Quantification of climate induced changes in groundwater levels using fuzzy rule-based models.

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1 Motivation

Direct prediction of groundwater levels from climate data.

- Assessment of future groundwater levels under the influence of climate change.
- Using direct link between climatic influences and groundwater levels.

2 Methodology

- Calculation of meteorological indices taking moving averages and time lags into account.
- Variable selection using Random Forest.
- Fitting station wise Fuzzy rule-based models.

  Rule system optimization using Simulated Annealing (Aarts and Korts, 1989).
- Fitting Multiple linear regression models (MLR).

  $GWL \sim f(meteorological\ indices)$
- Appling climate model data based on the RCP8.5 climate scenario.

3 Results

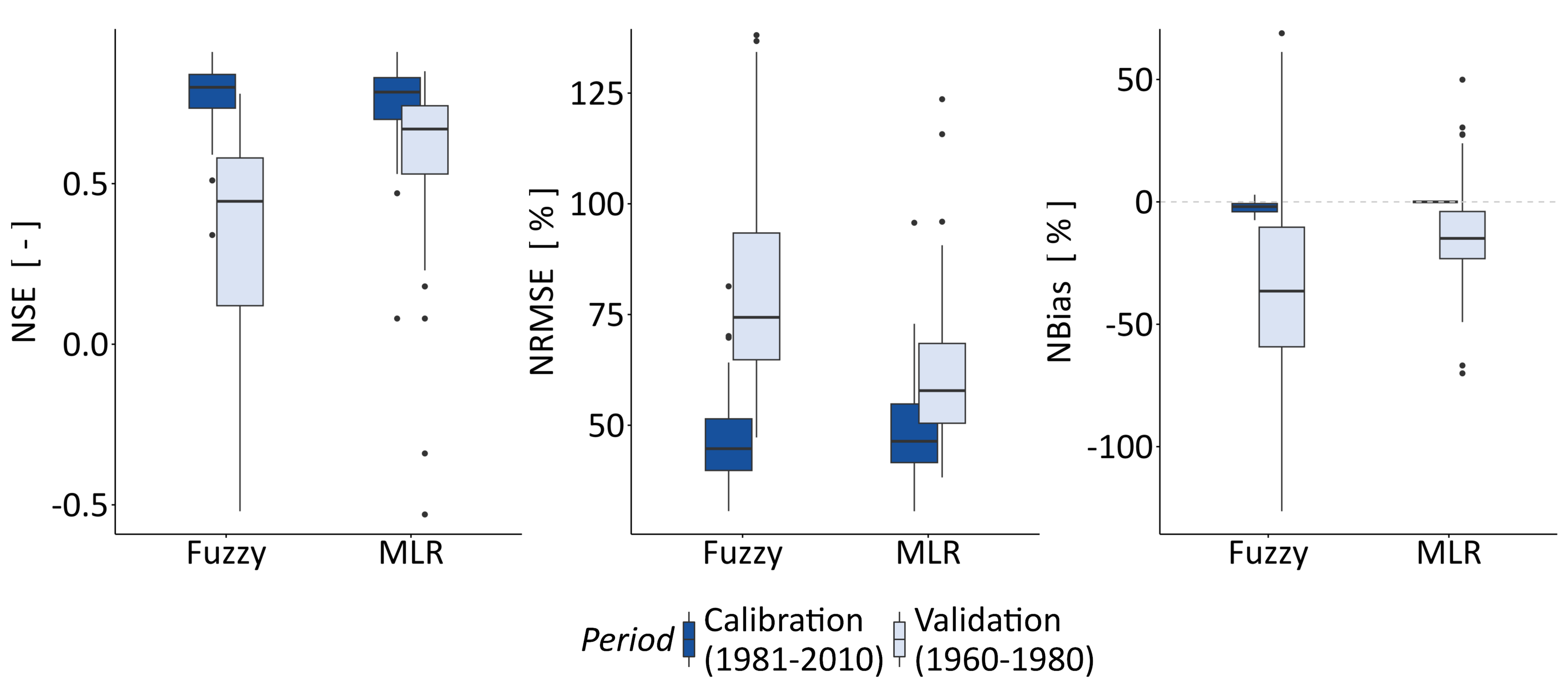

Fig. 1: Nash-Sutcliffe efficiency (NSE), normalised root mean square error (NRMSE) and normalised bias (NBias) of estimates from observed mean groundwater levels using Fuzzy rule-based models (Fuzzy) and Multiple linear regression models (MLR) for the calibration period (dark blue) and validation period (light blue) over 114 stations.

Groundwater levels in Lower Saxony can be described by meteorological indices using both fuzzy rule-based models and MLR approaches.

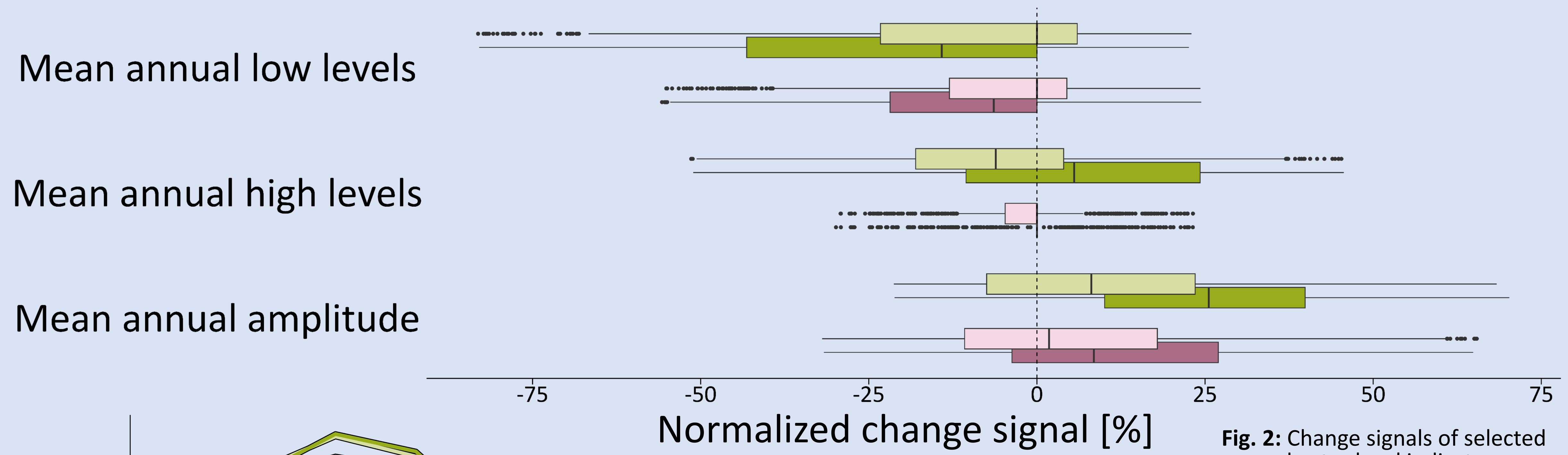

Fig. 2: Change signals of selected groundwater level indicators (Only 90% interval shown)

Multiple linear regression:
Near future 2021-2050
Far future 2071-2100

Fuzzy rule-based model:
Near future 2021-2050
Far future 2071-2100

Observation over reference period (1981-2010)

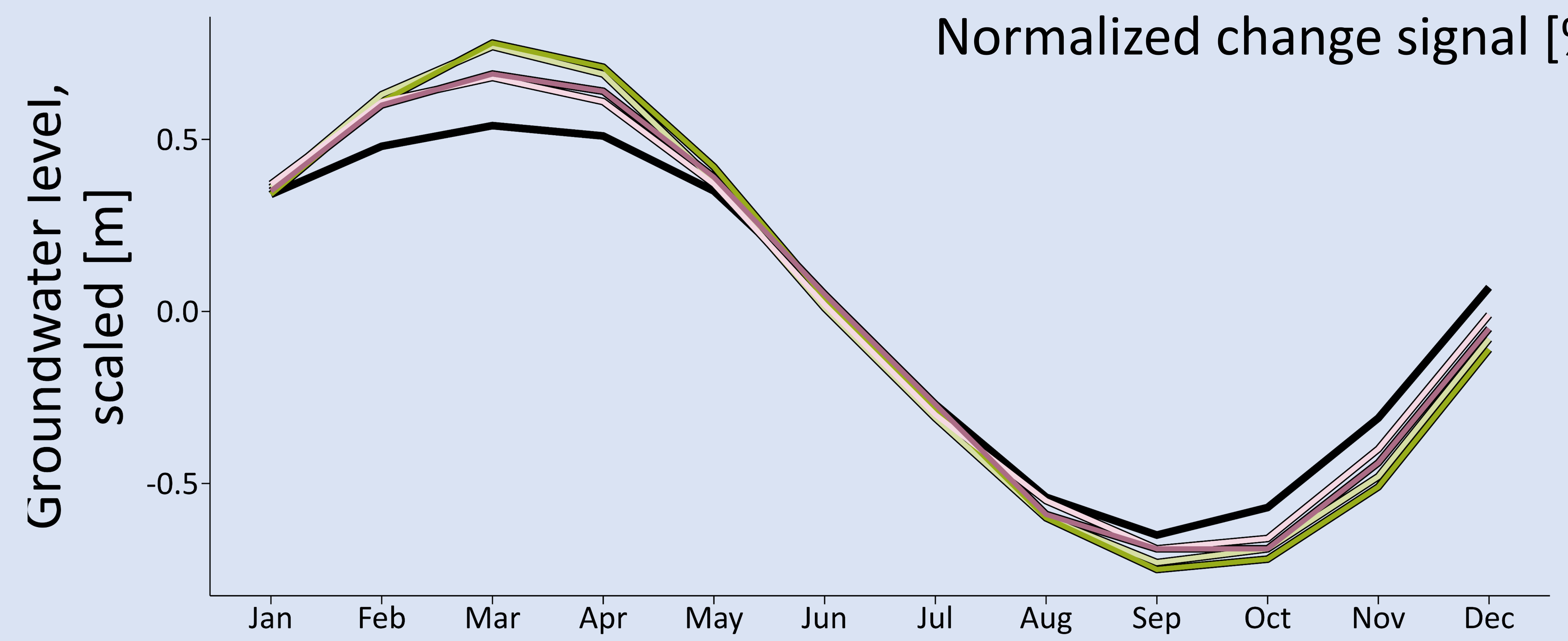

Fig. 3: Changes in the intra-annual dynamics of groundwater levels.

4 Conclusion

→ Model performance of MLR more robust than that of the currently calibrated Fuzzy rule-based models.

→ Both applied methods show similar change signals, with MLR showing slightly more pronounced changes.

→ Mean annual low levels decrease, while mean annual high levels decrease slightly. As a result, the mean annual amplitudes increase slightly.

→ Slightly delayed timing of the annual extremes.

→ The changes in the far future are in general more apparent than in the near future.

Photography encouraged

This presentation participates in OSPP — EGU — Outstanding Student & PhD candidate Presentation contest

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Additional Information

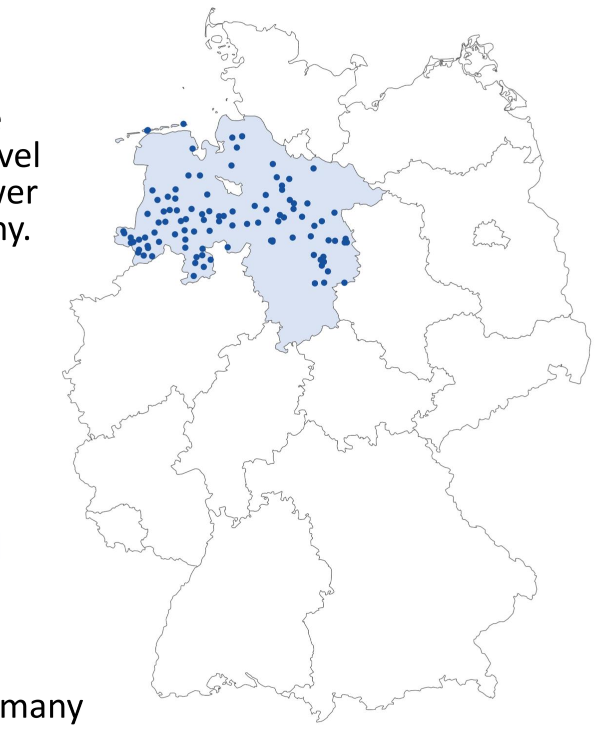

Fig. 4: Available groundwater level stations for Lower Saxony, Germany.

Study area and data

- Lower Saxony, Germany
- Observed monthly groundwater level data (144 stations with sufficient time series length)
- Observed daily climate data (Interpolated on 1x1km grid)
- Climate model data (Ensemble of 8 climate model projections based on RCP8.5 climate scenario)

Indices

- Mean Precipitation [mm/d]
- Minimum, average and maximum temperature [°C]
- Relative Humidity [%]
- Global radiation [W/m2]
- Groundwater recharge (Ertl et al., 2019) [mm/d]
- Evapotranspiration [mm/d]
- Mean climatic water balance [mm/d]
- Standardized Precipitation Index (McKee et al., 1993) [-]
- Standardized Precipitation-Evapotranspiration Index (Vicente-Serrano et al., 2010) [-]

Change signals

- Change signals calculated according to DeltaChange approach and normalised with standard deviation of the observed data of the reference period (1981-2010).
- Normalized change signal:

$$100 * \frac{\text{DeltaChange}}{\text{sd(obs)}_{\text{ref}}}\ [\%]$$

with: $\text{DeltaChange} = \text{obs} * \text{simulated change signals}$

REFERENCES

[1] Aarts, E., Korst, J., 1989. Simulated Annealing and Boltzmann Machines. John Wiley & Sons, New York, NY.

[2] Ertl, G., Erbracht, J., Engel, N., Bug, J., & Herrmann, F. (2019). Grundwasserneubildung von Niedersachsen und Bremen-Berechnungen mit dem Wasserhaushaltsmodell mGROWA18: Landesamt für Bergbau, Energie und Geologie.

[3] McKee, T.B., Doesken, N.J., Kleist, J. (1993). The relationship of drought frequency and duration to time scales. 8th Conference on Applied Climatology. American meteorological society, Boston, USA.

[4] Vicente-Serrano S.M., Begueria S., Lopez-Moreno J.I. (2010). A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index. Journal of Climate 23: 1696-1718.