Package 'CompoundEvents'

March 15, 2026

Type Package

Title Statistical Modeling of Compound Events

Version 1.0

Description Tools for extracting occurrences, assessing potential driving factors, predicting occurrences, and quantifying impacts of compound events in hydrology and climatology. Please see Hao Zengchao et al. (2022) <doi:10.1016/j.earscirev.2022.104241>.

Depends R (>= 4.0.0)

License GPL-3

Encoding UTF-8

Imports stats,pROC,mvtnorm

LazyData true

RoxygenNote 7.3.3

Suggests testthat (>= 3.0.0)

Config/testthat/edition 3

NeedsCompilation no

Author Zengchao Hao [aut, cre]

Maintainer Zengchao Hao <z.hao4univ@gmail.com>

Repository CRAN

Date/Publication 2026-03-15 12:40:09 UTC

Contents

`CompoundEvents-package`

Statistical Modeling of Compound Events

Description

Tools for extracting occurrences, assessing potential driving factors, predicting occurrences, and quantifying impacts of compound events (with focus on dry-hot events) in hydrology and climatology.

Details

Examples of compound events in hydroclimatology with focus on compound dry-hot events. The function `GetDH` is used for extracting occurrences based on thresholds of dry and hot indicators. The function `ChangeDH` is used for changes in compound dry and hot events. The function `DriverLogit` is used for assessing potential driving factors of compound events based on logistic regression model. The function `PredLogit` is used for predicting occurrences of compound events. The function `ImpactMGDH` is used for quantifying impacts of compound dry and hot events on a sector (e.g., crop yield, GPP,NDVI) based on meta-Gaussian model. The function `SCEIDH` is used for computing the standardized compound event index of compound dry-hot events.

Author(s)

Zengchao Hao

References

Hao, Z., et al.(2013). Changes in concurrent monthly precipitation and temperature extremes. Environ. Res. Lett. 8: 034014.

Hao, Z. et al. (2019). A monitoring and prediction system for compound dry and hot events. Environ. Res. Lett., 14:114034.

Hao, Z. et al. (2019). Statistical prediction of the severity of compound dry-hot events based on ENSO . J. Hydrol., 572: 243-250.

Feng, S. et al. (2019). Probabilistic evaluation of the impact of compound dry-hot events on global maize yields. Sci. Total. Environ., 689: 1228-1234.

Hao, Z et al. (2022). Compound droughts and hot extremes: Characteristics, drivers, changes, and impacts. Earth Sci. Rev., 235, 104241.

ACCU *Obtain the accumulation of monthly hydro-climatic variables*

Description

Obtain the accumulation of monthly hydro-climatic variables

Usage

```
ACCU(X, ts = 6)
```

Arguments

X	The vector of monthly hydro-climatic variables of n years. ts is the accumulated time scale.
ts	The accumulated time scale

Examples

```
X=runif(120, min = 0, max = 100) # 10-year monthly data
Y<-ACCU(X,ts=3) # Compute the 3 month  accumulated series
```

ChangeDH *Changes in compound dry-hot events*

Description

Assess absolute/relative changes in compound dry-hot (DH) events at the monthly scale and event occurrences at the annual scale.

Usage

```
ChangeDH(pre,tem,threp,thret)
```

Arguments

pre	monthly precipitation of several decades
tem	monthly temperature of several decades
threp	Threshold of precipitation (e.g., 20th percentile)
thret	Threshold of temperature (e.g., 80th percentile)

Value

The absolute/relative change for each month and annual occurrence

References

Hao, Z. et al. (2018). A multivariate approach for statistical assessments of compound extremes. J. Hydrol., 565: 87-94.

Hao, Z. et al. (2019). A monitoring and prediction system for compound dry and hot events. Environ. Res. Lett., 14:114034.

Examples

```
pre=runif(1200, min = 0, max = 100) # 100-year monthly precipitation
tem=runif(1200, min = 0, max = 100) # 100-year monthly temperature
threp=20 #Specify the percentile-based threshold
thret=80 # Specify the percentile-based threshold
chg<-ChangeDH(pre,tem,threp,thret) #  chg$abschg,chg$relchg, chg$yrtotal
```

`ChangeWH` *Changes in compound humid-hot events*

Description

Assess changes in compound humid-hot (WH) occurrences at monthly and annual scales.

Usage

```
ChangeWH(pre,tem,threp,thret)
```

Arguments

`pre`	monthly precipitation of several decades
`tem`	monthly temperature of several decades
`threp`	Threshold of precipitation (e.g., 80th percentile)
`thret`	Threshold of temperature (e.g., 80th percentile)

Value

The absolute/relative change for each month and annual occurrence

References

Hao, Z., AghaKouchak, A., Phillips, T.J., 2013. Changes in concurrent monthly precipitation and temperature extremes. Environ. Res. Lett. 8(3), 034014.

Examples

```
pre=runif(1200, min = 0, max = 100) # 100-year monthly precipitation
tem=runif(1200, min = 0, max = 100) # 100-year monthly temperature
threp=80 #Specify the percentile-based threshold
thret=80 # Specify the percentile-based threshold
chg<-ChangeWH(pre,tem,threp,thret) #  chg$abschg,chg$relchg, chg$yrtotal
```

dfptng — *Monthly precipitation (pre), temperature (tem), Niño3.4 (nino) and GPP(gpp)*

Description

A dataset of monthly precipitation, temperature, and Niño3.4 index for 1951-2016 and monthly GPP for 1981–2016 (1951-1980 are NAN).

Usage

```
data(dfptng)
```

Format

A data frame with 792 rows (12 months × 66 years) and 4 variables:

pre Monthly precipitation(unit:mm/month)

tem Monthly average temperature (unit: °C)

nino Monthly ENSO index (e.g., Nino3.4)

gpp GPP

Source

The data were obtained from ERA-5, NOAA, and FLUXCOM.

DriverLogit — *Assess potential driving factors of compound dry-hot events.*

Description

Use logistic regression model to establish relationship between climate indices (e.g., ENSO) and occurrences of compound dry-hot events.

Usage

```
DriverLogit(Y,X)
```

Arguments

Y	Occurrence of compound dry-hot events (0-1 binary variable)
X	Climate index as the driving factor of compound events (e.g., ENSO)

Value

slope parameter and associated p-value

References

Hao, Z. et al. (2019). A monitoring and prediction system for compound dry and hot events. Environ. Res. Lett., 14:114034.

Examples

```
X=c(-0.7,-1.2,1.3,0.7,-0.6,1.1,-0.5,0.8,0.5,
-0.5,1.6,-1.8,-0.5,-1.4,-0.1,2.2,-0.7,-1.1, 0.6, -1.7) # climate indices
Y=c(0,0,1,1,0,0,0,0,0,0,1,0,1,0,0,1,0,0,0,0 )   # dry-hot occurrences
div<-DriverLogit(Y,X)  # div$slope and div$pvalue
```

Empdis1 *Univariate empirical probability*

Description

Compute univariate empirical probability

Usage

```
Empdis1(mp)
```

Arguments

mp	monthly precipitation of a month for several decades

Value

The empirical probability

References

Hao, Z. et al., 2019a. Statistical prediction of the severity of compound dry-hot events based on El Ni??o-Southern Oscillation. J. Hydrol., 572, 243-250.

Examples

```
mp=matrix(rnorm(120,0,1),ncol=1)
ep1<-Empdis1(mp)
```

Empdis2 *Bivariate empirical probability*

Description

Compute bivariate empirical probability

Usage

```
Empdis2(mp,mt)
```

Arguments

mp	monthly precipitation of a month for several decades
mt	monthly temperature of a month for several decades

Value

The bivariate empirical probability

References

Hao, Z. et al., 2019a. Statistical prediction of the severity of compound dry-hot events based on El Ni??o-Southern Oscillation. J. Hydrol., 572, 243-250.

Examples

```
mp=matrix(rnorm(120,0,1),ncol=1)
mt=matrix(rnorm(120,0,1),ncol=1)
ep2<-Empdis2(mp,mt)
```

GetDH *Occurrence of compound dry-hot events*

Description

Get compound dry-hot (DH) events based on thresholds precipitation and temperature, resulting in a 0-1The binary variable

Usage

```
GetDH(mp,mt,threp,thret)
```

Arguments

mp	Precipitation
mt	Temperature
threp	Threshold of precipitation (e.g., 20th percentile)
thret	Threshold of temperature (e.g., 80th percentile)

Value

The occurrence of compound dry-hot events (0-1 binary variable)

References

Hao, Z. et al. (2018). A multivariate approach for statistical assessments of compound extremes. J. Hydrol., 565: 87-94.

Hao, Z. et al. (2019). A monitoring and prediction system for compound dry and hot events. Environ. Res. Lett., 14:114034.

Examples

```
mp=matrix(rnorm(60,0,1),ncol=1) # prec. of a month (e.g., August,60 years)
mt=matrix(rnorm(60,0,1),ncol=1) # temp. of a  month (e.g., August,60 years)
threp=20 #Specify the percentile-based threshold
thret=80 #Specify the percentile-based threshold
DH<-GetDH(mp,mt,threp,thret) # 0-1 series
```

GetWH *Occurrence of compound wet-hot events*

Description

Extract compound wet-hot (WH) occurrences based on thresholds of precipitation and temperature.The binary variable of the WH (or wet-warm,WW) event can be obtained.

Usage

```
GetWH(mp,mt,threp,thret)
```

Arguments

mp	Precipitation
mt	Temperature
threp	Threshold of precipitation (e.g., 80th percentile)
thret	Threshold of temperature (e.g., 80th percentile)

Value

The occurrence of compound wet-hot events (0-1 binary variable)

References

Hao, Z. et al (2013). Changes in concurrent monthly precipitation and temperature extremes. Environ. Res. Lett., 8(3): 034014.

Examples

```
mp=matrix(rnorm(120,0,1),ncol=1)
mt=matrix(rnorm(120,0,1),ncol=1)
threp=80
thret=80
WH<-GetWH(mp,mt,threp,thret)
```

ImpactMGDH *Impacts of concurrent droughts and hot extremes*

Description

Use meta-Gaussian model to construct conditional distributions of the standardized impact variable (SII) given SPI and STI (represented by random variables of Z, X, and Y). The output include (1) the conditional mean and variance of STI given SPI and STI (e.g., X0=-1.2 and y0=1.2) (2)The conditional probability of P(SII<=z0|SPI<=x0, STI>y0), or lower GPP given dry-hot conditions

Usage

```
ImpactMGDH(mp,mt,mi,x0,y0,z0=NULL)
```

Arguments

mp	monthly precipitation of a month (e.g., August)
mt	monthly temperature of a month (e.g., August)
mi	Impact variable of a month (e.g., GPP, Crop yield)
x0	Initial condition of SPI (e.g., -1.2, dry conditions)
y0	Initial condition of STI (e.g., 1.2, hot conditions)
z0	Initial condition of standardized impact indicator(e.g.,0, low GPP)

Value

(1) Conditional mean/variance at SPI=x0, STI=y0, here z0=NULL (2)conditional probability of lower SII given lower SPI and higher STI or P(SZI<=z0|SPI<=x0, STI>y0), here z0 should be specified

References

Feng S.,Hao Z., et al. (2019). Probabilistic evaluation of the impact of compound dry-hot events on global maize yields. Sci. Total. Environ., 689: 1228-1234.

Hao Z., et al. (2018). A multivariate approach for statistical assessments of compound extremes. J. Hydrol., 565: 87-94.

Examples

```
mp=matrix(rnorm(60,0,1),ncol=1) # precipitation of a month (60 years)
mt=matrix(rnorm(60,0,1),ncol=1) # temperature of a month  (60 years)
mi=matrix(rnorm(60,0,1),ncol=1)   # impact of a month (60 years)
imp1<-ImpactMGDH(mp,mt,mi,-1.2,1.2,NULL) # imp1$mu, imp1$sig
imp2<-ImpactMGDH(mp,mt,mi,-1.2,1.2,0)# imp2$Condprob
```

LMFDH *Likelihood multiplication factor (LMF) or probability multiplication factor (PMF) of compound dry-hot events*

Description

Compute joint probabilities of compound dry-hot events and the independent case.

Usage

```
LMFDH(mp,mt,threp,thret)
```

Arguments

mp	Precipitation
mt	Temperature
threp	Threshold of precipitation (e.g., 50th percentile)
thret	Threshold of temperature

Value

Joint probability of DH divided by that of independent case

References

Zscheischler, J. and S. I. Seneviratne (2017). Dependence of drivers affects risks associated with compound events. Science Advances, 3(6): e1700263.

Examples

```
mp=matrix(rnorm(120,0,1),ncol=1)
mt=matrix(rnorm(120,0,1),ncol=1)
threp=20
thret=80
res<-LMFDH(mp,mt,threp,thret)
```

PredLogit *Prediction of compound event occurrences*

Description

Fit the logistic regression model (LGR) based on occurrences of compound events (Y) and climate index (CI).The output is predicted probability of compound event occurrence for the given climate index value CI0 or the prediction performance (using AUC) and predicted values based on LOOCV

Usage

```
PredLogit(Y,X,type,x0=NULL)
```

Arguments

Y	Occurrences of compound events (0-1 binary variable) (L lead time)
X	Climate index (CI) as the driving factor (e.g., ENSO) with some lags
type	type is the "performance" or "prediction"
x0	Specified CI value based on which the prediction is issued

Value

(1) Probability of occurrences estimated at x0 if type="prediction", shouLd input x0 (2) AUC values and predictions LOOCV if type="performance", x0 is not needed

References

Hao, Z. et al. (2019). Statistical prediction of the severity of compound dry-hot events based on ENSO . J. Hydrol., 572: 243-250.

Examples

```
Y=as.matrix(c(0,0,1,1,0,0,0,0,0,0,1,0,1,0,0,1,0))
X=c(-0.7,-1.2,1.3,0.7,-0.6,1.1,-0.5,0.8,0.5,-0.5,
   1.6,-1.8,-0.5,-1.4,-0.1,2.2,-0.7) #  dry-hot (or other) 0-1 events
pred1<-PredLogit(Y,X,type="prediction",2) #pred1$predx0
pred2<-PredLogit(Y,X,type="performance") #pred2$aucvalue,pred2$predictions
```

SCEIDH *Standardized Compound Event Indicator (SCEI) for dry-hot events*

Description

Compute SCEI based on monthly precipitation and temperature.

Usage

```
SCEIDH(pre,tem,ts)
```

Arguments

pre	monthly precipitation of several decades
tem	monthly temperature of several decades
ts	time scale

Value

The monthly SCEI series of several decades

References

Hao, Z. et al., 2019. Statistical prediction of the severity of compound dry-hot events based on El Ni??o-Southern Oscillation. J. Hydrol., 572, 243-250.

Examples

```
pre=matrix(rnorm(120,0,1),ncol=1) # 10-year monthly precipitation
tem=matrix(rnorm(120,0,1),ncol=1) # 10-year monthly temperature
ts=1; # ts<=12 otherwise you should revise the function
SCEIDH(pre,tem,ts) #Generate monthly data
```

Index