SEPARATE

Storm Event Partitioning And Rainfall Analytics for Tipping-bucket rain gauge data Evaluation

User Manual
version 1.0

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SUMMARY

SEPARATE (or Storm Event Partitioning And Rainfall Analytics for Tipping-bucket rain gauge data Evaluation) is a software package developed by Dr. Brendan P. Murphy at Simon Fraser University and Dr. Scott R. David at Utah State University. SEPARATE was designed to streamline the identification, separation, and analysis of storm events from continuous rainfall datasets collected using tipping bucket rain gauges (TBRGs). This software was developed for the benefit of natural science researchers and practitioners engaged in environmental and hydrometeorological data collection and analysis, including rainfall-runoff analysis, resource management, hydrogeomorphic monitoring, natural hazard assessment, and more.

Key Features and Functionality

SEPARATE is available for download as a free, stand-alone Windows application with a user-friendly interface designed to simplify data inputs and analysis parameter selection. The executable bundles together all dependencies, meaning no other Python installations are required. As such, users are not required to deal with any programmatic scripts or macros to perform their rainfall data analysis. This reflects our overall objective of making the data processing and analysis required of rain gauge data more straightforward, efficient, and accessible to a broader audience.

SEPARATE is designed to handle standard TBRG data formats, accepting rainfall records logged as either cumulative counts of time-stamped tips or as rainfall depths recorded at fixed intervals. These formats align with the data outputs from commonly used commercial TBRGs, such as Onset HOBOware rain gauges, thus ensuring compatibility with widely available instrumentation. SEPARATE analyzes these data using robust and well-accepted methodologies, partitioning storm events using a fixed minimum inter-event time (MIT), which can either be user-defined or determined automatically by the software using a common approach that optimizes the likelihood of distinguishing statistically independent storm events.

The storm metrics calculated by SEPARATE are conveniently summarized in a single, formatted output table saved to an Excel file. These outputs include critical rainfall metrics for each of the identified storm, including event timing, duration, magnitude, storm-averaged rainfall intensity, peak storm rainfall intensities measured over a standard set of durations ranging from 5-minute to hourly, and the timing associated with each of these peak intensities. Additionally, the software produces a series of figures summarizing the rainfall record and enabling users to visualize the distributions of storm characteristics. Finally, users can also opt to have SEPARATE output detailed tabular data and graphical figures profiling each of the separated storm events, enhancing the potential for data analysis, interpretation, and applicability.

Benefits and Impact

The methodologies employed in SEPARATE are well-established and widely used by researchers and practitioners worldwide. While conceptually intuitive, performing this analysis can get complicated, clunky, thus presenting a barrier to entry for users who need to collect rainfall data but who may not have programming experience or knowledge of the statistical approaches used for processing and analyzing raw data outputs from TBRGs. With a user-friendly interface and robust, automated analytical capabilities, we hope that SEPARATE can serve as a useful tool to support environmental and natural resources research, management, and more widespread data collection in a rapidly changing world.

KEY DEFINITIONS

**Note: all length units are given here in mm, but SEPARATE outputs will reflect the user-defined tip units.*

Storm Magnitude [*mm*]

the cumulative or total depth of rainfall measured over the storm duration.

Storm Duration [*hr*]

the total amount of time between the first and last tip of an identified storm.

Storm Intensity [*mm/hr*]

the rate of rainfall as averaged over the storm duration:

$$I_s = \frac{R_s}{T_s}$$

where I_s is the storm intensity [mm/hr], R_s is the storm magnitude [mm], and T_s is the storm duration [hr].

Rainfall Intensity [*mm/hr*]

the rate of rainfall measured over a specified duration, typically expressed as cumulative depth of rainfall per hour. Standard intensity durations assessed in SEPARATE include 5, 10, 15, 30, and 60-minutes and are reported as the i5, i10, i15, i30, and i60, respectively. Rainfall intensities in SEPARATE are calculated as the backward differenced cumulative rainfall for a moving window applied at 1-minute intervals:

$$iD(t) = \frac{R(t) - R(t-D)}{D}, \qquad D \leq t \leq T_s$$

where iD is the rainfall intensity [mm/hr] for a specified duration D (e.g., $i5$), and $R(t)$ is the cumulative storm rainfall [mm] at time t. While D is typically presented in minutes, for the purpose of the calculation, both D and t are converted to hours. The backward moving window used to calculate $iD(t)$ is applied starting from a storm time, t, equal to the specified duration, D, through the storm duration, T_s.

Peak iD Rainfall Intensity [*mm/hr*]

the maximum rainfall intensity calculated over a specified duration, D, within any storm.

Consistent with standard protocols, the times associated with reported peak rainfall intensities represent the time at the *end* of the specified duration, such that the rainfall rate represents the rainfall conditions that occurred over the duration leading up to the reported time. For example, a peak i5 rainfall intensity reported at 12:05 would be representative of the rainfall rate that occurred between 12:00 and 12:05.

APPLICATION INTERFACE

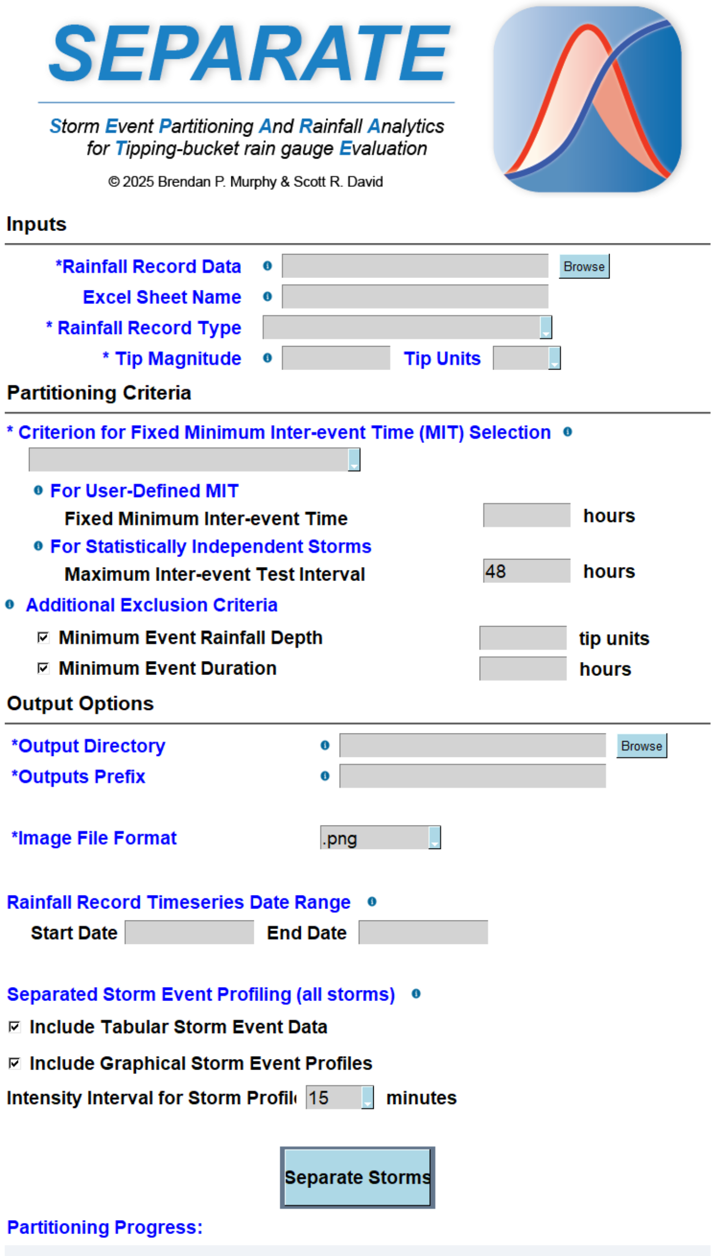


Figure 1. SEPARATE is a stand-alone Python-based application for desktop use, which includes a user-friendly interface, i.e., Graphical User Interface (GUI) shown at left, that loads when users open the software. Input parameters for the analysis of rainfall records are organized into three primary sections:

1) Inputs
2) Partitioning Criteria
3) Output Options

Any required inputs or parameters are noted in the GUI with a leading asterisk (*). Additionally, info buttons are included to provide users with critical details about inputs. However, these are not all inclusive and users should always refer to this user manual for more complete information.

INPUTS

Rainfall Record Data

**Required*

Description

Enter the file path or navigate to and select the tipping-bucket rain gauge (TBRG) data file.

SEPARATE can analyze TBRG data logged as either:

1) Cumulative Tips: timestamped count of cumulative tipping-bucket tips
   Example: HOBO RG3-M with pendant event logger
2) Fixed Interval: total rainfall depth measured over fixed logging intervals
   Example: HOBO S-RGB-M002 with Micro Station data logger set to log at x-minute intervals

File Format

Input file must be either an Excel Spreadsheet (.xlsx) or a comma-delimited text file (.csv) with data organized into two columns with a single row of column headers:

- Column 1: date & time formatted as MM/DD/YY HH:MM:SS
  - Do not separate date and time into two separate columns
  - Date: slash delimiter (ex: 06/07/24)
  - Time: colon delimiter in 24-hour format (ex: 17:06:23)
  - Do not include fractional seconds
- Column 2: cumulative tip count (integers) or fixed-interval rainfall depths associated with the date & time record in Column 1

Examples of Excel-formatted TBRG rainfall records displaying data that has been logged in both record types: A) cumulative tips, and B) fixed intervals (shown at 1-min logging intervals).

A. Cumulative Tips

Date & Time	Cumulative Tips
06/24/24 16:59:23	1
06/24/24 16:59:24	2
06/24/24 16:59:25	3
06/26/24 13:59:36	4
06/26/24 14:04:20	5
06/26/24 14:09:14	6
06/26/24 14:13:29	7
06/26/24 14:17:26	8
06/26/24 14:19:32	9
06/26/24 14:21:20	10
06/26/24 14:22:42	11
06/26/24 14:24:56	12
06/26/24 14:27:10	13
06/26/24 14:30:48	14
06/26/24 14:31:51	15

B. Fixed Interval

Date & Time	Depth, mm
07/02/24 16:39:17	0
07/02/24 16:40:17	0
07/02/24 16:41:17	0
07/02/24 16:42:17	0.2
07/02/24 16:43:17	0.2
07/02/24 16:44:17	0.2
07/02/24 16:45:17	0.6
07/02/24 16:46:17	0.4
07/02/24 16:47:17	0.6
07/02/24 16:48:17	0.2
07/02/24 16:49:17	0
07/02/24 16:50:17	0
07/02/24 16:51:17	0.2
07/02/24 16:52:17	0
07/02/24 16:53:17	0

Onset HOBOware Users: ***Tip for File Formatting***
For users who collect TBRG data using Onset-brand rain gauges and HOBOware software, the following instructions outline how to setup HOBOware preferences to ensure exported data files will automatically be formatted to meet all the criteria for seamless integration with SEPARATE.

Within HOBOware:
Navigate to Preferences > General > Export Settings and then adjust settings as detailed below:

Export file type: Excel (.xlsx)
Turn OFF the following options:

- Include line number column
- Include plot title in header
- Always show fractional seconds
- Separate date and time into two columns
- Include logger serial number
- Include sensor serial number or label if available
- Include plot details in exported file

Turn ON the following options:

- No quotes or commas in headings, properties in parentheses

Date format: M D Y
Date separator: Slash (/)
Time format: 24-hour
Positive number format: 1,234.56
Negative number format: -123

Excel Sheet Name

Optional

Description
If the input file is an Excel spreadsheet that includes more than 1 sheet or tab, then input the sheet name that contains the rainfall record to be analyzed. Text formatting should exactly match sheet name as written in Excel (case sensitive).

If the input Excel file contains multiple sheets but no sheet name is entered, then by default SEPARATE will attempt to extract data from the first sheet. If the input Excel file includes only one sheet, or if inputting a .csv file instead, this input can be left empty.

Rainfall Record Type

**Required*

Description
Specify the tipping-bucket rain gauge (TBRG) data logging method. Options include:

- Cumulative Tips – cumulative count of TBRG tips (ex: HOBO RG3-M with pendant event logger)
- Fixed Interval - TBRG data logged as total rainfall depth over fixed logging intervals (ex: HOBO S-RGB-M002 with Micro Station data logger set to log at 5-minute interval)

Tip Magnitude & Units

**Required*

Description
Specify the model-specific parameters for the tipping-bucket rain gauge (TBRG) used to collect the rainfall record. Parameters include:

- Tip Magnitude – the equivalent rainfall depth of each TBRG tip (e.g., 0.2 mm or 0.1 inch)
- Tip Units – the measurement units of the tip magnitude (*options*: mm, cm, or inch)

Note: SEPARATE will use the entered TBRG tip units for all output data units (e.g., cm/hour) and plotting.

PARTITIONING CRITERIA

Criterion for Fixed Minimum Inter-Event Time (MIT) Selection

**Required*

Description
Specify the criterion to be used for selecting the fixed minimum inter-event time (MIT) used for the separation of storm events in the continuous rainfall record.

Background
SEPARATE identifies and separates storm events recorded in continuous TBRG rainfall datasets using a fixed *minimum inter-event time* (MIT) - one of, if not the most common approaches. The essential premise of this approach is that whenever the duration between tips (i.e., the *inter-event time*) exceeds a pre-determined and fixed MIT value, these tips are identified as belonging to different storm events. Conversely, whenever the period of time between tips is less than the MIT, these tips are identified as belonging to the same storm.

This analytical method is, in and of itself, rather straightforward, however the challenge lies in determining the most appropriate or representative MIT value for distinguishing between storm events. While MIT values of 6 to 8 hours are commonly used to separate storms in continuous rainfall records, a compilation of MIT values from 26 studies found values ranging from 3 minutes up to 24 hours (Dunkerley, 2008). Regardless of the MIT value used, few studies provide any basis or justification for their decision, which can influence key storm parameters used in important applications, including but not limited to geohazard analysis and assessment (Gartner et al., 2014; Peres & Cancelliere, 2014), landscape evolution (Tucker & Bras, 2000), soil erosion (Dunkerley, 2019), and hydrologic analysis (Slater et al., 2021; Canham et al., 2025).

While a multitude of methods have been proposed for separating storm events from continuous records, SEPARATE provides users the option to select from one of the two most common approaches used for determining a fixed MIT value for storm event identification and separation. The two options currently incorporate into SEPARATE (*which are both described in more detail below*) include:

1) **User-Defined MIT (UDM)**
2) **Independent Storms Criterion (ISC)**

1. User-Defined MIT (UDM)

With this option, users must define the fixed MIT value (in hours) to be used for the separation and analysis of storm event characteristics. Users are encouraged to carefully consider their intended application and to evaluate the potential influence of their defined MIT value, but we note here for convenience that the most widely used values are typically between 6 hours to 8 hours (Dunkerley, 2008; Staley et al., 2017).

2. Independent Storms Criterion (ISC)

The Independent Storms Criterion, or "Independence Criterion" as it is sometimes called, is a statistical method proposed by Restrepo-Posada and Eagleson (1982) to identify a fixed inter-event time for storm event separation that aims to maximizes the likelihood of identifying statistically independent events for analysis of their storm characteristics (storm magnitude, duration, intensity, etc.). The underlying assumption of this approach is that the inter-event times of storm events at a given TBRG location will behave as a stochastic Poisson process, or in other words, all storms are independent events whose arrivals are completely random. If this assumption is true, then an exponential distribution should best fit the inter-event intervals separated using a fixed minimum inter-event time (MIT). The MIT that achieves this statistical criterion is then determined by testing a wide range of potential minimum inter-event times (t_b). Testing involves separating storm events from the continuous TBRG record based on the range of potential value, and then calculating the mean and standard deviation of inter-event times using each value of t_b. The MIT value that is ultimately used for separating independent storms (t_{b_0}) is then defined as the shortest tested interval (t_b) at which the coefficient of variation (CV = σ / μ) for inter-event times is less than or equal to unity.

If users select the ISC criterion, SEPARATE will provide additional graphical and tabular outputs. This includes two figures showing the CV analysis and exponential fit (e.g., Figures 2 & 3), as well as an Excel file with essential ISC analysis data including all tested inter-event intervals and the associated mean, standard deviation, and CV. Users who select the ISC option are strongly encouraged to evaluate these additional outputs to ensure the distribution of inter-event times in their data is reasonably well fit as an exponential (Figure 3) and that the tested bounds adequately achieved the CV = 1 selection criterion.

Figure 2. Example of additional graphical output with the ISC analysis, including trends in mean and standard deviation with tested inter-event time (left) and the associated coefficient of variation (right).

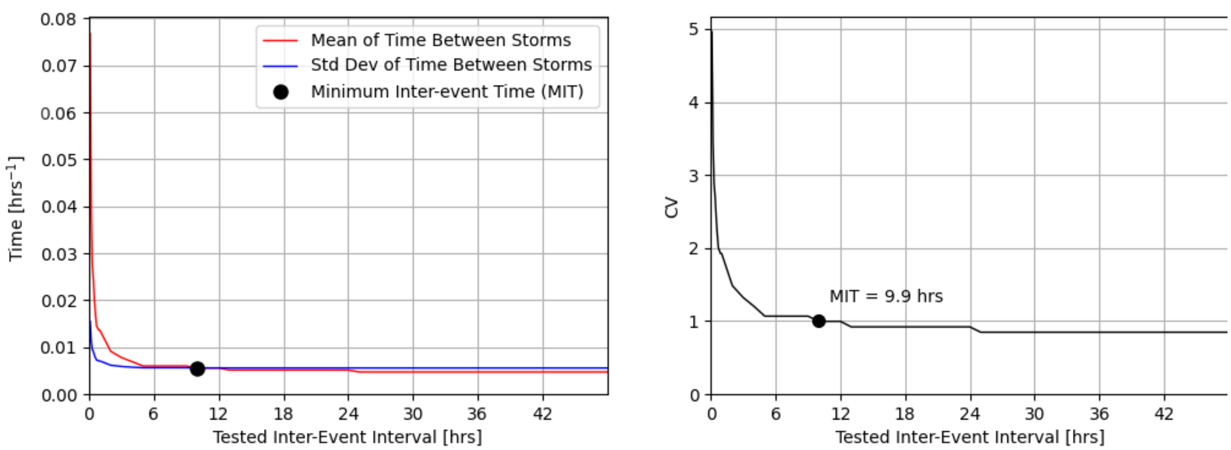
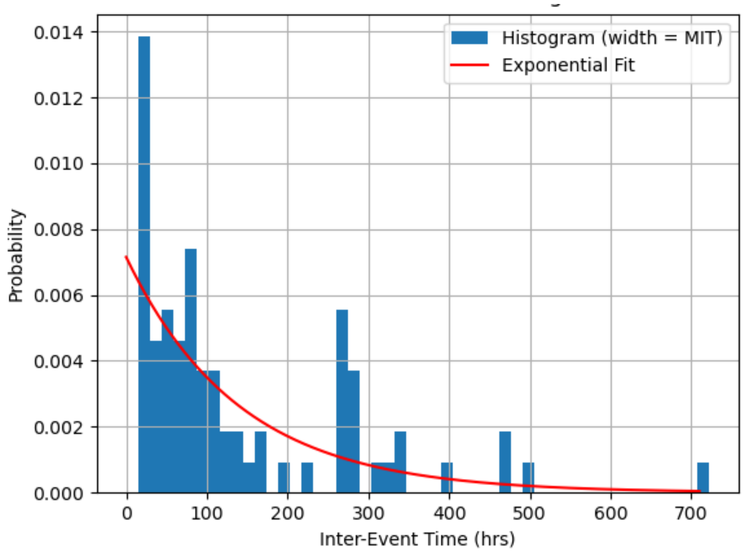


Figure 3. Example of an additional graphical output included with the ISC analysis displaying a probability distribution of the storm inter-event times based on the MIT for statistically independent storms and overlaid with a best-fit exponential regression.



Criterion Dependent Inputs

For User-Defined MIT

Fixed Minimum Inter-event Time (MIT)

**Conditional - Required*

Units: hours

Description

If ***User-Defined MIT (UDM)*** is selected, users are required to define a fixed MIT (in hours) for SEPARATE to use in the identification and separation of storm events.

For Independent Storms Criterion

Maximum Inter-event Test Interval

Conditional - Optional

Units: hours

Description

If the ***Independent Storms Criterion (ISC)*** is selected, users have the option to adjust the upper limit of the inter-event times (in hours) to be tested for the evaluation of statistical independence.

If the default entry (48) is left unchanged or no entry is made, SEPARATE will conduct event separation analysis using fixed inter-event times up to a default value of 48 hours. Testing inter-event intervals greater than 500 hours not currently allowed in SEPARATE.

Additional Criteria

Minimum Event Rainfall Depth

Optional
Units: same as tip units

Description
Specify a minimum total rainfall depth (in the same units as specified for the TBRG) that must be exceeded for storm events to be considered in the SEPARATE analysis and included in the summary output table.

Example
To suppress all events where only a single tip is recorded, then set Minimum Event Depth = Tip Magnitude.

Minimum Event Duration

Optional
Units: hours

Description
Specify a minimum duration (in hours) that must be exceeded for storm events to be considered in the SEPARATE analysis and included in the summary output table.

Example
To suppress all events less than 15 minutes, then set Minimum Event Duration = 0.25 hours.

Compounding of Criteria

Case 1: *No Additional Criteria Specified*
If both entries for additional identification criteria are left blank, then all identified storm events will be included in the SEPARATE analysis and final summary table of events. SEPARATE does not include any default minimum values.

Case 2: *Only One Additional Criteria Specified*
If only one additional identification criteria is specified, then only this condition will be applied to suppress events from the SEPARATE analysis and final summary table of events. SEPARATE does not include any default minimum values.

Case 3: *Both Additional Criteria Specified*
If minimum values are specified for both the Minimum Event Rainfall Depth Duration *and* Minimum Event Duration criteria, then the criteria will be compounded, such that any identified events that do not exceed *both* minimum criteria will be suppressed from the SEPARATE analysis and final summary table of events.

Example
If a user specifies a Minimum Event Rainfall Depth = 1 mm *and* a Minimum Event Duration = 0.25 hours, then an identified storm event with a storm magnitude of 0.4 mm and storm duration of 0.5 hours would be suppressed. Although it did exceed the user-defined Minimum Event Duration, it did not also exceed the user-defined Minimum Event Rainfall Depth.

Criteria Effects

For SEPARATE analysis conducted using either the **User-Defined MIT** or the **Travel Time Criterion**, the inclusion of additional criteria will not affect the storm event separation methods. Additional criteria will only influence the number of events included in the output table of rainfall metrics for each storm, as well as the corresponding summary plots. Any events that do not meet the additional criteria will be excluded.

For SEPARATE analysis conducted based on the **Independent Storms Criterion**, setting additional criteria could influence the determination of fixed MIT used to separate storms. Any events that do not meet the additional criteria will be suppressed from the rainfall record, such that the corresponding period will be assumed to be rainless (Balistrocchi & Bacchi, 2011). If there are a significant number of supressed events, this may influence the calculation of mean inter-event times used in the exponential fitting analysis.

In all cases, the summary output table will include the total number of events that were suppressed based on the additional criteria selected.

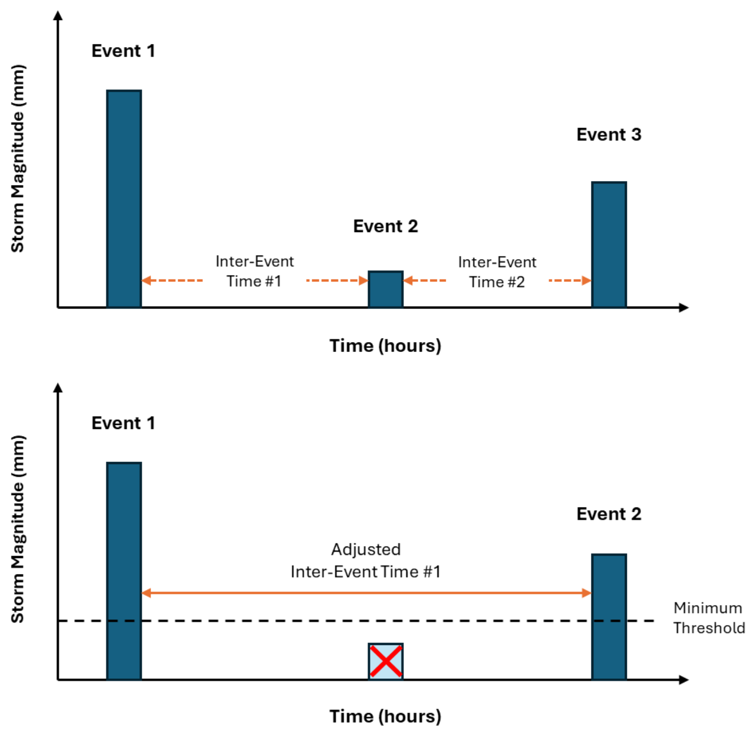


Figure 4. Conceptual diagram illustrating how the inclusion of additional criteria can influence calculated inter-event times in SEPARATE used in the ISC analysis. The top panel shows the initial determination of inter-event times in the ISC analysis, based on a test interval, or alternatively the case when no additional criteria are included. The bottom panel illustrates the outcome after the suppression of events that do not meet additional user-defined criteria related to minimum storm magnitude and/or duration. In this example, the initial event 2 is suppressed and the corresponding period between the initially identified event 1 and 3 (in the top panel) are assumed to be rainless, resulting in a longer inter-event time. This can influence the means and std. deviations used to determine an optimal fixed MIT value under the independence criterion.

OUTPUTS

Output Directory

**Required*

Description

Browse to and select the directory folder where the output files will be saved.

Output Prefix

**Required*

Description

This is the prefix assigned to all output files, as well as the prefix used for auto-generated storm ID names.

The selected prefix must start with a letter (a-z, A-Z). It cannot start with a number or any other symbol. After the first letter, the name can contain any combination of letters (a-z, A-Z), numbers (0-9), and underscores (_). Other symbols (e.g., spaces, hyphens, or special characters) are not allowed. We recommend a name that is identifiable to the data and selected analysis.

Image File Format

**Required*

Description

Select image file format for all output graphs – options include .png, .eps, .jpg, and .pdf

At a minimum this selection will influence the image formats default summary figures characterizing the storms separated in the rainfall record. If users also choose to output Graphical Storm Event Profiles for each storm, then these image files will also be formatted based on this selection.

Rainfall Record Timeseries Date Range

Optional

Description

For users with longer rainfall records that want to view the default timeseries graphs for a more specific, subset range of dates, there is an option to define date ranges based on the following three options*:

a) Start Date *only* – [YYYY-MM-DD] – the additional output timeseries figure will display rainfall that occurred *on or after* the defined start date through the end of the input rainfall record.
b) End Date *only* – [YYYY-MM-DD] – the additional output timeseries figure will display rainfall that occurred from the beginning of the rainfall record up until (*and inclusive of*) the defined end date.
c) Start *and* End Dates – [YYYY-MM-DD] – the additional output timeseries figure will display rainfall that occurred on or between the defined start and end dates.

*Note: If a subset range is input to SEPARATE here, the timeseries plots showing the full record of events will still be included in outputs.

Storm Event Profiling (All Storms)

Tabular Storm Event Data

Optional

Description

If selected, SEPARATE will include individual output tables for all separated storms displaying both absolute and relativized storm time, the cumulative event rainfall depth, and the rainfall intensity (based on the user-selected intensity interval).

Each storm profile table will be included within the output summary Excel file as separate sheets (or "tabs") named according to their storm ID assigned in the main summary table located in the first tab of the Excel spreadsheet.

Graphical Storm Event Profiles

Optional

Description

If selected, SEPARATE will include individual output figures displaying both the cumulative storm rainfall depth and rainfall intensity (based on the user-selected intensity interval). Graphical storm profiles also include annotations displaying pertinent storm details and rainfall metrics.

The image files of graphical profiles produced for all storms will be named according to their storm ID and saved to a subfolder (named: '[*OutputPrefix*]_storm_plots') in user-selected output folder.

Intensity Interval for Storm Profiles

Conditional

Description

For users that select the optional outputs of either tabular or graphical storm profiles, a specific rainfall intensity interval must be selected for graphing and inclusion in the tabular outputs. Users can either select from one of the standard sub-hourly to hourly intensity intervals available in the drop-down menu (5, 10, 15, 30, or 60-min).

Note that this selection only influences the storm profile outputs, not the main summary table. Regardless of selection here, the summary output table will still include peak storm rainfall intensities for all applicable intensity intervals (5, 10, 15, 30, and 60-min intervals).

SEPARATE OUTPUT FILES

Descriptions of Default Outputs

At a minimum, SEPARATE's default outputs include one Excel file and three image files. All of these output files will be saved to the output directory folder selected by the user in the GUI and will begin with the suffix input by the user ("Output Prefix"). Each of the default outputs are described in detail below.

Summary Output File

Filename: '[*OutputPrefix*]_SummaryTable.xlsx'

Output storm analytics are written to a single Excel file. The header of the first sheet includes both record and analysis metadata containing the following information:

Dataset ID:	[*OutputPrefix*]
Record Start Date:	YYYY-MM-DD
Record End Date:	YYYY-MM-DD
Tipping Bucket Record Type:	[Fixed Interval *or* Cumulative Tips]
Tip Magnitude:	[*user input*]
Tip Units:	[*user input*]
Logging Interval (min):	[*if fixed interval record*]
Fixed MIT Selection Criterion:	[*user selected*]
Minimum Inter-Event Time (hours):	[*criterion dependent*]
Number of Storms in Record:	XXX
Minimum Storm Depth (mm):	[*optional user input*]
Minimum Storm Duration (hrs):	[*optional user input*]
Number of Storms Suppressed:	XXX
Record Separated On:	YYYY-MM-DD
Data Input File:	C:/... filepath

Storm Analytics Summary Table:

Storm analytics for each identified storm are then summarized in a single table on the first sheet of the Excel file organized by row with the following 16 attribute fields organized by column:

Attribute Field Names & Descriptions:

StormID	auto-generated IDs formatted as: [*OutputPrefix*]_YYYY-MM-DD *note: if more than one storm per date, then ID receives additional suffix with storm number, e.g., [OutputPrefix]_YYYY-MM-DD_2*
Start	date and time of first storm tip (YYYY-MM-DD HH:MM:SS)
End	date and time of last storm tip (YYYY-MM-DD HH:MM:SS)
Duration	storm duration (hours)

Magnitude	cumulative storm magnitude or total storm rainfall depth (TBRG tip units)
Storm_Intensity	storm-averaged rainfall rate, i.e., =magnitude/duration (TBRG tip units per hour)
Peak_i5	peak 5-minute storm intensity calculated with a moving window (TBRG tip units per hour)
Peak_i10	peak 10-minute storm intensity calculated with a moving window (TBRG tip units per hour)
Peak_i15	peak 15-minute storm intensity calculated with a moving window (TBRG tip units per hour)
Peak_i30	peak 30-minute storm intensity calculated with a moving window (TBRG tip units per hour)
Peak_i60	peak 60-minute storm intensity calculated with a moving window (TBRG tip units per hour)
Peak_i5_time	date and time of peak 5-minute storm intensity (YYYY-MM-DD HH:MM:SS)
Peak_i10_time	date and time of peak 10-minute storm intensity (YYYY-MM-DD HH:MM:SS)
Peak_i15_time	date and time of peak 15-minute storm intensity (YYYY-MM-DD HH:MM:SS)
Peak_i30_time	date and time of peak 30-minute storm intensity (YYYY-MM-DD HH:MM:SS)
Peak_i60_time	date and time of peak 60-minute storm intensity (YYYY-MM-DD HH:MM:SS)

Example of Summary Table:

Columns A - K:

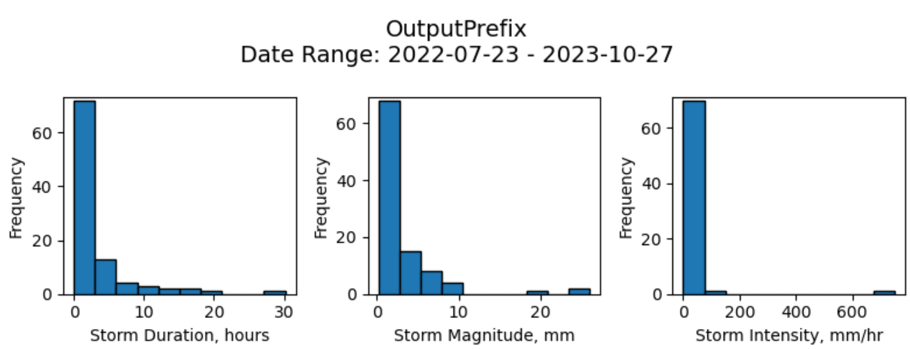
StormID	**Start**	**End**	**Duration**	**Magnitude**	**Storm_Intensity**	**Peak_i5**	**Peak_i10**	**Peak_i15**	**Peak_i30**	**Peak_i60**
Unique Identifier	*date_time*	*date_time*	*hours*	*mm*	*mm/hr*	*mm/hr*	*mm/hr*	*mm/hr*	*mm/hr*	*mm/hr*
OutputPrefix_2022-08-04	2022-08-04 14:00:23	2022-08-04 23:28:23	9.47	4.8	0.51	17.36	10.37	8.03	4.14	2.1
OutputPrefix_2022-08-10	2022-08-10 19:53:23	2022-08-10 22:16:23	2.38	9.6	4.03	85.43	52.82	36.36	18.43	9.26
OutputPrefix_2022-09-12	2022-09-12 12:00:23	2022-09-12 23:10:23	11.17	3.8	0.34	14.49	8.1	5.72	3.09	2.88
OutputPrefix_2022-09-14	2022-09-14 08:45:23	2022-09-14 17:17:23	8.53	9.4	1.1	8.41	7.81	7.21	6	4.89
OutputPrefix_2022-11-04	2022-11-04 11:25:29	2022-11-04 13:39:29	2.23	2.2	0.99	4.01	3.6	3.33	2.52	1.09
OutputPrefix_2022-11-04_2	2022-11-04 21:47:29	2022-11-04 23:52:29	2.08	3.8	1.82	12.02	11.41	9.31	2.5	0.21

Columns L - P:

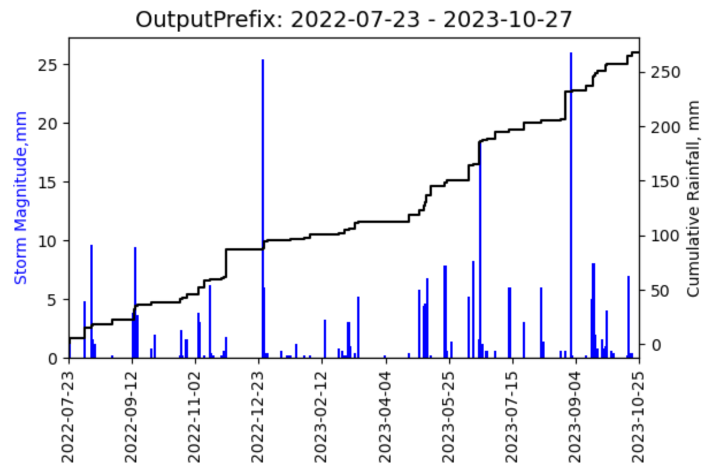
Peak_i5_time	**Peak_i10_time**	**Peak_i15_time**	**Peak_i30_time**	**Peak_i60_time**
date_time	*date_time*	*date_time*	*date_time*	*date_time*
2022-08-05 07:59:35	2022-08-05 08:04:23	2022-08-05 08:09:11	2022-08-05 08:24:11	2022-08-05 08:26:35
2022-08-10 22:22:23	2022-08-10 22:27:11	2022-08-10 22:31:23	2022-08-10 22:46:23	2022-08-10 23:16:23
2022-09-13 05:24:11	2022-09-13 06:00:11	2022-09-13 06:00:11	2022-09-13 06:00:11	2022-09-13 06:19:23
2022-09-14 19:17:59	2022-09-14 19:22:47	2022-09-14 19:28:11	2022-09-14 19:36:35	2022-09-14 20:06:35
2022-11-04 15:10:05	2022-11-04 15:14:17	2022-11-04 15:19:41	2022-11-04 15:34:41	2022-11-04 15:23:17
2022-11-05 01:48:53	2022-11-05 01:51:17	2022-11-05 01:50:05	2022-11-05 01:42:17	2022-11-05 01:27:17

Summary Figures

1) Histograms of storm duration, magnitude, and intensity of all storms in the rainfall record
   Filename: '[*OutputPrefix*]_summary_plot'

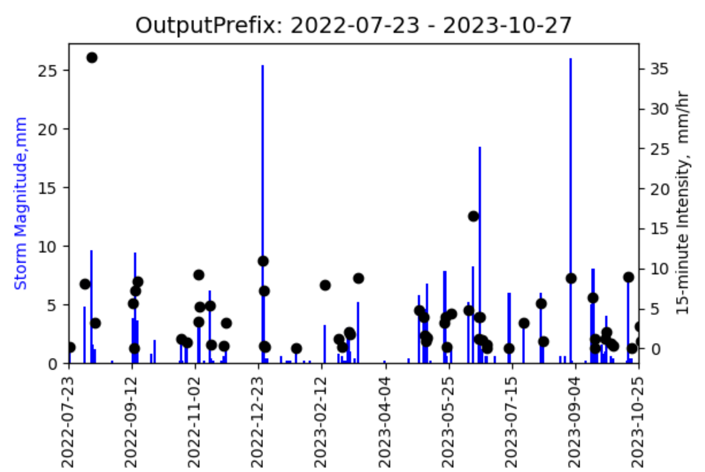


2) Timeseries of cumulative rainfall and storm magnitudes of all storms in the rainfall record
Filename: '[*OutputPrefix*]_magnitude_cumulative_rainfall_full'



Note: All storms are included the timeseries plots, including those potentially suppressed due to the inclusion of additional criteria.

3) Timeseries of storm magnitudes and peak storm intensities at the user-specified duration for all storms in the rainfall record
Filename: '[*OutputPrefix*]_magnitude_rainfall_intensity_full'



Descriptions of Optional Outputs

Based on user selected options, SEPARATE's outputs can also include the following:

Tabular Storm Event Data

If the option is selected, SEPARATE will include additional sheets within the Excel file, each containing the separated data from each storm event in the record and named according to their storm ID in the main summary table. This data includes both the raw TBRG data with time stamped tips, as well as the cumulative storm time and the moving window calculations for a selected rainfall intensity duration.

Each table of data includes a header containing key statistics about the storm:

Storm ID:	[*OutputPrefix*]_YYYY-MM-DD
Start Date & Time:	YYYY-MM-DD HH:MM:SS
Storm Duration (hrs):	XX.XX
Storm Magnitude (mm):	XX.XX
Peak 15-min Intensity (mm/hr):	XX.XX
Peak Intensity Date and Time:	YYYY-MM-DD HH:MM:SS
Number of Tips:	XX

This is then followed by two tables of data. The first includes recorded date and time of each recorded tip or logging interval, the cumulative storm time in hours starting from the time of the first tip or logging interval, and the cumulative rainfall in the TBRG units. An example of this table is shown below:

TBRG Time Stamp	Cumulative Storm Time (hours)	Cumulative Rainfall (mm)
2022-08-04 14:00:23	0	0.2
2022-08-04 14:30:23	0.5	0.4
2022-08-04 15:21:23	1.35	0.6
2022-08-04 15:36:23	1.6	0.8

The second table includes the cumulative storm time in hours and the associated rainfall intensity calculated at the user-selected interval (e.g., 15-minutes) in TBRG tip units per hour. Example below:

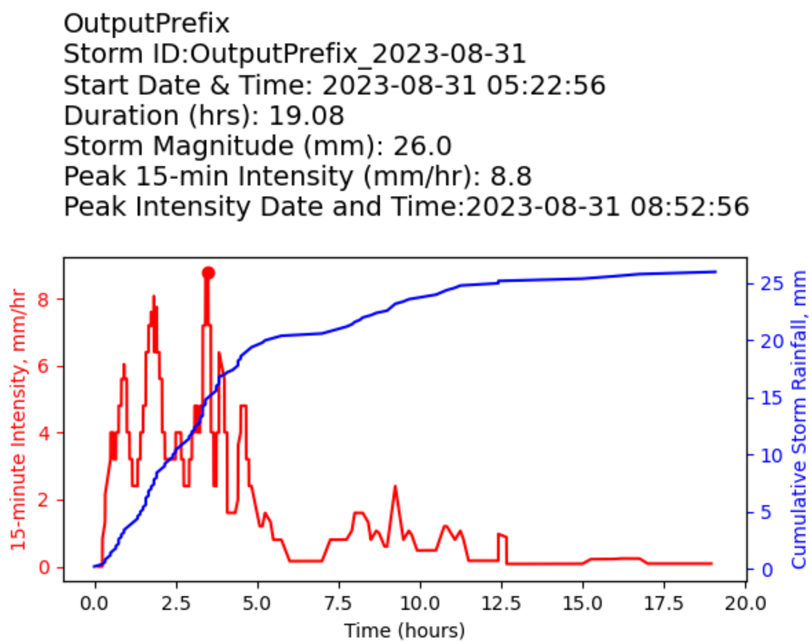
Cumulative Storm Time (hours)	15-min Intensity (mm/hr)
0.2500	2.78
0.2667	8.29
0.2833	13.81
0.3000	19.32

Graphical Storm Event Profiles

If the option is selected, SEPARATE will also include graphical profiles for each storm event. These figures are saved in a separate subfolder within the output directory folder named: [*OutputPrefix*]_storm_plots

Each of the image file will be named according to its storm ID. Every figure includes annotations detailing the key storm metrics, as well as the cumulative storm rainfall (in blue) and rainfall intensity at the user-specified duration in red. The timing of the peak storm intensity is identified graphically with a red dot, and the associated time is noted in the annotated details above. An example plot is shown below:

Figure 5. Example of the annotated graphical storm figures optionally output from SEPARATE.



Independent Storm Criterion (ISC) Outputs

If users select the ISC criterion, SEPARATE will provide additional graphical and tabular outputs. This includes two figures showing the CV analysis and exponential fit (e.g., Figures 2 & 3), as well as an Excel file (.xlsx) with essential ISC analysis data including all tested inter-event intervals and the associated mean, standard deviation, and CV. Users who select the ISC option are strongly encouraged to evaluate these additional outputs to ensure the distribution of inter-event times in their data is reasonably well fit as an exponential (Figure 3) and that the tested bounds adequately achieved the CV = 1 selection criterion.

All of the ISC analysis outputs will be saved to a separate subfolder within the output directory folder that will be named: [*OutputPrefix*]_ISC_analysis. Within this folder, users will find an Excel file containing data from interval testing ('[*OutputPrefix*]_ISC_analysis.xlsx'), a figure displaying the mean, standard deviation, and CV calculated at the tested inter-event intervals ('[*OutputPrefix*]_ isc_IndependenceCriterion'), a figure displaying the exponential distribution fit to the inter-event times that were determined based on the selected MIT value ('[*OutputPrefix*]_ isc_exponentialfit'), and a figure displaying the fraction of included versus suppressed storms as a function of the tested inter-event intervals, which vary with the selection of additional criteria such as minimum event depth ((‘[*OutputPrefix*]_isc_suppressed_storms’).

The header of the first sheet includes the same metadata for the rainfall record and SEPARATE analysis that is found in the main summary file:

Dataset ID:	[*OutputPrefix*]
Record Start Date:	YYYY-MM-DD
Record End Date:	YYYY-MM-DD
Tipping Bucket Record Type:	[Fixed Interval *or* Cumulative Tips]
Tip Magnitude:	[*user input*]
Tip Units:	[*user input*]
Logging Interval (min):	[*if fixed interval record*]
Fixed MIT Selection Criterion:	[*user selected*]
Minimum Inter-Event Time (hours):	[*criterion dependent*]
Number of Storms in Record:	XXX
Minimum Storm Depth (mm):	[*optional user input*]
Minimum Storm Duration (hrs):	[*optional user input*]
Number of Storms Suppressed:	XXX
Record Separated On:	YYYY-MM-DD
Data Input File:	C:/… filepath

The analysis table then includes the statistical results from the full range of tested minimum inter-event times (by default 0.1 to 48 hours, unless modified by user), including the mean and standard deviations of inter-event times of separated storms at the tested interval, the associated coefficient of variation – used to determine the optimal fixed MIT for analysis – as well as records of the number of storms that are included versus suppressed at each tested interval as a result of any additional user-defined criteria for the minimum storm magnitude and/or storm duration.

Minimum Storm Separation Time	Coefficient of Variation	Mean	Standard Deviation	Number of Included Storms	Number of Suppressed Storms
hours	*-/-*	*hours*	*hours*	-	-
0.1					
0.2					
0.3					
0.4					
0.5					
0.6					
0.7					
0.8					
0.9					
1					
2					
3					
4					
5					
…					
48					

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