Research Summary

Analysis of DTS Data - A Quantitative Approach

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Outline

- Personal Background
- Previous Work
- DTS – Overview and Principles
- Modeling
- Summary/Planned Work
- Outcomes

Personal Background

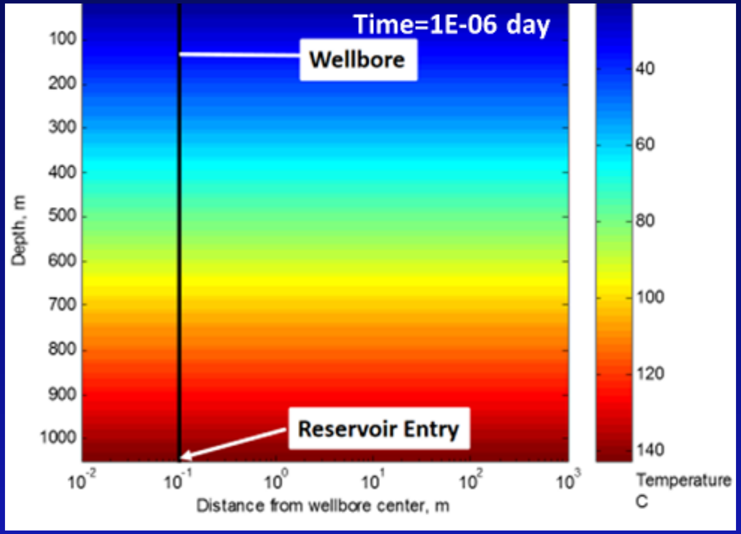
- BS in PE from Istanbul Technical University (2012)
- Started MS in ITU (2013)
- Worked on wellbore heat loss ~ 2 years
- In-House Simulator
- Transferred to CSM for MS (2015)
    - Started working for UREP
    - Became a FAST student member (2016)

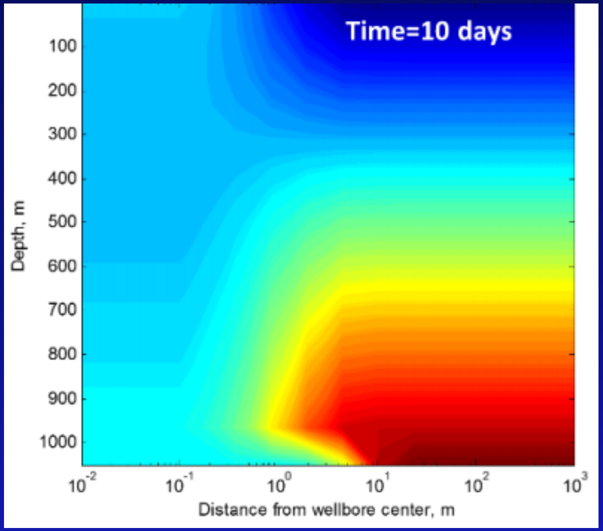
Previous Work

- Investigation of temperature profiles in geothermal wellbores:
- Modification and code porting of an existing geothermal simulator
- Investigation of wellbore temperatures and stabilization times in dynamic and static conditions
- Investigation of cross-flow between two layers
- f(t) correlation recommendation

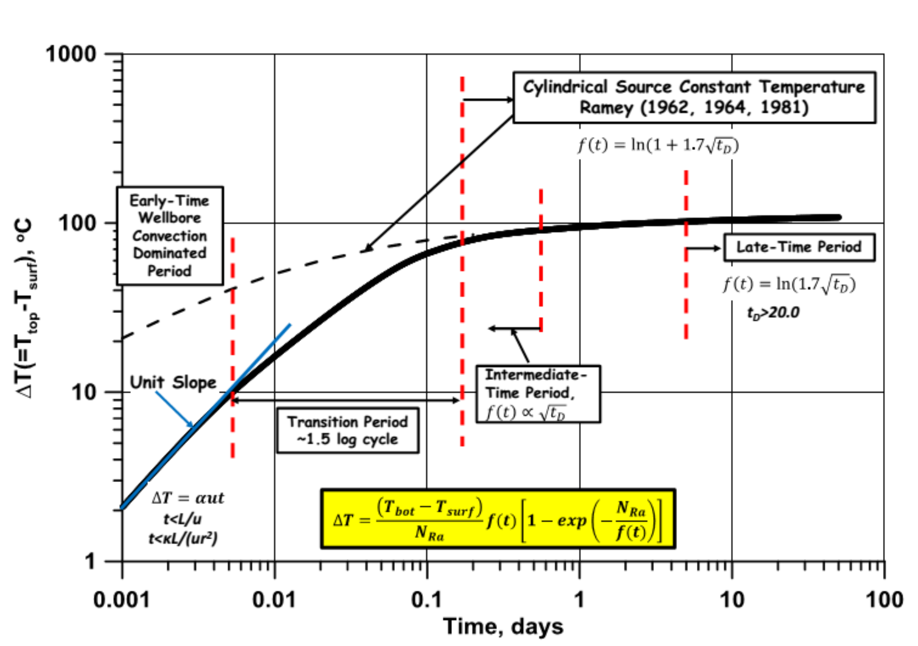
Injection with 60°C

Kutun et. al. (2014)





Previous Work



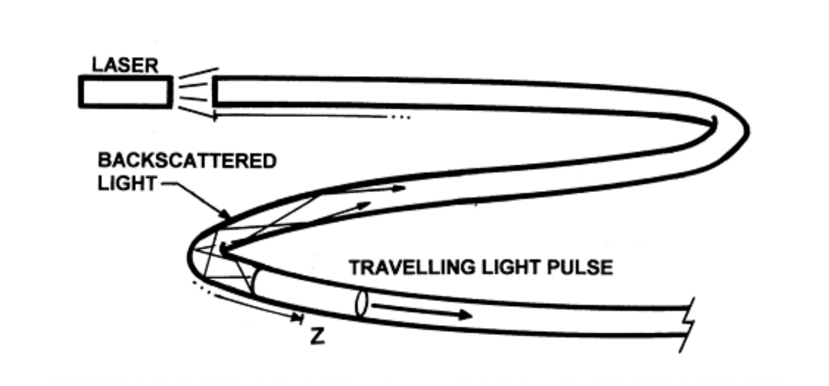
f(t) behavior in early, intermediate, and late times

Kutun et. al. (2015)

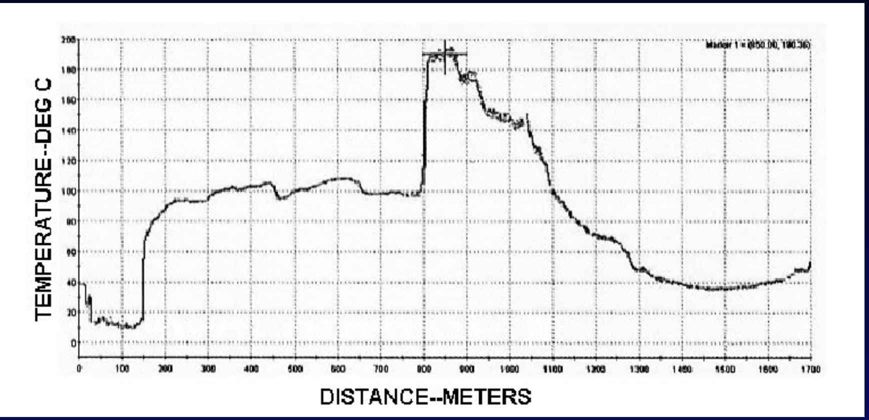
- Parameters are hard to extract when you have a single gauge
- Low industry interest
- Code simplification / interfacing for future use
  - Heat exchangers
  - Sandface temperature change with injection

DTS – Overview and Principles

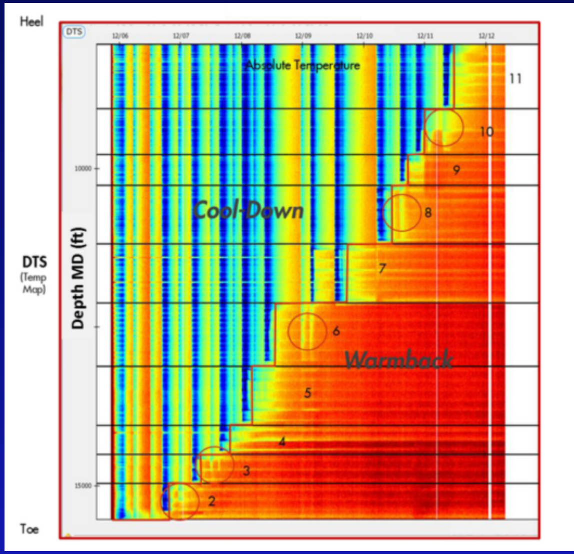
Measurement Principle[1]



Instantaneous Temperature Profile[1]

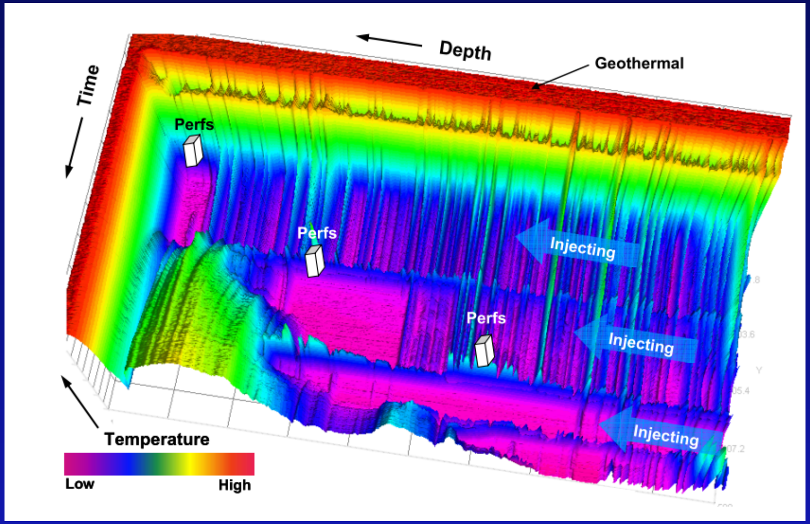


2D Temperature Profile vs Time[2]



1: Smolen & van der Spek (2003)
2: SPE179124MS
3: SPE 116182-MS

3D Temperature Profile vs Time[3]



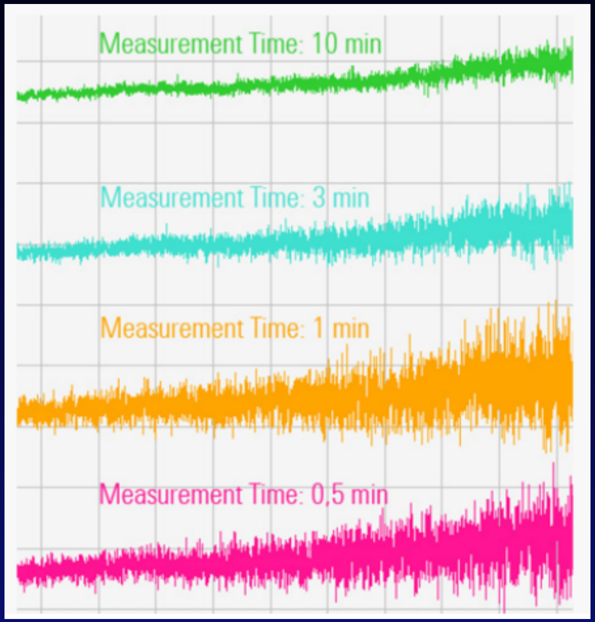
DTS – Overview and Principles

- The Good:
  - A lot of “sensors”
  - Already in place. Can capture transients
  - At first glance there are some PTT like behavior
  - Industry interest
- The Bad:
  - It is not a direct measurement. Has it’s own limitations
  - High signal to noise ratio
  - Quantitative approaches are scarce in literature
  - Very dependent on the wellbore
- The Ugly:
  - Getting the data
  - Unconventional multistage fracturing: Not too easy to model

DTS – Overview and Principles

Temporal resolution:

- Unlike DAS*, DTS pulses are averaged over a time interval (~30 sec – 6 hours)
- Due to the high signal/noise ratio in individual pulses
- Mechanical movement of multiplexer mirror



(Shoyer & Dria, 2016)

- Negative implications on modeling, especially if you are considering derivatives
- What happens when you go below 30 sec sampling intervals? How bad is it?

DTS – Overview and Principles

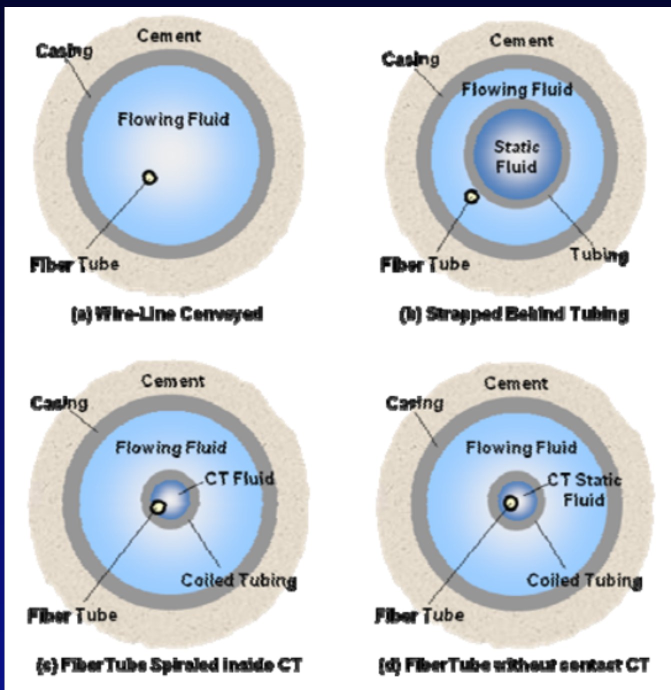
Calibration:

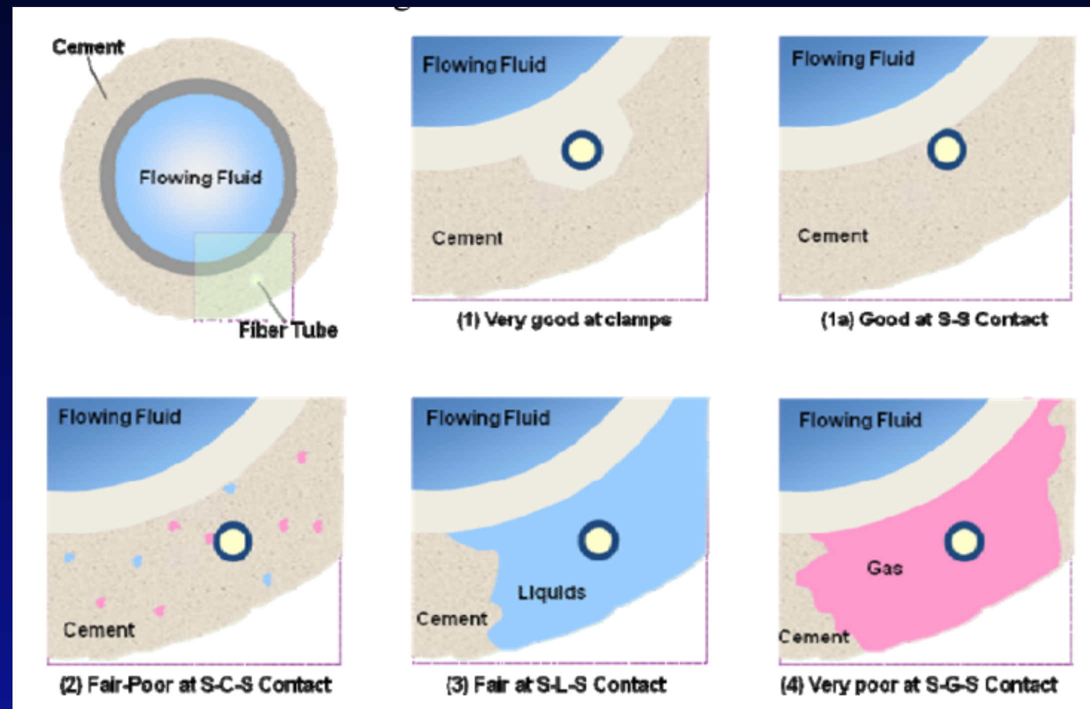
- Wellhead calibration coil and temperature gauge at BH
- Determination of wellbore entry
    - There is considerable amount of fiber at surface
- Sagging and winding/rotation makes depth correlation a challenge
- Getting lost in the wellbore, misidentification of clusters

(Shoyer & Dria, 2016)

DTS – Overview and Principles

Wellbore dependency





(Sierra et. al., 2008)

Modeling

- Lack of data
- Initial objectives are to gain:
  - The ability to create synthetic data
  - Numerical know-how on coupling WB-Frac-Reservoir flow
- Medium term objective is to have basic matching capability

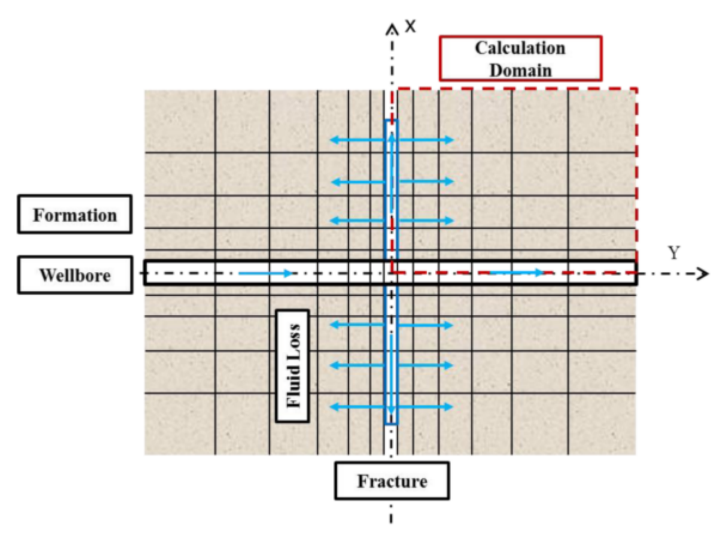
Modeling Approach

- Replicate/Use a recently published model by Li and Zhu (2016)
- Create a simple, conduction only, warm back model
  - Given initial temperature distribution

Modeling – Problem Overview / Challenges

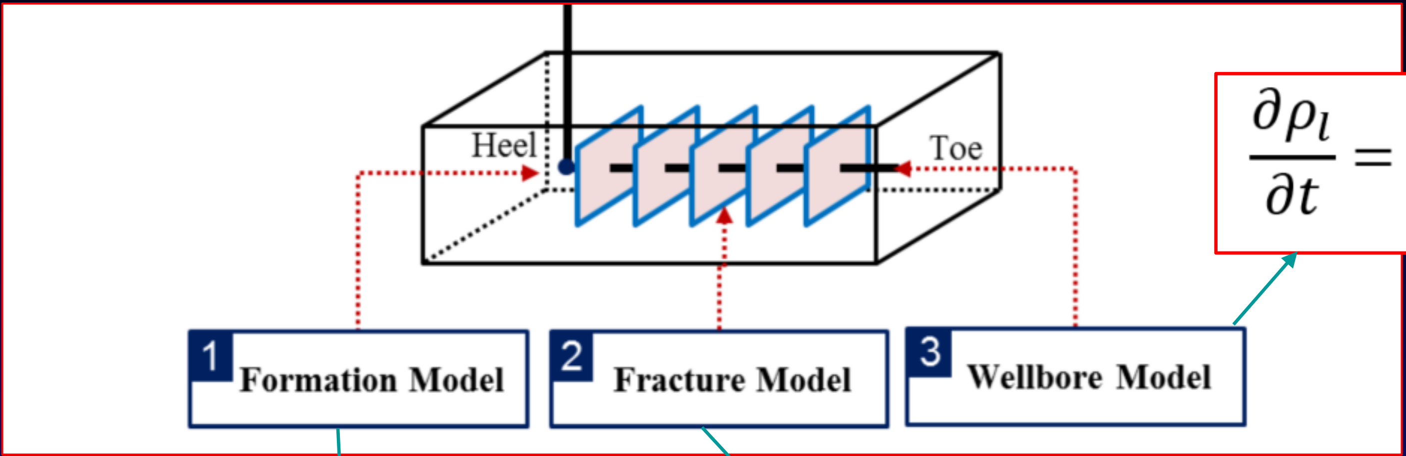
- Wellbore: Horizontal flow at very high rates
- Fracture: Changing length -> surface available to leakoff
- Reservoir: Leakoff into unconventional reservoir rock. Theory of flow in this medium is still developing.

- While assuming
  - Perfect cement and packers
  - Single cluster
  - Single phase flow, no chemical effects
  - Perpendicular, planar fractures



(Li and Zhu, 2016)

Modeling – Li and Zhu – Mass Balance



$$\frac{\partial \rho_l}{\partial t} = \frac{2\gamma}{R}\rho_l v_I - \frac{\partial \rho_l v}{\partial y}$$

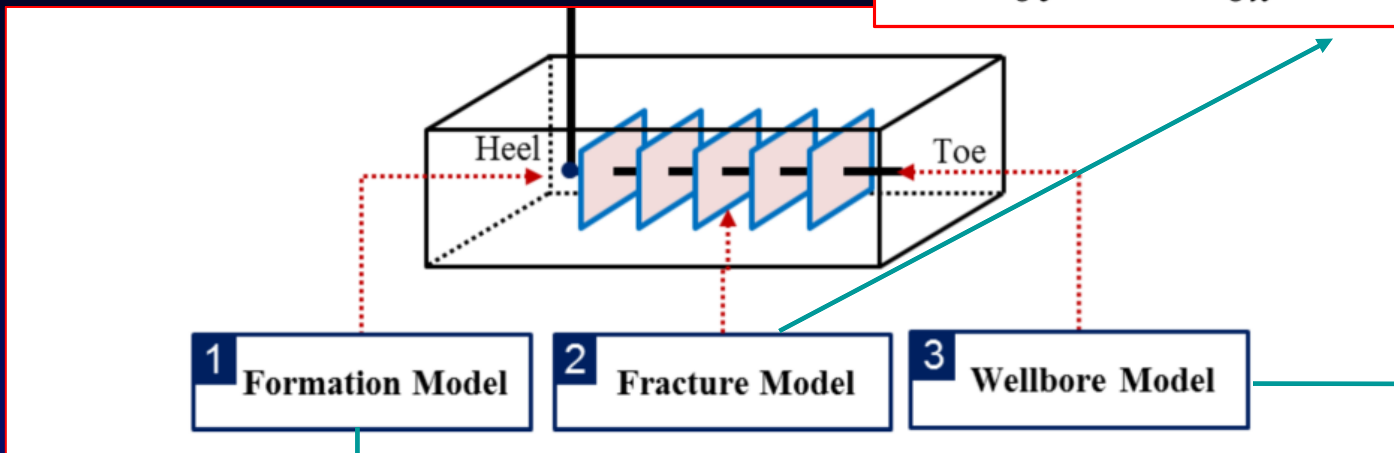
$$2wh\frac{dX_f}{dt} = whv_x(x,t) - 2h\int_0^{2X_f(t)} \frac{C_{lk}(t)}{\sqrt{t-\tau(x)}}dx$$

$$Y_{lk}(x) = \int_{\tau(x)}^{t} v_{lk}dt = \int_{\tau(x)}^{t} \frac{C_{lk}}{\sqrt{t-\tau(x)}}dt$$

Modeling – Li and Zhu – Heat Balance

•

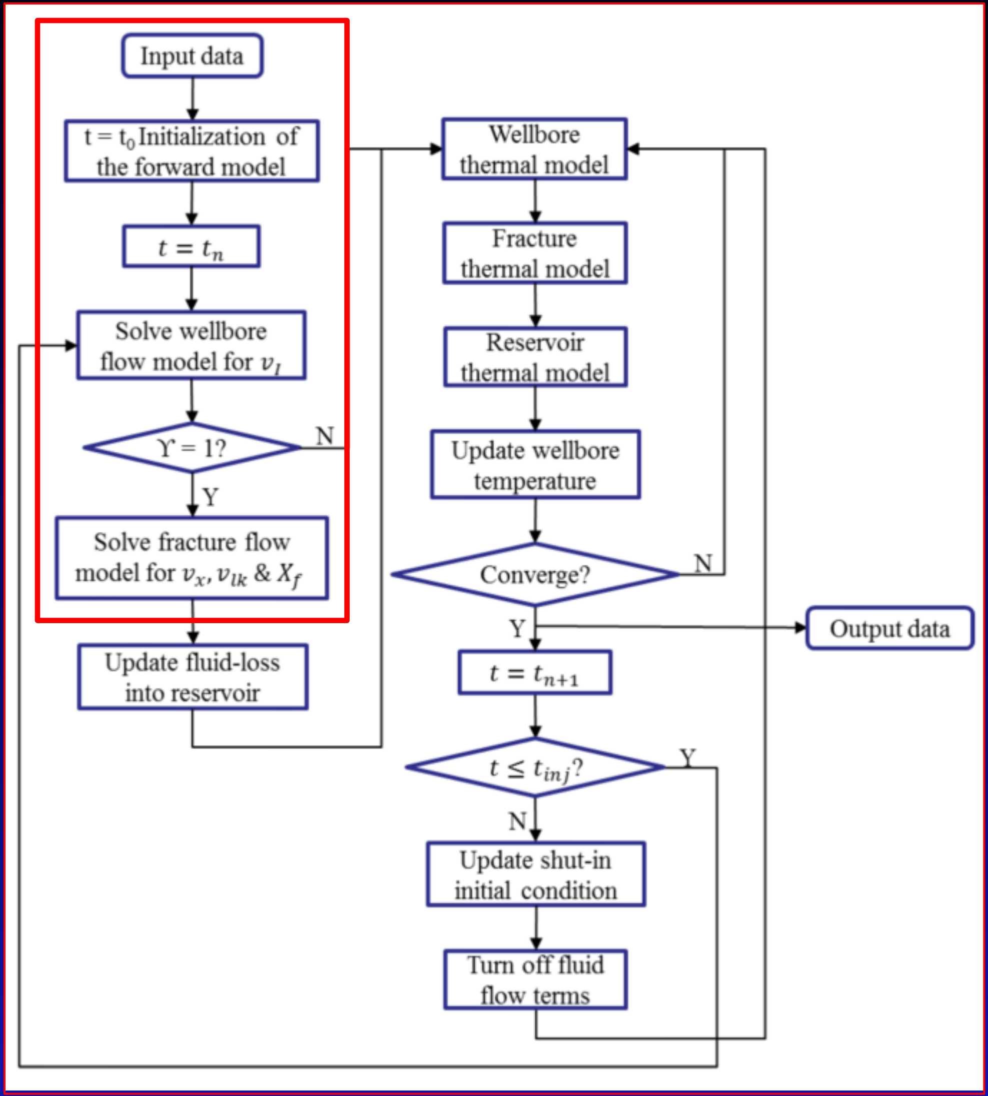
$$\rho_l \hat{C}_{pl} \frac{\partial T_l}{\partial t} = -\frac{\rho_l \hat{C}_{pl} v_x \partial T_l}{\partial x} - \frac{2\rho_l \hat{C}_{pl} v_{lk} T_l}{w} + \frac{2h_l (T_r - T_l)}{w}$$



$$\overline{\rho \hat{C}_p} \frac{\partial T_r}{\partial t} - \phi \beta T_r \frac{\partial p}{\partial t} = -\rho_l \hat{C}_{pl} v_{lk} \frac{\partial T_r}{\partial y} + (\beta T_r - 1) v_{lk} \frac{\partial p}{\partial y} + \frac{\partial}{\partial x}\left(K_e \frac{\partial T_r}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_e \frac{\partial T_r}{\partial y}\right)$$

$$\rho_l \hat{C}_{pl} \frac{\partial T}{\partial t} = \frac{2\gamma}{R} \rho_l \hat{C}_{pl} v_I (T_I - T) + \frac{2(1-\gamma)}{R} U_T (T_r - T) - \rho_l \hat{C}_{pl} v \frac{\partial T}{\partial y} - \rho_l v g \sin\theta$$

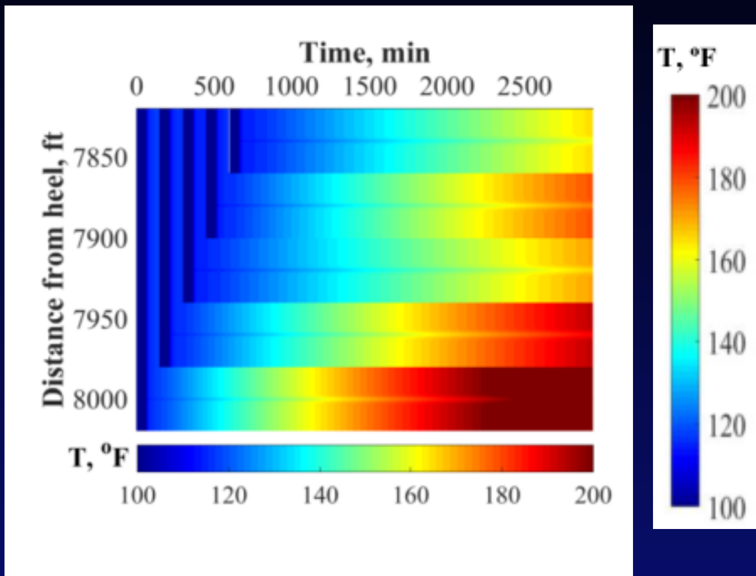
Modeling – Li and Zhu – Workflow

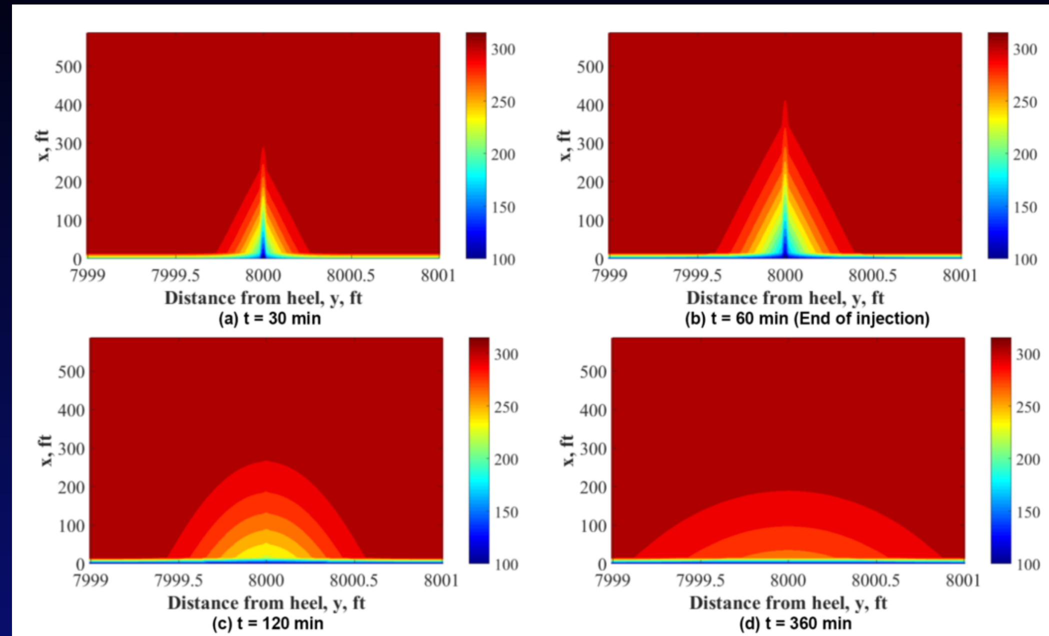


Concerns

- Reservoir flow is defined just by using the leakoff model. May over/under predict the flow away from the fracture
- Minimum time step is reported as 120 seconds in the study. Convergence issues?

Modeling – Li and Zhu





- This model is able to predict:
  - Simple single stage
  - Multistage fracturing job with different fracture/cluster characteristics
- Next step once the model is up and running is to identify critical assumptions and fix as many of them as feasible
- Then the result can be used as a synthetic dataset in future “inversion” schemes

Summary/Planned Work

- Keep learning about the tool and installations
- Get the model working, investigate assumptions
- Generate synthetic data and try to invert for:
    - Cluster efficiencies
    - Fluid distribution
    - Fracture geometry
- Investigate the derivatives:
    - Temporal and Spatial
- Be ready for real data

Outcomes

"A quantitative look into DTS data with the help of numerical models with the aim of extracting more information from present and future datasets"

- Cluster performance
- Fracture geometry
- Early identification of wellbore events/problems
- Added value to DTS data/installations
- Better understanding of near fracture temperatures

Questions

Thank you!
Any Questions or Comments?

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