

サッカーのキック動画解析: 飛ぶ・飛ばない・よい姿勢の違い

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1. はじめに

2. データの準備

3. ビデオ動画から得られた位置情報の統計解析

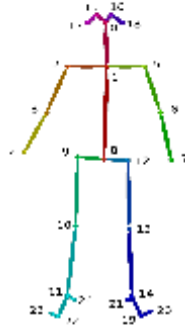
個人番号 ID を **Person** という列で付与しているので、2 人以上のフレームがついている場合でもトラッキング(追跡)することができるデータ・ファイルが **CSV** 形式でできあがっている。 **OpenPose** では、体の得られる点として 25 ポイントが得られるモデルを利用しているので、1 人ついて 25 個の関節を認識するようになっている。その番号と位置は図 1 に与えられている。

データがとれなかったゼロの入っているポイントがある。 P5, P19, 半身像では P11-12, P14-15, P18 と P20 以降, P19 以降である。

全身像でも向かって右肩 P5 と右足親指 P19 がゼロになる。

半身像の動画ファイル 4,5,6 では、P11-12, P14-15 がゼロ、ファイル 4 では P18 がゼロで P20 以降がゼロ、ファイル 5 と 6 では P19 以降がゼロとなっている。

図1 OpenPose25



OpenPose 25 のモデル

3.1 関節の角度の時間経過の計算

たとえば，ひじの位置を O ，肩を A ，手を B ，角 $AOB = \theta$ とする．それぞれの点の位置ベクトルが座標で与えられているので， $\vec{a} = \overrightarrow{OA}$, $\vec{b} = \overrightarrow{OB}$ が計算できて，

$$x = \cos\theta = \frac{\vec{a} \cdot \vec{b}}{\sqrt{|\vec{a}| |\vec{b}|}}$$

から， $\theta = \cos^{-1}x$ (プログラムでは `acos(t)` の部分) でひじの角度が計算できる．

3.2 関節の位置から関節の角度の計算を行う

プロセスの最後では，角度 θ を計算し，値を `theta` に保存している．その値は `theta(i,j)` であらわすが，ここで i は体の位置を計算したフレームの番号， j は 1, ..., 18 までの関節の番号である．

3.3 角度の図示

18 箇所の関節の角度を 6 つずつ表示する．

- 首からひじの角度の図示 図は左右のクビ，肩，ひじにかけての角度の動きを折れ線グラフで表したものである．
- 腰からひざの角度の図示 図は左右の腰，大腿部，ひざにかけての角度の動きを折れ線グラフで表したものである．
- 足首からつまさきの角度の図示 図は左右の足首，つま先，についての角度の動きを時間を折って折れ線グラフに表したものである．

x 座標は `t_movie` で，フレームの枚数が図に `index` として表示されている．

`t_movie` は 0 から 1 までの値を等分している．時刻の経過は，全体を 1 とした尺度(`t_movie`)で表している．

3.4 Fourier 解析による periodogram

周期的な振動を見つけようとするグラフである．グラフは 2 枚で一組で，下段の **Smoothed Periodogram** で見る．左の値の小さいものは，高い振動数なので，細かなブレということになる．基本的に細かなブレが観察されるが，大きなブレではっきりとした周期は見られないといえる．

3.5 Wavelet 解析による periodogram と cross-periodogram

フーリエ解析のピリオドグラムでは，どの周波数(振動数, x 軸)に対して強いスペクトル密度が観察されるかが示されている．しかし，その周期性が動画のどの時点での動きから得られた値であるかがわからない．ウェーブレット解析では，それが，時間の経過とともに周期性の強度（スペクトル密度）が変化していくかを測定することができる．

ウェーブレット解析の場合，スペクトル密度(強度)は色で表されている．赤が強いことを表している．x 軸は時間の流れである．y 軸は周波数(振動数)である．ピリオドグラムであるので，y 軸は周期(period)を表している．値が小さい方が周期が短く，振動数が大きいので，回転が速い(高周波)ということができる．

図は左右の関節部の角度が同調しているかどうかをクロス・ウェーブレット解析によって確かめてみる．図のなかで，強いスペクトル密度が観察されている赤い領域に，矢印が描かれているが，これは影響を与えている方向を示している．

最期の図は，計測されたスペクトル密度の値がゼロと違うかどうかの統計的有意性を調べている．赤い点が得られている周波数の点は強いスペクトル密度が得られているということができる．

各動画について，つぎの順番で図が示されている．

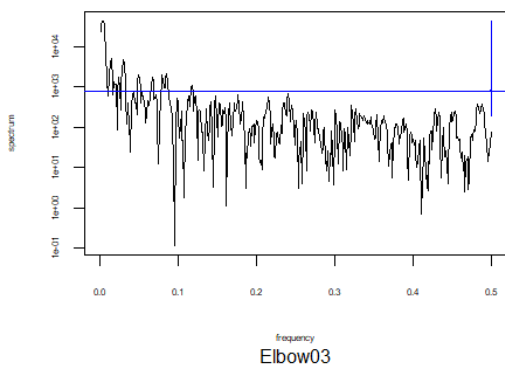
- 肩(02, 05)の関節の Fourier 解析による periodogram

- 肩(02, 05)の Wavelet 解析による periodogram と cross-periodogram
- ひじ(03, 06)の関節の Fourier 解析による periodogram
- ひじ(03, 06)の Wavelet 解析による periodogram と cross-periodogram
- 大腿部(09, 12)の Fourier 解析による periodogram
- 大腿部(09, 12)の Wavelet 解析による periodogram と cross-periodogram
- ひざ(10, 13)の Fourier 解析による periodogram
- ひざ(10, 13)の Wavelet 解析による periodogram と cross-periodogram
- 足首(11, 14)の Fourier 解析による periodogram
- 足首(11, 14)の Wavelet 解析による periodogram と cross-periodogram

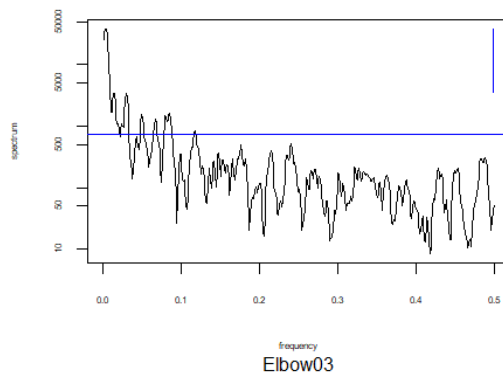
関節と番号	R の変数	関節と番号	R の変数
首左肩 01	theta[, 1]	右腰腿 12	theta[,10]
首右肩 01	theta[, 2]	左ひざ 10	theta[,11]
左肩 02	theta[, 3]	右ひざ 13	theta[,12]
右肩 05	theta[, 4]	左足首 11	theta[,13]
左ひじ 03	theta[, 5]	右足首 14	theta[,14]
右ひじ 06	theta[, 6]	右足先 19	theta[,15]
左腰胴 08	theta[, 7]	左足先 22	theta[,16]
右腰胴 08	theta[, 8]	左足甲 11	theta[,17]
左腰腿 09	theta[, 9]	右足甲 14	theta[,18]

飛ぶ人の動画

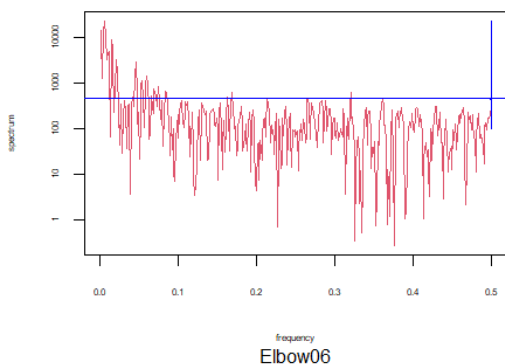
Fourier Spectrum Original Sakura_Tobu



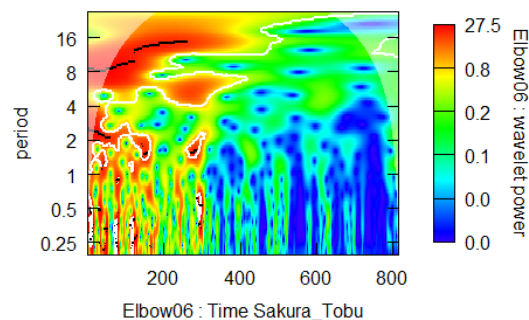
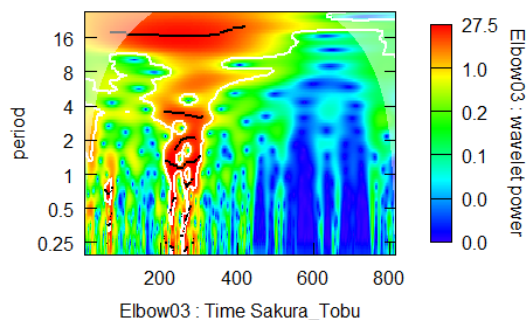
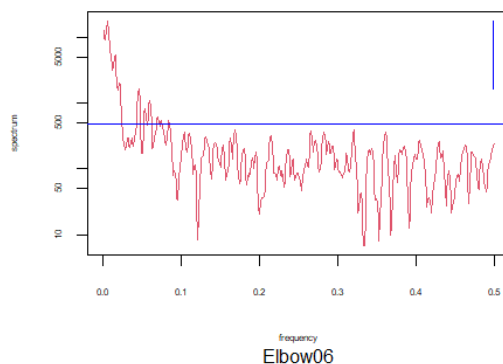
Fourier Spectrum Smoothed Sakura_Tobu

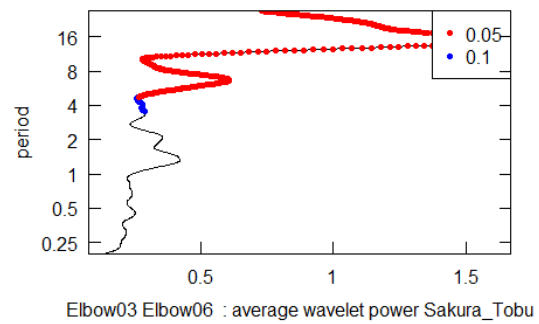
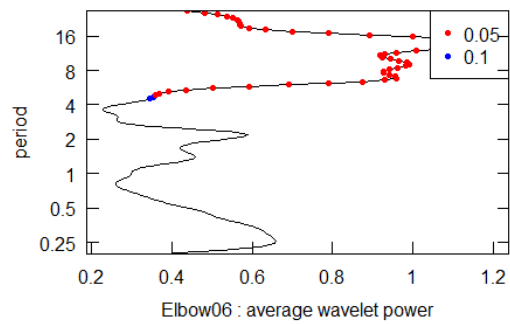
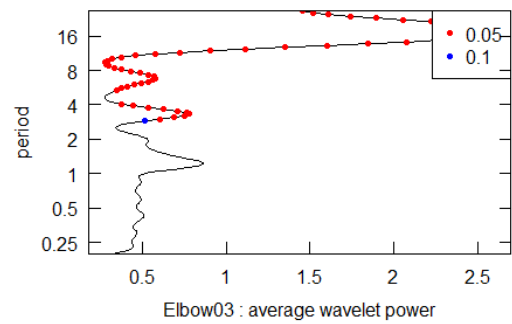
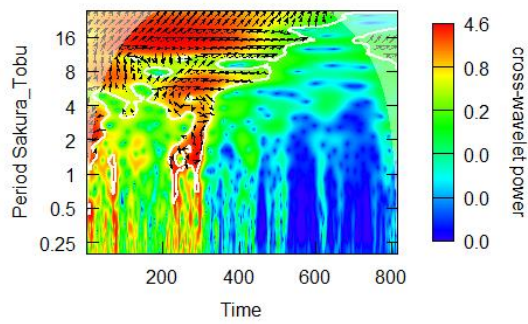


Fourier Spectrum Original Sakura_Tobu

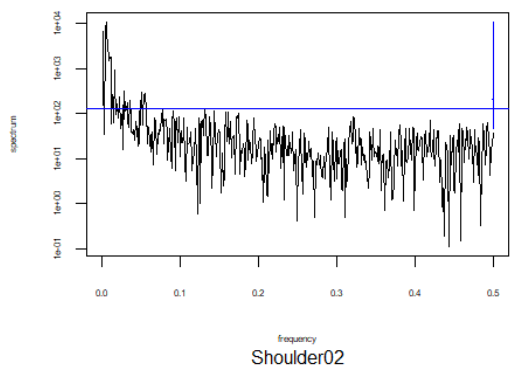


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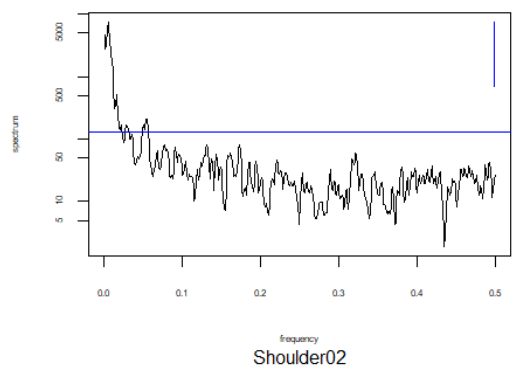




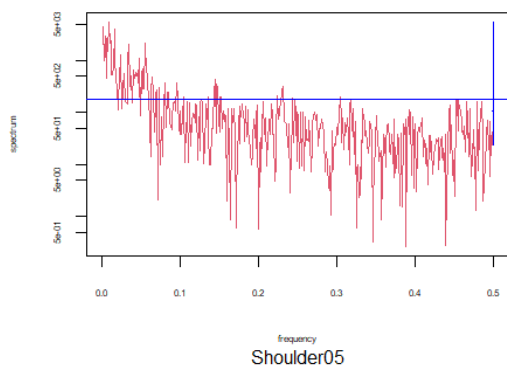
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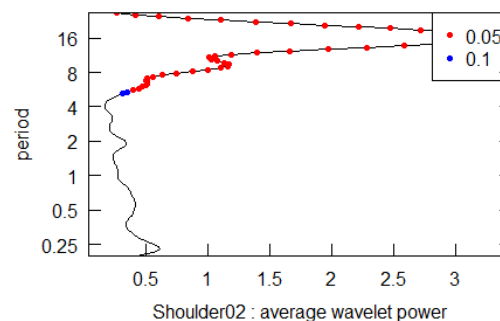
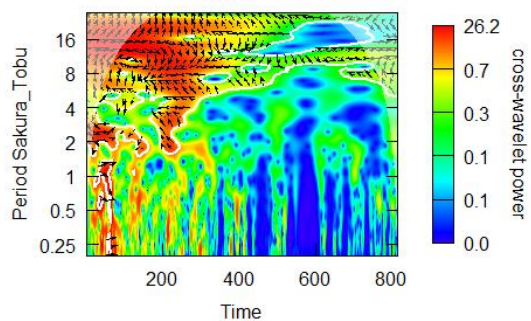
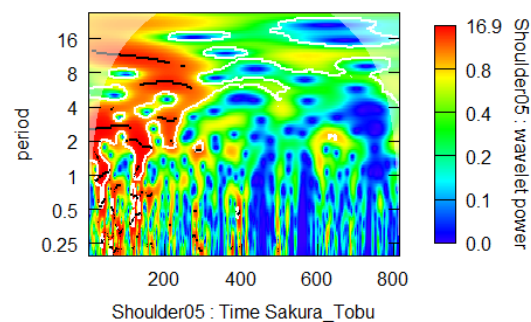
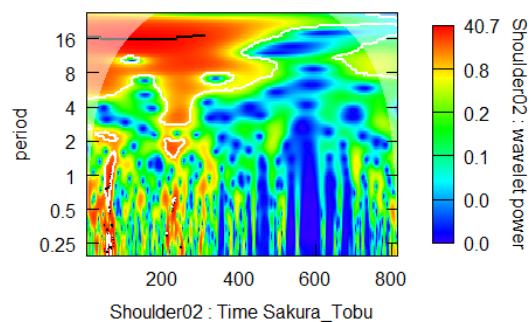
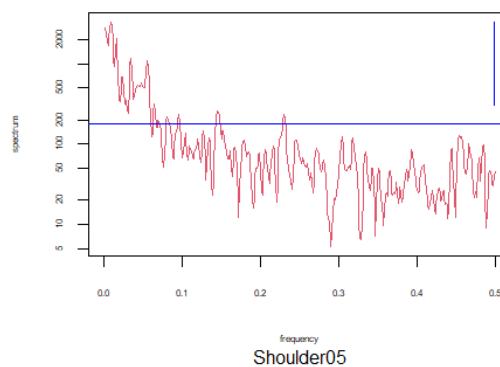
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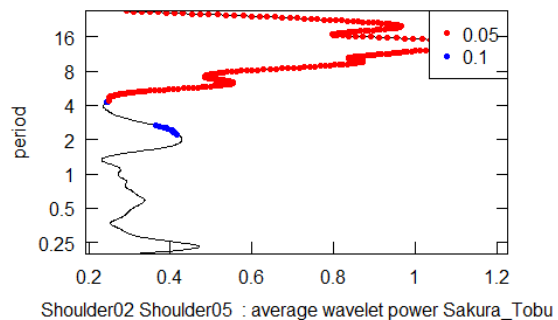
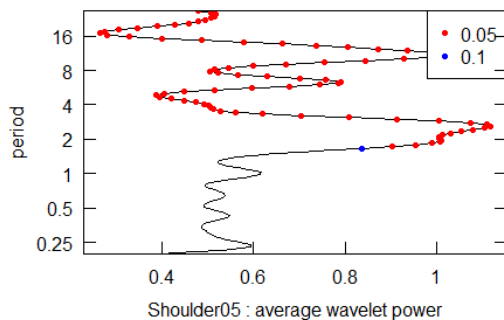


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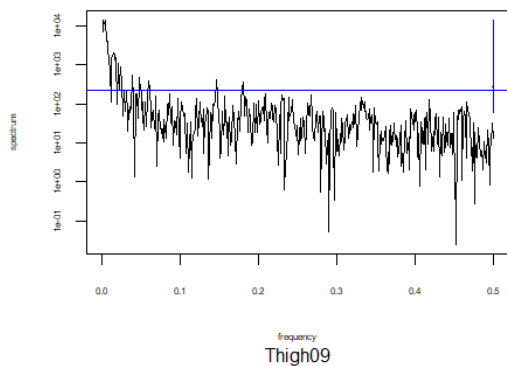


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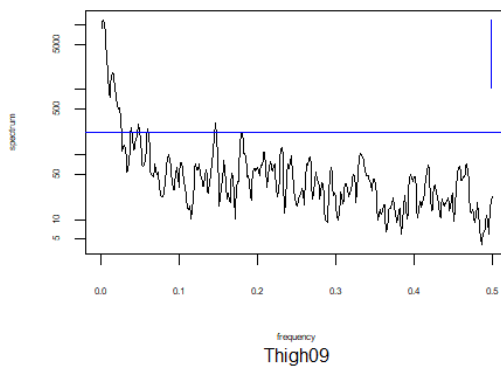




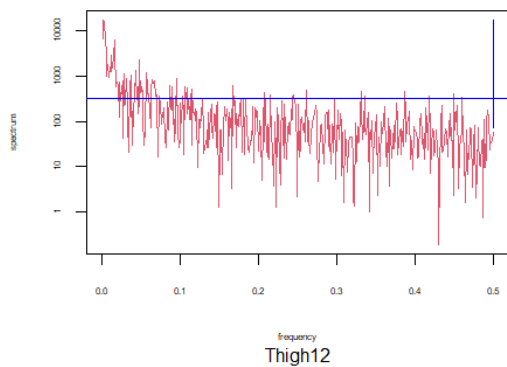
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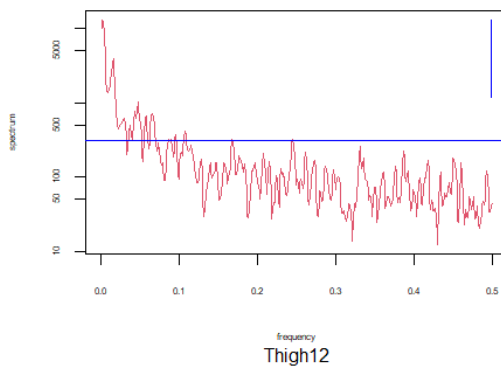
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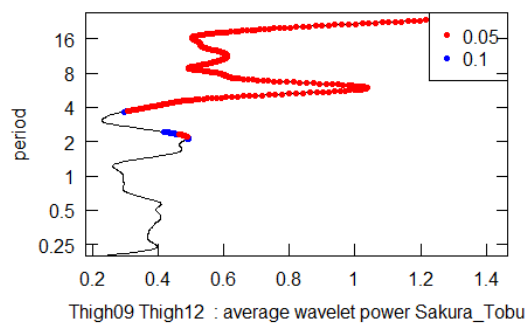
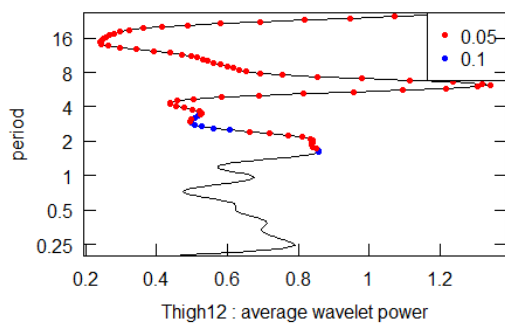
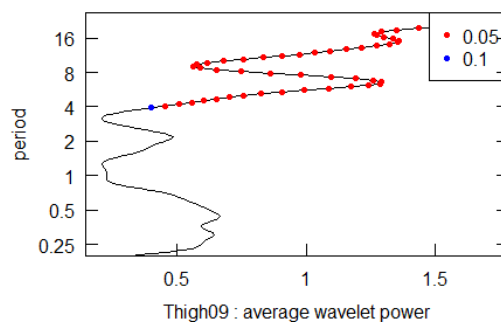
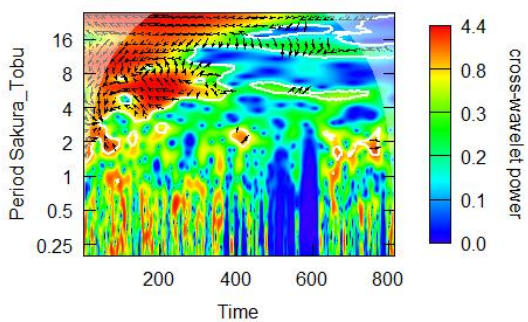
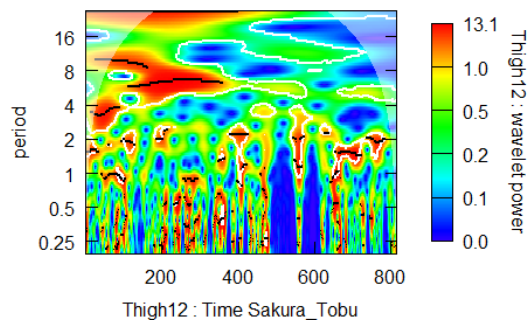
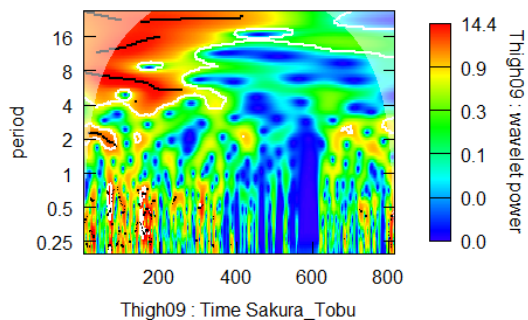


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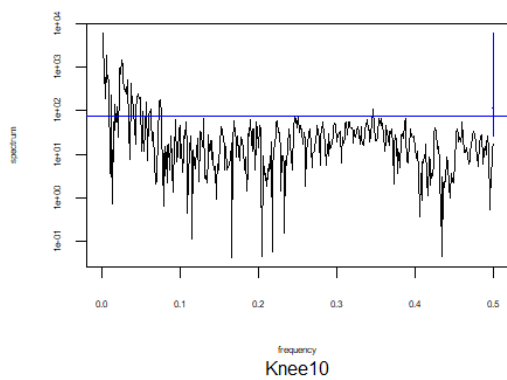


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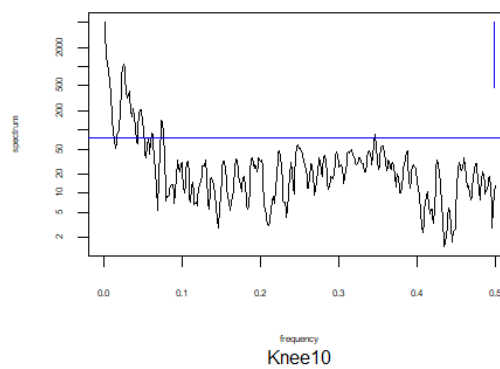




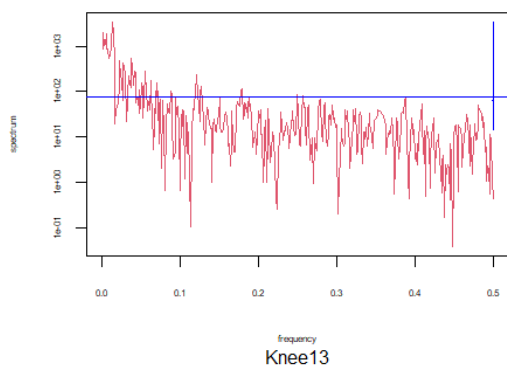
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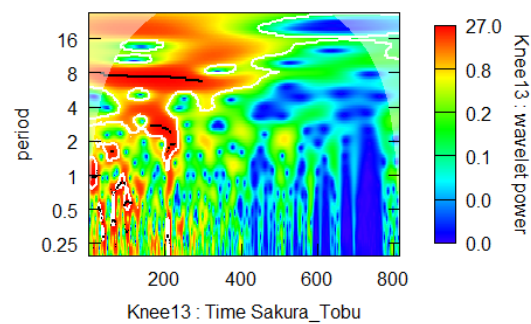
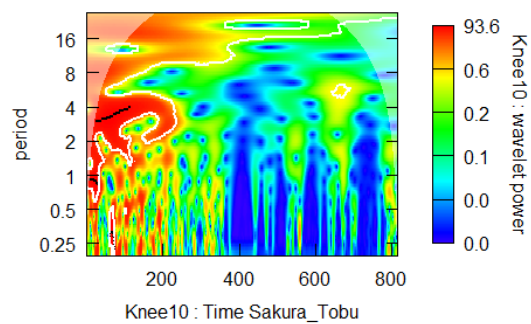
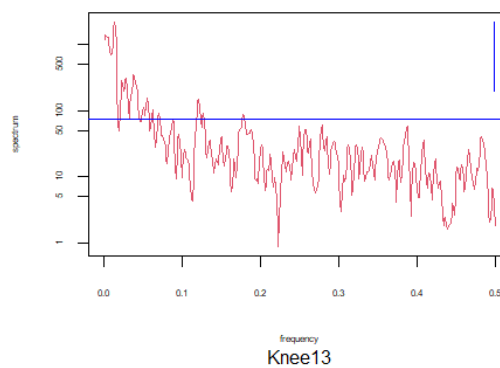
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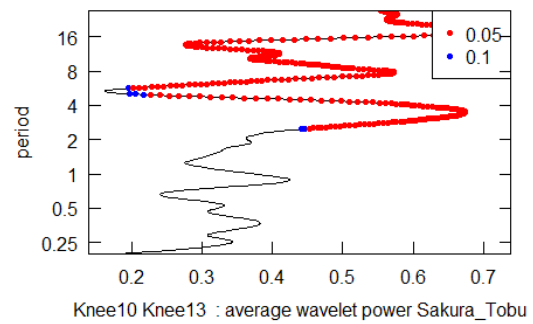
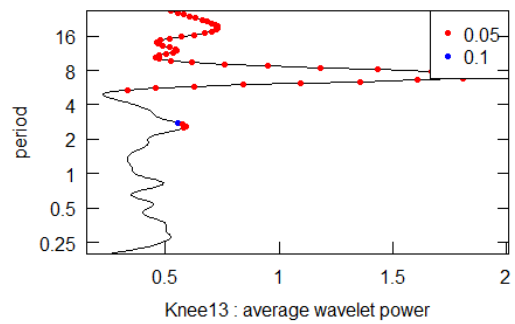
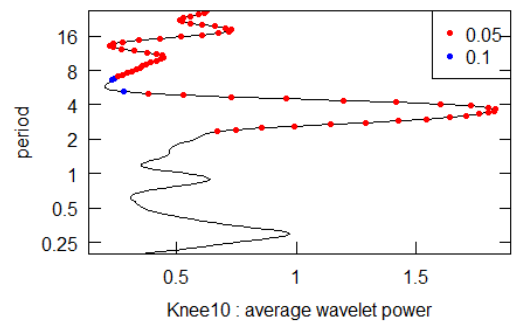
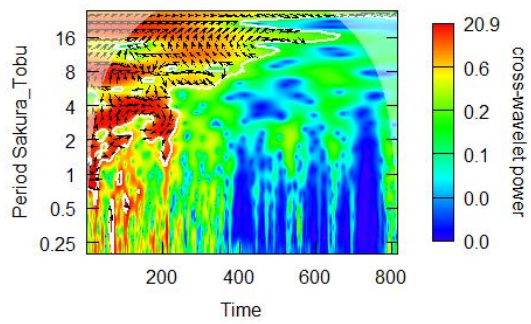


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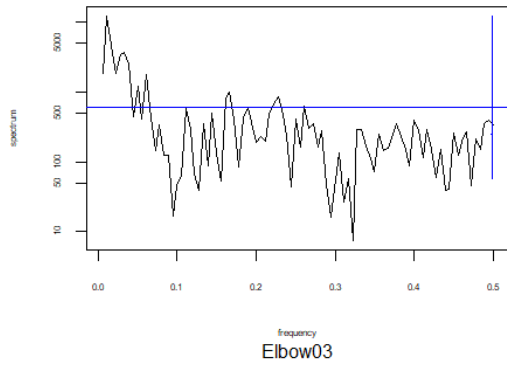
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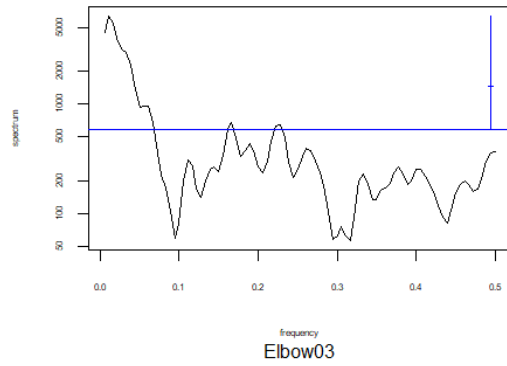


飛ぶ人の横からの動画

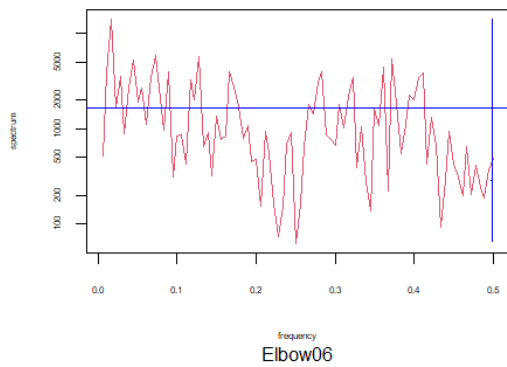
Fourier Spectrum Original Sakura_Tobu_Yoko



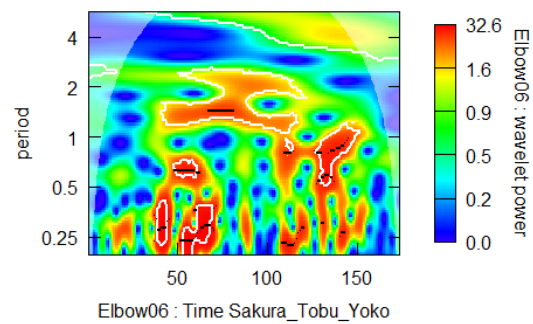
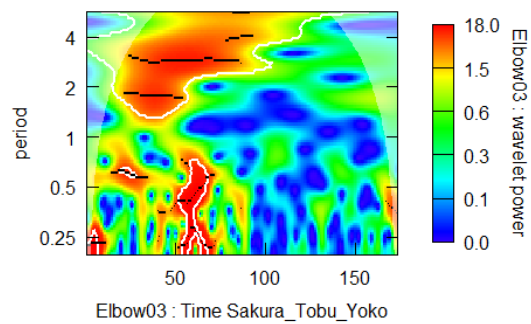
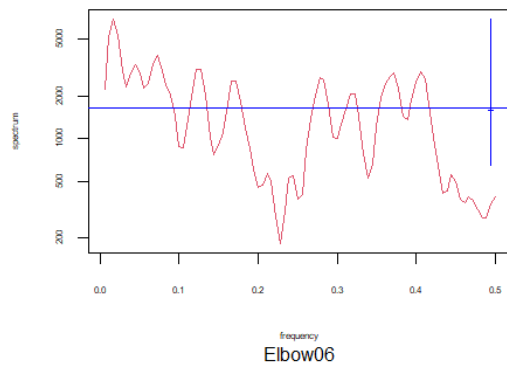
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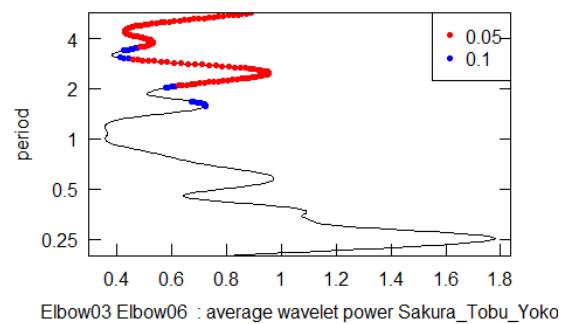
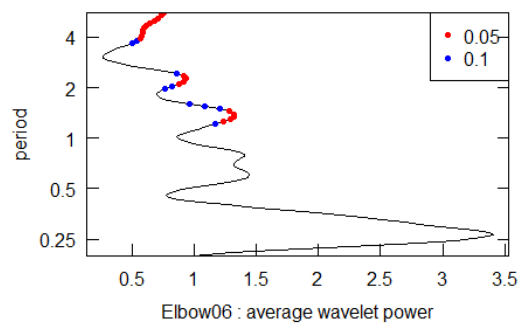
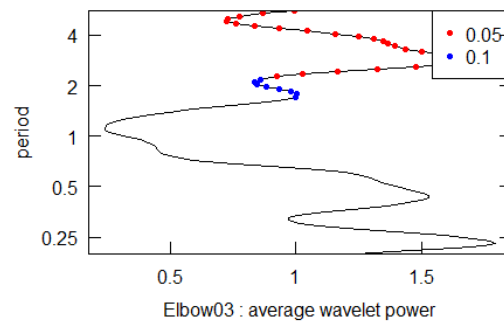
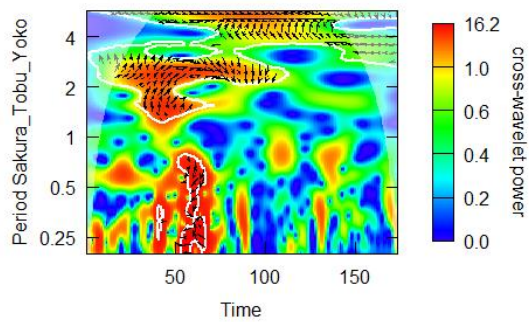


Fourier Spectrum Original Sakura_Tobu_Yoko

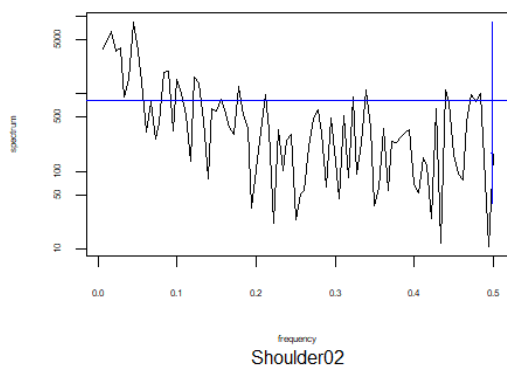


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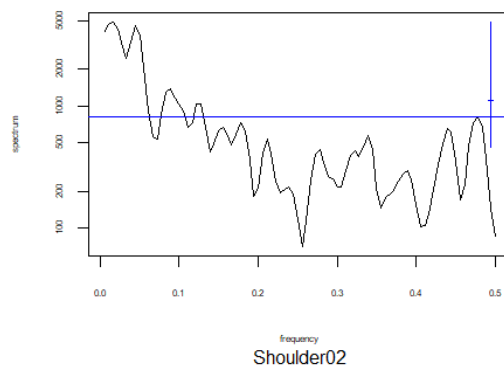




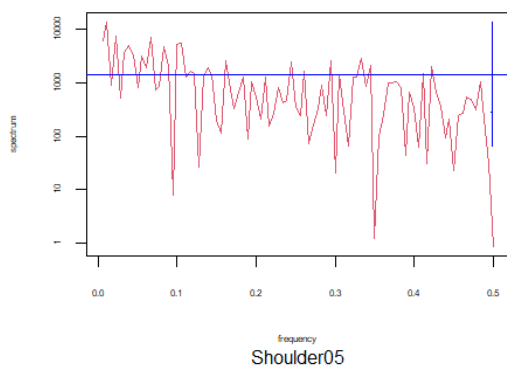
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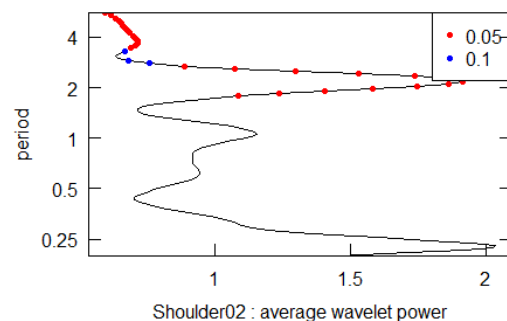
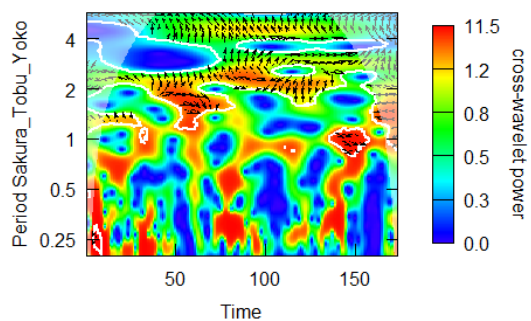
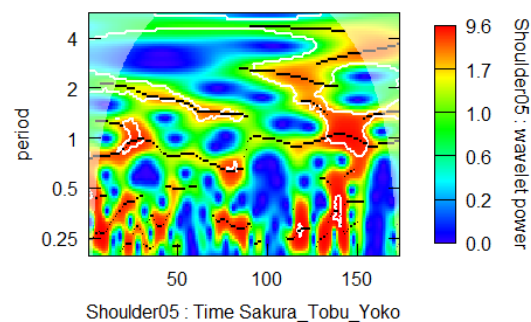
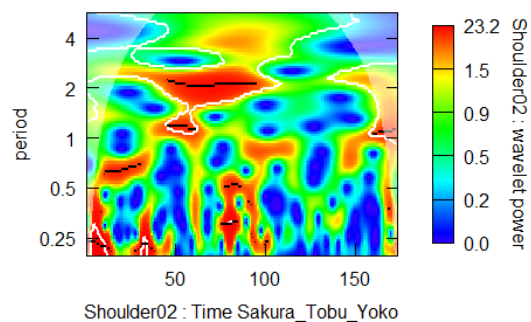
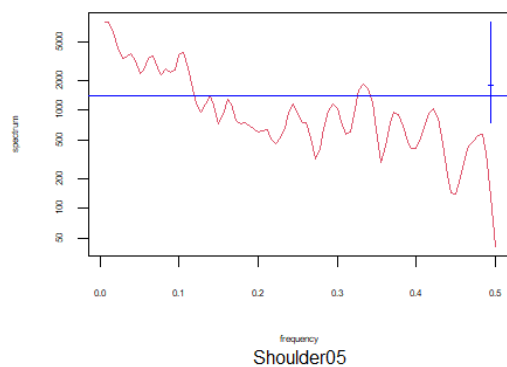
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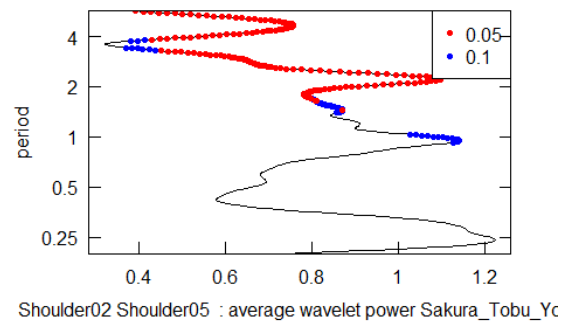
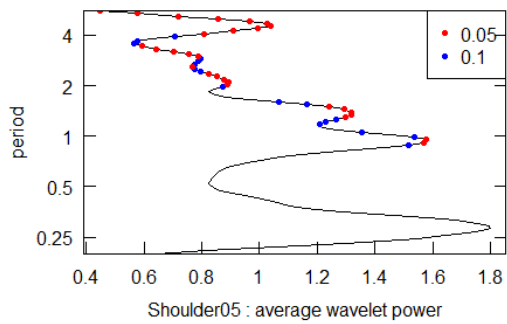


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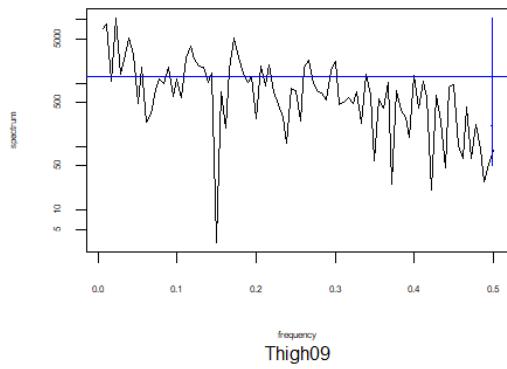


Fourier Spectrum Smoothed Sakura_Tobu_Yoko

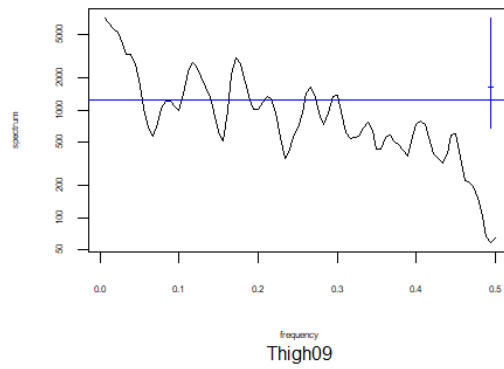




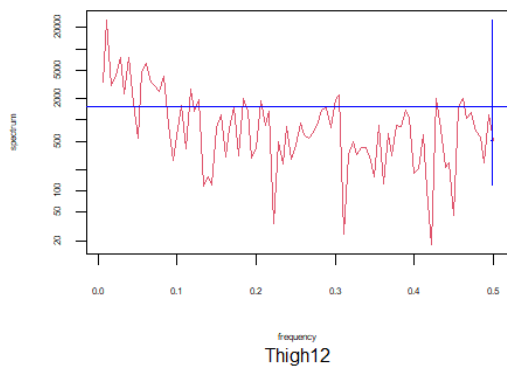
Fourier Spectrum Original Sakura_Tobu_Yoko



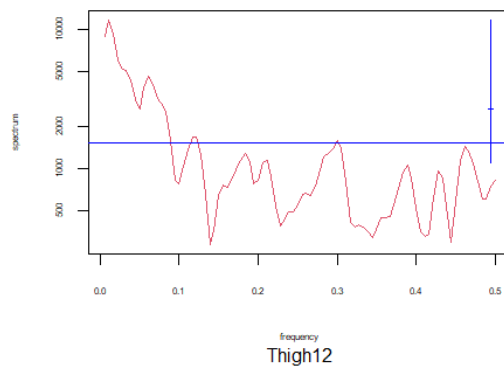
Fourier Spectrum Smoothed Sakura_Tobu_Yoko

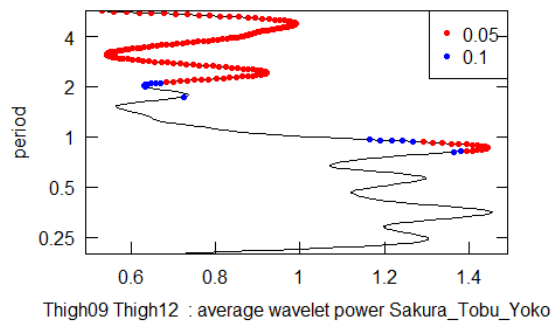
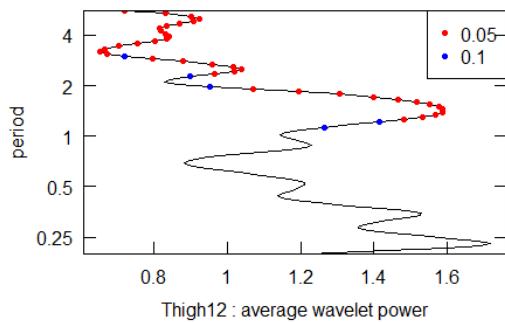
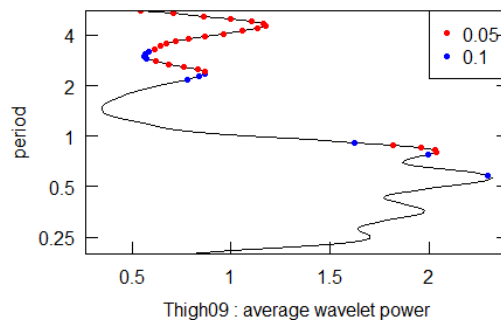
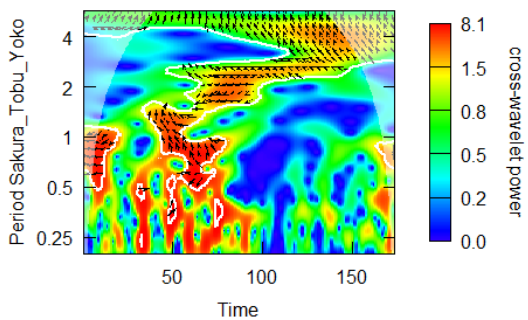
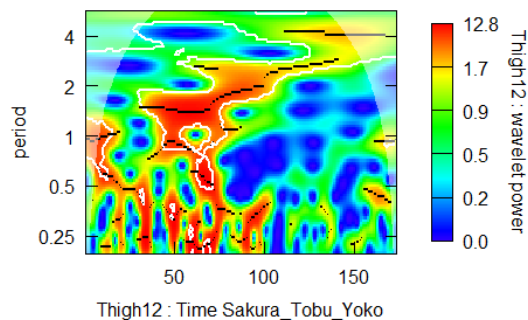
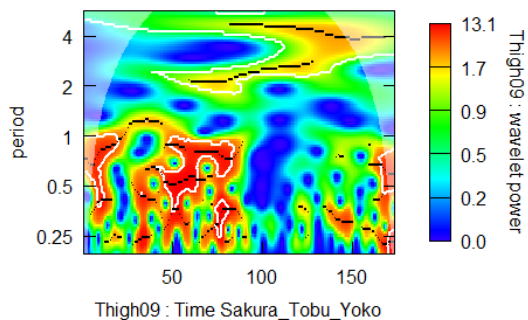


Fourier Spectrum Original Sakura_Tobu_Yoko

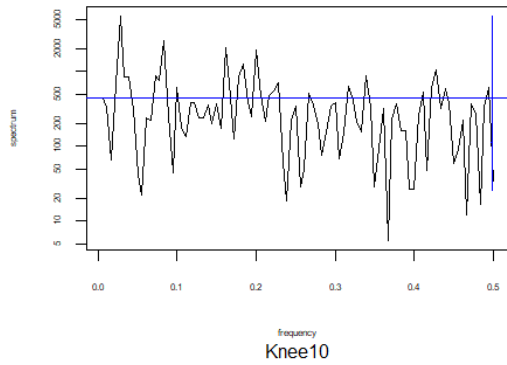


Fourier Spectrum Smoothed Sakura_Tobu_Yoko

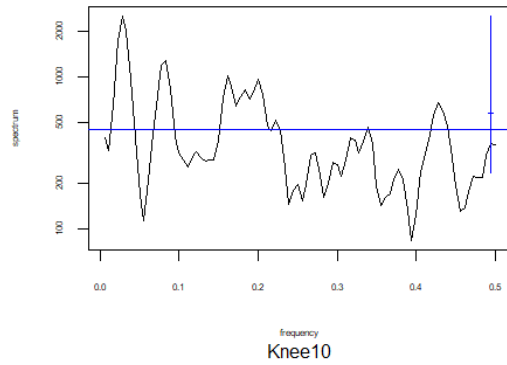




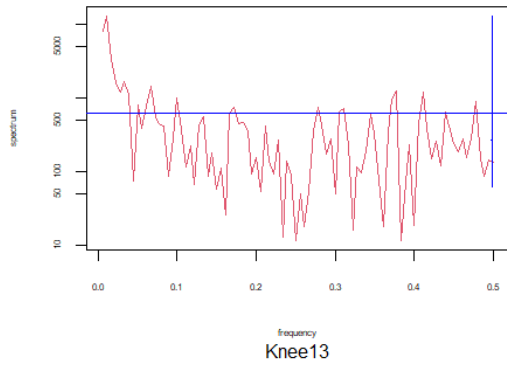
Fourier Spectrum Original Sakura_Tobu_Yoko



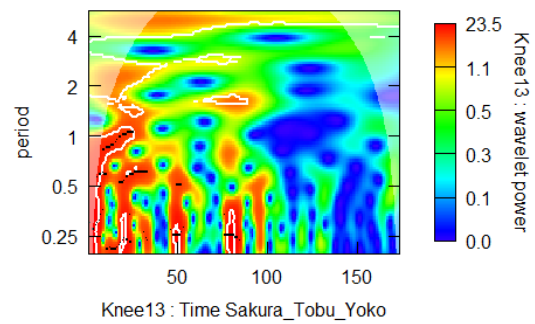
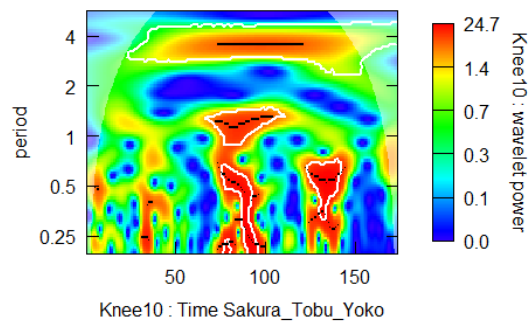
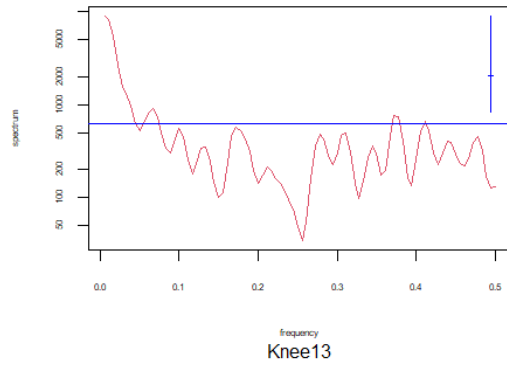
Fourier Spectrum Smoothed Sakura_Tobu_Yoko

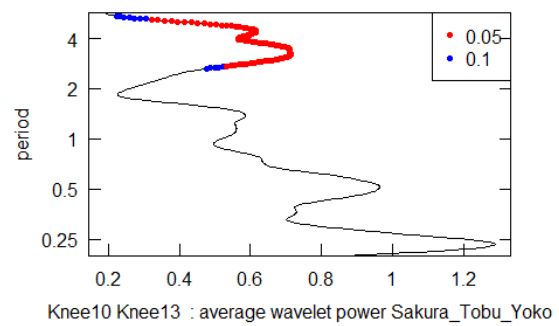
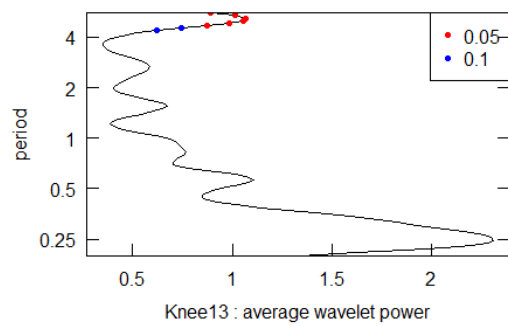
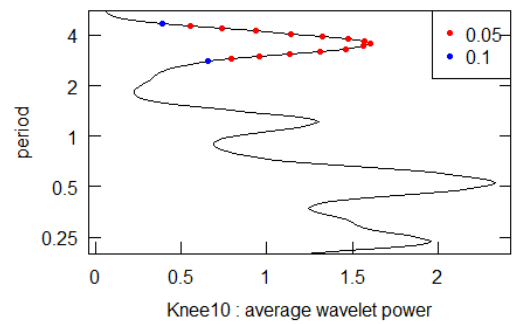
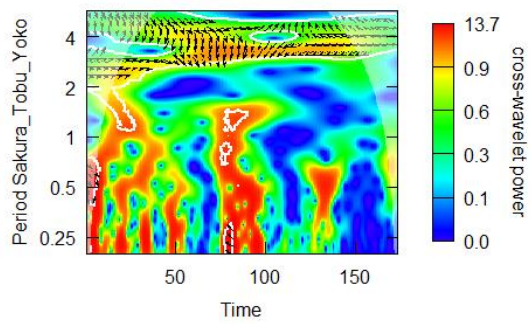


Fourier Spectrum Original Sakura_Tobu_Yoko



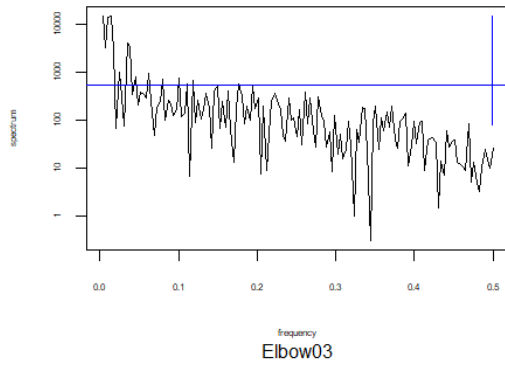
Fourier Spectrum Smoothed Sakura_Tobu_Yoko



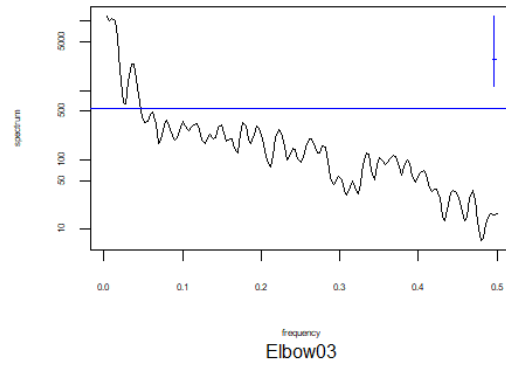


飛ばない人の動画

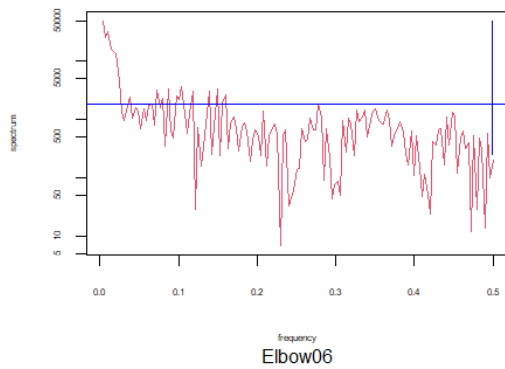
Fourier Spectrum Original Sakura_Tobanai



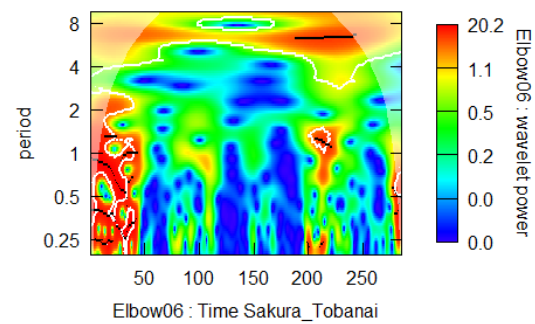
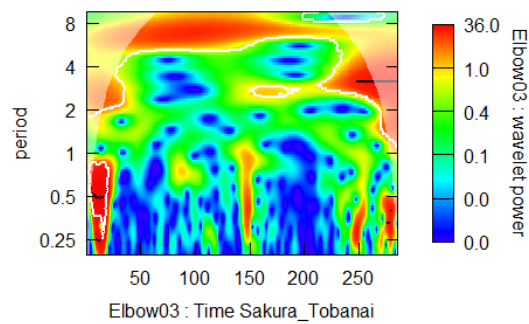
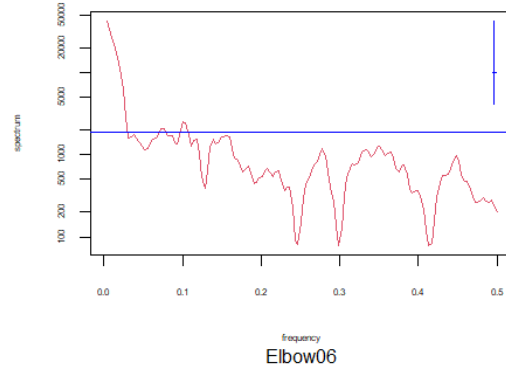
Fourier Spectrum Smoothed Sakura_Tobanai

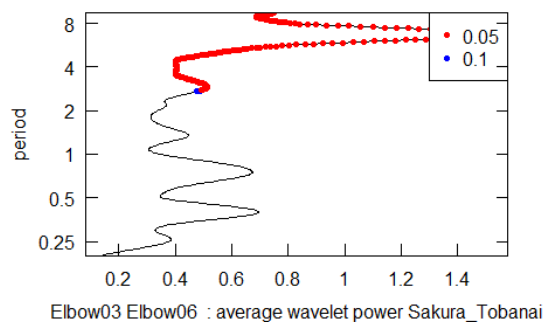
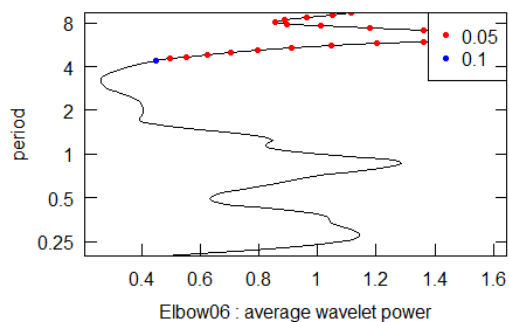
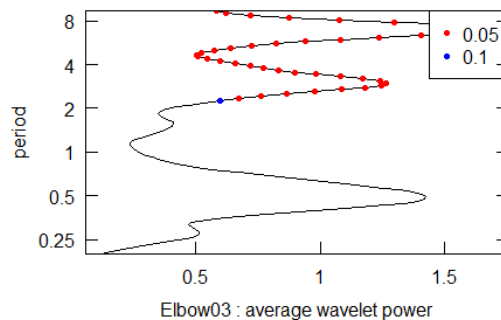
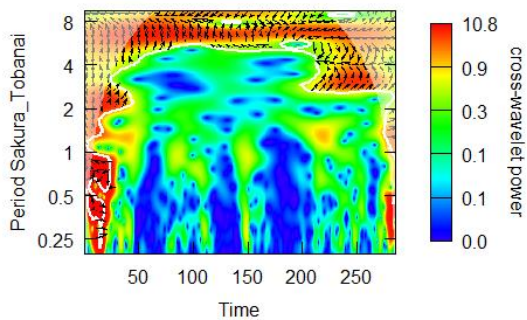


Fourier Spectrum Original Sakura_Tobanai

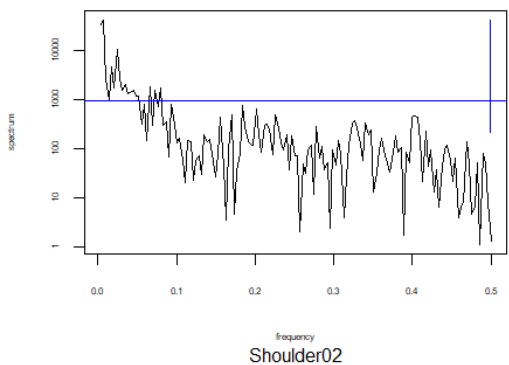


Fourier Spectrum Smoothed Sakura_Tobanai

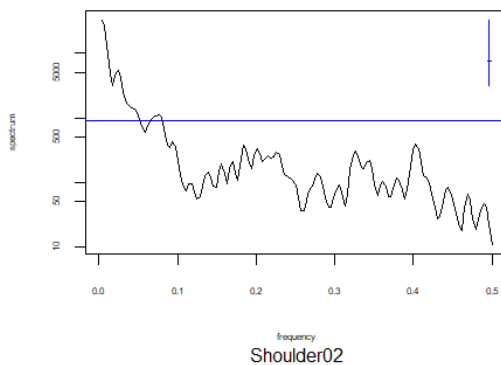




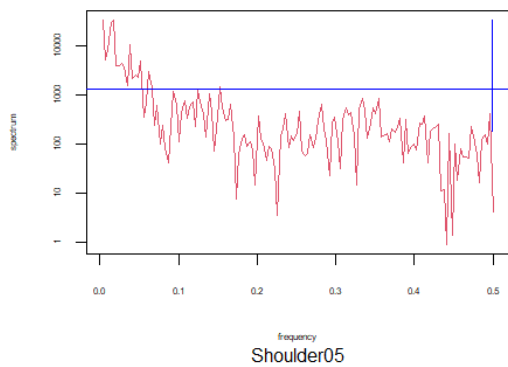
Fourier Spectrum Original Sakura_Tobanai



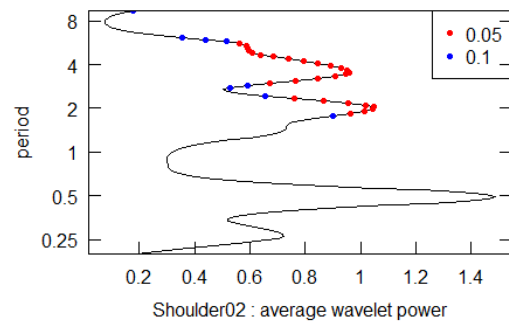
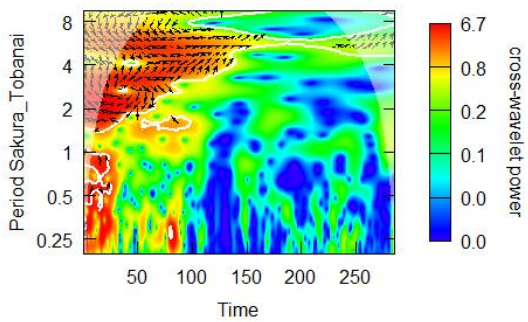
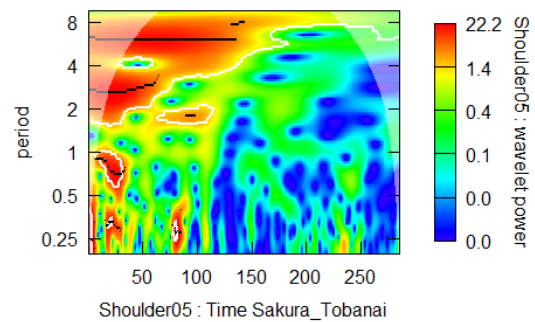
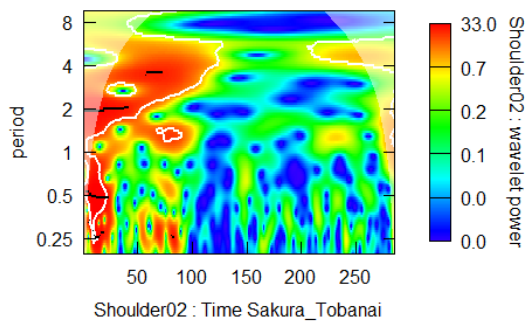
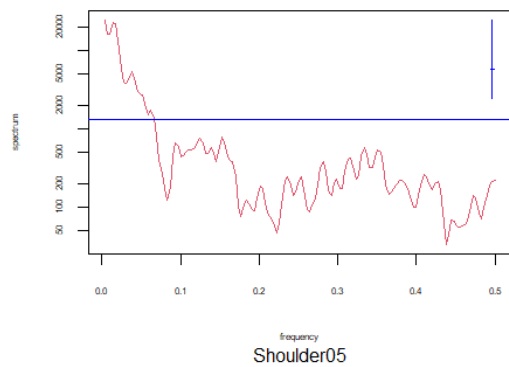
Fourier Spectrum Smoothed Sakura_Tobanai

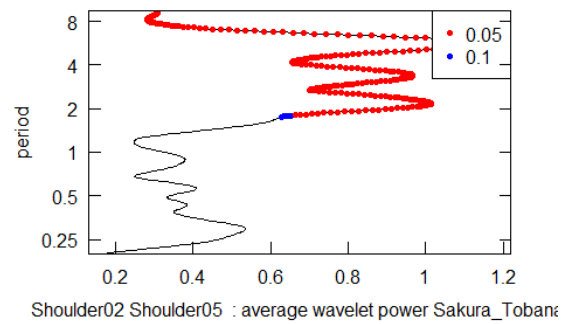
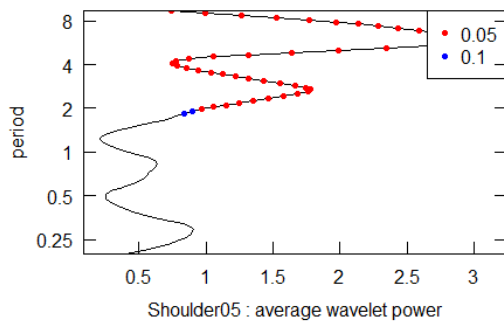


Fourier Spectrum Original Sakura_Tobanai

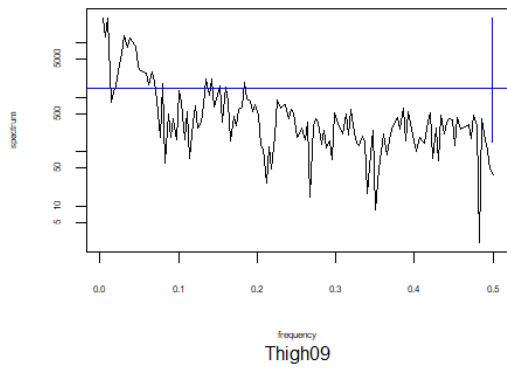


Fourier Spectrum Smoothed Sakura_Tobanai

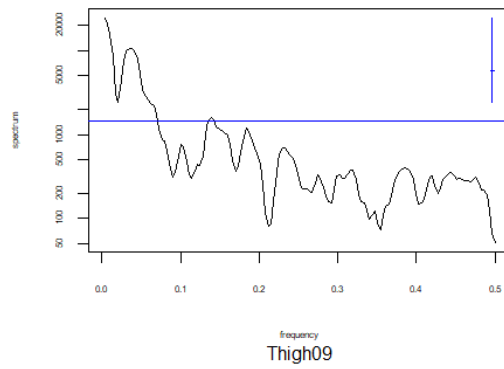




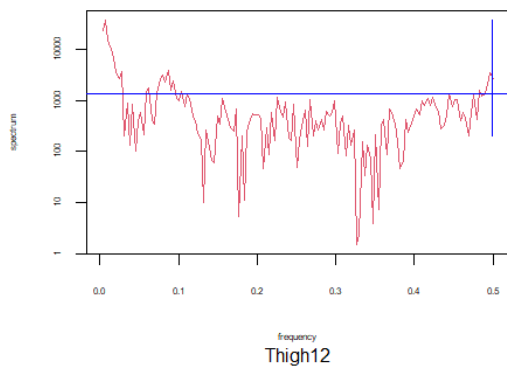
Fourier Spectrum Original Sakura_Tobanai



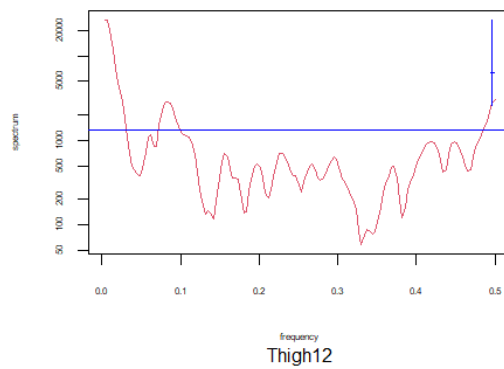
Fourier Spectrum Smoothed Sakura_Tobanai

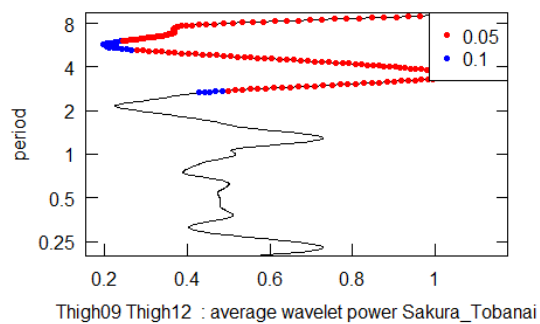
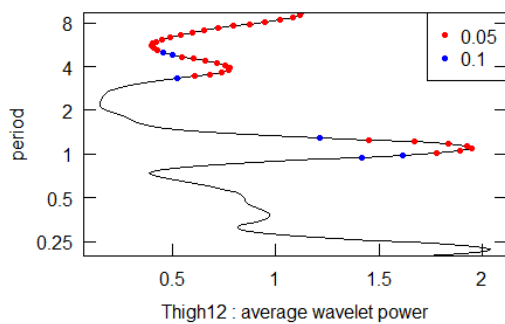
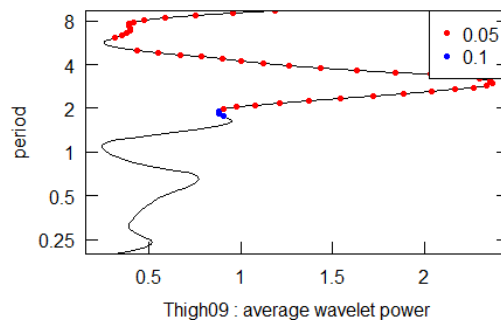
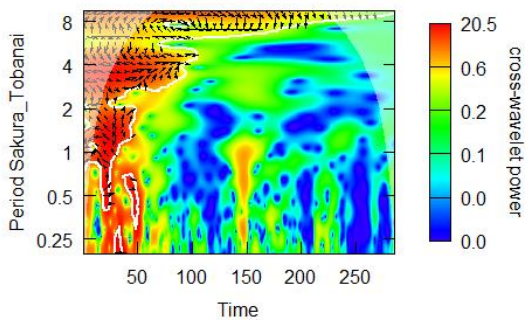
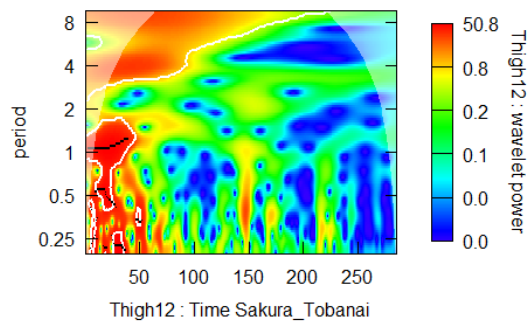
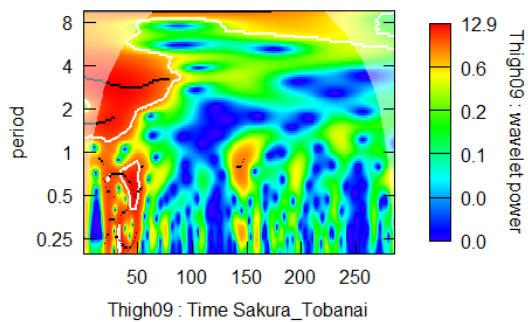


Fourier Spectrum Original Sakura_Tobanai

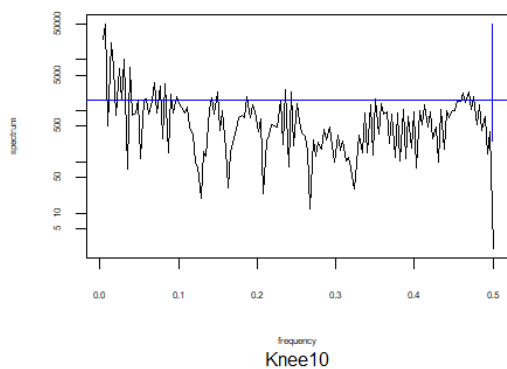


Fourier Spectrum Smoothed Sakura_Tobanai

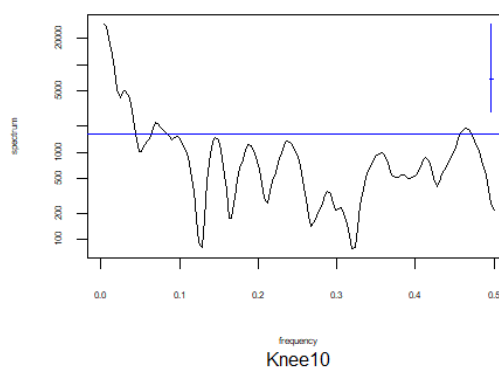




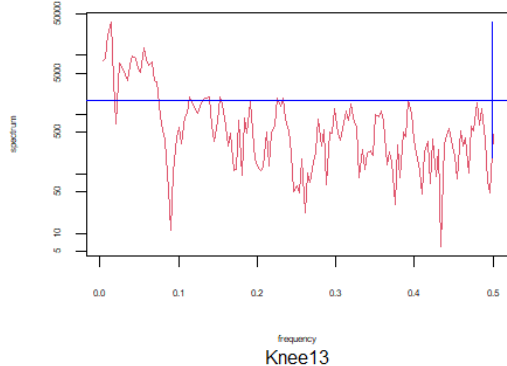
Fourier Spectrum Original Sakura_Tobanai



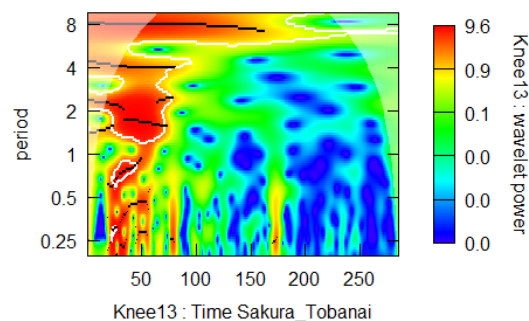
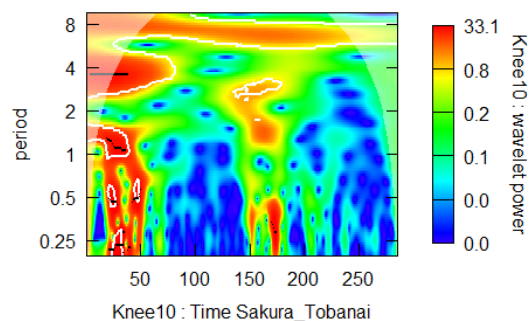
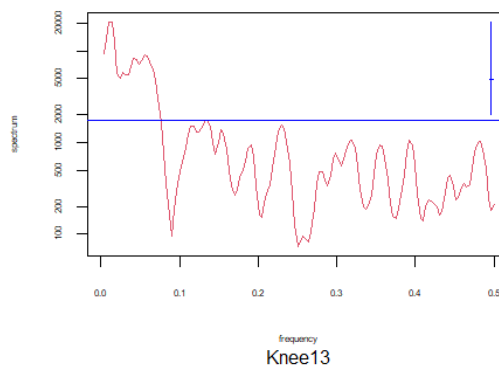
Fourier Spectrum Smoothed Sakura_Tobanai

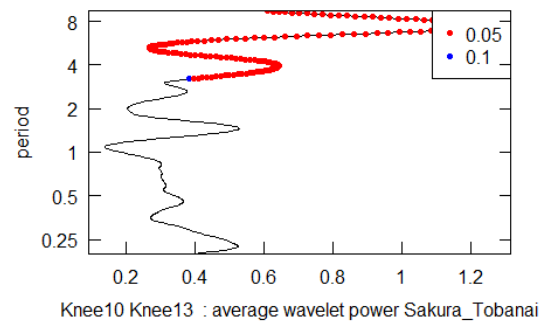
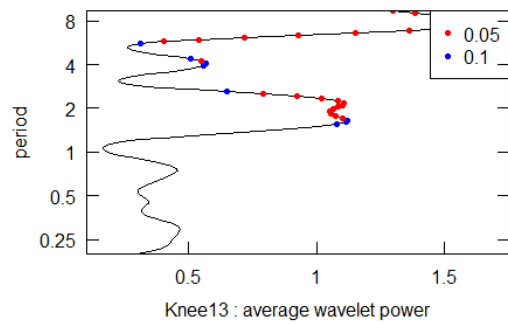
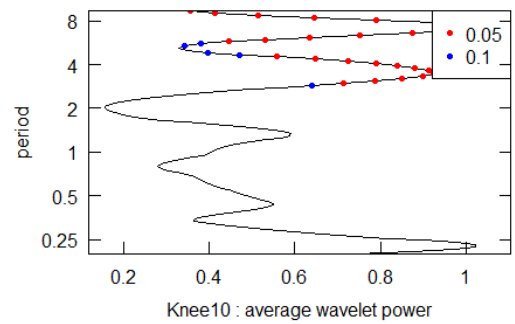
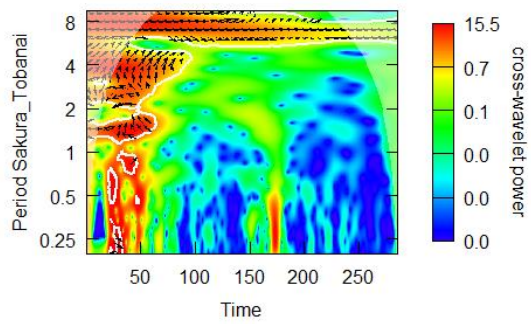


Fourier Spectrum Original Sakura_Tobanai



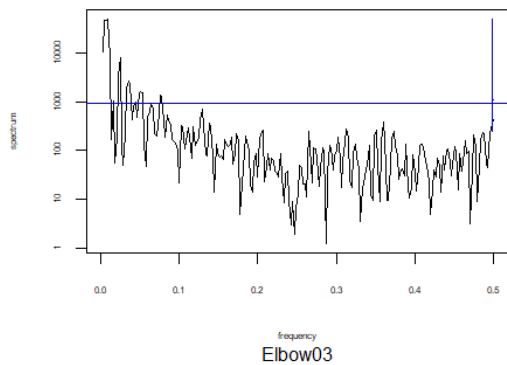
Fourier Spectrum Smoothed Sakura_Tobanai



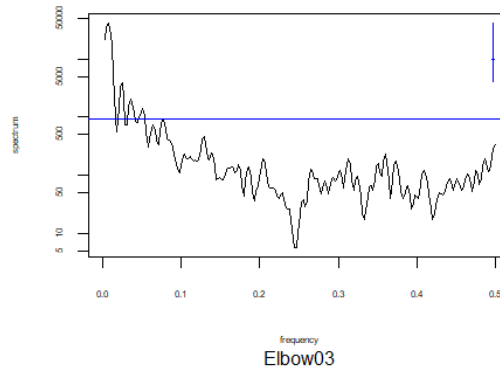


飛ばない人の横からの動画

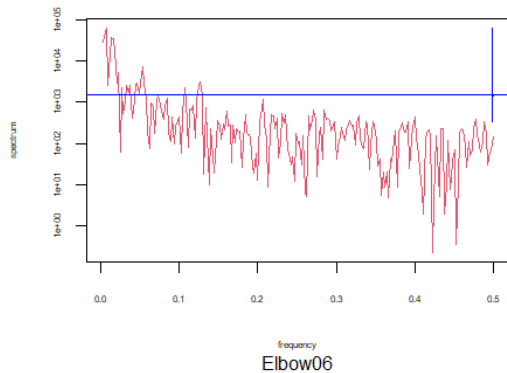
Fourier Spectrum Original Sakura_Tobanai_Yoko



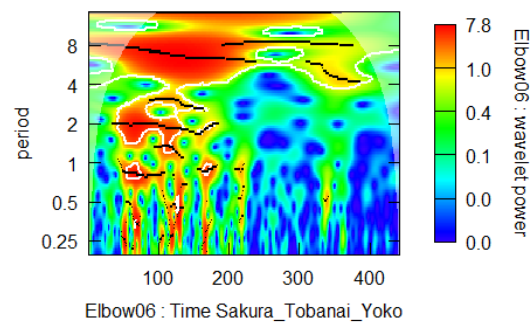
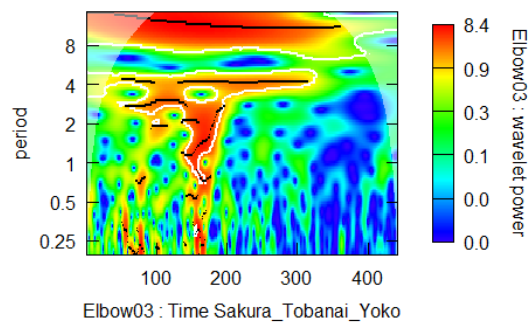
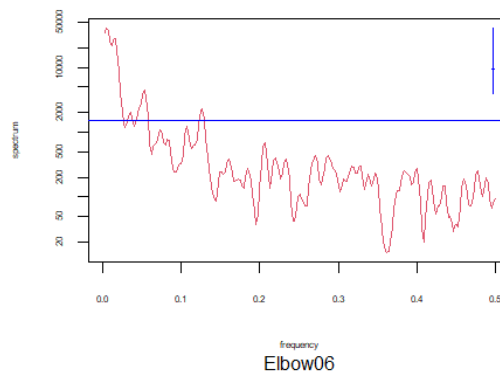
Fourier Spectrum Smoothed Sakura_Tobanai_Yo

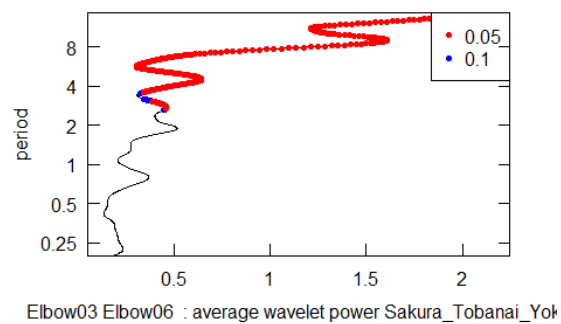
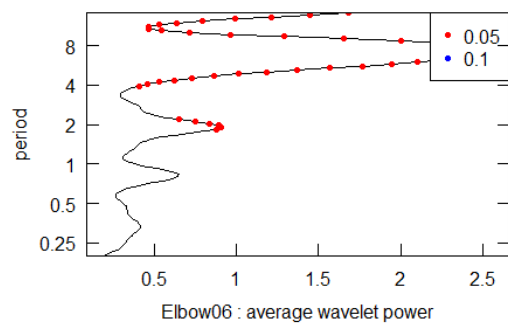
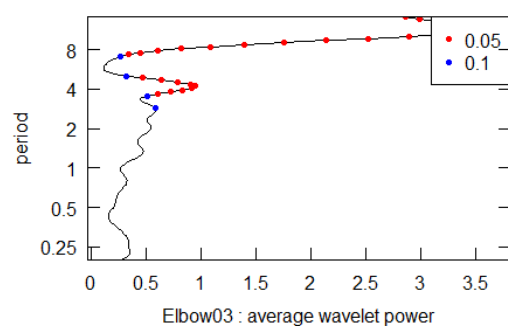
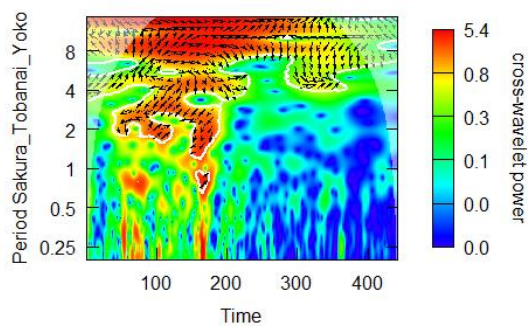


Fourier Spectrum Original Sakura_Tobanai_Yoko

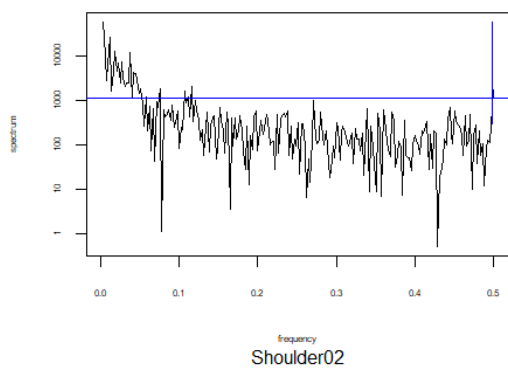


Fourier Spectrum Smoothed Sakura_Tobanai_Yo

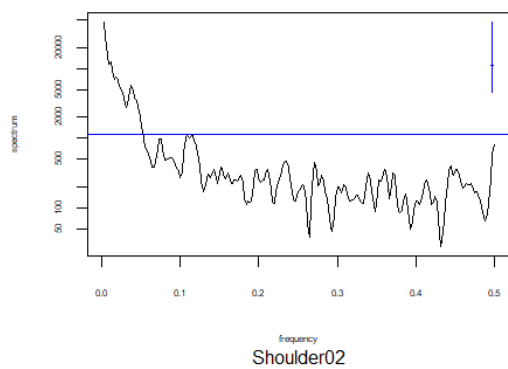




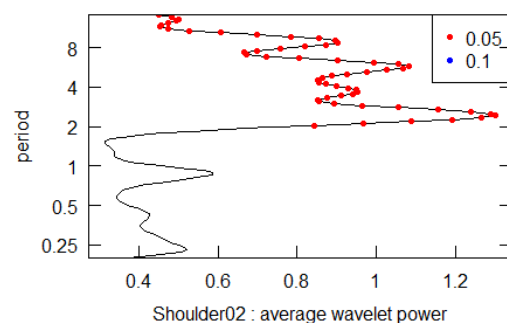
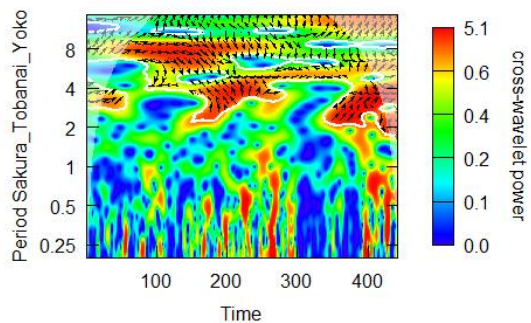
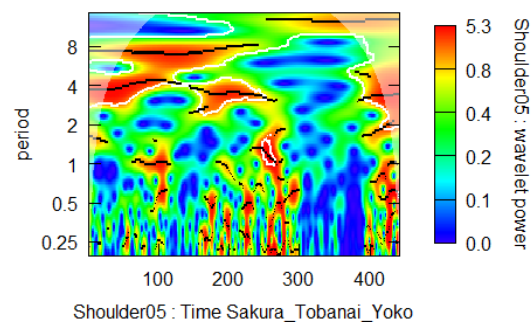
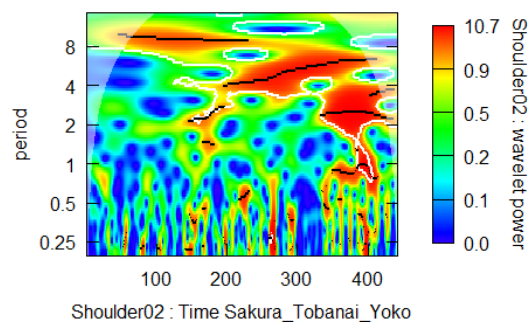
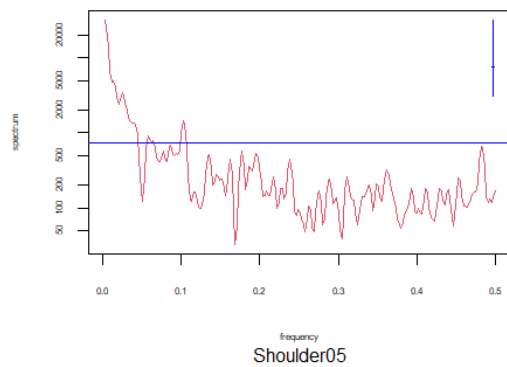
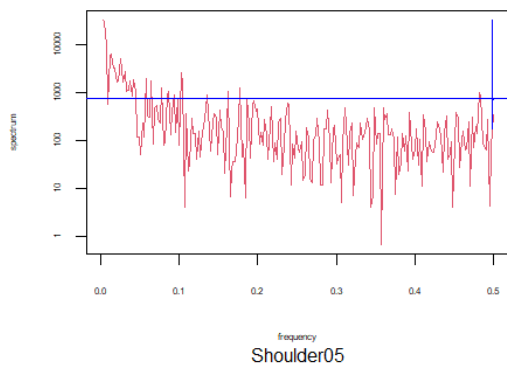
Fourier Spectrum Original Sakura_Tobanai_Yoko

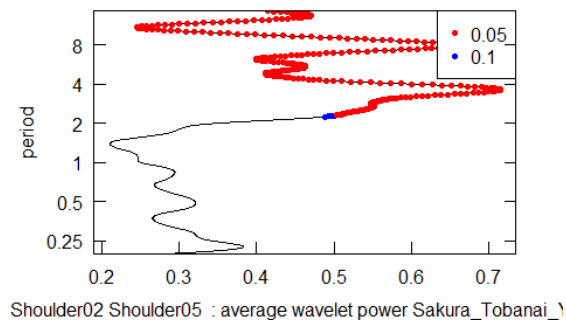
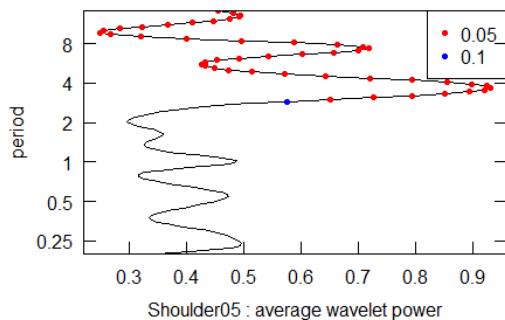


Fourier Spectrum Smoothed Sakura_Tobanai_Yoko

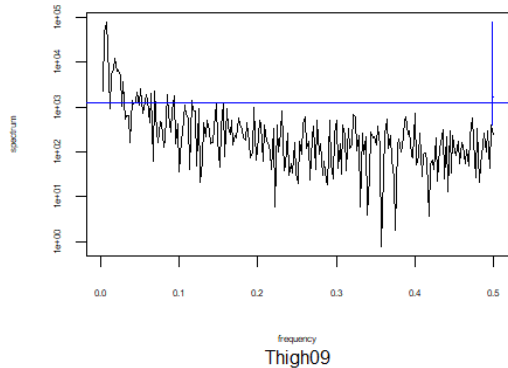


Fourier Spectrum Original Sakura_Tobanai_Yoko Fourier Spectrum Smoothed Sakura_Tobanai_Yol

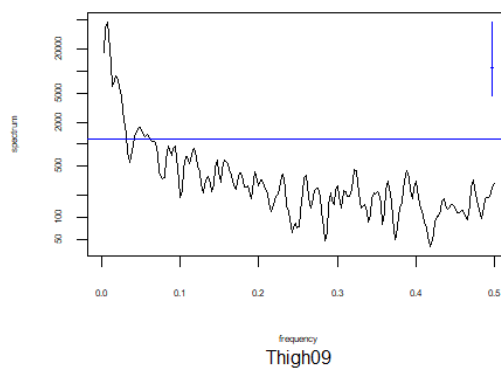




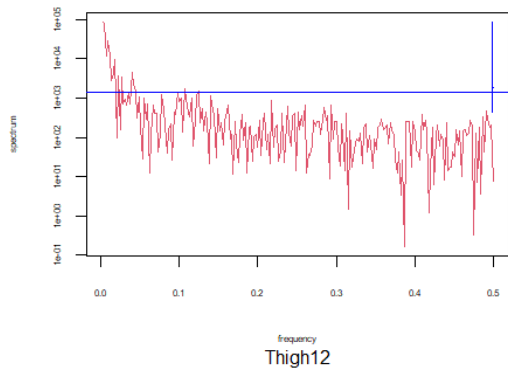
Fourier Spectrum Original Sakura_Tobanai_Yok



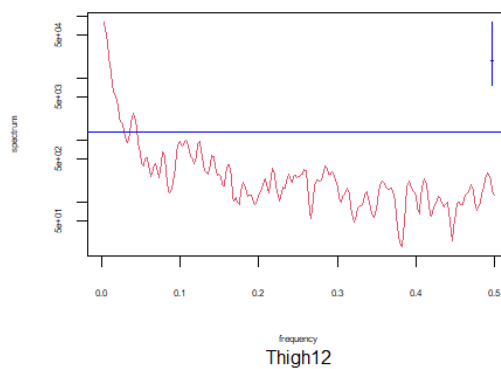
Fourier Spectrum Smoothed Sakura_Tobanai_Yol

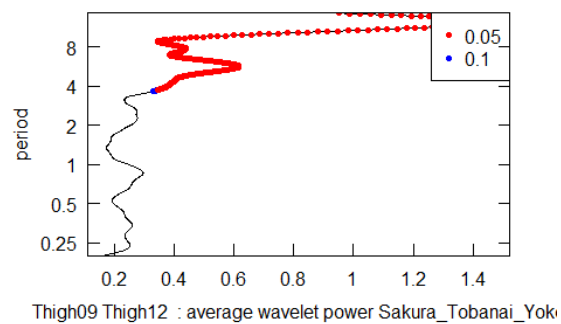
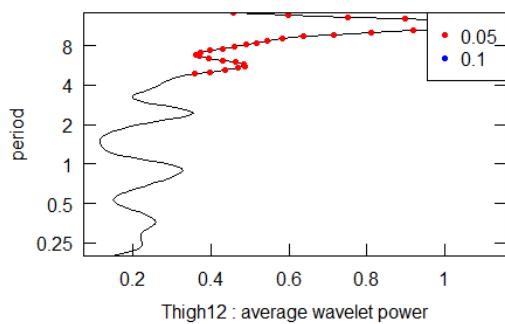
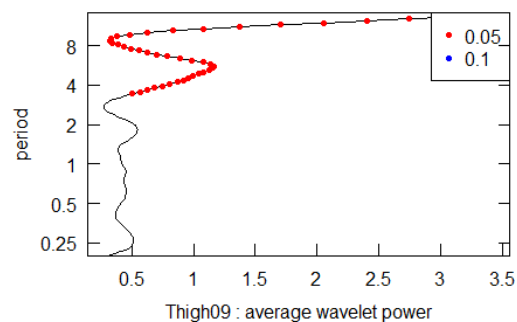
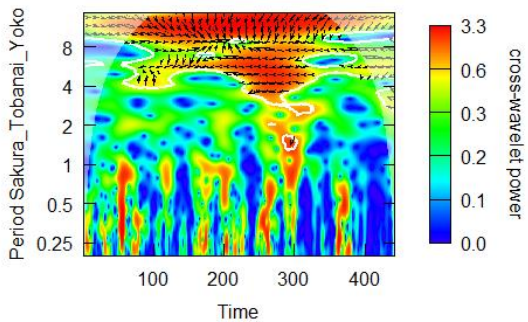
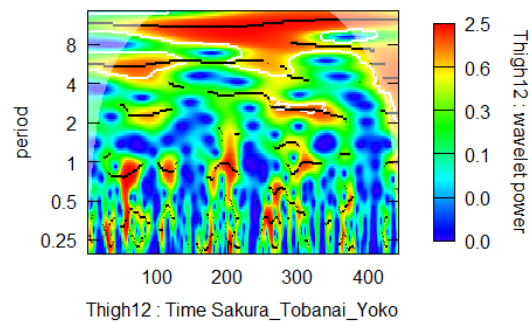
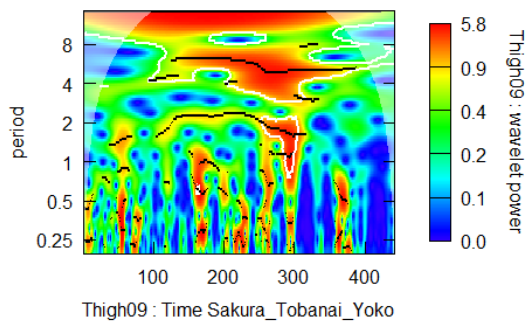


Fourier Spectrum Original Sakura_Tobanai_Yok

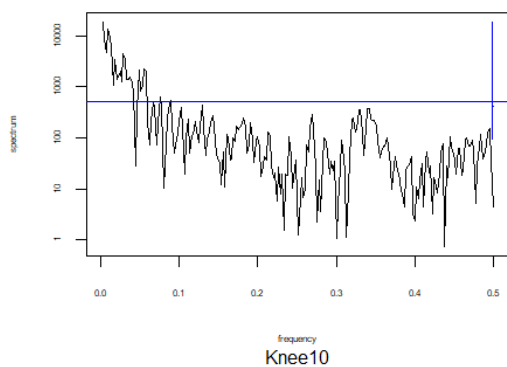


Fourier Spectrum Smoothed Sakura_Tobanai_Yol

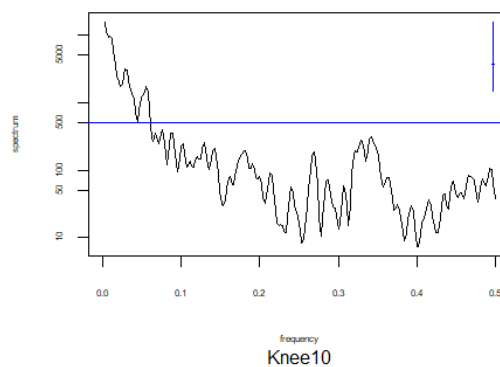




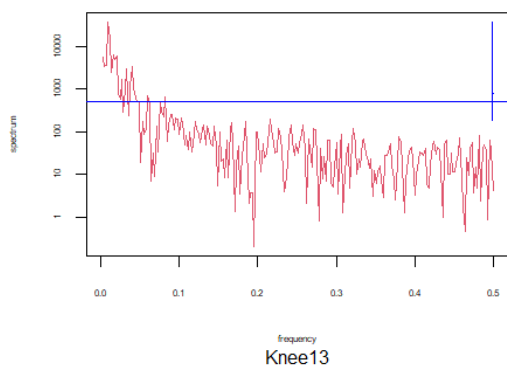
Fourier Spectrum Original Sakura_Tobanai_Yoko



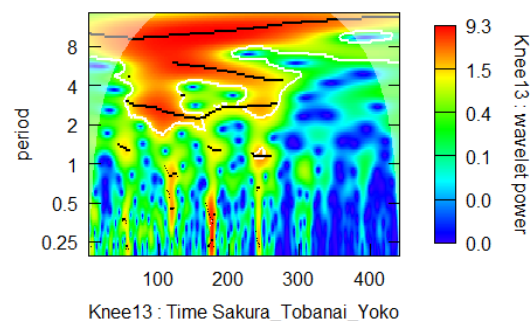
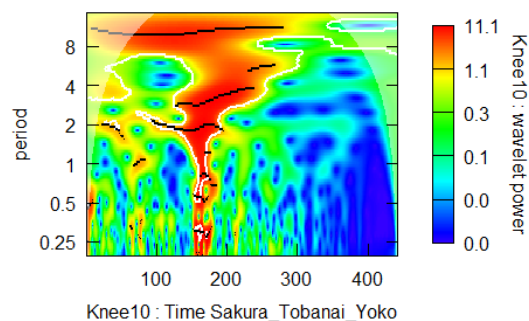
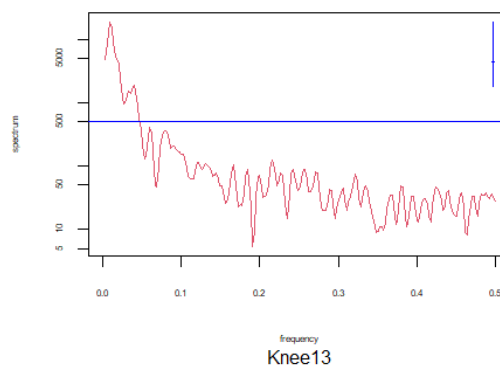
Fourier Spectrum Smoothed Sakura_Tobanai_Yol

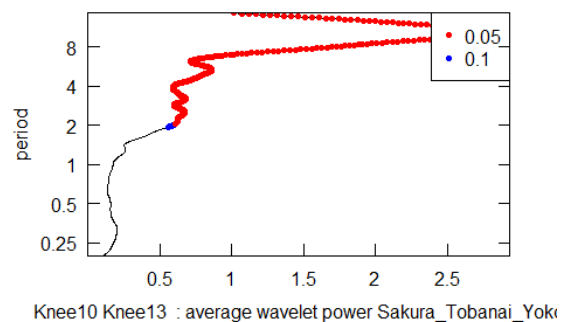
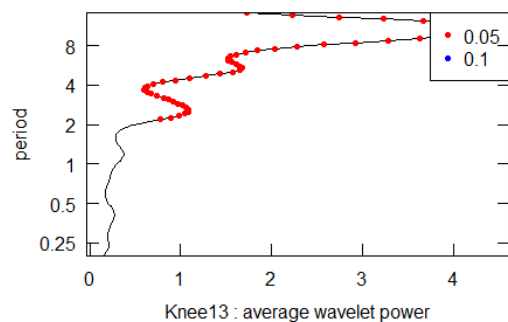
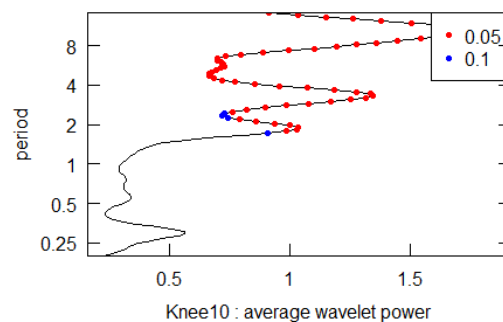
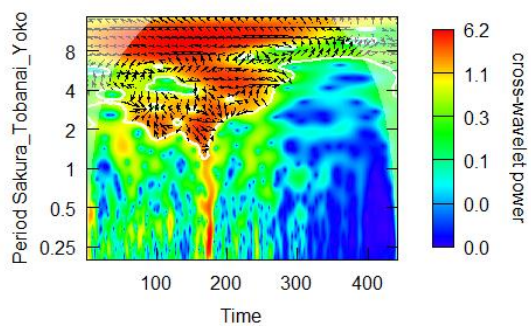


Fourier Spectrum Original Sakura_Tobanai_Yoko



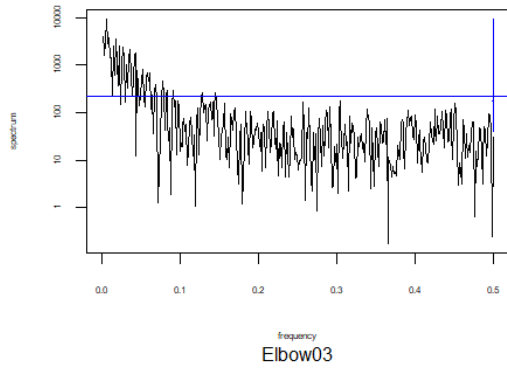
Fourier Spectrum Smoothed Sakura_Tobanai_Yol



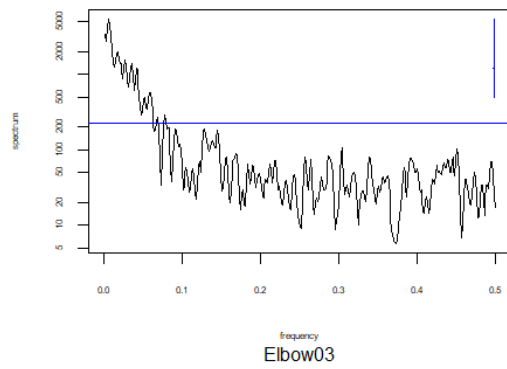


姿勢がいい人の動画

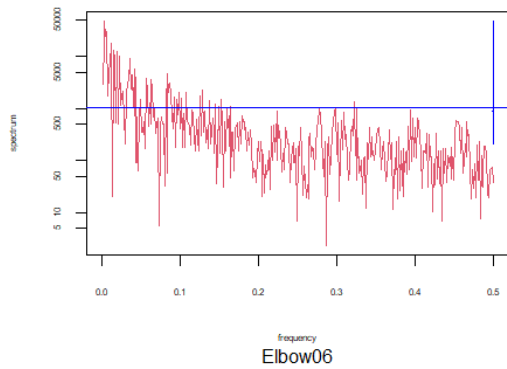
Fourier Spectrum Original Sakura_Shisei



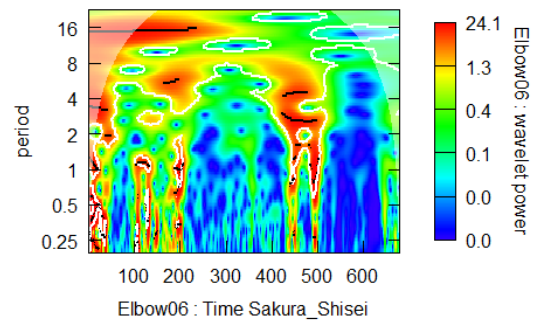
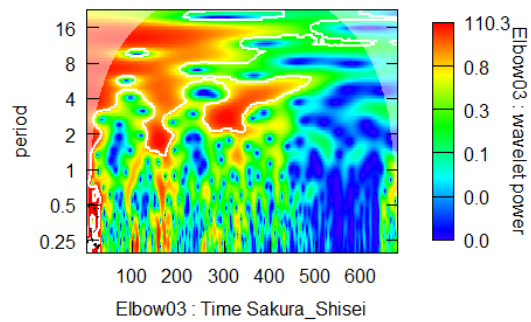
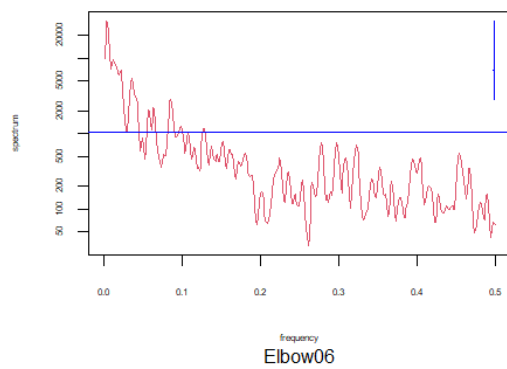
Fourier Spectrum Smoothed Sakura_Shisei

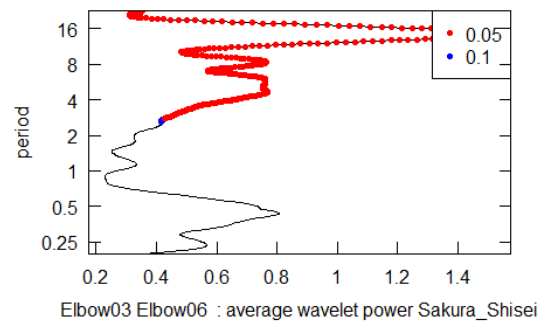
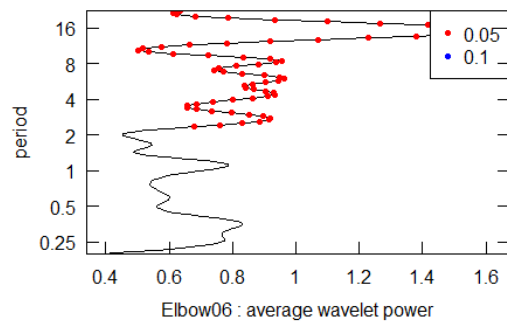
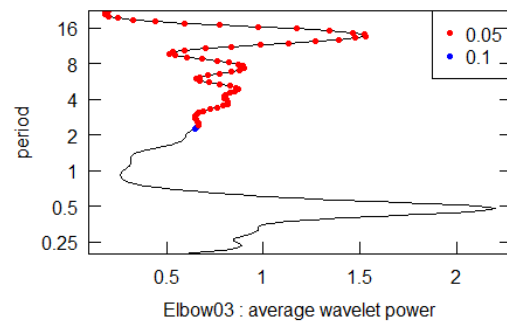
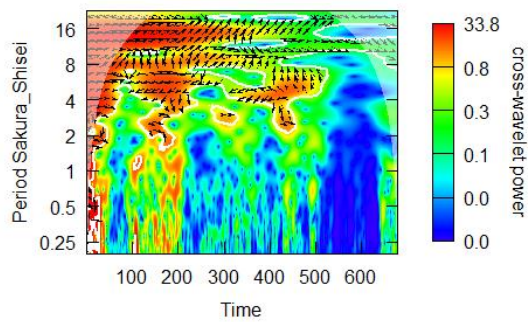


Fourier Spectrum Original Sakura_Shisei

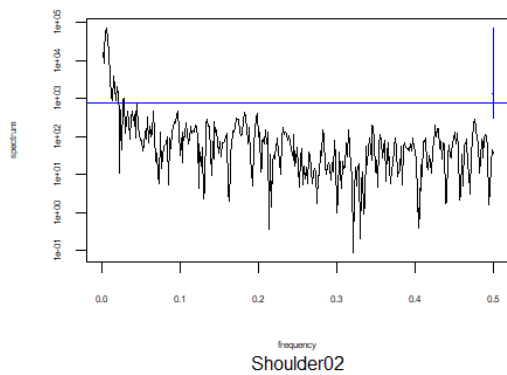


Fourier Spectrum Smoothed Sakura_Shisei

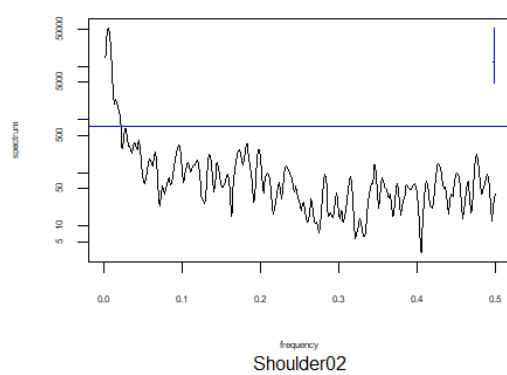




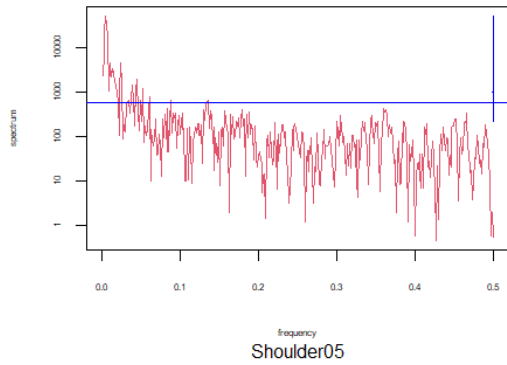
Fourier Spectrum Original Sakura_Shisei



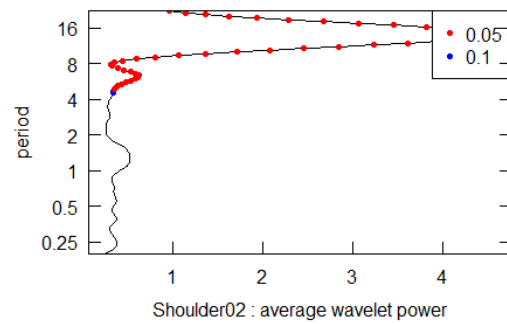
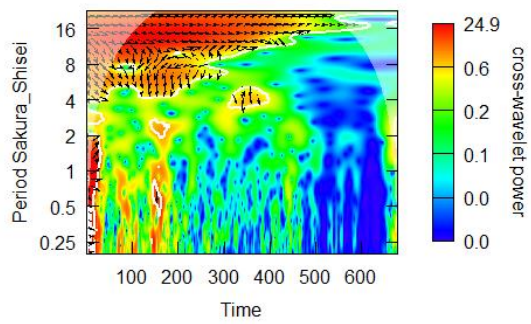
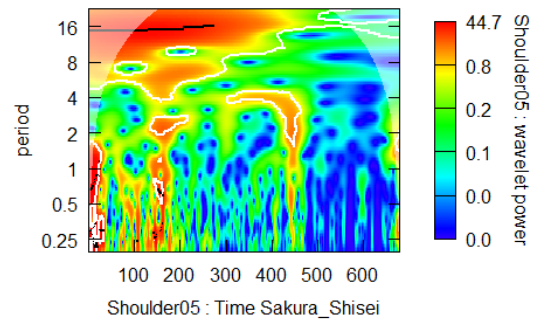
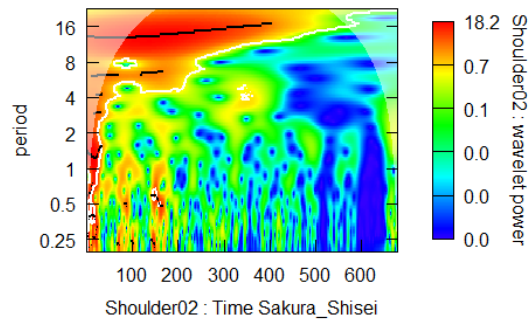
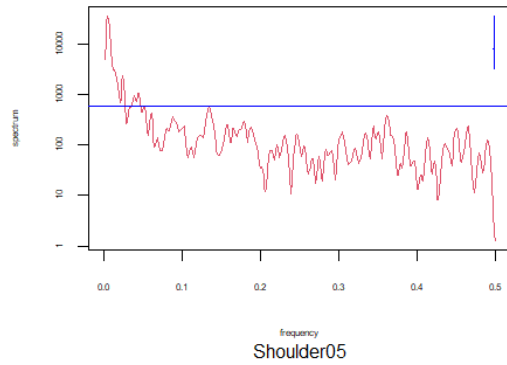
Fourier Spectrum Smoothed Sakura_Shisei

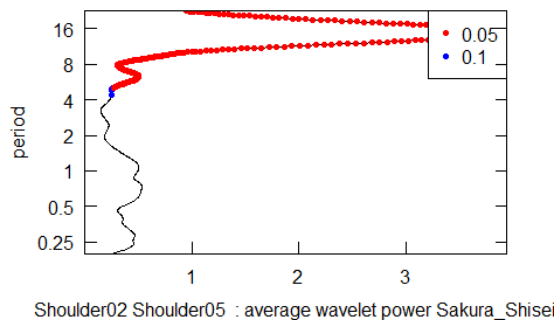
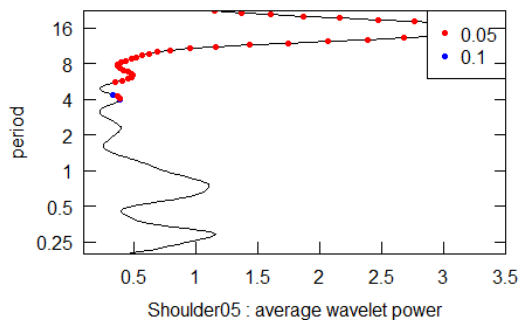


Fourier Spectrum Original Sakura_Shisei

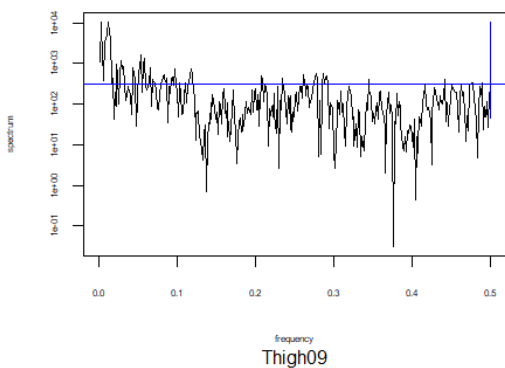


Fourier Spectrum Smoothed Sakura_Shisei

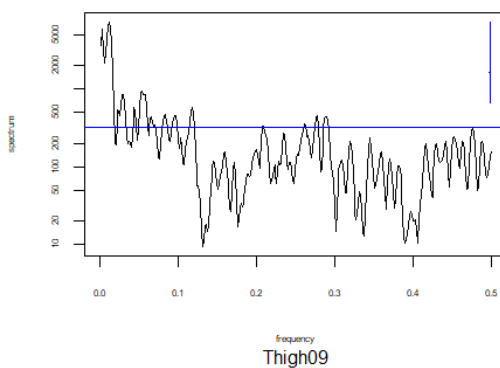




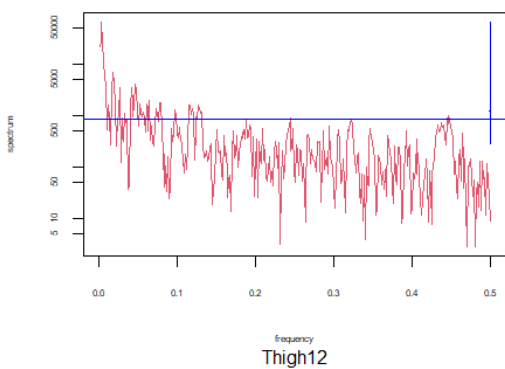
Fourier Spectrum Original Sakura_Shisei



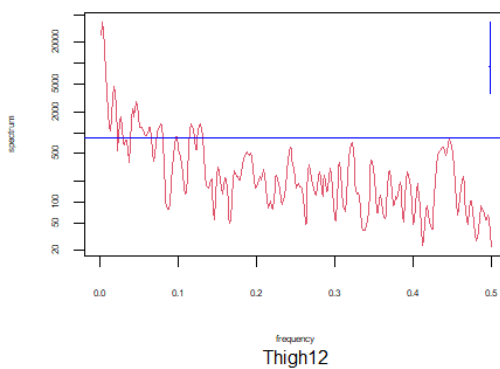
Fourier Spectrum Smoothed Sakura_Shisei

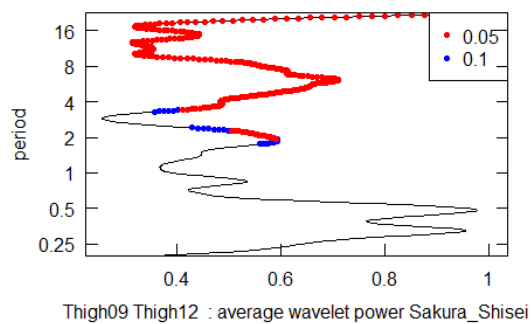
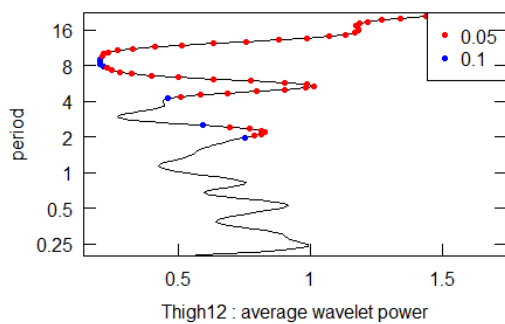
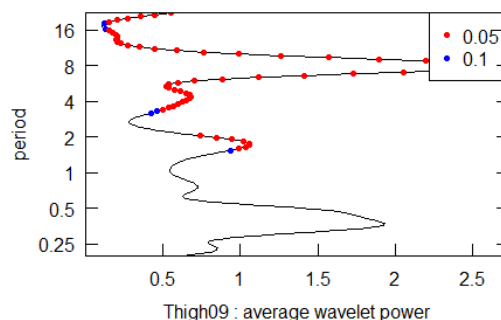
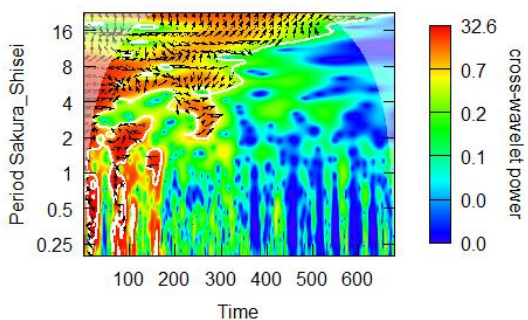
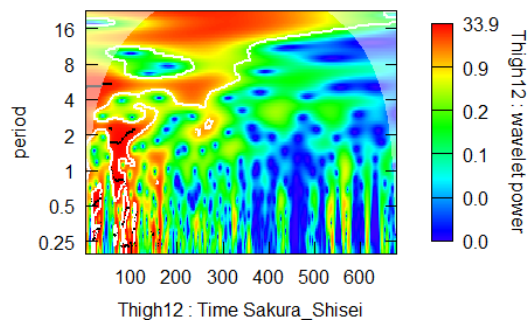
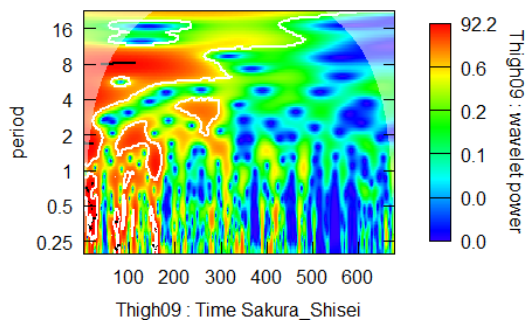


Fourier Spectrum Original Sakura_Shisei

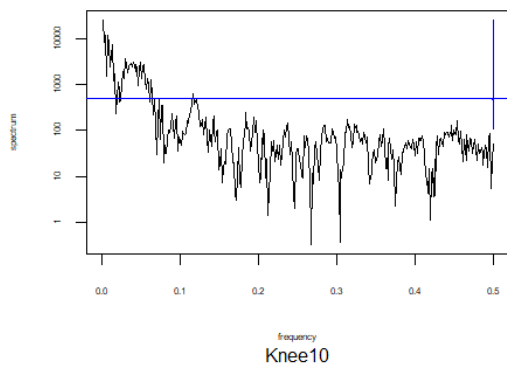


Fourier Spectrum Smoothed Sakura_Shisei

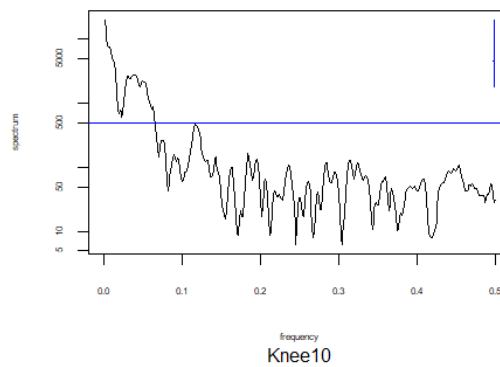




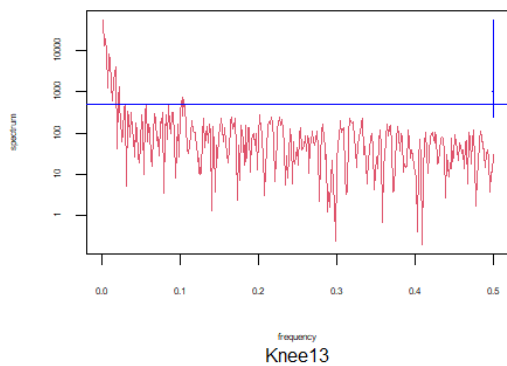
Fourier Spectrum Original Sakura_Shisei



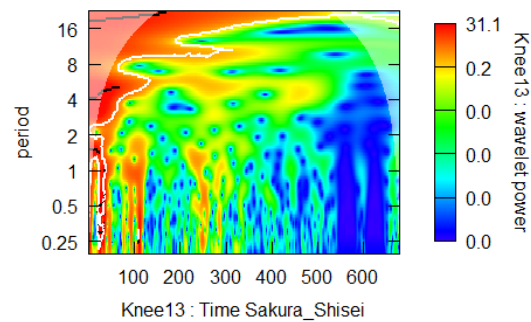
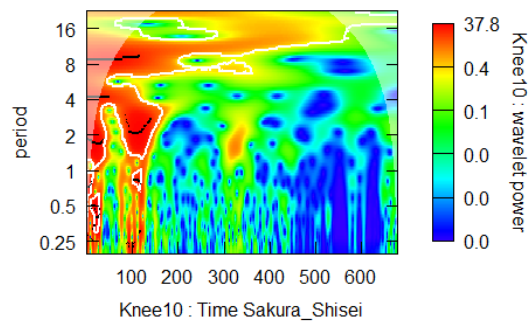
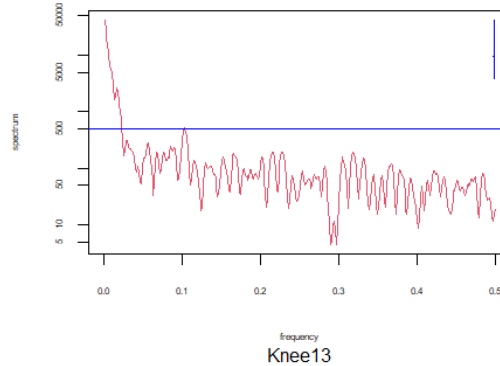
Fourier Spectrum Smoothed Sakura_Shisei

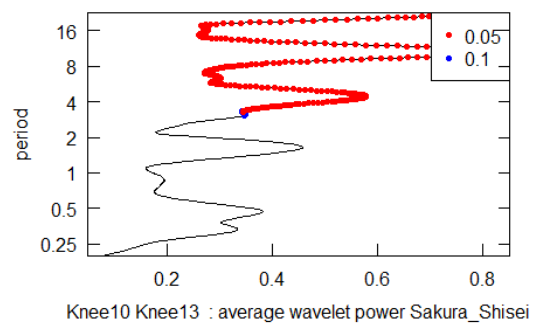
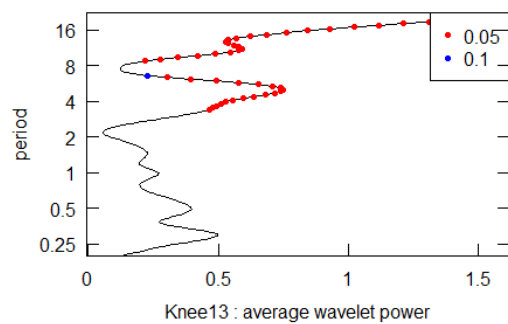
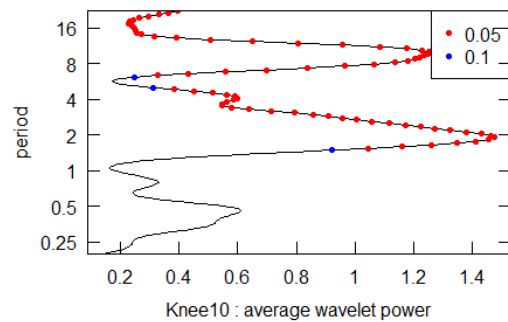
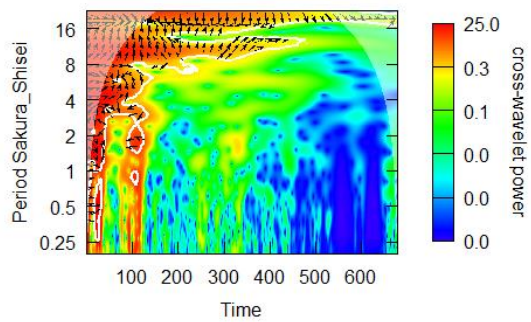


Fourier Spectrum Original Sakura_Shisei



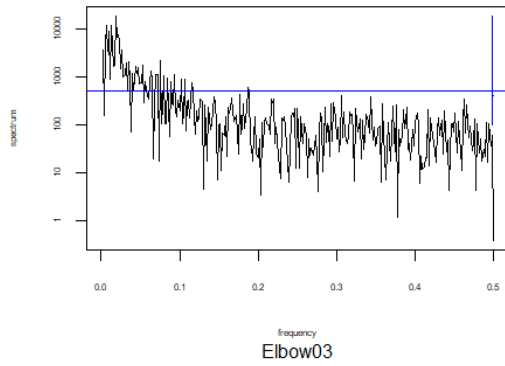
Fourier Spectrum Smoothed Sakura_Shisei



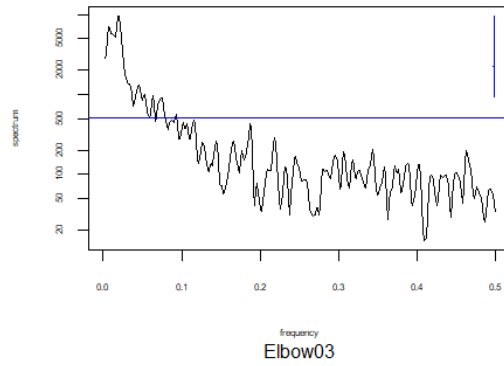


姿勢がいい人の横からの動画

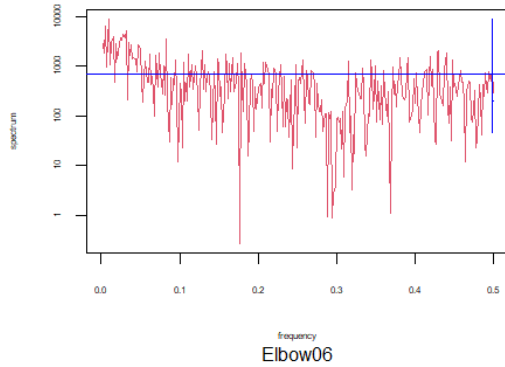
Fourier Spectrum Original Sakura_Shisei_Yoko



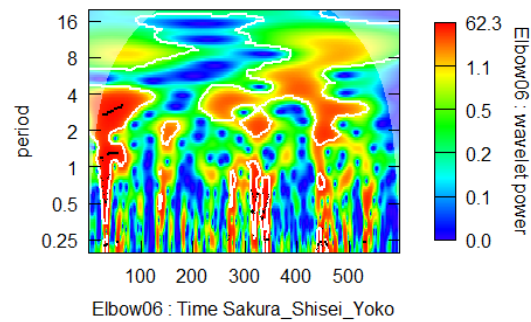
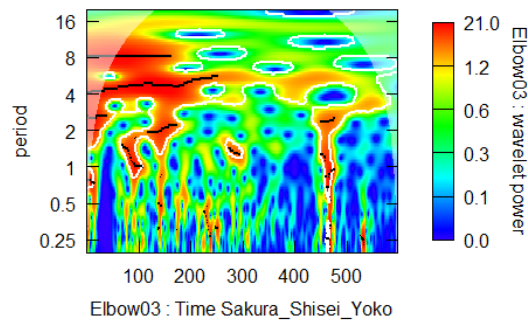
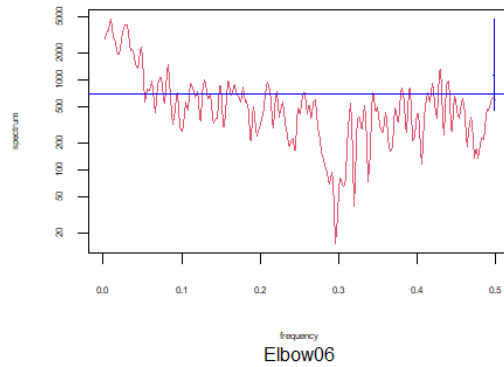
Fourier Spectrum Smoothed Sakura_Shisei_Yoko

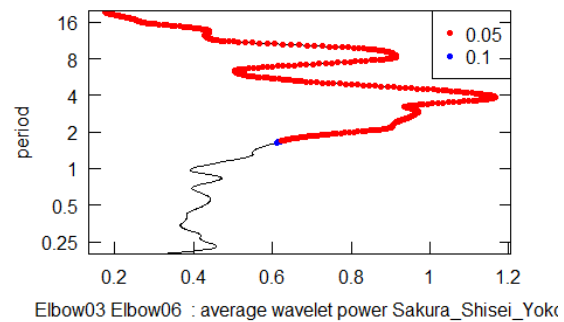
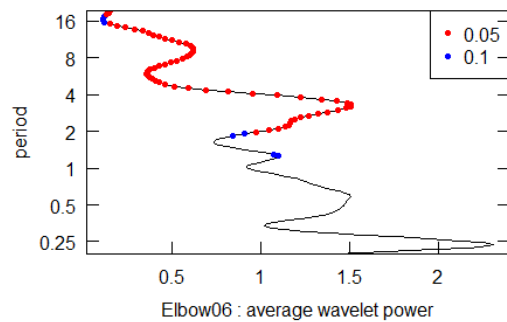
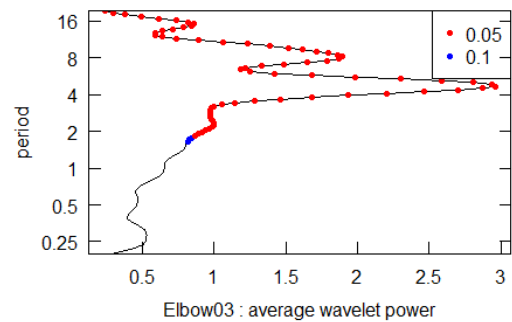
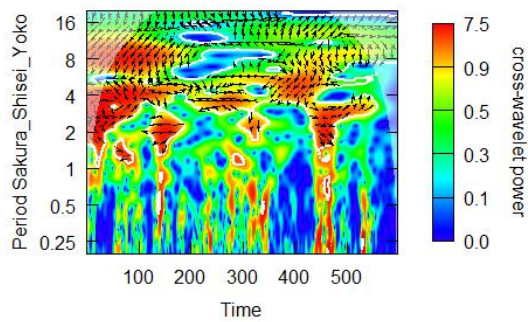


Fourier Spectrum Original Sakura_Shisei_Yoko

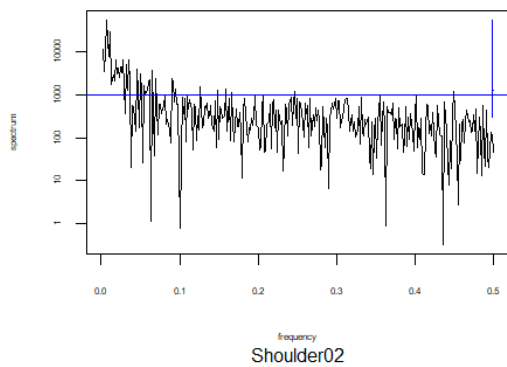


Fourier Spectrum Smoothed Sakura_Shisei_Yoko

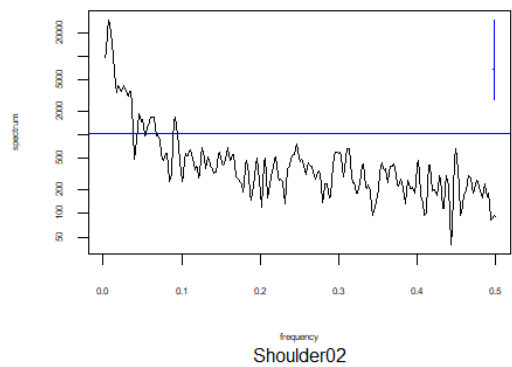




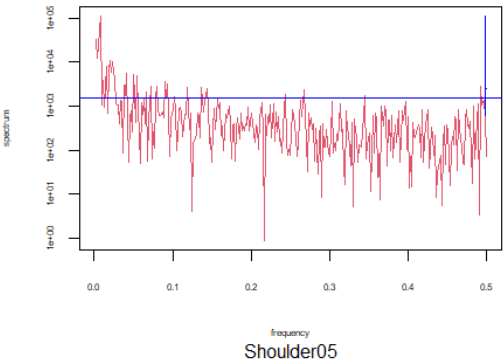
Fourier Spectrum Original Sakura_Shisei_Yoko



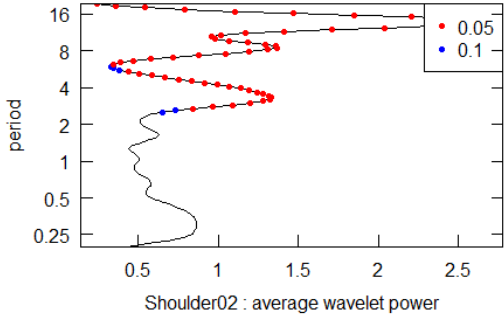
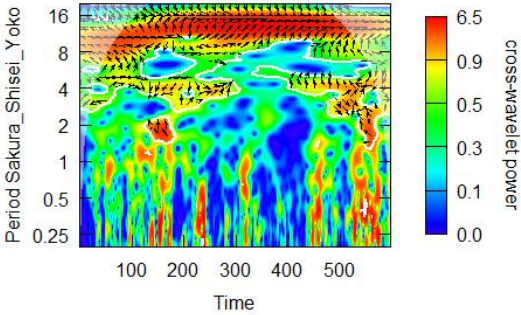
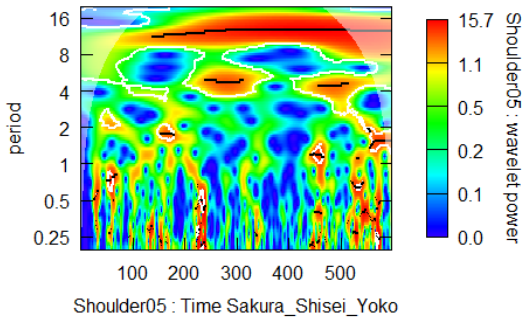
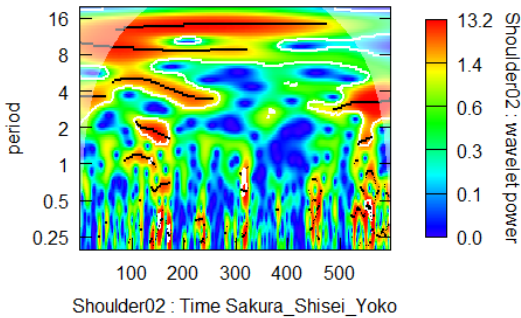
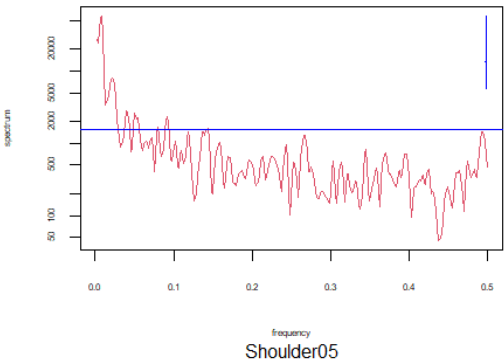
Fourier Spectrum Smoothed Sakura_Shisei_Yoko

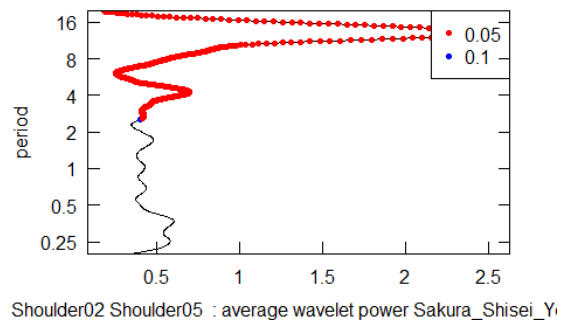
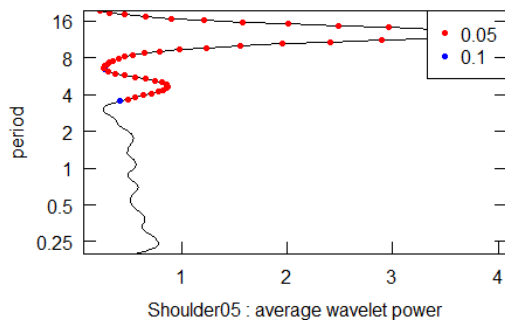


Fourier Spectrum Original Sakura_Shisei_Yoko

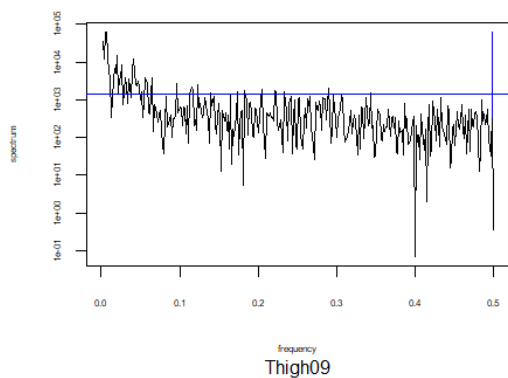


Fourier Spectrum Smoothed Sakura_Shisei_Yoko

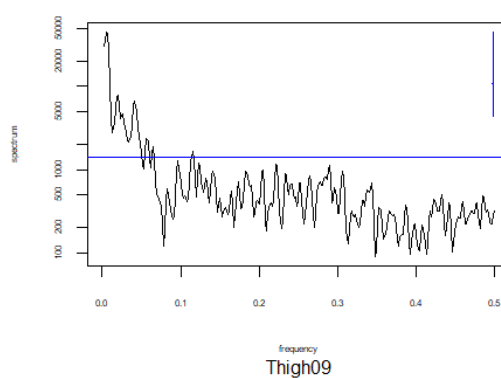




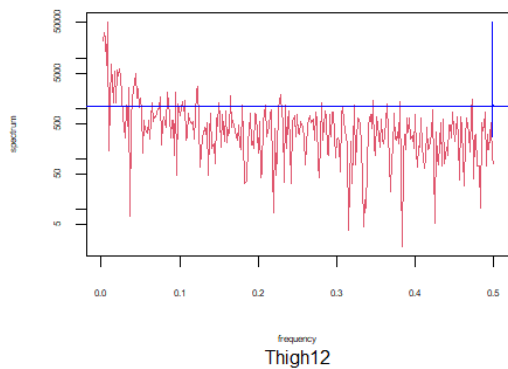
Fourier Spectrum Original Sakura_Shisei_Yoko



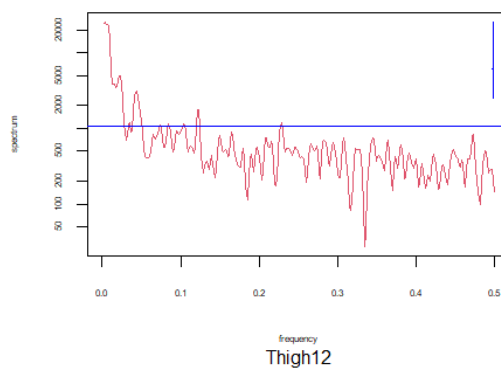
Fourier Spectrum Smoothed Sakura_Shisei_Yoko

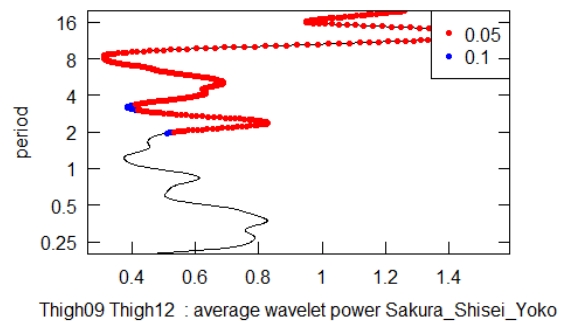
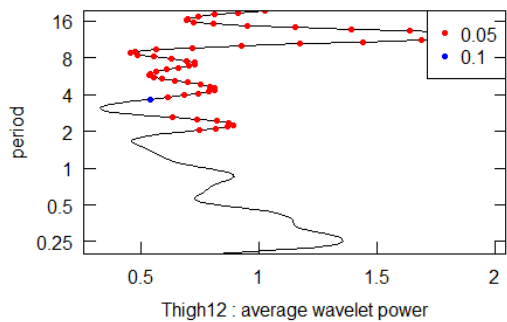
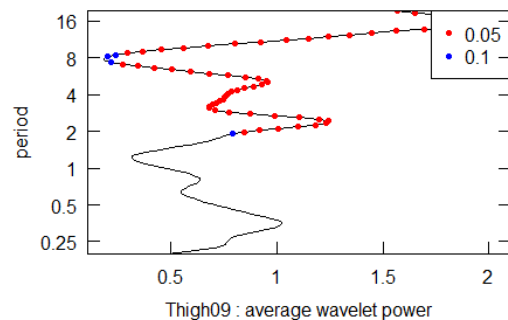
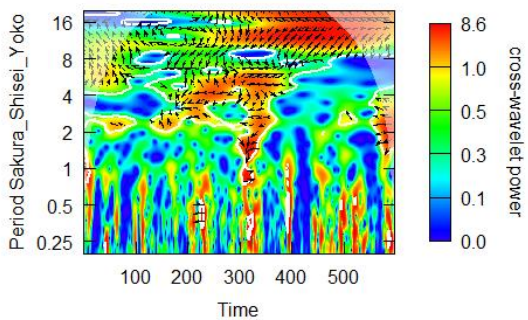
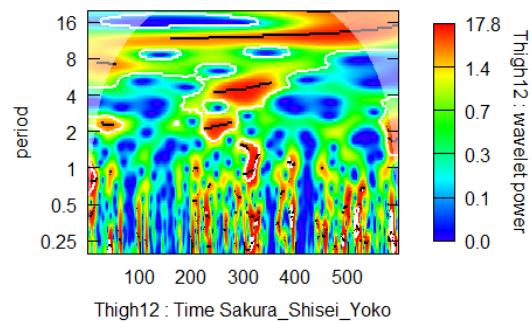
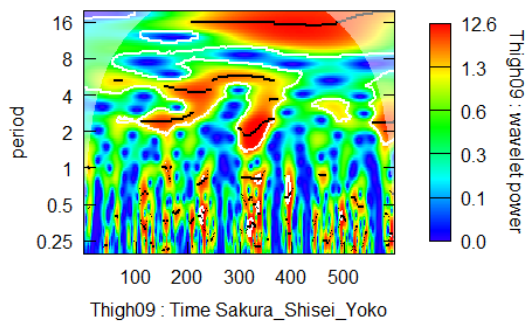


Fourier Spectrum Original Sakura_Shisei_Yoko

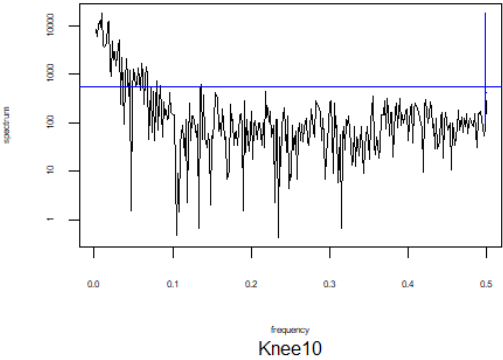


Fourier Spectrum Smoothed Sakura_Shisei_Yoko

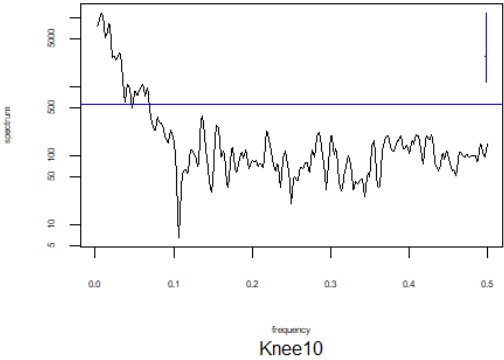




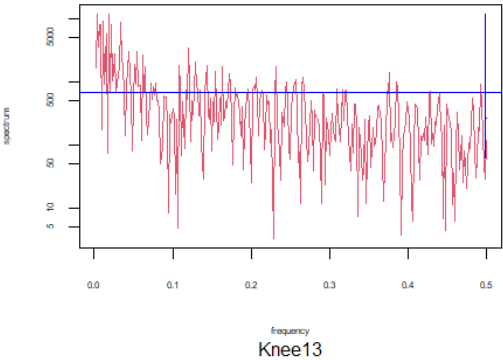
Fourier Spectrum Original Sakura_Shisei_Yoko



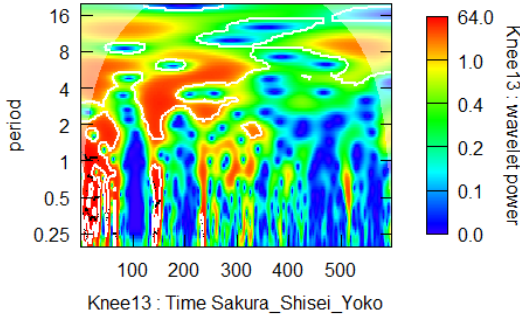
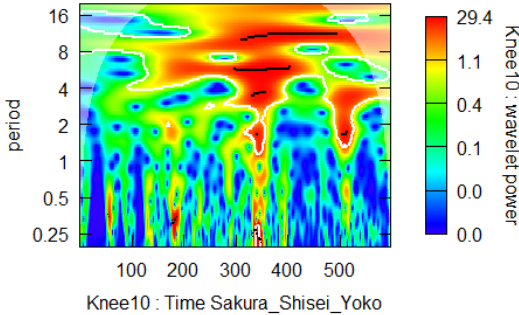
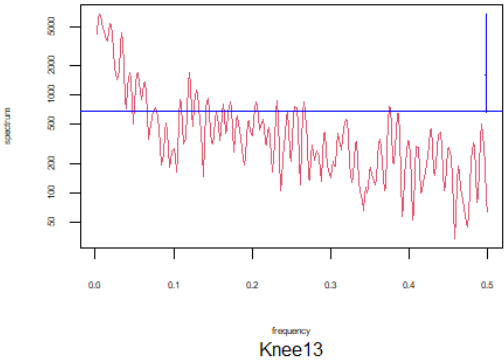
Fourier Spectrum Smoothed Sakura_Shisei_Yoko

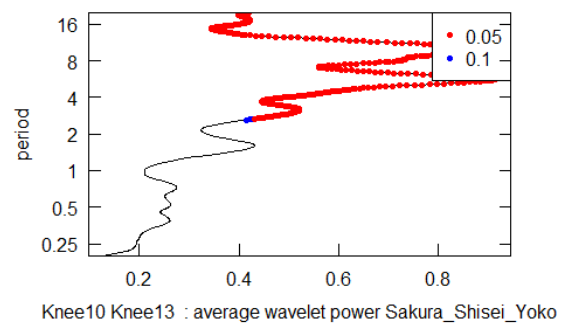
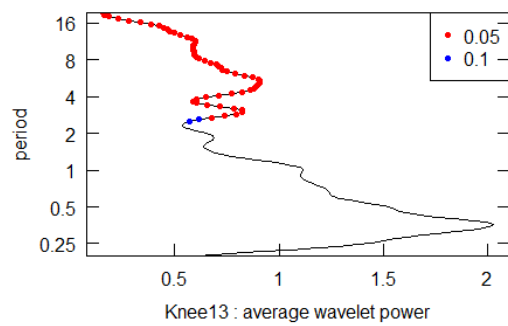
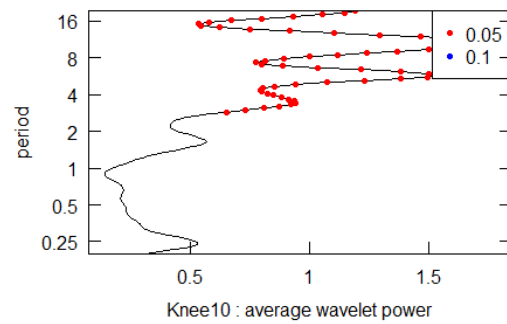
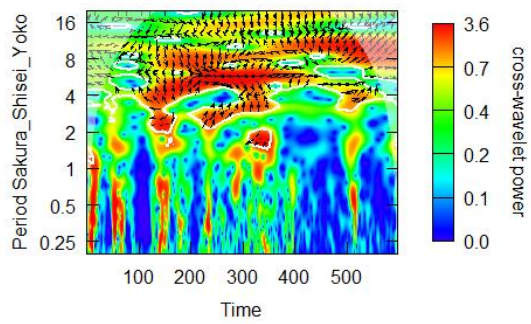


Fourier Spectrum Original Sakura_Shisei_Yoko



Fourier Spectrum Smoothed Sakura_Shisei_Yoko





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