Evaluation of global groundwater models using a new water table depth benchmark dataset

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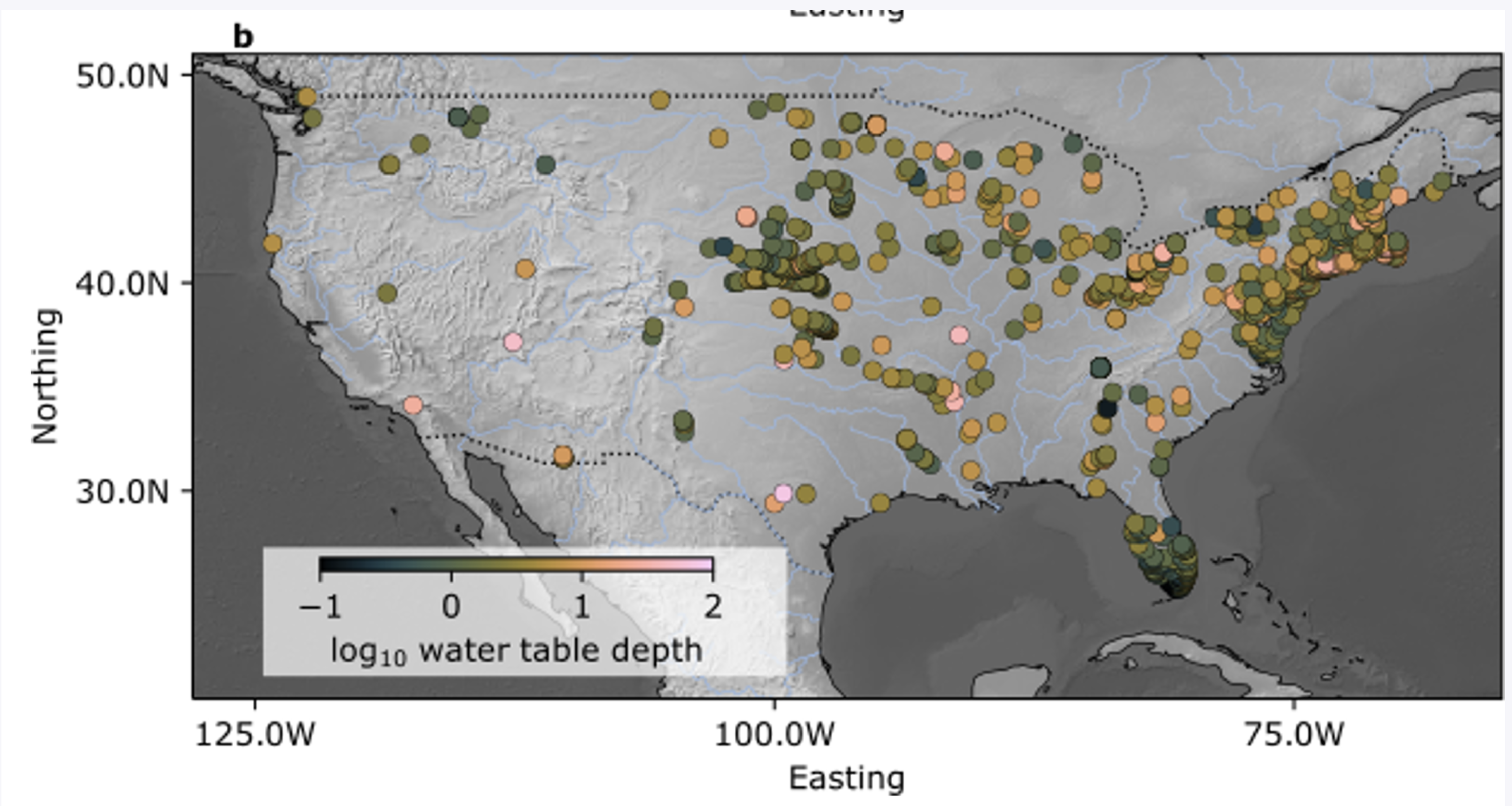
1 Summary

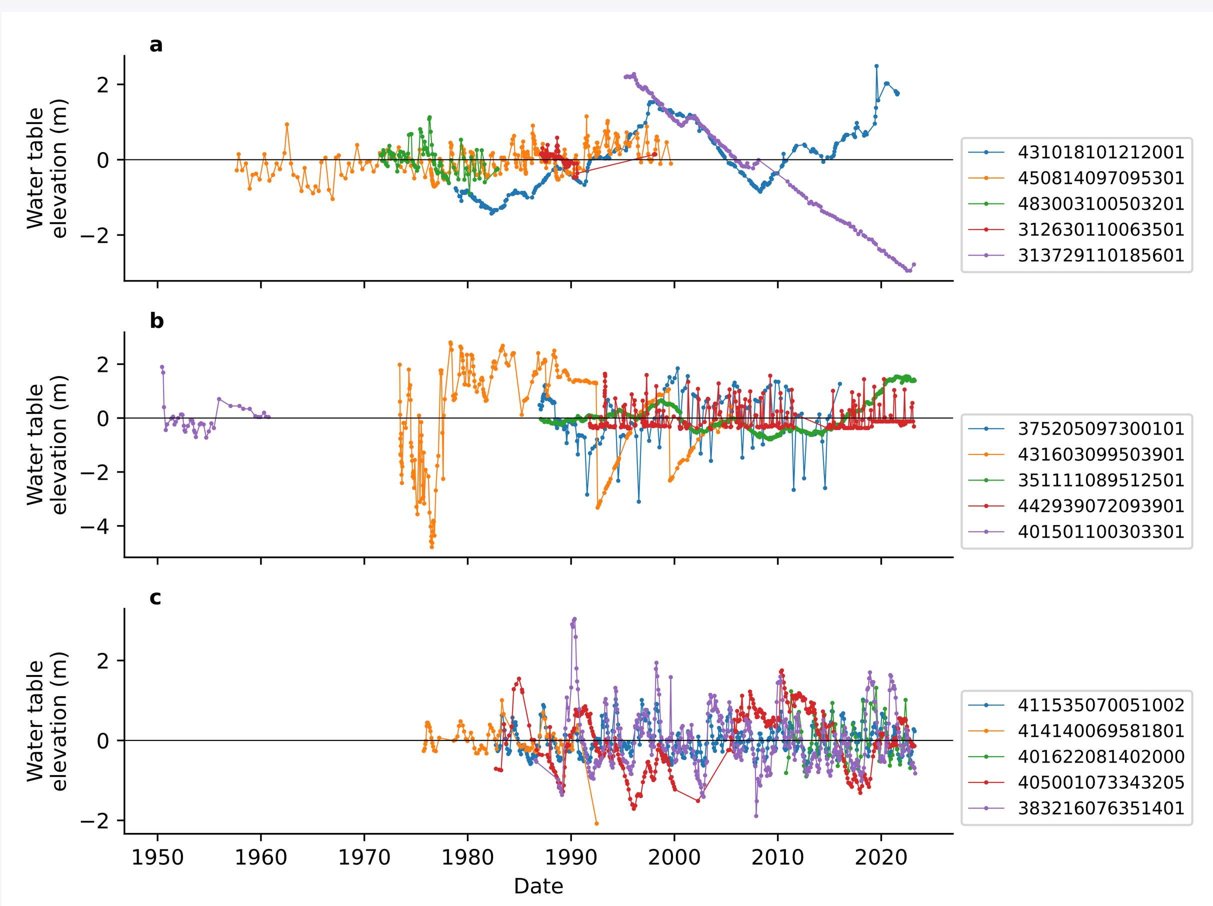
- Water table depth is important metric that governs the accessibility of groundwater resources and the interaction of groundwater with surface water and climate.
- However, the current generation of global groundwater models have only evaluated the fit to hydraulic head and not water table depth
- Here we generate a new benchmark water table depth dataset that represents natural unconfined conditions
- We use this dataset to evaluate global groundwater models and show that current global models fail to reproduce water table depths
- (note, this is a slight theme change from the original abstract title *"Estimation of transmissivity across the conterminous US using large water table and surface water datasets"*)

2 New water table benchmark data

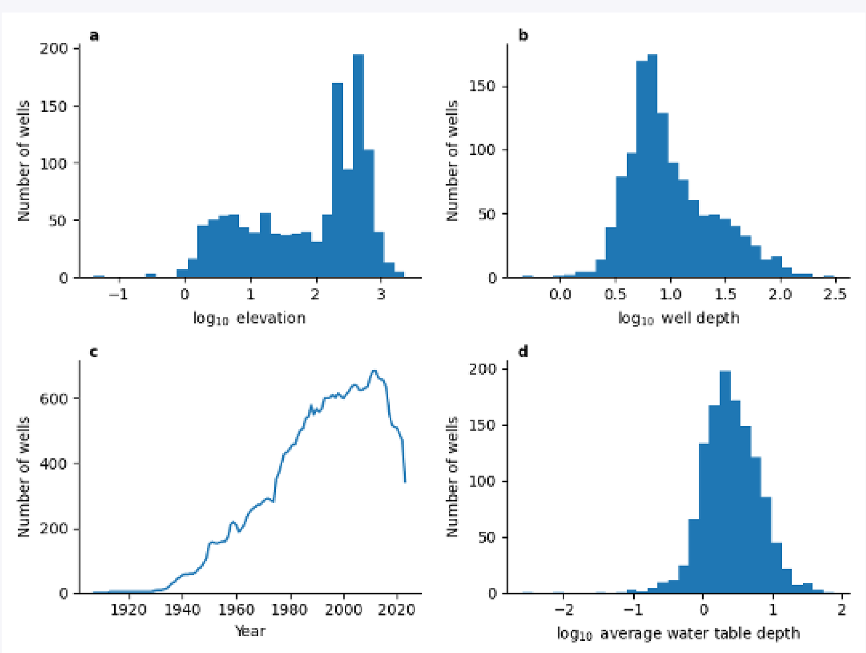
- We derived a new dataset of 1236 wells with long-term stable waterlevel data from the USGS NWIS database
- We filtered out wells for which pumping was recorded, that tapped deeper confined aquifers
- In addition, we filter out wells that may have been influenced by pumping in nearby wells using statistical analysis of trends and using a modified equation to estimate the maximum natural annual water table amplitude
- The resulting dataset is representative of long-term average natural water table in the top, unconfined aquifer



Water table depths in the new water table benchmark dataset



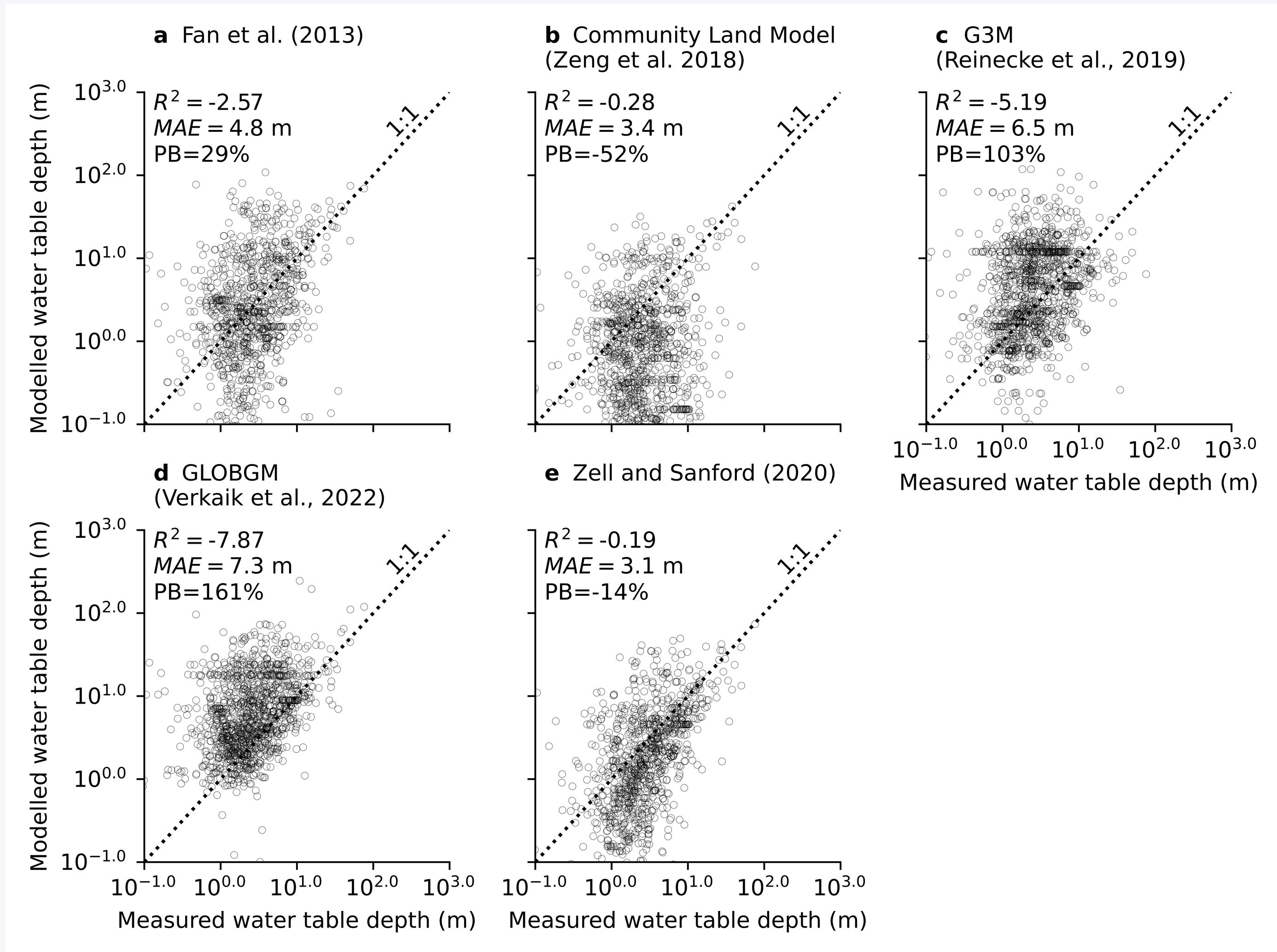
Water table timeseries for wells that showed statistically significant water level trends over time (panel a), wells that showed excessive water table fluctuation (panel b) and selected benchmark wells in which trends and excessive fluctuations were absent (panel c).



Elevation (panel a), well depth (b), temporal coverage (c) and long-term average water table depth (d) for the selected water table benchmark wells

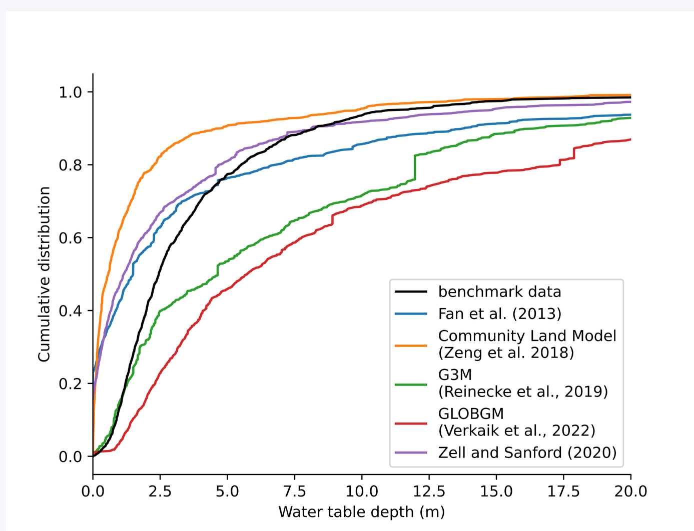
3 Evaluation of water table depth in models

- We compared water table depth int he benchmark dataset with four global groundwater models: Fan et al. (2013), the Community Land Model (Zeng et al. 2018), G3M (Reinecke et al. 2019), GLOBGM (Verkaik et al. 2022) and one model of the contiguous US (Zell and Sanford 2020)
- The comparison shows poor fit of the models to the data, with negative coefficients of determination (R^2), which signifies that the model error exceeds the variance of the water table dataset, and high values of bias (PB)
- The best performing model is the regional model of the USA by Zell and Sanford (2020). This is the only model for which extensive calibration of transmissivity was performed.



Comparison of modelled water table depth and the benchmark water table depth dataset for four global groundwater models (a-d) and one regional groundwater model (e). R2 is coefficient of determination, MAE is mean absolute error, PB is percent bias. The mean water table depth in the dataset is 4.0 m. Note that R2 can be negative if the variance of the model error exceeds the variance of the dataset.

- The divergence of the models and the water table data is also shown by the cumulative distribution of water table depths
- 40 % of the water table datapoints show a water table depth that is less than 2 meters. For the models, the values range 16% for GLOBGM (Verkaik et al., 2022), which strongly overestimates water table depths, to 78% for the Community Land Model (Zeng et al., 2018), which shows a strong underestimation of water table depth.



Cumulative distribution of water table depth in the benchmark dataset and in the global and large-scale models.

4 Conclusions

- We derived a new benchmark dataset for long-term natural water table depths by analysing water table timeseries and filtering out data that is influenced by pumping or that represented deeper confined aquifers.
- Comparison of modelled long-term average or steady-state water table depth by current global groundwater models with this new benchmark dataset showed that current models fail to reproduce water table depth.
- The implication is that current global models cannot reliably reproduce processes that are controlled by water table depth, such as groundwater utilisation by vegetation, groundwater discharge to streams, and the role of groundwater in droughts and floods.
- However, the result of our analysis show that model calibration of transmissivity can strongly improve the performance of groundwater models.