Package 'astrochron'

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Type Package

Title A Computational Tool for Astrochronology

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Description Routines for astrochronologic testing, astronomical time scale construction, and time series analysis <doi:10.1016/j.earscirev.2018.11.015>. Also included are a range of statistical analysis and modeling routines that are relevant to time scale development and paleoclimate analysis.

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Contents

astrochron-package   *astrochron: A Computational Tool for Astrochronology*

Description

This software provides routines for astrochronologic testing, astronomical time scale construction, and time series analysis <doi:10.1016/j.earscirev.2018.11.015>. Also included are a range of statistical analysis and modeling routines that are relevant to time scale development and paleoclimate analysis.

Details

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Note

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TO CITE THIS PACKAGE IN PUBLICATIONS, PLEASE USE:

Meyers, S.R. (2014). *Astrochron: An R Package for Astrochronology*. https://cran.r-project.org/package=astrochron

Also cite the original research papers that document the relevant algorithms, as referenced on the help pages for specific functions.

Some examples (including R scripts) demonstrating the application of the astrochron package can be found in Meyers (2019), Ma et al. (2017), and Crampton et al. (2018), among numerous other scientific publications. Please also see examples in the help pages for specific functions.

Author(s)

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References

J.S. Campton, S.R. Meyers, R.A. Cooper, P.M Sadler, M. Foote, D. Harte, 2018, *Pacing of Paleozoic macroevolutionary rates by Milankovitch grand cycles*: Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1714342115.

C. Ma, S.R. Meyers, B.B. Sageman, 2017 *Theory of chaotic orbital variations confirmed by Cretaceous geological evidence*: Nature v.542, 468-470, doi:10.1038/nature21402.

S.R. Meyers, 2019, *Cyclostratigraphy and the problem of astrochronologic testing*: Earth-Science Reviews v.190, 190-223, doi:10.1016/j.earscirev.2018.11.015.

---

accum   *Calculate geochemical proxy accumulation rates*

Description

Calculate geochemical proxy accumulation rates using defined sedimentation rate and dry bulk density. Sedimentation rate and dry bulk density data are piecewise linearly interpolated to data locations, to estimate bulk accumulation rate.

Usage

```
accum(dat,sedrate=NULL,density=NULL,genplot=T,check=T,verbose=T)
```

Arguments

dat   Stratigraphic series containing geochemical proxy data. First column should be
               location (e.g., depth), second column should be geochemical concentration in
               weight percent (0-100).

sedrate   Sedimentation rate. First column should be location (e.g., depth), second col-
               umn should be sedimentation rate (cm/ka). Alternatively, if a single value is
               given, a constant sedimentation rate is applied.

density   Dry bulk density. First column should be location (e.g., depth), second column
               should be dry bulk density (g/cm3/ka). Alternatively, if a single value is given,
               a constant bulk density is applied.

genplot   Generate summary plots? (T or F)

check   Conduct compliance checks before processing? (T or F). In general this should
               be activated; the option is included for Monte Carlo simulation.

verbose   Verbose output? (T or F)

Examples

```
# Generate an example geochemical data set, using a stochastic model
    ex=ar1(npts=1001)
# the first column in 'ex' is depth (m), and we will take the second column to be CaCO3
#  rescale second column to range from 0-100% CaCO3
    m=100/(max(ex[2])-min(ex[2]))
    b=100-(m*max(ex[2]))
    ex[2]= m*ex[2] +b
    autoPlot(ex)
# generate example sedimentation rate history, with a stepwise tripling
#  from 1m/kyr to 3m/kyr at 500 m
    sr=ex
    sr[1:500,2]=1
    sr[501:1001,2]=3
    autoPlot(sr)

# calculate accumulation rates
    res=accum(dat=ex,sedrate=sr,density=2.65)
```

---

anchorTime   *Anchor a floating astrochronology to a radioisotopic age*

Description

Anchor a floating astrochronology to a radioisotopic age. The floating astrochronology is centered
on a given ('floating') time datum and assigned the 'anchored' age.

Usage

```
anchorTime(dat,time,age,timeDir=1,flipOut=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series. First column should be floating time scale, second column should be data value.
time	'Floating' time datum to center record on. Units should be ka.
age	Radioisotopic age (or othwerwise) for anchoring at floating 'time' datum. Units should be ka.
timeDir	Direction of 'floating' time in input record; 1 = elapsed time towards present; 2 = elapsed time away from present
flipOut	Flip the output (sort so the ages are presented in decreasing order)? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

ar1	*Generate AR(1) surrogates*

Description

Generate AR(1) surrogates. Implement shuffling algorithm of Meyers (2012) if desired.

Usage

```
ar1(npts=1024,dt=1,mean=0,sdev=1,rho=0.9,shuffle=F,nsim=1,genplot=T,verbose=T)
```

Arguments

npts	number of time series data points
dt	sampling interval
mean	mean value for AR1 surrogate series
sdev	standard deviation for AR1 surrogate series
rho	AR(1) coefficient
shuffle	Apply secondary shuffle of Gaussian deviates before AR modeling
nsim	Number of AR1 surrogate series to generate
genplot	generate summary plots (T or F)
verbose	verbose output (T or F)

Details

These simulations use the random number generator of Matsumoto and Nishimura [1998]. If shuffle
= T, the algorithm from Meyers (2012, pg. 11) is applied: (1) two sets of random sequences of
the same length are generated, (2) the first random sequence is then sorted, and finally (3) the
permutation vector of the sorted sequence is used to reorder the second random number sequence.
This is done to guard against potential shortcomings in random number generation that are specific
to spectral estimation.

References

S.R. Meyers, 2012, *Seeing red in cyclic stratigraphy: Spectral noise estimation for astrochronology*:
Paleoceanography, v. 27, PA3328.

---

ar1etp	*AR(1) + ETP simulation routine*

Description

Simulate a combined AR(1) + ETP signal, plot spectrum and confidence levels

Usage

```
ar1etp(etpdat=NULL,nsim=100,rho=0.9,wtAR=1,sig=90,tbw=2,padfac=5,ftest=F,fmax=0.1,
       speed=0.5,pl=2,graphfile=0)
```

Arguments

etpdat	Eccentricity, tilt, precession astronmical series. First column = time, second column = ETP. If not entered will use default series from Laskar et al. (2004), spanning 0-1000 kyr.
nsim	Number of simulations.
rho	AR(1) coefficient for noise modeling.
wtAR	Multiplicative factor for AR1 noise (1= eqivalent to ETP variance). If < 0, etp signal will be excluded from the simulations (noise only)
sig	Demarcate what confidence level (percent) on plots?
tbw	MTM time-bandwidth product.
padfac	Pad with zeros to (padfac*npts) points, where npts is the number of data points.
ftest	Include MTM harmonic f-test results? (T or F)
fmax	Maximum frequency for plotting.
speed	Set the amount of time to pause before plotting new graph, in seconds.
pl	Plot (1) log frequency-log power or (2) linear frequency-linear power?
graphfile	Output a pdf or jpg image of each plot? 0 = no, 1 = pdf, 2 = jpeg. If yes, there will be no output to screen. Individual graphic files will be produced for each simluation, for assembling into a movie.

Details

Note: Setting wtAR=1 will provide equal variance contributions from the etp model and the ar1 model. More generally, set wtAR to the square root of the desired variance contribution (wtAR=0.5 will generate an AR1 model with variance that is 25% of the etp model). If you would like to exclusively evaluate the noise (no etp), set wtAR < 0.

Note: You may use the function etp to generate eccentricity-tilt-precession models.

References

Laskar, J., Robutel, P., Joutel, F., Gastineau, M., Correia, A.C.M., Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

See Also

[getLaskar](#), and [etp](#)

Examples

```
 ## Not run:

# run simulations using the default settings
ar1etp()

# compare with a second model:
# generate etp model spanning 0-2000 ka, with sampling interval of 5 ka.
ex1=etp(tmin=0,tmax=2000,dt=5)
# run simulations, with rho=-.7, and scaling noise to have 50 percent of the etp model variance
ar1etp(etpdat=ex1,rho=0.7,wtAR=sqrt(0.5))


## End(Not run)
```

---

arcsinT   *Arcsine transformation of stratigraphic series*

Description

Arcsine transformation of stratigraphic series

Usage

```
arcsinT(dat,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for arcsine transformation. Input can have any number of columns desired. If two or more columns are input, the first column must be location (e.g., depth), while remaining columns are data values for transformation.
genplot	Generate summary plots? (T or F). This is automatically deactivated if more than one variable is transformed.
verbose	Verbose output? (T or F)

See Also

[demean](), [detrend](), [divTrend](), [logT](), [prewhiteAR](), and [prewhiteAR1]()

---

armaGen   *Generate autoregressive moving-average model*

Description

Generate an autoregressive moving-average time series model

Usage

```
armaGen(npts=1024,dt=1,m=0,std=1,rhos=c(0.9),thetas=c(0),genplot=T,verbose=T)
```

Arguments

npts	Number of time series data points.
dt	Sampling interval.
m	Mean value of final time series.
std	Standard deviation of final time series.
rhos	Vector of AR coefficients for each order.
thetas	Vector of MA coefficients for each order.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

asm   *Average Spectral Misfit*

Description

Calculate Average Spectral Misfit with Monte Carlo spectra simulations, as updated in Meyers et al. (2012).

Usage

```
asm(freq,target,fper=NULL,rayleigh,nyquist,sedmin=1,sedmax=5,numsed=50,
    linLog=1,iter=100000,output=F,genplot=T)
```

Arguments

freq	A vector of candidate astronomical cycles observed in your data spectrum (cycles/m). Maximum allowed is 500.
target	A vector of astronomical frequencies to evaluate (1/ka). These must be in order of increasing frequency (e.g., e1,e2,e3,o1,o2,p1,p2). Maximum allowed is 50 frequencies.
fper	A vector of uncertainties on each target frequency (1/ka). Values should be from 0-1, representing uncertainty as a percent of each target frequency. The order of the uncertainties must follow that of the target vector. By default, no uncertainty is assigned.
rayleigh	Rayleigh frequency (cycles/m).
nyquist	Nyquist frequency (cycles/m).
sedmin	Minimum sedimentation rate for investigation (cm/ka).
sedmax	Maximum sedimentation rate for investigation (cm/ka).
numsed	Number of sedimentation rates to investigate in ASM optimization grid. Maximum allowed is 500.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log)
iter	Number of Monte Carlo simulations for significance testing. Maximum allowed is 100,000.
output	Return output as a new data frame? (T or F)
genplot	Generate summary plots? (T or F)

Details

This function will caculate the Average Spectral Misfit between a data spectrum and astronomical target spectrum, following the approach outlined in Meyers and Sageman (2007), and the improvements of Meyers et al. (2012).

Value

A data frame containing: Sedimentation rate (cm/ka), ASM (cycles/ka), Null hypothesis significance level (0-100 percent), Number of astronomical terms fit.

References

S.R. Meyers and B.B. Sageman, 2007, *Quantification of Deep-Time Orbital Forcing by Average Spectral Misfit*: American Journal of Science, v. 307, p. 773-792.

S.R. Meyers, B.B. Sageman and M.A. Arthur, 2012, *Obliquity forcing of organic matter accumulation during Oceanic Anoxic Event 2*: Paleoceanography, 27, PA3212, doi:10.1029/2012PA002286.

See Also

eAsm, eAsmTrack, testPrecession, timeOpt, and timeOptSim

Examples

```
## These frequencies are from modelA (type '?astrochron' for more information).
## They are for an 8 meter window, centered at 22 meters height. Units are cycles/m .
freq <- c(0.1599833,0.5332776,1.5998329,2.6797201,3.2796575,3.8795948,5.5194235,6.5459830)
freq <- data.frame(freq)

## Rayleigh frequency in cycles/m
rayleigh <- 0.1245274

## Nyquist frequency in cycles/m
nyquist <- 6.66597

## orbital target in 1/ky. Predicted periods for 94 Ma (see Meyers et al., 2012)
target <- c(1/405.47,1/126.98,1/96.91,1/37.66,1/22.42,1/18.33)

## percent uncertainty in orbital target
fper=c(0.023,0.046,0.042,0.008,0.035,0.004)

asm(freq=freq,target=target,fper=fper,rayleigh=rayleigh,nyquist=nyquist,sedmin=0.5,sedmax=3,
    numsed=100,linLog=1,iter=100000,output=FALSE)
```

---

autoPlot   *Automatically plot multiple stratigraphic series, with smoothing if desired*

Description

Automatically plot and smooth specified stratigraphic data, versus location. Data are smoothed with a Gaussian kernel if desired.

Usage

```
autoPlot(dat,cols=NULL,dmin=NULL,dmax=NULL,vertical=T,ydir=NULL,nrows=NULL,plotype=1,
         smooth=0,xgrid=1,output=F,genplot=T,verbose=T)
```

Arguments

dat	Your data frame; first column should be location identifier (e.g., depth).
cols	A vector that identifies the columns to extract (first column automatically extracted).
dmin	Minimum depth/height/time for plotting.
dmax	Maximum depth/height/time for plotting.
vertical	Generate vertical stratigraphic plots? (T or F) If F, will generate horizontal plots.
ydir	Direction for stratigraphic axis in plots (depth,height,time). If vertical=T, then -1 results in values increasing downwards, while 1 results in values increasing upwards. If vertical=F, then -1 results in values increasing toward the left, while 1 results in values increasing toward the right.
nrows	Number of rows in figure (if vertical = T; otherwise this will be the number of columns).
plotype	Type of plot to generate: 1= points and lines, 2 = points, 3 = lines
smooth	Width (temporal or spatial dimension) for smoothing with a Gaussian kernel (0 = no smoothing); the Gaussian kernel is scaled so that its quartiles (viewed as probability densities, that is, containing 50 percent of the area) are at +/- 25 percent of this value.
xgrid	For kernal smoothing: (1) evaluate on ORIGINAL sample grid, or (2) evaluate on EVENLY SPACED grid covering range.
output	Output data frame of smoothed values? (T or F)
genplot	Generate summary plots (T or F)
verbose	Verbose output (T or F)

---

bandpass	*Bandpass filter stratigraphic series*

Description

Bandpass filter stratigraphic series using rectangular, Gaussian or tapered cosine (a.k.a. Tukey) window. This function can also be used to notch fiter a record (see examples).

Usage

```
bandpass(dat,padfac=2,flow=NULL,fhigh=NULL,win=0,alpha=3,p=0.25,demean=T,
         detrend=F,addmean=T,output=1,xmin=0,xmax=Nyq,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for bandpass filtering. First column should be location (e.g., depth), second column should be data value.
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
flow	Lowest frequency to bandpass.
fhigh	Highest frequency to bandpass.
win	Window type for bandpass filter: 0 = rectangular , 1= Gaussian, 2= Cosine-tapered window (a.k.a. Tukey window).
alpha	Gaussian window parameter: alpha is 1/stdev, a measure of the width of the Dirichlet kernel. Choose alpha >= 2.5.
p	Cosine-tapered (Tukey) window parameter: p is the percent of the data series tapered (choose 0-1).
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
addmean	Add mean value to bandpass result? (T or F)
output	Output: (1) filtered series, (2) bandpass filter window.
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Value

bandpassed stratigraphic series.

See Also

lowpass, noKernel, noLow, prewhiteAR, prewhiteAR1, and taner

Examples

```
# generate example series with periods of 405 ka, 100 ka, 40ka, and 20 ka, plus noise
ex=cycles(freqs=c(1/405,1/100,1/40,1/20),end=1000,dt=5,noisevar=.1)

# bandpass precession term using cosine-tapered window
bandpass_ex <- bandpass(ex,flow=0.045,fhigh=0.055,win=2,p=.4)

# notch filter (remove) obliquity term using cosine-tapered window
#  if you'd like the final notch filtered record to be centered on the mean proxy
#  value, set addmean=FALSE
notch_ex <- bandpass(ex,flow=0.02,fhigh=0.03,win=2,p=.4,addmean=FALSE)
notch_ex[2] <- ex[2]-notch_ex[2]
pl(2)
plot(ex,type="l",main="Eccentricity+Obliquity+Precession")
plot(notch_ex,type="l",main="Following application of obliquity notch filter")
```

---

bergerPeriods	*Obliquity and precession periods of Berger et al. (1992)*

Description

Determine the predicted precession and obliquity periods based on Berger et al. (1992). Values are determined by piecewise linear interpolation.

Usage

```
bergerPeriods(age,genplot=T)
```

Arguments

age	Age (millions of years before present)
genplot	Generate summary plots? (T or F)

References

A. Berger, M.F. Loutre, and J. Laskar, 1992, *Stability of the Astronomical Frequencies Over the Earth's History for Paleoclimate Studies*: Science, v. 255, p. 560-566.

---

bicoherence	*bicoherence: Calculate bispectrum and bicoherence using WOSA method as detailed in Choudhury et al. (2008).*

Description

bicoherence: Calculate bispectrum and bicoherence using WOSA method as detailed in Choudhury et al. (2008). Kim and Powers (1979) bicoherence normalization is used, with a conditioning factor to reduce the potential for spurious bicoherence peaks.

Usage

```
bicoherence(dat,overlap=50,segments=8,CF=0,CL=95,padfac=2,demean=T,detrend=T,
        taper=T,maxF=Nyq,output=0,genplot=T,color=1,id=NULL,logpwr=F,logbis=F,
            check=T,verbose=T)
```

Arguments

dat	Stratigraphic series to analyze. First column should be location (e.g., depth, time), second column should be data value.
overlap	Percent overlap for WOSA segments (use 0-50 percent).
segments	Number of segments for WOSA.

CF	Conditioning factor for bicoherence estimation (see pg. 70 of Choudhury et al., 2008). When CF=0, this will be automatically estimated as the 75th percentile of the magnitude-squared bicoherence denominator
CL	Confidence level to identify with a contour on the plots (0-100).
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points per segment.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
taper	Apply Hanning taper? (T or F)
maxF	Maximum frequency for analysis/plotting.
output	Return output as new data frame? 0 = none, 1 = magnitude-squared bispectrum, 2 = magnitude-squared bicoherence, 3 = magnitude-squared bicoherence confidence levels, 4 = everything.
genplot	Generate summary plots? (T or F)
color	Use (1) grayscale or (2) viridis color scale for 3D plots?
id	A vector listing frequencies to identify on the plots as diagonal lines.
logpwr	Use a log scale for power spectrum? (T or F)
logbis	Use a log scale for bispectrum? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Details

This function accompanies the publication Sullivan et al. (2023, PNAS): "Bicoherence is a higher-order statistic, which quantifies coupling of individual frequencies (as combination and difference tones). For three frequencies, f1, f2 and f3, high bicoherence indicates that f1 + f2 = f3, with the additional property that their phases are also coupled in the data series. We employ the bicoherence approach of Choudhury, Shah and Thornhill (2008), which uses Welch Overlapping Spectral Analysis (WOSA), as this method includes improvements to the standard approach that reduce the potential for spurious bicoherence peaks. Note that reliable bicoherence estimates require a substantial increase in bandwidth resolution ("smoothing")".

References

Choudhury, A.A.S., Shah, S.L., and Thornhill, N.F. (2008), *Diagnosis of Process Nonlinearities and Valve Stiction: Data Driven Approaches*: Springer, 284 pp.

Kim, Y.C., and Powers, E.J. (1979), *Digital Bispectral Analysis and Its Applications to Nonlinear Wave Interactions*: IEEE Transactions on Plasma Science, v. PS-7, 120-131.

Sullivan, N.B., Meyers, S.R., Levy, R.H., McKay, R.M., Golledge, N.R., Cortese, G. (2023), *Millennial-scale variability of the Antarctic Ice Sheet during the Early Miocene*: Proceedings of the National Academy of Sciences, https://doi.org/10.1073/pnas.2304152120.

Welch, P.D. (1967), *The use of Fast Fourier Tranform for the estimation of power spectra: A method based on time averaging over short, modified periodograms*: IEEE Transactions on Audio and Electroacoustics, AU-5 (2): 70-73.

Examples

```
  ## Not run:
# Generate an example quadratic phase-coupled signal as in Choudhury et al. (2008, pg. 79)
    n = rnorm(500)
    t=1:500
   signal = sin(2*pi*0.12*t + pi/3) + sin(2*pi*0.18*t + pi/12) + sin(2*pi*0.3*t + 5*pi/12) + n
    ex=data.frame(cbind(t,signal))
    bicoherence(ex)

## End(Not run)
```

---

bioturb	*Bioturbate time series using diffusion model from Guinasso and Schinck (1975), as in Liu et al. (2021)*

Description

'bioturb' is a function for simulating the bioturbed time series when bioturbation is modeled as a diffusive process. It implements the methodology outlined in Liu et al. (2021), which builds on the approaches of (Guinasso and Schink, 1975), Goreau (1977), and Goreau (1980). Given the bioturbation parameters, an impulse response function is first calculated using function 'impulseResponse'. This function is then convolved with the input time series (true signal) to output the bioturbed time series. Note that the input true signal 'dat' and impulse response function are interpolated to the same resolution before convolution.

Usage

```
bioturb(dat, G, ML, v, output=1, genplot=TRUE, verbose=TRUE)
```

Arguments

dat	Stratigraphic series to be bioturbated. First column should be age (kyr), second column should be data value.
G	Control parameter in Guinasso and Schinck, 1975. G = D/ML/v
ML	Mix layer depth (cm)
v	Sedimentation rate (cm/kyr)
output	Which results would you like to return to the console? (0) no output; (1) return bioturbated series; (2) return impulse response
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

References

Guinasso, N.L. and Schinck, D.R., 1975, *Quantitative estimates of biological mixing rates in abyssal sediments*, J. Geophys. Res., 80, 3032-3043.

Goreau, T.J., 1977, *Quantitative effects of sediment mixing on stratigraphy and biogeochemistry: a signal theory approach*, Nature, 256, 730-732.

Goreau, T.J., 1980, *Frequency sensitivity of the deep-sea climatic record*, Nature, 287, 620-622.

Liu, H., Meyers, S.R., and Marcott, S.A., 2021, *Unmixing dee-sea paleoclimate records: A study on bioturbation effects through convolution and deconvolution*, Earth and Planetary Science Letters, 564, 116883.

Examples

```
# as a test series, use the three dominant precession terms from Berger et al. (1992)
ex1=cycles()

# mix it
res1 <- bioturb(ex1, G=4, ML=10, v=1, genplot = TRUE)

# un-mix it
res2=unbioturb(res1, G=4, ML=10, v=1, genplot = TRUE)

pl()
plot(ex1,type="l",main="black=signal, blue=bioturbated, red=unbioturbated",lwd=3)
lines(res2,col="red")
lines(res1,col="blue")
```

---

calcPeriods	*Calculate eccentricity, obliquity and precession periods in ka, given g, s and k in arcsec/yr*

Description

Calculate eccentricity, obliquity and precession periods in ka, given g, s and k in arcsec/yr.

Usage

```
calcPeriods(g,s=NULL,k,output=1)
```

Arguments

g	Required Data frame or matrix with columns representing the fundamental frequencies: g1, g2, g3, g4, g5. Frequencies must be in arcsec/yr.
s	Optional data frame or matrix with columns representing the fundamental frequencies: s1, s2, s3, s4, s5, s6. Frequencies must be in arcsec/yr. This is only required if you want to calculate obliquity periods.
k	Required data frame or vector with precession constant (frequency). Frequencies must be in arcsec/yr.
output	(1) return results as data frame, (2) return results as a numeric vector.

Examples

```
# calculate eccentricity and precession periods for one set of g's and k
gVal= c(5.579378,7.456665,17.366595,17.910194,4.257564)
kVal= 50.475838
calcPeriods(g=gVal, k=kVal)

# calculate eccentricity and precession periods for three sets of g's and k
gVal= matrix(c(5.579378,7.456665,17.366595,17.910194,4.257564,5.494302,7.452619,
       17.480760,18.348310,4.257451,5.531285,7.456848,17.320480,17.912240,4.257456),
       nrow=3,ncol=5,byrow=TRUE)

kVal= c(50.475838,51.280910,85.790450)

calcPeriods(g=gVal, k=kVal)
```

---

cb   *Combine multiple vectors*

Description

Bind two vectors together and return result as a data frame. Alternatively, extract specified columns from a data frame, bind them together, and return result as a data frame.

Usage

```
cb(a,b)
```

Arguments

a   first input vector OR a data frame with >1 column.

b   second input vector OR if a is a data frame with > 1 column, a list of columns
                to bind.

Examples

```
# example dataset
x<-rnorm(100)
dim(x)<-c(10,10)
x<-data.frame(x)

# bind two columns
cb(x[1],x[5])

# bind five columns
cb(x,c(1,2,4,7,9))
```

---

clipIt   *Create non-linear response by clipping stratigraphic series*

Description

Create non-linear response by clipping stratigraphic series below a threshold value. Alternatively, mute response below a threshold value using a contant divisor. Both approaches will enhance power in modulator (e.g., eccentricity) and diminish power the carrier (e.g., precession).

Usage

```
clipIt(dat,thresh=NULL,clipval=NULL,clipdiv=NULL,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series. First column should be location (e.g., depth), second column should be data value.
thresh	Clip below what theshold value? By default will clip at mean value.
clipval	What number should be assigned to the clipped values? By default, the value of thresh is used.
clipdiv	Clip using what divisor? A typical value is 2. By default, clipdiv is unity.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

confAdjust   *Adjust spectrum confidence levels for multiple comparisons*

Description

Adjust spectrum confidence levels for multiple comparisons, using the Bonferroni correction

Usage

```
confAdjust(spec,npts,dt,tbw=3,ntap=5,flow=NULL,fhigh=NULL,output=T,
    xmin=df,xmax=NULL,pl=1,genplot=T,verbose=T)
```

Arguments

spec	A data frame with three columns: frequency, power, background power. If more than 3 columns are input, the results are assumed to come from periodogram, mtm, mtmML96, lowspec or mtmPL.
npts	Number of points in stratigraphic series.
dt	Sampling interval of stratigraphic series.

tbw	MTM time-bandwidth product.
ntap	Number of DPSS tapers to use.
flow	Vector of lower bounds for each frequency band of interest. Order must match fhigh.
fhigh	Vector of upper bounds for each frequency band of interest. Order must match flow.
output	Output data frame? (T or F)
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
pl	Plotting option (1-4): 1=linear frequency & log power, 2=log frequency & power, 3=linear frequency & power, 4=log frequency & linear power.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

Multiple testing is a common problem in the evaluation of power spectrum peaks (Vaughan et al., 2011; Crampton et al., PNAS). To address the issue of multiple testing, a range of approaches have been advocated. This function will conduct an assessment using the Bonferroni correction, which is the simplest, and also the most conservative, of the common approaches (it is overly pessimistic).

If one is exclusively concerned with particular frequency bands a priori (e.g., those associated with Milankovitch cycles), the statistical power of the method can be improved by restricting the analysis to those frequency bands (use options 'flow' and 'fhigh').

Application of multiple testing corrections does not guarantee that the spectral background is appropriate. To address this issue, carefully examine the fit of the spectral background, and also conduct simulations with the function testBackground.

References

J.S. Campton, S.R. Meyers, R.A. Cooper, P.M Sadler, M. Foote, D. Harte, 2018, *Pacing of Paleozoic macroevolutionary rates by Milankovitch grand cycles*: Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1714342115.

S. Vaughan, R.J. Bailey, and D.G. Smith, 2011, *Detecting cycles in stratigraphic data: Spectral analysis in the presence of red noise*. Paleoceanography 26, PA4211, doi:10.1029/2011PA002195.

See Also

testBackground, multiTest, lowspec, and periodogram

Examples

```
# generate example series with periods of 400 ka, 100 ka, 40 ka and 20 ka
ex = cycles(freqs=c(1/400,1/100,1/40,1/20),start=1,end=1000,dt=5)

# add AR1 noise
noise = ar1(npts=200,dt=5,sd=.5)
```

```
ex[2] = ex[2] + noise[2]

# first, let's use mtm with conventional AR1 background
spec=mtm(ex,padfac=1,ar1=TRUE,output=1)

# when blindly prospecting for cycles, it is necessary to consider all of the
#  observed frequencies in the test
confAdjust(spec,npts=200,dt=5,tbw=3,ntap=5,output=FALSE)

# if, a priori, you are only concerned with the Milankovitch frequency bands,
#  restrict your analysis to those bands (as constrained by available sedimentation
#  rate estimates and the frequency resolution of the spectrum). in the example below,
#  the mtm bandwidth resolution is employed to search frequencies nearby the
#  Milankovitch-target periods.
flow=c((1/400)-0.003,(1/100)-0.003,(1/41)-0.003,(1/20)-0.003)
fhigh=c((1/400)+0.003,(1/100)+0.003,(1/41)+0.003,(1/20)+0.003)
confAdjust(spec,npts=200,dt=5,tbw=3,ntap=5,flow=flow,fhigh=fhigh,output=FALSE)

# now try with the lowspec method. this uses prewhitening, so it has one less data point.
spec=lowspec(ex,padfac=1,output=1)
flow=c((1/400)-0.003015075,(1/100)-0.003015075,(1/41)-0.003015075,(1/20)-0.003015075)
fhigh=c((1/400)+0.003015075,(1/100)+0.003015075,(1/41)+0.003015075,(1/20)+0.003015075)
confAdjust(spec,npts=199,dt=5,tbw=3,ntap=5,flow=flow,fhigh=fhigh,output=FALSE)

# for comparison...
confAdjust(spec,npts=199,dt=5,tbw=3,ntap=5,output=FALSE)
```

constantSedrate	*Apply a constant sedimentation rate model to transform a spatial series to temporal series*

Description

Apply a constant sedimentation rate model to transform a spatial series to temporal series.

Usage

```
constantSedrate(dat,sedrate,begin=0,timeDir=1,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series. First column should be location (e.g., depth), second column should be data value.
sedrate	Sedimentation rate, in same spatial units as dat.
begin	Time value to assign to first datum.
timeDir	Direction of floating time in tuned record: 1 = elapsed time increases with depth/height; -1 = elapsed time decreases with depth/height)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

conv_fft   *Convolution through Fast Fourier Transform*

Description

Convolution through Fast Fourier Transform

Usage

```
conv_fft(x, y, index, dt)
```

Arguments

x	Input signal that needs to be convolved
y	Green's function; impulse response function
index	index in the impulse response function that corresponds to the deposition time
dt	time resolution for the input series

Details

Function 'conv_fft' is used by function 'bioturb'. x and y do not need to be of the same length.

Value

z Convolved output series. length(z) = length(x)

---

cosTaper   *Apply cosine taper to stratigraphic series*

Description

Apply a "percent-tapered" cosine taper (a.k.a. Tukey window) to a stratigraphic series.

Usage

```
cosTaper(dat,p=.25,rms=T,demean=T,detrend=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for tapering. First column should be location (e.g., depth), second column should be data value. If no data is identified, will output a 256 point taper to evaluate the spectral properties of the window.
p	Cosine-tapered window parameter: p is the percent of the data series tapered (choose 0-1). When p=1, this is equivalent to a Hann taper.
rms	Normalize taper to RMS=1 to preserve power for white process? (T or F)
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

dpssTaper, gausTaper, and hannTaper

---

cycles   *Generate harmonic model*

Description

Make a time series with specified harmonic components and noise

Usage

```
cycles(freqs=NULL,phase=NULL,amp=NULL,start=0,end=499,dt=1,noisevar=0,genplot=T,
        verbose=T)
```

Arguments

freqs	Vector with frequencies to model ('linear' frequencies).
phase	Vector with phases for each frequency (phase in radians). Phases are subtracted.
amp	Vector with amplitudes for each frequency.
start	First time/depth/height for output.
end	Last time/depth/height for output.
dt	Sampling interval.
noisevar	Variance of additive Gaussian noise.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Value

modeled time series.

Examples

```
## test signal on pg 38 of Choudhury, Shah, and Thornhill (2008)
freqs=c(0.12,0.18,0.30,0.42)
phase=c(-pi/3,-pi/12,-pi/4,-3*pi/8)
amp=c(1,1,1,1)

cycles(freqs,phase,amp,start=0,end=4095,dt=1,noisevar=0.2)
```

---

deconv   *Wiener Deconvolution through Fast Fourier Transform*

Description

Wiener Deconvolution through Fast Fourier Transform.

Usage

```
deconv(x, y, index, dt, pt = 0.2, wiener = TRUE)
```

Arguments

x	Time series that needs to be deconvolved.
y	Green function/Impulse response function.
index	index in the impulse response function that corresponds to the deposition time.
dt	time resolution for the input series.
pt	Cosine-tapered window parameter: pt is the percent of the data series tapered (choose 0-1). When pt=1, this is equivalent to a Hann taper.
wiener	Apply Wiener filter? (T or F)

Details

function 'deconv' is used by function 'unbioturb'. A cosine taper is applied to remove edge effects. The signal-to-noise ratio is chosen to be 0.05, and gamma is also chosen to be 0.05. x and y do not need to be of the same length. For additional information see Liu et al. (2021)

Value

z deconvolved/un-bioturbed series. length(z) = length(x)

References

Liu, H., Meyers, S.R., and Marcott, S.A., 2021, *Unmixing dee-sea paleoclimate records: A study on bioturbation effects through convolution and deconvolution*, Earth and Planetary Science Letters, 564, 116883.

---

delPts   *Interactively delete points in plot*

Description

Interactively delete points in x,y plot.

Usage

```
delPts(dat,del=NULL,cols=c(1,2),ptsize=1,xmin=NULL,xmax=NULL,ymin=NULL,ymax=NULL,
        plotype=1,genplot=T,verbose=T)
```

Arguments

dat	Data frame containing stratigraphic variable(s) of interest. Any number of columns permitted.
del	A vector of indices indicating points to delete. If specified, the interactive plot is disabled.
cols	If you are using the graphical interface, which columns would you like to plot? (default = 1 & 2).
ptsize	Size of plotted points.
xmin	Minimum x-value (column 1) to plot
xmax	Maximum x-value (column 1) to plot
ymin	Minimum y-value (column 2) to plot
ymax	Maximum y-value (column 2) to plot
plotype	Type of plot to generate: 1= points and lines, 2 = points, 3 = lines
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

[idPts](), [iso](), [trim]() and [trimAT]()

demean   *Remove mean value from stratigraphic series*

Description

Remove mean value from stratigraphic series

Usage

```
demean(dat,genplot=T,verbose=T)
```

Arguments

dat   Stratigraphic series for mean removal. First column should be location (e.g., depth), second column should be data value.

genplot   Generate summary plots? (T or F)

verbose   Verbose output? (T or F)

See Also

[arcsinT](), [detrend](), [divTrend](), [logT](), [prewhiteAR](), and [prewhiteAR1]()

detrend   *Subtract linear trend from stratigraphic series*

Description

Remove linear trend from stratigraphic series

Usage

```
detrend(dat,output=1,genplot=T,verbose=T)
```

Arguments

dat   Stratigraphic series for linear detrending. First column should be location (e.g., depth), second column should be data value.

output   1= output detrended signal; 2= output linear trend

genplot   Generate summary plots? (T or F)

verbose   Verbose output? (T or F)

See Also

[arcsinT](), [demean](), [divTrend](), [logT](), [prewhiteAR](), and [prewhiteAR1]()

---

diffAccum   *Model differential accumulation*

Description

Model differential accumulation. The input variable (e.g., insolation, proxy value) is rescaled to sedimentation rate curve varying from sedmin to sedmax. Input series must be evenly sampled in time.

Usage

```
diffAccum(dat,sedmin=0.01,sedmax=0.02,dir=1,genplot=T,verbose=T)
```

Arguments

dat	Model input series with two columns. First column must be time in ka, second column should be data value. Data series must be evenly sampled in time.
sedmin	Minimum sedimentation rate (m/ka)
sedmax	Maximum sedimentation rate (m/ka)
dir	1=peaks have higher accumulation rate, -1=troughs have higher accumulation rate
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Examples

```
# generate model with one 20 ka cycle
ex <- cycles(1/20)

diffAccum(ex)
```

---

divTrend   *Divide by linear trend in stratigraphic series*

Description

Divide data series value by linear trend observed in stratigraphic series

Usage

```
divTrend(dat,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for div-trending. First column should be location (e.g., depth), second column should be data value.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

arcsinT, demean, detrend, logT, prewhiteAR, and prewhiteAR1

---

dpssTaper	*Apply DPSS taper to stratigraphic series*

Description

Apply a single Discrete Prolate Spheroidal Sequence (DPSS) taper to a stratigraphic series

Usage

```
dpssTaper(dat,tbw=1,num=1,rms=T,demean=T,detrend=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for tapering. First column should be location (e.g., depth), second column should be data value. If no data is identified, will output a 256 point taper to evaluate the spectral properties of the window.
tbw	Time-bandwidth product for the DPSS
num	Which one of the DPSS would you like to use?
rms	Normalize taper to RMS=1 to preserve power for white process? (T or F)
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

cosTaper, gausTaper, and hannTaper

---

eAsm   *Evolutive Average Spectral Misfit*

Description

Calculate Evolutive Average Spectral Misfit with Monte Carlo spectra simulations, as updated in Meyers et al. (2012).

Usage

```
eAsm(spec,siglevel=0.9,target,fper=NULL,rayleigh,nyquist,sedmin=1,sedmax=5,
    numsed=50,linLog=1,iter=100000,ydir=1,palette=2,output=4,genplot=F)
```

Arguments

spec	Time-frequency spectral results to evaluate. Must have the following format: column 1=frequency; remaining columns (2 to n)=probability; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eha.
siglevel	Threshold level for filtering peaks.
target	A vector of astronomical frequencies to evaluate (1/ka). These must be in order of increasing frequency (e.g., e1,e2,e3,o1,o2,p1,p2). Maximum allowed is 50 frequencies.
fper	A vector of uncertainties on each target frequency (1/ka). Values should be from 0-1, representing uncertainty as a percent of each target frequency. The order of the uncertainties must follow that of the target vector. By default, no uncertainty is assigned.
rayleigh	Rayleigh frequency (cycles/m).
nyquist	Nyquist frequency (cycles/m).
sedmin	Minimum sedimentation rate for investigation (cm/ka).
sedmax	Maximum sedimentation rate for investigation (cm/ka).
numsed	Number of sedimentation rates to investigate in ASM optimization grid. Maximum allowed is 500.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log)
iter	Number of Monte Carlo simulations for significance testing. Maximum allowed is 100,000.
ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.
palette	What color palette would you like to use? (1) rainbow, (2) viridis
output	Return output as a new data frame? (0 = nothing, 1 = Ho-SL, 2 = ASM, 3 = # astronomical terms, 4 = everything)
genplot	Generate summary plots? (T or F)

Details

Please see function asm for details.

References

S.R. Meyers and B.B. Sageman, 2007, *Quantification of Deep-Time Orbital Forcing by Average Spectral Misfit*: American Journal of Science, v. 307, p. 773-792.

S.R. Meyers, 2012, *Seeing Red in Cyclic Stratigraphy: Spectral Noise Estimation for Astrochronology*: Paleoceanography, 27, PA3228, doi:10.1029/2012PA002307.

S.R. Meyers, B.B. Sageman and M.A. Arthur, 2012, *Obliquity forcing of organic matter accumulation during Oceanic Anoxic Event 2*: Paleoceanography, 27, PA3212, doi:10.1029/2012PA002286.

See Also

asm, eAsmTrack, eha, testPrecession, timeOpt, and timeOptSim

Examples

```
 ## Not run:
# use modelA as an example
data(modelA)

# interpolate to even sampling interval
modelAInterp=linterp(modelA)

# perform EHA analysis, save harmonic F-test confidence level results to 'spec'
spec=eha(modelAInterp,win=8,step=2,pad=1000,output=4)

# perform Evolutive Average Spectral Misfit analysis, save results to 'res'
res=eAsm(spec,target=c(1/405.47,1/126.98,1/96.91,1/37.66,1/22.42,1/18.33),rayleigh=0.1245274,
        nyquist=6.66597,sedmin=0.5,sedmax=3,numsed=100,siglevel=0.8,iter=10000,output=4)

# identify minimum Ho-SL in each record and plot
pl(1)
eAsmTrack(res[1],threshold=0.05)

# extract Ho-SL result at 18.23 m
HoSL18.23=extract(res[1],get=18.23,pl=1)

# extract ASM result at 18.23 m
asm18.23=extract(res[2],get=18.23,pl=0)

## End(Not run)
```

---

eAsmTrack   *Track ASM null hypothesis significance level minima in eASM results*

Description

Track ASM null hypothesis significance level minima in eASM results.

Usage

```
eAsmTrack(res,threshold=.5,ydir=-1,genplot=T,verbose=T)
```

Arguments

res	eAsm results. Must have the following format: column 1=sedimentation rate; remaining columns (2 to n)=Ho-SL; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eAsm.
threshold	Threshold Ho-SL value for analysis and plotting.
ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

Please see function eAsm for details.

See Also

asm, eAsm, and eha

---

eha   *Evolutive Harmonic Analysis & Evolutive Power Spectral Analysis*

Description

Evolutive Harmonic Analysis & Evolutive Power Spectral Analysis using the Thomson multitaper method (Thomson, 1982)

Usage

```
eha(dat,tbw=2,pad,fmin,fmax,step,win,demean=T,detrend=T,siglevel=0.90,
    sigID=F,ydir=1,output=0,pl=1,palette=6,centerZero=T,ncolors=100,xlab,ylab,
    genplot=2,verbose=T)
```

Arguments

dat	Stratigraphic series to analyze. First column should be location (e.g., depth), second column should be data value.
tbw	MTM time-bandwidth product (<=10)
pad	Pad with zeros to how many points? Must not factor into a prime number >23. Maximum number of points is 200,000.
fmin	Smallest frequency for analysis and plotting.
fmax	Largest frequency for analysis and plotting.
step	Step size for EHA window, in units of space or time.
win	Window size for EHA, in units of space or time.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
siglevel	Significance level for peak identification/filtering (0-1)
sigID	Identify signficant frequencies on power, amplitude, and probabilty plots. Only applies when one spectrum is calculated. (T or F)
ydir	Direction for y-axis in EHA plots (depth,height,time). -1 = values increase downwards (slower plotting), 1 = values increase upwards
output	Return output as new data frame? 0=no; 1=all results; 2=power; 3=amplitude; 4=probability; 5=significant frequencies (only for one spectrum); 6=significant frequencies and their probabilities (only for one spectrum)
pl	Plot logarithm of spectral power (1) or linear spectral power (2)?
palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red (if values are negative and positive, white is centered on zero), (6) viridis
centerZero	Center color scale on zero (use an equal number of postive and negative color divisions)? (T or F)
ncolors	Number of colors steps to use in palette.
xlab	Label for x-axis. Default = "Frequency"
ylab	Label for y-axis. Default = "Location"
genplot	Plotting options. 0= no plots; 1= power, amplitude, f-test, probability; 2=data series, power, amplitude, probability; 3= data series, power, normalized amplitude (maximum in each window normalized to unity), normalized amplitude filtered at specified siglevel; 4= data series, normalized power (maximum in each window normalized to unity), normalized amplitude (maximum in each window normalized to unity), normalized amplitude filtered at specified siglevel
verbose	Verbose output? (T or F)

Details

The power spectrum normalization approach applied here divides the Fourier coefficients by the number of points (npts) in the stratigraphic series, which is equivalent to dividing the power by (npts*npts). The (npts*npts) normalization has the convenient property whereby – for an unpadded

series – the sum of the power in the positive frequencies is equivalent to half of variance; the other half of the variance is in the negative frequencies.

Note that the 'spec.mtm' function in package 'multitaper' (Rahim et al., 2014) is used for MTM spectrum estimation.

References

Thomson, D. J., 1982, *Spectrum estimation and harmonic analysis*, Proc. IEEE, 70, 1055-1096, doi:10.1109/PROC.1982.12433.

See Also

[extract](), [lowspec](), [mtmAR](), [mtmML96](), [periodogram](), [trackFreq]() and [traceFreq]()

Examples

```
## as an example, evaluate the modelA
data(modelA)

## interpolate to even sampling interval of 0.075 m
ex1=linterp(modelA, dt=0.075)

## perform EHA with a time-bandwidth parameter of 2, using an 7.95 meter window, 0.15 m step,
## and pad to 1000 points
## set labels for plots (optional)
eha(ex1,tbw=2,win=7.95,step=0.15,pad=1000,xlab="Frequency (cycles/m)",ylab="Height (m)")

## for comparison generate spectrum for entire record, using time-bandwidth parameter of 3, and
## pad to 5000 points
## start by making a new plot
pl(1)
eha(ex1,tbw=3,win=38,pad=5000,xlab="Frequency (cycles/m)")
```

---

eTimeOpt	*eTimeOpt: Evolutive implementation of TimeOpt (Meyers, 2015; Meyers, 2019)*

Description

eTimeOpt: Evolutive implementation of TimeOpt (Meyers, 2015; Meyers, 2019).

Usage

```
eTimeOpt(dat,win=dt*100,step=dt*10,sedmin=0.5,sedmax=5,numsed=100,linLog=1,
    limit=T,fit=1,fitModPwr=T,flow=NULL,fhigh=NULL,roll=NULL,targetE=NULL,targetP=NULL,
    detrend=T,ydir=1,palette=6,ncolors=100,output=1,genplot=T,check=T,verbose=1)
```

Arguments

dat	Stratigraphic series for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
win	Window size, in meters.
step	Step size for moving window, in meters.
sedmin	Minimum sedimentation rate for investigation (cm/ka).
sedmax	Maximum sedimentation rate for investigation (cm/ka).
numsed	Number of sedimentation rates to investigate in optimization grid.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log; default value is 1)
limit	Limit evaluated sedimentation rates to region in which full target signal can be recovered? (T or F).
fit	Test for (1) precession amplitude modulation or (2) short eccentricity amplitude modulation?
fitModPwr	Include the modulation periods in the spectral fit? (T or F)
flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka)
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka)
roll	Taner filter roll-off rate, in dB/octave.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with a first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
detrend	Remove linear trend from data series? (T or F)
ydir	Direction for y-axis in plots (depth,height,time). -1 = values increase downwards (slower plotting), 1 = values increase upwards
palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red (if values are negative and positive, white is centered on zero), (6) viridis
ncolors	Number of colors steps to use in palette.
output	Which results would you like to return to the console? (0) no output; (1) everything, (2) r^2_envelope, (3) r^2_power, (4) r^2_opt
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (0=nothing, 1=minimal, 2=a little more, 3=everything!)

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography, v.30, 1625-1640.

S.R. Meyers, 2019, *Cyclostratigraphy and the problem of astrochronologic testing*: Earth-Science Reviews v.190, 190-223.

See Also

tracePeak, trackPeak, timeOpt, timeOptSim, and eTimeOptTrack

Examples

```
## Not run:
# generate a test signal with precession and eccentricity
ex=cycles(freqs=c(1/405.6795,1/130.719,1/123.839,1/98.86307,1/94.87666,1/23.62069,
1/22.31868,1/19.06768,1/18.91979),end=4000,dt=5)

# convert to meters with a linearly increasing sedimentation rate from 0.01 m/kyr to 0.03 m/kyr
ex=sedRamp(ex,srstart=0.01,srend=0.03)

# interpolate to median sampling interval
ex=linterp(ex)

# evaluate precession & eccentricity power, and precession modulations
res=eTimeOpt(ex,win=20,step=1,fit=1,output=1)

# extract the optimal fits for the power optimization
sedrates=eTimeOptTrack(res[2])

# extract the optimal fits for the envelope*power optimization
sedrates=eTimeOptTrack(res[3])

# you can also interactively track the results using functions 'trackPeak' and 'tracePeak'
#  evaluate the results from the power optimization
sedrates=tracePeak(res[2])
sedrates=trackPeak(res[2])

#  evaluate the results from the envelope*power optimization
sedrates=tracePeak(res[3])
sedrates=trackPeak(res[3])

# evaluate precession & eccentricity power, and short-eccentricity modulations
eTimeOpt(ex,win=20,step=1,fit=2,output=0)

## End(Not run)
```

---

eTimeOptTrack   *Track eTimeOpt r2 maxima*

Description

Track eTimeOpt r2 maxima.

Usage

```
eTimeOptTrack(res,threshold=0,ydir=-1,genplot=T,verbose=T)
```

Arguments

res	eTimeOpt r2 results. Must have the following format: column 1=sedimentation rate; remaining columns (2 to n)=r2; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eTimeOpt.
threshold	Threshold r2-value for analysis and plotting.
ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

Please see function eTimeOpt for details.

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography, v.30, 1625-1640.

S.R. Meyers, 2019, *Cyclostratigraphy and the problem of astrochronologic testing*: Earth-Science Reviews v.190, 190-223.

See Also

[timeOpt](), and [eTimeOpt]()

Examples

```
## Not run:
# generate a test signal with precession and eccentricity
ex=cycles(freqs=c(1/405.6795,1/130.719,1/123.839,1/98.86307,1/94.87666,1/23.62069,
1/22.31868,1/19.06768,1/18.91979),end=4000,dt=5)

# convert to meters with a linearly increasing sedimentation rate from 0.01 m/kyr to 0.03 m/kyr
ex=sedRamp(ex,srstart=0.01,srend=0.03)

# interpolate to median sampling interval
ex=linterp(ex)

# evaluate precession & eccentricity power, and precession modulations
res=eTimeOpt(ex,win=20,step=1,fit=1,output=1)

# extract the optimal fits for the power optimization
sedrates=eTimeOptTrack(res[2])

# extract the optimal fits for the envelope*power optimization
sedrates=eTimeOptTrack(res[3])

# you can also interactively track the results using functions 'trackPeak' and 'tracePeak'
```

```
#  evaluate the results from the power optimization
sedrates=trackPeak(res[2])
sedrates=tracePeak(res[2])

#  evaluate the results from the envelope*power optimization optimization
sedrates=trackPeak(res[3])
sedrates=tracePeak(res[3])

## End(Not run)
```

---

etp   *Generate eccentricity-tilt-precession models*

Description

Calculate eccentricity-tilt-precession time series using the theoretical astronomical solutions. By default, the Laskar et al. (2004) solutions will be downloaded. Alternatively, one can specify the astronomical solution.

Usage

```
etp(tmin=NULL,tmax=NULL,dt=1,eWt=1,oWt=1,pWt=1,esinw=T,solution=NULL,standardize=T,
    genplot=T,verbose=T)
```

Arguments

tmin	Start time (ka before present, J2000) for ETP. Default value is 0 ka, unless the data frame 'solution' is specified, in which case the first time datum is used.
tmax	End time (ka before present, J2000) for ETP. Default value is 1000 ka, unless the data frame 'solution' is specified, in which case the last time datum is used.
dt	Sample interval for ETP (ka). Minimum = 1 ka.
eWt	Relative weight applied to eccentricity solution.
oWt	Relative weight applied to obliquity solution.
pWt	Relative weight applied to precession solution.
esinw	Use e*sinw in ETP calculation? (T or F). If set to false, sinw is used.
solution	A data frame containing the astronomical solution to use. The data frame must have four columns: Time (ka, positive and increasing), Precession Angle, Obliquity, Eccentricity.
standardize	Standardize (subtract mean, divide by standard deviation) precession, obliquity and eccentricity series before applying weight and combining? (T or F)
genplot	Generate summary plots? (T or F).
verbose	Verbose output? (T or F).

Details

Note: If you plan to repeatedly execute the etp function, it is advisable to download the astronomical solution once using the function getLaskar.

Note: It is common practice to construct ETP models that have specified variance ratios (e.g., 1:1:1 or 1:0.5:0.5) for eccentricity, obliquity and precession. In order to construct such models, it is necessary to choose 'standardize=T', and to set the individual weights (eWt, oWt, pWt) to the square root of the desired variance contribution.

Value

Eccentricity + tilt + precession.

References

Laskar, J., Robutel, P., Joutel, F., Gastineau, M., Correia, A.C.M., Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

Laskar, J., Fienga, A., Gastineau, M., Manche, H., 2011, *La2010: A new orbital solution for the long-term motion of the Earth*: Astron. Astrophys., Volume 532, A89.

Laskar, J., Gastineau, M., Delisle, J.-B., Farres, A., Fienga, A.: 2011, *Strong chaos induced by close encounters with Ceres and Vesta*: Astron. Astrophys., Volume 532, L4.

See Also

getLaskar

Examples

```
 ## Not run:
# create an ETP model from 10000 ka to 20000 ka, with a 5 ka sampling interval
# this will automatically download the astronomical solution
ex=etp(tmin=10000,tmax=20000,dt=5)

# alternatively, download the astronomical solution first
ex2=getLaskar()
ex=etp(tmin=10000,tmax=20000,dt=5,solution=ex2)

## End(Not run)
```

---

extract | *Extract record from EHA time-frequency output or eAsm output*

Description

Extract record from EHA time-frequency output or eAsm output: Use interactive graphical interface to identify record.

Usage

```
extract(spec,get=NULL,xmin=NULL,xmax=NULL,ymin=NULL,ymax=NULL,h=6,w=4,ydir=1,pl=0,
        ncolors=100,genplot=T,verbose=T)
```

Arguments

spec	Time-frequency spectral results to evaluate, or alternatively, eAsm results to evaluate. For time-frequency results, must have the following format: column 1=frequency; remaining columns (2 to n)=power, amplitude or probability; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eha. For eAsm results, must have the following format: column 1=sedimentation rate; remaining columns (2 to n)=Ho-SL or ASM; titles for columns 2 to n must be the location (depth or height).
get	Record to extract (height/depth/time). If no value given, graphical interface is activated.
xmin	Minimum frequency or sedimentation rate for PLOTTING.
xmax	Maximum frequency or sedimentation rate for PLOTTING.
ymin	Minimum depth/height for PLOTTING.
ymax	Maximum depth/height for PLOTTING.
h	Height of plot in inches.
w	Width of plot in inches.
ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.
pl	An option for the color plots (0=do nothing; 1=plot log of value [useful for plotting power], 2=normalize to maximum value [useful for plotting amplitude]).
ncolors	Number of colors to use in plot.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

[eha](#)

---

flip	*Flip stratigraphic series*

Description

Flip the stratigraphic order of your data series (e.g., convert stratigraphic depth series to height series, relative to a defined datum.)

Usage

```
flip(dat,begin=0,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series. First column should be location (e.g., depth), second column should be data value.
begin	Depth/height value to assign to (new) first stratigraphic datum.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

freq2sedrate	*Convert record of local spatial frequency (from EHA) to sedimentation rate curve*

Description

Convert record of local spatial frequency (from EHA) to sedimentation rate curve

Usage

```
freq2sedrate(freqs,period=NULL,ydir=1,genplot=T,verbose=T)
```

Arguments

freqs	Data frame containing depth/height in first column (meters) and spatial frequencies in second column (cycles/m)
period	Temporal period of spatial frequency (ka)
ydir	Direction for y-axis in plots (depth,height). -1 = values increase downwards (slower), 1 = values increase upwards
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

gausTaper	*Apply Gaussian taper to stratigraphic series*

Description

Apply a Gaussian taper to a stratigraphic series

Usage

```
gausTaper(dat,alpha=3,rms=T,demean=T,detrend=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for tapering. First column should be location (e.g., depth), second column should be data value. If no data is identified, will output a 256 point taper to evaluate the spectral properties of the window.
alpha	Gaussian window parameter: alpha is 1/stdev, a measure of the width of the Dirichlet kernel. Larger values decrease the width of data window, reduce discontinuities, and increase width of the transform. Choose alpha >= 2.5.
rms	Normalize taper to RMS=1 to preserve power for white process? (T or F)
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

References

Harris, 1978, *On the use of windows for harmonic analysis with the discrete Fourier transform*: Proceedings of the IEEE, v. 66, p. 51-83.

See Also

[cosTaper](), [dpssTaper](), and [hannTaper]()

---

getColor	*Query R for color information*

Description

Query R for color information.

Usage

```
getColor(color)
```

Arguments

color	The name of the color you are interested in, in quotes.

---

getData *Download file from astrochron data server*

Description

Download data file from astrochron server.

Usage

```
getData(dat="1262-a*")
```

Arguments

dat
A character string that specifies the data file to download. At present there are eleven options: "1262-a*" , "926B-18O", "graptolite", "Xiamaling-CuAl", "607-18O" , "AEB-18O" , "Newark-rank", "CDL-rank", "DVCP2017-18O", "AND2A-clast", "U1521A-clast"

---

getLaskar *Download Laskar et al. (2004, 2011a, 2011b) astronomical solutions*

Description

Download Laskar et al. (2004, 2011a, 2011b) astronomical solutions.

Usage

```
getLaskar(sol="la04",verbose=T)
```

Arguments

sol
A character string that specifies the astronomical solution to download: "la04","la10a","la10b","la10c","la

verbose
Verbose output? (T or F)

Details

la04 : three columns containing precession angle, obliquity, and eccentricity of Laskar et al. (2004)

la10a : one column containing the la10a eccentricity solution of Laskar et al. (2011a)

la10b : one column containing the la10b eccentricity solution of Laskar et al. (2011a)

la10c : one column containing the la10c eccentricity solution of Laskar et al. (2011a)

la10d : one column containing the la10d eccentricity solution of Laskar et al. (2011a)

la11 : one column containing the la11 eccentricity solution of Laskar et al. (2011b; please also cite 2011a)

insolation : one column containing insolation at 65 deg North (W/m^2) during summer solstice, from Laskar et al. (2004)

References

J. Laskar, P. Robutel, F. Joutel, M. Gastineau, A.C.M. Correia, and B. Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

Laskar, J., Fienga, A., Gastineau, M., Manche, H., 2011a, *La2010: A new orbital solution for the long-term motion of the Earth*: Astron. Astrophys., Volume 532, A89.

Laskar, J., Gastineau, M., Delisle, J.-B., Farres, A., Fienga, A.: 2011b, *Strong chaos induced by close encounters with Ceres and Vesta, Astron*: Astrophys., Volume 532, L4.

---

hannTaper	*Apply Hann taper to stratigraphic series*

Description

Apply a Hann (Hanning) taper to a stratigraphic series

Usage

```
hannTaper(dat,rms=T,demean=T,detrend=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for tapering. First column should be location (e.g., depth), second column should be data value. If no data is identified, will output a 256 point taper to evaluate the spectral properties of the window.
rms	Normalize taper to RMS=1 to preserve power for white process? (T or F)
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

cosTaper, dpssTaper, and gausTaper

---

headn   *List column numbers for each variable*

Description

Execute 'head' function, with column numbers indicated for each variable. (useful for functions such as 'autopl')

Usage

```
headn(dat)
```

Arguments

dat   Your data frame.

---

hilbert   *Hilbert transform of stratigraphic series*

Description

Calculate instantaneous amplitude (envelope) and phase via Hilbert Transform of stratigraphic series

Usage

```
hilbert(dat,phase=F,padfac=2,demean=T,detrend=F,output=T,addmean=F,genplot=T,check=T,
        verbose=T)
```

Arguments

dat	Stratigraphic series to Hilbert Transform. First column should be location (e.g., depth), second column should be data value.
phase	Calculate instantaneous phase? (T or F)
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
output	Return results as new data frame? (T or F)
addmean	Add mean value to instantaneous amplitude? (T or F)
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Examples

```
# generate example series with 3 precession terms and noise
ex <- cycles(noisevar=.0004,dt=5)
# bandpass precession terms using cosine-tapered window
res_ex <- bandpass(ex,flow=0.038,fhigh=0.057,win=2,p=.4)
# hilbert transform
hil_ex <- hilbert(res_ex)
```

---

idPts   *Interactively identify points in plot*

Description

Interactively identify points in x,y plot.

Usage

```
idPts(dat1,dat2=NULL,ptsize=0.5,xmin=NULL,xmax=NULL,ymin=NULL,ymax=NULL,
       logx=F,logy=F,plotype=1,annotate=1,iso=F,output=1,verbose=T)
```

Arguments

dat1	Data frame with one, two or three columns. If one column, dat2 must also be specified. If three columns, the data frame is assumed to represent a stratigraphic series, and the first column should be depth, height or time.
dat2	Data frame with one column.
ptsize	Size of plotted points.
xmin	Minimum x-value (column 1) to plot
xmax	Maximum x-value (column 1) to plot
ymin	Minimum y-value (column 2) to plot
ymax	Maximum y-value (column 2) to plot
logx	Plot x-axis using logarithmic scaling? (T or F)
logy	Plot y-axis using logarithmic scaling? (T or F)
plotype	Type of plot to generate: 1= points and lines, 2 = points, 3 = lines
annotate	Annotate plot with text indicating coordinates?: 0=none, 1=annotate above point, 2=annotate below point
iso	Isolate data between minimum and maximum x-values selected? (T or F) This option requires that both dat1 and dat2 have one column each, or if dat2 is null, dat1 has only two columns.
output	Return identified points as a data frame? (0) no, (1) return x and y, (2) return index, x and y. If dat1 contains three columns, option 2 will return index, location, x and y.
verbose	Verbose output? (T or F)

See Also

[delPts](), [iso](), [trim]() and [trimAT]()

---

imbrie   *Imbrie and Imbrie (1980) ice sheet model*

Description

An implementation of the Imbrie and Imbrie (1980) ice sheet model

Usage

```
imbrie(insolation=NULL,Tm=17,b=0.6,times=NULL,initial=0,burnin=100,standardize=T,
        output=T,genplot=1,check=T,verbose=T)
```

Arguments

insolation	Insolation, in ka (negative for future, positive for past). Default is insolation over the past 1000 ka from 65 deg. North, 21 June.
Tm	Vector of mean time constants in ka. Default is 17 ka. The order of the Tm values should match vectors b and times.
b	Vector of nonlinearity coefficient (a value ranging from 0 to 1). Default is 0.6. The order of the b values should match vectors Tm and times.
times	Vector of start times for each Tm and b listed above. Leave as NULL if you only need to model one Tm and b value.
initial	Initial value for ice volume, relative to centered record. Default is 0.
burnin	Number of points for model burn-in. This is required to achieve stable model results. Default is 100 points.
standardize	Standardize model output to maximum value of one and minimum value of zero? (T or F)
output	Output model results? (T or F)
genplot	Generate summary plots? (1) plot insolation and ice volume series, (2) plot animated insolation, ice volume and phase portrait.)
check	Conduct compliance checks before processing? (T or F). In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Details

This function will implement the ice volume model of Imbrie and Imbrie (1980), following the conventions of Paillard et al. (1996).

When using the 'times' vector, consider the following example:

times= c(500,1000)

Tm=c(15,5)

b=c(0.6,0.3)

In this case, a Tm of 15 (b of 0.6) will be applied to model from 0-500 ka, and a Tm of 5 (b of 0.3) will be applied to model 500-1000 ka.

References

Imbrie, J., and Imbrie, J.Z., (1980), *Modeling the Climatic Response to Orbital Variations*: Science, v. 207, p. 943-953.

Lisiecki, L. E., and M. E. Raymo, 2005, *A Pliocene-Pleistocene stack of 57 globally distributed benthic d18O records*, Paleoceanography, 20, PA1003, doi:10.1029/2004PA001071.

Paillard, D., L. Labeyrie and P. Yiou, (1996), *Macintosh program performs time-series analysis*: Eos Trans. AGU, v. 77, p. 379.

Examples

```
## Not run:
# make a very simple forcing (on/off)
forcing=cycles(0,end=300)
forcing[50:150,2]=1
plot(forcing,type="l")

# use this forcing to drive the imbrie ice model
# set b=0, Tm = 1
imbrie(forcing,b=0,Tm=1,output=F)

# let's view the evolution of the ice sheet
imbrie(forcing,b=0,Tm=1,output=F,genplot=2)

# now increase the response time
imbrie(forcing,b=0,Tm=10,output=F,genplot=2)

# now model slow growth, fast decay
imbrie(forcing,b=0.5,Tm=10,output=F,genplot=2)

# now make a 100 ka cyclic forcing
forcing=cycles(1/100,end=300)
imbrie(forcing,b=0,Tm=1,output=F,genplot=2)
imbrie(forcing,b=0,Tm=10,output=F,genplot=2)
imbrie(forcing,b=0.5,Tm=10,output=F,genplot=2)
# show burn-in
imbrie(forcing,b=0.5,Tm=10,output=F,genplot=2,burnin=0)
```

```
# now examine Malutin Milankovitch's hypothesis: 65 deg N, summer solstice
imbrie(b=0.5,Tm=10,output=F,genplot=2,burnin=900)

# use the ice model output to make a synthetic stratigraphic section
res=imbrie(b=0.5,T=10,output=T,genplot=1,burnin=100)
synthStrat(res,clip=F)

# generate ice model for last 5300 ka, using 65 deg. N insolation, 21 June
# allow b and Tm values to change as in Lisiecki and Raymo (2005):
insolation=getLaskar("insolation")
insolation=iso(insolation,xmin=0,xmax=5300)
#  b is 0.3 from 5300 to 3000 ka, then linearly increases to 0.6 between 3000 and 1500 ka.
#  b is 0.6 from 1500 ka to present.
set_b=linterp(cb(c(1500,3000),c(0.6,0.3)),dt=1)
set_b=rbind(set_b,c(5400,0.3))
# Tm is 5 ka from 5300 to 3000 ka, then linearly increases to 15 ka between 3000 and 1500 ka.
#  Tm is 15 ka from 1500 ka to present.
set_Tm=linterp(cb(c(1500,3000),c(15,5)),dt=1)
set_Tm=rbind(set_Tm,c(5400,5))
# now run model
ex=imbrie(insolation=insolation,Tm=set_Tm[,2],b=set_b[,2],times=set_b[,1])
# time-frequency analysis of model result
eha(ex,fmax=0.1,win=500,step=10,pad=5000,genplot=4,pl=2)


## End(Not run)
```

---

impulseResponse   *Impulse response function calculation*

Description

Calculate the analytical response function from an impulse forcing using the 1-D advection diffusion model proposed in Schink and Guinasso (1975) to model the bioturbation impact on climate time series.

Usage

```
impulseResponse(G, ML = NULL, v = NULL, nt = 500, genplot = FALSE,
  verbose = FALSE)
```

Arguments

G	Bioturbation parameter. G = D/ML/v
ML	Mix layer depth (cm)
v	Sedimentation rate (cm/kyr)
nt	Number of steps after the signal is deposited.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Value

fc Impulse response function

References

Guinasso, N.L. and Schinck, D.R., 1975, *Quantitative estimates of biological mixing rates in abyssal sediments*, J. Geophys. Res., 80, 3032-3043.

Goreau, T.J., 1977, *Quantitative effects of sediment mixing on stratigraphy and biogeochemistry: a signal theory approach*, Nature, 256, 730-732.

Goreau, T.J., 1980, *Frequency sensitivity of the deep-sea climatic record*, Nature, 287, 620-622.

Liu, H., Meyers, S.R., and Marcott, S.A., 2021, *Unmixing dee-sea paleoclimate records: A study on bioturbation effects through convolution and deconvolution*, Earth and Planetary Science Letters, 564, 116883.

Examples

```
G <- 4
ML <- 10
v <- 1
# take a look at the IRF
impulseResponse(G=4, ML = 10, v = 1, genplot = TRUE)
```

---

insoDiff   *insolation difference map using Laskar et al. (2004) insolation calculations*

Description

Generate map that show difference in insolation between two times using Laskar et al. (2004) insolation calculations. This is a wrapper function to calculate insolation using the palinsol package, following astrochron syntax.

Usage

```
insoDiff(t1,t2,S0=1365,verbose=T)
```

Arguments

t1	Time 1, in kyr (negative for future, positive for past; valid from -21000 to 51000)
t2	Time 2, in kyr (negative for future, positive for past; valid from -21000 to 51000)
S0	Solar constant, W/m^2
verbose	Verbose output? (T or F)

Details

This wrapper function generates maps with insolation calculations based on the Laskar et al. (2004) astronomical parameters, using the 'palinsol' package (Crucifix, 2016).

References

Crucifix, M., 2016, *palinsol: Insolation for Palaeoclimate Studies. R package version 0.93*: https://CRAN.R-project.org/package=palinsol

J. Laskar, P. Robutel, F. Joutel, M. Gastineau, A.C.M. Correia, and B. Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

---

insoMap	*generate an insolation map using Laskar et al. (2004) insolation calculations*

Description

Generate insolation maps using Laskar et al. (2004) insolation calculations. This is a wrapper function to calculate insolation using the palinsol package, following astrochron syntax.

Usage

```
insoMap(t=0,pick=0,S0=1365,output=F,verbose=T)
```

Arguments

t	Time for evaluation, in kyr (negative for future, positive for past; valid from -21000 to 51000)
pick	Interactively pick (1) latitude to examine seasonal insolation at that latitude, or (2) day to examine insolation across latitude
S0	Solar constant, W/m^2
output	Output insolation matrix (if pick=0) or selected insolation transect (if pick = 1 or 2)? (T or F)
verbose	Verbose output? (T or F)

Details

This wrapper function generates maps with insolation calculations based on the Laskar et al. (2004) astronomical parameters, using the 'palinsol' package (Crucifix, 2016).

Option 'pick' will allow you to extract insolation by (1) latitude or (2) season.

References

Crucifix, M., 2016, *palinsol: Insolation for Palaeoclimate Studies. R package version 0.93*: https://CRAN.R-project.org/package=palinsol

J. Laskar, P. Robutel, F. Joutel, M. Gastineau, A.C.M. Correia, and B. Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

---

insoSeries   *Laskar et al. (2004) insolation calculations*

Description

Laskar et al. (2004) insolation calculations. This is a wrapper function to calculate insolation using the palinsol package, following astrochron syntax.

Usage

```
insoSeries(tmin=0,tmax=1000,dt=1,opt=1,long=90,lat=65,threshold=400,l1=0,l2=70,S0=1365,
           genplot=TRUE,verbose=TRUE)
```

Arguments

tmin	Minimum time for evaluation, in kyr (negative for future, positive for past; valid from -21000 to 51000)
tmax	Maximum time for evaluation, in kyr (negative for future, positive for past; valid from -21000 to 51000)
dt	Sampling interval in kyr. Must be >= 1
opt	1=Calculate daily mean insolation for given day and latitude; 2=calculate caloric insolation for given latitude; 3=calculate integrated insolation for given latitude; 4=calculating integrated insolation for given latitude, with threshold
long	True solar longitude, in degrees, 0-360
lat	Latitude on the Earth for evaluation, in degrees, -90 to 90
threshold	Threshold insolation, in W/m^2
l1	Lower true solar longitude bound of the time-integral, in degrees, 0-360
l2	Upper true solar longitude bound of the time-integral, in degrees, 0-360
S0	Solar constant, W/m^2
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

This wrapper function performs four different types of insolation calculations based on the Laskar et al. (2004) astronomical parameters, using the 'palinsol' package (Crucifix, 2016).

The following 'palinsol' functions are used:

opt 1: Insol - Calculate Mean Insolation for Given Day and Latitude

opt 2: calins - Calculate Caloric Insolation for Given Latitude (Milankovitch; Berger, 1978)

opt 3: Insol_l1l2 - Calculate Integrated Insolation for Given Latitude (Berger et al., 2010)

opt 4: thrins - Calculate Integrated Insolation for Given Latitude, with Threshold (Huybers and Tziperman, 2008)

la04 - Calculate astronomical parameters (Laskar et al., 2004)

Please see those functions for further details.

If opt 1 is selected: specify 'long' and 'lat'

If opt 2 is selected: specify 'lat'

If opt 3 is selected: specify 'lat', 'l1' and 'l2'

If opt 4 is selected: specify 'lat' and 'threshold'

APPROXIMATE CONVENTIONAL DATES FOR A GIVEN MEAN LONGITUDE (long):

0: 21 March (equinox)

30: 21 April

60: 21 May

90: 21 June (solstice)

120: 21 July

150: 21 August

180: 21 September (equinox)

210: 21 October

240: 21 November

270: 21 December (solstice)

300: 21 January

330: 21 February

References

Berger, A., 1978, *Long-term variations of caloric insolation resulting from the earth's orbital elements*: Quaternary Research, 9, 139 - 167.

Berger, A., Loutre, M.F., Yin Q., 2010, *Total irradiation during any time interval of the year using elliptic integrals*: Quaternary Science Reviews, 29, 1968 - 1982, doi:10.1016/j.quascirev.2010.05.007

Crucifix, M., 2016, *palinsol: Insolation for Palaeoclimate Studies. R package version 0.93*: https://CRAN.R-project.org/package=palinsol

Huybers, P., Tziperman, E., 2008, *Integrated summer insolation forcing and 40,000-year glacial cycles: The perspective from an ice-sheet/energy-balance model*: Paleoceanography, 23.

J. Laskar, P. Robutel, F. Joutel, M. Gastineau, A.C.M. Correia, and B. Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

---

integratePower   *Determine the total power within a given bandwidth*

Description

Determine the total power within a given bandwidth, and also the ratio of this power to the total power in the spectrum (or up to a specified frequency). If bandwidth is not specified, generate interactive plots for bandwidth selection. For use with the function eha, integratePower can process spectrograms (time-frequency) or single spectra.

Usage

```
integratePower(spec,flow=NULL,fhigh=NULL,fmax=NULL,unity=F,f0=T,xmin=NULL,
               xmax=NULL,ymin=NULL,ymax=NULL,npts=NULL,pad=NULL,ydir=1,
               palette=6,ncolors=100,h=6,w=9,ln=F,genplot=T,verbose=T)
```

Arguments

spec	Spectral results to evaluate. If the data frame contains time-frequency results, it must have the following format: column 1=frequency; remaining columns (2 to n)=power; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eha. If the data frame contains one spectrum, it must have the following format: column 1=frequency, column 2=power.
flow	Low frequency cutoff for integration. If flow or fhigh are not specified, interactive plotting is activated.
fhigh	High frequency cutoff for integration. If flow or fhigh are not specified, interactive plotting is activated.
fmax	Integrate total power up to this frequency.
unity	Normalize spectra such that total variance (up to fmax) is unity. (T of F)
f0	Is f(0) included in the spectra? (T or F)
xmin	Minimum frequency for PLOTTING.
xmax	Maximum frequency for PLOTTING.
ymin	Minimum depth/height/time for PLOTTING. Only used if processing time-frequency results.
ymax	Maximum depth/height/time for PLOTTING. Only used if processing time-frequency results.
npts	The number of points in the processed time series window. This is needed for proper spectrum normalization.
pad	The total padded length of the processed time series window. This is needed for proper spectrum normalization.
ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards. Only used if processing time-frequency results.

palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red, (6) viridis
ncolors	Number of colors to use in plot. Only used if processing time-frequency results.
h	Height of plot in inches.
w	Width of plot in inches.
ln	Plot natural log of spectral results? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

Depending on the normalization used, you may want to preprocess the power spectra prior to integration.

See Also

[eha](#)

Examples

```
# generate etp signal over past 10 Ma
ex=etp(tmax=10000)

# evolutive power
pwr=eha(ex,win=500,fmax=.1,pad=2000,output=2,pl=2)

# integrate power from main obliquity term
integratePower(pwr,flow=0.02,fhigh=0.029,npts=501,pad=2000)
```

---

iso	*Isolate data from a specified stratigraphic interval*

Description

Isolate a section of a uni- or multi-variate stratigraphic data set for further analysis

Usage

```
iso(dat,xmin,xmax,col=2,logx=F,logy=F,genplot=T,verbose=T)
```

Arguments

dat	Data frame containing stratigraphic variable(s) of interest. First column must be location (e.g., depth).
xmin	Minimum depth/height/time for isolation. If xmin is not specified, it will be selected using a graphical interface.
xmax	Maximum depth/height/time for isolation. If xmax is not specified, it will be selected using a graphical interface.
col	If you are using the graphical interface to select xmin/xmax, which column would you like to plot? (default = 2).
logx	Plot x-axis using logarithmic scaling? (T or F)
logy	Plot y-axis using logarithmic scaling? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

[delPts](), [idPts](), [trim]() and [trimAT]()

---

linage	*Tune stratigraphic series to an astronomical target using graphical interface*

Description

Tune stratigraphic series to an astronomical target using graphical interface similar to Analyseries 'Linage' routine (Paillard et al, 1996).

Usage

```
linage(dat,target,extrapolate=F,xmin=NULL,xmax=NULL,tmin=NULL,tmax=NULL,size=1,plotype=1,
       output=1,genplot=T)
```

Arguments

dat	Stratigraphic series for tuning, with two columns. First column is depth/height.
target	Astronomical tuning target series. First column is time.
extrapolate	Extrapolate sedimentation rates above and below 'tuned' interval? (T or F)
xmin	Minimum height/depth to plot.
xmax	Maximum height/depth to plot.
tmin	Minimum time value to plot.
tmax	Maximum time value to plot.
size	Multiplicative factor to increase or decrease size of symbols and fonts.

plotype	Type of plot to generate: 1= points and lines, 2 = points, 3 = lines
output	Return which of the following? 1 = tuned stratigraphic series; 2 = age control points; 3 = tuned stratigraphic series and age control points
genplot	Generate additional summary plots (tuned record, time-space map, sedimentation rates)? (T or F)

References

Paillard, D., L. Labeyrie and P. Yiou, 1996), *Macintosh program performs time-series analysis*: Eos Trans. AGU, v. 77, p. 379.

Examples

```
 ## Not run:
# Check to see if this is an interactive R session, for compliance with CRAN standards.
# YOU CAN SKIP THE FOLLOWING LINE IF YOU ARE USING AN INTERACTIVE SESSION.
if(interactive()) {

# generate example series with 3 precession terms and noise using function 'cycles'
# then convert from time to space using sedimentation rate that increases from 1 to 7 cm/ka
ex=sedRamp(cycles(start=1,end=400, dt=2,noisevar=.00005),srstart=0.01,srend=0.07)

# create astronomical target series
targ=cycles(start=1,end=400,dt=2)

## manually tune
tuned=linage(ex,targ)

## should you need to flip the direction of the astronomical target series, use function 'cb':
tuned=linage(ex,cb(targ[1]*-1,targ[2]))

}


## End(Not run)
```

---

linterp *Piecewise linear interpolation of stratigraphic series*

Description

Interpolate stratigraphic series onto a evenly sampled grid, using piecewise linear interpolation

Usage

```
linterp(dat,dt,start,genplot=T,check=T,verbose=T)
```

Arguments

dat	Stratigraphic series for piecewise linear interpolation. First column should be location (e.g., depth), second column should be data value.
dt	New sampling interval.
start	Start interpolating at what time/depth/height value? By default, the first value of the stratigraphic series will be used.
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

---

linterpLH13	*Piecewise linear interpolation of stratigraphic series using the approach of Laepple and Huybers (2013)*

Description

Linearly interpolate stratigraphic series using the approach of Laepple and Huybers (2013), including anti-alias filtering.

Usage

```
linterpLH13(dat,dt=NULL,start=NULL,dtMin=NULL,thresh=0.7,beta=1,tbw=20,smooth=0.05,
        logF=F, antialias=T,roll=10^10,nsim=1,ncores=2,output=T,maxF=NULL,pl=1,
            genplot=T,check=T,verbose=1)
```

Arguments

dat	Stratigraphic series for piecewise linear interpolation. First column should be location (e.g., depth), second column should be data value.
dt	New optimal sampling interval. If dt is not specified, it will be estimated using the approach of Laepple and Huybers (2013).
start	Start interpolating at what time/depth/height value? By default, the first value of the stratigraphic series will be used.
dtMin	Very fine sampling interval for noise generation. If dt is not specified, the finest sample spacing of dat is used.
thresh	Threshold value for R2 (see details). Default value is 0.7 as in Laepple and Huybers (2013)
beta	Power law coefficient for stochastic surrogates, >=0.
tbw	MTM time-bandwidth product.
smooth	Smoothing parameter for spectral ratio R (see details).
logF	Smooth ratio R using log10 transformed frequency? (T or F)

antialias	Apply anti-alias filter? (T or F)
roll	Taner filter roll-off rate for anti-alias filter, in dB/octave.
nsim	Number of Monte Carlo simulations.
ncores	Number of cores to use for parallel processing.
maxF	Maximum frequency for spectrum plotting.
pl	Plot logarithm of spectral power (1) or linear spectral power (2)?
output	Return interpolated series as new data frame? (T or F)
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F). In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (0=none, 1=some reporting, 2=extensive reporting)

Details

This function seeks to estimate the optimal sampling interval for piecewise linear interpolation of an unevenly sampled stratigraphic series ("D"), so as to reduce bias when reconstructing the spectral background. The algorithm is slightly modified from Laepple and Huybers (2013), and consists of the following steps:

(1) Generate a 1/f stochastic noise signal, N. A sampling interval equivalent to the finest step of data set D is used for the noise model if dtMin is NULL.

(2) Subsample the 1/f noise (N) on the actual data set D sampling grid, yielding N2.

(3) Interpolate the subsampled 1/f noise (N2) to dtMin, yielding N3.

(4) Calculate the MTM power spectra for N (Spec_N) and N3 (Spec_N3), using a low resolution spectrum to provide a relatively smooth estimate of the continuum.

(5) Divide the resampled power spectrum (Spec_N3) by unresampled spectrum (Spec_N), yielding the ratio R.

(6) Smooth the ratio R using a Gaussian kernel, yielding R2.

(7) Estimate the highest reliable frequency (F) as the lowest frequency at which the ratio R2 < 0.7 (or specified thresh value).

(8) Calculate the optimal interpolation resolution, dt, as 0.5/F.

If anti-alias filtering is selected:

(9) Interpolate the data set D to 0.1*dt, yielding D2.

(10) Filter D2 using a Taner lowpass (anti-alias) filter with a cutoff frequency of 1.2/dt, yielding D3.

(11) Resample D3 at the optimal resolution dt, yielding D4.

If anti-alias filtering is not selected, instead of steps 9-11, resample D at the optimal resolution dt.

When anti-alias filtering is applied, the first and last value of the interpolated series (D4) have a tendency to be strongly biased if they closely align with the original sampling grid of D. To address this issue, the first and last interpolated points are removed if they are within 0.5*dt (the optimal interpolation interval) of the first or last sampling location of D.

NOTE: A finer (smaller increment) interpolation interval than the 'optimal' one proposed by linterpLH13 may be appropriate for astronomical signal detection, although the magnitude of the observed astronomical variability may be substantially underestimated.

References

T. Laepple and P. Huybers, 2013, *Reconciling discrepancies between Uk37 and Mg/Ca reconstructions of Holocene marine temperature variability*: Earth and Planetary Science Letters, v. 375, p. 418-429.

Examples

```
# generate example series from ar1 noise, 5 kyr sampling interval
ex = ar1(npts=501,dt=10)

# jitter sampling times
ex[1]=ex[1]+rnorm(501,sd=1)
# sort
ex = ex[order(ex[,1],na.last=NA,decreasing=FALSE),]

# view sampling statistics
strats(ex)

# run linterpLH13
linterpLH13(ex,output=FALSE)

# run linterpLH13 with multiple simulations
linterpLH13(ex,nsim=500,output=FALSE)
```

---

logT   *Log transformation of stratigraphic series*

Description

Log transformation of stratigraphic series.

Usage

```
logT(dat,c=0,opt=1,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for log transformation. Input can have any number of columns desired. If two or more columns are input, the first column must be location (e.g., depth), while remaining columns are data values for transformation.
c	Constant to add prior to log transformation. Default = 0.
opt	(1) use natural logarithm, (2) use log10. Default = 1.
genplot	Generate summary plots? (T or F). This is automatically deactivated if more than one variable is transformed.
verbose	Verbose output? (T or F)

See Also

[arcsinT](), [demean](), [detrend](), [divTrend](), [prewhiteAR](), and [prewhiteAR1]()

---

lowpass   *Lowpass filter stratigraphic series*

Description

Lowpass filter stratigraphic series using rectangular, Gaussian or tapered cosine window. This function can also be used to highpass filter a record (see examples).

Usage

```
lowpass(dat,padfac=2,fcut=NULL,win=0,demean=T,detrend=F,addmean=T,alpha=3,p=0.25,
        xmin=0,xmax=Nyq,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for lowpass filtering. First column should be location (e.g., depth), second column should be data value.
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
fcut	Cutoff frequency for lowpass filtering.
win	Window type for bandpass filter: 0 = rectangular , 1= Gaussian, 2= Cosine-tapered window.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
addmean	Add mean value to bandpass result? (T or F)
alpha	Gaussian window parameter: alpha is 1/stdev, a measure of the width of the Dirichlet kernal. Larger values decrease the width of data window, reduce discontinuities, and increase width of the transform. Choose alpha >= 2.5.
p	Cosine-tapered window parameter: p is the percent of the data series tapered (choose 0-1).
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

[bandpass](), [noKernel](), [noLow](), [prewhiteAR](), [prewhiteAR1](), and [taner]()

Examples

```
# generate example series with periods of 405 ka, 100 ka, 40ka, and 20 ka, plus noise
ex=cycles(freqs=c(1/405,1/100,1/40,1/20),end=1000,dt=5,noisevar=.1)

# lowpass filter eccentricity terms using cosine-tapered window
lowpass_ex=lowpass(ex,fcut=.02,win=2,p=.4)

# highpass filter obliquity and precession terms using cosine-tapered window
#  if you'd like the final notch filtered record to be centered on the mean proxy
#  value, set addmean=FALSE
highpass_ex=lowpass(ex,fcut=.02,win=2,p=.4,addmean=FALSE)
highpass_ex[2] <- ex[2]-highpass_ex[2]
pl(2)
plot(ex,type="l",main="Eccentricity+Obliquity+Precession")
plot(highpass_ex,type="l",main="Obliquity+Precession highpassed signal")
```

---

lowspec	*Robust Locally-Weighted Regression Spectral Background Estimation*

Description

LOWSPEC: Robust Locally-Weighted Regression Spectral Background Estimation (Meyers, 2012)

Usage

```
lowspec(dat,decimate=NULL,tbw=3,padfac=5,detrend=F,siglevel=0.9,setrho,
         lowspan,b_tun,output=0,CLpwr=T,xmin,xmax,pl=1,sigID=T,genplot=T,
         verbose=T)
```

Arguments

dat	Stratigraphic series for LOWSPEC. First column should be location (e.g., depth), second column should be data value.
decimate	Decimate statigraphic series to have this sampling interval (via piecewise linear interpolation). By default, no decimation is performed.
tbw	MTM time-bandwidth product (2 or 3 permitted)
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
detrend	Remove linear trend from data series? This detrending is performed following AR1 prewhitening. (T or F)
siglevel	Significance level for peak identification. (0-1)
setrho	Define AR1 coefficient for pre-whitening (otherwise calculated). If set to 0, no pre-whitening is applied.
lowspan	Span for LOWESS smoothing of prewhitened signal, usually fixed to 1. If using value <1, the method is overly conservative with a reduced false positive rate.

b_tun	Robustness weight parameter for LOWSPEC. By default, this will be estimated internally.
output	What should be returned as a data frame? (0=nothing; 1=pre-whitened spectrum + harmonic F-test CL + LOWSPEC background + LOWSPEC CL + 90%-99% LOWSPEC power levels; 2=sig peaks)
CLpwr	Plot LOWSPEC noise confidence levels on power spectrum? (T or F)
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
pl	Power spectrum plotting: (1) linear frequency-log spectral power, (2) linear frequency-linear spectral power (3) log frequency-log spectral power, (4) log frequency-linear spectral power
sigID	Identify significant frequencies on power and probabilty plots? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

LOWSPEC is a 'robust' method for spectral background estimation, designed for the identification of potential astronomical signals that are imbedded in red noise (Meyers, 2012). The complete algoritm implemented here is as follows: (1) initial pre-whitening with AR1 filter (default) or other filter as appropriate (e.g., see function prewhiteAR), (2) power spectral estimation via the multitaper method (Thomson, 1982), (3) robust locally weighted estimation of the spectral background using the LOWESS-based (Cleveland, 1979) procedure of Ruckstuhl et al. (2001), (4) assignment of confidence levels using a Chi-square distribution.

NOTE: If you choose to pre-whiten before running LOWSPEC (rather than using the default AR1 pre-whitening), specify setrho=0.

Candidiate astronomical cycles are subsequently identified via isolation of those frequencies that achieve the required (e.g., 90 percent) LOWSPEC confidence level and MTM harmonic F-test confidence level. Allowance is made for the smoothing inherent in the MTM power spectral estimate as compared to the MTM harmonic spectrum. That is, an F-test peak is reported if it achieves the required MTM harmonic confidence level, while also achieving the required LOWSPEC confidence level within +/- half the power spectrum bandwidth resolution. One additional criterion is included to further reduce the false positive rate, a requirement that significant F-tests must occur on a local power spectrum high, which is parameterized as occurring above the local LOWSPEC background estimate. See Meyers (2012) for futher information on the algorithm.

In this implementation, the 'robustness criterion' ('b' in EQ. 6 of Ruckstuhl et al., 2001) has been optimized for 2 and 3 pi DPSS, using a 'span' of 1. By default the robustness criterion will be estimated. Both 'b' and the 'span' can be expliclty set using parameters 'b_tun' and 'lowspan'. Note that it is permissible to decrease 'lowspan' from its default value, but this will result in an overly conservative false positive rate. However, it may be necessary to reduce 'lowspan' to provide an appropriate background fit for some stratigraphic data. Other options include decimating the data series prior to spectral estimation, or using an alternative pre-whitening filter (e.g., see function prewhiteAR).

Note that the 'rfbaseline' function in package 'IDPmisc' (Locher, 2024) is used for implementation of the procedure of Ruckstuhl et al. (2001).

Value

If option 1 is selected, a data frame containing the following is returned: Frequency, Prewhitened power, harmonic F-test CL, LOWSPEC CL, LOWSPEC background, 90%-99% LOWSPEC power levels. NOTE: as of version 0.8, the order of the columns in the output data frame has been changed, for consistency with functions mtm, mtmML96, and mtmPL.

If option 2 is selected, the 'significant' frequencies are returned (as described above).

References

W.S. Cleveland, 1979, *Locally weighted regression and smoothing scatterplots*: Journal of the American Statistical Association, v. 74, p. 829-836.

Locher R (2024). IDPmisc: 'Utilities of Institute of Data Analyses and Process Design (www.zhaw.ch/idp)'. R package version 1.1.21, https://CRAN.R-project.org/package=IDPmisc.

S.R. Meyers, 2012, *Seeing Red in Cyclic Stratigraphy: Spectral Noise Estimation for Astrochronology*: Paleoceanography, 27, PA3228, doi:10.1029/2012PA002307.

A.F. Ruckstuhl, M.P Jacobson, R.W. Field, and J.A. Dodd, 2001, *Baseline subtraction using robust local regression estimation*: Journal of Quantitative Spectroscopy & Radiative Transfer, v. 68, p. 179-193.

D.J. Thomson, 1982, *Spectrum estimation and harmonic analysis*: IEEE Proceedings, v. 70, p. 1055-1096.

See Also

eha, mtm, mtmAR, mtmML96, periodogram

Examples

```
# generate example series with periods of 400 ka, 100 ka, 40 ka and 20 ka
ex = cycles(freqs=c(1/400,1/100,1/40,1/20),start=1,end=1000,dt=5)

# add AR1 noise
noise = ar1(npts=200,dt=5,sd=.5)
ex[2] = ex[2] + noise[2]

# LOWSPEC analysis
pl(1, title="lowspec")
lowspec(ex)

# compare to MTM spectral analysis, with conventional AR1 noise test
pl(1,title="mtm")
mtm(ex,ar1=TRUE)

# compare to ML96 analysis
pl(1, title="mtmML96")
mtmML96(ex)

# compare to amplitudes from eha
pl(1,title="eha")
eha(ex,tbw=3,win=1000,pad=1000)
```

Description

Generate noise surrogates from a theoretical power spectrum.

Usage

```
makeNoise(S,dt=1,mean=0,sdev=1,addPt=F,nsim=1,genplot=T,verbose=T)
```

Arguments

S	Vector or 1-D data frame containing the theoretical power, from f(0) to the Nyquist frequency.
dt	Sampling interval for surrogate series
mean	Mean value for surrogate series
sdev	Standard deviation for surrogate series
addPt	Did you add a Nyquist frequency? (T or F)
nsim	Number of surrogate series to generate
genplot	generate summary plots (T or F)
verbose	verbose output (T or F)

Details

These simulations use the random number generator of Matsumoto and Nishimura [1998]. The algorithm of Timmer and Konig (1995) is employed to generate surrogates from any arbitrary theoretical power spectrum. See examples section below.

References

M. Matsumoto, and T. Nishimura, (1998), *Mersenne Twister: A 623-dimensionally equidistributed uniform pseudo-random number generator*, ACM Transactions on Modeling and Computer Simulation, 8, 3-30.

J. Timmer and K. Konig (1995), *On Generating Power Law Noise*, Astronomy and Astrophysics: v. 300, p. 707-710.

Examples

```
# create theoretical AR1 spectrum, using rho of 0.8
rho=0.8
freq=seq(0,.5,by=0.005)
Nyq=max(freq)
AR1 = (1-(rho^2)) / (  1 - (2*rho*cos(pi*freq/Nyq)) + (rho^2) )
plot(freq,AR1,type="l")
```

```
# make noise surrogates from the theoretical AR1 spectrum
makeNoise(AR1)
```

---

modelA   *Example stratigraphic model series*

Description

Example stratigraphic model series.

Usage

```
data(modelA)
```

Format

Height (meters), weight percent CaCO3

---

mtm   *Multitaper method spectral analysis*

Description

Multitaper method (MTM) spectral analysis (Thomson, 1982)

Usage

```
mtm(dat,tbw=3,ntap=NULL,padfac=5,demean=T,detrend=F,siglevel=0.9,ar1=T,output=0,
    CLpwr=T,xmin,xmax,pl=1,sigID=T,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for MTM spectral analysis. First column should be location (e.g., depth), second column should be data value.
tbw	MTM time-bandwidth product.
ntap	Number of DPSS tapers to use. By default, this is set to (2*tbw)-1.
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
siglevel	Significance level for peak identification. (0-1)
ar1	Estimate conventional AR(1) noise spectrum and confidence levels? (T or F)
CLpwr	Plot AR(1) noise confidence levels on power spectrum? (T or F)

output	What should be returned as a data frame? (0=nothing; 1= power spectrum + harmonic CL + AR1 CL + AR1 fit + 90%-99% AR1 power levels (ar1 must be set to TRUE to output AR model results); 2=significant peak frequencies; 3=significant peak frequencies + harmonic CL; 4=internal variables from spec.mtm). Option 4 is intended for expert users, and should generally be avoided.
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
pl	Power spectrum plotting: (1) linear frequency-log spectral power, (2) linear frequency-linear spectral power (3) log frequency-log spectral power, (4) log frequency-linear spectral power
sigID	Identify significant frequencies on power and probabilty plots? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

The power spectrum normalization approach applied here divides the Fourier coefficients by the number of points (npts) in the stratigraphic series, which is equivalent to dividing the power by (npts*npts). The (npts*npts) normalization has the convenient property whereby – for an unpadded series – the sum of the power in the positive frequencies is equivalent to half of variance; the other half of the variance is in the negative frequencies.

If ar1=T, candidiate astronomical cycles are identified via isolation of those frequencies that achieve the required (e.g., 90 percent) "red noise" confidence level and MTM harmonic F-test confidence level. Allowance is made for the smoothing inherent in the MTM power spectral estimate as compared to the MTM harmonic spectrum. That is, an F-test peak is reported if it achieves the required MTM harmonic confidence level, while also achieving the required red noise confidence level within +/- half the power spectrum bandwidth resolution. One additional criterion is included to further reduce the false positive rate, a requirement that significant F-tests must occur on a local power spectrum high, which is parameterized as occurring above the local red noise background estimate. See Meyers (2012) for futher information.

Note that the 'spec.mtm' function in package 'multitaper' (Rahim et al., 2014) is used for MTM spectrum estimation.

References

S.R. Meyers, 2012, *Seeing Red in Cyclic Stratigraphy: Spectral Noise Estimation for Astrochronology*: Paleoceanography, 27, PA3228, doi:10.1029/2012PA002307.

Rahim, K.J. and Burr W.S. and Thomson, D.J., 2014, *Applications of Multitaper Spectral Analysis to Nonstationary Data*. PhD thesis, Queen's University. R package version 1.0-17, https://CRAN.R-project.org/package=multitaper.

Thomson, D. J., 1982, *Spectrum estimation and harmonic analysis*, Proc. IEEE, 70, 1055-1096, doi:10.1109/PROC.1982.12433.

See Also

eha, lowspec, mtmAR, mtmML96, periodogram

Examples

```
# generate example series with periods of 400 ka, 100 ka, 40 ka and 20 ka
ex = cycles(freqs=c(1/400,1/100,1/40,1/20),start=1,end=1000,dt=5)

# add AR1 noise
noise = ar1(npts=200,dt=5,sd=.5)
ex[2] = ex[2] + noise[2]

# MTM spectral analysis, with conventional AR1 noise test
pl(1,title="mtm")
mtm(ex,ar1=TRUE)

# compare to ML96 analysis
pl(1, title="mtmML96")
mtmML96(ex)

# compare to analysis with LOWSPEC
pl(1, title="lowspec")
lowspec(ex)

# compare to amplitudes from eha
pl(1,title="eha")
eha(ex,tbw=3,win=1000,pad=1000)
```

---

mtmAR   *Intermediate spectrum test of Thomson et al. (2001)*

Description

Perform the 'intermediate spectrum test' of Thomson et al. (2001).

Paraphrased from Thomson et al. (2001): Form an intermediate spectrum by dividing MTM by AR estimate. Choose an order P for a predictor. A variety of formal methods are available in the literature, but practically, one keeps increasing P (the order) until the range of the intermediate spectrum Si(f) (equation (C4) of Thomson et al., 2001) stops decreasing rapidly as a function of P. If the intermediate spectrum is not roughly white, as judged by the minima, the value of P should be increased.

Usage

```
mtmAR(dat,tbw=3,ntap=NULL,order=1,method="mle",CItype=1,padfac=5,demean=T,detrend=F,
      output=1,xmin=0,xmax=Nyq,pl=1,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for analysis. First column should be location (e.g., depth), second column should be data value.
tbw	MTM time-bandwidth product.
ntap	Number of DPSS tapers to use. By default, this is set to (2*tbw)-1.

order	Order of the AR spectrum.
method	AR method ("yule-walker", "burg", "ols", "mle", "yw")
CItype	Illustrate (1) one-sided or (2) two-sided confidence intervals on plots
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
output	Output (1) intermediate spectrum and confidence levels, (2) intermediate spectrum, (3) confidence levels
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
pl	Plot logarithm of spectral power (1) or linear spectral power (2)?
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

The power spectrum normalization approach applied here divides the Fourier coefficients by the number of points (npts) in the stratigraphic series, which is equivalent to dividing the power by (npts*npts). The (npts*npts) normalization has the convenient property whereby – for an unpadded series – the sum of the power in the positive frequencies is equivalent to half of variance; the other half of the variance is in the negative frequencies.

Note that the 'spec.mtm' function in package 'multitaper' (Rahim et al., 2014) is used for MTM spectrum estimation.

References

Rahim, K.J. and Burr W.S. and Thomson, D.J., 2014, *Applications of Multitaper Spectral Analysis to Nonstationary Data*. PhD thesis, Queen's University. R package version 1.0-17, https://CRAN.R-project.org/package=multitaper.

Thomson, D. J., L. J. Lanzerotti, and C. G. Maclennan, 2001, *The interplanetary magnetic field: Statistical properties and discrete modes*, J. Geophys.Res., 106, 15,941-15,962, doi:10.1029/2000JA000113.

See Also

eha, lowspec, mtm, mtmML96, and periodogram

Examples

```
# generate example series with periods of 400 ka, 100 ka, 40 ka and 20 ka
ex = cycles(freqs=c(1/400,1/100,1/40,1/20),start=1,end=1000,dt=5)

# add AR1 noise
noise = ar1(npts=200,dt=5,sd=.5)
ex[2] = ex[2] + noise[2]
```

```
# MTM spectral analysis, with conventional AR1 noise test
pl(1,title="mtmAR")
mtmAR(ex)
```

---

mtmML96   *Mann and Lees (1996) robust red noise MTM analysis*

Description

Mann and Lees (1996) robust red noise MTM analysis. This function implements several improve-
ments to the algorithm used in SSA-MTM toolkit, including faster AR1 model optimization, and
more appropriate 'edge-effect' treatment.

Usage

```
mtmML96(dat,tbw=3,ntap=NULL,padfac=5,demean=T,detrend=F,medsmooth=0.2,
        opt=1,linLog=2,siglevel=0.9,output=0,CLpwr=T,xmin=0,xmax=Nyq,
        sigID=T,pl=1,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for MTM spectral analysis. First column should be location (e.g., depth), second column should be data value.
tbw	MTM time-bandwidth product.
ntap	Number of DPSS tapers to use. By default, this is set to (2*tbw)-1.
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
medsmooth	ML96 median smoothing parameter (1 = use 100% of spectrum; 0.20 = use 20%)
opt	Optimization method for robust AR1 model estimation (1=Brent's method:fast, 2=Gauss-Newton:fast, 3=grid search:slow)
linLog	Optimize AR1 model fit using (1) linear power or (2) log(power)?
siglevel	Significance level for peak identification. (0-1)
output	What should be returned as a data frame? (0=nothing; 1= power spectrum + harmonic CL + AR1 CL + AR1 fit + 90%-99% AR1 power levels + median smoothed spectrum; 2=significant peak frequencies; 3=significant peak frequencies + harmonic CL); 4= Robust AR1 noise model coefficients; 5= option 1+4
CLpwr	Plot ML96 AR(1) noise confidence levels on power spectrum? (T or F)
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
sigID	Identify significant frequencies on power and probabilty plots? (T or F)

pl	Power spectrum plotting: (1) linear frequency-log spectral power, (2) linear frequency-linear spectral power (3) log frequency-log spectral power, (4) log frequency-linear spectral power
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

This function conducts the Mann and Lees (1996; ML96) "robust red noise" analysis, with an improved median smoothing approach. The original Mann and Lees (1996) approach applies a truncation of the median smoothing window to include fewer frequencies near the edges of the spectrum; while truncation is required, its implementation in the original method often results in an "edge effect" that can produce excess false positive rates at low frequencies, commonly within the eccentricity-band (Meyers, 2012).

To help address this issue, an alternative median smoothing approach is applied that implements Tukey's robust end-point rule and symmetrical medians (see the function runmed for details). Numerical experiments indicate that this approach produces an approximately uniform false positive rate across the spectrum. It should be noted that the false positive rates are still inflated with this method, but they are substantially reduced compared to the original ML96 approach. For example, simulations using rho=0.9 (using identical parameters to those in Meyers, 2012) yield median false positive rates of 1.7%, 7.3% and 13.4%, for the 99%, 95% and 90% confidence levels (respectively). This compares with 4.7%, 11.4% and 17.8% using the original approach (see Table 2 of Meyers, 2012).

Candidate astronomical cycles are identified via isolation of those frequencies that achieve the required (e.g., 90 percent) "robust red noise" confidence level and MTM harmonic F-test confidence level. Allowance is made for the smoothing inherent in the MTM power spectral estimate as compared to the MTM harmonic spectrum. That is, an F-test peak is reported if it achieves the required MTM harmonic confidence level, while also achieving the required robust red noise confidence level within +/- half the power spectrum bandwidth resolution. One additional criterion is included to further reduce the false positive rate, a requirement that significant F-tests must occur on a local power spectrum high, which is parameterized as occurring above the local robust red noise background estimate. See Meyers (2012) for futher information.

The power spectrum normalization approach applied here divides the Fourier coefficients by the number of points (npts) in the stratigraphic series, which is equivalent to dividing the power by (npts*npts). The (npts*npts) normalization has the convenient property whereby – for an unpadded series – the sum of the power in the positive frequencies is equivalent to half of variance; the other half of the variance is in the negative frequencies.

NOTES: If the (fast) Brent or Gauss-Newton methods fail, use the (slow) grid search approach. The function 'spec.mtm' in package 'multitaper' (Rahim et al., 2014) is used for MTM spectrum estimation.

This version of the ML96 algorithm was first implemented in Patterson et al. (2014).

References

Mann, M.E., and Lees, J.M., 1996, *Robust estimation of background noise and signal detection in climatic time series*, Clim. Change, 33, 409-445.

Meyers, S.R., 2012, *Seeing red in cyclic stratigraphy: Spectral noise estimation for astrochronology*, Paleoceanography, 27, PA3228.

M.O. Patterson, R. McKay, T. Naish, C. Escutia, F.J. Jimenez-Espejo, M.E. Raymo, M.E., S.R. Meyers, L. Tauxe, H. Brinkhuis, and IODP Expedition 318 Scientists,2014, *Response of the East Antarctic Ice Sheet to orbital forcing during the Pliocene and Early Pleistocene*, Nature Geoscience, v. 7, p. 841-847.

Rahim, K.J. and Burr W.S. and Thomson, D.J., 2014, *Applications of Multitaper Spectral Analysis to Nonstationary Data*. PhD thesis, Queen's University. R package version 1.0-17, https://CRAN.R-project.org/package=multitaper.

Thomson, D. J., 1982, *Spectrum estimation and harmonic analysis*, Proc. IEEE, 70, 1055-1096, doi:10.1109/PROC.1982.12433.

http://www.meteo.psu.edu/holocene/public_html/Mann/tools/MTM-RED/

Tukey, J.W., 1977, *Exploratory Data Analysis*, Addison.

See Also

eha, lowspec, mtm, mtmAR, periodogram, and runmed

Examples

```
# generate example series with periods of 400 ka, 100 ka, 40 ka and 20 ka
ex = cycles(freqs=c(1/400,1/100,1/40,1/20),start=1,end=1000,dt=5)

# add AR1 noise
noise = ar1(npts=200,dt=5,sd=0.5)
ex[2] = ex[2] + noise[2]

# run ML96 analysis
pl(1, title="mtmML96")
mtmML96(ex)

# compare to analysis with conventional AR1 noise test
pl(1,title="mtm")
mtm(ex)

# compare to analysis with LOWSPEC
pl(1, title="lowspec")
lowspec(ex)

# compare to amplitudes from eha
pl(1,title="eha")
eha(ex,tbw=3,win=1000,pad=1000)
```

---

mtmPL   *Multitaper Method Spectral Analysis with Power Law (1/f) fit*

Description

Multitaper Method (MTM) Spectral Analysis with Power Law (1/f) fit

Usage

```
mtmPL(dat,tbw=3,ntap=NULL,padfac=5,demean=T,detrend=F,siglevel=0.9,flow=NULL,fhigh=NULL,
    output=0,CLpwr=T,xmin=0,xmax=Nyq,pl=1,sigID=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for MTM spectral analysis. First column should be location (e.g., depth), second column should be data value.
tbw	MTM time-bandwidth product.
ntap	Number of DPSS tapers to use. By default, this is set to (2*tbw)-1.
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
siglevel	Significance level for peak identification.
flow	Lowest frequency to include in 1/f fit
fhigh	Highest frequency to include in 1/f fit
output	What should be returned as a data frame? (0=nothing; 1=spectrum + CLs + power law fit; 2=sig peak freqs; 3=sig peak freqs + prob; 4=all)
CLpwr	Plot power law noise confidence levels on power spectrum (in addition to the power law fit)? (T or F)
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
pl	Power spectrum plotting: (1) linear frequency-log spectral power, (2) linear frequency-linear spectral power (3) log frequency-log spectral power, (4) log frequency-linear spectral power
sigID	Identify signficant frequencies on power and probabilty plots? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

Candidiate astronomical cycles are identified via isolation of those frequencies that achieve the required (e.g., 90 percent) power law confidence level and MTM harmonic F-test confidence level. Allowance is made for the smoothing inherent in the MTM power spectral estimate as compared to the MTM harmonic spectrum. That is, an F-test peak is reported if it achieves the required MTM harmonic confidence level, while also achieving the required power law confidence level within +/- half the power spectrum bandwidth resolution. One additional criterion is included to further reduce the false positive rate, a requirement that significant F-tests must occur on a local power

spectrum high, which is parameterized as occurring above the local red noise background estimate. See Meyers (2012) for futher information.

The power spectrum normalization approach applied here divides the Fourier coefficients by the number of points (npts) in the stratigraphic series, which is equivalent to dividing the power by (npts*npts). The (npts*npts) normalization has the convenient property whereby – for an unpadded series – the sum of the power in the positive frequencies is equivalent to half of variance; the other half of the variance is in the negative frequencies.

Note that the 'spec.mtm' function in package 'multitaper' (Rahim et al., 2014) is used for MTM spectrum estimation.

References

S.R. Meyers, 2012, *Seeing Red in Cyclic Stratigraphy: Spectral Noise Estimation for Astrochronology*: Paleoceanography, 27, PA3228, doi:10.1029/2012PA002307.

Rahim, K.J. and Burr W.S. and Thomson, D.J., 2014, *Appendix A: Multitaper R package in "Applications of Multitaper Spectral Analysis to Nonstationary Data"*, PhD diss., Queen's Univieristy, pp 149-183. http://hdl.handle.net/1974/12584

Thomson, D. J., 1982, *Spectrum estimation and harmonic analysis*, Proc. IEEE, 70, 1055-1096, doi:10.1109/PROC.1982.12433.

See Also

eha, lowspec, mtm, mtmAR, mtmML96, and periodogram

| multiTest | *Adjust spectral p-values for multiple comparisons* |

Description

Adjust spectral p-values for multiple comparisons, using a range of approaches.

Usage

```
multiTest(spec,flow=NULL,fhigh=NULL,pl=T,output=T,genplot=T,verbose=T)
```

Arguments

spec	A data frame with two columns: frequency, uncorrected confidence level. If more than 2 columns are input, the results are assumed to come from periodogram, mtm, mtmML96, lowspec or mtmPL.
flow	Vector of lower bounds for each frequency band of interest. Order must match fhigh.
fhigh	Vector of upper bounds for each frequency band of interest. Order must match flow.
pl	Include graphs of uncorrected p-values? (T or F)

output	Return results as new data frame? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

Multiple testing is a common problem in the evaluation of power spectrum peaks (Vaughan et al., 2011; Crampton et al., PNAS). To address the issue of multiple testing, a range of approaches have been advocated. This function will conduct an assessment using six approaches: Bonferroni, Holm (1979), Hochberg (1998), Hommel (1988), Benjamini & Hochberg (1995, a.k.a. "false discovery rate"), Benjamini & Yekutieli (2001, a.k.a. "false discovery rate"). See the function p.adjust for additional information on these six approaches.

In conducting these assessments, it is important that the spectral analysis is conducted without zero-padding. If one is exclusively concerned with particular frequency bands a priori (e.g., those associated with Milankovitch cycles), the statistical power of the method can be improved by restricting the analysis to those frequency bands (use options 'flow' and 'fhigh').

Application of these multiple testing corrections does not guarantee that the spectral background is appropriate. To address this issue, carefully examine the fit of the spectral background, and also conduct simulations with the function testBackground.

References

Y. Benjamini, and Y. Hochberg, 1995, *Controlling the false discovery rate: a practical and powerful approach to multiple testing*. Journal of the Royal Statistical Society Series B 57, 289-300.

Y. Benjamini, and D. Yekutieli, 2001, *The control of the false discovery rate in multiple testing under dependency*. Annals of Statistics 29, 1165-1188.

J.S. Campton, S.R. Meyers, R.A. Cooper, P.M Sadler, M. Foote, D. Harte, 2018, *Pacing of Paleozoic macroevolutionary rates by Milankovitch grand cycles*: Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1714342115.

S. Holm, 1979, *A simple sequentially rejective multiple test procedure*. Scandinavian Journal of Statistics 6, 65-70.

G. Hommel, 1988, *A stagewise rejective multiple test procedure based on a modified Bonferroni test*. Biometrika 75, 383-386.

Y. Hochberg, 1988, *A sharper Bonferroni procedure for multiple tests of significance*. Biometrika 75, 800-803.

J.P. Shaffer, 1995, *Multiple hypothesis testing. Annual Review of Psychology 46, 561-576*. (An excellent review of the area.)

S. Vaughan, R.J. Bailey, and D.G. Smith, 2011, *Detecting cycles in stratigraphic data: Spectral analysis in the presence of red noise*. Paleoceanography 26, PA4211, doi:10.1029/2011PA002195.

See Also

p.adjust, testBackground, confAdjust, lowspec, mtm, mtmML96, mtmPL, and periodogram

Examples

```
# generate example series with periods of 400 ka, 100 ka, 40 ka and 20 ka
ex = cycles(freqs=c(1/400,1/100,1/40,1/20),start=1,end=1000,dt=5)

# add AR1 noise
noise = ar1(npts=200,dt=5,sd=.5)
ex[2] = ex[2] + noise[2]

# first, let's look at mtm with conventional AR1 background
spec=mtm(ex,padfac=1,ar1=TRUE,output=1)

# when blindly prospecting for cycles, it is necessary to consider all of the
#  observed frequencies in the test
multiTest(cb(spec,c(1,4)),output=FALSE)

# if, a priori, you are only concerned with the Milankovitch frequency bands,
#  restrict your analysis to those bands (as constrained by available sedimentation
#  rate estimates and the frequency resolution of the spectrum). in the example below,
#  the mtm bandwidth resolution is employed to search frequencies nearby the
#  Milankovitch-target periods.
flow=c((1/400)-0.003,(1/100)-0.003,(1/41)-0.003,(1/20)-0.003)
fhigh=c((1/400)+0.003,(1/100)+0.003,(1/41)+0.003,(1/20)+0.003)
multiTest(cb(spec,c(1,4)),flow=flow,fhigh=fhigh,output=FALSE)

# now try with the lowspec method. this uses prewhitening, so it has one less data point.
spec=lowspec(ex,padfac=1,output=1)
flow=c((1/400)-0.003015075,(1/100)-0.003015075,(1/41)-0.003015075,(1/20)-0.003015075)
fhigh=c((1/400)+0.003015075,(1/100)+0.003015075,(1/41)+0.003015075,(1/20)+0.003015075)
multiTest(cb(spec,c(1,4)),flow=flow,fhigh=fhigh,output=FALSE)

# for comparison...
multiTest(cb(spec,c(1,4)),output=FALSE)
```

---

mwCor	*Calculate moving window correlation coefficient for two stratigraphic series, using a 'dynamic window'*

Description

Calculate moving window correlation coefficient for two stratigraphic series, using a 'dynamic window'. This routine adjusts the number of data points in the window so it has a constant duration in time or space, for use with unevenly sampled data.

Usage

```
mwCor(dat,cols=NULL,win=NULL,conv=1,cormethod=1,output=T,pl=1,genplot=T,verbose=T)
```

Arguments

dat	Your data frame containing stratigraphic data; any number of columns (variables) are permitted, but the first column should be a location identifier (e.g., depth, height, time).
cols	A vector that identifies the two variable columns to be extracted (first column automatically extracted).
win	Moving window size in units of space or time.
conv	Convention for window placement: (1) center each window on a stratigraphic level in 'dat' (DEFAULT), (2) start with the smallest location datum in 'dat', (3) start with the largest location datum in 'dat'. For options 2 and 3, the center of the window will not necessarily coincide with a measured stratigraphic level in 'dat', but edges of the data set are better preserved.
cormethod	Method used for calculation of correlation coefficient (1=Pearson, 2=Spearman, 3=Kendall)
output	Output results? (T or F)
pl	(1) Plot results at center of window, or (2) create "string of points plot" as in Sageman and Hollander (1999)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

References

B.B. Sageman and D.H. Hollander, 1999, *Cross correlation of paleoecological and geochemical proxies: A holistic approach to the study of past global change*, in E. Barrera and C.C. Johnson, eds., GSA Special Paper 332, p. 365-384.

Examples

```
# generate example series
ex <- cycles(freqs=c(1/40,1/20),noisevar=.2)

# add second variable
ex[3] <- cycles(freqs=c(1/40,1/20),noisevar=0.2)[2]

# jitter sampling times
ex[1]=ex[1]+rnorm(500,sd=1)
# sort
ex = ex[order(ex[,1],na.last=NA,decreasing=FALSE),]

# run mwCor
mwCor(ex,win=50)
```

mwin	*Determine 'dynamic moving window' for stratigraphic series, adjusting for changing sample density to maintain a window of constant duration*

Description

Determine start and end points for a moving window of fixed duration (e.g. 500 kiloyears). The dynamic window allows for adjustment of the number of data points in the window, so it has a constant duration in time or space.

Usage

```
mwin(dat,win,conv=1,verbose=T)
```

Arguments

dat	Your data frame containing stratigraphic data; any number of columns (variables) are permitted, but the first column should be a location identifier (e.g., depth, height, time).
win	Moving window size in units of space or time.
conv	Convention for window placement: (1) center each window on a stratigraphic level in 'dat' (DEFAULT), (2) start with the smallest location datum in 'dat', (3) start with the largest location datum in 'dat'. For options 2 and 3, the center of the window will not necessarily coincide with a measured stratigraphic level in 'dat', but edges of the data set are better preserved.
verbose	Verbose output? (T or F)

Details

This algorithm steps forward one stratigraphic datum at a time. The output consists of:

Average = this is the average of the depth/time values in the given window.

Center = this is the center of the 'win' size window.

Midpoint = this is midpoint between first and last observation in the window (for unevenly sampled data this is typically less than than the size of 'win').

Value

A data frame containing: Starting index for window, Ending index for window, Location (average), Location (center), Location (midpoint)

Examples

```
# generate some noise
ex1 <- ar1(npts=50,dt=1)

# jitter sampling times
ex1[1]=ex1[1]+rnorm(50,sd=3)
# sort
ex1 = ex1[order(ex1[,1],na.last=NA,decreasing=FALSE),]

# run mwin
mwin(ex1,win=10)
```

---

mwinGrid

Determine 'dynamic moving window' for stratigraphic series, adjusting for changing sample density to maintain a window of constant duration; output on evenly spaced grid

---

Description

Determine start and end points for a moving window of fixed duration (e.g. 500 kiloyears). The dynamic window allows for adjustment of the number of data points in the window, so it has a constant duration in time or space. This version will output an evenly spaced spatial/temporal grid.

Usage

```
mwinGrid(dat,win,step,start=NULL,end=NULL,verbose=T)
```

Arguments

dat	Your data frame containing stratigraphic data; any number of columns (variables) are permitted, but the first column should be a location identifier (e.g., depth, height, time).
win	Moving window size in units of space or time.
step	Step size for moving window, in units of space or time.
start	Start moving window at what depth/height/time; by default will use first value
end	End moving window at what depth/height/time; by default will use last value
verbose	Verbose output? (T or F)

Details

This algorithm is similar to function mwin, but instead of stepping forward one stratigraphic datum at a time, it generates an evenly spaced spatial/temporal grid.

Value

A data frame containing: Starting index for window, Ending index for window, Location (center)

Examples

```
# generate some noise
ex1 <- ar1(npts=50,dt=1)

# jitter sampling times
ex1[1]=ex1[1]+rnorm(50,sd=0.25)
# sort
ex1 = ex1[order(ex1[,1],na.last=NA,decreasing=FALSE),]

# run mwin
mwinGrid(ex1,win=10,step=2)
```

---

mwMinMax   *'Dynamic window' moving assessment of maxima and minima in
                                 stratigraphic series*

Description

'Dynamic window' moving assessment of maxima and minima in stratigraphic series. This routine
adjusts the number of data points in the window so it has a constant duration in time or space, for
use with unevenly sampled data.

Usage

```
mwMinMax(dat,cols=NULL,win=NULL,conv=1,output=T,genplot=T,verbose=T)
```

Arguments

dat	Your data frame containing stratigraphic data; any number of columns (variables) are permitted, but the first column should be a location identifier (e.g., depth, height, time).
cols	A vector that identifies the variable column to be extracted (first column automatically extracted).
win	Moving window size in units of space or time.
conv	Convention for window placement: (1) center each window on a stratigraphic level in 'dat' (DEFAULT), (2) start with the smallest location datum in 'dat', (3) start with the largest location datum in 'dat'. For options 2 and 3, the center of the window will not necessarily coincide with a measured stratigraphic level in 'dat', but edges of the data set are better preserved.
output	Output results? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Value

A data frame with five columns: Center of window, Minimum, Maximum, Maximum-Minimum,
Number of points in window

Examples

```
# generate example series from ar1 noise, 5 kyr sampling interval
ex = ar1(npts=1001,dt=5)

# jitter sampling times
ex[1]=ex[1]+rnorm(1001,sd=1)
# sort
ex = ex[order(ex[,1],na.last=NA,decreasing=FALSE),]

# run mwStats
mwMinMax(ex,win=100)
```

---

mwStats	*'Dynamic window' moving average, median and variance of stratigraphic series*

Description

'Dynamic window' moving average, median and variance of stratigraphic series. This routine adjusts the number of data points in the window so it has a constant duration in time or space, for use with unevenly sampled data.

Usage

```
mwStats(dat,cols=NULL,win=NULL,conv=1,ends=F,CI=0,output=T,genplot=T,verbose=T)
```

Arguments

dat	Your data frame containing stratigraphic data; any number of columns (variables) are permitted, but the first column should be a location identifier (e.g., depth, height, time).
cols	A vector that identifies the variable column to be extracted (first column automatically extracted).
win	Moving window size in units of space or time.
conv	Convention for window placement: (1) center each window on a stratigraphic level in 'dat' (DEFAULT), (2) start with the smallest location datum in 'dat', (3) start with the largest location datum in 'dat'. For options 2 and 3, the center of the window will not necessarily coincide with a measured stratigraphic level in 'dat', but ends of the data set are better preserved. See options 'ends'.
ends	Assign average values to ends, by averaging data before first window, and averaging data after last window? (T or F; only applicable for conv=1)
CI	What confidence interval should be calculated for the average value (0-100 percent). If set to 0, the confidence interval calculation is skipped.
output	Output results? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

If conv=1 is selected, the edges of the record are determined using a smaller window size. A constant value is assigned based on the observed values within the first and last 0.5*win of the record.

Value

A data frame with five or six columns: Center of window, Average, Median, Variance, Number of points in window. If CI>0, the sixth column is the value used to determine the confidence interval (add and subtract it from the average)

Examples

```
# generate example series from ar1 noise, 5 kyr sampling interval
ex = ar1(npts=1001,dt=5)

# jitter sampling times
ex[1]=ex[1]+rnorm(1001,sd=1)
# sort
ex = ex[order(ex[,1],na.last=NA,decreasing=FALSE),]

# run mwStats
mwStats(ex,win=100)
```

---

mwStatsGrid   *'Dynamic window' moving average, median and variance of strati-*
graphic series, using evenly spaced spatial/temporal grid

Description

'Dynamic window' moving average, median and variance of stratigraphic series. This routine adjusts the number of data points in the window so it has a constant duration in time or space, for use with unevenly sampled data. The results are output on an evenly spaced spatial/temporal grid (this contrasts with mwStats).

Usage

```
mwStatsGrid(dat,cols=NULL,win=NULL,step=NULL,start=NULL,end=NULL,output=T,norm=F,
            palette=6,ncolors=100,genplot=1,verbose=T)
```

Arguments

dat   Your data frame containing stratigraphic data; any number of columns (variables) are permitted, but the first column should be a location identifier (e.g., depth, height, time).

cols   A vector that identifies the variable column to be extracted (first column automatically extracted).

win	Moving window size, in units of space or time.
step	Moving window step size, in units of space or time.
start	Starting point for analysis, in units of space or time.
end	Ending point for analysis, in units of space or time.
norm	Normalize density estimates to maximum value? (T or F). If false, density estimates are normalized to unit area.
output	Output results? (T or F)
palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red, (6) viridis
ncolors	Number of colors to use in plot.
genplot	Generate summary plots? (0=none, 1=all time series, 2=kernel density estimates for each window, 3=kernel density estimates with median, 4=kernel density estimates with mean)
verbose	Verbose output? (T or F)

Value

A data frame with four columns: Center of window, Average, Median, Variance

Examples

```
# generate example series from ar1 noise, 5 kyr sampling interval
ex = ar1(npts=1001,dt=5)

# jitter sampling times
ex[1]=ex[1]+rnorm(1001,sd=1)
# sort
ex = ex[order(ex[,1],na.last=NA,decreasing=FALSE),]

# run mwStats
mwStatsGrid(ex,win=100)
```

---

noKernel *Remove Gaussian kernel smoother from stratigraphic series*

Description

Estimate trend and remove from stratigraphic series using a Gaussian kernel smoother

Usage

```
noKernel(dat,smooth=0.1,sort=F,output=1,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for smoothing. First column should be location (e.g., depth), second column should be data value.
smooth	Degree of smoothing with a Gaussian kernal (0 = no smoothing); for a value of 0.5, the kernel is scaled so that its quartiles (viewed as prob densities) are at +/- 25 percent of the data series length. Must be > 0.
sort	Sort data into increasing depth (required for ksmooth)? (T or F)
output	1= output residual values; 2= output Gaussian kernel smoother.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

bandpass, lowpass, noLow, prewhiteAR, and prewhiteAR1

---

noLow   *Fit and remove Lowess smoother from stratigraphic series*

Description

Fit and remove lowess smoother from stratigraphic series

Usage

```
noLow(dat,smooth=.20,output=1,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for lowess smoother removal. First column should be location (e.g., depth), second column should be data value.
smooth	Lowess smoothing parameter.
output	1= output residual values; 2= output lowess fit
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

bandpass, lowpass, noKernel, prewhiteAR, and prewhiteAR1

---

pad   *Pad stratigraphic series with zeros*

Description

Pad stratigraphic series with zeros ("zero padding")

Usage

```
pad(dat,zeros,genplot=T,verbose=T)
```

Arguments

dat   Stratigraphic series for mean removal. First column should be location (e.g.,
             depth), second column should be data value.

zeros   Number of zeros to add on the end of the series. By default, the number of points
             will be doubled.

genplot   Generate summary plots? (T or F)

verbose   Verbose output? (T or F)

---

peak   *Identify maxima of peaks in series, filter at desired threshold value*

Description

Identify maxima of peaks in any 1D or 2D series, filter at desired threshold value.

Usage

```
peak(dat,level,plateau=F,genplot=T,verbose=T)
```

Arguments

dat   1 or 2 dimensional series. If 2 dimesions, first column should be location (e.g.,
             depth), second column should be data value.

level   Threshold level for filtering peaks. By default all peak maxima reported.

plateau   Output plateau points not evaluated? If T, identified peaks will not be output. (T
             or F)

genplot   Generate summary plots? (T or F)

verbose   Verbose output? (T or F)

Examples

```
ex=cycles(genplot=FALSE)
peak(ex,level=0.02)
```

---

periodogram	*Simple periodogram*

Description

Calculate periodogram for stratigraphic series

Usage

```
periodogram(dat,padfac=2,demean=T,detrend=F,nrm=1,background=0,medsmooth=0.2,
            bc=F,output=0,f0=F,fNyq=T,xmin=0,xmax=Nyq,pl=1,genplot=T,check=T,
            verbose=T)
```

Arguments

dat	Stratigraphic series to analyze. First column should be location (e.g., depth), second column should be data value.
padfac	Pad with zeros to (padfac*npts) points, where npts is the original number of data points. padfac will automatically promote the total padded series length to an even number, to ensure the Nyquist frequency is calculated. padfac must be >= 1.
demean	Remove mean from data series? (T or F)
detrend	Remove linear trend from data series? (T or F)
nrm	Power normalization: 0 = no normalization; 1 = divide Fourier coefficients by npts.
background	Estimate noise model background spectrum and confidence levels? (0= No, 1= AR1, 2= Power Law, 3= Robust AR1)
medsmooth	Robust AR1 median smoothing parameter (1 = use 100% of spectrum; 0.20 = use 20%)
bc	Apply Bonferroni correction? (T or F)
output	Return output as new data frame? 0= no; 1= frequency, amplitude, power, phase (+ background fit and confidence levels if background selected); 2= frequency, real coeff., imag. coeff. If option 2 is selected, all frequencies from negative to positive Nyquist are returned, regardless of the f0 and fNyq settings; 3= noise model coefficients (if background selected); 4= option 1+3
f0	Return results for the zero frequency? (T or F)
fNyq	Return results for the Nyquist frequency? (T or F)
xmin	Smallest frequency for plotting.
xmax	Largest frequency for plotting.
pl	Power spectrum plotting: 1 = log power, 2 = linear power
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Details

The power spectrum normalization approach applied here (nrm=1) divides the Fourier coefficients by the number of points (npts) in the stratigraphic series, which is equivalent to dividing the power by (npts*npts). The (npts*npts) normalization has the convenient property whereby – for an un-padded series – the sum of the power in the positive frequencies is equivalent to half of variance; the other half of the variance is in the negative frequencies.

See Also

mtm and lowspec

Examples

```
# ***** PART 1: Demonstrate the impact of tapering
# generate example series with 10 periods: 100, 40, 29, 21, 19, 14, 10, 5, 4 and 3 ka.
ex=cycles(c(1/100,1/40,1/29,1/21,1/19,1/14,1/10,1/5,1/4,1/3),amp=c(1,.75,0.01,.5,.25,
            0.01,0.1,0.05,0.001,0.01))

# set zero padding amount for spectral analyses
# (pad= 1 results in no zero padding, pad = 2 will pad the series to two times its original length)
# start with pad = 1, then afterwards evaluate pad=2
pad=1

# calculate the periodogram with no tapering applied (a "rectangular window")
res=periodogram(ex,output=1,padfac=pad)

# save the frequency grid and the power for plotting
freq=res[1]
pwr_rect=res[3]

# now compare with results obtained after applying four different tapers:
#  Hann, 30% cosine taper, DPSS with a time-bandwidth product of 1, and DPSS
#  with a time-bandwidth product of 3
pwr_hann=periodogram(hannTaper(ex,demean=FALSE),output=1,padfac=pad)[3]
pwr_cos=periodogram(cosTaper(ex,p=.3,demean=FALSE),output=1,padfac=pad)[3]
pwr_dpss1=periodogram(dpssTaper(ex,tbw=1,demean=FALSE),output=1,padfac=pad)[3]
pwr_dpss3=periodogram(dpssTaper(ex,tbw=3,demean=FALSE),output=1,padfac=pad)[3]

# now plot the results
ymin=min(rbind (log(pwr_rect[,1]),log(pwr_hann[,1]),log(pwr_cos[,1]),log(pwr_dpss1[,1]),
        log(pwr_dpss3[,1]) ))
ymax=max(rbind (log(pwr_rect[,1]),log(pwr_hann[,1]),log(pwr_cos[,1]),log(pwr_dpss1[,1]),
        log(pwr_dpss3[,1]) ))

pl(2)
plot(freq[,1],log(pwr_rect[,1]),type="l",ylim=c(ymin,ymax),lwd=2,ylab="log(Power)",
     xlab="Frequency (cycles/ka)",
     main="Comparison of rectangle (black), cosine (blue) and Hann (orange) taper",
     cex.main=1)
lines(freq[,1],log(pwr_hann[,1]),col="orange",lwd=2)
lines(freq[,1],log(pwr_cos[,1]),col="blue")
points(c(1/100,1/40,1/29,1/21,1/19,1/14,1/10,1/5,1/4,1/3),rep(ymax,10),cex=.5,
```

```
     col="purple")

plot(freq[,1],log(pwr_rect[,1]),type="l",ylim=c(ymin,ymax),lwd=2,ylab="log(Power)",
      xlab="Frequency (cycles/ka)",
      main="Comparison of rectangle (black), 1pi DPSS (green) and 3pi DPSS (red) taper",
      cex.main=1)
lines(freq[,1],log(pwr_dpss1[,1]),col="green")
lines(freq[,1],log(pwr_dpss3[,1]),col="red",lwd=2)
points(c(1/100,1/40,1/29,1/21,1/19,1/14,1/10,1/5,1/4,1/3),rep(ymax,10),cex=.5,
       col="purple")


# ***** PART 2: Now add a very small amount of red noise to the series
#               (with lag-1 correlation = 0.5)
ex2=ex
ex2[2]=ex2[2]+ar1(rho=.5,dt=1,npts=500,sd=.005,genplot=FALSE)[2]

# compare the original series with the series+noise
pl(2)
plot(ex,type="l",lwd=2,lty=3,col="black",xlab="time (ka)",ylab="signal",
      main="signal (black dotted) and signal+noise (red)"); lines(ex2,col="red")
plot(ex[,1],ex2[,2]-ex[,2],xlab="time (ka)",ylab="difference",
      main="Difference between the two time series (very small!)")

# calculate the periodogram with no tapering applied (a "rectangular window")
res.2=periodogram(ex2,output=1,padfac=pad)

# save the frequency grid and the power for plotting
freq.2=res.2[1]
pwr_rect.2=res.2[3]

# now compare with results obtained after applying four different tapers:
#  Hann, 30% cosine taper, DPSS with a time-bandwidth product of 1, and DPSS
#  with a time-bandwidth product of 3
pwr_hann.2=periodogram(hannTaper(ex2,demean=FALSE),output=1,padfac=pad)[3]
pwr_cos.2=periodogram(cosTaper(ex2,p=.3,demean=FALSE),output=1,padfac=pad)[3]
pwr_dpss1.2=periodogram(dpssTaper(ex2,tbw=1,demean=FALSE),output=1,padfac=pad)[3]
pwr_dpss3.2=periodogram(dpssTaper(ex2,tbw=3,demean=FALSE),output=1,padfac=pad)[3]

# now plot the results
ymin=min(rbind (log(pwr_rect.2[,1]),log(pwr_hann.2[,1]),log(pwr_cos.2[,1]),
         log(pwr_dpss1.2[,1]),log(pwr_dpss3.2[,1]) ))
ymax=max(rbind (log(pwr_rect.2[,1]),log(pwr_hann.2[,1]),log(pwr_cos.2[,1]),
         log(pwr_dpss1.2[,1]),log(pwr_dpss3.2[,1]) ))

pl(2)
plot(freq.2[,1],log(pwr_rect.2[,1]),type="l",ylim=c(ymin,ymax),lwd=2,ylab="log(Power)",
     xlab="Frequency (cycles/ka)",
     main="Comparison of rectangle (black), cosine (blue) and Hann (orange) taper",
     cex.main=1)
lines(freq.2[,1],log(pwr_hann.2[,1]),col="orange",lwd=2)
lines(freq.2[,1],log(pwr_cos.2[,1]),col="blue")
points(c(1/100,1/40,1/29,1/21,1/19,1/14,1/10,1/5,1/4,1/3),rep(ymax,10),cex=.5,
```

```
        col="purple")

plot(freq.2[,1],log(pwr_rect.2[,1]),type="l",ylim=c(ymin,ymax),lwd=2,ylab="log(Power)",
        xlab="Frequency (cycles/ka)",
        main="Comparison of rectangle (black), 1pi DPSS (green) and 3pi DPSS (red) taper",
        cex.main=1)
lines(freq.2[,1],log(pwr_dpss1.2[,1]),col="green")
lines(freq.2[,1],log(pwr_dpss3.2[,1]),col="red",lwd=2)
points(c(1/100,1/40,1/29,1/21,1/19,1/14,1/10,1/5,1/4,1/3),rep(ymax,10),cex=.5,
        col="purple")

# ***** PART 3: Return to PART 1, but this time increase the zero padding to 2 (pad=2)
```

---

pl   *Set up plots*

Description

Open new device and set up for multiple plots, output to screen or PDF if desired.

Usage

```
pl(n,r,c,h,w,mar,file,title)
```

Arguments

n	Number of plots per page (1-25). When specified, this parameter takes precedence and the default settings for r and c are used (the r and c options below are ignored).
r	Number of rows of plots.
c	Number of columns of plots.
h	Height of new page (a.k.a. "device").
w	Width of new page (a.k.a. "device").
mar	A numerical vector of the form c(bottom, left, top, right) which gives the margin size specified in inches.
file	File name, in quotes. Accepted file formats include .pdf, .jpg, .png, .tiff, .bmp; the format must be indicated using the appropriate filename extension at the end of the file name. If a file name is not designated, the plot is output to the screen instead.
title	Plot title (must be in quotes)

---

plotEha   *Create color time-frequency plots from eha results.*

Description

Create color time-frequency plots from eha results.

Usage

```
plotEha(spec,xmin,xmax,ymin,ymax,h=6,w=4,ydir=1,pl=0,norm,palette=6,
     centerZero=T,ncolors=100,colorscale=F,xlab,ylab,filetype=0,output=T,verbose=T)
```

Arguments

spec
: Time-frequency spectral results to evaluate. Must have the following format: column 1=frequency; remaining columns (2 to n)=power, amplitude or probability; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eha.

xmin
: Minimum frequency for PLOTTING.

xmax
: Maximum frequency for PLOTTING.

ymin
: Minimum depth/height for PLOTTING.

ymax
: Maximum depth/height for PLOTTING.

h
: Height of plot in inches.

w
: Width of plot in inches.

ydir
: Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.

pl
: An option for the color plots (0=linear scale; 1=plot log of value [useful for plotting power], 2=normalize to maximum value in each window [useful for plotting amplitude], 3=use normalization provided in norm.

norm
: Optional amplitude normalization divisor, consisting of a single column dataframe. This option is provided in case you'd like to normalize a set of EHA results using the same scheme (e.g., before and after removal of spectral lines).

palette
: What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red (if values are negative and positive, white is centered on zero), (6) viridis

centerZero
: Center color scale on zero (use an equal number of postive and negative color divisions)? (T or F)

ncolors
: Number of colors steps to use in palette.

colorscale
: Include a color scale in the plot? (T or F)

xlab
: Label for x-axis. Default = "Frequency"

ylab
: Label for y-axis. Default = "Location"

filetype
: Generate .pdf, .jpeg, .png or tiff file? (0=no; 1=pdf; 2=jpeg; 3=png; 4=tiff)

output
: If amplitude is normalized (pl = 2), output normalization used? (T or F)

verbose
: Verbose output? (T or F)

Examples

```
## as an example, evaluate the modelA
data(modelA)

## interpolate to even sampling interval of 0.075 m
ex1=linterp(modelA, dt=0.075)

## perform EHA with a time-bandwidth parameter of 2, using an 7.95 meter window, 0.15 m step,
## and pad to 1000 points, output amplitude
res=eha(ex1,tbw=2,win=7.95,step=0.15,pad=1000,genplot=0,output=3)

# plot EHA amplitude, normalized to maximum value in each window
plotEha(res,xlab="Frequency (cycles/m)",ylab="Height (m)",pl=2)
```

---

plS	*Set default plotting parameters for vertical stratigraphic plots*

Description

Set default plotting parameters for vertical stratigraphic plots. This is ususally invoked after function pl.

Usage

```
plS(f=T,s=1)
```

Arguments

f	Are you plotting the first (leftmost) stratigraphic plot? (T or F)
s	Size of the symbols and text on plot. Default = 1

---

prewhiteAR	*Prewhiten stratigraphic series with autoregressive filter, order selected by Akaike Information Criterion*

Description

Prewhiten stratigraphic series using autoregressive (AR) filter. Appropriate AR order can be automatically determined using the Akaike Information Criterion, or alternatively, the order may be predefined.

Usage

```
prewhiteAR(dat,order=0,method="mle",aic=T,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for prewhitening. First column should be location (e.g., depth), second column should be data value for prewhitening. Series must have uniform sampling interval.
order	AR order for prewhitening (if aic=F), or alternatively, the maximum AR order to investigate (if aic=T). If order is set to <=0, will evaluate up to maximum default order (this varies based on method).
method	Method for AR parameter estimation: ("yule-walker", "burg", "ols", "mle", "yw")
aic	Select model using AIC? if F, will use order. AIC is only strictly valid if method is "mle".
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

References

Akaike, H. (1974), *A new look at the statistical model identification*, IEEE Trans. Autom. Control, 19, 716-723, doi:10.1109/TAC.1974.1100705.

See Also

[ar](), [arcsinT](), [bandpass](), [demean](), [detrend](), [divTrend](), [logT](), [lowpass](), [noKernel](), and [prewhiteAR1]()

---

prewhiteAR1	*Prewhiten stratigraphic series with AR1 filter, using 'standard' or unbiased estimate of rho*

Description

Prewhiten stratigraphic series using autoregressive-1 (AR1) filter. Rho can be estimated using the 'standard' approach, or following a bias correction.

Usage

```
prewhiteAR1(dat,setrho=NULL,bias=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for prewhitening. First column should be location (e.g., depth), second column should be data value for prewhitening. Series must have uniform sampling interval.
setrho	Specified lag-1 correlation coefficient (rho). By default, rho is calculated.
bias	Calculate unbiased estimate of rho, as in Mudelsee (2010, eq. 2.45). (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

References

M. Mudelsee, 2010, *Climate Time Series Analysis: Classical Statistical and Bootstrap Methods*, 474 pp., Springer, Dordrecht, Netherlands.

See Also

[arcsinT](), [bandpass](), [demean](), [detrend](), [divTrend](), [logT](), [lowpass](), [noKernel](), and [prewhiteAR]()

---

pwrLaw	*Generate power law (1/f) noise surrogates*

Description

Generate power law (1/f) noise surrogates, following the algorithm of Timmer and Konig (1995).

Usage

```
pwrLaw(npts=1024,dt=1,mean=0,sdev=1,beta=2,fcut=0,nsim=1,genplot=T,verbose=T)
```

Arguments

npts	number of data points for 1/f surrogate time series
dt	sampling interval
mean	mean value for 1/f surrogate series
sdev	standard deviation for 1/f surrogate series
beta	power law coefficient. Positive number will yield a negative slope.
fcut	frequency cutoff: below this frequency a plateau will be modeled. Set to zero (default) for no plateau.
nsim	Number of surrogate series to generate
genplot	generate summary plots (T or F)
verbose	verbose output (T or F)

Details

These simulations use the random number generator of Matsumoto and Nishimura (1998). Power law noise series are generated following the algorithm of Timmer and Konig (1995).

References

M. Matsumoto, and T. Nishimura, (1998), *Mersenne Twister: A 623-dimensionally equidistributed uniform pseudo-random number generator*, ACM Transactions on Modeling and Computer Simulation, 8, 3-30.

J. Timmer and K. Konig (1995), *On Generating Power Law Noise*, Astronomy and Astrophysics: v. 300, p. 707-710.

| pwrLawFit | *Estimate power law (1/f) fit to power spectrum* |

Description

Estimate power law (1/f) fit to power spectrum, following the algorithm of Vaughan (2005).

Usage

```
pwrLawFit(spec,dof=2,flow=NULL,fhigh=NULL,output=1,genplot=T,verbose=T)
```

Arguments

spec	Power spectrum. First column is frequency, second column is raw power (linear). Do not include the zero frequency and Nyquist.
dof	Degrees of freedom for power spectral estimate. Default is 2, for a simple periodogram.
flow	Lowest frequency to include in 1/f fit
fhigh	Highest frequency to include in 1/f fit
output	Output results of 1/f fit? (0=none; 1=Frequency,Power,Power Law CL,Unbiased Power Law fit,CL_90,CL_95,CL_99; 2=beta, unbiased log10N, biased log10N)
genplot	generate summary plots (T or F)
verbose	verbose output (T or F)

References

Vaughan, S. (2005), *A simple test for periodic signals in red noise*, Astronomy & Astrophysics.

Examples

```
# generate example series with periods of 400 ka, 100 ka, 40 ka and 20 ka
ex = cycles(freqs=c(1/400,1/100,1/40,1/20),start=1,end=1000,dt=5)

# add AR1 noise
noise = ar1(npts=200,dt=5,sd=.5)
ex[2] = ex[2] + noise[2]

# calculate periodogram
res=periodogram(ex,output=1,padfac=1)

# extract power and remove the Nyquist frequency
resPwr=cb(res,c(1,3))
resPwr=resPwr[-length(resPwr[,1]),]

pwrLawFit(resPwr)
```

---

rankSeries   *Create lithofacies rank series from bed thickness data*

Description

Create lithofacies rank series from bed thickness data.

Usage

```
rankSeries(dat,dt,start=0,genplot=T,verbose=T)
```

Arguments

dat	First column should be bed thickness, and second column should bed lithofacies rank.
dt	Sampling interval for piecewise linear interpolation. By default a grid spacing that is 5 times smaller than the thinnest bed is used. If dt is set to zero, interpolation is skipped.
start	Start at what time/depth/height value?
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Examples

```
# generate example series with random bed thicknesses
exThick=rnorm(n=20,mean=10,sd=2)
# assign alternating rank of 1 and 2
rank=double(20)
rank[seq(from=1,to=19,by=2)] <- 1
rank[seq(from=2,to=20,by=2)] <- 2

# combine into a dataframe
ex=cb(exThick,rank)

# generate lithofacies rank series
rankSeries(ex)
```

---

read   *Read data from file*

Description

Read stratigraphic data series from a file, either tab-delimited, CSV, or semicolon-delimited. First column MUST contain location data (depth, height, time). The function will remove missing entries, sort by location, average duplicate values, and generate summary plots.

Usage

```
read(file=NULL,d=1,h="auto",skip=0,srt=T,ave=T,check=T,genplot=T,verbose=T)
```

Arguments

file	An optional file name, which must be in quotes (use the full directory path if the file is not in your present working directory). When a file name is not specified (the default), the file will be selected using a graphical user interface.
d	What column delimiter is used? (0 = tab/.txt, 1 = comma/.csv, 2 = semicolon). CSV is the default option, which interfaces well with EXCEL.
h	Does the data file have column titles/headers? ("yes", "no", "auto"). "auto" will auto detect column titles/headers, which must be single strings and start with a character.
skip	Number of lines to skip before beginning to read file
srt	Sort data values by first column? (T or F)
ave	Average duplicate values? (T or F). Only applies if input file has 2 columns
check	Check for sorting, duplicates, and empty entries in the data frame? (T or F). If set to F, sorting, duplicate averaging and empty entry removal are disabled.
genplot	generate summary plots (T or F).
verbose	Verbose output? (T or F).

Details

Missing values (in the file that you are reading from) should be indicated by 'NA'. If you have included characters in the column titles that are not permitted by R, they will be modified!

---

readMatrix   *Read data matrix from file*

Description

Read data matrix from a file, either tab-delimited, CSV, or semicolon-delimited.

Usage

```
readMatrix(file=NULL,d=1,h="auto",skip=0,output=1,check=T,genplot=F,verbose=T)
```

Arguments

file	An optional file name, which must be in quotes (use the full directory path if the file is not in your present working directory). When a file name is not specified (the default), the file will be selected using a graphical user interface.
d	What column delimiter is used? (0 = tab/.txt, 1 = comma/.csv, 2 = semicolon). CSV is the default option, which interfaces well with EXCEL.

h	Does the data file have column titles/headers? ("yes", "no", "auto"). "auto" will auto detect column titles/headers, which must be single strings and start with a character.
skip	Number of lines to skip before beginning to read file
output	Return data as: 1= matrix, 2=data frame
check	Check for empty entries in the matrix? (T or F).
genplot	generate summary plots (T or F).
verbose	Verbose output? (T or F).

Details

Missing values (in the file that you are reading from) should be indicated by 'NA'. If you have included characters in the column titles that are not permitted by R, they will be modified!

---

repl0	*Replace values < 0 with 0*

Description

Replace all variable values < 0 with 0. If first column is location ID (depth/height/time), it will not be processed. Any number of variables (columns) permitted.

Usage

```
repl0(dat,ID=T,genplot=T,verbose=T)
```

Arguments

dat	Data series to process. If location is included (e.g., depth), it should be in the first column.
ID	Is a location ID included in the first column? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

replEps   *Replace values <= 0 with smallest positive value*

Description

Replace all variable values <= 0 with the smallest positive floating-point number (eps) that can be represented on machine. If first column is location ID (depth/height/time), it will not be processed. Any number of variables (columns) permitted.

Usage

```
replEps(dat,ID=T,genplot=T,verbose=T)
```

Arguments

dat	Data series to process. If location is included (e.g., depth), it should be in the first column.
ID	Is a location ID included in the first column? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

---

resample   *Resample stratigraphic series*

Description

Resample a stratigraphic series using a new (variably sampled) time or space axis. Values are piecewise-linearly interpolated from original data.

Usage

```
resample(dat,xout,genplot=T,check=T,verbose=T)
```

Arguments

dat	Stratigraphic series for resampling. First column should be location (e.g., depth), second column should be data value.
xout	Vector of new sampling locations.
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F). In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

---

rmNA   *Remove stratigraphic levels that contain one or more NAs*

Description

Remove stratigraphic levels that contain one or more NAs.

Usage

```
rmNA(dat,genplot=T,verbose=T)
```

Arguments

dat
: Data series to process. If location is included (e.g., depth), it should be in the first column.

genplot
: Generate summary plots? (T or F)

verbose
: Verbose output? (T or F)

---

s   *Standardize variable in stratigraphic series*

Description

Standardize variable in stratigraphic series (subtract mean value and divide by standard deviation)

Usage

```
s(dat,genplot=F,verbose=T)
```

Arguments

dat
: Stratigraphic series for standardization. First column should be location (e.g., depth), second column should be data value.

genplot
: Generate summary plots? (T or F)

verbose
: Verbose output? (T or F)

---

sedRamp	*Apply 'ramping' sedimentation rate model to convert time to stratigraphy*

Description

Apply a linearly increasing (or decreasing) sedimentation rate model to convert time to stratigraphy.

Usage

```
sedRamp(dat,srstart=0.01,srend=0.05,genplot=T,verbose=T)
```

Arguments

dat	Time series. First column should be time (in ka), second column should be data value.
srstart	Initial sedimentation rate (in m/ka).
srend	Final sedimentation rate (in m/ka).
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Value

modeled stratigraphic series.

Examples

```
# generate example series with 3 precession terms using function 'cycles'
# then convert from time to space using sedimentation rate that increases from 1 to 7 cm/ka
ex=sedRamp(cycles(),srstart=0.01,srend=0.07)
```

---

sedrate2time	*Integrate sedimentation rate curve to obtain time-space map*

Description

Integrate sedimentation rate curve to obtain time-space map.

Usage

```
sedrate2time(sedrates,timedir=1,genplot=T,check=T,verbose=T)
```

Arguments

sedrates	Data frame containing depth/height in first column (meters) and sedimentation rates in second column (cm/ka).
timedir	Floating time scale direction: 1= time increases with depth/height; 2= time decreases with depth/height.)
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

---

slideCor	*Identify optimal spatial/temporal shift to maximize correlation between two stratigraphic/time series.*

Description

Identify optimal spatial/temporal shift to maximize correlation between two stratigraphic/time series.

Usage

```
slideCor(dat1,dat2,rev=F,cormethod=1,minpts=NULL,detrend=F,rmin=NULL,
         output=T,genplot=T,verbose=T)
```

Arguments

dat1	Stratigraphic series 1. First column should be location (e.g., depth), second column should be data value.
dat2	Stratigraphic series 2. First column should be location (e.g., depth), second column should be data value.
rev	Reverse polarity of stratigraphic series 2 (multiply proxy data value by -1)? (T or F)
cormethod	Method used for calculation of correlation coefficient (1=Pearson, 2=Spearman rank, 3=Kendall)
minpts	Minimum number of data points for calculation of correlation coefficient.
detrend	Remove linear trend from each window? (T or F)
rmin	Minimum r and r2 value shown on plots. By default all r and r2 values will be displayed.
output	Output correlation coefficient results as a dataframe? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

slideCor is a general purpose tool to identify the optimal spatial/temporal correlation between two data sets. A few example applications include: (1) stratigraphic correlation of data series from two locations (as in Preto et al., 2004), (2) identification of the optimal spatial/temporal lag between two variables from the same site, and (3) identification of the optimal fit between a floating astrochronology and astronomical target (e.g, Mitchell et al., 2008).

Both series must be evenly sampled, but are not required to have the same sampling interval. If stratigraphic series of different duration/length are being compared, the shift (in spatial or temporal units) should be interpreted as the location within the longer stratigraphic series where the shorter stratigraphic series begins. If both stratigraphic series are of the same duration/length, then the shift is the location within dat1 where dat2 begins.

In some cases, it may be desirable to smooth or bandpass the data series before implementing slideCor (e.g., functions noLow, noKernel, bandpass, taner, etc.).

References

Preto, N., Hinnov, L.A., De Zanche, V., Mietto, P., and Hardie, L.A., 2004, *The Milankovitch interpretation of the Latemar Platform cycles (Dolomites, Italy): Implications for geochronology, biostratigraphy, and Middle Triassic carbonate accumulation*, SEPM Special Publication 81.

Mitchell, R.N., Bice, D.M., Montanari, A., Cleaveland, L.C., Christianson, K.T., Coccioni, R., and Hinnov, L.A., 2008, *Oceanic anoxic cycles? Orbital prelude to the Bonarelli Level (OAE 2)*, Earth Planet. Sci. Lett. 26, 1-16.

See Also

surrogateCor

Examples

```
# Example 1: generate AR1 noise
ex1 <- ar1(npts=1000,dt=1)
# isolate a section
ex2 <- iso(ex1,xmin=200,500)
ex2[1] <- ex2[1]-200

res=slideCor(ex1,ex2)

# Example 2: an astronomical signal
ex1=etp(tmin=0,tmax=1000)
# isolate a 200 ka section
ex2=iso(ex1,xmin=400,xmax=600)
# convert to a floating timescale (elapsed time)
ex2[1] <- ex2[1]-400

res=slideCor(ex1,ex2)
# now anchor the floating time scale
anchor <- ex1[res[which.max(res[,2]),1],1]
ex2.anchor <- anchorTime(dat=ex2, time=0, age=anchor, timeDir=2)
```

---

sortNave   *Remove missing entries, sort data, average duplicates*

Description

Sort and average duplicates in stratigraphic series, as performed in 'read' function.

Usage

```
sortNave(dat,sortDecr=F,ave=T,xmin=NULL,xmax=NULL,genplot=1,verbose=T)
```

Arguments

dat	Stratigraphic series for processing. First column should be location (e.g., depth), second column should be data value.
sortDecr	Sorting direction? (F=increasing, T=decreasing)
ave	Average duplicate values? (T or F)
xmin	Minimum x-axis value for plotting
xmax	Maximum x-axis value for plotting
genplot	Generate summary plots? 0=none, 1=stratigraphic series, distribution, box plot, Q-Q, 2=stratigraphic series
verbose	Verbose output? (T or F)

---

stepHeat   *Ar/Ar Geochronology: Generate an Ar/Ar age spectrum and calculate step-heating plateau age.*

Description

The stepHeat function will evaluate data from stepwise heating experiments, producing an Ar/Ar age spectrum, a weighted mean age with uncertainty, and other helpful statistics/plots (with interactive graphics for data culling). The function includes the option to generate results using the approach of IsoPlot 3.70 (Ludwig, 2008) or ArArCALC (Koppers, 2002).

Usage

```
stepHeat(dat,unc=1,lambda=5.463e-10,J=NULL,Jsd=NULL,CI=2,cull=-1,del=NULL,output=F,
         idPts=T,size=NULL,unit=1,setAr=95,color="black",genplot=T,verbose=T)
```

Arguments

dat	dat must be a data frame with seven columns, as follows: (1) %Ar39 released, (2) date, (3) date uncertainty (one or two sigma), (4) K/Ca, (5) %Ar40*, (6) F, and (7) F uncertainty (one or two sigma). NOTE: F is the ratio Ar40*/Ar39K (see Koppers, 2002).
unc	What is the uncertainty on your input dates? (1) one sigma, or (2) two sigma. DEFAULT is one sigma. This also applies to the F uncertainty, and the J-value uncertainty (if specified)
lambda	Total decay constant of K40, in units of 1/year. The default value is 5.463e-10/year (Min et al., 2000).
J	Neutron fluence parameter
Jsd	Uncertainty for J-value (neutron fluence parameter; as one or two sigma)
CI	Which convention would you like to use for the 95% confidence intervals? (1) ISOPLOT (Ludwig, 2008), (2) ArArCALC (Koppers, 2002)
cull	Would you like select dates with a graphical interface? (0=no, 1=select points to retain, -1=select points to remove)
del	A vector of indices indicating dates to remove from weighted mean calculation. If specified, this takes precedence over cull.
output	Return weighted mean results as new data frame? (T or F)
idPts	Identify datum number on each point? (T or F)
size	Multiplicative factor to increase or decrease size of symbols and fonts. The default is 1.4
unit	The time unit for your results. (1) = Ma, (2) = Ka
setAr	Set the %Ar40* level to be illustrated on the plot. The default is 95%.
color	Color to use for symbols. Default is black.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

This function performs weighted mean age calculations for step-heating data, including estimation of age uncertainties, mean square weighted deviation, and probability of fit.

The following plots are produced:

(1) %Ar40* versus %Ar39 released

(2) K/Ca versus %Ar39 released

(3) Ar/Ar age spectrum, with 2 sigma uncertainties for each step, and weighted mean with 95% confidence interval (in red)

If the J-value and its uncertainty are input, stepHeat will calculate and include the uncertainty associated with J. The uncertainty is calculated and propagated following equation 18 of Koppers (2002).

A NOTE regarding confidence intervals: There are two conventions that can be used to calculate the confidence intervals, selected with the option 'CI':

(1) ISOPLOT convention (Ludwig, 2008). When the probability of fit is $>= 0.15$, the confidence interval is based on 1.96*sigma. When the probability of fit is < 0.15, the confidence interval is based on t*sigma*sqrt(MSWD).

(2) ArArCALC convention (Koppers, 2002). When MSWD $<=1$, the confidence interval is based on 1.96*sigma. When MSWD > 1, the confidence interval is based on 1.96*sigma*sqrt(MSWD).

ADDITIONAL ADVICE: Use the function readMatrix to load your data in R (rather than the function read).

References

A.A.P. Koppers, 2002, *ArArCALC- software for 40Ar/39Ar age calculations*: Computers & Geosciences, v. 28, p. 605-619.

K.R. Ludwig, 2008, *User's Manual for Isoplot 3.70: A Geochronological Toolkit for Microsoft Excel*: Berkeley Geochronology Center Special Publication No. 4, Berkeley, 77 p.

I. McDougall and T.M. Harrison, 1991, *Geochronology and Thermochronology by the 40Ar/39Ar Method*: Oxford University Press, New York, 269 pp.

K. Min, R. Mundil, P.R. Renne, and K. Ludwig, 2000, *A test for systematic errors in 40Ar/39Ar geochronology through comparison with U/Pb analysis of a 1.1-Ga rhyolite*: Geochimica et Cosmochimica Acta, v. 64, p. 73-98.

I. Wendt and C. Carl, 1991, *The statistical distribution of the mean squared weighted deviation*: Chemical Geology, v. 86, p. 275-285.

See Also

wtMean

Examples

```
 ## Not run:
# Check to see if this is an interactive R session, for compliance with CRAN standards.
# YOU CAN SKIP THE FOLLOWING LINE IF YOU ARE USING AN INTERACTIVE SESSION.
if(interactive()) {

# Sample MT-09-09 incremental heating Ar/Ar data from Sageman et al. (2014).
perAr39 <- c(4.96,27.58,19.68,39.9,6.25,1.02,0.42,0.19)
age <- c(90.08,89.77,89.92,89.95,89.89,89.55,87.71,86.13)
sd <- c(0.18,0.11,0.08,0.06,0.14,0.64,1.5,3.22)
KCa <- c(113,138,101,195,307,27,17,24)
perAr40 <- c(93.42,99.42,99.64,99.79,99.61,97.99,94.64,90.35)
Fval <- c(2.148234,2.140643,2.144197,2.145006,2.143627,2.135163,2.090196,2.051682)
Fsd <- c(0.00439,0.00270,0.00192,0.00149,0.00331,0.01557,0.03664,0.07846)
ex <- data.frame(cbind(perAr39,age,sd,KCa,perAr40,Fval,Fsd))

stepHeat(ex)

# plot without points identified
stepHeat(ex,size=0,idPts=FALSE,cull=0)

}
```

```
## End(Not run)
```

---

stratPCA   *Principal Component Analysis on Stratigraphic Series*

Description

Perform principal component analysis on stratigraphic series.

Usage

```
stratPCA(dat,id=TRUE,rot=0,nPC=NULL,output=0,symSize=2,genplot=1)
```

Arguments

dat	Your data frame; should be in stratigraphic order. First column may be location identifier (e.g., depth). Can contain any number of variables.
id	Is the first column of dat an ID column (depth/height/time)? (T or F)
rot	Rotation method. 0=none, 1=varimax (orthogonal), 2=promax (oblique)
nPC	Number of principal components to extract. Default=all
output	What would you like to output? 0=nothing, 1=PC loadings, 2=scores
symSize	Size of symbols used in color plots? Default=2
genplot	Generate summary plots? (0) no plots, (1) standard plots, (2) additional plots

Examples

```
## Not run:
# create a test data set, composed of 7 variables:
#  antiphased 20 kyr cycles with noise,
#  antiphased 40 kyr cycles with noise,
#  antiphased 110 kyr cycles with noise,
#  and a variable that is entirely noise
noise=0.01
a=cycles(1/20,noisevar=noise,genplot=FALSE)
b=cycles(1/20,phase=pi,noisevar=noise,genplot=FALSE)
c=cycles(1/40,noisevar=noise,genplot=FALSE)
d=cycles(1/40,phase=pi,noisevar=noise,genplot=FALSE)
e=cycles(1/110,noisevar=noise,genplot=FALSE)
f=cycles(1/110,phase=pi, noisevar=noise,genplot=FALSE)
g=ar1(npts=500,genplot=FALSE)

ex=data.frame(cbind(a[,1],a[,2],b[,2],c[,2],d[,2],e[,2],f[,2],g[,2]))

stratPCA(ex)

stratPCA(ex,rot=1,nPC=4)
```

```
stratPCA(ex,rot=2,nPC=4)

## End(Not run)
```

---

strats   *Summary statistics for stratigraphic series*

Description

Summary statistics for stratigraphic series: sampling interval and proxy values.

Usage

```
strats(dat,output=0,genplot=1)
```

Arguments

dat	Stratigraphic series to evaluate. The first column should contain location (e.g., depth), and the second column should contain data value. This function also accepts non-stratigraphic (single column) input, in which case the sampling interval assessment is skipped.
output	Output: (0) nothing, (1) cumulative dt as percent of data points, (2) cumulative dt as percent of total interval duration, (3) dt by location
genplot	Generate summary plots? (0) none, (1) include plot of cumulative dt, (2) include dt histogram/density plot

Details

This function will generate a range of summary statistics for time series, including sampling interval information and the statistical distribution of proxy values.

---

surrogateCor   *Estimate correlation coefficient and significance for serially correlated data*

Description

Estimate correlation coefficient and significance for serially correlated data. This algorithm permits the analysis of data sets with different sampling grids, as discussed in Baddouh et al. (2016). The sampling grid from the data set with fewer points (in the common interval) is used for resampling. Resampling is conducted using piecewise-linear interpolation.

If either dat1 or dat2 have only one column, the resampling is skipped.

The significance of the correlation is determined using the method of Ebisuzaki W. (1997).

Usage

```
surrogateCor(dat1,dat2,firstDiff=F,cormethod=1,nsim=1000,output=2,genplot=T,check=T,
             verbose=T)
```

Arguments

dat1	Data series with one or two columns. If two columns, first should be location (e.g., depth), second column should be data value.
dat2	Data series with one or two columns. If two columns, first should be location (e.g., depth), second column should be data value.
firstDiff	Calculate correlation using first differences? (T or F)
cormethod	Method used for calculation of correlation coefficient (1=Pearson, 2=Spearman rank, 3=Kendall)
nsim	Number of phase-randomized surrogate series to generate. If nsim <=1, simulation is deactivated.
output	Return which of the following?: 1= correlation coefficients for each simulation; 2= correlation coefficient for data series; 3= data values used in correlation estimate (resampled)
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Details

Paraphrased from Baddouh et al. (2016): To provide a quantitative evaluation of the correlation between two data sets that do not share a common sampling grid, we introduce a statistical approach that employs sample interpolation, and significance testing with phase-randomized surrogate data (Ebisuzaki, 1997). The sparser sampling grid is used to avoid over-interpolation. Correlation is evaluated using Pearson, Spearman Rank, or Kendall rank coefficients. The statistical significance of the resulting correlation coefficients are estimated via Monte Carlo simulations using phase-randomized surrogates; the surrogates are subject to the same interpolation process, and compensate for potential serial correlation of data (Ebisuzaki, 1997).

The first-difference series of each variable can also evaluated, to assess correlation in the magnitude of change between sequential stratigraphic samples rather than absolute magnitude.

References

M. Baddouh, S.R. Meyers, A.R. Carroll, B.L. Beard, C.M. Johnson , 2016, *Lacustrine 87-Sr/86-Sr as a tracer to reconstruct Milankovitch forcing of the Eocene hydrologic cycle*: Earth and Planetary Science Letters.

W. Ebisuzaki, 1997, *A Method to Estimate the Statistical Significance of a Correlation When the Data Are Serially Correlated*: Journal of Climate, v. 10, p. 2147-2153.

See Also

[surrogates](#)

Examples

```
# generate two stochastic AR1 series
ex1 <- ar1(npts=100,dt=5)
ex2 <- ar1(npts=100,dt=6)

# calculate pearson correlation coefficient and p-value
surrogateCor(ex1,ex2)
```

---

surrogates	*Generate phase-randomized surrogate series as in Ebisuzaki (1997)*

Description

Generate phase-randomized surrogate series as in Ebisuzaki (1997).

Usage

```
surrogates(dat,nsim=1,preserveMean=T,std=T,genplot=T,verbose=T)
```

Arguments

dat	Data series with one or two columns. If two columns, first should be location (e.g., depth), second column should be data value.
nsim	Number of phase-randomized surrogate series to generate.
preserveMean	Should surrogate series have the same mean value as data series? (T or F)
std	Standardize results to guarantee equivalent variance as data series? (T or F)
genplot	Generate summary plots? Only applies if nsim=1. (T or F)
verbose	Verbose output? (T or F)

Details

This function will generate phase-randomized surrogate series as in Ebisuzaki (1997). It is an R-translation of the Matlab code by V. Moron (see link below), with modifications and additional features.

References

W. Ebisuzaki, 1997, *A Method to Estimate the Statistical Significance of a Correlation When the Data Are Serially Correlated*: Journal of Climate, v. 10, p. 2147-2153.

Matlab code by V. Moron: http://www.mathworks.com/matlabcentral/fileexchange/10881-weaclim/content/ebisuzaki.m

Original C-code by W. Ebisuzaki: http://www.ftp.cpc.ncep.noaa.gov/wd51we/random_phase/

Examples

```
# generate example series with 3 precession terms and noise
ex <- cycles(start=0,end=500,noisevar=.0004,dt=5)

# generate phase-randomized surrogates
ran_ex <- surrogates(ex,nsim=1)

# compare periodograms of data and surrogates
res1 <- periodogram(ex,padfac=0,output=1,genplot=FALSE)
res2 <- periodogram(ran_ex,padfac=0,output=1,genplot=FALSE)

pl(2)
plot(ex,type="l",main="black=original; red=surrogate")
lines(ran_ex,col="red",lty=4)
plot(res1[,1],res1[,2],type="l",lwd=2,main="black=original; red=surrogate",
     xlab="frequency",ylab="amplitude")
lines(res2[,1],res2[,2],col="red",lwd=2,lty=4)
```

---

synthStrat	*Synthesize stratigraphy from forcing function*

Description

Synthesize stratigraphy from forcing function.

Usage

```
synthStrat(signal=NULL,nfacies=4,clip=T,flip=F,fmax=0.1,output=F,genplot=2,verbose=T)
```

Arguments

signal	Forcing signal. First column should be time (in ka), second column should be forcing.
nfacies	Number of sedimentary facies to model.
clip	Clip forcing signal at mean value? (T or F)
flip	Reverse the sign of the forcing? (T or F)
fmax	Maximum frequency for spectra (if genplot=2).
output	Output facies series? (T or F)
genplot	Generate summary plots? (1) plot stratigraphy, (2) plot statigraphy and spectra.
verbose	Verbose output? (T or F)

Value

modeled stratigraphic series.

Examples

```
 ## Not run:
# EX.1: precession, unclipped
signal=etp(tmin=8400,tmax=8900,pWt=1,oWt=0,eWt=0)
synthStrat(signal,nfacies=4,clip=FALSE,genplot=2)

# EX.2: more finely resolved facies
#synthStrat(signal,nfacies=15,clip=FALSE,genplot=2)

# EX.3: couplets
#synthStrat(signal,nfacies=2,clip=FALSE,genplot=2)

# EX.4: precession, clipped
#synthStrat(signal,nfacies=4,genplot=2)

# EX.5: noise
noise=ar1(npts=501,rho=0.8)
#synthStrat(noise,nfacies=4,genplot=2)

# EX.6: precession + noise
#signal2=signal
#signal2[2]=signal2[2]+0.75*noise[2]
#synthStrat(signal2,nfacies=4,genplot=2)

# EX.7: p-0.5t, clipped (demonstrates interference pattern; compare with EX.4
#signal3=etp(tmin=8400,tmax=8900,pWt=1,oWt=-0.5,eWt=0)
#synthStrat(signal3,nfacies=4,genplot=2)

# EX.8: ice sheet model, using p-0.5t
#ice=imbrie()
#synthStrat(ice,nfacies=5,clip=FALSE,genplot=2)

# EX.9: precession, clipped, ramping sedimentation rate
#synthStrat(linterp(sedRamp(signal,genplot=FALSE),genplot=FALSE),nfacies=6,
# clip=TRUE,genplot=2,fmax=10)


## End(Not run)
```

---

taner   *Apply Taner bandpass or lowpass filter to stratigraphic series*

Description

Apply Taner bandpass or lowpass filter to stratigraphic series. This function can also be used to notch filter or highpass a record (see examples).

Usage

```
taner(dat,padfac=2,flow=NULL,fhigh=NULL,roll=10^3,demean=T,detrend=F,addmean=T,
       output=1,xmin=0,xmax=Nyq,genplot=T,check=T,verbose=T)
```

Arguments

`dat`	Stratigraphic series for bandpass filtering. First column should be location (e.g., depth), second column should be data value.
`padfac`	Pad with zeros to (padfac*npts) points, where npts is the original number of data points.
`flow`	Low frequency cut-off for Taner filter (half power point). If this value is not set (NULL), it will default to -1*fhigh, which will create a lowpass filter.
`fhigh`	High frequency cut-off for Taner filter (half power point).
`roll`	Roll-off rate, in dB/octave. Typical values are 10^3 to 10^12, but can be larger.
`demean`	Remove mean from data series? (T or F)
`detrend`	Remove linear trend from data series? (T or F)
`addmean`	Add mean value to bandpass result? (T or F)
`output`	Output: (1) filtered series, (2) bandpass filter window.
`xmin`	Smallest frequency for plotting.
`xmax`	Largest frequency for plotting.
`genplot`	Generate summary plots? (T or F)
`check`	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
`verbose`	Verbose output? (T or F)

Value

bandpassed stratigraphic series.

References

http://www.rocksolidimages.com/pdf/attrib_revisited.htm#_Toc328470897

See Also

[bandpass](), [lowpass](), [noKernel](), [noLow](), [prewhiteAR](), and [prewhiteAR1]()

Examples

```
# generate example series with periods of 405 ka, 100 ka, 40ka, and 20 ka, plus noise
ex=cycles(freqs=c(1/405,1/100,1/40,1/20),end=1000,dt=5,noisevar=.1)

# bandpass precession term using Taner window
bandpass_ex <- taner(ex,flow=0.045,fhigh=0.055,roll=10^10)

# lowpass filter eccentricity terms using Taner window
lowpass_ex=taner(ex,fhigh=.02,roll=10^10)

# notch filter (remove) obliquity term using Taner window
#  if you'd like the final notch filtered record to be centered on the mean proxy
#  value, set addmean=FALSE
```

```
notch_ex <- taner(ex,flow=0.02,fhigh=0.03,roll=10^10,addmean=FALSE)
notch_ex[2] <- ex[2]-notch_ex[2]
pl(2)
plot(ex,type="l",main="Eccentricity+Obliquity+Precession")
plot(notch_ex,type="l",main="Following application of obliquity notch filter")

# highpass filter obliquity and precession terms using Taner window
#  if you'd like the final highpass filtered record to be centered on the mean proxy
#  value, set addmean=FALSE
highpass_ex=taner(ex,fhigh=.02,roll=10^10,addmean=FALSE)
highpass_ex[2] <- ex[2]-highpass_ex[2]
pl(2)
plot(ex,type="l",main="Eccentricity+Obliquity+Precession")
plot(highpass_ex,type="l",main="Obliquity+Precession highpassed signal")
```

---

tanerFC   *Apply Taner bandpass or lowpass filter to Fourier coefficients*

Description

Apply Taner bandpass or lowpass filter to Fourier coefficients.

Usage

```
tanerFC(fc,npts,flow=NULL,fhigh=NULL,roll=10^3,output=1,genplot=T,verbose=T)
```

Arguments

fc	Fourier coefficients, as output by the function 'periodogram'. The first column is frequency, the second column contains the real coefficients, and the third column contains the imaginary coefficients.
npts	The number of points in the stratigraphic series used to estimate the Fourier coefficients.
flow	Low frequency cut-off for Taner filter (half power point). If this value is not set (NULL), it will default to -1*fhigh, which will create a lowpass filter.
fhigh	High frequency cut-off for Taner filter (half power point).
roll	Roll-off rate, in dB/octave. Typical values are 10^3 to 10^12, but can be larger.
output	Output: (1) filtered series, (2) bandpass filter window.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

This function is designed for cases when one needs to efficiently apply a range of filter parameters to a stratigraphic series. It is used within function 'timeOpt' to speed up processing. For more general use, function 'taner' is preferred, which also provides a range of plots for evaluating the filtering.

Fourier coefficients for 'tanerFC' can be determined with the function 'periodogram', using options 'output=2' and 'nrm=0'.

Value

bandpassed stratigraphic series.

References

http://www.rocksolidimages.com/pdf/attrib_revisited.htm#_Toc328470897

See Also

bandpass, lowpass, noKernel, noLow, prewhiteAR, and prewhiteAR1

Examples

```
# generate example series with periods of 405 ka, 100 ka, 40ka, and 20 ka, plus noise
ex=cycles(freqs=c(1/405,1/100,1/40,1/20),end=1000,dt=5,noisevar=.1)

# calculate the Fourier coefficients using periodogram function. this must be done with
# no normalization (nrm=0)
fc_ex <- periodogram(ex,demean=TRUE,output=2,nrm=0)

# bandpass precession term using Taner window
bandpass_ex <- tanerFC(fc=fc_ex,npts=201,flow=0.045,fhigh=0.055,roll=10^10)

# lowpass filter eccentricity terms using Taner window
lowpass_ex <- tanerFC(fc=fc_ex,npts=201,fhigh=.02,roll=10^10)
```

---

testBackground   *Evaluate power spectrum false positive rates via Monte Carlo simulation*

Description

This is a simulation tool to evaluate power spectrum false positive rates, the frequency distribution of the false positives, and the behavior of numerous "multiple correction" procedures, for a range of background estimation approaches that are implemented in Astrochron. The tool can be used to conduct surrogate analyses, alongside analysis of real data, to better understand the suitability of particular background estimation approaches. The resulting simulations are similar to those presented in Figure 3 of Meyers (2012) and Crampton et al. (PNAS).

Usage

```
testBackground(npts=1001,dt=5,noiseType="ar1",coeff=NULL,method="periodogramAR1",
            opt=NULL,demean=T,detrend=F,low=0,tbw=3,multi=F,iter=2000,output=F,
              genplot=F,verbose=T)
```

Arguments

npts	Number of points in simulated stratigraphic series (surrogates).
dt	Sampling interval for surrogates.
noiseType	Select "ar1" for AR1 noise surrogates, or "pwrLaw" for Power Law noise surrogates
coeff	AR1 coefficient (rho) or Power Law coefficient (beta) for surrogates.
method	Background estimation method: (1) "mtmAR1" (function mtm), (2) "mtmML96" (function mtmML96), (3) "lowspec" (function lowspec), (4) "mtmPL" (function mtmPL), (5) "periodogramPL" (function periodogram), (6) "periodogramAR1" (function periodogram)
opt	Method specific options. For mtmML96, this is medsmooth (see function mtmML96); for lowspec this is lowspan (see function lowspec); for periodogram this is percent cosine taper (see function cosTaper).
demean	Remove mean value from simulated surrogates? (T or F; this option does not apply to lowspec)
detrend	Remove linear trend from simulated surrogates? (T or F)
low	Remove long-term trend using a LOWESS smoother? Choose a value ranging from 0-1 (see function noLow). 0 = no long-term trend removal.
tbw	MTM time-bandwidth product. This option is ignored for methods 5 and 6.
multi	Evaluate a range of multiple-comparison tests too? (T or F)
iter	Number of iterations (surrogate series) for Monte Carlo simulation.
output	Output data frame? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

The Monte Carlo simulations can utilize AR1 or Power Law noise surrogates. Background estimation approaches include conventional AR1, ML96, LOWSPEC and Power Law. The function also allows evaluation of common data detrending approaches (linear trend removal, LOWESS trend removal).

Note that MTM-ML96 conducts the Mann and Lees (1996; ML96) "robust red noise" analysis, with an improved median smoothing approach. The original Mann and Lees (1996) approach applies a truncation of the median smoothing window to include fewer frequencies near the edges of the spectrum; while truncation is required, its implementation in the original method often results in an "edge effect" that can produce excess false positive rates at low frequencies, commonly within the eccentricity-band (Meyers, 2012). To help address this issue, an alternative median smoothing approach is applied that implements Tukey's robust end-point rule and symmetrical medians (see the

function mtmML96 for more details). This version of the ML96 algorithm was first implemented in Patterson et al. (2014).

See function multiTest for more information on the multiple comparison tests evaluated.

References

W.S. Cleveland, 1979, *Locally weighted regression and smoothing scatterplots*: Journal of the American Statistical Association, v. 74, p. 829-836.

J.S. Campton, S.R. Meyers, R.A. Cooper, P.M Sadler, M. Foote, D. Harte, 2018, *Pacing of Paleozoic macroevolutionary rates by Milankovitch grand cycles*: Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1714342115.

M.E. Mann, and J.M. Lees, 1996, *Robust estimation of background noise and signal detection in climatic time series*, Clim. Change, 33, 409-445.

S.R. Meyers, 2012, *Seeing Red in Cyclic Stratigraphy: Spectral Noise Estimation for Astrochronology*: Paleoceanography, 27, PA3228, doi:10.1029/2012PA002307.

M.O. Patterson, R. McKay, T. Naish, C. Escutia, F.J. Jimenez-Espejo, M.E. Raymo, M.E., S.R. Meyers, L. Tauxe, H. Brinkhuis, and IODP Expedition 318 Scientists,2014, *Response of the East Antarctic Ice Sheet to orbital forcing during the Pliocene and Early Pleistocene*, Nature Geoscience, v. 7, p. 841-847.

D.J. Thomson, 1982, *Spectrum estimation and harmonic analysis*: IEEE Proceedings, v. 70, p. 1055-1096.

See Also

confAdjust,multiTest,lowspec, mtm, mtmML96, mtmPL, and periodogram

Examples

```
 ## Not run:
# evaluate false positive rate for MTM-AR1 using AR1 surrogates
testBackground(noiseType="ar1",method="mtmAR1")

# evaluate false positive rate for MTM-AR1 using Power Law surrogates
testBackground(noiseType="pwrLaw",method="mtmAR1")

## End(Not run)
```

| testPrecession | *Astrochronologic testing via the precession amplitude modulation approach of Zeeden et al. (2015).* |

Description

Astrochronologic testing via the precession amplitude modulation approach of Zeeden et al. (2015), as updated in Zeeden et al. (2018 submitted).

Usage

```
testPrecession(dat,nsim=1000,gen=1,edge=0.025,maxNoise=1,rho=NULL,detrendEnv=T,
               solution=NULL,output=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series to analyze. First column should be location (time in ka, a positive value), second column should be data value.
nsim	Number of Monte Carlo simulations (phase-randomized surrogates or AR1 surrogates).
gen	Monte Carlo simulation generator: (1) use phase-randomized surrogates, (2) use AR1 surrogates.
edge	Percentage of record to exclude from beginning and end of data series, to remove edge effects. (a value from 0-1)
maxNoise	Maximum noise level to add in simulations. A value of 1 will apply maximum noise that is equivalent to 1 standard deviation of the data.
rho	Specified lag-1 correlation coefficient (rho). If rho is not specified, it will be calculated within the function.
detrendEnv	Linearly detrend envelope? (T or F)
solution	Theoretical solution used for astrochronologic testing. Solution should be in the format: time (ka), precession angle, obliquity, eccentricity (the output from function 'getLaskar'). By default this is automatically determined within the function, using the solution of Laskar et al. (2004).
output	Return results as a new data frame? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

This astrochronologic testing method compares observed precession-scale amplitude modulations to those expected from the theoretical eccentricity solutions. It is applicable for testing astrochronologies spanning 0-50 Ma. The technique implements a series of filters to guard against artificial introduction of eccentricity modulations during tuning and data processing, and evaluates the statistical significance of the results using Monte Carlo simulation (Zeeden et al., 2015).

The algorithm includes an improvement in the significance testing approach. Specifically, as a safeguard against artificially imposed modulations, an adaptive noise addition step is implemented (as outlined in Zeeden et al., submitted).

The astronomically-tuned data series under evaluation should consist of two columns: time in kiloyears & data value. Note that time must be positive. The default astronomical solutions used for the astrochronologic testing come from Laskar et al. (2004).

When reporting a p-value for your result, it is important to consider the number of simulations used. A factor of 10 is appropriate, such that for 1000 simulations one would report a minimum p-value of "p<0.01", and for 10000 simulations one would report a minimum p-value of "p<0.001".

Please be aware that the kernel density estimate plots, which summarize the simulations, represent 'smoothed' models. Due to the smoothing bandwidth, they can sometimes give the impression of simulation values that are larger or smaller than actually present. However, the reported p-value does not suffer from these issues.

IMPORTANT CHANGES (June 20, 2018): Note that this version has been updated to use 'solution' instead of 'esinw', for consistency with the function 'testTilt'. If you are invoking the default option, you do not need to make any changes to your script. Also note that the new option 'edge' has been added, which by default will truncate your data series by 5 percent (2.5 percent on each end of the record), to guard against edge effects that can be present in the amplitude envelope. Set edge to 0 to reconstruct the original (now legacy) 'testPrecession' approach.

Value

When nsim is set to zero, the function will output a data frame with five columns:

1=time, 2=precession bandpass filter output, 3=amplitude envelope of (2), 4=lowpass filter output of (3), 5=theoretical eccentricity (as extracted from precession modulations using the filtering algorithm), 6=(2) + noise, 7=amplitude envelope of (6), 8=lowpass filter output of (7)

When nsim is > 0, the function will output the correlation coefficients for each simulation.

References

C. Zeeden, S.R. Meyers, L.J. Lourens, and F.J. Hilgen, 2015, *Testing astronomically tuned age models*: Paleoceanography, 30, doi:10.1002/2014PA002762.

C. Zeeden, S.R. Meyers, F.J. Hilgen, L.J. Lourens, and J. Laskar, submitted, *Time scale evaluation and the quantification of obliquity forcing*: Quaternary Science Reviews.

J. Laskar, P. Robutel, F. Joutel, M. Gastineau, A.C.M. Correia, and B. Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

See Also

asm, eAsmTrack, timeOpt, and timeOptSim

Examples

```
 ## Not run:
### as a test series, use the three dominant precession terms from Berger et al. (1992)
ex<-cycles(start=0,end=1000,dt=2)

### now conduct astrochronologic testing
testPrecession(ex)


### if you plan to run testPrecession repeatedly, it is advisable to download the astronomical
### solution first
solution<-getLaskar()

### now conduct astrochronologic testing
testPrecession(ex,solution=solution)
```

```
## End(Not run)
```

---

testTilt | *Astrochronologic testing via the obliquity amplitude modulation approach of Zeeden et al. (2019).*

Description

Astrochronologic testing via the obliquity amplitude modulation approach of Zeeden et al. (2019).

Usage

```
testTilt(dat,nsim=1000,gen=1,edge=0.025,cutoff=1/150,maxNoise=0.25,rho=NULL,detrendEnv=T,
           solution=NULL,output=F,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series to analyze. First column should be location (time in ka, a positive value), second column should be data value.
nsim	Number of Monte Carlo simulations (phase-randomized surrogates or AR1 surrogates).
gen	Monte Carlo simulation generator: (1) use phase-randomized surrogates, (2) use AR1 surrogates.
edge	Percentage of record to exclude from beginning and end of data series, to remove edge effects. (0-1)
cutoff	Cutoff frequency for lowpass filtering.
maxNoise	Maximum noise level to add in simulations. A value of 1 will apply maximum noise that is equivalent to 1 sd of data.
rho	Specified lag-1 correlation coefficient (rho). This value is only used if gen=2. If rho is not specified, it will be calculated within the function.
detrendEnv	Linearly detrend envelope? (T or F)
solution	Theoretical solution used for astrochronologic testing. Solution should be in the format: time (ka), precession angle, obliquity, eccentricity (the output from function 'getLaskar'). By default this is automatically determined within the function, using the solution of Laskar et al. (2004).
output	Return results as a new data frame? (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

This astrochronologic testing method compares observed obliquity-scale amplitude modulations to those expected from the theoretical solutions. It is applicable for testing astrochronologies spanning 0-50 Ma. The technique implements a series of filters to guard against artificial introduction of modulations during tuning and data processing, and evaluates the statistical significance of the results using Monte Carlo simulation. The algorithm includes an adaptive noise addition step to improvement the significance testing approach. See Zeeden et al. (2019 submitted) for additional information.

The astronomically-tuned data series under evaluation should consist of two columns: time in kilo-years & data value. Note that time must be positive. The default obliquity solution used for the astrochronologic testing comes from Laskar et al. (2004).

When reporting a p-value for your result, it is important to consider the number of simulations used. A factor of 10 is appropriate, such that for 1000 simulations one would report a minimum p-value of "p<0.01", and for 10000 simulations one would report a minimum p-value of "p<0.001".

Please be aware that the kernel density estimate plots, which summarize the simulations, represent 'smoothed' models. Due to the smoothing bandwidth, they can sometimes give the impression of simulation values that are larger or smaller than actually present. However, the reported p-value does not suffer from these issues.

Value

When nsim is set to zero, the function will output a data frame with five columns:

1=time, 2=obliquity bandpass filter output, 3=amplitude envelope of (2), 4=lowpass filter output of (3), 5=theoretical obliquity (as extracted from modulations using the filtering algorithm), 6=(2) + noise, 7=amplitude envelope of (6), 8=lowpass filter output of (7)

When nsim is > 0, the function will output the correlation coefficients for each simulation.

References

C. Zeeden, S.R. Meyers, F.J. Hilgen, L.J. Lourens, and J. Laskar, 2019, *Time scale evaluation and the quantification of obliquity forcing*: Quaternary Science Reviews, 209, doi.org/10.1016/j.quascirev.2019.01.018.

C. Zeeden, S.R. Meyers, L.J. Lourens, and F.J. Hilgen, 2015, *Testing astronomically tuned age models*: Paleoceanography, 30, doi:10.1002/2014PA002762.

J. Laskar, P. Robutel, F. Joutel, M. Gastineau, A.C.M. Correia, and B. Levrard, B., 2004, *A long term numerical solution for the insolation quantities of the Earth*: Astron. Astrophys., Volume 428, 261-285.

See Also

asm, eAsmTrack, timeOpt, and timeOptSim

Examples

```
 ## Not run:
### as a test series, use the obliquity series from Laskar et al. (2004), spanning
### the past 4 million years
ex<-etp(tmin=0,tmax=4000,dt=2,eWt=0,oWt=1,pWt=0,standardize=FALSE)
```

```
### now conduct astrochronologic testing
testTilt(ex)

### if you plan to run testTilt repeatedly, it is advisable to download the astronomical
### solution
solution<-getLaskar()

### now conduct astrochronologic testing
testTilt(ex,solution=solution)

## End(Not run)
```

timeOpt	*TimeOpt: Evaluation of eccentricity-related amplitude modulation and bundling in paleoclimate data*

Description

TimeOpt: Evaluation of eccentricity-related amplitude modulation and bundling in paleoclimate data, as in Meyers (2015). The method can also be used to evaluate records that express obliquity, as in Meyers (2019).

Usage

```
timeOpt(dat,sedmin=0.5,sedmax=5,numsed=100,linLog=1,limit=T,fit=1,r2max=1,
        fitModPwr=T,flow=NULL,fhigh=NULL,roll=NULL,targetE=NULL,targetP=NULL,
        detrend=T,output=0,title=NULL,genplot=T,check=T,verbose=T)
```

Arguments

dat	Stratigraphic series for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
sedmin	Minimum sedimentation rate for investigation (cm/ka).
sedmax	Maximum sedimentation rate for investigation (cm/ka).
numsed	Number of sedimentation rates to investigate in optimization grid.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log; default value is 1)
limit	Limit evaluated sedimentation rates to region in which full target signal can be recovered? (T or F)
fit	Test for (1) precession amplitude modulation or (2) short eccentricity amplitude modulation?
r2max	Which maximum in r2 do you want to use for the time model calibration? (1) r^2_opt, (2) r^2_spectral, (3) r^2_envelope
fitModPwr	Include the modulation periods in the spectral fit? (T or F)

flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka)
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka)
roll	Taner filter roll-off rate, in dB/octave.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with a first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
detrend	Remove linear trend from data series? (T or F)
output	Which results would you like to return to the console? (0) no output; (1) return sedimentation rate grid, r^2_envelope, r^2_power, r^2_opt; (2) return optimal time series, filtered precession, precession envelope, TimeOpt-reconstructed eccentricity model, full TimeOpt-regression model
title	A character string (in quotes) specifying the title for the graphics window (optional)
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Details

TimeOpt is an astronomical testing algorithm for untuned (spatial) stratigraphic data. The algorithm identifies the sedimentation rate(s) that simultaneously optimizes: (1) eccentricity amplitude modulations within the precession band, and (2) the concentration of spectral power at specified target astronomical periods (Meyers, 2015). The method can also be adapted to evaluate records that express obliquity, as in Meyers (2019).

For each temporal calibration investigated (i.e., sedimentation rate), the observed precession band amplitude envelope is extracted using bandpass filtering and the Hilbert transform. The fit of the extracted precession envelope to the eccentricity periods is evaluated using a linear regression onto sine and cosine terms that reflect the five dominant eccentricity periods (~405.7, 130.7, 123.8, 98.9 and 94.9 kyr); amplitude and phase of the eccentricity terms are not assigned, but are determined during the linear model optimization. This approach is advantageous, as (1) the transfer functions associated with the climate and depositional systems can alter the amplitude and phase of the theoretical eccentricity terms (e.g, Laurin et al., 2005), and (2) the amplitude and phase of the eccentricity terms are unconstrained for deep-time investigations (>50 Ma). The quality of the "fit" is estimated by calculation of the correlation of the fitted eccentricity model time series to the observed precession band envelope (r^2_envelope), indicating the fraction of variance shared between the model and envelope.

The concentration of power at the target astronomical periods is evaluated using a linear regression of the temporally-calibrated series onto sine and cosine terms that reflect the dominant eccentricity and precession periods. As above, the amplitude and phase of each term is determined during the linear model optimization, and the quality of the "fit" is estimated by calculation of the correlation of the fitted astronomical model series to the temporally-calibrated series (r^2_spectral).

The final measure of fit (r^2_opt) is determined as:

r^2_opt = r^2_envelope * r^2_spectral

which is simply the product of the fraction of variance shared between "model and envelope" and "model and time-calibrated data". This optimization approach identifies the sedimentation rate at which the precession envelope strongly expresses expected eccentricity modulation, while simultaneously, spectral power is concentrated at the target astronomical periods. r^2_opt can take on values ranging from 0 to 1 (a perfect fit to the astronomical model), and provides a measure of overall quality of the astronomically calibrated time series. A similar approach is applicable to evaluate short eccentricity amplitude modulations. The statistical significance of the r^2_opt is determined via Monte Carlo simulation (see timeOptSim).

See the examples below and Meyers (2019) for a demonstration of how TimeOpt can be adapted to evaluate records that express obliquity.

Value

if output = 1, a data frame containing the following will be returned: Sedimentation rate (cm/ka), r^2_envelope, r^2_spectral, r^2_opt

if output = 2, a data frame containing the following will be returned: Time (ka), tuned time series, filtered precession, precession envelope, TimeOpt-reconstructed eccentricity model, full TimeOpt-regression model

References

J. Laurin, S.R. Meyers, B.B. Sageman, and D.A. Waltham, 2005, *Phase-lagged amplitude modulation of hemipelagic cycles: A potential tool for recognition and analysis of sea level change*: Geology, 33, doi.org/10.1130/G21350.1.

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulation and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography, 30, doi.org/10.1002/2015PA002850.

S.R. Meyers, 2019, *Cyclostratigraphy and the problem of astrochronologic testing*: Earth-Science Reviews, 190, doi.org/10.1016/j.earscirev.2018.11.015.

See Also

asm, eAsmTrack, testPrecession, timeOptPlot, and timeOptSim

Examples

```
 ## Not run:
# generate a test signal with precession and eccentricity
ex=etp(tmin=1,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE,genplot=FALSE,verbose=FALSE)
# convert to meters with sedimentation rate of 2 cm/kyr
ex[1]<-ex[1]*0.02
timeOpt(ex,sedmin=0.5,sedmax=5,numsed=100,fit=1,output=0)
# evaluate short eccentricity modulations
timeOpt(ex,sedmin=0.5,sedmax=5,numsed=100,fit=2,output=0)

# generate a test signal with precession
ex=etp(tmin=1,tmax=1000,dt=5,pWt=1,oWt=0,eWt=0,esinw=TRUE,genplot=FALSE,verbose=FALSE)
# convert to meters with sedimentation rate of 2 cm/kyr
ex[1]<-ex[1]*0.02
```

```
timeOpt(ex,sedmin=0.5,sedmax=5,numsed=100,fit=1,output=0)

# generate a test signal with precession, obliquity and eccentricity
ex=etp(tmin=1,tmax=1000,dt=5,pWt=1,oWt=1,eWt=1,esinw=TRUE,genplot=FALSE,verbose=FALSE)
# convert to meters with sedimentation rate of 2 cm/kyr
ex[1]<-ex[1]*0.02
# define target periods for obliquity and precession
targetOP=c(41.15226,23.62069,22.31868,19.06768,18.91979)
timeOpt(ex,sedmin=0.5,sedmax=5,numsed=100,fit=1,targetP=targetOP,output=0)

# generate a test signal with obliquity
ex=etp(tmin=1,tmax=1500,dt=5,pWt=0,oWt=1,eWt=0,genplot=FALSE,verbose=FALSE)
# convert to meters with sedimentation rate of 2 cm/kyr
ex[1]<-ex[1]*0.02
# define target periods for obliquity and obliquity amplitude modulation
targetO=c(41.15226)
targetO_AM=c(1250,175.4386,109.8901,95.2381)
timeOpt(ex,sedmin=0.5,sedmax=5,numsed=100,fit=1,fitModPwr=F,targetP=targetO,
  targetE=targetO_AM,flow=1/70,fhigh=1/26,roll=10^15,output=0)

## End(Not run)
```

---

timeOptMCMC   *TimeOptMCMC: Evaluation of eccentricity-related amplitude modulation and bundling in paleoclimate data ("TimeOpt"), with uncertainties via Markov-Chain Monte Carlo*

Description

TimeOptMCMC: Evaluation of eccentricity-related amplitude modulation and bundling in paleoclimate data ("TimeOpt"; Meyers, 2015), with uncertainties on all fitting parameters via Markov-Chain Monte Carlo (MCMC). This function follows the approach of Meyers and Malinverno (2018). MCMC is implemented using the Metropolis-Hastings algorithm. Optimization is conducted upon the sedimentation rate (constant within the study interval), the fundamental frequencies g1-g5, the precession constant k, and four hyperparameters associated with the residuals from the spectral and envelope fit. The priors for the k and g's are Gaussian, while other parameters (sedrate, hyperparameters) are uniform (uninformative).

Usage

```
timeOptMCMC(dat,iopt=1,sedmin=0.5,sedmax=5,sedstart=NULL,gAve=NULL,
        gSd=NULL,gstart=NULL,kAve=NULL,kSd=NULL,kstart=NULL,
      rhomin=0,rhomax=0.9999,rhostart=NULL,sigmamin=NULL,sigmamax=NULL,sigmastart=NULL,
      ran=T,fit=1,ftol=0.01,roll=10^3,nsamples=1000,epsilon=NULL,test=F,burnin=-1,
        detrend=T,output=1,savefile=F,genplot=1,verbose=T)
```

Arguments

dat	Stratigraphic series for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
iopt	(1) fit power and envelope, (2) fit power only.
sedmin	Minimum sedimentation rate for investigation (cm/ka).
sedmax	Maximum sedimentation rate for investigation (cm/ka).
sedstart	Initial sedimentation rate for MCMC search (cm/ka). Default is 0.5*(sedmin+sedmax). Alternatively, if set to negative number, a random value is selected from the prior distribution.
gAve	Vector which contains the average values for the g1 through g5 fundamental frequencies (arcsec/year). Must be in the following order: g1,g2,g3,g4,g5.
gSd	Vector which contains the standard deviation for the g1 through g5 fundamental frequencies (arcsec/year). Must be in the following order: g1,g2,g3,g4,g5.
gstart	Vector which contains the initial values for the g1 through g5 fundamental frequencies (arcsec/year). Must be in the following order: g1,g2,g3,g4,g5. Default is 0.5*(gmin+gmax). Alternatively, if set to negative number, a random value is selected from the prior distribution.
kAve	Average value for the precession constant (arcsec/year).
kSd	Standard deviation for the precession constant (arcsec/year).
kstart	Initial value for the precession constant (arcsec/year). Default is 0.5*(kmin+kmax). Alternatively, if set to negative number, a random value is selected from the prior distribution.
rhomin	Minimum value for residual lag-1 autocorrelation (for both spectral and envelope fit). Default is 0.
rhomax	Maximum value for residual lag-1 autocorrelation (for both spectral and envelope fit). Default is 0.9999
rhostart	Initial value for residual lag-1 autocorrelation (for both spectral and envelope fit). Default 0.5. Alternatively, if set to negative number, a random value is selected from the prior distribution.
sigmamin	Minimum value for residual sigma (for both spectral and envelope fit).
sigmamax	Maximum value for residual sigma (for both spectral and envelope fit).
sigmastart	Initial value for residual sigma (for both spectral and envelope fit). Default 0.5*(data standard deviation). Alternatively, if set to negative number, a random value is selected from the prior distribution.
ran	Would you like to randomly select the parameter for updating (T), or simultaneously update all the parameters (F)?
fit	Test for (1) precession amplitude modulation or (2) short eccentricity amplitude modulation? Option 2 is not yet functional!
ftol	Tolerance in cycles/ka used to define the precession bandpass. It is added to the highest precession frequency, and subtracted from the lowest precession frequency, to define the half power points for the Taner bandpass filter.
roll	Taner filter roll-off rate, in dB/octave.

nsamples   Number of candidate MCMC simluations to perform.

epsilon   Vector of dimension 11, which controls how large the jump is between each can-
                  didate value, e.g. sedimentation rate. For example, a value of 0.2 will yield max-
                  imum jump +/- 10 percent of sedimentation rate range. The vector must be ar-
                  ranged in the the following order: sedrate,k,g1,g2,g3,g4,g5,spec_rho,spec_sigma,env_rho,env_sigma.
                  If NULL, all epsilon values will be assigned 0.2

test   Activate epsilon testing mode? This option will assign all MCMC samples a log-
                  likelihood of unity. This provides a diagnostic check to ensure that the applied
                  epsilon values are sampling the entire range of parameter values. (T or F)

burnin   Threshold for detection of MCMC stability.

detrend   Remove linear trend from data series? (T or F)

output   Which results would you like to return to the console? (0) no output; (1) return
                  all MCMC candidates

savefile   Save MCMC samples to file MCMCsamples.csv? (T or F). If true, results are
                  output after every 1000 iterations (last iterations will not be reported if you do
                  not end on an even thousand!)

genplot   Generate summary plots? (0= none; 1=display all summary plots; 2=also in-
                  clude progress plot during iterations; 3=be quiet, but save all plots as pngs to the
                  working directory)

verbose   Verbose output? (T or F)

Details

TimeOpt is an astronomical testing algorithm for untuned (spatial) stratigraphic data. The algorithm
identifies the sedimentation rate(s) that simultaneously optimizes: (1) eccentricity amplitude mod-
ulations within the precession band, and (2) the concentration of spectral power at specified target
astronomical periods.

This version of TimeOpt uses MCMC via Metropolis-Hastings to estimate the parameters and their
uncertainties. The priors for the k and g's are Gaussian, while the other parameters (sedrate, hyper-
parameters) are uniform (uninformative).

When ran=T, the following approach is used to select the parameter to modify:

0.25 probability of changing sedimentation rate

0.25 probability of changing k

0.30 probability of changing g1,g2,g3,g4,g5 (simultaneously)

0.10 probability of changing sigma_spec,rho_spec (simultaneously)

0.10 probability of changing sigma_env,rho_env (simultaneously)

This is motivated by sensitivity tests, and the fact that we are most interested in g, k and s; moving
each group of parameters (sedrate, k or g's) has specific consequences we can isolate.

For additional guidance on the application of TimeOptMCMC, please see the guide "Bayesian In-
version with TimeOptMCMC" (Meyers, 2024), and Meyers and Malinverno (2018).

References

S.R. Meyers, 2024, *Bayesian Inversion with TimeOptMCMC*: EarthArXiv, https://doi.org/10.31223/X5DQ3H

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulation and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography, 30, doi:10.1002/2015PA002850.

S.R. Meyers and A. Malinverno, 2018, *Proterozoic Milankovitch cycles and the history of the solar system*: Proceedings of the National Academy of Sciences, www.pnas.org/cgi/doi/10.1073/pnas.1717689115.

---

timeOptPlot	*TimeOptPlot: Generate summary figure for TimeOpt analyses*

Description

TimeOptPlot: Generate summary figure for TimeOpt analyses.

Usage

```
timeOptPlot(dat=NULL,res1=NULL,res2=NULL,simres=NULL,fit=1,fitModPwr,flow=NULL,
            fhigh=NULL,roll=NULL,targetE=NULL,targetP=NULL,xlab="Depth (m)",
            ylab="Proxy Value",fitR=NULL,verbose=T)
```

Arguments

dat	Stratigraphic series used for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
res1	Data frame containing TimeOpt results: sedimentation rate grid, r^2_envelope, r^2_power, r^2_opt.
res2	Data frame containing the optimal-fitted time series, bandpassed series, envelope, and reconstructed eccentricity model.
simres	Data frame containing the r^2_opt value for each Monte Carlo simulation.
fit	Test for (1) precession amplitude modulation or (2) short eccentricity amplitude modulation?
fitModPwr	Include the modulation periods in the spectral fit? (T or F)
flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka).
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka).
roll	Taner filter roll-off rate, in dB/octave.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with a first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
xlab	Label for the depth/height axis.
ylab	Label for proxy variable evaluated.
fitR	The r2_opt value at the optimal sedimentation rate.
verbose	Verbose output? (T or F)

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulation and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography, 30, doi:10.1002/2015PA002850.

See Also

asm, eAsmTrack, testPrecession, timeOpt, and timeOptSim

Examples

```
 ## Not run:
# generate a test signal with precession and eccentricity
ex=etp(tmin=1,tmax=1000,dt=1,pWt=1,oWt=0,eWt=1,esinw=TRUE,genplot=FALSE,verbose=FALSE)
# convert to meters with sedimentation rate of 2 cm/kyr
ex[1]<-ex[1]*0.02
# evaluate precession modulations
res1=timeOpt(ex,sedmin=0.5,sedmax=5,numsed=100,fit=1,output=1)
res2=timeOpt(ex,sedmin=0.5,sedmax=5,numsed=100,fit=1,output=2)
simres=timeOptSim(ex,sedmin=0.5,sedmax=5,numsed=100,numsim=2000,fit=1,output=2)
timeOptPlot(ex,res1,res2,simres,flow=0.035,fhigh=0.065,roll=10^3,
 targetE=c(405.6795,130.719,123.839,98.86307,94.87666),
 targetP=c(23.62069,22.31868,19.06768,18.91979),xlab="Depth (m)",
 ylab="Value",fitR=0.832,verbose=T)

## End(Not run)
```

---

timeOptSim   *Monte Carlo simulation for TimeOpt*

Description

Perform Monte Carlo AR1 simulations to evaluate significance of TimeOpt results, as in Meyers (2015).

Usage

```
timeOptSim(dat,numsim=2000,rho=NULL,sedrate=NULL,sedmin=0.5,sedmax=5,numsed=100,
     linLog=1,limit=T,fit=1,r2max=1,fitModPwr=T,flow=NULL,fhigh=NULL,roll=NULL,
        targetE=NULL,targetP=NULL,detrend=T,ncores=2,output=0,genplot=T,
        check=T,verbose=T)
```

Arguments

dat	Stratigraphic series for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
numsim	Number of Monte Carlo AR1 simulations.

rho	AR1 coefficient to use in simulations. By default this will be estimated from the stratigraphic series.
sedrate	Sedimentation rate for investigation (cm/ka). This option is for compatibility with prior versions of timeOptSim. Please use sedmin, sedmax, numsed.
sedmin	Minimum sedimentation rate for investigation (cm/ka).
sedmax	Maximum sedimentation rate for investigation (cm/ka).
numsed	Number of sedimentation rates to investigate in optimization grid.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log)
limit	Limit evaluated sedimentation rates to region in which full target signal can be recovered? (T or F)
fit	Test for (1) precession amplitude modulation or (2) short eccentricity amplitude modulation?
r2max	Which maximum in r2 do you want to use for the time model calibration? (1) r^2_opt, (2) r^2_spectral, (3) r^2_envelope
fitModPwr	Include the modulation periods in the spectral fit? (T or F)
flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka)
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka)
roll	Taner filter roll-off rate, in dB/octave.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with a first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
detrend	Remove linear trend from data series? (T or F)
ncores	Number of cores to use for parallel processing. Must be >=2
output	Which results would you like to return to console? (0) no output; (1) p-value; (2) simulation r2 results
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F). In general this should be activated.
verbose	Verbose output? (T or F)

Details

TimeOpt is an astronomical testing algorithm for untuned (spatial) stratigraphic data. The algorithm identifies the sedimentation rate(s) that simultaneously optimizes: (1) eccentricity amplitude modulations within the precession band, and (2) the concentration of spectral power at specified target astronomical periods. The statistical significance of the r^2_opt is determined via Monte Carlo simulation using timeOptSim.

The present version of timeOptSim improves upon the original significance testing method of Meyers (2015), by conducting simulations across the entire sedimentation grid. This approach more rigorously protects against inflation of the p-value due to multiple testing. Parallel processing has been implemented to address the greater computational demand that is required.

See timeOpt for more information on the basic methodology.

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography.

See Also

asm, eAsm, eAsmTrack, testPrecession, timeOpt, and timeOptPlot

Examples

```
 ## Not run:
# generate a test signal with precession and eccentricity
ex=etp(tmin=1,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE,genplot=FALSE,verbose=FALSE)
# convert to meters with sedimentation rate of 2 cm/kyr
ex[1]<-ex[1]*0.02
# evaluate with timeOptSim. be patient, this may take a while to run.
timeOptSim(ex,sedmin=0.5,sedmax=5,numsed=100)

## End(Not run)
```

---

timeOptSimPwrLaw   *Monte Carlo simulation for TimeOpt, using power law (1/f) noise*

Description

Perform Monte Carlo power law (1/f) simulations to evaluate significance of TimeOpt results, as in Meyers (2015).

Usage

```
timeOptSimPwrLaw(dat,numsim=2000,beta=NULL,sedrate=NULL,sedmin=0.5,sedmax=5,numsed=100,
     linLog=1,limit=T,fit=1,r2max=1,fitModPwr=T,flow=NULL,fhigh=NULL,roll=NULL,
        targetE=NULL,targetP=NULL,detrend=T,ncores=2,output=0,genplot=T,
        check=T,verbose=T)
```

Arguments

dat	Stratigraphic series for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
numsim	Number of Monte Carlo power law (1/f) simulations.
beta	Power law coefficient for 1/f noise. Positive number yields a negative slope. By default this will be estimated from the stratigraphic series.
sedrate	Sedimentation rate for investigation (cm/ka). This option is for compatibility with prior versions of timeOptSim. Please use sedmin, sedmax, numsed.
sedmin	Minimum sedimentation rate for investigation (cm/ka).

sedmax	Maximum sedimentation rate for investigation (cm/ka).
numsed	Number of sedimentation rates to investigate in optimization grid.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log)
limit	Limit evaluated sedimentation rates to region in which full target signal can be recovered? (T or F)
fit	Test for (1) precession amplitude modulation or (2) short eccentricity amplitude modulation?
r2max	Which maximum in r2 do you want to use for the time model calibration? (1) r^2_opt, (2) r^2_spectral, (3) r^2_envelope
fitModPwr	Include the modulation periods in the spectral fit? (T or F)
flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka)
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka)
roll	Taner filter roll-off rate, in dB/octave.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with a first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
detrend	Remove linear trend from data series? (T or F)
ncores	Number of cores to use for parallel processing. Must be >=2
output	Which results would you like to return to console? (0) no output; (1) p-value; (2) simulation r2 results
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F). In general this should be activated.
verbose	Verbose output? (T or F)

Details

TimeOpt is an astronomical testing algorithm for untuned (spatial) stratigraphic data. The algorithm identifies the sedimentation rate(s) that simultaneously optimizes: (1) eccentricity amplitude modulations within the precession band, and (2) the concentration of spectral power at specified target astronomical periods. The statistical significance of the r^2_opt is determined via Monte Carlo simulation using timeOptSim.

The present version of timeOptSim improves upon the original significance testing method of Meyers (2015), by conducting simulations across the entire sedimentation grid. This approach more rigorously protects against inflation of the p-value due to multiple testing. Parallel processing has been implemented to address the greater computational demand that is required.

See timeOpt for more information on the basic methodology.

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography.

See Also

asm, eAsm, eAsmTrack, testPrecession, timeOpt, and timeOptPlot

Examples

```
 ## Not run:
# generate a test signal with precession and eccentricity
ex=etp(tmin=1,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE,genplot=FALSE,verbose=FALSE)
# convert to meters with sedimentation rate of 2 cm/kyr
ex[1]<-ex[1]*0.02
# evaluate with timeOptSim. be patient, this may take a while to run.
timeOptSimPwrLaw(ex,sedmin=0.5,sedmax=5,numsed=100)

## End(Not run)
```

---

timeOptTemplate   *TimeOpt analysis using variable sedimentation models*

Description

Evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data, as in
Meyers (2015) and Meyers (2019), adapted to allow the evaluation of a wide range of variable
sedimentation models, including: differential accumulation across bedding couplets, linear accu-
mulation rate change, step changes in sedimentation rate, etc.

Usage

```
timeOptTemplate(dat,template=NULL,sedmin=0.5,sedmax=5,difmin=NULL,difmax=NULL,fac=NULL,
      numsed=50,linLog=1,limit=T,fit=1,fitModPwr=T,iopt=3,flow=NULL,fhigh=NULL,
      roll=NULL,targetE=NULL,targetP=NULL,cormethod=1,detrend=T,detrendTemplate=F,
        flipTemplate=F,ncores=1,output=0,genplot=1,check=T,verbose=1)
```

Arguments

dat	Stratigraphic series for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
template	Instantaneous sedimentation rate template to fit. This represents a unitless pro-portional sedimentation rate history. Default model is a copy of dat, which will be scaled for instantaneous accumulation optimization.
sedmin	Minimum AVERAGE sedimentation rate for investigation (cm/ka).
sedmax	Maximum AVERAGE sedimentation rate for investigation (cm/ka).
difmin	Minimum instantaneous sedimentation rate to investigate (cm/ka).
difmax	Maximum instantaneous sedimentation rate to investigate (cm/ka). By default, this is ignored, and fac is used.

fac	Maximum instantaneous accumulation factor. Maximum rate is scaled to each investigated sedrate as fac*sedrate. Default value of 5 is based on experimentation. If larger than this, risk getting into local minimum during fit.
numsed	Number of sedimentation rates to investigate in optimization grid.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log)
limit	Limit evaluated sedimentation rates to region in which full target signal can be recovered? (T or F)
fit	Test for (1) precession amplitude modulations or (2) short eccentricity amplitude modulations?
fitModPwr	Include the modulation periods in the spectral fit? (T or F)
iopt	Optimize on (1) modulations, (2) spectral power, (3) modulations*spectral power
flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka)
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka)
roll	Taner filter roll-off rate, in dB/octave. Default value is 10^3.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
cormethod	Method used for calculation of correlation coefficient (1=Pearson, 2=Spearman)
detrend	Remove linear trend from data series? (T or F)
detrendTemplate	
	Remove linear trend from sedimentation rate template? (T or F)
flipTemplate	Flip direction of sedimentation rate template? (T or F)
ncores	Number of cores to use for parallel processing
output	Which results you like to return to console? (0) no output; (1) return sedimentation rate grid, r2opt; (2) return optimal time series, bandpassed series, Hilbert and fitted periods; (3) return the optimal sedimentation rate at each depth or height
genplot	Generate summary plots? (0 = nothing, 1=summary plot, 2=progress + summary plots)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (0 = nothing, 1=minimal, 2=everything)

Details

TimeOpt employs a probabilistic linear regression model framework to investigate amplitude modulation and frequency ratios (bundling) in stratigraphic data, while simultaneously determining the optimal time scale. This function further develops the method to optimize upon complex sedimentation templates. The approach is demonstrated below with a series of examples.

The statistical significance of the r^2_opt is determined via Monte Carlo simulation (see timeOptSim). See timeOpt for more information on the basic methodology.

Value

if output = 1, a data frame containing the following will be returned: Sedimentation rate (cm/ka), r-squared value (r^2_envelope, r^2_spectra, or r^2_opt)

if output = 2, a data frame containing the following will be returned: Time (ka), tuned time series, bandpassed series, envelope, TimeOpt-reconstructed eccentricity model

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography, v.30, 1625-1640.

S.R. Meyers, 2019, *Cyclostratigraphy and the problem of astrochronologic testing*: Earth-Science Reviews v.190, 190-223.

See Also

asm, eAsmTrack, testPrecession, timeOpt, timeOptSim, and timeOptTemplatePlot

Examples

```
## Not run:
# EXAMPLE (1): Differential accumulation across bedding couplets
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=diffAccum(ex,0.01,.05)
ex2=linterp(ex2)
# first with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
timeOptSim(ex2,sedmin=1,sedmax=4,numsed=100,numsim=2000)
# then with the timeOptTemplate approach
timeOptTemplate(ex2,sedmin=1,sedmax=4,difmin=.5,difmax=6,numsed=100,ncores=2)
timeOptTemplateSim(ex2,sedmin=1,sedmax=4,difmin=.5,difmax=6,numsed=100,numsim=1000,
 ncores=2)


# EXAMPLE (2): Linear sedimentation rate increase
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=sedRamp(ex,srstart=0.01,srend=0.05)
ex2=linterp(ex2)
# first with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
# then with the timeOptTemplate approach
# create linear model for input. the magnitude does not matter, it will be rescaled.
# (it just needs to be a line)
template=ex2; template[2]=ex2[1]
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=4,difmin=.5,difmax=6,numsed=100,ncores=2)
# view optimization procedure (must set ncores=1)
timeOptTemplate(ex2,template=template,sedmin=2.75,sedmax=3.25,difmin=.5,difmax=6,numsed=20,
ncores=1,genplot=2)


# EXAMPLE (3): Step increase in sedimentation rate, from 1 cm/kyr to 2 cm/kyr at 7 meters depth
```

```
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=ex
ex2[1]=ex[1]*.01
ex2[141:201,1]=ex2[141:201,1]*2-7
ex2=linterp(ex2)
# first with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
# then with the timeOptTemplate approach
# create step model for input. the magnitude does not matter, it will be rescaled.
template=ex2; template[1:140,2]=1; template[141:261,2]=2
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=4,numsed=100,ncores=2)
# view optimization procedure (must set ncores=1)
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=2,numsed=20,ncores=1,genplot=2)


# EXAMPLE (4): A record with a 100 kyr hiatus at 10 meters depth
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=delPts(ex,del=101:121)
# use a background sedimentation rate of 2 cm/kyr
ex2[1]=0:179*5*0.02
# first evaluate the distorted record with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
# then with the timeOptTemplate approach
#  create a constant sedimentation rate template with possible hiatus of unknown
#  duration at 10 m
template=ex2; template[2]=10; template[101,2]=1
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=3,difmax=3,numsed=100,ncores=2)
# now perform a finer grid search near the maximum, using power only
#  notice the oscillatory nature of the power fit.
res=timeOptTemplate(ex2,template=template,sedmin=1.5,sedmax=2,difmax=3,numsed=100,
 ncores=2,iopt=2,output=2)
# compare true eccentricity to TimeOpt-derived eccentricity
pl(2)
plot(ex,type="l",main="True Eccentricity Series",xlab="True Time (kyr)",ylab="")
plot(res[,1],res[,4],type="l",main="Black=TimeOpt precession AM; Red=TimeOpt eccentricity model",
xlab="TimeOpt derived time (kyr)",ylab="")
lines(res[,1],res[,5],col="red",lwd=2)

## End(Not run)
```

---

timeOptTemplatePlot   *TimeOptTemplatePlot: Generate summary figure for TimeOptTemplate analyses*

Description

TimeOptTemplatePlot: Generate summary figure for TimeOptTemplate analyses.

Usage

```
timeOptTemplatePlot(dat=NULL,template=NULL,detrend=T,detrendTemplate=F,flipTemplate=F,
  srMin=NULL,srMax=NULL,res1=NULL,simres=NULL,fit=1,flow=NULL,fhigh=NULL,roll=NULL,
  targetE=NULL,targetP=NULL,xlab="Depth (m)",ylab="Proxy Value",fitR=NULL,output=0,
  verbose=T)
```

Arguments

dat	Stratigraphic series used for astrochronologic assessment. First column should be depth or height (in meters), second column should be data value.
template	Instantaneous sedimentation rate template to fit. This represents a unitless proportional sedimentation rate history. Default model is a copy of dat, which will be scaled for instantaneous accumulation optimization.
detrend	Remove linear trend from data series? (T or F)
detrendTemplate	
	Remove linear trend from sedimentation rate template? (T or F)
flipTemplate	Flip direction of sedimentation rate template? (T or F)
srMin	Minimum sedimentation rate for template
srMax	Maximum sedimentation rate for template
res1	Data frame containing TimeOpt results: sedimentation rate grid, and one of the following - r^2_envelope, r^2_power, or r^2_opt.
simres	Data frame containing the r^2_opt value for each Monte Carlo simulation.
fit	Test for (1) precession amplitude modulation or (2) short eccentricity amplitude modulation?
flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka).
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka).
roll	Taner filter roll-off rate, in dB/octave.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with a first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
xlab	Label for the depth/height axis.
ylab	Label for proxy variable evaluated.
fitR	The r2 value at the optimal sedimentation rate.
output	Which results you like to return to console? (0) no output; (1) return optimal time series, bandpassed series, Hilbert and fitted periods; (2) return space-time map; (3) return the optimal sedimentation rate at each depth or height
verbose	Verbose output? (T or F)

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography, v.30, 1625-1640.

S.R. Meyers, 2019, *Cyclostratigraphy and the problem of astrochronologic testing*: Earth-Science Reviews v. 190, 190-223.

See Also

asm, eAsmTrack, testPrecession, timeOpt, timeOptSim, and timeOptTemplate

Examples

```
## Not run:
# EXAMPLE: Differential accumulation across bedding couplets
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=diffAccum(ex,0.01,.05)
ex2=linterp(ex2)

# evaluate with the timeOptTemplate approach
res1=timeOptTemplate(ex2,sedmin=1,sedmax=4,difmin=.5,difmax=6,numsed=100,output=1,ncores=2)
simres=timeOptTemplateSim(ex2,sedmin=1,sedmax=4,difmin=.5,difmax=6,numsed=100,numsim=1000,
 output=2,ncores=2)

timeOptTemplatePlot(ex2,template=ex2,srMin=1,srMax=4,res1=res1,simres=simres,
  targetP=c(23.62069,22.31868,19.06768,18.91979),
  targetE=c(405.6795,130.719,123.839,98.86307,94.87666))

## End(Not run)
```

---

timeOptTemplateSim   *Simulations for timeOptTemplate*

Description

Simulations for timeOptTemplate

Usage

```
timeOptTemplateSim(dat,template=NULL,corVal=NULL,numsim=2000,rho=NULL,sedmin=0.5,sedmax=5,
      difmin=NULL,difmax=NULL,fac=NULL,numsed=50,linLog=1,limit=T,fit=1,fitModPwr=T,
         iopt=3,flow=NULL,fhigh=NULL,roll=NULL,targetE=NULL,targetP=NULL,
      cormethod=1,detrend=T,detrendTemplate=F,flipTemplate=F,ncores=1,output=0,
         genplot=T,check=T,verbose=T)
```

Arguments

dat	Stratigraphic series for modulation assessment. First column should be depth or height (in meters), second column should be data value.
template	Instantaneous sedimentation rate template to fit. This represents a unitless proportional sedimentation rate history. Default template is a copy of dat, which will be scaled for instantaneous accumulation optimization.
corVal	r2opt value for data. By default this will be calculated.
numsim	Number of Monte Carlo AR1 simulations.
rho	AR1 coefficient to use in simulations. By default this will be estimated from the stratigraphic series.
sedmin	Minimum AVERAGE sedimentation rate for investigation (cm/ka).
sedmax	Maximum AVERAGE sedimentation rate for investigation (cm/ka).
difmin	Minimum instantaneous sedimentation rate to investigate (cm/ka).
difmax	Maximum instantaneous sedimentation rate to investigate (cm/ka). By default, this is ignored, and fac is used.
fac	Maximum instantaneous accumulation factor. Maximum rate is scaled to each investigated sedrate as fac*sedrate. Default value of 5 is based on experimentation. If larger than this, risk getting into local minimum during fit.
numsed	Number of sedimentation rates to investigate in optimization grid.
linLog	Use linear or logarithmic scaling for sedimentation rate grid spacing? (0=linear, 1=log)
limit	Limit evaluated sedimentation rates to region in which full target signal can be recovered? (T or F)
fit	Test for (1) precession amplitude modulations or (2) short eccentricity amplitude modulations? fit= 2 is not yet functional.
fitModPwr	Include the modulation periods in the spectral fit? (T or F)
iopt	Optimize on (1) modulations, (2) power, (3) mod*power
flow	Low frequency cut-off for Taner bandpass (half power point; in cycles/ka)
fhigh	High frequency cut-off for Taner bandpass (half power point; in cycles/ka)
roll	Taner filter roll-off rate, in dB/octave. Default value is 10^3.
targetE	A vector of eccentricity periods to evaluate (in ka). These must be in order of decreasing period, with first value of 405 ka.
targetP	A vector of precession periods to evaluate (in ka). These must be in order of decreasing period.
cormethod	Method used for calculation of correlation coefficient (1=Pearson, 2=Spearman)
detrend	Remove linear trend from data series? (T or F)
detrendTemplate	
	Remove linear trend from sedimentation rate template? (T or F)
flipTemplate	Flip direction of sedimentation rate template? (T or F)
ncores	Number of cores to use for parallel processing

output	Which results you like to return to console? (0) no output; (1) p-value; (2) simulation r2 results
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Details

TimeOpt employs a probabilistic linear regression model framework to investigate amplitude modulation and frequency ratios (bundling) in stratigraphic data, while simultaneously determining the optimal time scale. This function further develops the method to optimize upon complex sedimentation templates. The approach is demonstrated below with a series of examples.

The statistical significance of the r^2_opt is determined via Monte Carlo simulation (see timeOptSim). See timeOpt for more information on the basic methodology.

References

S.R. Meyers, 2015, *The evaluation of eccentricity-related amplitude modulations and bundling in paleoclimate data: An inverse approach for astrochronologic testing and time scale optimization*: Paleoceanography.

S.R. Meyers, 2019, *Cyclostratigraphy and the problem of astrochronologic testing*: Earth-Science Reviews.

Examples

```
## Not run:

# EXAMPLE (1): Differential accumulation across bedding couplets
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=diffAccum(ex,0.01,.05)
ex2=linterp(ex2)
# first with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
timeOptSim(ex2,sedmin=1,sedmax=4,numsed=100,numsim=2000)
# then with the timeOptTemplate approach
timeOptTemplate(ex2,sedmin=1,sedmax=4,difmin=.5,difmax=6,numsed=100,ncores=2)
timeOptTemplateSim(ex2,sedmin=1,sedmax=4,difmin=.5,difmax=6,numsed=100,numsim=1000,
 ncores=2)


# EXAMPLE (2): Linear sedimentation rate increase
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=sedRamp(ex,srstart=0.01,srend=0.05)
ex2=linterp(ex2)
# first with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
# then with the timeOptTemplate approach
# create linear model for input. the magnitude does not matter, it will be rescaled.
# (it just needs to be a line)
```

```
template=ex2; template[2]=ex2[1]
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=4,numsed=100,ncores=2)
# view optimization procedure
timeOptTemplate(ex2,template=template,sedmin=2.75,sedmax=3.25,numsed=20,ncores=1,genplot=2)

# EXAMPLE (3): Step increase in sedimentation rate, from 1 cm/kyr to 2 cm/kyr at 7 meters depth
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=ex
ex2[1]=ex[1]*.01
ex2[141:201,1]=ex2[141:201,1]*2-7
ex2=linterp(ex2)
# first with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
# then with the timeOptTemplate approach
# create step model for input. the magnitude does not matter, it will be rescaled.
template=ex2; template[1:140,2]=1; template[141:261,2]=2
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=4,numsed=100,ncores=2)
# view optimization procedure
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=2,numsed=20,ncores=1,genplot=2)


# EXAMPLE (4): A record with a 100 kyr hiatus at 10 meters depth
ex=etp(tmin=0,tmax=1000,dt=5,pWt=1,oWt=0,eWt=1,esinw=TRUE)
ex2=delPts(ex,del=101:121)
# use a background sedimentation rate of 2 cm/kyr
ex2[1]=0:179*5*0.02
# first evaluate the distorted record with the nominal timeOpt approach
timeOpt(ex2,sedmin=1,sedmax=4,numsed=100)
# then with the timeOptTemplate approach
# create a constant sedimentation rate model with possible hiatus of unknown
#  duration at 10 m
template=ex2; template[2]=10; template[101,2]=1
timeOptTemplate(ex2,template=template,sedmin=1,sedmax=3,difmax=3,numsed=100,ncores=2)
# now perform a finer grid search near the maximum, using power only
#  notice the oscillatory nature of the power fit.
res=timeOptTemplate(ex2,template=template,sedmin=1.5,sedmax=2,difmax=3,numsed=100,ncores=2,
 iopt=2,output=2)
# compare true eccentricity to TimeOpt-derived eccentricity
pl(2)
plot(ex,type="l",main="True Eccentricity Series",xlab="True Time (kyr)",ylab="")
plot(res[,1],res[,4],type="l",main="Black=TimeOpt precession AM; Red=TimeOpt eccentricity model",
xlab="TimeOpt derived time (kyr)",ylab="")
lines(res[,1],res[,5],col="red",lwd=2)

## End(Not run)
```

---

tones   *Calculate all possible difference and combinations tones*

Description

Determine all possible difference and combinations tones from a set of frequencies, and find the closest one to a specified frequency

Usage

```
tones(a=NULL,freqs=NULL,f=T)
```

Arguments

a	The frequency you are seeking to match, in cycles/ka.
freqs	The vector of frequencies from which to calculate difference and combination tones, in cycles/ka.
f	Output results as frequencies (cycles/ka)? If false, will output results as periods (ka). (T or F)

---

traceFreq	*Frequency-domain minimal tuning: Use interactive graphical interface to trace frequency drift*

Description

Frequency-domain minimal tuning: Use interactive graphical interface to trace frequency drift.

Usage

```
traceFreq(spec,color=2,h=6,w=4,xmin=NULL,xmax=NULL,ymin=NULL,ymax=NULL,ydir=1,
          palette=6,ncolors=100,path=1,pl=0)
```

Arguments

spec	Time-frequency spectral results to evaluate. Must have the following format: column 1=frequency; remaining columns (2 to n)=power, amplitude or probability; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eha.
color	Line color for tracing. 1 = transparent black; 2 = transparent white; 3 = transparent yellow
h	Height of plot in inches.
w	Width of plot in inches.
xmin	Minimum spatial frequency to plot.
xmax	Maximum spatial frequency to plot.
ymin	Minimum depth/height to plot.
ymax	Maximum depth/height to plot.

ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.
palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red, (6) viridis
ncolors	Number of colors to use in plot.
path	How do you want to represent the spatial frequency path?: 1=lines and points; 2=lines; 3=points
pl	An option for the color plots: 0=linear scale; 1=plot log of value, 2=normalize to maximum value

See Also

[eha](#) and [trackFreq](#)

Examples

```
 ## Not run:
# Check to see if this is an interactive R session, for compliance with CRAN standards.
# YOU CAN SKIP THE FOLLOWING LINE IF YOU ARE USING AN INTERACTIVE SESSION.
if(interactive()) {

# Generate example series with 3 terms using function 'cycles'.
# Then convert from time to space with sedimentation rate that increases from 1 to 5 cm/ka, using
# function 'sedramp'.
# Finally interpolate to median sampling interval using function 'linterp'.
dat=linterp(sedRamp(cycles(freqs=c(1/100,1/40,1/20),start=1,end=2500,dt=5)))

# EHA anlaysis, output amplitude results
out=eha(dat,output=3)

## Interactively track frequency drift
freq=traceFreq(out)

}

## End(Not run)
```

---

tracePeak	*A tool to interactively trace peak trajectories on plots*

Description

A tool to interactively trace peak trajectories on plots, for results from such functions as eTimeOpt, EHA, eAsm.

Usage

```
tracePeak(dat,color=2,h=6,w=4,xmin=NULL,xmax=NULL,ymin=NULL,ymax=NULL,
         ydir=-1,palette=6,ncolors=100,path=1)
```

Arguments

dat	Data frame with results to evaluate. It must have the following format: column 1=parameter to track (e.g., frequency, sedimentation rate, etc.; x-axis of plot); remaining columns (2 to n)=parameter to evaluate for peak identification (color on plot); titles for columns 2 to n must be the location (depth/height/time; y-axis of plot). Note that this format is ouput by functions eha, eTimeOpt, eAsm.
color	Line color for tracing. 1 = transparent black; 2 = transparent white; 3 = transparent yellow
h	Height of plot in inches.
w	Width of plot in inches.
xmin	Minimum parameter value to plot.
xmax	Maximum parameter value to plot.
ymin	Minimum depth/height/time to plot.
ymax	Maximum depth/height/time to plot.
ydir	Direction for y-axis in plots (depth/height/time). -1 = values increase downwards, 1 = values increase upwards.
palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red, (6) viridis
ncolors	Number of colors to use in plot.
path	How do you want to represent the path?: 1=lines and points; 2=lines; 3=points

See Also

[eha](#) and [eTimeOpt](#)

---

trackFreq	*Frequency-domain minimal tuning: Use interactive graphical interface and sorting to track frequency drift*

Description

Frequency-domain minimal tuning: Use interactive graphical interface and sorting algorithm to track frequency drift.

Usage

```
trackFreq(spec,threshold=NULL,pick=T,fmin=NULL,fmax=NULL,dmin=NULL,dmax=NULL,xmin=NULL,
        xmax=NULL,ymin=NULL,ymax=NULL,h=6,w=4,ydir=1,palette=6,ncolors=100,genplot=T,
          verbose=T)
```

Arguments

spec	Time-frequency spectral results to evaluate. Must have the following format: column 1=frequency; remaining columns (2 to n)=power, amplitude or probability; titles for columns 2 to n must be the location (depth or height). Note that this format is ouput by function eha.
threshold	Threshold level for filtering peaks. By default all peak maxima reported.
pick	Pick the peaks of interest using a graphical interface? (T or F). Only activated if genplot=T.
fmin	Minimum frequency for analysis.
fmax	Maximum frequency for analysis.
dmin	Minimum depth/height for analysis. NOT ACTIVATED YET!
dmax	Maximum depth/height for analysis. NOT ACTIVATED YET!
xmin	Minimum frequency for PLOTTING.
xmax	Maximum frequency for PLOTTING.
ymin	Minimum depth/height for PLOTTING.
ymax	Maximum depth/height for PLOTTING.
h	Height of plot in inches.
w	Width of plot in inches.
ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.
palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red, (6) viridis
ncolors	Number of colors to use in plot.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

eha and traceFreq

Examples

```
 ## Not run:
# Check to see if this is an interactive R session, for compliance with CRAN standards.
# YOU CAN SKIP THE FOLLOWING LINE IF YOU ARE USING AN INTERACTIVE SESSION.
if(interactive()) {

# Generate example series with 3 terms using function 'cycles'.
# Then convert from time to space with sedimentation rate that increases from 1 to 5 cm/ka, using
# function 'sedramp'.
# Finally interpolate to median sampling interval using function 'linterp'.
dat=linterp(sedRamp(cycles(freqs=c(1/100,1/40,1/20),start=1,end=2500,dt=5)))

# EHA anlaysis, output probability results
```

```
out=eha(dat,output=4)

## Isolate peaks with probability >= 0.8
freq=trackFreq(out,0.8)

}

## End(Not run)
```

---

trackPeak	*A tool to interactively select points to track peak trajectories on plots*

Description

A tool to interactively select points to track peak trajectories on plots, for results from functions such as eTimeOpt, EHA, eAsm.

Usage

```
trackPeak(dat,threshold=NULL,pick=T,minVal=NULL,maxVal=NULL,dmin=NULL,dmax=NULL,
         xmin=NULL,xmax=NULL,ymin=NULL,ymax=NULL,h=6,w=4,ydir=-1,
         palette=6,ncolors=100,genplot=T,verbose=T)
```

Arguments

dat	Data frame with results to evaluate. It must have the following format: column 1=parameter to track (e.g., frequency, sedimentation rate, etc.; x-axis of plot); remaining columns (2 to n)=parameter to evaluate for peak identification (color on plot); titles for columns 2 to n must be the location (depth/height/time; y-axis of plot). Note that this format is ouput by functions eha, eTimeOpt, eAsm.
threshold	Threshold level for filtering peaks. By default all peak maxima reported.
pick	Pick the peaks of interest using a graphical interface? (T or F). Only activated if genplot=T.
minVal	Minimum parameter value for analysis (e.g., frequency, sedimentation rate, etc.).
maxVal	Maximum parameter value for analysis (e.g., frequency, sedimentation rate, etc.).
dmin	Minimum depth/height/time for analysis. NOT ACTIVATED YET!
dmax	Maximum depth/height/time for analysis. NOT ACTIVATED YET!
xmin	Minimum parameter value for PLOTTING.
xmax	Maximum parameter value for PLOTTING.
ymin	Minimum depth/height/time for PLOTTING.
ymax	Maximum depth/height/time for PLOTTING.
h	Height of plot in inches.
w	Width of plot in inches.

ydir	Direction for y-axis in plots (depth or height). -1 = values increase downwards (slower plotting!), 1 = values increase upwards.
palette	What color palette would you like to use? (1) rainbow, (2) grayscale, (3) blue, (4) red, (5) blue-white-red, (6) viridis
ncolors	Number of colors to use in plot.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

[eha](#) and [eTimeOpt](#)

trim   *Remove outliers from stratigraphic series*

Description

Automatically remove outliers from stratigraphic series, using 'boxplot' algorithm.

Usage

```
trim(dat,c=1.5,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for outlier removal. First column should be location (e.g., depth), second column should be data value.
c	'c' defines the 'coef' variable for boxplot.stats. For more information: ?boxplot.stats
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

[delPts](#), [idPts](#), [iso](#) and [trimAT](#)

---

trimAT	*Remove outliers from stratigraphic series*

Description

Remove outliers from stratigraphic series, using specified threshold value.

Usage

```
trimAT(dat,thresh=0,dir=2,genplot=T,verbose=T)
```

Arguments

dat	Stratigraphic series for outlier removal. First column should be location (e.g., depth), second column should be data value.
thresh	Threshold value for outlier detection.
dir	Remove values (1) smaller than or (2) larger than this threshold?
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

See Also

[delPts](), [idPts](), [iso]() and [trim]()

---

trough	*Identify minima of troughs in series, filter at desired threshold value*

Description

Identify minima of troughs in any 1D or 2D series, filter at desired threshold value.

Usage

```
trough(dat,level,plateau=F,genplot=T,verbose=T)
```

Arguments

dat	1 or 2 dimensional series. If 2 dimesions, first column should be location (e.g., depth), second column should be data value.
level	Threshold level for filtering troughs. By default all trough minima reported.
plateau	Output plateau points not evaluated? If T, identified troughs will not be output. (T or F)
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Examples

```
ex=cycles(genplot=FALSE)
trough(ex,level=-0.02)
```

---

tune   *Tune stratigraphic series*

Description

Tune stratigraphic series from space to time, using specified control points

Usage

```
tune(dat,controlPts,extrapolate=F,genplot=T,check=T,verbose=T)
```

Arguments

dat	Stratigraphic series for tuning. First column should be location (e.g., depth), second column should be data value.
controlPts	Tuning control points. A data frame or matrix containing two columns: depth, time
extrapolate	Extrapolate sedimentation rates above and below 'tuned' interval? (T or F)
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

Examples

```
# generate example series with 3 precession terms using function 'cycles'
ex1=cycles()

# then convert from time to space using a sedimentation rate that increases from 1 to 7 cm/ka
ex2=sedRamp(ex1,srstart=0.01,srend=0.07)

# assemble tuning control points (this is the depth-time map)
controlPts=cbind(ex2[,1],ex1[,1])

# tune record
ex3=tune(ex2,controlPts=controlPts)
```

---

unbioturb	*Bioturbation removal function following the approach of Liu et al (2021)*

Description

'unbioturb' is a function to remove bioturbation effects from a time series given the bioturbation parameters. It implements the method outlined in Liu et al. (2021), which builds on the approaches of (Guinasso and Schink, 1975), Goreau (1977), and Goreau (1980). 'unbioturb' is the inverse of the function 'bioturb', both of which model bioturbation as a diffusive process (Guinasso and Schink, 1975). In 'unbioturb', the proxy series is deconvolved from an impulse response function determined by the bioturbation characteristics, G = D/ML/v.

Usage

```
unbioturb(dat, G, ML, v, pt = 0.2, wiener = TRUE, fhigh=NULL, output = 1,
  genplot = TRUE, check = TRUE, verbose = TRUE)
```

Arguments

dat	Stratigraphic series to be bioturbated. First column should be age (kyr), second column should be data value.
G	Control parameter in Guinasso and Schinck, 1975. G = D/ML/v
ML	Mix layer depth (cm)
v	Sedimentation rate (cm/kyr)
pt	Cosine-tapered window parameter: pt is the percent of the data series tapered (choose 0-1). When pt=1, this is equivalent to a Hann taper.
wiener	Apply Wiener filter for deconvolution stabilization? (T or F)
fhigh	Taner filter cut-off frequency for deconvolution stabilization. By default, no Taner lowpass filter is applied.
output	Which results would you like to return to the console? (0) no output; (1) return unbioturbated series; (2) return impulse response
genplot	Generate summary plots? (T or F)
check	Conduct compliance checks before processing? (T or F) In general this should be activated; the option is included for Monte Carlo simulation.
verbose	Verbose output? (T or F)

References

Guinasso, N.L. and Schinck, D.R., 1975, *Quantitative estimates of biological mixing rates in abyssal sediments*, J. Geophys. Res., 80, 3032-3043.

Goreau, T.J., 1977, *Quantitative effects of sediment mixing on stratigraphy and biogeochemistry: a signal theory approach*, Nature, 256, 730-732.

Goreau, T.J., 1980, *Frequency sensitivity of the deep-sea climatic record*, Nature, 287, 620-622.

Liu, H., Meyers, S.R., and Marcott, S.A., 2021, *Unmixing dee-sea paleoclimate records: A study on bioturbation effects through convolution and deconvolution*, Earth and Planetary Science Letters, 564, 116883.

Examples

```
# as a test series, use the three dominant precession terms from Berger et al. (1992)
ex1=cycles()

# mix it
res1 <- bioturb(ex1, G=4, ML=10, v=1, genplot = TRUE)

# un-mix it
res2=unbioturb(res1, G=4, ML=10, v=1, genplot = TRUE)

pl()
plot(ex1,type="l",main="black=signal, blue=bioturbated, red=unbioturbated",lwd=3)
lines(res2,col="red")
lines(res1,col="blue")
```

---

writeCSV   *Write CSV file*

Description

Write data frame as file with comma separated values

Usage

```
writeCSV(filename,output)
```

Arguments

filename	Desired filename, in quotes: "result.csv"
output	Data frame to write to file.

---

writeT	*Write tab-delimited file*

Description

Write data frame as file with tab-delimited values

Usage

```
writeT(filename,output)
```

Arguments

filename	Desired filename, in quotes: "result.tab"
output	Data frame to write to file.

---

wtMean	*Ar/Ar Geochronology: calculate weighted mean age, age uncertainty, and other associated statistics/plots (with interactive graphics for data culling).*

Description

The wtMean function is designed for Ar/Ar Geochronology, but is also useful as a general purpose weighted mean estimator. It will calculate weighted mean age, age uncertainty, and other helpful statistics/plots (with interactive graphics for data culling). The function includes the option to generate results using the approach of IsoPlot 3.70 (Ludwig, 2008) or ArArCALC (Koppers, 2002).

Usage

```
wtMean(dat,sd=NULL,unc=1,lambda=5.463e-10,J=NULL,Jsd=NULL,CI=2,cull=-1,del=NULL,
        sort=1,output=F,idPts=T,size=NULL,unit=1,setAr=95,color="black",
        genplot=T,verbose=T)
```

Arguments

dat	dat must contain one of the following: (1) a vector of dates/values for weighted mean calculation, (2) a matrix with two columns: date or value and uncertainty (one or two sigma), or (3) a matrix with six columns, as follows: date, date uncertainty (one or two sigma), K/Ca, %Ar40*, F, and F uncertainty (one or two sigma). NOTE: F is the ratio Ar40*/Ar39K (see Koppers, 2002). See "details" for more information.
sd	Vector of uncertainties associated with each date or value in 'dat', as one or two sigma. This option is ignored if dat has more than one column

unc	What is the uncertainty on your input dates/values? (1) one sigma, or (2) two sigma. DEFAULT is one sigma. This also applies to the F uncertainty, and the J-value uncertainty (if specified)
lambda	Relevant for Ar/Ar only- Total decay constant of K40, in units of 1/year. The default value is 5.463e-10/year (Min et al., 2000).
J	Relevant for Ar/Ar only- Neutron fluence parameter
Jsd	Relevant for Ar/Ar only- Uncertainty for J-value (neutron fluence parameter; as one or two sigma)
CI	Which convention would you like to use for the 95% confidence intervals? (1) ISOPLOT (Ludwig, 2008), (2) ArArCALC (Koppers, 2002) (see below for details)
cull	Would you like select dates/data with a graphical interface? (0=no, 1=select points to retain, -1=select points to remove)
del	A vector of indices indicating data points to remove from weighted mean calculation. If specified, this takes precedence over cull.
sort	Sort by date/values? (0=no; 1=sort into increasing order; 2=sort into decreasing order)
output	Return weighted mean results as new data frame? (T or F)
idPts	Identify datum number on each point? (T or F)
size	Multiplicative factor to increase or decrease size of symbols and fonts for plot.
unit	Relevant for geochronology only- The time unit for your results. (1) = Ma, (2) = Ka
setAr	Relevant for Ar/Ar only- Set the %Ar40* level to be illustrated on the plot. The default is 95%.
color	Color to use for symbols. Default is black.
genplot	Generate summary plots? (T or F)
verbose	Verbose output? (T or F)

Details

This function performs weighted mean age calculations, including estimation of age uncertainties, mean square weighted deviation, and probability of fit, following the approaches used in IsoPlot 3.70 (Ludwig, 2008) and ArArCALC (Koppers, 2002). It is also useful as a general purpose weighted mean estimator.

The function accepts input in three formats:

(1) each date/value and its uncertainty can be entered as individual vectors ('dat' and 'sd').

(2) a two column matrix can be input as 'dat', with each date or value (first column) and its uncertainty (second column).

(3) a six column matrix can be input as 'dat', with each date, its uncertainty, the associated K/Ca value, %Ar40*, F, and F uncertainty (one or two sigma). This option must be used if you wish to calculate and include the uncertainty associated with J. The uncertainty is calculated and propagated following equation 18 of Koppers (2002).

The following plots are produced:

(1) A normal Q-Q plot for the dates/values (in essence this is the same as IsoPlot's linearized probability plot).

(2) A cumulative Gaussian plot for the dates/values (a.k.a. cumulative probability plot). This is derived by summing the individual normal distributions for each date/value.

(3) A plot of each date/value with its 2-sigma uncertainties.

In addition, K/Ca and Ar40* data are plotted if provided.

A NOTE regarding confidence intervals: There are two conventions that can be used to calculate the confidence intervals, selected with the option 'CI':

(1) ISOPLOT convention (Ludwig, 2008). When the probability of fit is >= 0.15, the confidence interval is based on 1.96*sigma. When the probability of fit is < 0.15, the confidence interval is based on t*sigma*sqrt(MSWD).

(2) ArArCALC convention (Koppers, 2002). When MSWD <=1, the confidence interval is based on 1.96*sigma. When MSWD > 1, the confidence interval is based on 1.96*sigma*sqrt(MSWD).

ADDITIONAL ADVICE: Use the function readMatrix to load your data in R (rather than the function read).

References

A.A.P. Koppers, 2002, *ArArCALC- software for 40Ar/39Ar age calculations*: Computers & Geosciences, v. 28, p. 605-619.

K.R. Ludwig, 2008, *User's Manual for Isoplot 3.70: A Geochronological Toolkit for Microsoft Excel*: Berkeley Geochronology Center Special Publication No. 4, Berkeley, 77 p.

I. McDougall and T.M. Harrison, 1991, *Geochronology and Thermochronology by the 40Ar/39Ar Method*: Oxford University Press, New York, 269 pp.

K. Min, R. Mundil, P.R. Renne, and K. Ludwig, 2000, *A test for systematic errors in 40Ar/39Ar geochronology through comparison with U/Pb analysis of a 1.1-Ga rhyolite*: Geochimica et Cosmochimica Acta, v. 64, p. 73-98.

I. Wendt and C. Carl, 1991, *The statistical distribution of the mean squared weighted deviation*: Chemical Geology, v. 86, p. 275-285.

See Also

stepHeat

Examples

```
 ## Not run:
# Check to see if this is an interactive R session, for compliance with CRAN standards.
# YOU CAN SKIP THE FOLLOWING LINE IF YOU ARE USING AN INTERACTIVE SESSION.
if(interactive()) {

# Sample NE-08-01 Ar/Ar data from Meyers et al. (2012) supplement
age <- c(93.66,94.75,94.6,94.22,86.87,94.64,94.34,94.03,93.56,93.85,88.55,93.45,93.84,
         94.39,94.11,94.48,93.82,93.81,94.18,93.78,94.41,93.49,95.07,94.19)
sd2<- c(5.83,4.10,8.78,2.5,8.86,3.37,4.63,3.18,8.35,5.73,4.23,2.56,2.3,1.7,3.1,2.78,
         1.62,.92,.98,1.41,1.21,1.38,1.48,0.93)
sd <- sd2/2
```

```
wtMean(age,sd)

# to calculate the weighted mean without interactive plots and data culling
wtMean(age,sd,cull=0,output=TRUE,genplot=FALSE,verbose=FALSE)
}

## End(Not run)
```

---

xplot   *Generate cross-plot with kernel density estimates on axes*

Description

Generate a cross-plot with kernel density estimates on axes. If multiple data points are superposed in cross-plot, transparency of points reflects data density. Custom axes titles optional.

Usage

```
xplot(x,y,xlab=NULL,ylab=NULL,main=NULL,fill=T)
```

Arguments

x	Variable 1
y	Variable 2
xlab	Label for the x-axis, in quotes
ylab	Label for the y-axis, in quotes
main	Label for the plot, in quotes
fill	Use gray fill for density plots? (T or F)

Examples

```
# random numbers from a normal distribution
ex1<-rnorm(1000)
# random numbers from an exponential distribution
ex2<-rexp(1000)

xplot(ex1,ex2)
```

---

zoomIn   *Dynamically explore cross-plot, zoom-in into specified region*

Description

Dynamically explore cross-plot, zoom-in into specfied region. Accepts one dataframe/matrix with two columns, or two dataframes/vectors with one column.

Usage

```
zoomIn(dat1,dat2=NULL,ptsize=0.5,xmin=NULL,xmax=NULL,ymin=NULL,ymax=NULL,plotype=1,
        verbose=T)
```

Arguments

dat1	Data frame with one or two columns. If one column, dat2 must also be specified.
dat2	Data frame with one column.
ptsize	Size of plotted points.
xmin	Minimum x-value (column 1) to plot
xmax	Maximum x-value (column 1) to plot
ymin	Minimum y-value (column 2) to plot
ymax	Maximum y-value (column 2) to plot
plotype	Type of plot to generate: 1= points and lines, 2 = points, 3 = lines
verbose	Verbose output? (T or F)

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