

# Wavelet Clustering, a tool for analysing spatial and temporal patterns of epidemics based on their dynamical properties:

## Application to dengue in Thailand

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Models in Population Dynamic,  
UFSM - Santa Maria – Brazil, September 2012

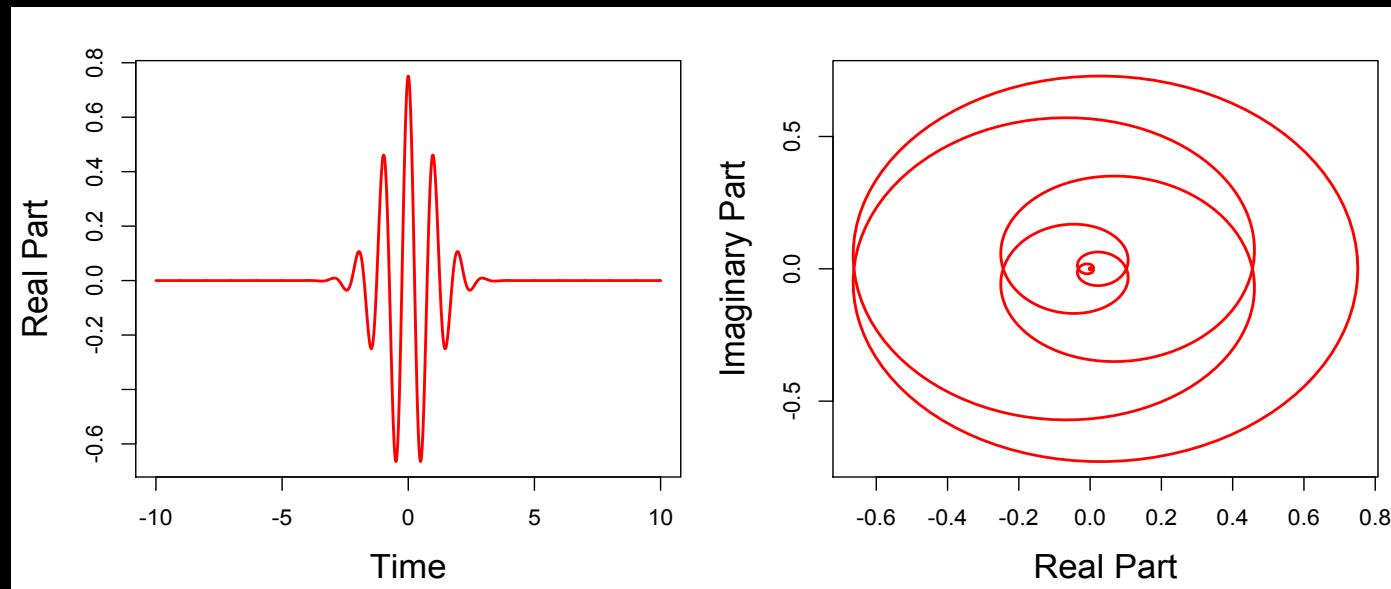


Dengue Research Framework For  
Resisting Epidemics In Europe  
Since-2012



# What are Wavelets

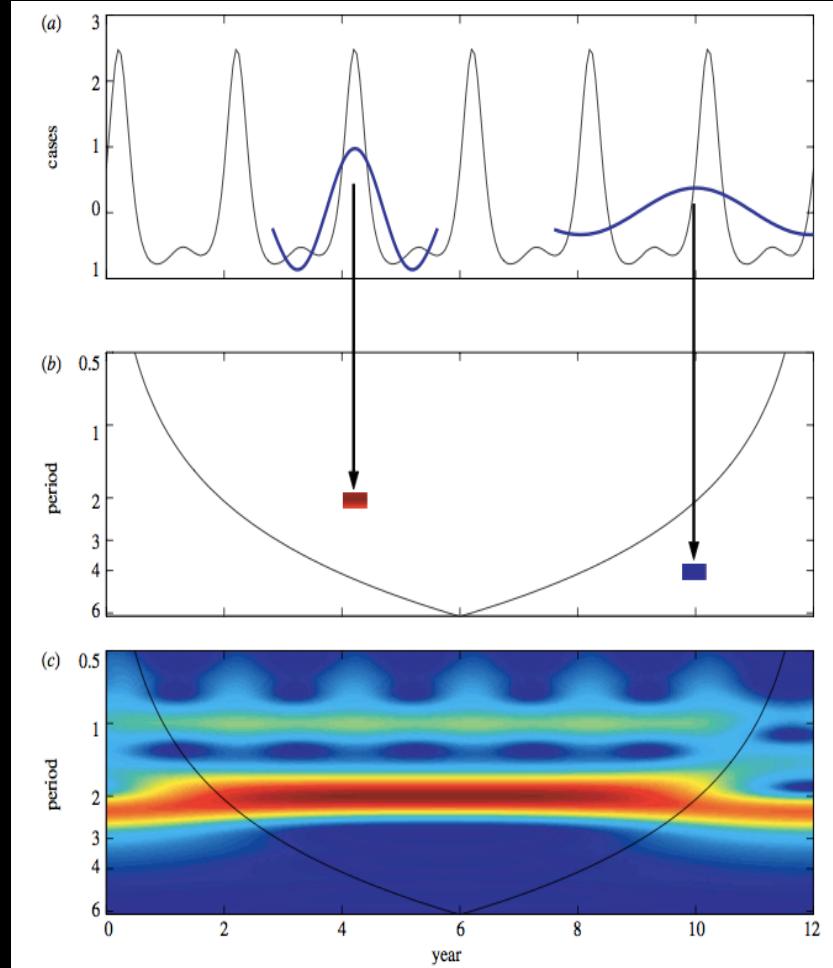
- Tools to analyse non stationary temporal series
- Using small signal form functions as Morlet wavelet to emphasise frequencies components
- Morlet function :  $\Psi_{f_0}(t) = \pi^{-1/4} \exp(2\pi f_0 t) \exp(-\frac{1}{2}t^2)$



# Wavelet Spectrum

- Using convolution between wavelet conjugate and time series to produce a Wavelet Spectrum
- Statistical tests exist to exhibit significant frequencies component
- Wavelet Transform :

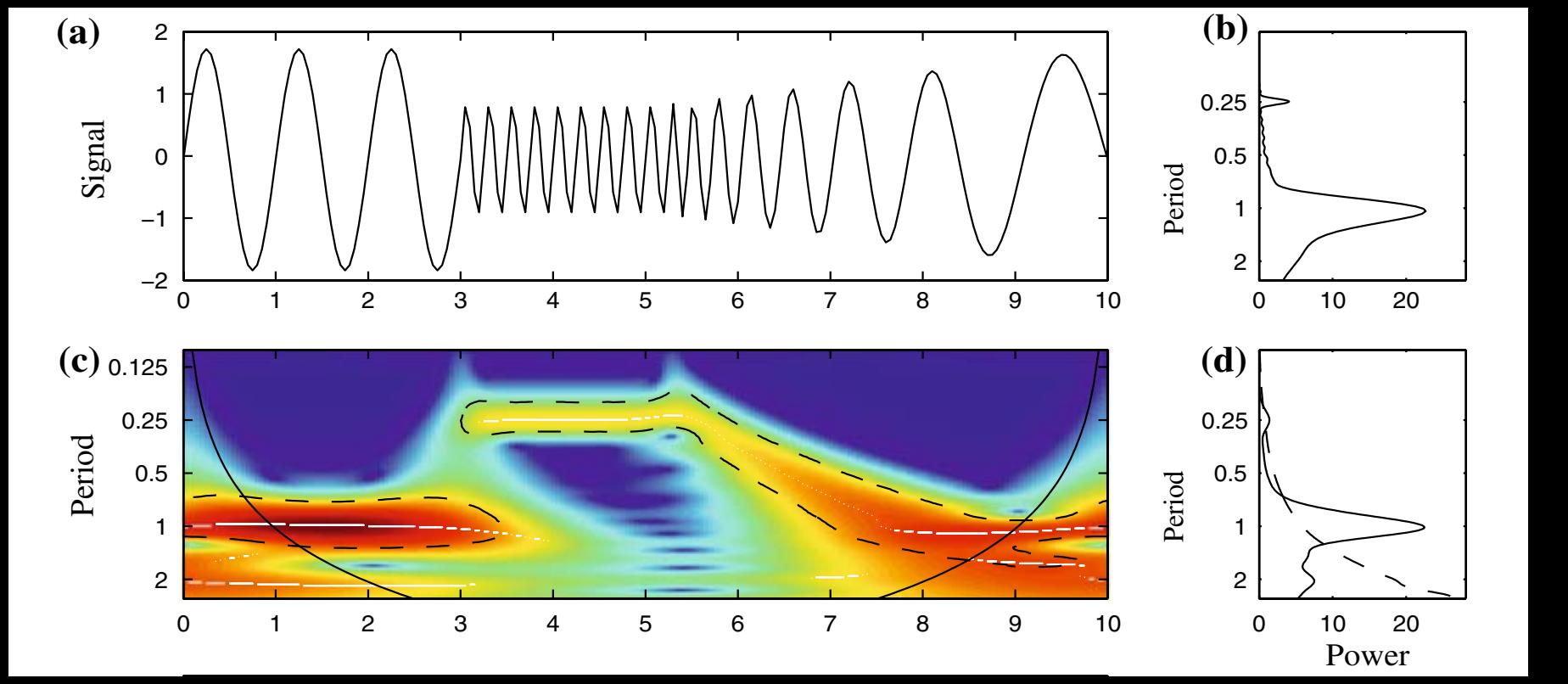
$$T(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t) \cdot \Psi^*(\frac{t-b}{a}) dt$$



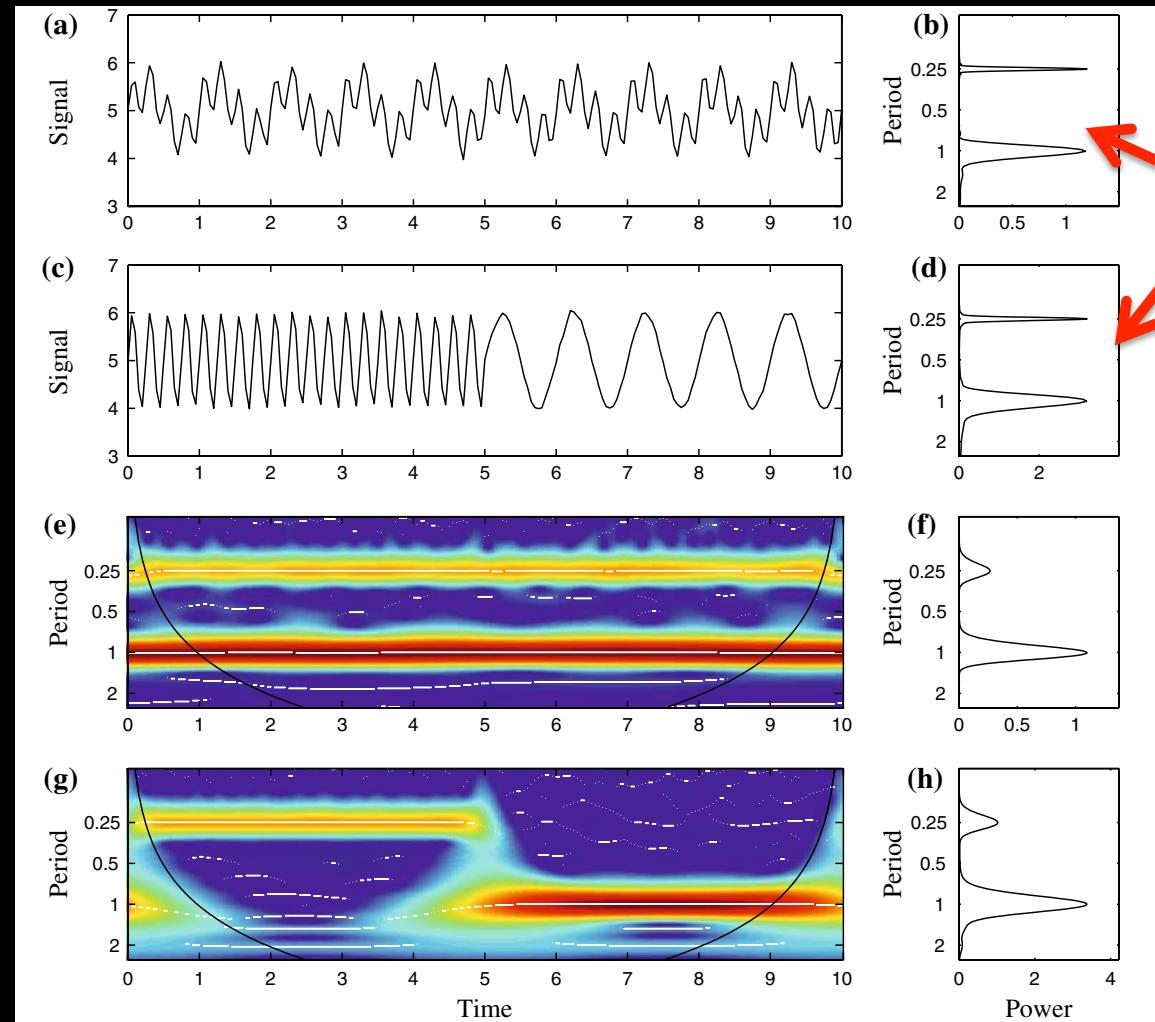
Cazelles B. et al., Interface, 2007

# Wavelet Spectrum vs Fourier Spectrum

- Wavelets are useful to emphasise non stationary dynamic



# Wavelet Spectrum vs Fourier Spectrum



Both have a similar Fourier Spectrum

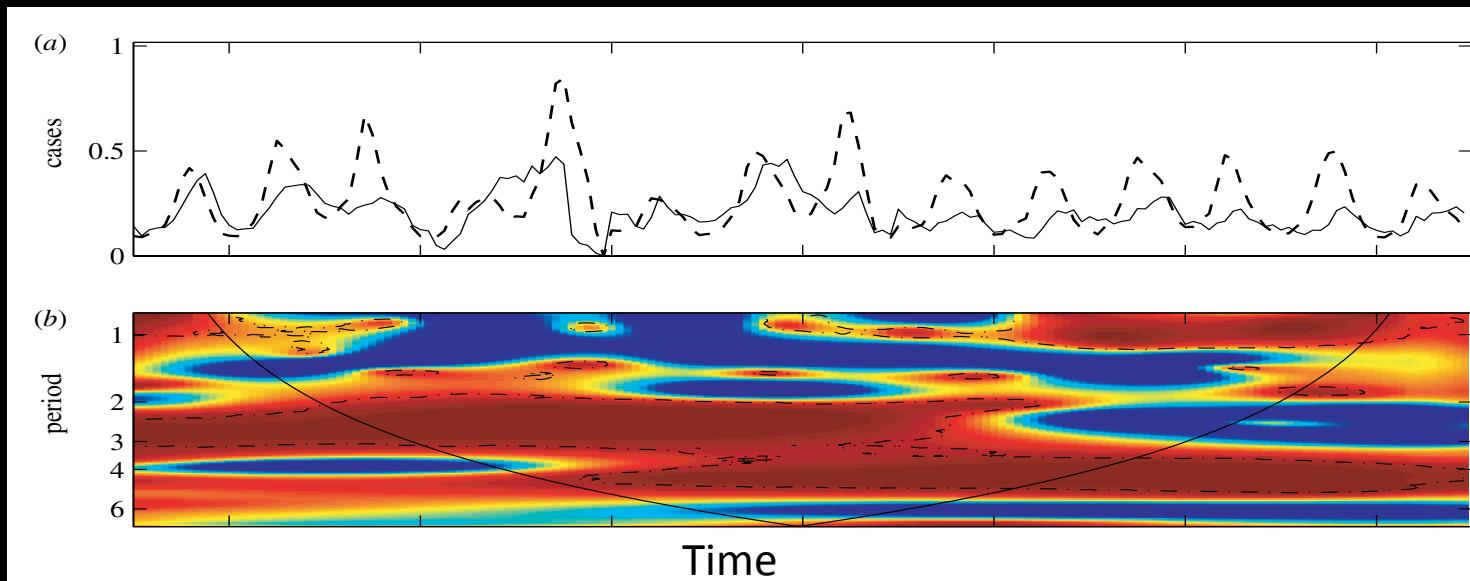
# Other Wavelets metrics

- CrossWavelet Power

$$W_{xy}(a,b) = \frac{W_x(a,b).W_y(a,b)^*}{\sigma_x \cdot \sigma_y}$$

-Wavelet Coherency

$$CW_{xy} = \frac{|W_{xy}(a,b)|^2}{|W_x(a,b)| \cdot |W_y(a,b)|}$$

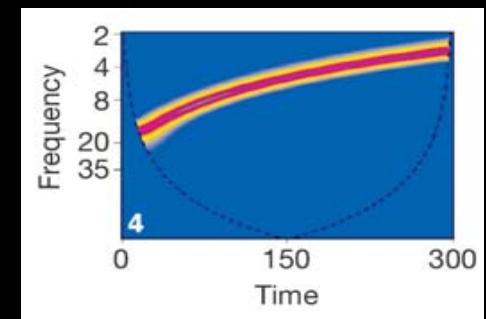
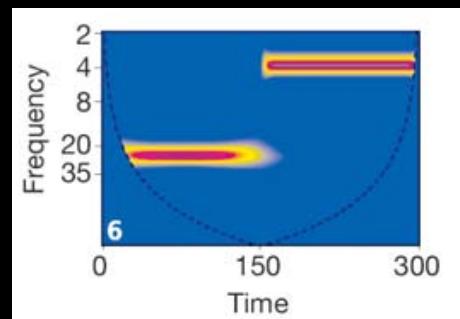
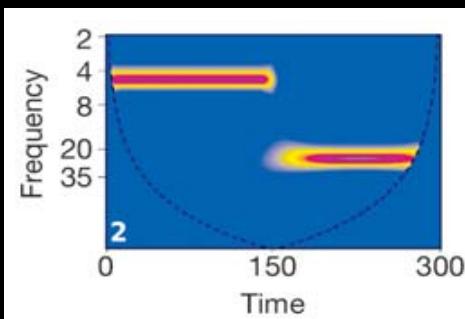
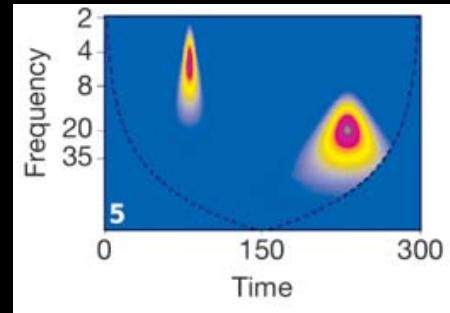
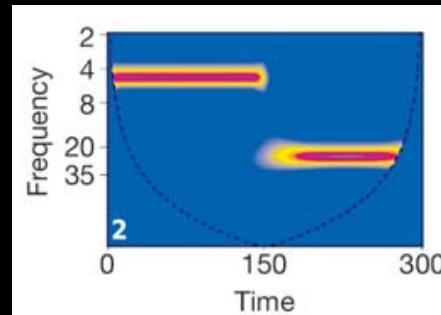
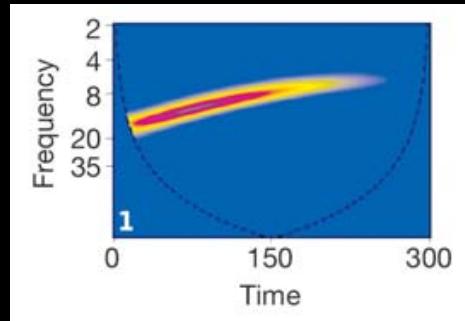


# Wavelet clustering

- Using wavelet spectra as a source of information
- Compare different temporal series of the same phenomenon (across space)
- Cluster temporal series
- Rouyer, *Mar Ecol Prog Ser*, 2008.

# Wavelet clustering 1/3

## 1. Get Spectra



Wavelet

**Wavelet Clustering**

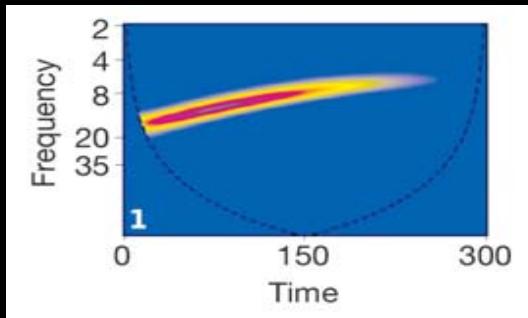
Dengue

Application

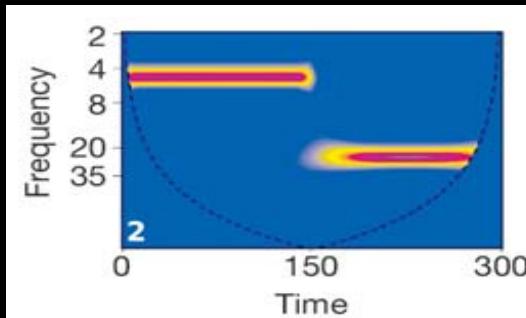
Perspectives

# Wavelet clustering 2/3

1. Get Spectra
2. Calculate a distance



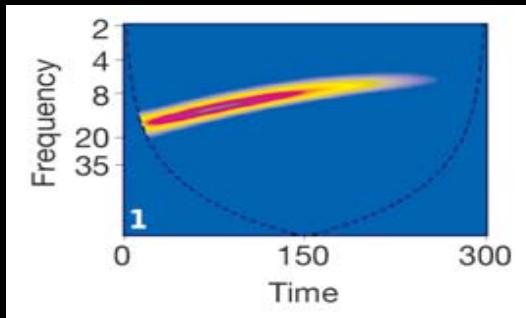
$W_i$



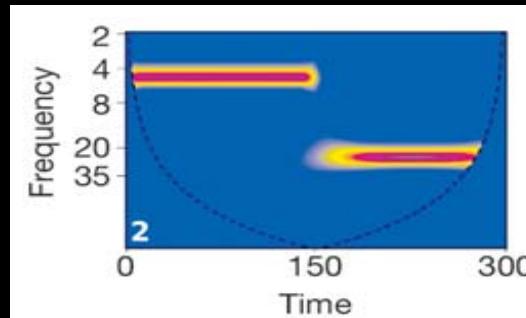
$W_j$

# Wavelet clustering 2/3

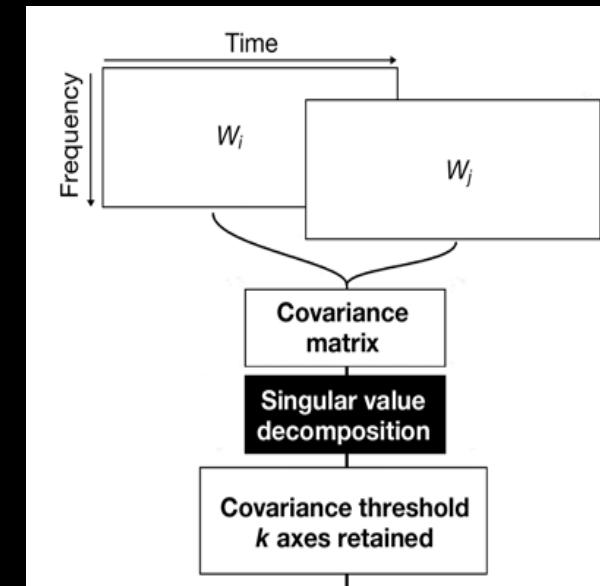
1. Get Spectra
2. Calculate a distance



$W_i$



$W_j$

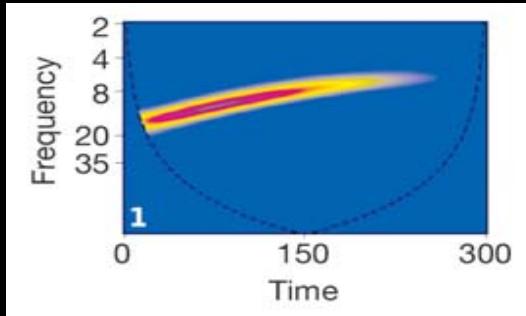


MCA (SVD)

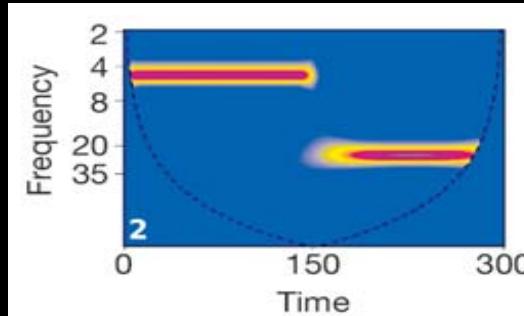
$$R_{i,j} = W_i W_j^t \longrightarrow R_{i,j} = U \Sigma V^t$$

# Wavelet clustering 2/3

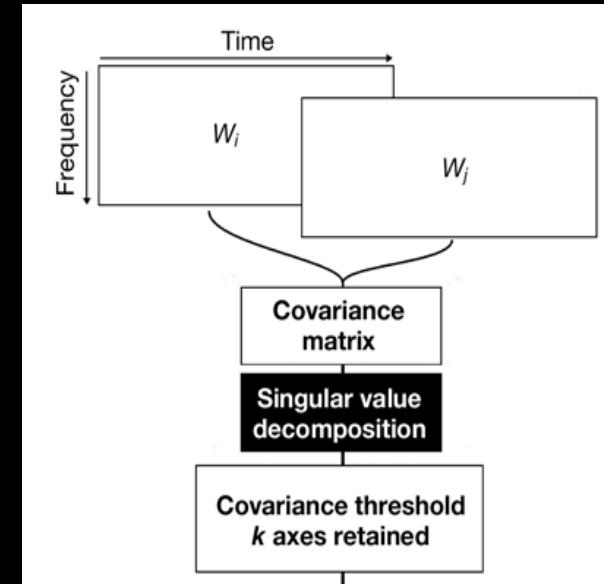
1. Get Spectra
2. Calculate a distance



$W_i$



$W_j$



Leadding patterns

$$L_i^k(t) = \sum_{f=1}^{F} \mathbf{U}^k \times W_i(f, t)$$

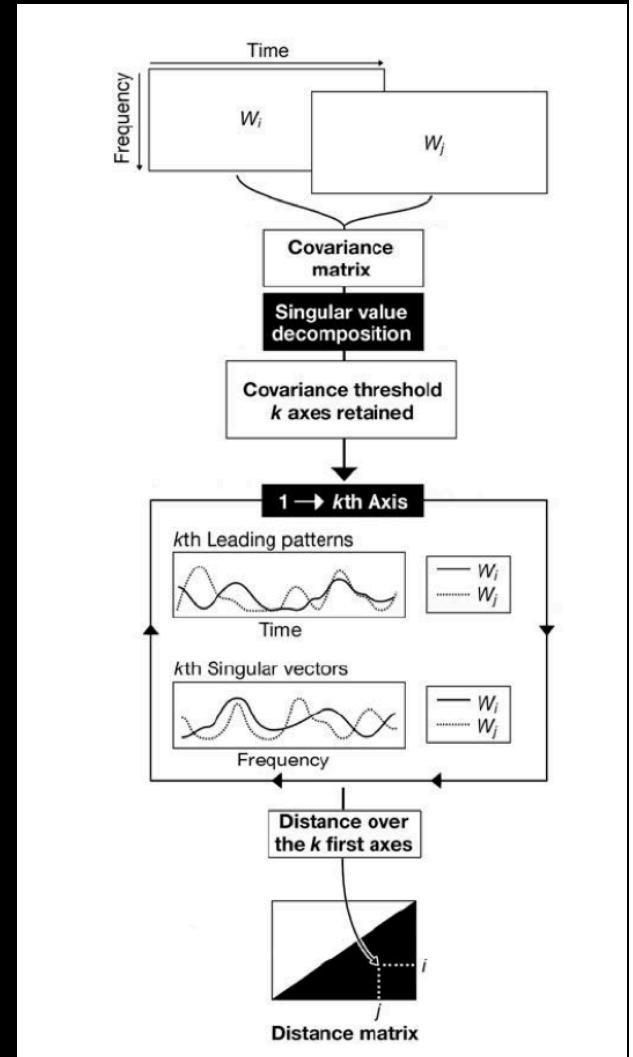
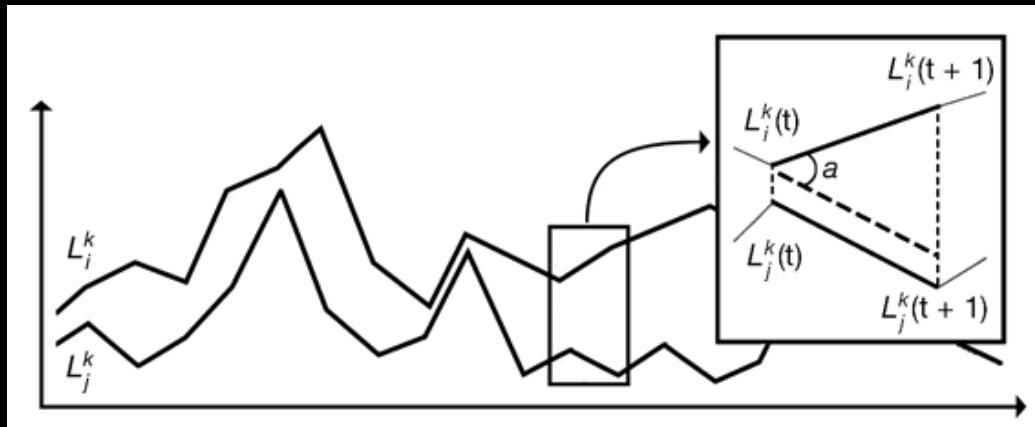
$$L_j^k(t) = \sum_{f=1}^{F} \mathbf{V}^k \times W_j(f, t)$$

$$R_{i,j} = W_i W_j^t \longrightarrow R_{i,j} = U \Sigma V^t$$

# Wavelet clustering 2/3

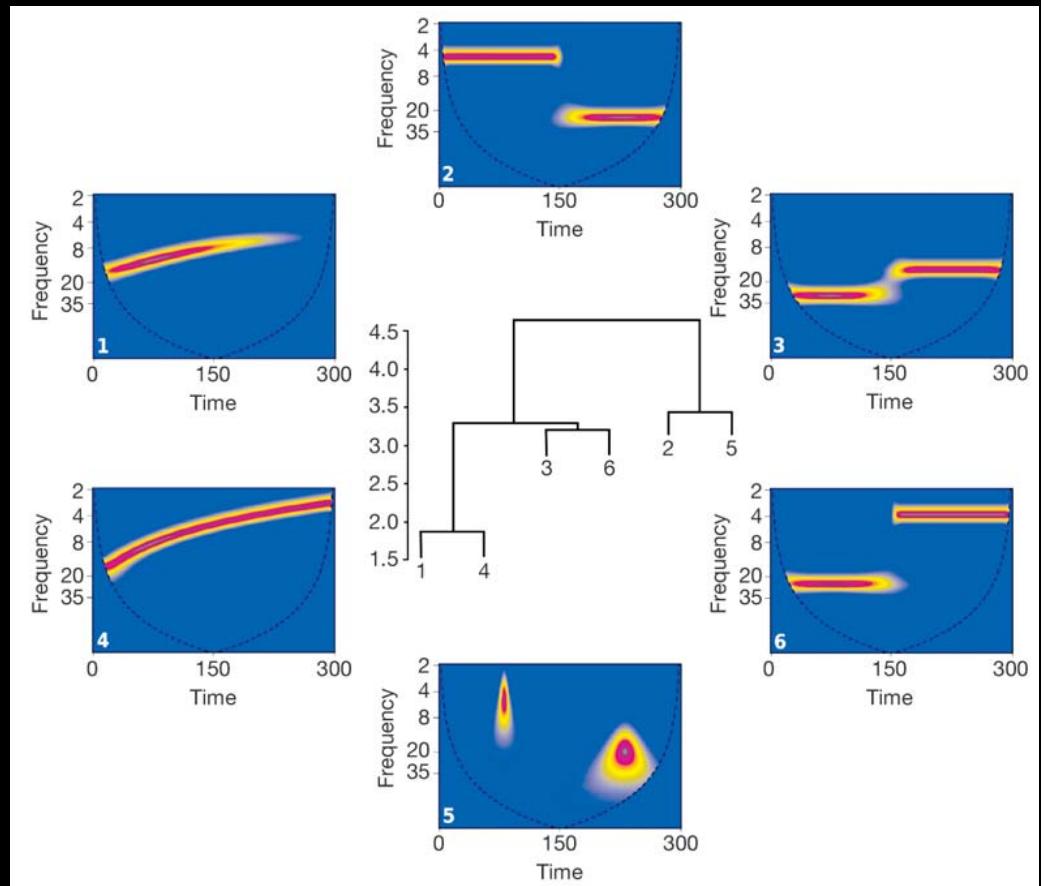
1. Get Spectra
2. Calculate a distance

To compare 2 wavelet spectra we compare the leading patterns



# Wavelet clustering 3/3

1. Get Spectra
2. Calculate a distance
3. Compute a HAC



# Dengue viruses

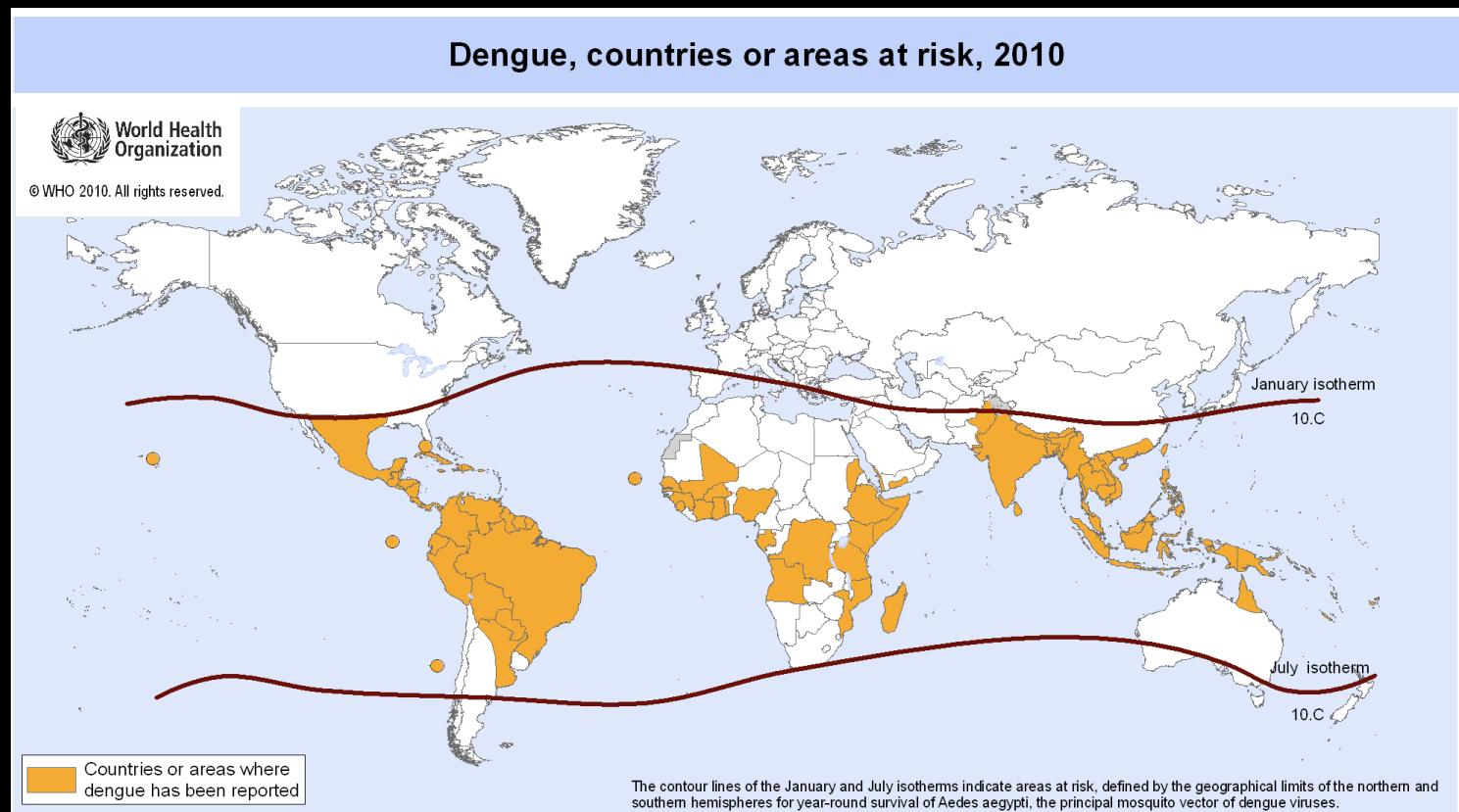
- Arborvirus, main vector is *Aedes aegypti*
- Four different serotypes
- Dengue's fever symptoms are common : Fewer, headache, skin rash ...
- Multiple infection (by different serotypes) could lead to haemorrhagic fever form



*Aedes aegypti*

# Global Dengue Risk

- 2,5 billions people concerned
- Most rapidly spreading vector borne disease



Wavelet

**Wavelet Clustering**

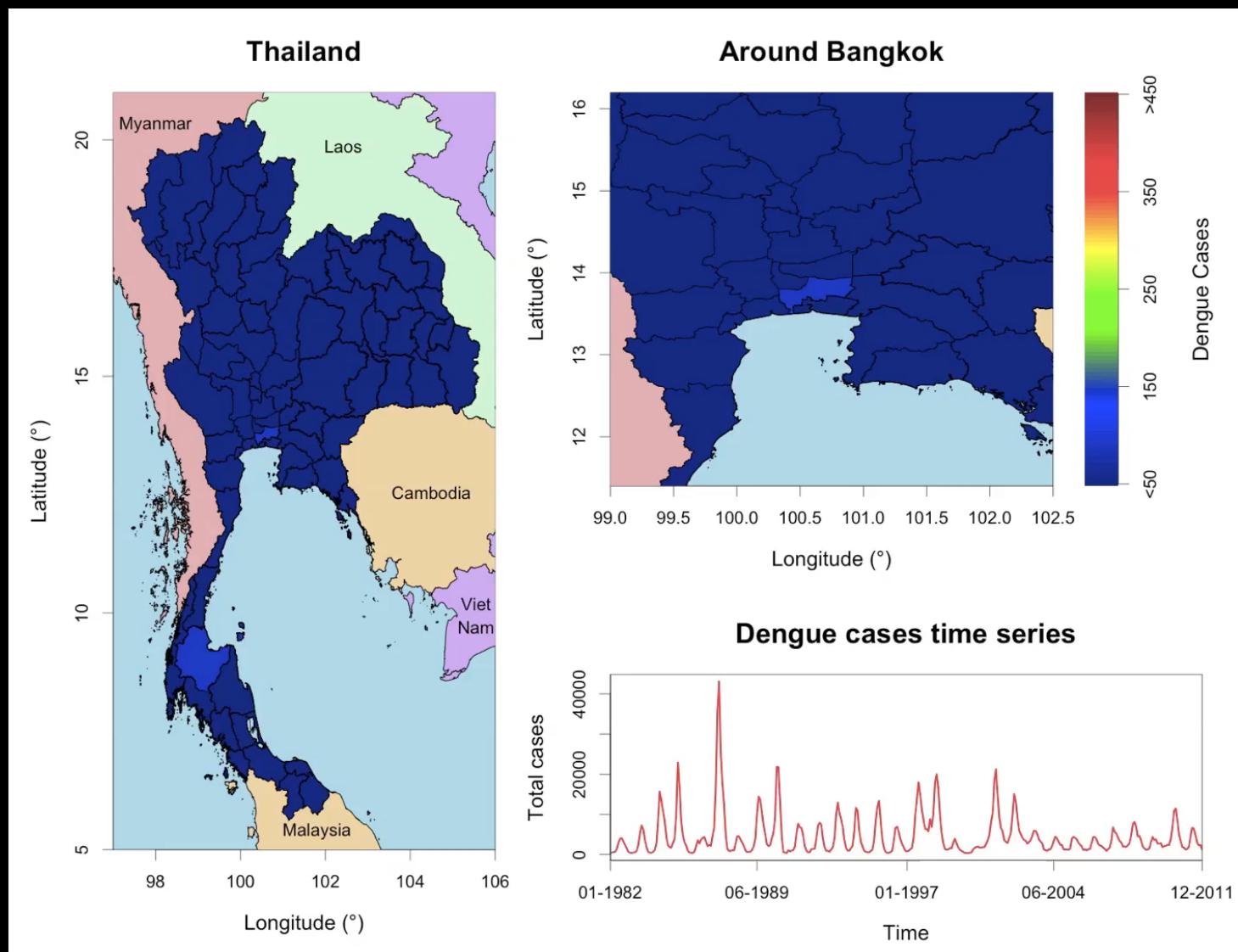
Dengue

Application

Perspectives

# Application : dengue fever in Thailand

- Haemorrhagic dengue fever cases for each province of Thailand from 1981 to 2002



Wavelet

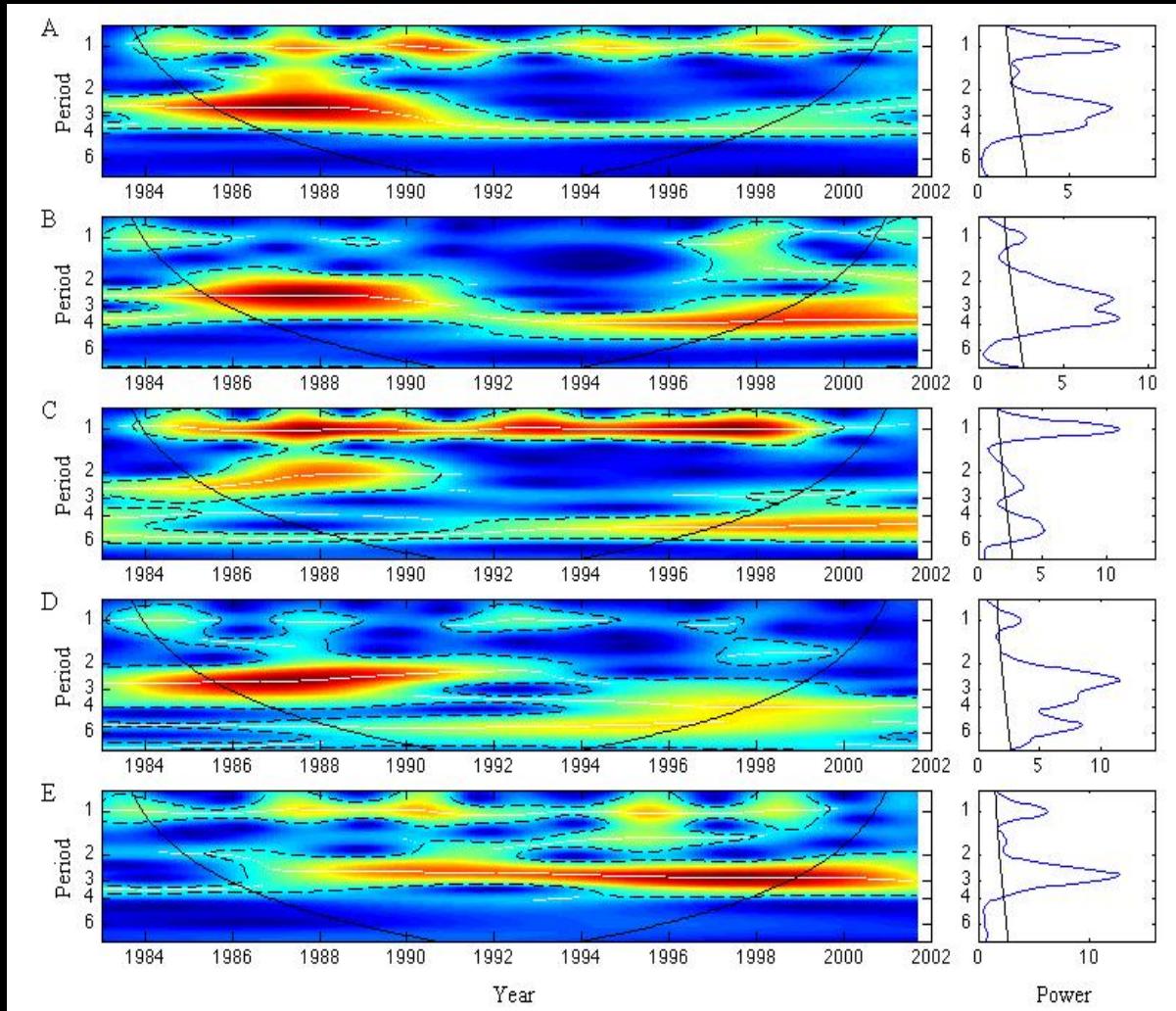
Wavelet Clustering

Dengue

**Application**

Perspectives

# Wavelet Spectra



Wavelet

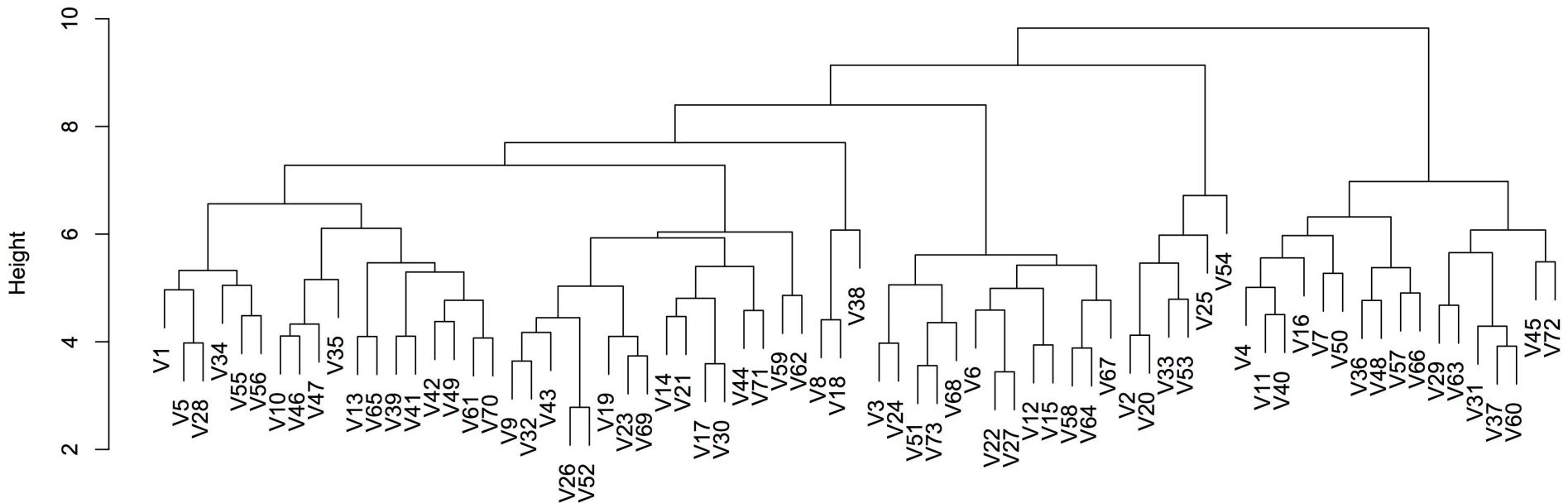
Wavelet Clustering

Dengue

**Application**

Perspectives

# Classification



Wavelet

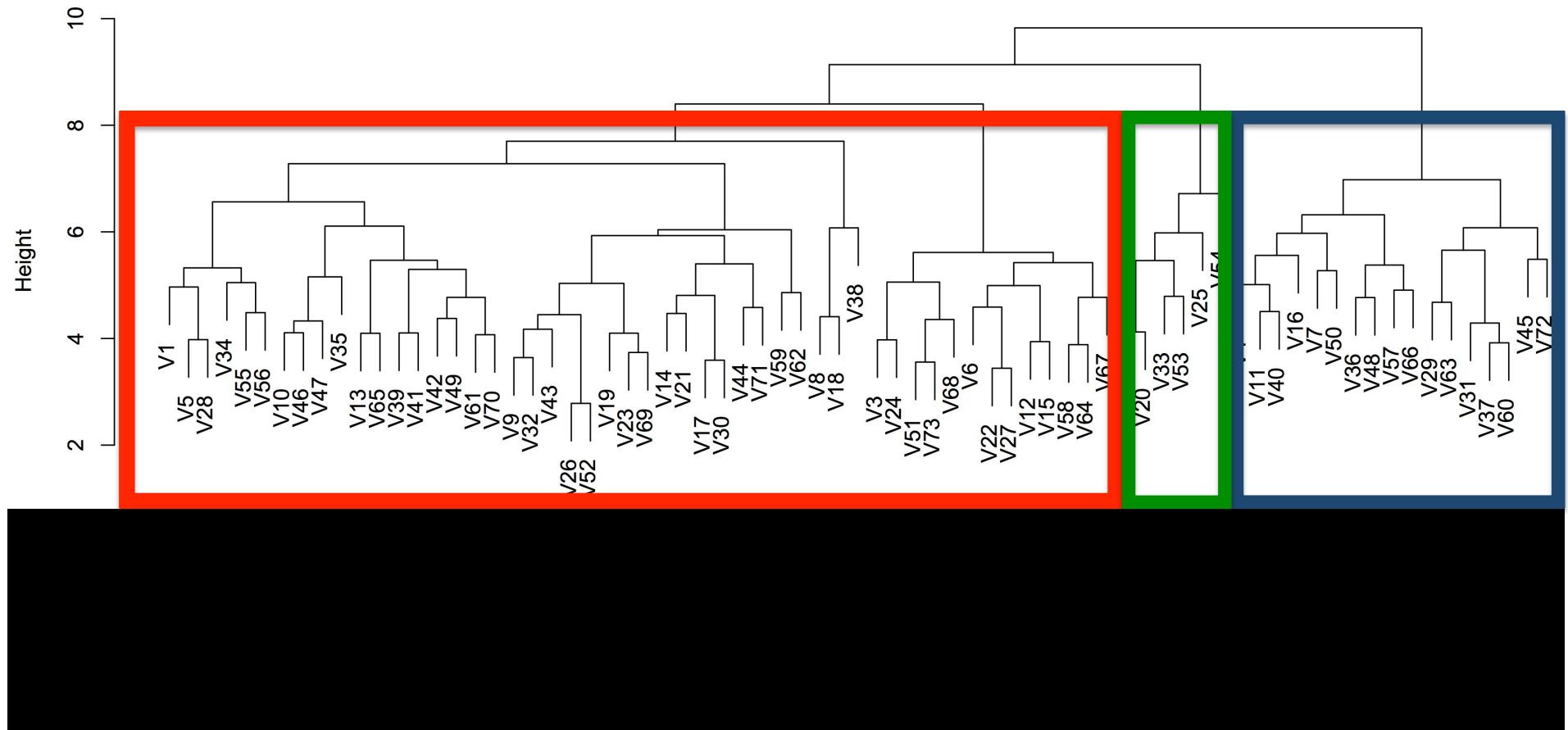
Wavelet Clustering

Dengue

**Application**

Perspectives

# Classification : 3 groups



Wavelet

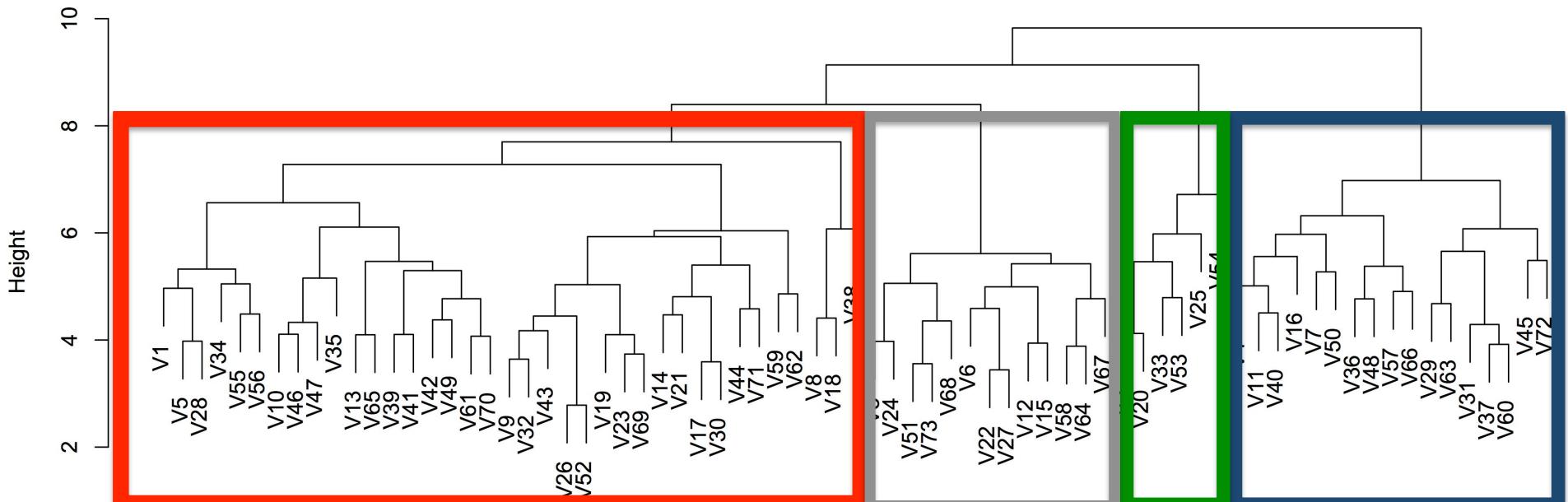
Wavelet Clustering

Dengue

**Application**

Perspectives

# Classification : 4 groups



Wavelet

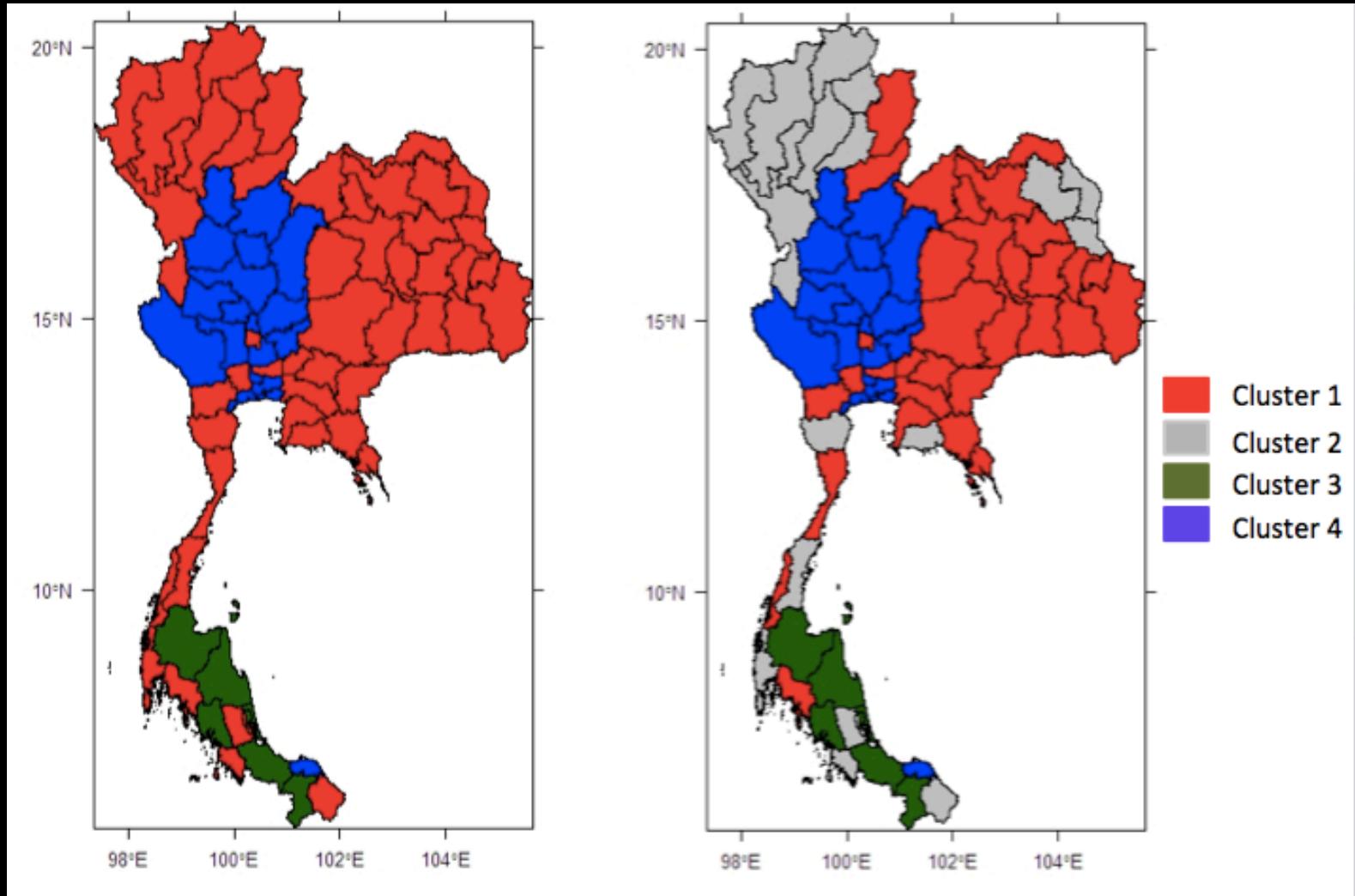
Wavelet Clustering

Dengue

**Application**

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# Spatial structure of dengue epidemic dynamic



Wavelet

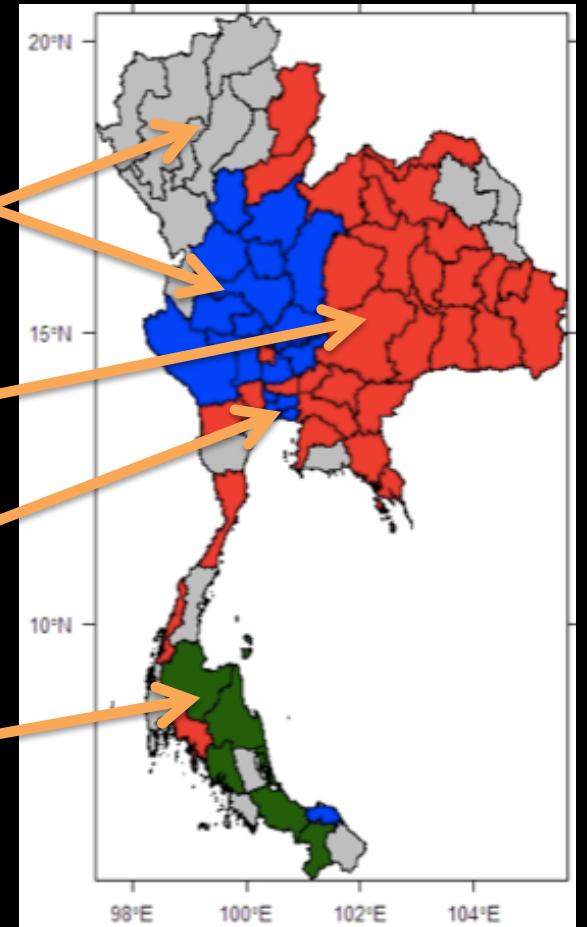
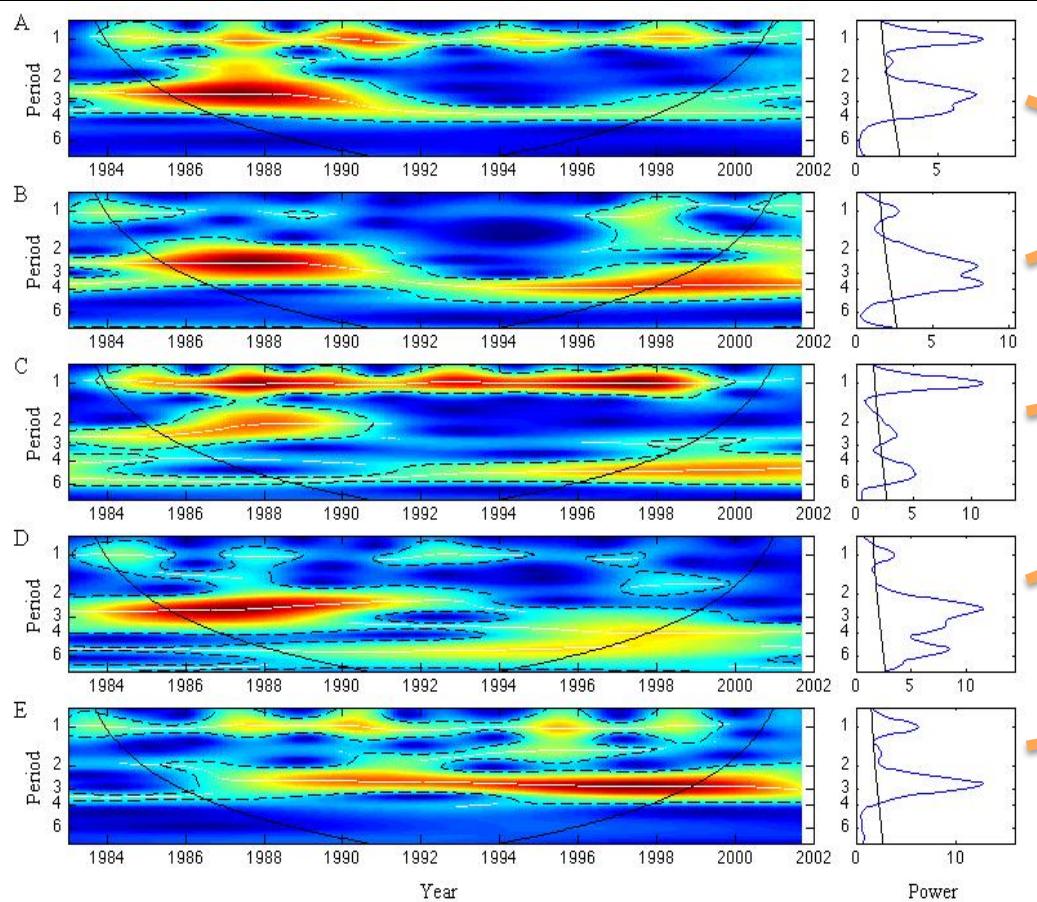
Wavelet Clustering

Dengue

**Application**

Perspectives

# Spatial structure of dengue epidemic dynamic



Wavelet

Wavelet Clustering

Dengue

**Application**

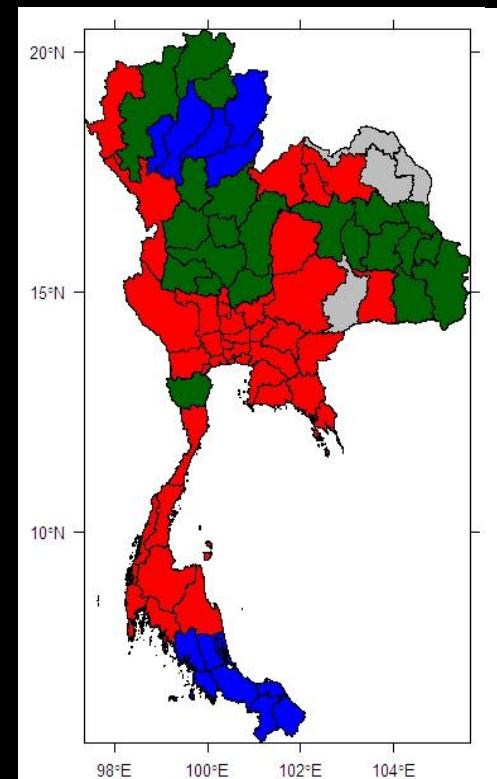
Perspectives

# Perspectives

- How can we explain these spatial structures?



Relief



Rainfall Clusters

Wavelet

Wavelet Clustering

Dengue

Application

**Perspectives**

# Perspectives

- Introduction of significant climatic variables in a mechanistic model (SEIR)
- Introduction of the spatial association in a spatial SEIR model

# Conclusion

- Wavelets provide rich information about dynamics properties of time series
- By using wavelets clustering we can use this piece of information and cluster dynamics
- This is a source of inspiration to create models.