SCENARIO MODELLING FOR HIGH TEMPERATURE UNDERGROUND HEAT STORAGE

JULIAN MINDEL, THOMAS DRIESNER

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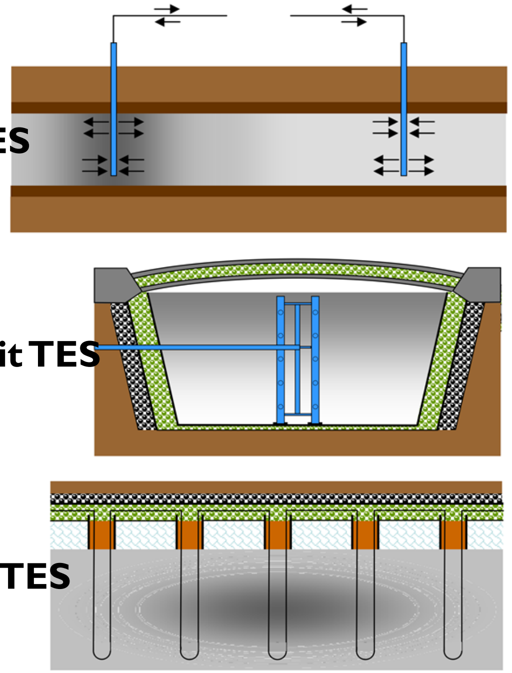
BACKGROUND

- Thermal Energy Storage (TES) systems are critical for improving the efficiency of energy use.
- Aquifer TES systems (ATES) have great potential in comparison to other Underground TES (UTES) systems:
  - simpler design
  - high injection and extraction rates
  - large thermal heat capacity at relatively lower costs
- Feasibility of ATES systems is heavily reliant on local favorable geology.
- HEATSTORE: 1 of 9 under GEOTHERMICA – ERA NET Cofund
  - Advancing the integration of Underground Thermal Energy Storage (UTES) systems with more traditional energy networks.
  - Geneva Project: Study the feasibility of an HT-ATES for seasonal buffering of ~50 GWh/yr from a waste incineration plant via water at 90 [°C] (+/-).



Diagrams above: Schmidt, T., Seasonal thermal energy storage pilot projects and experiences in Germany, Solites, www.solites.de

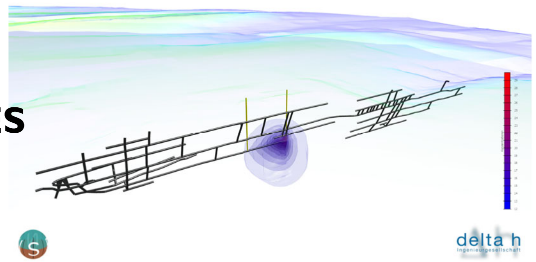


Diagram above: DriesnerT. (ed) 2019: HEATSTORE - Initial report on tools… GEOTHERMICA – ERA NET Cofund Geothermal. 146 pp.

ATES MODELLING PROCEDURE

- Ask questions:
  - What are the local underground characteristics? (static modelling)
  - Where will the hot water go? Can I get (most of) it back? (dynamic modelling)
- Obtain/develop/review a state-of-the-art numerical simulator with necessary characteristics.
- Due to uncertainties, develop possible dynamic scenarios based on known geology and hydrology.
- Study the efficiency of seasonal heat storage in each scenario.
- Assess the individual and combined impact of scenario parameters on the possibility of storing heat (i.e. optimize)
- Iterate.

GEO-01 (744m b.g.l.): Strike-slip fault system, E-W oriented
GEO-02 (1100m b.g.l.): Thust and back-thust structures
GEO-03 (1500m b.g.l.): Same as GEO-02 but deeper
GEO-04 (1500m b.g.l.): Directional well in a Strike-slip fault

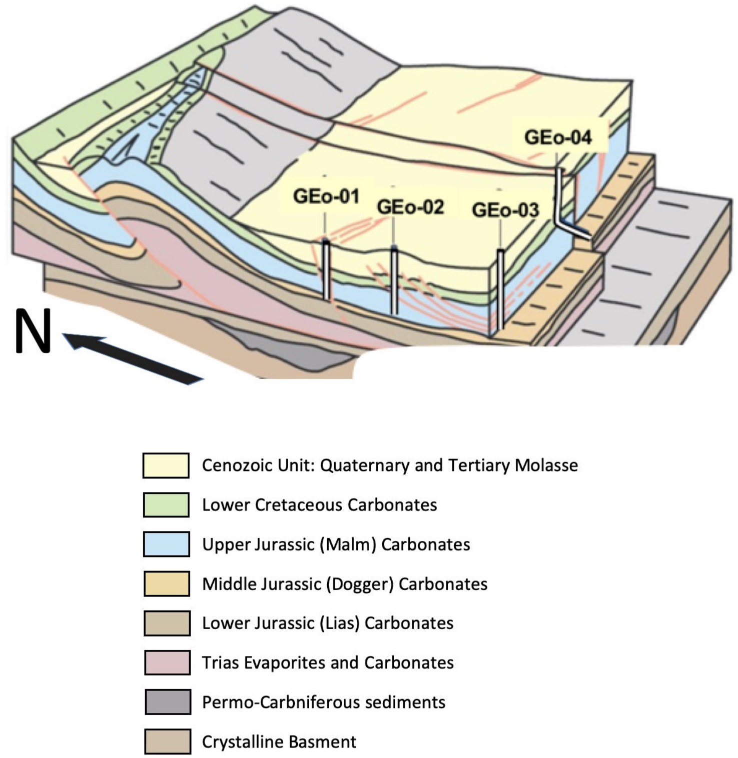


Figure: Illustration of the local geology, locations and targets of the planned GEO-series wells in the Geneva basin (modified from (Nawtratil del Bono, et al., 2019))

heatstore High Temperature Underground Thermal Energy Storage
ETH zürich
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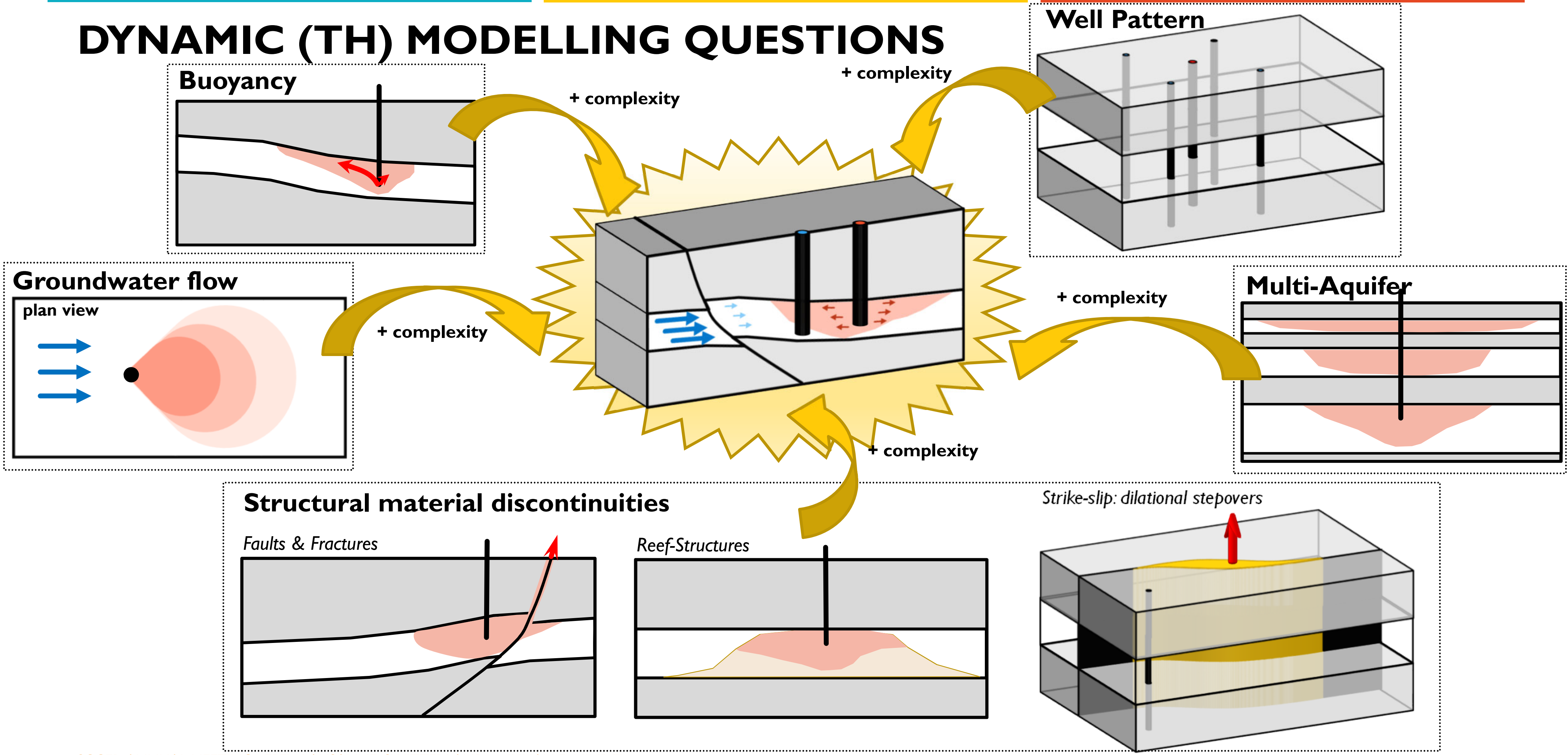
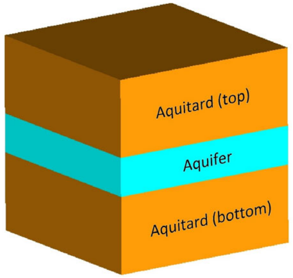
DYNAMIC (TH) MODELLING QUESTIONS

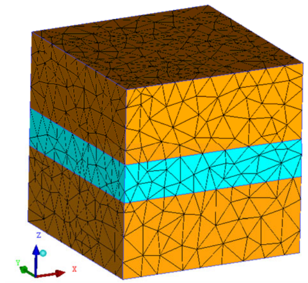


SCENARIO DEVELOPMENT

- Dynamic scenario parameters can be divided into three groups:



Geological model



Geometrical discretization

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e density rock   2670.0
e permeability   1e-13
e porosity   0.2
r well volume flow rate   0.06
end time     15   years
```

Simulation configuration parameters

- Allowing variation in some scenario parameters permits the study of their individual and combined effects on the results.

Aquifer Permeability	Aquifer Thickness	Well Strategy	Groundwater	Fracture Configuration	Aquifer Dip
K13	L200	single	YGW	F0	FLAT
5K13	L300	doublet	NGW	FU	INCL
K12	L400	5spot		FD	

Table: Summary of sub-scenario variant codes.

- Larger complexity leads to a larger parameter space. Picking the most site-relevant factors is key.

SCENARIO PARAMETERS

- Compressible, single phase, porous media flow.
- 15 yearly cycles: Charge (120 days), Store (60 days), Dischar (120 days), Store (65.25 days).
- Charging Temperature, 90 °C.
- Flow rate: 60 L/s
- Model size: $1\ [km^3]$

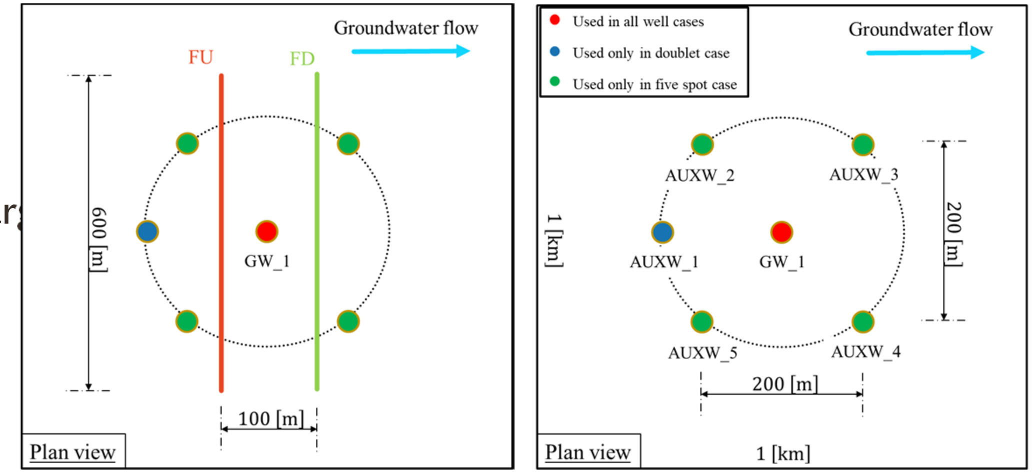
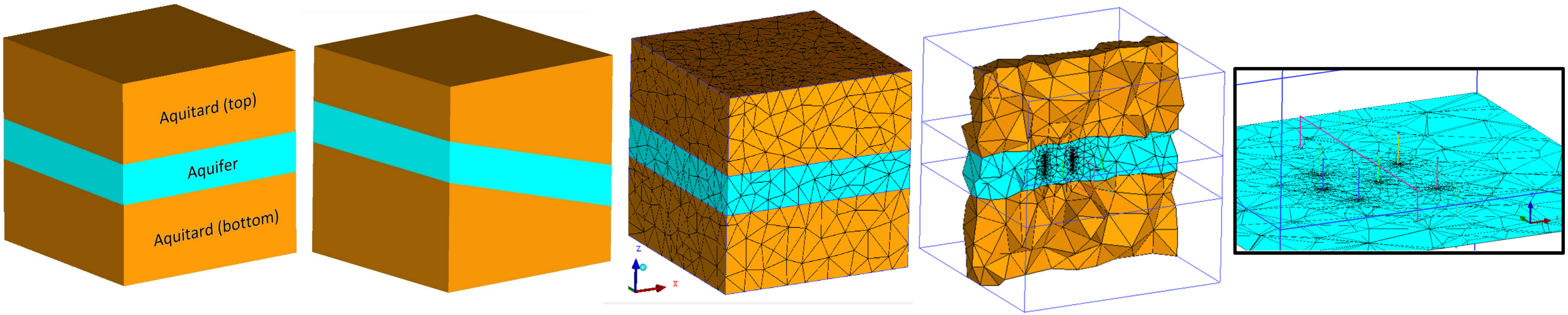
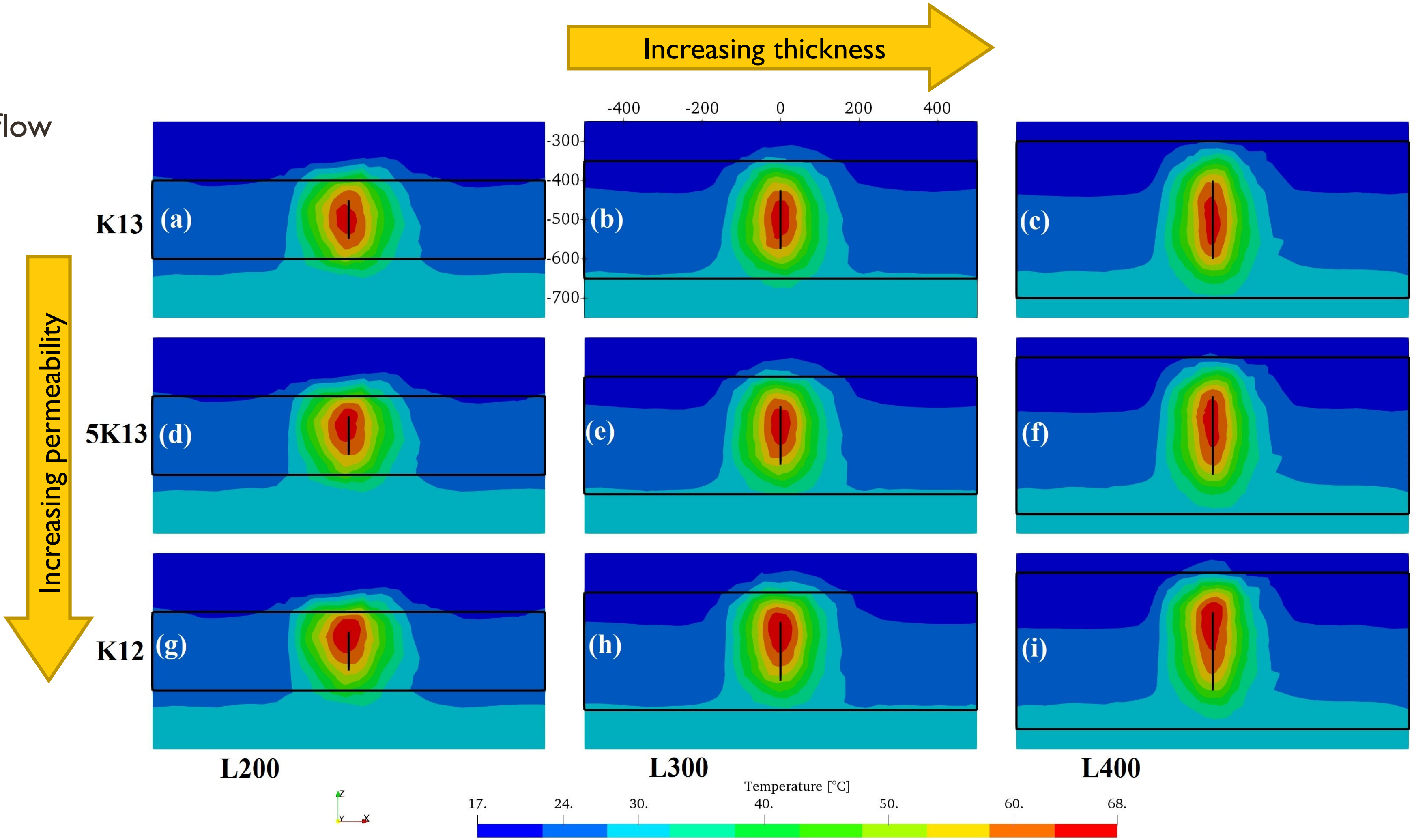


Figure: (above-left) Fracture locations with respect to wells, and (above-right) the specific x-y plane view of well locations and respective names .



RESULTS

- No groundwater flow
- No dip
- No fractures
- Single well

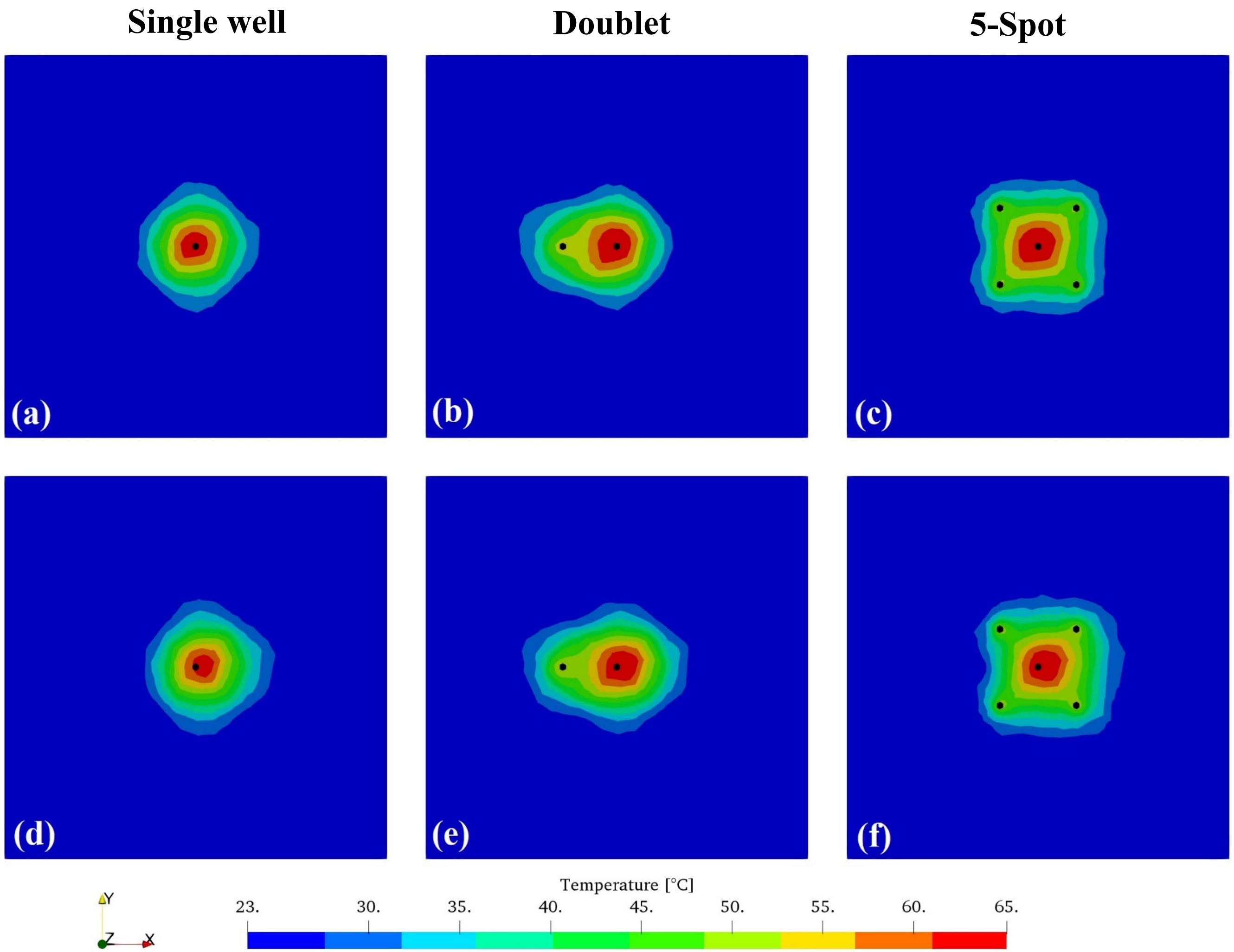


RESULTS

- Equal permeability (K12)
- Equal thickness (L200)
- No dip
- No fractures

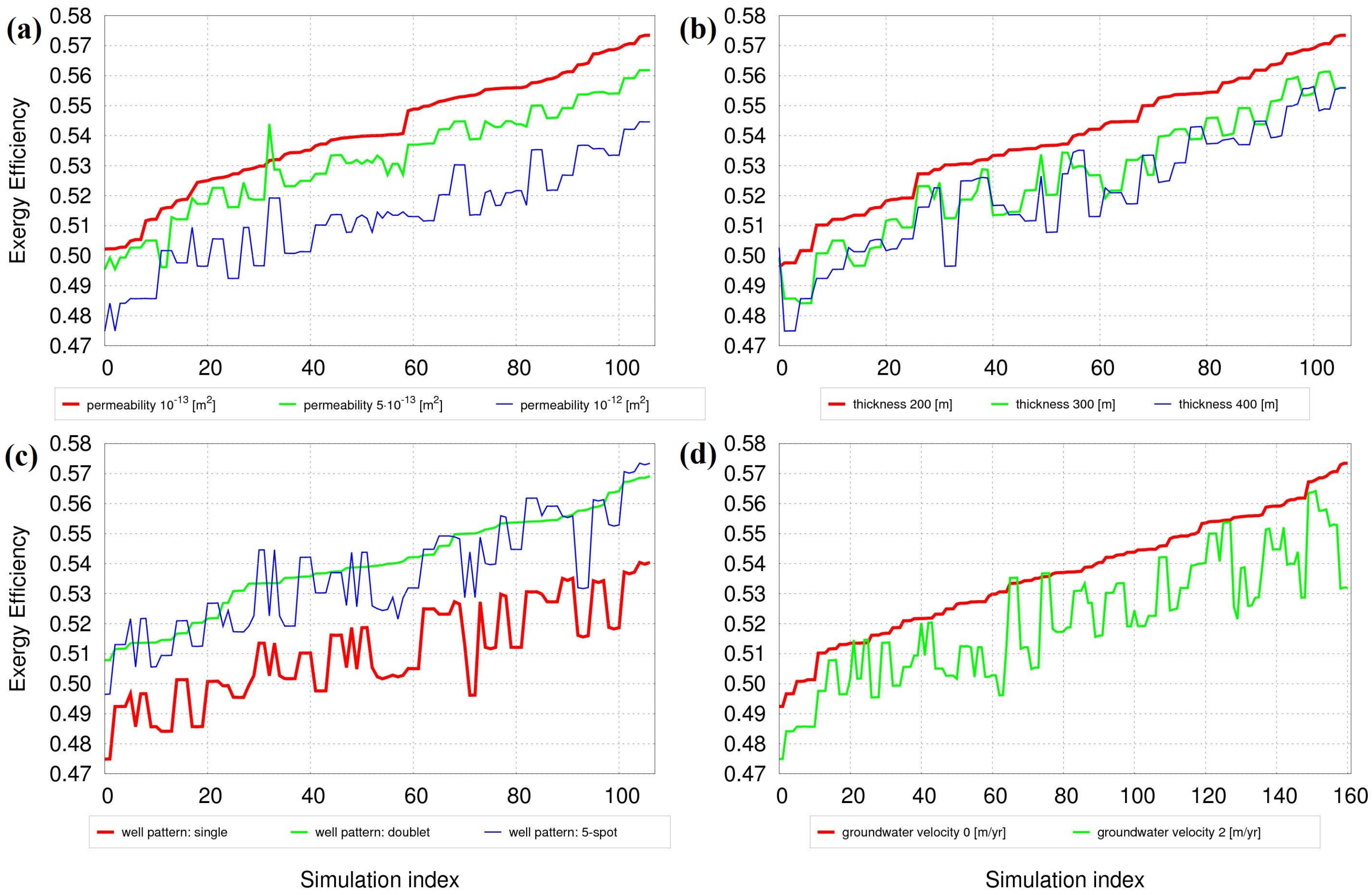
GW Flow: 0 $\left[\frac{m}{yr}\right]$

GW Flow: 2 $\left[\frac{m}{yr}\right]$



RESULTS

- EOL exergetic efficiency analysis based on:
  (a) aquifer permeability,
  (b) aquifer thickness
  (c) well pattern
  (d) groundwater velocity
- Each graph represents the effect of a single parameter while coupled to all others.
- Simulation index is an arbitrary number assigned upon ordering of the data.



SUMMARY

- We established a scenario modelling approach to help design and optimize an HT-ATES in Geneva.
- We have performed a sensitivity study analyzing:
  - Aquifer permeability, thickness, and dip.
  - Well pattern, groundwater flow, and fracture configuration.
- High permeability is not desirable…
- Thinner aquifers are more efficient...
- A 5-spot well pattern might not be cost-effective…
- Groundwater flow adversely affects efficiency.
- More iterations are needed.
- This work was also submitted as a paper to the WGC 2020 in Reykjavík, Iceland, titled **"HEATSTORE: Preliminary Design of a High Temperature Aquifer Thermal Energy Storage (HT-ATES) system in Geneva based on TH Simulations (Mindel, Driesner)"**