Efficiency of different signal processing methods to isolate signature characteristics in altimetric water level measurements

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Signals

Observed time-series of water transport in rivers can be perceived mathematically as a superposition of

- non-linear long-term trends
- periodic variations
- episodic events
- colored instrument noise
- etc.

Methods

This contribution will highlight the benefits of a few advanced signal processing methods for extracting relevant hydrometeorological information and causality analysis.

We employ a suite of 1D time-series analysis methods

- Fourier Transform
- Wavelets
- Singular Spectrum Analysis (SSA)
- Empirical Mode Decomposition (EMD)

and additional statistical assessments like

- Pruned Exact Linear Time (PELT) tests for change point detection

Data

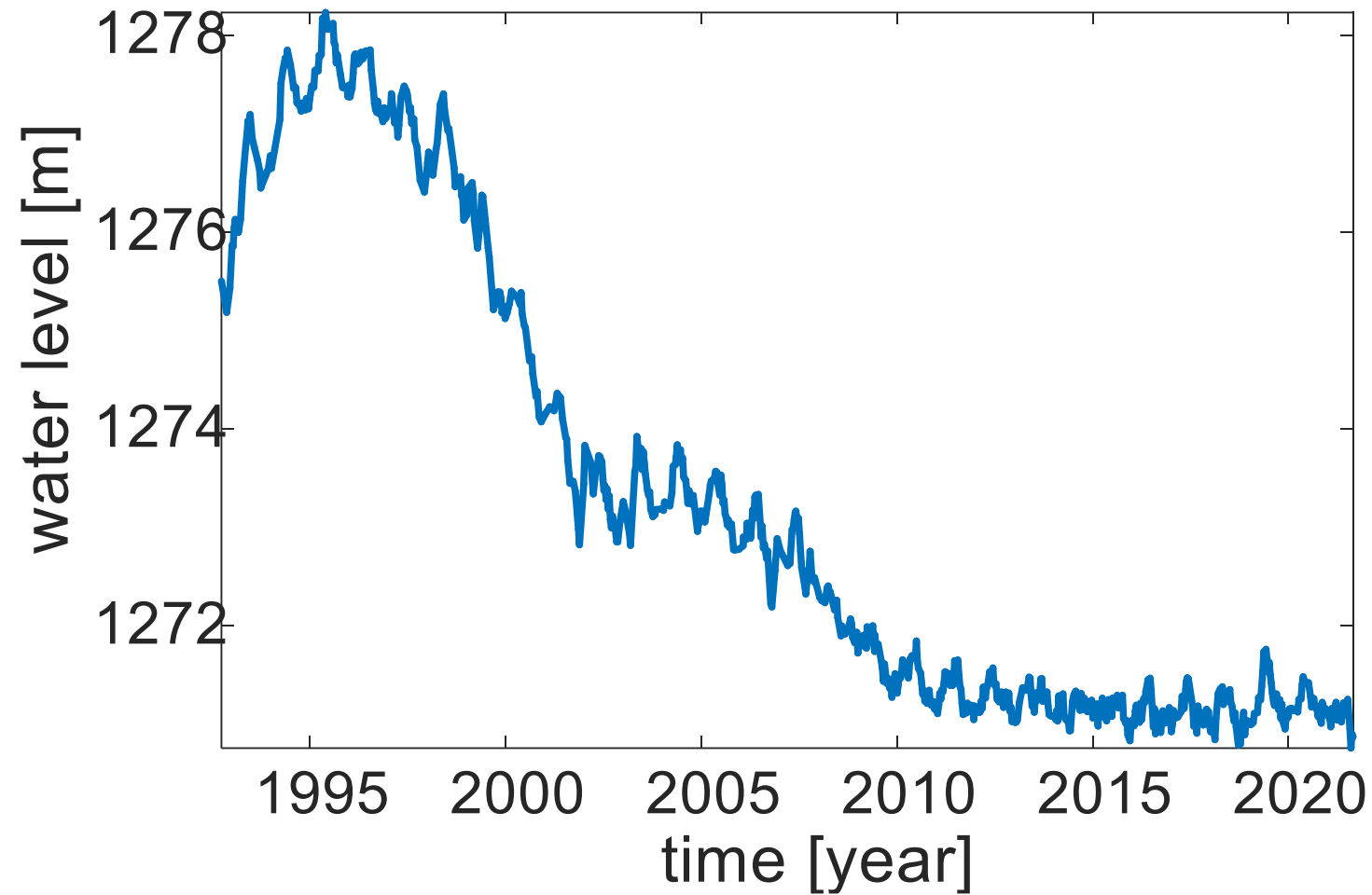We analyze data from two virtual stations at

- Urmia Lake (Iran), representative for semi-arid/arid conditions of Central Asia with small hydrological signal variations

- River Elbe (Germany), representative for the central European region with a rather humid climate

Urmia Lake (Iran)
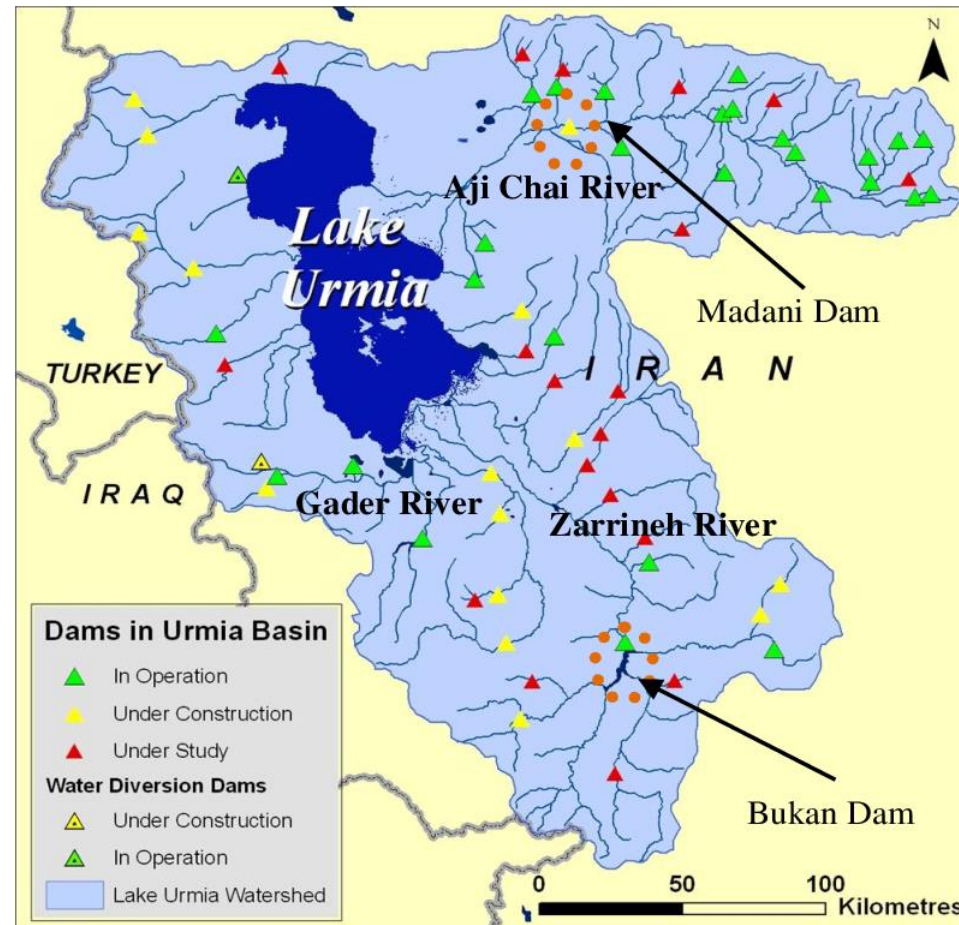
Zarrineh, N. and Azari, M. (2014). Integrated water resources management in Iran: Environmental, socio-economic and political review of drought in Lake Urmia. International Journal of Water Resources and Environmental Engineering. 6. 40-48. 10.5897/IJWREE2012.0380.
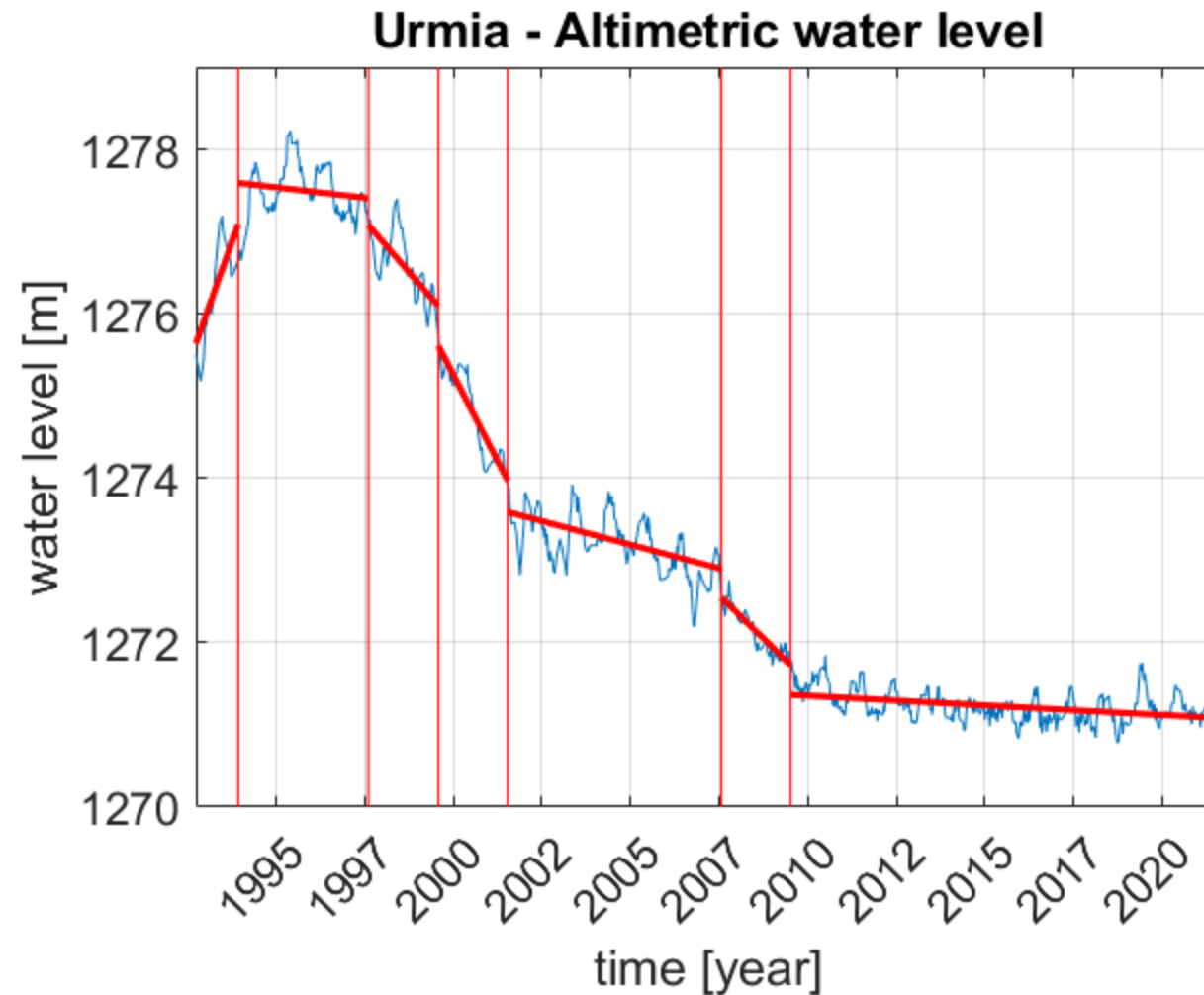
Urmia - Altimetric water level

Change points

Based on "Pruned Exact Linear Time (PELT)" for change point detection

Urmia - Altimetric water level

SSA decomposition

1st mode: non-linear trend

2nd mode: damping long periodic

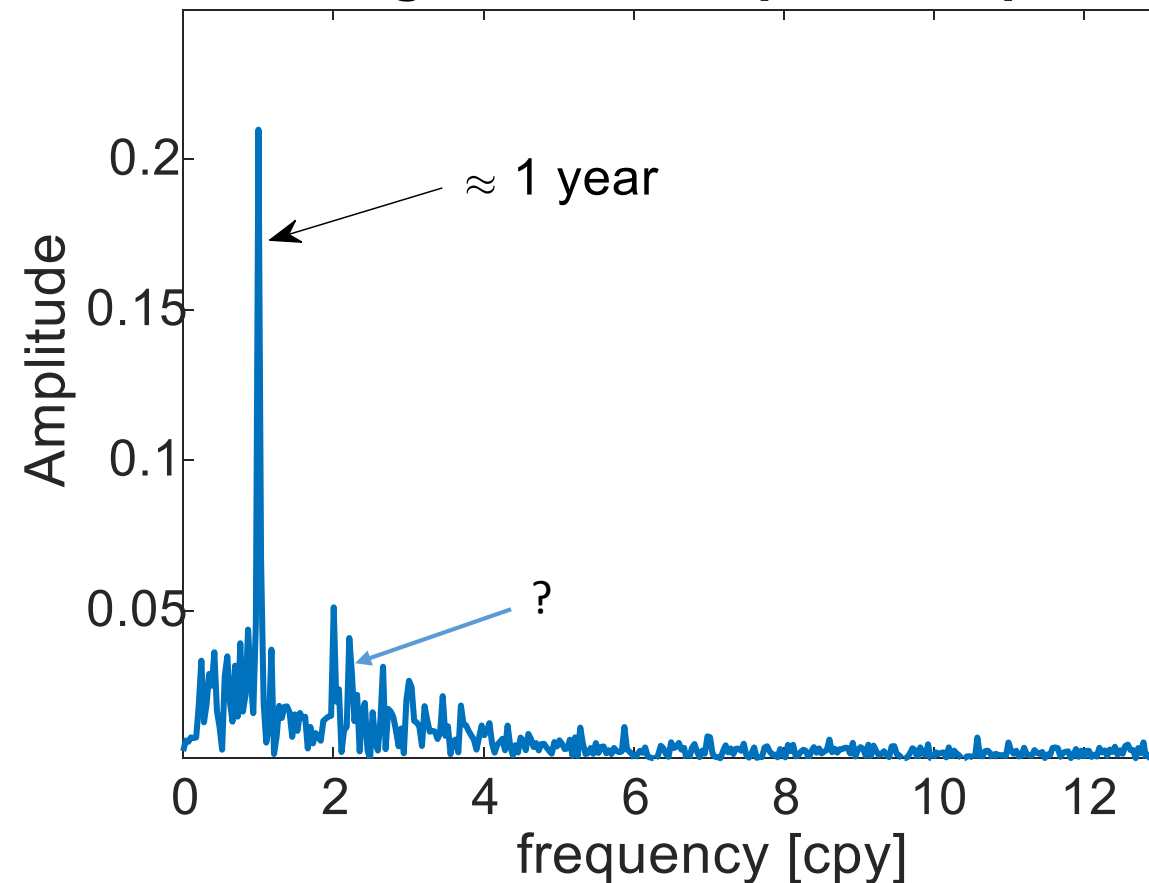significant changing amplitude
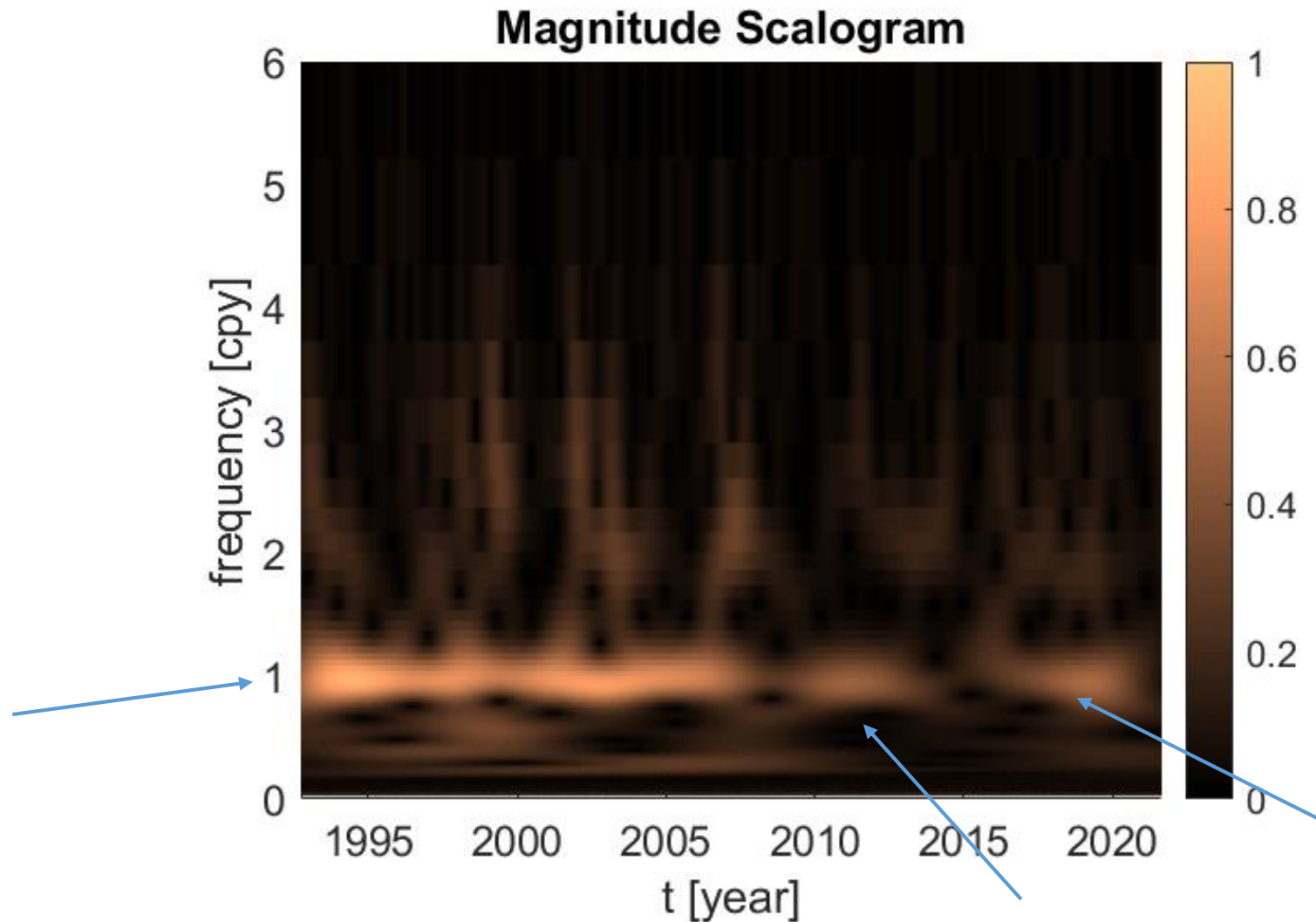
residual: full of other signatures

Fourier Transform

After SSA de-trend (1ˢᵗ and 2ⁿᵈ modes removal)
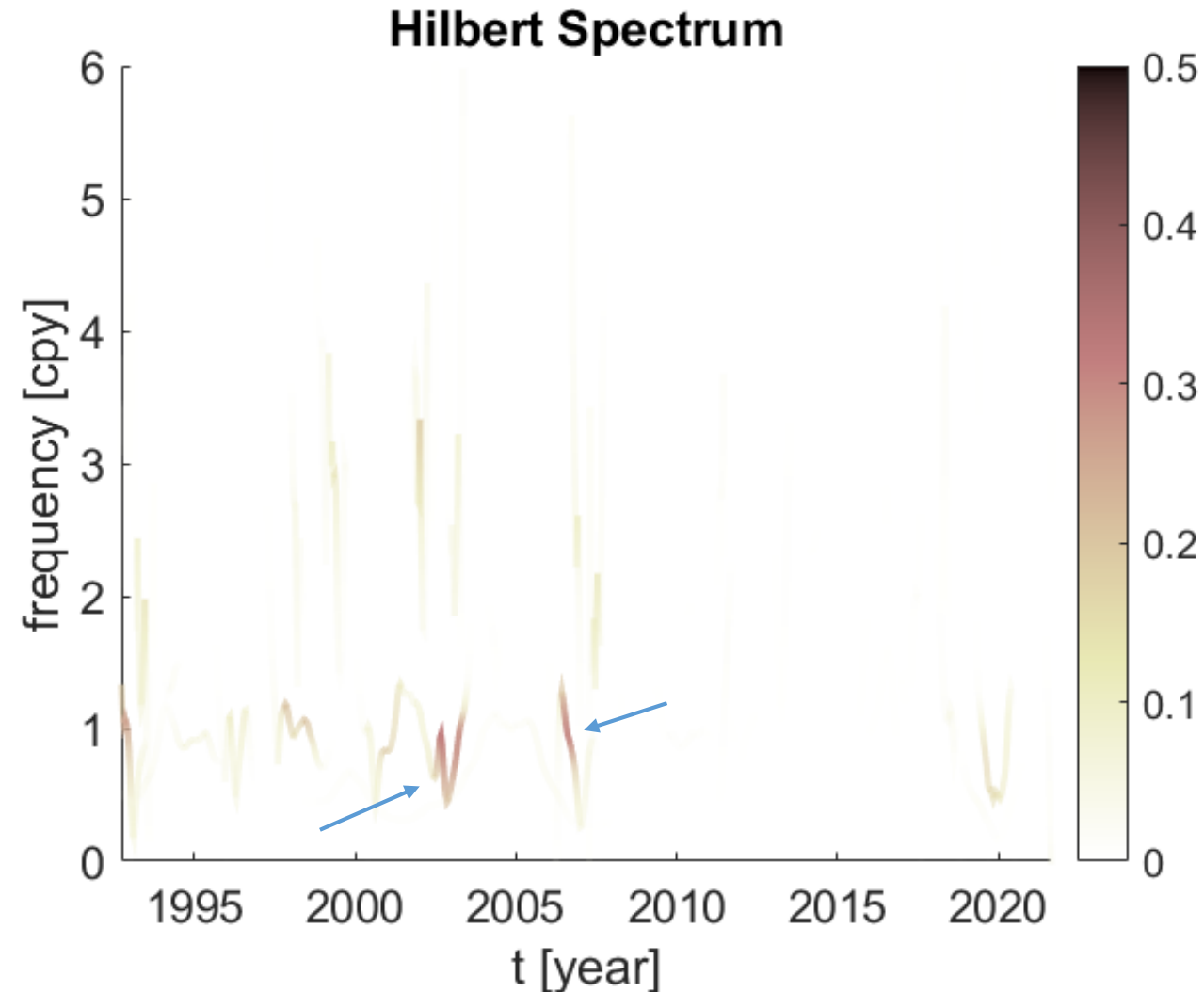

Single-Sided Amplitude Spectrum

Wavelet Transform

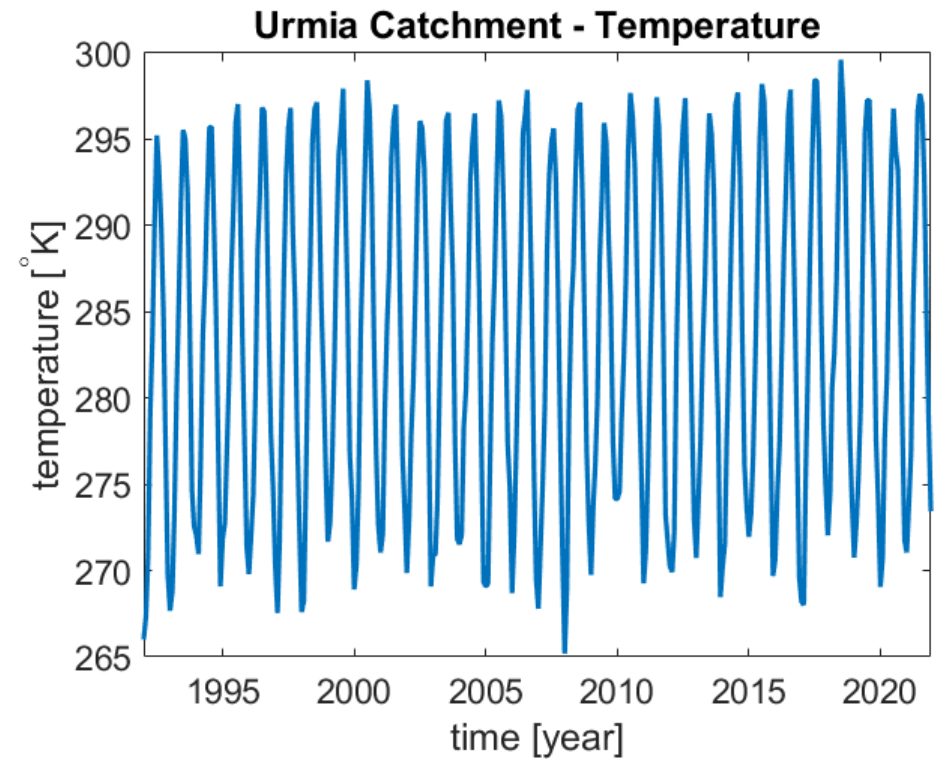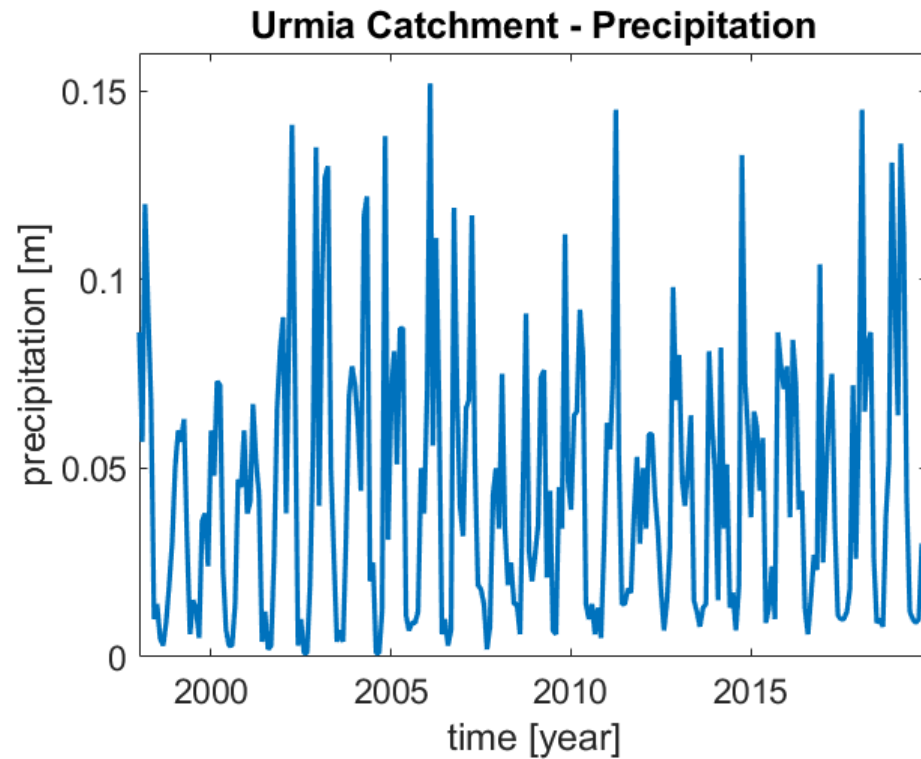After SSA de-trend (1st and 2nd modes removal)

EMD + Hilbert Transform

After SSA de-trend (1ˢᵗ and 2ⁿᵈ modes removal)

How to interpret those?

No specific trends or change points have been detected!

How to interpret those?

Several studies have shown that the water level changes (drops) are mainly caused by rapidly growing agricultural activities, constructing several small dams and withdrawing groundwater.

Lake Urmia: how Iran's most famous lake is disappearing

New research shows Iran's most famous lake has shrunk by nearly 90% since the 1970s. Scientists urge action

Why is Lake Urmia Drying up? Prognostic Modeling With Land-Use Data and Artificial Neural Network

A spaceborne multisensor approach to monitor the desiccation of Lake Urmia in Iran
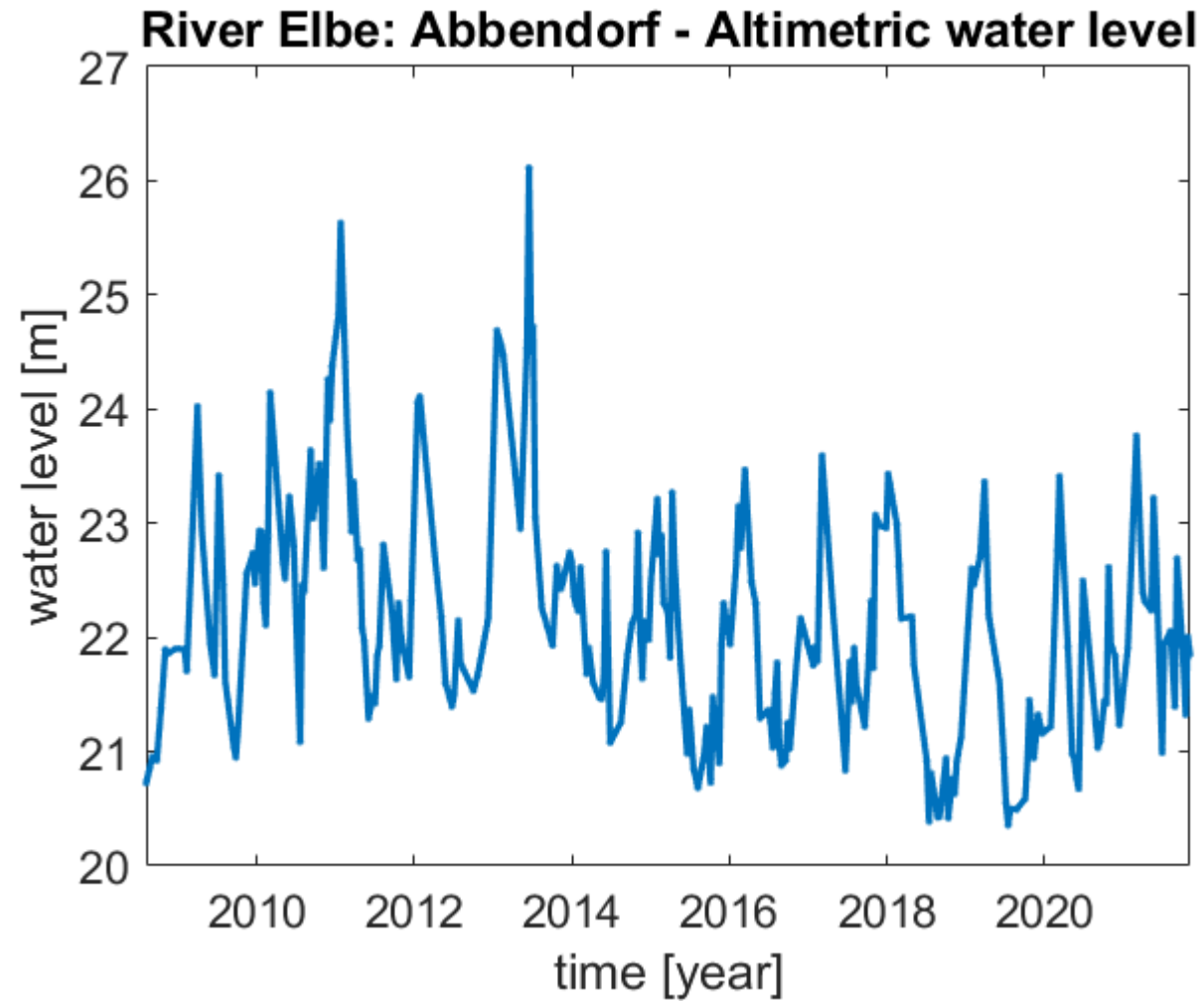
Commentary

Aral Sea syndrome desiccates Lake Urmia: Call for action
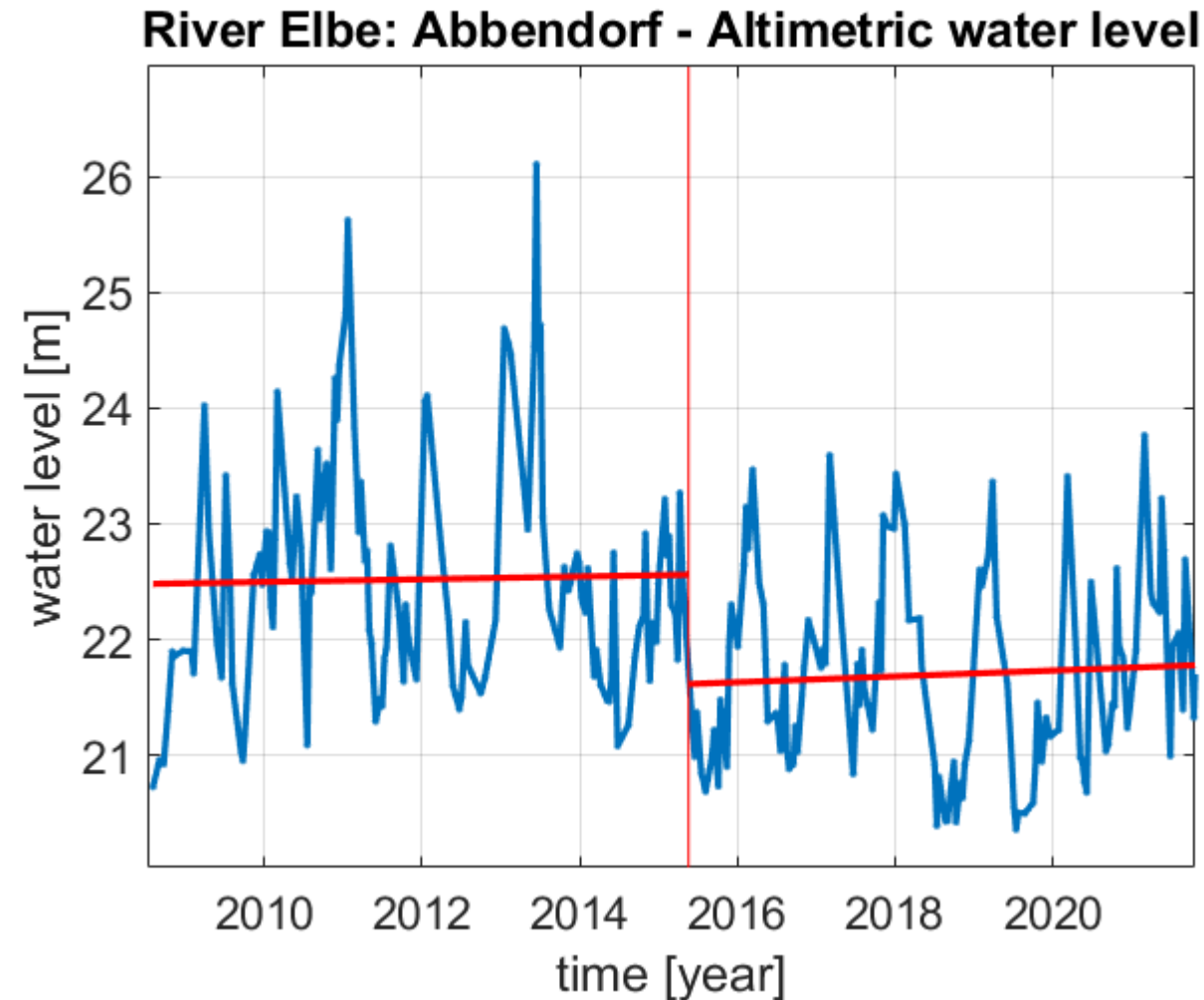
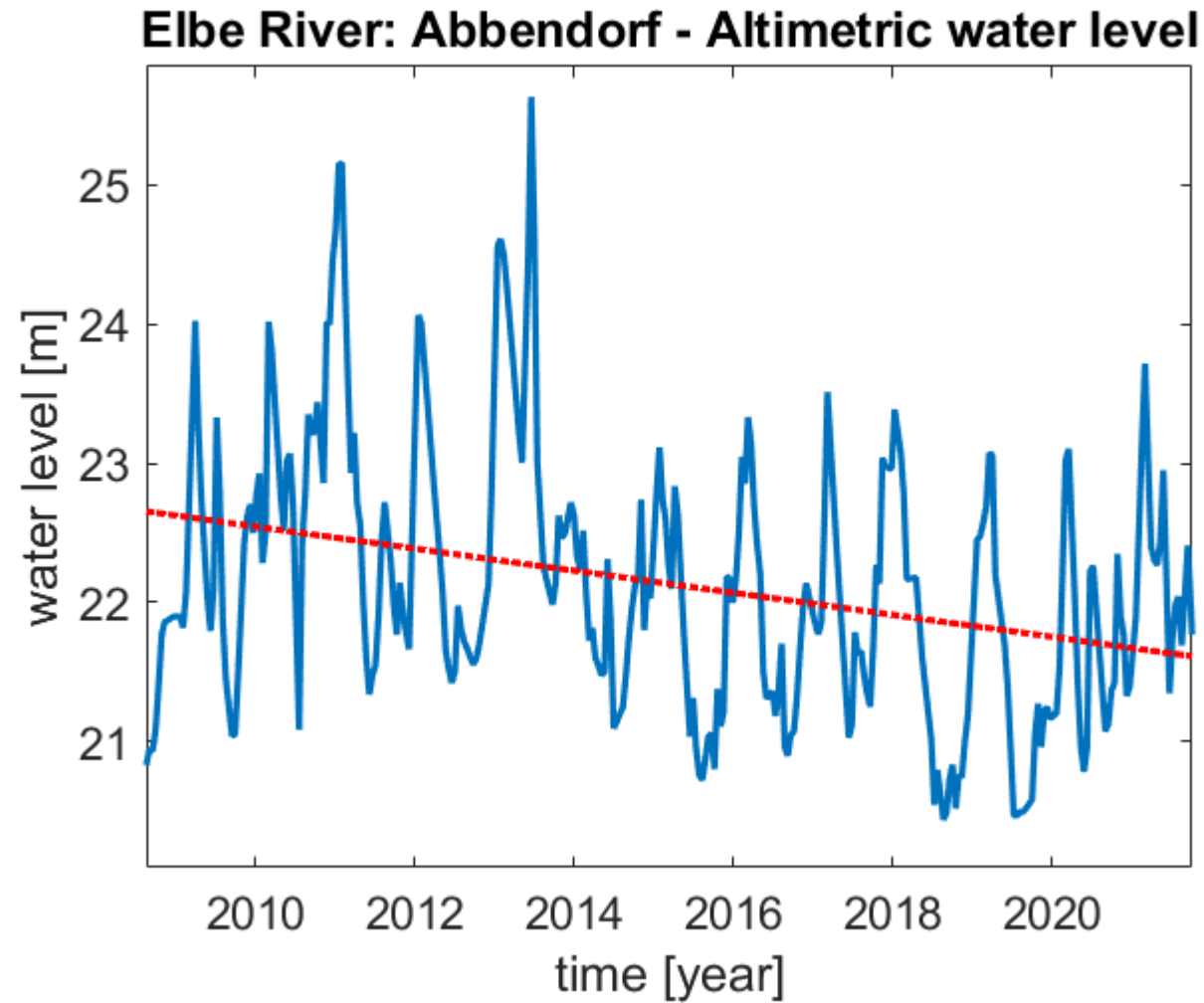# River Elbe: Abbendorf (Germany)

Wikipedia

From:
Database for Hydrological Time Series of Inland Waters (DAHITI)
Deutsches Geodätisches Forschungsinstitut
Technische Universität München

Change points

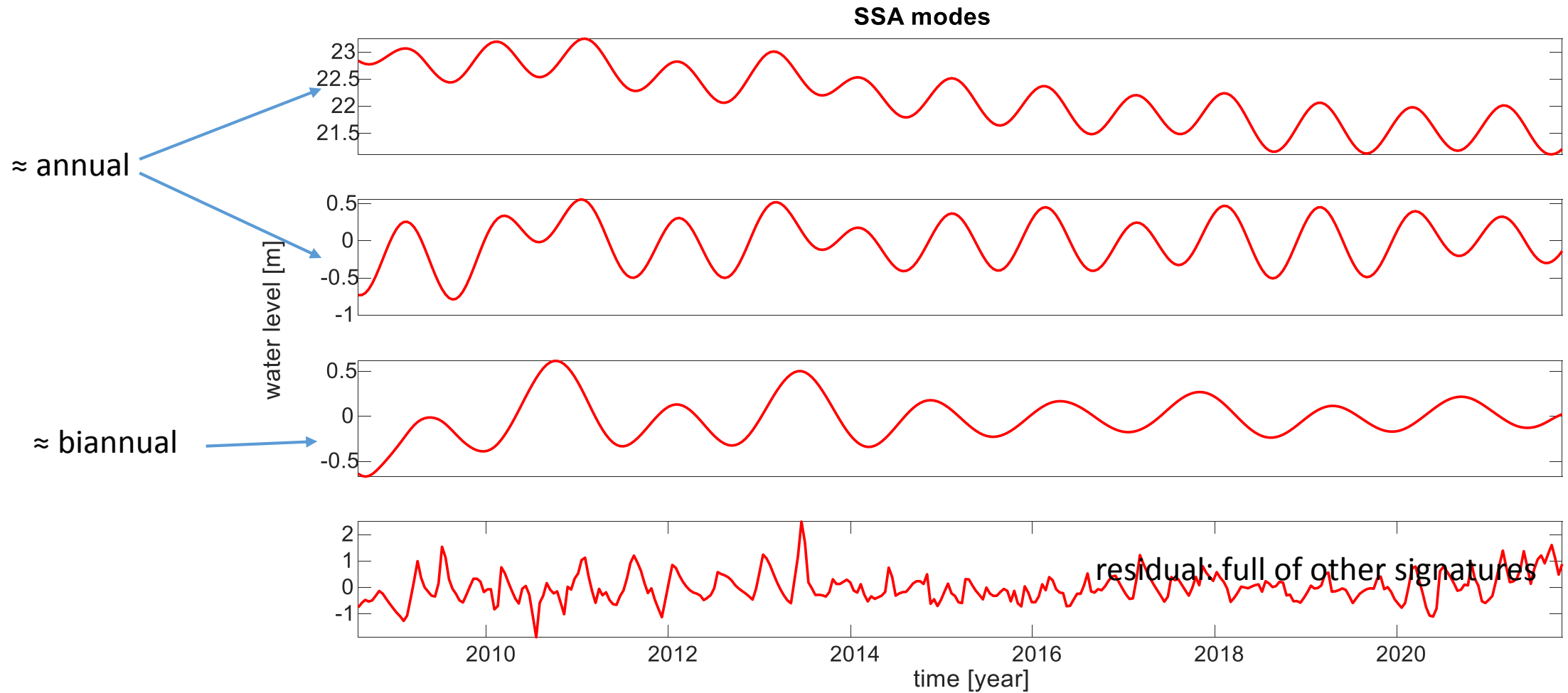Based on "Pruned Exact Linear Time (PELT)" for change point detection
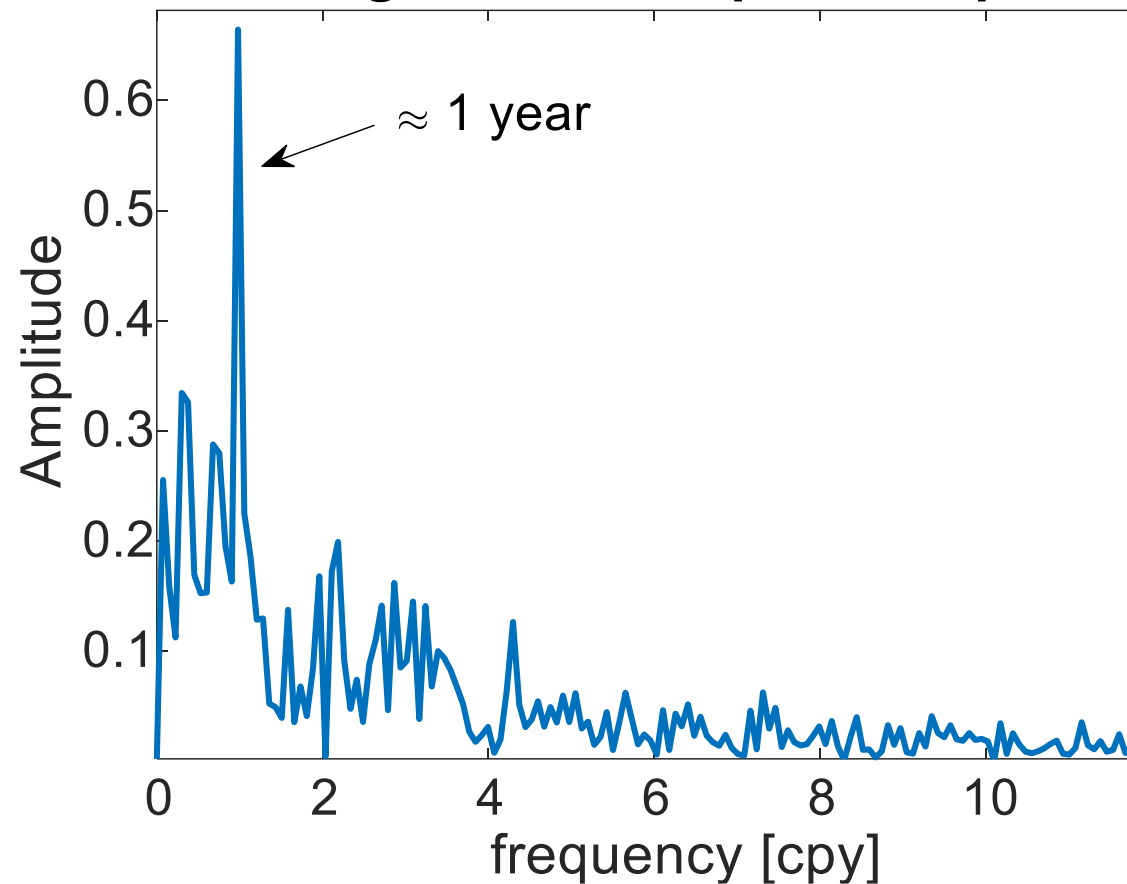
Linear trend

SSA decomposition

note changing amplitude

SSA modes

≈ annual

≈ biannual

water level [m]

residual: full of other signatures

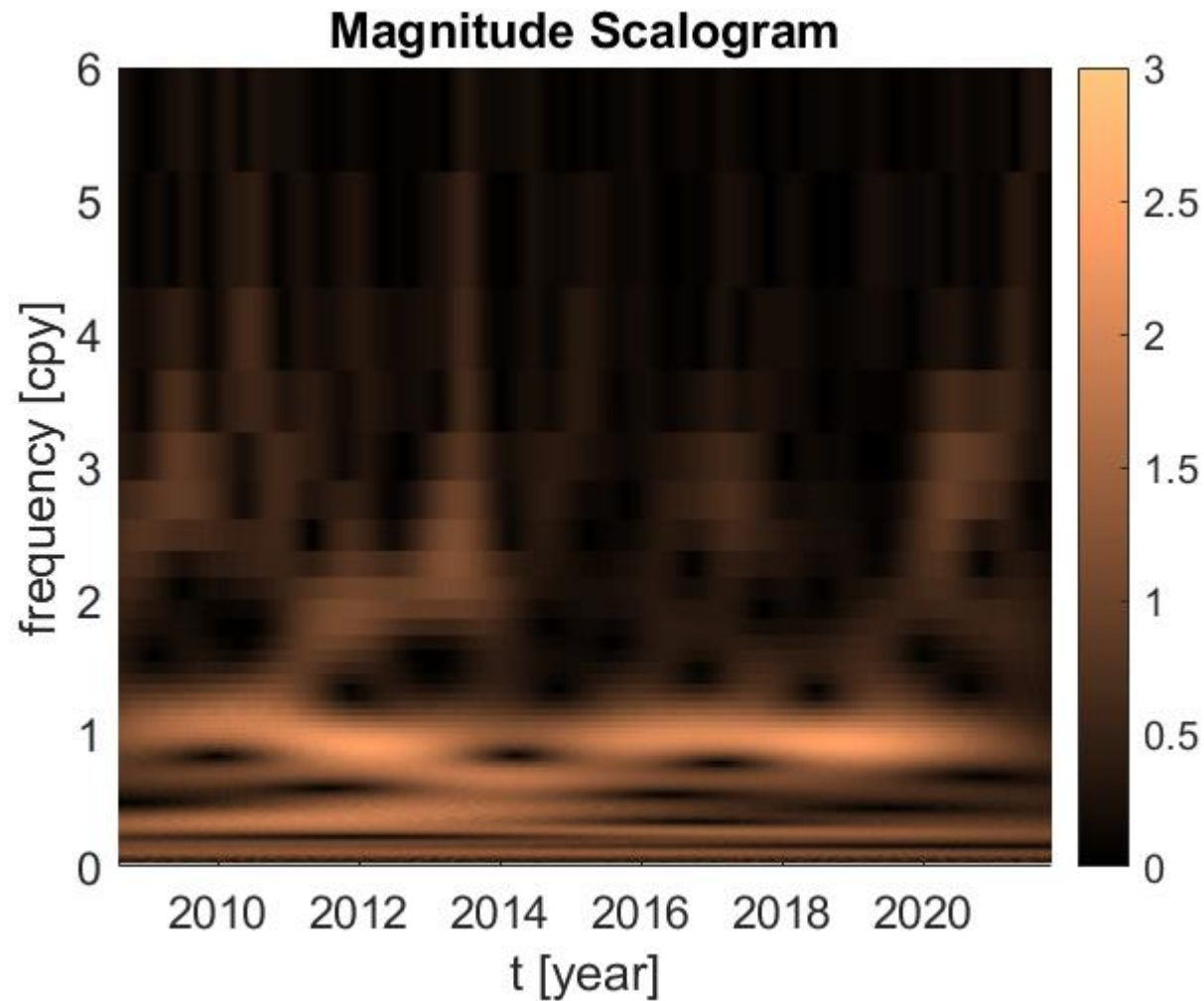time [year]

Fourier Transform

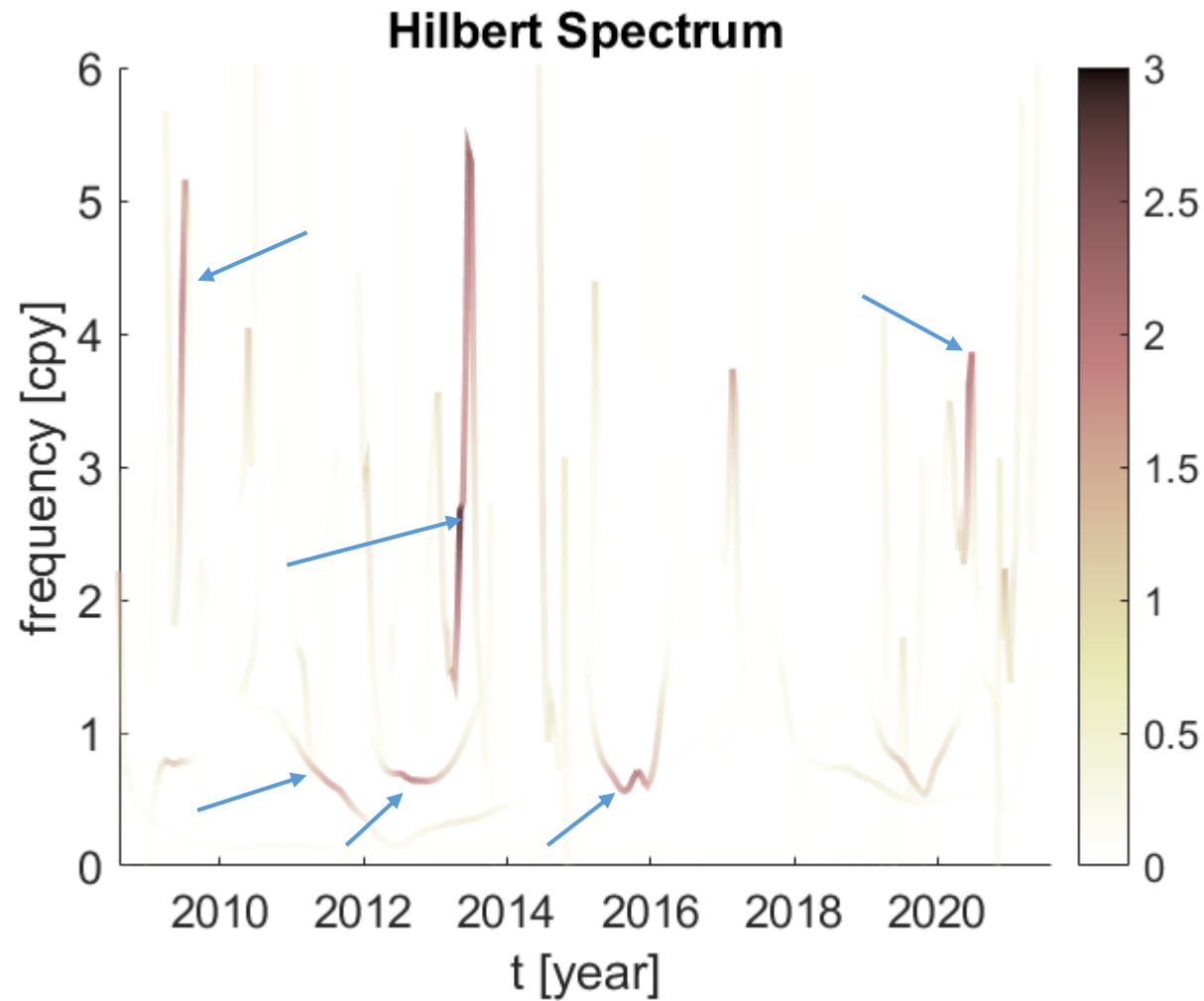After simple linear de-trend

Single-Sided Amplitude Spectrum
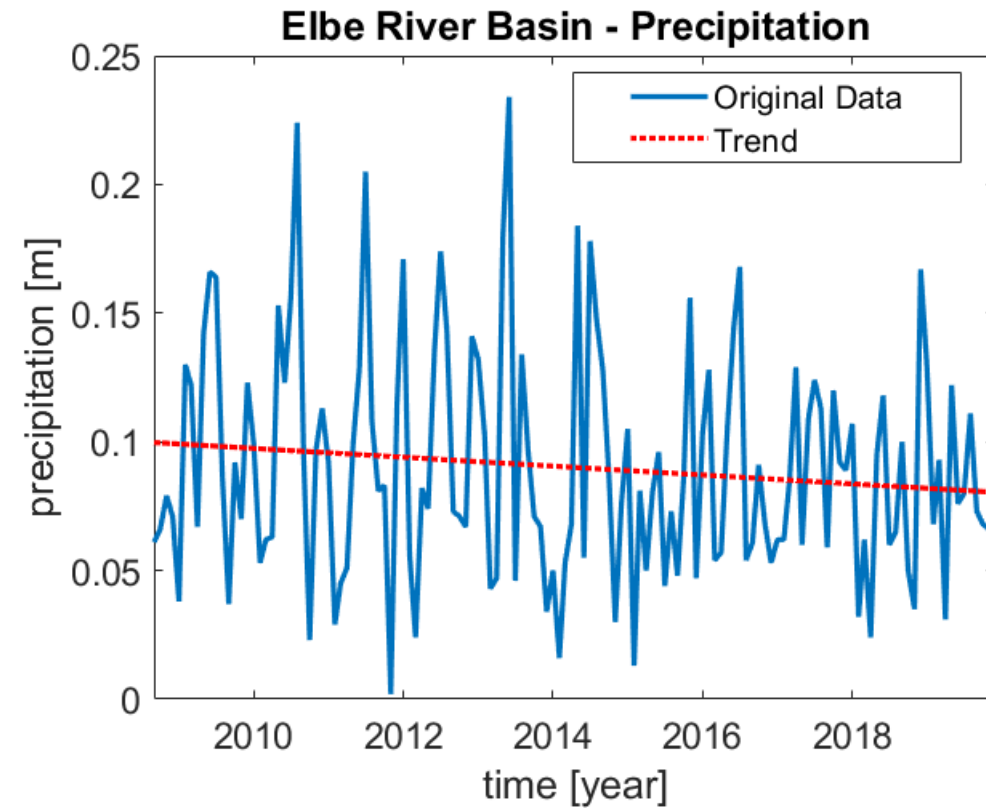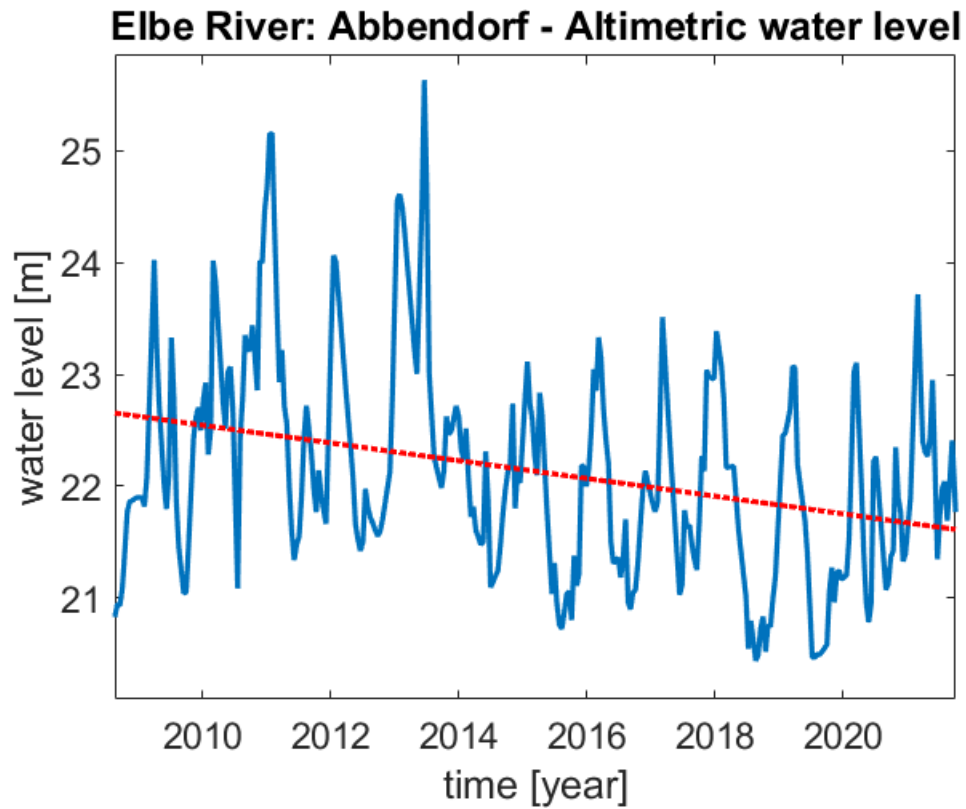
Wavelet Transform

After simple linear de-trend
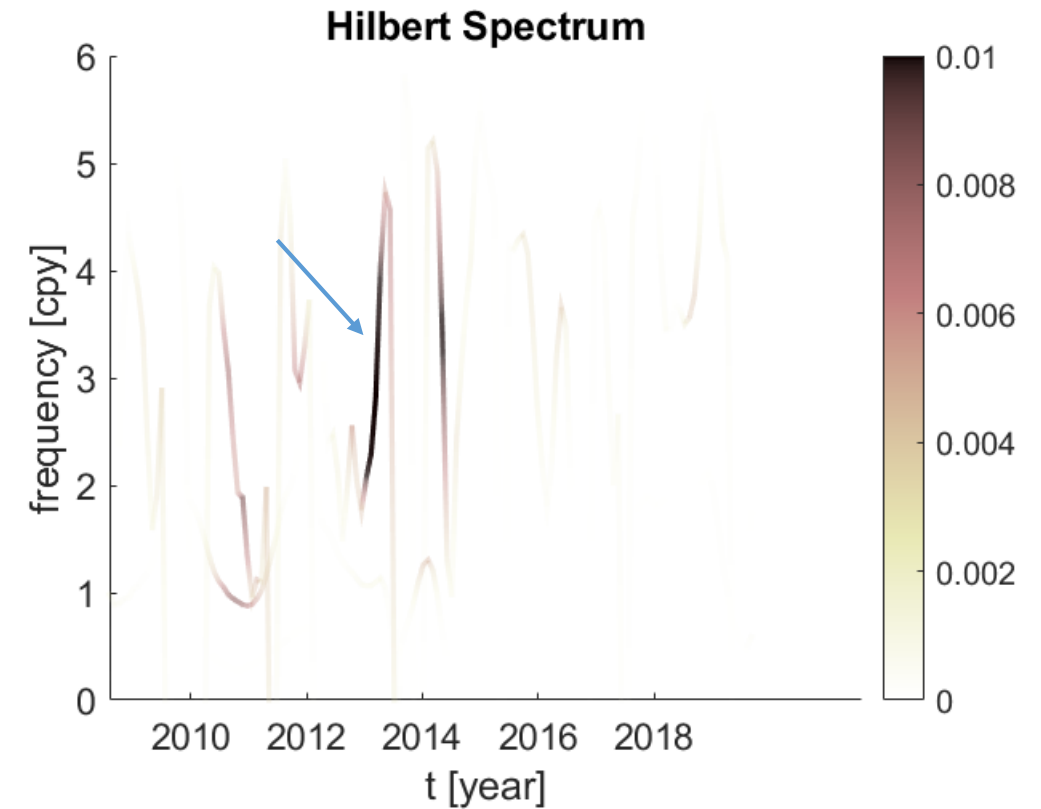
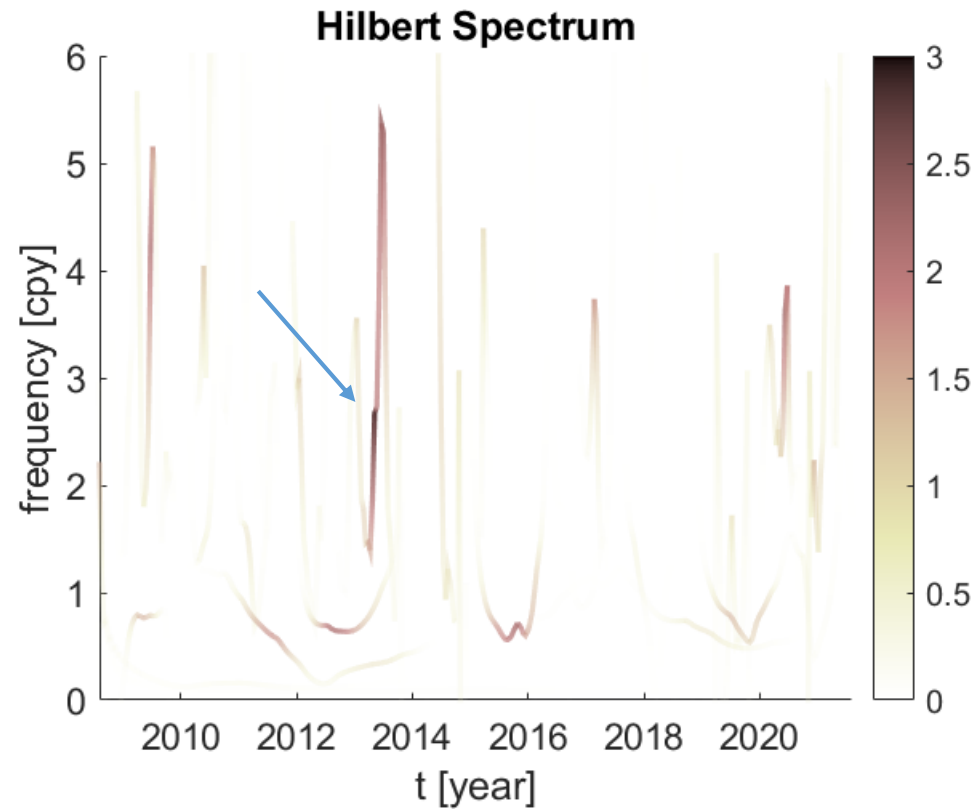# EMD + Hilbert Transform

After simple linear de-trend

How to interpret those?

Elbe River: Abbendorf - Altimetric water level

Elbe River Basin - Precipitation

slightly decreasing trend

How to interpret those?

Flood event of June 2013

water level

precipitation

How to interpret those?

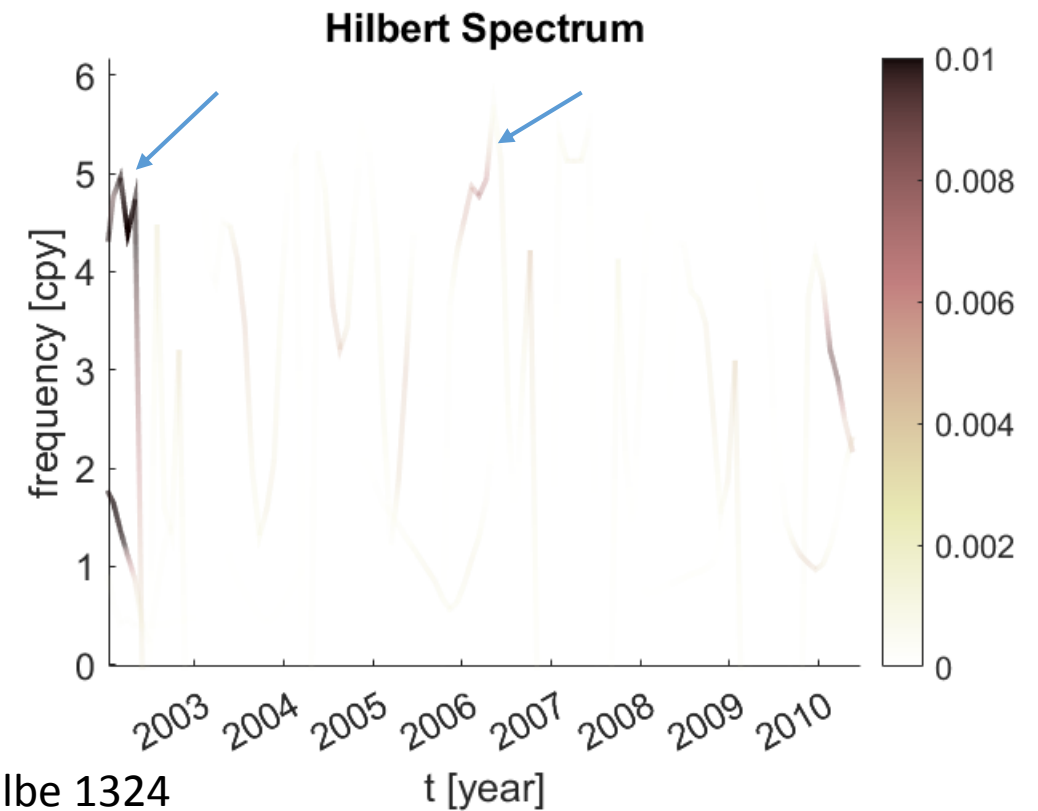Flood events of August 2002 and April 2006

Virtual Station: Elbe 1324
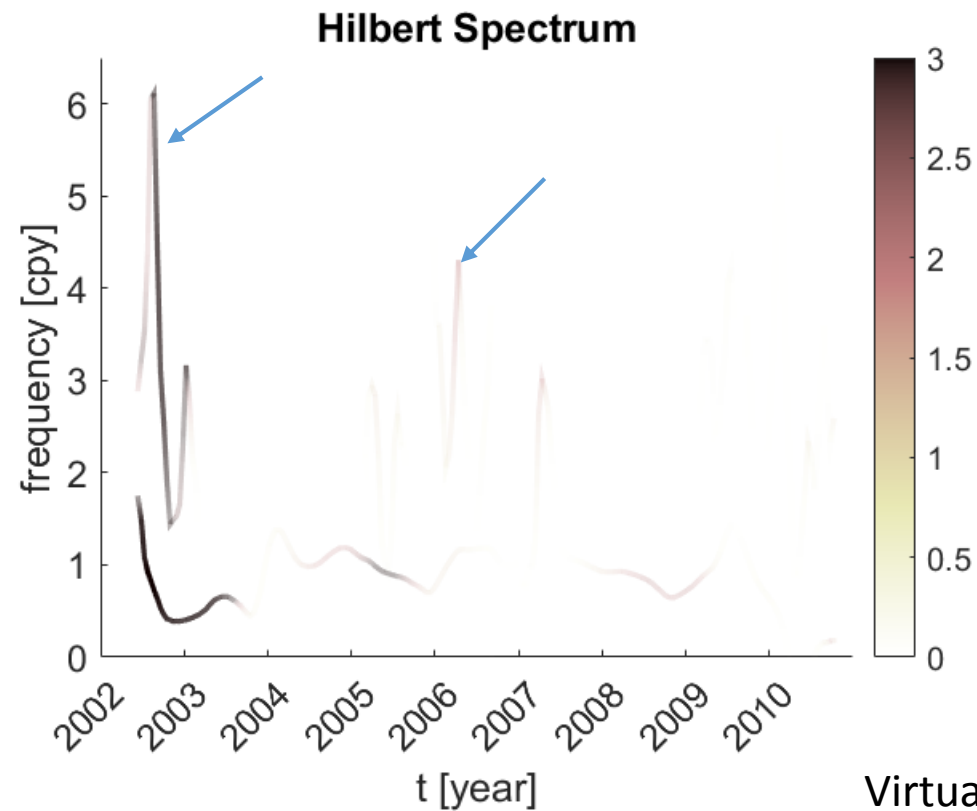
water level   precipitation

Message to take (conclusion)

Benefits of using different signal processing methods for extracting relevant hydrometeorological information and causality analysis!

References

- Truong, C., Oudre, L., Vayatis, N. (2020) Selective review of offline change point detection methods. Signal Processing, 167:107299.
- Huang, N.E., Shen, Z., Long, S.R., et al. (1998) The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis. Proc. R. Soc. A: Math. Phys. Eng. Sci., 454(1971), pp.903-995.
- Moghadaspour H., S. Iran Pour, S. Behzadpour, T. Mayer-Gürr, N. Sneeuw and A. R. Amiri-Simkooei, 2021 "Use of Empirical Mode Decomposition (EMD) method to investigate the solar storms impact on GRACE range-rate residuals", IAG Scientific Assembly, 28 June – 2 July 2021, Beijing, China.
- …

Thank you for your attention

For questions and discussions,
I am available during the G3.1 "Geodesy for Climate Research" session run through the virtual portal.