Downscaling of Extremes for Precipitation over 10 Alpine and 16 Iberian stations: Application of a Stochastic Algorithm based on a "Potential Precipitation Circulation Index" ("ppci") defined using NCEP Reanalysed Large Scale Z700 Geopotential field (1958-2000)

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Introduction and Motivation.

The aim of the STARDEX report D12 consists in a comparison of the relative performances of individual groups Downscaling Schemes for selected european regions. Two subsets of european stations were appointed to the CNRS group: 10 alpine stations (also appointed to USTUTT/FTS, ETH, and UNIBE), and 16 iberian ones (shared with KCL). Predictors should be taken from NCEP reanalysis in 2.5x2.5 deg resolution.

It was decided that the models should be calibrated on the periods 1958-1978 and 1994-2000. Subsequently the calibrated Downscaling scheme should produce annual values of a set of relevant STARDEX extreme precipitation seasonal indices for the period 1979-1993. This should be compared to index values computed from observations. Comparisons should be made in terms of bias, RMSE, and Spearman rank correlation coefficient (Spearman cc hereafter).

We present in Sect.1 The broad outlines of our Downscaling methodology, including the motivations for our choices (a more complete presentation may be found in our previous D10 report [Plaut, 2004]). Sect.1 ends with a short description of data.

In Sect.2 an evaluation is made of the performances of our schemes for alpine stations, using maps of seasonal Spearman cc for a few leading extreme indices: **Pav**, **PQ90**, **P5DMAX**, and **PCDD** which measure respectively: the seasonal average daily precipitation (including dry days, and therefore $\approx$ seasonal precipitation), the last *decile* of rainday precipitation amounts, the greatest 5-day total rainfall, and the maximum number of consecutive dry days. We also use maps of averaged (over all STARDEX extreme indices) seasonal Spearman cc.

In Sect.3 we go further into details for two alpine stations in order to get more insights into the successes and drawbacks of the model. Sect.4 (resp. 5) is analogous to Sect.2 (resp. 3) except that we now deal with iberian stations extreme precipitation indices. Summary and conclusions are given in Sect.6.

1. Downscaling Methodology.

1.1 Motivation.

In the particular case of the french Maritimes Alps, it was observed [Plaut et al., 2001] that **Intense Precipitation Events** (**IPE**s hereafter) mostly occur with one of a few types of **Large Scale Circulation** (**LSC** hereafter) patterns, and this feature was used as a clue for building a stochastic **Downscaling** (**DS** hereafter) scheme. Station precipitation series more or less behave like the Maritimes Alps one in that there always exists some link between LSC and precipitation. The algorithm we choosed to test relies on such links; it will of course operate with more or less skillfulness according to the importance of this link for each particular station (and season). It may be split into 3 main steps: we first look for the so-called (a naming we introduced!) **Precipitation Regimes** (**PR**s hereafter) which are fundamentally the main circulation patterns responsible for local **IPE**s; we then tentatively introduce a linear precipitation index, (the **ppci**), the value of which on a particular day depends on the similarity between this day circulation and the **PR**s. Finally we use this index (and precipitation archives) to (stochastically) generate a precipitation forecast for this particular day. Once precipitation series have been generated, statistics may be performed on the future of extreme events *according to our* **DS** *scheme.*

1.2 The Precipitation Regimes (PR)s.

We first define **IPE**s for the station of interest. Many definitions are *a priori* possible. Some of them use fixed thresholds whereas other ones use seasonal depending percentiles. We choosed to use fixed thresholds, the precise value of which depends on the station, in order to be left with ≈ 10 **IPE**s per year on average. With such a definition, **IPE**s are actually quite rare during the warm season in mediterranean countries, but this corresponds to common experience. Once **IPE** dates have been extracted, we select the corresponding Z700 maps over a wide Atlantic and European sector (60W-70E,30-80N) and like in [Plaut et al., 2001] we classify these maps into a small number of clusters. Z700 heights are taken from NCEP ReA available on the **STARDEX** WeB site. We propose to call **"Precipitation Regimes"** (**PR**s) the central patterns of these clusters. This new naming is a natural extension of the naming: **"Weather Regimes"** (**WR**s) which is now well established and refers (somewhat incorrectly, because it actually refers to LSC patterns, not directly to weather ones! although it was shown in [Plaut and Simonnet, 2001] that **WR** also practically correspond to prefered weather patterns...) to the central patterns of the clusters one obtains when classifying **all** the LSC patterns, *i.e.* **every day** circulation. By contrast, **PR**s are obtained if one classifies a restricted set of LSC patterns, namely those LSCs corresponding to **IPE**s at the station of interest. As a consequence, **PR**s may **highly depend on the station** although they are actually **LSC patterns**, not precipitation ones.

1.3 The potential precipitation circulation index (ppci).

Two peculiar qualities of **PR**s are worth noting: first they are very **robust**, and do not depend on the precise definition of **IPE**s. Secondly, at least some of them may own a high **discriminating power** in that whenever an actual circulation pattern is similar enough to a **PR**, **IPE** probability gets much higher that random [Plaut, 2004]. These features are our grounds for looking for an index which should describe the **potential power** of a given LSC pattern to produce precipitation. We call it a **potential precipitation circulation index** (**ppci** hereafter) and define it as the best regression of daily precipitation against the daily values of the **anomaly pattern corelation coefficients** (**apc** hereafter) with **PR**s and **WR**s. In [Plaut, 2004] where one can find more details, it was observed that, although there is no deterministic link between the **ppci** and precipitation at the daily level, there are strong statistical links: there are long periods (up to several months) during which the **ppci** stands negative or nearly negative; during such periods, precipitation remains very rare and weak. By contrast, for instance on espedially wet seasons, the **ppci** displays shorter (often $\approx 10/15$ days), and often recursive, large positive excursions during which **IPE**s get quite frequent, like during the last 4 months of 2000 in south-eastern France.

If one sums the daily values of precipitation anomalies and those of the **ppci** at the seasonal level, the correlation between anomalies gets much higher than at the daily level, with values $\approx .75/.8$ rather common, pointing to the actual strong physical link between LSCs and precipitation. This link was illustrated by the (contingency) **table 1** in [Plaut, 2004] on which it was observed that the occurence of the last *decile* of precipitation amounts was three times more frequent together with the last *vingtile* of the **ppci** than with any lower order **ppci** *vingtile*. Moreover, the last precipitation *decile* almost never occured together with the lower 12 or 13 **ppci** *vingtiles*.

1.4 The Downscaling (DS) algorithm.

Our stochastic Downscaling Algorithm merely takes advantage of this asymetry: starting from circulation, it computes the **ppci** and uses a random number generator in order to generate daily precipitation in agreement with the observed contingency table. An extensive discussion was given in [Plaut, 2004] where we insisted that unlike numerous so-called **"Downscaling"** schemes which use several *small scale* predictors like local (or sub-regional) winds, tropospheric temperatures, humidities, etc... our scheme is a **true Downscaling** one in that it does not depend on any local or sub-regional atmospheric parameter. This may be an advantage if one starts from Re-Anaysis data or GCM simulations since smaller scale ReA or GCM patterns often badly fit observations: for stations where the link between LSC and precipitation is strong, this shortcoming of ReA and GCM smaller patterns is thus bypassed.

In practice, we randomly choose an analog within the set of (*learning period*) days having their **ppci**'s belonging to the same *vingtile*. In this way, given a set of daily circulations, many precipitation series may be generated in a way somewhat analogous to ensemble dynamical regional forecasts starting from GCM forecasts [Marsigli et al., 2001], but without any computer time consumption! When interested in seasonal precipitation, we typically generate 100 (daily)precipitation series and take the mean of the 100 seasonal accumulations obtained. This mean appears to be extremely **robust**. Seasonal accumulations are also extremely **robust** with regards to many details of our scheme. Any other STARDEX extreme index may also easily be computed and statistics may be performed given the possibility to generate a large number of precipitation series.

1.5 Data and Validation procedure.

Daily precipitation for two particular subsets of european stations have been extracted from the "FIC481" data set which holds quality-controlled daily precipitation and temperatures for 481 European stations with a good spatial coverage for most of Europe from 1968 to 2000. The names of the stations appear on the skill-score maps.

As a Large Scale Circulation field, we use NCEP-ReA LSC fields. It is noteworthy that LSCs are often amongst the best forecast and analysed fields, whereas many other fields depend more or less on model *ad hoc* parametrisation schemes. Here, as already said, we limit ourselves to the Z700 height field which is often considered as the most appropriate LSC field for precipitation studies. As usual when proceeding with LSC patterns we first perform a PCA and then proceed to the classification in the 10-leading PC space. It was shown in [Plaut et al., 2001] that the precise number of leading PCs selected was quite irrelevant; at the end we were left with quite the same **PR**s, either we keep 5, 10, or 15 PCs.

2. Downscaling Precipitation over Alpine stations.

We validated our **DS** scheme over the period 1979-1993 for ten alpine stations; the learning period contains both years before 1979 and years after 1993.

2.1 Maps of Pav, average daily precipitation.

The skillfulness of our **DS** scheme has been measured through several skill score measures like the ordinary cc, the Spearman rank cc, the bias, the RMSE, or the ratio between RMSE and the observed variance as well as the ratio between forecast and observed variance. However, for a sake of simplicity, we limit here the discussion to the Spearman rank cc which is more relevant than the ordinary cc for extreme indices which display long-tailed distributions.

A first inspection of Fig.1 leads to the conclusion that for three seasons out of four the seasonal precipitation (which is proportional to **Pav**) is rather well forecast by our **DS** scheme, since Spearman correlations are always positive and often rather large. For summer, one can roughly divide the stations into two subsets. The 4 most south-western stations have nul scores, whereas to the north and east, a significant skill is still found, especially for Bologna and Locarno (in locarno, skill is high for all 4 seasons).

2.2 Maps of PQ90

The 90^{th} percentile of rainday precipitation amount is actually one (possible) standard measure of the intensity of each season extreme precipitation intensity. The scores of Fig.2 are much lower than for **Pav**, and one can say that there is no globally good season for our **PQ90 DS** forecasts. Except for automn, there are always several stations with negative skill. To the south-west (Montélimar and Nice), intermediate seasons are the only ones with some skill, while scores are always close to zero for the most northerly stations. Globally, the winter **PQ90** get the worst scores.

2.3 Maps of P5DMAX

The heaviest 5d precipitation is another measure of the intensity of each season extreme precipitation intensity. The scores of Fig.3 are again lower than those of Fig.1, but the red circles (with somewhat lower radii, pointing to somewhat lower correlations), still widely dominate. Negative scores occur only for Bobbio and Innsbruck (2 seasons) and München (3 seasons out of 4); except for the most northerly stations, they are much less frequent than in Fig.2. The relative improvement of **P5DMAX** skill scores relative to **PQ90** ones is likely to be due to the fact that precipitation are stochastically generated at the daily level, in such a way that: the longer the period favourable to **IPE**, the lower the stochastic character of the cumulated **DS** precipitation.

2.4 Maps of PCDD, the maximum duration of dry episodes

At a first inspection of Fig.4, it is striking that fall and winter longest dry period durations are much more accurately forecast than the highest daily intensity. This may be due to the role played by the **ppci** in our scheme: negative values of this index mostly correspond to precipitation inhibition, and this feature is naturally reproduced by our scheme. On the contrary the link between high positive **ppci** values and heavy precipitation is of a probabilistic nature: for instance, it was observed in [Plaut et al., 2001] that, in the case of the french Maritimes Alpes, **IPE**s were 3 times more frequent together with the last **ppci** *vingtile* than together with the previous *vingtile*. However the conditional **IPE** probability still remained $\approx$ 33%, so that the link between **ppci** category and precipitation is far from deterministic, which also explains that 5d precip are somewhat better simulated than daily ones (in addition, the actual level of intensity of a given day precipitation also depends on smaller scale details which even **RCM** may miss [Marsigli et al., 2001]).

2.5 Averaged scores and alternative DS schemes

On Fig.5 which displays averaged (over all STARDEX extreme indices) scores, there does not appear any striking different behaviour according to seasons, except for 4 out of the 5 most southern stations for which **DS** performs quite badly during summer. Globally, automn seems to be the most appropriate season for our **DS** scheme. Indeed, it is the only season for which all 10 averaged Spearman cc take positive values.

Although physically motivated since it calls to **PR**s, our scheme is a rather elaborated one, and one can remark that it essentially amounts to define a basic index (the **ppci**) which is a weighted sum of cosines within the leading PC-space: a simpler, although *a priori* poor-minded, choice would be to check a linear regression of daily precipitation against the leading PCs. One of us (ES) tried this alternative way. We compar on Figs 6 to 8 the relative skill scores of the 2 approaches. For each station the left circle corresponds to our previous **ppci** defined using the **PR**s, whereas the right one represents the Spearman cc one finds using the alternative approach. For **Pav**, the first scheme always performs a little better (Fig.6). But the reverse is true for **PQ90** (Fig.7). In both cases, differences in average skill as measured by Spearman correlation are quite unsignificant. In the case of **P5DMAX** (Fig.8), both schemes get truely equivalent scores! In view of the similarity of scores, the second, numerically simpler, approach may offer an efficient alternative way for **DS** studies.

3. More insight into 2 stations.

In order to allow the reader to be more aware of our **DS** scheme performances, we systematically compar observations and **DS** forecasts for each season and each STARDEX representative index on 15 year length plots.

3.1 DS forecasts for Locarno

Spring and summer (Fig.9) and fall and winter (Fig.10) forecast extreme indices (blue squares) are compared to observed ones (red circles). Since the model is able to instantaneously generate hundreds of daily precipitation series, we could also display intervals for the forecasts; the grey bars correspond to the 10%-90% significance level interval using a non-parametrical test.

There is one only index which satisfies the eye, and it is **Pav**, the mean daily precipitation (*i.e.* the seasonal precipitation, up to a factor $\approx$ 90): observations and simulations follow one another in a quite satisfactory way, correlations are high (up to **0.90** for spring), and interannual variability is not underestimated by the **DS** scheme (as is often the case for most other indices). Simulated **PQ90** miss the observed excursions to highest values, in all seasons, pointing to the criticism (in the case of Locarno precipitation, at least), that if our scheme successfully captures the LSC patterns responsible for precipitation (the **PR**s), since it correctly reproduces **Pav**, it does not capture the full mechanism responsible for the most intense precipitation (see discussion, Sect. 2.3 & 2.4). The same is true for **P5DMAX** where Spearman cc are never that bad, but where there are no true excursions to highest accumulations. As regards **P5DMAX**, only the automn score gets high enough. However, even for automn, the eye is not very satisfied.

To summary the situation with the Locarno series of extreme indices, Spearman cc often take quite satisfactory values, although variability is systematically underestimated, except for **Pav** for which our **DS** scheme simulates observations in a nice way.

3.1 DS forecasts for Montélimar

For spring (Fig.11, left), the only stisfactory simulation is again that of **Pav**, although **PQ90** has a high (0.80) Spearman cc, but with a tiny varability. Nothing looks satisfactory for summer (Fig.11, right). The qualitative sitution looks quite the same for the last 2 seasons (Fig.12): **Pav** simulations are not that bad, especially for winter. The variability of other indices is widely understimated for automn; on the contrary the model variability is much closer to observations during winter. For instance, the Montélimar **PCDD** histogram for winter looks quite satisfactory.

To summary, winter seems the the best simulated season, except that, like in Locarno, winter **PQ90** is badly reproduced. Spring is also not that bad, with the worst Spearman cc for **P5DMAX**, but the variability is more uunderestimated that for winter.

4. Downscaling Precipitation over Iberian stations.

The iberian station set clearly divides into 2 subsets: a western one (close to the Atlantic), with a majority of portuguese stations, and Alcuescar as the most eastern station of this first subset, and an eastern subset including 5 south-eastern spanish cities, close to the mediterranean boarder.

4.1 Maps of Pav, average daily precipitation.

Fig.13 is like Fig.1, but for the iberian stations. Winter (fourth map) is clearly the season when the **DS** operates best, with high Spearman cc over all western stations. Scores are markedly lower for the mediterranean stations. For intermediate seasons, scores continue rather high (but lower) to the west (and higher to the NW than to the SE for this group), whereas Spearman cc only remain marginally positive for the second, eastern set of stations. During summer, there remains only a marginal skillfulness to the north and west of the atlantic subset.

4.2 Maps of PQ90

The skill score patterns for **PQ90** (Fig.14) look rather similar to those for **Pav** above (Fig.13). The patterns are quite the same, with the best cc for the atlantic group, to the west, for winter; however, the Spearman cc take much lower values than for **Pav**, and the significance level is only marginally reached for most stations (red circles radii are rather small), except for winter to the west.

4.3 Maps of P5DMAX

If one compars the skill score maps for **P5DMAX** (Fig.15) to those for **PQ90** (previous Fig.14), several diffences are worthy of notice for automn and winter: automn cc are almost systematically higher than for **PQ90**, pointing to a better quality description of **P5DMAX** than **PQ90** for this season, at least for the atlanic side stations. A possible explanation has already been suggested in Sect. 2.3 & 2.4 above. Winter cc are more homogeneous than for **PQ90**. On the contrary, there is no qualitative changes between the patterns of Figs 13 and 14 for spring and summer (upper maps of both Figs).

4.4 Maps of PCDD, the maximum duration of dry episodes

There is a striking difference between the maps of Fig.15 (**P5DMAX**) and those of Fig.16 (**PCDD**). Whereas, on the atlantic side at least, winter remains the season with the highest (and homogeneos) Spearman cc, cc are quite low for automn, like for summer, and spring appears to be the second best season, especially for the 5 most southern atlantic stations where our **ppci** seems to accurately capture the mechanisms responsible for spring drought whereas it did not capture those responsible for intense precipitation over the same stations. For automns, the reverse is true, whereas both mechanisms seem to be captured for winter.

4.5 Average scores for Iberian stations

Spearman cc averaged over the whole set of STARDEX indices are displayed on the maps of Fig.17. Fig.17 confirms that our **DS** scheme performs best during winter, and better for atlantic than for mediterranean stations. On average, spring and fall get only marginally significant cc; these are much lower than for **Pav**, or **P5DMAX** (atlntic stations, automn), or **PCDD** (southern atlantic stations, spring), and there is almost no skill for summer.

To summary, our **DS** scheme based on the use of a **ppci** performs better for iberian western (atlantic) stations than for eastern (mediterranean) ones. The best model performance occurs for winter; then follow, on average, spring and automn, with significantly lower scores. Summer cc are close to nul. One should also notice that the western stations set is dense enough so that a spatially coherent behaviour manifest, with, for some seasons, higher cc for the most northern atlantic stations (*e.g.* **Pav**, spring), or the most southern ones (**PCDD**, spring). Such coherent behaviours did not appear with the alpine stations looser network.

The strikingly different behaviours of Murcia Alcantaril and Murcia San Javier are also worthy to notice!

5. More insight into 2 stations.

We proceed in the same way as for alpine stations and compar, for each extreme index, and each season, the observed series and that obtained through the application of **DS**. We will consider one station from each subset.

5.1 DS forecasts for Alicante

Observations and simulations for Alicante are compared on Figs 18 and 19. At a first glampse, it is clear that **DS** forecasts badly simulate observations. This is confirmed if one looks at the Spearman cc: their highest values approach **0.5**, and most of them are in the range **-0.1**, **0.3**. However, even with the highest values, the eye is quite unsatisfied, except, maybe, for automn **Pav** which is the only index displaying almost correct signs for year-to-year changes. Certainly our **DS** algorithm is inappropriate for climate change investigations regarding such a station like Alicante.

5.2 DS forecasts for Alvega

In Alvega, a station from the atlantic subset, the situation looks somewhat better. Spring **Pav** (Fig.20, left) are satisfactory, with a Spearman cc above **0.7**, and appropriate interannual variability. For spring, even **P5DMAX** (with a cc $\approx$ **0.6**), and **PQ90** (cc $\approx$ **0.5**) display most often right sign interannual changes, although with underestimated variability. Only **PCDD** is truely bad.

As already pointed, simulated summer indices get almost nul scores: but this failure may be irrelevant since summer precipitation are so rare and so scarce: observed **PQ90** most often stay below 10mm, and total summer precipitation mean does not exceed $\approx$ **30**mm!

The situation looks better with fall and winter that are the wettest seasons (Fig.21). The description of the interannual variability of **Pav** looks quite nice with a Spearman cc as high as **0.86** for winter, and an almost correct variance. **PCDD** also exhibits rather large cc for both these seasons (**0.56** and **0.66**), although the underestimation of interannual variance remains spectacular! For winter, both **PQ90** and **P5DMAX** cc are $\approx$ **0.60**, which is quite satisfactory, although variances are again underestimated!

6. Summary and conclusions

In this deliverable, we have checked the performances of our circulation based **DS** scheme over two (but actually three since iberian stations divide into two well distinct subsets) sets of stations. The retained validation period was 1979-1993 in agreement with STARDEX internal conventions.

For both alpine and iberian stations, **Pav** is far the best simulated index; the only exception being summer for the most south-western alpine stations and all the iberian ones except perhaps the most north-western ones.

Over the Alps, the skill scores are much lower for **PQ90**, with only some exceptions. **P5DMAX** has only marginally significant scores, but they are no more nul or negative; a noticeable exception being München where, for 3 seasons out of 4, Spearman cc are negative. **PCDD** scores are more satisfactory for fall and winter, suggesting that our **ppci** better captures precipitation inhibition mechanisms than intense precipitation ones which indeed include sub-regional (or even quasi-local) circulation dependent processes. One should also notice that during summer, the **DS** scheme gets almost nul scores for the 4 most south-western stations, which is not the case to the north and to the east of the "alpine" sector, except for München.

A detailed inspection for 2 stations has confirmed that **Pav** was the best simulated index. Other indices may get significant positive Spearman cc, but all three (**PQ90**, **P5DMAX**, and **PCDD**) suffer from an impressive underestimation of interannual variability, except, maybe, winter **PCDD** in Montélimar. The simulation of **P5DMAX** looks quite systematically better than that of **PQ90**; this may be due to compensations in 5d precipitation which makes this index less influenced by the stochastic features of our **DS** scheme. Spearman cc are noticeably higher for **PCDD** during fall and winter than for precipitation accumulation dependent indices, suggesting that our **potential precipitation circulation index** better captures the mechanisms which inhibate precipitation (see Sect. 2.3 & 2.4).

For iberian stations, the **ppci** based **DS** scheme operates systematically better for the atlantic side subset (11 stations). It badly performs for the mediterranean boarder ones.

To the atlantic side, winter is always the best simulated season, with generalised quite positive scores; Spearman cc are almost that high for **PCDD** than for **Pav**. They stand only a little lower for **P5DMAX** and **PQ90** (except the most southern stations in the last case). Best scores for spring are for **Pav**, then for **PCDD** to the *south* (surprisingly better than for **Pav**). **PQ90** and **P5DMAX** get only marginal significance , to the **north**!

Automn scores contrast with spring ones since **PCDD** scores all remain low, together with **PQ90** ones; on the contrary **P5DMAX** Spearman cc are rather high for most stations of this atlantic subset. Finally there only remains some scarce significance for summer extreme indices.

A detailed inspection of Alvega simulated precipitation series leads to conclusions not that different from those which we drew in the alpine case. **Pav** remains the best simulated index. Except for summer, several other simulated indices get rather high Spearman cc, although interannual variances are systematically underestimated; however, appropriate corrections could probably remedy this desease, in particular in the case of **PCDD** which very often gets nice scores, although with tiny variability.

As a general conclusion, we may notice that, except for summer where there is almost no skillfullness, for a given station, our scheme performs best for some extreme index for a given season, and for another one for another season. Spearman cc maps show spatially coherent behaviour for the atlantic iberian stations subset, suggesting that our **ppci** may more efficiently capture drought mechanisms for a given season, and intense precipitation mechanisms for another one, and this for the same subset of neighbouring stations. Such observations give indications of when, where, and for which indices, our **ppci** based **DS** scheme may be used as a rather confident tool, or not.

Finally, we pointed out that our approach may be simplified in a way that would allow much faster numerical investigations (when and where it works!), without significant loss of skill.

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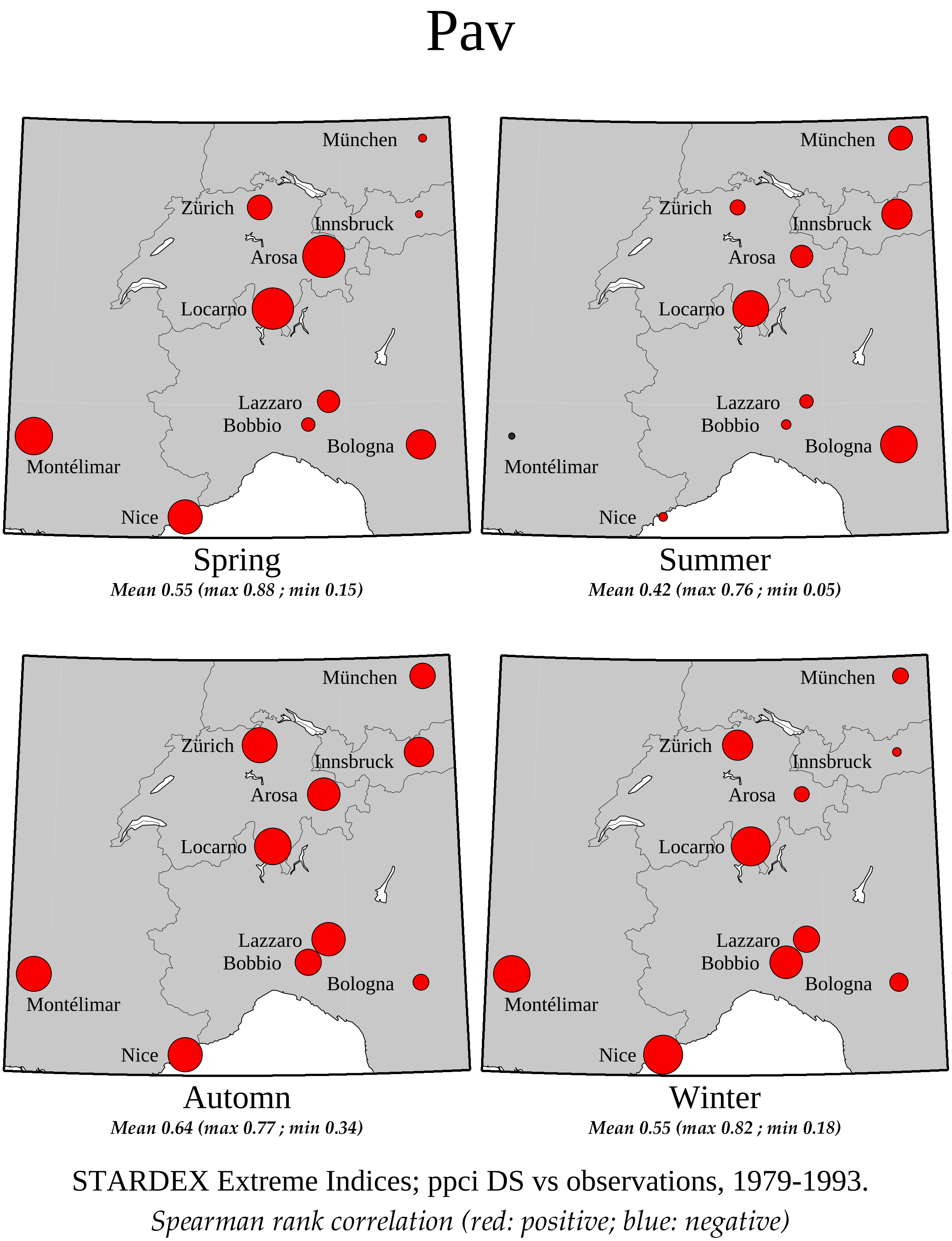

Pav
München
Zürich
Innsbruck
Arosa
Locarno
Lazzaro
Bobbio
Bologna
Montélimar
Nice
Spring
Mean 0.55 (max 0.88 ; min 0.15)
Summer
Mean 0.42 (max 0.76 ; min 0.05)
Automn
Mean 0.64 (max 0.77 ; min 0.34)
Winter
Mean 0.55 (max 0.82 ; min 0.18)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 1:

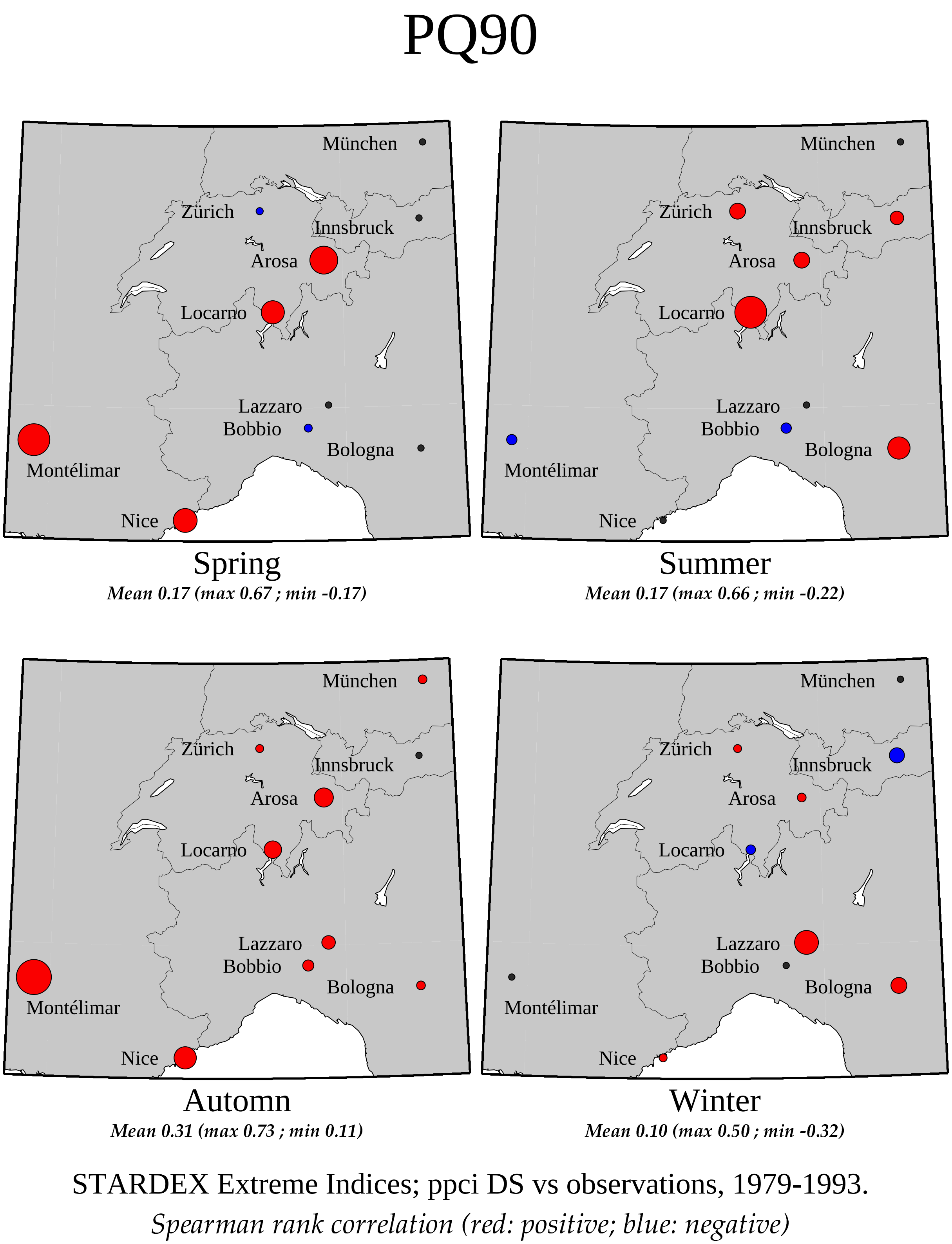

PQ90
München
Zürich
Innsbruck
Arosa
Locarno
Lazzaro
Bobbio
Bologna
Montélimar
Nice
Spring
Mean 0.17 (max 0.67 ; min -0.17)
Summer
Mean 0.17 (max 0.66 ; min -0.22)
Automn
Mean 0.31 (max 0.73 ; min 0.11)
Winter
Mean 0.10 (max 0.50 ; min -0.32)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 2:

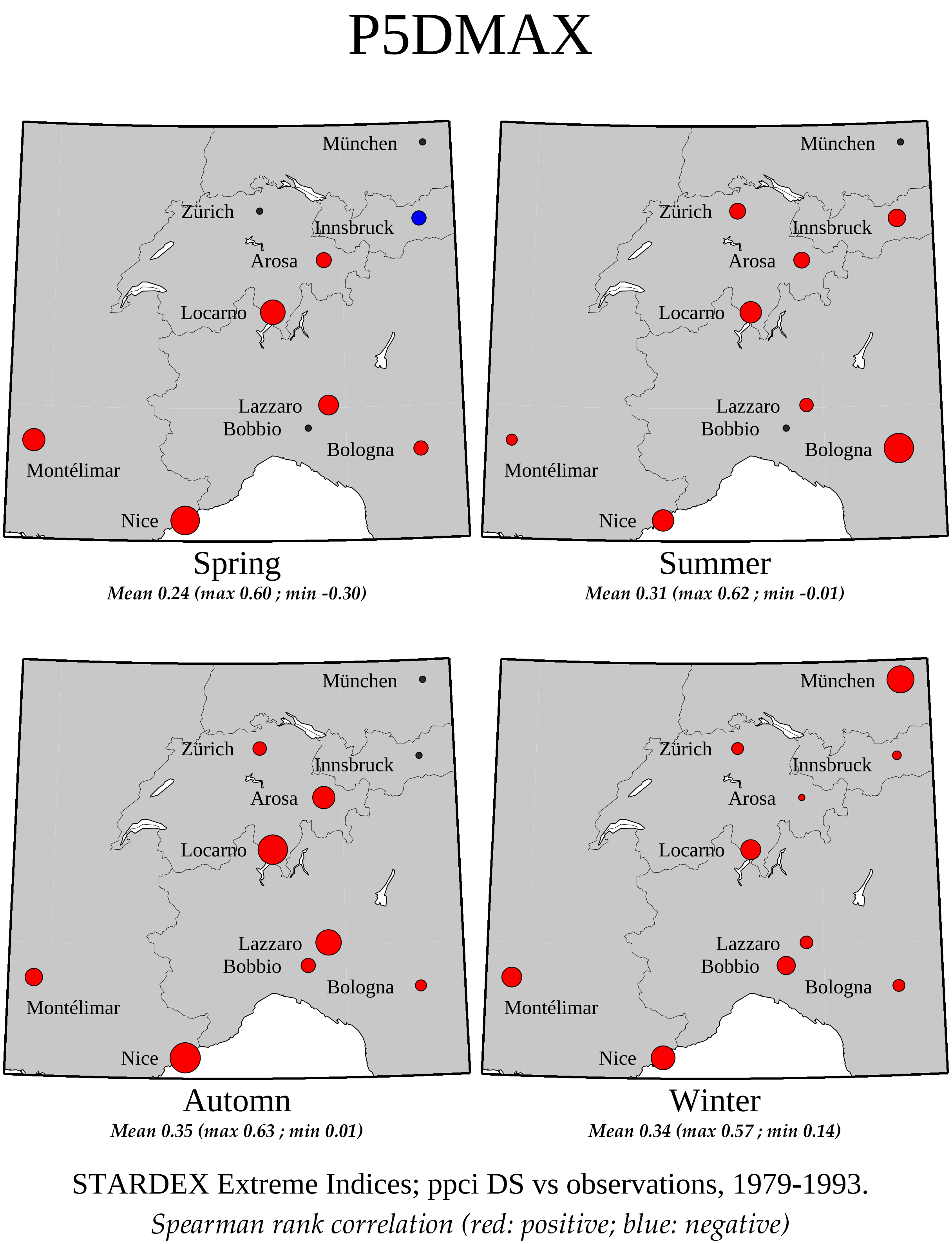
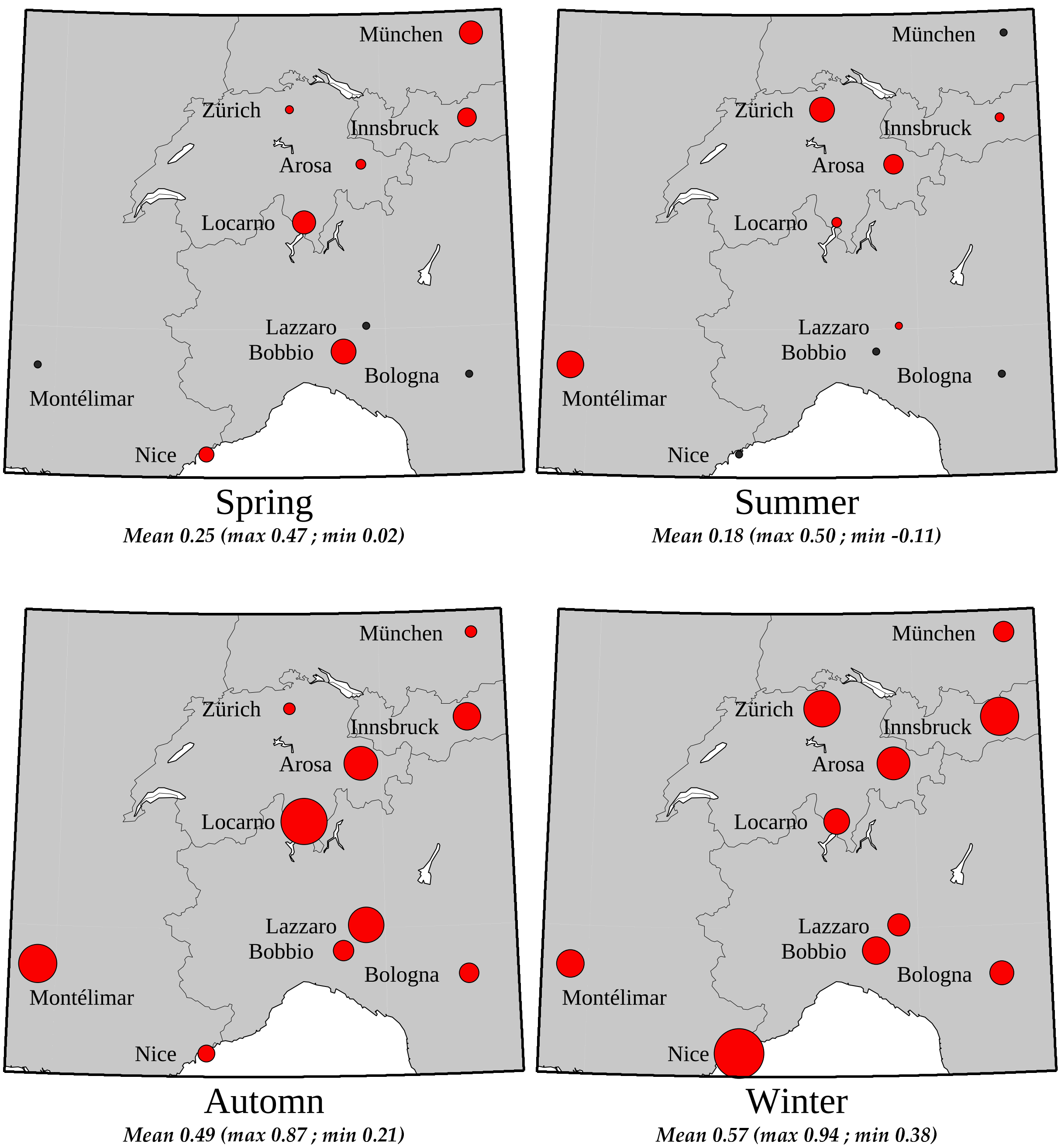

P5DMAX
München
Zürich
Innsbruck
Arosa
Locarno
Lazzaro
Bobbio
Bologna
Montélimar
Nice
Spring
Mean 0.24 (max 0.60 ; min -0.30)
Summer
Mean 0.31 (max 0.62 ; min -0.01)
Automn
Mean 0.35 (max 0.63 ; min 0.01)
Winter
Mean 0.34 (max 0.57 ; min 0.14)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 3:

PCDD



STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.

Spearman rank correlation (red: positive; blue: negative)

Figure 4:

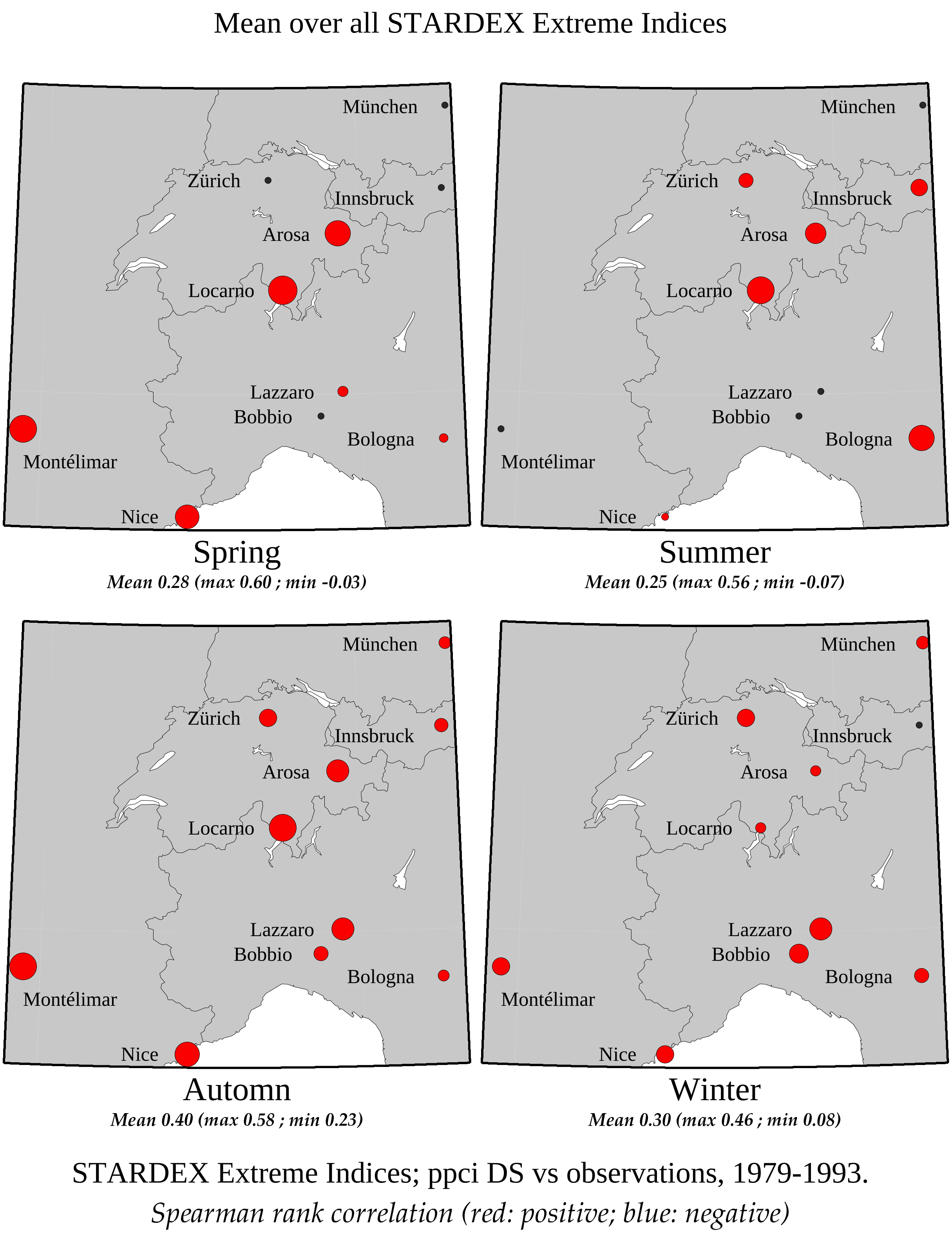
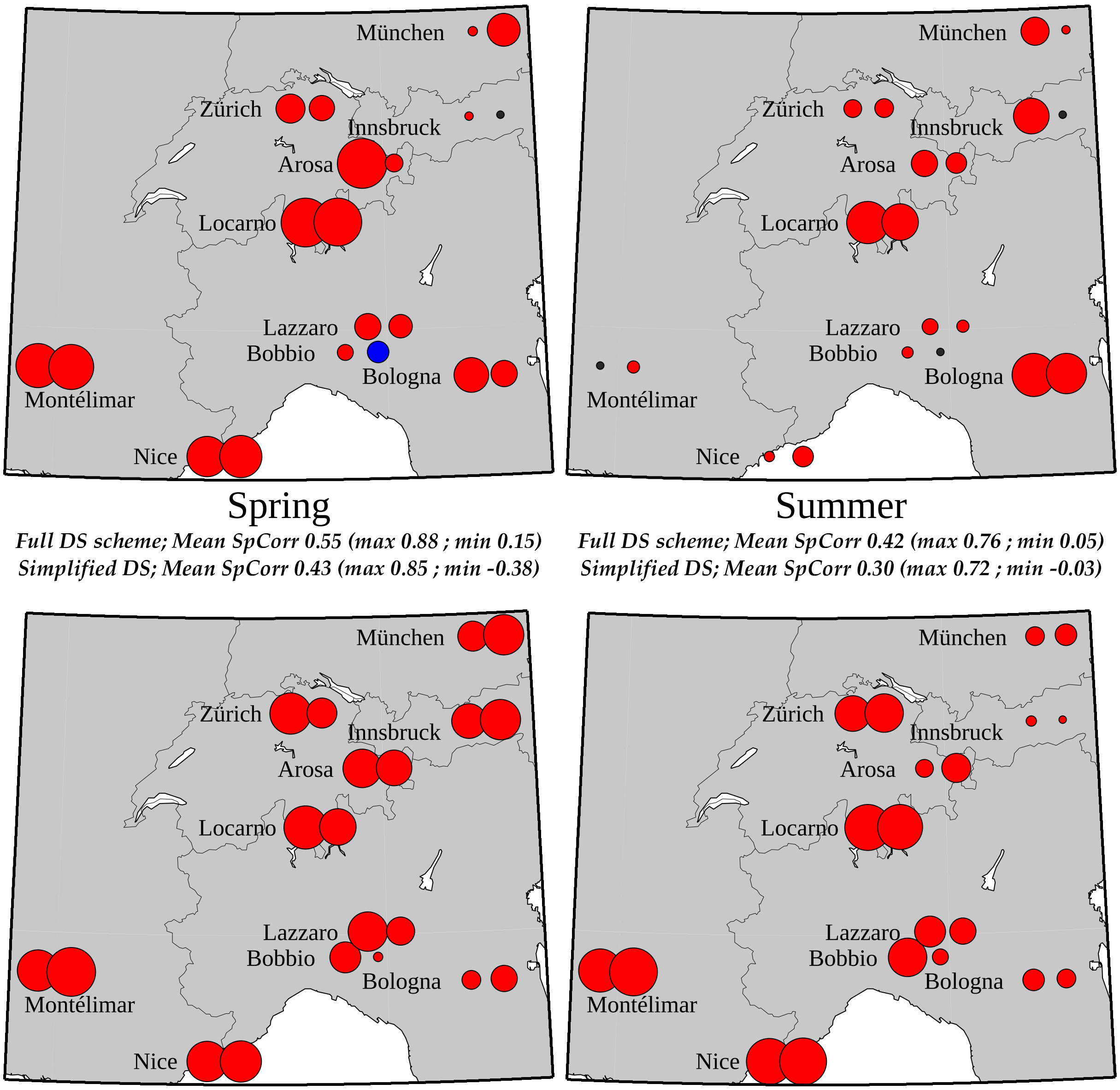

Mean over all STARDEX Extreme Indices
München
Zürich
Innsbruck
Arosa
Locarno
Lazzaro
Bobbio
Bologna
Montélimar
Nice
Spring
Mean 0.28 (max 0.60 ; min -0.03)
Summer
Mean 0.25 (max 0.56 ; min -0.07)
Automn
Mean 0.40 (max 0.58 ; min 0.23)
Winter
Mean 0.30 (max 0.46 ; min 0.08)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 5:

Pav



Spring
Full DS scheme; Mean SpCorr 0.55 (max 0.88 ; min 0.15)
Simplified DS; Mean SpCorr 0.43 (max 0.85 ; min -0.38)

Summer
Full DS scheme; Mean SpCorr 0.42 (max 0.76 ; min 0.05)
Simplified DS; Mean SpCorr 0.30 (max 0.72 ; min -0.03)

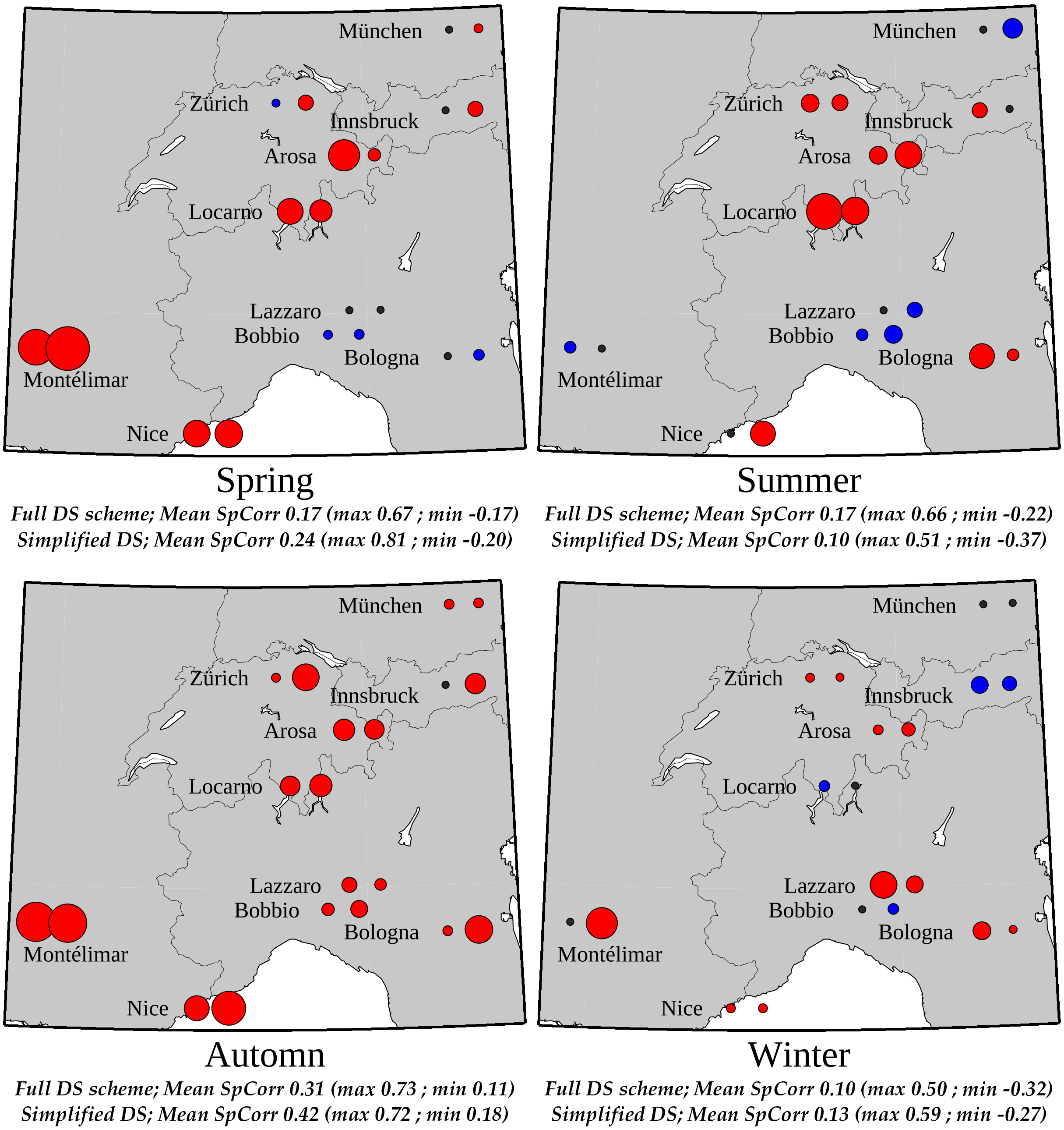
Automn
Full DS scheme; Mean SpCorr 0.64 (max 0.77 ; min 0.34)
Simplified DS; Mean SpCorr 0.60 (max 0.86 ; min 0.17)

Winter
Full DS scheme; Mean SpCorr 0.55 (max 0.82 ; min 0.18)
Simplified DS; Mean SpCorr 0.53 (max 0.85 ; min 0.13)

STARDEX Extreme Indices: Spearman rank correlation
between DS precipitation and observations (red: positive; blue: negative)
Left circles: full DS scheme, ppci using WRs & PRs; Right circles: simplified DS scheme.

Figure 6:

PQ90



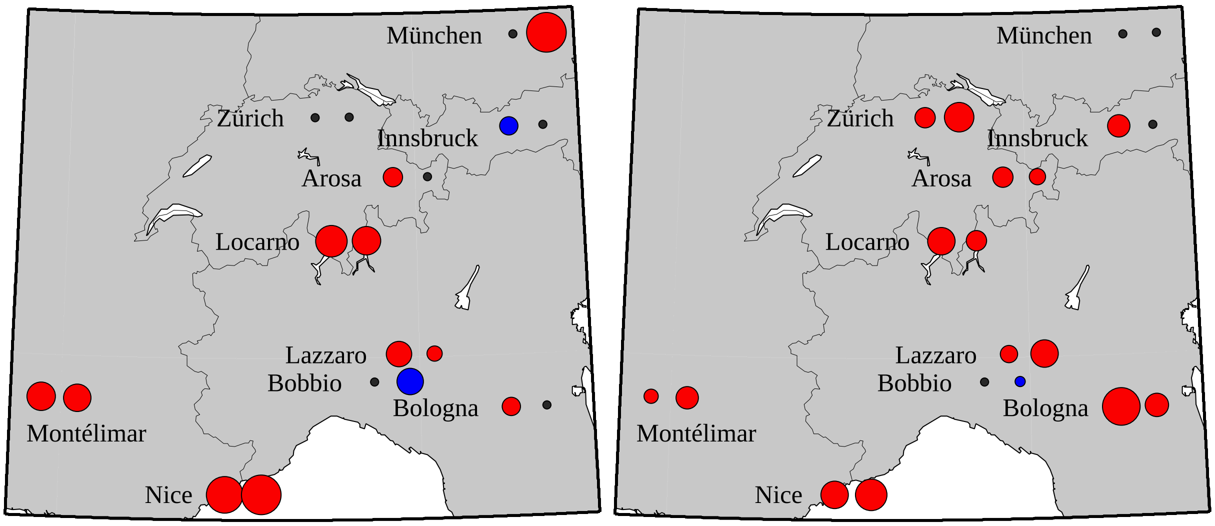
STARDEX Extreme Indices: Spearman rank correlation

between DS precipitation and observations (red: positive; blue: negative)

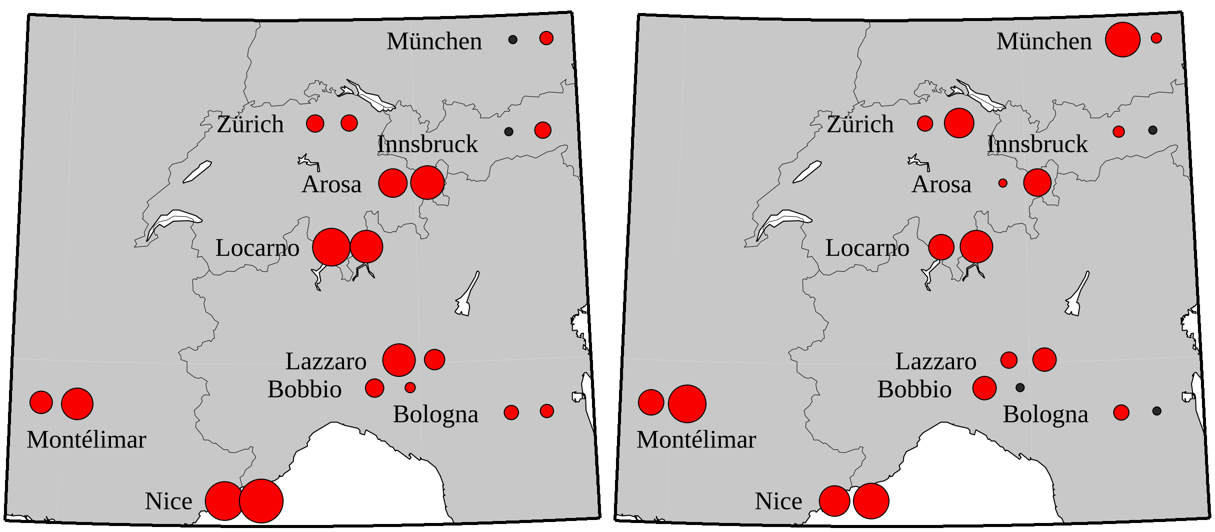
Left circles: full DS scheme, ppci using WRs & PRs; Right circles: simplified DS scheme.

Figure 7:

P5DMAX



Spring	Summer
Full DS scheme; Mean SpCorr 0.24 (max 0.60 ; min -0.30)	*Full DS scheme; Mean SpCorr 0.31 (max 0.62 ; min -0.01)*
Simplified DS; Mean SpCorr 0.22 (max 0.66 ; min -0.43)	*Simplified DS; Mean SpCorr 0.25 (max 0.52 ; min -0.16)*



Automn	Winter
Full DS scheme; Mean SpCorr 0.35 (max 0.63 ; min 0.01)	*Full DS scheme; Mean SpCorr 0.34 (max 0.57 ; min 0.14)*
Simplified DS; Mean SpCorr 0.38 (max 0.72 ; min 0.17)	*Simplified DS; Mean SpCorr 0.32 (max 0.62 ; min -0.06)*

STARDEX Extreme Indices: Spearman rank correlation

between DS precipitation and observations (red: positive; blue: negative)

Left circles: full DS scheme, ppci using WRs & PRs; Right circles: simplified DS scheme.

Figure 8:

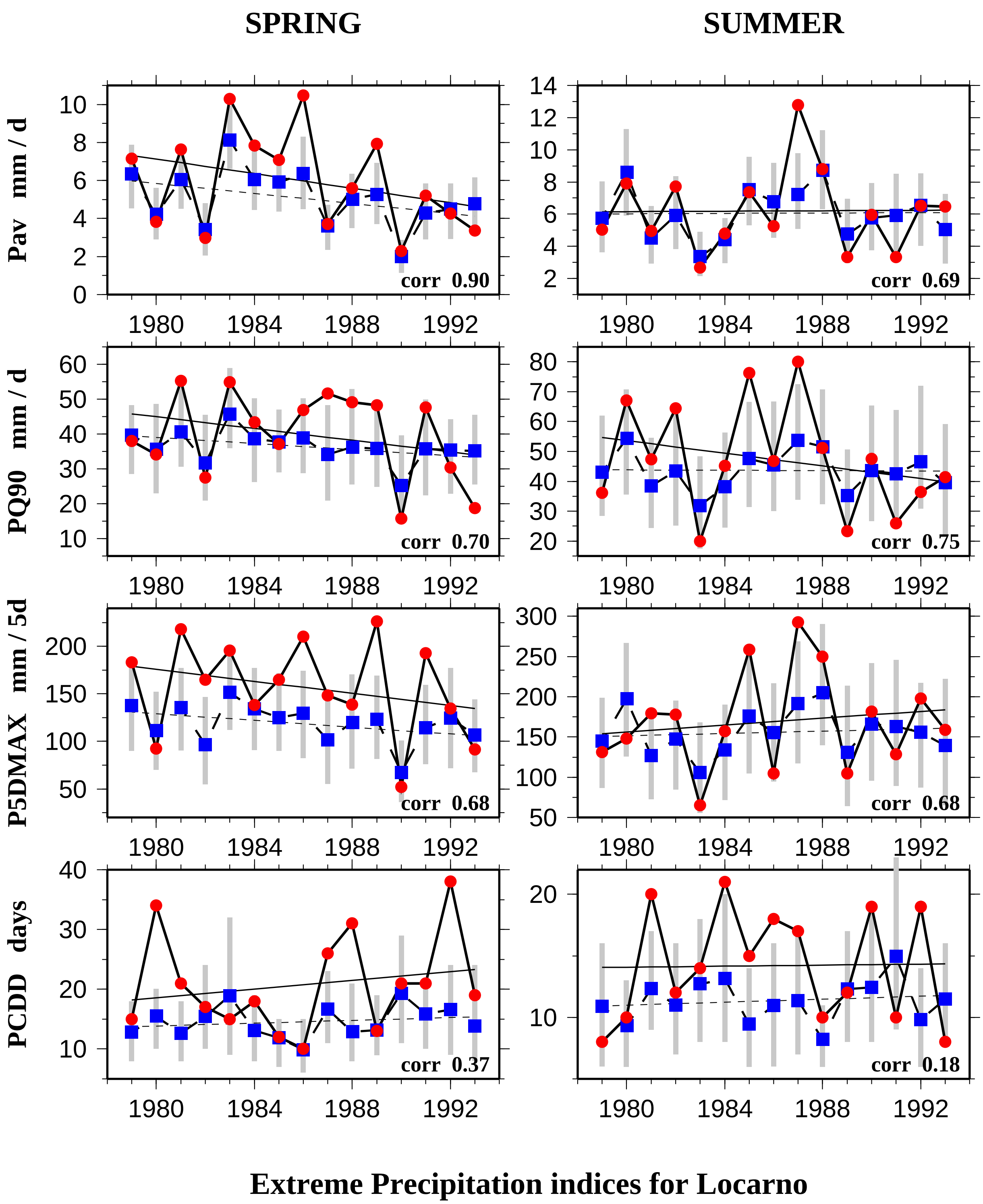

SPRING
SUMMER
Pav mm / d
PQ90 mm / d
P5DMAX mm / 5d
PCDD days
corr 0.90
corr 0.69
corr 0.70
corr 0.75
corr 0.68
corr 0.68
corr 0.37
corr 0.18
1980
1984
1988
1992
Extreme Precipitation indices for Locarno

Figure 9:

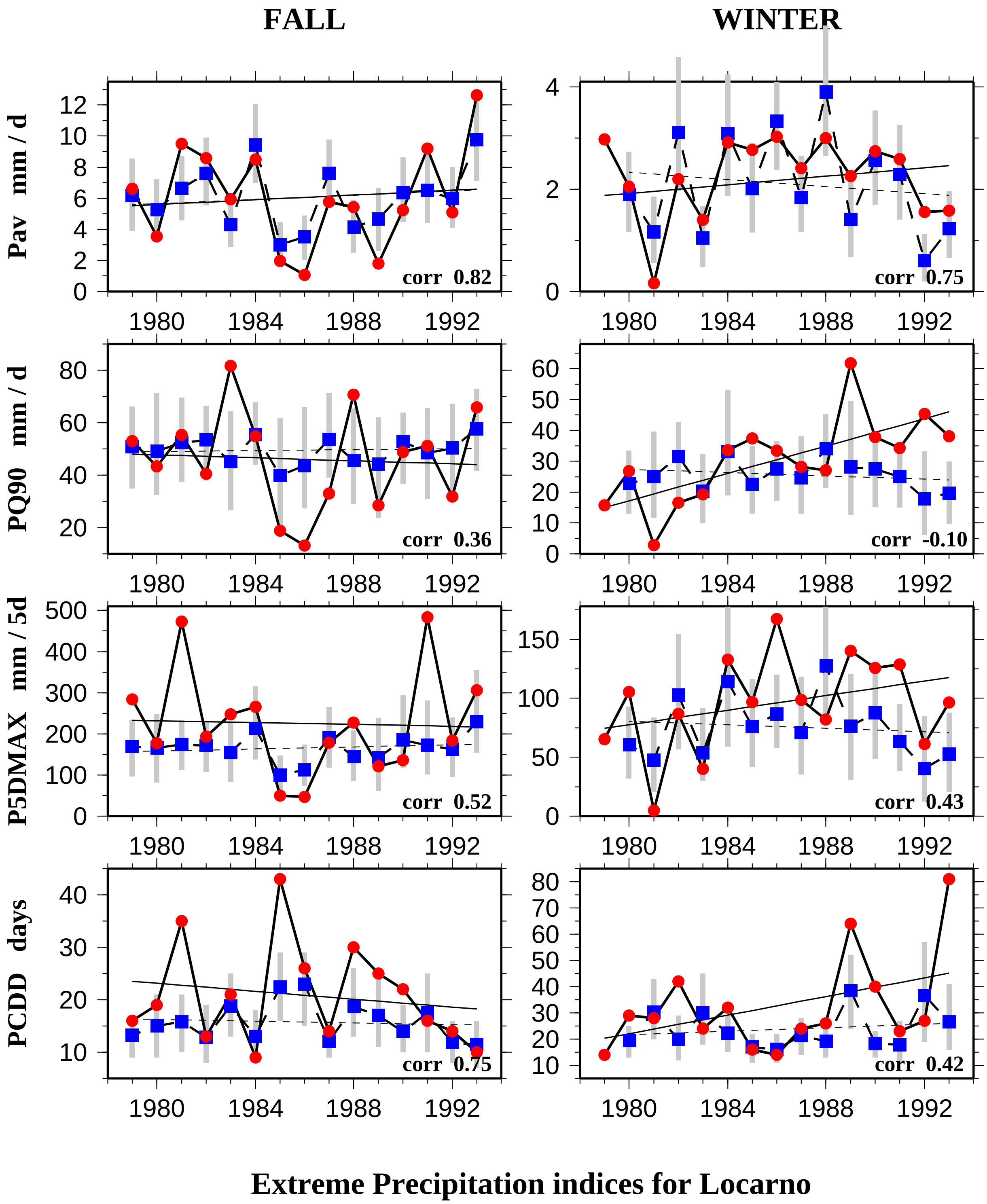
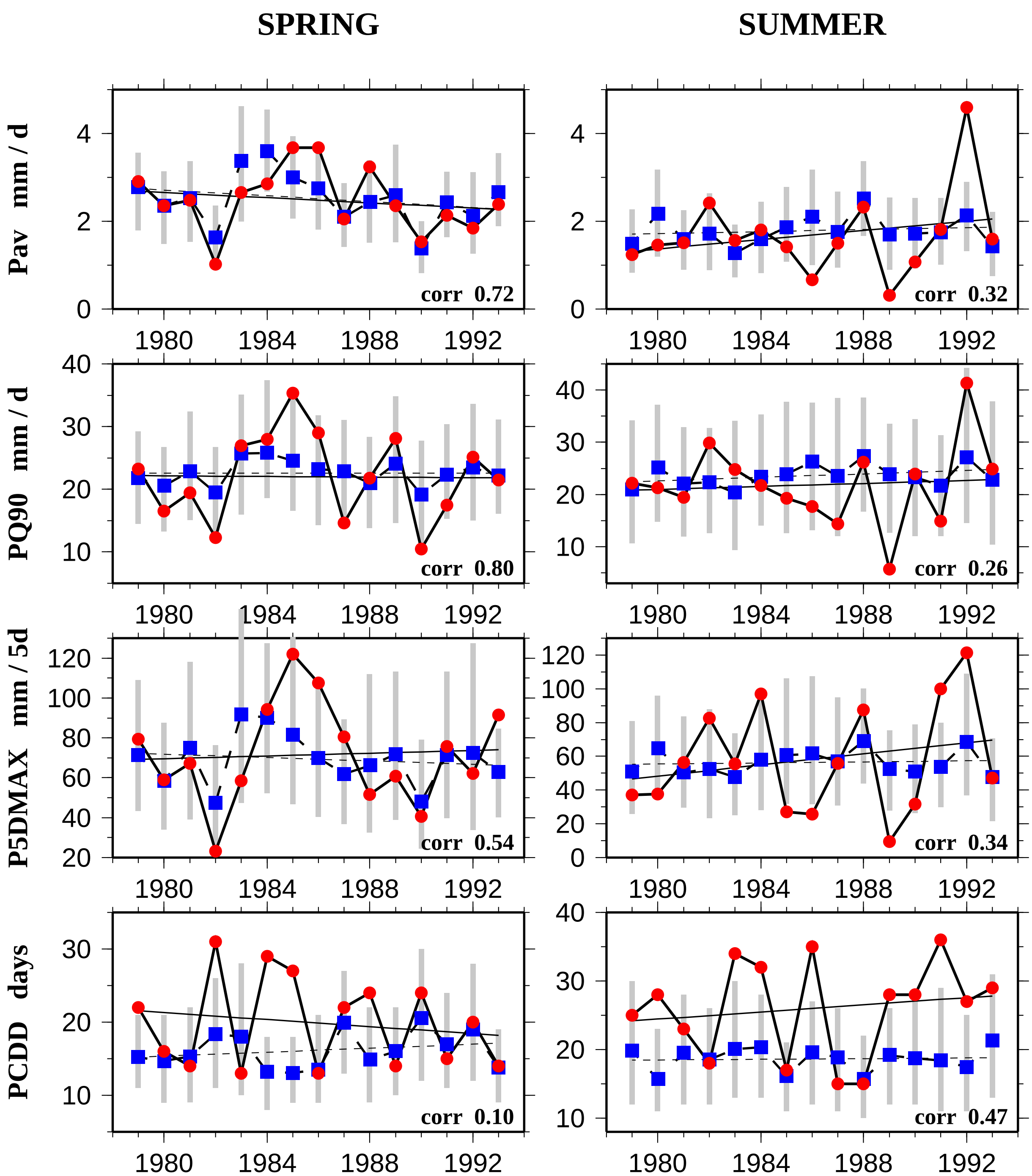

FALL
WINTER
Pav mm / d
PQ90 mm / d
P5DMAX mm / 5d
PCDD days
corr 0.82
corr 0.75
corr 0.36
corr -0.10
corr 0.52
corr 0.43
corr 0.75
corr 0.42
1980
1984
1988
1992
Extreme Precipitation indices for Locarno

Figure 10:



Extreme Precipitation indices for Montélimar

Figure 11:

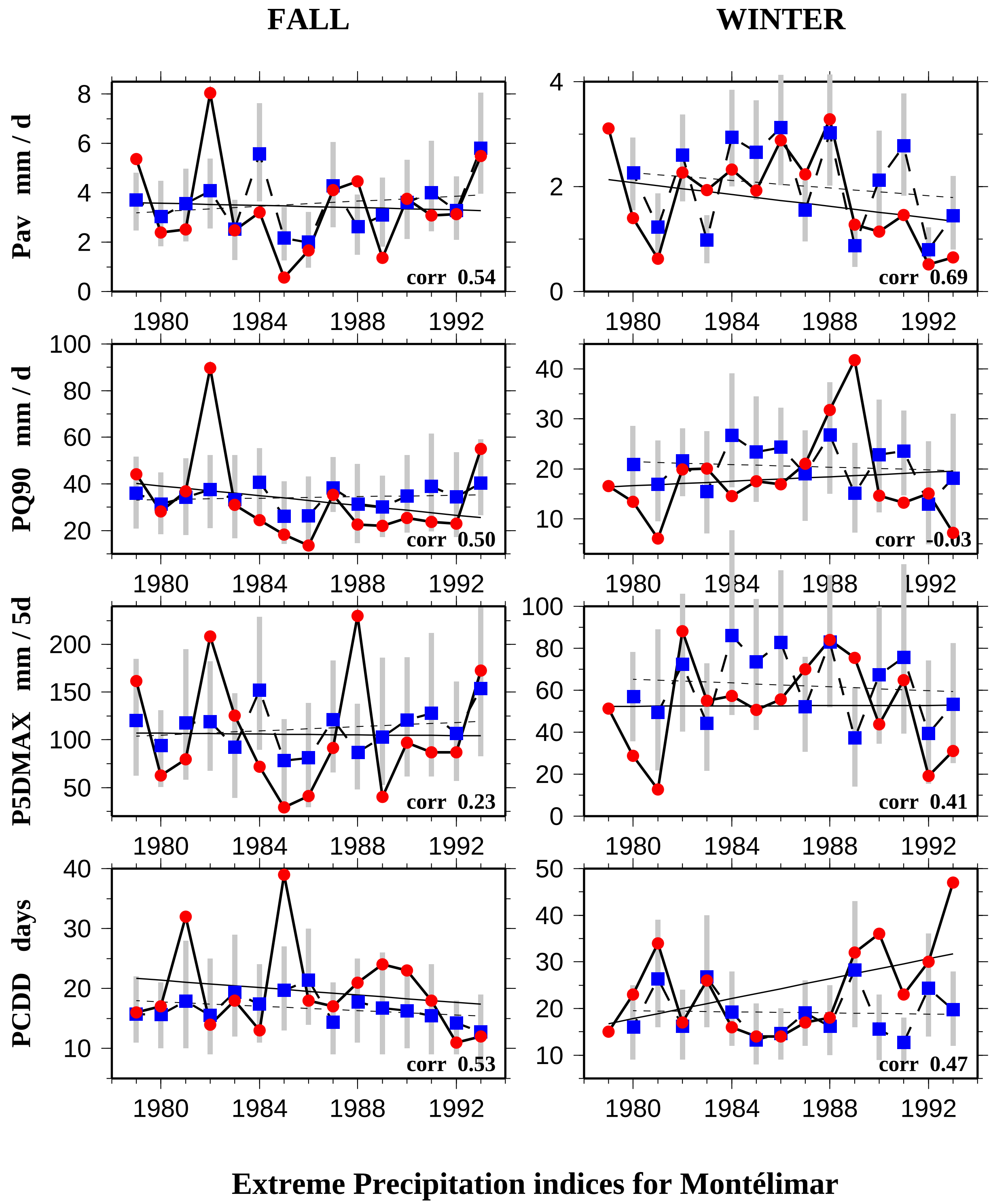

FALL
WINTER
Pav mm / d
PQ90 mm / d
P5DMAX mm / 5d
PCDD days
corr 0.54
corr 0.69
corr 0.50
corr -0.03
corr 0.23
corr 0.41
corr 0.53
corr 0.47
1980
1984
1988
1992
Extreme Precipitation indices for Montélimar

Figure 12:

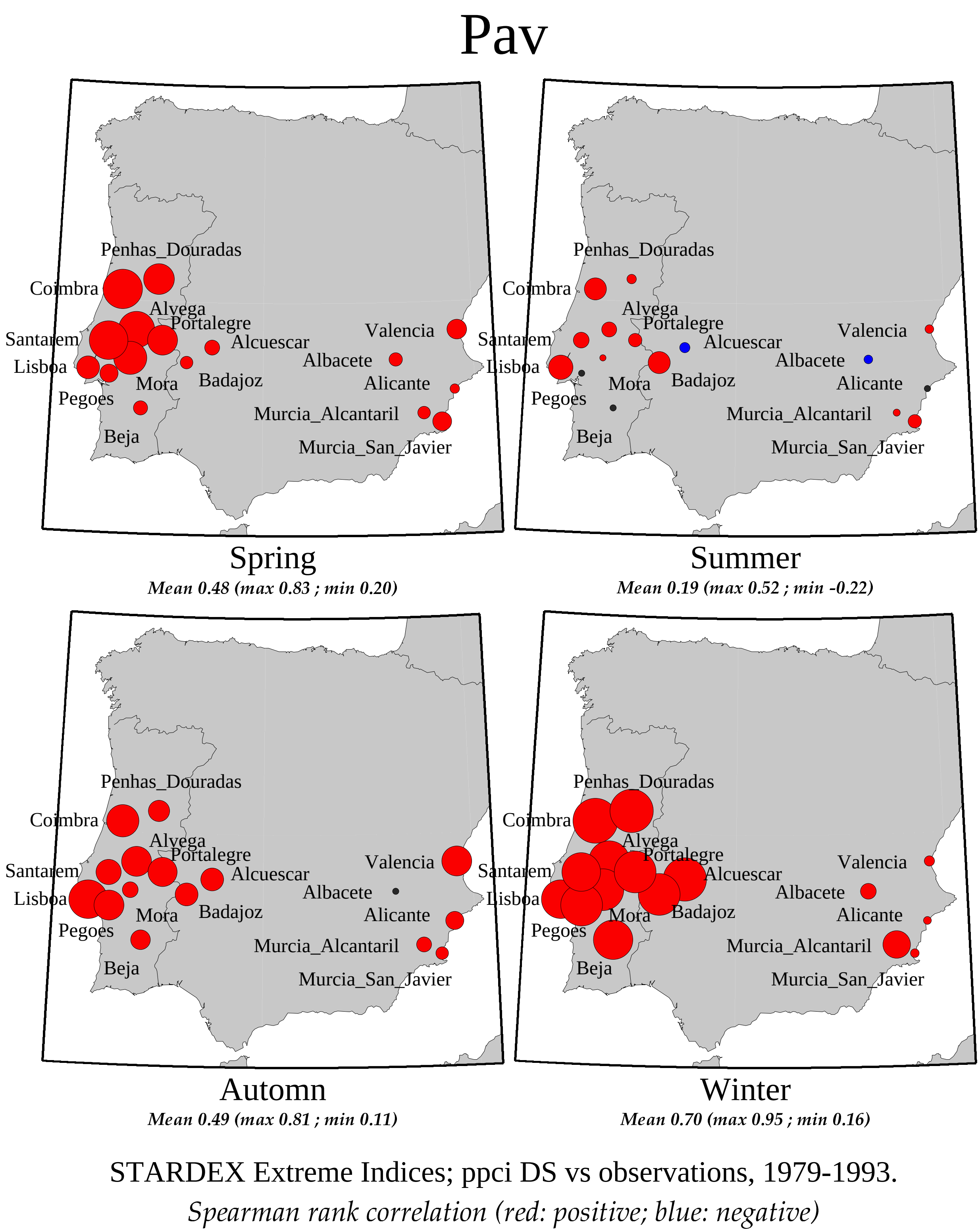

Pav
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Spring
Mean 0.48 (max 0.83 ; min 0.20)
Summer
Mean 0.19 (max 0.52 ; min -0.22)
Automn
Mean 0.49 (max 0.81 ; min 0.11)
Winter
Mean 0.70 (max 0.95 ; min 0.16)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 13:

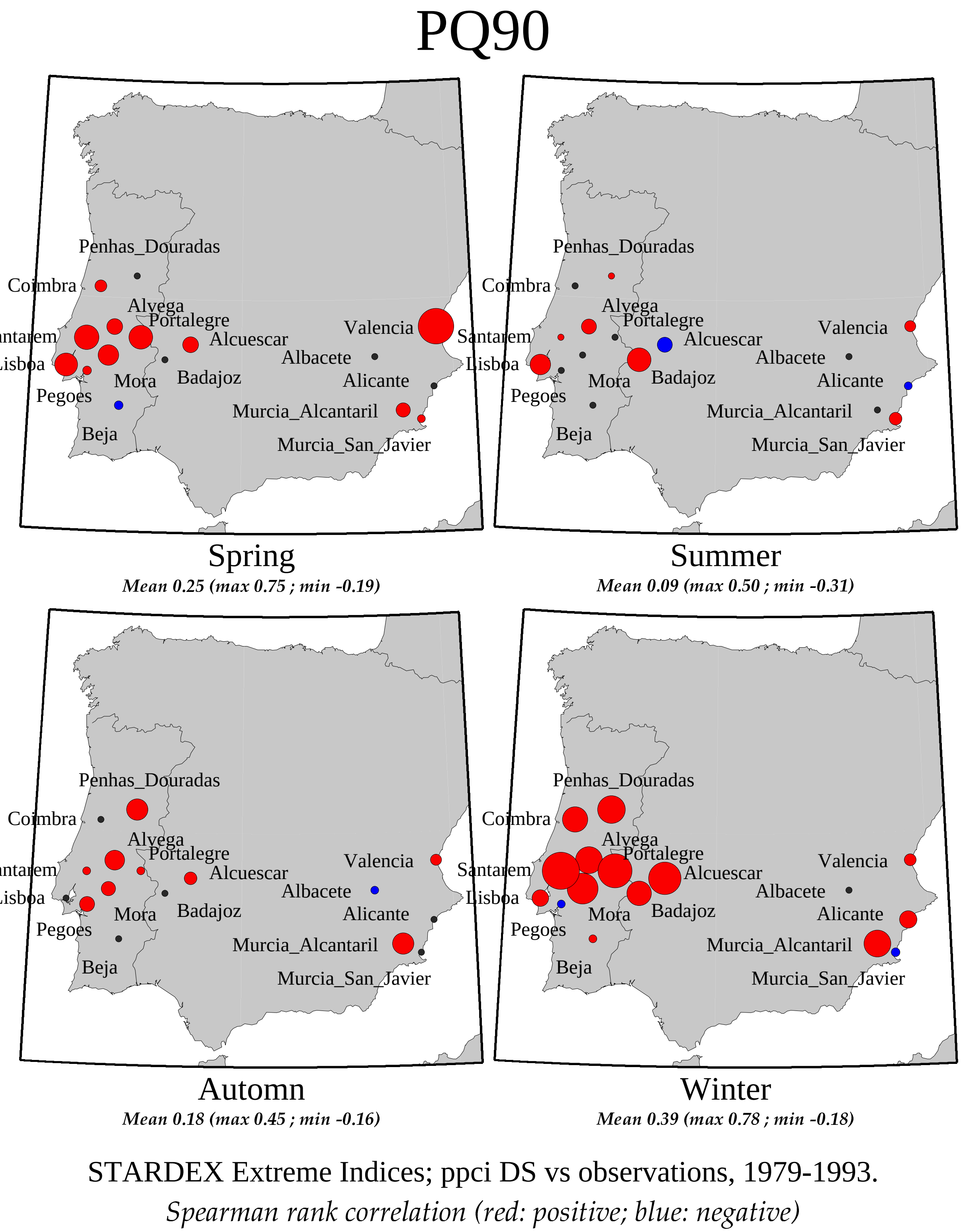

PQ90
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Spring
Mean 0.25 (max 0.75 ; min -0.19)
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Summer
Mean 0.09 (max 0.50 ; min -0.31)
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Automn
Mean 0.18 (max 0.45 ; min -0.16)
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Winter
Mean 0.39 (max 0.78 ; min -0.18)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 14:

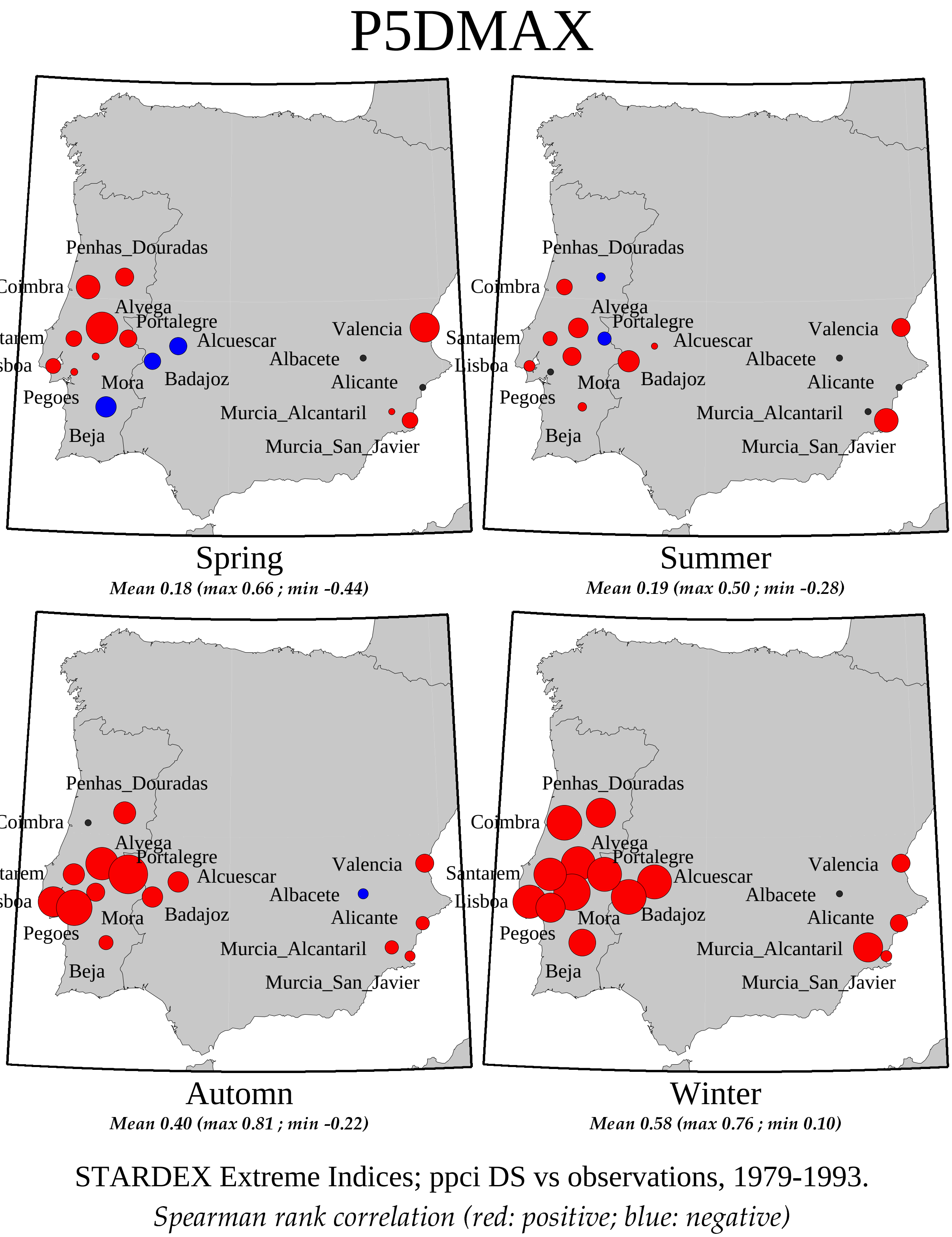

P5DMAX
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Spring
Mean 0.18 (max 0.66 ; min -0.44)
Summer
Mean 0.19 (max 0.50 ; min -0.28)
Automn
Mean 0.40 (max 0.81 ; min -0.22)
Winter
Mean 0.58 (max 0.76 ; min 0.10)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 15:

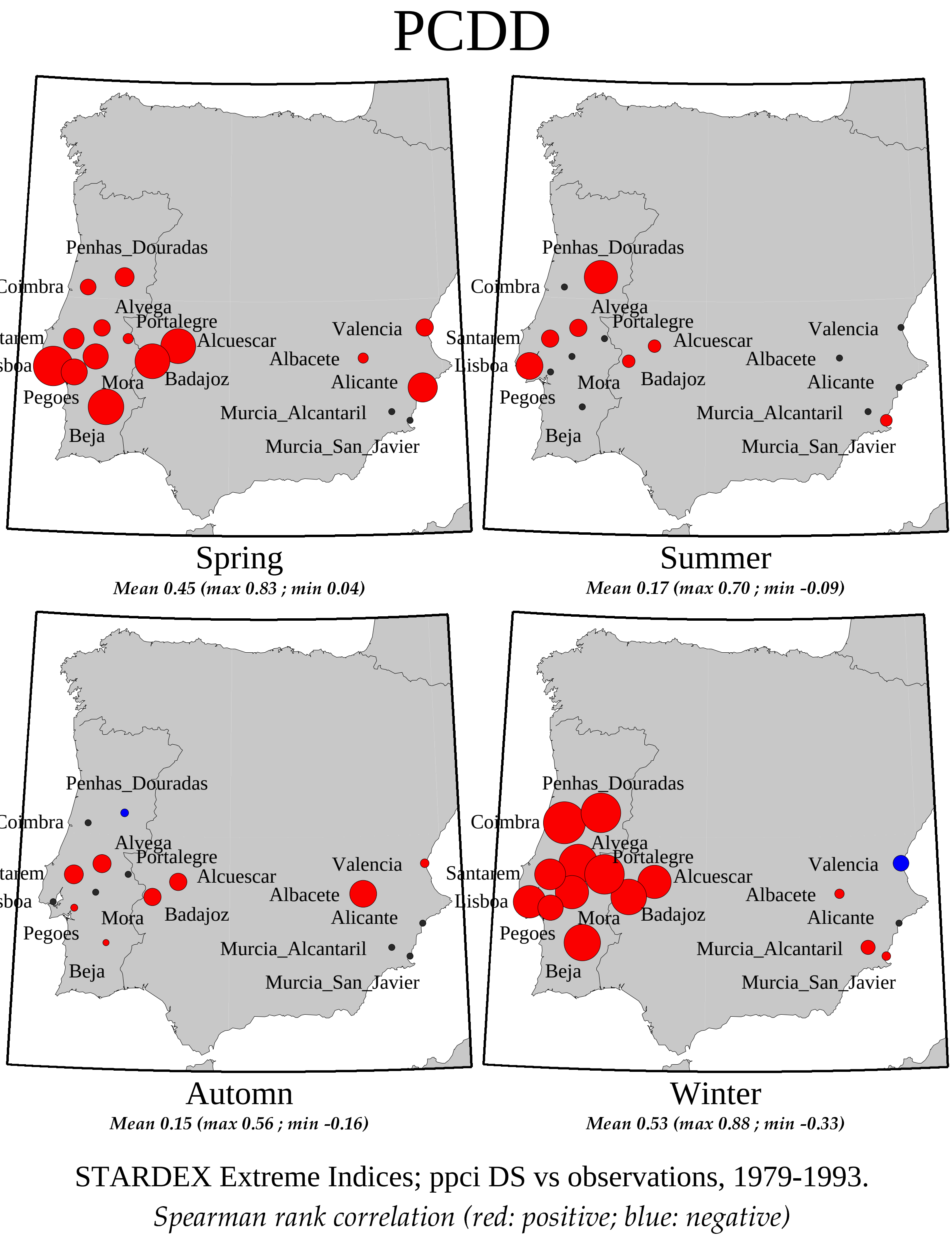

PCDD
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Spring
Mean 0.45 (max 0.83 ; min 0.04)
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Summer
Mean 0.17 (max 0.70 ; min -0.09)
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Automn
Mean 0.15 (max 0.56 ; min -0.16)
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Winter
Mean 0.53 (max 0.88 ; min -0.33)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 16:

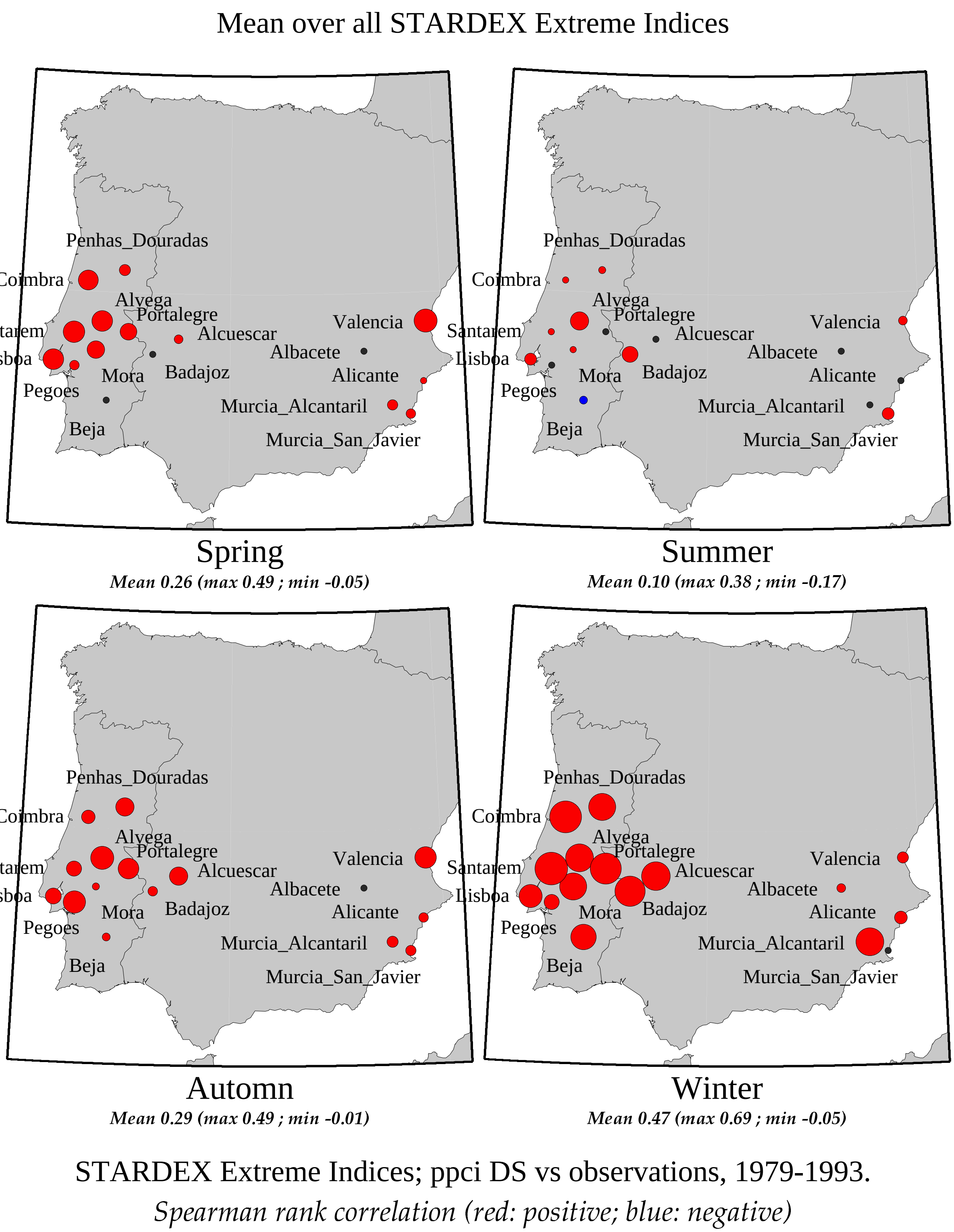
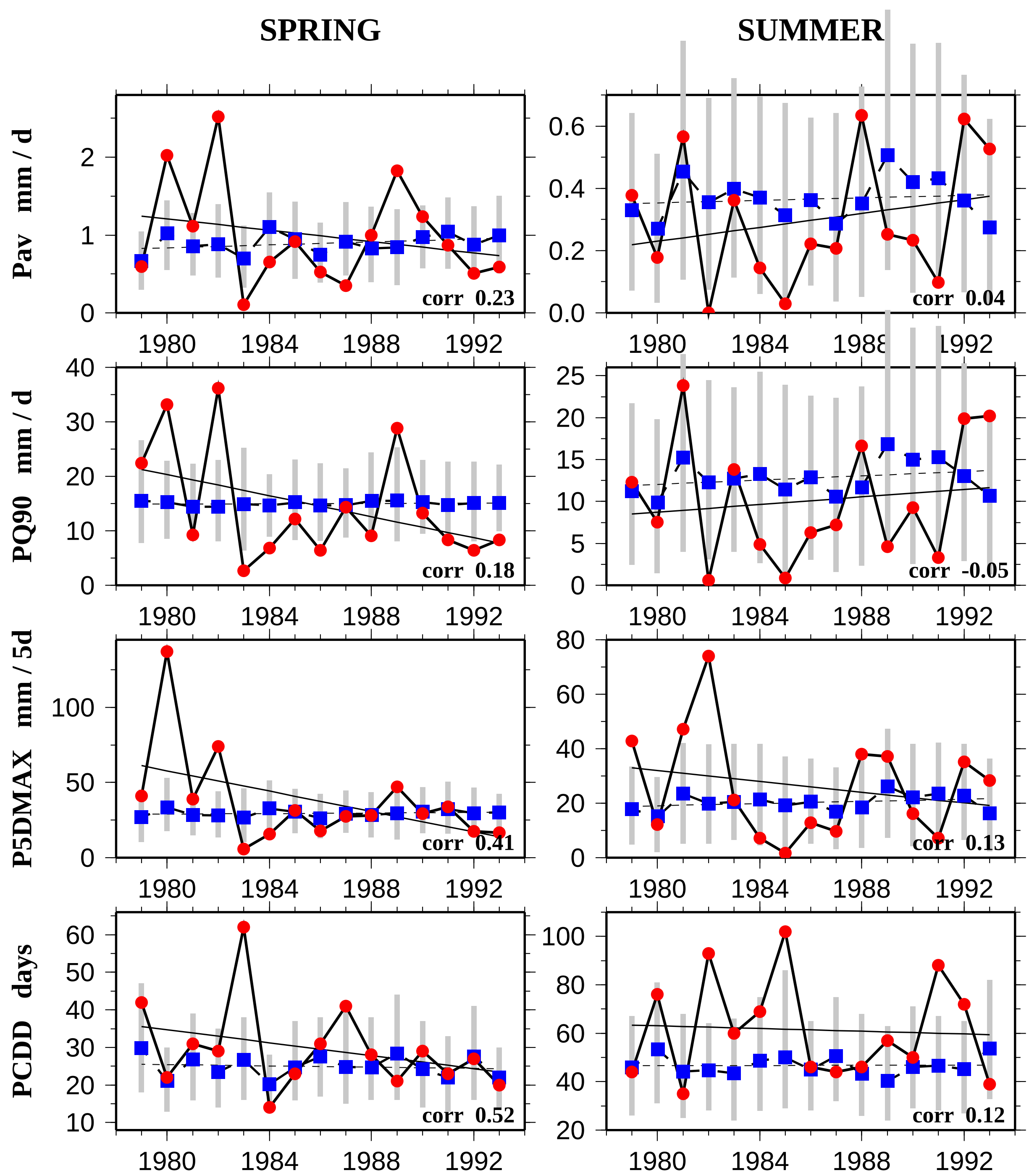

Mean over all STARDEX Extreme Indices
Penhas_Douradas
Coimbra
Alvega
Portalegre
Santarem
Alcuescar
Valencia
Albacete
Lisboa
Mora
Badajoz
Alicante
Pegoes
Murcia_Alcantaril
Beja
Murcia_San_Javier
Spring
Mean 0.26 (max 0.49 ; min -0.05)
Summer
Mean 0.10 (max 0.38 ; min -0.17)
Automn
Mean 0.29 (max 0.49 ; min -0.01)
Winter
Mean 0.47 (max 0.69 ; min -0.05)
STARDEX Extreme Indices; ppci DS vs observations, 1979-1993.
Spearman rank correlation (red: positive; blue: negative)

Figure 17:



Extreme Precipitation indices for Alicante

Figure 18:

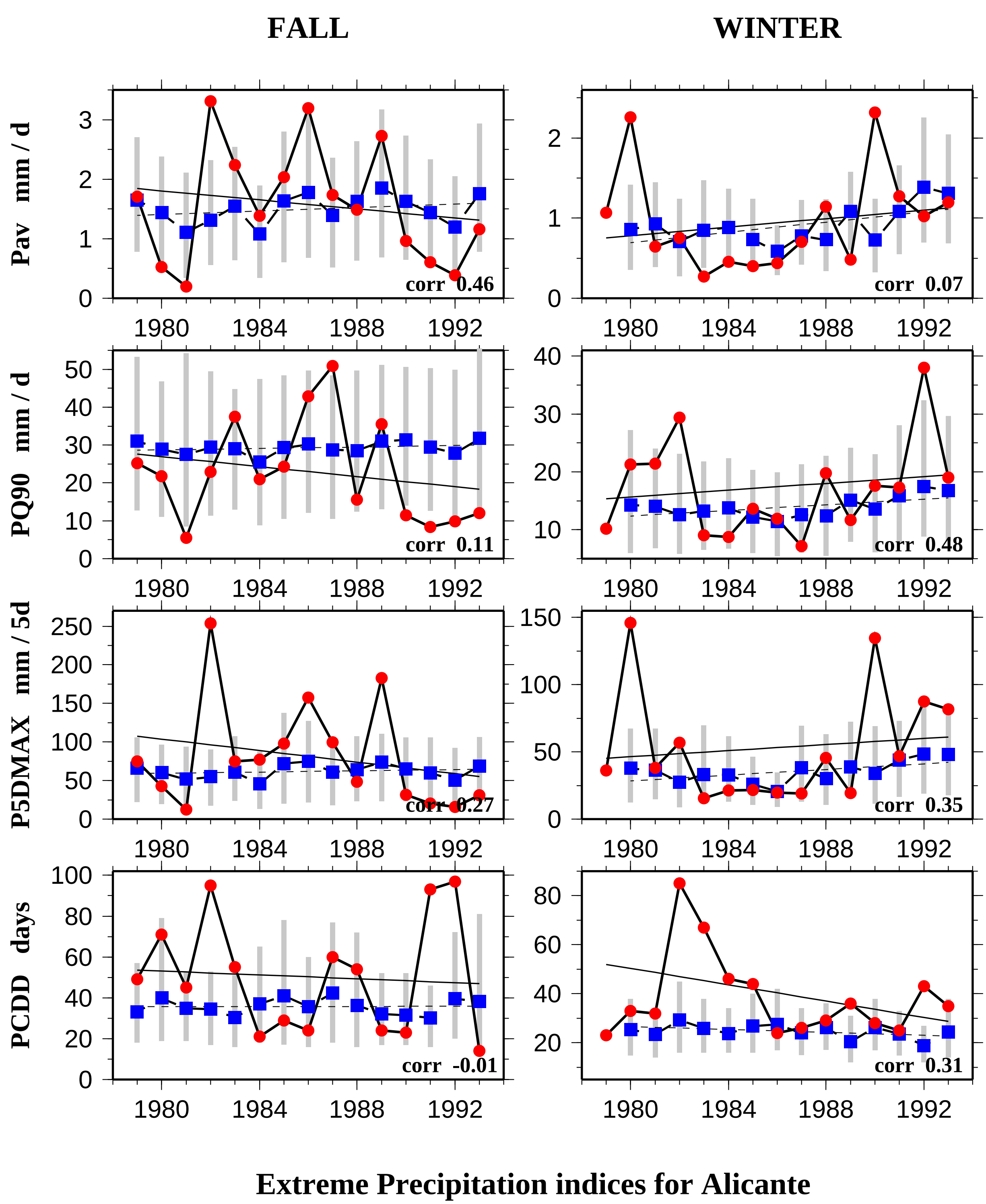

FALL
WINTER
Pav mm / d
PQ90 mm / d
P5DMAX mm / 5d
PCDD days
corr 0.46
corr 0.07
corr 0.11
corr 0.48
corr 0.27
corr 0.35
corr -0.01
corr 0.31
1980
1984
1988
1992
Extreme Precipitation indices for Alicante

Figure 19:

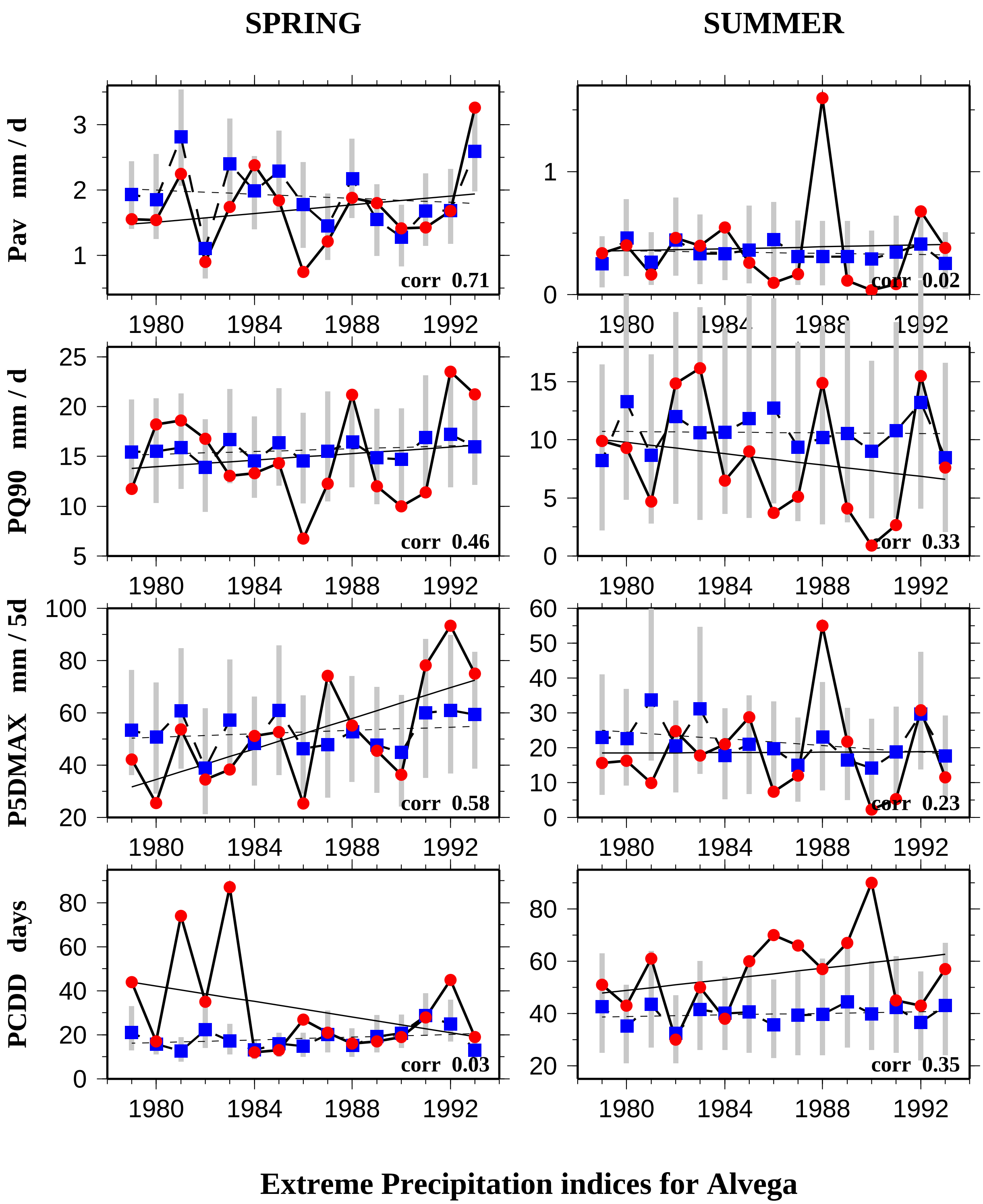
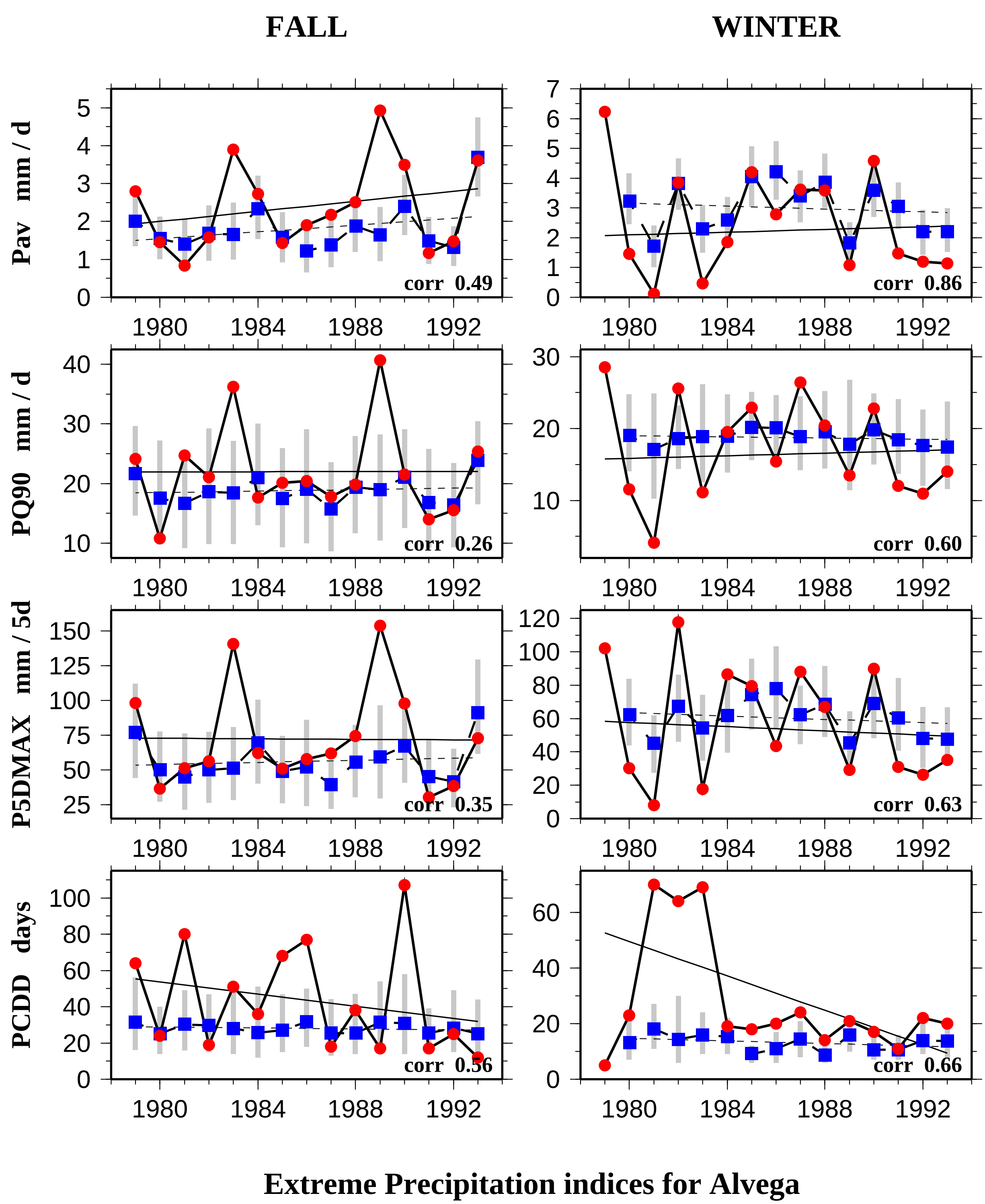

SPRING
SUMMER
Pav mm / d
PQ90 mm / d
P5DMAX mm / 5d
PCDD days
corr 0.71
corr 0.02
corr 0.46
corr 0.33
corr 0.58
corr 0.23
corr 0.03
corr 0.35
1980
1984
1988
1992
Extreme Precipitation indices for Alvega

Figure 20:



FALL
WINTER
Pav mm / d
PQ90 mm / d
P5DMAX mm / 5d
PCDD days
corr 0.49
corr 0.86
corr 0.26
corr 0.60
corr 0.35
corr 0.63
corr 0.56
corr 0.66
1980
1984
1988
1992
Extreme Precipitation indices for Alvega

Figure 21: