Reply to the reviewers

We would like to thank the reviewer for the comments. The title of the article is 'Identifying (subsurface) anthropogenic heat sources that influence temperature in the drinking water distribution system'. The objective is to find a method to identify heat sources and urban characteristics that locally influence the soil temperature. That is why we focus mainly in the methodology and not in the results of the measurement.

The major comments concern the structure of the article. We will restructure the document revising the method and discussion sections, as suggested by a couple of reviewers. The identification of the heat sources will be moved to the methods section and a short description of the heat sources will be included in the introduction. Additional information to enable a replication of the analysis in a different urban area will be added in the method section.

The described research is still ongoing. One of our latest conclusions is that the added value of analysing the tap water measurements is low, given the fact that they occur in random locations. Therefore, they are not focused to find the warmest locations. We will delete the sections 2.2 and 3.2. The last part of the section 2.2 focuses on the GIS analysis of the location of the 'potential' heat sources. This will be rewritten and we will further elaborate on the influence of the spatial scale in the analysis.

About the spatial scale we will elaborate more. Until now the urban heat island analyses or heat stress studies are performed at coarse spatial; scales (e.g. 1 km x 1 km or neighbourhood level), where local variations at smaller scales (e.g. 10m x 10 m) can be missed. In the discussion we will include that the optimal resolution of analysis depends on the objective of the analysis. We focus at small spatial scale that is related to the scale of the water distribution network. However it is still unknown what the optimal resolution is. To determine this, further research is needed for instance in two-dimensional or three-dimensional modelling or with intensive measurements.

In this article we focus on the method to identify the sources and warmest locations. We will elaborate more on the applicability of the proposed method to find the warmest locations in the city and we will provide recommendations for future measurement campaigns, e.g. time interval of the measurements. We will include a discussion of the results in terms of comparison to expected outcomes, comparison to results from previous studies, discussion of uncertainties associated with the obtained results, how representative the obtained results are, and regarding the transferability of the approach to other cities. We will rewrite the conclusion.

The results of the measurement campaign won't be completely added, because the analysis is still being conducted. Reporting and analysing them won't fit in the current article. These measurement results are only useful to improve the method and not yet to determine the heat sources.

Detailed reply to each of the reviewers is below in blue.

Reviewer 1

General comments:

The manuscript introduces a method to identify heat sources above and below ground that influence temperatures within the drinking water distribution system at a small spatial scale. While the manuscript has the potential to be an important and very useful paper, quite a bit of the analysis mentioned is never actually shown. The objective of the manuscript is"...to localize potential underground hotspot at a small spatial scale") (page 2, line 32), however, there is only one tiny map in the manuscript hinting at this small spatial scale. Overall the introduced method seems very interesting and promising, but the results given within this manuscript are too few to draw any conclusion on the significance, usefulness and actual potential of the method. Additionally the manuscript needs to be restructured, a lot of information within the results section should be part of the methods section (e.g. page 7 lines 17ff).

In relationship with the spatial scale, we will elaborate more as described above.

Specific comments:

1) Page 2 line 9: "Schwarz and Manceur (2015) concluded that mitigating the SUHI might lead to actually increasing mean temperatures" The explanation here needs to be extended; I assume this is either due to the wrong mitigation strategy or has to do with the seasonal variation of the SUHI?

We will include the article that:
Indeed SUHI and SSUHI vary with the seasons, but also inter-annually and it evolves with the growth of cities. SUHI and SSUHI are complex phenomenon that cannot be described with a single indicator. Schwarz and Manceur (2015) reported that although the maximum SUHI has been lowered in some locations, the mean temperatures are increasing. Ideally the SSUHI and SUHI are analysed over several years and it should be described at least seasonally reporting the maximum and the average SSUHI. Current analysis of heat stress are averaged for the summer and urban characteristics are aggregated to grids of ca. 1km x 1 km. Aggregation for summer will soften the peaks and aggregation in spatial scale can 'diffuse' the local heat locations."

2) Figure 1: what kind of meteorological data is used? Which possible heat sources are analysed and why?
The model uses hourly meteorological data: air temperature, relative humidity, global radiation, precipitation, wind speed and cloudiness. The analysed heat sources are solar radiation and anthropogenic sources which are simulated using a constant value. This will be included in the description of the method.

3) Page3 Line 15: please indicate which of these parameters change with time.
The soil density and the soil thermal properties change with soil moisture. Soil moisture changes continuously due to evaporation and rainfall, but also due to ground water level control or due to leaks from the sewer or drinking water networks.

The model has been validated for the summer, when soils are often dry and there is little precipitation. In this case a fixed value is assumed, for a yearly analysis the variation of these variables have to be considered. This assumption will be added in the text.

4) Table1: where do these values come from? What is their uncertainty? Some of them are apparently fitted using existing measurements. Please extend on that.

These values come from an earlier study, in that study a sensitivity analysis was performed. A short reference to the results of the sensitivity analysis will be added here.

These parameters are highly uncertain. Soil parameters are difficult to determine, they depend on the soil type, compaction and moisture level. In cities, it is really difficult to exactly determine these characteristics without influencing them. In theory we consider isotropic soils and conditions, although in reality they show three dimensional variations.

5) Page 4 Line 14: please give more information on tap water measurements including time and location of these measurements, as well as actual temperatures (or at least a mean)

As mentioned in the introduction, "Water temperature is an important determinant of water quality. In the Netherlands drinking water is distributed without an additional residual disinfectant and the temperature of drinking water at the customers' tap is not allowed to exceed 25 ºC (Drink Water Directive, 2011).

To monitor this, water companies perform random sampling monitoring of the water temperature at the tap. They select random addresses to measure the temperature. The measurement is taken after a prolonged flushing of the tap. In practice the temperature is measured after it stabilises, in such way that stagnation of water in the domestic distribution system does not influence the measurement.

The described research is still ongoing. One of our latest conclusions is that the added value of analysing the tap water measurements is really low, given the fact that they occur in random locations. Therefore, they are not focused to find the warmest locations. We will delete the sections 2.2 and 3.2. The last part of the section 2.2 focuses on the GIS analysis of the location of the 'potential' heat sources. This will be rewritten.

6) Page 5 line 5 "For the GIS analysed, the tap temperatures were plotted together with the spatial information from anthropogenic heat sources (from step 1)." Show this figure. Also, what spatial information from anthropogenic heat sources from step 1. So far (and in the results) nothing indicated that step one is done spatially resolved.

As mentioned in the earlier point, the analysis of the temperature at the tap will be deleted and replaced for a more detailed explanation of the GIS analysis.

7) Page 5 line 12ff: soil temperature measurements: Please show a map of measurement locations. Also, how did you handle different land cover types? Where you able to measure soil temperatures under sealed areas (e.g. streets)? Please give values for these measured temperatures; they are not in the results.

In the Netherlands, the drinking water pipes and other infrastructures, such as cables and district heating networks, are often installed under the sidewalk, under tiles. We performed measurements only under two different covers: grass and tiles.

In this article we focus on the method to identify the sources and warmest locations. We will elaborate more on the applicability of the proposed method to find the warmest locations in the city and we will provide recommendations for future measurement campaigns, e.g. time interval of the measurements.

8) Page 7 "3.3 Identification of heat sources" move to methods

The identification of the heat sources will be moved to the methods section and a short description of the heat sources will be included in the introduction.

9) Page 7 line 20 “The simulated range shows a good agreement with the measured T_soil” please show me the numbers.

As mentioned before, we will include a brief overview of the results.

Technical corrections:

10) Page 4 line 5ff: wrong format.
We will correct the format.

Reviewer 2

General comments:
The presented study addresses the interesting and important issue of increasing drinking water temperatures due to surface and subsurface urban warming. While the lack of a tools and methods to tackle this problem is correctly identified, the proposed method is not well enough elaborated in the current manuscript to be directly applicable in this context. Only few results of the conducted field study are shown, and they are neither sufficient to support the conclusions, nor meaningful enough to demonstrate the practicability of the proposed method.

The abstract should be restructured and more focus should be put on the developed method, results and conclusions, instead of on the background of the topic. While the aim of the study is specified as ‘developing a method to identify and to localise potential underground hot spots’ in the introduction, the method sections states that the aim is ‘a method to identify subsurface anthropogenic heat sources’. The authors should be clear about the specific aims, and how the method supports the achievement of the aims. As the authors state correctly in the introduction ‘only modelling or only random tap water sampling are not enough to identify urban underground hot spots’. However, the method developed in this study is mainly based on soil temperature modelling and random measurements of tap temperature.
In general, the method section does not provide enough details, e.g. on parameterisation and the specific data used, to enable a replication of the analysis in a different urban area. The individual steps and inputs shown in Figure 1, such as the input of potential heat sources, are not explained in detail. It might also be easier to follow the approach, if the subchapters were structured according to the steps (1-5) in Figure 1. In addition, it seems contradictive that a list of potential heat sources is required as an input, when identification of heat sources is the aim of the study. The results section partly contains information that is related to the methodology. In particular, section 3.3 is not based on observations from this study, but rather from literature. Oddly, the analysis of tap water measurements is based solely on a relative comparison to modelled soil temperatures. The absolute water temperatures, which are introduced as an important factor at the beginning, are neither shown nor discussed, and it is unclear how often the critical value of 25°C is actually exceeded. The result from the GIS are shown in a tiny figure that doesn’t enable the reader to make any meaningful observations. Results from the soil temperatures measurement plan are not shown at all, and the statement that the simulation results are in good agreement with the measurement cannot be verified by the reader. The content of section 3.6 does not match the section heading. It contains many observations, conclusions and recommendations that are not based on results shown in this study, neither are citations for the statements given. This section should be thoroughly revised. A discussion of the results is overall missing in terms of comparison to expected outcomes, comparison to results from previous studies, discussion of uncertainties associated with the obtained results, how representative the obtained results are, and regarding the transferability of the approach to other cities. Finally,

the conclusion section provides a very short statement of the aim and approach of the study, but it does not highlight important findings, neither does it provide any conclusions.

We will revise the abstract and section 3.6 thoroughly.

We will rephrase 'only modelling or only random tap water sampling are not enough to identify urban underground hot spots'. Actually in our method they were combined. This research is still ongoing, one of our latest conclusions is that the added value of analysing the tap water measurements is really low, given the fact that they occur in random locations. Therefore, they are not focused to find the warmest locations. We will restructure the article and delete the sections focusing on the temperature at the tap.

Temperatures above 25°C occur only during warm summers, but that does not indicate that there is not underground heat stress. We will elaborate on this in the article.

As mentioned, the focus of the article is the method. We will improve figure 6 and the explanation of the analysis.

Specific comments:

Page 1, line 20-21: please provide a citation for this statement.
We will add the citation (Blokker and Pieterse-Quirijns, 2013)

Page 1, line 26-28: please restructure this long sentence.
We will restructure this sentence.

Page 2, line 3: why specifically 10 x 10m?
The urban heat island analyses or heat stress studies are performed at coarse spatial; scales (e.g. 1 km x 1km or neighbourhood level), where local variations at scale of for instance can be missed. In the discussion we will include that the optimal resolution of analysis depends on the objective of the analysis. We focus at small spatial scale that is related to the scale of the water distribution network. However it is still unknown what the optimal resolution is. To determine it, it is further research needed for instance two-dimensional or three-dimensional modelling or intensive measurements."

Page 2, line 3: while the previous statement refers to subsurface temperature, you refer to surface temperatures here, and later again to subsurface. A better structure would help the reader to follow the reasoning in the introduction.

We will check the text for readability.

Page 2, line 14: please add a citation and some examples for this statement.
We will add references to energy balance studies where the (underground) anthropogenic sources are not considered.

Page 2, line 20-21: please provide some examples for the numerous anthropogenic heat sources.
We will provide examples and average values based on the climate local zones based on the research by Stewart and Oke (2012).

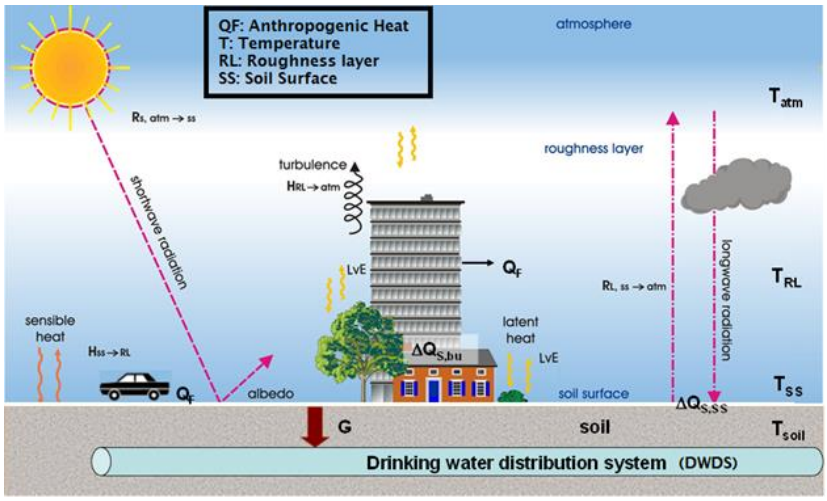
Page 2, line 22-23: please add a reference for the statement regarding the risk of exceeding the temperature limit.
We will add 'in the city' in the sentence and the reference:
Therefore, different areas *in the city* have a different risk of exceeding the threshold temperature (Agudelo-Vera et al. 2015a).

Page 2, line 30: please rephrase '(x, y, and z)'.
We will rephrase it.

Page 3, line 9: was the extension of the specified model part of the presented study or of Agudelo-Vera et al. (2015a)?
We will clarify that the extension of the model is described in Agudelo-Vera et al. (2015a).

Page 3, line 19-21: it is not clear here (and in entire paragraph) which heat fluxes, heat

We will include a schematic representation of the model and a more detailed explanation of the input data and the assumptions to allow repeatability.



Reviewer 3

(Page 1) L11 - L12: It is stated that the the temperature data is high compared to the model, and that hot spots are the reason for this. What if the model is instead poorly calibrated?

The model has been tested and validated by Blokker and Pieterse (2013). For Rotterdam it has been calibrated for the summer condition (Agudelo-Vera et al., 2015). We will make this clearer in the document and discuss the possible uncertainties and sources of error.

(Page 1) L23 - What are some of the water quality effects when the temperature goes over 25C?

The research about the effects on the water quality is still being conducted. An earlier study concluded that an increased risk for growth of *Legionella pneumophila* occurs when water temperatures are above 30°C for more than seven days. However, these experiments were performed with one strain of *L. pneumophila* and it might be possible that other strains of *L. pneumophila* have a slightly different temperature range of growth.

(Page 3) L16: LVE with subscript "v" or normal case, as in eq. (1) ?
(Page 4) L5: Some bold formatting issues.
(Page 5) L13 No capital B in Based.
(Page 6) L3: August, not "Augustus"

We will correct these issues in the document.

(Page 6) L14: Rather than stating that the number of hot spots in the data is "small", can a quantitative number be used? The data could also be used to relate back to the previous statement of 0.1% of samples being over 25 C?

As mentioned earlier, we will delete the subsections related to the analysis of the tap temperatures.

(Page 7) L21: How good is the alignment? Can this be defined numerically?
We will further elaborate on this in the results section.

Reviewer 4

The manuscript presents an interesting method to identify and to localise potential hot-spots at a small spatial scale. While the described method looks promising, the authors did not always thoroughly compare their work to other studies and the discussion is somewhat general (can certainly go deeper, please consider expanding the discussion).

Specific comments: Page 1, line 7 – 9: The sentence seems to be more suitable for the “Introduction” section (including references on the influence of water temperature on physical, chemical and microbial quality parameters).
We will revise the abstract and consider moving the sentence to the Introduction section.

Page 2, line Not clear why 10 m x 10 m is chosen.

We had a similar comment from other 2 reviewers, we will elaborate on the relation with the spatial scale.

Page 4, line 10: Table 1: How sensitive are these input parameters?
We will refer to the sensitivity analysis performed in an earlier study.

Page 4, line 24: Please check the format.
We will check the format.

Page 5, line 5 Please include the Figure in which “the tap temperatures were plotted together with the spatial information from anthropogenic heat sources”.
We will restructure the article. We will delete the subsections related to the tap temperatures and elaborate further on the GIS analysis of the heat sources.

Page 7, line 21 – Not clear which statistical measures were applied to evaluate the agreement between measured and modelled data. How big is the measurement error? Please include more discussion.

In this article we focus on the method to identify the sources and warmest locations. We will elaborate more on the applicability of the proposed method to find the warmest locations in the city and we will provide recommendations for replicability.

We will revise the discussion and the conclusions to reflect more the objective of the paper identifying heat sources that cause the hotspots.