Package ‘Evapotranspiration’

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Title Modelling Actual, Potential and Reference Crop Evapotranspiration
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Depends R (>= 3.5.0), zoo
Description Uses data and constants to calculate potential evapotranspiration (PET) and actual evapotranspiration (AET) from 21 different formulations including Penman, Penman-Monteith FAO 56, Priestley-Taylor and Morton formulations.
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R topics documented:

climatedata ................................................................. 2
constants ................................................................. 3
defaultconstants ....................................................... 5
ET ................................................................. 6
ET.Abtew ............................................................ 8
ET.BlaneyCriddle ..................................................... 10
ET.BrutsaertStrickler ............................................... 13
ET.ChapmanAustralian ............................................ 15
ET.GrangerGray ....................................................... 18
ET.Hamon ............................................................ 21
ET.HargreavesSamani .............................................. 23
ET.JensenHaise ....................................................... 25
ET.Linacre ........................................................... 27
**climatedata**

Raw Climate Data Required for Calculating Evapotranspiration

**Description**

This data set contains the raw climate data including the variables required for calculating evapotranspiration in function \( ET \) over the observation period between 1/3/2001 and 08/31/2004 at the Kent Town station in Adelaide, Australia.

**Usage**

```r
data(climatedata)
```

**Format**

A data frame containing 10240 observations of 9 objects:

- **Station.Number** - weather station number,
- **Year** - year of record,
- **Month** - month of record,
- **Day** - day of record,
- **Hour** - hour of record,
- **Tdew** - subdaily dew point temperature in degree Celcius,
- **RH** - subdaily relative humidity in percentage,
- **Rs** - subdaily solar radiation in Megajoule per square meter,
- **uz** - subdaily wind speed in meter per second.
## Description

This data set contains the universal constants, and examples of other variable constants required for calculating evapotranspiration in function $ET$, based on the climatic condition at Kent Town station in Adelaide, Australia.

## Usage

```r
data(constants)
```

## Format

A list containing 36 constant values including:

- 20 universal constants, which should be kept unchanged for most conditions:

  - \( \lambda \): latent heat of evaporation in = 2.45 MJ.kg\(^{-1}\) at 20 degree Celcius
  - \( \sigma \): Stefan-Boltzmann constant = 4.903*10\(^{-9}\) MJ.K\(^{-4}\).m\(^{-2}\).day\(^{-1}\)
  - \( G_{sc} \): solar constant = 0.0820 MJ.m\(^{-2}\).min\(^{-1}\)
  - \( \rho_{a} \): mean density of air = 1.2 kg.m\(^{-3}\) at 20 degree Celcius
  - \( C_{a} \): specific heat of air = 0.001013 MJ.kg\(^{-1}\).K\(^{-1}\)
  - \( G \): soil heat flux negligible for daily time-step = 0 (Allen et al., 1998, page 68)
  - \( \alpha_{A} \): Albedo for Class-A pan = 0.14

- \( \alpha_{PT} \): Priestley-Taylor coefficient:
  - = 1.26 for Priestley-Taylor formula (Priestley and Taylor, 1972, Sect. 6; Eichinger et al., 1996, p.163);
  - = 1.31 for Szilagyi-Jozsa formula (Szilagyi and Jozsa, 2008);
  - = 1.28 for Brutsaert-Strickler formula (Brutsaert and Strickler, 1979),

- \( a_{p} \): constant in Penpan formula = 2.4,
- \( b_{0} \): constant in Morton's procedure = 1 (Chiew and McMahon, 1991, Table A1),
- \( b_{1} \): constant in Morton's procedure = 14 W.m\(^{-2}\) (Chiew and McMahon, 1991, Table A1),

*Note: a re-calibrated value of 13.4 W.m\(^{-2}\) was recommended to achieve a Priestley-Taylor coefficient of 1.26 (Wang et al., 2009), rather than the original value (14 W.m\(^{-2}\)) used by Morton that gave a Priestley-Taylor coefficient of 1.32;

- \( b_{2} \): constant in Morton's procedure = 1.2 (Chiew and McMahon, 1991, Table A1),

*Note: a re-calibrated value of 1.13 was recommended to achieve a Priestley-Taylor coefficient of 1.26 (Wang et al., 2009), rather than the original value (1.2) used by Morton that gave a
Priestley-Taylor coefficient of 1.32;

\( e_0 \) constant for Blaney-Criddle formula = 0.81917 (Frevert et al., 1983, Table 1),
\( e_1 \) constant for Blaney-Criddle formula = -0.0040922 (Frevert et al., 1983, Table 1),
\( e_2 \) constant for Blaney-Criddle formula = 1.0705 (Frevert et al., 1983, Table 1),
\( e_3 \) constant for Blaney-Criddle formula = 0.065649 (Frevert et al., 1983, Table 1),
\( e_4 \) constant for Blaney-Criddle formula = -0.0059864 (Frevert et al., 1983, Table 1),
\( e_5 \) constant for Blaney-Criddle formula = -0.0005967 (Frevert et al., 1983, Table 1),
\( \epsilon_{Mo} \) Land surface emissivity in Morton’s procedure = 0.92,
\( \sigma_{Mo} \) Stefan-Boltzmann constant in Morton’s procedure = 5.67e-08 W.m\(^{-2}\).K\(^{-4}\).

- 16 variable constants, which are specific for the climatic condition at Kent Town station in Adelaide, Australia:

\( \text{lat} \) latitude = -34.9211 degrees for Kent Town station,
\( \text{lat}_\text{rad} \) latitude in radians = -0.6095 radians for Kent Town station,
\( \text{as} \) fraction of extraterrestrial radiation reaching earth on sunless days = 0.23 for Australia (Roderick, 1999, page 181),
\( \text{bs} \) difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days = 0.5 for Australia (Roderick, 1999, page 181),
\( \text{Elev} \) ground elevation above mean sea level = 48m for Kent Town station,
\( \text{z} \) height of wind instrument = 10m for Kent Town station,

\( \text{f}_z \) constant in Morton’s procedure:
= 28.0 W.m\(^{-2}\).mbar\(^{-1}\) for CRAE model for \( T \geq 0 \) degree Celcius;
*Note: a re-calibrated value of 29.2 W.m\(^{-2}\).mbar\(^{-1}\) was recommended to achieve a Priestley-Taylor coefficient of 1.26 (Wang et al., 2009), rather the original value (28.0 W.m\(^{-2}\).mbar\(^{-1}\)) used by Morton that gave a Priestley-Taylor coefficient of 1.32;
= 28.0 \times 1.15 W.m\(^{-2}\).mbar\(^{-1}\) for CRAE model for \( T < 0 \) degree Celcius;
= 25.0 W.m\(^{-2}\).mbar\(^{-1}\) for CRWE model for \( T \geq 0 \) degree Celcius;
= 28.75 W.m\(^{-2}\).mbar\(^{-1}\) for CRWE model for \( T < 0 \) degree Celcius (Morton, 1983a, page65).

\( \text{a}_0 \) constant for estimating sunshine hours from cloud cover data = 11.9 for Adelaide (Chiew and McMahon, 1991, Table A1),
\( \text{b}_0 \) constant for estimating sunshine hours from cloud cover data = -0.15 for Adelaide,
\( \text{c}_0 \) constant for estimating sunshine hours from cloud cover data = -0.25 for Adelaide,
\( \text{d}_0 \) constant for estimating sunshine hours from cloud cover data = -0.0107 for Adelaide, \text{gammaps} product of Psychrometric constant and atmospheric pressure as sea level:
= 0.66 mbar. degree Celcius\(^{-1}\) for CRAE model for \( T \geq 0 \) degree Celcius;
= 0.66/1.15 mbar. degree Celcius\(^{-1}\) for CRAE model for \( T < 0 \) degree Celcius.
\( \text{PA} \) annual precipitation = 285.8mm for Kent Town station,

\( \text{alpha}_Mo \) constant in Morton’s procedure:
= 17.27 when \( T \geq 0 \) degree Celcius;
= 21.88 when \( T < 0 \) degree Celcius.
betaMo constant in Morton’s procedure:
= 237.3 degree Celcius when T >= 0 degree Celcius;
= 265.5 degree Celcius when T < 0 degree Celcius.

lambdaMo latent heat of vaporisation in Morton’s procedure:
= 28.5W.day.kg^-1 when T >= 0 degree Celcius;
= 28.5*1.15W.day.kg^-1 when T < 0 degree Celcius.

References


See Also

defaultconstants

defaultconstants  Universal constants Required for Calculating Evapotranspiration

Description

This data set contains the universal constants required for calculating evapotranspiration in function ET, which should be kept unchanged for most conditions. Please note that additional constants may be ET models - check the manual for individual ET models for details.
Usage

data(defaultconstants)

Format

A list containing 20 constant values including:

- \( \lambda \) latent heat of evaporation = 2.45 MJ.kg\(^{-1}\) at 20 degree Celsius
- \( \sigma \) Stefan-Boltzmann constant = 4.903*10\(^{-9}\) MJ.K\(^{-4}\).m\(^{-2}\).day\(^{-1}\)
- \( G_{sc} \) solar constant = 0.0820 MJ.m\(^{-2}\).min\(^{-1}\)
- \( R_{oa} \) mean density of air = 1.2 kg.m\(^{-3}\) at 20 degree Celsius
- \( C_{a} \) specific heat of air = 0.001013 MJ.kg\(^{-1}\).K\(^{-1}\)
- \( G \) soil heat flux negligible for daily time-step = 0 (Allen et al., 1998, page 68)
- \( \alpha_{A} \) Albedo for Class-A pan = 0.14

\( \alpha_{PT} \) Priestley-Taylor coefficient:
- = 1.26 for Priestley-Taylor formula (Priestley and Taylor, 1972, Sect. 6; Eichinger et al., 1996, p.163);
- = 1.31 for Szilagyi-Jozsa formula (Szilagyi and Jozsa, 2008);
- = 1.28 for Brutsaert-Strickler formula (Brutsaert and Strickler, 1979),

- \( a_{p} \) constant in Penpan formula = 2.4,
- \( b_{0} \) constant in Morton’s procedure = 1 (Chiew and McMahon, 1991, Table A1),
- \( b_{1} \) constant in Morton’s procedure = 14 W.m\(^{-2}\) (Chiew and McMahon, 1991, Table A1),
- \( b_{2} \) constant in Morton’s procedure = 1.2 (Chiew and McMahon, 1991, Table A1),
- \( e_{0} \) constant for Blaney-Criddle formula = 0.81917 (Frevert et al., 1983, Table 1),
- \( e_{1} \) constant for Blaney-Criddle formula = -0.0040922 (Frevert et al., 1983, Table 1),
- \( e_{2} \) constant for Blaney-Criddle formula = 1.0705 (Frevert et al., 1983, Table 1),
- \( e_{3} \) constant for Blaney-Criddle formula = 0.065649 (Frevert et al., 1983, Table 1),
- \( e_{4} \) constant for Blaney-Criddle formula = -0.0059864 (Frevert et al., 1983, Table 1),
- \( e_{5} \) constant for Blaney-Criddle formula = -0.0005967 (Frevert et al., 1983, Table 1),
- \( \epsilon_{mo} \) Land surface emissivity in Morton’s procedure = 0.92,
- \( \sigma_{mo} \) Stefan-Boltzmann constant in Morton’s procedure = 5.67e-08 W.m\(^{-2}\).K\(^{-4}\).

Source

various references

See Also

- constants

---

ET

<table>
<thead>
<tr>
<th>ET Formulations</th>
</tr>
</thead>
</table>
Description

A generic function including 17 different specific methods that are all named following the format of \texttt{ET.methodname}. Once specific function is called the corresponding calculations are performed and a calculation summary is printed to screen.

Usage

\texttt{ET(data, constants, ...)}

Arguments

- \texttt{data} A list of climate data required for estimating evapotranspiration which differs for each evapotranspiration formulations, see specific formulations for details.
- \texttt{constants} A list named \texttt{constants} consists of constants required for the ET models which differ for specific ET models - refer to the manual for individual models for details.
- \texttt{...} Arguments to be passed to methods which differs for each evapotranspiration formulations, see specific formulations for details.

Details

Individual ET methods can be called by substituting the 'methodname' by the function name (e.g. \texttt{ET.Penman} to call the Penman model).

When the ET model selection is not specified by users, this function determines the default model to use based on the availability of climate data presented. Wherever data are available, the more comprehensive, physically-based models are always preferred over the empirical models, in the following hierarchy:

- If all variables of \texttt{Tmax/Tmin} and \texttt{RHmax/RHmin} and either \texttt{uz} or \texttt{u2}, and either \texttt{Rs} of \texttt{n} or \texttt{Cd} are available, and short crop surface is specified in argument: Penman-Monteith FAO56 (\texttt{ET.PenmanMonteith} with \texttt{crop = "short"});

- If all variables of \texttt{Tmax/Tmin} and \texttt{RHmax/RHmin} and either \texttt{uz} or \texttt{u2}, and either \texttt{Rs} of \texttt{n} or \texttt{Cd} are available, and long crop surface is specified in argument: Penman-Monteith ASCE-EWRI (\texttt{ET.PenmanMonteith} with \texttt{crop = "long"});

- If all variables of \texttt{Tmax/Tmin} and \texttt{RHmax/RHmin} and either \texttt{uz} or \texttt{u2}, and either \texttt{Rs} of \texttt{n} or \texttt{Cd} are available, and no surface is specified: Penman (\texttt{ET.Penman});

- If all variables of \texttt{Tmax/Tmin} and \texttt{RHmax/RHmin}, and either \texttt{Rs} of \texttt{n} or \texttt{Cd} are available: Priestley-Taylor (\texttt{ET.PriestleyTaylor});

- If all variables of \texttt{Tmax/Tmin} and either \texttt{Rs} of \texttt{n} or \texttt{Cd} are available: Makkink (\texttt{ET.Makkink});
- If all variables of $T_{max}/T_{min}$ are available:
  Hargreaves-Samani ($\text{ET.HargreavesSamani}$).

**Author(s)**

Danlu Guo

**Examples**

```r
# Use processed existing data set from kent Town, Adelaide
data("processeddata")
data("constants")

# Call generic function ET() - leads to the use of Penman model
results_default <- ET(processeddata, constants, save.csv="no")

# Call generic function ET() - leads to the use of Penman-Monteith model
results_crop <- ET(processeddata, constants, crop = "short", save.csv="no")
```

### ET.Abtew

**Abtew Formulation**

**Description**

Implementing the Abtew formulation for estimating actual evapotranspiration.

**Usage**

```r
## S3 method for class 'Abtew'
ET(data, constants, ts="daily", solar="sunshine hours", message="yes", AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

- `data` A list of data in class "Abtew" which contains the following items (climate variables) required by Abtew formulation:
  - $T_{max}, T_{min}$ (degree Celsius), $R_s$ (Megajoules per sqm) or $n$ (hour) or $C_d$ (okta)
- `constants` A list named constants consists of constants required for the calculation of Abtew formulation which must contain the following items:
  - $E_{lev}$ - ground elevation above mean sea level in m,
  - $\lambda$ - latent heat of vaporisation = 2.45 MJ.kg$^{-1}$,
  - $\lambda_{rad}$ - latitude in radians,
  - $G_{sc}$ - solar constant = 0.0820 MJ.m$^{-2}.min^{-1}$,
  - $\sigma$ - Stefan-Boltzmann constant = 4.903*10$^{-9}$ MJ.K$^{-4}.m^{-2}.day^{-1}$.

The following constants are also required when argument `solar` has value of sunshine hours:
- $as$ - fraction of extraterrestrial radiation reaching earth on sunless days,
hs - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

ts Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

solar Must be either data, sunshine hours, cloud or monthly precipitation: data indicates that solar radiation data is to be used directly for calculating evapotranspiration; sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours; cloud sunshine hours is to be estimated from cloud data; monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation. Default is sunshine hours.

message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated
- Option for calculating solar radiation (i.e. the value of argument solar)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

AdditionalStats "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

Details

The alternative calculation options can be selected through argument solar, please see Arguments for details.

Value

The function generates a list containing the following components:

ET.Daily Daily aggregated estimations of Abtew actual evapotranspiration.
ET.Monthly Monthly aggregated estimations of Abtew actual evapotranspiration.
ET.Annual Annually aggregated estimations of Abtew actual evapotranspiration.
ET.MonthlyAve Monthly averaged estimations of daily Abtew actual evapotranspiration.
ET.AnnualAve Annually averaged estimations of daily Abtew actual evapotranspiration.
ET_formulation Name of the formulation used which equals to Abtew.
ET_type Type of the estimation obtained which is Actual Evapotranspiration.
message1  A message to inform the users about how solar radiation has been calculated by using which data.

Author(s)
Danlu Guo

References

See Also
ET, processeddata, defaultconstants, constants

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Abtew under the generic function ET
results <- ET.Abtew(processeddata, constants, ts="daily", solar="sunshine hours", message="yes", AdditionalStats="yes", save.csv="no")
```

---

**ET.BlaneyCriddle**  
Blaney-Criddle Formulation

**Description**
Implementing the Blaney-Criddle formulation for estimating reference crop evapotranspiration.

**Usage**

```r
## S3 method for class 'BlaneyCriddle'
ET(data, constants, ts="daily", solar="sunshine hours", height = F, message="yes", AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>data</td>
<td>A list of data which contains the following items (climate variables) required by Blaney-Criddle formulation: (T_{max}, T_{min}) (degree Celcius), (RH_{min}) (per cent), (n) (hour) or (Cd) (okta), (u_2) or (u_z) (meter per second)</td>
</tr>
</tbody>
</table>
constants

A list named `constants` consists of constants required for the calculation of PenPan formulation which must contain the following items:

- `Elev` - ground elevation above mean sea level in m,
- `lambda` - latent heat of vaporisation = 2.45 MJ kg^-1,
- `lat_rad` - latitude in radians,
- `z` - height of wind instrument in m,
- `e0`, `e1`, `e2`, `e3`, `e4` - recommended values of 0.81917, -0.0040922, 1.0705, 0.065649, -0.0059684, -0.0005967 respectively (Table 1 in Frevert et al., 1983).

`ts`

Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

`solar`

Must be either sunshine hours or cloud:

- sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
- cloud sunshine hours is to be estimated from cloud data.

Default is sunshine hours.

`height`

Must be T or F, indicating if adjustment for site elevation for arid and semi-arid regions is applied in Blaney-Criddle formulation (Allen and Brockway, 1983). Default is F for no adjustment.

`message`

Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:

- ET model name and ET quantity estimated
- Evaporative surface
- Option for calculating solar radiation (i.e. the value of argument `solar`)
- If height adjustment has been applied on results (i.e. the value of argument `height`)
- Time step of the output ET estimates (i.e. the value of argument `ts`)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values

`AdditionalStats`

"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

`save.csv`

Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

Details

The alternative calculation options can be selected through argument `solar`, please see Arguments for details.

Height adjustment for the estimations is available through argument `height`, please see Arguments for details.
**Value**

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of Blaney-Criddle reference crop evapotranspiration.
- **ET.Monthly**: Monthly aggregated estimations of Blaney-Criddle reference crop evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of Blaney-Criddle reference crop evapotranspiration.
- **ET.MonthlyAve**: Monthly averaged estimations of daily Blaney-Criddle reference crop evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily Blaney-Criddle reference crop evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to Blaney-Criddle.
- **ET_type**: Type of the estimation obtained which is Reference Crop Evapotranspiration.
- **message1**: A message to inform the users about how solar radiation has been calculated by using which data.
- **message3**: A message to inform the users about if height adjustment has been applied to calculated Blaney-Criddle reference crop evapotranspiration.

**Author(s)**

Danlu Guo

**References**


**See Also**

*ET, processeddata, defaultconstants, constants*

**Examples**

```r
# Use processed existing data set and constants from Kent Town, Adelaide
data("processeddata")
data("constants")
```
# Call ET.BlaneyCriddle under the generic function ET
results <- ET.BlaneyCriddle(processeddata, constants, ts="daily", solar="sunshine hours",
height= FALSE, message="yes", AdditionalStats="yes", save.csv="no")

---

ET.BratsaertStrickler  

Brutsaert-Strickler Formulation

Description

Implementing the Brutsaert-Strickler formulation for actual areal evapotranspiration

Usage

```r
## S3 method for class 'BrutsaertStrickler'
ET(data, constants, ts="daily", solar="sunshine hours", alpha=0.23,
message="yes", AdditionalStats="yes", save.csv="no", ...)
```

Arguments

- **data**  
  A list of data which contains the following items (climate variables) required by Brutsaert-Strickler formulation:  
  - $T_{max}$, $T_{min}$ (degree Celsius), $RH_{max}$, $RH_{min}$ (per cent), $R_s$ (Megajoules per sqm) or $n$ (hour) or $C_d$ (okta), $u_2$ or $u_z$ (meter per second)

- **constants**  
  A list named constants consists of constants required for the calculation of Brutsaert-Strickler formulation which must contain the following items:  
  - $E_{lev}$ - ground elevation above mean sea level in m,  
  - $\lambda$ - latent heat of vaporisation = 2.45 MJ.kg$^{-1}$,  
  - $lat_{rad}$ - latitude in radians,  
  - $G_{sc}$ - solar constant = 0.0820 MJ.m$^{-2}$.min$^{-1}$,  
  - $z$ - height of wind instrument in m,  
  - $\sigma$ - Stefan-Boltzmann constant = 4.903*10$^{-9}$ MJ.K$^{-4}$.m$^{-2}$.day$^{-1}$.

  The following constants are also required when argument solar has value of sunshine hours:  
  - $as$ - fraction of extraterrestrial radiation reaching earth on sunless days,  
  - $bs$ - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

- **ts**  
  Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

- **solar**  
  Must be either data, sunshine hours, cloud or monthly precipitation:  
  - data indicates that solar radiation data is to be used directly for calculating evapotranspiration;  
  - sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;  
  - cloud sunshine hours is to be estimated from cloud data;
monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation. Default is sunshine hours.

alpha Any numeric value between 0 and 1 (dimensionless), albedo of the evaporative surface representing the portion of the incident radiation that is reflected back at the surface. Default is 0.23 for surface covered with short reference crop.

message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated
- Evaporative surface with values of albedo, surface resistance, crop height and roughness height
- Option for calculating solar radiation (i.e. the value of argument solar)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values

AdditionalStats "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

Details
The alternative calculation options can be selected through argument solar, please see Arguments for details.
User-defined evaporative surface is allowed through argument alpha, please see Arguments for details.

Value
The function also generates a list containing the following components:

ET.Daily Daily aggregated estimations of Brutsaert-Strickler actual areal evapotranspiration.
ET.Monthly Monthly aggregated estimations of Brutsaert-Strickler actual areal evapotranspiration.
ET.Annual Annually aggregated estimations of Brutsaert-Strickler actual areal evapotranspiration.
ET.MonthlyAve Monthly averaged estimations of daily Brutsaert-Strickler actual areal evapotranspiration.
ET.AnnualAve Annually averaged estimations of daily Brutsaert-Strickler actual areal evapotranspiration.
**ET.ChapmanAustralian**

- **ET_formulation**: Name of the formulation used which equals to Brutsaert-Strickler.
- **ET_type**: Type of the estimation obtained which is Actual Areal Evapotranspiration.
- **message**: A message to inform the users about how solar radiation has been calculated by using which data.

**Author(s)**

Danlu Guo

**References**


**See Also**

*ET.processeddata, defaultconstants, constants*

**Examples**

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.BrutsaertStrickler under the generic function ET
results <- ET.BrutsaertStrickler(processeddata, constants, ts="daily", solar="sunshine hours", alpha=0.23, message="yes", AdditionalStats="yes", save.csv="no")
```

**Description**

Implementing the Chapman formulation for estimating potential evapotranspiration.

**Usage**

```r
## S3 method for class 'ChapmanAustralian'
ET(data, constants, ts="daily", PenPan= T, solar="sunshine hours", alpha=0.23, message="yes", AdditionalStats="yes", save.csv="no", ...)
```
Arguments

data A list of data which contains the following items (climate variables) required by Chapman formulation:
Tmax, Tmin (degree Celsius), RHmax, RHmin (per cent), Rs (Megajoules per sqm) or n (hour) or Cd (okta), u2 or uz (meter per second)

constants A list named constants consists of constants required for the calculation of Chapman formulation which must contain the following items:
Elev - ground elevation above mean sea level in m,
lambda - latent heat of vaporisation = 2.45 MJ.kg^-1,
lat_rad - latitude in radians,
Gsc - solar constant = 0.0820 MJ.m^-2.min^-1,
z - height of wind instrument in m,
sigma - Stefan-Boltzmann constant = 4.903*10^-9 MJ.K^-4.m^-2.day^-1,
lat - latitude in degrees,
alphaA - albedo for Class-A pan,
ap - a constant in PenPan = 2.4.

The following constants are also required when argument solar has value of sunshine hours:
as - fraction of extraterrestrial radiation reaching earth on sunless days,
bs - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

ts Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

PenPan Must be T or F, indicating if the PenPan formulation is used for estimating Class-A pan evaporation required in Chapman formulation. If T PenPan will be used and if F the actual data of Class-A pan evaporation will be used. Default is T for using the PenPan formulation.

solar Must be either data, sunshine hours, cloud or monthly precipitation:
data indicates that solar radiation data is to be used directly for calculating evapotranspiration;
sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
cloud sunshine hours is to be estimated from cloud data;
monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation.
Default is sunshine hours.

alpha Any numeric value between 0 and 1 (dimensionless), albedo of the evaporative surface incident radiation that is reflected back at the surface.
Default is 0.23 for surface covered with short reference crop.

message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated, and the value of pan coefficient (only for when potential ET is estimated)
- Evaporative surface with values of albedo
- Option for calculating solar radiation (i.e. the value of argument solar)
- If the PenPan formulation is used for estimating Class-A pan evaporation required in Chapman formulation (i.e. the value of argument PenPan)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

**AdditionalStats**

"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

**save.csv**

Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

**Details**

The alternative calculation options can be selected through arguments PenPan and solar, please see Arguments for details.

**Value**

The function generates a list containing the following components:

- **ET.Daily** Daily aggregated estimations of Chapman potential evapotranspiration.
- **ET.Monthly** Monthly aggregated estimations of Chapman potential evapotranspiration.
- **ET.Annual** Annually aggregated estimations of Chapman equivalent Penmen-Monteith evapotranspiration.
- **ET.MonthlyAve** Monthly averaged estimations of daily Chapman potential evapotranspiration.
- **ET.AnnualAve** Annually averaged estimations of daily Chapman potential evapotranspiration.
- **ET_formulation** Name of the formulation used which equals to Chapman.
- **ET_type** Type of the estimation obtained which is Potential Evapotranspiration.
- **message1** A message to inform the users about how solar radiation has been calculated by using which data.
- **message5** A message to inform the users about if the Class-A pan evaporation is from actual data or from PenPan estimation.

**Author(s)**

Danlu Guo

**References**


See Also

`ET.processeddata, defaultconstants, constants, ET.PenPan`

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.ChapmanAustralian under the generic function ET
results <- ET.ChapmanAustralian(processeddata, constants, ts="daily", PenPan= TRUE, solar="sunshine hours", alpha=0.23, message="yes", AdditionalStats="yes", save.csv="no")
```

---

**ET.GrangerGray**  
**Granger-Gray Formulation**

Description

Implementing the Granger-Gray formulation for estimating actual areal evapotranspiration.

Usage

```r
## S3 method for class 'GrangerGray'
ET(data, constants, ts="daily", solar="sunshine hours", windfunction_ver=1948, alpha=0.23, message="yes", AdditionalStats="yes", save.csv="no", ...)
```

Arguments

- `data`  A list of data which contains the following items (climate variables) required by Granger-Gray formulation:
  - $T_{max}$, $T_{min}$ (degree Celcius), $RH_{max}$, $RH_{min}$ (per cent), $R_s$ (Megajoules per sqm) or $n$ (hour) or $C_d$ (okta), $u_2$ or $u_z$ (meter per second)

- `constants`  A list named constants consists of constants required for the calculation of Granger-Gray formulation which must contain the following items:
  - $E_{lev}$ - ground elevation above mean sea level in m,
  - $lambda$ - latent heat of vaporisation = 2.45 MJ.kg$^{-1}$,
  - $lat_{rad}$ - latitude in radians,
  - $G_{sc}$ - solar constant = 0.0820 MJ.m$^{-2}$.min$^{-1}$,
  - $z$ - height of wind instrument in m,
  - $sigma$ - Stefan-Boltzmann constant = 4.903*10$^{-9}$ MJ.K$^{-4}$.m$^{-2}$.day$^{-1}$.
  - $G$ - soil heat flux in MJ.m$^{-2}$.day$^{-1}$, = 0 when using daily time step.
The following constants are also required when argument solar has value of sunshine hours:

- **as** - fraction of extraterrestrial radiation reaching earth on sunless days,
- **bs** - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

**ts**
Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

**solar**
Must be either data, sunshine hours, cloud or monthly precipitation:  
- **data** indicates that solar radiation data is to be used directly for calculating evapotranspiration;  
- **sunshine hours** indicates that solar radiation is to be calculated using the real data of sunshine hours;  
- **cloud** sunshine hours is to be estimated from cloud data;  
- **monthly precipitation** indicates that solar radiation is to be calculated directly from monthly precipitation.  
Default is sunshine hours.

**windfunction_ver**
The version of Penman wind function that will be used within the Penman formulation. Must be either 1948 or 1956.  
- **1948** is for applying the Penman’s 1948 wind function (Penman, 1948);  
- **1956** is for applying the Penman’s 1956 wind function (Penman, 1956) Default is 1948.

**alpha**
Any numeric value between 0 and 1 (dimensionless), albedo of evaporative surface representing the portion of the incident radiation that is reflected back at the surface.  
Default is 0.23 for surface covered with short reference crop.

**message**
Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated  
- Evaporative surface with values of albedo  
- Option for calculating solar radiation (i.e. the value of argument solar)  
- The version of Penman wind function has been used (i.e. the value of argument windfunction_ver)  
- Time step of the output ET estimates (i.e. the value of argument ts)  
- Units of the output ET estimates  
- Time duration of the ET estimation  
- Number of ET estimates obtained in the entire time-series  
- Basic statistics of the estimated ET time-series including mean, max and min values.

**AdditionalStats**
"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

**save.csv**
Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

...  
Dummy for generic function, no need to define.
Details

The alternative calculation options can be selected through arguments `solar` and `windfunction_ver`, please see `Arguments` for details.
User-defined evaporative surface is allowed through argument `alpha`, please see `Arguments` for details.

Value

The function generates a list containing the following components:

- `ET.Annual`: Annually aggregated estimations of Granger-Gray actual areal evapotranspiration.
- `ET.AnnualAve`: Annually averaged estimations of daily Granger-Gray actual areal evapotranspiration.
- `ET_formulation`: Name of the formulation used which equals to Granger-Gray.
- `ET_type`: Type of the estimation obtained which is Actual Areal Evapotranspiration.
- `message1`: A message to inform the users about how solar radiation has been calculated by using which data.
- `message2`: A message to inform the users about which version of the Penman wind function has been used.

Author(s)

Danlu Guo

References


See Also

`ET.processeddata, defaultconstants, constants, ET.Penman`
Examples

# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.GrangerGray under the generic function ET
results <- ET.GrangerGray(processeddata, constants, ts="daily",
solar="sunshine hours", windfunction_ver=1948, alpha=0.23,
message="yes", AdditionalStats="yes", save.csv="no")

---

ET.Hamon

Hamon Formulation

Description

Implementing the Hamon formulation for estimating potential evapotranspiration.

Usage

```r
## S3 method for class 'Hamon'
ET(data, constants = NULL, ts="daily", message="yes", AdditionalStats="yes", save.csv="no", 
...)
```

Arguments

- **data**: A list of data which contains the following items (climate variables) required by Hamon formulation:
  - `Tmax`, `Tmin` (degree Celsius), `n` (hour)
- **constants**: Dummy argument with a NULL value.
- **ts**: Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.
- **message**: Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
  - ET model name and ET quantity estimated
  - Time step of the output ET estimates (i.e. the value of argument `ts`)
  - Units of the output ET estimates
  - Time duration of the ET estimation
  - Number of ET estimates obtained in the entire time-series
  - Basic statistics of the estimated ET time-series including `mean`, `max` and `min` values.
- **AdditionalStats**: "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.
- **save.csv**: Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.
- **...**: Dummy for generic function, no need to define.
Details

This formulation provides a single calculation method with no alternatives available.

Value

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of Hamon potential evapotranspiration.
- **ET.Monthly**: Monthly aggregated estimations of Hamon potential evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of Hamon potential evapotranspiration.
- **ET.MonthlyAve**: Monthly averaged estimations of daily Hamon potential evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily Hamon potential evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to Hamon.
- **ET_type**: Type of the estimation obtained which is Potential Evapotranspiration.

Author(s)

Danlu Guo

References


See Also

- ET.processeddata

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Hamon under the generic function ET
results <- ET.Hamon(processeddata, ts="daily", message="yes", AdditionalStats="yes", save.csv="no")
```
Description

Implementing the Hargreaves-Samani formulation for estimating reference crop evapotranspiration.

Usage

```r
## S3 method for class 'HargreavesSamani'
ET(data, constants, ts="daily", message="yes", AdditionalStats="yes", save.csv="no", ...)
```

Arguments

data: A list of data which contains the following items (climate variables) required by Hargreaves-Samani formulation: Tmax, Tmin (degree Celcius)

constants: A list named constants consists of constants required for the calculation of Hargreaves-Samani formulation which must contain the following items:
- Elev - ground elevation above mean sea level in m,
- lambda - latent heat of vaporisation = 2.45 MJ.kg^-1,
- lat_rad - latitude in radians,
- Gsc - solar constant = 0.0820 MJ.m^-2.min^-1.

ts: Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

message: Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated
- Evaporative surface with values of albedo
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

AdditionalStats: "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv: Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

Details

This formulation provides a single calculation method with no alternatives available.
Value

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of Hargreaves-Samani reference crop evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of Hargreaves-Samani reference crop evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily Hargreaves-Samani reference crop evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to Hargreaves-Samani.
- **ET_type**: Type of the estimation obtained which is Reference Crop Evapotranspiration.

Author(s)

Danlu Guo

References


See Also

- **ET.processeddata**, **defaultconstants**, **constants**

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.HargreavesSamani under the generic function ET
results <- ET.HargreavesSamani(processeddata, constants, ts="daily", message="yes", AdditionalStats="yes", save.csv="no")
```
**Jensen-Haise Formulation**

**Description**
Implementing the Jensen-Haise formulation for estimating potential evapotranspiration.

**Usage**

```r
## S3 method for class 'JensenHaise'
ET(data, constants, ts="daily", solar="sunshine hours", message="yes", AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

- `data` A list of data which contains the following items (climate variables) required by Jensen-Haise formulation: `Tmax`, `Tmin`, `Rs` or `n` or `Cd Tmax`, `Tmin` (degree Celsius), `Rs` (Megajoules per sqm) or `n` (hour) or `Cd` (okta).

- `constants` A list named `constants` consists of constants required for the calculation of Jensen-Haise formulation which must contain the following items:
  - `Elev` - ground elevation above mean sea level in m,
  - `lambda` - latent heat of vaporisation = 2.45 MJ.kg^{-1},
  - `lat_rad` - latitude in radians,
  - `Gsc` - solar constant = 0.0820 MJ.m^{-2}.min^{-1}. The following constants are also required when argument `solar` has value of `sunshine hours`:
  - `as` - fraction of extraterrestrial radiation reaching earth on sunless days,
  - `bs` - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

- `ts` Must be either `daily`, `monthly` or `annual`, which indicates the desired time step that the output ET estimates should be on. Default is `daily`.

- `solar` Must be either data, sunshine hours, cloud or monthly precipitation: `data` indicates that solar radiation data is to be used directly for calculating evapotranspiration; `sunshine hours` indicates that solar radiation is to be calculated using the real data of sunshine hours; `cloud` sunshine hours is to be estimated from cloud data; `monthly precipitation` indicates that solar radiation is to be calculated directly from monthly precipitation. Default is `sunshine hours`.

- `message` Must be either `yes` or `no`, indicating whether message should be printed for calculation summary including the following elements:
  - ET model name and ET quantity estimated
  - Option for calculating solar radiation (i.e. the value of argument `solar`)
- Time step of the output ET estimates (i.e. the value of argument \( \text{ts} \))
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including \( \text{mean} \), \( \text{max} \) and \( \text{min} \) values.

\text{AdditionalStats}
- "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

\text{save.csv}
- Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

\text{...}
- Dummy for generic function, no need to define.

\text{Details}
This formulation provides a single calculation method with no alternatives available.

\text{Value}
The function also generates a list containing the following components:

- \text{ET.Daily} Daily aggregated estimations of Jensen-Haise potential evapotranspiration.
- \text{ET.Monthly} Monthly aggregated estimations of Jensen-Haise potential evapotranspiration.
- \text{ET.Annual} Annually aggregated estimations of Jensen-Haise potential evapotranspiration.
- \text{ET.MonthlyAve} Monthly averaged estimations of daily Jensen-Haise potential evapotranspiration.
- \text{ET.AnnualAve} Annually averaged estimations of daily Jensen-Haise potential evapotranspiration.
- \text{ET_formulation} Name of the formulation used which equals to Jensen-Haise.
- \text{ET_type} Type of the estimation obtained which is Potential Evapotranspiration.

\text{Author(s)}
Danlu Guo

\text{References}


ET.Linacre

See Also

ET.processeddata, defaultconstants, constants

Examples

# Use processed existing data set and constants from Kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.JensenHaise under the generic function ET
results <- ET.JensenHaise(processeddata, constants, ts="daily", solar="sunshine hours", message="yes", AdditionalStats="yes", save.csv="no")

ET.Linacre

Linacre Formulation

Description

Implementing the Linacre formulation for estimating actual evapotranspiration.

Usage

## S3 method for class 'Linacre'
ET(data, constants, ts="daily", message="yes", AdditionalStats="yes", save.csv="no", ...)

Arguments

data A list of data which contains the following items (climate variables) required by Linacre formulation:
- Tmax, Tmin, Tdew (degree Celsius)

constants A list named constants consists of constants required for the calculation of Linacre formulation which must contain the following items:
- Elev - ground elevation above mean sea level in m,
- lat - latitude in degrees.

ts Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.
ET.Linacre

AdditionalStats

"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv

Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

Details

This formulation provides a single calculation method with no alternatives available.

Value

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of Linacre actual evapotranspiration.
- **ET.Monthly**: Monthly aggregated estimations of Linacre actual evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of Linacre actual evapotranspiration.
- **ET.MonthlyAve**: Monthly averaged estimations of daily Linacre actual evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily Linacre actual evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to Linacre.
- **ET_type**: Type of the estimation obtained which is Actual Evapotranspiration.

Author(s)

Danlu Guo

References


See Also

ET, processeddata, defaultconstants, constants

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Linacre under the generic function ET
results <- ET.Linacre(processeddata, constants, ts="daily",
message="yes", AdditionalStats="yes", save.csv="no")
```
**Description**

Implementing the Makkink formulation for estimating reference crop evapotranspiration.

**Usage**

```r
## S3 method for class 'Makkink'
ET(data, constants, ts="daily", solar="sunshine hours", message="yes", AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

- `data` A list of data which contains the following items (climate variables) required by Makkink formulation:
  - `Tmax`, `Tmin` (degree Celcius), `Rs` (Megajoules per sqm) or `n` (hour) or `Cd` (okta)

- `constants` A list named constants consists of constants required for the calculation of Makkink formulation which must contain the following items:
  - `Elev` - ground elevation above mean sea level in m,
  - `lambda` - latent heat of vaporisation = 2.45 MJ.kg^-1,
  - `lat_rad` - latitude in radians,
  - `Gsc` - solar constant = 0.0820 MJ.m^-2.min^-1.

  The following constants are also required when argument `solar` has value of sunshine hours:
  - `as` - fraction of extraterrestrial radiation reaching earth on sunless days,
  - `bs` - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

- `ts` Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

- `solar` Must be either data, sunshine hours, cloud or monthly precipitation:
  - data indicates that solar radiation data is to be used directly for calculating evapotranspiration;
  - sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
  - cloud sunshine hours is to be estimated from cloud data;
  - monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation.
  Default is sunshine hours.

- `message` Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
  - ET model name and ET quantity estimated
  - Option for calculating solar radiation (i.e. the value of argument solar)
  - Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

**AdditionalStats**

"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

**save.csv**

Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

...  

Dummy for generic function, no need to define.

**Details**

The alternative calculation options can be selected through argument `solar`, please see [Arguments](#) for details.

**Value**

The function generates a list containing the following components:

- **ET.Daily**  
  Daily aggregated estimations of Makkink reference crop evapotranspiration.
- **ET.Monthly**  
  Monthly aggregated estimations of Makkink reference crop evapotranspiration.
- **ET.Annual**  
  Annually aggregated estimations of Makkink reference crop evapotranspiration.
- **ET.MonthlyAve**  
  Monthly averaged estimations of daily Makkink reference crop evapotranspiration.
- **ET.AnnualAve**  
  Annually averaged estimations of daily Makkink reference crop evapotranspiration.
- **ET_formulation**  
  Name of the formulation used which equals to Makkink.
- **ET_type**  
  Type of the estimation obtained which is Reference crop evapotranspiration.
- **message1**  
  A message to inform the users about how solar radiation has been calculated by using which data.

**Author(s)**

Danlu Guo

**References**


See Also

\texttt{ET.processeddata.defaultconstants.constants}

Examples

\begin{verbatim}
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Makkink under the generic function ET
results <- ET.Makkink(processeddata, constants, ts="daily", solar="sunshine hours",
message="yes", AdditionalStats="yes", save.csv="no")
\end{verbatim}

---

\textbf{Description}

Implementing the Matt-Shuttleworth formulation for reference crop evapotranspiration

\textbf{Usage}

\begin{verbatim}
## S3 method for class 'MattShuttleworth'
ET(data, constants, ts="daily", solar="sunshine hours",
alpha=0.23, r_s=70, CH=0.12, message="yes", AdditionalStats="yes", save.csv="no", ...)
\end{verbatim}

\textbf{Arguments}

\begin{itemize}
\item \textbf{data} A list which contains the following items (climate variables) required by Matt-Shuttleworth formulation: \texttt{Tmax}, \texttt{Tmin} (degree Celcius), \texttt{RHmax}, \texttt{RHmin} (per cent), \texttt{Rs} (Megajoules per sqm) or \texttt{n} (hour) or \texttt{Cd} (okta), \texttt{u2} or \texttt{u2} (meter per second)
\item \textbf{constants} A list named constants consists of constants required for the calculation of Matt-Shuttleworth formulation which must contain the following items: \texttt{Elev} - ground elevation above mean sea level in m, \texttt{lambda} - latent heat of vaporisation = 2.45 MJ.kg^{-1}, \texttt{lat_rad} - latitude in radians, \texttt{Gsc} - solar constant = 0.0820 MJ.m^{-2}.min^{-1}, \texttt{z} - height of wind instrument in m, \texttt{sigma} - Stefan-Boltzmann constant = 4.903*10^{-9} MJ.K^{-4}.m^{-2}.day^{-1}, \texttt{Roua} - mean air density = 1.20 kg.m^{-3}, \texttt{Ca} - specific heat of air = 0.001013 MJ.kg^{-1}.oC^{-1}.
\end{itemize}

The following constants are also required when argument solar has value of sunshine hours:
as - fraction of extraterrestrial radiation reaching earth on sunless days,
bs - difference between fraction of extraterrestrial radiation reaching full-sun
days and that on sunless days.

ts  Must be either daily, monthly or annual, which indicates the desired time step
that the output ET estimates should be on. Default is daily.

solar  Must be either data, sunshine hours, cloud or monthly precipitation:
data indicates that solar radiation data is to be used directly for calculating evap-
transpiration;
sunshine hours indicates that solar radiation is to be calculated using the real
data of sunshine hours;
cloud sunshine hours is to be estimated from cloud data;
monthly precipitation indicates that solar radiation is to be calculated di-
rectly from monthly precipitation.
Default is sunshine hours.

alpha  Any numeric value between 0 and 1 (dimensionless), albedo of evaporative sur-
face representing the portion of the incident radiation that is reflected back at the
surface.
Default is 0.23 for surface covered with short reference crop, which is for the
calculation of Matt-Shuttleworth reference crop evaporation.

r_s  Any value (seconds per metre), surface resistance depends on the type of refer-
ence crop.
Default is 70 for short reference crop.

CH  Any value (metres), crop height depends on the reference crop.
Default is 0.12 for short reference crop.

message  Must be either yes or no, indicating whether message should be printed for
calculation summary including the following elements:
- ET model name and ET quantity estimated
- Evaporative surface with values of albedo, surface resistance and crop height
- Option for calculating solar radiation (i.e. the value of argument solar)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min
values.

AdditionalStats
"yes" or "no" indicating whether monthly averaged and annual averaged ET
should be calculated.

save.csv  Must be either yes or no, indicating whether a .csv of ET estimates should be
saved to working directory.

...  Dummy for generic function, no need to define.

Details
The alternative calculation options can be selected through argument solar, please see Arguments
for details.
User-defined evaporative surface is allowed through arguments alpha, r_s and CH, please see Arguments for details.

**Value**

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of Matt-Shuttleworth reference crop evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of Matt-Shuttleworth reference crop evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily Matt-Shuttleworth reference crop evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to *Matt-Shuttleworth*.
- **ET_type**: Type of the estimation obtained which is *Reference Crop Evapotranspiration*.
- **message1**: A message to inform the users about how solar radiation has been calculated by using which data.

**Author(s)**

Danlu Guo

**References**


**See Also**

- `ET.processeddata`, `defaultconstants`, `constants`

**Examples**

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.MattShuttleworth under the generic function ET
results <- ET.MattShuttleworth(processeddata, constants, ts="daily",
solar="sunshine hours", alpha=0.23, r_s=70, CH=0.12,
message="yes", AdditionalStats="yes", save.csv="no")
```
**Description**

Implementing the McGuinness-Bordne formulation for estimating potential evapotranspiration.

**Usage**

```r
## S3 method for class 'McGuinnessBordne'
ET(data, constants, ts="daily", message="yes",
    AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

- `data`: A list of data which contains the following items (climate variables) required by McGuinness-Bordne formulation: Tmax, Tmin (degree Celcius)
- `constants`: A list named constants consists of constants required for the calculation of Jensen-Haise formulation which must contain the following items: Elev - ground elevation above mean sea level in m, lambda - latent heat of vaporisation = 2.45 MJ.kg^-1, lat_rad - latitude in radians, Gsc - solar constant = 0.0820 MJ.m^-2.min^-1.
- `ts`: Must be either `daily`, `monthly` or `annual`, which indicates the desired time step that the output ET estimates should be on. Default is `daily`.
- `message`: Must be either `yes` or `no`, indicating whether message should be printed for calculation summary including the following elements: - ET model name and ET quantity estimated - Time step of the output ET estimates (i.e. the value of argument `ts`) - Units of the output ET estimates - Time duration of the ET estimation - Number of ET estimates obtained in the entire time-series - Basic statistics of the estimated ET time-series including mean, max and min values.
- `AdditionalStats`: "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.
- `save.csv`: Must be either `yes` or `no`, indicating whether a .csv of ET estimates should be saved to working directory.
- `...`: Dummy for generic function, no need to define.

**Details**

This formulation provides a single calculation method with no alternatives available.
ET.McGuinnessBordne

Value

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of McGuinness-Bordne potential evapotranspiration.
- **ET.Monthly**: Monthly aggregated estimations of McGuinness-Bordne potential evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of McGuinness-Bordne potential evapotranspiration.
- **ET.MonthlyAve**: Monthly averaged estimations of daily McGuinness-Bordne potential evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily McGuinness-Bordne potential evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to McGuinness-Bordne.
- **ET_type**: Type of the estimation obtained which is Potential Evapotranspiration.

Author(s)

Danlu Guo

References


See Also

- ET.processeddata, defaultconstants, constants

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.McGuinnessBordne under the generic function ET
results <- ET.McGuinnessBordne(processeddata, constants, ts="daily", message="yes", AdditionalStats="yes", save.csv="no")
```
Description

Implementing the Morton CRAE formulation for estimating potential evapotranspiration, wet-environment areal evapotranspiration and actual areal evapotranspiration.

Usage

```r
## S3 method for class 'MortonCRAE'
ET(data, constants, ts="monthly", est="potential ET", solar="sunshine hours", Tdew=T, alpha=NULL, message="yes", AdditionalStats="yes", save.csv="no", ...)
```

Arguments

data A list of data which contains the following items (climate variables) required by Morton CRAE formulation:
- `Tmax`, `Tmin`, `Tdew` (degree Celcius) or `va` or `RHmax` and `RHmin`, `Rs` (Megajoules per sqm) or `n` (hour) or `Cd` (okta)

constants A list named `constants` consists of constants required for the calculation of Morton CRAE formulation which must contain the following items:
- `Elev` - ground elevation above mean sea level in m,
- `lat_rad` - latitude in radians,
- `PA` - annual precipitation in mm, required when precipitation data is not available,
- `sigma` - Stefan-Boltzmann constant = 4.903*10^-9 MJ.K^-4.m^-2.day^-1,
- `lat` - latitude in degrees,
- `epsilonMo` - surface emissivity = 0.92 (Morton, 1986),
- `fz` - A constant in Morton’s procedure = 28.0 Wm^-2.mbar^-1 for T >= 0 degree Celcius, and = 28.0*1.15 Wm^-2.mbar^-1 for T >= 0 degree Celcius for CRAE model (Morton, 1983),
- `b0` - a constants in Morton’s procedure, = 1 for CRAE model (Morton, 1983),
- `b1` - a constant in Morton’s procedure, = 14 for CRAE model (Morton, 1983),
- `b2` - a constant in Morton’s procedure, = 1.2 for CRAE model (Morton, 1983),
- `gammaps` - Produce of Psychrometric constant and atmospheric pressure as sea level, = 0.66 mbar. degree Celcius^-1 for T >= 0 degree Celcius, = 0.66/1.15 mbar. degree Celcius^-1 for T < 0 degree Celcius (Morton, 1983),
- `alphaMo` - a constant in Morton’s procedure, = 17.27 when T >= 0 degree Celcius, = 21.88 when T < 0 degree Celcius (Morton, 1983),
- `betaMo` - a constant in Morton’s procedure, = 237.3 degree Celcius when T >= 0 degree Celcius, = 265.5 degree Celcius, when T < 0 degree Celcius (Morton, 1983),
- `sigmaMo` - Stefan-Boltzmann constant in Morton’s procedure, = 5.67e-08 W.m^-2.K^-4 (Morton, 1983),
$\lambda_{Mo}$ - Latent heat of vaporisation in Morton’s procedure, = 28.5 W.day kg$^{-1}$ when $T \geq 0$ degree Celsius, = 28.5*$1.15$ W.day kg$^{-1}$ when $T < 0$ degree Celsius.

**ts**
Must be either monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is monthly.

**solar**
Must be either data, sunshine hours, cloud or monthly precipitation:
data indicates that solar radiation data is to be used directly for calculating evapotranspiration;
sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
cloud sunshine hours is to be estimated from cloud data;
monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation.
Default is sunshine hours.

**est**
Must be either potential ET, wet areal ET or actual areal ET:
potential ET proceeds to estimating potential evapotranspiration;
wet areal ET proceeds to estimating wet-environmental areal evapotranspiration;
actual areal ET proceeds to estimating actual areal evapotranspiration.
Default is potential ET.

**Tdew**
Must be T or F, indicating if real data of dew point temperature is used for calculating the radiation in Morton’s formulations, if T the data will be used and if F the dew point temperature will be calculated from data of daily vapour pressure. Default is T for using actual dew point temperature data.

**alpha**
Only needed if argument solar has value of data.
Any numeric value between 0 and 1 (dimensionless), albedo of evaporative surface representing the portion of the incident radiation that is reflected back at the surface.
Default is NULL in line with the default use of sunshine hours to estimate solar radiation (i.e. argument solar is sunshine hours).

**message**
Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated (i.e. the value of argument est)
- Option for calculating solar radiation (i.e. the value of argument solar)
- If the actual dew point temperature data are used (i.e. the value of argument Tdew)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

**AdditionalStats**
"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.
save.csv  Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

...  Dummy for generic function, no need to define.

Details

The type of evapotranspiration calculated can be selected through argument est, please see Arguments for details. The alternative calculation options can be selected through argument solar and Tdew, please see Arguments for details.

Value

The function generates a list containing the following components:

ET.Daily  Daily aggregated estimations of Morton CRAE potential evapotranspiration, wet-environment areal evapotranspiration or actual areal evapotranspiration.

ET.Monthly  Monthly aggregated estimations of Morton CRAE potential evapotranspiration, wet-environment areal evapotranspiration or actual areal evapotranspiration.

ET.Annual  A zoo object containing annually aggregated estimations of Morton CRAE potential evapotranspiration, wet-environment areal evapotranspiration or actual areal evapotranspiration.

ET.MonthlyAve  A zoo object containing monthly averaged estimations of daily Morton CRAE potential evapotranspiration, wet-environment areal evapotranspiration or actual areal evapotranspiration.

ET.AnnualAve  A zoo object containing annually averaged estimations of daily Morton CRAE potential evapotranspiration, wet-environment areal evapotranspiration or actual areal evapotranspiration.

ET_formulation  Name of the formulation used which equals to MortonCRAE.

ET_type  Type of the estimation obtained which is either Potential Evapotranspiration, Wet-environment Areal Evapotranspiration and Actual Areal Evapotranspiration.

message1  A message to inform the users about how solar radiation has been calculated by using which data.

message6  A message to inform the users about if actual dew point temperature has been used in the calculations or alternative calculations has been performed without dew point temperature data.

Author(s)

Danlu Guo

References


ET.MortonCRWE

Morton CRWE Formulation

Description

Implementing the Morton CRWE formulation for estimating potential evapotranspiration or shallow lake evaporation.

Usage

```r
## S3 method for class 'MortonCRWE'
ET(data, constants, ts="monthly", est="potential ET", solar="sunshine hours", Tdew= TRUE, alpha = NULL, message="yes", AdditionalStats="yes", save.csv="no", ...)"'
```

Arguments

data: A list of data which contains the following items (climate variables) required by Morton CRWE formulation:
- Tmax, Tmin, Tdew (degree Celcius) or va or RHmax and RHmin, Rs (Megajoules per sqm) or n (hour) or Cd (okta)

constants: A list named constants consists of constants required for the calculation of Morton CRWE formulation which must contain the following items:
- Elev - ground elevation above mean sea level in m,
- lat_rad - latitude in radians,
- PA - annual precipitation in mm, required when precipitation data is not available,
- sigma - Stefan-Boltzmann constant = 4.903*10^-9 MJ.K^-4.m^-2.day^-1,
- lat - latitude in degrees,
- epsilonMo - surface emissivity = 0.92 (Morton, 1986),
- fz - A constant in Morton’s procedure = 25.0 Wm^-2.mbar^-1 for T >= 0 degree Celcius, and = 28.75 Wm^-2.mbar^-1 for T >= 0 degree Celcius for CRWE
model (Morton, 1986),
b0 - A constant in Morton’s procedure, = 1.12 for CRWE model (Morton, 1986)
b1 - A constant in Morton’s procedure, = 13 for CRWE model (Morton, 1986),
b2 - A constant in Morton’s procedure, = 1.12 for CRWE model (Morton, 1986),
gamma_{ps} - Produce of Psychrometric constant and atmospheric pressure as sea level, = 0.66 mbar. degree Celsius^-1 for T >= 0 degree Celsius, = 0.66/1.15 mbar. degree Celsius^-1 for T < 0 degree Celsius (Morton, 1983),
alpha_{Mo} - a constant in Morton’s procedure, = 17.27 when T >= 0 degree Celcius, = 21.88 when T < 0 degree Celcius (Morton, 1983),
beta_{Mo} - a constant in Morton’s procedure, = 237.3 degree Celcius when T >= 0 degree Celcius, = 265.5 degree Celcius, when T < 0 degree Celcius (Morton, 1983),
sigma_{Mo} - Stefan-Boltzmann constant in Morton’s procedure, = 5.67e-08 W.m^-2.K^-4 (Morton, 1983),
lambda_{Mo} - Latent heat of vaporisation in Morton’s procedure, = 28.5W.day.kg^-1 when T >= 0 degree Celcius, = 28.5*1.15W.day.kg^-1 when T < 0 degree Celcius,

ts Must be either monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is monthly.
solar Must be either data, sunshine hours, cloud or monthly precipitation:
data indicates that solar radiation data is to be used directly for calculating evapotranspiration;
sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
cloud sunshine hours is to be estimated from cloud data;
monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation.
Default is sunshine hours.
est Must be either potential ET or shallow lake ET:
potential ET proceeds to estimating potential evapotranspiration;
shallow lake ET proceeds to estimating shallow lake evaporation.
Default is potential ET.
T_dew Must be T or F, indicating if real data of dew point temperature is used for calculating the radiation in Morton’s formulations, if T the data will be used and if F the dew point temperature will be calculated from data of daily vapour pressure. Default is T for using actual dew point temperature data.
alpha Only needed if argument solar has value of data.
Any numeric value between 0 and 1 (dimensionless), albedo of evaporative surface representing the portion of the incident radiation that is reflected back at the surface.
Default is NULL in line with the default use of sunshine hours to estimate solar radiation (i.e. argument solar is sunshine hours).
message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
ET.MortonCRWE

- ET model name and ET quantity estimated (i.e. the value of argument est)
- Option for calculating solar radiation (i.e. the value of argument solar)
- If the actual dew point temperature data are used (i.e. the value of argument Tdew)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

**AdditionalStats**
"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

**save.csv**
Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

**Details**
The type of evapotranspiration calculated can be selected through argument est, please see Arguments for details. The alternative calculation options can be selected through argument solar and Tdew, please see Arguments for details.

**Value**
The function generates a list containing the following components:

- **ET.Daily**
  Daily aggregated estimations of MortonCRWE potential evapotranspiration or shallow lake evaporation.
- **ET.Monthly**
  Monthly aggregated estimations of MortonCRWE potential evapotranspiration or shallow lake evaporation.
- **ET.Annual**
  Annually aggregated estimations of MortonCRWE potential evapotranspiration or shallow lake evaporation.
- **ET.MonthlyAve**
  Monthly averaged estimations of daily MortonCRWE potential evapotranspiration or shallow lake evaporation.
- **ET.AnnualAve**
  Annually averaged estimations of daily MortonCRWE potential evapotranspiration or shallow lake evaporation.
- **ET_formulation**
  Name of the formulation used which equals to MortonCRWE.
- **ET_type**
  Type of the estimation obtained which is either Potential Evapotranspiration or Shallow Lake Evaporation.
- **message1**
  A message to inform the users about how solar radiation has been calculated by using which data.
- **message6**
  A message to inform the users about if actual dew point temperature has been used in the calculations or alternative calculations has been performed without dew point temperature data.
Author(s)

Danlu Guo

References


See Also

processeddata, defaultconstants, constants, ET.MortonCRWE

Examples

# Use processed existing data set and constants from
# kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.MortonCRWE under the generic function ET
results <- ET.MortonCRWE(processeddata, constants, ts="monthly",
est="potential ET", solar="sunshine hours", Tdew= TRUE,
alpha = NULL, message="yes", AdditionalStats="yes", save.csv="no")

ET.Penman

Penman Formulation

Description

Implementing the Penman formulation for estimating open-water evaporation or potential evapotranspiration

Usage

## S3 method for class 'Penman'
ET(data, constants, ts="daily", solar="sunshine hours",
wind="yes", windfunction_ver=1948, alpha=0.08, z0=0.001, message="yes",
AdditionalStats="yes", save.csv="no", ...)
Arguments

data  A list which contains the following items (climate variables) required by Penman formulation:
  Tmax, Tmin, RHmax, RHmin, Rs or n or Cd, u2 or uz

constants  A list named constants consists of constants required for the calculation of Penman formulation which must contain the following items:
  Elev - ground elevation above mean sea level in m,
  lambda - latent heat of vaporisation = 2.45 MJ.kg^-1,
  lat_rad - latitude in radians,
  Gsc - solar constant = 0.0820 MJ.m^-2.min^-1,
  z - height of wind instrument in m,
  sigma - Stefan-Boltzmann constant = 4.903*10^-9 MJ.K^-4.m^-2.day^-1.

The following constants are also required when argument solar has value of sunshine hours:
  as - only for when cloud data is used for calculating radiation i.e. solar = "cloud"
  - fraction of extraterrestrial radiation reaching earth on sunless days,
  bs - only for when cloud data is used for calculating radiation i.e. solar = "cloud"
  - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

ts  Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

solar  Must be either data, sunshine hours, cloud or monthly precipitation:
  data indicates that solar radiation data is to be used directly for calculating evapotranspiration;
  sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
  cloud sunshine hours is to be estimated from cloud data;
  monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation.
  Default is sunshine hours.

wind  Must be either yes or no.
  yes indicates that the calculation will use real data of wind speed;
  no indicates that the alternative calculation without using wind data will be used in Penman formulation (Valiantzas 2006, Equation33).
  Default is yes.

windfunction_ver  The version of Penman wind function that will be used within the Penman formulation. Must be either 1948 or 1956.
  1948 is for applying the Penman’s 1948 wind function (Penman, 1948);
  1956 is for applying the Penman’s 1956 wind function (Penman, 1956) Default is 1948.

alpha  Any numeric value between 0 and 1 (dimensionless), albedo of evaporative surface representing the portion of the incident radiation that is reflected back at the surface.
  Default is 0.08 for open-water surface which is for the calculation of Penman
open-water evaporation, all other values will trigger the calculation of Penman potential evapotranspiration.

\( z_0 \)  
Any value (metres), roughness height of the evaporative surface. Default is 0.001 for open-water surface which is for the calculation of Penman open-water evaporation, all other values will trigger the calculation of Penman potential evapotranspiration.

message  
Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated
- Evaporative surface with values of albedo and roughness height
- Option for calculating solar radiation (i.e. the value of argument solar)
- If actual wind data has been used for calculation (i.e. the value of argument wind) and which version of Penman wind function has been used (i.e. the value of argument windfunction_ver)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values

AdditionalStats  
"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv  
Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

...  
Dummy for generic function, no need to define.

Details

The alternative calculation options can be selected through arguments solar, wind and windfunction_ver, please see Arguments for details.

User-defined evaporative surface is allowed through arguments alpha and z0, please see Arguments for details.

Value

The function generates a list containing the following components:

ET.Daily  
Daily aggregated estimations of Penman open-water evaporation or potential evapotranspiration.

ET.Monthly  
Monthly aggregated estimations of Penman open-water evaporation or potential evapotranspiration.

ET.Annual  
Annually aggregated estimations of Penman open-water evaporation or potential evapotranspiration.

ET.MonthlyAve  
Monthly averaged estimations of daily Penman open-water evaporation or potential evapotranspiration.
ET.Penman

**ET.AnnualAve**  Annually averaged estimations of daily Penman open-water evaporation or potential evapotranspiration.

**ET_formulation**  Name of the formulation used which equals to Penman.

**ET_type**  Type of the estimation obtained which is either Open-water Evaporation or Potential Evapotranspiration.

**message1**  A message to inform the users about how solar radiation has been calculated by using which data.

**message2**  A message to inform the users about if actual wind data has been used in the calculations or alternative calculations has been performed without wind data, and which version of the Penman wind function has been used.

**Author(s)**

Danlu Guo

**References**


**See Also**

ET,processeddata,defaultconstants,constants

**Examples**

```r
# Use processed existing data set and constants from
# kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Penman under the generic function ET
results <- ET.Penman(processeddata, constants, ts="daily",
solar="sunshine hours", wind="yes",
windfunction_ver = "1948", alpha = 0.08, z0 = 0.001,
message="yes", AdditionalStats="yes", save.csv="no")
```
ET.PenmanMonteith  

**Penman-Monteith Formulation**

**Description**

Implementing the Penman-Monteith formulation (including the method for FAO-56 hypothetical short grass and the method for ASCE-EWRI Standardised crop) for estimating reference crop evapotranspiration

**Usage**

```r
## S3 method for class 'PenmanMonteith'
ET(data, constants, ts="daily", solar="sunshine hours", wind="yes", crop="short", message="yes", AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

- **data**: A list which contains the following items (climate variables) required by Penman-Monteith formulation: 
  - `Tmax`, `Tmin`, `RHmax`, `RHmin`, `Rs` or `n` or `Cd`, `u2` or `uz`

- **constants**: A list named `constants` consists of constants required for the calculation of Penman-Monteith formulation which must contain the following items:
  - `Elev` - ground elevation above mean sea level in m,
  - `lambda` - latent heat of vaporisation = 2.45 MJ.kg^-1,
  - `lat_rad` - latitude in radians,
  - `Gsc` - solar constant = 0.0820 MJ.m^-2.min^-1,
  - `z` - height of wind instrument in m,
  - `sigma` - Stefan-Boltzmann constant = 4.903*10^-9 MJ.K^-4.m^-2.day^-1.
  - `G` - soil heat flux in MJ.m^-2.day^-1, = 0 when using daily time step.

  The following constants are also required when argument `solar` has value of `sunshine hours`:
  - `as` - only for when cloud data is used for calculating radiation i.e. `solar = "cloud"`
  - `bs` - only for when cloud data is used for calculating radiation i.e. `solar = "cloud"`

- **ts**: Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

- **solar**: Must be either data, sunshine hours, cloud or monthly precipitation: 
  - `data` indicates that solar radiation data is to be used directly for calculating evapotranspiration; 
  - `sunshine hours` indicates that solar radiation is to be calculated using the real data of sunshine hours; 
  - `cloud` sunshine hours is to be estimated from cloud data; 
  - `monthly precipitation` indicates that solar radiation is to be calculated directly from monthly precipitation. 

  Default is sunshine hours.
wind Must be either yes or no. 
  yes indicates that the calculation will use real data of wind speed;  
  no indicates that the alternative calculation without using wind data will be used  
  in Penman formulation (Valiantzas 2006, Equation33).  
  Default is yes.

crop Must be either short or tall.  
  short indicates that the method for FAO-56 hypothetical short grass will be applied (Allen et al., 1998, Equation 6);  
  tall indicates that the method for ASCE-EWRI Standardised crop will be applied (ASCE, 2005, Equation 1, Table 1).  
  Default is short.

message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:  
- ET model name and ET quantity estimated  
- Evaporative surface with values of albedo, surface resistance, crop height and roughness height  
- Option for calculating solar radiation (i.e. the value of argument solar)  
- If actual wind data has been used for calculation (i.e. the value of argument wind)  
- Time step of the output ET estimates (i.e. the value of argument ts)  
- Units of the output ET estimates  
- Time duration of the ET estimation  
- Number of ET estimates obtained in the entire time-series  
- Basic statistics of the estimated ET time-series including mean, max and min values.

AdditionalStats "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

Details  
The alternative calculation options can be selected through arguments solar and wind, please see Arguments for details.  
User-defined evaporative surface is allowed through arguments crop, please see Arguments for details.

Value  
The function generates a list containing the following components:


**ET.PenmanMonteith**

ET.Annual  Annually aggregated estimations of Penman-Monteith reference crop evapotranspiration.


ET.AnnualAve  Annually averaged estimations of daily Penman-Monteith reference crop evapotranspiration.

ET_formulation  Name of the formulation used which equals to either Penman-Monteith FAO56 or Penman-Monteith ASCE-EWRI Standardised.

ET_type  A character string containing the type of the estimation obtained which is Reference Crop Evapotranspiration.

message1  A message to inform the users about how solar radiation has been calculated by using which data.

message2  A message to inform the users about if actual wind data has been used in the calculations or alternative calculations has been performed without wind data.

Author(s)
Danlu Guo

References


See Also
ET.processeddata, defaultconstants, constants

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.PenmanMonteith under the generic function ET
results <- ET.PenmanMonteith(processeddata, constants, ts="daily", solar="sunshine hours", wind="yes", crop = "short", message="yes", AdditionalStats="yes", save.csv="no")
```
**ET.PenPan**

*PenPan Formulation*

---

**Description**

Implementing the PenPan formulation for Class-A pan evaporation.

**Usage**

```r
## S3 method for class 'PenPan'
ET(data, constants, ts="daily", solar="sunshine hours",
    alpha=0.23, est="potential ET", pan_coeff=0.71, overest= F, message="yes",
    AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

- **data**
  A list of data which contains the following items (climate variables) required by PenPan formulation:
  - $T_{max}$, $T_{min}$ (degree Celcius), $RH_{max}$, $RH_{min}$ (per cent), $R_s$ (Megajoules per sqm) or $n$ (hour) or $Cd$ (okta), $u_2$ or $u_z$ (meter per second)

- **constants**
  A list named constants consists of constants required for the calculation of PenPan formulation which must contain the following items:
  - $Elev$ - ground elevation above mean sea level in m,
  - $lambda$ - latent heat of vaporisation = 2.45 MJ.kg$^{-1}$,
  - $lat_{rad}$ - latitude in radians,
  - $G_{sc}$ - solar constant = 0.0820 MJ.m$^{-2}$.min$^{-1}$,
  - $z$ - height of wind instrument in m,
  - $sigma$ - Stefan-Boltzmann constant = 4.903*10$^{-9}$ MJ.K$^{-4}$.m$^{-2}$.day$^{-1}$,
  - $lat$ - latitude in degrees,
  - $alpha_A$ - albedo for Class-A pan,
  - $ap$ - a constant in PenPan = 2.4.

The following constants are also required when argument solar has value of sunshine hours:
- $as$ - fraction of extraterrestrial radiation reaching earth on sunless days,
- $bs$ - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

- **ts**
  Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

- **solar**
  Must be either data, sunshine hours, cloud or monthly precipitation:
  - data indicates that solar radiation data is to be used directly for calculating evapotranspiration;
  - sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
  - cloud sunshine hours is to be estimated from cloud data;
monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation. Default is sunshine hours.

**alpha**

Any numeric value between 0 and 1 (dimensionless), albedo of surface surrounding the evaporation pan representing the portion of the incident radiation that is reflected back at the surface. Default is 0.23 for surface covered with short reference crop.

**overest**

Must be T or F, indicating if adjustment for the overestimation (i.e. divided by 1.078) of Class-A pan evaporation for Australian data is applied in PenPan formulation. Default is F for no adjustment.

**est**

Must be either pan or potential ET to specify if estimation for the Class-A pan evaporation or potential evapotranspiration is performed. Default is potential ET for estimating potential evapotranspiration.

**pan_coeff**

Only required if argument est has value of potential ET, which defines the pan coefficient used to adjust the estimated pan evaporation to the potential ET required.

**message**

Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:

- ET model name and ET quantity estimated (i.e. the value of argument est), and the value of pan coefficient (only for when potential ET is estimated)
- Evaporative surface with values of albedo
- Option for calculating solar radiation (i.e. the value of argument solar)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

**AdditionalStats**

"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

**save.csv**

Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

**Details**

The alternative calculation options can be selected through argument solar, please see Arguments for details.

User-defined evaporative surface is allowed through argument alpha, please see Arguments for details.

Adjustment for overestimation on the estimations are available through argument height, please see Arguments for details.
Value
The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of PenPan Class-A pan evaporation/potential evapotranspiration.
- **ET.Monthly**: Monthly aggregated estimations of PenPan Class-A pan evaporation/potential evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of PenPan Class-A pan evaporation/potential evapotranspiration.
- **ET.MonthlyAve**: Monthly averaged estimations of daily PenPan Class-A pan evaporation/potential evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily PenPan Class-A pan evaporation/potential evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to PenPan.
- **ET_type**: Type of the estimation obtained which is Class-A Pan Evaporation or Potential Evapotranspiration depending on the value of est.
- **message1**: A message to inform the users about how solar radiation has been calculated by using which data.

Author(s)
Danlu Guo

References

See Also
*ET*, *processeddata*, *defaultconstants*, *constants*

Examples

```
# Use processed existing data set and constants from
# kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.PenPan under the generic function ET
results <- ET.PenPan(processeddata, constants, ts="daily",
solar="sunshine hours", alpha=0.23,
est="potential ET", pan_coeff=0.71, overest= FALSE,
message="yes", AdditionalStats="yes", save.csv="no")
```
**Priestley-Taylor Formulation**

**Description**

Implementing the Priestley-Taylor formulation for potential evaporation

**Usage**

```r
## S3 method for class 'PriestleyTaylor'
ET(data, constants, ts="daily", solar="sunshine hours", alpha=0.23,
    message="yes", AdditionalStats="yes", save.csv="no", ...)
```

**Arguments**

- **data**
  A list which contains the following items (climate variables) required by Priestley-Taylor formulation:
  - `Tmax`, `Tmin` (degree Celsius), `RHmax`, `RHmin` (per cent), `Rs` (MegaJoules per sqm) or `n` (hour) or `Cd` (okta)

- **constants**
  A list named `constants` consists of constants required for the calculation of Priestley-Taylor formulation which must contain the following items:
  - `Elev` - ground elevation above mean sea level in m,
  - `lambda` - latent heat of vaporisation = 2.45 MJ.kg^-1,
  - `lat_rad` - latitude in radians,
  - `Gsc` - solar constant = 0.0820 MJ.m^-2.min^-1,
  - `sigma` - Stefan-Boltzmann constant = 4.903*10^-9 MJ.K^-4.m^-2.day^-1,
  - `alphaPT` - Priestley-Taylor coefficient = 1.26 for Priestley-Taylor model (Priestley and Taylor, 1972)
  - `G` - soil heat flux in MJ.m^-2.day^-1, = 0 when using daily time step.

The following constants are also required when argument `solar` has value of sunshine hours:
- `as` - fraction of extraterrestrial radiation reaching earth on sunless days,
- `bs` - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.

- **ts**
  Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

- **solar**
  Must be either data, sunshine hours, cloud or monthly precipitation:
  - data indicates that solar radiation data is to be used directly for calculating evapotranspiration;
  - sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours;
  - cloud sunshine hours is to be estimated from cloud data;
  - monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation.
  Default is sunshine hours.
alpha

Any numeric value between 0 and 1 (dimensionless), albedo of evaporative surface representing the portion of the incident radiation that is reflected back at the surface. Default is 0.23 for surface covered with short reference crop, which is for the calculation of Priestly-Taylor reference crop evaporation.

message

Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated
- Evaporative surface with values of albedo
- Option for calculating solar radiation (i.e. the value of argument solar)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

AdditionalStats

"yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv

Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

Details

The alternative calculation options can be selected through argument solar, please see Arguments for details.
User-defined evaporative surface is allowed through argument alpha, please see Arguments for details.

Value

The function generates a list containing the following components, which is saved into a csv file named as ETPriestleyTaylor.csv in the working directory:

ET.Daily
Daily aggregated estimations of Priestley-Taylor potential evaporation.

ET.Monthly
Monthly aggregated estimations of Priestley-Taylor potential evaporation.

ET.Annual
Annually aggregated estimations of Priestley-Taylor potential evaporation.

ET.MonthlyAve
Monthly averaged estimations of daily Priestley-Taylor potential evaporation.

ET.AnnualAve
Annually averaged estimations of daily Priestley-Taylor potential evaporation.

ET_formulation
A character string containing the name of the formulation used which equals to Priestley-Taylor.

ET_type
Type of the estimation obtained which is Potential Evaporation.

message1
A message to inform the users about how solar radiation has been calculated by using which data.
Author(s)
Danlu Guo

References


See Also
ET, processeddata, defaultconstants, constants

Examples

```r
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.PriestleyTaylor under the generic function ET
results <- ET.PriestleyTaylor(processeddata, constants, ts="daily",
solar="sunshine hours", alpha=0.23, message="yes", AdditionalStats="yes", save.csv="no")
```

Description
Implementing the Romanenko formulation for estimating potential evapotranspiration.

Usage
```r
## S3 method for class 'Romanenko'
ET(data, constants = NULL, ts="daily",
message="yes", AdditionalStats="yes", save.csv="no", ...)
```

Arguments

data A list of data which contains the following items (climate variables) required by Romanenko formulation: Tmax, Tmin (degree Celsius), RHmax, RHmin (per cent)

constants Dummy argument with a NULL value.

ts Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.
message  Must be either yes or no, indicating whether message should be printed for
calculation summary including the following elements:
- ET model name and ET quantity estimated
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min
  values.

AdditionalStats  "yes" or "no" indicating whether monthly averaged and annual averaged ET
should be calculated.

save.csv  Must be either yes or no, indicating whether a .csv of ET estimates should be
saved to working directory.

...  Dummy for generic function, no need to define.

Details

This formulation provides a single calculation method with no alternatives available.

Value

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of Romanenko potential evapotranspiration.
- **ET.Monthly**: Monthly aggregated estimations of Romanenko potential evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of Romanenko potential evapotranspiration.
- **ET.MonthlyAve**: Monthly averaged estimations of daily Romanenko potential evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily Romanenko potential evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to Romanenko.
- **ET_type**: Type of the estimation obtained which is Potential Evapotranspiration.

Author(s)

Danlu Guo

References

*Which potential evapotranspiration input for a lumped rainfall-runoff model?*: Part 2-Towards a
simple and efficient potential evapotranspiration model for rainfall-runoff modelling. Journal of

See Also

ET.processeddata
ET.SzilagyiJozsa

Examples

# Use processed existing data set and constants from Kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Romanenko under the generic function ET
results <- ET.Romanenko(processeddata, ts="daily", message="yes",
AdditionalStats="yes", save.csv="no")

ET.SzilagyiJozsa

Szilagyi-Jozsa Formulation

Description

Implementing the Szilagyi-Jozsa formulation for estimating actual evapotranspiration

Usage

## S3 method for class 'SzilagyiJozsa'

ET(data, constants, ts="daily", solar="sunshine hours", wind="yes",
windfunction_ver=1948, alpha=0.23, z0=0.2, message="yes", AdditionalStats="yes",
save.csv="no", ...)

Arguments

data A list of data which contains the following items (climate variables) required by
Szilagyi-Jozsa formulation:
Tmax, Tmin (degree Celcius), RHmax, RHmin (per cent), Rs (Megajoules per
sqm) or n (hour) or Cd (okta), u2 or uz (meter per second)

constants A list named constants consists of constants required for the calculation of
Szilagyi-Jozsa formulation which must contain the following items:
Elev - ground elevation above mean sea level in m,
lambda - latent heat of vaporisation = 2.45 MJ.kg^-1,
lat_rad - latitude in radians,
Gsc - solar constant = 0.0820 MJ.m^-2.min^-1,
z - height of wind instrument in m,
sigma - Stefan-Boltzmann constant = 4.903*10^-9 MJ.K^-4.m^-2.day^-1.

The following constants are also required when argument solar has value of
sunshine hours:
as - fraction of extraterrestrial radiation reaching earth on sunless days,
bs - difference between fraction of extraterrestrial radiation reaching full-sun
days and that on sunless days.

ts Must be either daily, monthly or annual, which indicates the desired time step
that the output ET estimates should be on. Default is daily.
solar Must be either data, sunshine hours, cloud or monthly precipitation: data indicates that solar radiation data is to be used directly for calculating evapotranspiration; sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours; cloud sunshine hours is to be estimated from cloud data; monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation. Default is sunshine hours.

wind Must be either yes or no. yes indicates that the calculation will use real data of wind speed; no indicates that the alternative calculation without using wind data will be used in Penman formulation (Valiantzas 2006, Equation33), which is required in the Szilagyi-Jozsa model. Default is yes.

windfunction_ver The version of Penman wind function that will be used within the Penman formulation. Must be either 1948 or 1956. 1948 is for applying the Penman’s 1948 wind function (Penman, 1948); 1956 is for applying the Penman’s 1956 wind function (Penman, 1956) Default is 1948.

alpha Any numeric value between 0 and 1 (dimensionless), albedo of evaporative surface representing the portion of the incident radiation that is reflected back at the surface. Default is 0.23 for short reference crop.

z0 Any value (metres), roughness height of the evaporative surface. Default is 0.23 for short reference crop.

message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements: - ET model name and ET quantity estimated - Evaporative surface with values of albedo, as well as the roughness height - Option for calculating solar radiation (i.e. the value of argument solar) - If actual wind data has been used for calculation (i.e. the value of argument wind) and which version of Penman wind function has been used (i.e. the value of argument windfunction_ver) - Time step of the output ET estimates (i.e. the value of argument ts) - Units of the output ET estimates - Time duration of the ET estimation - Number of ET estimates obtained in the entire time-series - Basic statistics of the estimated ET time-series including mean, max and min values.

AdditionalStats "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.
Details

The alternative calculation options can be selected through arguments `solar`, `wind` and `windfunction_ver`, please see Arguments for details.
User-defined evaporative surface is allowed through arguments `alpha` and `z0`, please see Arguments for details.

Value

The function generates a list containing the following components:

- **ET.Daily**: Daily aggregated estimations of Szilagyi-Jozsa actual evapotranspiration.
- **ET.Monthly**: Monthly aggregated estimations of Szilagyi-Jozsa actual evapotranspiration.
- **ET.Annual**: Annually aggregated estimations of Szilagyi-Jozsa actual evapotranspiration.
- **ET.MonthlyAve**: Monthly averaged estimations of daily Szilagyi-Jozsa actual evapotranspiration.
- **ET.AnnualAve**: Annually averaged estimations of daily Szilagyi-Jozsa actual evapotranspiration.
- **ET_formulation**: Name of the formulation used which equals to Szilagyi-Jozsa.
- **ET_type**: A character string containing the type of the estimation obtained which is Actual Evapotranspiration.
- **message1**: A message to inform the users about how solar radiation has been calculated by using which data.
- **message2**: A message to inform the users about if actual wind data has been used in the calculations or alternative calculations has been performed without wind data, and which version of the Penman wind function has been used.

Author(s)

Danlu Guo

References


See Also

ET.processeddata, defaultconstants, constants, ET.Penman

Examples

# Use processed existing data set and constants from Kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.SzilagyiJozsa under the generic function ET
results <- ET.SzilagyiJozsa(processeddata, constants, ts="daily",
solar="sunshine hours", wind="yes", windfunction_ver=1948, alpha=0.23, z0=0.2,
message="yes", AdditionalStats="yes", save.csv="no")

---

**ET.Turc**

**Turc Formulation**

Description

Implementing the Turc formulation for estimating reference crop evapotranspiration.

Usage

```r
## S3 method for class 'Turc'
ET(data, constants, ts="daily", solar="sunshine hours", humid= F,
message="yes", AdditionalStats="yes", save.csv="no", ...)
```

Arguments

data A list of data which contains the following items (climate variables) required by Turc formulation:
- $T_{max}, T_{min}$ (degree Celcius),
- $R_s$ (Megajoules per sqm) or $n$ (hour) or $C_d$ (okta)

constants A list named constants consists of constants required for the calculation of Turc formulation which must contain the following items:
- $E_{lev}$ - ground elevation above mean sea level in m,
- $\lambda$ - latent heat of vaporisation = 2.45 MJ.kg^{-1},
- $lat_{rad}$ - latitude in radians,
- $G_{sc}$ - solar constant = 0.0820 MJ.m^{-2}.min^{-1},
- $\sigma$ - Stefan-Boltzmann constant = 4.903*10^{-9} MJ.K^{-4}.m^{-2}.day^{-1}.

The following constants are also required when argument solar has value of sunshine hours:
- $as$ - fraction of extraterrestrial radiation reaching earth on sunless days,
- $bs$ - difference between fraction of extraterrestrial radiation reaching full-sun days and that on sunless days.
ts Must be either daily, monthly or annual, which indicates the desired time step that the output ET estimates should be on. Default is daily.

solar Must be either data, sunshine hours, cloud or monthly precipitation: data indicates that solar radiation data is to be used directly for calculating evapotranspiration; sunshine hours indicates that solar radiation is to be calculated using the real data of sunshine hours; cloud sunshine hours is to be estimated from cloud data; monthly precipitation indicates that solar radiation is to be calculated directly from monthly precipitation. Default is sunshine hours.

humid Must be T or F, indicating if adjustment for non-humid conditions is applied in Turc formulation (Alexandris et al., 2008, Equation 5b). Default is F for no adjustment.

message Must be either yes or no, indicating whether message should be printed for calculation summary including the following elements:
- ET model name and ET quantity estimated
- Evaporative surface
- Option for calculating solar radiation (i.e. the value of argument solar)
- if adjustment for non-humid conditions has been applied (i.e. the value of argument humid)
- Time step of the output ET estimates (i.e. the value of argument ts)
- Units of the output ET estimates
- Time duration of the ET estimation
- Number of ET estimates obtained in the entire time-series
- Basic statistics of the estimated ET time-series including mean, max and min values.

AdditionalStats "yes" or "no" indicating whether monthly averaged and annual averaged ET should be calculated.

save.csv Must be either yes or no, indicating whether a .csv of ET estimates should be saved to working directory.

... Dummy for generic function, no need to define.

Details

The alternative calculation options can be selected through argument solar, please see Arguments for details.
Humidity adjustment for the estimations is available through argument humid, please see Arguments for details.

Value

The function generates a list containing the following components:

ET.Daily Daily aggregated estimations of Turc reference crop evapotranspiration.
ET.Monthly  Monthly aggregated estimations of Turc reference crop evapotranspiration.
ET.Annual   Annually aggregated estimations of Turc reference crop evapotranspiration.
ET.MonthlyAve Monthly averaged estimations of daily Turc reference crop evapotranspiration.
ET.AnnualAve Annually averaged estimations of daily Turc reference crop evapotranspiration.
ET_formulation Name of the formulation used which equals to Turc.
ET_type Type of the estimation obtained which is Reference Crop Evapotranspiration.
message1 A message to inform the users about how solar radiation has been calculated by using which data.
message4 A message to inform the users about if adjustment for non-humid conditions has been applied to calculated Turc reference crop evapotranspiration.

Author(s)
Danlu Guo

References

See Also
ET.processeddata,defaultconstants,constants

Examples
# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Turc under the generic function ET
results <- ET.Turc(processeddata, constants, ts="daily", solar="sunshine hours", humid=FALSE, message="yes", AdditionalStats="yes", save.csv="no")
ETComparison

Compare esimated evapotranspiration among multiple sets of result

Description

Produce comparison plots for results and statistics from different estimations produced by using different formulations and/or different input data. The number of different sets of results can be between 2 and 7. Plotting type can be selected among daily aggregation, monthly aggregation, annual aggregation, monthly average and annual average. For each type three comparison plots will be produced including time series, non-exceedance probability and box plot.

Usage

ETComparison(results1, results2, results3 = NULL, results4 = NULL, results5 = NULL, results6 = NULL, results7 = NULL, labs, Sdate = NULL, Edate = NULL, type = "Monthly", ylim = rep(NA,2))

Arguments

results1
A list named results which has been derived from function ET which can be from any model such as Penman, Penman-Monteith or Priestley-Taylor.

results2
A list named results which has been derived from function ET which can be from any model such as Penman, Penman-Monteith or Priestley-Taylor.

results3
A list named results which has been derived from function ET which can be from any model such as Penman, Penman-Monteith or Priestley-Taylor. The default is NULL if the user requires the comparison between only two sets of results.

results4
A list named results which has been derived from function ET which can be from any model such as Penman, Penman-Monteith or Priestley-Taylor. The default is NULL if the user requires the comparison among only three sets of results.

results5
A list named results which has been derived from function ET which can be from any model such as Penman, Penman-Monteith or Priestley-Taylor. The default is NULL if the user requires the comparison among only four sets of results.

results6
A list named results which has been derived from function ET which can be from any model such as Penman, Penman-Monteith or Priestley-Taylor. The default is NULL if the user requires the comparison among only five sets of results.

results7
A list named results which has been derived from function ET which can be from any model such as Penman, Penman-Monteith or Priestley-Taylor. The default is NULL if the user requires the comparison among only six sets of results.
labs  A character vector with the length equal to the number of sets of results to compare, defining the labels for the comparison plots

Sdate  Only used when argument type is Daily, Monthly or Annual to define the start date for the plotting windows, which can be defined by user in the format YYYY-MM-DD; if missing the default is the first day of data is used.

Edate  Only used when argument type is Daily, Monthly or Annual to define the end date for the plotting windows, which can be defined by user in the format YYYY-MM-DD; if missing the default is the last day of data is used.

ylim  A numeric vector of length 2 defining the lower and upper limit of the y-axis for plotting, if missing the default is from 0 to 1.5 times of maximum value from the first set of result that is used to compare with others.

type  A character string indicating the type of plot produced, can be one of the following:
    Daily - comparison plots of estimated daily evapotranspiration;
    Monthly - comparison plots of monthly aggregated evapotranspiration;
    Annual - comparison plots of annually aggregated evapotranspiration;
    MonthlyAve - comparison plots of monthly averaged daily evapotranspiration;
    AnnualAve - comparison plots of annually averaged daily evapotranspiration.

Value

Three plots are generated for each type of comparison plot selected, including:
  1) time series plot of the estimated/aggregated/averaged values from each set of result;
  2) non-exceedance plot of the distribution of estimated/aggregated/averaged values from each set of result;
  3) box plot of the distribution of estimated/aggregated/averaged values from each set of result.

Author(s)

Danlu Guo

See Also

ETPlot

Examples

# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Penman under the generic function ET
results_Penman <- ET.Penman(processeddata, constants, ts="daily", solar="sunshine hours", wind="yes", windfunction_ver = "1948", alpha = 0.08, z0 = 0.001, save.csv="no")

# Call ET.PenmanMonteith under the generic function ET
results_PenmanMonteith <- ET.PenmanMonteith(processeddata, constants, ts="daily", solar="sunshine hours", wind="yes", crop = "short", save.csv="no")
# Plot the estimated Penman open-water evaporation against average temperature
ETComparison(results_Penman, results_PenmanMonteith, type = "Monthly", ylim=c(0,400), labs=c("Penman","PenmanMonteith"))

---

**ETForcings**

*Plot estimated evapotranspiration with climate variables*

**Description**

Produce plot of daily, monthly and annual averaged estimated evapotranspiration with selected climate variables of the same time step.

**Usage**

ETForcings(data, results, forcing)

**Arguments**

- **data**: A list of data named data which must contain a component with the name of a climate variable that the estimated evapotranspiration should be plotted against, see forcing.
- **results**: A list named results which has been derived from function ET.
- **forcing**: A character string as the name of a climate variable that the estimated evapotranspiration should be plotted against, can be any of:
  - **Tmax**: maximum temperature,
  - **Tmin**: minimum temperature,
  - **u2**: average wind speed at 2m,
  - **uz**: average wind speed,
  - **Rs**: solar radiation,
  - **n**: daily sunshine hours,
  - **Precip**: precipitation,
  - **Epan**: Class-A pan evaporation,
  - **RHmax**: maximum relative humidity,
  - **RHmin**: minimum relative humidity,
  - **Tdew**: average dew point temperature.

**Value**

Three plots are generated for the response of calculated evapotranspiration to each climate variable, including:
1) daily evapotranspiration estimate vs. daily average temperature;
2) monthly mean daily evaporationion estimate vs. monthly average temperature;
3) annual mean daily evaporationion estimate vs. annual average temperature.
ETPlot

Author(s)
Danlu Guo

See Also
ETPlot

Examples

# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Penman under the generic function ET
results <- ET.Penman(processeddata, constants, ts="daily", solar="sunshine hours",
wind="yes", windfunction_ver = "1948", alpha = 0.08, z0 = 0.001, save.csv="no")

# Plot the estimated Penman open-water evaporation against average temperature
ETForcings(processeddata, results, forcing = "Tmax")

ETPlot

Plot the daily, monthly and annual aggregations of estimated evapotranspiration

Description

Produce plot of aggregated estimations of evapotranspiration in daily, monthly and annual steps, or averaged daily estimations in monthly or annual steps.

Usage

ETPlot(results, type = "Aggregation", OBS, OBSplot, Sdate = time(results$ET.Daily)[1],
Edate = time(results$ET.Daily)[length(results$ET.Daily)])

Arguments

results A list named results which has been derived from function ET.()
type A character string of either Aggregation or Average to indicate the type of plot required. The default is Aggregation. For aggregation plot the user can define the start and end date of plotting or by default using the calculation period for plotting. For average plot the plotting period equals to the calculation period.
OBS A list named OBS which has been derived from function ReadOBSEvaporation.
OBSplot Must be either TRUE or FALSE. TRUE indicates that the observed evaporation will be plotted together with the estimations and FALSE indicates that the observations will not be shown on the plots.
Sdate Only used when type = Aggregation to define the start date for the plotting windows, the default is the first day for the estimate evapotranspiration, but can be defined by user in the format YYYY-MM-DD.

Edate Only used when type = Aggregation to define the end date for the plotting windows, the default is the last day for the estimate evapotranspiration, but can be defined by user in the format YYYY-MM-DD.

Value

If argument type is Aggregation, three plots are displayed in the following order (the next one appears after pressing enter):
1) Daily evapotranspiration estimates;
2) Monthly evapotranspiration estimates aggregated from daily estimates;
3) Annual evapotranspiration estimates aggregated from daily estimates.

If argument type is Average, two plots are displayed in the following order
1) Monthly averaged daily estimations of evapotranspiration;
2) Annually averaged daily estimations of evapotranspiration.

Author(s)

Danlu Guo

See Also

ETComparison

Examples

# Use processed existing data set and constants from kent Town, Adelaide
data("processeddata")
data("constants")

# Call ET.Penman under the generic function ET
results <- ET.Penman(processeddata, constants, ts="daily", solar="sunshine hours",
wind="yes", windfunction_ver = "1948", alpha = 0.08, z0 = 0.001, save.csv="no")

# Read evaporation data
data("E_OBS")
OBS <- ReadOBSEvaporation(E_OBS, processeddata)

# Plot the aggregation of estimated Penman open-water evaporation with observed evaporation
ETPlot(results, type = "Aggregation", OBS, OBSplot = TRUE, Sdate = "2001-05-01",
Edate = "2004-05-01"
**E_OBS**

*Observed Class-A Pan Evaporation*

**Description**

This data set contains the Class-A pan evaporation observed over the period between 1/3/2001 and 31/8/2004 at the Kent Town station in Adelaide, Australia.

**Usage**

data(E_OBS)

**Format**

A list containing 48 observations of 5 variables

**Source**

Bureau of Meteorology, Kent Town, Adelaide, Australia

**processeddata**

*Processed Climate Data Required for Calculating Evapotranspiration*

**Description**

This data set contains the processed climate data including the variables required for calculating evapotranspiration in function ET over the observation period between 1/3/2001 and 31/8/2004 at the Kent Town station in Adelaide, Australia.

**Usage**

data(processeddata)

**Format**

A list containing 11 non-empty variables:

- *Date.daily* - date in daily time step,
- *Date.monthly* - date in monthly time step,
- *J* - julian days,
- *i* - month,
- *ndays* - days in month,
- *Tmax* - daily maximum temperature in degree Celsius,
- *Tmin* - daily minimum temperature in degree Celsius,
- *RHmax* - daily maximum relative humidity in percentage,
- *RHmin* - daily minimum relative humidity in percentage,
- *uz* - daily wind speed in meters per second,
- *Rs* - daily solar radiation in Megajoule per square meter.
Source
Bureau of Meteorology, Kent Town, Adelaide, Australia

ReadInputs
ReadInputs raw date and climate data

Description
Load raw date and climate data, perform pre-processing, check for missing and error entries and then compile data list of daily time step.

Usage
ReadInputs(varnames, climatedata, constants, stopmissing, timestep = "daily",
interp_missing_days = FALSE,
interp_missing_entries = FALSE,
interp_abnormal = FALSE,
missing_method = NULL,
abnormal_method = NULL,
message = "yes")

Arguments

varnames A character vector with length equals to the number of climate variables to be processed. Can include any element from: Tmax, Tmin, Temp, Tdew, RHmax, RHmin, RH, Rs, n, Cd, Precip, uz, u2, Epan, va, vs.

Each variable is detailed as below:
Tmax - daily maximum temperature in degree Celcius,
Tmin - daily minimum temperature in degree Celcius,
Temp - subdaily temperature in degree Celcius
Tdew - dew point temperature in degree Celcius, either daily or subdaily accepted,
RHmax - daily maximum relative humidity in percentage,
RHmin - daily minimum relative humidity in percentage,
RH - subdaily relative humidity in percentage,
Rs - incoming solar radiation in Megajoules per square metres per day, either daily or subdaily accepted,
n - daily sunshine hour in hours,
Cd - daily cloud cover in oktas,
Precip - precipitation in millimetres, either daily or subdaily accepted,
u2 - wind speed measured at 2 metres from the ground surface in metres per second, either daily or subdaily accepted,
uz - wind speed in metres per second, either daily or subdaily accepted,
Epan - daily Class-A pan evaporation in millimetres,
va - average vapour pressure in KPa, either daily or subdaily accepted,
vs - saturated vapour pressure in KPa, either daily or subdaily accepted.

climatedata A data frame named "climatedata" containing the raw data of date and climate variables.
The data frame must have objects named as Year, Month and Day to indicate the date.
The climate variables to include should be consistent with varnames.
In order to determine which variables are needed for ET estimation, please see ET for the specific data requirements for different formulations.

timestep Should be either daily or subdaily to specify the time step of raw climate data used.

constants A list named "constants" consists of constants required for data pre-processing which may contain the following items: 
a_0, b_0, c_0, d_0.
These four constants which are constants required to calculate daily sunshine hours from daily cloud cover (see Equation S3.10 in McMahon et al., 2012) - if the user requires such calculation these constants must be included in "constants".
The suggested values for various Australian locations are presented in Chiew and McMahon (1991), in which the four constants are named as a0, b0, c0, d0.

stopmissing A numeric vector of length 3:
- the first value represents the maximum percentage of missing data that the user can tolerate;
- the second value represents the maximum percentage of the duration of missing data to the total data duration that the user can tolerate;
- the third value represents the maximum percentage of missing days (within the date data, as a fraction of the total number of days) that the user can tolerate. All values should be numbers between 1 and 99.
The percentages of the number and duration of missing data in the date data and each input variable are compared to the corresponding threshold; if any of the threshold is exceeded the program will be terminated due to unsatisfactory data quality.

interp_missing_days
T or F, indicating if missing days (within the date data) should be interpolated, with a default of F which assigns NA to data at the missing days.

interp_missing_entries
T or F, indicating if missing data entries within individual climate variables should be interpolated, with a default of F which assigns NA to the missing entries.

interp_abnormal
T or F, if abnormal values within individual climate variables should be interpolated, with a default of F which leaves the abnormal values unchanged. Abnormal values are defined differently according to the input variable, as following:

- Tmax > 100 or < -50 degree Celcius
- $T_{min}$ > $T_{max}$ or < -50 degree Celsius
- Temp > 100 or < -50 degree Celsius
- $T_{dew}$ > 100 or < -50 degree Celsius
- $RH_{max}$ > 100 or < 0 per cent
- $RH_{min}$ > $RH_{max}$ or < 0 per cent
- RH > 100 per cent
- $Rs$ < 0 MJ.m$^2$
- $n$ < 0 hour
- $Cd$ < 0 Okta
- Precip < 0 mm
- $u_z$ < 0 m/s
- $u_2$ < 0 m/s
- $E_{pan}$ < 0 mm
- $vs$ < 0 KPa
- $va$ < 0 KPa

missing_method

A character string for the name of the interpolated methods chosen for filling in missing days and missing data entries. Can be either:

- monthly average - replacement with same-month average (adapted from Narapusetty et al., 2009);
- seasonal average - replacement with same-season average (adapted from Narapusetty et al., 2009);
- DoY average - replacement with same day-of-the-year average (Narapusetty et al., 2009);
- neighbouring average - interpolation between the two bounding values, which is only suitable for time increments in which values are available at adjacent increments (McMahon et al., 2013). When there is more than one consecutive missing entry, this interpolation fails, with a warning given.

abnormal_method

A character string for the name of the interpolated methods chosen for replacing data entries with abnormal values. Can be either:

- monthly average - replacement with same-month average (adapted from Narapusetty et al., 2009);
- seasonal average - replacement with same-season average (adapted from Narapusetty et al., 2009);
- DoY average - replacement with same day-of-the-year average (Narapusetty et al., 2009);
- neighbouring average - interpolation between the two bounding values, which is only suitable for time increments in which non-abnormal values are available at adjacent increments (McMahon et al., 2013). When there is more than one consecutive abnormal entry, this interpolation fails, with a warning given.

message

"yes" or "no" indicating whether checking messages should be printed on screen.
Value

This function returns a list with all components of class zoo which have been processed from the raw data, including:

- **Date.daily**: A zoo object containing the date in daily step in the format of yyyy-mm-dd.
- **Date.monthly**: A zoo object containing the date in daily step in the format of mmm-yyyy.
- **J**: A zoo object containing the Julian Day for every day during the period that the data spans.
- **i**: A zoo object containing the month number for every day during the period that the data spans.
- **ndays**: A zoo object containing the number of days for every month during the period that the data spans.
- **Tmax**: A zoo object containing the daily maximum temperatures in degree Celcius.
- **Tmin**: A zoo object containing the daily minimum temperatures in degree Celcius.
- **u2**: A zoo object containing the daily wind speed at 2m from the ground in m/s.
- **uz**: A zoo object containing the daily wind speed measured at the height of wind instrument in m/s.
- **Rs**: A zoo object containing the daily solar radiation in MJ/m^2/day.
- **n**: A zoo object containing the daily sunshine hours.
- **Cd**: A zoo object containing the daily cloud cover in oktas.
- **Precip**: A zoo object containing the daily precipitation in mm.
- **Epan**: A zoo object containing the daily Class-A pan evaporation in mm.
- **RHmax**: A zoo object containing the daily maximum relative humidity in percentage.
- **RHmin**: A zoo object containing the daily minimum relative humidity in percentage.
- **Tdew**: A zoo object containing the average daily dew temperatures in degree Celcius.

Note that the components might have value of NULL when the corresponding input variable cannot be found in the raw data (i.e. "climatedata").

Author(s)

Danlu Guo

References


See Also

ET, climatedata.data

Examples

# ReadInputs climate data
data("climatedata")
data("constants")
data <- ReadInputs(varnames = c("Temp", "Tdew", "n", "RH", "uz"),
                   climatedata,
                   constants,
                   stopmissing = c(10, 10, 3),
                   timestep = "subdaily",
                   interp_missing_days = FALSE,
                   interp_missing_entries = FALSE,
                   interp_abnormal = FALSE,
                   missing_method = NULL,
                   abnormal_method = NULL)

Description

Load raw data and evaporation data and then compile data list of daily time step.

Usage

ReadOBSEvaporation(E_OBS, data)

Arguments

E_OBS  A list of evaporation data named E_OBS which must contain the following columns:
Year, Month, Day as the date and,
EVAP.Obs as the observed evaporation in mm.
The observations can be of daily and monthly time steps and must match with
the corresponding dates recorded.

data  A list of data named data which contains data of climate variables over the same
period as the evaporation data

Value

This function returns a list with all components of class zoo which have been processed from the
raw data, including:

Date.OBS  A zoo object containing the date data with time step consistent with the raw
evaporation data in E_OBS.
E_obs.Daily  A zoo object containing the daily evaporation data.
E_obs.Monthly  A zoo object containing the monthly aggregated observed evaporation in mm.
E_obs.Annual  A zoo object containing the annually aggregated observed evaporation in mm.
E_obs.MonthlyAve  A zoo object containing the monthly averaged daily evaporation from observation in mm/day.
E_obs.AnnualAve  A zoo object containing the annually average daily evaporation from observation in mm/day.

Note that the components might have value of NULL when the corresponding raw data cannot be found in E_OBS.

Author(s)

Danlu Guo

Examples

# Get the time period from "data"
# Use processed existing data set from kent Town, Adelaide
data("processeddata")
data("constants")

# Reading observations of evaporation within specified time period
data("E_OBS")
OBS <- ReadOBSEvaporation(E_OBS, processeddata)
Index

* ASCE
  ET.PenmanMonteith, 46
* Abtew
  ET.Abtew, 8
* BlaneyCriddle
  ET.BlaneyCriddle, 10
* BrutsaertStrickler
  ET.BrutsaertStrickler, 13
* Chapman
  ET.ChapmanAustralian, 15
* Class-A pan evaporation
  ET.PenPan, 49
* FAO-56
  ET.PenmanMonteith, 46
* Granger-Gray
  ET.GrangerGray, 18
* Hamon
  ET.Hamon, 21
* Hargreaves-Samani
  ET.HargreavesSamani, 23
* Jensen-Haise
  ET.JensenHaise, 25
* Linacre
  ET.Linacre, 27
* Makkink
  ET.Makkink, 29
* Matt-Shuttleworth
  ET.MattShuttleworth, 31
* McGuinness-Bordne
  ET.McGuinnessBordne, 34
* MortonCRAE
  ET.MortonCRAE, 36
* MortonCRWE
  ET.MortonCRWE, 39
* PenPan
  ET.PenPan, 49
* Penman-Monteith
  ET.PenmanMonteith, 46
* Penman
  ET.Penman, 42
* Priestley-Taylor
  ET.PriestleyTaylor, 52
* ReadInputs
  ReadInputs, 68
* Reading
  ReadOBSEvaporations, 72
* Reference crop evapotranspiration
  ET.PenmanMonteith, 46
* Romanenko
  ET.Romanenko, 54
* Szilagy-Jozsa
  ET.SzilagyJozsa, 56
* Turc
  ET.Turc, 59
* actual areal evapotranspiration
  ET.BrutsaertStrickler, 13
  ET.MortonCRAE, 36
* actual evapotranspiration
  ET.Abtew, 8
  ET.Linacre, 27
  ET.SzilagyJozsa, 56
* climate
  ETComparison, 62
  ETForcings, 64
* data pre-processing
  ReadInputs, 68
* datasets
  climatodata, 2
  constants, 3
  defaultconstants, 5
  E_OBS, 67
  processeddata, 67
* evapotranspiration
  ET, 6
  ET.Abtew, 8
  ET.BlaneyCriddle, 10
  ET.BrutsaertStrickler, 13
  ET.ChapmanAustralian, 15
* **reference crop evapotranspiration**
  - ET.BlaneyCriddle, 10
  - ET.HargreavesSamani, 23
  - ET.Makkink, 29
  - ET.MattShuttleworth, 31
  - ET.Turc, 59

* **shallow lake**
  - ET.MortonCRWE, 39

* **wet-environment areal evapotranspiration**
  - ET.MortonCRAE, 36

climatedata, 2, 72

constants, 3, 6, 10, 12, 15, 18, 20, 24, 27, 28, 31, 33, 35, 39, 42, 45, 48, 51, 54, 59, 61

data, 72
defaultconstants, 5, 5, 10, 12, 15, 18, 20, 24, 27, 28, 31, 33, 35, 39, 42, 45, 48, 51, 54, 59, 61, 67, 69, 72

time, 2

**E_OBS, 67**

ET, 2, 3, 5, 6, 10, 12, 15, 18, 20, 24, 27, 31, 33, 35, 39, 42, 45, 48, 51, 54, 59, 61, 67, 69, 72

ET.Abtew, 8

ET.BlaneyCriddle, 10

ET.BrutsaertStrickler, 13

ET.ChapmanAustralian, 15

ET.GrangerGray, 18

ET.Hamon, 21

ET.HargreavesSamani, 8, 23

ET.JensenHaise, 25

ET.Linacre, 27

ET.Makkink, 7, 29

ET.MattShuttleworth, 31

ET.McGuinnessBordne, 34

ET.MortonCRAE, 36

ET.MortonCRWE, 39, 39, 42

ET.Penman, 7, 20, 42, 59

ET.PenmanMonteith, 7, 46

ET.PenPan, 18, 49

ET.PriestleyTaylor, 7, 52

ET.Romanenko, 54

ET.Szilagyijozsa, 56

ET.Turc, 59

ETComparison, 62, 66

ETForcings, 64

ETPlot, 65, 65

ReadInputs, 68

ReadOBSEvaporations, 72

* **forcing**
  - ETComparison, 62
  - ETForcings, 64

* **observation**
  - ReadOBSEvaporations, 72

* **open-water evaporation**
  - ET, 6
  - ET.GrangerGray, 18
  - ET.Penman, 42

* **plot**
  - ETComparison, 62
  - ETForcings, 64
  - ETPlot, 65

* **potential evaporation**
  - ET.PriestleyTaylor, 52

* **potential evapotranspiration**
  - ET, 6
  - ET.ChapmanAustralian, 15
  - ET.GrangerGray, 18
  - ET.Hamon, 21
  - ET.JensenHaise, 25
  - ET.McGuinnessBordne, 34
  - ET.MortonCRAE, 36
  - ET.MortonCRWE, 39
  - ET.Penman, 42
  - ET.PenPan, 49
  - ET.Romanenko, 54
processeddata, 10, 12, 15, 18, 20, 22, 24, 27, 28, 31, 33, 35, 39, 42, 45, 48, 51, 54, 55, 59, 61, 67

ReadInputs, 68
ReadOBSEvaporation
  (ReadOBSEvaporations), 72
ReadOBSEvaporations, 72