Timeseries modeling of piezometric heads: determination of precipitation response in the presence of other stresses and hydrogeologic heterogeneity

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Abstract

Time series of piezometric head implicitly contain information about groundwater system. This information is reflected in the impulse response function of precipitation. In order to use these functions as a signature of the system, they must be determined with appropriate reliability. In order to investigate the effect of other influences on the determination of the precipitation response, piezometric data have been studied from a transect running from dunes along the Dutch North Sea coast with natural vegetation into a polder area with agricultural and urban land use. In the dune area, there are several drinking water abstractions with known abstraction rates or levels. Each time series of piezometric head has been modeled with precipitation, evaporation and up to 4 extractions as explanatory variables. The precipitation impulse response functions from these models have been evaluated per piezometer and compared to neighboring piezometers. Over-parametrization gives more problems for the determination of the precipitation impulse response than the presence of other influences as long as these are not too correlated with the precipitation. The reliability of the precipitation response can be assessed using spatial correlation with neighboring piezometers and the local hydrogeology. Reliable impulse response functions can be used for interpolation and prediction of heads and for characterisaton of the hydrogeological settings.

TIME SERIES MODELING OF PIEZOMETRIC HEADS

DETERMINATION OF PRECIPITATION RESPONSE IN THE PRESENCE OF OTHER STRESSES AND HYDROGEOLOGICAL HETEROGENEITY

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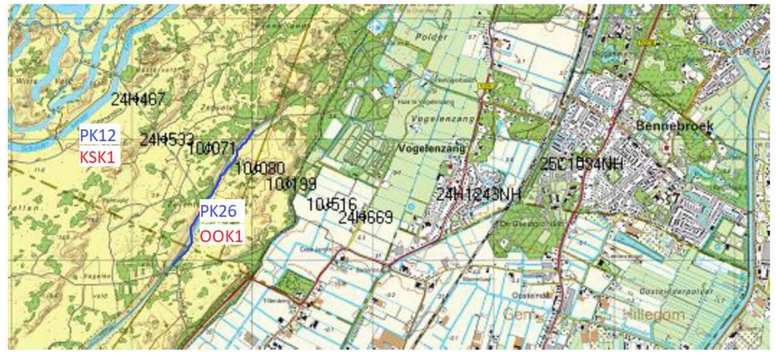


ABSTRACT

Time series of piezometric head implicitly contain information about groundwater system. This information is reflected in the impulse response function of precipitation. In order to use these functions as a signature of the system, they must be determined with appropriate reliability.
In order to investigate the effect of other influences on the determination of the precipitation response, piezometric data have been studied from a transect running from dunes along the Dutch North Sea coast with natural vegetation into a polder area with agricultural and urban land use. In the dune area, there are several drinking water abstractions with known abstraction rates or levels.
Each time series of piezometric head has been modeled with precipitation, evaporation and up to 4 extractions as explanatory variables. The precipitation impulse response functions from these models have been evaluated per piezometer and compared to neighboring piezometers. Over-parametrization gives more problems for the determination of the precipitation impulse response than the presence of other influences as long as these are not too correlated with the precipitation. The reliability of the precipitation response can be assessed using spatial correlation with neighboring piezometers and the local hydrogeology.
Reliable impulse response functions can be used for interpolation and prediction of heads and for characterization of the hydrogeological settings.

CONCLUSION

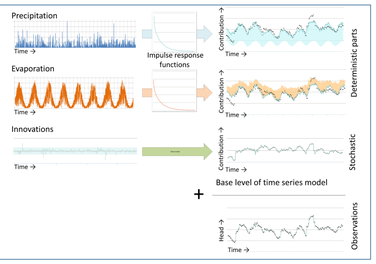
Stricter acceptance criteria for time series models select models with a better impulse response function for precipitation.

This does not guarantee a reliable precipitation response in time series models, especially with a large effect of an influence not included in the time series model as explanatory variable.

The spatial pattern of the response together with hydrologic boundary conditions with the geology provides useful information in judging the calculated precipitation response in the time series model.

BACKGROUND

TNO Geological Survey of the Netherlands makes available time series models of the piezometric heads in the national database DINO at:
https://www.grondwatertools.nl/grondwatertools-viewer
The models are transfer noise models with precipitation and reference evaporation as explanatory variables.
To answer the question "*How good is the modeled impulse response function?*", we evaluate the step response corresponding to the precipitation impulse response function which is determined in the time series model. The step response is denoted by M0 as it is the zeroth raw moment of the impulse response function.

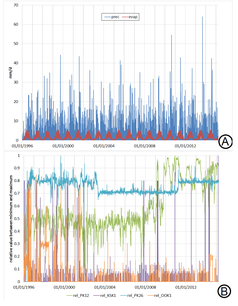


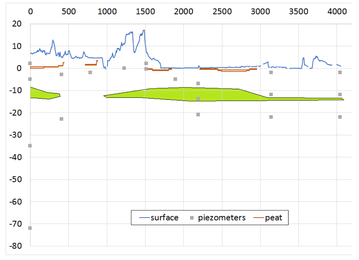
PILOT SITE

Row of piezometers running from dune area used for drinking water production toward polder area.

Drinking water production with extraction canals and extraction well series and managed aquifer recharge.

Piezometer row crosses two extraction canals (recorded water levels) and two series of extraction wells (recorded pumping)





Geology and hydrological boundary conditions

RESULTS WITH ONLY N AND E AS EXPLANATORY VARIABLES

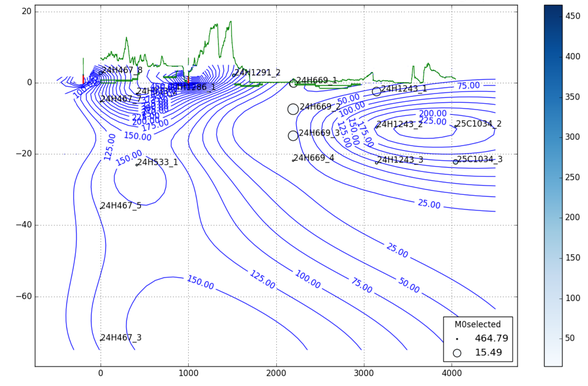
The standard approach of the groundwater tools website using only precipitation and evaporation as explanatory varyables results in the step responses M0 of the precipitation and evaluation scores (good - regimeok == 1; ok – modelok == 1; bad – modelok == 0) as given below:

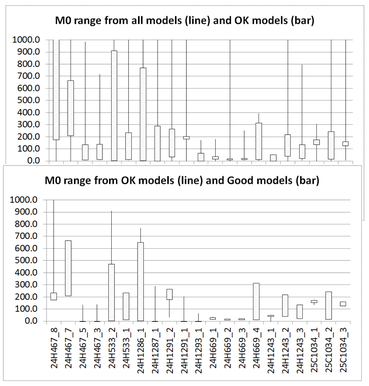
all2f	24H467_8	_7	_5	24H467_3	24H533_2	24H533_1	24H1286	24H1287	24H1291_2	24H1291_1	24H1293	24H669_1	_2	_3	24H669_4	24H1243_1	_2	24H1243_3	25C1034_1	_2	25C1034_3
M0prec	534.9	18.6	134.8	138.3	2.0	156.1	368.8	289.1	258.8	202.8	11.8	28.1	15.9	17.3	15.0	39.3	204.3	95.2	145.3	223.6	146.5
modok	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
regimeok	0	0	0	0	0	1	1	0	1	0	0	1	1	1	0	0	1	1	0	1	1

RESULTS IN TSA WITH MORE INPUT SERIES

For each of the 21 piezometers a large number of time series models have been created with one or more extraction time series as extra explanatory variables in addition to the precipitation and reference evapoporation. Models with one, two, and four extraction series. For each model the precipitation step response M0 and the model evaluation criteria modok ('OK' model) and regimeok ('good' model) have been determined.

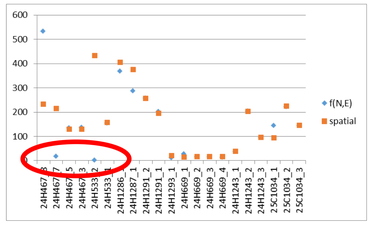
The values for M0 from the models with the good time series models (regimeok==1) have been plotted in the cross section and interpolated using MqTim (Zaadnoordijk & Bakker, 2017). Not all piezometers are present in the graph because several piezometers did not have any model with regimeok==1.





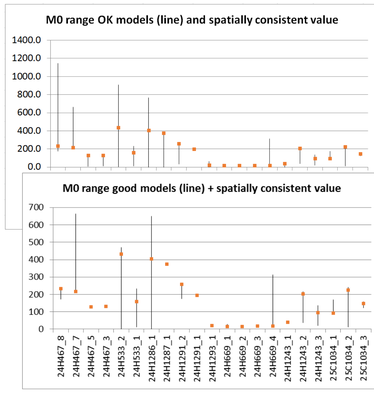
DISCUSSION

The precipitation response determined for time series models with only precipitation and evaporation gives very unlikely results for some of the pilot piezometers.



Creating models with more explanatory variables gave large ranges for the step response. The model selection criteria for 'OK' and 'good' models narrowed these ranges while enclosing values from a spatial interpolation between the most likely 'good' models.

The resulting pattern of the M0 values from the MqTim interpolation is consistent with the geology and the hydrological boundary conditions, so it was considered suitable as a check for the M0 values from the time series models.



100 YEARS OF GEOLOGICAL MAPPING

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