Regional Analysis of downscaling methods

Deliverable D12 - Regional analysis: Purpose and methods

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Introduction

Different downscaling methods have been developed to model either daily series of precipitation/ temperature or seasonal extreme indices of daily precipitation/ temperature from large-scale climate variables. The purpose of this report is to inter-compare the performances of the different methods in modelling the seasonal extreme indices of precipitation and temperature for selected stations within the German part of the Rhine basin. The methods include those developed locally and for the entire European region.

Data and Methods

Results obtained from different downscaling methods developed by different partners in downscaling extreme precipitation and temperature indices at 10 selected FIC stations (shown in figure 1) were inter-compared. The methods implement a range of large-scale predictor variables taken from the NCEP reanalysis. Table 1 summarizes the methods inter-compared in this analysis and the corresponding large-scale predictor variables used in each of the methods.

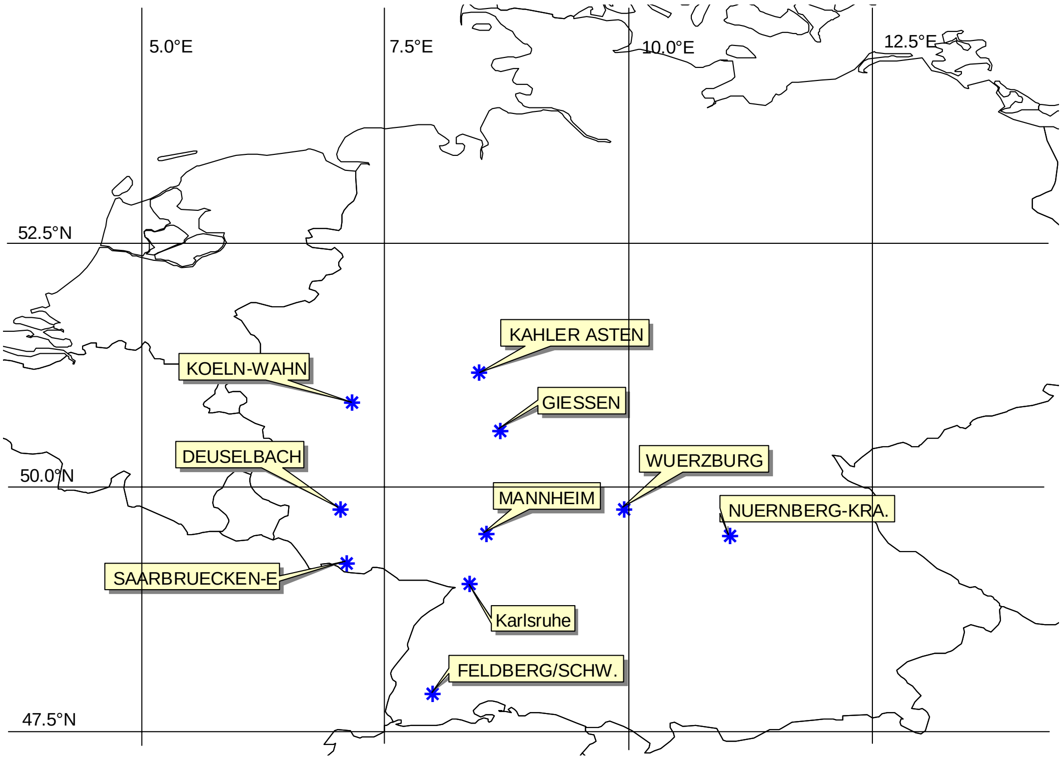

Figure 1: Locations of the 10 FIC stations used for common regional analysis

Table 1: Downscaling methods and their corresponding large-scale predictor variables

Method	Partner	Predictors	Downscaled variable	Developed for
Canonical correlation analysis (UEA-cca)	UEA	MSLP SH700 RH700 T700	Seasonal indices of precipitation and temperature	European-wide
Two-step analogue (FIC-anal2)	FIC	Geostrophic wind patterns at 500 and 100hPa Low troposphere humidity Thickness between 1000 and 850hPa Thickness between 1000 and 500hPa Thermal advection at 850hPa	Daily temperatute and precipitation	European-wide
Conditional weather generator (DMI-cwg)	DMI	Surface vorticity Lower troposphere humidity	Daily precipitation	European-wide
Multivariate auto-regressive model (USTUTT-mar)	USTUTT	MSLP circulation pattern Moisture flux at 700hPa	Daily precipitation	Local
Multiple linear regression model (USTUTT-mlr)	USTUTT	MSLP circulation pattern Moisture flux at 700hPa Vorticity at 500,700,850hPa Divergence at 500,700,850hPa RH500,700,850 HGT500,700,850 T500,700,850	Seasonal indices of precipitation and temperature	Local

Comparison of results

Comparison of the performances of all the different methods was done based on the skills of the methods in downscaling the seasonal indices at 10 selected stations from the FIC data set, which are shown in figure 1. The root mean square error and the correlation between the modeled and the observed indices over the validation period (1979 – 1993) were used as standard skill cores. Further comparison of the locally developed methods was done based on their skills in downscaling the indices over 100 stations selected from denser stations within the study area obtained from the German Weather Service. A set of precipitation and temperature related indices (shown in table 2) were considered for evaluating the performance of the models

Precipitation related indices

The performance of the models in downscaling the precipitation related indices varies from index to index, method to method and season to season. Table 3 shows summary of the seasonal skills of each of the methods and figure 2 shows a histogram of the correlations of each method averaged over all the stations for all indices in each season. Although there is no apparent indication on the superiority of any of the methods over the others, the locally developed models (USTUTT-mar and USTUTT-mlr) and one of the European-wide developed models (FIC-anal2) perform better for most of the indices in winter and autumn. In spring, there are no consistently better performing methods for all indices; all show more or less similar performance for each of the indices. In summer FIC-anal2 and USTUTT-mlr generally do better than the others for most of the indices.

Table 2: Precipitation and temperature related indices for which methods are evaluated

Designation	Index
	Precipitation related indices
Pav	Mean daily rainfall
Pq90	90^{th} percentile of rainday amounts
Px5d	Greatest 5 day total rainfall
Pint	Simple daily intensity
Pxcdd	Maximum number of consecutive dry days
Pf90	% of total rainfall from events > long-term 90^{th} percentile of raindays
Pn90	No. of events > long-term 90^{th} percentile of raindays
	Temperature related indices
Txav	Mean maximum temperature
Tnav	Mean minimum temperature
Txq90	90^{th} percentile maximum temperature
Tnq10	10^{th} percentile minimum temperature
Tnfd	Number of frost days
Txhw90	Heat wave duration index (percentile based)

Regarding the skill of the methods in downscaling the different indices, pav is the best-estimated index by all methods in all seasons. Pxcdd and pnl90 are the next best estimated indices by most of the methods. On the other hand, pfl90 is an index estimated with the least skill by most of the methods. Figure 3 shows a histogram summarizing the average seasonal correlations of all methods over all the stations for each index.

The seasonal variability of the performance of each method varies from index to index. Pav is best estimated in winter and spring by most methods, while FIC-anal2 shows more or less similar performance in all seasons for this index with the highest correlation and the least RMSE. Pint is best estimated in winter followed by spring by FIC-anal2, USTUTT-mar USTUTT-mlr, while the other methods show their best performance for the index in spring. Pq90 is on the other hand best estimated in winter by all methods, with UEA-cca and DMI-cwg showing relatively lower skill than the others. The best estimate of px5d is in spring by most of the methods with all of them showing similar skills. USTUTT-mlr shows a slightly better performance in winter for this index. The best estimate of pfl90 is in winter by most methods except UEA-cca and DMI-cwg, which have their best estimates in spring and autumn respectively. Pnl90 is best estimated in spring by many of the methods with FICanal2 and USTUTT-mar showing slightly better performance in winter. In summary, considering the average performance of all the methods in estimating each of the indices, the best performance of the models is either in winter or spring depending on the index in question. This can also be seen in figure 3.

Comparison of the seasonal skill scores of the locally developed methods for the precipitation related indices over 100 stations within the German side of the Rhine is shown in table 4. The average performance of the models is more or less similar with their corresponding average performance over the 10 FIC stations. The performance of the two models in winter is more or less similar. However, it can be seen that generally, the model for downscaling the seasonal indices directly performs slightly better than the other in summer and vice versa in spring and autumn.

Temperature related indices

For temperature related indices, three methods were inter-compared: UEA-cca, FIC-anal2, and USTUTT-mlr. Table 5 shows summary of the seasonal skills of the three methods for each of the temperature related indices and figure 4 shows the seasonal correlations of each of the methods averaged over all the stations for the individual indices.

Generally, the FIC-anal2 shows a better performance for all indices except txhw90 in all seasons followed by USTUTT-mlr. Although the correlations for txhw90 are generally higher in FIC-anal2, the corresponding RMSE are larger than that of the other methods.

Generally, txav and tnav are indices downscaled with the best skills in all seasons. But the differences in the skills between indices for a given method and season are not that strong like in the case of precipitation indices as shown in figure 5. The seasonal skills of a given downscaling method for a given index are not also that much variable, but generally the skills in winter are a bit higher for most of the indices.

Conclusions

From the foregoing discussion, it can be concluded that it is difficult to choose the best method for precipitation related indices, as the relative performance of each method varies depending on the index and the season. Although there is a seasonal variation in performance of each method for each index, it is also difficult to tell which method is superior in terms of performance in a given season. The relative skill of the methods varies from index to index.

There is no clear indication that the locally developed methods perform better than the methods developed based on the European-wide data set. In winter and autumn, the locally developed methods and one of the European wide developed methods (FIC-anal2) show competing performances with even FIC-anal2 showing slightly better skill for many of the indices, while in spring all the methods show more or less similar performances. In summer also FIC-anal2 shows better performance than the others for most of the indices.

It is also difficult to make any general statement on the performance difference between methods that directly downscale seasonal indices and those that downscale daily series of precipitation except that for the locally developed models the one that downscales the seasonal indices directly performs slightly better than the other in summer and vise versa in spring and autumn.

For temperature related indices, generally FIC-anal2 shows a better performance than the other methods for all indices except txhw90 in all seasons.

Table 3: Summary of the seasonal skill scores of the downscaling methods for precipitation related indices over the 10 German stations

Index	Method	Winter				Spring				Summer				Autumn			
		mean rmse	min cor.	max cor.	mean cor.	mean rmse	min cor.	max cor.	mean cor.	mean rmse	min cor.	max cor.	mean cor.	mean rmse	min cor.	max cor.	mean cor.
pav	UEA-cca	0.50	0.37	0.75	0.61	0.62	0.31	0.74	0.49	0.76	0.15	0.57	0.33	0.64	0.25	0.66	0.43
	FIC-anal2	0.40	0.50	0.88	0.75	0.52	0.61	0.87	0.75	0.64	0.37	0.80	0.69	0.44	0.48	0.84	0.71
	DMI-cwg	0.67	0.35	0.63	0.49	0.61	0.37	0.75	0.56	0.83	0.03	0.70	0.38	0.61	-0.20	0.62	0.38
	USTUTT-mar	0.54	0.33	0.89	0.64	0.55	0.45	0.87	0.67	0.73	0.12	0.65	0.44	0.54	0.28	0.81	0.48
	USTUTT-mlr	0.46	0.58	0.85	0.72	0.51	0.34	0.86	0.65	0.65	0.29	0.71	0.50	0.52	0.31	0.73	0.50
pint	UEA-cca	1.39	-0.15	0.21	0.05	1.07	-0.06	0.61	0.31	1.38	-0.18	0.48	0.11	1.40	-0.43	0.56	-0.16
	FIC-anal2	1.03	-0.02	0.87	0.46	1.06	-0.08	0.74	0.38	1.28	-0.38	0.77	0.31	1.20	-0.15	0.47	0.17
	DMI-cwg	1.17	-0.32	0.44	0.12	1.05	-0.09	0.76	0.24	1.34	-0.45	0.63	0.05	1.20	-0.32	0.43	0.19
	USTUTT-mar	1.07	-0.15	0.68	0.38	1.11	-0.38	0.66	0.25	1.41	-0.06	0.66	0.15	1.30	-0.13	0.47	0.13
	USTUTT-mlr	1.01	0.12	0.74	0.40	1.08	-0.24	0.69	0.32	1.38	-0.31	0.38	0.08	1.26	-0.19	0.70	0.28
pq90	UEA-cca	3.58	-0.32	0.25	0.07	3.43	-0.63	0.50	0.07	3.77	-0.31	0.62	0.02	4.07	-0.57	0.74	-0.03
	FIC-anal2	2.76	-0.07	0.61	0.34	3.38	-0.33	0.77	0.24	3.51	-0.22	0.75	0.27	3.83	-0.09	0.57	0.29
	DMI-cwg	3.21	-0.44	0.62	0.03	3.85	-0.25	0.50	0.03	4.17	-0.38	0.85	0.09	4.41	-0.52	0.49	0.11
	USTUTT-mar	2.96	-0.20	0.68	0.30	3.45	-0.21	0.70	0.10	3.78	-0.18	0.54	0.13	4.02	-0.14	0.49	0.13
	USTUTT-mlr	2.64	-0.11	0.68	0.37	3.71	-0.49	0.35	0.03	3.50	-0.46	0.66	0.20	4.02	0.02	0.39	0.26
px5d	UEA-cca	20.08	-0.38	0.39	-0.05	15.74	0.13	0.70	0.37	19.07	-0.10	0.41	0.20	21.49	-0.40	0.38	0.01
	FIC-anal2	13.75	-0.08	0.64	0.34	15.83	0.08	0.66	0.43	18.08	-0.13	0.74	0.48	17.90	0.13	0.76	0.42
	DMI-cwg	18.86	-0.60	0.31	-0.04	16.15	0.17	0.64	0.42	19.58	-0.32	0.70	0.06	19.62	-0.27	0.49	0.17
	USTUTT-mar	17.95	-0.09	0.51	0.27	15.40	0.07	0.75	0.38	20.46	-0.14	0.46	0.14	18.30	0.10	0.56	0.32
	USTUTT-mlr	15.15	0.06	0.74	0.44	15.78	0.07	0.81	0.40	17.75	-0.01	0.53	0.34	19.49	0.05	0.69	0.30
pxcdd	UEA-cca	5.14	0.17	0.89	0.45	4.14	-0.08	0.70	0.30	4.54	-0.17	0.70	0.30	6.07	0.16	0.54	0.32
	FIC-anal2	4.47	-0.24	0.65	0.29	4.72	0.13	0.63	0.38	4.25	0.05	0.71	0.45	4.67	0.29	0.85	0.64
	DMI-cwg	4.07	0.30	0.79	0.52	2.41	0.09	0.66	0.45	2.45	-0.10	0.74	0.36	2.21	-0.27	0.22	0.00
	USTUTT-mar	3.89	0.25	0.57	0.47	3.94	0.25	0.71	0.51	4.86	-0.17	0.66	0.24	5.70	0.25	0.68	0.45
	USTUTT-mlr	4.45	0.06	0.72	0.42	3.76	0.11	0.76	0.46	3.99	0.07	0.76	0.54	5.79	-0.02	0.65	0.41
pfl90	UEA-cca	0.16	-0.43	0.34	0.04	0.14	-0.48	0.44	0.16	0.14	-0.48	0.65	0.11	0.15	-0.31	0.61	0.04
	FIC-anal2	0.13	-0.06	0.63	0.37	0.14	-0.29	0.78	0.20	0.16	-0.36	0.44	0.11	0.14	-0.13	0.67	0.31
	DMI-cwg	0.15	-0.70	0.36	-0.09	0.14	-0.21	0.42	0.04	0.15	-0.40	0.30	-0.03	0.14	-0.26	0.50	0.13
	USTUTT-mar	0.14	-0.33	0.55	0.19	0.14	-0.51	0.53	0.07	0.15	-0.38	0.52	0.03	0.14	-0.06	0.58	0.21
	USTUTT-mlr	0.12	0.01	0.61	0.31	0.15	-0.36	0.40	0.10	0.14	-0.49	0.57	0.09	0.15	-0.28	0.41	0.13
pnl90	UEA-cca	2.36	-0.09	0.62	0.25	1.83	-0.06	0.60	0.35	1.67	-0.15	0.59	0.34	1.85	-0.28	0.70	0.07
	FIC-anal2	2.87	0.17	0.72	0.48	2.81	0.22	0.77	0.45	3.36	-0.06	0.63	0.44	3.13	0.02	0.73	0.44
	DMI-cwg	2.21	-0.28	0.45	0.18	1.94	0.17	0.71	0.39	1.79	-0.18	0.74	0.22	1.68	-0.12	0.47	0.18
	USTUTT-mar	2.04	-0.16	0.77	0.35	1.88	-0.05	0.66	0.31	1.81	-0.40	0.53	0.17	1.84	0.06	0.60	0.33
	USTUTT-mlr	1.84	0.09	0.69	0.42	1.75	0.05	0.74	0.46	1.64	-0.36	0.60	0.27	1.65	-0.18	0.68	0.25

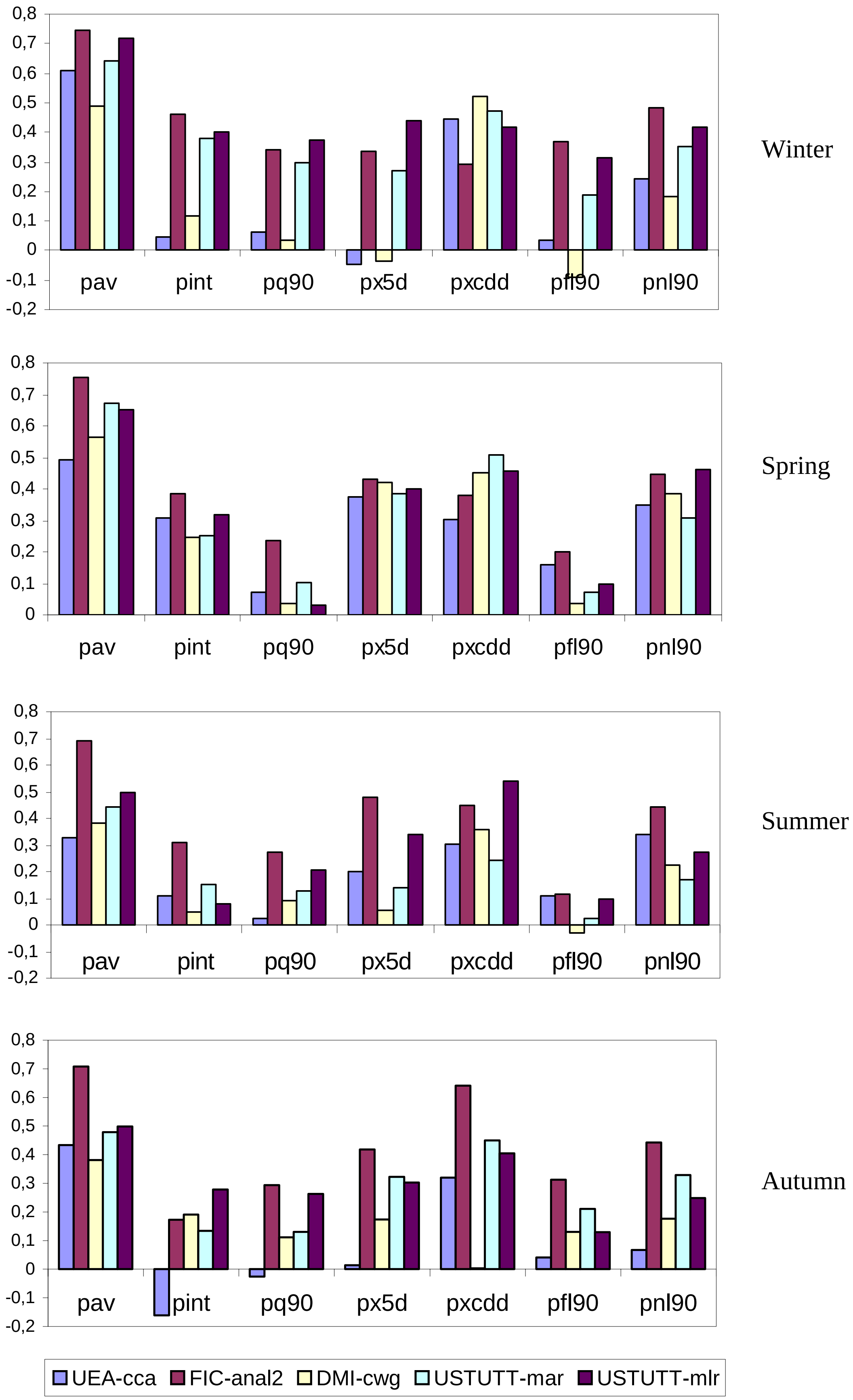

Figure 2: Average correlation over the 10 FIC stations for precipitation indices

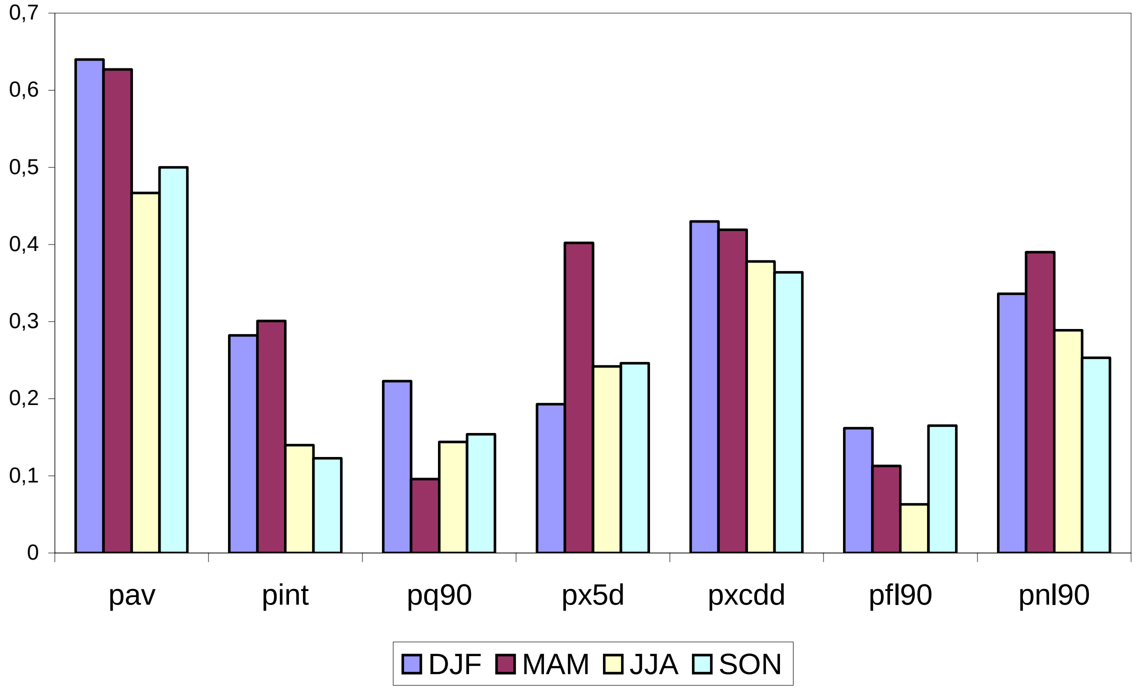

Figure 3: Average seasonal correlations of all the methods over all the stations for precipitation related indices

Table 4: Summary of the seasonal skill scores of the downscaling methods for precipitation related indices over the 100 German stations

Index	Method	Winter				Spring				Summer				Autumn			
		mean rmse	min cor.	max cor.	mean cor.	mean rmse	min cor.	max cor.	mean cor.	mean rmse	min cor.	max cor.	mean cor.	mean rmse	min cor.	max cor.	mean cor.
pav	USTUTT-mar	0.49	0.11	0.91	0.66	0.50	0.39	0.90	0.71	0.70	-0.10	0.75	0.41	0.55	0.05	0.86	0.46
	USTUTT-mlr	0.45	0.32	0.90	0.71	0.51	0.30	0.90	0.64	0.63	0.16	0.88	0.52	0.49	-0.13	0.86	0.50
pint	USTUTT-mar	1.09	-0.15	0.76	0.41	1.05	-0.38	0.73	0.35	1.42	-0.55	0.85	0.15	1.28	-0.28	0.64	0.16
	USTUTT-mlr	1.03	-0.14	0.82	0.41	1.13	-0.34	0.82	0.28	1.44	-0.46	0.77	0.12	1.26	-0.44	0.73	0.16
pq90	USTUTT-mar	3.02	-0.30	0.79	0.33	3.03	-0.31	0.80	0.29	3.98	-0.51	0.78	0.12	3.63	-0.55	0.78	0.22
	USTUTT-mlr	3.15	-0.60	0.81	0.29	3.22	-0.28	0.74	0.23	3.84	-0.68	0.76	0.20	3.89	-0.43	0.71	0.14
px5d	USTUTT-mar	16.75	-0.09	0.78	0.35	14.60	-0.23	0.84	0.47	19.50	-0.49	0.70	0.13	17.77	-0.21	0.74	0.33
	USTUTT-mlr	15.84	-0.06	0.81	0.41	15.54	-0.33	0.80	0.39	18.32	-0.29	0.79	0.29	18.64	-0.58	0.81	0.19
pxcdd	USTUTT-mar	4.15	-0.12	0.73	0.38	3.74	-0.06	0.82	0.47	5.76	-0.56	0.68	0.18	5.56	0.14	0.84	0.49
	USTUTT-mlr	4.21	-0.24	0.74	0.31	3.94	-0.39	0.87	0.40	4.94	-0.15	0.90	0.45	5.94	-0.12	0.77	0.41
pfl90	USTUTT-mar	0.14	-0.33	0.78	0.29	0.14	-0.51	0.81	0.20	0.15	-0.65	0.72	0.10	0.14	-0.43	0.85	0.22
	USTUTT-mlr	0.13	-0.08	0.80	0.33	0.15	-0.30	0.69	0.14	0.15	-0.61	0.66	0.11	0.16	-0.51	0.51	0.04
pnl90	USTUTT-mar	1.98	-0.28	0.86	0.42	1.89	-0.05	0.90	0.45	1.90	-0.56	0.88	0.21	1.81	-0.54	0.80	0.30
	USTUTT-mlr	1.92	-0.07	0.90	0.48	1.84	-0.12	0.86	0.42	1.80	-0.22	0.77	0.32	1.75	-0.50	0.81	0.21

Table 5: Summary of the seasonal skill scores of the downscaling methods for temperature related indices over the 10 German stations

Index	Method	Winter				Spring				Summer				Autumn			
		mean rmse	min. Cor	max. Cor	mean Cor	mean rmse	min. Cor	max. Cor	mean Cor	mean rmse	min. Cor	max. Cor	mean Cor	mean rmse	min. Cor	max. Cor	mean Cor
txav	UEA-cca	1.05	0.64	0.89	0.74	0.82	0.70	0.90	0.79	0.85	0.59	0.85	0.67	0.80	0.32	0.49	0.42
	FIC-anal2	0.33	0.98	0.99	0.99	0.50	0.90	0.96	0.93	0.43	0.92	0.97	0.95	0.33	0.91	0.97	0.93
	USTUTT-mlr	0.72	0.83	0.98	0.90	0.38	0.89	0.98	0.94	0.52	0.83	0.95	0.90	0.53	0.63	0.96	0.76
txq90	UEA-cca	1.23	0.21	0.81	0.49	1.71	0.14	0.39	0.33	1.02	0.54	0.74	0.64	1.79	0.15	0.51	0.40
	FIC-anal2	0.83	0.76	0.96	0.85	1.16	0.86	0.96	0.90	0.92	0.67	0.86	0.79	0.82	0.78	0.94	0.91
	USTUTT-mlr	0.95	0.60	0.86	0.76	0.85	0.81	0.96	0.90	0.73	0.77	0.92	0.84	1.10	0.71	0.90	0.85
tnav	UEA-cca	1.15	0.63	0.86	0.73	0.61	0.73	0.87	0.81	0.61	0.22	0.86	0.54	0.52	0.61	0.88	0.75
	FIC-anal2	0.36	0.98	1.00	0.99	0.24	0.96	0.99	0.97	0.23	0.92	0.98	0.95	0.36	0.85	0.96	0.91
	USTUTT-mlr	0.81	0.81	0.99	0.87	0.37	0.85	0.97	0.92	0.34	0.85	0.92	0.88	0.39	0.65	0.96	0.80
tnq10	UEA-cca	2.51	0.67	0.80	0.73	1.78	0.23	0.63	0.47	0.91	-0.09	0.47	0.18	1.70	0.35	0.64	0.53
	FIC-anal2	1.30	0.87	0.99	0.93	0.73	0.83	0.94	0.91	0.54	0.72	0.90	0.82	0.82	0.83	0.97	0.92
	USTUTT-mlr	1.54	0.82	0.98	0.88	1.16	0.47	0.86	0.66	0.51	0.56	0.87	0.70	1.21	0.77	0.95	0.84
tnfd	UEA-cca	8.17	0.52	0.75	0.65	6.13	0.35	0.77	0.60					5.59	0.20	0.72	0.53
	FIC-anal2	4.32	0.88	0.97	0.93	4.21	0.75	0.92	0.85					3.27	0.78	0.97	0.88
	USTUTT-mlr	7.60	0.58	0.86	0.73	4.55	0.59	0.78	0.70					4.00	0.76	0.92	0.83
txhw90	UEA-cca	2.51	0.22	0.60	0.37	2.23	0.09	0.42	0.20	1.61	0.15	0.62	0.45	2.08	-0.15	0.30	0.09
	FIC-anal2	4.92	0.46	0.89	0.72	4.26	0.55	0.92	0.72	4.75	0.23	0.77	0.39	3.35	-0.15	0.78	0.43
	USTUTT-mlr	2.17	0.46	0.75	0.63	2.03	0.35	0.63	0.47	1.35	0.41	0.74	0.61	1.99	-0.09	0.51	0.25

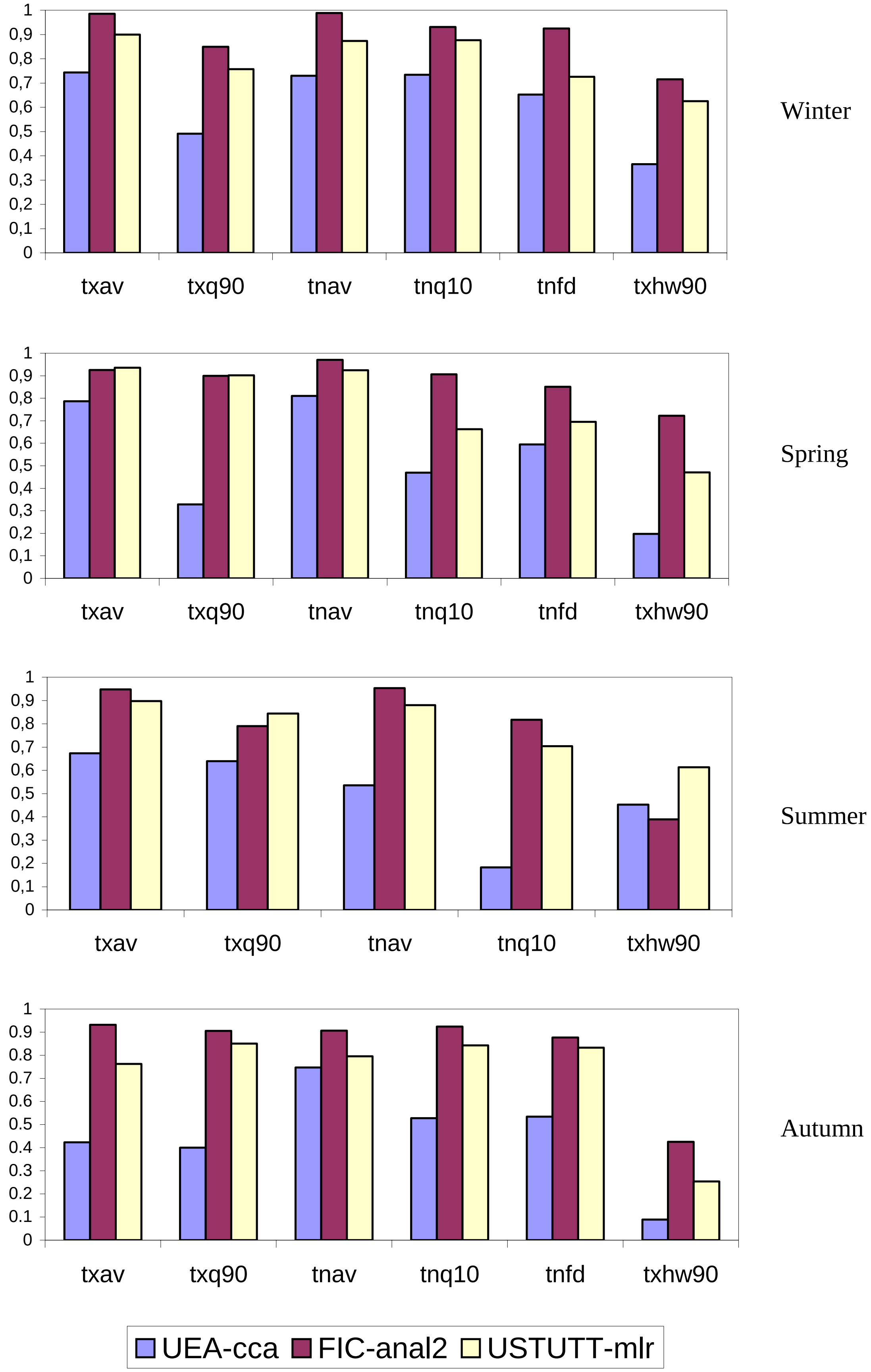

Figure 4: Average correlation over the 10 FIC stations for temperature indices

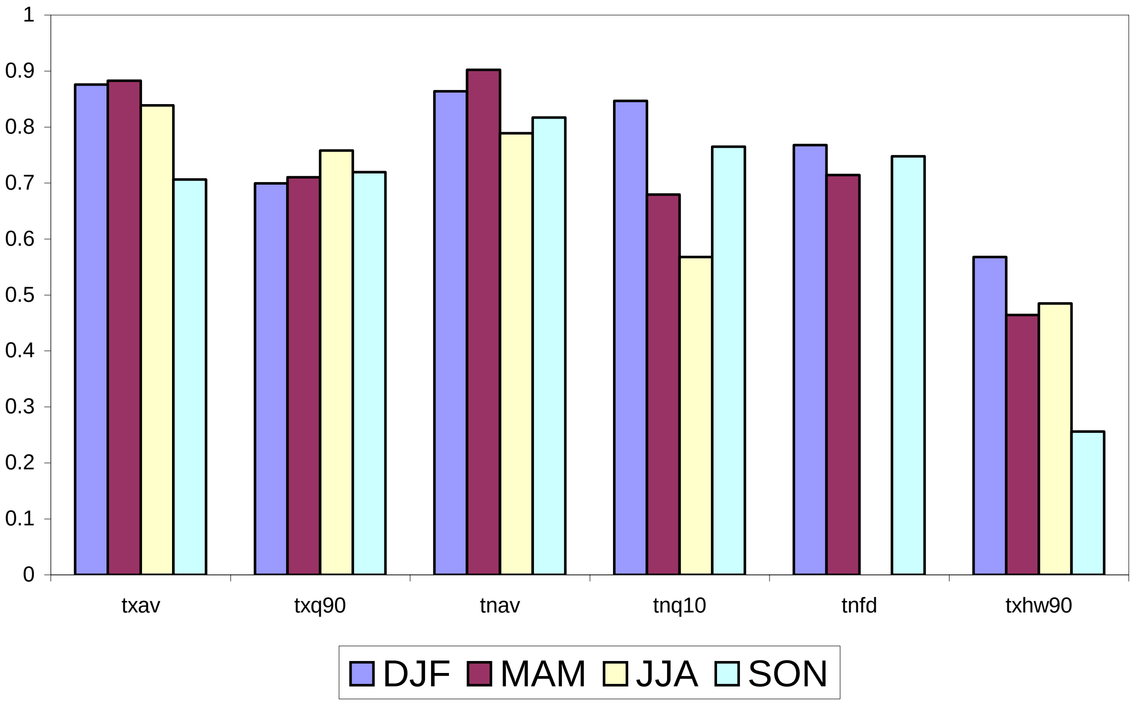

Figure 5: Average seasonal correlations of all the methods over all the stations for temperature related indices