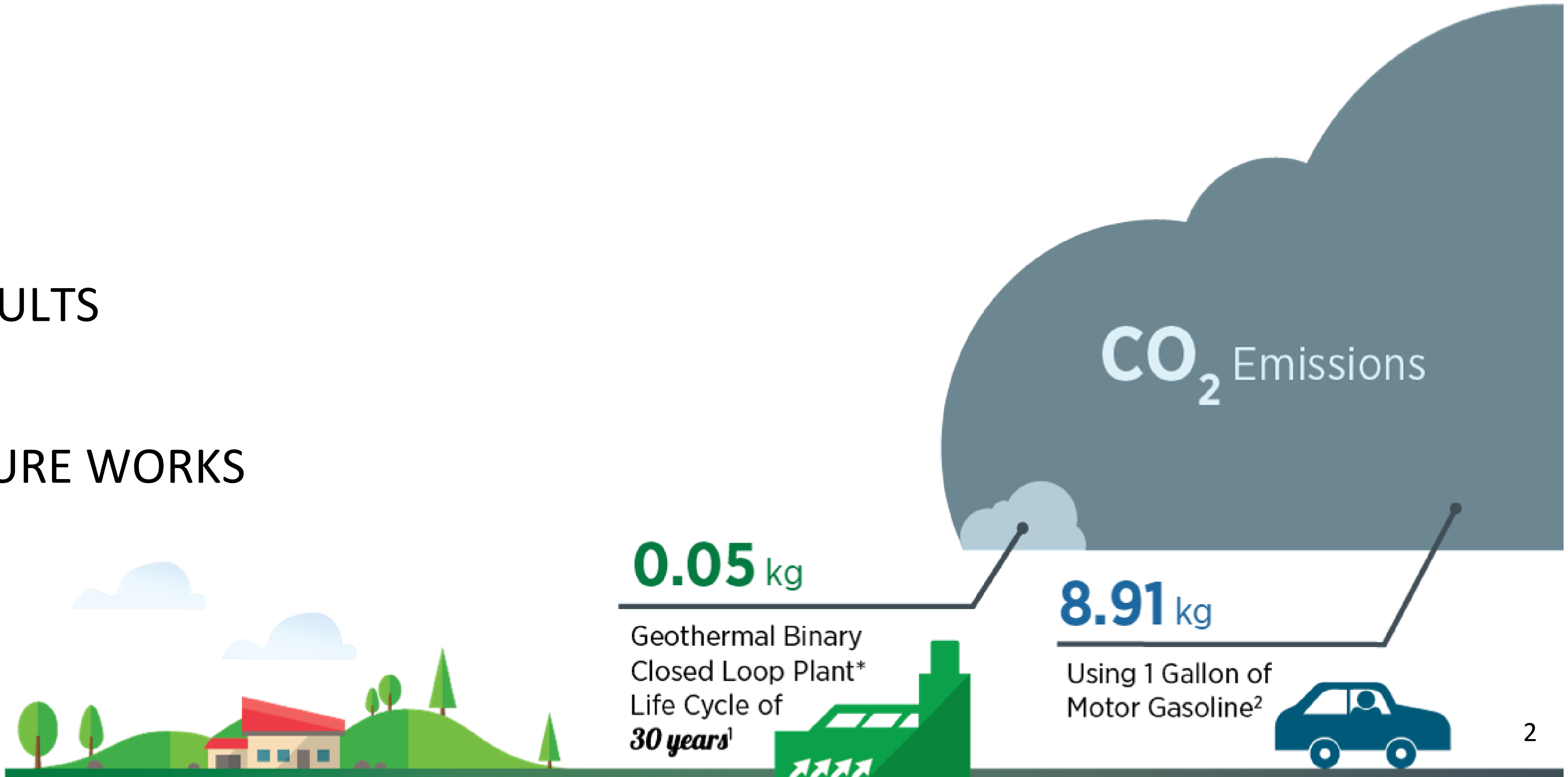
National Central University
Graduate Institute of Applied Geology

Impact of multi variables of aquifer properties on groundwater flow and heat transport in heterogeneous porous media

Speaker : Thi-Thanh-Thuy Doan
Advisor: Prof. Chuen-Fa Ni
Date: 2022/11/25

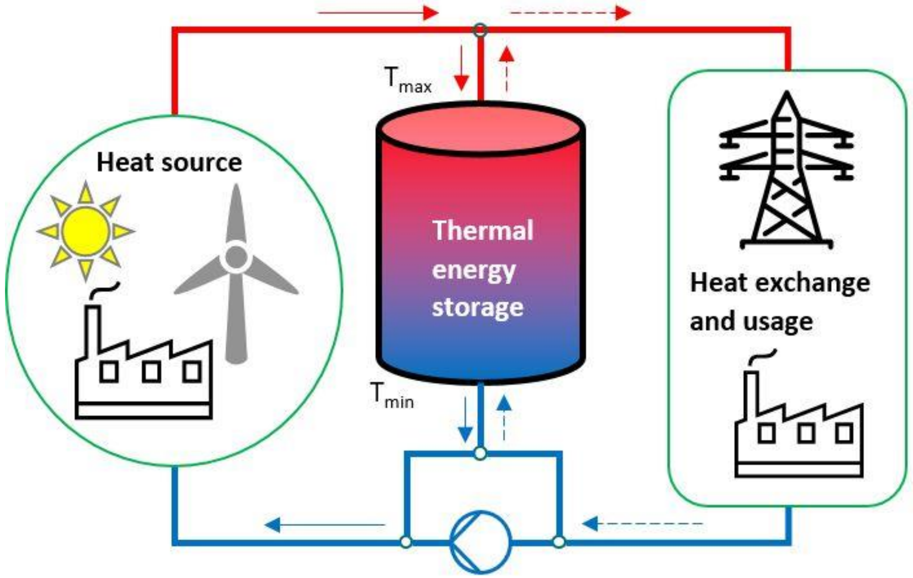
CONTENT



CO2 Emissions
0.05 kg
Geothermal Binary Closed Loop Plant* Life Cycle of 30 years1
8.91 kg
Using 1 Gallon of Motor Gasoline2

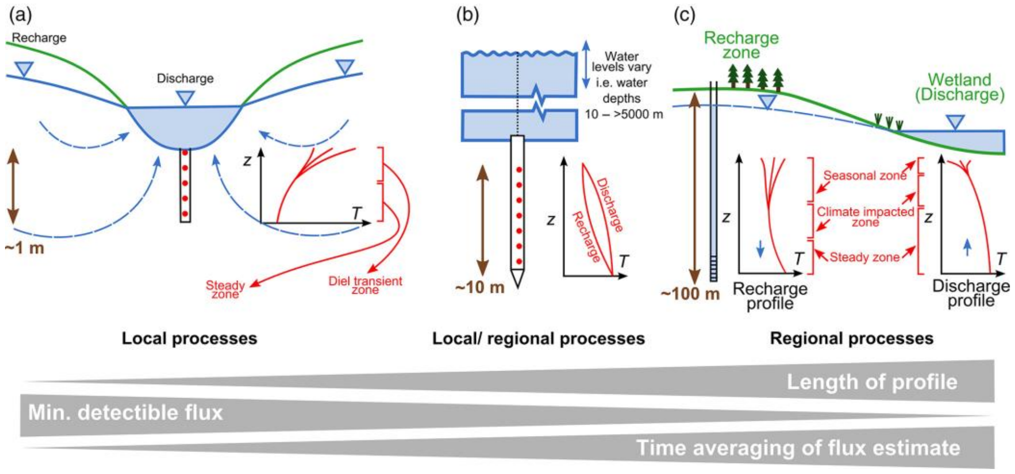
Flow & heat

- Interaction
  - Groundwater-surface
  - Groundwater-seawater
- Energy security & Environmental issues



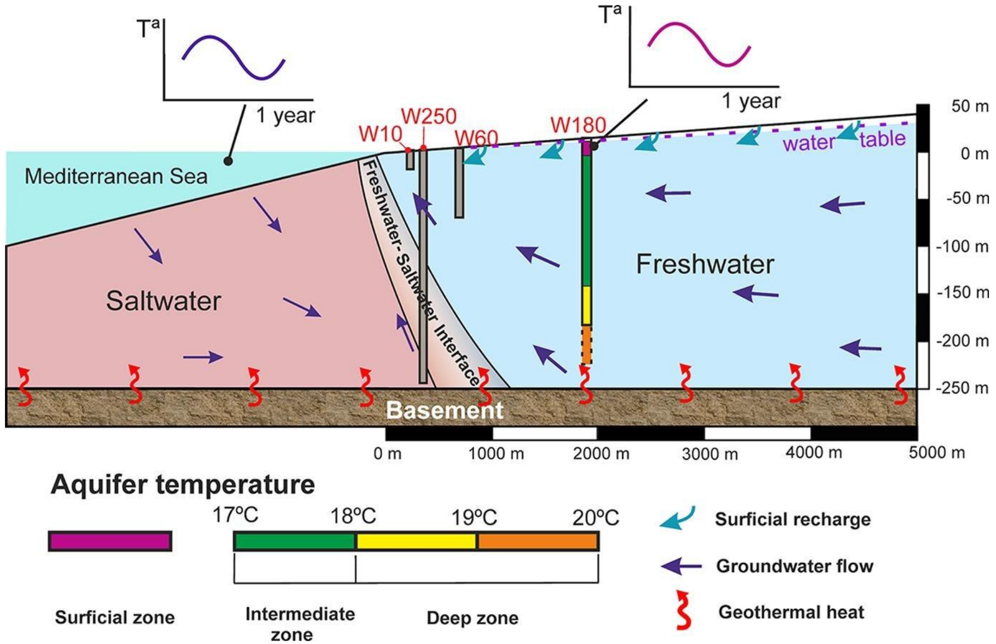
Geothermal system

https://www.ites.kit.edu/english/732.php



Local to regional processes subsurface

(Kurylyk et al., 2018)



Groundwater-seawater interaction

(Blanco-Corona et al., 2021)

? What is the behavior of flow & heat transport in the subsurface?

Literature reviews

Blanco-Coronas et al., (2021) showed temperature distribution of the different scenarios changed in the order of magnitude of hundred of meters, depending on the value of the K

Heat distribution strongly depends on the thermal properties of the soil.

Pu et al., (2020) assumed soil media is homogeneous,

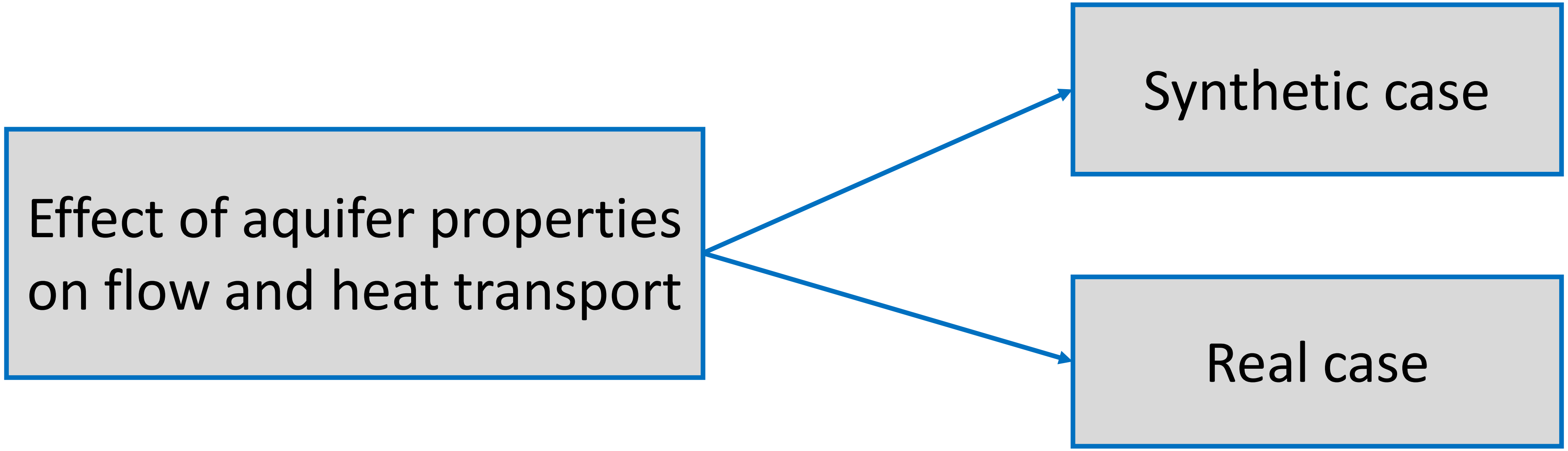
But natural aquifers are commonly heterogeneous with varying thermal conductivities.

Complex geologic and hydraulic systems strongly influence the GCHP efficiency, especially groundwater.

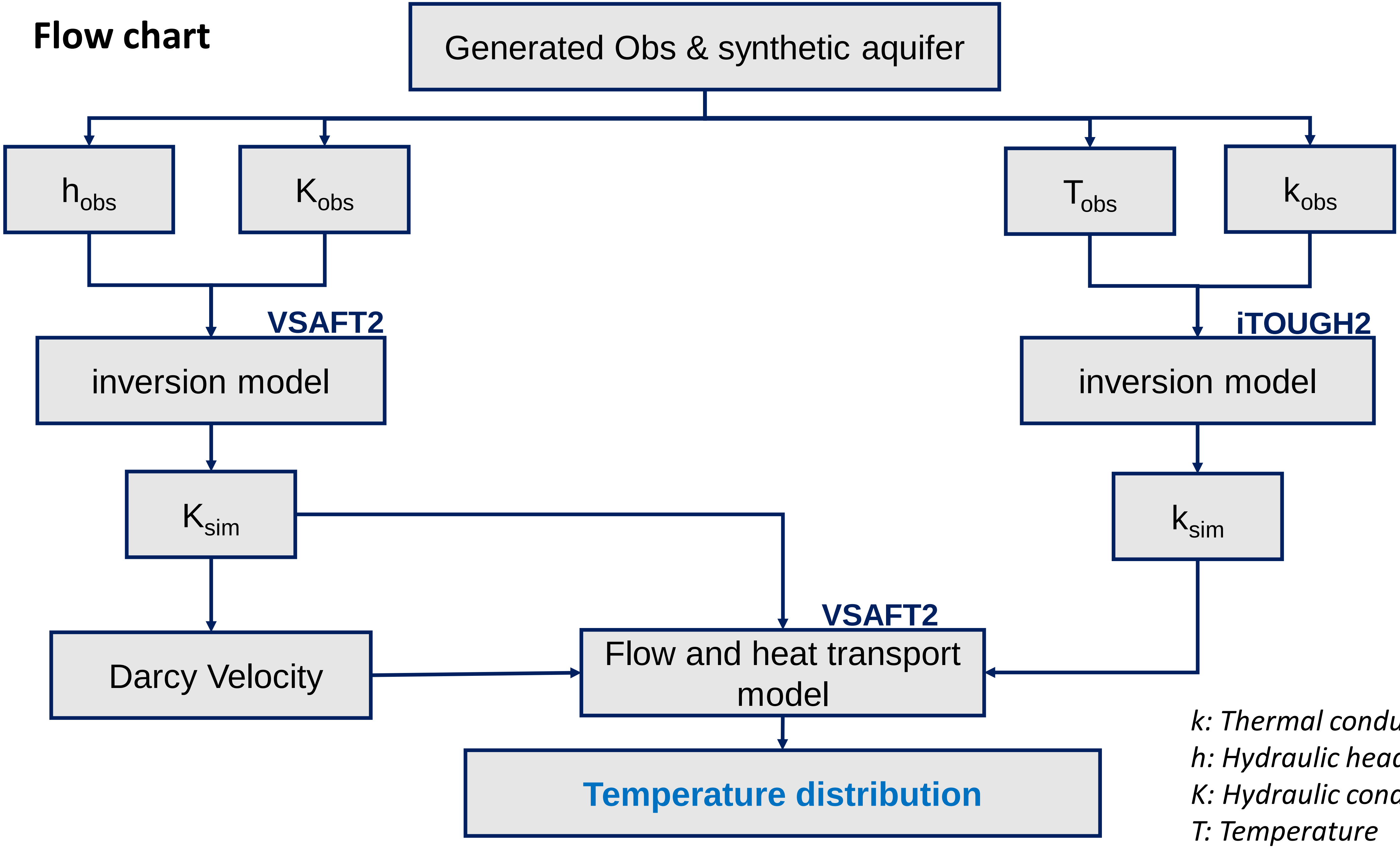
We need further exploration to facilitate the ongoing groundwater-associated research including Borehole thermal storage. (Diao et al. 2004, Green et al 2006, Zhao et al 2018, Zhao et al. 2022).

Objectives

- Estimating **aquifer properties** such as hydraulic and thermal conductivity
- Simulating **flow and heat transport model**



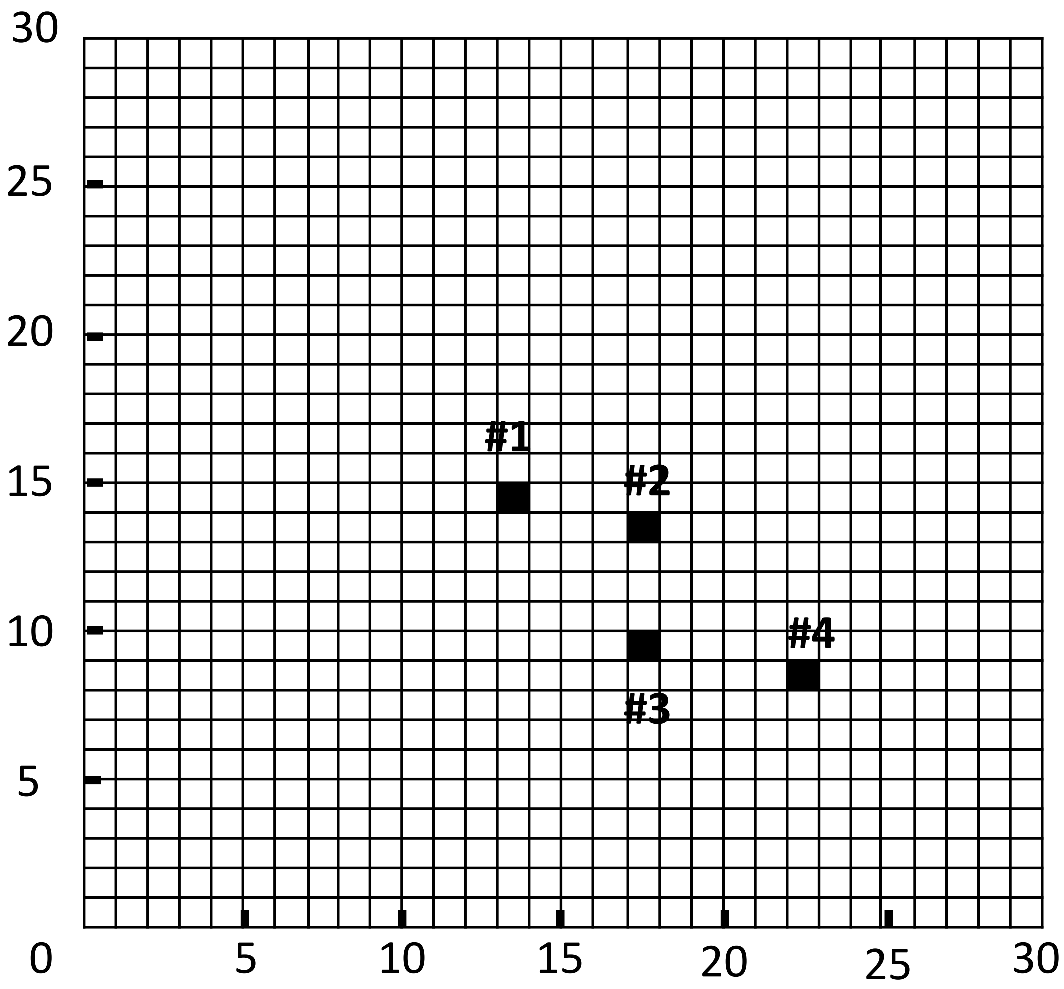
Flow chart



k: Thermal conductivity
h: Hydraulic head
K: Hydraulic conductivity
T: Temperature

	VSAFT2	iTOUGH2
Support	Available saturated **flow and transport finite element model** in 2D **(Yeh, et al., 1993)**	• Parameters estimation • Sensitivity analysis • Uncertainty propagation analysis (**Pruess, 1987, 1991**)
Advantages	• Including several **geostatistical model** setup features such as **random field generation** of input parameters • Taking advantage of a **Sequential Successive Linear Estimator** (SSLE)	• Including **multiphase flow** processes • Detailed knowledge about the data used for calibration • An **understanding of parameter estimation** theory and **correct interpretation of inverse modeling** results
Disadvantages	• Focusing on flow & transport	• Required high-computation cost

Synthetic case



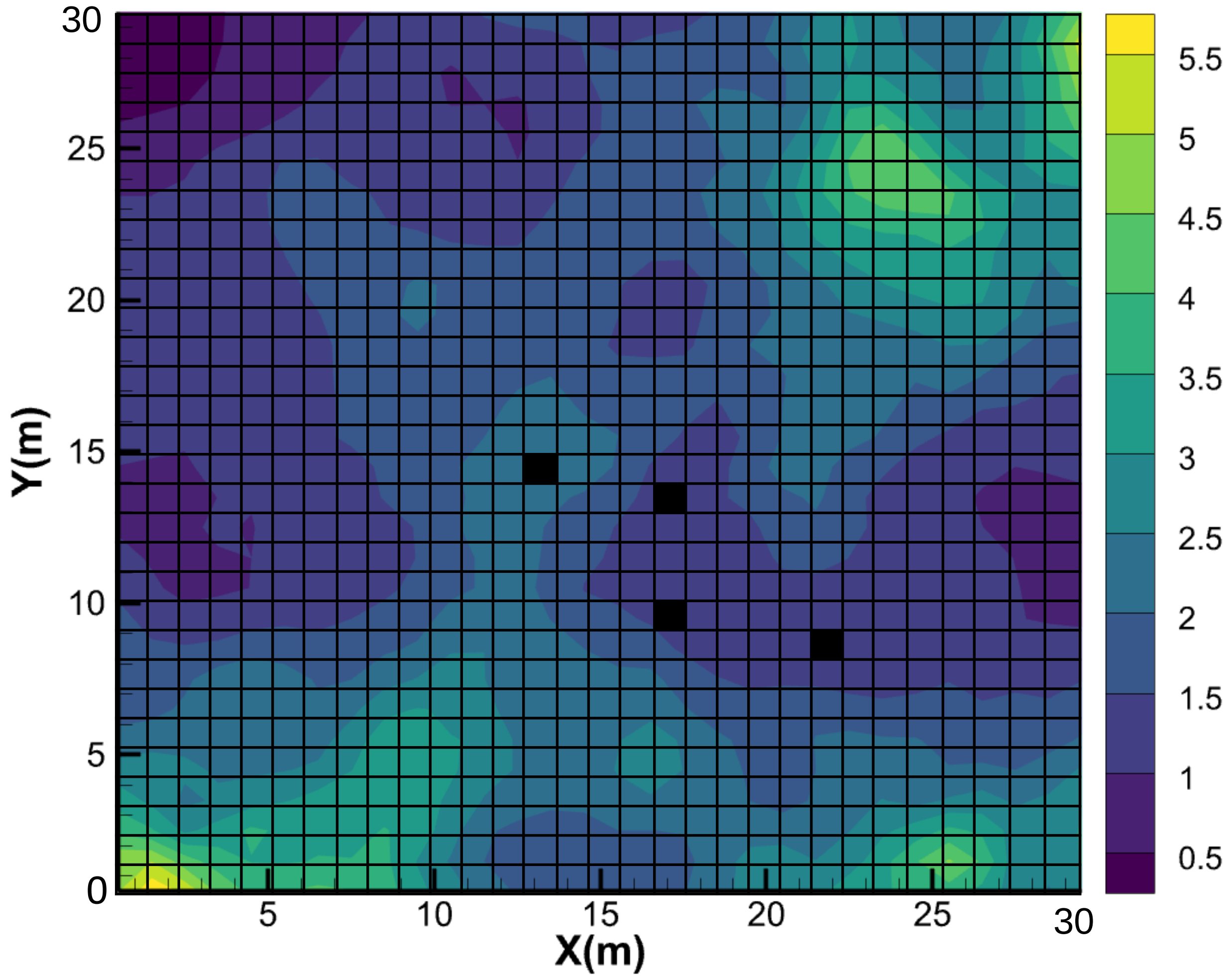
Computational domain (900 elements)

	Steady-state	Transient
Grid	30 m x 30m	
Material	heterogeneous	
Specific storage	-	0.0001
Porosity	0.336	
Longitudinal dispersivity (m)	10	
Transverse dispersivity (m)	0.1	
Bulk specific heat capacity of soil (J$kg^{-1o}C^{-1}$)	1789	
Bulk density of soil (kgm^{-3})	2571	
Pumping rate (m^3/day)	10.6	

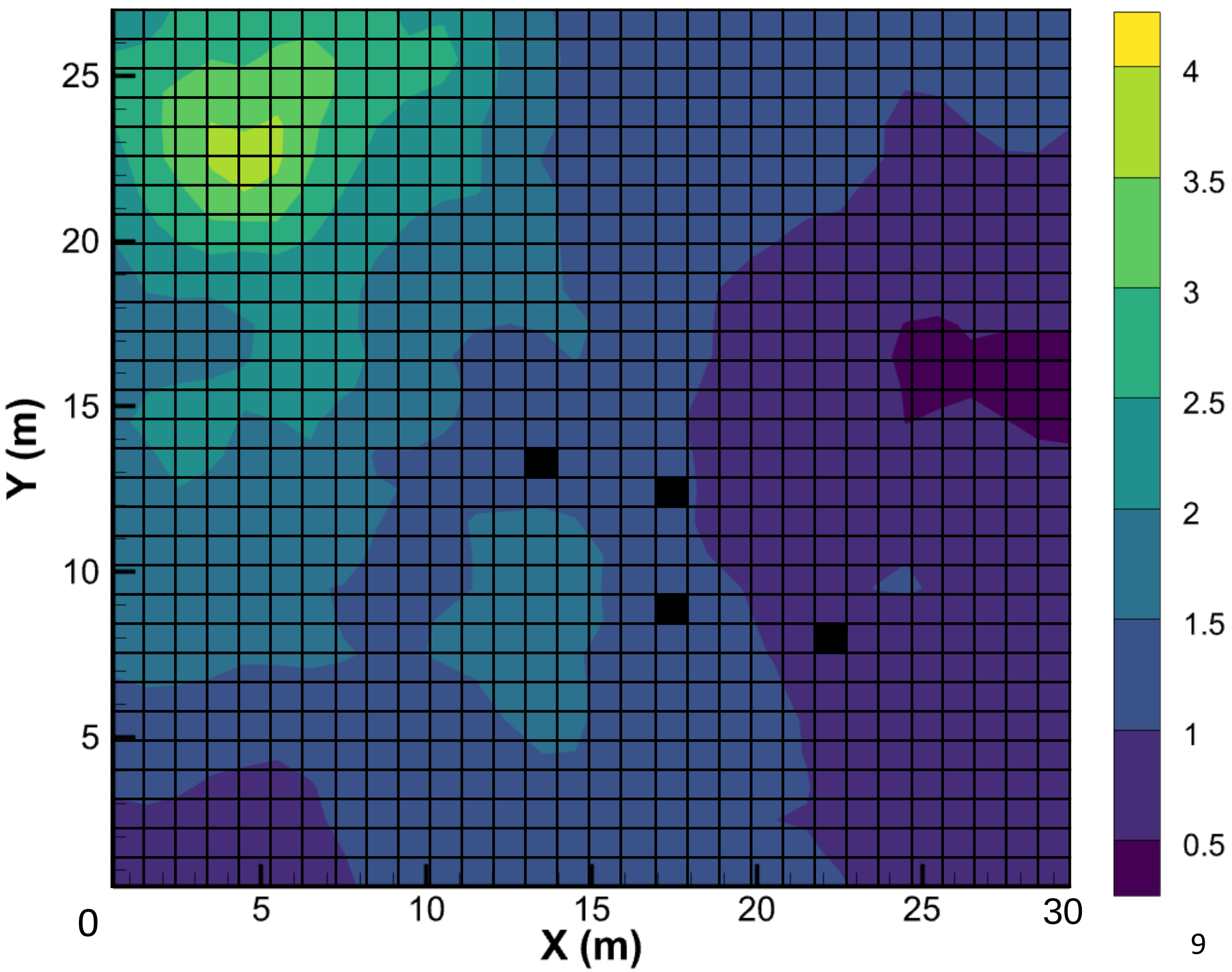
Generated synthetic aquifer

Mean (u) + variances (σ) → **Random field generator** → Hydraulic and thermal conductivity

Generated K, u = 1.76 (m/day) & $\sigma = 0.5$

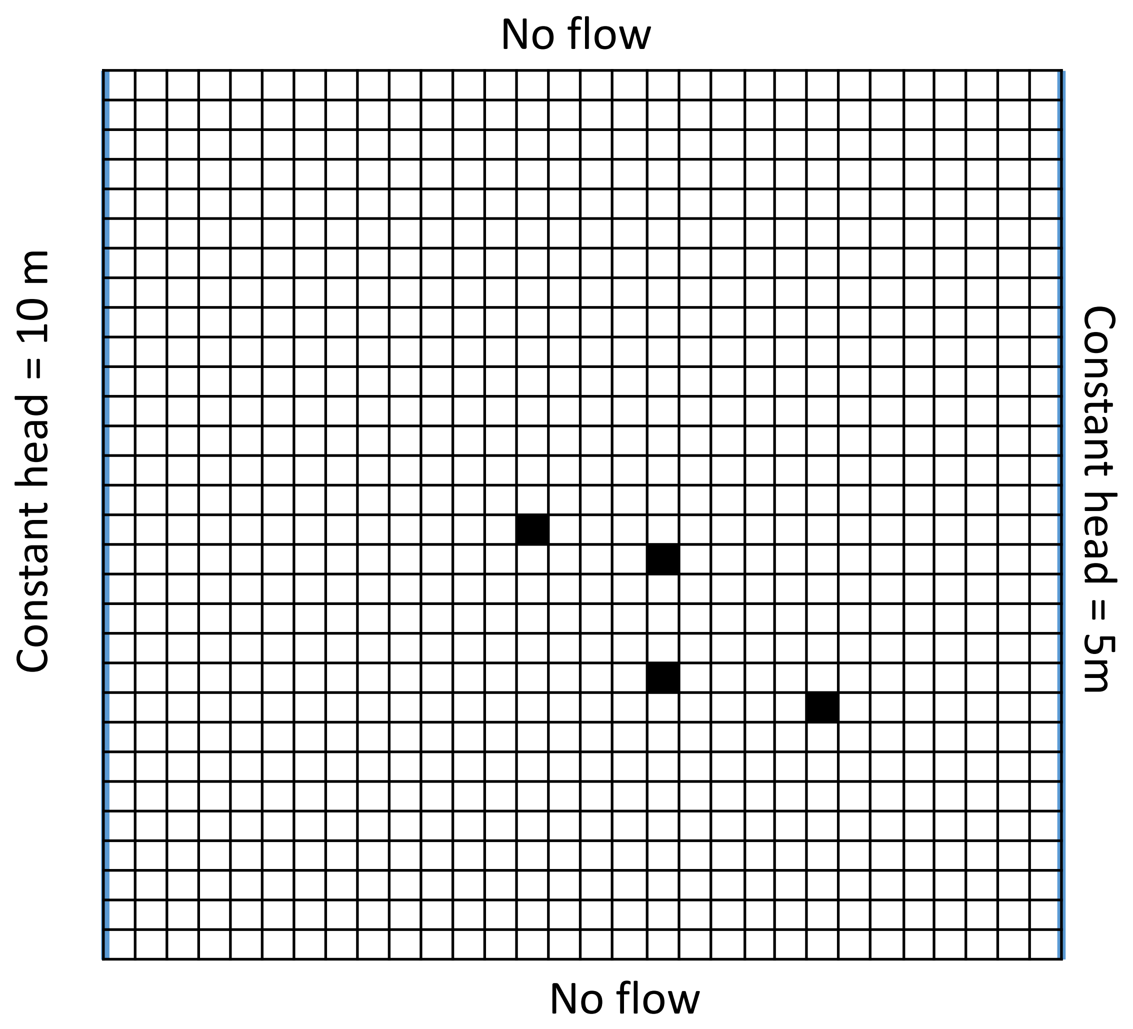


Generated k, u = 1.255 W/mK & $\sigma = 0.5$



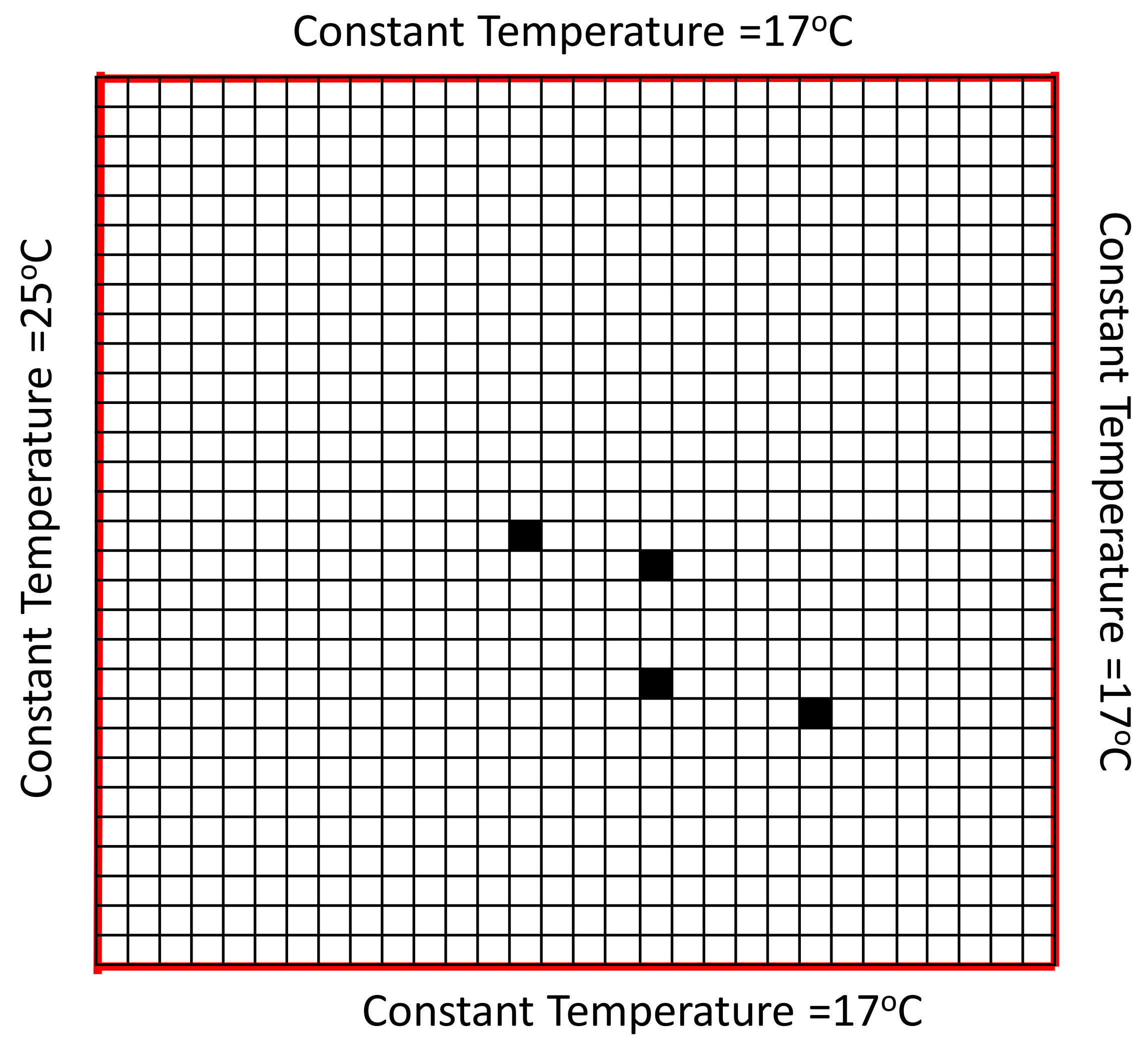
Model set-up

Flow model



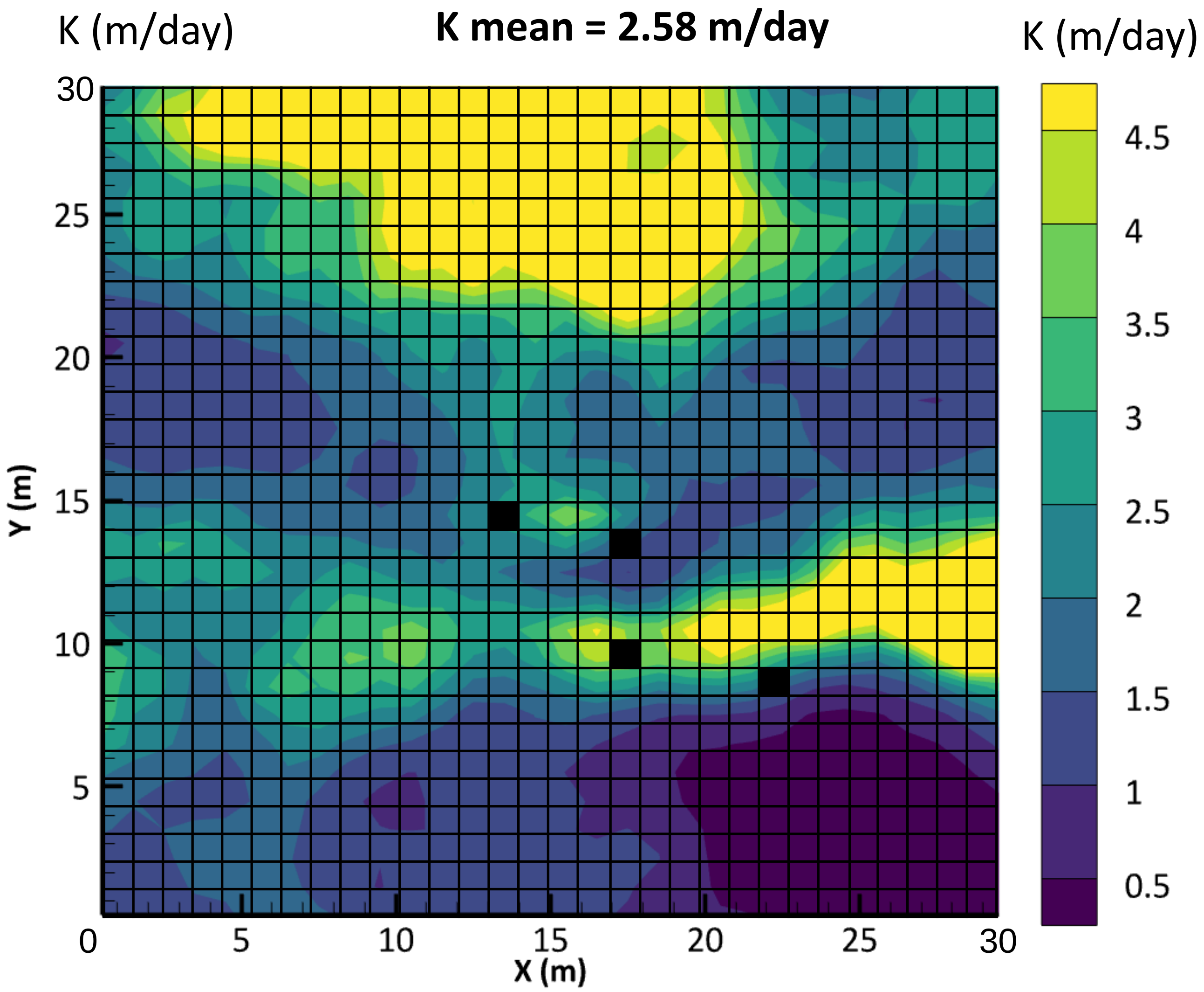
Initial condition head = 5m

Heat model



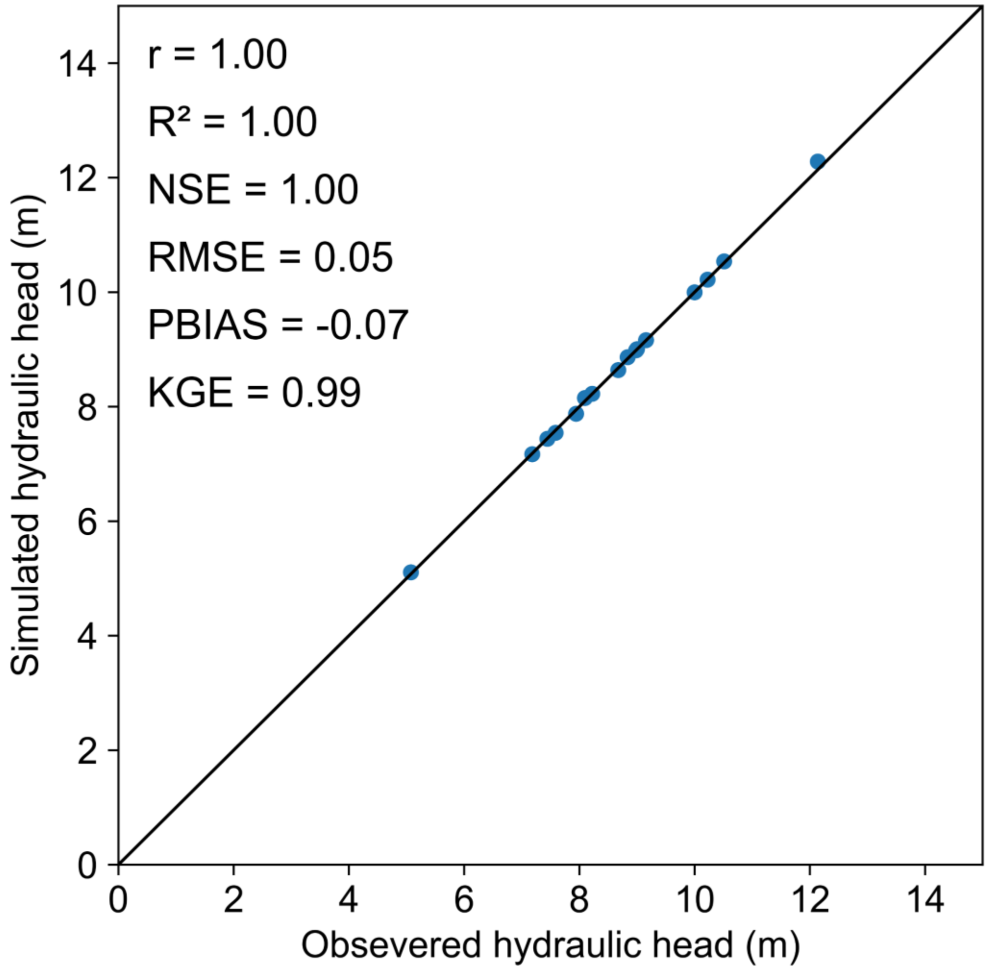
Initial condition temperature = 17°C

The simulated K, Steady-state

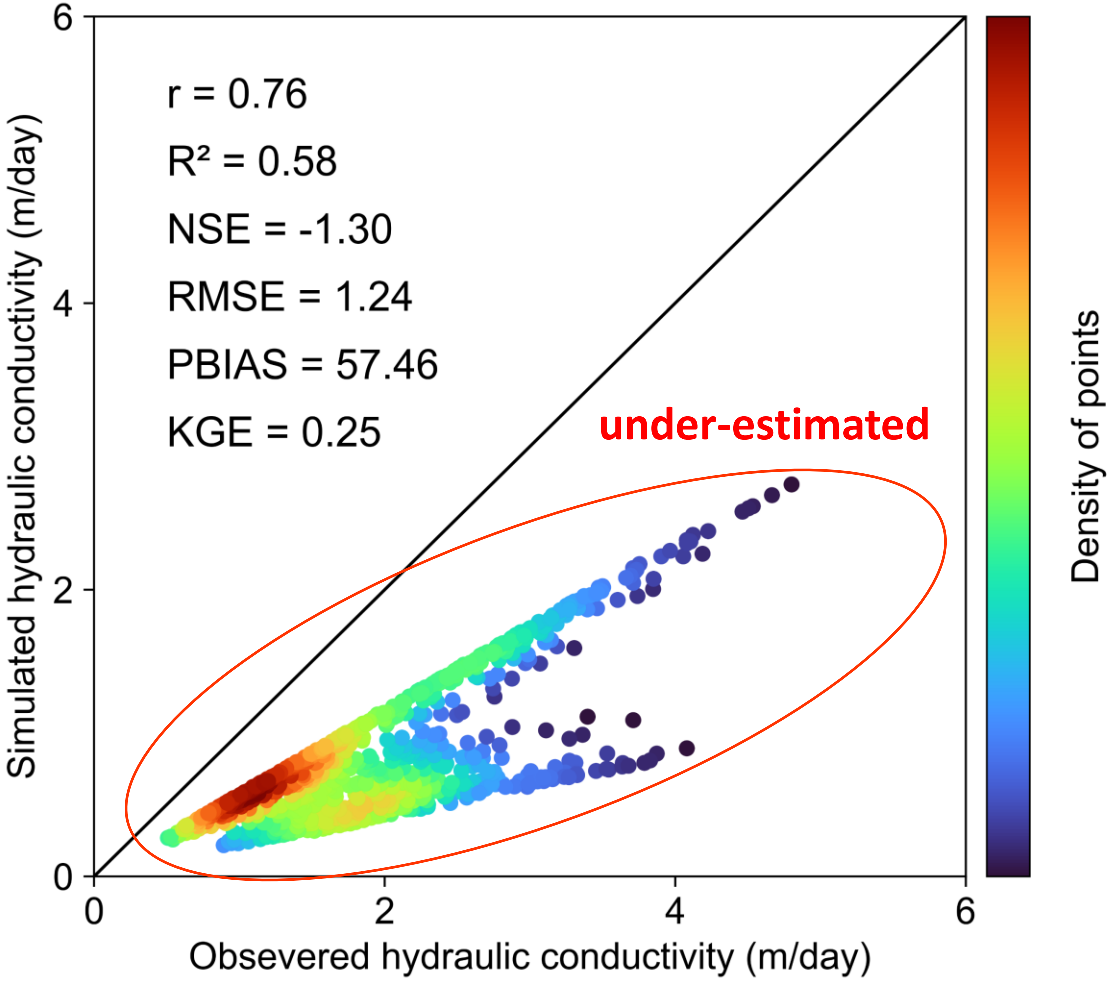


The pattern of sim K is certainly in agreement with the observed K

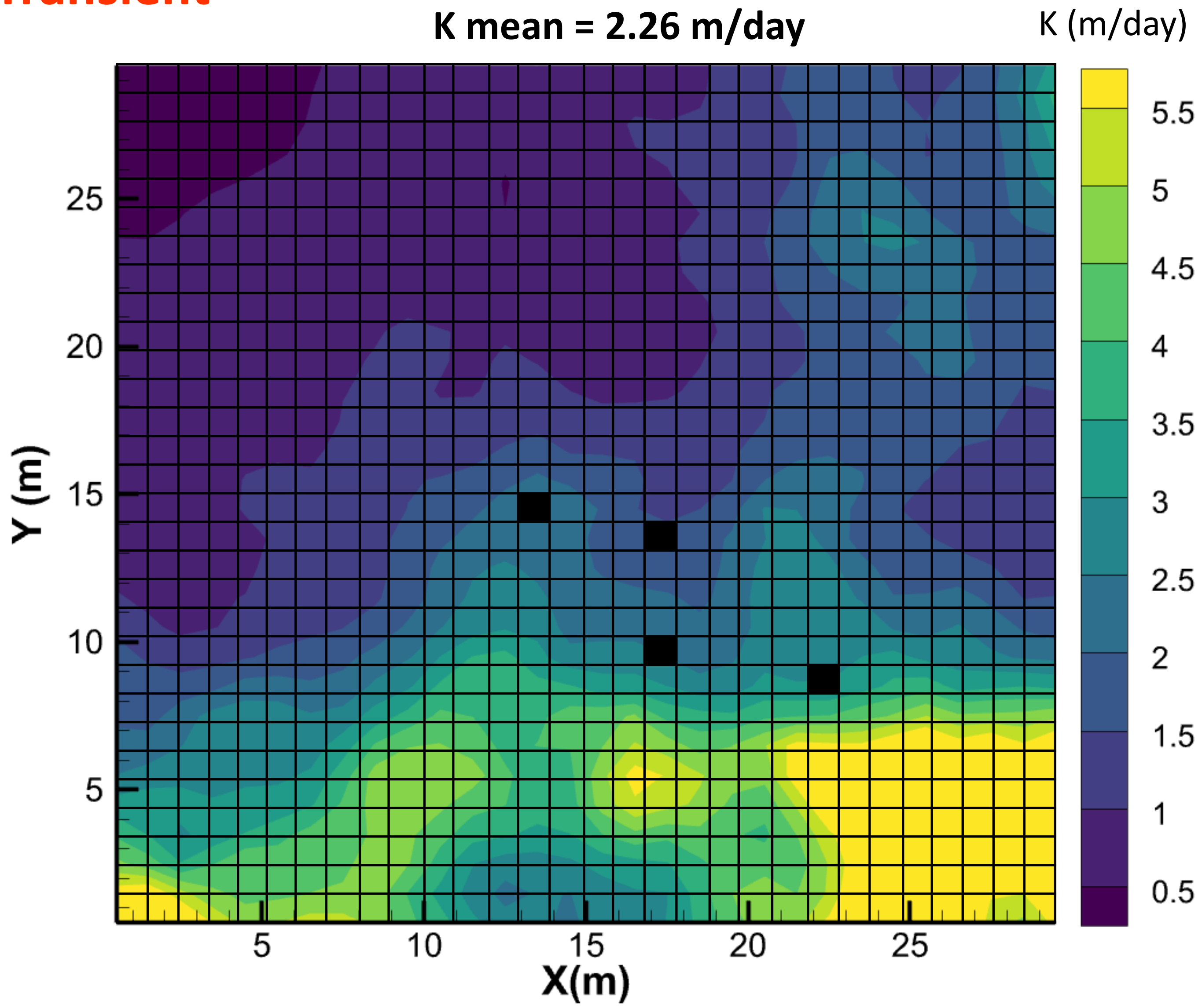
High agreement between obs. vs sim. h



Reasonable agreement between obs. vs sim. K

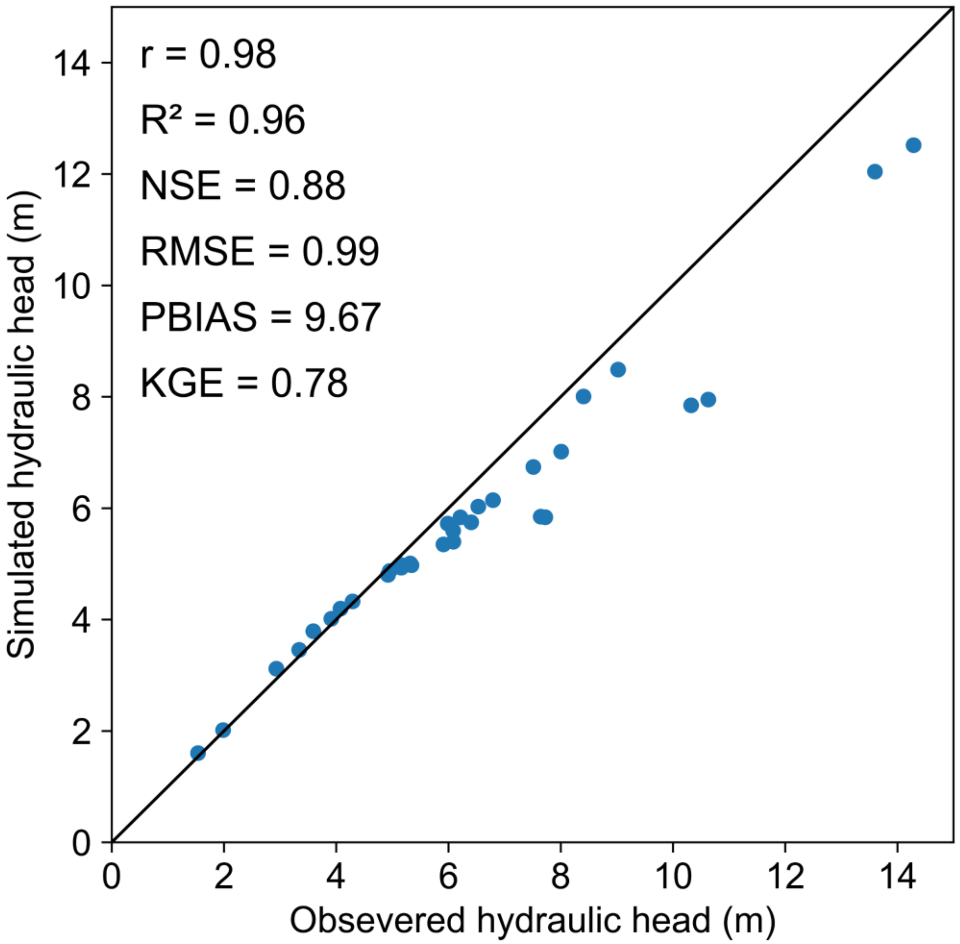


The simulated K, Transient

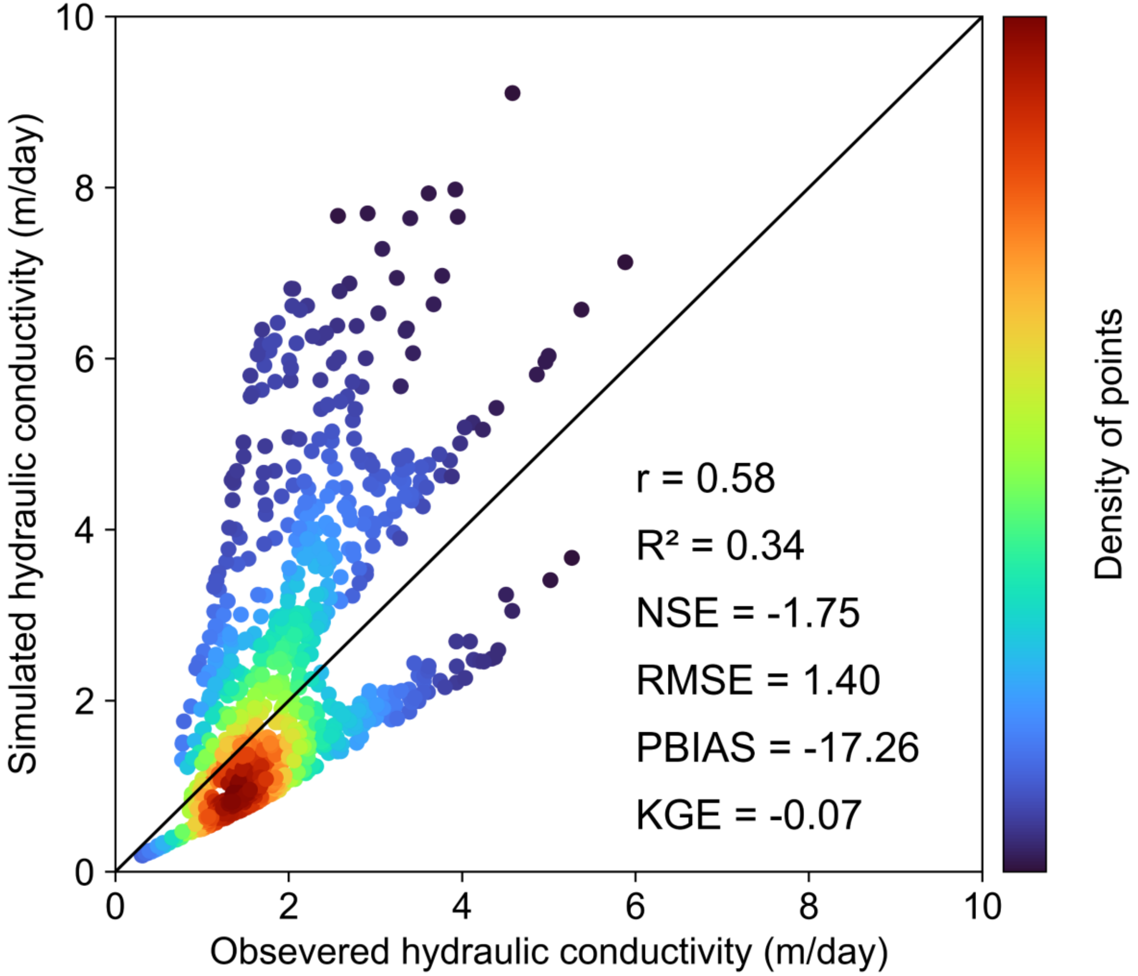


The pattern of sim K is certainly in agreement with the observed K

High agreement between obs. vs sim. h



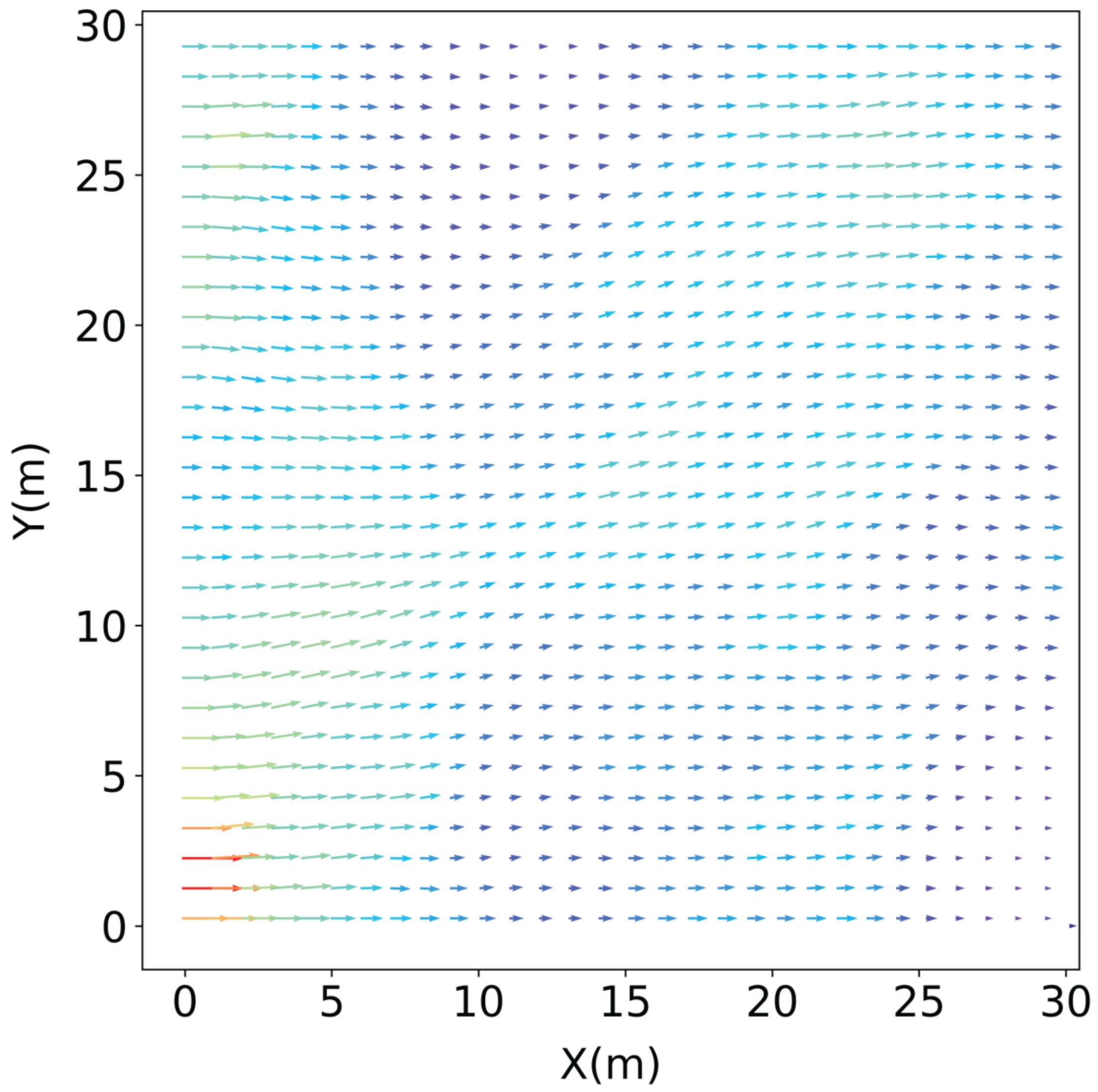
Reasonable agreement between obs. vs sim. K



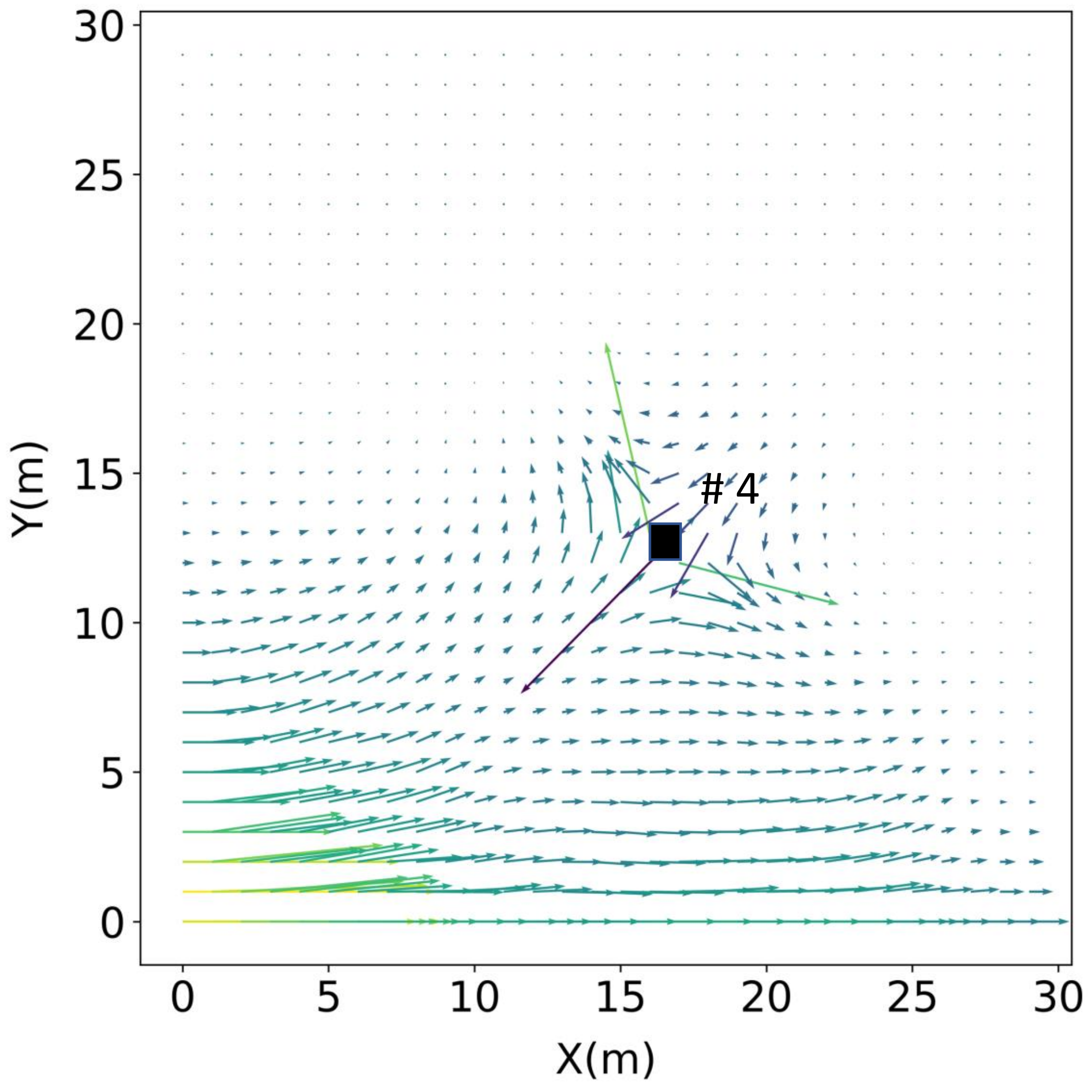
The high concentration of points close to the mean of ob. K =1.79 m/day

Velocity

Without pumping test



with pumping test, Q=10.6 m^3/day

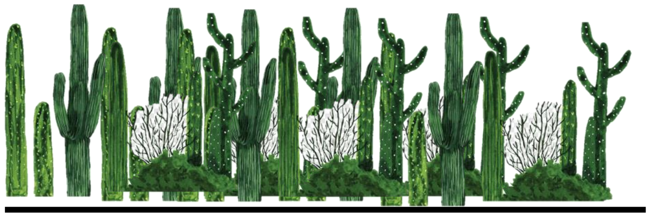


Summary

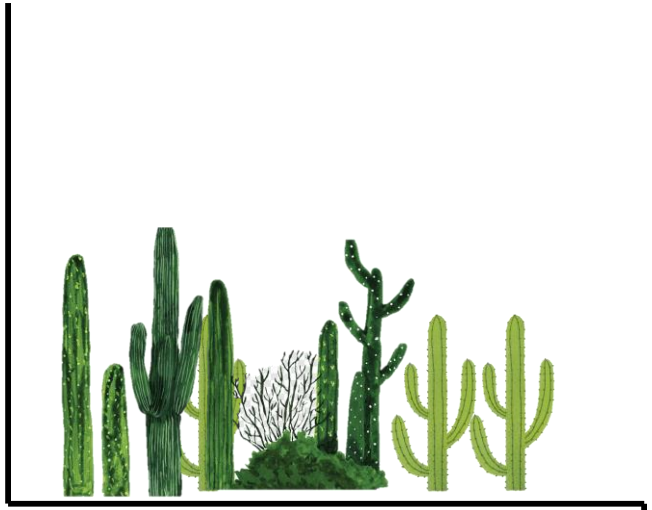
- This study generated the obs. & synthetic aquifer properties for heterogeneous porous media. And also completed the flow part for the synthetic case, highly agreement in h & reasonable K from the hydraulic inverse model.

- Reasonable K might have come from fewer wells (4 wells) in the domain. It leads to a decrease in the accuracy of the estimation.

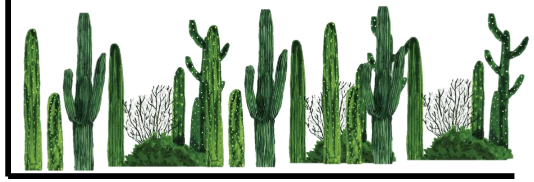
Future works



To simulate **the heat flow**



To run **iTOUGH2**



for the thermal inverse model

THANK YOU