LOW TEMPERATURE GEOTHERMAL ENERGY: HEAT EXCHANGE SIMULATION IN AQUIFERS THROUGH MODFLOW/MT3DMS CODES

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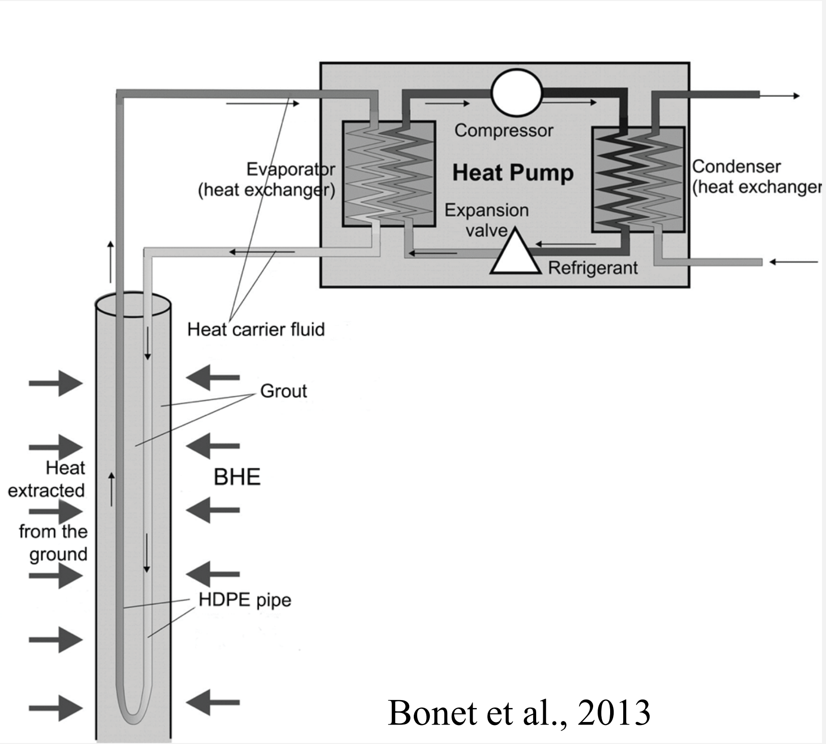
OUTLINE

- Introduction
- Methodology
- Result
- Conclusions
- Future works

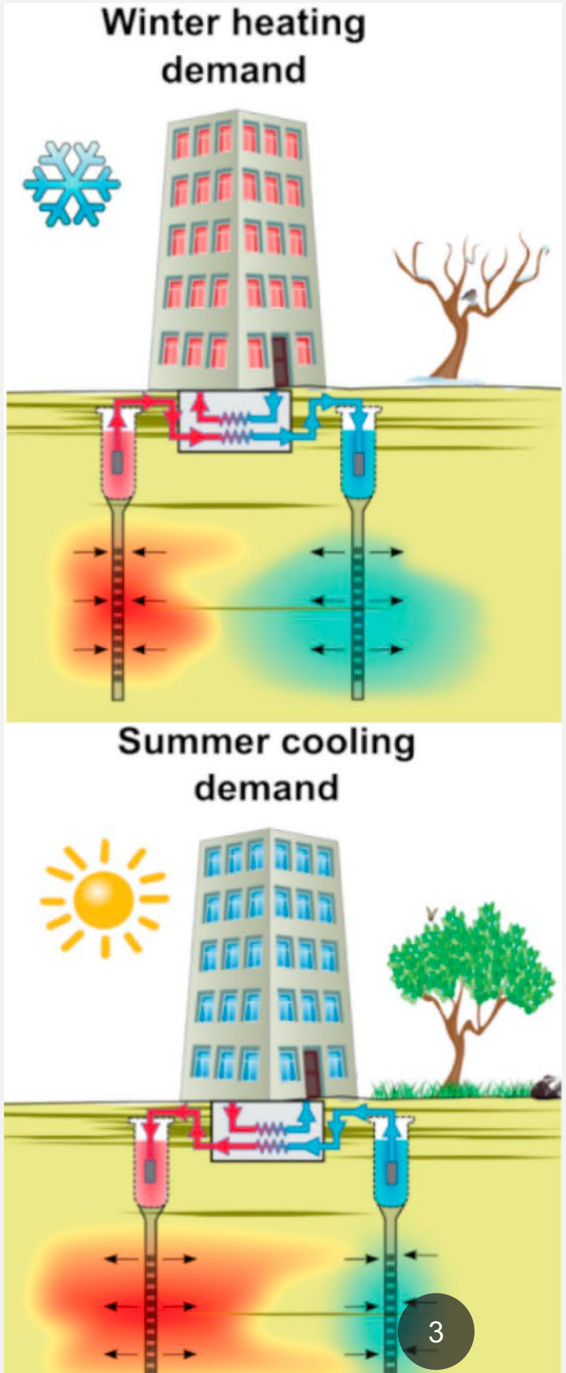
INTRODUCTION

GROUND-SOURCE HEAT PUMP (GSHP)

- GSHP : cleanest & energy efficient in heating and cooling systems
- BHE : Borehole Heat Exchanger



Bonet et al., 2013



Alberti et al., 2013

TRNSYS & MODFLOW

TRNSYS

- Be able to simulate the heat transfer process between the BHE and the ground.
- Doesn't consider the effects of a groundwater flow.

MODFLOW

- MODFLOW can be used to solve the groundwater flow equation.
- MT3DMS is not explicitly designed to simulate heat transport

GOAL

- MODFLOW/MT3DMS to simulate a full BHE having a U-pipe geometry without groundwater flow.
- Difference between MODFLOW/MT3D and TRNSYS in case of groundwater flow.

METHODOLOGY

MODFLOW/MT3DMS

- MT3DMS : simulation of advection, dispersion, and chemical reactions of contaminants in groundwater systems

$$\left(1+\frac{\rho_b K_d}{\theta}\right)\frac{\partial\left(\theta C^k\right)}{\partial t}=\frac{\partial}{\partial x_i}\left(\theta D_{ij}\frac{\partial C^k}{\partial x_j}\right)-\frac{\partial}{\partial x_i}\left(\theta v_i C^k\right)+q_s C_s^k$$

source

MODFLOW/MT3DMS

$$\left(1+\frac{\rho_b K_d}{\theta}\right)\frac{\partial\left(\theta C^k\right)}{\partial t}=\frac{\partial}{\partial x_i}\left(\theta D_{ij}\frac{\partial C^k}{\partial x_j}\right)-\frac{\partial}{\partial x_i}\left(\theta v_i C^k\right)+q_s C_s^k$$

$$\left[1+\frac{\rho_b K_d}{\theta}\right]\frac{\partial\left(\theta T\right)}{\partial t}=\frac{\partial}{\partial x}\left(\theta\left[D^*+D_{ij}\right]\frac{\partial T}{\partial x_j}\right)-\frac{\partial}{\partial x_i}\left(\theta v_i T\right)+q_s T_s$$

CASE STUDY

- The case : 100 m polyethylene U-pipe, 2 cm inner diameter, 6 cm pipe-to-pipe centers distance.
- The U-pipe is located into a 200 m saturated sandy aquifer, assumed homogeneous.
- The aquifer has an initial uniform temperature of 11.8°C.

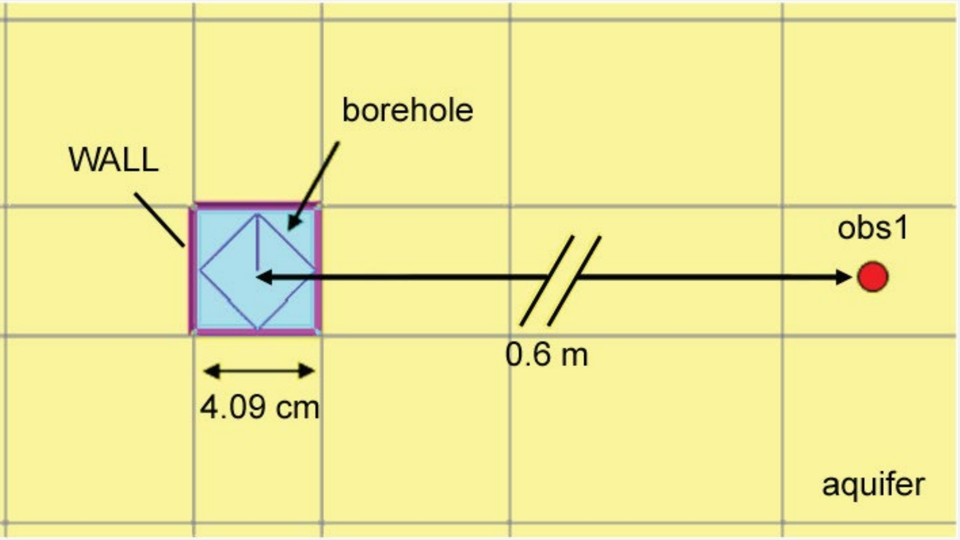
	First winter (1^{st} Jan – 15^{th} Apr)	First pause (16^{th} Apr – 31^{st} May)	Summer (1^{st} Jun – 31^{st} Aug)	Second pause (1^{st} Sep – 15^{th} Oct)	Second winter (16^{th} Oct – 31^{st} Dec)
Time [d]	105	46	92	45	77
T_{in} [°C]	6	-	30	-	6
Mass rate [kg/h]	1000	0	1000	0	1000

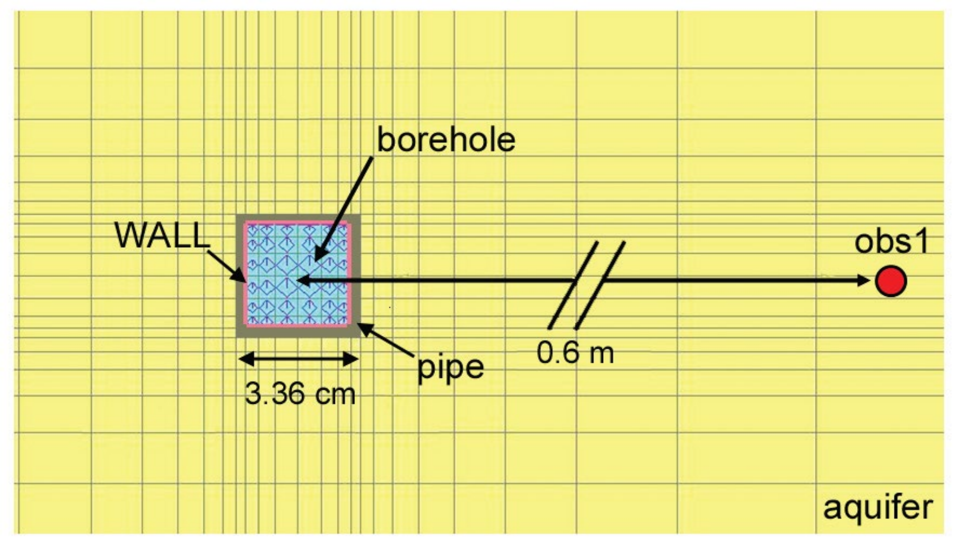
Alberti et al., 2013

MODEL IN MODFLOW/MT3DMS

- Constant Head (CH = 100cm) and Constant Temperature (T = 11.8°C)

Descending branch of the U pipe → Thermal resistance of the plastic pipe





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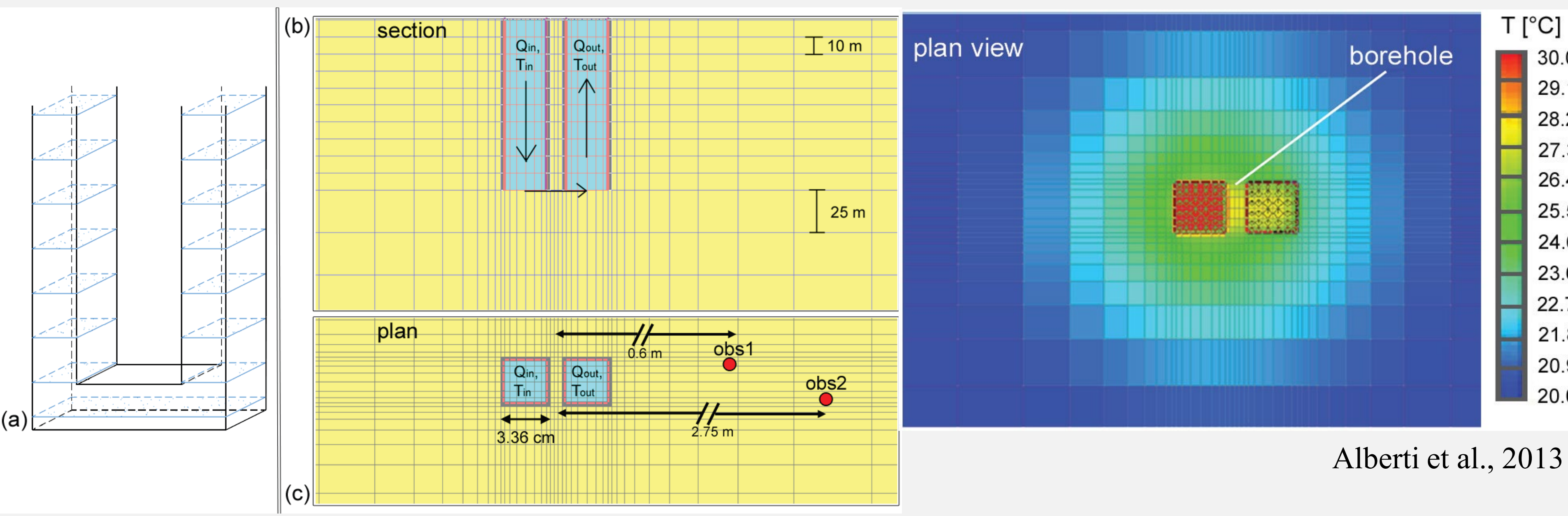
MODEL IN MODFLOW/MT3DMS

The entire U pipe



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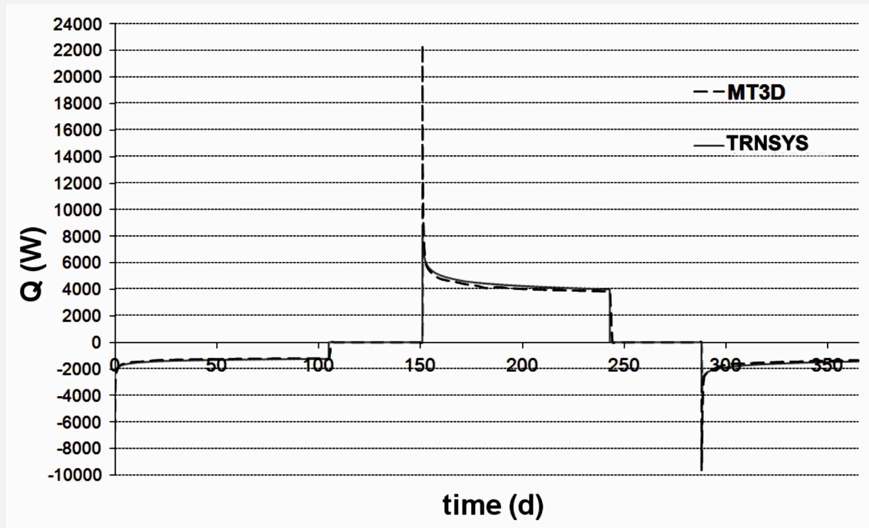
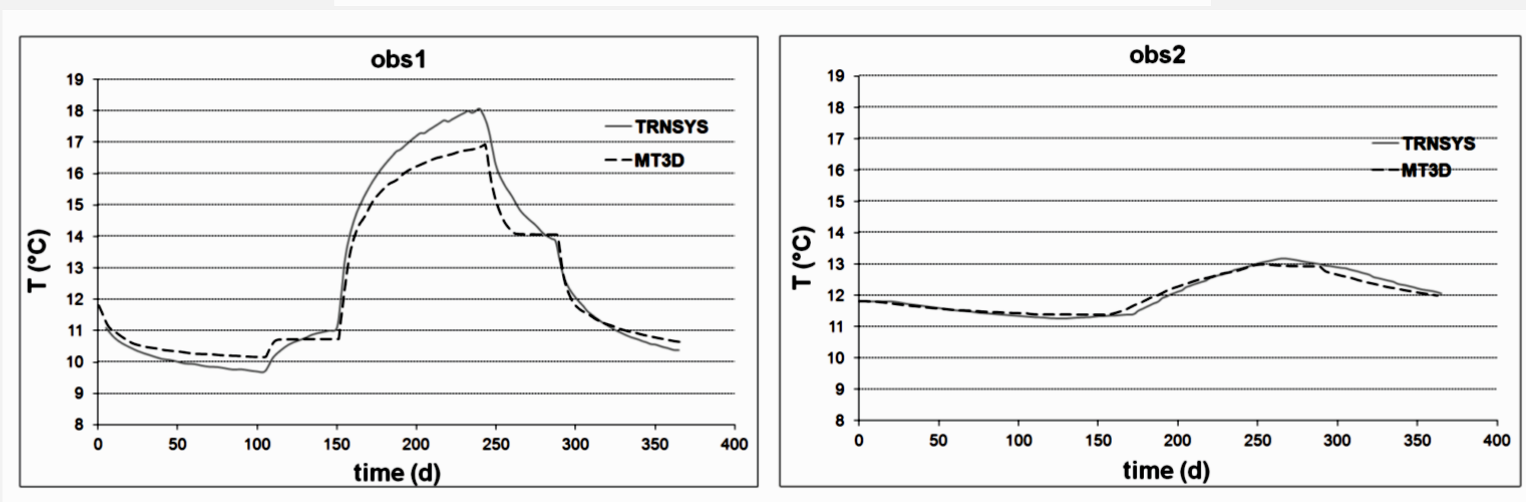
RESULT

SIMULATIONS WITHOUT GROUNDWATER FLOW





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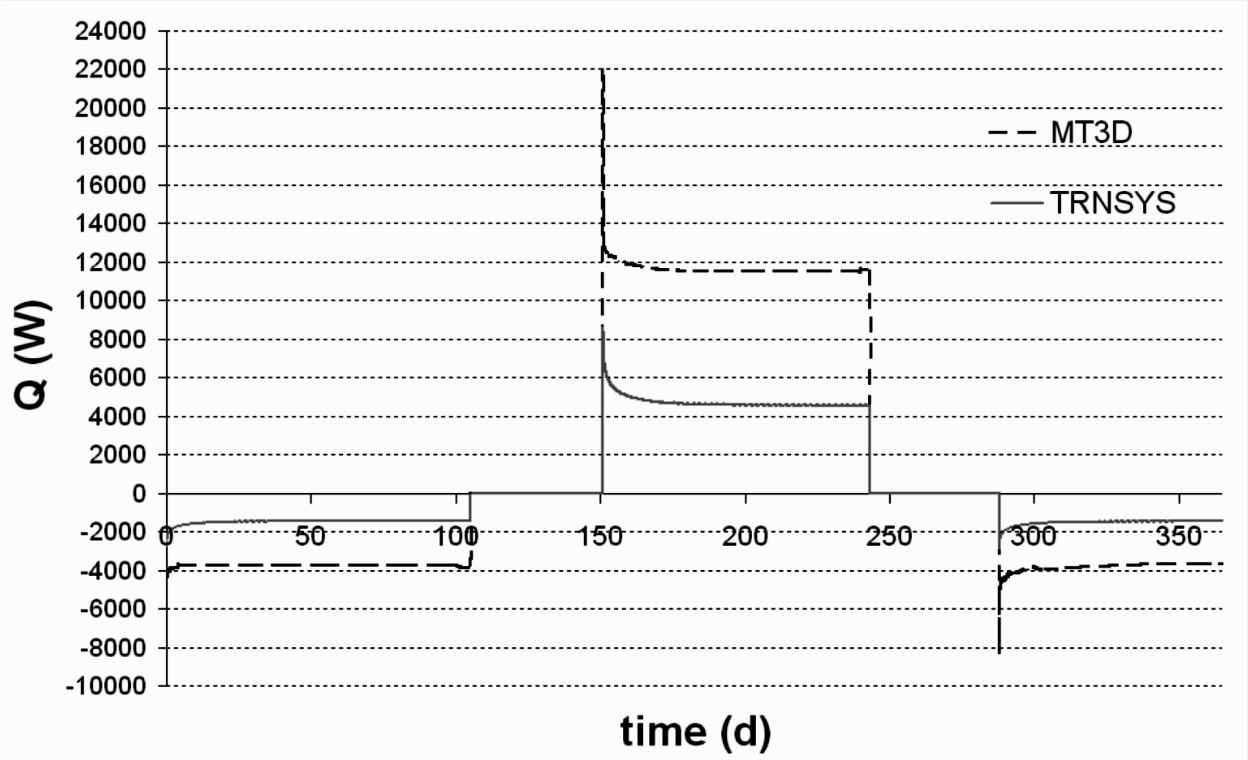
SIMULATIONS WITH GROUNDWATER FLOW



Alberti et al., 2013

CONCLUSIONS

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- It is a good agreement between the results of the two software, In the absence of groundwater flow.
- MODFLOW/MT3DMS looks to be more suitable to represent cases where groundwater flow can’t be neglected.

FUTURE WORKS

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- Using GemPy to build a geological model with known borehole data.

- Combining MODFLOW with geological models.

THANK YOU FOR YOUR ATTENTION