Temperature as a powerful tool in understanding the subsurface process and properties

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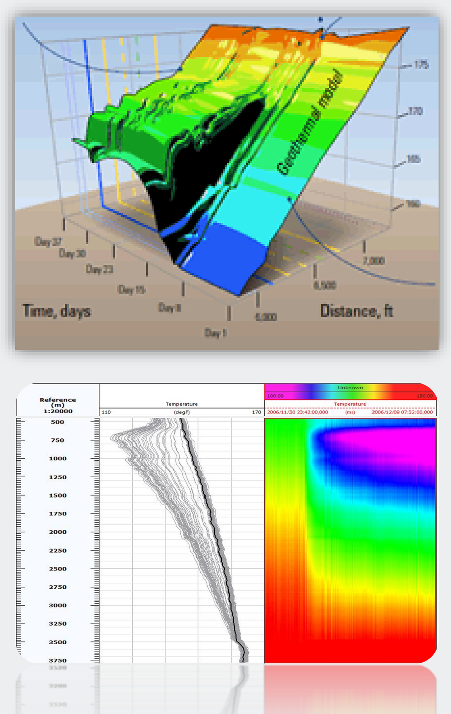
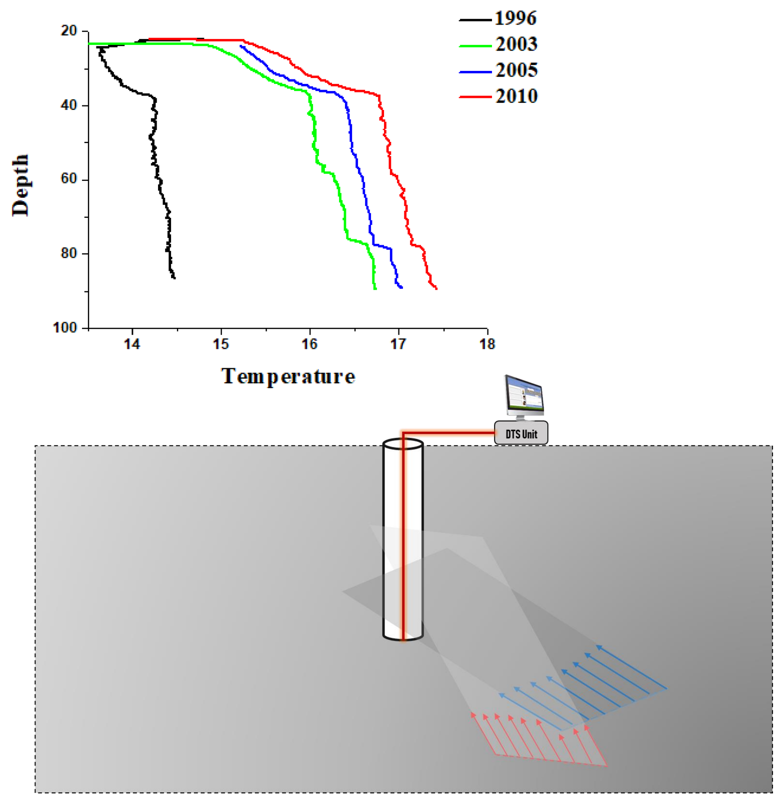
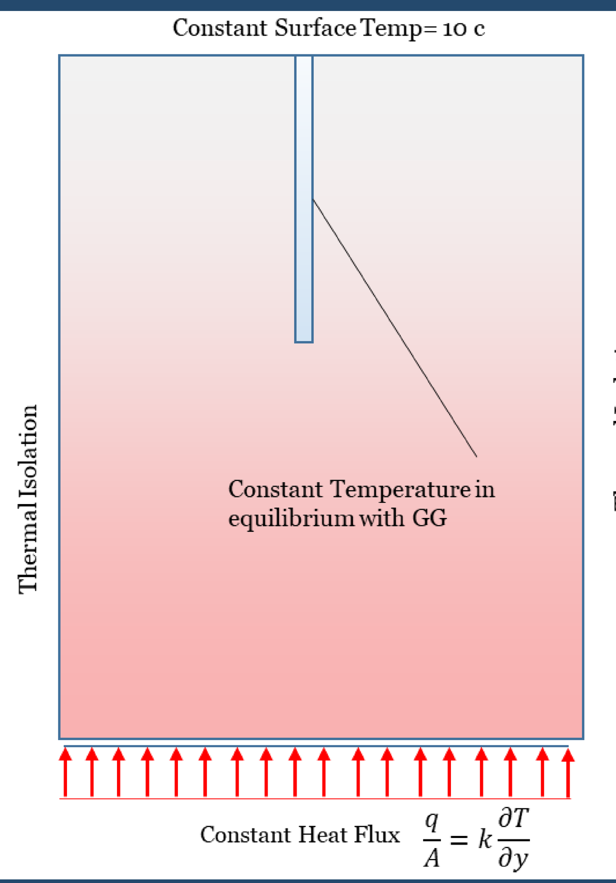
Introduction

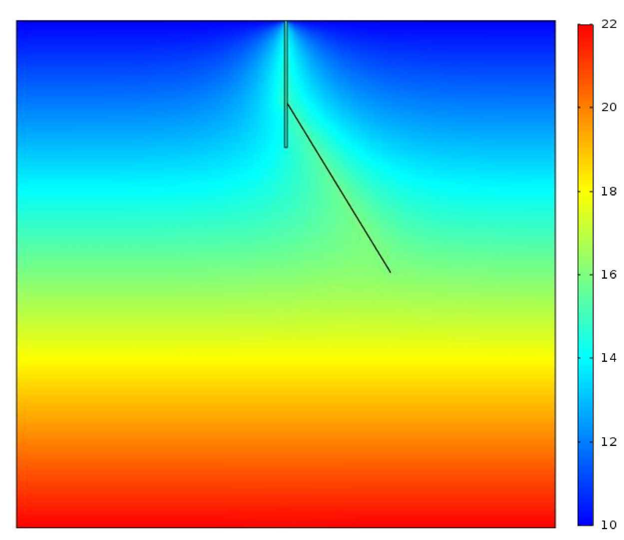
Fiber Optic Distributed Temperature Sensing (FO-DTS) is an innovative tool that allows continuous temperature monitoring with an excellent spatial resolution. Recent applications demonstrate the utility of passive FO-DTS for characterizing flows and monitoring thermal tracer tests in heterogeneous media. Passive methods are however often limited to qualitative information about flow distribution. Active methods, which consists in using heated cables or local thermal sources showed very promising results to quantify distributed flow velocities. In this project we intend to employ Fiber Optic DTS for measurement and real time monitoring of subsurface flow in both fractured and heterogeneous porous media aquifers. In the first part of the project we want to show the value of long term temperature monitoring in description of the fractured aquifer system. In second part, using so called Active-DTS techniques (in which heat is added to the system in order to improve sensitivity of the DTS temperature measurement to fluid flow) that serve to enhance the applicability of DTS in heterogeneous sedimentary aquifer systems.



Values of Long term Temperature Evolution monitoring in understanding of heat redistribution in Fractured System







- **Observation:** Temperature Evolution with time in Fractured Aquifer
- **Motivation:** Understanding about the fracture system (effective flow path, etc.) and redistribution of the heat in Fractured Aquifer
- Investigating the long term heat distribution in fractured aquifer through using numerical models

Flow Profiling

- **Flowing Zone**

$$\frac{dH}{dz} - \frac{g}{Jg_c} + \frac{v}{Jg_c}\frac{dv}{dz} = \pm\frac{Q}{W} \quad [1]$$

$$dH = \left(\frac{\partial H}{\partial T}\right)_P dT + \left(\frac{\partial H}{\partial P}\right)_T dP = C_p dT - C_J C_p dT$$

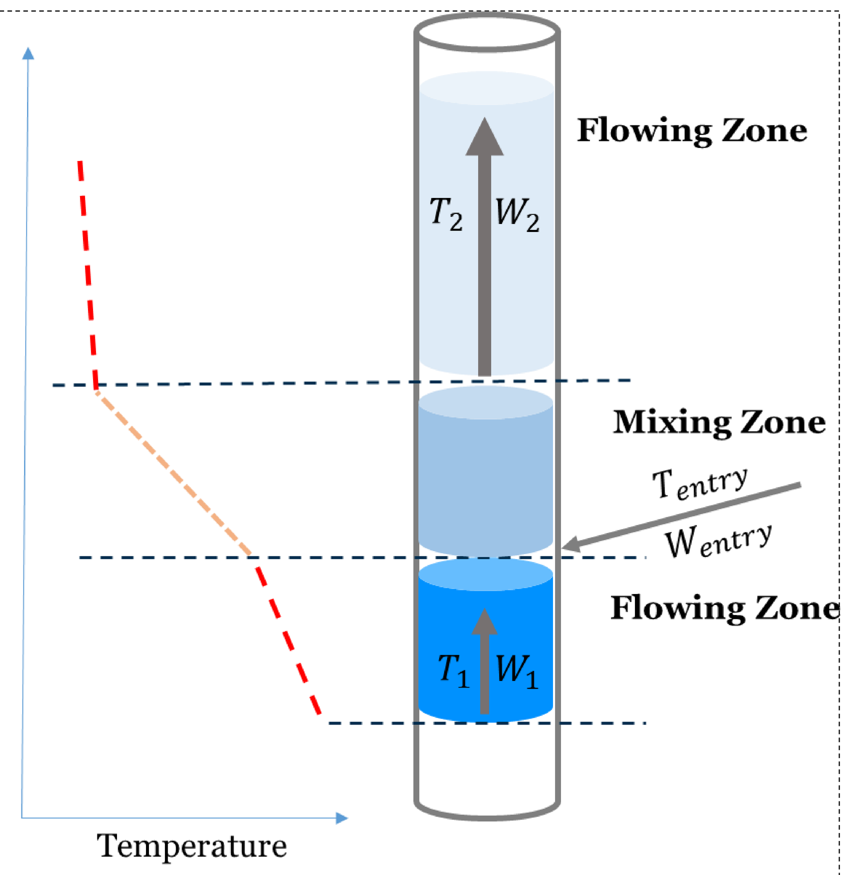
$$\frac{dT_f}{dz} = C_J\frac{dP}{dz} + \frac{1}{C_p}\left[-\frac{Q}{W} + \frac{g}{Jg_c} - \frac{v}{Jg_c}\frac{dv}{dz}\right]$$

$$T_f = (T_{bh} - a\times z) + a\times A\times\left(1 - e^{-\frac{z}{A}}\right) + (T_{if} - T_{ei})e^{-\frac{z}{A}} \quad [2]$$

- **Mixing Zone**

$$W_1\left(\frac{dH}{dz} - \frac{g}{Jg_c} + \frac{v}{Jg_c}\frac{dv}{dz}\right) + \frac{W_{entry}C_p(T_f - T_{entry})}{dz} = -Q \quad [1]$$

$$\frac{dT_f}{dz} + \frac{(1-\lambda)}{\lambda}\frac{T_f - T_{entry}}{dz} = \frac{L_R}{\lambda}(T_{ei} - T_f) + \left(\frac{g}{Jg_c C_p} - \emptyset\right) \qquad \lambda = \frac{W_1}{W_1 + W_{entry}}$$



- **Approach**

Primary estimation of flow rate in each flowing zone

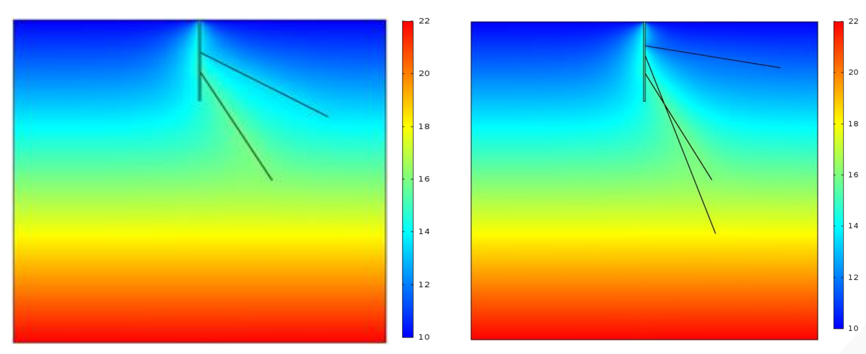
$$\frac{dT_f}{dz} = (-a) + a\times A\times\frac{1}{A}\left(e^{-\frac{z}{A}}\right) - \frac{1}{A}(T_{if} - T_{ei})e^{-\frac{z}{A}} \qquad \left.\frac{dT_f}{dz}\right|_{z=0} = (-a) + a\times A\times\frac{1}{A} - \frac{1}{A}(T_{if} - T_{ei})$$

$$\left.\frac{dT_f}{dz}\right|_{z=0} = \frac{1}{A}(T_{if} - T_{ei}) \qquad A(t) = \frac{W\times C_p\times f(t)}{2\pi k}$$

Then we use the primary estimated flow rate as an initial input to SPSA algorithm to decrease the mismatch between observed data and predicted data by Rami equation.

$$f(q) = \sum|T_{observed} - T_f|$$

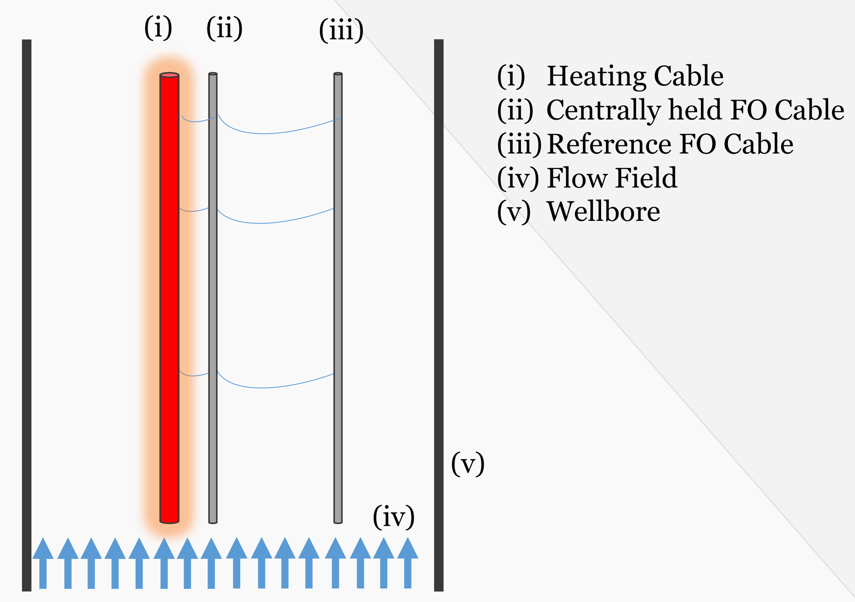
- Obtain Flow rate in each flowing zone using above approach
- Obtain Flow rate of each Fracture from equation in Flowing zone (W2-W1)
- Obtain fluid temperature for each fracture from mixing zone equation (T_{entry})



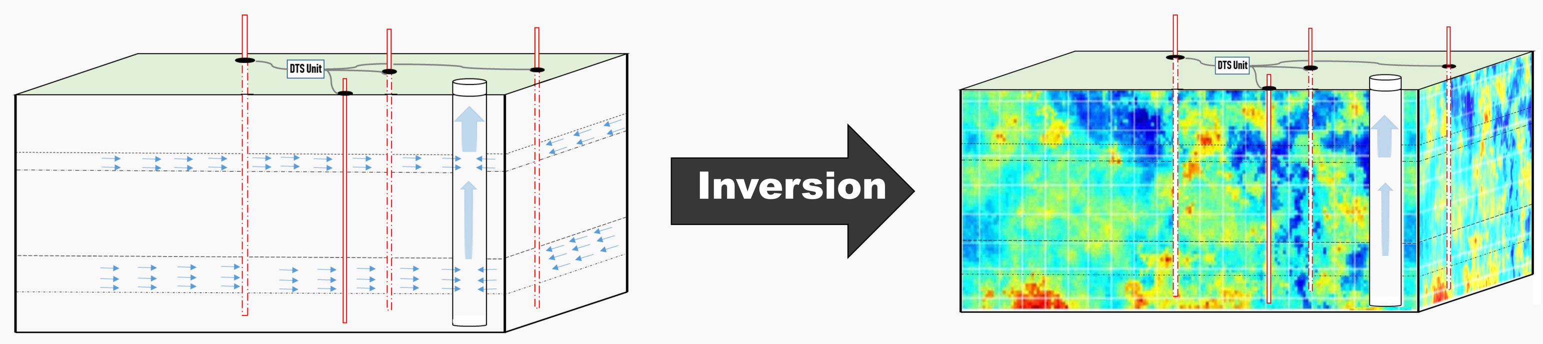
- To be done next
1. Validating Flow Profiling approach using a numerical Model
2. Applying the approach to analysis seasonal temperature variation and recharge to understand about change of fluxes

A-FO DTS for ground water velocity in heterogeneous aquifers

- Active Fiber Optic DTS is a method of DTS data collection based on using a heated fiber optics cable(s) and monitoring the thermal response during the heating and/or the cooling phase. Active DTS can be used for measurement of thermal properties and directly dependent quantities like advective fluxes of water and air [3].



- **Prospective**
- Testing the use of Active Fiber optic DTS in a pilot porous media for sensing of fluid velocity
- How to use the measured velocity for better understanding of the aquifer properties (inversion approach)
- How to manage the measurement (Number and Location of A-FO DTS) to have more efficient information for further processing
- The limitation and advantage of this approach



References

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ITN Enigma

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