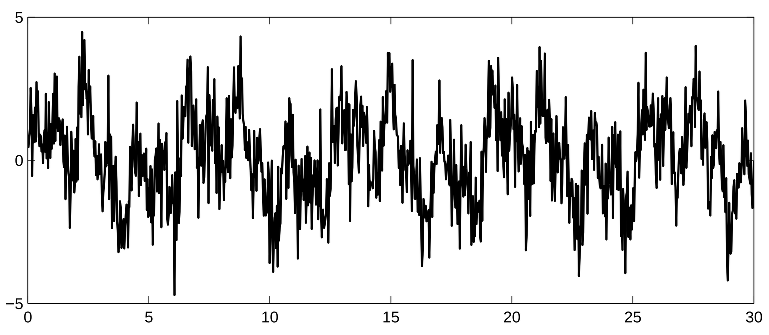
A new method to extract time series features in different scales

with application to the analysis of sea temperature variation in Norwegian and Barents sea

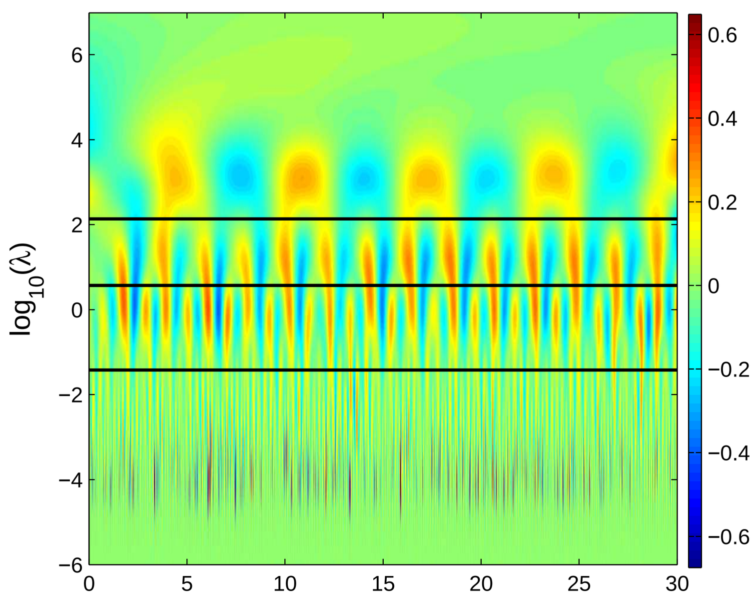
Päivi Laukkanen-Nevala[1], Leena Pasanen[2], Ilkka Launonen[2], Ann Kristin Østrem[3], Sergey Prusov[4], Lasse Holmström[2], Eero Niemelä[1]

[1] Finnish Game and Fisheries Research Institute, Finland, [2] Department of Mathematical Sciences, University of Oulu, Finland, [3] Institute of Marine Research, Norway, [4] Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Russia

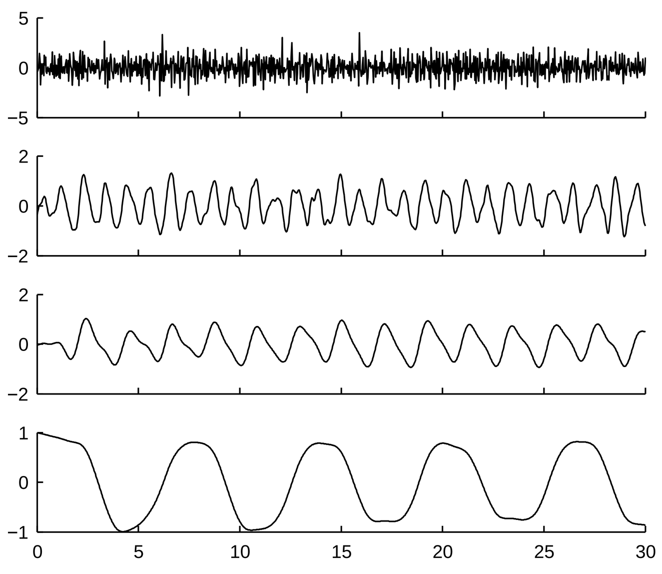
An artificial example:



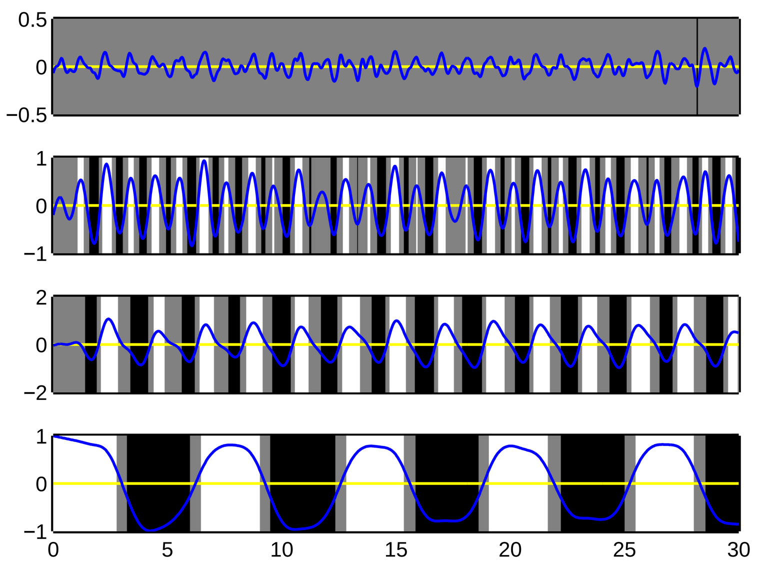
The data:
A sum of three sine waves and a noise.



The scale-derivative map:
The waves can be seen as oscillating bands of red and blue. The higher the frequency of the wave, the lower it is shown in the map.

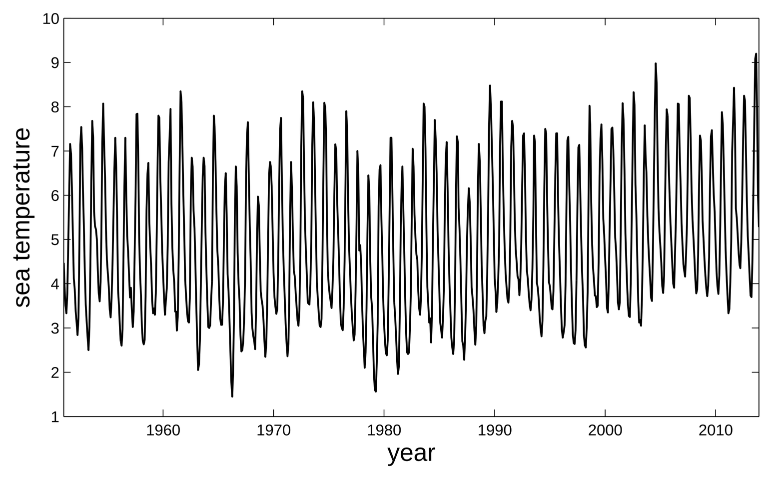


The components:
The estimates of the noise and the three sine waves, obtained by using differences of smooths. The smoothing levels used are indicated by the black lines in the scale-derivative map.

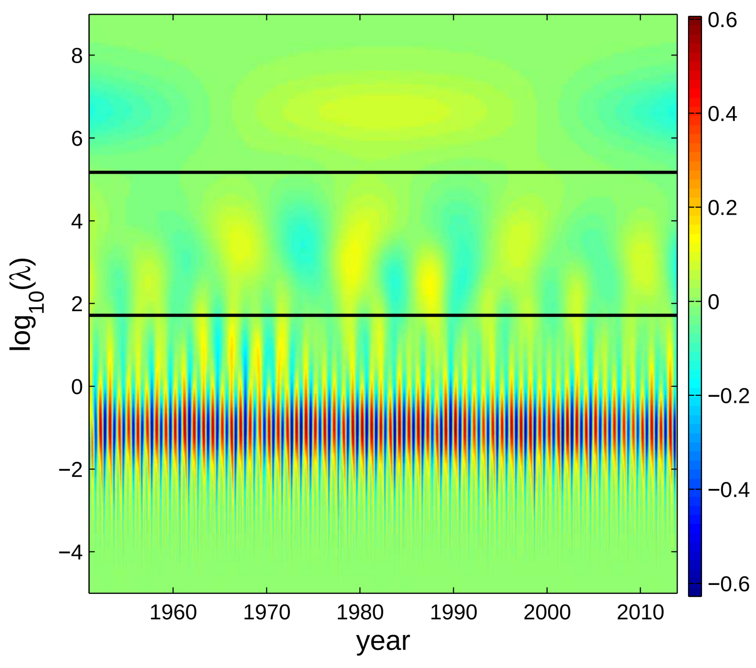


The credibility analysis:
White, black and gray background means time points that are credibly positive, negative or neither.

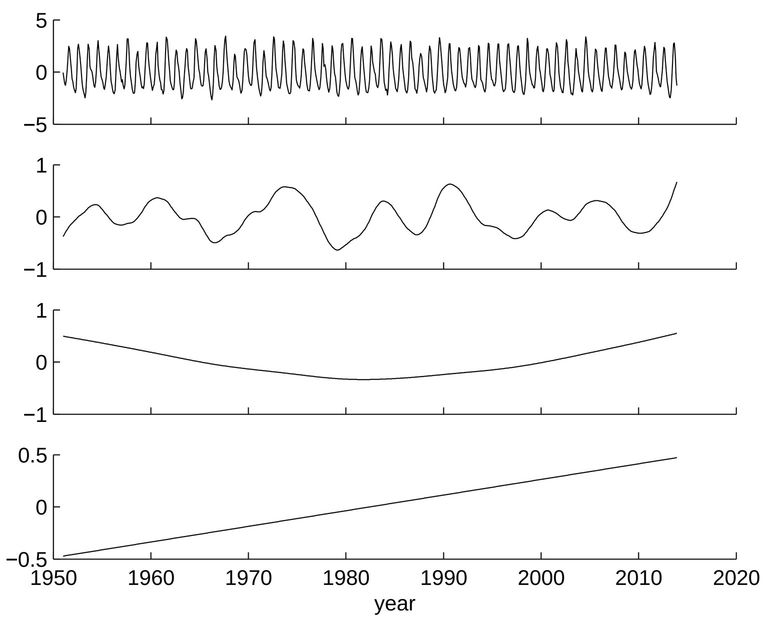
Long-term warming, especially after the millenium (Kola section of Barents sea):



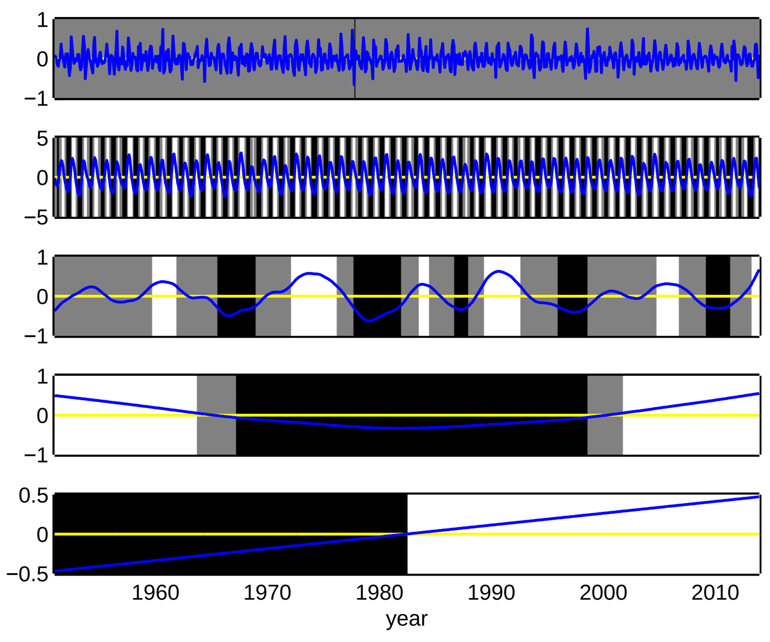
The data:
Sea temperatures (depth 0-50m) from Kola section of Barents sea, since 1951.



The scale-derivative map:
The seasonal and larger scale variations can be seen as oscillating bands. Also, a clear u-shape can be seen.

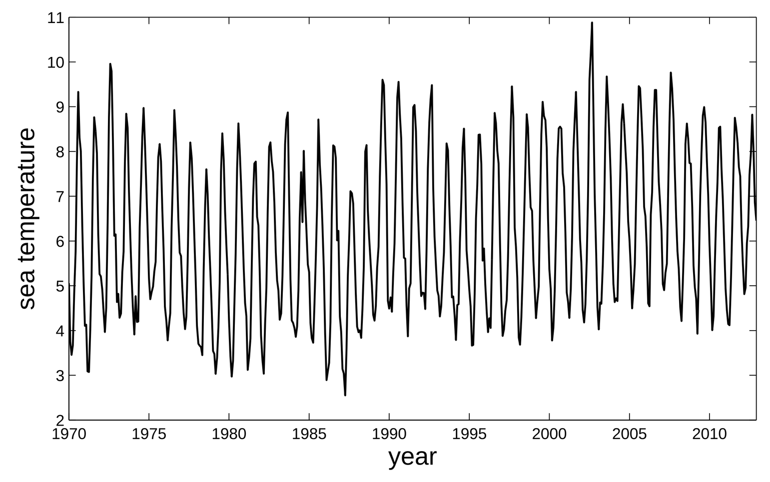


The components:
In addition to the seasonal variation a larger scale component, u-shaped component and a linear trend has been extracted.

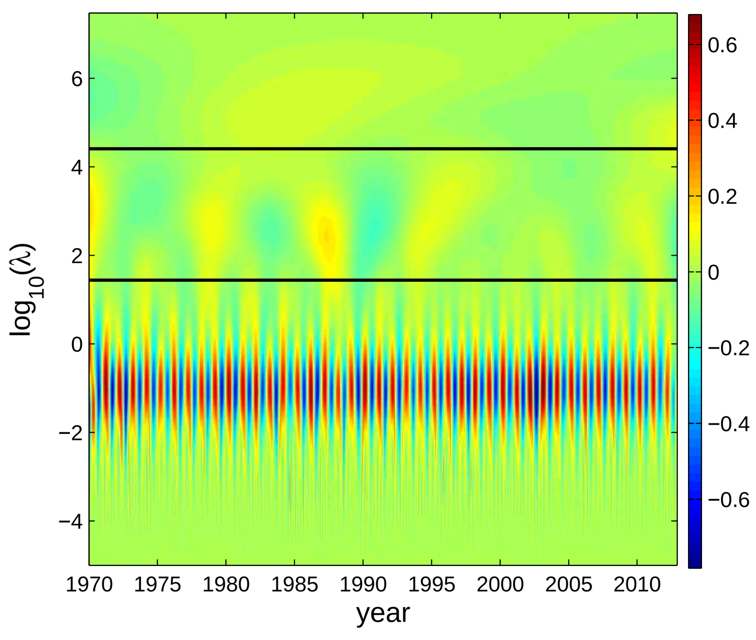


The credibility analysis:
For each decade, warm and cool periods are suggested by the middle component. The fourth component shows an around 30 years long cool period from 1968 to 2000.

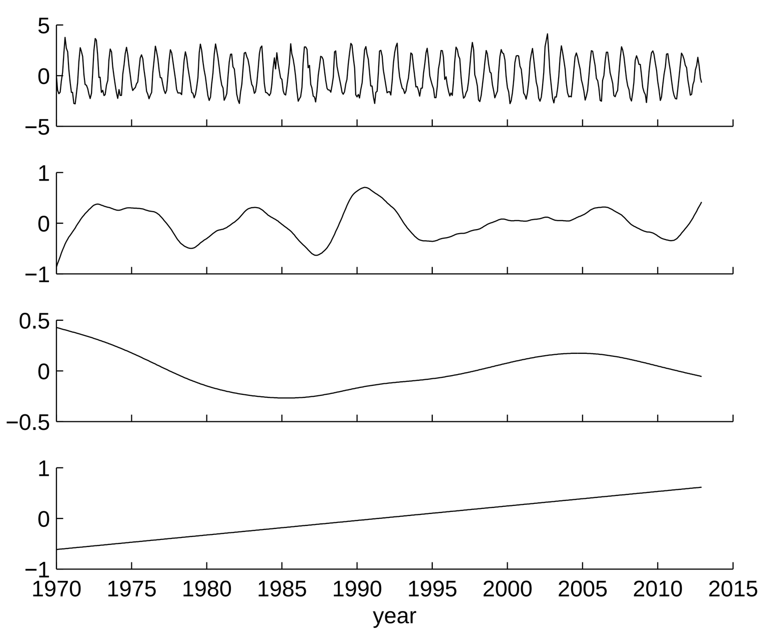
Positive linear trend, but no additional warming recently (Ingøy, Norway):



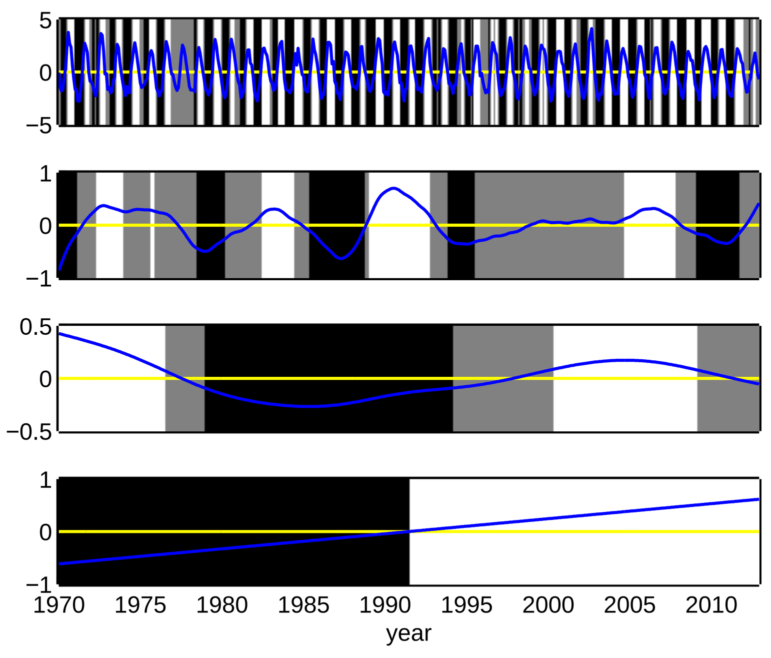
The data:
Sea temperatures (depth 0-50m) in Ingøy, Norway, since 1970.



The scale-derivative map:
The seasonal variation can be seen as oscillating bands of red and blue and larger scale variation with yellow and cyan.



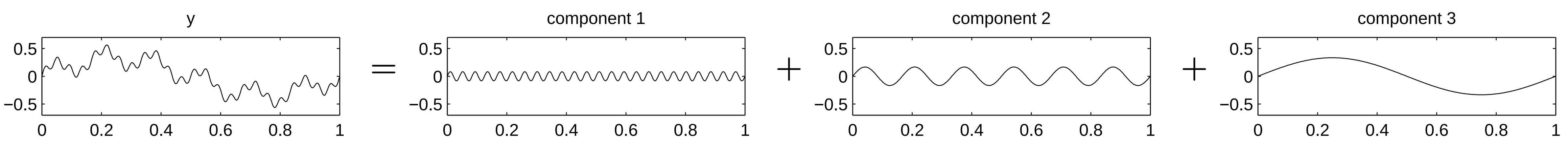
The components:
In addition to the seasonal variation, two larger scale components and a linear trend has been extracted.



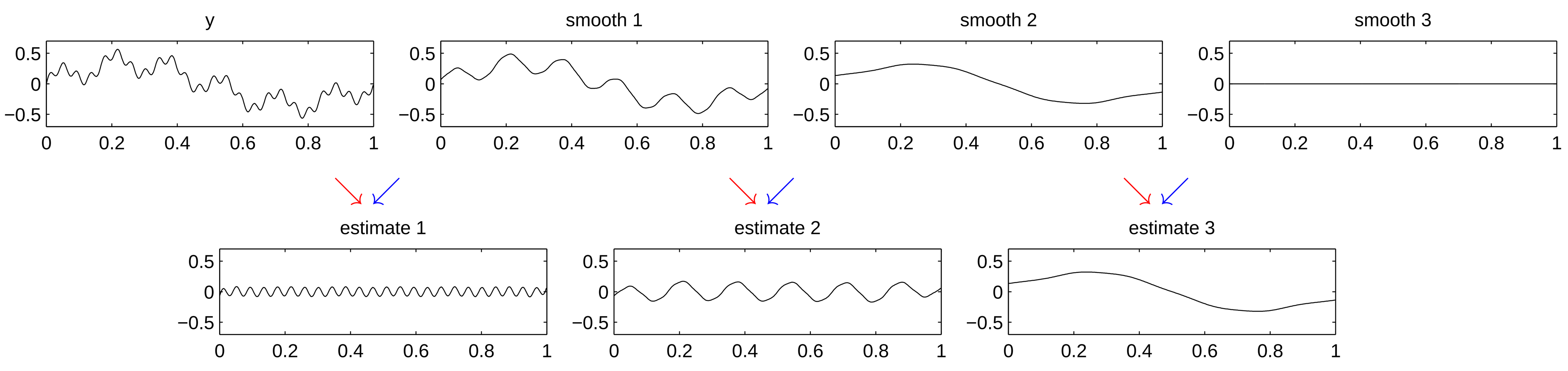
The credibility analysis:
In early 1970's, a warmer period was observed as is also from 2000 to 2007. The intervening cooler period lasted around 15 years.

The basic idea:

- To reveal time series' features in all time scales
- First, consider a sum of three waves with different wavelengths:



- Our aim is to obtain the components when only their sum y is observed
- This is done by computing differences of smooths:



- The estimates are close to the true components
- How many smooths should be used?
  How to choose the smoothing levels?
  → Use a so-called scale-derivative map
- The credibility of the features in the estimates can be evaluated using Bayesian inference

Conclusion:

- The commonly used traditional time series decomposition only detects three components (noise, seasonal and large scale components), but here the large scale variation can be separated into more components and also a credibility analysis is provided.
- The scale derivative map can be used both as an explorative and inference tool.
- The new method offers various possibilities to study long-term variation in other time-series such as variation of salinity, oxygen conditions or chlorophyll content over time.

Reference:

Pasanen, L., Launonen, I. and Holmström, L. (2013), A scale space multiresolution method for extraction of time series features. *Stat*, *2*: 273-291.