Package 'ClimClass'

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Type Package

Title Climate Classification According To Several Indices

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

License GPL (>= 2)

Depends R(>= 2.10.0),geosphere,ggplot2,reshape2

Suggests stringr

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`ClimClass-package` *Climate classifications and graphics*

Description

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

Details

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License:	GPL (>= 2)

The package collects several criteria for climate classification. The most general is Koeppen - Geiger's classification, as described in Trewartha (1980), implemented in function `koeppen_geiger`. Almost all sub-classes have been considered, with the only exception of those whose attribution is based on qualitative assessment of climatic features.

A classic graphical visualization of temperature and precipitation, according to Bagnouls and Gaussen (1953), is provided by function `bagn_gau`. A similar, but more sophisticated representation of the same variable, is that of Walter - Lieth (Lieth et al., CD). This function is implemented in library `climatol` (http://www.climatol.eu/).

Function `arid` calculates a set of six annual aridity indices (Emberger, 1955; Lang, R., 1920; Rivas - Martinez, (website); and UNEP, 1997; De Martonne, 1925; Thornthwaite, 1948). For the latter two also a monthly index is calculated.

A set of four continentality indices is proposed by function `contin` (Gorczynski, L., 1920; Conrad, 1946; Gams, 1932; Rivas - Martinez, web page).

Thornthwaite's method for the assessment of soil water balance (Thornthwaite, 1948; Thornthwaite and Mather, 1955; Thornthwaite and Mather, 1957) makes use of monthly series to calculate the main quantities in water balance: evapotranspiration, soil water deficit, soil water surplus. From these series, quantiles are calculated for every month, to infer climatic features concerning soil water. Function `thornthwaite` provides such analysis, and function `plot` manages the plot of the quantiles of the relevant quantities.

The assessment of potential evapotranspiration by Thornthwaite and Mather's algorithm requires the estimation of extra-atmospheric radiation, which is calculated by function `ExAtRa`, based on the algorithm of Allen et al., 2005.

Function `as.datcli` tranforms a data frame as in example dataset `Trent_climate` into a data frame format like `datcli` in `climatol` package. It can be used to plot Walter - Lieth's climographs (see examples documentation).

The data set included in the library is formed by monthly time series of temperature and precipitation from Trentino, Italy (courtesy of Autonomous Province of Trento - Meteotrentino, and of Fondazione Edmund Mach, San Michele all'Adige). Climatic normals are calculated, too (output of function `climate`). The output of function `thornthwaite` is present in the data set `Trent_climate`, as input for function `plot`.

Reference tables for aridity and continentality indices are provided as lists, to rank the classifications on standard scales (`arid_ind_tables` and `continental_ind_tables`, respectively).

Author(s)

Emanuele Eccel, Emanuele Cordano, Giambattista Toller

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References

Allen, R.G., Walter, I.A., Elliott, R.L., Howell, T.A., Itenfisu, D., Jensen, M.E., and Snyder, R.L. (eds.), 2005: ASCE Standardized Reference Evapotranspiration Equation. 216 pp.

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.

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

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.

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.

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

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

Lieth, H., Berlekamp, J., Fuest, S., and Riediger, S.: Walter-Lieth: Climate Diagram World Atlas, CD-Series I of Climate and Biosphere, 1st edit.

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

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

Rivas-Martinez - http://www.iao.florence.it/training/geomatics/BenSlimane/Marocco21_3_1_2.htm

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

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

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

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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). Lang, R., 1920.

5 Rivas-Martinez - Io (annual only). Rivas - Martinez, website http://www.iao.florence.it/training/geomatics/BenSlimane/Mar

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.iao.florence.it/training/geomatics/BenSlimane/Marocco21_3_1_2.htm

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.

aridity_Y<-lapply(clima_81_10, coeff_rad=coeff_rad, FUN=arid, monthly=FALSE, indices=c(1,2,5))
```

---

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

http://www.climatol.eu/, http://www.zoolex.org/walter.html

Examples

```
### Not Run!!
# Install 'climatol' from 'http://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 'http://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 \code{\link{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)
}
```

`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)
```

---

contin *Continentality indices*

Description

Calculates climate continentality / oceanicity according to several indices.

Usage

```
contin(clim_norm, latitude = NULL, elevation = NULL,
  Michalet_correction = FALSE, indices = 1:4)
```

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 4).

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).

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

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)
```

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)
```

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.

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 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)

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

class = climatic class, resulting from the merging of "climate" (A to E) and sub-type(s)

Value

A one-line data frame reporting a resume of climatic features useful for the classification, 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)
```

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.
`l_y_scale_magn`	magnification of range below lower limit, to set lower y-scale limit; default is 0.1.
`u_y_scale_magn`	magnification of range above upper limit, to set upper y-scale limit; default is 0.
`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)
```

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 (libr. geosphere).

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)
```

`Trent_climate` *Data set of Trentino climate*

Description

Data set for definition of climate of Trentino, Italy. It includes monthly series of temperature and precipitation, and reference tables for definition of aridity and continentality / oceanicity.

Usage

```
data(Trent_climate)
```

Format

`lista_cli` a list of 40 data frames (one for each station), with monthly time series of precipitation and temperature (minimum and maximum).

`clima_81_10` a list (one table for each station) of 40 monthly climatic normals of precipitation and temperature (minimum, maximum, and mean) for the climatic period 1981 - 2010. It has been calculated by function `climate`.

thornt_lst an S3 object: a "hyperlist" (list of lists of lists), one list of lists for each station. For every station, the first 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.

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

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

coord_elev is a data frame of coordinates and elevation for each station in the data set. Fields are: station id, northing (degrees), easting (degrees), elevation (m).

coeff_rad is a vector of 12 "radiative energy coefficients" for Hargreaves' equation, corresponding to the daily extra-atmospheric solar radiation energy. It is the output of function ExAtRa.

arid_ind_tables is a list formed by six data frames. Used for reference in aridity indices assessment (see function arid and references for data sources).

continental_ind_tables is a list formed by three data frames. Used for reference in continentality / oceanicity indices assessment (see function contin and references for data sources).

Source

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).

Examples

```
data(Trent_climate)
```

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