

Package ‘meteoland’

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License GPL (>= 2)

URL <https://vegmod.ctfc.cat/software/meteoland/>

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AEMET download	<i>Download data from AEMET</i>
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Description

Download data from the Spanish National Meterology Agency (AEMET)

Usage

```
downloadAEMETHistoricalstationlist(api)
downloadAEMETHistorical(api, dates, station_id, export = FALSE, exportDir = getwd(),
  exportFormat = "meteoland/txt", metadataFile = "MP.txt",
  verbose = TRUE)
downloadAEMETcurrentday(api, daily = TRUE, verbose = TRUE)
```

Arguments

api	String with the AEMET API key (see https://opendata.aemet.es/).
dates	An object of class Date .
station_id	A string vector containing station ids (the list of stations for which historical climatic series are available is given by <code>downloadAEMETHistoricalstationlist</code>).
export	If <code>export = FALSE</code> the downloaded data is stored in memory. Otherwise the result is written on the disk (using the format specified in <code>exportFormat</code>).
exportDir	Output directory for downloaded meteorology.
exportFormat	Format of meteorological data. Current accepted formats are "castanea" and "meteoland".
metadataFile	The name of the file that will store the meta data describing all written files.
verbose	Boolean flag to print process information.
daily	Boolean flag. Are data to be returned at a daily or hourly scale?

Details

API key needs to be acquired from AEMET (<https://opendata.aemet.es/>)

Value

Function `downloadAEMETHistoricalstationlist` returns a [SpatialPointsDataFrame-class](#) object containing the list of AEMET weather stations for which historical climatic series are available and can be retrieved using `downloadAEMETHistorical`.

Function `downloadAEMETHistorical` downloads data for the specified AEMET stations and dates. Data are available for dates up to 4 days before current date. If `export = FALSE`, function `downloadAEMETHistorical` returns a [SpatialPointsMeteorology-class](#) object with the downloaded meteorology for each station (point). Otherwise the function writes on the disk at the location specified by `exportDir` and solely returns a [SpatialPointsDataFrame-class](#) object containing the files metadata.

Function `downloadAEMETcurrentday` downloads recent weather (the last 24h) from all currently available stations and returns data frame if `daily = FALSE` or a [SpatialPointsDataFrame-class](#) object with observations aggregated at the daily scale if else.

Note

The list of stations available in `downloadAEMETcurrentday` (current observations) is different from the list given by `downloadAEMETHistoricalstationlist` and available in `downloadAEMETHistorical` (stations with historical climate series).

Author(s)

Antoine Cabon, CTFC

Miquel De Cáceres Ainsa, CTFC

References

AEMET should be acknowledged as author of information when using this data.

See Also

[SpatialPointsMeteorology-class](#)

averagearea

Averages area weather

Description

Averages the weather data series of points or grid pixels.

Usage

```
averagearea(object, na.rm = TRUE)
```

Arguments

`object` An object of class [SpatialPointsMeteorology-class](#), [SpatialGridMeteorology-class](#) or [SpatialPixelsMeteorology-class](#).

`na.rm` Boolean flag to indicate that missing values should be excluded from averages.

Details

Assumes that all points/pixels represent the same area.

Value

An object of class as the input `SpatialPointsMeteorology`-class with weather series corresponding to the spatial average of the input.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[weathergeneration](#)

Examples

```
data(examplegridtopography)
data(exampleinterpolationdata)

#Interpolation of meteorology over a grid for two days
ml = interpolationgrid(exampleinterpolationdata, examplegridtopography,
                      as.Date(c("2001-02-03", "2001-06-03")))

#Call averaging function
pa = averagearea(ml)

#Spatial information
pa

#Weather data
pa@data[[1]]
```

correctionpoints

Statistical correction of meteorological variables for a set of points

Description

Functions `correctionpoint` and `correctionpoints` perform correction of predicted climatic data by applying statistical correction methods (unbiasing, scaling, or quantile mapping) to meteorological variables. Function `correctionpoints.errors` allows evaluating, for each point, the bias and mean absolute error (MAE) obtained before and after correcting the climate model for the historical period.

Usage

```

correctionpoint(obs, mod, proj, dates = NULL,
                params = defaultCorrectionParams(), verbose=TRUE)
correctionpoints(object, points, topodata = NULL, dates = NULL,
                 export = FALSE, exportDir = getwd(), exportFile = NULL,
                 exportFormat = "meteoland/txt", metadataFile = "MP.txt",
                 corrOut = FALSE, verbose = TRUE)
correctionpoints.errors(object, points, topodata = NULL,
                        error.type="residuals.cv", keep.data = FALSE, verbose = FALSE)

```

Arguments

obs	A data frame with observed meteorology.
mod, proj	Data frame with predicted meteorology for the reference and projection periods, respectively.
params	A list with correction params (see defaultCorrectionParams).
object	An object of class MeteorologyUncorrectedData-class containing the meteorology of more than one point.
points	An object of class SpatialPointsMeteorology-class with the coordinates and historical meteorological data of the locations for which correction of predicted climatic data has to be done. Alternatively, an object of class SpatialPointsDataFrame-class containing the meta data (columns dir, filename and possibly format) of meteorological files that will be read from the disk.
topodata	A data frame with topographic data for each point (i.e. three columns named elevation, slope and aspect). If topodata = NULL then Penman's potential evapotranspiration is not calculated.
dates	An object of class Date with a subset of dates of the projection period to be corrected. If dates = NULL then all dates in proj or the projection data of object are processed.
export	If export = FALSE the result of correction is stored in memory. Otherwise the result is written in the disk (using the format specified in exportFormat).
exportDir	Output directory for corrected meteorology data (txt/rds format).
exportFile	Output file for corrected meteorology data (netCDF format).
metadataFile	The name of the file that will store the meta data describing all written files.
exportFormat	Export format for meteorological data (see writemeteorologypoint). If format is "meteoland/txt", "meteoland/rds", "castanea/txt" or "castanea/rds" the function tries to write one file per point in exportDir. If format is "netCDF" the function will write data to a single file specified by exportFile.
corrOut	Boolean flag to indicate that correction parameters (i.e. calculated biases) should be included with the output. Setting corrOut = TRUE changes the returned value.
verbose	Boolean flag to print process information.
error.type	String to specify the error to be evaluated, either "before" (before correction), "residual" (after correction) or "residual.cv" (after correction, but using cross-validation).
keep.data	Boolean flag to return the uncorrected/corrected data for the historical period.

Details

Function `correctionpoints` performs statistical correction of predicted climatic data for all points supplied in `points` whereas `correctionpoint` performs statistical correction of one single point. Observed meteorological data for each point typically comes from a nearby meteorological station, but they can be the result of interpolating the meteorology of several stations (see [MeteorologyInterpolationData](#)) or they can be extracted from reanalyzed meteorology (e.g. EU-WATCH) (see [extractNetCDF](#)).

For each target point, `correctionpoints` function first determines the predicted cell where the point falls according to the euclidean distance in the geographic space of `object`. Then it calls `correctionpoint`. In turn, `correctionpoint` determines the dates that are shared in observed and predicted data for the historical period. These meteorological data of dates are used to conduct the correction of predicted climatic data for the future period. Corrections biases are calculated and applied for the twelve months separately. The user can control the methods used for correction of each meteorological variable by changing the slot params in `object` (see class [MeteorologyUncorrectedData-class](#)) or the parameter params to `correctionpoint`. Three options are allowed (see [defaultCorrectionParams](#)): (a) 'unbias' for shifting the mean; (b) 'scaling' for multiplication by a factor; and (c) 'quantmap' for empirical quantile mapping between observed and modelled data (Déqué 2007).

A difficulty arises for quantile mapping when the variables bounded by zero, such as precipitation. As the models tend to drizzle (or may have lower frequency of precipitation events), the probability of precipitation in the model may be greater or lower than that observed. To correct this, when model precipitation is zero an observed value is randomly chosen in the interval where the observed cumulative frequency is less than or equal to the probability of no precipitation in the model. This procedure ensures that the probability of precipitation after correction is equal to that observed (Boé 2007).

Value

- Function `correctionpoint` returns a data frame.
- If `export = FALSE`, the function `correctionpoints` returns an object of class [SpatialPointsMeteorology-class](#) with the bias-corrected meteorology for each point. If `export=TRUE` then bias-corrected data is written into the disk. For `txt/rds` export formats, the function returns an object of class [SpatialPointsDataFrame-class](#) containing the meta data of the files written in the disk. For `netCDF` export format the function returns `NULL`. If `corrOut = TRUE` the function returns a list which contains any previous output and an object with the calculated correction factors (biases, mappings) for each point and month.
- Function `correctionpoints.errors` (`keep.data = FALSE`) returns a data frame with the mean absolute error (MAE) and bias for each variable and point. If `keep.data = TRUE` then the function also returns a list of data frames with the uncorrected/corrected series used in the comparisons with observations.

Author(s)

Miquel De Cáceres Ainsa, CTFC

Nicolas Martin, INRA-Avignon

References

Boé J, Terray L, Habets F, Martin E (2007) Statistical and dynamical downscaling of the Seine basin climate for hydro-meteorological studies. *Int J Climatol* 27:1643–1655. doi: 10.1002/joc.1602

De Caceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

Déqué M (2007) Frequency of precipitation and temperature extremes over France in an anthropogenic scenario: Model results and statistical correction according to observed values. *Glob Planet Change* 57:16–26. doi: 10.1016/j.gloplacha.2006.11.030

See Also

[penman](#), [SpatialPointsMeteorology-class](#), [writemeteorologypointfiles](#), [MeteorologyUncorrectedData](#), [MeteorologyInterpolationData](#)

Examples

```
data(examplegridtopography)
data(exampleinterpolationdata)
data(examplecorrectiondata)

#Creates spatial topography points from the grid
p = 1:2
spt = as(examplegridtopography, "SpatialPointsTopography")[p]

#Interpolation of two points for the whole time period (2000-2003)
historical = interpolationpoints(exampleinterpolationdata, spt)

#Downscaling of future predictions (RCM models, year 2023)
predicted = correctionpoints(examplecorrectiondata, historical, spt@data)

#Plot predicted mean temperature for point 1
meteoplot(predicted, 1, "MeanTemperature", ylab="Temperature (Celsius)", ylim=c(-5,40))
meteoplot(predicted, 1, "MinTemperature", add=TRUE, col="blue")
meteoplot(predicted, 1, "MaxTemperature", add=TRUE, col="red")
#Add uncorrected mean temperature data (cell #3)
lines(examplecorrectiondata@dates,
      examplecorrectiondata@projection_data[[3]]$MeanTemperature,
      lty=3)
lines(examplecorrectiondata@dates,
      examplecorrectiondata@projection_data[[3]]$MinTemperature,
      col="blue", lty=3)
lines(examplecorrectiondata@dates,
      examplecorrectiondata@projection_data[[3]]$MaxTemperature,
      col="red", lty=3)
legend("topright", legend=c("corrected","uncorrected", "Maximum", "Mean", "Minimum"),
      col=c("black","black", "red","black","blue"), lty=c(1,3,1,1,1), bty="n")

#Scatter plot
plot(examplecorrectiondata@projection_data[[3]]$MeanTemperature,
```



```

    predicted@data[[1]]$MeanTemperature, cex=0.1, asp=1,
    ylab="Corrected mean temperature", xlab="Uncorrected mean temperature")
abline(a=0,b=1,col="gray")

#Plot predicted precipitation for point 1
meteoplot(predicted, 1, "Precipitation", ylab="Precipitation (mm)", ylim=c(0,120))
#Add uncorrected mean temperature data (cell #3)
lines(examplecorrectiondata@dates,
      examplecorrectiondata@projection_data[[3]]$Precipitation,
      col="red", lty=3)
legend("topleft", legend=c("corrected", "uncorrected"), col=c("black", "red"), lty=c(1,3), bty="n")

#Scatter plot
plot(examplecorrectiondata@projection_data[[3]]$Precipitation,
      predicted@data[[1]]$Precipitation, cex=0.1, asp=1,
      ylab="Corrected precipitation (mm)", xlab="Uncorrected precipitation (mm)")
abline(a=0,b=1,col="gray")

```

correction_lowlevel *Low-level correction functions*

Description

Low-level function to perform bias correction.

Usage

```
correction_series(obs, mod, proj = NULL, method = "unbias", isPrec=TRUE, qstep=0.01)
```

Arguments

obs	Observed series for the reference (historical) period.
mod	Modelled series for the reference (historical) period.
proj	Modelled series for the projected period. If missing, the reference (historical) period is corrected.
method	Correction method, either "unbias", "scaling", "quantmap"
isPrec	A flag to indicate that variable is precipitation (only relevant for quantile mapping).
qstep	Probability step for quantile mapping (see defaultCorrectionParams).

Value

Returns a vector with corrected values.

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnologic Forestal de Catalunya

References

De Cáceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

See Also

[correctionpoints](#), [defaultCorrectionParams](#)

defaultCorrectionParams

Default correction parameters

Description

Returns a list with the default parameterization for statistical correction.

Usage

```
defaultCorrectionParams()
```

Value

A list with the following items (default values in brackets):

- **methods**: A list with the correction method for each variable (options are "unbias" (shift of the mean), "scaling" (factor multiplication), "quantmap" (empirical quantile mapping) or "none" (for no correction)). Defaults are:
 - MeanTemperature = "unbias"
 - MinTemperature = "quantmap"
 - MaxTemperature = "quantmap"
 - Precipitation = "quantmap"
 - MeanRelativeHumidity = "unbias"
 - Radiation = "unbias"
 - WindSpeed = "quantmap"
- **fill_wind** [= TRUE]: A logical flag to fill wind speed values with uncorrected values when reference data is missing.
- **allow_saturated** [= FALSE]: A logical flag to indicate whether relative humidity values above saturation (>100%) are permitted (bias correction is performed on specific humidity).
- **wind_height** [= 10]: Wind measurement height (in m).
- **qstep** [= 0.01]: a numeric value between 0 and 1. Quantile mapping is fitted only for the quantiles defined by `quantile(0, 1, probs=seq(0, 1, by=qstep))`.

Author(s)

Miquel De Cáceres Ainsa, CTFC

References

De Caceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

See Also

[MeteorologyInterpolationData](#), [MeteorologyUncorrectedData](#)

defaultGenerationParams

Default generation parameters

Description

Returns a list with the default parameterization for weather generation.

Usage

```
defaultGenerationParams()
```

Value

A list with the following items (default values in brackets):

- `conditional` [= "none"]: A string to indicate whether multi-year weather should be conditioned or not. If `conditional` = "arima", annual precipitation is conditioned on a stationary auto-regressive model. If `conditional` = "window", a moving-window is used to subset the years used to parametrize the weather generation algorithm for each target year (see parameter `range_size_years`). In this last case, annual precipitation is conditioned to a log-normal variate with parameters fitted from the selected years.
- `dry_wet_threshold` [= 0.3]: Precipitation threshold (mm) for separating dry from wet days.
- `wet_extreme_quantile_threshold` [= 0.8]: Quantile for separating wet from extremely wet days.
- `range_size_days` [= 5]: Minimum half range size to select the subset of dates with DOY similar to the currently simulated.
- `range_size_years` [= 12]: Half range size to select the subset of years in a moving-window around the current year (if `conditional` = "window").
- `n_knn_annual` [= 100]: Number of years to be re-sampled using K-nearest neighbour for annual precipitation (if `conditional` = "arima" or `conditional` = "window").
- `adjust_annual_precip` [= TRUE]: A logical flag to indicate that annual precipitation generated by the algorithm should be adjusted to fit either overall input annual precipitation or simulated annual precipitation.
- `min_ratio` [= 0.9]: Minimum adjustment ratio for precipitation.
- `max_ratio` [= 1.2]: Minimum adjustment ratio for precipitation.

Author(s)

Miquel De Cáceres Ainsa, CTFC

References

Apipattanavis, S., G. Podesta, B. Rajagopalan, and R. W. Katz (2007), A semiparametric multivariate and multisite weather generator, *Water Resour. Res.*, 43, W11401, doi:10.1029/2006WR005714.

Steinschneider S. & Brown C. (2013) A semiparametric multivariate, multisite weather generator with low-frequency variability for use in climate risk assessments. *Water Resour. Res.* 49, 7205-7220. doi:10.1002/wrcr.20528.

See Also

[weathergeneration](#)

defaultInterpolationParams

Default interpolation parameters

Description

Returns a list with the default parameterization for interpolation. Most parameter values are set according to Thornton et al. (1997).

Usage

```
defaultInterpolationParams()
```

Value

A list with the following items (default values in brackets):

- `initial_Rp [= 140000]`: Initial truncation radius.
- `iterations [= 3]`: Number of station density iterations.
- `alpha_MinTemperature [= 3.0]`: Gaussian shape parameter for minimum temperature.
- `alpha_MaxTemperature [= 3.0]`: Gaussian shape parameter for maximum temperature.
- `alpha_DewTemperature [= 3.0]`: Gaussian shape parameter for dew-point temperature.
- `alpha_PrecipitationEvent [= 5.0]`: Gaussian shape parameter for precipitation events.
- `alpha_PrecipitationAmount [= 5.0]`: Gaussian shape parameter for the regression of precipitation amounts.
- `alpha_Wind [= 3.0]`: Gaussian shape parameter for wind.
- `N_MinTemperature [= 30]`: Average number of stations with non-zero weights for minimum temperature.

- N_MaxTemperature [= 30]: Average number of stations with non-zero weights for maximum temperature.
- N_DewTemperature [= 30]: Average number of stations with non-zero weights for dew-point temperature.
- N_PrecipitationEvent [= 5]: Average number of stations with non-zero weights for precipitation events.
- N_PrecipitationAmount [= 20]: Average number of stations with non-zero weights for the regression of precipitation amounts.
- N_Wind [= 2]: Average number of stations with non-zero weights for wind.
- St_Precipitation [= 5]: Number of days for the temporal smoothing of precipitation.
- St_TemperatureRange [= 15]: Number of days for the temporal smoothing of temperature range.
- pop_crit [= 0.50]: Critical precipitation occurrence parameter.
- f_max [= 0.6]: Maximum value for precipitation regression extrapolations (0.6 equals to a maximum of 4 times extrapolation).
- wind_height [= 10]: Wind measurement height (in m).

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

References

Thornton, P.E., Running, S.W., White, M. A., 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. *J. Hydrol.* 190, 214–251. doi:10.1016/S0022-1694(96)03128-9.

De Cáceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

See Also

[MeteorologyInterpolationData](#)

examplecorrectiondata *Example data set for statistical correction of RCM predictions*

Description

Example data set including the predictions of Regional Climate Model (CCLM4-8-17; driving global model CNRM-CERFACS-CNRM-CM5) for 3 model cells in a small area in Catalonia (NE Spain). Meteorological data covers an historical (reference) period (2000-2003) and a future (projection) period (2020-2023), the latter simulated under rcp4.5 scenario.

Usage

```
data("examplecorrectiondata")
```

Format

Formal class `'MeteorologyUncorrectedData-class'`

Source

ESFG web site (<http://esgf.llnl.gov/>) that centralizes climate data from GCM and RCM uploaded in the frame of different international consortium, including the EURO-CORDEX regionalisation project.

Examples

```
data(examplecorrectiondata)
```

examplegridtopography *Example spatial grid topography*

Description

'SpatialGridTopography' object describing topographic features for a grid of 5 km x 5 km and cell size of 100 m in Catalonia (NE Spain).

Usage

```
data("examplegridtopography")
```

Format

Formal class `'SpatialGridTopography'`

Source

'Institut Cartogràfic de Catalunya' (ICC)

Examples

```
data(examplegridtopography)
```

`exampleinterpolationdata`*Example data set for interpolation from weather stations*

Description

Example data set of spatial location, topography and daily meteorological records from 38 weather stations in Catalonia (NE Spain) corresponding to years 2000-2003.

Usage

```
data("exampleinterpolationdata")
```

Format

Formal class `'MeteorologyInterpolationData-class'`

Source

'Servei Meteorològic de Catalunya' (SMC) and 'Agencia Española de Meteorología' (AEMET)

Examples

```
data(exampleinterpolationdata)
```

`extractdates`*Extracts meteorological data*

Description

Extracts meteorological data from an object.

Usage

```
extractdates(object, dates = NULL, verbose=FALSE)
extractvars(object, vars, verbose=FALSE)
extractgridindex(grid, index)
extractgridpoints(grid, points, verbose=FALSE)
```

Arguments

object	An object of class SpatialPointsMeteorology , SpatialGridMeteorology or SpatialPixelsMeteorology .
dates	A vector of Date with a (subset) of dates to be extracted. If NULL all dates will be returned.
vars	A character vector with the set of variables to be extracted.
grid	An object of class SpatialGridMeteorology-class or SpatialPixelsMeteorology-class with the meteorological data for a full grid or a subset of grid cells, respectively. Alternatively, a string specifying a NetCDF to be read from the disk.
index	An integer with a grid index.
points	An object of class SpatialPoints .
verbose	Boolean flag to print process information.

Details

Function `extractpoints` is deprecated, because its functionality can be achieved using subsetting of spatial classes [SpatialGridMeteorology](#) and [SpatialPixelsMeteorology](#).

Value

- Function `extractdates()`, returns a list with the same length as `dates`. Each element of the list is a spatial object ([SpatialPointsDataFrame](#), [SpatialGridDataFrame](#) or [SpatialPixelsDataFrame](#), depending on the input) with the meteorological data for all the spatial elements. If only one date is asked, the function returns directly the spatial object, without embedding it into a list.
- Function `extractvars()`, returns a list with the same length as `vars`. Each element of the list is a spatial object ([SpatialPointsDataFrame](#), [SpatialGridDataFrame](#) or [SpatialPixelsDataFrame](#), depending on the input) with the meteorological data for all the spatial elements. If only one variable is asked, the function returns directly the spatial object, without embedding it into a list.
- Function `extractgridindex()` returns a data frame.
- Function `extractgridpoints()` returns an object of class [SpatialPointsMeteorology](#).

Author(s)

Miquel De Cáceres Ainsa, CTFC

extractNetCDF

Extraction of climatic data from NetCDF files (deprecated)

Description

This function reads a set of NetCDF files (one per variable) and extracts data for a set of NetCDF cells that are specified using a boundary box (in lon/lat format) or a set of (x,y) grid indices.

Usage

```
extractNetCDF(ncdf_files, bbox = NULL, offset = 0, cells = NULL, export = TRUE,  
             exportDir = getwd(), exportFormat = "meteoland/txt", mpfilename = "MP.txt")
```

Arguments

<code>ncdf_files</code>	Character vector containing files to read
<code>bbox</code>	Boundary box (2 x 2 matrix) specifying the limit coordinates of a study area (in lon/lat format).
<code>offset</code>	A buffer to include NetCDF cells that are at a certain distance around the boundary box.
<code>cells</code>	A (n x 2) matrix specifying the x and y indices of n cells in a grid.
<code>export</code>	If <code>export = FALSE</code> the extracted data is stored in memory. Otherwise the result is written in the disk (using the format specified in <code>exportFormat</code>).
<code>exportFormat</code>	Export format for meteorological data (see writemeteorologypoint).
<code>exportDir</code>	Output directory for extracted meteorology.
<code>mpfilename</code>	The name of the file that will store the meta data describing all written files.

Details

Function `extractNetCDF` first identifies which cells in NetCDF data should be extracted according to `bbox` (or the cells are indicated by the user using `cells`), and the overall period (days). If neither `bbox` or `cells` is supplied, then all NetCDF cells will be processed. For each cell to be processed, the function loops over all files (which can describe different variables and time periods) and extracts the corresponding data. The function transforms units to the units used in `meteoland`. If specific humidity and mean temperature are available, the function calculates mean relative humidity.

Extracted meteorological data (a data frame with days in rows and meteorological variables in columns) can be stored in an object [SpatialPointsMeteorology-class](#) or it can be written in the disk (one file per cell). In the latter case, the output format can be chosen and the function also writes a supplementary file containing the meta data (i.e. the coordinates and filename of each file).

Humidity in climate model files is given as specific humidity. This is converted to relative humidity and the conversion may produce values above saturation (>100%) (see also [defaultCorrectionParams](#) for the same issue when performing bias correction).

Value

If `export = FALSE`, the function returns an object of class [SpatialPointsMeteorology-class](#) with the meteorological series for each cell (represented by a spatial point). Otherwise the function returns an object of class [SpatialPointsDataFrame-class](#) containing the meta data of the files written in the disk.

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnològic Forestal de Catalunya
Nicolas Martin, INRA-Avignon

See Also

[correctionpoints](#), [writemeteorologypointfiles](#), [SpatialPointsMeteorology-class](#)

humidity

Humidity conversion tools

Description

Functions to transform specific humidity to relative humidity and viceversa.

Usage

```
humidity_specific2relative(Tc, HS, allowSaturated = FALSE)
humidity_relative2specific(Tc, HR)
```

Arguments

Tc	A numeric vector of temperature in degrees Celsius.
HS	A numeric vector of specific humidity (unitless).
HR	A numeric vector of relative Humidity (in %).
allowSaturated	Logical flag to allow values over 100%

Value

A numeric vector with specific or relative humidity.

Author(s)

Nicholas Martin-StPaul, INRA
Miquel De Cáceres Ainsa, CTFC

See Also

[meteocomplete](#)

`interpolation.coverage`*Spatial and temporal coverage of interpolation data*

Description

Function `interpolation.coverage` calculates, for each meteorological variable, the number of stations with data per date or the number of dates with data per station in an object of class [MeteorologyInterpolationData-class](#).

Usage

```
interpolation.coverage(object, type = "spatial", percent = FALSE)
```

Arguments

<code>object</code>	An object of class MeteorologyInterpolationData-class .
<code>type</code>	A string with the coverage summary to be produced (either "spatial" or "temporal").
<code>percent</code>	A boolean flag to indicate that percentages should be returned instead of counts.

Value

If `type = "spatial"` the function returns an object of class `SpatialPointsDataFrame` with the number (or percentage) of dates with data per station and meteorological variable. If `type = "temporal"` the function returns an object of class `data.frame` with the number (or percentage) of stations with data per day and meteorological variable.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

References

De Cáceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

See Also

[MeteorologyInterpolationData](#)

Examples

```
data(exampleinterpolationdata)

#Number of days with data per station
head(interpolation.coverage(exampleinterpolationdata))

#Number of stations with data per day
head(interpolation.coverage(exampleinterpolationdata, type = "temporal"))
```

interpolation.cv

Calibration and validation of interpolation procedures

Description

Function `interpolation.calibration` determines optimal interpolation parameters 'N' and 'alpha' for a given meteorological variable. Optimization is done by minimizing mean absolute error (MAE) (Thornton et al. 1997). Function `interpolation.cv` calculates average mean absolute errors (MAE) for the prediction period of an object of class 'MeteorologyInterpolationData'. Function `summary.interpolation.cv` returns a data.frame with cross-validation summaries and `plot.interpolation.cv` plots cross-validation results. In both calibration and validation procedures, predictions for each weather station are made using a leave-one-out procedure (i.e. after excluding the station from the predictive set).

Usage

```
interpolation.calibration(object, stations = NULL, variable="Tmin",
                          N_seq = seq(5,30, by=5), alpha_seq = seq(0.25,10, by=0.25),
                          verbose = FALSE)
interpolation.calibration.fmax(object, stations = NULL,
                               fmax_seq = seq(0.05,0.95, by=0.05),
                               verbose = FALSE)
interpolation.cv(object, stations = NULL, verbose = FALSE)
## S3 method for class 'interpolation.cv'
summary(object, ...)
## S3 method for class 'interpolation.cv'
plot(x, type = "stations", ...)
```

Arguments

object	In the case of function <code>interpolation.cv</code> , an object of class MeteorologyInterpolationData-class . In the case of function <code>summary</code> , an object of class interpolation.cv
stations	A numeric vector containing the indices of stations to be used to calculate mean absolute errors (MAE) in the calibration or cross-validation analysis. All the stations with data are included in the training set but predictive MAE are calculated for the 'stations' subset only.

variable	A string indicating the meteorological variable for which interpolation parameters 'N' and 'alpha' will be calibrated. Accepted values are 'Tmin' (for minimum temperature), 'Tmax' (for maximum temperature), 'Tdew' (for dew-point temperature), 'PrecEvent' (for precipitation events), 'PrecAmount' (for regression of precipitation amounts), 'Prec' (for precipitation with the same values for precipitation events and regression of precipitation amounts).
N_seq	Set of average number of points to be tested.
alpha_seq	Set of alpha values to be tested.
fmax_seq	Set of f_max values to be tested.
verbose	A logical flag to generate additional console output.
x	A S3 object of class <code>interpolation.cv</code> with cross-validation results.
type	A string of the plot type to be produced (either "stations" or "dates").
...	Additional parameters passed to summary and plot functions.

Value

Function `interpolation.calibration` returns an object of class `'interpolation.calibration'` with the following items:

- MAE: A numeric matrix with the mean absolute error values (averaged across stations) for each combination of parameters 'N' and 'alpha'.
- minMAE: Minimum MAE value.
- N: Value of parameter 'N' corresponding to the minimum MAE.
- alpha: Value of parameter 'alpha' corresponding to the minimum MAE.
- Observed: A matrix with observed values.
- Predicted: A matrix with predicted values for the optimum parameter combination.

Function `interpolation.cv` returns a list of class `'interpolation.cv'` with the following items:

- stations: A data frame with as many rows as weather stations and the following columns:
 - MinTemperature-Bias: Bias (in degrees), calculated over the prediction period, of minimum temperature estimations in weather stations.
 - MinTemperature-MAE: Mean absolute errors (in degrees), averaged over the prediction period, of minimum temperature estimations in weather stations.
 - MaxTemperature-Bias: Bias (in degrees), calculated over the prediction period, of maximum temperature estimations in weather stations.
 - MaxTemperature-MAE: Mean absolute errors (in degrees), averaged over the prediction period, of maximum temperature estimations in weather stations.
 - Precipitation-Total: Difference in the total precipitation of the studied period.
 - Precipitation-DPD: Difference in the proportion of days with precipitation.
 - Precipitation-Bias: Bias (in mm), calculated over the days with precipitation, of precipitation amount estimations in weather stations.
 - Precipitation-MAE: Mean absolute errors (in mm), averaged over the days with precipitation, of precipitation amount estimations in weather stations.

- RelativeHumidity-Bias: Bias (in percent), calculated over the prediction period, of relative humidity estimations in weather stations.
- RelativeHumidity-MAE: Mean absolute errors (in percent), averaged over the prediction period, of relative humidity estimations in weather stations.
- Radiation-Bias: Bias (in MJ/m²), calculated over the prediction period, of incoming radiation estimations in weather stations.
- Radiation-MAE: Mean absolute errors (in MJ/m²), averaged over the prediction period, of incoming radiation estimations in weather stations.
- dates: A data frame with as many rows as weather stations and the following columns:
 - MinTemperature-Bias: Daily bias (in degrees), averaged over the stations, of minimum temperature estimations.
 - MinTemperature-MAE: Daily mean absolute error (in degrees), averaged over the stations, of minimum temperature estimations.
 - MaxTemperature-Bias: Daily bias (in degrees), averaged over the stations, of maximum temperature estimations.
 - MaxTemperature-MAE: Daily mean absolute error (in degrees), averaged over the stations, of maximum temperature estimations.
 - Precipitation-Bias: Daily bias (in mm), averaged over the stations, of precipitation amount estimations.
 - Precipitation-MAE: Daily mean absolute error (in mm), averaged over the stations, of precipitation amount estimations.
 - RelativeHumidity-Bias: Daily bias (in percent), averaged over the stations, of relative humidity estimations.
 - RelativeHumidity-MAE: Daily mean absolute error (in percent), averaged over the stations, of relative humidity estimations.
 - Radiation-Bias: Daily bias (in MJ/m²), averaged over the stations, of incoming radiation estimations.
 - Radiation-MAE: Daily mean absolute errors (in MJ/m²), averaged over the stations, of incoming radiation estimations.
- MinTemperature: A data frame with predicted minimum temperature values.
- MinTemperatureError: A matrix with predicted minimum temperature errors.
- MaxTemperature: A data frame with predicted maximum temperature values.
- MaxTemperatureError: A matrix with predicted maximum temperature errors.
- Precipitation: A data frame with predicted precipitation values.
- PrecipitationError: A matrix with predicted precipitation errors.
- RelativeHumidity: A data frame with predicted relative humidity values.
- RelativeHumidityError: A matrix with predicted relative humidity errors.
- Radiation: A data frame with predicted radiation values.
- RadiationError: A matrix with predicted radiation errors.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

References

Thornton, P.E., Running, S.W., 1999. An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. *Agric. For. Meteorol.* 93, 211–228. doi:10.1016/S0168-1923(98)00126-9.

De Caceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

See Also

[MeteorologyInterpolationData](#)

Examples

```
data(exampleinterpolationdata)

#Calibration procedure
precEv_cal = interpolation.calibration(exampleinterpolationdata, variable="PrecEvent",
                                     stations = 1:5,
                                     N_seq=c(5,10,15), alpha_seq=seq(0.25,1.0, by=0.25),
                                     verbose = TRUE)

precAm_cal = interpolation.calibration(exampleinterpolationdata, variable="PrecAmount",
                                     stations = 1:5,
                                     N_seq=c(5,10,15), alpha_seq=seq(0.25,1.0, by=0.25),
                                     verbose = TRUE)

#Set 'alpha' and 'N' parameters to values found in calibration
exampleinterpolationdata@params$N_PrecipitationEvent = precEv_cal$N
exampleinterpolationdata@params$alpha_PrecipitationEvent = precEv_cal$alpha

exampleinterpolationdata@params$N_PrecipitationAmount = precAm_cal$N
exampleinterpolationdata@params$alpha_PrecipitationAmount = precAm_cal$alpha

#Run cross validation
cv = interpolation.cv(exampleinterpolationdata, stations = 1:5, verbose = TRUE)

#Print cross validation summaries
summary(cv)

#Plot results
plot(cv)
```

interpolationpoints *Interpolate daily meteorology over a landscape*

Description

Functions to interpolate meteorological data for spatial locations (at points, grid pixels or full grids) using an object of class [MeteorologyInterpolationData-class](#).

Usage

```

interpolationpoints(object, points, dates = NULL, export = FALSE,
                    exportDir = getwd(), exportFile = NULL,
                    exportFormat = "meteoland/txt",
                    metadataFile = "MP.txt", verbose=TRUE)
interpolationpixels(object, pixels, dates = NULL,
                   exportFile = NULL, exportFormat = "netCDF",
                   add = FALSE, overwrite = FALSE, verbose=TRUE)
interpolationgrid(object, grid, dates = NULL,
                  exportFile = NULL, exportFormat = "netCDF",
                  add = FALSE, overwrite = FALSE, verbose=TRUE)

```

Arguments

object	An object of class MeteorologyInterpolationData-class .
points	An object of class SpatialPointsTopography-class .
pixels	An object of class SpatialPixelsTopography-class representing the target landscape.
grid	An object of class SpatialGridTopography-class representing the target landscape.
dates	An object of class Date . If this is NULL then all dates in object are processed.
export	If export = FALSE the result of interpolation is stored in memory. Otherwise the result is written in the disk (using the format specified in exportFormat).
exportDir	Output directory for interpolated meteorology data files (txt/rds format).
exportFile	Output file for interpolated meteorology data (netCDF format).
exportFormat	Export format for meteorological data (see writemeteorologypoint). If format is "meteoland/txt", "meteoland/rds", "castanea/txt" or "castanea/rds" the function tries to write one file per point in exportDir. If format is "netCDF" the function will write data to a single file specified by exportFile.
metadataFile	The name of the ascii text file that will store the meta data describing all written files.
verbose	Boolean flag to print process information.
add	Boolean flag to indicate that NetCDF exists and data should be added/replaced.
overwrite	Boolean flag to force overwriting an existing NetCDF.

Details

If CRS projection is different between object and points/pixels/grid, the function transforms the coordinates of points/pixels/grid to adapt them to the CRS of object.

Value

If export = FALSE, function interpolationpoints returns an object of [SpatialPointsMeteorology-class](#). If export = TRUE files are written in the disk. For text/rds format the function returns an object of class [SpatialPointsDataFrame-class](#) containing point meta data.

If `export = FALSE`, function `interpolationpixels` returns an object of [SpatialPixelsMeteorology-class](#), or an object of [SpatialPixelsDataFrame-class](#) if a single date is interpolated. If `export = TRUE`, the function writes the results in a NetCDF.

If `export = FALSE`, function `interpolationgrid` returns an object of [SpatialGridMeteorology-class](#), or an object of [SpatialGridDataFrame-class](#) if a single date is interpolated. If `export = TRUE`, the function writes the results in files and a data.frame with columns 'dir' and 'filename' is returned.

Author(s)

Miquel De Cáceres Ainsa, CTFC

References

Thornton, P.E., Running, S.W., White, M. A., 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. *J. Hydrol.* 190, 214–251. doi:10.1016/S0022-1694(96)03128-9.

De Cáceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

See Also

[penman](#), [SpatialPointsTopography-class](#), [SpatialGridTopography](#), [SpatialPixelsTopography](#), [MeteorologyInterpolationData](#)

Examples

```
data(examplegridtopography)
data(exampleinterpolationdata)

##### INTERPOLATION on particular POINTS

#Creates spatial topography points from the grid
p = 1:2
spt = as(examplegridtopography, "SpatialPointsTopography")[p]

#Interpolation of two points for the whole time period (2000-2003)
mp = interpolationpoints(exampleinterpolationdata, spt)

#Plot interpolated meteorological series
meteoplot(mp,1, ylab="Mean temperature")

##### INTERPOLATION on PIXELS
# Creates spatial topography pixels as a subset of grid pixels
# and select pixels at maximum distance of 2km from center
spt = as(examplegridtopography, "SpatialPointsTopography")
cc = spt@coords
center = 5160
d = sqrt((cc[,1]-cc[center,1])^2+(cc[,2]-cc[center,2])^2)
spxt = as(spt[which(d<2000)], "SpatialPixelsTopography")
```

```

# Interpolation of meteorology over pixels for two days
m1 = interpolationpixels(exampleinterpolationdata, spxt,
                        as.Date(c("2001-02-03", "2001-06-03")))

#Plot PET corresponding to 2001-06-03
splot(m1,2,"PET")

##### INTERPOLATION over a complete GRID
#Interpolation of meteorology over a grid for two days
m1 = interpolationgrid(exampleinterpolationdata, examplegridtopography,
                    as.Date(c("2001-02-03", "2001-06-03")))
#Plot PET corresponding to 2001-06-03
splot(m1,2,"PET")

```

interpolation_lowlevel

Low-level interpolation functions

Description

Low-level functions to interpolate meteorology (one day) on a set of points.

Usage

```

interpolation_dewtemperature(Xp, Yp, Zp, X, Y, Z, T,
                            iniRp = 140000, alpha = 3.0, N = 30, iterations = 3)
interpolation_temperature(Xp, Yp, Zp, X, Y, Z, T,
                          iniRp = 140000, alpha = 3.0, N = 30, iterations = 3)
interpolation_precipitation(Xp, Yp, Zp, X, Y, Z, P, Psmooth,
                            iniRp = 140000, alpha_event = 6.25, alpha_amount = 6.25,
                            N_event = 20, N_amount = 20, iterations = 3, popcrit = 0.5,
                            fmax = 0.95)
interpolation_wind(Xp, Yp, WS, WD, X, Y,
                  iniRp = 140000, alpha = 2.0, N = 1, iterations = 3,
                  directionsAvailable = TRUE)

```

Arguments

Xp, Yp, Zp	Spatial coordinates and elevation (Zp; in m.a.s.l) of target points.
X, Y, Z	Spatial coordinates and elevation (Zp; in m.a.s.l) of reference locations (e.g. meteorological stations).
T	Temperature (e.g., minimum, maximum or dew temperature) at the reference locations (in degrees).
P	Precipitation at the reference locations (in mm).
Psmooth	Temporally-smoothed precipitation at the reference locations (in mm).

WS, WD	Wind speed (in m/s) and wind direction (in degrees from north clock-wise) at the reference locations.
iniRp	Initial truncation radius.
iterations	Number of station density iterations.
alpha, alpha_amount, alpha_event	Gaussian shape parameter.
N, N_event, N_amount	Average number of stations with non-zero weights.
popcrit	Critical precipitation occurrence parameter.
fmax	Maximum value for precipitation regression extrapolations (0.6 equals to a maximum of 4 times extrapolation).
directionsAvailable	A flag to indicate that wind directions are available (i.e. non-missing) at the reference locations.

Value

All functions return a vector with interpolated values for the target points.

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnologic Forestal de Catalunya

References

Thornton, P.E., Running, S.W., White, M. A., 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. *J. Hydrol.* 190, 214–251. doi:10.1016/S0022-1694(96)03128-9.

De Cáceres M, Martin-StPaul N, Turco M, Cabon A, Granda V (2018) Estimating daily meteorological data and downscaling climate models over landscapes. *Environmental Modelling and Software* 108: 186-196.

See Also

[defaultInterpolationParams](#)

Examples

```
data("exampleinterpolationdata")
mxt100 = exampleinterpolationdata@MaxTemperature[,100]
Psmooth100 = exampleinterpolationdata@SmoothedPrecipitation[,100]
P100 = exampleinterpolationdata@Precipitation[,100]
mismxt = is.na(mxt100)
misP = is.na(P100)
Z = exampleinterpolationdata@elevation
X = exampleinterpolationdata@coords[,1]
Y = exampleinterpolationdata@coords[,2]
Zpv = seq(0,1000, by=100)
```

```

xp = 360000
yp = 4640000
xpv = rep(xp, 11)
ypv = rep(yp, 11)

interpolation_temperature(xpv, ypv, Zpv,
                          X[!mismxt], Y[!mismxt], Z[!mismxt],
                          mxt100[!mismxt])
interpolation_precipitation(xpv, ypv, Zpv,
                            X[!misP], Y[!misP], Z[!misP],
                            P100[!misP], Psmooth100[!misP])

```

mergegrids

Merges meteorological data

Description

Merges point or gridded meteorological data into a single object

Usage

```

mergepoints(..., verbose=TRUE)
mergegrids(..., verbose=TRUE)

```

Arguments

...	Objects to be merged, either of class <code>SpatialPointsMeteorology</code> , <code>SpatialGridMeteorology</code> or <code>SpatialPixelsMeteorology</code> . All objects of the same class.
verbose	A logical flag to indicate console output.

Details

Function `mergepoints` requires all coordinate reference systems to be the same. The function allows merging data from the same points (i.e. if they have the same coordinates). Function `mergegrids` pools dates and variables, but spatial structures (i.e. grid topology, pixel indices, reference system, ...) should be the same for all objects to be merged.

Value

Function `codemergepoints` returns an object `SpatialPointsMeteorology-class`. Function `mergegrids` returns an object `SpatialGridMeteorology-class` or an object `SpatialPixelsMeteorology-class`, depending on the input.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[SpatialPointsMeteorology-class](#), [SpatialGridMeteorology-class](#), [SpatialPixelsMeteorology-class](#)

`meteocomplete`*Complete daily meteorological variables*

Description

Fills missing values of relative humidity, radiation and potential evapotranspiration from a data frame with daily values of minimum/maximum/mean temperature and precipitation.

Usage

```
meteocomplete(x, latitude, elevation, slope, aspect)
```

Arguments

<code>x</code>	A data frame with dates as row names and columns named 'MeanTemperature', 'MaxTemperature', 'MinTemperature' and 'Precipitation'
<code>latitude</code>	Latitude in degrees North.
<code>elevation</code>	Elevation in m.a.s.l.
<code>slope</code>	Slope in degrees.
<code>aspect</code>	Aspect in degrees from North.

Details

The function fills values for humidity, radiation and PET only if they are missing in the input data frame. If a column 'SpecificHumidity' is present in the input data, relative humidity is calculated from it. Otherwise, relative humidity is calculated assuming that dew point temperature equals the minimum temperature. Potential solar radiation is calculated from latitude, slope and aspect. Incoming solar radiation is then corrected following Thornton & Running (1999) and potential evapotranspiration following Penman (1948).

Value

A data frame copied from `x` but with filled values for variables:

- `MeanRelativeHumidity`: Mean daily relative humidity (in percent).
- `MinRelativeHumidity`: Minimum daily relative humidity (in percent).
- `MaxRelativeHumidity`: Maximum daily relative humidity (in percent).
- `Radiation`: Incoming solar radiation (MJ/m2).
- `PET`: Potential evapotranspiration (in mm of water).

Author(s)

Miquel De Cáceres Ainsa, CTFC

References

Thornton, P.E., Running, S.W., 1999. An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. *Agric. For. Meteorol.* 93, 211-228.

Penman, H. L. 1948. Natural evaporation from open water, bare soil and grass. *Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences*, 193, 120-145.

See Also

[penman](#), [radiation_solarRadiation](#)

MeteoGalicía download *Download data from MeteoGalicía*

Description

Download data from the Galician Meteorology Agency (MeteoGalicía)

Usage

```
downloadMGstationlist()
downloadMGhistorical(date_from, date_to, station_id = NULL,
                    verbose = TRUE)
downloadMGcurrentday(station_id = NULL, daily = TRUE, verbose = TRUE)
```

Arguments

date_from, date_to	Strings or objects of class Date specifying first and last date of the desired period.
station_id	A string vector containing station ids (the list of stations presently operative is given by <code>downloadMGstationlist</code>). If <code>NULL</code> all stations with available data are returned.
verbose	Boolean flag to print process information.
daily	Boolean flag. Are data to be returned at a daily or hourly scale?

Details

See available data services of MeteoGalicía at https://www.meteogalicía.gal/web/RSS/rssIndex.action?request_locale=es.

Value

Function `downloadMGstationlist` returns a [SpatialPointsDataFrame-class](#) object containing the list of MeteoGalicia weather stations currently operative. Function `downloadMGhistorical` downloads data for the specified MG weather stations (or all) and dates and returns a [SpatialPointsMeteorology-class](#) object with the downloaded meteorology for each station (point).

Function `downloadMGcurrentday` downloads recent weather data (the last 24h) from all currently available stations and returns data frame if `daily = FALSE` or a [SpatialPointsDataFrame-class](#) object with observations aggregated at the daily scale otherwise.

Author(s)

Miquel De Cáceres Ainsa, CTFC

References

MeteoGalicia (from the Conselleria de Medio Ambiente, Territorio e Vivenda of Xunta de Galicia) should be acknowledged as source of information when using this data.

See Also

[SpatialPointsMeteorology-class](#)

meteoplot	<i>Plots point meteorological series</i>
-----------	--

Description

Simple plotting of a meteorological series for a given point.

Usage

```
meteoplot(object, index=1, var="MeanTemperature",
          fun=NULL, freq=NULL, dates = NULL, months = NULL, add = FALSE,...)
```

Arguments

object	A data frame with daily meteorological data (in this case <code>index</code> is not used) or an object of class SpatialPointsMeteorology . Alternatively, an object of class SpatialPointsDataFrame containing the meta data (columns <code>dir</code> , <code>filename</code> and possibly <code>format</code>) of meteorological files.
index	An integer to indicate the point in the SpatialPointsMeteorology object (or the SpatialPointsDataFrame object).
var	The meteorological variable to be plotted.
fun	The name of a function to be calculated for summaries (only valid if <code>freq</code> is specified).

freq	A string giving an interval specification for summaries (e.g., "week", "month", "quarter" or "year").
dates	An object of class <code>Date</code> to define the period to be plotted. If <code>dates = NULL</code> then all dates in object are processed.
months	A numeric vector to indicate the subset of months for which plotting is desired (e.g. <code>c(7,8)</code> for July and August). When combined with <code>fun</code> and <code>freq</code> , this parameter allows plotting summaries for particular seasons. For example <code>fun = "sum"</code> <code>freq = "years"</code> and <code>months = 6:8</code> leads to plotting the sum over summer months of each year.
add	A flag to indicate whether drawing should be done on the current plot (using function lines).
...	Additional parameters for functions <code>plot</code> or <code>lines</code> .

Details

Daily precipitation is plotted using bars (i.e. `type = "h"` when calling `plot`). Otherwise the function draws lines (i.e. `type = "l"` when calling `plot`). If object is of class `SpatialPointsDataFrame-class` then the function reads the meteorological data to be plotted from the disk.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[summarypoints](#)

Examples

```
data(examplegridtopography)
data(exampleinterpolationdata)

#Creates spatial topography points from the grid
p = 1:2
spt = as(examplegridtopography, "SpatialPointsTopography")[p]

#Interpolation of two points for the whole time period (2000-2003)
mp = interpolationpoints(exampleinterpolationdata, spt)

#Plot interpolated meteorological series
meteoplot(mp,1, ylab="Daily mean temperature")

meteoplot(mp,1, ylab="Monthly mean temperature", fun=mean, freq="months")
```

 MeteorologyInterpolationData

Creates an object of class 'MeteorologyInterpolationData'

Description

Initializes an object for meteorology interpolation over landscapes using weather station data and the methods described in Thornton et al. (1997) and Thornton & Running (1999).

Usage

```
MeteorologyInterpolationData(points, elevation = NULL, slope = NULL, aspect = NULL,
                             MinTemperature = NULL, MaxTemperature = NULL,
                             Precipitation = NULL, RelativeHumidity = NULL,
                             Radiation = NULL, WindSpeed = NULL,
                             WindDirection = NULL, WindFields = NULL,
                             params = defaultInterpolationParams())
```

Arguments

points	An object of class SpatialPointsMeteorology , an object of SpatialPointsTopography or an object of class SpatialPoints (see 'Details').
elevation	A numeric vector with elevation values of weather stations (in meters).
slope	A numeric vector with slope values of weather stations (in degrees). Needed for cross-validation of interpolation routines.
aspect	A numeric vector with aspect values of weather stations (in degrees from North). Needed for cross-validation of interpolation routines.
MinTemperature	A matrix with minimum temperature recordings (in degrees Celsius) for all weather stations (in rows) and all days (in columns).
MaxTemperature	A matrix with maximum temperature recordings (in degrees Celsius) for all weather stations (in rows) and all days (in columns).
Precipitation	A matrix with precipitation recordings (in mm of water) for all weather stations (in rows) and all days (in columns).
RelativeHumidity	A matrix with (mean) relative humidity recordings (in percent) for all weather stations (in rows) and all days (in columns).
Radiation	A matrix with relative radiation recordings (in MJ/m ²) for all weather stations (in rows) and all days (in columns). Needed for cross-validation only.
WindSpeed	A matrix with wind speed recordings (in m/s) for all weather stations (in rows) and all days (in columns).
WindDirection	A matrix with wind direction recordings (in degrees from North) for all weather stations (in rows) and all days (in columns).
WindFields	Object of class "list". See function readWindNinjaWindFields .
params	A list containing interpolation parameters.

Details

There are three ways of building an object of [MeteorologyInterpolationData](#):

1. The first way is using an object of [SpatialPointsMeteorology](#) containing both the coordinates and meteorological series of stations. In this case elevation has to be provided, but aspect and slope may be omitted. Parameters `MinTemperature` to `WindDirection` can be left as `NULL`.
2. The second way is using an object of class of [SpatialPointsTopography](#) containing the coordinates of stations and topographic variables. In this case parameters `MinTemperature`, `MaxTemperature` and `Precipitation` will need to be supplied, each being a matrix with weather stations in rows and days in columns, but `RelativeHumidity` to `WindDirection` may be left as `NULL`.
3. The third way is using an object of [SpatialPoints](#) containing the coordinates of stations only. In this case elevation has to be provided, but aspect and slope may be omitted. As in the second case, parameters `MinTemperature`, `MaxTemperature` and `Precipitation` will need to be supplied, each being a matrix with weather stations in rows and days in columns, but `RelativeHumidity` to `WindDirection` may be left as `NULL`.

Value

An object of class [MeteorologyInterpolationData](#).

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

References

Thornton, P.E., Running, S.W., 1999. An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. *Agric. For. Meteorol.* 93, 211–228. doi:10.1016/S0168-1923(98)00126-9.

Thornton, P.E., Running, S.W., White, M. a., 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. *J. Hydrol.* 190, 214–251. doi:10.1016/S0022-1694(96)03128-9.

See Also

[MeteorologyInterpolationData](#), [defaultInterpolationParams](#).

Examples

```
## TO BE DONE ##
```

MeteorologyInterpolationData-class
Class "MeteorologyInterpolationData"

Description

An S4 class to interpolate meteorology over a landscape.

Objects from the Class

Objects can be created by calls of the form `new("MeteorologyInterpolationData", ...)`, or by calls to the function `MeteorologyInterpolationData`.

Slots

dates: Object of class "Date" describing the time period for which meteorological estimates are possible.

bbox: Object of class "matrix" with the boundary box that sets meteorological estimation boundaries.

proj4string: Object of class "CRS" with the projection string of station spatial coordinates.

coords: Object of class "matrix" containing the coordinates of weather stations (each row is a point).

elevation: A numeric vector with elevation values of weather stations (in meters).

slope: A numeric vector with slope values of weather stations (in degrees). Needed for cross-validation only.

aspect: A numeric vector with aspect values of weather stations (in degrees from North). Needed for cross-validation only.

MinTemperature: Object of class "data.frame" with minimum temperature recordings (in degrees Celsius) for all weather stations (in rows) and all days (in columns).

MaxTemperature: Object of class "data.frame" with maximum temperature recordings (in degrees Celsius) for all weather stations (in rows) and all days (in columns).

SmoothedTemperatureRange: Object of class "matrix" with temporally smoothed temperature range recordings (in degrees Celsius) for all weather stations (in rows) and all days (in columns).

Precipitation: Object of class "matrix" with precipitation recordings (in mm of water) for all weather stations (in rows) and all days (in columns).

SmoothedPrecipitation: Object of class "matrix" with temporally smoothed precipitation recordings (in mm of water) for all weather stations (in rows) and all days (in columns).

RelativeHumidity: Object of class matrix with relative humidity recordings (in percent) for all weather stations (in rows) and all days (in columns).

Radiation: Object of class matrix with relative radiation recordings (in MJ/m2) for all weather stations (in rows) and all days (in columns). Needed for cross-validation only.

WindSpeed: Object of class "matrix" with wind speed recordings (in m/s) for all weather stations (in rows) and all days (in columns).

WindDirection: Object of class "matrix" with wind direction recordings (in degrees from North) for all weather stations (in rows) and all days (in columns).

WindFields: Object of class "list". See function [readWindNinjaWindFields](#).

WFIndex: Object of class "matrix" with the closest windfield index for each stations in each day.

WFFactor: Object of class "matrix" with the multiplication factor for the wind speed of each stations in each day.

params: A "list" containing interpolation parameters.

Extends

Class "[MeteorologyProcedureData](#)", directly. Class "[Spatial](#)", by class "MeteorologyProcedureData", distance 2

Methods

subsample signature(object = "MeteorologyInterpolationData"): Generates a [MeteorologyInterpolationData](#) object for a smaller area and a subset of dates.

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnologic Forestal de Catalunya

See Also

[MeteorologyInterpolationData](#), [MeteorologyProcedureData-class](#), [subsample](#)

Examples

```
#Structure of the S4 object
showClass("MeteorologyInterpolationData")
```

MeteorologyProcedureData-class
Class "MeteorologyProcedureData"

Description

A virtual class for estimating meteorology over landscapes

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

dates: Object of class "Date" describing the time period for which meteorological estimates are possible.

bbox: Object of class "matrix" with the boundary box that sets meteorological estimation boundaries.

proj4string: Object of class "CRS" with the projection string of accepted coordinates.

Methods

subsample signature(object = "MeteorologyProcedureData"): Generates MeteorologyProcedureData objects for a smaller area and a subset of dates.

Extends

Class "[Spatial](#)", directly.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[MeteorologyInterpolationData-class](#), [MeteorologyUncorrectedData-class](#)

Examples

```
showClass("MeteorologyProcedureData")
```

MeteorologyUncorrectedData

Creates an object of class 'MeteorologyUncorrectedData'

Description

Initializes an object for statistical correction of meteorological data over landscapes.

Usage

```
MeteorologyUncorrectedData(points, reference_data, projection_data, dates,  
  params = defaultCorrectionParams())
```

Arguments

points	An object of class SpatialPoints .
reference_data	Reference (historic) meteorological data used to calibrate correction factors when compared with observations. A vector of data frames (one per point) or a single data frame containing the meta data (columns <code>dir</code> and <code>filename</code>) of meteorological files that will be read from the disk.
projection_data	Projected meteorological data to be corrected. A vector of data frames (one per point) or a single data frame containing the meta data (columns <code>dir</code> and <code>filename</code>) of meteorological files that will be read from the disk.
dates	Object of class "Date" describing the time period for which meteorological correction is possible (corresponding to <code>projection_data</code>).
params	A "list" containing correction parameters.

Details

See correction details in vignettes or in [correctionpoints](#).

Value

An object of class [MeteorologyUncorrectedData](#).

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[MeteorologyUncorrectedData](#), [examplecorrectiondata](#), [defaultCorrectionParams](#).

MeteorologyUncorrectedData-class

Class "MeteorologyUncorrectedData"

Description

An S4 class to conduct statistical correction of meteorology over a landscape.

Objects from the Class

Objects can be created by calls of the form `new("MeteorologyUncorrectedData", ...)`, or by calls to the function [MeteorologyUncorrectedData](#).

Slots

- dates:** Object of class "Date" describing the time period for which meteorological estimates are possible.
- bbox:** Object of class "matrix" with the boundary box that sets meteorological estimation boundaries.
- proj4string:** Object of class "CRS" with the projection string of station spatial coordinates.
- coords:** Object of class "matrix" containing the coordinates of weather stations (each row is a point).
- reference_data:** Reference (historic) meteorological data used to calibrate correction factors when compared with observations. A vector of data frames (one per point) or a single data frame containing the meta data (columns dir and filename) of meteorological files that will be read from the disk.
- projection_data:** Projection meteorological data to be corrected. A vector of data frames (one per point) or a single data frame containing the meta data (columns dir and filename) of meteorological files that will be read from the disk.
- params:** A "list" containing correction parameters.

Extends

Class "[MeteorologyProcedureData](#)", directly. Class "[Spatial](#)", by class "MeteorologyProcedureData", distance 2

Methods

subsample signature(object = "MeteorologyUncorrectedData"): Generates a [MeteorologyUncorrectedData](#) object for a smaller area and a subset of dates.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[MeteorologyUncorrectedData](#), [MeteorologyProcedureData-class](#), [examplecorrectiondata](#), [subsample](#)

Examples

```
#Structure of the S4 object
showClass("MeteorologyUncorrectedData")
```

NetCDFutils

Utility functions for NetCDFs

Description

Functions to read spatial and temporal coordinates from NetCDFs.

Usage

```
readNetCDFdates(file)
readNetCDFpoints(file)
readNetCDFgridtopology(file)
readNetCDFproj4string(file)
```

Arguments

file String of the NetCDF whose spatial/temporal coordinates are desired.

Value

- Function `readNetCDFdates` returns a [Date](#) vector.
- Function `readNetCDFpoints` returns an object [SpatialPoints-class](#).
- Function `readNetCDFgridtopology` returns an object [GridTopology-class](#).
- Function `readNetCDFproj4string` returns an object [CRS-class](#).

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[readmeteorologypoints](#), [readmeteorologygrid](#)

penman

Potential evapotranspiration

Description

Functions to calculate potential evapotranspiration using Penman or Penman-Monteith.

Usage

```
penman(latrad, elevation, slorad, asprad, J,
       Tmin, Tmax, RHmin, RHmax, R_s, u,
       z=2.0, z0 = 0.001, alpha = 0.08, windfun="1956")
penmanmonteith(rc, elevation, Tmin, Tmax, RHmin, RHmax,
              Rn, u = NA)
```


Arguments

latrad	Latitude in radians.
elevation	Elevation (in m).
slorad	Slope (in radians).
asprad	Aspect (in radians from North).
J	Julian day, number of days since January 1, 4713 BCE at noon UTC.
Tmax	Maximum temperature (degrees Celsius).
Tmin	Minimum temperature (degrees Celsius).
RHmin	Minimum relative humidity (percent).
RHmax	Maximum relative humidity (percent).
R_s	Solar radiation (MJ/m ²).
u	With wind speed (m/s).
z	Wind measuring height (m).
z0	Roughness height (m).
alpha	Albedo.
windfun	Wind speed function version, either "1948" or "1956".
rc	Canopy vapour flux (stomatal) resistance (s·m ⁻¹).
Rn	Daily net radiation (MJ·m ⁻² ·day ⁻¹).

Details

The code was adapted from package 'Evapotranspiration', which follows McMahon et al. (2013). If wind speed is not available, an alternative formulation for potential evapotranspiration is used as an approximation (Valiantzas 2006)

Value

Potential evapotranspiration (in mm of water).

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

References

- Penman, H. L. 1948. Natural evaporation from open water, bare soil and grass. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences, 193, 120-145.
- Penman, H. L. 1956. Evaporation: An introductory survey. Netherlands Journal of Agricultural Science, 4, 9-29.
- McMahon, T.A., Peel, M.C., Lowe, L., Srikanthan, R., McVicar, T.R. 2013. Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis. Hydrology & Earth System Sciences 17, 1331–1363. doi:10.5194/hess-17-1331-2013.

See Also

[interpolationpoints](#)

precipitation

Precipitation utils

Description

Function `precipitation_concentration()` calculates daily precipitation concentration (Martin-Vide et al. 2004). Function `precipitation_rainfallErosivity()` calculates a multi-year average of monthly rainfall erosivity using the MedREM model proposed by Diodato and Bellochi (2010) for the Mediterranean area (see also Guerra et al. 2016).

Usage

```
precipitation_concentration(p)
precipitation_rainfallErosivity(x, long, scale = "month", average = TRUE)
```

Arguments

<code>p</code>	A numeric vector with daily precipitation values.
<code>x</code>	A data frame of meteorological variables (dates as row names and variables as columns).
<code>long</code>	Longitude in degrees.
<code>scale</code>	Either 'month' or 'year'.
<code>average</code>	Boolean flag to calculate multi-year averages before applying MedREM's formula.

Details

MedREM model is: $R_m = b_0 \cdot P \cdot \sqrt{d} \cdot (\alpha + b_1 \cdot \text{longitude})$, where P is cumulated precipitation and d is maximum daily precipitation. Parameters used for the MedREM model are $b_0 = 0.117$, $b_1 = -0.015$, $\alpha = 2$. Note that there is a mistake in Guerra et al. (2016) regarding parameters b_1 and α .

Value

Function `precipitation_concentration()` returns a value between 0 (equal distribution of rainfall) and 1 (one day concentrates all rainfall). Function `precipitation_rainfallErosivity()` returns a vector of twelve values (one for each month) (in $\text{MJ} \cdot \text{mm} \cdot \text{ha}^{-1} \cdot \text{h}^{-1} \cdot \text{month}^{-1}$) or one value (in $\text{MJ} \cdot \text{mm} \cdot \text{ha}^{-1} \cdot \text{h}^{-1} \cdot \text{yr}^{-1}$) depending on the scale.

Author(s)

Miquel De Cáceres Ainsa, CTFC.

References

- Diodato, N., Bellocchi, G., 2010. MedREM, a rainfall erosivity model for the Mediterranean region. *J. Hydrol.* 387, 119–127, doi:10.1016/j.jhydrol.2010.04.003.
- Guerra CA, Maes J, Geijzendorffer I, Metzger MJ (2016) An assessment of soil erosion prevention by vegetation in Mediterranean Europe: Current trends of ecosystem service provision. *Ecol Indic* 60:213–222. doi: 10.1016/j.ecolind.2015.06.043.
- Martin-Vide J (2004) Spatial distribution of a daily precipitation concentration index in peninsular Spain. *International Journal of Climatology* 24, 959–971. doi:10.1002/joc.1030.

radiation

Solar radiation utility functions

Description

Set of functions used in the calculation of incoming solar radiation and net radiation.

Usage

```
radiation_dateStringToJulianDays(dateStrings)
radiation_daylength(latrad, slorad, asprad, delta)
radiation_daylengthseconds(latrad, slorad, asprad, delta)
radiation_directDiffuseInstant(solarConstant, latrad, slorad, asprad, delta,
                               hrad, R_s, clearday)
radiation_directDiffuseDay(solarConstant, latrad, slorad, asprad, delta,
                           R_s, clearday, nsteps = 24)
radiation_potentialRadiation(solarConstant, latrad, slorad, asprad, delta)
radiation_julianDay(year, month, day)
radiation_skyLongwaveRadiation(Tair, vpa, c)
radiation_outgoingLongwaveRadiation(solarConstant, latrad, elevation, slorad,
                                     asprad, delta, vpa, tmin, tmax, R_s)
radiation_netRadiation(solarConstant, latrad, elevation, slorad, asprad, delta,
                       vpa, tmin, tmax, R_s, alpha = 0.08)
radiation_solarConstant(J)
radiation_solarDeclination(J)
radiation_solarElevation(latrad, delta, hrad)
radiation_solarRadiation(solarConstant, latrad, elevation, slorad, asprad, delta,
                          diffTemp, diffTempMonth, vpa, precipitation)
radiation_sunRiseSet(latrad, slorad, asprad, delta)
```

Arguments

dateStrings	A character vector with dates in format "YYYY-MM-DD".
latrad	Latitude (in radians North).
slorad	Slope (in radians).
asprad	Aspect (in radians from North).

delta	Solar declination (in radians).
solarConstant	Solar constant (in kW·m ⁻²).
hrad	Solar hour (in radians).
R_s	Daily incident solar radiation (MJ·m ⁻²).
clearDay	Boolean flag to indicate a clearsky day (vs. overcast).
nsteps	Number of daily substeps.
J	Julian day (integer), number of days since January 1, 4713 BCE at noon UTC.
year, month, day	Year, month and day as integers.
alpha	Surface albedo (from 0 to 1).
Tair	Air temperature (in degrees Celsius).
vpa	Average daily vapor pressure (kPa).
c	Proportion of sky covered by clouds [0-1].
tmin, tmax	Minimum and maximum daily temperature (°C).
elevation	Elevation above sea level (in m).
precipitation	Precipitation (in mm).
diffTemp	Difference between maximum and minimum temperature (°C).
diffTempMonth	Difference between maximum and minimum temperature, averaged over 30 days (°C).

Value

Values returned for each function are:

- `radiation_dateStringToJulianDays`: A vector of Julian days (i.e. number of days since January 1, 4713 BCE at noon UTC).
- `radiation_daylength`: Day length (in hours).
- `radiation_daylengthseconds`: Day length (in seconds).
- `radiation_directDiffuseInstant`: A vector with instantaneous direct and diffusive radiation rates (for both SWR and PAR).
- `radiation_directDiffuseDay`: A data frame with instantaneous direct and diffusive radiation rates (for both SWR and PAR) for each subdaily time step.
- `radiation_potentialRadiation`: Daily (potential) solar radiation (in MJ·m⁻²).
- `radiation_julianDay`: Number of days since January 1, 4713 BCE at noon UTC.
- `radiation_skyLongwaveRadiation`: Instantaneous incoming (sky) longwave radiation (W·m⁻²).
- `radiation_outgoingLongwaveRadiation`: Daily outgoing longwave radiation (MJ·m⁻²·day⁻¹).
- `radiation_netRadiation`: Daily net solar radiation (MJ·m⁻²·day⁻¹).
- `radiation_solarConstant`: Solar constant (in kW·m⁻²).
- `radiation_solarDeclination`: Solar declination (in radians).

- radiation_solarElevation: Angle of elevation of the sun with respect to the horizon (in radians).
- radiation_solarRadiation: Daily incident solar radiation (MJ-m-2-day-1).
- radiation_sunRiseSet: Sunrise and sunset hours in hour angle (radians).

Note

Code for radiation_julianDay(), radiation_solarConstant() and radiation_solarDeclination() was translated to C++ from R code in package 'insol' (by J. G. Corripio).

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnologic Forestal de Catalunya

References

Danby, J. M. Eqn. 6.16.4 in Fundamentals of Celestial Mechanics, 2nd ed. Richmond, VA: Willmann-Bell, p. 207, 1988.

Garnier, B.J., Ohmura, A., 1968. A method of calculating the direct shortwave radiation income of slopes. J. Appl. Meteorol. 7: 796-800

McMahon, T. A., M. C. Peel, L. Lowe, R. Srikanthan, and T. R. McVicar. 2013. Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis. Hydrology & Earth System Sciences 17:1331–1363. See also: <http://www.fao.org/docrep/x0490e/x0490e06.htm>.

Reda, I. and Andreas, A. 2003. Solar Position Algorithm for Solar Radiation Applications. 55 pp.; NREL Report No. TP-560-34302, Revised January 2008. <http://www.nrel.gov/docs/fy08osti/34302.pdf>

Spitters, C.J.T., Toussaint, H.A.J.M. and Goudriaan, J. (1986). Separating the diffuse and direct components of global radiation and its implications for modeling canopy photosynthesis. I. Components of incoming radiation. Agricultural and Forest Meteorology, 38, 231–242.

See Also

[interpolationpoints](#)

readmeteorologygrid *Reads gridded meteorology from the disk*

Description

Functions to read gridded meteorological data from the disk.

Usage

```
readmeteorologygrid(files, format = "netCDF", varmapping = NULL,
                    dates = NULL, bbox = NULL, offset = 0, verbose = FALSE)
readmeteorologypixels(files, format = "netCDF", varmapping = NULL,
                      dates = NULL, bbox = NULL, offset = 0, verbose = FALSE)
readmeteorologygridpoints(files, format = "netCDF", varmapping = NULL,
                          dates = NULL, bbox = NULL, offset = 0,
                          relativehumidity = FALSE, verbose = FALSE)
```

Arguments

files	Character vector with the file names to be read.
format	Format of meteorological data. Currently, the only accepted format is "netCDF".
varmapping	Named character vector specifying a mapping of variables in the NetCDF into variables used in meteoland (e.g. c(MinTemperature = "tmn") specifies a map of variable 'tmn' to MinTemperature).
dates	A character or Date vector to specify subset of dates to be read.
bbox	Boundary box (2 x 2 matrix) specifying the minimum and maximum coordinates of a study area.
offset	A buffer to include NetCDF cells that are at a certain distance around the boundary box.
relativehumidity	A logical flag to indicate estimation of relative humidity from specific humidity if possible.
verbose	A logical flag to output process information in the console.

Details

Function `readmeteorologygrid` reads one or several files containing the meteorology over a grid for a set of days. Function `readmeteorologypixels` reads one or several file containing the meteorology over a grid for a set of days and filters those pixels with missing data. If more than one file is specified, the functions read all of them and then try to merge the data into a single meteorology object (see function [mergegrids](#)).

Function `readmeteorologygridpoints` is similar to the preceding ones, but is meant to extract specific grid pixels and return them as spatial points. If more than one file is specified, the function reads all of them and then tries to merge the data into a single meteorology object (see function [mergepoints](#)).

The functions are primarily meant to read NetCDF written by package `meteoland`, but also to import data written by other software. In this case, a mapping can be supplied to map variable names in the netCDF to variables used in `meteoland`. Rotated grids should not be read using functions `readmeteorologygrid` or `readmeteorologypixels`.

Value

- Function `readmeteorologygrid` returns an object [SpatialGridMeteorology-class](#).
- Function `readmeteorologypixels` returns an object [SpatialPixelsMeteorology-class](#).
- Function `readmeteorologygridpoints` returns an object [SpatialPointsMeteorology-class](#).

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[writemeteorologygrid](#), [writemeteorologypixels](#), [SpatialPointsMeteorology-class](#), [SpatialGridMeteorology-class](#), [SpatialPixelsMeteorology-class](#), [mergegrids](#), [mergepoints](#)

readmeteorologypoint *Reads point meteorology from the disk*

Description

Functions to read point meteorological data from the disks in different formats.

Usage

```
readmeteorologypoint(file, dates = NULL, format = "meteoland/txt", sep="\t")
readmeteorologypointfiles(points, files=NULL, dates = NULL, format="meteoland/txt",
                           sep="\t")
readmeteorologypoints(files, dates = NULL, stations = NULL, format = "netCDF",
                      varmapping = NULL, verbose = FALSE)
```

Arguments

file	A string of the file to be read.
points	An object of class SpatialPoints-class (in this case files cannot be NULL) or object of class SpatialPointsDataFrame-class with two data columns: 'dir' and 'filename' (and possibly 'format').
files	A vector of strings to be read (when points is of class SpatialPoints-class). Length and order must match points.
dates	Object of class "Date" describing a subset of dates to be extracted from meteorological series. If NULL the whole period read from files is kept.
format	Format of meteorological data. Current accepted formats for readmeteorologypoint and readmeteorologypointfiles are "meteoland/txt", "meteoland/rds", "castanea/txt" and "castanea/rds". The only accepted format for readmeteorologypoints is "netCDF".
sep	The field separator character for ascii text files (see read.table).
stations	An integer vector or string vector identifying point indices or station names in the netCDF.
varmapping	Named character vector specifying a mapping of variables in the NetCDF into variables used in meteoland (e.g. c(MinTemperature = "tmn") specifies a map of variable 'tmn' to MinTemperature).
verbose	A logical flag to output process information in the console.

Details

Function `readmeteorologypoint` reads data series of a single location from an ascii or rds file and returns a data frame. Function `readmeteorologypointfiles` can be used to read multiple ascii/rds files and build an object of [SpatialPointsMeteorology-class](#). This is done by supplying an `points` object of class `SpatialPointsDataFrame-class` with point meta data. In `readmeteorologypointfiles` the value of `format` is used as default but can be overloaded if `points` includes a column `'format'`.

Function `readmeteorologypoints` is used to read multiple point data from a netCDF. In this case, a mapping can be supplied to map variable names in the netCDF to variables used in `meteoland`.

Author(s)

Miquel De Cáceres Ainsa, CTFC

Nicolas Martin, INRA-Avignon

See Also

[writemeteorologypoint](#), [read.table](#), [SpatialPointsMeteorology-class](#)

`readWindNinjaWindFields`

Reads WindNinja results

Description

Reads the wind fields generated by 'WindNinja' (<http://www.firelab.org/project/windninja>) for combinations of domain-level wind speed and wind direction classes.

Usage

```
readWindNinjaWindFields(filebase, resolution = "100m",
                        directionClasses = c(0, 45, 90, 135, 180, 225, 270, 315),
                        speedClasses = c(5, 15, 25), proj4string = CRS(as.character(NA)))
```

Arguments

<code>filebase</code>	A string to indicate the template for accessing WindNinja files. Resolution, wind directions and wind speed class values are appended to this string to obtain the filename to read.
<code>resolution</code>	Resolution string.
<code>directionClasses</code>	A vector of wind speed directions (in degrees).
<code>speedClasses</code>	A vector of wind class values (in m/s).
<code>proj4string</code>	Object of class "CRS" with the projection string of wind field rasters.

Value

A list with the following items:

- `directionClasses`: The vector of wind direction classes.
- `speedClasses`: The vector of wind speed classes.
- `indexTable`: A numeric matrix indicating the raster index of each combination of domain-level wind directions and wind speed classes.
- `windSpeed`: An object of class `SpatialGridDataFrame` containing wind speed rasters (in m/s) for each combination of domain-level wind direction and wind speed.
- `windDirection`: An object of class `SpatialGridDataFrame` containing wind direction rasters (in degrees from North) for each combination of domain-level wind direction and wind speed.

Note

WindNinja should be run with m/s as wind speed units and for all the combinations of domain-level wind speed and wind direction required.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

References

Forthofer, J.M., Butler, B.W., Wagenbrenner, N.S., 2014. A comparison of three approaches for simulating fine-scale surface winds in support of wildland fire management. Part I. Model formulation and comparison against measurements. *Int. J. Wildl. Fire* 23, 969–981.

See Also

[MeteorologyInterpolationData](#)

Examples

```
## TO BE DONE ##
```

reshapeworldmet

Reshapes data from 'worldmet' or 'weathercan'

Description

Reshapes weather station data acquired using the 'worldmet' or 'weathercan' R packages into formats useful for meteoland

Usage

```

reshapeworldmet(hourly_data, output = "SpatialPointsMeteorology",
                 proj4string = NULL, complete = TRUE,
                 verbose = TRUE)
reshapeweathercan(hourly_data, daily_data = NULL, output = "SpatialPointsMeteorology",
                  proj4string = NULL, complete = TRUE, verbose = TRUE)

```

Arguments

hourly_data	Hourly weather data. In the case of <code>reshapeworldmet</code> , a tibble or data frame returned by function <code>'importNOAA'</code> . In the case of <code>reshapeweathercan</code> , a tibble or data frame returned by function <code>'weather_dl'</code> with <code>'interval="hour"</code> .
daily_data	Daily weather data (only for <code>reshapeweathercan</code>), a tibble or data frame returned by function <code>'weather_dl'</code> with <code>'interval="day"</code> .
output	Kind of output desired. Either <code>'SpatialPointsTopography'</code> , <code>'SpatialPointsMeteorology'</code> or <code>'MeteorologyInterpolationData'</code> .
proj4string	A string or CRS to change the coordinate reference system of the output. If NULL the spatial reference will be geographic coordinates (i.e. <code>CRS("+proj=longlat")</code>). When reshaping to <code>MeteorologyInterpolationData</code> it is recommended to use a reference system with meters in units, such as UTM.
complete	A flag to indicate that missing variables should be completed using function meteocomplete
verbose	A flag to show information of the reshape process in the console output.

Details

Note that to have precipitation included in downloads from `'worldmet'` you should set `'precip = TRUE'` when calling function `'importNOAA'`. In the case of `weathercan`, precipitation is only provided for daily data (i.e. setting `'interval="day"` when calling `'weather_dl'`), whereas wind speed and relative humidity are only available for hourly data (i.e., setting `'interval="hour"` when calling `'weather_dl'`). Hence, in `meteoland` we recommend downloading both daily and hourly data and then calling function `reshapeweathercan` to merge the two sources.

Value

An object of the class indicated in output.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[meteocomplete](#)

SMC download	<i>Download data from SMC</i>
--------------	-------------------------------

Description

Download data from the Catalan automatic weather station network (XEMA from Servei Meteorològic de Catalunya)

Usage

```
downloadSMCvarmetadata(api, type = "current")
downloadSMCstationlist(api, date = NULL)
downloadSMCcurrentday(api, daily_meteoland = TRUE, variable_code=NULL,
                      station_id=NULL, date = Sys.Date(), verbose=TRUE)
downloadSMChistorical(api, dates, station_id=NULL, variable_code=NULL, export = FALSE,
                     exportDir = getwd(), exportFormat = "meteoland/txt",
                     metadataFile = "MP.txt", verbose=TRUE)
```

Arguments

api	String with the SMC API key (the procedure to apply for an api key is explained in https://apidocs.meteocat.gencat.cat/).
type	Either 'current' or 'historical' for current day variable metadata or historical variable metadata, respectively.
daily_meteoland	When daily_meteoland = TRUE all the usual variables in meteoland are downloaded and aggregated at the daily scale. When daily_meteoland = FALSE, the user can choose the desired variables using variable_code.
variable_code	A character vector with variable codes to be queried. If NULL in downloadSMChistorical all the usual variables for meteoland are downloaded. Otherwise, the results are returned as a data frame.
dates	An object of class <code>Date</code> with dates comprised within the last two years.
date	An object of class <code>Date</code> . By default the current day in the case of downloadSMCcurrentday(). In the case of downloadSMCstationlist() a date for which operational stations are queried.
station_id	A string vector containing station ids (the list of stations for which climatic series are available is given by downloadSMCstationlist()). If NULL, all available stations are queried. Otherwise, only the data corresponding to the specified stations will be returned.
export	If export = FALSE the downloaded data is stored in memory. Otherwise the result is written on the disk (using the format specified in exportFormat).
exportDir	Output directory for downloaded meteorology.
exportFormat	Format of meteorological data. Current accepted formats are "castanea" and "meteoland".
metadataFile	The name of the file that will store the meta data describing all written files.
verbose	Boolean flag to print process information.

Details

API key needs to be requested from SMC (<https://apidocs.meteocat.gencat.cat/>).

Value

Function `downloadSMCstationlist` returns a [SpatialPointsDataFrame-class](#) object containing the list of SMC operational weather stations for the date given.

Function `downloadSMCvarmetadata` returns a data frame with weather variables, their units and acronym to be used in queries (see parameter `variable_code`).

Function `downloadSMCcurrentday` downloads recent weather (the last 24h or the weather for a given date) from all currently available stations and returns data frame if `daily_meteoland = FALSE` or a [SpatialPointsDataFrame-class](#) object with observations aggregated at the daily scale otherwise.

Function `downloadSMChistorical` downloads historical daily weather corresponding to a given time period from a set (or all currently available) stations. Results are returned (or exported) after formatting data as a [SpatialPointsMeteorology-class](#) if `variable_code = NULL`, or as a data frame otherwise.

Author(s)

Antoine Cabon, CTFC

Miquel De Cáceres Ainsa, CTFC

References

Servei Meteorològic de Catalunya (SMC) should be acknowledged as author of information when accessing weather data with these functions.

See Also

[SpatialPointsMeteorology-class](#)

SpatialGridMeteorology

Creates a 'SpatialGridMeteorology'

Description

Initializes an object of class `SpatialGridMeteorology-class`

Usage

```
SpatialGridMeteorology(grid, proj4string=CRS(as.character(NA)), data, dates)
```

Arguments

grid	An object of class GridTopology-class
proj4string	Object of class "CRS" with the projection string.
data	A vector of data frames (one per date).
dates	Object of class "Date" describing the time period of meteorological estimates.

Value

An object of class [SpatialGridMeteorology-class](#)

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnològic Forestal de Catalunya

See Also

[SpatialGridMeteorology-class](#)

SpatialGridMeteorology-class

Class "SpatialGridMeteorology"

Description

An S4 class that represents a spatial grid with meteorology daily data.

Objects from the Class

Objects can be created by calls of the form `new("SpatialGridMeteorology", ...)`, or by calls to the function [SpatialGridMeteorology](#).

Slots

dates: Object of class "Date" describing the time period for which meteorological estimates are available.

data: A vector of "data.frame" objects, each one containing the grid data for one date.

bbox: Object of class "matrix" with the boundary box.

proj4string: Object of class "CRS" with the projection string.

Extends

Class "[SpatialGrid](#)", directly. Class "[Spatial](#)", by class "SpatialGrid", distance 2.

Methods

[signature(x = "SpatialGridMeteorology", i = "ANY", j = "ANY", drop = "ANY"): subsets the grid and associated meteorology; only rows (x values) and columns (y values) can be subsetted.

coerce signature(x = "SpatialGridMeteorology", to = "STFDF"): coerces into a spacetime STFDF object.

coerce signature(x = "SpatialGridMeteorology", to = "stars"): coerces into a stars object.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[SpatialGridTopography](#), [SpatialGridDataFrame-class](#)

Examples

```
#Structure of the S4 object
showClass("SpatialGridMeteorology")
```

SpatialGridTopography *Creates a 'SpatialGridTopography'*

Description

Function SpatialGridTopography creates an object of class [SpatialGridTopography-class](#) containing topographic variables over a landscape.

Usage

```
SpatialGridTopography(grid, elevation, slope = NULL, aspect = NULL,
  proj4string = CRS(as.character(NA)))
```

Arguments

grid	An object of class GridTopology-class or SpatialGrid-class .
elevation	A vector of elevation values for all cells of the grid (in m.a.s.l.).
slope	A vector of slope angles for all cells of the grid (in degrees). If slope=NULL, slope is calculated as indicated in details.
aspect	A vector of aspect angles for all cells of the grid (in degrees from North clockwise). aspect=NULL, aspect values are calculated as indicated in details.
proj4string	An object of class CRS-class .

Details

Slope and aspect calculations were adapted from functions in package 'SDMTools', which used the approach described in Burrough & McDonell (1998).

The rate of change (delta) of the surface in the horizontal (dz/dx) and vertical (dz/dy) directions from the center cell determines the slope and aspect. The values of the center cell and its eight neighbors determine the horizontal and vertical deltas. The neighbors are identified as letters from 'a' to 'i', with 'e' representing the cell for which the aspect is being calculated. The rate of change in the x direction for cell 'e' is calculated with the algorithm:

$$[dz/dx] = ((c + 2f + i) - (a + 2d + g)) / (8 * x_cell_size)$$

The rate of change in the y direction for cell 'e' is calculated with the following algorithm:

$$[dz/dy] = ((g + 2h + i) - (a + 2b + c)) / (8 * y_cell_size)$$

The algorithm calculates slope as: $rise_run = \sqrt{[dz/dx]^2 + [dz/dy]^2}$.

From this value, one can calculate the slope in degrees or radians as:

$$slope_degrees = ATAN(rise_run) * 57.29578$$

$$slope_radians = ATAN(rise_run)$$

Taking the rate of change in both the x and y direction for cell 'e', aspect is calculated using:

$$aspect = 57.29578 * atan2([dz/dy], -[dz/dx])$$

The aspect value is then converted to compass direction values (0-360 degrees).

Value

Function SpatialGridTopography returns an object '[SpatialGridTopography-class](#)'.

Author(s)

Miquel De Cáceres Ainsa, CTFC

References

Burrough, P. A. and McDonell, R.A., 1998. Principles of Geographical Information Systems (Oxford University Press, New York), p. 190.

See Also

[SpatialGridTopography-class](#)

Examples

```
data(examplegridtopography)

#Display data
splot(examplegridtopography, variable="elevation", scales=list(draw=TRUE))

#Grids can be subsetted
sgt = examplegridtopography[1:50, 1:50]
splot(sgt, variable="elevation", scales=list(draw=TRUE))
```

SpatialGridTopography-class
Class "SpatialGridTopography"

Description

An S4 class that represents topography over a grid of coordinates.

Objects from the Class

Objects can be created by calls of the form `new("SpatialGridTopography", ...)`, or by calls to the function `SpatialGridTopography`.

Slots

`grid`: Object of class `GridTopology`.

`data`: Object of class "data.frame" containing the elevation (in m), slope (in degrees) and aspect (in degrees from North) of every cell.

`bbox`: Object of class "matrix" with the boundary box.

`proj4string`: Object of class "CRS" with the projection string.

Extends

Class "`SpatialGridDataFrame`", directly. Class "`SpatialGrid`", by class "SpatialGridDataFrame", distance 2. Class "`Spatial`", by class "SpatialGridDataFrame", distance 3.

Methods

[`signature(x = "SpatialGridTopography", i = "ANY", j = "ANY", drop = "ANY")`]: subsets the grid and associated topography; only rows (x values) and columns (y values) can be subsetted.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[SpatialGridTopography](#), [SpatialGridDataFrame-class](#)

Examples

```
#Structure of the S4 object
showClass("SpatialGridTopography")
```

SpatialPixelsMeteorology

Creates a 'SpatialPixelsMeteorology'

Description

Initializes an object of class `SpatialPixelsMeteorology-class`

Usage

```
SpatialPixelsMeteorology(points, data, dates,  
                          tolerance = sqrt(.Machine$double.eps),  
                          proj4string = CRS(as.character(NA)), round = NULL,  
                          grid = NULL)
```

Arguments

<code>points</code>	An object of class <code>SpatialPoints-class</code> .
<code>data</code>	A vector of data frames (one per date).
<code>dates</code>	Object of class "Date" describing the time period of meteorological estimates.
<code>tolerance</code>	Precision up to which extent points should be exactly on a grid.
<code>proj4string</code>	Object of class <code>CRS</code> in the first form only used when points does not inherit from <code>Spatial</code> .
<code>round</code>	default <code>NULL</code> , otherwise a value passed to as the <code>digits</code> argument to <code>round</code> for setting cell size.
<code>grid</code>	Grid topology using an object of class <code>GridTopology</code> ; a value of <code>NULL</code> implies that this will be derived from the point coordinates.

Value

An object of class `SpatialPixelsMeteorology-class`

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnologic Forestal de Catalunya

See Also

`SpatialPixelsMeteorology-class`

SpatialPixelsMeteorology-class
Class "SpatialPixelsMeteorology"

Description

An S4 class that represents meteorology data that has locations on a regular grid.

Objects from the Class

Objects can be created by calls of the form `new("SpatialPixelsMeteorology", ...)`, or by calls to the function `SpatialPixelsMeteorology`.

Slots

dates: Object of class "Date" describing the time period for which meteorological estimates are available.

data: A vector of "data.frame" objects, each one containing the pixel data for one date.

grid: Grid parameters (see `GridTopology`).

grid.index: Index of points in full grid.

coords: Object of class "matrix" with the spatial coordinates.

bbox: Object of class "matrix" with the boundary box.

proj4string: Object of class "CRS" with the projection string.

Extends

Class "`SpatialPixels`", directly. Class "`SpatialPoints`", by class "SpatialPixels", distance 2. Class "`Spatial`", by class "SpatialPixels", distance 3.

Methods

[`signature(x = "SpatialPixelsMeteorology", i = "ANY", ..., drop = "ANY")`]: subsets the pixels and associated topography; only one dimension can be subsetted. If `drop = TRUE` the boundary box is recalculated.

coerce `signature(x = "SpatialPixelsMeteorology", to = "STFDF")`: coerces into a spacetime STFDF object.

coerce `signature(x = "SpatialPixelsMeteorology", to = "stars")`: coerces into a stars object.

splot `signature(object = "SpatialPixelsMeteorology")`: allows plotting maps.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[SpatialPixelsTopography](#), [SpatialPixelsDataFrame-class](#)

Examples

```
#Structure of the S4 object
showClass("SpatialPixelsMeteorology")
```

```
SpatialPixelsTopography
  Creates a 'SpatialPixelsTopography'
```

Description

Function `SpatialPixelsTopography` creates an object of class [SpatialPixelsTopography-class](#) containing topographic variables for a set of points.

Usage

```
SpatialPixelsTopography(points, elevation, slope, aspect,
                        tolerance = sqrt(.Machine$double.eps),
                        proj4string = CRS(as.character(NA)), round = NULL,
                        grid = NULL)
```

Arguments

<code>points</code>	An object of class SpatialPoints-class or a numeric matrix of coordinates.
<code>elevation</code>	Elevation values (in m) of the points.
<code>slope</code>	Slope values (in degrees) of the points.
<code>aspect</code>	Aspect values (in degrees from North) of the points.
<code>tolerance</code>	Precision up to which extent points should be exactly on a grid.
<code>proj4string</code>	Object of class CRS in the first form only used when points does not inherit from Spatial .
<code>round</code>	default NULL, otherwise a value passed to as the <code>digits</code> argument to round for setting cell size.
<code>grid</code>	Grid topology using an object of class GridTopology ; a value of NULL implies that this will be derived from the point coordinates.

Value

Function `SpatialPixelsTopography` returns an object `'SpatialPixelsTopography-class'`.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[SpatialPixelsTopography-class](#)

Examples

```
data(examplegridtopography)

#Creates spatial topography pixels as a subset of points in the grid
spt = as(examplegridtopography,"SpatialPointsTopography")
cc = spt@coords
center = 5160
d = sqrt((cc[,1]-cc[center,1])^2+(cc[,2]-cc[center,2])^2)
p = which(d<3000) #Select points at maximum distance of 3km from center
spxt = SpatialPixelsTopography(spt[p], spt$elevation[p],
                              spt$slope[p],
                              spt$aspect[p])

#Alternatively, use coercing and subsetting (drop = TRUE causes grid to be recalculated)
spxt = as(examplegridtopography, "SpatialPixelsTopography")[p, drop=TRUE]

#Display data
splot(spxt, variable="elevation", scales=list(draw=TRUE))
splot(spxt, variable="slope", scales=list(draw=TRUE))
splot(spxt, variable="aspect", scales=list(draw=TRUE))
```

```
SpatialPixelsTopography-class
      Class "SpatialPixelsTopography"
```

Description

An S4 class that represents topography that has locations on a regular grid.

Objects from the Class

Objects can be created by calls of the form `new("SpatialPixelsTopography", ...)`, or by calls to the function [SpatialPixelsTopography](#).

Slots

data: Object of class "data.frame" containing the elevation (in m), slope (in degrees) and aspect (in degrees from North) of every cell.

coords.nrs: Inherited from `SpatialPointsDataFrame` but not used.

grid: Object of class [GridTopology](#).

grid.index: Index of points in full grid.

coords: Object of class "matrix" with the spatial coordinates.

bbox: Object of class "matrix" with the boundary box.

proj4string: Object of class "CRS" with the projection string.

Extends

Class "[SpatialPixelsDataFrame](#)", directly. Class "[SpatialPixels](#)", by class "SpatialPixelsDataFrame", distance 2. Class "[SpatialPointsDataFrame](#)", by class "SpatialPixelsDataFrame", distance 2. Class "[SpatialPoints](#)", by class "SpatialPixelsDataFrame", distance 3. Class "[Spatial](#)", by class "SpatialPixelsDataFrame", distance 4.

Methods

[signature(x = "SpatialGridTopography", i = "ANY", ..., drop = "ANY"): subsets the pixels and associated topography; only one dimension can be subsetted. If drop = TRUE the boundary box is recalculated.

spplot signature(object = "SpatialPixelsTopography"): allows plotting topography maps.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[SpatialPixelsTopography](#), [SpatialPixelsDataFrame-class](#)

Examples

```
#Structure of the S4 object
showClass("SpatialPixelsTopography")
```

SpatialPointsMeteorology

Creates a 'SpatialPointsMeteorology'

Description

Initializes an object of class [SpatialPointsMeteorology-class](#)

Usage

```
SpatialPointsMeteorology(points, data, dates, dataByDate = FALSE)
```

Arguments

points	An object of class SpatialPoints-class . Row names of point coordinates are used to identify points.
data	A list of data frames. If dataByDate = FALSE the elements of data are assumed to correspond to points. If dataByDate = TRUE the elements of data are assumed to correspond to dates (see 'Details').
dates	Object of class "Date" describing the time period of meteorological estimates.

`dataByDate` A flag to indicate that elements of data correspond to dates, as opposed to the default (`dataByDate = FALSE`) which assumes that elements correspond to points (see 'Details').

Details

There are two ways of building an object of of class `SpatialPointsMeteorology-class`. The first way (`dataByDate = FALSE`) is to supply as value for `data` a vector of data frames with one data frame per spatial point, with dates as rows and meteorological variables as columns. In this case all data frames must have the same number of rows (dates) and columns (variables). The second way (if `dataByDate = TRUE`) is to supply as value for `data` a vector of data frames with one data frame per date, with points as rows and meteorological variables as columns. In this case, the data frames may have different rows and different columns. Only the information corresponding to points will be taken and some variables may be missing.

Value

An object of class `SpatialPointsMeteorology-class`

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnologic Forestal de Catalunya

See Also

`SpatialPointsMeteorology-class`

`SpatialPointsMeteorology-class`

Class "SpatialPointsMeteorology"

Description

An S4 class that represents a set of points with meteorology data series.

Objects from the Class

Objects can be created by calls of the form `new("SpatialPointsMeteorology", ...)`, or by calls to the function `SpatialPointsMeteorology`.

Slots

`dates`: Object of class "Date" describing the time period for which meteorological estimates are available.

`data`: A vector of "data.frame" objects, each one corresponding to one spatial point.

`coords`: Object of class "matrix" with the spatial coordinates.

`bbox`: Object of class "matrix" with the boundary box.

`proj4string`: Object of class "CRS" with the projection string.

Extends

Class "[SpatialPoints](#)", directly. Class "[Spatial](#)", by class "SpatialPoints", distance 2.

Methods

[signature(x = "SpatialPointsMeteorology", i = "ANY", j = "ANY", drop = "ANY"): subsets the spatial points and the corresponding list of meteorological data; only rows (points) can be subsetted.

coerce signature(x = "SpatialPointsMeteorology", to = "STFDF"): coerces into a spacetime STFDF object.

coerce signature(x = "SpatialPointsMeteorology", to = "stars"): coerces into a stars object.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[SpatialPointsTopography-class](#), [SpatialPoints-class](#)

Examples

```
#Structure of the S4 object
showClass("SpatialPointsMeteorology")
```

SpatialPointsTopography

Creates a 'SpatialPointsTopography'

Description

Function `SpatialPointsTopography` creates an object of class [SpatialPointsTopography-class](#) containing topographic variables for a set of points.

Usage

```
SpatialPointsTopography(points, elevation, slope = NULL, aspect = NULL,
  proj4string = CRS(as.character(NA)))
```

Arguments

<code>points</code>	An object of class SpatialPoints-class .
<code>elevation</code>	Elevation values (in m) of the points.
<code>slope</code>	Slope values (in degrees) of the points.
<code>aspect</code>	Aspect values (in degrees from North) of the points.
<code>proj4string</code>	Object of class CRS in the first form only used when points does not inherit from Spatial .

Details

If either `slope = NULL` or `aspect = NULL` then when estimating weather on the object locations radiation will be calculated assuming a flat surface.

Value

Function `SpatialPointsTopography` returns an object '`SpatialPointsTopography-class`'.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[SpatialPointsTopography-class](#)

Examples

```
data(examplegridtopography)

#Creates spatial topography points from the grid
p = 1:2
points = as(examplegridtopography, "SpatialPoints")[p]
spt = SpatialPointsTopography(points, examplegridtopography$elevation[p],
                              examplegridtopography$slope[p],
                              examplegridtopography$aspect[p])

spt

#Alternatively, use coercing and subsetting
spt = as(examplegridtopography, "SpatialPointsTopography")[p]
spt
```

```
SpatialPointsTopography-class
  Class "SpatialPointsTopography"
```

Description

An S4 class that represents topography over a grid of coordinates.

Objects from the Class

Objects can be created by calls of the form `new("SpatialPointsTopography", ...)`, or by calls to the function [SpatialPointsTopography](#).

Slots

data: Object of class "data.frame" containing the elevation (in m), slope (in degrees) and aspect (in degrees from North) of every point.

coords: Object of class "matrix" with the spatial coordinates.

bbox: Object of class "matrix" with the boundary box.

proj4string: Object of class "CRS" with the projection string.

Extends

Class "[SpatialPointsDataFrame](#)", directly. Class "[SpatialPoints](#)", by class "SpatialPointsDataFrame", distance 2. Class "[Spatial](#)", by class "SpatialPointsDataFrame", distance 3.

Methods

[signature(x = "SpatialPointsTopography", i = "ANY", j = "ANY", drop = "ANY"): subsets the spatial points and associated topography; only rows (points) can be subsetted.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[SpatialPointsTopography](#), [SpatialPointsDataFrame-class](#)

Examples

```
#Structure of the S4 object
showClass("SpatialPointsTopography")
```

spplot

Spatial grid plots

Description

Function `spplot` for [SpatialGridTopography-class](#) and [SpatialPixelsTopography-class](#) objects allows drawing maps of topographic attributes. Function `spplot` for [SpatialGridMeteorology-class](#) and [SpatialPixelsMeteorology-class](#) objects allows drawing maps of meteorological variables corresponding to specific dates.

Usage

```
## S4 method for signature 'SpatialGridTopography'
spplot(obj, variable="elevation",...)
## S4 method for signature 'SpatialGridMeteorology'
spplot(obj, date, variable="MeanTemperature", ...)
## S4 method for signature 'SpatialPixelsTopography'
spplot(obj, variable="elevation",...)
## S4 method for signature 'SpatialPixelsMeteorology'
spplot(obj, date, variable="MeanTemperature", ...)
```

Arguments

obj	An object of class <code>SpatialGridTopography</code> .
variable	A string of the variable to be plotted (only <code>type="elevation"</code> , <code>type="slope"</code> , <code>type="aspect"</code> are allowed).
...	Additional parameters to function <code>spplot</code> .
date	A string or an integer for the date to be plotted.

Author(s)

Miquel De Cáceres Ainsa, Biodiversity and Landscape Ecology Laboratory, Centre Tecnologic Forestal de Catalunya

See Also

[meteoplot](#)

Examples

```
data(examplegridtopography)

#Display data
spplot(examplegridtopography, type="elevation", scales=list(draw=TRUE))
spplot(examplegridtopography, type="slope", scales=list(draw=TRUE))
spplot(examplegridtopography, type="aspect", scales=list(draw=TRUE))
```

subsample

Sub-sampling procedure data

Description

Generates a spatial and/or temporal subset of procedure data

Usage

```
## S4 method for signature 'MeteorologyUncorrectedData'
subsample(object, bbox = NULL, stations = NULL, dates = NULL, buffer = 0)
## S4 method for signature 'MeteorologyInterpolationData'
subsample(object, bbox = NULL, stations = NULL, dates = NULL, buffer = 0)
```

Arguments

object	An object of a sub-class MeteorologyProcedureData-class .
bbox	A 2x2 numeric matrix with the boundaries of the target area. If NULL, the original boundary box is kept (except if stations is specified).
stations	A numeric, character or logical vector specifying a subset of weather stations. If NULL all original weather stations are kept (except if bbox is specified).
dates	A vector of Date with the subset of dates of interest. If NULL, all dates are kept.
buffer	A buffer to put around bbox for the spatial selection of data.

Value

An object of the same class as object.

Methods

subsample signature(object = "MeteorologyUncorrectedData"): Generates a [MeteorologyUncorrectedData](#) object for a smaller area and a subset of dates.

subsample signature(object = "MeteorologyInterpolationData"): Generates a [MeteorologyInterpolationData](#) object for a smaller area and a subset of dates.

Examples

```
data(exampleinterpolationdata)

oridates = exampleinterpolationdata@dates

#Interpolation data using the first ten dates (same boundary box)
subdata = subsample(exampleinterpolationdata, dates = oridates[1:10])
```

summarypoints

Summaries of meteorological data

Description

Summarizes the meteorology of a single location, a set of spatial points, pixels in a grid, or weather stations of interpolation data.

Usage

```

summarypoint(x, var, fun = mean, freq = NULL, dates = NULL, months = NULL, ...)
summarypoints(points, var, fun = mean, freq = NULL, dates = NULL, months = NULL, ...)
summarygrid(grid, var, fun = mean, freq = NULL, dates = NULL, months = NULL, ...)
summarypixels(pixels, var, fun = mean, freq = NULL, dates = NULL, months = NULL, ...)
summaryinterpolationdata(object, var, fun = mean, freq = NULL, dates = NULL,
                          months = NULL, ...)

```

Arguments

x	A data frame with dates in rows and meteorological variables in columns.
points	An object of class SpatialPointsMeteorology-class with the coordinates and meteorological data of the locations for which summaries are desired. Alternatively, an object of class SpatialPointsDataFrame-class containing the meta data (columns dir, filename and possibly format) of meteorological files that will be sequentially read from the disk. Finally, points can also be a string pointing to a netCDF.
var	The name of the meteorological variable to be summarized.
fun	The function to be calculated on values of each point. If freq is specified, the function will be calculated by intervals.
freq	A string giving an interval specification (e.g., "week", "month", "quarter" or "year"). If NULL then no intervals are defined.
dates	An object of class Date to define the period to be summarized. If dates = NULL then all dates in points are processed.
months	A numeric vector to indicate the subset of months for which summary is desired (e.g. c(7, 8) for July and August). This parameter allows studying particular seasons, when combined with freq. For example freq = "years" and months = 6:8 leads to summarizing summer months of each year.
...	Additional parameters to fun.
grid	An object of class SpatialGridMeteorology-class with the meteorological data for a grid, or a string pointing to a NetCDF.
pixels	An object of class SpatialPixelsMeteorology-class with the meteorological data for grid pixels, or a string pointing to a NetCDF.
object	An object of class MeteorologyInterpolationData-class .

Details

If var="ALL" then function summarypoints produces a summary of all variables with default statistics and returns an object of class [SpatialPointsMeteorology](#).

Value

- Function summarypoint returns a named vector of values with dates as names.
- Functions summarypoints and summaryinterpolationdata return an object of class [SpatialPointsDataFrame](#) containing summaries (either one variable or several if freq is specified).
- Functions summarygrid and summarypixels return an object of class [SpatialGridDataFrame](#) and [SpatialPixelsDataFrame](#), respectively, containing the summaries analogously to summarypoints.

Author(s)

Miquel De Cáceres Ainsa, CTFC

Antoine Cabon, CTFC

See Also

[SpatialPointsMeteorology-class](#)

Examples

```
data(examplegridtopography)
data(exampleinterpolationdata)

#Creates spatial topography points from the grid
p = 1:2
spt = as(examplegridtopography, "SpatialPointsTopography")[p]

#Interpolation of two points for the whole time period (2000-2003)
mp = interpolationpoints(exampleinterpolationdata, spt)

#PET sums by months
mp.sum = summarypoints(mp, var="PET", freq="months", fun=sum)

mp.sum
```

utils

Physical utility functions

Description

Set of functions used in the calculation of physical variables.

Usage

```
utils_airDensity(temperature, Patm)
utils_atmosphericPressure(elevation)
utils_averageDailyVP(Tmin, Tmax, RHmin, RHmax)
utils_averageDaylightTemperature(Tmin, Tmax)
utils_latentHeatVaporisation(temperature)
utils_latentHeatVaporisationMol(temperature)
utils_psychrometricConstant(temperature, Patm)
utils_saturationVP(temperature)
utils_saturationVaporPressureCurveSlope(temperature)
```

Arguments

temperature	Air temperature (°C).
Tmin, Tmax	Minimum and maximum daily temperature (°C).
RHmin, RHmax	Minimum and maximum relative humidity (%).
Patm	Atmospheric air pressure (in kPa).
elevation	Elevation above sea level (in m).

Value

Values returned for each function are:

- `utils_airDensity`: air density (in kg·m⁻³).
- `utils_atmosphericPressure`: Air atmospheric pressure (in kPa).
- `utils_averageDailyVP`: average (actual) vapour pressure (in kPa).
- `utils_averageDaylightTemperature`: average daylight air temperature (in °C).
- `utils_latentHeatVaporisation`: Latent heat of vaporisation (MJ·kg⁻¹).
- `utils_latentHeatVaporisationMol`: Latent heat of vaporisation (J·mol⁻¹).
- `utils_psychrometricConstant`: Psychrometric constant (kPa·°C⁻¹).
- `utils_saturationVP`: saturation vapour pressure (in kPa).
- `utils_saturationVaporPressureCurveSlope`: Slope of the saturation vapor pressure curve (kPa·°C⁻¹).

Author(s)

Miquel De Cáceres Ainsa, Centre Tecnologic Forestal de Catalunya

References

McMurtrie, R. E., D. A. Rook, and F. M. Kelliher. 1990. Modelling the yield of *Pinus radiata* on a site limited by water and nitrogen. *Forest Ecology and Management* 30:381–413.

McMahon, T. A., M. C. Peel, L. Lowe, R. Srikanthan, and T. R. McVicar. 2013. Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis. *Hydrology & Earth System Sciences* 17:1331–1363. See also: <http://www.fao.org/docrep/x0490e/x0490e06.htm>

weathergeneration	<i>Weather generation</i>
-------------------	---------------------------

Description

A semiparametric multivariate, multisite weather generator. The algorithm can be interpreted as a way to resample the original data to create synthetic data sets of the same length and similar properties.

Usage

```
weathergeneration(object, params = defaultGenerationParams(), verbose=TRUE)
```

Arguments

object	An object of class SpatialPointsMeteorology-class , SpatialGridMeteorology-class or SpatialPixelsMeteorology-class .
params	A list with parameters for the weather generator (see defaultGenerationParams()).
verbose	Boolean flag to print process information.

Details

The implemented algorithm is based on Apipattanavis et al. (2007) for the non-conditional version, and is similar to Steinschneider et al. (2013) for the conditional one. Part of the code was adapted from package 'weathergen' by Jeffrey D. Walker, whom we are grateful. Conditioning is controlled via the element conditional of params list, which can be:

- "none" - The non-conditional version is used, which is based on a first order Markov chain (MC) to simulate weather states (dry/wet/extreme wet) and a K-nearest neighbour (KNN) algorithm to select pairs of days with the same transition and similar weather for the initial state (as in Apipattanavis et al. 2007).
- "arima" - Annual precipitation is conditioned using a stationary auto-regressive (ARIMA) model and then a K-nearest neighbour algorithm is used to select a set of years to train the MC-KNN algorithm (similar to Steinschneider et al. 2013). Recommended if low-frequency variation of annual precipitation is to be accounted for in long series.
- "window" - The MC-KNN algorithm is trained with the subset of the input data corresponding to a window around the target year. Annual precipitation is conditioned using a lognormal random trial of the precipitation corresponding to the selected years. Recommended to generate stochastic series from climate change projections.

Value

An object of the same class as the input object. Generated meteorological series are of the same length as the input.

Author(s)

Miquel De Cáceres Ainsa, CTFC

References

Apipattanavis, S., G. Podesta, B. Rajagopalan, and R. W. Katz (2007), A semiparametric multivariate and multisite weather generator, *Water Resour. Res.*, 43, W11401, doi:10.1029/2006WR005714.

Steinschneider S., and Brown C. (2013) A semiparametric multivariate, multisite weather generator with low-frequency variability for use in climate risk assessments. *Water Resour. Res.*, 49, 7205-7220, doi:10.1002/wrcr.20528.

See Also

[defaultGenerationParams](#)

Examples

```
data(examplegridtopography)
data(exampleinterpolationdata)

#Creates spatial topography points from the grid
p = 1:2
spt = as(examplegridtopography, "SpatialPointsTopography")[p]

#Interpolation of two points for the whole time period (2000-2003)
mp = interpolationpoints(exampleinterpolationdata, spt)

#Plot interpolated meteorological series
meteoplot(mp,1, ylab="Mean temperature")

#Generate a stochastic series using interpolated data as template
y = weathergeneration(mp)

#Plot generated meteorological series
meteoplot(y,1, ylab="Mean temperature")
```

writemeteorologygrid *Writes grid meteorology to the disk*

Description

Functions to write grid meteorological data to the file system.

Usage

```
writemeteorologygrid(object, file, dates = NULL, format = "netCDF",
  byPixel = FALSE, chunksizes = NA, add = FALSE, overwrite = FALSE,
  verbose = FALSE)
writeemptymeteorologygrid(file, grid, proj4string, dates,
  byPixel = FALSE, chunksizes = NA, overwrite = FALSE,
  verbose = FALSE)
writemeteorologypixels(object, file, dates = NULL, format = "netCDF",
  byPixel = FALSE, chunksizes = NA, add = FALSE, overwrite = FALSE,
  verbose = FALSE)
writemeteorologygridpixel(file, index, data, verbose = FALSE)
```

Arguments

object	An object of class SpatialGridMeteorology-class or class SpatialPixelsMeteorology-class with the meteorological data to be written.
file	A string with the file name to be written.
dates	A Date vector object or a character string indicating the dates to be written.
format	Format of meteorological data. The only accepted format is "netCDF".
byPixel	Boolean flag to specify whether file will be written/read by pixels. This forces a different (supposedly) more efficient chunking based on time series data instead of daily grids.
chunksizes	Specifies the size of data chunks to be read/written. If set, this must be a vector of three integers corresponding to XYT.
add	Boolean flag to indicate that NetCDF exists and data should be added/replaced.
grid	An object of class GridTopology-class
proj4string	Object of class CRS .
overwrite	Boolean flag to force overwriting an existing NetCDF.
verbose	A logical flag to output process information in the console.
index	Integer indicating the grid index position to be written.
data	A data frame with meteorological data corresponding to a pixel.

Details

Functions `writemeteorologygrid` and `writemeteorologypixels` writes grided meteorological data (i.e. class [SpatialGridMeteorology-class](#) or class [SpatialPixelsMeteorology-class](#), respectively) into a netCDF, with the possibility to overwrite existing data. Function `writemeteorologygridpixel` is meant to add/replace data in a netCDF corresponding to a specific pixel identified by its grid index. Function `writemeteorologygrid` creates an empty netCDF with the specified grid dimensions, coordinate reference system and dates.

Author(s)

Miquel De Cáceres Ainsa, CTFC

See Also

[readmeteorologygrid](#), [SpatialGridMeteorology-class](#)

writemeteorologypoint *Writes point meteorology to the disk*

Description

Functions to write point meteorological data to disk files in different formats.

Usage

```
writemeteorologypoint(data, file, format = "meteoland/txt")
writemeteorologypointfiles(object, dir=getwd(), format = "meteoland/txt",
                             metadataFile="MP.txt")
writemeteorologypoints(object, file, format = "netCDF",
                        add = FALSE, overwrite = FALSE, verbose = FALSE)
```

Arguments

data	An data frame with meteorological data.
file	A string with the file name to be written.
format	Output format of meteorological data. Current accepted formats are "meteoland/txt", "meteoland/rds", "castanea/txt" and "castanea/rds".
object	An object of class SpatialPointsMeteorology-class with the meteorological data to be written.
dir	Output directory for meteorology data.
metadataFile	The name of the file that will store the meta data describing all written files.
add	Boolean flag to indicate that NetCDF exists and data should be added/replaced (see details).
overwrite	Boolean flag to force overwriting an existing NetCDF.
verbose	A logical flag to output process information in the console.

Details

Function `writemeteorologypoint` writes data series of a single location (i.e. a data frame) to ascii or rds files. Function `writemeteorologypointfiles` takes an object of [SpatialPointsMeteorology-class](#) and writes one file for each data point in the same formats as `writemeteorologypoint`. In addition, it writes a metadata file (see argument `metadataFile`) with point coordinates, station names and file names. Both functions share the same accepted formats, which are "meteoland/txt", "meteoland/rds", "castanea/txt" and "castanea/rds".

Function `writemeteorologypoints` takes an object of [SpatialPointsMeteorology-class](#) and writes all its content in a single file (i.e. a netCDF). The same function can be used to replace data from an existing file or to add new points to the netCDF. This is done by using `add=TRUE`, and profits from the fact that some netCDF dimensions (in this case the number of points) can be defined as unlimited. If data is added to an existing netCDF, the coordinate reference system and the dates of object must be the same as those in the netCDF.

Author(s)

Miquel De Cáceres Ainsa, CTFC

Nicolas Martin, INRA-Avignon

See Also

[readmeteorologypoint](#), [SpatialPointsMeteorology-class](#)

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