Package ‘npphen’

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Type Package

Title Vegetation Phenological Cycle and Anomaly Detection using Remote Sensing Data

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Description Calculates phenological cycle and anomalies using a non-parametric approach applied to time series of vegetation indices derived from remote sensing data or field measurements. The package implements basic and high-level functions for manipulating vector data (numerical series) and raster data (satellite derived products). Processing of very large raster files is supported.

Depends R (>= 3.5.0), raster, ks

Imports methods, graphics, stats, rgdal, lubridate, snow

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npphen *npphen*

Description

The functions in this package estimate the expected annual phenological cycle from time series or raster stack of vegetation (greenness) indexes. The algorithm to estimate the annual phenological cycle (used by the functions in npphen) uses a bivariate kernel density estimator in the index-time space. In this space, the x-axis corresponds to days of the growing season (1-365) and the y-axis to the vegetation index values, which range's values are set using the rge argument (see each function's vignette for details). The expected value of the index for each day of the growing season (the expected phenology) is approximated by the maximum value of the kernel at that day. Anomalies are calculated as deviations from the expected values at given days. The package implements basic and high-level functions for manipulating vector data (numerical series) and raster data (satellite derived products). Processing of very large raster files is supported. For methodological details of kernel density estimation see Wand & Jones (1994).

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References

Wand, M.P. & Jones, M.C. (1994) Kernel smoothing. Crc Press.

See Also

Phen, PhenMap, PhenAnoma, PhenAnoMap, PhenKplot

Phen *Phen*

Description

Estimates the annual phenological cycle from a time series of vegetation greenness.

Usage

```
Phen(x, dates, h, nGS, rge)
```

Arguments

`x` Numeric vector with greenness values

`dates` Vector with dates at which the greenness values were recorded

`h` Numeric. Indicates the geographic hemisphere to define the starting date of the growing season. h=1 if the vegetation is in the Northern Hemisphere (season starting at January 1st), h=2 if it is in the Southern Hemisphere (season starting at July 1st)

`nGS` Numeric. Number of greenness values within a single growing season. For example, nGS=23 for MODIS Vegetation Index 16-days composites

`rge` A vector containing minimum and maximum values of the response variable used in the analysis. We suggest the use of theoretically based limits. For example in the case of MODIS NDVI or EVI, it ranges from 0 to 10,000, so rge =c(0,10000)

Details

Derives the annual phenological cycle for a standard growing season using a numeric vector of vegetation canopy greenness values (e.g. Leaf Area Index, LAI) or satellite based greenness proxies such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI). A vector with dates for the greenness values is also required.

Value

A numeric vector of length = nGS, where each value represents the expected greeness at that date

See Also

`PhenMap`

Examples

```
library(lubridate)

## Testing North Hemisphere data. Raster data from Slovenia (EVI index), h=1 ##

# Load data
sl.path<-system.file("extdata/HN_slovenia",package="npphen")
sl_rasters<-list.files(path=sl.path, pattern=glob2rx("slovenia*.tif"), full.names=TRUE)
Slovenia_rasters<-stack(sl_rasters)
sl_dates<-read.csv(system.file("extdata/date_tables/Slovenia_dates.csv", package="npphen"))
Slovenia_dates <- as.Date(sl_dates$date, format='%d/%m/%Y')

# Generate a Raster time series using a raster stack and a date database from Slovenia
# Obtain data from a particular pixel generating a time series
sl_pixel<-cellFromXY(Slovenia_rasters,c(474368,5096979))
sl_pixelts<-as.numeric(Slovenia_rasters[sl_pixel])
plot(Slovenia_dates,sl_pixelts, type='l')
```

```
# Phenology for the given pixel
Phen(x=sl_pixelts,dates=Slovenia_dates,h=1,nGS=23,rge=c(0,10000))


## Testing South Hemisphere data. Raster data from Chile (EVI index), h=2 ##

# Load data
ay.path<-system.file("extdata/HS_aysen",package="npphen")
ayrasters<-list.files(path=ay.path, pattern=glob2rx("aysen*.tif"), full.names=TRUE)
Aysen_rasters<-stack(ayrasters)
ay_dates<-read.csv(system.file("extdata/date_tables/Aysen_dates.csv", package="npphen"))
Aysen_dates <- as.Date(ay_dates$date, format='%d/%m/%Y')

# Generate a Raster time series using a raster stack and a date database from Aysen
# Obtain data from a particular pixel generating a time series
ay_pixel<-cellFromXY(Aysen_rasters,c(228373,4806975))
ay_pixelts<-as.numeric(Aysen_rasters[ay_pixel])
plot(Aysen_dates,ay_pixelts, type = 'l')

# Phenology for the given pixel
Phen(x=ay_pixelts,dates=Aysen_dates,h=2,nGS=23,rge=c(0,10000))
```

PhenAnoma *PhenAnoma*

Description

Calculates anomalies with respect to the regular phenological cycle using time series (numeric vector) of vegetation greenness.

Usage

```
PhenAnoma(x, dates, h, refp, anop, rge)
```

Arguments

x	Numeric vector with greenness values
dates	Vector with dates at which the greenness values were recorded
h	Numeric. Indicates the geographic hemisphere to define the starting date of the growing season. h=1 if the vegetation is in the Northern Hemisphere (season starting at January 1st), h=2 if it is in the Southern Hemisphere (season starting at July 1st)
refp	Numeric vector with the correlative number of dates to be used as reference period. For example, refp=c(1:393) for MODIS Vegetation Index 16-days composites (18/02/2000 – 06/06/2017)

`anop` Numeric vector with the correlative number of dates for the period in which the anomalies will be calculated. For example refp=c(21:43) for the first complete year for MODIS Vegetation Index 16-days composites (01/01/2001 – 19/12/2001). anop y refp can be overlapped

`rge` A vector containing minimum and maximum values of the response variable used in the analysis. We suggest the use of theoretically based limits. For example in the case of MODIS NDVI or EVI, it ranges from 0 to 10,000, so rge =c(0,10000)

Details

Calculates phenological anomalies using a numeric vector of vegetation canopy greenness values (e.g. Leaf Area Index, LAI) or satellite based greenness proxies such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI). For this purpose, it divides the time series (numeric vector) of vegetation greeness into 2: the reference period, from which the annual phenological cycle is calculated (same as Phen function), and the observation period, for which we want to calculate anomalies with respect to the annual phenological cycle. Negative anomalies correspond to observed values lower than the reference and positive anomalies to values higher than the reference.

Value

A numeric vector of length = nGS, where each value represents the expected greeness at that date

See Also

`PhenAnoMap`

Examples

```
library(lubridate)

## Testing North Hemisphere data. Raster data from Slovenia (EVI index), h=1 ##

# Load data
sl.path<-system.file("extdata/HN_slovenia",package="npphen")
sl_rasters<-list.files(path=sl.path, pattern=glob2rx("slovenia*.tif"), full.names=TRUE)
Slovenia_rasters<-stack(sl_rasters)
sl_dates<-read.csv(system.file("extdata/date_tables/Slovenia_dates.csv", package="npphen"))
Slovenia_dates <- as.Date(sl_dates$date, format='%d/%m/%Y')

# Generate a Raster time series using a raster stack and a date database from Slovenia
# Obtain data from a particular pixel generating a time series
sl_pixel<-cellFromXY(Slovenia_rasters,c(474368,5096979))
sl_pixelts<-as.numeric(Slovenia_rasters[sl_pixel])
plot(Slovenia_dates,sl_pixelts, type ='l')

# Calculating the anomalies for the last growing season [343:365], refp [1:342]
# In this case refp and anop do not overlap
PhenAnoma(x=sl_pixelts,dates=Slovenia_dates,h=1,refp=c(1:342),
anop=c(343:365), rge=c(0,10000))


## Testing South Hemisphere data. Raster data from Chile (EVI index), h=2 ##

# Load data
ay.path<-system.file("extdata/HS_aysen",package="npphen")
ayrasters<-list.files(path=ay.path, pattern=glob2rx("aysen*.tif"), full.names=TRUE)
Aysen_rasters<-stack(ayrasters)
ay_dates<-read.csv(system.file("extdata/date_tables/Aysen_dates.csv", package="npphen"))
Aysen_dates <- as.Date(ay_dates$date, format='%d/%m/%Y')

# Generate a Raster time series using a raster stack and a date database from Aysen
# Obtain data from a particular pixel generating a time series
ay_pixel<-cellFromXY(Aysen_rasters,c(228373,4806975))
ay_pixelts<-as.numeric(Aysen_rasters[ay_pixel])
plot(Aysen_dates,ay_pixelts, type='l')

# Anomaly for the period [309:331], reference period [1:354]. In this case, ref and anop overlaps
PhenAnoma(x=as.vector(ay_pixelts),dates=Aysen_dates,h=2,refp=c(1:354),
anop=c(309:331), rge=c(0,10000))
```

PhenAnoMap *PhenAnoMap*

Description

Calculates anomalies with respect to the regular phenological cycle using time series (raster) of vegetation greenness.

Usage

```
PhenAnoMap(s, dates, h, refp, anop, nCluster, outname, format, datatype, rge)
```

Arguments

`s` Raster stack with greenness (e,g. NDVI or EV) values

`dates` Vector with dates at which the greenness values were recorded

`h` Numeric. Indicates the geographic hemisphere to define the starting date of the growing season. h=1 if the vegetation is in the Northern Hemisphere (season starting at January 1st), h=2 if it is in the Southern Hemisphere (season starting at July 1st)

`refp` Numeric vector with the correlative number of dates to be used as reference period. For example, refp=c(1:393) for MODIS Vegetation Index 16-days composites (18/02/2000 – 06/06/2017) `anop` Numeric vector with the correlative number of dates for the period in which the anomalies will be calculated. For example refp=c(21:43) for the first complete year for MODIS Vegetation Index 16-days composites (01/01/2001 – 19/12/2001). anop y refp can be overlapped

`nCluster` Numeric. Number of CPU cores to be used for computational calculations

`outname` Character vector with the output path and filename with extension or only the filename and extension if work directory was set. For example outname="output_phen.tif". See `writeRaster`

`format` Character. Output file type. See `writeFormats`

`datatype` Character. Output data type. See `dataType`

`rge` A vector containing minimum and maximum values of the response variable used in the analysis. We suggest the use of theoretically based limits. For example in the case of MODIS NDVI or EVI, it ranges from 0 to 10,000, so rge =c(0,10000)

Details

Similar to PhenAnoma, it calculates phenological anomalies but using a raster stack instead of a numeric vector of vegetation canopy greenness values (e.g. Leaf Area Index, LAI) or satellite based greenness proxies such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI). For this purpose, it divides the time series (raster stack) of vegetation greeness into 2: the reference period, from which the annual phenological cycle is calculated (same as the Phen function), and the observation period, for which we want to calculate anomalies with respect to the annual phenological cycle. Negative anomalies correspond to observed values lower than the reference and positive anomalies to values higher than the reference. It delivers a raster stack with anomalies per date.

Value

RasterStack

See Also

`PhenAnoma`

Examples

```
## Not run:
##DEPENDING ON HARDWARE, THIS PROCESS CAN BE HIGHLY TIME CONSUMING##

## Testing North Hemisphere data. Raster data from Slovenia (EVI index), h=1 ##

# Load data
sl.path<-system.file("extdata/HN_slovenia",package="npphen")
sl_rasters<-list.files(path=sl.path, pattern=glob2rx("slovenia*.tif"), full.names=TRUE)
Slovenia_rasters<-stack(sl_rasters)
sl_dates<-read.csv(system.file("extdata/date_tables/Slovenia_dates.csv", package="npphen"))
Slovenia_dates <- as.Date(sl_dates$date, format='%d/%m/%Y')
```

```
# Calculating the anomalies for the last growing season [343:365], refp [1:342]
# In this case refp and anop do not overlap

library(snow)

# Define the number of cores to be use. In this example we use 1
nc1<-1

PhenAnoMap(s=Slovenia_rasters,dates=Slovenia_dates,h=1,refp=c(1:342), anop=c(343:365),
nCluster=nc1,outname=”ano_slov.tif”, format=”GTiff”, datatype=”FLT4S”, rge=c(0,10000))
#map_an1<-raster(”ano_slov.tif”)#run only for load anomaly brick
#plot(map_an1)


## Testing South Hemisphere data. Raster data from Chile (EVI index), h=2 ##

# Load data
ay.path<-system.file(”extdata/HS_aysen”,package=”npphen”)
ayrasters<-list.files(path=ay.path, pattern=glob2rx(”aysen*.tif”), full.names=TRUE)
Aysen_rasters<-stack(ayrasters)
ay_dates<-read.csv(system.file(”extdata/date_tables/Aysen_dates.csv”, package=”npphen”))
Aysen_dates <- as.Date(ay_dates$date, format='%d/%m/%Y')

# Making the LSP raster, n bands = 23
# Define the number of cores to be use. In this example we use 1
nc1<-1

PhenAnoMap(s=Aysen_rasters,dates=Aysen_dates,h=2,refp=c(1:354), anop=c(309:331),
nCluster=nc1,outname=”ano_aysen.tif”, format=”GTiff”, datatype=”FLT4S”,rge=c(0,10000))
#map_an2<-raster(”ano_aysen.tif”)#run only for load anomaly brick
#plot(map_an2)


## End(Not run)
```

PhenKplot *PhenKplot*

Description

Plot the most probable vegetation greenness values.

Usage

```
PhenKplot(x, dates, h, nGS, xlab, ylab, rge)
```

Arguments

`x`	Numeric vector with greenness values
`dates`	Vector with dates at which the greenness values were recorded

`h` Numeric. Indicates the geographic hemisphere to define the starting date of the growing season. h=1 if the vegetation is in the Northern Hemisphere (season starting at January 1st), h=2 if it is in the Southern Hemisphere (season starting at July 1st)

`nGS` Numeric. Number of greenness values within a single growing season. For example, nGS=23 for MODIS Vegetation Index 16-days composites

`xlab` Character vector (or expression) giving plot title in x axis label

`ylab` Caracter vector (or expression) giving plot title in y axis label

`rge` A vector containing minimum and maximum values of the response variable used in the analysis. We suggest the use of theoretically based limits. For example in the case of MODIS NDVI or EVI, it ranges from 0 to 10,000, so rge =c(0,10000)

Details

It is the graphical version of the Phen function. It calculates and plot a likelihood map of the vegetation-greenness – time space using a numeric vector of vegetation canopy greenness values (e.g. Leaf Area Index (LAI) or greenness proxies values such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI). Also a vector with dates for the greenness values is required. This function calculates the confidence areas on a per year basis. Functions for confidence intervals on per day basis are under development. This function is partially based on the ci2d function on package gplots.

See Also

Phen

Examples

```
library(lubridate)

## Testing North Hemisphere data. Raster data from Slovenia (EVI index), h=1 ##

# Load data
sl.path<-system.file("extdata/HN_slovenia",package="npphen")
sl_rasters<-list.files(path=sl.path, pattern=glob2rx("slovenia*.tif"), full.names=TRUE)
Slovenia_rasters<-stack(sl_rasters)
sl_dates<-read.csv(system.file("extdata/date_tables/Slovenia_dates.csv", package="npphen"))
Slovenia_dates <- as.Date(sl_dates$date, format='%d/%m/%Y')

# Generate a Raster time series using a raster stack and a date database from Slovenia
# Obtain data from a particular pixel generating a time series
sl_pixel<-cellFromXY(Slovenia_rasters,c(474368,5096979))
sl_pixelts<-as.numeric(Slovenia_rasters[sl_pixel])
plot(Slovenia_dates,sl_pixelts, type='l')

# Phenology for the given pixel
PhenKplot(x=sl_pixelts,dates=Slovenia_dates,h=1,nGS=23, xlab="DOY",
ylab="EVI", rge=c(0,10000))
```

```
## Testing South Hemisphere data. Raster data from Chile (EVI index), h=2 ##

# Load data
ay.path<-system.file("extdata/HS_aysen",package="npphen")
ayrasters<-list.files(path=ay.path, pattern=glob2rx("aysen*.tif"), full.names=TRUE)
Aysen_rasters<-stack(ayrasters)
ay_dates<-read.csv(system.file("extdata/date_tables/Aysen_dates.csv", package="npphen"))
Aysen_dates <- as.Date(ay_dates$date, format='%d/%m/%Y')

# Generate a Raster time series using a raster stack and a date database from Aysen
# Obtain data from a particular pixel generating a time series
ay_pixel<-cellFromXY(Aysen_rasters,c(228373,4806975))
ay_pixelts<-as.numeric(Aysen_rasters[ay_pixel])
plot(Aysen_dates,ay_pixelts, type = 'l')

# Phenology for the given pixel
PhenKplot(x=ay_pixelts,dates=Aysen_dates,h=2,nGS=23, xlab="DOY",
ylab="EVI", rge=c(0,10000))
```

PhenMap *PhenMap*

Description

Estimates annual Land Surface Phenology (LSP) using time series of a vegetation greenness raster stack.

Usage

```
PhenMap(s, dates, h, nGS, nCluster, outname, format, datatype, rge)
```

Arguments

`s` Raster stack with greenness (e,g. NDVI or EV) values

`dates` Vector with dates at which the greenness values were recorded

`h` Numeric. Indicates the geographic hemisphere to define the starting date of the growing season. h=1 if the vegetation is in the Northern Hemisphere (season starting at January 1st), h=2 if it is in the Southern Hemisphere (season starting at July 1st)

`nGS` Numeric. Number of greenness values within a single growing season. For example, nGS=23 for MODIS Vegetation Index 16-days composites

`nCluster` Numeric. Number of CPU cores to be used for computational calculations

`outname` Character vector with the output path and filename with extension or only the filename and extension if work directory was set. For example outname="output_phen.tif". See `writeRaster` `format` Character. Output file type. See `writeFormats`

`datatype` Character. Output data type. See `dataType`

`rge` A vector containing minimum and maximum values of the response variable used in the analysis. We suggest the use of theoretically based limits. For example in the case of MODIS NDVI or EVI, it ranges from 0 to 10,000, so rge =c(0,10000)

Details

Derives the annual Land Surface Phenological (LSP) cycle for a standard growing season using a raster stack of satellite based greenness values such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI). The LSP cycle is calculated for all pixels of the input raster stack in the same way as for the Phen function. The output is a multiband raster where every band is the expected greeness value at a given time step of the standard growing season. For example, for MODIS Vegetation Index 16-days composites the number of time steps of the growing season (nGS) is 23 , and therefore, the output raster will have 23 bands. A vector with dates for the greenness values is also required.

Value

RasterStack

See Also

`Phen`

Examples

```
## Not run:
##DEPENDING ON HARDWARE, THIS PROCESS CAN BE HIGHLY TIME CONSUMING##

## Testing North Hemisphere data. Raster data from Slovenia (EVI index), h=1 ##

# Load data
sl.path<-system.file(”extdata/HN_slovenia”,package=”npphen”)
sl_rasters<-list.files(path=sl.path, pattern=glob2rx(”slovenia*.tif”), full.names=TRUE)
Slovenia_rasters<-stack(sl_rasters)
sl_dates<-read.csv(system.file(”extdata/date_tables/Slovenia_dates.csv”, package=”npphen”))
Slovenia_dates <- as.Date(sl_dates$date, format='%d/%m/%Y')

# Making the LSP raster, n bands = 23

library(snow)

# Define the number of cores to be use. In this example we use 1
nc1<-1

PhenMap(s=Slovenia_rasters,dates=Slovenia_dates,h=1,nGS=23, nCluster=nc1,
outname=”phen_slov.tif”, format=”GTiff”, datatype=”FLT4S”,rge=c(0,10000))
#map1<-raster(”phen_slov.tif”)#run only for load phenology brick
#plot(map1)
```

```
## Testing South Hemisphere data. Raster data from Chile (EVI index), h=2 ##

# Load data
ay.path<-system.file("extdata/HS_aysen",package="npphen")
ayrasters<-list.files(path=ay.path, pattern=glob2rx("aysen*.tif"), full.names=TRUE)
Aysen_rasters<-stack(ayrasters)
ay_dates<-read.csv(system.file("extdata/date_tables/Aysen_dates.csv", package="npphen"))
Aysen_dates <- as.Date(ay_dates$date, format='%d/%m/%Y')

# Making the LSP raster, n bands = 23
# Define the number of cores to be use. In this example we use 1
nc1<-1

PhenMap(s= Aysen_rasters,dates=Aysen_dates,h=2,nGS=23, nCluster=nc1,
outname="phen_aysen.tif", format="GTiff", datatype="FLT4S",rge=c(0,10000))
#map2<-raster("phen_aysen.tif") #run only for load phenology brick
#plot(map2)

## End(Not run)
```

Index