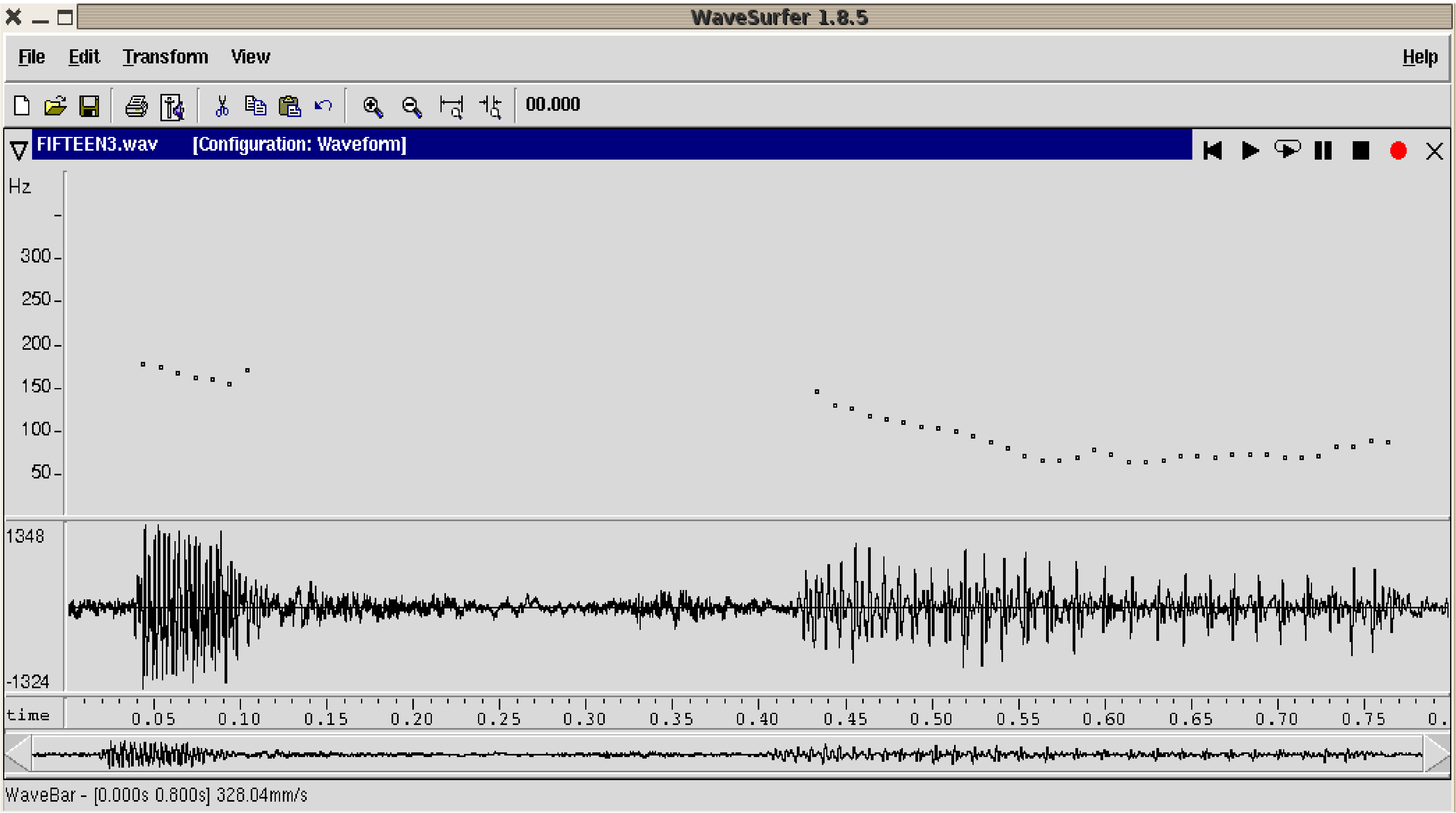
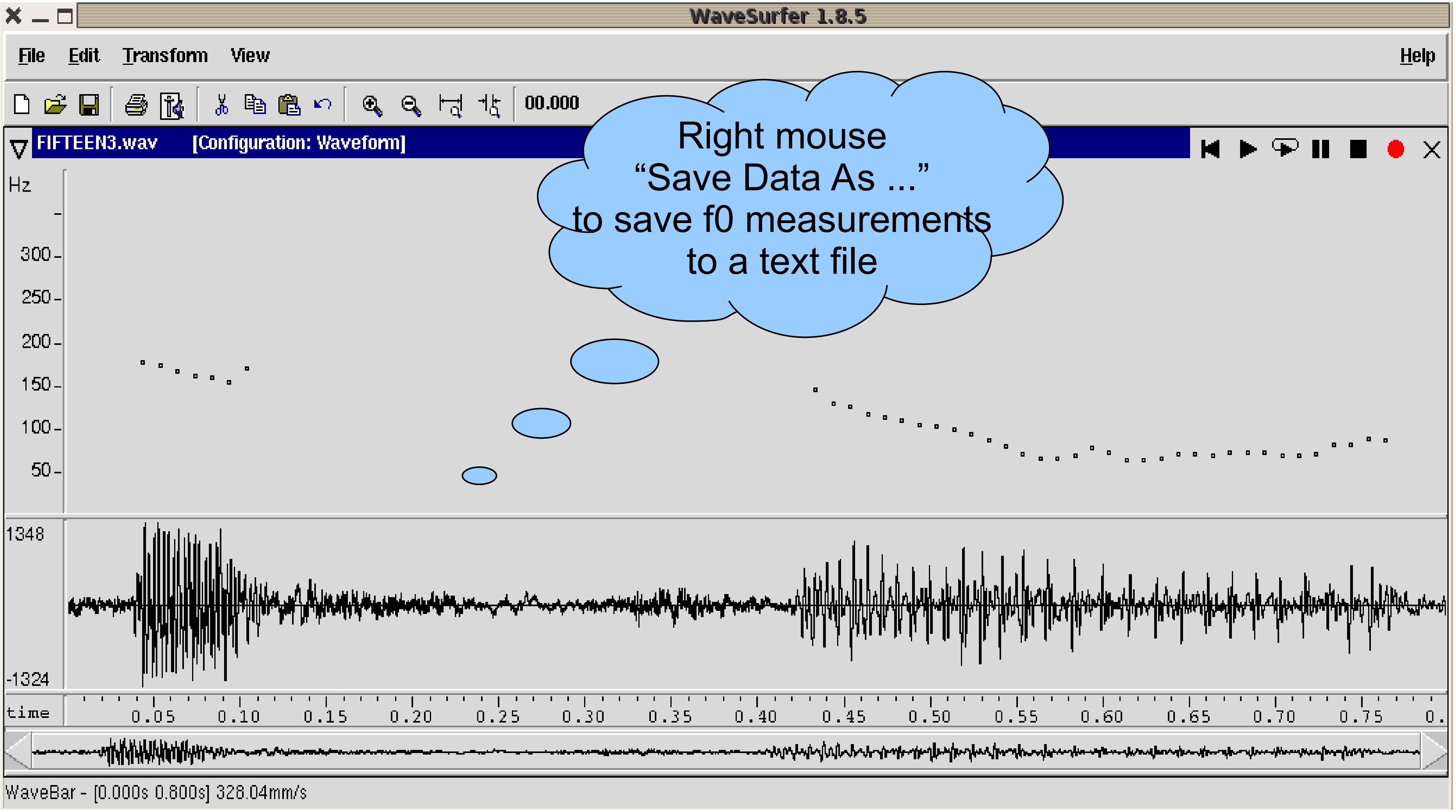
Intonation of FIFTEEN

- Using wavesurfer, ESPS get_f0 to obtain f_0 time-series



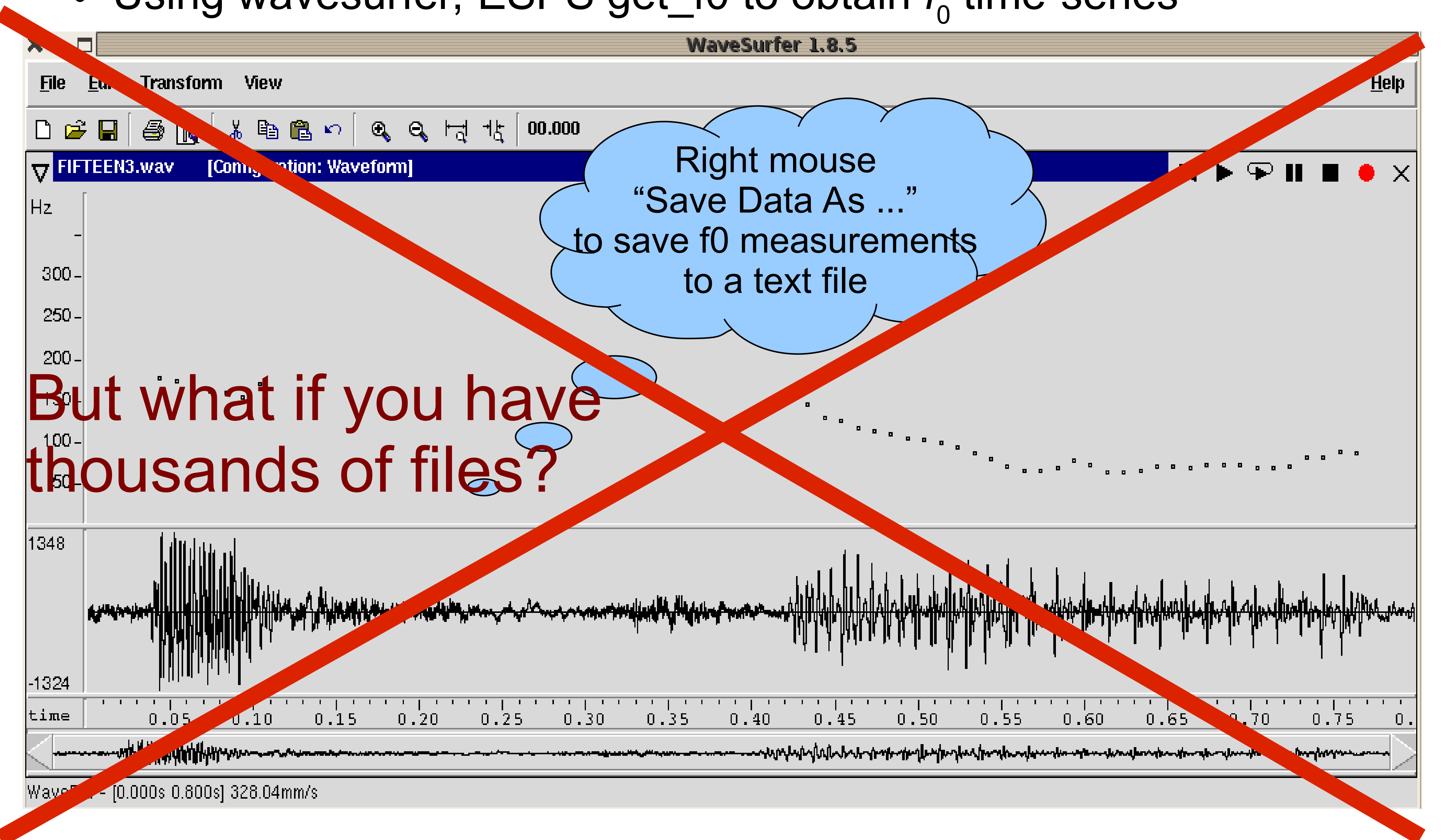
Intonation of FIFTEEN

- Using wavesurfer, ESPS get_f0 to obtain f_0 time-series



Intonation of FIFTEEN

- Using wavesurfer, ESPS get_f0 to obtain f_0 time-series



Intonation of FIFTEEN

- wavesurfer uses the ESPS get_f0 command to obtain f_0 time-series
- syntax: get_f0 [options] *input_file output_file*

ESPS is a package of UNIX-like commands and programming libraries for speech signal processing.

You can download a recent .deb package for ESPS from http://www.phon.ox.ac.uk/releases

David Talkin's paper on get_f0 is here: http://www.ee.columbia.edu/~dpwe/papers/Talkin95-rapt.pdf

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Intonation of FIFTEEN

- Using wavesurfer, ESPS `get_f0` to obtain f_0 time-series
- syntax: `get_f0` [options] *input_file output_file*

```
for i in *.wav
> do get_f0 $i $i.f0
> pplain $i.f0 >$i.f0.csv
> done
```

On one line, that's:

```
for i in *.wav; do get_f0 $i $i.f0; pplain $i.f0 >$i.f0.csv; done
```

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- These .csv files are simple ASCII text files like this: ------------→

- The first column is f_0, the second is voicing; ignore the other two

```
0 0 0 0.272821
0 0 34.4253 0.551759
0 0 44.9999 0.641592
0 0 242.326 0.515299
176.894 1 401.017 0.553706
174.434 1 399.113 0.931412
167.352 1 378.998 0.951326
162.623 1 358.704 0.927735
160.734 1 356.843 0.931884
154.345 1 250.132 0.617554
170.107 1 159.65 0.843205
0 0 82.2662 0.494668
0 0 92.7429 0.730789
0 0 110.42 0.433576
0 0 71.1711 0.53332
0 0 59.6541 0.419894
0 0 62.9074 0.538716
0 0 53.2908 0.319767
0 0 47.034 0.288603
0 0 38.5281 0.346631
0 0 47.2128 0.452121
0 0 50.4091 0.43822
0 0 44.2441 0.568226
--More--(28%)
```

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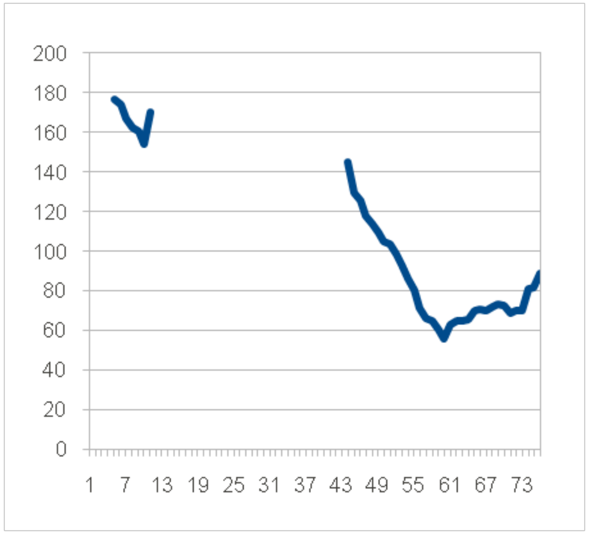
Intonation of FIFTEEN3

- You can open a .csv file in a spreadsheet programme, and plot the data (see, you don't have to have Praat or wavesurfer to draw speech parameters)



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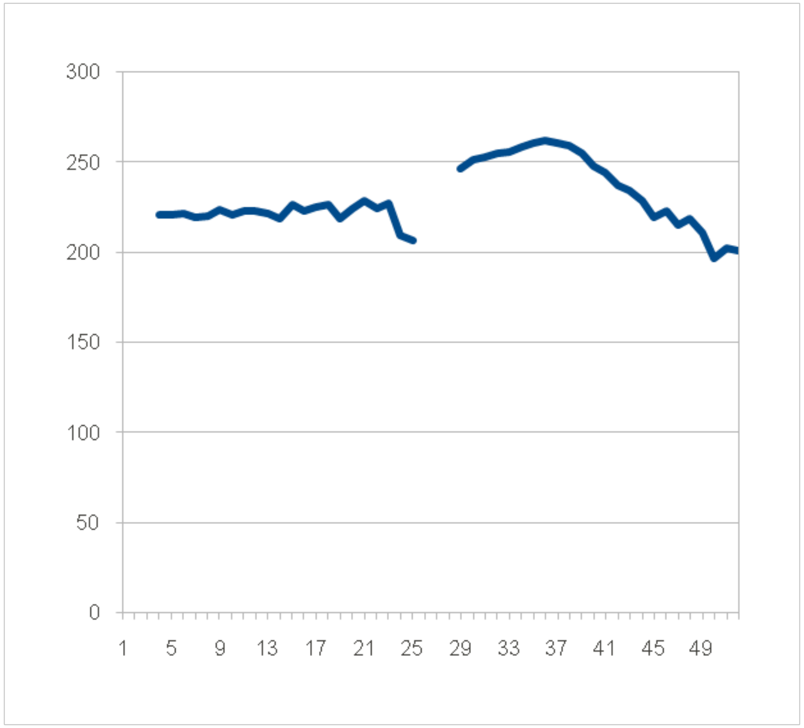
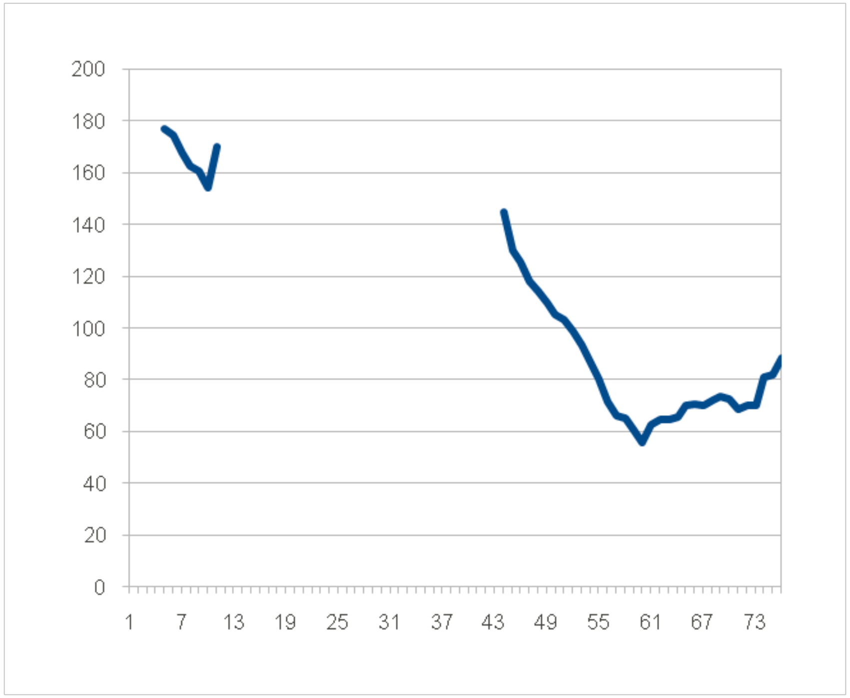
Intonation of FIFTEEN165

- You can open a .csv file in a spreadsheet programme, and plot the data (see, you don't have to have Praat or wavesurfer to draw speech parameters)



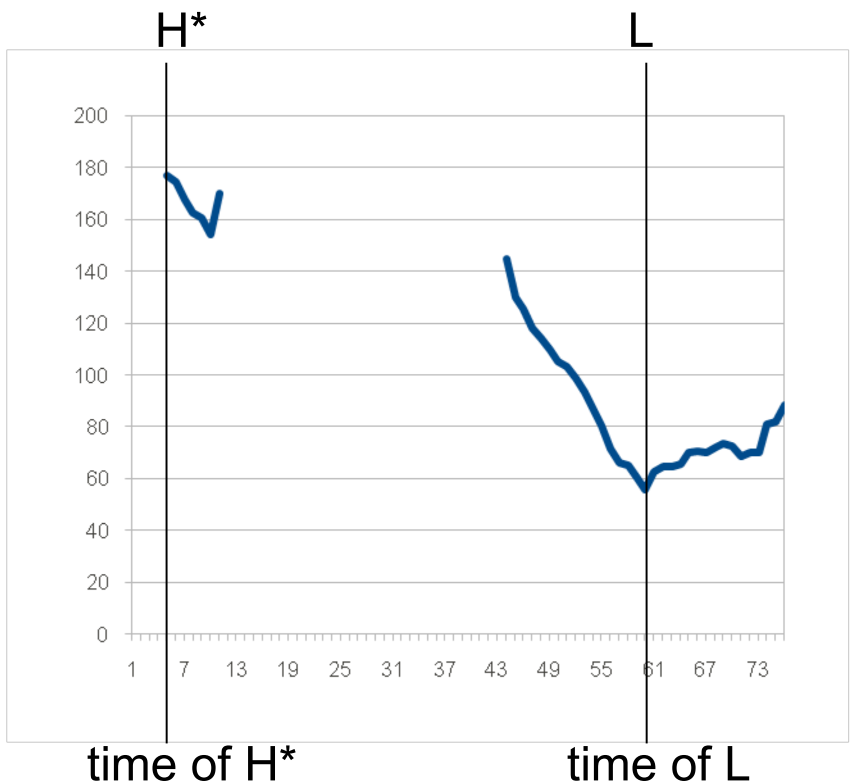
How you *could* analyse intonation ...

- Many approaches to phonetic analysis focus on particular points of interest in the time series, e.g.



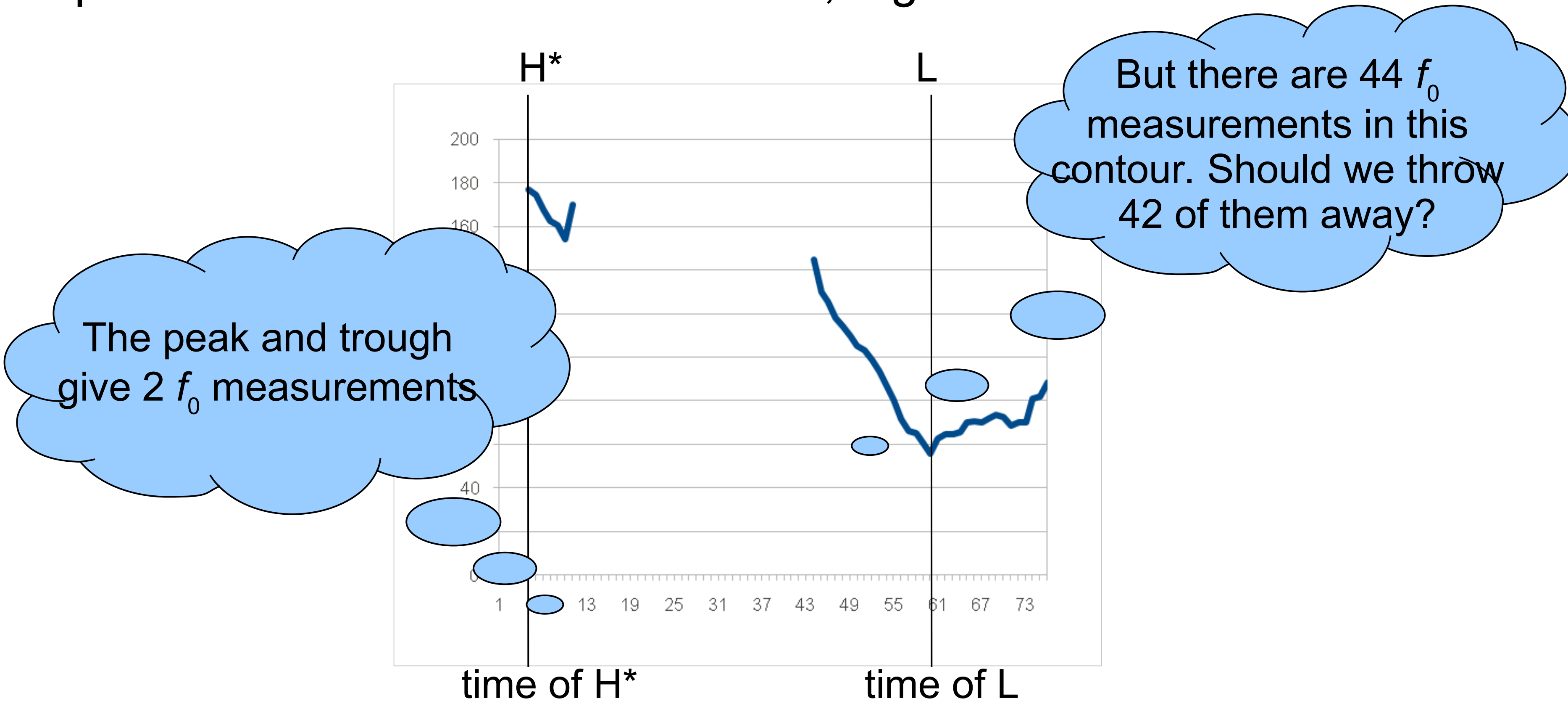
How you *could* analyse intonation ...

- Many approaches to phonetic analysis focus on particular points of interest in the time series, e.g.



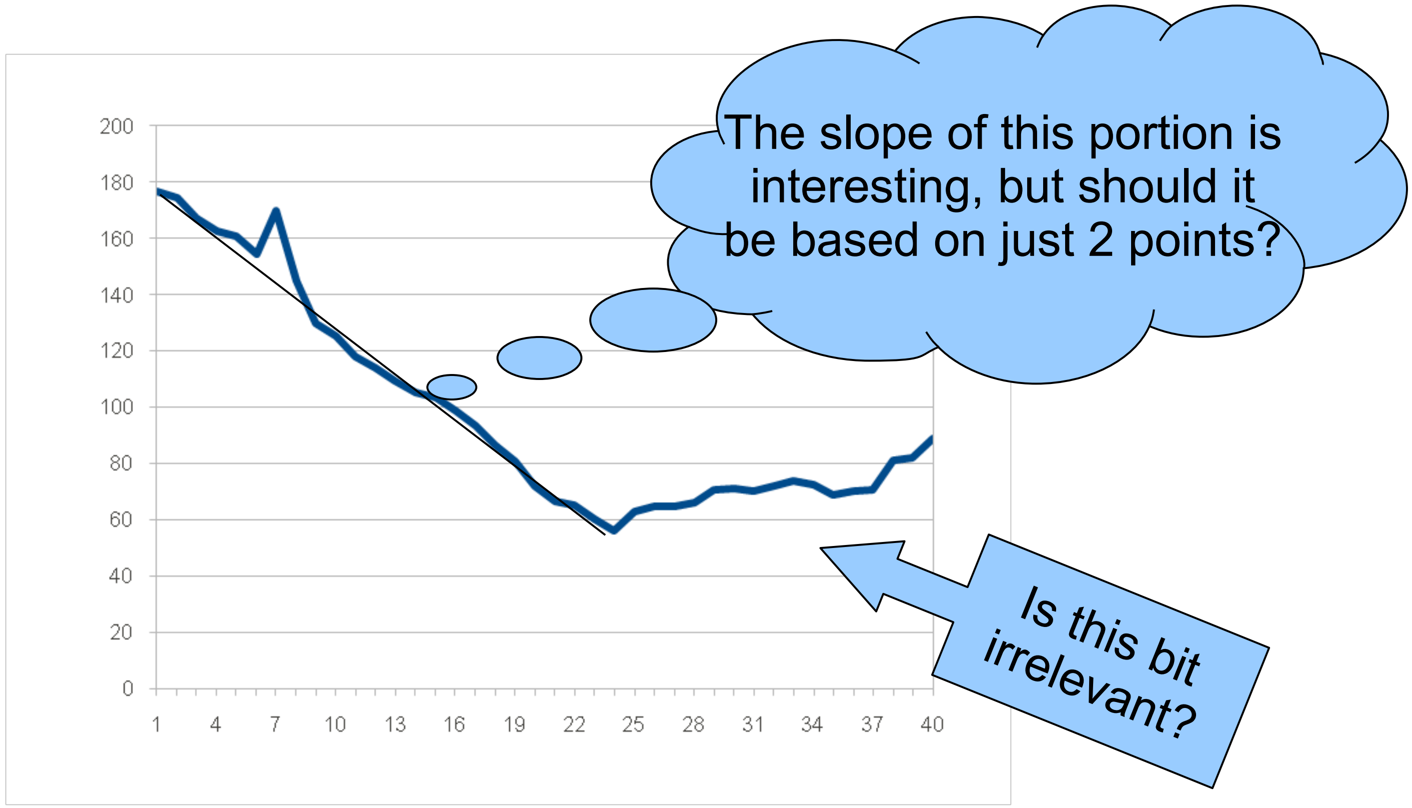
How you *could* analyse intonation ...

- Many approaches to phonetic analysis focus on particular points of interest in the time series, e.g.



Intonation of FIFTEEN3

- With the discontinuity (voiceless portion) excised:



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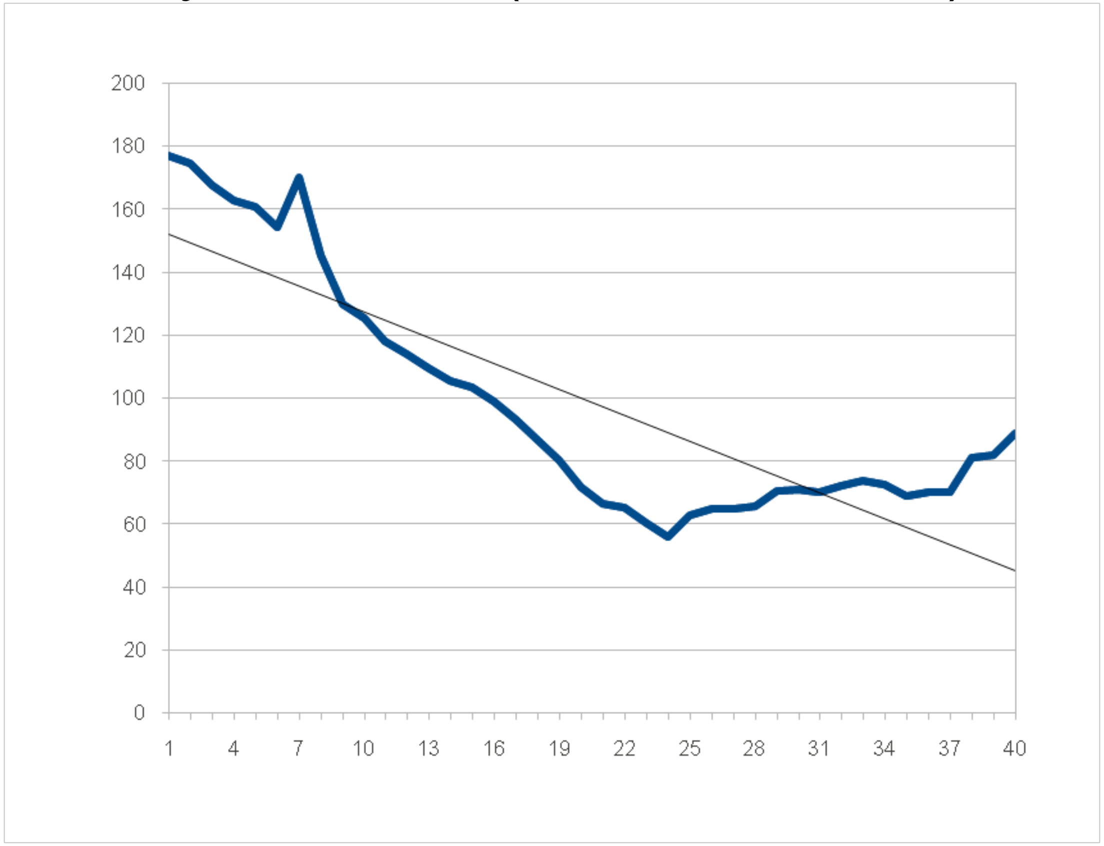
Intonation of FIFTEEN3

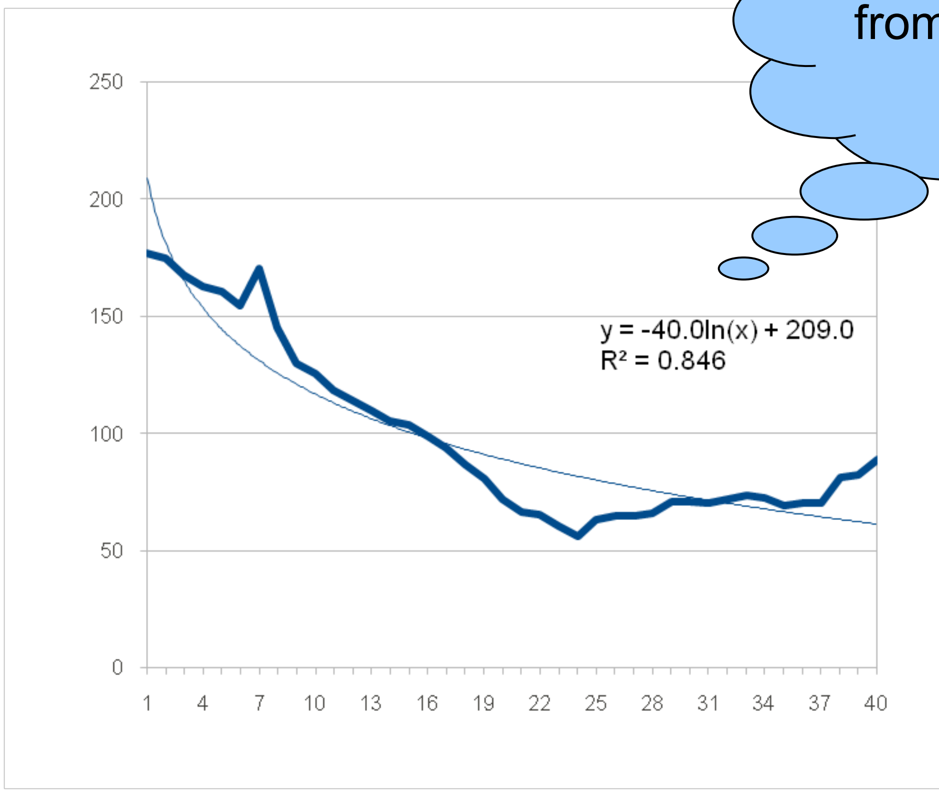
- Cf. a linear regression line; it may not look quite so good, but it's actually a better fit (to the *whole* line)



Intonation of FIFTEEN3

- A logarithmic regression curve fits better

Could we discover anything from the details of this equation?



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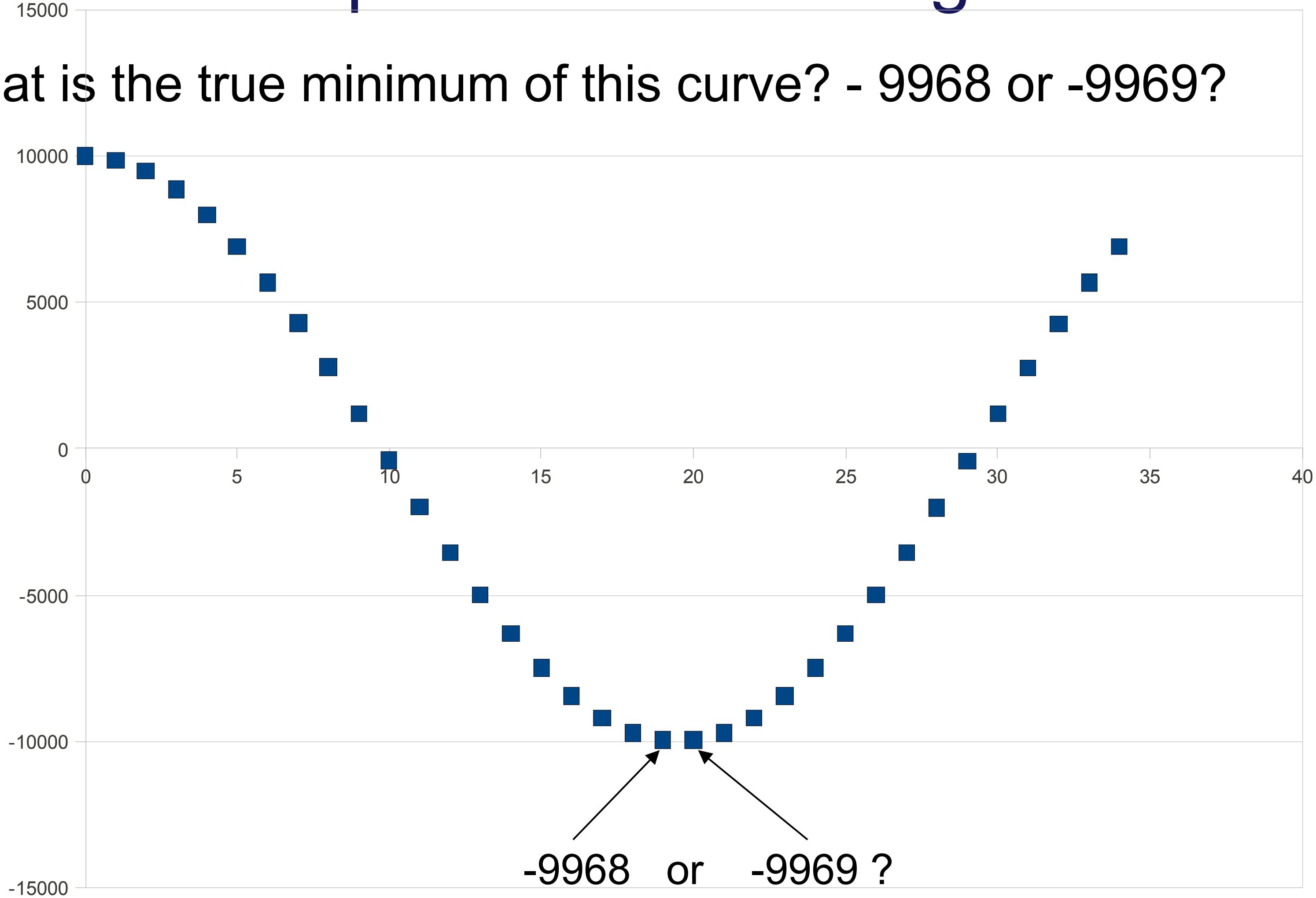
Why single-point measurements of sampled data are not great

- What is the true minimum of this curve? - 9968 or -9969?



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Why single-point measurements of sampled data are not great

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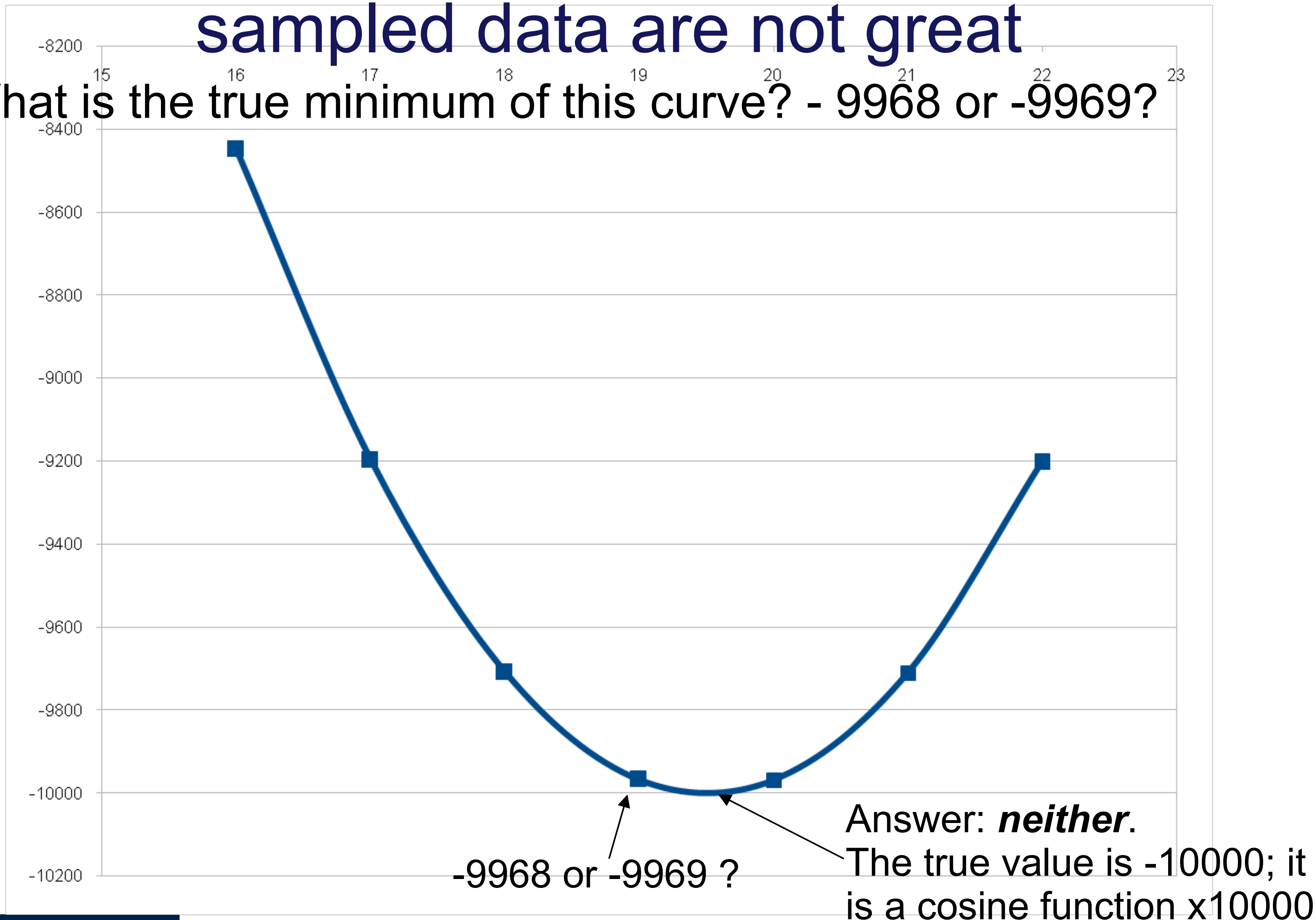

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Functional Data Analysis

- Modelling sampled data using (continuous) functions

- General approach:

  – Possibly smooth the data a bit, to iron out irrelevant wiggles
  – Possibly normalize the data
  – Registration: some sort of time alignment of the individual tokens (not always necessary)

Functional Data Analysis

Choose a general kind of (basis) function that looks like your data

- For periodic data: Fourier series
- For nonperiodic data: B-splines
  sometimes: Orthogonal Polynomials (Example 1)
- *others are possible*

- Probability density functions
- E.g., for normally-distributed data: Gaussians (Example 2)

Fit the function to the data
i.e. find the parameters of the function that minimizes the differences between the function and the data

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Orthogonal polynomials in Octave/Matlab

- Put numeric data into Matlab's vector notation:

```
f0 = load('FIFTEEN3.wav.f0.csv');
y = f0(:,1);
y = y(y>0);
```

```
y =
[176.894;
174.434;
167.352;
162.623;
160.734;
...
88.6733];
```

- Normalize it:
- (Better:

```
yn = y/mean(y)-1;
ym = yn/max(abs(yn));
```

- Normalize the time dimension to the interval [-1 1], and turn it into a column vector:

```
x = ((1:length(yn))-length(yn)/2)/(length(yn)/2);
x = x';
```

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Orthogonal polynomials in Octave/Matlab

- Fit the normalized data to a polynomial (e.g. a cubic)

$$y = a_1 x^3 + a_2 x^2 + a_3 x + a_4$$

```
[a,S] = polyfit(x,yn,3);
```

Output values: a = 0.19321 0.63340 -0.70280 -0.19866

- The fitted function is given by

```
fit = getfield(S,'yf');
```

and restored to the original units (e.g. Hz)

```
ysynth = mean(y)*(fit+1);
```

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Orthogonal polynomials in Octave/Matlab

- Fit the normalized data to a polynomial (e.g. a cubic)

$$y = a_1 x^3 + a_2 x^2 + a_3 x + a_4$$

average height

```
[a,S] = polyfit(x,yn,3);
```

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Orthogonal polynomials in Octave/Matlab

- Fit the normalized data to a polynomial (e.g. a cubic)

$$y = a_1 x^3 + a_2 x^2 + a_3 x + a_4$$

slope (steepness anddirection)

average height

Output values: a = 0.19321 0.63340 -0.70280 -0.19866

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Orthogonal polynomials in Octave/Matlab

- Fit the normalized data to a polynomial (e.g. a cubic)

$$y = a_1 x^3 + a_2 x^2 + a_3 x + a_4$$

$a_2 x^2$	$a_3 x$	a_4
breadth of curvature	slope (steepness anddirection)	average height

Output values: a = 0.19321 0.63340 -0.70280 -0.19866

Orthogonal polynomials in Octave/Matlab

- Fit the normalized data to a polynomial (e.g. a cubic)

$$y = a_1 x^3 + a_2 x^2 + a_3 x + a_4$$

$a_1 x^3$	$a_2 x^2$	$a_3 x$	a_4
amount of ~ -shaped wiggle	breadth of curvature	slope (steepness and direction)	average height

Output values: a = 0.19321 0.63340 -0.70280 -0.19866

•The fitted function is given by

```
fit = getfield(S,'yf');
```

and can be restored to the original units (e.g. Hz) by

```
ysynth = mean(y)*(fit+1);
```

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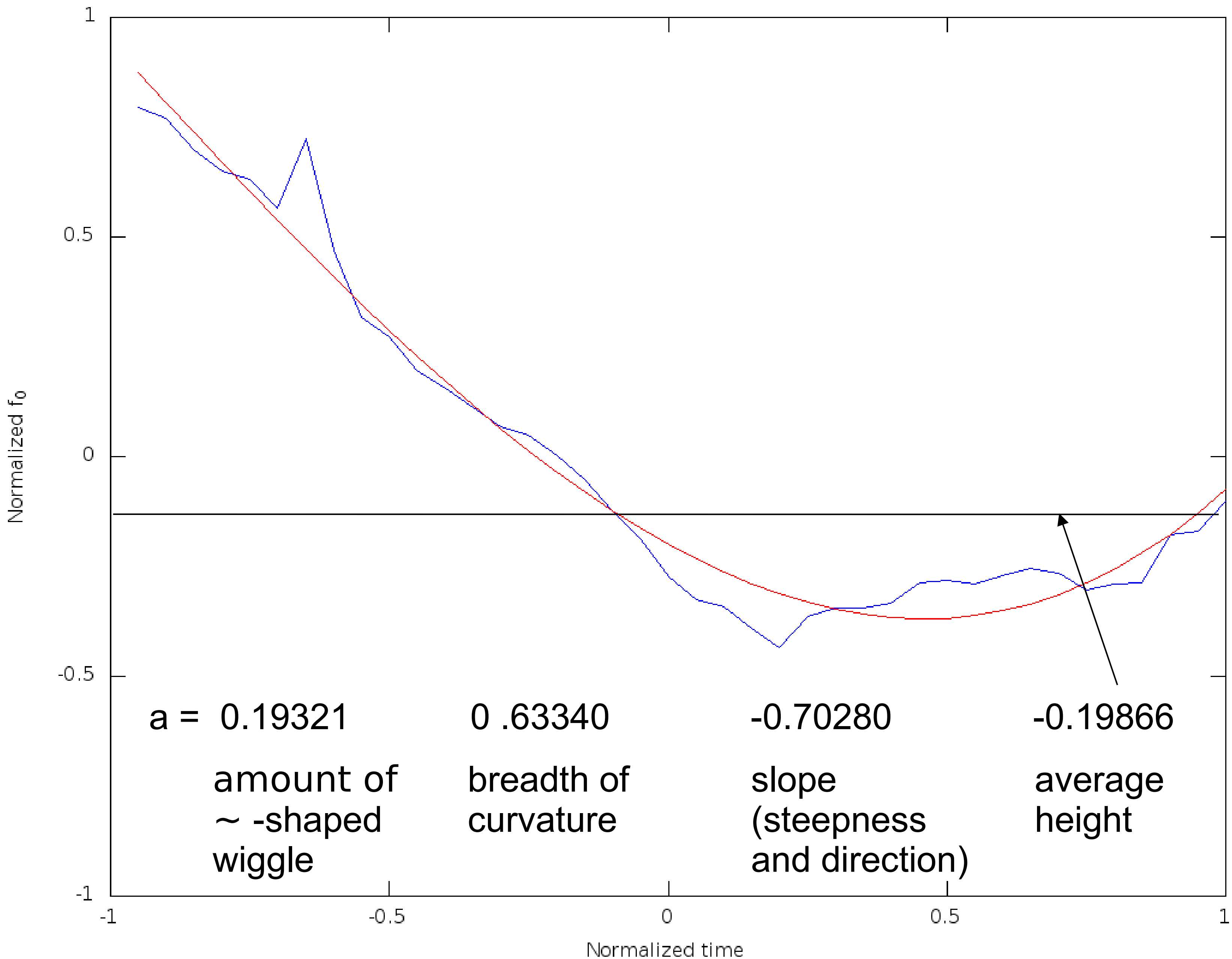
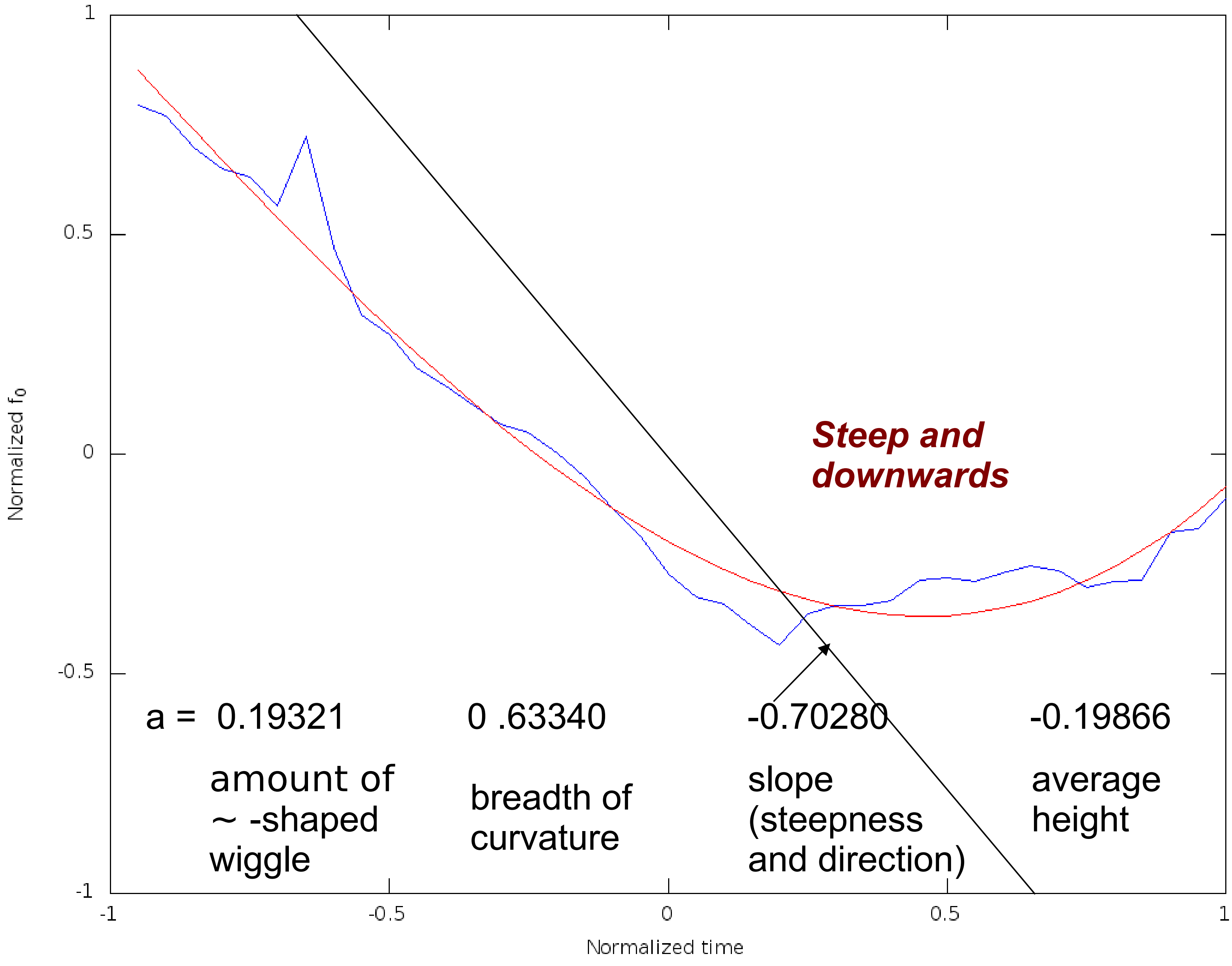
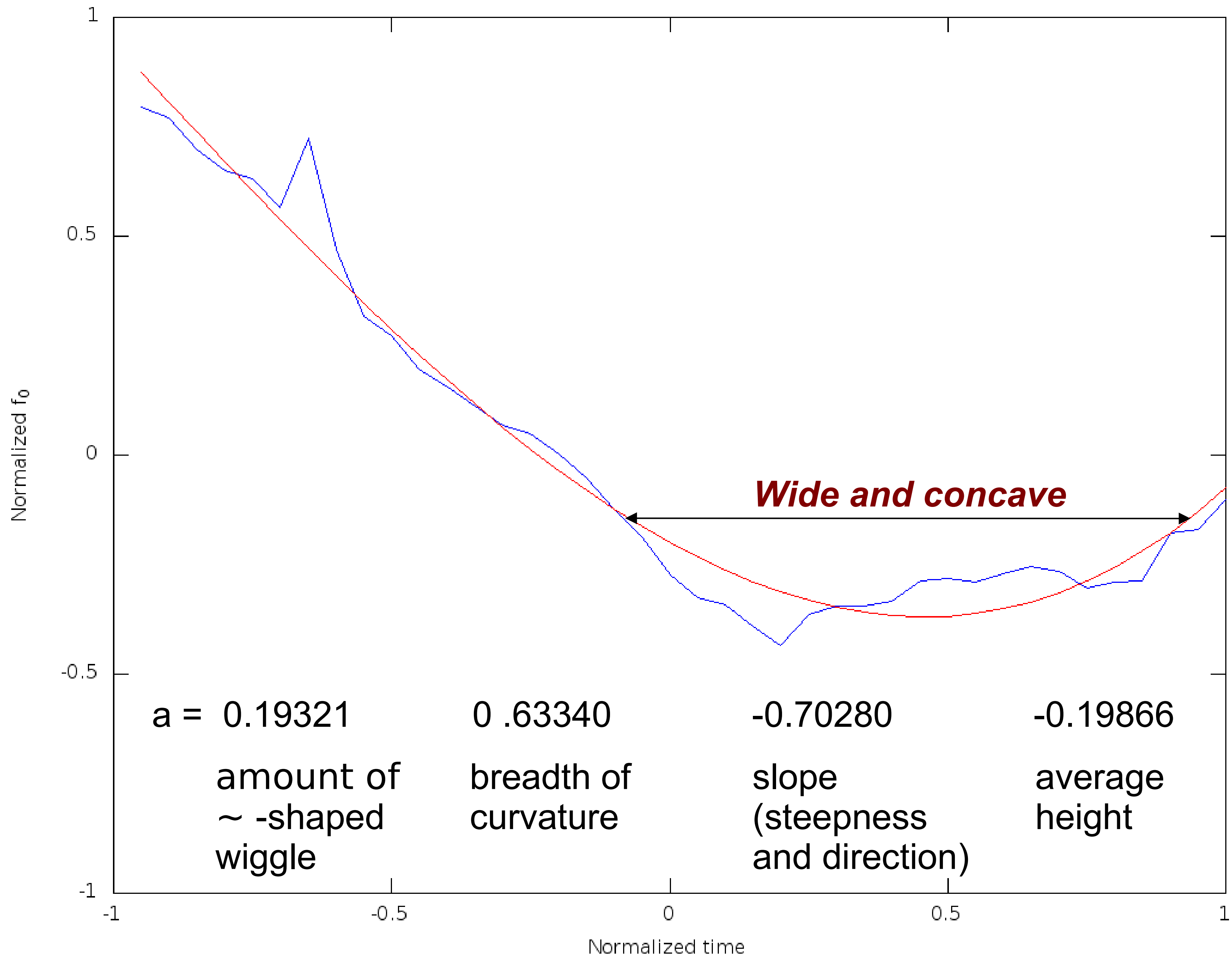
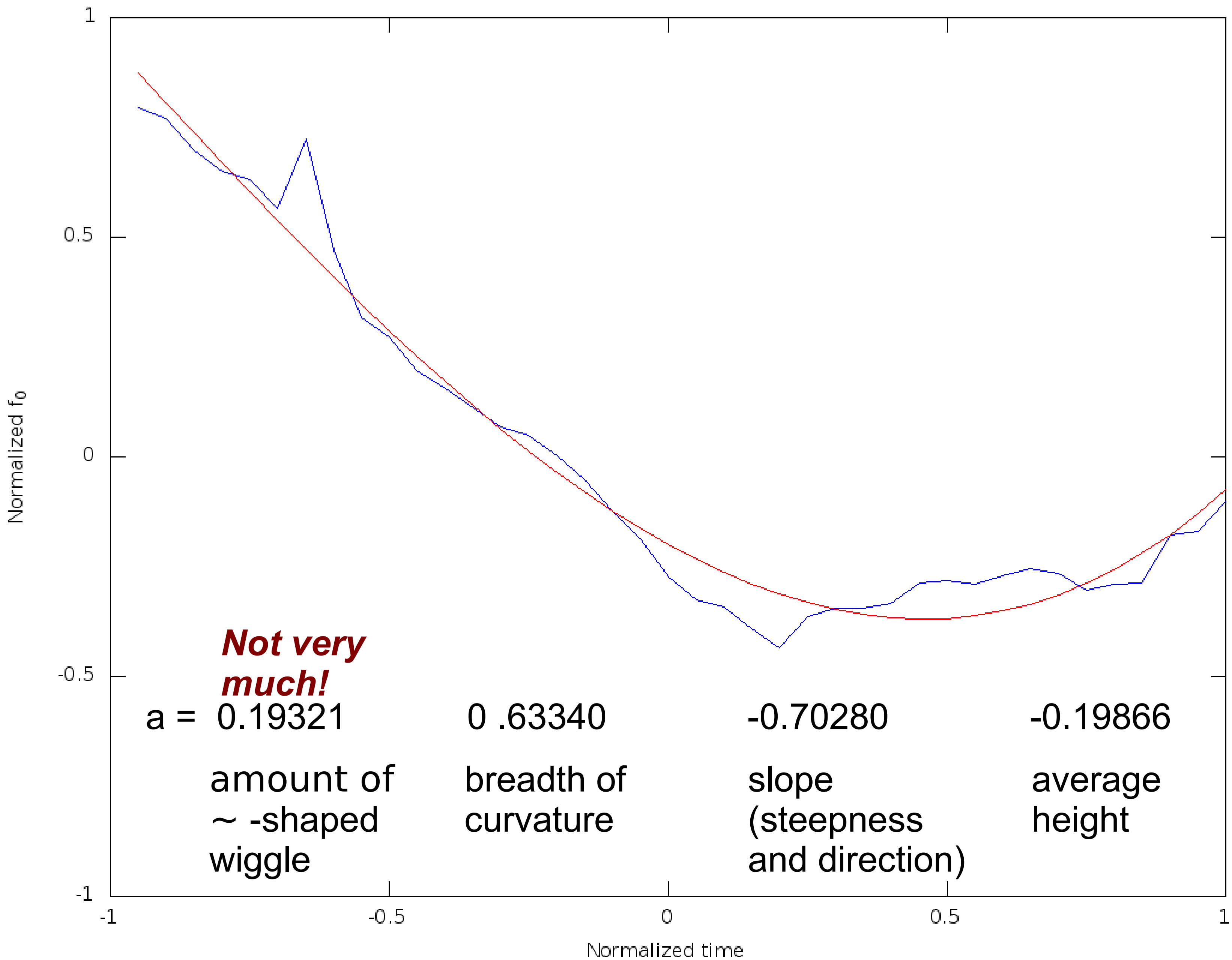
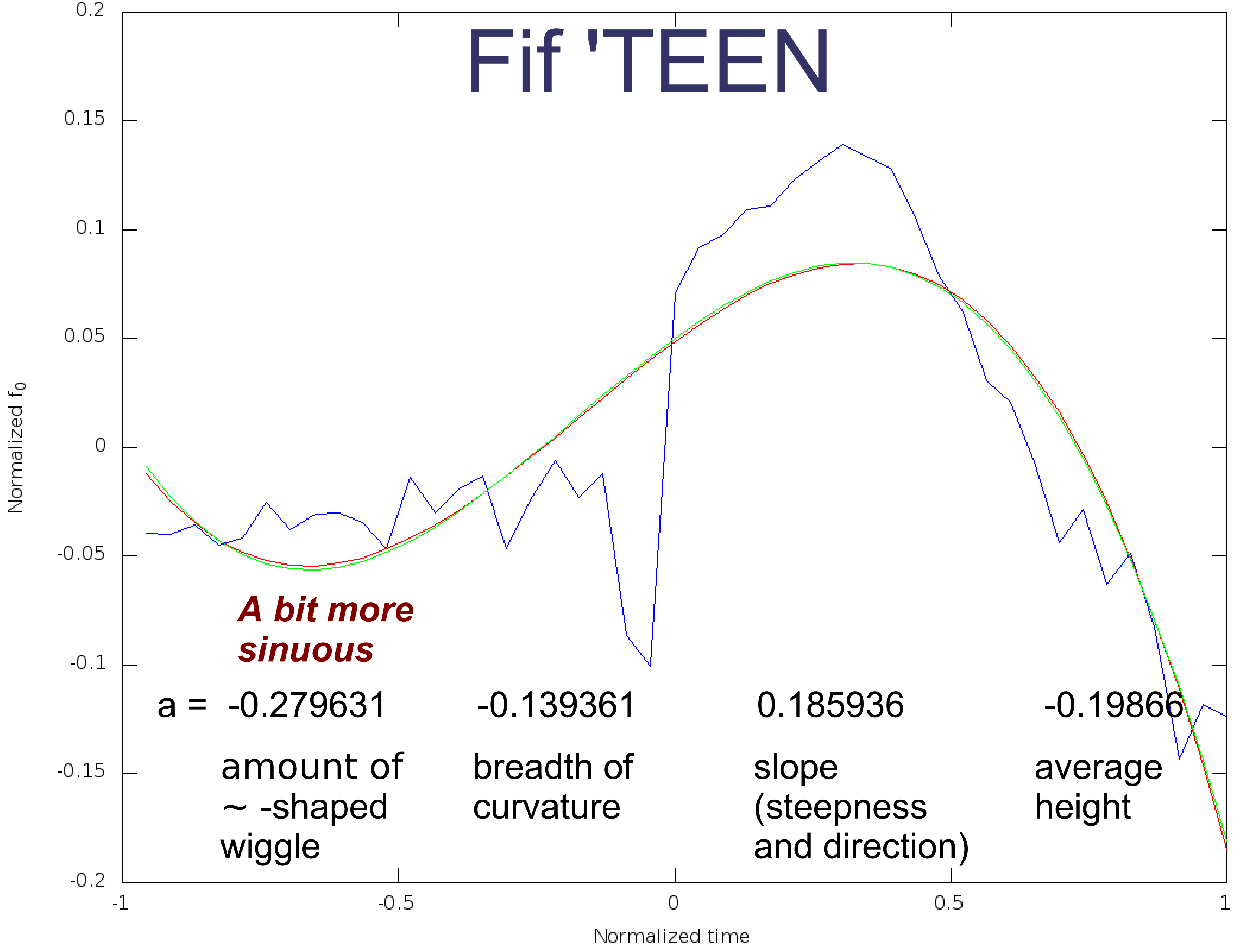

1
0.5
0
-0.5
-1
Normalized f0
-1
-0.5
0
0.5
1
Normalized time
a = 0.19321
0 .63340
-0.70280
-0.19866
amount of ~ -shaped wiggle
breadth of curvature
slope (steepness and direction)
average height

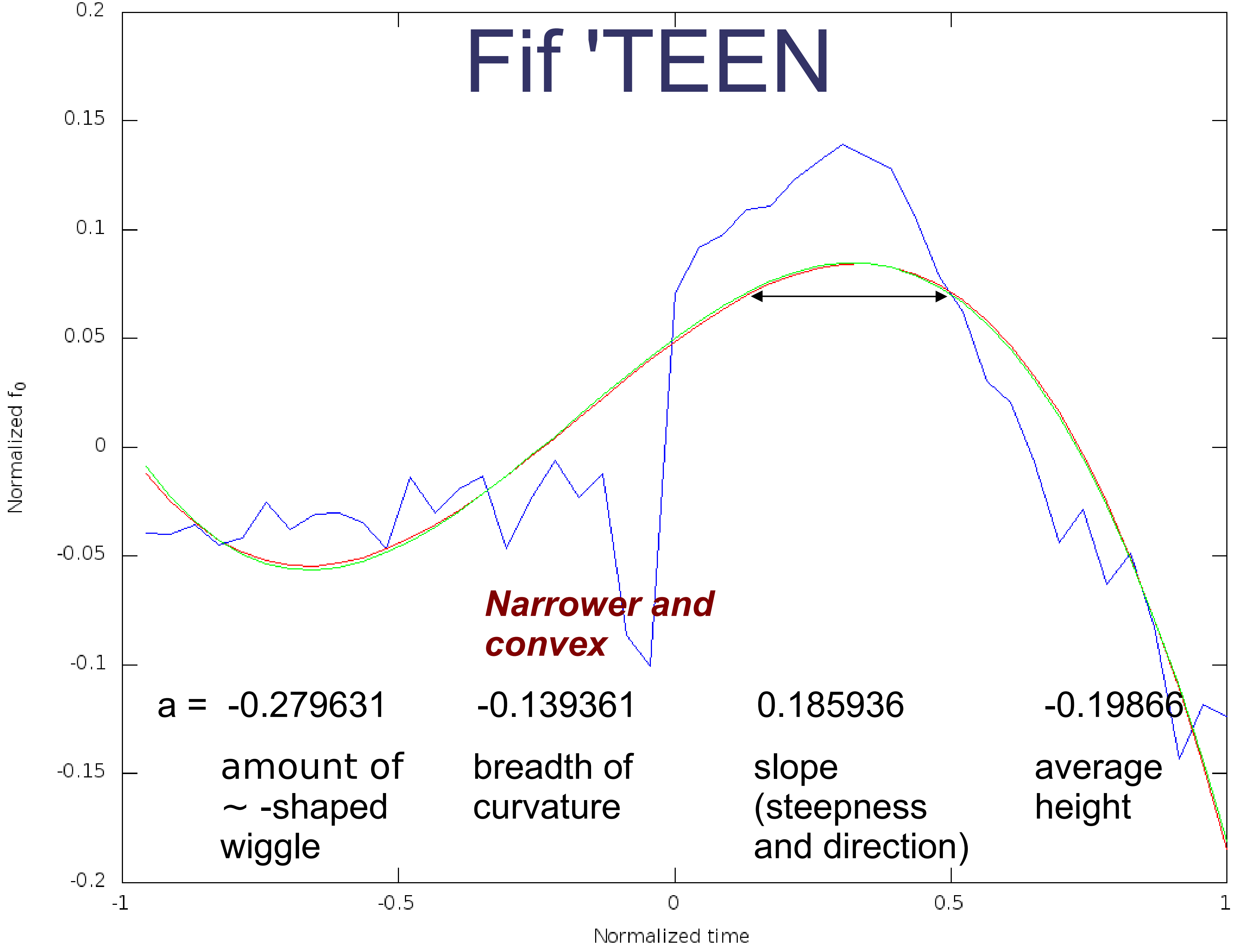


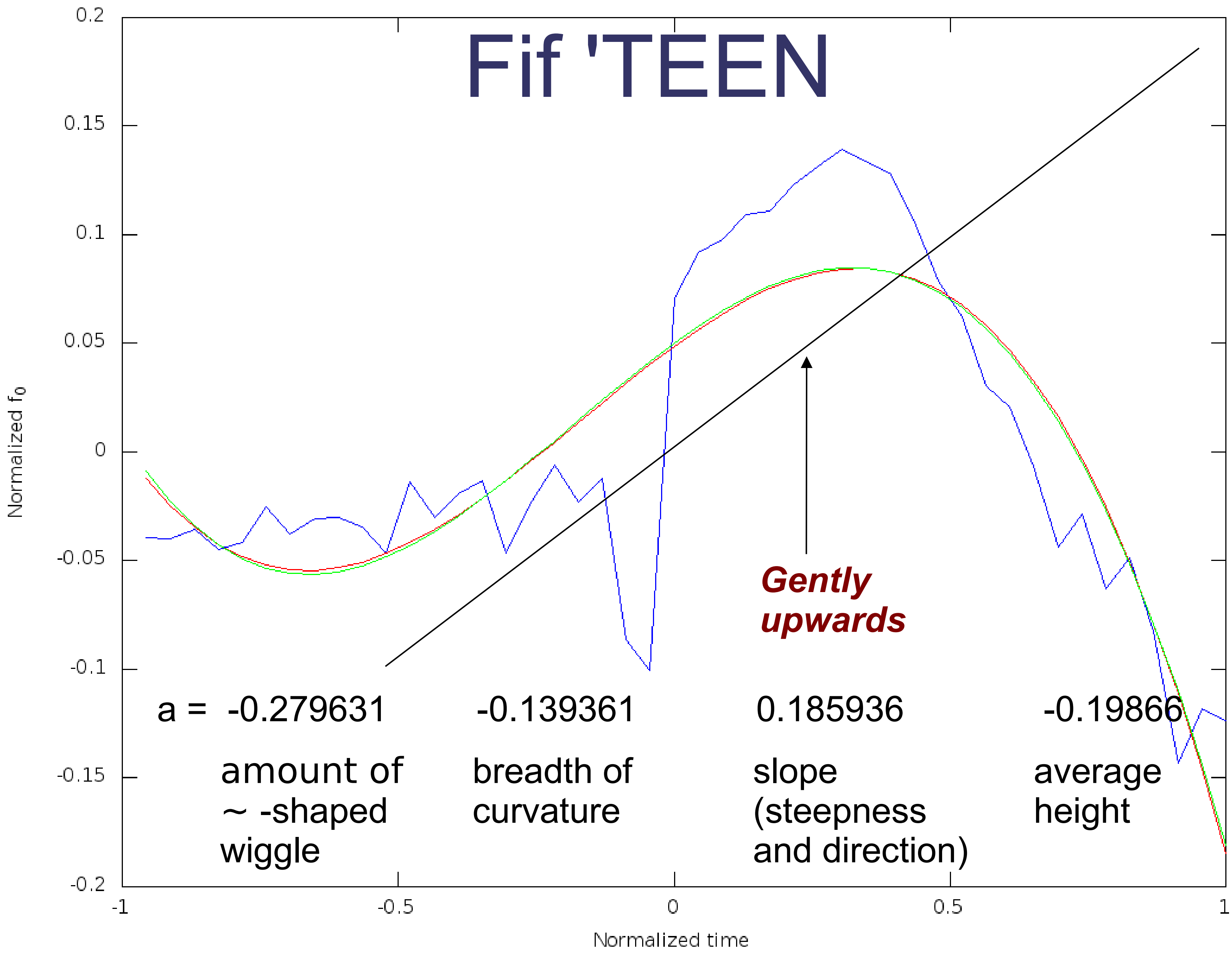
Normalized f_0
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
Normalized time
Steep and downwards
a = 0.19321
0 .63340
-0.70280
-0.19866
amount of ~ -shaped wiggle
breadth of curvature
slope (steepness and direction)
average height


Wide and concave
a = 0.19321
0 .63340
-0.70280
-0.19866
amount of ~ -shaped wiggle
breadth of curvature
slope (steepness and direction)
average height
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
Normalized f_0
Normalized time

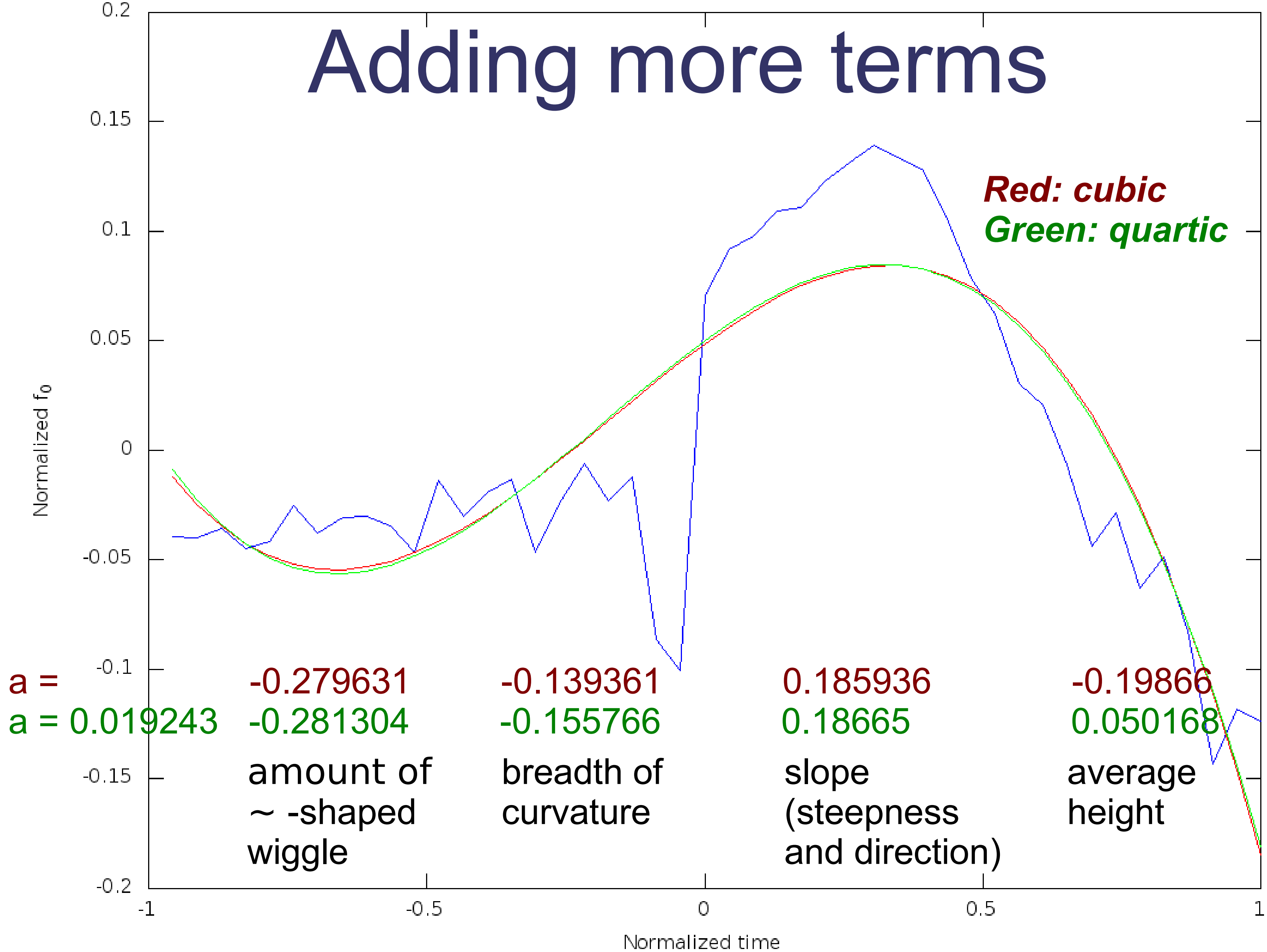

1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
Normalized f_0
Normalized time
Not very much!
a = 0.19321
0 .63340
-0.70280
-0.19866
amount of ~ -shaped wiggle
breadth of curvature
slope (steepness and direction)
average height


Fif 'TEEN
A bit more sinuous
a = -0.279631
-0.139361
0.185936
-0.19866
amount of ~ -shaped wiggle
breadth of curvature
slope (steepness and direction)
average height
Normalized f_0
Normalized time
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-1
-0.5
0
0.5
1


Fif 'TEEN
Narrower and convex
a = -0.279631
-0.139361
0.185936
-0.19866
amount of ~ -shaped wiggle
breadth of curvature
slope (steepness and direction)
average height
Normalized f0
Normalized time
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-1
-0.5
0
0.5
1


Fif 'TEEN
Gently upwards
a = -0.279631
amount of ~ -shaped wiggle
-0.139361
breadth of curvature
0.185936
slope (steepness and direction)
-0.19866
average height
Normalized f_0
Normalized time
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-1
-0.5
0
0.5
1

Adding more terms



Orthogonalisation

- Translate polynomial coeffients into *orthogonal* (Legendre) polynomial coeffs:

```
c = [0.4*a(1) 2*a(2)/3 a(3)+6*a(1)/5 a(4)]
```

%% a = 0.19321 0.63340 -0.70280 -0.19866
%% c = 0.077284 0.422269 -0.470948 -0.198659

Loop over all the “good” files

```
for i = 2:172
   eval(['fid = fopen(''FIFTEEN',int2str(i),'.wav.f0.csv'');']);
   if (fid ~= -1) %% checks file FIFTEEN i ... exists
      eval(['f0 = load(''FIFTEEN',int2str(i),'.wav.f0.csv'');']);
      y = f0(:,1);
      y = y(y>0);
      yn = y/mean(y)-1;
      x = ((1:length(yn))-length(yn)/2)/(length(yn)/2);
      x = x';
      [a,S] = polyfit(x,yn,3);
      c = [0.4*a(1) 2*a(2)/3 a(3)+6*a(1)/5 a(4)];
      C(i,:) = [i c];
   end
end
save('coeffs.csv','C');
```

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Now do your statistics

- Rather than applying statistical tests to the raw data, examine the means, variances etc of the coefficients of the functions you're using to model the data