Package ‘sirad’

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Title Functions for Calculating Daily Solar Radiation and Evapotranspiration
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Description Calculating daily global solar radiation at horizontal surface using several well-known models (i.e. Angstrom-Prescott, Supit-Van Kappel, Hargreaves, Bristow and Campbell, and Mahmood-Hubbard), and model calibration based on ground-truth data, and (3) model auto-calibration. The FAO Penmann-Monteith equation to calculate evapotranspiration is also included.
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Description

Calculates daily solar radiation at horizontal surface using several well-known models (Bristow-Campbell, Hargreaves, Supit-Van Kappel, Mahmood-Hubbard, Angstrom-Prescott). It also includes functions for model calibration based on groud-truth data as well as a function for auto-calibration. The FAO Penmann-Monteith equation to calculate evapotranspiration is also included.

Details

- **Package**: sirad
- **Type**: Package
- **Version**: 2.3-3
- **Date**: 2016-10-17
- **License**: GPL-2
- **LazyLoad**: yes
ap

Angstrom-Prescott solar radiation model

Description

Angstrom-Prescott model is used to calculate daily global irradiance for a horizontal surface based on sunshine duration.

Usage

ap(days, lat, lon, extraT=NULL, A=NA, B=NA, SSD)

Arguments

- **days**: Vector of class ‘Date’ of length n.
- **lat**: Latitude in decimal degrees.
- **lon**: Longitude in decimal degrees.
- **extraT**: Optional. Vector of length n of extraterrestrial solar radiation [MJm\(^{-2}\)]. If ‘NULL’ then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
- **A**: Angstrom-Prescott model ‘A’ coefficient. If 'NA' then A is derived from the map of interpolated coefficients estimated from Meteosat solar radiation data. See details.
- **B**: Angstrom-Prescott model ‘B’ coefficient. If 'NA' then B is derived from the map of interpolated coefficients estimated from Meteosat solar radiation data. See details.
- **SSD**: Vector of length n containing sunshine duration [in hours].
Details

Model proposed by Angstrom (1924) and modified by Prescott (1940) assumed linear relationship between: (1) a proportion of bright sunshine hours and astronomical day length and (2) proportion of incoming daily global solar radiation and daily extra-terrestrial radiation. This linear relationship is described by empirical model coefficients: A - intercept, B - slope. Both astronomical day length and daily extra-terrestrial radiation are calculated within this function based on location and time. Model coefficients A and B (if not provided) are derived from interpolated Meteosat-based coefficients from Bojanowski et al. 2013.

Value

Vector of length n of daily solar radiation [MJm-2].

Note

SSD input can contain NA's, but length of vectors 'SSD' and 'days' has to be the identical.

Author(s)

Jedrzej S. Bojanowski

References


See Also

'apcal' to calibrate the model

Examples

```r
require(zoo)
#A <- 0.21
#B <- 0.57
sunshine <- Metadata$meteo$SUNSHINE
days <- Metadata$meteo$DAY
lat <- Metadata$LATITUDE
lon <- Metadata$LONITUDE
plot(zoo(ap(days,lat,lon, extraT=NULL,A=NA,B=NA,sunshine),order.by=days))
```
Calibrate Angstrom-Prescott model

Description
Function estimates Angstrom-Prescott model coefficients 'A' and 'B' based on reference data.

Usage
apcal(lat, days, rad_mea, extraT=NULL, DL=NULL, SSD)

Arguments
- lat: Latitude in decimal degrees.
- days: Vector of class 'Date' of length n.
- rad_mea: Vector of length n containing reference (e.g. measured) solar radiation [MJm-2].
- extraT: Optional. Vector of length n of extraterrestrial solar radiation [MJm-2]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
- DL: Optional. Vector of length n of day length [h]. If 'NULL' then it is calculated by the function. Providing day length speeds up the computation.
- SSD: Vector of length n containing sunshine duration [in hours].

Details
Function estimates Angstrom-Prescott model coefficients 'A' and 'B' based on reference (e.g. measured) solar radiation data. It performs a linear regression in which 'rad_mea' is dependent variable and a proportion of 'SSD' and astronomical day length is an independent variable.

Value
Vector containing:
- APA: Angstrom-Prescott 'A' coefficient
- APB: Angstrom-Prescott 'B' coefficient
- APR2: Coefficient of determination of performed linear regression

Author(s)
Jedrzej S. Bojanowski

References
See Also 'ap' to use Angstrom-Prescott model

Examples

```r
## Calibrate the model based on measured data
data(Metadata)
sunshine <- Metadata$meteo$SUNSHINE
days <- Metadata$meteo$DAY
lat <- Metadata$LATITUDE
rad_mea <- Metadata$meteo$RAD_MEA
apcal(lat=lat,days=days,rad_mea,extraT=NULL,DL=NULL,SSD=sunshine)
```

bc \textit{Bristow-Campbell model}

Description

'bc' calculates daily solar radiation based on daily temperature range using Bristow-Campbell model.

Usage

```r
bc(days, lat, BCb, extraT=NULL, Tmax, Tmin, BCc = 2, tal)
```

Arguments

- **days**: Vector of class 'Date' of length n.
- **lat**: Latitude in decimal degrees.
- **BCb**: Bristow-Campbell model coefficient 'B'.
- **extraT**: Optional. Vector of length n of extraterrestrial solar radiation [MJm^{-2}]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
- **Tmax**: Vector of length n containing daily maximum temperature [C].
- **Tmin**: Vector of length n containing daily minimum temperature [C].
- **BCc**: Bristow-Campbell model coefficient 'C' usually equaled to 2.
- **tal**: Clear sky transmissivity.

Details

Bristow and Campbell proposed a method for estimating solar radiation from air temperature measurements. They developed an empirical relationship to express the daily total atmospheric transmittance as a function of daily range in air temperature.
Value

Vector of length n of daily solar radiation [MJm⁻²].

Note

'Tmax', 'Tmin' can contain NA's, but length of vectors 'Tmax', 'Tmin' and 'days' has to be the same.

Author(s)

Jedrzej S. Bojanowski

References


See Also

'bccal' to calibrate model using reference data, 'bcauto' to perform auto-calibration, and 'ha' to use Hargreaves model to calculate solar radiation based on temperature range.

Examples

```r
require(zoo)
data(Metdata)
B <- 0.11
tmax <- Metdata$meteo$TEMP_MAX
tmin <- Metdata$meteo$TEMP_MIN
days <- Metdata$meteo$DAY
lat <- Metdata$LATITUDE
plot(zoo(bc(days, lat, BCb=B, extraT=NULL, tmax, tmin, Bcc=2, tal=0.76),order.by=days))
```

bcauto

Auto-calibrate Bristow-Campbell model

Description

Function estimates Bristow-Campbell model coefficient 'B' based on auto-calibration procedure

Usage

```r
bcauto(lat, lon, days, extraT=NULL, Tmax, Tmin, tal, BCC=2, 
BCb_guess=0.13, epsilon=0.5, perce=NA, dcoast=NA)
```
Arguments

`lat` Latitude in decimal degrees.

`lon` Longitude in decimal degrees.

`days` Vector of class ‘Date’ of length n.

`extrat` Optional. Vector of length n of extraterrestrial solar radiation [MJm-2]. If ‘NULL’ then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.

`tmax` Vector of length n containing daily maximum temperature [C].

`tmin` Vector of length n containing daily minumum temperature [C].

`tal` Clear sky transmissivity.

`BCC` Bristow-Campbell model coefficient ‘C’ usually equaled to 2.

`Bcb_guess` Assumption of Bristow-Campbell coefficient. Default set to 0.13.

`epsilon` A value of which potential radiation is decreased. See “details”.

`perce` Percent of clear days. In ‘NA’ then perce is estimated based on the Cloud Fraction Cover map.

`dcoast` Distance to the coast [km].

Details

The auto-calibration method bases on the assumption that on the clear-sky days model should not overpredict potential values. To define those clear-sky days, we estimate daily solar radiation using Bristow and Campbell model with default values of B = 0.13 and tal = 0.72 and we select those days for which estimated daily solar radiation is the closest to the potential values (extraterrestrial*tal). The number of clear-sky days is estimated based on the mean Cloud Fraction Cover map. Next, based on selected clear-sky days, we perform a non-linear least squares regression to derive B coefficient treating potential values decreased by ‘epsilon’ as a reference solar radiation values. The analysis of auto-calibration results showed clear correlation between optimal ‘epsilon’ and distance to the coast. We proposed simplified method in which ‘epsilon’ is equal to 0.1 MJm-2 or to 0.5 MJm-2 when distance to the coast is smaller or bigger than 15 km respectively.

Value

Bcb Bristow-Campbell ‘B’ coefficient

Author(s)

Jedrzej S. Bojanowski

References


See Also

‘bc’ to use Bristow-Campbell model, and ‘bccal’ to perform calibration based on reference data.
**Examples**

```r
data(Metadata)
tmax <- Metadata$meteo$TEMP_MAX
tmin <- Metadata$meteo$TEMP_MIN
days <- Metadata$meteo$DAY
lat <- Metadata$LATITUDE
lon <- Metadata$LONGITUDE
rad_mea <- Metadata$meteo$RAD_MEA
dcoast <- Metadata$DCOAST

bcauto(lat,lon,days,extraT=NULL,tmax,tmin,perce=NA,dcoast)
```

---

**bccal**

*Calibrate Bristow-Campbell model*

**Description**

Function estimates Bristow-Campbell model coefficient 'B' based on reference data

**Usage**

```r
bccal(lat, days, rad_mea, extraT=NULL, BCc=2, Tmax, Tmin, tal)
```

**Arguments**

- `lat`: Latitude in decimal degrees.
- `days`: Vector of class 'Date' of length n.
- `rad_mea`: Vector of length n containing reference (e.g. measured) solar radiation [MJm-2].
- `extraT`: Optional. Vector of length n of extraterrestrial solar radiation [MJm-2]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
- `BCc`: Bristow-Campbell model coefficient 'C' usually equaled to 2.
- `Tmax`: Vector of length n containing daily maximum temperature [C].
- `Tmin`: Vector of length n containing daily minimum temperature [C].
- `tal`: Clear sky transmissivity.

**Details**

Function estimates Bristow-Campbell model coefficient 'B' based on reference (e.g. measured) solar radiation data. It performs a non-linear least squares regression.

**Value**

- `BCb`: Bristow-Campbell 'B' coefficient
**Author(s)**

Jedrzej S. Bojanowski

**References**


**See Also**

‘bc’, and ‘bcauto’ to perform auto-calibration

**Examples**

```r
data(Metdata)
tmax <- Metdata$meoteo$TEMP_MAX
tmin <- Metdata$meoteo$TEMP_MIN
days <- Metdata$meoteo$DAY
l <- Metdata$LATITUDE
radd_mea <- Metdata$meoteo$RAD_MEA
bccal(l, days, radd_mea, extraT=NULL, Bcc=2, tmax, tmin, tal=0.76)
```

---

**cst**  

*Estimate clear sky transmissivity*

**Description**

Function estimates a clear sky transmissivity based on reference data (e.g. measured)

**Usage**

cst(RefRad, days, lat, extraT=NULL, perce = 3, sepYear = FALSE, stat='median')

**Arguments**

- **RefRad**: Vector of length n of reference solar radiation data [MJm-2]
- **days**: Vector of class ‘Date’ of length n.
- **lat**: Latitude in radians
- **extraT**: Optional. Vector of length n of extraterrestrial solar radiation [MJm-2]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation
- **perce**: Percent of days to be chosen as clear days
- **sepYear**: Logical value. If 'TRUE' percent of days given by 'perce' of every single year are taken for calculation. If 'FALSE' percent of days given by 'perce' of all years are taken for calculation
Method used to estimate final value of the clear sky transmissivity from the values derived from selected clear-sky days. Default is 'median' which is more conservative, while alternative 'max' is sensitive to outliers. If 'max' is used the value of 'perce' is not important. If 'stat' is numeric then (instead of 'median' or 'max') 'quantile' is used. 'Stat' is sent as quantile's 'probs' parameter. See ?quantile for details.

Value

Numeric. Clear sky transmissivity.

Author(s)

Jedrzej S. Bojanowski

See Also

cstRead

Examples

data(Metdata)
ref <- Metdata$meteo$RAD_MEA
i <- dayOfYear(Metdata$meteo$DAY)
latr <- radians(Metdata$LATITUDE)
cst(ref, i, latr)

cstRead(lat, lon)

Arguments

lat Longitude in decimal degrees.
lon Longitude in decimal degrees.

Value

Clear sky transmissivity
Author(s)

Jedrzej S. Bojanowski

See Also

'cst'

Examples

cstRead(50, 16)

dayOfYear[1] Convert 'Date' to number of day in a year
dayOfYear

Description

Function gives a day number of the year (julian day of the year) based on the date in class 'Date'.

Usage

dayOfYear(dat)

Arguments

dat Date in class 'Date'.

Value

Numeric number of day in a year.

Author(s)

Jedrzej S. Bojanowski

Examples

dayOfYear(as.Date("2009-01-11"))
degrees \hspace{1cm} \textit{Convert radians to degrees}

\textbf{Description} \\
Converts radians to degrees

\textbf{Usage} \\
degrees(radians)

\textbf{Arguments} \\
radians \hspace{1cm} \text{numeric}

\textbf{Value} \\
Degrees.

\textbf{Author(s)} \\
Jedrzej S. Bojanowski

\textbf{See Also} \\
'\text{radians}'

\textbf{Examples} \\
degrees(0.95)

\textbf{deltaVP} \hspace{1cm} \textit{Slope of saturation vapour pressure curve}

\textbf{Description} \\
'deltaVP' estimates the slope of saturation vapour pressure curve

\textbf{Usage} \\
deltaVP(Tmax,Tmin)

\textbf{Arguments} \\
Tmax \hspace{1cm} \text{Vector of length n containing daily maximum temperature [C].} \\
Tmin \hspace{1cm} \text{Vector of length n containing daily minumum temperature [C].}
Value
Slope of saturation vapour pressure curve [kPaC⁻¹]

Author(s)
Jedrzej S. Bojanowski

References

Examples
deltaVP(Tmax=17,Tmin=16)

---

'es'

Mean saturation vapour pressure

Description
'es' calculates mean saturation vapour pressure based on air temperature.

Usage
es(Tmax,Tmin)

Arguments

Tmax
Vector of length n containing daily maximum temperature [C].

Tmin
Vector of length n containing daily minimum temperature [C].

Value
Vector of length n of mean saturation vapour pressure [kPa]

Author(s)
Jedrzej S. Bojanowski

References
et0

Description

'et0' estimates evapotranspiration based on FAO Penman-Monteith equation

Usage

et0(Tmax, Tmin, vap_pres, sol_rad, tal, z, uz, meah=10, extraT=NA, days=NA, lat=NA)

Arguments

Tmax Vector of length n containing daily maximum temperature [°C].
Tmin Vector of length n containing daily minimum temperature [°C].
vap_pres Vector of length n of mean daily vapour pressure [kPa].
sol_rad Vector of length n of daily solar radiation [MJm-2d-1].
tal Clear sky transmissivity [0-1].
z Altitude above the sea level [m].
uz Wind speed measured at heith 'meah' [ms-1].
meah The height (above the ground level) of the wind speed measurement [m].
extraT Optional. Vector of length n of extraterrestrial solar radiation [MJm-2d-1]. If 'NA' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
days Required only if extraT=NA. Vector of class 'Date' of length n.
lat Required only if extraT=NA. Latitude in decimal degrees.

Value

Vector of length n of daily reference evapotranspiration. [mm/d]

Author(s)

Jedrzej S. Bojanowski

References

Examples

data(Metadata)
tmax <- Metadata$meteo$TEMP_MAX
tmin <- Metadata$meteo$TEMP_MIN
vpres <- Metadata$meteo$VAP_PRES
days <- Metadata$meteo$DAY
lat <- Metadata$LATITUDE
rad_mea <- Metadata$meteo$RAD_MEA
z <- Metadata$ALTIMET
wind <- Metadata$meteo$WIND

tal <- cst(rad_mea,dayOfYear(Metadata$meteo$DAY),radians(Metadata$LATITUDE))
et0(Tmax=tmax,Tmin=tmin, vap_pres=vpres,sol_rad=rad_mea,tal=tal,z=Metadata$ALTIMET,
uz=wind,meah=10,extraT=NA,days=days,lat=lat)

extrat Calculate extraterrestrial solar radiation

Description

'extrat' calculates hourly and daily extraterrestrial solar radiation for a given time and location.

Usage

extrat(i, lat)

Arguments

i day number in the year (julian day)
lat latitude in radians

Details

Solar radiation outside of the earth’s atmosphere is called extraterrestrial solar radiation. It can be calculated based on solar geometry.

Value

List of 3 elements:
ExtraTerrestrialSolarRadiationDaily
daily sum of extraterrestrial radiation [MJm-2]
TerrestrialSolarRadiationHourly
vector of length 24 of hourly sums of extraterrestrial radiation [MJm-2]
DayLength day length in hours
Author(s)
Jedrzej S. Bojanowski

Examples

```r
## extraterrestrial radiation and daylength for 1 January and latitude 55 degrees
extrat(dayOfYear("2011-01-01"), radians(55))
```

Description

'ha()' calculates daily solar radiation based on daily temperature range using Hargreaves model.

Usage

```r
ha(days, lat, lon, extrat=NULL, A=NA, B=NA, Tmax, Tmin)
```

Arguments

- `days`: Vector of class 'Date' of length n.
- `lat`: Latitude in decimal degrees.
- `lon`: Longitude in decimal degrees.
- `extrat`: Optional. Vector of length n of extraterrestrial solar radiation [MJm-2]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
- `A`: Hargreaves model coefficient 'A'. If 'NA' then A is derived from the map of interpolated coefficients estimated from Meteosat solar radiation data. See details.
- `B`: Hargreaves model coefficient 'B'. If 'NA' then B is derived from the map of interpolated coefficients estimated from Meteosat solar radiation data. See details.
- `Tmax`: Vector of length n containing daily maximum temperature [C].
- `Tmin`: Vector of length n containing daily minimum temperature [C].

Details

Hargreaves proposed a method for estimating solar radiation from air temperature measurements. Model coefficients A and B (if not provided) are derived from interpolated Meteosat-based coefficients from Bojanowski et al. 2013.

Value

Vector of length n of daily solar radiation [MJm-2].
Note
'Tmax', 'Tmin' can contain NA's, but length of vectors 'Tmax', 'Tmin' and 'days' has to be the same.

Author(s)
Jedrzej S. Bojanowski

References

See Also
'hacal' to calibrate model using reference data, 'bc' to use Bristow-Campbell model to calculate solar radiation based on temperature range.

Examples
```r
require(zoo)
data(Metdata)
tmax <- Metdata$meteo$TEMP_MAX
tmin <- Metdata$meteo$TEMP_MIN
days <- Metdata$meteo$DAY
lat <- Metdata$LATITUDE
lon <- Metdata$LONGITUDE
plot(zoo(ha(days, lat, lon, extraT=NULL, A=NA, B=NA, Tmax=tmax, Tmin=tmin),order.by=days))
```

hacal

Calibrate Hargreaves model

Description
Function estimates Hargreaves model coefficients 'A' and 'B' based on reference data

Usage
```r
hacal(lat, days, rad_mea, extraT=NULL, tmax, tmin)
```
Arguments

lat: Latitude in decimal degrees.
days: Vector of class 'Date' of length n.
rad_mea: Vector of length n containing reference (e.g. measured) solar radiation [MJm^-2].
extraT: Optional. Vector of length n of extraterrestrial solar radiation [MJm^-2]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
tmax: Vector of length n containing daily maximum temperature [C].
tmin: Vector of length n containing daily minumum temperature [C].

Details

Function estimates Hargreaves model coefficients 'A' and 'B' based on reference (e.g. measured) solar radiation data. It performs a linear regression.

Value

Vector of length 3 containing:

Ha: Hargreaves 'A' coefficient
Hb: Hargreaves 'B' coefficient
Hr2: Coefficient of determination of performed linear regression

Author(s)

Jedrzej S. Bojanowski

References


See Also

'ha'

Examples

data(Metadata)
tmax <- Metadata$meteo$TEMP_MAX
tmin <- Metadata$meteo$TEMP_MIN
days <- Metadata$meteo$DAY
lat <- Metadata$LATITUDE
rad_mea <- Metadata$meteo$RAD_MEAN
hacal(lat=lat, days=days, rad_mea, extraT=NULL, tmax=tmax, tmin=tmin)
**Auto-calibrate Hargreaves model**

**Description**

Function estimates Hargreaves model coefficients 'A' and 'B' based on autocalibration procedure.

**Usage**

```r
hauto(lat, lon, days, extraT = NULL, Tmax, Tmin, tal,
ha_guess = 0.16, hb_guess = 0.1, epsilon=0.5, perce = NA)
```

**Arguments**

- `lat`: Latitude in decimal degrees.
- `lon`: Longitude in decimal degrees.
- `days`: Vector of class 'Date' of length n.
- `extraT`: Optional. Vector of length n of extraterrestrial solar radiation [MJm⁻²]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation.
- `Tmax`: Vector of length n containing daily maximum temperature [C].
- `Tmin`: Vector of length n containing daily minimum temperature [C].
- `tal`: Clear sky transmissivity.
- `ha_guess`: Assumption of Hargreaves Ha coefficient. Default set to 0.16.
- `hb_guess`: Assumption of Hargreaves Hb coefficient. Default set to 0.1.
- `epsilon`: A value of which potential radiation is decreased. See "details".
- `perce`: Percent of clear days. Default set to 1.

**Details**

The auto-calibration method bases on the assumption that on the clear-sky days model should not overpredict potential values. To define those clear-sky days, we estimate daily solar radiation using Hargreaves model with default values of A = 0.16, B = 0.1 and tal = 0.72 and we select those days for which estimated daily solar radiation is the closest to the potential values (extra-terrestrial*tal). The number of clear-sky days is estimated based on the mean Cloud Fraction Cover map. Next, based on selected clear-sky days, we perform a non-linear least squares regression to derive A and B coefficients treating potential values decreased by 'epsilon' as a reference solar radiation values. The analysis of auto-calibration results showed clear correlation between optimal 'epsilon' and distance to the coast. We proposed simplified method in which 'epsilon' is equal to 0.1 MJm⁻² or to 0.5 MJm⁻² when distance to the coast is smaller or bigger than 15 km respectively.
Value

Vector of length 3 containing:

- H a: Hargreaves 'A' coefficient
- H b: Hargreaves 'B' coefficient
- H r 2: Coefficient of determination of performed linear regression

Author(s)

Jedrzej S. Bojanowski

References


See Also

'hacal'

Examples

data(Metdata)
Tmax <- Metdata$meteo$TEMP_MAX
Tmin <- Metdata$meteo$TEMP_MIN
days <- Metdata$meteo$DAY
lat <- Metdata$LATITUDE
lon <- Metdata$LONGITUDE
hauto(lat,lon,days,extraT=NULL,Tmax,Tmin,tal=0.76)

Description

This dataset contains two years of daily data of sunshine hours, solar radiation, minimum temperature, maximum temperature, cloud coverage, vapour pressure, and wind speed.

Usage

data(Metdata)
Format

<table>
<thead>
<tr>
<th>NAME</th>
<th>chr</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>LATITUDE</td>
<td>numeric</td>
<td>Latitude (decimal degree)</td>
</tr>
<tr>
<td>LONGITUDE</td>
<td>numeric</td>
<td>Longitude (decimal degree)</td>
</tr>
<tr>
<td>DCOAST</td>
<td>numeric</td>
<td>Distance to the coast (km)</td>
</tr>
<tr>
<td>ALTITUDE</td>
<td>numeric</td>
<td>Altitude above the sea level (m)</td>
</tr>
<tr>
<td>DAY</td>
<td>Date</td>
<td>Date</td>
</tr>
<tr>
<td>SUNSHINE</td>
<td>numeric</td>
<td>Sunshine (hours)</td>
</tr>
<tr>
<td>RAD_MEA</td>
<td>numeric</td>
<td>Solar radiation (MJm-2)</td>
</tr>
<tr>
<td>TEMP_MIN</td>
<td>numeric</td>
<td>Minimum temperature (degrees C)</td>
</tr>
<tr>
<td>TEMP_MAX</td>
<td>numeric</td>
<td>Maximum temperature (degrees C)</td>
</tr>
<tr>
<td>CLOUD_DAYTIME_TOTAL</td>
<td>numeric</td>
<td>Cloud coverage (octas)</td>
</tr>
<tr>
<td>VAP_PRES</td>
<td>numeric</td>
<td>Vapour pressure (kPa)</td>
</tr>
<tr>
<td>WIND_10</td>
<td>numeric</td>
<td>Wind speed at 10 m height (ms-1)</td>
</tr>
</tbody>
</table>

Examples

```r
data(Metadata)
str(Metadata)
```

### Description

'`mh()`' calculates daily solar radiation based on daily temperature range using Mahmood-Hubbard model.

### Usage

```r
mh(days, lat, Tmax, Tmin)
```

### Arguments

- **days**: Vector of class 'Date' of length n.
- **lat**: Latitude in decimal degrees.
- **Tmax**: Vector of length n containing daily maximum temperature [C].
- **Tmin**: Vector of length n containing daily minimum temperature [C].

### Details

Mahmood and Hubbard proposed a method for estimating solar radiation from air temperature measurements without a need of calibraing empirical coefficients.
**modeval**

**Value**

Vector of length n of daily solar radiation [MJm\(^{-2}\)].

**Author(s)**

Jedrzej S. Bojanowski

**References**


**See Also**

'bc' and 'ha' to calculate solar radiation based on temperature range using different models.

**Examples**

```r
require(zoo)
data(Metdata)
tmax <- Metdata$meteo$TEMP_MAX
tmin <- Metdata$meteo$TEMP_MIN
days <- Metdata$meteo$DAY
lat <- Metdata$LATITUDE
plot(zoo(mh(days=days, lat=lat, Tmax=tmax, Tmin=tmin),order.by=days))
```

**modeval**

*Model performance statistics.*

**Description**

Function estimates several statistics comparing modelled and reference (measured) values.

**Usage**

```r
modeval(calculated, measured,
stat=c("N","pearson","MBE","RMBE","MAE","RMAE","RMSE","RRMSE","R2","slope",
"intercept","EF","SD","CRM","MPE","AC","ACu","AC2"),minlength=4)
```

**Arguments**

- **calculated**: Vector of length n of the calculated (modelled) values.
- **measured**: Vector of length n of the reference (measured) values.
- **stat**: Statistics which are going to be calculated. By default all possible.
- **minlength**: Minimum number of non-NA data pairs. If below this value, the NA’s are produced.
Details

The two input vectors can include NA's. Only non-NA calculated-mesured pairs are used. See 'na.omit' for details.

Value

List of 13 statistics:

- N: number of observations
- person: Pearson’s Correlation Coefficient
- MBE: Mean (Bias) Error
- RMSE: Relative Mean (Bias) Error
- MAE: Mean Absolute Error
- RMAE: Relative Mean Absolute Error
- RMSE: Root Mean Square Error
- RRMS: Relative Root Mean Square Error
- R2: Coefficient of determination from linear model
- slope: Slope from linear model
- intercept: Intercept from linear model
- EF: Modelling Efficiency
- SD: Standard deviation of differences
- CRM: Coefficient of Residual Mass
- MPE: Mean Percentage Error
- AC: Agreement Coefficient
- ACu: Unsystematic Agreement Coefficient
- ACs: Systematic Agreement Coefficient

Author(s)

Jedrzej S. Bojanowski

References


Examples

data(Metadata)
B <- 0.11
tmax <- Metadata$meteo$TEMP_MAX
tmin <- Metadata$meteo$TEMP_MIN
days <- Metadata$meteo$DAY
lat <- Metadata$LATITUDE
solrad_measured <- Metadata$meteo$RAD_MEA
solrad_BC <- bc(days, lat, extra=NULL, BCb=B, tmax, tmin, BCc=2, tal=0.76)

modeval(solrad_BC,solrad_measured)
modeval(solrad_BC,solrad_measured,stat="EF")

psychC

Psychrometric constant

Description

'psychC' estimates the psychrometric constant.

Usage

psychC(Tmax,Tmin,z)

Arguments

Tmax  Vector of length n containing daily maximum temperature [C].
Tmin  Vector of length n containing daily minimum temperature [C].
z     Altitude above the sea level [m].

Value

Psychrometric constant [kPaC-1]

Author(s)

Jedrzej S. Bojanowski

References


Examples

psychC(17,16,1800)
radians

Convert degrees to radians

Description
Converting degrees to radians

Usage
radians(degrees)

Arguments
degrees numeric

Value
Radians.

Author(s)
Jedrzej S. Bojanowski

See Also
'degrees'

Examples
radians(55)

rnl
Net longwave radiation

Description
'rnl' computes daily net energy flux emitted by the Earth's surface.

Usage
rnl(Tmax,Tmin,sol_rad,vap_pres,extraT,tal)
Arguments

- **tmax**: Vector of length `n` containing daily maximum temperature [°C].
- **tmin**: Vector of length `n` containing daily minimum temperature [°C].
- **sol_rad**: Vector of length `n` of daily solar radiation [MJ m⁻² d⁻¹].
- **vap_pres**: Vector of length `n` of mean daily vapour pressure [kPa].
- **extraT**: Vector of length `n` of extraterrestrial solar radiation [MJ m⁻² d⁻¹].
- **tal**: Clear sky transmissivity.

Details

According to the Stefan-Boltzmann law, the longwave energy emission is proportional to the absolute temperature of the surface raised to the fourth power. This longwave energy is corrected by two factors: humidity (‘ea’) and cloudiness (estimated based on relation of actual and potential solar radiation). See Allen et al. (1998) for details.

Value

Vector of length `n` of daily net longwave radiation. [MJ m⁻² d⁻¹]

Author(s)

Jedrzej S. Bojanowski

References


See Also

See ‘ea’, ‘extrat’ and ‘cst’ to calculate necessary input data.

Examples

```r
rnl(Tmax=25.1, Tmin=19.1, sol_rad=14.5, vap_pres=2.1, extraT=23.5, tal=0.8)
```
Description

'rnS' computes daily the net shortwave radiation, resulting from the balance between incoming and reflected solar radiation.

Usage

\[
\text{rnS(sol\_rad, albedo=0.23)}
\]

Arguments

sol\_rad Vector of length n of daily solar radiation [MJm\(^{-2}\)d\(^{-1}\)].

albedo Albedo or canopy reflection coefficient, which is 0.23 for the hypothetical grass reference crop [dimensionless].

Details

Daily net shortwave radiation results from the balance between incoming and reflected solar radiation.

Value

Vector of length n of daily net shortwave radiation. [MJm\(^{-2}\)d\(^{-1}\)]

Author(s)

Jedrzej S. Bojanowski

References


Examples

\[
\text{rnS(sol\_rad=14.5)}
\]
Description

'su()' calculates daily solar radiation based on daily cloud coverage and temperature range using Supit-Van Kappel model.

Usage

su(days, lat, lon, extrat=NULL, A=NA, B=NA, C=NA, tmax, tmin, CC)

Arguments

days Vector of class 'Date' of length n.
lat Latitude in decimal degrees.
lon Longitude in decimal degrees.
extrat Optional. Vector of length n of extraterrestrial solar radiation [MJm-2]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation
A Supit-Van Kappel model coefficient 'A'. If 'NA' then A is derived from the map of interpolated coefficients estimated from Meteosat solar radiation data. See details.
B Supit-Van Kappel model coefficient 'B'. If 'NA' then B is derived from the map of interpolated coefficients estimated from Meteosat solar radiation data. See details.
C Supit-Van Kappel model coefficient 'C'. If 'NA' then C is derived from the map of interpolated coefficients estimated from Meteosat solar radiation data. See details.
tmax Vector of length n containing daily maximum temperature [C].
tmin Vector of length n containing daily minimum temperature [C].
CC Vector of length n containing daily cloud coverage [octas].

Details

Supit and Van Kappel proposed a method for estimating solar radiation from daily cloud coverage and temperature range. Model coefficients A, B and C (if not provided) are derived from interpolated Meteosat-based coefficients from Bojanowski et al. 2013.

Value

Vector of length n of daily solar radiation [MJm-2].
Note

'CC', 'Tmax', 'Tmin' can contain NA's, but length of vectors 'CC', 'Tmax', 'Tmin' and 'days' has to be the identical.

Author(s)

Jedrzej S. Bojanowski

References


See Also

'sucal' to calibrate the model.

Examples

```r
require(zoo)
data(Metadata)
tmax <- Metadata$meteo$TEMP_MAX
tmin <- Metadata$meteo$TEMP_MIN
cc <- Metadata$meteo$CLOUD_DAYTIME_TOTAL
days <- Metadata$meteo$DAY
lat <- Metadata$LATITUDE
lon <- Metadata$LONGITUDE
plot(zoo(su(days=days, lat=lat, lon=lon, extraT=NULL, A=NA, B=NA, C=-NA, tmax=tmax, tmin=tmin, CC=cc),order.by=days))
```

suca1

Calibrate Supit-Van Kappel model

Description

Function estimates Supit-Van Kappel model coefficients 'A', 'B' and 'C' based on reference data

Usage

```r
suca1(days, lat, rad_mea, extraT=NULL, tmax, tmin, cc)
```
Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>days</td>
<td>Vector of class 'Date' of length n.</td>
</tr>
<tr>
<td>lat</td>
<td>Latitude in decimal degrees.</td>
</tr>
<tr>
<td>rad_mea</td>
<td>Vector of length n containing reference (e.g. measured) solar radiation [MJm-2].</td>
</tr>
<tr>
<td>extraT</td>
<td>Optional. Vector of length n of extraterrestrial solar radiation [MJm-2]. If 'NULL' then it is calculated by the function. Providing extraterrestrial solar radiation speeds up the computation</td>
</tr>
<tr>
<td>tmax</td>
<td>Vector of length n containing daily maximum temperature [C].</td>
</tr>
<tr>
<td>tmin</td>
<td>Vector of length n containing daily minimum temperature [C].</td>
</tr>
<tr>
<td>cc</td>
<td>Vector of length n containing daily cloud coverage [octas].</td>
</tr>
</tbody>
</table>

Details

Function estimates Supit-Van Kappel model coefficients 'A', 'B' and 'C' based on reference (e.g. measured) solar radiation data. It performs a linear regression.

Value

Vector of length 3:

- Sa: Supit-Van Kappel 'A' coefficient
- Sb: Supit-Van Kappel 'B' coefficient
- Sc: Supit-Van Kappel 'C' coefficient
- Sr2: Coefficient of determination of performed linear regression

Author(s)

Jedrzej S. Bojanowski

References


See Also

'su'.

Examples

data(Metdata)
tmax <- Metdata$meteo$TEMP_MAX
tmin <- Metdata$meteo$TEMP_MIN
days <- Metdata$meteo$DAY
lat <- Metdata$LATITUDE
Description

'wind2' converts a wind speed measured at a certain height 'z' above the ground level to the wind speed at the standard height (2 meters).

Usage

wind2(uz, meah)

Arguments

uz Wind speed measured at height 'z' [ms-1].
meah The height (above the ground level) of the wind speed measurement [m].

Details

Wind speed is slowest at the surface and increases with height. The measurements taken at different heights above the ground level must be standardized to 2 meters (default in agrometeorology).

Value

Wind speed at standard 2 meters. [ms-1]

Author(s)

Jedrzej S. Bojanowski

References


Examples

wind2(uz=5, meah=10)
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