Package ‘dendroTools’

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Type Package

Title Linear and Nonlinear Methods for Analyzing Daily and Monthly Dendroclimatological Data

Version 1.2.8

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Description Provides novel dendroclimatological methods, primarily used by the Tree-ring research community. There are four core functions. The first one is daily_response(), which finds the optimal sequence of days that are related to one or more tree-ring proxy records. Similar function is daily_response_seascorr(), which implements partial correlations in the analysis of daily response functions. For the enthusiast of monthly data, there is monthly_response() function. The last core function is compare_methods(), which effectively compares several linear and nonlinear regression algorithms on the task of climate reconstruction.

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URL https://github.com/jernejjevsenak/dendroTools

BugReports https://github.com/jernejjevsenak/dendroTools/issues

Encoding UTF-8

LazyData true

Suggests testthat, rmarkdown

RoxygenNote 7.1.2

Imports ggplot2(>= 2.2.0), brnn(>= 0.6), reshape2(>= 1.4.2), scales(>= 0.4.1), stats, oce(>= 1.2-0), MLmetrics(>= 1.1.1), dplyr(>= 0.7.0), knitr(>= 1.19), magrittr(>= 1.5), plotly(>= 4.7.1), randomForest(>= 4.6-14), Cubist(>= 0.2.2), lubridate(>= 1.7.4), psych(>= 1.8.3.3), boot(>= 1.3-22), viridis(>= 0.5.1), dplR(>= 1.7.2)

Depends R(>= 3.4)

NeedsCompilation no

Repository CRAN

VignetteBuilder knitr

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Description

Calculates performance metrics for train and test data. Calculated performance metrics are correlation coefficient (r), root mean squared error (RMSE), root relative squared error (RRSE), index of agreement (d), reduction of error (RE), coefficient of efficiency (CE), detrended efficiency (DE) and bias.
calculate_metrics

Usage

```r
calculate_metrics(
    train_predicted,
    test_predicted,
    train_observed,
    test_observed,
    digits = 4,
    formula,
    test
)
```

Arguments

- `train_predicted`: a vector indicating predicted data for training set
- `test_predicted`: a vector indicating predicted data for testing set
- `train_observed`: a vector indicating observed data for training set
- `test_observed`: a vector indicating observed data for training set
- `digits`: integer of number of digits to be displayed
- `formula`: an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted. This additional argument is needed to calculate DE metrics.
- `test`: data frame with test data.

Value

A data frame of calculated test and train metrics

References


Lorenz, E.N., 1956. Empirical Orthogonal Functions and Statistical Weather Prediction. Massachusetts Institute of Technology, Department of Meteorology.


Examples

```r
data(example_dataset_1)
test_data <- example_dataset_1[1:30, ]
train_data <- example_dataset_1[31:55, ]
lin_mod <- lm(MVA ~ ., data = train_data)
```
train_predicted <- predict(lin_mod, train_data)
test_predicted <- predict(lin_mod, test_data)
train_observed <- train_data[, 1]
test_observed <- test_data[, 1]
calculate_metrics(train_predicted, test_predicted, train_observed, test_observed, test = test_data, formula = MVA ~.)

compare_methods <- example_dataset_1[1:20, ]
train_data <- example_dataset_1[21:55, ]
library(brnn)
lin_mod <- brnn(MVA ~., data = train_data)
train_predicted <- predict(lin_mod, train_data)
test_predicted <- predict(lin_mod, test_data)
train_observed <- train_data[, 1]
test_observed <- test_data[, 1]
calculate_metrics(train_predicted, test_predicted, train_observed, test_observed, test = test_data, formula = MVA ~.)

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**Description**

Calculates performance metrics for calibration (train) and validation (test) data of different regression methods: multiple linear regression (MLR), artificial neural networks with Bayesian regularization training algorithm (BRNN), (ensemble of) model trees (MT) and random forest of regression trees (RF). With the subset argument, specific methods of interest could be specified. Calculated performance metrics are the correlation coefficient (r), the root mean squared error (RMSE), the root relative squared error (RRSE), the index of agreement (d), the reduction of error (RE), the coefficient of efficiency (CE), the detrended efficiency (DE) and mean bias. For each of the considered methods, there are also residual diagnostic plots available, separately for calibration, holdout and edge data, if applicable.

**Usage**

```r
compare_methods(formula, dataset, k = 10, repeats = 2, optimize = TRUE, dataset_complete = NULL, BRNN_neurons = 1, MT_committees = 1, MT_neighbors = 5, MT_rules = 200, MT_unbiased = TRUE, MT_extrapolation = 100, ```
compare_methods

MT_sample = 0,
RF_ntree = 500,
RF_maxnodes = 5,
RF_mtry = 1,
RF_nodesize = 1,
seed_factor = 5,
digits = 3,
blocked_CV = FALSE,
PCA_transformation = FALSE,
log_preprocess = TRUE,
components_selection = "automatic",
eigenvalues_threshold = 1,
N_components = 2,
round_bias_cal = 15,
round_bias_val = 4,
n_bins = 30,
edge_share = 0.1,
MLR_stepwise = FALSE,
stepwise_direction = "backward",
methods = c("MLR", "BRNN", "MT", "RF"),
tuning_metric = "RMSE",
BRNN_neurons_vector = c(1, 2, 3),
MT_committees_vector = c(1, 5, 10),
MT_neighbors_vector = c(0, 5),
MT_rules_vector = c(100, 200),
MT_unbiased_vector = c(TRUE, FALSE),
MT_extrapolation_vector = c(100),
MT_sample_vector = c(0),
RF_ntree_vector = c(100, 250, 500),
RF_maxnodes_vector = c(5, 10, 20, 25),
RF_mtry_vector = c(1),
RF_nodesize_vector = c(1, 5, 10),
holdout = NULL,
holdout_share = 0.1,
holdout_manual = NULL,
total_reproducibility = FALSE
)

Arguments

formula an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted.
dataset a data frame with dependent and independent variables as columns and (optional) years as row names.
k number of folds for cross-validation
repeats number of cross-validation repeats. Should be equal or more than 1
optimize if set to TRUE (default), the optimal values for the tuning parameters will be selected in a preliminary cross-validation procedure
optional, a data frame with the full length of tree-ring parameter, which will be used to reconstruct the climate variable specified with the formula argument

number of neurons to be used for the brnn method

an integer: how many committee models (e.g. boosting iterations) should be used?

how many, if any, neighbors should be used to correct the model predictions

an integer (or NA): define an explicit limit to the number of rules used (NA let’s Cubist decide).

a logical: should unbiased rules be used?

a number between 0 and 100: since Cubist uses linear models, predictions can be outside of the outside of the range seen the training set. This parameter controls how much rule predictions are adjusted to be consistent with the training set.

a number between 0 and 99.9: this is the percentage of the dataset to be randomly selected for model building (not for out-of-bag type evaluation)

number of trees to grow. This should not be set to too small a number, to ensure that every input row gets predicted at least a few times

maximum number of terminal nodes trees in the forest can have

number of variables randomly sampled as candidates at each split

minimum size of terminal nodes. Setting this number larger causes smaller trees to be grown (and thus take less time).

an integer that will be used to change the seed options for different repeats.

integer of number of digits to be displayed in the final result tables

default is FALSE, if changed to TRUE, blocked cross-validation will be used to compare regression methods.

if set to TRUE, all independent variables will be transformed using PCA transformation.

if set to TRUE, variables will be transformed with logarithmic transformation before used in PCA

character string specifying how to select the Principal Components used as predictors. There are three options: "automatic", "manual" and "plot_selection". If parameter is set to automatic, all scores with eigenvalues above 1 will be selected. This threshold could be changed by changing the eigenvalues_threshold argument. If parameter is set to "manual", user should set the number of components with N_components argument. If component selection is se to "plot_selection", Scree plot will be shown and user must manually enter the number of components used as predictors.

threshold for automatic selection of Principal Components

number of Principal Components used as predictors
**compare_methods**

- **round_bias_cal**: number of digits for bias in calibration period. Effects the outlook of the final ggplot of mean bias for calibration data (element 3 of the output list).
- **round_bias_val**: number of digits for bias in validation period. Effects the outlook of the final ggplot of mean bias for validation data (element 4 of the output list).
- **n_bins**: number of bins used for the histograms of mean bias.
- **edge_share**: the share of the data to be considered as the edge (extreme) data. This argument could be between 0.10 and 0.50. If the argument is set to 0.10, then the 5 considered to be the edge data.
- **MLR_stepwise**: if set to TRUE, stepwise selection of predictors will be used for the MLR method.
- **stepwise_direction**: the mode of stepwise search, can be one of "both", "backward", or "forward", with a default of "backward".
- **methods**: a vector of strings related to methods that will be compared. A full method vector is methods = c("MLR", "BRNN", "MT", "RF"). To use only a subset of methods, pass a vector of methods that you would like to compare.
- **tuning_metric**: a string that specifies what summary metric will be used to select the optimal value of tuning parameters. By default, the argument is set to "RMSE". It is also possible to use "RSquared".
- **BRNN_neurons_vector**: a vector of possible values for BRNN_neurons argument optimization.
- **MT_committees_vector**: a vector of possible values for MT_committees argument optimization.
- **MT_neighbors_vector**: a vector of possible values for MT_neighbors argument optimization.
- **MT_rules_vector**: a vector of possible values for MT_rules argument optimization.
- **MT_unbiased_vector**: a vector of possible values for MT_unbiased argument optimization.
- **MT_extrapolation_vector**: a vector of possible values for MT_extrapolation argument optimization.
- **MT_sample_vector**: a vector of possible values for MT_sample argument optimization.
- **RF_ntree_vector**: a vector of possible values for RF_ntree argument optimization.
- **RF_maxnodes_vector**: a vector of possible values for RF_maxnodes argument optimization.
- **RF_mtry_vector**: a vector of possible values for RF_mtry argument optimization.
- **RF_nodesize_vector**: a vector of possible values for RF_nodesize argument optimization.
- **holdout**: this argument is used to define observations, which are excluded from the cross-validation and hyperparameters optimization. The holdout argument must be a character with one of the following inputs: "early", "late" or "manual". If "early" or "late" characters are specified, then the early or late years will be used as a holdout data. How many of the "early" or "late" years are used as a
compare_methods

holdout is specified with the argument holdout_share. If the argument holdout is set to “manual”, then supply a vector of years (or row names) to the argument holdout_manual. Defined years will be used as a holdout. For the holdout data, the same statistical measures are calculated as for the cross-validation. The results for holdout metrics are given in the output element $holdout_results.

**holdout_share**

the share of the whole dataset to be used as a holdout. Default is 0.10.

**holdout_manual**

a vector of years (or row names) which will be used as a holdout. calculated as for the cross-validation.

**total_reproducibility**

logical, default is FALSE. This argument ensures total reproducibility despite the inclusion/exclusion of different methods. By default, the optimization is done only for the methods, that are included in the methods vector. If one method is absent or added, the optimization phase is different, and this affects all the final cross-validation results. By setting the total_reproducibility = TRUE, all methods will be optimized, even though they are not included in the methods vector and the final results will be subset based on the methods vector. Setting the total_reproducibility to TRUE will result in longer optimization phase as well.

**Value**

da list with 18 elements:

1. $mean_std - data frame with calculated metrics for the selected regression methods. For each regression method and each calculated metric, mean and standard deviation are given
2. $ranks - data frame with ranks of calculated metrics: mean rank and share of rank_1 are given
3. $edge_results - data frame with calculated performance metrics for the central-edge test. The central part of the data represents the calibration data, while the edge data, i.e. extreme values, represent the test/validation data. Different regression models are calibrated using the central data and validated for the edge (extreme) data. This test is particularly important to assess the performance of models for the predictions of the extreme data. The share of the edge (extreme) data is defined with the edge_share argument
4. $holdout_results - calculated metrics for the holdout data
5. $bias_cal - ggplot object of mean bias for calibration data
6. $bias_val - ggplot object of mean bias for validation data
7. $transfer_functions - ggplot or plotly object with transfer functions of methods
8. $transfer_functions_together - ggplot or plotly object with transfer functions of methods plotted together
9. $parameter_values - a data frame with specifications of parameters used for different regression methods
10. $PCA_output - princomp object: the result output of the PCA analysis
11. $reconstructions - ggplot object: reconstructed dependent variable based on the dataset_complete argument, facet is used to split plots by methods
12. $reconstructions_together - ggplot object: reconstructed dependent variable based on the dataset_complete argument, all reconstructions are on the same plot
13. $\text{normal\_QQ\_cal}$ - normal q-q plot for calibration data
14. $\text{normal\_QQ\_holdout}$ - normal q-q plot for holdout data
15. $\text{normal\_QQ\_edge}$ - normal q-q plot for edge data
16. $\text{residuals\_vs\_fitted\_cal}$ - residuals vs fitted values plot for calibration data
17. $\text{residuals\_vs\_fitted\_holdout}$ - residuals vs fitted values plot for holdout data
18. $\text{residuals\_vs\_fitted\_edge}$ - residuals vs fitted values plot for edge data

References


Examples

```r
# An example with default settings of machine learning algorithms
library(dendroTools)
data(example_dataset_1)
example_1 <- compare_methods(formula = MVA~., dataset = example_dataset_1,
edge_share = 0, holdout = "late")
ex$$mean_std
ex$$holdout_results
ex$$edge_results
ex$$ranks
ex$$bias_cal
ex$$bias_val
ex$$transfer_functions
ex$$transfer_functions_together
ex$$PCA_output
ex$$parameter_values
```
Description

Calculates critical value of Pearson correlation coefficient for a selected alpha.
Usage
critical_r(n, alpha = 0.05)

Arguments
n number of observations
alpha significance level

Value
calculated critical value of Pearson correlation coefficient

Examples
threshold_1 <- critical_r(n = 55, alpha = 0.01)
threshold_2 <- critical_r(n = 55, alpha = 0.05)

daily_response
daily_response
daily_response
daily_response

daily_response
daily_response

Description
Function calculates all possible values of a selected statistical metric between one or more response variables and daily sequences of environmental data. Calculations are based on moving window which is defined with two arguments: window width and a location in a matrix of daily sequences of environmental data. Window width could be fixed (use fixed_width) or variable width (use lower_limit and upper_limit arguments). In this case, all window widths between lower and upper limit will be used. All calculated metrics are stored in a matrix. The location of stored calculated metric in the matrix is indicating a window width (row names) and a location in a matrix of daily sequences of environmental data (column names).

Usage
daily_response(
    response,
    env_data,
    method = "cor",
    metric = "r.squared",
    cor_method = "pearson",
    lower_limit = 30,
    upper_limit = 90,
    fixed_width = 0,
    previous_year = FALSE,
    neurons = 1,
    brnn_smooth = TRUE,
    remove_insignificant = FALSE,
    alpha = 0.05,
row_names_subset = FALSE,
PCA_transformation = FALSE,
log_preprocess = TRUE,
components_selection = "automatic",
eigenvalues_threshold = 1,
N_components = 2,
aggregate_function = "mean",
temporal_stability_check = "sequential",
k = 2,
k_running_window = 30,
cross_validation_type = "blocked",
subset_years = NULL,
plot_specific_window = NULL,
ylimits = NULL,
seed = NULL,
tidy_env_data = FALSE,
reference_window = "start",
boot = FALSE,
boot_n = 1000,
boot_ci_type = "norm",
boot_conf_int = 0.95,
day_interval = ifelse(c(previous_year == TRUE, previous_year == TRUE), c(-1, 366),
                     c(1, 366)),
dc_method = NULL,
dc_nyrs = NULL,
dc_f = 0.5,
dc_pos_slope = FALSE,
dc_constrain.nls = c("never", "when.fail", "always"),
dc_span = "cv",
dc_bass = 0,
dc_difference = FALSE,
cor_na_use = "everything"
}

Arguments

response a data frame with tree-ring proxy variables as columns and (optional) years as row names. Row.names should be matched with those from a env_data data frame. If not, set row_names_subset = TRUE.

env_data a data frame of daily sequences of environmental data as columns and years as row names. Each row represents a year and each column represents a day of a year. Row.names should be matched with those from a response data frame. If not, set row_names_subset = TRUE. Alternatively, env_data could be a tidy data with three columns, i.e. Year, DOY and third column representing values of mean temperatures, sum of precipitation etc. If tidy data is passed to the function, set the argument tidy_env_data to TRUE.

method a character string specifying which method to use. Current possibilities are "cor" (default), "lm" and "brnn".
**daily_response**

- **metric**: a character string specifying which metric to use. Current possibilities are "r.squared" and "adj.r.squared". If method = "cor", metric is not relevant.
- **cor_method**: a character string indicating which correlation coefficient is to be computed. One of "pearson" (default), "kendall", or "spearman".
- **lower_limit**: lower limit of window width
- **upper_limit**: upper limit of window width
- **fixed_width**: fixed width used for calculation. If fixed_width is assigned a value, upper_limit and lower_limit will be ignored
- **previous_year**: if set to TRUE, env_data and response variables will be rearranged in a way, that also previous year will be used for calculations of selected statistical metric.
- **neurons**: positive integer that indicates the number of neurons used for brnn method
- **brnn_smooth**: if set to TRUE, a smoothing algorithm is applied that removes unrealistic calculations which are a result of neural net failure.
- **remove_insignificant**: if set to TRUE, removes all correlations below the significant threshold level, based on a selected alpha. For "lm" and "brnn" method, squared correlation is used as a threshold
- **alpha**: significance level used to remove insignificant calculations.
- **row_names_subset**: if set to TRUE, row.names are used to subset env_data and response data frames. Only years from both data frames are kept.
- **PCA_transformation**: if set to TRUE, all variables in the response data frame will be transformed using PCA transformation.
- **log_preprocess**: if set to TRUE, variables will be transformed with logarithmic transformation before used in PCA
- **components_selection**: character string specifying how to select the Principal Components used as predictors. There are three options: "automatic", "manual" and "plot_selection". If argument is set to automatic, all scores with eigenvalues above 1 will be selected. This threshold could be changed by changing the eigenvalues_threshold argument. If parameter is set to "manual", user should set the number of components with N_components argument. If components selection is set to "plot_selection", Scree plot will be shown and a user must manually enter the number of components to be used as predictors.
- **eigenvalues_threshold**: threshold for automatic selection of Principal Components
- **N_components**: number of Principal Components used as predictors
- **aggregate_function**: character string specifying how the daily data should be aggregated. The default is 'mean', the two other options are 'median' and 'sum'
- **temporal_stability_check**: character string, specifying, how temporal stability between the optimal selection and response variable(s) will be analysed. Current possibilities are "sequential", "progressive" and "running_window". Sequential check will split data into
k splits and calculate selected metric for each split. Progressive check will split data into k splits, calculate metric for the first split and then progressively add 1 split at a time and calculate selected metric. For running window, select the length of running window with the k_running_window argument.

k
integer, number of breaks (splits) for temporal stability and cross validation analysis.

k_running_window
the length of running window for temporal stability check. Applicable only if temporal_stability argument is set to running window.

cross_validation_type
character string, specifying, how to perform cross validation between the optimal selection and response variables. If the argument is set to "blocked", years will not be shuffled. If the argument is set to "randomized", years will be shuffled.

subset_years
a subset of years to be analyzed. Should be given in the form of subset_years = c(1980, 2005)

plot_specific_window
integer representing window width to be displayed for plot_specific

ylimits
limit of the y axes for plot_extreme and plot_specific. It should be given in the form of: ylimits = c(0,1)

seed
optional seed argument for reproducible results

tidy_env_data
if set to TRUE, env_data should be inserted as a data frame with three columns: "Year", "DOY", "Precipitation/Temperature/etc."

reference_window
character string, the reference_window argument describes, how each calculation is referred. There are three different options: 'start' (default), 'end' and 'middle'. If the reference_window argument is set to 'start', then each calculation is related to the starting day of window. If the reference_window argument is set to 'middle', each calculation is related to the middle day of window calculation. If the reference_window argument is set to 'end', then each calculation is related to the ending day of window calculation. For example, if we consider correlations with window from DOY 15 to DOY 35. If reference window is set to 'start', then this calculation will be related to the DOY 15. If the reference window is set to 'end', then this calculation will be related to the DOY 35. If the reference_window is set to 'middle', then this calculation is related to DOY 25. The optimal selection, which describes the optimal consecutive days that returns the highest calculated metric and is obtained by the $plot_extreme output, is the same for all three reference windows.

boot
logical, if TRUE, bootstrap procedure will be used to calculate estimates correlation coefficients, R squared or adjusted R squared metrics

boot_n
The number of bootstrap replicates

boot_ci_type
A character string representing the type of bootstrap intervals required. The value should be any subset of the values c("norm","basic", "stud", "perc", "bca").

boot_conf_int
A scalar or vector containing the confidence level(s) of the required interval(s)
**daily_response**

- **day_interval**: A vector of two values: lower and upper time interval of days that will be used to calculate statistical metrics. Negative values indicate previous growing season days. This argument overwrites the calculation limits defined by lower_limit and upper_limit arguments.

- **dc_method**: A character string to determine the method to detrend climate (environmental) data. Possible values are c("Spline", "ModNegExp", "Mean", "Friedman", "ModHugershoff"). Defaults to "none" (see dplR R package).

- **dc_nyrs**: A number giving the rigidity of the smoothing spline, defaults to 0.67 of series length if nyrs is NULL (see dplR R package).

- **dc_f**: A number between 0 and 1 giving the frequency response or wavelength cutoff. Defaults to 0.5 (see dplR R package).

- **dc_pos.slope**: A logical flag. Will allow for a positive slope to be used in method "ModNegExp" and "ModHugershoff". If FALSE the line will be horizontal (see dplR R package).

- **dc_constrain.nls**: A character string which controls the constraints of the "ModNegExp" model and the "ModHugershoff" (see dplR R package).

- **dc_span**: A numeric value controlling method "Friedman", or "cv" (default) for automatic choice by cross-validation (see dplR R package).

- **dc_bass**: A numeric value controlling the smoothness of the fitted curve in method "Friedman" (see dplR R package).

- **dc_difference**: A logical flag. Compute residuals by subtraction if TRUE, otherwise use division (see dplR R package).

- **cor_na_use**: An optional character string giving a method for computing covariances in the presence of missing values for correlation coefficients. This must be (an abbreviation of) one of the strings "everything" (default), "all.obs", "complete.obs", "na.or.complete", or "pairwise.complete.obs". See also the documentation for the base cor() function.

**Value**

A list with 17 elements:

1. **Calculations**: A matrix with calculated metrics
2. **Method**: The character string of a method
3. **Metric**: The character string indicating the metric used for calculations
4. **Analysed_period**: The character string specifying the analysed period based on the information from row names. If there are no row names, this argument is given as NA
5. **Optimized_return**: Data frame with two columns, response variable and aggregated (averaged) daily data that return the optimal results. This data.frame could be directly used to calibrate a model for climate reconstruction
6. **Optimized_return_all**: A data frame with aggregated daily data, that returned the optimal result for the entire env_data (and not only subset of analysed years)
7. **Transfer_function**: A ggplot object: scatter plot of optimized return and a transfer line of the selected method
8. $temporal_stability - a data frame with calculations of selected metric for different temporal subsets
9. $cross_validation - a data frame with cross validation results
10. $plot_heatmap - ggplot2 object: a heatmap of calculated metrics
11. $plot_extreme - ggplot2 object: line plot of a row with the highest value in a matrix of calculated metrics
12. $plot_specific - ggplot2 object: line plot of a row with a selected window width in a matrix of calculated metrics
13. $PCA_output - princomp object: the result output of the PCA analysis
14. $type - the character string describing type of analysis: daily or monthly
15. $reference_window - character string, which reference window was used for calculations
16. $boot_lower - matrix with lower limit of confidence intervals of bootstrap calculations
17. $boot_upper - matrix with upper limit of confidence intervals of bootstrap calculations
18. $aggregated_climate - matrix with all aggregated climate series

Examples

# Load the dendroTools R package
library(dendroTools)

# Load data
data(data_MVA)
data(data_TRW)
data(data_TRW_1)
data(example_proxies_individual)
data(example_proxies_1)
data(LJ_daily_temperatures)

# 1 Example with fixed width. Lower and upper limits are ignored.
example_daily_response <- daily_response(response = data_MVA,
env_data = LJ_daily_temperatures,
method = "cor", fixed_width = 30, cor_method = "spearman",
row_names_subset = TRUE, previous_year = TRUE,
remove_insignificant = TRUE,
alpha = 0.05, aggregate_function = "mean",
reference_window = "start")

summary(example_daily_response)
plot(example_daily_response, type = 1)
plot(example_daily_response, type = 2)

# 2 Example for past and present. Use subset_years argument.
example_MVA_early <- daily_response(response = data_MVA,
env_data = LJ_daily_temperatures, cor_method = "kendall",
method = "cor", lower_limit = 21, upper_limit = 90,
row_names_subset = TRUE, previous_year = TRUE,
remove_insignificant = TRUE, alpha = 0.05,
```r
plot_specific_window = 60, subset_years = c(1940, 1980),
aggregate_function = 'sum')

example_MVA_late <- daily_response(response = data_MVA,
  env_data = LJ_daily_temperatures,
  method = "cor", lower_limit = 21, upper_limit = 60,
  row_names_subset = TRUE, previous_year = TRUE,
  remove_insignificant = TRUE, alpha = 0.05,
  plot_specific_window = 60, subset_years = c(1981, 2010),
  aggregate_function = 'sum')

plot(example_MVA_early, type = 1)
plot(example_MVA_late, type = 1)
plot(example_MVA_early, type = 2)
plot(example_MVA_late, type = 2)

# 3 Example PCA
example_PCA <- daily_response(response = example_proxies_individual,
  env_data = LJ_daily_temperatures, method = "lm",
  lower_limit = 21, upper_limit = 180,
  row_names_subset = TRUE, remove_insignificant = TRUE,
  alpha = 0.01, PCA_transformation = TRUE,
  components_selection = "manual", N_components = 2)
summary(example_PCA$PCA_output)
summary(example_PCA)
plot(example_PCA, type = 2)

# 4 Example negative correlations
example_neg_cor <- daily_response(response = data_TRW_1,
  env_data = LJ_daily_temperatures, previous_year = TRUE,
  method = "cor", lower_limit = 21, upper_limit = 90,
  row_names_subset = TRUE, remove_insignificant = TRUE,
  alpha = 0.05)
summary(example_neg_cor)
plot(example_neg_cor, type = 1)
plot(example_neg_cor, type = 2)
example_neg_cor$temporal_stability

# 5 Example of multiproxy analysis
summary(example_proxies_1)
cor(example_proxies_1)

example_multiproxy <- daily_response(response = example_proxies_1,
  env_data = LJ_daily_temperatures,
  method = "lm", metric = "adj.r.squared",
  lower_limit = 21, upper_limit = 180,
  row_names_subset = TRUE, previous_year = FALSE,
  remove_insignificant = TRUE, alpha = 0.05)
plot(example_multiproxy, type = 1)
```
# 6 Example to test the temporal stability
```r
eexample_MVA_ts <- daily_response(response = data_MVA, 
   env_data = LJ_daily_temperatures, method = "brnn", 
   lower_limit = 100, metric = "adj.r.squared", upper_limit = 180, 
   row_names_subset = TRUE, remove_insignificant = TRUE, alpha = 0.05, 
   temporal_stability_check = "running_window", k_running_window = 10)
e
eexample_MVA_ts$temporal_stability
```

# 7 Example with nonlinear brnn estimation
```r
eexample_brnn <- daily_response(response = data_MVA, 
   env_data = LJ_daily_temperatures, method = "brnn", boot = FALSE, 
   lower_limit = 100, metric = "adj.r.squared", upper_limit = 101, 
   row_names_subset = TRUE, remove_insignificant = TRUE, boot_n = 10)
e
esummary(example_brnn)
```

---

**Description**

Function calculates all possible partial correlation coefficients between tree-ring chronology and daily environmental (usually climate) data. Calculations are based on moving window which is defined with two arguments: lower_limit and upper_limit. All calculated (partial) correlation coefficients are stored in a matrix. The location of stored correlation in the matrix is indicating a window width (row names) and a location in a matrix of daily sequences of environmental data (column names).

**Usage**

```r
daily_response_seascorr(
   response, 
   env_data_primary, 
   env_data_control, 
   lower_limit = 30, 
   upper_limit = 90, 
   fixed_width = 0, 
   previous_year = FALSE, 
   pcor_method = "pearson", 
   remove_insignificant = TRUE, 
   alpha = 0.05, 
   row_names_subset = FALSE, 
   PCA_transformation = FALSE, 
   log_preprocess = TRUE, 
   components_selection = "automatic", 
)```
eigenvalues_threshold = 1,
N_components = 2,
aggregate_function_env_data_primary = "mean",
aggregate_function_env_data_control = "mean",
temporal_stability_check = "sequential",
k = 2,
k_running_window = 30,
subset_years = NULL,
plot_specific_window = NULL,
ylimits = NULL,
seed = NULL,
tidy_env_data_primary = FALSE,
tidy_env_data_control = FALSE,
reference_window = "start",
boot = FALSE,
boot_n = 1000,
boot_ci_type = "norm",
boot_conf_int = 0.95,
day_interval = ifelse(c(previous_year == TRUE, previous_year == TRUE), c(-1, 366),
                     c(1, 366)),
dc_method = NULL,
dc_nyrs = NULL,
dc_f = 0.5,
dc_pos.slope = FALSE,
dc_constrain.nls = c("never", "when.fail", "always"),
dc_span = "cv",
dc_bass = 0,
dc_difference = FALSE,
pcor_na_use = "pairwise.complete"
)

Arguments

response

A data frame with tree-ring proxy variable and (optional) years as row names. Row names should be matched with those from env_data_primary and env_data_control data frame. If not, set the row_names_subset argument to TRUE.

env_data_primary

Primary data frame of daily sequences of environmental data as columns and years as row names. Each row represents a year and each column represents a day of a year. Row names should be matched with those from the response data frame. If not, set the argument row_names_subset to TRUE. Alternatively, env_data_primary could be a tidy data with three columns, i.e. Year, DOY and third column representing values of mean temperatures, sum of precipitation etc. If tidy data is passed to the function, set the argument tidy_env_data_primary to TRUE.

env_data_control

A data frame of daily sequences of environmental data as columns and years as row names. This data is used as control for calculations of partial correlation coefficients. Each row represents a year and each column represents a
day of a year. Row.names should be matched with those from the response
data frame. If not, set the row_names_subset argument to TRUE. Alternatively,
env_data_control could be a tidy data with three columns, i.e. Year, DOY and
third column representing values of mean temperatures, sum of precipitation etc.
If tidy data is passed to the function, set the argument tidy_env_data_control to
TRUE.

lower_limit  lower limit of window width
upper_limit  upper limit of window width
fixed_width  fixed width used for calculation. If fixed_width is assigned a value, upper_limit
and lower_limit will be ignored
previous_year  if set to TRUE, env_data_primary, env_data_control and response variables will
be rearranged in a way, that also previous year will be used for calculations of
selected statistical metric.

pcor_method  a character string indicating which partial correlation coefficient is to be com-
puted. One of "pearson" (default), "kendall", or "spearman", can be abbreviated.

remove_insignificant  if set to TRUE, removes all correlations bellow the significant threshold level,
 based on a selected alpha.

alpha  significance level used to remove insignificant calculations.

row_names_subset  if set to TRUE, row.names are used to subset env_data_primary, env_data_control
and response data frames. Only years from all three data frames are kept.

PCA_transformation  if set to TRUE, all variables in the response data frame will be transformed using
PCA transformation.

log_preprocess  if set to TRUE, variables will be transformed with logarithmic transformation
before used in PCA

components_selection  character string specifying how to select the Principal Components used as pre-
ddictors. There are three options: "automatic", "manual" and "plot_selection". If
argument is set to automatic, all scores with eigenvalues above 1 will be selected.
This threshold could be changed by changing the eigenvalues_threshold argu-
ment. If parameter is set to "manual", user should set the number of components
with N_components argument. If components selection is set to "plot_selection",
Scree plot will be shown and a user must manually enter the number of compo-
nents to be used as predictors.

eigenvalues_threshold  threshold for automatic selection of Principal Components

N_components  number of Principal Components used as predictors

aggregate_function_env_data_primary  character string specifying how the daily data from env_data_primary should be
aggregated. The default is 'mean', the two other options are 'median' and 'sum'

aggregate_function_env_data_control  character string specifying how the daily data from env_data_control should be
aggregated. The default is 'mean', the two other options are 'median' and 'sum'
temporal_stability_check
character string, specifying how temporal stability between the optimal selection and response variable(s) will be analysed. Current possibilities are "sequential", "progressive" and "running_window". Sequential check will split data into k splits and calculate selected metric for each split. Progressive check will split data into k splits, calculate metric for the first split and then progressively add 1 split at a time and calculate selected metric. For running window, select the length of running window with the k_running_window argument.

k
integer, number of breaks (splits) for temporal stability

k_running_window
the length of running window for temporal stability check. Applicable only if temporal_stability argument is set to running window.

subset_years
a subset of years to be analyzed. Should be given in the form of subset_years = c(1980, 2005)

plot_specific_window
integer representing window width to be displayed for plot_specific

ylimits
limit of the y axes for plot_extreme and plot_specific. It should be given in the form of: ylimits = c(0,1)

seed
optional seed argument for reproducible results

tidy_env_data_primary
if set to TRUE, env_data_primary should be inserted as a data frame with three columns: "Year", "DOY", "Precipitation/Temperature/etc."

tidy_env_data_control
if set to TRUE, env_data_control should be inserted as a data frame with three columns: "Year", "DOY", "Precipitation/Temperature/etc."

reference_window
character string, the reference_window argument describes, how each calculation is referred. There are three different options: 'start' (default), 'end' and 'middle'. If the reference_window argument is set to 'start', then each calculation is related to the starting day of window. If the reference_window argument is set to 'middle', each calculation is related to the middle day of window calculation. If the reference_window argument is set to 'end', then each calculation is related to the ending day of window calculation. For example, if we consider correlations with window from DOY 15 to DOY 35. If reference window is set to 'start', then this calculation will be related to the DOY 15. If the reference window is set to 'end', then this calculation will be related to the DOY 35. If the reference_window is set to 'middle', then this calculation is related to DOY 25. The optimal selection, which describes the optimal consecutive days that returns the highest calculated metric and is obtained by the $plot_extreme output, is the same for all three reference windows.

boot
logical, if TRUE, bootstrap procedure will be used to calculate partial correlation coefficients

boot_n
The number of bootstrap replicates

boot_ci_type
A character string representing the type of bootstrap intervals required. The value should be any subset of the values c("norm", "basic", "stud", "perc", "bca").
A scalar or vector containing the confidence level(s) of the required interval(s)

day_interval
a vector of two values: lower and upper time interval of days that will be used to
calculate statistical metrics. Negative values indicate previous growing season
days. This argument overwrites the calculation limits defined by lower_limit
and upper_limit arguments.

dc_method
a character string to determine the method to detrend climate (environmental) data. Possible values are c("Spline", "ModNegExp", "Mean", "Friedman",
"ModHugershoff"). Defaults to "none" (see dplR R package).

dc_nyrs
a number giving the rigidity of the smoothing spline, defaults to 0.67 of series
length if nyrs is NULL (see dplR R package).

dc_f
a number between 0 and 1 giving the frequency response or wavelength cutoff.
Defaults to 0.5 (see dplR R package).

dc_pos.slope
a logical flag. Will allow for a positive slope to be used in method "ModNeg-
Exp" and "ModHugershoff". If FALSE the line will be horizontal (see dplR R
package).

dc_constrain.nls
a character string which controls the constraints of the "ModNegExp" model
and the "ModHugershoff" (see dplR R package).

dc_span
a numeric value controlling method "Friedman", or "cv" (default) for automatic
choice by cross-validation (see dplR R package).

dc_bass
a numeric value controlling the smoothness of the fitted curve in method "Fried-
man" (see dplR R package).

dc_difference
a logical flag. Compute residuals by subtraction if TRUE, otherwise use division
(see dplR R package).

pcor_na_use
an optional character string giving a method for computing covariances in the
presence of missing values for partial correlation coefficients. This must be
(an abbreviation of) one of the strings "all.obs", "everything", "complete.obs",
"na.or.complete", or "pairwise.complete.obs" (default). See also the documenta-
tion for the base partial.r in psych R package

Value

a list with 15 elements:

1. $calculations - a matrix with calculated metrics
2. $method - the character string of a method
3. $metric - the character string indicating the metric used for calculations
4. $analysed_period - the character string specifying the analysed period based on the informa-
tion from row names. If there are no row names, this argument is given as NA
5. $optimized_return - data frame with two columns, response variable and aggregated (aver-
aged) daily data that return the optimal results. This data.frame could be directly used to
calibrate a model for climate reconstruction
6. $optimized_return_all - a data frame with aggregated daily data, that returned the optimal
result for the entire env_data_primary (and not only subset of analysed years)
7. Transfer_function - a ggplot object: scatter plot of optimized return and a transfer line of the selected method
8. Temporal_stability - a data frame with calculations of selected metric for different temporal subsets
9. Cross_validation - not available for partial correlations
10. Plot_heatmap - ggplot2 object: a heatmap of calculated metrics
11. Plot_extreme - ggplot2 object: line plot of a row with the highest value in a matrix of calculated metrics
12. Plot_specific - ggplot2 object: line plot of a row with a selected window width in a matrix of calculated metrics
13. SPCA_output - princomp object: the result output of the PCA analysis
14. Type - the character string describing type of analysis: daily or monthly
15. Reference_window - character string, which reference window was used for calculations
16. Aggregated_climate_primary - matrix with all aggregated climate series of primary data
17. Aggregated_climate_control - matrix with all aggregated climate series of control data

Examples

```r
# Load the dendroTools R package
library(dendroTools)

# Load data
data(data_MVA)
data(data_TRW)
data(data_TRW_1)
data(example_proxies_individual)
data(example_proxies_1)
data(LJ_daily_temperatures)
data(LJ_daily_precipitation)

# 1 Basic example
daily_response_seascorr(response = data_MVA,
                         env_data_primary = LJ_daily_temperatures,
                         env_data_control = LJ_daily_precipitation,
                         row_names_subset = TRUE, fixed_width = 25,
                         lower_limit = 35, upper_limit = 45,
                         remove_insignificant = TRUE,
                         aggregate_function_env_data_primary = 'median',
                         aggregate_function_env_data_control = 'median',
                         alpha = 0.05, pcor_method = "spearman",
                         tidy_env_data_primary = FALSE,
                         previous_year = FALSE, boot = TRUE,
                         tidy_env_data_control = TRUE, boot_n = 10,
                         reference_window = "end", k = 5,
                         day_interval = c(-100, 250))

summary(example_basic)
plot(example_basic, type = 1)
```
A dataset with a mean vessel area (MVA) chronology of Quercus robur from a lowland oak forest in Eastern Slovenia and a mean April temperature. This dataset includes years for the period 2012-1934. For a detailed description about the MVA chronology development, sampling site and the calculations of mean monthly correlations, see Jevšenak and Levanič (2015).

Usage

dataset_MVA

Format

A data frame with 79 rows and 2 variables:

MVA  Mean vessel area measurements from 2012 - 1934
T_Apr Mean April temperature for the meteorological station Maribor from 2012 - 1934
Source

Example of dataset with individual chronologies of MVA and mean April temperature

Description
A dataset of individual tree-ring chronologies from a lowland forest in Slovenia. The first row represents a value of a year in 2015.

Usage
dataset_MVA_individual

Format
A data frame with 56 rows and 54 columns:

T_Apr  mean April temperature for Ljubljana
MVA_1  Mean vessel area chronology for tree 1
MVA_2  Mean vessel area chronology for tree 2 [mm^2]
MVA_3  Mean vessel area chronology for tree 3 [mm^2]
MVA_4  Mean vessel area chronology for tree 4 [mm^2]
MVA_5  Mean vessel area chronology for tree 5 [mm^2]
MVA_6  Mean vessel area chronology for tree 6 [mm^2]
MVA_7  Mean vessel area chronology for tree 7 [mm^2]
MVA_8  Mean vessel area chronology for tree 8 [mm^2]
MVA_9  Mean vessel area chronology for tree 9 [mm^2]
MVA_10 Mean vessel area chronology for tree 10 [mm^2]

Source
Slovenian Forestry Institute, Večna pot 2, Ljubljana, Slovenia
**dataset_TRW**

**Description**

A dataset with a tree-ring width (TRW) chronology of Pinus nigra from Albania and mean June-July temperature. This TRW chronology has a span of 59 years (period 2009 - 1951) and was already used to reconstruct summer temperatures by Levanić et al. (2015). In this paper, all the details about sample replication, site description and correlation statistics are described.

**Usage**

dataset_TRW

**Format**

A data frame with 59 rows and 2 variables:

- **TRW** Standardised tree-ring width chronology of Pinus nigra from Albania
- **T_Jun_Jul** Mean June - July temperature for Albania downloaded from KNMI Climate Explorer

**Source**


**dataset_TRW_complete**

**Description**

A dataset with a tree-ring width (TRW) chronology of Pinus nigra from Albania. This TRW chronology has a span of 551 years (period 2009 - 1459) and was already used to reconstruct summer temperatures by Levanić et al. (2015). In this paper, all the details about sample replication, site description and correlation statistics are described.

**Usage**

dataset_TRW_complete

**Format**

A data frame with 551 rows and 1 variable:

- **TRW** Standardised tree-ring width chronology of Pinus nigra from Albania

**Source**

**Source**


---

**Description**

A dataset with MVA proxy records from a lowland forest Mlače in Slovenia. The first row represents a value of a year in 2012. Row names represent years.

**Usage**

data_MVA

**Format**

A data frame with 73 rows and 1 variable:

- **MVA** Mean vessel area [mm^2] indices from 2012 - 1940

**Source**

Jernej Jevšenak, Slovenian Forestry Institute, Večna pot 2, Ljubljana, Slovenia

---

**Description**

Transforms daily data with two columns (date and variable) into data frame suitable for daily or monthly analysis with dendroTools.

**Usage**

data_transform(input, 
              format = "daily", 
              monthly_aggregate_function = "auto", 
              date_format = "ymd"
)
Arguments

- **input**: typical daily data format: Data frame with two columns, first column represents date, second column represents variable, such as mean temperature, precipitation, etc. Date should be in format Year-Month-Day (e.g. "2019-05-15")
- **format**: character string indicating the desired output format. Should be "daily" or "monthly". Daily format returns a data frame with 366 columns (days), while monthly format returns data frame with 12 columns (months). Years are indicated as row names.
- **monthly_aggregate_function**: character string indicating, how to aggregate daily into monthly data. It can be "mean" or "sum". Third option is "auto" (default). In this case function will try to guess whether input is temperature or precipitation data. For temperature, it will use "mean", for precipitation "sum".
- **date_format**: Describe the format of date. It should be one of "ymd", "ydm", "myd", "mdy", "dmy", "dym".

Value

env_data suitable for daily or monthly analysis with dendroTools.

Examples

```r
data(swit272_daily_temperatures)
proper_daily_data <- data_transform(swit272_daily_temperatures, format = "daily", date_format = "ymd")

proper_monthly_data <- data_transform(swit272_daily_temperatures, format = "monthly", date_format = "ymd")
data(swit272_daily_precipitation)
proper_daily_data <- data_transform(swit272_daily_precipitation, format = "daily", date_format = "ymd")

proper_monthly_data <- data_transform(swit272_daily_precipitation, format = "monthly", date_format = "ymd")
```

data_TRW

Tree-ring width (TRW) example proxy from 1981 - 1757

Description

A dataset with TRW proxy records from a site in Slovenian Alps - Vrsic. The first row represents a TRW value in a year 1757. Row names represent years.

Usage

data_TRW
data_TRW_1

Format

A data frame with 225 rows and 1 variable:

TRW residual TRW indices from 1981 - 1757

Source

• https://www.ncei.noaa.gov/access/paleo-search/study/4728

---

data_TRW_1

Tree-ring width (TRW) data from 2012 - 1961

Description

A dataset of tree-ring widths (TRW) from a site in Krakovo forest (Slovenia). The first row represents a value of a year in 1961.

Usage

data_TRW_1

Format

A data frame with 52 rows and 1 variable:

TRW Standardized tree-ring width indices from 2012 - 1961

Source

Tom Levanič, Slovenian Forestry Institute, Večna pot 2, Ljubljana, Slovenia

---

example_dataset_1

Example of dataset as required for compare_methods()

Description

A dataset of Mean Vessel Area (MVA) tree-ring parameter from a lowland forest in Slovenia. The first row represents a value of a year in 2012.

Usage

eample_dataset_1
example_proxies_1

Format

A data frame with 58 rows and 3 columns:

- **MVA** Mean Vessel Area measurements from 2012 - 1955
- **T_APR** Mean April temperatures from 2012 - 1955
- **T_aug_sep** Mean August-September temperatures from preceding growing season from 2012 - 1955

Source

Jernej Jevšenak, Slovenian Forestry Institute, Večna pot 2, Ljubljana, Slovenia

Description

A dataset with three tree-ring proxy records from a site near Ljubljana (Slovenia). The first row represents a value of a year in 1961. The three proxy records are MVA (Mean vessel area [mm^2]), O (stable oxygen isotope ratios) and TRW (Tree-ring widths)

Usage

example_proxies_1

Format

A data frame with 55 rows and 3 variables:

- **MVA** Mean vessel area [mm^2] indices from 2015 - 1961
- **O18** Scaled Stable oxygen isotope ratios from 2015 - 1961
- **TRW** Tree-ring widths from 2015 - 1961

Source

Jernej Jevšenak, Slovenian Forestry Institute, Večna pot 2, Ljubljana, Slovenia
**Example of dataset with individual chronologies of MVA.**

**Description**

A dataset of individual tree-ring chronologies from a lowland forest in Slovenia. The first row represents a value of a year in 2015.

**Usage**

example_proxies_individual

**Format**

A data frame with 56 rows and 54 columns:

- **MVA_1** Mean vessel area chronology for tree 1
- **MVA_2** Mean vessel area chronology for tree 2
- **MVA_3** Mean vessel area chronology for tree 3
- **MVA_4** Mean vessel area chronology for tree 4
- **MVA_5** Mean vessel area chronology for tree 5
- **MVA_6** Mean vessel area chronology for tree 6
- **MVA_7** Mean vessel area chronology for tree 7
- **MVA_8** Mean vessel area chronology for tree 8
- **MVA_9** Mean vessel area chronology for tree 9
- **MVA_10** Mean vessel area chronology for tree 10

**Source**

Jernej Jevšenak, Slovenian Forestry Institute, Večna pot 2, Ljubljana, Slovenia

---

**glimpse_daily_data**  
**glimpse_daily_data**

**Description**

Visual presentation of daily data to spot missing values.
Usage

glimpse_daily_data(
  env_data,
  na.color = "red",
  low_color = "blue",
  high_color = "green",
  tidy_env_data = FALSE
)

Arguments

env_data          a data frame of daily sequences of environmental data as columns and years as row names. Each row represents a year and each column represents a day of a year. Alternatively, env_data could be a tidy data with three columns, i.e. Year, DOY and third column representing values of mean temperatures, sum of precipitation etc. If tidy data is passed to the function, set the argument tidy_env_data to TRUE.
na.color          color to use for missing values
low_color         colours for low end of the gradient
high_color        colours for high end of the gradient
tidy_env_data     if set to TRUE, env_data should be inserted as a data frame with three columns: "Year", "DOY", "Precipitation/Temperature/etc."

Examples

library(dendroTools)
data("LJ_daily_temperatures")
glimpse_daily_data(env_data = LJ_daily_temperatures,
  tidy_env_data = FALSE, na.color = "white")
data("LJ_daily_precipitation")
glimpse_daily_data(env_data = LJ_daily_precipitation,
  tidy_env_data = TRUE, na.color = "white")

KRE_daily_temperatures

Daily mean temperatures for Kredarica (Alps in Slovenia) from 2017 - 1955

Description

A dataset of daily mean temperatures in Kredarica (Slovenia). The first row represents temperatures in 1955. The first column represents the first day of a year, the second column represents the second day of a year, etc. Row names represent years.
Usage

KRE_daily_temperatures

Format

A data frame with 63 rows and 366 variables:

X1  Temperatures on the day 1 of a year
X2  Temperatures on the day 2 of a year
X3  Temperatures on the day 3 of a year
X4  Temperatures on the day 4 of a year
X5  Temperatures on the day 5 of a year
X6  Temperatures on the day 6 of a year
X7  Temperatures on the day 7 of a year
X8  Temperatures on the day 8 of a year
X9  Temperatures on the day 9 of a year
X10 Temperatures on the day 10 of a year
X11 Temperatures on the day 11 of a year
X12 Temperatures on the day 12 of a year
X13 Temperatures on the day 13 of a year
X14 Temperatures on the day 14 of a year
X15 Temperatures on the day 15 of a year
X16 Temperatures on the day 16 of a year
X17 Temperatures on the day 17 of a year
X18 Temperatures on the day 18 of a year
X19 Temperatures on the day 19 of a year
X20 Temperatures on the day 20 of a year
X21 Temperatures on the day 21 of a year
X22 Temperatures on the day 22 of a year
X23 Temperatures on the day 23 of a year
X24 Temperatures on the day 24 of a year
X25 Temperatures on the day 25 of a year
X26 Temperatures on the day 26 of a year
X27 Temperatures on the day 27 of a year
X28 Temperatures on the day 28 of a year
X29 Temperatures on the day 29 of a year
X30 Temperatures on the day 30 of a year
X31 Temperatures on the day 31 of a year
X32 Temperatures on the day 32 of a year
X33  Temperatures on the day 33 of a year
X34  Temperatures on the day 34 of a year
X35  Temperatures on the day 35 of a year
X36  Temperatures on the day 36 of a year
X37  Temperatures on the day 37 of a year
X38  Temperatures on the day 38 of a year
X39  Temperatures on the day 39 of a year
X40  Temperatures on the day 40 of a year
X41  Temperatures on the day 41 of a year
X42  Temperatures on the day 42 of a year
X43  Temperatures on the day 43 of a year
X44  Temperatures on the day 44 of a year
X45  Temperatures on the day 45 of a year
X46  Temperatures on the day 46 of a year
X47  Temperatures on the day 47 of a year
X48  Temperatures on the day 48 of a year
X49  Temperatures on the day 49 of a year
X50  Temperatures on the day 50 of a year
X51  Temperatures on the day 51 of a year
X52  Temperatures on the day 52 of a year
X53  Temperatures on the day 53 of a year
X54  Temperatures on the day 54 of a year
X55  Temperatures on the day 55 of a year
X56  Temperatures on the day 56 of a year
X57  Temperatures on the day 57 of a year
X58  Temperatures on the day 58 of a year
X59  Temperatures on the day 59 of a year
X60  Temperatures on the day 60 of a year
X61  Temperatures on the day 61 of a year
X62  Temperatures on the day 62 of a year
X63  Temperatures on the day 63 of a year
X64  Temperatures on the day 64 of a year
X65  Temperatures on the day 65 of a year
X66  Temperatures on the day 66 of a year
X67  Temperatures on the day 67 of a year
X68  Temperatures on the day 68 of a year
X69  Temperatures on the day 69 of a year
X70  Temperatures on the day 70 of a year
X71  Temperatures on the day 71 of a year
X72  Temperatures on the day 72 of a year
X73  Temperatures on the day 73 of a year
X74  Temperatures on the day 74 of a year
X75  Temperatures on the day 75 of a year
X76  Temperatures on the day 76 of a year
X77  Temperatures on the day 77 of a year
X78  Temperatures on the day 78 of a year
X79  Temperatures on the day 79 of a year
X80  Temperatures on the day 80 of a year
X81  Temperatures on the day 81 of a year
X82  Temperatures on the day 82 of a year
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KRE_daily_temperatures

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Temperatures on the day 366 of a year

Source
http://meteo.arso.gov.si/met/sl/archive/
**LJ_daily_precipitation**

*Daily precipitation for Ljubljana from 2017 - 1900*

**Description**

A dataset of daily sum of precipitation [mm] in Ljubljana (Slovenia). The first row represents precipitation in 1900 on DOY 1.

**Usage**

LJ_daily_precipitation

**Format**

A data frame with 43067 rows and 3 variables:

- **Year** year
- **DOY** day of year
- **Precipitation** Sum of precipitation in mm

**Source**

[http://climexp.knmi.nl/start.cgi](http://climexp.knmi.nl/start.cgi)

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**LJ_daily_temperatures**

*Daily mean temperatures for Ljubljana from 2016 - 1930*

**Description**

A dataset of daily mean temperatures in Ljubljana (Slovenia). The first row represents temperatures in 1930. The first column represents the first day of a year, the second column represents the second day of a year, etc.

**Usage**

LJ_daily_temperatures
Format

A data frame with 87 rows and 366 variables:

X1  Temperatures on the day 1 of a year
X2  Temperatures on the day 2 of a year
X3  Temperatures on the day 3 of a year
X4  Temperatures on the day 4 of a year
X5  Temperatures on the day 5 of a year
X6  Temperatures on the day 6 of a year
X7  Temperatures on the day 7 of a year
X8  Temperatures on the day 8 of a year
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LJ_daily_temperatures

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X296  Temperatures on the day 296 of a year  
X297  Temperatures on the day 297 of a year  
X298  Temperatures on the day 298 of a year  
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Temperatures on the day 366 of a year

Source
http://climexp.knmi.nl/start.cgi
LJ_monthly_precipitation

*Monthly sums of precipitation for Ljubljana from 2018 - 1900. Tidy format.*

**Description**

A dataset of monthly sums of precipitations in Ljubljana (Slovenia). The first row represents precipitation sum for January 1900.

**Usage**

LJ_monthly_precipitation

**Format**

A data frame with 1417 rows and 3 variables:

- **Year** year
- **Month** Month
- **Precipitation** Sum of precipitation

**Source**

http://climexp.knmi.nl/start.cgi

LJ_monthly_temperatures

*Monthly mean air temperatures for Ljubljana from 2015 - 1900*

**Description**

A dataset of monthly mean air temperatures in Ljubljana (Slovenia). The first row represents temperatures in 2015. The first column represents mean January temperature, the second column represents mean February temperature. etc. Row names represent year.

**Usage**

LJ_monthly_temperatures
monthly_response

Format

A data frame with 116 rows and 12 variables:

- **Jan**: Mean monthly air temperature for January from 1900 to 2015
- **Feb**: Mean monthly air temperature for February from 1900 to 2015
- **Mar**: Mean monthly air temperature for March from 1900 to 2015
- **Apr**: Mean monthly air temperature for April from 1900 to 2015
- **May**: Mean monthly air temperature for May from 1900 to 2015
- **Jun**: Mean monthly air temperature for June from 1900 to 2015
- **Jul**: Mean monthly air temperature for July from 1900 to 2015
- **Aug**: Mean monthly air temperature for August from 1900 to 2015
- **Sep**: Mean monthly air temperature for September from 1900 to 2015
- **Oct**: Mean monthly air temperature for October from 1900 to 2015
- **Nov**: Mean monthly air temperature for November from 1900 to 2015
- **Dec**: Mean monthly air temperature for December from 1900 to 2015

Source

http://meteo.arso.gov.si/met/sl/archive/

Description

Function calculates all possible values of a selected statistical metric between one or more response variables and monthly sequences of environmental data. Calculations are based on moving window which slides through monthly environmental data. All calculated metrics are stored in a matrix. The location of stored calculated metric in the matrix is indicating a window width (row names) and a location in a matrix of monthly sequences of environmental data (column names).

Usage

```r
monthly_response(
  response,
  env_data,
  method = "cor",
  metric = "r.squared",
  cor_method = "pearson",
  previous_year = FALSE,
  neurons = 1,
  lower_limit = 1,
  upper_limit = 12,
  fixed_width = 0,
)```

brnn_smooth = TRUE,
remove_insignificant = TRUE,
alpha = 0.05,
row_names_subset = FALSE,
PCA_transformation = FALSE,
log_preprocess = TRUE,
components_selection = "automatic",
eigenvalues_threshold = 1,
N_components = 2,
aggregate_function = "mean",
temporal_stability_check = "sequential",
k = 2,
k_running_window = 30,
cross_validation_type = "blocked",
subset_years = NULL,
plot_specific_window = NULL,
ylimits = NULL,
seed = NULL,
tidy_env_data = FALSE,
boot = FALSE,
boot_n = 1000,
boot_ci_type = "norm",
boot_conf_int = 0.95,
month_interval = ifelse(c(previous_year == TRUE, previous_year == TRUE), c(-1, 12),
c(1, 12)),
dc_method = NULL,
dc_nyrs = NULL,
dc_f = 0.5,
dc_pos.slope = FALSE,
dc_constrain.nls = c("never", "when.fail", "always"),
dc_span = "cv",
dc_bass = 0,
dc_difference = FALSE,
cor_na_use = "everything"
)

Arguments

response a data frame with tree-ring proxy variables as columns and (optional) years as row names. Row.names should be matched with those from a env_data data frame. If not, set row_names_subset = TRUE.

env_data a data frame of monthly sequences of environmental data as columns and years as row names. Each row represents a year and each column represents a day of a year (or month). Row.names should be matched with those from a response data frame. If not, set row_names_subset = TRUE. Alternatively, env_data could be a tidy data with three columns, i.e. Year, DOY (Month) and third column representing values of mean temperatures, sum of precipitation etc. If tidy data is passed to the function, set the argument tidy_env_data to TRUE.
**monthly_response**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>method</td>
<td>a character string specifying which method to use. Current possibilities are &quot;cor&quot; (default), &quot;lm&quot; and &quot;brnn&quot;.</td>
</tr>
<tr>
<td>metric</td>
<td>a character string specifying which metric to use. Current possibilities are &quot;r.squared&quot; and &quot;adj.r.squared&quot;. If method = &quot;cor&quot;, metric is not relevant.</td>
</tr>
<tr>
<td>cor_method</td>
<td>a character string indicating which correlation coefficient is to be computed. One of &quot;pearson&quot; (default), &quot;kendall&quot;, or &quot;spearman&quot;.</td>
</tr>
<tr>
<td>previous_year</td>
<td>if set to TRUE, env_data and response variables will be rearranged in a way, that also previous year will be used for calculations of selected statistical metric.</td>
</tr>
<tr>
<td>neurons</td>
<td>positive integer that indicates the number of neurons used for brnn method</td>
</tr>
<tr>
<td>lower_limit</td>
<td>lower limit of window width (i.e. number of consecutive months to be used for calculations)</td>
</tr>
<tr>
<td>upper_limit</td>
<td>upper limit of window width (i.e. number of consecutive months to be used for calculations)</td>
</tr>
<tr>
<td>fixed_width</td>
<td>fixed width used for calculations (i.e. number of consecutive months to be used for calculations)</td>
</tr>
<tr>
<td>brnn_smooth</td>
<td>if set to TRUE, a smoothing algorithm is applied that removes unrealistic calculations which are a result of neural net failure.</td>
</tr>
<tr>
<td>remove_insignificant</td>
<td>if set to TRUE, removes all correlations bellow the significant threshold level, based on a selected alpha. For &quot;lm&quot; and &quot;brnn&quot; method, squared threshold is used, which corresponds to R squared statistics.</td>
</tr>
<tr>
<td>alpha</td>
<td>significance level used to remove insignificant calculations.</td>
</tr>
<tr>
<td>row_names_subset</td>
<td>if set to TRUE, row.names are used to subset env_data and response data frames. Only years from both data frames are kept.</td>
</tr>
<tr>
<td>PCA_transformation</td>
<td>if set to TRUE, all variables in the response data frame will be transformed using PCA transformation.</td>
</tr>
<tr>
<td>log_preprocess</td>
<td>if set to TRUE, variables will be transformed with logarithmic transformation before used in PCA</td>
</tr>
<tr>
<td>components_selection</td>
<td>character string specifying how to select the Principal Components used as predictors. There are three options: &quot;automatic&quot;, &quot;manual&quot; and &quot;plot_selection&quot;. If argument is set to automatic, all scores with eigenvalues above 1 will be selected. This threshold could be changed by changing the eigenvalues_threshold argument. If parameter is set to &quot;manual&quot;, user should set the number of components with N_components argument. If components selection is set to &quot;plot_selection&quot;, Scree plot will be shown and a user must manually enter the number of components to be used as predictors.</td>
</tr>
<tr>
<td>eigenvalues_threshold</td>
<td>threshold for automatic selection of Principal Components</td>
</tr>
<tr>
<td>N_components</td>
<td>number of Principal Components used as predictors</td>
</tr>
<tr>
<td>aggregate_function</td>
<td>character string specifying how the monthly data should be aggregated. The default is 'mean', the two other options are 'median' and 'sum'</td>
</tr>
</tbody>
</table>
temporal_stability_check
character string, specifying how temporal stability between the optimal selection and response variable(s) will be analysed. Current possibilities are "sequential", "progressive" and "running_window". Sequential check will split data into k splits and calculate selected metric for each split. Progressive check will split data into k splits, calculate metric for the first split and then progressively add 1 split at a time and calculate selected metric. For running window, select the length of running window with the k_running_window argument.

k
integer, number of breaks (splits) for temporal stability and cross validation analysis.

cross_validation_type
character string, specifying how to perform cross validation between the optimal selection and response variables. If the argument is set to "blocked", years will not be shuffled. If the argument is set to "randomized", years will be shuffled.

subset_years
a subset of years to be analyzed. Should be given in the form of subset_years = c(1980, 2005)

plot_specific_window
integer representing window width to be displayed for plot_specific

ylimits
limit of the y axes for plot_extreme and plot_specific. It should be given in the form of: ylimits = c(0,1)

seed
optional seed argument for reproducible results

tidy_env_data
if set to TRUE, env_data should be inserted as a data frame with three columns: "Year", "Month", "Precipitation/Temperature/etc."

boot
logical, if TRUE, bootstrap procedure will be used to calculate estimates correlation coefficients, R squared or adjusted R squared metrics

boot_n
The number of bootstrap replicates

boot_ci_type
A character string representing the type of bootstrap intervals required. The value should be any subset of the values c("norm","basic","stud","perc","bca").

boot_conf_int
A scalar or vector containing the confidence level(s) of the required interval(s)

month_interval
a vector of two values: lower and upper time interval of months that will be used to calculate statistical metrics. Negative values indicate previous growing season months. This argument overwrites the calculation limits defined by lower_limit and upper_limit arguments.

dc_method
a character string to determine the method to detrend climate (environmental) data. Possible values are c("Spline", "ModNegExp", "Mean", "Friedman", "ModHugershoff"). Defaults to "none" (see dplR R package).

dc_nyrs
a number giving the rigidity of the smoothing spline, defaults to 0.67 of series length if nyrs is NULL (see dplR R package).

dc_f
a number between 0 and 1 giving the frequency response or wavelength cutoff. Defaults to 0.5 (see dplR R package).
**monthly_response**

dc_pos.slope a logical flag. Will allow for a positive slope to be used in method "ModNeg-Exp" and "ModHugershoff". If FALSE the line will be horizontal (see dplR R package).

dc_constrain.nls a character string which controls the constraints of the "ModNegExp" model and the "ModHugershoff" (see dplR R package).

dc_span a numeric value controlling method "Friedman", or "cv" (default) for automatic choice by cross-validation (see dplR R package).

dc_bass a numeric value controlling the smoothness of the fitted curve in method "Friedman" (see dplR R package).

dc_difference a logical flag. Compute residuals by subtraction if TRUE, otherwise use division (see dplR R package).

cor_na_use an optional character string giving a method for computing covariances in the presence of missing values for correlation coefficients. This must be (an abbreviation of) one of the strings "everything" (default), "all.obs", "complete.obs", "na.or.complete", or "pairwise.complete.obs". See also the documentation for the base cor() function.

**Value**

a list with 17 elements:

1. Calculations - a matrix with calculated metrics
2. $method - the character string of a method
3. $metric - the character string indicating the metric used for calculations
4. $analysed_period - the character string specifying the analysed period based on the information from row names. If there are no row names, this argument is given as NA
5. $optimized_return - data frame with two columns, response variable and aggregated (averaged) monthly data that return the optimal results. This data.frame could be directly used to calibrate a model for climate reconstruction
6. $optimized_return_all - a data frame with aggregated monthly data, that returned the optimal result for the entire env_data (and not only subset of analysed years)
7. $transfer_function - a ggplot object: scatter plot of optimized return and a transfer line of the selected method
8. $temporal_stability - a data frame with calculations of selected metric for different temporal subsets
9. $cross_validation - a data frame with cross validation results
10. $plot_heatmap - ggplot2 object: a heatmap of calculated metrics
11. $plot_extreme - ggplot2 object: line or bar plot of a row with the highest value in a matrix of calculated metrics
12. $plot_specific - not available for monthly_response()
13. $PCA_output - princomp object: the result output of the PCA analysis
14. $type - the character string describing type of analysis: daily or monthly
15. $reference_window - character string, which reference window was used for calculations
16. $boot_lower - matrix with lower limit of confidence intervals of bootstrap calculations
17. $boot_upper - matrix with upper limit of confidence intervals of bootstrap calculations
18. $aggregated_climate - matrix with all aggregated climate series

Examples

# Load the dendroTools R package
library(dendroTools)

# Load data used for examples
data(data_MVA)
data(data_TRW)
data(data_TRW_1)
data(example_proxies_individual)
data(example_proxies_1)
data(LJ_monthly_temperatures)
data(LJ_monthly_precipitation)

# 1 Example with tidy precipitation data
example_tidy_data <- monthly_response(response = data_MVA,
   lower_limit = 1, upper = 12,
   env_data = LJ_monthly_precipitation, fixed_width = 0,
   method = "cor", row_names_subset = TRUE, metric = "adj.r.squared",
   remove_insignificant = TRUE, previous_year = FALSE,
   alpha = 0.05, aggregate_function = 'sum', boot = TRUE,
   tidy_env_data = TRUE, boot_n = 100, month_interval = c(-5, 10))

summary(example_tidy_data)
plot(example_tidy_data, type = 1)
plot(example_tidy_data, type = 2)

# 2 Example with split data for early and late
example_MVA_early <- monthly_response(response = data_MVA,
   env_data = LJ_monthly_temperatures,
   method = "cor", row_names_subset = TRUE, previous_year = TRUE,
   remove_insignificant = TRUE, alpha = 0.05,
   subset_years = c(1940, 1980), aggregate_function = 'mean')

example_MVA_late <- monthly_response(response = data_MVA,
   env_data = LJ_monthly_temperatures,
   method = "cor", row_names_subset = TRUE, alpha = 0.05,
   previous_year = TRUE, remove_insignificant = TRUE,
   subset_years = c(1981, 2010), aggregate_function = 'mean')

summary(example_MVA_late)
plot(example_MVA_early, type = 1)
plot(example_MVA_late, type = 1)
plot(example_MVA_early, type = 2)
plot(example_MVA_late, type = 2)
# 3 Example with principal component analysis

```r
eexample_PCA <- monthly_response(response = example_proxies_individual,  
env_data = LJ_monthly_temperatures, method = "lm",  
row_names_subset = TRUE, remove_insignificant = TRUE,  
alpha = 0.01, PCA_transformation = TRUE, previous_year = TRUE,  
components_selection = "manual", N_components = 2, boot = TRUE)

summary(example_PCA$PCA_output)
plot(example_PCA, type = 1)
plot(example_PCA, type = 2)
```

# 4 Example negative correlations

```r
eexample_neg_cor <- monthly_response(response = data_TRW_1, alpha = 0.05,  
env_data = LJ_monthly_temperatures,  
method = "cor", row_names_subset = TRUE,  
remove_insignificant = TRUE, boot = TRUE)

summary(example_neg_cor)
plot(example_neg_cor, type = 1)
plot(example_neg_cor, type = 2)
eexample_neg_cor$temporal_stability
```

# 5 Example of multiproxy analysis

```r
cor(example_proxies_1)
```

```
eexample_multiproxy <- monthly_response(response = example_proxies_1,  
env_data = LJ_monthly_temperatures,  
method = "lm", metric = "adj.r.squared",  
row_names_subset = TRUE, previous_year = FALSE,  
remove_insignificant = TRUE, alpha = 0.05)

summary(example_multiproxy)
plot(example_multiproxy, type = 1)
```

# 6 Example to test the temporal stability

```r
eexample_MVA_ts <- monthly_response(response = data_MVA,  
env_data = LJ_monthly_temperatures,  
method = "lm", metric = "adj.r.squared", row_names_subset = TRUE,  
remove_insignificant = TRUE, alpha = 0.05,  
temporal_stability_check = "running_window", k_running_window = 10)

summary(example_MVA_ts)
eexample_MVA_ts$temporal_stability
```
Description

Function calculates all possible partial correlation coefficients between tree-ring chronology and monthly environmental (usually climate) data. All calculated (partial) correlation coefficients are stored in a matrix. The location of stored correlation in the matrix is indicating a window width (row names) and a location in a matrix of monthly sequences of environmental data (column names).

Usage

```r
monthly_response_seascorr(
    response,
    env_data_primary,
    env_data_control,
    previous_year = FALSE,
    pcor_method = "pearson",
    remove_insignificant = TRUE,
    lower_limit = 1,
    upper_limit = 12,
    fixed_width = 0,
    alpha = 0.05,
    row_names_subset = FALSE,
    PCA_transformation = FALSE,
    log_preprocess = TRUE,
    components_selection = "automatic",
    eigenvalues_threshold = 1,
    N_components = 2,
    aggregate_function_env_data_primary = "mean",
    aggregate_function_env_data_control = "mean",
    temporal_stability_check = "sequential",
    k = 2,
    k_running_window = 30,
    subset_years = NULL,
    plot_specific_window = NULL,
    ylims = NULL,
    seed = NULL,
    tidy_env_data_primary = FALSE,
    tidy_env_data_control = FALSE,
    boot = FALSE,
    boot_n = 1000,
    boot_ci_type = "norm",
    boot_conf_int = 0.95,
    month_interval = ifelse(c(previous_year == TRUE, previous_year == TRUE), c(-1, 12),
                           c(1, 12)),
    dc_method = NULL,
    dc_nyrs = NULL,
    dc_f = 0.5,
    dc_pos.slope = FALSE,
    dc_constrain.nls = c("never", "when.fail", "always"),
    dc_span = "cv",
)`
Arguments

response a data frame with tree-ring proxy variable and (optional) years as row names. Row.names should be matched with those from env_data_primary and env_data_control data frame. If not, set the row_names_subset argument to TRUE.

env_data_primary primary data frame of monthly sequences of environmental data as columns and years as row names. Each row represents a year and each column represents a day of a year. Row.names should be matched with those from the response data frame. If not, set the argument row_names_subset to TRUE. Alternatively, env_data_primary could be a tidy data with three columns, i.e. Year, Month and third column representing values of mean temperatures, sum of precipitation etc. If tidy data is passed to the function, set the argument tidy_env_data_primary to TRUE.

env_data_control a data frame of monthly sequences of environmental data as columns and years as row names. This data is used as control for calculations of partial correlation coefficients. Each row represents a year and each column represents a day of a year. Row.names should be matched with those from the response data frame. If not, set the row_names_subset argument to TRUE. Alternatively, env_data_control could be a tidy data with three columns, i.e. Year, Month and third column representing values of mean temperatures, sum of precipitation etc. If tidy data is passed to the function, set the argument tidy_env_data_control to TRUE.

previous_year if set to TRUE, env_data_primary, env_data_control and response variables will be rearranged in a way, that also previous year will be used for calculations of selected statistical metric.

pcor_method a character string indicating which partial correlation coefficient is to be computed. One of "pearson" (default), "kendall", or "spearman", can be abbreviated.

remove_insignificant if set to TRUE, removes all correlations bellow the significant threshold level, based on a selected alpha.

lower_limit lower limit of window width (i.e. number of consecutive months to be used for calculations)

upper_limit upper limit of window width (i.e. number of consecutive months to be used for calculations)

fixed_width fixed width used for calculations (i.e. number of consecutive months to be used for calculations)

alpha significance level used to remove insignificant calculations.

row_names_subset if set to TRUE, row.names are used to subset env_data_primary, env_data_control and response data frames. Only years from all three data frames are kept.
PCA_transformation
if set to TRUE, all variables in the response data frame will be transformed using PCA transformation.

log_preprocess
if set to TRUE, variables will be transformed with logarithmic transformation before used in PCA

components_selection
character string specifying how to select the Principal Components used as predictors. There are three options: "automatic", "manual" and "plot_selection". If argument is set to automatic, all scores with eigenvalues above 1 will be selected. This threshold could be changed by changing the eigenvalues_threshold argument. If parameter is set to "manual", user should set the number of components with N_components argument. If components selection is set to "plot_selection", Scree plot will be shown and a user must manually enter the number of components to be used as predictors.

eigenvalues_threshold
threshold for automatic selection of Principal Components

N_components
number of Principal Components used as predictors

aggregate_function_env_data_primary
character string specifying how the monthly data from env_data_primary should be aggregated. The default is 'mean', the two other options are 'median' and 'sum'

aggregate_function_env_data_control
character string specifying how the monthly data from env_data_control should be aggregated. The default is 'mean', the two other options are 'median' and 'sum'

temporal_stability_check
character string, specifying, how temporal stability between the optimal selection and response variable(s) will be analysed. Current possibilities are "sequential", "progressive" and "running_window". Sequential check will split data into k splits and calculate selected metric for each split. Progressive check will split data into k splits, calculate metric for the first split and then progressively add 1 split at a time and calculate selected metric. For running window, select the length of running window with the k_running_window argument.

k
integer, number of breaks (splits) for temporal stability

k_running_window
the length of running window for temporal stability check. Applicable only if temporal_stability argument is set to running window.

subset_years
a subset of years to be analyzed. Should be given in the form of subset_years = c(1980, 2005)

plot_specific_window
integer representing window width to be displayed for plot_specific

ylimits
limit of the y axes for plot_extreme and plot_specific. It should be given in the form of: ylimits = c(0,1)

seed
optional seed argument for reproducible results

tidy_env_data_primary
if set to TRUE, env_data_primary should be inserted as a data frame with three columns: "Year", "Month", "Precipitation/Temperature/etc."
tidy_env_data_control
if set to TRUE, env_data_control should be inserted as a data frame with three
columns: "Year", "Month", "Precipitation/Temperature/etc."

boot
logical, if TRUE, bootstrap procedure will be used to calculate partial correlation
coefficients

boot_n
The number of bootstrap replicates

boot_ci_type
A character string representing the type of bootstrap intervals required. The
value should be any subset of the values c("norm","basic", "stud", "perc", "bca").

boot_conf_int
A scalar or vector containing the confidence level(s) of the required interval(s)

month_interval
a vector of two values: lower and upper time interval of months that will be used
to calculate statistical metrics. Negative values indicate previous growing season
months. This argument overwrites the calculation limits defined by lower_limit
and upper_limit arguments.

dc_method
a character string to determine the method to detrend climate (environmental)
data. Possible values are c("Spline", "ModNegExp", "Mean", "Friedman",
"ModHugershoff"). Defaults to "none" (see dplR R package).

dc_nyrs
a number giving the rigidity of the smoothing spline, defaults to 0.67 of series
length if nyrs is NULL (see dplR R package).

dc_f
a number between 0 and 1 giving the frequency response or wavelength cutoff.
Defaults to 0.5 (see dplR R package).

dc_pos.slope
a logical flag. Will allow for a positive slope to be used in method "ModNeg-
Exp" and "ModHugershoff". If FALSE the line will be horizontal (see dplR R
package).

dc_constrain.nls
a character string which controls the constraints of the "ModNegExp" model
and the "ModHugershoff" (see dplR R package).

dc_span
a numeric value controlling method "Friedman", or "cv" (default) for automatic
choice by cross-validation (see dplR R package).

dc_bass
a numeric value controlling the smoothness of the fitted curve in method "Fried-
man" (see dplR R package).

dc_difference
a logical flag. Compute residuals by subtraction if TRUE, otherwise use division
(see dplR R package).

pcor_na_use
an optional character string giving a method for computing covariances in the
presence of missing values for partial correlation coefficients. This must be
(an abbreviation of) one of the strings "all.obs", "everything", "complete.obs",
"na.or.complete", or "pairwise.complete.obs" (default). See also the documenta-
tion for the base partial.r in psych R package

Value
a list with 15 elements:

1. $calculations - a matrix with calculated metrics
2. $method - the character string of a method
3. $metric - the character string indicating the metric used for calculations
4. $analysed_period - the character string specifying the analysed period based on the information from row names. If there are no row names, this argument is given as NA

5. $optimized_return - data frame with two columns, response variable and aggregated (averaged) monthly data that return the optimal results. This data.frame could be directly used to calibrate a model for climate reconstruction

6. $optimized_return_all - a data frame with aggregated monthly data, that returned the optimal result for the entire env_data_primary (and not only subset of analysed years)

7. $transfer_function - a ggplot object: scatter plot of optimized return and a transfer line of the selected method

8. $temporal_stability - a data frame with calculations of selected metric for different temporal subsets

9. $cross_validation - not available for partial correlation method

10. $plot_heatmap - ggplot2 object: a heatmap of calculated metrics

11. $plot_extreme - ggplot2 object: line plot of a row with the highest value in a matrix of calculated metrics

12. $plot_specific - ggplot2 object: line plot of a row with a selected window width in a matrix of calculated metrics

13. $PCA_output - princomp object: the result output of the PCA analysis

14. $type - the character string describing type of analysis: monthly or monthly

15. $reference_window - character string, which reference window was used for calculations

16. $aggregated_climate_primary - matrix with all aggregated climate series of primary data

17. $aggregated_climate_control - matrix with all aggregated climate series of control data

Examples

```r
# Load the dendroTools R package
library(dendroTools)

# Load data
data(data_MVA)
data(data_TRW)
data(data_TRW_1)
data(example_proxies_individual)
data(example_proxies_1)
data(LJ_monthly_temperatures)
data(LJ_monthly_precipitation)

# 1 Basic example
eample_basic <- monthly_response_seascorr(response = data_MVA,
  fixed_width = 11,
  env_data_primary = LJ_monthly_temperatures,
  env_data_control = LJ_monthly_precipitation,
  row_names_subset = TRUE,
  remove_insignificant = TRUE,
  aggregate_function_env_data_primary = 'median',
  aggregate_function_env_data_control = 'median',
```
alpha = 0.05, pcor_method = "spearman",
 tidy_env_data_primary = FALSE,
tidy_env_data_control = TRUE,
previous_year = TRUE)

summary(example_basic)
plot(example_basic, type = 1)
plot(example_basic, type = 2)
plot(example_basic, type = 3)
example_basic$optimized_return
example_basic$optimized_return_all
example_basic$temporal_stability

# 2 Extended example
example_extended <- monthly_response_seascorr(response = data_MVA,
 env_data_primary = LJ_monthly_temperatures,
 env_data_control = LJ_monthly_precipitation,
 row_names_subset = TRUE,
 remove_insignificant = TRUE,
 aggregate_function_env_data_primary = 'mean',
 aggregate_function_env_data_control = 'mean',
 alpha = 0.05,
 tidy_env_data_primary = FALSE,
tidy_env_data_control = TRUE)

summary(example_extended)
plot(example_extended, type = 1)
plot(example_extended, type = 2)
example_extended$optimized_return
example_extended$optimized_return_all

---

swit272  Standardised tree-ring width chronology swit272, Larix decidua Mill.

Description


Usage

swit272

Format

A data frame with 273 rows and 1 variable:

TRWi  Standardised tree-ring width chronology
swit272_daily_precipitation

*Source*

https://www.ncei.noaa.gov/access/paleo-search/study/14108

---

swit272_daily_precipitation

*Daily precipitation for swit272 chronology*

---

**Description**

Sum of daily precipitation in millimeters for the period 1950 - 2019. This gridded E-OBS data on 0.1° regular grid, version 20e. Extracted data is for the grid point with lon = 9.75 and lat = 46.45.

**Usage**

swit272_daily_precipitation

**Format**

A data frame with 25414 rows and 2 variables:

- **date**: character string describing date
- **p_sum**: mean temperature

**Details**


**Source**

https://www.ecad.eu/download/ensembles/download.php
swit272_daily_temperatures

*Daily temperatures for swit272 chronology*

**Description**

Mean daily temperature in Celsius for the period 1950 - 2019. This gridded E-OBS data on 0.1° regular grid, version 20e. Extracted data is for the grid point with lon = 9.75 and lat = 46.45.

**Usage**

`swit272_daily_temperatures`

**Format**

A data frame with 25414 rows and 2 variables:

- **date** character string describing date
- **t_avg** mean temperature

**Details**


**Source**


---

years_to_rownames

*Function returns a data frame with row names as years*

**Description**

Function returns a data frame with row names as years

**Usage**

```
years_to_rownames(data, column_year)
```

**Arguments**

- **data** a data frame to be manipulated
- **column_year** string specifying a column with years
Value

a data frame with years as row names

Examples

data <- data.frame(years = seq(1950, 2015), observations = rnorm(66))
new_data <- years_to_rownames(data = data, column_year = "years")

data <- data.frame(observations1 = rnorm(66), years = seq(1950, 2015),
observations2 = rnorm(66), observations3 = rnorm(66))
new_data <- years_to_rownames(data = data, column_year = "years")
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