Package 'qualypsoss'

October 13, 2022

Type Package

Date 2022-08-31

License GPL-3

Title Uncertainties of Climate Projections using Smoothing Splines

Version 1.1.1

Author Guillaume Evin [aut, cre]

Maintainer Guillaume Evin <guillaume.evin@inrae.fr>

Imports foreach, doParallel, stats, utils, MASS, mvtnorm, graphics, grDevices,ggthemes,QUALYPSO

Description These functions use smoothing-splines for the assessment of single-member ensembles of climate projections.
- Cheng, C.-I. and P. L. Speckman (2012) <doi:10.1016/j.csda.2012.05.020>.

Depends R (>= 2.10)

Encoding UTF-8

RoxygenNote 7.1.2

NeedsCompilation no

Suggests knitr, rmarkdown

VignetteBuilder knitr

Repository CRAN

Date/Publication 2022-08-31 11:50:02 UTC

R topics documented:

`compute.change.variable`

Compute change variables

Description

Compute change variables

Usage

```
compute.change.variable(climResponse, lOpt, lDim, iCpredContUnique, iCpredCont)
```

Arguments

climResponse	output from extract.climate.response
lOpt	list of options, returned by QUALYPSOSS.check.option
lDim	list of dimensions
iCpredContUnique	index in 1:nP indicating the reference continuous predictor for the computation of change variables.
iCpredCont	index in 1:nT indicating the reference period (reference period) for the computation of change variables.

Value

list with the following fields:

- **phiStar.MCMC**: MCMC draws of climate change response
- **etaStar.MCMC**: MCMC draws of deviation from the climate change response

Author(s)

Guillaume Evin

---

extract.climate.response

Extract climate response for one time series z

Description

Extract climate response for one time series z

Usage

```
extract.climate.response(
  ClimateProjections,
  predCont,
  predContUnique,
  nMCMC,
  lam,
  uniqueFit,
  spar = spar,
  listCR = NULL
)
```

Arguments

ClimateProjections	matrix of climate projections
predCont	matrix of continuous predictor corresponding to the climate projections
predContUnique	vector of predictors for which we need fitted climate reponses
nMCMC	number of MCMC samples
lam	fixed smoothing parameter lambda
uniqueFit	logical value indicating if only one fit is applied
spar	smoothing parameter spar in smooth.spline: must be greater than zero
listCR	list of objects for the extraction of the climate response

Value

list with the following fields:

- **phi.MCMC**: MCMC draws of climate response
- **eta.MCMC**: MCMC draws of deviation from the climate response
- **deltaIV.MCMC**: MCMC draws of deltaRV
- **listCR**: list of objects for faster computation on grids

Author(s)

Guillaume Evin

---

formatQUALYPSSoutput *formatQUALYPSSoutput*

Description

formatQUALYPSSoutput

Usage

```
formatQUALYPSSoutput(
  lOpt,
  lDim,
  lScen,
  ANOVA.step1,
  ANOVA.step2,
  ANOVA.step3,
  climResponse,
  change.variable
)
```

Arguments

lOpt	list of options, returned by QUALYPSOSS.check.option
lDim	list of dimensions
lScen	list of scenario characteristics, output from QUALYPSOSS.process.scenario
ANOVA.step1	list provided by QUALYPSOSS.ANOVA.step1
ANOVA.step2	list provided by QUALYPSOSS.ANOVA.step2
ANOVA.step3	list provided by QUALYPSOSS.ANOVA.step3
climResponse	list containing phi, eta, provided by extract.climate.response
change.variable	list containing phiStar, etaStar, provided by compute.change.variable

Value

list with the following fields:

- **POINT**: list containing the mean estimate of different quantities: RESIDUALVAR (residual variability), INTERNALVAR (internal variability), GRANDMEAN (grand mean for all time steps), MAINEFFECT (list with one item per discrete predictor i, containing matrices nT x nEffi, where nEffi is the number of possible values for the discrete predictor i). EFFECTVAR, uncertainty related to the different main effect, TOTVAR Total variability, DECOMPVAR, decomposition of the total variability (percentages) for the different components, CONTRIB_EACH_EFFECT, contribution of each individual effects (percentages) to the corr. effect uncertainty.
- **BAYES**: list containing quantiles of different estimated quantities, listed in **POINT**.
- **MCMC**: MCMC draws for the different quantities.

Author(s)

Guillaume Evin

---

get.det.AR1 *get.det.AR1 return the determinant of the matrix provided by get.matrix.AR1*

Description

get.det.AR1 return the determinant of the matrix provided by get.matrix.AR1

Usage

```
get.det.AR1(nP, rho, nMO)
```

Arguments

nP	number of continuous predictors (e.g. future times)
rho	AR(1) correlation parameter in (-1,1)
nMO	number of possible simulation chains (missing and non-missing)

Value

determinant of the AR1 matrix

Author(s)

Guillaume Evin

`get.det.KMS` *get.det.KMS return the determinant of the KMS matrix*

Description

get.det.KMS return the determinant of the KMS matrix

Usage

```
get.det.KMS(nP, rho)
```

Arguments

`nP`	number of continuous predictors (e.g. future times)
`rho`	AR(1) correlation parameter in (-1,1)

Value

determinant of the KMS matrix

Author(s)

Guillaume Evin

`get.logdet.W` *get.logdet.W Return the logarithm of the determinant of the matrix W*

Description

get.logdet.W Return the logarithm of the determinant of the matrix W

Usage

```
get.logdet.W(weight.hetero, nMO, nP, rho)
```

Arguments

weight.hetero	output of get.vec.weight.hetero
nMO	number of possible simulation chains (missing and non-missing)
nP	number of continuous predictors (e.g. future times)
rho	AR(1) correlation parameter in (-1,1)

Value

logarithm of the determinant of the matrix W

Author(s)

Guillaume Evin

---

get.matrix.AR1 *get.matrix.AR1 return the matrix of AR(1) correlations corresponding to the entire ensemble*

Description

get.matrix.AR1 return the matrix of AR(1) correlations corresponding to the entire ensemble

Usage

```
get.matrix.AR1(nP, rho, nMO)
```

Arguments

nP	number of continuous predictors (e.g. future times)
rho	AR(1) correlation parameter in (-1,1)
nMO	number of possible simulation chains (missing and non-missing)

Value

C matrix n x n of AR(1) correlations where coden is the total number of predictions (all the predictions for all the possible simulation chains)

Author(s)

Guillaume Evin

`get.matrix.AR1.inv` *get.matrix.AR1.inv return the inverse matrix of AR(1) correlations corresponding to the entire ensemble*

Description

get.matrix.AR1.inv return the inverse matrix of AR(1) correlations corresponding to the entire ensemble

Usage

```
get.matrix.AR1.inv(nP, rho, nMO)
```

Arguments

`nP`	number of continuous predictors (e.g. future times)
`rho`	AR(1) correlation parameter in (-1,1)
`nMO`	number of possible simulation chains (missing and non-missing)

Value

inverse matrix n x n of AR(1) correlations where coden is the total number of predictions (all the predictions for all the possible simulation chains)

Author(s)

Guillaume Evin

`get.matrix.hetero` *get.matrix.hetero returns the matrix of weights for the computation of heteroscedastic errors corresponding to the entire ensemble*

Description

get.matrix.hetero returns the matrix of weights for the computation of heteroscedastic errors corresponding to the entire ensemble

Usage

```
get.matrix.hetero(weight.hetero, nMO)
```

Arguments

`weight.hetero`	output of `get.vec.weight.hetero`
`nMO`	number of possible simulation chains (missing and non-missing)

Value

V matrix n x n of weights where coden is the total number of predictions (all the predictions for all the possible simulation chains)

Author(s)

Guillaume Evin

`get.matrix.hetero.inv` *get.matrix.hetero.inv returns the inverse of the matrix of weights for the computation of heteroscedastic errors corresponding to the entire ensemble*

Description

get.matrix.hetero.inv returns the inverse of the matrix of weights for the computation of heteroscedastic errors corresponding to the entire ensemble

Usage

```
get.matrix.hetero.inv(weight.hetero, nMO)
```

Arguments

`weight.hetero`	output of `get.vec.weight.hetero`
`nMO`	number of possible simulation chains (missing and non-missing)

Value

inverse matrix n x n of weights where coden is the total number of predictions (all the predictions for all the possible simulation chains)

Author(s)

Guillaume Evin

`get.matrix.KMS` *get.matrix.KMS Return the square Kac-Murdoch-Szego matrix for a rho correlation and n lines/colums*

Description

get.matrix.KMS Return the square Kac-Murdoch-Szego matrix for a rho correlation and n lines/colums

Usage

```
get.matrix.KMS(n, rho)
```

Arguments

`n`	nummber of lines/columns of the square matrix
`rho`	correlation parameter in [0,1]

Value

n x n Kac-Murdock-Szego matrix

Author(s)

Guillaume Evin

References

Kac, M., W. L. Murdock, and G. Szego. 1953. 'On the Eigen-Values of Certain Hermitian Forms' Journal of Rational Mechanics and Analysis 2: 767-800.

`get.matrix.KMSinv` *get.matrix.KMSinv return the inverse of the square Kac-Murdock-Szego matrix for a rho correlation and n lines/colums*

Description

get.matrix.KMSinv return the inverse of the square Kac-Murdock-Szego matrix for a rho correlation and n lines/colums

Usage

```
get.matrix.KMSinv(n, rho)
```

Arguments

`n`	nummber of lines/columns of the square matrix
`rho`	correlation parameter in (-1,1)

Value

n x n Kac-Murdock-Szego matrix

Author(s)

Guillaume Evin

References

Kac, M., W. L. Murdock, and G. Szego. 1953. 'On the Eigen-Values of Certain Hermitian Forms' Journal of Rational Mechanics and Analysis 2: 767-800.

`get.matrix.W` *get.matrix.W return the matrix of W = V x C x V for the treatment of heteroscedastic and AR(1) errors see Wang (2011) section 5.3 for further details*

Description

get.matrix.W return the matrix of W = V x C x V for the treatment of heteroscedastic and AR(1) errors see Wang (2011) section 5.3 for further details

Usage

```
get.matrix.W(weight.hetero, nMO, nP, rho)
```

Arguments

`weight.hetero`	output of `get.vec.weight.hetero`
`nMO`	number of possible simulation chains (missing and non-missing)
`nP`	number of continuous predictors (e.g. future times)
`rho`	AR(1) correlation parameter in (-1,1)

Value

matrix n x n where coden is the total number of predictions (all the predictions for all the possible simulation chains)

Author(s)

Guillaume Evin

References

Wang, Y. 2011. 'Spline Smoothing with Heteroscedastic and/or Correlated Errors.' Smoothing Splines. Chapman and Hall/CRC. https://doi.org/10.1201/b10954-11.

`get.matrix.Winv` *get.matrix.Winv return the inverse matrix of W = V x C x V for the treatment of heteroscedastic and AR(1) errors see Wang (2011) section 5.3 for further details*

Description

get.matrix.Winv return the inverse matrix of W = V x C x V for the treatment of heteroscedastic and AR(1) errors see Wang (2011) section 5.3 for further details

Usage

```
get.matrix.Winv(weight.hetero, nMO, nP, rho)
```

Arguments

`weight.hetero`	output of `get.vec.weight.hetero`
`nMO`	number of possible simulation chains (missing and non-missing)
`nP`	number of continuous predictors (e.g. future times)
`rho`	AR(1) correlation parameter in (-1,1)

Value

inverse matrix n x n of weights where coden is the total number of predictions (all the predictions for all the possible simulation chains)

Author(s)

Guillaume Evin

References

Wang, Y. 2011. 'Spline Smoothing with Heteroscedastic and/or Correlated Errors' Smoothing Splines. Chapman and Hall/CRC. https://doi.org/10.1201/b10954-11.

`get.spectral.decomp` *get.spectral.decomp*

Description

compute different objects used for the application of Smoothing-Splines ANOVA (SS-ANOVA)

Usage

```
get.spectral.decomp(SIGMA)
```

Arguments

SIGMA	reproducing kernel

Value

list with the following fields:

- **Q**: Matrix of eigen vectors n x r,
- **D**: Vector of nonzero eigen values (size r),
- **r**: Number of nonzero eigen values (scalar).

Author(s)

Guillaume Evin

---

get.target.logdensity.rho

get.target.density.rho Return the log-density of the full conditional distribution for the parameter rho

---

Description

get.target.density.rho Return the log-density of the full conditional distribution for the parameter rho

Usage

```
get.target.logdensity.rho(nFull, deltaRV, distSS, weight.hetero, nMO, nP, rho)
```

Arguments

nFull	nP x nMO
deltaRV	variance of the residual terms for the max value of the continuous predictor
distSS	sum of square distances between the climate change responses and the ANOVA model
weight.hetero	output of get.vec.weight.hetero
nMO	number of possible simulation chains (missing and non-missing)
nP	number of continuous predictors (e.g. future times)
rho	AR(1) correlation parameter in (-1,1)

Value

log-density of the full conditional distribution

Author(s)

Guillaume Evin

get.vec.weight.hetero *get.vec.weight.hetero returns the vector of weights for the computation of heteroscedastic errors corresponding to one simulation chain*

Description

get.vec.weight.hetero returns the vector of weights for the computation of heteroscedastic errors corresponding to one simulation chain

Usage

```
get.vec.weight.hetero(nP, type.weight.hetero)
```

Arguments

nP	length of the continuous predictor for which we want to obtain the prediction (e.g. time) we suppose that continuous predictor is regularly spaced (e.g. 1990,2000,2010,...)
type.weight.hetero	"constant" (homoscedastic) or "linear" (heteroscedastic)

Value

vector of square roots of weights of the same length than predContUnique

Author(s)

Guillaume Evin

get.yMCMC *get.yMCMC*

Description

Get matrix nMCMC x nFull of climate responses where nMCMC is the number of MCMC draws and nFull is the number of possible combinations of predictors (discrete AND continuous),

Usage

```
get.yMCMC(lOpt, lDim, lScen, change.variable)
```

Arguments

lOpt	list of options, returned by QUALYPSOSS.check.option
lDim	list of dimensions
lScen	list of scenario characteristics, output from QUALYPSOSS.process.scenario
change.variable	output from compute.change.variable containing MCMC draws of climate change response

Value

strongyMCMC: matrix nMCMC x nFull of climate responses

Author(s)

Guillaume Evin

---

plotQUALYPSOSSClimateChangeResponse *plotQUALYPSOSSClimateChangeResponse*

Description

Plot climate change responses.

Usage

```
plotQUALYPSOSSClimateChangeResponse(
  QUALYPSOSSOUT,
  lim = NULL,
  col = NULL,
  xlab = "Years",
  ylab = expression(phi^{     star }),
  ...
)
```

Arguments

QUALYPSOSSOUT	output from QUALYPSOSS
lim	y-axis limits (default is NULL)
col	color for the lines
xlab	x-axis label
ylab	y-axis label
...	additional arguments to be passed to plot

Author(s)

Guillaume Evin

plotQUALYPSOSSClimateResponse *plotQUALYPSOSSClimateResponse*

Description

Plot climate responses.

Usage

```
plotQUALYPSOSSClimateResponse(
  QUALYPSOSSOUT,
  lim = NULL,
  col = NULL,
  xlab = "Years",
  ylab = expression(phi),
  ...
)
```

Arguments

QUALYPSOSSOUT	output from QUALYPSOSS
lim	y-axis limits (default is NULL)
col	color for the lines
xlab	x-axis label
ylab	y-axis label
...	additional arguments to be passed to plot

Author(s)

Guillaume Evin

plotQUALYPSOSSeffect *plotQUALYPSOSSeffect*

Description

Plot prediction of ANOVA effects for one main effect. By default, we plot we plot the credible intervals corresponding to a probability 0.95.

Usage

```
plotQUALYPSOSSeffect(
  QUALYPSOSSOUT,
  iEff,
  CIlevel = c(0.025, 0.975),
  lim = NULL,
  col = 1:20,
  xlab = "Continuous predictor",
  ylab = "Effect",
  addLegend = TRUE,
  ...
)
```

Arguments

QUALYPSOSSOUT	output from QUALYPSOSS
iEff	index of the main effect to be plotted in QUALYPSOSSOUT$listScenario$predDiscreteUnique
CIlevel	probabilities for the credible intervals, default is equal to c(0.025,0.975)
lim	y-axis limits (default is NULL)
col	colors for each effect
xlab	x-axis label
ylab	y-axis label
addLegend	if TRUE, a legend is added
...	additional arguments to be passed to plot

Author(s)

Guillaume Evin

---

plotQUALYPSOSSgrandmean

plotQUALYPSOSSgrandmean

Description

Plot prediction of grand mean ensemble. By default, we plot the credible interval corresponding to a probability 0.95.

Usage

```
plotQUALYPSOSSgrandmean(
  QUALYPSOSSOUT,
  CIlevel = c(0.025, 0.975),
  lim = NULL,
  col = "black",
  xlab = "Continuous predictor",
  ylab = "Grand mean",
  addLegend = T,
  ...
)
```

Arguments

QUALYPSOSSOUT	output from QUALYPSOSS
CIlevel	probabilities for the credible intervals, default is equal to c(0.025,0.975)
lim	y-axis limits (default is NULL)
col	color for the overall mean and the credible interval
xlab	x-axis label
ylab	y-axis label
addLegend	if TRUE, a legend is added
...	additional arguments to be passed to plot

Author(s)

Guillaume Evin

---

plotQUALYPSOSSTotalVarianceDecomposition *plotQUALYPSOSSTotalVarianceDecomposition*

Description

Plot fraction of total variance explained by each source of uncertainty.

Usage

```
plotQUALYPSOSSTotalVarianceDecomposition(
  QUALYPSOSSOUT,
 col = c("orange", "yellow", "cadetblue1", "blue1", "darkgreen", "darkgoldenrod4",
    "darkorchid1"),
  xlab = "Continuous predictor",
  ylab = "% Total Variance",
  addLegend = TRUE,
  ...
)
```

Arguments

QUALYPSOSSOUT	output from QUALYPSOSS
col	colors for each source of uncertainty, the first two colors corresponding to internal variability and residual variability, respectively
xlab	x-axis label
ylab	y-axis label
addLegend	if TRUE, a legend is added
...	additional arguments to be passed to plot

Author(s)

Guillaume Evin

---

predGlobTemp *Annual average of global temperatures simulated by different CMIP5 GCMs at the planetary scale for the period 1971-2099*

Description

Annual average of global temperatures simulated by different CMIP5 GCMs at the planetary scale for the period 1971-2099

Usage

```
data(predGlobTemp)
```

Format

matrix 129 years x 20 scenarios

Author(s)

Guillaume Evin <guillaume.evin@inrae.fr>

predGlobTempUnique *Equally spaced vector of simulated global temperatures over the period 1971-2099 for the RCP8.5*

Description

Equally spaced vector of simulated global temperatures over the period 1971-2099 for the RCP8.5

Usage

```
data(predGlobTempUnique)
```

Format

vector of length 13

Author(s)

Guillaume Evin <guillaume.evin@inrae.fr>

predTime *Years 1971-2099 repeated for the 20 scenarios*

Description

Years 1971-2099 repeated for the 20 scenarios

Usage

```
data(predTime)
```

Format

matrix 129 years x 20 scenarios

Author(s)

Guillaume Evin <guillaume.evin@inrae.fr>

predTimeUnique *Equally spaced vector of years over the period 1971-2099*

Description

Equally spaced vector of years over the period 1971-2099

Usage

```
data(predTimeUnique)
```

Format

vector of length 13

Author(s)

Guillaume Evin <guillaume.evin@inrae.fr>

QUALYPSOSS *QUALYPSOSS*

Description

QUALYPSOSS

Usage

```
QUALYPSOSS(
  ClimateProjections,
  scenAvail,
  vecYears = NULL,
  predCont = NULL,
  predContUnique = NULL,
  iCpredCont = NULL,
  iCpredContUnique = NULL,
  listOption = NULL,
  RK = NULL
)
```

Arguments

`ClimateProjections`
: matrix `nT` x `nS` of climate projections where `nT` is the number of values for the continuous predictor (years, global temperature) and `nS` the number of scenarios.

`scenAvail`
: matrix of scenario characteristics `nS` x `nK` where `nK` is the number of discrete predictors.

`vecYears`
: (optional) vector of years of length `nT` (by default, a vector `1:nT`).

`predCont`
: (optional) matrix `nT` x `nS` of continuous predictors.

`predContUnique`
: (optional) vector of length `nP` corresponding to the continuous predictor for which we want to obtain the prediction.

`iCpredCont`
: (optional) index in `1:nT` indicating the reference period (reference period) for the computation of change variables.

`iCpredContUnique`
: (optional) index in `1:nP` indicating the reference continuous predictor for the computation of change variables.

`listOption`
: (optional) list of options

- **spar**: if `uniqueFit` is true, smoothing parameter passed to the function smooth.spline.
- **lambdaClimateResponse**: smoothing parameter > 0 for the extraction of the climate response.
- **lambdaHyperParANOVA**: hyperparameter b for the λ parameter related to each predictor g.
- **typeChangeVariable**: type of change variable: "abs" (absolute, value by default) or "rel" (relative).
- **nBurn**: number of burn-in samples (default: 1000). If `nBurn` is too small, the convergence of MCMC chains might not be obtained.
- **nKeep**: number of kept samples (default: 2000). If `nKeep` is too small, MCMC samples might not be represent correctly the posterior distributions of inferred parameters.
- **quantileCompress**: vector of probabilities (in [0,1]) for which we compute the quantiles from the posterior distributions `quantileCompress = c(0.005,0.025,0.05,0.5,0.95,0.975,0.995)` by default.
- **uniqueFit**: logical, if `FALSE` (default), climate responses are fitted using Bayesian smoothing splines, otherwise,if `TRUE`, a unique cubic smoothing spline is fitted for each run, using the function smooth.spline.
- **returnMCMC**: logical, if `TRUE`, the list `MCMC` contains MCMC chains.
- **returnOnlyCR**: logical, if `TRUE` (default), only Climate Responses are fitted and returned.
- **type.temporal.dep**: "iid" for independent errors or "AR1" (default) for autocorrelated errors.
- **type.hetero**: "constant" for homoscedastic errors or "linear" (default) for heteroscedastic errors.

`RK`
: Reproducing kernels: list

Value

list with the following fields:

- **POINT**: list containing the mean estimate of different quantities: `RESIDUALVAR` (residual variability), `INTERNALVAR` (internal variability), `GRANDMEAN` (grand mean for all time steps), `MAINEFFECT` (list with one item per discrete predictor `i`, containing matrices `nT` x `nEffi`, where `nEffi` is the number of possible values for the discrete predictor `i`). `EFFECTVAR`, uncertainty related to the different main effect, `TOTVAR` Total variability, `DECOMPVAR`, decomposition of the total variability (percentages) for the different components, `CONTRIB_EACH_EFFECT`, contribution of each individual effects (percentages) to the corr. effect uncertainty.
- **BAYES**: list containing quantiles of different estimated quantities, listed in **POINT**.
- **MCMC**: list containing the MCMC chains (not returned by default).
- **climateResponse**: list containing different objects related to the extraction of the climate response. phiStar (ϕ^*) is an array `nQ` x `nS` x `nP` containing climate change responses, where `nQ` is the number of returned quantiles, `nS` is the number of scenarios and `nP` is the length of `predContUnique` (e.g. number of future years). Similarly, etaStar (η^*) contains the deviation from the climate change response. phi (ϕ) contains the climate responses and eta (η) contains the deviations from the climate responses.
- **listCR**: list containing objects created during the extraction of the climate responses
- **ClimateProjections**: argument of the call to the function, for records.
- **predCont**: (optional) argument of the call to the function, for records.
- **predContUnique**: (optional) argument of the call to the function, for records.
- **predDiscreteUnique**: list of possible values taken by the discrete predictors given in `scenAvail`.
- **listOption**: list of options
- **listScenario**: list of scenario characteristics (obtained from `QUALYPSOSS.process.scenario`)
- **RK**: list containing the reproducing kernels

Author(s)

Guillaume Evin

Examples

```
##############################################################################
# SYNTHETIC SCENARIOS
##############################################################################
# create nS=3 fictive climate scenarios with 2 GCMs and 2 RCMs, for a period of nY=20 years
n=20
t=1:n/n

# GCM effects (sums to 0 for each t)
effGCM1 = t*2
effGCM2 = t*-2

# RCM effects (sums to 0 for each t)
effRCM1 = t*1
```

```
effRCM2 = t*-1

# These climate scenarios are a sum of effects and a random gaussian noise
scenGCM1RCM1 = effGCM1 + effRCM1 + rnorm(n=n,sd=0.5)
scenGCM1RCM2 = effGCM1 + effRCM2 + rnorm(n=n,sd=0.5)
scenGCM2RCM1 = effGCM2 + effRCM1 + rnorm(n=n,sd=0.5)
ClimateProjections = cbind(scenGCM1RCM1,scenGCM1RCM2,scenGCM2RCM1)

# Here, scenAvail indicates that the first scenario is obtained with the combination of the
# GCM "GCM1" and RCM "RCM1", the second scenario is obtained with the combination of
# the GCM "GCM1" and RCM "RCM2" and the third scenario is obtained with the combination
# of the GCM "GCM2" and RCM "RCM1".
scenAvail = data.frame(GCM=c('GCM1','GCM1','GCM2'),RCM=c('RCM1','RCM2','RCM1'))

listOption = list(nBurn=20,nKeep=30,type.temporal.dep="iid",type.hetero="constant")
QUALYPSOSSOUT = QUALYPSOSS(ClimateProjections=ClimateProjections,scenAvail=scenAvail,
listOption=listOption)

# QUALYPSOSSOUT output contains many different information about climate projections uncertainties,
# which can be plotted using the following functions.

# plotQUALYPSOSSClimateResponse draws the climate responses, for all simulation chains,
# in comparison to the raw climate responses.
plotQUALYPSOSSClimateResponse(QUALYPSOSSOUT)

# plotQUALYPSOSSClimateChangeResponse draws the climate change responses, for all simulation chains.
plotQUALYPSOSSClimateChangeResponse(QUALYPSOSSOUT)

# plotQUALYPSOSSeffect draws the estimated effects, for a discrete predictor specified by iEff,
# as a function of the continuous predictor.
plotQUALYPSOSSeffect(QUALYPSOSSOUT, iEff = 1)
plotQUALYPSOSSeffect(QUALYPSOSSOUT, iEff = 2)

# plotQUALYPSOSSgrandmean draws the estimated grand mean, as a function of the continuous predictor.
plotQUALYPSOSSgrandmean(QUALYPSOSSOUT)

# plotQUALYPSOSSTotalVarianceDecomposition draws the decomposition of the total variance responses,
# as a function of the continuous predictor.
plotQUALYPSOSSTotalVarianceDecomposition(QUALYPSOSSOUT)
```

QUALYPSOSS.ANOVA.step1

QUALYPSOSS.ANOVA.step1

Description

SSANOVA decomposition of the ensemble of climate change responses using a Bayesian approach. The different fields of the returned list contain n samples from the posterior distributions of the different inferred quantities. In this first step, the residual errors are assumed iid

Usage

```
QUALYPSOSS.ANOVA.step1(lOpt, lDim, yMCMC, RK)
```

Arguments

`lOpt`	list of options, returned by `QUALYPSOSS.check.option`
`lDim`	list of dimensions
`yMCMC`	array `nMCMC` x `nFull` of climate change responses
`RK`	large object containing the reproducing kernels, returned by `QUALYPSOSS.get.RK`

Value

list containing diverse information aboutwith the following fields:

- **g.MCMC**: Smooth effects `g`: array `n` x `nFull` x `K` where `nFull` is the number of possible combinations of predictors (discrete AND continuous),
- **nu.MCMC**: Smooth effects `nu`, a list with matrices of eigen vectors
- **lambda.MCMC**: Smoothing parameters: matrix `n` x `K`,
- **deltaRV.MCMC**: Residual variance: vector of length `n`,
- **g.hat**: Smooth effects estimates: matrix `nFull` x `K` where
- **nu.hat**: Smooth effects estimates: a list with estimates of eigen vectors,
- **lambda.hat**: Smoothing parameters estimates: vector of length `K`,
- **deltaRV.hat**: Residual variance estimate.
- **logLK**: vector of log-likelihood values of the draws
- **logPost**: vector of log-posterior values of the draws
- **Schwarz**: Schwarz criteria
- **BIC**: BIC criteria

Author(s)

Guillaume Evin

`QUALYPSOSS.ANOVA.step2`

QUALYPSOSS.ANOVA.step2

Description

SSANOVA decomposition of the ensemble of climate change responses using a Bayesian approach. In this second step, we infer deltaRV (variance of the residual errors) and phi (autocorrelation lag-1) considering hetero-autocorrelated residual errors, conditionally to smooth effects inferred in `QUALYPSOSS.ANOVA.step1`

Usage

```
QUALYPSOSS.ANOVA.step2(lOpt, lDim, yMCMC, gSum.step1, deltaRV.step1)
```

Arguments

lOpt	list of options, returned by QUALYPSOSS.check.option
lDim	list of dimensions
yMCMC	array nMCMC x nFull of climate change responses
gSum.step1	sum of smooth effect estimates provided by QUALYPSOSS.ANOVA.step1
deltaRV.step1	residual variance estimate provided by QUALYPSOSS.ANOVA.step1

Value

list containing diverse information aboutwith the following fields:

- **rho.MCMC**: autocorrelation parameter of the AR(1) process: vector of length n
- **deltaRV.MCMC**: Residual variance: vector of length n,
- **rho.hat**: autocorrelation parameter estimate of the AR(1) process,
- **deltaRV.hat**: Residual variance estimate.

Author(s)

Guillaume Evin

QUALYPSOSS.ANOVA.step3

QUALYPSOSS.ANOVA.step3

Description

SSANOVA decomposition of the ensemble of climate change responses using a Bayesian approach. In this second step, we infer deltaRV (variance of the residual errors) and phi (autocorrelation lag-1) considering hetero-autocorrelated residual errors, conditionally to smooth effects inferred in QUALYPSOSS.ANOVA.step1

Usage

```
QUALYPSOSS.ANOVA.step3(
  lOpt,
  lDim,
  yMCMC,
  RK,
  g.step1,
  lambda.step1,
  rho.step2,
  deltaRV.step2
)
```

Arguments

lOpt	list of options, returned by QUALYPSOSS.check.option
lDim	list of dimensions
yMCMC	array nMCMC x nFull of climate change responses
RK	large object containing the reproducing kernels, returned by QUALYPSOSS.get.RK
g.step1	smooth effect estimates provided by QUALYPSOSS.ANOVA.step1
lambda.step1	smooth parameter estimates provided by QUALYPSOSS.ANOVA.step1
rho.step2	lag-1 autocorrelation estimate provided by QUALYPSOSS.ANOVA.step2
deltaRV.step2	residual variance estimate provided by QUALYPSOSS.ANOVA.step2

Value

list containing diverse information aboutwith the following fields:

- **g.MCMC**: Smooth effects g: array n x nFull x K where nFull is the number of possible combinations of predictors (discrete AND continuous),
- **g.hat**: Smooth effects estimates: matrix nFull x K where nFull is the number of possible combinations of predictors (discrete AND continuous),
- **Schwarz**: Schwarz criteria
- **BIC**: BIC criteria

Author(s)

Guillaume Evin

QUALYPSOSS.check.option

QUALYPSOSS.check.option

Description

Check if input options provided in QUALYPSOSS are valid and assigned default values if missing.

Usage

```
QUALYPSOSS.check.option(listOption)
```

Arguments

listOption	list of options

Value

List containing the complete set of options.

Author(s)

Guillaume Evin

`QUALYPSOSS.get.RK` *QUALYPSOSS.get.RK*

Description

Get reproducing kernel for each discrete predictor

Usage

```
QUALYPSOSS.get.RK(X, nK)
```

Arguments

`X`	matrix of predictors
`nK`	number of discrete predictors

Value

strongRK: list containing the reproducing kernels, obtained using spectral decomposition

Author(s)

Guillaume Evin

`QUALYPSOSS.process.scenario` *QUALYPSOSS.process.scenario*

Description

compute different objects used for the application of Smoothing-Splines ANOVA (SS-ANOVA), these objects being processed outputs of the scenario characteristics

Usage

```
QUALYPSOSS.process.scenario(scenAvail, predContUnique)
```

Arguments

`scenAvail`	matrix of scenario characteristics `nS` x `nK`.
`predContUnique`	(optional) unique values of continuous predictors.

Value

list containing diverse information aboutwith the following fields:

- **scenAvail**: Record first argument of the function,
- **predContUnique**: Record second argument of the function,
- **XFull**: data.frame with all possible combinations of predictors (continuous AND discrete),
- **nFull**: number of rows of `XFull`,
- **nK**: Number of columns of `ScenAvail` (i.e. number of discrete predictors),
- **predDiscreteUnique**: List containing possible values for each discrete predictor.

Author(s)

Guillaume Evin

`reproducing.kernel` *reproducing.kernel*

Description

see par 2.3 in Cheng and Speckman

Usage

```
reproducing.kernel(x, y = NULL, type, typeRK = "Cheng")
```

Arguments

`x`	vector of predictors (continuous or discrete)
`y`	vector of predictors (continuous or discrete)
`type`	'continuous' or 'discrete'
`typeRK`	type of reproducing kernels: c('Cheng','Gu','Gaussian')

Value

matrix n x n

Author(s)

Guillaume Evin

scenAvail *scenAvail gives the GCM and RCM which have been used for the 20 climate projections*

Description

scenAvail gives the GCM and RCM which have been used for the 20 climate projections

Usage

```
data(scenAvail)
```

Format

data.frame with 20 rows and two columns: GCM and RCM

Author(s)

Guillaume Evin <guillaume.evin@inrae.fr>

vecYears *vecYears gives the years corr. to Y, i.e. from 1971 to 2099*

Description

vecYears gives the years corr. to Y, i.e. from 1971 to 2099

Usage

```
data(vecYears)
```

Format

vectors of length 129

Author(s)

Guillaume Evin <guillaume.evin@inrae.fr>

Y *climate projections of mean winter (DJF) temperature over the SREX region CEU simulated by 20 combinations of CMIP5 GCMs and RCMs for the period 1971-2099*

Description

climate projections of mean winter (DJF) temperature over the SREX region CEU simulated by 20 combinations of CMIP5 GCMs and RCMs for the period 1971-2099

Usage

```
data(Y)
```

Format

matrix 129 years x 20 scenarios

Author(s)

Guillaume Evin <guillaume.evin@inrae.fr>

References

Seneviratne, S. I. et al. Changes in Climate Extremes and their Impacts on the Natural Physical Environment, in: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change, edited by: Field, C., Barros, V., Stocker, T., and Dahe, Q., Cambridge University Press, Cambridge, 109-230, https://doi.org/10.1017/CBO9781139177245.006, 2012

Index