Similarities and differences in groundwater responses to droughts across Germany

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Background

Motivation

- Groundwater droughts threaten numerous water needs, e.g. drinking or irrigation water
- Diverging groundwater responses
- Groundwater heads are not only an effect of meteorological droughts, but also catchment and aquifer properties and anthropogenic impacts
  → Memory (autocorrelation)
- Need for knowledge on boundaries of sustainable management *in face of future challenges*

Research questions

1 Are there regional **similarities and differences**?

2 What are main **controls**: meteorological drivers and/or other landscape properties?

3 Can we infer **vulnerable zones**?

Methods

- 6677 wells across Germany [1]
- Monthly groundwater heads (1991-2020)
- Characterizing groundwater head anomalies using the standardized groundwater index (SGI) [2]
  SGI < 0 → drought
- K-means clustering based on SGI time series
- Link to characteristics
  - Droughts characteristics (duration, severity, autocorrelation)
  - Cross-correlation with meteorological drought indices (SPI, SPEI) [3]
  - Landscape properties (e.g. topography, hydrogeology, unsaturated zone)

1

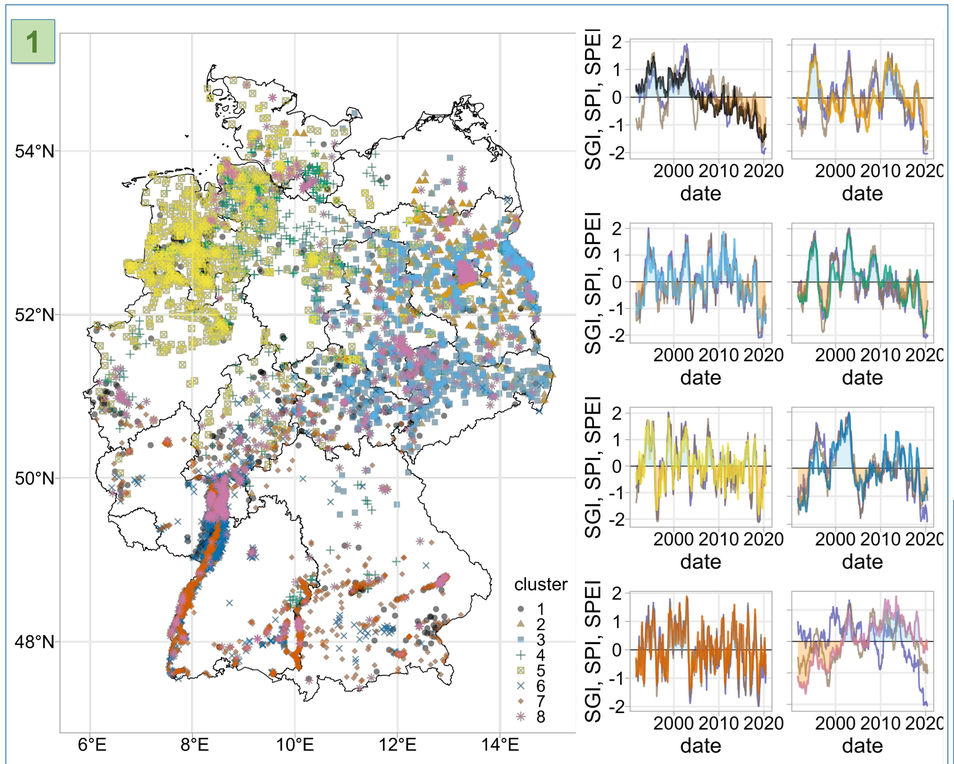

Figure 1: Cluster of groundwater drought responses

Figure 2: SGI of clusters (orange - SGI<0) and individual wells (grey)

2

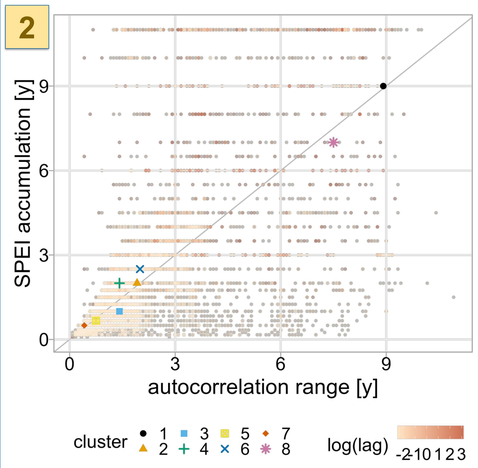

Figure 3: Memory – lag and attenuation of meteo drivers

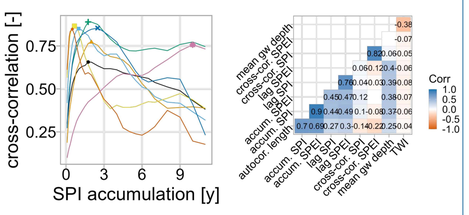

Figure 4:

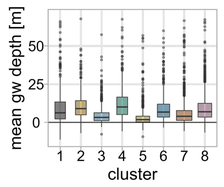

Figure 4:

Outcome

Results

- 8 clusters were identified with emergent regional patterns
- Autocorrelation length ranges up to 11 years (median 1.5 years)
- Cross-correlations between groundwater and meteorological drought indices mostly >0.7

Take Home Messages

- Regional patterns in groundwater responses emerged and linked to intrinsic properties of the time series
- Drought propagation is characterized by a combination of attenuation and lag of the meteorological signal
- Depth to groundwater somewhat linked to clusters but stratigraphic data would help to disentangle

Outlook

Hierarchical clustering

Linkages between characteristics and patterns

- Unsaturated zone thickness
- Distance to stream
- Stratigraphy?

3 ?

References:

[1] CORRECTIV.Lokal (2022): Grundwasser-Atlas „grundwasser-data“ https://github.com/correctiv/grundwasser-data
[2] Bloomfield, J. P., & Marchant, B. P. (2013). Analysis of groundwater drought building on the standardised precipitation index approach. *Hydrol. Earth Syst. Sci., 17*(12), 4769-4787. 10.5194/hess-17-4769-2013

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