

Package ‘wsyn’

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Title Wavelet Approaches to Studies of Synchrony in Ecology and Other Fields

Description Tools for a wavelet-based approach to analyzing spatial synchrony, principally in ecological data. Some tools will be useful for studying community synchrony. See, for instance, Sheppard et al (2016) <doi:10.1038/NCLIMATE2991>, Sheppard et al (2017) <doi:10.1051/epjnbp/2017000>, Sheppard et al (2019) <doi:10.1371/journal.pcbi.1006744>.

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Author Daniel C. Reuman [aut, cre],
Thomas L. Anderson [aut],
Jonathan A. Walter [aut],
Lei Zhao [aut],
Lawrence W. Sheppard [aut]

Maintainer Daniel C. Reuman <reuman@ku.edu>

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addranks	<i>Adds rank information to a coh or wlmtest object</i>
----------	---

Description

When a coh or wlmtest object is created, the ranks slot is NA. This function fills it in.

Usage

```
addranks(obj)
```

Arguments

obj An object of class coh or wlmtest

Value

addranks returns another coh or wlmtest object with ranks slot now included. If obj\$ranks was not NA, the object is returned as is.

Note

Internal function, no error checking performed

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

See Also

[coh](#), [wlmtest](#), [bandtest](#), [browseVignettes\("wsyn"\)](#)

addwmfs	<i>Adds wavelet mean field information to a clust object</i>
---------	--

Description

When a clust object is created, the wmfs slot is NA. This function fills it in.

Usage

```
addwmfs(obj)
```

Arguments

obj An object of class clust

Details

This function uses the values of `scale.min`, `scale.max.input`, `sigma` and `f0` stored in `obj$methodspecs`. It is possible to create a `clust` object with bad values for these slots. This function throws an error in that case. You can use a correlation-based method for calculating the synchrony matrix and still pass values of `scale.min`, `scale.max.input`, `sigma` and `f0` to `clust` (in fact, this happens by default) - they won't be used by `clust`, but they will be there for later use by `addwmfs` and `addwpmfs`.

Value

`addwmfs` returns another `clust` object with `wmfs` slot now included. If `obj$wmfs` was not `NA`, the object is returned as is.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[clust](#), [addwpmfs](#), [browseVignettes\("wsyn"\)](#)

Examples

```
sig<-matrix(.8,5,5)
diag(sig)<-1
lents<-50
if (requireNamespace("mvtnorm",quietly=TRUE))
{
  dat1<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
  dat2<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
}else
{
  dat1<-t(matrix(rep(rnorm(lents),times=5),lents,5))
  dat2<-t(matrix(rep(rnorm(lents),times=5),lents,5))
}
dat<-rbind(dat1,dat2)
times<-1:lents
dat<-cleandat(dat,times,clev=1)$cdat
coords<-data.frame(Y=rep(0,10),X=1:10)
method<-"coh.sig.fast"
clustobj<-clust(dat,times,coords,method,nsurrog = 100)
res<-addwmfs(clustobj)
```

addwpmfs	<i>Adds wavelet phasor mean field information to a clust object</i>
----------	---

Description

When a `clust` object is created, the `wpmfs` slot is NA. This function fills it in, or adds to it.

Usage

```
addwpmfs(  
  obj,  
  level = 1:length(obj$clusters),  
  sigmethod = "quick",  
  nrand = 1000  
)
```

Arguments

<code>obj</code>	An object of class <code>clust</code>
<code>level</code>	The clustering level(s) to use. 1 corresponds to no clustering. The default is all levels of clustering.
<code>sigmethod</code>	Method for significance testing the <code>wpmf</code> , one of <code>quick</code> , <code>fft</code> , <code>aaft</code> (see details of the <code>wpmf</code> function)
<code>nrand</code>	The number of randomizations to be used for significance testing

Details

This function uses the values of `scale.min`, `scale.max.input`, `sigma` and `f0` stored in `obj$methodspecs`. It is possible to create a `clust` object with bad values for these slots. This function throws an error in that case. You can use a correlation-based method for calculating the synchrony matrix and still pass values of `scale.min`, `scale.max.input`, `sigma` and `f0` to `clust` (in fact, this happens by default) - they won't be used by `clust`, but they will be there for later use by `addwmfs` and `addwpmfs`.

Value

`addwpmfs` returns another `clust` object with `wpmfs` slot now included, or more filled in than it was previously. With values of `sigmethod` other than `"quick"`, this function can be slow, particularly with large `nrand`. So in that case the user may want to set `level` equal only to one clustering level of interest. Unlike `wmf`, old values in `obj$wpmfs` are overwritten.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[clust](#), [addwmfs](#), [browseVignettes\("wsyn"\)](#)

Examples

```

sig<-matrix(.8,5,5)
diag(sig)<-1
lents<-50
if (requireNamespace("mvtnorm",quietly=TRUE))
{
  dat1<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
  dat2<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
}else
{
  dat1<-t(matrix(rep(rnorm(lents),times=5),lents,5))
  dat2<-t(matrix(rep(rnorm(lents),times=5),lents,5))
}
dat<-rbind(dat1,dat2)
times<-1:lents
dat<-cleandat(dat,times,clev=1)$cdat
coords<-data.frame(Y=rep(0,10),X=1:10)
method<-"coh.sig.fast"
clustobj<-clust(dat,times,coords,method,nsurrogs = 100)
res<-addwpmfs(clustobj)

```

bandtest

Aggregate significance across a timescale band

Description

Computes the aggregate significance of coherence (coh) or of a wavelet linear model test object (wlmtest) across a timescale band, accounting for non-independence of timescales. Also gets the average phase across the band, in the case of coherence.

Usage

```

bandtest(object, ...)

## Default S3 method:
bandtest(object, ...)

## S3 method for class 'coh'
bandtest(object, band, ...)

## S3 method for class 'wlmtest'
bandtest(object, band, ...)

```

Arguments

object	An object of class coh or wlmtest, must have a non-NA signif slot
...	Passed from the generic to specific methods. Not currently used.
band	A length-two numeric vector indicating a timescale band

Value

bandtest returns an object of the same class as its first input but with a bandp slot added. Or if there was already a bandp slot, the output has a bandp slot with an additional row. For a coh object, the bandp slot is a data frame with four columns, the first two indicating the timescale band and the third an associated p-value for the test of coherence over that band. The fourth column is the average phase over the band. For a wlmtest object, the result is only the first three of the above columns.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

See Also

[coh](#), [wlm](#), [wlmtest](#), [browseVignettes\("wsyn"\)](#)

Examples

```
#Example for a coh object
times<-(-3:100)
ts1<-sin(2*pi*times/10)
ts2<-5*sin(2*pi*times/3)
artsig_x<-matrix(NA,11,length(times)) #the driver
for (counter in 1:11)
{
  artsig_x[counter,]=ts1+ts2+rnorm(length(times),mean=0,sd=1.5)
}
times<-0:100
artsig_y<-matrix(NA,11,length(times)) #the driven
for (counter1 in 1:11)
{
  for (counter2 in 1:101)
  {
    artsig_y[counter1,counter2]<-mean(artsig_x[counter1,counter2:(counter2+2)])
  }
}
artsig_y<-artsig_y+matrix(rnorm(length(times)*11,mean=0,sd=3),11,length(times))
artsig_x<-artsig_x[,4:104]
artsig_x<-cleandat(artsig_x,times,1)$cdat
artsig_y<-cleandat(artsig_y,times,1)$cdat
cohobj<-coh(dat1=artsig_x,dat2=artsig_y,times=times,norm="powall",sigmethod="fast",nrand=1000,
           f0=0.5,scale.max.input=28)
cohobj<-bandtest(cohobj,c(2,4))

#Example for a wlmtest object - see vignette
```

bctrans

The one-parameter family of Box-Cox transformations

Description

The one-parameter family of Box-Cox transformations

Usage

```
bctrans(y, lambda)
```

Arguments

y	A numeric, positive values assumed
lambda	The Box-Cox parameter

Details

Internal function. No error checking done. It is assumed the entries of y are positive.

Value

bctrans gives $(y^\lambda - 1)/\lambda$ for $\lambda \neq 0$ or $\ln(y)$ for λ equal to 0.

Author(s)

Daniel Reuman, <reuman@ku.edu>

References

Box, GEP and Cox, DR (1964) An analysis of transformations (with discussion). Journal of the Royal Statistical Society B, 26, 211–252.

Venables, WN and Ripley, BD (2002) Modern Applied Statistics with S. Fourth edition. Springer.

See Also

[cleandat](#), `browseVignettes("wsyn")`

cleandat	<i>Clean (spatio)temporal data matrices to make them ready for analyses using the wsyn package</i>
----------	--

Description

A data cleaning function for optimal Box-Cox transformation, detrending, standardizing variance, de-meaning

Usage

```
cleandat(dat, times, clev, lambdas = seq(-10, 10, by = 0.01), mints = NA)
```

Arguments

dat	A locations x time data matrix, or a time series vector (for 1 location)
times	The times of measurement, spacing 1
clev	The level of cleaning to do, 1 through 5. See details.
lambdas	A vector of lambdas to test for optimal Box-Cox transformation, if Box-Cox is performed. Ignored for <code>clev<4</code> . Defaults to <code>seq(-10,10, by=0.01)</code> . See details.
mints	If <code>clev</code> is 4 or 5, then time series are shifted to have this minimum value before Box-Cox transformation. Default NA means use the smallest difference between consecutive, distinct sorted values. NaN means perform no shift.

Details

NAs, Infs, etc. in `dat` trigger an error. If `clev==1`, time series are (individually) de-meaned. If `clev==2`, time series are (individually) linearly detrended and de-meaned. If `clev==3`, time series are (individually) linearly detrended and de-meaned, and variances are standardized to 1. If `clev==4`, an optimal Box-Cox normalization procedure is applied jointly to all time series (so the same Box-Cox transformation is applied to all time series after they are individually shifted depending on the value of `mints`). Transformed time series are then individually linearly detrended, de-meaned, and variances are standardized to 1. If `clev==5`, an optimal Box-Cox normalization procedure is applied to each time series individually (again after individually shifting according to `mints`), and transformed time series are then individually linearly detrended, de-meaned, and variances are standardized to 1. Constant time series and perfect linear trends trigger an error for `clev>=3`. If `clev>=4` and the optimal lambda for one or more time series is a boundary case or if there is more than one optimal lambda, it triggers a warning. A wider range of lambda should be considered in the former case.

Value

`cleandat` returns a list containing the cleaned data, `clev`, and the optimal lambdas from the Box-Cox procedure (NA for `clev<4`, see details).

Author(s)

Jonathan Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>; Lei Zhao, <lei.zhao@cau.edu.cn>

References

Box, GEP and Cox, DR (1964) An analysis of transformations (with discussion). *Journal of the Royal Statistical Society B*, 26, 211–252.

Venables, WN and Ripley, BD (2002) *Modern Applied Statistics with S*. Fourth edition. Springer.

Sheppard, LW, et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. *Nature Climate Change*. DOI: 10.1038/nclimate2881

See Also

[wt](#), [wmf](#), [wpmf](#), [coh](#), [wlm](#), [wlmtest](#), [clust](#), `browseVignettes("wsyn")`

Examples

```
times<-1:100
dat<-rnorm(100)
res1<-cleandat(dat,times,1) #this removes the mean
res2<-cleandat(dat,times,2) #detrends and removes the mean
res3<-cleandat(dat,times,3) #variances also standardized
res4<-cleandat(dat,times,4) #also joint Box-Cox applied
res5<-cleandat(dat,times,5) #1-3, also indiv Box-Cox
```

cluseigen

Community structure detection in networks

Description

Community structure detection in networks based on the leading eigenvector of the community matrix

Usage

```
cluseigen(adj)
```

Arguments

`adj` An adjacency matrix. Should be symmetric with diagonal containing zeros.

Details

The difference between this function and the algorithm described by Newman is that this function can be used on an adjacency matrix with negative elements, which is very common for correlation matrices and other measures of pairwise synchrony of time series.

Value

cluseigen returns a list with one element for each of the splits performed by the clustering algorithm. Each element is a vector with entries corresponding to rows and columns of adj and indicating the module membership of the node, following the split. The last element of the list is the final clustering determined by the algorithm when its halting condition is satisfied. The first element is always a vector of all 1s (corresponding to before any splits are performed).

Author(s)

Lei Zhao, <lei.zhao@cau.edu.cn>; Daniel Reuman, <reuman@ku.edu>

References

Gomez S., Jensen P. & Arenas A. (2009). Analysis of community structure in networks of correlated data. Phys Rev E, 80, 016114.

Newman M.E.J. (2006). Finding community structure in networks using the eigenvectors of matrices. Phys Rev E, 74, 036104.

Newman M.E.J. (2006) Modularity and community structure in networks. PNAS 103, 8577-8582.

See Also

[clust](#), [modularity](#), [browseVignettes\("wsyn"\)](#)

Examples

```
adj<-matrix(0, 10, 10) # create a fake adjacency matrix
adj[lower.tri(adj)]<-runif(10*9/2, -1, 1)
adj<-adj+t(adj)
colnames(adj)<-letters[1:10]
z<-cluseigen(adj)
```

clust

Detection and description of clusters of synchronous locations

Description

Generator function for the clust S3 class, which supports tools for detecting clusters (aka, modules, sub-networks, communities, etc.) of especially synchronous locations.

Usage

```
clust(
  dat,
  times,
  coords,
  method,
```

```

    tsrange = c(0, Inf),
    nsurrogs = 1000,
    scale.min = 2,
    scale.max.input = NULL,
    sigma = 1.05,
    f0 = 1,
    weighted = TRUE,
    sigthresh = 0.95
)

```

Arguments

<code>dat</code>	A locations (rows) x time (columns) matrix of measurements
<code>times</code>	The times at which measurements were made, spacing 1
<code>coords</code>	A data frame containing X,Y coordinates of locations in data, with column names either X and Y or lon and lat or longitude and latitude. The data frame may contain other columns with additional meta-information about the sites.
<code>method</code>	Method for synchrony calculation. See details.
<code>tsrange</code>	A vector containing the min and max of the focal timescale range. Defaults to all timescales that are valid given choices for <code>scale.min</code> , <code>scale.max.input</code> , <code>f0</code> , <code>sigma</code> . Only used for wavelet-based methods.
<code>nsurrogs</code>	Number of surrogates for significance test. Defaults to 1000. Only used for surrogate-based methods.
<code>scale.min</code>	The smallest scale of fluctuation that will be examined. At least 2. Used only for wavelet-based methods.
<code>scale.max.input</code>	The largest scale of fluctuation guaranteed to be examined. Only used for wavelet-based methods.
<code>sigma</code>	The ratio of each time scale examined relative to the next timescale. Should be greater than 1. Only used for wavelet-based methods.
<code>f0</code>	The ratio of the period of fluctuation to the width of the envelope. Only used for wavelet-based methods.
<code>weighted</code>	If TRUE, create a weighted network. If FALSE, create a binary network using statistical significance. Binary networks are only allowed for networks based on significance.
<code>sigthresh</code>	Significance threshold needed, if <code>weighted</code> is false, for a network link to be realized. Typically 0.95, 0.99, or 0.999, etc. Only used if <code>weighted</code> is FALSE.

Details

The following values are valid for `method`: "pearson", "pearson.sig.std", "pearson.sig.fft", "pearson.sig.aaft", "spearman", "spearman.sig.std", "spearman.sig.fft", "spearman.sig.aaft", "kendall", "kendall.sig.std", "kendall.sig.fft", "kendall.sig.aaft", "ReXWT", "ReXWT.sig.fft", "ReXWT.sig.aaft", "ReXWT.sig.fast", "coh", "coh.sig.fft", "coh.sig.aaft", "coh.sig.fast",

"phasecoh", "phasecoh.sig.fft", and "phasecoh.sig.aaft". The first portions of these identifiers correspond to the Pearson, Spearman, and Kendall correlations, the real part of the cross-wavelet transform, the wavelet coherence, and the wavelet phase coherence. The second portions of these identifiers, when present, indicates that significance of the measure specified in the first portion of the identifies is to be used for establishing the synchrony matrix. Otherwise the value itself is used. The third part of the method identifier indicates what type of significance is used.

Significance testing is performed using standard approaches (method flag containing `std`; for correlation coefficients, although these are inappropriate for autocorrelated data), or surrogates generated using the Fourier (method flag containing `fft`) or amplitude adjusted Fourier surrogates (`aaft`). For `coh` and `ReXWT`, the fast testing algorithm of Sheppard et al. (2017) is also implemented (`fast`). That method uses implicit Fourier surrogates. The choice of wavelet coherence (method flag containing `coh`) or the real part of the cross-wavelet transform (method flag containing `ReXWT`) depends mainly on treatment of out-of-phase relationships. The `ReXWT` is more akin to a correlation coefficient in that strong in-phase relationships approach 1 and strong antiphase relationships approach -1. Wavelet coherence allows any phase relationship and ranges from 0 to 1. Power normalization is applied for `coh` and for `ReXWT`. All significance tests are one-tailed. Synchrony matrices for significance-based methods when `weighted` is `TRUE` contain 1 minus the p-values.

Clustering is performed using the the eigenvector-based modularity method of Newman (2006).

Value

`clust` returns an object of class `clust`. Slots are:

<code>dat</code>	The input
<code>times</code>	The input
<code>coords</code>	The input
<code>methodspecs</code>	A list with elements specifying the method used, and methodological parameters that were in the input.
<code>adj</code>	The adjacency matrix that defines the synchrony network
<code>clusters</code>	A list with one element for each successive split of the networks into subcomponents carried out by the clustering algorithm. Each element is a vector of length equal to the number of nodes in the original network, giving cluster membership of the nodes. The first element is a vector of all 1s, corresponding to before the first clustering split was performed.
<code>modres</code>	A list of the same length as <code>clusters</code> , with each element containing the results of calling <code>modularity</code> on the network split to that level.
<code>mns</code>	Mean time series for modules. A list of the same length as <code>clusters</code> .
<code>wmfs</code>	Wavelet mean fields for modules. <code>NA</code> when <code>clust</code> is first called, but <code>addwmfs</code> causes this entry to be added. It is a list. See documentation for the method <code>addwmfs</code> .
<code>wpmfs</code>	Wavelet phasor mean fields for modules. <code>NA</code> when <code>clust</code> is first called, but <code>addwpmfs</code> causes this entry to be added. It is a list. See documentation for the method <code>addwpmfs</code> .

Author(s)

Jonathan Walter, <jaw3es@virginia.edu>; Daniel Reuman, <reuman@ku.edu>; Lei Zhao, <lei.zhao@cau.edu.cn>

References

Walter, J. A., et al. (2017) The geography of spatial synchrony. *Ecology Letters*. doi: 10.1111/ele.12782

Newman M.E.J. (2006). Finding community structure in networks using the eigenvectors of matrices. *Phys Rev E*, 74, 036104.

Newman M.E.J. (2006) Modularity and community structure in networks. *PNAS* 103, 8577-8582.

See Also

[cluseigen](#), [modularity](#), [addwmfs](#), [addwpmfs](#), [clust_methods](#), [synmat](#), [plotmap](#), [browseVignettes\("wsyn"\)](#)

Examples

```
sig<-matrix(.8,5,5)
diag(sig)<-1
lents<-50
if (requireNamespace("mvtnorm",quietly=TRUE))
{
  dat1<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
  dat2<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
}else
{
  dat1<-t(matrix(rep(rnorm(lents),times=5),lents,5))
  dat2<-t(matrix(rep(rnorm(lents),times=5),lents,5))
}
dat<-rbind(dat1,dat2)
times<-1:lents
dat<-cleandat(dat,times,clev=1)$cdat
coords<-data.frame(Y=rep(0,10),X=1:10)
method<-"coh.sig.fast"
res<-clust(dat,times,coords,method,nsurrogs = 50)
#nsurrogs should be much higher for a real application
```

clust_methods

Basic methods for the clust class

Description

Set, get, summary, and print methods for the clust class.

Usage

```
## S3 method for class 'clust'  
summary(object, ...)  
  
## S3 method for class 'clust'  
print(x, ...)  
  
## S3 method for class 'clust'  
set_times(obj, newval)  
  
## S3 method for class 'clust'  
set_adj(obj, newval)  
  
## S3 method for class 'clust'  
set_clusters(obj, newval)  
  
## S3 method for class 'clust'  
set_modres(obj, newval)  
  
## S3 method for class 'clust'  
set_mns(obj, newval)  
  
## S3 method for class 'clust'  
set_dat(obj, newval)  
  
## S3 method for class 'clust'  
set_coords(obj, newval)  
  
## S3 method for class 'clust'  
set_methodspecs(obj, newval)  
  
## S3 method for class 'clust'  
set_wmfs(obj, newval)  
  
## S3 method for class 'clust'  
set_wpmfs(obj, newval)  
  
## S3 method for class 'clust'  
get_times(obj)  
  
## S3 method for class 'clust'  
get_adj(obj)  
  
## S3 method for class 'clust'  
get_clusters(obj)  
  
## S3 method for class 'clust'  
get_modres(obj)
```

```

## S3 method for class 'clust'
get_mns(obj)

## S3 method for class 'clust'
get_dat(obj)

## S3 method for class 'clust'
get_coords(obj)

## S3 method for class 'clust'
get_methodspec(obj)

## S3 method for class 'clust'
get_wmfs(obj)

## S3 method for class 'clust'
get_wpmfs(obj)

```

Arguments

object, x, obj	An object of class <code>clust</code>
...	Not currently used. Included for argument consistency with existing generics.
newval	A new value, for the <code>set_*</code> methods

Value

`summary.clust` produces a summary of a `clust` object. A `print.clust` method is also available. For `clust` objects, `set_*` and `get_*` methods are available for all slots (see the documentation for `clust` for a list). The `set_*` methods just throw an error, to prevent breaking the consistency between the slots of a `clust` object.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[clust](#)

Examples

```

sig<-matrix(.8,5,5)
diag(sig)<-1
lents<-50
if (requireNamespace("mvtnorm",quietly=TRUE))
{
  dat1<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
  dat2<-t(mvtnorm::rmvnorm(lents,mean=rep(0,5),sigma=sig))
}else

```



```

{
  dat1<-t(matrix(rep(rnorm(lents),times=5),lents,5))
  dat2<-t(matrix(rep(rnorm(lents),times=5),lents,5))
}
dat<-rbind(dat1,dat2)
times<-1:lents
dat<-cleandat(dat,times,clev=1)$cdat
coords<-data.frame(Y=rep(0,10),X=1:10)
method<-"coh.sig.fast"
h<-clust(dat,times,coords,method,nsurrogs = 50)
#nsurrogs should be much higher for a real application
get_times(h)
summary(h)
print(h)

```

coh

Coherence

Description

Wavelet coherence and wavelet phase coherence, spatial or for single time series. Also the generator function for the coh class, which inherits from the list class.

Usage

```

coh(
  dat1,
  dat2,
  times,
  norm,
  sigmethod = "none",
  nrand = 1000,
  scale.min = 2,
  scale.max.input = NULL,
  sigma = 1.05,
  f0 = 1
)

```

Arguments

dat1	A locations (rows) x time (columns) matrix (for spatial coherence), or a single time series
dat2	Same format as dat1, same locations and times
times	The times at which measurements were made, spacing 1
norm	The normalization of wavelet transforms to use. Controls the version of the coherence that is performed. One of "none", "phase", "powall", "powind". See details.

sigmethod	The method for significance testing. One of "none", "fftsurrog1", "fftsurrog2", "fftsurrog12", "aftsurrog1", "aftsurrog2", "aftsurrog12", "fast". See details.
nrand	Number of surrogate randomizations to use for significance testing.
scale.min	The smallest scale of fluctuation that will be examined. At least 2.
scale.max.input	The largest scale of fluctuation guaranteed to be examined
sigma	The ratio of each time scale examined relative to the next timescale. Should be greater than 1.
f0	The ratio of the period of fluctuation to the width of the envelope

Details

If the dimensions of `dat1` and `dat2` are N by T (N is 1 for vector `dat1` and `dat2`), and if the wavelet transform of the n th row of `dati` is denoted $W_{i,n,\sigma}(t)$, then the coherence is the average, over all locations n and times t for which wavelet transforms are available, of the quantity $w_{1,n,\sigma}(t)w_{2,n,\sigma}(t)^*$, where the $*$ represents complex conjugation and $w_{i,n,\sigma}(t)$ is a normalization of the wavelet transform. The normalization used depends on `norm`. If `norm` is "none" then raw wavelet transforms are used. If `norm` is "phase" then $w_{i,n,\sigma}(t) = W_{i,n,\sigma}(t)/|W_{i,n,\sigma}(t)|$, which gives the wavelet phase coherence, or the spatial wavelet phase coherence if $N > 1$. If `norm` is "powall" then the normalization is that described in the "Wavelet mean field" section of the Methods of Sheppard et al. (2016), giving the version of the coherence that was there called simply the wavelet coherence, or the spatial wavelet coherence if $N > 1$. If `norm` is "powind", then $w_{i,n,\sigma}(t)$ is obtained by dividing $W_{i,n,\sigma}(t)$ by the square root of the average of $W_{i,n,\sigma}(t)W_{i,n,\sigma}(t)^*$ over the times for which it is defined; this is done separately for each i and n .

The slot `signif` is NA if `sigmethod` is "none". Otherwise, and if `sigmethod` is not "fast", then `signif$coher` is the same as `coher`, and `signif$scoher` is a matrix of dimensions `nrand` by `length(coher)` with rows with magnitudes equal to coherences of surrogate datasets, computed using the normalization specified by `norm`. The type of surrogate used (Fourier surrogates or amplitude adjusted Fourier surrogates, see `surrog`), as well as which of the datasets surrogates are computed on (`dat1`, `dat2`, or both) is determined by `sigmethod`. The first part of the value of `sigmethod` specifies the type of surrogate used, and the numbers in the second part (1, 2, or 12) specify whether surrogates are applied to `dat1`, `dat2`, or both, respectively. Synchrony-preserving surrogates are used. A variety of statements of significance (or lack thereof) can be made by comparing `signif$coher` with `signif$scoher` (see the `plotmag`, `plotrank`, and `bandtest` methods for the `coh` class). If `sigmethod` is "fast", the fast algorithm of Sheppard et al. (2017) is used. In that case `signif$coher` can be compared to `signif$scoher` to make significance statements about the coherence in exactly the same way, but `signif$coher` will no longer precisely equal `coher`, and `coher` should not be compared directly to `signif$scoher`. Statements about significance of the coherence should be made using `signif$coher` and `signif$scoher`, whereas `coher` should be used whenever the actual value of the coherence is needed. No fast algorithm exists for `norm` equal to "phase" (the phase coherence; Sheppard et al, 2017), so if `norm` is "phase" and `sigmethod` is "fast", the function throws an error.

The slots `ranks` and `bandp` are empty on an initial call to `coh`. They are made to compute and hold aggregate significance results over any timescale band of choice. These are filled in when needed by other methods, see `plotrank` and `bandtest`.

Regardless of what the variables represent, the normalized transform of `dat1` is multiplied by the conjugate of the normalized transform of `dat2`. Thus, a positive phase of the coherence indicates `dat1` would be leading `dat2`.

Value

`coh` returns an object of class `coh`. Slots are:

<code>dat1, dat2</code>	The input data
<code>times</code>	The times associated with the data
<code>sigmethod</code>	The method for significance testing, as inputted.
<code>norm</code>	The normalization of the wavelet transforms that will be used in computing the coherence. Different values result in different versions of the coherence. One of "none", "phase", "powall", "powind". See details.
<code>wtopt</code>	The inputted wavelet transform options <code>scale.min</code> , <code>scale.max.input</code> , <code>sigma</code> , <code>f0</code> in a list
<code>timescales</code>	The timescales associated with the coherence
<code>coher</code>	The complex magnitude of this quantity is the coherence, calculated in the usual way (which depends on <code>norm</code> , see details), and with scalloping of the transforms.
<code>signif</code>	A list with information from the significance testing. Elements are <code>coher</code> and <code>scoher</code> . See details.
<code>ranks</code>	A list with ranking information for <code>signif</code> . NA until <code>plotrank</code> is called, see documentation for <code>plotrank</code> .
<code>bandp</code>	A data frame containing results of computing significances of the coherence across timescale bands. Empty on an initial call to <code>coh</code> , filled in by the function <code>bandtest</code> . See details.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. *Nature Climate Change*. DOI: 10.1038/nclimate2881

Sheppard, L.W., et al. (2017) Rapid surrogate testing of wavelet coherences. *European Physical Journal, Nonlinear and Biomedical Physics*, 5, 1. DOI: 10.1051/epjnbp/2017000

See Also

[cleandat](#), [coh_methods](#), [bandtest](#), [plotmag](#), [plotphase](#), [plotrank](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-1:100
dat1<-matrix(rnorm(1000),10,100)
dat2<-matrix(rnorm(1000),10,100)
dat1<-cleandat(dat1,times,1)$cdat
dat2<-cleandat(dat2,times,1)$cdat
norm<-"powall"
sigmethod<-"fast"
nrand<-10
res<-coh(dat1,dat2,times,norm,sigmethod,nrand)
#for real applications, use a much bigger nrand
```

coh_methods

Basic methods for the coh class

Description

Set, get, summary, and print methods for the coh class.

Usage

```
## S3 method for class 'coh'
summary(object, ...)

## S3 method for class 'coh'
print(x, ...)

## S3 method for class 'coh'
set_times(obj, newval)

## S3 method for class 'coh'
set_timescales(obj, newval)

## S3 method for class 'coh'
set_coher(obj, newval)

## S3 method for class 'coh'
set_dat1(obj, newval)

## S3 method for class 'coh'
set_dat2(obj, newval)

## S3 method for class 'coh'
set_wtopt(obj, newval)

## S3 method for class 'coh'
```

```
set_norm(obj, newval)

## S3 method for class 'coh'
set_sigmethod(obj, newval)

## S3 method for class 'coh'
set_signif(obj, newval)

## S3 method for class 'coh'
set_ranks(obj, newval)

## S3 method for class 'coh'
set_bandp(obj, newval)

## S3 method for class 'coh'
get_times(obj)

## S3 method for class 'coh'
get_timescales(obj)

## S3 method for class 'coh'
get_coher(obj)

## S3 method for class 'coh'
get_dat1(obj)

## S3 method for class 'coh'
get_dat2(obj)

## S3 method for class 'coh'
get_wtopt(obj)

## S3 method for class 'coh'
get_norm(obj)

## S3 method for class 'coh'
get_sigmethod(obj)

## S3 method for class 'coh'
get_signif(obj)

## S3 method for class 'coh'
get_ranks(obj)

## S3 method for class 'coh'
get_bandp(obj)
```

Arguments

object, x, obj An object of class coh
 ... Not currently used. Included for argument consistency with existing generics.
 newval A new value, for the set_* methods

Value

summary.coh produces a summary of a coh object. A print.coh method is also available. For coh objects, set_* and get_* methods are available for all slots (see the documentation for coh for a list). The set_* methods just throw an error, to prevent breaking the consistency between the slots of a coh object.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[coh](#)

Examples

```
times<-1:100
dat1<-matrix(rnorm(1000),10,100)
dat2<-matrix(rnorm(1000),10,100)
dat1<-cleandat(dat1,times,1)$cdat
dat2<-cleandat(dat2,times,1)$cdat
norm<-"powall"
sigmethod<-"fast"
nrand<-10
h<-coh(dat1,dat2,times,norm,sigmethod,nrand)
get_times(h)
summary(h)
print(h)
```

errcheck_std
Error check for appropriate spatio-temporal data

Description

Error checking whether a times vector and a matrix with each row a time series make a legitimate spatio-temporal data set for wavelet analysis

Usage

```
errcheck_std(times, dat, callfunc)
```

Arguments

times the times of measurement, spacing 1
dat each row is a time series - must have at least two rows
callfunc the function calling this one, for error tracking

Value

errcheck_stddev returns nothing but throws an error if inputs not appropriate

Author(s)

Daniel Reuman, <reuman@ku.edu>

errcheck_times *Error check times*

Description

Error check whether a vector can represent times at which data suitable for wavelet transforms were measured

Usage

```
errcheck_times(times, callfunc)
```

Arguments

times Tests whether this is a numeric vector with unit-spaced increasing values
callfunc Function calling this one, for better error messaging

Value

errcheck_times returns nothing but throws an error if the conditions are not met

Author(s)

Daniel Reuman, <reuman@ku.edu>

errcheck_tsdats *Error check for appropriate temporal data*

Description

Error checking whether a times vector and t.series vector make a legitimate time series for wavelet analysis

Usage

```
errcheck_tsdats(times, t.series, callfunc)
```

Arguments

times	times of measurement, spacing 1
t.series	the measurements
callfunc	the function from which this one was called, for error tracking

Value

errcheck_tsdats returns nothing but throws an error if inputs not appropriate

Author(s)

Daniel Reuman, <reuman@ku.edu>

errcheck_tts *Error check whether inputs are suitable for a tts object*

Description

Error check whether inputs are suitable for a tts object

Usage

```
errcheck_tts(times, timescales, values, callfunc)
```

Arguments

times	times of measurement, spacing 1
timescales	timescales of analysis
values	a times by timescales matrix
callfunc	the function from which this one was called, for error tracking

Value

errcheck_tts returns nothing but throws an error if inputs not appropriate

Author(s)

Daniel Reuman, <reuman@ku.edu>

errcheck_wavparam *Error check wavelet transform parameters*

Description

Error check the parameters `scale.min`, `scale.max.input`, `sigma`, `f0`

Usage

```
errcheck_wavparam(scale.min, scale.max.input, sigma, f0, times, callfunc)
```

Arguments

<code>scale.min</code>	The smallest scale of fluctuation that will be examined. At least 2.
<code>scale.max.input</code>	The largest scale of fluctuation that is guaranteed to be examined
<code>sigma</code>	The ratio of each time scale examined relative to the next timescale. Should be greater than 1.
<code>f0</code>	The ratio of the period of fluctuation to the width of the envelope. Defaults to 1.
<code>times</code>	The times data were measured at, spacing 1
<code>callfunc</code>	Function calling this one, for better error messaging

Value

errcheck_wavparam returns nothing but throws an error if the conditions are not met

Author(s)

Daniel Reuman, <reuman@ku.edu>

fastcohtest	<i>Fast algorithm for significance testing coherence using Fourier surrogates</i>
-------------	---

Description

This is the algorithm of Sheppard et al. (2017) (see references).

Usage

```
fastcohtest(
  dat1,
  dat2,
  scale.min,
  scale.max.input,
  sigma,
  f0,
  nrand,
  randnums,
  randbits,
  norm
)
```

Arguments

dat1	A locations (rows) x time (columns) matrix (for spatial coherence), or a single time series
dat2	Same format as dat1, same locations and times
scale.min	The smallest scale of fluctuation that will be examined. At least 2.
scale.max.input	The largest scale of fluctuation guaranteed to be examined
sigma	The ratio of each time scale examined relative to the next timescale. Should be greater than 1.
f0	The ratio of the period of fluctuation to the width of the envelope
nrand	Number of surrogate randomizations to use for significance testing
randnums	A bunch of independent random numbers uniformly distributed on (0,1). There must be nrand*floor((dim(dat1)[2]-1)/2) of these.
randbits	A bunch of random bits (0 or 1). There must be nrand of these if time series are of odd length and 2*nrand if even length. You may pass more than this, so, in particular, you may pass 2*nrand for even or odd length.
norm	The normalization of wavelet transforms to use. Controls the version of the coherence that is performed. One of "none", "powall", "powind". See details in the documentation of coh.

Value

fastcohtest returns a list with these elements:

timescales	The timescales used
coher	The magnitude of this is the fast-algorithm version of the coherence between the two datasets, for comparison with scoher
scoher	A matrix with nrand rows, the magnitude of each one is the fast-algorithm version of the coherence for a surrogate

Note

Internal function, minimal error checking.

Author(s)

Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2017) Rapid surrogate testing of wavelet coherences. European Physical Journal, Nonlinear and Biomedical Physics, 5, 1. DOI: 10.1051/epjnbp/2017000

fftsurrog *Surrogate time series using Fourier surrogates*

Description

Creates surrogate time series using Fourier surrogates

Usage

```
fftsurrog(dat, nsurrogs, syncpres)
```

Arguments

dat	A locations x time matrix of observations
nsurrogs	The number of surrogates to produce
syncpres	Logical. TRUE for "synchrony preserving" surrogates (same phase randomizations used for all time series). FALSE leads to independent phase randomizations for all time series.

Value

fftsurrog returns a list of nsurrogs surrogate datasets

Note

For internal use, no error checking

Author(s)

Jonathan Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, LW, et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

Schreiber, T and Schmitz, A (2000) Surrogate time series. Physica D 142, 346-382.

Prichard, D and Theiler, J (1994) Generating surrogate data for time series with several simultaneously measured variables. Physical Review Letters 73, 951-954.

is.connected

Tests if a graph is connected

Description

Tests if a graph represented by an adjacency matrix is connected.

Usage

```
is.connected(adj)
```

Arguments

adj An adjacency matrix. Must be a numeric matrix with non-negative entries.

Details

Idea by Ed Scheinerman, circa 2006. Source: <http://www.ams.jhu.edu/~ers/matgraph/>; routine: matgraph@graph.isconnected.m

Value

is.connected returns TRUE or FALSE depending on whether the graph represented in adj is a connected graph.

Author(s)

Lei Zhao, <lei.zhao@cau.edu.cn>

See Also

[cluseigen](#), [clust](#), [browseVignettes\("wsyn"\)](#)

Examples

```
g1<-matrix(c(0,0,0,1,1,0,0,0,0,1,0,0,0,0,1,0),4,4)
is.connected(g1)
g2<-matrix(c(0,1,0,0,1,0,0,0,0,0,0,1,0,0,1,0),4,4)
is.connected(g2)
```

makeunweighted	<i>For converting certain synchrony matrices to unweighted versions</i>
----------------	---

Description

Convenience function for converting certain synchrony matrices to unweighted versions

Usage

```
makeunweighted(mat, sigthresh)
```

Arguments

mat	A synchrony matrix based on significance testing
sigthresh	Significance threshold to use

Value

makeunweighted converts to an unweighted version of the input. Entries of mat less than sigthresh become a 1, other entries become a 0. The diagonal is NA.

Note

Internal function, no error checking

Author(s)

Lei Zhao, <lei.zhao@cau.edu.cn>, Daniel Reuman <reuman@ku.edu>

mnphase	<i>Mean phase of coherence</i>
---------	--------------------------------

Description

Gets the mean phase of a bunch of complex numbers

Usage

```
mnphase(nums)
```

Arguments

nums	A vector of complex numbers
------	-----------------------------

Value

mnphase returns the mean phase

Note

Internal funcion, no error catching

Author(s)

Daniel Reuman, <reuman@ku.edu>

modularity	<i>Modularity of a community structure of a graph</i>
------------	---

Description

Computes the modularity of partitioning of a graph into sub-graphs. Similar to the modularity function in the igraph package, but allows negative edge weights.

Usage

```
modularity(adj, membership, decomp = FALSE)
```

Arguments

adj	An adjacency matrix, which should be symmetric with zeros on the diagonal.
membership	Vector of length equal to the number of graph nodes (columns/rows of adj) indicating the cluster/sub-graph each nodes belongs to.
decomp	Logical. If TRUE, calculate the decomposition of modularity by modules and nodes. Default FALSE.

Details

The difference between this function and the function `modularity` in the package `igraph` is that this function can be used with an adjacency matrix with negative elements. This is a common case for matrices arising from a correlation matrix or another synchrony matrix. If the matrix is non-negative, the result of this function should be exactly the same as the result from `modularity` in the `igraph` package.

Value

`modularity` returns a list containing the following:

<code>totQ</code>	The total modularity. This is the only output if <code>decomp=FALSE</code>
<code>modQ</code>	The contribution of each module to the total modularity
<code>nodeQ</code>	The contribution of each node to the total modularity

Note

Adapted from code developed by Robert J. Fletcher, Jr.

Author(s)

Jonathan Walter, <jonathan.walter@ku.edu>; Lei Zhao, <lei.zhao@cau.edu.cn>; Daniel Reuman, <reuman@ku.edu>

References

Fletcher Jr., R.J., et al. (2013) Network modularity reveals critical scales for connectivity in ecology and evolution. *Nature Communications*. doi: 10.1038/ncomms3572.

Gomez S., Jensen P. & Arenas A. (2009). Analysis of community structure in networks of correlated data. *Phys Rev E*, 80, 016114.

Newman M.E. (2006). Finding community structure in networks using the eigenvectors of matrices. *Phys Rev E*, 74, 036104.

See Also

[clust](#), [cluseigen](#), [browseVignettes\("wsyn"\)](#)

Examples

```
adj<-matrix(0, 10, 10) # create a fake adjacency matrix
adj[lower.tri(adj)]<-runif(10*9/2, -1, 1)
adj<-adj+t(adj)
colnames(adj)<-letters[1:10]
m<-cluseigen(adj)
z<-modularity(adj, m[[length(m)]], decomp=TRUE)
```

normforcoh	<i>Normalization for the coh function</i>
------------	---

Description

A convenience function for performing the normalization step for the coh function.

Usage

```
normforcoh(W, norm)
```

Arguments

W	An array of wavelet transforms, locations by times by timescales
norm	The normalization of wavelet transforms to use. Controls the version of the coherence that is performed. One of "none", "phase", "powall", "powind". See details section of the documentation for coh.

Value

normforcoh returns an array the same dimensions as W of normalized transforms

Note

Internal function, no error checking

Author(s)

Daniel Reuman, <reuman@ku.edu>

plotmag	<i>For plotting the magnitude of values in tts, coh and wlmtest objects</i>
---------	---

Description

For plotting the magnitude of values in tts objects (and derived classes) against time and timescale, and coh and wlmtest objects against timescale

Usage

```
plotmag(object, ...)  
  
## S3 method for class 'tts'  
plotmag(  
  object,  
  zlims = NULL,  
  neat = TRUE,  
  colorfill = NULL,  
  colorbar = TRUE,  
  title = NULL,  
  filename = NA,  
  ...  
)  
  
## S3 method for class 'wt'  
plotmag(  
  object,  
  zlims = NULL,  
  neat = TRUE,  
  colorfill = NULL,  
  colorbar = TRUE,  
  title = NULL,  
  filename = NA,  
  ...  
)  
  
## S3 method for class 'wmf'  
plotmag(  
  object,  
  zlims = NULL,  
  neat = TRUE,  
  colorfill = NULL,  
  colorbar = TRUE,  
  title = NULL,  
  filename = NA,  
  ...  
)  
  
## S3 method for class 'wpmf'  
plotmag(  
  object,  
  zlims = NULL,  
  neat = TRUE,  
  colorfill = NULL,  
  sigthresh = 0.95,  
  colorbar = TRUE,  
  title = NULL,
```

```

    filename = NA,
    ...
)

## S3 method for class 'coh'
plotmag(
  object,
  sigthresh = c(0.95, 0.99),
  bandprows = "all",
  filename = NA,
  ...
)

## S3 method for class 'wlmtest'
plotmag(
  object,
  sigthresh = c(0.95, 0.99),
  bandprows = "all",
  filename = NA,
  ...
)

## Default S3 method:
plotmag(object, ...)

```

Arguments

object	An object of class <code>tts</code> or some class that inherits from <code>tts</code> or of class <code>coh</code> or <code>wlmtest</code>
...	Additional graphics parameters passed to <code>image</code> (graphics package) if <code>colorbar==FALSE</code> , or to <code>image.plot</code> (fields package) if <code>colorbar==TRUE</code> (for <code>tts</code> objects)
zlims	z axis limits. If specified, must encompass the range of <code>Mod(get_values(object))</code> . Default <code>NULL</code> uses this range.
neat	Logical. Should timescales with no values be trimmed?
colorfill	Color spectrum to use, set through <code>colorRampPalette</code> . Default value <code>NULL</code> produces jet colors from Matlab.
colorbar	Logical. Should a colorbar legend be plotted?
title	Title for the top of the plot.
filename	Filename (without extension), for saving as pdf. Default value <code>NA</code> saves no file and uses the default graphics device.
sigthresh	Significance threshold(s). Numeric vector with values between 0 and 1. Typically 0.95, 0.99, 0.999, etc. For <code>wpmf</code> objects, contours are plotted at these values; for <code>coh</code> and <code>wlmtest</code> objects the thresholds are plotted on coherence plots.
bandprows	The rows of <code>object\$bandp</code> for which to display results in <code>coh</code> plots

Details

For `coh` (respectively, `wlmtest`) objects, the modulus of `object$coher` (respectively, `object$wlmobj$coher`) is plotted using a solid red line, and the modulus of `object$signif$coher` is plotted using a dashed red line. The two coherences agree except for `sigmethod="fast"`, for which they are close. The dashed line is what should be compared to the distribution of surrogate coherences (black lines, which only appear for `coh` objects if `signif` is not NA). Horizontal axis ticks are labeled as timescales, but are spaced on the axis as $\log(1/\text{timescale})$, i.e., log frequencies.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. *Nature Climate Change*. DOI: 10.1038/nclimate2881

Sheppard, LW et al. (2019) Synchrony is more than its top-down and climatic parts: interacting Moran effects on phytoplankton in British seas. *Plos Computational Biology* 15, e1006744. doi: 10.1371/journal.pcbi.1006744

See Also

[tts](#), [wt](#), [wmf](#), [wpmf](#), [coh](#), [wlmtest](#), [plotphase](#), [bandtest](#), [plotrank](#), [browseVignettes\("wsyn"\)](#)

Examples

```
#For a wt object
time1<-1:100
time2<-101:200
ts1p1<-sin(2*pi*time1/15)
ts1p2<-0*time1
ts2p1<-0*time2
ts2p2<-sin(2*pi*time2/8)
ts1<-ts1p1+ts1p2
ts2<-ts2p1+ts2p2
ts<-c(ts1,ts2)
ra<-rnorm(200,mean=0,sd=0.5)
t.series<-ts+ra
t.series<-t.series-mean(t.series)
times<-c(time1,time2)
res<-wt(t.series, times)
plotmag(res)

#For a wmf object
x1<-0:50
x2<-51:100
x<-c(x1,x2)
ts1<-c(sin(2*pi*x1/10),sin(2*pi*x2/5))+1.1
dat<-matrix(NA,11,length(x))
```

```

for (counter in 1:dim(dat)[1])
{
  ts2<-3*sin(2*pi*x/3+2*pi*runif(1))+3.1
  ts3<-rnorm(length(x),0,1.5)
  dat[counter,]<-ts1+ts2+ts3
  dat[counter,]<-dat[counter,]-mean(dat[counter,])
}
times<-x
res<-wmf(dat,times)
plotmag(res)

#similar calls for wpmf, coh, wlm, wlmtest objects
#see documentation

```

plotmap

Map clusters from a clust object

Description

Produces a map of the locations of sampling for a `clust` object, with colors indicating module (cluster) identity. The sizes of nodes (locations) are scaled according to the strength of membership in its module.

Usage

```

plotmap(
  inclust,
  spltlvl = length(inclust$clusters),
  nodesize = c(1, 3),
  filename = NA
)

```

Arguments

<code>inclust</code>	A <code>clust</code> object, as created with <code>wsyn::clust</code>
<code>spltlvl</code>	The split level in the clustering to use. This is the index of <code>inclust\$clusters</code> . Default the final split.
<code>nodesize</code>	A length = 2 vector giving the minimum and maximum node size for plotting. Defaults to <code>c(1,3)</code> .
<code>filename</code>	a filename, possibly including path info, but without a file extension. If present, exports the plot as a <code>.pdf</code> using the specified filename. Default <code>NA</code> uses the default plotting device.

Value

`plotmap` produces a map.

Author(s)

Jonathan Walter, <jaw3es@virginia.edu>

References

Walter, J. A., et al. (2017) The geography of spatial synchrony. Ecology Letters. doi: 10.1111/ele.12782

See Also

[clust](#), [browseVignettes\("wsyn"\)](#)

Examples

```
Tmax<-500
tim<-1:Tmax
ts1<-sin(2*pi*tim/5)
ts1s<-sin(2*pi*tim/5+pi/2)
ts2<-sin(2*pi*tim/12)
ts2s<-sin(2*pi*tim/12+pi/2)
gp1A<-1:2
gp1B<-3:4
gp2A<-5:6
gp2B<-7:8
d<-matrix(NA,Tmax,8)
d[,c(gp1A,gp1B)]<-ts1
d[,c(gp2A,gp2B)]<-ts1s
d[,c(gp1A,gp2A)]<-d[,c(gp1A,gp2A)]+matrix(ts2,Tmax,4)
d[,c(gp1B,gp2B)]<-d[,c(gp1B,gp2B)]+matrix(ts2s,Tmax,4)
d<-d+matrix(rnorm(Tmax*8,0,2),Tmax,8)
d<-t(d)
d<-cleandat(d,1:Tmax,1)$cdat
coords<-data.frame(X=c(rep(1,4),rep(2,4)),Y=rep(c(1:2,4:5),times=2))
c15<-clust(dat=d,times=1:Tmax,coords=coords,method="ReXWT",tsrange=c(4,6))
plotmap(c15)
c112<-clust(dat=d,times=1:Tmax,coords=coords,method="ReXWT",tsrange=c(11,13))
plotmap(c112)
```

plotphase

For plotting the phases of values in tts and coh objects

Description

For plotting the phases of values in `tts` objects (and derived classes) against time and timescale, and `coh` objects against timescale

Usage

```

plotphase(object, ...)

## S3 method for class 'tts'
plotphase(object, filename = NA, ...)

## S3 method for class 'wt'
plotphase(object, filename = NA, ...)

## S3 method for class 'wmf'
plotphase(object, filename = NA, ...)

## S3 method for class 'wpmf'
plotphase(object, filename = NA, ...)

## S3 method for class 'coh'
plotphase(object, bandprows = "all", filename = NA, ...)

## Default S3 method:
plotphase(object, ...)

```

Arguments

object	A coh object.
...	Passed from the generic to specific methods. The plotphase.tss method passes it to fields::image.plot.
filename	Filename (without extension), for saving as pdf. Default value NA saves no file and uses the default graphics device.
bandprows	The rows of object\$bandp for which to display p-value results in the plot

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

See Also

[tts](#), [wt](#), [wmf](#), [wpmf](#), [coh](#), [plotmag](#), [plotrank](#), [browseVignettes\("wsyn"\)](#)

Examples

```

#For a tts object
times<-1:100

```

```

timescales<-1:100
cplx<-complex(modulus=1,argument=seq(from=-pi,to=pi,length.out=100))
values1<-matrix(cplx,length(times),length(timescales))
tts1<-tts(times,timescales,values1)
plotphase(tts1)

#For a coh object
times<-(-3:100)
ts1<-sin(2*pi*times/10)
ts2<-5*sin(2*pi*times/3)
artsig_x<-matrix(NA,11,length(times)) #the driver
for (counter in 1:11)
{
  artsig_x[counter,]=ts1+ts2+rnorm(length(times),mean=0,sd=1.5)
}
times<-0:100
artsig_y<-matrix(NA,11,length(times)) #the driven
for (counter1 in 1:11)
{
  for (counter2 in 1:101)
  {
    artsig_y[counter1,counter2]<-mean(artsig_x[counter1,counter2:(counter2+2)])
  }
}
artsig_y<-artsig_y+matrix(rnorm(length(times)*11,mean=0,sd=3),11,length(times))
artsig_x<-artsig_x[,4:104]
artsig_x<-cleandat(artsig_x,times,1)$dat
artsig_y<-cleandat(artsig_y,times,1)$dat
res<-coh(dat1=artsig_x,dat2=artsig_y,times=times,norm="powall",sigmethod="fast",nrand=50,
         f0=0.5,scale.max.input=28)
res<-bandtest(res,c(2,4))
res<-bandtest(res,c(4,30))
res<-bandtest(res,c(8,12))
plotphase(res)

```

plotrank

Plots ranks slot for coh and wlmtest objects

Description

Plots the ranks slot for coh and wlmtest objects to help identify statistical significance of coherence

Usage

```
plotrank(object, ...)
```

```
## S3 method for class 'coh'
```

```
plotrank(object, sigthresh = 0.95, bandprows = "all", filename = NA, ...)
```

```
## S3 method for class 'wlmtest'
plotrank(object, sigthresh = 0.95, bandprows = "all", filename = NA, ...)

## Default S3 method:
plotrank(object, ...)
```

Arguments

object	A coh or wlmtest object. Must have a non-NA signif slot.
...	Passed from the generic to specific methods. Not currently used.
sigthresh	Significance threshold(s). Numeric vector with values between 0 and 1. Typically 0.95, 0.99, 0.999, etc. The threshold(s) are plotted on the rank plot as dashed horizontal line(s).
bandprows	The rows of object\$bandp for which to display p-value results in the plot
filename	Filename (without extension), for saving as pdf. Default value NA saves no file and uses the default graphics device.

Details

The plot shows the modulus of object\$rank\$coher versus $\log(1/\text{object}\$timescales)$. Horizontal axis ticks are labeled as timescales, but are spaced on the axis as $\log(1/\text{timescale})$, i.e., log frequencies. p-values from object\$bandp are displayed above the rank plot.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

Sheppard, LW et al. (2019) Synchrony is more than its top-down and climatic parts: interacting Moran effects on phytoplankton in British seas. Plos Computational Biology 15, e1006744. doi: 10.1371/journal.pcbi.1006744

See Also

[coh](#), [wlmtest](#), [bandtest](#), [plotphase](#), [plotmag](#), [browseVignettes\("wsyn"\)](#)

Examples

```
#For a coh object
times<-(-3:100)
ts1<-sin(2*pi*times/10)
ts2<-5*sin(2*pi*times/3)
artsig_x<-matrix(NA,11,length(times)) #the driver
for (counter in 1:11)
{
```



```

  artsig_x[counter,]=ts1+ts2+rnorm(length(times),mean=0,sd=1.5)
}
times<-0:100
artsig_y<-matrix(NA,11,length(times)) #the driven
for (counter1 in 1:11)
{
  for (counter2 in 1:101)
  {
    artsig_y[counter1,counter2]<-mean(artsig_x[counter1,counter2:(counter2+2)])
  }
}
artsig_y<-artsig_y+matrix(rnorm(length(times)*11,mean=0,sd=3),11,length(times))
artsig_x<-artsig_x[,4:104]
artsig_x<-cleandat(artsig_x,times,1)$cdat
artsig_y<-cleandat(artsig_y,times,1)$cdat
res<-coh(dat1=artsig_x,dat2=artsig_y,times=times,norm="powall",sigmethod="fast",
nrand=100,f0=0.5,scale.max.input=28)
#use larger nrand for a real application
res<-bandtest(res,c(2,4))
res<-bandtest(res,c(8,12))
plotrank(res)

#For a wlmtest object, see vignette

```

power

Power of a tts object

Description

Returns the power of a tts object, i.e., the mean over time of the squared magnitude (which is a function of timescale)

Usage

```

power(object)

## S3 method for class 'tts'
power(object)

```

Arguments

object A tts object

Value

power returns a data frame with columns timescales and power

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[tts](#), [wt](#), [wmf](#), [wpmf](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-1:10
timescales<-1:10
values<-matrix(rep(complex(modulus=1,argument=2*pi*c(0:9)/10),times=10),10,10)
ttsobj<-tts(times,timescales,values)
res<-power(ttsobj)
```

predsync

Predicted synchrony of a wavelet linear model

Description

Predicted synchrony of a wlm object. This is described in the first paragraph of Appendix S15 of Sheppard et al (2019).

Usage

```
predsync(wllobj)
```

```
## S3 method for class 'wlm'
predsync(wllobj)
```

Arguments

wllobj A wlm object

Value

predsync returns a tts object. Plotting the magnitude (see `plotmag`) displays a picture of predicted synchrony versus time and timescale that is comparable with the wavelet mean field (see `wmf`) of the response variable of the model. Calling the power function on that tts object should give the same results as one of the columns of output of `syncexpl`. Only `norm="powall"` implemented so far.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, LW et al. (2019) Synchrony is more than its top-down and climatic parts: interacting Moran effects on phytoplankton in British seas. Plos Computational Biology 15, e1006744. doi: 10.1371/journal.pcbi.1006744

See Also

[wlm](#), [tts](#), [plotmag](#), [wfm](#), [power](#), [syncexpl](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-(-3:100)
ts1<-sin(2*pi*times/10)
ts2<-5*sin(2*pi*times/3)
artsig_x<-matrix(NA,11,length(times)) #the driver
for (counter in 1:11)
{
  artsig_x[counter,]<-ts1+ts2+rnorm(length(times),mean=0,sd=.5)
}
times<-0:100
artsig_y<-matrix(NA,11,length(times)) #the driven
for (counter1 in 1:11)
{
  for (counter2 in 1:101)
  {
    artsig_y[counter1,counter2]<-mean(artsig_x[counter1,counter2:(counter2+2)])
  }
}
artsig_y<-artsig_y+matrix(rnorm(length(times)*11,mean=0,sd=1),11,length(times))
artsig_x<-artsig_x[,4:104]
artsig_i<-matrix(rnorm(11*length(times)),11,length(times)) #the irrelevant
artsig_x<-cleandat(artsig_x,times,1)$cdat
artsig_y<-cleandat(artsig_y,times,1)$cdat
artsig_i<-cleandat(artsig_i,times,1)$cdat
dat<-list(driven=artsig_y,driver=artsig_x,irrelevant=artsig_i)
resp<-1
pred<-2:3
norm<-"powall"
wlmobj<-wlm(dat,times,resp,pred,norm)

res<-predsync(wlmobj)
```

print.summary_wsyn *Print method for summary_wsyn class*

Description

Print method for summary_wsyn class

Usage

```
## S3 method for class 'summary_wsyn'
print(x, ...)
```

Arguments

x A summary_wsyn object
 ... Not currently used. Included for argument consistency with existing generics.

Value

print.summary_wsyn is called for its effect of printing to the screen.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[tts_methods](#), [wt_methods](#), [wmf_methods](#), [wpmf_methods](#), [coh_methods](#), [wlm_methods](#), [wlmtest_methods](#), [clust_methods](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-1:10
timescales<-1/c(1:10)
values<-matrix(1,length(times),length(timescales))
h<-tts(times,timescales,values)
print(summary(h))
```

setmints

Shifts a vector according to the argument mints

Description

Shifts a vector according to the argument mints

Usage

```
setmints(ts, mints)
```

Arguments

ts A vector of numeric values representing a time series
 mints The time series is shifted to have this minimum value. Default NA means use the smallest difference between consecutive, distinct sorted values of the time series. NaN means perform no shift.

Value

setmints returns the shifted vector.

Daniel Reuman, <reuman@ku.edu>

Note

This is an internal function, and no error checking is done.

set_adj	<i>Set and get methods for classes in the wsyn package</i>
---------	--

Description

Set and get methods for classes in the wsyn package. There are methods for each slot of each class, named set_* and get_* for * the slot name. Below are listed function specs for the generics and the default methods.

Usage

```
set_adj(obj, newval)
```

```
## Default S3 method:  
set_adj(obj, newval)
```

```
set_clusters(obj, newval)
```

```
## Default S3 method:  
set_clusters(obj, newval)
```

```
set_modres(obj, newval)
```

```
## Default S3 method:  
set_modres(obj, newval)
```

```
set_mns(obj, newval)
```

```
## Default S3 method:  
set_mns(obj, newval)
```

```
set_coords(obj, newval)
```

```
## Default S3 method:  
set_coords(obj, newval)
```

```
set_methodspecs(obj, newval)
```

```
## Default S3 method:
set_methodspecs(obj, newval)

set_wmfs(obj, newval)

## Default S3 method:
set_wmfs(obj, newval)

set_wpmfs(obj, newval)

## Default S3 method:
set_wpmfs(obj, newval)

get_adj(obj)

## Default S3 method:
get_adj(obj)

get_clusters(obj)

## Default S3 method:
get_clusters(obj)

get_modres(obj)

## Default S3 method:
get_modres(obj)

get_mns(obj)

## Default S3 method:
get_mns(obj)

get_coords(obj)

## Default S3 method:
get_coords(obj)

get_methodspec(obj)

## Default S3 method:
get_methodspec(obj)

get_wmfs(obj)

## Default S3 method:
get_wmfs(obj)
```

```
get_wpmfs(obj)

## Default S3 method:
get_wpmfs(obj)

set_coher(obj, newval)

## Default S3 method:
set_coher(obj, newval)

set_dat1(obj, newval)

## Default S3 method:
set_dat1(obj, newval)

set_dat2(obj, newval)

## Default S3 method:
set_dat2(obj, newval)

set_norm(obj, newval)

## Default S3 method:
set_norm(obj, newval)

set_sigmethod(obj, newval)

## Default S3 method:
set_sigmethod(obj, newval)

set_ranks(obj, newval)

## Default S3 method:
set_ranks(obj, newval)

set_bandp(obj, newval)

## Default S3 method:
set_bandp(obj, newval)

get_coher(obj)

## Default S3 method:
get_coher(obj)

get_dat1(obj)

## Default S3 method:
```

```
get_dat1(obj)

get_dat2(obj)

## Default S3 method:
get_dat2(obj)

get_norm(obj)

## Default S3 method:
get_norm(obj)

get_sigmethod(obj)

## Default S3 method:
get_sigmethod(obj)

get_ranks(obj)

## Default S3 method:
get_ranks(obj)

get_bandp(obj)

## Default S3 method:
get_bandp(obj)

set_times(obj, newval)

## Default S3 method:
set_times(obj, newval)

set_timescales(obj, newval)

## Default S3 method:
set_timescales(obj, newval)

set_values(obj, newval)

## Default S3 method:
set_values(obj, newval)

get_times(obj)

## Default S3 method:
get_times(obj)

get_timescales(obj)
```



```
## Default S3 method:
get_timescales(obj)

get_values(obj)

## Default S3 method:
get_values(obj)

set_coefs(obj, newval)

## Default S3 method:
set_coefs(obj, newval)

set_modval(obj, newval)

## Default S3 method:
set_modval(obj, newval)

set_wts(obj, newval)

## Default S3 method:
set_wts(obj, newval)

get_coefs(obj)

## Default S3 method:
get_coefs(obj)

get_modval(obj)

## Default S3 method:
get_modval(obj)

get_wts(obj)

## Default S3 method:
get_wts(obj)

set_wlmbj(obj, newval)

## Default S3 method:
set_wlmbj(obj, newval)

set_drop(obj, newval)

## Default S3 method:
set_drop(obj, newval)
```

```
get_wlmlobj(obj)

## Default S3 method:
get_wlmlobj(obj)

get_drop(obj)

## Default S3 method:
get_drop(obj)

set_signif(obj, newval)

## Default S3 method:
set_signif(obj, newval)

get_signif(obj)

## Default S3 method:
get_signif(obj)

set_dat(obj, newval)

## Default S3 method:
set_dat(obj, newval)

set_wtopt(obj, newval)

## Default S3 method:
set_wtopt(obj, newval)

get_dat(obj)

## Default S3 method:
get_dat(obj)

get_wtopt(obj)

## Default S3 method:
get_wtopt(obj)
```

Arguments

obj	An object of one of the classes defined in the package
newval	A newvalue of the slot in question, for the set_* methods

Details

There are methods for the `tts`, `wt`, `wmf`, `wpmf`, `coh`, `wlm`, `wlmtest`, and `clust` classes. See documentation for the generator functions for these classes (which in all cases have the same name as the class) for lists of slots for each class.

Value

`set_*` methods throw an error - setting of individual slots is not allowed, as it breaks consistency with the other slots. `get_*` just returns the value in question.

Author(s)

Daniel Reuman, <reuman@ku.edu>

Examples

```
times<-1:10
timescales<-1/c(1:10)
values<-matrix(1,length(times),length(timescales))
h<-tts(times,timescales,values)
get_times(h)
```

surrog	<i>Creates surrogate time series, either Fourier surrogates or amplitude adjusted Fourier surrogates</i>
--------	--

Description

For significance testing wavelet coherence and other purposes

Usage

```
surrog(dat, nsurrogs, surrtype, syncpres)
```

Arguments

dat	A locations x time matrix of observations (for multiple-time series input), or a single vector
nsurrogs	The number of surrogates to produce
surrtype	Either "fft" (for Fourier surrogates) or "aaft" (for amplitude adjusted Fourier surrogates). Fourier surrogates are appropriate for time series with normal marginals; otherwise consider aaft surrogates.
syncpres	Logical. TRUE for "synchrony preserving" surrogates (same phase randomizations used for all time series). FALSE leads to independent phase randomizations for all time series.

Details

Fourier surrogates are somewhat faster than aaft surrogates, and may be much faster when some of the time series in the data have ties. Prenormalization (e.g., using cleandat) can make it possible to use fft surrogates.

Value

surrog returns a list of nsurrogs surrogate datasets

Author(s)

Jonathan Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, LW, et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

Schreiber, T and Schmitz, A (2000) Surrogate time series. Physica D 142, 346-382.

Prichard, D and Theiler, J (1994) Generating surrogate data for time series with several simultaneously measured variables. Physical Review Letters 73, 951-954.

See Also

[wpmf](#), [coh](#), [wlmtest](#), [synmat](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-1:100
dat<-sin(2*pi*times/10)
nsurrogs<-10
surrtype<-"fft"
syncpres<-TRUE
res<-surrog(dat, nsurrogs, surrtype, syncpres)
```

syncexpl

Amount of synchrony explained, and related quantities

Description

Gives amount of synchrony explained by a wavelet linear model, as a function of timescale, and related quantities (see details)

Usage

```
syncexpl(object)

## S3 method for class 'wlm'
syncexpl(object)
```

Arguments

object A wlm object

Details

This function only works for `norm="powall"` at present. See Sheppard et al (2018) for details of the meaning and computation of the columns.

Value

`syncexpl` returns a data frame with columns for `timescales`, `sync` (the time-averaged square magnitude of the wavelet mean field of the response transforms), `syncexpl` (synchrony explained by the model predictors), columns named for each predictor (synchrony explained by that predictor), interactions (synchrony explained by all interaction effects), columns named for each pair of predictors (synchrony explained by individual pairwise interactions). There are also columns for `crossterms` and `resids` (residuals). The cross terms must be small for a given timescale band for the other results to be meaningful. All columns are functions of timescales.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, LW et al. (2019) Synchrony is more than its top-down and climatic parts: interacting Moran effects on phytoplankton in British seas. *Plos Computational Biology* 15, e1006744. doi: 10.1371/journal.pcbi.1006744

See Also

[wlm](#), [predsync](#), [wlmtest](#), `browseVignettes("wsyn")`

Examples

```
times<-(-3:100)
ts1<-sin(2*pi*times/10)
ts2<-5*sin(2*pi*times/3)
artsig_x<-matrix(NA,11,length(times)) #the driver
for (counter in 1:11)
{
  artsig_x[counter,]=ts1+ts2+rnorm(length(times),mean=0,sd=1.5)
}
```

```

times<-0:100
artsig_y<-matrix(NA,11,length(times)) #the driven
for (counter1 in 1:11)
{
  for (counter2 in 1:101)
  {
    artsig_y[counter1,counter2]<-mean(artsig_x[counter1,counter2:(counter2+2)])
  }
}
artsig_y<-artsig_y+matrix(rnorm(length(times)*11,mean=0,sd=3),11,length(times))
artsig_x<-artsig_x[,4:104]
artsig_i<-matrix(rnorm(11*length(times)),11,length(times)) #the irrelevant
artsig_x<-cleandat(artsig_x,times,1)$dat
artsig_y<-cleandat(artsig_y,times,1)$dat
artsig_i<-cleandat(artsig_i,times,1)$dat

dat<-list(driven=artsig_y,driver=artsig_x,irrelevant=artsig_i)
resp<-1
pred<-2:3
norm<-"powall"
wlmobj<-wlm(dat,times,resp,pred,norm)

res<-syncexpl(wlmobj)

```

synmat

Synchrony matrices

Description

Calculate synchrony matrices using a variety of methods

Usage

```

synmat(
  dat,
  times,
  method,
  tsrange = c(0, Inf),
  nsurrogs = 1000,
  scale.min = 2,
  scale.max.input = NULL,
  sigma = 1.05,
  f0 = 1,
  weighted = TRUE,
  sigthresh = 0.95
)

```

Arguments

<code>dat</code>	A locations (rows) x time (columns) matrix of measurements
<code>times</code>	The times at which measurements were made, spacing 1
<code>method</code>	Method for synchrony calculation. See details.
<code>tsrange</code>	A vector containing the min and max of the focal timescale range. Defaults to all timescales that are valid given choices for <code>scale.min</code> , <code>scale.max.input</code> , <code>f0</code> , <code>sigma</code> . Only used for wavelet-based methods.
<code>nsurrogs</code>	Number of surrogates for significance test. Defaults to 1000. Only used for surrogate-based methods.
<code>scale.min</code>	The smallest scale of fluctuation that will be examined. At least 2. Used only for wavelet-based methods.
<code>scale.max.input</code>	The largest scale of fluctuation guaranteed to be examined. Only used for wavelet-based methods.
<code>sigma</code>	The ratio of each time scale examined relative to the next timescale. Should be greater than 1. Only used for wavelet-based methods.
<code>f0</code>	The ratio of the period of fluctuation to the width of the envelope. Only used for wavelet-based methods.
<code>weighted</code>	If TRUE, create a weighted network. If FALSE, create a binary network using statistical significance. Binary networks are only allowed for networks based on significance.
<code>sigthresh</code>	Significance threshold needed, if <code>weighted</code> is false, for a network link to be realized. Typically 0.95, 0.99, or 0.999, etc. Only used if <code>weighted</code> is FALSE.

Details

The following values are valid for `method`: "pearson", "pearson.sig.std", "pearson.sig.fft", "pearson.sig.aaft", "spearman", "spearman.sig.std", "spearman.sig.fft", "spearman.sig.aaft", "kendall", "kendall.sig.std", "kendall.sig.fft", "kendall.sig.aaft", "ReXWT", "ReXWT.sig.fft", "ReXWT.sig.aaft", "ReXWT.sig.fast", "coh", "coh.sig.fft", "coh.sig.aaft", "coh.sig.fast", "phasecoh", "phasecoh.sig.fft", and "phasecoh.sig.aaft". The first portions of these identifiers correspond to the Pearson, Spearman, and Kendall correlations, the real part of the cross-wavelet transform, the wavelet coherence, and the wavelet phase coherence. The second portions of these identifiers, when present, indicates that significance of the measure specified in the first portion of the identifies is to be used for establishing the synchrony matrix. Otherwise the value itself is used. The third part of the method identifier indicates what type of significance is used.

Significance testing is performed using standard approaches (method flag containing `std`; for correlation coefficients, although these are inappropriate for autocorrelated data), or surrogates generated using the Fourier (method flag containing `fft`) or amplitude adjusted Fourier surrogates (`aaft`). For `coh` and `ReXWT`, the fast testing algorithm of Sheppard et al. (2017) is also implemented (`fast`). That method uses implicit Fourier surrogates. The choice of wavelet coherence (method flag containing `coh`) or the real part of the cross-wavelet transform (method flag containing `ReXWT`) depends mainly on treatment of out-of-phase relationships. The `ReXWT` is more akin to a correlation coefficient in that strong in-phase relationships approach 1 and strong antiphase relationships approach -1. Wavelet coherence allows any phase relationship and ranges

from 0 to 1. Power normalization is applied for "coh" and for "ReXWT". All significance tests are one-tailed. Synchrony matrices for significance-based methods when weighted is TRUE contain 1 minus the p-values.

Value

synmat returns a synchrony matrix, of type depending on the method argument. See details. Diagonal entries are left as NA.

Author(s)

Jonathan Walter, <jaw3es@virginia.edu>; Daniel Reuman, <reuman@ku.edu>; Lei Zhao, <lei.zhao@cau.edu.cn>

References

Walter, J. A., et al. (2017) The geography of spatial synchrony. Ecology Letters. doi: 10.1111/ele.12782

See Also

[clust](#), [coh](#), [surrog](#), [browseVignettes\("wsyn"\)](#)

Examples

```
sig<-matrix(.9,5,5)
diag(sig)<-1
if (requireNamespace("mvtnorm",quietly=TRUE))
{
  dat1<-t(mvtnorm::rmvnorm(30,mean=rep(0,5),sigma=sig))
  dat2<-t(mvtnorm::rmvnorm(30,mean=rep(0,5),sigma=sig))
}else
{
  dat1<-t(matrix(rep(rnorm(30),times=5),30,5))
  dat2<-t(matrix(rep(rnorm(30),times=5),30,5))
}
dat<-rbind(dat1,dat2)
times<-1:30
dat<-cleandat(dat,times,clev=2)$cdat
method<-"pearson.sig.fft"
res<-synmat(dat,times,method,nsurrogs=100,weighted=FALSE,
            sigthresh=0.95)
```

tts

Creator function for the tts class

Description

The `tts` (time/timescale) class is for matrices for which the rows correspond to times and the columns correspond to timescales. This is a general class from which other classes inherit (e.g., `wt`, `wmf`, `wpmf`). `tts` inherits from the `list` class.

Usage

```
tts(times, timescales, values)
```

Arguments

`times` A numeric vector of increasing real values, spacing 1
`timescales` A numeric vector with positive entries
`values` A complex or numeric matrix of dimensions `length(times)` by `length(timescales)`

Value

`tts` returns an object of class `tts`. Slots are:

`times` a numeric vector of evenly spaced times
`timescales` a numeric vector of positive timescales
`values` a complex or numeric matrix of dimensions `length(times)` by `length(timescales)`

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[tts_methods](#), [wt](#), [wmf](#), [wpmf](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-1:10  
timescales<-1/c(1:10)  
values<-matrix(1,length(times),length(timescales))  
h<-tts(times,timescales,values)
```

tts_methods

Basic methods for the tts class

Description

Set, get, summary, and print methods for the `tts` class.

Usage

```
## S3 method for class 'tts'  
summary(object, ...)  
  
## S3 method for class 'tts'  
print(x, ...)  
  
## S3 method for class 'tts'  
set_times(obj, newval)  
  
## S3 method for class 'tts'  
set_timescales(obj, newval)  
  
## S3 method for class 'tts'  
set_values(obj, newval)  
  
## S3 method for class 'tts'  
get_times(obj)  
  
## S3 method for class 'tts'  
get_timescales(obj)  
  
## S3 method for class 'tts'  
get_values(obj)
```

Arguments

object, x, obj	An object of class <code>tts</code>
...	Not currently used. Included for argument consistency with existing generics.
newval	A new value, for the <code>set_*</code> methods

Value

`summary.tts` produces a summary of a `tts` object. A `print.tts` method is also available. For `tts` objects, `set_*` and `get_*` methods are available for all slots, i.e., `*` equal to `times`, `timescales`, and `values`. The `set_*` methods just throw an error. Although class `tts` is flexible enough that setting of individual slots could have been allowed, because `wt` and other classes are based on it and because individual slots of those classes should not be changed, for consistency the same is forced for the `tts` class.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[tts](#)

Examples

```

times<-1:10
timescales<-1/c(1:10)
values<-matrix(1,length(times),length(timescales))
h<-tts(times,timescales,values)
get_times(h)
summary(h)
print(h)

```

warray	<i>Creates an array of wavelet transforms from input timeseries</i>
--------	---

Description

Creates an array of wavelet transforms from input timeseries

Usage

```
warray(dat, times, scale.min = 2, scale.max.input = NULL, sigma = 1.05, f0 = 1)
```

Arguments

dat	A locations (rows) x time (columns) matrix
times	A vector of timestep values (e.g. years), spacing 1
scale.min	The smallest scale of fluctuation that will be examined. At least 2.
scale.max.input	The largest scale of fluctuation that will be examined. Note that if this is set too high relative to the length of the timeseries it will be truncated.
sigma	The ratio of each time scale examined relative to the next timescale. Greater than 1.
f0	The ratio of the period of fluctuation to the width of the envelope

Value

warray returns a list containing:

wavarray	locations x time x timescales array of wavelet transforms
times	the time steps specified (e.g., years)
timescales	the timescales (1/frequency) computed for the wavelet transforms

Note

Important for interpreting the phase: the phases grow through time, i.e., they turn anti-clockwise. This function is internal, no error checking.

Author(s)

Lauren Hallett, <hallett@uoregon.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

wavmatwork	<i>Facilitates the computations in synmat for coherence and ReXWT methods</i>
------------	---

Description

Worker/utility function serving the analysis carried out in synmat for methods based on coherence or real part of the cross-wavelet transform.

Usage

```
wavmatwork(dat, times, scale.min, scale.max.input, sigma, f0, norm, treatment)
```

Arguments

dat	A locations (rows) x time (columns) matrix of measurements
times	The times at which measurements were made, spacing 1
scale.min	The smallest scale of fluctuation that will be examined. At least 2. Used only for wavelet-based methods.
scale.max.input	The largest scale of fluctuation guaranteed to be examined. Only used for wavelet-based methods.
sigma	The ratio of each time scale examined relative to the next timescale. Should be greater than 1. Only used for wavelet-based methods.
f0	The ratio of the period of fluctuation to the width of the envelope. Only used for wavelet-based methods.
norm	The normalization of wavelet transforms to be used. One of "none", "phase", "powind".
treatment	Either "Mod" or "Re"

Value

wavmatwork returns a list consisting of:

timescales	The timescales of analysis
wavarray	An array, locations by locations by timescales, containing either the coherences (for treatment="Mod") or the real parts of the cross-wavelet transforms (for treatment="Re") between locations.

Note

Internal function, no error checking done.

Author(s)

Daniel Reuman, <reuman@ku.edu>

wlm

Wavelet linear models

Description

Fits wavelet linear models. Also the generator function of the wlm class, which inherits from the list class.

Usage

```
wlm(
  dat,
  times,
  resp,
  pred,
  norm,
  scale.min = 2,
  scale.max.input = NULL,
  sigma = 1.05,
  f0 = 1
)
```

Arguments

dat	A list of matrices representing the data (or in the case of one location, a list of vectors). All the same dimensions (respectively, lengths)
times	The times at which measurements were made, spacing 1
resp	Index in dat for the response variable of the model
pred	Vector of indices in dat for the predictor variables of the model; must differ from resp
norm	The normalization of wavelet transforms to use. One of "none", "powall", "powind". See details.
scale.min	The smallest scale of fluctuation that will be examined. At least 2.
scale.max.input	The largest scale of fluctuation that will be examined. Note that if this is set too high relative to the length of the timeseries it will be truncated.
sigma	The ratio of each time scale examined relative to the next timescale. Greater than 1.
f0	The ratio of the period of fluctuation to the width of the envelope

Details

Normalization is as specified in the documentation for `coh`, HOWEVER, only the "powall" option is currently implemented, other choices throw an error. Details are specified in appendices S7 and S9 of Sheppard et al, 2018. The output `modval` is `v` in appendix S7, and `coefs` are the betas in equation 12 in that appendix.

Value

`wlm` returns an object of class `wlm`. Slots are:

<code>dat</code>	The input data list, but reordered and subsetted so the response is first and only used predictors are included
<code>times</code>	The times associated with the data
<code>norm</code>	The input
<code>wtopt</code>	The inputted wavelet transform options <code>scale.min</code> , <code>scale.max</code> , <code>input</code> , <code>sigma</code> , <code>f0</code> in a list
<code>wts</code>	List of transforms, normalized as specified in <code>norm</code> . Same length as the output <code>dat</code> , each entry a locations x time x timescales array of transforms.
<code>timescales</code>	The timescales associated with the wavelet transforms of the data
<code>coefs</code>	A list (data frame, actually) of complex vectors, each of length the same as <code>timescales</code> . These are the model coefficients (which depend on timescale), and correspond to the <code>wts</code> .
<code>modval</code>	The model values.
<code>coher</code>	Appropriately normalized version of coherence of the model and response transforms. See details.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, LW et al. (2019) Synchrony is more than its top-down and climatic parts: interacting Moran effects on phytoplankton in British seas. *Plos Computational Biology* 15, e1006744. doi: 10.1371/journal.pcbi.1006744

See Also

[wlm_methods](#), [wlmtest](#), [syncexpl](#), [predsync](#), `browseVignettes("wsyn")`

Examples

```
times<-1:30
dat<-list(v1=matrix(rnorm(300),10,30),v2=matrix(rnorm(300),10,30),v3=matrix(rnorm(300),10,30),
v4=matrix(rnorm(300),10,30),v5=matrix(rnorm(300),10,30))
dat<-lapply(FUN=function(x){cleandat(x,times,1)$cdat},X=dat)
```

```
resp<-2
pred<-c(1,3,4)
norm<-"powall"
res<-wlm(dat,times,resp,pred,norm)
```

wlmfit*Fits a wavelet linear model*

Description

Stripped down internal function for doing the fitting

Usage

```
wlmfit(wts, norm)
```

Arguments

wts	List of normalized transforms, normalized as specified in norm. Each entry a locations x time x timescales array of transforms. The first is the response variable, others are the predictors.
norm	The normalization that was used. One of "none", "powall", "powind". See details.

Details

Only norm="powall" works now, other options throw an error.

Value

wlmfit returns a list with these elements:

coefs	Model coefficients
modval	The right had side of the model
coher	Appropriately normalized coherence of the model and response variable

Note

Internal function, no error checking done.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, LW et al. (2019) Synchrony is more than its top-down and climatic parts: interacting Moran effects on phytoplankton in British seas. *Plos Computational Biology* 15, e1006744. doi: 10.1371/journal.pcbi.1006744

wlmtest

Statistical comparison of wavelet linear models

Description

Compares a wavelet linear model with a nested model. Also the generator function for the wlmtest class.

Usage

```
wlmtest(wlmbj, drop, sigmethod, nrand = 1000)
```

Arguments

wlmbj	A wlm object
drop	Either names or indices of variables in wlmbj\$dat that are being dropped to form the simpler, nested model. The first variable in wlmbj\$dat, which is the response, is not allowed here.
sigmethod	Method for significance testing. One of "fft", "aaft", "fast". See details.
nrand	The number of randomizations to do for significance

Details

The slot `signif` provides the core information on significance. If `sigmethod` is not "fast", then `signif$coher` is the same as `wlmbj$coher`, and `signif$scoher` is a matrix of dimensions `nrand` by `length(signif$coher)` with rows equal to coherences between refitted models and the response-variable transforms, for datasets where the variables specified in `drop` have been replaced by surrogates. Normalization as specified in `norm` is used. The type of surrogate used (Fourier surrogates or amplitude adjusted Fourier surrogates, see `surrog`) is determined by `sigmethod` ("fft" or "aaft"). Synchrony-preserving surrogates are used. A variety of statements of significance (or lack thereof) can be made by comparing `signif$coher` with `signif$scoher` (see the `plotmag`, `plotrank`, and `bandtest` methods for the `wlmtest` class). If `sigmethod` is "fast", a fast algorithm of Lawrence Sheppard is used which is a generalization to wavelet linear models of the fast algorithm for coherence described in Sheppard et al (2017). In that case `signif$coher` can be compared to `signif$scoher` to make significance statements about the coherence in exactly the same way, but `signif$scoher` will no longer precisely equal `wlmbj$coher`, and `wlmbj$coher` should not be compared directly to `signif$scoher`. Statements about significance of the coherence should be made using `signif$coher` and `signif$scoher`, whereas `wlmbj$coher` should be used whenever the actual value of the coherence is needed.

The slots `ranks` and `bandp` are empty on an initial call to `wlmtest`. They are made to compute and hold aggregate significance results over any timescale band of choice. These are filled in when needed by other methods, see `plotrank` and `bandtest`.

Value

wlmtest returns an object of class wlmtest. Slots are:

wlmbj	The input
drop	The input
signif	A list with information from the significance testing. Elements are sigmethod (the input), coher and scoher. See details.
ranks	A list with ranking information for signif. NA until plotrank or bandtest is called.
bandp	A data frame containing results of computing significances across timescale bands. Empty on an initial call to wlmtest, filled in by the function bandtest. See details.

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

Sheppard, L.W., et al. (2017) Rapid surrogate testing of wavelet coherences. European Physical Journal, Nonlinear and Biomedical Physics, 5, 1. DOI: 10.1051/epjnbp/2017000

Sheppard, LW et al. (2019) Synchrony is more than its top-down and climatic parts: interacting Moran effects on phytoplankton in British seas. Plos Computational Biology 15, e1006744. doi: 10.1371/journal.pcbi.1006744

See Also

[wlm](#), [plotrank](#), [bandtest](#), [coh](#), [wlmtest_methods](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-1:30
dat<-list(v1=matrix(rnorm(300),10,30),v2=matrix(rnorm(300),10,30),v3=matrix(rnorm(300),10,30),
        v4=matrix(rnorm(300),10,30),v5=matrix(rnorm(300),10,30))
dat<-lapply(FUN=function(x){cleandat(x,times,1)$cdat},X=dat)
resp<-1
pred<-2:3
norm<-"powall"
wlmbj<-wlm(dat,times,resp,pred,norm)
drop<-3
sigmethod<-"fft"
res<-wlmtest(wlmbj,drop,sigmethod,nrand=10)
```

wlmtest_methods *Basic methods for the wlmtest class*

Description

Set, get, summary, and print methods for the wlmtest class.

Usage

```
## S3 method for class 'wlmtest'  
summary(object, ...)
```

```
## S3 method for class 'wlmtest'  
print(x, ...)
```

```
## S3 method for class 'wlmtest'  
set_wlmobj(obj, newval)
```

```
## S3 method for class 'wlmtest'  
set_drop(obj, newval)
```

```
## S3 method for class 'wlmtest'  
set_signif(obj, newval)
```

```
## S3 method for class 'wlmtest'  
set_ranks(obj, newval)
```

```
## S3 method for class 'wlmtest'  
set_bandp(obj, newval)
```

```
## S3 method for class 'wlmtest'  
get_wlmobj(obj)
```

```
## S3 method for class 'wlmtest'  
get_drop(obj)
```

```
## S3 method for class 'wlmtest'  
get_signif(obj)
```

```
## S3 method for class 'wlmtest'  
get_ranks(obj)
```

```
## S3 method for class 'wlmtest'  
get_bandp(obj)
```

Arguments

object, x, obj An object of class wlmtest

... Not currently used. Included for argument consistency with existing generics.
 newval A new value, for the set_* methods

Value

summary.wlmtest produces a summary of a wlmtest object. A print.wlmtest method is also available. For wlmtest objects, set_* and get_* methods are available for all slots (see the documentation for wlmtest for a list). The set_* methods just throw an error, to prevent breaking the consistency between the slots of a wlmtest object.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[wlmtest](#)

Examples

```
times<-1:30
dat<-list(v1=matrix(rnorm(300),10,30),v2=matrix(rnorm(300),10,30),v3=matrix(rnorm(300),10,30),
        v4=matrix(rnorm(300),10,30),v5=matrix(rnorm(300),10,30))
dat<-lapply(FUN=function(x){cleandat(x,times,1)$cdat},X=dat)
resp<-1
pred<-2:3
norm<-"powall"
wlmobj<-wlm(dat,times,resp,pred,norm)
drop<-3
sigmethod<-"fft"
h<-wlmtest(wlmobj,drop,sigmethod,nrand=10)
get_times(get_wlmobj(h))
summary(h)
print(h)
```

Description

Set, get, summary, and print methods for the wlm class.

Usage

```
## S3 method for class 'wlm'  
summary(object, ...)  
  
## S3 method for class 'wlm'  
print(x, ...)  
  
## S3 method for class 'wlm'  
set_times(obj, newval)  
  
## S3 method for class 'wlm'  
set_timescales(obj, newval)  
  
## S3 method for class 'wlm'  
set_coefs(obj, newval)  
  
## S3 method for class 'wlm'  
set_modval(obj, newval)  
  
## S3 method for class 'wlm'  
set_coher(obj, newval)  
  
## S3 method for class 'wlm'  
set_dat(obj, newval)  
  
## S3 method for class 'wlm'  
set_wtopt(obj, newval)  
  
## S3 method for class 'wlm'  
set_norm(obj, newval)  
  
## S3 method for class 'wlm'  
set_wts(obj, newval)  
  
## S3 method for class 'wlm'  
get_times(obj)  
  
## S3 method for class 'wlm'  
get_timescales(obj)  
  
## S3 method for class 'wlm'  
get_coefs(obj)  
  
## S3 method for class 'wlm'  
get_modval(obj)  
  
## S3 method for class 'wlm'  
get_coher(obj)
```

```
## S3 method for class 'wlm'  
get_dat(obj)  
  
## S3 method for class 'wlm'  
get_wtopt(obj)  
  
## S3 method for class 'wlm'  
get_norm(obj)  
  
## S3 method for class 'wlm'  
get_wts(obj)
```

Arguments

object, x, obj An object of class wlm
... Not currently used. Included for argument consistency with existing generics.
newval A new value, for the set_* methods

Value

summary.wlm produces a summary of a wlm object. A print.wlm method is also available. For wlm objects, set_* and get_* methods are available for all slots (see the documentation for wlm for a list). The set_* methods just throw an error, to prevent breaking the consistency between the slots of a wlm object.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[wlm](#)

Examples

```
times<-1:30  
dat<-list(v1=matrix(rnorm(300),10,30),v2=matrix(rnorm(300),10,30),v3=matrix(rnorm(300),10,30),  
          v4=matrix(rnorm(300),10,30),v5=matrix(rnorm(300),10,30))  
dat<-lapply(FUN=function(x){cleandat(x,times,1)$cdat},X=dat)  
resp<-2  
pred<-c(1,3,4)  
norm<-"powall"  
h<-wlm(dat,times,resp,pred,norm)  
get_times(h)  
summary(h)  
print(h)
```

wmf *Computes the wavelet mean field from a matrix of spatiotemporal data. Also the creator function for the wmf class.*

Description

Computes the wavelet mean field from a matrix of spatiotemporal data. Also the creator function for the wmf class. The wmf class inherits from the tts class, which inherits from the list class.

Usage

```
wmf(dat, times, scale.min = 2, scale.max.input = NULL, sigma = 1.05, f0 = 1)
```

Arguments

dat	A locations (rows) x time (columns) matrix
times	A vector of time step values (e.g., years), spacing 1
scale.min	The smallest scale of fluctuation that will be examined. At least 2.
scale.max.input	The largest scale of fluctuation that will be examined. Note that if this is set too high relative to the length of the timeseries it will be truncated.
sigma	The ratio of each time scale examined relative to the next timescale. Greater than 1.
f0	The ratio of the period of fluctuation to the width of the envelope

Value

wmf returns an object of class wmf. Slots are:

values	A matrix of complex numbers containing the wavelet mean field, of dimensions <code>length(times)</code> by the number of timescales. Entries not considered reliable (longer timescales, near the edges of the time span) are set to NA.
times	The time steps specified (e.g., years)
timescales	The timescales (1/frequency) computed for the wavelet transforms
dat	The data matrix (locations by time) from which the wmf was computed
wtopt	The inputted wavelet transform options <code>scale.min</code> , <code>scale.max.input</code> , <code>sigma</code> , <code>f0</code> in a list

Author(s)

Jonathan Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

See Also

[wmf_methods](#), [tts](#), [wpmf](#), [plotmag](#), [browseVignettes\("wsyn"\)](#)

Examples

```
times<-1:30 #generate time steps
#generate fake count data for 20 locations
dat<-matrix(rpois(20*length(times),20),nrow=20,ncol=length(times))
dat<-cleandat(dat=dat,times=times,clev=2)$cdat #detrend and demean
wmf<-wmf(dat,times)
```

 wmf_methods

Basic methods for the wmf class

Description

Set, get, summary, and print methods for the wmf class.

Usage

```
## S3 method for class 'wmf'
summary(object, ...)

## S3 method for class 'wmf'
print(x, ...)

## S3 method for class 'wmf'
set_times(obj, newval)

## S3 method for class 'wmf'
set_timescales(obj, newval)

## S3 method for class 'wmf'
set_values(obj, newval)

## S3 method for class 'wmf'
set_dat(obj, newval)

## S3 method for class 'wmf'
set_wtopt(obj, newval)

## S3 method for class 'wmf'
get_times(obj)

## S3 method for class 'wmf'
get_timescales(obj)
```

```
## S3 method for class 'wmf'
get_values(obj)

## S3 method for class 'wmf'
get_dat(obj)

## S3 method for class 'wmf'
get_wtopt(obj)
```

Arguments

object, x, obj An object of class wmf

... Not currently used. Included for argument consistency with existing generics.

newval A new value, for the set_* methods

Value

summary.wmf produces a summary of a wmf object. A print.wmf method is also available. For wmf objects, set_* and get_* methods are available for all slots, i.e., * equal to times, timescales, wtopt, values, and dat. The set_* methods just throw an error, to prevent breaking the consistency between the slots of a wmf object.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[wmf](#)

Examples

```
times<-1:30 #generate time steps
#generate fake count data for 20 locations
dat<-matrix(rpois(20*length(times),20),nrow=20,ncol=length(times))
dat<-cleandat(dat=dat,times=times,clev=2)$cdat #detrrend and demean
h<-wmf(dat,times)
get_times(h)
summary(h)
print(h)
```


wpmf

*Wavelet phasor mean field***Description**

Computes the wavelet phasor mean field from a matrix of spatiotemporal data. Also the creator function for the wpmf class. The wpmf class inherits from the tts class, which inherits from the list class.

Usage

```
wpmf(
  dat,
  times,
  scale.min = 2,
  scale.max.input = NULL,
  sigma = 1.05,
  f0 = 1,
  sigmethod = "none",
  nrand = 1000
)
```

Arguments

dat	A locations (rows) x time (columns) matrix
times	A vector of time step values, spacing 1
scale.min	The smallest scale of fluctuation that will be examined. At least 2.
scale.max.input	The largest scale of fluctuation guaranteed to be examined
sigma	The ratio of each time scale examined relative to the next timescale. Should be greater than 1.
f0	The ratio of the period of fluctuation to the width of the envelop
sigmethod	Method for significance testing the wpmf, one of quick, fft, aaft (see details)
nrand	The number of randomizations to be used for significance testing

Details

For sigmethod equal to quick, the empirical wpmf is compared to a distribution of magnitudes of sums of random phasors, using the same number of phasors as there are time series. The signif output is a list with first element "quick" and second element a vector of nrand magnitudes of sums of random phasors. For sigmethod equal to fft, the empirical wpmf is compared to wpmfs of Fourier surrogate datasets. The signif output is a list with first element "fft", second element equal to nrand, and third element the fraction of surrogate-based wpmf magnitudes that the empirical wpmf magnitude is greater than (times by timescales matrix). For sigmethod equal to aaft, aaft surrogates are used instead. Output has similar format to the fft case. Values other than quick, fft, and aaft for sigmethod result in no significance testing.

Value

wpmf returns an object of class wpmf. Slots are:

values	A matrix of complex numbers containing the wavelet phasor mean field, of dimensions <code>length(times)</code> by the number of timescales. Entries not considered reliable (longer timescales, near the edges of the time span) are set to NA.
times	The times associated with the data and the wpmf
timescales	The timescales associated with the wpmf
signif	A list with information from the significance testing. Format depends on <code>sigmethod</code> (see details).
dat	The data matrix (locations by time) from which the wpmf was computed
wtopt	The inputted wavelet transform options <code>scale.min</code> , <code>scale.max</code> , <code>input</code> , <code>sigma</code> , <code>f0</code> in a list

Author(s)

Thomas Anderson, <anderst1@gmail.com>, Jon Walter, <jaw3es@virginia.edu>; Lawrence Sheppard, <lwsheppard@ku.edu>; Daniel Reuman, <reuman@ku.edu>

References

Sheppard, L.W., et al. (2016) Changes in large-scale climate alter spatial synchrony of aphid pests. Nature Climate Change. DOI: 10.1038/nclimate2881

See Also

[wpmf_methods](#), [wpmf](#), [tts](#), [plotmag](#), `browseVignettes("wsyn")`

Examples

```
times<-1:30 #generate time steps
#generate fake count data for 20 locations
dat<-matrix(rpois(20*length(times),20),nrow=20,ncol=length(times))
dat<-cleandat(dat=dat,times=times,clev=2)$cdat #detrend and demean
res<-wpmf(dat,times)
```

wpmf_methods

Basic methods for the wpmf class

Description

Set, get, summary, and print methods for the wpmf class.

Usage

```
## S3 method for class 'wpmf'  
summary(object, ...)  
  
## S3 method for class 'wpmf'  
print(x, ...)  
  
## S3 method for class 'wpmf'  
set_times(obj, newval)  
  
## S3 method for class 'wpmf'  
set_timescales(obj, newval)  
  
## S3 method for class 'wpmf'  
set_values(obj, newval)  
  
## S3 method for class 'wpmf'  
set_dat(obj, newval)  
  
## S3 method for class 'wpmf'  
set_wtopt(obj, newval)  
  
## S3 method for class 'wpmf'  
set_signif(obj, newval)  
  
## S3 method for class 'wpmf'  
get_times(obj)  
  
## S3 method for class 'wpmf'  
get_timescales(obj)  
  
## S3 method for class 'wpmf'  
get_values(obj)  
  
## S3 method for class 'wpmf'  
get_dat(obj)  
  
## S3 method for class 'wpmf'  
get_wtopt(obj)  
  
## S3 method for class 'wpmf'  
get_signif(obj)
```

Arguments

object, x, obj	An object of class wpmf
...	Not currently used. Included for argument consistency with existing generics.
newval	A new value, for the set_* methods

Value

summary.wpmf produces a summary of a wpmf object. A print.wpmf method is also available. For wpmf objects, set_* and get_* methods are available for all slots, i.e., * equal to times, timescales, wtopt, values, dat, and signif. The set_* methods just throw an error, to prevent breaking the consistency between the slots of a wpmf object.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[wpmf](#)

Examples

```
times<-1:30 #generate time steps
#generate fake count data for 20 locations
dat<-matrix(rpois(20*length(times),20),nrow=20,ncol=length(times))
dat<-cleandat(dat=dat,times=times,clev=2)$cdat #detrend and demean
h<-wpmf(dat,times)
get_times(h)
summary(h)
print(h)
```

wt

Computes the wavelet transform of a timeseries. Also the creator function for the wt class.

Description

Computes the wavelet transform of a timeseries. Also the creator function for the wt class. The wt class inherits from the tts class, which inherits from the list class.

Usage

```
wt(
  t.series,
  times,
  scale.min = 2,
  scale.max.input = NULL,
  sigma = 1.05,
  f0 = 1
)
```

Arguments

t.series	A timeseries of real values
times	A vector of time step values (e.g., years), spacing 1
scale.min	The smallest scale of fluctuation that will be examined. At least 2.
scale.max.input	The largest scale of fluctuation that is guaranteed to be examined
sigma	The ratio of each time scale examined relative to the next timescale. Should be greater than 1.
f0	The ratio of the period of fluctuation to the width of the envelope. Defaults to 1.

Value

wt returns an object of class wt. Slots are:

values	A matrix of complex numbers, of dimensions <code>length(t.series)</code> by the number of timescales. Entries not considered reliable (longer timescales, near the edges of the time span) are set to NA.
times	The time steps specified (e.g. years)
wtopt	The inputted wavelet transform options <code>scale.min</code> , <code>scale.max.input</code> , <code>sigma</code> , <code>f0</code> in a list
timescales	The timescales (1/frequency) computed for the wavelet transform
dat	The data vector from which the transform was computed

Note

Important for interpreting the phase: the phases grow through time, i.e., they turn anti-clockwise.

Author(s)

Lawrence Sheppard <lwsheppard@ku.edu>, Jonathan Walter <jaw3es@virginia.edu>, Daniel Reuman <reuman@ku.edu>

See Also

[wt_methods](#), [tts](#), [plotmag](#), [plotphase](#), [browseVignettes\("wsyn"\)](#)

Examples

```
time1<-1:100
time2<-101:200
ts1p1<-sin(2*pi*time1/15)
ts1p2<-0*time1
ts2p1<-0*time2
ts2p2<-sin(2*pi*time2/8)
ts1<-ts1p1+ts1p2
ts2<-ts2p1+ts2p2
ts<-c(ts1,ts2)
ra<-rnorm(200,mean=0,sd=0.5)
```

```
t.series<-ts+ra
t.series<-t.series-mean(t.series)
times<-c(time1,time2)
res<-wt(t.series, times)
```

wt_methods

Basic methods for the wt class

Description

Set, get, summary, and print methods for the wt class.

Usage

```
## S3 method for class 'wt'
summary(object, ...)
```

```
## S3 method for class 'wt'
print(x, ...)
```

```
## S3 method for class 'wt'
set_times(obj, newval)
```

```
## S3 method for class 'wt'
set_timescales(obj, newval)
```

```
## S3 method for class 'wt'
set_values(obj, newval)
```

```
## S3 method for class 'wt'
set_dat(obj, newval)
```

```
## S3 method for class 'wt'
set_wtopt(obj, newval)
```

```
## S3 method for class 'wt'
get_times(obj)
```

```
## S3 method for class 'wt'
get_timescales(obj)
```

```
## S3 method for class 'wt'
get_values(obj)
```

```
## S3 method for class 'wt'
get_dat(obj)
```

```
## S3 method for class 'wt'
get_wtopt(obj)
```

Arguments

object, x, obj An object of class wt
 ... Not currently used. Included for argument consistency with existing generics.
 newval A new value, for the set_* methods

Value

summary.wt produces a summary of a wt object. A print.wt method is also available. For wt objects, set_* and get_* methods are available for all slots, i.e., * equal to times, timescales, wtopt, values, and dat. The set_* methods just throw an error, to prevent breaking the consistency between the slots of a wt object.

Author(s)

Daniel Reuman, <reuman@ku.edu>

See Also

[wt](#)

Examples

```
time1<-1:100
time2<-101:200
ts1p1<-sin(2*pi*time1/15)
ts1p2<-0*time1
ts2p1<-0*time2
ts2p2<-sin(2*pi*time2/8)
ts1<-ts1p1+ts1p2
ts2<-ts2p1+ts2p2
ts<-c(ts1,ts2)
ra<-rnorm(200,mean=0,sd=0.5)
t.series<-ts+ra
t.series<-t.series-mean(t.series)
times<-c(time1,time2)
h<-wt(t.series, times)
get_times(h)
summary(h)
print(h)
```

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