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Supplement of

Hydrograph separation: an impartial parametrisation for an imperfect method

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Package 'baseflow'

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Type Package

Title Computes Hydrograph Separation

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Depends R (>= 3.0.3)

Imports methods, graphics, airGR

Description Computes hydrograph separation using the conceptual automated process from Pelletier and Andreassian (2019) <doi:10.5194/hess-2019-503>. Contains scalar and vectorized functions to compute correlation criterion to calibrate the baseflow separation model.

License GPL-2

SystemRequirements cargo (>= 1.36.0), rustc, GNU make

Collate REXPORT.R BasinData.R BaseflowFilter.R Criteria.R

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R topics documented:

`BaseflowFilter` *Constructor function of class* `BaseflowFilter`

Description

Standard construction function of `BaseflowFilter` objects, used by package `baseflow` to store filtering information for a given catchment. The object is created with NA values of baseflow and level of filtering reservoir, it is then necessary to run `perform_filtering` function to compute them.

Usage

```
BaseflowFilter(BasinData, alpha, updateFunction = "quadr")
```

Arguments

`BasinData`	A `BasinData` object containing hydroclimatic data for the catchment under study.
`alpha`	Numeric parameter of the filtering reservoir. Its dimension depends on the used update function.
`updateFunction`	Character string giving reservoir function : must be one of `"quadr"`, `"lin"` or `"exp"`. Defalut is `"quadr"`.

Value

A `BaseflowFilter` object containing provided data. Baseflow numeric field `R` and reservoir level `V` are filled with `NA`, it is thus necessary to call `perform_filtering` function to compute `R` and `V`.

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

BasinData

BaseflowFilter

BasinData

perform_filtering

Examples

```
library(baseflow)

# Loading example data from airGR package
data(L0123001, package = 'airGR')

# Defining BasinData object

Name <- BasinInfo$BasinName
startDate <- BasinObs$DatesR[1]
endDate <- BasinObs$DatesR[length(BasinObs$DatesR)]
P <- BasinObs$P
PET <- BasinObs$E
Qobs <- BasinObs$Qmm

BasinData_Example <- BasinData(Name, startDate, endDate, P, PET, Qobs, fill = "GR4J")

# Creating BaseflowFilter object
BaseflowFilter_Example <- BaseflowFilter(BasinData_Example, 1000, updateFunction = 'quadr')

# Computing baseflow
BaseflowFilter_Example <- perform_filtering(BaseflowFilter_Example)

# Plotting computed separation
plot(BaseflowFilter_Example)
```

BaseflowFilter-class *Class* BaseflowFilter

Description

Class used by package *baseflow* to store results of a baseflow filtering for a given catchment.

Objects from the Class

Objects can be created by calls of the form `new("BaseflowFilter",...)`, but it is recommended to use `BaseflowFilter` function to create this object.

Slots

`BasinData`: Object of class `"BasinData"` giving hydroclimatic data of catchment (see BasinData-class).

`R`: Vector of class `"numeric"` giving filtered baseflow.

`V`: Vector of class `"numeric"` giving storage of the conceptual reservoir.

`update`: Vector of class `"logical"`, `TRUE` at timesteps in which reservoir's level is updated, `FALSE` otherwise.

`updateFunction`: Object of class `"character"` equal to `"quadr"`, `"lin"` or `"exp"`, giving the nature of the conceptual reservoir.

`alpha`: Object of class `"numeric"` : value of `"alpha"` reservoir parameter.

Methods

as.data.frame `signature(x = "BaseflowFilter")`: transforms object into dataframe.

plot `signature(x = "BaseflowFilter")`: plots baseflow separation on the hydrograph.

print `signature(x = "BaseflowFilter")`: prints object to console.

show `signature(object = "BaseflowFilter")`: shows object in console.

summary `signature(object = "BaseflowFilter")`: shows a summary of the object.

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

`BaseflowFilter`

`perform_filtering`

`BasinData`

Examples

```
showClass("BaseflowFilter")
```

BasinData *Constructor function of class* BasinData

Description

Standard construction function of BasinData objects, used by package baseflow to store daily hydroclimatic data for a given catchment. As the separation algorithm proposed in baseflow does not handle missing streamflow values, a filling routine using airGR package is provided.

Usage

```
BasinData(Name, startDate, endDate, P, PET, Qobs, fill = "none")
```

Arguments

Name	Character string giving the name of the catchment. Can be a code or a plain-text description.
startDate	Starting date of hydroclimatic data as a POSIXct object.
endDate	End date of hydroclimatic data as a POSIXct object.
P	Numeric vector giving daily total lumped precipitation over the catchment, in mm. Must be of the same length as PET and Qobs.
PET	Numeric vector giving daily total lumped potential evapotranspiration over the catchment, in mm. Must be of the same length as P and Qobs.
Qobs	Numeric vector giving daily streamflow of the catchment, as depth of runoff in mm. Must be of the same length as PET and Qobs.
fill	Character string describing filling methods. Must be one of the following : "none" (no filling, default), "GR4J", "GR5J" or "GR6J".

Details

The expected length of data vectors is equal to the number of days between the two provided dates. It is recommended to store data into a data frame before using this function. This function does not handle missing values : any NA will produce an error. If there are missing values in streamflow, the fill argument must be different from "none". Filling routine requires airGR package. One of the following hydrological lumped models can be used : GR4J, GR5J or GR6J. See airGR documentation for further details.

Value

A BasinData object containing provided data.

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

BasinData

BaseflowFilter

BaseflowFilter

Examples

```
library(baseflow)

# Loading example data from airGR package
data(L0123001, package = 'airGR')

# Defining BasinData object

Name <- BasinInfo$BasinName
startDate <- BasinObs$DatesR[1]
endDate <- BasinObs$DatesR[length(BasinObs$DatesR)]
P <- BasinObs$P
PET <- BasinObs$E
Qobs <- BasinObs$Qmm

BasinData_Example <- BasinData(Name, startDate, endDate, P, PET, Qobs, fill = "GR4J")
```

BasinData-class *Class* BasinData

Description

Class used by package *baseflow* to store hydroclimatic data from a given catchment.

Objects from the Class

Objects can be created by calls of the form `new("BasinData", ...)`, but it is recommended to use `BasinData` function to create this object.

Slots

`Name`: Object of class `"character"` giving the name of the catchment (e.g. '`Seine in Paris`'

`Dates`: Vector of `"POSIXct"` dates giving timestamps of measures

`nbTimeStep`: Object of class `"integer"` giving the number of measures

`P`: Vector of total precipitation of length '`nbTimeStep`'

`PET`: Vector of potential evapotranspiration of length '`nbTimeStep`'

`Qobs`: Vector of observed streamflow of length '`nbTimeStep`'

Methods

as.data.frame `signature(x = "BasinData")`: transforms object into a data frame.

print `signature(x = "BasinData")`: prints object to console

show `signature(object = "BasinData")`: shows object

summary `signature(object = "BasinData")`: show a summary of object

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

`BasinData`

`BaseflowFilter`

Examples

```
showClass("BasinData")
```

---

bfi *Baseflow index computing function*

Description

Function provided by package `baseflow` to compute baseflow index from a `BaseflowFilter` object.

Usage

```
bfi(filter)
```

Arguments

`filter`	A `BaseflowFilter` object created by `BaseflowFilter` function.

Details

Computes baseflow index from a `BaseflowFilter` object, created by `BaseflowFilter` function. If the baseflow values have not been computed yet in the object, a Rust routine is called to compute baseflow ; else, baseflow is computed directly from baseflow and observed streamflow values. Providing a non-`BaseflowFilter` object creates an error.

Value

A numeric giving computed baseflow index.

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

BaseflowFilter

BaseflowFilter

perform_filtering

Examples

```
library(baseflow)

# Loading example data from airGR package
data(L0123001, package = 'airGR')

# Defining BasinData object

Name <- BasinInfo$BasinName
startDate <- BasinObs$DatesR[1]
endDate <- BasinObs$DatesR[length(BasinObs$DatesR)]
P <- BasinObs$P
PET <- BasinObs$E
Qobs <- BasinObs$Qmm

BasinData_Example <- BasinData(Name, startDate, endDate, P, PET, Qobs, fill = "GR4J")

# Creating BaseflowFilter object
BaseflowFilter_Example <- BaseflowFilter(BasinData_Example, 1000, updateFunction = 'quadr')

# Computing baseflow
BaseflowFilter_Example <- perform_filtering(BaseflowFilter_Example)

# Plotting computed separation
plot(BaseflowFilter_Example)

# Computing baseflow index
bfi(BaseflowFilter_Example)
```

corr_crit *Baseflow correlation criterion computation*

Description

Computation function of correlation criterion used by package `baseflow` to calibrate parameters of the baseflow separation algorithm. A vectorized version of this function `correlation_criteria_vectorized` also exists.

Usage

```
corr_crit(BasinData, alpha, tau, updateFunction = "quadr")
```

Arguments

`BasinData`	A `BasinData` object containing hydroclimatic data for the catchment under study.
`alpha`	Numeric parameter of the filtering reservoir. Its dimension depends on the used update function. Must be positive.
`tau`	Number of days used to compute cumulative effective rainfall. Must be a positive integer or any object that can be coerced to a positive integer.
`updateFunction`	Character string giving reservoir function : must be one of `"quadr"`, `"lin"` or `"exp"`. Default is `"quadr"`.

Details

NA values are not permitted for parameters `alpha` and `tau`. If a vector is supplied, the first element is used.

Usage of gradient-based optimization algorithms is not recommended to find the maximum value of this criterion. It is a better option to use vectorized function `correlation_criteria_vectorized` to perform a grid-search; a non-gradient-based optimization algorithm, like differential evolution, may be used to refine the optimal point afterwards.

Value

A numeric value of the computed criterion, between -1 and 1.

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

perform_filtering

BaseflowFilter

corr_crit_vect

bfi

Examples

```
library(baseflow)

# Loading example data from airGR package
data(L0123001, package = 'airGR')

# Defining BasinData object

Name <- BasinInfo$BasinName
startDate <- BasinObs$DatesR[1]
endDate <- BasinObs$DatesR[length(BasinObs$DatesR)]
P <- BasinObs$P
PET <- BasinObs$E
Qobs <- BasinObs$Qmm

BasinData_Example <- BasinData(Name, startDate, endDate, P, PET, Qobs, fill = "GR4J")

# Computing correlation criterion
corr_crit(BasinData_Example, 1500, 110, updateFunction = "quadr")
```

---

corr_crit_vect *Baseflow vectorized correlation criteria computation*

Description

Vectorized computation function of correlation criteria used by package `baseflow` to calibrate parameters of the baseflow separation algorithm. A scalar version of this function `correlation_criteria` also exists.

Usage

```
corr_crit_vect(BasinData, alphas, taus, updateFunction = "quadr")
```

Arguments

`BasinData`	A `BasinData` object containing hydroclimatic data for the catchment under study.
`alphas`	Numeric vector of parameters of the filtering reservoir. Their dimension depends on the used update function. They must be positive.

taus	Vector of numbers of days used to compute cumulative effective rainfall. Must be an integer vector or any object that can be coerced to an integer vector. All values must be positive.
updateFunction	Character string giving reservoir function : must be one of "quadr", "lin" or "exp". Default is "quadr".

Details

Providing empty vectors or vectors containing missing or non-positive values for parameters alphas and taus throws an error.

Value

A dataframe containing four columns and length(alphas) * length(taus) rows. Colums are the following:

alpha	Values of alpha
tau	Values of tau
bfi	Values of baseflow index, which depends on alpha
crit	Computed values of correlation criterion

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

perform_filtering

BaseflowFilter

corr_crit

bfi

Examples

```
library(baseflow)

# Loading example data from airGR package
data(L0123001, package = 'airGR')

# Defining BasinData object

Name <- BasinInfo$BasinName
startDate <- BasinObs$DatesR[1]
```

```
endDate <- BasinObs$DatesR[length(BasinObs$DatesR)]
P <- BasinObs$P
PET <- BasinObs$E
Qobs <- BasinObs$Qmm

BasinData_Example <- BasinData(Name, startDate, endDate, P, PET, Qobs, fill = "GR4J")

# Computing correlation criteria
data_crit <- corr_crit_vect(BasinData_Example,
                            alphas = seq(from = 100, to = 2000, by = 100),
                            taus = seq(from = 10, to = 370, by = 10),
                            updateFunction = "quadr")
```

`perform_filtering` *Baseflow filtering function*

Description

Function provided by package `baseflow` to compute baseflow variables from a raw `BaseflowFilter` object. It must be called after calling the `BaseflowFilter` function.

Usage

```
perform_filtering(filter)
```

Arguments

`filter`	A `BaseflowFilter` object created by `BaseflowFilter` function.

Details

Providing a non-`BaseflowFilter` object creates an error. The function calls a Rust routine to compute vectors `R` (baseflow) and `V` (reservoir level) from parameters and hydroclimatic data stored in `filter` object.

Value

A `BaseflowFilter` object with the same parameters and `BasinData` slots as input, but `R`, `V` and `update` slots are replaced by computed values.

Author(s)

Pelletier and Andreassian (<antoine.pelletier@irstea.fr>)

References

Pelletier, A. and Andréassian, V.: Hydrograph separation: an impartial parametrization for an imperfect method, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-503, in review, 2019

See Also

BaseflowFilter

BaseflowFilter

bfi

Examples

```
library(baseflow)

# Loading example data from airGR package
data(L0123001, package = 'airGR')

# Defining BasinData object

Name <- BasinInfo$BasinName
startDate <- BasinObs$DatesR[1]
endDate <- BasinObs$DatesR[length(BasinObs$DatesR)]
P <- BasinObs$P
PET <- BasinObs$E
Qobs <- BasinObs$Qmm

BasinData_Example <- BasinData(Name, startDate, endDate, P, PET, Qobs, fill = "GR4J")

# Creating BaseflowFilter object
BaseflowFilter_Example <- BaseflowFilter(BasinData_Example, 1000, updateFunction = 'quadr')

# Computing baseflow
BaseflowFilter_Example <- perform_filtering(BaseflowFilter_Example)

# Plotting computed separation
plot(BaseflowFilter_Example)
```

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