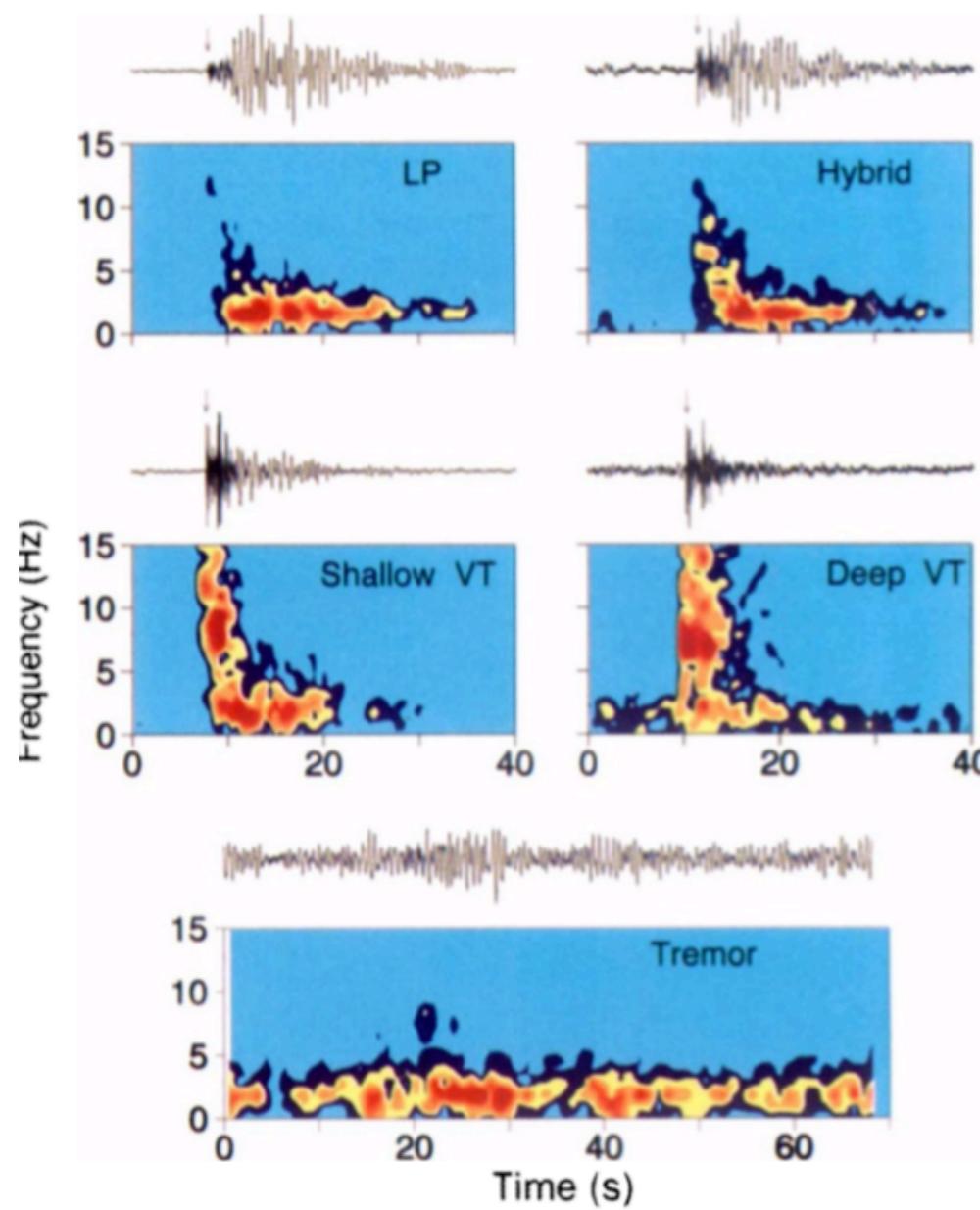


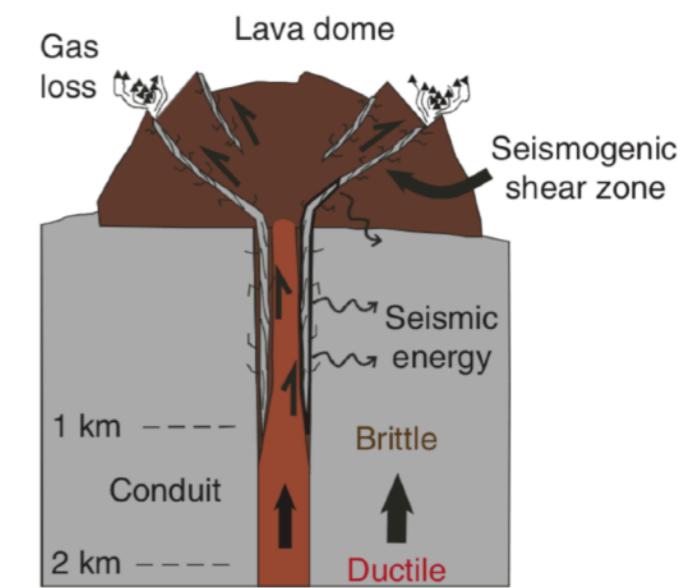
# **Long-term evolution of the spectral content of continuous seismo-volcanic signals from a network-based analysis**

**Emmanuel Caballero, Nikolai Shapiro, Cyril Journeau,  
Léonard Seydoux, Jean Soubestre, Andrés Barajas**

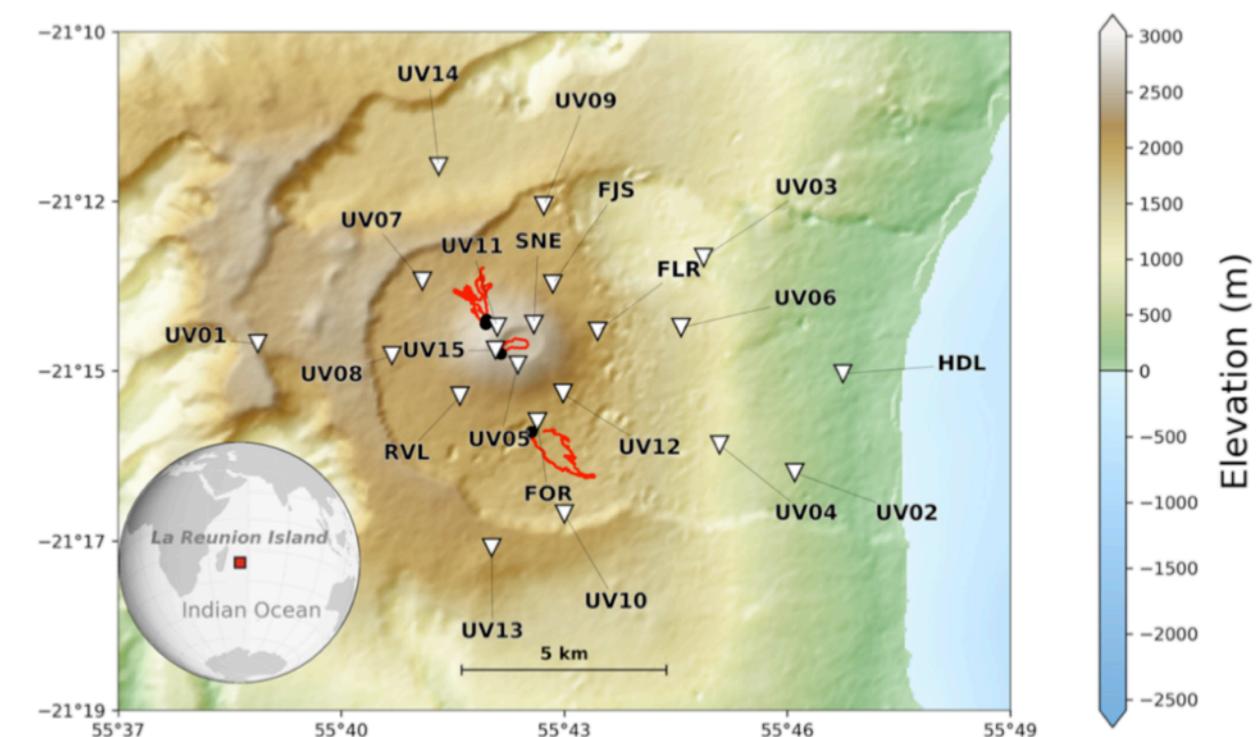
# Volcanic signals and changes in volcanoes?



Chouet (1996)

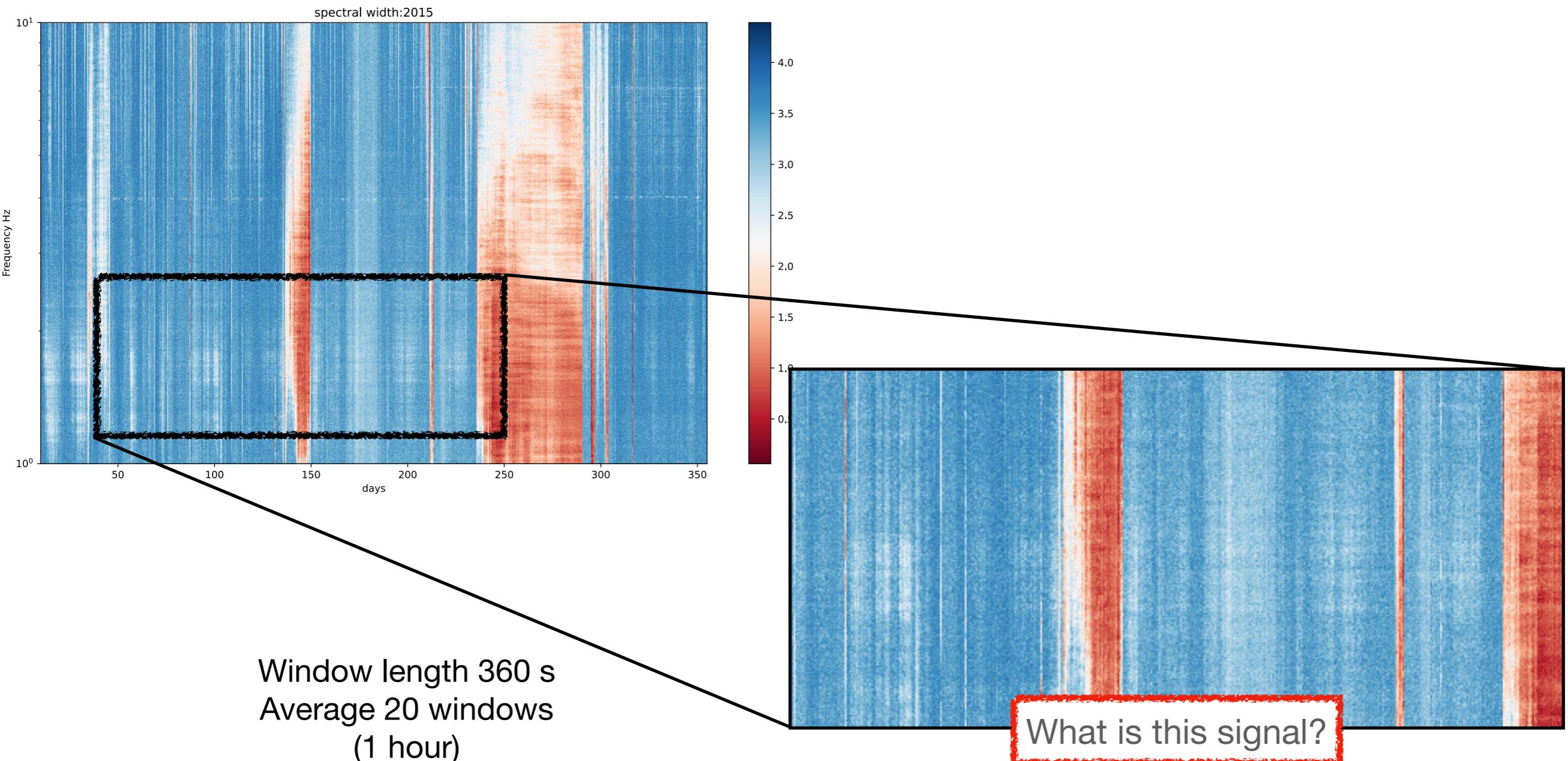


Chouet & Matoza (2012)



Journeau et al. (2020)

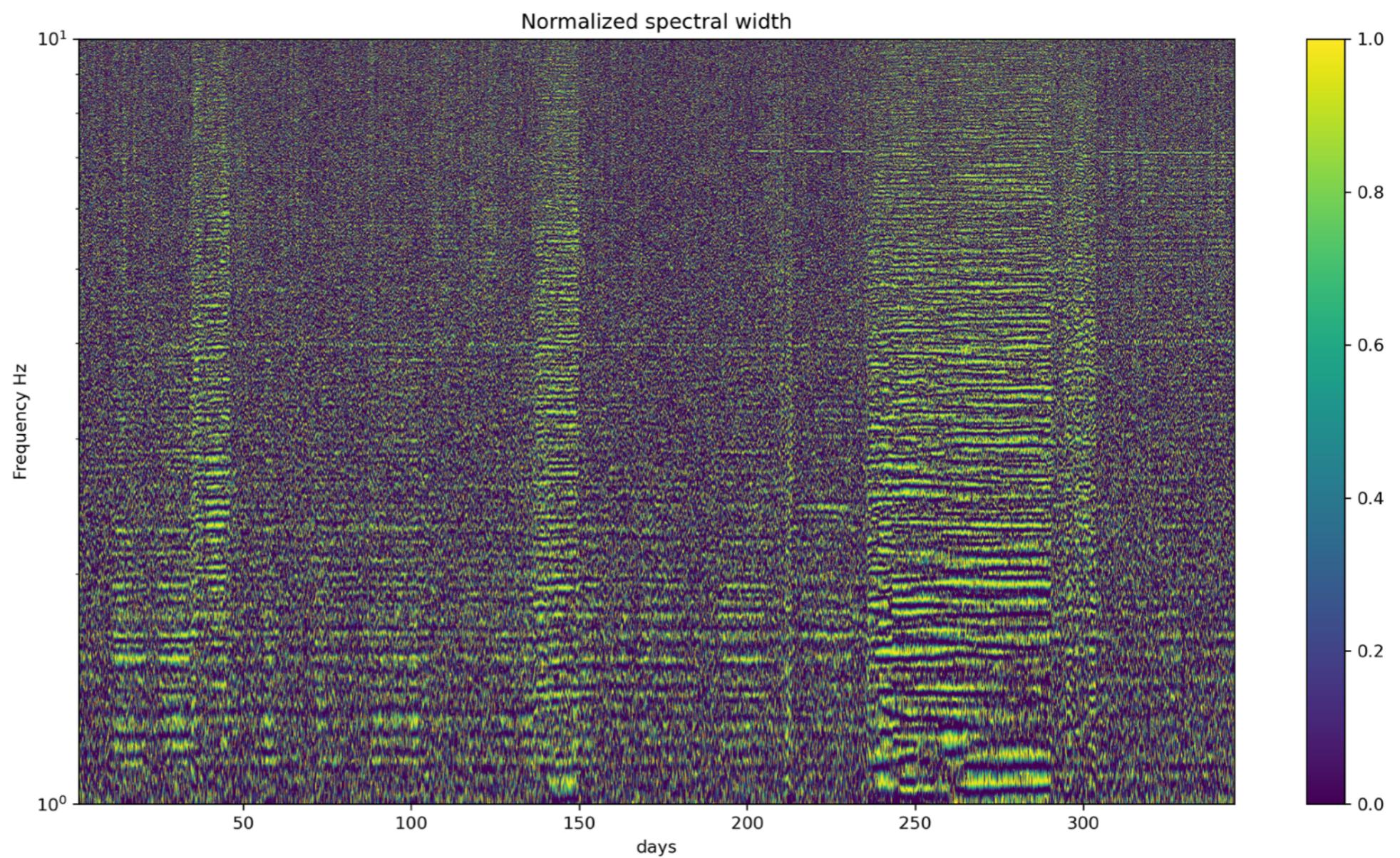
# Methodology: Covariance Matrix Spectral width 2015



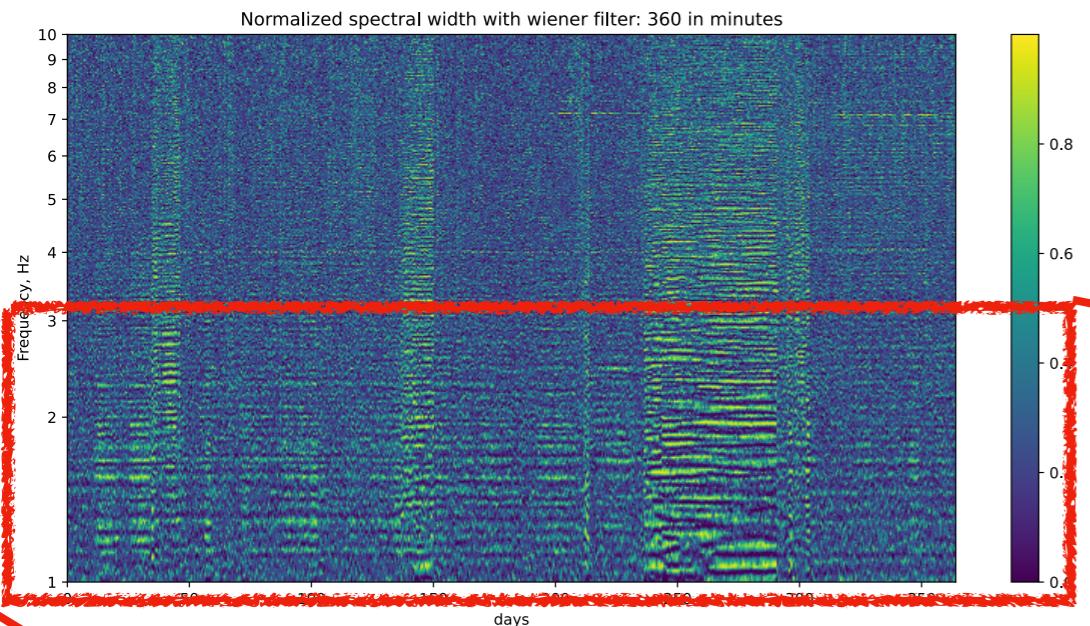
# Spectral width normalised in frequency

2015

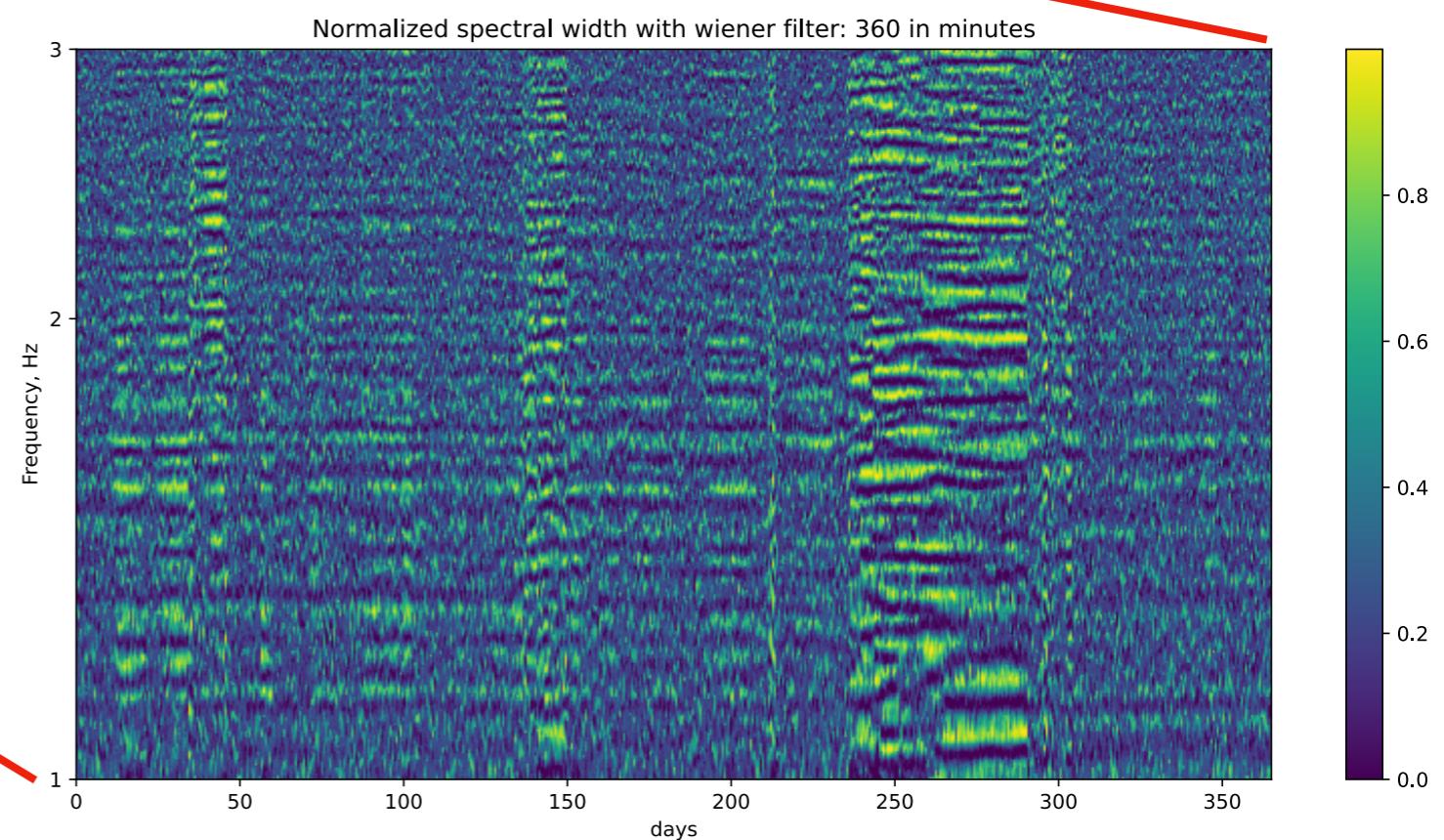
Window length 360s  
Average 20 windows  
Total time = 1 hr  
Smoothing (0.05 Hz)  
Threshold 0.05



# Spectral width filtered in time



Window length 360s  
Average 20 windows  
Total time = 1 hr  
Smoothing (0.05 Hz)  
Threshold 0.05  
Wiener filter = 360 min

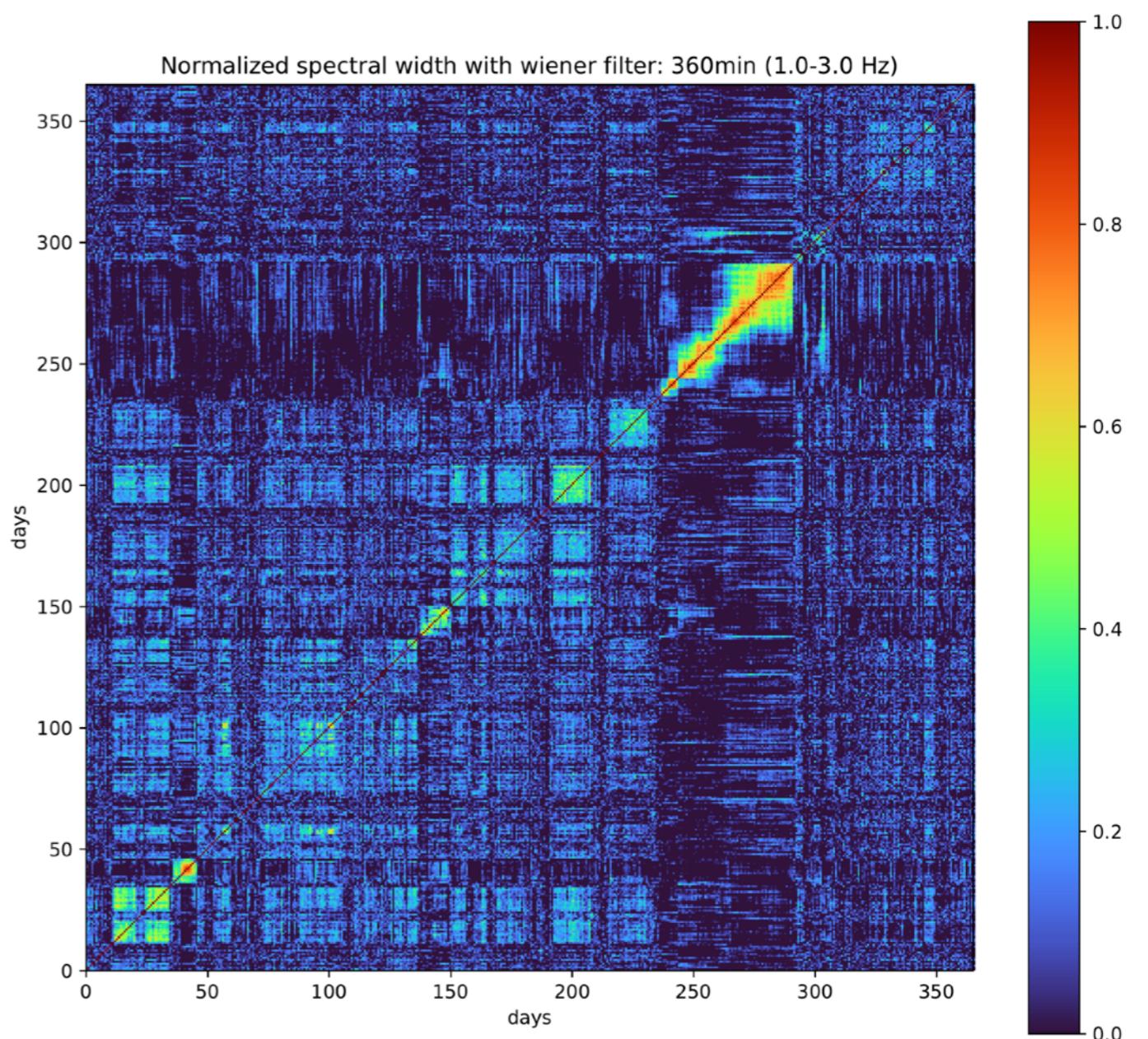


# Correlation coefficient

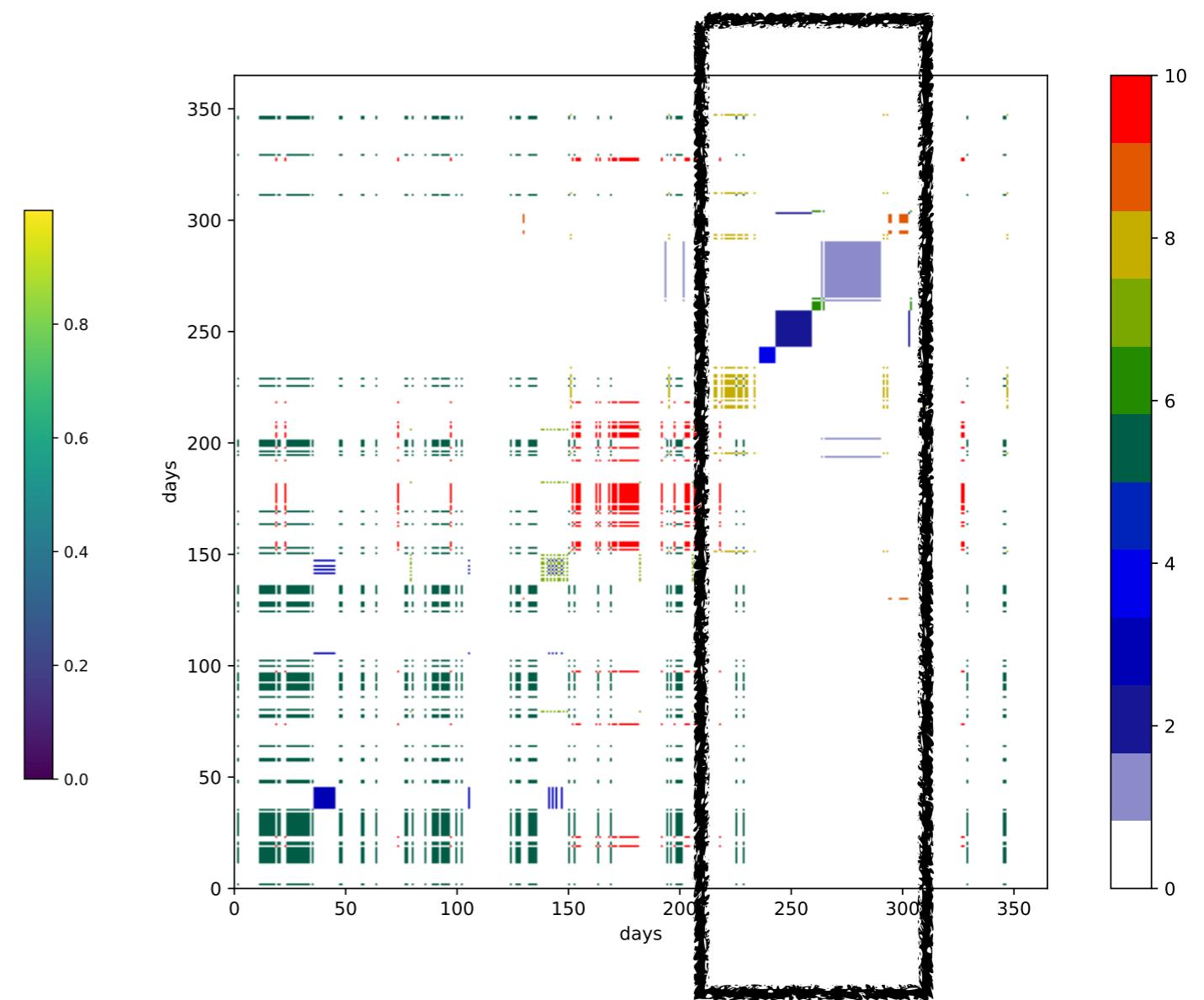
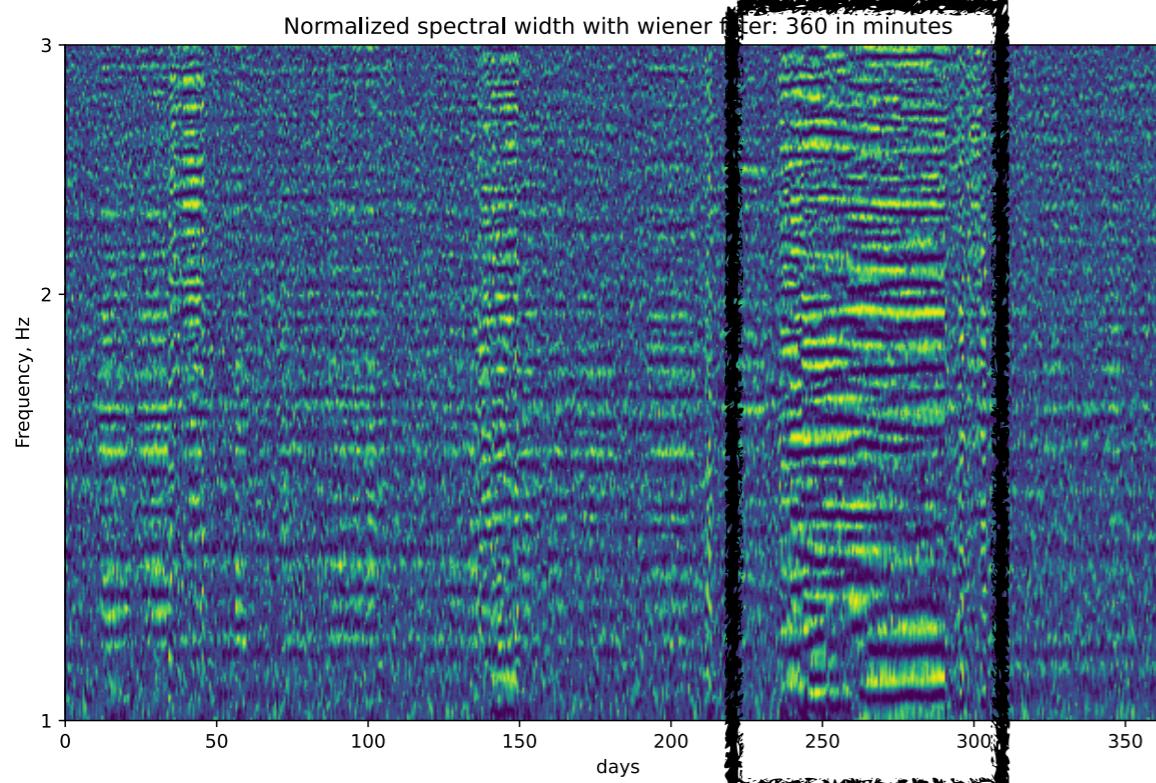
2015

Pearson correlation  
coefficient

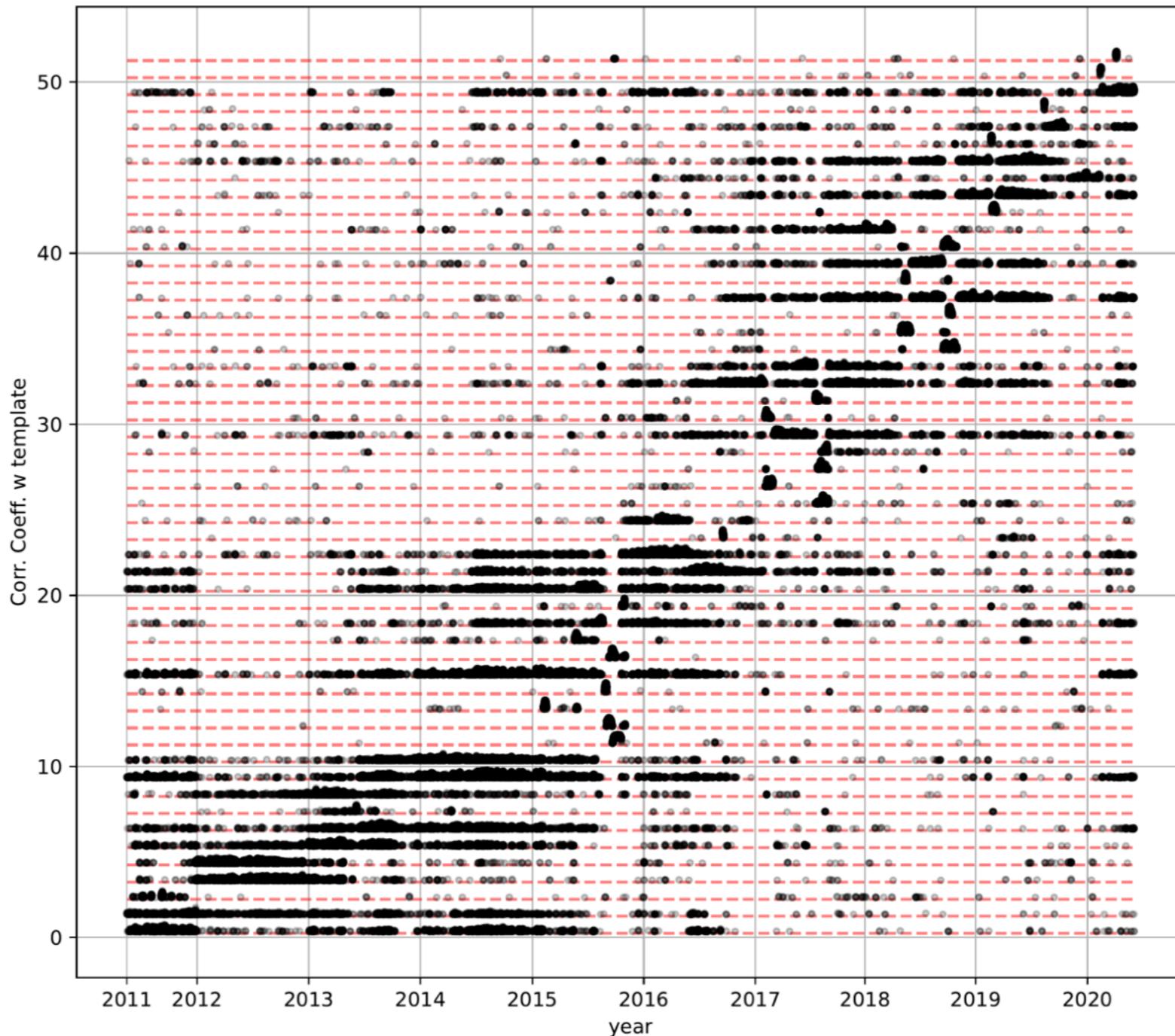
$$CC_{j,k} = \frac{\sum_{i=1}^{nFr} (\sigma(f_i)^j - \bar{\sigma}(f_i)^j)(\sigma(f_i)^k - \bar{\sigma}(f_i)^k)}{\sqrt{\sum_{i=1}^{nFr} (\sigma(f_i)^j - \bar{\sigma}(f_i)^j)} \sqrt{\sum_{i=1}^{nFr} (\sigma(f_i)^k - \bar{\sigma}(f_i)^k)}}$$



# Clusters for the 2015 year

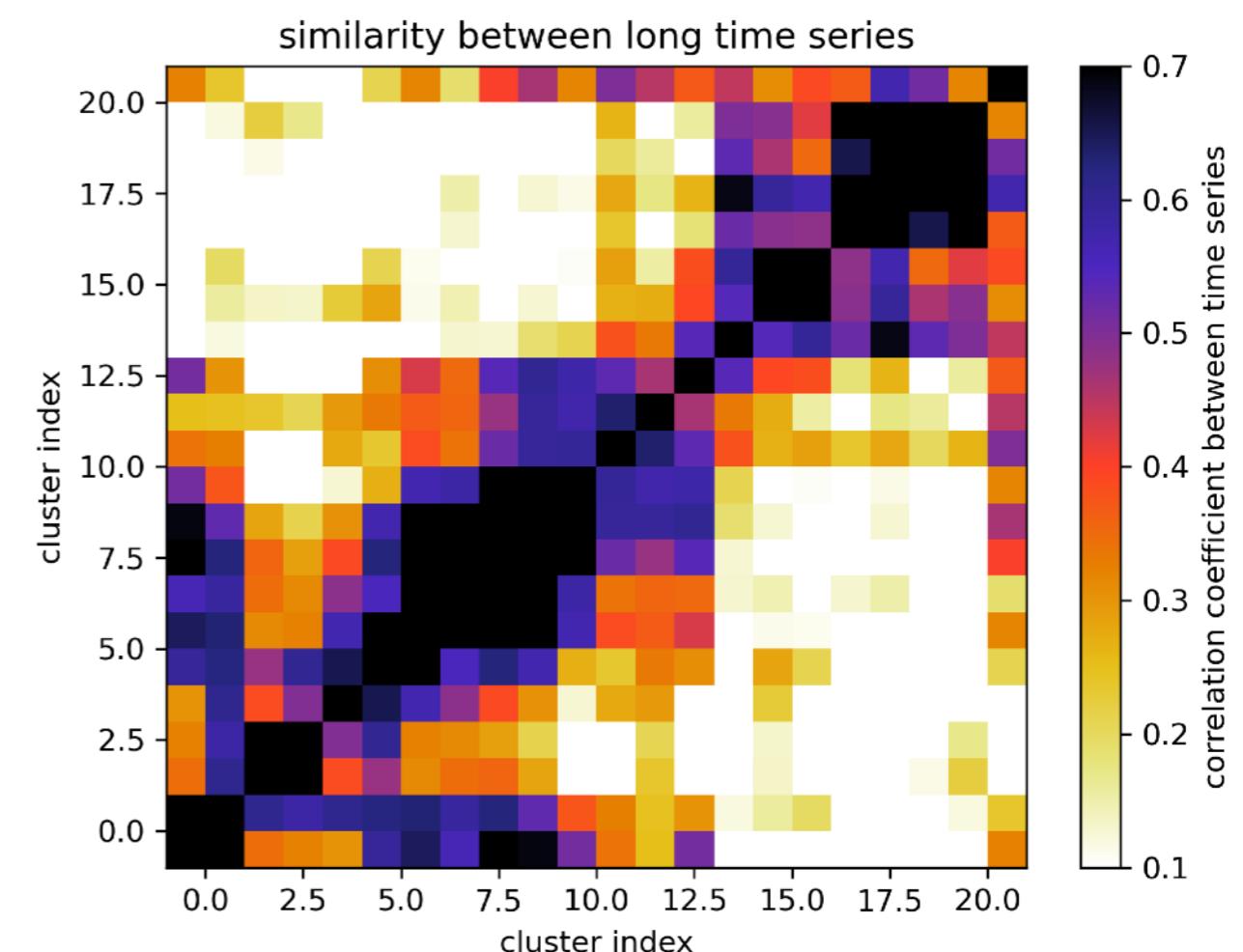
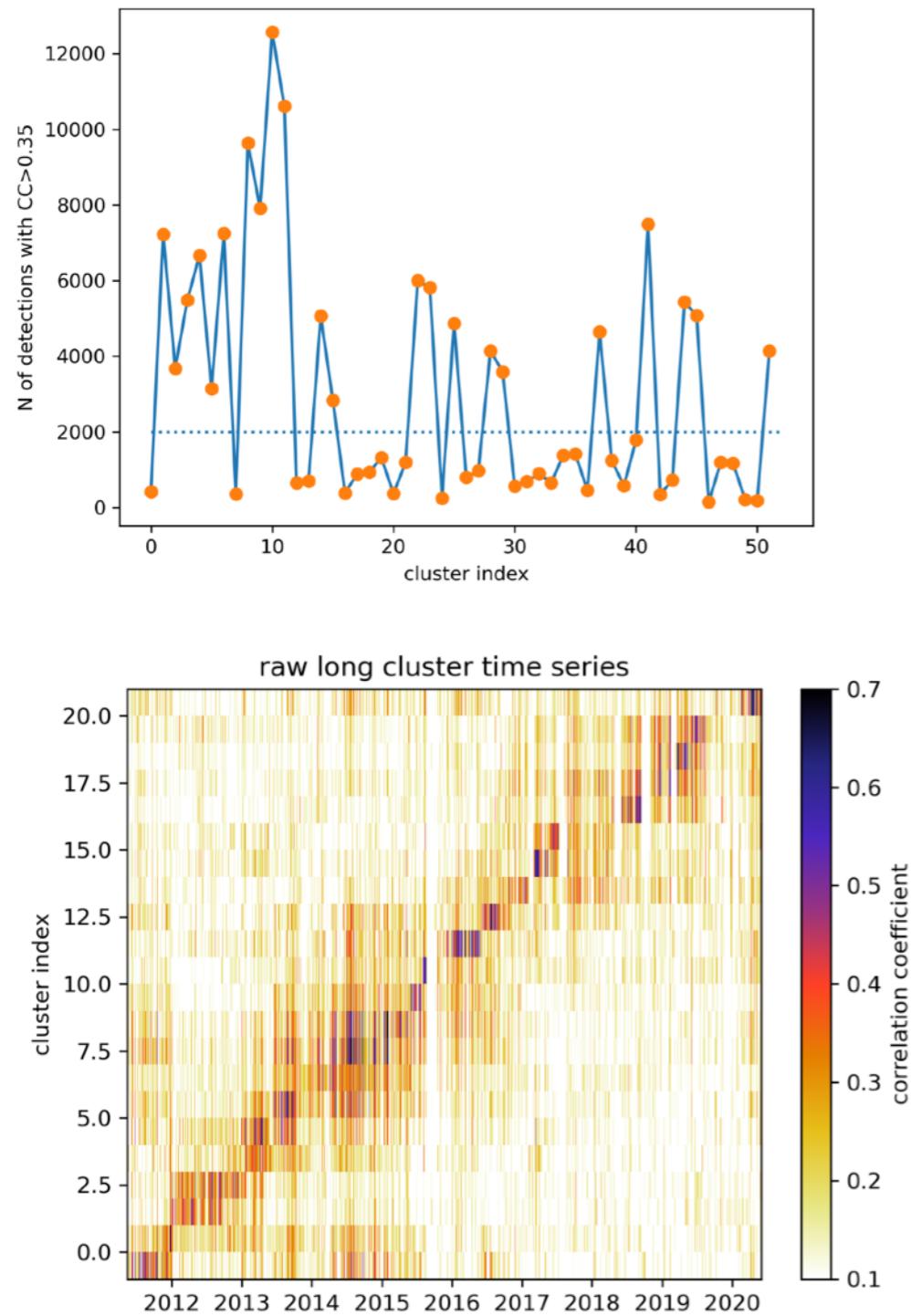


# Correlation coefficient with clusters templates > 0.35



# Correlation coefficient analysis

## “Long clusters” inter-eruption activity CC>0.35

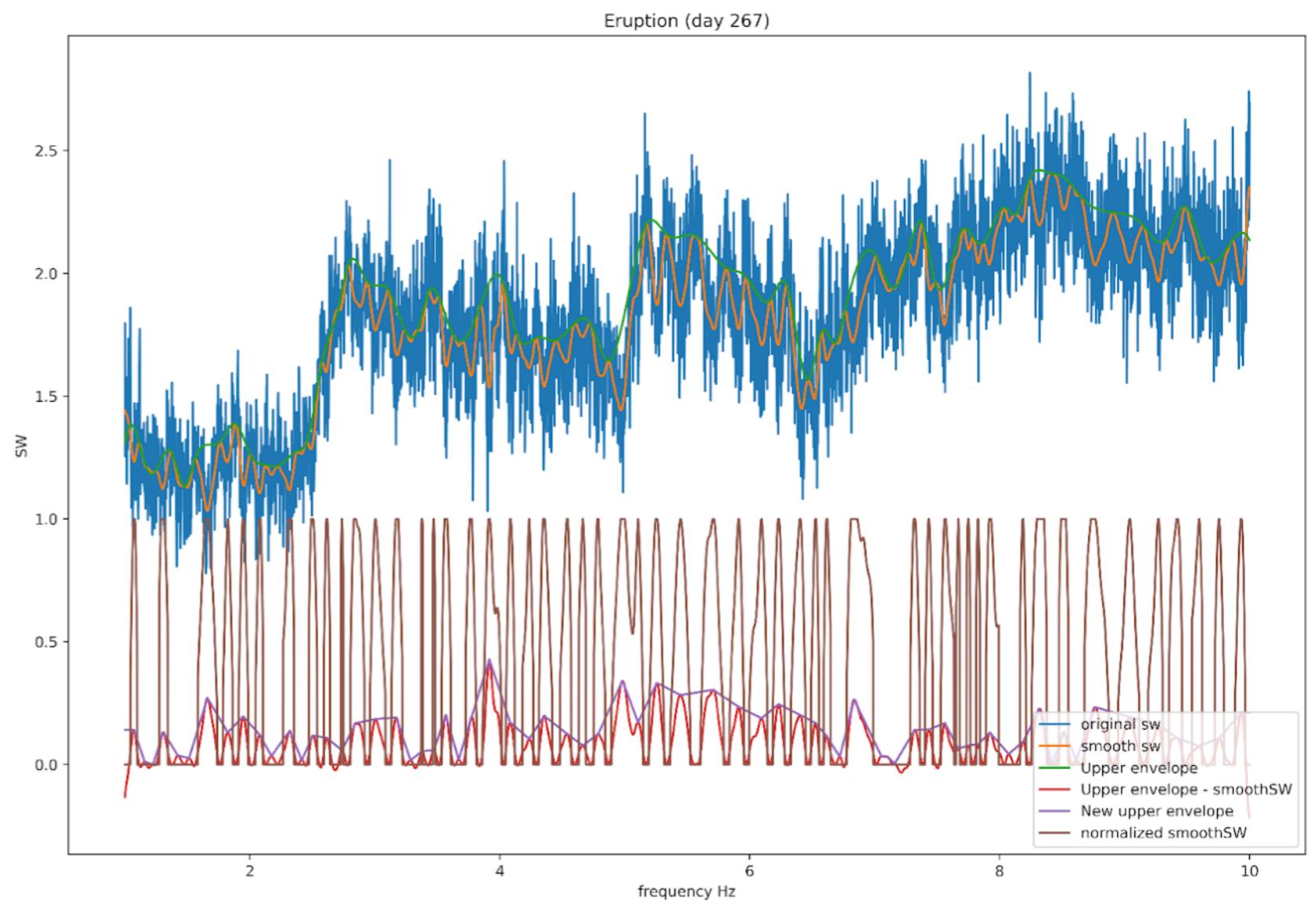


**Thank you**

# Normalization process

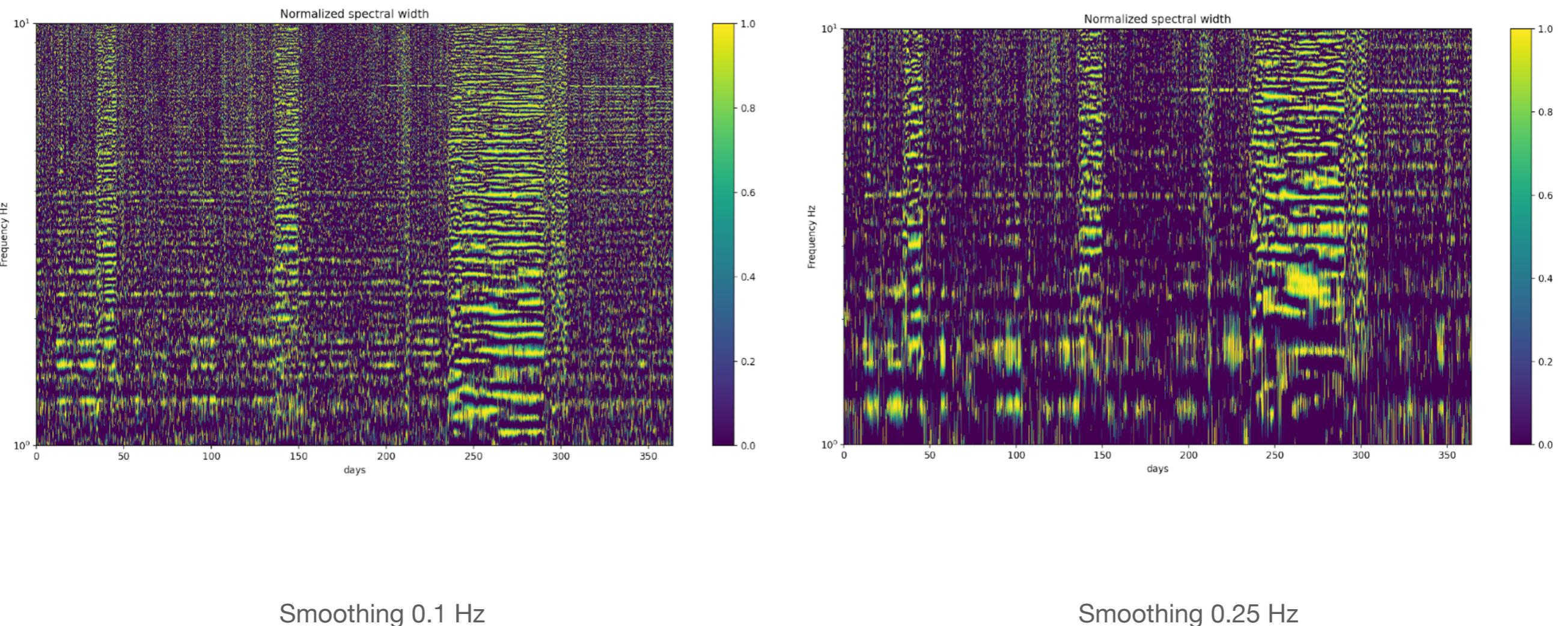
## Example for a eruptive window

- Smooth the SW
- Calculate the upper envelope
- Subtract the upper envelope
- Calculate a new upper envelope
- For the new SW
  - $SW < 0.05 = 0$
- Divide by the new upper envelope



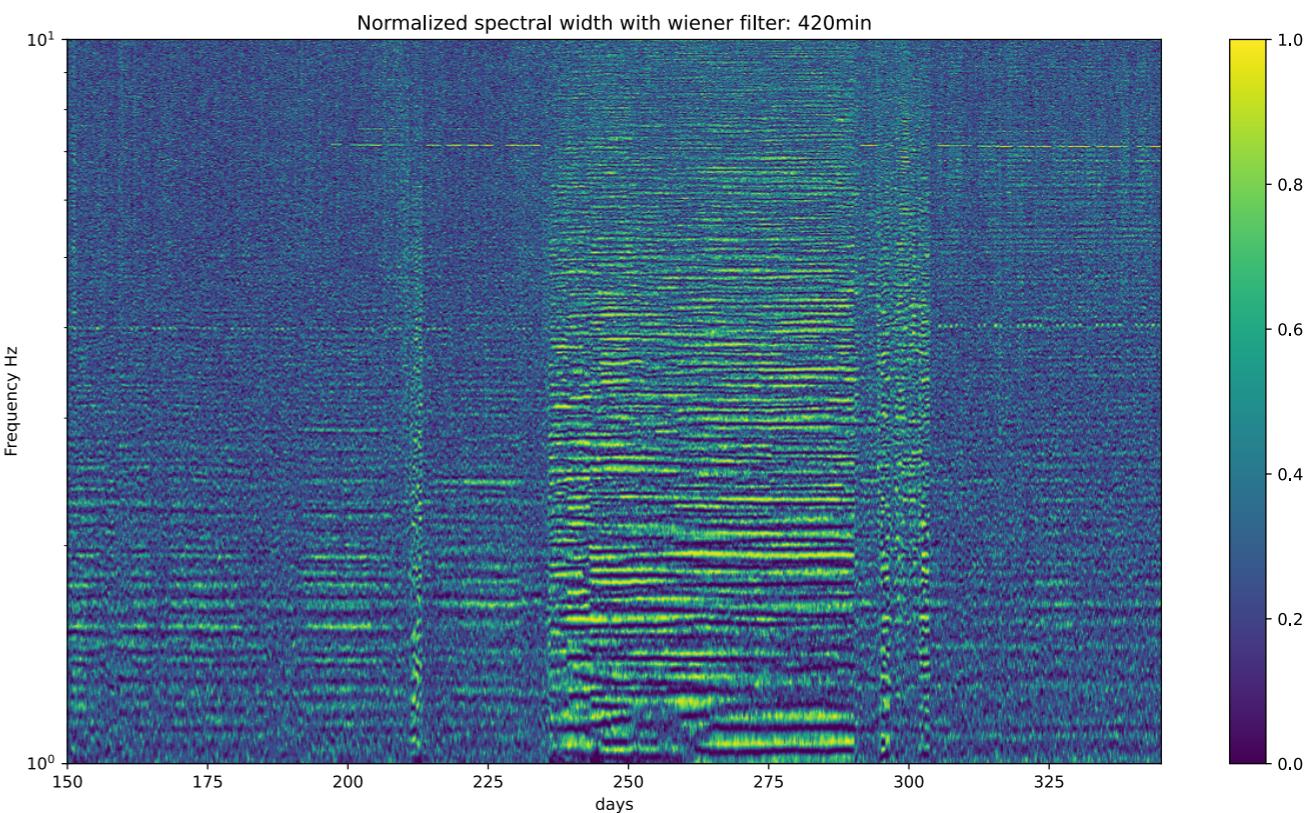
# Normalization process

## Comparison of smoothing parameter

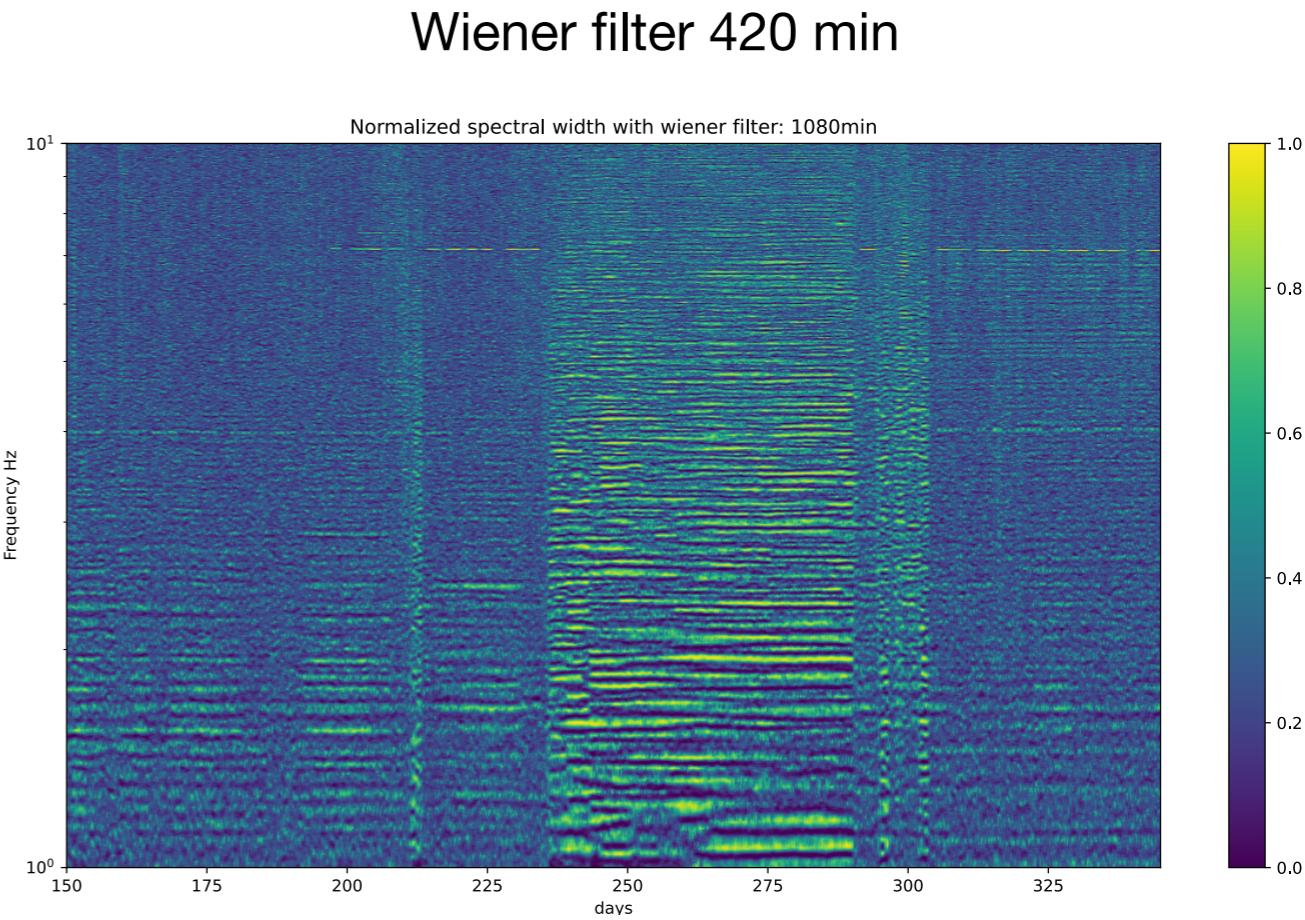


# Spectral width filter in time

2015



Window length 360s  
Average 20 windows  
Total time = 1 hr  
Smoothing (0.05 Hz)  
Threshold 0.05

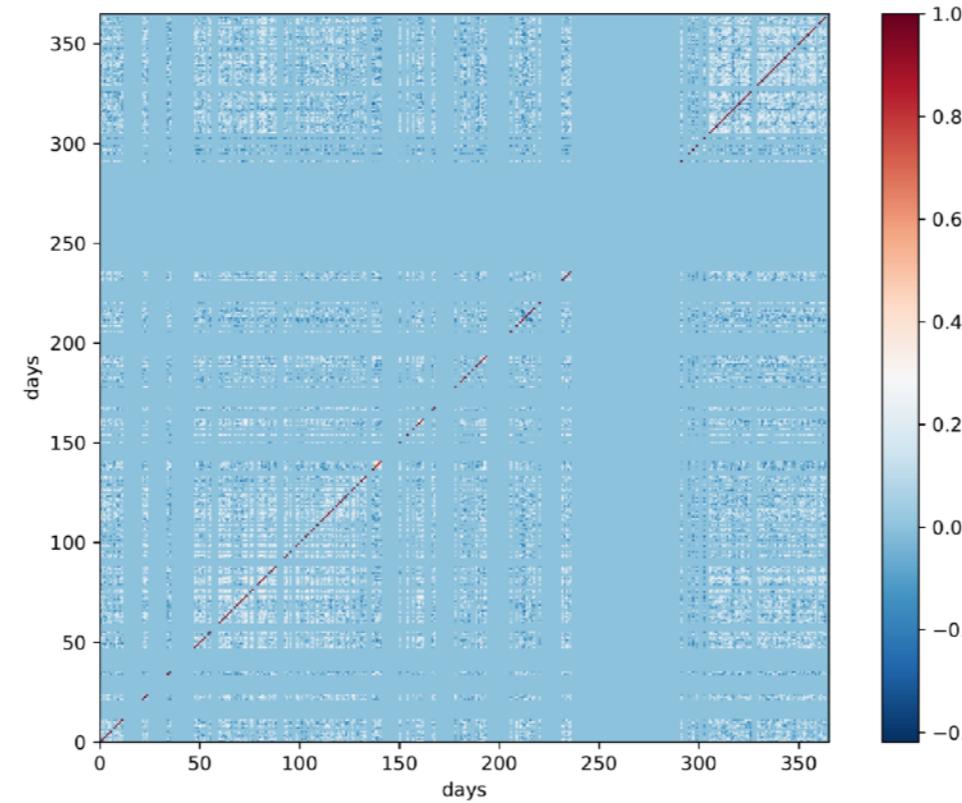
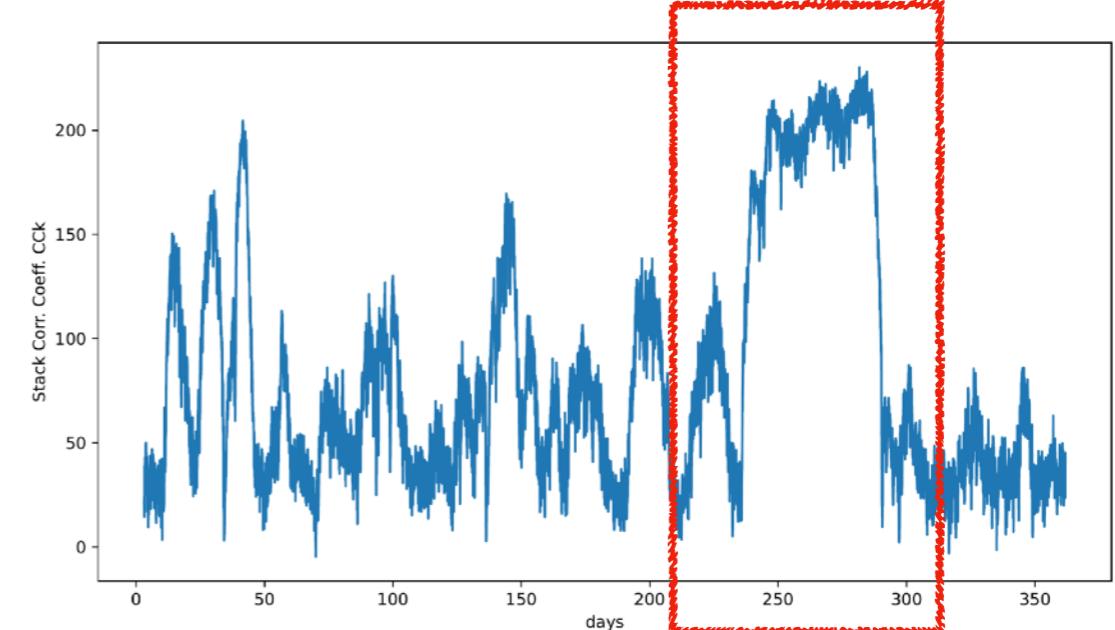


# Correlation coefficient

## Defining clusters from spectral lines

Average correlation coefficient

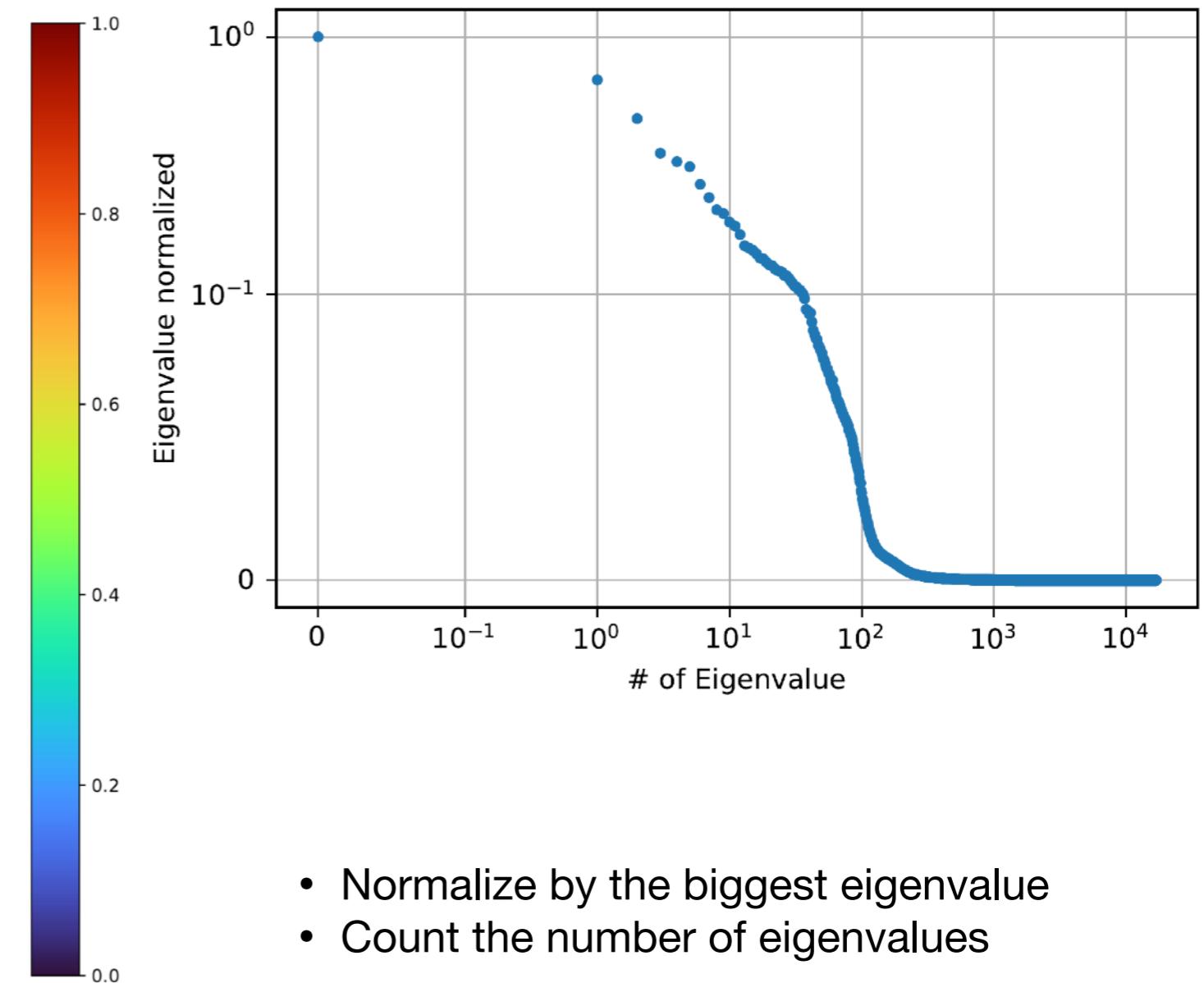
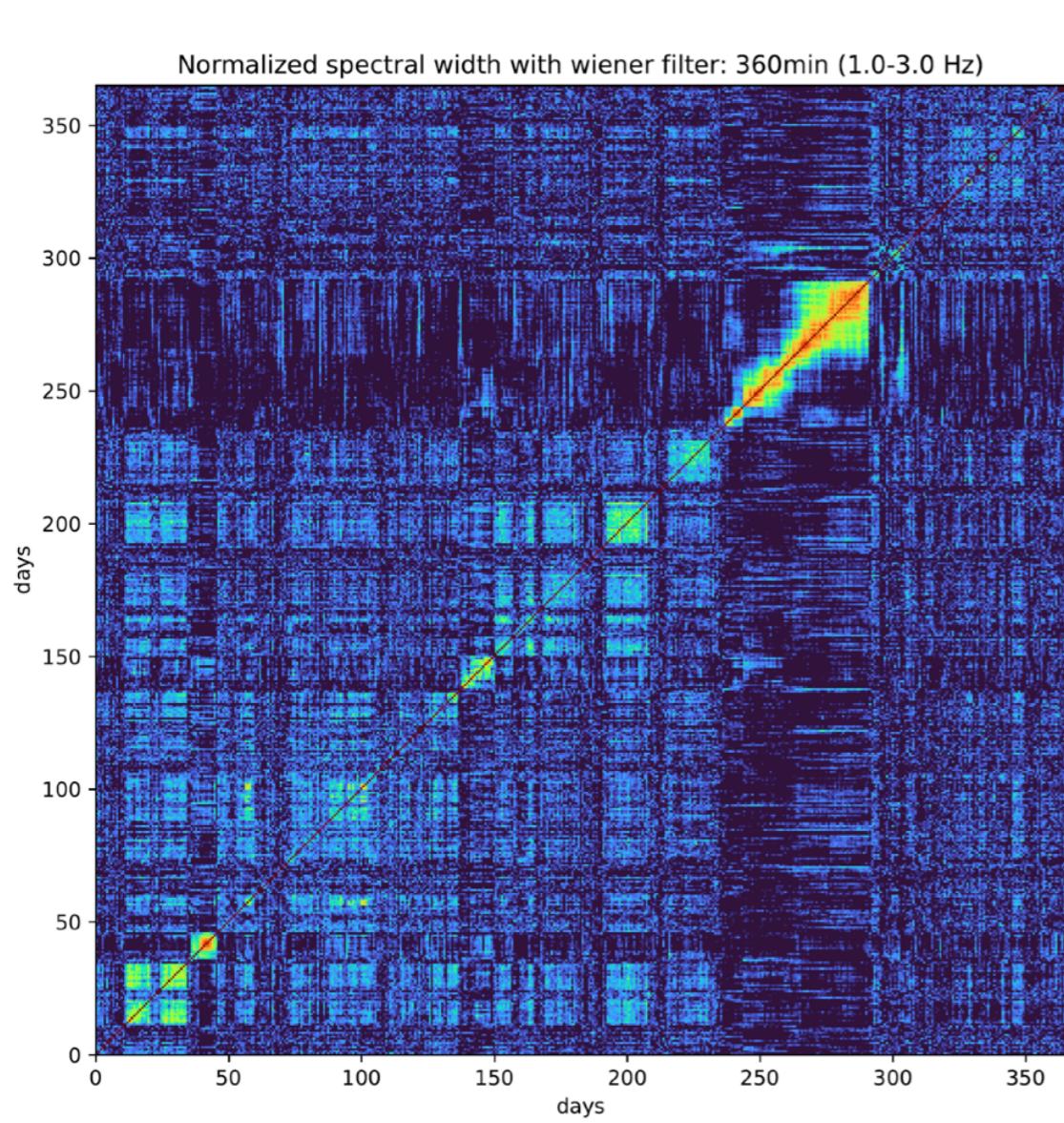
$$CC_j = \sum_{l=k-3\text{days}}^{l=k+3\text{days}} CC_{j,l}$$



Cluster windows  
CC<sub>j,k</sub> > 0.25

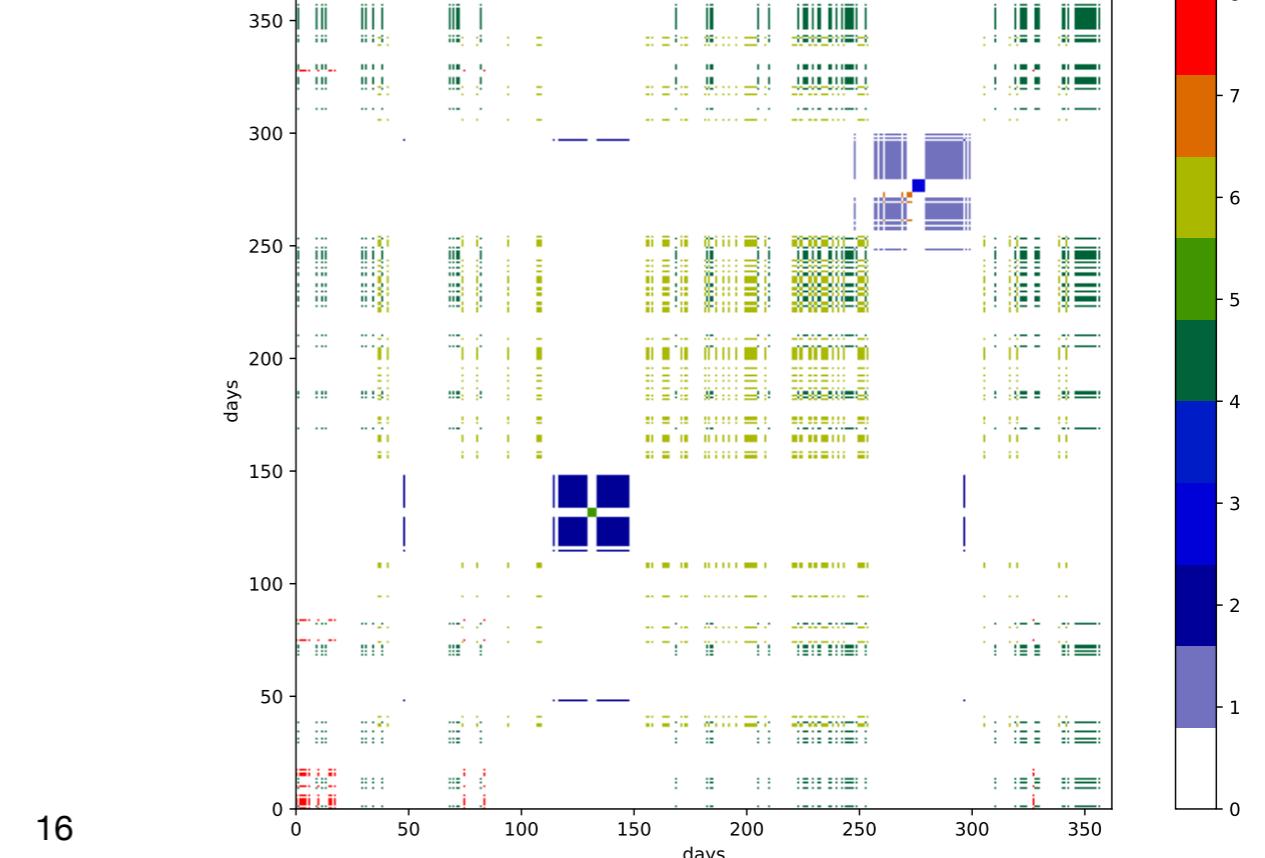
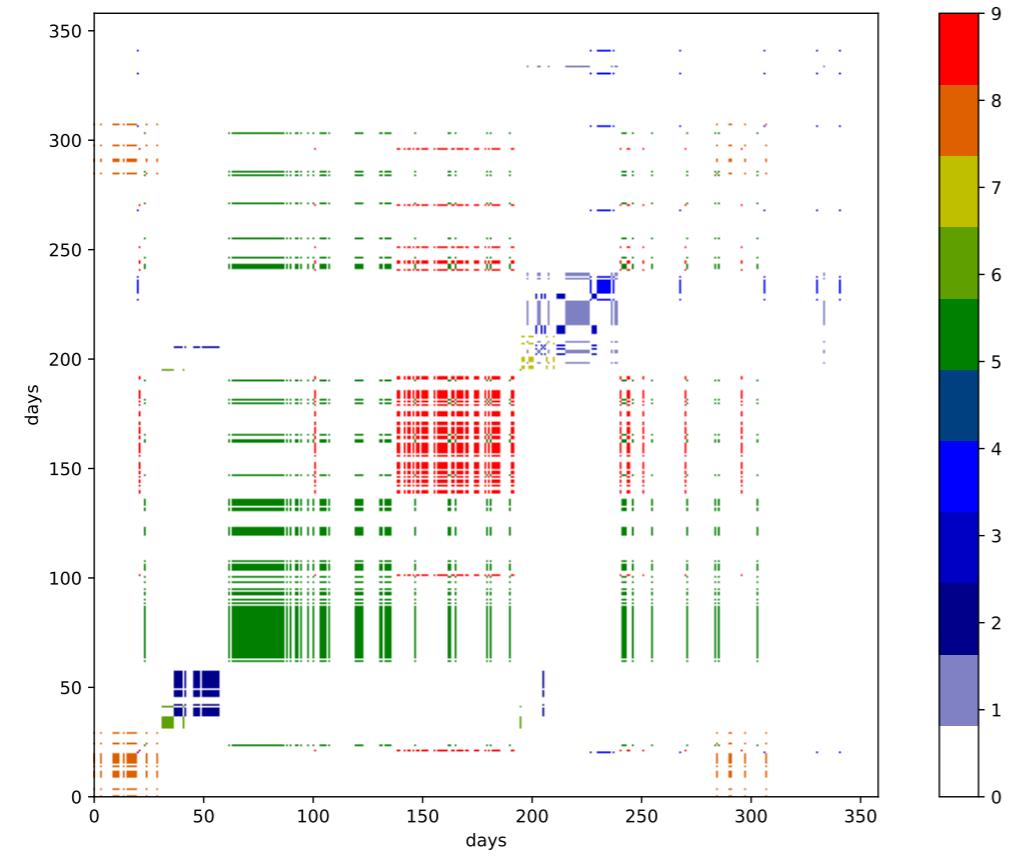
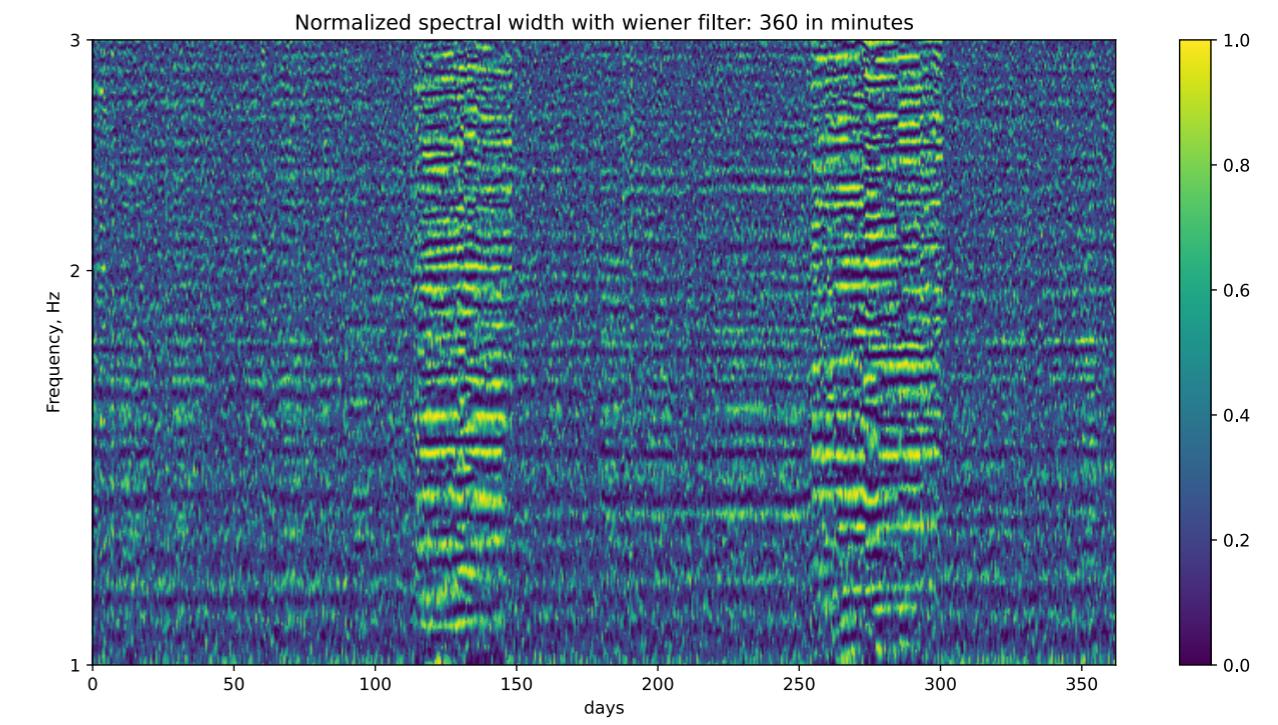
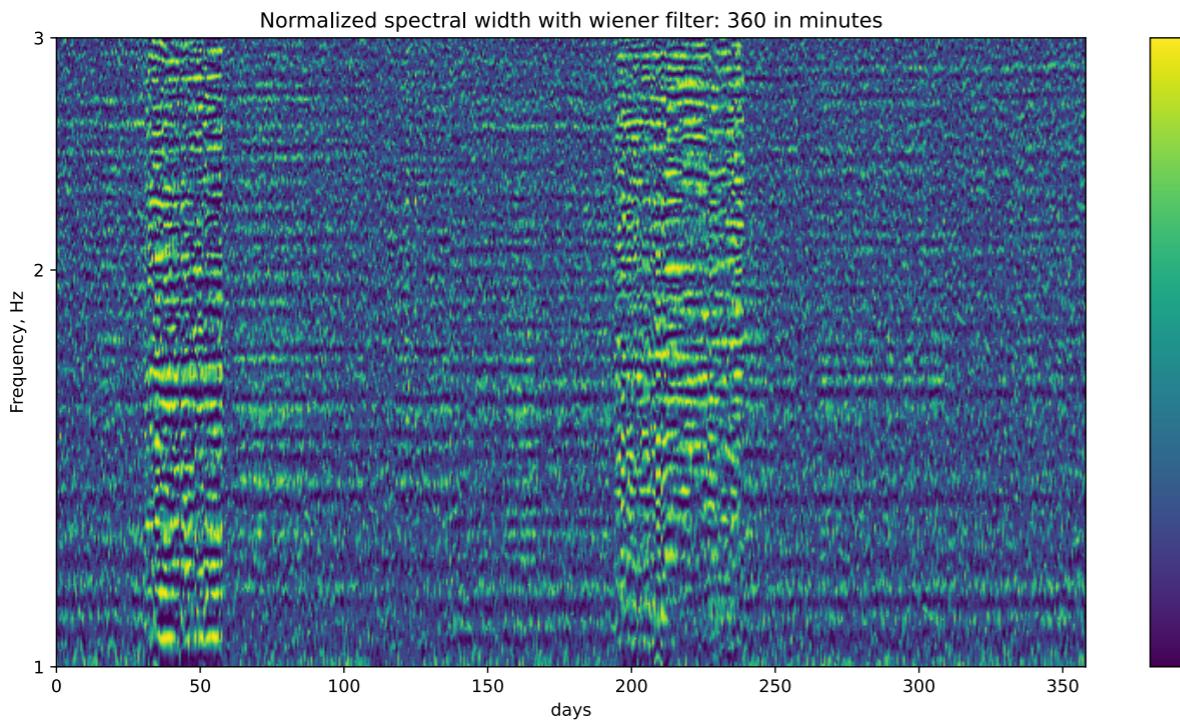
# Definition of number of clusters

2015

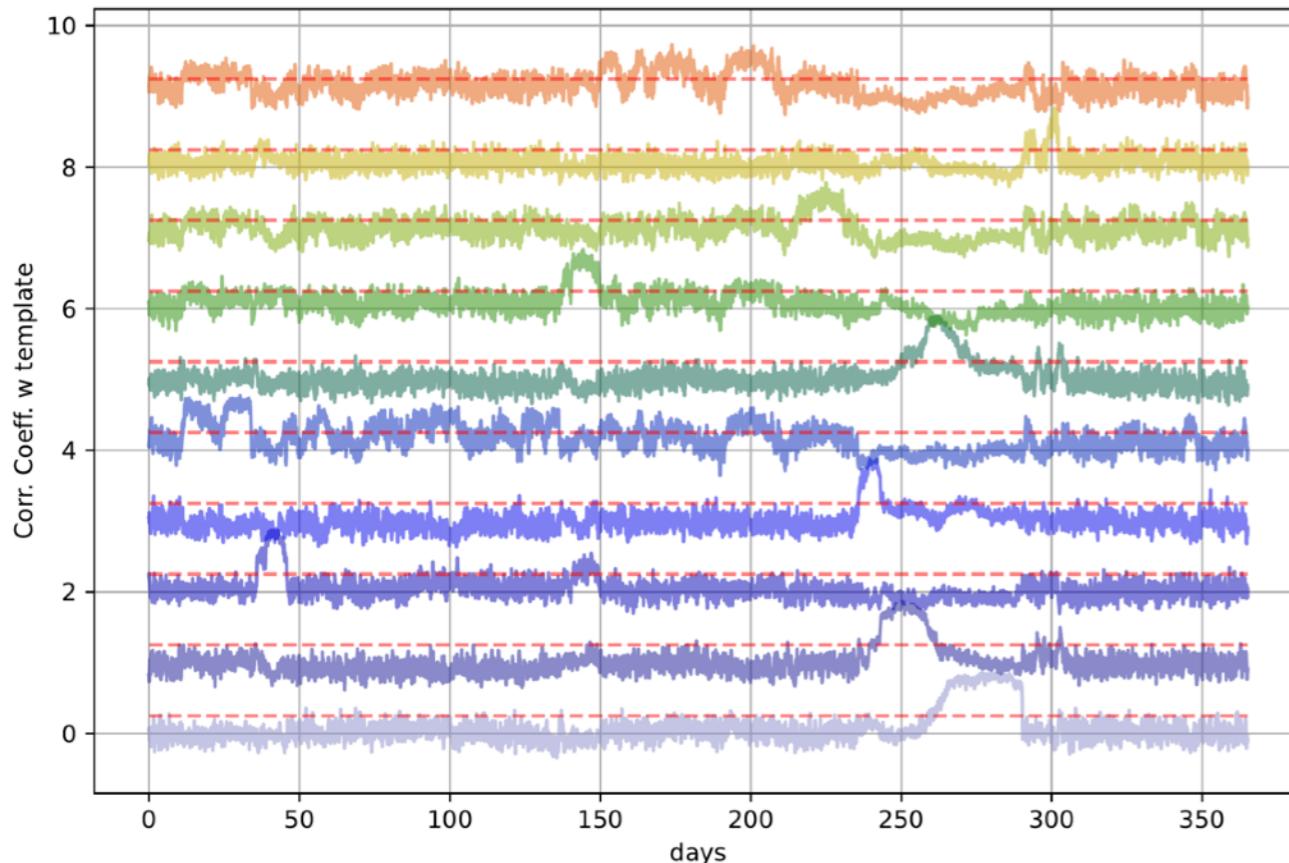


- Normalize by the biggest eigenvalue
- Count the number of eigenvalues

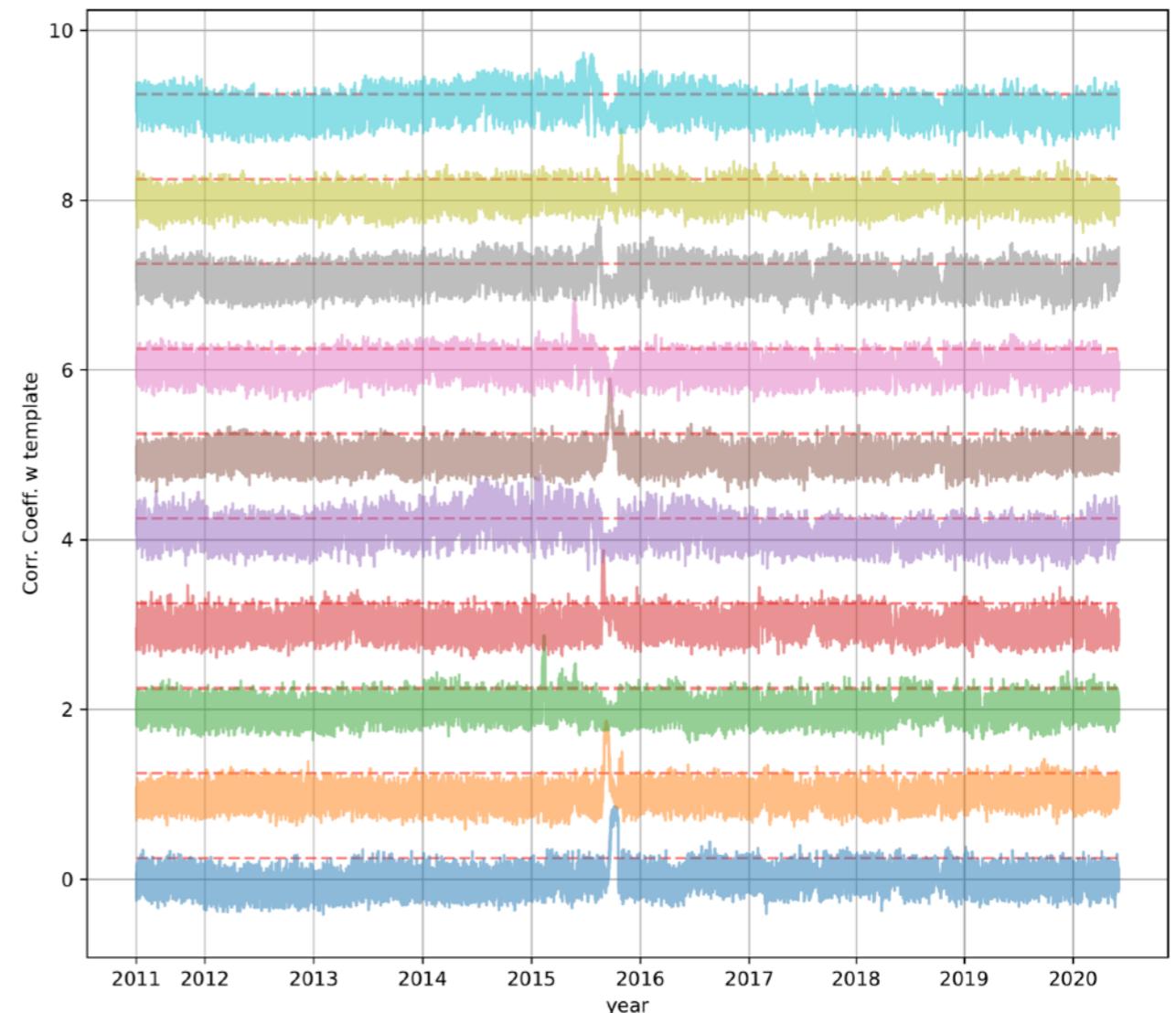
# Year 2017



# Correlation coefficient with clusters templates



Clusters templates  
from 2015



Clusters templates  
from 2015 for all the  
period

# Correlation coefficient analysis

## Ordering templates by the biggest cc

