Observed controls on the seasonal variability of urban groundwater thermal regimes

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1. Introduction

The subsurface Urban Heat Island (sUHI) effect provides the potential for low-enthalpy geothermal energy in cities above shallow aquifers, however seasonal variance in groundwater temperatures (GWTs) can lead to irregular system efficiency. Understanding controls on the Zone of Seasonal Fluctuation or ZSF (the depth to which GWTs are affected by seasonal oscillations in air temperature) would allow ground source heating systems to be installed at optimal depths to exploit the sUHI whilst ensuring stable temperatures throughout the year.

2. Aim & Methodology

The aim of this study is to identify controls on seasonal variance in GWTs & their relative role. To do this 40 boreholes were profiled each month for 13 months to determine the nature of the ZSF. Relationships between seasonal variability & lithology, lithostratigraphy, aquifer depth, thickness of confining clays, building density, surface cover & thermal diffusivity are explored.

3. Characterising the Zone of Seasonal Fluctuation

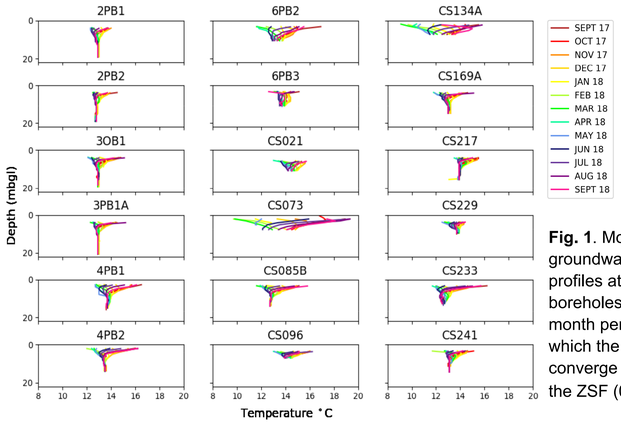

Fig. 1. Monthly groundwater temperature profiles at subset of boreholes over a 13 month period. Depth at which the profiles converge is the base of the ZSF (0.2°C error)

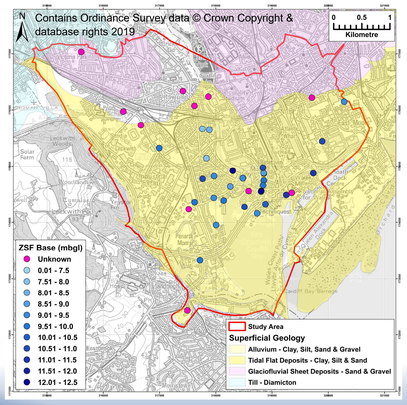

Fig. 2. (left) Map shows the location of the profiled boreholes, coloured by depth to the ZSF

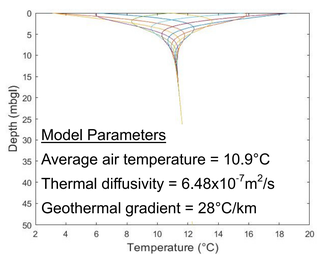

Fig. 3. (above) Conduction-only model of expected ZSF using homogenous thermal properties

4. Controls on Seasonal Variability

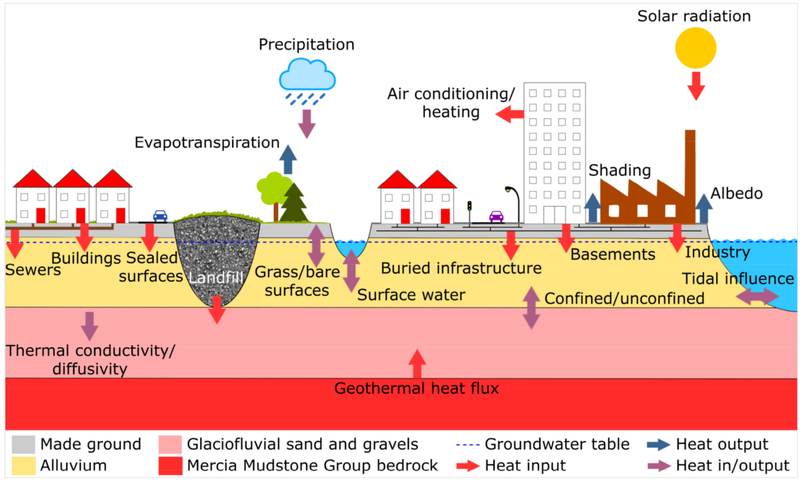

Fig. 4. Conceptual model showing potential mechanisms & controls of heat transport through the

5. Statistical Analysis

The following plots show correlations between the observed seasonal variance & the measured variables. For each borehole a buffer of 100m has been applied as a 'zone of influence' within which factors such as the percentage of sealed surface cover or building density were measured.

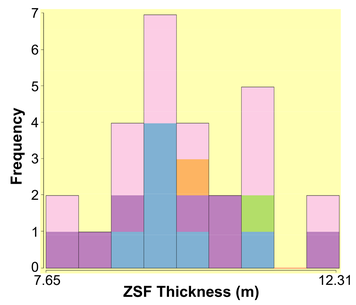

Fig. 5. Frequency distribution of the ZSF thickness (m). Colours show the lithology in which the base of the ZSF is found at each site. Blue = Clay, Purple = Gravel, Pink = Sand & Gravel, Orange = Sand, Green = Peat

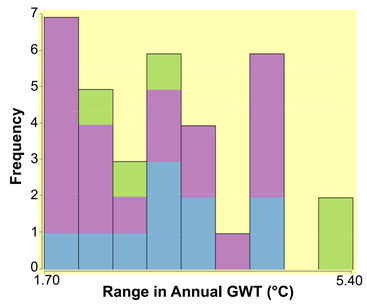

Fig. 6. Frequency distribution of the range in annual temperature (°C) at the top of the water column. Colours show the lithostratigraphy at the ZSF base at each site. Blue = Alluvium, Purple = Glaciofluvial Sand & Gravels, Green = Mercia Mudstone Group Bedrock

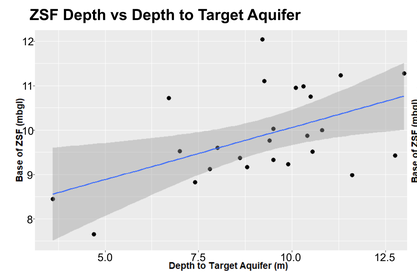

Fig. 7. Plot shows an increase in the depth of the ZSF with increasing depth to the aquifer

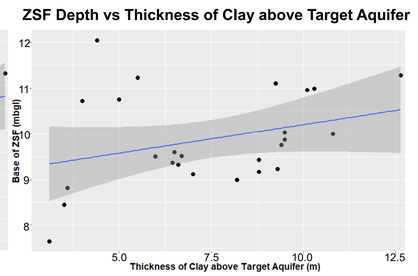

Fig. 8. Plot shows an increase in the depth of the ZSF with increasing thickness of confining clay

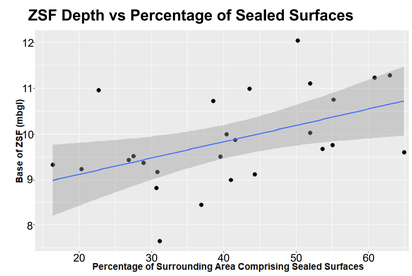

Fig. 9. Plot shows the ZSF penetrates deeper in areas with greater surface sealing (concrete, Tarmac or paving slabs)

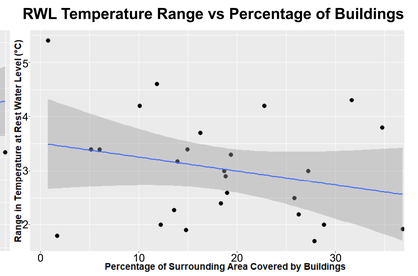

Fig. 10. Plot shows the annual variance at the top of the water column (RWL) decreases with building density

6. Key Findings

- ZSF base ranges from 7.6->16.2mbgl while the variance in annual temperatures at the rest water level ranges from 1.7-9.6°C
- The mean penetration depth of the ZSF is 9.87mbgl & the mean variance in annual temperature at the rest water level is 3.45°C
- The coolest & warmest months for groundwater temperature are not the same at each site
- 92% of sites had a shallower ZSF base than predicted by the tested thermal diffusivity model
- No single control on seasonal variance but 43% of the variance in the ZSF base depth can be explained by the depth to aquifer, the degree of surface sealing & lithology
- Weak correlation between ZSF base & thickness of confining clay (r=0.31), & moderate correlation between ZSF base & the month at which warmest temperatures occur (r=-0.57)
- No regression model predicted the annual variance at the rest water level, nor the coolest & warmest months, but there was moderate correlation with lithostratigraphy (r=-0.44)
- Further variables must be tested, including site specific thermal diffusivity data

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