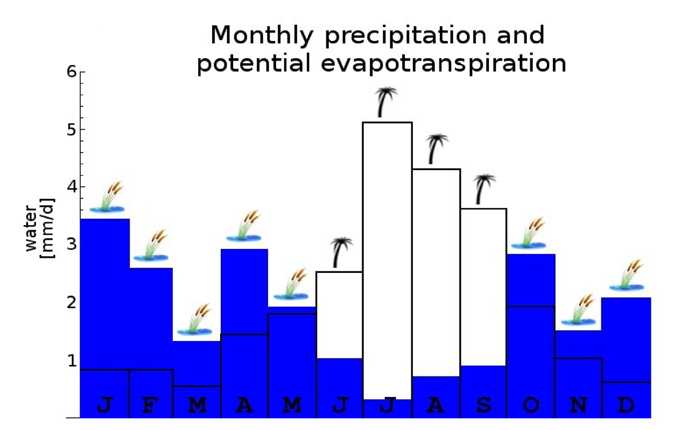
This poster presents an improved statistical method to find *climate analogues* and illustrates its application on 12 European cities.

An analogue to Paris, for example, is defined as the place whose present climate is most similar to the projected climate of Paris in 2100. In order to find it, we define climate similarity by the 3-dimensional Kolmogorov-Smirnov statistic applied to a 30-year distribution of the 3 climate indicators aridity index, cooling degree days and heating degree days.

Larger scale maps of such analogues illustrate the problem of climate change impacts and the southward relocation trend very well. Since analogues are model and scenario dependent, showing this variability helps to gain a better understanding of the uncertainties in the relocation trend.

Methods

Climate for an urban area was characterized by the 30-year annual distribution of these three widely used climate indicators: *Aridity Index*, *Heating Degree Days* and *Cooling Degree Days*.

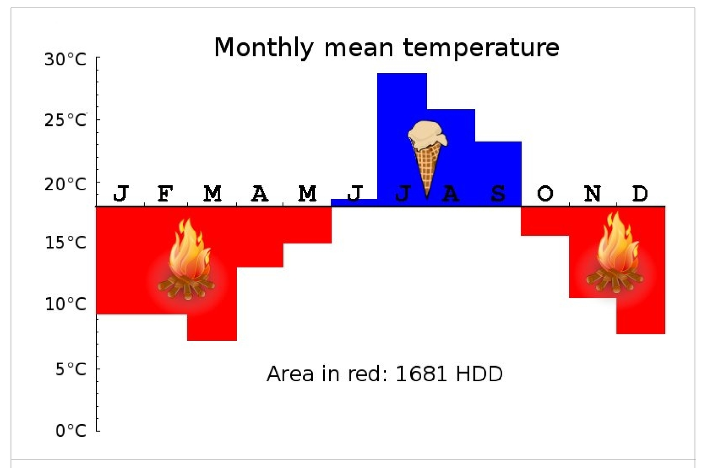


Aridity Index

Aridity Index (AI)

Aridity Index describes water availability and is a fundamental indicator for a climate's vegetation. The annual aridity index is defined from monthly precipitation and potential evapotranspiration following Thornthwaite (1948).

$$AI=\frac{\sum_{i=1}^{12}\delta_i(e_i-p_i)}{\sum_{i=1}^{12}\delta_i e_i};\quad \delta_i=\begin{cases}1; e_i>p_i\\0; e_i\le p_i\end{cases}$$



Defintion of heating and cooling degree days.

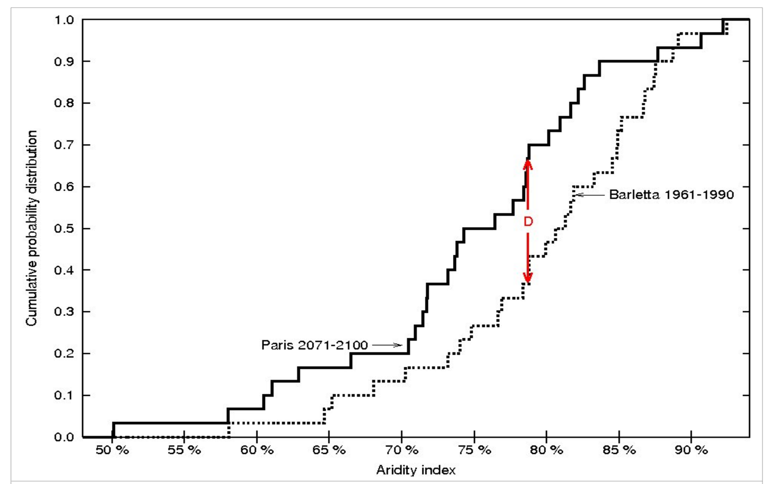
Heating/Cooling Degree Days (HDD/CDD)

Heating (resp. cooling) degree days are standard indicators, known to correlate well with heating (resp. air conditioning) energy demand. They add up when temperatures drop below (resp. rise above) a certain reference temperature (commonly 18°C). We used Thom (1954) to estimate HDD and CDD from monthly average temperatures.

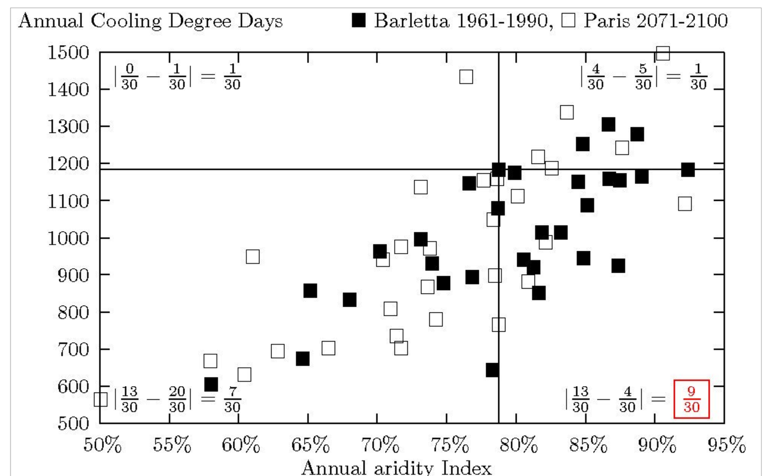
$$HDD=\sum_{i=1}^{365}\delta_i(b-t_i);\quad \delta_i=\begin{cases}1; b>p_i\\0; b\le p_i\end{cases}$$

Statistical comparison

The Kolmogorov-Smirnov statistic compares two samples by the maximum vertical distance between their cumulative distributions. We used Franceschini and Fasano's (1987) generalization (illustrated below in 2 dimensions) to compare the joint distribution of the 3 climate indicators.



1-dimensional Kolmogorov-Smirnov statistic



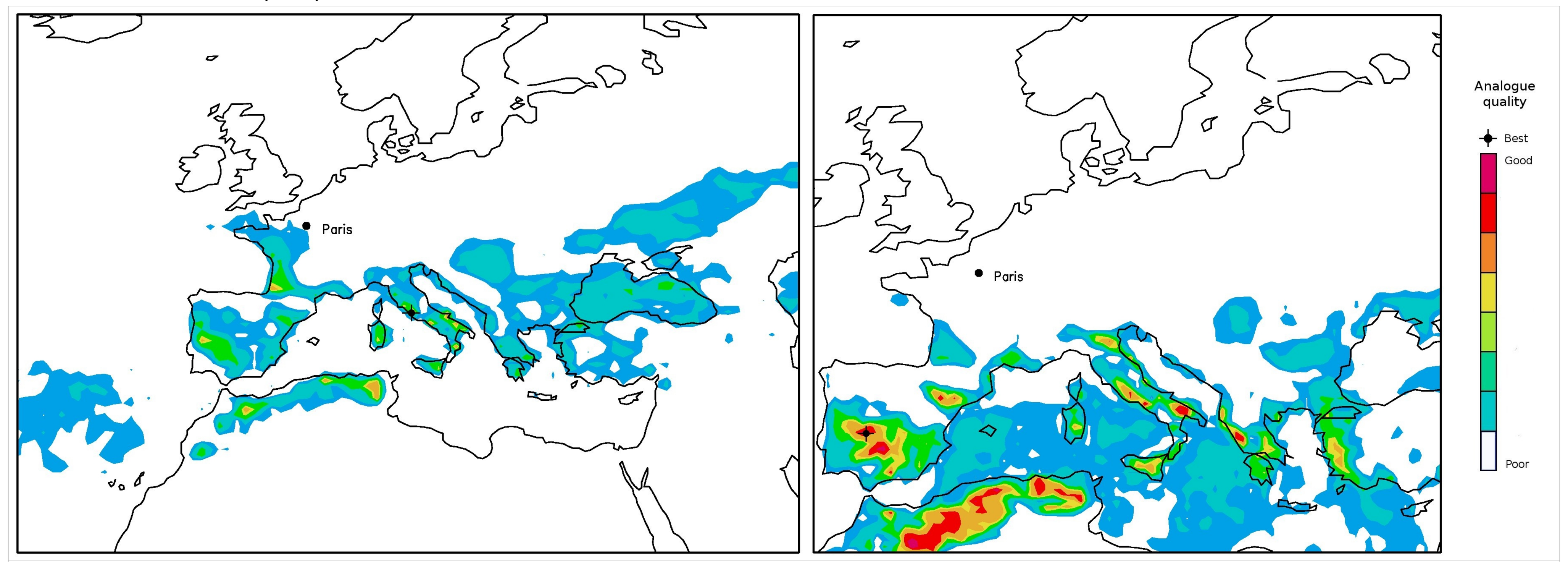
2-dimensional Kolmogorov-Smirnov statistic

Data

Climate analogues were computed by comparing the recorded climate from 1961-1990 with two possible future scenarios for 2071-2100, using results from regional climate simulation models that provide 2D fields of mean monthly surface temperatures and precipitations for all of Europe. The employed datasets explore global warming within IPCC scenarios with the ARPEGE-Climate model from CNRM/Météo-France simulating a moderate and the HadRM3H model from the Hadley Centera a strong warming.

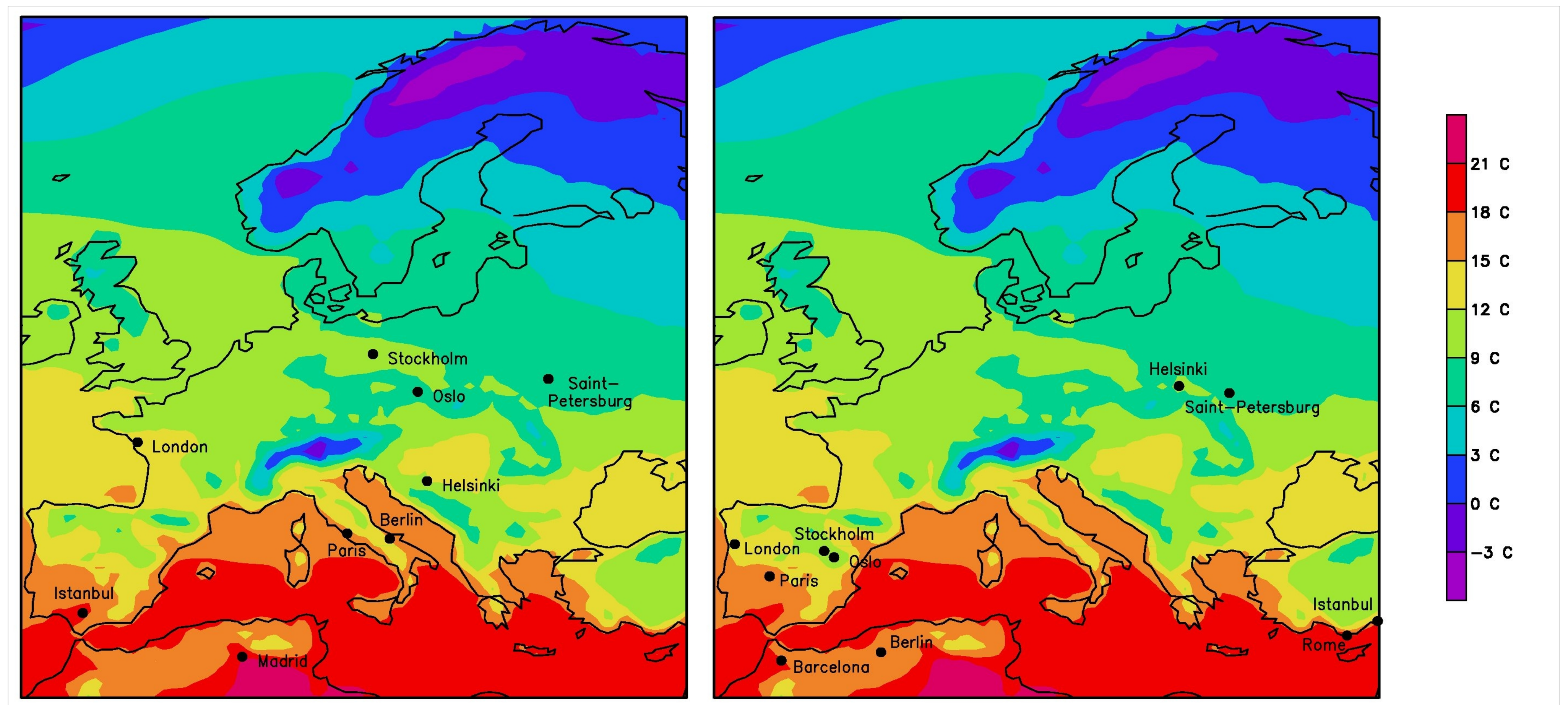
Results

The maps below show the location of today's climate analogue of simulated future Paris for the two different datasets. For the HadRM3H model (right), reasonable analogues of Paris are situated in Southern Spain and Northern Africa with the Spanish city of Badajoz as the best analogue. With the ARPEGE model (left), Rome stands out as the best candidate instead.



Current climate analogues of the future climate of Paris (redish regions indicate suitable analogues, best analogue marked) as simulated by the ARPEGE (left) and HadRM3H (right) models.

The second set of maps shows the best climate analogues for 12 European cities. The background colors indicate present-day average temperatures. Both IPCC based scenarios exhibit a clear trend. Paris goes to Badajoz or Rome (as discussed above), London goes to Villa Real or Nantes, etc. Despite these large residual uncertainties, a general southward drift of climate analogues is clearly visible. The lack of proper analogues in some scenarios for some cities such as Athens and Madrid might indicate that their projected future climates are simply not found within Europe at present. Extension of the analogue search on global scale may yield appropriate locations.



Current climate analogues of the future climates of several European cities (on temperature background of the current climate). ARPEGE (left), HadRM3H (right).

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Conclusions

The developed methodology of visualizing modelling results with the aid of climate analogues proved very useful for preliminary interpretation as well as easy inter-model comparison in order to assess uncertainty.

The applied method is statistically well founded and the three used indicators are believed to be sufficiently descriptive for a city's climate. The results are robust and in accordance with the expected relocation trends. Additionally, the entire procedure is numerically well tractable on personal computer as it does not require large computing. The limitations of the approach lie primarily with the assumption of climate stationarity and the interpretation of a density map by its maximum alone (the *best* analogue).

Observed uncertainties are partly expression of our incomplete knowledge of environmental processes and as such might be reduced by a better understanding of climate processes and ever greater computing power. There is, however, an additional source of uncertainty arising from the unpredictability of human behaviour such as e.g the exact course of action regarding greenhouse gas emissions.

References

S. Kopf, S. Hallegatte, and M. Ha-Duong. L'évolution climatique des villes européennes. *Dossier Pour la Science*, 54:48–52, Jan-Mar 2007.

S. Hallegatte, J.-C. Hourcade, and P. Ambrosi. Using climate analogues for assessing climate change economic impacts in urban areas. *Climatic Change*, online first 15.02.2007.

S. Kopf, S. Hallegatte, and M. Ha-Duong. Using analogues to assess the uncertainty in urban-area climate relocation. *CIRED technical report.*

C. W. Thornthwaite. An approach toward a rational classification of climate. *Geographical Review*, 38(1):55–94, 1948.

H. C. S. Thom. The rational relationship between heating degree days and temperature. *Monthly Weather Review*, 82(1):1–6, 1954.

A. Franceschini and G. Fasano. A multidimensional version of the Kolmogorov-Smirnov test. *Monthly Notices of the Royal Astronomical Society*, 225:150–170, 1987.

Corresponding author:
s.kopf@iu-bremen.de