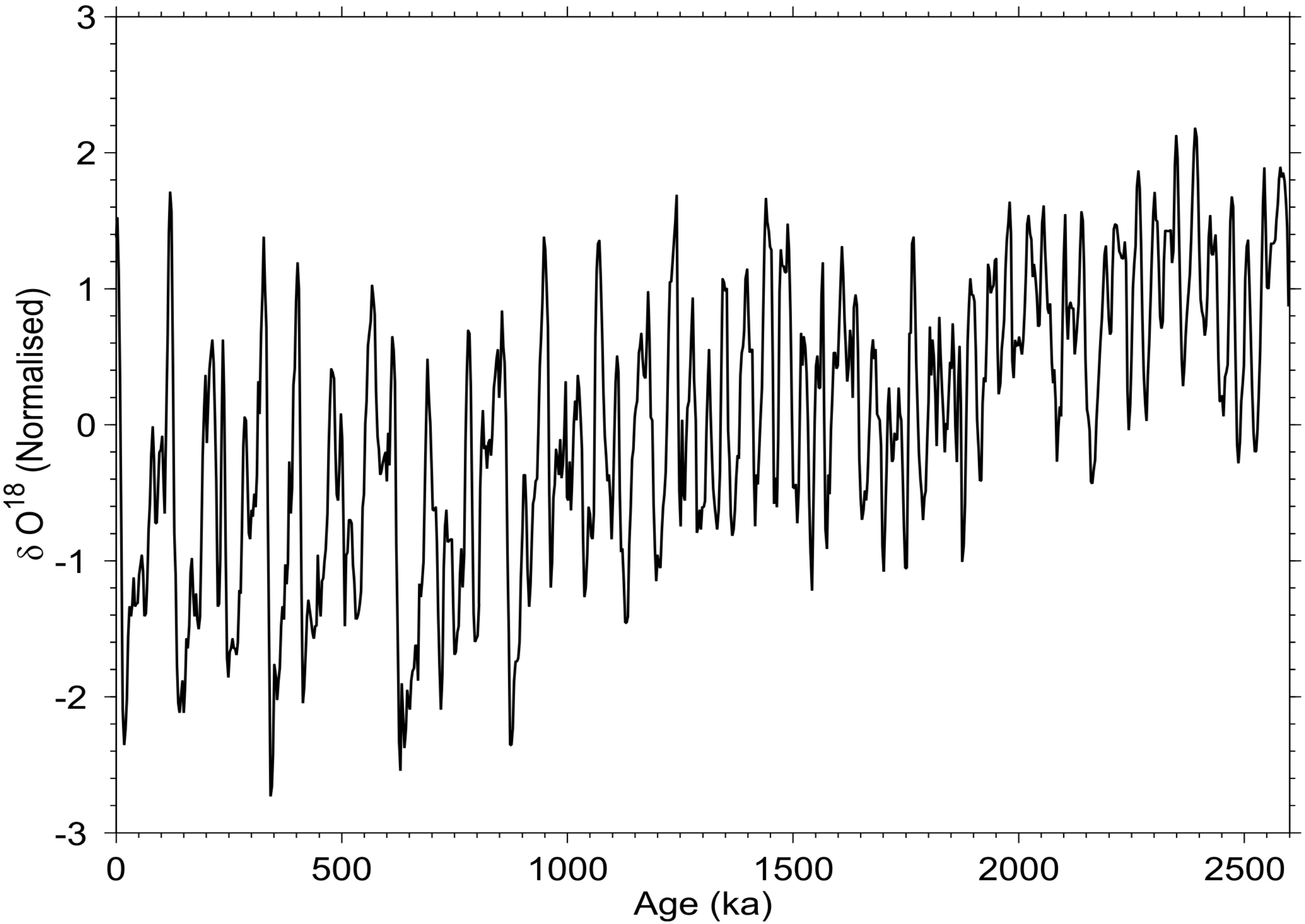
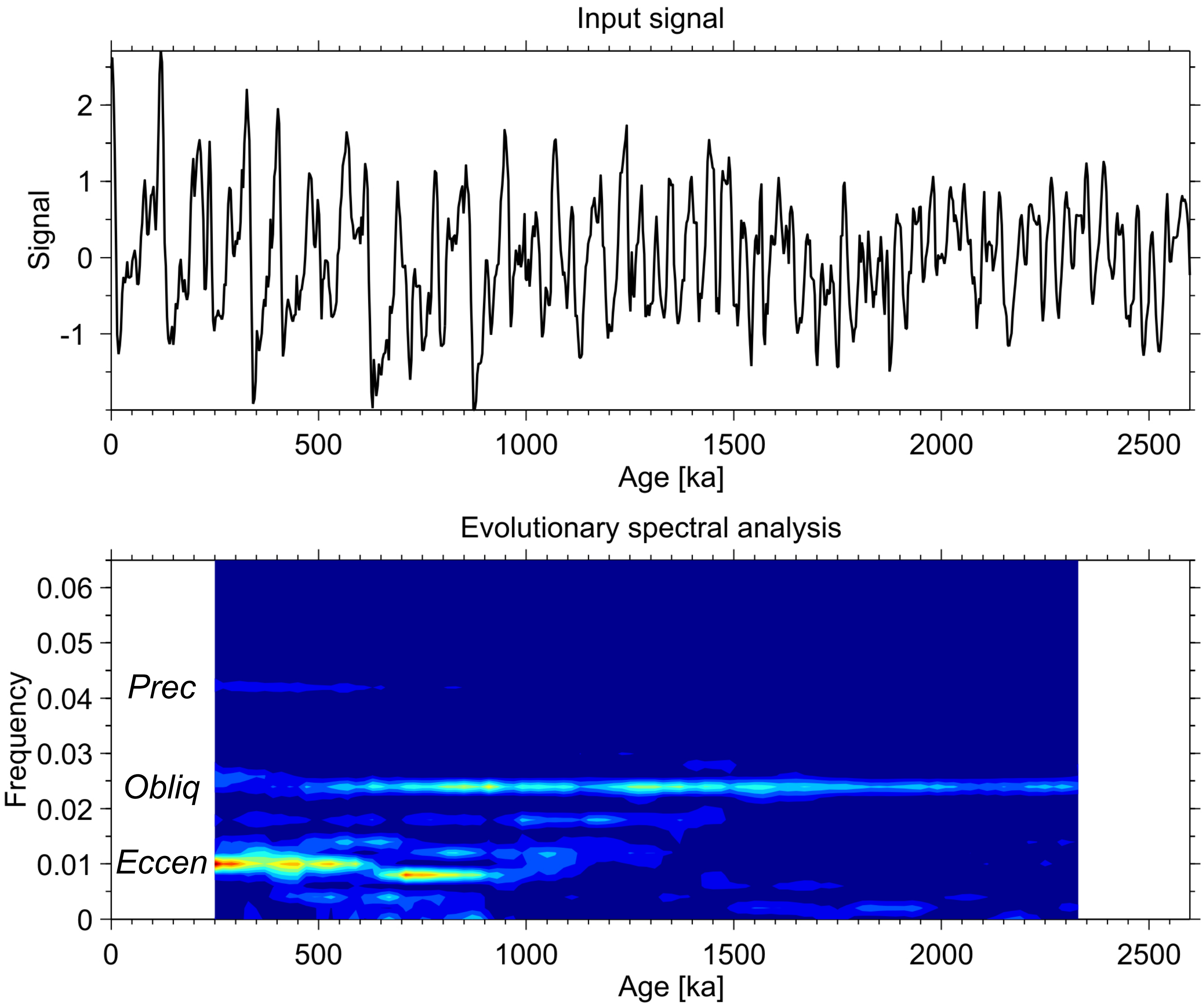
ODP677 Benthic Oxygen Isotope Record

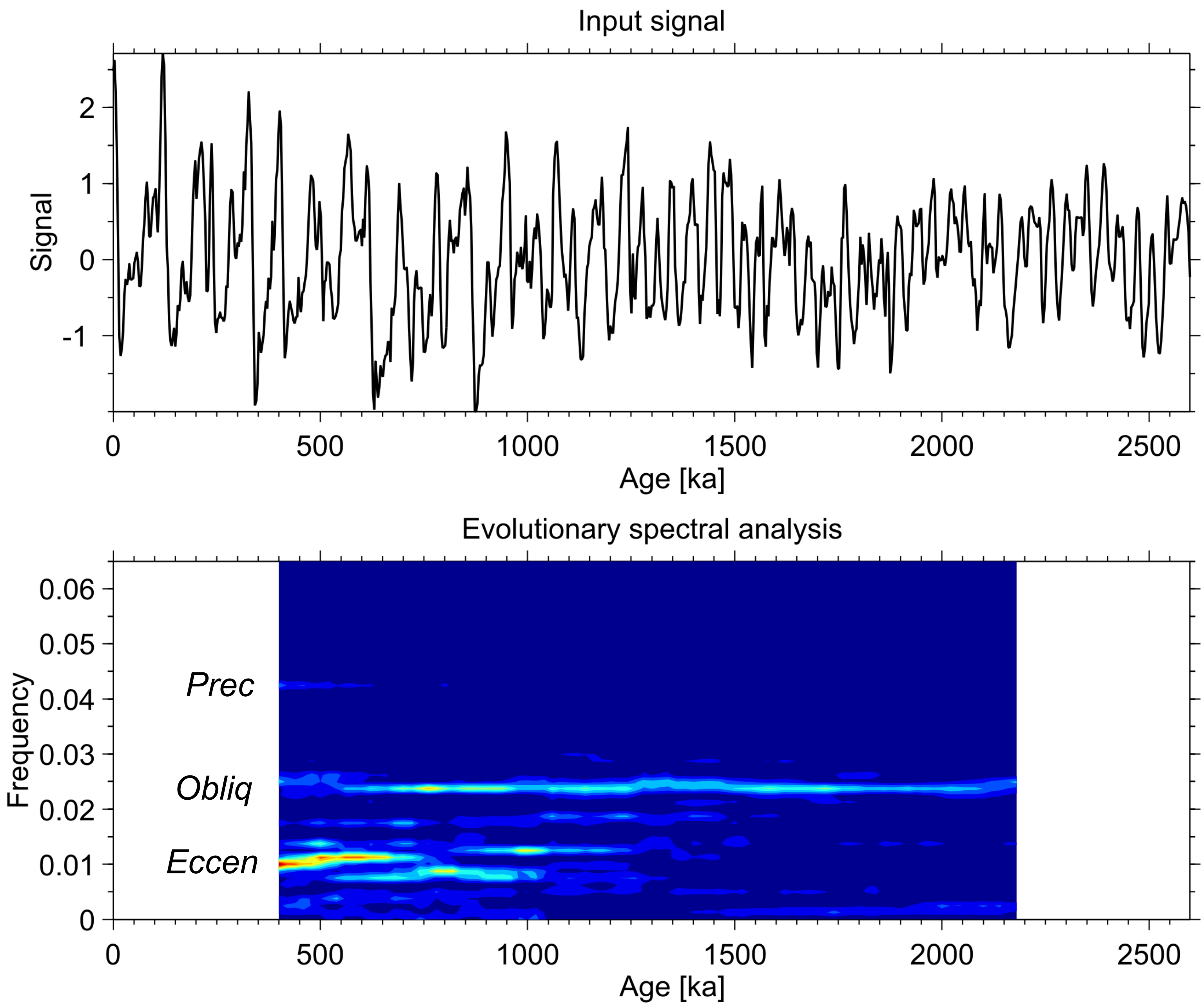


Make a time-frequency investigation of the ODP677 record, what can you say concerning changes in the climate cycles through time?

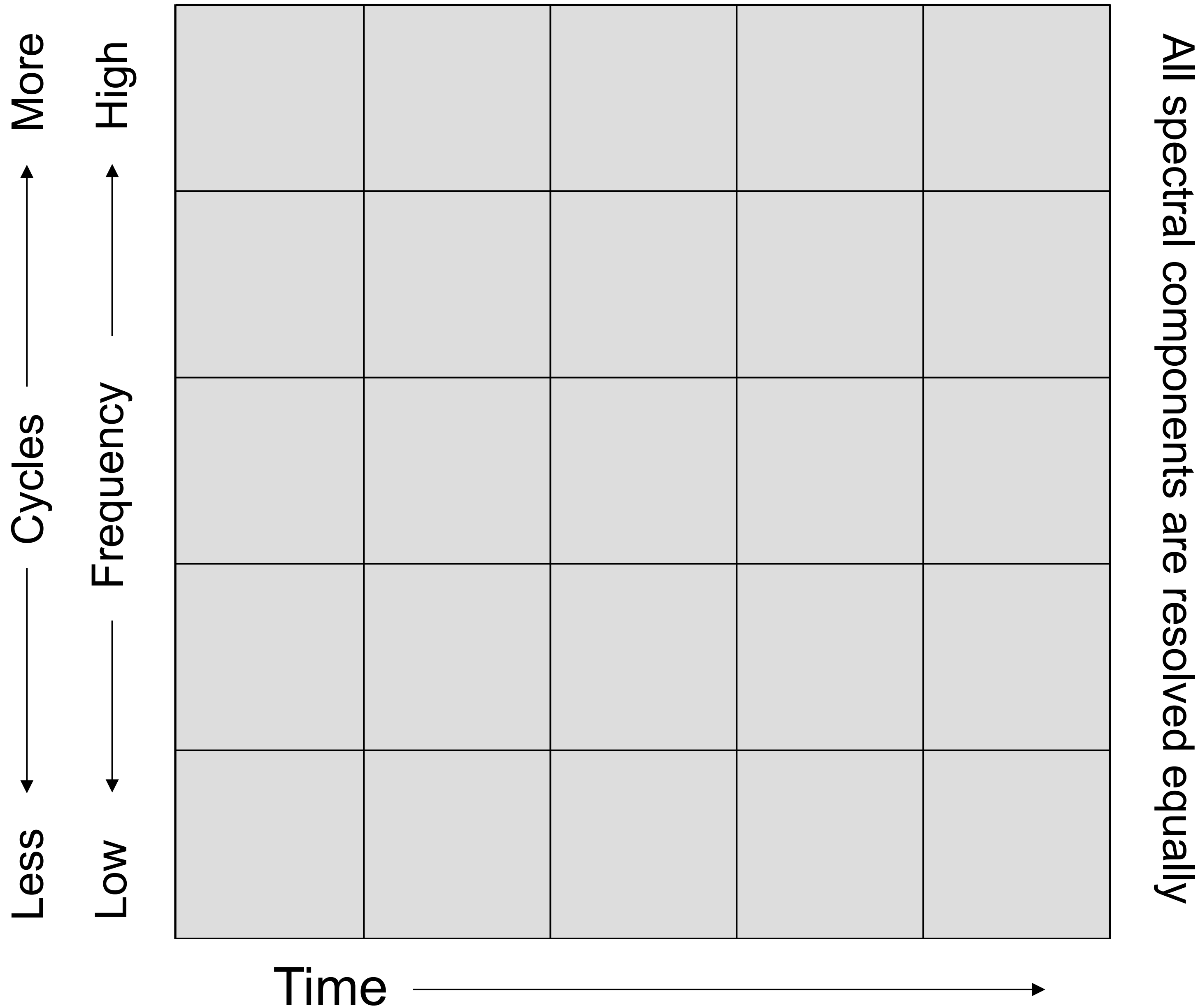
STFT: Detrended ODP677 Data with 500 kyr window



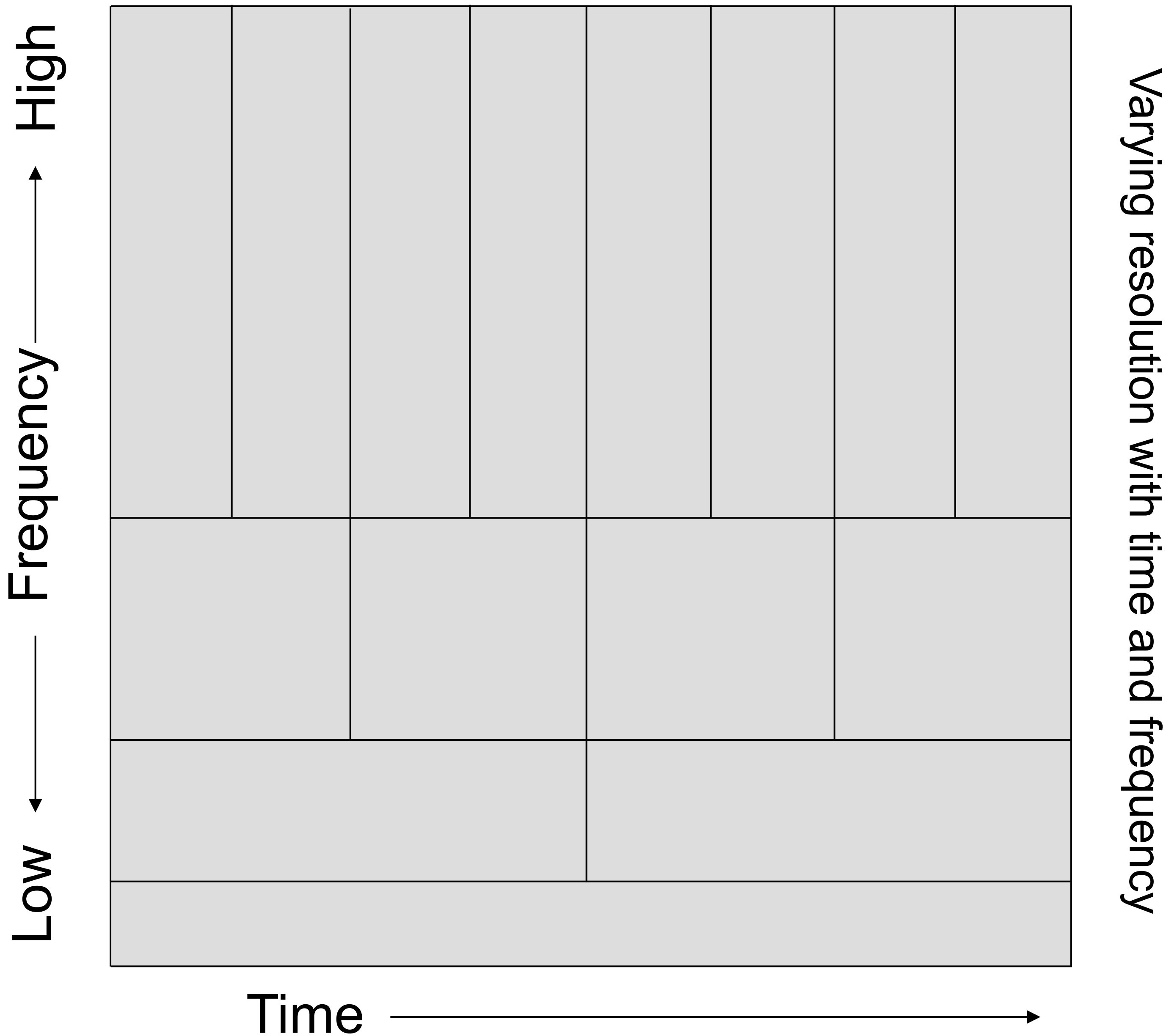
STFT: Detrended ODP677 Data with 800 kyr window



STFT transform in the time-frequency plane



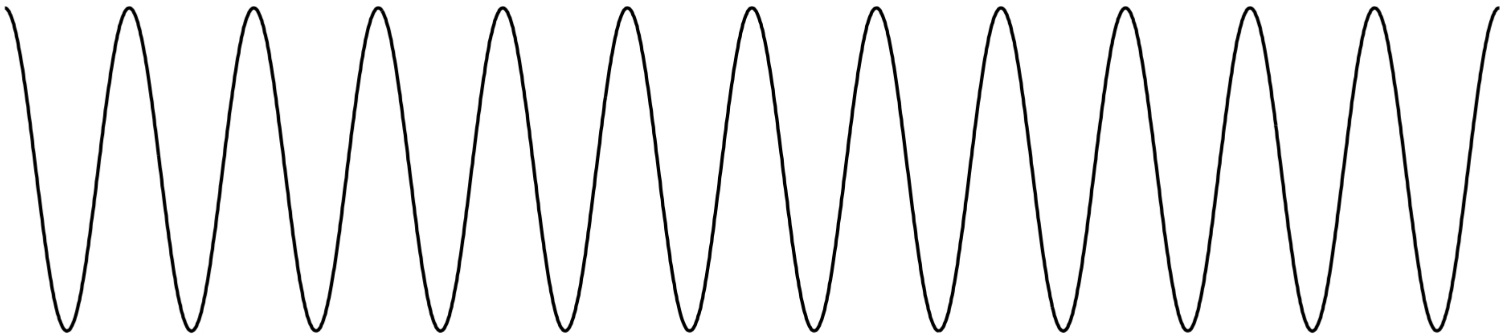
Wavelet transform in the time-frequency plane



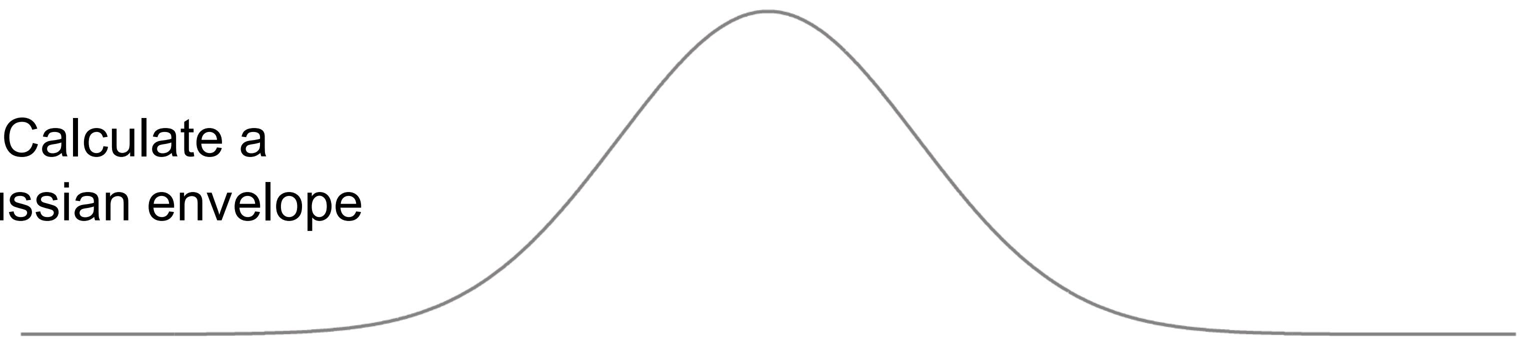
Construction of a Morlet Wavelet

We start with a sine wave

Infinite span (uniform in time)

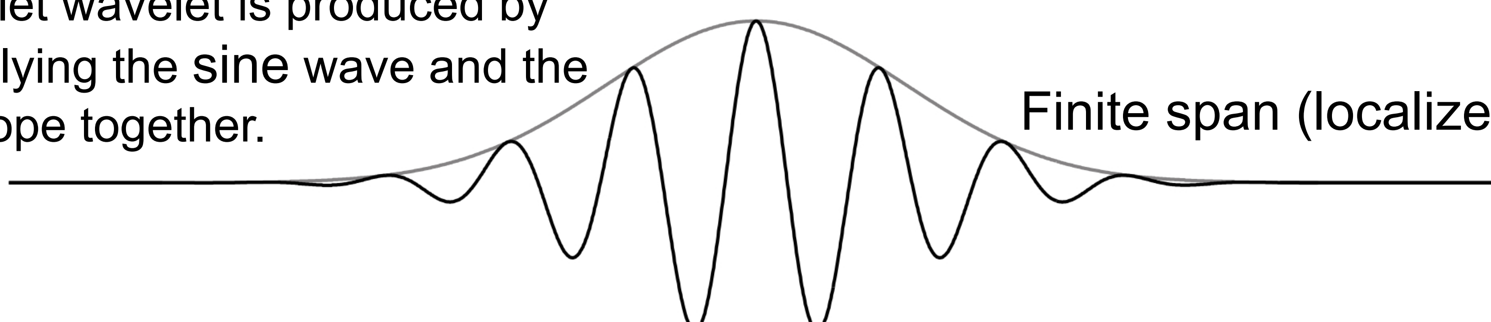


Calculate a Gaussian envelope



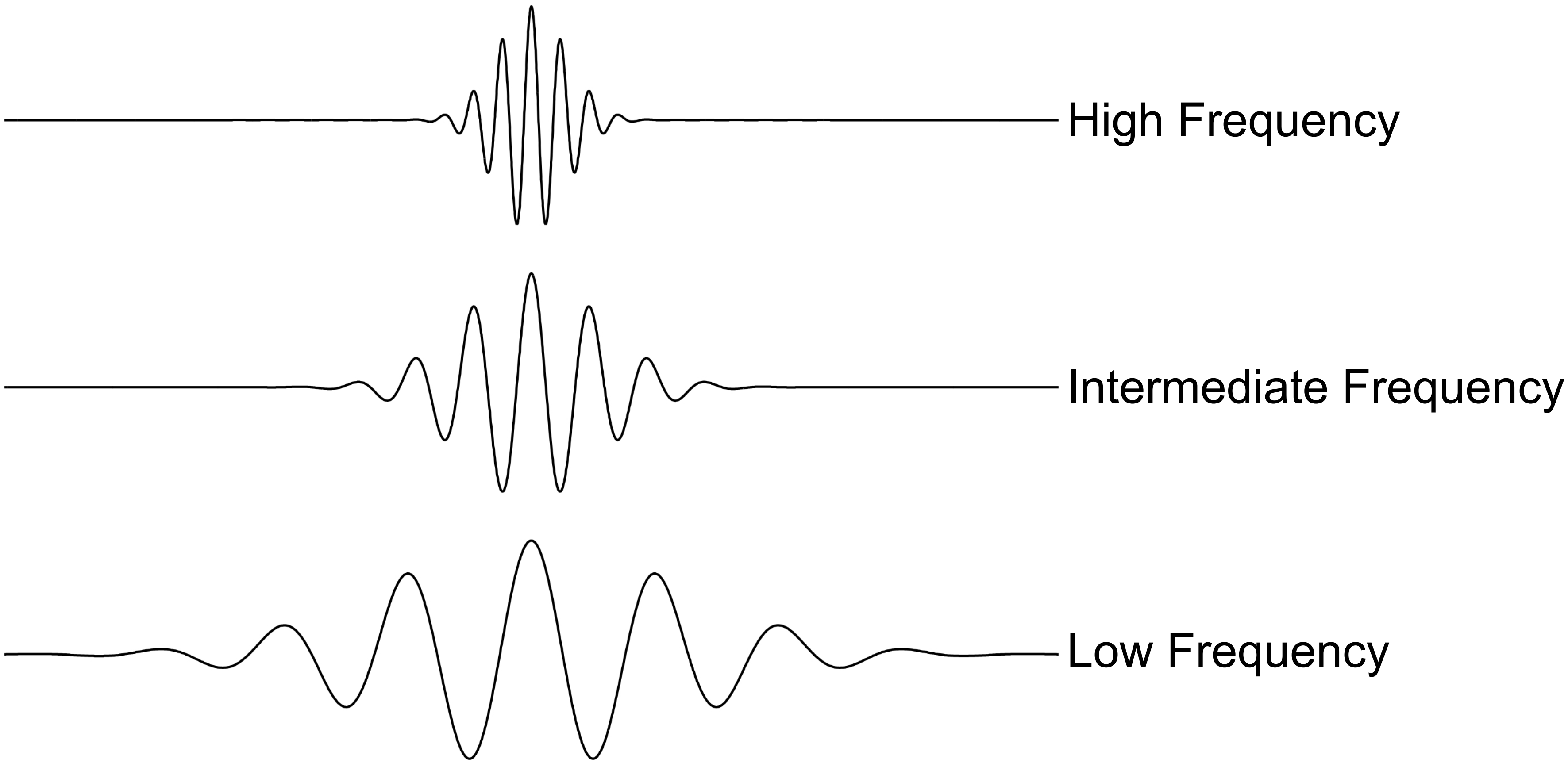
A Morlet wavelet is produced by multiplying the sine wave and the envelope together.

Finite span (localized in time)



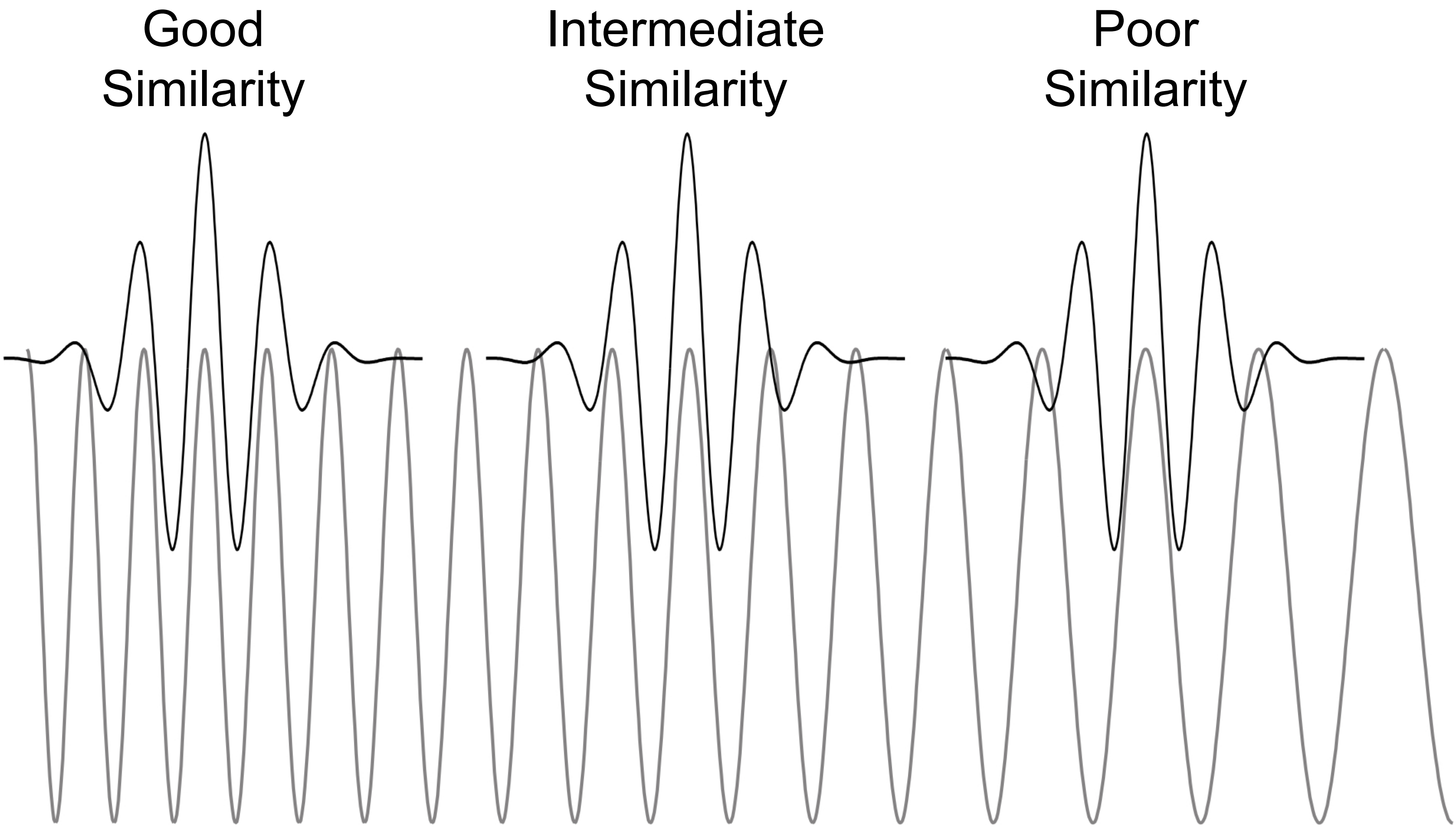
An important property of wavelets is that they can be stretched and compressed.

This is termed ***scaling*** and allows different frequencies to be represented.

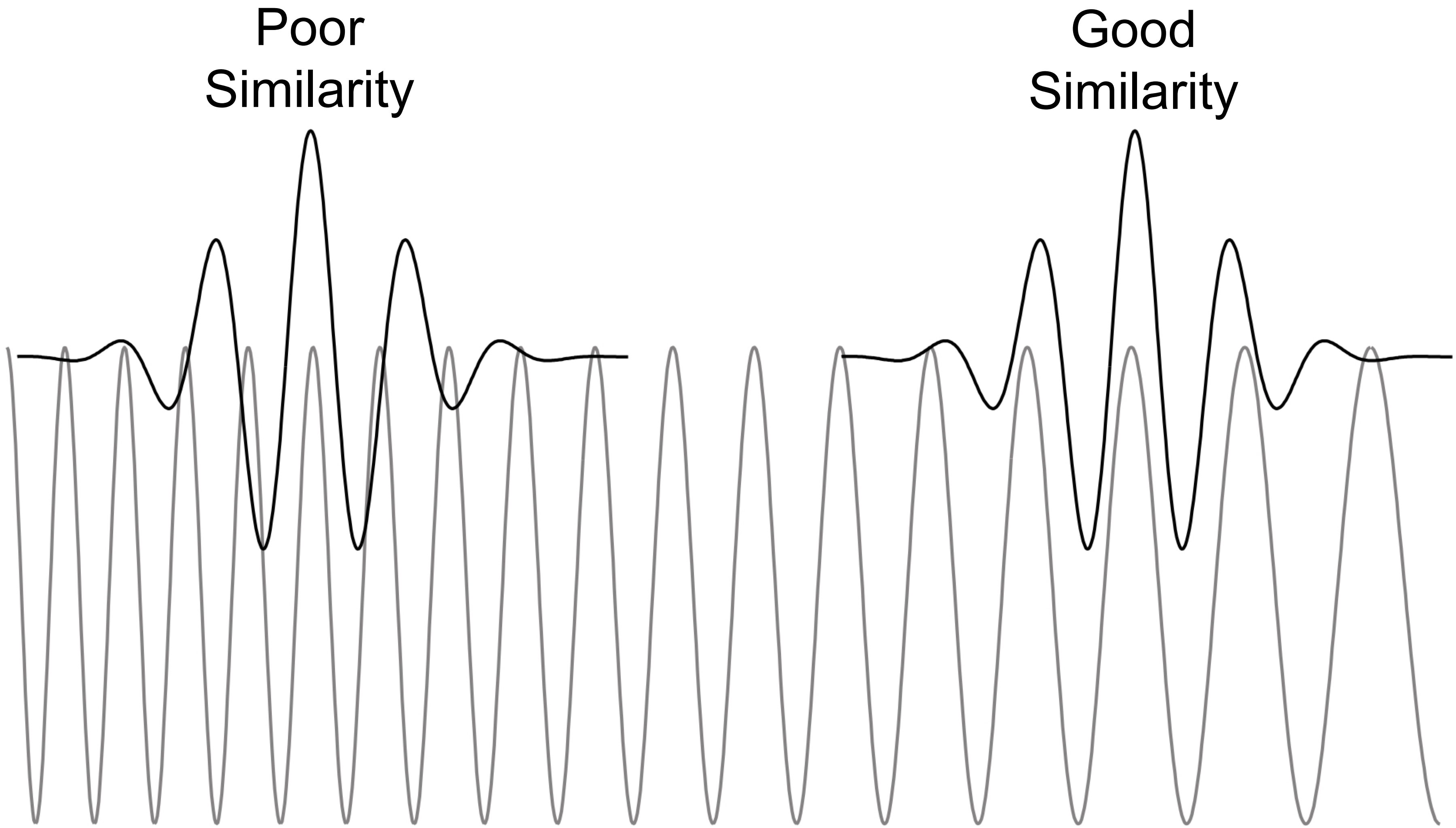


Wavelets are scaled for different frequency components, but the same number of cycles is always sampled.

For any given wavelet scale the similarity of the frequency content can be compared to a given time series at any position.

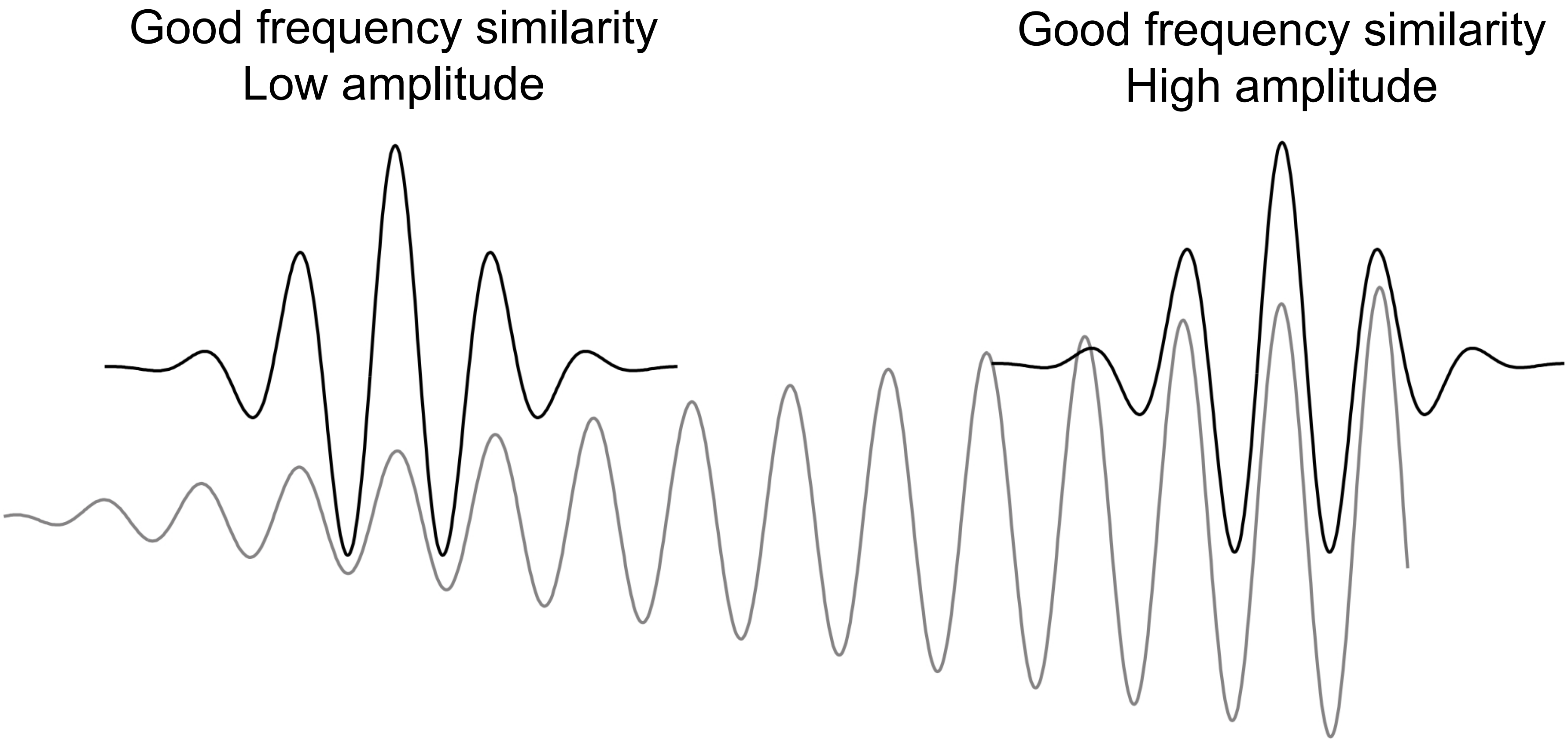


Because the wavelet can be scaled, we can change the scaling to find the best fit for each of the different parts of the time series.



A longer period wavelet fits the low frequency parts of the time series better, but shows a poor similarity with the high frequency parts.

Wavelets can also provide a measure of the amplitude of a given frequency component of the time series.



High wavelet power will be seen when the wavelet and time series have similar frequencies and the time series has a high amplitude

Steps of the Wavelet Transform

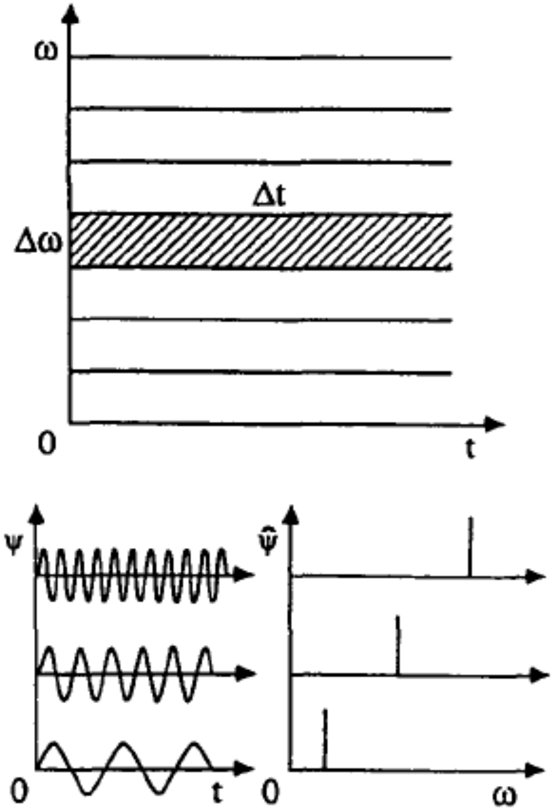
The wavelet transform gives information on the amplitude of periodic signals and the variation of amplitude with time. Therefore, the WT is 2-dimensional and decomposes a signal into time and frequency space simultaneously.

A wavelet of scale, s, is placed on the time series at $t = 0$ and their similarity is assessed. The wavelet is then moved on to $t = 1$ and the similarity is assessed again. This process is repeated for all values of t.

The scale is then changed and the wavelet is again migrated through the time series. This procedure is repeated for all desired values of s.

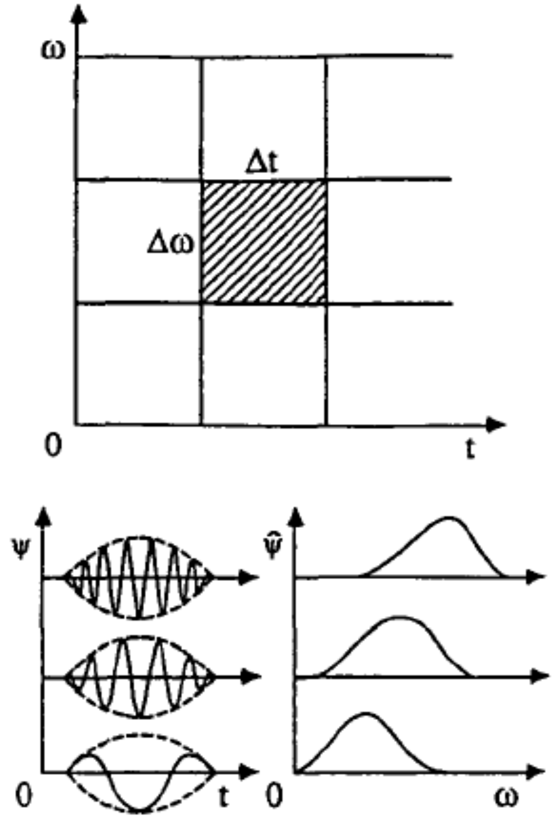
A Time-Scale (Frequency or period)-Power matrix is formed.

Fourier Transform



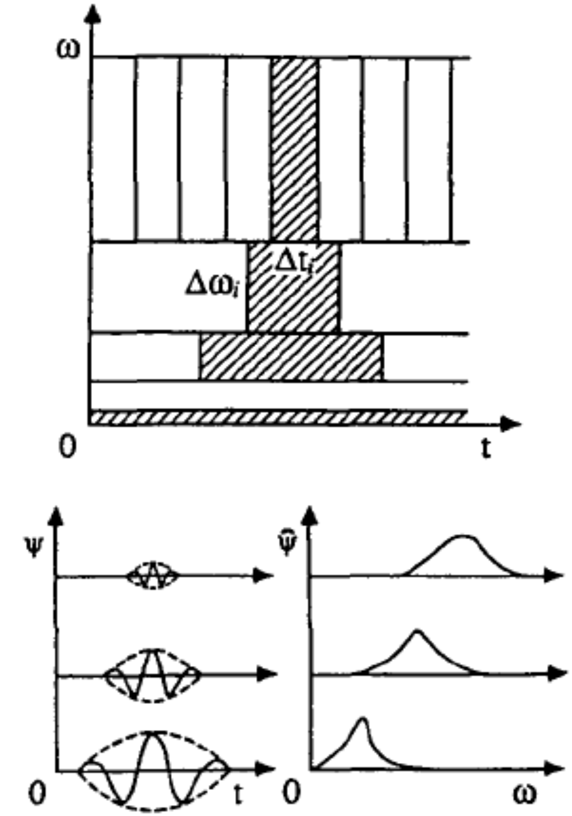
No time information in the frequency domain

STFT



Window contains a large number of high frequency cycles but only a small number of low frequency cycles

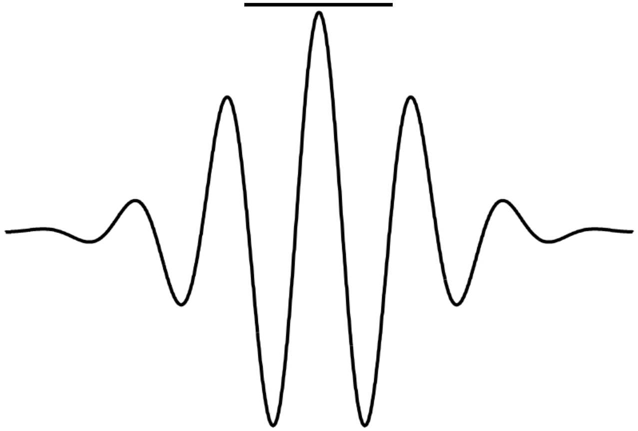
Wavelet Transform



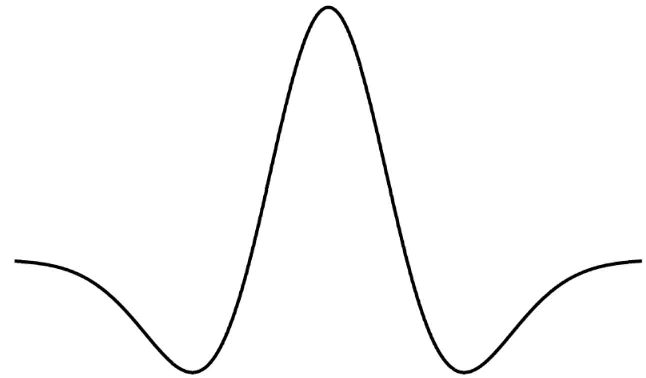
Window adapts to obtain the optimum time-frequency resolution within the limits of the *uncertainty principle*.

There are different types of wavelet

Morlet

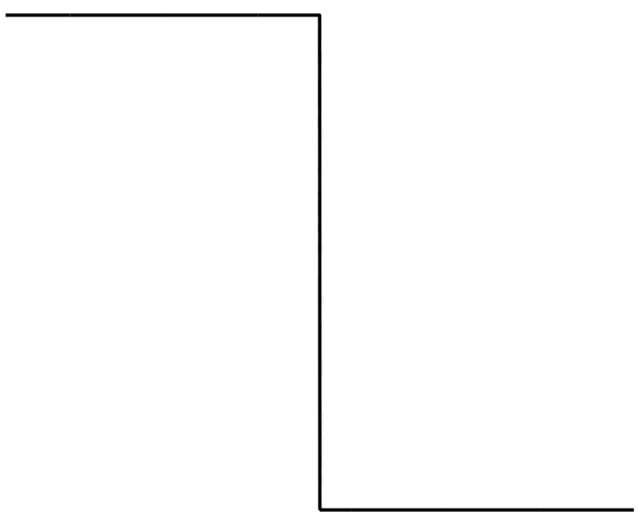


Mexican Hat



Also known as the DOG
(derivative of Gaussian)

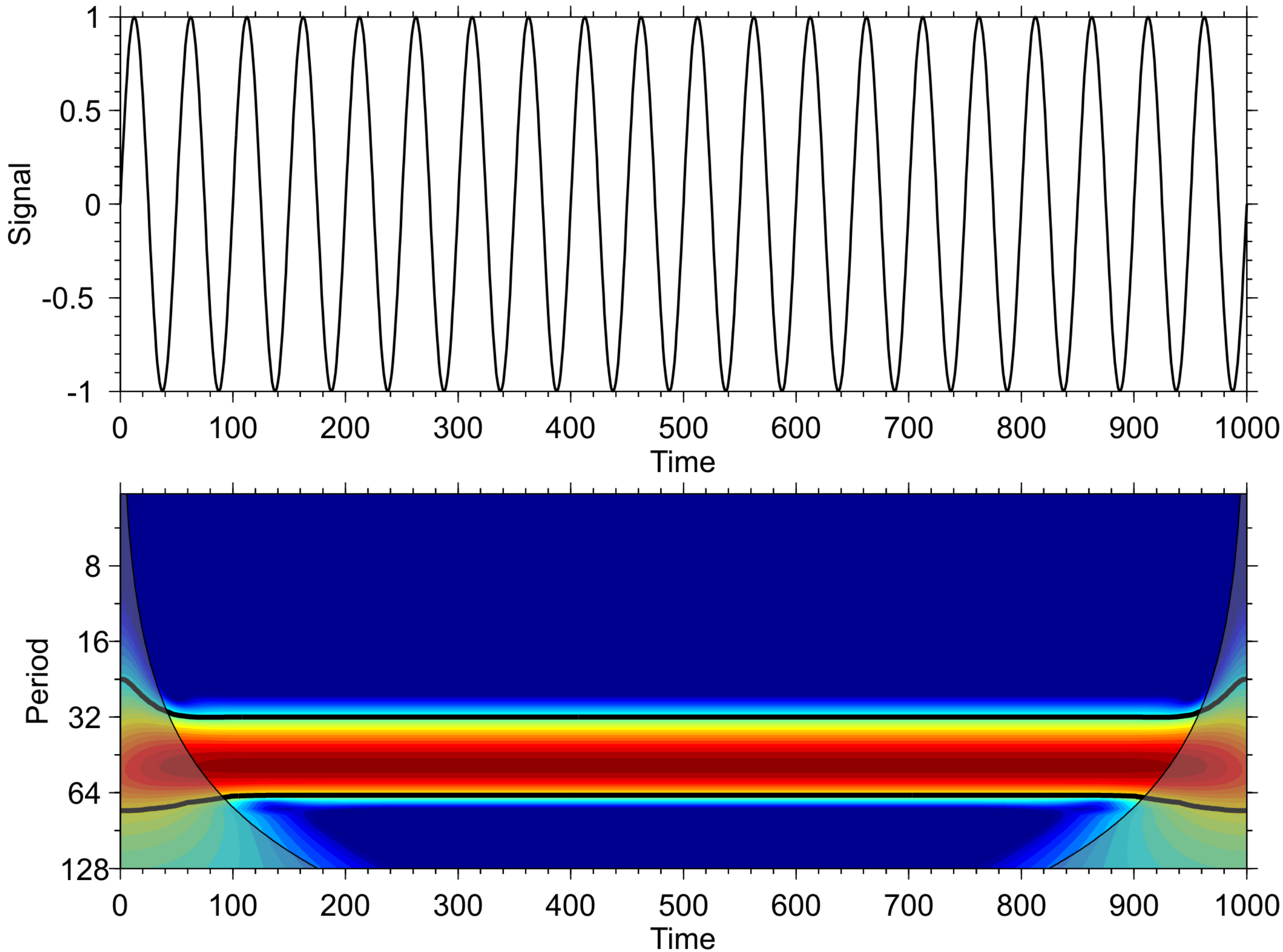
Haar

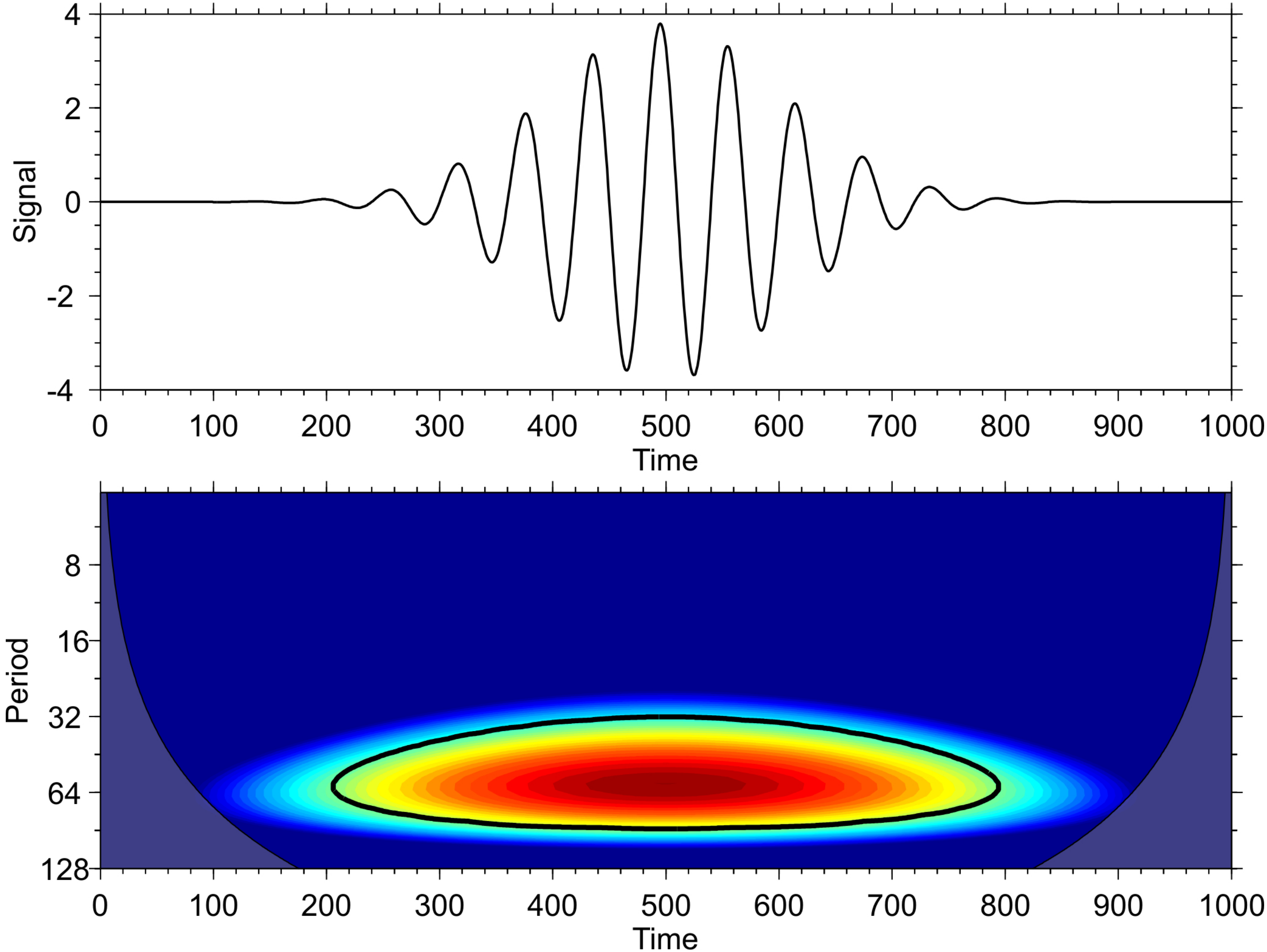


The type of wavelet used to analyse a time series depends on the shape of the expected cycles. The Morlet wavelet is generally used the most and has been shown to be applicable to many geophysical signals.

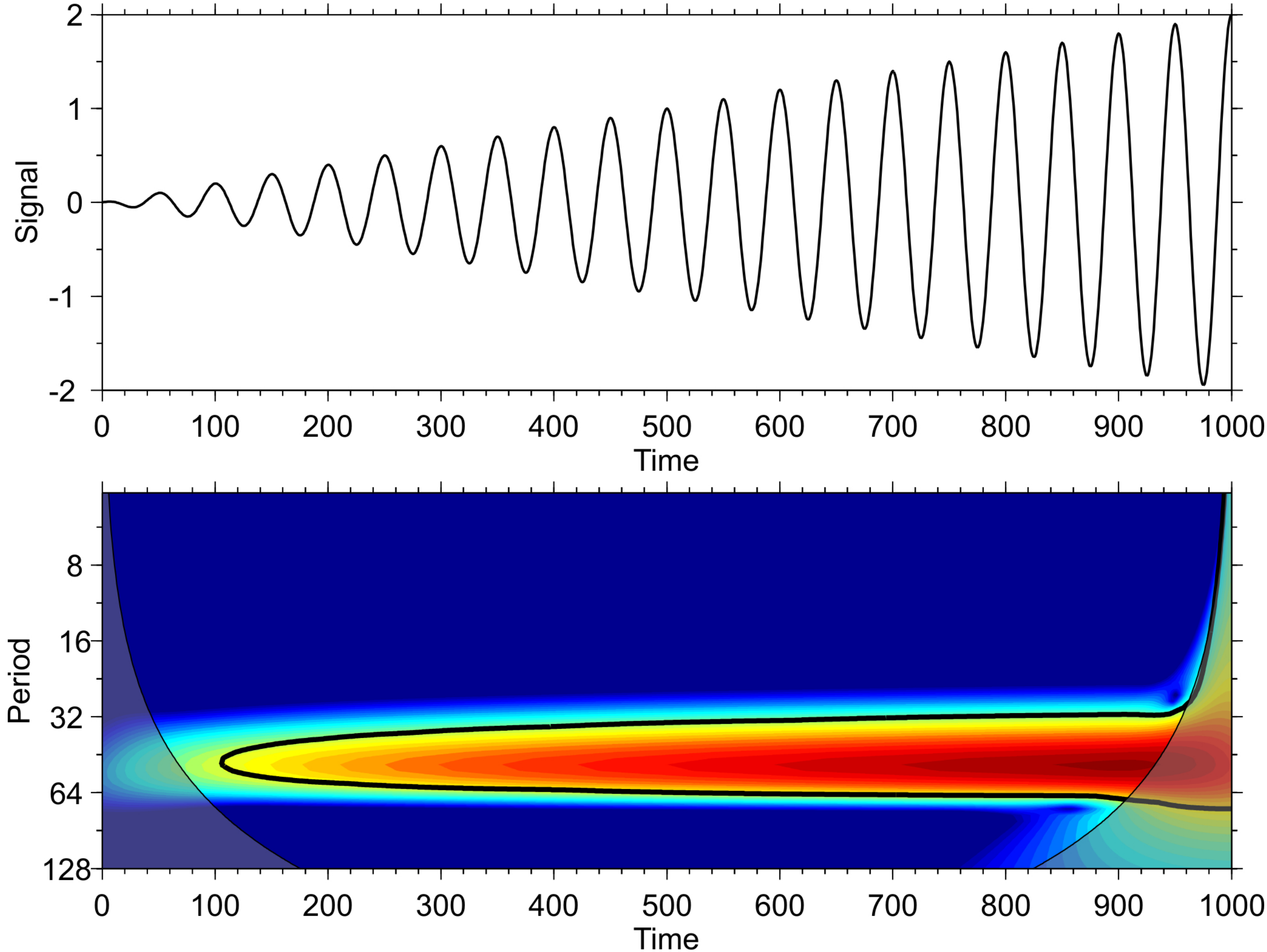
Wavelet transform of a sine wave.

Notice the edge effects (cone of influence) where the wavelet "falls off the end of the data"





Signal
4
2
0
-2
-4
0
100
200
300
400
500
600
700
800
900
1000
Time
Period
8
16
32
64
128
0
100
200
300
400
500
600
700
800
900
1000
Time

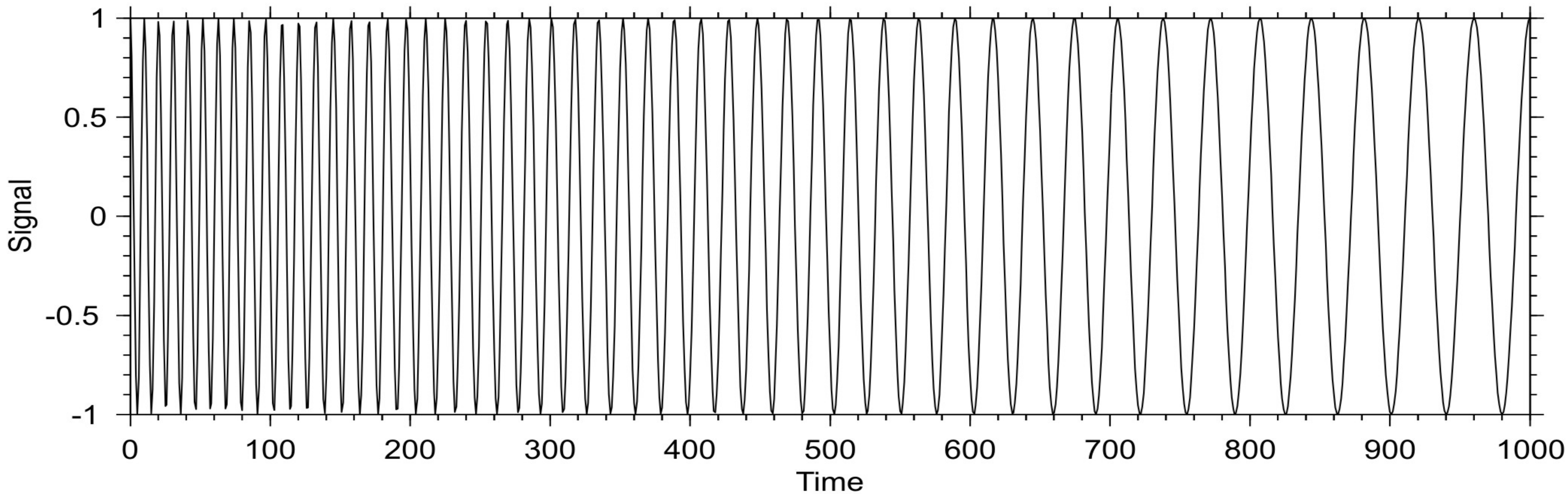


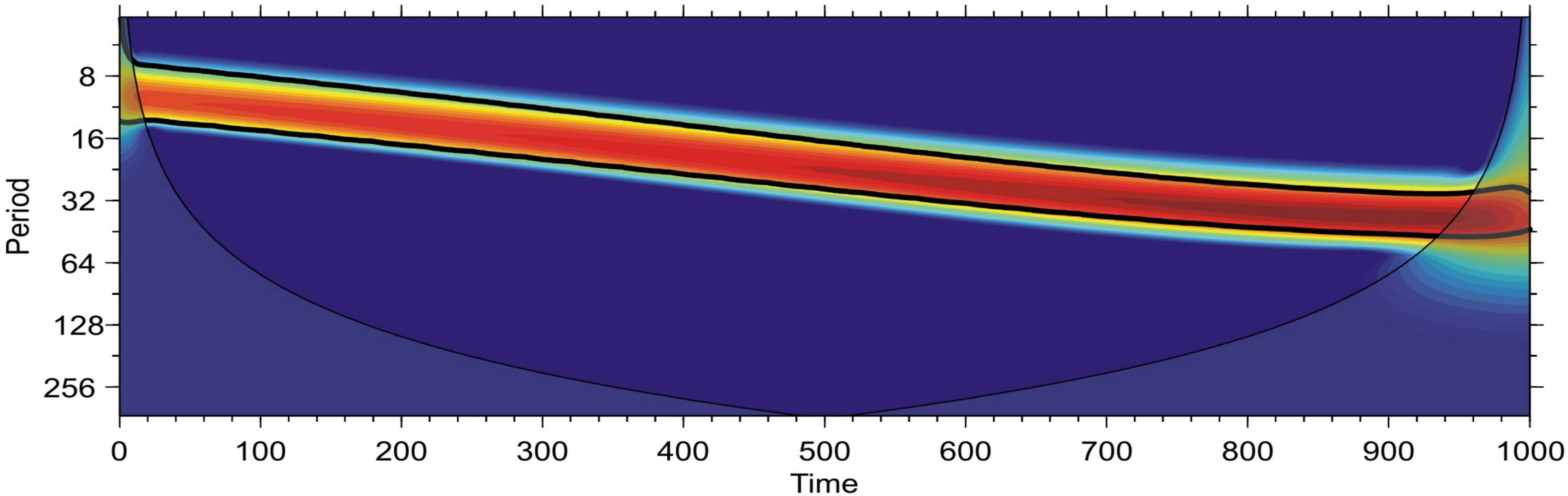
Signal
2
1
0
-1
-2
0
100
200
300
400
500
600
700
800
900
1000
Time
Period
8
16
32
64
128
0
100
200
300
400
500
600
700
800
900
1000
Time

>> load chirp there are two variables; *time* and *signal*

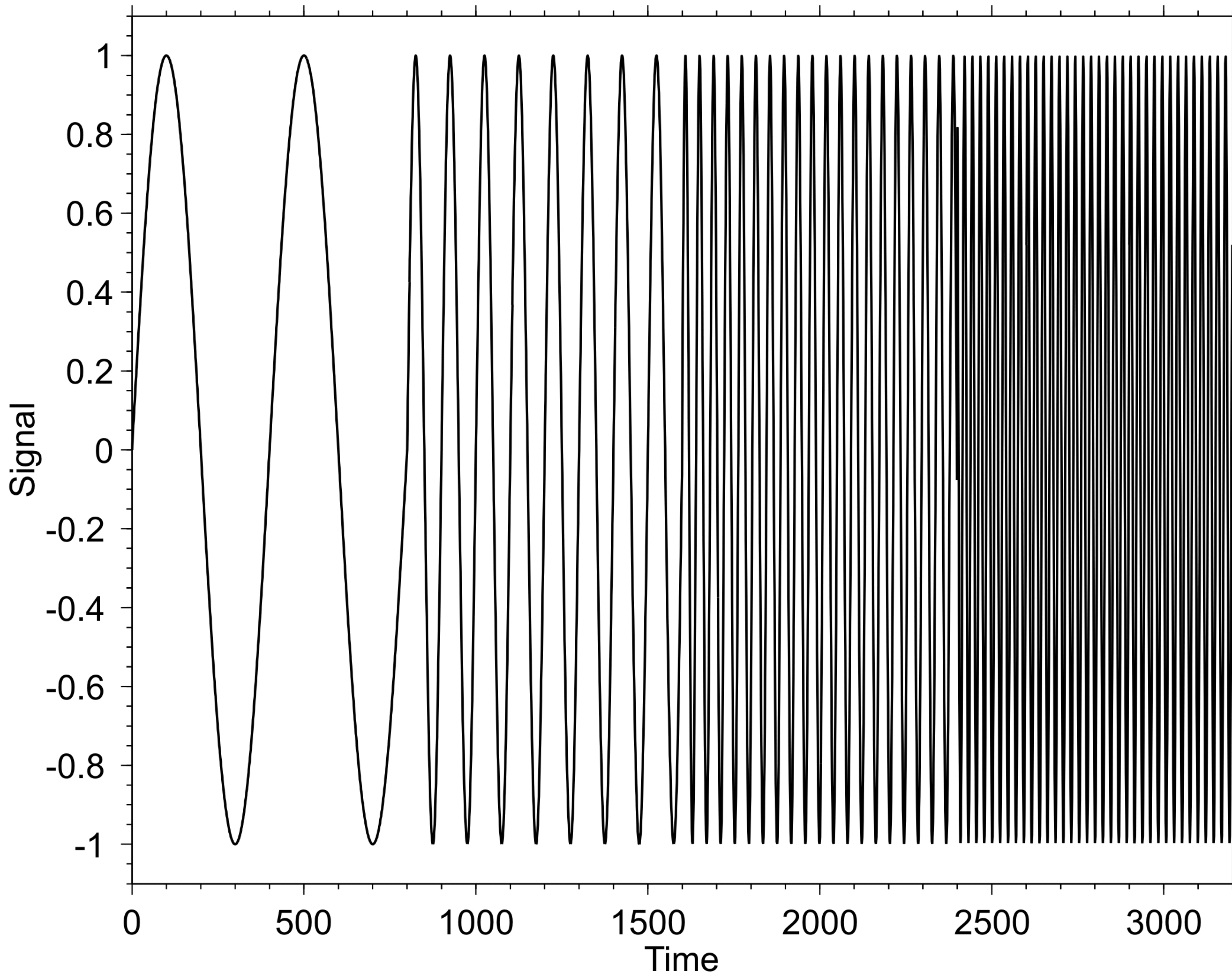
>> input=[time(:),signal(:)] Arrays as columns and placed into one matrix.

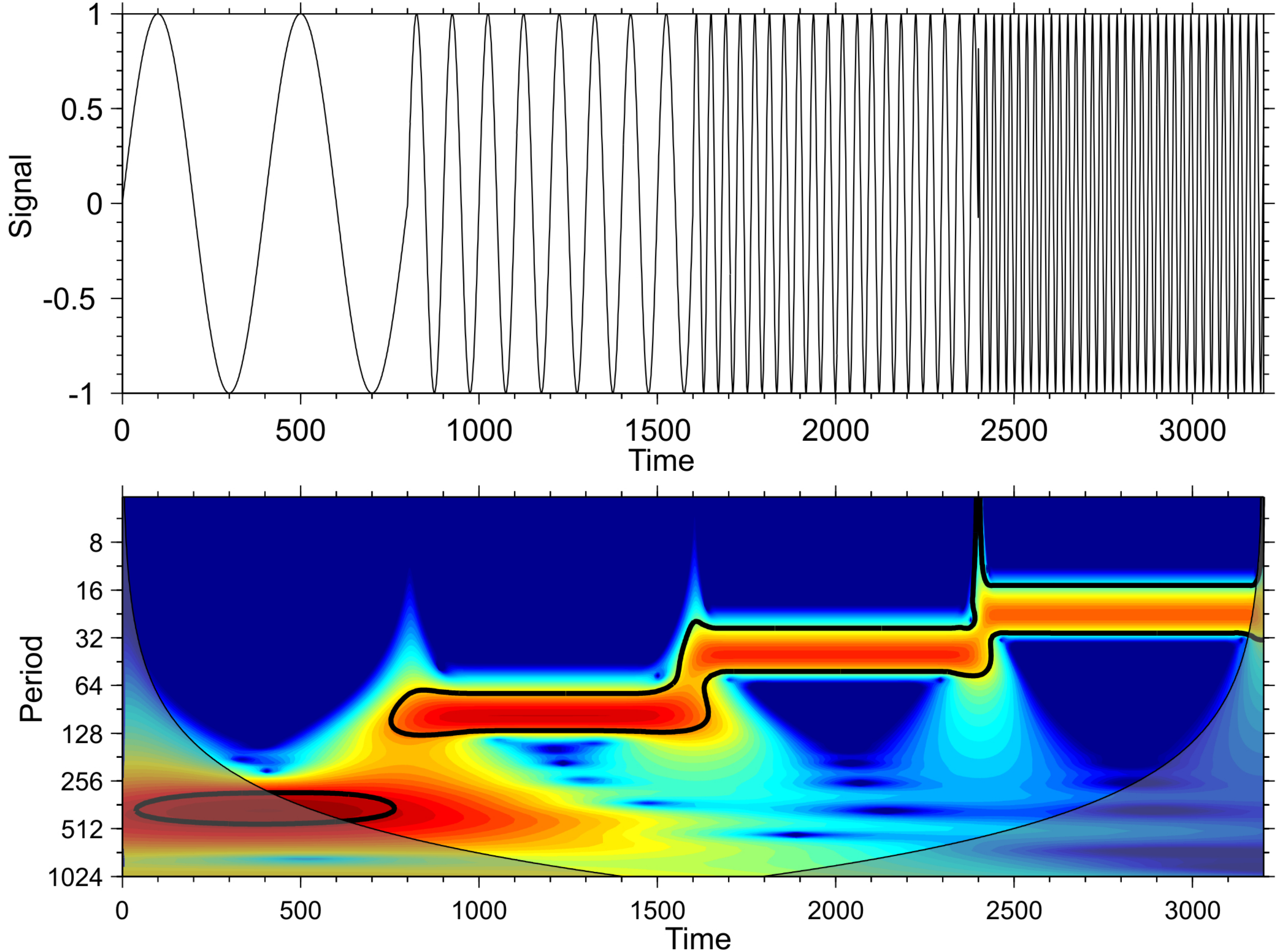
>> wt(input)





A nonstationary signal

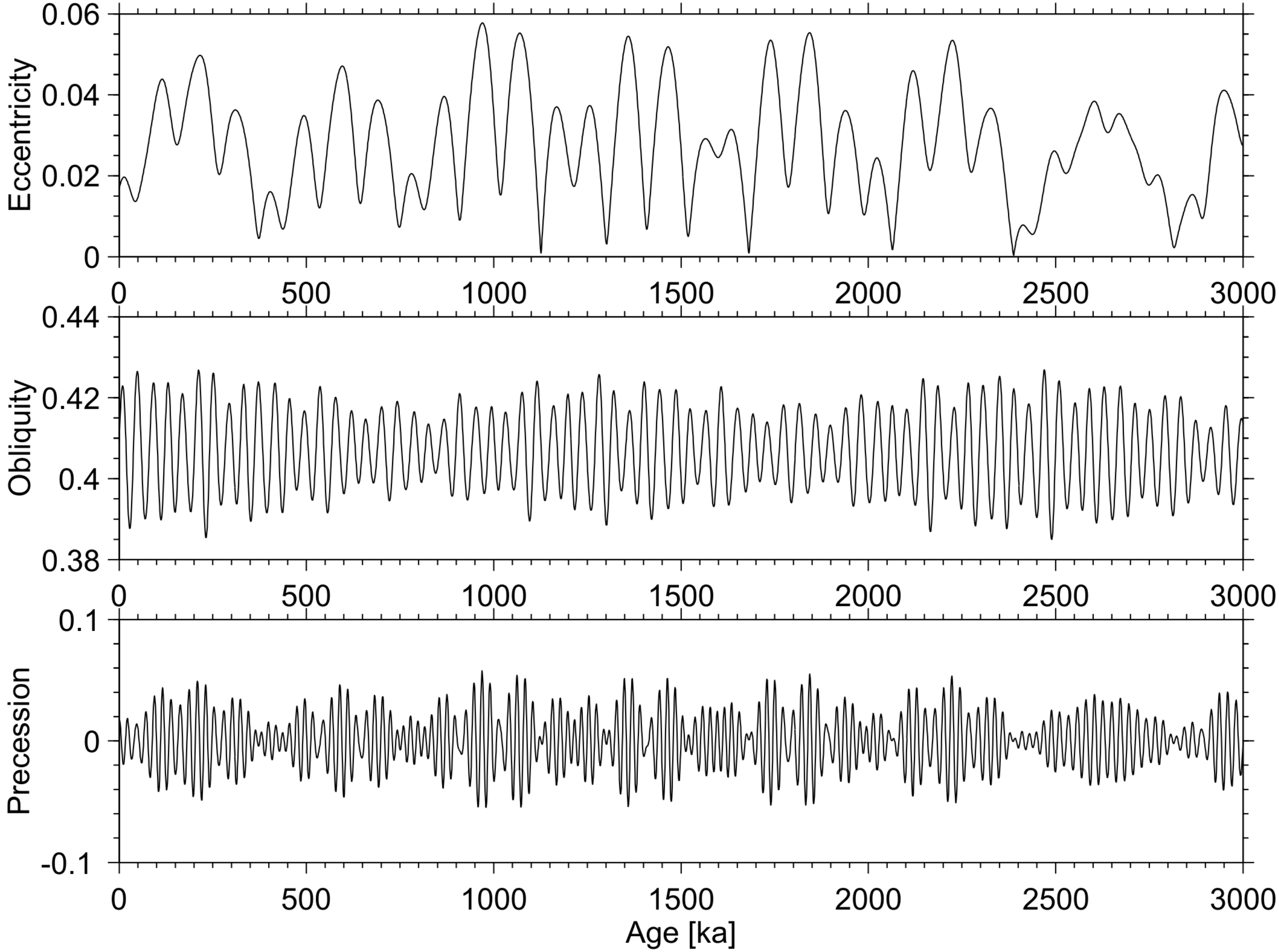


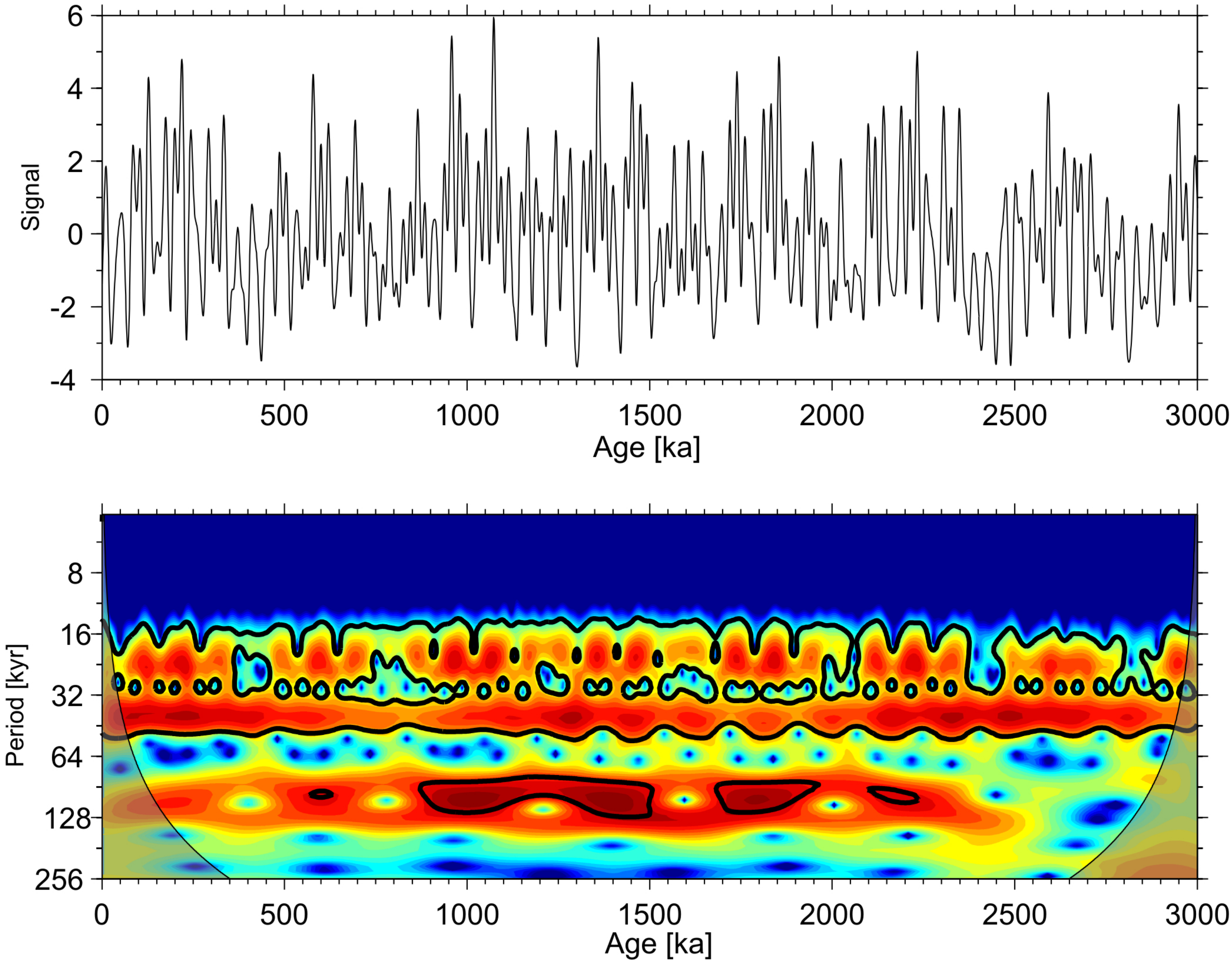


Signal
1
0.5
0
-0.5
-1
0
500
1000
1500
2000
2500
3000
Time
Period
8
16
32
64
128
256
512
1024
0
500
1000
1500
2000
2500
3000
Time

Theoretical calculation of orbital parameters since 3 Ma.

The combination of these curves gives the ETP curves (eccentricity+tilt-precession)



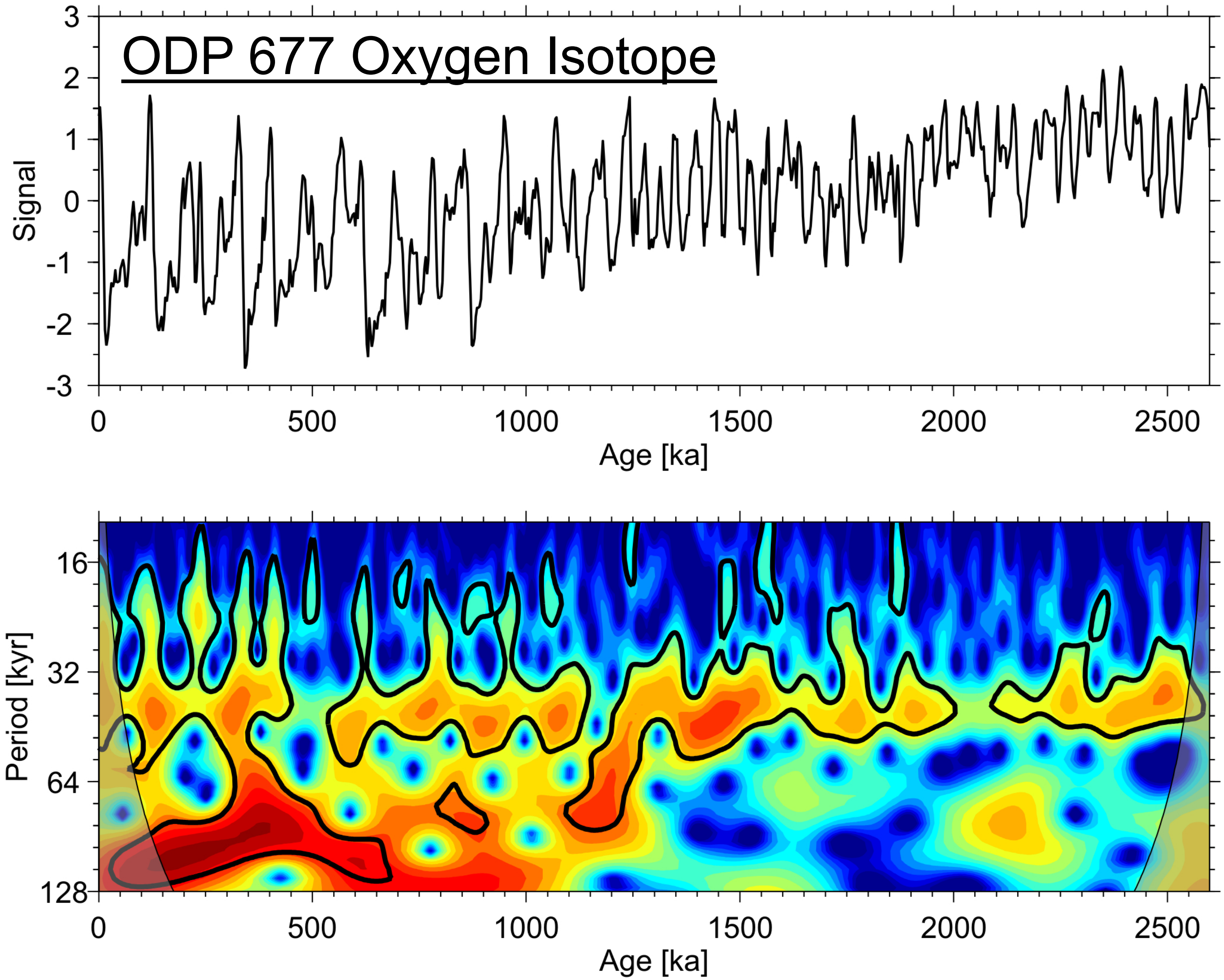


Signal
6
4
2
0
-2
-4
0
500
1000
1500
2000
2500
3000
Age [ka]
Period [kyr]
8
16
32
64
128
256
0
500
1000
1500
2000
2500
3000
Age [ka]

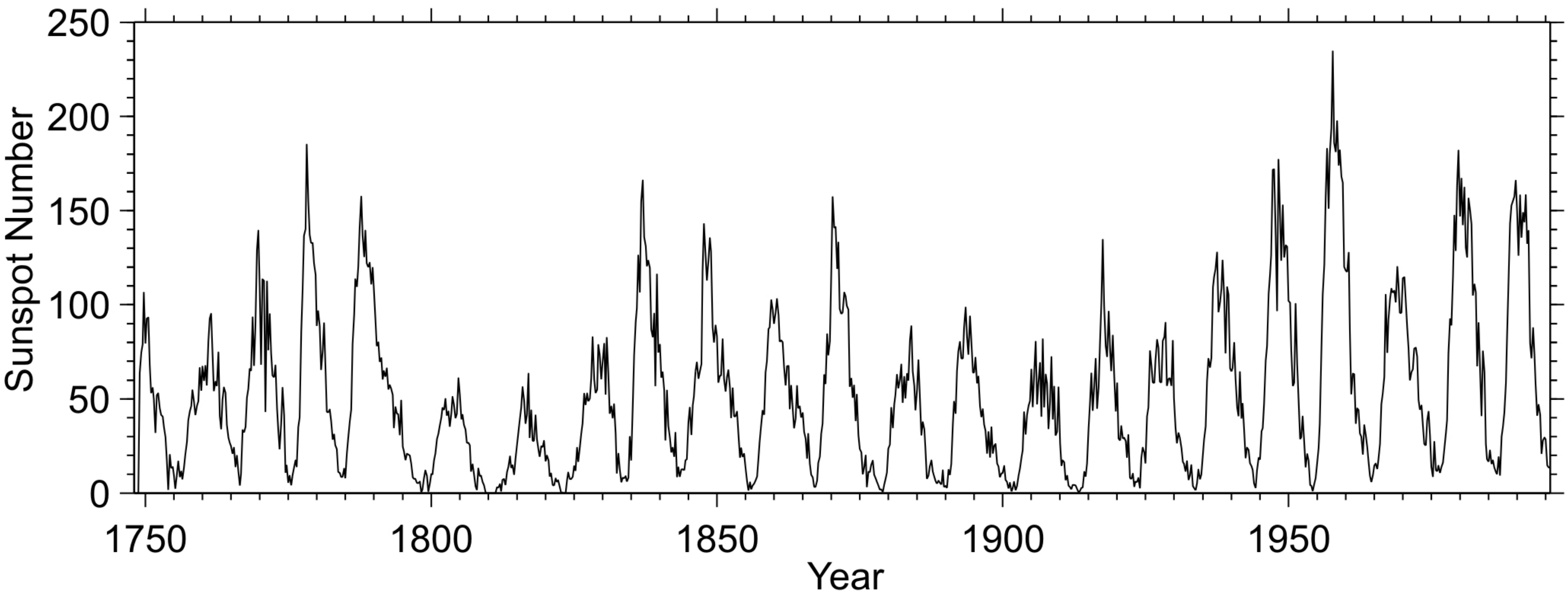
```
>> load odp677
>> input=[age(:),data(:)]
>> wt(input)
```

there are two variables; *time* and *signal*

Arrays as columns and placed into one matrix.

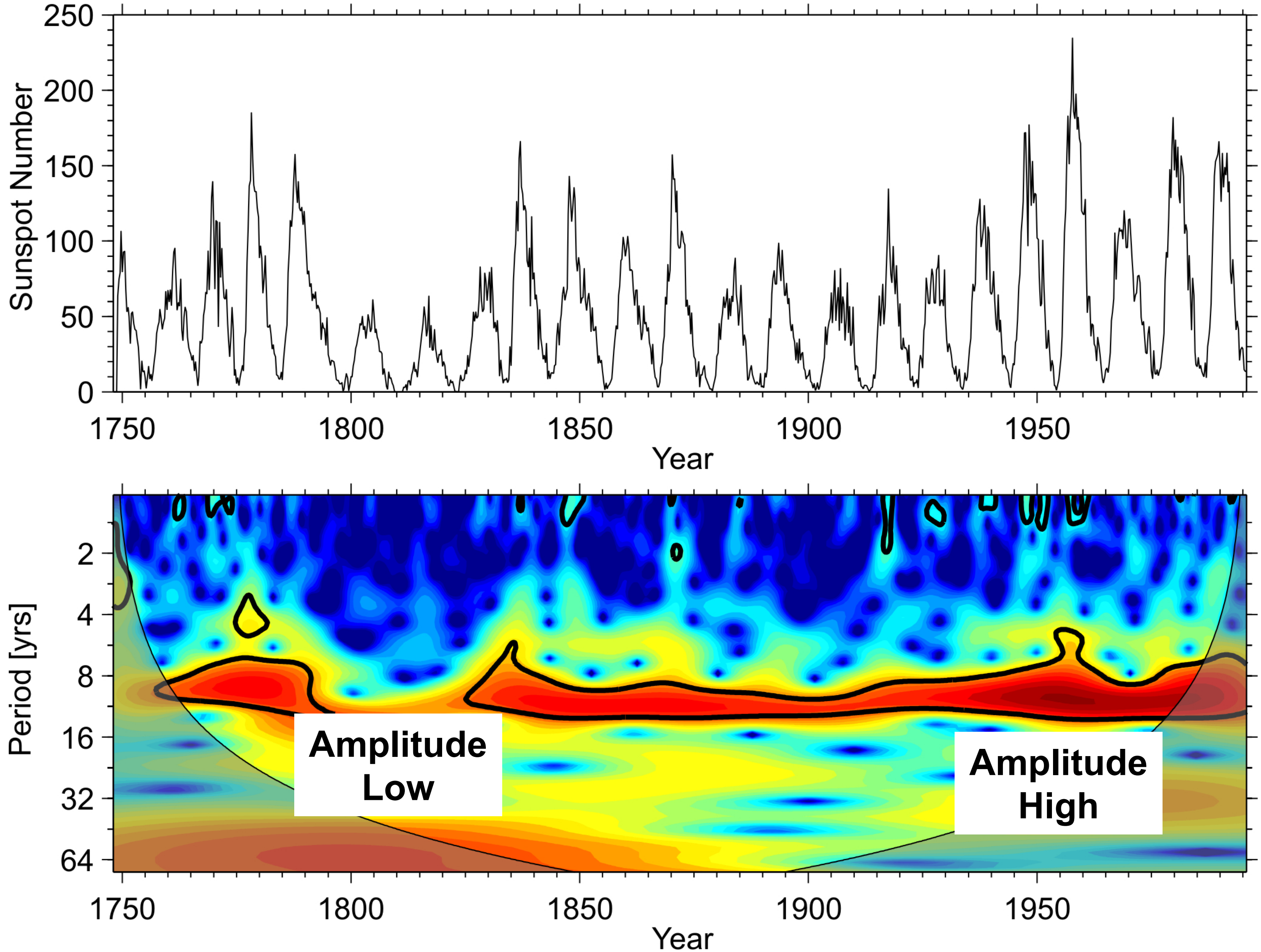


Wolf Sunspot Number



Perform a wavelet analysis on the sunspot number data (stored in the file: sunspots).
Make an interpretation of the wavelet transform in terms of both signal frequency and amplitude.

Wolf Sunspot Number



An example exam question (taken from last years exam paper)

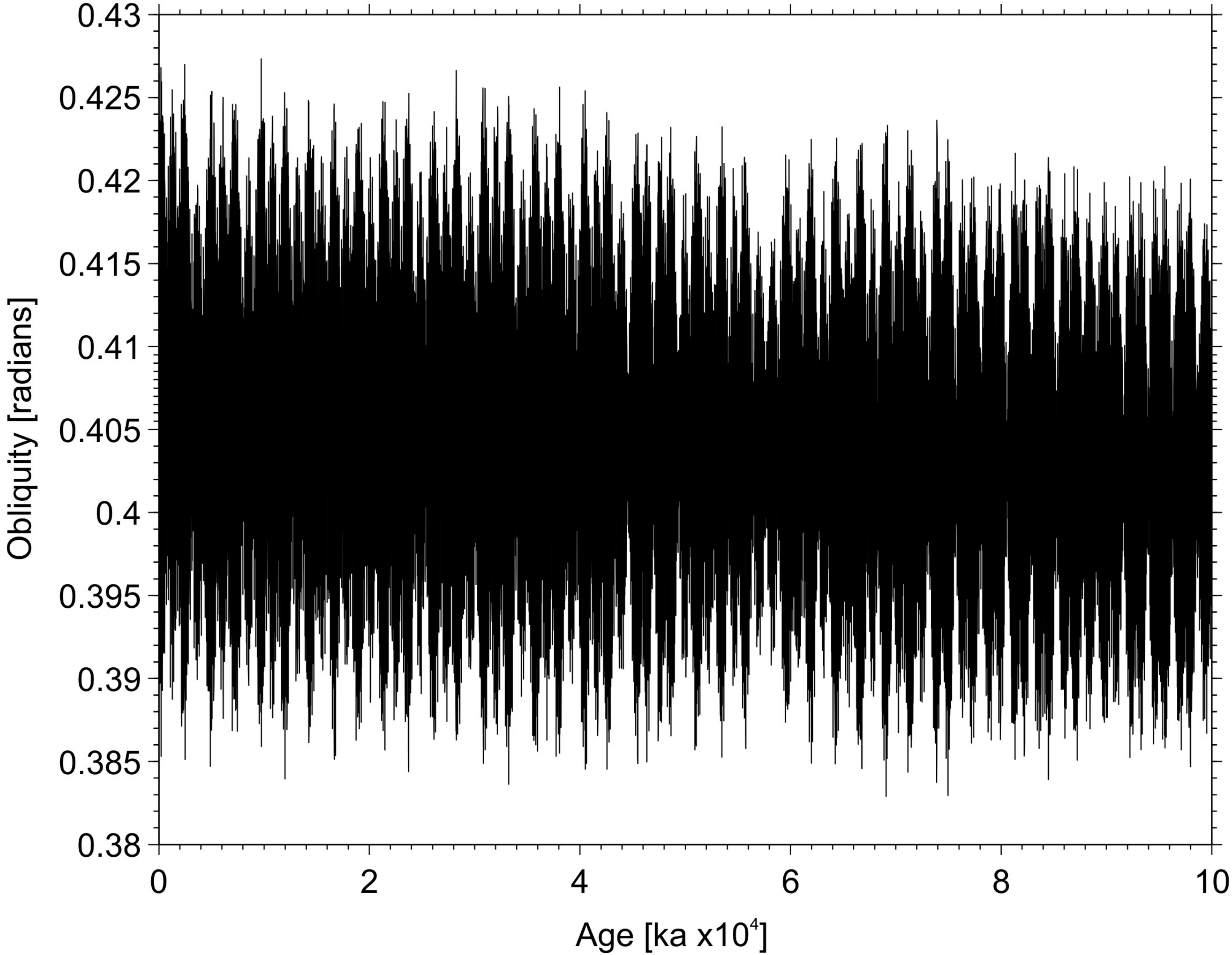
Currently the period of Earth's obliquity cycle is $\sim$41 kyr, however this value has changed through geological time as the moon (very slowly) moves away from the Earth. In the MATLAB file *obliquity.mat* you will find calculated obliquity values (variable *obliq* with units of *radians*) for the past 100 Myr (variable *age* with units of *ka*).

WARNING: The data set is very large (over 50,000 data points), so you will need to think of efficient ways to handle the data. For example, if you try to calculate a wavelet transform for the whole data set you will have to wait a very long time to get the result.

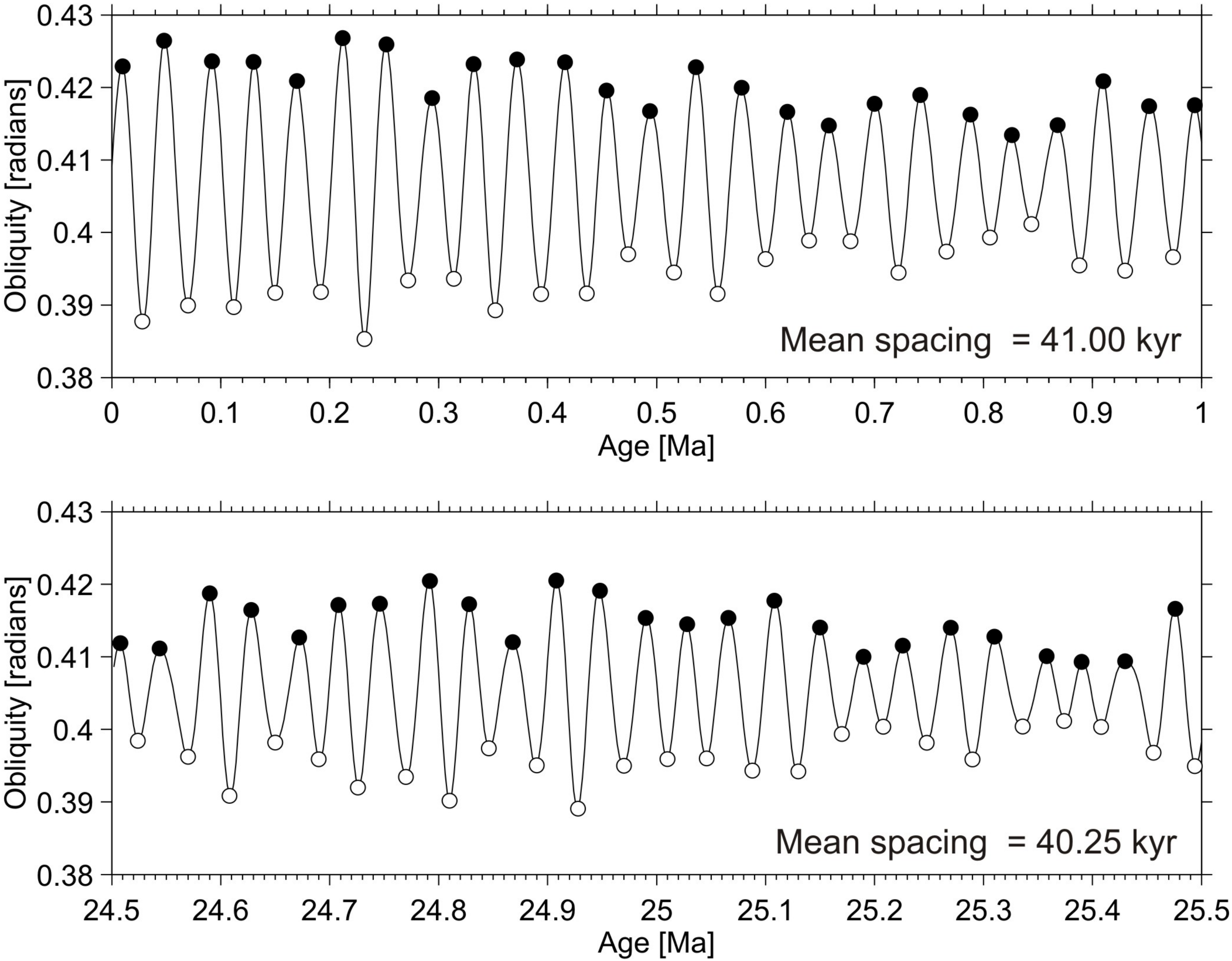
(a) Showing how you obtained your results, estimate the frequency and period of the obliquity cycle at ages of 0 Ma (present day), 25 Ma, 50 Ma and 100 Ma.

(b) Based on your results from the first part of the question what would you estimate as the obliquity period at an age of 500 Ma?

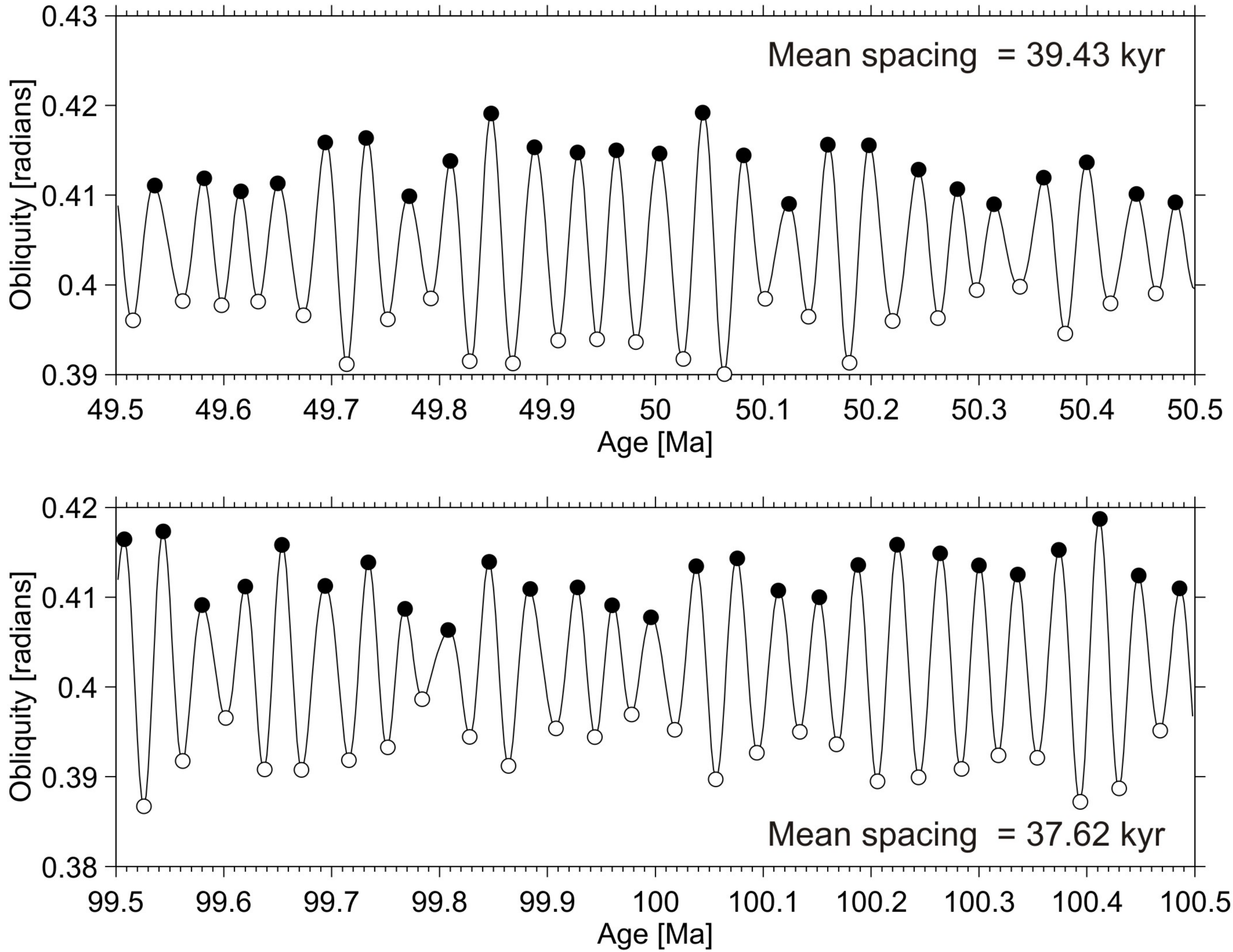
How would you attempt this question?



0.43
0.425
0.42
0.415
0.41
0.405
0.4
0.395
0.39
0.385
0.38
Obliquity [radians]
0
2
4
6
8
10
Age [ka x10^4]



0.43
0.42
0.41
0.4
0.39
0.38
Obliquity [radians]
Mean spacing = 41.00 kyr
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Age [Ma]
0.43
0.42
0.41
0.4
0.39
0.38
Obliquity [radians]
Mean spacing = 40.25 kyr
24.5
24.6
24.7
24.8
24.9
25
25.1
25.2
25.3
25.4
25.5
Age [Ma]


Mean spacing = 39.43 kyr
Obliquity [radians]
0.43
0.42
0.41
0.4
0.39
49.5
49.6
49.7
49.8
49.9
50
50.1
50.2
50.3
50.4
50.5
Age [Ma]
Mean spacing = 37.62 kyr
Obliquity [radians]
0.42
0.41
0.4
0.39
0.38
99.5
99.6
99.7
99.8
99.9
100
100.1
100.2
100.3
100.4
100.5
Age [Ma]

Period [kyr] = -0.0340*Age[Ma] + 41.0606
Period at 500 Ma = ~24.1 kyr