

# Package ‘HyetosMinute’

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**Type** Package

**Title** A package for temporal stochastic simulation of rainfall at fine time scales

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**Description** HyetosMinute is a package for temporal stochastic simulation of rainfall process at fine time scales, i.e. from daily down to 1-minute, based on the Bartlett-Lewis rectangular pulse model. It operates on several modes and combinations of them (depending on data availability), such as the operational or the testing mode, and simple sequential simulation or disaggregation. In the latter case, it uses the Bartlett-Lewis model to generate rainfall events along with proven disaggregation techniques that adjust the finer scale (e.g., hourly) variables in order to obtain the given coarser scale (e.g., daily) value. The package comprises various variants of the Bartlett-Lewis model, graphical capabilities, import/export tools as well as an optimization tool for the estimation of model parameters.

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HyetosMinute-package	<i>A package for temporal stochastic simulation of rainfall at fine time scales</i>
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## Description

**HyetosMinuteR** is a package for the temporal stochastic simulation of rainfall process at **fine time scales, i.e. from daily down to 1-minute**, based on the **Bartlett-Lewis rectangular pulse model**. It operates on several modes and combinations of them (depending on data availability), such as the operational or the testing mode, and simple **sequential simulation** or **disaggregation**. In the latter case, it uses the Bartlett-Lewis model to generate rainfall events along with proven disaggregation techniques that adjust the finer scale (e.g., hourly) variables in order to obtain the given coarser scale (e.g., daily) value. The package comprises **various variants of the Bartlett-Lewis model**, **graphical capabilities**, **import/export tools** as well as an **optimization tool** for the estimation of model parameters.

## Details

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## Author(s)

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## References

More details on the disaggregation methodology can be found in:

- Koutsoyiannis, D., and C. Onof, Rainfall disaggregation using adjusting procedures on a Poisson cluster model, Journal of Hydrology, 246, 109-122, 2001. (<http://itia.ntua.gr/el/docinfo/368/>)
- Koutsoyiannis, D., and C. Onof, A computer program for temporal rainfall disaggregation using adjusting procedures (HYETOS), XXV General Assembly of European Geophysical Society, Nice, Geophysical Research Abstracts, 2, 2000. (<http://itia.ntua.gr/en/docinfo/59/>)

For **Bartlett-Lewis rectangular pulse rainfall model** the user is referenced to:

- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, Some models for rainfall based on stochastic point processes, Proc. R. Soc. Lond., A 410, 269-288, 1987.
- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, A point process model for rainfall: Further developments, Proc. R. Soc. Lond., A 417, 283-298, 1988.
- Onof, C. and H. S. Wheater, Modelling of British rainfall using a Random Parameter Bartlett-Lewis Rectangular Pulse Model, Journal of Hydrology, 149, 67-95, 1993.
- Onof, C. and H. S. Wheater, Improvements to the modelling of British rainfall using a Modified Random Parameter Bartlett-Lewis Rectangular Pulse Model, Journal of Hydrology, 157, 177-195, 1994.
- Onof, C., Chandler, R.E., Kakou, A., Northrop, P., Wheater, H.S., Isham, V., 2000. Rainfall modelling using Poisson-cluster processes: a review of developments. Stoch. Environ. Res. Risk Assess. 14, 384?411. doi:10.1007/s004770000043
- Kaczmarska, J., Isham, V., Onof, C., 2014. Point process models for fine-resolution rainfall. Hydrol. Sci. J. 140806131733005. doi:10.1080/02626667.2014.925558

For **disaggregation by adjusting procedures** the user is referenced to:

- Koutsoyiannis, D., A stochastic disaggregation method for design storms and flood synthesis, Journal of Hydrology, 156, 193-225, 1994.
- Koutsoyiannis, D., and A. Manetas, Simple disaggregation by accurate adjusting procedures, Water Resources Research, 32(7), 2105-2117, 1996.
- Koutsoyiannis, D., Coupling stochastic models of different time scales, Water Resources Research, 37(2), 379-391, 2001.
- Koutsoyiannis, D., Rainfall Disaggregation Methods: Theory and Applications, Workshop on Statistical and Mathematical Methods for Hydrological Analysis, Rome, 2003.

Find other versions of HyetosMinute on <http://itia.ntua.gr/en/softinfo/3/>

The **the evolutionary annealing-simplex optimization method** and details of its application are described in:

- Efstratiadis, A., and D. Koutsoyiannis, An evolutionary annealing-simplex algorithm for global optimisation of water resource systems, Proceedings of the Fifth International Conference on Hydroinformatics, Cardiff, UK, 1423-1428, International Water Association, 2002. (<http://itia.ntua.gr/el/docinfo/524/>)
- Rozos, E., A. Efstratiadis, I. Nalbantis, and D. Koutsoyiannis, Calibration of a semi-distributed model for conjunctive simulation of surface and groundwater flows, Hydrological Sciences Journal, 49 (5), 819-842, 2004. (<http://itia.ntua.gr/el/docinfo/630/>)

Find the original Pascal-Delphi code of optimisation algorithms on <http://itia.ntua.gr/el/docinfo/524/>.

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DisagSimul	<i>Disaggregate daily rainfall depths into shorter time intervals (with daily input)</i>
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## Description

This function enables the disaggregation of daily rainfall series into hourly or sub-hourly rainfall series. This is similar to DisagSimul.test function. The difference is that the input file contains only **daily** values. This is the usual case for the model application. It cannot provide any means for testing.

## Usage

```
DisagSimul(TimeScale=1,BLpar=list(lambda,phi,kappa,alpha,v,mx,sxmx),
CellIntensityProp=list(Weibull=FALSE,iota=NA),
RepetOpt=list(DistAllowed=0.1,FacLevel1Rep=20,
MinLevel1Rep=50,TotalRepAllowed=5000),
NumOfSequences=10,
Statistics=list(print=TRUE,plot=TRUE),
ImportHistData=list(file="histdata.txt",FileContent=c("WetDays","AllDays"),
DaysPerSeason=31,na.values="NA"),
ExportSynthData=list(exp=FALSE,file="SynthData.txt",
FileContent=c("WetDays","AllDays")),PlotHyetographs=FALSE,RandSeed=NULL)
```

## Arguments

TimeScale	A positive number that specifies the time scale at which the daily values are to be disaggregated. Please make sure that for the argument TimeScale the units are hours (h). The default value is 1, meaning that the daily rainfall depths are going to be disaggregated into hourly depths. For sub-hourly time scales, use subdivisions of hour. For instance, to disaggregate daily rainfall into 1 minute depths use 1/60, 1/30 for 2 minute, 1/6 for 10 minute etc. See Examples for further information.
BLpar	List of the Bartlett-Lewis model parameters. See Details for further information.
CellIntensityProp	List of arguments that specifies the distribution of cell intensity. See Details for further information.
RepetOpt	List of parameters specifying the disaggregation algorithm behavior. See Details for further information.
NumOfSequences	A positive integer that specifies the number of clusters of wet days to be disaggregated. To disaggregate all clusters, set a large number (e.g., 1000). Default is NumOfSequences=10.
Statistics	List of logical variables (TRUE/FALSE) that indicates whether the main statistical characteristics of historical and disaggregated data should be printed or plotted. If print=TRUE (the default) the statistics are printed and if plot=TRUE (the default) the statistics are also plotted. See Details for further information.
ImportHistData	List of parameters that specifies the import of historical rainfall depths from an external file. See Details for important special features of ImportHistData parameters.

**ExportSynthData**

List of parameters that specifies the export of disaggregated rainfall depths to an output file. See **Details** for important special features of **ExportSynthData** parameters.

**PlotHyetographs**

A logical variable (TRUE/FALSE) that indicates whether original and synthetic hyetographs is to be plotted. See **Details** for further information. Default is **PlotHyetographs=FALSE**.

**RandSeed**

An integer value for the random number generator. If it is equal to NULL, then a random seed is not inserted.

**Details**

The function **DisagSimul** enables the disaggregation of daily rainfall into hourly or sub-hourly rainfall depths. It uses the **Bartlett-Lewis rainfall model** as a background stochastic model for hourly or sub-hourly rainfall generation. Then, it uses **repetitions** to derive a synthetic rainfall series that resembles the given series at the daily scale and, then, an appropriate **adjusting procedure**, namely the proportion adjusting procedure, to make the generated series fully consistent with the given daily series. For more detailed information on the disaggregation scheme, see the list of references.

The statistics of the generated series can be either printed or displayed graphically. Additionally, the disaggregated series and the synthetic hyetograph of each cluster of wet days can be exported to an output file.

**Bartlett-Lewis model description**

Argument **BLpar** is a list that specifies **the Bartlett-Lewis rectangular pulse model parameters**. The general assumptions of the Bartlett-Lewis rectangular pulse model (Rodriguez-Iturbe et Al., 1987, 1988) are:

1. Storm origins  $t_i$  occur following a Poisson process with rate  $\lambda$  (argument **lambda**).
2. Cell origins  $t_{ij}$  occur following a Poisson process with rate  $\beta$ .
3. Cell arrivals terminate after a time  $v_i$  exponentially distributed with parameter  $\gamma$ .
4. Each cell has a duration  $w_{ij}$  exponentially distributed with parameter  $\eta$ .
5. Each cell has a uniform intensity  $X_{ij}$  with a specified distribution.

In the original version of the model (Bartlett-Lewis Rectangular Pulse Model), the parameters associated with cells are assumed constant among different storms.

In the modified version (random parameter Bartlett-Lewis model), the parameter  $\eta$  is randomly varied from storm to storm according to a gamma distribution with shape parameter  $\alpha$  (argument **alpha**) and scale parameter  $\nu$  (argument **v**). Subsequently, parameters  $\beta$  and  $\gamma$  also vary so that the ratios  $\kappa = \beta/\eta$  (argument **kappa**) and  $\phi = \gamma/\eta$  (argument **phi**) are constant.

**HyetosMinute** package implements also the Random Parameter Bartlett-Lewis Rectangular Pulse Model with dependent intensity-duration (Kaczmarzka et al., 2014) that allows  $\mu_x$  to vary in proportion to the cell duration parameter,  $\eta$ , so as the ratio  $\iota = \mu_x/\eta$  (argument **iota**) is kept constant.

The distribution of the cell intensity  $X_{ij}$  is typically assumed exponential with mean  $\mu_x$ . Alternatively, it can be assumed two-parameter gamma distribution with mean  $\mu_x$  and standard deviation  $\sigma_x$ . The package also supports Weibull distribution for cell intensity with mean  $\mu_x$  and shape parameter.

Thus, in its most simplified version the model uses five parameters, namely  $\lambda$ ,  $\beta$ ,  $\gamma$ ,  $\eta$  and  $\mu_x$  (or equivalently  $\lambda$ ,  $\kappa$ ,  $\phi$ ,  $\eta$  and  $\mu_x$ ) and in its most enriched version seven parameters, namely  $\lambda$ ,  $\kappa$ ,  $\phi$ ,

$\alpha, \nu, \mu_x, \sigma_x$ . Normally, one parameter set corresponds to one month but it can be also correspond to a season of e.g. three months or even the whole year.

**HyetosMinute** package supports both the original and the random model version with exponential, gamma or Weibull intensities. By default, the random model is assumed. To implement the original model version with constant parameter  $\eta$ , set argument alpha greater than 100 and insert the value of parameter  $\eta$  in argument v.

To implement the random model with with dependent intensity-duration, set the value of ratio  $\iota = \mu_x/\eta$  in argument iota.

To implement exponential or gamma distribution for cell intensity then set argument Weibull in CellIntensityProp list as FALSE. To implement the exponential distribution set mean  $\mu_x$  in argument mx and the ratio  $\mu_x/\sigma_x$  (argument sxmx) equals to 1. If the argument sxmx is not equal to 1 then the gamma distribution is assumed with a specific ratio sxmx.

To implement Weibull distribution, then set argument weibTF equal to TRUE. In this case, the intensity follows the Weibull distribution with mean  $\mu_x$  (argument mx) and shape parameter (put in argument sxmx).

In the case of random model with with dependent intensity-duration and exponential distribution, set the value of ratio  $\iota = \mu_x/\eta$  in argument iota, argument mx as NA and argument sxmx equals to 1. To implement gamma distribution, set argument mx as NA and specify the ratio  $\mu_x/\sigma_x$  (argument sxmx). To implement Weibull distribution set argument mx as NA and specify the shape parameter in argument sxmx.

**Please make sure that for parameters  $\mu_x$  and  $\sigma_x$  the length units are millimeters (mm) and for parameters  $\lambda, \nu, \mu_x$  and  $\sigma_x$  the time units are days (d).**

### Disaggregation scheme options

Argument RepetOpt is a list of parameters that specifies any changes to the default values of **dis-aggregation repetition scheme**.

The scheme incorporates four levels of repetition. The number of **Level 1** repetitions is determined by multiplying the FacLevel1Rep by the number of attempts to establish an appropriate sequence of wet days (**Level 0** repetitions, which is not given by the user but rather is determined by the program). In this manner, the more the number of required Level 0 repetitions is, the more the number of Level 1 repetitions, and the less the number of Level 2 repetitions, will be. This results in a faster algorithm. The number of allowed Level 1 repetitions cannot be set lower than MinLevel1Rep. The total number of Level 1 and Level 2 repetitions cannot exceed the TotalRepAllowed.

In the case that the model is not able to establish an appropriate sequence of wet days (**Level 0** repetitions) after a large number of repetitions (10\*TotalRepAllowed), then NA values are returned. NA values are also returned in the case that the system is not able to obtain cell intensities with the desired properties (**Level 1** repetitions). The wet days that were not disaggregated successfully are excluded from the statistical analysis.

**DistAllowed** A positive number that specifies the distance used to judge whether synthetic daily depths resemble the real ones. Default is DistAllowed=0.1.

**FacLevel1Rep** A positive number that specifies the factor for Level 1 repetitions. Default is FacLevel1Rep=20.

**MinLevel1Rep** A positive integer that specifies the minimum number of Level 1 repetitions. Default is FacLevel1Rep=50.

**TotalRepAllowed** A positive integer that specifies the total repetitions. Default is TotalRepAllowed=5000.

Argument Statistics is a list of logical variables (TRUE/FALSE) that indicates whether the main **statistical characteristics** of synthetic data are to be printed or plotted. The statistics are computed

and printed if `print=TRUE`. Additionally, if `plot=TRUE` bar plots and auto-correlation function plots are produced on screen devices.

### Read daily data from file

Argument `ImportHistData` is a list of parameters specifying the features of **input file** that contains the **daily** rainfall depths to be disaggregated. This file must have a specific format (see examples).

**file** A character string that specifies the name of the file or connection of the daily rainfall data that is imported. The input files are text files with the ".txt" extension (e.g. `file="histdata.txt"`).

**FileContent** A character string that indicates if dry days (with zero rainfall depths) are also contained in the input file. If `FileContent=c("WetDays")` the input file contains only the daily rainfall depths of wet days. If `FileContent=c("AllDays")` the input file contains the daily rainfall depths of wet and dry days. Default is `DailyValues=c("WetDays")`.

**DaysPerSeason** A positive integer, typically 30 or 31, that specifies the number of days of the month or season of the input data. Default is `DaysPerSeason=31`.

**na.values** A character vector of strings which are to be interpreted as NA values. Default is `na.values="NA"`.

### The input file must not contain any header lines or the Bartlett-Lewis model parameters.

The three first columns of the input file determine the dates of the data. The first column corresponds to the "Day", the second column corresponds to the "Month" and the third column corresponds to the "Year". The fourth column contains the daily values (mm).

The "Year" field in the input file does not necessarily correspond to a real year. Thus, the sequence of years could be 1, 2, ..., or 49, 50, ..., instead of 1949, 1950, ... .

The "Day" and "Month" fields in the input file do not necessarily correspond to a real month. A "Month" can well be a season containing e.g. three months or even the whole year. In the latter case the number of days of month should be set to 366 and the "Day" field should be the Julian number of the date.

### Export synthetic data to file

Argument `ExportSynthData` is a list of parameters that specifies the features of **output file** if synthetic data is to be exported to a text file. The output file has similar structure as the input file. The output file always contains the synthetic rainfall depths listed in increasing order of date.

**exp** A logical variable (TRUE/FALSE) that indicates whether synthetic rainfall depths should be written to an output file. If `exp=TRUE`, synthetic data are exported to a text file. Default is `exp=FALSE`.

**file** A character string that specifies the name of the file or connection where the rainfall data is to be exported. The output files are text files with the ".txt" extension (e.g. `file="SynthData.txt"`).

**FileContent** A character string indicating whether dry days will be also written in the output file. If `FileContent=c("WetDays")` the output file will contain only the rainfall depths of wet days. If `FileContent=c("AllDays")` the output file will contain the rainfall depths of wet and dry days. Default is `DailyValues=c("WetDays")`.

**DaysPerSeason** A positive integer, typically 30 or 31, that specifies the number of days of the month or season of the output data. Default is `DaysPerSeason=31`.

Argument `PlotHyetographs` is a logical variable (TRUE/FALSE) indicating whether original and synthetic hyetographs is to be plotted. If `PlotHyetographs=TRUE`, **hyetographs** of different sequences (clusters) of wet days are exported as PDF files, in the chosen working directory. The name of each external pdf file corresponds to the starting date of disaggregated cluster.

**The examples below and the used parameters are indicative. Subsequently, new parameters for the Bartlett-Lewis model should be estimated for other datasets.**

## Value

A list with the following components:

### Disaggregated rainfall depths

A list of matrices containing the disaggregated rainfall depths of each cluster of wet days.

**Statistics** A list of matrices containing the main statistics of all data values, wet day values and wet hour values. The statistics are printed if `print=TRUE`. See Details for further information.

The statistics are plotted on screen device if `plot` is `TRUE`.

The disaggregated rainfall depths are exported to a text file, if `exp` is `TRUE`. See Details for further information.

The historical and synthetic hyetograph of each cluster of wet days are plotted, if `PlotHyetographs` is `TRUE`. See Details for further information.

## Author(s)

Kossieris Panagiotis <pkossier@central.ntua.gr>

## References

The methodology of **HyetosMinute** and details of its application are described in:

- Panagiotis Kossieris, Christos Makropoulos, Christian Onof, Demetris Koutsoyiannis, A rainfall disaggregation scheme for sub-hourly time scales: Coupling a Bartlett-Lewis based model with adjusting procedures, Journal of Hydrology, Available online 11 July 2016, ISSN 0022-1694, <http://dx.doi.org/10.1016/j.jhydrol.2016.07.015>.  
<http://www.sciencedirect.com/science/article/pii/S0022169416304450> or  
<https://www.itia.ntua.gr/el/docinfo/1640/>
- Koutsoyiannis, D., and C. Onof, Rainfall disaggregation using adjusting procedures on a Poisson cluster model, Journal of Hydrology, 246, 109-122, 2001.  
<http://itia.ntua.gr/el/docinfo/368/>
- Koutsoyiannis, D., and C. Onof, A computer program for temporal rainfall disaggregation using adjusting procedures (HYETOS), XXV General Assembly of European Geophysical Society, Nice, Geophysical Research Abstracts, 2, 2000.  
<http://itia.ntua.gr/en/docinfo/59/>

For **Bartlett-Lewis rectangular pulse rainfall model** the user is referenced to:

- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, Some models for rainfall based on stochastic point processes, Proc. R. Soc. Lond., A 410, 269-288, 1987.
- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, A point process model for rainfall: Further developments, Proc. R. Soc. Lond., A 417, 283-298, 1988.
- Onof, C. and H. S. Wheater, Modelling of British rainfall using a Random Parameter Bartlett-Lewis Rectangular Pulse Model, Journal of Hydrology, 149, 67-95, 1993.
- Onof, C. and H. S. Wheater, Improvements to the modelling of British rainfall using a Modified Random Parameter Bartlett-Lewis Rectangular Pulse Model, Journal of Hydrology, 157, 177-195, 1994.
- Onof, C., Chandler, R.E., Kakou, A., Northrop, P., Wheater, H.S., Isham, V., 2000. Rainfall modelling using Poisson-cluster processes: a review of developments. Stoch. Environ. Res. Risk Assess. 14, 384?411. doi:10.1007/s004770000043

- Kaczmarska, J., Isham, V., Onof, C., 2014. Point process models for fine-resolution rainfall. *Hydrol. Sci. J.* 140806131733005. doi:10.1080/02626667.2014.925558

For **disaggregation by adjusting procedures** the user is referenced to:

- Koutsoyiannis, D., A stochastic disaggregation method for design storms and flood synthesis, *Journal of Hydrology*, 156, 193-225, 1994.
- Koutsoyiannis, D., and A. Manetas, Simple disaggregation by accurate adjusting procedures, *Water Resources Research*, 32(7), 2105-2117, 1996.
- Koutsoyiannis, D., Coupling stochastic models of different time scales, *Water Resources Research*, 37(2), 379-391, 2001.
- Koutsoyiannis, D., Rainfall Disaggregation Methods: Theory and Applications, Workshop on Statistical and Mathematical Methods for Hydrological Analysis, Rome, 2003.

Find older versions of Hyetos at <http://itia.ntua.gr/en/softinfo/3/>

## See Also

[SequentialSimul](#), [DisagSimul.test](#)

## Examples

```
# Example 1: Disaggregate daily rainfall into hourly values
# with the random parameter Bartlett-Lewis gamma model
# Import daily time series from "HistDailyData.txt" file

# To load the data set "HistDailyData" use
data(HistDailyData)

# To export the daily rainfall depths of "HistDailyData"
# data set in the chosen working directory use
write.table(HistDailyData,file="HistDailyData.txt",sep="\t",
            quote=FALSE,row.names=FALSE,col.names=FALSE)

# To disaggregate the daily rainfall depths of first 5 clusters of wet days use
ex21 <- DisagSimul(TimeScale=1,BLpar=list(lambda=0.569748,phi=0.048387,kappa=0.5996395,
alpha=7.2933199,v=0.052517913,mx=30.4825,sxmx=32.391/30.4825),CellIntensityProp=list(Weibull=FALSE,
iota=NA),RepetOpt=list(DistAllowed=0.1,FacLevel1Rep=20,MinLevel1Rep=50,
TotalRepAllowed=5000),NumOfSequences=5,Statistics=list(print=TRUE,plot=FALSE),
ExportSynthData=list(exp=TRUE,FileContent=c("AllDays"),file="HistDailyData_Disag.txt"),
ImportHistData=list(file="HistDailyData.txt",na.values="NA",FileContent=c("AllDays"),
DaysPerSeason=30),PlotHyetographs=FALSE,RandSeed=5)

# Example 2: Disaggregate daily rainfall into 10-min values
# with the random parameter Bartlett-Lewis model
# Import daily time series from "HistDailyData2.txt" file

# To load the data set "HistDailyData2" use
data(HistDailyData2)

# To export the daily rainfall depths of "HistDailyData2" data set
# in the chosen working directory use
write.table(HistDailyData2,file="HistDailyData2.txt",sep="\t",
            quote=FALSE,row.names=FALSE,col.names=FALSE)

# To disaggregate the daily rainfall depths of first 5 clusters of wet days use
```

```
x22 <- DisagSimul(TimeScale=1/6,BLpar=list(lambda=0.9396,phi=0.0568,kappa=1.05819,
alpha=2.69519,v=0.006282916666,mx=24.33408,sxm=1),CellIntensityProp=list(Weibull=FALSE,
iota=NA),RepetOpt=list(DistAllowed=0.1,FacLevel1Rep=20,MinLevel1Rep=50,
TotalRepAllowed=5000),NumOfSequences=5,Statistics=list(print=TRUE,plot=FALSE),
ExportSynthData=list(exp=TRUE,FileContent=c("WetDays"),file="HistDailyData2_Disag.txt"),
ImportHistData=list(file="HistDailyData2.txt",na.values="NA",
FileContent=c("WetDays"),DaysPerSeason=31),
PlotHyetographs=FALSE,RandSeed=5)
```

**DisagSimul.test**

*Disaggregate daily rainfall into shorter time intervals (with or without input data)*

**Description**

This function enables the disaggregation of daily rainfall series into hourly or sub-hourly rainfall depths. The initial daily sequence either is generated using the Bartlett-Lewis rainfall model or is read from a file. This function is appropriate for testing the entire model performance including the appropriateness of the Bartlett-Lewis model and its parameters and the disaggregation model, by comparing original and disaggregated rainfall depths statistics.

**Usage**

```
DisagSimul.test(Length=1000,TimeScale=1,BLpar=list(lambda,phi,kappa,alpha,v,mx,sxm),
CellIntensityProp=list(Weibull=FALSE,iota=NA),
RepetOpt=list(DistAllowed=0.1,FacLevel1Rep=20,MinLevel1Rep=50,TotalRepAllowed=5000),
NumOfSequences=10,Statistics=list(print=TRUE,plot=TRUE),
ImportHistData=list(imp=FALSE,file="histdata.txt",ImpDataTimeScale=1,
FileContent=c("WetDays","AllDays"),DaysPerSeason=31,DailyValues=TRUE,na.values="NA",
ImpDataTimeScale=1),ExportSynthData=list(exp=FALSE,file="SynthData.txt",
FileContent=c("WetDays","AllDays"),DaysPerSeason=31),PlotHyetographs=FALSE,RandSeed=NULL)
```

**Arguments**

- |                   |  |
|-------------------|--|
| Length            | A positive integer that specifies the length of synthetic time series of rainfall depth which is generated through the Bartlett-Lewis model, in the case that historic data is not imported from an external file.   |
| TimeScale         | A positive number that specifies the time scale at which the daily values are to be disaggregated. Please make sure that for the argument TimeScale the units are hours (h). The default value is 1 meaning that the daily rainfall series are going to be disaggregated into hourly depths. For sub-hourly time scales, use subdivisions of hour. For instance, to disaggregate daily rainfall into 1 minute depths use 1/60, 1/30 for 2 minute depths, 1/6 for 10 minute depths etc. See Examples for further information. |
| BLpar             | List of the Bartlett-Lewis model parameters. See Details for further information.  |
| CellIntensityProp | List of arguments that specifies the distribution of cell intensity. See Details for further information.  |

RepetOpt	List of parameters that specifies the disaggregation algorithm behavior. See Details for further information.
NumOfSequences	A positive integer that specifies the number of wet days sequences to be disaggregated. To disaggregate all clusters of wet days set a large number (e.g., 1000). Default is NumOfSequences=10.
Statistics	List of logical variables (TRUE/FALSE) that indicate whether the main statistical characteristics of historical and disaggregated data should be printed or plotted. If print=TRUE (the default) the statistics are printed and if plot=TRUE (the default) the statistics are plotted. See Details for further information.
ImportHistData	List of parameters that specifies the import of historical rainfall depths from an external file. See Details for important special features of ImportHistData parameters.
ExportSynthData	List of parameters that specifies the export of disaggregated rainfall depths to an output file. See Details for important special features of ExportSynthData parameters.
PlotHyetographs	A logical variable (TRUE/FALSE) indicating whether original and synthetic hyetographs should be plotted. See Details for further information. Default is PlotHyetographs=FALSE.
RandSeed	An integer value for the random number generator. If it is equal to NULL, then a random seed is not inserted.

## Details

The function DisagSimul.test enables the disaggregation of daily rainfall into hourly or sub-hourly rainfall. It uses the **Bartlett-Lewis rainfall model** as a background stochastic model for rainfall generation. Then, it uses **repetitions** to derive a synthetic rainfall series that resembles the given series at the daily scale and, then, an appropriate **adjusting procedure**, namely the proportion adjusting procedure, to make the generated series fully consistent with the given daily series. For more detailed information on the disaggregation scheme, see the list of references.

If an input file of rainfall depths is not available (imp=FALSE), an initial sequence of storms is generated using the Bartlett-Lewis model with the given parameters and then via aggregation the daily series is obtained. The daily sequence serves then as an "original" series, which is disaggregated, thus producing another synthetic lower-level series. The length of synthetic time series of rainfall depth which is generated through the Bartlett-Lewis model is specifying by Length argument. If an input file of rainfall depths is available (imp=TRUE), the daily sequence is imported from this file rather than generated.

The main statistical characteristics of the original and synthetic data can be either printed or displayed graphically. Additionally, the disaggregated rainfall depths and the synthetic hyetograph of each cluster of wet days can be exported to an output file.

### Bartlett-Lewis model description

Argument BLpar is a list that specifies the **Bartlett-Lewis rectangular pulse model parameters**. The general assumptions of the Bartlett-Lewis rectangular pulse model (Rodriguez-Iturbe et Al., 1987, 1988) are:

1. Storm origins  $t_i$  occur following a Poisson process with rate  $\lambda$  (argument lambda).
2. Cell origins  $t_{ij}$  occur following a Poisson process with rate  $\beta$ .
3. Cell arrivals terminate after a time  $v_i$  exponentially distributed with parameter  $\gamma$ .

4. Each cell has a duration  $w_{ij}$  exponentially distributed with parameter  $\eta$ .
5. Each cell has a uniform intensity  $X_{ij}$  with a specified distribution.

In the original version of the model (Bartlett-Lewis Rectangular Pulse Model), the parameters associated with cells are assumed constant among different storms.

In the modified version (random parameter Bartlett-Lewis model), the parameter  $\eta$  is randomly varied from storm to storm according to a gamma distribution with shape parameter  $\alpha$  (argument `alpha`) and scale parameter  $\nu$  (argument `v`). Subsequently, parameters  $\beta$  and  $\gamma$  also vary so that the ratios  $\kappa = \beta/\eta$  (argument `kappa`) and  $\phi = \gamma/\eta$  (argument `phi`) are constant.

**HyetosMinute** package implements also the Random Parameter Bartlett-Lewis Rectangular Pulse Model with dependent intensity-duration (Kaczmarzka et al., 2014) that allows  $\mu_x$  to vary in proportion to the cell duration parameter,  $\eta$ , so as the ratio  $\iota = \mu_x/\eta$  (argument `iota`) is kept constant.

The distribution of the cell intensity  $X_{ij}$  is typically assumed exponential with mean  $\mu_x$ . Alternatively, it can be assumed two-parameter gamma distribution with mean  $\mu_x$  and standard deviation  $\sigma_x$ . The package also supports Weibull distribution for cell intensity with mean  $\mu_x$  and shape parameter.

Thus, in its most simplified version the model uses five parameters, namely  $\lambda, \beta, \gamma, \eta$  and  $\mu_x$  (or equivalently  $\lambda, \kappa, \phi, \eta$  and  $\mu_x$ ) and in its most enriched version seven parameters, namely  $\lambda, \kappa, \phi, \alpha, \nu, \mu_x, \sigma_x$ . Normally, one parameter set corresponds to one month but it can be also correspond to a season of e.g. three months or even the whole year.

**HyetosMinute** package supports both the original and the random model version with exponential, gamma or Weibull intensities. By default, the random model is assumed. To implement the original model version with constant parameter  $\eta$ , set argument `alpha` greater than 100 and insert the value of parameter  $\eta$  in argument `v`.

To implement the random model with with dependent intensity-duration, set the value of ratio  $\iota = \mu_x/\eta$  in argument `iota`.

To implement exponential or gamma distribution for cell intensity then set argument `Weibull` in `CellIntensityProp` list as FALSE. To implement the exponential distribution set mean  $\mu_x$  in argument `mx` and the ratio  $\mu_x/\sigma_x$  (argument `sxmx`) equals to 1. If the argument `sxmx` is not equal to 1 then the gamma distribution is assumed with a specific ratio `sxmx`.

To implement Weibull distribution, then set argument `weibTF` equal to TRUE. In this case, the intensity follows the Weibull distribution with mean  $\mu_x$  (argument `mx`) and shape parameter (put in argument `sxmx`).

In the case of random model with with dependent intensity-duration and exponential distribution, set the value of ratio  $\iota = \mu_x/\eta$  in argument `iota`, argument `mx` as NA and argument `sxmx` equals to 1. To implement gamma distribution, set argument `mx` as NA and specify the ratio  $\mu_x/\sigma_x$  (argument `sxmx`). To implement Weibull distribution set argument `mx` as NA and specify the shape parameter in argument `sxmx`.

**Please make sure that for parameters  $\mu_x$  and  $\sigma_x$  the length units are millimeters (mm) and for parameters  $\lambda, \nu, \mu_x$  and  $\sigma_x$  the time units are days (d).**

### Disaggregation scheme options

Argument `RepetOpt` is a list of parameters that specifies any changes to the default values of **dis-aggregation repetition scheme**.

The scheme incorporates four levels of repetition. The number of **Level 1** repetitions is determined by multiplying the `FacLevel1Rep` by the number of attempts to establish an appropriate sequence of wet days (**Level 0** repetitions, which is not given by the user but rather is determined by the program). In this manner, the more the number of required Level 0 repetitions is, the more the number of Level 1 repetitions, and the less the number of Level 2 repetitions, will be. This results in a faster

algorithm. The number of allowed Level 1 repetitions cannot be set lower than `MinLevel1Rep`. The total number of Level 1 and Level 2 repetitions cannot exceed the `TotalRepAllowed`.

In the case that the model is not able to establish an appropriate sequence of wet days (**Level 0** repetitions) after a large number of repetitions ( $10 * \text{TotalRepAllowed}$ ), then NA values are returned. NA values are also returned in the case that the system is not able to obtain cell intensities with the desired properties (**Level 1** repetitions). The wet days that were not disaggregated successfully are excluded from the statistical analysis.

**DistAllowed** A positive number that specifies the distance used to judge whether synthetic daily depths resemble the real ones. Default is `DistAllowed=0.1`.

**FacLevel1Rep** A positive number that specifies the factor for Level 1 repetitions. Default is `FacLevel1Rep=20`.

**MinLevel1Rep** A positive integer that specifies the minimum number of Level 1 repetitions. Default is `FacLevel1Rep=50`.

**TotalRepAllowed** A positive integer that specifies the total repetitions. Default is `TotalRepAllowed=5000`.

Argument `Statistics` is a list of logical variables (TRUE/FALSE) that indicates whether the main **statistical characteristics** of synthetic data are to be printed or plotted. The statistics are computed and printed if `print=TRUE`. Additionally, if `plot=TRUE` bar plots and auto-correlation function plots are produced on screen devices.

#### Read historical data from file

Argument `ImportHistData` is a list of parameters specifying the features of **input file** that contains the original rainfall depths to be disaggregated. The input file must have a specific format (see examples).

**imp** A logical variable (TRUE/FALSE) that indicates if original rainfall depths should be imported from an input file. If `imp=TRUE`, the original data is imported from a file. Default is `imp=FALSE`.

**file** A character string that specifies the name of the file or connection where the rainfall data are located. The input files are text files with the ".txt" extension (e.g. `file="histdata.txt"`).

**ImpDateTimeScale** The time scale of rainfall data to be imported. It defaults to 1 that means that hourly rainfall data is imported. For sub-hourly time scales, use subdivisions of hour. To import 1 minute rainfall depths, set 1/60, 1/30 for 2 minutes data, 1/6 for 10 minutes data etc.

**FileContent** A character string indicating if dry days (with zero rainfall depths) are also included in the input file. If `FileContent=c("WetDays")` the input file contains only the rainfall depths of wet days. If `FileContent=c("AllDays")` the input file contains the rainfall depths of wet and dry days. Default is `DailyValues=c("WetDays")`.

**DaysPerSeason** A positive integer, typically 30 or 31, that specifies the number of days of the month or season of the input data. Default is `DaysPerSeason=31`.

**DailyValues** A logical variable (TRUE/FALSE) that specifies if the daily rainfall depths are contained in the input file. If `DailyValues=FALSE`, the imported rainfall depths are aggregated into daily scale. Default is `DailyValues=TRUE`.

**na.values** A character vector of strings which are to be interpreted as NA values. Default is `na.values="NA"`.

**In the case that the time scale of input data (ImpDateTimeScale argument) is greater than the time scale of disaggregation (TimeScale argument), then the system ignores the input data and generates a new "original" series via Bartlett-Lewis model.**

**The input file must not contain any header lines or the Bartlett-Lewis model parameters.**

In the input file, each row contains the data of a single day. The three first columns in an input file determine the dates of the original data. The first column corresponds to the "Day", the second

column corresponds to the "Month" and the third column corresponds to the "Year". The fourth column contains "the daily values (mm)" if available (DailyValues=TRUE). The rest columns contain the data of rainfall depth.

The "Year" field in the input file does not necessarily correspond to a real year. Thus, the sequence of years could be 1, 2, ..., or 49, 50, ..., instead of 1949, 1950, ... .

The "Day" and "Month" fields in the input file do not necessarily correspond to a real month. A "Month" can well be a season containing e.g. three months or even the whole year. In the latter case the number of days of month should be set to 366 and the "Day" field should be the Julian number of the date.

### Export synthetic data to file

Argument ExportSynthData is a list of parameters that specifies the features of **output file** if synthetic data is to be exported to a text file. The output file has similar structure as the input file. The output file always contains the synthetic rainfall depths listed in increasing order of date.

**exp** A logical variable (TRUE/FALSE) that indicates whether synthetic rainfall depths should be written to an output file. If exp=TRUE, synthetic data are exported to a text file. Default is exp=FALSE.

**file** A character string that specifies the name of the file or connection where the rainfall data is to be exported. The output files are text files with the ".txt" extension (e.g. file="SynthData.txt").

**FileContent** A character string indicating whether dry days will be also written in the output file. If FileContent=c("WetDays") the output file will contain only the rainfall depths of wet days. If FileContent=c("AllDays") the output file will contain the rainfall depths of wet and dry days. Default is DailyValues=c("WetDays").

**DaysPerSeason** A positive integer, typically 30 or 31, that specifies the number of days of the month or season of the output data. Default is DaysPerSeason=31.

Argument PlotHyetographs is a logical variable (TRUE/FALSE) indicating whether original and synthetic hyetographs is to be plotted. If PlotHyetographs=TRUE, **hyetographs** of the clusters of wet days are exported as PDF files, in the chosen working directory. The name of each pdf file corresponds to the starting date of disaggregated cluster.

**The examples below and the used parameters are indicative. Subsequently, new parameters for the Bartlett-Lewis model should be estimated for other datasets.**

### Value

A list with the following components:

#### Disaggregated rainfall depths

A list of matrices that contains the disaggregated rainfall depths of each cluster of wet days.

**Statistics** List of matrices of the the main statistical characteristics of the historical and synthetic data (all data values, wet days values and wet hours values). The statistics are printed if print=TRUE. See Details for further information.

If plot is TRUE, the statistics are plotted on screen device .

If exp is TRUE, the disaggregated rainfall depths are exported to a text file. See Details for further information.

If PlotHyetographs is TRUE, the historical and synthetic hyetograph of each cluster of wet days are plotted, . See Details for further information.

**Author(s)**

Kossieris Panagiotis <pkossier@central.ntua.gr>

**References**

The methodology of **HyetosMinute** and details of its application are described in:

- Panagiotis Kossieris, Christos Makropoulos, Christian Onof, Demetris Koutsoyiannis, A rainfall disaggregation scheme for sub-hourly time scales: Coupling a Bartlett-Lewis based model with adjusting procedures, Journal of Hydrology, Available online 11 July 2016, ISSN 0022-1694, <http://dx.doi.org/10.1016/j.jhydrol.2016.07.015>.  
<http://www.sciencedirect.com/science/article/pii/S0022169416304450> or  
<https://www.itia.ntua.gr/el/docinfo/1640/>
- Koutsoyiannis, D., and C. Onof, Rainfall disaggregation using adjusting procedures on a Poisson cluster model, Journal of Hydrology, 246, 109-122, 2001.  
<http://itia.ntua.gr/el/docinfo/368/>
- Koutsoyiannis, D., and C. Onof, A computer program for temporal rainfall disaggregation using adjusting procedures (HYETOS), XXV General Assembly of European Geophysical Society, Nice, Geophysical Research Abstracts, 2, 2000.  
<http://itia.ntua.gr/en/docinfo/59/>

For **Bartlett-Lewis rectangular pulse rainfall model** the user is referenced to:

- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, Some models for rainfall based on stochastic point processes, Proc. R. Soc. Lond., A 410, 269-288, 1987.
- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, A point process model for rainfall: Further developments, Proc. R. Soc. Lond., A 417, 283-298, 1988.
- Onof, C. and H. S. Wheater, Modelling of British rainfall using a Random Parameter Bartlett-Lewis Rectangular Pulse Model, Journal of Hydrology, 149, 67-95, 1993.
- Onof, C. and H. S. Wheater, Improvements to the modelling of British rainfall using a Modified Random Parameter Bartlett-Lewis Rectangular Pulse Model, Journal of Hydrology, 157, 177-195, 1994.
- Onof, C., Chandler, R.E., Kakou, A., Northrop, P., Wheater, H.S., Isham, V., 2000. Rainfall modelling using Poisson-cluster processes: a review of developments. Stoch. Environ. Res. Risk Assess. 14, 384?411. doi:10.1007/s004770000043
- Kaczmarska, J., Isham, V., Onof, C., 2014. Point process models for fine-resolution rainfall. Hydrol. Sci. J. 140806131733005. doi:10.1080/02626667.2014.925558

For **disaggregation by adjusting procedures** the user is referenced to:

- Koutsoyiannis, D., A stochastic disaggregation method for design storms and flood synthesis, Journal of Hydrology, 156, 193-225, 1994.
- Koutsoyiannis, D., and A. Manetas, Simple disaggregation by accurate adjusting procedures, Water Resources Research, 32(7), 2105-2117, 1996.
- Koutsoyiannis, D., Coupling stochastic models of different time scales, Water Resources Research, 37(2), 379-391, 2001.
- Koutsoyiannis, D., Rainfall Disaggregation Methods: Theory and Applications, Workshop on Statistical and Mathematical Methods for Hydrological Analysis, Rome, 2003.

Find older versions of Hyetos at <http://itia.ntua.gr/en/softinfo/3/>

## See Also

[SequentialSimul](#), [DisagSimul](#)

## Examples

```
# Example 1: Disaggregate daily rainfall depths into hourly,
# using the the original Bartlett-Lewis model
# The original hourly series is generated by the model

# To disaggregate the daily rainfall depths of first 5 clusters of wet days use
ex11 <- DisagSimul.test(Length=100,TimeScale=1,BLpar=list(lambda=0.19104,phi=0.06620544,
kappa=0.3529412,alpha=150,v=40.8,mx=71.6544,sxm=1),
CellIntensityProp=list(Weibull=FALSE,iota=NA),RepetOpt=list(DistAllowed=0.1,
FacLevel1Rep=20,MinLevel1Rep=50,TotalRepAllowed=5000),NumOfSequences=5,
Statistics=list(print=TRUE,plot=FALSE),ExportSynthData=list(exp=FALSE,FileContent=c("AllDays"),
file="BLts.txt",DaysPerSeason=31),ImportHistData=list(imp=FALSE,file="heathrow1a.txt",
na.values="NA",FileContent=c("WetDays"),DailyValues=TRUE,DaysPerSeason=31,ImpDataTimeScale=1),
PlotHyetographs=FALSE,RandSeed=5)

# Example 2: Disaggregate historical daily rainfall depths
# into hourly, with the random parameter
# Bartlett-Lewis model, with cell intensities
# from gamma distribution
# The original (daily and hourly) data is imported
# from the "HistHourlyData2.txt" file
# The synthetic hourly depths are exported to "DisagHistHourlyData2.txt" file

# To load the data set "HistHourlyData2" use
data(HistHourlyData2)

# To export the daily and hourly rainfall depths of "HistHourlyData2" data
#in the chosen working directory use
write.table(HistHourlyData2,file="HistHourlyData2.txt",sep="\t",
quote=FALSE,row.names=FALSE,col.names=FALSE)

# To disaggregate the daily rainfall depths of first 5 clusters of wet days use
ex12 <- DisagSimul.test(Length=100,TimeScale=1,BLpar=list(lambda=0.45967,phi=0.03946,
kappa=0.1479426,alpha=3.9529358,v=0.014187,mx=158.109,sxm=55.6506/158.109),
CellIntensityProp=list(Weibull=FALSE,iota=NA),RepetOpt=list(DistAllowed=0.1,
FacLevel1Rep=20,MinLevel1Rep=50,TotalRepAllowed=5000),NumOfSequences=5,
Statistics=list(print=TRUE,plot=FALSE),ExportSynthData=list(exp=TRUE,
FileContent=c("AllDays"),file="DisagHistHourlyData2.txt",DaysPerSeason=30),
ImportHistData=list(imp=TRUE,file="HistHourlyData2.txt",na.values="NA",FileContent=c("AllDays"),
DailyValues=TRUE,DaysPerSeason=30,ImpDataTimeScale=1),PlotHyetographs=FALSE,RandSeed=5)

# Example 3: Disaggregate daily rainfall depths into 5-min intervals,
# with the random parameter Bartlett-Lewis model, with cell intensities
# from gamma distribution
# The original 5-min series is generated by the model
# The daily data is produced via aggregation of the original 5-min data
# Disaggregated 5-min data is exported to "SynthRPBLGM.txt" file

# To disaggregate the daily rainfall depths of first 5 clusters of wet days use
ex13 <- DisagSimul.test(Length=100,TimeScale=1/12,BLpar=list(lambda=0.024*24,phi=0.040,
kappa=0.173,alpha=2,v=0.1855804/24,mx=NA,sxm=1),CellIntensityProp=list(Weibull=FALSE,
iota=0.879),RepetOpt=list(DistAllowed=0.1,FacLevel1Rep=20,MinLevel1Rep=50,TotalRepAllowed=5000),
```

```

NumOfSequences=5,Statistics=list(print=TRUE,plot=FALSE),
ExportSynthData=list(exp=TRUE,FileContent=c("AllDays"),file="Disag10minData.txt",DaysPerSeason=31),
ImportHistData=list(imp=FALSE,file="data.txt",na.values="NA",FileContent=c("AllDays"),
DailyValues=TRUE,DaysPerSeason=31,ImpDataTimeScale=1/12),PlotHyetographs=FALSE,RandSeed=5)

# Example 4: Disaggregate daily rainfall depths into 5-min intervals,
# with the random parameter Bartlett-Lewis model, with cell intensities
# from gamma distribution
# The original 5-min series is imported from "Hist5minData.txt" file

# Disaggregated 5-min data is exported to "Hist5minData_Disag.txt" file

# To load the data set "HistHourlyData2" use
data(Hist5minData)

# To export the daily and hourly rainfall depths of "HistHourlyData2" data
#in the chosen working directory use
write.table(Hist5minData,file="Hist5minData.txt",sep="\t",
quote=FALSE,row.names=FALSE,col.names=FALSE)

# To disaggregate the daily rainfall depths of first 5 clusters of wet days use
ex14 <- DisagSimul.test(Length=100,TimeScale=1/12,BLpar=list(lambda=0.024*24,phi=0.040,
kappa=0.173,alpha=2,v=0.1855804/24,mx=NA,sxmx=1),CellIntensityProp=list(Weibull=FALSE,
iota=0.879),RepetOpt=list(DistAllowed=0.1,FacLevel1Rep=20,MinLevel1Rep=50,TotalRepAllowed=5000),
NumOfSequences=5,Statistics=list(print=TRUE,plot=FALSE),
ExportSynthData=list(exp=TRUE,FileContent=c("AllDays"),file="Hist5minData_Disag.txt",
DaysPerSeason=31),ImportHistData=list(imp=TRUE,file="Hist5minData.txt",
na.values="NA",FileContent=c("AllDays"),DailyValues=TRUE,DaysPerSeason=31,
ImpDataTimeScale=1/12),PlotHyetographs=FALSE,RandSeed=5)

```

## Description

An enhanced version of the evolutionary annealing-simplex optimization method for the estimation of Bartlett-Lewis model parameters.

## Usage

```
eas(n,m,xmin,xmax,xlow,xup,fn,maxeval=1500,ftol=1.e-07,ratio=0.99,pmut=0.9,
beta=2,maxclimbs=5,...)
```

## Arguments

n	An integer that specifies the problem dimension (number of control variables).
m	A positive integer, greater than n, that specifies the population size ( $m \geq n + 1$ ).
xmin	A vector, with length equal to n, that defines the interior lower parameter bounds (feasible space of initial population).
xmax	A vector, with length equal to n, that defines the interior upper parameter bounds (feasible space of initial population).

xlow	A vector, with length equal to n, that defines the exterior lower parameter bounds.
xup	A vector, with length equal to n, that defines the exterior upper parameter bounds.
fn	Objective function that is to be optimized. A vector function that takes a real vector as argument and returns the value of the function at that point.
maxeval	A positive integer that specifies the maximum number of function evaluations. Default is maxeval=1500. Suggested value is maxeval>100*n.
ftol	A positive number that specifies the fractional convergence tolerance to be achieved in the function value. Default is ftol=1.e-07.
ratio	A positive number, typically between 0.80-0.99, that specifies the fraction of temperature reduction, when a local minimum is found. Default is ratio=0.99.
pmut	A positive number, between 0.5-0.95, that specifies the probability of accepting an offspring generated via mutation. Default is pmut=0.9. Higher values are suggested for very hard problems, when it is essential to increase randomness.
beta	A positive integer, greater than 1, that specifies the annealing schedule parameter. Default is beta=2.
maxclimbs	A positive integer, typically between 3-5, that specifies the maximum number of uphill steps. Default is maxclimbs=5.
...	Further arguments to be passed in the objective function.

## Details

The evalutionary annealing-simplex algorithm (2002), for solving global optimisation problems have been proposed by Efstratiadis and Koutsoyiannis (2002). The evalutionary annealing-simplex algorithm (eas) is a probabilistic heuristic global optimization technique, combining the robustness of simulated annealing in rough response surface, with the efficiency of hill-climbing methods in convex areas.

During one generation, the population evolves as follows: First, a simplex-based pattern is formulated, using random sampling. Next, a candidate individual is selected to die, according to a modified objective function of the form:

$$g(\mathbf{x}) = f(\mathbf{x}) + uT$$

where  $f$  is the original objective function,  $T$  is the current “temperature” and  $u$  is a random number from the uniform distribution. The temperature is gradually reduced, according to an appropriate annealing cooling schedule, automatically adapted during the evolution. Consequently, the probability of replacing individuals with poor performance increases, since the procedure gradually moves from a random walk to a local search.

The recombination operator is based on the well-known downhill simplex transitions (Nelder and Mead, 1965). According to the relatives values of the objective function at the vertices, the simplex is reflected, expanded, contracted or shrinks, where quasi-stochastic scale factors are employed instead of constant ones. To ensure more flexibility, additional transformations are introduced, namely multiple expansion towards the direction of reflection, when a downhill path (i.e., the gradient of the function) is located, and similar expansions but on the opposite (uphill) direction, in order to escape from the nearest local minimum. If any of the above transitions improves the function value, the new individual is generated through nutation. The related oerator employs a random perturbation scheme outside of the usual range of the population, as determined on the basis of the average and standard deviation values of its coordinates.

R adaption, with some modifications, by Panagiotis Kossieris and Hristos Tyralis, from the original Pascal-Delphi code by Andreas Efstratiadis (2007).

In the current version, the calculation of the reflection point is changed, and the simplex is not reflected toward the direction of the geometrical centroid but towards a weighted centroid, where

the weights are assigned on the basis of the objective function value. This allows for a more accurate estimator of the gradient, which ensures a much more efficient search in multidimensional feasible spaces.

For more details, the reader may refer either to the original work of Efstratiadis (2001) and Efstratiadis and Koutsoyiannis (2002), or to the tutorial style introduction of **HyetosR** package.

### Value

A list with the following components:

bestpar	A vector containing the best set of parameters found.
bestval	The value of fn corresponding to bestpar.
nfeval	Number of function fn evaluations.
niter	Number of iterations taken by algorithm.
ftolpop	Fractional convergence tolerance of population generated at the last iteration.
pop	The population generated at the last iteration.

### Author(s)

Kossieris Panagiotis <pankoss@hotmail.com>, with Hristos Tyralis <montchrister@gmail.com> and Andreas Efstratiadis <A.Efstratiadis@itia.ntua.gr>.

### References

The methodology of **the evolutionary annealing-simplex optimization method** and details of its application are described in:

- Efstratiadis, A., and D. Koutsoyiannis, An evolutionary annealing-simplex algorithm for global optimisation of water resource systems, Proceedings of the Fifth International Conference on Hydroinformatics, Cardiff, UK, 1423-1428, International Water Association, 2002. (<http://itia.ntua.gr/en/docinfo/524/>)
- Rozos, E., A. Efstratiadis, I. Nalbantis, and D. Koutsoyiannis, Calibration of a semi-distributed model for conjunctive simulation of surface and groundwater flows, Hydrological Sciences Journal, 49 (5), 819-842, 2004. (<http://itia.ntua.gr/en/docinfo/630/>)

Find the original Pascal-Delphi code of optimisation algorithms on <http://itia.ntua.gr/en/docinfo/524/>.

### Examples

```
# Historical statistics
mean1=0.1226;var1 = 0.6323;cov1lag1 = 0.3271;pdr1 = 0.9183
mean6=0.7358;var6 = 10.1490;cov6lag1 = 4.0773;pdr6 = 0.8251
mean12 = 1.4705;var12 = 29.357;cov12lag1 =7.6865;pdr12 = 0.7476
mean24 = 2.9410;var24 = 76.667;cov24lag1 =10.2886;pdr24 = 0.6238

### Fitting the Original Bartlett-Lewis model (with constant parameter n) ###

# Define the objective function that will be used in model fitting:

fopt <- function(x,Weibull) {
  l<-x[1];g<-x[2];b<-x[3];n<-x[4];mx<-x[5];sxmx<-x[6]
```

```
w1=1;w2=1;w3=1;w4=1
S1 <- w1*((meanBLRPM(1,g,b,n,mx,h=1)/mean1)-1)^2+
  w2*((varBLRPM(1,g,b,n,mx,sxmx,h=1,Weibull)/var1)-1)^2+
  w3*((covarBLRPM(1,g,b,n,mx,sxmx,h=1,lag=1,Weibull)/cov1lag1)-1)^2+
  w4*((pdrBLRPM(1,g,b,n,h=1)/pdr1)-1)^2
S6 <- w1*((meanBLRPM(1,g,b,n,mx,h=6)/mean6)-1)^2+
  w2*((varBLRPM(1,g,b,n,mx,sxmx,h=6,Weibull)/var6)-1)^2+
  w3*((covarBLRPM(1,g,b,n,mx,sxmx,h=6,lag=1,Weibull)/cov6lag1)-1)^2+
  w4*((pdrBLRPM(1,g,b,n,h=6)/pdr6)-1)^2
S12 <- w1*((meanBLRPM(1,g,b,n,mx,h=12)/mean12)-1)^2+
  w2*((varBLRPM(1,g,b,n,mx,sxmx,h=12,Weibull)/var12)-1)^2+
  w3*((covarBLRPM(1,g,b,n,mx,sxmx,h=12,lag=1,Weibull)/cov12lag1)-1)^2+
  w4*((pdrBLRPM(1,g,b,n,h=12)/pdr12)-1)^2
S24 <- w1*((meanBLRPM(1,g,b,n,mx,h=24)/mean24)-1)^2+
  w2*((varBLRPM(1,g,b,n,mx,sxmx,h=24,Weibull)/var24)-1)^2+
  w3*((covarBLRPM(1,g,b,n,mx,sxmx,h=24,lag=1,Weibull)/cov24lag1)-1)^2+
  w4*((pdrBLRPM(1,g,b,n,h=24)/pdr24)-1)^2
S<-S1+S6+S12+S24
if(is.infinite(S)) {S<-10^8}
if(is.na(S)) {S<-10^8}
return(S)
}

# In the case of EXPONENTIAL distribution for cell intensity,
# set upper and lower bound of sxmx (last element) equal to 1
xlow<-c(0.001,0.0001,0.001,0.001,0.001,1)
xup<-c(0.1,5,5,5,5,1)

# In the case of GAMMA or WEIBULL distribution for cell intensity:
xlow<-c(0.001,0.0001,0.001,0.001,0.001,1)
xup<-c(0.1,5,5,5,5,5)

# Fitting the model with evalutionary annealing-simplex method
# EXPONENTIAL or GAMMA distribution for cell intensities
modecal<-eas(n=6,m=30,xmin=xlow,xmax=xup,xlow=xlow,xup=xup,fn=fopt,maxeval=1500,ftol=1.e-07,
             ratio=0.99,pmut=0.9,beta=2,maxclimbs=5,Weibull=FALSE)

# WEIBULL distribution for cell intensities
modecal<-eas(n=6,m=30,xmin=xlow,xmax=xup,xlow=xlow,xup=xup,fn=fopt,maxeval=1500,ftol=1.e-07,
             ratio=0.99,pmut=0.9,beta=2,maxclimbs=5,Weibull=TRUE)

l<-modecal$bestpar[1];g<-modecal$bestpar[2];b<-modecal$bestpar[3]
n<-modecal$bestpar[4];mx<-modecal$bestpar[5];sxmx<-modecal$bestpar[6]

# To use the optimised set of parameters in the functions of HyetosMinute
# please be sure that for parameters mx the length units are millimeters (mm)
# and for parameters l, g, b, n, and mx the time units are days (d).
# Due to this, the following unit conversions (hourly to daily) are needed:

l<-l*24;g<-g*24;b<-b*24;n<-n*24
mx<-mx*24;sxmx<-sxmx

# The parameter set used in HyetosMinute functions will be

BLpar=list(lambda=l,phi=g/n,kappa=b/n,alpha=150,v=n,mx=mx,sxmx=sxmx)
# To implement Weibull distribution set: CellIntensityProp=list(Weibull=TRUE,iota=NA)
```

```

# To implement Exponential or Gamma distribution set: CellIntensityProp=list(Weibull=FALSE,iota=NA)

### Fitting the Random Bartlett-Lewis model (with varying parameter n) ###

# Define the objective function that will be used in model fitting:

fopt <- function(x,Weibull) {

  a<-x[1];l<-x[2];v<-x[3];k<-x[4];f<-x[5];mx<-x[6];sxmx<-x[7]

  w1=1;w2=1;w3=1;w4=1

  S1 <- w1*((meanRPBLRPM(a,l,v,k,f,mx,h=1)/mean1)-1)^2+
    w2*((varRPBLRPM(a,l,v,k,f,mx,sxmx,h=1,Weibull)/var1)-1)^2+
    w3*((covarRPBLRPM(a,l,v,k,f,mx,sxmx,h=1,Weibull,lag=1)/cov1lag1)-1)^2+
    w4*((pdrRPBLRPM(a,l,v,k,f,h=1)/pdr1)-1)^2
  S6 <- w1*((meanRPBLRPM(a,l,v,k,f,mx,h=6)/mean6)-1)^2+
    w2*((varRPBLRPM(a,l,v,k,f,mx,sxmx,h=6,Weibull)/var6)-1)^2+
    w3*((covarRPBLRPM(a,l,v,k,f,mx,sxmx,h=6,Weibull,lag=1)/cov6lag1)-1)^2+
    w4*((pdrRPBLRPM(a,l,v,k,f,h=6)/pdr6)-1)^2
  S12 <- w1*((meanRPBLRPM(a,l,v,k,f,mx,h=12)/mean12)-1)^2+
    w2*((varRPBLRPM(a,l,v,k,f,mx,sxmx,h=12,Weibull)/var12)-1)^2+
    w3*((covarRPBLRPM(a,l,v,k,f,mx,sxmx,h=12,Weibull,lag=1)/cov12lag1)-1)^2+
    w4*((pdrRPBLRPM(a,l,v,k,f,h=12)/pdr12)-1)^2
  S24 <- w1*((meanRPBLRPM(a,l,v,k,f,mx,h=24)/mean24)-1)^2+
    w2*((varRPBLRPM(a,l,v,k,f,mx,sxmx,h=24,Weibull)/var24)-1)^2+
    w3*((covarRPBLRPM(a,l,v,k,f,mx,sxmx,h=24,Weibull,lag=1)/cov24lag1)-1)^2+
    w4*((pdrRPBLRPM(a,l,v,k,f,h=24)/pdr24)-1)^2
  S<-S1
  # +S6+S12+S24
  if(is.infinite(S)) {S<-10^8}
  if(is.na(S)) {S<-10^8}
  return(S)
}

# In the case of EXPONENTIAL distribution for cell intensity,
# set upper and lower bound of sxmx (last element) equal to 1
xlow <- c(1.0001,0.001,0.001,0.001,0.001,0.001,1)
xup <- c(15,0.1,20,20,1,50,1)
# In the case of GAMMA or WEIBULL distribution for cell intensity:
xlow <- c(1.0001,0.001,0.001,0.001,0.001,0.001,1)
xup <- c(15,0.1,20,20,1,50,5)

## Fitting the model with evalutionary annealing-simplex method
# EXPONENTIAL or GAMMA distribution for cell intensities
modecal<-eas(n=7,m=30,xmin=xlow,xmax=xup,xlow=xlow,xup=xup,fn=fopt,maxeval=1500,ftol=1.e-07,
              ratio=0.99,pmut=0.9,beta=2,maxclimbs=5,Weibull=FALSE)

# WEIBULL distribution for cell intensities
modecal<-eas(n=7,m=30,xmin=xlow,xmax=xup,xlow=xlow,xup=xup,fn=fopt,maxeval=1500,ftol=1.e-07,
              ratio=0.99,pmut=0.9,beta=2,maxclimbs=5,Weibull=TRUE)

a<-modecal$bestpar[1];l<-modecal$bestpar[2];v<-modecal$bestpar[3]
k<-modecal$bestpar[4];f<-modecal$bestpar[5];mx<-modecal$bestpar[6]
sxmx<-modecal$bestpar[7]

```

```

# To use the optimised set of parameters in the functions of HyetosMinute
# please be sure that for parameters mx the length units are millimeters (mm)
# and for parameters l, v, and mx the time units are days (d).
# Due to this, the following unit conversions (hourly to daily) are needed:

l<-l*24;v<-v/24;mx<-mx*24

# The parameter set used in HyetosMinute functions will be

BLpar=list(lambda=l,phi=f,kappa=k,alpha=a,v=v,mx=mx,sxmx=sxmx)
# To implement Weibull distribution set: CellIntensityProp=list(Weibull=TRUE,iota=NA)
# To implement Exponential or Gamma distribution set: CellIntensityProp=list(Weibull=FALSE,iota=NA)

### Random Bartlett-Lewis model with dependent cell intensity-duration ###

## Historical statistics
mean5min=0.0073 ;var5min=0.00137;cov5minlag1=0.00108; pdr5min=0.89333
mean1=0.08738 ;var1=0.11229;cov1lag1=0.0662;pdr1=0.82894
mean6=0.52145 ;var6=2.05341 ;cov6lag1=0.81562;pdr6=0.67014
mean12=1.0414 ;var12=5.79845;cov12lag1=1.92132;pdr12=0.55893
mean24=2.07883;var24=15.00291;cov24lag1=4.93788;pdr24=0.42905

## Define the objective function that will be used in model fitting:

fopt <- function(x,Weibull) {

  a<-x[1];l<-x[2];v<-x[3];k<-x[4];f<-x[5];i<-x[6];sxmx<-x[7]

  w1=1;w2=1;w3=1;w4=1
  S5min <- w1*((meanBLRPRX(l,k,f,i,h=5/60)/mean5min)-1)^2+
    w2*((varBLRPRX(a,l,v,k,f,i,sxmx,h=5/60,Weibull)/var5min)-1)^2+
    w3*((covarBLRPRX(a,l,v,k,f,i,sxmx,h=5/60,Weibull,lag=1)/cov5minlag1)-1)^2+
    w4*((pdrBLRPRX(a,l,v,k,f,h=5/60)/pdr5min)-1)^2
  S1h <- w1*((meanBLRPRX(l,k,f,i,h=1)/mean1)-1)^2+
    w2*((varBLRPRX(a,l,v,k,f,i,sxmx,h=1,Weibull)/var1)-1)^2+
    w3*((covarBLRPRX(a,l,v,k,f,i,sxmx,h=1,Weibull,lag=1)/cov1lag1)-1)^2+
    w4*((pdrBLRPRX(a,l,v,k,f,h=1)/pdr1)-1)^2
  S6h <- w1*((meanBLRPRX(l,k,f,i,h=6)/mean6)-1)^2+
    w2*((varBLRPRX(a,l,v,k,f,i,sxmx,h=6,Weibull)/var6)-1)^2+
    w3*((covarBLRPRX(a,l,v,k,f,i,sxmx,h=6,Weibull,lag=1)/cov6lag1)-1)^2+
    w4*((pdrBLRPRX(a,l,v,k,f,h=6)/pdr6)-1)^2
  S12h <- w1*((meanBLRPRX(l,k,f,i,h=12)/mean12)-1)^2+
    w2*((varBLRPRX(a,l,v,k,f,i,sxmx,h=12,Weibull)/var12)-1)^2+
    w3*((covarBLRPRX(a,l,v,k,f,i,sxmx,h=12,Weibull,lag=1)/cov12lag1)-1)^2+
    w4*((pdrBLRPRX(a,l,v,k,f,h=12)/pdr12)-1)^2
  S24h <- w1*((meanBLRPRX(l,k,f,i,h=24)/mean24)-1)^2+
    w2*((varBLRPRX(a,l,v,k,f,i,sxmx,h=24,Weibull)/var24)-1)^2+
    w3*((covarBLRPRX(a,l,v,k,f,i,sxmx,h=24,Weibull,lag=1)/cov24lag1)-1)^2+
    w4*((pdrBLRPRX(a,l,v,k,f,h=24)/pdr24)-1)^2
  S<-S5min+S1h+S24h
  if(is.infinite(S)) {S<-10^8}
  if(is.na(S)) {S<-10^8}
  return(S)
}

# In the case of EXPONENTIAL distribution for cell intensity,

```

```

# set upper and lower bound of sxmx (last element) equal to 1
xlow<-c(2.0001,0.0001,0.001,0.001,0.001,0.001,1)
xup<-c(20,20,20,20,20,1,1)
# In the case of GAMMA or WEIBULL distribution for cell intensity:
xlow<-c(2.0001,0.0001,0.001,0.001,0.001,0.001,1)
xup<-c(20,20,20,20,20,1,5)

## Fitting the model with evalutionary annealing-simplex method

# Exponential or Gamma distribution for cell intensities
modecal<-eas(n=7,m=30,xmin=xlow,xmax=xup,xlow=xlow,xup=xup,fn=fopt,maxeval=1500,ftol=1.e-07,
              ratio=0.99,pmut=0.9,beta=2,maxclimbs=5,Weibull=FALSE)
# Weibull distribution for cell intensities
modecal<-eas(n=7,m=30,xmin=xlow,xmax=xup,xlow=xlow,xup=xup,fn=fopt,maxeval=1500,ftol=1.e-07,
              ratio=0.99,pmut=0.9,beta=2,maxclimbs=5,Weibull=TRUE)

a<-modecal$bestpar[1];l<-modecal$bestpar[2];v<-modecal$bestpar[3]
k<-modecal$bestpar[4];f<-modecal$bestpar[5];i<-modecal$bestpar[6]
sxmx<-modecal$bestpar[7]

# To use the optimised set of parameters in the functions of HyetosMinute
# please be sure that for parameters mx the length units are millimeters (mm)
# and for parameters l and v the time units are days (d).
# Due to this, the following unit conversions (hourly to daily) are needed:

l<-l*24;v<-v/24;

# The parameter set used in HyetosMinute functions will be

BLpar=list(lambda=l,phi=f,kappa=k,alpha=a,v=v,rx=NA,sxmx=sxmx)
# To implement Weibull distribution set: CellIntensityProp=list(Weibull=TRUE,iota=i)
# To implement Exponential or Gamma distribution set: CellIntensityProp=list(Weibull=FALSE,iota=i)

```

## Description

This function enables the generation of synthetic rainfall series via the Bartlett-Lewis rectangular pulse model without performing any disaggregation.

## Usage

```
SequentialSimul(Length=1000,BLpar=list(lambda,phi,kappa,alpha,v,rx,sxmx),
CellIntensityProp=list(Weibull=FALSE,iota=NA),
TimeScale=1,Statistics=list(print=TRUE,plot=TRUE),
ImportHistData=list(imp=FALSE,file="histdata.txt",ImpDataTimeScale=1,
FileContent=c("WetDays","AllDays"),DailyValues=TRUE,DaysPerSeason=31,na.values="NA"),
ExportSynthData=list(exp=FALSE,file="SynthData.txt",
FileContent=c("WetDays","AllDays"),DaysPerSeason=31),PlotTs=FALSE,RandSeed=NULL)
```

## Arguments

Length	A positive integer that specifies the length of time series. For argument Length the units are days (d). The default value is 1000 days. See Examples.
BLpar	List of parameters of the Bartlett-Lewis model. See Details for further information.
CellIntensityProp	List of arguments that specifies the distribution of cell intensity. See Details for further information.
TimeScale	A positive number that specifies the time scale of the time series. Please make sure that for the argument TimeScale the units are hours (h). It defaults to 1 that means that hourly rainfall depths are generated. For sub-hourly time scales, use subdivisions of 1 hour. For instance, use 1/60 for 1 minute time scale, 1/30 for 2 minute, 1/6 for 10 minute etc. See Examples for further information.
Statistics	A list of logical variables (TRUE/FALSE) indicating whether the matrix of the historical, synthetic and theoretical statistics of rainfall should be printed or plotted. If print=TRUE (the default) the matrix of the statistics is printed and if plot=TRUE (the default) the statistics are also plotted. See Details for further information.
ImportHistData	A list of parameters that specifies the import of historical rainfall depths from an input file. See Details for important special features of ImportHistData parameters.
ExportSynthData	A list of parameters specifying the export of synthetic rainfall depths to an output file. See Details for important special features of ExportSynthData parameters.
PlotTs	A logical variable (TRUE/FALSE) indicating whether the synthetic time series should be plotted. Default is PlotTs=TRUE.
RandSeed	An integer value for the random number generator. If it equals to NULL, then a random seed is not inserted.

## Details

The function SequentialSimul enables the generation of synthetic rainfall time series via the Bartlett-Lewis rectangular pulse model with the given parameters, **without performing any disaggregation**. This function is appropriate for testing (e.g., by comparing simulated, theoretical and historical (if available) statistics) the model performance including the appropriateness of the Bartlett-Lewis model and its parameters. The statistics and the simulated time series can be either printed or displayed graphically. Additionally, the simulated time series can be exported to an output file.

### Bartlett-Lewis model description

Argument BLpar is a list that specifies **the Bartlett-Lewis rectangular pulse model parameters**. The general assumptions of the Bartlett-Lewis rectangular pulse model (Rodriguez-Iturbe et al., 1987, 1988) are:

1. Storm origins  $t_i$  occur following a Poisson process with rate  $\lambda$  (argument lambda).
2. Cell origins  $t_{ij}$  occur following a Poisson process with rate  $\beta$ .
3. Cell arrivals terminate after a time  $v_i$  exponentially distributed with parameter  $\gamma$ .
4. Each cell has a duration  $w_{ij}$  exponentially distributed with parameter  $\eta$ .
5. Each cell has a uniform intensity  $X_{ij}$  with a specified distribution.

In the original version of the model (Bartlett-Lewis Rectangular Pulse Model), the parameters associated with cells are assumed constant among different storms.

In the modified version (random parameter Bartlett-Lewis model), the parameter  $\eta$  is randomly varied from storm to storm according to a gamma distribution with shape parameter  $\alpha$  (argument `alpha`) and scale parameter  $\nu$  (argument `v`). Subsequently, parameters  $\beta$  and  $\gamma$  also vary so that the ratios  $\kappa = \beta/\eta$  (argument `kappa`) and  $\phi = \gamma/\eta$  (argument `phi`) are constant.

**HyetosMinute** package implements also the Random Parameter Bartlett-Lewis Rectangular Pulse Model with dependent intensity-duration (Kaczmarzka et al., 2014) that allows  $\mu_x$  to vary in proportion to the cell duration parameter,  $\eta$ , so as the ratio  $\iota = \mu_x/\eta$  (argument `iota`) is kept constant.

The distribution of the cell intensity  $X_{ij}$  is typically assumed exponential with mean  $\mu_x$ . Alternatively, it can be assumed two-parameter gamma distribution with mean  $\mu_x$  and standard deviation  $\sigma_x$ . The package also supports Weibull distribution for cell intensity with mean  $\mu_x$  and shape parameter.

Thus, in its most simplified version the model uses five parameters, namely  $\lambda$ ,  $\beta$ ,  $\gamma$ ,  $\eta$  and  $\mu_x$  (or equivalently  $\lambda$ ,  $\kappa$ ,  $\phi$ ,  $\eta$  and  $\mu_x$ ) and in its most enriched version seven parameters, namely  $\lambda$ ,  $\kappa$ ,  $\phi$ ,  $\alpha$ ,  $\nu$ ,  $\mu_x$ ,  $\sigma_x$ .

Normally, one parameter set corresponds to one month but it can be also correspond to a season of e.g. three months or even the whole year.

**HyetosMinute** package supports both the original and the random model version with exponential, gamma or Weibull intensities. By default, the random model is assumed. To implement the original model version with constant parameter  $\eta$ , set argument `alpha` greater than 100 and insert the value of parameter  $\eta$  in argument `v`.

To implement the random model with with dependent intensity-duration, set the value of ratio  $\iota = \mu_x/\eta$  in argument `iota`.

To implement exponential or gamma distribution for cell intensity then set argument `Weibull` in `CellIntensityProp` list as FALSE. To implement the exponential distribution set mean  $\mu_x$  in argument `mx` and the ratio  $\mu_x/\sigma_x$  (argument `sxm`) equals to 1. If the argument `sxm` is not equal to 1 then the gamma distribution is assumed with a specific ratio `sxm`.

To implement Weibull distribution, then set argument `weibTF` equal to TRUE. In this case, the intensity follows the Weibull distribution with mean  $\mu_x$  (argument `mx`) and shape parameter (put in argument `sxm`).

In the case of random model with with dependent intensity-duration and exponential distribution, set the value of ratio  $\iota = \mu_x/\eta$  in argument `iota`, argument `mx` as NA and argument `sxm` equals to 1. To implement gamma distribution, set argument `mx` as NA and specify the ratio  $\mu_x/\sigma_x$  (argument `sxm`). To implement Weibull distribution set argument `mx` as NA and specify the shape parameter in argument `sxm`.

**Please make sure that for parameters  $\mu_x$  and  $\sigma_x$  the length units are millimeters (mm) and for parameters  $\lambda$ ,  $\nu$ ,  $\mu_x$  and  $\sigma_x$  the time units are days (d).**

#### Read data from file

Argument `ImportHistData` is a list of parameters specifying the features of **input file** if original data is to be read from a file. This file must have a specific format (see examples).

**imp** A logical variable (TRUE/FALSE) that indicates if rainfall depths are to be read from an input file. If `imp=TRUE`, original data is imported from a file. Default is `imp=FALSE`.

**file** A character string that specifies the name of the file or connection of the rainfall data. The input files are text files with the ".txt" extension (e.g. `file="histdata.txt"`).

**ImpDataTimeScale** The time scale of rainfall data to be imported. It defaults to 1 that means that hourly rainfall data is imported. For sub-hourly time scales, use subdivisions of hour. For instance 1/60 for 1 minute data, 1/30 for 2 minute data, 1/6 for 10 minute data etc.

**FileContent** A character string indicating if dry days (with zero rainfall depths) are also contained in the input file. If FileContent=c("WetDays") the input file contains only the rainfall depths of wet days. If FileContent=c("AllDays") the input file contains the rainfall depths of wet and dry days. Default is DailyValues=c("WetDays").

**DailyValues** A logical variable (TRUE/FALSE) that specifies if the daily rainfall depths are contained in the input file. If DailyValues=FALSE, the imported rainfall depths are aggregated into daily scale. Default is DailyValues=TRUE.

**DaysPerSeason** A positive integer, typically 30 or 31, that specifies the number of days of the month or season of the input data. Default is DaysPerSeason=31.

**na.values** A character vector of strings which are to be interpreted as NA values. Default is na.values="NA".

#### The input file must not contain any header lines or the Bartlett-Lewis model parameters.

In the input file, each row contains the data of a single day. The three first columns of the input file determine the dates of the data. The first column corresponds to the "Day", the second column corresponds to the "Month" and the third column corresponds to the "Year". The fourth column contains "the daily values (mm)", if available (DailyValues=TRUE). The rest columns contain the rainfall depths.

The "Year" field in the input file does not necessarily correspond to a real year. Thus, the sequence of years could be 1, 2, ..., or 49, 50, ..., instead of 1949, 1950, ... .

The "Day" and "Month" fields in the input file do not necessarily correspond to a real month. A "Month" can well be a season containing e.g. three months or even the whole year. In the latter case the number of days of month should be set to 366 and the "Day" field should be the Julian number of the date.

#### Write synthetic data to file

Argument ExportSynthData is a list of parameters that specifies the features of **output file** if synthetic data is to be exported to a text file. The output file has similar structure as the input file, without any header line.

**exp** A logical variable (TRUE/FALSE) that indicates whether synthetic rainfall depths is to be written to an output file. If exp=TRUE, synthetic data is exported to a text file. Default is exp=FALSE.

**file** A character string that specifies the name of the file or connection to which the rainfall data are to be exported. The output files are text files with the ".txt" extension (e.g. file="SynthData.txt").

**FileContent** A character string indicating if dry days (with zero rainfall depths) will be also written in the output file. If FileContent=c("WetDays") the output file will contain only the rainfall depths of wet days. If FileContent=c("AllDays") the output file will contain the rainfall depths of wet and dry days. Default is DailyValues=c("WetDays").

**DaysPerSeason** A positive integer, typically 30 or 31, that specifies the number of days of the month or season of the output data. Default is DaysPerSeason=31.

Argument Statistics is a list of logical variables (TRUE/FALSE) that indicates whether the matrix of the main historical (if applicable), synthetic and theoretical **statistics** is to be printed or plotted. The statistics are computed and printed if print=TRUE. Additionally, if plot=TRUE bar plots and auto-correlation function plots are produced on screen devices in order to compare the historical (if applicable), synthetic and theoretical statistics.

**The examples below and the used parameters are indicative. Subsequently, new parameters for the Bartlett-Lewis model should be estimated for other data-sets.**

### Value

A list with the following components:

- |             |   |
|-------------|---|
| Time series | Vector of synthetic rainfall depths.  |
| Statistics  | Matrix of the main synthetic as well as theoretical statistical characteristics, and optionally historical statistics if available ( <code>ImportHistData=TRUE</code> ). The statistics are printed if <code>print=TRUE</code> . See Details for further information. |

The statistics are plotted on screen devices if `plot` is TRUE. See Details for further information.

The generated rainfall depths are exported to a text file (i.e., ".txt" format), if `exp` is TRUE. See Details for further information.

The synthetic time series is plotted on screen device, if `PlotTs` is TRUE. It is worth noting that for sub-hourly time scales this process is time-consuming.

### Author(s)

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### References

For the **Bartlett-Lewis rectangular pulse model** the user is referenced to:

- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, Some models for rainfall based on stochastic point processes, Proc. R. Soc. Lond., A 410, 269-288, 1987.
- Rodriguez-Iturbe I., D. R. Cox, and V. Isham, A point process model for rainfall: Further developments, Proc. R. Soc. Lond., A 417, 283-298, 1988.
- Onof, C. and H. S. Wheater, Modelling of British rainfall using a Random Parameter Bartlett-Lewis Rectangular Pulse Model, Journal of Hydrology, 149, 67-95, 1993.
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- Kaczmarska, J., Isham, V., Onof, C., 2014. Point process models for fine-resolution rainfall. Hydrol. Sci. J. 140806131733005. doi:10.1080/02626667.2014.925558

### See Also

[DisagSimul](#), [DisagSimul.test](#)

### Examples

```
# Example 1: Generate hourly rainfall series
# for 100 days, using the original
# Bartlett-Lewis model (without historical data imported)
# Hourly data are exported to "SynthBLRPM.txt" file

ex1 <- SequentialSimul(Length=100,BLpar=list(lambda=0.19104,phi=0.06620544,kappa=0.3529412,
alpha=150,v=40.8,mx=71.6544,sxm=1),CellIntensityProp=list(Weibull=FALSE,iota=NA),
TimeScale=1,ExportSynthData=list(exp=TRUE,FileContent=c("AllDays"),DaysPerSeason=31,
file="SynthBLRPM.txt"),ImportHistData=list(imp=FALSE,file="data.txt",
```

```

ImpDateTimeScale=1,na.values="NA",FileContent=c("WetDays"),DaysPerSeason=31,DailyValues=TRUE),
PlotTs=FALSE,Statistics=list(print=TRUE,plot=FALSE),RandSeed=5)

# Example 2: Generate hourly rainfall series
# for 100 days, using the random parameter
# Bartlett-Lewis model
# Hourly data is imported from "HistHourlyData.txt" file
# Hourly data is exported to "SynthRPBLM.txt" file

# To load the data set "HistHourlyData" use
data(HistHourlyData)

# To export the daily and hourly rainfall depths of
# "HistHourlyData" data in the chosen working directory use
write.table(HistHourlyData,file="HistHourlyData.txt",sep="\t",
            quote=FALSE,row.names=FALSE,col.names=FALSE)

# To generate synthetic rainfall series using the random parameter Bartlett-Lewis model
# (compared them to historical data) use

ex2 <- SequentialSimul(Length=100,BLpar=list(lambda=0.9396,phi=0.0568,kappa=1.05819,
alpha=2.69519,v=0.006283,mx=24.33408,sxmx=1),CellIntensityProp=list(Weibull=FALSE,
iota=NA),TimeScale=1,ExportSynthData=list(exp=TRUE,FileContent=c("AllDays"),DaysPerSeason=31,
file="SynthRPBLM.txt"),ImportHistData=list(imp=TRUE,file="HistHourlyData.txt",
ImpDateTimeScale=1,na.values="NA",FileContent=c("AllDays"),DaysPerSeason=31,DailyValues=TRUE),
PlotTs=FALSE,Statistics=list(print=TRUE,plot=FALSE),RandSeed=5 )



# Example 3: Generate 100 daily rainfall depths,
# with the random parameter Bartlett-Lewis model,
# with cell intensities from Gama distribution
# Hourly data is imported from "HistHourlyData2.txt" file
# The daily data is produced via aggregation of the hourly
# Daily data is exported to "SynthRPBLGM.txt" file

# To load the data set "HistHourlyData2" use
data(HistHourlyData2)

# To export the daily and hourly rainfall depths of
# "HistHourlyData2" data in the chosen working directory use
write.table(HistHourlyData2,file="HistHourlyData2.txt",sep="\t",
            quote=FALSE,row.names=FALSE,col.names=FALSE)

# To generate synthetic rainfall series using the random parameter Bartlett-Lewis gamma model
# (compared them to historical data) use

ex3 <- SequentialSimul(Length=100,BLpar=list(lambda=0.4596792,phi=0.0394698,
kappa=0.1479426,alpha=3.9529358,v=0.0141872,mx=158.1091152,sxmx=55.6506624/158.1091152),
CellIntensityProp=list(Weibull=FALSE,iota=NA),TimeScale=24,ExportSynthData=list(exp=TRUE,
FileContent=c("AllDays"),DaysPerSeason=30,file="SynthRPBLGM.txt"),
ImportHistData=list(imp=TRUE,file="HistHourlyData2.txt",
ImpDateTimeScale=1,na.values="NA",FileContent=c("AllDays"),
DaysPerSeason=30,DailyValues=TRUE),PlotTs=FALSE,
Statistics=list(print=TRUE,plot=FALSE),RandSeed=5)

# Example 4: Generate 10-min rainfall depths
# for 100 days, with the random parameter

```

```
# Bartlett-Lewis model, with dependent intensity-duration
# 10-min data is exported to "SynthRPBLMD.txt" file

ex4 <- SequentialSimul(Length=100,BLpar=list(lambda=0.528,phi=0.042,kappa=0.996,
alpha=2.075,v=0.01724338,mx=NA,sxmx=1),
CellIntensityProp=list(Weibull=FALSE,iota=0.164),
TimeScale=1/6,ExportSynthData=list(exp=TRUE,FileContent=c("AllDays"),
DaysPerSeason=31,file="SynthRPBLMD.txt"),ImportHistData=list(imp=FALSE,
file="data.txt",ImpDataTimeScale=6,na.values="NA",FileContent=c("WetDays"),
DaysPerSeason=31,DailyValues=TRUE),PlotTs=FALSE,Statistics=list(print=TRUE,plot=FALSE),RandSeed=5)
```

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