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Description Classification of climate according to Koeppen - Geiger, of aridity indices, of continentality indices, of water balance after Thornthwaite, of viticultural bioclimatic indices. Drawing climographs: Thornthwaite, Peguy, Bagnouls-Gaussen.

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`arid` *Aridity indices*

Description

Calculates aridity according to several indices.

Usage

```
arid(
  clim_norm,
  coeff_rad = NULL,
  coeff_Hargr = rep(0.75, 12),
  monthly = FALSE,
  indices = 1:6
)
```

Arguments

clim_norm	climatic normals
coeff_rad	mean monthly solar radiation; used only for Thornthwaite's annual index Im. Default is NULL
coeff_Hargr	(vector of monthly) correction coefficient(s) for Hargreaves' equation
monthly	logic. Sets calculation to the monthly mode if TRUE. Default is FALSE.
indices	set of aridity indices to be listed. Default is all indices (1 to 6 for annual, 1 to 2 for monthly).

Details

clim_norm is a monthly data frame of climate normals, with column names: "P", "Tn", "Tx", "Tm" (precipitation, minimum, maximum and mean temperature, respectively). It can be the output of function climate.

Monthly potential evapotranspiration (PE) is calculated via the Hargreaves' formula (Hargreaves and Samani, 1985):

PE = (0.0023*(clim_norm$Tx - clim_norm$Tn)^(0.5)*(clim_norm$Tm+17.8)*coeff_rad)* lmv * coeff_Hargr

where Tn, Tx, Tm are min, max, and mean temperatures, respectively, and lmv is the number of days in any month.

coeff_rad and coeff_Hargr are needed only by Thornthwaite's annual index Im and UNEP's Ai index, whose PE term is calculated via Hargreaves' equation.

coeff_rad corresponds to the mean monthly extra-atmospheric radiation (see function ExAtRa).

coeff_Hargr is either a single value or a vector of 12 coefficients to adjust Hargreaves' estimation of potential evapotranspiration (implemented in Im and Ai indices). From calibration in 6 stations from the same network of Trent_climate, its average value is 0.75.

When monthly is TRUE, a data frame with monthly detail is generated for one station, instead of a synthetic single-line data frame.

indices' values are the following:

1 De Martonne - Ia (annual or monthly). De Martonne, 1925.

2 Thornthwaite - Im (annual or monthly). Thornthwaite, 1948.

3 Emberger - Q (annual only). Emberger, 1955.

4 Lang - R (annual only) - only for positive mean annual temperature. Lang, R., 1920.

5 Rivas-Martinez - Io (annual only). Rivas - Martinez, website http://www.globalbioclimatics.org/

6 UNEP - Ai (annual only). UNEP, 1997.

A reference for the aridity degree for any index is given in the list object arid_ind_tables (see Trent_climate.

Value

Either a single-line data frame (when monthly = FALSE) with the desired aridity index(es), or a data frame (monthly = TRUE), with monthly values of the desired index(es).

Author(s)

Emanuele Eccel

References

De Martonne E., 1925: Traite de Geographie Physique: 3 tomes, Paris.

Emberger, L., 1955. Une classification biogeographique des climats. Receuil des travaux des laboratoires de botanique, geologie et zoologie de la faculte des sciences de l'universite de Montpellier (Serie Botanique), Fascicule 7, 3-43.

Hargreaves, G.H., and Samani, Z.A., 1985. Reference crop evapotranspiratin from temperature. Applied Engineering in Agriculture, 1(2):96-99

Lang, R., 1920. Verwitterung und Bodenbildung als Einfuehrung in die Bodenkunde. Schweizerbart Science Publishers, Stuttgart

Rivas-Martinez - http://www.globalbioclimatics.org/

Thornthwaite, C. W., 1948: An Approach toward a Rational Classification of Climate. Geographical Review, Vol. 38, No. 1(Jan.):55-94.

UNEP (United Nations Environment Programme), 1997. World atlas of desertification 2ED. UNEP, London.

See Also

`climate`, `ExAtRa`

Examples

```
data(Trent_climate)
# clima_81_10 is a list of data frames having climatic means of temperature and precipitation
# as required by the aridity indices algorithms, each one referring to one station.
# It can be the output of function climate.
# coeff_rad is a monthly vector of average daily extra-atmospheric solar radiation,
# calculated e.g. by function ExAtRa.
```

`arid_ind_tables` *Aridity index*

Description

Used for reference in aridity indices assessment (see function `arid` and references for data sources).

Usage

```
data(Trent_climate)
```

Format

List formed by six data frames.

as.datcli *as.datcli*

Description

Tranforms a data frame (see example dataset) into a data frame format like 'datcli' in 'climatol' package

Usage

```
as.datcli(
  df,
  station,
  MonthField = "month",
  PrecField = "P",
  MinTempField = "Tn",
  MaxTempField = "Tx",
  MeanTempField = "Tm",
  AbsMinTempField = "AbsTn",
  AbsMinTempOffset = 4,
  StationField = "station"
)
```

Arguments

df	data frame or list
station	name
MonthField	character string for month field in df. Default is "month".
PrecField	character string for Mean Precipitation field in df. Default is "P".
MinTempField	character string for Mean Daily Minimum Temperature field in df. Default is "Tn".
MaxTempField	character string for Mean Daily Maximum Temperature field in df. Default is "Tx".
MeanTempField	character string for Mean Daily Maximum Temperature field in df. Default is "Tm".
AbsMinTempField	character string for Absolute Monthly Minimum Temperature field in df. Default is "AbsTn".
AbsMinTempOffset	estimated offset between Average Min Temperature and Absolute Min Temperature.
StationField	character string for Station field in df. Default is "station".

Author(s)

Emanuele Cordano

See Also

https://www.climatol.eu

Examples

```
### Not Run!!
# Install 'climatol' from 'https://www.climatol.eu/' first
### Then load the package, uncomment and run the following line
# library(climatol)
 library(stringr)
 data(Trent_climate)

 TrentinoClimateDf <- do.call(rbind,clima_81_10)
 names <- rownames(TrentinoClimateDf)
 TrentinoClimateDf$station <-
 unlist(lapply(X=str_split(names,pattern="[.]"),FUN=function(x) {x[1]}))


 station <- "T0129"
datcli <- as.datcli(TrentinoClimateDf,station=station)

### Not Run!!
# Install 'climatol' from 'https://www.climatol.eu/' first
### Then load the package, uncomment and run the following line
# diagwl(datcli,est=station,alt=100,per="Period",mlab="en") ## plots a Walter-Lieth's climograph
```

---

bagn_gau *Bagnouls - Gaussen graphs*

Description

Plots Bagnouls - Gaussen climatic charts of precipitation and temperature. Conventionally, in this chart the scale of precipitation has a double extension with respect to the scale of temperature (Bagnouls and Gaussen, 1953).

Usage

```
bagn_gau(
  clim_norm_sta,
  save_dir = NULL,
  format = NULL,
  main_title = NULL,
  st_name = NULL,
  trace_grid = TRUE,
  tick_step = 20,
  bar_width = 30,
  bar_col = "grey",
```

```
  trace_0.line = TRUE,
  ...
)
```

Arguments

clim_norm_sta	data frame with climatic normals
save_dir	name of destination directory for graphs (if any).
format	graphical format of graphs; default is NULL.
main_title	main title for all charts; e.g., it may include references to station id. Default is NULL.
st_name	name to be included into graphs titles. Only for file output. Default is NULL.
trace_grid	logic. If TRUE (default) adds a grid.
tick_step	step for Y axis (precipitation). Default is 20 (mm)
bar_width	width of bars in the chart. Default is 30.
bar_col	color of bars. Default is "grey".
trace_0.line	logic. If TRUE (default), a line at P = 0 and T = 0 is traced.
...	arguments to be passed to methods, such as graphical parameters (see par).

Details

clim_norm_sta can be e.g. one element of the output of function climate. See examples.

If format is NULL (default), graphs are sent to the console. Otherwise, a file is produced and saved. format is used only if the graphs are to be sent to files. Values allowed are: "png", "jpeg", "tiff", "bmp".

If one or more data are missing, the chart is not processed.

Most graphic parameters for functions plot, axis, and mtext are accepted.

Value

Bagnouls - Gaussen's charts of precipitation and temperature.

Note

A conflict is generated if parameters already used by the function are passed (e.g. col - use col.main, col.axis, ..., instead).

Author(s)

Emanuele Eccel

References

Bagnouls, F., and Gaussen, H., 1953: Saison seche et indice xerothermique. Docum. pour les Cartes des Prod. Veget. Serie: Generalite, 1 (1953), pp. 1-49

See Also

climate

Examples

```
data(Trent_climate)
# clima_81_10 can be generated from monthly time series by function "climate".
par(ask=TRUE)
for(sta in 1:length(clima_81_10)) {
  bagn_gau(clim_norm_sta= clima_81_10 [[sta]],
   main_title=paste(names(clima_81_10[sta]), "  1981-2010")
 , bar_width=40)
}
```

---

clima_81_10 *Climatic normals of precipitation and temperatures*

Description

Climatic normals of precipitation and temperature (minimum, maximum, and mean) for the climatic period 1981 - 2010. It has been calculated by function climate.

Usage

```
data(Trent_climate)
```

Format

A list (one table for each station) of 28 monthly climatic normals

---

climate *Climate normals*

Description

Creates climate mean monthly values from a monthly series of temperature and precipitation.

Usage

```
climate(series, first.yr = NULL, last.yr = NULL, max.perc.missing)
```

Arguments

series	the monthly series of temperature and precipitation.
first.yr	first year of the period over which climatology is calculated
last.yr	last year of the period over which climatology is calculated
max.perc.missing	maximum acceptable percentage of missing data in the averaging period from first.yr to last.yr (0-99).

Details

series is a data frame with years, months, temperature (and precipitation) values. Names in series columns must include: year, month, Tn and Tx (minimum and maximum temperatures, respectively) or, as an alternative, Tm (mean temperatures).

If first.yr or last.yr are NULL (default), the lowest and highest values in series are taken as the period.

Value

A data frame with climatic monthly values of: precipitation, minimum and maximum temperatures (if existing in series), mean temperature (either averaged from existing values in series, or calculated by the function as (Tn + Tx)/2), absolute minimum monthly temperature.

Author(s)

Emanuele Eccel

Examples

```
data(Trent_climate)

# clima_81_10 is a list of data frames of the type series,
# each one referring to one station
# having climatic means of temperature and precipitation

clima_81_10<-lapply(lista_cli, FUN=climate, first.yr=1981, last.yr=2010, max.perc.missing=15)
```

---

coeff_rad *Radiative energy coefficients*

Description

"Radiative energy coefficients" for Hargreaves' equation, corresponding to the daily extra-atmospheric solar radiation energy. It is the output of function ExAtRa.

Usage

```
data(Trent_climate)
```

Format

An array of 12 numerics

`contin` *Continentality indices*

Description

Calculates climate continentality / oceanicity according to several indices.

Usage

```
contin(
  clim_norm,
  latitude = NULL,
  elevation = NULL,
  Michalet_correction = FALSE,
  indices = 1:5
)
```

Arguments

`clim_norm`	climatic normals
`latitude`	station latitude in degrees. Used in Gorczynski's and Conrad's classifications (indices 1 and 2). Default is `NULL`.
`elevation`	station elevation in m. Used in Gams' classification (index 3). Default is `NULL`.
`Michalet_correction`	logic: if `TRUE`, Michalet's correction is applied to index 3 (Gams). Default is `FALSE`.
`indices`	set of aridity indices to be listed. Default is all indices (1 to 5).

Details

clim_norm is a monthly data frame of climate normals, with column names: "P", "Tn", "Tx", "Tm" (precipitation, minimum, maximum and mean temperature, respectively). It can be the output of function `climate`.

`indices`' values are the following:

1: Gorczynski - K.G. (Gorczynski, L., 1920).

2: Conrad - K.C. (Conrad, 1946).

3: Gams - alpha. (Gams, H., 1932). For Michalet's correction: Michalet and Souchier, 1991.

4: Rivas-Martinez - Ic. (Rivas - Martinez, web page).

5: Amann - H. (Amann, 1929)

A reference for the continentality / oceanicity degree is given in the list object `continental_ind_tables` of data set `Trent_climate`.

If Michalet's correction is applied to Gams' hygric continentality index, the value of precipitation is proportionally diminished for elevations below 900 m a.s.l. See also Lebourgeoise, 2010.

Value

A single-line data frame with the desired continentality index(es).

Author(s)

Emanuele Eccel

References

Amann, J., 1929: L'hygrothermie du climat, facteur determinant la repartition des especes atlantiques. Revue Bryol., 56:126-133.

Conrad, V., 1946: Usual formulas of continentality and their limits of validity. Transactions, American Geophysical Union, Volume 27, Issue 5, p. 663-664.

Gams, H., 1932: Die klimatische Begrenzung von Pflanzenarealen und die Verteilung der hygrischen Kontinentalitaet in den Alpen. Zeitschr. Ges. Erdkunde, Berlin.

Gorczynski, L., 1920: Sur le calcul du degre de continentalisme et son application dans la climatologie. Geografiska Annaler 2, 324-331.

Lebourgeoise, F., 2010: Cours de bioclimatologie a l'usage des forestiers. Departement SIAFEE, UFR Forets, Arbres et Milieux Naturels. ENGREF, Nancy Cedex.

Michalet, R., and Souchier, B., 1991: Une approche synthetique biopedoclimatique del montagnes mediterraneennes: l'exemple du Maroc septemptrional. Thesis, Univ. J. Fourier, Grenoble, 273 pp.

Rivas-Martinez: http://www.globalbioclimatics.org/.

See Also

climate

Examples

```
data(Trent_climate)


# clima_81_10 is a list of data frames having climatic means of temperature and precipitation as
# required by the aridity indices algorithms, each one referring to one station.
# It can be the output of function climate.

# creates a data frame with all the continentality indices for all stations in clima_81_10

latit<-coord_elev$North
elev<-coord_elev$Elevation

contin_I<-NULL
for(i in 1:length(clima_81_10)) {
  contin_I[[i]]<-contin(clima_81_10[[i]],
   latitude=latit[i],
   elevation=elev[i],
   Michalet_correction=TRUE)
}
names(contin_I)<-names(clima_81_10)
```

continental_ind_tables *Continentality/oceanicity indices*

Description

Used for reference in continentality/oceanicity indices assessment (see function `contin` and references for data sources).

Usage

```
data(Trent_climate)
```

Format

List of 4 data frames

coord_elev *Geographical position for each meteorological station*

Description

Coordinates and elevation for each station in the data set. Coordinates are geographical and elevation is measured in meters above mean sea level.

Usage

```
data(Trent_climate)
```

Format

Data frame of 40 observations of 4 variables

ExAtRa *Extra-Atmospheric Radiation*

Description

Calculates Extra-Atmospheric Radiation. Called by function `arid` for Thornthwaite's index.

Usage

```
ExAtRa(DOY, latitude, Gsc = 0.082, unit = "mm", T = 12)
```

Arguments

`DOY`	day of the year.
`latitude`	latitude in degrees (negative for S emishpere).
`Gsc`	solar constant in MJ m-2 min-1 (default: 0.0820).
`unit`	unit for solar radiation. Accepted values are "mm" and "MJ".
`T`	temperature in degrees C. Default is 12.

Details

If `unit` = "mm", the calculated value represents the water height evaporated by solar radiation, calculated by the latent heat for vaporization. Otherwise (`unit` = "MJ") output is the solar radiation energy in MJ. Temperature `T` is used only for the assessment of latent heat of vaporization, when `unit` = "mm".

Value

The daily extra-atmospheric solar radiation energy, espressed either in MJ or in mm of evaporated water.

Author(s)

Emanuele Eccel

See Also

`arid`

Examples

```
data(Trent_climate)
# creates a vector with middle days for every month in a year
quinci   <- paste(15,"/",1:12,"/",2014,sep="")
posixlt  <- strptime(quinci, format="%d/%m/%Y")
yDay     <- posixlt$yday+1  # field yday starts from 0
latitude<-46
```

```
# generates 12 values, one for each month
coeff_rad<- ExAtRa(DOY=yDay,latitude=latitude, unit="mm")
```

`koeppen_geiger` *Koeppen - Geiger's climate classification*

Description

General climate classification after Koeppen - Geiger.

Usage

```
koeppen_geiger(
  clim_norm,
  A_B_C_special_sub.classes = FALSE,
  clim.resume_verbose = TRUE,
  class.nr = FALSE
)
```

Arguments

`clim_norm`	average values (climate normals) for the desired period.
`A_B_C_special_sub.classes`	logical. Sets if calculations have to consider sub-classes based on rain features in climate types A, B, and C (see details). Default is `FALSE`.
`clim.resume_verbose`	logical. If `TRUE` (default) a resume of the climatic indices used for the Koeppen - Geiger classification is added to the output.
`class.nr`	logical. If `FALSE` (default) class is expressed by letters, otherwise by numbers (see details).

Details

`clim_norm` is a monthly data frame of climate normals, with column names: "P", "Tn", "Tx", "Tm" (precipitation, minimum, maximum and mean temperature, respectively). It can be the output of function `climate`.

Koeppen - Geiger's classification is based on Trewartha and Lyle, 1980. The function also holds for Southern emisphere, except for the "Gange" sub-type ("Ag" and "Cg"). Type "H" (highland climate) and sub-types "Bn" and "Cn" (where n stands for Nebel) are never attributed, being based on a qualitative description in the quoted reference.

Sub-type "w" (wet-and-dry) or "m" (monsoon) in climate "A" is set according to the definition after Encyclopaedia Britannica (http://www.britannica.com/EBchecked/topic/322068/Koppen-climate-classificatio
if P in the 4 driest months is less than 1/5 of the wettest months and if both the 4 driest and wettest months are split over non-contiguous seasons (either 2 months per season or 1 and 3 months per season), then sub-type is "".

For climate "A", the letter "m" is attributed to the first sub-type.

Climates "Cx" have P[May + June] >= 1.3 P [Aug. + Sept.] in N emisphere, and P[Nov. + Dec.] >= 1.3 P[Febr. + March] in S emisphere.

`A_B_C_special_sub.classes`, if `TRUE`, adds a letter to the second sub-type of climates: "i" or "g" (climate A), "w" or "s" (climate B), and "i", "g", or "x" (climate C).

The returned data frame contains the following fields:

`T_w.m` = temperature of the warmest month (degrees C)

`T_c.m` = temperature of the coldest month (degrees C)

`T_avg` = average temperature (degrees C)

`P_tot` = total precipitation depth (mm)

`P_wint` = precipitation depth in the 6 coldest (winter) months (mm)

`P_summ` = precipitation depth in the 6 warmest (summer) months (mm)

`P_d.m` = precipitation depth in the driest month (mm)

`P_d.m.summ` = precipitation depth in the driest month of "summer" half of the year (mm)

`P_d.m.wint` = precipitation depth in the driest month of "winter" half of the year (mm)

`P_w.m` = precipitation depth in the wettest month (mm)

`P_w.m.summ` = precipitation depth in the driest month of "summer" half of the year (mm)

`P_w.m.wint` = precipitation depth in the wettest month of "winter" half of the year (mm)

`T_4th_w.m` = temperature of the 4th warmest month (degrees C)

`class` = climatic class. If `class.nr=FALSE` (default), it results from the merging of "climate" (A to E) and sub-type(s). If `class.nr=TRUE` the class comes from the sum of the numeric equivalent of "type" (A,..E) + "first sub type" (only first letter), according to the following scheme:

A B C D E

10 20 30 40 50

f W s s T –> 1

w S w w F –> 2

m f f –> 3

(e.g: Af = 11, Cw = 32, EF = 52)

Value

A one-line data frame reporting a resume of climatic features useful for the classification (if `clim.resume_verbose` is `TRUE`), and one last field (1 type - or "climate" - plus 1 or 2 sub-types) reporting Koeppen - Geiger's climate classification. See details.

Author(s)

Emanuele Eccel

References

Trewartha, G.T. and Lyle, H.H., 1980: An Introduction to Climate. MacGraw - Hill, 5th Ed. Appendix: Koeppen's Classification of Climates.

See Also

climate

Examples

```
data(Trent_climate)
# clima_81_10 is a list of data frames having climatic means of temperature and precipitation as
# required by Koeppen - Geiger classification, each one referring to one station.
# It can be the output of function climate.
class_clim_l<-lapply(clima_81_10, FUN=koeppen_geiger, A_B_C_special_sub.classes=TRUE)
```

---

lista_cli *Dataset of meteorological measures*

Description

A list of 28 data frames (one for each station of the meteorological network), with monthly time series of precipitation and temperature (minimum and maximum).

Usage

```
data(Trent_climate)
```

Format

List of 28 elements, each is a data frame of 5 variables and 636 observations

---

oiv_ind *OIV bioclimatic indices for viticulture*

Description

Calculation of OIV bio-climatic indices for viticulture (ref.: http://www.oiv.int/oiv/info/enresolution2012?lang=en).

Usage

```
oiv_ind(
  daily_Tn = NULL,
  daily_Tx = NULL,
  daily_Tm = NULL,
  daily_P = NULL,
  first.yr = NULL,
  last.yr = NULL,
  subs_missing = TRUE,
  coeff_HI = 1.04,
```

```
  quant_Tn_rest = 0.5,
  quant_Tn_veg = 0.5,
  quant_Tx_veg = 0.5,
  indices = 1:10
)
```

Arguments

daily_Tn	series of daily minimum temperature (data frame). Must include the following columns (and names): "year", "month", "day" and one or more station id(s), each column one Tn series.
daily_Tx	series of daily maximum temperature (data frame). Must include the following columns (and names): "year", "month", "day" and one or more station id(s), each column one Tx series.
daily_Tm	series of daily mean temperature (data frame). Must include the following columns (and names): "year", "month", "day" and one or more station id(s), each column one Tm series.
daily_P	series of daily precipitation (data frame). Must include the following columns (and names): "year", "month", "day" and one or more station id(s), each column one P series.
first.yr	first year of the period over which indices are calculated
last.yr	last year of the period over which indices are calculated
subs_missing	logical: if TRUE (default), missing values in input series are replaced by corresponding average values for each day in the series.
coeff_HI	Huglin's daylength correction, as long as the number of stations, or a single coeffient; in this case it is recycled on all stations. See details.
quant_Tn_rest	quantile (0..1) for the choice of the position of the representative year in the series, referred to the minimum temperature during "rest" period. Default is 0.5 (median)
quant_Tn_veg	quantile (0..1) for the choice of the position of the representative year in the series, referred to the minimum temperature during the "vegetative" period. Default is 0.5 (median)
quant_Tx_veg	quantile (0..1) for the choice of the position of the representative year in the series, referred to the maximum temperature during the "vegetative" period. Default is 0.5 (median)
indices	set of OIV indices to be listed. Default is all indices (1 to 10). See details for numbered list of indices.

Details

General info about OIV indices can be sought at http://www.oiv.int/oiv/info/enresolution2012?lang=en. In general, if first.yr or last.yr are NULL (default), the lowest and highest values in series are taken as begin and end of calculation period. A coherence check is done on input of start / end years.

If any input is missing, corresponding indices are not be calculated. If daily_Tm is missing and both daily_Tn and daily_Tx are passed to the function, daily_Tm is calculated as the mean of daily_Tn and daily_Tx.

OIV indices are the following:

Tm_veg: 1 - mean temperature during vegetation period. The latter is April - October (N emisphere) or October - April (S emisphere). The case (N or S) is automatically recognised by temperature data.

WI: 2 - Winkler index (degree days with a 10 C base, summation over vegetative period), see note on Tm_veg. Ref: Amerine and Winkler, 1944.

BEDD: 3 - biologically active degree days. Degree days with a lower threhold of 10 C and an upper threshold at 19 C. Ref: Gladstone, 2004.

HI: 4 - heliothermic Huglin index. A degree day summation of the average between mean and maximum temperature above 10 C, corrected by a coefficient of daylength duration. The coefficient is given by the author in a table according to latitude. If one value is given, it is used for all stations. Default is 1.04 (lat. 44-46). Ref.: Huglin, P., 1978

CNI: 5 - cool night index. Mean of September (N emisphere) or March (S emisphere) minimum temperatures. Ref.: Tonietto and Carbonneau, 2004.

FSI: 6 - Fregoni's simplified index. Given by the product between the summation of thermal range (Tx - Tn) and the number of days with Tm > 10 C, for 30 days before ripening. The period before ripening is taken as September (N emisphere) or March (S emisphere). Ref.: Fregoni et Pezzutto, 2000.

BI: 7 - Branas' hydrothermic index. The only index not included in OIV list, used for fungine infection proneness. It is given by the product of precipitation (mm) by the mean temperature (C) during the period April - October (N emisphere) or October - April (S emisphere). Ref: Eynard and Dal Masso, 1990.

Tn_rest: 8 - minimum temperature during rest period. Useful for assessing winter severity. The rest period is November - March (N emisphere) or May - September (S emisphere). The case (N or S) is automatically recognised by temperature data.

Tn_veg: 9 - minimum temperature during vegetative period. Useful for assessing spring frosts. See note on Tm_veg for periods.

Tx_veg: 10 - maximum temperature during vegetative period. Useful for assessing summer hot spells. See note on Tm_veg for periods.

quant_Tn_rest, quant_Tn_veg, quant_Tx_veg define the statistical rank of the year to be chosen as representative for assessing Tn_rest, Tn_veg, and Tx_veg, respectfully. 0.5 (default) is the median year, 0 is the minimum (lowest temperature), 1 is the maximum (highest temperature).

The only missing index among those selected by OIV is Riou's Drought Index, which is calculated by function RDI on monthly series.

Value

A table (one line per station) reporting OIV bioclimatic indices. The Branas' index is added.

Author(s)

Emanuele Eccel

References

Amerine, M.A., and Winkler, A.J., 1944. Composition and quality of musts and wines of California grapes. Hilgardia. 15(6): 493-673.

Eccel, E., Zollo, A.L., Mercogliano, P., Zorer, R., 2016: Simulations of quantitative shift in bioclimatic indices in the viticultural areas of Trentino (Italian Alps) by an open source R package. Computers and Electronics in Agriculture 127 (2016) 92-100.

Eynard, I. e Dal Masso, G., 1990: Viticoltura moderna. Manuale pratico. Hoepli Milano. 778 pp.

Fregoni, C., et Pezzutto, S., 2000 : Principes et premieres approches de l'indice bioclimatique de qualite Fregoni, Progr.Agric.Vitic. 117: 390-396.

Gladstones, J.S., 2004: Climate and Australian Viticulture. In 'Viticulture. Volume 1-Resources'. (Eds Dry PR, Coombe BG) pp. 90-118.

Huglin, M.P., 1978: Nouveau mode d'evaluation des possibilites heliothermiques d'un milieu viticole. Comptes Rendus de l'Academie de l'Agriculture de France. 64: 1117-1126.

Tonietto, J., and Carbonneau, A., 2004. A multicriteria climatic classification system for grape-growing regions worldwide. Agricultural and Forest Meteorology. 124(1/2): 81-97.

See Also

RDI

Examples

```
data(Trent_climate)
oiv_ind(daily_Tn=Tn,daily_Tx=Tx, daily_P=P, first.yr=1981, last.yr=2010, subs_missing=FALSE)
```

P *Precipitation*

Description

The daily data frame of precipitation for a number of stations. It is used in function oiv_ind

Usage

```
data(Trent_climate)
```

Format

Data frame: 19358 obervations of 39 variables (stations)

peguy *Peguy Climograph*

Description

Representation of Peguy Climograph from monthly weather data (Mean Temperature, Precipitation)

Usage

```
peguy(
  data = NULL,
  TemperatureTriangleCoords = c(0, 23.4, 15),
  PrecipitationTriangleCoords = c(0, 40, 200),
  ylab = "Precipitation[mm]",
  xlab = "Mean Temperature [degC]",
  lambda.label = 1.75,
  climate.label = c("Temperate", "Cool", "Arid", "Hot"),
  xyField = c("Tn", "P"),
  pointsField = "month",
  StationsField = "station",
  color.scale = "monthly",
  ...
)
```

Arguments

data	input dataset with climatological monthly weather data
TemperatureTriangleCoords	Temperature coordinates for triangle vertices in the Peguy Climograph. Default coordinates are expressed in Celsius Degrees.
PrecipitationTriangleCoords	Precipitation coordinates for triangle vertices in the Peguy Climograph. Default coordinates are expressed in millimeters.
xlab, ylab	xy axis labels
lambda.label	numeric value used to locate climate attribute labels
climate.label	string vector containing climate attributes. Default is c("Temperate", "Cold", "Arid", "Hot"). Alternatively it can be translated into any other languange.
xyField	column names of data for the x and y variables used in the Peguy Climate Diagram.
pointsField	column name of data containing the fields to be represented with different point colors. Default is "month".
StationsField	column name of data containing the fields with station ID names. Default is "station".
color.scale	character scale indicating a use of a specific color scale. Default is "monthly".
...	further arguments

Author(s)

Emanuele Cordano

References

Peguy, C.P. (1970) Precis de climatologie, ed. Masson, Paris.

Examples

```
library(stringr)
data(Trent_climate)


TrentinoClimateDf <- do.call(rbind,clima_81_10)
names <- rownames(TrentinoClimateDf)
TrentinoClimateDf$station <- unlist(lapply(X=str_split(names,pattern="[.]"),FUN=function(x) {x[1]}))



data <- TrentinoClimateDf[TrentinoClimateDf$station %in% unique(TrentinoClimateDf$station)[1:3],]
p <- peguy(data=data)
```

---

plot.thornthwaite *Thornthwaite - Mather's quantile plot*

Description

'plot' method implementation for 12-month quantile climate charts from output of function thornthwaite (Thornthwaite and Mather's water balance).

Usage

```
## S3 method for class 'thornthwaite'
plot(
  x,
  save_dir = NULL,
  format = NULL,
 variables = c("Precipitation", "Et0", "Storage", "Prec. - Evap.", "Deficit", "Surplus"),
  title = TRUE,
  trace_grid = TRUE,
  st_name = NULL,
  u_y_scale_magn = 0.2,
  l_y_scale_magn = 0,
  leg_pos = "topleft",
  ...
)
```

Arguments

x	a list of quantile data frames of water balance variables to be plotted, as output of function thornthwaite.
save_dir	name of destination directory for graphs (if any). Default is NULL.
format	graphic format of graphs; default is NULL (charts are sent to console).
variables	character vector of variables to be plotted.
title	logic. If TRUE inserts titles in charts.
trace_grid	logic. If TRUE (default) adds a grid.
st_name	name to be included into graphs titles. If NULL (default), no title is written.
u_y_scale_magn	magnification of range above upper limit, to set upper y-scale limit; default is 0.
l_y_scale_magn	magnification of range below lower limit, to set lower y-scale limit; default is 0.1.
leg_pos	legend position. Default is "topleft". If NULL, no legend is added.
...	arguments to be passed to methods, such as graphical parameters (see par).

Details

Default for plot variables is all those calculated by function thornthwaite: "Precipitation", "Et0", "Storage", "Prec. - Evap.", "Deficit", "Surplus". See function thornthwaite for details on variables.

If format is NULL (default), graphs are sent to the console. Otherwise, a file is produced and saved to the save_dir directory. Values allowed are: "png", "jpeg", "tiff", "bmp".

l_y_scale_magn and u_y_scale_magn are the magnification coefficients (lower and upper, respectively), for y scale. If rng is the range between maximum and minimum values in all sets of series within a plot, the lower limit for y scale will be (rng * l_y_scale_magn) below the lower value, and the upper limit will be (rng * u_y_scale_magn) above the upper value of series.

Allowed values for leg_pos are the same of x in function legend.

Most graphic parameters for functions plot and legend are accepted.

Value

Charts of quantiles for water balance variables (12-month climatic values). They can be sent to the console or saved as graphic files.

Note

A conflict is generated if parameters already used by the function are passed (e.g. x for legend: use leg_pos instead).

Author(s)

Emanuele Eccel

See Also

thornthwaite

Examples

```
data(Trent_climate)


# quantiles is the list ("thornthwaite" S3 object)of quantile tables generated
# by function thornthwaite;
# it is the second element of the output list,
# which can be split into two separate lists (see function thornthwaite)
sta <- 1     # 1st station in the list of quantile tables
q_list=quantiles[[sta]]
class(q_list) <- "thornthwaite" ## q_list is coerced to a "thornthwaite" S3 object
plot(q_list,
st_name=names(quantiles)[sta], variables=c("Precipitation",  "Et0"),
leg_pos = "topleft", col=c(1:6,1), pch=c(1:6,16),
lty=1, horiz=TRUE,  y.intersp=0.1)
```

---

quantiles *Monthly quantiles of the meteorological variables*

Description

The second list (quantiles) in thornt_lst organized according to stations. See Examples in function thornthwaite for its construction.

Usage

```
data(Trent_climate)
```

Format

Data frame of 28 observations of 4 variables

RDI *Riou's drought index*

Description

Calculation of Riou's drought index described in OIV bio-climatic indices for viticulture (see references)

Usage

```
RDI(
  series,
  clim_norm = NULL,
  first.yr = NULL,
  last.yr = NULL,
  TAW = 200,
  coeff_rad,
  coeff_Hargr = rep(0.75, 12),
  quant = c(0, 0.1, 0.5)
)
```

Arguments

series	series of mean monthly weather values
clim_norm	the reference climatic values for each month, used for gap filling. Default is NULL (no replacement of missing values)
first.yr	of the period over which water balance is calculated. Default is NULL (calculations start with the first year of the series)
last.yr	of the period over which water balance is calculated. Default is NULL (calculations start with the last year of the series)
TAW	total available water content of soil
coeff_rad	vector of solar radiation coefficients (12 values) for calculation of potential evapotranspiration
coeff_Hargr	(vector of monthly) correction coefficient(s) for Hargreaves' equation
quant	vector of quantiles for the statistical ranking of the year representative for balance (0..1)

Details

For full description of algorithm see OIV standards at http://www.oiv.int/oiv/info/enresolution2012?lang=en and the references: Riou, 1994; Tonietto, 1999. Evapotranspiration is calculated by Hargreaves' equation (see arid).

series is a data frame of the monthly series (means) of: cumulated precipitation (mm), minimum temperature, maximum temperature, mean temperature (optional) - all in deg. C. Includes the following columns (and names): "year", "month", "P", "Tn", "Tx", "Tm" (optional), for precipitation, minimum, maximum and mean temperature, respectively. If Tm is missing it is calculated as (Tn + Tx)/2. Format is the same of lista_cli.

clim_norm is a monthly data frame of 12 climate normals, with the same column names of series, except "year". It can be the output of function climate. If clim_norm is not NULL, any missing value in the monthly series is substituted by the corresponding climatic value in clim_norm.

A default value of 200 mm for TAW is suggested by the authors of the index. It can be changed according to the known pedological features of soil.

coeff_rad corresponds to the mean monthly extra-atmospheric radiation (see function ExAtRa). It is required in Hargreaves' equation.

coeff_Hargr is either a single value or a vector of 12 coefficients to adjust Hargreaves' estimation of potential evapotranspiration. From calibration in 6 stations from the same network of Trent_climate, its average value is 0.75.

quant_vector a vector of minimum one element. 0 yields minimum absolute case, 0.5 the median. Values range from 0 to 1 (inappropropriate if > 0.5).

The algorithm described in OIV assesses water balance at the last month of the ripenining period, early autumn. However, in humid or sub-humid climates the driest period for soil generally falls in summer. For this reason, the output table reports both cases ("harvest" time value and monthly minimum over the season, "WB_harv" and "WB_min", respectfully). Harvest time is conventionally September (N emisphere) or March (S emisphere).

Value

A two-column table reporting Riou's drought indices for each quantile chosen (one line each, minimum is 1). Both "harvest time" and minimum values are calculated (see details).

Author(s)

Emanuele Eccel

References

Riou, C. 1994. Le determinisme climatique de la maturation du raisin: application au zonage de la teneur en sucre dans la Communaute Europeenne (E. Commission, ed.). Office des Publications Officielles des Communautes Europeennes, Luxembourg, 322p.

Tonietto, J. 1999. Les Macroclimats Viticoles Mondiaux et l'Influence du Mesoclimat sur la Typicite de la Syrah et du Muscat de Hambourg dans le Sud de la France Methodologie de Caracterisation. These de doctorat, Ecole Nationale Superieure Agronomique de Montpellier, Montpellier (France), 216p.

See Also

oiv_ind, arid

Examples

```
data(Trent_climate)
RDI(lista_cli[[1]], clim_norm=clima_81_10[[1]], first.yr=1981, last.yr=2010, coeff_rad=coeff_rad)
```

---

thornt_lst *Input for the Thornthwaite function*

Description

For every station, the first element (a list, Thornth._W._bal) reports the monthly series of water balance quantities for the station, each in one data frame (see function thornthwaite for details). The second list (quantiles) reports the monthly quantiles for the same quantities.

Usage

```
data(Trent_climate)
```

Format

S3 object: a "hyperlist" (list of lists of lists), one list of lists for each station

---

thornthwaite *Thornthwaite and Mather's water balance*

Description

Calculates Thornthwaite and Mather's water balance from monthly series of precipitation and temperature. Aimed at a classification of a site's climate according to its water balance features.

Usage

```
thornthwaite(
  series,
  latitude,
  clim_norm = NULL,
  first.yr = NULL,
  last.yr = NULL,
  quant = c(0, 0.1, 0.25, 0.5, 0.75, 0.9, 1),
  snow.init = 20,
  Tsnow = -1,
  TAW = 100,
  fr.sn.acc = 0.95,
  snow_melt_coeff = 1
)
```

Arguments

series	the monthly series of temperature and precipitation.
latitude	latitude of the station in degrees.
clim_norm	climatic normals.
first.yr	first year of the period over which water balance is calculated. Default is NULL (calculations start with the first year of the series).
last.yr	last year of the period over which water balance is calculated. Default is NULL (calculations stop with the last year of the series).
quant	vector of quantiles for which water balance has to be assessed. Default is: min, 10th, 25th 50th, 75th, 90th, max.
snow.init	initial water equivalent for snowpack (mm). Default is 20.
Tsnow	maximum temperature (monthly mean) for precipitation to be treated as snowfall. Default is -1 degree C.

TAW	maximum (field capacity) for soil water retention, and initial soil water content (mm). Default is 100.
fr.sn.acc	fraction of snow that contributes to snowpack (0-1). 1 - fr.sn.acc is treated as liquid monthly precipitation Default is 0.95.
snow_melt_coeff	monthly coefficient(s) for snowmelt. Default is 1.

Details

The algorithm for the calculation of water balance is adapted from Thornthwaite, 1948; Thornthwaite and Mather, 1955; Thornthwaite and Mather, 1957.

series is a data frame with years, months, temperature and precipitation values. Names in series columns must include: year, month, Tn and Tx (minimum and maximum temperatures, respectively) or, as an alternative, Tm (mean temperatures), and P (mandatory).

clim_norm is a monthly data frame of climate normals, with column names: "P", "Tn", "Tx", "Tm" (precipitation, minimum, maximum and mean temperature, respectively). It can be the output of function climate. If clim_norm is not NULL, any missing value in the monthly series is substituted by the corresponding climatic value in clim_norm.

At any winter season, the maximum monthly snowpack height is attained in the last month before "spring" conditions (Tm >= Tsnow), even if a month with Tm < Tsnow may occur later.

snow_melt_coeff is (are) the coefficient(s) for snow melt fraction(s) at any month where the condition for melting exists. If snow_melt_coeff = 1 (default), all the melting occurs in the first month when Tm >= Tsnow; if it is a vector, melting is spread over more than one month. If the sum of coefficients is less than 1, the residual melting occurs in one further month.

The output function is a list of two lists of data frames (balance and quantile). In both lists, data frame (and names) are the following (all variables in mm):

Precipitation (repeats input values);

Et0 (potential evapotranspiration);

Storage (water stored in soil);

Prec. - Evap. (difference between precipitation and potential evapotranspiration);

Deficit (difference between potential and real evapotranspiration, due to water unavailability in soil);

Surplus (water surplus in soil, routed to runoff).

Please, refer to the quoted references for details.

This function requires the function daylength from the **geosphere** package.

Value

A thornthwaite S3 object, consisting on a list of two lists. The first (name: W_balance) is a list of data frames containing the monthly series of all indices, the second (name: quantiles) the relevant quantiles. See details for meanings of single variables.

Author(s)

Giambattista Toller and Emanuele Eccel

References

Thornthwaite, C. W., 1948: An Approach toward a Rational Classification of Climate. Geographical Review, Vol. 38, No. 1(Jan.):55-94.

Thornthwaite, C. W., and Mather, J.R., 1955: The water balance. Publications in Climatology, Volume 8(1), Laboratory of Climatology

Thornthwaite, C. W., and Mather, J.R., 1957: Instructions and tables for computing potential evapotranspiration and the water balance. Publications in climatology, Volume 10(3), Laboratory of Climatology

See Also

climate, ExAtRa, plot.thornthwaite

Examples

```
data(Trent_climate)


# lista_cli is a list of data frames of the type "series",
# each one referring to one station - see function "climate".
# clima_81_10 is a list of data frames having climatic means
# of temperature and precipitation, each one referring to one station.
# It can be the output of function "climate".
library(geosphere) # required for function daylength
thornt_lst<-NULL
lista_cli <- lista_cli[1:3] ## lista_cli is reduced to diminish elapsed time of execution!
for(k in 1 : length(lista_cli[1:3])) {
  thornt_lst[[k]]<-thornthwaite(series=lista_cli[[k]],
  clim_norm=clima_81_10[[k]],
  latitude = 46, first.yr=1981,
  last.yr=2010, snow_melt_coeff=c(0.5,0.5 )  )
}
names(thornt_lst)<-names(lista_cli)

# splits list into two lists
W_balance<-NULL; quantiles<-NULL
for(k in 1 : length(lista_cli))
{
  W_balance[[k]]<-thornt_lst[[k]]$W_balance
  quantiles[[k]]<-thornt_lst[[k]]$quantiles
 }
 names(W_balance)<-names(thornt_lst); names(quantiles)<-names(thornt_lst)
```

Tm *Mean daily temperature*

Description

The daily data frame of mean daily temperature for a number of stations, used in function `oiv_ind`

Usage

```
data(Trent_climate)
```

Format

Data frame: 19358 obervations of 15 variables (stations)

`Tn` *Minimum daily temperature*

Description

The daily data frame of minimum daily temperature for a number of stations, used in function `oiv_ind`

Usage

```
data(Trent_climate)
```

Format

Data frame: 19358 obervations of 15 variables (stations)

`Trent_climate` *Data set of Trentino climate*

Description

A group of datasets used consistently throughout the ClimClass manual and examples. It is used as reference definition of the climate for the Trentino region, Italy. It includes monthly series of temperature and precipitation, and reference tables for the definition of aridity and continentality/oceanicity

Usage

```
data(Trent_climate)
```

Details

Series like "Txxxx" were supplied by the Autonomous Province of Trento - Meteotrentino (I). Series like "FEMxx" were supplied by Fondazione Edmund Mach, San Michele all'Adige (I).

Tx *Maximum daily temperature*

Description

The daily data frame of maximum daily temperature for a number of stations, used in function `oiv_ind`

Usage

```
data(Trent_climate)
```

Format

Data frame: 19358 obervations of 15 variables (stations)

W_balance *Water balance*

Description

Is the first list (`W_balance`) in `thornt_lst` organized according to stations. See Examples in function `thornthwaite` for its construction.

Usage

```
data(Trent_climate)
```

Format

List of 28 elements, each is a data frame of 5 variables and 636 observations

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