Observed influence of ambient temperature fluctuations on the analysis of ground thermal response tests

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What is a ground thermal response test (TRT)?

Experimental observations relating to ambient temperature fluctuations
- Average ground temperature
- Ground thermal conductivity and borehole resistance

Implications for TRT practice and the design of direct geothermal energy systems.
Thermal response test setup

Thermal response test unit:
- Hydraulic pump
- Heating element applies power $Q$

- Ground heat exchanger (GHE) with embedded absorber pipes
- Power rejection $q$ per unit length
- Insulation to reduce heat loss to the air

- Circulating fluid
- Flow meter

Ground (thermal properties $\lambda$, $\alpha = \frac{S_{vc}}{\lambda}$ and $T_0$)
Thermal response test analysis

- Measure the change in mean fluid temperature ($\Delta T_{mean} = T_{mean} - T_0$) over time ($t$) in response to a constant applied power per metre length of the GHE ($q$)
  - $\lambda = 2.303q/4\pi m$
  - $R_b = (c/q) - (2.303/4\pi \lambda)\log(4\alpha/\gamma' r_b^2)$
Experimental setup
Observed ground temperature variation

Temperature (°C)

- 0.5m
- 1 m
- 2 m
- 5 m
- 30 m

Date:
- 1/1/11
- 18/12/11
- 3/12/12

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## Average ground temperature

<table>
<thead>
<tr>
<th>Depth range</th>
<th>Range of average temperature (°C)</th>
<th>Mean average temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5 m</td>
<td>14.5 – 20.5</td>
<td>17.5</td>
</tr>
<tr>
<td>0 – 10 m</td>
<td>16.3 – 19.6</td>
<td>17.8</td>
</tr>
<tr>
<td>0 – 20 m</td>
<td>17.4 – 19.4</td>
<td>18.4</td>
</tr>
<tr>
<td>0 – 30 m</td>
<td>17.8 – 19.4</td>
<td>18.6</td>
</tr>
</tbody>
</table>
Thermal response test observations

Temperature (°C) vs. Elapsed days

- $T_{\text{mean}}$
- Average daily ambient temperature
- Applied power

Applied power (kW)
Thermal response test observations

Average daily temperature (°C)

Elapsed seconds (log scale)

ΔT_{mean} (°C)

Days 4-6

Days 7-10
## Summary of interpretation

<table>
<thead>
<tr>
<th>Time period</th>
<th>Average ambient temperature (°C)</th>
<th>$q$ (W/m)</th>
<th>$\lambda$ (W/mK)</th>
<th>$R_b$ (mK/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 – 17 days</td>
<td>21.3</td>
<td>94.5</td>
<td>2.73</td>
<td>0.055</td>
</tr>
<tr>
<td>4 – 6 days</td>
<td>24.8</td>
<td>95.4</td>
<td>2.57</td>
<td>0.051</td>
</tr>
<tr>
<td>7 – 10 days</td>
<td>17.7</td>
<td>94.0</td>
<td>3.02</td>
<td>0.060</td>
</tr>
<tr>
<td>11 – 13 days</td>
<td>24.1</td>
<td>94.7</td>
<td>2.47</td>
<td>0.047</td>
</tr>
<tr>
<td>14 – 17 days</td>
<td>17.8</td>
<td>94.0</td>
<td>2.89</td>
<td>0.060</td>
</tr>
</tbody>
</table>
Concluding remarks

- TRTs assess thermal conductivity based on a measurement of the ground temperature change in response to heat energy applied over some time period. GHE design is typically based on the thermal conductivity assessed from the TRT.

- ‘Background’ temperature change occurs due to naturally occurring variations in ambient temperatures which apply energy to or extract energy from the ground.

- Interpretation of TRT results and GHE design needs to take the background temperature changes into account. The importance of these changes is expected to be greater for relatively shallow GHEs compared to deep GHEs.
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Thank you for your attention