Revealing the Structure of Precipitation Extremes:

a spatio-temporal Wavelet Approach

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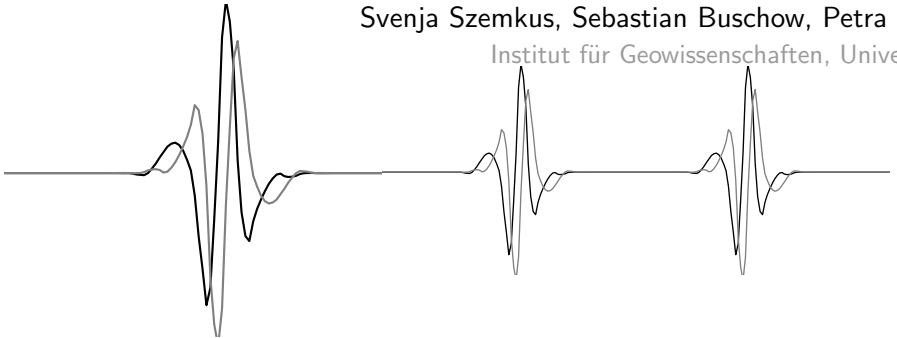

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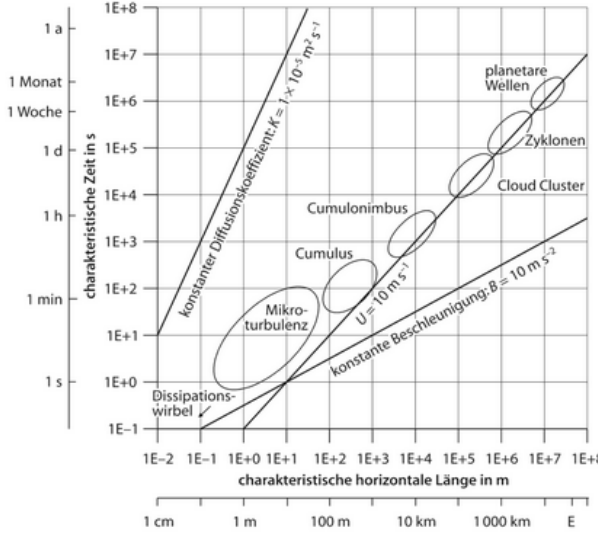
Motivation

Analyse spatio-temporal structure of precipitation extremes.

1) Evaluate & compare datasets on their representation of extreme precipitation.

2) Detect changes in spatio temporal structure of precipitation extremes.



space-time characteristics of various atmospheric processes.
Source: Kraus, H. (2007)

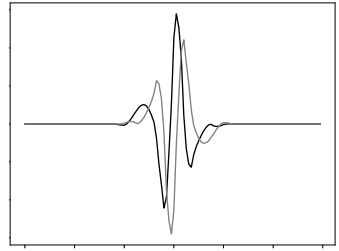
The Wavelet-Transform (Space/Time)

One dimension:

$\longrightarrow d^{j_t}(k_t) = \langle h(t), \psi^{k_t, j_t}(t) \rangle_t$

j_t: scale, k_t: location

$\longrightarrow$ Dual tree complex wavelet transform (Kingsbury, 1998)

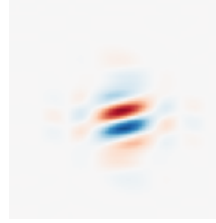


Two dimensions:

$\longrightarrow d_q^{j_{x,y}}(k_x, k_y) = \langle g(x,y), \psi_q^{(k_x,k_y),j_{x,y}}(x,y) \rangle_{x,y}.$

$j_{x,y}$: scale, k_x, k_y: location, q: orientation

$\longrightarrow$ Application to spatial precipitation fields: Buschow 2024, Buschow & Friederichs 2021, ...



The Wavelet-Transform (Space & Time)

Three dimensions:

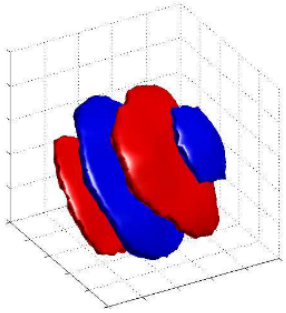
$$\longrightarrow d_q^{j_{x,y,t}}(k_x, k_y, k_t) = \langle f(x,y,t)\psi^{(k_x,k_y,k_t),j_{x,y,t}}(x,y,t)\rangle_{x,y,t}$$

$j_{x,y,t}$: scale, k_t, k_x, k_y: location, q: orientation

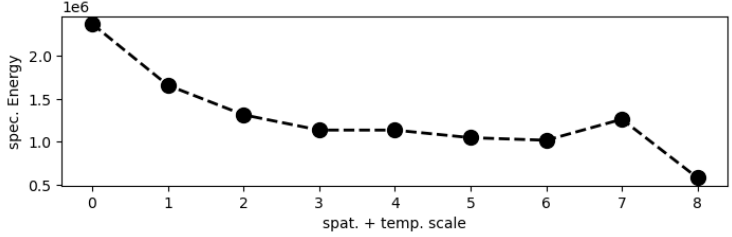
$\longrightarrow$ 3D dualtree Wavelet Transform: Selesnick (2003)

$\longrightarrow$ Python Package: *dtcwt*

$\longrightarrow$ Problem: Interpretation of scale parameter $j_{x,y,t}$.



Source: Selesnick et al. 2003



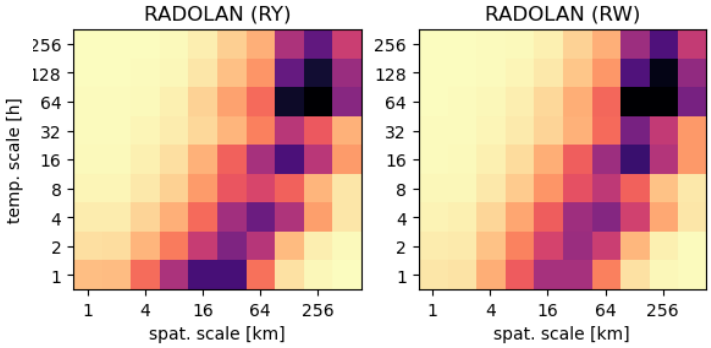
The Wavelet-Transform (Space & Time)

Our approach:

$$\longrightarrow d_q^{j_{x,y},j_t}(k_x,k_y,k_t) = \langle f(x,y,t)\ \psi^{k_t,j_t}(t)\ \psi_q^{(k_x,k_y),j_{x,y}}(x,y)\rangle_{t,(x,y)}$$

$j_t, j_{x,y}$: scale, k_t, k_x, k_y: location, q: orientation

$\longrightarrow$ Effective separation of spatial & temporal scale.



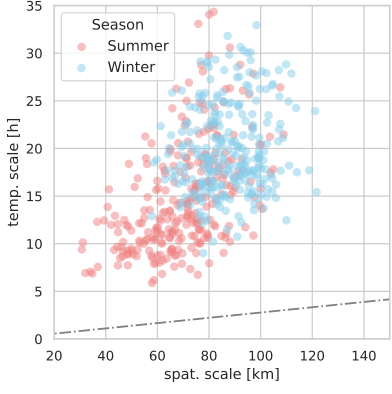
Application to observation data

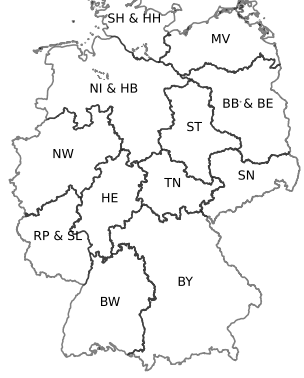
Dataset: RadKlim hourly precipitation data

Coverage: German federal states

Event Type: Maximum precipitation events during Summer & Winter

Focus: Peak 4-day precipitation events per region



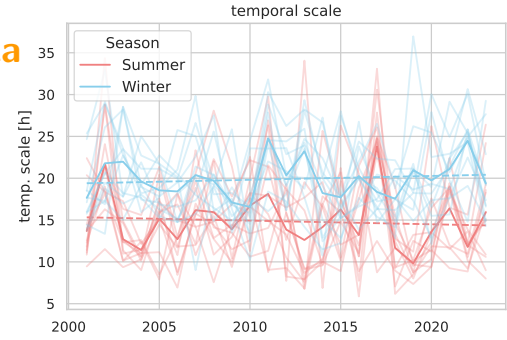


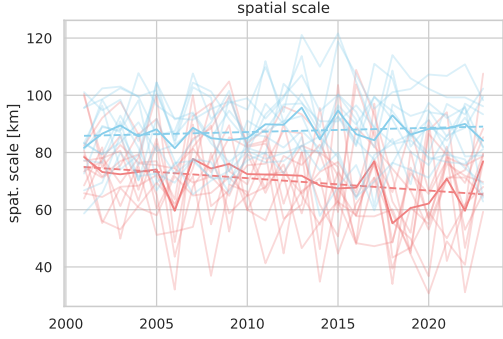
Application to observation data

Changes in spatio-temporal structure of extreme precipitation probable

$\longrightarrow$ In line with results from CPM-Simulations (Hundhausen et al. 2024)

$\longrightarrow$ Strongest signal in spatial scale





Summary & Conclusion

- Compact description framework for spatio-temporal precipitation extremes:
  → Python code available on request
  → Paper in preparation
- Suitable for analysing the spatio-temporal characteristics of extreme precipitation events:
  → ClimXtreme report on Flood situation May/June 2024.
- Detecting changes in the spatio-temporal structure of precipitation extremes:
  → Wavelet transform could uncover changes hidden in raw data (data compression).
  → Need for improved observational data to enhance event estimation accuracy.

References

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