Package ‘sebkc’

July 23, 2026

Type Package

Title Surface Energy Balance and Crop Coefficient Evapotranspiration Estimation

Version 1.0-6

Date 2026-07-15

Description Computes and integrates surface energy balance components of evapotranspiration (ET), sensible heat (H), soil heat flux (G) and net radiation (Rn) into the Food and Agriculture Organization (FAO) Irrigation and Drainage Paper 56 (FAO-56) water balance model. The package can perform single crop coefficient (Kc), dual Kc and the integration of thermal-based evaporative fractions in a water balance model. The surface energy balance models include Two-Source Surface Energy Balance (TSEB) models, namely the Priestley-Taylor TSEB (TSEB-PT), the Penman-Monteith TSEB (TSEB-PM) and TSEB-Parallel, as well as One-Source Surface Energy Balance (OSEB) models, namely the Surface Energy Balance Algorithm for Land (SEBAL), Mapping Evapotranspiration at high Resolution with Internalized Calibration (METRIC), Surface Energy Balance Index (SEBI), Simplified Surface Energy Balance (SSEB) and Surface Energy Balance System (SEBS). Methods are described in Allen et al. (2007) <doi:10.1061/(ASCE)0733-9437(2007)133:4(380)> and Bastiaanssen et al. (1998) <doi:10.1016/S0022-1694(98)00253-4>.

Depends R (>= 3.5.0), raster (>= 2.5), sp (>= 1.2)

Imports gstat, stats, graphics, grDevices, utils

License GPL-2

Encoding UTF-8

URL https://github.com/gowusu/sebkc

BugReports https://github.com/gowusu/sebkc/issues

NeedsCompilation no

Config/roxygen2/version 8.0.0

Author George Owusu [aut, cre]

Maintainer George Owusu <owusugeorge@ug.edu.gh>

Repository CRAN

Date/Publication 2026-07-23 12:40:08 UTC

Contents

biomass	*Biomass and yield estimation of crops and plants*

Description

This function uses Wageningen procedure (De Wit, 1968; Slabbers et al., 1979) to compute the point or spatial possible maximum yield of a standard crop based on a Rs data. This function can also perform internal interpolation of data if longitude and latitude are provided. See datails and examples below.

Usage

```
biomass(
  Tday = NULL,
  T24,
  Rs,
  latitude,
  longitude = NULL,
  HI = NULL,
  plantdate,
  harvestdate,
  c30 = 0.0108,
  adaptability = 3,
  LAI = 5,
  crop = NULL
)
```

Arguments

`Tday`	numeric. Average Day time temperature in degrees Celsius for the growing period. A Remote sensing surface Temperature can also be used
`T24`	numeric. Average 24-hour (including night hours) temperature in degrees Celsius for the growing period.
`Rs`	A shortwave radiation data [ca^-2 day^-1]. RasterLayer data can be supplied.
`latitude`	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
`longitude`	The longitude of the measurement site i.e. geographical coordinates in decimal degrees for the weather station. It should be negative for West and positive for East.
`HI`	numeric. Harvest Index. It can be list or spatial
`plantdate`	character. A date of planting in the form "YYYY-mm-dd"
`harvestdate`	character. A date of harvest in the form "YYYY-mm-dd"
`c30`	numeric. A maintenance respiration coefficient (c30) at 30 oC. it takes either a value of 0.0108 for non-legume crop or 0.0283 for legumes

adaptability — numeric. The climate adaptability group number. It takes values of 1,2,3,or 4. it depends on the temperature profile of study area. See references (eg. FAO (1981)) for more explanation.

LAI — Leaf Area Index, dimensionless

crop — character. A crop type. For example "maize"

Details

The function can be used in several ways:

biomass can compute biomass and yield for one location. Each input data must be given only one value

Point EstimaPoint Estimation for several locations The function can compute biomass and yields for more than one location. Input data must be a list or array.

Spatial Estimation Input data such as Rs, Tday, T24, HI or LAI can be spatial.

Spatial Estimation with internal interpolation It takes Tday, for example from satellite image, and do interpolation for the rest of the data. Both longitude, latitude, and the variables must be of the same length. If longitude is not provided no interpolation will be done.

@references

- De Wit, C. T. (1968). Plant production Miscellaneous Papers: Landbouw Hogeschool, Wageningen.
- Slabbers, P. J., Herrendorf, V. S., & Stapper, M. (1979). Evaluation of simplified water-crop yield models. Agricultural Water Management, 2(2), 95-129. doi: http://dx.doi.org/10.1016/0378-3774(79)90026-X
- FAO (1981). Report on the Agro-ecological Zones Project: Food and Agriculture Organization of the United Nations.

Value

yield and biomass in t/ha

Author(s)

George Owusu

Examples

```
## Not run:
################# Point Estimation ##################
# Identify the climatic input data on
latitude=11.18 #in decimal degrees
Rs= 452 #Average shortwave radiation over the growing period (cal-2day-1)
Tday = 26.9 # Average day time difference (oC) over the growing period
T24 =25.3 #Average 24 hour mean temperature over the growing period
# Gather crop Information
crop="maize"
plantdate="2015-05-1" #Start date
harvestdate="2015-08-29" #end date 120 days
```

```
HI=0.4 #Harvest index for maize
adaptability=3 #crop climate adaptability group III
LAI = 4 #Leaf Area Index
pointmod=biomass(Tday,T24,Rs,latitude,longitude=NULL,HI,
plantdate,harvestdate,c30=0.0108,adaptability=3,LAI=5,crop=NULL)

################# Point Estimation for several locations#################
latitude=c(10,11.18,12,9)
longitude=c(-1.4,-2,-1,-2.6)
Rs= c(450,452,400,500)
Tday = c(25,26.9,24,20,30)
T24=c(24,25.3,23,28)
HI=c(0.4,0.4,0.5,0.25)
plantdate=c("1-03-2015","1-04-2015","1-05-2015")
harvestdate=c("29-08-2015","29-08-2015","29-08-2015")

# computing several points
pointSmod=biomass(Tday,T24,Rs,latitude,longitude=longitude,HI,
plantdate,harvestdate,c30=0.0108,adaptability=3,LAI=5,crop=NULL)
yield=pointSmod$yield #tabular data
biomass=pointSmod$output #tabular data
#access on biomass
pointSmod$output$yield

## End(Not run)
## Not run:
############## Spatial Estimation with internal interpolation ###########################
#generate spatial data
folder=system.file("extdata","stack",package="sebkc")
modauto=landsat578(data=folder, welev=362)
Tday=modauto$Ts-273.15 #temperature in degree celcius
LAI=modauto$LAI
latitude=seq(7.544,7.590,0.001) #for interpolation
longitude=seq(-1.211,-1.187,0.001) #for interpolation
latitude=latitude[1:length(longitude)] #to make sure they are of the same length
spatialmodint=biomass(Tday,T24,Rs,latitude,longitude=longitude,HI,
plantdate,harvestdate,c30=0.0108,adaptability=3,LAI=LAI,crop=NULL)
# Rs, T24, and HI are interpolated
plot(spatialmodint$yield)
############## Spatial Estimation  ###########################
Rs= 452
T24 =25.3
HI=0.4
spatialmod=biomass(Tday,T24,Rs,latitude,longitude=longitude,HI,
plantdate,harvestdate,c30=0.0108,adaptability=3,
LAI=LAI,crop=NULL)
plot(spatialmod$yield)

## End(Not run)
```

`cal.kc` *Calibration of crop coefficients*

Description

This function can estimate up to 23 parameters of FAO single and dual crop parameters. The parameters include soil parameters: WP,FC, REW; crop parameters: kcini,kcmid,kcend,kcbini,kcbmid,kcbend,h,Zr; the evaporation parameters: p and Ze, runoff coefficients: CNII or rc, as well as groundwater and capillary rise parameters: initgw,a1,b1,a2,b2,a3,b3,a4,b4. For each parameter initial, maximum and range values must be provided if one wants to optimise it. There are also 12 goodness of fit tests for the evaluation of the model with `fitting` :r-square, index of agreement, F-value, p-value, sse,sst, AIC, BIC, RMSE, NRMSE and nashSutcliffe coefficients. A calibrated model that uses more parameters gets punished by AIC and BIC as well as adjusted R2, RMSE, NRMSE.

Both point and spatial model can be calibrated. The actual model is available at `kc`

Usage

```
cal.kc(
  ETo,
  P,
  RHmin,
  soil,
  crop,
  I = 0,
  CNII = c(30, 100, 1),
  u2 = 2,
  FC = NULL,
  WP = NULL,
  h = NULL,
  Zr = NULL,
  Ze = c(0.1, 0.15, 0.01),
  kc = c(c(0.1, 0.3, 0.05), c(0.1, 1, 0.1), c(0.1, 1, 0.1)),
  p = c(0.1, 1, 0.1),
  lengths = NULL,
  fw = 0.8,
  fc = NULL,
  kctype = "dual",
  region = NULL,
  regexpr = "sweet",
  initgw = 50,
  LAI = 3,
  rc = NULL,
  Kb = 0,
  Rn = NULL,
  hmodel = "gaussian",
  Zrmodel = "linear",
  xydata = NULL,
  REW = c(2, 12, 0.5),
  a1 = 360,
  b1 = c(-1, 1, 0.1),
  a2 = 240,
  b2 = c(-1, 1, 0.1),
```

```
  a3 = c(-2, 1, 0.1),
  b3 = 6.6,
  a4 = 4.6,
  b4 = c(-1.5, 1, 0.1),
  ETa = NULL,
  report = "stages",
  time = "06:00",
  HWR = 1,
  latitude = NULL,
  density = "full",
  DOY = NULL,
  slope = NULL,
  y = NULL,
  r1 = 100,
  nongrowing = "weeds",
  theta = NULL,
  profile = "variable",
  Kcmin = 0.15,
  Ky = NULL
)
```

Arguments

`ETo`	Numeric. Reference evapotranspiration [mm]. This can be estimated with `ETo`
`P`	numeric. Precipitation [mm]
`RHmin`	numeric. Minimum Relative Humidity [per cent]
`soil`	character. Name of soil texture as written in FAO56 TABLE 19
`crop`	character. Name of the crop as written on FAO56 Table 11, TABLE 12 and TABLE 17
`I`	numeric. Irrigation [mm]
`CNII`	numeric. The initial Curve Number of the study site. This can be calibrated with `cal.kc`.
`u2`	numeric. Wind speed of the nearby weather station [m/s] measured at 2m
`FC`	numeric. soil water content at field capacity [-][m3 m-3]. This can be calibrated with `cal.kc`.
`WP`	numeric. soil water content at wilting point [-][m3 m-3]. This can be calibrated with `cal.kc`.
`h`	numeric. Maximum crop height [m]. See details below. This can be calibrated with `cal.kc`
`Zr`	numeric. Rooting depth. See details below. This can be calibrated with `cal.kc`
`Ze`	numeric. The depth of the surface soil layer that is subject to drying by way of evaporation [0.10-0.15 m]. This can be calibrated with `cal.kc`
`kc`	list. The tabulated Kc values for single crop c(kcini,kcmid,kcend) or dual crop model c(kcbini,kcbmid,kcbend). To use with `sebal` or any of the Surface Energy Balance models, it should be linked as list(model1,model2,model3) or

	c(model1$EF,model2$EF,model3$EF) but not a mixture of both. This can be calibrated with `cal.kc`
`p`	The depletion coefficient. This can be calibrated with `cal.kc`
`lengths`	list. The lengths of the crop growth stages. It can take dates in the form of c(start of planting ('YYYY-mm-dd), start of rapid growth, start of mid season, start of maturity, harvesting) or in the form number of days: c(initial days, dev days, mid days, late days). See FAO56 TABLE 11. If performing time series simulation, different dates or one season dates can be set; for instance two seasons simulation can be of the form c(initial days, dev days, mid days, late days, initial days, dev days, mid days, late days) or just c(initial days, dev days, mid days, late days)
`fw`	list or numeric or character. This can take different fw values throughout the growing season. It can also take one numeric value and this will be transform depending on the type of wetting. If the wetting event is only Precipitation, it is set to 1; if it is only Irrigation it is set to the provided fw value. If it is both Precipitation and Irrigation weights are assigned for calculation of fw. fw can also take a character such as "Drip", "Sprinkler", "Basin", "Border", "alternated furrows", "Trickle", "narrow bed" and "wide bed". In this case fw values from FAO56 are assigned.
`fc`	numeric. fraction of ground covered by tree canopy
`kctype`	character. The type of model either "single" or "double". In spatial modelling involving Evaporation Fraction, kctype can be set to "METRIC" or "SSEB" so that Actual Evapotranspiration will be estimated as ETo*EF else it will be estimated with Rn as ETa=(EF*Rn)/2.45. Note that Rn is in MJm-2 day-1.
`region`	character. The region of the crop as on FAO56 TABLE 11
`regexpr`	character. Extra term that can be used to search crop names on FAO56 Tables
`initgw`	numeric. Initial ground water level [m]
`LAI`	numeric. Leaf Area Index
`rc`	numeric Runoff coefficient [0-1]. This must be used if there is no information on Curve Number. This can be calibrated with `cal.kc`
`Kb`	ground water (base flow) recession parameter. The default is zero where no baseflow occurs
`Rn`	Net daily radiation [w/m2]. Estimated this with `ETo`
`hmodel`	character. The type of crop growth model during the simulation. It takes "gaussian","linear", "exponential"
`Zrmodel`	character. The type of root growth model during the simulation. It takes "gaussian","linear", "exponential"
`xydata`	list c(longitude, latitude). The observation points of the model. This should be set only if the model is spatial.
`REW`	numeric Readily Evaporable Water. It can be calibrated with `cal.kc`
`a1`	soil water storage to maximum root depth (Zr) at field capacity
`b1`	Liu et al. (2006) parameter for computing capillary rise [-0.17]. It can calibrated with `cal.kc`

`a2`	Liu et al. (2006) parameter for computing capillary rise [240]. It can be calibrated with `cal.kc`
`b2`	Liu et al. (2006) parameter for computing capillary rise [-0.27]. It can be calibrated with `cal.kc`
`a3`	Liu et al. (2006) parameter for computing capillary rise [-1.3]. It can be calibrated with `cal.kc`
`b3`	Liu et al. (2006) parameter for computing capillary rise [6.6]. It can be calibrated with `cal.kc`
`a4`	Liu et al. (2006) parameter for computing capillary rise [4.6]. It can be calibrated with `cal.kc`
`b4`	Liu et al. (2006) parameter for computing capillary rise [-0.65]. It can be calibrated with `cal.kc`
`ETa`	Measured Actual Evapotranspiration [mm]
`report`	list. In case of spatial modelling, which days' map should be reported. The default is "stages" where the periods of stages maps are reported as values. In an ascending order it can take values such as 1:12 days or c(1,3,6:12) days.
`time`	character. Time of the occurrence Irrigation or Precipitation.
`HWR`	numeric. Default is 1. Height to width ratio of individual plants or groups of plants when viewed from the east or from the west [-].
`latitude`	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
`density`	character. density factor for the trees, vines or shrubs on how they are arranged. It can take "full", "row" or "random" or "round".
`DOY`	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
`slope`	numeric. slope of saturation vapour pressure curve at air temperature T [kPa oC-1].
`y`	numeric. psychometric constant [kPa oC-1]
`r1`	leaf resistance FOR STOMATAL CONTROL [s/m]
`nongrowing`	character. The type of surface during non-growing season. It can take "weeds", "bare", or "mulch"
`theta`	numeric. The measured soil water content [m3/m3] in the profile. Leave those days without measured data blank.
`profile`	numeric or character. The profile depth to perform water balance. It takes "variable" when updating the depth with root growth (default). Or taking "fixed" when the maximum root zone is used. It can also take numeric value and this can be longer than maximum root length.
`Kcmin`	Minimum Kc value
`Ky`	list or array. yield response factor [-] in the form of c(initial Ky,crop dev't Ky, mid season Ky, late season Ky, total season Ky). For instance Maize Ky is c(0.4,0.4,1.3,0.5,1.25). Ky values for other crops are tabulated in FAO Irrigation and Drainage Paper 33 (Doorenbos and Kassam, 1979) and Paper 56 (Allen et al., 1998). If only one Ky value is supplied it will be repeated for all the seasons.

Details

There are several ways to use cal.kc:

The kc model can be calibrated against either Actual Evapotranspiration (ETa) or Available Soil Water; the user must specify theta. If the calibration is done on a point data then time series for that location must be provided. If multiple locations are provided with xydata and corresponding multiple locations as input data, then ETa or theta must be provided for all locations. See also kc for more details on locations.

Measured DataNumber of optimised parameters and Goodness of fit There is a need to limit the number of calibrated parameters. One can compare models by observing the adjusted goodness of fit tests. The more parameters that one uses the less are the values of R-square but RMSE, BIC, AIC increases. Unadjusted and adjusted goodness of fit tests are provided with this function.

Value

The function returns optimised parameters as "parameters", goodness of fit as "fit", and calibrated model as "mod". It also prints candidates of parameters and goodness of fit of the local optimum values. For the explanation of calibrated model output and optimised parameters see the return values of `kc`. Here, only goodness of fit tests explanations are given.

mod: The optimised model. See return of `kc` for more details

parameters: parameters of the optimised model

fit: Goodness of fit tests. See `fitting` for explanation of variables

Author(s)

George Owusu

See Also

`kc`

Examples

```
## Not run:
#fewer iteration
file=system.file("extdata","sys","irrigation.txt",package="sebkc")
data=read.table(file,header=TRUE)
P=data$P
rc=0
I=data$I
ETo=data$ETo
Zr=data$Zr
p=0.6
FC=0.23
WP=0.10
u2=1.6
RHmin=35
soil="sandy loam"
```

```
crop="Broccoli"
#single kc calibration with fewer iteration
cal=cal.kc(ETo,P,RHmin,soil,crop,I=0,kc=NULL,CNII=67,
u2=2,FC=NULL,WP=NULL,h=NULL,Zr=NULL,lengths=NULL,fc=NULL,
kctype="single",region=NULL,regexpr=NULL,initgw=50,LAI=3,
rc=NULL,Rn=NULL,hmodel="gaussian",Zrmodel="linear",
xydata=NULL,ETa=ETo,a1=360,b1=-0.17,a2=240,b2=-0.27,
a3=-1.3,b3=6.6,a4=4.6,b4=-0.65)
parameters=cal$parameters
output=cal$mod$output
gof=cal$fit
ETc=cal$mod$output$ETc
TAW=cal$mod$output$TAW

#Single kc with different kcs. kc uses default values
#RMSE_adj and NRMSE_adj equal to NAN because the number of parameters more than time steps(days)
cal=cal.kc(ETo,P,RHmin,soil,crop,I=0,CNII=67,u2=2,FC=NULL,WP=NULL,
h=NULL,Zr=NULL,lengths=NULL,fc=NULL,kctype="single",region=NULL,
regexpr=NULL,initgw=50,a1=c(100,400,10),b1=c(-1,-0.1,0.1),
a2=c(100,400,10),b2=c(-1,1,0.1),a3=c(-2,1,0.1),b3=c(1,10,1),
a4=c(1,10,1),b4=c(-1.5,1,0.1),LAI=3,rc=NULL,
Rn=NULL,hmodel="gaussian",Zrmodel="linear",xydata=NULL,ETa=ETo)

#Example with fixed kcs
cal=cal.kc(ETo,P,RHmin,soil,crop,I=0,CNII=67,kc=c(0.1,1.15,1),
u2=2,FC=NULL,WP=NULL,h=NULL,Zr=NULL,lengths=NULL,
fc=NULL,kctype="single",region=NULL,regexpr=NULL,initgw=50,
b1=c(-1,-0.1,0.1),b2=c(-1,1,0.1),LAI=3,rc=NULL,Rn=NULL,
hmodel="gaussian",Zrmodel="linear",xydata=NULL,ETa=ETo)

#Example with spatial kcs
#landsat folder with original files but a subset
folder=system.file("extdata","stack",package="sebkc")
sebiauto=sebi(folder=folder,welev=317,Tmax=31,Tmin=28) #sebi model
kc2=stack(sebiauto$EF/2,sebiauto$EF,sebiauto$EF/3) #assign EF to kc
xydata=data.frame(cbind(longitude=data$longitude,latitude=data$latitude))
modEF=kc(ETo,P=P,RHmin,soil,crop,I,kc=kc2,Rn=8,lengths = c(4,4,2,2),xydata=xydata)
ETa=modEF$ETcxy[3:14]

calsp=cal.kc(ETo,P,RHmin,soil,crop,I=0,CNII=67,kc=kc2,u2=2,FC=NULL,
 WP=WP,h=NULL,Zr=NULL,lengths = c(4,4,2,2),fc=NULL,kctype="single",
 region=NULL,regexpr=NULL,initgw=50,b1=c(-1,-0.1,0.1),b2=c(-1,1,0.1),
 LAI=3,rc=NULL,Rn=7,hmodel="gaussian",Zrmodel="linear",xydata=xydata,ETa=ETa)
 gof=cal$fit
r2=cal$fit$r2
AIC=cal$fit$AIC
ETcxy=cal$mod$ETcxy
TAW=cal$mod$TAW

## End(Not run)
```

`coldhot` *Automatic computation of hot and cold pixels from Radiometric Surface Temperature (Ts)*

Description

This function computes temperature coordinates of a hot and cold pixels based on only Surface Temperature. This function uses ranges of temperature.

Usage

```
coldhot(Tmin, Tmax, Ts = NULL, folder = NULL, welev = NULL)

## Default S3 method:
coldhot(Tmin, Tmax, Ts = NULL, folder = NULL, welev = NULL)
```

Arguments

`Tmin`	Numeric. Minimum surface Temperature in map units (eg. Kilvin) that you want computation from. You can keep changing untill you get your desired values
`Tmax`	Numeric. Maximum surface Temperature in map units (eg. Kilvin) that you want computation from. You can keep changing untill you get your desired values
`Ts`	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.
`folder`	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
`welev`	Weather station elevation in meters

Details

The function first divides the selected area into a number of clusters. The mean and standard deviations are computed. The cluster means with the lowest standard deviations and qualifying for upper (Ts) and lower (NDVI) limits (see above) are selected. The provided upper and lower probabilities are also used to select the final Ts.

Value

Ts: The selected or input Ts

Tshot: The Temperature of hot pixel

Tscold: The Temperature of cold pixel

xyhot: combined x and y coordinates

candidates: The similar candidates' pixels that can be used

Author(s)

George Owusu

References

Allen, R. G., Burnett, B., Kramber, W., Huntington, J., Kjaersgaard, J., Kilic, A., Kelly, C., & Trezza, R. 2013. Automated Calibration of the METRIC-Landsat Evapotranspiration Process. JAWRA Journal of the American Water Resources Association, 49(3): 563-576.

See Also

coldTs, hotTs, coldTs2

Examples

```
## Not run:
 folder=system.file("extdata","stack",package="sebkc")
  model=coldhot(Tmin=300,Tmax=310,folder=folder,welev=170)
  spplot(model$Tshot)
  spplot(model$Tscold)
  modauto=sebal(folder = folder,welev = 380,xycold=model$xycold,xyhot=model$xyhot)
## End(Not run)
```

---

coldTs — *Automatic computation of cold pixel Radiometric Surface Temperature*

Description

This function computes temperature of a cold pixel based on NDVI, Surface Temperature, DEM and albedo. It plots histograms indicating the selected values. The main difference with coldTs2 is that preference is given to temperature selection before considering NDVI and albedo selection.

Usage

```
coldTs(
  Ts,
  NDVI,
  albedo = NULL,
  sunangle = NULL,
  DEM = NULL,
  cluster = 8,
  extent = "interactive",
  upper = 0.95,
  lower = 0.2,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
```

```
  welev = NULL,
  clip = NULL,
  iter.max = 100,
  seed = NULL
)

## Default S3 method:
coldTs(
  Ts = NULL,
  NDVI,
  albedo = NULL,
  sunangle = NULL,
  DEM = NULL,
  cluster = 8,
  extent = "interactive",
  upper = 0.95,
  lower = 0.2,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
  welev = NULL,
  clip = NULL,
  iter.max = 100,
  seed = NULL
)
```

Arguments

`Ts`	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.
`NDVI`	A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.
`albedo`	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
`sunangle`	sun angle (degree) above the horizon.
`DEM`	A digital elevation model[m]
`cluster`	numeric, a value indicating the number of clusters.
`extent`	A subset of the raster file than include c(xmin, xmax, ymin, ymax). You can set it to "interactive" where you can digitise polygon. You can set to "auto" where it will be automatically generated. You can set it to "full" where all the image dimension will be used. See layout parameter below for more details. see `extent`
`upper`	The quantile probability at which NDVI should be included in the selection project. It ranges from 0-1. The default is 0.95

`lower`	The quantile probability at which Ts should be included in the slection project.The default is 0.2
`plot`	logical:TRUE or FALSE. To indicate if histograms or triangle should be plotted
`layout`	character. It takes "portrait" or "landscape". If extent is set to "auto" the middle part of the image will be used so that NAs can be avoided. You indicate whether the automatic slection should indicate west-east (landscape) or north-south direction (portraite)
`draw`	interactive. The method of digitisation if extent is set "auto". It takes "poly" or "rect"
`folder`	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
`welev`	Weather station elevation in meters
`clip`	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)
`iter.max`	The number iterations that kmeans cluster should use.
`seed`	optional single number. Passed to `set.seed` before the k-means clustering so the pixel selection is reproducible. The default `NULL` leaves the random-number stream untouched.

Details

The function first divides the selected area into a number of clusters. The mean and standard devaitions are computed. The cluster means with the lowest standard devaitions and qualifying for upper (NDVI) and lower (Ts) limits (see above) are slected. The provided upper and lower probabilities are also used to select the final Ts.

Value

Ts: The selected or input Ts [K]

Tscold: The Temperature of cold pixe [K]

TC: The average temperature of the cold pixels [K]

x: The x cordinate of the cold pixel

y: The y cordinate of the cold pixel

xycold: combined x and y coordinates

candidates: The similiar candidates' pixels that can be used

Author(s)

George Owusu

References

Allen, R. G., Burnett, B., Kramber, W., Huntington, J., Kjaersgaard, J., Kilic, A., Kelly, C., & Trezza, R. 2013. Automated Calibration of the METRIC-Landsat Evapotranspiration Process. JAWRA Journal of the American Water Resources Association, 49(3): 563-576.

See Also

hotTs

Examples

```
## Not run:
#using landsat folder
folder=system.file("extdata","stack",package="sebkc")
modcold=coldTs(folder=folder,welev=170,extent="auto")

#use object of
folder=system.file("extdata","stack",package="sebkc")
data=landsat578(data=folder, welev=362)
modcold=coldTs(folder=data,welev=170,extent="auto",cluster=3)

modcoldTs=coldTs(data,welev=170,extent="auto",cluster=3)

#using input different input data
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
#simulate with default parameters without albedo
modcold=coldTs(Ts=Ts,NDVI=NDVI,sunangle=50.7)
#simulate with albedo but set extent to "auto" and cluster to 7
modcold=coldTs(Ts=Ts,NDVI=NDVI,albedo=albedo,sunangle=50,cluster=7,
extent="auto")

## End(Not run)
```

---

coldTs2 *Optional Automatic computation of cold pixel Radiometric Surface Temperature*

Description

This function computes temperature of a cold pixel based on NDVI, Surface Temperature, DEM and albedo. The main difference with coldTs is that preference is given to temperature selection before considering NDVI and albedo selection. Moreover, this is a simple end member selection where no clustering is done.

Usage

```
coldTs2(
  Ts,
  NDVI,
  albedo = NULL,
  sunangle = NULL,
  DEM = NULL,
  cluster = 10,
```

```
  extent = "interactive",
  upper = 0.2,
  lower = 0.1,
  NDVI.probs = 0.95,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
  welev = NULL
)

## Default S3 method:
coldTs2(
  Ts = NULL,
  NDVI,
  albedo = NULL,
  sunangle = NULL,
  DEM = NULL,
  cluster = 10,
  extent = "interactive",
  upper = 0.2,
  lower = 0.1,
  NDVI.probs = 0.6,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
  welev = NULL
)
```

Arguments

`Ts` A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.

`NDVI` A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.

`albedo` A RasterLayer data that has albedo values. You can also provide file path or location on your computer

`sunangle` sun angle (degree) above the horizon.

`DEM` A digital elevation model[m]

`cluster` numeric, a value indicating the number of clusters.

`extent` A subset of the raster file than include c(xmin, xmax; serastercond row: ymin, ymax). You can set it to "interactive" where you can digitise polygon. You can set to "auto" where it will be automatically generated. See layout parameter below for more details. see `extent`

`upper`	The quantile probability at which NDVI should be included in the selection project. It ranges from 0-1. The default is 0.95
`lower`	The quantile probability at which Ts should be included in the selection project.The default is 0.2
`NDVI.probs`	The probability of selecting quantile NDVI that is above the threshold. The value of 0.6 means only NDVI values that is above 60 the analyses.
`plot`	logical:TRUE or FALSE. To indicate if histograms or triangle should be plotted
`layout`	character. It takes "portrait" or "landscape". If extent is set to "auto" the middle part of the image will be used so that NAs can be avoided. You indicate whether the automatic selection should indicate west-east (landscape) or north-south direction (portrait)
`draw`	interactive. The method of digitisation if extent is set "auto". It takes "poly" or "rect"
`folder`	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
`welev`	Weather station elevation in meters

Details

The function first divides the selected area into a number of clusters. The mean and standard deviations are computed. The cluster means with the lowest standard devaitions and qualifying for upper (NDVI) and lower (Ts) limits (see above) are selected. The provided upper and lower probabilities are also used to select the final Ts.

Value

Ts: The selected or input Ts [K]

Tscold: The Temperature of cold pixel [K]

TC: The average temperature of the cold pixels [K]

x: The x coordinate of the cold pixel

y: The y coordinate of the cold pixel

xycold: combined x and y coordinates

candidates: The similar candidates' pixels that can be used

Author(s)

George Owusu

References

Allen, R. G., Burnett, B., Kramber, W., Huntington, J., Kjaersgaard, J., Kilic, A., Kelly, C., & Trezza, R. 2013. Automated Calibration of the METRIC-Landsat Evapotranspiration Process. JAWRA Journal of the American Water Resources Association, 49(3): 563-576.

See Also

coldTs, hotTs, hotTs2

Examples

```
## Not run:
#using landsat folder
folder=system.file("extdata","stack",package="sebkc")
modcold=coldTs2(folder=folder,welev=170,extent="auto")

#use object of
folder=system.file("extdata","stack",package="sebkc")
data=landsat578(data=folder, welev=362)
modcold=coldTs2(folder=data,welev=170,extent="auto",cluster=3)

modcoldTs2=coldTs2(data,welev=170,extent="auto",cluster=3)

#using input different input data
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
#simulate with default parameters without albedo
modcold=coldTs2(Ts=Ts,NDVI=NDVI,sunangle=50.7)
#simulate with albedo but set extent to "auto" and cluster to 7
modcold=coldTs2(Ts=Ts,NDVI=NDVI,albedo=albedo,sunangle=50,cluster=7,
extent="auto")

## End(Not run)
```

---

cropsebkc *Reprojecting and cropping images*

Description

This function returns the subset of x object as defined by y extent object. See crop and extent for more details. The difference between crop and cropsebkc is the ability for the latter to reproject y object with x object projection.

Usage

```
cropsebkc(x, y)
```

Arguments

x	object to be extracted
y	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform x

Value

cropped x and reprojected y

Author(s)

George Owusu

See Also

crop

Examples

```
## Not run:
folder=system.file("extdata","stack",package="sebkc")
stack=sebkcstack(folder=folder)
data=cropsebkc(stack$data,stack$data)

## End(Not run)
```

---

dl — *Day length calculation*

Description

Day length calculation

Usage

```
dl(latitude, DOY, model = "CBM", Tmax = NULL, Tmin = NULL, p = 0.5)
```

Arguments

latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
DOY	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
model	character Type of model:"CBM" (Schoolfield, 1982),"BGC" (Running & Coughlan, 1988), "CERES" (Ritchie, 1991) or "FAO56"
Tmax	Numeric. Maximum air Temperature in degree Celsius
Tmin	Numeric. Minimum air Temperature in degree Celsius
p	numeric. CMB parameter

Value

DL

Author(s)

George Owusu

References

- Schoolfield R. (1982). Expressing daylength as a function of latitude and Julian date.
- Running S. W. and Coughlan J. C. (1988). A general model of forest ecosystem processes for regional applications I. Hydrologic balance, canopy gas exchange and primary production processes. Ecological Modelling, 42(2), 125-154 http://dx.doi.org/10.1016/0304-3800(88)90112-3.
- Ritchie J. T. (1991). Wheat Phasic Development. Modeling Plant and Soil Systems. Agronomy Monograph, 31.
- Allen R. G., Pereira L. S., Raes D. and Smith M. (1998). Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper, 56, 300.

Examples

```
DOY="2001-8-1"
latitude=0
model="CBM"
Tmax=31
Tmin=26
mod=dl(latitude,DOY,model,Tmax,Tmin=Tmin)
```

ETo *24 Hour FAO 56 and ASCE-EWRI Reference Evapotranspiration ETo*

Description

24 Hour FAO 56 and ASCE-EWRI Reference Evapotranspiration ETo

Usage

```
ETo(
  Tmax,
  Tmin,
  DOY,
  latitude,
  longitude = NULL,
  z = NULL,
  uz = 2,
  altitude = NULL,
  RHmax = NULL,
  RHmin = NULL,
  n = NULL,
  Krs = 0.16,
```

```
  albedo = 0.23,
  as = 0.25,
  bs = 0.5,
  Rs = NULL,
  Rn = NULL,
  G = 0,
  EF = NULL,
  wmo = NULL,
  airport = NULL,
  scale = "sine function",
  Kc = NULL,
  surface = "grass"
)

## Default S3 method:
ETo(
  Tmax,
  Tmin,
  DOY,
  latitude,
  longitude = NULL,
  z = NULL,
  uz = 2,
  altitude = NULL,
  RHmax = NULL,
  RHmin = NULL,
  n = NULL,
  Krs = 0.16,
  albedo = 0.23,
  as = 0.25,
  bs = 0.5,
  Rs = NULL,
  Rn = NULL,
  G = 0,
  EF = NULL,
  wmo = NULL,
  airport = NULL,
  scale = "evaporative fraction",
  Kc = NULL,
  surface = "grass"
)
```

Arguments

`Tmax`	Numeric. Maximum air Temperature in degree Celsius
`Tmin`	Numeric. Minimum air Temperature in degree Celsius
`DOY`	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY

`latitude`	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
`longitude`	The longitude of the measurement site i.e. geographical coordinates in decimal degrees for the weather station. It should be negative for West and positive for East.
`z`	The height above surface where wind speed was measured, in metres.
`uz`	The wind speed in m/s
`altitude`	The elevation of the weather station, in metres
`RHmax`	Maximum Relative Humidity in percent
`RHmin`	Minimum Relative Humidity in percent
`n`	Sunshine hours
`Krs`	Relationship between the fraction of extraterrestrial radiation that reaches the earth's surface, Rs/Ra, and the air temperature difference Tmax - Tmin for interior (Krs = 0.16) and coastal (Krs = 0.19) regions
`albedo`	albedo values. For grass it is 0.23[dimensionless]
`as`	Regression constant, intercept, expressing the fraction of extra-terrestrial radiation reaching the earth on overcast days (n = 0); either a calibrated value or as = 0.25 can be used.
`bs`	regression constant, slope, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0); either a calibrated value or bs = 0.5 can be used.
`Rs`	shortwave incoming radiation [MJ/m2/day]
`Rn`	Net daily radiation in MJ/m2/day. If it is NULL, it will be computed
`G`	Daily Soil heat flux in W/m2
`EF`	Spatial. ET fraction [-] from sebal or tseb sebs. It is advisable to link it to any of the two functions.
`wmo`	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at `https://www.wunderground.com/` [Accessed on 2016-5-6] or `https://www.wetterzentrale.de/` [Accessed on 2016-5-6]
`airport`	numeric. IATA or ICAO code. They are alphabetically listed at `https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A` [Accessed on 2016-5-6]
`scale`	character The type of scale models to upscale instantaneous ET to daily ET. it takes "Evaporative Fraction" (Bastiaanssen et al 1998); "Sine Function" (Jackson et al 1983); "Solar Radiation" (French et al 2005). Remember the blank spaces between the parameters. You can also respectively use "evaporative" or "solar" or "sine".
`Kc`	Crop coefficient
`surface`	character. It is either "grass" or "alfalfa"

Value

ETo: 24 hour reference ETo [mm/day]

ETa: 24 hour actual ET. It is not NULL if EF has a numeric value

ETc: 24 hour crop ET. It is not NULL if Kc has a numeric value

Rn: Net daily Radiation [W/m2]

Rn_mj_m2_day: Net daily Radiation [MJ/m2/day]

y: psychrometric constant [kPa/degree Celsius]

slope: slope of saturation vapour pressure curve [kPa/degree Celsius]

vpd: Vapour pressure deficit[kPa]

Author(s)

George Owusu

References

ALLEN, R. G., PEREIRA, L. S., RAES, D., & SMITH, M. 1996. Crop Evapotranspiration (guidelines for computing crop water requirements) FAO Irrigation and Drainage Paper No. 56: FAO.

See Also

ETohr

Examples

```
#with minimal data
PET=ETo(Tmax=31,Tmin=28,latitude=5.6,DOY="6-2-2001")
PET$ETo
#with enough data as in FAO56 EXAMPLE 18 on 6 July in Uccle (Brussels, Belgium)
#located at 50 degrees 48 minutes N and at 100 m above sea level
PET24=ETo(Tmax=21.5,Tmin=12.3,z=10,uz=2.78,altitude=100,
RHmax=84,RHmin=63,n=9.25,DOY=187,latitude=50.8)
PET24$ETo
```

ETohr *Hourly FAO-56 and ASCE-EWRI Reference Evapotranspiration*

Description

The function calculates hourly or less than hour FAO-56 (grass) and ASCE-EWRI Reference (alfalfa) Evapotranspiration (ETo ETr). The "surface" parameter determines #' the type of ET. The function can also be used to scale hourly or less than hour actual evapotranspiration. The daily ET is implemented in ETo.

Usage

```
ETohr(
  Tmean,
  RH,
  DOY,
  Lz,
  t1,
  time,
  Lm,
  latitude,
  longitude = NULL,
  n = NULL,
  uz = 2,
  Rs = NULL,
  Rn = NULL,
  G = NULL,
  altitude = NULL,
  z = NULL,
  Krs = 0.16,
  Tmax = NULL,
  Tmin = NULL,
  albedo = 0.23,
  as = 0.25,
  bs = 0.5,
  ETins = NULL,
  ETr24 = NULL,
  wmo = NULL,
  airport = NULL,
  map = NULL,
  surface = "grass",
  period = "daytime"
)

## Default S3 method:
ETohr(
  Tmean,
  RH,
  DOY,
  Lz,
  t1 = 1,
  time,
  Lm,
  latitude,
  longitude = NULL,
  n = NULL,
  uz = 2,
  Rs = NULL,
  Rn = NULL,
```

```
  G = NULL,
  altitude = NULL,
  z = NULL,
  Krs = 0.16,
  Tmax = NULL,
  Tmin = NULL,
  albedo = 0.23,
  as = 0.25,
  bs = 0.5,
  ETins = NULL,
  ETr24 = NULL,
  wmo = NULL,
  airport = NULL,
  map = NULL,
  surface = "grass",
  period = "daytime"
)
```

Arguments

Tmean	Numeric. Hourly Mean Air Temperature in degree Celsius
RH	Hourly Mean Relative Humidity in percent
DOY	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
Lz	longitude of the centre of the local time zone [degrees west of Greenwich]. MUST BE POSITIVE Lz = 0 degrees for Greenwich.
t1	The length of the calculation period in hour; 1 for hour, 0.5 for 30 minutes 0.25 for 15 minutes.
time	The midpoint of the time of measurement[hour]; for example time is 12.5 for a period between 12:00 and 13:00
Lm	longitude of the measurement site [degrees west of Greenwich]. MUST BE POSITIVE
latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
longitude	The longitude of the measurement site i.e. geographical coordinates in decimal degrees for the weather station. It should be negative for West and positive for East.
n	Sunshine hours
uz	The wind speed in m/s
Rs	solar radiation [MJ/m2/hr]
Rn	net radiation [MJ/m2/hr]
G	Daily Soil heat flux in W/m2
altitude	The elevation of the weather station, in metres
z	The height above surface where wind speed was measured, in metres.

Krs	Relationship between the fraction of extraterrestrial radiation that reaches the earth's surface, Rs/Ra, and the air temperature difference Tmax - Tmin for interior (Krs = 0.16) and coastal (Krs = 0.19) regions
Tmax	Numeric. Maximum air Temperature in degree Celsius
Tmin	Numeric. Minimum air Temperature in degree Celsius
albedo	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
as	Regression constant, intercept, expressing the fraction of extra-terrestrial radiation reaching the earth on overcast days (n = 0); either a calibrated value or as = 0.25 can be used.
bs	regression constant, slope, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0); either a calibrated value or bs = 0.5 can be used.
ETins	model. It takes ET model from sebal or tseb and retrieve instantaneous ET estimates. This helps to estimate ET24, T24, E24, EF, Kc, EFs, EFc
ETr24	daily grass or alfalfa reference Evapotranspiration (mm/day)
wmo	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at https://www.wunderground.com/ [Accessed on 2016-5-6] or https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
airport	numeric. IATA or ICAO code. They are alphabetically listed at https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A [Accessed on 2016-5-6]
map	spatial raster data for inverse distance interpolation
surface	character. It is either "grass" or "alfalfa"
period	character. Time of day for the calculation: "daytime" or "nighttime". The default is "daytime".

Details

sebal, sebi,sebs,sseb, tseb

Value

ETo: hour reference ETo [mm/hr]

ETa: hour actual ET. It is not NULL if EF has a numeric value

ETc: hour crop ET. It is not NULL if Kc has a numeric value

Rn: Net Radiation [W/m2]

Rnwm_2: Net Radiation [MJ/m2/hr]

y: psychrometric constant [kPa/degree Celsius]

slope: slope of saturation vapour pressure curve [kPa/degree Celsius]

vpd: Vapour pressure deficit[kPa]

Author(s)

George Owusu

References

- ALLEN, R. G., PEREIRA, L. S., RAES, D., & SMITH, M. 1998. Crop Evapotranspiration (guidelines for computing crop water requirements) FAO Irrigation and Drainage Paper No. 56: FAO.
- Jackson, R. D., Hatfield, J. L., Reginato, R. J., Idso, S. B., & Pinter Jr, P. J. (1983). Estimation of daily evapotranspiration from one time-of-day measurements. Agricultural Water Management, 7(1-3), 351-362. doi: http://dx.doi.org/10.1016/0378-3774(83)90095-1
- French, A. N., Fitzgerald, G., Hunsaker, D., Barnes, E., Clarke, T., Lesch, S., . . . Pinter, P. (2005). Estimating spatially distributed cotton water use from thermal infrared aerial imagery. Paper presented at the World Water Congress 2005: Impacts of Global Climate Change - Proceedings of the 2005 World Water and Environmental Resources Congress, Reston, Va.
- Colaizzi, P. D., Kustas, W. P., Anderson, M. C., Agam, N., Tolk, J. A., Evett, S. R., . . . O'Shaughnessy, S. A. (2012). Two-source energy balance model estimates of evapotranspiration using component and composite surface temperatures. Advances in Water Resources, 50, 134-151. doi: http://dx.doi.org/10.1016/j.advwatres.2012.06.004

See Also

`ETo`

Examples

```
#FAO56 Example 19 14:00-15:00 h using Cd = 0.24 instead 0.34 in FAO56
ET1hr=ETohr(Tmean=38,RH=52,DOY=274,Lz=15,t1=1,time=14.5,Lm=16.25,latitude=16.22,uz=3.3,Rs=2.450)
ET1hr$ETo
```

`fitting` *Goodness of fit Test*

Description

Goodness of fit Test

Usage

```
fitting(obs, est, P = 1)
```

Arguments

`obs`	Observed data
`est`	Estimated data
`P`	Number of parameters

Value

r2: R-square [-]

r2_adj: An adjusted R-square [-]

d: Index of agreement[-]

p_value: p value

sse: Sum of square error

sst: Sum of square total

AIC: AIC

BIC: BIC

RMSE: Root Mean Square Error

RMSE_adj: adjusted Root Mean Square Error

NRMSE Normalised Root Mean Square Error

NRMSE_adj: adjusted Normalised Root Mean Square Error

E: Nash Sutcliffe Coefficient

b: coefficients of regression

AAE: average absolute error

ARE: average relative error

MBE: Mean Bias error

MPE: Mean Percentage error

Examples

```
file=system.file("extdata","sys","irrigation.txt",package="sebkc")
data=read.table(file,header=TRUE)
obs=data$ETo
est=data$ETc
P=4
mod=fitting(obs,est,P)
r2=mod$r2
```

---

hotTs *Automatic computation of hot pixel Radiometric Surface Temperature (Ts)*

Description

This function computes temperature of a hot pixel based on NDVI, Surface Temperature, DEM and albedo. The main difference with hotTs2 is that preference is given to temperature selection before considering NDVI and albedo selection. Moreover, this is a simple end member selection where no clustering is done.

Usage

```
hotTs(
  Ts,
  NDVI,
  albedo = NULL,
  DEM = NULL,
  cluster = 8,
  extent = "interactive",
  upper = 0.8,
  lower = 0.2,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
  welev = NULL,
  clip = NULL,
  iter.max = 500,
  seed = NULL
)

## Default S3 method:
hotTs(
  Ts = NULL,
  NDVI,
  albedo = NULL,
  DEM = NULL,
  cluster = 8,
  extent = "interactive",
  upper = 0.8,
  lower = 0.2,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
  welev = NULL,
  clip = NULL,
  iter.max = 500,
  seed = NULL
)
```

Arguments

`Ts` A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.

`NDVI` A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.

`albedo`	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
`DEM`	A digital elevation model[m]
`cluster`	numeric, a value indicating the number of clusters.
`extent`	A subset of the raster file than include c(xmin, xmax; serastercond row: ymin, ymax). You can set it to "interactive" where you can digitise polygon. You can set to "auto" where it will be automatically generated. See layout parameter below for more details. see `extent`
`upper`	The quantile probability at which Ts should be included in the selection project. It ranges from 0-1. The default is 0.8
`lower`	The quantile probability at which NDVI should be included in the selection project. The default is 0.2
`plot`	logical:TRUE or FALSE. To indicate if histograms or triangle should be plotted
`layout`	character. It takes "portrait" or "landscape". If extent is set to "auto" the middle part of the image will be used so that NAs can be avoided. You indicate whether the automatic selection should indicate west-east (landscape) or north-south direction (portrait)
`draw`	interactive. The method of digitisation if extent is set "auto". It takes "poly" or "rect"
`folder`	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
`welev`	Weather station elevation in meters
`clip`	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)
`iter.max`	maximum iterations of sensible heat calculation.
`seed`	optional single number. Passed to `set.seed` before the k-means clustering so the pixel selection is reproducible. The default `NULL` leaves the random-number stream untouched.

Details

The function first divides the selected area into a number of clusters. The mean and standard deviations are computed. The cluster means with the lowest standard deviations and qualifying for upper (Ts) and lower (NDVI) limits (see above) are selected. The provided upper and lower probabilities are also used to select the final Ts.

Value

Ts: The selected or input Ts

Tshot: The Temperature of hot pixel

TX: The average temperature of the hot pixels

x: The x coordinate of the hot pixel

y: The y coordinate of the hot pixel

xyhot: combined x and y coordinates

candidates: The similar candidates' pixels that can be used

Author(s)

George Owusu

References

Allen, R. G., Burnett, B., Kramber, W., Huntington, J., Kjaersgaard, J., Kilic, A., Kelly, C., & Trezza, R. 2013. Automated Calibration of the METRIC-Landsat Evapotranspiration Process. JAWRA Journal of the American Water Resources Association, 49(3): 563-576.

See Also

coldTs

Examples

```
## Not run:
 folder=system.file("extdata","stack",package="sebkc")
  modhot=hotTs(folder=folder,welev=170,extent="auto",cluster=3)

   #use object of  landsat578
folder=system.file("extdata","stack",package="sebkc")
data=landsat578(data=folder, welev=170)
modfhot=hotTs(folder=data,welev=170,extent="auto",cluster=3)

#Or Ts = data
modhotTs=hotTs(data,welev=170,extent="auto",cluster=3)
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
#simulatte with default parameters without albedo
modhot=hotTs(Ts=Ts,NDVI=NDVI,extent="auto",cluster=3)
#simulate with albedo but set extent to "auto" and cluster to 7
modhot=hotTs(Ts=Ts,NDVI=NDVI,albedo=albedo,cluster=7,
extent="auto")

## End(Not run)
```

---

hotTs2	*Automatic computation of hot pixel Radiometric Surface Temperature (Ts)*

Description

This function computes temperature of a hot pixel based on NDVI, Surface Temperature, DEM and albedo. It plots histograms indicating the selected values

Usage

```
hotTs2(
  Ts,
  NDVI,
  albedo = NULL,
  sunangle = NULL,
  DEM = NULL,
  cluster = 10,
  extent = "interactive",
  upper = 0.95,
  lower = 0.8,
  NDVI.probs = 0.1,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
  welev = NULL
)

## Default S3 method:
hotTs2(
  Ts = NULL,
  NDVI,
  albedo = NULL,
  sunangle = NULL,
  DEM = NULL,
  cluster = 10,
  extent = "interactive",
  upper = 0.95,
  lower = 0.8,
  NDVI.probs = 0.2,
  plot = TRUE,
  layout = "portrait",
  draw = "poly",
  folder = NULL,
  welev = NULL
)
```

Arguments

`Ts` A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.

`NDVI` A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.

`albedo` A RasterLayer data that has albedo values. You can also provide file path or location on your computer

`sunangle`	sun angle (degree) above the horizon.
`DEM`	A digital elevation model[m]
`cluster`	numeric, a value indicating the number of clusters.
`extent`	A subset of the raster file than include c(xmin, xmax; serastercond row: ymin, ymax). You can set it to "interactive" where you can digitise polygon. You can set to "auto" where it will be automatically generated. See layout parameter below for more details. see `extent`
`upper`	The quantile probability at which Ts should be included in the selection project. It ranges from 0-1. The default is 0.8
`lower`	The quantile probability at which NDVI should be included in the slection project.The default is 0.2
`NDVI.probs`	The probability of selecting quantile NDVI that is above the threshold. The value of 0.6 means only NDVI values that is above 60 the analyses.
`plot`	logical:TRUE or FALSE. To indicate if histograms or triangle should be plotted
`layout`	character. It takes "portrait" or "landscape". If extent is set to "auto" the middle part of the image will be used so that NAs can be avoided. You indicate whether the automatic selection should indicate west-east (landscape) or north-south direction (portrait)
`draw`	interactive. The method of digitisation if extent is set "auto". It takes "poly" or "rect"
`folder`	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
`welev`	Weather station elevation in meters

Details

The function first divides the selected area into a number of clusters. The mean and standard deviations are computed. The cluster means with the lowest standard deviations and qualifying for upper (Ts) and lower (NDVI) limits (see above) are selected. The provided upper and lower probabilities are also used to select the final Ts.

Value

Ts: The selected or input Ts

Tshot: The Temperature of hot pixel

TX: The average temperature of the hot pixels

x: The x cordinate of the hot pixel

y: The y cordinate of the hot pixel

xyhot: combined x and y coordinates

candidates: The similar candidates' pixels that can be used

Author(s)

George Owusu

References

Allen, R. G., Burnett, B., Kramber, W., Huntington, J., Kjaersgaard, J., Kilic, A., Kelly, C., & Trezza, R. 2013. Automated Calibration of the METRIC-Landsat Evapotranspiration Process. JAWRA Journal of the American Water Resources Association, 49(3): 563-576.

See Also

coldTs, hotTs, coldTs2

Examples

```
## Not run:
 folder=system.file("extdata","stack",package="sebkc")
  modhot=hotTs2(folder=folder,welev=170,extent="auto",cluster=3)

   #use object of  landsat578
folder=system.file("extdata","stack",package="sebkc")
data=landsat578(data=folder, welev=170)
modfhot=hotTs2(folder=data,welev=170,extent="auto",cluster=3)

#Or Ts = data
modhotTs2=hotTs2(data,welev=170,extent="auto",cluster=3)
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
#simulate  with default parameters without albedo
modhot=hotTs2(Ts=Ts,NDVI=NDVI,extent="auto",cluster=3)
#simulate with albedo but set extent to "auto" and cluster to 7
modhot=hotTs2(Ts=Ts,NDVI=NDVI,albedo=albedo,cluster=7,
extent="auto")

## End(Not run)
```

---

invdist — *Inverse distance interpolation*

Description

This function performs inverse distance interpolation based on projection and geometry of input spatial data 'ext'.

Usage

```
invdist(longitude, latitude, var, ext, idp = 0.5)
```

Arguments

longitude	The longitude of the measurement site i.e. geographical coordinates in decimal degrees for the weather station. It should be negative for West and positive for East.
latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
var	numeric variable. The length should be same as the length of latitude and longitude
ext	RasterLayer object.
idp	Neighbourhood parameter

Value

var: interpolated values

Author(s)

George Owusu

Examples

```
 ## Not run:
#Get ext data
folder=system.file("extdata","stack",package="sebkc")
data=landsat578(data=folder, welev=362)
temp=data$Ts
latitude=seq(7.544,7.590,0.001)
longitude=seq(-1.211,-1.187,0.001)
var=seq(20,30,0.2)
latitude=latitude[1:length(longitude)]
var=var[1:length(longitude)]
map=invdist(longitude,latitude,var,ext=temp)

## End(Not run)
```

---

kc *Estimating FAO56 Single and Dual Crop coefficients with a water balance model in R*

Description

This function computes FAO56 crop coefficients and water balance. The output of the model includes crop evapotranspiration, water stress coefficient, irrigation requirements, soil available water, etc. In addition to point estimation, spatial modelling is integrated using Evaporation fractions from sebal, sebi, ETo, sseb, sebs. cal.kc can be used to calibrate the model.

Usage

```
kc(
  ETo,
  P,
  RHmin,
  soil = "Sandy Loam",
  crop,
  I = 0,
  CNII = 67,
  u2 = 2,
  FC = NULL,
  WP = NULL,
  h = NULL,
  Zr = NULL,
  Ze = 0.1,
  kc = NULL,
  p = NULL,
  lengths = NULL,
  fw = 0.8,
  fc = NULL,
  kctype = "dual",
  region = NULL,
  regexpr = "sweet",
  initgw = 50,
  LAI = 3,
  rc = NULL,
  Kb = 0,
  Rn = NULL,
  hmodel = "gaussian",
  Zrmodel = "linear",
  xydata = NULL,
  REW = NULL,
  a1 = 360,
  b1 = -0.17,
  a2 = 240,
  b2 = -0.27,
  a3 = -1.3,
  b3 = 6.6,
  a4 = 4.6,
  b4 = -0.65,
  report = "stages",
  time = "06:00",
  HWR = 1,
  latitude = NULL,
  density = "full",
  DOY = NULL,
  slope = NULL,
  y = NULL,
```

```
    r1 = 100,
    nongrowing = "weeds",
    theta = NULL,
    profile = "variable",
    Kcmin = 0.15,
    Ky = NULL
  )

  ## Default S3 method:
  kc(
    ETo,
    P,
    RHmin,
    soil = "Sandy Loam",
    crop,
    I = 0,
    CNII = 67,
    u2 = 2,
    FC = NULL,
    WP = NULL,
    h = NULL,
    Zr = NULL,
    Ze = 0.1,
    kc = NULL,
    p = NULL,
    lengths = NULL,
    fw = 1,
    fc = NULL,
    kctype = "dual",
    region = NULL,
    regexpr = "sweet",
    initgw = 50,
    LAI = 3,
    rc = NULL,
    Kb = 0,
    Rn = NULL,
    hmodel = "gaussian",
    Zrmodel = "linear",
    xydata = NULL,
    REW = NULL,
    a1 = 360,
    b1 = -0.17,
    a2 = 240,
    b2 = -0.27,
    a3 = -1.3,
    b3 = 6.6,
    a4 = 4.6,
    b4 = -0.65,
```

```
    report = "stages",
    time = "06:00",
    HWR = 1,
    latitude = NULL,
    density = "full",
    DOY = NULL,
    slope = NULL,
    y = NULL,
    r1 = 100,
    nongrowing = "weeds",
    theta = NULL,
    profile = "variable",
    Kcmin = 0.15,
    Ky = NULL
  )

  ## S3 method for class 'kc'
  plot(
    x,
    output = "AW_measured",
    main = NULL,
    cex = 1,
    legend = TRUE,
    pos = "top",
    horiz = FALSE,
    ...
  )

  fit.kc(x, output = "AW_measured")
```

Arguments

ETo	Numeric. Reference evapotranspiration [mm]. This can be estimated with ETo
P	numeric. Precipitation [mm]
RHmin	numeric. Minimum Relative Humidity [per cent]
soil	character. Name of soil texture as written in FAO56 TABLE 19
crop	character. Name of the crop as written on FAO56 Table 11, TABLE 12 and TABLE 17
I	numeric. Irrigation [mm]
CNII	numeric. The initial Curve Number of the study site. This can be calibrated with cal.kc.
u2	numeric. Wind speed of the nearby weather station [m/s] measured at 2m
FC	numeric. soil water content at field capacity [-][m3 m-3]. This can be calibrated with cal.kc.
WP	numeric. soil water content at wilting point [-][m3 m-3]. This can be calibrated with cal.kc.

`h`	numeric. Maximum crop height [m]. See details below. This can be calibrated with `cal.kc`
`Zr`	numeric. Rooting depth. See details below. This can be calibrated with `cal.kc`
`Ze`	numeric. The depth of the surface soil layer that is subject to drying by way of evaporation [0.10-0.15 m]. This can be calibrated with `cal.kc`
`kc`	list. The tabulated Kc values for single crop c(kcini,kcmid,kcend) or dual crop model c(kcbini,kcbmid,kcbend). To use with `sebal` or any of the Surface Energy Balance models, it should be linked as list(model1,model2,model3) or c(model1$EF,model2$EF,model3$EF) but not a mixture of both. This can be calibrated with `cal.kc`
`p`	The depletion coefficient. This can be calibrated with `cal.kc`
`lengths`	list. The lengths of the crop growth stages. It can take dates in the form of c(start of planting ('YYYY-mm-dd), start of rapid growth, start of mid season, start of maturity, harvesting) or in the form number of days: c(initial days, dev days, mid days, late days). See FAO56 TABLE 11. If performing time series simulation, different dates or one season dates can be set; for instance two seasons simulation can be of the form c(initial days, dev days, mid days, late days, initial days, dev days, mid days, late days) or just c(initial days, dev days, mid days, late days)
`fw`	list or numeric or character. This can take different fw values throughout the growing season. It can also take one numeric value and this will be transform depending on the type of wetting. If the wetting event is only Precipitation, it is set to 1; if it is only Irrigation it is set to the provided fw value. If it is both Precipitation and Irrigation weights are assigned for calculation of fw. fw can also take a character such as "Drip", "Sprinkler", "Basin", "Border", "alternated furrows", "Trickle", "narrow bed" and "wide bed". In this case fw values from FAO56 are assigned.
`fc`	numeric. fraction of ground covered by tree canopy
`kctype`	character. The type of model either "single" or "double". In spatial modelling involving Evaporation Fraction, kctype can be set to "METRIC" or "SSEB" so that Actual Evapotranspiration will be estimated as ETo*EF else it will be estimated with Rn as ETa=(EF*Rn)/2.45. Note that Rn is in MJm-2 day-1.
`region`	character. The region of the crop as on FAO56 TABLE 11
`regexpr`	character. Extra term that can be used to search crop names on FAO56 Tables
`initgw`	numeric. Initial ground water level [m]
`LAI`	numeric. Leaf Area Index
`rc`	numeric Runoff coefficient [0-1]. This must be used if there is no information on Curve Number. This can be calibrated with `cal.kc`
`Kb`	ground water (base flow) recession parameter. The default is zero where no baseflow occurs
`Rn`	Net daily radiation [w/m2]. Estimated this with `ETo`
`hmodel`	character. The type of crop growth model during the simulation. It takes "gaussian","linear", "exponential"

`Zrmodel`	character. The type of root growth model during the simulation. It takes "gaussian","linear", "exponential"
`xydata`	list c(longitude, latitude). The observation points of the model. This should be set only if the model is spatial.
`REW`	numeric Readily Evaporable Water. It can be calibrated with `cal.kc`
`a1`	soil water storage to maximum root depth (Zr) at field capacity
`b1`	Liu et al. (2006) parameter for computing capillary rise [-0.17]. It can calibrated with `cal.kc`
`a2`	Liu et al. (2006) parameter for computing capillary rise [240]. It can be calibrated with `cal.kc`
`b2`	Liu et al. (2006) parameter for computing capillary rise [-0.27]. It can be calibrated with `cal.kc`
`a3`	Liu et al. (2006) parameter for computing capillary rise [-1.3]. It can be calibrated with `cal.kc`
`b3`	Liu et al. (2006) parameter for computing capillary rise [6.6]. It can be calibrated with `cal.kc`
`a4`	Liu et al. (2006) parameter for computing capillary rise [4.6]. It can be calibrated with `cal.kc`
`b4`	Liu et al. (2006) parameter for computing capillary rise [-0.65]. It can be calibrated with `cal.kc`
`report`	list. In case of spatial modelling, which days' map should be reported. The default is "stages" where the periods of stages maps are reported as values. In an ascending order it can take values such as 1:12 days or c(1,3,6:12) days.
`time`	character. Time of the occurrence Irrigation or Precipitation.
`HWR`	numeric. Default is 1. Height to width ratio of individual plants or groups of plants when viewed from the east or from the west [-].
`latitude`	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
`density`	character. density factor for the trees, vines or shrubs on how they are arranged. It can take "full", "row" or "random" or "round".
`DOY`	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
`slope`	numeric. slope of saturation vapour pressure curve at air temperature T [kPa oC-1].
`y`	numeric. psychometric constant [kPa oC-1]
`r1`	leaf resistance FOR STOMATAL CONTROL [s/m]
`nongrowing`	character. The type of surface during non-growing season. It can take "weeds", "bare", or "mulch"
`theta`	numeric. The measured soil water content [m3/m3] in the profile. Leave those days without measured data blank.

`profile`	numeric or character. The profile depth to perform water balance. It takes "variable" when updating the depth with root growth (default). Or taking "fixed" when the maximum root zone is used. It can also take numeric value and this can be longer than maximum root length.
`Kcmin`	Minimum Kc value
`Ky`	list or array. yield response factor [-] in the form of c(initial Ky,crop dev't Ky, mid season Ky, late season Ky, total season Ky). For instance Maize Ky is c(0.4,0.4,1.3,0.5,1.25). Ky values for other crops are tabulated in FAO Irrigation and Drainage Paper 33 (Doorenbos and Kassam, 1979) and Paper 56 (Allen et al., 1998). If only one Ky value is supplied it will be repeated for all the seasons.
`x`	a return object of the function.
`output`	The kind of plot that should be displayed. It takes 'AW_measured' for plotting Available and modelled soil moisture; 'TS_measured' for Total Available and modelled soil moisture; 'Kc' for displaying Kcb and Kc 'Evaporation' for displaying of Evaporation and Transpiration 'balance' for displaying Irrigation, precipitation, ETa and critical water deficit
`main`	Title of the plot
`cex`	the relative font size of the texts. Vlaues: "horiz"; logical: if TRUE, set the legend horizontally rather than vertically
`legend`	logical. TRUE or FALSE. Whether a legend should be displayed or not.
`pos`	the position of legend. It takes one of the following 'top', 'topright', 'topleft', 'bottom', 'bottomright' 'bottomleft', 'center'. This must be set so that the legend should not obscure the main plot.
`horiz`	logical; if TRUE the legend is drawn horizontally rather than vertically.
`...`	further arguments passed to the plotting functions.

Details

Using Existing Tables The function include backend database of FAO Tables. The user can use the parameter values such as Zr, h, p, FC, WP, etc from FAO56 tables. Most of the parameters with NULL values can take default values from FAO56 Tables. When a crop name results in 3 crops, the user can differentiate that with regexpr parameter. For example, a crop parameter with a name "maize" can match two crops on FAO Table 12. Including regexpr parameter with "sweet" with match only one.

Modelling crop height and Rooting Depth At each time step a crop height or root depth is estimated. The crop or rooting depth growth model can take exponential model of the form hday=0+0.75*max(h)*(1-exp(-day/0.75*max(days))) or Zrday=0+0.75*Zr*(1-exp(-day/0.75*max(days))) The gaussian model is of the form hday=0+0.75*max(h)*(1-exp(-day^2/(0.75*max(days)^2))) or Zrday=0+0.75*(1-exp(-day^2/(0.75*max(day))^2)) The linear model is of the form hday=(day*max(h))/max(days), Zrday=(day*Zr)/max(days)

Point modeling with Single and dual crop coefficients The function can estimate kc curve for the growing period by using the traditional kcini, kcmid and kcend and crop lengths growth stages, in case of single crop coefficients. Just like single crop coefficients, the dual crop coefficients kcbini, kcbmid, kcbend are embedded in kc parameter. The "kc" parameter must take 3 values as c(initial, mid, end). The values of "lengths" parameter must also be specified as c(initial, dev, mid, late). See example section for more details.

Spatial modeling With Evaporation Fraction Instead of supplying kcs values as described above, Evaporation Fraction (EF) from can be used. The corresponding EF at initital, mid amd end seasons can be supplied. The EF curve will be developed for each location at each time step and ETa derived from (EF*Rn)/2.45.

Interpolation of Input data Once EF is used instead of Kcs, one can provide longitudes and latitudes in xydata parameter data frame. A 2D column data of P, I,ETo,RHmin, u2, Rn for each time step for each location can be provided. At each time step an inverse distance interpolation will be perform to get continuous surface. In case of initial and static input column data such as CNII, FC, WP, initgw, Zr, h can also be interpolated.

Calibration A calibration of unmeasured variables can be done with `cal.kc`

Value

The output of the function depends of the kctype and kc data type. For single and dual crop coefficient, an "output" dataframe contains variables such as TAW,RAW,Runoff,Ks,Kcb,h,Kc,ETc,DP,CR,Drend,Kr,De,AW,E,Ke,C
In case kc is set to EF the function returns Kc,Kcxy,ETc,ETcxy,Drend,Drendxy,TAW,TAWxy,RAW,RAWxy,AW,Awcxy,Ineed

output: dataframe of the return values

ETc_adj: The soil water stress adjusted ETc [mm]

Ya_by_Ym: actual yield by potential yield

yield_decrease: The relative yield decrease: 1-Ya/Ym

ETdecrease: The relative evapotranspiration deficit :1- ETc_adj/ETc

yield_by_ET_decrease: he relative yield decrease: 1-Ya/Ym and the relative evapotranspiration deficit in one dataframe

Awcxy: Available Soil water for each location at each time step [mm]

CR: capillary rise [mm/day]

GW: Updated ground water depth

CN: Curve Number

De: cumulative depth of evaporation (depletion) from the soil surface layer [mm] at the end of the day [mm/day]

DP: Deep Percolation [mm/day]

Drend: cumulative depth of evapotranspiration (depletion) from the root zone at the end of the day [mm]. This is equal to the amount of water needed to bring soil water to field capacity

Drendxy: cumulative depth of evapotranspiration (depletion) from the root zone at the end of the day [mm] for each xydata location at each time step. This is equal to the amount of water needed to bring soil water to field capacity

E: evaporation [mm/day]

ETc: crop evapotranspiration [mm/day]. If water stress coefficient (Ks) is less than 1, ETc is crop evapotranspiration under non-standard conditions else ETc is crop evapotranspiration under standard conditions

ETcxy: crop evapotranspiration [mm/day] for each location at each time step. crop evapotranspiration under standard conditions

h: crop height [m]

Ineed: Amount of soil water that is below maximum allowed depletion [mm]

Ineedxy: Amount of soil water that is below maximum allowed depletion for each xydata location at each time step [mm]

Kc: standard crop coefficient [-]

Kc_adj: adjusted crop coefficient [-]

EF: Evaporation Fraction [-]

EFxy: Evaporation Fraction for each monitored location [-]

kcb: basal crop coefficient for the growing season [-]

Kcxy: crop coefficient for each location at each time step [-]

Ke: soil evaporation coefficient

Kr: soil evaporation reduction coefficient [-]

Ks: Water stress coefficient [-]

RAW: Readily Available Water [mm]

RAwcxy: Readily Available Soil water for each xydata location at each time step [mm]

Runoff: Runoff [mm/day]

TAW: Total Available Water [mm]

TAwcxy: Total Available Soil water for each location at each time step [mm]

Author(s)

George Owusu

References

- Allen, R. G., PEREIRA, L. S., RAES, D., & SMITH, M. (1998). Crop Evapotranspiration (guidelines for computing crop water requirements) FAO Irrigation and Drainage Paper No. 56: FAO.
- Allen, R.G., Wright, J.L., Pruitt, W.O., Pereira, L.S., Jensen, M.E., 2007. Water requirements. In: Hoffman, G.J., Evans, R.G., Jensen, M.E., Martin, D.L., Elliot, R.L. (Eds.), Design and Operation of Farm Irrigation Systems. , 2nd edition. ASABE, St. Joseph, MI, pp. 208-288.
- Liu, Y., Pereira, L.S., Fernando, R.M., 2006. Fluxes through the bottom boundary of the root zone in silty soils: parametric approaches to estimate groundwater contribution and percolation. Agric. Water Manage. 84, 27-40.

See Also

cal.kc

Examples

```
## Not run:
#FAO56 Example 32: Calculation of the crop coefficient (Kcb + Ke) under sprinkler irrigation
FAO56Example32=kc(ETo=7,P=0,RHmin=20,soil="sandy loam",crop="Broccoli",I=10,
kctype = "dual",u2=3,kc=c(0.9,0,0),h=1,Zr=0.1)
FAO56Example32$output$fc
```

```
FAO56Example32$output$Kc_adj
#FAO56 Example 33: Calculation of the crop coefficient (Kcb + Ke) under furrow irrigation
FAO56Example33=kc(ETo=7,P=0,RHmin=20,soil="sandy loam",crop="Broccoli",I=10,
         kctype = "dual",u2=3,kc=c(0.9,0,0),h=1,Zr=0.1,fw=0.3)
#FAO56 Example 34: Calculation of the crop coefficient (Kcb + Ke) under drip irrigation
FAO56Example34=kc(ETo=7,P=0,RHmin=20,soil="sandy loam",crop="Broccoli",I=10,
           kctype = "dual",u2=3,kc=c(0.9,0,0),h=1,Zr=0.1,fw="drip")

file=system.file("extdata","sys","irrigation.txt",package="sebkc")
data=read.table(file,header=TRUE)
P=data$P
rc=0
I=data$I
ETo=data$ETo
Zr=data$Zr
p=0.6
FC=0.23
WP=0.10
u2=1.6
RHmin=35
soil="sandy loam"
crop="Broccoli"
############Single crop coefficient model###########
modsingle=kc(ETo,P=P,RHmin,soil,crop,I)
#dataframe of the return values
modsingle$output
modsingle$output$TAW #Total Avalaible water [mm]
#Single with runoff coefficient
############Dual crop coefficient model###########
moddual=kc(ETo,P=P,RHmin,soil,crop,I,kctype = "dual",FC=FC,p=p,WP=WP,u2=u2,kc=c(0.3,0,0),Zr=Zr)
#Reproducing FAO56 Example 36
fc=(0.00667*1:12)+0.07333
h=1:12/1:12*0.3
 moddual=kc(ETo,P=P,RHmin,soil,crop,I,kctype = "dual",FC=FC,p=p,WP=WP,u2=u2,rc=0,
 kc=data$Kcb,Zr=Zr,lengths = c(4,4,2,2),h=h,hmodel="linear",fc=fc,fw=0.8)
 plot(moddual$output$Day,moddual$output$Kc_adj,type="l",ylim=c(0,1.2))
 lines(moddual$output$Day,moddual$output$Kcb,type="l", lty=2)
###########Spatial model I: Evaporation Fraction (EF) Model###################
#landsat folder with original files but a subset
folder=system.file("extdata","stack",package="sebkc")

sebiauto=sebi(folder=folder,welev=317,Tmax=31,Tmin=28) #sebi model
kc2=stack(sebiauto$EF/2,sebiauto$EF,sebiauto$EF/3) #assign EF to kc
modEF=kc(ETo,P=P,RHmin,soil,crop,I,kc=kc2,Rn=8,lengths = c(4,4,2,2))
spplot(modEF$EF)

#############Spatial model II: interpolating precipitation #####################
h=1:12
Zr=1:12/12
xydata=data.frame(cbind(longitude=data$longitude,latitude=data$latitude))
print(xydata) #take a look at xydata
P2=data.frame(matrix(rep(P,12),ncol=12))
print(P2) #take a look at the format of precipitation data
```

```
modEFh=kc(ETo,P=P2,RHmin,soil,crop,I,kc=kc2,Rn=8,lengths = c(4,4,2,2),h=h,Zr=Zr,xydata=xydata)
#Amount of irrigation water needed
spplot(modEFh$Drend)
#Amount of water Irrigation that is critically needed to reach maximum allowed depletion level
modEFh$Ineedxy
ETcxy=modEFh$ETcxy ##get ETc for each location at each time step
TAW=modEFh$TAW ##


############FAO56 Example 41: Estimation of mid-season crop coefficient for Trees or weeds ########
FAOExample41 =kc(fc=0.3,DOY=200,latitude=40,u2=1.5,h=2,density="row",lengths=c(0,0,1,0),
ETo=0,P=0,RHmin=55,soil="sand",crop="Broccoli",kctype="dual")
FAOExample41$output$Kcb

#FAO56 Example 43: Estimation of Kcb mid from ground cover with reduction for stomatal control
FAOExample43 =kc(fc=0.196,DOY=180,latitude=30,u2=2,h=5,density="round",y=0.0676,slope=0.189,
r1=420,RHmin=25,lengths=c(0,0,1,0),ETo=0,P=0,soil="sand",crop="Broccoli",kctype="dual")
FAOExample43$output$Kcb

## End(Not run)
```

`kumasi1960_2015` *Historical Weather data of Kumasi from 1960 to 2015*

Description

A dataset containing Rain, maximum and minimum temperature, wind speed, sunshine hours, and minimum and maximum Relative Humidity.

Format

A data frame with 20454 rows and 8 variables:

DOY Day of the Year in dates

Tmax Maximum Temperature [oC]

Tmin Minimum Temperature [oC]

RHmin Minimum Relative Humidity [per cent]

RHmax Maximum Relative Humidity [per cent]

n sunshine hours

uz wind speed [m/s]

P Daily precipitation [mm]

Author(s)

George Owusu

kumasircp262016_2050 *A 2.6 RCP downscaled Weather data of Kumasi from 2016 to 2050*

Description

A dataset containing Rain, maximum and minimum temperature, wind speed, sunshine hours, and minimum and maximum Relative Humidity. The RCPs 2.6 assumes that green house gas will peak in between 2010-2020 and declines throughout 21st Century.

Format

A data frame with 12784 rows and 8 variables:

DOY Day of the Year in dates

Tmax Maximum Temperature [oC]

Tmin Minimum Temperature [oC]

RHmin Minimum Relative Humidity [per cent]

RHmax Maximum Relative Humidity [per cent]

n sunshine hours

uz wind speed [m/s]

P Daily precipitation [mm]

Author(s)

George Owusu

kumasircp452016_2050 *A 4.5 RCP downscaled Weather data of Kumasi from 2016 to 2050*

Description

A dataset containing Rain, maximum and minimum temperature, wind speed, sunshine hours, and minimum and maximum Relative Humidity. The RCP 4.5 assumes that green house gas will peak in 2040 and declines throughout 21st Century.

Format

A data frame with 12784 rows and 8 variables:

DOY Day of the Year in dates

Tmax Maximum Temperature [oC]

Tmin Minimum Temperature [oC]

RHmin Minimum Relative Humidity [per cent]

RHmax Maximum Relative Humidity [per cent]

n sunshine hours

uz wind speed [m/s]

P Daily precipitation [mm]

Author(s)

George Owusu

`kumasircp852016_2050` *A 8.5 RCP downscaled Weather data of Kumasi from 2016 to 2050*

Description

A dataset containing Rain, maximum and minimum temperature, wind speed, sunshine hours, and minimum and maximum Relative Humidity. The RCP 8.5 assumes that green house gas will rise throughout 21st Century.

Format

A data frame with 12784 rows and 8 variables:

DOY Day of the Year in dates

Tmax Maximum Temperature [oC]

Tmin Minimum Temperature [oC]

RHmin Minimum Relative Humidity [per cent]

RHmax Maximum Relative Humidity [per cent]

n sunshine hours

uz wind speed [m/s]

P Daily precipitation [mm]

Author(s)

George Owusu

landsat578 *Radiometric correction and processing of Landsat Images*

Description

`landsat578` performs radiometric collection of landsat 5,7,and 8 images. It returns albedo, NDVI, fractional vegetation cover, surface temperature SAVI,radiance and reflectance of the image

Usage

```
landsat578(
  data,
  welev,
  sensor = NULL,
  gain = "low",
  sunelev = NULL,
  date = NULL,
  weights = "auto",
  grescale = "auto",
  brescale = "auto",
  ESUNx = "auto",
  Mp = NULL,
  Ap = NULL,
  K1 = NULL,
  K2 = NULL,
  Rp = 0.91,
  Rsky = 1.32,
  tNB = 0.886,
  DOY = NULL,
  clip = NULL,
  folder = NULL
)

## Default S3 method:
landsat578(
  data = NULL,
  welev,
  sensor = NULL,
  gain = "low",
  sunelev = NULL,
  date = NULL,
  weights = "auto",
  grescale = "auto",
  brescale = "auto",
  ESUNx = "auto",
  Mp = NULL,
  Ap = NULL,
```

```
  K1 = NULL,
  K2 = NULL,
  Rp = 0.91,
  Rsky = 1.32,
  tNB = 0.886,
  DOY = NULL,
  clip = NULL,
  folder = NULL
)
```

Arguments

data	An original folder containing Landsat data or Raster brick or raster stack. Arrange the bands in ascending order: c(band1,band2,band3,band4,band5,band6,band7) for Landsat 5 and 7. And a similar order for Landsat 8. On folder see sebkcstack See also details.
welev	Weather station elevation in meters
sensor	Numeric. Type of landsat satellite; it takes 5,7, or 8
gain	Band-specific sensor gain. It takes either "high" or "low"
sunelev	Angle of Sun elevation in degrees, as found in the meta data of the satellite image
date	DATE_ACQUIRED of the image, see metadata
weights	albedo bands weights for each band. list as in order c(band1,band2,band3,band4,band5,band6,band7) for landsat 5 and 7. The default is "auto" where sebal weights are used.
grescale	list as in order weights. Band-specific sensor values. The default for landsat 5 and 7 is from Chander et.al (2009). For Landsat 8 use ML Radiance scale in the metadata; i.e. Band specific multiplicative rescaling factor from the metadata (MTL file) (RADIANCE_MULT_BAND_x, where x is the band number).
brescale	list. Band-specific sensor values. The default for landsat 5 and 7 is from Chander et.al (2009). for Landsat 8 use AL Radiance scale in the metadata; i.e. Band specific multiplicative rescaling factor from the metadata (MTL file) (RADIANCE_MULT_BAND_x, where x is the band number).
ESUNx	list. The mean solar exo-atmospheric irradiance for each band. It is used for reflectance correction. The default is taken from SEBAL manual
Mp	Reflectance scale for Landsat 8. Band specific multiplicative rescaling factor from the metadata (MTL file) (REFLECTANCE_MULT_BAND_x, where x is the band number).
Ap	Reflectance scale for Landsat 8. Band specific additive rescaling factor from the metadata (MTL file) (REFLECTANCE_ADD_BAND_x, where x is the band number)
K1	Temperature constants for each Landsat image. Default is taken from landsat handbook
K2	Temperature constants for each Landsat image. Default is taken from landsat handbook

Rp	path radiance in the 10.4-12.5 um band. MODTRAN runs can accurately estimate this. The default is taken from Allen et al(2007) to be 0.91,
Rsky	narrow band downward thermal radiation. MODTRAN runs can accurately estimate this. The default is taken from Allen et al(2007) to be 1.32
tNB	narrow band transmissivity of air (10.4-12.5) um range. MODTRAN runs can accurately estimate this. The default is taken from Allen et al(2007) to be 0.866
DOY	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
clip	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)
folder	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported

Details

If you set the data to landsat folder that contains landsat band and meta data `sebkcstack` is used to compute the parameters. The user must specify welev and may use default parameters. The data must always be a raster brick or stack. To use the default values please order bind the bands c(band1,band2,band3,band4,band5,band6,band7). The defaults values are for landsat 5 and 7. For landsat 8, use the meta data.

Value

albedo: albedo values

Ts: Surface Temperature

NDVI: NDVI values

SAVI: SAVI values

fc: Fractional vegetation cover

radiance: radiance values

reflectance: TOA reflectance

Author(s)

George Owusu

References

- Chander, G., Markham, B. L., & Helder, D. L. 2009. Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. Remote Sensing of Environment, 113(5): 893-903.
- Waters, R. 2002. SEBAL: Surface Energy Balance Algorithms for Land. Idaho Implementation, Advanced Training and Users Manual. Kimberly, Idaho: University of Idaho.
- Survey, U. S. G. 2015. Landsat 8 (L8) data users handbook: 97p. from https://landsat.usgs.gov/documents/Landsat8Data

Examples

```
## Not run:
#Automatic detection of parameters
folder=system.file("extdata","stack",package="sebkc")
modauto=landsat578(data=folder, welev=362)

#Manual estimation with input parameters
landsat7_6feb2004=brick(system.file("extdata","landsat7_6feb2004.grd",
package="sebkc"))
mod=landsat578(data=landsat7_6feb2004,welev=317.1,sensor=7,gain="high",
sunelev=50.71154048,weights="auto",grescale="auto",brescale="auto",
ESUN="auto",K1=666.09,K2=1282.71,date="2002-2-6")
#acces albedo value
albedo=mod$albedo

## End(Not run)
```

---

lonlatreproject — *Reproject WGS 84 longitude and latitude into a new raster coordinates and vice versa*

Description

Reproject WGS 84 longitude and latitude into a new raster coordinates and vice versa

Usage

```
lonlatreproject(x, y = NULL, var = NA, map, epsg = 4326)
```

Arguments

x	a longitude or raster or vector object
y	a latitude or raster or vector object
var	numeric variable. The length should be same as the length of latitude and longitude
map	Raster* object that will be used to define the new coordinates.
epsg	coordinate reference number. The default is WGS 84: 4326

Details

If x is a list of longitudes then new horizontal coordinates based on map coordinates. If x is a raster object with horizontal coordinates then it will be projected to WGS 84.

Value

New x, y and map

Author(s)

George Owusu

Examples

```
folder=system.file("extdata","stack",package="sebkc")
data=landsat578(data=folder, welev=362)
temp=data$Ts
latitude=seq(7.544,7.590,0.001)
longitude=seq(-1.211,-1.187,0.001)
var=seq(20,30,0.2)
latitude=latitude[1:length(longitude)]
var=var[1:length(longitude)]
newlonlat=lonlatreproject(longitude,latitude,var=var,map=temp)
longitude=newlonlat$longitude
map=newlonlat$map
```

---

mapmatrix *Internal function for doing interpolation*

Description

Internal function for doing interpolation

Usage

```
mapmatrix(xydata, i, map)
```

Arguments

xydata	x and y data
i	index
map	geographical map

Value

map

Author(s)

George Owusu

Examples

```
## Not run:
folder=system.file("extdata","stack",package="sebkc")
sebiauto=sebi(folder=folder,welev=317,Tmax=31,Tmin=28)
points=sampleRandom(sebiauto$EF,100,sp=TRUE)
pt=cbind(points@coords,points@data)
longitude=pt$x
latitude=pt$y
value=pt$layer
mapmatrix=mapmatrix(xydata,2)
map=invdist(longitude,latitude,var=value,ext=sebiauto$EF)

## End(Not run)
```

`rastercon` *Spatial Conditional function on raster object*

Description

It computes equivalent of logical if function in R

Usage

```
rastercon(condition, trueValue, falseValue)
```

Arguments

`condition`	logical
`trueValue`	logical
`falseValue`	logical

Value

Return True or False

Author(s)

George Owusu

Examples

```
## Not run:
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
LAI=raster(system.file("extdata","LAI.grd",package="sebkc"))
  eNB=rastercon( NDVI<0 & albedo<0.47,0.99,rastercon(LAI>=3,0.98,0.97+(LAI*0.0033)))

## End(Not run)
```

sebal — *R computation of Surface Energy Balance Algorithm for Land and METRIC*

Description

This R function computes Bastiaanssen (1998) surface energy balance components of evapotranspiration (ET), Sensible heat(H), soil heat flux(G) and Net Radiation(Rn).

Usage

```
sebal(
  albedo,
  Ts,
  NDVI,
  SAVI,
  welev,
  xyhot = "auto",
  xycold = "auto",
  DOY = NULL,
  sunelev,
  zx = 10,
  u = 2,
  zomw = 2,
  zom = NULL,
  LAI = NULL,
  DEM = NULL,
  lapse = 0.0065,
  Rn24 = NULL,
  ETr = NULL,
  ETr24 = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  latitude = NULL,
  t1 = 1,
  time = NULL,
  Lz = NULL,
  Lm = NULL,
  model = "SEBAL",
  iter.max = 7,
  clip = NULL,
  folder = NULL
)

## Default S3 method:
```

```
sebal(
  albedo = NULL,
  Ts = NULL,
  NDVI = NULL,
  SAVI = NULL,
  welev,
  xyhot = "auto",
  xycold = "auto",
  DOY = NULL,
  sunelev = NULL,
  zx = 10,
  u = 2,
  zomw = 2,
  zom = NULL,
  LAI = NULL,
  DEM = NULL,
  lapse = 0.0065,
  Rn24 = NULL,
  ETr = NULL,
  ETr24 = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  latitude = NULL,
  t1 = 1,
  time = NULL,
  Lz = NULL,
  Lm = NULL,
  model = "SEBAL",
  iter.max = 7,
  clip = NULL,
  folder = NULL
)
```

Arguments

albedo	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
Ts	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.
NDVI	A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.
SAVI	A RasterLayer data that indicates SAVI(Soil-adjusted Vegetation Index) values. You can also point to file on your computer.
welev	Weather station elevation in meters

`xyhot`	numeric or "auto". A list of x and y coordinates of a hot pixel in the form c(x,y). If it is set to "auto", `hotTs` will be used to compute it.
`xycold`	numeric or "auto". A list of x and y coordinates of a cold pixel in the form of c(x,y). If it set to "auto", `coldTs` will be used to compute it.
`DOY`	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
`sunelev`	Angle of Sun elevation in degrees, as found in the meta data of the satellite image
`zx`	The height above the weather station where the wind speed is measured [m]
`u`	The satellites overpass time wind speed at the weather station [m/s]
`zomw`	the roughness length for the weather station surface [m]
`zom`	the momentum roughness length for each pixel [m]. You can also point to a raster file on your computer
`LAI`	Leaf Area Index, dimensionless
`DEM`	A digital elevation model[m]
`lapse`	A local lapse rate that is applied to correct DEM [K/m]. Default value is 0.0065
`Rn24`	A 24 hour net radiation [W/m2]. It is needed to estimate daily ET. It can be computed with `ETo` with even a minimal data of Tmax and Tmin. You can also point to raster file on your computer
`ETr`	an alfalfa or grass reference ET at the time of satellites overpass. It only needed if you set model to "metric" [mm/hr]
`ETr24`	daily grass or alfalfa reference Evapotranspiration (mm/day)
`wmo`	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at https://www.wunderground.com/ [Accessed on 2016-5-6] or https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
`airport`	numeric. IATA or ICAO code. They are alphabetically listed at https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A [Accessed on 2016-5-6]
`Krs`	Relationship between the fraction of extraterrestrial radiation that reaches the earth's surface, Rs/Ra, and the air temperature difference Tmax - Tmin for interior (Krs = 0.16) and coastal (Krs = 0.19) regions
`surface`	character. It is either "grass" or "alfalfa"
`latitude`	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
`t1`	numeric. The length of the calculation period in hour; 1 for hour, 0.5 for 30 minutes 0.25 for 15 minutes
`time`	The midpoint of the time of measurement[hour]; for example time is 12.5 for a period between 12:00 and 13:00
`Lz`	longitude of the centre of the local time zone [degrees west of Greenwich]. MUST BE POSITIVE Lz = 0 degrees for Greenwich.
`Lm`	longitude of the measurement site [degrees west of Greenwich]. MUST BE POSITIVE

model character. The type of model. It takes either "SEBAL" or "METRIC"

iter.max maximum iterations of sensible heat calculation.

clip extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)

folder An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported

Details

Computing SEBAL or METRIC sebal can compute either SEBAL(Bastiaanssen et al,1998) or METRIC (Allen et al 2007). In the case of METRIC, input data such as DEM, local lapse rate, and ETr must be provided. See Allen et al (2007) for more details.

Using Landsat Folder as input data Though this sebkc function is not sensor dependent, one can point the folder parameter to a Landsat TM(5), ETM(7) or 8 folder that contains landsat bands and metadata. One can also point the folder parameter to object of landsat578

Automatic computation When xycold and xyhot are set to "auto", about 80 per cent of the input image pixels are used to compute cold and hot pixels. This avoids using NAs in classification of pixels.

Taking long time to Simulate? If you point the folder to landsat files and set xycold and xyhot to "auto", it will take about 2 hours for the function to run. Without these "autos", it will take about 45 minutes. It is advisable to perform 3 step analyses of using three functions as follows: sebkcstack, landsat578, hotTs, coldTs. You need not to go through this if you have your albedo, Ts, NDVI, SAVI from MODIS, ASTER etc

Value

LE: latent heat flux [W/m2]

Rn: Net Radiation [W/m2]

H: Sensible Heat Flux [W/m2]

G: Soil heat flux [W/m2]

ETins: instantaneous ET if model = "METRIC" [mm/hr]

ET24: 24 hour Evapotranspiration only if Rn24 is not NULL [mm/day]

ETrF: METRIC ET fraction [dimensionless]

EF: ET fraction [dimensionless]

Ta: Air temperature = Ts-dT [K]

iter.coef: Parameters from sensible heat iteration

Author(s)

George Owusu

References

- Bastiaanssen, W. G. M., Menenti, M., Feddes, R. A., & Holtslag, A. A. M. 1998. A remote sensing surface energy balance algorithm for land (SEBAL), part 1: formulation. Journal of Hydrology: 212-213: 198-212.
- Bastiaanssen, W. G. M., Pelgrum, H., Wang, J., Ma, Y., Moreno, J. F., Roerink, G. J., & van der Wal, T. 1998. A remote sensing surface energy balance algorithm for land (SEBAL).: Part 2: Validation. Journal of Hydrology, 212-213(0): 213-229.
- Allen, R., Tasumi, M., & Trezza, R. 2007. Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration (METRIC)-Model. Journal of Irrigation and Drainage Engineering, 133(4): 380-394.
- Allen, R., Tasumi, M., Morse, A., Trezza, R., Wright, J., Bastiaanssen, W., Kramber, W., Lorite, I., & Robison, C. 2007. Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration (METRIC)-Applications. Journal of Irrigation and Drainage Engineering, 133(4): 395-406.

Examples

```
## Not run:
#use original landsat 8 data by specifying folder path
folder=system.file("extdata","stack",package="sebkc")
modauto=sebal(folder = folder,welev = 380,xycold="full",xyhot="full")
#plot ET fraction
plot(modauto$EF)

#Semi-auto
#load individual input files, for example from MODIS, ASTER etc
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
LAI=raster(system.file("extdata","LAI.grd",package="sebkc"))
mod=sebal(albedo=albedo,Ts=Ts,NDVI=NDVI,SAVI=NULL,
iter.max=7,xyhot="full",xycold="full",
DOY=37,sunelev=50.71154048,welev=317.1,zx=10,
u=2,zomw=3,zom=NULL,LAI=LAI,DEM=NULL,
lapse=0.0065,Rn24=NULL,ETr=NULL,model="SEBAL")
#get latent heat flux
mod$LE
#evaporation fraction
mod$EF

#3 step simulation using landsat 7 with SLC OFF
##step one: prepare the input data
### point to landsat 7 data with strips
folder=system.file("extdata","slc",package="sebkc")
#####get the data stacked and remove strips
rawdata=sebkcstack(folder,remove_cloud = 2,gap_fill = TRUE)
###### check if strips are removed
plot(rawdata$data)
#get Ts, Albedo, NDVI, SAVI, sunelev, DOY from landsat data
welev=278
```

```
 data=landsat578(rawdata,welev=welev)
 #perform semi-auto simulation mod=sebal(data,welev=welev)
# Determine xyhot. Digitize polygon on the Ts map
modhot=hotTs(data,welev=welev,extent="auto",cluster=2)
#determine the cold. Digitize polygon on the Ts map
modcold=coldTs(data,welev=welev,extent="auto",cluster=2)
xyhot=modhot$xyhot
xycold=modcold$xycold
modsebal=sebal(folder=data,xyhot=xyhot,xycold=xycold,welev=welev)

## End(Not run)
```

---

sebi *SEBI Evapotranspiration Fraction Estimation in R*

Description

`sebi` computes Evapotranspiration Fraction Estimation based on Menenti& Choudhury (1993) parameterization of land surface evaporation by means of location dependent potential evaporation and surface temperature range.

Usage

```
sebi(
  albedo,
  Ts,
  Tmax,
  Tmin,
  RHmax = NULL,
  RHmin = NULL,
  latitude = NULL,
  NDVI,
  SAVI,
  iter.max = 7,
  xyhot = "auto",
  xycold = "auto",
  DOY,
  sunelev,
  welev,
  zx = 10,
  u = 2,
  zomw = 2,
  zom = NULL,
  LAI = NULL,
  DEM = NULL,
  lapse = 0.0065,
  Rn24 = NULL,
  wmo = NULL,
```

```
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  model = "sebi",
  clip = NULL,
  folder = NULL
)

## Default S3 method:
sebi(
  albedo = NULL,
  Ts,
  Tmax,
  Tmin,
  RHmax = NULL,
  RHmin = NULL,
  latitude = NULL,
  NDVI,
  SAVI,
  iter.max = 7,
  xyhot = "auto",
  xycold = "auto",
  DOY,
  sunelev,
  welev,
  zx = 10,
  u = 2,
  zomw = 2,
  zom = NULL,
  LAI = NULL,
  DEM = NULL,
  lapse = 0.0065,
  Rn24 = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  model = model,
  clip = NULL,
  folder = NULL
)
```

Arguments

albedo	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
Ts	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file

on your computer.

Tmax	Numeric. Maximum air Temperature in degree Celsius
Tmin	Numeric. Minimum air Temperature in degree Celsius
RHmax	Maximum Relative Humidity in percent
RHmin	Minimum Relative Humidity in percent
latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
NDVI	A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.
SAVI	A RasterLayer data that indicates SAVI(Soil-adjusted Vegetation Index) values. You can also point to file on your computer.
iter.max	maximum iterations of sensible heat calculation.
xyhot	numeric or "auto". A list of x and y coordinates of a hot pixel in the form c(x,y). If it is set to "auto", hotTs will be used to compute it.
xycold	numeric or "auto". A list of x and y coordinates of a cold pixel in the form of c(x,y). If it set to "auto", coldTs will be used to compute it.
DOY	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
sunelev	Angle of Sun elevation in degrees, as found in the meta data of the satellite image
welev	Weather station elevation in meters
zx	The height above the weather station where the wind speed is measured [m]
u	The satellites overpass time wind speed at the weather station [m/s]
zomw	the roughness length for the weather station surface [m]
zom	the momentum roughness length for each pixel [m]. You can also point to a raster file on your computer
LAI	Leaf Area Index, dimensionless
DEM	A digital elevation model[m]
lapse	A local lapse rate that is applied to correct DEM [K/m]. Default value is 0.0065
Rn24	A 24 hour net radiation [W/m2]. It is needed to estimate daily ET. It can be computed with ETo with even a minimal data of Tmax and Tmin. You can also point to raster file on your computer
wmo	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at https://www.wunderground.com/ [Accessed on 2016-5-6] or https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
airport	numeric. IATA or ICAO code. They are alphabetically listed at https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A [Accessed on 2016-5-6]
Krs	Relationship between the fraction of extraterrestrial radiation that reaches the earth's surface, Rs/Ra, and the air temperature difference Tmax - Tmin for interior (Krs = 0.16) and coastal (Krs = 0.19) regions

surface	character. It is either "grass" or "alfalfa"
model	character. The type of model. It takes either "SEBAL" or "METRIC"
clip	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)
folder	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported

Details

Function ETo will be automatically used to estimate parameters y (psychrometric constant), slope (slope of saturation vapour pressure curve) and vpd (Vapour pressure deficit).

Value

EF Evapotranspiration Fraction

Author(s)

George Owusu

References

Menenti, M., & Choudhury, B. 1993. Parameterization of land surface evaporation by means of location dependent potential evaporation and surface temperature range. Paper presented at the Proceedings of IAHS conference on Land Surface Processes.

See Also

sebal , ETo, sebs

Examples

```
## Not run:
#using folder parameter
folder=system.file("extdata","stack",package="sebkc")
sebiauto=sebi(folder=folder,welev=317,Tmax=31,Tmin=28)

#manual input of parameters
#data
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
LAI=raster(system.file("extdata","LAI.grd",package="sebkc"))
#model
modsebi=sebi(albedo=albedo,Ts=Ts,Tmax=31,Tmin=28,RHmax=84,
RHmin=63,NDVI=NDVI,SAVI=NULL,iter.max=7,xyhot="full",
xycold="full",DOY=37,sunelev=50.71154048,welev=317.1,zx=10,
u=2,zomw=2,zom=NULL,LAI=LAI,Rn24=NULL,model="sebi")
```

```
#Another interactive example
#get Ts, Albedo, NDVI, SAVI, sunelev, DOY from landsat data
welev=278
data=landsat578(rawdata,welev=welev)
 #perform semi-auto simulation
#Determine xyhot. Digitize polygon on the Ts map
modhot=hotTs(data,welev=300,extent="auto",cluster=2)
#determine the cold. Digitize polygon on the Ts map
modcold=coldTs(data,welev=275,extent="auto",cluster=2)
xyhot=modhot$xyhot
xycold=modcold$xycold
#use object of \code{\link{coldTs}} or \code{\link{hotTs}} in different ways
modsebi=sebi(data,xyhot=modhot,xycold=xycold,welev=welev,
Tmax=Tmax,Tmin=Tmin,RHmax=RHmax,RHmin=RHmin)

## End(Not run)
```

`sebkc.tryCatch` *Internal function to Catch errors and warnings*

Description

Internal function to Catch errors and warnings

Usage

```
sebkc.tryCatch(expr)
```

Arguments

`expr`	an R expression to evaluate

Value

value a list with 'value' and 'warning', where value may be an error caught

Examples

```
thiserror=str( sebkc.tryCatch( log( "a" ) ) )$value
```

sebkcstack *Stacking, gap-filling, cloud removal of Landsat image ET Model*

Description

This function prepares landsat 5, 7, and 8 data for landsat578. First, it reads meta data and returns many input parameters for landsat578 and sebal. Second, it stacks 7 landsat layers: it stacks bands 1-7 for landsat 5 and 7; and bands 2-7,10 for landsat 8.. Third, it removes landsat clouds based on Martinuzzi et al(2009) method. Fourth, it gap-fills landsat 7 strips due to SLC-off as well as gap-filling NAs in other landsat sensors. It can also process any selected bands.

Usage

```
sebkcstack(
  folder,
  meta_pattern = "MTL.txt",
  remove_cloud = FALSE,
  gap_fill = FALSE,
  gap_loop = 8,
  clip = NULL
)

## Default S3 method:
sebkcstack(
  folder,
  meta_pattern = "MTL.txt",
  remove_cloud = FALSE,
  gap_fill = FALSE,
  gap_loop = 8,
  clip = NULL
)
```

Arguments

folder	The folder or directory of landsat files
meta_pattern	The regular expression pattern to identify metadata file. The default is "MTL.txt". The function works on the new landsat metadata only.
remove_cloud	TRUE FALSE, 1, or 2. To indicate the cloud cover removal from the image. Default is FALSE. If it is set to 1, the overlapping areas of band 1 DN values between 120 and 255 and band 6 DN values of 102 to 128 are used. If it is set to 2 the union of the DN ranges are used; and clouds as well as urban, barren, quarries, rocks, and sand are removed; otherwise only clouds are removed. See Martinuzzi et al(2009) for more details. At the moment only landsat 5 and 7 clouds are removed.
gap_fill	Logical (TRUE or FALSE).It replaces strips in landsat 7 or NAs in other data set. It uses focal neighbourhood approach. It is an automated Version of

USGS "Gap-Filling Landsat 7 SLC-off Single Scenes Using Erdas Imagine TM". Like USGS, it also takes approximately one hour to complete. see details at http://landsat.usgs.gov/ERDAS_Approach.php

`gap_loop` numeric. The number of loops or repetitions that gap-fill should be run. The default is 8 for one landsat scene. If the landsat image is smaller, it can be reduced.

`clip` extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)

Details

The function can simulate any of the activities described in the description section. It takes several minutes to replace strips (1 hour) and remove clouds (30 minutes) on one landsat scene. But stacking of bands and reading of metadata take few seconds. One can save the stacked and processed data in the same "folder" with `writesebkc`. The output file name is "sebkcstack.tif".

Value

data: raster stacked data. If crop is not NULL then crop Extent object is returned

brescale: brescale of the stacked data

grescale: grescale of the stacked data

sunelev: sun elevation for stacked data

date: Acquired date of the raster stacked data

viewangle: view angle of landsat 8

azimuth: azimuth angle of the image

sensor: Type of satellite

K1: K1 of landsat 8 thermal band 10

K2: K2 of landsat 8 thermal band 10

cc: cloud cover percentage

quality: Image quality

row: WRS_ROW of the image

path: WRS_PATH of the image

Author(s)

George Owusu

References

Martinuzzi, S., Gould, W.A., Ramos Gonzales, O.M. 2007. Creating Cloud-Free Landsat ETM+ Data Sets in Tropical Landscapes: Cloud and Cloud-Shadow Removal. USDA Forest Service General Technical Report IITF-GTR-32.

USGS Using Landsat 7 Data http://landsat.usgs.gov/ERDAS_Approach.php

Examples

```
## Not run:
folder=system.file("extdata","stack",package="sebkc")
stack=sebkcstack(folder=folder)
#returns data and grescale
stack$data
stack$grescale

## End(Not run)
```

---

sebs *SEBS Estimation of Evapotranspiration Fraction*

Description

sebs computes Su (2002) Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes

Usage

```
sebs(
  albedo,
  Ts,
  Tmax,
  Tmin,
  RHmax = NULL,
  RHmin = NULL,
  n = NULL,
  NDVI,
  SAVI,
  iter.max = 7,
  xyhot,
  xycold,
  DOY,
  sunelev,
  welev,
  zx,
  u,
  zomw,
  zom = NULL,
  LAI = NULL,
  DEM = NULL,
  lapse = 0.0065,
  Rn24 = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
```

```
  surface = "grass",
  latitude = NULL,
  model = "SEBS",
  clip = NULL,
  folder = NULL
)

## Default S3 method:
sebs(
  albedo = NULL,
  Ts,
  Tmax,
  Tmin,
  RHmax = NULL,
  RHmin = NULL,
  n = NULL,
  NDVI,
  SAVI,
  iter.max = 7,
  xyhot = "auto",
  xycold = "auto",
  DOY = NULL,
  sunelev,
  welev,
  zx = 10,
  u = 2,
  zomw = 2,
  zom = NULL,
  LAI = NULL,
  DEM = NULL,
  lapse = 0.0065,
  Rn24 = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  latitude = NULL,
  model = "SEBS",
  clip = NULL,
  folder = NULL
)
```

Arguments

albedo	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
Ts	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file

on your computer.

Tmax	Numeric. Maximum air Temperature in degree Celsius
Tmin	Numeric. Minimum air Temperature in degree Celsius
RHmax	Maximum Relative Humidity in percent
RHmin	Minimum Relative Humidity in percent
n	Sunshine hours
NDVI	A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.
SAVI	A RasterLayer data that indicates SAVI(Soil-adjusted Vegetation Index) values. You can also point to file on your computer.
iter.max	maximum iterations of sensible heat calculation.
xyhot	numeric or "auto". A list of x and y coordinates of a hot pixel in the form c(x,y). If it is set to "auto", hotTs will be used to compute it.
xycold	numeric or "auto". A list of x and y coordinates of a cold pixel in the form of c(x,y). If it set to "auto", coldTs will be used to compute it.
DOY	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
sunelev	Angle of Sun elevation in degrees, as found in the meta data of the satellite image
welev	Weather station elevation in meters
zx	The height above the weather station where the wind speed is measured [m]
u	The satellites overpass time wind speed at the weather station [m/s]
zomw	the roughness length for the weather station surface [m]
zom	the momentum roughness length for each pixel [m]. You can also point to a raster file on your computer
LAI	Leaf Area Index, dimensionless
DEM	A digital elevation model[m]
lapse	A local lapse rate that is applied to correct DEM [K/m]. Default value is 0.0065
Rn24	A 24 hour net radiation [W/m2]. It is needed to estimate daily ET. It can be computed with ETo with even a minimal data of Tmax and Tmin. You can also point to raster file on your computer
wmo	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at https://www.wunderground.com/ [Accessed on 2016-5-6] or https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
airport	numeric. IATA or ICAO code. They are alphabetically listed at https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A [Accessed on 2016-5-6]
Krs	Relationship between the fraction of extraterrestrial radiation that reaches the earth's surface, Rs/Ra, and the air temperature difference Tmax - Tmin for interior (Krs = 0.16) and coastal (Krs = 0.19) regions
surface	character. It is either "grass" or "alfalfa"

latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
model	character. The type of model. It takes either "SEBAL" or "METRIC"
clip	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)
folder	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported

Details

Function ETo will be automatically used to estimate parameters y (psychrometric constant), slope (slope of saturation vapour pressure curve) and vpd (Vapour pressure deficit). For information on data input procedure see 'details' at sebal

Value

EF Evapotranspiration Fraction

Author(s)

George Owusu

References

Su, Z. 2002. The Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes. Hydrol. Earth Syst. Sci., 6(1): 85-100.

See Also

sebal , ETo, sebi

Examples

```
## Not run:
#define Input data
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
LAI=raster(system.file("extdata","LAI.grd",package="sebkc"))
Tmax=31
Tmin=28
RHmax=84
RHmin=63
#perform simulation
modsebs=sebs(albedo=albedo,Ts=Ts,Tmax=Tmax,Tmin=Tmin,RHmax=RHmax,
RHmin=RHmin,NDVI=NDVI,SAVI=NULL,iter.max=7,xyhot="full",
xycold="full",DOY=37,sunelev=50.71154048,welev=317.1,zx=10,
u=2,zomw=2,zom=NULL,LAI=LAI,Rn24=NULL,model="SEBS")
```

```
#use original landsat 7 data by specifying folder path
folder=system.file("extdata","stack",package="sebkc")
modauto=sebs(folder = folder,welev = 380,Tmax=Tmax,
Tmin=Tmin,RHmax=RHmax,RHmin=RHmin)
#plot ET fraction
plot(modauto$EF)

#get Ts, Albedo, NDVI, SAVI, sunelev, DOY from landsat data
welev=278
data=landsat578(rawdata,welev=welev)
 #perform semi-auto simulation
#Determine xyhot. Digitize polygon on the Ts map
modhot=hotTs(data,welev=300,extent="auto",cluster=2)
#determine the cold. Digitize polygon on the Ts map
modcold=coldTs(data,welev=275,extent="auto",cluster=2)
xyhot=modhot$xyhot
xycold=modcold$xycold
#use object of \code{\link{coldTs}} or \code{\link{hotTs}} in different ways
modsebs=sebs(data,xyhot=modhot,xycold=xycold,welev=welev,
Tmax=Tmax,Tmin=Tmin,RHmax=RHmax,RHmin=RHmin)

## End(Not run)
```

---

sseb *Simplified Surface Energy Balance*

Description

Senay etal (2011) Simplified Surface Energy Balance (SSEB) approach for estimating landscape ET

Usage

```
sseb(
  Ts,
  welev = NULL,
  TH = "auto",
  TC = "auto",
  sunelev = NULL,
  NDVI = NULL,
  DEM = NULL,
  albedo = NULL,
  NDVImax = 0.7,
  cc = 0.65,
  KL = 0.0065,
  ETo = NULL,
  wmo = NULL,
  airport = NULL,
```

```
  Krs = 0.16,
  surface = "grass",
  x = 1,
  Tmax = NULL,
  Tmin = NULL,
  zx = NULL,
  u = 2,
  DOY = NULL,
  latitude = NULL,
  n = NULL,
  RHmax = NULL,
  RHmin = NULL,
  clip = NULL,
  folder = NULL
)

## Default S3 method:
sseb(
  Ts = NULL,
  welev = NULL,
  TH = "auto",
  TC = "auto",
  sunelev = NULL,
  NDVI = NULL,
  DEM = NULL,
  albedo = NULL,
  NDVImax = 0.7,
  cc = 0.65,
  KL = 0.0065,
  ETo = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  x = 1.2,
  Tmax = NULL,
  Tmin = NULL,
  zx = NULL,
  u = 2,
  DOY = NULL,
  latitude = NULL,
  n = NULL,
  RHmax = NULL,
  RHmin = NULL,
  clip = NULL,
  folder = NULL
)
```

Arguments

Ts	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.
welev	Weather station elevation in meters
TH	the average of the representative 3 hot pixels selected for hot "bare" areas. If it is set to "auto" TH will be estimated from hotTs
TC	the average of representative 3 cold pixels selected from the irrigated fields. When it is set to "auto" TC will be estimated from coldTs
sunelev	Angle of Sun elevation in degrees, as found in the meta data of the satellite image
NDVI	A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.
DEM	A digital elevation model[m]
albedo	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
NDVImax	numeric, NDVI value for heavily green-vegetated area in the image
cc	numeric, the correction coefficient if the NDVI approaches 0.0
KL	numeric, the assumed lapse rate of air moving along the terrain
ETo	numeric, a standardized clipped grass reference ET. when it is set to NULL, it is automatically estimated from ETo
wmo	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at https://www.wunderground.com/ [Accessed on 2016-5-6] or https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
airport	numeric. IATA or ICAO code. They are alphabetically listed at https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A [Accessed on 2016-5-6]
Krs	Relationship between the fraction of extraterrestrial radiation that reaches the earth's surface, Rs/Ra, and the air temperature difference Tmax - Tmin for interior (Krs = 0.16) and coastal (Krs = 0.19) regions
surface	character. It is either "grass" or "alfalfa"
x	multiplier needed to estimate ET for tall, full cover crops such as alfalfa, corn and wheat. Default is 1.2.
Tmax	Numeric. Maximum air Temperature in degree Celsius
Tmin	Numeric. Minimum air Temperature in degree Celsius
zx	The height above the weather station where the wind speed is measured [m]
u	The satellites overpass time wind speed at the weather station [m/s]
DOY	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere

n	Sunshine hours
RHmax	Maximum Relative Humidity in percent
RHmin	Minimum Relative Humidity in percent
clip	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)
folder	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported

Value

ET24: Actual 24 hour ET

EF: ET fraction

ETo: 24 hour reference ETo

Author(s)

George Owusu

References

Senay, G. B., Budde, M. E., & Verdin, J. P. 2011. Enhancing the Simplified Surface Energy Balance (SSEB) approach for estimating landscape ET: Validation with the METRIC model. Agricultural Water Management, 98(4): 606-618.

Examples

```
## Not run:
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
#minimal data
modsseb=sseb(Ts=Ts,TH="full",TC="full",sunelev=50,NDVI=NDVI,DEM=NULL,
albedo=albedo,NDVImax=0.7,cc=0.65,KL=0.0065,
ETo="auto",x=1.2,Tmax=31,Tmin=28,zx=10,
u=2,DOY=37,latitude=5.6,n=NULL,RHmax=NULL,RHmin=NULL)

#uaing the folder parameters
folder=system.file("extdata","stack",package="sebkc")
ssebauto=sseb(folder=folder,welev=317,Tmax=31,Tmin=28, latitude=5.6)

#Another interactive example
#get Ts, Albedo, NDVI, SAVI, sunelev, DOY from landsat data
welev=278
data=landsat578(rawdata,welev=welev)
#perform semi-auto simulation
#Determine xyhot. Digitize polygon on the Ts map
modhot=hotTs(data,welev=300,extent="auto",cluster=2)
#determine the cold. Digitize polygon on the Ts map
```

```
modcold=coldTs(data,welev=275,extent="auto",cluster=2)
xyhot=modhot$Tshot
xycold=modcold$Tscold
#use object of \code{\link{coldTs}} or \code{\link{hotTs}} in different ways
modsseb=sseb(Ts=Ts,TH=xyhot,TC=modcold,sunelev=50,NDVI=NDVI,DEM=NULL,
albedo=albedo,NDVImax=0.7,cc=0.65,KL=0.0065,
ETo="auto",x=1.2,Tmax=31,Tmin=28,zx=10,
u=2,DOY=37,latitude=5.6,n=NULL,
RHmax=NULL,RHmin=NULL)

## End(Not run)
```

---

ssebi *S-SEBI Evapotranspiration Fraction*

Description

ssebi computes Roerink et. al (2000) S-SEBI: A simple remote sensing algorithm to estimate the surface energy balance.

Usage

```
ssebi(
  Ts,
  albedo = NULL,
  threshold = 0.2,
  plot = TRUE,
  Rn24 = NULL,
  folder = NULL,
  welev = NULL
)

## Default S3 method:
ssebi(
  Ts = NULL,
  albedo = NULL,
  threshold = 0.2,
  plot = TRUE,
  Rn24 = NULL,
  folder = NULL,
  welev = NULL
)
```

Arguments

Ts	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.

albedo	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
threshold	numeric. Albedo inflection point threshold
plot	logical:TRUE or FALSE. To indicate if histograms or triangle should be plotted
Rn24	A 24 hour net radiation [W/m2]. It is needed to estimate daily ET. It can be computed with ETo with even a minimal data of Tmax and Tmin. You can also point to raster file on your computer
folder	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
welev	Weather station elevation in meters

Value

EF, amax,bmax,amin,bmin

Author(s)

George Owusu

References

Roerink, G. J., Su, Z., & Menenti, M. 2000. S-SEBI: A simple remote sensing algorithm to estimate the surface energy balance. Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere , 25(2): 147-157.

Examples

```
## Not run:
#Manual data specification
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
mod=ssebi(Ts=Ts,albedo=albedo,threshold=0,plot=TRUE)

#Using landsat folder
folder=system.file("extdata","stack",package="sebkc")
ssebiauto=ssebi(folder=folder,welev=278)

## End(Not run)
```

---

tseb *Computing Two Source Surface Energy Balance (TSEB) in R*

Description

This function estimates evaporation (E), transpiration (T), and evapotranspiration(ET) of land surface. The computation is based on Norman et al (1995) and Colaizzi et al(2012) models.

Usage

```
tseb(
  albedo,
  Ts,
  LAI,
  DOY,
  xyhot = "auto",
  xycold = "auto",
  TA = "sebal",
  Tmax,
  Tmin,
  RHmax = NULL,
  RHmin = NULL,
  n = NULL,
  latitude = NULL,
  zom = NULL,
  NDVI,
  SAVI,
  hc = 2,
  DEM = NULL,
  viewangle = 0,
  sunelev,
  welev,
  u = 2,
  s = 2,
  C = 90,
  lapse = 0.0065,
  Rn24 = NULL,
  ETr = NULL,
  ETr24 = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  time = NULL,
  Lz = NULL,
  Lm = NULL,
  t1 = 1,
  zx,
  zomw,
  xPT = 1.3,
  rc = c(70, 1000, 100),
  series = "xPT",
  clump = 1,
  fg = 1,
  fc = "auto",
  network = "parallel",
  clip = NULL,
```

```
  folder = NULL,
  iter.max = 7
)

## Default S3 method:
tseb(
  albedo = NULL,
  Ts = NULL,
  LAI = NULL,
  DOY = NULL,
  xyhot = "auto",
  xycold = "auto",
  TA = "sebal",
  Tmax,
  Tmin,
  RHmax = NULL,
  RHmin = NULL,
  n = NULL,
  latitude = NULL,
  zom = NULL,
  NDVI,
  SAVI,
  hc = 2,
  DEM = NULL,
  viewangle = 0,
  sunelev,
  welev,
  u = 2,
  s = 2,
  C = 90,
  lapse = 0.0065,
  Rn24 = NULL,
  ETr = NULL,
  ETr24 = NULL,
  wmo = NULL,
  airport = NULL,
  Krs = 0.16,
  surface = "grass",
  time = NULL,
  Lz = NULL,
  Lm = NULL,
  t1 = 1,
  zx = 200,
  zomw = 2,
  xPT = c(1.26, 0, 0.1),
  rc = c(50, 1000, 100),
  series = "PM",
  clump = 1,
```

```
  fg = 1,
  fc = "auto",
  network = "series",
  clip = NULL,
  folder = NULL,
  iter.max = 7
)
```

Arguments

`albedo`	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
`Ts`	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.
`LAI`	Leaf Area Index, dimensionless
`DOY`	Numeric or Date [YYYY-mm-dd]. Day of the Year. If you give data in the form of date [YYYY-mm-dd], it will be converted to DOY
`xyhot`	numeric or "auto". A list of x and y coordinates of a hot pixel in the form c(x,y). If it is set to "auto", `hotTs` will be used to compute it.
`xycold`	numeric or "auto". A list of x and y coordinates of a cold pixel in the form of c(x,y). If it set to "auto", `coldTs` will be used to compute it.
`TA`	Air temperature[K]. It can take "sebal" or 'Tmax' or 'Tmin' or numeric value. When it is set to sebal, TA = Ts-dT. The 'Tmax' and 'Tmin' correspond to maximum and minimum temperature.
`Tmax`	Numeric. Maximum air Temperature in degree Celsius
`Tmin`	Numeric. Minimum air Temperature in degree Celsius
`RHmax`	Maximum Relative Humidity in percent
`RHmin`	Minimum Relative Humidity in percent
`n`	Sunshine hours
`latitude`	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
`zom`	the momentum roughness length for each pixel [m]. You can also point to a raster file on your computer
`NDVI`	A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.
`SAVI`	A RasterLayer data that indicates SAVI(Soil-adjusted Vegetation Index) values. You can also point to file on your computer.
`hc`	numeric. it is canopy height[m]
`DEM`	A digital elevation model[m]
`viewangle`	angle of view of the sensor in degrees
`sunelev`	Angle of Sun elevation in degrees, as found in the meta data of the satellite image

welev	Weather station elevation in meters
u	The satellites overpass time wind speed at the weather station [m/s]
s	numeric. Mean leaf size; it is four times the leaf area divided by the perimeter. The default is 2 (Grace et al., 1981).
C	coefficient. Weighting a coefficient in the equation for leaf boundary layer. A value of 90 s^0.5/m (Norman et al, 1995).
lapse	A local lapse rate that is applied to correct DEM [K/m]. Default value is 0.0065
Rn24	A 24 hour net radiation [W/m2]. It is needed to estimate daily ET. It can be computed with ETo with even a minimal data of Tmax and Tmin. You can also point to raster file on your computer
ETr	an alfalfa or grass reference ET at the time of satellites overpass. It only needed if you set model to "metric" [mm/hr]
ETr24	daily grass or alfalfa reference Evapotranspiration (mm/day)
wmo	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at https://www.wunderground.com/ [Accessed on 2016-5-6] or https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
airport	numeric. IATA or ICAO code. They are alphabetically listed at https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A [Accessed on 2016-5-6]
Krs	Relationship between the fraction of extraterrestrial radiation that reaches the earth's surface, Rs/Ra, and the air temperature difference Tmax - Tmin for interior (Krs = 0.16) and coastal (Krs = 0.19) regions
surface	character. It is either "grass" or "alfalfa"
time	The midpoint of the time of measurement[hour]; for example time is 12.5 for a period between 12:00 and 13:00
Lz	longitude of the centre of the local time zone [degrees west of Greenwich]. MUST BE POSITIVE Lz = 0 degrees for Greenwich.
Lm	longitude of the measurement site [degrees west of Greenwich]. MUST BE POSITIVE
t1	numeric. The length of the calculation period in hour; 1 for hour, 0.5 for 30 minutes 0.25 for 15 minutes
zx	The height above the weather station where the wind speed is measured [m]
zomw	the roughness length for the weather station surface [m]
xPT	coefficient(s). The Priestley-Taylor equation coefficient (Norman et al, 2005). It can take a single coefficient or in the form c(initial, minimum, increment). Example is xPT=c(1.26,1,0.1). It must be noted this is a decreasing increment from the initial value .i.e 1.26. The subsequent increment is only meant for a cell where LEs is negative.
rc	coefficient. Penman-Monteith equation coefficient (Colaizzi et al,2012). It can take a single coefficient or in the form c(initial, maximum, increment). Example is rc=c(0,1000,100). Unlike xPT, this is positively incremented.
series	character.The type of series. It takes "xPT" for Priestley-Taylor equation(Norman, 1995) or "PM" for Penman-Monteith equation (Colaizzi et al, 2012)

`clump`	coefficient. A canopy clumping coefficient used for calculation of directional fc (fractional cover of vegetation)
`fg`	numeric. The fraction of LA1 that is green. If no information is available on fg, then it is assumed to be unity (1).
`fc`	fraction (0-1).Directional vegetation cover. The default uses Norman et al(1995) fc equation
`network`	character. It takes either "parallel" (Norman et al, 1995) or "series" (Colaizzi et al, 2012; Norman et al, 1995).
`clip`	extent object or raster object or polygon from which an Extent object can be extracted. A polygon or raster will be reprojected to conform the data to be cropped. for example clip can take the form of c(xmin, xmax, ymin, ymax)
`folder`	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
`iter.max`	maximum iterations of sensible heat calculation.

Details

Theory This function separately computes LEs, LEs using Net radiation (Rn), sensible heat flux (H) and soil heat flux (G). The Rn was first computed with `sebal`. The soil net radiation computed as `Rns=(sebal$Rn*exp(0.9*log(1-fc)))` . The canopy radiation was computed as `Rnc=sebal$Rn-Rns` . The G was computed from `sebal`. The canopy sensible heat (Hc) and soil sensible heat (Hs) were computed based on corresponding canopy Temperature (Tc) and soil temperature (Tsoil). Two different approaches were employed to sensible heat fluxes. The first is Norman et al(1995) parallel network. The second is Norman (1995) secant series but uses Priestley-Taylor equation (xPT).

Default Parameter These parameters have been set based on literature

Value

LEc: canopy latent heat flux [W/m2]

LEs: Soil latent heat flux[W/m2]

T24: 24 hour Transpiration [mm/day]

E24: 24 hour Evaporation [mm/day]

ET24: 24 hour Evapotranspiration [mm/day]

EF: ET24 (daily Evapotranspiration) Evaporative Fraction. EF corresponds to the type of scaling method used: see `ETohr` for details

EFs: E(Evaporation) Evaporative Fraction

EFc: T (Transpiration) Evaporative Fraction

Author(s)

George Owusu

References

- Norman JM, Kustas WP, Humes KS (1995). A two-source approach for estimating soil and vegetation energy fluxes from observations of directional radiometric surface temperature. Agric For Meteorol 1995;77:263-93.
- Colaizzi, Paul; Kustas, William P.; Anderson, Martha C.; Agam, Nurit; Tolk, Judy A.; Evett, Steven R.; Howell, Terry A.; Gowda, Prasanna H.; and O'Shaughnessy, Susan A., "Two-source energy balance model estimates of evapotranspiration using component and composite surface temperatures" (2012). Publications from USDA-ARS / UNL Faculty. Paper 1147. http://digitalcommons.unl.edu/usdaarsfacpub/1147
- Grace, J., 1981. Some effects of wind on plants. In: J. Grace, E.D. Ford and P.G. Jarvis (Editors), Plants and their Atmospheric Environment. Blackwell Scientific, London, pp. 31-56.
- Ronglin Tang, Zhao-Liang Li, Yuanyuan Jia, Chuanrong Li, Kun-Shan Chen, Xiaomin Sun & Jinyong Lou (2012): Evaluating one- and two-source energy balance models in estimating surface evapotranspiration from Landsat-derived surface temperature and field measurements, International Journal of Remote Sensing. http://dx.doi.org/10.1080/01431161.2012.716529
- KUSTAS, W. & ANDERSON, M. 2009. Advances in thermal infrared remote sensing for land surface modeling. Agricultural and Forest Meteorology, 149, 2071-2081.

Examples

```
## Not run:
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
LAI=raster(system.file("extdata","LAI.grd",package="sebkc"))
Parallel=tseb(Ts=Ts,LAI=LAI,DOY=37,xyhot="full",
xycold="full",albedo=albedo,Tmax=31,
Tmin=28,RHmax=NULL,RHmin=NULL,zom=NULL,NDVI=NDVI,SAVI=NULL,hc=20,
DEM=NULL,viewangle=0,sunelev=50,welev=345,u=2,
s=2,C=90,lapse=0.0065,Rn24=NULL,zx=200,zomw=2,
xPT=1.3,clump=1,fg=1,fc="auto",network="parallel",
latitude=5.6,n=6.5)

series=tseb(Ts=Ts,LAI=LAI,DOY=37,xyhot="full",
xycold="full",albedo=albedo,Tmax=31,
Tmin=28,RHmax=NULL,RHmin=NULL,zom=NULL,NDVI=NDVI,SAVI=NULL,hc=20,
DEM=NULL,viewangle=0,sunelev=50,welev=345,u=2,
s=2,C=90,lapse=0.0065,Rn24=NULL,zx=200,zomw=2,
xPT=1.3,clump=1,fg=1,fc="auto",network="series",
latitude=5.6,n=6.5)

#using landsat folder parameters
folder=system.file("extdata","stack",package="sebkc")
tsebautoseries=tseb(folder=folder,welev=317,Tmax=31,Tmin=27,
latitude=5.6,n=6.5)
tsebautoparallel=tseb(folder=folder,welev=317,Tmax=31,Tmin=27,
latitude=5.6,n=6.5,network="parallel")
```

```
#3 step simulation using landsat 7 with SLC OFF
##step one: prepare the input data
### point to landsat 7 data with strips

#####get the data stacked and remove strips
rawdata=sebkcstack(folder)
###### check if strips are removed
plot(rawdata$data)
#get Ts, Albedo, NDVI, SAVI, sunelev, DOY from landsat data
welev=278
 data=landsat578(rawdata,welev=welev)
 #perform semi-auto simulation
# Determine xyhot. Digitize polygon on the Ts map
modhot=hotTs(data,welev=300,extent="auto",cluster=2)
#determine the cold. Digitize polygon on the Ts map
modcold=coldTs(data,welev=275,extent="auto",cluster=2)
xyhot=modhot$xyhot
xycold=modcold$xycold
modTSEB2=tseb(data,Tmax=31,Tmin=28,
latitude=5.6,n=6.5)
#the same
modTSEB2=tseb(data,Tmax=33,Tmin=28,welev=345,xyhot=xyhot,xycold=xycold,
latitude=5.6,n=6.5)
#the same
modTSEB2=tseb(data,Tmax=33,Tmin=28,welev=345,xyhot=modhot,xycold=modcold,
latitude=5.6,n=6.5)

## End(Not run)
```

---

wdi *Water Deficit Index (WDI)*

Description

Moran et. al (1994) Estimation of crop water deficit using surface-air temperature and spectral vegetation index.

Usage

```
wdi(
  Ts = NULL,
  Ta,
  NDVI,
  albedo = NULL,
  Tsmax = "auto",
  Tsmin = "auto",
  sunelev = NULL,
  folder = NULL,
```

```
  welev = NULL,
  Rn24 = NULL
)

wdi(
  Ts = NULL,
  Ta,
  NDVI,
  albedo = NULL,
  Tsmax = "auto",
  Tsmin = "auto",
  sunelev = NULL,
  folder = NULL,
  welev = NULL,
  Rn24 = NULL
)
```

Arguments

Ts	A RasterLayer data that indicates radiometric surface temperature values from remote sensing image, preferably in Kelvin (K). You can also point to raster file on your computer.
Ta	numeric. Air temperature. If not available you can use
NDVI	A RasterLayer data that indicates NDVI (Normalized Difference Vegetation Index) values. You can also point to a file on your computer.
albedo	A RasterLayer data that has albedo values. You can also provide file path or location on your computer
Tsmax	numeric. Maximum sensor surface temperature [K]
Tsmin	numeric. Minimum sensor surface temperature [K] sebal to get pixel based Ta.
sunelev	Angle of Sun elevation in degrees, as found in the meta data of the satellite image
folder	An original directory of the images that contains all landsat 5,7 or 8 bands and metadata. At the moment only Landsat folder is supported
welev	Weather station elevation in meters
Rn24	A 24 hour net radiation [W/m2]. It is needed to estimate daily ET. It can be computed with ETo with even a minimal data of Tmax and Tmin. You can also point to raster file on your computer

Details

Note that surface temperature (Tsmin and Tsmax) are different from air temperature (Tmin and Tmax) in ETo, sseb, sebs

You can get Ta from sebal Ta

Value

EF: standardised wdi excluding negatives and one plus

index: raw wdi including negatives and more than one

Author(s)

George Owusu

References

Moran, M. S., Clarke, T. R., Inoue, Y., & Vidal, A. 1994. Estimating crop water deficit using the relation between surface-air temperature and spectral vegetation index. Remote Sensing of Environment, 49(3): 246-263.

See Also

sseb and sebi

Examples

```
 ## Not run:
albedo=raster(system.file("extdata","albedo.grd",package="sebkc"))
Ts=raster(system.file("extdata","Ts.grd",package="sebkc"))
NDVI=raster(system.file("extdata","NDVI.grd",package="sebkc"))
modWDI=wdi(Ts=Ts,Ta=299,NDVI=NDVI,albedo=NULL,Tsmax="auto",
Tsmin="auto",sunelev=50)
plot(modWDI$EF)

#Using folder parameter
folder=system.file("extdata","stack",package="sebkc")
wdiauto=wdi(folder=folder,welev=317,Tsmax=31,Tsmin=28,Ta=290)

#' #Another interactive example
#get Ts, Albedo, NDVI, SAVI, sunelev, DOY from landsat data
welev=278
data=landsat578(rawdata,welev=welev)
#perform semi-auto simulation
#Determine xyhot. Digitize polygon on the Ts map
modhot=hotTs(data,welev=300,extent="auto",cluster=2)
#determine the cold. Digitize polygon on the Ts map
modcold=coldTs(data,welev=275,extent="auto",cluster=2)
Tsmax=modhot$Tshot
Tsmin=modcold$Tscold
#use object of \code{\link{coldTs}} or \code{\link{hotTs}} in different ways
modWDI2=wdi(data,Ta=299,Tsmax=Tsmax,Tsmin=modcold,sunelev=50)
plot(modWDI2$EF)

## End(Not run)
```

weather	*Retrieval of Weather Data from WMO and NASA Surface meteorology and Solar Energy*

Description

The function retrieves weather data from the World Meteorological Organization and NASA SSE. The retrieval is based on airports IATA or ICAO codes or WMO weather station codes. The actual WMO data is from Weather Underground . Internet connection is therefore needed before data can be accessed

Usage

```
weather(
  data = NULL,
  wmo = NULL,
  airport = NULL,
  date = "YYYY-m-d",
  time = NULL,
  latitude = NULL,
  longitude = NULL,
  NASA.SSE = list(from = "YYYY-m-d", to = "YYYY-m-d"),
  folder = NULL
)
```

Arguments

data	dataframe that can contain all or part of the input data
wmo	numeric. World Meteorological Organization weather station code. You can use the Worldwide Station List at https://www.wunderground.com/ [Accessed on 2016-5-6] or https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
airport	numeric. IATA or ICAO code. They are alphabetically listed at https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code:_A [Accessed on 2016-5-6]
date	date in the form of "YYYY-mm-dd" for example "2016-01-01"
time	time in the form of "H:M" or decimal hours only. For example "14:21" or 14.35
latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere
longitude	The longitude of the measurement site i.e. geographical coordinates in decimal degrees for the weather station. It should be negative for West and positive for East.
NASA.SSE	list of NASA SSE data dates in the form of "YYYY-mm-dd". For example NASA.SSE=list(from=""2001-01-01"", to="2001-04-01"). Note that SSE date is from 1983 to 2005: https://power.larc.nasa.gov/ [Accessed on 2016-5-6] if the parameter is not provided, date parameter will be used provided longitude and latitude are provided.

folder The path of the folder where the data can be written.

Value

WMO and NASE.SSE. The WMO contains hour and day data. The NASE.SSE contains meta and data. See example below.

Author(s)

George Owusu

References

- Worldwide Station List.https://www.wetterzentrale.de/ [Accessed on 2016-5-6]
- List of airports by IATA code. https://en.wikipedia.org/wiki/List_of_airports_by_IATA_code [Accessed on 2016-5-6]
- Weather Underground https://www.wunderground.com/ [Accessed on 2016-5-6]

Examples

```
## Not run:
#all hours data at Lincoln Airport, Nabraska
lincoln=weather(airport = "KLNK", date="2011-08-04")
lincoln$WMO$hour
lincoln$WMO$day
#current hour data at London
london.now=weather(airport = "LON", date=format(Sys.time(), "%Y-%m-%d"),
time=format(Sys.time(), "%H:%M"))
london.now$WMO$hour
#NASA SSE data for Kumasi, Ghana
kumasi=weather(longitude = -1.5,latitude = 6.7,NASA.SSE = list(from="2001-04-01",
to="2002-04-01"))

#Hour, daily and SSE data at JFK
JFK=weather(airport = "JFK", date="2001-02-02",time="17:20", latitude=40.6413,
longitude=73.7781)
JFK$WMO$hour
JFK$WMO$day
JFK$NASA.SEE$data
JFK$NASA.SEE$meta

#' #Hour, daily and SSE slice data at Kotoka International Airport, ACCRA
accra=weather(airport = "ACC", date="2001-02-02",time="17:20", latitude=40.6413, longitude=73.7781,
NASA.SSE=list(from="2001-01-01",to="2004-01-01"))
accra$WMO$hour
accra$WMO$hour
accra$NASA.SEE$data
accra$NASA.SEE$meta

#Using wmo code
kumasi.now=weather(wmo="65442", date=format(Sys.time(), "%Y-%m-%d"),time=format(Sys.time(),
```

```
"%H:%M"))
kumasi.now$WMO$hour

#retrieve daily data for a specific period i.e 1 month
lincoln=weather(airport = "KLNK", date=c("2011-08-04","2011-09-04"))
#kumasi and accra data for a time slice. May not work for different
#geographical regions; write the results to a file
accrakumasi=weather(airport ="ACC", date=c("2011-08-04","2011-10-04"),
folder="C:/Users/george/Documents/")

## End(Not run)
```

`writesebkc` *Writing sebkc object to a folder*

Description

This function writes spatial output of the following functions `sebal`, `sebi`,`ssebi`, `wdi`,`sebs`,`sseb`, `tseb` and `landsat578`

Usage

```
writesebkc(object, folder = NULL, xy = NULL, overwrite = TRUE)
```

Arguments

`object`	sebkc object
`folder`	Folder the files should be written to.If it is set to NULL, it is written to the input folder of sebkc object.
`xy`	A dataframe of of xy coordinates in in decimal degrees or meters in the order of c(x,y). If it is not set NULL, the corresponding values are extracted and written to the folder
`overwrite`	logical whether the file should be over written

Value

Writes output to a folder

Examples

```
## Not run:
folder=system.file("extdata","stack",package="sebkc")
stack=landsat578(data=folder, welev=362)
writesebkc(stack)
sebaloutput=sebal(folder = folder,welev = 317)
writesebkc(sebaloutput)


## End(Not run)
```

xyextract — *Reprojecting and extracting Raster values*

Description

The function reprojects longitudes and latitudes into map coordinates and extract raster values

Usage

```
xyextract(map, longitude, latitude)
```

Arguments

map	a raster object.
longitude	The longitude of the measurement site i.e. geographical coordinates in decimal degrees for the weather station. It should be negative for West and positive for East.
latitude	geographical coordinates in decimal degrees. It should be negative for southern hemisphere

Value

data

Author(s)

George Owusu

Examples

```
## Not run:
lonlat=read.table(system.file("extdata","sys","xyvalues.txt",package="sebkc"),header=TRUE)
longitude=lonlat$longitude
latitude=lonlat$latitude
folder=system.file("extdata","stack",package="sebkc")
data=landsat578(data=folder, welev=362)
Ts=data$Ts
Tsdata=xyextract(Ts,longitude,latitude)


## End(Not run)
```

Index