Sustainable operation of a BHE field in a vocational school considering groundwater flow and land cover change

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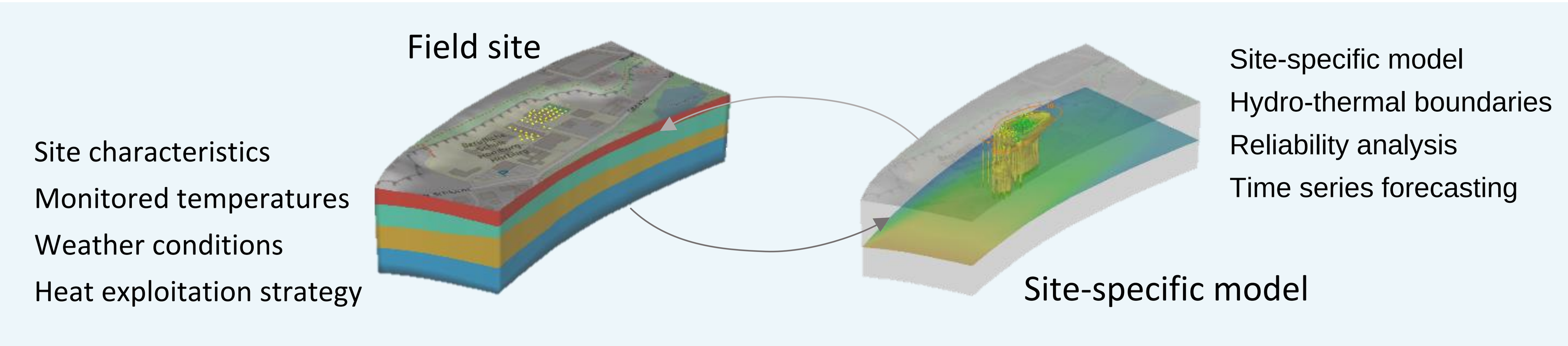
Introduction

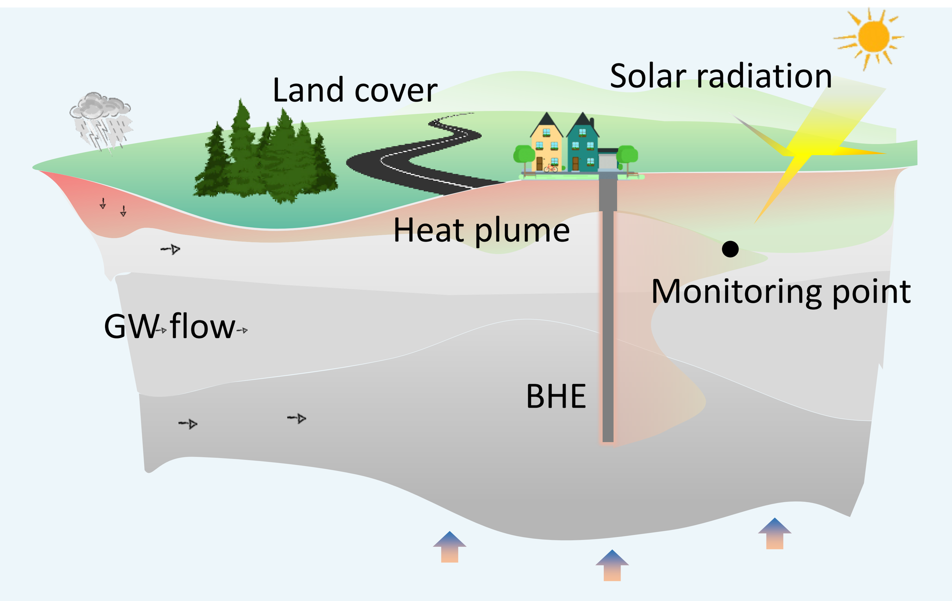
Shallow geothermal energy has been popularly used for house heating and cooling by combining borehole heat exchangers (BHEs) with a heat pump. In recent years, the issue of how to maintain the efficiency and sustainability of BHE systems has received increasing attention. An effective way to address this issue is to develop site-specific models that can provide accurate predictions of system performance. This site-specific forecasting model needs to meet some basic requirements, which allow

- to adequately account for important site characteristics that affect the performance of the BHE system
- to be able to calibrate and optimize the model based on field measurements
- to provide reliable model predictions and robustness



Methods

- A novel model was developed that is able to take into account all of the important factors. In addition to the geothermal gradient and ground heat conductivity, factors that have significant impacts on the heat production of a BHE system include groundwater flow velocity, heat flux on the ground surface, and subsurface heterogeneity [1].
- The developed model integrates site-specific geologic and hydrogeologic conditions, land cover changes, and solar radiation. This is because the monitored ground temperatures include not only the effects of BHE operation, but also thermal convection due to groundwater flow. Surface heat transfer and land cover changes can also have a significant impact on ground temperatures at shallow depths [2-3].
- Model calibration and validation was performed based on field measurements, including groundwater temperatures measured at multiple depths in monitoring wells.



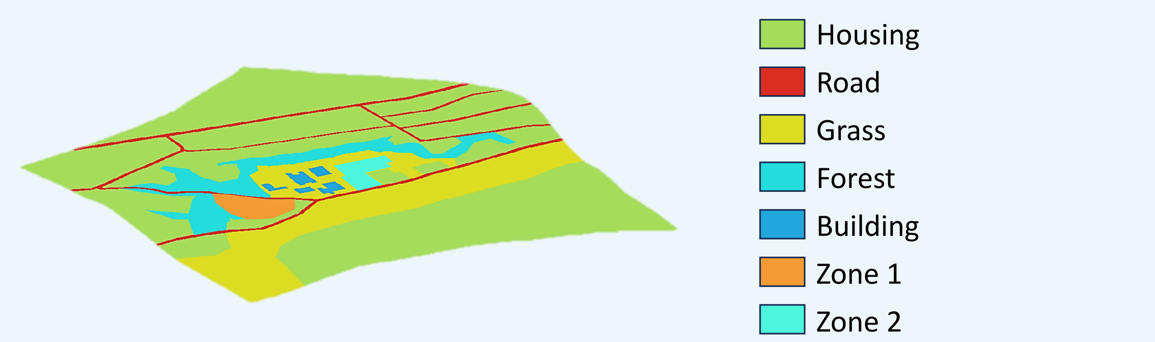
Case study

A BHE site located at a vocational school in Hamburg was selected for the case study. A total of 47 BHEs were installed at this site and have been in operation since 2015. Heat regeneration from solar radiation and air conditioning was considered at this site. In order to optimize the heat exploitation strategy and maintain the efficiency of this BHE system, a site-specific model was developed based on available site characteristics and information on land use change.

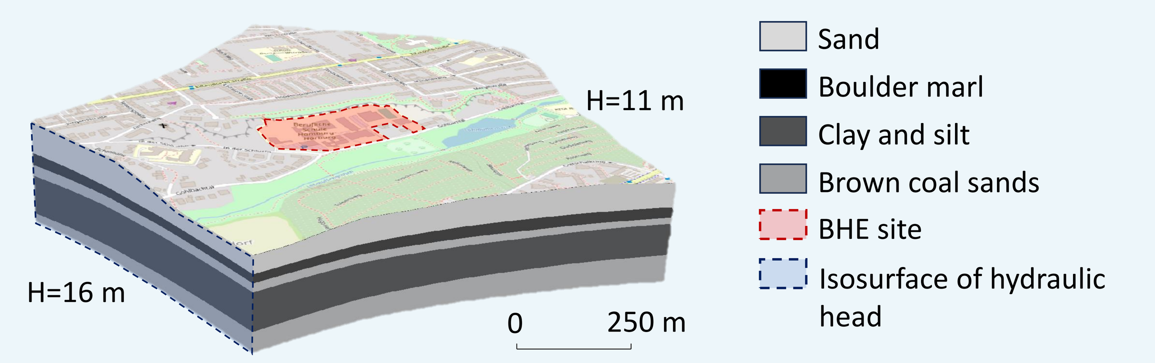
- Land cover change

(Satellite imagery from Google Earth)

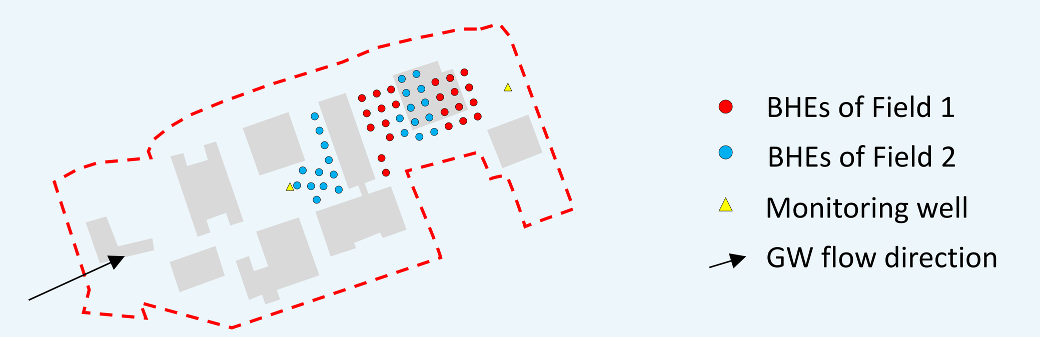
- Land use classification



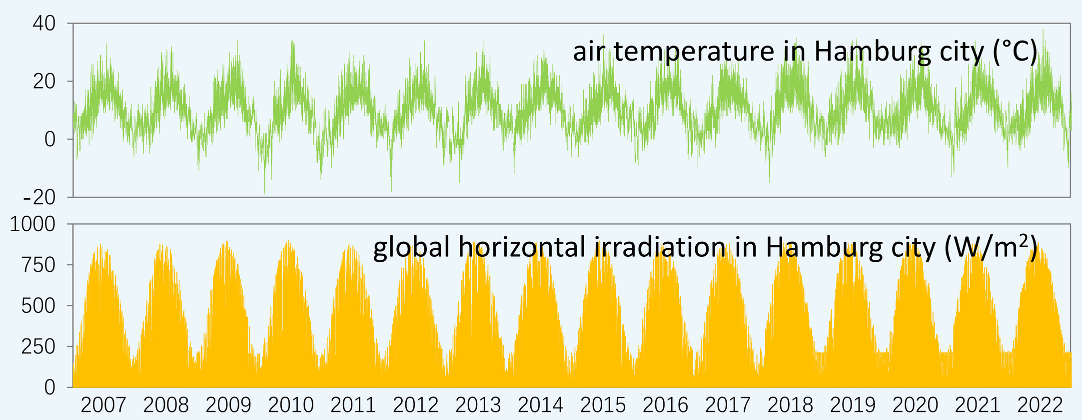
- Geologic and hydrogeologic conditions



- Arrangement of BHEs and monitoring wells



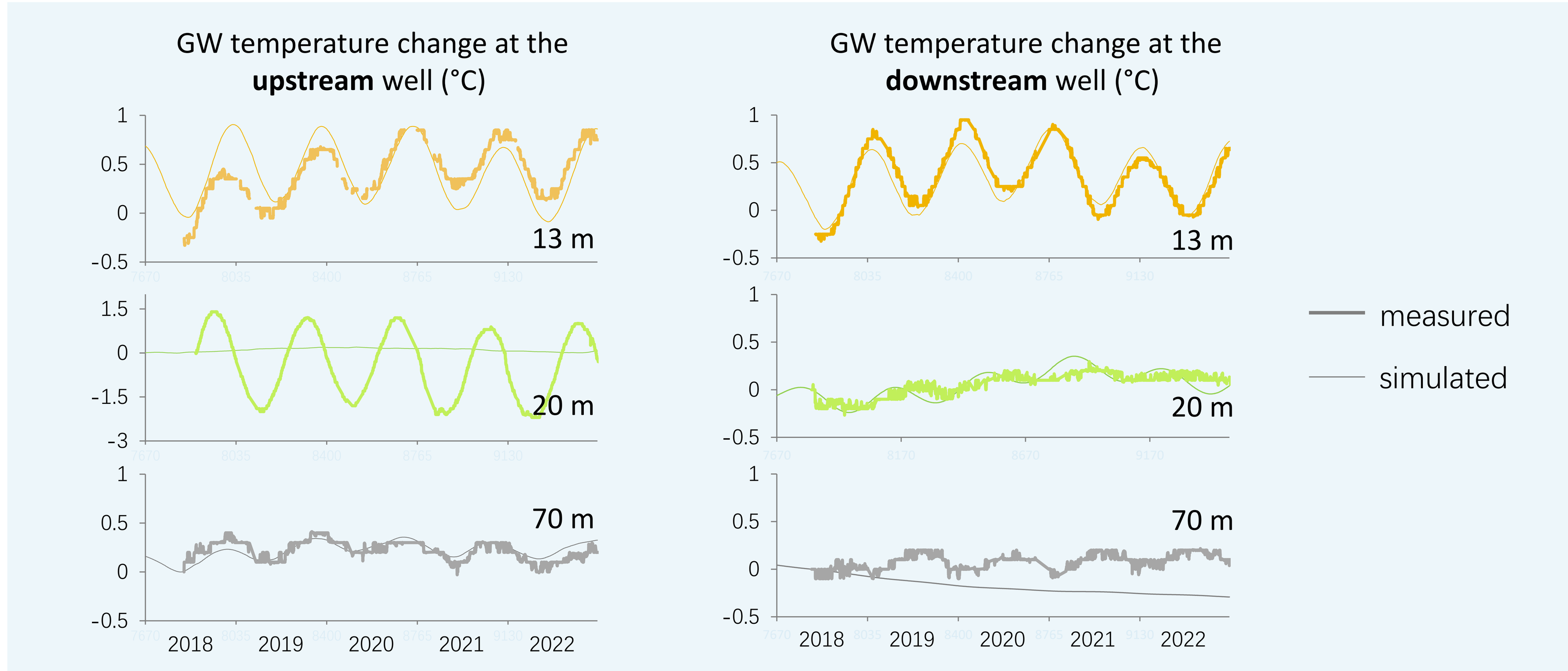
- Historical weather data



(Data from http://solcast.com)

Results

- Model calibration based on the measured temperatures in monitoring wells



- Forecasting the SCOP (seasonal coefficient of performance) of heat pumps for the next 5 years, when repeating the heating strategy of 2018 and 2021

Conclusion

- A novel model was developed for the Hamburg BHE site, which can consider subsurface heterogeneity, groundwater flow, complex surface heat transfer, and land cover change.
- Simulation results were in good agreement with the measured groundwater temperatures in monitoring wells.
- The SCOP of the BHE system was predicted for the coming five years using the calibrated model.

The developed model can be further used for sustainability assessment of the BHE system performance at the Hamburg site and for optimization of the heat exploitation strategy when considering heat regeneration.

Reference

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