Comparing Landsat 8-derived Surface Temperatures and Field-Collected Air Temperatures in the City of Richmond, VA.

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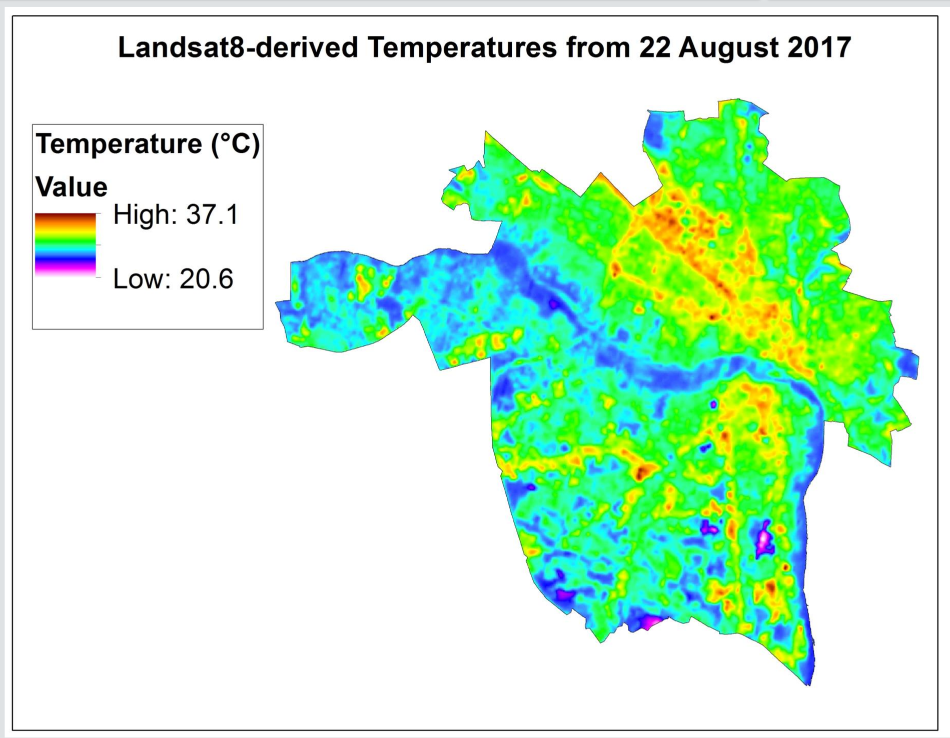
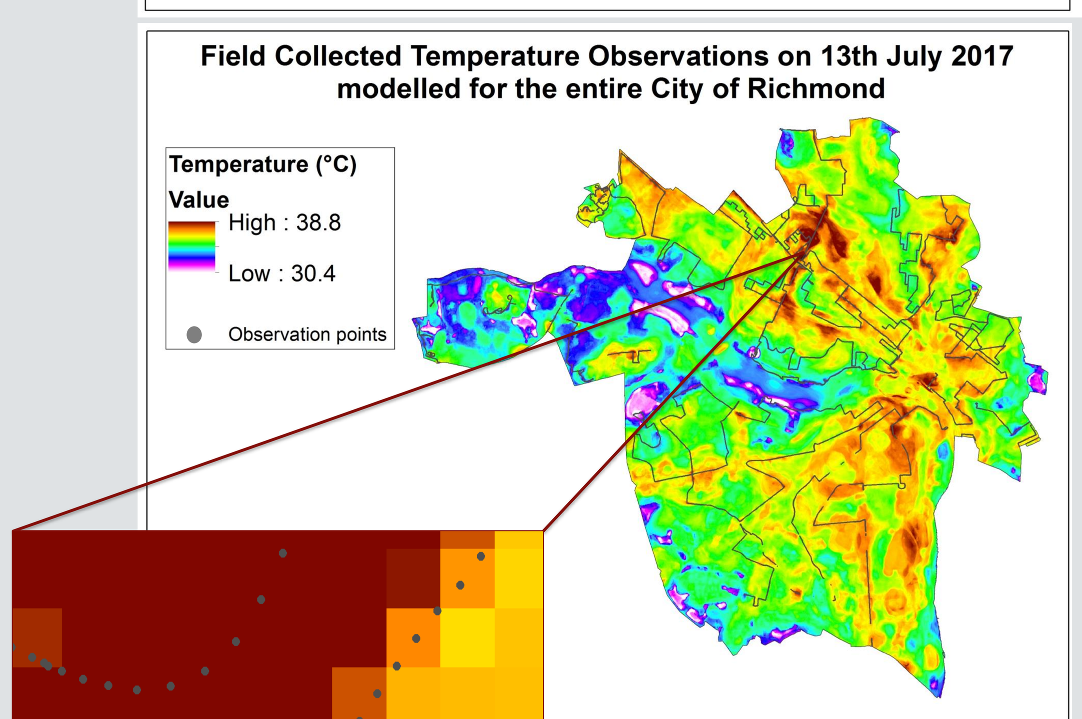
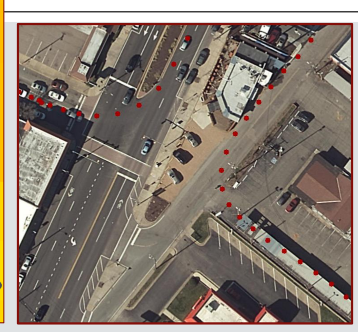
Abstract

Satellite data is a cost-effective and easily accessible information source that is widely used in a variety of applications. When it comes to temperature data, satellites receive thermal electromagnetic energy emitted by the earth's surface from which surface temperature is empirically derived. Despite such data being a relatively accurate representation of surface temperature, it does not necessarily replicate the true air temperature patterns of a place. Depending on the type of data used, research studies can arrive at considerably different outcomes, and subsequently induce different public policies related to heat extremes, especially in cities. In this project, relations between surface temperature and air temperature during unusually hot summer days are examined for the City of Richmond, Virginia, a mid-sized city located in the Southeast Climate Region. This is achieved by comparing satellite-derived surface temperatures from Landsat 8 imagery retrieved on 22nd August 2017 to air temperatures collected in the field (from thermistors mounted on bicycles and cars) and modelled on 13th July 2017. Three types of comparisons are made, in which the 2 variables demonstrate considerable differences aiding understanding of the limitations of Landsat8-derived temperatures. Subsequently, this will help further research seeking to inform the identification of populations vulnerable to the Urban Heat Island effect within the City of Richmond. This is an important contribution to the development of public policy responses to Urban Heat Island phenomena.

The 2 datasets






Plan view of N. Boulevard St and Myers St, Richmond, VA where temperature observations were collected

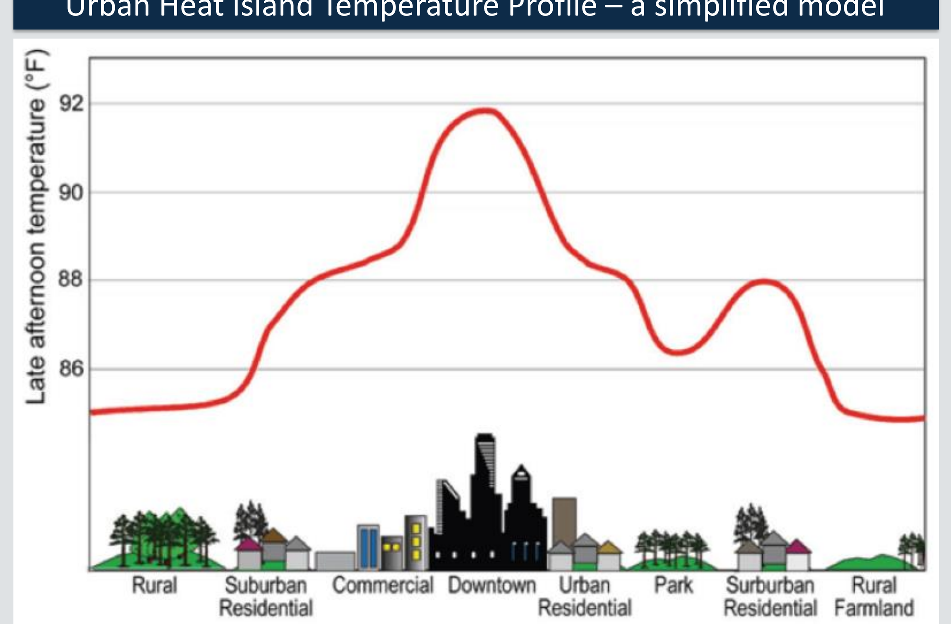
The Urban Heat Island Effect

Despite differences in temperature patterns being evident in the 2 maps, they both demonstrate higher temperatures in urban environments compared to the surrounding rural areas. This can be explained by the higher concentration of buildings, roads and other infrastructure as well as the lower concentration of trees and vegetation within metropolitan areas, both leading to faster heat absorption within cities, and the Urban Heat Island phenomenon to take place.

The Urban Heat Island phenomenon poses risks for people living in cities, the effects of which are potentially augmented by the current global warming trend (which leads to even hotter temperatures in urban areas). Higher temperatures increase exposure to ground-level ozone, and increase risk of heat stress, heat stroke or heart and lung problems.

It is therefore important to assess and identify the populations more vulnerable to the negative effects of such phenomena, so that the most appropriate measures are taken by decision makers, in order to minimize effects and contribute towards sustainability within (but not restricted to) the City of Richmond.

Urban Heat Island Temperature Profile – a simplified model



3 different comparisons

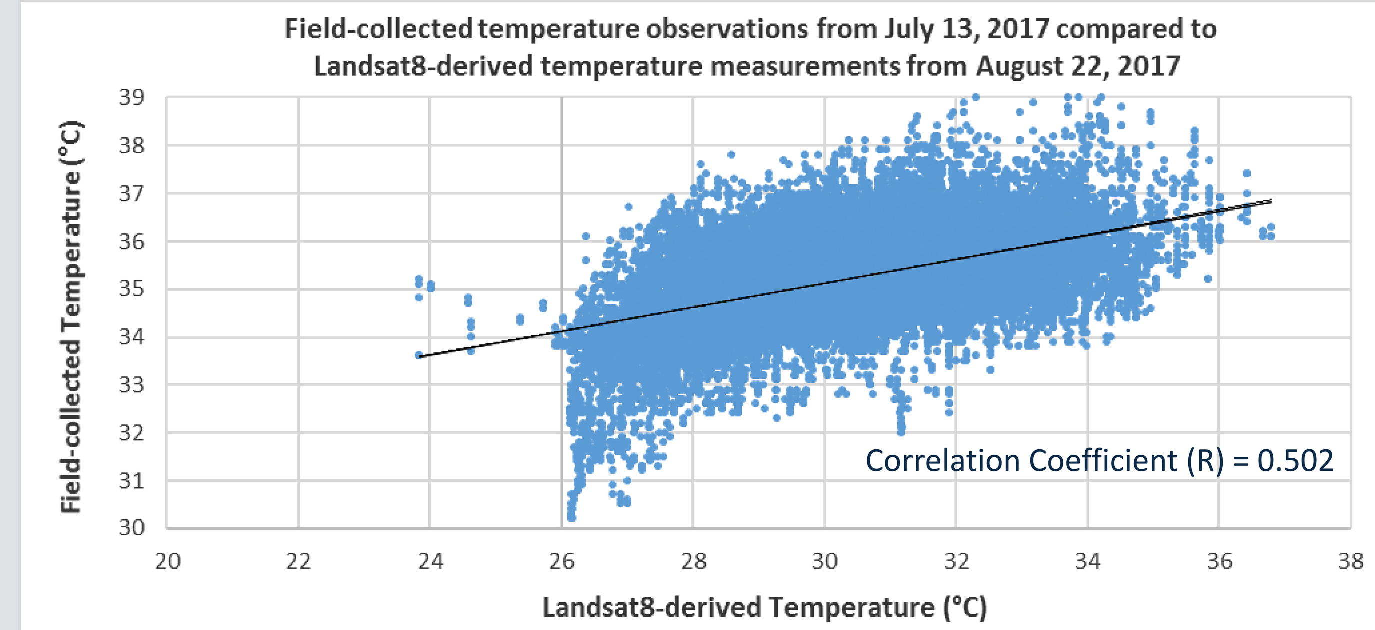


Figure 1: Temperature measurements derived from Landsat8 are in the form of 30 by 30m raster cells. In contrast, field-collected temperatures are taken at points few meters apart from each other, along a predetermined track. As a result, more that one temperature observation point falls within each satellite cell.

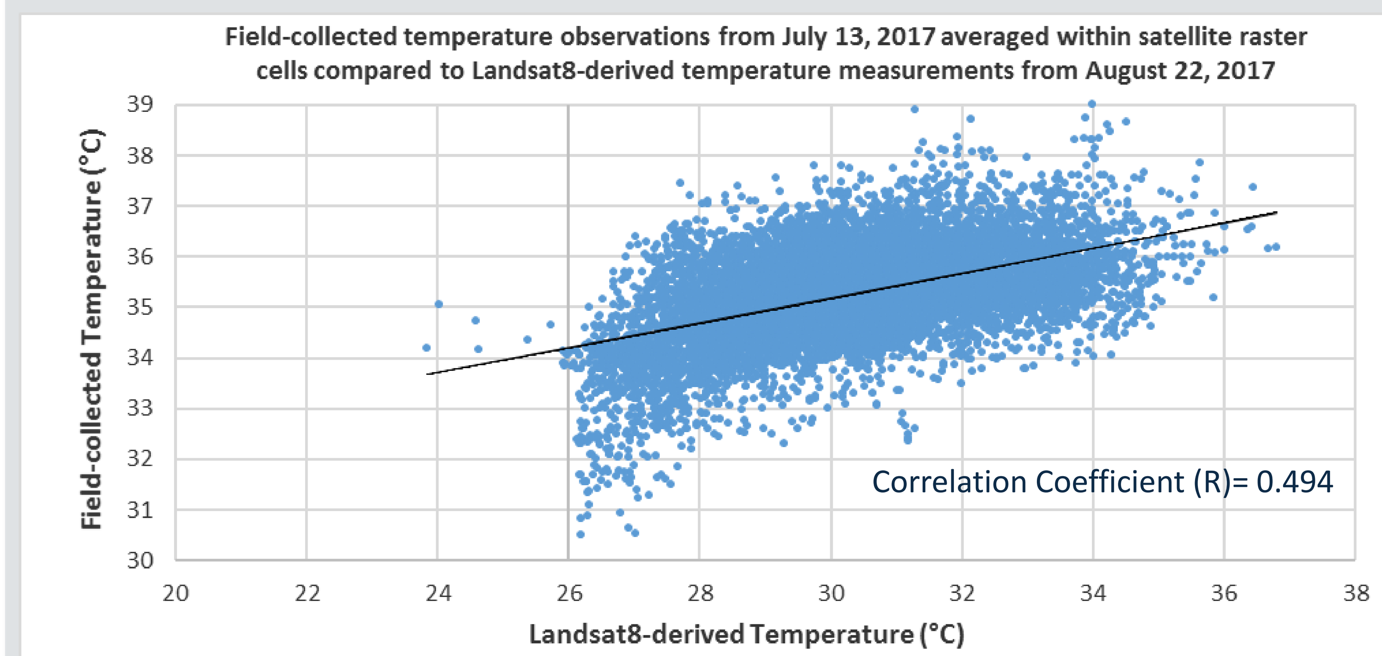


Figure 2: To better understand the true relationship between the 2 variables, the field-collected temperature observations are averaged within satellite cells, so that the 2 datasets are in the same resolution.

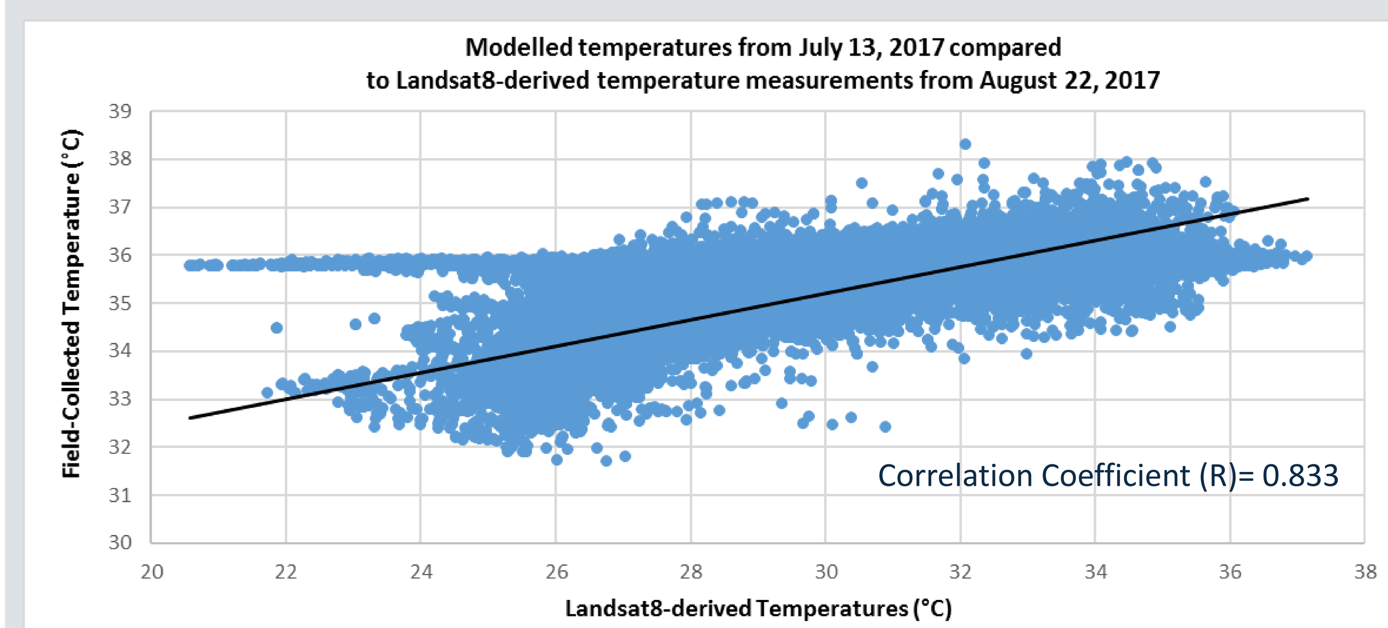


Figure 3: To aid comparisons, the field-collected temperatures are modelled for the entire city of Richmond (by relating with other factors, such as land cover). The two datasets are spatially related and the relationship between the 2 temperatures within each raster cell is examined (presented in the graph above).

Results' Interpretation:

Even though the variables exhibit a relatively weak correlation (as expected), the very different resolutions of the 2 datasets produce misleading results. Multiple observation points (each with a different temperature) fall within each satellite raster cell (same temperature) resulting in vertically aligned points on the graph.

The observed relationship is still relatively weak, supporting the idea that satellite-derived and actual temperatures do indeed differ significantly. Moreover, the 2 variables seem to exhibit non-linearity, suggesting that the relationship of the 2 temperature datasets is even more complex.

When the interpolated model is used in the comparison, correlation is significantly stronger but, differences still persist. For example, a horizontal line of outliers around 36°C is evident on the graph, which we are unable to explain. It is likely that those deviations originate from methods of temperature data collection. Nevertheless, the hypothesis that satellite-derived and actual temperatures differ significantly is supported by this comparison.

Conclusions

There exist considerable differences between temperature derived from satellites and the actual temperature of an area. For example, as the images below show, temperatures over water appear to be lower when derived form the Satellite, than when interpolated from actual observations (even if we account for the fact that the 2 datasets were taken on different days), leading to deceptive interpretation of temperature patterns over the given area. Such differences can potentially be justified, by taking into account factors such as land cover data.

However, some of the observed deviations might be a result of the methods used in temperature data collection and subsequently the development of the interpolated model. Nevertheless, further research should focus on identifying and understanding the factors affecting this relationship, with the aim of developing a model that replicates true temperatures more accurately. Subsequently, future studies can use it to generate improved results, and advice public policy in anticipation to contemporary issues, such as global warming.


Satellite imagery over James River in Richmond, VA.


Temperatures as suggested by the interpolated model, using field-collected observations.


Temperatures as derived from the satellite.

References and Acknowledgements

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