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Use of MODFLOW as an interpolation method

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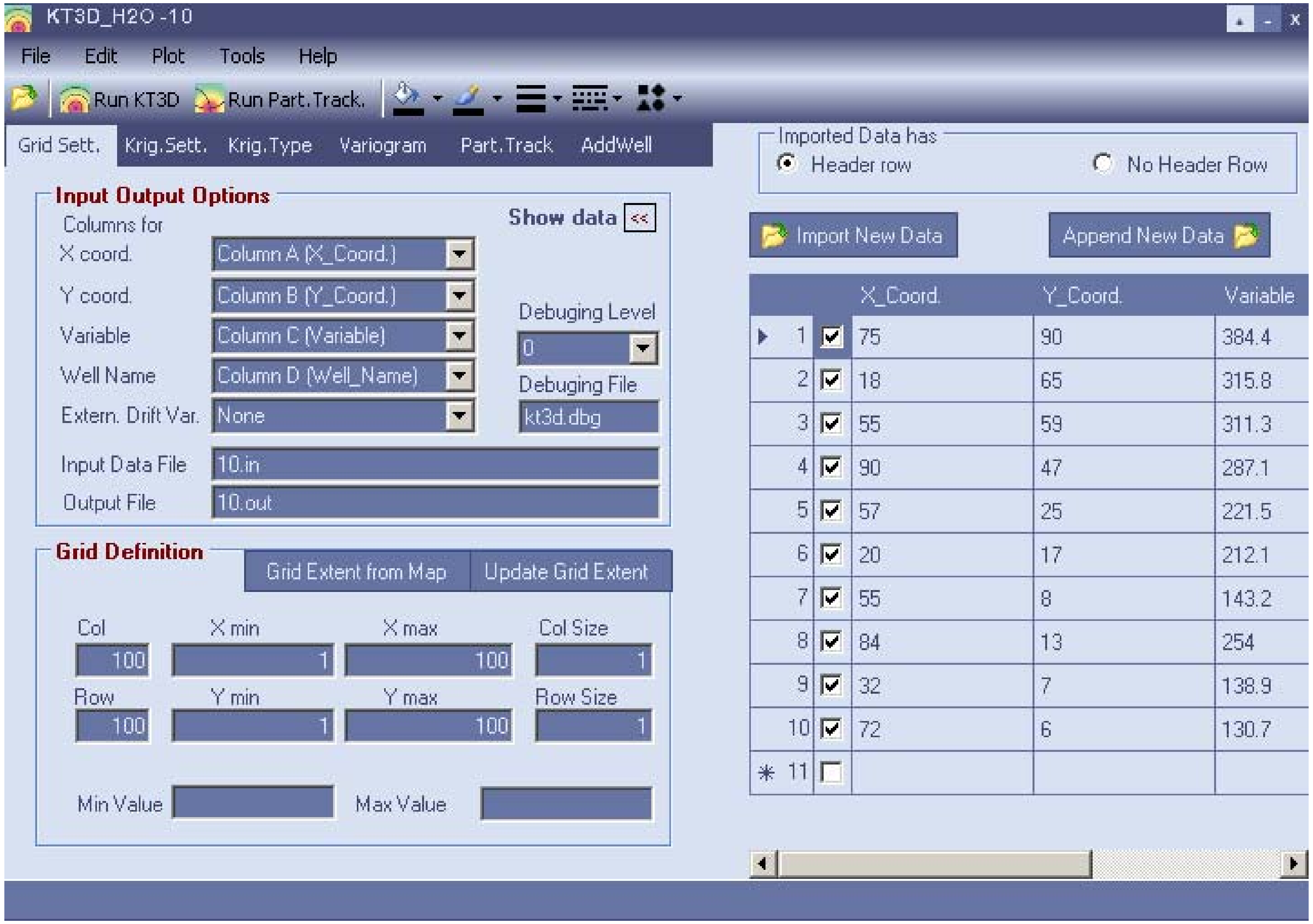
1. Introduction

Kriging is the most common method used for interpolations in groundwater applications. This pure statistical approach has the disadvantage that it does not guarantee that the values of the interpolated hydraulic heads are consistent with the groundwater flow physics (Rivest et al., 2008). This weakness is mitigated in the Universal Kriging (UK) method with the use of the so-called drifts. In this study a method based on the use of MODFLOW is proposed as an alternative to the UK method. The two methods are tested on a synthetic aquifer with steady state stresses. Two hypothetical observation networks, with 68 and 10 measurement points, provide the required data for the interpolations.

2. Method 1: Universal Kriging (UK)

For the interpolations based on UK the MapWindow plugin KT3D_H2O (SSP&A, 2008) is used. KT3D_H2O interpolates the water level data using the technique of the hydrological drift terms (Tonkin and Larson, 2002).

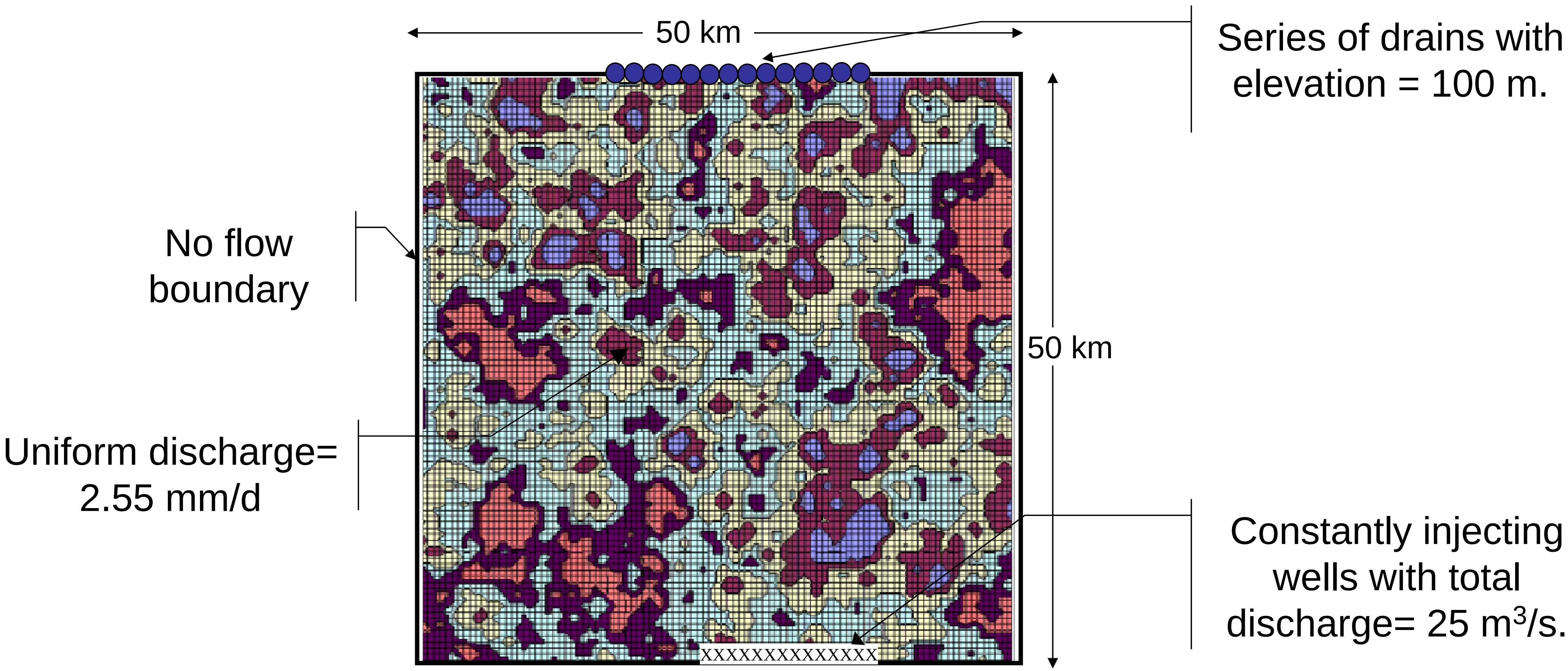


3. Method 2: MODFLOW

The idea explored is to use MODFLOW as an interpolation method to simulate the aquifer without the requirement to represent accurately the water budget. Instead, the MODFLOW parameters and stresses are calibrated to minimize the residuals between the simulated and observed hydraulic heads. Consequently, the estimated parameters do not have a specific physical meaning (i.e. this is not an inverse modelling type of application) but are rather considered as the parameters of the MODFLOW-driven interpolation.

4. Synthetic aquifer

The synthetic values of conductivity are produced by a stochastic model that is an extension in two dimensions of the Symmetric Moving Average algorithmic scheme (Koutsoyiannis, 2000; Theodoratos, 2004), which is appropriate to simulate fields with long-range dependence (Hurst effect).

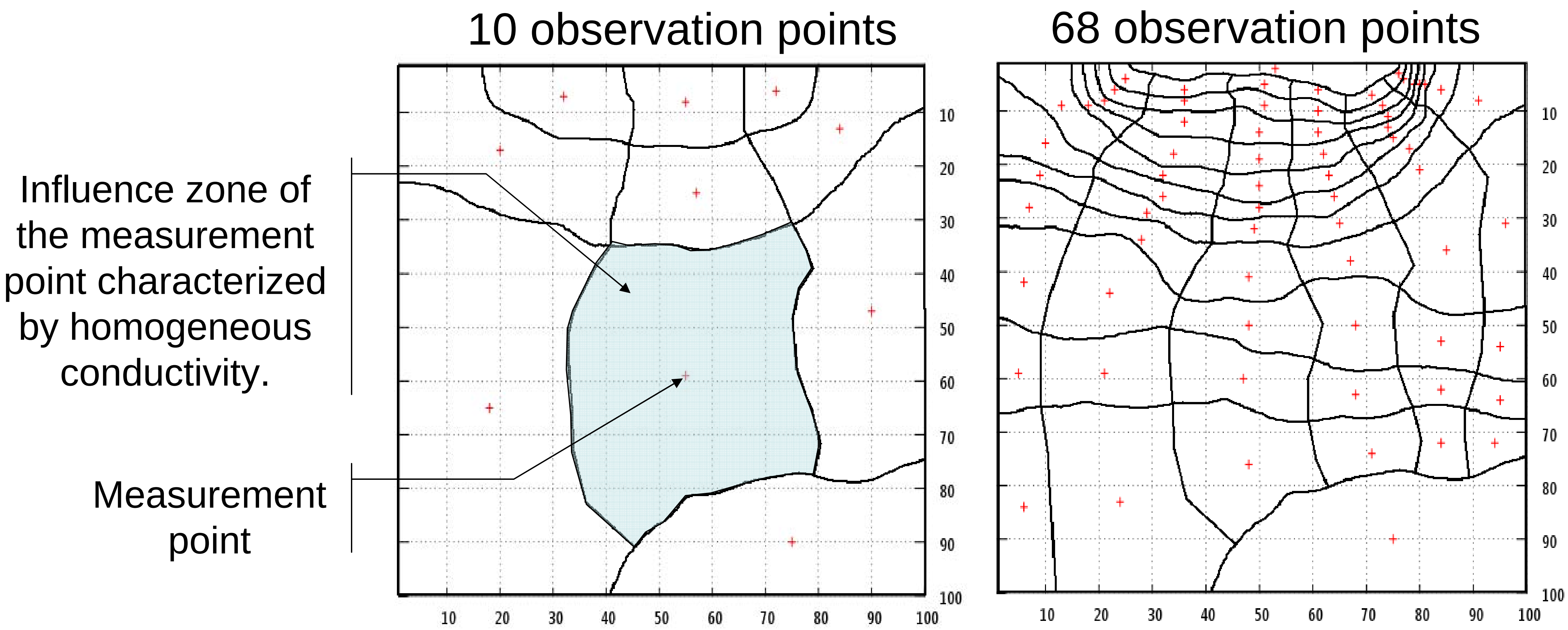


5. Observations – reference equipotentials

The steady state synthetic aquifer is simulated with MODFLOW. Hydraulic heads are recorded using two hypothetical observation networks, one with 10 and another with 68 measurement points. These observations are used as input data in the examined interpolation methods. The reference map of equipotential lines is also derived from this simulation. This map is used for accessing the efficiencies of the two interpolation methods.

6. MODFLOW: Influence zones

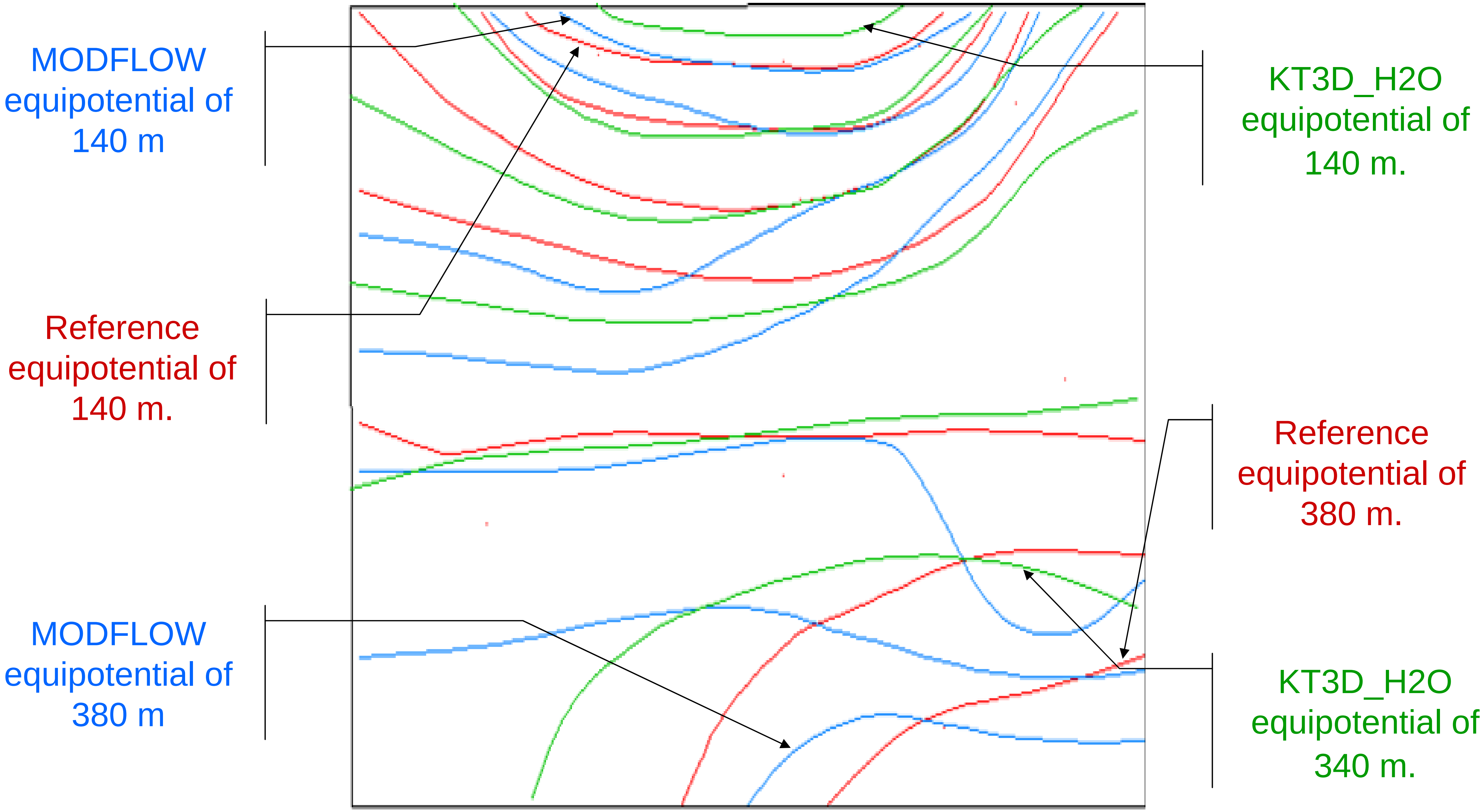
- The first step for interpolating with MODFLOW is to define the influence zone for each measurement point. These zones are considered to be homogeneous areas. The shape of these zones should be based on the equipotential lines therefore a prior estimation of them is required.



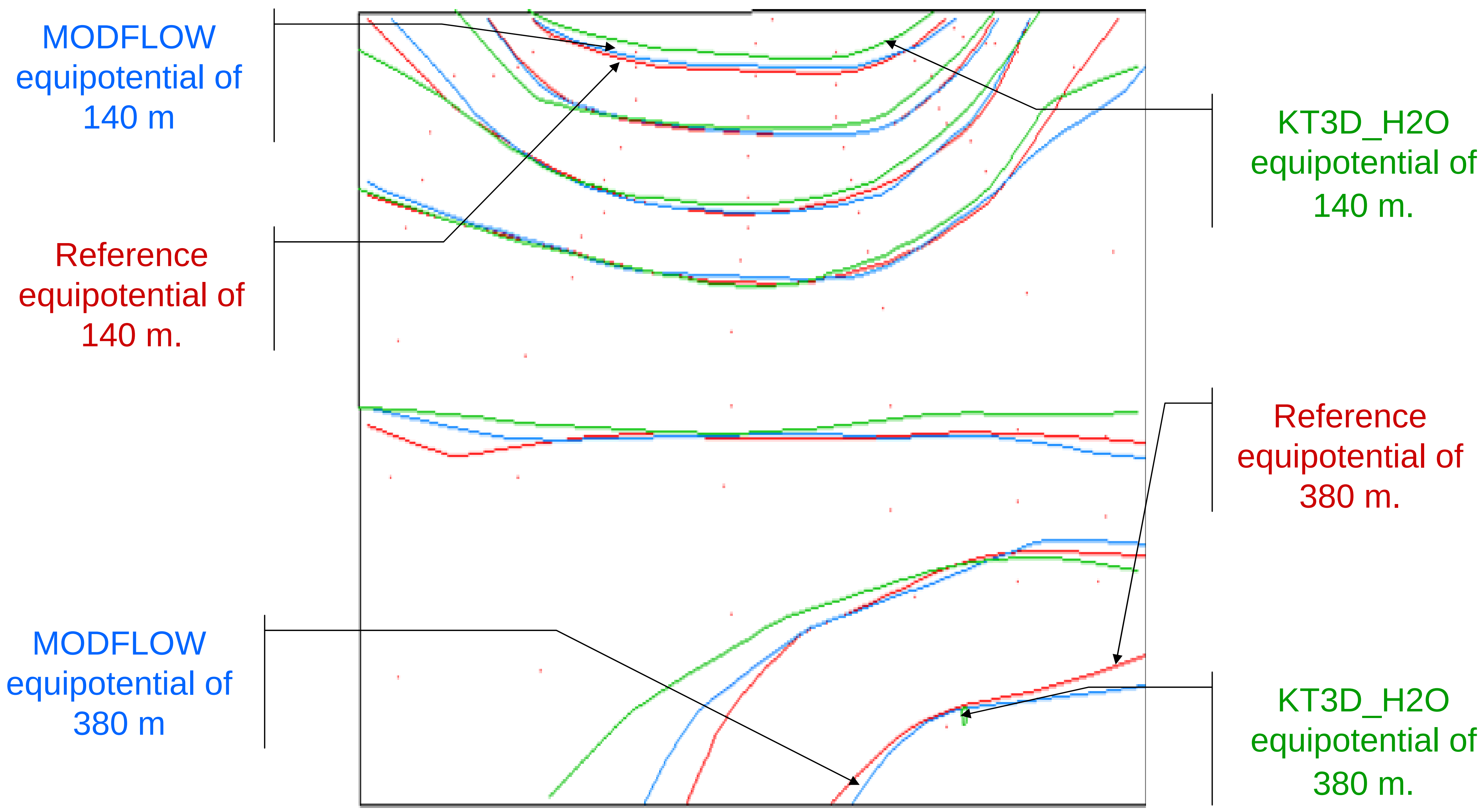
7. MODFLOW: Parameter optimization

The influence zones actually constitute a zone-based parameterization of the aquifer. At each zone a conductivity parameter is assigned. This type of parameterization, based on equipotential lines, introduces to the optimization procedure indirect information about the aquifer properties. One more parameter is used for the constant uniform recharge on the aquifer. The boundary conditions are identical with those of the synthetic aquifer except the injecting wells (these wells correspond to a type of recharge which typically is not directly measurable, like infiltration from mountainous areas, and hence unknown during the interpolation). The PEST algorithm (SSP&A, 2005) is used for the optimization of the parameters.

8. Results: 10 observation points



9. Results: 68 observation points



10. Methods comparison

	MODFLOW & PEST	KT3D_H2O
Speed	LOW	HIGH
Simplicity	LOW	HIGH
Reliability (limited measurements)	LOW	MEDIUM
Reliability (measurements abundance)	HIGH	HIGH

11. Conclusions

- KT3D_H2O performed satisfactory even with limited number of measurements.
- The use of MODFLOW as interpolation method has fallen short despite the indirect information introduced by the parameterization method. This interpolation method has also the disadvantage of requiring considerable preparative work.
- However MODFLOW can be used to achieve a better interpolation accuracy in cases where a dense network of measurement points is available, along with prior information about the functioning of the aquifer.
- Otherwise, we do not recommend the method we have tried!

12. References

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