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Contents

dcc . . . 2
dlm . . . 6
exclude_from . . . 8
g_test . . . 9
muc_clim . . . 10
muc_fake . . . 10
muc_spruce . . . 11
norw015 . . . 11
norway_prec . . . 12
norway_temp . . . 12
rt_prec . . . 13
rt_spruce . . . 13
rt_temp . . . 14
seascorr . . . 14
skills . . . 17
spai020 . . . 19
spain_prec . . . 19
spain_temp . . . 20
tc_design . . . 20
traceplot . . . 21
treeclim-modifiers . . . 21
treeclim-shifters . . . 22

Index **24**

`dcc` *Response and correlation function analysis*

Description

This function calculates (potentially moving or evolving) response and correlation functions from tree-ring chronologies and monthly climatic data. For the moving case, the calculation is performed repeatedly for consecutive time windows. Function parameters may be bootstrapped to calculate their significance and confidence intervals.

Usage

```
dcc(
  chrono,
  climate,
  selection = -6:9,
  method = "response",
  dynamic = "static",
  moving,
  win_size = 25,
  win_offset = 1,
```

```
  start_last = TRUE,
  timespan = NULL,
  var_names = NULL,
  ci = 0.05,
  boot = "stationary",
  sb = TRUE,
  verbose = TRUE
)
```

Arguments

chrono	data.frame containing a tree-ring chronologies, e.g. as obtained by chron of package dplR.
climate	either a data.frame or matrix with climatic data in monthly resolution, with year, month and climate parameters in columns (all columns except year and month will be recognized as parameters for response or correlation functions), or a single data.frame or matrix in 13-column format (see below), or a (potentially named) list of one or several of the latter.
selection	either a numeric vector, a modifier, or a chain of modifiers specifying the parameter selection for the model (see Details).
method	character string specifying the calculation method. Possible values are "response" and "correlation". Partial strings are ok.
dynamic	character; should the analyis be carried out in a static, moving, or evolving fashion. One of c("static", "moving", "evolving"). Defaults to "static". Partial strings are ok.
moving	deprecated, use dynamic instead.
win_size	integer giving the window size for each recalculation in years for a moving analysis, and the initial window size for an evolving analysis.
win_offset	integer giving the number of years between each window start in years.
start_last	logical flag indicating whether the first window should start at the rear end (youngest part of the series) or not.
timespan	integer vector of length 2 specifying the time interval (in years) to be considered for analysis. Defaults to the maximum possible interval.
var_names	character vector with variable names. Defaults to corresponding column names of parameter climate if given as data.frame, or its names if given as list.
ci	numerical value to set the test level for significance test (values 0.01, 0.05 and 0.1 are allowed); the confidence intervals are adapted accordingly.
boot	character indicating which bootstrap method should be used, one of c("stationary", "std", "exact")
sb	logical flag indicating whether textual status bar for moving case should be suppressed. Suppression is recommended for e.g. Sweave files.
verbose	logical flag indicating if informative messages should be written to the console (default is 'TRUE').

Details

This function builds upon and extents the functionality of programme DENDROCLIM2002 (Biondi and Waikul, 2004), and will calculate bootstrapped (and non-bootstrapped) moving and static response and correlation functions in a similar fashion as described in the above mentioned paper. Important extensions include a very flexible parameter selection model (see below), the possibility to use an unlimited number of climate parameters, and the option to use exact bootstrapping.

Input chronology data can be a `data.frame` such as produced by function `chron` of package dplR. It has to be a `data.frame` with at least one column containing the tree-ring indices, and the corresponding years as `rownames`.

For climatic input data, there are three possibilities: Firstly, input climatic data can be a `data.frame` or `matrix` consisting of at least 3 rows for years, months and at least one climate parameter in the given order. Secondly, input climatic data can be a single `data.frame` or `matrix` in the style of the original DENDROCLIM2002 input data, i.e. one parameter with 12 months in one row, where the first column represents the year. Or thirdly, input climatic data can be a (potentially named) list of one or several of the latter described `data.frame` or `matrices`. If a named list is provided, potentially provided variable names through argument `var_names` are ignored. As an internal format dispatcher checks the format automatically, it is absolutely necessary that in all three cases, only complete years (months 1-12) are provided. It is not possible to mix different formats in one go.

Parameters can be selected with the 'selection' parameter in two different ways:

- simple selections: as an example -6:9 selects from all climate variables all months from previous year's June (-6, previous year's months are specified as negative integers) to current years September (9, months of the current year are specified as positive integers) as model parameters. Months from the previous year and the year before that can be selected using treeclim-shifters like `..(6)` to refer to July of the year before the previous year.
- using *modifiers*: More complex parameter selections can be obtained by the *modifiers* provided in treeclim: `.range`, `.mean`, and `.sum`. These modifiers can also be chained to create complex selections. See treeclim-modifiers for details.

For the exclusion of months, the convenience function `exclude_from` (or short `exfr`) is provided.

1000 bootstrap samples are taken from the original distributions of climate and tree-ring data, either using the stationary bootstrap (Politis and Romano 1994, `boot = "stationary"`) or classical bootstrap (DENDROCLIM2002-style, `boot = "std"`). The stationary bootstrap mimics the stationary properties of the original time series in the resampled time series by resampling within blocks. Within each block, the number of observations is random and has a geometric distribution. Consequently, the choice of the distribution parameter will affect the autocorrelation structure of the resampled time series. Optimal (expected) block length is chosen according to Politis and White (2004). In the case of response function analysis, an eigen decomposition of the standardized predictor matrix is performed. Nonrelevant eigenvectors are removed using the PVP criterion (Guiot, 1990), principal component scores are then calculated from the matrices of reduced eigenvectors and standardized climatic predictors. Response coefficients are found via singular value decomposition, and tested for significance using the 95% percentile range method (Dixon, 2001). In case of correlation function analysis, the coefficients are Pearson's correlation coefficients. The same method for significance testing is applied.

There is also the option to use exact bootstrapping like implemented in seascorr (Meko et al. 2011, `boot = "exact"`). In this case, circulant embedding is used to simulate the tree-ring data 1000

times as time series with the same frequency characteristics like the original time-series (Percival & Constantine, 2006). Empirical non-exceedence probabilities are used to test the coefficients of the response/correlation function with the original data for significance. For the exact bootstrapping case, no confidence intervals for the response/correlation coefficients can be computed.

Value

'dcc' returns an 'object' of class '"tc_dcc"'.

The functions 'summary' and 'plot' are used to obtain and print a summary of the results, and to create a plot. The function 'coef' can be used to extract the coefficients.

An object of class '"tc_dcc"' is a list containing at least the following components:

`call`	the call made to function 'dcc'
`coef`	the coefficients, themselves being an object of class 'tc_coef' for the static case, and of class 'tc_mcoef' for the moving case. Objects of class 'tc_coef' are single data.frames, while objects of class 'tc_mcoef' are lists of seperate data.frames for the coefficients (element 'coef'), upper and lower confidence interval (elements 'ci_upper' and 'ci_lower'), and significance flags (element 'significant')
`design`	the design matrix on which this call to 'dcc' operates
`truncated`	the input data truncated to the common timespan or the specified timespan
`original`	the original input data, with the climate data being recast into a single data.frame

Author(s)

Christian Zang; the original MATLAB code for exact bootstrapping was written by Dave Meko

References

Biondi, F & Waikul, K (2004) DENDROCLIM2002: A C++ program for statistical calibration of climate signals in tree-ring chronologies. *Computers & Geosciences* 30:303-311

Dixon, PM (2001) Bootstrap resampling. In: El-Shaarawi, AH, Piegorsch, WW (Eds.), *The Encyclopedia of Environmetrics*. Wiley, New York.

Guiot, J (1991) The boostrapped response function. *Tree-Ring Bulletin* 51:39-41

Meko DM, Touchan R, Anchukaitis KJ (2011) Seascorr: A MATLAB program for identifying the seasonal climate signal in an annual tree-ring time series. *Computers & Geosciences* 37:1234-241

Percival DB, Constantine WLB (2006) Exact simulation of Gaussian Time Series from Nonparametric Spectral Estimates with Application to Bootstrapping. *Statistics and Computing* 16:25-35

Patton, A. and D.N. Politis and H. White (2009), "CORRECTION TO 'Automatic block-length selection for the dependent bootstrap' by D. Politis and H. White", Econometric Reviews 28(4), 372-375.

Politis, D.N. and H. White (2004), Automatic block-length selection for the dependent bootstrap, Econometric Reviews 23(1), 53-70.

Examples

```
dc_resp <- dcc(muc_spruce, muc_clim)
```

dlm *Dendro-flavoured linear model*

Description

This is a wrapper around `lm` for working with the same data structures and modifiers as `dcc` does.

Usage

```
dlm(
  chrono,
  climate,
  selection,
  timespan = NULL,
  var_names = NULL,
  param_names = NULL,
  intercept = TRUE,
  scale = FALSE,
  verbose = TRUE
)
```

Arguments

`chrono`	`data.frame` containing a tree-ring chronologies, e.g. as obtained by `chron` of package dplR.
`climate`	either a `data.frame` or `matrix` with climatic data in monthly resolution, with year, month and climate parameters in columns (all columns except year and month will be recognized as parameters for response or correlation functions), or a single `data.frame` or `matrix` in 13-column format (see below), or a (potentially named) list of one or several of the latter.
`selection`	either a numeric vector, a modifier, or a chain of modifiers specifying the parameter selection for the model (see Details).
`timespan`	`integer` vector of length 2 specifying the time interval (in years) to be considered for analysis. Defaults to the maximum possible interval.
`var_names`	`character` vector with variable names. Defaults to corresponding column names of parameter `climate` if given as `data.frame`, or its names if given as `list`.
`param_names`	`character` vector with parameter names. Defaults to auto-generated (potentially compound) names.
`intercept`	`logical`: should intercept be included in model?
`scale`	`logical`: should data be scaled prior to computing model? If `TRUE`, `intercept` will be set to `FALSE`.
`verbose`	`logical` flag indicating if informative messages should be written to the console (default is 'TRUE').

Details

Input chronology data can be a `data.frame` such as produced by function `chron` of package dplR. It has to be a `data.frame` with at least one column containing the tree-ring indices, and the corresponding years as `rownames`.

For climatic input data, there are three possibilities: Firstly, input climatic data can be a `data.frame` or `matrix` consisting of at least 3 rows for years, months and at least one climate parameter in the given order. Secondly, input climatic data can be a single `data.frame` or `matrix` in the style of the original DENDROCLIM2002 input data, i.e. one parameter with 12 months in one row, where the first column represents the year. Or thirdly, input climatic data can be a (potentially named) list of one or several of the latter described `data.frame` or `matrices`. If named list is provided, potentially provided variable names through argument `var_names` are ignored. As an internal format dispatcher checks the format automatically, it is absolutely necessary that in all three cases, only complete years (months 1-12) are provided. It is not possible to mix different formats in one go.

In 'dlm', there is no default parameter selection, in contrast to 'dcc'. Parameters can be selected with the 'selection' parameter in two different ways:

- simple selections: as an example -6:9 selects from all climate variables all months from previous year's June (-6, previous year's months are specified as negative integers) to current years September (9, months of the current year are specified as positive integers) as model parameters. Months from the previous year and the year before that can be selected using treeclim-shifters like `..(6)` to refer to July of the year before the previous year.
- using *modifiers*: More complex parameter selections can be obtained by the *modifiers* provided in treeclim: `.range`, `.mean`, and `.sum`. These modifiers can also be chained to create complex selections. See treeclim-modifiers for details.

For the exclusion of months, the convenience function `exclude_from` (or short `exfr`) is provided.

With 'dlm' one would usually try to keep the number of predictors low.

For pretty output of the resulting linear model, parameters can be renamed, to e.g. reflect the season they represent.

Value

'dlm' returns an 'object' of class '"tc_dlm"', which is a superclass of 'lm'. Additional elements to what is included in standard 'lm' objects:

`call_dlm`	the call made to function 'dlm'
`design`	the design matrix on which this call to 'dlm' operates
`truncated`	the input data truncated to the common timespan or the specified timespan
`original`	the original input data, with the climate data being recast into a single data.frame

Author(s)

Christian Zang

Examples

```
dlm1 <- dlm(rt_spruce, rt_prec, .sum(6:8), param_names = "summer_prec")
summary(dlm1)

dlm2 <- dlm(rt_spruce, list(rt_prec, rt_temp),
  .sum(6:8, "prec") + .mean(6:8, "temp"), var_names = c("prec", "temp"),
  param_names = c("summer_prec", "summer_temp"))
summary(dlm2)
anova(dlm1, dlm2)
```

---

exclude_from *Exclude months from analysis*

Description

Single months or ranges of months can be excluded from analysis. This is helpful for e.g. excluding winter months without cambial activity.

Usage

```
exclude_from(month, exclude = NULL)

exfr(month, exclude = NULL)
```

Arguments

month	range of numeric month ids
exclude	range or set of months to exclude

Details

These convenience function is provided for the exclusion of months. E.g., `.range(exclude_from(-6:10, -11:3))` will yield the monthly values of all parameters for the months previous June (-6) to current October (10), but without the months previous November (-11) to current March (3) in between. While it is also possible to supply arbitrary vectors as month specification, and not only ranges as shown in most of the examples here, this way of excluding e.g. the dormant season is far more convenient.

Value

a reduced set of numeric month ids

See Also

link{.range}, link{.mean}, link{.sum}

Examples

```
exfr(-5:10, -10:3)
```

g_test *Gershunov test for spurious low-frequency modulations*

Description

This function provides a test to decide whether low-frequency modulations in the relationship between climate and tree-growth are significantly stronger or weaker than could be expected by chance.

Usage

```
g_test(x, boot = FALSE, sb = TRUE, check_duration = TRUE)
```

Arguments

x	an object of class '"tc_dcc"' as returned from a call to dcc with moving correlations enabled
boot	logical shall the individual correlations be bootstrapped? (see details)
sb	logical shall a status bar be drawn?
check_duration	logical should the duration be checked before running with individually boostrapped correlations? The default is 'TRUE', set to 'FALSE' to suppress interactive selections and messages to the console.

Details

This function is a multivariate extension of the test for spurious low-frequency modulations for moving correlations of time series as proposed by Gershunov et al. (2001). In short, 1000 simulations of random data sets are generated, where the climate data is simulated as Gaussian noise, and the tree-data as linear combinations of the climate parameters using the original coefficients of the correlation function, and an error component with a variance equal to the variance unexplained by the individual parameters.

For each iteration, a moving correlation function is calculated with exactly the same settings as the original model. The standard deviation over the individual windows for each parameter is then compared to the bootstrapped distribution of the standard deviation of the simulated data to test for significantly higher or lower low-frequency modulations.

Value

a data.frame with p values for the testing the null hypothesis that the low-frequency modulation of the correlations of the variables with tree-growth can be considered as noise.

References

Gershunov, A., N. Schneider, and T. Barnett. 2001. Low-frequency modulation of the ENSO-Indian Monsoon rainfall relationship: Signal or noise? Journal of Climate 14:2486-2492.

Examples

```
dc_cor <- dcc(muc_spruce, muc_clim, 3:9, method = "cor", moving = TRUE)
g_test(dc_cor)
```

`muc_clim` *Monthly Mean Temperature and Total Precipitation for Forstenrieder Park, Munich*

Description

This dataset gives the monthly mean temperature and total precipitation at Forstenrieder Park, Munich, Bavaria, Germany.

Usage

```
data(muc_clim)
```

Format

A `data.frame` containing four columns with year, month, temperature and precipitation.

Source

Zang C, Pretzsch H, Rothe A (2012) Size-dependent responses to summer drought in Scots pine, Norway spruce and common oak. Trees - Structure and Function, 26, 557-569.

`muc_fake` *Modeled Tree-Ring Chronology of a Spruce Population near Munich*

Description

This dataset gives the modelled tree-ring widths for *Picea abies* at Forstenrieder Park, Munich, Bavaria, Germany. Tree growth was modeled as a response of low temperatures in previous and current July and August, high temperatures in current February and March, and high precipitation amounts in current July and August.

Usage

```
data(muc_fake)
```

Format

A `data.frame` containing tree-ring indices and replication depth with respective years as `rownames`.

Source

Zang C, Pretzsch H, Rothe A (2012) Size-dependent responses to summer drought in Scots pine, Norway spruce and common oak. Trees - Structure and Function, 26, 557-569.

`muc_spruce` *Tree-Ring Chronology of a Spruce Population near Munich*

Description

This dataset gives the tree-ring indices for *Picea abies* at Forstenrieder Park, Munich, Bavaria, Germany. The chronology represents 20 cores from 10 trees. The series were read in using `read.rwl` from package `dplR`, detrended using a 60a spline with 50% frequency cutoff (function `detrend`), and averaged to a chronology using a robust mean `chron`.

Usage

```
data(muc_spruce)
```

Format

A `data.frame` containing tree-ring indices and replication depth with respective years as `rownames`.

Source

Zang C, Pretzsch H, Rothe A (2012) Size-dependent responses to summer drought in Scots pine, Norway spruce and common oak. Trees - Structure and Function, 26, 557-569.

`norw015` *Tree-Ring Chronology of a Pine Population at Visdalen, Norway*

Description

This dataset gives the tree-ring indices for *Pinus sylvestris* at a site near Visdalen, Norway. The chronology represents 34 dated series and spans the period between 1600 and 1983. The raw measurements were obtained from the ITRDB (see source), and read in, detrended with cubic splines (frequency cutoff of 50 percent at two thirds of the series length) and averaged using `read.rwl`, `detrend`, and `chron` from package `dplR`.

Usage

```
data(norw015)
```

Format

A `data.frame` containing tree-ring indices and replication depth with respective years as `rownames`.

Source

Briffa K. Briffa - Visdalen - PISY - ITRDB NORW015. http://hurricane.ncdc.noaa.gov/pls/paleox/f?p=519:1:::::P1_STUDY_
Accessed 2014/07/03.

`norway_prec` *Monthly Precipitation Sums for Norway*

Description

This data set gives the monthly precipitation sums at country level for Norway in a decadal (DENDROCLIM2002-style) format from the TYN CY 1.1 data set.

Usage

```
data(norway_prec)
```

Format

A `data.frame` containing thirteen columns with year and twelve months of temperature data in degree Celsius.

Source

Mitchell TD, Carter TR, Jones PD, Hulme M, New M, et al. (2004) A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Tyndall Centre for Climate Change Research Working Paper 55, 25.

`norway_temp` *Monthly Temperature Means for Norway*

Description

This data set gives the monthly temperature means at country level for Norway in a decadal (DENDROCLIM2002-style) format from the TYN CY 1.1 data set.

Usage

```
data(norway_temp)
```

Format

A `data.frame` containing thirteen columns with year and twelve months of temperature data in degree Celsius.

Source

Mitchell TD, Carter TR, Jones PD, Hulme M, New M, et al. (2004) A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Tyndall Centre for Climate Change Research Working Paper 55, 25.

`rt_prec` *Monthly Precipitation Sums for Rothenburg ob der Tauber, Germany*

Description

This dataset gives the monthly precipitation sum at Rothenburg ob der Tauber, Bavaria, Germany in a decadal (DENDROCLIM2002-style) format)

Usage

```
data(rt_prec)
```

Format

A `data.frame` containing thirteen columns with year and twelve months of precipitation data in mm rainfall.

Source

Zang C, Rothe A, Weis W, Pretzsch H (2011) Zur Baumarteneignung bei Klimawandel: Ableitung der Trockenstress-Anfaelligkeit wichtiger Waldbaumarten aus Jahrringbreiten. Allgemeine Forst- und Jagdzeitung, 182, 98-112.

`rt_spruce` *Tree-Ring Chronology of a Spruce Population at Rothenburg ob der Tauber*

Description

This dataset gives the tree-ring indices for *Picea abies* at Rothenburg ob der Tauber, Bavaria, Germany. The chronology represents 20 cores from 10 trees. The series were read in using `read.rwl` from package `dplR`, detrended using a 60a spline with 50% frequency cutoff (function `detrend`), and averaged to a chronology using a robust mean `chron`.

Usage

```
data(rt_spruce)
```

Format

A `data.frame` containing tree-ring indices and replication depth with respective years as `rownames`.

Source

Zang C, Rothe A, Weis W, Pretzsch H (2011) Zur Baumarteneignung bei Klimawandel: Ableitung der Trockenstress-Anfaelligkeit wichtiger Waldbaumarten aus Jahrringbreiten. Allgemeine Forst- und Jagdzeitung, 182, 98-112.

`rt_temp` *Monthly Temperature Means for Rothenburg ob der Tauber, Germany*

Description

This dataset gives the monthly temperature means at Rothenburg ob der Tauber, Bavaria, Germany in a decadal (DENDROCLIM2002-style) format)

Usage

```
data(rt_temp)
```

Format

A `data.frame` containing thirteen columns with year and twelve months of temperature data in degree Celsius.

Source

Zang C, Rothe A, Weis W, Pretzsch H (2011) Zur Baumarteneignung bei Klimawandel: Ableitung der Trockenstress-Anfaelligkeit wichtiger Waldbaumarten aus Jahrringbreiten. Allgemeine Forst- und Jagdzeitung, 182, 98-112.

`seascorr` *Seasonal (partial) correlation analysis*

Description

Calculate seasonal correlation with primary and secondary climate variables and tree-ring data, similar to the seascorr function for MATLAB.

Usage

```
seascorr(
  chrono,
  climate,
  var_names = NULL,
  timespan = NULL,
  complete = 9,
  season_lengths = c(1, 3, 6),
```

```
  primary = 1,
  secondary = 2,
  ci = 0.05,
  verbose = TRUE
)
```

Arguments

chrono	data.frame containing a tree-ring chronologies, e.g. as obtained by chron of package dplR.
climate	either a data.frame or matrix with climatic data in monthly resolution, with year, month and climate parameters in columns (all columns except year and month will be recognized as parameters for response or correlation functions), or a single data.frame or matrix in 13-column format (see below), or a (potentially named) list of one or several of the latter.
var_names	character vector with variable names. Defaults to corresponding column names of parameter climate if given as data.frame, or its names if given as list.
timespan	integer vector of length 2 specifying the time interval (in years) to be considered for analysis. Defaults to the maximum possible interval.
complete	integer scalar, month when tree-ring growth is expected to have finished.
season_lengths	numeric vector giving the lengths of the seasons for variable grouping
primary	position numeric or name character of primary climate variable
secondary	position numeric or name character of secondary climate variable
ci	numerical value to set the test level for significance test (values 0.01, 0.05 and 0.1 are allowed); the confidence intervals are adapted accordingly.
verbose	logical flag indicating if informative messages should be written to the console (default is 'TRUE').

Details

This function mimicks the behaviour of the MATLAB function seascorr (Meko et al. 2011), which calculates partial correlations of tree-ring data with a primary and a secondary climatic variable for seasons of different lengths.

Input chronology data can be a data.frame such as produced by function chron of package dplR. It has to be a data.frame with at least one column containing the tree-ring indices, and the corresponding years as rownames.

For climatic input data, there are three possibilities: Firstly, input climatic data can be a data.frame or matrix consisting of at least 3 rows for years, months and at least one climate parameter in the given order. Secondly, input climatic data can be a single data.frame or matrix in the style of the original DENDROCLIM2002 input data, i.e. one parameter with 12 months in one row, where the first column represents the year. Or thirdly, input climatic data can be a list of several of the latter described data.frame or matrices. As an internal format dispatcher checks the format automatically, it is absolutely necessary that in all three cases, only complete years (months 1-12) are provided. It is not possible to mix different formats in one go.

The 'complete' parameter specifies the months of the current year in which tree-growth is assumed to finish. This month marks the last month of the first season, and starting from here, 14 different

seasons are computed for each specified season length in one-month steps. E.g., for a starting value of 9 (current September) and season length of 3 months, the first season comprises current July to current September, the second season comprises current June to current August, and the last season comprises previous June to previous August. This results in 14 seasons for a given season length. An arbitrary number of season lengths can be specified.

The choice for primary vs. secondary variable can be made either via numeric selection (the integer value 1 stands for the first variable in the supplied climate data set), or by name ("temp", when one of the variables is named "temp"). The correlation of the primary variable with tree-growth is computed as the simple (Pearson) correlation coefficient, while the influence of the secondary variable on tree-growth is computed with the influence of the primary variable on tree-growth removed.

Like in the original seascorr program, the significance of each (partial) correlation is evaluated using exact bootstrapping by circulant embedding of the tree-ring data (Percival & Constantine, 2006).

Value

'seascorr' returns an 'object' of class '"tc_seascorr"'.

The 'plot' function is used to obtain a plot of the results.

An object of class '"tc_seascorr"' is a list containing at least the following components:

`call`	the call made to 'seascorr'
`seasons`	a list of length n, where n is the number of season lengths provided; each list element consists of a data.frame with end month, correlation coefficient and significance flag
`truncated`	the input data truncated to the common timespan or the specified timespan
`original`	the original input data, with the climate data being recast into a single data.frame

Author(s)

Christian Zang; the procedure incl. exact bootstrapping was implemented first by Dave Meko in MATLAB

References

Meko DM, Touchan R, Anchukaitis KJ (2011) Seascorr: A MATLAB program for identifying the seasonal climate signal in an annual tree-ring time series. Computers & Geosciences, 37, 1234-1241.

Percival DB, Constantine WLB (2006) Exact simulation of Gaussian Time Series from Nonparametric Spectral Estimates with Application to Bootstrapping. Statistics and Computing 16:25-35

Examples

```
sc <- seascorr(muc_fake, muc_clim)
sc
plot(sc)
```

skills *Evaluate reconstruction skills using split-calibration*

Description

This function allows to evaluate the reconstruction skills for a given proxy time series in split-calibration approach.

Usage

```
skills(
  object,
  target = NULL,
  model = "ols",
  calibration = "50%",
  timespan = NULL
)
```

Arguments

object	an object of class "tc_dcc", "tc_dlm", or "tc_seascorr"
target	a treeclim selection modifier specifying the climate target to be reconstructed, see below for details
model	one of "ols" or "rma"
calibration	which part of the data shall be used as calibration subset? Given as either a range of years, an integer corresponding to the first or last number of observations, or a percentage as character string corresponding to the part of the data set to be used as calibration subset.
timespan	timespan to be used to truncate the data

Details

The result of a call to dcc, dlm, or seascorr can be used as object for the function. The required data is then taken from this object and no further processing of the tree and climate variables has to be done for by the user. This reflects the flow of analysis, where first general climate/growth relations are explored, and then the strongest ones are deployed for reconstruction purposes.

target is an aggregation modifier (one of .mean, .sum, and .range). The user should be aware of the fact that in case the aggregation modifier evaluates to more than one variable (e.g., summer means for both temperature and precipiation), a warning message is issued, and only the first variable is taken into consideration for evaluating the reconstruction skills. If not specified, the selection from the original call to dcc, seascorr, or dlm is used.

The type of regression model (ordinary least squares or errors-in-variables via reduced major axis regression) can be selected.

The part of the data to be used as a calibration subset can be specified in three different ways: 1) as a range of years, these are then taken as calibration period; 2) as a single integer, if positive, this

number of observations at the recent end of the data set is taken as calibration set, if negative, this number of oldest observations is taken; and 3) as a character string giving a percentage of values, e.g., "-40%" would select the 40% oldest observations, while "55%" would select the 55% most recent ones.

The relationship between climate and tree-ring data is evaluated for the calibration period and the complete data set. Frequently used verification statistics are computed: reduction of error (RE), coefficient of efficiency (CE), and the Durban-Watson statistic (DW) (Cook et al. 1994, Durbin and Watson, 1951).

Value

'skills' returns an 'object' of class '"tc_skills"'.

An object of class '"tc_skills"' is a list containing at least the following components:

`call`	the call made to function 'skills'
`target`	the target used for reconstruction
`r.cal`	the coefficient of correlation for the calibration timespan
`r.full`	the coefficient of correlation for the complete data set
`coef.cal`	regression coefficients for the calibration model
`coef.full`	regression coefficients for the full model
`p.cal`	significance for the calibration model
`p.full`	significance for the full model
`RE`	reduction of error statistic
`CE`	coefficient of efficiency statistic
`DW`	Durbin-Watson statistic
`RMSE`	The root mean squared error for the prediction interval
`cal.model`	the complete calibration model (an object of class 'lmodel2')
`full.mode`	the complete full model (an object of class 'lmodel2')

References

Cook E, Briffa K, Jones P (1994) Spatial regression methods in dendroclimatology: A review and comparison of two techniques. International Journal of Climatology, 14, 379-402.

Durbin, J, Watson, GS (1951) Testing for serial correlation in least squares regression. Biometrika 38:159-78.

Examples

```
dc <- dcc(muc_fake, muc_clim, .mean(6:9, "temp") + .sum(6:9,
"prec"))
sk <- skills(dc)
sk
plot(sk)
```

spai020 *Tree-Ring Chronology of a Pine Population at Penota, Spain*

Description

This dataset gives the tree-ring indices for *Pinus sylvestris* at a site near Penota, Spain. The chronology represents 18 dated series and spans the period between 1763 and 1991. The chronology was obtained from the ITRDB (see source), and read in using `read.crn` from package `dplR`.

Usage

```
data(spai020)
```

Format

A `data.frame` containing tree-ring indices and replication depth with respective years as `rownames`.

Source

Fernandez-Cancio A, Genova Fuster M: Fernandez-Cancio - Penota - PISY - ITRDB SPAI020, http://hurricane.ncdc.noaa.gov/pls/paleox/f?p=519:1:::::P1_STUDY_ID:3255, accessed 2014/07/03.

spain_prec *Monthly Precipitation Sums for Spain*

Description

This data set gives the monthly precipitation sums at country level for Spain in a decadal (DENDROCLIM2002-style) format from the TYN CY 1.1 data set.

Usage

```
data(spain_prec)
```

Format

A `data.frame` containing thirteen columns with year and twelve months of temperature data in degree Celsius.

Source

Mitchell TD, Carter TR, Jones PD, Hulme M, New M, et al. (2004) A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Tyndall Centre for Climate Change Research Working Paper 55, 25.

spain_temp *Monthly Temperature Means for Spain*

Description

This data set gives the monthly temperature means at country level for Spain in a decadal (DENDROCLIM2002-style) format from the TYN CY 1.1 data set.

Usage

```
data(spain_temp)
```

Format

A `data.frame` containing thirteen columns with year and twelve months of temperature data in degree Celsius.

Source

Mitchell TD, Carter TR, Jones PD, Hulme M, New M, et al. (2004) A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Tyndall Centre for Climate Change Research Working Paper 55, 25.

tc_design *Deparse list structure from month specification and return parameter set*

Description

Deparse list structure from month specification into single calls, call an aggregating function to collect the data, and return a parameter set for calibration. In general, the months must be specified as a list or nested list structure. Possible cases are: list() list(...) list(list(...)) list(list(...), list(...), ...)

Usage

```
tc_design(selection, climate, check_2 = TRUE)
```

Arguments

`selection`	the list structure to specify the month selection
`climate`	the climate data as returned by make_pmat
`check_2`	should there be a check for less than 2 variables in the design matrix?

Value

a data.frame

traceplot *Trace the temporal development of response or correlation coefficients*

Description

This is a plotting function that takes the output from a dynamic ("moving" or "evolving") dcc run to trace the temporal development of all or selected variables. The variables can be selected using their name, partial matching is allowed.

Usage

```
traceplot(x, variables = NULL, facet = FALSE)
```

Arguments

x	an object returned from a call to dcc with parameter dynamic set to either "moving" or "evolving".
variables	a character vector of variable names to be plotted; if NULL (default), all variables will be traced
facet	logical: shall the plot be splitted into facets for different variables?

Value

an object of class "gg".

Examples

```
dc_resp <- dcc(muc_spruce, muc_clim, 4:9, dynamic = "evolving")
traceplot(dc_resp, c("prec.curr.may", "prec.curr.jun"))
```

treeclim-modifiers *Modifiers for climate parameter selection*

Description

These modifiers are used to select specific months from specific climate parameters, and potentially transform the selections into their respective sums or means. The modifiers can be chained together using '+'. .range corresponds to using all specified months separately, while .sum and .mean will use the sums and means of the specified months. These modifiers also allow to select specific climatic variables, addressed by name. Thus, .mean(4:8, "temp") will select the mean for climate parameter "temp" for the months April to August. Not only ranges, but also individual vectors can be used for month specification, like e.g., .range(c(1, 3, 4, 5).

The modifiers can be chained together using the '+' symbol, which makes it possible to create arbitrarily complex selections of climate parameters for calibration. E.g., .mean(2:5,"temp") +

`.sum(2:5, "prec")` will yield the February-to-May mean for the variable "temp" and the sum of the variable "prec" for the same time. While there is no limitation for number of lists that can be chained together, 'dcc' will not check for meaningful specifications. Testing smart hypotheses is up the researcher.

Usage

```
.range(.months = NULL, .variables = NULL)

.mean(.months = NULL, .variables = NULL)

.sum(.months = NULL, .variables = NULL)
```

Arguments

`.months`	numeric identifiers for the months (-1 for previous January until 12 for current December, with -6 for previous June, etc.)
`.variables`	names of the variables the modifier shall be applied to

Value

An object of class 'tc_paramlist' defining a list of climate variables for further processing, consisting of specifications for the time frame (months) and the selected variables.

Examples

```
my_calib <- dcc(rt_spruce, list(prec = rt_prec, temp = rt_temp),
  .range(4:9, "temp") + .mean(-5:-9, "temp") + .sum(3:10, "prec"))
plot(my_calib)
```

`treeclim-shifters` *Shift months one or two years back*

Description

These functions are used to specify months from previous years for the design matrix. `.(1)` is the same as `-1`, and specifies previous year's January, whereas `..(1)` signifies January of the year prior to the last year.

Usage

```
.(x)

..(x)
```

Arguments

`x`	numeric identifier (of length 1) for the months (1 for January, ..., 12 for December)

Value

an integer value specifying the month for selection

Index

∗ **datasets**
  muc_clim, 10
  muc_fake, 10
  muc_spruce, 11
  norw015, 11
  norway_prec, 12
  norway_temp, 12
  rt_prec, 13
  rt_spruce, 13
  rt_temp, 14
  spai020, 19
  spain_prec, 19
  spain_temp, 20
∗ **manip**
  exclude_from, 8
∗ **test**
  g_test, 9
. *(*treeclim-shifters*)*, 22
.mean, *17*
.mean *(*treeclim-modifiers*)*, 21
.range, *17*
.range *(*treeclim-modifiers*)*, 21
.sum, *17*
.sum *(*treeclim-modifiers*)*, 21

chron, *11*, *13*

dcc, 2, *6*, *9*, *17*
detrend, *11*, *13*
dlm, 6, *17*

exclude_from, *4*, *7*, 8
exfr, *4*, *7*
exfr *(*exclude_from*)*, 8

g_test, 9

lm, *6*

muc_clim, 10
muc_fake, 10
muc_spruce, 11

norw015, 11
norway_prec, 12
norway_temp, 12

read.crn, *19*
read.rwl, *11*, *13*
rt_prec, 13
rt_spruce, 13
rt_temp, 14

seascorr, 14, *17*
skills, 17
spai020, 19
spain_prec, 19
spain_temp, 20

tc_design, 20
traceplot, 21
treeclim-modifiers, *4*, *7*, 21
treeclim-shifters, *4*, *7*, 22