DOCTORAL PROGRAMME CLIMATE CHANGE

KARL-FRANZENS-UNIVERSITÄT GRAZ
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FWF-DK Climate Change

Estimation of groundwater recharge from time series modeling of groundwater levels in non-linear systems

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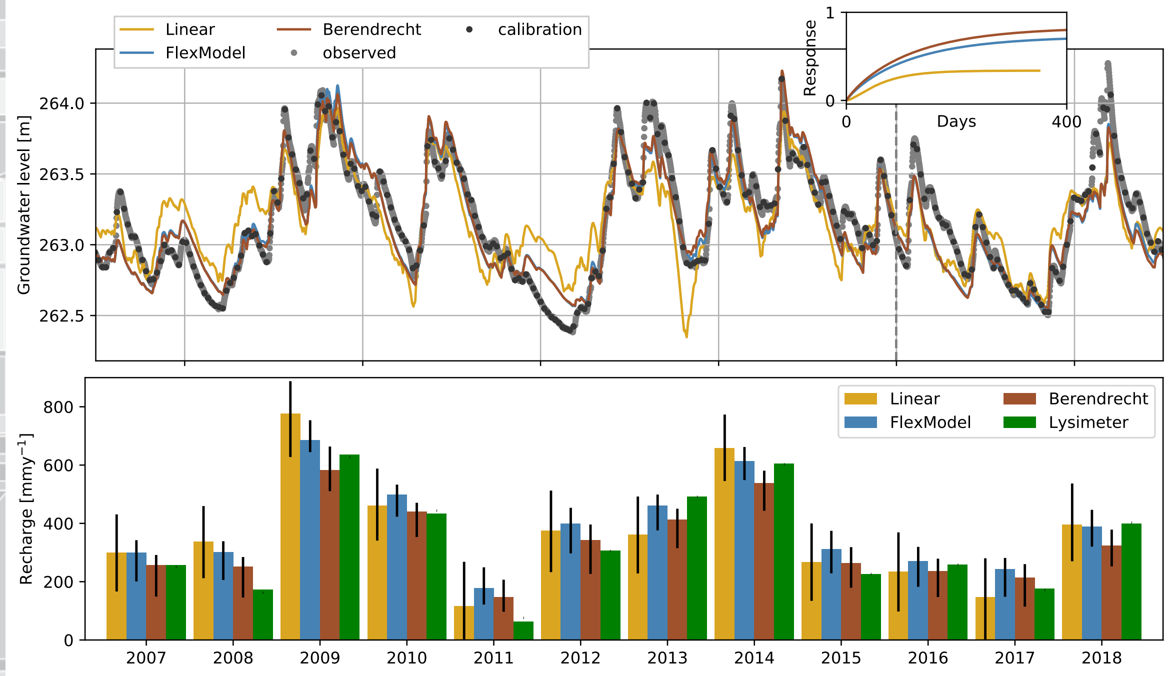

Abstract EGU2020-15104

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Research Objective

Estimate groundwater recharge and improve the simulation of groundwater levels using non-linear transfer-noise models and impulse response functions

Novelties:

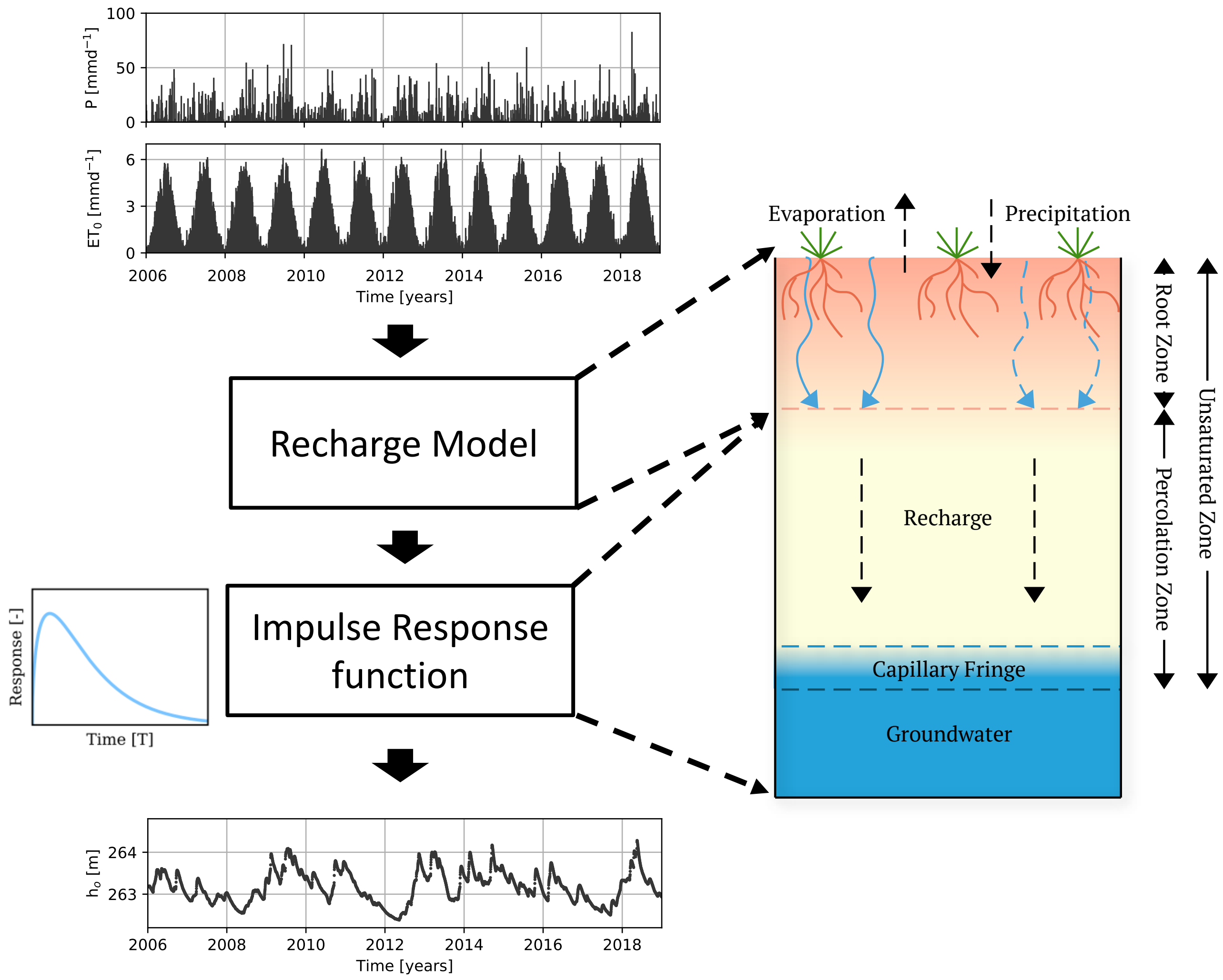
- Comparison of recharge estimates from TFN models with lysimeter measurements
- Recharge estimation using transfer function noise (TFN) models using impulse response function at sub-annual time scales

Earlier work already showed applicability of TFN models using impulse response functions to estimate annual recharge rates[1,2]

(1) Obergfell, C., Bakker, M., and Maas, K.: Estimation of average diffuse aquifer recharge using time series modeling of groundwater heads, Water Resources Research, 0.
(2) Peterson, T. J. and Fulton, S.: Joint Estimation of Gross Recharge, Groundwater Usage, and Hydraulic Properties within HydroSight, Groundwater, 57, 860–876,

Methodology

- The transfer function noise (TFN) model translates the precipitation and evapotranspiration into groundwater levels
- A recharge model is used to compute recharge from precipitation and evapotranspiration.
- The recharge flux is translated into groundwater levels by convolution of the flux with an impulse response function (e.g., Gamma).
- The parameters of the recharge model and impulse response function are estimated by calibrating the entire TFN model to observed groundwater levels.
- The recharge estimate is an intermediate model result that is not calibrated for.



Further reading : Collenteur, R. A., Bakker, M., Caljé, R., Klop, S. A., and Schaars, F.: Pastas: Open Source Software for the Analysis of Groundwater Time Series, Groundwater, 0,

Non-linear Recharge models

Three models are used to calculate the recharge (R) to the groundwater:

Linear (Baseline model)

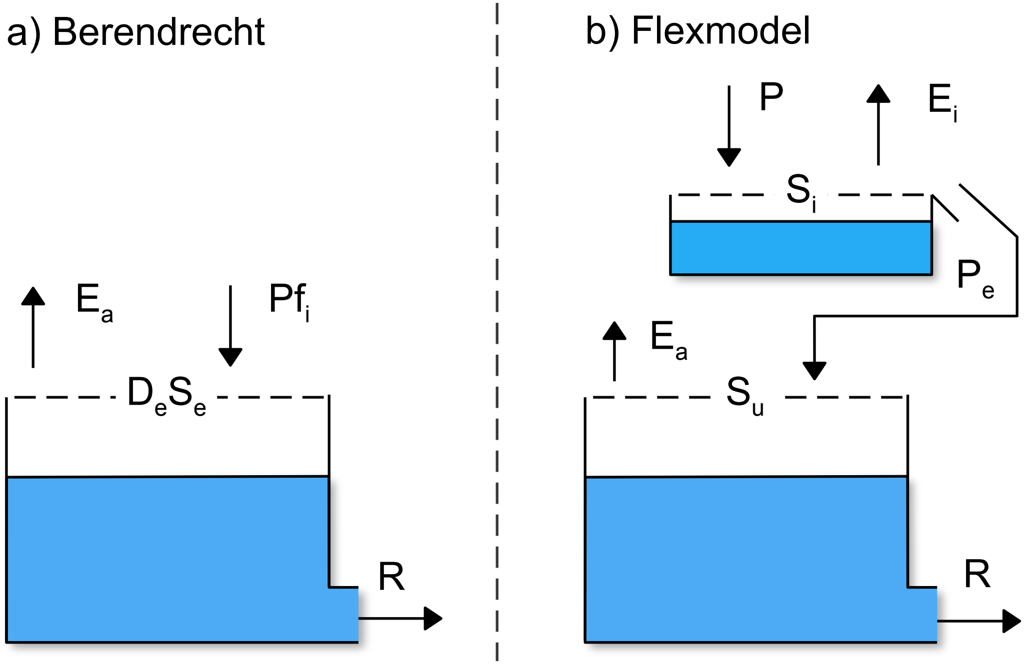
$$R = P - f\,ET_0$$

Berendrecht[1]

$$R(S_e) = K_s S_e^{\lambda}\,(1-(1-S_e^{1/m})^m)^2$$

Flexmodel[2]

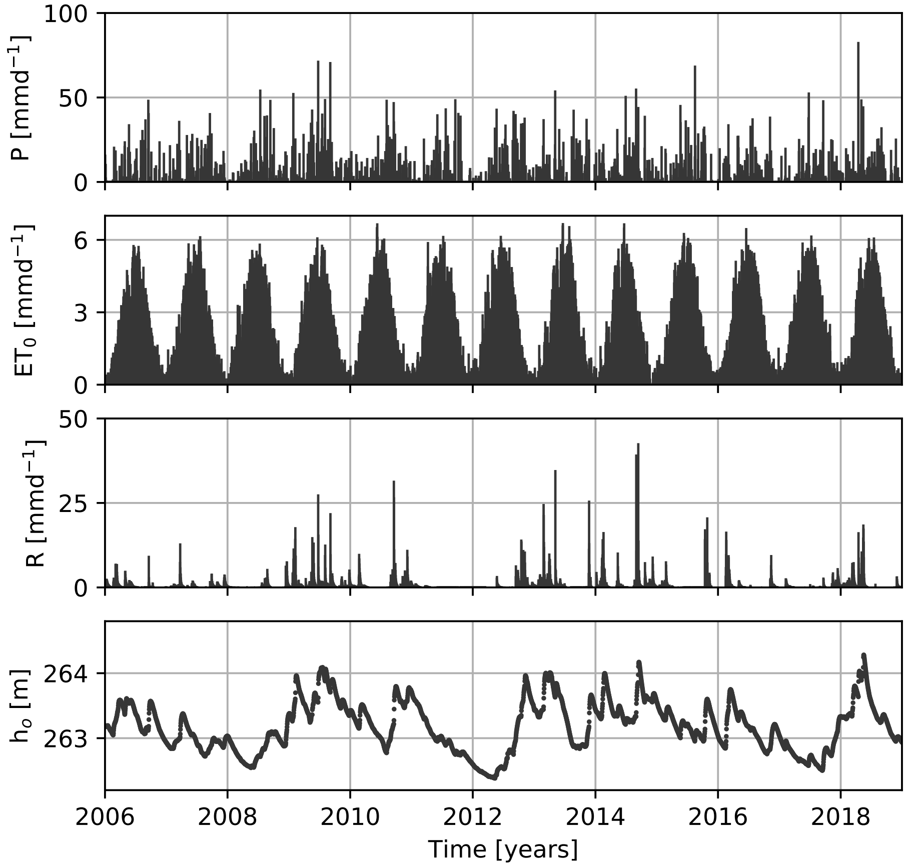
$$R = K_s(\frac{S}{S_u})^{\gamma}$$



(1) Berendrecht, W. L., Heemink, A. W., van Geer, F. C., and Gehrels, J. C.: A non-linear state space approach to model groundwater fluctuations, Advances in Water Resources, 29, 959–973.
(2) Savenije, H. H. G.: HESS Opinions "Topography driven conceptual modelling (FLEX-Topo)", Hydrology and Earth System Sciences, 14, 2681–2692,

Case Study Area: Wagna, Austria

- Hydrological Research Site Wagna in Austria is used as a case study site.
- Meteorological time series available from weather station at the site.
- Recharge (R) is measured with lysimeters at the site, operated by JR-AquaConSol.
- Groundwater table (H_0) is approximately 4 meters below the land surface.
- Groundwater levels are expected to be the result of recharge, no rivers and groundwater pumping nearby.



Results: Groundwater level simulation

- The non-linear models (Flexmodel and Berendrecht) improve the simulation of the groundwater levels.
- The GWL simulated by the non-linear models is practically the same. The Flexmodel may be preferred when considering the number of parameters
- The linear model is not appropriate to simulate low groundwater levels due to its lack of representation of important unsaturated zone dynamics.

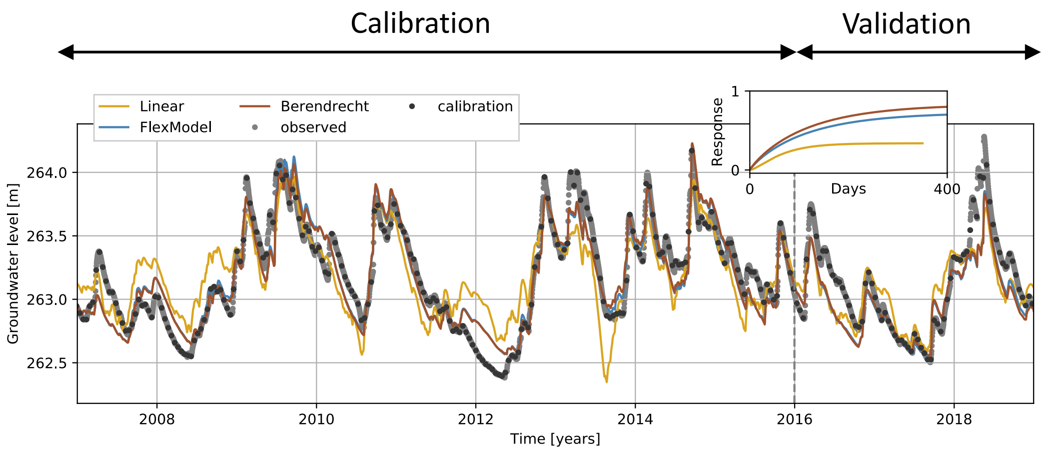


Table 1. Performance metrics for the groundwater level simulation.

	Linear		FlexModel		Berendrecht		Lysimeter	
	Cal.	Val.	Cal.	Val.	Cal.	Val.	Cal.	Val.
MAE	0.20	0.18	0.12	0.15	0.12	0.16	0.15	0.17
R^2	0.66	0.71	0.87	0.88	0.87	0.87	0.81	0.77
NSE	0.66	0.66	0.87	0.73	0.87	0.72	0.76	0.71
KGE	0.72	0.63	0.92	0.73	0.92	0.72	0.66	0.63

Results: Annual Recharge Estimation

- Figure shows the estimated and observed annual recharge rate, including 95% confidence intervals of the estimate.

- All three models provide reasonable estimates of annual groundwater recharge.

- Berendrecht model shows the lowest absolute error and smallest confidence intervals.

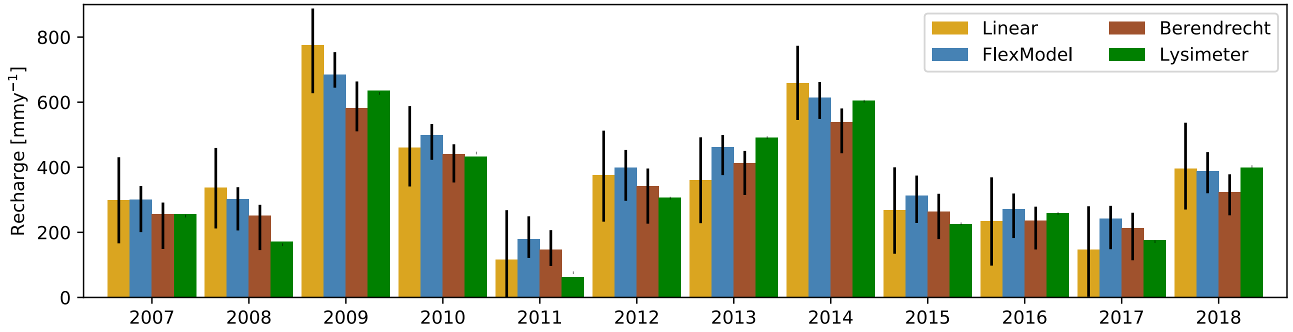


Table 2. Descriptive statistics for the absolute error (in mm/year) between estimated and observed recharge.

	Linear	FlexModel	Berendrecht
mean	65.06	59.27	48.27
std	51.67	40.84	29.15

Results: 2-weekly Recharge Estimation

- Figure shows the estimated and observed recharge rates for two-week periods. The Blue band denotes the 95% confidence interval for the recharge estimate.
- The Flexmodel and Berendrecht model generally simulate the recharge rates well, with similar event-based recharge behaviour that is also observed in the lysimeter data.
- Recharge is overestimated during periods of extreme drought (e.g., 2012). This may be caused by an underestimation of the evapotranspiration.

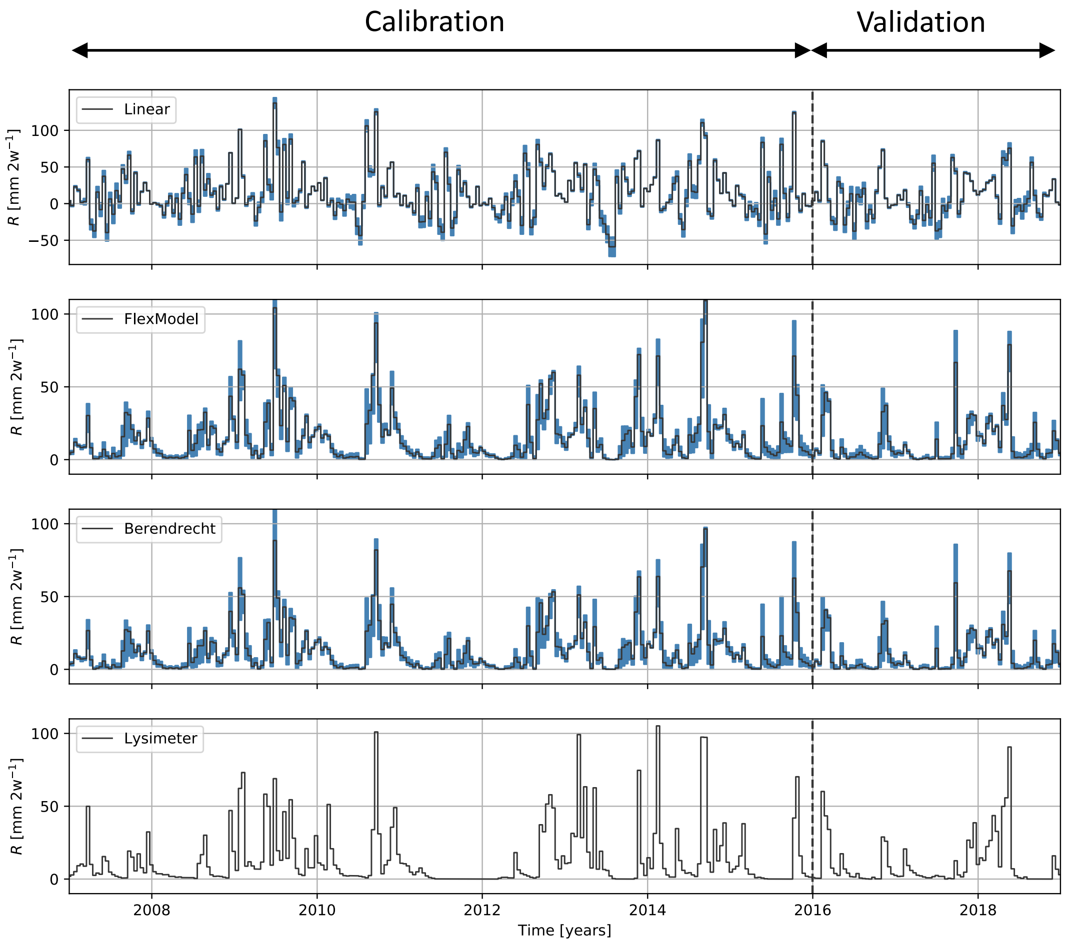
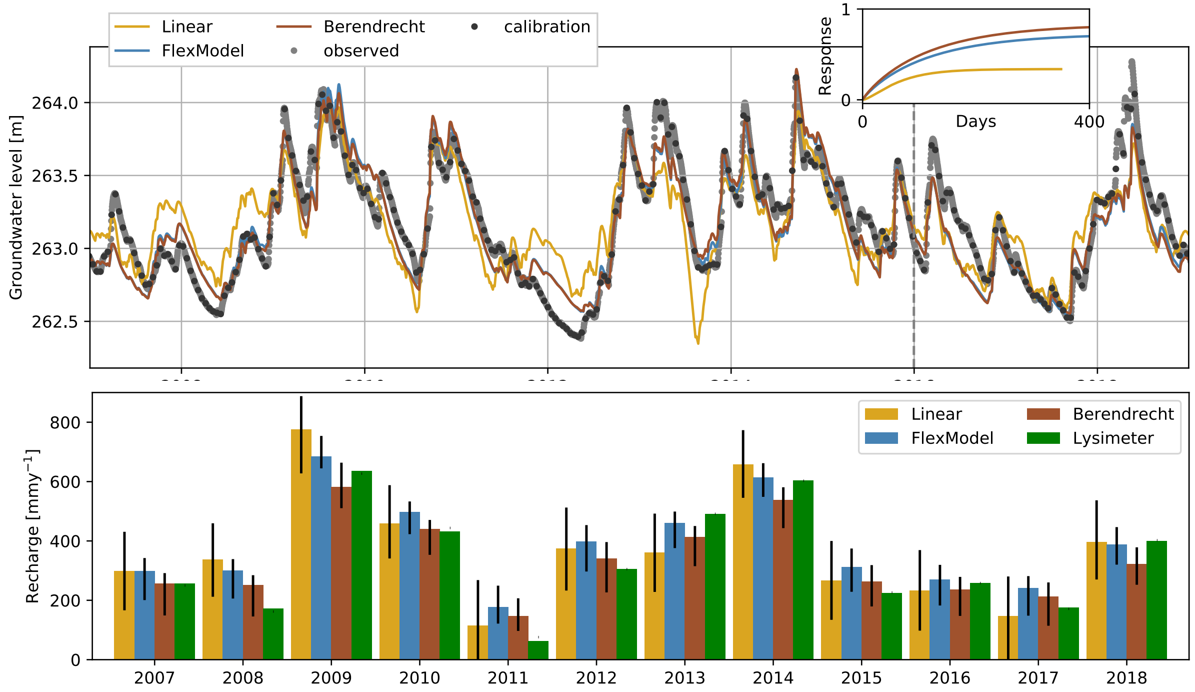


Table 3. Performance metrics for the groundwater recharge estimation.

	Linear		FlexModel		Berendrecht	
	Cal.	Val.	Cal.	Val.	Cal.	Val.
MAE	21.29	18.30	7.95	5.34	7.69	5.20
R^2	0.29	0.31	0.69	0.74	0.69	0.73
NSE	-0.89	-0.86	0.67	0.73	0.68	0.71
KGE	0.36	0.12	0.66	0.71	0.72	0.73

Conclusions



Groundwater level simulation

- Non-linear approaches can improve the simulation of groundwater levels by taking unsaturated zone processes into account.
- Linear TFN models should not be used to simulate groundwater levels under drought conditions

Recharge Estimation

- Linear and non-linear TFN model can be used to obtain reasonable annual recharge estimates.
- Non-linear TFN models can be also used to obtain recharge estimates at smaller time scales.

Advantages of the proposed method

- The method requires little information, only precipitation, calculated evapotranspiration and groundwater level time series are required as input.
- Other hydrological variables (e.g., pumping, rivers) influencing the groundwater fluctuations can be easily be included in the model.

Example Jupyter Notebook available here: https://github.com/pastas/pastas/blob/master/examples/notebooks/13_non_linear_recharge.ipynb