Royal Netherlands
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*Ministry of Infrastructure
and Water Management*

Climatology of sunshine duration: data analysis of the summer half-year midday (9-14 UTC)

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Royal Netherlands Meteorological Institute
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CLIMATOLOGY OF SUNSHINE DURATION

Data Analysis of the Summer Half-year Midday (9-14 UTC)

Imke Okkerman

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Preface

As part of my traineeship at Rijkswaterstaat, I have chosen to fulfill one of my trainee periods at the RDWK department of KNMI from April 2019 till October 2019. This specific study has been performed during the last two months of this trainee period and arose from the outcome of my stakeholder analysis that I have done during the first four months. For both projects, Michiel van Weele has been my supervisor. Wouter Knap en Jan Fokke Meirink are the reviewers of this report, from which I am the first (and only) writer.

The Python scripts that have been used for the data analysis is publicly accessible for all KNMI staff members. These scripts are named *Sunshine_Climatology.py* and *Sunshine_Anomaly.py*, and can be requested via Michiel van Weele.

Abstract

Sunshine duration tells us how many hours a day the sun is shining. The Royal Netherlands Meteorological Institute (KNMI) has already done studies about the trends in global solar radiation, but similar studies for sunshine duration have not been done thus far. The National Institute for Public Health and the Environment (RIVM) and the Queen Wilhelmina Fund (KWF) have asked KNMI for information about the sunshine duration trend, since a possible increase of the sunshine duration could be one of the reasons why the occurrence of skin cancer has increased so rapidly the last couple of years in the Netherlands. Although solar radiation gives more detailed information about the power of the sun, sunshine duration is a popular parameter to use for communication towards society.

During this study, a data analysis has been performed to get a better view about sunshine duration since 1981. In interest of this study, only the summer half-year (April-September) and midday hours (9-14 UTC) have been examined, since during this time the sun can cause the most severe damage to the skin. During this study, the climatologies of the 30-year periods 1981-2010 and 1989-2018 have been compared. The results show that during a normal summer half-year, the sun typically shines 50% of the time during midday. The spring months (April and May) have become sunnier (increase of 2 and 3 hours of sunshine, respectively), the summer months (June, July and August) have stayed the same and the September has become sunnier (increase of 3 hours of sunshine).

Keywords: sunshine duration, summer half-year, weather stations, KNMI, climatology and anomaly.

Contents

1 Introduction

Sunshine or sunshine duration is a specific kind of parameter that states whether the sun is shining or not. Sunshine duration can be derived from the incoming global radiation (GHI, Global Horizontal Irradiance) or can be measured directly. When it is measured directly, the direct solar radiation (DNI, Direct Normal Irradiance) is compared to a certain threshold. This threshold is described as when an object makes a shadow or not. In scientific terms this means that the DNI has to be higher than 120 W/m^2 (WMO).

The goal of this study is to get an image of the climatology and changes of the amount of sunshine duration over the last couple of decades in the Netherlands. A study like that has not been performed as yet. It could be a nice supplement to studies that have been done about GHI, for example the study of Meirink [Meirink *et al.* 2019].

Furthermore, KNMI has been asked by the RIVM and KWF to come up with numbers for the sunshine duration during the summer. The reason for this is that the occurrence of skin cancer has extremely increased over the couple of years in the Netherlands. This increase can partly be explained by the change in behaviour: people expose themselves more frequently to the sun and also dress differently (less covered) than before. However, other factors could play an important roll in the increased occurrence of skin cancer as well. One of those possible factors is an increase of sunshine duration during the summer half-year (April-September).

Lastly, sunshine duration (unit: hours) is easier to understand than solar radiation (unit: W/m^2) by the general public. In the battle against skin cancer, it is better to communicate in terms of sunshine duration to raise awareness and reach as many people as possible. This is the main reason why RIVM and KWF specifically asked for numbers about the sunshine duration instead of solar radiation.

2 Method

2.1 Used Data

The used data for this sunshine duration data analysis is shown in Table (1). Hourly sunshine data, derived from the GHI, has been available for most KNMI weather stations since 1981, which is why this year is selected to be the starting year of this study. Considering the purpose of this study, it is chosen to only look at the summer half-year and the midday hours, since this is the time where people have the highest chance to develop skin damage caused by the sun.

Table 1: Data specification for the sunshine duration data analysis.

Years	From 1981 till 2018
Months	Summer half-year (April-September)
Hours	11-16 local time (9-14 UTC)
Weather stations	De Kooy, De Bilt, Eelde, Vlissingen and Maastricht

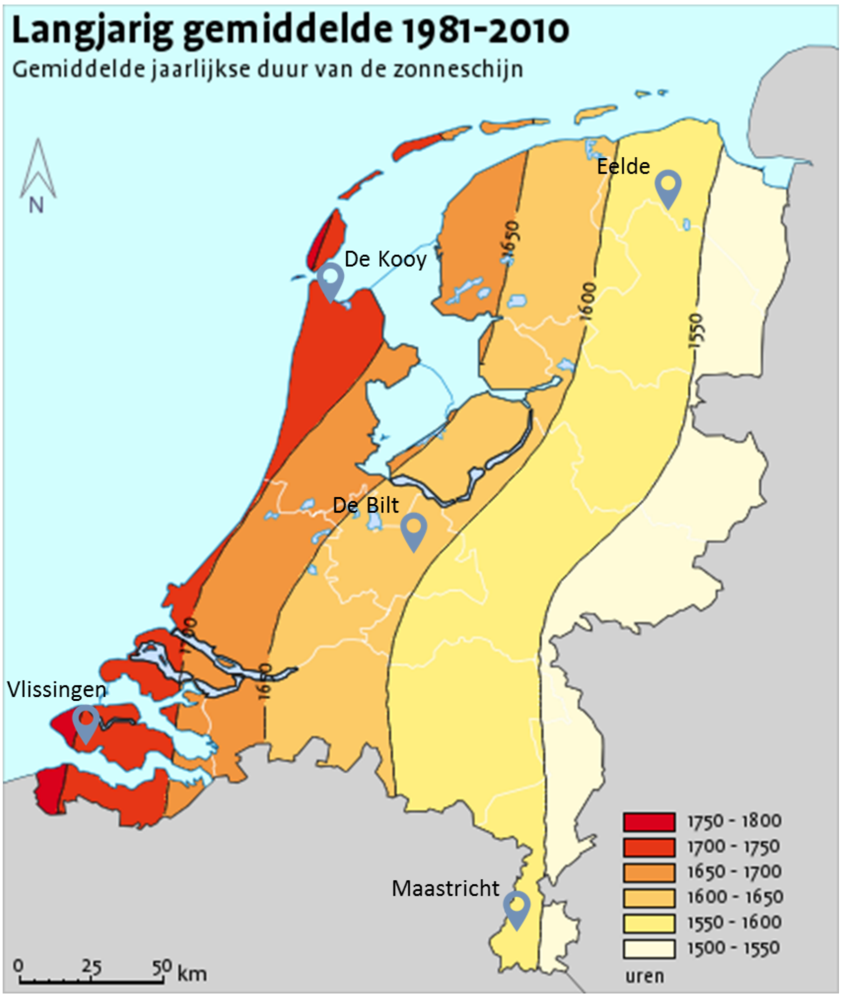

Figure 1: The five weather stations used for the sunshine duration data analysis.

The choice of weather stations agrees with the study of Meirink [Meirink *et al.* 2019] and presents a nice distribution over the Netherlands: from east to west, from north to south and from coastal to inland. The exact locations of the five weather stations is shown in Figure (1).

During the data analysis it was found that some data for the weather station in Vlissingen is missing (from October 1992 till July 1994). It is decided to fill up this gap with a data set from the weather station in Wilhelminadorp, which is located 15 kilometers from Vlissingen, also at a coastal area. It is thought that the difference with the missing data will not be significant [Van Dun, J., Personal Communication, September 12, 2019].

2.2 Distribution

Before the data analysis was performed, the distribution of sunshine duration was examined. The visualisation of the distribution of the data points for the month of April from all five weather stations are shown in Figure (2). At first the shape of this distribution seems quite odd, where the minimum and the maximum are over-represented. However, baring in mind that sunshine duration is a binary parameter (the sun shines or it does not), this shape actually makes more sense. Unlike the GHI parameter, the sunshine duration parameter does not make distinction between a sunny hour or a very sunny hour: both will lead to a sunshine duration of 1 hour. Same applies to a cloudy hour and a very cloudy hour: both will lead to a sunshine duration of 0 hours.

Next to that, the chance to have 0 or 5 hours of sunshine in a row is increased by the persistence of weather circumstances. In other words, when there is no sunshine during a certain hour, the chance is higher that the next hour will also be without sunshine than that there will be sunshine (and vice versa). This could be another factor to help explaining the shape of the distribution. However, the fact that sunshine duration has a directional character already proves this on its own [Knap 2019].

The sunshine duration data that is used during this data analysis, is derived from the GHI. To make sure that this derivation gives the true sunshine duration value, a little study is done where the derived sunshine duration was compared with the real measured sunshine duration for the years 2017 and 2018 at the weather station in Cabauw (the only location in the Netherlands where DNI is measured). The results showed that the two data sets strongly agree, even better for the five-hour-long period between 9-14 UTC than for the complete day. Therefor it is justified to use these derived sunshine duration data points to perform this data analysis [Knap 2019].

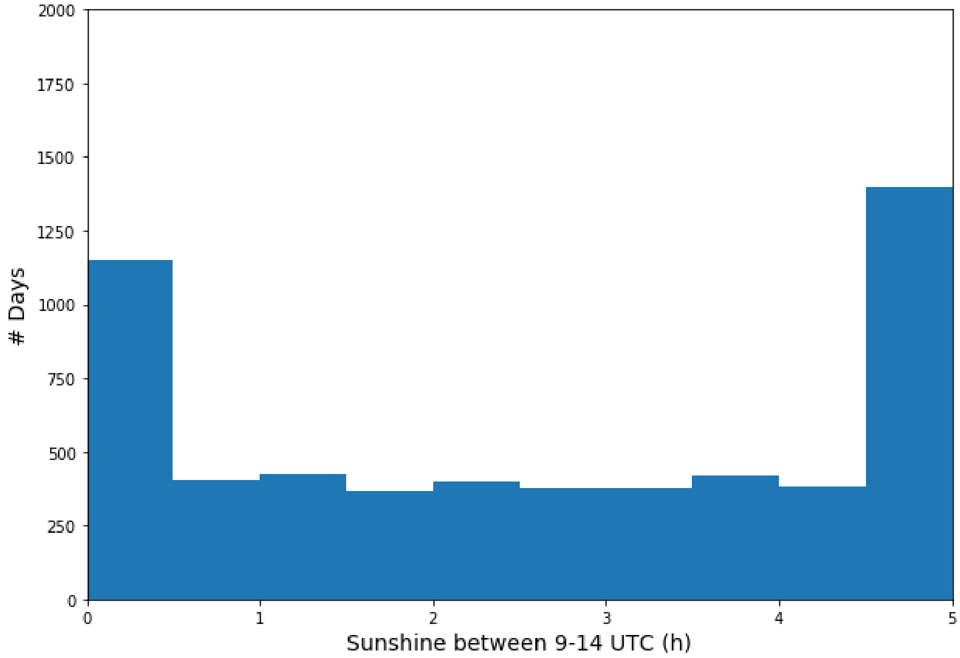

Figure 2: Sunshine distribution in April for 1981-2018.

For the distribution shown in Figure (2), the mean and the mode are significantly different. This means that one should be careful with the interpretation of these data. This distribution states that half of the days in April were sunny between 9-14 UTC and half of the days were not, but one can not say that the sun was shining 2.5 hours between 9-14 UTC every day in April.

The shape as presented in Figure (2) also appeared for the distribution visualisation of months other than April. The only difference found between the months was the length of the peaks at 0 and 5 hours: during the summer half-year the peak at 5 hours was higher than the peak at 0 hours and vice versa for the winter half-year. During some winter months (December and January), this leads to distribution shapes where only the minimum is over-represented.

3 Results

3.1 Climatology

The sunshine climatologies between 9-14 UTC for the 30-year-periods 1981-2010 and 1989-2018 are presented in Figure (3). Both climatologies show sunshine percentage of approximately 50% during the summer half-year, with slightly higher values for the coastal weather stations (De Kooy and Vlissingen). Next to that, both climatologies, especially Figure (3b), show a small dip in between day 150 and 180, which roughly corresponds with the month of June. A comparison between the two climatologies is made and presented in Table (2) further on in this chapter.

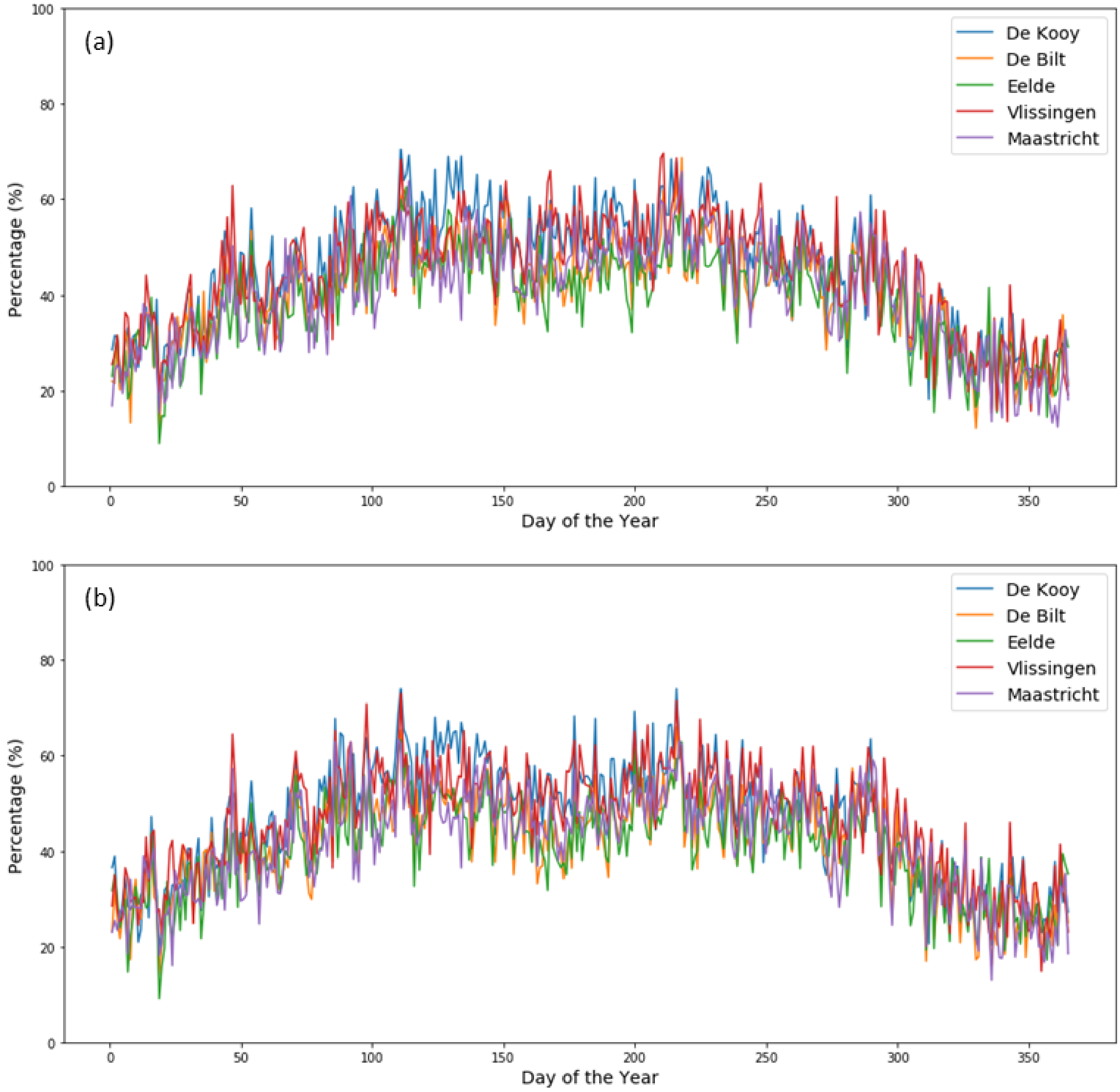

Figure 3: Sunshine climatology between 9-14 UTC for the 30-year periods (a) 1981-2010 and (b) 1989-2018.

3.2 Anomalies

For the years 1981-2018 (38 years in total), sunshine anomaly calculations have been performed, based on the climatology for the 30-year period 1981-2010. The plots belonging to these calculations can be found in Appendix Figures (A1) to (A7). Some of these plots will be analysed in this section.

In Figure (4) the average sunshine anomaly plot is shown for the summer half-year, based on the data points from the five different weather stations. Here, and further on in this report, 'average sunshine' stands for the average sunshine of all five weather stations. No trend line has been drawn in this plot (or any other plots), since the inter-annual variability is reasonably big and the period is relatively short (38 years). However, to prove whether there is no statistically significant trend, more research should be performed. Figure (4) tells us that during the period 1981-2000, 50% of the summer half-year anomalies were positive and this percentage increased to 69% for the period 2000-2018.

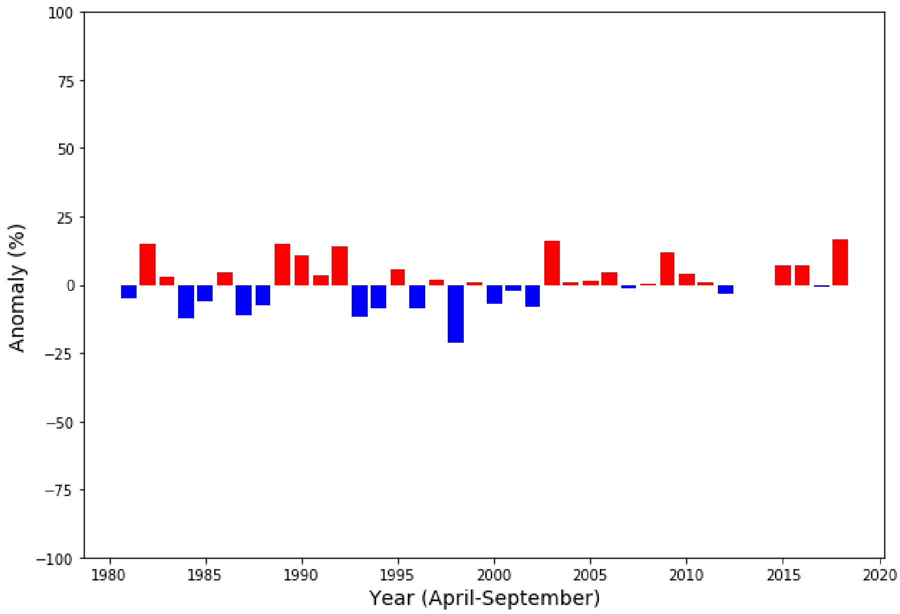

Figure 4: Average sunshine anomaly for the summer half-year between 9-14 UTC (Baseline 1981-2010).

Figure (5) shows the sunshine anomaly for April in Vlissingen. The first thing that strikes is the inter-annual variability, which is notably bigger than in Figure (4). This is also the case for all other single-month sunshine anomaly plots. Furthermore, this plot shows that during the period 1981-2000, 40% of the April month anomalies were positive and this percentage increased to 72% for the period 2000-2018. The average sunshine anomaly for April shows percentages of 35% and 59% respectively (see Figure (A2)).

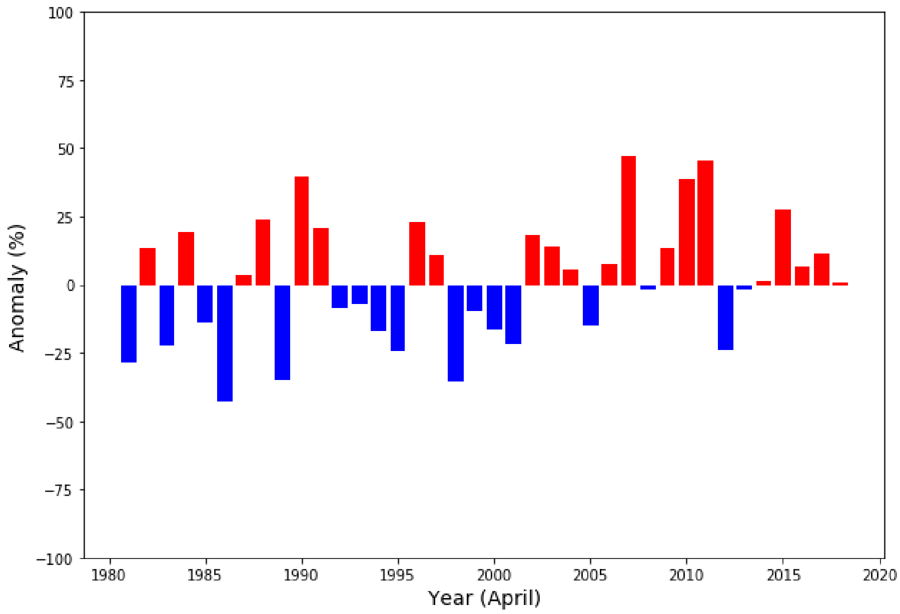

Figure 5: Vlissingen sunshine anomaly for April between 9-14 UTC (Baseline 1981-2010).

In Figure (6) the sunshine anomaly for July in De Kooy is presented. During the period 1981-2000, 55% of the July month anomalies were positive and during the period 2000-2018, this slightly decreased to 53%. The average sunshine anomaly for July shows percentages of 50% and 44% respectively (see Figure (A5)).

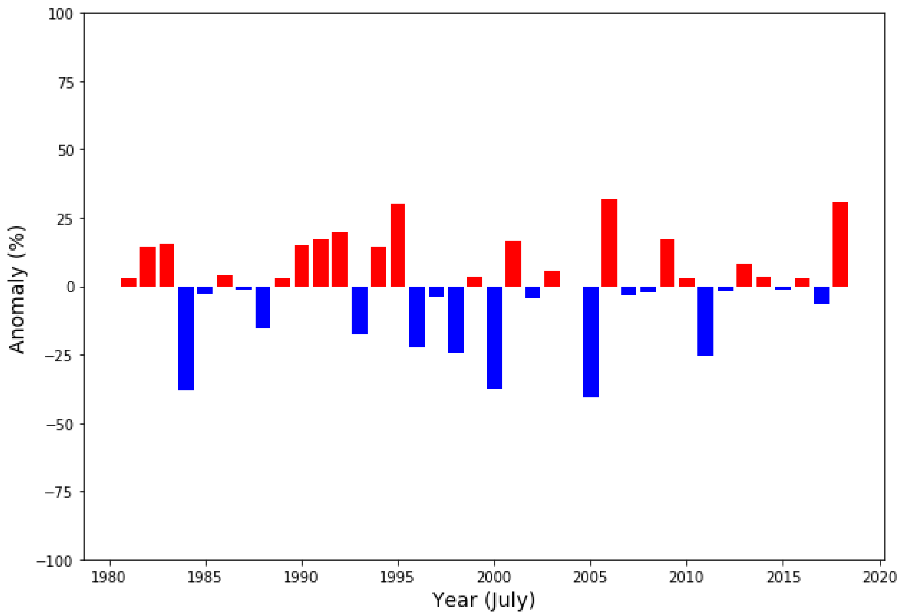

Figure 6: De Kooy sunshine anomaly for July between 9-14 UTC (Baseline 1981-2010).

Figure (7) shows the sunshine anomaly for September in Maastricht. During the period 1981-2000, 45% of the September month anomalies were positive and during the period 2000-2018, this increased to 78%. The average sunshine anomaly for July shows percentages of 50% and 72% respectively (see Figure (A7)).

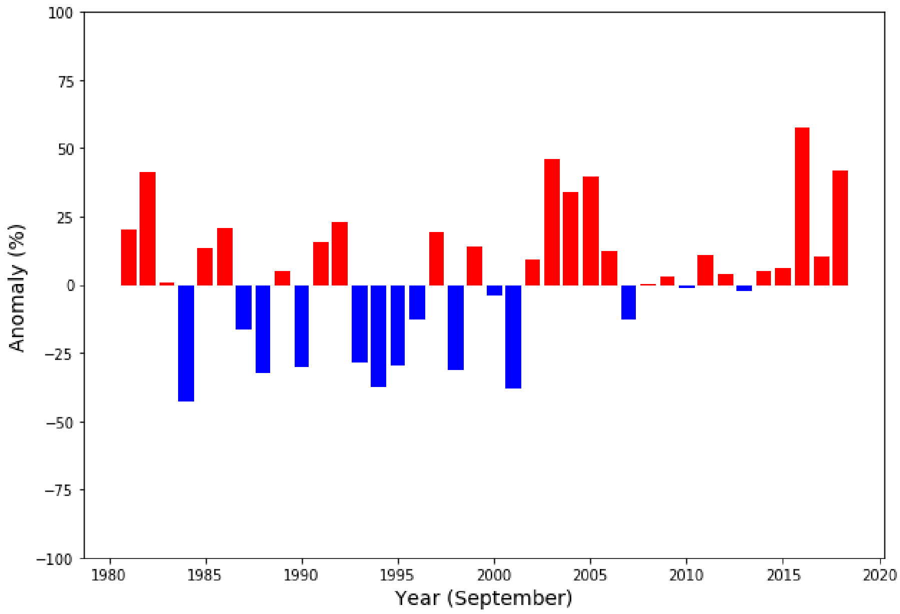

Figure 7: Maastricht sunshine anomaly for September between 9-14 UTC (Baseline 1981-2010).

To get a better overview of the absolute baseline values for all months and weather stations, and to compare the two climatologies from Figure (3), Table (2) has been constructed. Looking at every weather station, this table shows that the average amount of sunshine hours per analysed month has increased with two hours for Vlissingen and with one hour for the other four weather stations. Looking at every month, this table shows that the average amount of sunshine hours per month has not increased for June and August and has increased with one hour for July, with two hours for April and with three hours for May and September. The average amount of sunshine hours for the summer half-year has increased with one hour. The highest increase happened in Vlissingen during the month of September, with an increase of 5 sunshine hours. A decline of sunshine hours only happened four times: in De Bilt during the month of August, in Vlissingen during the month of June and in Maastricht during the months of July and August. For all four cases, the decline was one hour. From all weather stations, Vlissingen is the weather station with the highest range in change: from -1 hour in June to +5 hours in September. De Kooy and Eelde show the lowest range in change: from +1 tot +3 hours. From all months, July shows the highest range in change: from -1 hour in Maastricht to +3 hours in Eelde. June shows the lowest range in change: from 0 tot -1 hour. For every month, the two coastal weather stations show remarkably higher values than the three inland weather stations (De Bilt, Eelde and Maastricht). Lastly, Table (2) confirms the dip in sunshine hours for the month of June, which is visible in both Figures (3a) and (3b).

Since the maximum sunshine hours is different for every month, it is not directly clear which month is for example the sunniest. Therefor, Table (A1) has been attached to the Appendix with percentages in stead of absolute values. In both tables, the monthly average has been calculated with rounded values, which causes some uncertainty in those numbers.

Table 2: Monthly sunshine duration in hours between 9-14 UTC.

Climatology 1981-2010	April*	May**	June*	July**	August**	September*	*Average*
De Kooy	84	90	79	85	86	72	*83*
De Bilt	73	77	66	74	77	66	*72*
Eelde	73	75	63	70	73	65	*70*
Vlissingen	80	81	79	84	85	74	*81*
Maastricht	71	74	69	77	80	68	*73*
Average	*76*	*79*	*71*	*78*	*80*	*69*	*76*
Climatology 1989-2018	April*	May**	June*	July**	August**	September*	*Average*
De Kooy	87 (+3)	92 (+2)	79 (=)	86 (+1)	86 (=)	74 (+2)	*84 (+1)*
De Bilt	74 (+1)	78 (+1)	66 (=)	74 (=)	76 (-1)	69 (+3)	*73 (+1)*
Eelde	73 (=)	76 (+1)	63 (=)	73 (+3)	75 (+2)	67 (+2)	*71 (+1)*
Vlissingen	83 (+3)	85 (+4)	78 (-1)	84 (=)	86 (+1)	79 (+5)	*83 (+2)*
Maastricht	72 (+1)	78 (+4)	69 (=)	76 (-1)	79 (-1)	71 (+3)	*74 (+1)*
Average	*78 (+2)*	*82 (+3)*	*71 (=)*	*79 (+1)*	*80 (=)*	*72 (+3)*	*77 (+1)*

* Maximum is 150 sunshine hours.
** Maximum is 155 sunshine hours.

4 Discussion

The results show that the amount of sunshine hours during the summer half-year has increased over the last couple of years (2011-2018) compared to the period of 1981-2010. This increase is not uniformly distributed over all months and is also not the same for each weather station.

The results indicate that April and May have become sunnier during the last couple of years. This outcome raised the question whether this would also be the case for the months of March and February. Although the analysis of these winter months does not contribute to this particular study, a quick data run was performed which showed a similar situation for March, but not for February.

During the month of June, both climatologies show a small dip in the amount of sunshine hours. This dip could be attributed to the so-called 'Schaapsscheerderskou', which is a term for the weather pattern that results in cloudy skies with cool temperatures during June. During this month, the North Sea is still relatively cold and is often covered with grey clouds. When the wind direction changes to northerly or northwesterly wind, this cloud cover flows above the Netherlands and leads to cloudier and colder weather [Geurts 2002]. However, very little research has been done about this effect, so it is only a hypothesis that this causes the dip in the climatologies during the month of June.

It is allowed to state that the summer months (June, July and August) have neither become sunnier nor less sunnier. The data points admittedly show that July was a bit more sunnier, but this was caused by the remarkable increase of three hours at the weather station in Eelde. Therefor, this increase is not considered significantly.

September, comparable with April and May, has become sunnier. Also here, a quick data run was performed for the months of October and November. This resulted in a similar trend for October, but not for November.

The results clearly show a separation between the coastal weather stations and the inland weather stations. During all months of the summer half-year, it is seriously sunnier at coastal areas than at inland areas. This difference is supported by the effect of coastal clearance due to the supply of relatively cold air from the sea, which suppresses cloud formation [KNMI 2016].

The inter-monthly variation is very dependent on the specific weather station. However, on average there is not much variation between the different months, only slightly for June and September. Respectively, this can possibly be declared by the 'Schaapsscheerderskou' and the fact that September has the least possible sunshine hours of all analysed months.

The missing data for the weather station in Vlissingen, that has been filled up with a data set from the weather station in Wilhelminadorp, has not caused any disturbance of the results during this data analysis. Probably because the sunshine duration in Wilhelminadorp is very similar to the one in Vlissingen, but also because it was only a fraction of total data used during this data analysis. Next to that, the most important results were averaged values (over 38 years), which makes a possible disturbance less noticeable and important.

5 Conclusions

The sun shines typically 50% of the time between 9-14 UTC during the summer half-year. Considering the distribution of the data points, this means that roughly half of the days are sunny and half of the days are not.

Compared to the climatology of the 30-year period 1981-2010, the spring months (March, April and May) have become sunnier, as well as most of the fall months (September and October) during the last eight years. The summer months (June, July and August) do not show any big changes. Attribution of this increase in sunshine duration was not part of this study, but it would be interesting to investigate this similar to the studies that have been done about the changes in cloudiness and GHI [Boers *et al.* 2013, Boers *et al.* 2019].

Variation for sunshine hours is clearly found for the coastal weather stations and inland weather stations, but variation is smaller for the different months. More research could be performed to examine the notable dip in sunshine hours during the month of June, possibly caused by the 'Schaapsscheerderskou'.

For the interest of this study - related to health issues - only the summer half-year and the five-hour-long period between 9-14 UTC has been analysed. However, for the interest of KNMI in general, it could be interesting to also look at the winter months and complete days.

Lastly, this study did not include any statistical analysis and can therefor be seen as a pilot or first orientation of the sunshine duration topic. Further research should be done to prove whether significant trends can be found in the development of sunshine duration.

References

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Appendix

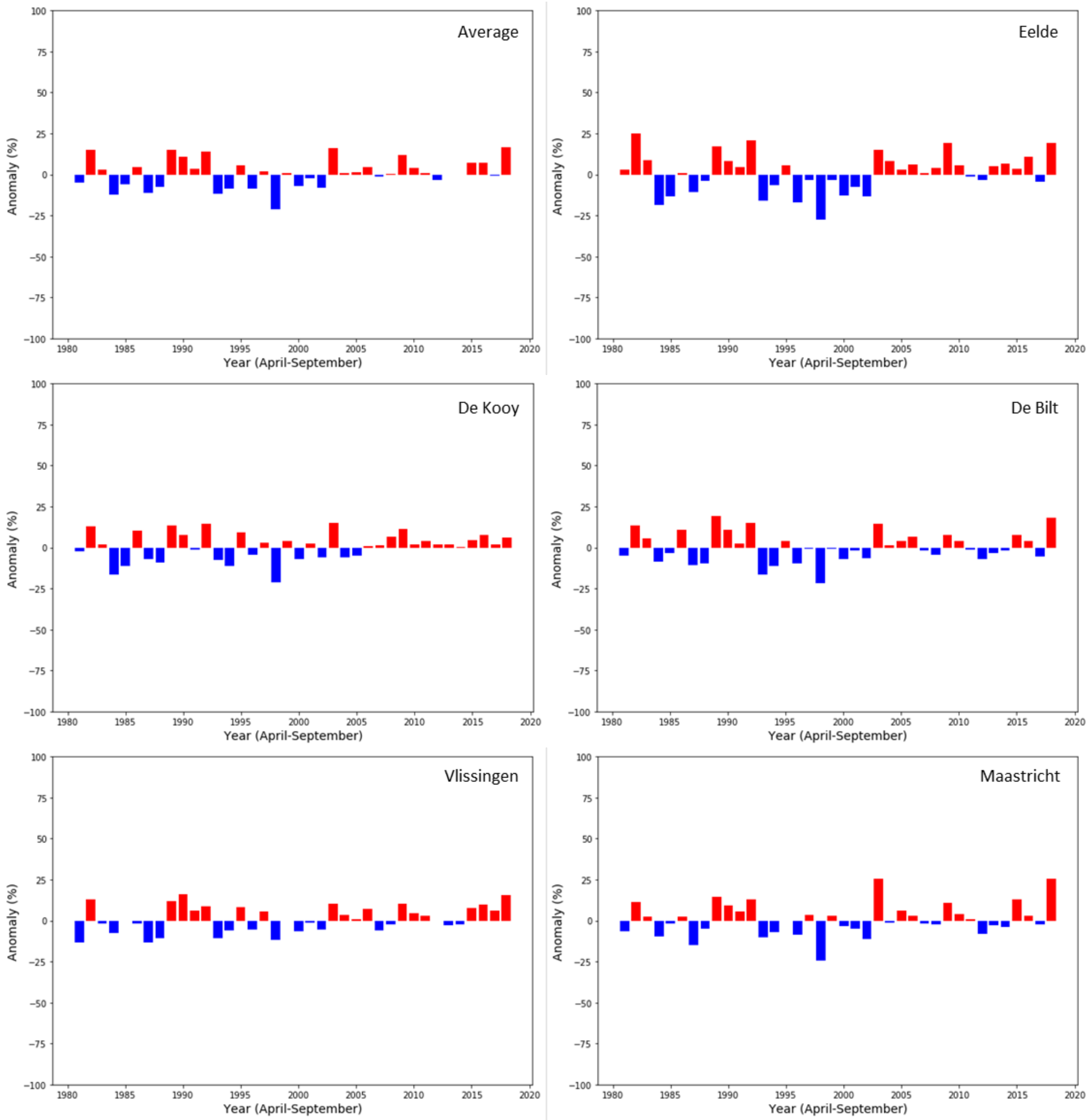

Figure A1: Sunshine anomaly for the summer half-year between 9-14 UTC (Baseline 1981-2010).

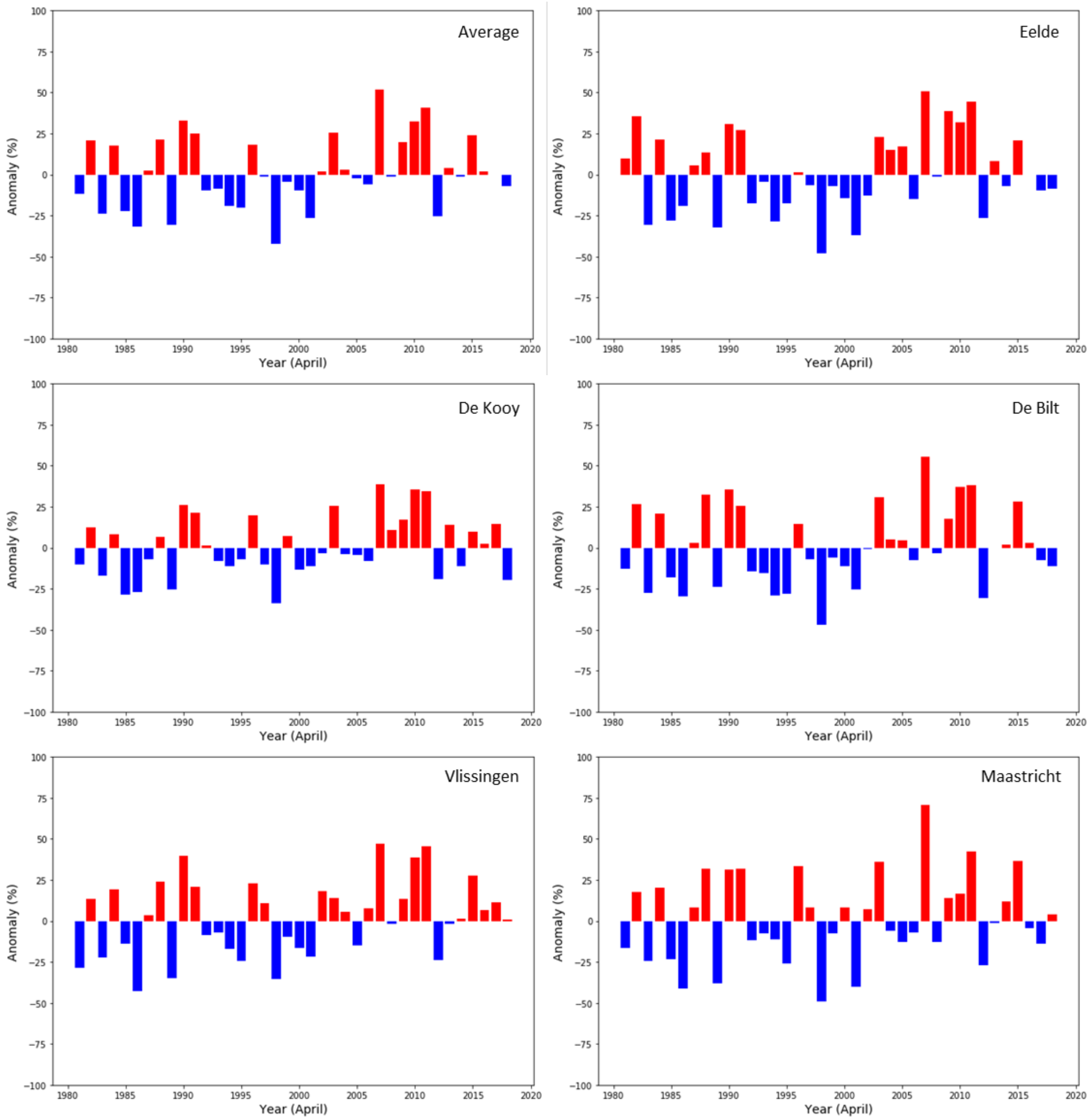

Figure A2: Sunshine anomaly for April between 9-14 UTC (Baseline 1981-2010).

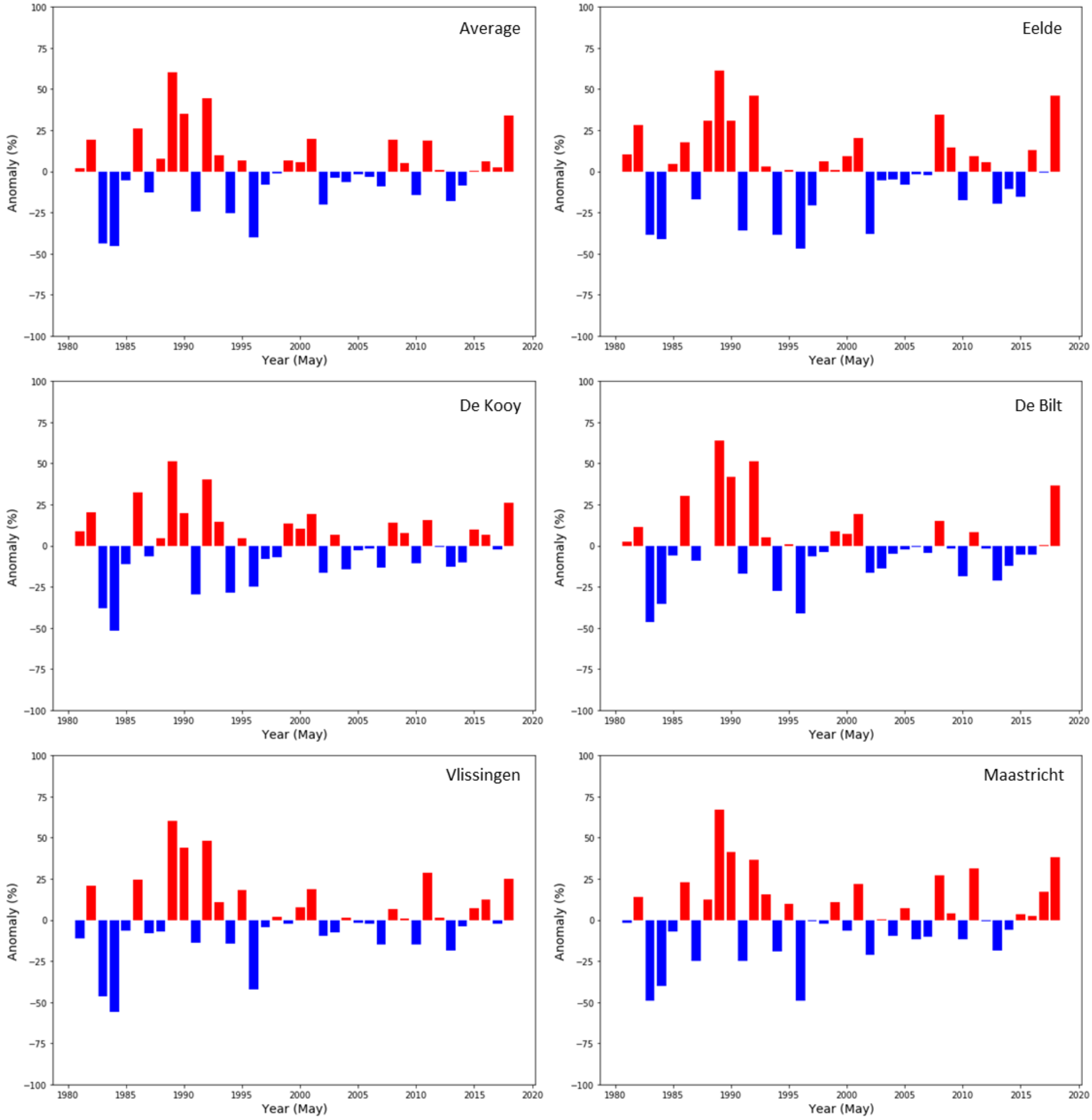

Figure A3: Sunshine anomaly for May between 9-14 UTC (Baseline 1981-2010).

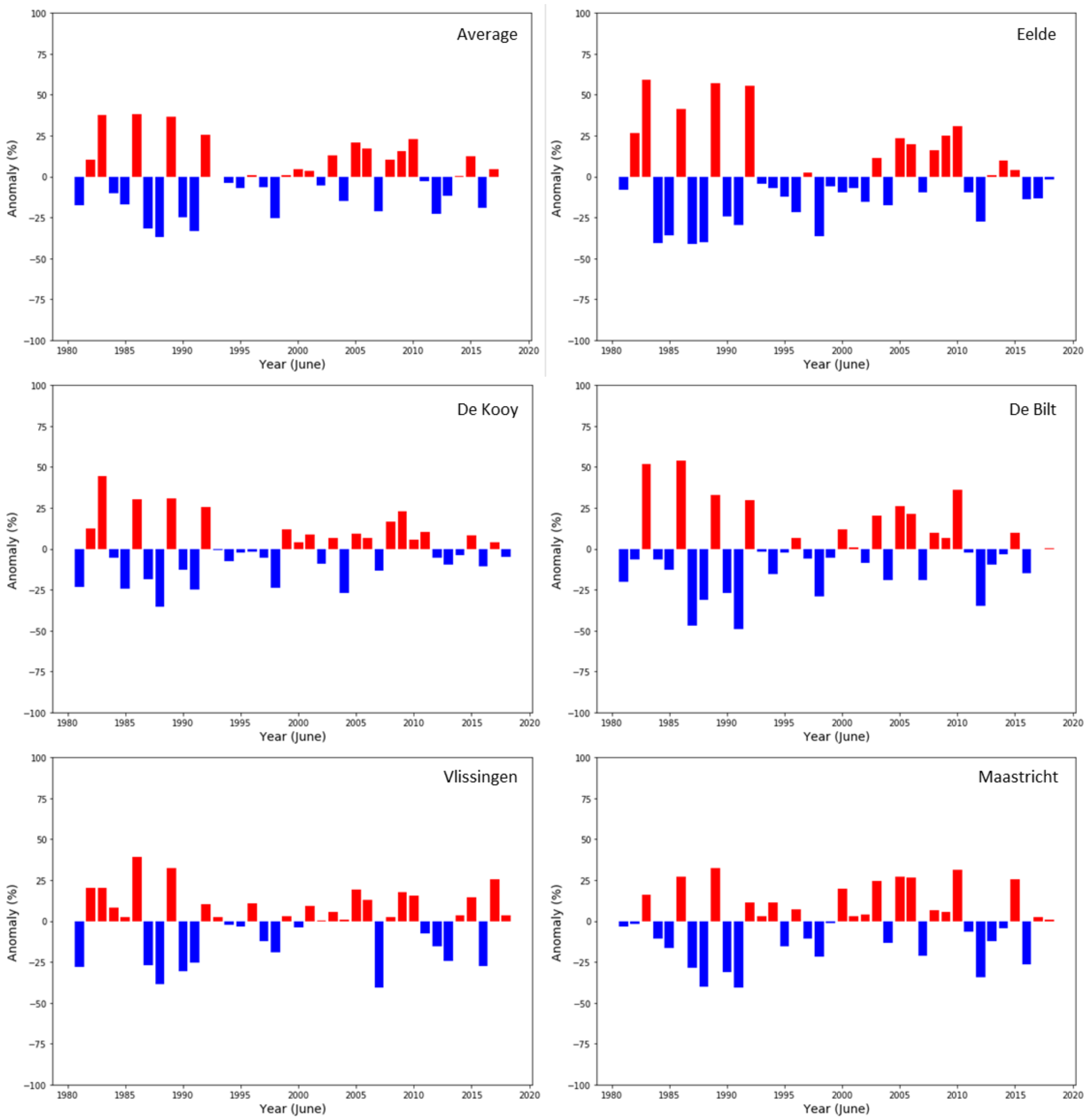

Figure A4: Sunshine anomaly for June between 9-14 UTC (Baseline 1981-2010).

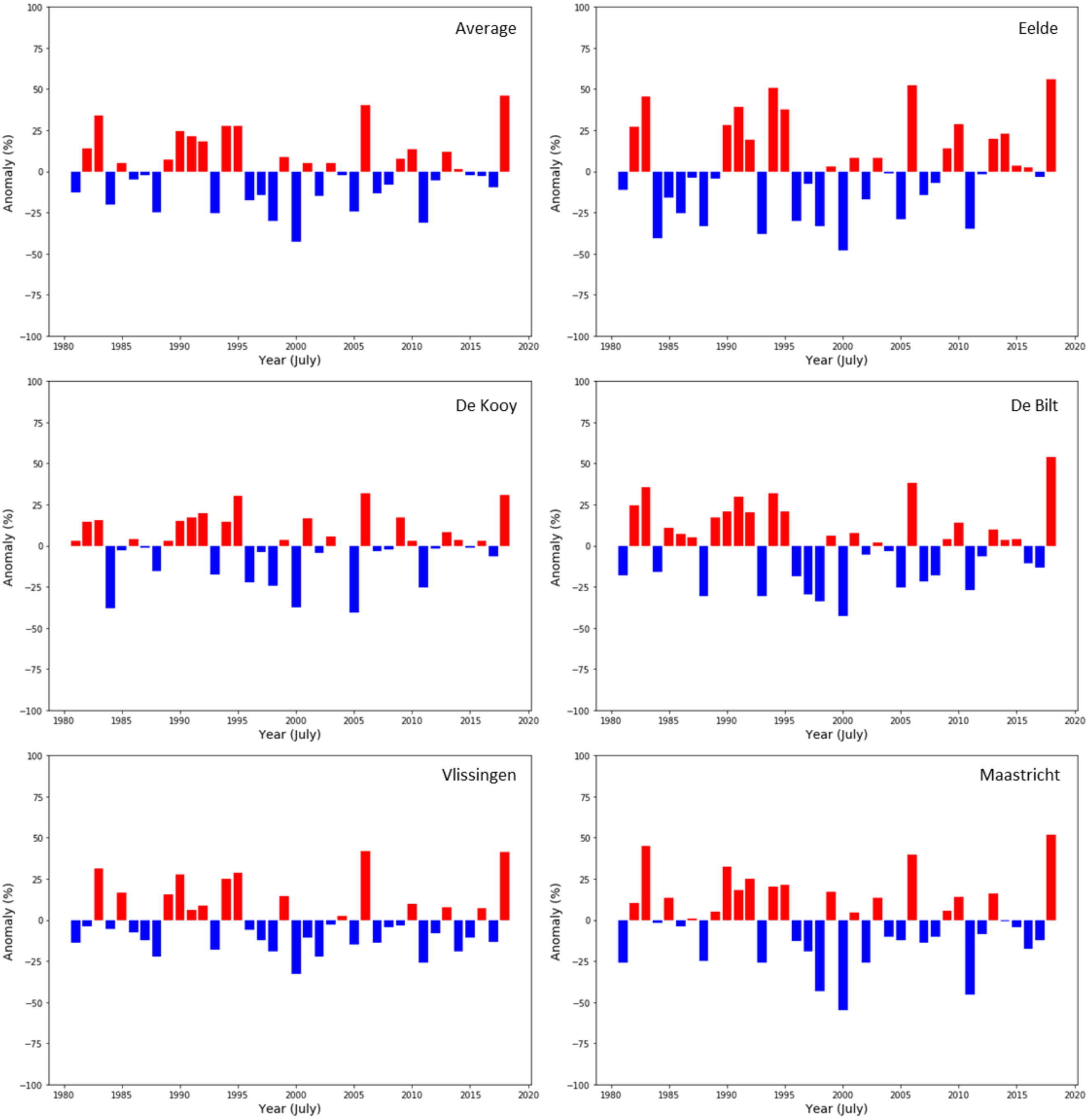

Figure A5: Sunshine anomaly for July between 9-14 UTC (Baseline 1981-2010).

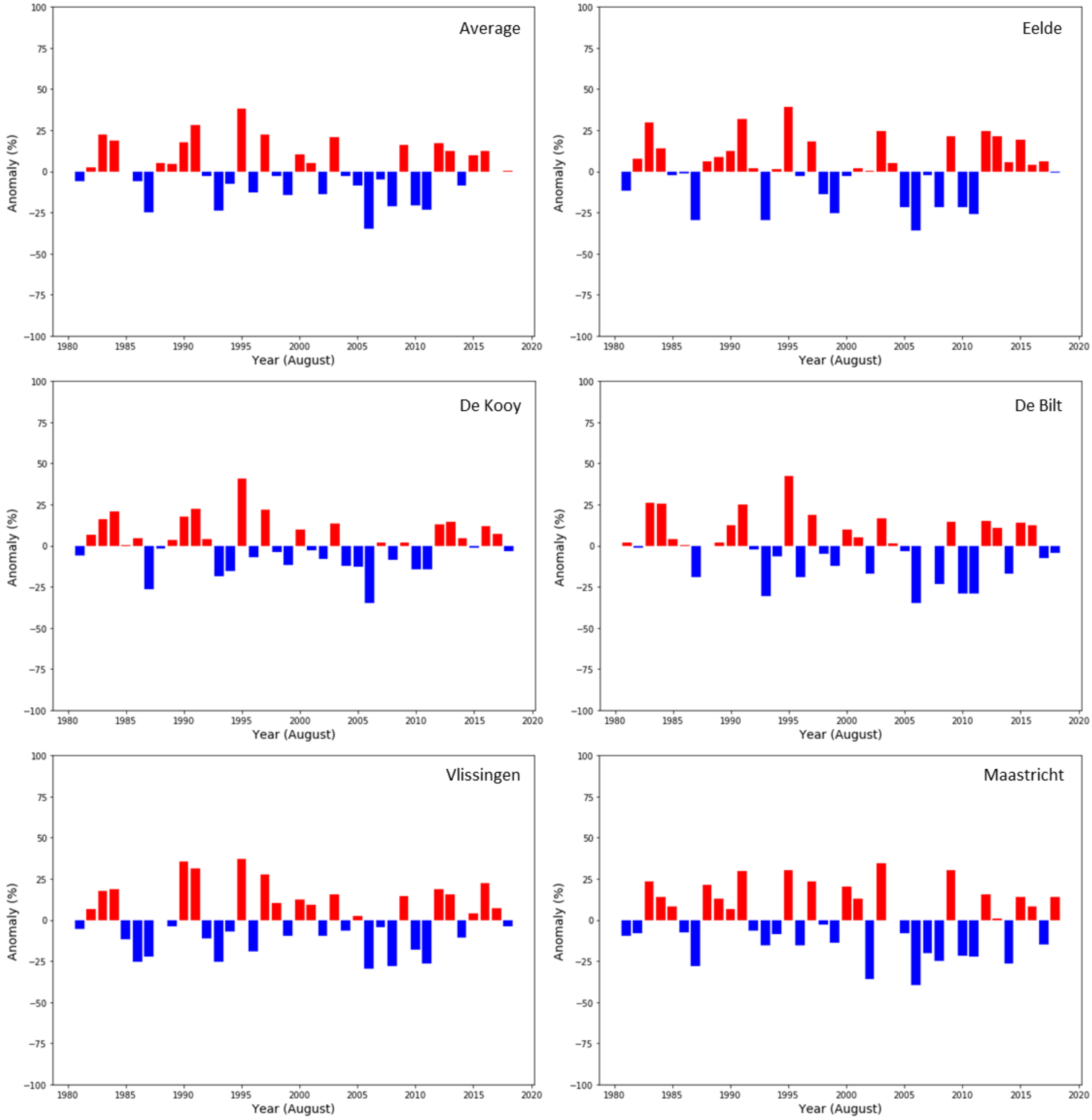

Figure A6: Sunshine anomaly for August between 9-14 UTC (Baseline 1981-2010).

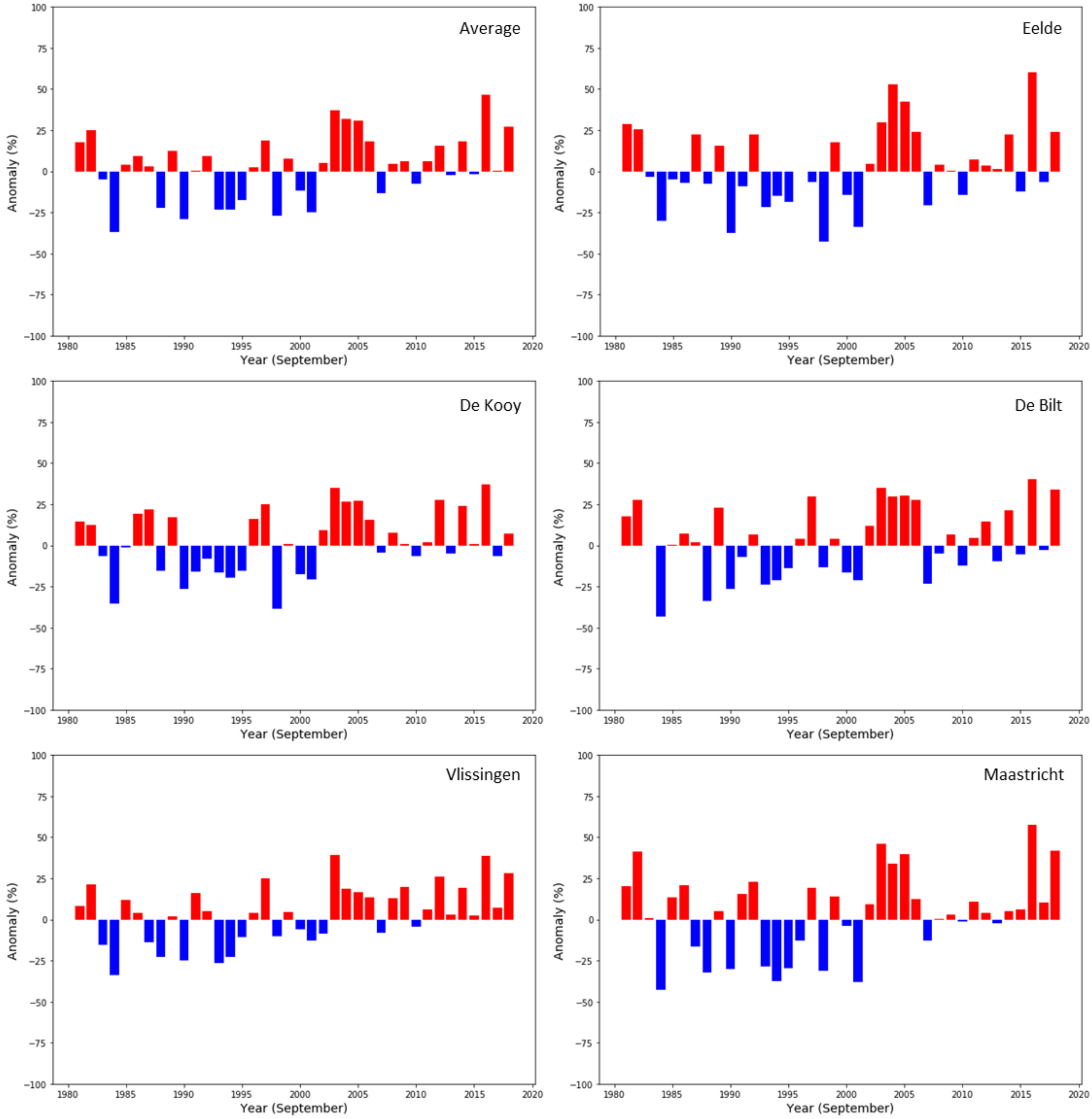

Figure A7: Sunshine anomaly for September between 9-14 UTC (Baseline 1981-2010).

Table A1: Monthly sunshine duration in percentages between 9-14 UTC.

Climatology 1981-2010	April*	May**	June*	July**	August**	September*	*Average*
De Kooy	56	58	53	55	55	48	*54*
De Bilt	49	50	44	48	50	44	*47*
Eelde	49	48	42	45	47	43	*46*
Vlissingen	53	52	52	54	55	49	*53*
Maastricht	47	48	46	50	52	45	*48*
Average	*51*	*51*	*47*	*50*	*52*	*46*	*50*
Climatology 1989-2018	April*	May**	June*	July**	August**	September*	*Average*
De Kooy	58	59	53	55	55	49	*55*
De Bilt	49	50	44	48	49	46	*48*
Eelde	49	49	42	45	48	45	*47*
Vlissingen	55	55	52	54	55	53	*54*
Maastricht	48	50	46	50	51	47	*49*
Average	*52*	*53*	*47*	*50*	*52*	*48*	*51*

* Maximum is 150 sunshine hours.
** Maximum is 155 sunshine hours.

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