

Package ‘phenofit’

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Type Package

Title Extract Remote Sensing Vegetation Phenology

Version 0.3.11

Description The merits of 'TIMESAT' and 'phenopix' are adopted. Besides, a simple and growing season dividing method and a practical snow elimination method based on Whittaker were proposed. 7 curve fitting methods and 4 phenology extraction methods were provided. Parameters boundary are considered for every curve fitting methods according to their ecological meaning. And 'optimx' is used to select best optimization method for different curve fitting methods.

Reference:

Kong, D., (2020). R package: A state-of-the-art Vegetation Phenology extraction package, phenofit version 0.3.1, <[doi:10.5281/zenodo.5150204](https://doi.org/10.5281/zenodo.5150204)>;

Kong, D., Zhang, Y., Wang, D., Chen, J., & Gu, X. (2020). Photoperiod Explains the Asynchronization Between Vegetation Carbon Phenology and Vegetation Greenness Phenology. Journal of Geophysical Research: Biogeosciences, 125(8), e2020JG005636. <[doi:10.1029/2020JG005636](https://doi.org/10.1029/2020JG005636)>;

Kong, D., Zhang, Y., Gu, X., & Wang, D. (2019). A robust method for reconstructing global MODIS EVI time series on the Google Earth Engine.

ISPRS Journal of Photogrammetry and Remote Sensing, 155, 13–24;

Zhang, Q., Kong, D., Shi, P., Singh, V.P., Sun, P., 2018. Vegetation phenology on the Qinghai-Tibetan Plateau and its response to climate change (1982–2013).

Agric. For. Meteorol. 248, 408–417. <[doi:10.1016/j.agrformet.2017.10.026](https://doi.org/10.1016/j.agrformet.2017.10.026)>.

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Imports Rcpp, purrr, dplyr (>= 1.1.0), stringr, magrittr, lubridate, data.table, zoo, gridExtra, ggplot2, optimx, ucminf, numDeriv, methods, zeallot

Suggests knitr, rmarkdown, testthat (>= 2.1.0)

URL <https://github.com/eco-hydro/phenofit>

BugReports <https://github.com/eco-hydro/phenofit/issues>

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CA_NS6	<i>MOD13A1 EVI observations at flux site CA-NS6</i>
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Description

- Variables in CA-NS6:
- site: site name
 - y: EVI
 - date: date of image
 - t: date of compositing image
 - w: weights of data point
 - QC_flag: QC flag of y, in the range of c("snow", "cloud", "shadow", "aerosol", "marginal", "good")

Usage

```
data('CA_NS6')
```

Format

An object of class `data.table` (inherits from `data.frame`) with 161 rows and 6 columns.

check_input	<i>check_input</i>
-------------	--------------------

Description

Check input data, interpolate NA values in y, remove spike values, and set weights for NA in y and w.

Usage

```

check_input(
  t,
  y,
  w,
  QC_flag,
  nptperyear,
  south = FALSE,
  wmin = 0.2,
  wsnow = 0.8,
  ymin,
  missval,
  maxgap,
  alpha = 0.02,
  alpha_high = NULL,
  date_start = NULL,
  date_end = NULL,
  mask_spike = TRUE,
  na.rm = FALSE,
  ...
)

```

Arguments

t	Numeric vector, Date variable
y	Numeric vector, vegetation index time-series
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be wmin, the others will be 1.0.
QC_flag	Factor (optional) returned by qcFUN, levels should be in the range of c("snow", "cloud", "shadow", "aerosol", "marginal", "good"), others will be categorized into others. QC_flag is used for visualization in get_pheno() and plot_curvefits() .
nptperyear	Integer, number of images per year.
south	Boolean. In south hemisphere, growing year is 1 July to the following year 31 June; In north hemisphere, growing year is 1 Jan to 31 Dec.
wmin	Double, minimum weight of bad points, which could be smaller the weight of snow, ice and cloud.
wsnow	Double. Reset the weight of snow points, after get ylu. Snow flag is an important flag of ending of growing season. Snow points is more valuable than marginal points. Hence, the weight of snow should be great than that of marginal.
ymin	If specified, ylu[1] is constrained greater than ymin. This value is critical for bare, snow/ice land, where vegetation amplitude is quite small. Generally, you can set ymin=0.08 for NDVI, ymin=0.05 for EVI, ymin=0.5 gC m ⁻² s ⁻¹ for GPP.
missval	Double, which is used to replace NA values in y. If missing, the default value is ylu[1].

maxgap	Integer, nptperyear/4 will be a suitable value. If continuous missing value numbers less than maxgap, then interpolate those NA values by zoo::na.approx; If false, then replace those NA values with a constant value ylu[1]. Replacing NA values with a constant missing value (e.g. background value ymin) is inappropriate for middle growing season points. Interpolating all values by na.approx, it is unsuitable for large number continuous missing segments, e.g. in the start or end of growing season.
alpha	Double, in $[0, 1]$, quantile prob of ylu_min.
alpha_high	Double, $[0, 1]$, quantile prob of ylu_max. If not specified, alpha_high=alpha.
date_start, date_end	starting and ending date of the original vegetation time-series (before add_HeadTail)
mask_spike	Boolean. Whether to remove spike values?
na.rm	Boolean. If TRUE, NA and spike values will be removed; otherwise, NA and spike values will be interpolated by valid neighbours.
...	Others will be ignored.

Value

A list object returned:

- t : Numeric vector
- y0: Numeric vector, original vegetation time-series.
- y : Numeric vector, checked vegetation time-series, NA values are interpolated.
- w : Numeric vector
- Tn: Numeric vector
- ylu = [ymin, ymax]. w_critical is used to filter not too bad values.
If the percentage good values (w=1) is greater than 30\
- The else, if the percentage of w ≥ 0.5 points is greater than 10\ w_critical=0.5. In boreal regions, even if the percentage of w ≥ 0.5 points is only 10\
- We can't rely on points with the wmin weights. Then,
y_good = y[w $\geq$ w_critical],
ymin = pmax(quantile(y_good, alpha/2), 0)
ymax = max(y_good).

Examples

```
data("CA_NS6")
d = CA_NS6
# head(d)

nptperyear = 23
INPUT <- check_input(d$t, d$y, d$w, QC_flag = d$QC_flag,
  nptperyear = nptperyear, south = FALSE,
  maxgap = nptperyear/4, alpha = 0.02, wmin = 0.2)
plot_input(INPUT)
```

check_ylu	<i>check_ylu</i>
-----------	------------------

Description

Curve fitting values are constrained in the range of ylu. Only constrain trough value for a stable background value. But not for peak value.

Usage

```
check_ylu(yfit, ylu)
```

Arguments

yfit	Numeric vector, curve fitting result
ylu	limits of y value, [ymin, ymax]

Value

yfit, the numeric vector in the range of ylu.

Examples

```
check_ylu(1:10, c(2, 8))
```

curvefit	<i>Fine curve fitting</i>
----------	---------------------------

Description

Curve fit vegetation index (VI) time-series of every growing season using fine curve fitting methods.

Usage

```
curvefit(  
  y,  
  t = index(y),  
  tout = t,  
  methods = c("AG", "Beck", "Elmore", "Gu", "Klos", "Zhang"),  
  w = NULL,  
  ...,  
  type = 1L,  
  use.cpp = FALSE  
)
```

Arguments

y	Vegetation time-series index, numeric vector
t	The corresponding day of x
tout	The output interpolated time.
methods	Fine curve fitting methods, can be one or more of c('AG', 'Beck', 'Elmore', 'Gu', 'Klos', 'Zhang').
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be wmin, the others will be 1.0.
...	other parameters passed to curve fitting function.
type	integer, 1 or -1 • 1: trough-to-trough curve fitting • -1: peak-to-peak curve fitting
use.cpp	(unstable, not used) boolean, whether to use c++ defined fine fitting function? If FALSE, R version will be used.

Value

fFITS S3 object, see [fFITS\(\)](#) for details.

Note

'Klos' have too many parameters. It will be slow and not stable.

See Also

[fFITS\(\)](#)

Examples

```
library(phenofit)
# simulate vegetation time-series
FUN = doubleLog.Beck
par = c(mn = 0.1, mx = 0.7, sos = 50, rsp = 0.1, eos = 250, rau = 0.1)
t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
y <- FUN(par, t)

methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout = tout, methods)
```

curvefits

*Fine Curve fitting***Description**

Fine Curve fitting for INPUT time-series.

Usage

```
curvefits(INPUT, brks, options = list(), ...)
```

Arguments

INPUT	A list object with the elements of 't', 'y', 'w', 'Tn' (optional) and 'ylu', returned by check_input.
brks	A list object with the elements of 'fit' and 'dt', returned by season or season_mov, which contains the growing season division information.
options	see section: options for fitting for details.
...	other parameters to curvefit()

Value

List of phenofit fitting object.

options for fitting

- `methods` (default `c('AG', 'Beck', 'Elmore', 'Zhang')```): Fine curve fitting methods, can be one or more of 'Beck', 'Elmore', 'Zhang', 'Gu', 'Klos'. Note that 'Gu' and 'Klos' are very slow.
- `iters` (default 2): max iterations of fine fitting.
- `wFUN` (default `wTSM`): Character or function, weights updating function of fine fitting function.
- `wmin` (default 0.1): min weights in the weights updating procedure.
- `use.rough` (default `FALSE`): Whether to use rough fitting smoothed time-series as input? If false, smoothed VI by rough fitting will be used for Phenological metrics extraction; If true, original input y will be used (rough fitting is used to divide growing seasons and update weights).
- `use.y0` (default `TRUE`): boolean. whether to use original y0 as the input of plot_input, note that not for curve fitting. y0 is the original value before the process of check_input.
- `nextend` (default 2): Extend curve fitting window, until nextend good or marginal points are found in the previous and subsequent growing season.
- `maxExtendMonth` (default 1): Search good or marginal good values in previous and subsequent maxExtendMonth period.
- `minExtendMonth` (default 0.5): Extend period defined by nextend and maxExtendMonth, should be no shorter than minExtendMonth. When all points of the input time-series are good value, then the extending period will be too short. In that situation, we can't make sure the connection between different growing seasons is smoothing.

- minPercValid: (default 0, not use). If the percentage of good- and marginal- quality points is less than minPercValid, curve fitting result is set to NA.
- minT: (not use). If Tn not provided in INPUT, minT will not be used. minT use night temperature Tn to define background value (days with Tn < minT treated as ungerminating season).

See Also

[FitDL\(\)](#)

Examples

```
data("CA_NS6")
d = CA_NS6

nptperyear <- 23
INPUT <- check_input(d$t, d$y, d$w, QC_flag = d$QC_flag,
  nptperyear = nptperyear, south = FALSE,
  maxgap = nptperyear/4, alpha = 0.02, wmin = 0.2)
# plot_input(INPUT)

# Rough fitting and growing season dividing
wFUN <- "wTSM"
brks2 <- season_mov(INPUT,
  options = list(
    rFUN = "smooth_wWHIT", wFUN = wFUN,
    r_min = 0.05, ypeak_min = 0.05,
    lambda = 10,
    verbose = FALSE
  ))
# plot_season(INPUT, brks2, d)
# Fine fitting
fits <- curvefits(
  INPUT, brks2,
  options = list(
    methods = c("AG", "Beck", "Elmore", "Zhang"), #,"klos", "Gu"
    wFUN = wFUN,
    nextend = 2, maxExtendMonth = 2, minExtendMonth = 1, minPercValid = 0.2
  )
)

r_param = get_param(fits)
r_pheno = get_pheno(fits)
r_gof = get_GOF(fits)
d_fit = get_fitting(fits)

g <- plot_curvefits(d_fit, brks2)
grid::grid.newpage(); grid::grid.draw(g)
```

curvefits_LocalModel *curvefits by local model functions of TIMESAT*

Description

Local model functions $f_L(t)$, $f_C(t)$ and $f_R(t)$ describe the VI variation in intervals around the left minima, the central maxima and the right minima.

Local model function are merged into global model function via [merge_LocalModels\(\)](#) and Per Jönsson et al. (2004; their Eq. 12), where cut-off function sharply drop from 1 to 0 in small intervals around $(t_L + t_C)/2$ and $(t_C + t_R)/2$.

$$F(t) = \begin{cases} \alpha(t)f_L(t) + [1 - \alpha(t)]f_C(t), & t_L < t < t_C \\ \beta(t)f_C(t) + [1 - \beta(t)]f_R(t), & t_C < t < t_R \end{cases}$$

Usage

```
curvefits_LocalModel(INPUT, brks, options = list(), ...)
```

```
merge_LocalModels(fits)
```

Arguments

INPUT	A list object with the elements of 't', 'y', 'w', 'Tn' (optional) and 'ylu', returned by check_input.
brks	A list object with the elements of 'fit' and 'dt', returned by season or season_mov, which contains the growing season division information.
options	see section: options for fitting for details.
...	other parameters to curvefit()
fits	List objects returned by curvefits_LocalModel() (not curvefits()).

options for fitting

- `methods` (default `c('AG', 'Beck', 'Elmore', 'Zhang')```): Fine curve fitting methods, can be one or more of 'Beck', 'Elmore', 'Zhang', 'Gu', 'Klos'. Note that 'Gu' and 'Klos' are very slow.
- `iters` (default 2): max iterations of fine fitting.
- `wFUN` (default `wTSM`): Character or function, weights updating function of fine fitting function.
- `wmin` (default 0.1): min weights in the weights updating procedure.
- `use.rough` (default `FALSE`): Whether to use rough fitting smoothed time-series as input? If false, smoothed VI by rough fitting will be used for Phenological metrics extraction; If true, original input y will be used (rough fitting is used to divide growing seasons and update weights).
- `use.y0` (default `TRUE`): boolean. whether to use original y0 as the input of plot_input, note that not for curve fitting. y0 is the original value before the process of check_input.

- nextend (default 2): Extend curve fitting window, until nextend good or marginal points are found in the previous and subsequent growing season.
- maxExtendMonth (default 1): Search good or marginal good values in previous and subsequent maxExtendMonth period.
- minExtendMonth (default 0.5): Extend period defined by nextend and maxExtendMonth, should be no shorter than minExtendMonth. When all points of the input time-series are good value, then the extending period will be too short. In that situation, we can't make sure the connection between different growing seasons is smoothing.
- minPercValid: (default 0, not use). If the percentage of good- and marginal- quality points is less than minPercValid, curve fitting result is set to NA.
- minT: (not use). If Tn not provided in INPUT, minT will not be used. minT use night temperature Tn to define background value (days with Tn < minT treated as ungrowing season).

References

1. Per J'onsson, P., Eklundh, L., 2004. TIMESAT - A program for analyzing time-series of satellite sensor data. Comput. Geosci. 30, 833-845. doi:10.1016/j.cageo.2004.05.006.

See Also

[curvefits\(\)](#)

Examples

```
## Not run:
library(phenofit)

data("CA_NS6")
d = CA_NS6

nptperyear <- 23
INPUT <- check_input(d$t, d$y, d$w, QC_flag = d$QC_flag,
  nptperyear = nptperyear, south = FALSE,
  maxgap = nptperyear/4, alpha = 0.02, wmin = 0.2)
# plot_input(INPUT)

# Rough fitting and growing season dividing
wFUN <- "wTSM"
brks2 <- season_mov(INPUT,
  options = list(
    rFUN = "smooth_wWHIT", wFUN = wFUN,
    r_min = 0.05, ypeak_min = 0.05,
    lambda = 10,
    verbose = FALSE
  ))
# plot_season(INPUT, brks2, d)

# Fine fitting
fits <- curvefits_LocalModel(
  INPUT, brks2,
```

```

options = list(
  methods = c("AG", "Beck", "Elmore", "Zhang", "Gu"), #,"klos", "Gu"
  wFUN = wFUN,
  nextend = 2, maxExtendMonth = 2, minExtendMonth = 1, minPercValid = 0.2
),
constrain = TRUE
)
# merge local model function into global model function
fits_merged = merge_LocalModels(fits)

## Visualization -----
l_fitting = map(fits %>% guess_names, get_fitting) %>% melt_list("period")

d_merged = get_fitting(fits_merged[[2]]) %>% cbind(type = "Merged")
d_raw = l_fitting[2:4] %>% set_names(c("Left", "Central", "Right")) %>%
  melt_list("type")
d_obs = d_raw[, .(t, y, QC_flag)] %>% unique()
d_fit = rbind(d_merged, d_raw)[meth == "Zhang"]

levs = c("Left", "Central", "Right", "Merged")
levs_new = glue("({letters[1:4]}) {levs}") %>% as.character()
d_fit$type %<>% factor(levs, levs_new)

p = ggplot(d_obs, aes(t, y)) +
  geom_point() +
  geom_line(data = d_fit, aes(t, ziter2, color = type)) +
  facet_wrap(~type) +
  labs(x = "Date", y = "EVI") +
  scale_x_date(date_labels = "%b %Y", expand = c(1, 1)*0.08) +
  theme_bw(base_size = 13) +
  theme(legend.position = "none",
        strip.text = element_text(size = 14))

p

## End(Not run)

```

findpeaks

findpeaks

Description

Find peaks (maxima) in a time series. This function is modified from `pracma::findpeaks`.

Usage

```

findpeaks(
  x,
  nups = 1,
  ndowns = nups,
  zero = "0",

```

```

    peakpat = NULL,
    minpeakheight = -Inf,
    minpeakdistance = 1,
    h_min = 0,
    h_max = 0,
    npeaks = 0,
    sortstr = FALSE,
    include_gregexpr = FALSE,
    IsPlot = F
)

```

Arguments

x	Numeric vector.
nups	minimum number of increasing steps before a peak is reached
ndowns	minimum number of decreasing steps after the peak
zero	can be +, -, or 0; how to interpret succeeding steps of the same value: increasing, decreasing, or special
peakpat	define a peak as a regular pattern, such as the default pattern <code>[+]{1,}[-]{1,}</code> ; if a pattern is provided, the parameters <code>nups</code> and <code>ndowns</code> are not taken into account
minpeakheight	The minimum (absolute) height a peak has to have to be recognized as such
minpeakdistance	The minimum distance (in indices) peaks have to have to be counted. If the distance of two maximum extreme value less than <code>minpeakdistance</code> , only the real maximum value will be left.
h_min	<code>h</code> is defined as the difference of peak value to the adjacent left and right trough value (<code>h_left</code> and <code>h_right</code> respectively). The real peaks should follow <code>min(h_left, h_right) >= h_min</code> .
h_max	Similar as <code>h_min</code> , the real peaks should follow <code>max(h_left, h_right) >= h_min</code> .
npeaks	the number of peaks to return. If <code>sortstr = true</code> , the largest <code>npeaks</code> maximum values will be returned; If <code>sortstr = false</code> , just the first <code>npeaks</code> are returned in the order of index.
sortstr	Boolean, Should the peaks be returned sorted in decreasing order of their maximum value?
include_gregexpr	Boolean (default FALSE), whether to include the matched <code>gregexpr</code> ?
IsPlot	Boolean, whether to plot?

Note

In versions before v0.3.4, `findpeaks(c(1, 2, 3, 4, 4, 3, 1))` failed to detect peaks when a flat pattern exit in the middle.

From version v0.3.4, the peak pattern was changed from `[+]{%d,}[-]{%d,}` to `[+]{%d,}[0]{0,}[-]{%d,}`. The latter can escape the flat part successfully.

Examples

```
x <- seq(0, 1, len = 1024)
pos <- c(0.1, 0.13, 0.15, 0.23, 0.25, 0.40, 0.44, 0.65, 0.76, 0.78, 0.81)
hgt <- c(4, 5, 3, 4, 5, 4.2, 2.1, 4.3, 3.1, 5.1, 4.2)
wdt <- c(0.005, 0.005, 0.006, 0.01, 0.01, 0.03, 0.01, 0.01, 0.005, 0.008, 0.005)
pSignal <- numeric(length(x))
for (i in seq(along=pos)) {
  pSignal <- pSignal + hgt[i]/(1 + abs((x - pos[i])/wdt[i]))^4
}

plot(pSignal, type="l", col="navy"); grid()
x <- findpeaks(pSignal, npeaks=3, h_min=4, sortstr=TRUE)
points(val~pos, x$X, pch=20, col="maroon")
```

FitDL

Fine fitting

Description

Fine curve fitting function is used to fit vegetation time-series in every growing season.

Usage

```
FitDL.Zhang(y, t = index(y), tout = t, method = "nlm", w, type = 1L, ...)
FitDL.AG(y, t = index(y), tout = t, method = "nlminb", w, type = 1L, ...)
FitDL.AG2(y, t = index(y), tout = t, method = "nlminb", w, type = 1L, ...)
FitDL.Beck(y, t = index(y), tout = t, method = "nlminb", w, type = 1L, ...)
FitDL.Elmore(y, t = index(y), tout = t, method = "nlminb", w, type = 1L, ...)
FitDL.Gu(y, t = index(y), tout = t, method = "nlminb", w, type = 1L, ...)
FitDL.Klos(y, t = index(y), tout = t, method = "BFGS", w, type = 1L, ...)
```

Arguments

y	input vegetation index time-series.
t	the corresponding doy(day of year) of y.
tout	the time of output curve fitting time-series.
method	method passed to optimx or optim function.
w	weights
type	integer, 1 or -1

- 1: trough-to-trough curve fitting
- -1: peak-to-peak curve fitting

... other paraters passed to `optim_pheno()`.

Value

- tout: The time of output curve fitting time-series.
- zs : Smoothed vegetation time-series of every iteration.
- ws : Weights of every iteration.
- par : Final optimized parameter of fine fitting.
- fun : The name of fine fitting.

References

1. Beck, P.S.A., Atzberger, C., Hogda, K.A., Johansen, B., Skidmore, A.K., 2006. Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI. *Remote Sens. Environ.* <https://doi.org/10.1016/j.rse.2005.10.021>.
2. Elmore, A.J., Guinn, S.M., Minsley, B.J., Richardson, A.D., 2012. Landscape controls on the timing of spring, autumn, and growing season length in mid-Atlantic forests. *Glob. Chang. Biol.* 18, 656-674. <https://doi.org/10.1111/j.1365-2486.2011.02521.x>.
3. Gu, L., Post, W.M., Baldocchi, D.D., Black, TRUE.A., Suyker, A.E., Verma, S.B., Vesala, TRUE., Wofsy, S.C., 2009. Characterizing the Seasonal Dynamics of Plant Community Photosynthesis Across a Range of Vegetation Types, in: Noormets, A. (Ed.), *Phenology of Ecosystem Processes: Applications in Global Change Research*. Springer New York, New York, NY, pp. 35-58. https://doi.org/10.1007/978-1-4419-0026-5_2.
4. <https://github.com/cran/phenopix/blob/master/R/FitDoubleLogGu.R>

Examples

```
# simulate vegetation time-series
t   <- seq(1, 365, 8)
par <- c(mn = 0.1, mx = 0.7, sos = 50, rsp = 0.1, eos = 250, rau = 0.1)
y   <- doubleLog.Beck(par, t)
data <- data.frame(t, y)
# methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang")
tout <- seq(1, 365, 1)
r <- FitDL.Elmore(y, t, tout)

plot(r, data)
get_GOF(r, data)
get_param(r)
```

f_goal

*Goal function of fine curve fitting methods***Description**

Goal function of fine curve fitting methods

Usage

```
f_goal(par, fun, y, t, pred, w, ylu, ...)
```

Arguments

par	A vector of parameters
fun	A curve fitting function, can be one of <code>doubleAG</code> , <code>doubleLog.Beck</code> , <code>doubleLog.Elmore</code> , <code>doubleLog.Gu</code> , <code>doubleLog.Klos</code> , <code>doubleLog.Zhang</code> , see Logistic() for details.
y	Numeric vector, vegetation index time-series
t	Numeric vector, Date variable
pred	Numeric Vector, predicted values
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be <code>wmin</code> , the others will be 1.0.
ylu	[<code>ymin</code> , <code>ymax</code>], which is used to force <code>ypred</code> in the range of <code>ylu</code> .
...	others will be ignored.

Value

RMSE Root Mean Square Error of curve fitting values.

Examples

```
library(phenofit)

par = c( mn = 0.1 , mx = 0.7 , sos = 50 , rsp = 0.1 , eos = 250, rau = 0.1)
par0 = c( mn = 0.15, mx = 0.65, sos = 100, rsp = 0.12, eos = 200, rau = 0.12)

# simulate vegetation time-series
fFUN = doubleLog_Beck
t     <- seq(1, 365, 8)
tout  <- seq(1, 365, 1)
y     <- fFUN(par, t)

f_goal(par0, fFUN, y, t)
```

get_fitting	getFittings
-------------	-------------

Description

Get curve fitting data.frame

Usage

```
get_fitting(x)

## S3 method for class 'list'
get_fitting(x)

## S3 method for class 'fFITS'
get_fitting(x)
```

Arguments

x fFITS object returned by `curvefit()`, or list of fFITS objects

Examples

```
library(phenofit)
# simulate vegetation time-series
FUN = doubleLog.Beck
par = c( mn = 0.1, mx = 0.7, sos = 50, rsp = 0.1, eos = 250, rau = 0.1)
t    <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
y <- FUN(par, t)
methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout, methods) # `fFITS` (fine-fitting) object
fits <- list(`2001` = fit, `2002` = fit) # multiple years

l_param  <- get_param(fits)
d_GOF    <- get_GOF(fits)
d_fitting <- get_fitting(fits)
l_pheno  <- get_pheno(fits, "AG", IsPlot=TRUE)
```

get_GOF	get_GOF
---------	---------

Description

Goodness-of-fitting (GOF) of fine curve fitting results.

Usage

```

get_GOF(x, ...)

## S3 method for class 'list'
get_GOF(x, ...)

## S3 method for class 'fFITs'
get_GOF(x, ...)

## S3 method for class 'fFIT'
get_GOF(x, data, ...)

```

Arguments

x	fFITs object returned by <code>curvefit()</code> , or list of fFITs objects
...	ignored.
data	A data.frame with the columns of <code>c('t', 'y')</code>

Value

- meth: The name of fine curve fitting method
- RMSE: Root Mean Square Error
- NSE : Nash-Sutcliffe model efficiency coefficient
- R : Pearson-Correlation
- R2 : determined coefficient
- pvalue: pvalue of R
- n : The number of observations

References

1. https://en.wikipedia.org/wiki/Nash-Sutcliffe_model_efficiency_coefficient
2. https://en.wikipedia.org/wiki/Pearson_correlation_coefficient

See Also

[curvefit\(\)](#)

Examples

```

library(phenofit)
# simulate vegetation time-series
FUN = doubleLog.Beck
par = c( mn = 0.1, mx = 0.7, sos = 50, rsp = 0.1, eos = 250, rau = 0.1)
t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
y <- FUN(par, t)

```

```

methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout, methods) # `fFITS` (fine-fitting) object
fits <- list(`2001` = fit, `2002` = fit) # multiple years

l_param   <- get_param(fits)
d_GOF     <- get_GOF(fits)
d_fitting <- get_fitting(fits)
l_pheno   <- get_pheno(fits, "AG", IsPlot=TRUE)

```

get_param

Get parameters from curve fitting result

Description

Get parameters from curve fitting result

Usage

```

get_param(x)

## S3 method for class 'list'
get_param(x)

## S3 method for class 'fFITS'
get_param(x)

## S3 method for class 'fFIT'
get_param(x)

```

Arguments

x fFITS object returned by `curvefit()`, or list of fFITS objects

Value

A list of tibble with the length being equal to the number of methods. Each line of tibble cotains the corresponding parameters of each growing season.

Examples

```

library(phenofit)
# simulate vegetation time-series
FUN = doubleLog.Beck
par = c( mn = 0.1, mx = 0.7, sos = 50, rsp = 0.1, eos = 250, rau = 0.1)
t   <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
y <- FUN(par, t)
methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout, methods) # `fFITS` (fine-fitting) object

```

```
fits <- list(`2001` = fit, `2002` = fit) # multiple years

l_param <- get_param(fits)
d_GOF <- get_GOF(fits)
d_fitting <- get_fitting(fits)
l_pheno <- get_pheno(fits, "AG", IsPlot=TRUE)
```

get_pheno

get_pheno

Description

Get yearly vegetation phenological metrics of a curve fitting method

Usage

```
get_pheno(x, ...)

## S3 method for class 'rfit'
get_pheno(x, TRS = c(0.2, 0.5), asymmetric = TRUE, ...)

## S3 method for class 'list'
get_pheno(
  x,
  method,
  TRS = c(0.2, 0.5, 0.6),
  analytical = FALSE,
  smoothed.spline = FALSE,
  IsPlot = FALSE,
  show.title = TRUE,
  ...
)

## S3 method for class 'fFITS'
get_pheno(
  x,
  method,
  TRS = c(0.2, 0.5),
  analytical = FALSE,
  smoothed.spline = FALSE,
  IsPlot = FALSE,
  title.left = "",
  show.PhenoName = TRUE,
  ...
)
```

Arguments

x	One of: • rfit (rough fitting object), returned by <code>brks2rfit()</code>. • fFITS (fine fitting object), return by multiple curve fitting methods by <code>curvefit()</code> for a growing season. • list of <code>fFITS()</code> object, for multiple growing seasons.
...	ignored.
TRS	Threshold for PhenoTrs.
asymmetric	If true, background value in spring season and autumn season is regarded as different.
method	Which fine curve fitting method to be extracted?
analytical	If true, numDeriv package grad and hess will be used; if false, D1 and D2 will be used.
smoothed.spline	Whether apply smooth.spline first?
IsPlot	Boolean. Whether to plot figure?
show.title	Whether to show the name of fine curve fitting method in top title?
title.left	String of growing season flag.
show.PhenoName	Whether to show phenological methods names in the top panel?
fFITS	fFITS object returned by <code>curvefits()</code>

Value

List of every year phenology metrics

Examples

```
library(phenofit)
# simulate vegetation time-series
FUN = doubleLog.Beck
par = c( mn = 0.1, mx = 0.7, sos = 50, rsp = 0.1, eos = 250, rau = 0.1)
t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
y <- FUN(par, t)
methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout, methods) # `fFITS` (fine-fitting) object
fits <- list(`2001` = fit, `2002` = fit) # multiple years

l_param <- get_param(fits)
d_GOF <- get_GOF(fits)
d_fitting <- get_fitting(fits)
l_pheno <- get_pheno(fits, "AG", IsPlot=TRUE)
```

GOF	<i>GOF</i>
-----	------------

Description

Good of fitting

Usage

```
GOF(Y_obs, Y_sim, w, include.r = TRUE, include.cv = FALSE)
```

Arguments

Y_obs	Numeric vector, observations
Y_sim	Numeric vector, corresponding simulated values
w	Numeric vector, weights of every points. If w included, when calculating mean, Bias, MAE, RMSE and NSE, w will be taken into considered.
include.r	If true, r and R2 will be included.
include.cv	If true, cv will be included.

Value

- RMSE root mean square error
- NSE NASH coefficient
- MAE mean absolute error
- AI Agreement index (only good points ($w == 1$)) participate to calculate. See details in Zhang et al., (2015).
- Bias bias
- Bias_perc bias percentage
- n_sim number of valid obs
- cv Coefficient of variation
- R2 correlation of determination
- R pearson correlation
- pvalue pvalue of R

References

Zhang Xiaoyang (2015), <http://dx.doi.org/10.1016/j.rse.2014.10.012>

Examples

```
Y_obs = rnorm(100)
Y_sim = Y_obs + rnorm(100)/4
GOF(Y_obs, Y_sim)
```

input_single	<i>input object with one growing season per year</i>
--------------	--

Description

Variables in input_single:

- t: date of compositing image
- y: EVI
- w: weights of data point
- ylu: lower and upper boundary
- nptperyear: points per year
- south: boolean, whether in south Hemisphere?

Usage

```
data('input_single')
```

Format

An object of class list of length 6.

Logistic	<i>Fine fitting functions</i>
----------	-------------------------------

Description

double logistics, piecewise logistics and many other functions to curve fit VI time-series.

Usage

```
Logistic(par, t)
```

```
doubleLog.Zhang(par, t)
```

```
doubleLog.AG(par, t)
```

```
doubleLog.AG2(par, t)
```

```
doubleLog.Beck(par, t)
```

```
doubleLog.Elmore(par, t)
```

```
doubleLog.Gu(par, t)
```

```
doubleLog.Klos(par, t)
```

Arguments

<code>par</code>	A vector of parameters
<code>t</code>	A Date or numeric vector

Details

- `Logistic` The traditional simplest logistic function. It can be only used in half growing season, i.e. vegetation green-up or senescence period.
- `doubleLog.Zhang` Piecewise logistics, (Zhang Xiaoyang, RSE, 2003).
- `doubleAG` Asymmetric Gaussian.
- `doubleLog.Beck` Beck logistics.
- `doubleLog.Gu` Gu logistics.
- `doubleLog.Elmore` Elmore logistics.
- `doubleLog.Klos` Klos logistics.

All of those function have `par` and `formula` attributes for the convenience for analytical D1 and D2

References

1. Beck, P.S.A., Atzberger, C., Hogda, K.A., Johansen, B., Skidmore, A.K., 2006. Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI. *Remote Sens. Environ.* <https://doi.org/10.1016/j.rse.2005.10.021>.
2. Elmore, A.J., Guinn, S.M., Minsley, B.J., Richardson, A.D., 2012. Landscape controls on the timing of spring, autumn, and growing season length in mid-Atlantic forests. *Glob. Chang. Biol.* 18, 656-674. <https://doi.org/10.1111/j.1365-2486.2011.02521.x>.
3. Gu, L., Post, W.M., Baldocchi, D.D., Black, TRUE.A., Suyker, A.E., Verma, S.B., Vesala, TRUE., Wofsy, S.C., 2009. Characterizing the Seasonal Dynamics of Plant Community Photosynthesis Across a Range of Vegetation Types, in: Noormets, A. (Ed.), *Phenology of Ecosystem Processes: Applications in Global Change Research*. Springer New York, New York, NY, pp. 35-58. https://doi.org/10.1007/978-1-4419-0026-5_2.
4. Peter M. Atkinson, et al., 2012, RSE, 123:400-417
5. <https://github.com/cran/phenopix/blob/master/R/FitDoubleLogGu.R>

Examples

```
# simulate vegetation time-series
t <- seq(1, 365, 8)
par <- c(mn = 0.1, mx = 0.7, sos = 50, rsp = 0.1, eos = 250, rau = 0.1)
y <- doubleLog.Beck(par, t)
data <- data.frame(t, y)
# methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang")
tout <- seq(1, 365, 1)
r <- FitDL.Elmore(y, t, tout)

plot(r, data)
```



```
get_GOF(r, data)
get_param(r)
```

MOD13A1

MOD13A1

Description

A data.table dataset, raw data of MOD13A1 data, clipped in 10 representative points ('DE-Obe', 'IT-Col', 'CN-Cha', 'AT-Neu', 'ZA-Kru', 'AU-How', 'CA-NS6', 'US-KS2', 'CH-Oe2', 'CZ-wet').

Usage

```
data('MOD13A1')
```

Format

An object of class `list` of length 2.

Details

Variables in MOD13A1:

- dt: vegetation index data
 - system:index: image index
 - DayOfYear: Numeric, Julian day of year
 - DayOfYear: corresponding doy of compositing NDVI and EVI
 - DetailedQA: VI quality indicators
 - SummaryQA: Quality reliability of VI pixel
 - EVI: Enhanced Vegetation Index
 - NDVI: Normalized Difference Vegetation Index
 - date: Date, corresponding date
 - site: String, site name
 - sur_refl_b01: Red surface reflectance
 - sur_refl_b02: NIR surface reflectance
 - sur_refl_b03: Blue surface reflectance
 - sur_refl_b07: MIR surface reflectance
 - .geo: geometry
- st: station info
 - ID: site ID
 - site: site name
 - lat: latitude
 - lon: longitude
 - IGBPname: IGBP land cover type

References

1. <https://code.earthengine.google.com/dataset/MODIS/006/MOD13A1>

movmean	<i>movmean</i>
---------	----------------

Description

NA and Inf values in the yy will be ignored automatically.

Usage

```
movmean(y, halfwin = 1L, SG_style = FALSE, w = NULL)
```

Arguments

y	A numeric vector.
halfwin	Integer, half of moving window size
SG_style	If true, head and tail values will be in the style of SG (more weights on the center point), else traditional moving mean style.
w	Corresponding weights of yy, same long as yy.

Examples

```
x <- 1:100
x[50] <- NA; x[80] <- Inf
s1 <- movmean(x, 2, SG_style = TRUE)
s2 <- movmean(x, 2, SG_style = FALSE)
```

optim_pheno	<i>optim_pheno</i>
-------------	--------------------

Description

Interface of optimization functions for double logistics and other parametric curve fitting functions.

Usage

```

optim_pheno(
  prior,
  sFUN,
  y,
  t,
  tout,
  method,
  w,
  nptperyear,
  ylu,
  iters = 2,
  wFUN = wTSM,
  lower = -Inf,
  upper = Inf,
  constrain = TRUE,
  verbose = FALSE,
  ...,
  use.cpp = FALSE
)

```

Arguments

prior	A vector of initial values for the parameters for which optimal values are to be found. prior is suggested giving a column name.
sFUN	The name of fine curve fitting functions, can be one of 'FitAG', 'FitDL.Beck', 'FitDL.Elmore', 'F
y	Numeric vector, vegetation index time-series
t	Numeric vector, Date variable
tout	Corresponding doy of prediction.
method	The name of optimization method to solve fine fitting, one of 'BFGS', 'CG', 'Nelder-Mead', 'L-BFGS-B' and 'spg', 'Rcgmin', 'Rvmmmin', 'newuoa', 'bobyqa', 'nmkb', 'hjbk'.
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be wmin, the others will be 1.0.
nptperyear	Integer, number of images per year, passed to wFUN. Only <code>wTSM()</code> needs nptperyear. If not specified, nptperyear will be calculated based on t.
ylu	[ymin, ymax], which is used to force ypred in the range of ylu.
iters	How many times curve fitting is implemented.
wFUN	weights updating function, can be one of 'wTSM', 'wChen' and 'wBisquare'.
lower, upper	vectors of lower and upper bounds, replicated to be as long as start. If unspecified, all parameters are assumed to be unconstrained.
constrain	boolean, whether to use parameter constrain
verbose	Whether to display intermediate variables?
...	other parameters passed to <code>I_optim()</code> or <code>I_optimx()</code> .
use.cpp	(unstable, not used) boolean, whether to use c++ defined fine fitting function? If FALSE, R version will be used.

Value

A `ffit()` object, with the element of:

- `tout`: The time of output curve fitting time-series.
- `zs`: Smoothed vegetation time-series of every iteration.
- `ws`: Weights of every iteration.
- `par`: Final optimized parameter of fine fitting.
- `fun`: The name of fine fitting.

See Also

`ffit()`, `stats::nlminb()`

Examples

```
# library(magrittr)
# library(purrr)

# simulate vegetation time-series
t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)

FUN = doubleLog_Beck
par = c( mn = 0.1 , mx = 0.7 , sos = 50 , rsp = 0.1 , eos = 250, rau = 0.1)
par0 = c( mn = 0.15, mx = 0.65, sos = 100, rsp = 0.12, eos = 200, rau = 0.12)

y <- FUN(par, t)

methods = c("BFGS", "ucminf", "nlm", "nlminb")
opt1 <- I_optim(par0, doubleLog_Beck, y, t, methods) # "BFGS", "ucminf", "nlm",
# opt2 <- I_optimx(prior, fFUN, y, t, tout, )

sFUN = "doubleLog.Beck" # doubleLog.Beck
r <- optim_pheno(par0, sFUN, y, t, tout, method = methods[4],
  nptperyear = 46, iters = 2, wFUN = wTSM, verbose = FALSE, use.julia = FALSE)
```

opt_FUN

Unified optimization function

Description

`I_optimx` is rich of functionality, but with a low computing performance. Some basic optimization functions are unified here, with some input and output format.

- `opt_ncminf` General-Purpose Unconstrained Non-Linear Optimization, see `ucminf::ucminf()`.
- `opt_nlminb` Optimization using PORT routines, see `stats::nlminb()`.
- `opt_nlm` Non-Linear Minimization, `stats::nlm()`.
- `opt_optim` General-purpose Optimization, see `stats::optim()`.

Usage

```

opt_ucminf(par0, objective, ...)

opt_nlm(par0, objective, ...)

opt_optim(par0, objective, method = "BFGS", ...)

opt_nlmminb(par0, objective, ...)

```

Arguments

<code>par0</code>	Initial values for the parameters to be optimized over.
<code>objective</code>	A function to be minimized (or maximized), with first argument the vector of parameters over which minimization is to take place. It should return a scalar result.
<code>...</code>	other parameters passed to <code>objective</code> .
<code>method</code>	optimization method to be used in <code>p_optim</code> . See stats::optim() .

Value

- `convcode`: An integer code. 0 indicates successful convergence. Various methods may or may not return sufficient information to allow all the codes to be specified. An incomplete list of codes includes
 - 1: indicates that the iteration limit `maxit` had been reached.
 - 20: indicates that the initial set of parameters is inadmissible, that is, that the function cannot be computed or returns an infinite, NULL, or NA value.
 - 21: indicates that an intermediate set of parameters is inadmissible.
 - 10: indicates degeneracy of the Nelder–Mead simplex.
 - 51: indicates a warning from the "L-BFGS-B" method; see component message for further details.
 - 52: indicates an error from the "L-BFGS-B" method; see component message for further details.
 - 9999: error
- `value`: The value of `fn` corresponding to `par`
- `par`: The best parameter found
- `nitns`: the number of iterations
- `fevals`: The number of calls to `objective`.

See Also

[optim_pheno\(\)](#), [I_optim\(\)](#)

Examples

```

library(phenofit)
library(ggplot2)
library(magrittr)
library(purrr)
library(data.table)

# simulate vegetation time-series
fFUN = doubleLog_Beck
par = c( mn = 0.1 , mx = 0.7 , sos = 50 , rsp = 0.1 , eos = 250, rau = 0.1)
par0 = c( mn = 0.15, mx = 0.65, sos = 100, rsp = 0.12, eos = 200, rau = 0.12)

t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
y <- fFUN(par, t)

optFUNs <- c("opt_ucminf", "opt_nlminb", "opt_nlm", "opt_optim") %>% set_names(., .)
opts <- lapply(optFUNs, function(optFUN){
  optFUN <- get(optFUN)
  opt <- optFUN(par0, f_goal, y = y, t = t, fun = fFUN)
  opt$ysim <- fFUN(opt$par, t)
  opt
})

# visualization
df <- map(opts, "ysim") %>% as.data.table() %>% cbind(t, y, .)
pdat <- data.table::melt(df, c("t", "y"), variable.name = "optFUN")

ggplot(pdat) +
  geom_point(data = data.frame(t, y), aes(t, y), size = 2) +
  geom_line(aes(t, value, color = optFUN), linewidth = 0.9)

```

PhenoDeriv

Phenology extraction in Derivative method (DER)

Description

Phenology extraction in Derivative method (DER)

Usage

```

PhenoDeriv(x, t, ...)

## S3 method for class 'fFIT'
PhenoDeriv(x, t = NULL, analytical = FALSE, smoothed.spline = FALSE, ...)

## Default S3 method:
PhenoDeriv(x, t, der1, IsPlot = TRUE, show.legend = TRUE, ...)

```

Arguments

<code>x</code>	numeric vector, or fFIT object returned by <code>curvefit()</code> .
<code>t</code>	doy vector, corresponding doy of vegetation index.
<code>...</code>	Other parameters will be ignored.
<code>analytical</code>	If true, numDeriv package grad and hess will be used; if false, D1 and D2 will be used.
<code>smoothed.spline</code>	Whether apply smooth.spline first?
<code>der1</code>	the first order difference
<code>IsPlot</code>	whether to plot?
<code>show.legend</code>	whether show figure llegend?

References

1. Filippa, G., Cremonese, E., Migliavacca, M., Galvagno, M., Forkel, M., Wingate, L., ... Richardson, A. D. (2016). Phenopix: A R package for image-based vegetation phenology. Agricultural and Forest Meteorology, 220, 141–150. doi:10.1016/j.agrformet.2016.01.006

See Also

`PhenoTrs()`, `PhenoGu()`, `PhenoK1()`

PhenoGu	<i>Phenology extraction in GU method (GU)</i>
---------	---

Description

Phenology extraction in GU method (GU)

Usage

```
PhenoGu(x, t, ...)

## S3 method for class 'fFIT'
PhenoGu(x, t = NULL, analytical = FALSE, smoothed.spline = FALSE, ...)

## Default S3 method:
PhenoGu(x, t, der1, IsPlot = TRUE, ...)
```

Arguments

<code>x</code>	numeric vector, or fFIT object returned by <code>curvefit()</code> .
<code>t</code>	doy vector, corresponding doy of vegetation index.
<code>...</code>	other parameters to <code>PhenoGu.default()</code> or <code>PhenoGu.fFIT()</code>
<code>analytical</code>	If true, numDeriv package grad and hess will be used; if false, D1 and D2 will be used.
<code>smoothed.spline</code>	Whether apply <code>smooth.spline</code> first?
<code>der1</code>	the first order difference
<code>IsPlot</code>	whether to plot?

Value

A numeric vector, with the elements of:

- UD: upturn date
- SD: stabilisation date
- DD: downturn date
- RD: recession date

References

1. Gu, L., Post, W. M., Baldocchi, D. D., Black, T. A., Suyker, A. E., Verma, S. B., ... Wofsy, S. C. (2009). Characterizing the Seasonal Dynamics of Plant Community Photosynthesis Across a Range of Vegetation Types. In A. Noormets (Ed.), *Phenology of Ecosystem Processes: Applications in Global Change Research* (pp. 35–58). New York, NY: Springer New York. doi:10.1007/9781441900265_2
2. Filippa, G., Cremonese, E., Migliavacca, M., Galvagno, M., Forkel, M., Wingate, L., ... Richardson, A. D. (2016). Phenopix: A R package for image-based vegetation phenology. *Agricultural and Forest Meteorology*, 220, 141–150. doi:10.1016/j.agrformet.2016.01.006

Examples

```
# `doubleLog.Beck` simulate vegetation time-series
t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
par = c( mn = 0.1 , mx = 0.7 , sos = 50 , rsp = 0.1 , eos = 250, rau = 0.1)
y <- doubleLog.Beck(par, t)

methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout, methods)
x <- fit$model$AG # one model

par(mfrow = c(2, 2))
PhenoTrs(x)
PhenoDeriv(x)
PhenoGu(x)
PhenoKl(x)
```

PhenoKl	<i>Phenology extraction in Inflection method (Zhang)</i>
---------	--

Description

Phenology extraction in Inflection method (Zhang)

Usage

```
PhenoKl(
  fFIT,
  t = NULL,
  analytical = FALSE,
  smoothed.spline = FALSE,
  IsPlot = TRUE,
  show.legend = TRUE,
  ...
)
```

Arguments

fFIT	object return by <code>curvefit()</code>
t	doy vector, corresponding doy of vegetation index.
analytical	If true, numDeriv package grad and hess will be used; if false, D1 and D2 will be used.
smoothed.spline	Whether apply <code>smooth.spline</code> first?
IsPlot	whether to plot?
show.legend	whether show figure legend?
...	Other parameters will be ignored.

Value

A numeric vector, with the elements of: Greenup, Maturity, Senescence, Dormancy.

References

1. Zhang, X., Friedl, M. A., Schaaf, C. B., Strahler, A. H., Hodges, J. C. F. F., Gao, F., ... Huete, A. (2003). Monitoring vegetation phenology using MODIS. Remote Sensing of Environment, 84(3), 471–475. doi:[10.1016/S00344257\(02\)001359](https://doi.org/10.1016/S00344257(02)001359)

Examples

```
# `doubleLog.Beck` simulate vegetation time-series
t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
par = c( mn = 0.1 , mx = 0.7 , sos = 50 , rsp = 0.1 , eos = 250, rau = 0.1)
y <- doubleLog.Beck(par, t)

methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout, methods)
x <- fit$model$AG # one model

par(mfrow = c(2, 2))
PhenoTrs(x)
PhenoDeriv(x)
PhenoGu(x)
PhenoKl(x)
```

PhenoTrs

Phenology extraction in Threshold method (TRS)

Description

Phenology extraction in Threshold method (TRS)

Usage

```
PhenoTrs(
  x,
  t = NULL,
  approach = c("White", "Trs"),
  trs = 0.5,
  asymmetric = TRUE,
  IsPlot = TRUE,
  ...
)

## S3 method for class 'fFIT'
PhenoTrs(x, t = NULL, ...)

## Default S3 method:
PhenoTrs(
  x,
  t = NULL,
  approach = c("White", "Trs"),
  trs = 0.5,
  asymmetric = TRUE,
  IsPlot = TRUE,
  ...
)
```

Arguments

x	numeric vector, or fFIT object returned by <code>curvefit()</code> .
t	doy vector, corresponding doy of vegetation index.
approach	to be used to calculate phenology metrics. 'White' (White et al. 1997) or 'Trs' for simple threshold.
trs	threshold to be used for approach "Trs", in (0, 1).
asymmetric	If true, background value in spring season and autumn season is regarded as different.
IsPlot	whether to plot?
...	other parameters to PhenoPlot

See Also

[PhenoDeriv\(\)](#), [PhenoGu\(\)](#), [PhenoKl\(\)](#)

Examples

```
# `doubleLog.Beck` simulate vegetation time-series
t <- seq(1, 365, 8)
tout <- seq(1, 365, 1)
par = c( mn = 0.1 , mx = 0.7 , sos = 50 , rsp = 0.1 , eos = 250, rau = 0.1)
y <- doubleLog.Beck(par, t)

methods <- c("AG", "Beck", "Elmore", "Gu", "Zhang") # "Klos" too slow
fit <- curvefit(y, t, tout, methods)
x <- fit$model$AG # one model

par(mfrow = c(2, 2))
PhenoTrs(x)
PhenoDeriv(x)
PhenoGu(x)
PhenoKl(x)
```

plot_curvefits

plot_curvefits

Description

plot_curvefits

Usage

```
plot_curvefits(
  d_fit,
  seasons,
  d_obs = NULL,
```

```

    title = NULL,
    xlab = "Time",
    ylab = "Vegetation Index",
    yticks = NULL,
    font.size = 14,
    theme = NULL,
    cex = 2,
    shape = "point",
    angle = 30,
    show.legend = TRUE,
    layer_extra = NULL,
    ...
  )

```

Arguments

<code>d_fit</code>	data.frame of curve fittings returned by <code>get_fitting()</code> .
<code>seasons</code>	growing season division object returned by <code>season()</code> and <code>season_mov()</code> .
<code>d_obs</code>	data.frame of original vegetation time series, with the columns of <code>t</code> , <code>y</code> and <code>QC_flag</code> . If not specified, it will be determined from <code>d_fit</code> .
<code>title</code>	String, title of figure.
<code>xlab, ylab</code>	String, title of xlab and ylab.
<code>yticks</code>	ticks of y axis
<code>font.size</code>	Font size of axis.text
<code>theme</code>	ggplot theme
<code>cex</code>	point size for VI observation.
<code>shape</code>	the shape of input VI observation? line or point
<code>angle</code>	text.x angle
<code>show.legend</code>	Boolean
<code>layer_extra</code>	(not used) extra ggplot layers
<code>...</code>	ignored

Examples

```

data("CA_NS6")
d = CA_NS6

nptperyear <- 23
INPUT <- check_input(d$t, d$y, d$w, QC_flag = d$QC_flag,
  nptperyear = nptperyear, south = FALSE,
  maxgap = nptperyear/4, alpha = 0.02, wmin = 0.2)
# plot_input(INPUT)

# Rough fitting and growing season dividing
wFUN <- "wTSM"
brks2 <- season_mov(INPUT,

```

```

    options = list(
      rFUN = "smooth_wWHIT", wFUN = wFUN,
      r_min = 0.05, ypeak_min = 0.05,
      lambda = 10,
      verbose = FALSE
    )
# plot_season(INPUT, brks2, d)
# Fine fitting
fits <- curvefits(
  INPUT, brks2,
  options = list(
    methods = c("AG", "Beck", "Elmore", "Zhang"), #,"klos", "Gu"
    wFUN = wFUN,
    nextend = 2, maxExtendMonth = 2, minExtendMonth = 1, minPercValid = 0.2
  )
)

r_param = get_param(fits)
r_pheno = get_pheno(fits)
r_gof = get_GOF(fits)
d_fit = get_fitting(fits)

g <- plot_curvefits(d_fit, brks2)
grid::grid.newpage(); grid::grid.draw(g)

```

plot_input

Plot INPUT returned by check_input

Description

Plot INPUT returned by check_input

Usage

```
plot_input(INPUT, wmin = 0.2, show.y0 = TRUE, ylab = "VI", ...)
```

Arguments

INPUT	A list object with the elements of t, y, w, Tn (optional) and ylu, returned by check_input() .
wmin	double, minimum weighth (i.e. weight of snow, ice and cloud).
show.y0	boolean. Whether to show original time-series y0 or processed time-series y by check_input() ?
ylab	y axis title
...	other parameter will be ignored.

Examples

```
library(phenofit)
data("CA_NS6"); d = CA_NS6
# global parameter
IsPlot = TRUE
nptperyear = 23
ypeak_min = 0.05

INPUT    <- check_input(d$t, d$y, d$w, d$QC_flag, nptperyear,
                        maxgap = nptperyear/4, alpha = 0.02, wmin = 0.2)
plot_input(INPUT)
```

plot_season	<i>plot_season</i>
-------------	--------------------

Description

Plot growing season divding result.

Usage

```
plot_season(
  INPUT,
  brks,
  plotdat,
  IsPlot.OnlyBad = FALSE,
  show.legend = TRUE,
  ylab = "VI",
  title = NULL,
  show.shade = TRUE,
  margin = 0.35
)
```

Arguments

INPUT	A list object with the elements of t, y, w, Tn (optional) and ylu, returned by check_input() .
brks	A list object returned by season or season_mov.
plotdat	(optional) A list or data.table, with t, y and w. Only if IsPlot=TRUE, plot_input() will be used to plot. Known that y and w in INPUT have been changed, we suggest using the original data.table.
IsPlot.OnlyBad	If true, only plot partial figures whose NSE < 0.3.
show.legend	Whether to show legend?
ylab	y axis title
title	The main title (on top)
show.shade	Boolean, period inside growing cycle colored as shade?
margin	ylim = c(ymin, ymax + margin * A); A = ymax - ymin.

qcFUN

*Initial weights according to qc***Description**

- `getBits`: Extract bitcoded QA information from bin value
- `qc_summary`: Initial weights based on Quality reliability of VI pixel, suit for MOD13A1, MOD13A2 and MOD13Q1 (SummaryQA band).
- `qc_5l`: Initial weights based on Quality control of five-level confidence score, suit for MCD15A3H(LAI, FparLai_QC), MOD17A2H(GPP, Psn_QC) and MOD16A2(ET, ET_QC).
- `qc_StateQA`: Initial weights based on StateQA, suit for MOD09A1, MYD09A1.
- `qc_FparLai`: For MODIS LAI
- `qc_NDVI3g`: For AVHRR NDVI3g
- `qc_NDVIv4`: For AVHRR NDVIv4

Usage

```

getBits(x, start, end = start)

qc_summary(QA, wmin = 0.2, wmid = 0.5, wmax = 1)

qc_StateQA(QA, wmin = 0.2, wmid = 0.5, wmax = 1)

qc_FparLai(QA, FparLai_QC = NULL, wmin = 0.2, wmid = 0.5, wmax = 1)

qc_5l(QA, wmin = 0.2, wmid = 0.5, wmax = 1)

qc_NDVIv4(QA, wmin = 0.2, wmid = 0.5, wmax = 1)

qc_NDVI3g(QA, wmin = 0.2, wmid = 0.5, wmax = 1)

qc_SPOT(QA, wmin = 0.2, wmid = 0.5, wmax = 1)

```

Arguments

<code>x</code>	Binary value
<code>start</code>	Bit starting position, count from zero
<code>end</code>	Bit ending position
<code>QA</code>	quality control variable
<code>wmin</code>	Double, minimum weight (i.e. weight of snow, ice and cloud).
<code>wmid</code>	Double, middle weight, i.e. marginal
<code>wmax</code>	Double, maximum weight, i.e. good
<code>FparLai_QC</code>	Another QC flag of MCD15A3H

Details

If FparLai_QC specified, I_margin = SCF_QC >= 2 & SCF_QC <= 3.

Value

A list object with

- **weights**: Double vector, initial weights.
- **QC_flag**: Factor vector, with the level of c("snow", "cloud", "shadow", "aerosol", "marginal", "good")

Note

qc_5l and qc_NDVIv4 only returns weight, without QC_flag.

References

https://developers.google.com/earth-engine/datasets/catalog/MODIS_006_MOD13A1

https://developers.google.com/earth-engine/datasets/catalog/MODIS_006_MCD15A3H

Erwin Wolters, Else Swinnen, Carolien Toté, Sindy Sterckx. SPOT-VGT COLLECTION 3 PRODUCTS USER MANUAL V1.2, 2018, P47

See Also

[qc_sentinel2\(\)](#)

Examples

```
set.seed(100)
QA <- as.integer(runif(100, 0, 2^7))

r1 <- qc_summary(QA, wmin = 0.2, wmid = 0.5, wmax = 1)
r2 <- qc_StateQA(QA, wmin = 0.2, wmid = 0.5, wmax = 1)
r_5l <- qc_5l(QA, wmin = 0.2, wmid = 0.5, wmax = 1)
r_NDVI3g <- qc_NDVI3g(QA, wmin = 0.2, wmid = 0.5, wmax = 1)
r_NDVIv4 <- qc_NDVIv4(QA, wmin = 0.2, wmid = 0.5, wmax = 1)
```


Description

SCL Value	Description	Quality	weight
1	Saturated or defective	Bad	w_{min}
2	Dark Area Pixels	Bad	w_{min}
3	Cloud Shadows	Bad	w_{min}
4	Vegetation	Good	w_{max}
5	Bare Soils	Good	w_{max}
6	Water	Good	w_{max}
7	Clouds Low Probability / Unclassified	Good	w_{max}
8	Clouds Medium Probability	Marginal	w_{mid}
9	Clouds High Probability	Bad	w_{mid}
10	Cirrus	Good	w_{mid}
11	Snow / Ice	Bad	w_{mid}

Usage

```
qc_sentinel2(SCL, wmin = 0.2, wmid = 0.5, wmax = 1)
```

Arguments

SCL	quality control variable for sentinel2
wmin	Double, minimum weight (i.e. weight of snow, ice and cloud).
wmid	Double, middle weight, i.e. marginal
wmax	Double, maximum weight, i.e. good

References

https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S2_SR

Examples

```
qc_sentinel2(1:11)
```

rcpp_wSG

Weighted Savitzky-Golay written in RcppArmadillo

Description

NA and Inf values in the yy has been ignored automatically.

Usage

```
rcpp_wSG(y, halfwin = 1L, d = 1L, w = NULL)

rcpp_SG(y, halfwin = 1L, d = 1L)
```

Arguments

y	colvec
halfwin	halfwin of Savitzky-Golay
d	polynomial of degree. When d = 1, it becomes moving average.
w	colvec of weight

Examples

```
y <- 1:15
w <- seq_along(y)/length(y)

frame = 5
d = 2
s1 <- rcpp_wSG(y, frame, d, w)
s2 <- rcpp_SG(y, frame, d)
```

season_mov	<i>Moving growing season division</i>
------------	---------------------------------------

Description

Moving growing season division

Usage

```
season_mov(INPUT, options = list(), ..., years.run = NULL)
```

Arguments

INPUT	A list object with the elements of t, y, w, Tn (optional) and ylu, returned by check_input() .
options	see the following section options for season for details.
...	others parameter to set_options()
years.run	Numeric vector. Which years to run? If not specified, it is all years.

options for season

(a) Parameters for rough fitting:

- rFUN : character (default smooth_wWHIT), the name of rough curve fitting function, can be one of c("smooth_wSG", "smooth_wWHIT", "smooth_wHANTS"), which are corresponding to [smooth_wSG\(\)](#), [smooth_wWHIT\(\)](#) and [smooth_wHANTS\(\)](#).
- wFUN : character (default wTSM), the name of weights updating functions, can be one of c("wTSM", "wChen", "wBisquare", "wSELF"). See [wTSM\(\)](#), [wChen\(\)](#), [wBisquare\(\)](#) and [wSELF\(\)](#) for details.
- iters : integer (default 2), the number of rough fitting iterations.
- wmin : double, the minimum weight of bad points (i.e. snow, ice and cloud).
- verbose : logical (default FALSE). If TRUE, options\$season will be printed on the console.
- lambda : double (default NULL), the smoothing parameter of [smooth_wWHIT\(\)](#).
 - If lambda = NULL, V-curve theory will be employed to find the optimal lambda. See [lambda_vcurve\(\)](#) for details.
- frame : integer (default NULL), the parameter of [smooth_wSG\(\)](#), moving window size.
 - If frame = NULL, frame will be reset as floor(nptperyear/5)*2 + 1 (referred by TIME-SAT).
- nf : integer (default 4), the number of frequencies in [smooth_wHANTS\(\)](#).
- maxExtendMonth: integer (default 12), previous and subsequent maxExtendMonth (in month) data were added to the current year for rough fitting.
- nextend : integer (default NULL), same as maxExtendMonth, but in points.
 - If nextend provided, maxExtendMonth will be ignored.
 - If nextend = NULL, nextend will be reset as ceiling(maxExtendMonth/12*nptperyear)

(b) Parameters for growing season division:

- minpeakdistance : double (default NULL), the minimum distance of two peaks (in points). If the distance of two maximum extreme value less than minpeakdistance, only the maximum one will be kept.
 - If minpeakdistance = NULL, it will be reset as nptperyear/6.
- r_max : double (default 0.2; in (0, 1)). r_max and r_min are used to eliminate fake peaks and troughs.
 - The real peaks should satisfy:
 1. $\max(h_{peak,L}, h_{peak,R}) > r_{max}A$
 2. $\min(h_{peak,L}, h_{peak,R}) > r_{min}A$, where $h_{peak,L}, h_{peak,R}$ are height difference from the peak to the left- and right-hand troughs.
 - The troughs should satisfy:
 1. $\max(h_{trough,L}, h_{trough,R}) > r_{max}A$, where $h_{trough,L}, h_{trough,R}$ are height difference from the trough to the left- and right-hand peaks.
- r_min : double (default 0.05; in (0, 1)), see above r_max for details. $r_{min} < r_{max}$.
- rtrough_max : double (default 0.6, in (0, 1)), $y_{peak} \leq rtrough_{max} * A + ylu[1]$.
- ypeak_min : double 0.1 (in VI unit), $y_{peak} \geq ypeak_{min}$.
- .check_season : logical (default TRUE). check the growing season length according to len_min and len_max. If FALSE, len_min and len_max will lose their effect.
- len_min : integer (default 45), the minimum length (in days) of growing season

- `len_max` : integer (default 650), the minimum length (in days) of growing season
- `adj.param` : logical. If TRUE (default), if there are too many or too less peaks and troughs, `phenofit` will automatically adjust rough curve fitting function parameters. See `MaxPeaksPerYear` and `MaxTroughsPerYear` for details.
- `MaxPeaksPerYear` (optional) : integer (default 2), the max number of peaks per year. If `PeaksPerYear > MaxPeaksPerYear`, then `lambda = lambda*2`.
- `MaxTroughsPerYear` (optional) : integer (default 3), the max number of troughs per year. If `TroughsPerYear > MaxTroughsPerYear`, then `lambda = lambda*2`.
- `calendarYear` : logical (default FALSE). If TRUE, the start and end of a calendar year will be regarded as growing season division (North Hemisphere is from 01 Jan to 31 Dec; South Hemisphere is from 01 Jul to 30 Jun).
- `rm.closed` : logical (default TRUE). If TRUE, closed peaks (or troughs) will be further tidied. Only the maximum
- `is.continuous` (not used): logical (default TRUE). This parameter is for `fluxnet2015` fluxsite data, where the input might be not continuous.

References

1. Kong, D., Zhang, Y., Wang, D., Chen, J., & Gu, X. (2020). Photoperiod Explains the Asynchronization Between Vegetation Carbon Phenology and Vegetation Greenness Phenology. *Journal of Geophysical Research: Biogeosciences*, 125(8), e2020JG005636. <https://doi.org/10.1029/2020JG005636>
2. Kong, D., Zhang, Y., Gu, X., & Wang, D. (2019). A robust method for reconstructing global MODIS EVI time series on the Google Earth Engine. *ISPRS Journal of Photogrammetry and Remote Sensing*, 155, 13-24.

See Also

[season\(\)](#)

Examples

```
data("CA_NS6")
d <- CA_NS6

nptperyear <- 23
INPUT <- check_input(d$t, d$y, d$w,
  QC_flag = d$QC_flag,
  nptperyear = nptperyear, south = FALSE,
  maxgap = nptperyear / 4, alpha = 0.02, wmin = 0.2
)

# curve fitting by year
brks_mov <- season_mov(INPUT,
  options = list(
    rFUN = "smooth_wWHIT", wFUN = "wTSM",
    lambda = 10,
    r_min = 0.05, ypeak_min = 0.05,
    verbose = TRUE
  )
)
```

```

plot_season(INPUT, brks_mov)

rfit <- brks2rfit(brks_mov)
# Phenological Metrics from rough fitting
r <- get_pheno(rfit)

```

set_options

*set and get phenofit option***Description**

set and get phenofit option

Usage

```

set_options(..., options = NULL)

get_options(names = NULL)

```

Arguments

...	list of phenofit options FUN_season: character, season_mov or season rFUN: character, rough fitting function. smooth_wWHIT, smooth_wSG or smooth_wHANTS.
options	If not NULL, options will overwrite the default parameters (get_options()). • qcFUN : function to process qc flag, see qcFUN() for details. • nptperyear : Integer, number of images per year. • wFUN : character (default wTSM), the name of weights updating functions, can be one of c("wTSM", "wChen", "wBisquare", "wSELF"). See wTSM(), wChen(), wBisquare() and wSELF() for details. – If options\$season\$wFUN or options\$season\$wFUN is NULL, the options\$wFUN will overwrite it. • wmin : double, the minimum weight of bads points (i.e. snow, ice and cloud). – If options\$season\$wmin or options\$season\$wmin is NULL, the options\$wmin will overwrite it. • season : See the following part: options for season for details. • fitting : See the following part: options for fitting for details.
names	vector of character, names of options

options for season**(a) Parameters for rough fitting:**

- rFUN : character (default smooth_wWHIT), the name of rough curve fitting function, can be one of c("smooth_wSG", "smooth_wWHIT", "smooth_wHANTS"), which are corresponding to [smooth_wSG\(\)](#), [smooth_wWHIT\(\)](#) and [smooth_wHANTS\(\)](#).

- `wFUN` : character (default `wTSM`), the name of weights updating functions, can be one of `c("wTSM", "wChen", "wBisquare", "wSELF")`. See `wTSM()`, `wChen()`, `wBisquare()` and `wSELF()` for details.
- `iters` : integer (default 2), the number of rough fitting iterations.
- `wmin` : double, the minimum weight of bad points (i.e. snow, ice and cloud).
- `verbose` : logical (default `FALSE`). If `TRUE`, `options$season` will be printed on the console.
- `lambda` : double (default `NULL`), the smoothing parameter of `smooth_wWHIT()`.
 - If `lambda = NULL`, V-curve theory will be employed to find the optimal `lambda`. See `lambda_vcurve()` for details.
- `frame` : integer (default `NULL`), the parameter of `smooth_wSG()`, moving window size.
 - If `frame = NULL`, `frame` will be reset as `floor(nptperyear/5)*2 + 1` (referred by `TIME-SAT`).
- `nf` : integer (default 4), the number of frequencies in `smooth_wHANTS()`.
- `maxExtendMonth`: integer (default 12), previous and subsequent `maxExtendMonth` (in month) data were added to the current year for rough fitting.
- `nextend` : integer (default `NULL`), same as `maxExtendMonth`, but in points.
 - If `nextend` provided, `maxExtendMonth` will be ignored.
 - If `nextend = NULL`, `nextend` will be reset as `ceiling(maxExtendMonth/12*nptperyear)`

(b) Parameters for growing season division:

- `minpeakdistance` : double (default `NULL`), the minimum distance of two peaks (in points). If the distance of two maximum extreme value less than `minpeakdistance`, only the maximum one will be kept.
 - If `minpeakdistance = NULL`, it will be reset as `nptperyear/6`.
- `r_max` : double (default 0.2; in (0, 1)). `r_max` and `r_min` are used to eliminate fake peaks and troughs.
 - The real peaks should satisfy:
 1. $\max(h_{peak,L}, h_{peak,R}) > r_{max}A$
 2. $\min(h_{peak,L}, h_{peak,R}) > r_{min}A$, where $h_{peak,L}, h_{peak,R}$ are height difference from the peak to the left- and right-hand troughs.
 - The troughs should satisfy:
 1. $\max(h_{trough,L}, h_{trough,R}) > r_{max}A$, where $h_{trough,L}, h_{trough,R}$ are height difference from the trough to the left- and right-hand peaks.
- `r_min` : double (default 0.05; in (0, 1)), see above `r_max` for details. `r_min` < `r_max`.
- `rtrough_max` : double (default 0.6, in (0, 1)), $y_{peak} \leq rtrough_{max} * A + ylu[1]$.
- `ypeak_min` : double 0.1 (in VI unit), $y_{peak} \geq ypeak_{min}$.
- `.check_season` : logical (default `TRUE`). check the growing season length according to `len_min` and `len_max`. If `FALSE`, `len_min` and `len_max` will lose their effect.
- `len_min` : integer (default 45), the minimum length (in days) of growing season
- `len_max` : integer (default 650), the minimum length (in days) of growing season
- `adj.param` : logical. If `TRUE` (default), if there are too many or too less peaks and troughs, `phenofit` will automatically adjust rough curve fitting function parameters. See `MaxPeaksPerYear` and `MaxTroughsPerYear` for details.
- `MaxPeaksPerYear` (optional) : integer (default 2), the max number of peaks per year. If `PeaksPerYear > MaxPeaksPerYear`, then `lambda = lambda*2`.

- `MaxTroughsPerYear` (optional) : integer (default 3), the max number of troughs per year. If `TroughsPerYear > MaxTroughsPerYear`, then $\lambda = \lambda * 2$.
- `calendarYear` : logical (default FALSE). If TRUE, the start and end of a calendar year will be regarded as growing season division (North Hemisphere is from 01 Jan to 31 Dec; South Hemisphere is from 01 Jul to 30 Jun).
- `rm.closed` : logical (default TRUE). If TRUE, closed peaks (or troughs) will be further tidied. Only the maximum
- `is.continuous` (not used): logical (default TRUE). This parameter is for fluxnet2015 fluxsite data, where the input might be not continuous.

options for fitting

- `methods` (default `c('AG', 'Beck', 'Elmore', 'Zhang')```): Fine curve fitting methods, can be one or more of `'Beck', 'Elmore', 'Zhang', 'Gu', 'Klos'`. Note that `'Gu'` and `'Klos'` are very slow.
- `iters` (default 2): max iterations of fine fitting.
- `wFUN` (default `wTSM`): Character or function, weights updating function of fine fitting function.
- `wmin` (default 0.1): min weights in the weights updating procedure.
- `use.rough` (default FALSE): Whether to use rough fitting smoothed time-series as input? If false, smoothed VI by rough fitting will be used for Phenological metrics extraction; If true, original input `y` will be used (rough fitting is used to divide growing seasons and update weights).
- `use.y0` (default TRUE): boolean. whether to use original `y0` as the input of `plot_input`, note that not for curve fitting. `y0` is the original value before the process of `check_input`.
- `nextend` (default 2): Extend curve fitting window, until `nextend` good or marginal points are found in the previous and subsequent growing season.
- `maxExtendMonth` (default 1): Search good or marginal good values in previous and subsequent `maxExtendMonth` period.
- `minExtendMonth` (default 0.5): Extend period defined by `nextend` and `maxExtendMonth`, should be no shorter than `minExtendMonth`. When all points of the input time-series are good value, then the extending period will be too short. In that situation, we can't make sure the connection between different growing seasons is smoothing.
- `minPercValid`: (default 0, not use). If the percentage of good- and marginal- quality points is less than `minPercValid`, curve fitting result is set to NA.
- `minT`: (not use). If `Tn` not provided in INPUT, `minT` will not be used. `minT` use night temperature `Tn` to define background value (days with `Tn < minT` treated as ungrowing season).

Examples

```
set_options(verbose = FALSE)
get_options("season") %>% str()
```

smooth_wHANTS

*Weighted HANTS SMOOTH***Description**

Weighted HANTS smoother

Usage

```
smooth_wHANTS(
  y,
  t,
  w,
  nf = 3,
  ylu,
  periodlen = 365,
  nptperyear,
  wFUN = wTSM,
  iters = 2,
  wmin = 0.1,
  ...
)
```

Arguments

y	Numeric vector, vegetation index time-series
t	Numeric vector, Date variable
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be wmin, the others will be 1.0.
nf	number of frequencies to be considered above the zero frequency
ylu	[low, high] of time-series y (curve fitting values are constrained in the range of ylu).
periodlen	length of the base period, measured in virtual samples (days, dekads, months, etc.). nptperyear in timesat.
nptperyear	Integer, number of images per year.
wFUN	weights updating function, can be one of 'wTSM', 'wChen' and 'wBisquare'.
iters	How many times curve fitting is implemented.
wmin	Double, minimum weight (i.e. weight of snow, ice and cloud).
...	Additional parameters are passed to wFUN.

Value

- ws: weights of every iteration
- zs: curve fittings of every iteration

Author(s)

Wout Verhoef, NLR, Remote Sensing Dept. June 1998 Mohammad Abouali (2011), Converted to MATLAB Dongdong Kong (2018), introduced to R and modified into weighted model.

Examples

```
library(phenofit)
data("MOD13A1")
dt <- tidy_MOD13(MOD13A1$dt)
d <- dt[site == "AT-Neu", ]

l <- check_input(d$t, d$y, d$w, nptperyear=23)
r_wHANTS <- smooth_wHANTS(l$y, l$t, l$w, ylu = l$ylu, nptperyear = 23, iters = 2)
```

smooth_wSG

*Weighted Savitzky-Golay***Description**

Weighted Savitzky-Golay

Usage

```
smooth_wSG(
  y,
  w,
  nptperyear,
  ylu,
  wFUN = wTSM,
  iters = 2,
  frame = floor(nptperyear/5) * 2 + 1,
  d = 2,
  ...
)
```

Arguments

y	Numeric vector, vegetation index time-series
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be wmin, the others will be 1.0.
nptperyear	Integer, number of images per year.
ylu	(optional) [low, high] value of time-series y (curve fitting values are constrained in the range of ylu).
wFUN	weights updating function, can be one of 'wTSM', 'wChen' and 'wBisquare'.
iters	How many times curve fitting is implemented.
frame	Savitzky-Golay windows size

`d` polynomial of degree. When `d = 1`, it becomes moving average.
`...` Additional parameters are passed to `wFUN`.

Value

- `ws`: weights of every iteration
- `zs`: curve fittings of every iteration

References

1. Chen, J., Jönsson, P., Tamura, M., Gu, Z., Matsushita, B., Eklundh, L., 2004. A simple method for reconstructing a high-quality NDVI time-series data set based on the Savitzky-Golay filter. *Remote Sens. Environ.* 91, 332-344. <https://doi.org/10.1016/j.rse.2004.03.014>.
2. https://en.wikipedia.org/wiki/Savitzky%E2%80%93Golay_filter

Examples

```
library(phenofit)
data("MOD13A1")
dt <- tidy_MOD13(MOD13A1$dt)
d <- dt[site == "AT-Neu", ]

l <- check_input(d$t, d$y, d$w, nptperyear=23)
r_wSG <- smooth_wSG(l$y, l$w, l$ylu, nptperyear = 23, iters = 2)
```

smooth_wWHIT

Weigthed Whittaker Smoother

Description

Weigthed Whittaker Smoother

Usage

```
smooth_wWHIT(
  y,
  w,
  ylu,
  nptperyear,
  wFUN = wTSM,
  iters = 1,
  lambda = 15,
  second = FALSE,
  ...
)
```

Arguments

y	Numeric vector, vegetation index time-series
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be wmin, the others will be 1.0.
ylu	[low, high] of time-series y (curve fitting values are constrained in the range of ylu).
nptperyear	Integer, number of images per year.
wFUN	weights updating function, can be one of 'wTSM', 'wChen' and 'wBisquare'.
iters	How many times curve fitting is implemented.
lambda	scaler or numeric vector, whittaker parameter. • If lambda = NULL, V-curve theory will be applied to retrieve the optimal lambda. • If multiple lambda provided (numeric vector), a list of the smoothing results with the same length of lambda will be returned.
second	If true, in every iteration, Whittaker will be implemented twice to make sure curve fitting is smooth. If curve has been smoothed enough, it will not care about the second smooth. If no, the second one is just prepared for this situation. If lambda value has been optimized, second smoothing is unnecessary.
...	Additional parameters are passed to wFUN.

Value

- ws: weights of every iteration
- zs: curve fittings of every iteration

Note

Whittaker smoother of the second order difference is used!

References

1. Eilers, P.H.C., 2003. A perfect smoother. Anal. Chem. doi:10.1021/ac034173t
2. Frasso, G., Eilers, P.H.C., 2015. L- and V-curves for optimal smoothing. Stat. Modelling 15, 91-111. doi:10.1177/1471082X14549288.

See Also

[lambda_vcurve\(\)](#)

Examples

```
data("MOD13A1")
dt <- tidy_MOD13(MOD13A1$dt)
d <- dt[site == "AT-Neu", ]

l <- check_input(d$t, d$y, d$w, nptperyear=23)
```

```
r_wWHIT <- smooth_wWHIT(l$y, l$w, l$ylu, nptperyear = 23, iters = 2)

## Optimize `lambda` by V-curve theory
# (a) optimize manually
lambda_vcurve(l$y, l$w, plot = TRUE)

# (b) optimize automatically by setting `lambda = NULL` in smooth_wWHIT
r_wWHIT2 <- smooth_wWHIT(l$y, l$w, l$ylu, nptperyear = 23, iters = 2, lambda = NULL) #
```

whit2	<i>Weighted Whittaker smoothing with a second order finite difference penalty</i>
-------	---

Description

This function smoothes signals with a finite difference penalty of order 2. This function is modified from ptw package.

Usage

```
whit2(y, lambda, w = rep(1, ny))
```

Arguments

y	signal to be smoothed: a vector
lambda	smoothing parameter: larger values lead to more smoothing
w	weights: a vector of same length as y. Default weights are equal to one

Value

A numeric vector, smoothed signal.

Author(s)

Paul Eilers, Jan Gerretzen

References

1. Eilers, P.H.C. (2004) "Parametric Time Warping", *Analytical Chemistry*, **76** (2), 404 – 411.
2. Eilers, P.H.C. (2003) "A perfect smoother", *Analytical Chemistry*, **75**, 3631 – 3636.

Examples

```
library(phenofit)
data("MOD13A1")
dt <- tidy_MOD13(MOD13A1$dt)
y <- dt[site == "AT-Neu", ][1:120, y]

plot(y, type = "b")
lines(whit2(y, lambda = 2), col = 2)
lines(whit2(y, lambda = 10), col = 3)
lines(whit2(y, lambda = 100), col = 4)
legend("bottomleft", paste("lambda = ", c(2, 10, 15)), col = 2:4, lty = rep(1, 3))
```

wSELF

Weight updating functions

Description

- wSELF weight are not changed and return the original.
- wTSM weight updating method in TIMESAT.
- wBisquare Bisquare weight update method. wBisquare has been modified to emphasis on upper envelope.
- wBisquare0 Traditional Bisquare weight update method.
- wChen Chen et al., (2004) weight updating method.
- wBeck Beck et al., (2006) weight updating method. wBeck need sos and eos input. The function parameter is different from others. It is still not finished.

Usage

```
wSELF(y, yfit, w, ...)

wTSM(y, yfit, w, iter = 2, nptperyear, wfact = 0.5, ...)

wBisquare0(y, yfit, w, ..., wmin = 0.2)

wBisquare(y, yfit, w, ..., wmin = 0.2, .toUpper = TRUE)

wChen(y, yfit, w, ..., wmin = 0.2)

wKong(y, yfit, w, ..., wmin = 0.2)
```

Arguments

y	Numeric vector, vegetation index time-series
yfit	Numeric vector curve fitting values.
w	(optional) Numeric vector, weights of y. If not specified, weights of all NA values will be wmin, the others will be 1.0.

...	other parameters are ignored.
iter	iteration of curve fitting.
nptperyear	Integer, number of images per year.
wfact	weight adaptation factor (0-1), equal to the reciprocal of 'Adaptation strength' in TIMESAT.
wmin	Double, minimum weight of bad points, which could be smaller the weight of snow, ice and cloud.
.toUpper	Boolean. Whether to approach the upper envelope?

Value

wnew Numeric Vector, adjusted weights.

Author(s)

wTSM is implemented by Per Jönsson, Malmö University, Sweden <per.jonsson@ts.mah.se> and Lars Eklundh, Lund University, Sweden <lars.eklundh@nateko.lu.se>. And Translated into Rcpp by Dongdong Kong, 01 May 2018.

References

1. Per Jönsson, P., Eklundh, L., 2004. TIMESAT - A program for analyzing time-series of satellite sensor data. Comput. Geosci. 30, 833-845. <https://doi.org/10.1016/j.cageo.2004.05.006>.
2. https://au.mathworks.com/help/curvefit/smoothing-data.html#bq_6ys3-3
3. Garcia, D., 2010. Robust smoothing of gridded data in one and higher dimensions with missing values. Computational statistics & data analysis, 54(4), pp.1167-1178.
4. Chen, J., Jönsson, P., Tamura, M., Gu, Z., Matsushita, B., Eklundh, L., 2004. A simple method for reconstructing a high-quality NDVI time-series data set based on the Savitzky-Golay filter. Remote Sens. Environ. 91, 332-344. <https://doi.org/10.1016/j.rse.2004.03.014>.
5. Beck, P.S.A., Atzberger, C., Hogda, K.A., Johansen, B., Skidmore, A.K., 2006. Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI. Remote Sens. Environ. <https://doi.org/10.1016/j.rse.2005.10.021>
6. <https://github.com/kongdd/phenopix/blob/master/R/FitDoubleLogBeck.R>

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