Quinto Congreso Nacional de Riego y Drenaje
COMEII-AURPAES 2019
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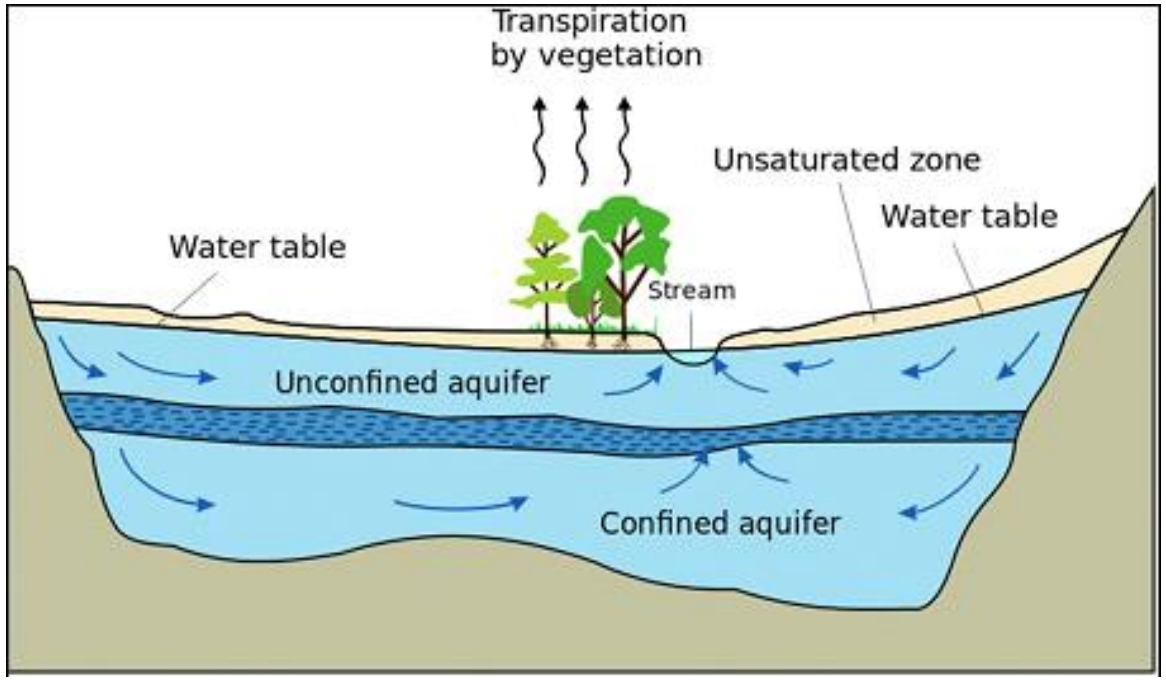
Identification of Groundwater Basin Shape and Boundary using Hydraulic Tomography

KWANKWAI DARANOND AND TIAN-CHYI JIM YEH

Outline

- Introduction
- Materials and Methods
- Results and Discussions
- Conclusion

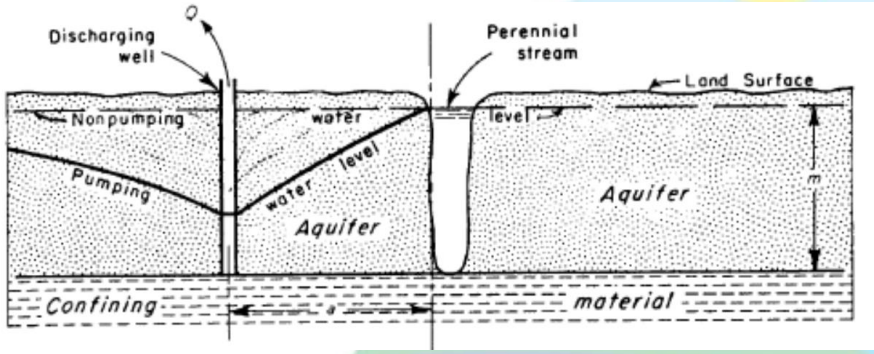
Groundwater basin and boundary



Desert Research Institute - https://www.dri.edu/theoretical-analysis-of-optimal-groundwater-basin-development

Constant head boundary

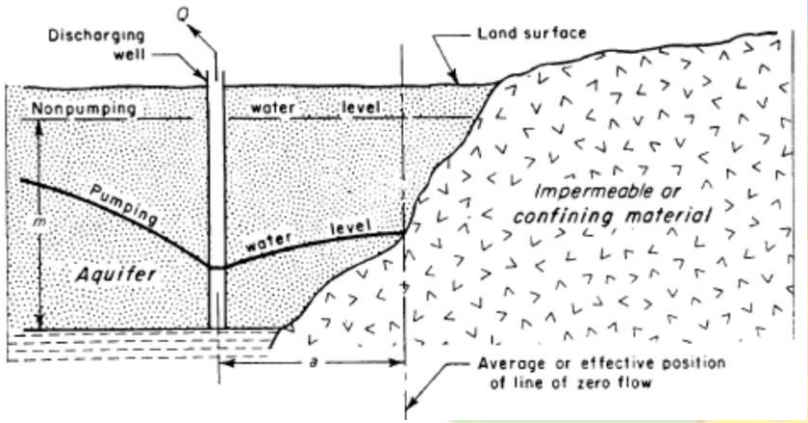
(Ferris et al. 1962)



Lake, River

Flux boundary

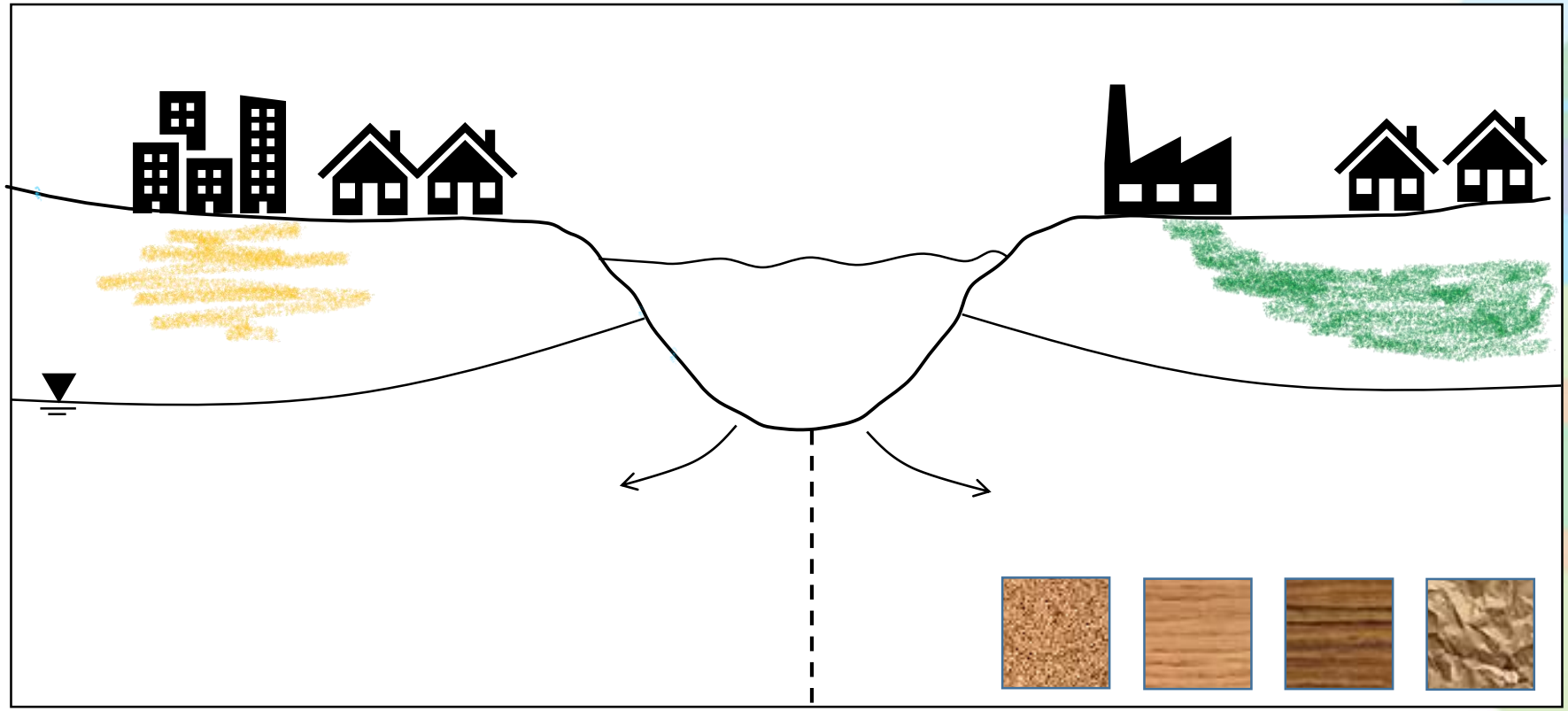
(Ferris et al. 1962)



Infiltration, impermeable material

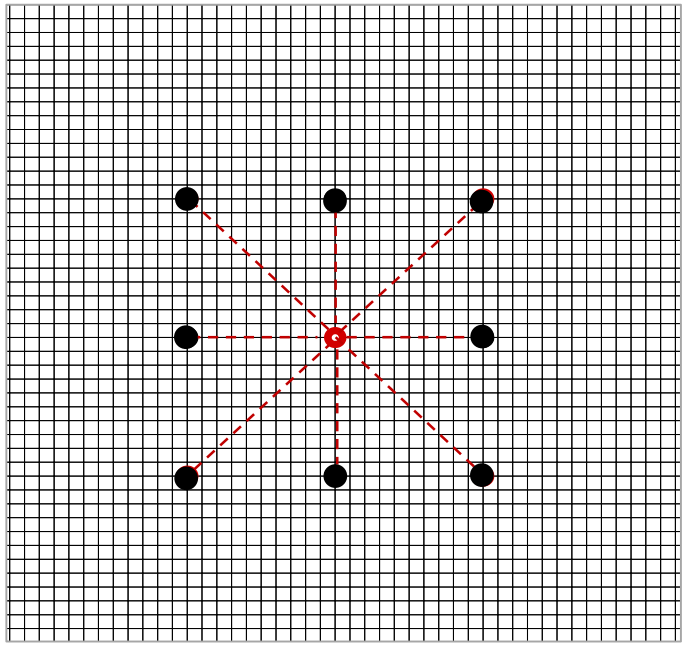
Groundwater basin and boundary

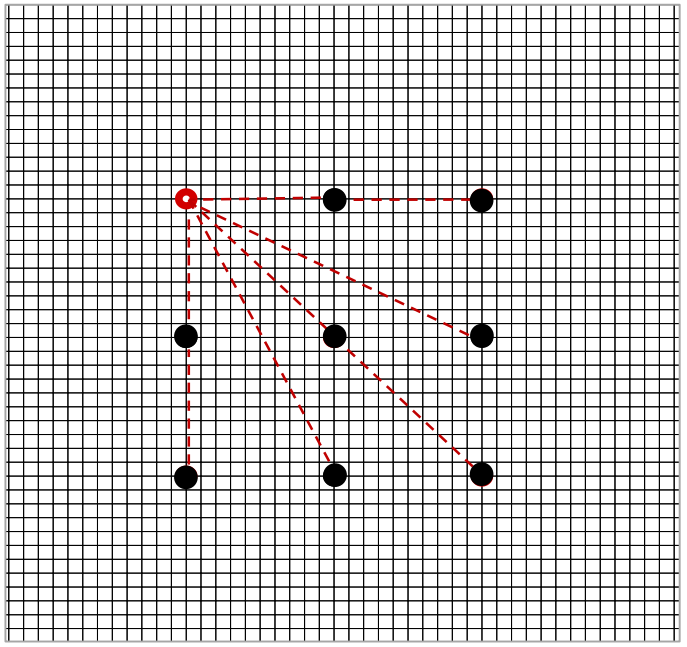
- The importance of identification of basin boundary and heterogeneity

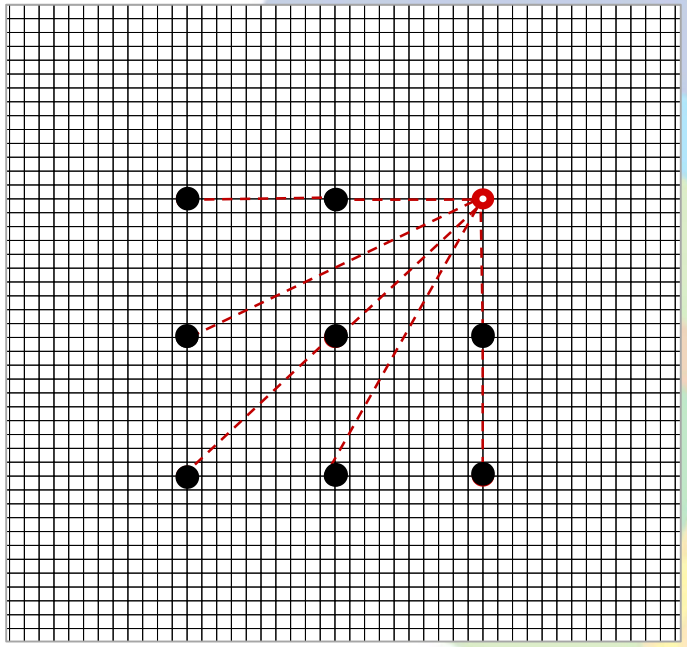


Hydraulic Tomography

- More details of aquifer with limited number of wells
- Contain more information from different views of aquifer

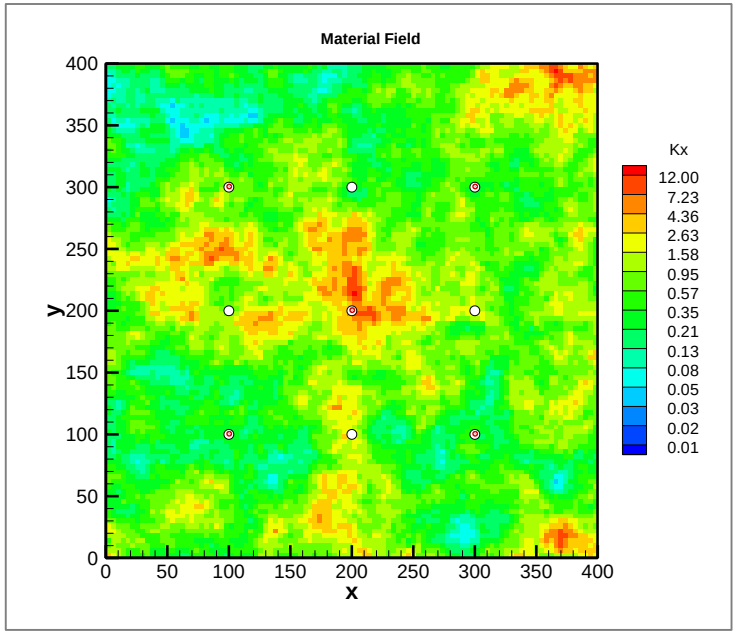




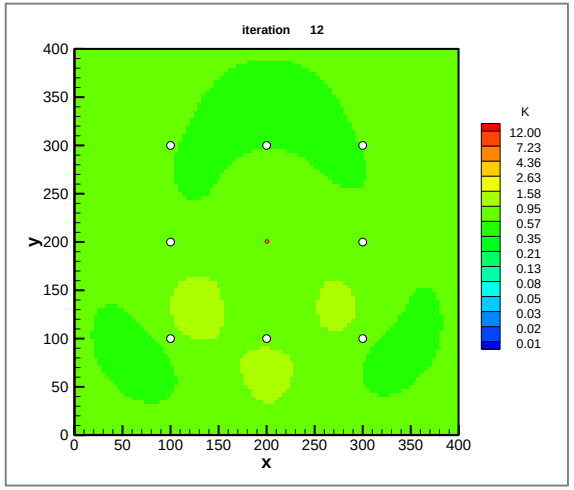


Hydraulic Tomography

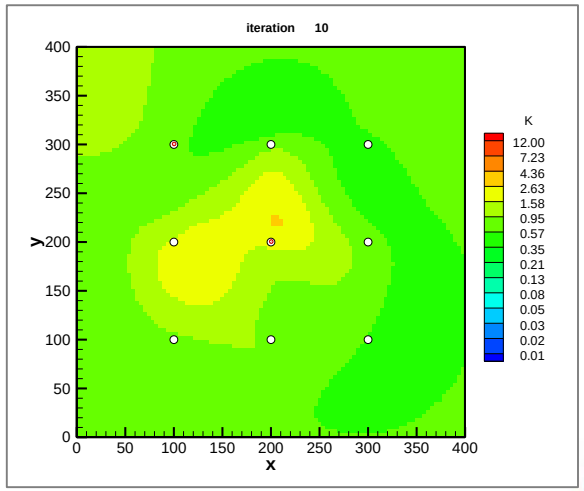
True material



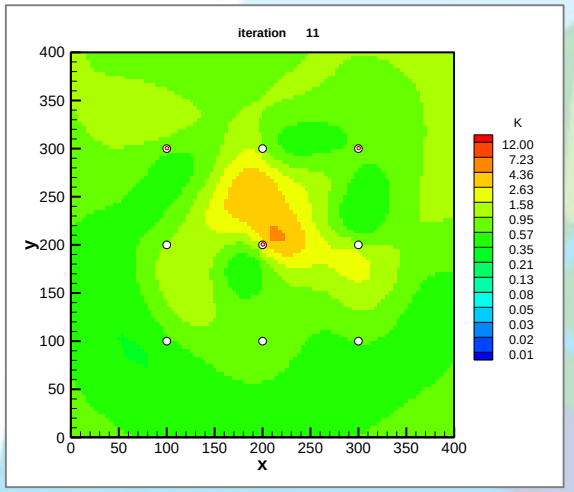
1 Pumping test



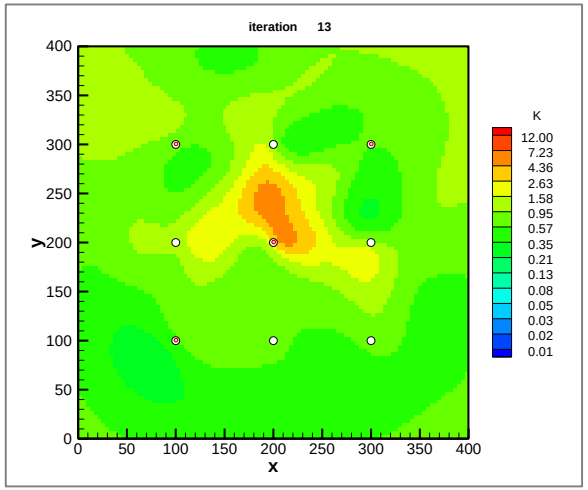
2 Pumping tests



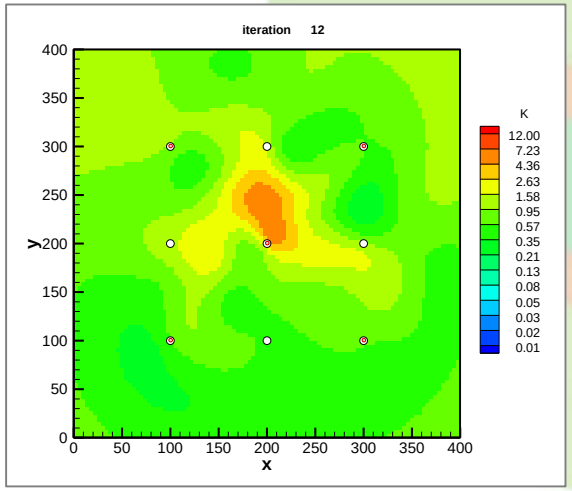
3 Pumping tests



4 Pumping tests



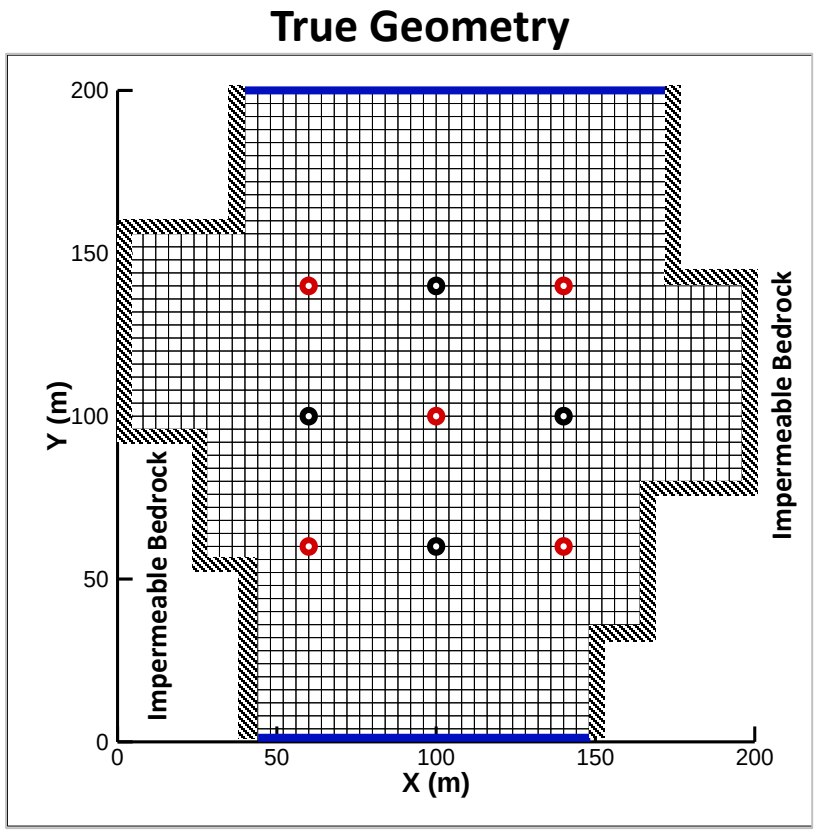
5 Pumping tests

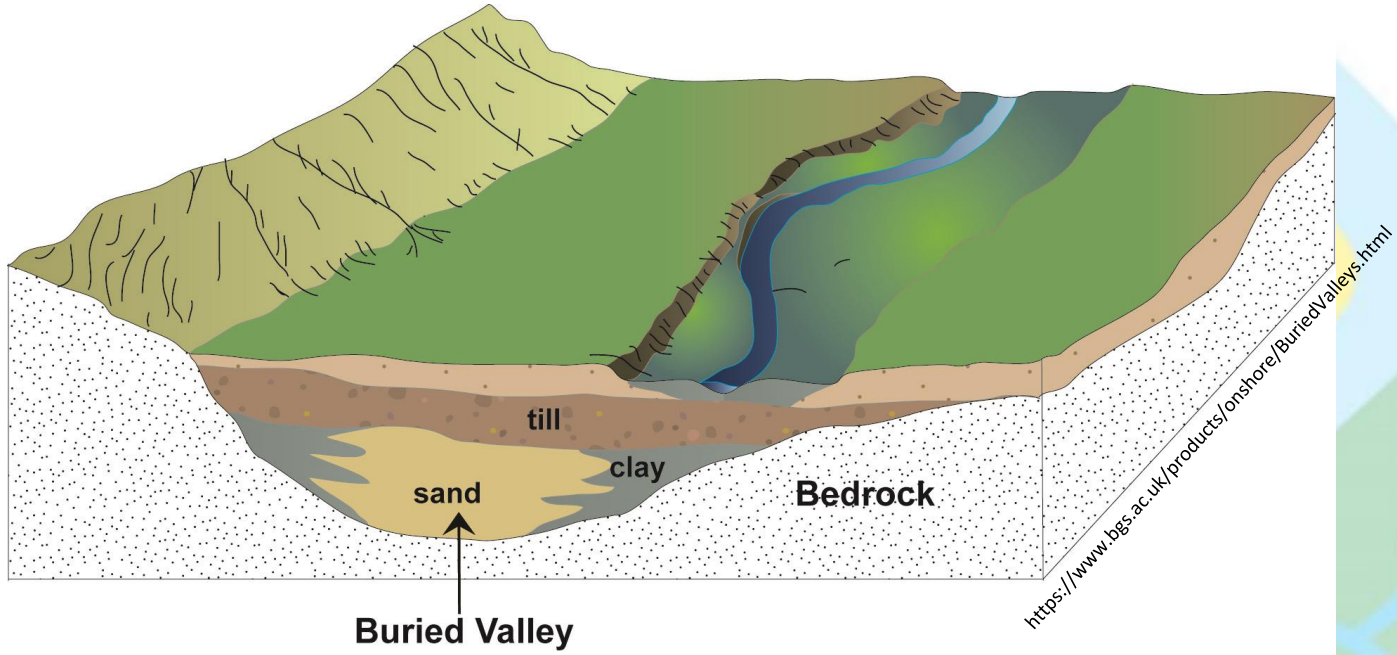


Questions

1. Identification of the true geometry and boundary with incorrect geometry and boundary model.
2. The effect of unknown geometry on the estimates inside the domain.
3. Role of the prior information to the improvement of parameter estimation.

Scenario

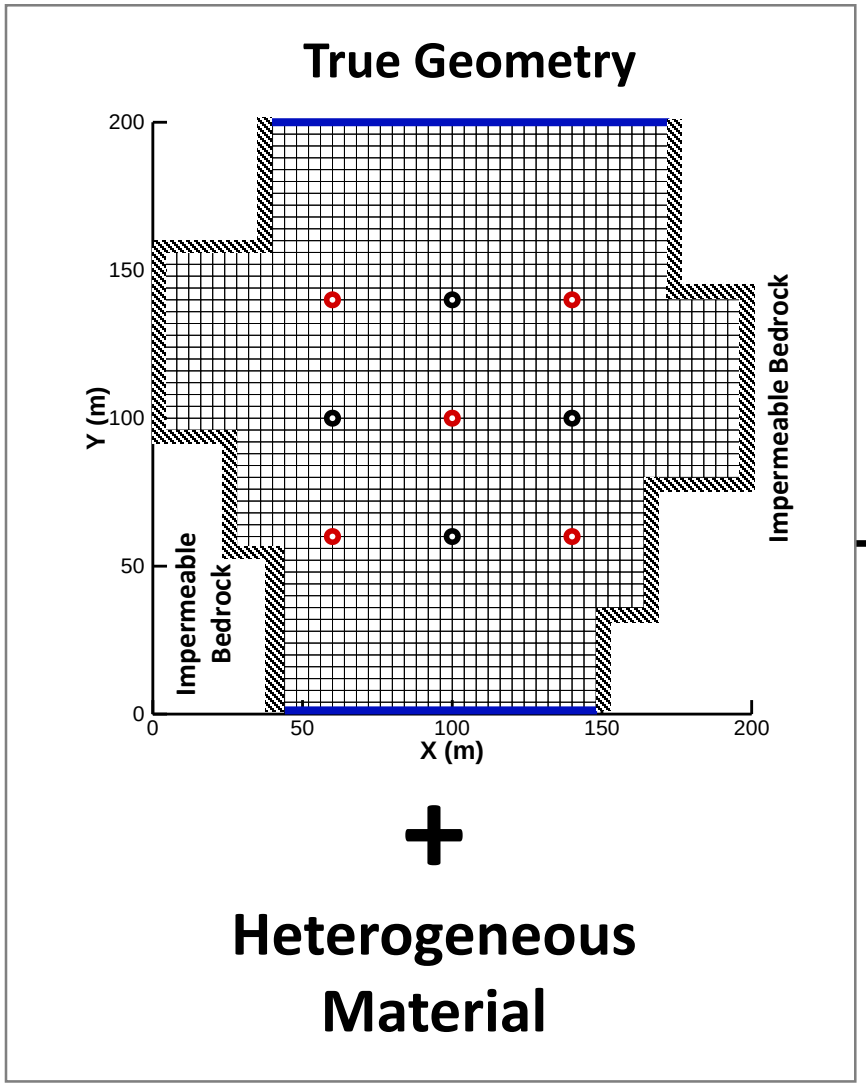




- 5 pumping tests, 8 observation wells
  - **Grid spacing**: 4 m
  - **Mean lnT**: -1.498 m2/d **var lnT**: 1.61
  - **Mean lnS**: -7.457 **var lnS**: 1.10
  - **Correlation scale**: 50 in x and y

Q1: Identification of basin geometry using HT

Q1: Identification of basin geometry

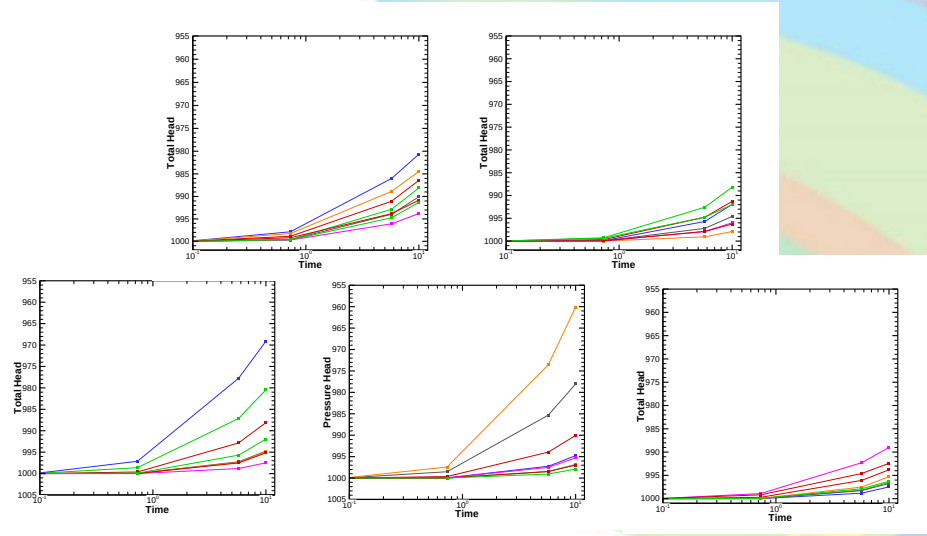


Forward Model

Drawdown Data

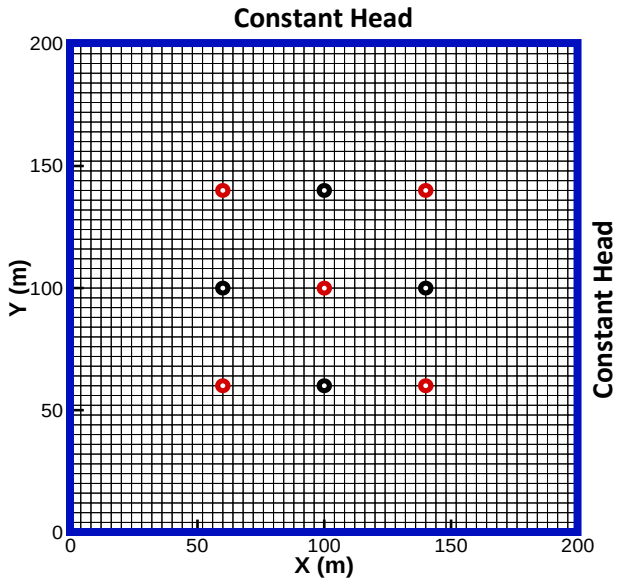
Steady State

Transient State



Q1: Identification of basin geometry

Incorrect Geometry Model



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Drawdown Data

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Uniform Initial Guess

Inverse Model

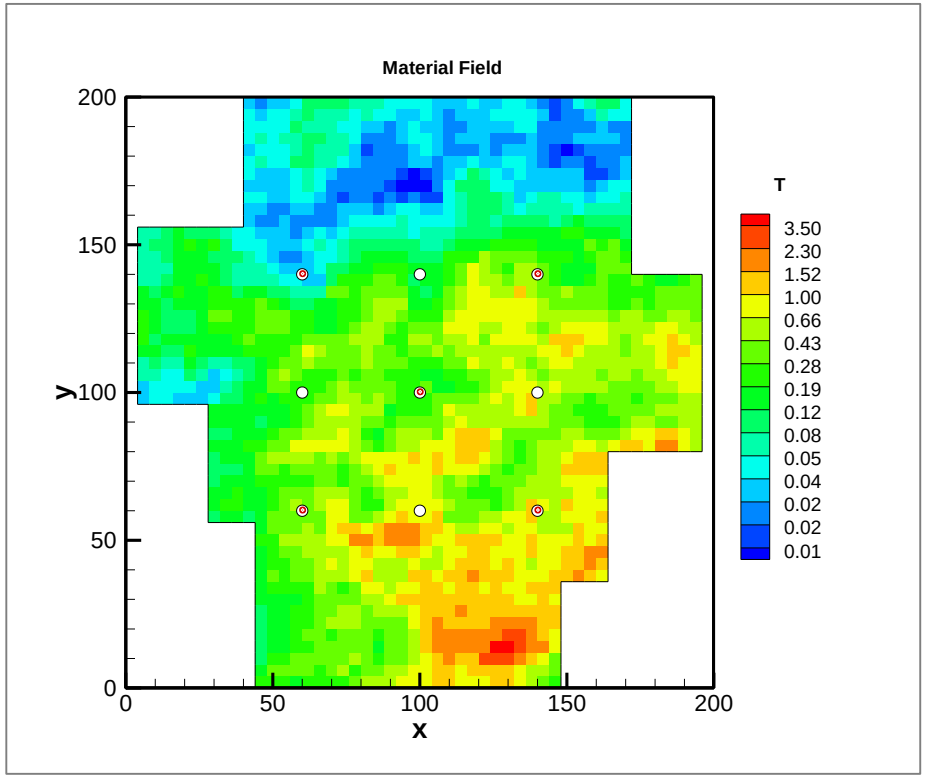
Steady State Estimation

Transient State Estimation

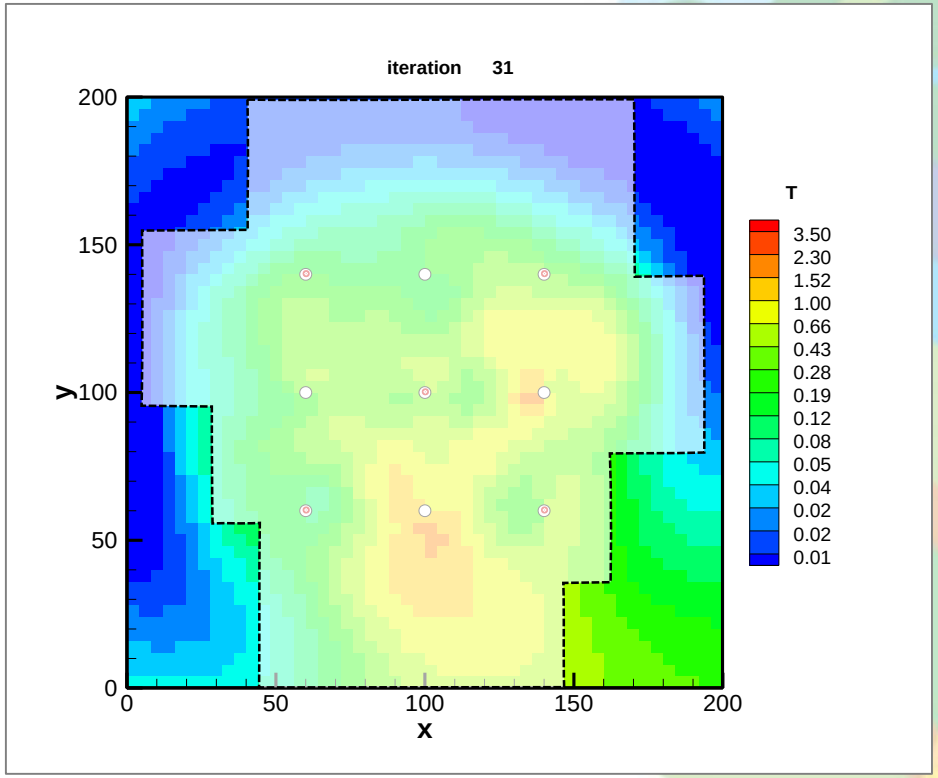
Q1: Identification of basin geometry

Estimated transmissivity (T): Steady State

True Material



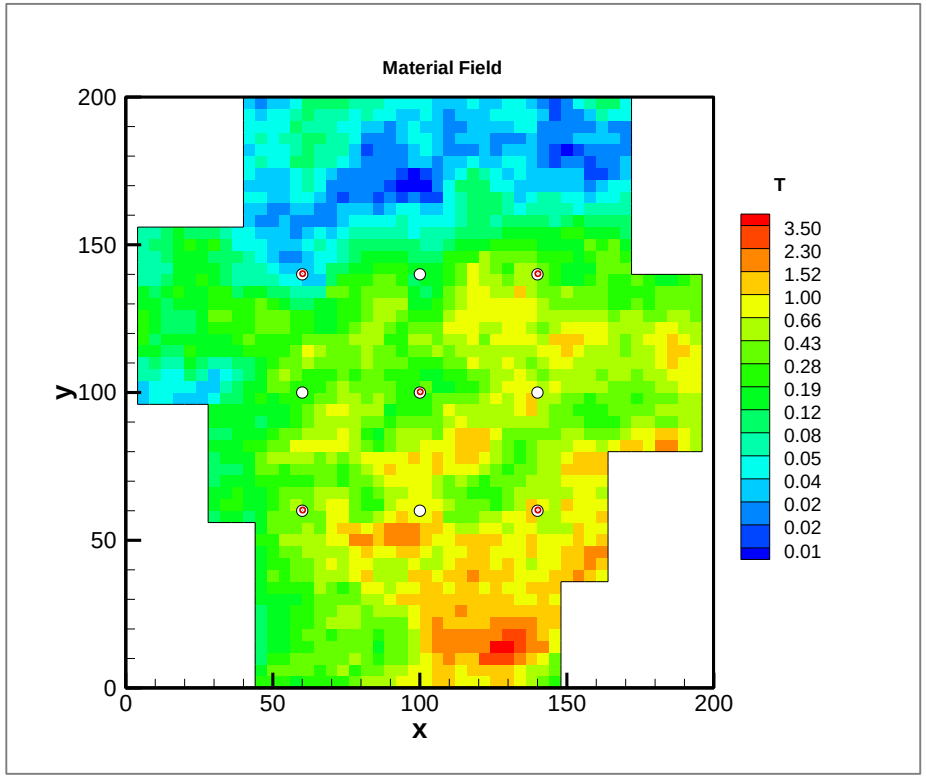
Incorrect Geometry and Boundary Model



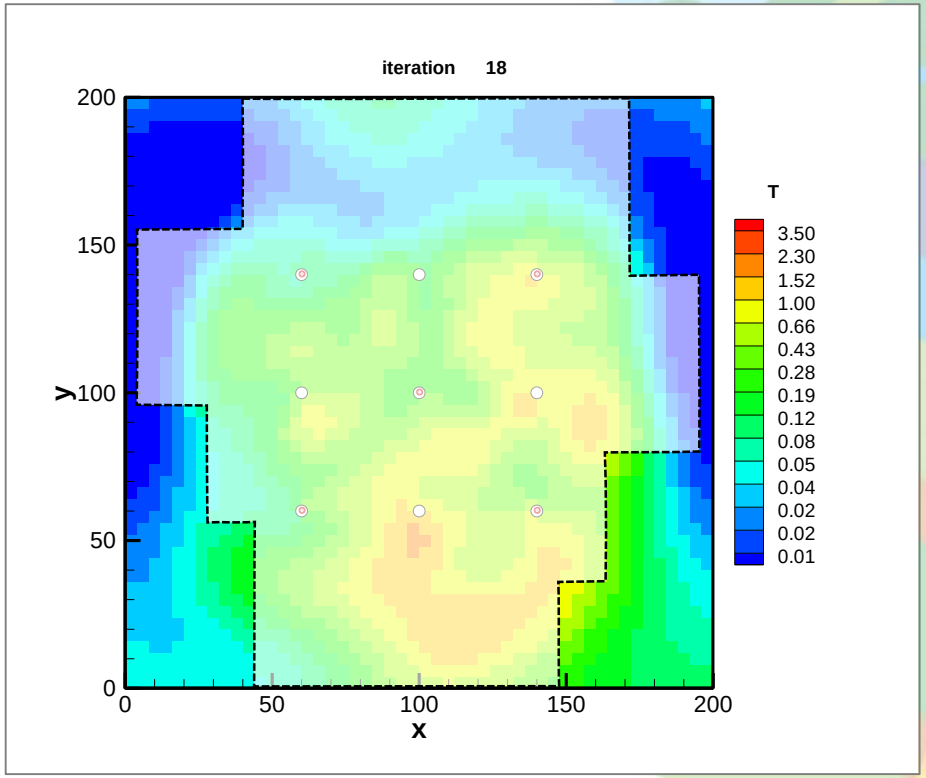
Q1: Identification of basin geometry

Estimated transmissivity (T): Transient State

True Material

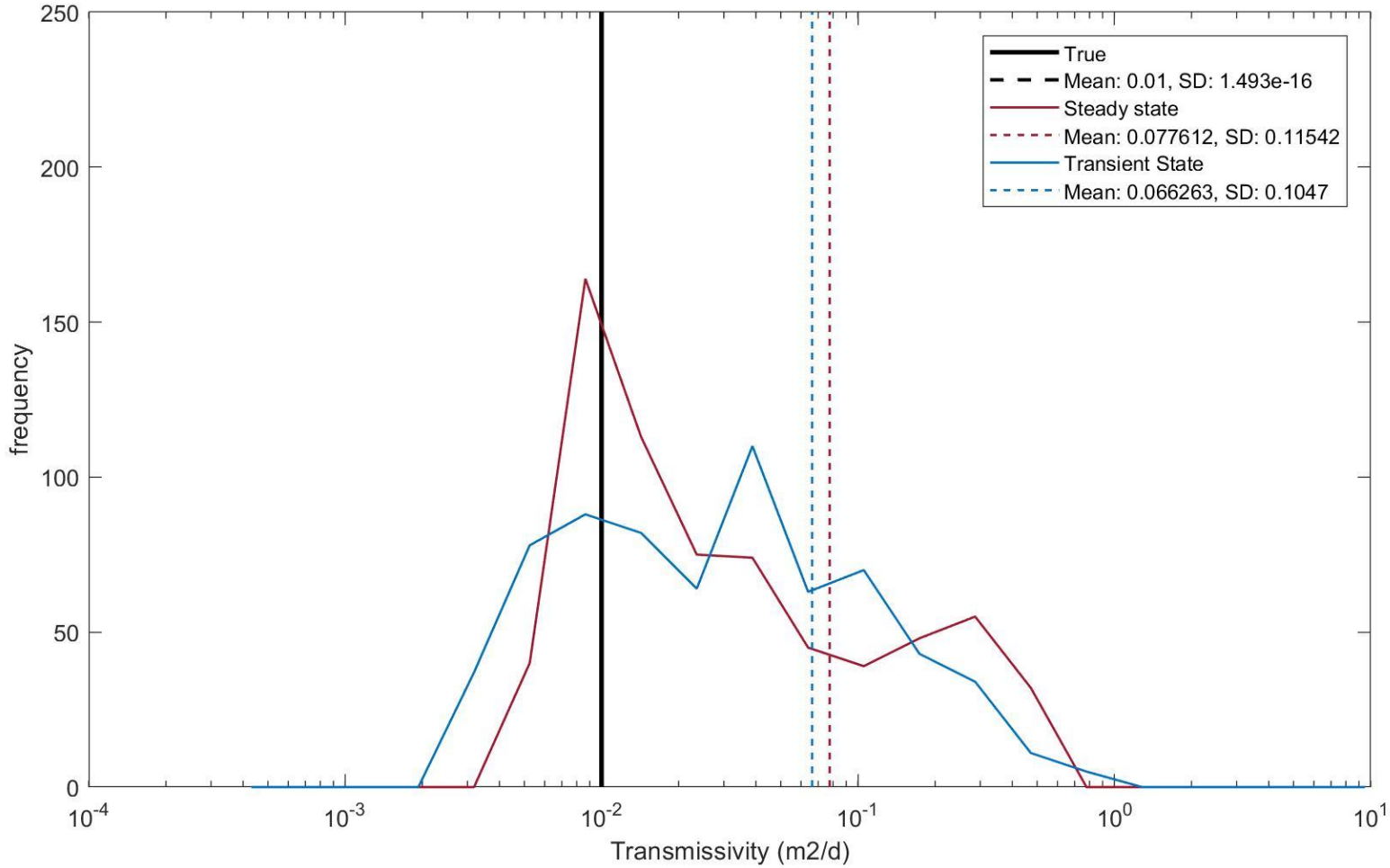


Incorrect Geometry and Boundary Model



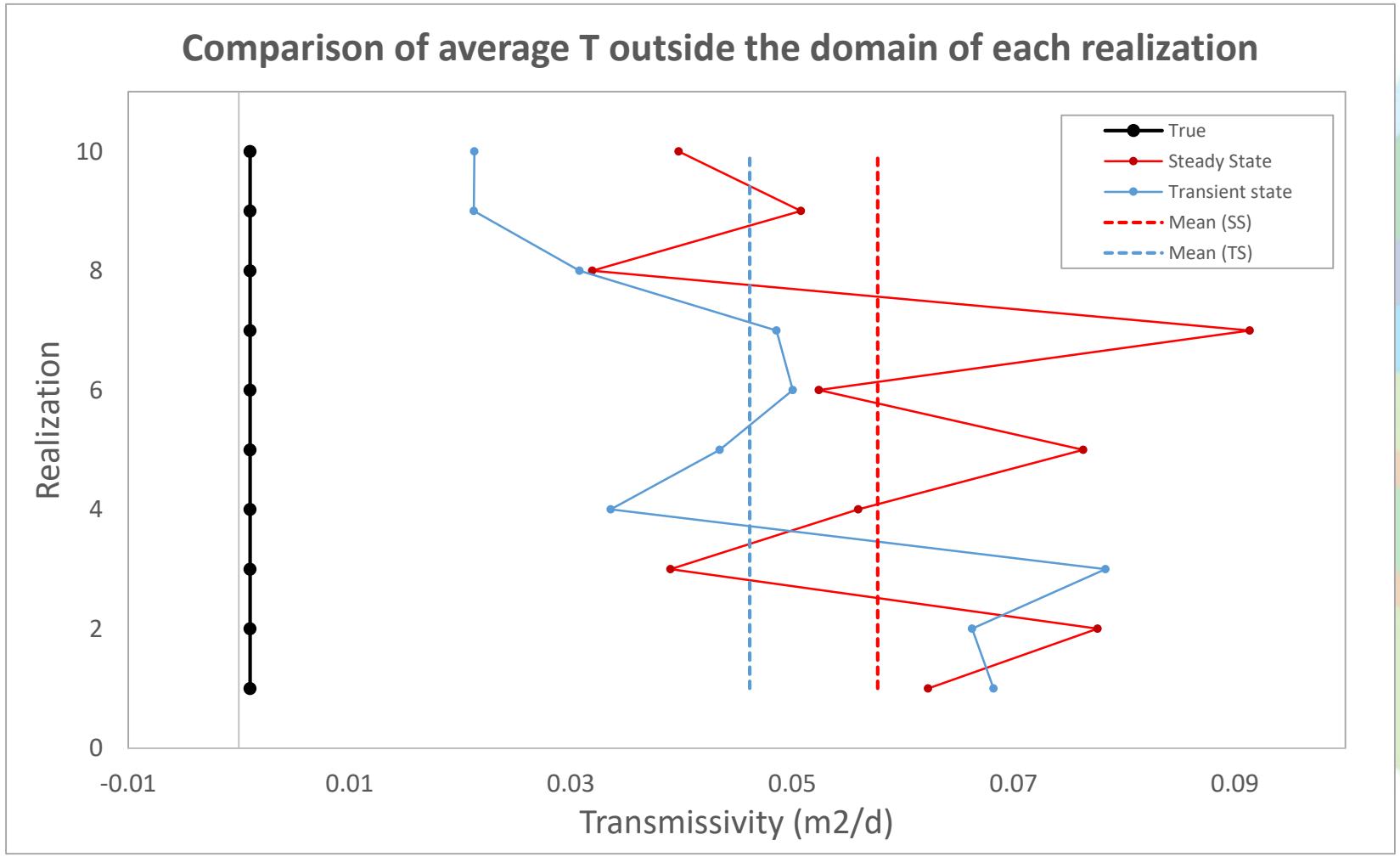
Q1: Identification of basin geometry

Histogram of estimated T outside the true domain



Q1: Identification of basin geometry

Average estimated T outside the true domain of 10 realizations



Q1: Identification of basin geometry

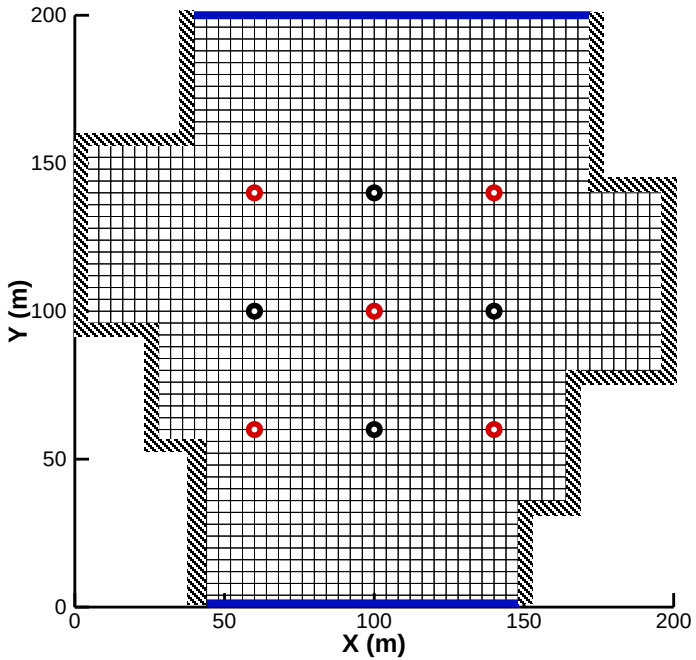
Q1 Conclusion

- Both steady and transient state estimation can delineate the impermeable material zones by representing them as low T values.
- The estimation using transient state results in the better approximation of the low permeable medium outside the domain; mean value is much closer to the true mean than using steady state.

Q2: Effects of unknown basin geometry on the estimates inside the domain

Q2: Effects of unknown basin geometry

True Geometry



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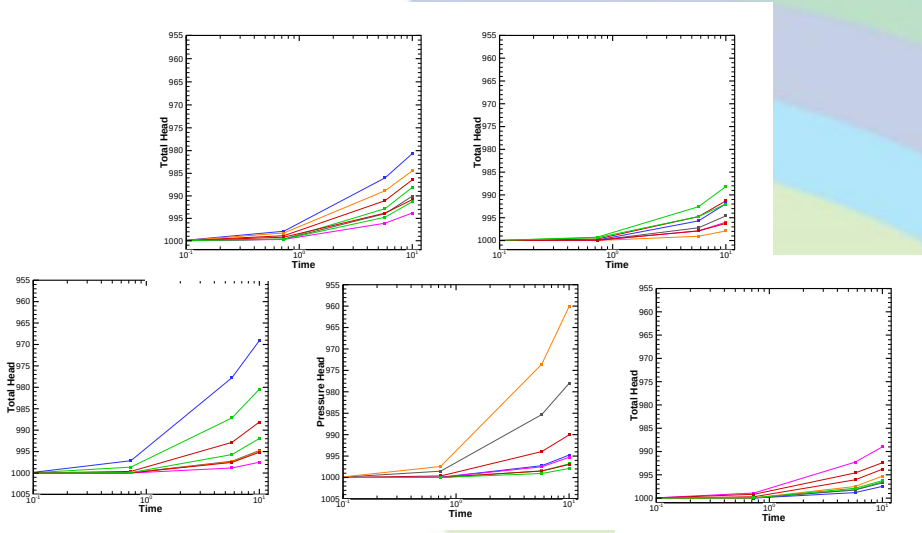
Heterogeneous Material

Forward Model

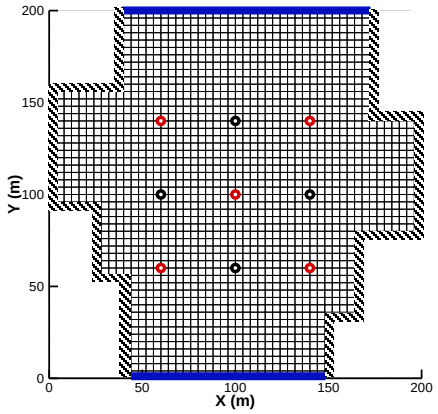
Drawdown Data

Transient State



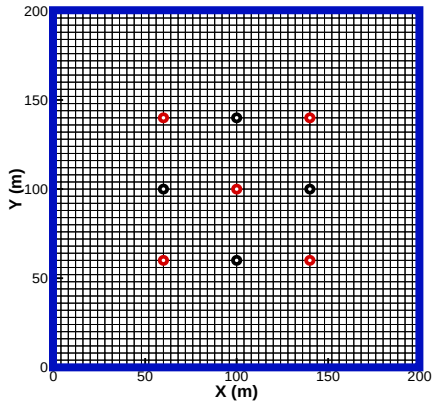
Q2: Effects of unknown basin geometry

True Geometry



VS

Incorrect Geometry



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Drawdown Data

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Uniform Initial Guess

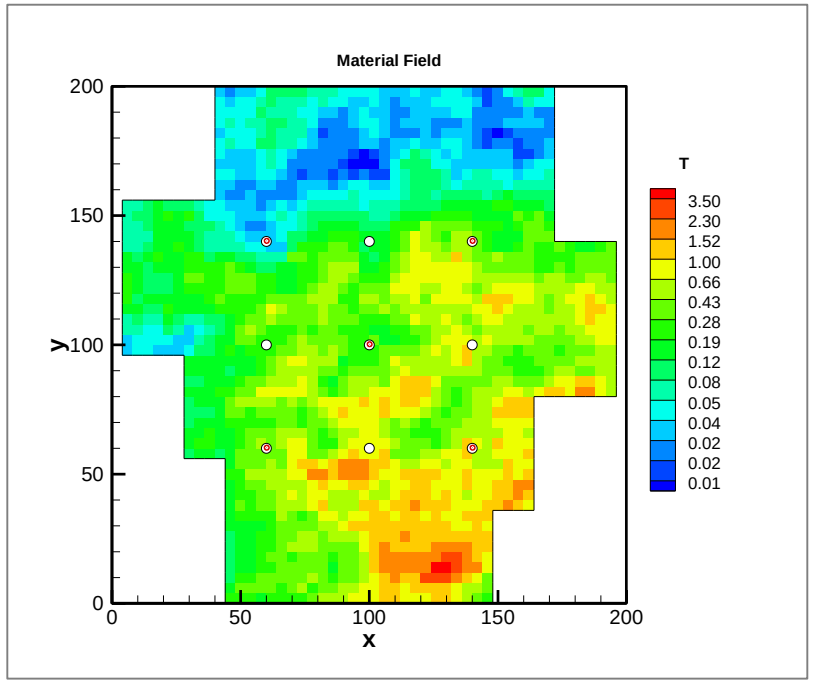
Inverse Model →

Transient State Estimation

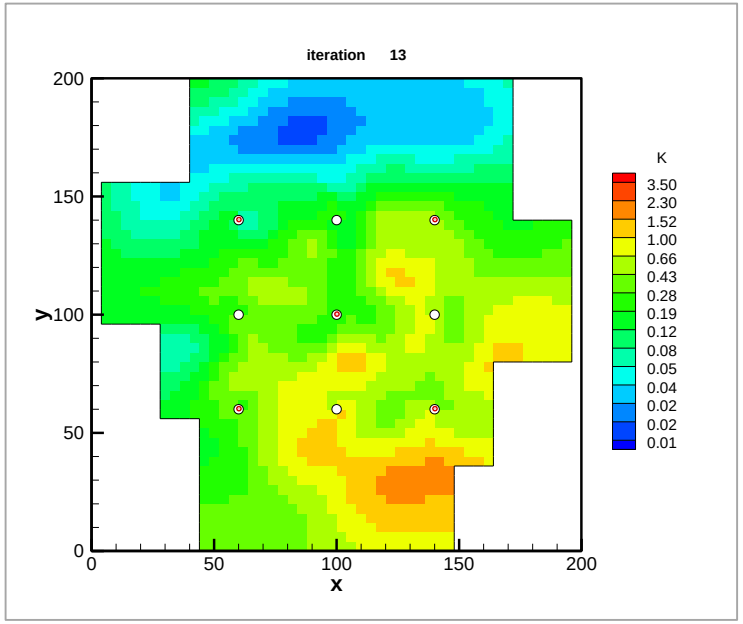
Q2: Effects of unknown basin geometry

Estimated T

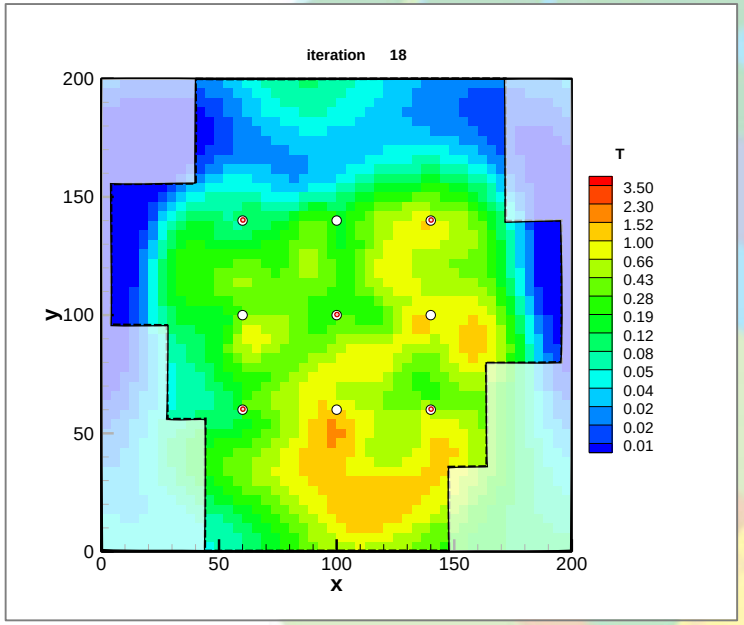
True Material



True Geometry

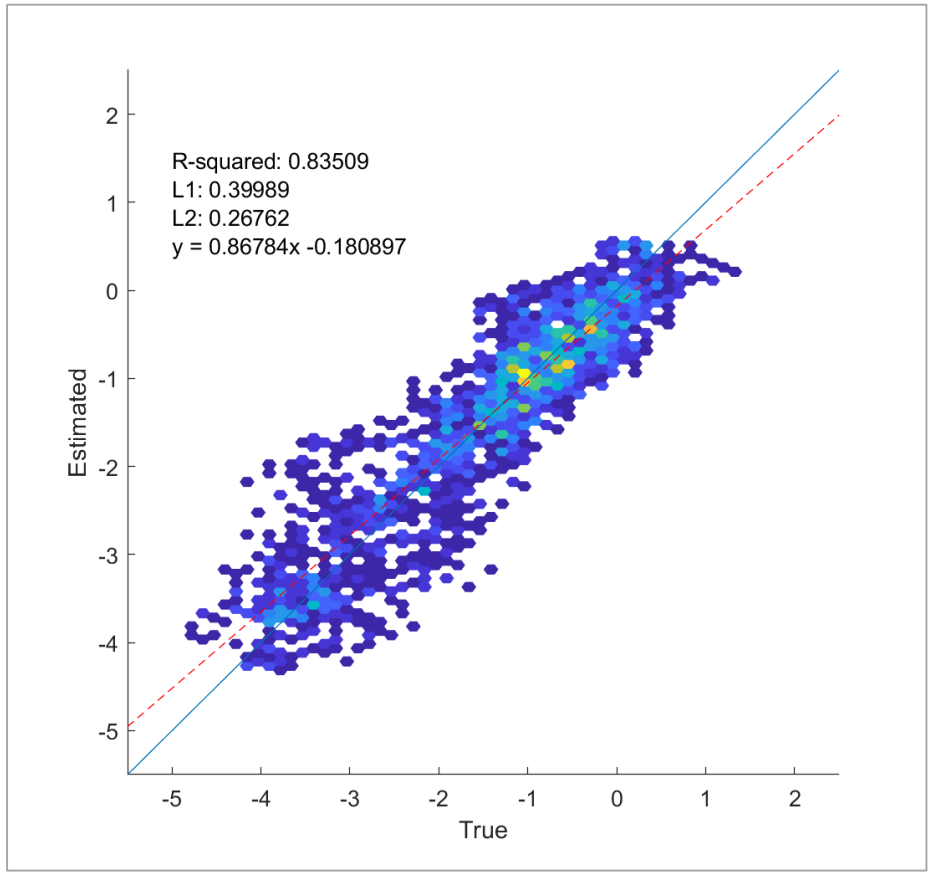


Incorrect Geometry

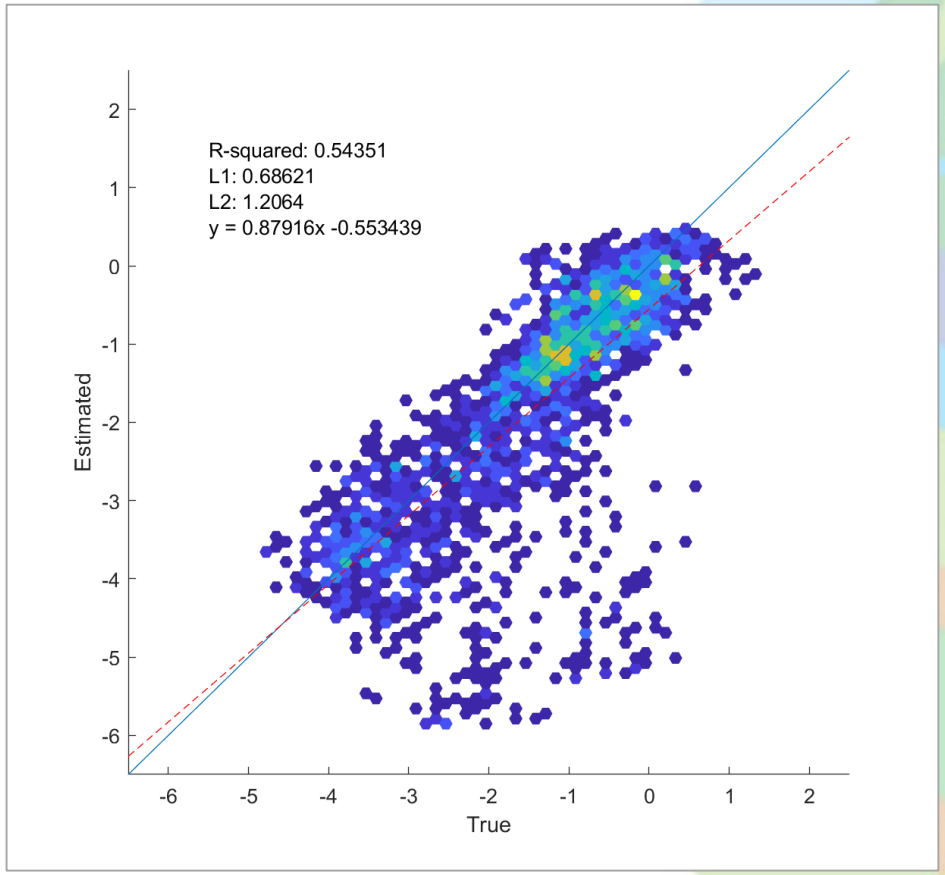


Q2: Effects of unknown basin geometry

True Geometry



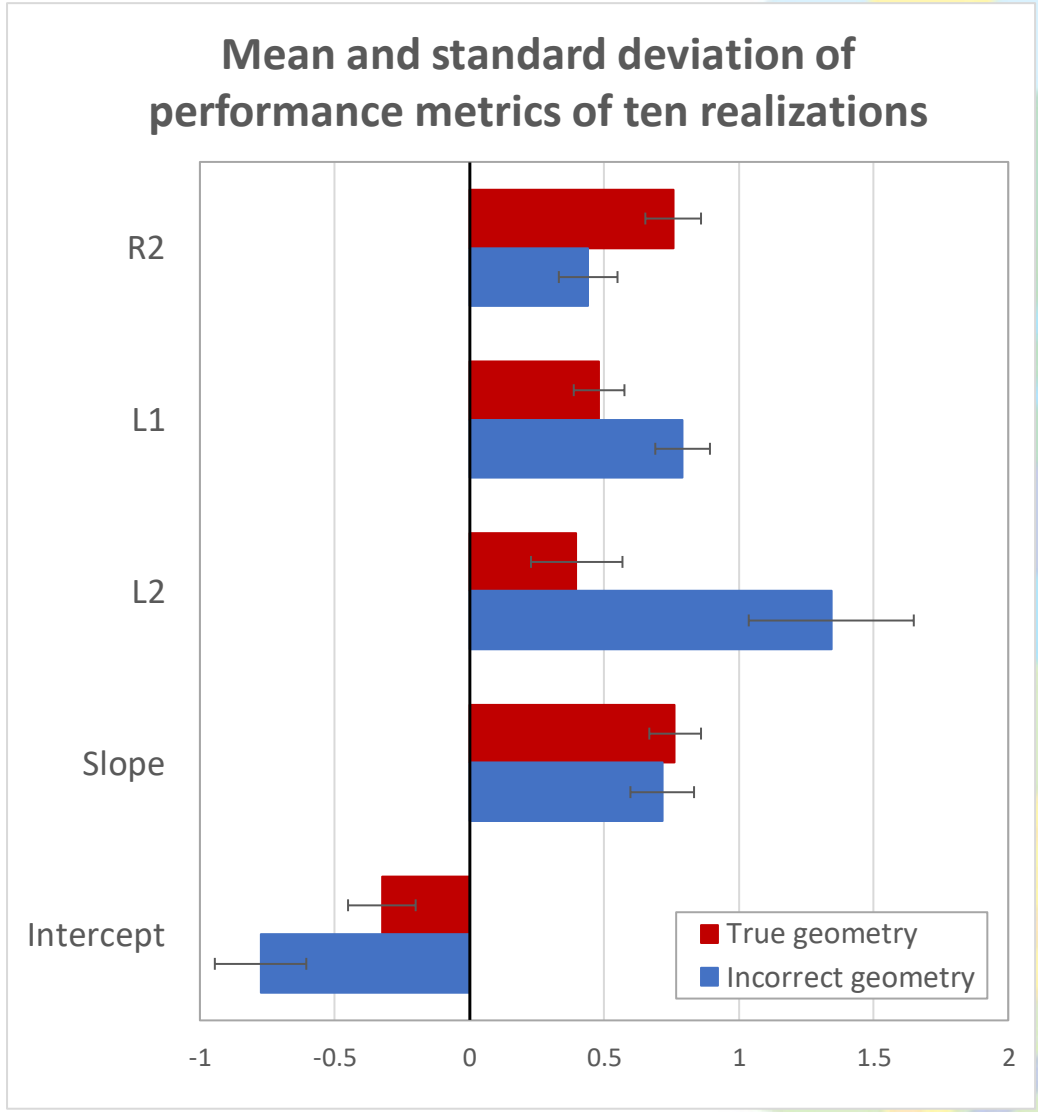
Incorrect Geometry



Q2: Effects of unknown basin geometry

Q2 Conclusion

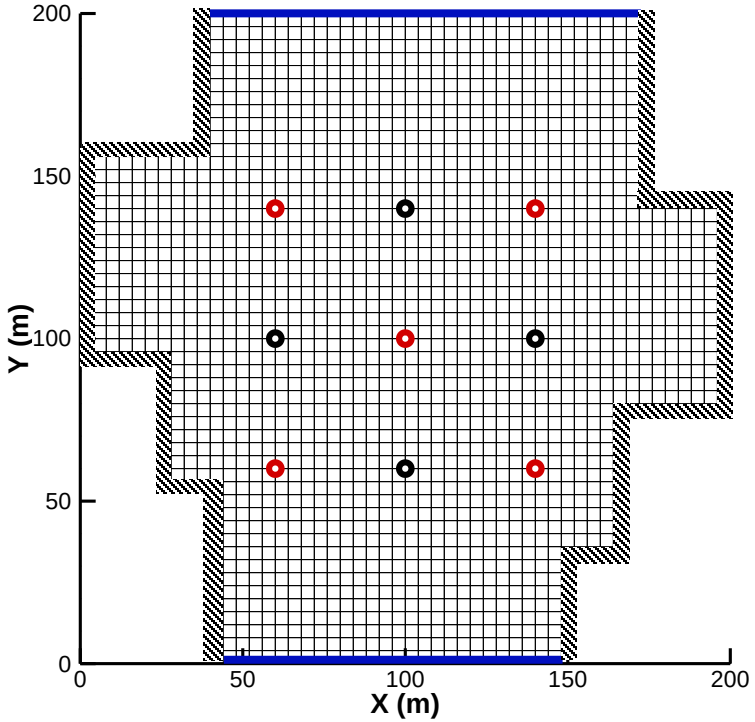
- T estimation using correct geometry and type of the boundary yields better result of the estimation inside the domain.
- Estimation with the incorrect geometry model results in lower average T due to low permeable region along the no flow boundaries.
- Knowing true geometry and boundary type can improve the estimation.



Q3: Role of prior information

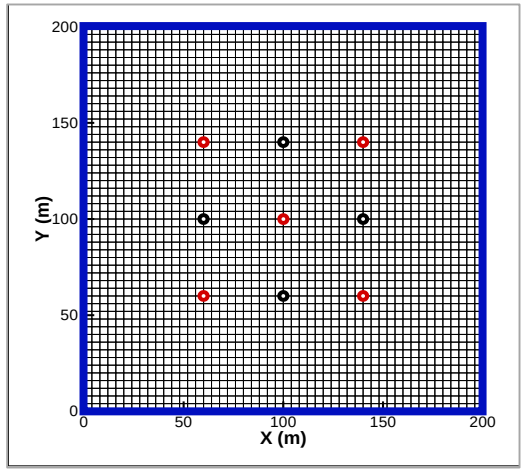
Q3: Role of prior information

True Geometry



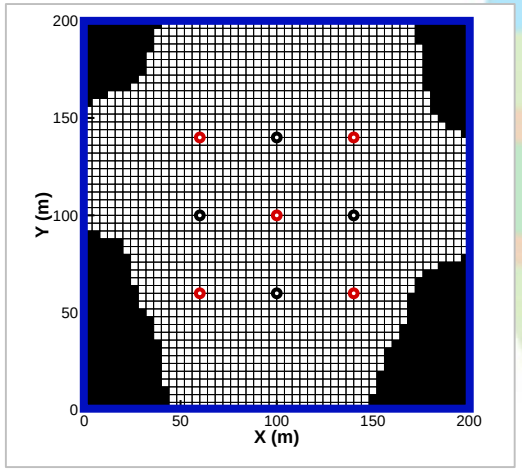
Prior information of mean T

Case A



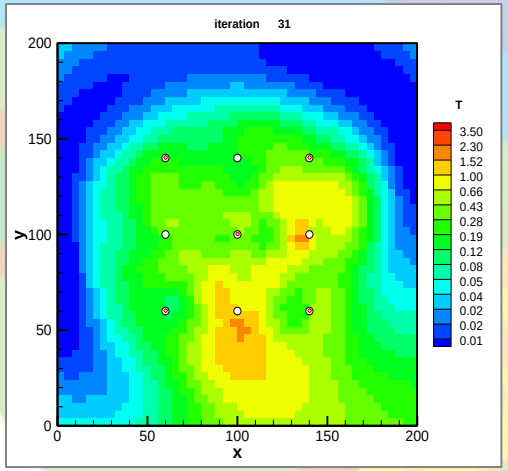
Prior information of geology

Case B



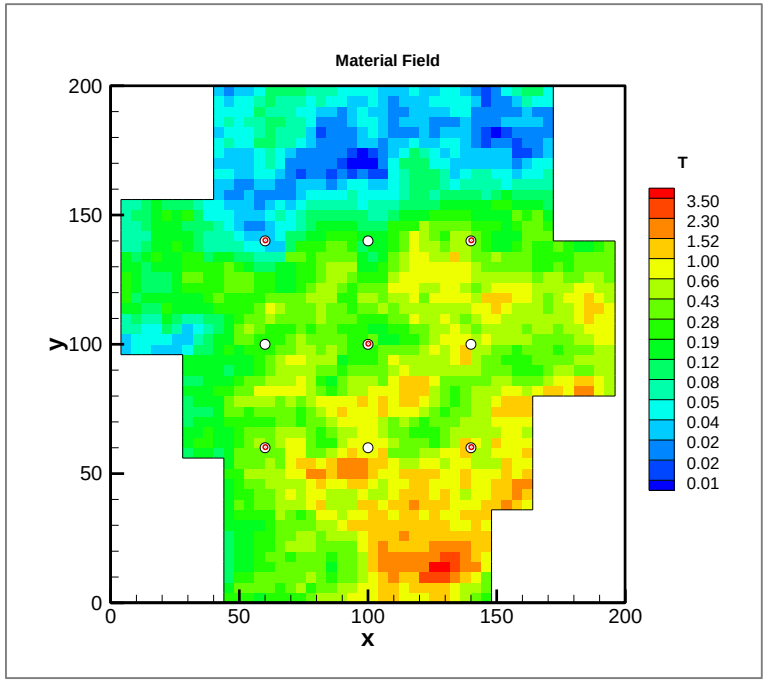
Prior information of estimated T

Case C

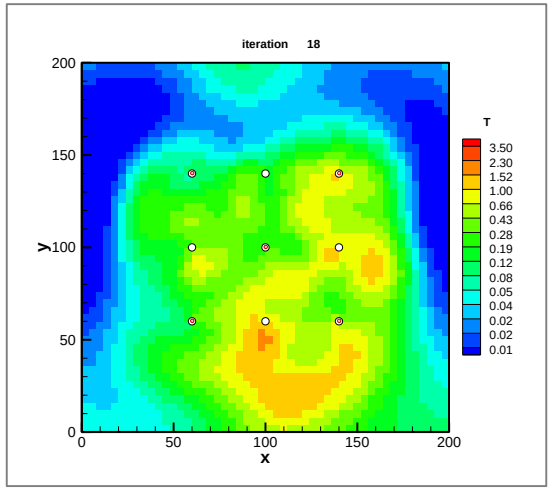


Q3: Role of prior information

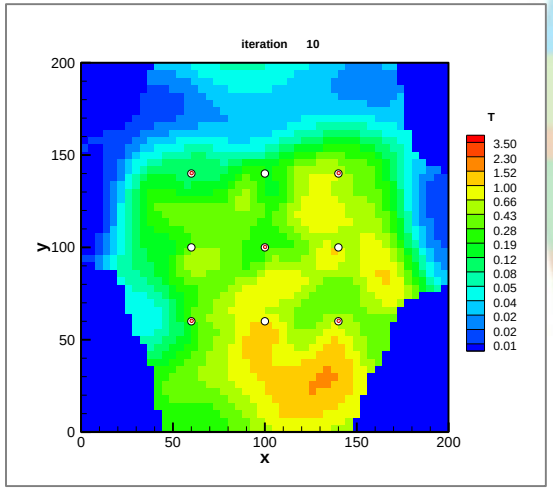
True Material



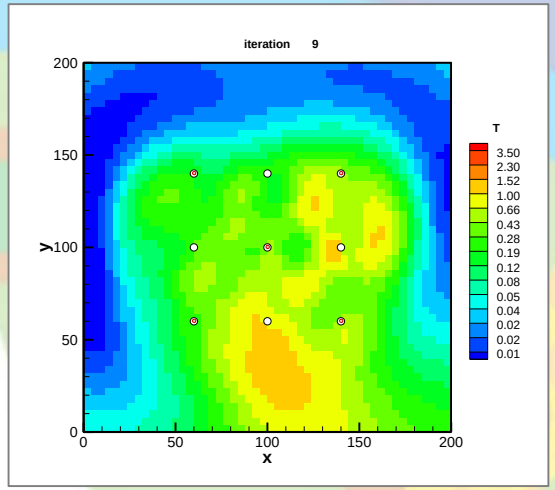
Case A



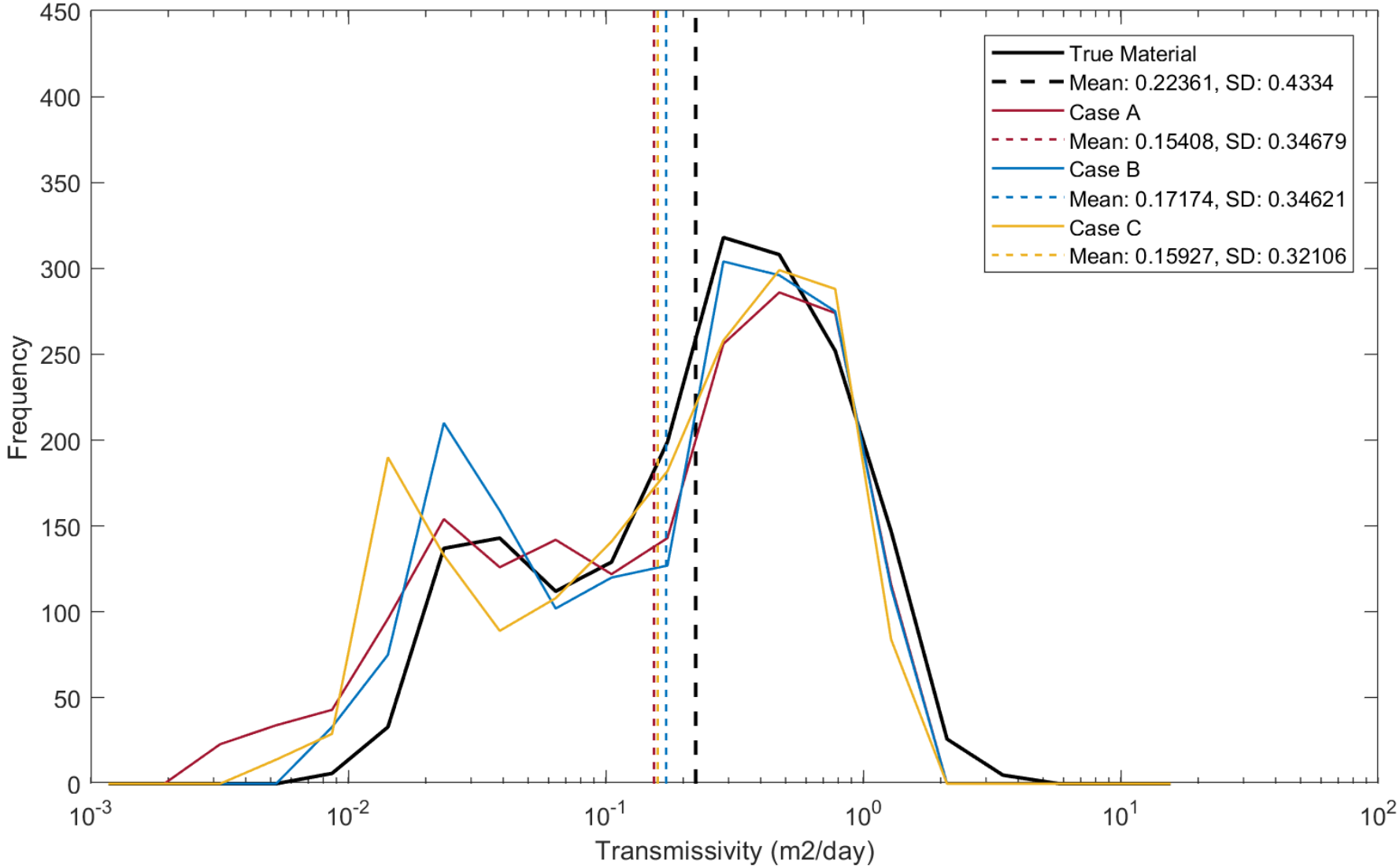
Case B



Case C



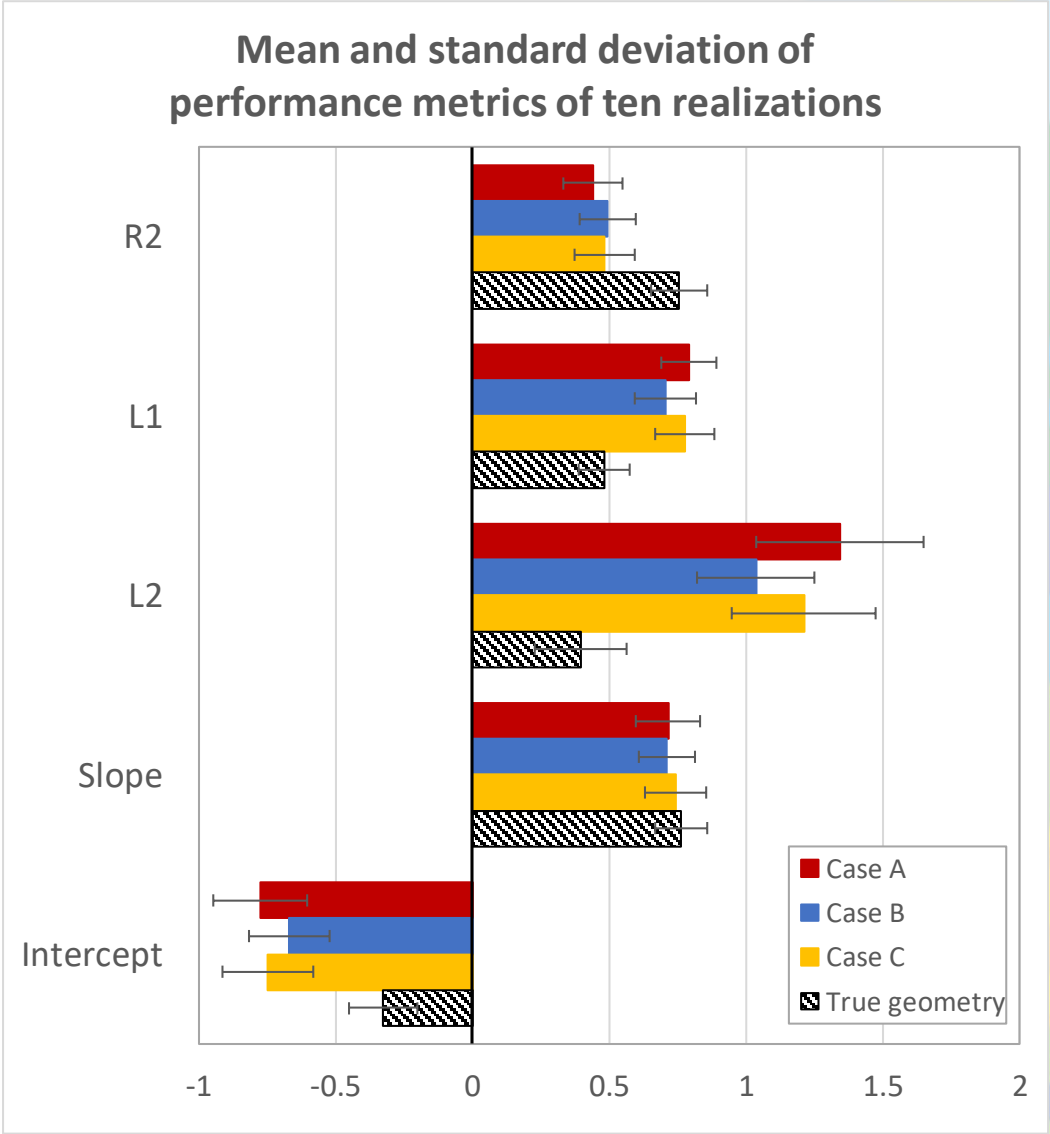
Q3: Role of prior information



Q3: Role of prior information

Q3 Conclusion

- Using geology information (Case B), the mean value of estimated T inside the basin is closer the true mean than the other cases.
- The performance metrics of ten realizations indicates that the prior information of geology (Case B) and distribution of T (Case C) can improve the estimation in the basin area



Conclusion

Based on ten realizations…

- With the incorrect assigned boundary, HT can delineate the no-flow boundary and geometry and also can estimate the heterogeneity inside the domain.
- More prior information about the basin, e.g., geology, hydraulic conductivity, can improve the estimation of the heterogeneity.

- More realizations have to be taken into account in order to create more robust conclusion.

GRACIAS

THE UNIVERSITY OF ARIZONA

UA SCIENCE
Hydrology & Atmospheric Sciences

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AURPAES, S.C.

Contacto

Kwankwai Daranond

The University of Arizona

daranondk@email.Arizona.edu

Performance metrics

- **R-squared:** $R^2 = 1 - \frac{\sum_{i=1}^{N}(x_i - \hat{x}_i)^2}{\sum_{i=1}^{N}(x_i - \bar{x})^2}$
- **L1 (MAE):** $L_1 = \frac{1}{N}\sum_{i=1}^{N}|x_i - \hat{x}_i|$
- **L2 (MSE):** $L_2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \hat{x}_i)^2$

- Simple Linear Regression Equation: Y=**m**X+**b**
  - **Slope:** m
  - **Intercept:** b

where
i = Element number
x_i = True T value at the element *i th*
$\hat{x}_i$ = Estimated T value at the element *i* th
N = Total number of elements