Trends of extreme precipitation and temperature associated climatic conditions in the German part of the Rhine basin from 1958 to 2001

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Introduction

It has been reported that an increase of precipitation has occurred in different parts of the world over the last 100 years. An increase by 10 – 50% has been observed over Northern and Western Europe (Watson et al., 1998). Although it has been difficult to link this increase with the often-mentioned global warming phenomenon, many climate model studies suggest an increase in the mean precipitation and the frequency of extremes due to an increase in the atmospheric temperature (Bony et al., 1995; Meehl et al., 2000).

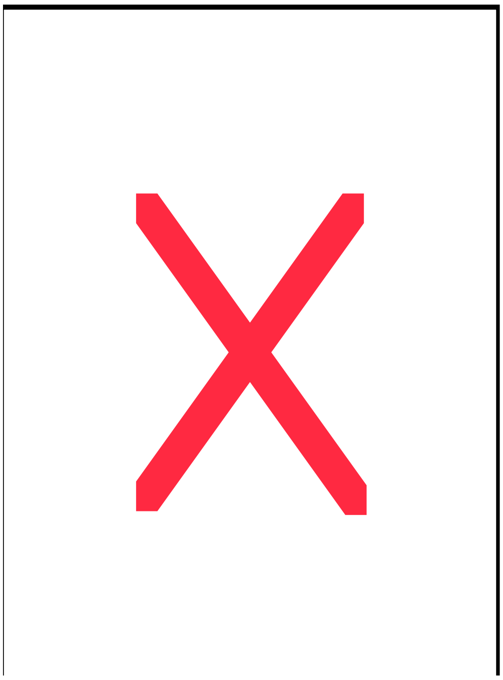
In this study, analysis of precipitation and temperature data from many observation stations in the Rhine basin was made to investigate whether there have been any significant changes in the extreme precipitation and temperature over the last half century. Further investigation was also made to see whether the observed changes in precipitation are scale dependant.

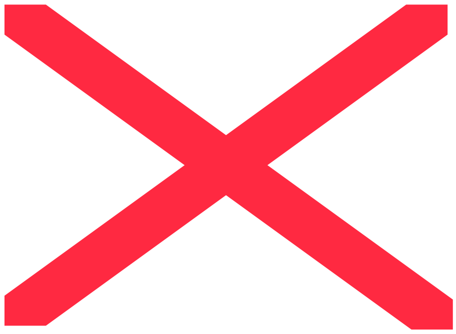
Database and Methodology

Daily time series of precipitation for the period between 1958 and 2001were obtained from the German weather service for well over 1500 stations that are distributed over the German part of the Rhine basin. Maximum and minimum daily temperature time series were also obtained for the same time period from around 300 stations covering the area of interest. Based on the amount of missing records, data from 611 precipitation stations and 232 temperature stations were used for this study. Figures 1 shows the precipitation stations and temperature stations used in this study.

Annual and seasonal extreme indices related to precipitation and temperature were calculated on the yearly basis for the entire period of investigation for all precipitation and temperature stations using the STARDEX Diagnostic Extremes Indices Software and detailed investigation was carried out on the selected indices shown in table 1. The base period for normals was chosen from 1961 to 1990.

As precipitation shows more spatial and temporal variability than temperature, the indices related to precipitation were also investigated at different spatial scales. The daily precipitation amounts were interpolated on grid basis over the study area and the indices were calculated for all grids. The interpolation was carried out using the External Drift Kriging approach (Ahmed & de Marsily, 1987) by making use of variograms calculated for each day and considering elevation as a drift parameter. The investigation was carried out for grid sizes of 5, 10, 25, and 50km.





a) Precipitation stations b) temperature stations

Fig. 1: Geographic distribution of the precipitation and temperature stations.

Table 1: STARDEX Diagnostic Extreme Indices on which detailed investigation was made

Designation	Description
	a) Precipitation related indices
Prec90p	90th percentile of rainday amounts (mm/day)
644R5d	Greatest 5-day total rainfall
646SDII	Simple Daily Intensity (rain per rainday)
641CDD	Max no. of consecutive dry days
691R90T	% of total rainfall from events > long-term 90th percentile
692R90N	No. of events > long-term 90th percentile of raindays
	b) Temperature related indices
Tmax90p	Tmax 90th percentile
Tmin10p	Tmin 10th percentile
125Fd	Number of frost days Tmin < 0 °C
144HWDI	Heat wave Duration

Results

The results of the trend analysis for the precipitation stations and temperature stations are summarized in tables 2 and 3 respectively. The spatial patterns of the trends and their significances are shown in the appendix.

Precipitation related indices

As shown in table 2, the trends in all the selected indices show seasonal variability. The indices related to heavy precipitation show clear positive trends in winter with a large number of significant trends. Although there were a few stations with negative trends, almost none show significant negative trend. The spatial distribution of the stations with significant trends also shows that many of them are located along the higher elevation zones. In contrast, the indice related to drought condition, 641CDD, showed more negative trend than positive, although none of them are significant.

In spring and autumn, the indices related to heavy precipitation show more positive trends than negative. But there are very few stations that show negative significant trends. Although a clear positive trend like in the winter is not obtained, there are a considerable number of stations with positive significant trends. 98% of the stations show a negative trend in autumn for the indice 641CDD with a large number of significant trends, while negative and positive trends are nearly balanced with little significant trends in spring.

In summer, the indices related to heavy precipitation show negative trends with a considerable number of stations with significant negative trends. The indice related to drought condition also shows a positive trend with none of the stations showing a negative significant trend.

The effect of spatial and temporal variability of precipitation is noticed in the spatial pattern of the trends and the corresponding significances of the indices calculated for interpolated grid based precipitation series at different scales. The location of highly concentrated significant trends didn't show change due to up scaling. But pockets of significant trends were noticed to disappear at larger scales due to aggregation. The same happened with the magnitudes of the trends. Larger trend magnitudes encircled by lower magnitudes were noticed to be lowered and in some cases even a sign change in the trends was noticed (see appendix).

Indices related to temperature

The trends in the temperature related indices were also found to show seasonal variability (see table 3 and appendix). The maximum temperature shows a positive trend in winter, spring and summer with a large number of significant trends. In autumn, the trend is more of negative although less significant.

Positive significant trends were obtained for the minimum temperature in spring and summer, with 96% of the stations showing a positive trend with a lot of significant ones. The trend is balanced between negative and positive for winter and autumn with little significant trends.

The number of frost days has shown a significant decrease in winter and spring, whereas in summer and autumn a balance between positive and negative trends was observed with little significance.

The heat wave duration index has shown a positive trend in all seasons. But it was significant only in winter.

Summary

Indices related to heavy precipitation have shown a clear and significant positive trend in winter and significant negative trend in summer. In spring and autumn, the indices showed positive trend, although not as significant as in winter. The indice related to drought condition showed no significant trend in winter and spring, while positive and negative significant trends were noticed for summer and autumn respectively.

Up scaling of interpolated precipitation resulted in aggregation of pockets of areas with significant trend into non-significant ones.

All seasons except autumn have observed a significant increase in the maximum temperature, while no significant change was noticed for autumn. The minimum temperature has also increased significantly in spring and summer, while it remained fairly stable in the other seasons.

Table 2: Number of precipitation stations with positive/negative trends and the corresponding no. of significant ($p < 5\%$) trends for selected indices

Index	Winter				Spring				Summer				Autumn				Annual			
	+	+ sig	-	- sig	+	+ sig	-	- sig	+	+ sig	-	- sig	+	+ sig	-	- sig	+	+ sig	-	- sig
Prec90P	546	107	65	1	407	42	204	5	203	10	408	67	422	55	189	3	390	87	221	18
644R5D	599	121	12	0	415	21	196	0	149	5	462	54	446	53	165	2	403	59	208	10
646SDII	589	172	22	1	391	48	220	7	176	13	435	95	395	48	216	9	396	130	215	27
641CDD	122	0	489	2	395	11	216	3	496	65	115	0	8	0	603	122	69	0	542	50
691R90T	560	97	51	2	426	35	185	2	209	9	402	44	373	38	238	7	366	65	245	24
692R90N	541	86	70	1	461	37	150	2	122	4	489	82	534	121	77	2	417	83	194	11

Table 3: Number of temperature stations with positive/negative trends and the corresponding no. of significant ($p < 5\%$) trends for selected indices

Index	Winter				Spring				Summer				Autumn				Annual			
	+	+ sig	-	- sig	+	+ sig	-	- sig	+	+ sig	-	- sig	+	+ sig	-	- sig	+	+ sig	-	- sig
Tmax90p	217	128	15	1	201	81	31	3	198	97	34	9	76	14	156	24	201	102	31	7
Tmin10p	139	20	93	8	225	86	7	1	223	93	9	2	90	7	142	8	201	44	30	3
125Fd	47	18	185	86	21	9	211	76	30	10	130	23	84	14	148	22	30	18	202	96
144HWDI	189	88	22	1	198	26	33	3	199	29	23	4	186	2	46	4	203	66	28	3

References

Ahmed, S. and de Marsily, G., 1987. Comparison of geostatistical methods for estimating transmissivity using data on transmissivity and specific capacity. *Water Resour. Res*., 23(9): 1717 – 1737.

Bony, S., Duvel, J.P., and LeTreut, H., 1995. Observed dependence of the water vapour and clear-sky greenhouse effect on sea surface temperature. Climate Dyn., 11: 307 – 320.

Meehl, G.A., Zwiers, F., Evans, J., Knutson, T., Mearns, L., and Whetton, P., 2000. Trends in Extreme weather and climate events: Issues related to modelling extremes in projections of future climate change, Bulletin of the American Meteorological Society, 81(3): 427-436.

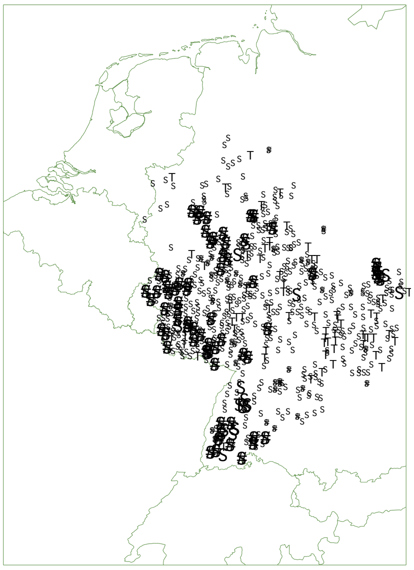
Watson, R.T., Zinyowera, M.C., and Moss, R.H., (Eds.),1998. The Regional Impacts of Climate Change. An Assessment of vulnerability, Cambridge.

Appendix

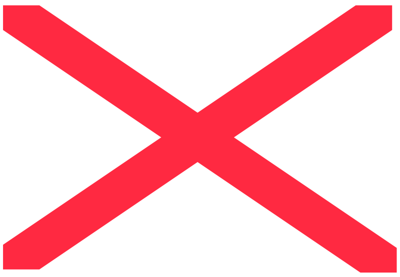
Trends of Precipitation related indices for the stations

Trend in the90th percentile of rainday amounts(prec90p)

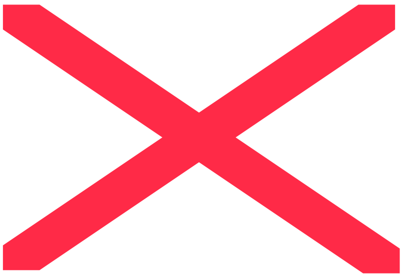
Annual



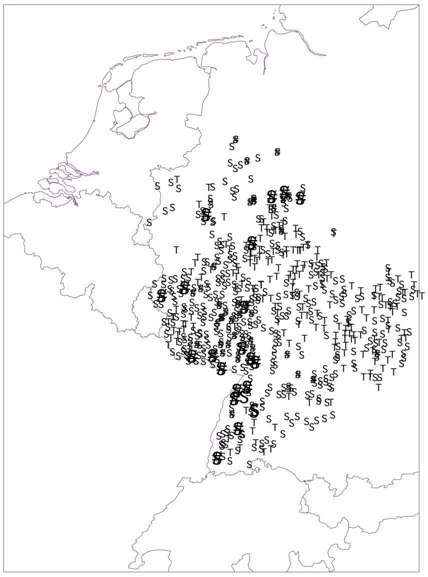
Winter



Spring



Summer



Autumn

Trend magnitudes

∆ < -30%

- -30% - -10%

. -10% – 0%

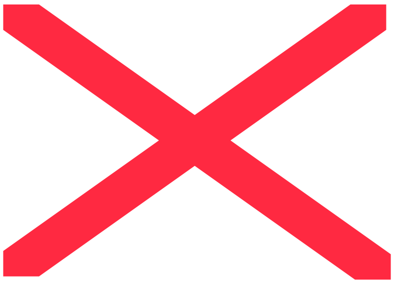
_ 0% – 10%

_ 10% – 30%

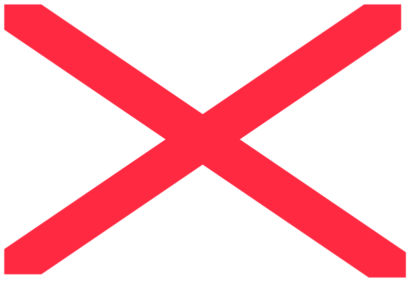
_ >30%

Dark- significant

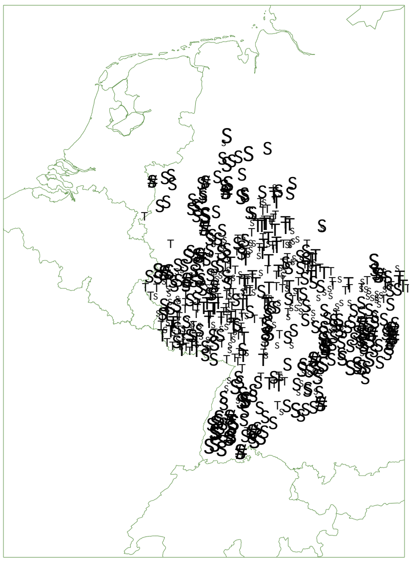
Trend in the greatest 5 day total rainfall (644R5D)



Annual

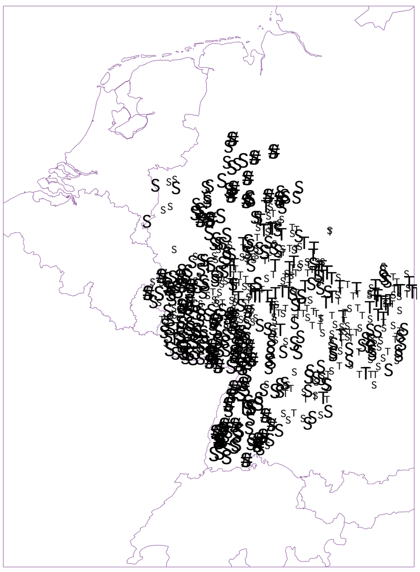


Winter



Spring

Summer



Autumn

Trend magnitudes

∆ < -30%

-30% - -10%

-10 – 0%

0% – 10%

10% – 30%

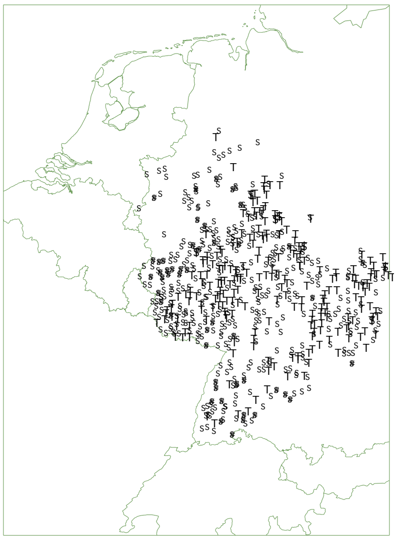
>30%

Dark- significant

Trend in Simple daily intensity (646SDII)

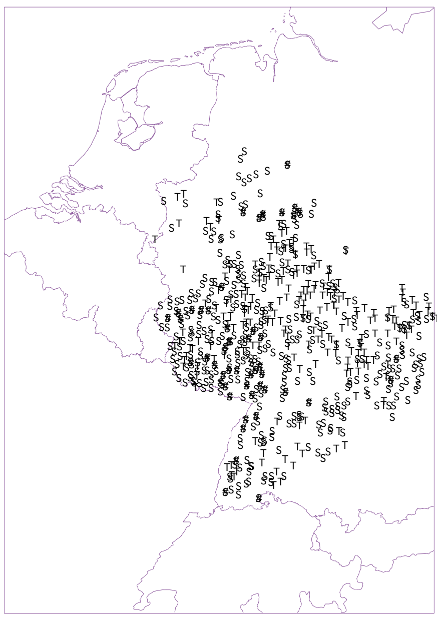
Annual

Winter



Spring

Summer



Autumn

Trend magnitudes

Δ < -30%

- -30% - -10%

- -10 – 0%

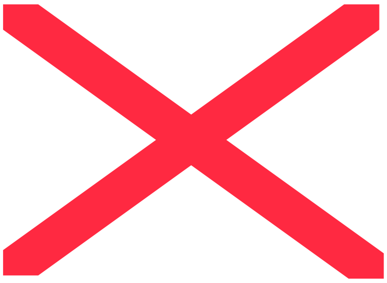
_ 0% – 10%

_ 10% – 30%

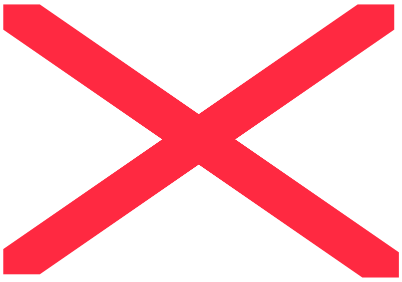
_ >30%

Dark- significant

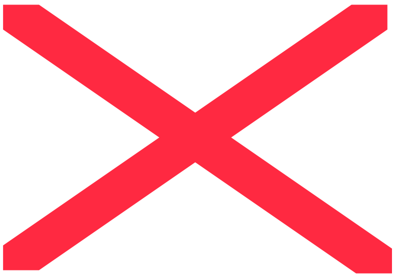
Trend in maximum number of consecutive dry days (641CDD)



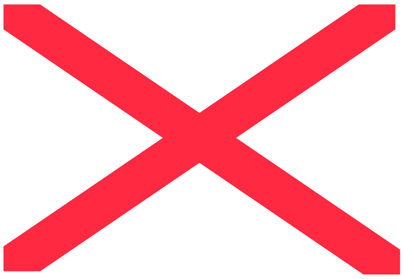
Annual



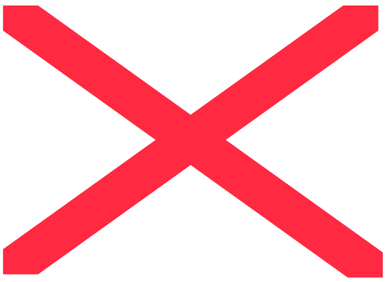
Winter



Spring



Summer



Trend magnitudes

Δ < -30%

-30% - -10%

-10 – 0%

0% – 10%

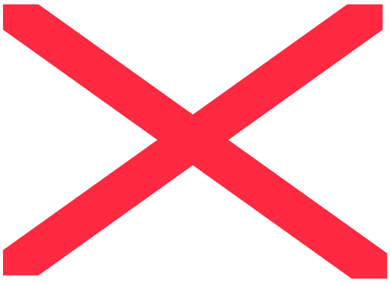
10% – 30%

>30%

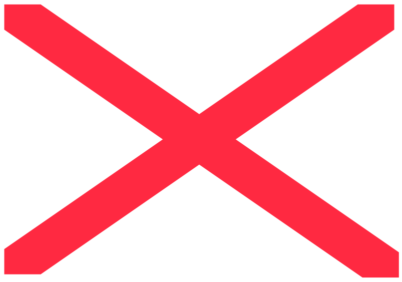
Dark- significant

Autumn

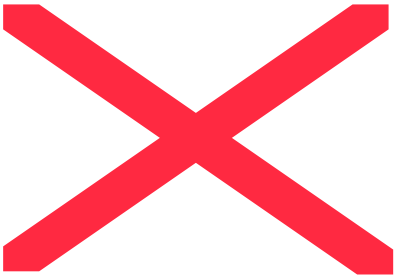
Trend in the % of total rainfall from events greater than long term 90th percentile (691R90T)



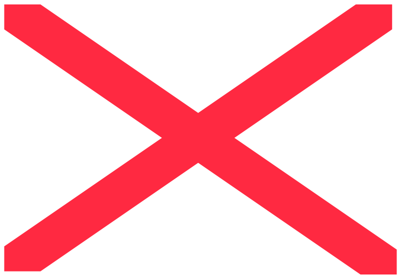
Annual



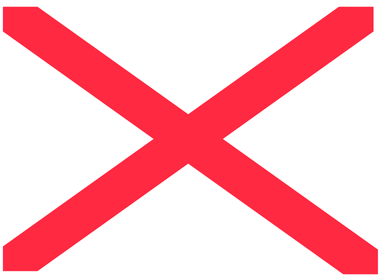
Winter



Spring



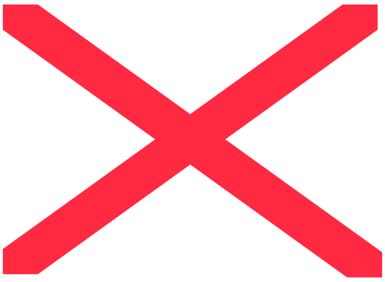
Summer



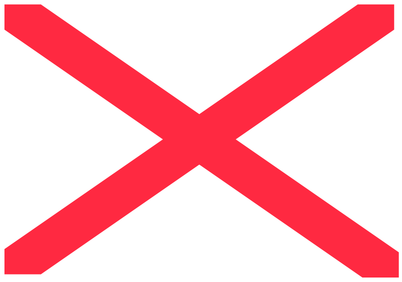
Autumn

Trend magnitudes
Δ < -30%
-30% - -10%
-10 – 0%
0% – 10%
10% – 30%
>30%
Dark- significant

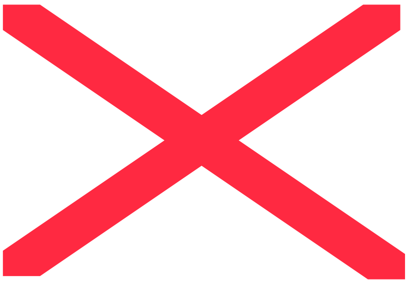
Trend in the number of events greater than the long term 90th percentile of raindays (692R90N)



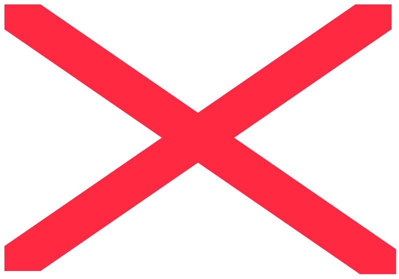
Annual



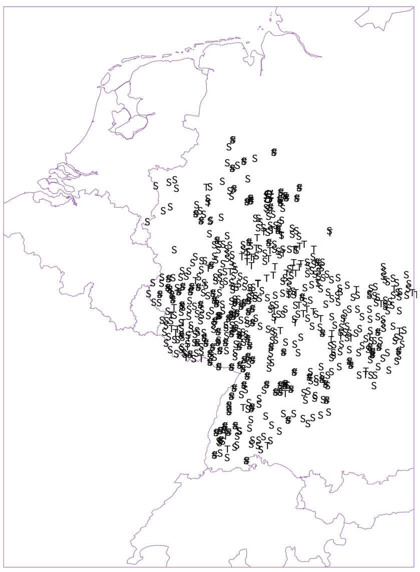
Winter



Spring



Summer



Autumn

Trend magnitudes

∆ < -30%

-30% - -10%

-10 – 0%

0% – 10%

10% – 30%

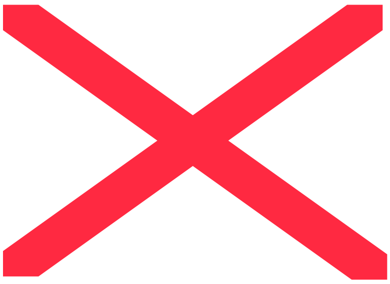
>30%

Dark- significant

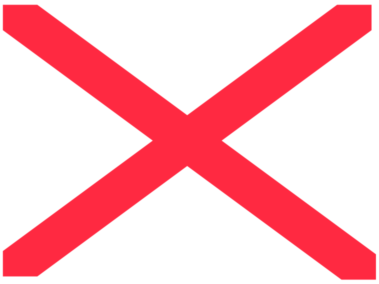
Trends of indices for grid based interpolated precipitation

(5km grid size)

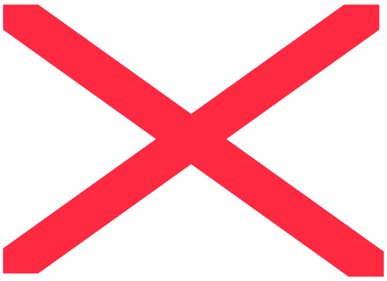
Trend in the 90th percentile of rainday amounts (prec90P)



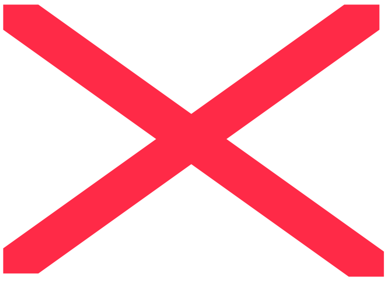
Annual



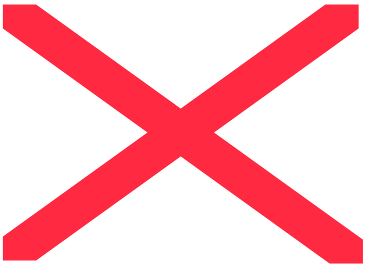
Winter



Spring



Summer

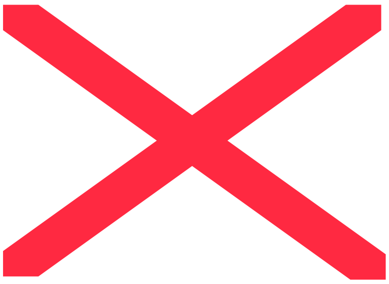


Autumn

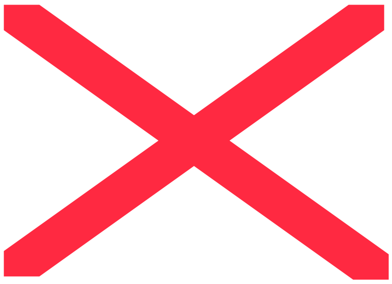
Trend magnitude

- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

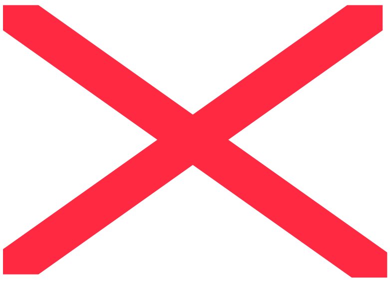
Significance of trend in prec90P



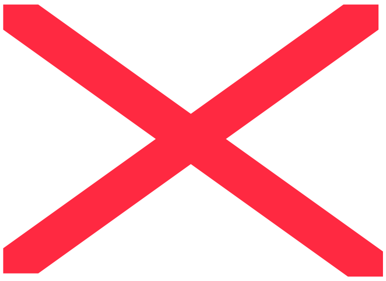
Annual



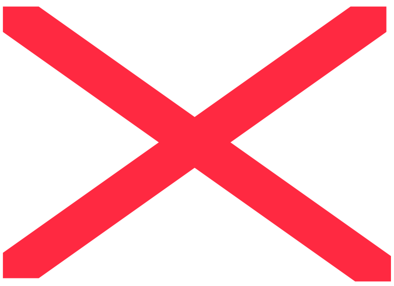
Winter



Spring



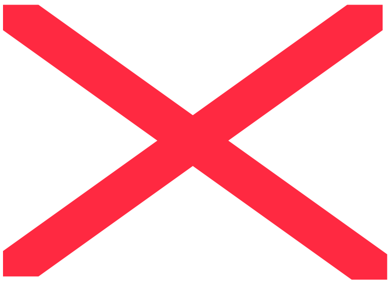
Summer



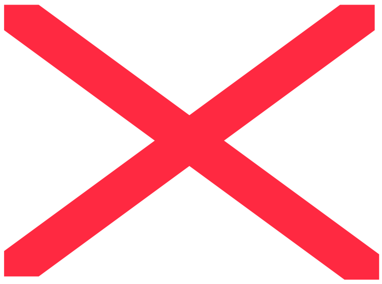
Autumn

Trend significance
Significant
Non significant

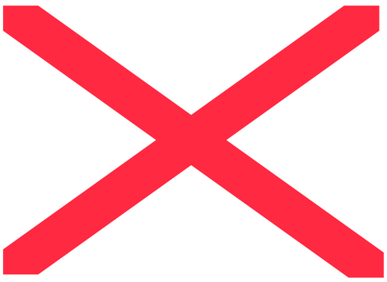
Trend in the greatest 5-day total rainfall (644R5d)



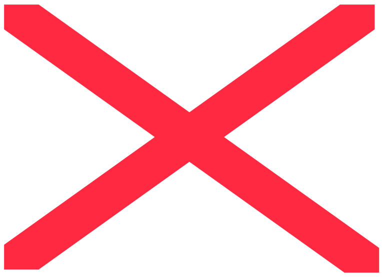
Annual



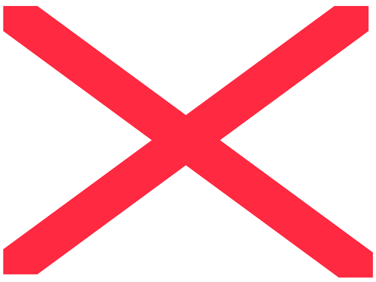
Winter



Spring



Summer

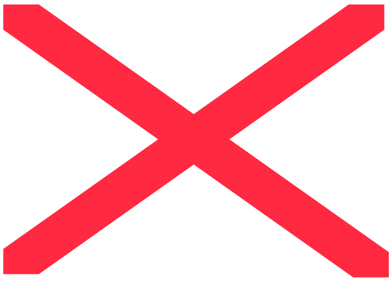


Trend magnitude

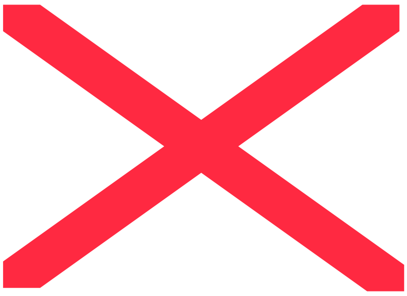
- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

Autumn

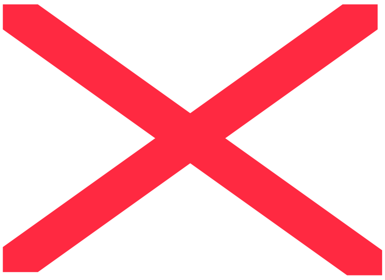
Significance of trend in 644R5d



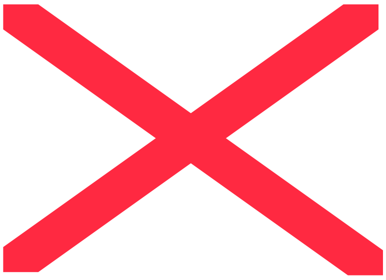
Annual



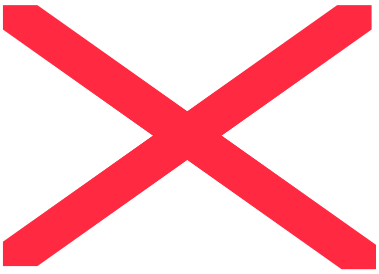
Winter



Spring



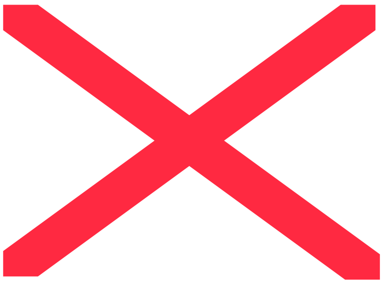
Summer



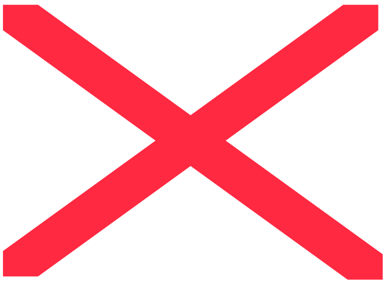
Autumn

Trend significance
Significant
Non significant

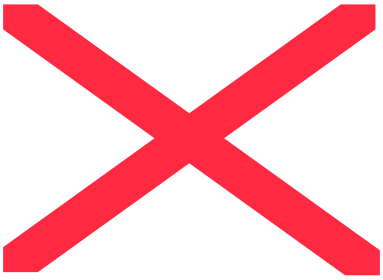
Trend in simple day intensity (646SDII)



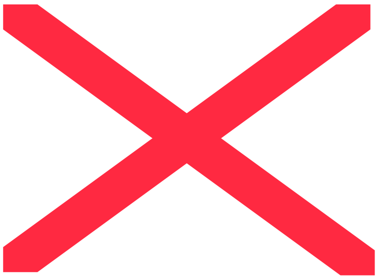
Annual



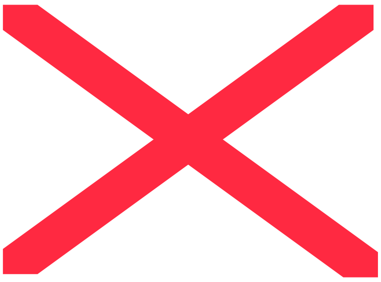
Winter

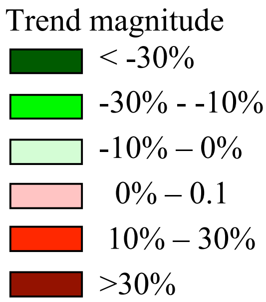


Spring



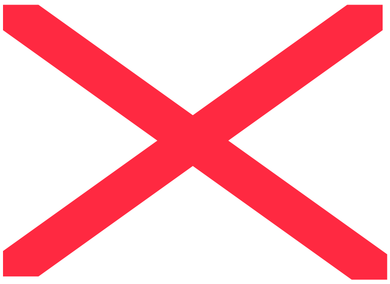
Summer



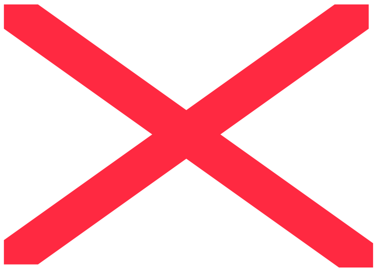


Autumn

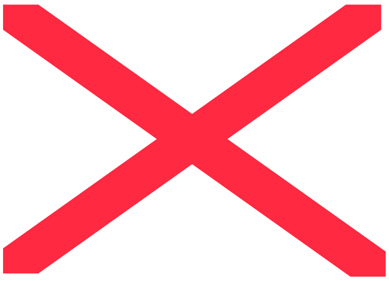
Significance of trend in 646SDII



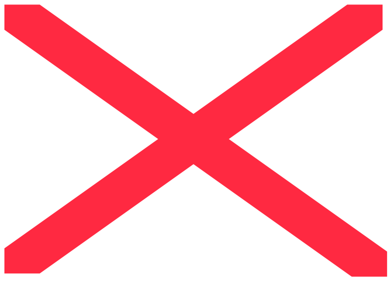
Annual



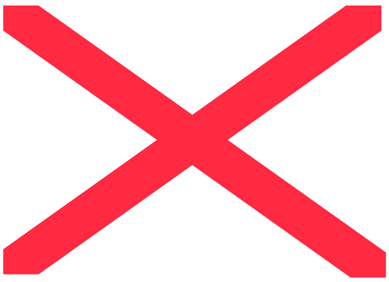
Winter



Spring



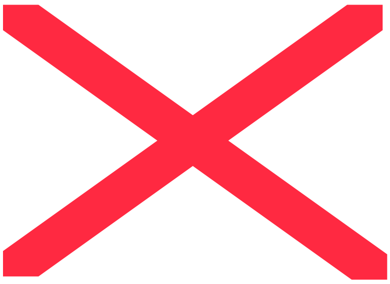
Summer



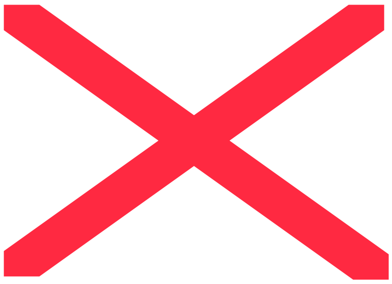
Autumn

Trend significance
Significant
Non significant

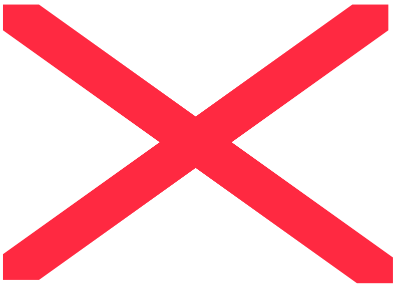
Trend in the maximum number of consecutive dry days (641CDD)



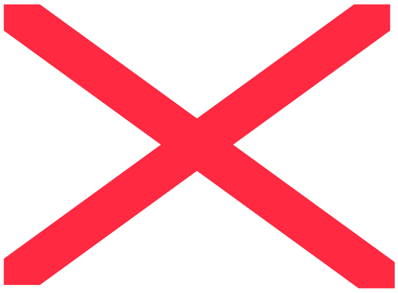
Annual



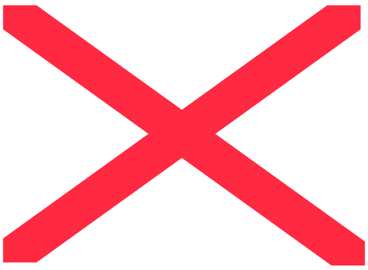
Winter



Spring



Summer

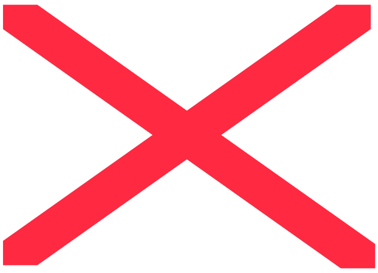


Autumn

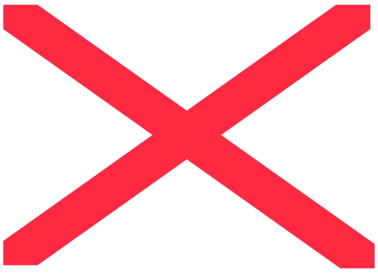
Trend magnitude

- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

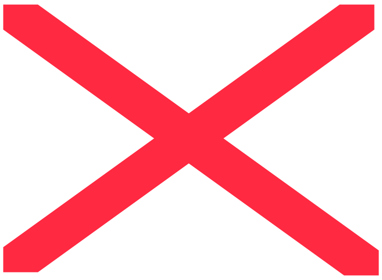
Significance of trend in 641CDD



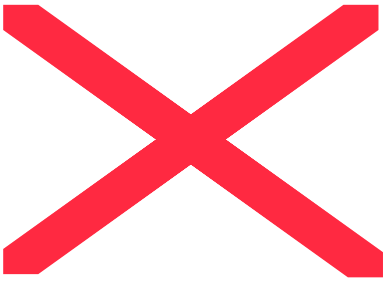
Annual



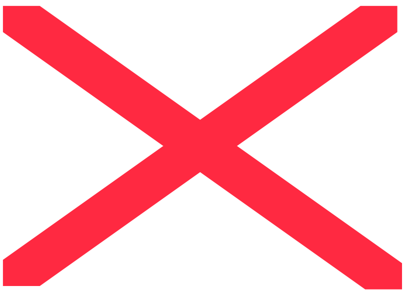
Winter



Spring



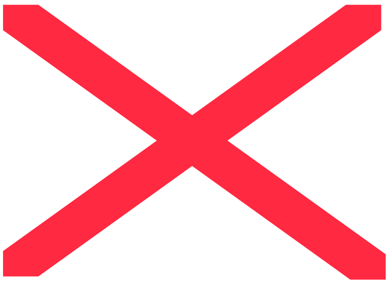
Summer



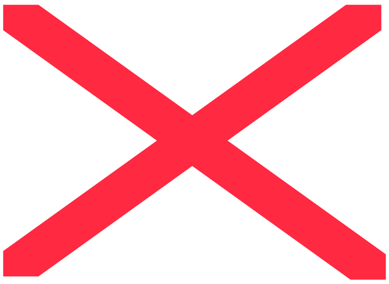
Trend significance
Significant
Non significant

Autumn

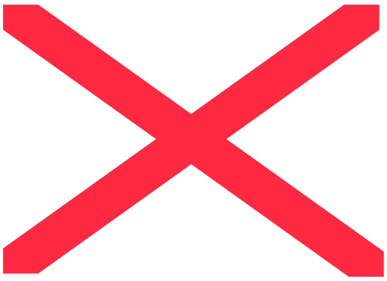
Trend in the % of total rainfall from events greater than long-term 90th percentile (691R90T)



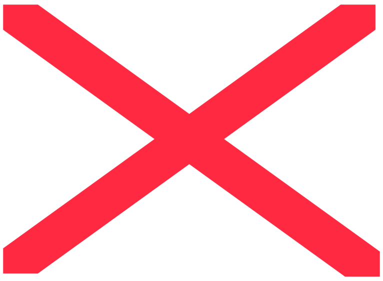
Annual



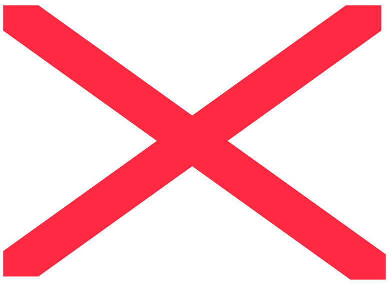
Winter



Spring



Summer

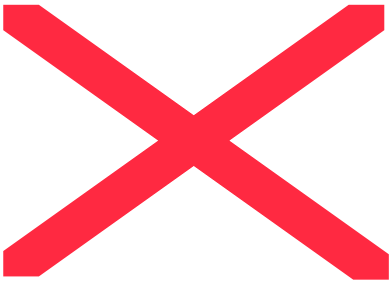


Trend magnitude

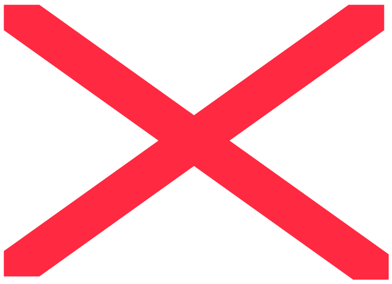
- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

Autumn

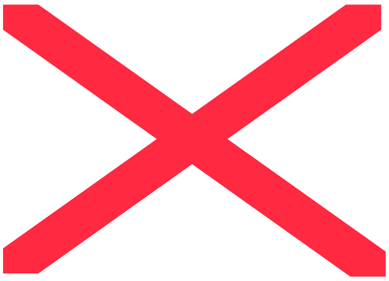
Significance of trend in 691R90T



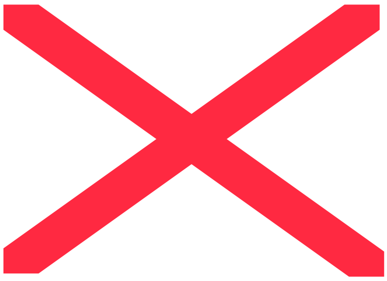
Annual



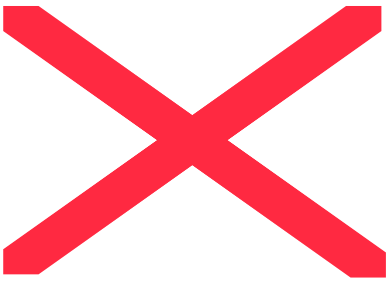
Winter



Spring



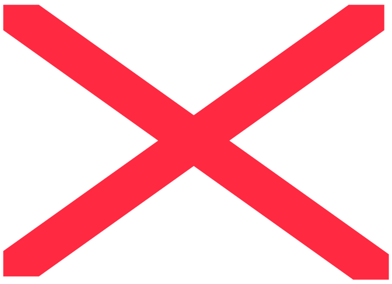
Summer



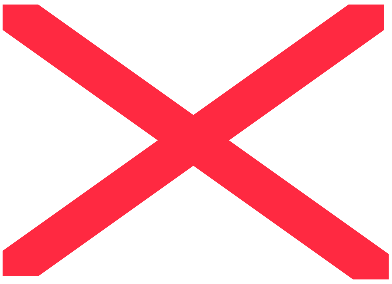
Autumn

Trend significance
Significant
Non significant

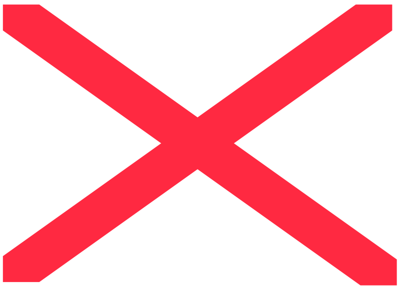
Trend in the number of events greater than the long term 90th percentile of raindays (692R90N)



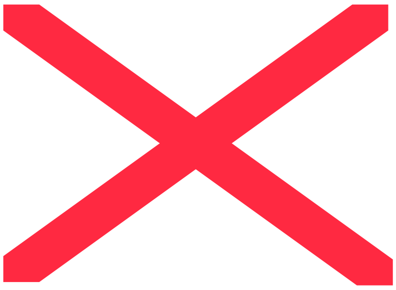
Annual



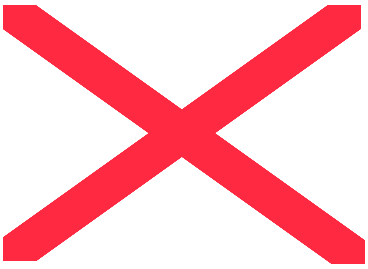
Winter

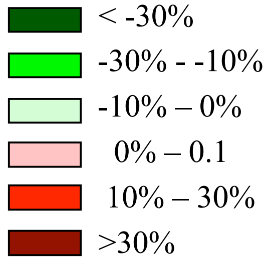


Spring



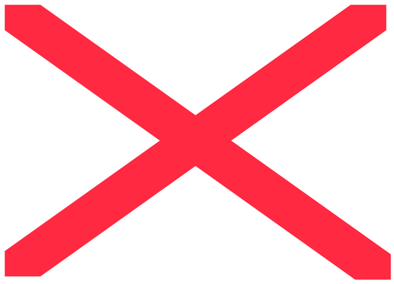
Summer



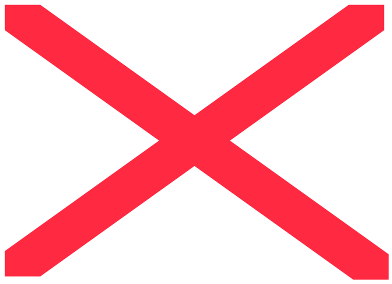


Autumn

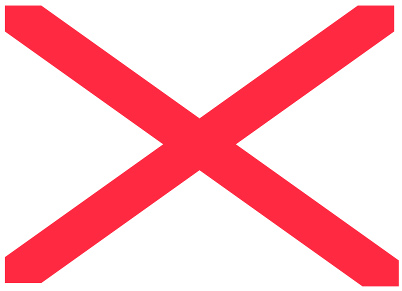
Significance of trends in 692R90N



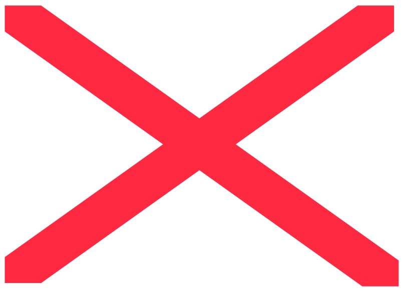
Annual



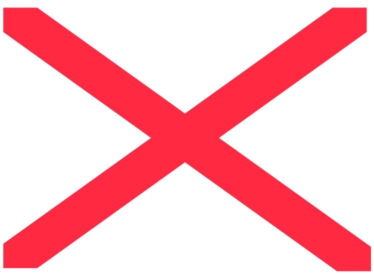
Winter



Spring



Summer

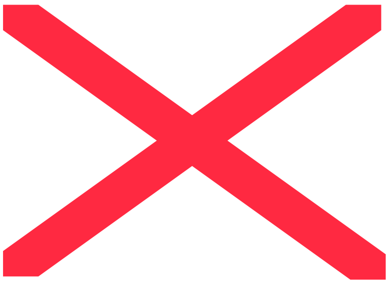


Autumn

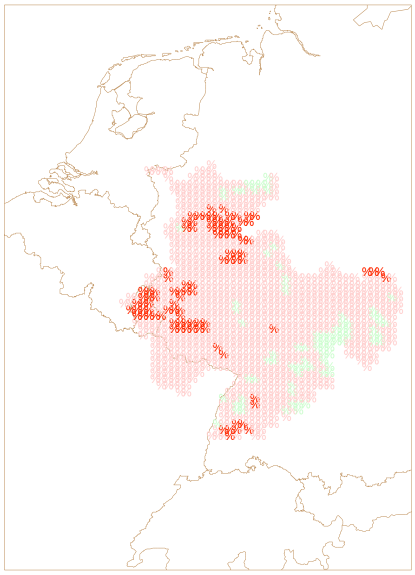
Trends of indices for grid based interpolated precipitation

(10km grid size)

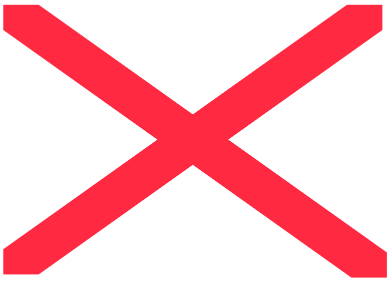
Trend in the 90th percentile of rainday amounts (prec90p)



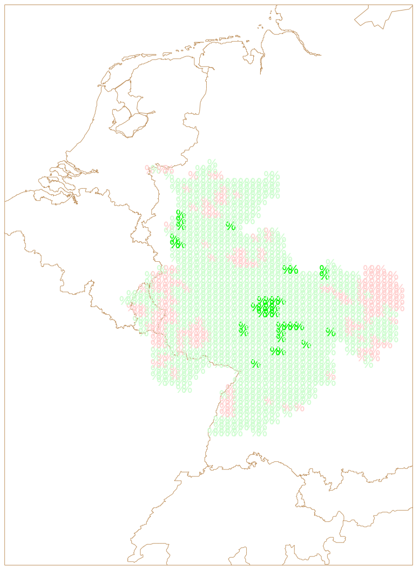
Annual



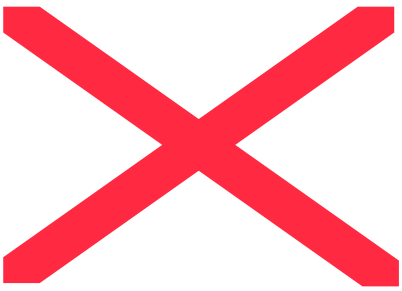
Winter

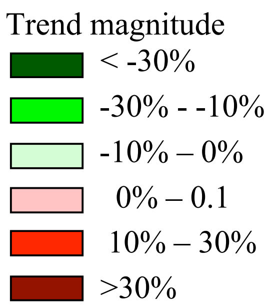


Spring



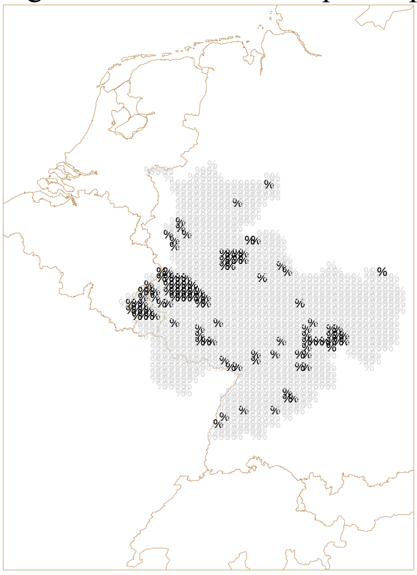
Summer



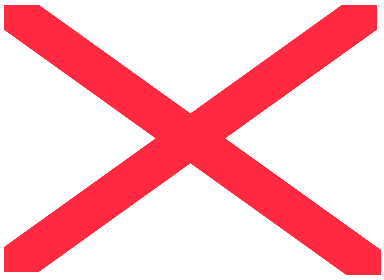


Autumn

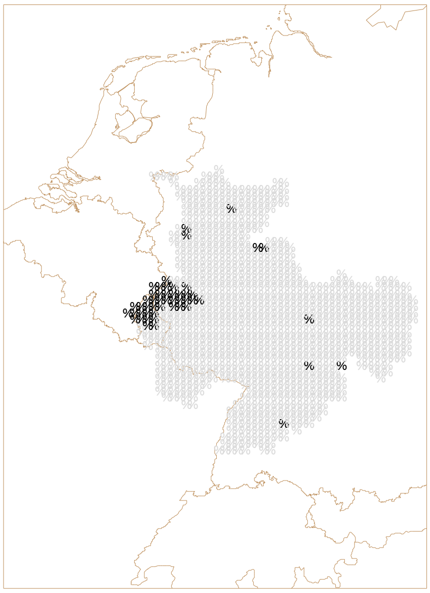
Significance of trends in prec90p



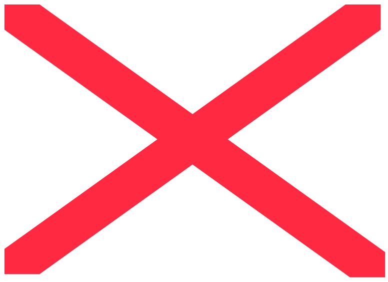
Annual



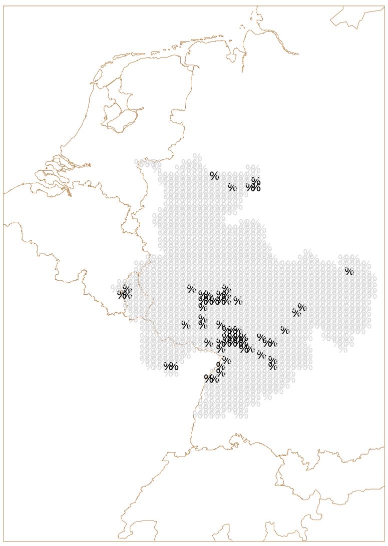
Winter



Spring



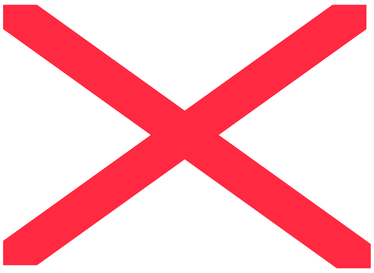
Summer



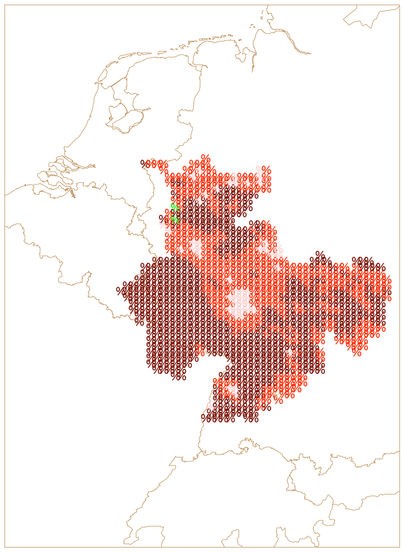
Autumn

Trend significance
Significant
Non significant

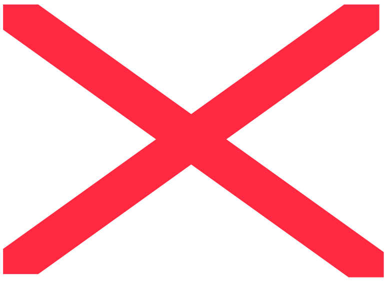
Trend in the greatest 5-day total rainfall (644R5d)



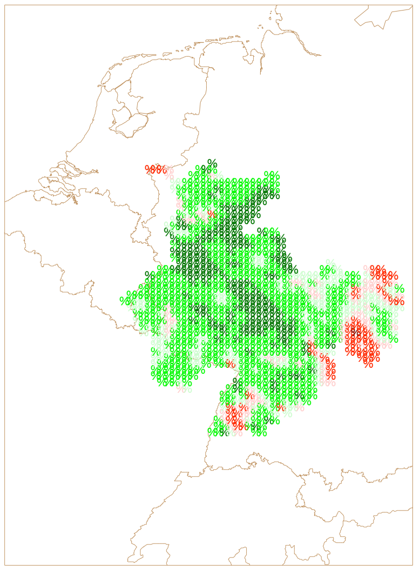
Annual



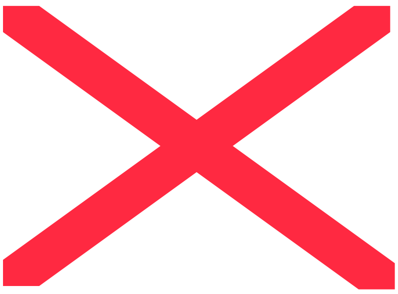
Winter

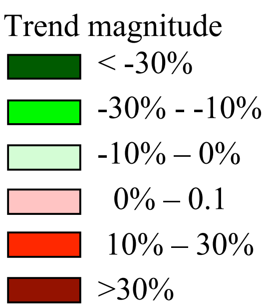


Spring



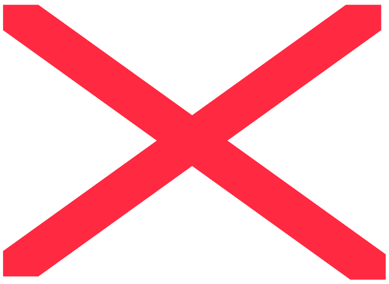
Summer



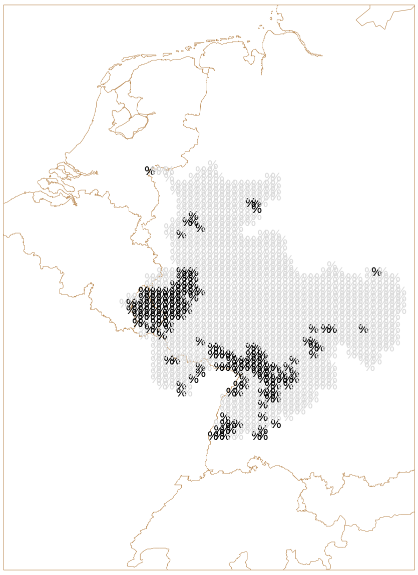


Autumn

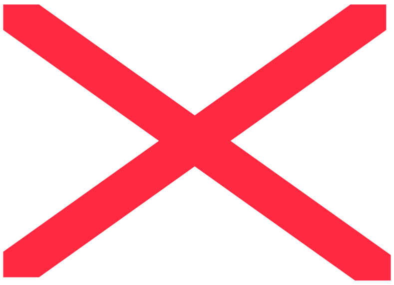
Significance of trends in 644R5d



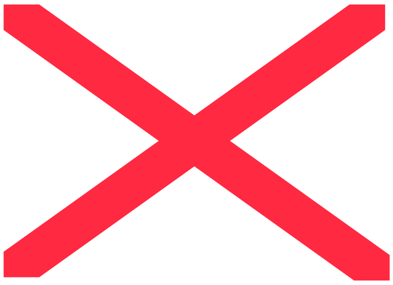
Annual



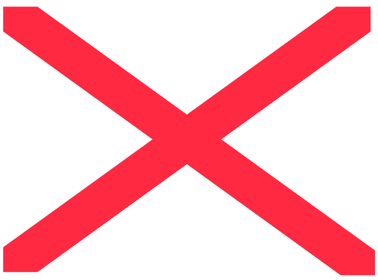
Winter



Spring



Summer

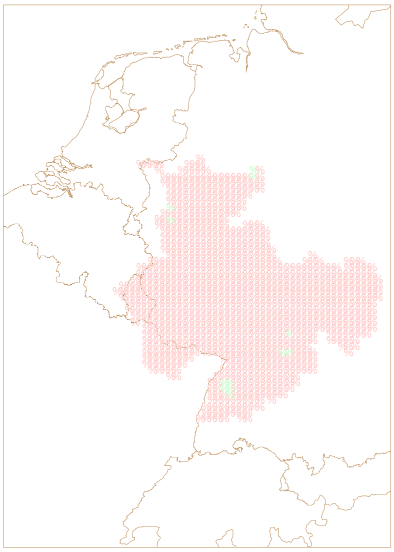


Trend significance
Significant
Non significant

Autumn

Trend in Simple daily intensity (646SDII)

Annual



Winter

Spring

Summer

Autumn

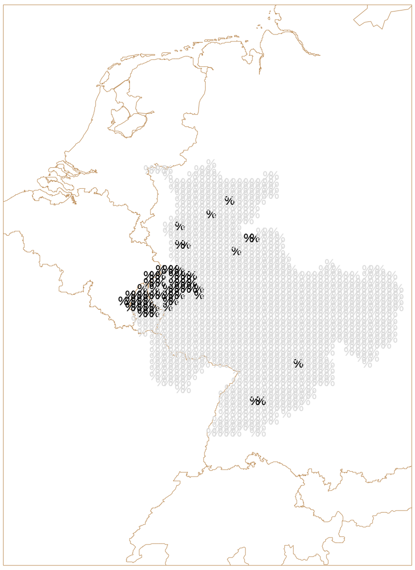
Trend magnitude

- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

Significance of trends in 646SDII

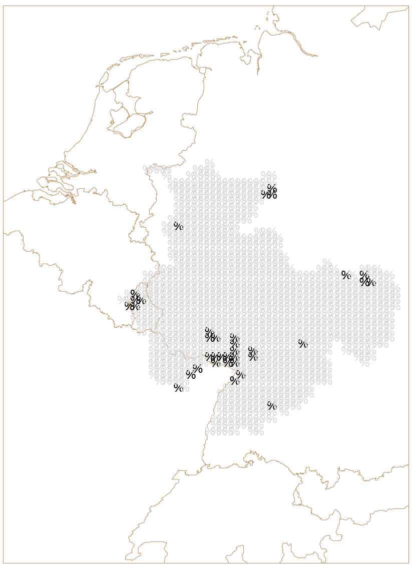
Annual

Winter



Spring

Summer



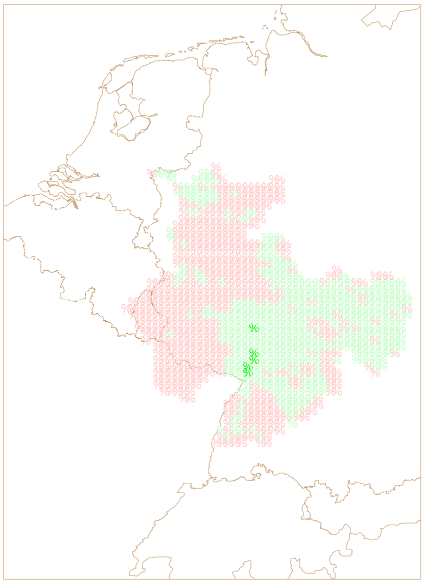
Autumn

Trend significance
Significant
Non significant

Trend in maximum number of consecutive dry days (641CDD)

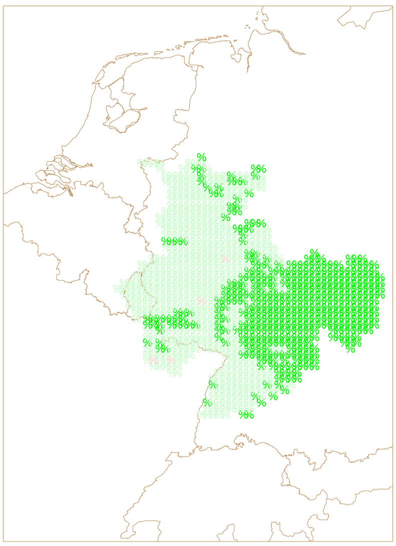
Annual

Winter



Spring

Summer



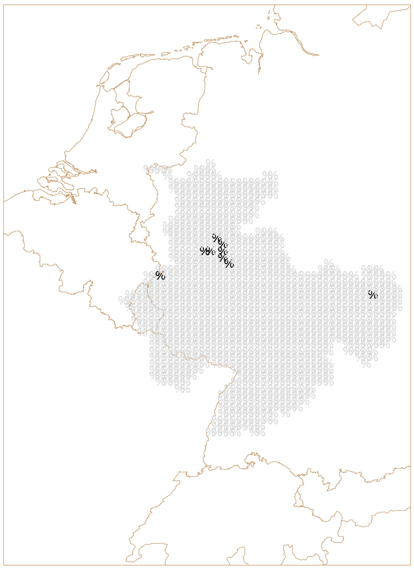
Autumn

Trend magnitude
- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

Significance of trends in 641CDD

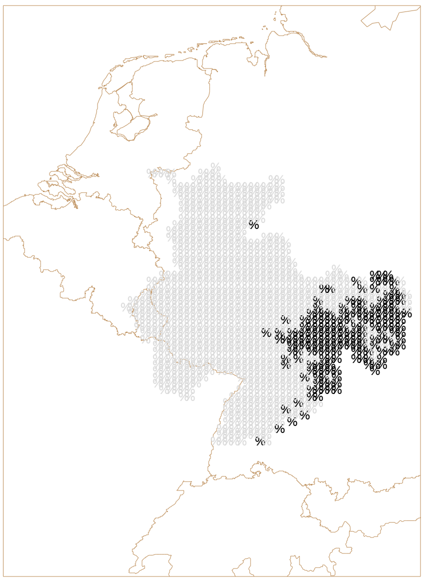
Annual

Winter



Spring

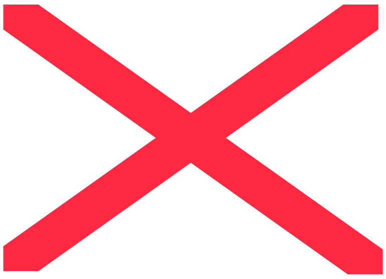
Summer



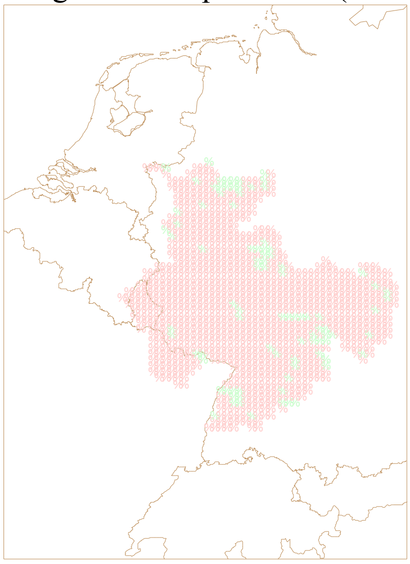
Autumn

Trend significance
Significant
Non significant

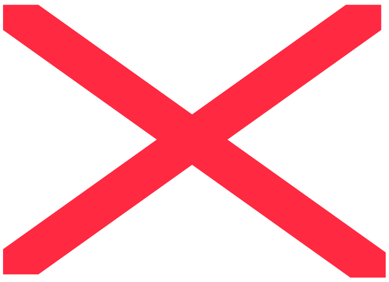
Trend in the % of total rainfall from events greater than the long-term 90th percentile (691R90T)



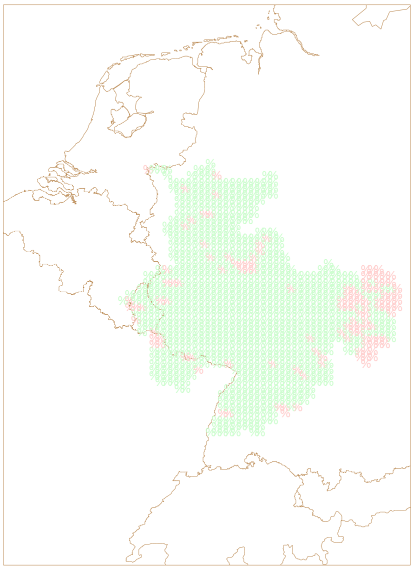
Annual



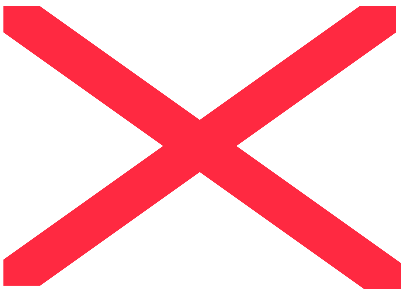
Winter

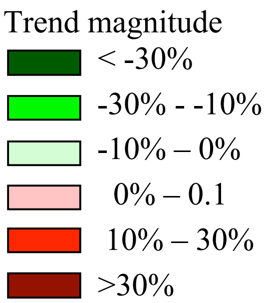


Spring



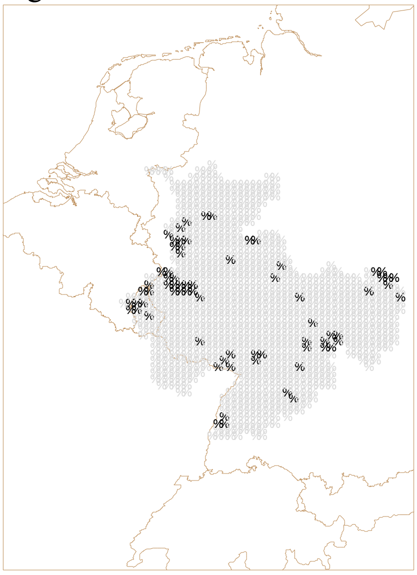
Summer



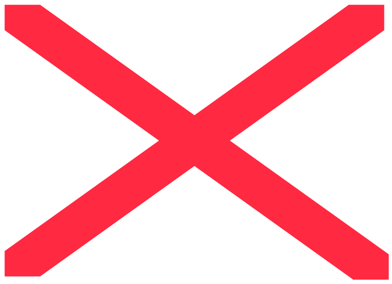


Autumn

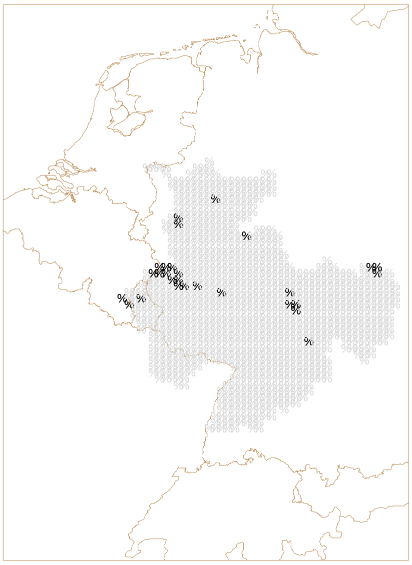
Significance of trends in 691R90T



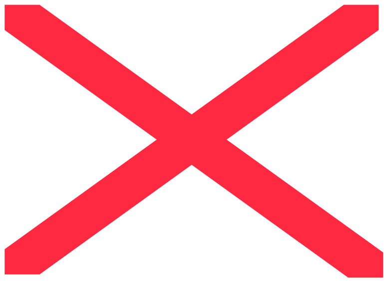
Annual



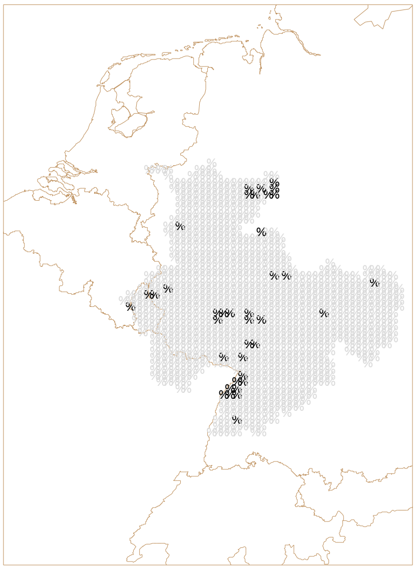
Winter



Spring



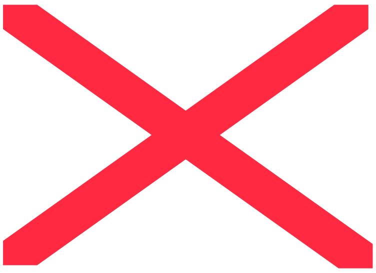
Summer



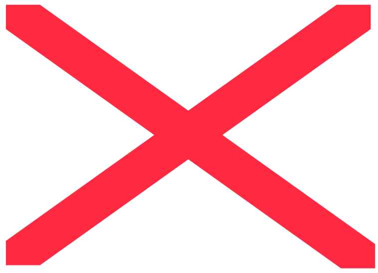
Autumn

Trend significance
Significant
Non significant

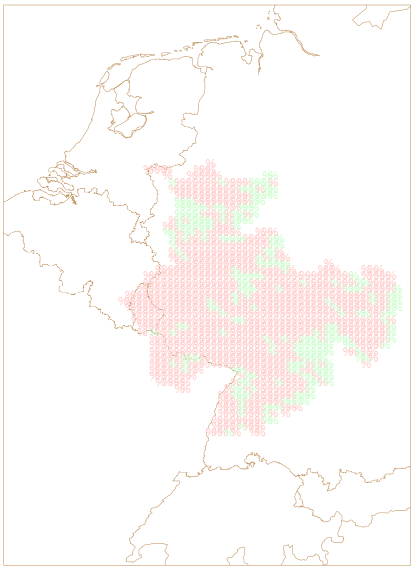
Trend in the number of events greater than the long-term 90th percentile of raindays (692R90N)



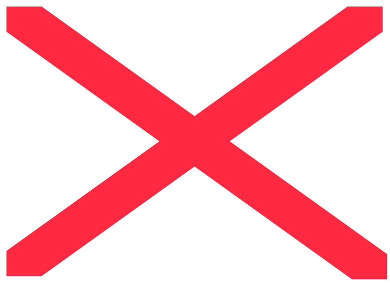
Annual



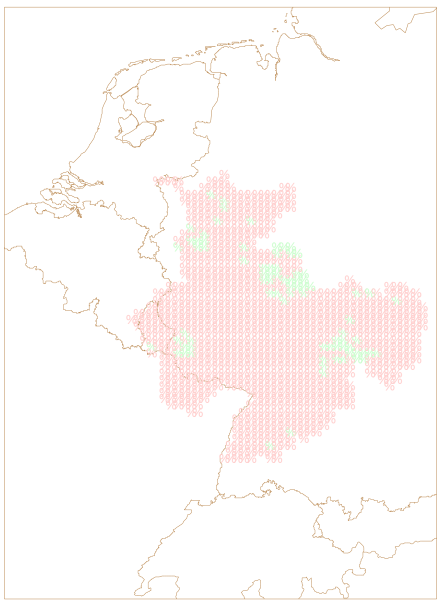
Winter



Spring

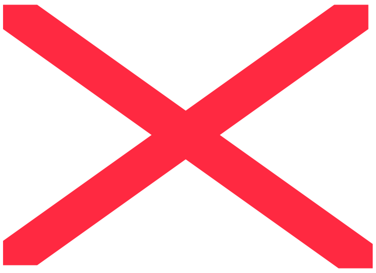


Summer

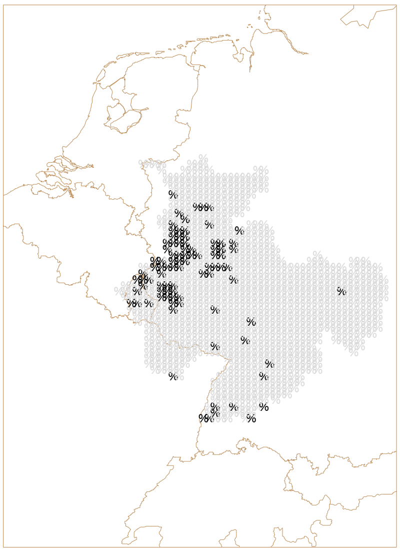


Autumn

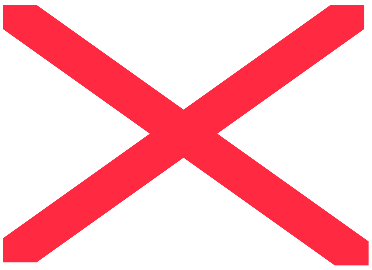
Significance of trends in 692R90N



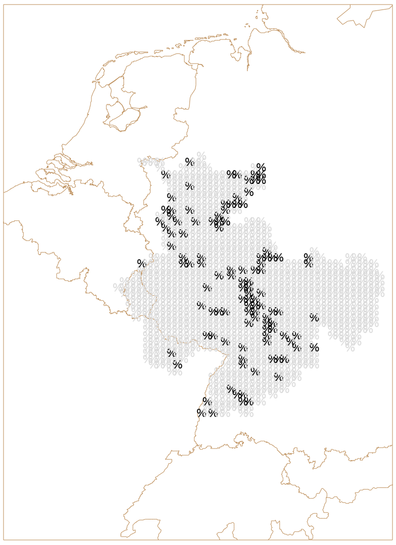
Annual



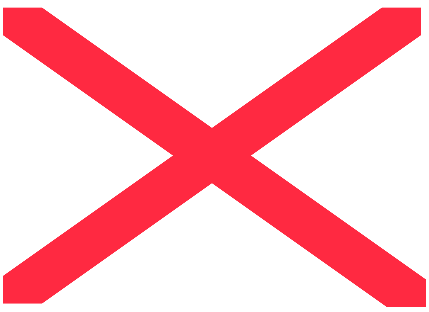
Winter



Spring



Summer



Autumn

Trend significance

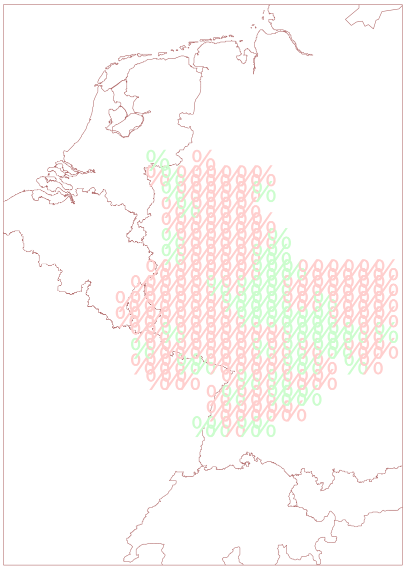
Significant

Non significant

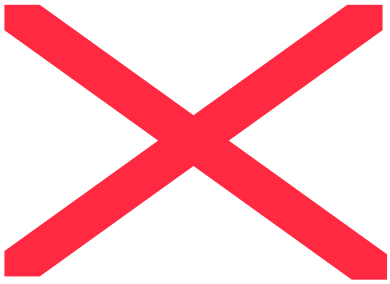
Trends of indices for grid based interpolated precipitation

(25km grid size)

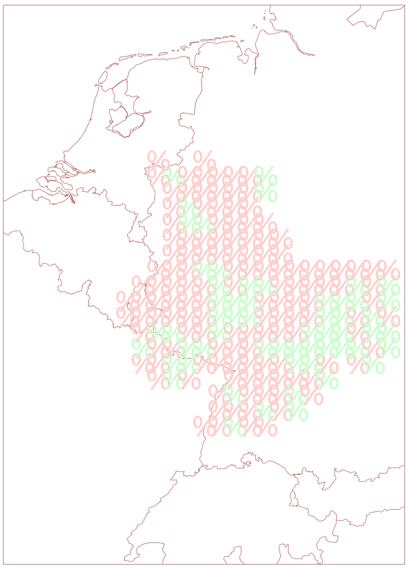
Trend in the 90th percentile of rainday amounts (prec90p)



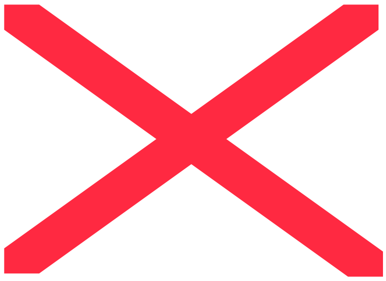
Annual



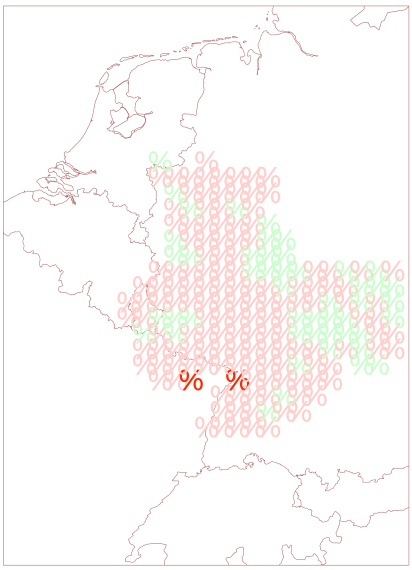
Winter



Spring



Summer

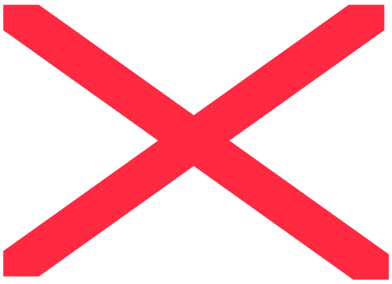


Autumn

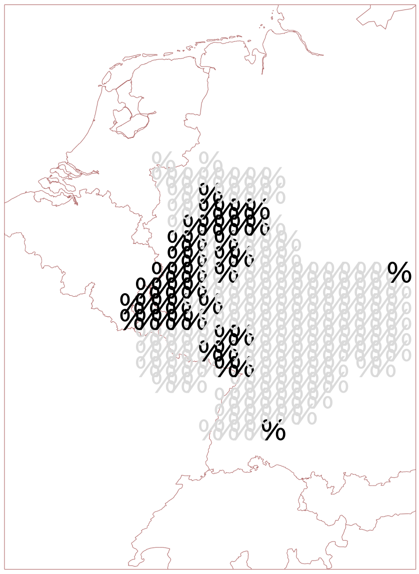
Trend magnitude

- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

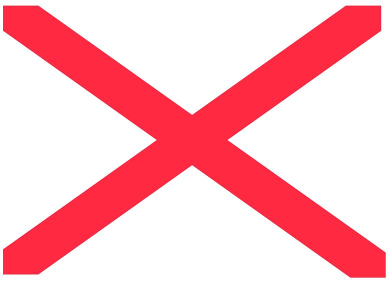
Significance of trends in prec90p



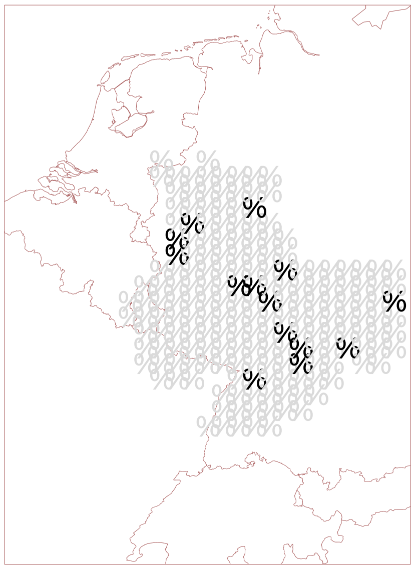
Annual



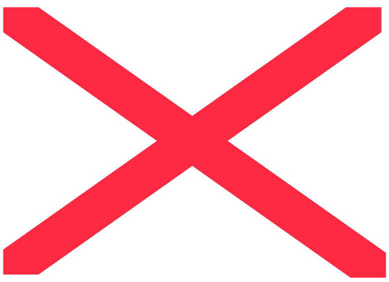
Winter



Spring



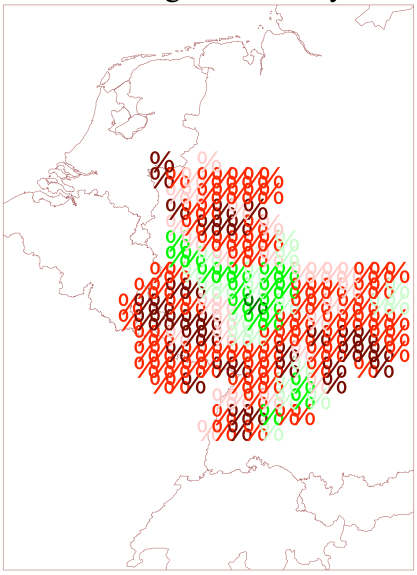
Summer



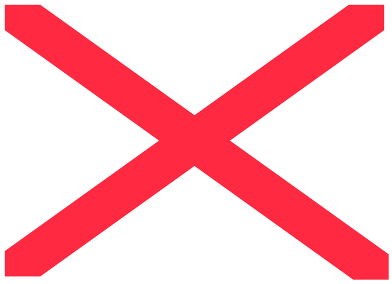
Autumn

Trend significance
Significant
Non significant

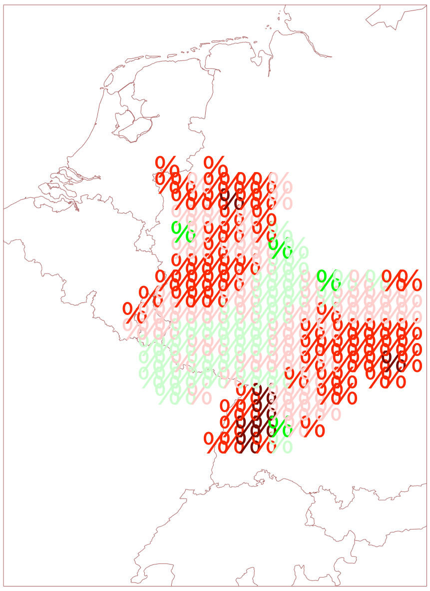
Trend in the greatest 5-day total rainfall (644R5d)



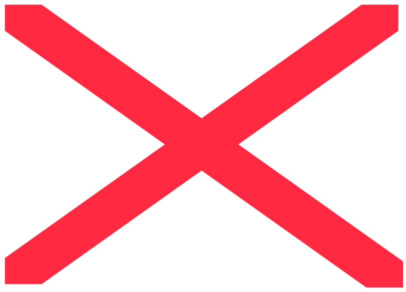
Annual



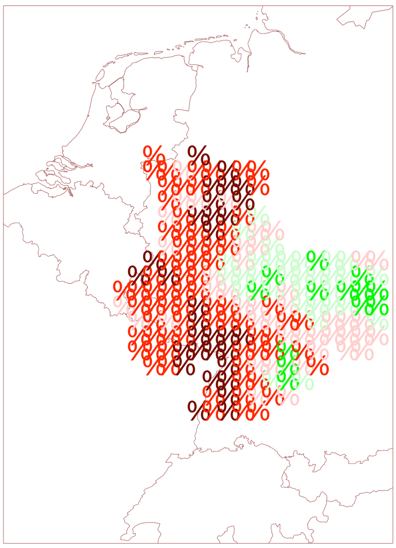
Winter



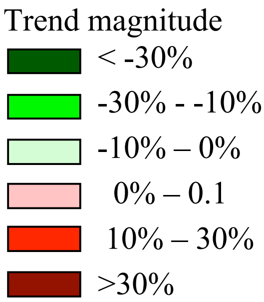
Spring



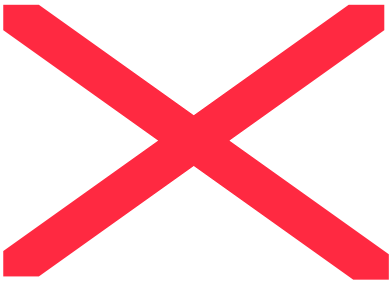
Summer



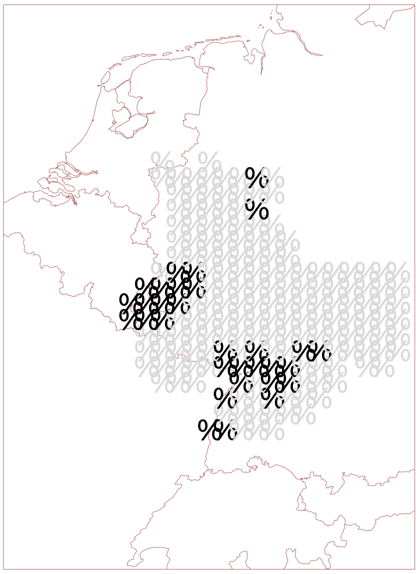
Autumn



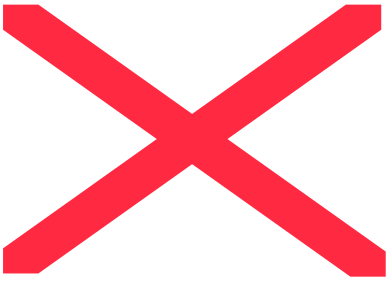
Significance of trends in 644R5d



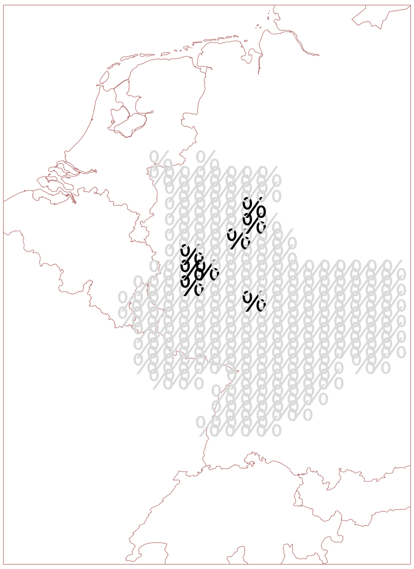
Annual



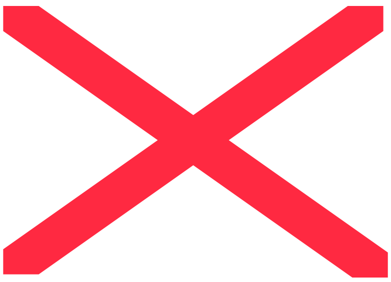
Winter



Spring



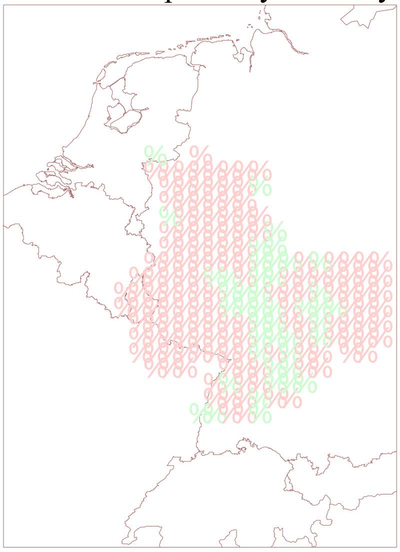
Summer



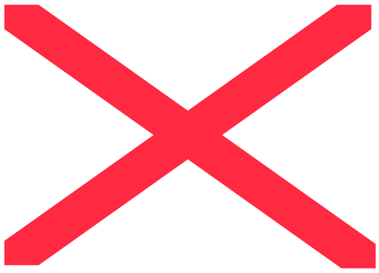
Autumn

Trend significance
- Significant
- Non significant

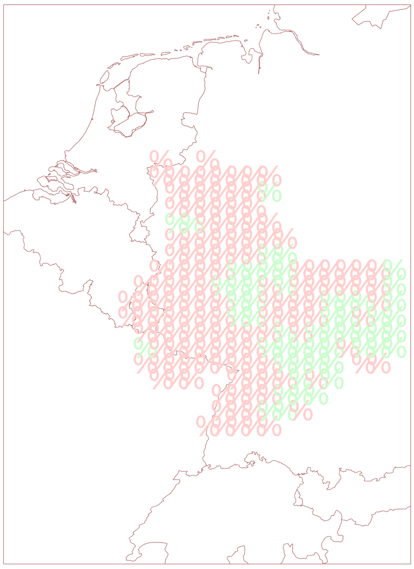
Trend in simple daily intensity (646SDII)



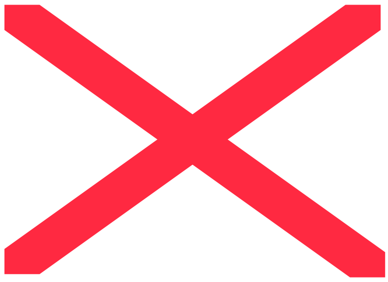
Annual



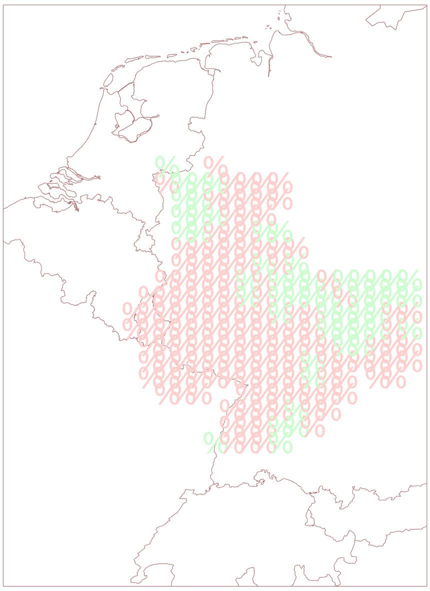
Winter



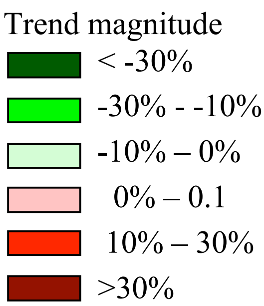
Spring



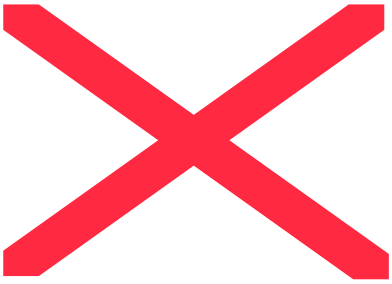
Summer



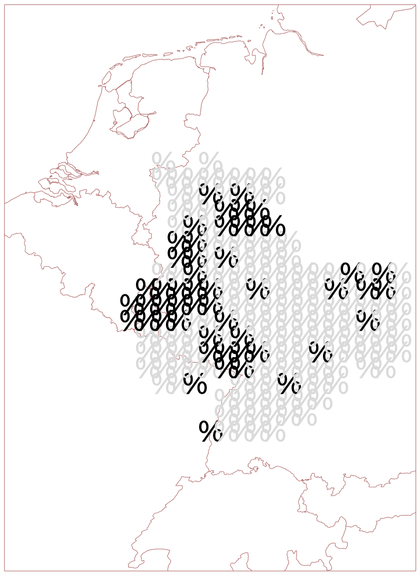
Autumn



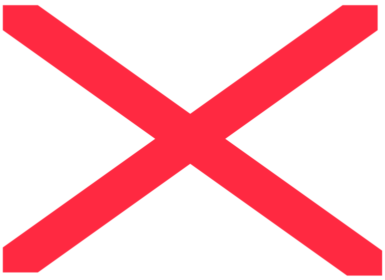
Significance of trends in 646SDII



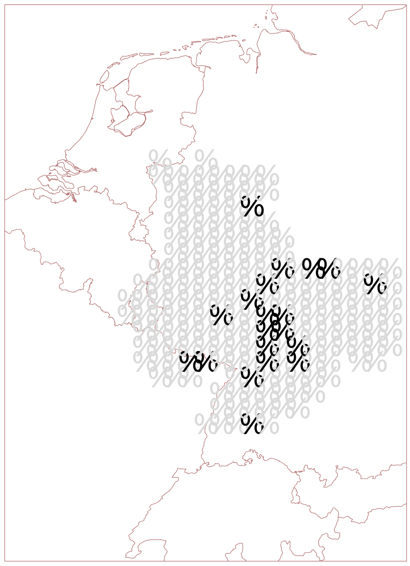
Annual



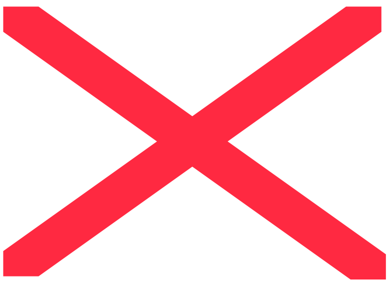
Winter



Spring



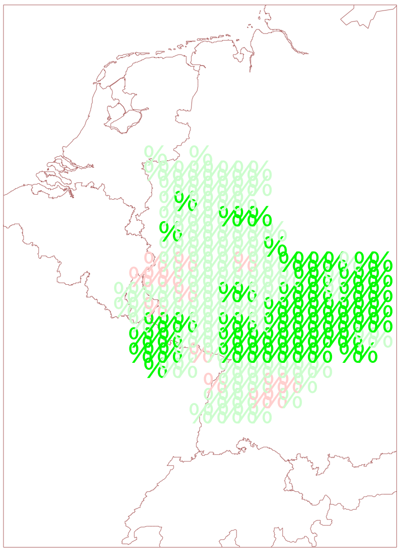
Summer



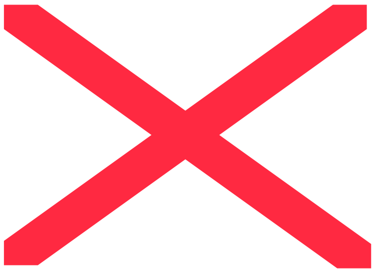
Autumn

Trend significance
Significant
Non significant

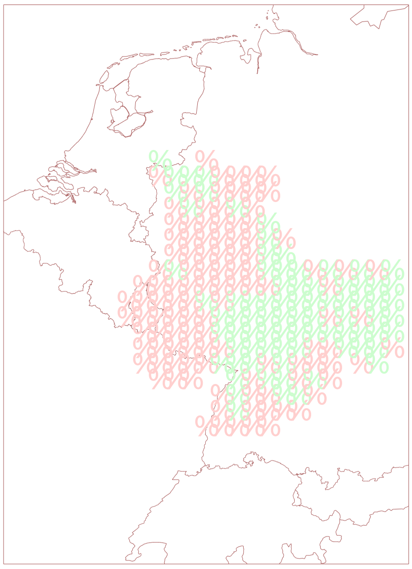
Trend in maximum number of consecutive dry days (641CDD)



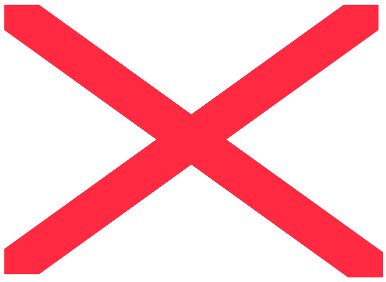
Annual



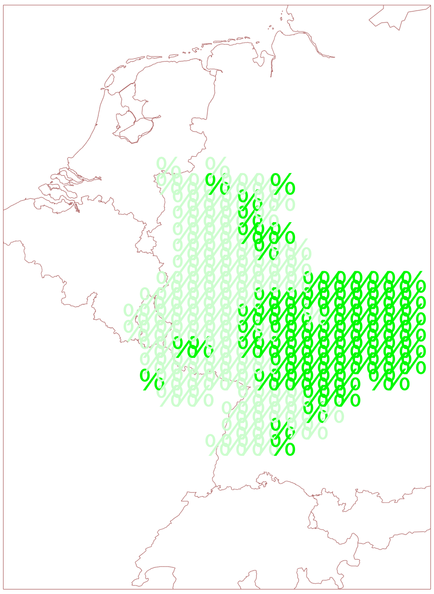
Winter



Spring



Summer

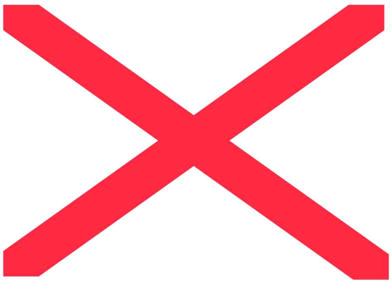


Autumn

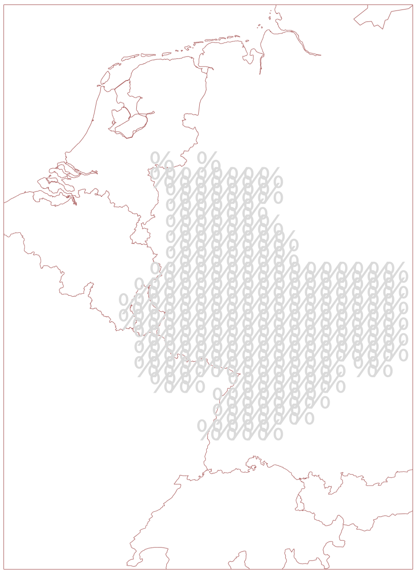
Trend magnitude

- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

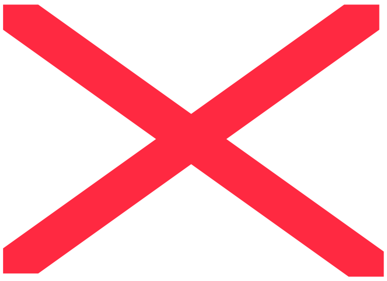
Significance of trends in 641CDD



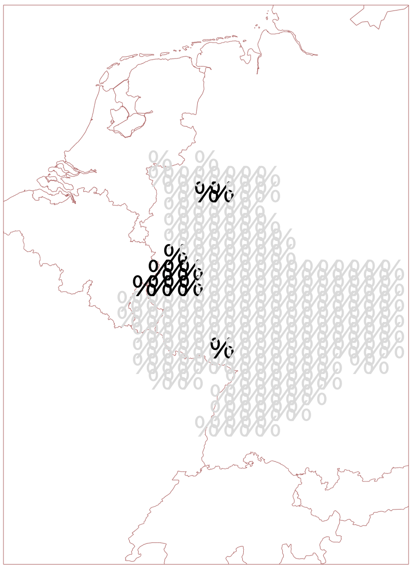
Annual



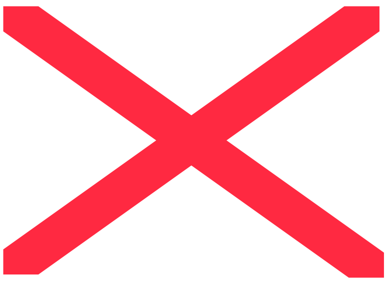
Winter



Spring



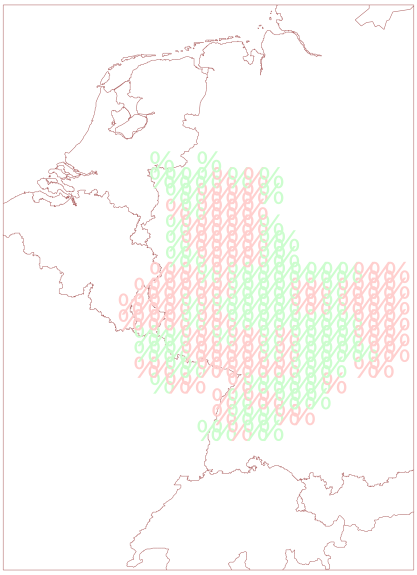
Summer



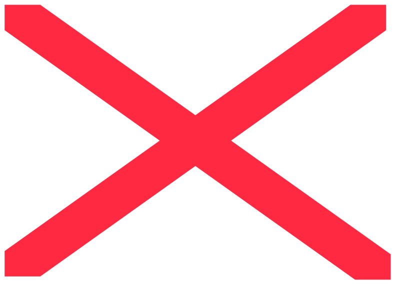
Autumn

Trend significance
Significant
Non significant

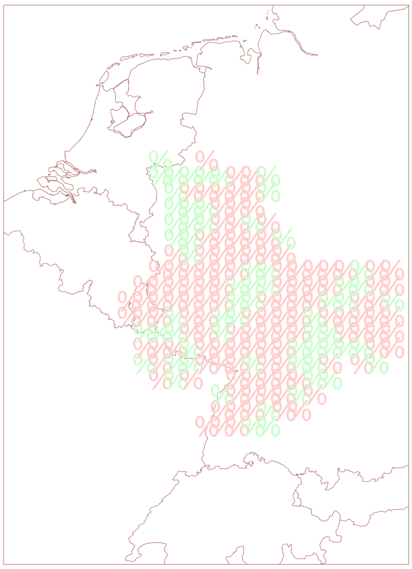
Trend in % of total rainfall from events greater than the long-term 90th percentile (691R90T)



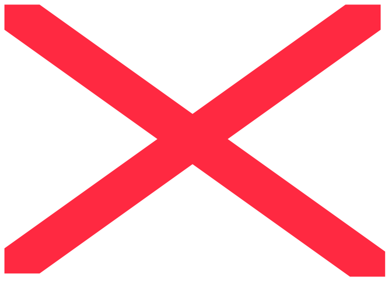
Annual



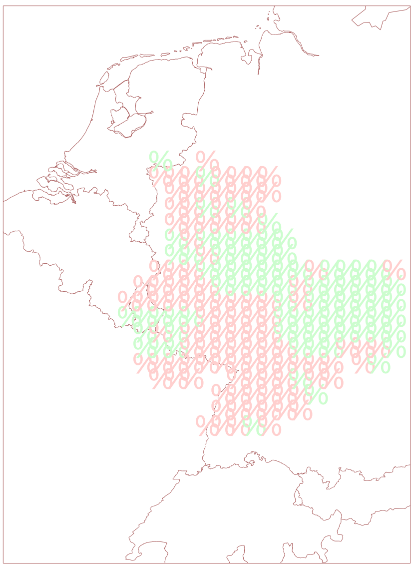
Winter



Spring



Summer

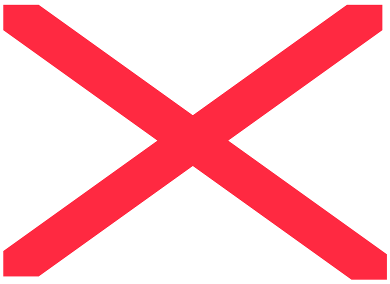


Autumn

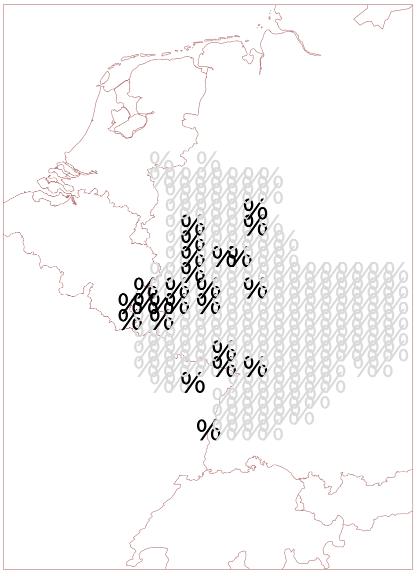
Trend magnitude

- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

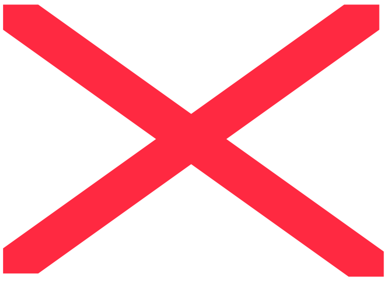
Significance of trends in 691R90T



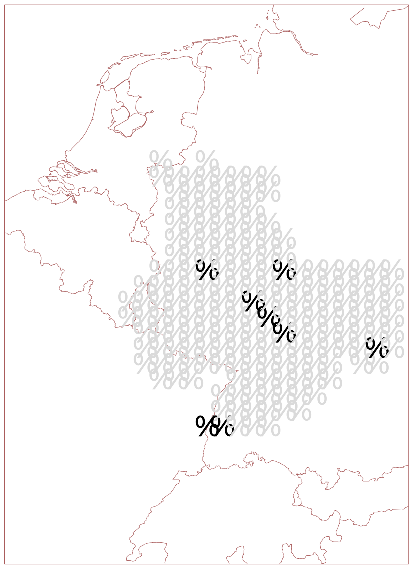
Annual



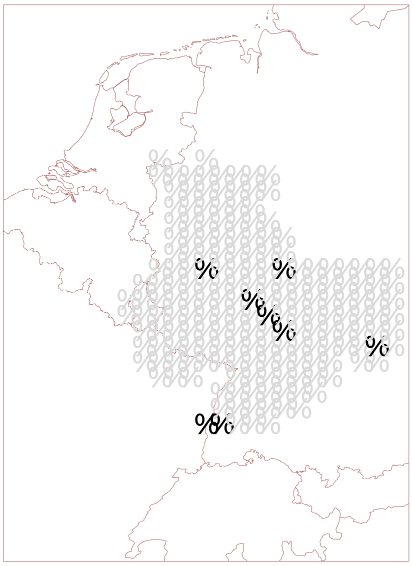
Winter



Spring



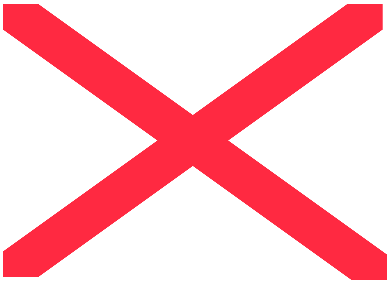
Summer



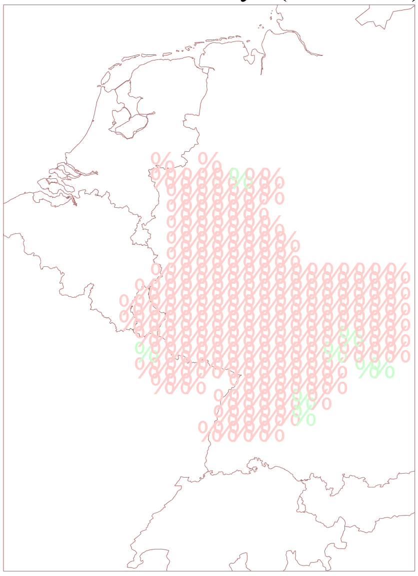
Autumn

Trend significance
Significant
Non significant

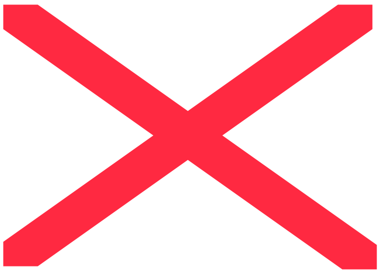
Trend in number of events greater than the long-term 90th percentile of raindays (692R90N)



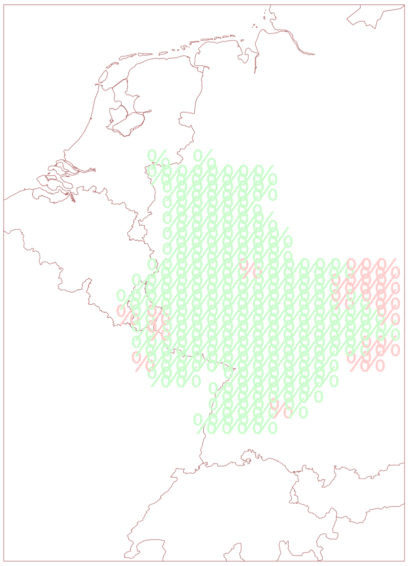
Annual



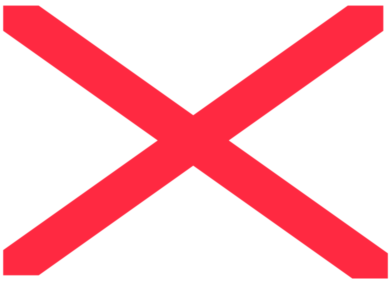
Winter



Spring



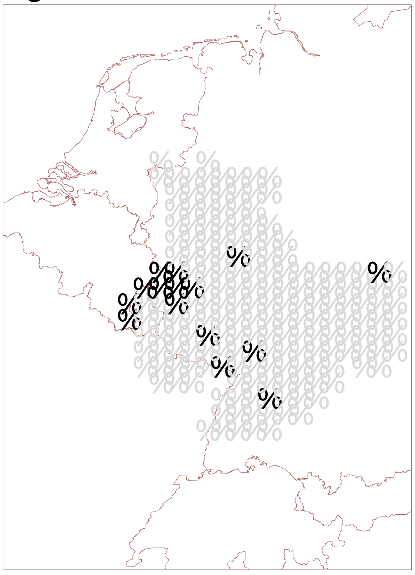
Summer



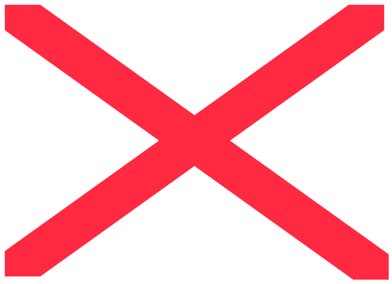
Trend magnitude
- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

Autumn

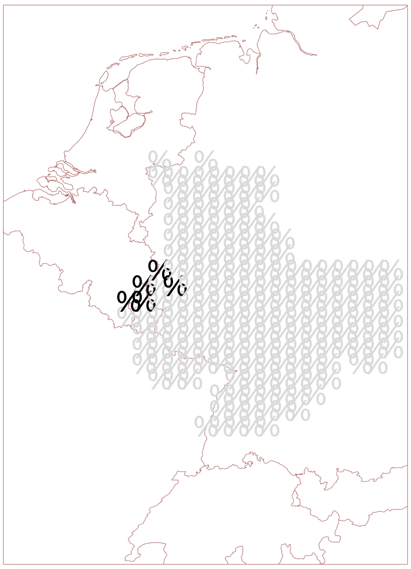
Significance of trends in 692R90N



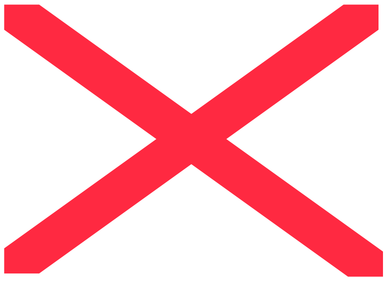
Annual



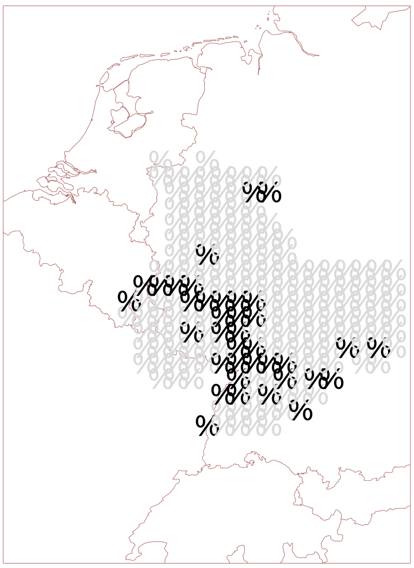
Winter



Spring



Summer



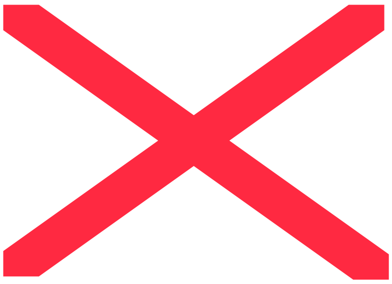
Autumn

Trend significance
- Significant
- Non significant

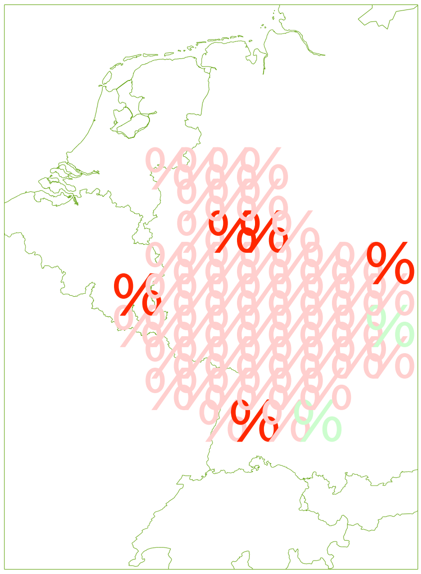
Trends of indices for grid based interpolated precipitation

(50km grid size)

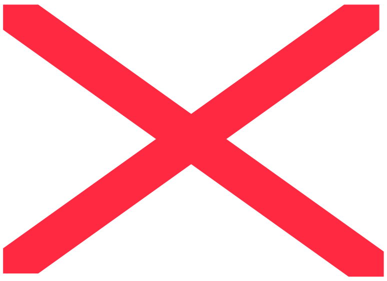
Trend in the 90th percentile of rainday amounts (prec90p)



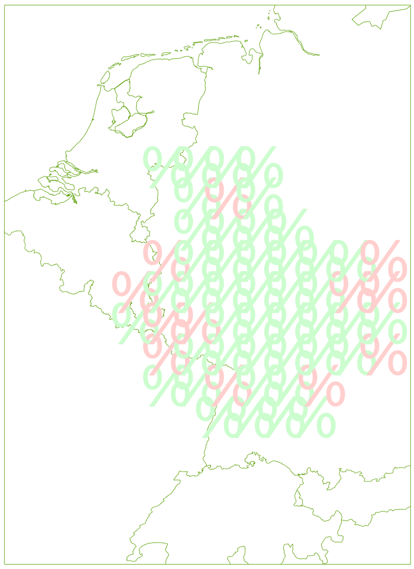
Annual



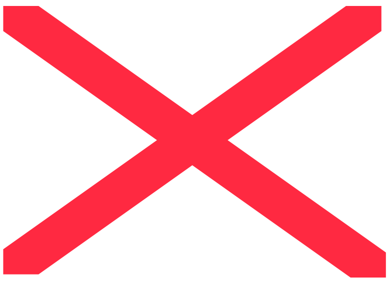
Winter

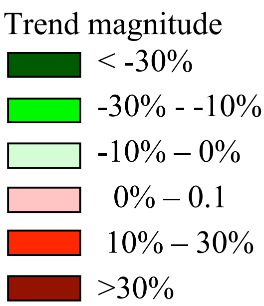


Spring



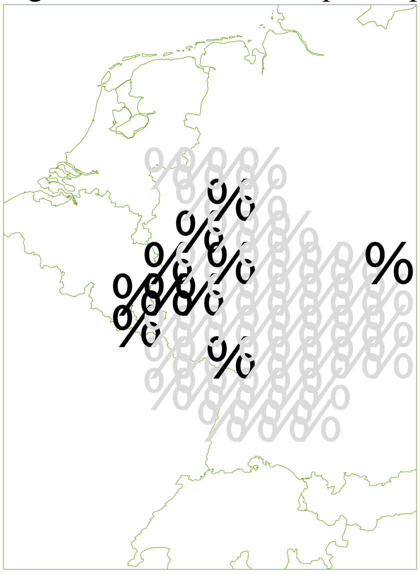
Summer



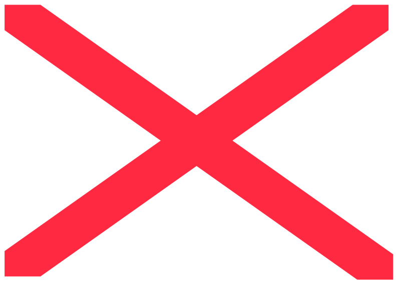


Autumn

Significance of trends in prec90p

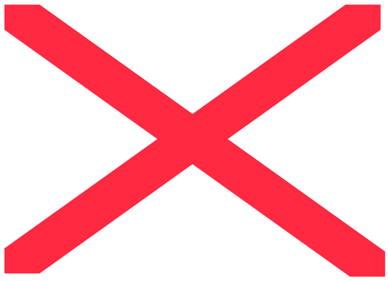


Annual

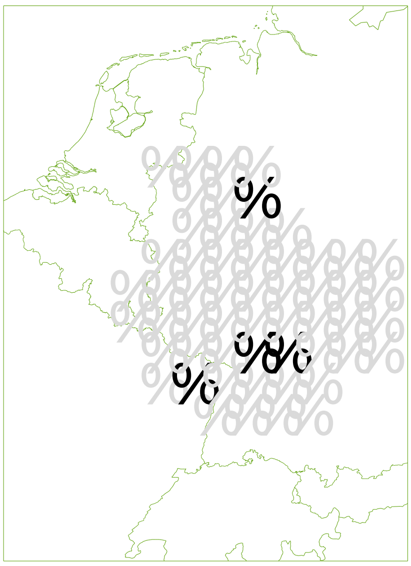


Winter

Spring



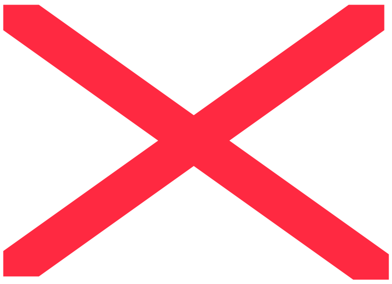
Summer



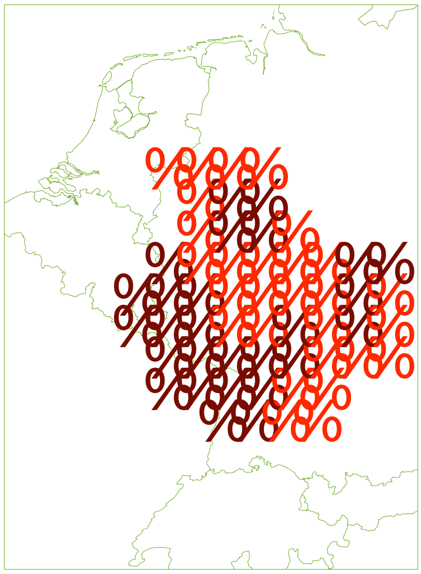
Autumn

Trend significance
- Significant
- Non significant

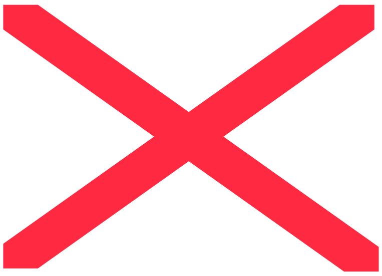
Trend in the greatest 5-day total rainfall (644R5d)



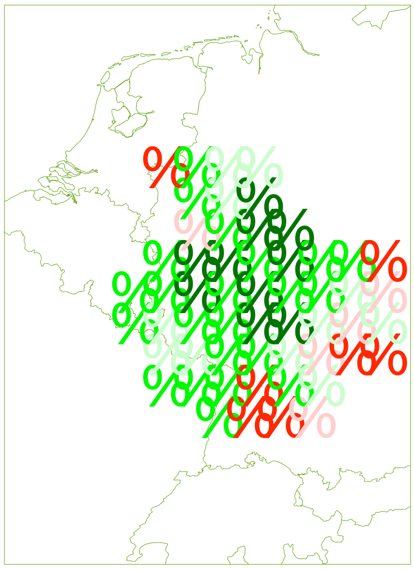
Annual



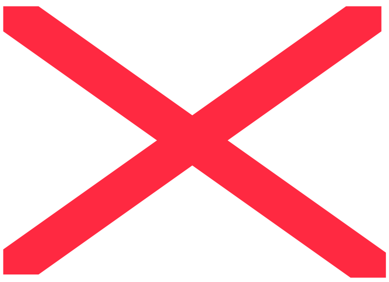
Winter



Spring



Summer

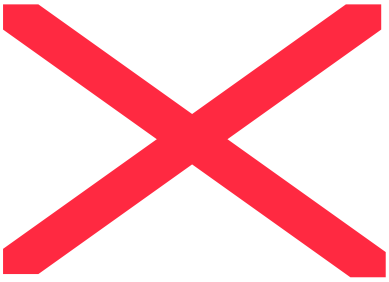


Trend magnitude

- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

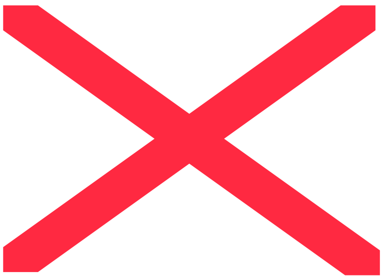
Autumn

Significance of trends in 644R5d

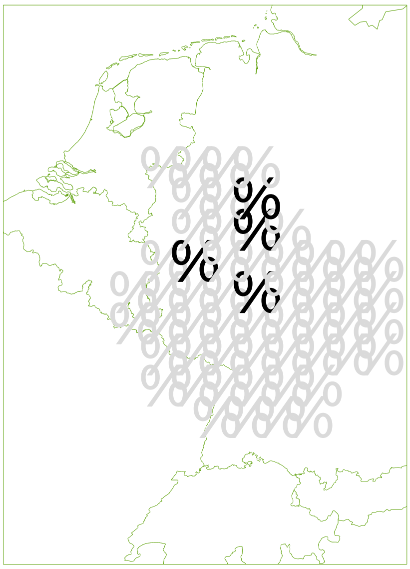


Annual

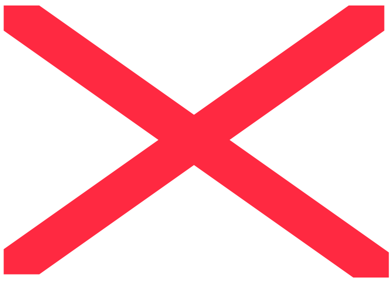
Winter



Spring



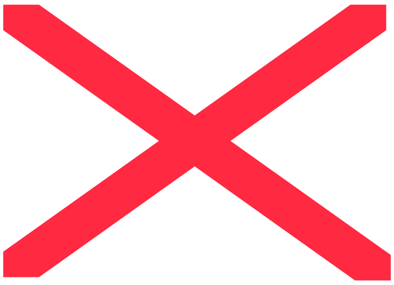
Summer



Trend significance
Significant
Non significant

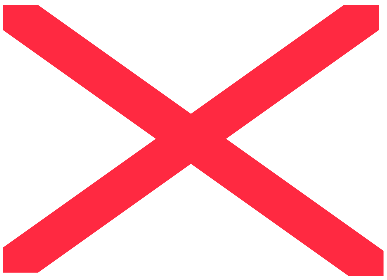
Autumn

Trend in simple daily intensity (646SDII)

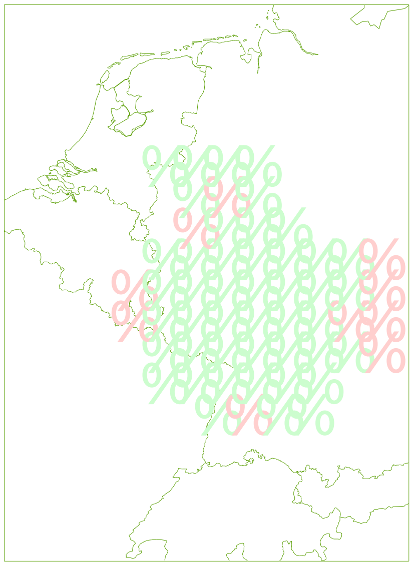


Annual

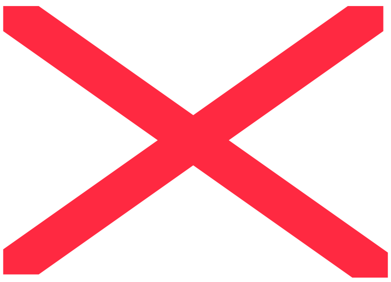
Winter

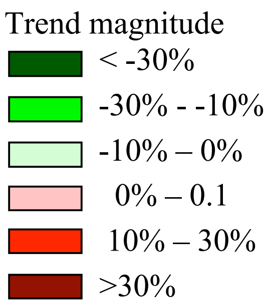


Spring



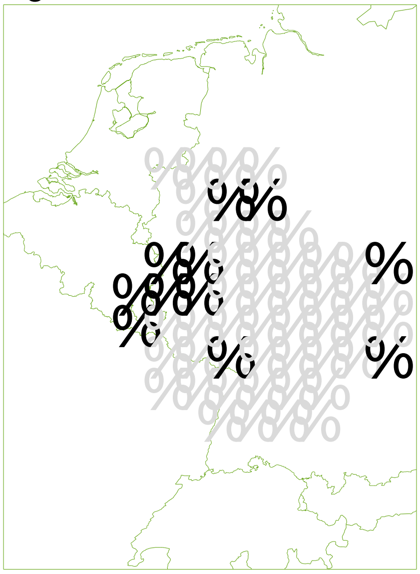
Summer



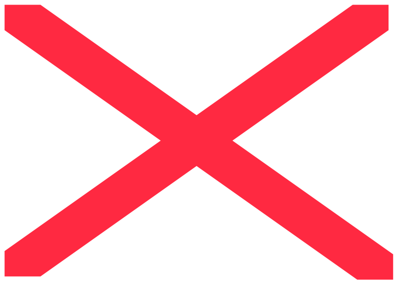


Autumn

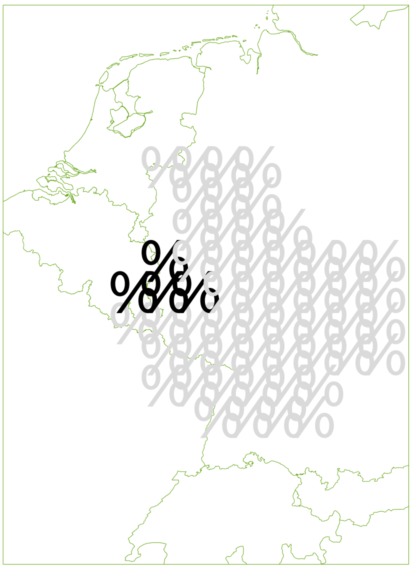
Significance of trends in 646SDII



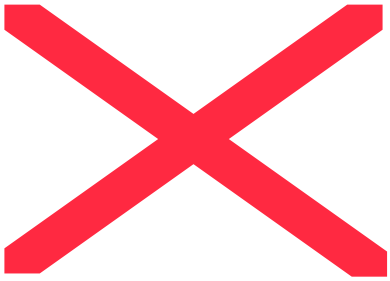
Annual



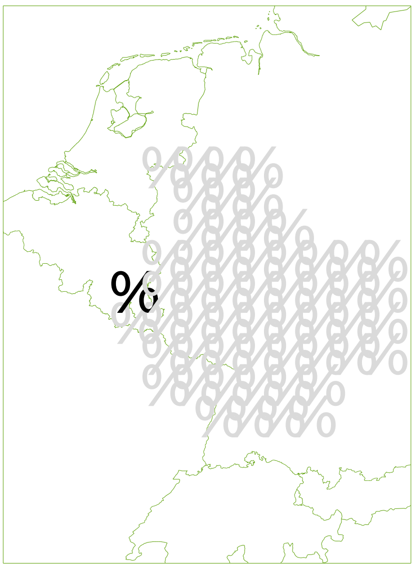
Winter



Spring



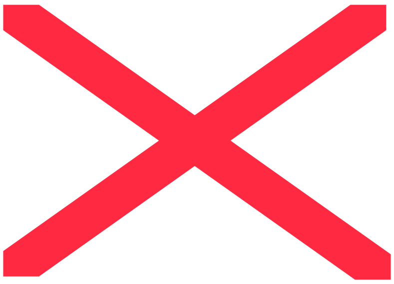
Summer



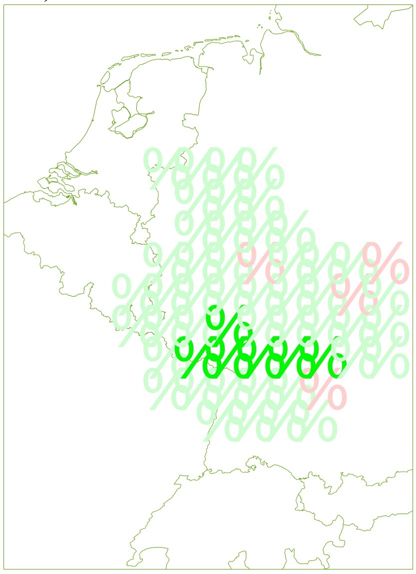
Autumn

Trend significance
Significant
Non significant

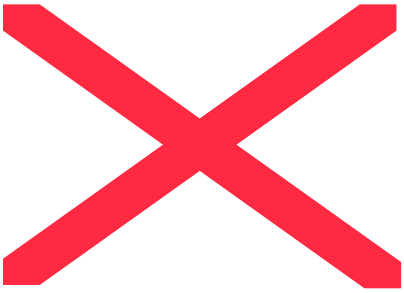
Trend in maximum number of consecutive dry days (641CDD)



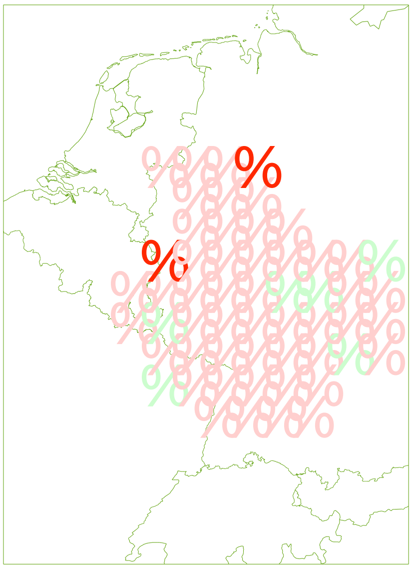
Annual



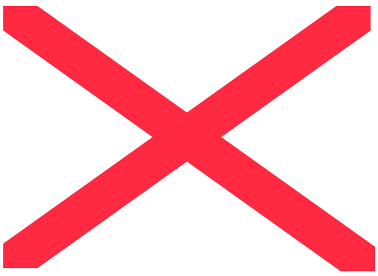
Winter



Spring



Summer

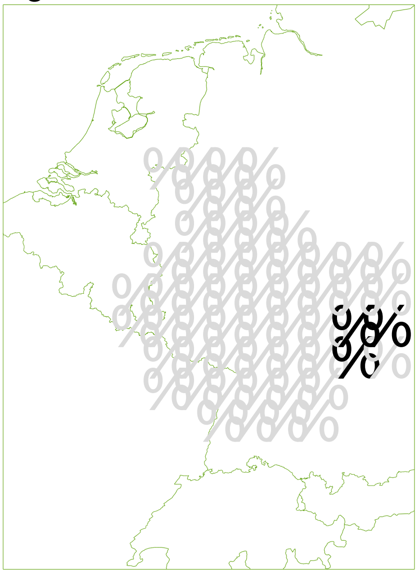


Trend magnitude

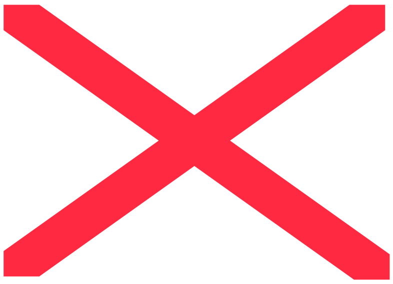
- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

Autumn

Significance of trends in 641CDD

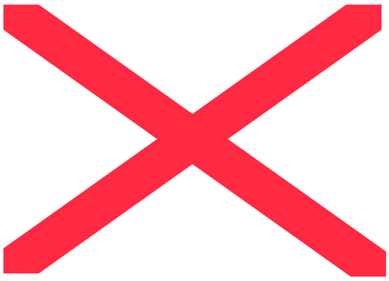


Annual



Winter

Spring

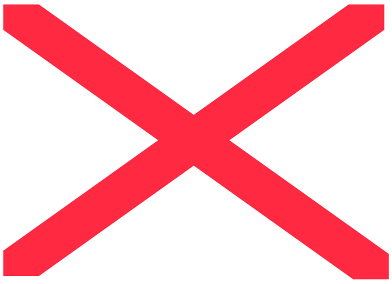


Summer

Autumn

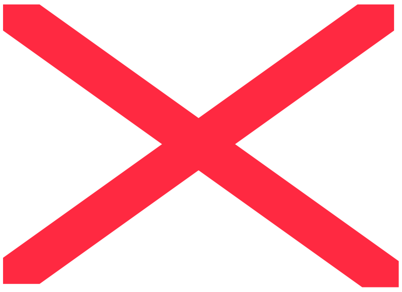
Trend significance
Significant
Non significant

Trend in % of total rainfall from events greater than the long-term 90th percentile (691R90T)

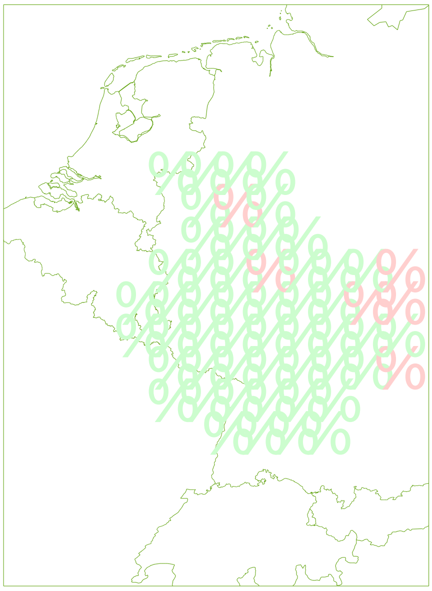


Annual

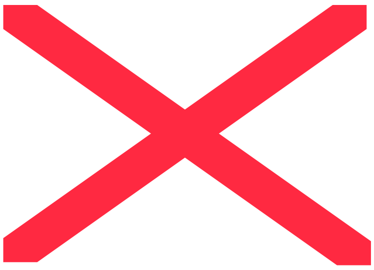
Winter



Spring



Summer

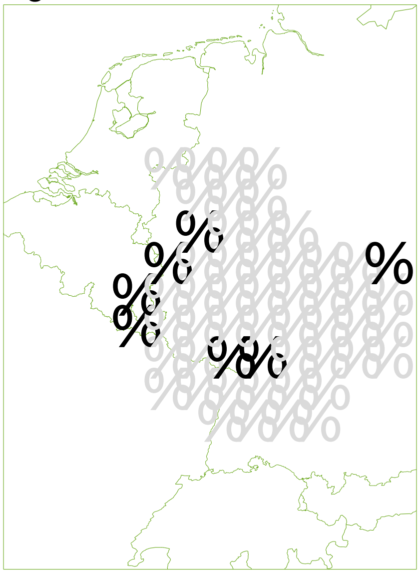


Trend magnitude

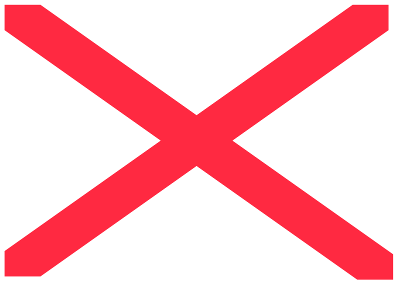
- < -30%
- -30% - -10%
- -10% – 0%
- 0% – 0.1
- 10% – 30%
- >30%

Autumn

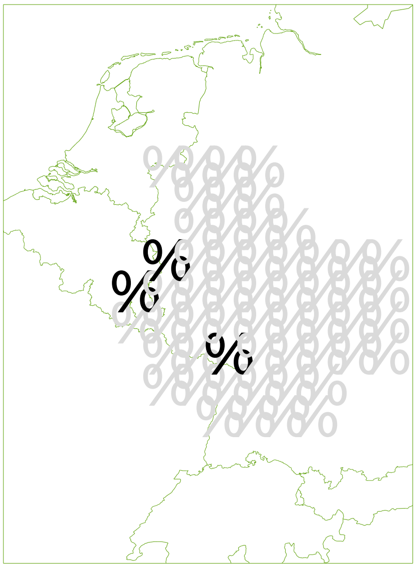
Significance of trends in 691R90T



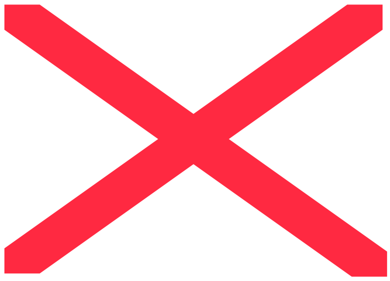
Annual



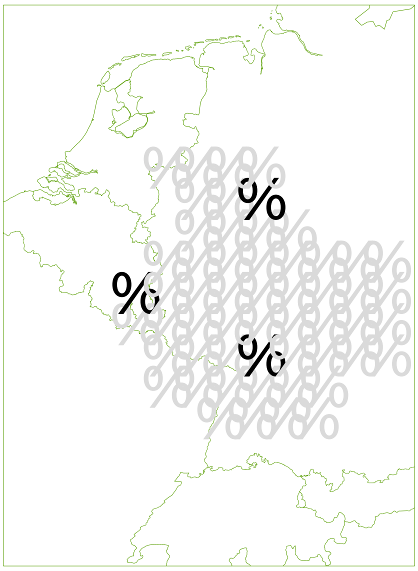
Winter



Spring



Summer

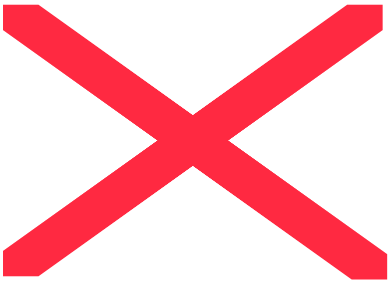


Autumn

Trend significance

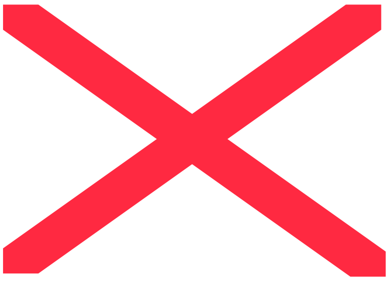
- Significant
- Non significant

Trend in number of events greater than the long-term 90th percentile of raindays (692R90N)

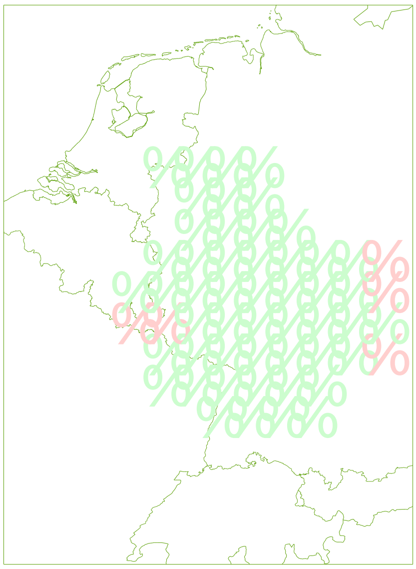


Annual

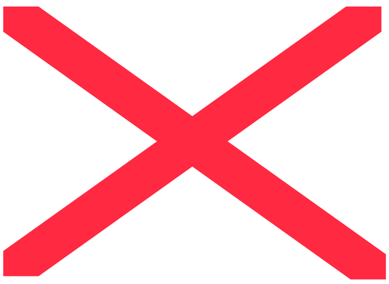
Winter

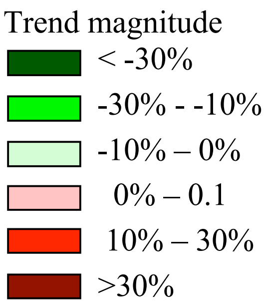


Spring



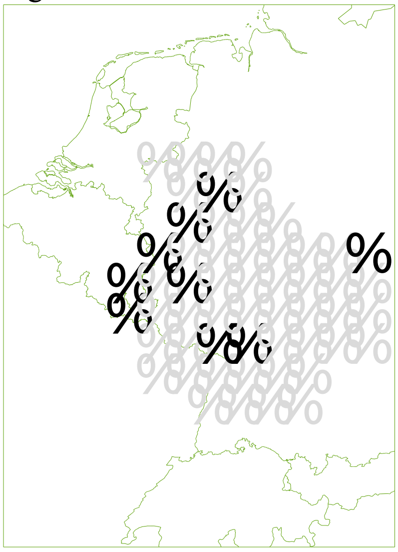
Summer



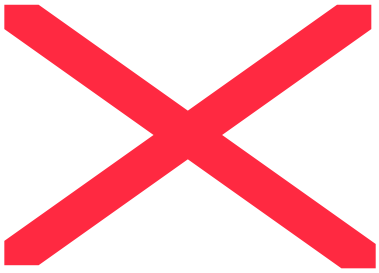


Autumn

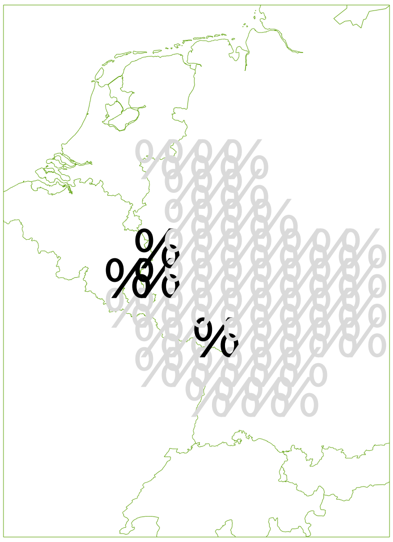
Significance of trends in 692R90N



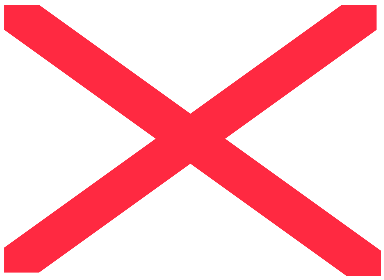
Annual



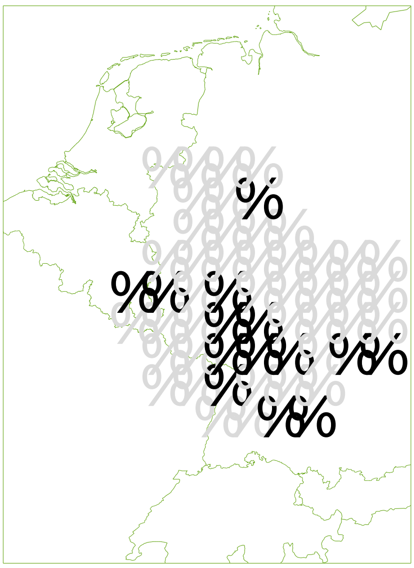
Winter



Spring



Summer

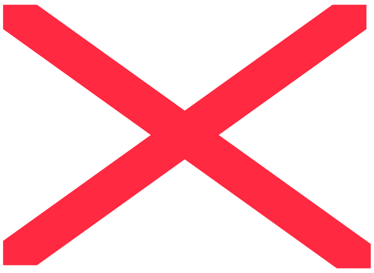


Autumn

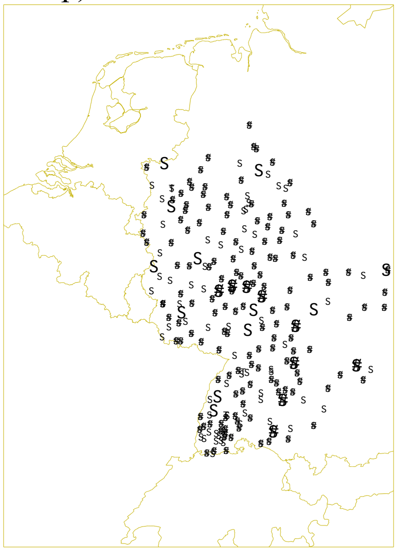
Trend significance
Significant
Non significant

Trends of temperature related indices for the stations

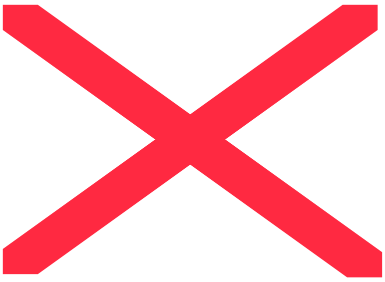
Trend in the 90th percentile of maximum temperatures (tmax90p)



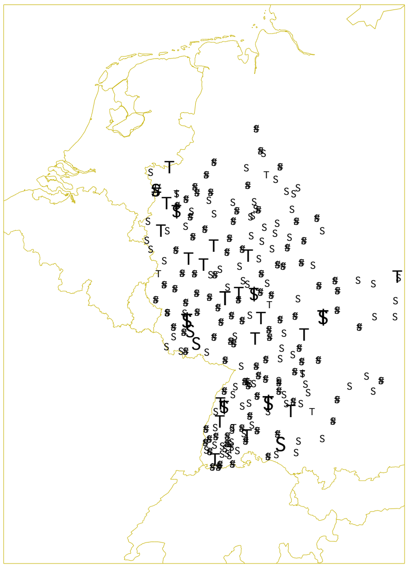
Annual



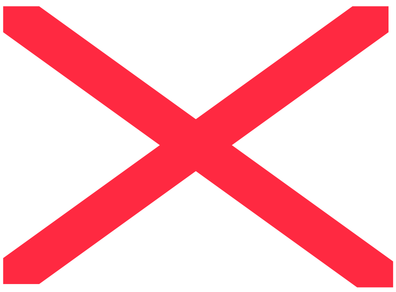
Winter



Spring



Summer



Trend magnitudes

Δ < -30%

-30% - -10%

-10 – 0%

0% – 10%

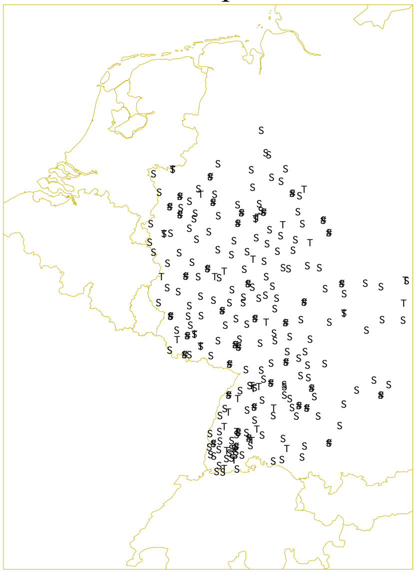
10% – 30%

>30%

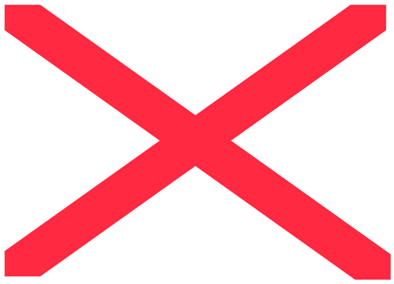
Dark- significant

Autumn

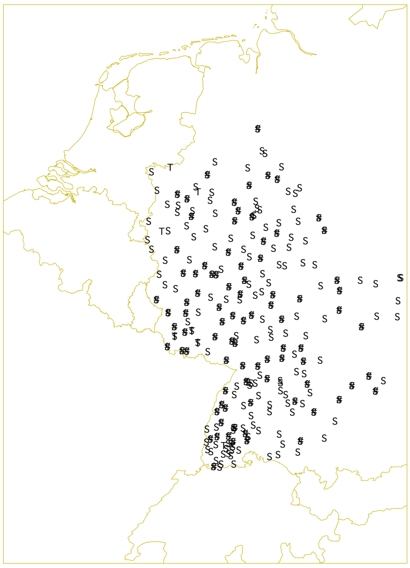
Trend in the 10th percentile of minimum temperatures (tmin10p)



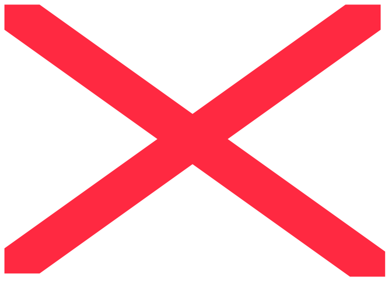
Annual



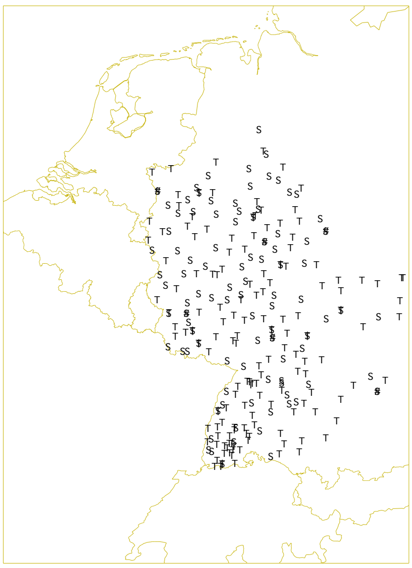
Winter



Spring



Summer



Autumn

Trend magnitudes

Δ < -30%

-30% - -10%

-10 – 0%

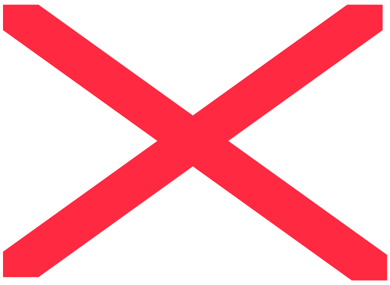
0% – 10%

10% – 30%

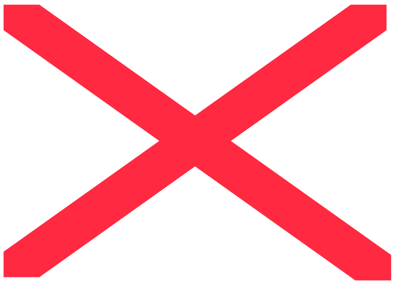
>30%

Dark- significant

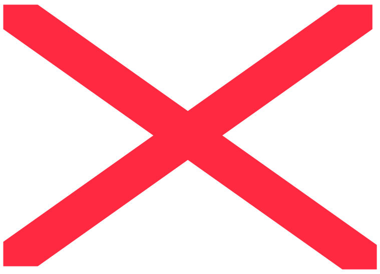
Trend in the number of frost days Tmin < 0 °C (125FD)



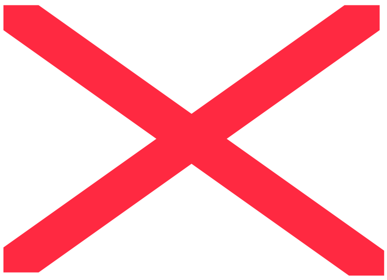
Annual



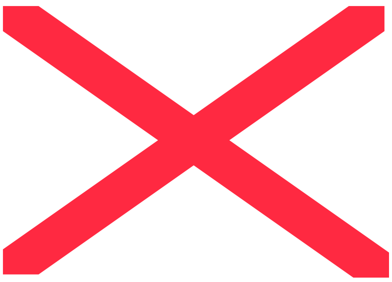
Winter



Spring



Summer



Autumn

Trend magnitudes

Δ < -30%

- -30% - -10%

-10 – 0%

0% – 10%

10% – 30%

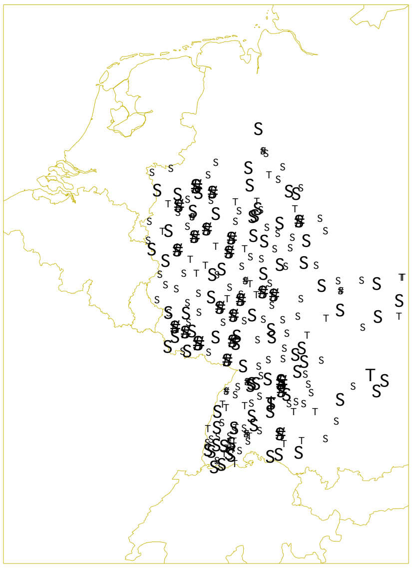
>30%

Dark- significant

Trend in Heat wave duration (144HWDI)

Annual

Winter



Spring

Summer

Trend magnitudes

∆ < -30%

- -30% - -10%

. -10 – 0%

_ 0% – 10%

_ 10% – 30%

__ >30%

Dark- significant

Autumn