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no. 09/2005
Climate

On the influence of predictors area in statistical downscaling of daily parameters

RegClim results

Élodie Fernandez

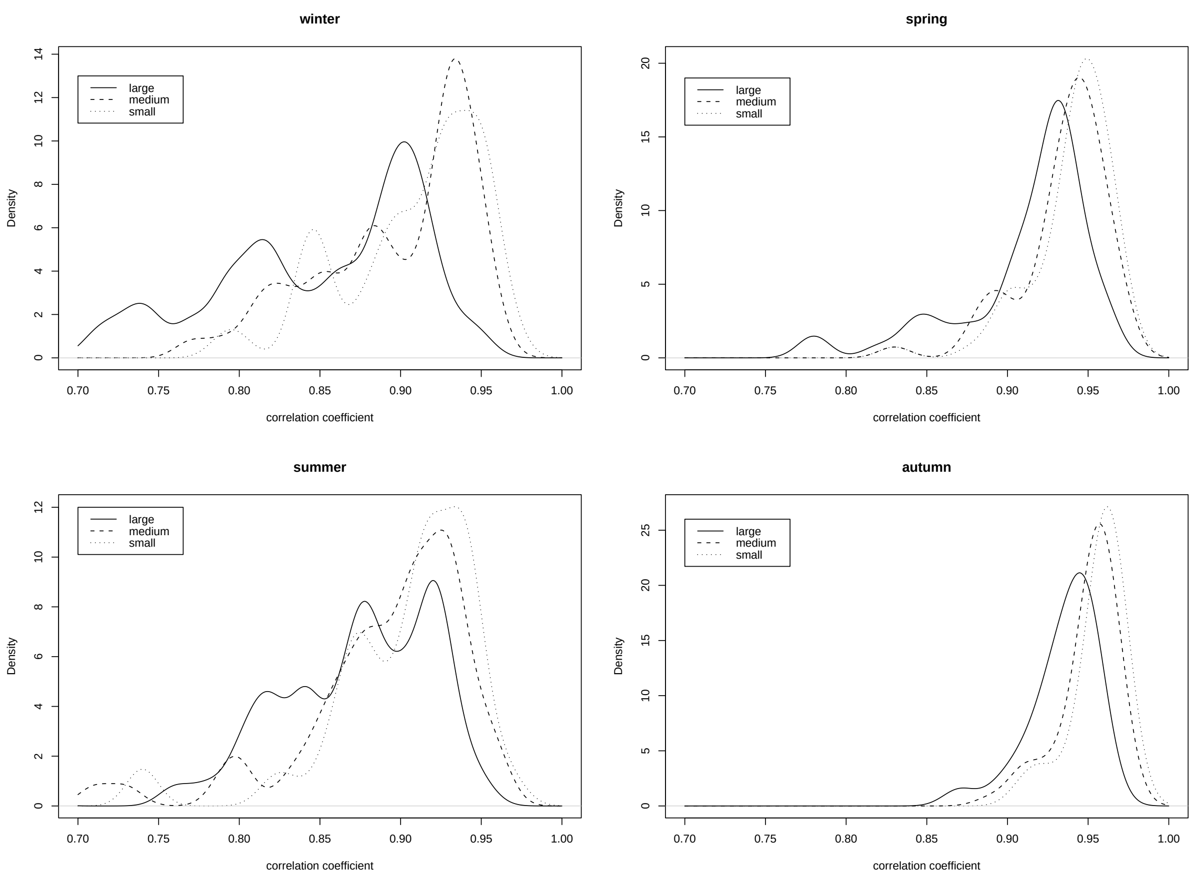

Figure 1: Correlation coefficient for temperature downscaling with varying areas.

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Abstract

Statistical downscaling has been applied to both daily mean temperature and precipitation, in different locations all around Europe. Daily mean temperature has been estimated using linear method, whereas the analog model has been used for 24-hour precipitation. The downscaling has been tested with different predictors area.

The downscaling domain choice has shown a weak impact on the results for daily mean temperature, and no influence on 24-hour precipitation estimation. However, in this latter case, the analog model is strongly influenced by the predictor chosen and the number of EOFs retained in the model.

Keywords

statistical downscaling, analog method, linear method, daily mean temperature, daily precipitation

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Contents

1 Introduction

Numerical models, referred to as general circulation models (GCMs), are able to simulate the evolution of the atmosphere, using physical laws. Coupled atmosphere-ocean general circulation models (AOGCMs) can predict future large-scale dynamics and thermodynamics, and therefore estimate the global climate evolution. An eventual climate change may have potentially severe consequences for our society, so it is important to be able to detect future trends. Unfortunately, the AOGCMs spatial resolution is too low to predict local climate (Grotch and MacCracken, 1991), which is influenced by atmospheric circulation and local parameters (*e.g.* topography, land-use, land-sea distribution). However, it is still possible to use these models for local and regional predictions, when employing downscaling techniques. Dynamical downscaling consists in nesting GCMs with increasingly higher spatial resolution (Giorgi and Mearns, 1999), whereas statistical downscaling relies on the historical relationship between large-scale features, the predictors, and local climate variables, the predictands (Zorita and von Storch, 1997). One statistical approach is to use linear model (Benestad, 2001b), which can reproduce skillfully normally distributed parameters, like temperature. In the case of non-gaussian variables, the analog method can be used instead (Imbert, 2003; Zorita and von Storch, 1999).

Benestad (2001a) suggested that the predictors area used for downscaling could influence the results. The aim of this study is to check the robustness of the method to this area, for different locations in Europe and in all seasons. The predictands used are 24-hour precipitation and daily mean temperature, using sea-level pressure and temperature as predictors.

2 Methods & Data

2.1 Downscaling method

The downscaling is carried out in two steps: first realizing a Principal Component Analysis (PCA) of the predictors, and then doing the downscaling with the results of the PCA.

2.1.1 Empirical Orthogonal Function

Before downscaling the data, the predictors are filtered using Empirical Orthogonal Functions (EOF), a variant of PCA used in climatology. This alternative method introduces geographical weighting factors, to take into account the Earth's spherical shape and variation in grid box area with latitude. Then, only the N leading EOFs are used to train the downscaling model (Benestad, 2001a). This technique permits to reduce the degrees of freedom and consequently the computational demands, as well as to filter the noise.

Let the matrix X contain the predictor field. $X \in \mathcal{M}_{RT}$ where T is the length of the time-series and R the number of grid-boxes where observations are made. The parameters of interest are actually the anomalies of the predictor field, defined as following $A_{rt} = X_{rt} - \bar{X}_{r\bullet},\ t \in [1;T],\ r \in [1;R]$.

The objective, using EOF, is to project the variables in a space of dimension N, with $N << R$, while retaining as much variance as possible. The space is defined by the leading eigenvectors of the variance-covariance matrix of A, $C = A^T A$. The eigenvectors are the vectors $(e_s)_{s\in[1,R]}$ such as $Ce_s = \lambda_s e_s$, where λ_s is the eigenvalue associated with the eigenvector e_s. To determine these vectors, the matrix A is decomposed by singular value decomposition (SVD): $A = UWV^T$, where U and V are orthogonal and W is a diagonal matrix whose elements are A's singular values. Then, the matrix C can be written as following

$$\begin{aligned} C &= A^T A \\ &= (UWV^T)^T (UWV^T) \\ &= VW^2V^T \end{aligned}$$

After a right operation of V, $CV = VW^2$. The eigenvectors of C are identified as the columns of V and the associated eigenvalues are the diagonal elements of W^2. The predictors used henceforth are the N leading principal components (PCs), *i.e.* the columns of V associated with the N larger eigenvalues. The predictors matrix is then P, composed of N rows and T columns, $P \in \mathcal{M}_{NT}$.

For temperature downscaling, the 20 leading PCs are retained in the model, and a stepwise selection is performed to keep only the informative ones. For precipitation downscaling, only the 8 first are used as predictors, for computational reasons.

2.1.2 Linear method

The linear method consists in finding a linear relationship between the local climate and the PCs of the large-scale circulation. If $(p_n(t))_{n \in [1,N]}$ are the coordinates of the predictors at time t and $y(t)$ the local variable at time t, the linear relation is

$$y(t) = \beta_0 + \sum_{n=1}^{N} \beta_n p_n(t) + \epsilon_t$$

where $(\beta_i)_{i=0..N}$ are the model parameters to estimate and ϵ_t the residuals. The model parameters are estimated using least-squares algorithm. The residuals are assumed to be $nid(0, \sigma^2)$.

The overall goodness of fit is assessed by calculating the coefficient of determination, R^2, which is the fraction of total variance explained by the model. An analysis of variance (ANOVA) is also performed, to check the significance of the fit. A high p-value associated with the Fisher test leads to rejecting the model. Some plots are used to check that the assumptions are valid: a normal probability plot to check the normality of the residuals and a scatter plot of studentized residuals versus time to detect any other anomaly (heteroscedasticity, outliers, patterns).

A caveat of the linear method is that it requires the predictand variables to be normally distributed. This assumption is fulfilled for daily mean temperature, but not for daily rainfalls. In this latter case, the analog method will be used instead.

2.1.3 Analog method

The basic idea of the analog method is to associate the simulated large-scale circulation with the most similar case, its analog, taken from a set of historical observations. Then, the simultaneously observed local climate is used as a prediction. The advantage with this technique is that no particular assumptions are made about the distribution of the local variables. Besides, the variability level of these parameters is properly reproduced (Zorita and von Storch, 1999). On the other hand, finding an analog for any large-scale circulation requires a pool of observations of several thousand years. However, the use of EOF and the geographical restriction to the area of interest considerably reduce the number of degrees of freedom.

A distance in the EOF space has to be defined to compare the large-scale circulations. If $(y_n)_{n \in [1,N]}$ are the coordinates of the pattern whose analog has to be found, then the analog is defined as the circulation p at time t, minimizing the distance

$$d(t) = \sum_{n=1}^{N} (y_n - p_n(t))^2$$

To improve the model, weights are introduced, each EOF being weighted by its eigenvalue (Imbert, 2003).

The criterion used to assess the quality of the downscaling is the percentage of explained variance, *var*, which is the ratio between the variance of the observations and the predicted values, for the independent period. The Pearson correlation coefficient, *cor*, between the observed and predicted time series for the control period, and the root mean-square error, *rmse*, are also retained.

The downscaling is performed using contributed **R**-packages *clim.pact* (Benestad, 2004) and *anm* (Imbert, 2003), where the former package is used for EOF computing and linear regression and the latter for the analog method. The **R**-software and the contributed packages are freely available from the website *cran.r-project.org*.

2.2 Predictands

The predictands used are daily mean temperature and daily precipitations taken from the EUMETNET/ECSN Climate Data Set (Version 1 - November 2001). Data and metadata are available at *http://eca.knmi.nl* (Klein Tank and Coauthors, 2002). The study has been carried out for stations covering all Europe. The locations are listed in Table 1 and plotted in Figure 1.

2.3 Predictors

The predictors used are taken from ERA-40 reanalysis (Simmons and Gibson, 2000). Temperature downscaling is realized with large-scale two-meter temperature fields. For precipitations, this latter field is mixed with large-scale sea level pressure (SLP).

The study period is divided into two time slices: 1957–1977 is used as calibrate and 1978–1997 as control period. For both parameters, the downscaling has been carried out for each season: winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November).

To test the sensitivity of the downscaling method to the predictor domain, it is used, for each station and each season, with three different domains (see Figure 8 in annexe A):

- large area - covering all Europe, including Iceland and North Africa (30W-40E 30N-75N).
- medium area - one fourth of the large area (35^o in longitude and 22.5^o in latitude).
- small area - domains covering 10^o in latitude and 20^o in longitude.

station	location	country	lon	lat	alt	temp	prec
5901	Wien	Austria	16.35	48.23	199	x	x
15410	Sonnblick		12.95	47.05	3106	x	x
27080	Tranebjerg	Denmark	10.60	55.85	11		x
30380	København		12.53	55.68	9	x	
304	Helsinki	Finland	24.95	60.17	4	x	x
7501	Sodankyla		26.65	67.37	179	x	x
13055001	Marseille	France	5.40	43.31	75	x	x
18033001	Bourges		2.37	47.07	161	x	x
31069001	Toulouse		1.38	43.62	152	x	x
33281001	Bordeaux		- 0.70	44.83	49	x	x
36063001	Châteauroux		1.72	46.87	160	x	x
66136001	Perpignan		2.87	42.73	43	x	x
69029001	Lyon		4.94	45.73	172	x	x
2698	Karlsruhe	Germany	8.38	49.02	114	x	x
4199	München		11.50	48.17	515	x	x
641	Corfu	Greece	19.92	39.62	4	x	x
648	Larissa		22.45	39.65	74	x	x
716	Hellinikon		23.75	37.90	15	x	x
734	Methoni		21.70	36.83	52	x	x
754	Heraklion		25.18	35.33	39	x	x
1	Reykjavik	Iceland	-21.90	64.13	52	x	x
675	Teigarhorn		-15.24	64.68	14	x	x
953	Valentia	Ireland	-10.24	51.94	9	x	x
980	Malin-Head		- 7.34	55.37	20	x	x
90	Verona	Italy	10.87	45.38	68	x	x
239	Roma		12.58	41.78	105	x	x
320	Brindisi		17.93	40.63	10	x	x
560	Cagliari		9.05	39.23	2	x	x
260	De Bilt	Netherlands	5.18	52.10	2	x	x
5350	Nord-Odal	Norway	11.57	60.38	147		x
16740	Kjøremsgrende		9.05	62.10	626	x	
18700	Oslo		10.72	59.95	94	x	
39100	Oksøy		8.05	58.07	9	x	
39220	Mestad		7.88	58.22	151		x
47020	Nedstrand		5.80	59.35	55		x
47300	Utsira		4.88	59.30	55	x	
50350	Samnanger		5.90	60.47	370		x
68330	Lien-I-Selbu		11.12	63.22	255		x
80700	Glomfjord		13.98	66.82	39	x	
86850	Barkestad		14.80	68.82	3		x
93300	Suolovuopmi		23.53	69.58	374		x
97250	Karasjok		25.52	69.47	129	x	
98550	Vardø		31.08	70.37	14	x	
99710	Bjørnøya		19.02	74.52	16	x	x
99950	Jan Mayen		- 8.67	70.93	10	x	
535	Lisboa	Portugal	- 9.15	38.72	77	x	x
546	Porto		- 8.60	41.13	93	x	x
575	Bragança		- 6.73	41.80	690	x	x
1024	San Sebastián	Spain	- 2.04	43.31	259	x	x
2462	Navacerrada		- 4.01	40.78	1890		x
2867	Salamanca		- 5.49	40.95	790	x	x
3195	Madrid		- 3.68	40.41	667		x
4452	Badajoz		- 6.83	38.88	185	x	x
6155	Málaga		- 4.49	36.67	7	x	x
7038	Torrevieja		- 0.71	37.98	1	x	x
8416	Valencia		- 0.38	39.48	11	x	x
9434	Zaragoza		- 1.01	41.66	247	x	x
9981	Tortosa		0.49	40.82	48	x	x
8525	Linköping	Sweden	15.53	58.40	93	x	x
15772	Stensele		17.15	65.07	325	x	x
2220	Säntis	Switzerland	9.35	47.25	2490	x	x
3700	Zürich		8.57	47.38	556	x	x
9480	Lugano		8.97	46.00	273	x	x
0	CET	United Kingdom	- 1.83	52.42	0	x	
44841	Hull		- 0.37	53.77	2		x
256225	Oxford		- 1.27	51.77	63		x
610122	Eskdalemuir		- 3.20	55.32	242		x
770765	Wick		- 3.08	58.45	36		x
947811	Armagh		- 6.65	54.35	62		x

Table 1: *Stations used in the study. The locations are plotted in Figure 1.*

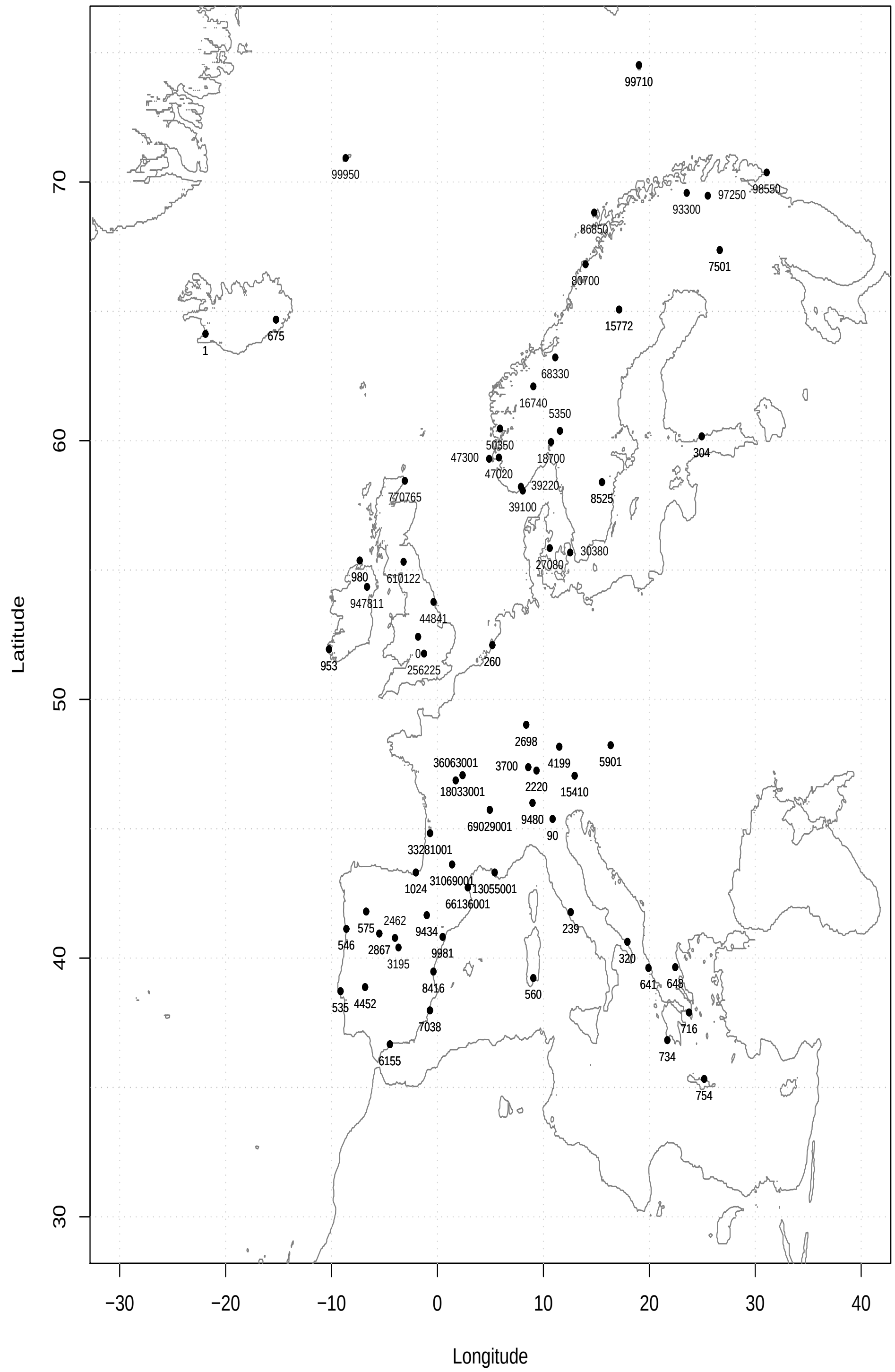

Figure 1: *Location of the stations used in the study.*

3 Results

3.1 Temperature downscaling

The results from daily mean temperature downscaling, using linear model, are summarized in Tables 2, 3, 4, 5, in annexe B. For each station and season, the method has been tested using three different predictors areas.

First of all, the $p - value$ associated with the Fisher test of overall fit is always zero, which means that the relationship between predictors and predictands is significant in all cases. Besides, the Pearson correlation coefficient, cor, between predictions and observations for the independent period, is varying from 0.62 to 0.98, showing a very good representation of the data by the model, especially in spring and autumn.

To detect a possible influence of the downscaling area, the density of the correlation coefficient, cor, is plotted, for each season and size of zone (see Figure 2). For all seasons, the results obtained with the small and medium areas are similar. A slight shift can be observed with the largest area, covering all Europe: the correlation is weaker than with smaller areas. Winter and summer are the seasons more sensible to the predictors area.

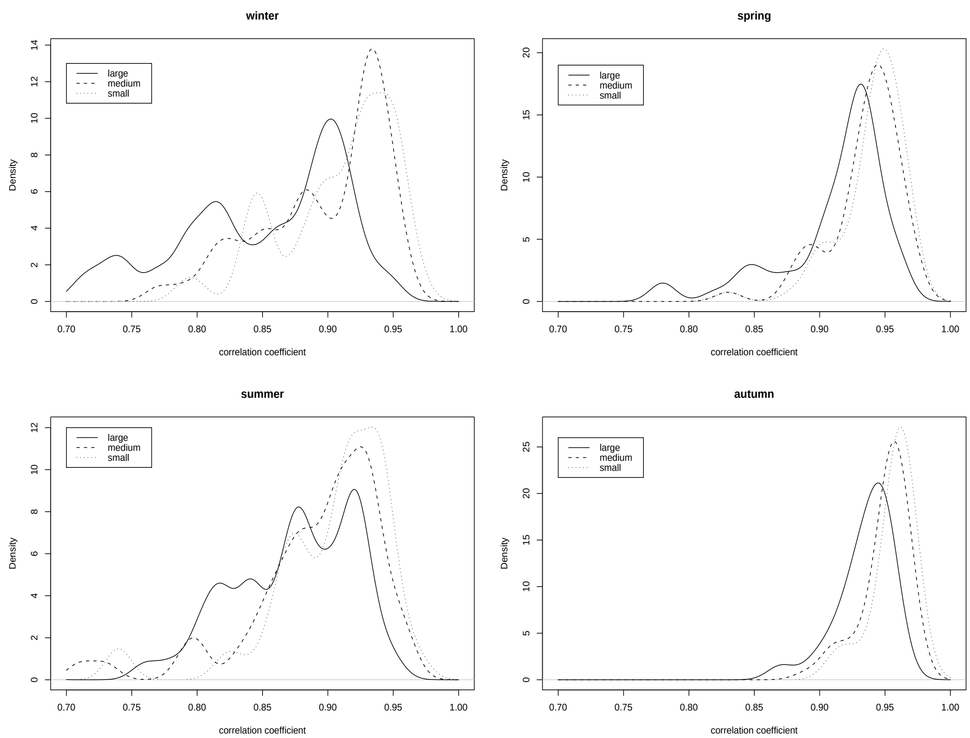

Figure 2: *Daily mean temperature downscaling: density of Pearson correlation coefficient for independent period, with varying areas (small, medium, large) and seasons.*

3.2 Precipitation downscaling

The results from daily precipitation downscaling, using analog method, are summarized in Tables 6, 7, 8, 9, in annexe C. For each station and season, the method has been tested using three different predictors areas. The rate of variance reproduced ranges from 0.02 to 4.49. However, 75% of the results are within the interval $0.72 - 1.06$ (see Figure 3), which indicates a good reproduction of the variance level for most stations. The width range is due to some severe outliers, which are studied in more detail afterwards. Moreover, the succession of dry and wet days is properly reproduced by the analog method (see Figure 4).

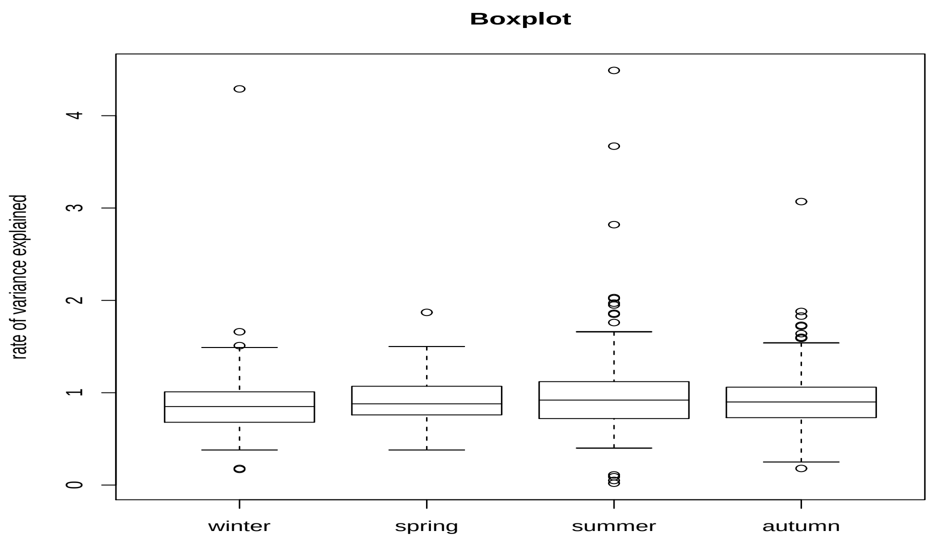

Figure 3: *Boxplot of rate of variance explained, for each season.*

Disregarding these outliers, a density plot of the rate of variance reproduced (see Figure 5) shows no significant influence of the predictors domain size. This observation is confirmed by Figure 6, where the root mean-square error density shows no sensitivity to downscaling area.

The analog model is unable to reproduce faithfully the variance level for the following stations: Heraklion and Methoni in summer, and Torrevieja in winter and autumn, for which the simulated variance is far too low compared to the observed one ($var \in [0.02; 0.18]$). For Tortosa, Tranebjerg, Zaragoza, Lisboa, Bragança, Badajoz, Oxford, Porto, Hellinikon, Valencia, Corfu, Navacerrada, Málaga, Perpignan, Heraklion and Marseille, the downscaled time-series are too variable for at least one season, with a rate of variance reproduced varying from 1.51 to 4.29.

The case of Tortosa's station has been studied in more detail, as the variance rate is very high in winter, spring and summer. In order to find out the cause of this variability, the density of the observed and predicted time-series (in summer and with large area) are plotted, to check in which cases the model fails. From Figure 7, it appears that the high variance rate ($var = 3.67$) is due to only a few days when very high amounts of precipitation are simulated. Moreover, when using only sea-level pressure as predictor (instead of both sea-level pressure and temperature), the rate of variance reproduced decreases to 1.31, which shows a good agreement between model and data. On the other hand, when retaining the 4 leading EOFs in the model (instead of the 8 first), its accuracy increases also ($var = 1.14$), as well as when the medium size area is used instead of the larger one ($var = 1.42$). The downscaled results in this particular station are therefore very unstable, and highly sensitive to the predictor field, number of EOFs as well as downscaling area.

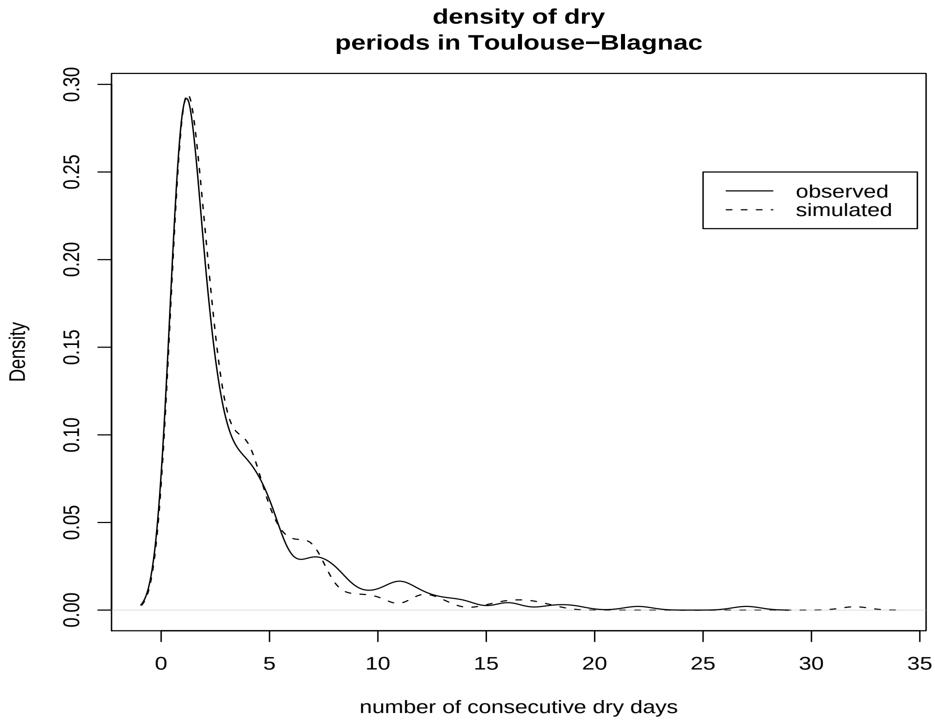

Figure 4: *Frequency distribution of observed and predicted dry-spell lengths in Toulouse, in winter and with large area.*

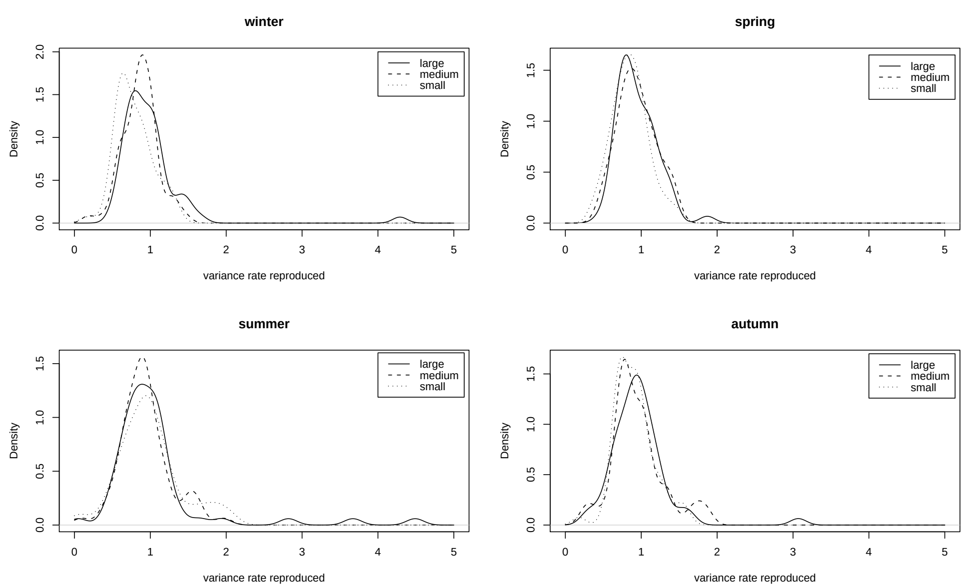

Figure 5: *Daily precipitation downscaling: density of variance rate for independent period, with varying areas (small, medium, large) and seasons.*

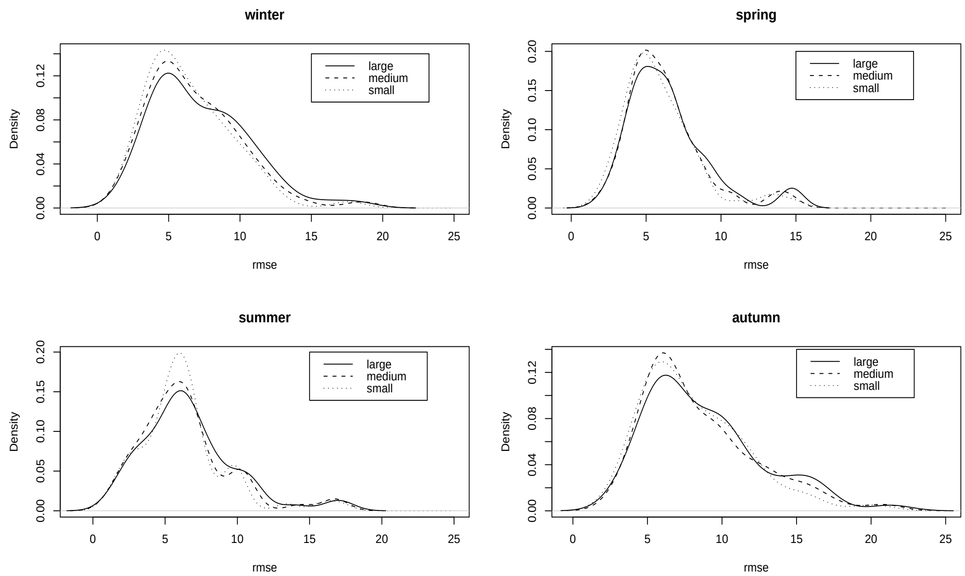

Figure 6: *Daily precipitation downscaling: density of root mean-square error (rmse) for independent period, with varying areas (small, medium, large) and seasons.*

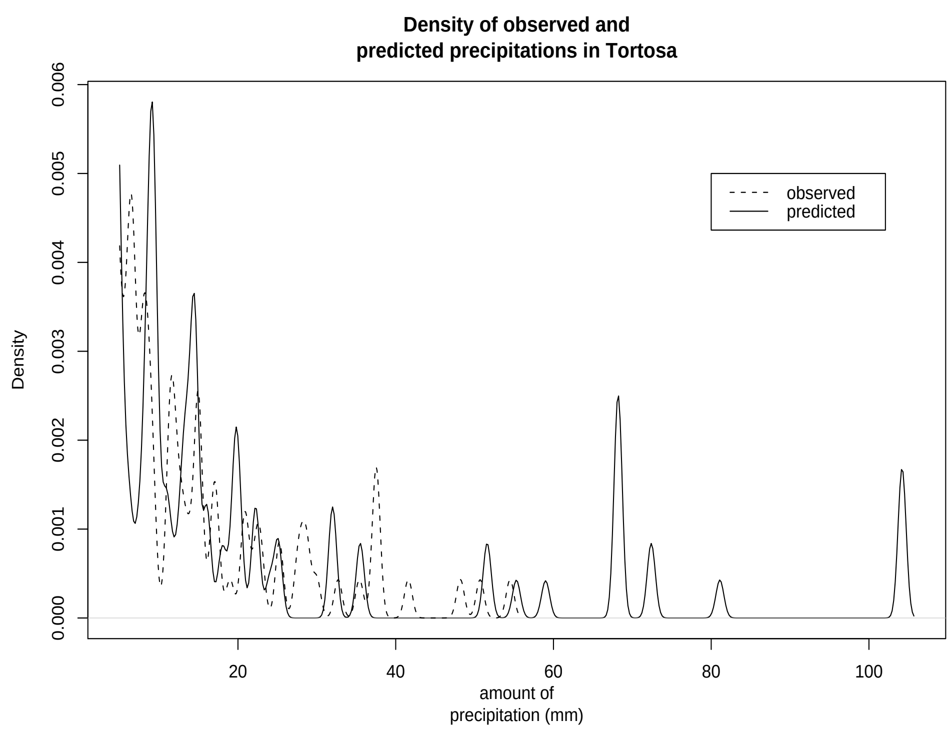

Figure 7: *Density of predicted and observed precipitation series in Tortosa, in summer and with large predictor area.*

4 Conclusion

The influence of the predictors area has been tested on downscaling of 24-hour precipitation, using analog model, and daily mean temperature, with linear regression. The downscaling methods have been tuned with 1957–1977 observations and evaluated against the following twenty years.

The relationship between the observations and the reconstructed time-series reveal that the downscaling techniques used are generally able to reproduce skillfully daily mean temperature, with linear method, and 24-hour precipitation, using analog model.

The predictor domain choice has a weak impact on the results for daily temperature, even if they are somewhat more skillful for the smaller area. Regarding precipitations, the analog method is insensitive to the predictor zone used. However, the predictor field chosen and the number of EOFs retained in the model have a strong influence on the results with this latter technique.

Acknowledgments

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A Downscaling areas

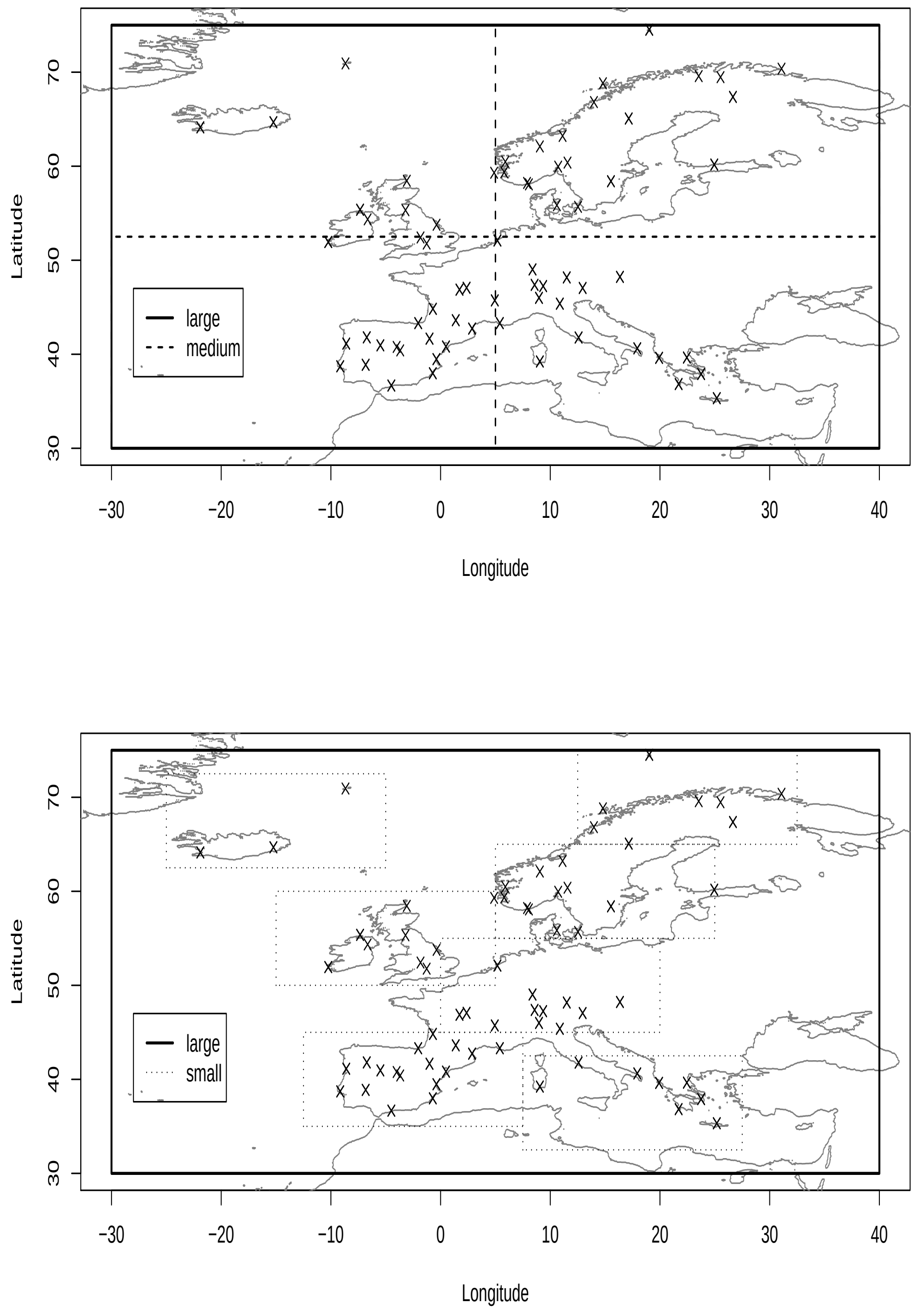

Figure 8: *Predictor domains.*

B Daily mean temperature

		small area			medium area			large area		
station	location	R2	pval	cor	R2	pval	cor	R2	pval	cor
575	Bragança	0.78	0	0.88	0.75	0	0.86	0.52	0	0.75
9434	Zaragoza	0.72	0	0.84	0.71	0	0.85	0.50	0	0.73
4452	Badajoz	0.73	0	0.89	0.73	0	0.88	0.55	0	0.77
980	Malin-Head	0.85	0	0.93	0.83	0	0.92	0.67	0	0.82
9981	Tortosa	0.73	0	0.85	0.71	0	0.85	0.57	0	0.74
953	Valentia	0.85	0	0.92	0.82	0	0.91	0.68	0	0.82
9480	Lugano	0.61	0	0.84	0.56	0	0.81	0.44	0	0.74
98550	Vardø	0.81	0	0.93	0.75	0	0.88	0.69	0	0.84
535	Lisboa	0.80	0	0.90	0.76	0	0.87	0.56	0	0.81
90	Verona	0.57	0	0.79	0.54	0	0.77	0.47	0	0.71
2867	Salamanca	0.81	0	0.92	0.79	0	0.92	0.63	0	0.84
6155	Málaga	0.54	0	0.80	0.57	0	0.79	0.49	0	0.72
8416	Valencia	0.76	0	0.90	0.76	0	0.90	0.61	0	0.82
7038	Torrevieja	0.62	0	0.87	0.63	0	0.86	0.55	0	0.79
546	Porto	0.78	0	0.89	0.75	0	0.88	0.60	0	0.82
5901	Wien	0.89	0	0.95	0.86	0	0.93	0.80	0	0.88
15410	Sonnblick	0.72	0	0.88	0.70	0	0.85	0.65	0	0.81
66136001	Perpignan	0.74	0	0.84	0.73	0	0.83	0.66	0	0.77
239	Roma	0.80	0	0.89	0.77	0	0.88	0.70	0	0.83
31069001	Toulouse	0.84	0	0.92	0.83	0	0.92	0.73	0	0.86
0	CET	0.90	0	0.95	0.88	0	0.94	0.78	0	0.89
320	Brindisi	0.76	0	0.85	0.71	0	0.82	0.67	0	0.79
2220	Säntis	0.71	0	0.85	0.67	0	0.81	0.64	0	0.79
18700	Oslo	0.84	0	0.95	0.82	0	0.94	0.74	0	0.89
33281001	Bordeaux	0.89	0	0.94	0.88	0	0.93	0.79	0	0.88
734	Methoni	0.80	0	0.90	0.80	0	0.89	0.72	0	0.85
13055001	Marseille	0.84	0	0.91	0.79	0	0.88	0.76	0	0.86
560	Cagliari	0.69	0	0.85	0.68	0	0.84	0.61	0	0.80
18033001	Bourges	0.91	0	0.95	0.91	0	0.95	0.85	0	0.90
36063001	Châteauroux	0.91	0	0.95	0.91	0	0.95	0.85	0	0.90
1	Reykjavik	0.88	0	0.93	0.88	0	0.93	0.83	0	0.89
675	Teigarhorn	0.88	0	0.93	0.88	0	0.93	0.82	0	0.89
716	Hellinikon	0.87	0	0.93	0.86	0	0.93	0.79	0	0.89
97250	Karasjok	0.79	0	0.90	0.77	0	0.89	0.73	0	0.86
69029001	Lyon	0.84	0	0.91	0.82	0	0.89	0.78	0	0.87
641	Corfu	0.70	0	0.84	0.67	0	0.82	0.65	0	0.80
648	Larissa	0.73	0	0.85	0.70	0	0.83	0.67	0	0.81
1024	San Sebastián	0.87	0	0.94	0.86	0	0.94	0.78	0	0.90
2698	Karlsruhe	0.88	0	0.95	0.85	0	0.93	0.80	0	0.91
7501	Sodankyla	0.84	0	0.94	0.83	0	0.93	0.78	0	0.90
8525	Linköping	0.88	0	0.95	0.87	0	0.95	0.82	0	0.91
39100	Oksøy	0.86	0	0.96	0.84	0	0.95	0.81	0	0.92
80700	Glomfjord	0.88	0	0.95	0.87	0	0.94	0.83	0	0.91
99950	Jan Mayen	0.86	0	0.93	0.86	0	0.94	0.82	0	0.91
260	De Bilt	0.93	0	0.97	0.87	0	0.95	0.85	0	0.94
754	Heraklion	0.80	0	0.90	0.80	0	0.90	0.72	0	0.87
15772	Stensele	0.82	0	0.92	0.81	0	0.93	0.78	0	0.91
16740	Kjøremsgrende	0.85	0	0.93	0.84	0	0.93	0.77	0	0.90
4199	München	0.88	0	0.95	0.84	0	0.93	0.81	0	0.92
47300	Utsira	0.89	0	0.96	0.84	0	0.94	0.83	0	0.93
30380	København	0.85	0	0.92	0.84	0	0.91	0.81	0	0.90
99710	Bjørnøya	0.84	0	0.93	0.83	0	0.93	0.82	0	0.91
3700	Zürich	0.89	0	0.94	0.87	0	0.94	0.84	0	0.92
304	Helsinki	0.90	0	0.96	0.89	0	0.96	0.87	0	0.95

Table 2: *Daily temperature in winter. The stations are sorted by increasing robustness, which is defined as the opposite of the variability to domain size:* $\Delta = |cor_M - cor_L| + |cor_M - cor_S|$.

		small area			medium area			large area		
station	location	R2	pval	cor	R2	pval	cor	R2	pval	cor
8416	Valencia	0.67	0	0.88	0.65	0	0.88	0.43	0	0.78
7038	Torrevieja	0.59	0	0.90	0.59	0	0.89	0.47	0	0.82
980	Malin-Head	0.76	0	0.93	0.74	0	0.92	0.57	0	0.86
9981	Tortosa	0.69	0	0.92	0.64	0	0.90	0.51	0	0.85
1024	San Sebastián	0.84	0	0.94	0.81	0	0.93	0.69	0	0.87
546	Porto	0.73	0	0.90	0.70	0	0.89	0.57	0	0.84
953	Valentia	0.69	0	0.90	0.66	0	0.88	0.52	0	0.84
535	Lisboa	0.86	0	0.94	0.84	0	0.94	0.69	0	0.88
66136001	Perpignan	0.72	0	0.90	0.70	0	0.89	0.59	0	0.85
0	CET	0.87	0	0.96	0.86	0	0.96	0.72	0	0.91
6155	Málaga	0.43	0	0.83	0.44	0	0.83	0.34	0	0.78
9480	Lugano	0.72	0	0.95	0.62	0	0.93	0.59	0	0.90
320	Brindisi	0.71	0	0.93	0.63	0	0.92	0.55	0	0.90
1	Reykjavik	0.88	0	0.96	0.88	0	0.96	0.82	0	0.93
239	Roma	0.78	0	0.95	0.72	0	0.94	0.65	0	0.92
260	De Bilt	0.84	0	0.96	0.76	0	0.93	0.74	0	0.93
575	Bragança	0.86	0	0.94	0.85	0	0.94	0.77	0	0.91
39100	Oksøy	0.75	0	0.96	0.71	0	0.95	0.60	0	0.93
47300	Utsira	0.79	0	0.96	0.70	0	0.94	0.64	0	0.93
80700	Glomfjord	0.84	0	0.96	0.81	0	0.95	0.76	0	0.93
98550	Vardø	0.84	0	0.96	0.83	0	0.96	0.77	0	0.93
99710	Bjørnøya	0.82	0	0.94	0.81	0	0.94	0.78	0	0.91
99950	Jan Mayen	0.86	0	0.95	0.86	0	0.95	0.81	0	0.92
560	Cagliari	0.64	0	0.90	0.60	0	0.90	0.49	0	0.88
675	Teigarhorn	0.85	0	0.93	0.84	0	0.93	0.81	0	0.91
716	Hellinikon	0.72	0	0.96	0.68	0	0.95	0.60	0	0.94
2698	Karlsruhe	0.85	0	0.96	0.84	0	0.96	0.83	0	0.94
8525	Linköping	0.81	0	0.97	0.80	0	0.97	0.76	0	0.95
30380	København	0.80	0	0.94	0.78	0	0.95	0.72	0	0.94
97250	Karasjok	0.70	0	0.92	0.66	0	0.92	0.60	0	0.90
90	Verona	0.76	0	0.95	0.71	0	0.94	0.65	0	0.93
641	Corfu	0.65	0	0.94	0.60	0	0.93	0.53	0	0.92
734	Methoni	0.70	0	0.94	0.65	0	0.93	0.57	0	0.92
4452	Badajoz	0.81	0	0.95	0.81	0	0.95	0.71	0	0.93
9434	Zaragoza	0.82	0	0.95	0.81	0	0.95	0.77	0	0.93
13055001	Marseille	0.75	0	0.94	0.69	0	0.93	0.64	0	0.92
33281001	Bordeaux	0.82	0	0.95	0.81	0	0.95	0.73	0	0.93
36063001	Châteauroux	0.82	0	0.95	0.83	0	0.94	0.78	0	0.93
304	Helsinki	0.80	0	0.97	0.80	0	0.97	0.73	0	0.96
648	Larissa	0.72	0	0.95	0.70	0	0.95	0.63	0	0.94
754	Heraklion	0.67	0	0.91	0.63	0	0.90	0.58	0	0.90
2867	Salamanca	0.84	0	0.95	0.84	0	0.95	0.80	0	0.94
3700	Zürich	0.91	0	0.97	0.90	0	0.97	0.88	0	0.96
4199	München	0.87	0	0.96	0.86	0	0.96	0.84	0	0.95
5901	Wien	0.89	0	0.97	0.87	0	0.96	0.82	0	0.96
15410	Sonnblick	0.76	0	0.92	0.77	0	0.92	0.75	0	0.91
15772	Stensele	0.74	0	0.95	0.73	0	0.95	0.68	0	0.94
16740	Kjøremsgrende	0.76	0	0.95	0.74	0	0.95	0.72	0	0.94
18700	Oslo	0.81	0	0.97	0.79	0	0.97	0.72	0	0.96
18033001	Bourges	0.84	0	0.95	0.84	0	0.94	0.80	0	0.94
2220	Säntis	0.84	0	0.94	0.84	0	0.94	0.82	0	0.93
7501	Sodankyla	0.75	0	0.94	0.73	0	0.94	0.70	0	0.93
31069001	Toulouse	0.80	0	0.94	0.79	0	0.94	0.73	0	0.93
69029001	Lyon	0.79	0	0.94	0.79	0	0.94	0.78	0	0.94

Table 3: *Daily temperature in spring. The stations are sorted by increasing robustness*

		small area			medium area			large area		
station	location	R2	pval	cor	R2	pval	cor	R2	pval	cor
1	Reykjavik	0.64	0	0.85	0.57	0	0.80	0.35	0	0.67
546	Porto	0.64	0	0.82	0.59	0	0.79	0.42	0	0.66
99710	Bjørnøya	0.76	0	0.90	0.69	0	0.86	0.53	0	0.76
675	Teigarhorn	0.45	0	0.74	0.47	0	0.73	0.25	0	0.62
535	Lisboa	0.79	0	0.91	0.77	0	0.90	0.58	0	0.80
6155	Málaga	0.32	0	0.74	0.26	0	0.71	0.22	0	0.64
47300	Utsira	0.78	0	0.92	0.77	0	0.91	0.65	0	0.84
99950	Jan Mayen	0.62	0	0.88	0.60	0	0.88	0.36	0	0.80
66136001	Perpignan	0.65	0	0.89	0.61	0	0.88	0.51	0	0.82
39100	Oksøy	0.72	0	0.88	0.66	0	0.84	0.60	0	0.81
8416	Valencia	0.49	0	0.88	0.46	0	0.88	0.35	0	0.82
953	Valentia	0.62	0	0.87	0.55	0	0.83	0.45	0	0.81
98550	Vardø	0.82	0	0.94	0.81	0	0.93	0.72	0	0.88
90	Verona	0.79	0	0.93	0.77	0	0.91	0.71	0	0.88
980	Malin-Head	0.67	0	0.87	0.66	0	0.87	0.51	0	0.82
1024	San Sebastián	0.75	0	0.91	0.73	0	0.90	0.63	0	0.86
7038	Torrevieja	0.41	0	0.87	0.39	0	0.86	0.33	0	0.82
9981	Tortosa	0.55	0	0.90	0.49	0	0.88	0.37	0	0.85
80700	Glomfjord	0.84	0	0.92	0.82	0	0.91	0.76	0	0.87
754	Heraklion	0.60	0	0.83	0.55	0	0.80	0.53	0	0.78
648	Larissa	0.75	0	0.91	0.72	0	0.89	0.66	0	0.87
9480	Lugano	0.68	0	0.92	0.67	0	0.91	0.59	0	0.88
18700	Oslo	0.82	0	0.92	0.80	0	0.91	0.76	0	0.88
13055001	Marseille	0.69	0	0.91	0.64	0	0.89	0.57	0	0.87
0	CET	0.84	0	0.94	0.82	0	0.93	0.74	0	0.90
260	De Bilt	0.82	0	0.94	0.75	0	0.91	0.76	0	0.90
575	Bragança	0.84	0	0.94	0.82	0	0.93	0.74	0	0.90
4452	Badajoz	0.84	0	0.95	0.83	0	0.95	0.76	0	0.91
239	Roma	0.74	0	0.93	0.72	0	0.92	0.67	0	0.90
320	Brindisi	0.62	0	0.87	0.55	0	0.85	0.49	0	0.84
641	Corfu	0.70	0	0.91	0.64	0	0.89	0.61	0	0.88
716	Hellinikon	0.66	0	0.87	0.63	0	0.87	0.60	0	0.84
734	Methoni	0.61	0	0.89	0.54	0	0.87	0.52	0	0.86
3700	Zürich	0.89	0	0.97	0.89	0	0.96	0.86	0	0.94
8525	Linköping	0.79	0	0.91	0.79	0	0.90	0.75	0	0.88
16740	Kjøremsgrende	0.82	0	0.92	0.82	0	0.91	0.79	0	0.89
9434	Zaragoza	0.83	0	0.95	0.83	0	0.95	0.78	0	0.92
304	Helsinki	0.76	0	0.90	0.76	0	0.90	0.73	0	0.88
560	Cagliari	0.57	0	0.86	0.55	0	0.86	0.45	0	0.84
15410	Sonnblick	0.84	0	0.92	0.85	0	0.93	0.84	0	0.92
30380	København	0.79	0	0.86	0.77	0	0.85	0.72	0	0.84
97250	Karasjok	0.83	0	0.92	0.83	0	0.92	0.81	0	0.90
2698	Karlsruhe	0.86	0	0.95	0.84	0	0.94	0.83	0	0.93
2867	Salamanca	0.80	0	0.94	0.80	0	0.94	0.75	0	0.92
5901	Wien	0.86	0	0.94	0.85	0	0.93	0.82	0	0.92
31069001	Toulouse	0.81	0	0.94	0.81	0	0.93	0.79	0	0.92
36063001	Châteauroux	0.84	0	0.94	0.83	0	0.93	0.81	0	0.92
2220	Säntis	0.90	0	0.96	0.90	0	0.96	0.89	0	0.95
15772	Stensele	0.75	0	0.88	0.75	0	0.88	0.73	0	0.87
33281001	Bordeaux	0.79	0	0.93	0.81	0	0.93	0.77	0	0.92
69029001	Lyon	0.82	0	0.93	0.80	0	0.92	0.81	0	0.92
4199	München	0.86	0	0.94	0.85	0	0.94	0.83	0	0.93
18033001	Bourges	0.86	0	0.94	0.85	0	0.93	0.83	0	0.93
7501	Sodankyla	0.82	0	0.92	0.83	0	0.92	0.81	0	0.92

Table 4: *Daily temperature in summer. The stations are sorted by increasing robustness.*

		small area			medium area			large area		
station	location	R2	pval	cor	R2	pval	cor	R2	pval	cor
546	Porto	0.71	0	0.92	0.67	0	0.91	0.54	0	0.87
953	Valentia	0.72	0	0.92	0.70	0	0.91	0.60	0	0.87
980	Malin-Head	0.80	0	0.95	0.78	0	0.94	0.65	0	0.90
535	Lisboa	0.82	0	0.97	0.79	0	0.96	0.63	0	0.93
8416	Valencia	0.72	0	0.96	0.70	0	0.95	0.58	0	0.92
2220	Säntis	0.77	0	0.91	0.74	0	0.89	0.76	0	0.90
6155	Málaga	0.42	0	0.92	0.39	0	0.91	0.31	0	0.89
98550	Vardø	0.86	0	0.98	0.83	0	0.97	0.75	0	0.95
18033001	Bourges	0.81	0	0.97	0.81	0	0.96	0.73	0	0.94
0	CET	0.80	0	0.96	0.77	0	0.95	0.67	0	0.93
260	De Bilt	0.78	0	0.96	0.70	0	0.94	0.68	0	0.93
320	Brindisi	0.67	0	0.95	0.59	0	0.93	0.53	0	0.92
675	Teigarhorn	0.84	0	0.94	0.83	0	0.93	0.77	0	0.91
1024	San Sebastián	0.86	0	0.95	0.85	0	0.94	0.79	0	0.92
16740	Kjøremsgrende	0.80	0	0.96	0.79	0	0.96	0.70	0	0.93
97250	Karasjok	0.77	0	0.95	0.76	0	0.95	0.67	0	0.92
99950	Jan Mayen	0.86	0	0.96	0.87	0	0.96	0.80	0	0.93
31069001	Toulouse	0.77	0	0.96	0.76	0	0.95	0.67	0	0.93
33281001	Bordeaux	0.82	0	0.96	0.81	0	0.95	0.69	0	0.93
1	Reykjavik	0.86	0	0.96	0.86	0	0.96	0.80	0	0.94
239	Roma	0.76	0	0.97	0.71	0	0.96	0.64	0	0.95
575	Bragança	0.81	0	0.97	0.80	0	0.97	0.70	0	0.95
641	Corfu	0.68	0	0.96	0.62	0	0.95	0.57	0	0.94
2867	Salamanca	0.79	0	0.97	0.78	0	0.96	0.74	0	0.95
4452	Badajoz	0.73	0	0.97	0.72	0	0.97	0.63	0	0.95
9434	Zaragoza	0.67	0	0.96	0.67	0	0.96	0.61	0	0.94
9480	Lugano	0.65	0	0.97	0.55	0	0.95	0.53	0	0.95
9981	Tortosa	0.67	0	0.96	0.64	0	0.95	0.57	0	0.94
15772	Stensele	0.82	0	0.97	0.82	0	0.97	0.75	0	0.95
18700	Oslo	0.79	0	0.97	0.77	0	0.96	0.65	0	0.95
39100	Oksøy	0.77	0	0.96	0.74	0	0.96	0.64	0	0.94
47300	Utsira	0.83	0	0.97	0.78	0	0.96	0.73	0	0.95
80700	Glomfjord	0.87	0	0.96	0.86	0	0.96	0.82	0	0.94
99710	Bjørnøya	0.85	0	0.96	0.84	0	0.96	0.81	0	0.94
13055001	Marseille	0.79	0	0.96	0.74	0	0.95	0.70	0	0.94
36063001	Châteauroux	0.82	0	0.96	0.81	0	0.96	0.73	0	0.94
66136001	Perpignan	0.62	0	0.93	0.59	0	0.92	0.54	0	0.91
560	Cagliari	0.68	0	0.95	0.64	0	0.95	0.58	0	0.93
754	Heraklion	0.70	0	0.94	0.68	0	0.93	0.62	0	0.92
7038	Torrevieja	0.55	0	0.95	0.53	0	0.95	0.46	0	0.93
90	Verona	0.63	0	0.96	0.58	0	0.95	0.53	0	0.95
304	Helsinki	0.84	0	0.97	0.84	0	0.97	0.79	0	0.96
648	Larissa	0.70	0	0.97	0.70	0	0.96	0.66	0	0.96
716	Hellinikon	0.83	0	0.97	0.78	0	0.97	0.74	0	0.96
734	Methoni	0.71	0	0.96	0.69	0	0.96	0.64	0	0.95
2698	Karlsruhe	0.72	0	0.96	0.69	0	0.95	0.68	0	0.95
3700	Zürich	0.82	0	0.97	0.80	0	0.97	0.78	0	0.96
4199	München	0.79	0	0.96	0.78	0	0.96	0.76	0	0.95
5901	Wien	0.78	0	0.97	0.74	0	0.96	0.69	0	0.96
7501	Sodankyla	0.84	0	0.96	0.83	0	0.96	0.79	0	0.95
8525	Linköping	0.80	0	0.96	0.79	0	0.96	0.70	0	0.95
69029001	Lyon	0.75	0	0.95	0.74	0	0.95	0.70	0	0.94
15410	Sonnblick	0.73	0	0.91	0.73	0	0.91	0.73	0	0.91
30380	København	0.77	0	0.95	0.76	0	0.95	0.70	0	0.95

Table 5: *Daily temperature in autumn. The stations are sorted by increasing robustness.*

C Daily precipitation

		small area			medium area			large area		
station	location	var	rmse	cor	var	rmse	cor	var	rmse	cor
1	Reykjavik	0.70	4.87	0.33	0.83	4.89	0.36	0.95	5.60	0.21
90	Verona	0.65	5.67	0.23	0.61	5.86	0.17	0.66	6.11	0.12
239	Roma	0.59	7.27	0.32	0.59	7.24	0.33	0.74	8.30	0.18
260	De Bilt	0.85	4.63	0.34	0.95	5.09	0.25	1.39	5.81	0.20
304	Helsinki	0.95	3.49	0.24	0.92	3.36	0.28	1.06	3.83	0.13
320	Brindisi	0.57	7.77	0.13	0.73	7.85	0.19	0.57	8.18	0.03
535	Lisboa	0.85	8.29	0.35	0.90	8.76	0.29	1.02	9.14	0.27
546	Porto	0.77	11.03	0.36	0.85	11.43	0.33	0.80	11.69	0.29
560	Cagliari	1.24	6.45	0.10	0.95	6.03	0.10	1.05	6.44	0.02
575	Bragança	0.68	7.22	0.41	1.01	8.00	0.39	0.74	7.57	0.37
641	Corfu	0.98	11.35	0.29	1.02	12.01	0.22	1.09	13.44	0.06
648	Larissa	0.60	4.60	0.20	0.58	4.76	0.13	0.79	5.26	0.05
675	Teigarhorn	0.60	9.48	0.29	0.80	9.97	0.28	1.02	10.71	0.26
716	Hellinikon	0.55	6.37	0.22	0.59	6.88	0.10	0.92	7.72	0.06
734	Methoni	0.68	8.73	0.20	0.68	8.74	0.20	0.80	9.53	0.10
754	Heraklion	1.18	7.42	0.28	1.46	8.39	0.19	1.49	9.17	0.04
953	Valentia	0.94	8.55	0.30	1.02	8.64	0.31	0.85	8.78	0.23
980	Malin-Head	0.59	5.63	0.28	1.01	6.67	0.18	0.71	6.15	0.19
1024	San Sebastián	0.71	10.53	0.28	0.83	10.39	0.34	0.79	11.02	0.24
2220	Säntis	0.49	12.72	0.45	0.59	14.22	0.32	0.67	15.94	0.18
2462	Navacerrada	0.71	11.39	0.36	0.83	12.43	0.28	0.72	12.34	0.24
2698	Karlsruhe	0.57	4.99	0.28	0.60	5.18	0.23	0.80	5.52	0.21
2867	Salamanca	1.31	3.91	0.28	1.31	4.02	0.25	1.43	4.40	0.14
3195	Madrid	0.79	4.15	0.35	0.85	4.52	0.25	0.93	4.78	0.20
3700	Zürich	0.76	5.71	0.30	1.01	6.24	0.27	1.16	6.68	0.22
4199	München	0.57	4.29	0.22	0.76	4.80	0.11	0.64	4.68	0.10
4452	Badajoz	0.91	5.26	0.36	1.01	5.48	0.33	1.04	5.86	0.25
5350	Nord-Odal	1.34	3.85	0.27	1.34	3.90	0.25	1.38	4.13	0.18
5901	Wien	0.97	3.79	0.18	1.07	4.10	0.09	0.99	4.02	0.09
6155	Málaga	0.65	9.38	0.30	0.76	9.91	0.27	1.18	11.69	0.18
7038	Torrevieja	0.17	7.16	0.11	0.18	7.39	0.04	0.50	8.51	-0.01
7501	Sodankyla	0.57	2.00	0.28	0.62	2.15	0.18	0.62	2.20	0.14
8416	Valencia	0.49	6.64	0.22	0.38	6.76	0.12	0.98	8.35	0.05
8525	Linköping	0.67	2.68	0.21	0.86	2.90	0.16	1.12	3.21	0.10
9434	Zaragoza	0.52	2.80	0.17	0.71	2.89	0.20	1.51	3.80	0.06
9480	Lugano	0.63	8.02	0.39	0.73	8.49	0.35	0.84	9.55	0.22
9981	Tortosa	1.10	6.04	0.11	1.23	6.08	0.16	4.29	10.12	0.03
15410	Sonnblick	0.74	6.38	0.46	0.89	7.77	0.24	0.87	7.84	0.21
15772	Stensele	1.27	2.60	0.20	1.04	2.44	0.21	1.29	2.69	0.15
27080	Tranebjerg	1.21	3.50	0.25	1.27	3.63	0.21	1.66	3.90	0.23
39220	Mestad	0.88	10.59	0.39	1.04	11.08	0.38	1.13	12.38	0.26
44841	Hull	0.68	4.39	0.24	1.00	5.06	0.14	0.76	4.66	0.18
47020	Nedstrand	0.83	10.12	0.38	0.87	10.58	0.34	0.79	10.66	0.30
50350	Samnanger	0.92	17.58	0.55	0.92	18.52	0.50	0.74	18.26	0.47
68330	Lien-I-Selbu	1.01	4.05	0.36	1.03	4.41	0.24	1.01	4.53	0.19
86850	Barkestad	1.11	8.19	0.44	1.12	9.12	0.30	1.01	9.02	0.29
93300	Suolovuopmi	1.11	2.62	0.19	0.79	2.35	0.24	0.67	2.39	0.16
99710	Bjørnøya	0.56	2.72	0.16	0.57	2.76	0.14	0.60	2.82	0.11
256225	Oxford	0.86	4.26	0.25	0.88	4.43	0.20	1.11	4.75	0.18
610122	Eskdalemuir	0.63	8.88	0.42	0.65	9.85	0.29	0.64	9.80	0.29
770765	Wick	0.89	4.75	0.18	0.89	4.86	0.14	0.87	4.86	0.13
947811	Armagh	0.86	4.56	0.28	0.98	5.00	0.19	0.82	4.78	0.19
13055001	Marseille	0.61	6.55	0.26	0.87	7.68	0.12	0.83	7.59	0.12
18033001	Bourges	0.77	4.26	0.27	0.90	4.35	0.28	1.10	4.65	0.26
31069001	Toulouse	0.64	4.42	0.29	0.80	4.60	0.29	0.90	5.07	0.18
33281001	Bordeaux	0.60	6.50	0.40	0.89	6.91	0.41	0.88	7.43	0.31
36063001	Châteauroux	0.81	4.76	0.25	0.85	4.71	0.28	1.06	4.90	0.30
66136001	Perpignan	0.40	9.03	0.07	0.52	9.08	0.13	0.70	10.14	0.02
69029001	Lyon	0.96	5.37	0.14	0.99	5.44	0.13	0.98	5.32	0.17

Table 6: *Daily precipitation in winter.*

		small area			medium area			large area		
station	location	var	rmse	cor	var	rmse	cor	var	rmse	cor
1	Reykjavik	0.69	4.57	0.22	0.76	4.65	0.22	0.71	4.87	0.11
90	Verona	0.87	7.19	0.20	1.07	8.14	0.07	1.28	8.28	0.13
239	Roma	0.84	6.16	0.23	0.97	6.62	0.17	0.89	6.71	0.11
260	De Bilt	0.76	4.82	0.19	0.92	5.30	0.10	0.85	5.19	0.10
304	Helsinki	0.75	3.28	0.18	1.42	4.03	0.10	1.00	3.73	0.07
320	Brindisi	0.58	5.86	0.12	0.95	6.31	0.17	0.66	5.94	0.14
535	Lisboa	0.99	5.70	0.34	1.18	6.47	0.22	1.35	7.15	0.12
546	Porto	1.12	8.03	0.38	1.04	8.19	0.32	1.07	8.90	0.21
560	Cagliari	0.88	4.48	0.17	1.07	4.83	0.12	1.05	4.93	0.08
575	Bragança	0.75	4.69	0.37	1.13	5.59	0.26	1.17	5.78	0.22
641	Corfu	1.16	8.18	0.13	1.05	7.96	0.14	1.14	8.45	0.07
648	Larissa	0.65	4.26	0.27	0.82	4.93	0.11	0.83	5.08	0.06
675	Teigarhorn	0.55	7.62	0.28	0.82	8.46	0.22	0.71	8.55	0.16
716	Hellinikon	0.38	4.76	0.17	0.58	5.21	0.10	0.66	5.59	0.02
734	Methoni	0.98	5.54	0.14	0.93	5.53	0.13	1.13	6.21	0.00
754	Heraklion	1.29	6.14	0.14	1.22	6.08	0.13	1.13	6.21	0.05
953	Valentia	0.79	7.00	0.15	0.74	6.62	0.22	0.76	6.91	0.15
980	Malin-Head	1.01	4.67	0.23	0.92	4.68	0.19	0.92	4.79	0.15
1024	San Sebastián	0.82	11.12	0.21	0.71	10.68	0.23	0.80	11.26	0.19
2220	Säntis	0.63	13.11	0.26	0.77	14.01	0.22	0.76	14.79	0.12
2462	Navacerrada	0.91	8.82	0.32	1.44	10.50	0.25	1.16	10.61	0.13
2698	Karlsruhe	0.38	5.57	0.12	0.64	6.06	0.11	0.95	6.68	0.08
2867	Salamanca	0.54	3.48	0.16	0.85	3.75	0.17	0.65	3.72	0.10
3195	Madrid	0.66	4.18	0.20	1.17	4.79	0.18	0.81	4.69	0.07
3700	Zürich	0.86	7.09	0.22	0.79	7.23	0.15	0.84	7.47	0.12
4199	München	0.71	6.68	0.15	0.79	7.05	0.10	0.78	7.15	0.06
4452	Badajoz	0.88	4.37	0.30	0.93	4.78	0.18	0.80	4.89	0.09
5350	Nord-Odal	0.96	4.32	0.19	1.18	4.44	0.23	0.89	4.40	0.12
5901	Wien	0.69	5.74	0.14	1.11	6.43	0.13	0.70	5.90	0.09
6155	Málaga	0.94	5.32	0.24	0.97	5.58	0.18	0.80	5.65	0.08
7038	Torrevieja	0.49	3.29	0.16	0.80	3.81	0.05	1.14	4.06	0.09
7501	Sodankyla	0.73	2.72	0.16	0.96	2.87	0.17	0.96	3.01	0.09
8416	Valencia	0.56	5.34	0.17	0.50	5.57	0.06	0.85	6.22	0.04
8525	Linköping	1.31	3.62	0.11	1.35	3.60	0.13	1.07	3.53	0.05
9434	Zaragoza	0.97	5.07	0.10	0.61	4.76	0.03	0.78	4.77	0.12
9480	Lugano	1.00	13.49	0.29	0.88	13.42	0.25	1.08	14.58	0.20
9981	Tortosa	1.50	6.02	0.19	1.35	6.16	0.10	1.87	6.86	0.09
15410	Sonnblick	1.41	8.51	0.34	1.33	9.21	0.20	1.41	9.62	0.16
15772	Stensele	0.76	2.76	0.20	1.20	3.13	0.17	1.35	3.43	0.07
27080	Tranebjerg	1.04	3.58	0.16	1.39	4.04	0.09	1.12	3.85	0.07
39220	Mestad	0.83	8.84	0.20	0.89	8.77	0.24	0.86	9.16	0.16
44841	Hull	0.69	4.17	0.18	0.68	4.37	0.10	0.78	4.45	0.11
47020	Nedstrand	1.13	8.57	0.27	0.97	8.41	0.23	1.36	9.49	0.19
50350	Samnanger	0.90	14.90	0.42	0.76	14.70	0.40	0.77	14.82	0.39
68330	Lien-I-Selbu	1.20	4.39	0.17	1.12	4.42	0.13	1.23	4.58	0.11
86850	Barkestad	1.06	6.53	0.30	1.41	7.01	0.31	0.97	6.84	0.20
93300	Suolovuopmi	1.10	2.81	0.06	1.20	2.90	0.05	1.16	2.90	0.03
99710	Bjørnøya	0.47	1.96	0.18	0.46	1.96	0.17	0.47	2.10	0.03
256225	Oxford	0.77	4.31	0.16	0.73	4.39	0.11	0.69	4.18	0.17
610122	Eskdalemuir	0.59	7.33	0.27	0.54	7.37	0.24	0.63	7.70	0.20
770765	Wick	0.81	4.18	0.12	0.79	4.22	0.09	0.87	4.28	0.10
947811	Armagh	0.84	4.20	0.24	0.99	4.50	0.19	0.79	4.38	0.15
13055001	Marseille	1.05	7.15	0.11	0.63	6.33	0.13	0.68	6.47	0.12
18033001	Bourges	0.96	5.02	0.20	1.00	4.96	0.23	0.99	5.19	0.15
31069001	Toulouse	0.77	5.57	0.24	0.81	5.91	0.16	1.02	6.43	0.10
33281001	Bordeaux	0.65	6.06	0.20	0.76	6.13	0.22	0.60	6.12	0.15
36063001	Châteauroux	0.95	5.23	0.21	0.94	5.23	0.20	0.92	5.37	0.15
66136001	Perpignan	0.94	7.03	0.28	0.55	7.13	0.07	1.37	8.52	0.13
69029001	Lyon	0.86	6.85	0.18	0.86	6.99	0.14	0.67	6.72	0.12

Table 7: *Daily precipitation in spring.*

		small area			medium area			large area		
station	location	var	rmse	cor	var	rmse	cor	var	rmse	cor
1	Reykjavik	1.03	4.82	0.13	0.91	4.69	0.12	0.91	4.89	0.05
90	Verona	0.40	10.14	0.18	0.47	10.55	0.14	0.43	10.67	0.10
239	Roma	1.16	5.97	0.11	0.78	5.69	0.02	0.78	5.64	0.03
260	De Bilt	1.24	6.34	0.18	1.18	6.41	0.14	1.14	6.47	0.11
304	Helsinki	0.50	6.20	0.13	0.65	6.56	0.11	0.66	6.58	0.10
320	Brindisi	0.83	3.35	0.08	1.58	4.06	0.04	0.72	3.37	0.01
535	Lisboa	1.85	2.55	0.20	1.12	2.33	0.09	1.26	2.45	0.06
546	Porto	1.33	4.18	0.27	1.53	4.25	0.31	1.95	5.19	0.12
560	Cagliari	0.67	2.18	0.03	1.10	2.49	0.00	0.68	2.23	0.00
575	Bragança	2.02	4.52	0.15	1.21	3.89	0.13	1.65	4.53	0.01
641	Corfu	1.22	5.12	0.08	0.69	4.62	0.02	0.92	4.98	-0.01
648	Larissa	1.66	5.23	0.02	0.96	4.48	0.02	0.78	4.12	0.09
675	Teigarhorn	0.97	9.63	0.30	0.81	10.14	0.15	0.67	9.98	0.11
716	Hellinikon	1.22	2.61	0.04	1.65	2.92	-0.01	2.82	3.47	0.02
734	Methoni	0.11	1.47	-0.01	0.73	1.83	0.00	0.88	1.91	-0.01
754	Heraklion	0.02	1.13	0.00	0.09	1.17	0.00	0.05	1.15	0.01
953	Valentia	0.66	7.30	0.19	0.65	7.32	0.18	0.82	8.06	0.09
980	Malin-Head	0.94	5.50	0.17	0.94	5.61	0.14	1.11	6.02	0.09
1024	San Sebastián	0.63	9.20	0.24	0.83	10.50	0.11	1.04	11.39	0.06
2220	Säntis	1.29	17.12	0.27	0.98	16.88	0.17	1.11	17.31	0.18
2462	Navacerrada	0.82	5.70	0.17	0.86	5.82	0.15	1.02	6.60	0.00
2698	Karlsruhe	0.96	7.17	0.11	0.91	7.08	0.11	1.03	7.36	0.10
2867	Salamanca	1.08	4.04	0.14	1.06	4.22	0.05	0.52	3.74	-0.01
3195	Madrid	1.17	3.31	0.12	0.79	3.05	0.09	0.56	3.01	-0.02
3700	Zürich	0.96	9.77	0.27	0.97	10.47	0.17	1.07	11.12	0.10
4199	München	0.69	9.93	0.15	0.78	9.83	0.21	0.82	10.56	0.11
4452	Badajoz	1.86	3.35	0.04	1.97	3.38	0.06	1.09	2.91	0.01
5350	Nord-Odal	0.72	6.52	0.21	0.89	7.30	0.09	0.86	7.13	0.12
5901	Wien	1.02	7.81	0.12	0.98	7.85	0.09	1.10	8.28	0.05
6155	Málaga	0.44	2.60	0.03	0.40	2.58	0.01	1.15	3.23	-0.01
7038	Torrevieja	0.50	2.03	0.03	0.59	1.97	0.14	0.57	2.01	0.09
7501	Sodankyla	0.71	5.37	0.20	0.69	5.56	0.13	0.75	5.94	0.04
8416	Valencia	0.90	5.02	0.01	0.87	4.16	0.31	1.03	5.24	-0.01
8525	Linköping	0.92	6.25	0.11	0.68	5.88	0.10	0.90	6.32	0.08
9434	Zaragoza	0.95	4.56	0.04	0.66	4.17	0.05	0.68	4.33	-0.01
9480	Lugano	0.75	15.86	0.22	0.70	16.66	0.12	0.91	16.68	0.21
9981	Tortosa	1.76	6.51	0.10	1.42	6.34	0.03	3.67	8.93	0.01
15410	Sonnblick	0.99	7.84	0.34	0.92	8.53	0.19	1.13	9.13	0.16
15772	Stensele	0.95	6.34	0.17	0.95	6.32	0.18	1.09	6.87	0.09
27080	Tranebjerg	0.68	5.78	0.11	0.66	5.66	0.13	0.72	5.92	0.09
39220	Mestad	0.80	10.11	0.24	0.70	10.10	0.20	0.72	10.65	0.12
44841	Hull	0.80	5.63	0.16	0.85	6.02	0.07	0.91	6.10	0.06
47020	Nedstrand	0.97	9.60	0.26	1.01	10.24	0.17	1.01	10.01	0.21
50350	Samnanger	0.80	13.41	0.33	0.91	14.29	0.28	0.87	13.97	0.30
68330	Lien-I-Selbu	0.57	6.31	0.18	0.57	6.29	0.19	0.84	7.15	0.09
86850	Barkestad	1.03	6.62	0.29	0.96	6.64	0.26	0.93	7.04	0.16
93300	Suolovuopmi	1.09	5.68	0.06	1.14	5.76	0.05	1.38	6.31	-0.01
99710	Bjørnøya	1.02	2.95	0.09	0.92	2.95	0.04	1.15	3.20	0.00
256225	Oxford	2.03	5.95	0.14	1.52	5.51	0.11	4.49	8.53	0.03
610122	Eskdalemuir	0.91	7.31	0.29	0.80	7.54	0.21	0.99	7.88	0.21
770765	Wick	1.08	4.66	0.14	1.14	4.90	0.07	1.14	4.95	0.06
947811	Armagh	1.55	5.39	0.22	1.57	5.73	0.12	1.32	5.57	0.08
13055001	Marseille	0.61	4.89	0.12	0.44	4.73	0.08	0.66	5.21	0.03
18033001	Bourges	1.20	6.49	0.21	1.26	6.93	0.12	0.59	6.07	0.04
31069001	Toulouse	0.89	6.75	0.18	0.94	7.14	0.11	0.48	6.34	0.09
33281001	Bordeaux	0.92	6.63	0.21	0.96	6.87	0.17	1.18	7.57	0.09
36063001	Châteauroux	1.15	6.64	0.11	1.15	6.63	0.11	0.84	6.23	0.08
66136001	Perpignan	1.53	5.80	0.09	0.83	4.88	0.11	0.73	4.94	0.03
69029001	Lyon	0.68	7.41	0.23	0.92	8.11	0.19	0.88	8.00	0.19

Table 8: *Daily precipitation in summer.*

station	location	small area var	rmse	cor	medium area var	rmse	cor	large area var	rmse	cor
1	Reykjavik	0.93	5.19	0.20	1.26	5.38	0.27	1.12	5.39	0.22
90	Verona	0.68	8.28	0.28	0.67	8.67	0.20	0.70	9.42	0.07
239	Roma	0.60	9.82	0.29	0.46	9.94	0.21	0.73	11.28	0.13
260	De Bilt	1.17	6.05	0.30	0.84	5.81	0.24	1.01	6.28	0.19
304	Helsinki	1.27	5.92	0.19	1.33	6.06	0.17	1.12	5.73	0.18
320	Brindisi	0.73	8.94	0.14	0.68	8.99	0.11	0.83	9.67	0.05
535	Lisboa	0.73	8.28	0.35	1.01	9.57	0.25	0.85	10.08	0.10
546	Porto	0.92	10.72	0.37	0.75	10.75	0.31	0.61	10.91	0.24
560	Cagliari	0.81	6.55	0.20	0.76	6.51	0.19	0.96	7.52	0.02
575	Bragança	0.69	6.90	0.34	0.59	7.32	0.21	0.60	7.35	0.21
641	Corfu	1.54	16.08	0.17	1.72	17.42	0.09	1.35	16.50	0.05
648	Larissa	0.66	8.04	0.06	0.28	6.84	0.14	0.29	7.07	0.08
675	Teigarhorn	1.05	10.58	0.26	0.80	9.98	0.25	0.94	10.62	0.21
716	Hellinikon	0.84	6.83	0.10	0.36	6.00	0.07	0.59	6.67	0.01
734	Methoni	1.28	12.46	0.12	1.09	12.21	0.08	0.51	10.38	0.09
754	Heraklion	1.30	7.98	0.24	0.90	7.63	0.16	1.64	9.65	0.04
953	Valentia	0.72	9.56	0.22	0.75	9.45	0.25	0.64	9.72	0.16
980	Malin-Head	0.99	6.75	0.23	0.87	7.08	0.10	0.90	6.89	0.16
1024	San Sebastián	0.71	11.80	0.27	0.98	12.74	0.26	1.10	14.00	0.16
2220	Säntis	0.98	15.07	0.24	1.05	15.67	0.20	0.91	15.47	0.16
2462	Navacerrada	1.22	12.02	0.42	1.60	14.92	0.24	1.22	15.32	0.06
2698	Karlsruhe	0.79	6.10	0.13	0.76	5.82	0.19	0.68	5.93	0.13
2867	Salamanca	0.89	4.74	0.24	1.37	5.56	0.16	0.89	5.22	0.07
3195	Madrid	1.35	5.78	0.29	1.01	5.69	0.19	1.04	6.05	0.10
3700	Zürich	0.71	7.60	0.23	0.84	8.22	0.15	0.97	8.20	0.21
4199	München	0.55	6.26	0.19	0.74	7.01	0.07	0.73	6.99	0.08
4452	Badajoz	0.73	6.44	0.26	0.77	6.81	0.18	0.93	7.71	0.04
5350	Nord-Odal	0.98	6.61	0.22	0.85	6.55	0.18	1.13	7.09	0.17
5901	Wien	0.73	5.07	0.17	0.96	5.47	0.14	0.84	5.46	0.09
6155	Málaga	0.97	11.78	0.20	1.73	14.86	0.08	0.46	11.08	0.05
7038	Torrevieja	0.18	8.22	0.08	0.25	8.51	0.06	0.32	8.92	0.01
7501	Sodankyla	0.72	3.61	0.24	1.15	4.24	0.16	0.90	4.04	0.13
8416	Valencia	0.67	9.25	0.17	0.85	10.14	0.10	1.59	12.32	0.04
8525	Linköping	1.04	4.35	0.21	1.12	4.61	0.15	1.10	4.66	0.12
9434	Zaragoza	1.06	4.94	0.15	1.83	6.07	0.07	1.26	5.52	0.04
9480	Lugano	0.74	14.95	0.33	0.69	15.96	0.22	0.71	16.64	0.16
9981	Tortosa	0.97	11.16	0.13	1.36	12.33	0.11	1.49	13.27	0.02
15410	Sonnblick	0.89	7.49	0.40	0.80	7.95	0.28	0.82	8.52	0.18
15772	Stensele	0.99	3.71	0.19	1.05	3.75	0.20	0.82	3.50	0.22
27080	Tranebjerg	0.90	4.70	0.14	0.75	4.47	0.16	1.03	4.92	0.12
39220	Mestad	0.90	13.00	0.36	0.78	12.63	0.36	1.01	14.96	0.20
44841	Hull	0.68	5.16	0.09	1.19	5.85	0.10	1.00	5.55	0.11
47020	Nedstrand	0.82	11.72	0.36	0.82	12.60	0.27	0.88	12.72	0.27
50350	Samnanger	1.13	20.12	0.47	0.99	20.82	0.39	0.98	21.31	0.36
68330	Lien-I-Selbu	1.15	5.51	0.29	1.04	5.47	0.26	1.04	5.51	0.25
86850	Barkestad	1.50	10.01	0.32	1.34	9.43	0.36	1.21	9.76	0.26
93300	Suolovuopmi	0.72	3.36	0.18	0.73	3.43	0.15	0.66	3.55	0.06
99710	Bjørnøya	1.06	3.35	0.12	1.04	3.39	0.09	1.02	3.40	0.07
256225	Oxford	1.01	5.24	0.19	1.03	5.39	0.16	0.76	5.15	0.11
610122	Eskdalemuir	0.91	10.27	0.28	0.95	10.63	0.24	0.87	10.65	0.21
770765	Wick	0.73	5.78	0.12	0.87	5.98	0.12	0.76	5.91	0.09
947811	Armagh	0.91	5.42	0.21	0.97	5.99	0.07	1.09	5.97	0.12
13055001	Marseille	1.59	10.15	0.21	1.06	9.81	0.07	1.19	10.04	0.08
18033001	Bourges	0.78	5.59	0.19	0.68	5.41	0.20	1.21	6.55	0.10
31069001	Toulouse	0.88	5.14	0.21	0.74	5.21	0.13	1.27	6.07	0.09
33281001	Bordeaux	0.63	7.13	0.35	0.63	7.14	0.35	0.91	8.68	0.16
36063001	Châteauroux	0.59	5.62	0.20	0.71	5.96	0.16	0.94	6.44	0.13
66136001	Perpignan	0.98	9.93	0.25	1.88	13.26	0.08	3.07	16.25	0.03
69029001	Lyon	0.83	9.16	0.23	0.79	9.56	0.14	0.65	9.29	0.12

Table 9: *Daily precipitation in autumn.*