Analysis of Earthquake and Ground water data in Visual Signal

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- Why needs to do removal of Non-Periodical Signal?
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- Summary

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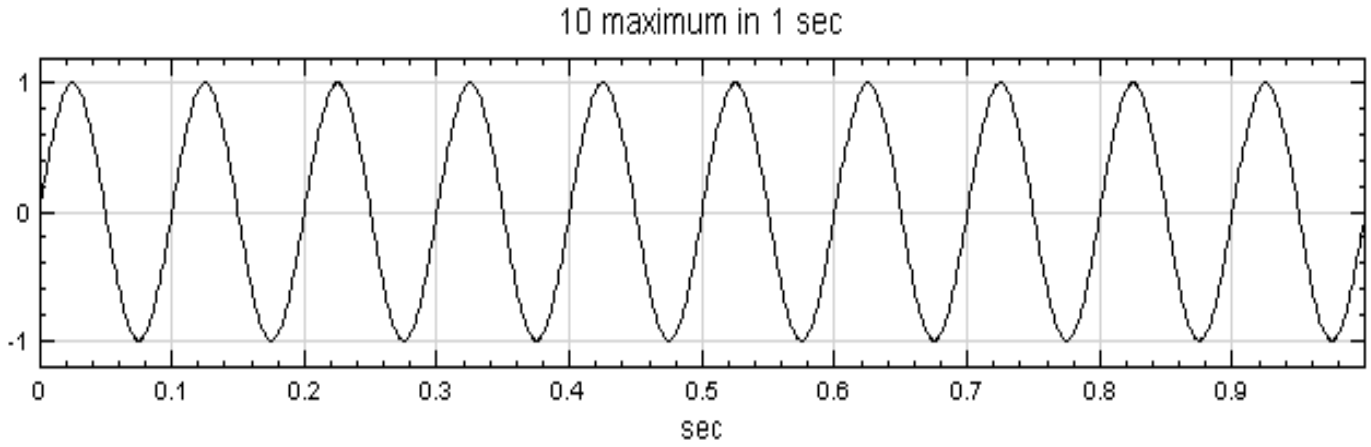
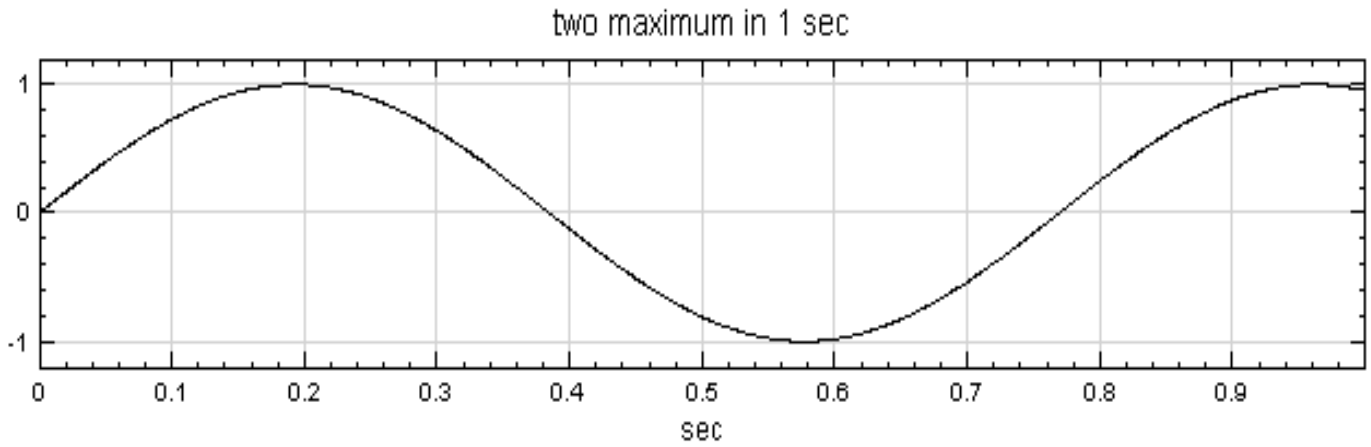
What is frequency?

Frequency definition (1)

- Period is defined as number of events in duration of time. And frequency is the inverse of period.





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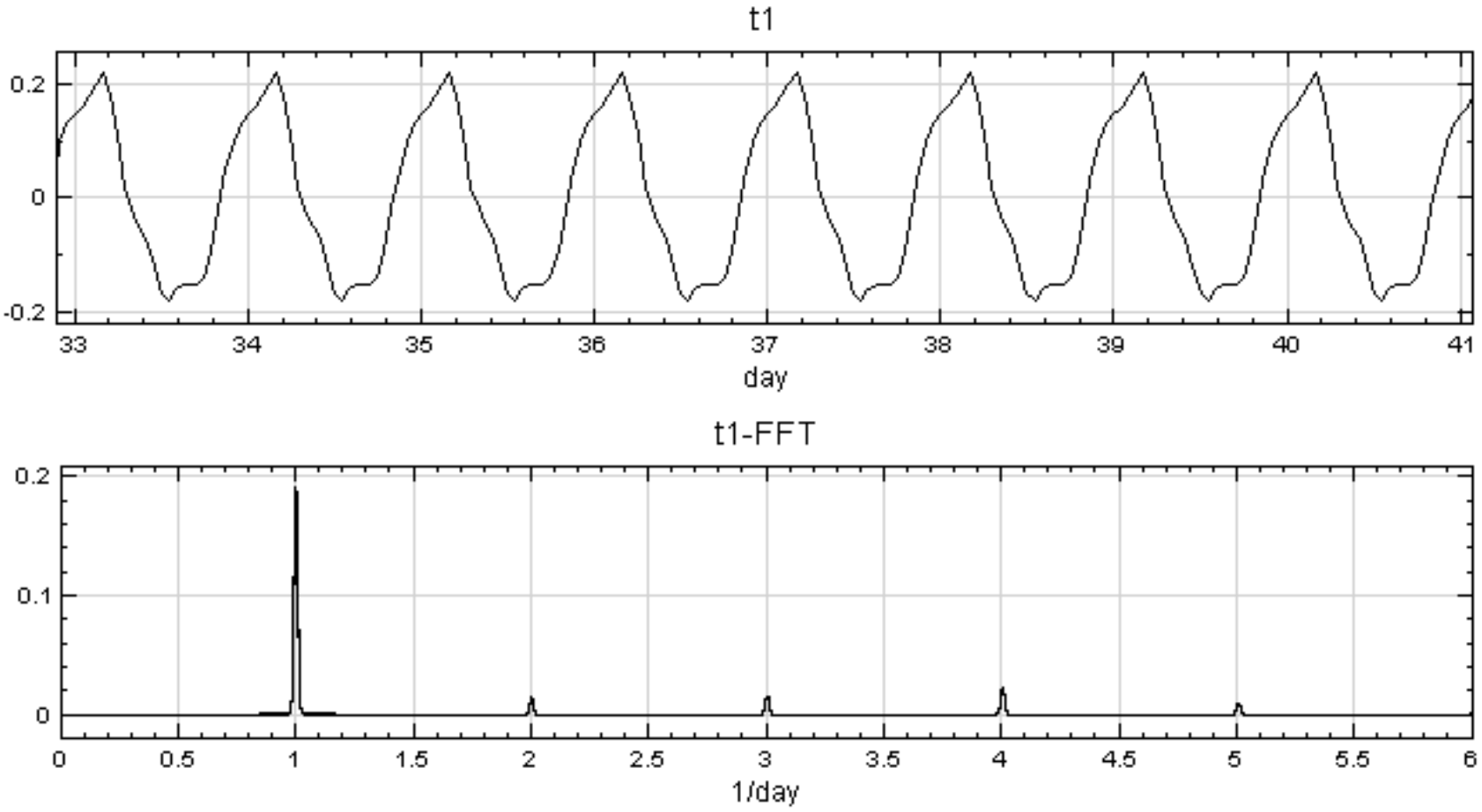
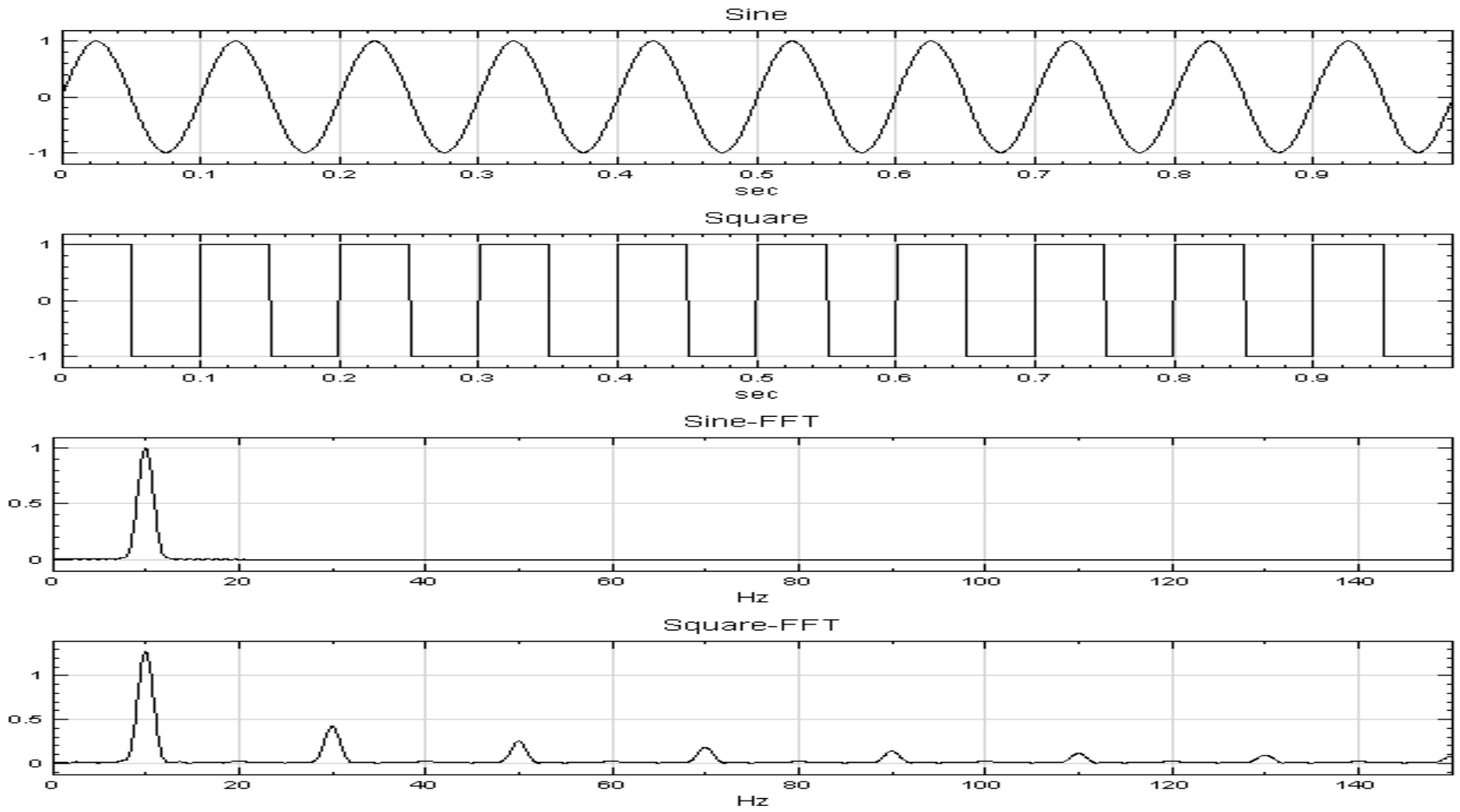
Spectrum of 美濃(1)



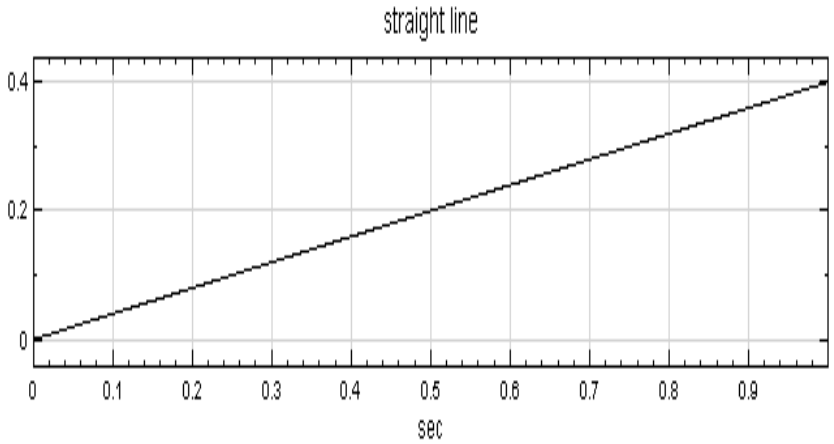
Single Frequency and Harmonics

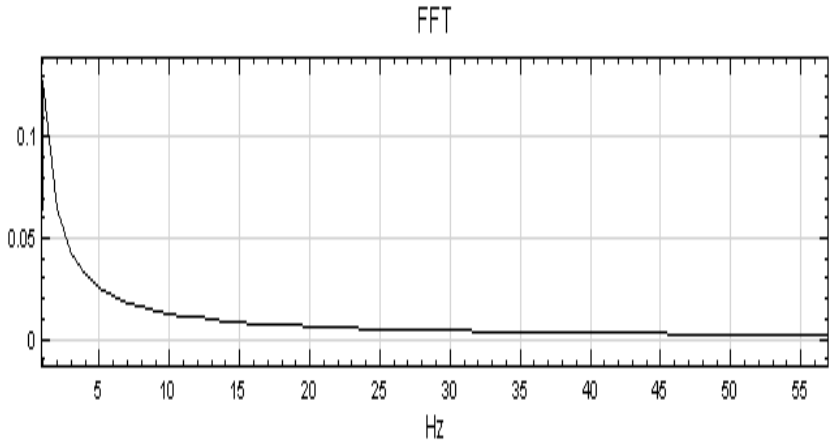


Why needs to do removal of Non-Periodical Signal?

Non-Periodical Signal of many frequencies?

- Does a straight has a frequency?
- Putting on Fourier glasses, we see so many frequencies from a straight line.
- Again what do we want to see?





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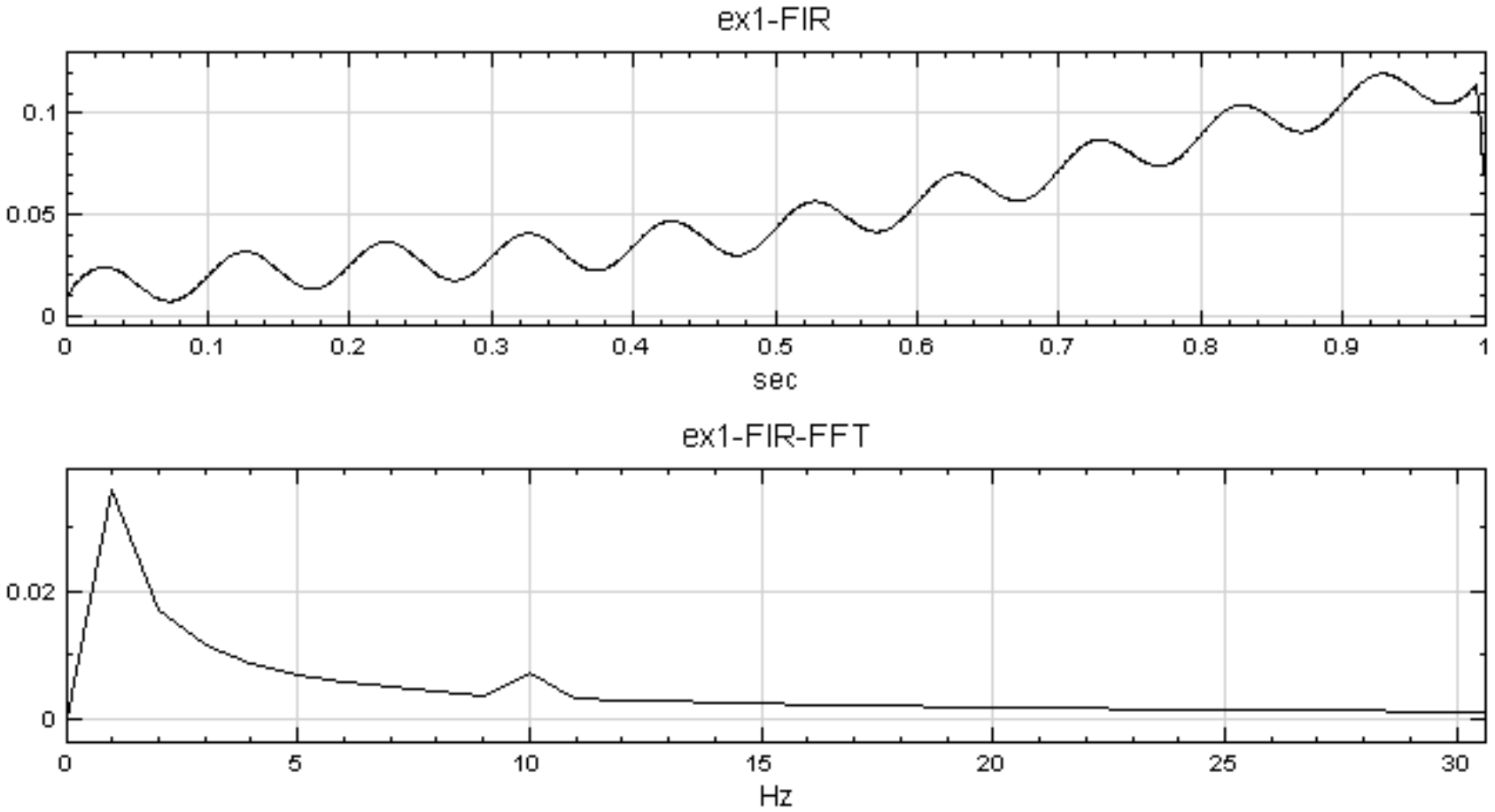
FIR Filter



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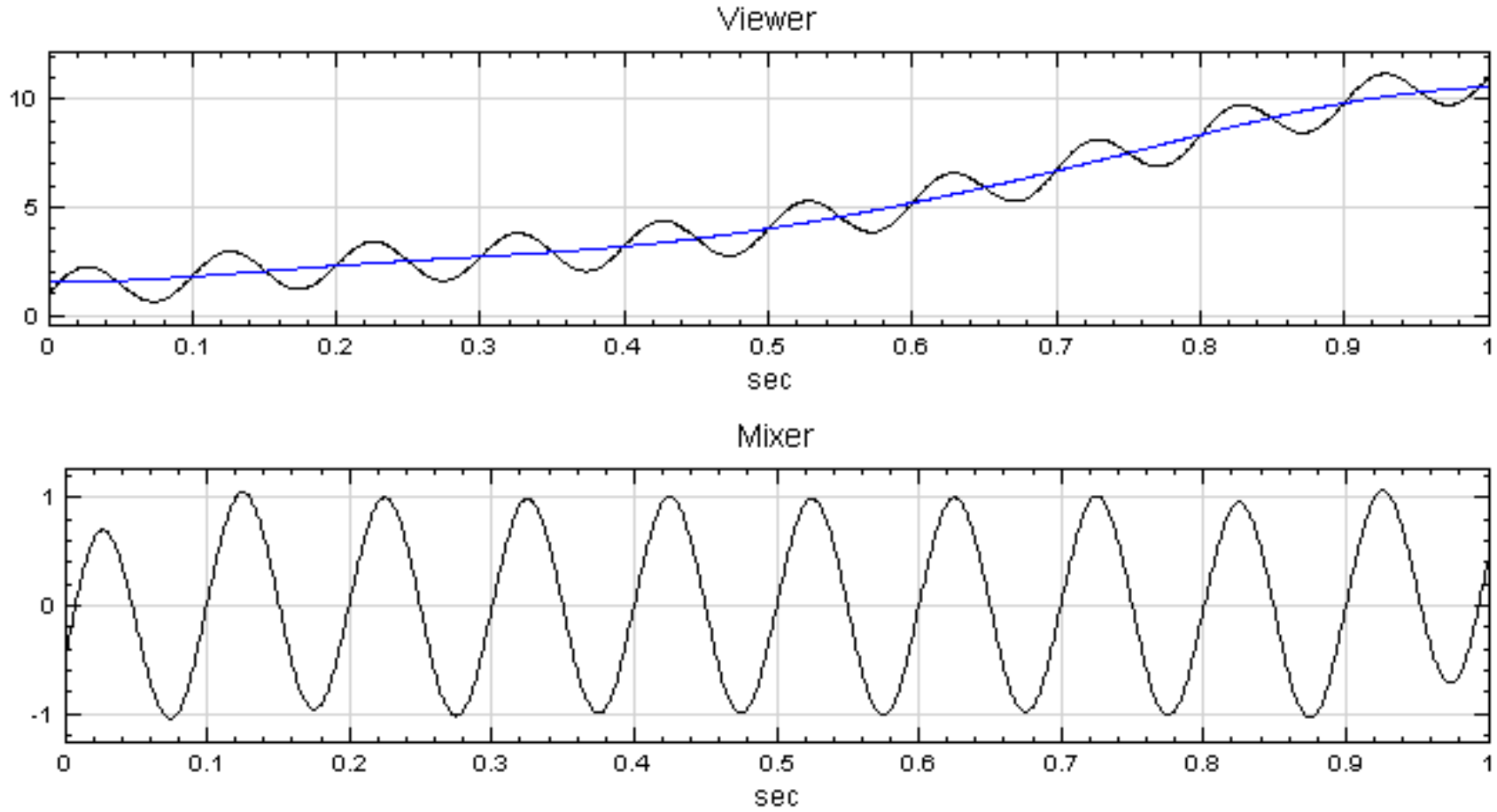
Iterative Gaussian Filter



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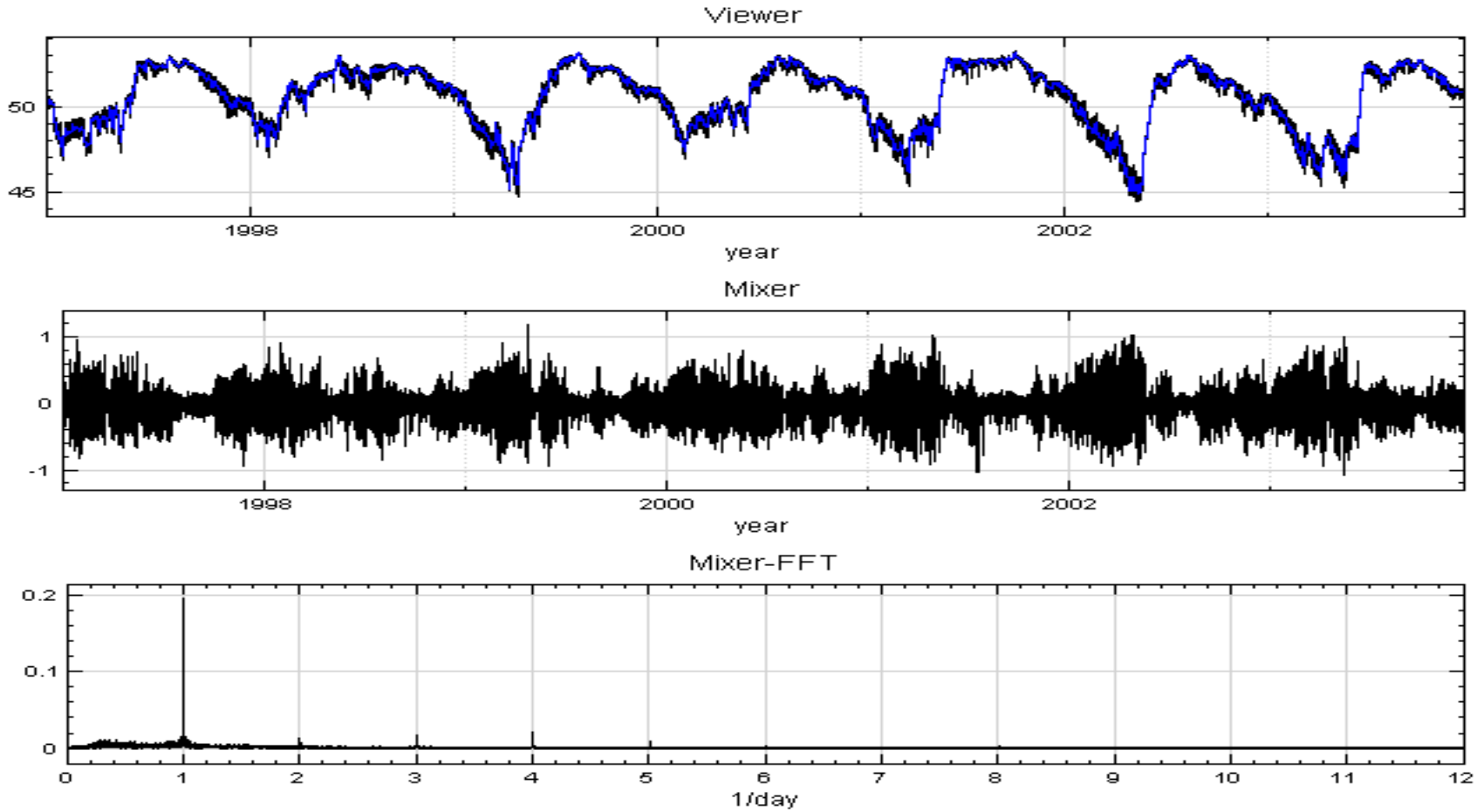
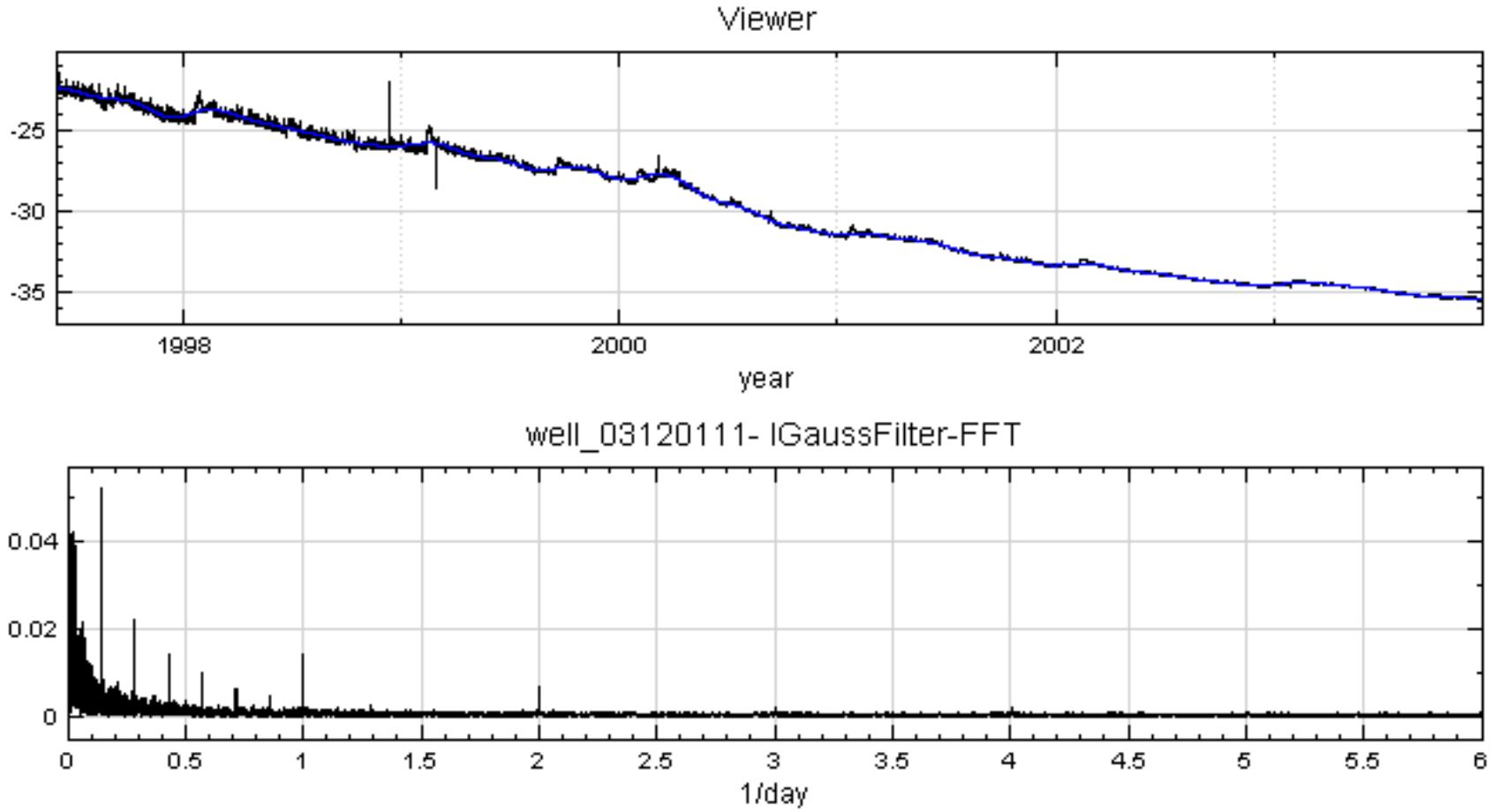
美濃(1)


Viewer
50
45
1998
2000
2002
year
Mixer
1
0
-1
1998
2000
2002
year
Mixer-FFT
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10
11
12
1/day

樹林(1)


Viewer
-25
-30
-35
1998
2000
2002
year
well_03120111- IGaussFilter-FFT
0.04
0.02
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
1/day

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What do we want? Data perception.

- For data perception, we want to be able to separate signal into
  - Non-periodical part ⇨ time series plot
  - Periodical part ⇨ **time-frequency plot**
  - Noise ⇨ taken cared without introducing undesired alias
  - Jump/discontinuity ⇨ eliminated

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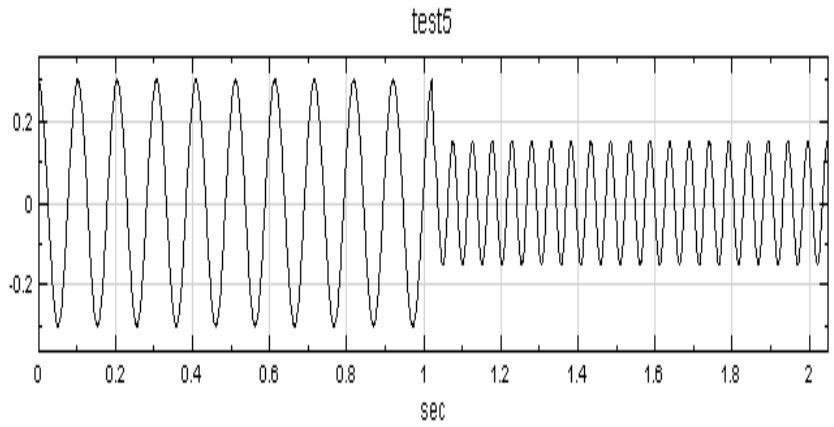
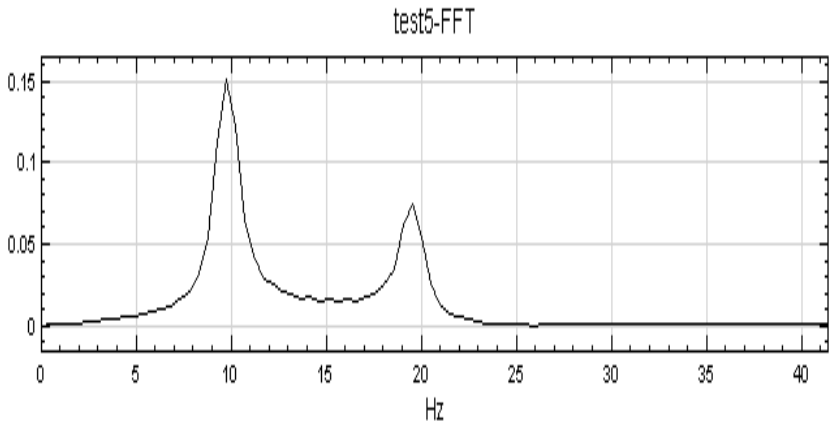
Why Time-Frequency Analysis (TFA)?

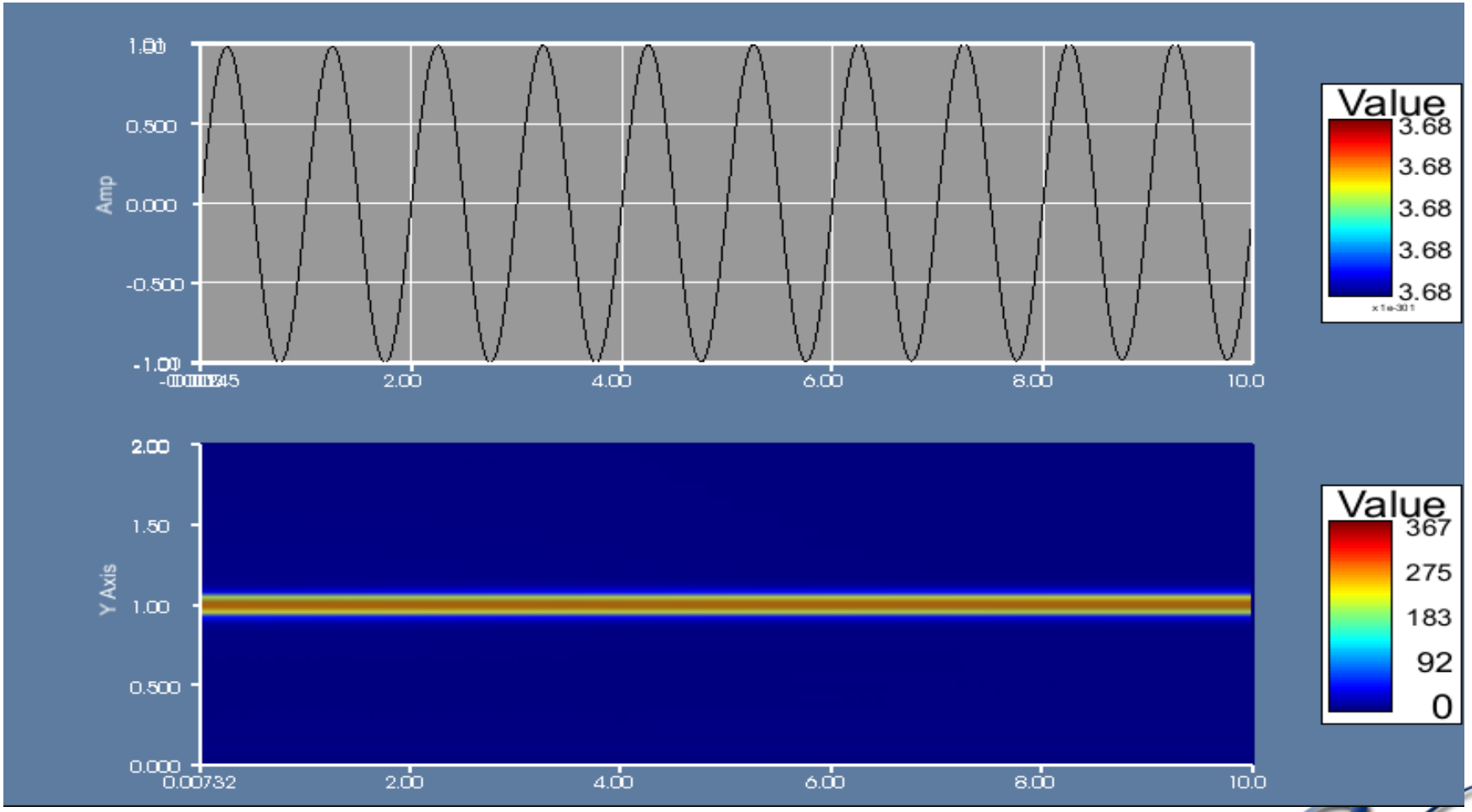
Is FFT good enough for you?

- With only FFT, we cannot see the frequency/amplitude change with time.





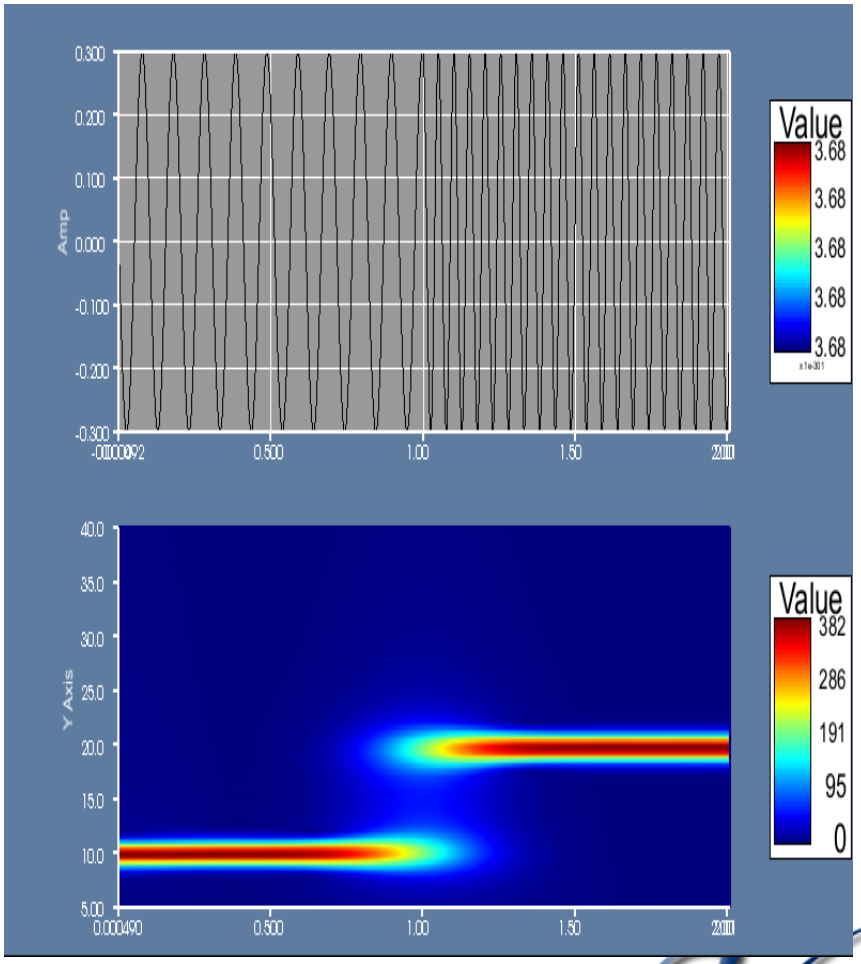
TF Plot: Single frequency



TF Plot: Change of frequency

- Signal with abrupt change of frequency.

$$x(t) = \begin{cases} 0.30\cos(2\times 10\pi t) & ,0 \le t < 1 \\ 0.30\cos(2\times 20\pi t) & ,1 \le t < 2 \end{cases}$$



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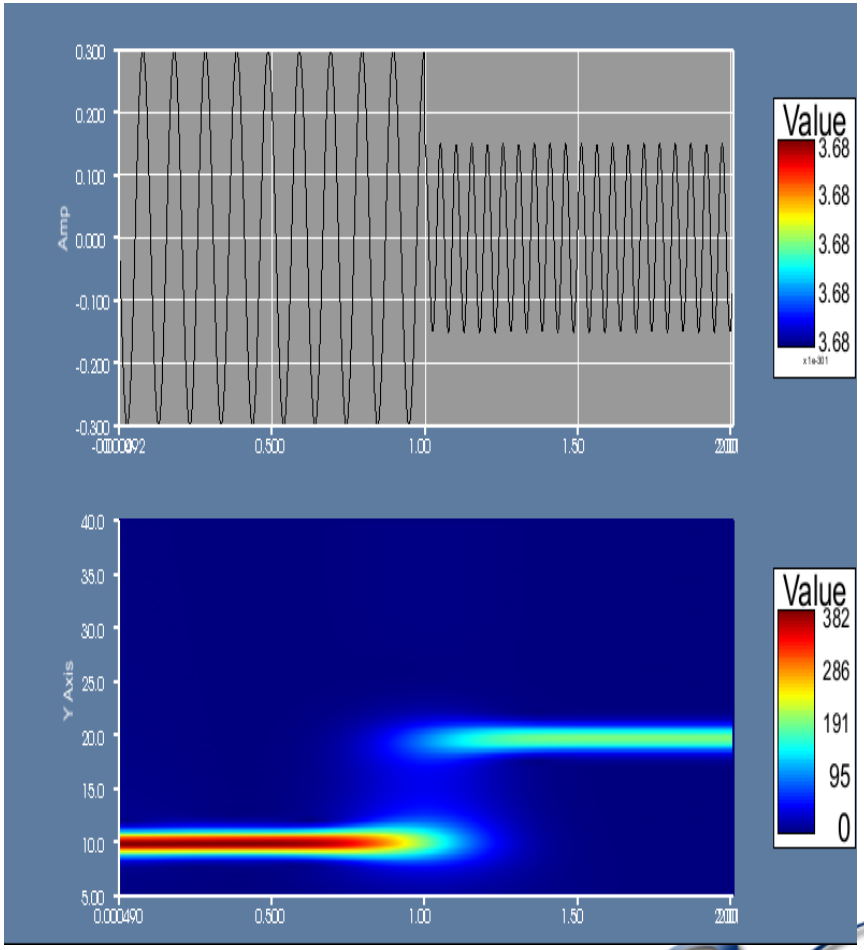
TF Plot: Change of frequency and amplitude

- Signal with abrupt change of frequency and amplitude

$$x(t) = \begin{cases} 0.30\cos(2\times 10\pi t) & ,0 \le t < 1 \\ 0.15\cos(2\times 20\pi t) & ,1 \le t < 2 \end{cases}$$



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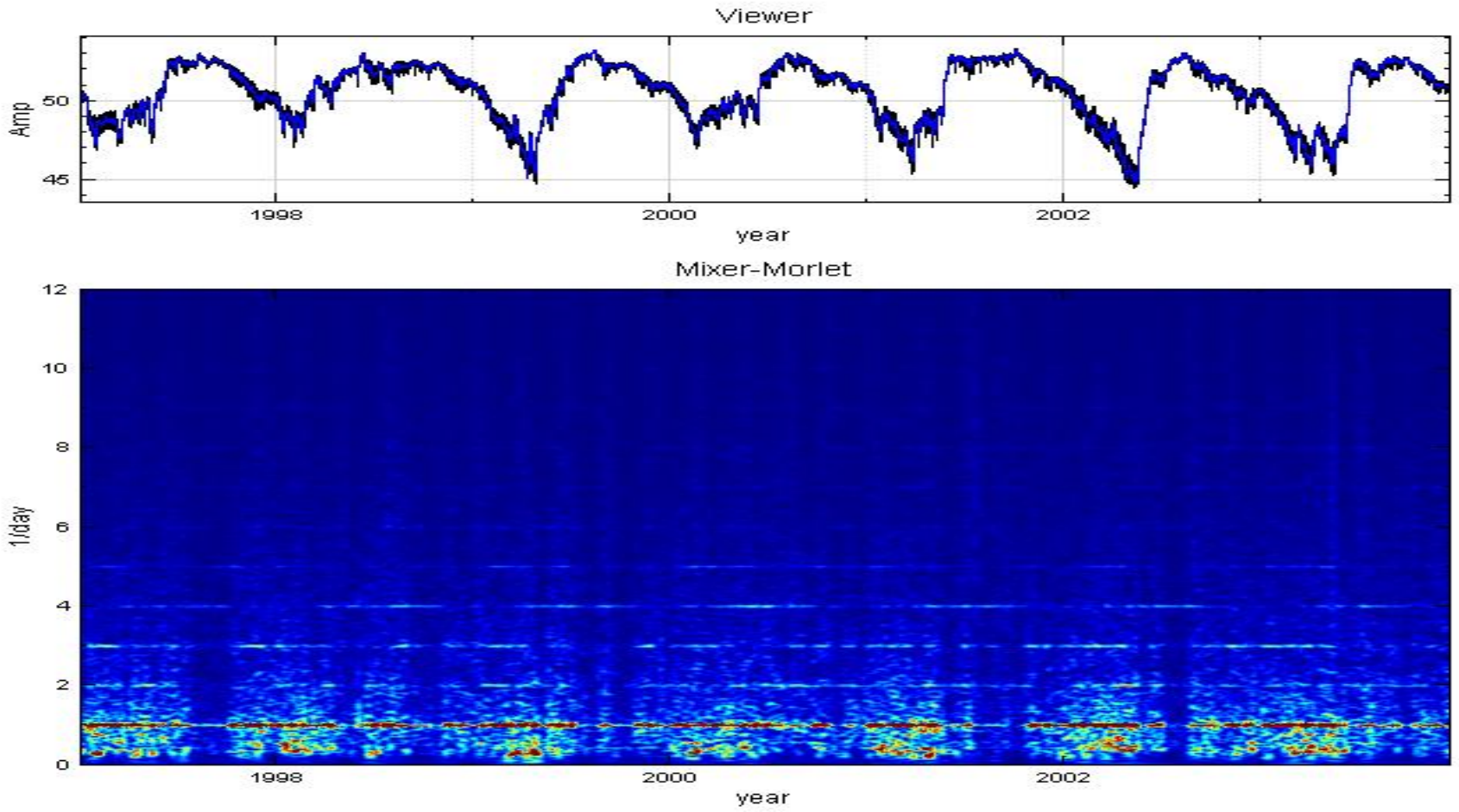
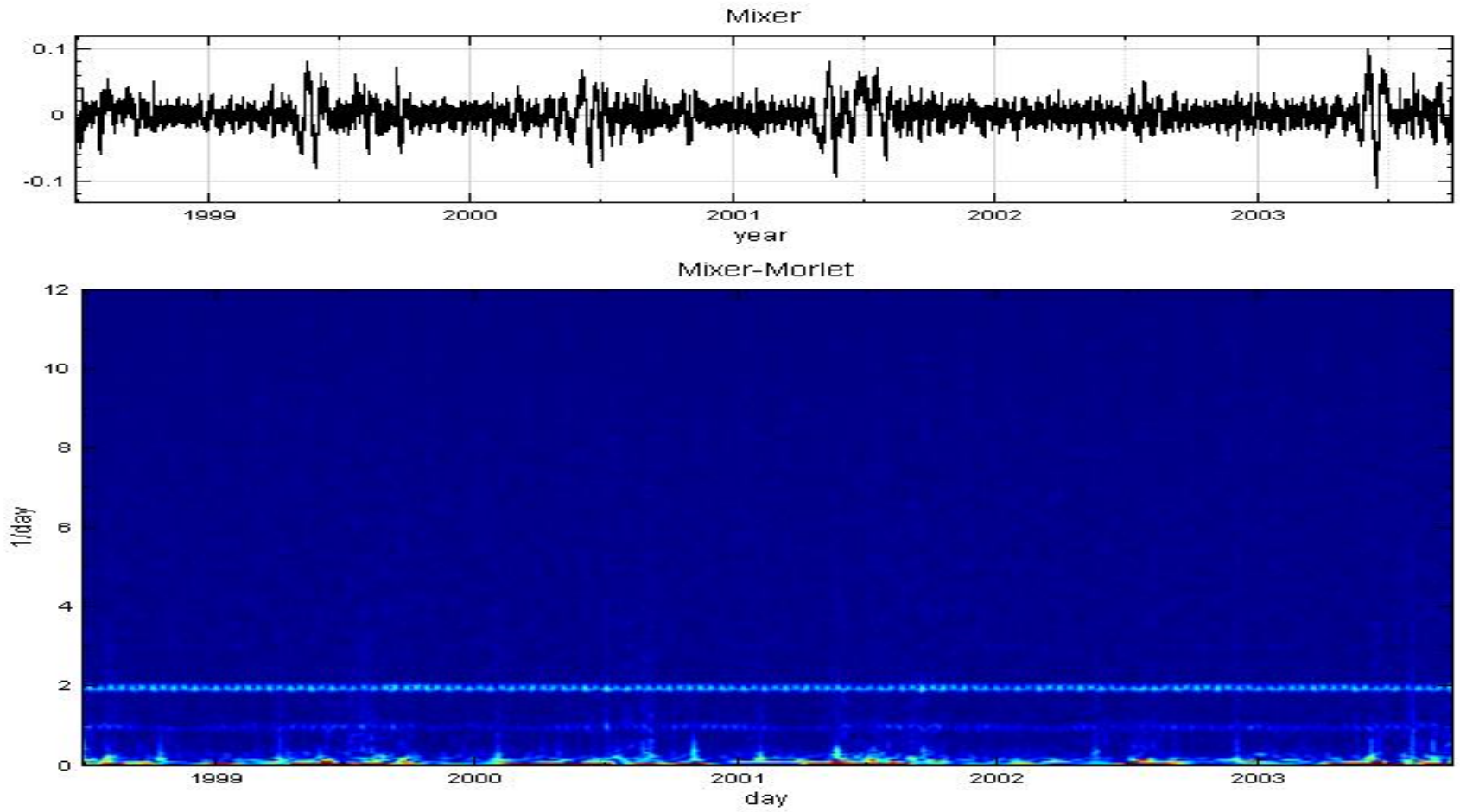
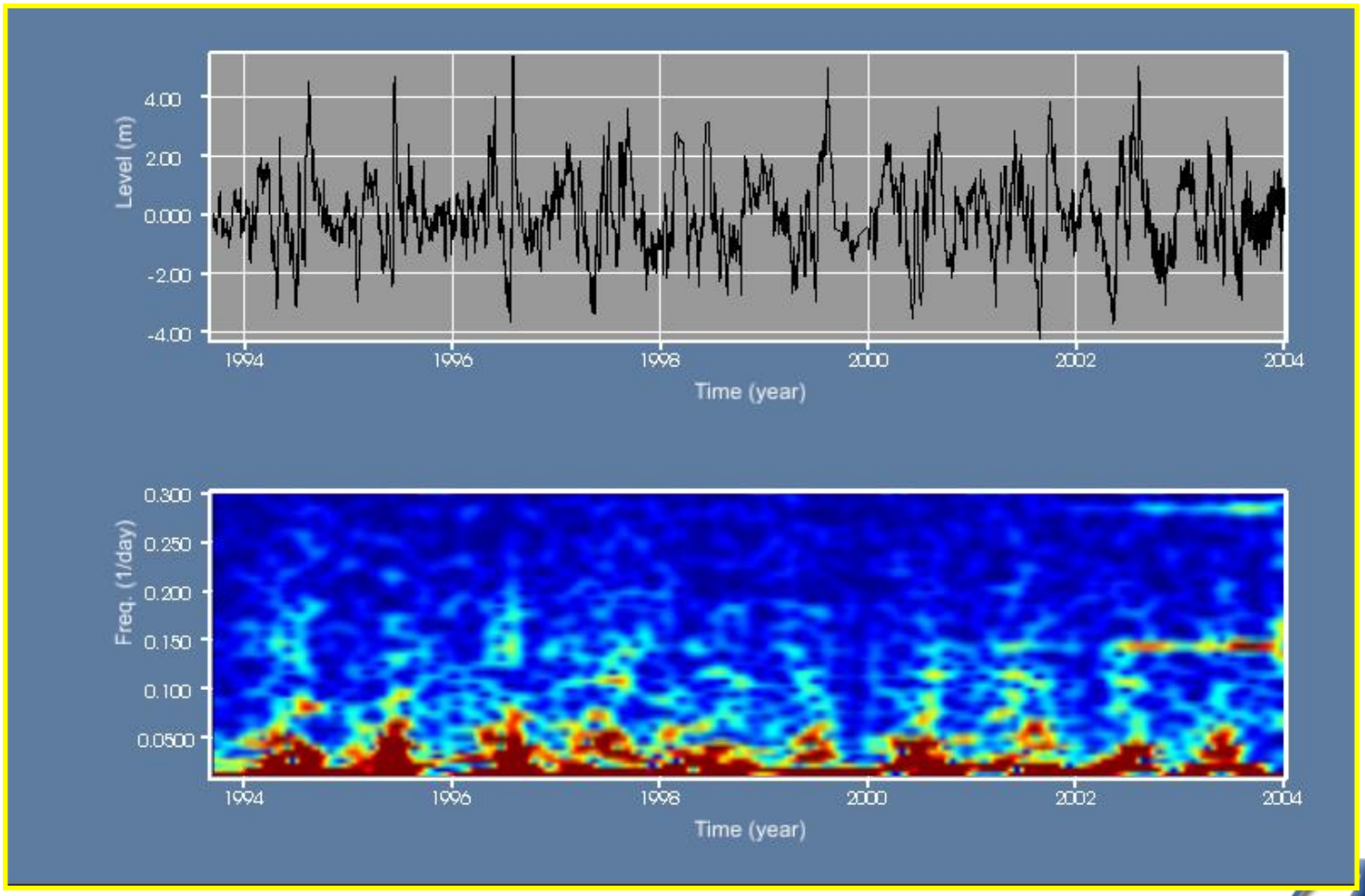
TF Plot of 美濃(1)



TF Plot of 吉洋人工湖(2)



Abnormal Pumping



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Why Visual Programming?

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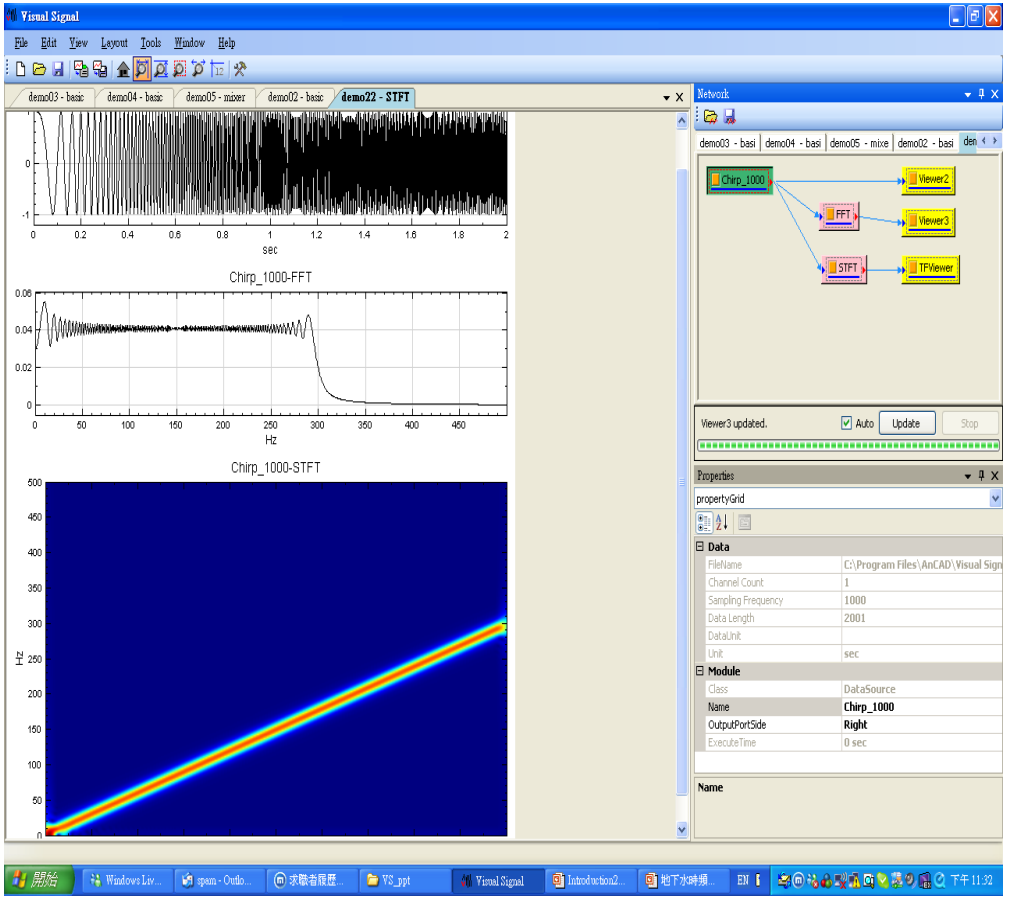
Signal processing without coding

- Visually create network structure to present workflow of your signal processing.



Data Interface

- Input data format supported
  - Plain text (.txt)
  - VS internal (.tfa)
  - Sac reader (.sac)
  - Excel reader (.csv)
  - Sound/speech (.wav, mp3)
  - WFDB Reader (.hea)
- Exported data format
  - Excel (.csv)
  - Plain text (.txt)
  - VS internal (.tfa)

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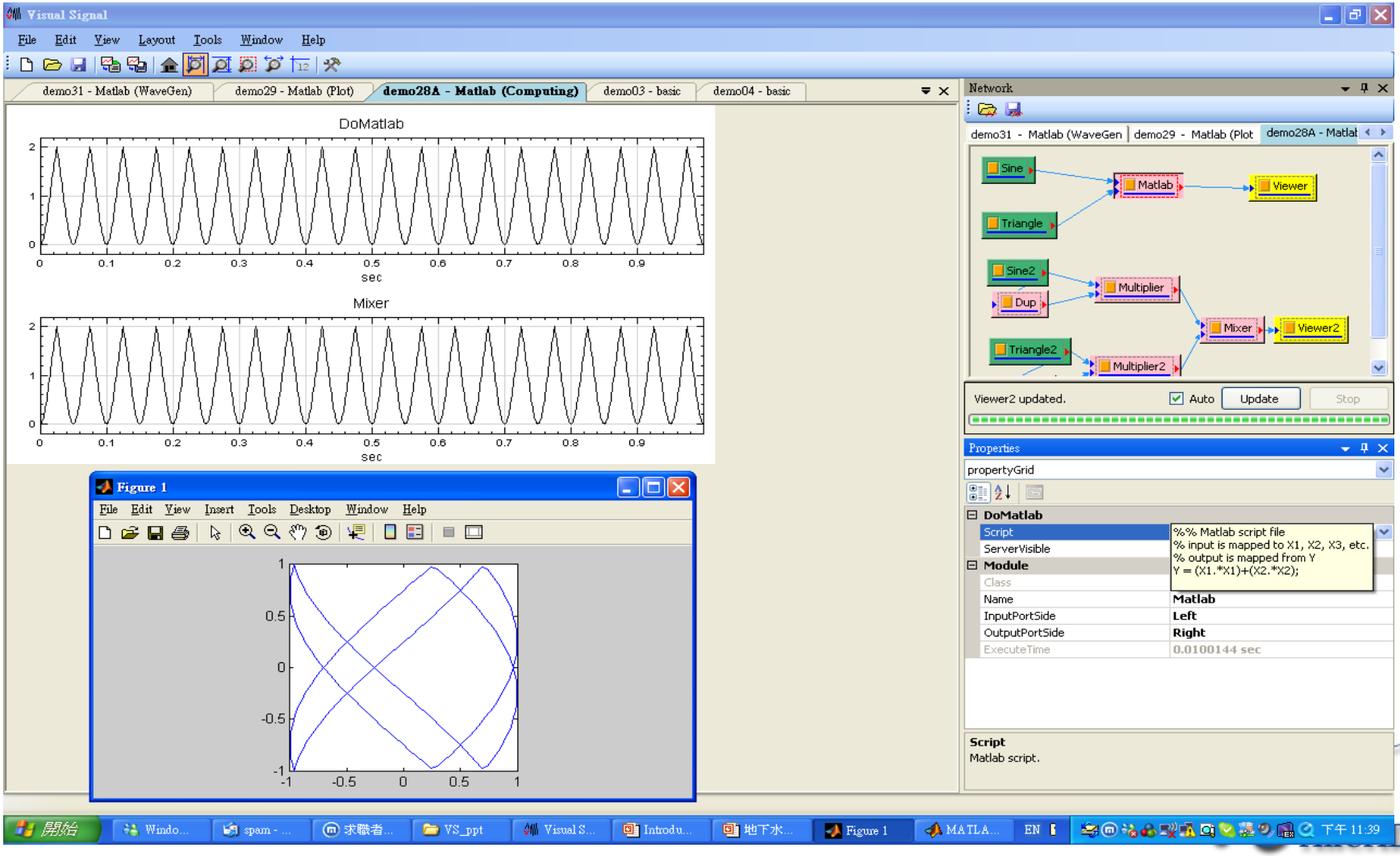
Matlab integration



TFA in Visual Signal

- Short-Term Fourier Transform (Spectrogram)
- Morlet Transform (Wavelet Transform)
- Enhanced Morlet Transform
- Hilbert Transform
- Hilbert-Huang Transform

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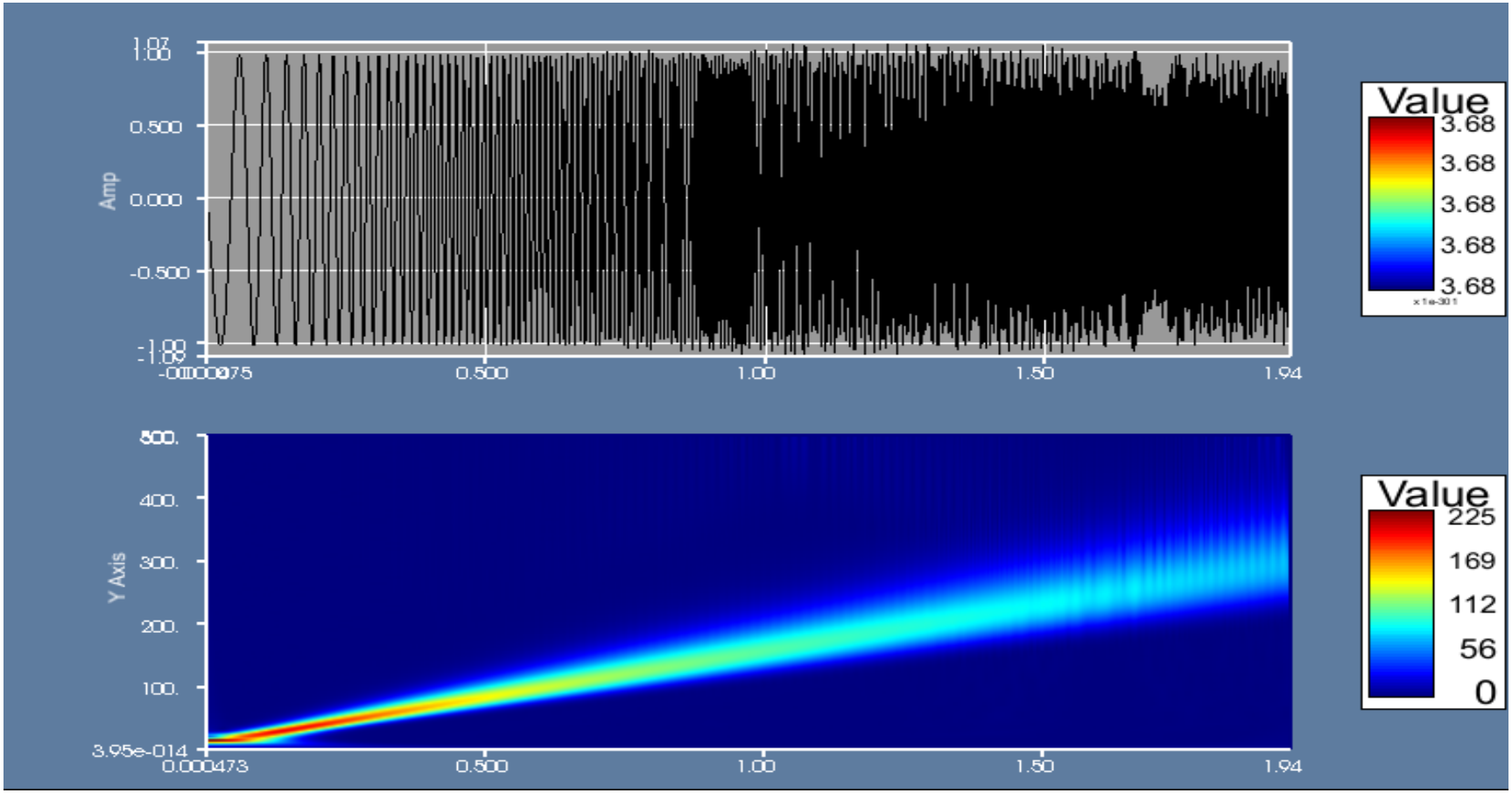
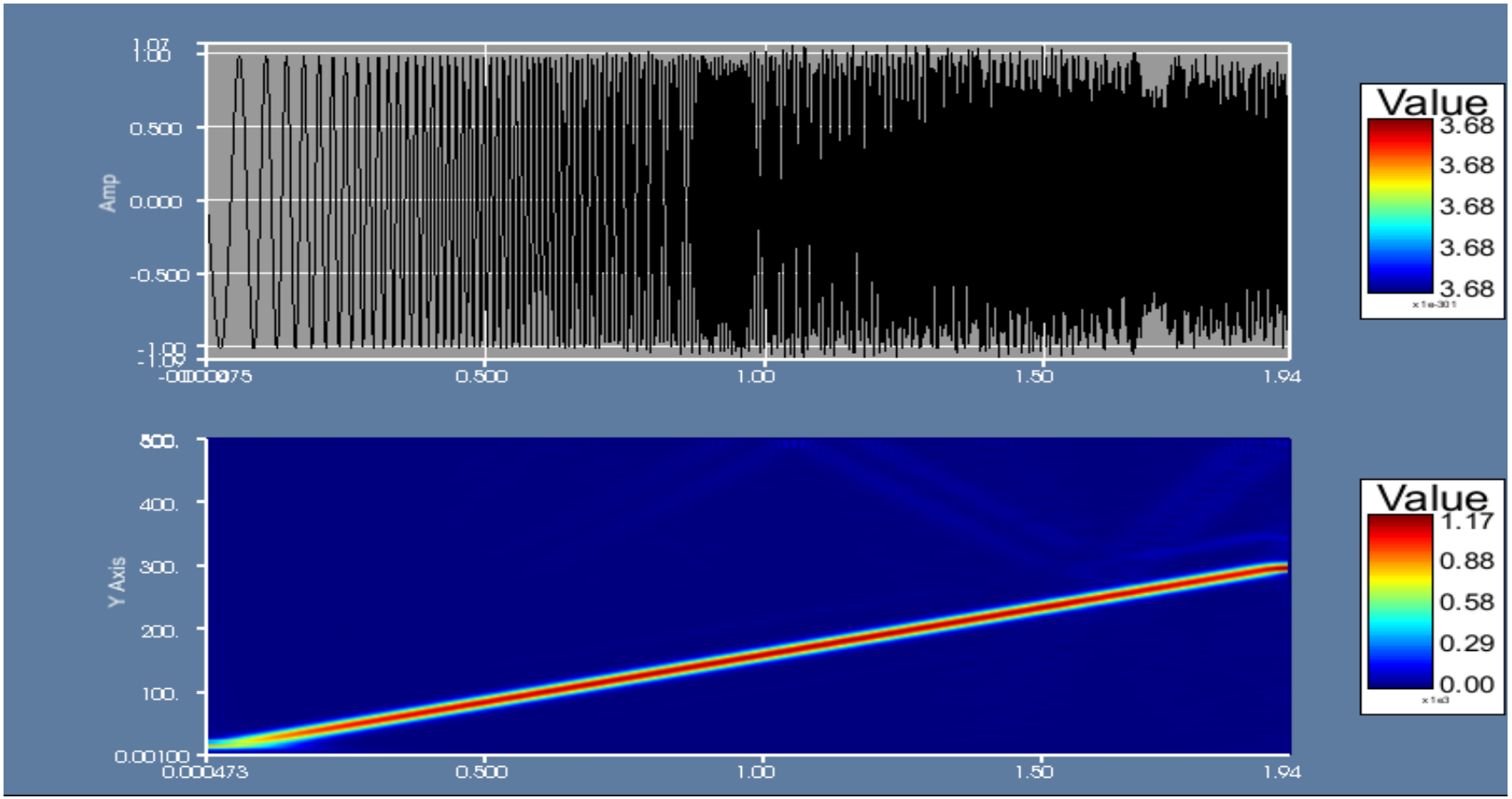
Morlet transform



Enhanced Morlet Transform



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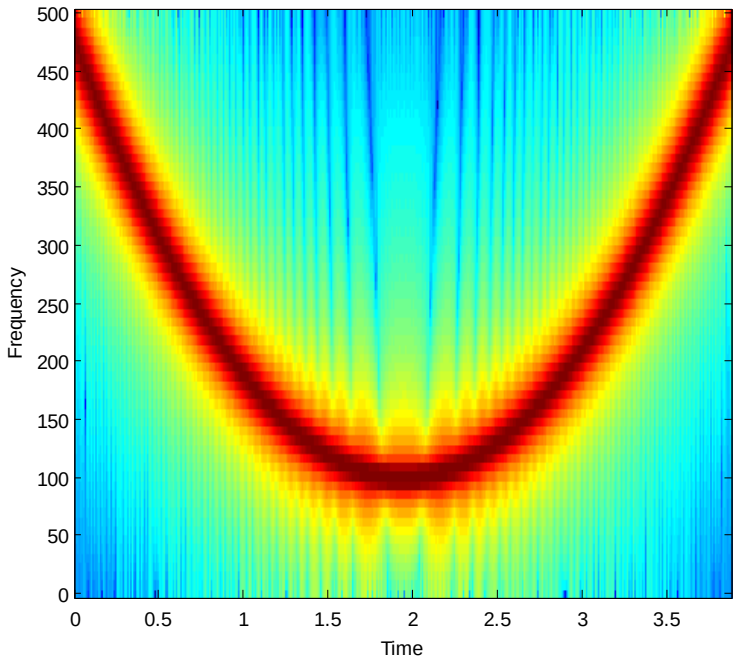
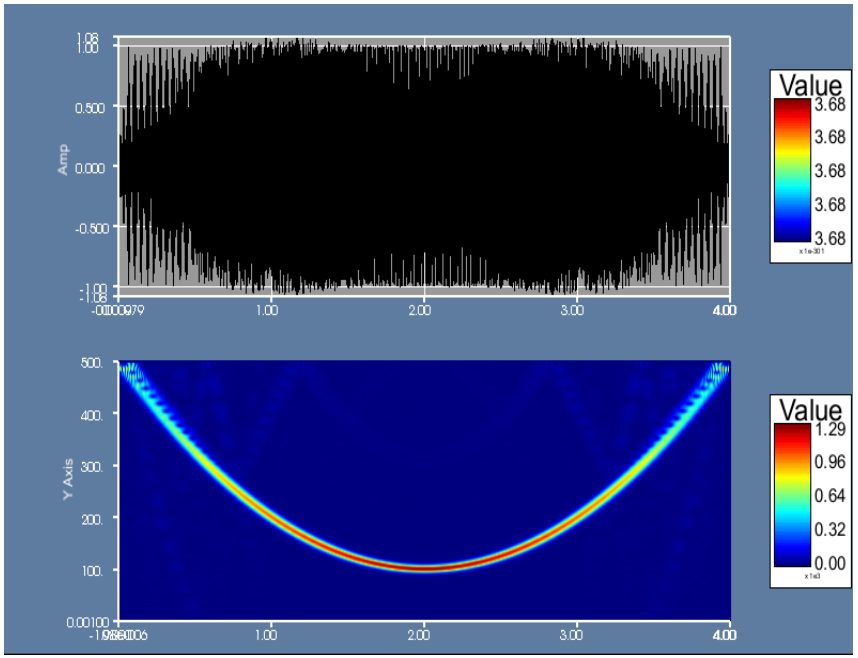
Quadratic Chirp Signal



Spectrogram, MATLAB



Morlet-Jeng, MATFOR

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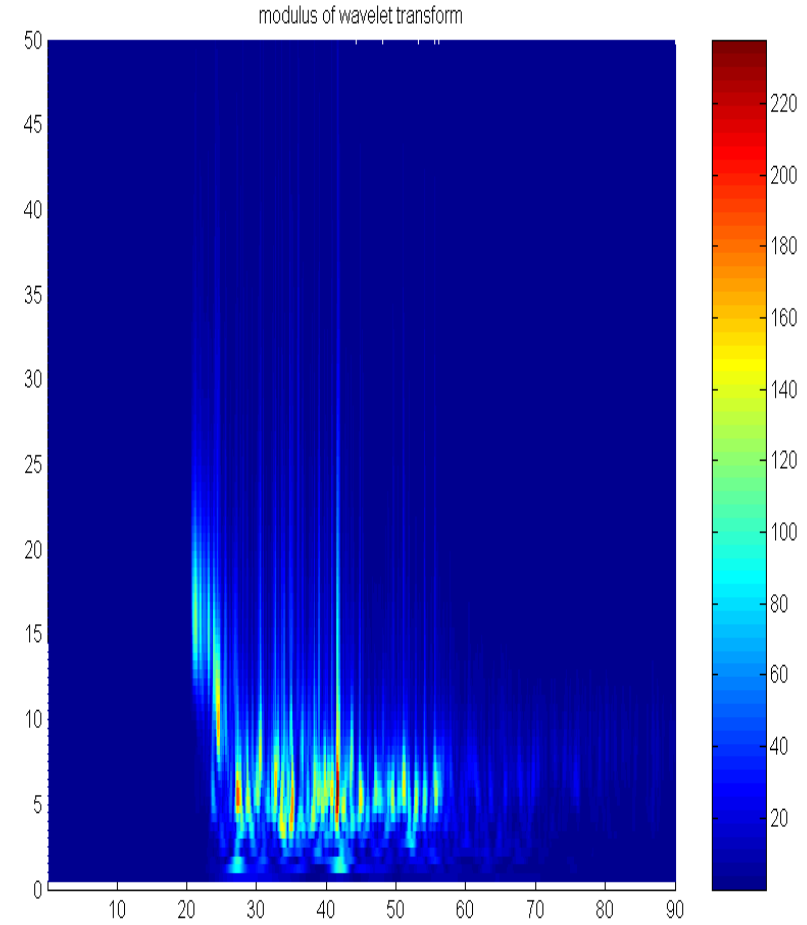
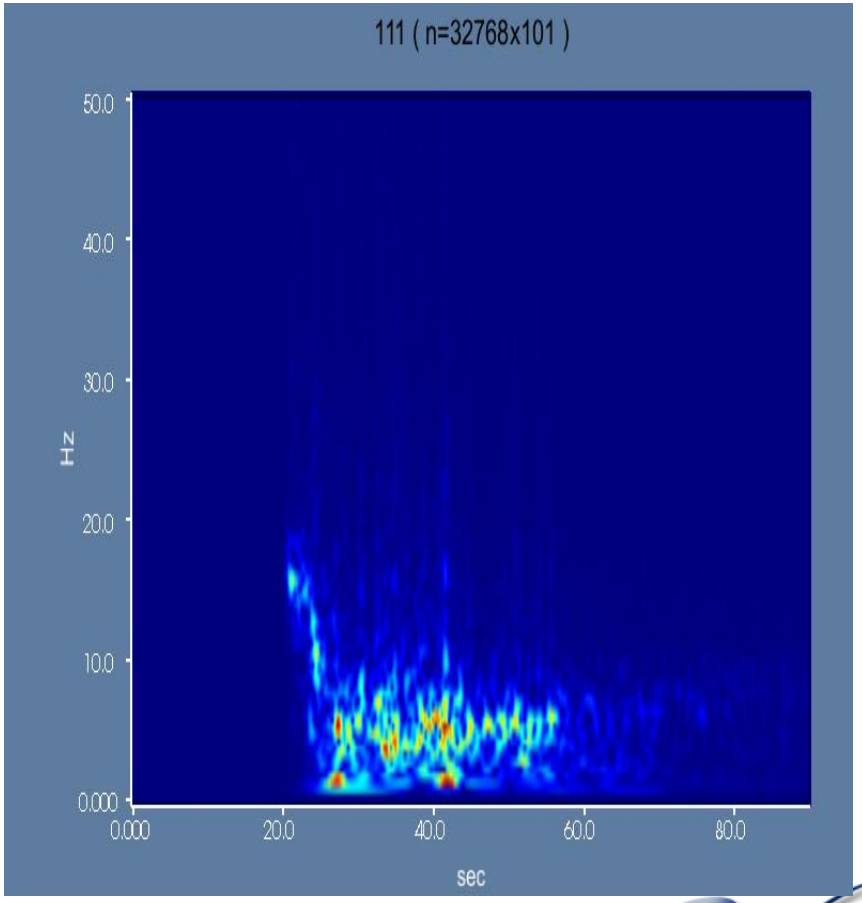
Chi-Chi (921) Earthquake



Morlet Transform by MATLAB



Morlet-Jeng Transform

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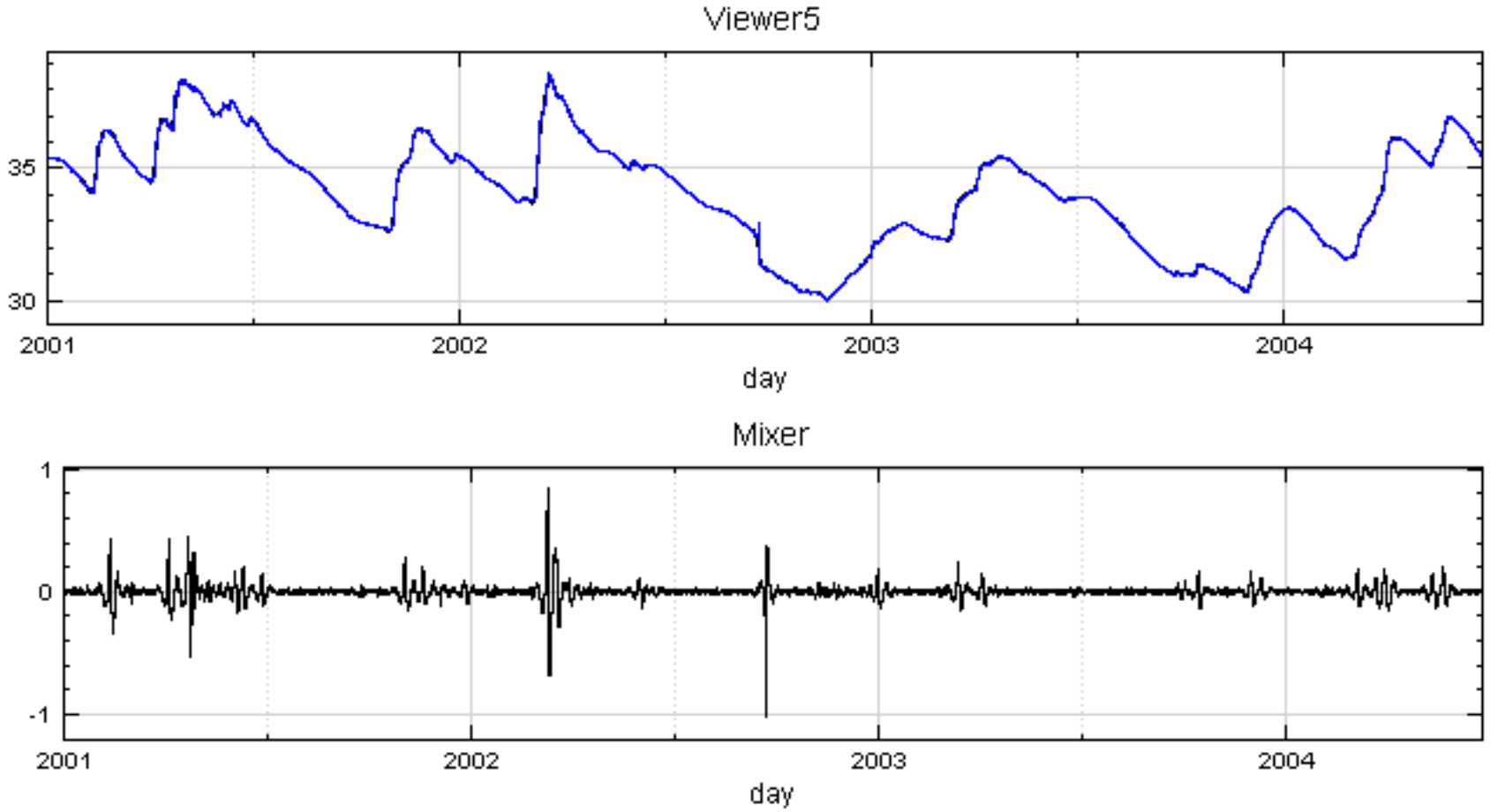
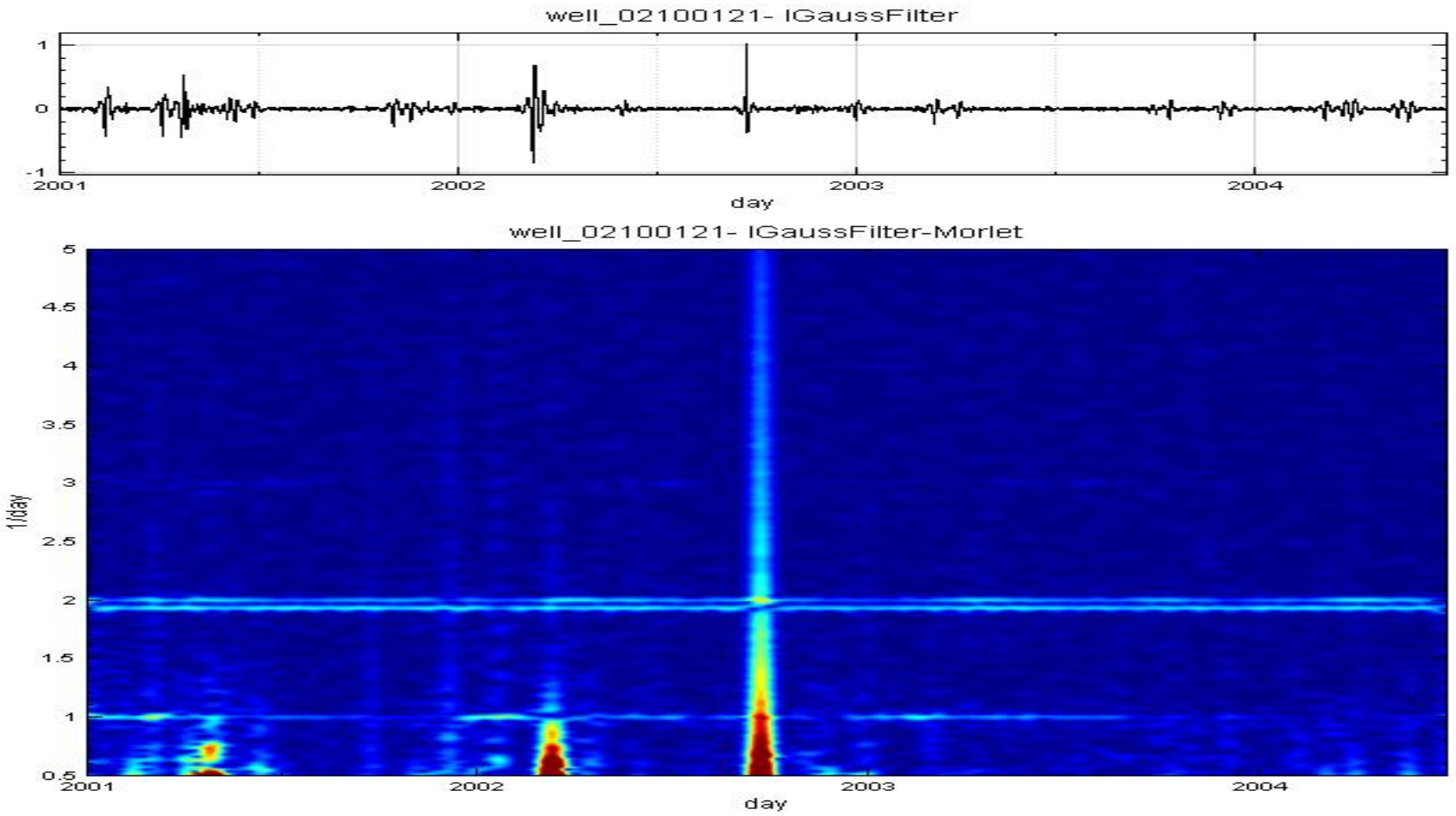
Diurnal/Semi-Diurnal Tide Separation using EMD

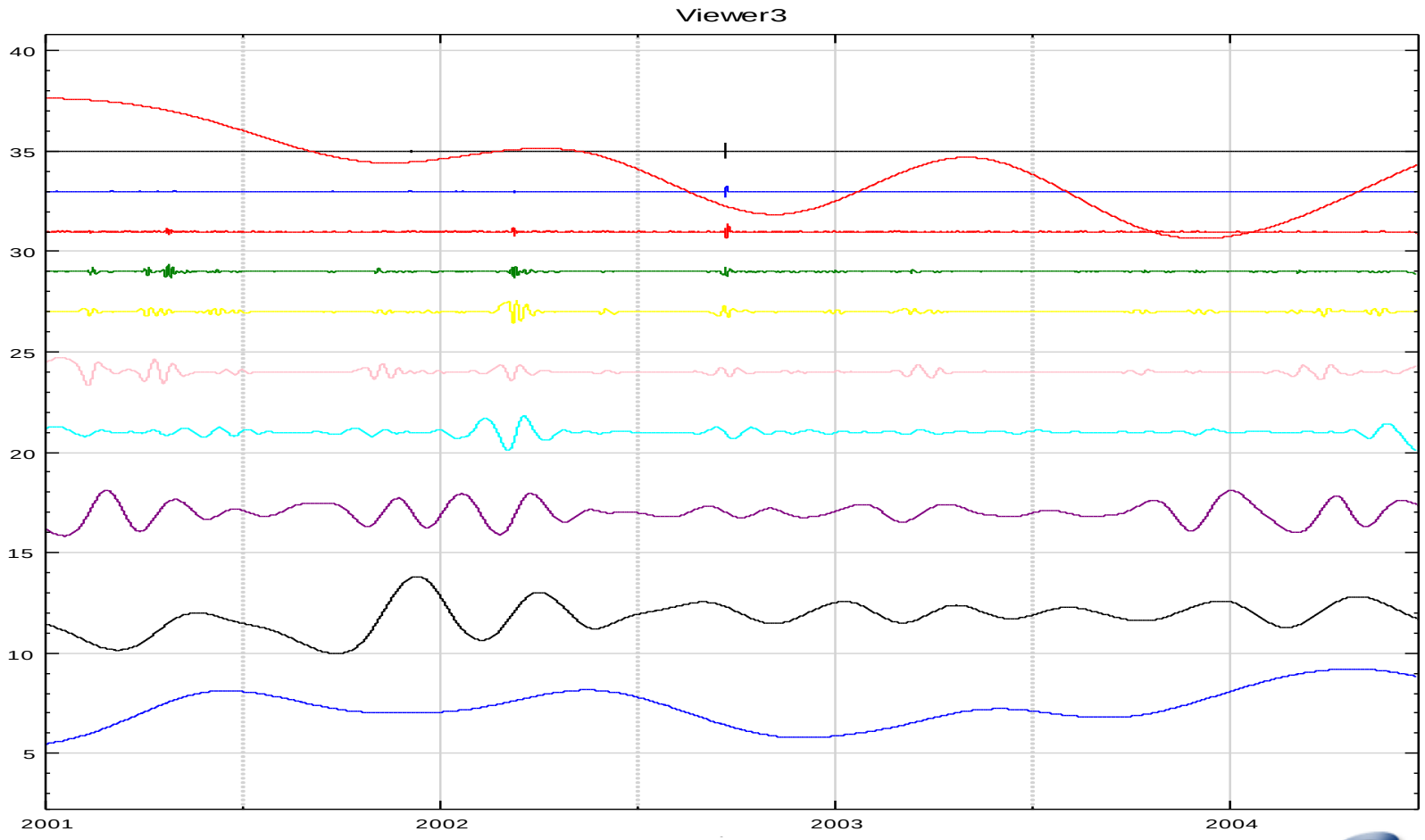
宜蘭大隱


Viewer5
35
30
2001
2002
2003
2004
day
Mixer
1
0
-1
2001
2002
2003
2004
day

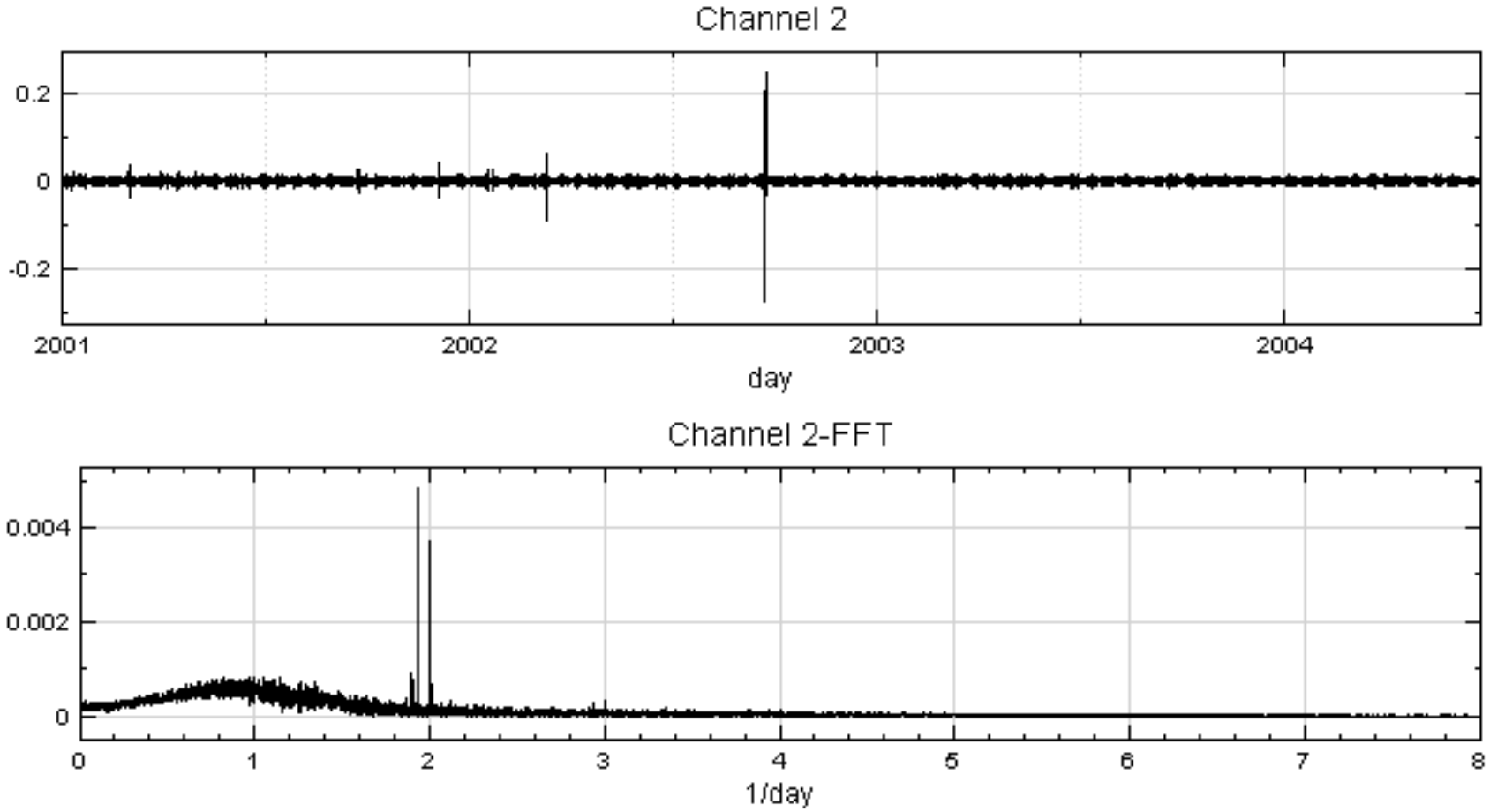
宜蘭大隱


well_02100121- IGaussFilter
1
0
-1
2001
2002
2003
2004
day
well_02100121- IGaussFilter-Morlet
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
1/day
2001
2002
2003
2004
day

宜蘭大隱(EMD)

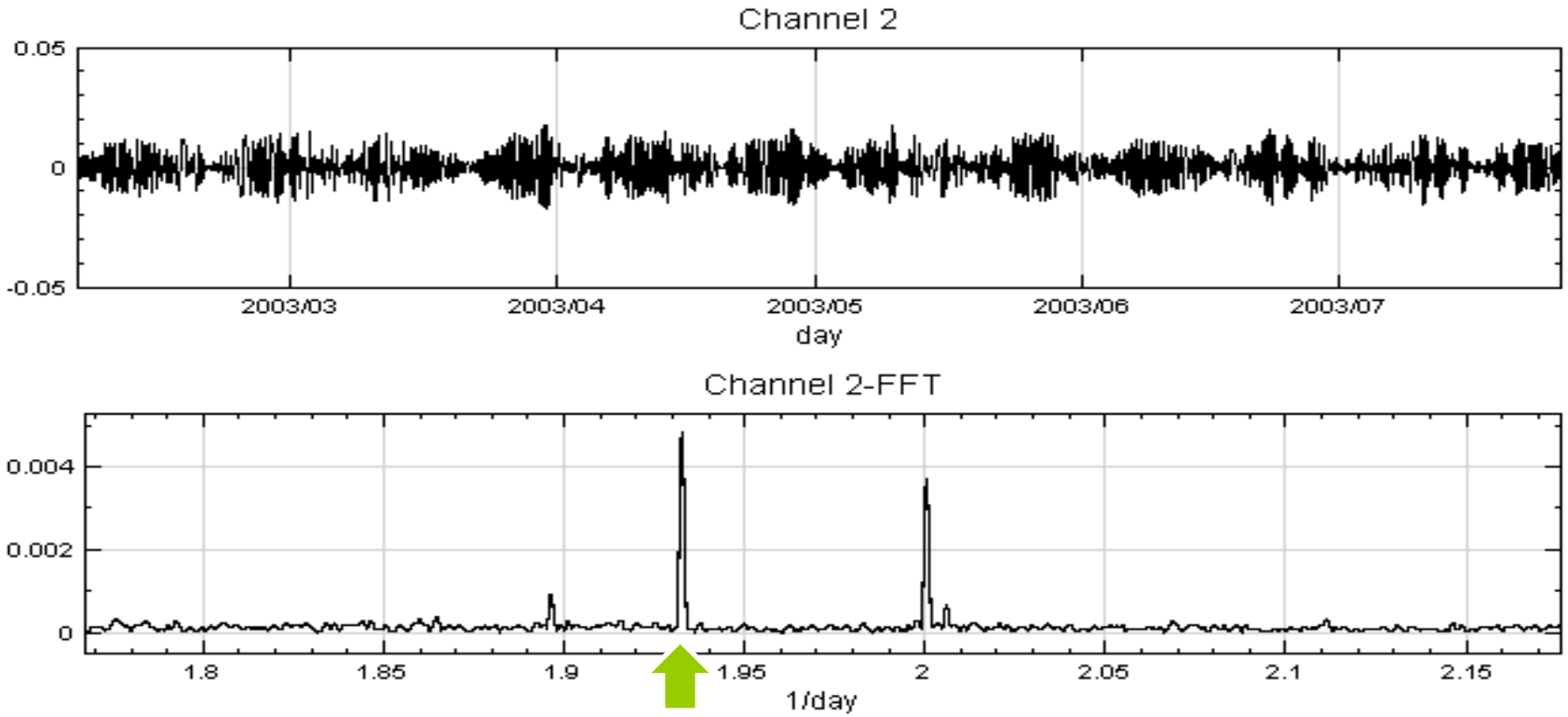


IMF2 (semi-diurnal tide)



IMF2 (semi-diurnal tide)

Beat wave occurs twice per month.



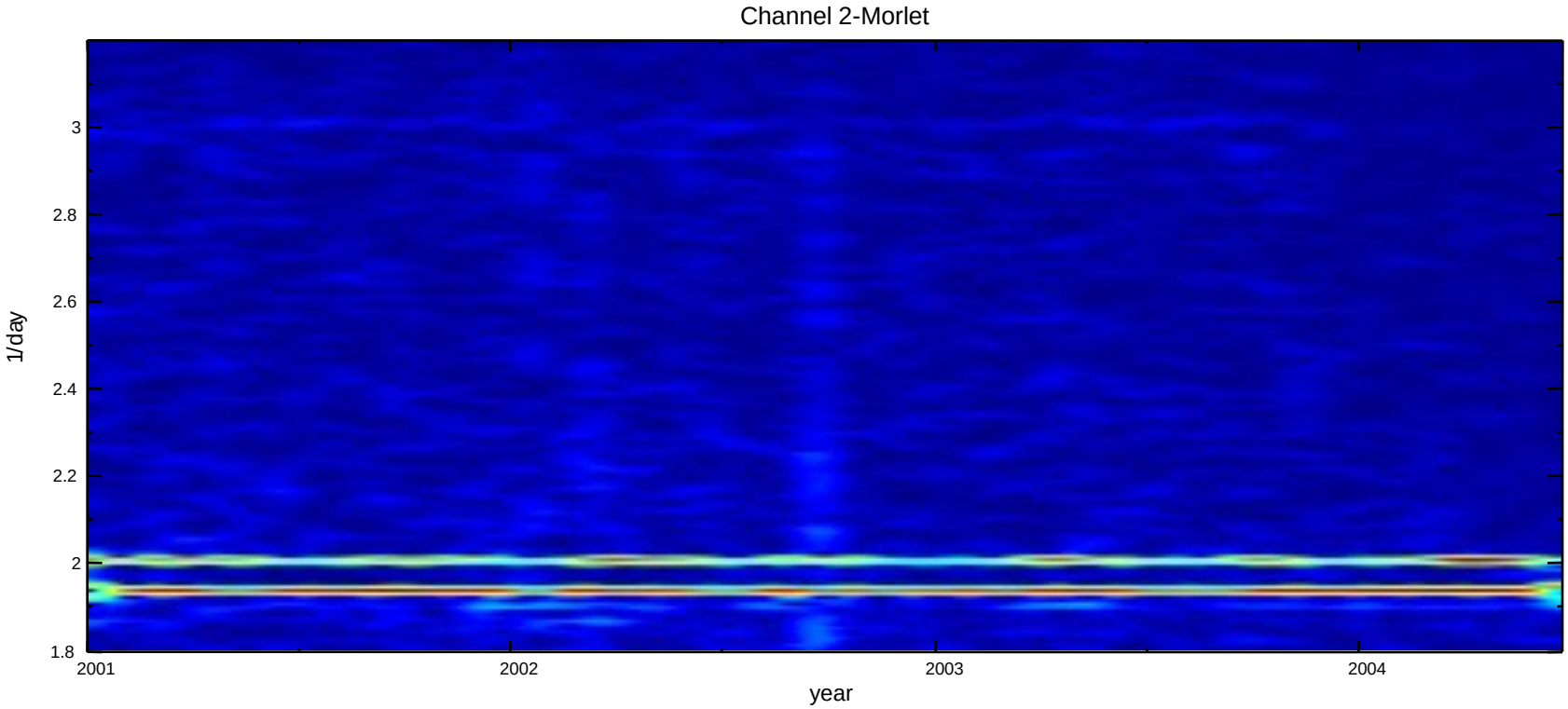
1.9323

Beat wave

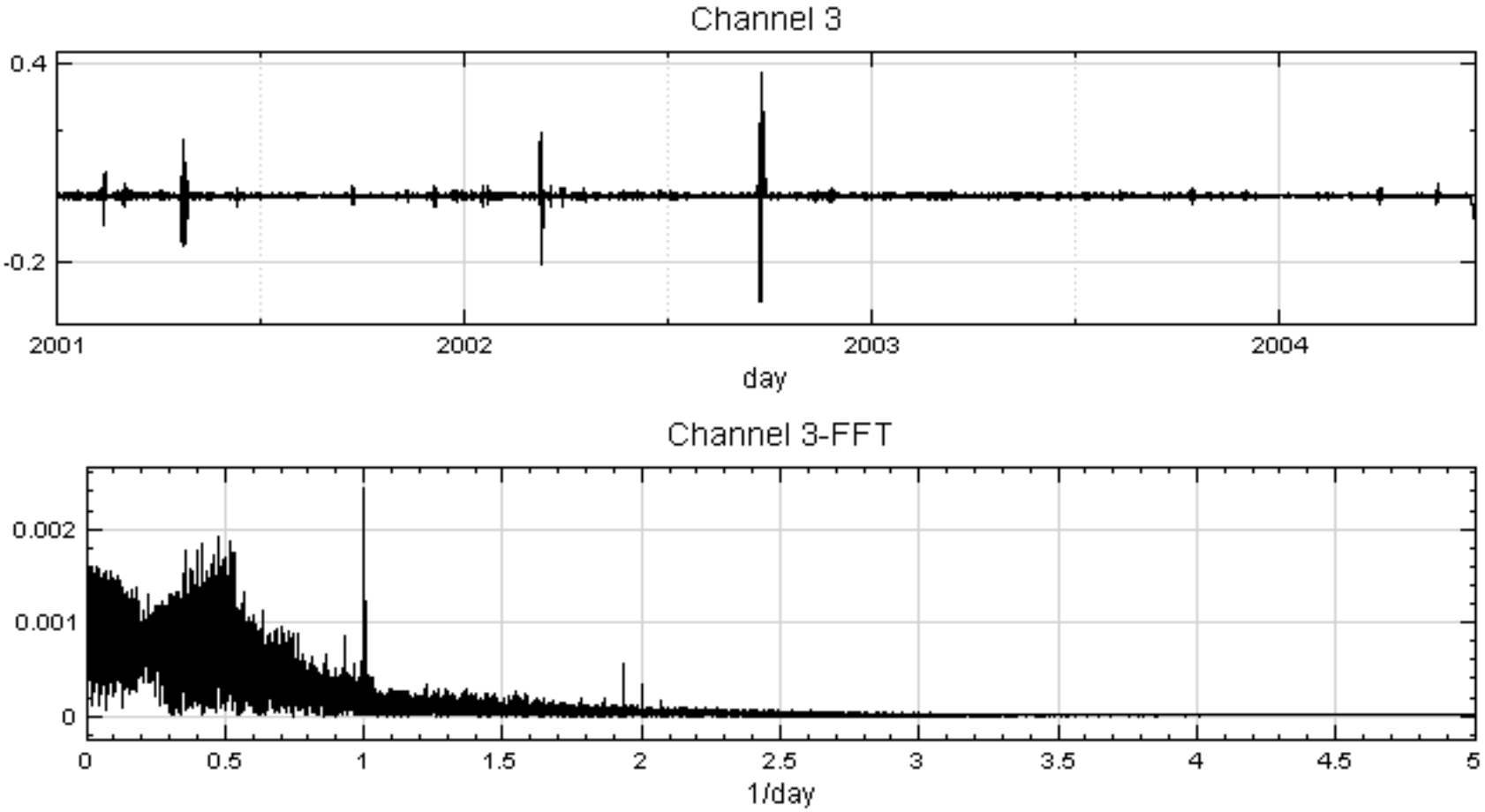
$$\cos(\omega t)+\cos((\omega+\delta\omega)t)\cong 2\cos(\omega t)\cos(\frac{\delta\omega}{2}t)$$

$$T=\frac{2}{f}=\frac{2}{2-1.9323}=29.5 \text{ (days)}$$

IMF2 (semi-diurnal tide)



IMF3 (once per day)



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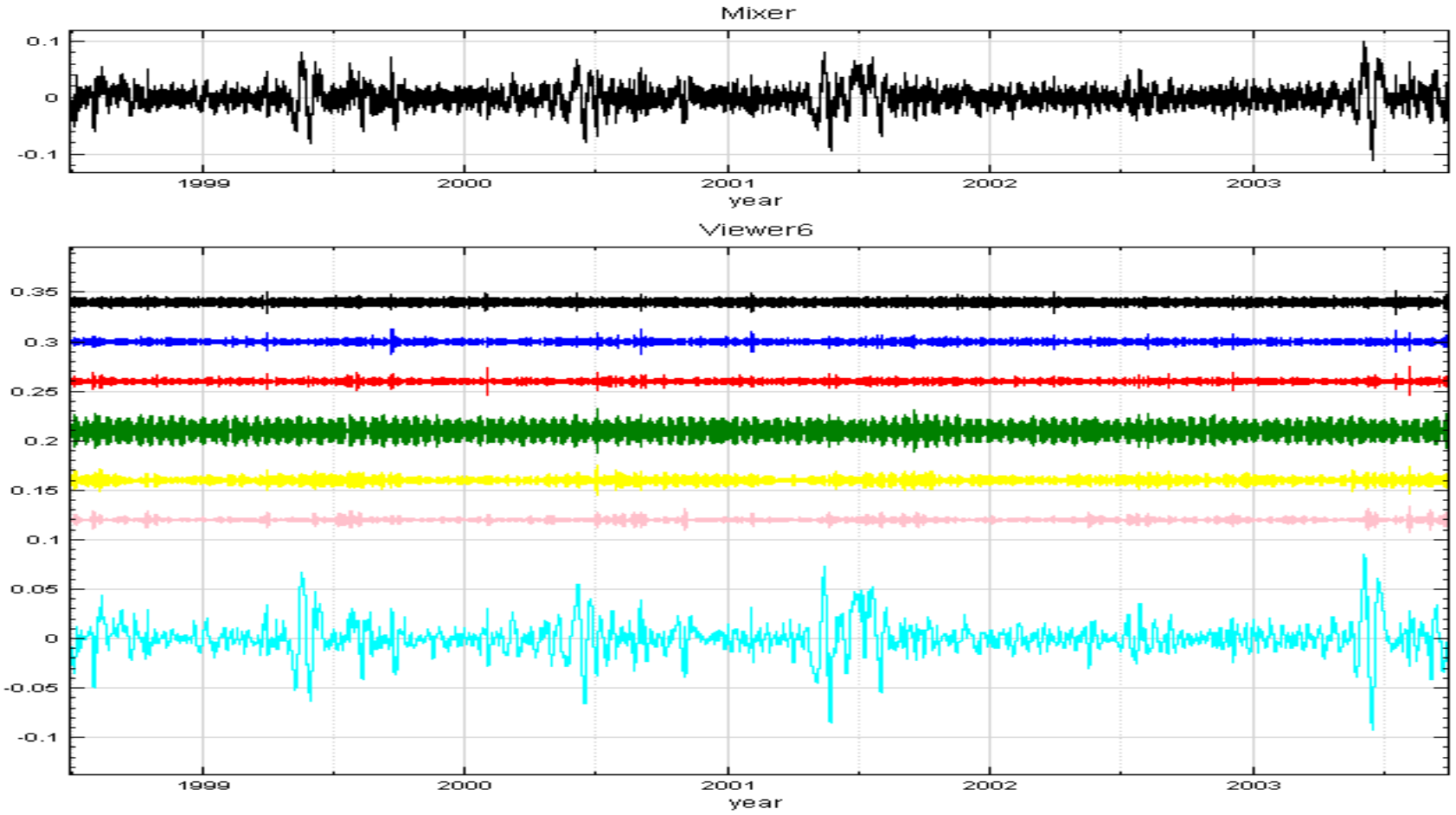
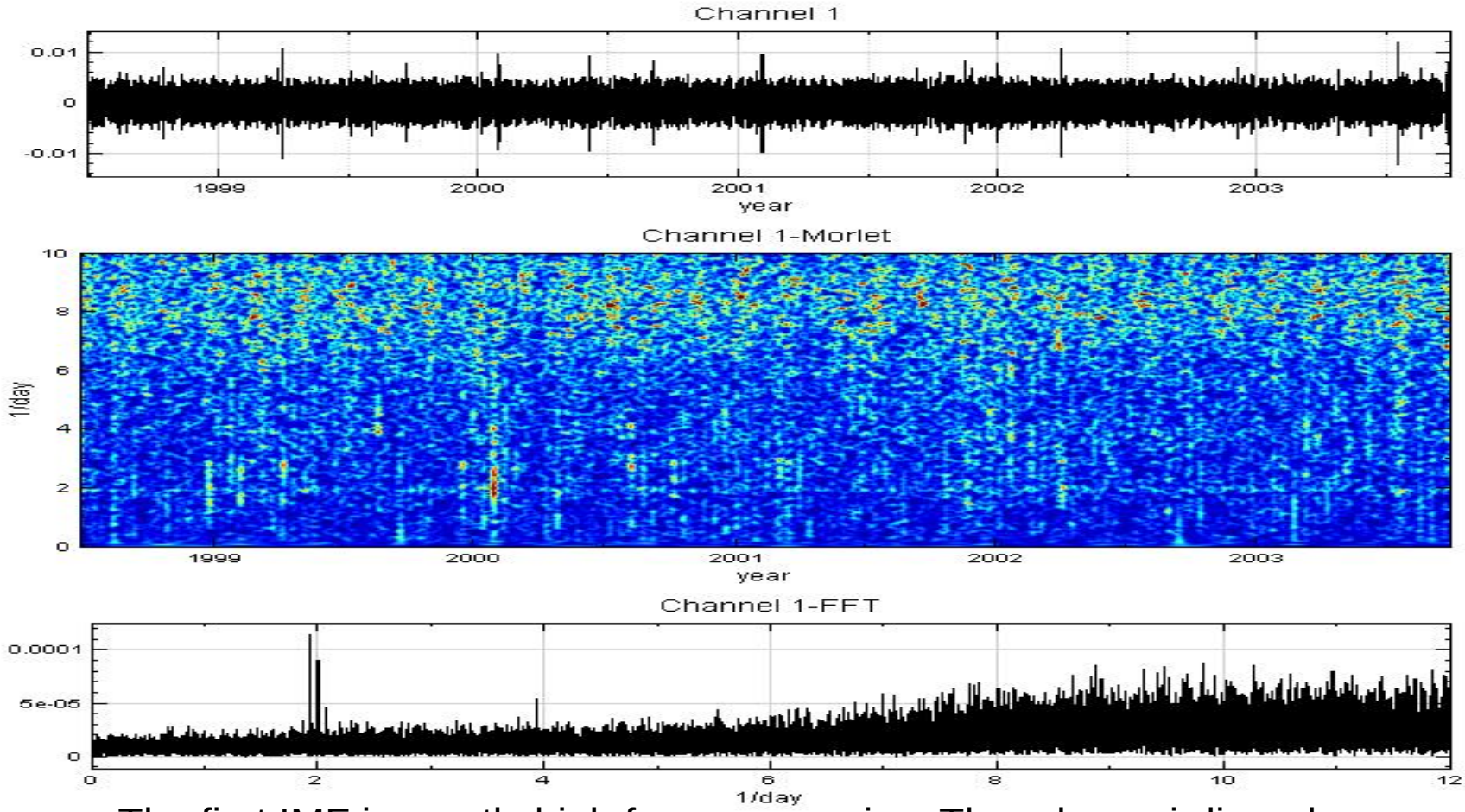
Empirical Mode Decomposition



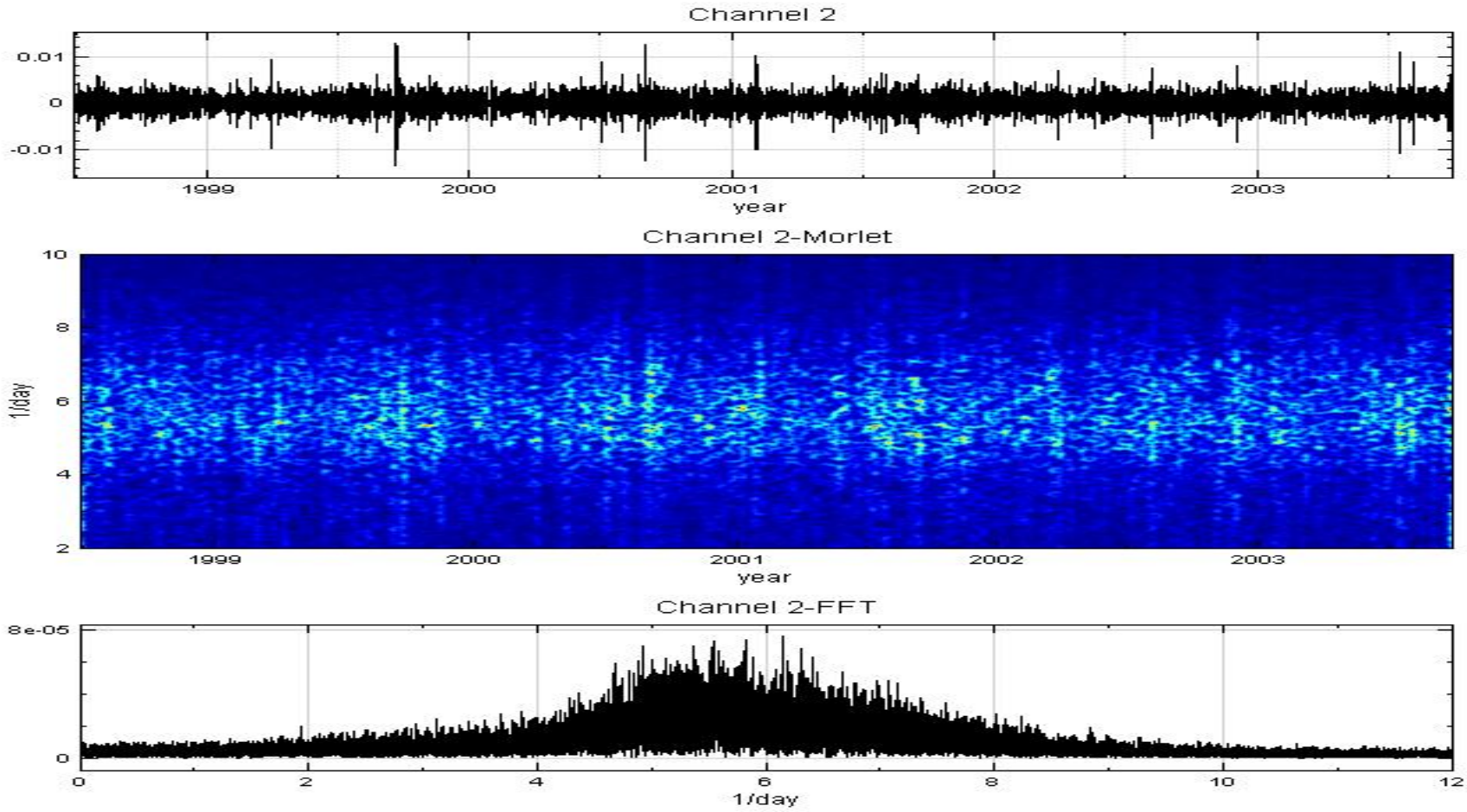
AnCAD

IMF1



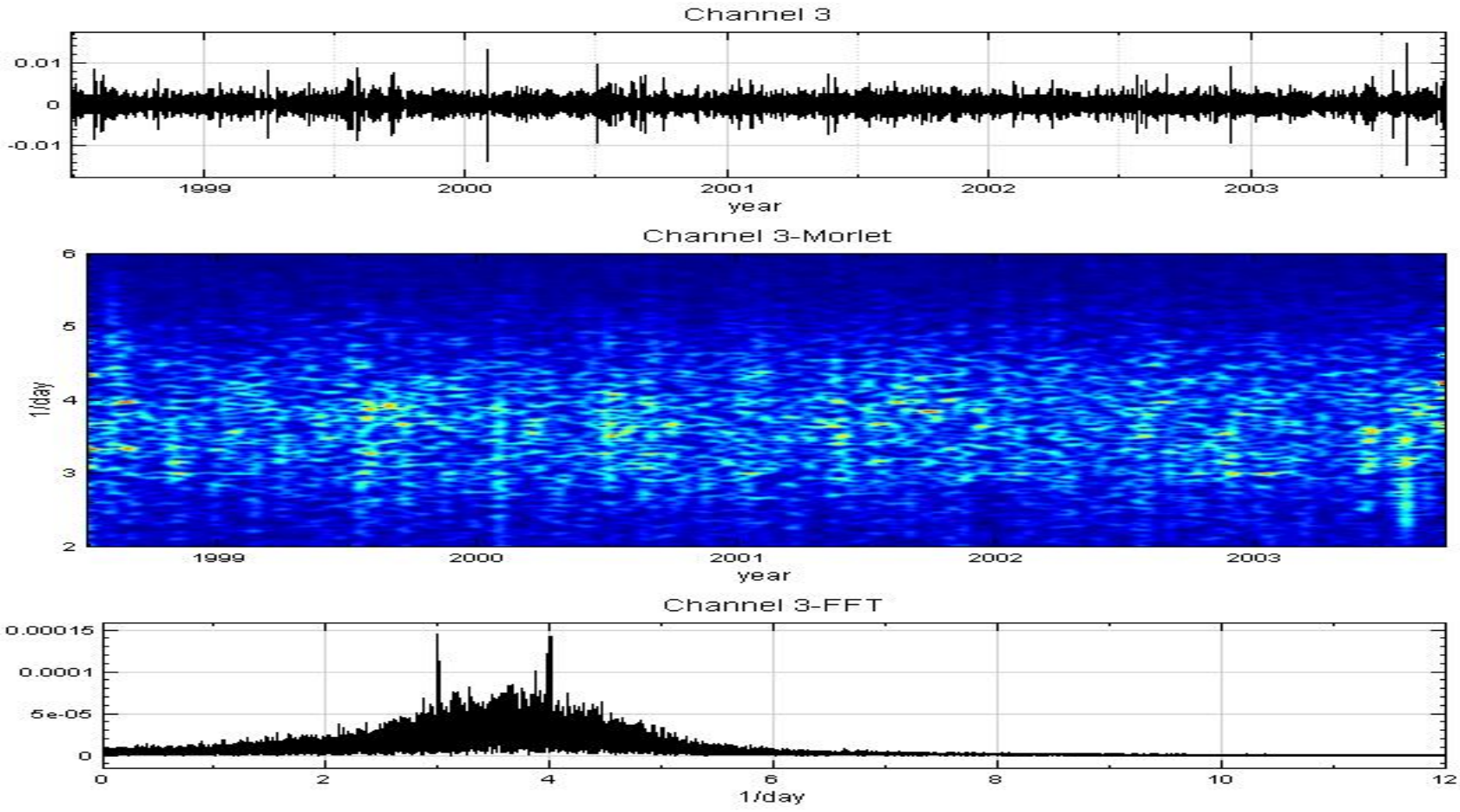
The first IMF is mostly high frequency noise. Though semi-diurnal Frequency appears, its amplitude is small.

IMF2



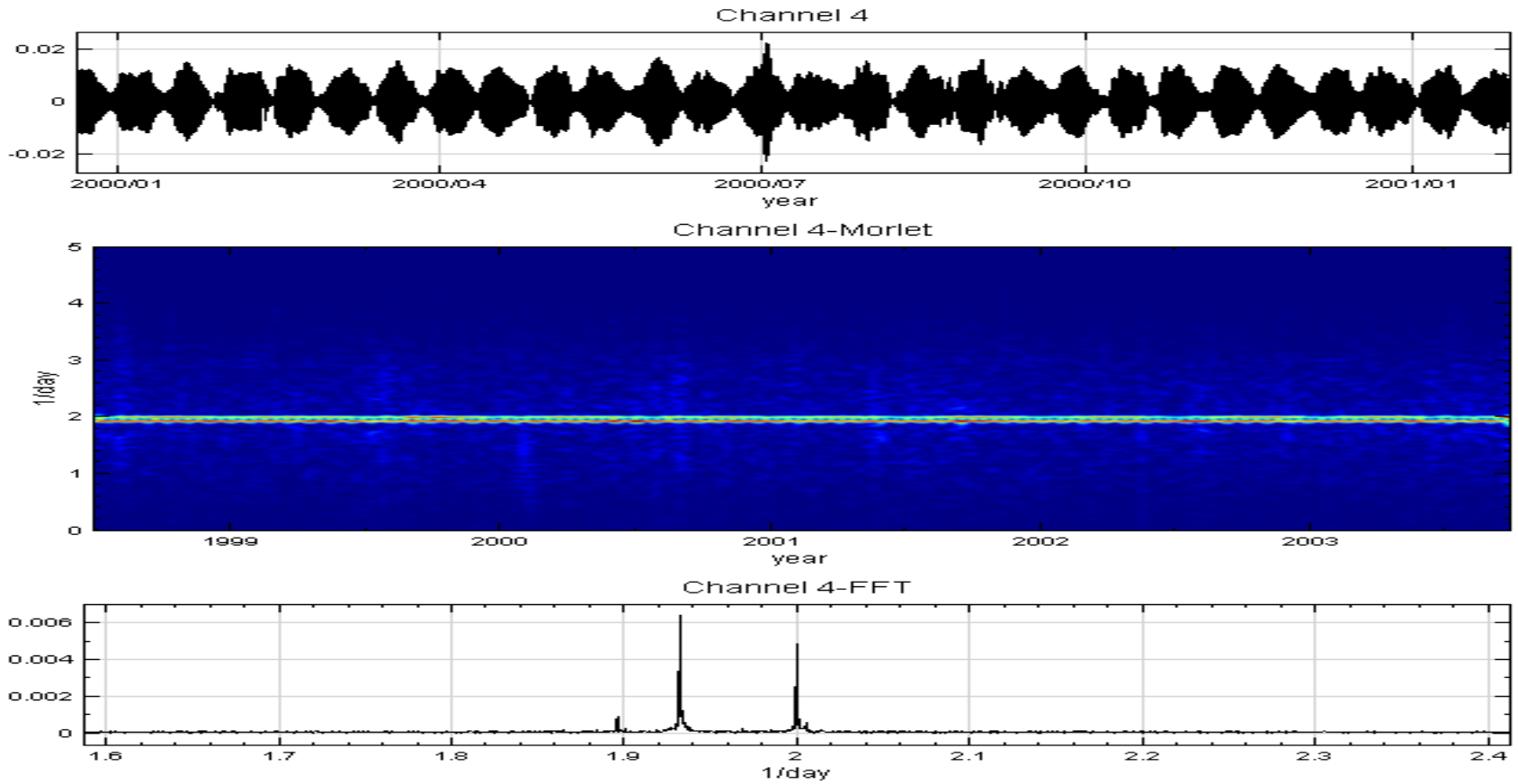
The component is relatively small compared to other IMFs.

IMF3


Channel 3
0.01
0
-0.01
1999
2000
2001
2002
2003
year
Channel 3-Morlet
6
5
4
3
2
1/day
1999
2000
2001
2002
2003
year
Channel 3-FFT
0.00015
0.0001
5e-05
0
0
2
4
6
8
10
12
1/day

AnCAD

IMF4: Semi-diurnal tide



The frequency does not change seasonally. It appears nothing to do with precipitation.
The centrifugal and centripetal forces from the Sun cause the semi-diurnal variation.
Gravitational force from the Moon results in the monthly beat wave phenomena.

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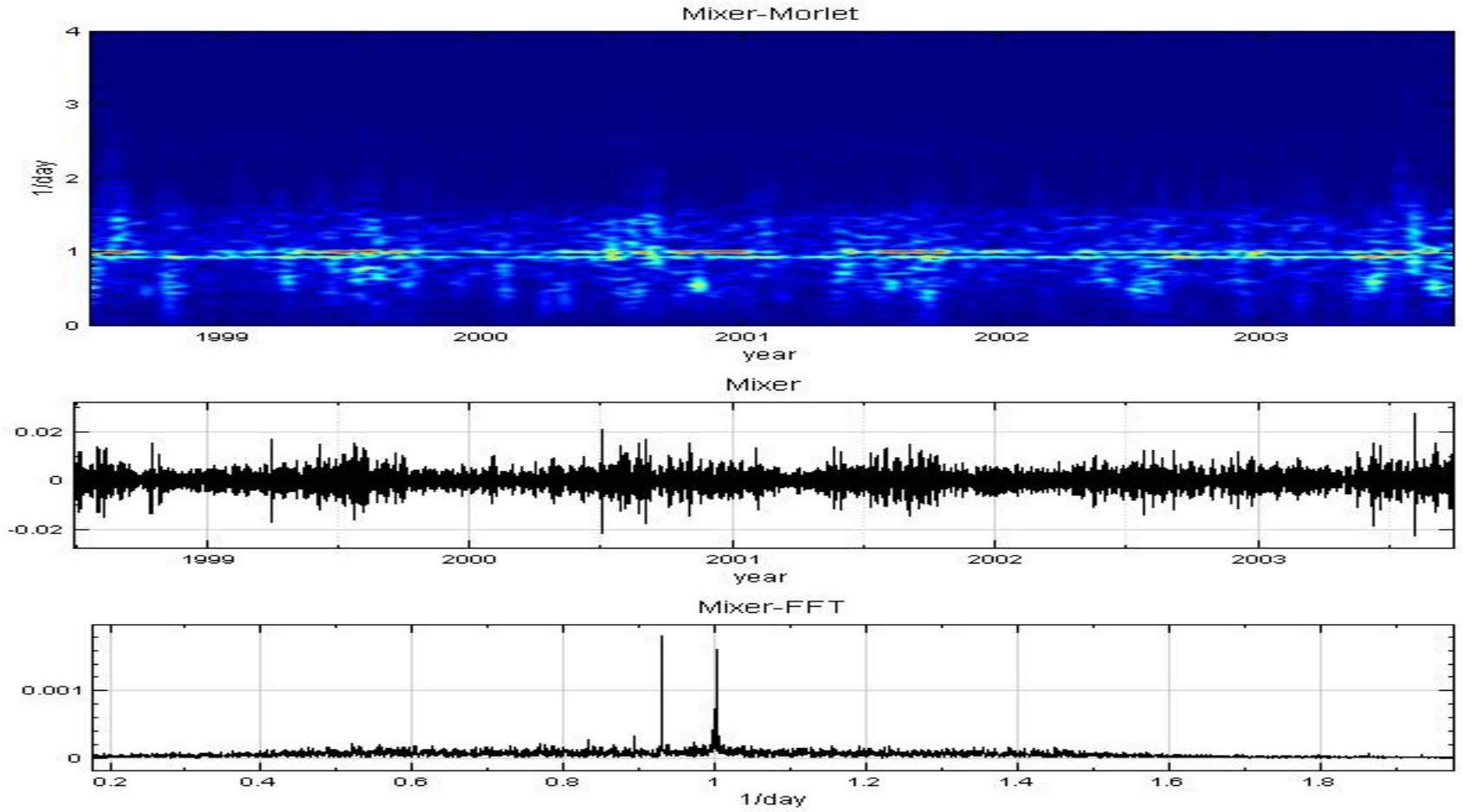
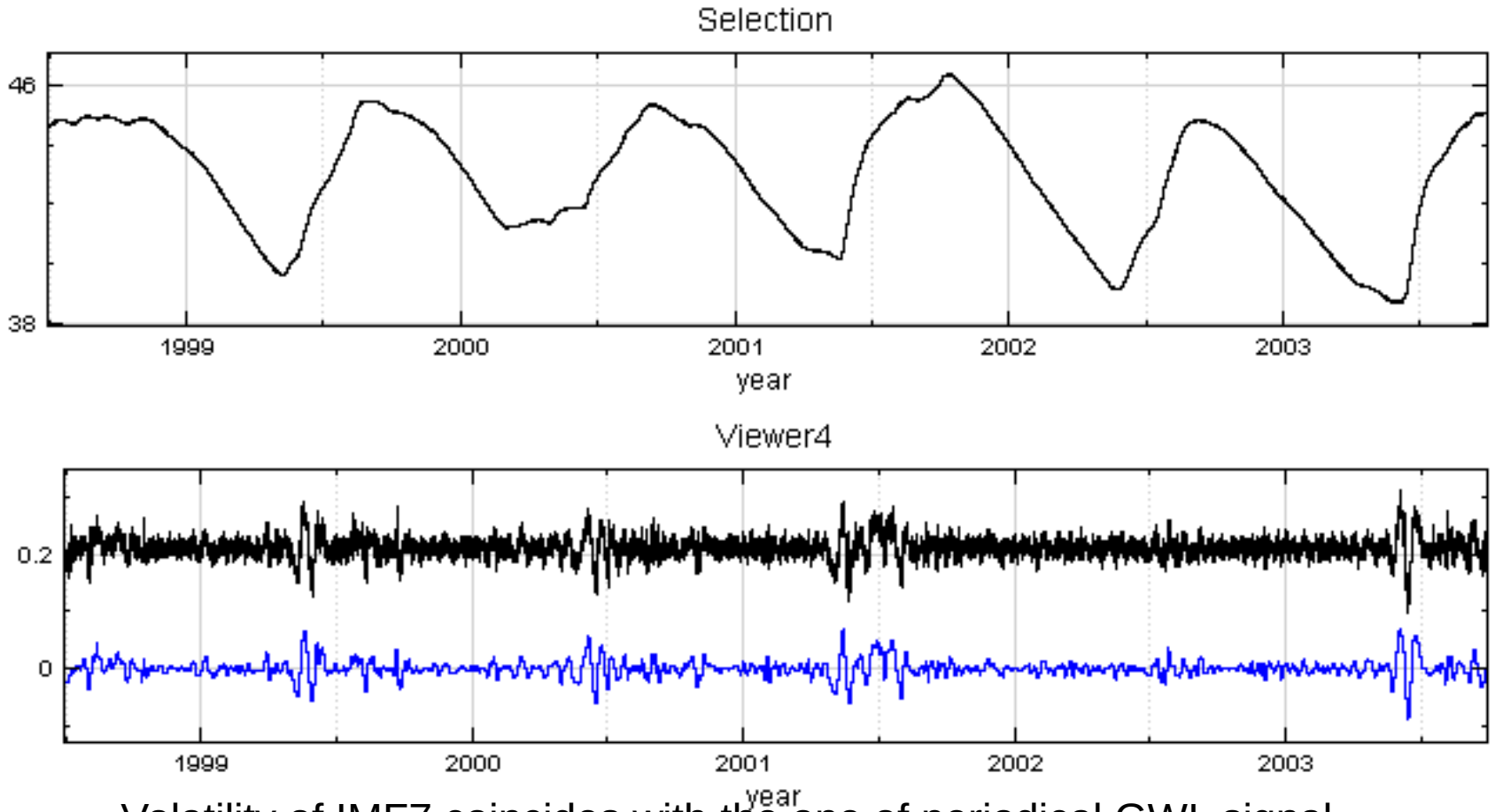
IMF5+IMF6: diurnal period



Note that in TF plot diurnal intensity varies with precipitation.
It might suggest diurnal frequency is caused by precipitate injection to the reservoir.

IMF7: precipitation



Volatility of IMF7 coincides with the one of periodical GWL signal. Increase of volatility correlates with the increase of GWL. This suggests IMF7 is related to precipitation which in this case is the major contribution to the raise of GWL.

Time-Frequency Analysis in Visual Signal

	Fourier Transform	STFT	**Morlet / Enhanced Morlet***	Hilbert Transform	**HHT***
Instantaneous frequency	n/a	distribution	**distribution**	Single value	**Discrete values**
Frequency change with time	no	yes	**yes**	yes	**yes**
Frequency resolution	good	ok	**ok/good**	good	**good**
Adaptive base	no	no	**no**	n/a	**yes**
Handling non-linear effect	n/a	no	**no**	yes	**yes**

*Algorithm used in this study

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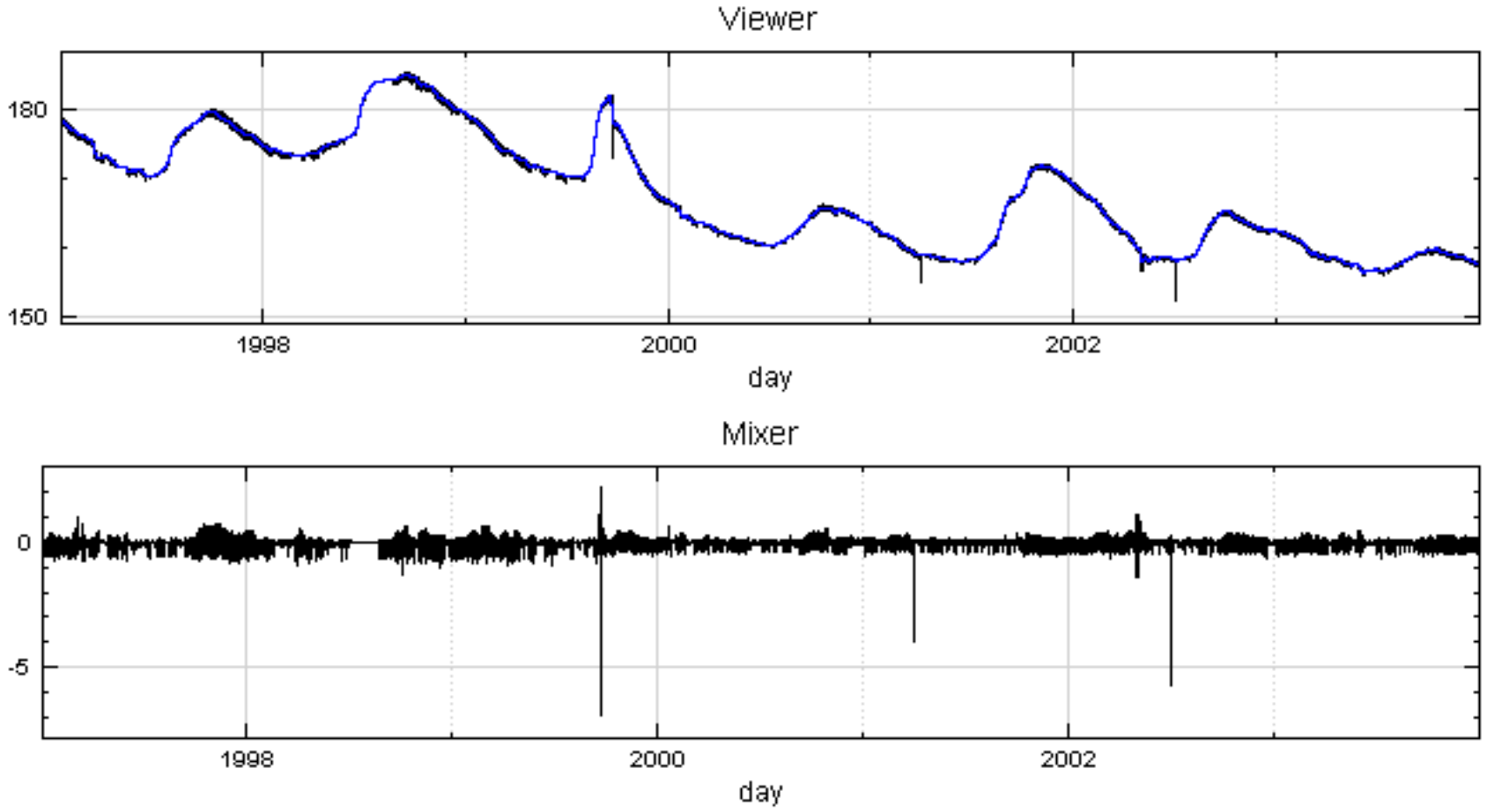
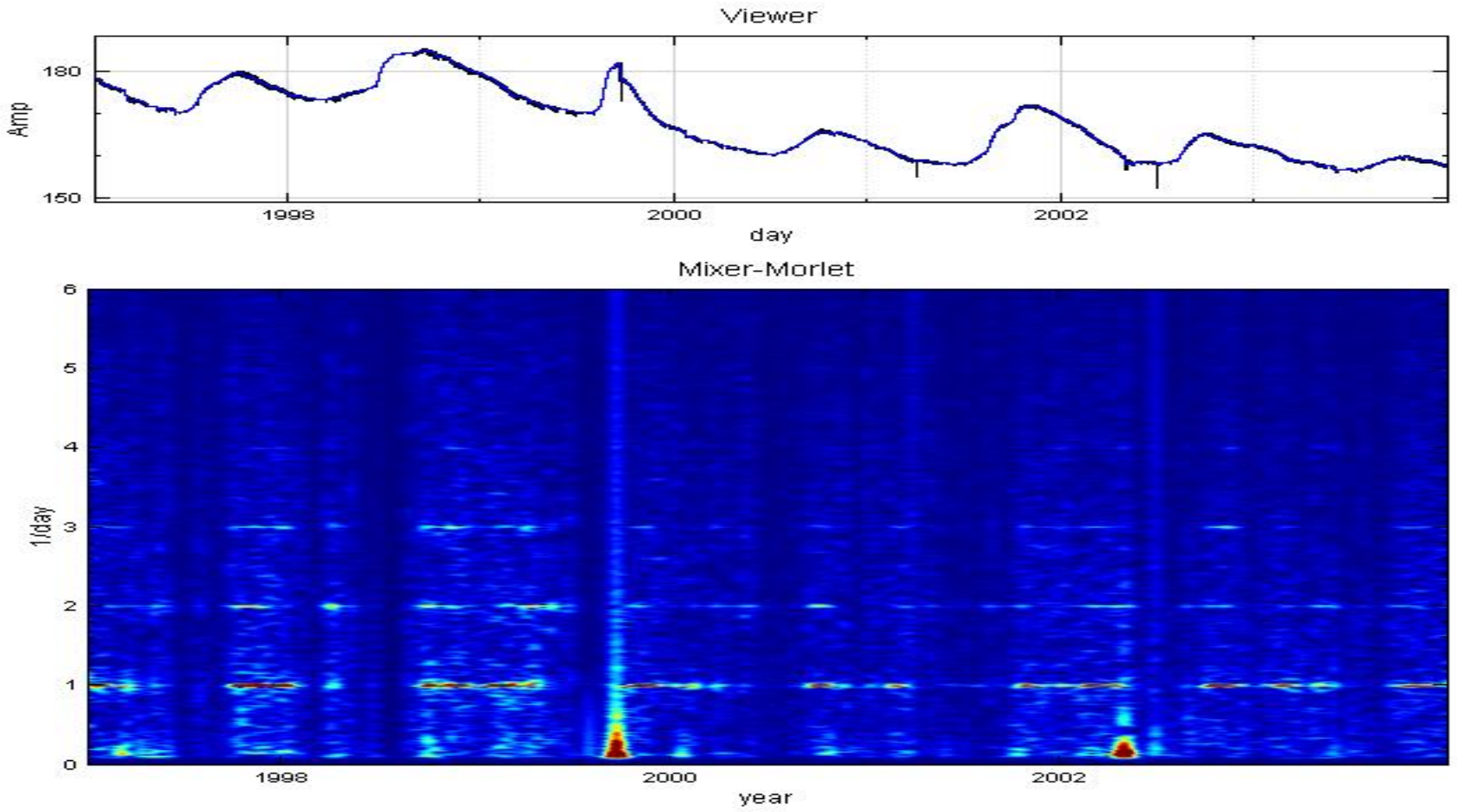
Missing Harmonics: a Precursor to Earthquake?

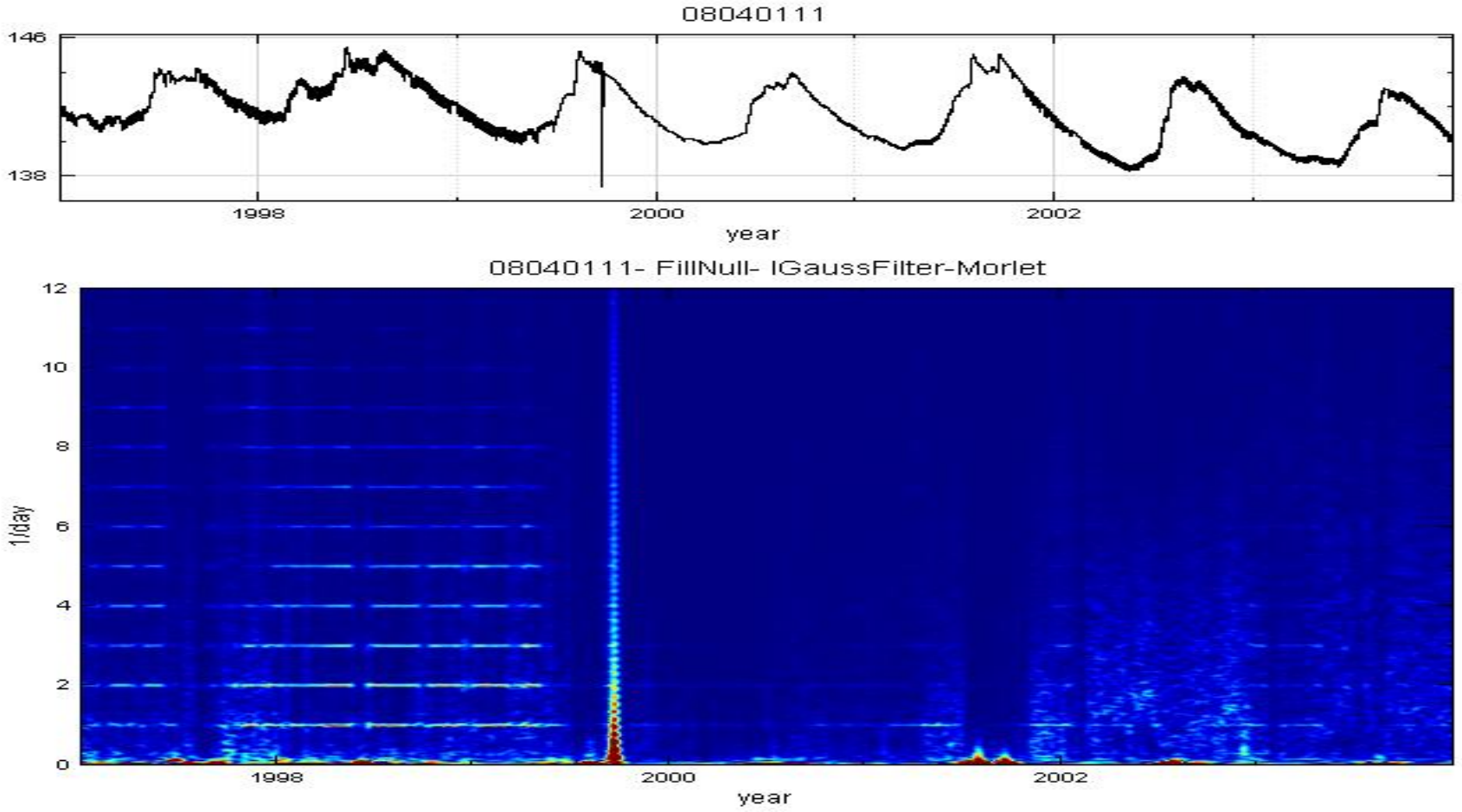
Well around Chi-Chi Earthquake (南投新光)



Well around Chi-Chi Earthquake (南投新光)



Well around Chi-Chi Earthquake (南投竹山(1))



To be clarified

- What is non-periodical signal?
- **How to remove non-periodical signal?**
- **What is frequency? What is instantaneous frequency?**
- What is noise? How to eliminate noise?
- How to identified jump and discontinuity?
- Signal trace is finite. How to eliminate end effects occurred very often in signal processing?

AnCAD

Thank you!