

Package ‘HydroPortailStats’

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Type Package

Title 'HydroPortail' Statistical Functions

Version 1.1.0

Description

Statistical functions used in the French 'HydroPortail' <<https://hydro.eaufrance.fr/>>.

This includes functions to estimate distributions, quantile curves and uncertainties, along with various other utilities.

Technical details are available (in French) in Renard (2016) <<https://hal.inrae.fr/hal-02605318>>.

License GPL-3

Encoding UTF-8

LazyData true

URL <https://github.com/benRenard/HydroPortailStats>

BugReports <https://github.com/benRenard/HydroPortailStats/issues>

Depends R (>= 3.5.0)

Imports stats, graphics, evd, mvtnorm, numDeriv

RoxygenNote 7.2.3

Suggests knitr, rmarkdown

NeedsCompilation no

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Contents

distInfo	2
Generate	3
GenerateWithinBounds	4
GetCdf	4
GetEmpFreq	5
GetEstimate_BAY	6
GetEstimate_HBay	7
GetEstimate_HYDRO2	9
GetEstimate_LMOM	10
GetEstimate_ML	11
GetEstimate_MOM	12
GetEstimate_ROUGH	13
GetParFeas	14
GetParName	14
GetParNumber	15
GetPdf	15
GetQfromT	16
GetQuantile	17
GetReducedVariate	17
GetTfromQ	18
GetUncertainty_ML	19
HBay_Plot	20
Hydro3_Estimation	21
Hydro3_HBay	23
Hydro3_Plot	26
Import_HBayConfig	27
KS	28
mcmoptions_def	29
Metropolis_OAAT	29
Metropolis_OAAT_adaptive	30
Metropolis_OAAT_jump	31
MK	32
options_def	33
Pettitt	33
Index	34

distInfo

Information on available distributions

Description

A named list containing information (parameters, constraints, notes, warnings, etc.) for all available univariate distributions.

Usage

distInfo

Format

A named list where each element is itself a list containing:

parName parameters short names

parLongName parameters long names

parSymbol parameters typical symbols

constraints constraints on parameters

url link to more information

note notes

warning warnings: read carefully since this highlights in particular differences with "standard" parameterizations found in e.g. Wikipedia or R.

Generate

Random numbers generator

Description

Generate random realizations from a distribution

Usage

```
Generate(dist, par, n = 1)
```

Arguments

dist	character, distribution name
par	numeric vector, parameter vector
n	integer, number of values to generate

Value

The generated values as a numeric vector.

Examples

```
Generate('Normal', c(0,1), 10)
Generate('GEV', c(100, 25, -0.2), 10)
Generate('GEV', c(100, 25, 0.2), 10)
Generate('Poisson', 0.75, 10)
```

GenerateWithinBounds *Constrained random numbers generator*

Description

Generate random realizations from a distribution, constraining these realizations to stay within bounds.

Usage

```
GenerateWithinBounds(dist, par, n = 1, lowerBound = -Inf, higherBound = Inf)
```

Arguments

dist	character, distribution name
par	numeric vector, parameter vector
n	integer, number of values to generate
lowerBound	Numeric, lower bound
higherBound	Numeric, higher bound, should be strictly larger than the lower bound

Value

The generated values as a numeric vector.

Examples

```
set.seed(123456)
y0=GenerateWithinBounds(dist='GEV',par=c(0,1,-0.2),n=1000)
y1=GenerateWithinBounds(dist='GEV',par=c(0,1,-0.2),n=1000,lowerBound=0,higherBound=5)
plot(y0);points(y1,col='red')
```

GetCdf *Cumulative Distribution Function (cdf)*

Description

Evaluates the cdf of a distribution

Usage

```
GetCdf(y, dist, par)
```

Arguments

y	numeric, value at which the cdf is evaluated
dist	character, distribution name
par	numeric vector, parameter vector

Value

The cdf as a numeric.

Examples

```
GetCdf(0, 'Normal', c(0, 1))
GetCdf(200, 'GEV', c(100, 25, -0.2))
GetCdf(200, 'GEV', c(100, 25, 0.2))
GetCdf(3, 'Poisson', 0.75)
```

GetEmpFreq	<i>Empirical nonexceedance frequency</i>
------------	--

Description

Computes the empirical nonexceedance frequency of the *i*th sorted value amongst *n*

Usage

```
GetEmpFreq(i, n, formula = "Hazen")
```

Arguments

i	integer or integer vector, observation rank(s)
n	integer, number of observations
formula	character, formula, available: 'Hazen', 'Standard', 'MinusOne', 'Weibull', 'Bernard', 'Cunnane', 'Beard', 'Blom', 'Gringorten', 'Landwehr', 'Tukey'.

Value

The nonexceedance frequency.

Examples

```
GetEmpFreq(i=1:10, n=10)
GetEmpFreq(i=1:10, n=10, formula='Standard')
GetEmpFreq(i=1:10, n=10, formula='MinusOne')
GetEmpFreq(i=1:10, n=10, formula='Cunnane')
```

GetEstimate_BAY *Bayesian estimation of a distribution*

Description

Returns MCMC samples from the posterior distribution.

Usage

```
GetEstimate_BAY(
  y,
  dist,
  prior,
  par0,
  mult = 0.1,
  eps = 0.1,
  batch.length = 100,
  batch.n = 100,
  moverate.min = 0.1,
  moverate.max = 0.5,
  mult.down = 0.9,
  mult.up = 1.1
)
```

Arguments

y	numeric vector, data
dist	character, distribution name
prior	list of lists, prior distributions. For each parameter to be estimated, the prior is a list of the form <code>pr=list(dist=..., par=...)</code> . See example below.
par0	numeric vector, initial parameter guess. You may use <code>GetEstimate_ROUGH()</code> .
mult	numeric, initial jump standard deviations are set to <code>mult * abs(par0)</code>
eps	numeric, where <code>par0</code> is zero, initial jump standard deviations are set to <code>eps</code> (to avoid jumps of size zero)
batch.length	integer, MCMC parameter: length of each non-adaptive batch
batch.n	integer, MCMC parameter: number of batches (= adaptation period). Total number of simulations is <code>nsim=batch.n*batch.length</code>
moverate.min	numeric in (0;1), MCMC parameter: lower bound for the desired move rate interval
moverate.max	numeric in (0;1), MCMC parameter: upper bound for the desired move rate interval
mult.down	numeric in (0;1), MCMC parameter: multiplication factor used to decrease jump size when move rate is too low.
mult.up	numeric (>1, avoid 1/mult.down), MCMC parameter: multiplication factor used to increase jump size when move rate is too high.

Value

A list with the following components:

x numeric matrix $n_{\text{sim}} \times \text{length}(\text{par0})$, MCMC simulations
fx numeric vector, corresponding values $f(x)$

Examples

```
y=c(9.2,9.5,11.4,9.5,9.4,9.6,10.5,11.1,10.5,10.4)
prior1=list(dist='FlatPrior',par=NULL)
prior2=list(dist='LogNormal',par=c(1,1))
prior3=list(dist='Normal',par=c(0,0.25))
prior=list(prior1,prior2,prior3)
par0=GetEstimate_ROUGH(y,'GEV')$par
mcmc=GetEstimate_BAY(y,'GEV',prior,par0,batch.length=50,batch.n=50)
graphicalpar=par(mfrow=c(2,3))
plot(mcmc$x[,1],type='l'); plot(mcmc$x[,2],type='l'); plot(mcmc$x[,3],type='l')
hist(mcmc$x[,1]); hist(mcmc$x[,2]); hist(mcmc$x[,3])
par(graphicalpar)
```

GetEstimate_HBay

Bayesian estimation using historical data

Description

Bayesian estimation of a GEV or Gumbel distribution based on a mixed sample containing point (i.e. perfectly known) or interval (i.e. known to be within bounds) data. Systematic errors induced by rating curve errors can also be accounted for. Returns MCMC samples from the posterior distribution.

Usage

```
GetEstimate_HBay(
  y,
  dist,
  prior,
  SysErrorIndex = rep(0, NROW(y)),
  SysErrorPrior = list(),
  par0 = GetEstimate_ROUGH(0.5 * (y[, 1] + y[, 2])[is.finite(y[, 1] + y[, 2])], dist)$par,
  SysError0 = rep(1, length(SysErrorPrior)),
  mult = 0.1,
  eps = 0.1,
  batch.length = 100,
  batch.n = 100,
  moverate.min = 0.1,
  moverate.max = 0.5,
  mult.down = 0.9,
  mult.up = 1.1
)
```

Arguments

<code>y</code>	numeric 2-column matrix, data. The first column gives the lower bound, the second column gives the upper bound. Where $y[i,1]=y[i,2]$, the value is assumed perfectly known (up to systematic errors, see below). Where $y[i,1]<y[i,2]$, the value is assumed to be in the interval $[y[i,1];y[i,2]]$ -Inf and +Inf are allowed for data being only right- or left-censored (i.e. values known to be smaller than or larger than some threshold).
<code>dist</code>	character, distribution name. Only distributions 'GEV' and 'Gumbel' are supported.
<code>prior</code>	list of lists, prior distributions. For each parameter to be estimated, the prior is a list of the form <code>pr=list(dist=..., par=...)</code> . See example below.
<code>SystErrorIndex</code>	integer vector, length <code>NROW(y)</code> . Index of systematic errors. Rows where <code>SystErrorIndex==k</code> are all affected by the same multiplicative error <code>gamma_k</code> , typically induced by the <code>k</code> th rating curve. <code>SystErrorIndex==0</code> means no systematic error. Should only contain integer values between 0 and <code>N_{systematic errors}</code> .
<code>SystErrorPrior</code>	list of lists, prior distribution for each systematic error. For instance for a systematic error in the range +/- 20%, you may use a Uniform between 0.8 and 1.2, or a triangular distribution with the same bounds and peak at 1.
<code>par0</code>	numeric vector, initial parameter guess.
<code>SystError0</code>	numeric vector, initial guess for systematic errors. Typically a vector of 1.
<code>mult</code>	numeric, initial jump standard deviations are set to <code>mult * abs(par0)</code>
<code>eps</code>	numeric, where <code>par0</code> is zero, initial jump standard deviations are set to <code>eps</code> (to avoid jumps of size zero)
<code>batch.length</code>	integer, MCMC parameter: length of each non-adaptive batch
<code>batch.n</code>	integer, MCMC parameter: number of batches (= adaptation period). Total number of simulations is <code>nsim=batch.n*batch.length</code>
<code>moverate.min</code>	numeric in (0;1), MCMC parameter: lower bound for the desired move rate interval
<code>moverate.max</code>	numeric in (0;1), MCMC parameter: upper bound for the desired move rate interval
<code>mult.down</code>	numeric in (0;1), MCMC parameter: multiplication factor used to decrease jump size when move rate is too low.
<code>mult.up</code>	numeric (>1, avoid <code>1/mult.down</code>), MCMC parameter: multiplication factor used to increase jump size when move rate is too high.

Value

A list with the following components:

<code>x</code>	numeric matrix <code>nsim * (length(par0)+length(SystError0))</code> , MCMC simulations
<code>fx</code>	numeric vector, corresponding values <code>f(x)</code>

Examples

```

set.seed(98765)
n=50;n_censored=30
y0=Generate('GEV',c(100,50,-0.2),n)
y=cbind(y0,y0)
# Mimics censoring between 0 and 300 for first n_censored years
y[1:n_censored,1][y0[1:n_censored]<300]=0
y[1:n_censored,2][y0[1:n_censored]<300]=300
plot(y[,1]);points(y[,2])
# Systematic errors
SysErrorIndex=c(rep(1,n_censored),rep(2,n-n_censored))
SysErrorPrior=list(list(dist="Triangle",par=c(1,0.7,1.3)),
                   list(dist="Triangle",par=c(1,0.95,1.05)))
# Priors on GEV parameters
prior=list(list(dist="FlatPrior",par=NULL),
           list(dist="FlatPrior",par=NULL),
           list(dist="Normal",par=c(0,0.25)))
# Go!
mcmc=GetEstimate_HBay(y=y,dist='GEV',prior=prior,
                     SysErrorIndex=SysErrorIndex,
                     SysErrorPrior=SysErrorPrior,
                     # The values below aim at making this example fast to run.
                     # In practice, it is recommended to use the default values
                     # (batch.length=100,batch.n=100) or larger.
                     batch.length=25,batch.n=20)
graphicalpar=par(mfrow=c(2,3))
for(i in 1:5){hist(mcmc$x[,i])}
par(graphicalpar)

```

GetEstimate_HYDRO2 *Hydro2 estimate of a distribution*

Description

Returns an estimate of a distribution as it was computed in the old HYDRO2 software. Only available for distributions 'Normal', 'LogNormal', and 'Gumbel'.

Usage

```
GetEstimate_HYDRO2(y, dist)
```

Arguments

y	numeric vector, data
dist	character, distribution name

Value

A list with the following components:

par	numeric vector, estimated parameter vector.
obj	numeric, objective fonction (NA for this estimate)
ok	logical, did computation succeed?
err	integer, error code (0 if ok)
message	error message

Examples

```
y=c(9.2,9.5,11.4,9.5,9.4,9.6,10.5,11.1,10.5,10.4)
GetEstimate_HYDRO2(y, 'Normal')
GetEstimate_HYDRO2(y, 'LogNormal')
GetEstimate_HYDRO2(y, 'Gumbel')
GetEstimate_HYDRO2(y, 'GEV')
GetEstimate_HYDRO2(y, 'Poisson')
```

GetEstimate_LMOM	<i>L-Moment estimate of a distribution</i>
------------------	--

Description

Returns an estimate of a distribution using the method of L-moments. Note that for some distributions, this is not strictly speaking the L-moment estimate: For LogNormal and LogPearsonIII, the L-moment estimate of log(data) is used.

Usage

```
GetEstimate_LMOM(y, dist)
```

Arguments

y	numeric vector, data
dist	character, distribution name

Value

A list with the following components:

par	numeric vector, estimated parameter vector.
obj	numeric, objective fonction (NA for this estimate)
ok	logical, did computation succeed?
err	integer, error code (0 if ok)
message	error message

Examples

```

y=c(9.2,9.5,11.4,9.5,9.4,9.6,10.5,11.1,10.5,10.4)
GetEstimate_LMOM(y,'Normal')
GetEstimate_LMOM(y,'LogNormal')
GetEstimate_LMOM(y,'Gumbel')
GetEstimate_LMOM(y,'GEV')
GetEstimate_LMOM(y,'Poisson')

```

GetEstimate_ML

Maximum-likelihood estimate of a distribution

Description

Returns an estimate of a distribution using the method of maximum likelihood.

Usage

```

GetEstimate_ML(
  y,
  dist,
  par0 = NULL,
  method = optim_method_def,
  lower = -Inf,
  upper = Inf
)

```

Arguments

y	numeric vector, data
dist	character, distribution name
par0	numeric vector, initial parameter guess. You may use GetEstimate_ROUGH().
method	character, method used to maximize likelihood, see ?optim
lower	numeric vector, lower bounds, see ?optim
upper	numeric vector, upper bounds, see ?optim

Value

A list with the following components:

par	numeric vector, estimated parameter vector.
obj	numeric, objective fonction (maximum log-likelihood)
ok	logical, did computation succeed?
err	integer, error code (0 if ok)
message	error message

Examples

```

y=c(9.2,9.5,11.4,9.5,9.4,9.6,10.5,11.1,10.5,10.4)
GetEstimate_ML(y, 'Normal')
GetEstimate_ML(y, 'LogNormal')
GetEstimate_ML(y, 'Gumbel')
GetEstimate_ML(y, 'Gumbel', par0=GetEstimate_ROUGH(y, 'Gumbel')$par)
GetEstimate_ML(y, 'GEV', par0=GetEstimate_ROUGH(y, 'GEV')$par)
GetEstimate_ML(y, 'Poisson')

```

GetEstimate_MOM	<i>Moment estimate of a distribution</i>
-----------------	--

Description

Returns an estimate of a distribution using the method of moments. Note that for some distributions, this is not strictly speaking the moment estimate. For LogPearsonIII for instance, the moment estimate of $\log(\text{data})$ is used. Also for GPD3, the threshold is estimated as $\min(\text{data})$.

Usage

```
GetEstimate_MOM(y, dist)
```

Arguments

y	numeric vector, data
dist	character, distribution name

Value

A list with the following components:

par	numeric vector, estimated parameter vector.
obj	numeric, objective fonction (NA for this estimate)
ok	logical, did computation succeed?
err	integer, error code (0 if ok)
message	error message

Examples

```

y=c(9.2,9.5,11.4,9.5,9.4,9.6,10.5,11.1,10.5,10.4)
GetEstimate_MOM(y, 'Normal')
GetEstimate_MOM(y, 'LogNormal')
GetEstimate_MOM(y, 'Gumbel')
GetEstimate_MOM(y, 'GEV')
GetEstimate_MOM(y, 'Poisson')

```

GetEstimate_ROUGH	<i>Rough estimate of a distribution</i>
-------------------	---

Description

Returns a rough first-guess estimate of a distribution. This estimate may be poor but it solely aims at being used as a starting point for more advanced estimation approaches (e.g. max-likelihood or Bayesian). It is therefore chosen as an easy-to-compute explicit formula, robust and error-proof.

Usage

```
GetEstimate_ROUGH(y, dist)
```

Arguments

y	numeric vector, data
dist	character, distribution name

Value

A list with the following components:

par	numeric vector, estimated parameter vector.
obj	numeric, objective fonction (NA for this estimate)
ok	logical, did computation succeed?
err	integer, error code (0 if ok)
message	error message

Examples

```
y=c(9.2,9.5,11.4,9.5,9.4,9.6,10.5,11.1,10.5,10.4)
GetEstimate_ROUGH(y,'Normal')
GetEstimate_ROUGH(y,'LogNormal')
GetEstimate_ROUGH(y,'Gumbel')
GetEstimate_ROUGH(y,'GEV')
GetEstimate_ROUGH(y,'Poisson')
```

GetParFeas	<i>Parameter feasibility</i>
------------	------------------------------

Description

Evaluates whether a parameter vector is feasible (for instance, are scale parameters >0 ?)

Usage

```
GetParFeas(dist, par)
```

Arguments

dist	character, distribution name
par	numeric vector, parameter vector

Value

A logical.

Examples

```
# Feasible
GetParFeas('Normal',c(0,1))
# Not feasible because second parameter (standard deviation) is negative
GetParFeas('Normal',c(0,-1))
```

GetParName	<i>Parameter names.</i>
------------	-------------------------

Description

Returns the names of the parameters of a distribution, in French (default) or English.

Usage

```
GetParName(dist, lang = "fr")
```

Arguments

dist	character, distribution name
lang	character, language ('en' or 'fr')

Value

A character vector.

Examples

```

GetParName('Normal')
GetParName('GEV')
GetParName('GEV', lang='en')

```

GetParNumber	<i>Number of parameters.</i>
--------------	------------------------------

Description

Returns the number of parameters of a distribution.

Usage

```
GetParNumber(dist)
```

Arguments

dist	character, distribution name
------	------------------------------

Value

An integer.

Examples

```

GetParNumber('Normal')
GetParNumber('GEV')

```

GetPdf	<i>Probability Density Function (pdf)</i>
--------	---

Description

Evaluates the pdf of a distribution

Usage

```
GetPdf(y, dist, par, log = FALSE)
```

Arguments

y	numeric, value at which the pdf is evaluated
dist	character, distribution name
par	numeric vector, parameter vector
log	logical, returns log-pdf if TRUE

Value

The pdf or the log-pdf as a numeric.

Examples

```
GetPdf(0, 'Normal', c(0,1))
GetPdf(200, 'GEV', c(100,25,-0.2))
GetPdf(200, 'GEV', c(100,25,0.2))
GetPdf(3, 'Poisson', 0.75)
```

 GetQfromT

Get quantile from return period

Description

Compute the T-quantile from the results of Hydro3_Estimation()

Usage

```
GetQfromT(RP, H3, options = options_def)
```

Arguments

RP	numeric, return period
H3	list, resulting from a call to Hydro3_Estimation()
options	list, see ?Hydro3_Estimation

Value

A list with the following components:

q	numeric, quantile
IC	numeric vector, uncertainty interval

Examples

```
y=stats::rnorm(50)
H3=Hydro3_Estimation(y, 'Normal')
GetQfromT(100,H3)
```

GetQuantile	<i>Quantile Function</i>
-------------	--------------------------

Description

Evaluates the quantiles of a distribution

Usage

```
GetQuantile(p, dist, par)
```

Arguments

p	numeric in (0;1), nonexceedance probability
dist	character, distribution name
par	numeric vector, parameter vector

Value

The p-quantile as a numeric.

Examples

```
GetQuantile(0.99, 'Normal', c(0,1))
GetQuantile(0.99, 'GEV', c(100,25,-0.2))
GetQuantile(0.99, 'GEV', c(100,25,0.2))
GetQuantile(0.99, 'Poisson', 0.75)
```

GetReducedVariate	<i>Reduced variate</i>
-------------------	------------------------

Description

Returns the 'reduced variate' that is used in some quantile plots (see e.g. quantile curve on Gumbel paper)

Usage

```
GetReducedVariate(p, dist)
```

Arguments

p	numeric in (0;1), nonexceedance probability
dist	character, distribution name

Value

The reduced variate with nonexceedance probability p .

Examples

```
GetReducedVariate(0.99, 'Normal')
GetReducedVariate(0.99, 'Gumbel')
GetReducedVariate(0.99, 'GEV')
GetReducedVariate(0.99, 'Poisson')
```

 GetTfromQ

Get return period from value

Description

Compute the return period associated with a value from the results of Hydro3_Estimation()

Usage

```
GetTfromQ(q, H3, options = options_def)
```

Arguments

q	numeric, value
H3	list, resulting from a call to Hydro3_Estimation()
options	list, see ?Hydro3_Estimation

Value

A list with the following components:

RP	numeric, return period
IC	numeric vector, uncertainty interval

Examples

```
y=rstats::rnorm(50)
H3=Hydro3_Estimation(y, 'Normal')
GetTfromQ(3, H3)
```

GetUncertainty_ML	<i>Maximum-likelihood estimation of uncertainty</i>
-------------------	---

Description

Returns an estimate of the uncertainty around the maximum-likelihood estimate, in the form of a covariance matrix and some simulations from the corresponding Gaussian distribution.

Usage

```
GetUncertainty_ML(y, dist, par, nsim = nsim_def)
```

Arguments

y	numeric vector, data
dist	character, distribution name
par	numeric vector, estimated parameter (using GetEstimate_ML()).
nsim	integer, number of simulated parameter replicates.

Value

A list with the following components:

cov	numeric matrix npar*npar, covariance matrix.
sim	numeric matrix nsim*npar, simulated parameter replicates.
ok	logical, did computation succeed?
err	integer, error code (0 if ok)
message	error message

Examples

```
y=c(9.2,9.5,11.4,9.5,9.4,9.6,10.5,11.1,10.5,10.4)
estim=GetEstimate_ML(y,'Gumbel',par0=GetEstimate_ROUGH(y,'Gumbel')$par)
GetUncertainty_ML(y,'Gumbel',par=estim$par)
```

HBay_Plot

*HBay plot***Description**

Plot summarizing the results of Hydro3_HBay()

Usage

```
HBay_Plot(H3, curve_color = "black")
```

Arguments

H3 list, resulting from a call to Hydro3_HBay()
 curve_color color, color used for quantile curve

Value

nothing (just creates a plot)

Examples

```
set.seed(98765)
n=50;n_censored=30
y0=Generate('GEV',c(100,50,-0.2),n)
y=cbind(y0,y0)
# Mimics censoring between 0 and 300 for first n_censored years
y[1:n_censored,1][y0[1:n_censored]<300]=0
y[1:n_censored,2][y0[1:n_censored]<300]=300
plot(y[,1]);points(y[,2])
# Systematic errors
SysErrorIndex=c(rep(1,n_censored),rep(2,n-n_censored))
SysErrorPrior=list(list(dist="Triangle",par=c(1,0.7,1.3)),
                   list(dist="Triangle",par=c(1,0.95,1.05)))
# Priors on GEV parameters
prior=list(list(dist="FlatPrior",par=NULL),
          list(dist="FlatPrior",par=NULL),
          list(dist="Normal",par=c(0,0.25)))
# Handle MCMC options
# The values below aim at making this example fast to run.
# In practice, it is recommended to use the default values
# (batch.length=100,batch.n=100) or larger.
mcmcoptions=mcmcoptions_def
mcmcoptions$batch.length=25
mcmcoptions$batch.n=20
# Go!
H3=Hydro3_HBay(y=y,dist='GEV',prior=prior,
              SysErrorIndex=SysErrorIndex,
              SysErrorPrior=SysErrorPrior,
```

```

                                mcmcoptions=mcmcoptions)
# HBay plot
HBay_Plot(H3)

```

Hydro3_Estimation *Hydro3 estimation*

Description

Main estimation function used in the HydroPortal. In short, this function estimates a distribution and the associated uncertainty, and returns all needed information to display and plot the results (parameter estimates, quantile curves, etc.)

Usage

```

Hydro3_Estimation(
  y,
  dist,
  Emeth = Emeth_def,
  Umeth = Umeth_def,
  options = options_def,
  mcmcoptions = mcmcoptions_def,
  prior = GetDefaultPrior(GetParNumber(dist)),
  do.KS = TRUE,
  do.MK = TRUE,
  do.Pettitt = TRUE
)

```

Arguments

<code>y</code>	numeric vector, data.
<code>dist</code>	character, distribution name. See dataset <code>distInfo</code> for a description of available distributions. In particular, type <code>names(distInfo)</code> for the list of available distributions, and <code>distInfo[['GEV']]</code> for more information on a particular distribution (here, GEV).
<code>Emeth</code>	character, estimation method. Default is 'LMOM' (L-Moments), available: 'MOM' (Moments), 'ML' (Maximum Likelihood), 'BAY' (Bayesian).
<code>Umeth</code>	character, uncertainty quantification method. Default is 'PBOOT' (Parametric bootstrap), available: 'BOOT' (Bootstrap, not recommended), 'NONE', 'ML' (only usable when <code>Emeth='ML'</code> as well), and 'BAY' (the only usable method when <code>Emeth='BAY'</code>).
<code>options</code>	list, options, see details below.
<code>mcmcoptions</code>	list, MCMC options, see details below.
<code>prior</code>	list, prior distributions, only used when <code>Emeth='BAY'</code> . See <code>?GetEstimate_BAY</code> for details.
<code>do.KS</code> , <code>do.MK</code> , <code>do.Pettitt</code>	logical, perform KS/MK/Pettitt tests?

Details

The argument 'options' allows controlling various properties of the analysis and results. It is a list with the following components:

- FreqFormula, character, formula for computing nonexceedance frequency, see ?GetEmpFreq.
- pgrid, numeric vector, probabilities defining the x values where pdf $f(x)$ and cdf $F(x)$ are computed. These x values are quantiles from the estimated distribution with probabilities pgrid.
- Tgrid, numeric vector, return periods where quantile function $q(T)$ is computed.
- IClevel, numeric, level of uncertainty interval.
- p2T, numeric, conversion factor between nonexceedance probability p and return period T . $p=1-1/(p2T*T)$. In general $p2T=1$ but for a peak-over-threshold approach leading to say 3 events per year on average, $p2T=3$.
- invertT, logical, when invertT=TRUE, LARGE return periods correspond to SMALL data values. This is typically used for low-flow statistics.
- splitZeros, logical, when splitZeros=TRUE zero and negative values are removed from the data y before estimating the distribution, and are used to estimate the probability of zeros p_0 . This is typically used for low-flow statistics to estimate the probability of zero streamflow.
- lang, character, language ('fr' or 'en').
- nsim, integer, number of replicated parameters representing uncertainty.

The argument 'mcmcoptions' is only used when Emeth='BAY' and is a list controlling MCMC properties:

- mult, numeric, see ?Metropolis_OAAT_adaptive
- eps, numeric, see ?Metropolis_OAAT_adaptive
- batch.length, integer, see ?Metropolis_OAAT_adaptive
- batch.n, integer, see ?Metropolis_OAAT_adaptive
- moverate.min, numeric, see ?Metropolis_OAAT_adaptive
- moverate.max, numeric, see ?Metropolis_OAAT_adaptive
- mult.down, numeric, see ?Metropolis_OAAT_adaptive
- mult.up, numeric, see ?Metropolis_OAAT_adaptive
- burn, numeric, burn-in factor, e.g. if burn=0.2 the first 20 percents of MCMC samples are discarded
- slim, integer, sliming factor, e.g. if slim=5 only one MCMC sample every 5 is kept (after burn-in)

Value

A list with the following components:

dist	character, estimated distribution.
ok	logical, did estimation succeed?
err	integer, error code (0 if ok).

message	error message.
empirical	data frame, sorted data and empirical estimates (nonexceedance frequency, return period and reduced variate)
pcdf	data frame, estimated pdf and cdf
quantile	data frame, estimated quantiles and uncertainty intervals
par	data frame, estimated parameters and uncertainty intervals
KS	list, result of the Kolmogorov-Smirnov test, see ?KS
MK	list, result of the Mann-Kendall test, see ?MK
Pettitt	list, result of the Pettitt test, see ?Pettitt
u	list, parameter uncertainty in the form of a covariance matrix (\$cov) and simulated parameter replicates (\$sim). Also contains error-handling flags \$ok, \$err and \$message.

Examples

```

y=stats::rnorm(50)
H3=Hydro3_Estimation(y,'Normal')
H3=Hydro3_Estimation(y,'GEV',Emeth='ML',Umeth='ML')

```

Hydro3_HBay

Bayesian estimation using historical data

Description

Bayesian estimation of a GEV or Gumbel distribution based on a mixed sample containing point (i.e. perfectly known) or interval (i.e. known to be within bounds) data. Systematic errors induced by rating curve errors can also be accounted for. Returns an Hydro3 object

Usage

```

Hydro3_HBay(
  y,
  dist,
  prior = GetDefaultPrior(GetParNumber(dist)),
  SystemErrorIndex = rep(0, NROW(y)),
  SystemErrorPrior = list(),
  options = options_def,
  mcmcoptions = mcmcoptions_def,
  do.KS = TRUE,
  do.MK = TRUE,
  do.Pettitt = TRUE
)

```

Arguments

<code>y</code>	numeric 2-column matrix, data. The first column gives the lower bound, the second column gives the upper bound. Where $y[i,1]=y[i,2]$, the value is assumed perfectly known (up to systematic errors, see below). Where $y[i,1]<y[i,2]$, the value is assumed to be in the interval $[y[i,1];y[i,2]]$ -Inf and +Inf are allowed for data being only right- or left-censored (i.e. values known to be smaller than or larger than some threshold).
<code>dist</code>	character, distribution name. Only distributions 'GEV' and 'Gumbel' are supported.
<code>prior</code>	list of lists, prior distributions. For each parameter to be estimated, the prior is a list of the form <code>pr=list(dist=..., par=...)</code> . See example below.
<code>SystErrorIndex</code>	integer vector, length <code>NROW(y)</code> . Index of systematic errors. Rows where <code>SystErrorIndex==k</code> are all affected by the same multiplicative error γ_k , typically induced by the k th rating curve. <code>SystErrorIndex==0</code> means no systematic error. Should only contain integer values between 0 and $N_{\text{systematic errors}}$.
<code>SystErrorPrior</code>	list of lists, prior distribution for each systematic error. For instance for a systematic error in the range $\pm 20\%$, you may use a Uniform between 0.8 and 1.2, or a triangular distribution with the same bounds and peak at 1.
<code>options</code>	list, options, see details below.
<code>mcmcoptions</code>	list, MCMC options, see details below.
<code>do.KS, do.MK, do.Pettitt</code>	logical, perform KS/MK/Pettitt tests?

Details

The argument 'options' allows controlling various properties of the analysis and results. It is a list with the following components:

- `FreqFormula`, character, formula for computing nonexceedance frequency, see `?GetEmpFreq`.
- `pgrid`, numeric vector, probabilities defining the x values where pdf $f(x)$ and cdf $F(x)$ are computed. These x values are quantiles from the estimated distribution with probabilities `pgrid`.
- `Tgrid`, numeric vector, return periods where quantile function $q(T)$ is computed.
- `IClevel`, numeric, level of uncertainty interval.
- `p2T`, numeric, conversion factor between nonexceedance probability p and return period T . $p=1-1/(p2T*T)$. Here $p2T=1$ in general since GEV/Gumbel are applied to annual maxima in general.
- `invertT`, logical, when `invertT=TRUE`, LARGE return periods correspond to SMALL data values. This is typically used for low-flow statistics. Unused here.
- `splitZeros`, logical, when `splitZeros=TRUE` zero and negative values are removed from the data `y` before estimating the distribution, and are used to estimate the probability of zeros p_0 . This is typically used for low-flow statistics to estimate the probability of zero streamflow. Unused here.
- `lang`, character, language ('fr' or 'en').

- nsim, integer, number of replicated parameters representing uncertainty. Unused here (derives from mcmc options)

The argument 'mcmcoptions' is a list controlling MCMC properties:

- mult, numeric, see ?Metropolis_OAAT_adaptive
- eps, numeric, see ?Metropolis_OAAT_adaptive
- batch.length, integer, see ?Metropolis_OAAT_adaptive
- batch.n, integer, see ?Metropolis_OAAT_adaptive
- moverate.min, numeric, see ?Metropolis_OAAT_adaptive
- moverate.max, numeric, see ?Metropolis_OAAT_adaptive
- mult.down, numeric, see ?Metropolis_OAAT_adaptive
- mult.up, numeric, see ?Metropolis_OAAT_adaptive
- burn, numeric, burn-in factor, e.g. if burn=0.2 the first 20 percents of MCMC samples are discarded
- slim, integer, sliming factor, e.g. if slim=5 only one MCMC sample every 5 is kept (after burn-in)

Value

A list with the following components:

dist	character, estimated distribution.
ok	logical, did estimation succeed?
err	integer, error code (0 if ok).
message	error message.
empirical	data frame, sorted data and empirical estimates (nonexceedance frequency, return period and reduced variate). NOTE: interval data are replaced by a value randomly sampled from a GEV constrained in this interval. See ?GenerateWithinBounds.
pcdf	data frame, estimated pdf and cdf
quantile	data frame, estimated quantiles and uncertainty intervals
par	data frame, estimated parameters and uncertainty intervals
KS	list, result of the Kolmogorov-Smirnov test, see ?KS. NOTE: interval data are replaced by a value randomly sampled from a GEV constrained in this interval. See ?HBay_simGEV.
MK	list, result of the Mann-Kendall test, see ?MK. Same note as KS test.
Pettitt	list, result of the Pettitt test, see ?Pettitt. Same note as KS test.
u	list, parameter uncertainty in the form of a covariance matrix (\$cov) and simulated parameter replicates (\$sim). Also contains error-handling flags \$ok, \$err and \$message.

Examples

```

set.seed(98765)
n=50;n_censored=30
y0=Generate('GEV',c(100,50,-0.2),n)
y=cbind(y0,y0)
# Mimics censoring between 0 and 300 for first n_censored years
y[1:n_censored,1][y0[1:n_censored]<300]=0
y[1:n_censored,2][y0[1:n_censored]<300]=300
plot(y[,1]);points(y[,2])
# Systematic errors
SysErrorIndex=c(rep(1,n_censored),rep(2,n-n_censored))
SysErrorPrior=list(list(dist="Triangle",par=c(1,0.7,1.3)),
                  list(dist="Triangle",par=c(1,0.95,1.05)))
# Priors on GEV parameters
prior=list(list(dist="FlatPrior",par=NULL),
          list(dist="FlatPrior",par=NULL),
          list(dist="Normal",par=c(0,0.25)))
# Handle MCMC options
# The values below aim at making this example fast to run.
# In practice, it is recommended to use the default values
# (batch.length=100,batch.n=100) or larger.
mcmcoptions=mcmcoptions_def
mcmcoptions$batch.length=25
mcmcoptions$batch.n=20
# Go!
H3=Hydro3_HBay(y=y,dist='GEV',prior=prior,
              SysErrorIndex=SysErrorIndex,
              SysErrorPrior=SysErrorPrior,
              mcmcoptions=mcmcoptions)
Hydro3_Plot(H3)

```

Hydro3_Plot

Hydro3 plot

Description

Plot summarizing the results of Hydro3_Estimation()

Usage

```

Hydro3_Plot(
  H3,
  useU = FALSE,
  lwd = 2,
  cex.lab = 2,
  cex.axis = 1.3,
  pch = 19,
  col = "red"
)

```

Arguments

H3	list, resulting from a call to Hydro3_Estimation()
useU	logical, use reduced variate u rather than return period T in plots?
lwd, cex.lab, cex.axis, pch	numeric, graphical parameters, see ?graphics::par
col	character, graphical parameter (points color)

Value

nothing (just creates a plot)

Examples

```
y=stats::rnorm(50)
H3=Hydro3_Estimation(y, 'Normal')
Hydro3_Plot(H3)
```

Import_HBayConfig *Import HBay Configuration folder*

Description

Imports configuration data as specified with HBay executable. Returns NULL if configuration folder is not found

Usage

```
Import_HBayConfig(path)
```

Arguments

path	character, path to configuration folder.
------	--

Value

A list with the following components (see ?Hydro3_HBay for details):

y	numeric matrix, data.
dist	character, distribution name.
prior	list of lists, prior distributions.
SystemErrorIndex	integer vector, index of systematic errors.
SystemErrorPrior	list of lists, prior distribution for each systematic error.
options	list, inference options.
mcmcoptions	list, MCMC options.
year	numeric vector, years.

Examples

```

config=Import_HBayConfig('path/to/config')
if(!is.null(config)){
  H3=Hydro3_HBay(y=config$y,dist=config$dist,prior=config$prior,
                SysErrorIndex=config$SysErrorIndex,
                SysErrorPrior=config$SysErrorPrior,
                options=config$options,
                mcmcoptions=config$mcmcoptions)
  Hydro3_Plot(H3)
}

```

KS

Kolmogorov-Smirnov Test

Description

Applies a one-sample Kolmogorov-Smirnov test (see `?stats::ks.test`)

Usage

```
KS(y, dist, par)
```

Arguments

y	numeric vector, data
dist	character, distribution name
par	numeric vector, parameter vector

Value

A list with the following components:

pval	numeric, p-value of the test
stat	numeric, test statistics
xtra	numeric, xtra information: empty for this test

Examples

```

y=stats::rnorm(20)
KS(y, 'Normal', c(0,1))
KS(y, 'Normal', c(1,1))
KS(y, 'Gumbel', c(0,1))

```

mcmcoptions_def	<i>Default MCMC options</i>
-----------------	-----------------------------

Description

A named list containing the default MCMC options. See ?Hydro3_Estimation for more details.

Usage

```
mcmcoptions_def
```

Format

An object of class list of length 10.

Metropolis_OAAT	<i>One-At-A-Time Metropolis sampler</i>
-----------------	---

Description

Performs nsim iterations of the OAAT Metropolis sampler (simulated vector is updated one component at a time). a.k.a block Metropolis sampler with blocks of length one. Sometimes also called 'Metropolis-within-Gibbs'.

Usage

```
Metropolis_OAAT(f, x0, nsim, sdjump, ...)
```

Arguments

f	function, log-pdf of the target distribution
x0	numeric vector, starting point
nsim	integer, number of simulations
sdjump	numeric vector, standard deviation of the Gaussian jump for each component
...	other arguments passed to f

Value

A list with the following components:

x	numeric matrix nsim*length(x0), MCMC simulations
fx	numeric vector, corresponding values f(x)
moverate	numeric vector, move rate associated with each component

Examples

```
# Bivariate target distribution: beta(0.8,0.4) X exp(1)
f=function(x){stats::dbeta(x[1],0.8,0.4,log=TRUE)+stats::dexp(x[2],log=TRUE)}
x0=c(0.5,2)
sdjump=c(0.5,1)
mcmc=Metropolis_OAAT(f,x0,1000,sdjump)
graphicalpar=par(mfrow=c(1,3))
plot(mcmc$x);hist(mcmc$x[,1]); hist(mcmc$x[,2])
par(graphicalpar)
```

Metropolis_OAAT_adaptive

Adaptive One-At-A-Time Metropolis sampler

Description

Performs nsim iterations of the Adaptive version of the OAAT Metropolis sampler (see ?Metropolis_OAAT). Adaptation is performed by monitoring move rates every batch.length iterations, and increasing / decreasing the jump standard deviation if the move rate is not within specified bounds.

Usage

```
Metropolis_OAAT_adaptive(
  f,
  x0,
  sdjump,
  ...,
  batch.length = 100,
  batch.n = 100,
  moverate.min = 0.1,
  moverate.max = 0.5,
  mult.down = 0.9,
  mult.up = 1.1
)
```

Arguments

f	function, log-pdf of the target distribution
x0	numeric vector, starting point
sdjump	numeric vector, initial standard deviation of the Gaussian jump for each component
...	other arguments passed to f
batch.length	integer, length of each non-adaptive batch
batch.n	integer, number of batches (= adaptation period). Total number of simulations is nsim=batch.n*batch.length

<code>moverate.min</code>	numeric in (0;1), lower bound for the desired move rate interval
<code>moverate.max</code>	numeric in (0;1), upper bound for the desired move rate interval
<code>mult.down</code>	numeric in (0;1), multiplication factor used to decrease jump size when move rate is too low.
<code>mult.up</code>	numeric (>1, avoid 1/mult.down) multiplication factor used to increase jump size when move rate is too high.

Value

A list with the following components:

<code>x</code>	numeric matrix <code>nsim*length(x0)</code> , MCMC simulations
<code>fx</code>	numeric vector, corresponding values <code>f(x)</code>

Examples

```
# Bivariate target distribution: beta(0.8,0.4) X exp(1)
f=function(x){stats::dbeta(x[1],0.8,0.4,log=TRUE)+stats::dexp(x[2],log=TRUE)}
x0=c(0.5,2)
sdjump=c(0.5,1)
mcmc=Metropolis_OAAT_adaptive(f,x0,sdjump)
graphicalpar=par(mfrow=c(1,3))
plot(mcmc$x);hist(mcmc$x[,1]); hist(mcmc$x[,2])
par(graphicalpar)
```

Metropolis_OAAT_jump *One-At-A-Time Metropolis sampler*

Description

Performs a single iteration of the OAAT Metropolis sampler (simulated vector is updated one component at a time). a.k.a block Metropolis sampler with blocks of length one. Sometimes also called 'Metropolis-within-Gibbs'.

Usage

```
Metropolis_OAAT_jump(f, x0, fx0, sdjump, ...)
```

Arguments

<code>f</code>	function, log-pdf of the target distribution
<code>x0</code>	numeric vector, starting point
<code>fx0</code>	numeric, <code>f(x0)</code>
<code>sdjump</code>	numeric vector, standard deviation of the Gaussian jump for each component
<code>...</code>	other arguments passed to <code>f</code>

Value

A list with the following components:

x	numeric vector, updated point after the iteration
fx	numeric, updated value f(x)
move	logical vector, TRUE for components of the vector x that changed

Examples

```
# Bivariate target distribution: beta(2,10) X exp(1)
f=function(x){stats::dbeta(x[1],2,10,log=TRUE)+stats::dexp(x[2],log=TRUE)}
x0=c(0.5,0.5)
fx0=f(x0)
sdjump=c(0.1,0.1)
Metropolis_0AAT_jump(f,x0,fx0,sdjump)
```

 MK

Mann-Kendall Test

Description

Applies the Mann-Kendall trend test

Usage

```
MK(y)
```

Arguments

y	numeric vector, data
---	----------------------

Value

A list with the following components:

pval	numeric, p-value of the test
stat	numeric, test statistics
xtra	numeric, xtra information: empty for this test

Examples

```
y=stats::rnorm(50)
MK(y)
y=y+0.1*(1:length(y))
MK(y)
```

options_def	<i>Default estimation options</i>
-------------	-----------------------------------

Description

A named list containing the default estimation options. See ?Hydro3_Estimation for more details.

Usage

```
options_def
```

Format

An object of class list of length 9.

Pettitt	<i>Pettitt Test</i>
---------	---------------------

Description

Applies the Pettitt step-change test

Usage

```
Pettitt(y)
```

Arguments

y	numeric vector, data
---	----------------------

Value

A list with the following components:

pval	numeric, p-value of the test
stat	numeric, test statistics
xtra	numeric, xtra information: position of the step change

Examples

```
y=stats::rnorm(50)
Pettitt(y)
y[26:50]=y[26:50]+2
Pettitt(y)
```

Index

* datasets

- distInfo, [2](#)
- mcmcoptions_def, [29](#)
- options_def, [33](#)

distInfo, [2](#)

Generate, [3](#)

GenerateWithinBounds, [4](#)

GetCdf, [4](#)

GetEmpFreq, [5](#)

GetEstimate_BAY, [6](#)

GetEstimate_HBay, [7](#)

GetEstimate_HYDRO2, [9](#)

GetEstimate_LMOM, [10](#)

GetEstimate_ML, [11](#)

GetEstimate_MOM, [12](#)

GetEstimate_ROUGH, [13](#)

GetParFeas, [14](#)

GetParName, [14](#)

GetParNumber, [15](#)

GetPdf, [15](#)

GetQfromT, [16](#)

GetQuantile, [17](#)

GetReducedVariate, [17](#)

GetTfromQ, [18](#)

GetUncertainty_ML, [19](#)

HBay_Plot, [20](#)

Hydro3_Estimation, [21](#)

Hydro3_HBay, [23](#)

Hydro3_Plot, [26](#)

Import_HBayConfig, [27](#)

KS, [28](#)

mcmcoptions_def, [29](#)

Metropolis_OAAT, [29](#)

Metropolis_OAAT_adaptive, [30](#)

Metropolis_OAAT_jump, [31](#)

MK, [32](#)

options_def, [33](#)

Pettitt, [33](#)