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Validation of the HIC rain gauges data

Year 2024

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Abstract

This report summarizes the results of the validation of the data recorded during the year 2024 by 19 rain gauges operated by HIC. This validation is made by RMI and integrates two aspects.
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Report on the validation of the HIC rain gauges data of 2024

Michel Journée, Royal Meteorological Institute (RMI)

Abstract

This report summarizes the results of the validation of the data recorded during the year 2024 by 19 rain gauges operated by HIC. This validation is made by RMI and integrates two aspects. First, a human operator routinely monitors the data on successive periods of 24 hours. Issues detected on that daily timeframe are directly corrected. Second, monthly and annual values from the validated HIC data are compared against neighboring stations data as well as radar-derived rainfall estimates. Both validation aspects are treated in this report.

Contents

1 Introduction

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Precipitation overview in 2024 in Belgium

The annual rainfall in 2024 in Uccle is with 1170.7mm around 40% above the 1991–2020 normal value (837.1 mm). This is the largest annual total observed in Brussels-Uccle since 1833. This precipitation quantity is distributed on 209 precipitation days (normal value: 189.8 days), as shown in Figure 1, (left panel). The monthly precipitation values in Uccle exceed or equal the monthly normal values for all months except December (Figure 1, right panel). In Uccle, the precipitation excess is particularly marked for the period from January to September. During the last quarter of 2024 (October to December), the precipitation amounts were close-to-normal.

In the RMI climatological stations located in the Flemish Region (around 100 stations), the annual total varies between 734 mm (in Zwevegem) and 1283 mm (in Balen) and exceeds the 1991–2020 normal values everywhere except locally in the provinces of West and East Flanders (Figure 2).

As illustrated in Figure 3, the monthly precipitation accumulations exceeds the 1991–2020 normal values on average for the Flemish Region for 7 months (January, February, March, April, May, July and September 2024). On average for the Flemish Region, a precipitation excess of 18% can be noted for the year 2024 versus the reference period 1991-2020.

The monthly precipitation accumulations spatially averaged for the main flemish river catchments are finally compared to their respective 1991-2020 normal values in Figure 4.

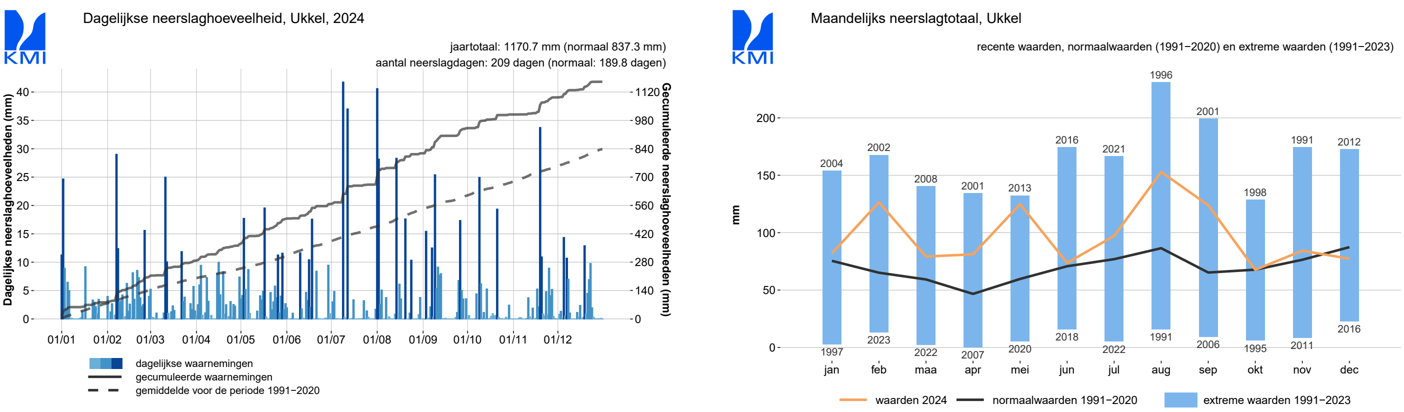

Figure 1: Daily and monthly precipitation values in Uccle in 2024.

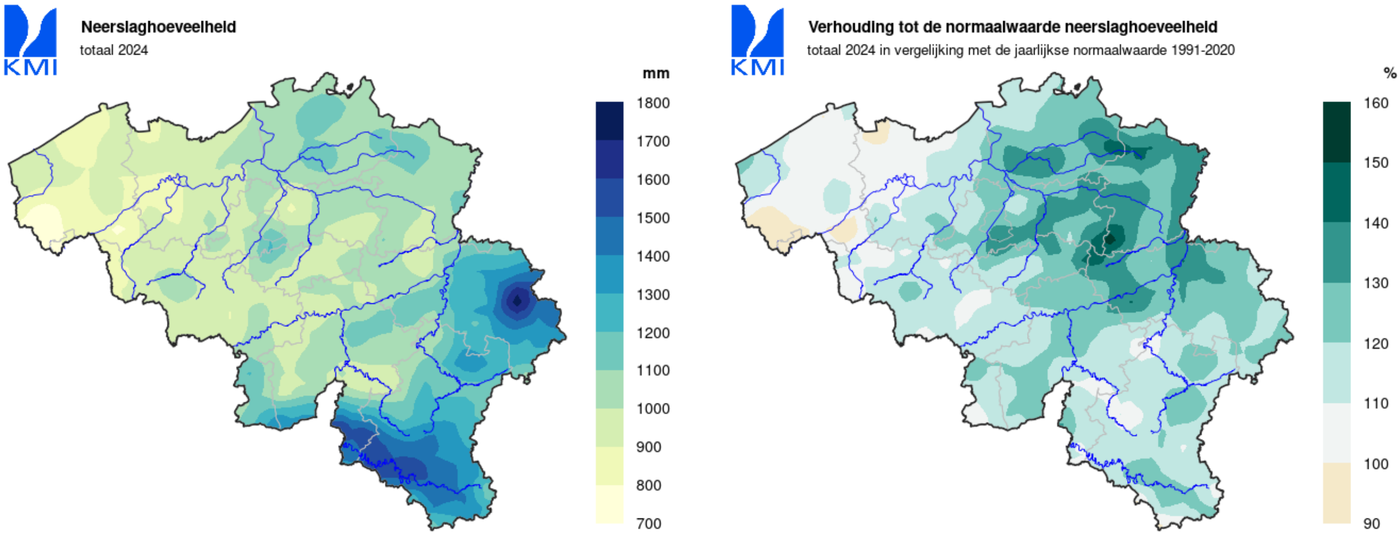

Figure 2: Map of the annual rainfall in Belgium in 2024 (left panel) and its deviation versus the 1991–2020 normal values (right panel). Local extremes are slightly smoothed in these maps.

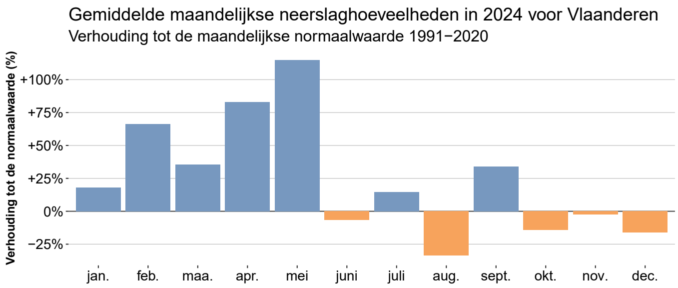

Figure 3: Monthly precipitation anomalies with respect to the period 1991-2020 on average for the Flemish Region from January to December 2024.

Figure 4: Monthly precipitation anomalies with respect to the period 1991-2020 on average for the flemish river catchments from January to December 2024.

HIC rain gauges data

The locations of the HIC rain gauges are listed in Table 1 and displayed on a map in Figure 5. The following changes have been made to some rain gauges in 2024:

- The rain gauge plu11a (Lot) was temporally closed from 15th June 2023 to 5th March 2024 because of works at a pumping station.

In total, 19 rain gauges have provided rainfall measurements in 2024. All rain gauges are weighing rain gauges of the manufacturer OTT. Precipitation quantities are recorded every 5-min with a resolution of 2 decimals.

Table 1: Code, name and location of the HIC rain gauges.

code	location	latitude	longitude	remark
plu01a	Aarschot	50.982	4.851	
plu02a	Bornem	51.108	4.239	
plu03a	Boortmeerbeek	50.991	4.579	
plu04a	Brugge	51.221	3.234	closed between June 2020 and April 2022
plu05a	Denderleeuw	50.874	4.077	closed in August 2020
plu06a	Elst	50.812	3.739	
plu07a	Genk	50.927	5.513	closed in February 2020
plu07b	Genk	50.935	5.493	opened in August 2019
plu08a	Kanne	50.811	5.671	
plu09a	Lo-Fintele	50.958	2.736	
plu10a	Lommel	51.248	5.263	
plu11a	Lot	50.767	4.270	temporarily closed from 15th June 2023 to 5th March 2024
plu12a	Ronse	50.739	3.554	
plu13a	Sint-Baafs-Vijve	50.914	3.416	
plu14a	Sint-Laureins	51.233	3.534	
plu15a	Tienen	50.790	4.914	
plu16a	Vlamertinge	50.844	2.811	
plu17a	Zele	51.046	4.047	
plu18a	Zoutleeuw	50.841	5.109	
plu19a	Zwevegem	50.824	3.345	
plu20a	Ninove	50.838	4.039	opened in February 2021

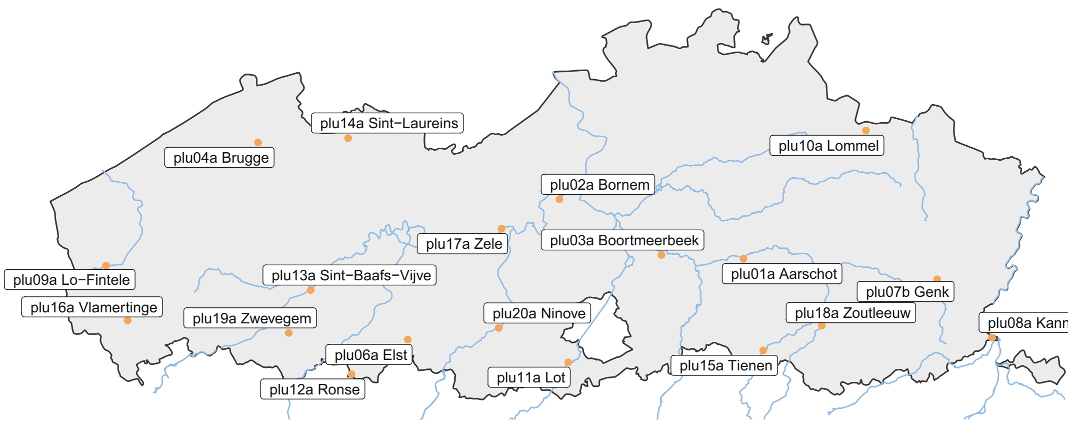

Figure 5: Location of the operational HIC rain gauges in 2024.

2 Data validation method

The Royal Meteorological Institute (RMI) is in charge of the validation of the 5-min timeseries of the HIC rain gauges since January 1, 2019.

RMI has a solid experience in meteorological data validation, and in particular in rain gauges data validation. Rain gauges observations in Belgium are verified routinely at RMI as an operational task. Each business day, an operator checks the latest rain gauges data with the help of data visualisation and manipulation tools. These tools are internally developped and accessible within a user-friendly interface named *PluvioControl*. The validation procedure is semi-automated in the sense that suspicious values are highlighted by this tool and proposed to the operator for further checks who takes the final decision to validate or to correct these values.

PluvioControl allows the operator to interact with observations from automatic rain gauges (5-min data) as well as manual rain gauges (daily precipitation totals). Till the end of 2018, RMI performed a routine validation of the rain gauges data recorded within the Belgian climatological network (around 200 stations), by 15 automatic rain gauges in RMI stations and by around 90 weighing rain gauges operated by the Walloon hydrological services. Since January 2019, rain gauges data from the HIC stations have been integrated in this routine validation.

Because the daily observations in the Belgian climatological network are made each morning at 08:00 (local time), the validation of both manual and automatic rain gauges is made on periods from 08:00 on a given day to 08:00 on the next day. In this way, daily totals from automatic rain gauges can be accordingly compared to daily values from manual rain gauges.

Each business day D, the data received since the previous validation period till 08:00 on day D are verified (i.e., on Mondays, data from Friday 08:00 till Monday 08:00 are typically verified, while on Tuesdays, the validation concerns the data from Monday 08:00 till Tuesday 08:00).

The following tools are available in PluvioControl to detect suspicious values:

- An overview provides various statistics about data availability.
- Interactive maps (based on the Google maps API) allows a spatial visualization of daily and hourly precipitation values (Figures 6 and 7). These values can be compared across the various observation networks. Overlays with radar accumulation products as well with cloud masks derived from Meteosat Second Generation data are also available.
- For each stations, time series plots compare hourly and daily values against corresponding values from neighboring stations (i.e., against an inverse distance weighing interpolation of the 5 closest stations) and radar data (Figure 8).
- A set of statistical plausibility tests performed at various timescales (5-min, 1-hour and daily data) enables to highlight suspicious cases.
- For each station, a spatial analysis lists the daily totals from the closest rain gauges. Data from the rain gauges operated by VMM are available in PluvioControl even if these data are not checked for inconsistencies.
- As snow can be an issue for precipitation observations (especially for the previous tipping bucket rain gauges), all available observations regarding snow (snowfall and snow depth) are centralized in a page of PluvioControl.

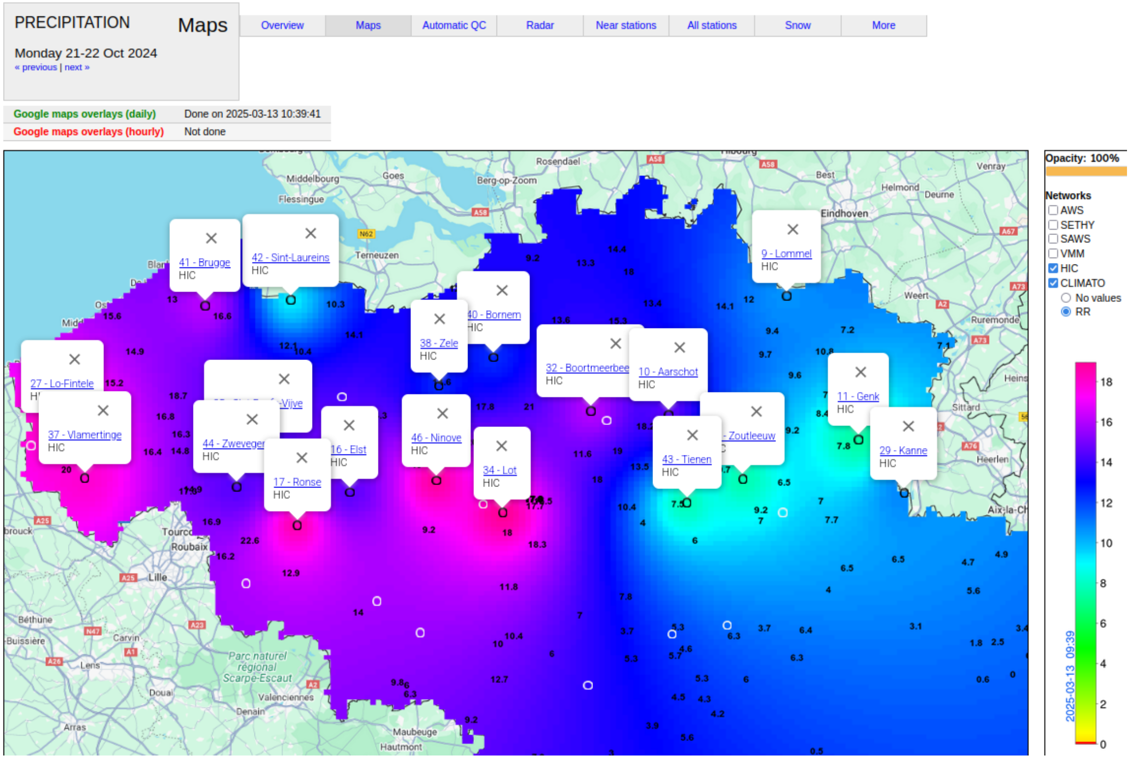

Figure 6: Data visualisation on maps in PluvioControl: comparison against daily observations of climatological stations (case of October 21, 2024). The background field is an interpolation of the daily values recorded in the HIC stations while the numbers correspond to the observations of the climatological stations.

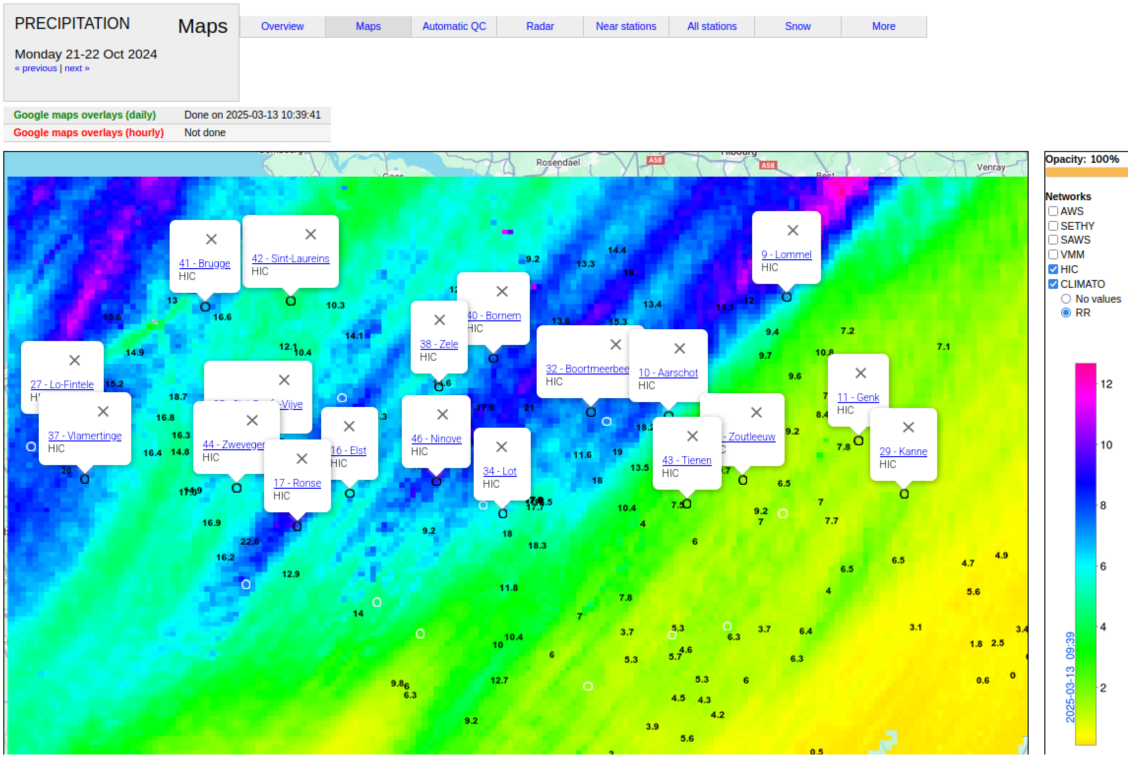

Figure 7: Data visualisation on maps in PluvioControl: comparison against daily radar data (case of October 21, 2024). The background field represents the estimations of the radar of Jabbeke. The numbers correspond to the observations of the climatological stations.

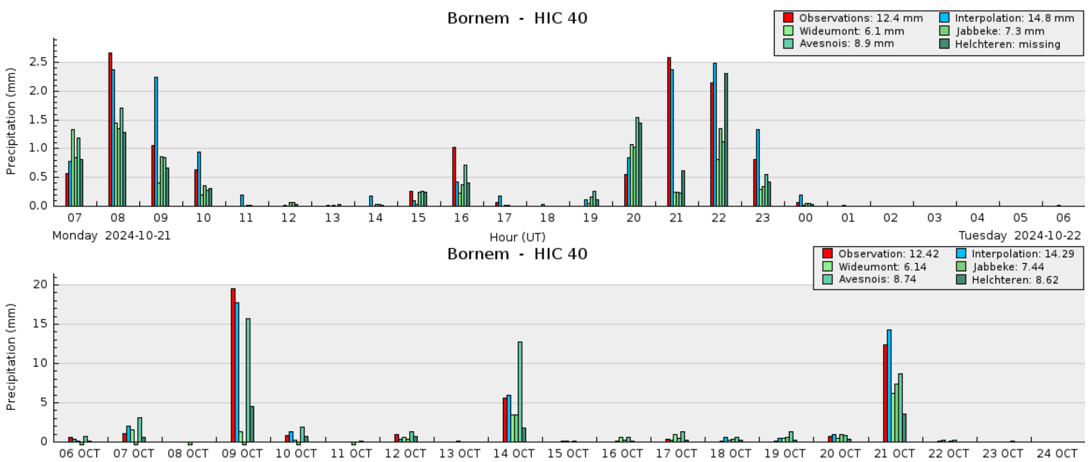

Figure 8: Comparison of hourly (top panel, case of October 21, 2024 for Bornem) and daily (bottom panel, illustration of a period of 20 days including October 21, 2024 for Bornem) data against an inverse distance weighing interpolation of neighboring stations and radar estimations.

With the help of these tools, the operator checks all suspicious cases one by one and corrects the data when necessary. Corrections can be applied directly on the 5-min data. Alternatively, corrections can also be set for hourly or daily totals and then automatically reported on the 5-min data. Missing data are systematically filled with estimations which are mostly based on neighboring stations data. The operator has however the possibility to use radar estimates instead, which are in some cases more appropriate (e.g., case of small-scale convective precipitation). Once the suspicious values have all been checked, the remaining unverified data are considered as valid. Quality flags with value either 'valid', 'suspicious' or 'corrected' are attributed to each 5-min data.

3 Validation statistics

The 5-min time series of the 19 HIC rain gauges represent almost values in 2024. The heat maps in Figures 9 and 10 provide some results regarding the validation of these time series. These plots illustrate for each station and month the amount of valid, missing/unfeasible, suspicious and erroneous data. Unfeasible 5-min data are those that are negative or larger than 50mm. Erroneous values are values between 0mm and 50mm that had to be corrected.

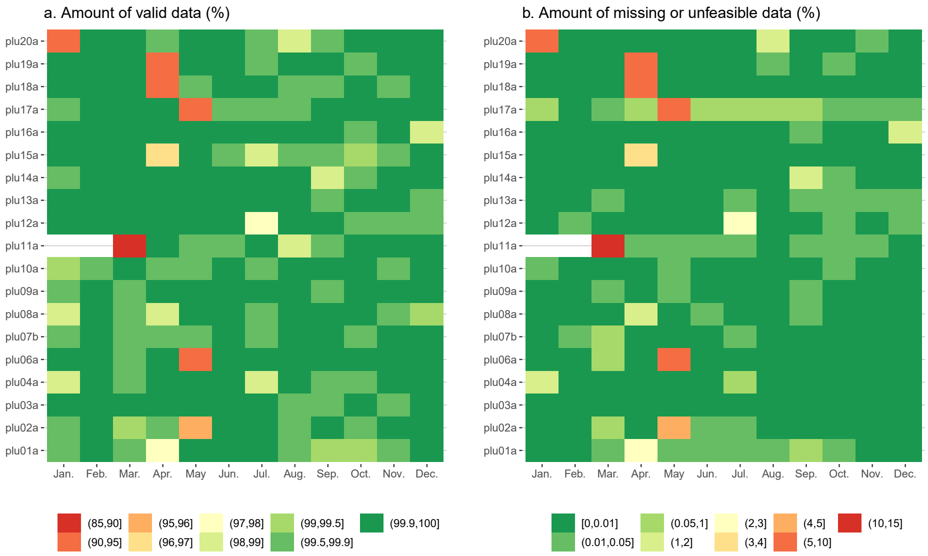

Figure 9: Illustration of the amount in % of valid and missing/unfeasible data per station and month. Unfeasible 5-min data are those with a negative value or a value larger than 50mm.

Figure 10: Illustration of the amount in % of suspicious and erroneous data per station and month. Erroneous values are those between 0mm and 50mm that had to be corrected.

The results in Figures 9 and 10 indicate that most of the data are considered as valid (i.e., 99.6%). The remaining 0.4% of data are mainly missing data for which estimations have been provided. Suspicious data are quite rare and correspond to small non-zero precipitation values recorded during dry periods (according to both neighboring station and radar data), i.e., so-called phantom precipitations. Erroneous data are also rare and are of 2 types: small non-zero precipitation values during dry period (phantom precipitations) or excessively large values confirmed neither by neighboring stations nor by radar data. Phantom precipitations are a well-know potential issue of OTT rain gauges (depending on the firmware version) but are not really of concern for the HIC network as this problem occurs infrequently.

The series plu11a (Lot) that was temporally closed between 15th June 2023 and 5th March 2024 has been filled with estimations based on neighboring stations during that period.

4 Comparative analysis against neighboring stations

In this section, the validated data of the HIC rain gauges are compared against data from neighboring rain gauges. For each HIC station, the 4 closest stations with complete and validated time series in 2024 are considered. These neighboring stations are either RMI stations (manual or weighing rain gauges) or OTT weighing rain gauges of the Walloon hydrological services.

When comparing observations from different sensors and location, it is important to keep in mind the recommendations of the World Meteorological Organization (WMO). The WMO defines for all meteorological measurements an *achievable measurement uncertainty* which is "based on sensor performance under nominal and recommended exposure that can be achieved in operational practice. It should be regarded as a practical aid to users in defining achievable and affordable requirements" (WMO, 2018). In the case of precipitations, the recommended achievable measurement uncertainty is "the larger of 5% or 0.1 mm".

In Figure 11, annual totals derived from the validated 5-min time series of the 19 rain gauges are compared against annual totals from neighboring stations. The blue errorbar displays deviation of ±5% around the annual total of the HIC stations in order to highlight the WMO recommended achievable measurement uncertainty.

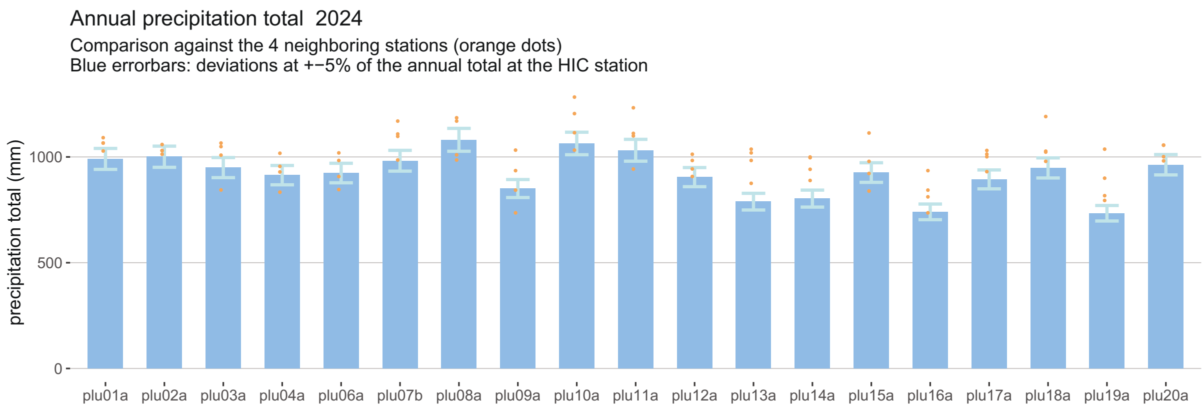

Figure 11: Comparison of the annual total of the HIC stations against the corresponding values of the 4 closest rain gauges (orange dots).

For most HIC stations, there are values of neighboring stations within the ±5% range around the annual total. For the other stations, a comparison of the monthly and daily values against the closest stations (see Appendix A) does however not highlight any specific issue. The largest discrepancies with the neighboring stations mostly result from small-scale intense convective precipitation events inducing significant differences in daily precipitations for some specific days.

The annual number of precipitation days based on 4 threshold values (i.e., number of days with at least 0.1, 1, 5 and 10 mm precipitation) are compared in Figure 12 against corresponding values of the 4 neighboring stations. Regarding the lowest threshold at 0.1mm, the number of precipitation days in the HIC stations matches well with those in neighboring stations. For the other thresholds, the values in the HIC stations are either within or below the range of those in neighboring stations. A station-wise comparison of the monthly number of precipitation days is provided in the Appendix A. These graphs do however not highlight any specific issue.

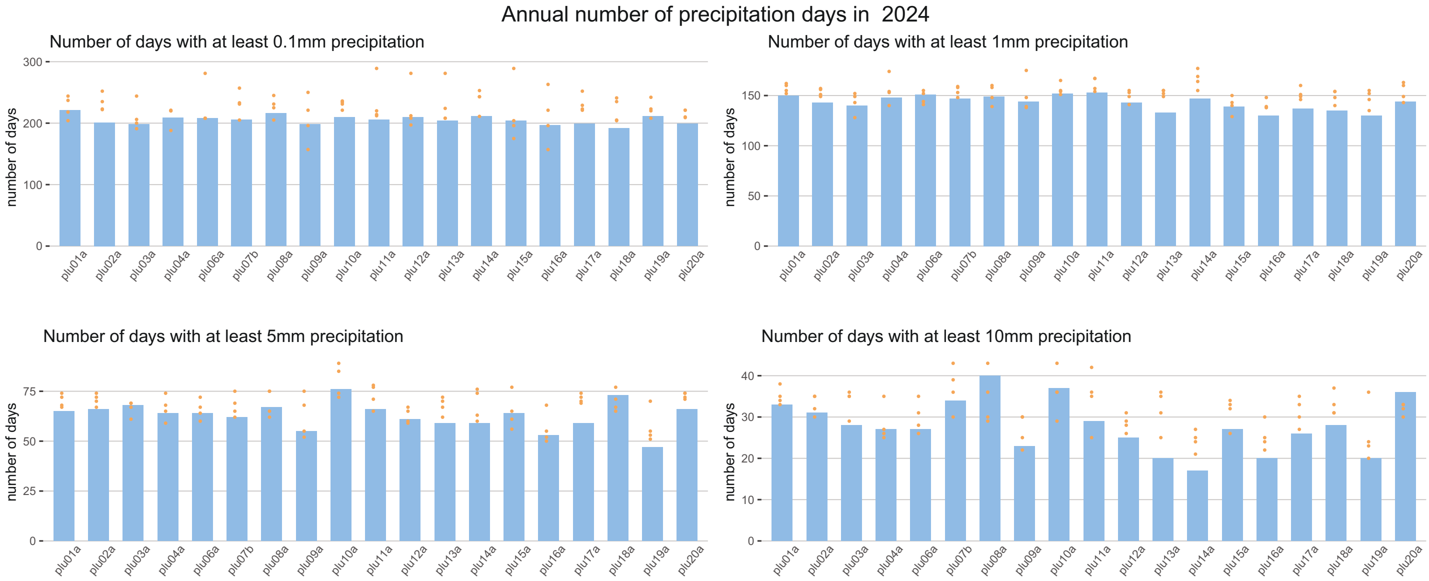

Figure 12: Comparison of the annual number of days with at least 0.1, 1, 5 or 10mm rainfall in the HIC stations against corresponding values of the 4 closest rain gauges (orange dots).

More detailed comparison results against the 4 closest stations are provided in the Appendix A for each HIC station.

5 Comparative analysis against radar data

In this section, the validated data of the HIC rain gauges are compared against radar-derived ground rainfall data. Annual and monthly radar-based precipitation totals are derived for the 19 locations of the HIC rain gauges from the daily composite RADQPE radar product (Goudenhoofdt, 2019).

This RADQPE product results from an advanced processing of the 3D radar reflectivity measurements including beam blockage correction, mitigation of non-meteorological echoes, precipitation classification and correction for the vertical profile of reflectivity. The rain rates are accumulated over a given duration by taking into account the movement of precipitation. The estimates are then adjusted to rain gauge measurements using a single bias correction. Estimations from single radars are combined into a composite using a distance-weighted scheme for the cold months and by taking the maximum value for the warm months. The composite product considered in the comparisons below integrates data from the radars of Wideumont, Jabbeke and Avesnois. The average radar bias is estimated based on the automatic rain gauges operated by RMI, SPW, HIC and VMM.

The annual total of the HIC rain gauges are compared against corresponding radar-derived values in Figure 13. The annual radar-based values overestimate the ground observations. In spite of this overestimation, the radar-derived values reproduce quite well the station-wise variability of the observed annual totals at the HIC stations (Figure 13).

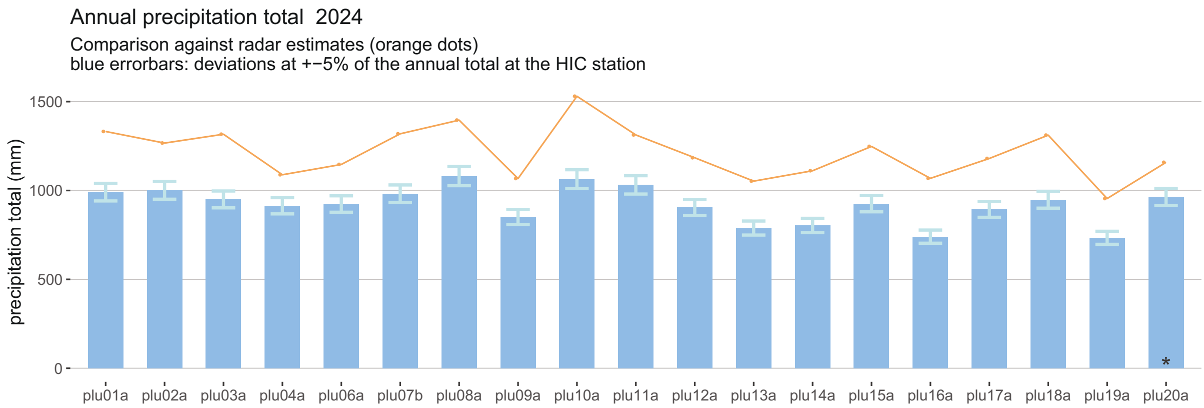

Figure 13: Comparison of the annual total of the HIC stations against radar-derived estimates.

Similar comparisons for monthly precipitation totals are provided in Figures 14 (bar plots per stations) and 15 (scatter plots per month). The analysis of the monthly values highlights a rather good match between rain gauges and radar estimations in January to April as well as in October to December for all stations. Large radar overestimations are observed from May to September.

Figure 14: Comparison of the monthly totals of the HIC stations against radar-derived estimates.

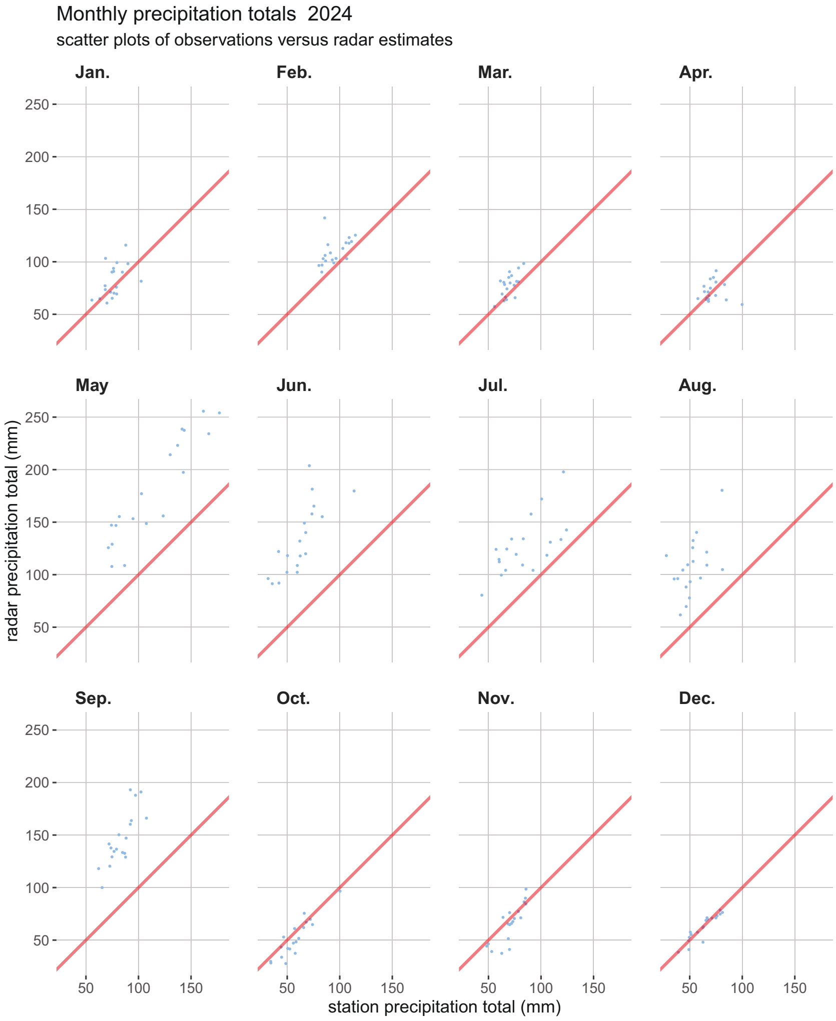

Figure 15: Scatter plots of the monthly totals of the HIC stations versus radar-derived estimates.

In spite of the limitations inherent to remote sensing observations, the radar data allows to compare the various rain gauges against a same reference. These analyses do not highlight specific outliers in the monthly and annual values of the HIC stations.

6 Conclusion

The routine daily validation of the data of the 19 HIC rain gauges indicates that most values are valid and corrections mainly concern missing values. Erroneous values are infrequent and either related to small non-zero values in dry periods (i.e., phantom precipitations) or excessively large values.

The daily validation enables to highlight and correct issues that can be detected when analyzing 24 hours of data. Issues such as small but persistent biases or drifts need however longer time frames to be detected. It is therefore useful to complement the routine daily validation with a comparative analysis of monthly and annual values.

This report therefore also summarizes comparative results of monthly and annual values derived from the validated HIC data against neighboring stations data as well as radar-derived rainfall estimates. These validations did not highlight specific issues in the HIC data. When comparing the HIC data against neighboring stations data in terms of monthly and annual precipitation totals or precipitation days, it appears that the HIC values are either within the range of neighoring stations or below this range, but rarely above it. A slight under estimation for some HIC rain gauges is thus possible but difficult to assess. Rain gauges data from 2024 are summarized in annual precipitation totals in Figure 16.

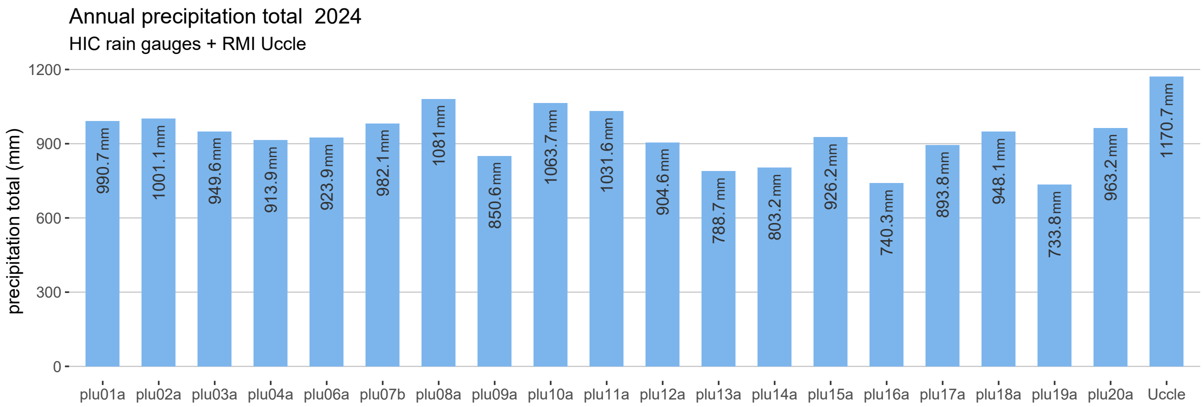

Figure 16: Annual precipitation total in the HIC stations and in the RMI station in Uccle.

Finally, in addition to the measurement uncertainty related to the sensor performance, there are uncertainties related to the influence of the close environment of the rain gauge on the measurements. In this context, WMO defines a siting classification (WMO, 2018b). RMI automatic rain gauges are classified either as "Class 1" (i.e., reference site) or "Class 2" (i.e., additional estimated uncertainty added by siting up to 5%). For sites of "Class 3", "Class 4" or "Class 5", an additional estimated uncertainty added by siting has to been into account that ranges up to 15%, 25% or 100%, respectively.

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World Meteorological Organization (WMO), 2018. Operational Measurement Uncertainty Requirements and Instrument Performance. Annex 1.E. of the guide to meteorological instruments and methods of observation (CIMO guide). Geneva, Switzerland: Secretariat of the World Meteorological Organization. WMO No. 8.

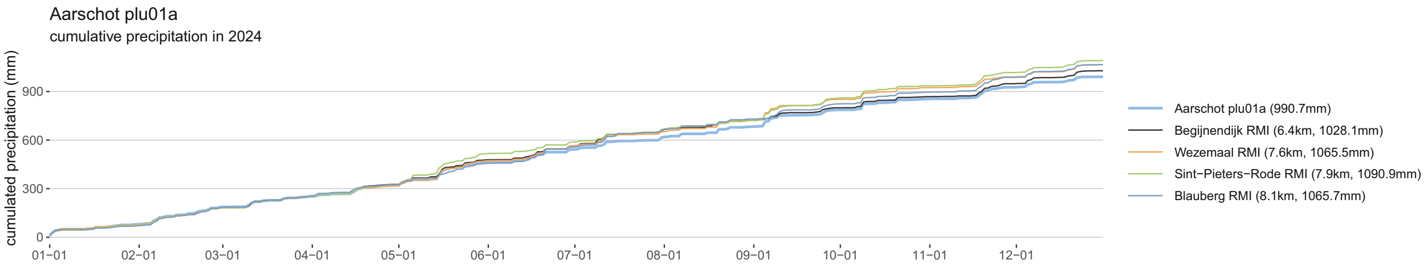
World Meteorological Organization (WMO), 2018b. Siting Classifications for Surface Observing Stations on Land. Annex 1.B of the guide to meteorological instruments and methods of observation (CIMO guide). Geneva, Switzerland: Secretariat of the World Meteorological Organization. WMO No. 8.

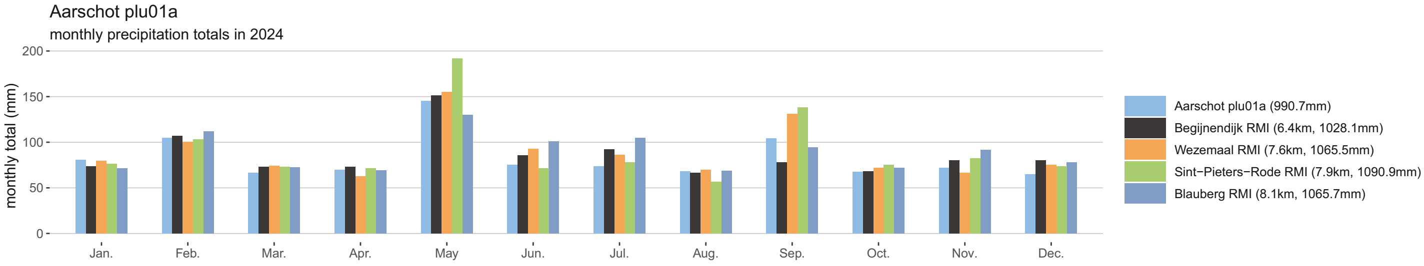
A Comparative analysis against neighboring stations: results per HIC station

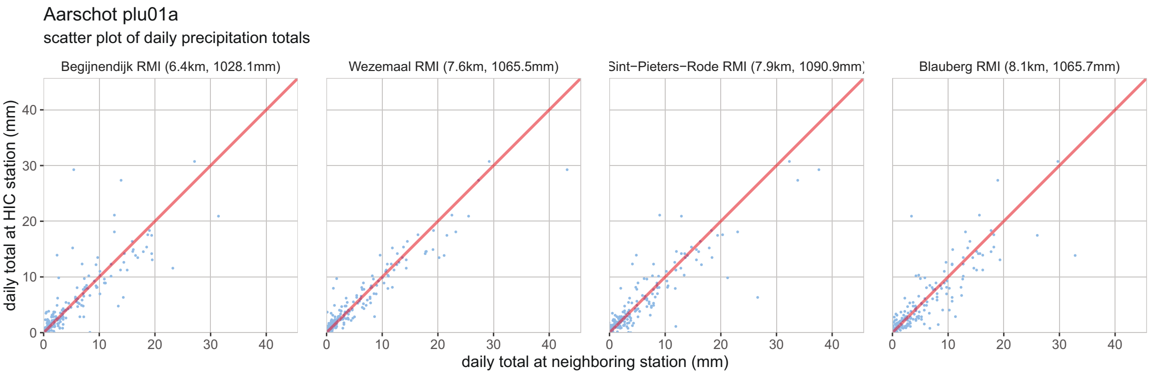
This appendix provides detailed comparison results of the validated data of the HIC rain gauges against data from the 4 closest stations with complete and validated time series in 2024. These neighboring stations are either RMI stations (manual or automatic) or weighing rain gauges from the Walloon hydrological services (SPW). For each station, 5 types of graphs are provided:

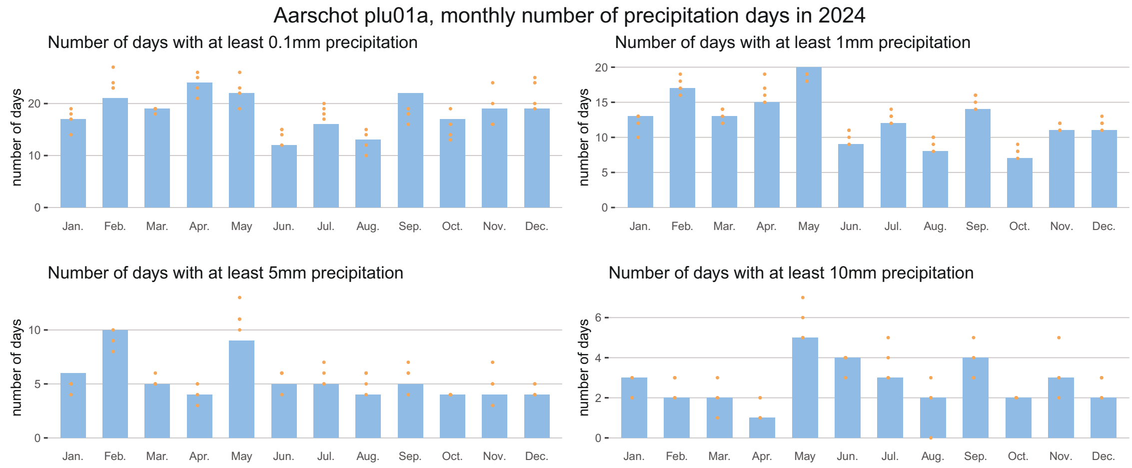
- cumulative precipitation plots,
- bar plots of monthly totals,
- scatter plots of daily values,
- bar plots of the monthly number of days with 0.1, 1, 5 and 10mm precipitation (orange dots represent corresponding values of the 4 neighboring stations).
- bar plots with annual values compared to the estimated 1991-2020 normal.

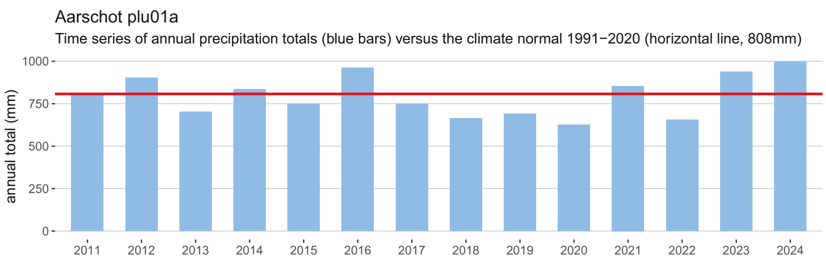
A.1 plu01a Aarschot



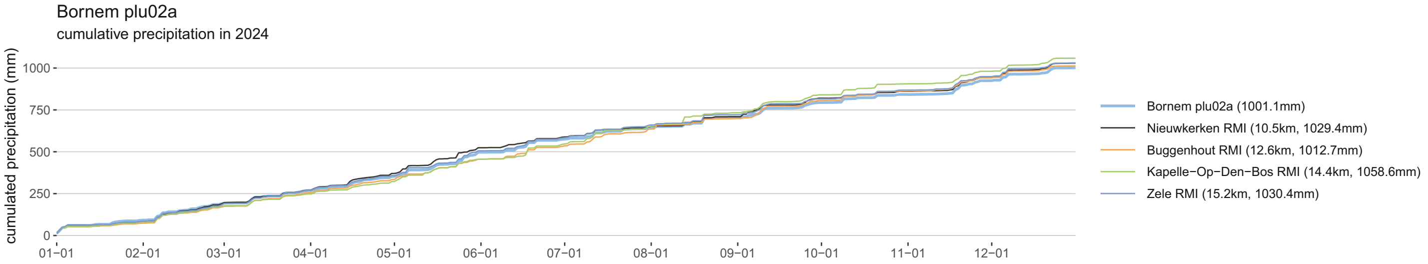


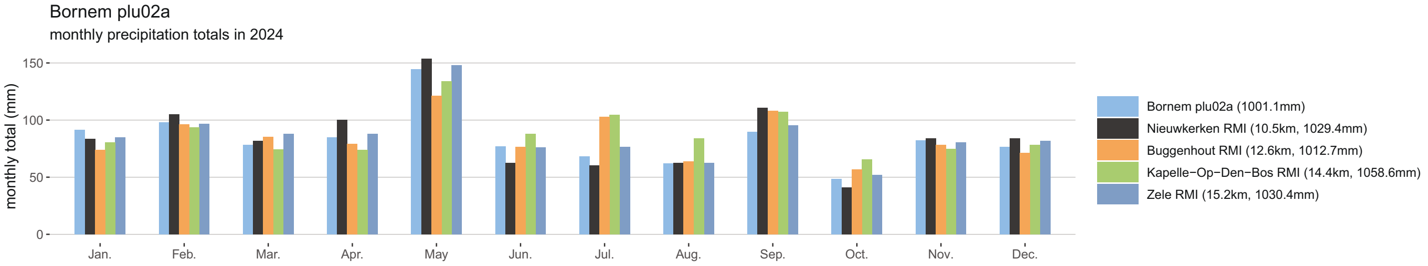


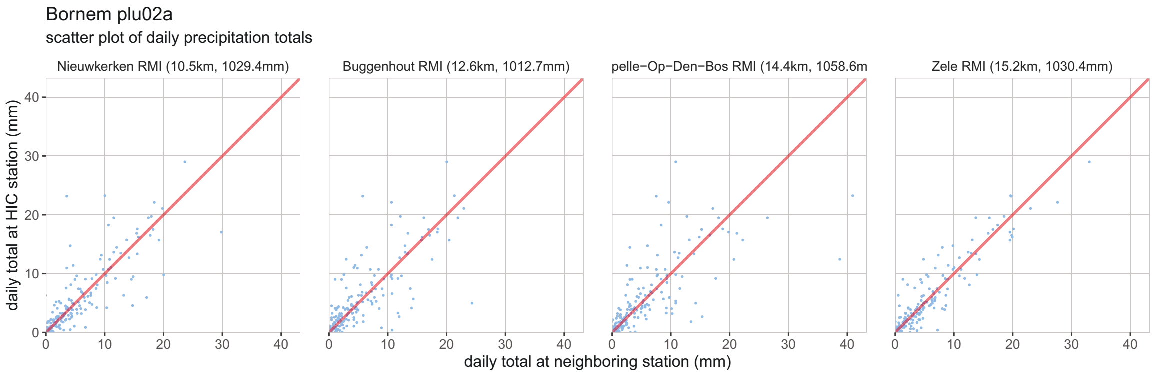


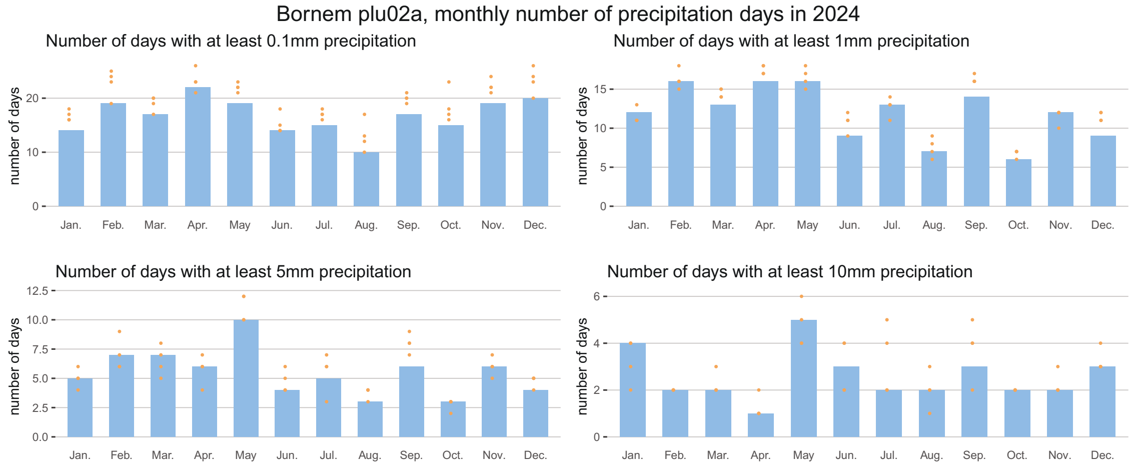


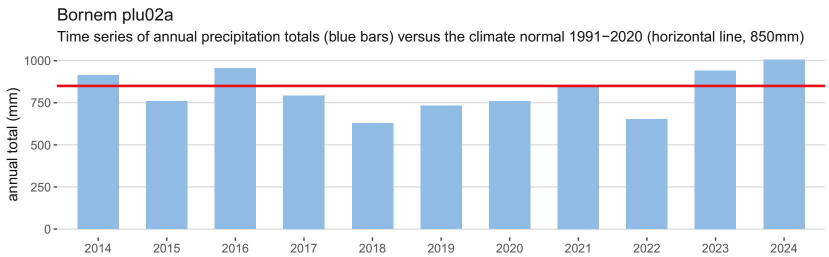
A.2 plu02a Bornem



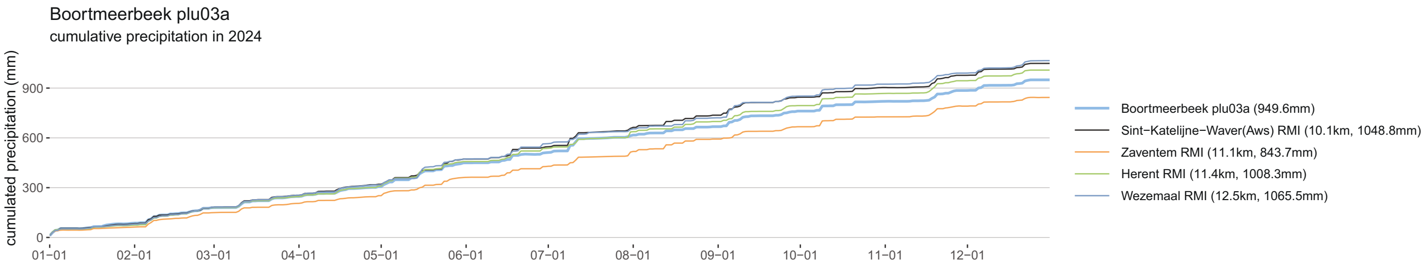


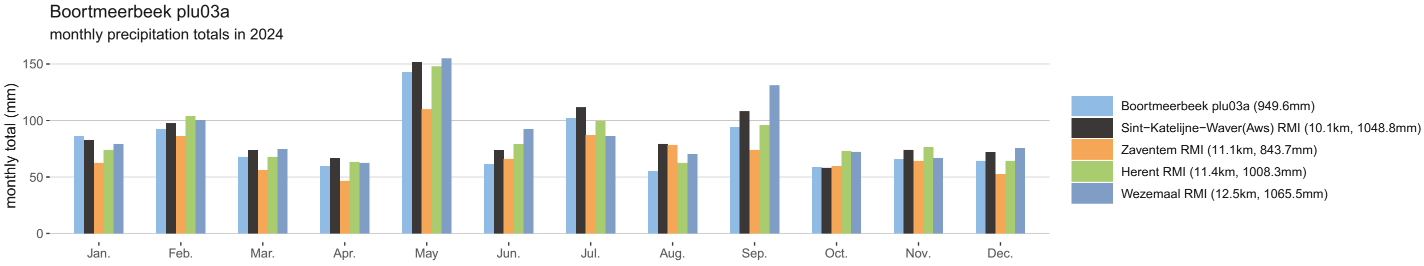


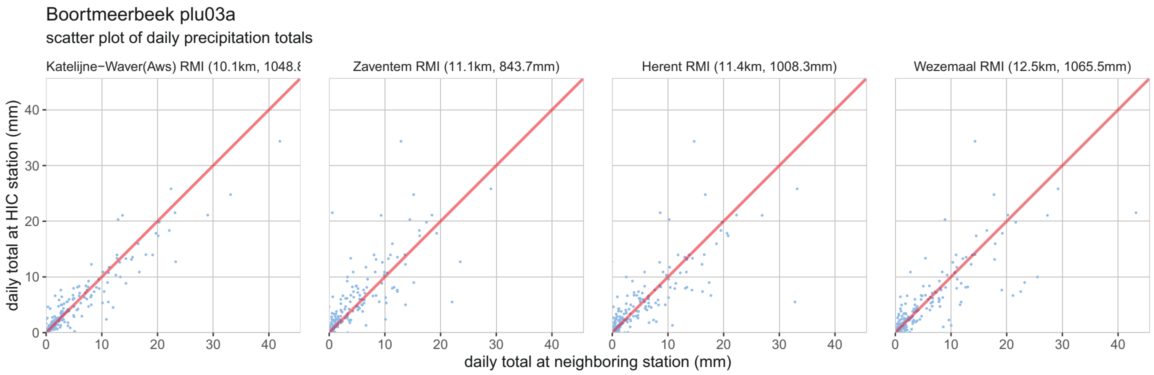


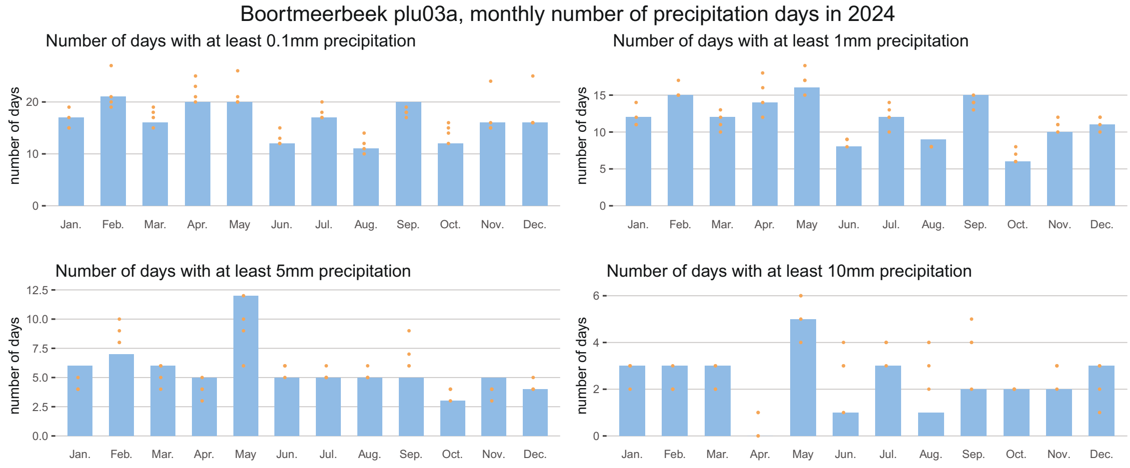


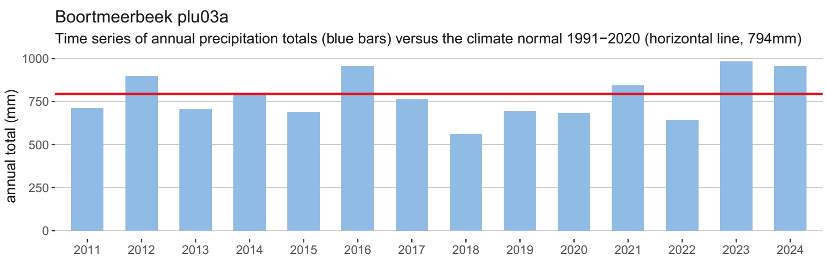
A.3 plu03a Boortmeerbeek



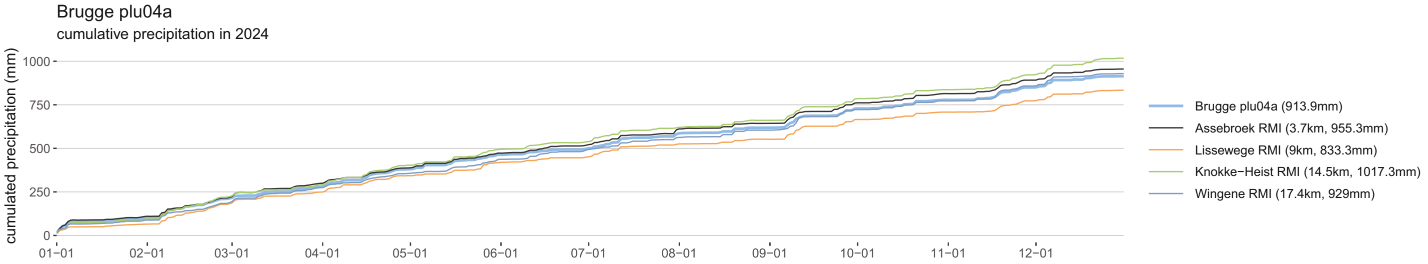


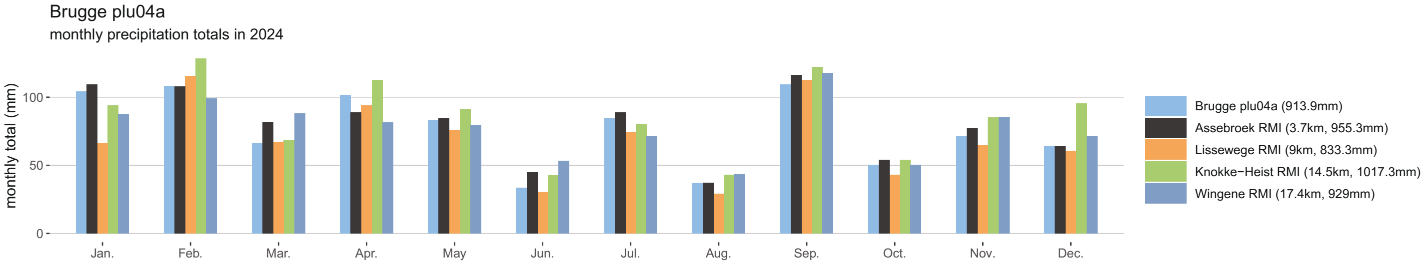


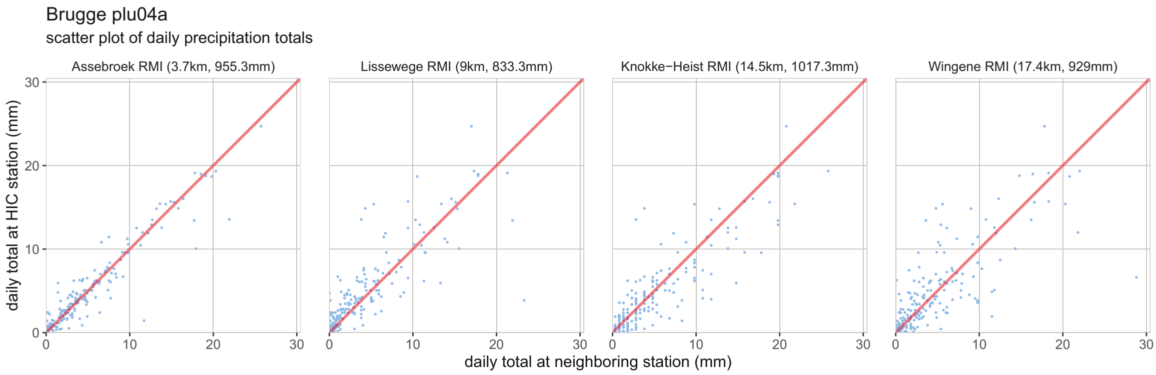


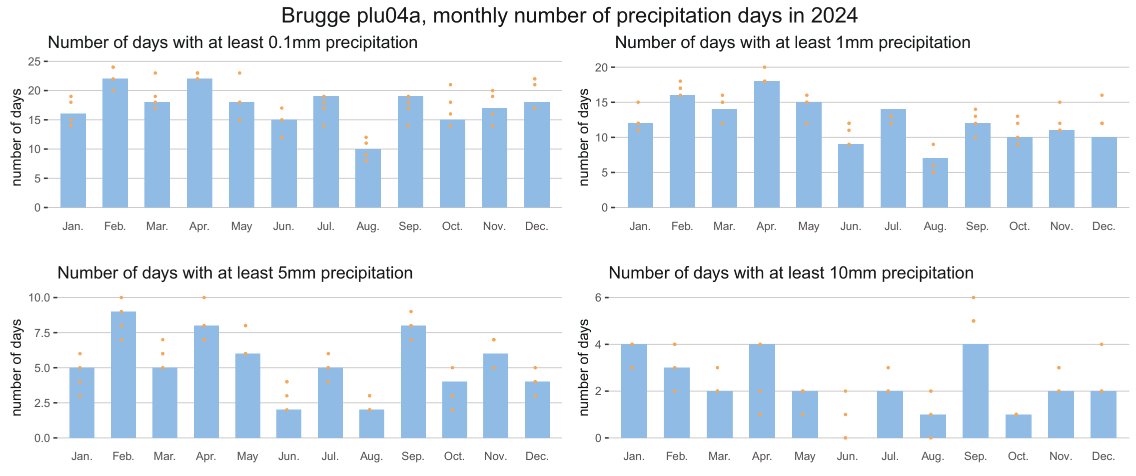


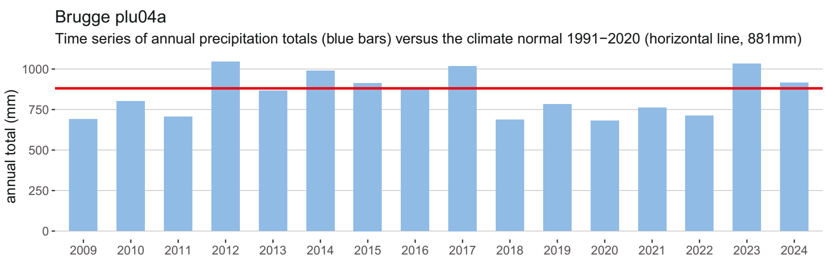
A.4 plu04a Brugge



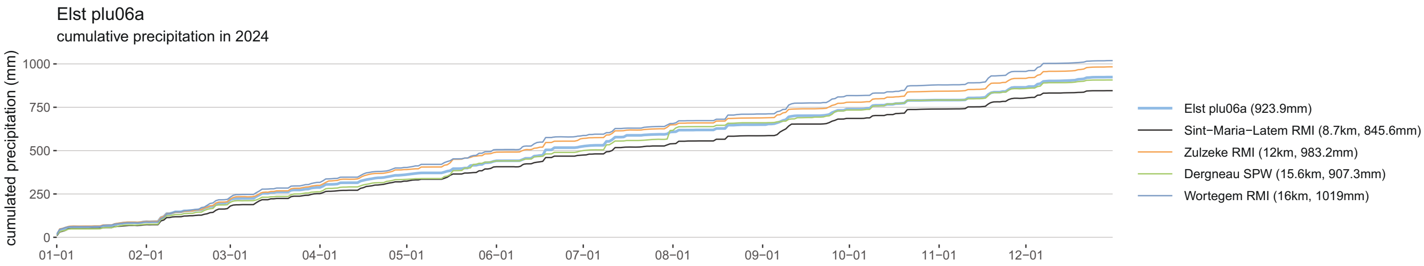


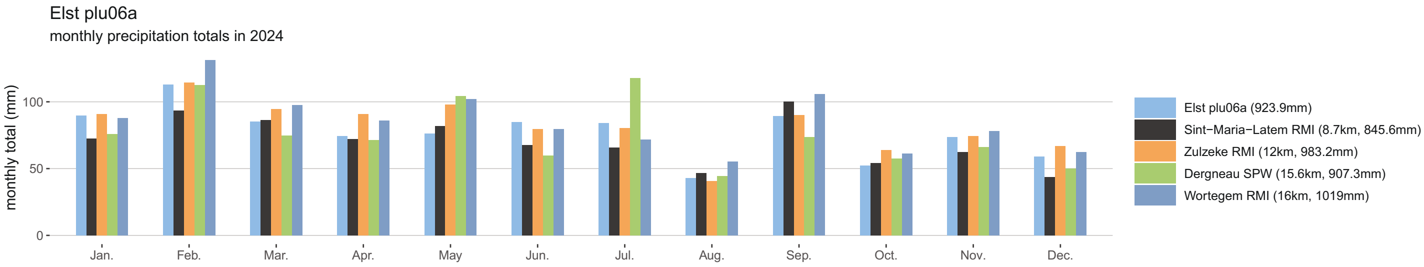


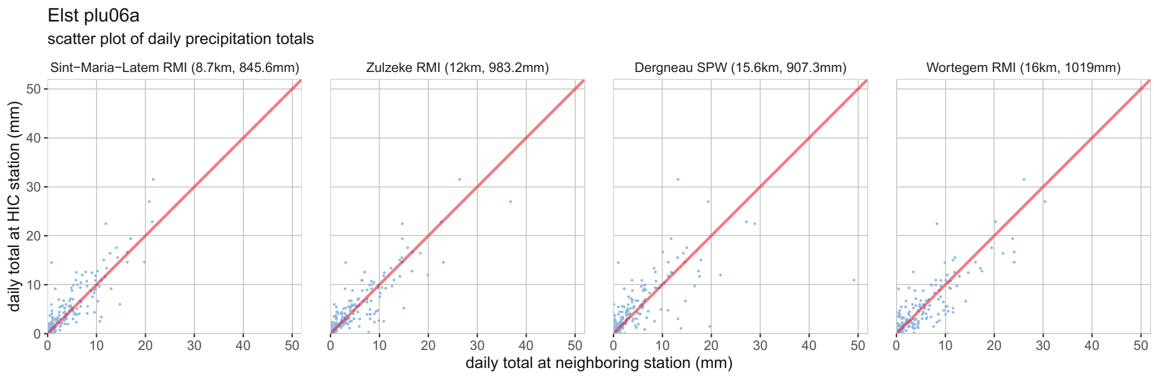


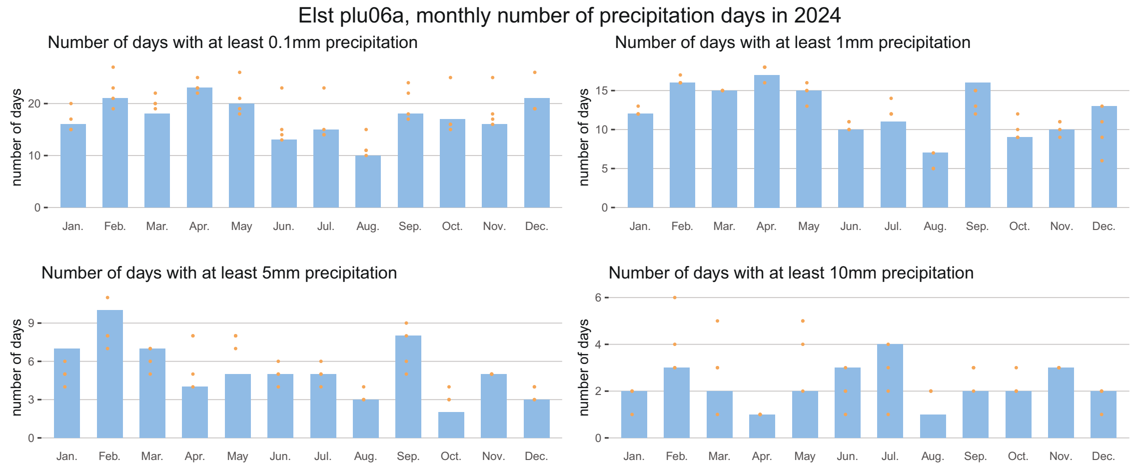


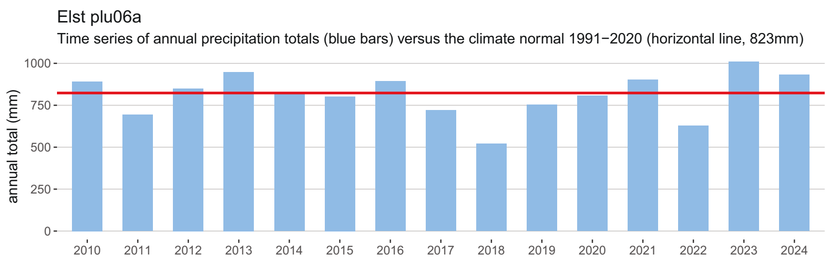
A.5 plu06a Elst



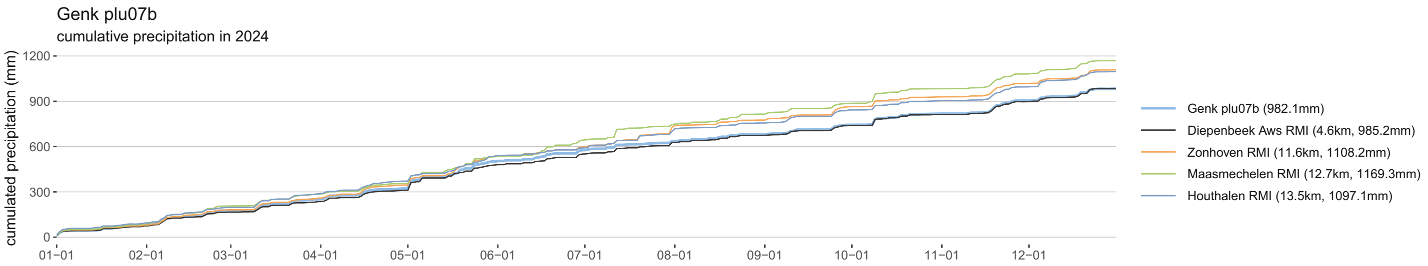


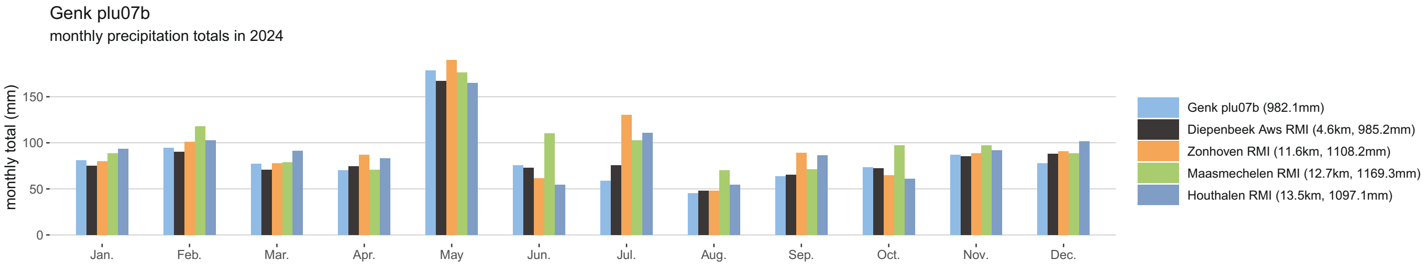


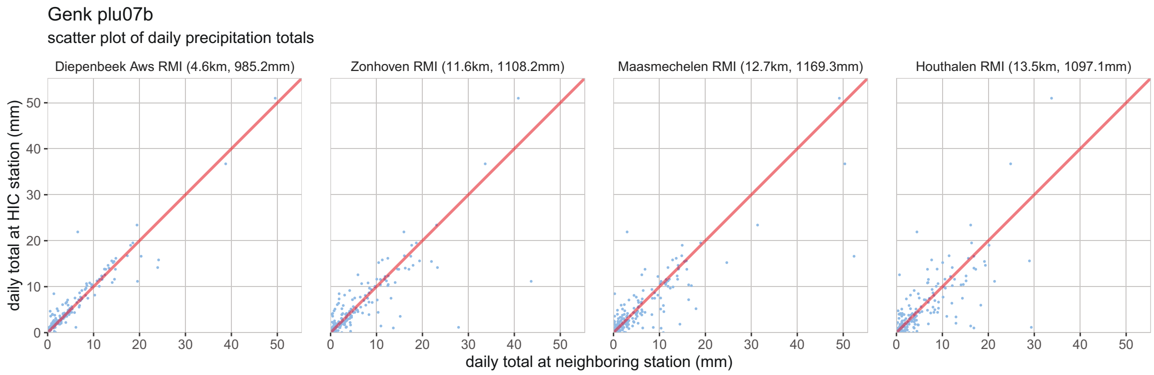


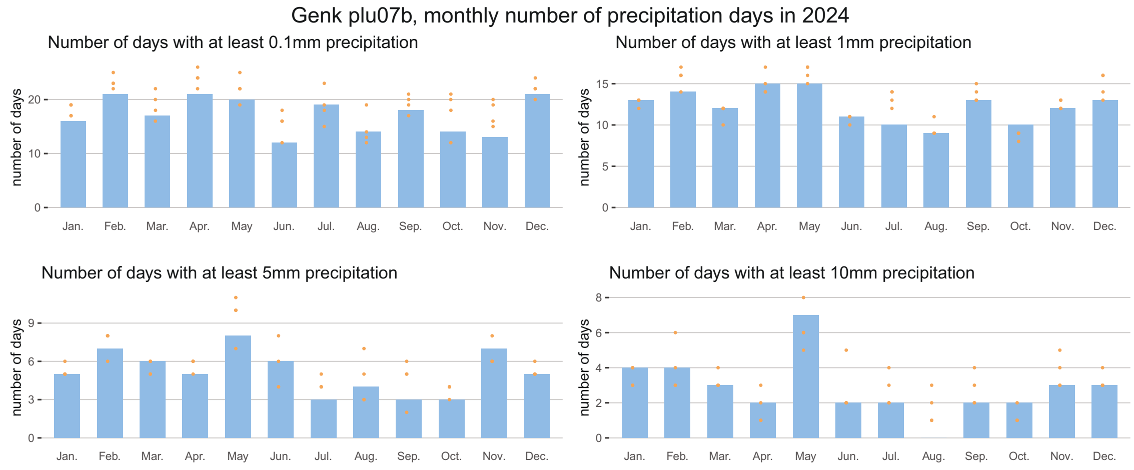


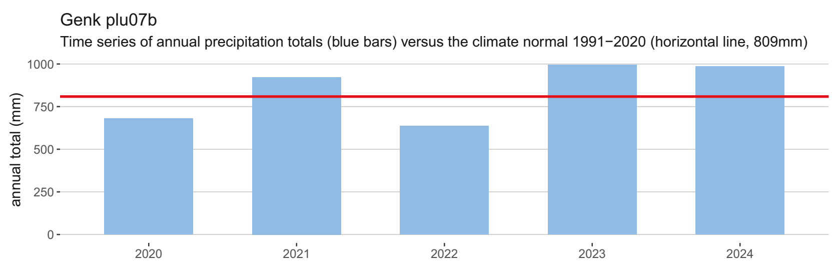
A.6 plu07b Genk



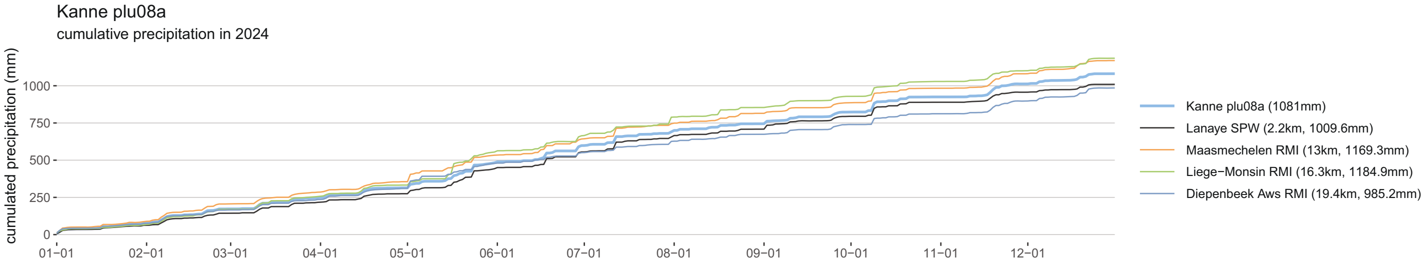


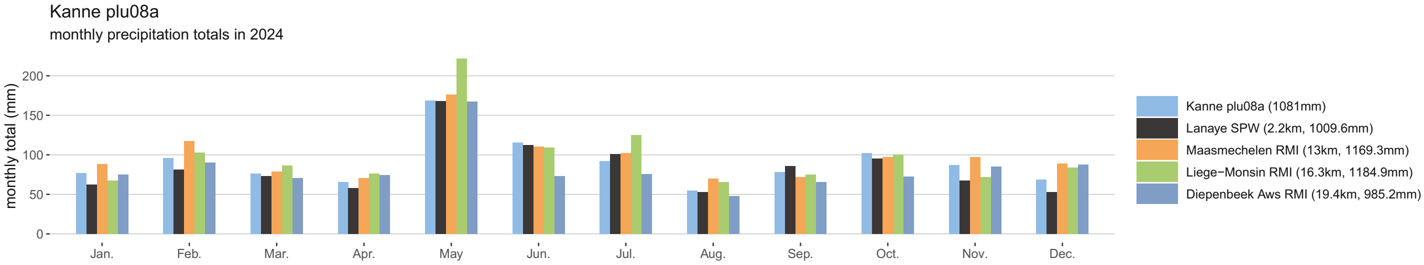


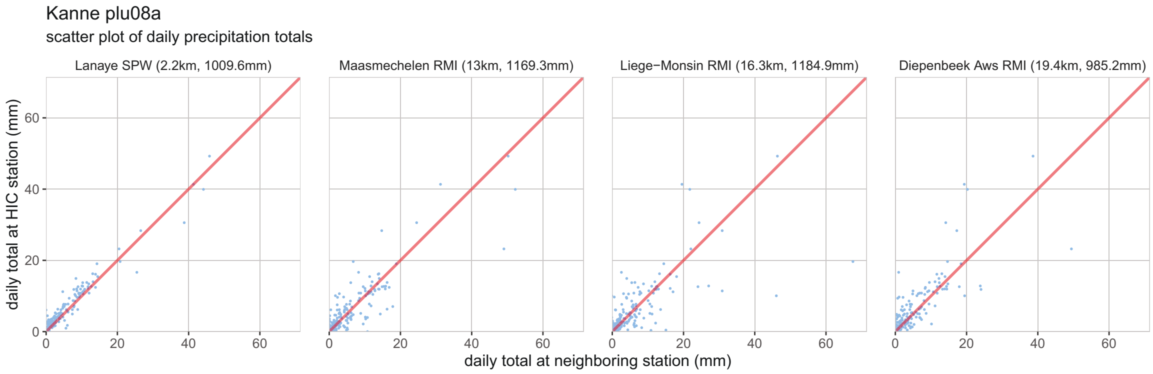


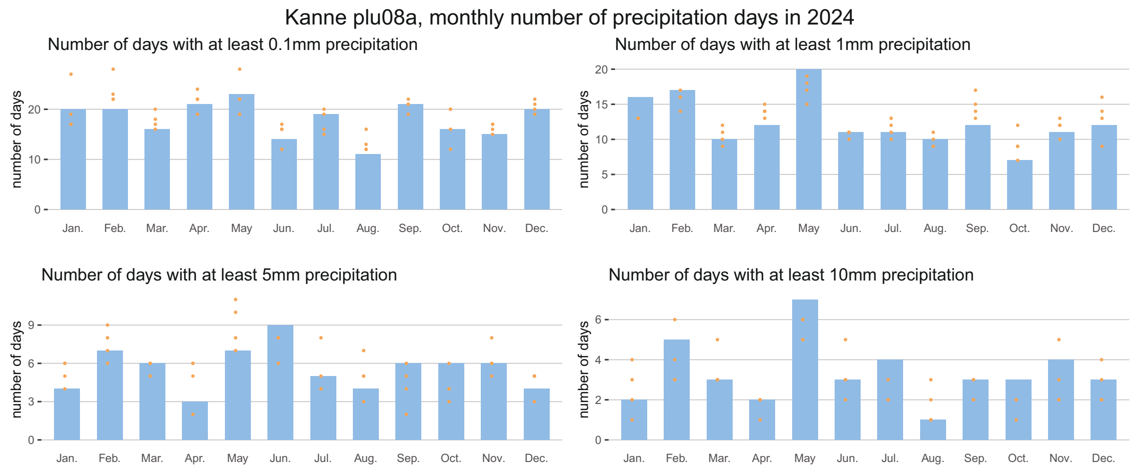


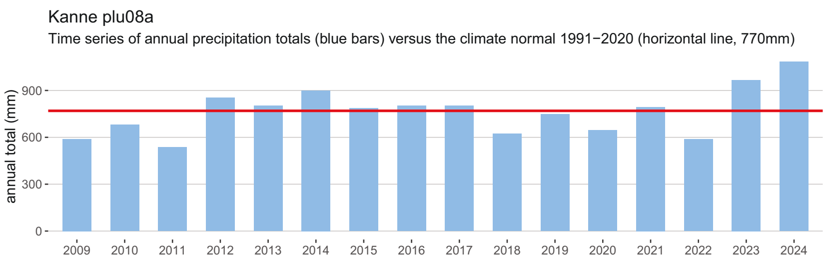
A.7 plu08a Kanne



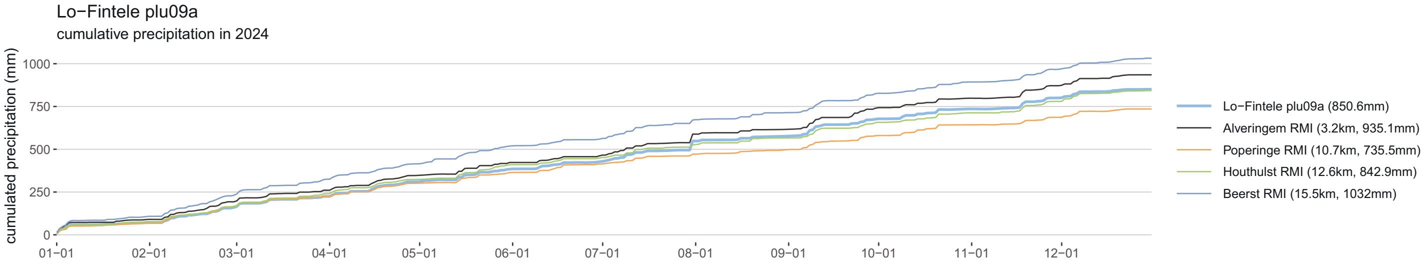


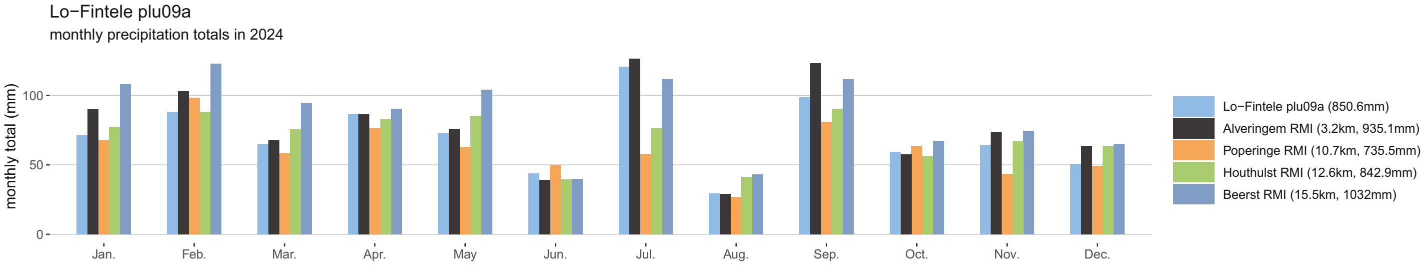


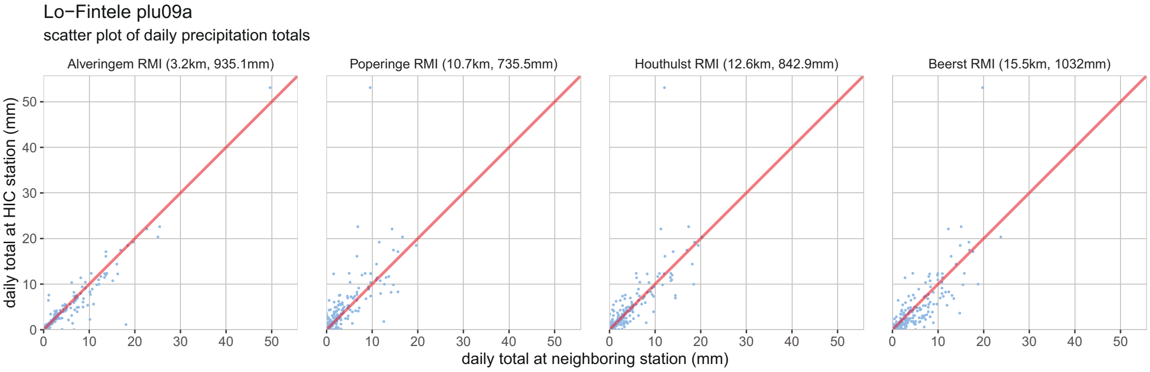


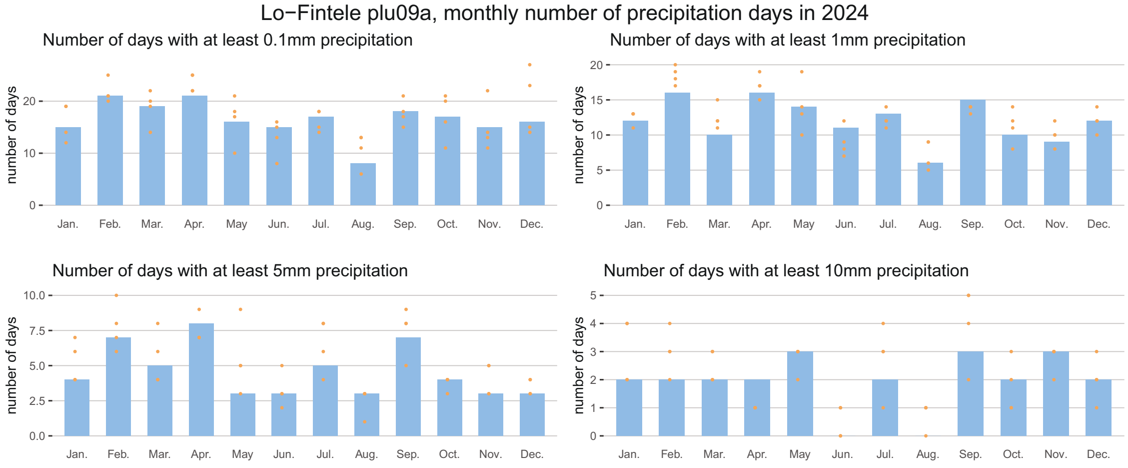


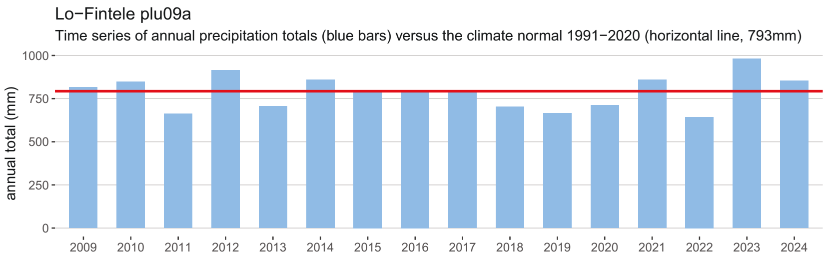
A.8 plu09a Lo-Fintele





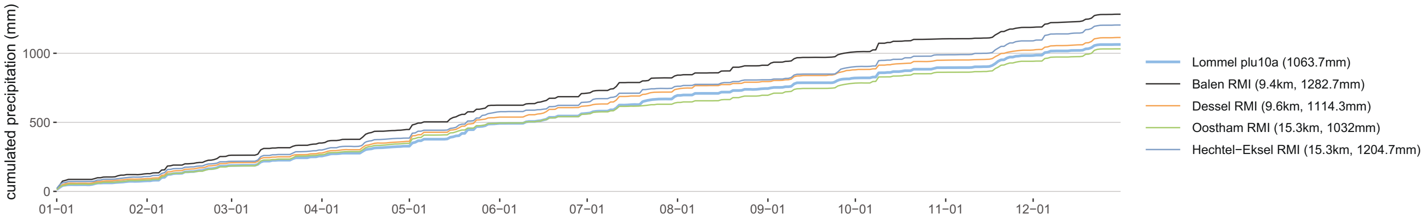




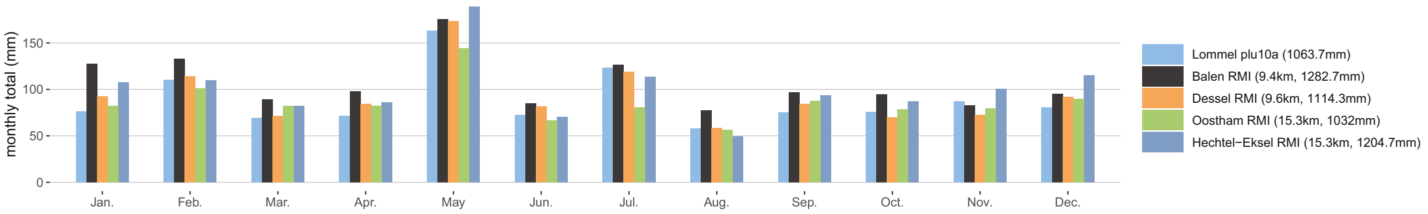


A.9 plu10a Lommel

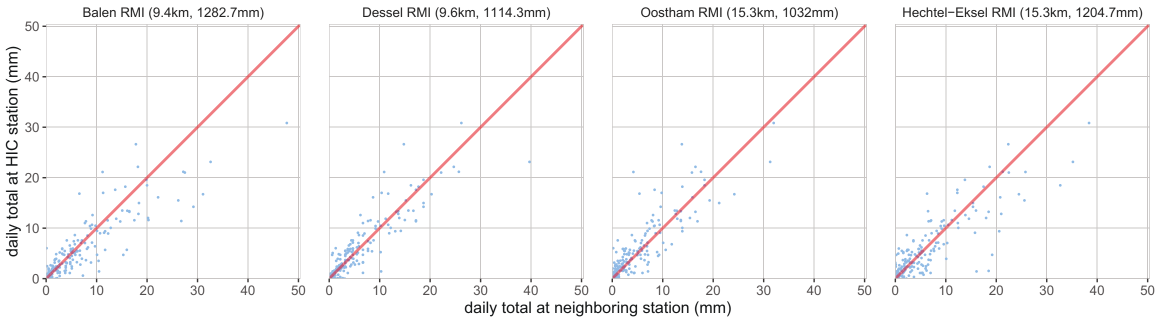
Lommel plu10a
cumulative precipitation in 2024



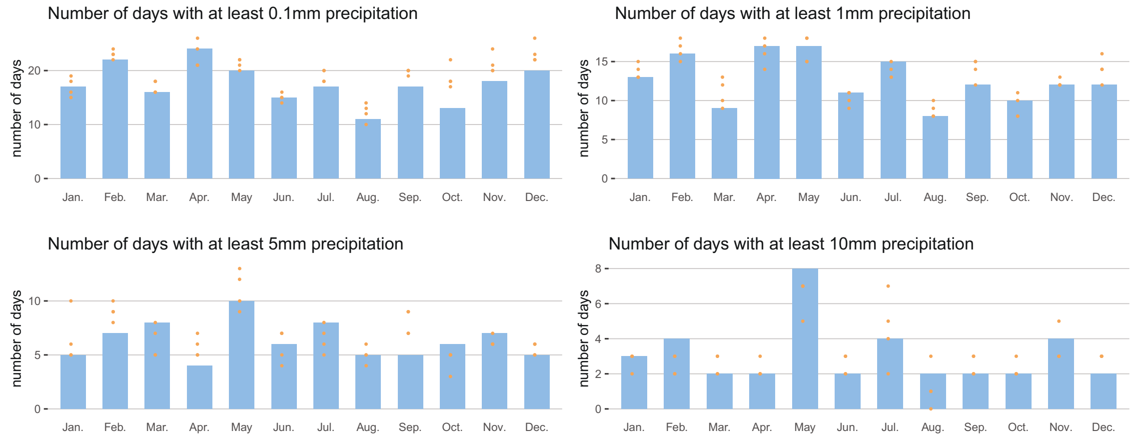
Lommel plu10a
monthly precipitation totals in 2024



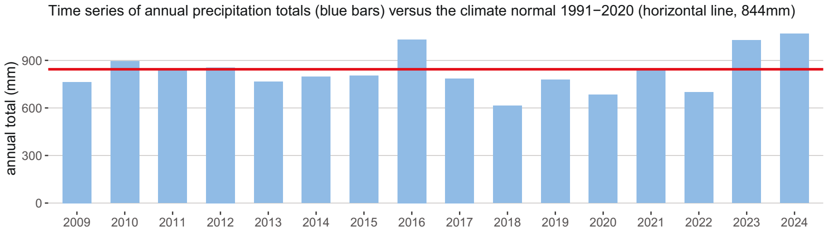
Lommel plu10a
scatter plot of daily precipitation totals



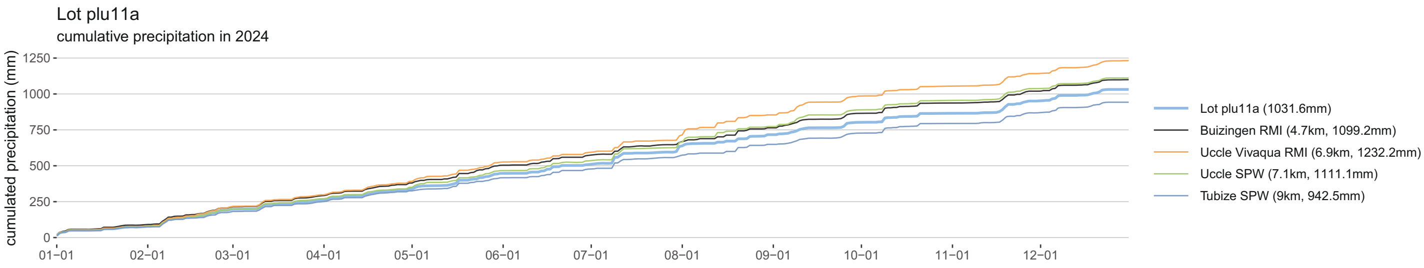
Lommel plu10a, monthly number of precipitation days in 2024

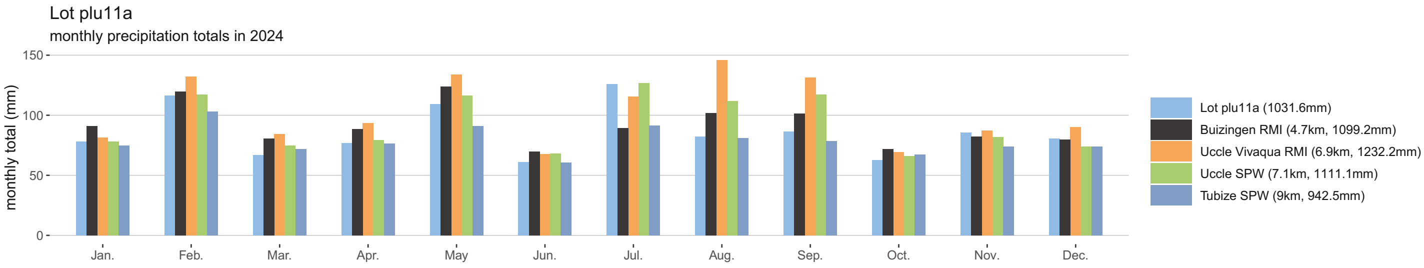


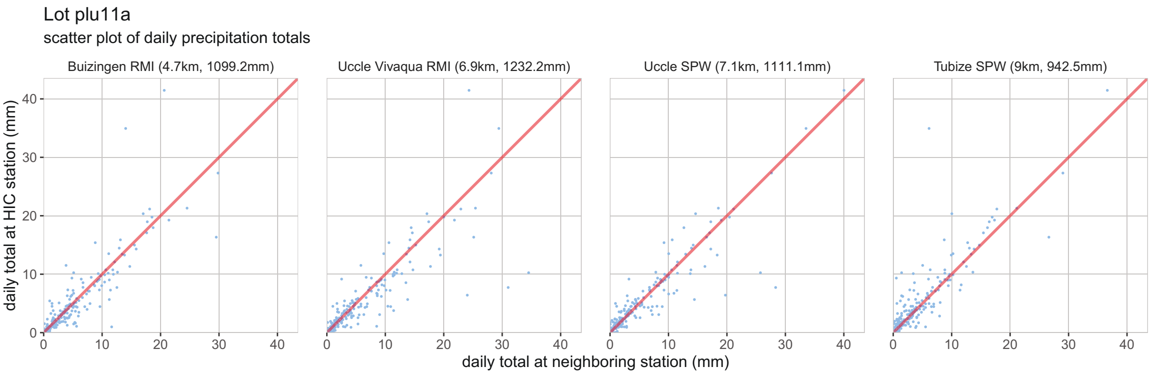
Lommel plu10a
Time series of annual precipitation totals (blue bars) versus the climate normal 1991−2020 (horizontal line, 844mm)

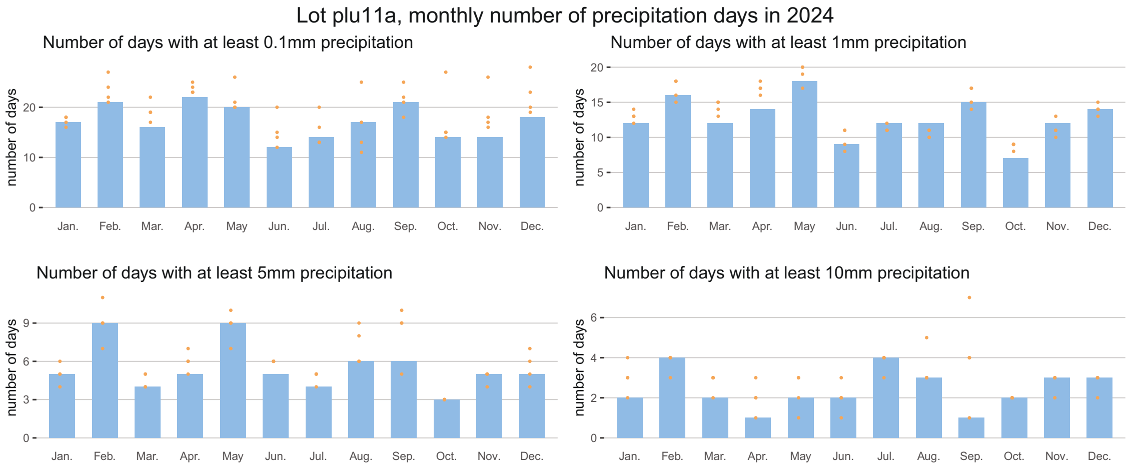


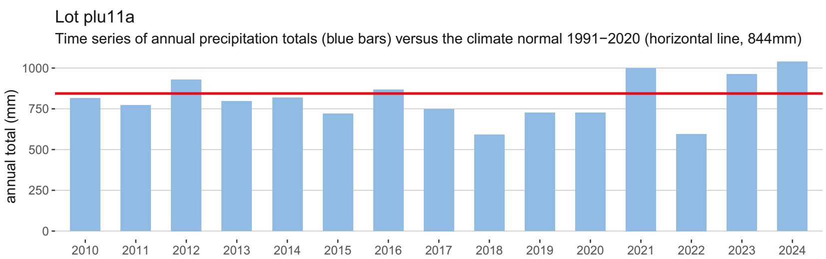
A.10 plu11a Lot



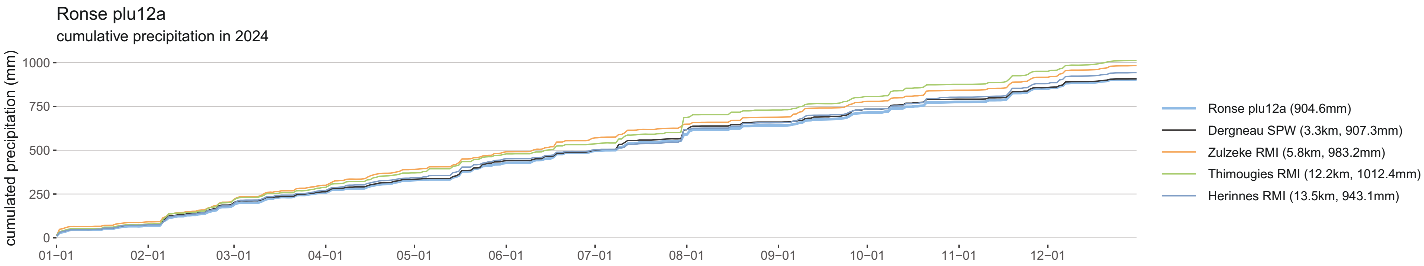


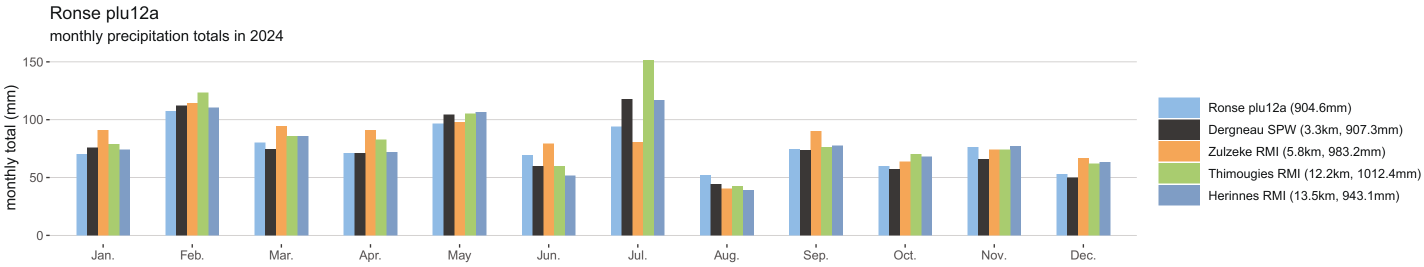


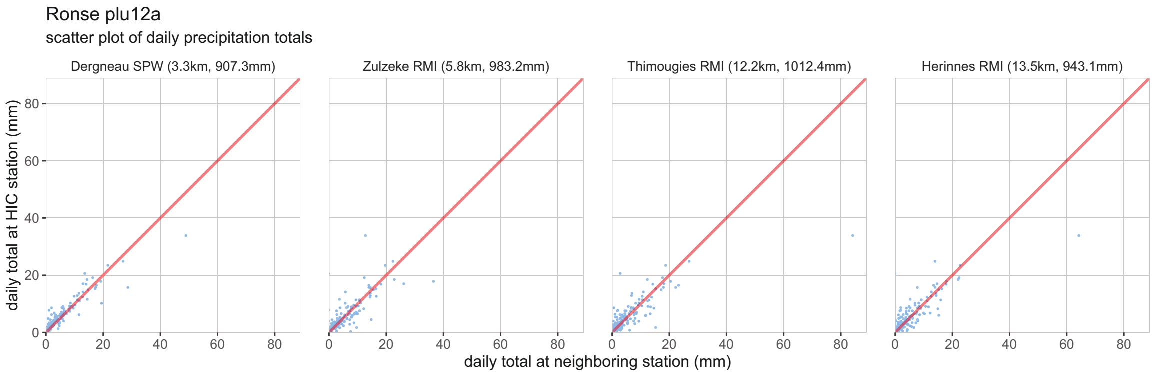


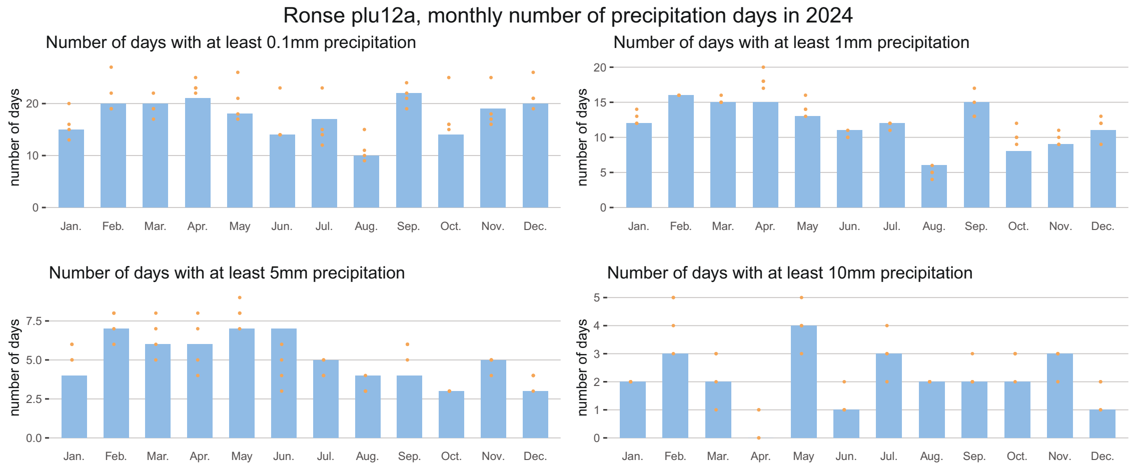


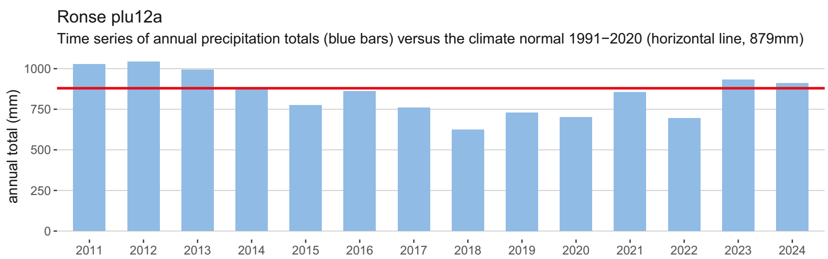
A.11 plu12a Ronse



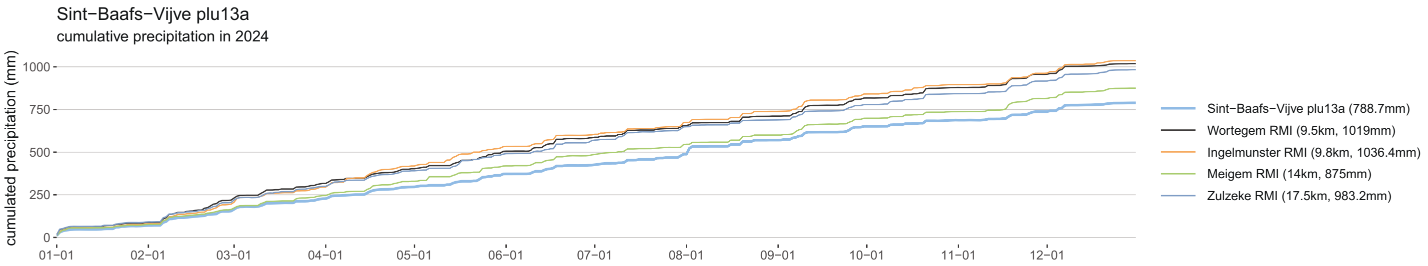


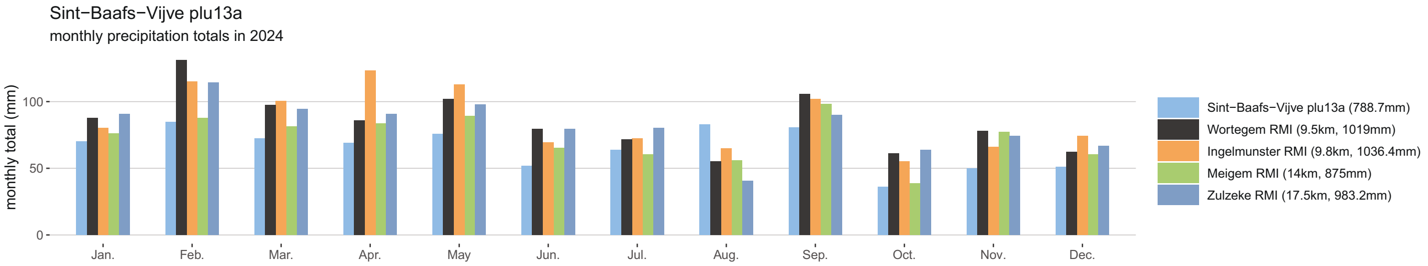


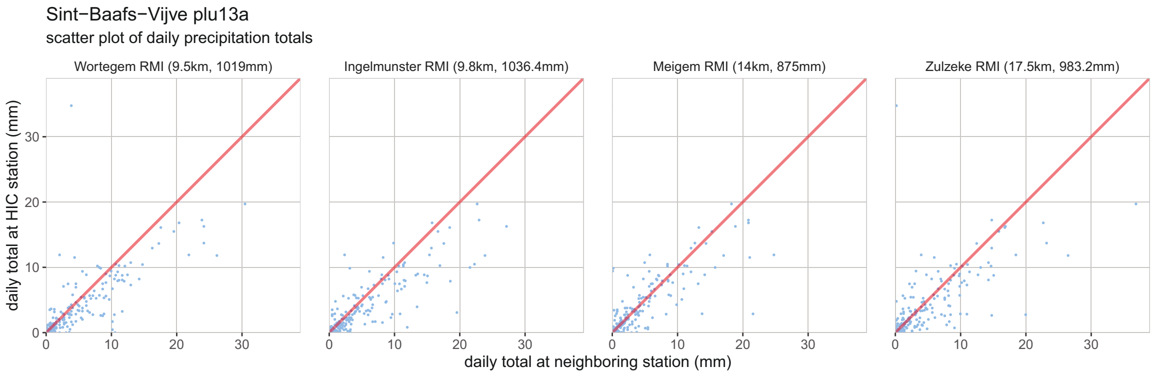


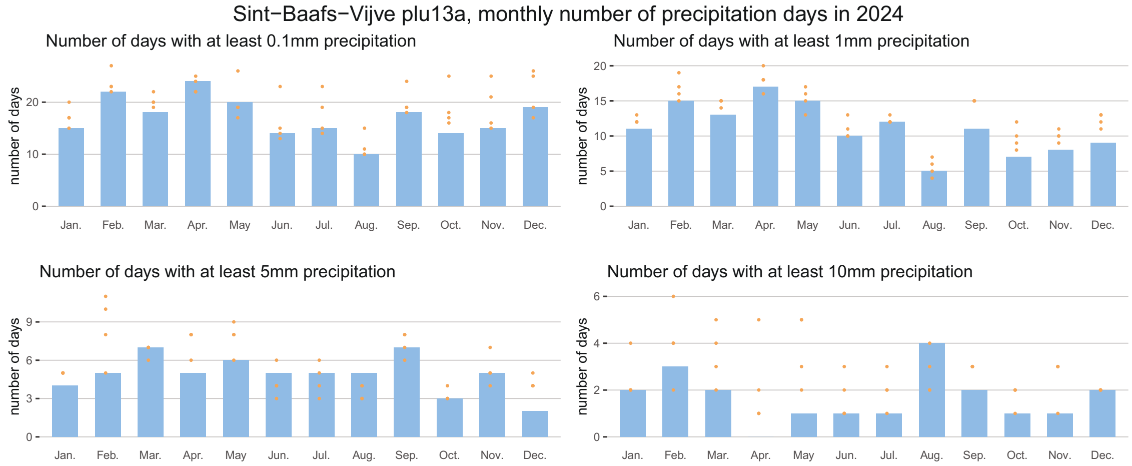


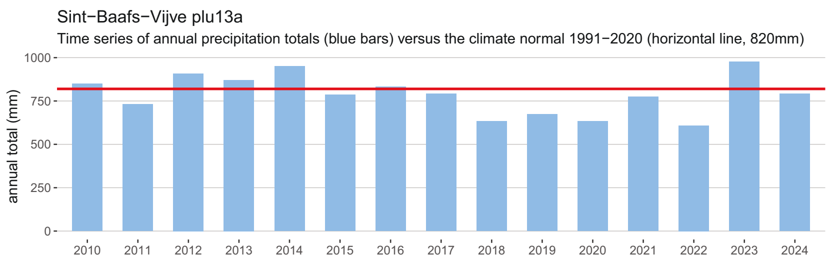
A.12 plu13a Sint-Baafs-Vijve



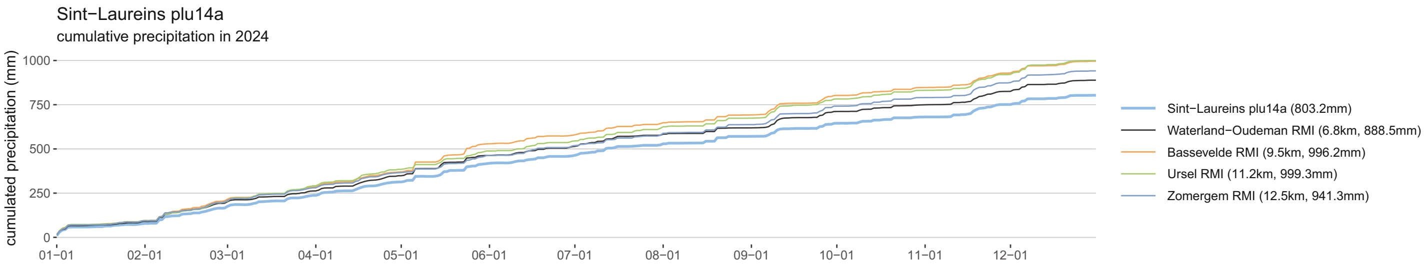


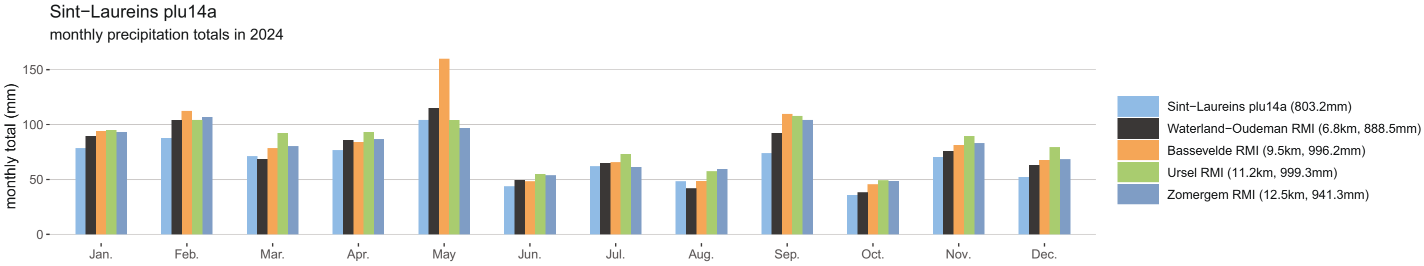


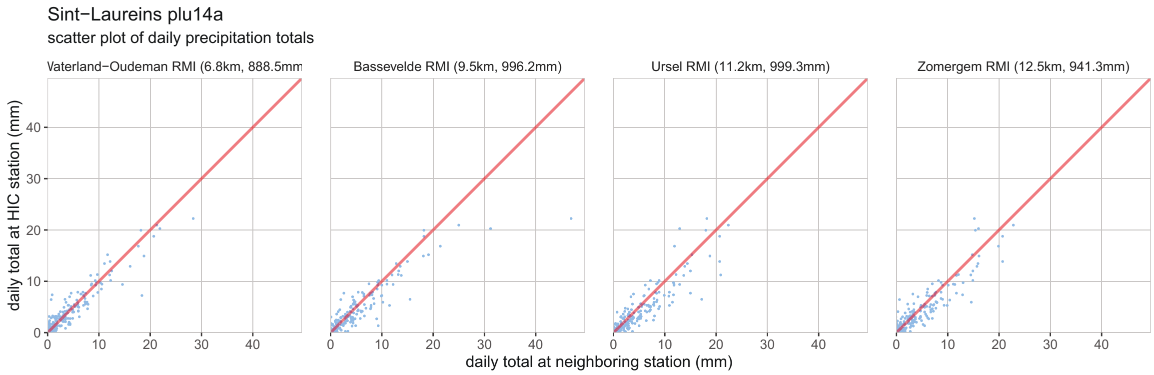


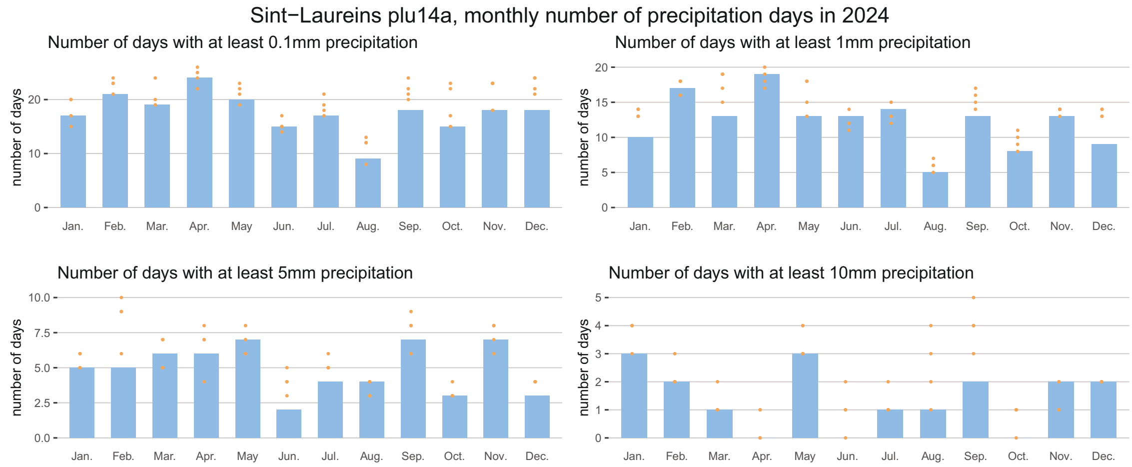


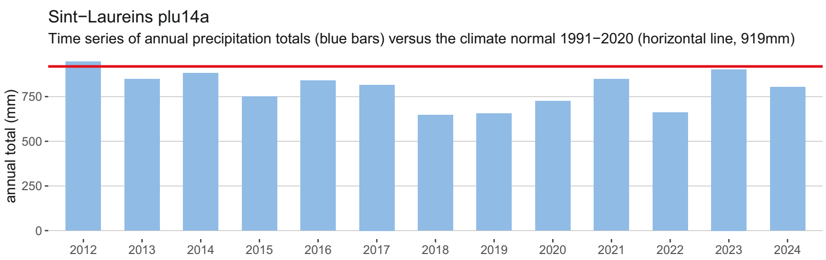
A.13 plu14a Sint-Laureins



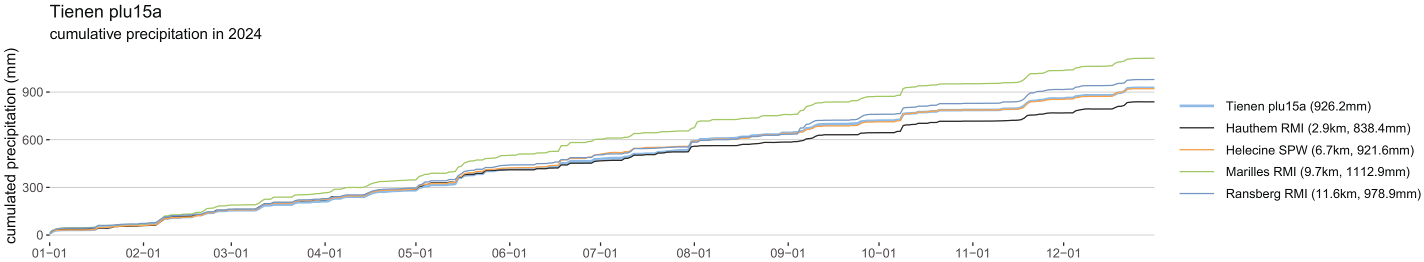


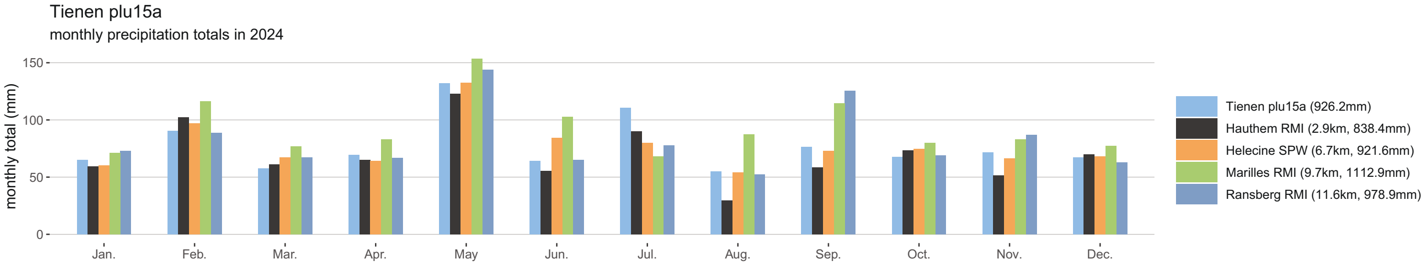


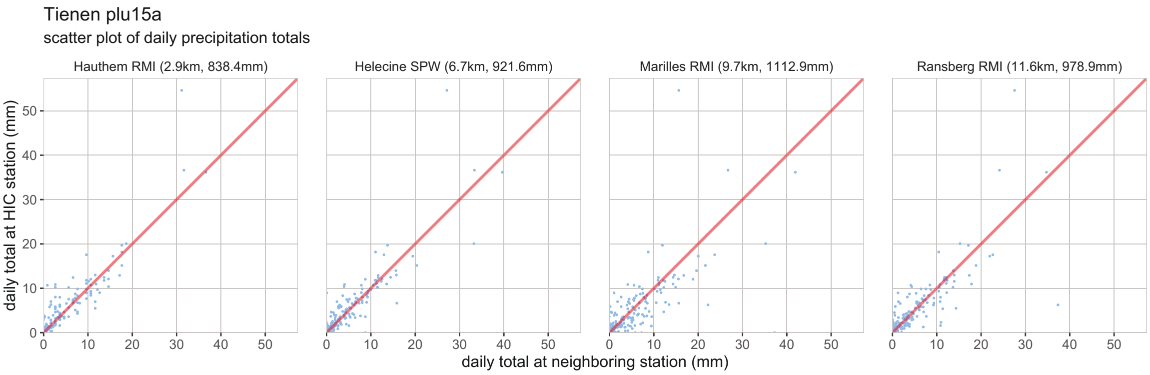


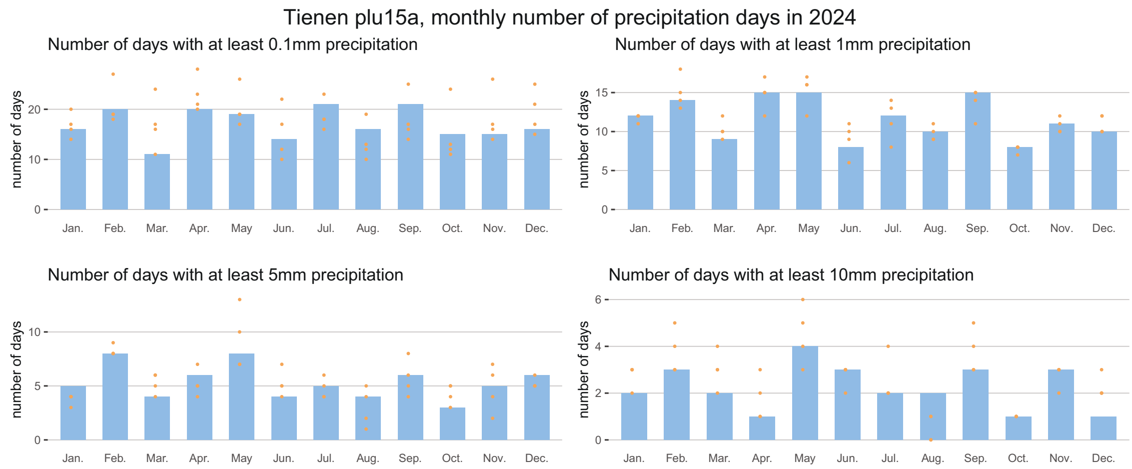


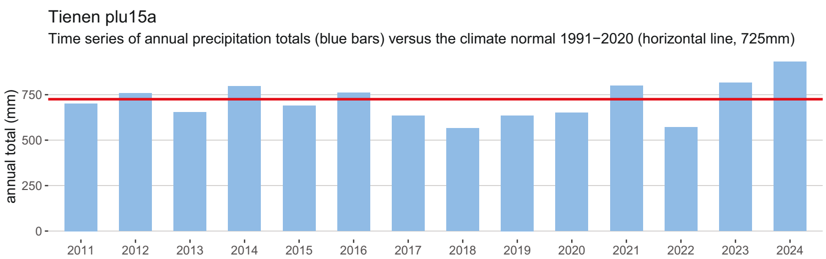
A.14 plu15a Tienen



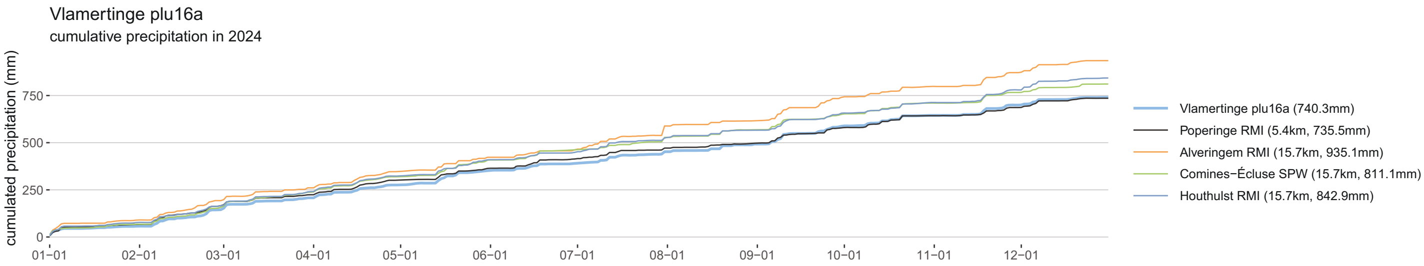


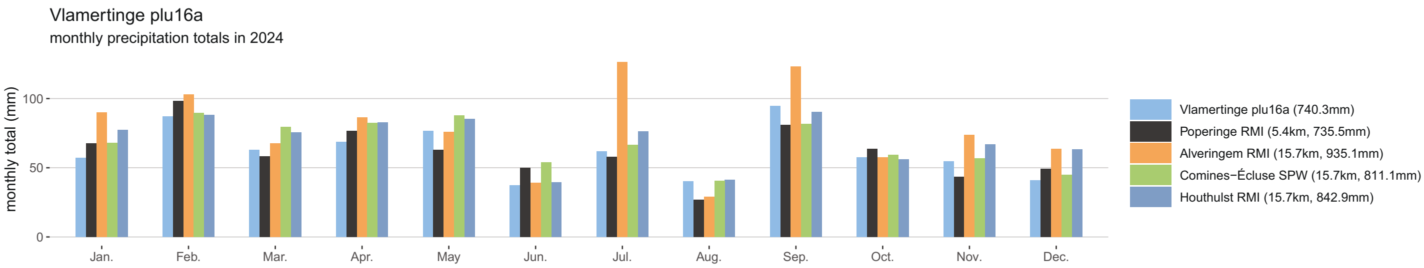


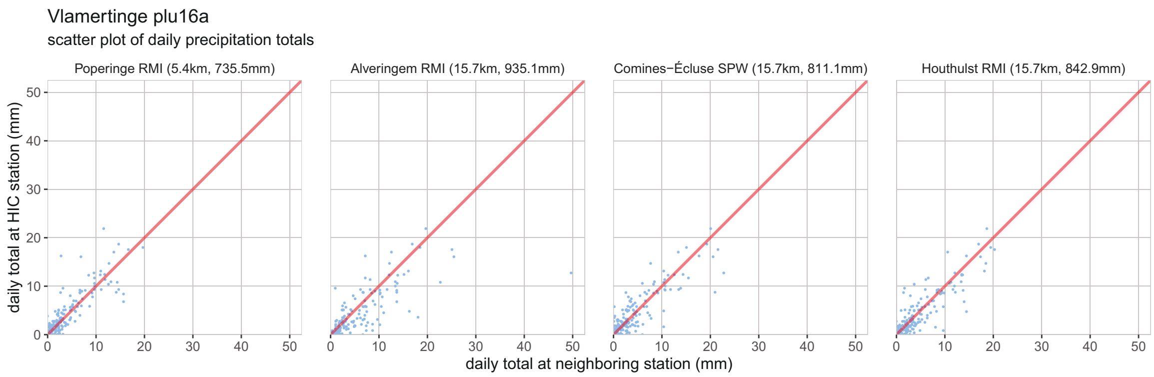


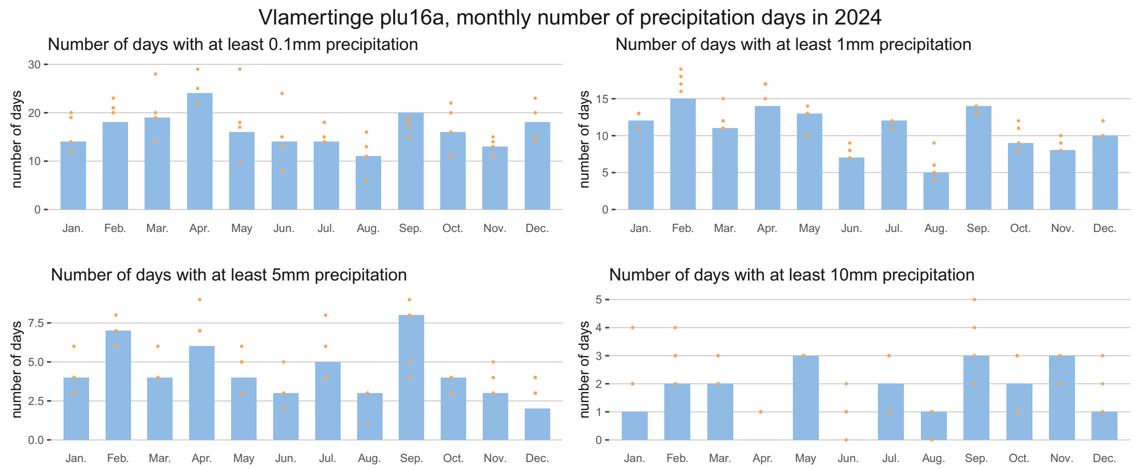


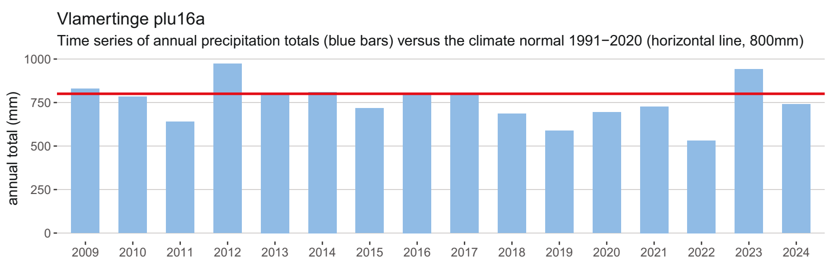
A.15 plu16a Vlamertinge



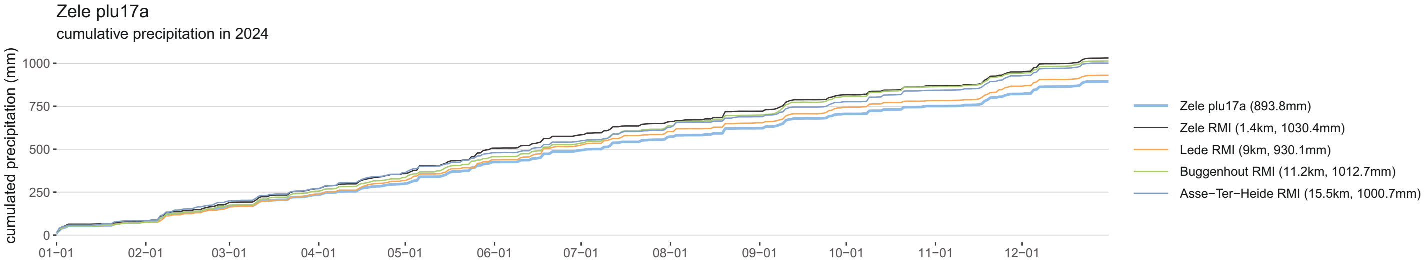


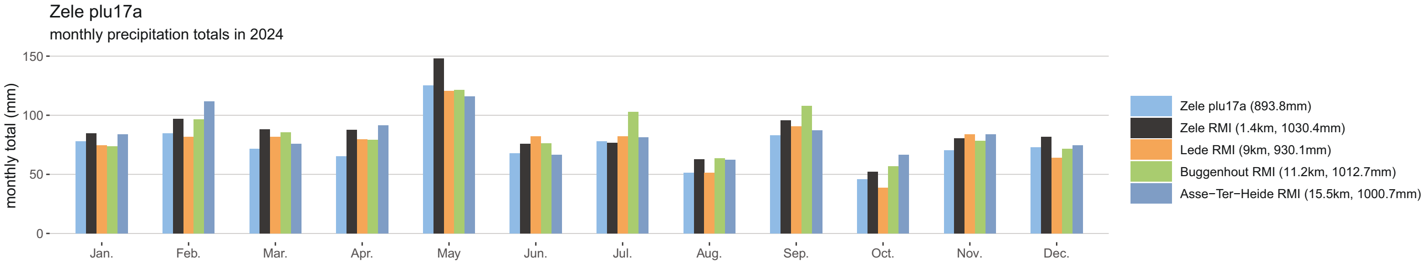


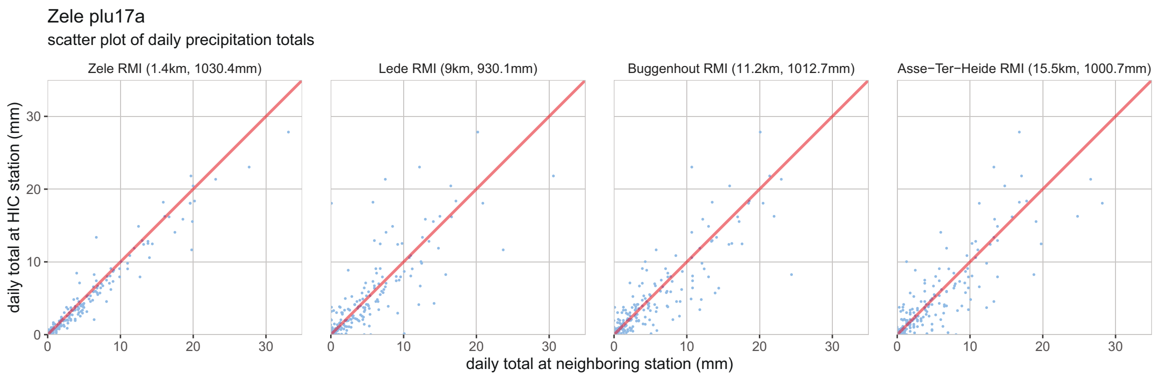


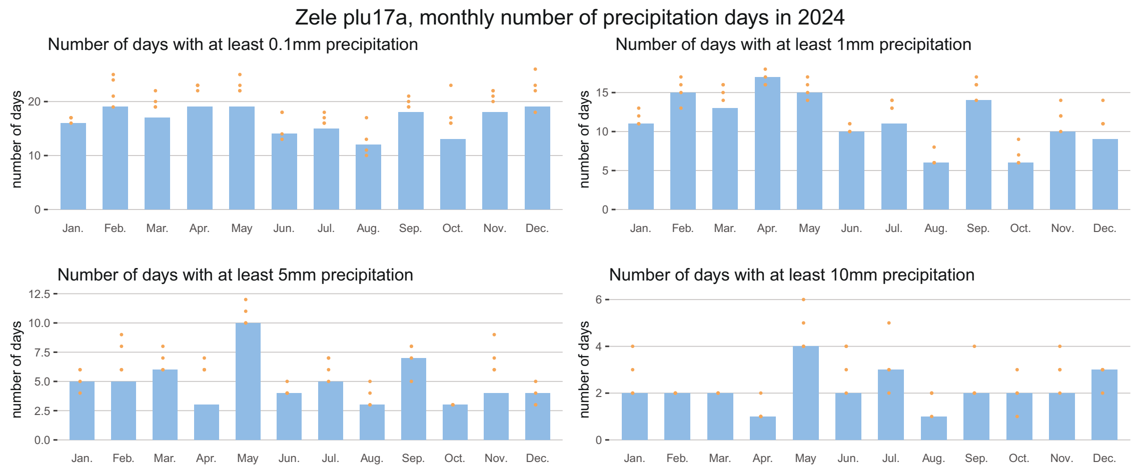


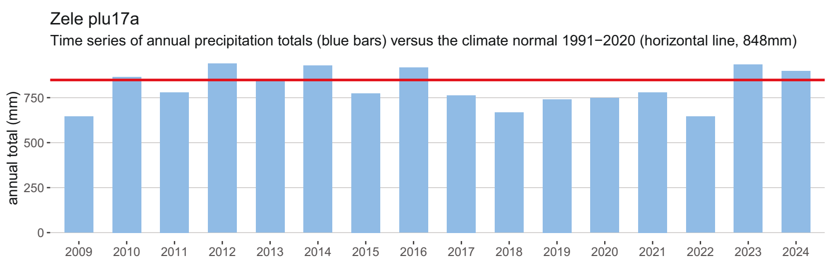
A.16 plu17a Zele



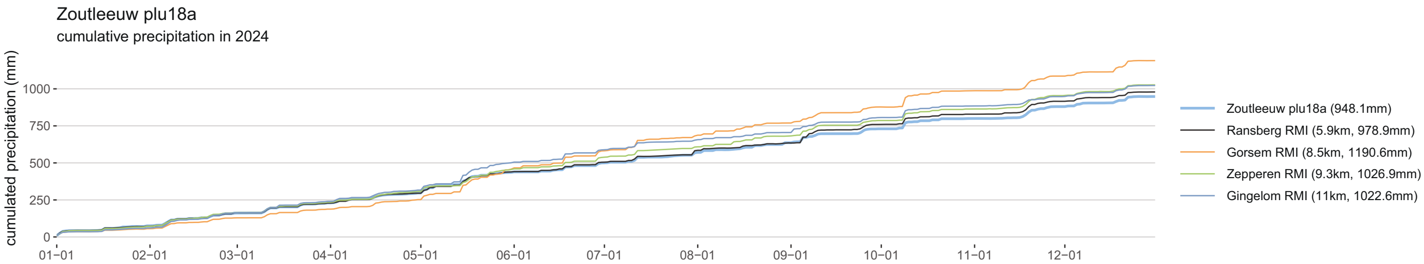


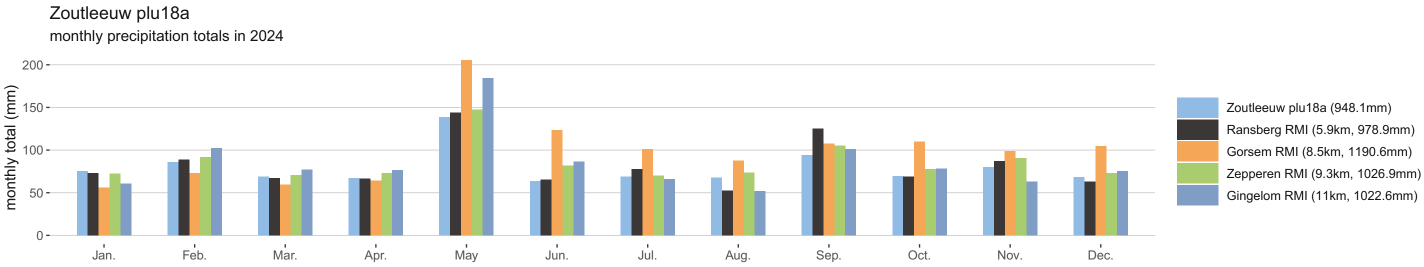


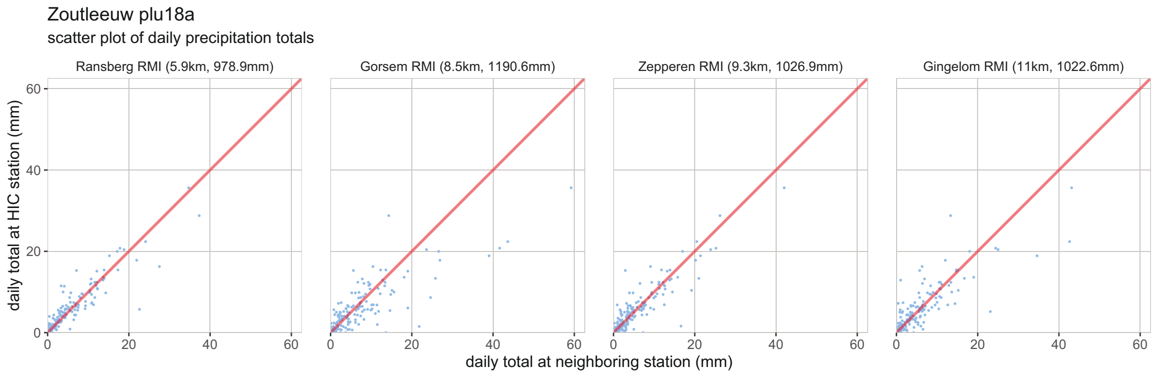


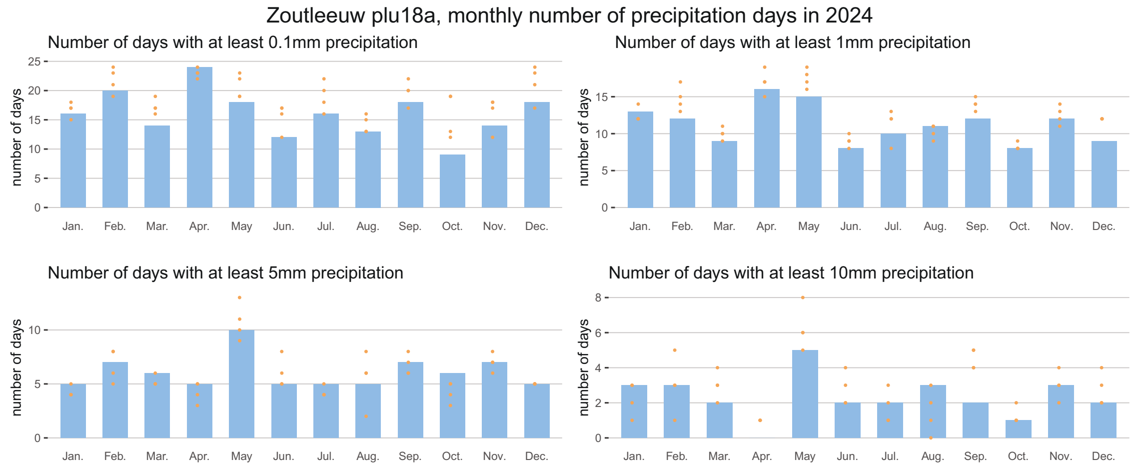


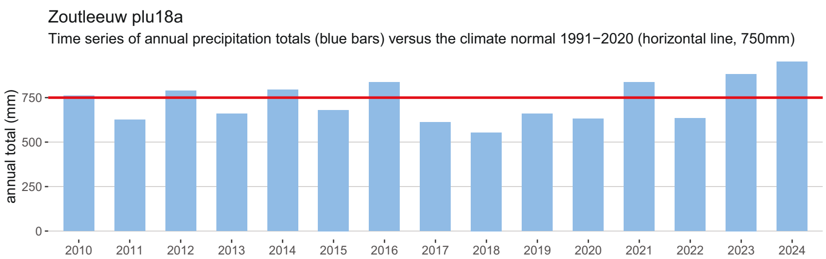
A.17 plu18a Zoutleeuw



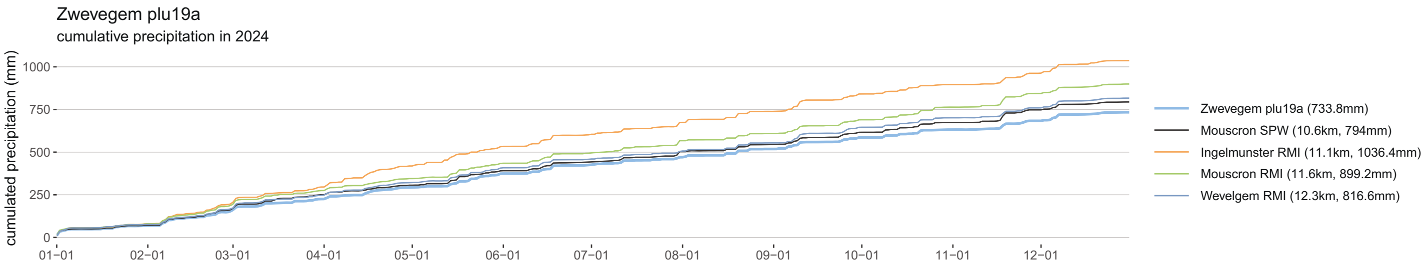


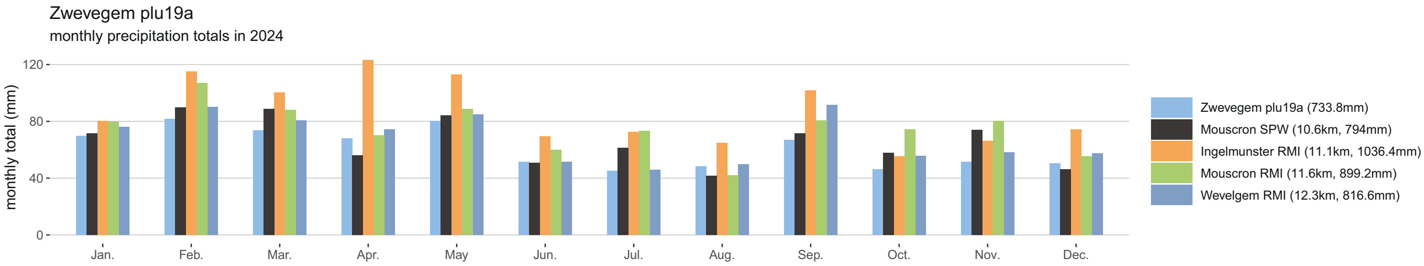


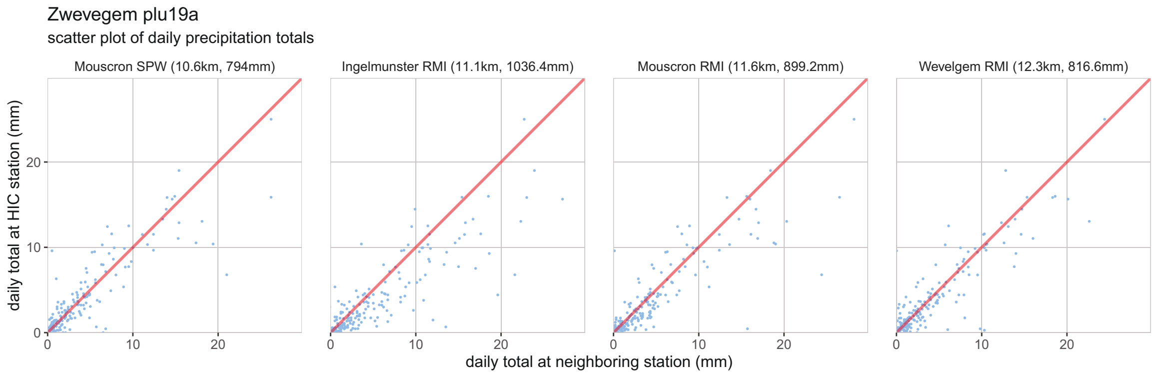


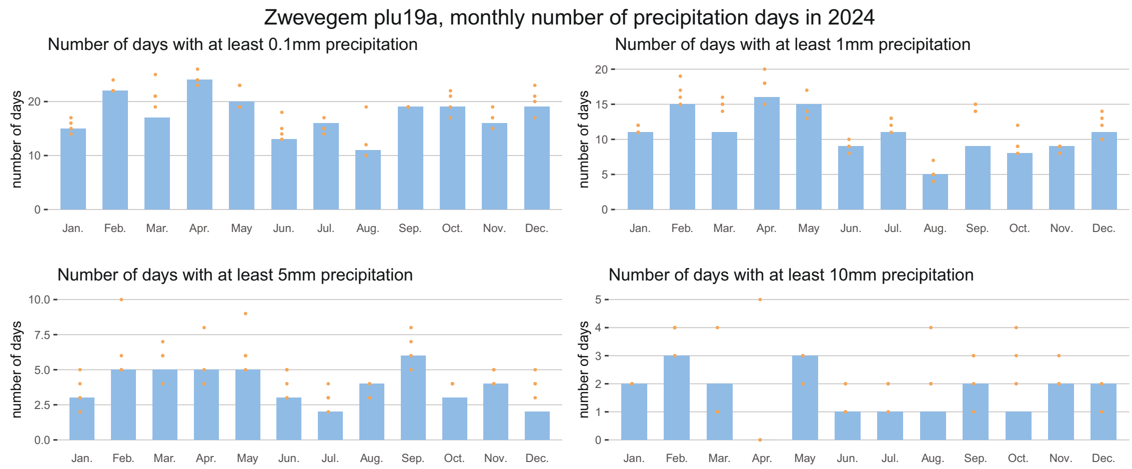


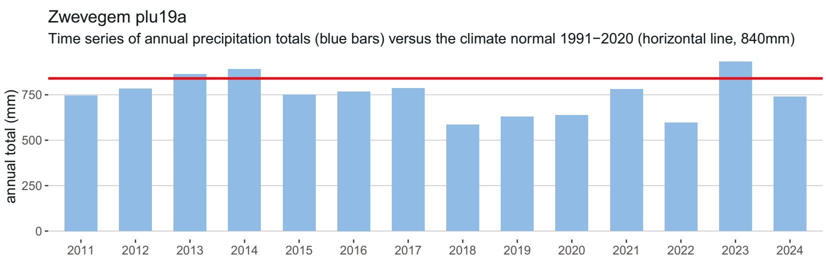
A.18 plu19a Zwevegem



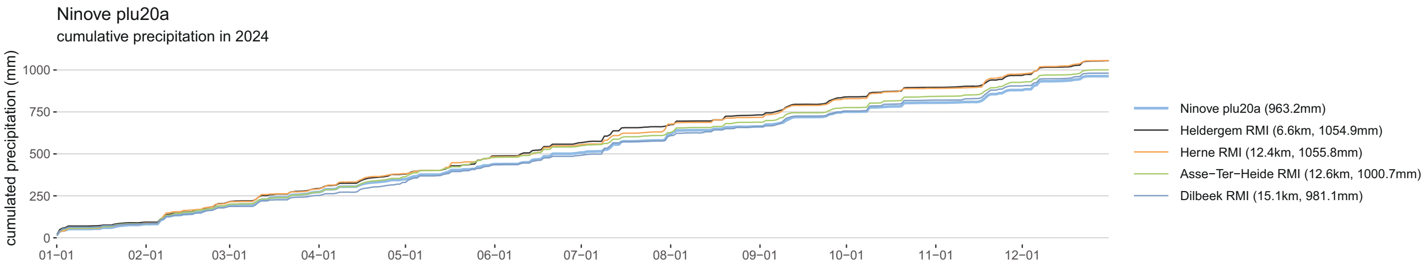


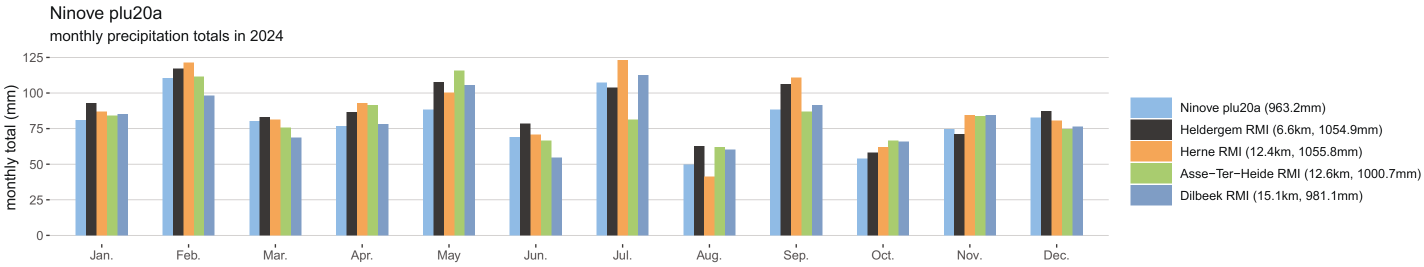


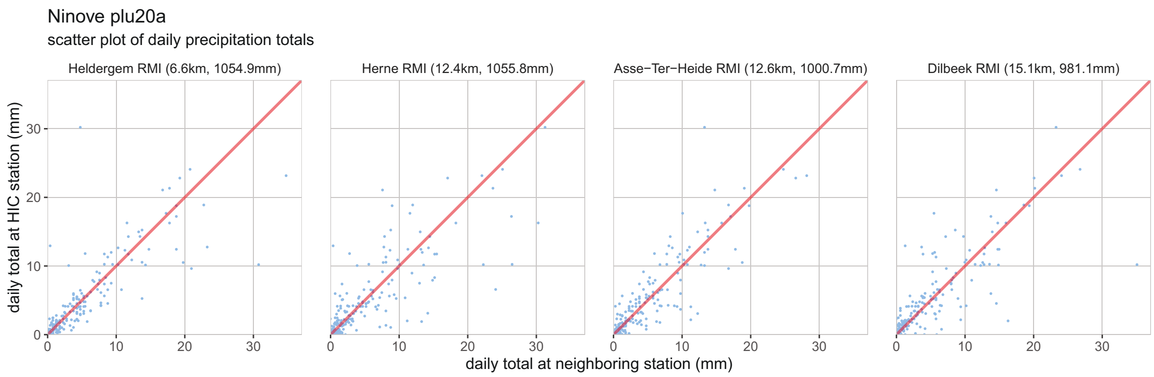


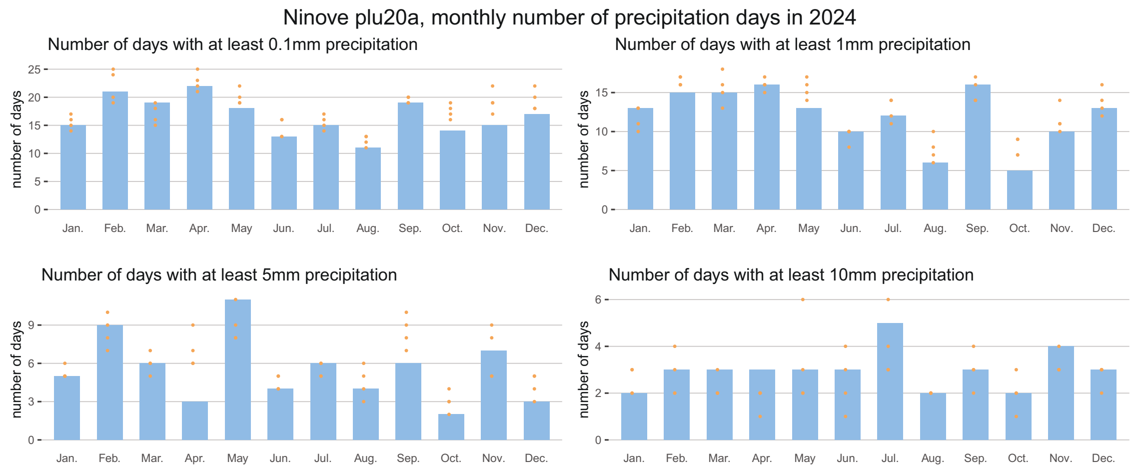


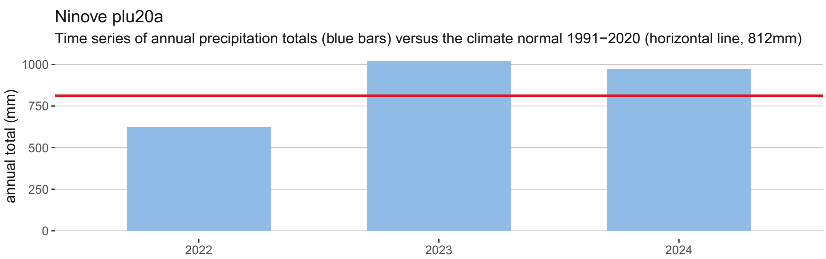
A.19 plu20a Ninove











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