

# Package ‘GWEX’

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**Type** Package

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**License** GPL-3

**Title** Multi-Site Stochastic Models for Daily Precipitation and Temperature

**Version** 1.1.3

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**Imports** Rcpp (>= 1.0.11), EnvStats, MASS, mvtnorm, nleqslv, fGarch, parallel, abind, foreach, doParallel, Renext, lmomco, methods, stats

**LinkingTo** Rcpp, RcppArmadillo

**Description** Application of multi-site models for daily precipitation and temperature data.

This package is designed for an application to 105 precipitation and 26 temperature gauges located in Switzerland.

It applies fitting procedures and provides weather generators described in the following references:

- Evin, G., A.-C. Favre, and B. Hingray. (2018) <doi:10.5194/hess-22-655-2018>.

- Evin, G., A.-C. Favre, and B. Hingray. (2018) <doi:10.1007/s00704-018-2404-x>.

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---

<code>agg.matrix</code>	<i>agg.matrix</i>
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---

### Description

Simple accumulation of a matrix of precipitation

### Usage

```
agg.matrix(mat, k, average = F)
```

### Arguments

<code>mat</code>	matrix nDates x nStations to be aggregated
<code>k</code>	number of days for the accumulation
<code>average</code>	logical: should we average over the different periods (default=F)

### Value

aggregated matrix

### Author(s)

Guillaume Evin

---

autocor.emp.int      *autocor.emp.int*

---

### Description

Finds empirical autocorrelations (lag-1) between intensities corresponding to a degree of autocorrelation of an AR(1) process

### Usage

```
autocor.emp.int(rho, nChainFit, Xt, parMargin, typeMargin)
```

### Arguments

rho	autocorrelation of the AR(1) process
nChainFit	number of simulated variates
Xt	simulated occurrences, nChainFit x 2 matrix
parMargin	parameters of the margins 2 x 3
typeMargin	type of marginal distribution: 'EGPD' or 'mixExp'

### Value

scalar	correlation between simulated intensities
--------	---

### Author(s)

Guillaume Evin

---

cor.emp.int      *cor.emp.int*

---

### Description

Finds observed correlations between intensities corresponding to a degree of correlation of Gaussian multivariate random numbers

### Usage

```
cor.emp.int(zeta, nChainFit, Xt, parMargin, typeMargin)
```

**Arguments**

zeta	correlation of Gaussian multivariates
nChainFit	number of simulated variates
Xt	simulated occurrences, n x 2 matrix
parMargin	parameters of the margins 2 x 3
typeMargin	type of marginal distribution: 'EGPD' or 'mixExp'

**Value**

scalar	correlation between simulated intensities
--------	---

**Author(s)**

Guillaume Evin

---

cor.emp.occ

*cor.emp.occ*

---

**Description**

Finds observed correlations between occurrences corresponding to a degree of correlation of Gaussian multivariate random numbers

**Usage**

```
cor.emp.occ(w, Qtrans.mat, mat.comb, nLag, nChainFit, myseed = 1)
```

**Arguments**

w	correlation of Gaussian multivariates
Qtrans.mat	transition probabilities, 2 x ncomb matrix
mat.comb	matrix of logical: ncomb x nlag
nLag	order of the Markov chain
nChainFit	number of simulated variates
myseed	seed of random variates

**Value**

scalar	correlation between occurrences
--------	---------------------------------

**Author(s)**

Guillaume Evin

---

 cor.obs.occ

*cor.obs.occ*


---

**Description**

provide observed correlations between occurrences for all pairs of stations see Mhanna et al. (2012)

**Usage**

```
cor.obs.occ(pi00, pi0, pi1)
```

**Arguments**

pi00	joint probability of having dry states
pi0	probability of having a dry state
pi1	probability of having a wet state

**Value**

scalar	matrix of observed correlations
--------	---------------------------------

**Author(s)**

Guillaume Evin

**References**

Mhanna, Muamaraldin, and Willy Bauwens. "A Stochastic Space-Time Model for the Generation of Daily Rainfall in the Gaza Strip." *International Journal of Climatology* 32, no. 7 (June 15, 2012): 1098–1112. doi:10.1002/joc.2305.

---

 dailyPrecipGWEX

*daily observations of precipitation data*


---

**Description**

Example of daily observations of precipitation (mm) for three fictive stations, for a period of ten years.

**Usage**

```
data(dailyPrecipGWEX)
```

**Format**

matrix of Observed precipitation: 3652 days x 3 stations

**Author(s)**

Guillaume Evin <guillaume.evin@irstea.fr>

**References**

Evin, G., A.-C. Favre, and B. Hingray. 2018. "Stochastic Generation of Multi-Site Daily Precipitation Focusing on Extreme Events". *Hydrol. Earth Syst. Sci.* 22 (1): 655–672.

---

dailyTemperGWEX      *daily observations of temperature data*

---

**Description**

Example of daily observations of temperature (mm) for three fictive stations, for a period of ten years.

**Usage**

```
data(dailyTemperGWEX)
```

**Format**

matrix of Observed temperature: 3652 days x 3 stations

**Author(s)**

Guillaume Evin <guillaume.evin@irstea.fr>

**References**

Evin G., A.C. Favre, and B. Hingray. 2018. Stochastic Generators of Multi Site Daily Temperature: Comparison of Performances in Various Applications. *Theoretical and Applied Climatology*.

---

disag.3D.to.1D      *disag.3D.to.1D*

---

**Description**

disag.3D.to.1D

**Usage**

```
disag.3D.to.1D(Yobs, YObsAgg, mObsAgg, YSimAgg, mSimAgg, prob.class)
```

**Arguments**

Yobs	matrix of observed intensities at 24h: (nTobs*3) x nStation
YObsAgg	matrix of observed 3-day intensities: nTobs x nStation
mObsAgg	vector of season corresponding to YobsAgg
YSimAgg	matrix of simulated intensities per 3-day period: nTsim x nStation
mSimAgg	vector of season corresponding to the period simulated
prob.class	vector of probabilities indicating class of "similar" mean intensities

**Value**

list	Ysim matrix of disaggregated daily precipitation, codeDisag matrix of disaggregation codes
------	--

**Author(s)**

Guillaume Evin

---

dist.functions.EGPD.GI

*dEGPD.GI, pEGPD.GI, qEGPD.GI, rEGPD.GI*

---

**Description**

Density function, distribution function, quantile function, random generation for the unified EGPD distribution

**Usage**

dEGPD.GI(x, kappa, sig, xi)

pEGPD.GI(x, kappa, sig, xi)

qEGPD.GI(p, kappa, sig, xi)

rEGPD.GI(n, kappa, sig, xi)

**Arguments**

x	Vector of quantiles
kappa	transformation parameter greater than 0
sig	Scale parameter
xi	Shape parameter
p	Vector of probabilities
n	Number of observations

**Value**

dEGPD.GI gives the density function, pEGPD.GI gives the distribution function, qEGPD.GI gives the quantile function, and rEGPD.GI generates random deviates.

**Author(s)**

Guillaume Evin

---

dry.day.frequency      *dry.day.frequency*

---

**Description**

Estimate the dry day frequency (proportion of dry days) for all stations

**Usage**

dry.day.frequency(mat.prec, th)

**Arguments**

mat.prec      matrix of precipitation (possibly for one month/period)  
th              threshold above which we consider that a day is wet (e.g. 0.2 mm)

**Value**

vector of numeric  
dry day frequencies

**Author(s)**

Guillaume Evin

---

EGPD.GI.fit.PWM      *EGPD.GI.fit.PWM*

---

**Description**

Parameter estimation of the unified EGPD distribution with the PWM method. Numerical solver of the system of nonlinear equations

**Usage**

EGPD.GI.fit.PWM(x, xi = 0.05)

**Arguments**

x                    vector of parameters kappa,sig  
xi                    shape parameter

**Value**

estimated parameters kappa, sig, xi

**Author(s)**

Guillaume Evin

---

EGPD.GI.fPWM

*EGPD.GI.fPWM*

---

**Description**

Parameter estimation of the unified EGPD distribution with the PWM method. Set of equations which have to be equal to zero

**Usage**

EGPD.GI.fPWM(par, pwm, xi)

**Arguments**

par                    vector of parameters kappa,sig,xi  
pwm                    set of probability weighted moments of order 0, 1 and 2  
xi                    shape parameter

**Value**

differences between expected and target weighted moments

**Author(s)**

Guillaume Evin

---

find.autocor	<i>find.autocor</i>
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---

**Description**

finds the autocorrelation leading to observed autocorrelation

**Usage**

```
find.autocor(autocor.emp, nChainFit, Xt, parMargin, typeMargin)
```

**Arguments**

autocor.emp	target correlation between intensities
nChainFit	number of simulations
Xt	simulated occurrences, nChainFit x 2 matrix
parMargin	parameters of the margins 2 x 3
typeMargin	type of marginal distribution: 'EGPD' or 'mixExp'

**Value**

scalar	needed correlation
--------	--------------------

**Author(s)**

Guillaume Evin

---

find.omega	<i>find.omega</i>
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---

**Description**

finds the correlation between normal variates leading to correlation between occurrences

**Usage**

```
find.omega(rho.emp, Qtrans.mat, mat.comb, nLag, nChainFit)
```

**Arguments**

rho.emp	target correlation between occurrences
Qtrans.mat	transition probabilities, 2 x ncomb matrix
mat.comb	matrix of logical: ncomb x nlag
nLag	order of the Markov chain
nChainFit	length of the simulated chains used during the fitting

**Value**

scalar          needed correlation

**Author(s)**

Guillaume Evin

---

find.zeta

*find.zeta*

---

**Description**

finds the correlation between normal variates leading to correlation between intensities

**Usage**

```
find.zeta(eta.emp, nChainFit, Xt, parMargin, typeMargin)
```

**Arguments**

eta.emp          target correlation between intensities  
nChainFit        number of simulations  
Xt                simulated occurrences, n x 2 matrix  
parMargin        parameters of the margins 2 x 3  
typeMargin       type of marginal distribution: 'EGPD' or 'mixExp'

**Value**

scalar          needed correlation

**Author(s)**

Guillaume Evin

---

fit.copula.amount	<i>fit.copula.amount</i>
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---

**Description**

estimate parameters which control the spatial dependence between intensities using a copula

**Usage**

```
fit.copula.amount(P.mat, isPeriod, th, copulaInt, M0)
```

**Arguments**

P.mat	precipitation matrix
isPeriod	vector of logical n x 1 indicating the days concerned by a 3-month period
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)
copulaInt	type of dependence between inter-site amounts: 'Gaussian' or 'Student'
M0	covariance matrix of gaussianized prec. amounts for all pairs of stations

**Value**

list	list of estimates (e.g., M0, dfStudent)
------	---

**Author(s)**

Guillaume Evin

---

fit.GWex.prec	<i>fit.GWex.prec</i>
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---

**Description**

estimate all the parameters for the G-Wex model of precipitation

**Usage**

```
fit.GWex.prec(objGwexObs, parMargin, listOption = NULL)
```

## Arguments

objGwexObs	object of class <a href="#">GwexObs</a>
parMargin	if not NULL, list where each element parMargin[[iM]] corresponds to a month iM=1...12 and contains a matrix nStation x 3 of estimated parameters of the marginal distributions (EGPD or mixture of exponentials)
listOption	list with the following fields: <ul style="list-style-type: none"> <li>• <b>th</b>: threshold value in mm above which precipitation observations are considered to be non-zero (=0.2 by default)</li> <li>• <b>nLag</b>: order of the Markov chain for the transitions between dry and wet states (=2 by default)</li> <li>• <b>typeMargin</b>: 'EGPD' (Extended GPD) or 'mixExp' (Mixture of Exponentials). 'EGPD' by default</li> <li>• <b>copulaInt</b>: 'Gaussian' or 'Student': type of dependence for amounts (= 'Student' by default)</li> <li>• <b>isMAR</b>: logical value, do we apply a Autoregressive Multivariate Autoregressive model (order 1) =TRUE by default</li> <li>• <b>is3Damount</b>: logical value, do we apply the model on 3D-amount. =FALSE by default</li> <li>• <b>nChainFit</b>: integer, length of the runs used during the fitting procedure. =100000 by default</li> <li>• <b>nCluster</b>: integer, number of clusters which can be used for the parallel computation</li> </ul>

## Value

a list containing the list of options listOption and the list of estimated parameters listPar. The parameters of the occurrence process are contained in parOcc and the parameters related to the precipitation amounts are contained in parInt. Each type of parameter is a list containing the estimates for each month. In parOcc, we find:

- **p01**: For each station, the probability of transition from a dry state to a wet state.
- **p11**: For each station, the probability of staying in a wet state.
- **list.pr.state**: For each station, the probabilities of transitions for a Markov chain with lag p.
- **list.mat.omega**: The spatial correlation matrix of occurrences  $\Omega$  (see Evin et al., 2018).

In parInt, we have:

- **parMargin**: list of matrices nStation x nPar of parameters for the marginal distributions (one element per Class).
- **cor.int**: Matrices nStation x nStation  $M_0, A, \Omega_Z$  representing the spatial and temporal correlations between all the stations (see Evin et al., 2018). For the Student copula, dfStudent indicates the  $\nu$  parameter.

## Author(s)

Guillaume Evin

## References

Evin, G., A.-C. Favre, and B. Hingray. 2018. 'Stochastic Generation of Multi-Site Daily Precipitation Focusing on Extreme Events.' *Hydrol. Earth Syst. Sci.* 22 (1): 655-672. doi.org/10.5194/hess-22-655-2018.

---

fit.MAR1.amount	<i>fit.MAR1.amount</i>
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---

## Description

estimate parameters which control the dependence between intensities with a MAR(1) process

## Usage

```
fit.MAR1.amount(P.mat, isPeriod, th, copulaInt, M0, A)
```

## Arguments

P.mat	precipitation matrix
isPeriod	vector of logical n x 1 indicating the days concerned by a 3-month period
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)
copulaInt	type of dependance between inter-site amounts: 'Gaussian' or 'Student'
M0	covariance matrix of gaussianized prec. amounts for all pairs of stations
A	Matrix containing the autocorrelation (temporal) correlations

## Value

list with the following items

- **M0** covariance matrix of gaussianized prec. amounts for all pairs of stations
- **A** omega correlations for all pairs of stations
- **covZ** covariance matrix of the MAR(1) process
- **sdZ** standard deviation of the diagonal elements
- **corZ** correlation matrix of the MAR(1) process
- **dfStudent** degrees of freedom for the Student copula if CopulaInt is equal to "Student"

## Author(s)

Guillaume Evin

## References

Matalas, N. C. 1967. "Mathematical Assessment of Synthetic Hydrology." *Water Resources Research* 3 (4): 937–45. <https://doi.org/10.1029/WR003i004p00937>.

Bárdossy, A., and G. G. S. Pegram. 2009. "Copula Based Multisite Model for Daily Precipitation Simulation." *Hydrology and Earth System Sciences* 13 (12): 2299–2314. <https://doi.org/10.5194/hess-13-2299-2009>.

---

fit.margin.cdf	<i>fit.margin.cdf</i>
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---

**Description**

estimate parameters which control the marginal distribution of precipitation amounts

**Usage**

```
fit.margin.cdf(P.mat, isPeriod, th, type = c("EGPD", "mixExp"))
```

**Arguments**

P.mat	precipitation matrix
isPeriod	vector of logical n x 1 indicating the days concerned by a 3-month period
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)
type	distribution: 'EGPD' or 'mixExp'

**Value**

matrix	matrix of estimates p x 3
--------	---------------------------

**Author(s)**

Guillaume Evin

---

fitGwexModel	<i>fitGwexModel: fit a GWex model to observations.</i>
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---

**Description**

fitGwexModel: fit a GWex model to observations.

**Usage**

```
fitGwexModel(objGwexObs, parMargin = NULL, listOption = NULL)
```

**Arguments**

- objGwexObs** an object of class [GwexObs](#)
- parMargin** (not required for temperature) list **parMargin** where each element corresponds to a month (1...12) and contains a matrix  $nStation \times 3$  of pre-estimated parameters of the marginal distributions (EGPD or Mixture of Exponentials)
- listOption** for precipitation, a list with the following fields:
- **th**: threshold value in mm above which precipitation observations are considered to be non-zero (=0.2 by default)
  - **nLag**: order of the Markov chain for the transitions between dry and wet states (=2 by default)
  - **typeMargin**: 'EGPD' (Extended GPD) or 'mixExp' (Mixture of Exponentials). 'mixExp' by default
  - **copulaInt**: 'Gaussian' or 'Student': type of dependence for amounts (= 'Gaussian' by default)
  - **isMAR**: logical value, do we apply a Autoregressive Multivariate Autoregressive model (order 1) = FALSE by default
  - **is3Damount**: logical value, do we apply the model on 3D-amount. =FALSE by default
  - **nChainFit**: integer, length of the runs which are generated during the fitting procedure. =100000 by default
  - **nCluster**: integer, number of clusters which can be used for the parallel computation

and for temperature, a list with the following fields:

- **hasTrend**: logical value, do we fit a linear trend for the long-term change, =FALSE by default
- **objGwexPrec**: object of class [GwexObs](#) containing precipitation observations. If provided, we assume that temperature must be modelled and simulated according to the precipitation states 'dry' and 'wet'. For each state, a seasonal cycle is fitted (mean and sd).
- **typeMargin**: 'SGED' (default) or 'Gaussian': type of marginal distribution.
- **depStation**: 'MAR1' (default) or 'Gaussian': MAR1 (Multivariate Autoregressive model order 1) for the spatial and temporal dependence or 'Gaussian' for the spatial dependence only.

**Value**

Return an object of class [GwexFit](#) with:

- **p**: The number of station,
- **version**: package version,
- **variable**: the type of variable,
- **fit**: a list containing the list of options **listOption** and the list of estimated parameters **listPar**.

**Author(s)**

Guillaume Evin

**Examples**

```

# Format dates corresponding to daily observations of precipitation and temperature
vecDates = seq(from=as.Date("01/01/2005", format="%d/%m/%Y"),
to=as.Date("31/12/2014", format="%d/%m/%Y"), by='day')

#####
#           FIT THE PRECIPITATION MODEL
#####

# Format observations: create a Gwex object for one station only to show a quick
# example. The syntax is similar for multi-site applications.
myObsPrec = GwexObs(variable='Prec', date=vecDates, obs=dailyPrecipGWEX[,1,drop=FALSE])

# Fit precipitation model with a threshold of 0.5 mm to distinguish wet and dry
# states (th) and keep default options otherwise, e.g. a Gaussian
# copula for the spatial dependence (copulaInt) and a mixExp distribution for
# marginal intensities ('typeMargin')
myParPrec = fitGwexModel(myObsPrec, listOption=list(th=0.5))
myParPrec # print object

#####
#           FIT THE TEMPERATURE MODEL, COND. TO PRECIPITATION
#####

# Format observations: create a G-Wex object
myObsTemp = GwexObs(variable='Temp', date=vecDates, obs=dailyTemperGWEX)

# Fit temperature model with a long-term linear trend ('hasTrend'), Gaussian margins
# ('typeMargin') and Gaussian spatial dependence ('depStation')
myParTemp = fitGwexModel(myObsTemp, listOption=list(hasTrend=TRUE, typeMargin='Gaussian',
depStation='Gaussian'))
myParTemp # print object

```

---

functions.EGPD.GI      *EGPD.pGI, EGPD.dGI, EGPD.qGI*

---

**Description**

First parametric family for  $G(v) = v^\kappa$ : distribution, density and quantile function

**Usage**

EGPD.pGI(v, kappa)

EGPD.dGI(v, kappa)

EGPD.qGI(p, kappa)

**Arguments**

v	probability
kappa	transformation parameter greater than 0
p	probability

**Value**

distribution, density and quantile of EGPD

**Author(s)**

Guillaume Evin

---

<i>get.df.Student</i>	<i>get.df.Student</i>
-----------------------	-----------------------

---

**Description**

Estimates the nu parameter (degrees of freedom) of the multivariate Student distribution when the correlation matrix Sig is given

**Usage**

```
get.df.Student(P, Sig, max.df = 20)
```

**Arguments**

P	matrix of non-zero precipitation (zero precipitation are set to NA)
Sig	correlation matrix
max.df	maximum degrees of freedom tested (default=20)

**Value**

nu estimate

**Author(s)**

Guillaume Evin

**References**

McNeil et al. (2005) "Quantitative Risk Management"

---

`get.emp.cdf.matrix`      *get.df.Student*

---

**Description**

get the cdf values (empirical distribution) of positive precipitation

**Usage**

`get.emp.cdf.matrix(X)`

**Arguments**

`X`                      matrix of positive precipitation

**Value**

matrix with cdf values (NA if zero precipitation)

**Author(s)**

Guillaume Evin

---

`get.list.month`              *get.list.month*

---

**Description**

return a vector of 3-char tags of the 12 months

**Usage**

`get.list.month()`

---

`get.list.season`              *get.list.season*

---

**Description**

get the vector of the four seasons `c('DJF','MAM','JJA','SON')`

**Usage**

`get.list.season()`

**Author(s)**

Guillaume Evin

---

get.listOption	<i>get.listOption</i>
----------------	-----------------------

---

**Description**

get default options and check values proposed by the user

**Usage**

```
get.listOption(listOption)
```

**Arguments**

listOption	list containing fields corr. to the different options. Can be NULL if no options are set
------------	--

**Value**

listOption	list of options
------------	-----------------

**Author(s)**

Guillaume Evin

---

get.M0	<i>get.M0</i>
--------	---------------

---

**Description**

find matrix of correlations leading to estimates cor between intensities

**Usage**

```
get.M0(  
  cor.obs,  
  infer.mat.omega.out,  
  nLag,  
  parMargin,  
  typeMargin,  
  nChainFit,  
  isParallel  
)
```

**Arguments**

cor.obs	matrix $p \times p$ of observed correlations between intensities for all pairs of stations
infer.mat.omega.out	output of <code>infer.mat.omega</code>
nLag	order of the Markov chain
parMargin	parameters of the margins $p \times 3$
typeMargin	type of marginal distribution: 'EGPD' or 'mixExp'
nChainFit	integer indicating the length of simulated chains
isParallel	logical: indicate computation in parallel or not (easier for debugging)

**Value**

list with two items

- **Xt** long simulation of the wet/dry states according to the model
- **M0** covariance matrix of gaussianized prec. amounts for all pairs of stations

**Author(s)**

Guillaume Evin

---

get.mat.omega

*get.mat.omega*

---

**Description**

find omega correlation leading to estimates cor between occurrences

**Usage**

```
get.mat.omega(cor.obs, Qtrans.mat, mat.comb, nLag, nChainFit, isParallel)
```

**Arguments**

cor.obs	matrix $p \times p$ of observed correlations between occurrences for all pairs of stations
Qtrans.mat	transition probabilities, $2 \times ncomb$ matrix
mat.comb	matrix of logical: $ncomb \times nlag$
nLag	order of the Markov chain
nChainFit	length of the simulated chains used during the fitting
isParallel	logical: indicate computation in parallel or not (easier for debugging)

**Value**

matrix omega correlations for all pairs of stations

**Author(s)**

Guillaume Evin

---

`get.period.fitting.month`  
*get.period.fitting.month*

---

**Description**

`get.period.fitting.month`

**Usage**

`get.period.fitting.month(m.char)`

**Arguments**

<code>m.char</code>	3-letter name of a month (e.g. 'JAN') return the 3 indices corresponding to the 3-month period of a month ('JAN')
---------------------	--

---

`get.vec.autocor`      *get.vec.autocor*

---

**Description**

find rho autocorrelation leading to empirical estimates

**Usage**

`get.vec.autocor(vec.ar1.obs, Xt, parMargin, typeMargin, nChainFit, isParallel)`

**Arguments**

<code>vec.ar1.obs</code>	vector of observed autocorrelations for all stations
<code>Xt</code>	simulated occurrences given model parameters of wet/dry states
<code>parMargin</code>	parameters of the margins $p \times 3$
<code>typeMargin</code>	type of marginal distribution: 'EGPD' or 'mixExp'
<code>nChainFit</code>	integer indicating the length of the simulated chains
<code>isParallel</code>	logical: indicate computation in parallel or not (easier for debugging)

**Value**

vector      vector of rho parameters to simulate the MAR process

**Author(s)**

Guillaume Evin

---

```
getGwexFitPrec      getGwexFitPrec
```

---

### Description

get object GwexFit derived from the parameters replicated for each month

### Usage

```
getGwexFitPrec(
  listOption = NULL,
  p,
  condProbaWDstates,
  parMargin,
  vec.ar1 = NULL,
  M0 = NULL,
  mat.omega = NULL
)
```

### Arguments

listOption	list of options (see <a href="#">fitGwexModel</a> )
p	number of stations
condProbaWDstates	vector of length $nLag^2$ of transition probabilities corresponding to the nlag possible transitions between dry/wet states <code>expand.grid(lapply(numeric(nLag), function(x) c(F,T)))</code>
parMargin	parameters of the margins: vector of length 3
vec.ar1	vector of observed autocorrelations for all stations
M0	<b>M0</b> : covariance matrix of gaussianized prec. amounts for all pairs of stations
mat.omega	<b>mat.omega</b> : The spatial correlation matrix of occurrences $\Omega$

### Value

Return an object of class [GwexFit](#) with:

- **p**: The number of station,
- **version**: package version,
- **variable**: the type of variable,
- **fit**: a list containing the list of options listOption and the list of estimated parameters listPar.

### Examples

```
exFitGwexPrec = getGwexFitPrec(p=2,condProbaWDstates=c(0.7,0.3,0.2,0.1),
  parMargin=c(0.5,0.1,0.4),vec.ar1=rep(0.7,2),M0=rbind(c(1,0.6),c(0.6,1)),
  mat.omega=rbind(c(1,0.8),c(0.8,1)))
```

---

Gwex-class	<i>Class Gwex</i>
------------	-------------------

---

**Description**

Defines a generic [Gwex](#) object. GWex objects contain two slots: - the version ('vX.X.X') - the type of variable ('Prec' or 'Temp')

**Author(s)**

Guillaume Evin

---

GwexFit-class	<i>Class GwexFit</i>
---------------	----------------------

---

**Description**

Defines a [GwexFit](#) object which is a [Gwex](#) object containing 'fit', a list containing the fitted parameters, and 'p', the number of stations. See [fitGwexModel](#) for some examples.

**Author(s)**

Guillaume Evin

---

GwexObs	<i>Constructor</i>
---------	--------------------

---

**Description**

Constructor of class [[GwexObs](#)]

**Usage**

```
GwexObs(variable, date, obs)
```

**Arguments**

variable	'Prec' or 'Temp'
date	vector of class 'Date'
obs	matrix nTime x nStations of observations

**Value**

An object of class [[GwexObs](#)]

**Examples**

```
# Format dates corresponding to daily observations of precipitation and temperature
vecDates = seq(from=as.Date("01/01/2005",format="%d/%m/%Y"),
to=as.Date("31/12/2014",format="%d/%m/%Y"),by='day')

# build GwexObs object with precipitation data
myObsPrec = GwexObs(variable='Prec',date=vecDates,obs=dailyPrecipGWEX)

# print GwexObs object
myObsPrec

# build GwexObs object with temperature data
myObsTemp = GwexObs(variable='Temp',date=vecDates,obs=dailyTemperGWEX)

# print GwexObs object
myObsTemp
```

---

GwexObs-class

Class [GwexObs](#)


---

**Description**

Defines a [GwexObs](#) object which is a [Gwex](#) object containing dates and a matrix of observations.

**Author(s)**

Guillaume Evin

**Examples**

```
# Format dates corresponding to daily observations of precipitation and temperature
vecDates = seq(from=as.Date("01/01/2005",format="%d/%m/%Y"),
to=as.Date("31/12/2014",format="%d/%m/%Y"),by='day')

# build GwexObs object with precipitation data
myObsPrec = GwexObs(variable='Prec',date=vecDates,obs=dailyPrecipGWEX)

# print GwexObs object
myObsPrec

# build GwexObs object with temperature data
myObsTemp = GwexObs(variable='Temp',date=vecDates,obs=dailyTemperGWEX)

# print GwexObs object
myObsTemp
```

---

GwexSim-class	<i>Defines a <a href="#">GwexSim</a> object which is a <a href="#">Gwex</a> object containing 'sim', an array containing the simulations, and 'dates', a vector of dates. See <a href="#">simGwexModel</a> for some examples.</i>
---------------	---

---

**Description**

Defines a [GwexSim](#) object which is a [Gwex](#) object containing 'sim', an array containing the simulations, and 'dates', a vector of dates. See [simGwexModel](#) for some examples.

**Author(s)**

Guillaume Evin

---

infer.autocor.amount	<i>infer.autocor.amount</i>
----------------------	-----------------------------

---

**Description**

special case of [infer.dep.amount](#) where there is only one station

**Usage**

```
infer.autocor.amount(  
  P.mat,  
  pr.state,  
  isPeriod,  
  nLag,  
  th,  
  parMargin,  
  typeMargin,  
  nChainFit,  
  isMAR,  
  isParallel  
)
```

**Arguments**

P.mat	precipitation matrix
pr.state	probabilities of transitions for a Markov chain with lag p.
isPeriod	vector of logical n x 1 indicating the days concerned by a 3-month period
nLag	order of the Markov chain for the transitions between dry and wet states (=2 by default)
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)

parMargin	parameters of the margins 2 x 3
typeMargin	'EGPD' (Extended GPD) or 'mixExp' (Mixture of Exponentials). 'EGPD' by default
nChainFit	integer, length of the runs used during the fitting procedure. =100000 by default
isMAR	logical value, do we apply a Autoregressive Multivariate Autoregressive model (order 1) =TRUE by default
isParallel	logical: indicate computation in parallel or not (easier for debugging)

**Value**

list	list of estimates (e.g., MO, dfStudent)
------	---

**Author(s)**

Guillaume Evin

---

<code>infer.dep.amount</code>	<i>infer.dep.amount</i>
-------------------------------	-------------------------

---

**Description**

estimate parameters which control the spatial dependence between intensities using a copula

**Usage**

```
infer.dep.amount(
  P.mat,
  isPeriod,
  infer.mat.omega.out,
  nLag,
  th,
  parMargin,
  typeMargin,
  nChainFit,
  isMAR,
  copulaInt,
  isParallel
)
```

**Arguments**

P.mat	precipitation matrix
isPeriod	vector of logical n x 1 indicating the days concerned by a 3-month period
infer.mat.omega.out	output of <code>infer.mat.omega</code>

nLag	order of the Markov chain for the transitions between dry and wet states (=2 by default)
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)
parMargin	parameters of the margins 2 x 3
typeMargin	'EGPD' (Extended GPD) or 'mixExp' (Mixture of Exponentials). 'EGPD' by default
nChainFit	integer, length of the runs used during the fitting procedure. =100000 by default
isMAR	logical value, do we apply a Autoregressive Multivariate Autoregressive model (order 1) =TRUE by default
copulaInt	'Gaussian' or 'Student': type of dependence for amounts (= 'Student' by default)
isParallel	logical: indicate computation in parallel or not (easier for debugging)

**Value**

list	list of estimates (e.g., M0, dfStudent)
------	---

**Author(s)**

Guillaume Evin

---

infer.mat.omega	<i>infer.mat.omega</i>
-----------------	------------------------

---

**Description**

find omega correlation leading to estimates cor between occurrences

**Usage**

```
infer.mat.omega(P.mat, isPeriod, th, nLag, pr.state, nChainFit, isParallel)
```

**Arguments**

P.mat	matrix of precipitation n x p
isPeriod	vector of logical n x 1 indicating the days concerned by a 3-month period
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)
nLag	order of the Markov chain
pr.state	output of function <a href="#">lagTransProbaMatrix</a>
nChainFit	length of the simulated chains used during the fitting
isParallel	logical: indicate computation in parallel or not (easier for debugging)

**Value**

A list with different objects

- **Qtrans.mat**: matrix nStation x n.comb of transition probabilities
- **mat.comb**: matrix of possible combination n.comb x nLag
- **mat.omega**: The spatial correlation matrix of occurrences  $\Omega$  (see Evin et al., 2018).

**Author(s)**

Guillaume Evin

---

joint.proba.occ      *joint.proba.occ*

---

**Description**

joint probabilities of occurrences for all pairs of stations

**Usage**

```
joint.proba.occ(P, th)
```

**Arguments**

P	matrix of precipitation
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)

**Value**

list      list of joint probabilities

**Author(s)**

Guillaume Evin

---

lagTransProbaMatrix    *lagTransProbaMatrix*

---

**Description**

Estimate the transition probabilities between wet and dry states, for nlag previous days, for all stations

**Usage**

```
lagTransProbaMatrix(mat.prec, isPeriod, th, nlag)
```

**Arguments**

mat.prec	matrix of precipitation
isPeriod	vector of logical n x 1 indicating the days concerned by a 3-month period
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)
nlag	number of lag days

**Value**

list            list with one item per station, where each item is a matrix  $nLag^2 \times (nLag+1)$  of transition probability between dry/wet state. The first nLag columns indicate the wet/dry states for the previous nLag days

**Author(s)**

Guillaume Evin

---

lagTransProbaVector    *lagTransProbaVector*

---

**Description**

Estimate the transition probabilities between wet and dry states, for nlag previous days, for one station

**Usage**

```
lagTransProbaVector(vec.prec, isPeriod, th, nlag)
```

**Arguments**

<code>vec.prec</code>	vector $n \times 1$ of precipitation for one station
<code>isPeriod</code>	vector of logical $n \times 1$ indicating the days concerned by a 3-month period
<code>th</code>	threshold above which we consider that a day is wet (e.g. 0.2 mm)
<code>nlag</code>	number of lag days

**Value**

<code>matrix</code>	matrix $nLag^2 \times (nLag+1)$ of transition probability between dry/wet state. The first $nLag$ columns indicate the wet/dry states for the previous $nLag$ days
---------------------	--

**Author(s)**

Guillaume Evin

---

`mask.GWex.Yt`

*mask.GWex.Yt*

---

**Description**

Mask intensities where there is no occurrence

**Usage**

`mask.GWex.Yt(Xt, Yt)`

**Arguments**

<code>Xt</code>	simulated occurrences
<code>Yt</code>	simulated intensities

**Value**

<code>matrix</code>	matrix $n \times p$ of simulated precipitations
---------------------	---

**Author(s)**

Guillaume Evin

---

modify.cor.matrix	<i>modify.cor.matrix</i>
-------------------	--------------------------

---

**Description**

Modify a non-positive definite correlation matrix in order to have a positive definite matrix

**Usage**

```
modify.cor.matrix(cor.matrix)
```

**Arguments**

cor.matrix      possibly non-positive definite correlation matrix

**Value**

positive definite correlation matrix

**Author(s)**

Guillaume Evin

**References**

Rousseeuw, P. J. and G. Molenberghs. 1993. Transformation of non positive semidefinite correlation matrices. *Communications in Statistics: Theory and Methods* 22(4):965-984.

Rebonato, R., & Jackel, P. (2000). The most general methodology to create a valid correlation matrix for risk management and option pricing purposes. *J. Risk*, 2(2), 17-26.

---

month2season	<i>month2season</i>
--------------	---------------------

---

**Description**

transform vector of months to seasons

**Usage**

```
month2season(vecMonth)
```

**Arguments**

vecMonth      a vector of months given as integers 1:12

**Author(s)**

Guillaume Evin

---

```
print,Gwex-method      print-methods: Create a method to print Gwex objects.
```

---

### Description

print-methods: Create a method to print Gwex objects.

### Usage

```
## S4 method for signature 'Gwex'
print(x)

## S4 method for signature 'GwexObs'
print(x)

## S4 method for signature 'GwexFit'
print(x)

## S4 method for signature 'GwexSim'
print(x)
```

### Arguments

x                    [Gwex object](#)

### Examples

```
# Format dates corresponding to daily observations of precipitation and temperature
vecDates = seq(from=as.Date("01/01/2005",format="%d/%m/%Y"),
to=as.Date("31/12/2014",format="%d/%m/%Y"),by='day')

# build GwexObs object with temperature data
myObsTemp = GwexObs(variable='Temp',date=vecDates,obs=dailyTemperGWEX)

# print GwexObs object
myObsTemp
```

---

```
PWM.EGPD.GI
```

```
EGPD.GI.mu0, EGPD.GI.mu1, EGPD.GI.mu2
```

---

### Description

Probability Weighted Moments of order 0, 1 and 2 of the unified EGPD distribution

**Usage**

EGPD.GI.mu0(kappa, sig, xi)

EGPD.GI.mu1(kappa, sig, xi)

EGPD.GI.mu2(kappa, sig, xi)

**Arguments**

kappa	transformation parameter greater than 0
sig	Scale parameter
xi	Shape parameter

**Value**

Probability Weighted Moments

**Author(s)**

Guillaume Evin

---

QtransMat2Array	<i>QtransMat2Array</i>
-----------------	------------------------

---

**Description**

reshape Qtrans.mat to an array

**Usage**

QtransMat2Array(n, p, Qtrans.mat)

**Arguments**

n	matrix of precipitation
p	number of stations
Qtrans.mat	transition probabilities, 2 x ncomb matrix

**Value**

array of transition probabilities with dimension n x p x n.comb

**Author(s)**

Guillaume Evin

---

show, Gwex-method      *show-methods: Create a method to show Gwex objects.*

---

### Description

show-methods: Create a method to show Gwex objects.

### Usage

```
## S4 method for signature 'Gwex'
show(object)

## S4 method for signature 'GwexObs'
show(object)

## S4 method for signature 'GwexFit'
show(object)

## S4 method for signature 'GwexSim'
show(object)
```

### Arguments

object      [Gwex](#) object

### Examples

```
# Format dates corresponding to daily observations of precipitation and temperature
vecDates = seq(from=as.Date("01/01/2005", format="%d/%m/%Y"),
to=as.Date("31/12/2014", format="%d/%m/%Y"), by='day')

# build GwexObs object with temperature data
myObsTemp = GwexObs(variable='Temp', date=vecDates, obs=dailyTemperGWEX)

# show GwexObs object
myObsTemp
```

---

sim.GWex.occ      *sim.GWex.occ*

---

### Description

generate boolean variates which describe the dependence between intersite occurrence correlations and wet/dry persistence

**Usage**

```
sim.GWex.occ(objGwexFit, vecMonth)
```

**Arguments**

objGwexFit	object of class GwexFit
vecMonth	vector n x 1 of integers indicating the months

**Value**

matrix of logical  
occurrences simulated

**Author(s)**

Guillaume Evin

---

sim.GWex.prec.1it	<i>sim.GWex.prec.1it</i>
-------------------	--------------------------

---

**Description**

Simulate one scenario of precipitation from the GWex model

**Usage**

```
sim.GWex.prec.1it(objGwexFit, vecDates, myseed, objGwexObs, prob.class)
```

**Arguments**

objGwexFit	object of class GwexFit
vecDates	vector of continuous dates
myseed	seed of the random generation, to be fixed if the results need to be replicated
objGwexObs	optional: necessary if we need observations to simulate (e.g. disaggregation of 3-day periods)
prob.class	vector of probabilities indicating class of "similar" mean intensities

**Value**

matrix  
Precipitation simulated for the dates contained in vec.Dates at the different stations

**Author(s)**

Guillaume Evin

---

 sim.GWex.Yt

*sim.GWex.Yt*


---

**Description**

Inverse PIT: from the probability space to the precipitation space

**Usage**

```
sim.GWex.Yt(objGwexFit, vecMonth, Yt.Pr)
```

**Arguments**

objGwexFit	object of class GwexFit
vecMonth	vector of integer indicating the months
Yt.Pr	uniform variates describing dependence between inter-site amounts

**Value**

matrix	matrix n x p of simulated non-zero precipitation intensities
--------	--

**Author(s)**

Guillaume Evin

---

sim.GWex.Yt.Pr

*sim.GWex.Yt.Pr*


---

**Description**

generate uniform variates which describe the dependence between intersite amount correlations

**Usage**

```
sim.GWex.Yt.Pr(objGwexFit, vecMonth)
```

**Arguments**

objGwexFit	object of class GwexFit
vecMonth	vector n x 1 of integer indicating the months

**Value**

matrix	matrix n x p of uniform dependent variates
--------	--

**Author(s)**

Guillaume Evin

---

```
sim.GWex.Yt.Pr.get.param
    sim.GWex.Yt.Pr.get.param
```

---

**Description**

get relevant parameters

**Usage**

```
sim.GWex.Yt.Pr.get.param(objGwexFit, iM)
```

**Arguments**

objGwexFit	object of class GwexFit
iM	integer indicating the month

**Value**

list	list of parameters
------	--------------------

**Author(s)**

Guillaume Evin

---

```
sim.Zt.MAR    sim.Zt.MAR
```

---

**Description**

generate gaussian variates which describe the spatial and temporal dependence between the sites (MAR(1) process)

**Usage**

```
sim.Zt.MAR(PAR, copulaInt, Zprev, p)
```

**Arguments**

PAR	parameters for this class
copulaInt	'Gaussian' or 'Student'
Zprev	previous Gaussian variate
p	number of stations

**Value**

matrix                    matrix n x p of uniform dependent variates

**Author(s)**

Guillaume Evin

---

sim.Zt.Spatial            *sim.Zt.Spatial*

---

**Description**

generate gaussian variates which describe the spatial dependence between the sites

**Usage**

sim.Zt.Spatial(PAR, copulaInt, p)

**Arguments**

PAR                    parameters for a class  
 copulaInt            'Gaussian' or 'Student'  
 p                      number of stations

**Value**

matrix                    matrix n x p of uniform dependent variates

**Author(s)**

Guillaume Evin

---

simGwexModel            *simGwexModel*

---

**Description**

Simulate from a GWex model

**Usage**

```
simGwexModel(
  objGwexFit,
  nb.rep = 10,
  d.start = as.Date("01011900", "%d%m%Y"),
  d.end = as.Date("31121999", "%d%m%Y"),
  objGwexObs = NULL,
  prob.class = c(0.5, 0.75, 0.9, 0.99),
  objGwexSim = NULL,
  nCluster = 1
)
```

**Arguments**

objGwexFit	an object of class <a href="#">GwexFit</a>
nb.rep	number of repetitions of scenarios
d.start	a starting date for the simulation
d.end	an ending date for the simulation
objGwexObs	optional: an object of class <a href="#">GwexObs</a> if we need the observations to simulate (disaggregation prec 3D -> 1D)
prob.class	vector of probabilities indicating class of "similar" mean intensities
objGwexSim	optional: an object of class <a href="#">GwexSim</a> if we need simulations to simulate (temp conditional to prec)
nCluster	optional, number of clusters which can be used for the parallel computation

**Value**

GwexSim	an object of class <a href="#">GwexSim</a> . Contains sim (3D-array with the simulations) and a vector of dates
---------	---

**Author(s)**

Guillaume Evin

**Examples**

```
# vector of dates
vecDates = seq(from=as.Date("01/01/2005", format="%d/%m/%Y"),
to=as.Date("31/12/2014", format="%d/%m/%Y"), by='day')

#####
# FIT AND SIMULATE FROM THE PRECIPITATION MODEL
#####
# Format observations: create a G-Wex object
myObsPrec = GwexObs(variable='Prec',date=vecDates,obs=dailyPrecipGWEX[,1,drop=FALSE])

# Fit GWEX precipitation model, default options except for the threshold th
myParPrec = fitGwexModel(myObsPrec,listOption=list(th=0.5)) # fit model
```

```

# Generate 2 scenarios for one year, using the 'GwexFit' object
mySimPrec = simGwexModel(objGwexFit=myParPrec, nb.rep=2, d.start=vecDates[1],
d.end=vecDates[10])
mySimPrec # print object

#####
# FIT AND SIMULATE FROM THE TEMPERATURE MODEL
#####
# Format observations: create a G-Wex object
myObsTemp = GwexObs(variable='Temp',date=vecDates,obs=dailyTemperGWEX)

# Fit GWEX temperature model
myParTemp = fitGwexModel(myObsTemp,listOption=list(hasTrend=TRUE,typeMargin='Gaussian',
depStation='Gaussian'))

# Generate 2 scenarios for one year, using an existing 'GwexFit' object
mySimTemp = simGwexModel(objGwexFit=myParTemp, nb.rep=2, d.start=vecDates[1],
d.end=vecDates[365],objGwexObs=myObsPrec)
mySimTemp # print object

```

---

simPrecip0cc

*simPrecipOcc*


---

### Description

find matrix of correlations leading to estimates cor between intensities

### Usage

```
simPrecip0cc(nLag, n, pr)
```

### Arguments

nLag	order of the Markov chain
n	integer indicating the length of simulated chains
pr	vector of probabilies corr. to the conditional transition probabilities

### Value

a vector Xt of length n with values 0/1 corr. to dry/wet states

### Author(s)

Guillaume Evin

---

unif.to.prec	<i>unif.to.prec</i>
--------------	---------------------

---

**Description**

from uniform variates to precipitation variates

**Usage**

```
unif.to.prec(pI, typeMargin, U)
```

**Arguments**

pI	vector of three parameters of the marginal distributions
typeMargin	type of marginal distribution: 'EGPD' or 'mixExp'
U	vector of uniform variates

**Value**

matrix	matrix of estimates p x 3
--------	---------------------------

**Author(s)**

Guillaume Evin

---

wet.day.frequency	<i>wet.day.frequency</i>
-------------------	--------------------------

---

**Description**

Estimate the wet day frequency (proportion of wet days) for all stations

**Usage**

```
wet.day.frequency(mat.prec, th)
```

**Arguments**

mat.prec	matrix of precipitation (possibly for one month/period)
th	threshold above which we consider that a day is wet (e.g. 0.2 mm)

**Value**

vector of numeric	wet day frequencies
-------------------	---------------------

**Author(s)**

Guillaume Evin

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