Package ‘IRISSeismic’

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VignetteBuilder knitr

Description Provides classes and methods for seismic data analysis. The
       base classes and methods are inspired by the python code found in
       the 'ObsPy' python toolbox <https://github.com/obsypy/obspy>. Additional classes and
       methods support data returned by web services provided by the 'IRIS DMC'
       <http://service.iris.edu/>.

Collate Class-Trace.R Class-Stream.R Class-IrisClient.R

License GPL (>= 2)
Repository CRAN

NeedsCompilation yes

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Description

This package provides S4 classes for downloading and processing seismological data available from the IRIS Data Management Center (DMC) (http://www.iris.edu/dms/nodes/dmc/). Core classes Trace, Stream and IrisClient and their associated methods are inspired by the functionality available in the python ObsPy package (http://obspy.org/).

Introduction

The "IRISSeismic-intro" vignette gives introductory examples on using the package.

History

version 1.5.2
- updated getDataAvailability to use new fdsnws availability web service specification
- fixed bug in getDataAvailability when mergequality=FALSE
- fixed bug in getDataAvailability affecting start/end times, introduced in version 1.5.1
- fixed bug in mergeTraces when trace has gap at end, introduced in version 1.5.1

version 1.5.1
- changed a subset of time format OS to OS6
- fixed bug in mergeTraces when fdsnws/dataselect implementation cuts on records instead of sample

version 1.5.0
- added spacing as an option to getEvalresp
- modified getEvalresp to use IrisClient service_type
- new getDataAvailability() to return dataframe of miniseed data extents in the IRIS archive using IRIS web service http://service.iris.edu/irisws/availability/1/
- minor change to src code to pass CRAN checks

version 1.4.9
- additional error handling
- minor updates to the plot.Trace and plot.Stream functions
- updated src/libmseed to version 2.19.6

version 1.4.8
- updated src/libmseed to version 2.19.5
- fix bug related to leap seconds
- functions that call web services now follow redirects
- some error outputs have changed slightly
- rmsVariance function, na.rm=TRUE calculates data length minus NA values
- rmsVariance.Stream now honors na.rm=TRUE
- getGaps() error handling now checks for negative sample rates
- getEvent, getEvalresp now truncates start and end input times to seconds (time format OS0 instead of OS) to fix error when user set options(digits secs=) > 3

version 1.4.7
- additional error handling for getDistaz
- added input service_type to IrisClient, defaults to fdsnws
- plot.Trace x-axis labels are "MM dd" instead of days of week for traces > 1 day and < 1 week
- getDataselect will retry once if it encounters http code 401
- additional error handling for spectralUtils

version 1.4.6
- bug fix for IRISSeismic::slice

version 1.4.5
- fixed bug in noiseModels for low noise model results at periods > 10000 seconds
- retry if getEvent returns a service unavailable message

version 1.4.4
- modified error messages for getEvalresp() and getDistaz()

version 1.4.3

version 1.4.2
- updated libmseed version to 2.19

version 1.4.1
- updated libmseed version to 2.18
- fix for reading miniseed with out of order records

version 1.4.0
- addition of repository argument to getDataselect and getSNCL, to match change in fdsnws-dataselect web service

version 1.3.9
- fixes compile warning generated by clang
- removes followlocation=TRUE from getDataselect RCurl options
version 1.3.8

- getDataselect does not add a quality indicator to url by default. IRIS webservices itself defaults to quality="M"
- getStation and getChannel do not add includerestricted indicator to url by default. IRIS webservices itself defaults to TRUE
- better handling of textConnections

version 1.3.7

- users can now supply instrument response information in the form of frequency, amplitude, phase to the functions psdStatistics, psdList2NoiseMatrix, psdPlot, in place of the getEvalresp webservice call. Function argument order for psdPlot is changed.
- added showMedian option to psdPlot

version 1.3.5

- added ignoreEpoch option to getDataselect

version 1.3.4 – webservices and plotting

- getDistaz changes output dataframe column name ellipsoid..attrs to ellipsoid.name
- plot.Trace allows for user supplied ylab and xlab input

version 1.3.3 – documentation

- Updated documentation and corrected outdated links

version 1.3.2 – bug fix

- noiseModels(), minor correction to the New High Noise Model

version 1.3.1 – bug fixes

- psdStatistics() correctly handles NA values when calculating high and low PDF bin limits and returns pct_above and pct_below vectors of correct length

version 1.3.0 – compatibility with IRIS webservices

- getDistaz() returns new variables from output of http://services.iris.edu/irisws/distaz/1/

version 1.2.2 – PDF bug fix

- psdList2NoiseMatrix() adds 1 second to start time in getEvalresp call to work around a quirk in http://services.iris.edu/irisws/evalresp/1/ webservice that will not return a response if the start time is exactly on a metadata epoch boundary.

version 1.2.1 – PDF

- psdPlot() now compatible with changes to psdStatistics() in previous version. Adds ylo, yhi arguments to customize y-axis limits in plot.

version 1.2.0 – PDF
• psdStatistics() changes method of setting PDF bins from fixed values to bins based on the high and low PSD values and shifts bin centers by 0.5 dB. The result now matches output from http://services.iris.edu/mustang/noise-pdf.

version 1.1.7 – improved error handling
• getDataselect(), getNetwork(), getStation(), getChannel(), getAvailability(), getEvalresp(), getTraveltime() error handling now report unexpected http status codes.

version 1.1.6 – bug fixes
• getGaps() fixes issues with multiple sample rates and setting minimum gap length.
• mergeTraces.Stream() relaxes criteria for acceptable sample rate jitter.

version 1.1.5 – trace rotation
• rotate2D() changes orthogonality test tolerance from 5 degrees to 3 degrees.

version 1.1.4 – trace rotation
• rotate2D() exits if traces are not orthogonal.

version 1.1.3 – bug fix
• psdStatistics() fixes bug in calculation of pct_above and pct_below.

version 1.1.1 – bug fixes
• getGaps() minor bug fix.
• mergeTraces.Stream() minor bug fix.

version 1.0.10 – new data request argument and bug fixes
• Imports seismicRoll (>= 1.1.0).
• getGaps() fixes bugs in calculation of initial and final gap of Trace.
• getDataselect(), getSNCL() adds "inclusiveEnd" argument, a logical that determines whether a data point that falls exactly on the requested endtime is included in the Trace.
• libmseed change, when multiple sample rates exist in miniseed records use the mode of all sample rates instead of using the sample rate in the first record.
• psdList() added rule for octave generation for channel codes that start with "V".

version 1.0.9 – Trace class expansion and bug fixes
• Improved error handling for getAvailability(), getChannel(), getDataselect(), getEvalresp(), miniseed2Stream().
• parseMiniSEED.c, unpackdata.c updated. Fixes protection stack overflow issue.
• getGaps() includes a 0.5/sampling_rate tolerance factor.
• miniseed2Stream() uses endtime from parseMiniSEED instead of calculating from the sample rate.
• Trace class now contains slots for optional metadata "latitude", "longitude", "elevation", "depth", "azimuth", "dip", "SensitivityFrequency".
• rotate2D() uses Trace class "azimuth" slot information to identify channel orientation before rotation instead of assuming lead and lag channel from trace input order.

version 1.0.8 – fixes required by ISPAQ
• Removed 'maps' and 'mapdata' from Suggested: packages.
• Changed URL syntax for FDSN web services to use "format=..." instead of "output=...".
• Fixed bug in getSNCL() so that it works when the "quality" argument is missing.

version 1.0.6 – CRAN updates required
• Removed "mode" argument from Trace.as.vector() signature.

version 1.0.4 – name change to IRISSeismic
• Name change required because 'seismic' was recently taken.
• Using explicit references for 'utils' and 'stats' package functions as this is now required for CRAN.

version 1.0.3 – cleanup for submission to CRAN
• Updated libmseed to version 2.16

version 0.2.8.0 – minor tweaks to 0.2.7
• Updated links to IRIS web services in the documentation.
• McNamaraBins() ignores bin #0 (~= DC)
• McNamaraPSD() conversion to dB occurs after binning, not before

version 0.2.7.0 – hilbert transform
• New hilbertFFT() function.
• New hilbert() trace method.

version 0.2.6.0 – cross correlation
• Added surfaceDistance() function.
• Added rotate2D() function.

version 0.2.5.0 – channel orientation
• Jumping to version 0.2.5 to match project milestone names.
• Added getSNCL() convenience wrapper for getDataselect() method.
• Added getDistaz() method of IrisClient.
• Added miniseed2Stream() and readMiniseedFile() functions.
• Added getRotation() method of IrisClient.

version 0.2.3.0 – cross spectrum
• Moved McNamaraPSD() from trace method to spectral utility function.
• Added spectral utility functions:
IRISSeismic-package

- crossSpectrum()
- McNamaraBins()

- All get- methods that return dataframes now guarantee a default ordering of rows.

version 0.2.2.0 – PSD and friends

- Add dependency on pracma package.
- Use pracma::detrend() function in DDT.Trace().
- Added "increment" parameter to STALTA.Trace().
- Removed STALTA.Trace() algorithm "classic_LR2".
- Fixed URL generation for getEvalresp() when location="".
- Added NamaraPSD.Trace() method.
- Added PSD/PDF utility functions:
  - noiseMatrix2PdfMatrix()
  - noiseModels()
  - psdDF2NoiseMatrix()
  - psdList()
  - psdList2NoiseMatrix()
  - psdStatistics()
  - psdPlot()

version 0.2.1.1 – Bug fix release

- Removed dependency on signal, XML packages.

version 0.2.1.0 – FDSN web services

- Conversion to FDSN web services including the following new/rewritten methods: getNetwork, getStation, getChannel, getAvailability, getUnavailability
- Updated version of getEvent to return a dataframe with columns named "latitude" and "longitude" for consistency with all other web services
- Updated documentation and Rscripts to match the API changes in the conversion to FDSN web services.
- Removal of all StationXML classes in favor of storing that information in slots of the Trace class.
- Updates to Trace object slots @Sensor, @InstrumentSensitivity and @InputUnits to store information as character, numeric and character instead of StationXML classes.
- The TraceHeader@quality slot now reflects the data quality returned in the miniSEED record rather than the quality that was requested by getDataselect. (Requests with quality=B for "Best" typically return quality=M.)
- Improved STALTA.Trace() method removes experimental algorithms and now uses C++ code from package rollSeismic to calculate rolling means.
- Updated IrisClient now uses web services from http://service.iris.edu for the following methods: getDataselect, getEvalresp, getEvent
version 0.2.0.0

- Removed PSD methods of Stream and Trace. PSD algorithms are now part of the PSD metric.
- Improved `mergeTraces.Stream()` method now accepts `fillMethod="fillZero"`.

version 0.1.9.0

- New `rollSeismic` package for fast rolling algorithms implemented in C++/Rcpp.
- New `num_spikes` metric based on `seismicRoll::roll_hampel` outlier detection.
- New correlation metric.
- New scripts `glitchMetrics.Rscript`, `correlationMetric.Rscript`, `pressureCorrelation.Rscript`
- New `trace@stats@processing` slot for data processing information.
- New Stream methods: `mergeTraces`, `plot`
- Improved `getGaps.Stream()` method properly handles initial and final gaps.
- Improved MCR error messing.

version 0.1.8.0 – IrisClient methods `getEvent` and `getTraveltime`, improved SNR metric
version 0.1.7.0 – PSD
version 0.1.6.0 – improved errors, miniSEED parser
version 0.1.5.0 – code cleanup, improved errors, package vignette
version 0.1.4.0 – STA/LTA, upDownTimes, basic plotting
version 0.1.3.0 – SNR, memory profiling
version 0.1.2.0 – ...
version 0.1.1.0 – ...

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

- ObsPy: [http://obspy.org/](http://obspy.org/)
- IRIS DMC web services: [http://service.iris.edu/](http://service.iris.edu/)

See Also

- `IrisClient-class`, `Trace-class`, `Stream-class`,
Examples

```r
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient", debug=TRUE)

starttime <- as.POSIXct("2010-02-27 06:45:00", tz="GMT")
etime <- as.POSIXct("2010-02-27 07:45:00", tz="GMT")

# Get the seismic data
st <- getDataselect(iris,"IU","ANMO","00","BHZ",starttime,endtime)

# Extract the first trace, display the metadata and plot it
tr1 <- st@traces[[1]]
show(tr1@stats)
plot(tr1)
```

---

**basicStats**

**Length, Max, Mean, Median, Min and Standard Deviation**

**Description**

Basic statistics on the data in Trace and Stream objects.

**Usage**

```r
# length(x)
# max(x, ...)
mean(x, ...)
# median(x, na.rm)
# min(x, ...)
sd(x, na.rm)
parallelLength(x)
parallelMax(x, na.rm)
parallelMean(x, na.rm)
parallelMedian(x, na.rm)
parallelMin(x, na.rm)
parallelSd(x, na.rm)
```

**Arguments**

- **x** a Trace or Stream object
- **na.rm** a logical specifying whether missing values should be removed
- **...** arguments to be passed to underlying methods, e.g. the `mean` function:
  
  - `na.rm` – as above (default=FALSE)
Details

Trace methods
When \( x \) is a Trace object, methods \( \text{length}, \text{max}, \text{mean}, \text{median}, \text{min} \) and \( \text{sd} \) operate on the data slot of the Trace and are equivalent to, e.g., \( \text{max}(x@\text{data}, \text{na.rm} = \text{FALSE}) \).

Stream methods
When \( x \) is a Stream object, methods \( \text{length}, \text{max}, \text{mean}, \text{median}, \text{min} \) and \( \text{sd} \) are applied to the concatenation of data from every Trace in the Stream, treating this as a single data series.

The parallel versions of these methods are available only on Stream objects and return a vector of values, one for each Trace.

By default, the Stream-method versions of these methods use \( \text{na.rm} = \text{FALSE} \) as there should be no missing datapoints in each Trace. The Trace methods default to \( \text{na.rm} = \text{TRUE} \) to accommodate merged traces where gaps have been filled with NAs.

Value
For the simple statistics, a single numeric value is returned or NA if the Trace or Stream has no data.

For the parallel versions of these methods, available on Stream objects, a numeric vector is returned of the same length as \( \text{Stream@traces} \).

Note
See the R documentation on the respective base functions for further details.

The \( \text{length.Stream} \) method only counts the number of actual data values in the individual Traces in the Stream object. Missing values associated with the gaps between Traces are not counted.

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>

Examples

```
## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2012-01-24", tz="GMT")
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)

# Get the first trace and generate some statistics
tr1 <- st@traces[[1]]
length(tr1)
max(tr1)
mean(tr1)
sd(tr1)
```
butterworth

Apply Butterworth filter

Description

The butterworth method of Trace objects returns a new Trace where data in the @data slot have been modified by applying a Butterworth filter.

Usage

butterworth(x, n, low, high, type)

Arguments

x a Trace object
n filter order
low frequency used in low- or stop/band-pass filters
high frequency used in high or stop/band-pass filters
type type of filter – 'low', 'high', 'pass' or 'stop'

Details

This method creates a Butterworth filter with the specified characteristics and applies it to the Trace data.

When only n and low are specified, a high pass filter is applied. When only n and high are specified, a low pass filter is applied. When n and both low and high are specified, a band pass filter is applied. To apply a band stop filter you must specify n, low, high and type='stop'

Value

A new Trace object is returned.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

See Also

signal::butter, signal::filter
## Examples

```r
## Not run:
# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

# Compare to the results in figure 2a of
# "Determination of New Zealand Ocean Bottom Seismometer Orientation
# via Rayleigh-Wave Polarization", Stachnik et al.
# http://srl.geoscienceworld.org/content/83/4/704
# (note: since publication, ZU.NZ19..BH1 has been renamed BH2 and ZU.NZ19..BH2 has been renamed BH1)

starttime <- as.POSIXct("2009-02-18 22:01:07", tz="GMT")
endtime <- starttime + 630
verticalLines <- starttime + seq(30, 630, 100)

# Get data
stZ <- getSNCL(iris,"ZU.NZ19..BHZ", starttime, endtime)
st2 <- getSNCL(iris,"ZU.NZ19..BH2", starttime, endtime)
st1 <- getSNCL(iris,"ZU.NZ19..BH1", starttime, endtime)

# Demean, Detrend, Taper
trZ <- DDT(stZ@traces[[1]], TRUE, TRUE, 0.05)
tr2 <- DDT(st2@traces[[1]], TRUE, TRUE, 0.05)
tr1 <- DDT(st1@traces[[1]], TRUE, TRUE, 0.05)

# Bandpass filter
trZ_f <- butterworth(trZ, 2, 0.02, 0.04, type='pass')
tr2_f <- butterworth(tr2, 2, 0.02, 0.04, type='pass')
tr1_f <- butterworth(tr1, 2, 0.02, 0.04, type='pass')

# 3 rows
layout(matrix(seq(3)))

# Plot
plot(trZ_f)
abline(v=verticalLines, col='gray50', lty=2)
plot(tr2_f)
abline(v=verticalLines, col='gray50', lty=2)
plot(tr1_f)
abline(v=verticalLines, col='gray50', lty=2)

# Restore default layout
layout(1)
```

## End(Not run)
Description

The crossSpectrum() function is based on R’s spec.pgram() function and attempts to provide complete results of cross-spectral FFT analysis in a programmer-friendly fashion.

Usage

crossSpectrum(x, spans = NULL, kernel = NULL, taper = 0.1, pad = 0, fast = TRUE, demean = FALSE, detrend = TRUE, na.action = stats::na.fail)

Arguments

x multivariate time series
spans vector of odd integers giving the widths of modified Daniell smoothers to be used to smooth the periodogram
kernel alternatively, a kernel smoother of class "tskernel"
taper specifies the proportion of data to taper. A split cosine bell taper is applied to this proportion of the data at the beginning and end of the series
pad proportion of data to pad. Zeros are added to the end of the series to increase its length by the proportion pad
fast logical. if TRUE, pad the series to a highly composite length
demean logical. If TRUE, subtract the mean of the series
detrend logical. If TRUE, remove a linear trend from the series. This will also remove the mean
na.action NA action function

Details

The multivariate timeseries passed in as the first argument should be a union of two separate time-series with the same sampling rate created in the following manner:

```r
ts1 <- ts(data1,frequency=sampling_rate)
ts2 <- ts(data2,frequency=sampling_rate)
x <- ts.union(ts1,ts2)
```

The crossSpectrum() function borrows most of its code from R’s spec.pgram() function. It omits any plotting functionality and returns a programmer-friendly dataframe of all cross-spectral components generated during Fourier analysis for use in calculating transfer functions.

The naming of cross-spectral components is borrowed from the Octave version of MATLAB’s pwelch() function.
Value
A dataframe with the following columns:

- freq: spectral frequencies
- spec1: 'two-sided' spectral amplitudes for ts1
- spec2: 'two-sided' spectral amplitudes for ts2
- coh: magnitude squared coherence between ts1 and ts2
- phase: cross-spectral phase between ts1 and ts2
- Pxx: periodogram for ts1
- Pyy: cross-periodogram for ts1 and ts2
- Pxy: periodogram for ts2

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>

References
Octave pwelch() source code
Normalization of Power Spectral Density estimates

See Also
McNamaraPSD

Examples
## Not run:
# Create a new IrisClient
iris <- new("IrisClient")

# Get seismic data
starttime <- as.POSIXct("2011-05-01", tz="GMT")
endtime <- starttime + 3600

st1 <- getDataselect(iris,"CI","PASC","00","BHZ",starttime,endtime)
st2 <- getDataselect(iris,"CI","PASC","10","BHZ",starttime,endtime)
tr1 <- st1@traces[[1]]
tr2 <- st2@traces[[1]]

# Both traces have a sampling rate of 40 Hz
sampling_rate <- tr1@stats@sampling_rate

ts1 <- ts(tr1@data,frequency=sampling_rate)
ts2 <- ts(tr2@data,frequency=sampling_rate)

# Calculate the cross spectrum
DF <- crossSpectrum(ts.union(ts1,ts2),spans=c(3,5,7,9))
# Calculate the transfer function
transferFunction <- DF$Pxy / DF$Pxx
transferAmp <- Mod(transferFunction)
transferPhase <- pracma::mod(Arg(transferFunction) * 180/pi, 360)

# 2 rows
layout(matrix(seq(2)))

# Plot
plot(1/DF$freq, transferAmp, type='l', log='x',
     xlab="Period (sec)",
     main="Transfer Function Amplitude")

plot(1/DF$freq, transferPhase, type='l', log='x',
     xlab="Period (sec)", ylab="degrees",
     main="Transfer Function Phase")

# Restore default layout
layout(1)
#
## End(Not run)

---

**DDT**

*Apply demean, detrend, cosine taper*

---

**Description**

The DDT method of Trace objects returns a new Trace where data in the @data slot have been modified. This is typically required before performing any kind of spectral analysis on the seismic trace.

**Usage**

`DDT(x, demean, detrend, taper)`

**Arguments**

- `x`: a Trace object
- `demean`: logical specifying whether to demean (default=TRUE)
- `detrend`: logical specifying whether to detrend (default=TRUE)
- `taper`: proportion of the signal to be tapered at each end (default=0.1)

**Details**

Use taper=0 for no tapering.
Value

A new Trace object is returned.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

```r
# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

# P-wave onset for a big quake
starttime <- as.POSIXct("2010-02-27 06:30:00", tz="GMT")
endtime <- as.POSIXct("2010-02-27 07:00:00", tz="GMT")
st <- getDataselect(iris,"IU","ANMO","00","BHZ",starttime,endtime)

tr <- st@traces[[1]]
trClean <- DDT(tr,TRUE,TRUE,0.1)
layout(matrix(seq(2)))
plot(tr)
abline(h=0,col="gray60")
mtext("Raw",side=3,line=-2,adj=0.05,col="red")
plot(trClean)
abline(h=0,col="gray60")
mtext("Demean - Detrend - Cosine Taper",line=-2,side=3,adj=0.05,col="red")

# Restore default layout
layout(1)
```

envelope

**Envelope of a seismic signal**

Description

The envelope method of Trace objects returns a Trace whose data have been replaced with the envelope of the seismic signal.

Usage

```r
envelope(x)
```

Arguments

- `x` a Trace object
Details

Before calculating the envelope, the seismic trace is 'cleaned up' by removing the mean, the trend and by applying a cosine taper. See DDT for more details.

The seismic envelope is defined as:

\[ E(t) = \sqrt{T^2(t) + H^2(t)} \]

where \( T(t) \) is the seismic trace and \( H(t) \) is the Hilbert transform of \( T(t) \).

Value

A Trace whose data have been replaced with the envelope of the seismic signal.

Note

This algorithm is adapted from code in the seewave package.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

```r
## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2010-02-27 06:00:00", tz="GMT")
endtime <- as.POSIXct("2010-02-27 09:00:00", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"IU","ANMO","00","BHZ",starttime,endtime)
tr <- st@traces[[1]]

# Demean, detrend, cosine taper
tr <- DDT(tr)

tenv <- envelope(tr)

## End(Not run)
```
**eventWindow**

*Return a portion of a trace surrounding an event.*

**Description**

The `eventWindow` method of `Trace` uses the picker returned by the `STALTA()` method to center a window around the event detected by the picker.

**Usage**

```r
eventWindow(x, picker, threshold, windowSecs)
```

**Arguments**

- `x` : a `Trace` object
- `picker` : a picker as returned by the `STALTA()` method applied to this `Trace`
- `threshold` : the threshold at which the picker is `triggered`
- `windowSecs` : the size of the window in secs

**Details**

This utility function uses the trace method `triggerOnset()` to determine p-wave onset followed by the `slice()` method to return a new `Trace` object of the desired size centered near the event onset.

When no threshold value is supplied, the default value is calculated as:

```r
threshold=quantile(picker,0.999,na.rm=TRUE)
```

**Value**

A new `Trace` object is returned.

**Author(s)**

Jonathan Callahan <jonathan@mazamascience.com>

**See Also**

`STALTA`, `triggerOnset`

**Examples**

```r
## Not run:
# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

starttime <- as.POSIXct("2002-04-20", tz="GMT")
endtime <- as.POSIXct("2002-04-21", tz="GMT")
```
# Get the waveform
st <- getDataset(iris,"US","OXF","","BHZ",starttime,endtime)

# Seismic signal in third trace
tr <- st@traces[[3]]

# Create a picker
picker <- STALTA(tr,3,30)
threshold <- quantile(picker,0.99999,na.rm=TRUE)

# 3 rows
layout(matrix(seq(3)))

# Plot trace and p-wave closeups
closeup1 <- eventWindow(tr,picker,threshold,3600)
closeup2 <- eventWindow(tr,picker,threshold,600)
plot(tr)
plot(closeup1,subsampling=1)
abline(v=length(closeup1)/2, col="red")
plot(closeup2,subsampling=1)
abline(v=length(closeup2)/2, col="red")

# Restore default layout
layout(1)

## End(Not run)

---

### getAvailability

**Retrieve Channel metadata from IRIS DMC**

**Description**

The `getAvailability` method obtains channel metadata for available channels from the IRIS DMC station web service and returns it in a dataframe.

**Usage**

```r
getAvailability(obj, network, station, location, channel, 
                starttime, endtime, includerestricted,
                latitude, longitude, minradius, maxradius)
```

**Arguments**

- **obj** IrisClient object
- **network** character string with the two letter seismic network code
- **station** character string with the station code
- **location** character string with the location code
- **channel** character string with the three letter channel code
getAvailability

starttime  POSIXct class specifying the starttime (GMT)
endtime  POSIXct class specifying the endtime (GMT)
include_restricted  optional logical identifying whether to report on restricted data (default=FALSE)
latitude  optional latitude used when specifying a location and radius
longitude  optional longitude used when specifying a location and radius
minradius  optional minimum radius used when specifying a location and radius
maxradius  optional maximum radius used when specifying a location and radius

Details

The getAvailability method uses the station web service to obtain data for all available channels that meet the criteria defined by the arguments and returns that data in a dataframe. Each row of the dataframe represents a unique channel-epoch. This method is equivalent to the getChannel method with the following additional parameters attached to the url:

&includeavailability=true&matchtimeseries=true

Each of the arguments network, station, location or channel may contain a valid code or a wildcard expression, e.g. "BH?" or "*". Empty strings are converted to "*". Otherwise the ascii string that is used for these values is simply inserted into the web service request URL. (For non-available channels use getUnavailability.)

For more details see the web service documentation.

Value

A dataframe with the following columns:

network, station, location, channel, latitude, longitude, elevation,
    depth, azimuth, dip, instrument, scale, scalefreq, scaleunits,
    samplerate, starttime, endtime, snclId

Rows are ordered by snclId.

The snclId column, eg. "US.OCWA..BHE", is generated as a convenience. It is not part of the normal return from the station web service.

Note: The snclId is not a unique identifier. If the time span of interest crosses an epoch boundary where instrumentation was changed then multiple records (rows) will share the same snclId.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>
getChannel

Retrieve Channel metadata from IRIS DMC

Description

The getChannel method obtains channel metadata from the IRIS DMC station web service and returns it in a dataframe.

Usage

getChannel(obj, network, station, location, channel, starttime, endtime, includerestricted, latitude, longitude, minradius, maxradius)
getChannel

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>obj</td>
<td>IrisClient object</td>
</tr>
<tr>
<td>network</td>
<td>character string with the two letter seismic network code</td>
</tr>
<tr>
<td>station</td>
<td>character string with the station code</td>
</tr>
<tr>
<td>location</td>
<td>character string with the location code</td>
</tr>
<tr>
<td>channel</td>
<td>character string with the three letter channel code</td>
</tr>
<tr>
<td>starttime</td>
<td>POSIXct class specifying the starttime (GMT)</td>
</tr>
<tr>
<td>endtime</td>
<td>POSIXct class specifying the endtime (GMT)</td>
</tr>
<tr>
<td>includerestricted</td>
<td>optional logical identifying whether to report on restricted data</td>
</tr>
<tr>
<td>latitude</td>
<td>optional latitude used when specifying a location and radius</td>
</tr>
<tr>
<td>longitude</td>
<td>optional longitude used when specifying a location and radius</td>
</tr>
<tr>
<td>minradius</td>
<td>optional minimum radius used when specifying a location and radius</td>
</tr>
<tr>
<td>maxradius</td>
<td>optional maximum radius used when specifying a location and radius</td>
</tr>
</tbody>
</table>

Details

The getChannel method uses the station web service to obtain data for all channels that meet the criteria defined by the arguments and returns that data in a dataframe. Each row of the dataframe represents a unique channel-epoch.

Each of the arguments network, station, location or channel may contain a valid code or a wildcard expression, e.g. "BH?" or ".*". Empty strings are converted to "*". Otherwise the ascii string that is used for these values is simply inserted into the web service request URL.

For more details see the webservice documentation.

Value

A dataframe with the following columns:

- network
- station
- location
- channel
- latitude
- longitude
- elevation
- depth
- azimuth
- dip
- instrument
- scale
- scalefreq
- scaleunits
- samplerate
- starttime
- endtime
- snclId

Rows are ordered by snclId.

The snclId column, eg. "US.OCWA..BHE", is generated as a convenience. It is not part of the normal return from the station web service.

Note: The snclIds is not a unique identifier. If the time span of interest crosses an epoch boundary where instrumentation was changed then multiple records (rows) will share the same snclId.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>
References

The IRIS DMC station webservice:

http://service.iris.edu/fdsnws/station/1/

This implementation was inspired by the functionality in the obspy get_stations() method.


See Also

IrisClient-class, getAvailability, getUnavailability

Examples

# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

# Date of Nisqually quake
starttime <- as.POSIXct("2001-02-28", tz="GMT")
endtime <- starttime + 2*24*3600

# Use the getEvent web service to determine what events happened in this time period
events <- getEvent(iris, starttime, endtime, 6.0)
events

# biggest event is Nisqually
eIndex <- which(events$magnitude == max(events$magnitude))
e <- events[eIndex[1],]

# Which stations in the US network are within 5 degrees of the quake epicenter?
stations <- getStation(iris, "US", ",", ",", "BHZ", starttime, endtime,
                        lat=e$latitude, long=e$longitude, maxradius=5)
stations

# Get some detailed information on any BHZ channels at the "Octopus Mountain" station
channels <- getChannel(iris, "US", "OCWA", ",", "BHZ", starttime, endtime)
channels

getDataAvailability  Retrieve miniseed trace extents from IRIS DMC

Description

The getDataAvailability method obtains miniseed time extents from the IRIS DMC availability web service and returns it in a dataframe.
getDataAvailability

Usage

ggetDataAvailability(obj, network, station, location, channel, starttime, endtime,  
mergequality, mergesamplerate, mergeoverlap, mergetolerance,  
includerestricted, excludetoolarge)

Arguments

obj IrisClient object  
network character string with the two letter seismic network code  
station character string with the station code  
location character string with the location code  
channel character string with the three letter channel code  
starttime POSIXct class specifying the starttime (GMT)  
endtime POSIXct class specifying the endtime (GMT)  
mergequality optional logical identifying if timespans with differing qualities are grouped together (default=TRUE)  
mergesamplerate optional logical identifying if timespans from data with differing sample rates are grouped together (default=FALSE)  
mergeoverlap optional logical identifying if overlapping timespans are merged together (default=TRUE)  
mergetolerance optional numeric. Time spans separated by less than or equal to the mergetolerance value in seconds are merged together. To have an effect, the mergetolerance value must be larger than 1.5 times the sample period. This implements the mergegaps option in the fdsnws availability web service specification.  
includerestricted optional logical identifying whether to report on restricted data (default=FALSE)  
excludetoolarge optional logical, if TRUE sets the fdsnws availability web service option "limit=500000". default=TRUE

Details

The getDataAvailability method uses the FDSNWS availability service to obtain start and endtimes for all continuous trace segments in the IRIS (or other) archive for the requested network, station, location, channels and returns that data in a dataframe. Each row of the dataframe represents a unique data trace extent.

Each of the arguments network, station, location or channel may contain a valid code or a wildcard expression, e.g. "BH?" or "*". Empty strings are converted to "*". Otherwise the ascii string that is used for these values is simply inserted into the web service request URL.

For more details see the web service documentation.
**Value**

A dataframe with the following columns:
mergequality=TRUE and mergesamplerate=FALSE (defaults):

```
  network, station, location, channel, samplerate, starttime, endtime, snclId
```

mergequality=TRUE and mergesamplerate=TRUE:

```
  network, station, location, channel, starttime, endtime, snclId
```

mergequality=FALSE and mergesamplerate=FALSE:

```
  network, station, location, channel, quality, samplerate, starttime, endtime, snclId
```

mergequality=FALSE and mergesamplerate=TRUE:

```
  network, station, location, channel, quality, starttime, endtime, snclId
```

Rows are ordered by snclId.
The snclId column, e.g. "US.OCWA..BHE", is generated as a convenience. It is not part of the normal return from the station web service.

**Author(s)**

Gillian Sharer <gillian@iris.washington.edu>

**References**

The IRIS DMC station web service:

http://service.iris.edu/fdsnws/availability/1/http://service.iris.edu/ph5ws/availability/1/

**See Also**

`IrisClient-class`

**Examples**

```r
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2018-01-01", tz="GMT")
endtime <- as.POSIXct("2019-01-01", tz="GMT")
network <- "TA"
station <- "M22K"
```
getDataselect

```r
channel <- "BH3"
traceList <- getDataAvailability(iris, network, station, "\*", channel, starttime, endtime)
traceList
```

getDataselect

Retrieve seismic data from IRIS DMC

Description

The getDataselect method makes a request of the IRIS DMC dataselect webservice and returns a Stream object in which individual Traces have been sorted by start time.

Usage

```r
getDataselect(obj, network, station, location, channel,
  starttime, endtime, ...)
```

Arguments

- `obj` IrisClient object
- `network` character string with the two letter seismic network code
- `station` character string with the station code
- `location` character string with the location code
- `channel` character string with the three letter channel code
- `starttime` POSIXct class specifying the starttime (GMT)
- `endtime` POSIXct class specifying the endtime (GMT)
- `...` optional arguments
  - `quality` optional character string identifying the quality. IRIS webservices defaults to quality="M". repository optional character string identifying whether to exclusively search primary archive or realtime collection buffers. Acceptable values are "primary" or "realtime". If not specified, IRIS webservices defaults to both repositories.
  - `inclusiveEnd` optional logical determining whether the endtime is inclusive (default = TRUE) ignoreEpoch optional logical defining behavior when multiple epochs are encountered (default = FALSE)

Details

This is the primary method for retrieving seismic data. Data requests are made through the dataselect webservice and returned data are parsed using the internal miniseed2Stream() function.

If the location argument contains an empty string to specify a 'blank' location code, a location code of "--" will be used in the dataselect request URL. (See dataselect documentation.)

If inclusiveEnd=FALSE, then getDataselect will subtract 0.000001 seconds from the endtime before passing the value to the dataselect webservice. An endtime of, e.g., `as.POSIXct("2016-01-03", tz="GMT")`
will be passed into dataselect as end=2016-01-02T23:59:59.999999. A data sample at time 2016-01-03T00:00:00 will not be returned unless inclusiveEnd=TRUE.

Error returns from the webservice will stop evaluation and generate an error message.
Sometimes the station webservice will return multiple records for the same SNCL, each with a different scale or starttime. These represent different epochs with potentially different metadata parameters for the SNCL and, by default, will cause a `Multiple epochs` error message to be generated.
Handling all possible metadata differences so that the data may be merged is beyond the scope of this package. Instead, to avoid errors, users may specify ignoreEpoch=TRUE in which case the very first SNCL-epoch encountered will be used and all others will be discarded.
For access to restricted data, getDataselect will look for system environmental variable "IrisClient_netrc" which should point to a .netrc authentication file.

Value
A new Stream object is returned.

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>

References
The IRIS DMC dataselect webservice:
http://service.iris.edu/fdsnws/dataselect/1/
This implementation is similar in functionality to the obspy dataselect function:
http://docs.obspy.org/_modules/obspy/clients/fdsn/client.html#Client.dataselect

See Also
getSNCL, IrisClient-class

Examples
```r
## Not run:
# Open a connection to IRIS DMC webservises
iris <- new("IrisClient")
options("nanotimeFormat"="%Y-%m-%d %H-%M-%E9S")

# Use getDataselect to request data for II.JTS.00.BHZ
starttime <- as.POSIXct("2001-02-28",tz="GMT")
endtime <- as.POSIXct("2001-03-01",tz="GMT")

st <- getDataselect(iris, "II","JTS","00","BHZ",starttime, endtime, inclusiveEnd=FALSE,ignoreEpoch=TRUE)

# Display structure of trace(s)
```
**getDistaz**

Retrieve great circle distance information from IRIS DMC

---

**Description**

The `getDistaz` method obtains great circle distance data from the IRIS DMC distaz web service.

**Usage**

```r
getDistaz(obj, latitude, longitude, staLatitude, staLongitude)
```

**Arguments**

- `obj` an IrisClient object
- `latitude` latitude of seismic event
- `longitude` longitude of seismic event
- `staLatitude` latitude of seismic station
- `staLongitude` longitude of seismic station

**Details**

The distance-azimuth service will calculate the great-circle angular distance, azimuth, and back azimuth between two geographic coordinate pairs. Azimuth and back azimuth are measured clockwise from North.

**Value**

A dataframe with the following columns:

- ellipsoid.semiMajorAxis
- ellipsoid.flattening
- ellipsoid.name
- fromlat
- fromlon
- tolat
- tolon
- azimuth
- backAzimuth
- distance
- distanceMeters

Where `fromlat` is the event latitude, `fromlon` is the event longitude, `tolat` is the station latitude, and `tolon` is the station longitude. `azimuth`, `backAzimuth`, and `distance` are measured in degrees. `distanceMeters` is distance in meters. `ellipsoid.semiMajorAxis`, `ellipsoid.flattening`, and `ellipsoid.name` refer to the World Geodetic System standard coordinate system version used to correct for ellipticity when converting to geocentric latitudes.

Only a single row is returned.
getEvalresp

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>

References
The IRIS DMC distaz webservice:
http://service.iris.edu/irisws/distaz/1/

See Also
IrisClient-class

getEvalresp

Retrieve instrument response information from IRIS DMC

Description
The getEvalresp method obtains instrument response data from the IRIS DMC evalresp web-service.

Usage
getEvalresp(obj, network, station, location, channel, time, minfreq, maxfreq, nfreq, units, output, spacing)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>obj</td>
<td>an IrisClient object</td>
</tr>
<tr>
<td>network</td>
<td>character string with the two letter seismic network code</td>
</tr>
<tr>
<td>station</td>
<td>character string with the station code</td>
</tr>
<tr>
<td>location</td>
<td>character string with the location code</td>
</tr>
<tr>
<td>channel</td>
<td>character string with the three letter channel code</td>
</tr>
<tr>
<td>time</td>
<td>POSIXct class specifying the time at which response is evaluated (GMT)</td>
</tr>
<tr>
<td>minfreq</td>
<td>optional minimum frequency at which response will be evaluated</td>
</tr>
<tr>
<td>maxfreq</td>
<td>optional maximum frequency at which response will be evaluated</td>
</tr>
<tr>
<td>nfreq</td>
<td>optional number of frequencies at which response will be evaluated</td>
</tr>
<tr>
<td>units</td>
<td>optional code specifying unit conversion</td>
</tr>
<tr>
<td>output</td>
<td>optional code specifying output type (default=&quot;fap&quot;)</td>
</tr>
<tr>
<td>spacing</td>
<td>optional code specifying spacing, accepted values are &quot;lin&quot; or &quot;linear&quot;, &quot;log&quot; or &quot;logarithmic&quot; (default=&quot;log&quot;)</td>
</tr>
</tbody>
</table>
getEvent

Details

The evalresp webservice responds to requests with data that can be used to remove instrument response from a seismic signal.

Each of network, station or channel should contain a valid code without wildcards. The ascii string that is used for these values is simply passed through to evalresp.

If the location argument contains an empty string to specify a 'blank' location code, a location code of "--" will be used in the dataselect request URL. (See dataselect documentation.)

The response from evalresp is converted into a dataframe with rows in order of increasing frequency.

Value

For output="fap", a dataframe with columns named:

freq, amp, phase

For output="cs", a dataframe with columns named:

freq, real, imag

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

The IRIS DMC evalresp webservice:

http://service.iris.edu/irisws/evalresp/1/

See Also

IrisClient-class,

---

getEvent

Retrace seismic event information from the USGS NEIC

Description

The getEvent method obtains seismic event data from the USGS NEIC event webservice.

Usage

getEvent(obj, starttime, endtime, minmag, maxmag, magtype, mindepth, maxdepth)
Arguments

- **obj**: an IrisClient object
- **starttime**: POSIXct class limiting results to events occurring after starttime (GMT)
- **endtime**: POSIXct class limiting results to events occurring before endtime (GMT)
- **minmag**: optional minimum magnitude
- **maxmag**: optional maximum magnitude
- **magtype**: optional magnitude type
- **mindepth**: optional minimum depth (km)
- **maxdepth**: optional maximum depth (km)

Details

The getEvent method uses the event web service to obtain data for all events that meet the criteria defined by the arguments and returns that data in a dataframe. Each row of the dataframe represents a unique event.

getEvent calls to the IRIS event webservice now go to https://earthquake.usgs.gov/fdsnws/event/1/. If obj@site is something other than "http://service.iris.edu", getEvent will point to obj@site/fdsnws/event/1/. The event service must be able to output format=text.

Value

A dataframe with the following columns:

```
eventId , time, latitude, longitude, depth, author, cCatalog, contributor, 
    contributorId, magType, magnitude, magAuthor, eventLocationName
```

Rows are ordered by time.

**NOTE**: column names are identical to the names returned from the event web service with the exception of "latitude" for "lat" and "longitude" for "lon". The longer names are used for internal consistency – all other web services return columns named "latitude" and "longitude".

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

The USGS event webservice: https://earthquake.usgs.gov/fdsnws/event/1/

See Also

IrisClient-class,
Examples

```r
# \dontrun{
# NOTE: 'maps' and 'mapdata' packages must be installed
#require(maps)
#require(mapdata)

# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

# Get events > mag 5.0 over a week in June of 2012
starttime <- as.POSIXct("2012-06-21", tz="GMT")
endtime <- starttime + 3600 * 24 * 7
events <- getEvent(iris, starttime, endtime, minmag=5.0)

# Look at all events
print(paste(nrow(events),"earthquakes found with magnitude > 5.0"))

# Plot events on a map
#map('world')
#points(events$longitude, events$latitude, pch=16, cex=1.5, col='red')
#labels <- paste(" ", as.character(round(events$magnitude,1)), sep="")
#text(events$longitude, events$latitude, labels=labels, pos=4, cex=1.2, col='red3')
#}
```
Details

This method first checks the SNCL id of each Trace to make sure they are identical and generates an error if they are not. Mismatches in the sampling_rate will also generate an error.

The data gaps (in seconds) within a Stream are determined and the associated sampling_rate is used to calculate the number of missing values in each gap. The length of the gaps and nsamples vectors in the returned list will be one more than the number of Traces (initial gap + gaps between traces + final gap).

Gaps smaller than min_gap are set to 0. Values of min_gap smaller than 1/sampling_rate will be ignored and the default value will be used instead.

Overlaps will appear as gaps with negative values.

Value

A list is returned with the following elements:

- gaps numeric vector of data gaps within a Stream
- nsamples number of missing samples associated with each gap

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

```r
## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2012-01-24", tz="GMT")
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)

# Save the gap analysis in a variable
gapInfo <- getGaps(st)

# See what information is available
names(gapInfo)

# Look at a histogram of data dropouts
hist(gapInfo$nsamples, breaks=50,
     main="Data Gaps in AK.PIN..BHZ Jan 24, 2012",
     xlab="number of missing samples per gap")

## End(Not run)
```
getNetwork

Retrieve Network metadata from IRIS DMC

Description

The getNetwork method obtains network metadata from the IRIS DMC station web service and returns it in a dataframe.

Usage

getNetwork(obj, network, station, location, channel, starttime, endtime, includerestricted, latitude, longitude, minradius, maxradius)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>obj</td>
<td>IrisClient object</td>
</tr>
<tr>
<td>network</td>
<td>character string with the two letter seismic network code</td>
</tr>
<tr>
<td>station</td>
<td>character string with the station code</td>
</tr>
<tr>
<td>location</td>
<td>character string with the location code</td>
</tr>
<tr>
<td>channel</td>
<td>character string with the three letter channel code</td>
</tr>
<tr>
<td>starttime</td>
<td>POSIXct class specifying the starttime (GMT)</td>
</tr>
<tr>
<td>endtime</td>
<td>POSIXct class specifying the endtime (GMT)</td>
</tr>
<tr>
<td>includerestricted</td>
<td>optional logical identifying whether to report on restricted data (default=FALSE)</td>
</tr>
<tr>
<td>latitude</td>
<td>optional latitude used when specifying a location and radius</td>
</tr>
<tr>
<td>longitude</td>
<td>optional longitude used when specifying a location and radius</td>
</tr>
<tr>
<td>minradius</td>
<td>optional minimum radius used when specifying a location and radius</td>
</tr>
<tr>
<td>maxradius</td>
<td>optional maximum radius used when specifying a location and radius</td>
</tr>
</tbody>
</table>

Details

The getNetwork method utilizes the station web service to return data for all stations that meet the criteria defined by the arguments and returns that data in a dataframe. Each row of the dataframe represents a unique network.

Each of the arguments network, station, location or channel may contain a valid code or a wildcard expression, e.g. "BH?" or "*". Empty strings are converted to "*". Otherwise, the ascii string that is used for these values is simply inserted into the web service request URL.

For more details see the web service documentation.
Value
A dataframe with the following columns:

network, description, starttime, endtime, totalstations

Rows are ordered by network.

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>

References
The IRIS DMC station web service:
http://service.iris.edu/fdsnws/station/1/
This implementation was inspired by the functionality in the obspy get_stations() method.

See Also
IrisClient-class

Examples
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

# Date of Nisqually quake
starttime <- as.POSIXct("2001-02-28", tz="GMT")
endtime <- starttime + 2*24*3600

# Use the getEvent web service to determine what events happened in this time period
events <- getEvent(iris, starttime, endtime, 6.0)
events

# biggest event is Nisqually
eIndex <- which(events$magnitude == max(events$magnitude))
e <- events[eIndex[1],]

# Which seismic networks have BHZ stations within 5 degrees of the quake epicenter?
networks <- getNetwork(iris,"*","*","*","BHZ", starttime, endtime,
                        lat=e$latitude, lon=e$longitude, maxradius=5)
networks
getRotation

Retrieve rotated seismic data from IRIS DMC

Description

The getRotation method makes a request of the IRIS DMC rotation web service and returns a list of 3 Stream objects.

Usage

getRotation(obj, network, station, location, channelSet, starttime, endtime, processing)

Arguments

obj IrisClient object
network character string with the two letter seismic network code
station character string with the station code
location character string with the location code
channelSet the first two characters of the selected source channels
starttime POSIXct class specifying the starttime (GMT)
endtime POSIXct class specifying the endtime (GMT)
processing optional character string with processing commands

Details

The rotation web service returns a triplet of seismic Streams, rotated according to the processing commands.

If the location argument contains an empty string to specify a 'blank' location code, a location code of "--" will be used in the dataselect request URL.

The processing parameter can be used to specify any type of processing supported by the rotation webs service. This string must begin with an ampersand and be ready to be appended to the request url, e.g. processing="&components=ZRT&azimuth=23.1". This gives the user complete control over the number and order of processing commands. (See rotation documentation.)

Error returns from the web service will stop evaluation and generate an error message.

Value

A list of three Stream objects is returned.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>
getSNCL

References

The IRIS DMC rotation web service:
http://service.iris.edu/irisws/rotation/1/

See Also

IrisClient-class

Description

The getSNCL() method is a convenience wrapper for the getSNCL() method and returns a Stream object in which individual Traces have been sorted by start time.

Usage

getSNCL(obj, sncl, starttime, endtime, ...)

Arguments

obj IrisClient object
sncl character string with the SNCL code
starttime POSIXct class specifying the starttime (GMT)
endtime POSIXct class specifying the endtime (GMT)
... optional arguments

Details

The SNCL argument should be ordered network-station-location channel, e.g. IU.ANMO.00.LHZ. This argument is split into component parts which are then used in a call to the getSNCL() method.

Value

A new Stream object is returned.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>
getStation

Retrieve Station metadata from IRIS DMC

Description

The getStation method obtains station metadata from the IRIS DMC station web service and returns it in a dataframe.

Usage

getStation(obj, network, station, location, channel, starttime, endtime, includerestricted, latitude, longitude, minradius, maxradius)
getStation

Arguments

- **obj**  
  IrisClient object

- **network**  
  character string with the two letter seismic network code

- **station**  
  character string with the station code

- **location**  
  character string with the location code

- **channel**  
  character string with the three letter channel code

- **starttime**  
  POSIXct class specifying the starttime (GMT)

- **endtime**  
  POSIXct class specifying the endtime (GMT)

- **includerestricted**  
  optional logical identifying whether to report on restricted data

- **latitude**  
  optional latitude used when specifying a location and radius

- **longitude**  
  optional longitude used when specifying a location and radius

- **minradius**  
  optional minimum radius used when specifying a location and radius

- **maxradius**  
  optional maximum radius used when specifying a location and radius

Details

The getStation method utilizes the station web service to obtain data for all stations that meet the criteria defined by the arguments and returns that data in a dataframe. Each row of the dataframe represents a unique station.

Each of the arguments network, station, location or channel may contain a valid code or a wildcard expression, e.g. "BH?" or "*". Empty strings are converted to "*". Otherwise, the ascii string that is used for these values is simply inserted into the web service request URL.

For more details see the web service documentation.

Value

A dataframe with the following columns:

- network, station, latitude, longitude, elevation, sitename, starttime, endtime

Rows are ordered by network-station.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

The IRIS DMC station web service:

http://service.iris.edu/fdsnws/station/1/

This implementation was inspired by the functionality in the obspy get_stations() method.

getTraveltime

See Also

IrisClient-class

Examples

```
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

# Date of Nisqually quake
starttime <- as.POSIXct("2001-02-28",tz="GMT")
endtime <- starttime + 2*24*3600

# Use the getEvent web service to determine what events happened in this time period
events <- getEvent(iris,starttime,endtime,6.0)
events

# biggest event is Nisqually
eIndex <- which(events$magnitude == max(events$magnitude))
e <- events[eIndex[1],]

# Which stations in the US network are within 5 degrees of the quake epicenter?
stations <- getStation(iris,"US","*","*","BHZ",starttime,endtime,
lat=e$latitude,long=e$longitude,maxradius=5)
stations
```

getTraveltime

**Retrieve seismic traveltime information from IRIS DMC**

Description

The `getTraveltime` method obtains seismic traveltime data from the IRIS DMC traveltime web service and returns it in a dataframe.

Usage

```
getTraveltime(obj, latitude, longitude, depth, staLatitude, staLongitude)
```

Arguments

- **obj**: an IrisClient object
- **latitude**: latitude of seismic event
- **longitude**: longitude of seismic event
- **depth**: depth of seismic event
- **staLatitude**: latitude of seismic station
- **staLongitude**: longitude of seismic station
getTraveltime

Details

The traveltime web service calculates travel-times for seismic phases using a 1-D spherical earth model.

Value

A dataframe with the following columns:

distance, depth, phaseName, travelTime, rayParam, takeoff, incident

puristDistance, puristName

Rows are ordered by travelTime.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

The IRIS DMC traveltime web service:

http://service.iris.edu/irisws/traveltime/1/

See Also

IrisClient-class

Examples

## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

# Two days around the "Nisqually Quake"
starttime <- as.POSIXct("2001-02-27", tz="GMT")
endtime <- starttime + 3600 * 24 * 2

# Find biggest seismic event over these two days -- it's the "Nisqually"
events <- getEvent(iris, starttime, endtime, minmag=5.0)
bigOneIndex <- which(events$magnitude == max(events$magnitude))
bigOne <- events[bigOneIndex[1],]

# Find US stations that are available within an hour of the event
start <- bigOne$time
end <- start + 3600
availability <- getAvailability(iris, "US", "", "", "BHZ",
start_time=start, end_time=end,
latitude=bigOne$latitude, longitude=bigOne$longitude,
min_radius=0, max_radius=10)

# Get the station the furthest East
minLonIndex <- which(availability$longitude == max(availability$longitude))
snclE <- availability[minLonIndex,]

# Plot the BHZ signal from this station
st <- getDataselect(iris, snclE$network, snclE$station, snclE$location, snclE$channel, start, end)

# Check that there is only a single trace and then plot it
length(st@traces)
tr <- st@traces[[1]]
plot(tr, subsampling=1) # need subsampling=1 to add vertical lines with abline()

# Find travel times to this station
traveltimes <- getTraveltime(iris, bigOne$latitude, bigOne$longitude, bigOne$depth, snclE$latitude, snclE$longitude)

# Look at the list
traveltimes

# mark the P and S arrival times
pArrival <- start + traveltimes$travelTime[traveltimes$phaseName=="P"]
sArrival <- start + traveltimes$travelTime[traveltimes$phaseName=="S"]
abline(v=pArrival, col='red')
abline(v=sArrival, col='blue')

## End(Not run)

---

**getUnavailability**  
*Retrieve Channel metadata from IRIS DMC*

**Description**

The `getUnavailability` method obtains metadata for channels that are not available from the IRIS DMC station web service and returns it in a dataframe.

**Usage**

```r
getUnavailability(obj, network, station, location, channel,
                  startime, endtime, includerestricted,
                  latitude, longitude, minradius, maxradius)
```

**Arguments**

- **obj**  
  IrisClient object
- **network**  
  character string with the two letter seismic network code
- **station**  
  character string with the station code
- **location**  
  character string with the location code
- **channel**  
  character string with the three letter channel code
getUnavailability

starttime POSIXct class specifying the starttime (GMT)
endtime POSIXct class specifying the endtime (GMT)
includerestricted optional logical identifying whether to report on restricted data (default=FALSE)
latitude optional latitude used when specifying a location and radius
longitude optional longitude used when specifying a location and radius
minradius optional minimum radius used when specifying a location and radius
maxradius optional maximum radius used when specifying a location and radius

Details

The getUnavailability method compares the results of the getAvailability and getChannel methods and returns those records found only in the output of getChannel.

Each of the arguments network, station, location or channel may contain a valid code or a wildcard expression, e.g. "BH?" or ".". Empty strings are converted to ".". Otherwise the ascii string that is used for these values is simply inserted into the web service request URL.

For more details see the webservice documentation.

Value

A dataframe with the following columns:

- network
- station
- location
- channel
- latitude
- longitude
- elevation
- depth
- azimuth
- dip
- instrument
- scale
- scalefreq
- scaleunits
- samplerate
- starttime
- endtime

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

The IRIS DMC station webservice:

http://service.iris.edu/fdsnws/station/1/

This implementation was inspired by the functionality in the obspy get_stations() method.


See Also

IrisClient-class, getAvailability, getChannel
Examples

# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

# Date of Nisqually quake
starttime <- as.POSIXct("2001-02-28",tz="GMT")
endtime <- starttime + 2*24*3600

# Use the getEvent web service to determine what events happened in this time period
events <- getEvent(iris,starttime,endtime,6.0)

# biggest event is Nisqually
eIndex <- which(events$magnitude == max(events$magnitude))
e <- events[eIndex[1],]

# Find all BHZ channels that were NOT collecting data at the time of the quake
# and within 5 degrees of the quake epicenter (or are otherwise unavailable from IRIS).
channels <- getUnavailability(iris,"*","*","*","BHZ",starttime,endtime,
                                lat=e$latitude,long=e$longitude,maxradius=5)

getUpDownTimes

Determine times when a channel starts/stops collecting data

Description

The getUpDownTimes method determines the on/off times for data collection within a Stream and returns a list containing these times, ignoring Traces with a duration less than min_signal as well as data dropouts that are less than min_gap.

Usage

getUpDownTimes(x, min_signal, min_gap)

Arguments

x Stream object

min_signal minimum Trace duration in seconds (default=30)

min_gap minimum gap in seconds (default=60)

Details

A Stream object returned by getDataselect contains a list of individual Trace objects, each of which is guaranteed to contain a continuous array of data in the Trace@data slot. Each Trace also contains a starttime and an endtime representing a period of uninterrupted data collection. Data dropouts are determined by first rejecting any Traces of duration less than min_signal. The temporal spacing between Traces is then analyzed, ignoring spaces shorter than min_gap.
This method first checks the SNCL id of each Trace to make sure they are identical and throws an error if they are not.

The first element returned is always the starttime associated the first Trace. The last element is always the endtime associated with the last trace. Thus, when the first element is identical to the starttime of the web services data request this does not necessarily mean that the channel was down before this.

**NOTE:** Even when data are complete for the duration of the requested timespan, the last element returned may be earlier than the endtime of the web services data request by up to a second.

**Value**

A vector of POSIXct datetimes associated with on/off transitions.

**Author(s)**

Jonathan Callahan <jonathan@mazamascience.com>

**See Also**

plotUpDownTimes

**Examples**

```r
## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2012-01-24", tz="GMT")
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)

# Determine up/down transitions, ignoring Traces < 3 min and gaps < 5 min
upDownTimes <- getUpDownTimes(st, min_signal=180, min_gap=300)

# Or just plot them directly
plotUpDownTimes(st, min_signal=180, min_gap=300)

## End(Not run)
```

---

**hilbert**

*Hilbert of a seismic signal*

**Description**

The hilbert method of Trace objects returns a Trace whose data have been replaced with the Hilbert transform of the seismic signal.
hilbert

Usage

 hilbert(x)

Arguments

 x a Trace object

Details

Before calculating the Hilbert transform, the seismic trace is `cleaned up` by removing the mean, the trend and by applying a cosine taper. See DDT for more details.

Value

A Trace whose data have been replaced with the Hilbert transform of the seismic signal.

Note

This algorithm is adapted from code in the seewave package.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2010-02-27 06:00:00", tz="GMT")
endtime <- as.POSIXct("2010-02-27 09:00:00", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"IU","ANMO","00","BHZ",starttime,endtime)
tr <- st@traces[[1]]

# Create Hilbert transform of the trace
trh <- hilbert(tr)

# Plot signal data and hilbert data
plot(tr@data, type='l', col='gray80')
points(trh@data, type='l', col='blue')

## End(Not run)
hilbertFFT

Description
The hilbertFFT function returns the complex Hilbert FFT of a timeseries signal.

Usage
hilbertFFT(x)

Arguments
x
a numeric vector

Details
This function is intended for internal use by the hilbert() and envelope() methods of Trace objects.

Value
A complex vector containing the Hilbert FFT of x.

Note
This algorithm is adapted from code in the seewave package.

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>

Examples
## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2010-02-27 06:00:00", tz="GMT")
endtime <- as.POSIXct("2010-02-27 09:00:00", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"IU","ANMO","00","BHZ",starttime,endtime)
tr <- st@traces[[1]]

# Demean, detrend, cosine taper
tr <- DDT(tr)

# Calculate Hilbert FFT of the trace data
hfft <- hilbertFFT(tr@data)
# Plot signal, with Hilbert envelope
layout(1)
plot(tr@data, type='l', col='gray80', main="Signal and Envelope")
points(Mod(hfft), type='l', col='blue')

# 2 rows
layout(matrix(seq(2)))

# Show that Imaginary component of Hilbert transform has the
# original signal shifted by 90 degrees
ccf(tr@data,tr@data,lag.max=200,main="Auto-correlation of signal data")
ccf(tr@data,lm(hfft),lag.max=200,main="90 deg phase shift with Hilbert transform")

# Restore default layout
layout(1)

## End(Not run)

---

**IrisClient-class**

**Class** "IrisClient"

**Description**

A class for making data and metadata requests from IRIS DMC web services.

**Slots**

- `site`: Object of class "character": this is the first part of the url that the web service will be pointed to, defaults to http://service.iris.edu
- `service_type`: Object of class "character": defaults to fdsnws; for data retrieval from the IRIS PH5 repository, set this to ph5ws;
- `debug`: Object of class "logical": when set to TRUE will cause any web service requestURL to be printed
- `useragent`: Object of class "character": client identification string

**Methods**

- `getAvailability` makes a channel request of the station web service and returns the result as a dataframe; see `getAvailability`
- `getChannel` makes a channel request of the station web service and returns the result as a dataframe; see `getChannel`
- `getDataAvailability` makes a channel request of the irisws availability web service and returns the result as a dataframe; see `getDataAvailability`
- `getDataselect` makes a request of the dataselect web service and returns a Stream object; see `getDataselect`
- `getDistaz` makes a request of the distaz web service and returns the information as a dataframe; see `getDistaz"
getEvalresp makes a request of the instrument response web service and returns the information as a dataframe; see getEvalresp

getEvent makes a request of the event web service and returns the information as a dataframe, if site="http://service.iris.edu" then getEvent will direct to "https://earthquake.usgs.gov/fdsnws/event/1/query?"; see getEvent

getNetwork makes a network request of the station web service and returns the result as a dataframe; see getNetwork

getSNCL: calls the getDataselect method and returns a Stream object; see getSNCL

getStation makes a station request of the station web service and returns the result as a dataframe; see getStation

getTraveltime makes a request of the traveltime web service and returns the information as a dataframe; see getTraveltime

getUnavailability makes a channel request of the station web service and returns the result as a dataframe; see getUnavailability

Note

The IrisClient object is inspired by the clients.fdsn.client.Client class found in the python ObsPy package (http://docs.obspy.org/packages/autogen/obspy.clients.fdsn.client.Client.html#obspy.clients.fdsn.client.Client).

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

```r
## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient", debug=TRUE)

starttime <- as.POSIXct("2012-01-24", tz="GMT")
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)
mean(st)

## End(Not run)
```

<table>
<thead>
<tr>
<th>McNamaraBins</th>
<th>McNamara Binning</th>
</tr>
</thead>
</table>

Description

Usage

McNamaraBins(df, loFreq, hiFreq, alignFreq)

Arguments

df
    an R dataframe object
loFreq
    optional lo end of frequency binning range (default=.005)
hiFreq
    optional hi end of frequency binning range (default=10)
alignFreq
    optional alignment frequency for determining frequency bins (default=0.1)

Details

The McNamaraBins() function accepts a dataframe with an arbitrary number of columns. At least
one of the columns must be named 'freq' and must contain frequency values. These frequencies will
be used to assign all associated values into appropriate bins according to the McNamara algorithm:
Frequencies for binning are generated at 1/8 octave intervals aligned to alignFreq. Binned values
associated with each frequency bin are calculated by averaging incoming values over an entire
octave centered on that frequency.

Value

A dataframe containing binned values is returned with the same column names as the incoming df
argument.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

Seismic Noise Analysis System Using Power Spectral Density Probability Density Functions (Mc-
Namara and Boaz 2005)

See Also

McNamaraPSD

Description

The McNamaraPSD() function implements the spectral density algorithm specified in the "Data
Preparation and Processing" section of Seismic Noise Analysis System Using Power Spectral Den-
sity Probability Density Functions.
Usage

McNamaraPSD(tr, loFreq=.005, hiFreq=10, alignFreq=0.1, binned=TRUE)

Arguments

tr  a Trace object
loFreq  optional lo end of frequency binning range
hiFreq  optional hi end of frequency binning range
alignFreq  optional alignment frequency for determining frequency bins
binned  logical determining whether the return spectrum is binned

Details

This PSD algorithm is designed to be used on one to three hour segments of seismic data and will return a PSD object containing the (potentially binned) spectrum for that segment. See the psdList function for automatic segmenting of longer Stream objects.

The McNamara PSD algorithm is similar to MATLAB’s pwelch() function and has the following steps:

1. Calculate averaged spectrum

   # Truncate incoming segment of trace data to nearest power of 2 samples.
   # Divide each truncated segment into 13 chunks with 75% overlap. The first
   # chunk begins at 0/16 and ends at 4/16. The 13'th chunk begins at 12/16
   # and ends at 16/16. The chunks overlap like this:
   #   # 1---5---9---3---
   #   # 2---6---0---
   #   # 3---7---1---
   #   # 4---8---2---
   # # Deman, detrend and taper the chunk.
   # # Calculate the 'one-sided' spectrum for the chunk.
   # # Average together all 13 spectra to get an averaged spectrum.

2. Create smoothed version of spectrum with binning

   When binned=TRUE, McNamara style binning is turned on and a smoothed spectrum is returned that contains many fewer points than the full spectrum. When these arguments are not specified, binning is automatically turned off and the full spectrum is returned.

   Frequencies for binning are generated at 1/8 octave intervals aligned to alignFreq. The power (dB) associated with each frequency bin is calculated by averaging over an entire octave centered on that frequency.

   Note: The spectra returned by McNamaraPSD() have not had instrument correction applied. Use getEvalresp to get instrument correction values for specific frequencies.

3. convert binned spectra to decibels
mergeTraces

Value

An R list object with the following named elements:

freq, spec, snclq, starttime, endtime

Elements freq and spec are numeric vectors while snclq, starttime and endtime are single values.

Note

During the binning process, an arithmetic mean is used to average together power levels in decibels. This is equivalent to averaging of power levels before conversion to dB using a geometric mean.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References


See Also

McNamaraBins, psdList

mergeTraces  Merge multiple traces into a single trace

Description

The mergeTraces method of Stream objects returns a new Stream where all Traces have been merged into a single Trace. Gaps between traces are replaced with values determined by the fillMethod parameter.

Usage

mergeTraces(x, fillMethod)

Arguments

x  Stream object
fillMethod  method to use when filling gaps between Traces (default="fillNA")
mergeUpDownTimes

**Details**

Available values for fillMethod include:

- fillNA – gaps are filled with NA (R's missing value flag)
- fillZero – gaps are filled with 0.0

**Value**

A new Stream object containing a single Trace is returned.

**Author(s)**

Jonathan Callahan <jonathan@mazamascience.com>

**Examples**

```r
## Not run:
# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2002-04-20", tz="GMT")
endtime <- as.POSIXct("2002-04-21", tz="GMT")
st4 <- getDataselect(iris,"US","OXF","","BHZ",starttime,endtime)
stm4 <- mergeTraces(st4)

# plot merged trace
plot(stm4@traces[[1]])
mtext(paste(length(st4@traces),"traces"), side=3, line=0.5, adj=0.05, cex=1.5)

## End(Not run)
```

---

**mergeUpDownTimes**

_Determine overlaps in two sets of upDownTimes._

**Description**

The `mergeUpDownTimes` function determines the overlaps in two sets of times representing up/down (on/off) periods for a single or a set of channels. This function can be used to determine overall station up/down periods.

**Usage**

`mergeUpDownTimes(udt1, udt2, bothOn)`

**Arguments**

- `udt1` vector of POSIXct times representing up/down transitions
- `udt2` vector of POSIXct times representing up/down transitions
- `bothOn` logical specifying whether overlaps are determined with AND or OR (default=FALSE: udt1 OR udt2)
mergeUpDownTimes

Details

When bothOn=FALSE, the default, this function returns the times of transitions from "either to neither" and back. When bothOn=TRUE, this function returns the times of transitions from "both to either" and back.

If an empty vector is passed in for udt1 or udt2 then the other vector is returned unchanged. This can be useful when merging the upDownTimes for multiple channels. See the example below.

Value

A vector of POSIXct datetimes associated with on/off transitions.

Note

The vector of times in udt1 and udt2 has no information on the values of min_signal or min_gap that were used to generate the timeseries. It is up to the user to make sure that the incoming vectors are appropriate for comparison. See getUpDownTimes.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

See Also

getUpDownTimes, plotUpDownTimes

Examples

```R
## Not run:
# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

# Three Streams, each with different upDownTimes
starttime <- as.POSIXct("2012-07-01", tz="GMT")
endtime <- as.POSIXct("2012-07-02", tz="GMT")
stE <- getDataselect(iris,"IU","XMAS","10","BHE",starttime,endtime)
stN <- getDataselect(iris,"IU","XMAS","10","BHN",starttime,endtime)
stZ <- getDataselect(iris,"IU","XMAS","10","BHZ",starttime,endtime)
udtE <- getUpDownTimes(stE)
udtN <- getUpDownTimes(stN)
udtZ <- getUpDownTimes(stZ)

udtAll <- c()
udtAny <- c()
for (udt in list(udtE, udtN, udtZ)) {
  udtAll <- mergeUpDownTimes(udtAll,udt,bothOn=TRUE)
  udtAny <- mergeUpDownTimes(udtAny,udt,bothOn=FALSE)
}

# 5 rows
layout(matrix(seq(5)))
```
```r
# Plot the results
par(mar=c(3,4,3,2)) # adjust margins
plotUpDownTimes(udtE); title("BHE")
plotUpDownTimes(udtN); title("BHN")
plotUpDownTimes(udtZ); title("BHZ")
plotUpDownTimes(udtAll); title("ALL channels up")
plotUpDownTimes(udtAny); title("ANY channel up")

# Restore default layout
layout(1)

## End(Not run)
```

---

**miniseed2Stream**

*Convert miniSEED bytes to Stream object*

**Description**

The `miniseed2Stream` function converts raw miniSEED bytes into a Stream object.

**Usage**

```r
miniseed2Stream(miniseed, url, requestedStarttime, requestedEndtime,
               sensor, scale, scalefreq, scaleunits, latitude, longitude, 
               elevation, depth, azimuth, dip)
```

**Arguments**

- `miniseed` a vector of raw bytes read from a miniSEED file
- `url` character source location (see `getDataselect`)
- `requestedStarttime` POSIXct time associated with the requested starttime (see `getDataselect`)
- `requestedEndtime` POSIXct time associated with the requested endtime (see `getDataselect`)
- `sensor` character description of the Sensor type associated with this Station-Network-Channel-Location (SNCL) (see Trace)
- `scale` character description of the InstrumentSensitivity associated with this SNCL (see Trace)
- `scalefreq` numeric description of frequency at which the InstrumentSensitivity is correct, the SensitivityFrequency (see Trace)
- `scaleunits` character description of the InputUnits associated with this SNCL (see Trace)
- `latitude` numeric latitude associated with this SNCL (see Trace)
- `longitude` numeric longitude associated with this SNCL (see Trace)
- `elevation` numeric elevation associated with this SNCL (see Trace)
- `depth` numeric depth associated with this SNCL (see Trace)
- `azimuth` numeric channel azimuth associated with this SNCL (see Trace)
- `dip` numeric channel dip associated with this SNCL (see Trace)
multiplyBy

Details
This function takes raw bytes read in from a file or URL and converts them to a Stream object. Metadata information is optional. This function is primarily for internal use.

Value
A Stream object.

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>

See Also
readMiniseedFile

Description
The multiplyBy methods of Trace and Stream objects return like objects where all data slots have been multiplied by a constant.

Usage
multiplyBy(x, y)

Arguments
x a Trace or Stream object
y a numeric multiplier

Value
A new Trace or Stream object is returned.

Author(s)
Jonathan Callahan <jonathan@mazamascience.com>
Examples

## Not run:

# Open a connection to IRIS DMC webservices
iris <- new("IrisClient")

starttime <- as.POSIXct("2011-01-24", tz="GMT")
endtime <- as.POSIXct("2011-01-25", tz="GMT")

# Get the waveform
stRaw <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)

# obtain an instrument sensitivity value with getChannel metadata)
c <- getChannel(iris, "AK","PIN","","BHZ",starttime, endtime)
sensitivityValue <- c$scale

# convert raw data
st <- multiplyBy(stRaw, 1/sensitivityValue)

rmsVariance(st)

# plot trace
plot(st, ylab=c$scaleunits)

## End(Not run)

noiseMatrix2PdfMatrix  Convert matrix of PSDs to matrix of Probability Density Functions

Description

This function converts a noiseMatrix returned by either psdList2NoiseMatrix or psdDF2NoiseMatrix into a matrix of Probability Density values as defined by McNamara and Boaz 2005.

Usage

noiseMatrix2PdfMatrix(noiseMatrix, lo, hi, binSize)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>noiseMatrix</td>
<td>a noiseMatrix returned from either psdList2NoiseMatrix or psdDF2NoiseMatrix</td>
</tr>
<tr>
<td>lo</td>
<td>lowest frequency bin (power level in dB) for the PDF y-axis (default=-200)</td>
</tr>
<tr>
<td>hi</td>
<td>highest frequency bin (power level in dB) for the PDF y-axis (default=-50)</td>
</tr>
<tr>
<td>binSize</td>
<td>size in dB of each bin (default=1)</td>
</tr>
</tbody>
</table>

Details

The McNamara and Boaz paper describes creating histograms of the discretized power levels at each frequency bin associated with a set of PSDs. The value in each cell of the PDF matrix is the fraction of the corrected PSDs that have that power level at that frequency bin.

To return a PDF matrix that matches those in the McNamara paper, use the default settings.
Value

A matrix is returned with one row for each power level (-250:-50 dB) and one column for each frequency bin.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References


See Also

McNamaraPSD, psdDF2NoiseMatrix, psdList, psdPlot, psdStatistics

Examples

```r
## Not run:
# Create a new IrisClient
iris <- new("IrisClient", debug=TRUE)

# Get seismic data
starttime <- as.POSIXct("2011-05-05", tz="GMT")  # 2011.125
endtime <- starttime + 1*24*3600
st <- getDataselect(iris,"IU","GRFO","--","BHE",starttime,endtime)

# Generate power spectral density for each hour long segment
psdList <- psdList(st)

# Convert into corrected "noiseMatrix"
noiseMatrix <- psdList2NoiseMatrix(psdList)

# Convert into McNamara "pdfMatrix"
pdfMatrix <- noiseMatrix2PdfMatrix(noiseMatrix)

# NOTE: Data need to be flipped and tranposed for the XY axes in the
# NOTE: image() function to match rows and columns in our pdfMatrix
# Plot pdfMatrix
image(t(pdfMatrix[,ncol(pdfMatrix):1]),
    col=c("gray90",rainbow(9)),
    axes=FALSE)

## End(Not run)
```
noiseModels  

*Generate NHNM and NLNM noise models*

**Description**

The `noiseModels` function returns the New High Noise Model and New Low Noise Model from the Peterson paper referenced below. Values are returned for the specific frequencies specified in the `freq` argument.

**Usage**

```
noiseModels(freq)
```

**Arguments**

- `freq`  
  a vector of frequencies at which to generate noise model values

**Value**

A list is returned with elements `nhnm` and `nlnm` containing the high and low noise models, respectively.

**Author(s)**

Jonathan Callahan <jonathan@mazamascience.com>

**References**

- Observations of Modeling and Seismic Background Noise (Peterson 1993)

**See Also**

- `psdStatistics`

---

**psdDF2NoiseMatrix**  

*Apply instrument correction to PSDs*

**Description**

The `psdDF2NoiseMatrix` function uses the `snclq` identifier associated with the first PSD in the dataframe to obtain instrument correction information at the specified frequencies from the `getEvalresp` web service if instrumentation correction information is not supplied as an argument. This correction is applied to every PSD in the dataframe and the now corrected PSD values are returned as a matrix.
Usage

psdDF2NoiseMatrix(DF, evalresp=NULL)

Arguments

DF                a dataframe of PSDs obtained from the getPSDMeasurements method of IrisClient.

evalresp          dataframe of freq, amp, phase information matching output of getEvalresp, optional.

Details

This function is identical in behavior to psdList2NoiseMatrix except that the input object is a dataframe of PSD values obtained from the MUSTANG Backend Storage System.

Value

A matrix is returned with one row for each instrument-corrected PSD and one column for each frequency bin.

Note

The incoming dataframe is checked to make sure that it represents only a single SNCL (Station-Network-Channel-Location). An error is generated if more than one is found. However, the psdDF is not checked to make sure that no changes to the instrument correction happened during the time period covered by the psdDF. This occurs at an 'epoch' boundary when an instrument is replaced.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References


See Also

McNamaraPSD, psdList, psdList2NoiseMatrix, psdPlot, psdStatistics
psdList  

Apply McNamara PSD algorithm to a seismic signal

**Description**

The `psdList` function subsets a seismic Stream object into a series of shorter segments with 50% overlap and uses the McNamaraPSD method to return a smoothed (aka binned) Power Spectral Density (PSD) for each segment.

**Usage**

```r
psdList(st)
```

**Arguments**

- `st`  
  a Stream object

**Details**

A Stream will be subset into segments depending upon the channel identifier (@stats@channel) associated with this seismic data. The binning frequencies are also channel dependent as exemplified in this code extract where Z is the segment length in seconds:

```r
anAlignFreq <- 0.1

if (stringr::str_detect(channel, "^L") ) {
  Z <- 3 * 3600
  loFreq <- 0.001
  hiFreq <- 0.5 * tr_merged@stats@sampling_rate
} else if (stringr::str_detect(channel, "^M") ) {
  Z <- 2 * 3600
  loFreq <- 0.0025
  hiFreq <- 0.5 * tr_merged@stats@sampling_rate
} else {
  Z <- 3600
  loFreq <- 0.005
  hiFreq <- 0.5 * tr_merged@stats@sampling_rate
}
```

Each new segment starts half way through the previous segment. (50% overlap)

**Value**

A list of PSD objects is returned. Each element of the list is an R list object with the following elements:

- `freq`, `spec`, `snclq`, `starttime`, `endtime`

**Note:** Individual PSDs have not had instrument correction applied.
psdList2NoiseMatrix

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References


See Also

McNamaraPSD, psdList2NoiseMatrix, psdPlot, psdStatistics,

Examples

## Not run:
# Create a new IrisClient
iris <- new("IrisClient", debug=TRUE)

# Get seismic data
starttime <- as.POSIXct("2011-05-05", tz="GMT") # 2011.125
datetime <- startttme + 1*24*3600
st <- getDataselect(iris,"IU","GRFO","--","BHE",starttime,endtime)

# Generate power spectral density for each hour long segment
psdList <- psdList(st)

# Plot uncorrected PSDs
period <- 1/psdList[[1]]$freq
plot(period, psdList[[1]]$spec, log="x", type='l',
  xlab="Period (Sec)", ylab="Power (dB)",
  main="Uncorrected PSDs")

for (i in seq(2:length(psdList))) {
  points(period, psdList[i]$spec, type='l')
}

## End(Not run)

psdList2NoiseMatrix

Apply instrument correction to PSDs

Description

The psdList2NoiseMatrix function uses the snclq identifier associated with the first PSD in the list to obtain instrument correction information at the specified frequencies from the getEvalresp web service if instrumentation correction information is not supplied as an argument. This correction is applied to every PSD in the list and the now corrected PSD values are returned as a matrix.
Usage

psdList2NoiseMatrix(psdList, evalresp=NULL)

Arguments

- **psdList**: a list of PSDs generated by the `psdList` function
- **evalresp**: dataframe of freq, amp, phase information matching output of `getEvalresp`, optional

Value

A matrix is returned with one row for each instrument-corrected PSD and one column for each frequency bin.

Note

The `psdList` function generates a `psdList` from a single Stream of data and should thus only contain data for a single SNCL (Station-Network-Channel-Location). However, the `psdList` is not checked to make sure that no changes to the instrument correction happened during the time period covered by the `psdList`. This occurs at an 'epoch' boundary when an instrument is replaced.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References


See Also

- McNamaraPSD, psdDF2NoiseMatrix, psdList, psdPlot, psdStatistics,

Examples

```r
## Not run:
# Create a new IrisClient
iris <- new("IrisClient", debug=TRUE)

# Get seismic data
starttime <- as.POSIXct("2011-05-05", tz="GMT") # 2011.125
dtime <- startime + 1*24*3600
st <- getDataselect(iris,"IU","GRFO","--","BHE",starttime,endtime)

# Generate power spectral density for each hour long segment
psdList <- psdList(st)

# Convert into corrected "noiseMatrix"
noiseMatrix <- psdList2NoiseMatrix(psdList)
```
# Plot corrected PSDs
period <- 1/psdList[[1]]$freq
plot(period, noiseMatrix[,1], log='x', type='l',
     ylim=c(-200,-50),
     xlab="Period (Sec)", ylab="Power (dB)",
     main="Corrected PSDs")

for (i in seq(2:nrow(noiseMatrix))) {
   points(period, noiseMatrix[i,], type='l')
}

## End(Not run)

psdPlot

Generate plots from a set of PSDs

Description
The psdPlot function is used to generate plots from the data in a psdList or psdDF dataframe.

Usage
psdPlot(PSDs, style='psd', evalresp=NULL, ylo=-200, yhi=-50, showNoiseModel=TRUE,
        showMaxMin=TRUE, showMode=TRUE, showMean=FALSE, showMedian=FALSE, ...)

Arguments
- **PSDs**: either a list as returned by psdList or a dataframe of PSD values obtained from the BSS
- **style**: character identifier of plot type: 'psd' plots PSD lines, 'pdf' plots the pdfMatrix
- **evalresp**: dataframe of freq, amp, phase information matching output of getEvalresp, optional
- **ylo**: numeric setting lower limit of plot y-axis (default=-200)
- **yhi**: numeric setting upper limit of plot y-axis (default=-50)
- **showNoiseModel**: logical controlling plotting of noise model lines (default=TRUE)
- **showMaxMin**: logical controlling plotting of PSD max and min lines (default=TRUE)
- **showMode**: logical controlling plotting of PDF mode line (default=TRUE)
- **showMean**: logical controlling plotting of PSD mean line (default=FALSE)
- **showMedian**: logical controlling plotting of PSD median line (default=FALSE)
- **...**: arguments to be passed to plotting methods

Details
The psdPlot function creates visualizations for sets of PSDs. Plots generated with style='pdf' mimic the plots presented in the McNamara paper.
Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References


See Also

McNamaraPSD, psdList, psdStatistics

Examples

```r
## Not run:
# Create a new IrisClient
iris <- new("IrisClient", debug=TRUE)

# Get seismic data
starttime <- as.POSIXct("2011-05-05", tz="GMT") # 2011.125
endtime <- starttime + 1*24*3600
st <- getDataselect(iris,"IU","GRFO","--","BHE",starttime,endtime)

# Generate power spectral density for each hour long segment
psdList <- psdList(st)

# 'psd' line plot
psdPlot(psdList,style='psd',type='l',col=adjustcolor('black',0.3))

# McNamara 'pdf' plot
psdPlot(psdList,style='pdf')

## End(Not run)
```

psdStatistics

Return statistics for a set of PSDs

Description

The psdStatistics function calculates a variety of information associated with the incoming set of PSDs.

Usage

```r
psdStatistics(PSDs, evalresp=NULL)
```
Arguments

PSDs either a list as returned by psdList or a dataframe of PSD values obtained from the BSS
evalresp dataframe of freq, amp, phase information matching output of getEvalresp, optional

Value

A list of elements:

- noiseMatrix – matrix of corrected power levels; rows=PSDs, columns=frequencies
- pdfMatrix – matrix of probability density values; rows=dB level, columns=frequencies
- freq – vector of frequencies associated statistics vectors and with matrix columns
- pdfBins – vector of power values (dB) associated with pdfMatrix rows
- max – maximum power level at each frequency
- min – minimum power level at each frequency
- mean – mean power level at each frequency
- median – median power level at each frequency
- mode – mode of power level at each frequency (obtained from pdfMatrix)
- nlrm – low noise model power level at each frequency
- nhnm – high noise model power level at each frequency
- pct_above – percent of PSDs above the high noise model at each frequency
- pct_below – percent of PSDS below the low noise model at each frequency

A variety of plots can be generated form the information in this list.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References


See Also

McNamaraPSD, psdList, psdPlot
Examples

```r
## Not run:
# Create a new IrisClient
iris <- new("IrisClient", debug=TRUE)

# Get seismic data
starttime <- as.POSIXct("2011-05-05", tz="GMT") # 2011.125
datetime <- starttime + 1*24*3600
st <- getDataselect(iris,"IU","GRFO","--","BHE",starttime,endtime)

# Generate power spectral density for each hour long segment
psdList <- psdList(st)

# Generate Statistics
stats <- psdStatistics(psdList)

# Just for fun plot
logPeriod <- log10(1/stats$freq)
plot(logPeriod,stats$max,ylim=c(-200,-50), las=1,
     xlab="log10(period)", ylab="Power (dB)",
     main="Model 'normal background noise' area and area of seismic signal.")
points(logPeriod,stats$min)

# Overlay a polygon showing the range between the noise models
x <- c(logPeriod,rev(logPeriod),logPeriod[1])
y <- c(stats$nhnm,rev(stats$nlnm),stats$nhnm[1])
transparentBlack <- adjustcolor('black',0.4)
polygon(x,y,col=transparentBlack)

# Overlay a polygon showing the range of measured values
y <- c(stats$max,rev(stats$min),stats$max[1])
transparentBlue <- adjustcolor('blue',0.6)
polygon(x,y,col=transparentBlue)

## End(Not run)
```

readMiniseedFile

Convert miniSEED file to Stream object

Description

The readMiniseedFile function converts a raw miniSEED file into a Stream object.

Usage

```
readMiniseedFile(file,sensor,scale,scalefreq,scaleunits,
     latitude,longitude,elevation,depth,azimuth,dip)
```
**Arguments**

- **file**: character path of a miniSEED file
- **sensor**: character description of the Sensor associated with this Station-Network-Channel-Location (SNCL) (see Trace)
- **scale**: numeric description of the InstrumentSensitivity associated with this SNCL (see Trace)
- **scalefreq**: numeric description of frequency at which the InstrumentSensitivity is correct, the SensitivityFrequency (see Trace)
- **scaleunits**: character description of the InputUnits associated with this SNCL (see Trace)
- **latitude**: numeric latitude associated with this SNCL (see Trace)
- **longitude**: numeric longitude associated with this SNCL (see Trace)
- **elevation**: numeric elevation associated with this SNCL (see Trace)
- **depth**: numeric depth associated with this SNCL (see Trace)
- **azimuth**: numeric channel azimuth associated with this SNCL (see Trace)
- **dip**: numeric channel dip associated with this SNCL (see Trace)

**Details**

This function reads in a raw miniSEED file and converts it to a Stream object. Metadata information is optional.

**Value**

A Stream object.

**Author(s)**

Jonathan Callahan <jonathan@mazamascience.com>

**See Also**

miniseed2Stream

---

**rms**

*Root Mean Square and RMS Variance*

**Description**

The rms and rmsVariance methods of Trace and Stream objects compute the Root Mean Square (RMS) amplitude or RMS variance of the associated data in each object. RMS variance removes the DC level from the seismic signal so that the zero line is consistent.
Usage

```
rms(x, na.rm)
parallelRms(x, na.rm)
rmsVariance(x, na.rm)
parallelRmsVariance(x, na.rm)
```

Arguments

- `x` a `Trace` or `Stream` object
- `na.rm` a logical specifying whether missing values should be removed

Details

**Trace method**

The RMS amplitude of a single `Trace` is calculated as:

\[
\text{rms}(x) = \sqrt{\frac{\sum_{i=1}^{n} (x_i)^2}{n}}
\]

The RMS variance of a single `Trace` is calculated as:

\[
\text{rmsVariance}(x) = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}}
\]

where \( x \) is the vector of data values and \( n \) is the length of that vector.

**Stream methods**

For `Stream` objects, data from all `Trace`s in the stream are first extracted and concatenated into a single numeric vector after which the algorithm is applied.

The `parallel~` version of this method is only available on `Stream` objects and returns a vector of values, one for each `Trace`.

By default, the `Stream` versions of these methods use `na.rm=FALSE` as there should be no missing datapoints in each `Trace`. The `Trace` methods default to `na.rm=TRUE` to accommodate merged traces where gaps between traces have been filled with NAs.

Value

A single numeric value is returned or `NA` if the trace has no data.

A numeric vector is returned for `parallelRmsVariance`.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>
Examples

## Not run:

```r
# Open a connection to IRIS DMC webservises
iris <- new("IrisClient")

starttime <- as.POSIXct("2012-01-24", tz="GMT")
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)

# Get the first trace and generate some statistics
tr <- st@traces[[1]]
rmsVariance(tr)

## End(Not run)
```

---

**rotate2D**

*Rotate horizontal components of a seismic signal*

**Description**

The `rotate2D()` function rotates the two horizontal components of a seismic signal into Radial and Transverse components returned as a list of 2 `Stream` objects.

**Usage**

```r
rotate2D(st1, st2, angle)
```

**Arguments**

- **st1**: horizontal `Stream` from a channel set (channel name usually ending in "N", "E", "1", or "2")
- **st2**: horizontal `Stream` from a channel set, complementary to st1
- **angle**: angle (degrees) of the rotation

**Details**

The rotation web service returns Radial and Transverse seismic Streams, generated by rotating st1 and st2 by angle degrees.

The rotation service uses the following transformation matrix to change the output vectors for 2-D horizontal transformations

\[
M_{2D} = \begin{bmatrix}
\cos \alpha & \sin \alpha \\
-\sin \alpha & \cos \alpha
\end{bmatrix}
\]
\[
\begin{bmatrix}
R \\
T
\end{bmatrix} = M_{2D} \begin{bmatrix}
N \\
E
\end{bmatrix}
\]

where:

N and E represent data from the original (horizontal) orientations.
R and T represent the Radial and Transverse components.
\(\alpha\) is the azimuth angle measured clockwise from north.

Value

A list of two Stream objects stR and stT is returned.

Note

N and E are determined by the Stream @stats@azimuth values. If Stream @stats@azimuth values are not defined, st1 is assumed to be N and st2 is assumed to be E. Orthogonality is also assumed to be correct.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

IRIS DMC rotation web service documentation:
http://service.iris.edu/irisws/rotation/docs/1/help/

---

**slice**

_Slice a section out of a Trace or Stream_

**Description**

The slice methods of Trace and Stream objects return like objects that are subsets of the original.

**Usage**

`slice(x, starttime, endtime)`

**Arguments**

- **x** a Trace or Stream object
- **starttime** time at which the slice should begin
- **endtime** time at which the slice should end
Details

The returned object will always be a subset of the x argument whose time range is the intersection of the original time range and the requested range. When there is no intersection or when \( \text{start} > \text{end} \) an error is generated.

All metadata associated with the returned Trace or Stream will reflect the new object, rather than the original.

Value

A new Trace or Stream object is returned.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

```r
## Not run:
# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

starttime <- as.POSIXct("2002-04-20", tz="GMT")
endtime <- as.POSIXct("2002-04-21", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"US","OXF","","BHZ",starttime,endtime)

# This Stream object consists of 5 Traces
length(st@traces)

# Plotting the third trace shows a small quake
plot(st@traces[[3]])

# We can slice out the hour that has the quake signal
sliceStart <- as.POSIXct("2002-04-20 10:30:00", tz="GMT")
sliceEnd <- as.POSIXct("2002-04-20 11:30:00", tz="GMT")
stSlice <- slice(st, sliceStart, sliceEnd)

# Now we only have one Trace of an hour duration
length(stSlice@traces)
stSlice@traces[[1]]@stats

# And a better look at the quake signal
plot(stSlice@traces[[1]])

## End(Not run)
```
Description

The STALTA method of Trace objects applies one of several STA/LTA "first break picking" algorithms to Trace data in order to automatically detect seismic events.

Usage

STALTA(x, staSecs, ltaSecs, algorithm, demean, detrend, taper, increment)

Arguments

- x: a Trace object
- staSecs: length of the Short averaging window in secs (default=3)
- ltaSecs: length of the Long averaging window in secs (default=30)
- algorithm: algorithm to be used (default="classic_LR")
- demean: boolean flag determining whether to demean the data before applying the algorithm (default=TRUE)
- detrend: boolean flag determining whether to detrend the data before applying the algorithm (default=TRUE)
- taper: proportion of the signal to be tapered at each end before applying the algorithm (default=0.0)
- increment: the increment to use when sliding the averaging windows to the next location (default=1).

Details

By default, this method uses the "classic_LR" algorithm which calculates the average power in the Trace data over a short window (STA) and a long window (LTA). With this algorithm, windows are "left/right aligned" meaning that the point for which STA/LTA is calculated is at the leftmost edge of the STA window and the rightmost edge of the LTA window. The resulting STA/LTA ratio thus has the same number of points as the original data. This is a standard method of "first break picking" and can be used to identify the onset of a seismic event.

Three different algorithms are currently available:

1) algorithm="classic_RR" This is the original STA/LTA algorithm with "right alignment".

\[
STA(x_i) = \frac{1}{ns} \sum_{j=i-ns}^{i} x_j^2
\]

\[
LTA(x_i) = \frac{1}{nl} \sum_{j=i-nl}^{i} x_j^2
\]

\[
r_i = \frac{STA_i}{LTA_i}
\]
2) algorithm="classic_LR" (default) This algorithm has the index at the left edge of the STA window and the right edge of the LTA window

\[
STA(x_i) = \frac{1}{ns} \sum_{j=i}^{i+ns} x_j^2
\]

\[
LTA(x_i) = \frac{1}{nl} \sum_{j=i-nl}^{i} x_j^2
\]

\[
r_i = \frac{STA_i}{LTA_i}
\]

3) algorithm="EarleAndShearer_envelope"

\[
STA(x_i) = \frac{1}{ns} \sum_{j=i}^{i+ns} Mod(H(x))_j
\]

\[
LTA(x_i) = \frac{1}{nl} \sum_{j=i-nl}^{i} Mod(H(x))_j
\]

\[
r_i = \frac{STA_i}{LTA_i}
\]

where \( H(x) \) is the Hilbert transform of the data and \( Mod(H(x)) \) is the 'envelope' of the seismic signal. Note that because the Hilbert transform involves performing an FFT of the data it can take significantly longer than the "classic" algorithms for longer seismic signals (>500K pts).

Value

A vector of values is returned of the same length as the data in the Trace.

Note

The returned vector will contain NA near the edges of the trace where insufficient data are available to fill the windows. Additional NA values will appear for every index that is skipped over when the increment parameter is greater than one.

For higher resolution channels, picking an increment of \( 2/sampling\_rate \) can greatly speed up processing times and still generate reasonable results.
Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

First break picking (Wikipedia)
Automatic time-picking of first arrivals on noisy microseismic data (Wong et. al. 2009)
Automatic first-breaks picking: New strategies and algorithms (Sabbione and Velis 2010)
Adaptive microseismic event detection and automatic time picking (Akram and Eaton 2012)

See Also

ttriggerOnset

Examples

```r
## Not run:
# Open a connection to IRIS DMC webservies
iris <- new("IrisClient")

starttime <- as.POSIXct("2010-02-27", tz="GMT")
endtime <- as.POSIXct("2010-02-28", tz="GMT")

# Get the waveform
st <- getDataselect(iris, "IU", "ANMO", "00", "BHZ", starttime, endtime)
tr <- st@traces[[1]]
picker <- STALTA(tr, 3, 30)

# Plot the trace and overlay the picker
plot(tr)
par(new=TRUE)
plot(picker, type="l", col="red", axes=FALSE, xlab="", ylab="")
mtext("Picker", side=1, line=-8, adj=0.05, col="red")
par(new=FALSE)

## End(Not run)
```

Stream-class

Class "Stream"

Description

A Stream object containing a list of Trace objects.
Objects from the Class

Objects are typically created by calls to `getDataselect`.

Slots

- **url**: Object of class "character": URL request used to generate this Stream.
- **requestedStartTime**: Object of class "POSIXct": starttime used when requesting data with `getDataselect`.
- **requestedEndTime**: Object of class "POSIXct": endtime used when requesting data with `getDataselect`.
- **act_flags**: Object of class "integer": Accumulators for the act_flags bits in each miniSEED record.
- **io_flags**: Object of class "integer": Accumulators for the io_flags bits in each miniSEED record.
- **dq_flags**: Object of class "integer": Accumulators for the dq_flags bits in each miniSEED record.
- **timing_qual**: Object of class "numeric": Average timing quality associated with miniSEED records.
- **traces**: Object of class "list": List of Trace objects.

Methods

- **getGaps** signature(x="Stream") - returns information on data dropouts between Traces; see `getGaps`
- **getUpDownTimes** signature(x="Stream", min_signal="numeric", min_gap="numeric") - returns a vector of datetimes associated with channel up/down transitions; see `getUpDownTimes`
- **length** signature(x="Stream") - returns the total number of data points in all Traces
- **max** signature(x="Stream") - returns the overall data maximum for all data in all Traces
- **median** signature(x="Stream", na.rm = "logical") - returns the overall data median for all data in all Traces
- **mean** signature(x="Stream") - returns the overall data mean for all data in all Traces
- **mergeTraces** signature(x="Stream", fillMethod="fillNA") - returns a new Stream object where all Traces have been merged into a single Trace `mergeTraces`
- **min** signature(x="Stream") - returns the overall data minimum for all data in all Traces
- **multiplyBy** signature(x="Stream", y="numeric") - returns a new Stream object where the data in every Trace have been multiplied by y; see `multiplyBy`
- **parallelLength** signature(x="Stream") - returns a vector of data lengths, one for each Trace
- **parallelMax** signature(x="Stream") - returns a vector of data maxima, one for each Trace
- **parallelMedian** signature(x="Stream", na.rm = "logical") - returns a vector of data medians, one for each Trace
- **parallelMean** signature(x="Stream") - returns a vector of data means, one for each Trace
- **parallelMin** signature(x="Stream") - returns a vector of data minima, one for each Trace
- **parallelRms** signature(x="Stream") - returns a vector of RMS calculations, one for each Trace; see `rmsVariance`
**parallelRmsVariance** signature(x="Stream"): returns a vector of RMS variance calculations, one for each Trace; see rmsVariance

**parallelSd** signature(x="Stream", na.rm="logical"): returns a vector of standard deviation calculations, one for each Trace

**plot** signature(x="Stream"): default plot of the merged Traces in a Stream with appropriate labeling

**plotUpDownTimes** signature(x="Stream", min_signal="numeric", min_gap="numeric"): plots the times at which a Stream transitions from data collection to non-collection (on/off); see getUpDownTimes

**rms** signature(x="Stream"): returns the overall Root Mean Square amplitude for all data in all Traces; see rmsVariance

**rmsVariance** signature(x="Stream"): returns the overall RMS variance for all data in all Traces; see rmsVariance

**sd** signature(x="Stream", na.rm="logical"): returns the overall standard deviations for all data in all Traces

**slice** signature(x="Stream", starttime="POSIXct", endtime="POSIXct"): returns a new Stream sliced out of an existing Stream (see slice)

**uniqueIds** signature(x="Stream"): returns a vector of SNCLQ identifiers, one for each Trace

### Note

The Stream object is inspired by the Stream class found in the python ObsPy package ([http://docs.obspy.org/packages/autogen/obspy.core.stream.Stream.html](http://docs.obspy.org/packages/autogen/obspy.core.stream.Stream.html)).

The miniSEED flags and timing_qual values are described in the SEED manual ([http://www.fdsn.org/seed_manual/SEEDManual_V2.4.pdf](http://www.fdsn.org/seed_manual/SEEDManual_V2.4.pdf)). The "accumulators" contain counts of the number of times each bit flag was set during the parsing of a miniSEED file. These attributes are retained primarily for assessing data quality issues within the IRIS DMC.

The following code documentation describes how each of the flags is used within miniSEED files:

```python
# act_flags
# [1] Calibration signals present
# [2] Time correction applied
# [3] Beginning of an event, station trigger
# [4] End of an event, station detrigger
# [5] A positive leap second happened in this record
# [6] A negative leap second happened in this record
# [7] Event in progress
# [8] Undefined bit set

# io_flags
# [1] Station volume parity error possibly present
# [2] Long record read (possibly no problem)
# [3] Short record read (record padded)
# [4] Start of time series
# [5] End of time series
# [6] Clock locked
```
# [7] Undefined bit set
# [8] Undefined bit set

# dq_flags
# [1] Amplifier saturation detected
# [2] Digitizer clipping detected
# [3] Spikes detected
# [4] Glitches detected
# [5] Missing/padded data present
# [6] Telemetry synchronization error
# [7] A digital filter may be charging
# [8] Time tag is questionable

**Author(s)**

Jonathan Callahan <jonathan@mazamascience.com>

**Examples**

```r
## Not run:
# Open a connection to IRIS DMC web services
iris <- new("IrisClient")

starttime <- as.POSIXct("2012-01-24", tz="GMT")
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)
min(st)
median(st)
mean(st)
max(st)
sd(st)
rms(st)
rmsVariance(st)

## End(Not run)
```

---

**surfaceDistance**

*Earth surface distance between two points*

**Description**

The `surfaceDistance()` function calculates the distance in kilometers between any two lat-lon pairs using the Haversine equation.

**Usage**

`surfaceDistance(lat1_deg, lon1_deg, lat2_deg, lon2_deg)`
Arguments

latitude 1 (degrees)
longitude 1 (degrees)
latitude 2 (degrees)
longitude 2 (degrees)

Value

Distance in kilometers

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

References

http://en.wikipedia.org/wiki/Haversine_formula

Trace-class

Class "Trace"

Description

A Trace object containing a seismic trace – a continuous timeseries.

Objects from the Class

Objects occupy the traces slot of a Stream-class object and are typically populated by calls to getDataselect.

Slots

id: Object of class "character": Unique "SNCL" identifier specifying the Network, Station, Location, Channel and Quality factor associated with this trace: eg. AK.PIN..VEA.M. The id is generated automatically when the trace is first created and is intended for read only.

Sensor: Object of class "character": Instrument name.

InstrumentSensitivity: Object of class "numeric": The total sensitivity for a channel, representing the complete acquisition system expressed as a scalar. Equivalent to SEED stage 0 gain.

SensitivityFrequency: Object of class "numeric": The frequency at which the total sensitivity is correct.

InputUnits: Object of class "character": The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

stats: Object of class "TraceHeader": Container with metadata information describing the trace. (see TraceHeader-class)

data: Object of class "numeric": Vector of data values.
Methods

as.vector signature(x="Trace"): returns the data slot; equivalent to x@data

DDT signature(x="Trace", demean="logical", detrend="logical", taper="numeric"): returns a new trace that has been `cleaned up` for further processing by applying demean, detrend, and taper techniques (see DDT)

evelope signature(x="Trace"): returns the envelope of the seismic signal (see envelope)

isDC signature(x="Trace"): returns TRUE if trace data consist of a DC signal

length signature(x="Trace"): returns the length of the data; equivalent to length(x@data)

max signature(x="Trace"): returns the maximum value of the data; equivalent to max(x@data)

median signature(x="Trace", na.rm="logical"): returns the median value of the data; equivalent to median(x@data)

mean signature(x="Trace"): returns the mean value of the data; equivalent to mean(x@data)

min signature(x="Trace"): returns the minimum value of the data; equivalent to min(x@data)

multiplyBy signature(x="Trace", y="numeric"): returns a new Trace where the data have been multiplied by y (see multiplyBy)

plot signature(x="Trace"): default plot of the Trace data with appropriate labeling

rms signature(x="Trace"): returns the Root Mean Square amplitude of the data (see rms)

rmsVariance signature(x="Trace"): returns the RMS variance of the data (see rmsVariance)

sd signature(x="Trace", na.rm="logical"): returns the standard deviation of the data; equivalent to sd(x@data)

slice signature(x="Trace", starttime="POSIXct", endtime="POSIXct"): returns a new Trace subset of an existing Trace (see slice)

STALTA signature(x="Trace", staSecs="numeric", ltaSecs="numeric", algorithm="character", ...): returns the STALTA picker result (see STALTA)

triggerOnset signature(x="Trace", picker="numeric", threshold="numeric", ...): returns the time or index of an event onset as determined by the STALTA picker (see triggerOnset)

Note

The Trace object is inspired by the Trace class found in the python ObsPy package (http://docs.obspy.org/packages/autogen/obspy.core.trace.Trace.html).

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

```r
## Not run:
# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

# Set the starttime and endtime
starttime <- as.POSIXct("2012-01-24", tz="GMT")
```
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)

# Get the first trace and generate some statistics
tr1 <- st@traces[[1]]
min(tr1)
median(tr1)
mean(tr1)
max(tr1)
sd(tr1)
rms(tr1)
rmsVariance(tr1)

## End(Not run)

---

**TraceHeader-class**  
**Class** "TraceHeader"

**Description**

A container for metadata associated with a Trace object. Originally populated by information in the miniseed trace header; it now has the option of including additional station and channel metadata.

**Objects from the Class**

Objects can be created by calls of the form `new("TraceHeader", headerList, headerLine, ...)`.

The stats slot of a Trace object will contain a TraceHeader object, typically populated by a webservice request. (see IrisClient-class)

**Slots**

- `sampling_rate`: Object of class "numeric": Sampling rate in hertz.
- `delta`: Object of class "numeric": Sample interval in seconds.
- `calib`: Object of class "numeric": Calibration factor.
- `npts`: Object of class "integer": Number of sample points.
- `network`: Object of class "character": Seismic network name.
- `location`: Object of class "character": Location code.
- `station`: Object of class "character": Station name.
- `channel`: Object of class "character": Channel code.
- `quality`: Object of class "character": Data quality code.
- `starttime`: Object of class "POSIXct": Start time.
- `endtime`: Object of class "POSIXct": End time.
- `latitude`: Object of class "numeric": Latitude.
longitude: Object of class "numeric": Longitude.
et elevation: Object of class "numeric": Elevation.
depth: Object of class "numeric": Depth.
azimuth: Object of class "numeric": Azimuth.
dip: Object of class "numeric": Dip.
processing: Object of class "list": Information strings describing processing applied to this trace.

Methods

as.headerLine signature(obj = "TraceHeader"): Prints out the information in the TraceHeader as an ascii header line, not including any station and channel metadata not found in the miniseed trace header, e.g.,

```
TIMESERIES LD_POTS__HHZ_M, 351 samples, 100.503 sps, \n2012-01-29T00:00:00.006000, SLIST, INTEGER, COUNTS
```

show signature(object = "TraceHeader"): Prettyprints the information in the TraceHeader

Note

The TraceHeader object is inspired by the Stats class found in the python ObsPy package (http://docs.obspy.org/packages/autogen/obspy.core.trace.Stats.html).

Retaining the ObsPy class name Stats would have generated a tremendous amount of confusion in the context of R. Instead, the name TraceHeader has been adopted. Nevertheless, the TraceHeader object still lives in the Trace@stats slot to retain as much similarity to ObsPy as possible.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

Examples

```r
## Not run:
# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

starttime <- as.POSIXct("2012-01-24", tz="GMT")
endtime <- as.POSIXct("2012-01-25", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"AK","PIN","","BHZ",starttime,endtime)

# Get the first trace and show the associated metadata
tr1 <- st@traces[[1]]
show(tr1@stats)

## End(Not run)
```
triggerOnset  Event onset triggering

Description

The triggerOnset method of Trace objects uses the numeric vector returned by the STALTA \textit{“first break picking”} method and a user selected threshold to determine the arrival time of a seismic event.

Usage

\begin{verbatim}
triggerOnset(x, picker, threshold, index)
\end{verbatim}

Arguments

\begin{itemize}
\item \texttt{x} a Trace object
\item \texttt{picker} results from applying the STALTA method to this trace
\item \texttt{threshold} optional numeric value of the threshold at which triggering should occur
\item \texttt{index} optional logical to return the index (rather than the time) of event onset (default=FALSE)
\end{itemize}

Details

This method simply identifies the point at which the picker first rises above the threshold. When no threshold is supplied, an appropriate value is calculated from the picker with:

\begin{verbatim}
threshold <- quantile(picker, 0.999, na.rm=TRUE)
\end{verbatim}

Value

A single value is returned identifying the onset of the seismic event or \texttt{NA} if none is detected. The returned value will be a \texttt{POSIXct} time by default or a numeric index if \texttt{index=TRUE}.

Note

The appropriate value for the threshold will depend upon the exact STA/LTA algorithm used and the noise level in the signal.

Author(s)

Jonathan Callahan <jonathan@mazamascience.com>

See Also

STALTA
Examples

# Open a connection to IRIS DMC webservice
iris <- new("IrisClient")

starttime <- as.POSIXct("2010-02-27 06:00:00", tz="GMT")
endtime <- as.POSIXct("2010-02-27 09:00:00", tz="GMT")

# Get the waveform
st <- getDataselect(iris,"IU","ANMO","00","BHZ",starttime,endtime)
tr <- st@traces[[1]]
picker <- STALTA(tr,3,30)

# Identify the onset of the event
to <- triggerOnset(tr,picker)

plot(tr)
abline(v=to, col="red", lwd=2)


unHistogram

Histgram to Vector

Description

If vec represents a set of binned counts of incrementing values (ascending) return a vector of associated bin values with the proper count of each value. Intended for internal use.

Usage

unHistogram(vec, startVal, incr)

Arguments

 vec a histogram vector or ordered set of binned counts
 startVal the initial value of the first bin element
 incr the increment rate of each subsequent bin value

Value

A vector of bin values with appropriate counts of each.

Author(s)

Rob Casey <rob@iris.washington.edu>
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