Initial estimates of anthropogenic heat emissions for the City of Durban

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1. INTRODUCTION

Cities in South Africa are key hotspots for regional emissions and climate change impacts including the urban heat island effect. Anthropogenic Heat (AH) emission is an important driver of warming in urban areas. The implementation of mitigation measures within urban sectors such as transport, industry, community and local government can have co-benefits for ameliorating the urban heat island effect and improving air quality. Characterizing atmospheric emissions is a first step for the generation of empirical evidence to identify policy measures that are most likely to simultaneously meet development needs that allow for societal wellbeing and economic growth whilst living within environmental thresholds.

This study provides an initial estimate of AH emissions for Durban for 2011. A top down emission model was developed to quantify the AH emissions using municipality energy consumption statistics.

2. METHODOLOGY

AH emissions were quantified from energy consumption data from the eThekwini (Durban) Greenhouse Gas Emission Inventory. AH emissions were quantified for the commercial, residential, industrial, traffic and human metabolic sectors. These sectors have been acknowledged to be the primary sources of AH emissions related to buildings, transport and population (Iamarino et al. 2012).

Equation 1 is proposed to quantify the anthropogenic heat emissions from fuel combustion ($Q_{(f)}$) and was adapted from Quah and Roth (2012). The equation was applied for the quantification of AH emissions from buildings and traffic.

$$Q_{(f)(h)} = \sum_k C_k(h) \times NHC_k / A \quad [\text{W.m}^{-2}] \quad (1)$$

Where k indicates fuel type, and C_k is the mean hourly consumption of fuel type k at hour (h), NHC_k is the net heat of combustion factor for fuel type k and A is the size of the source emission area (m^2). The source emission area for traffic was the total surface area covered by roads. The source emission area for buildings was the surface area covered by urban land uses such as industrial, commercial and residential. The net heat of combustion factor is also known as the net calorific value and the information is acquired from the South Africa Department of Energy (DoE, 2010).

Equation 2 is proposed to quantify anthropogenic heat emissions from buildings due to electricity consumption ($Q_{B(e)}$) and is modified from Quah and Roth (2012).

$$Q_{B(e)(h)} = \sum E(h) / A \quad [\text{W.m}^{-2}] \quad (2)$$

Where E is the mean electricity consumption at hour (h) in Watts, and A is the size of the source emission area (m^2). It is assumed that all energy consumed by all buildings is released into the environment after use (Iamarino et al. 2012).

AH emissions from human metabolism (Q_M) were quantified using the formulae adapted from Allen et al. (2011) indicated in Equation 3.

$$Q_M = \frac{PH_M}{A} \quad [\text{W.m}^{-2}] \quad (3)$$

Where the human population is indicated by P. The area of the domain is A in m^2 and the metabolic heat rate is indicated by H_M which is acquired from Sailor et al. (2015). Human population data were collected from Statistics South Africa.

Spatial disaggregation of the AH emissions were achieved by adapting the methodology of Lee et al. (2009) indicated in Equation 4.

$$Q_i = \sum (Q_i . LUF_i) \quad (4)$$

Where Q_i is the mean AH emission, LUF is the land use area fraction of sectors i including residential, industrial and industrial land uses. The South African national land cover data for 2013 to 2014 is used to identify sectoral land uses. The road data was provided by eThekwini Municipality.

3. Results and Discussion

The total hourly averaged AH emission for Durban is 77 W.m^{-2} for 2011. The primary contributors to the total AH emission is traffic and industry. The spatial distribution of the AH emissions from these sectors are indicated in Figure 1. As indicated in Figure 2, total AH emissions are composed by 56.3% traffic, 31.1% industry, 10.7% commercial and the remainder by human metabolism and residential.

The objective to compiling AH emission maps were to identify key emission hotspots. The spatial distribution of the total AH emissions are indicated in Figure 3. The maximum emission intensity ranges between 3.25 and 4.56 W.m^{-2} with areas of the highest emission intensity located in the Durban South region which is an industrial agglomeration in proximity to the main roads that occur in the city. Other areas with relatively greater AH emissions also were found to be located in largely industrial areas with a high surface area of roads. These areas include Isipingo, Tongaat, Cato Ridge/Hammarsdale and Pinetown. Additionally the areas of Durban North and Umhlanga Rocks are major transport regions which are key commercial and light industrial centres.

Efforts to reduce anthropogenic heat emissions, will contribute to urban heat island mitigation and the road transport and industrial sector should be prioritised.

4. Conclusion

This is one of the first studies to quantify AH emissions for a South African city. AH emissions are essential factors in city-scale atmospheric circulation and surface temperature and as such this type of analysis ultimately will improve our ability to quantify these emissions in South African cities at a temporal and spatial scale that can support urban climate assessments. Future work will include the comparison of the AH emission estimates quantified in this study to other modelled estimates for Durban completed at a global scale.

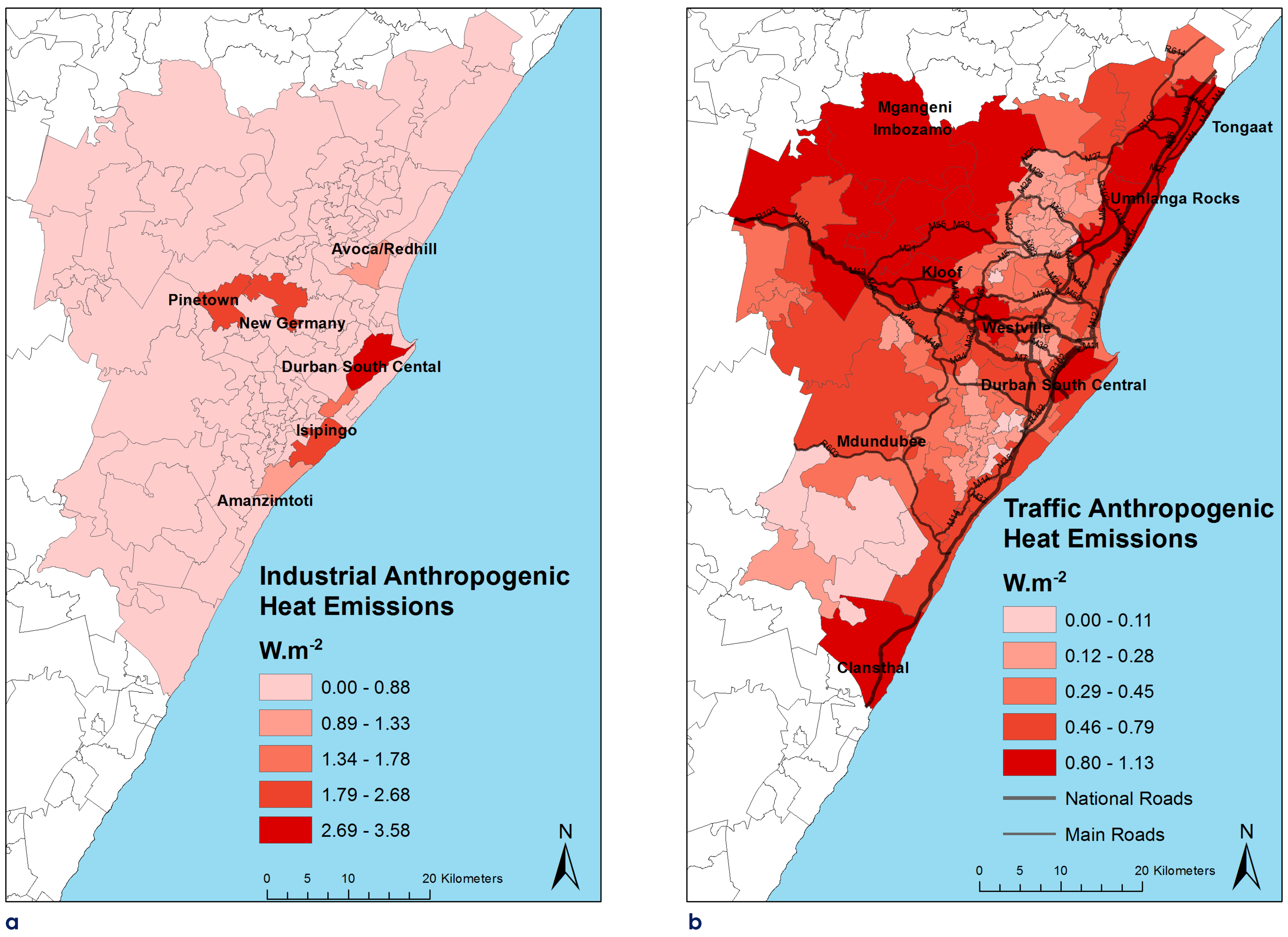

Figure 1: Anthropogenic heat emissions of Durban for a. traffic and b. industry

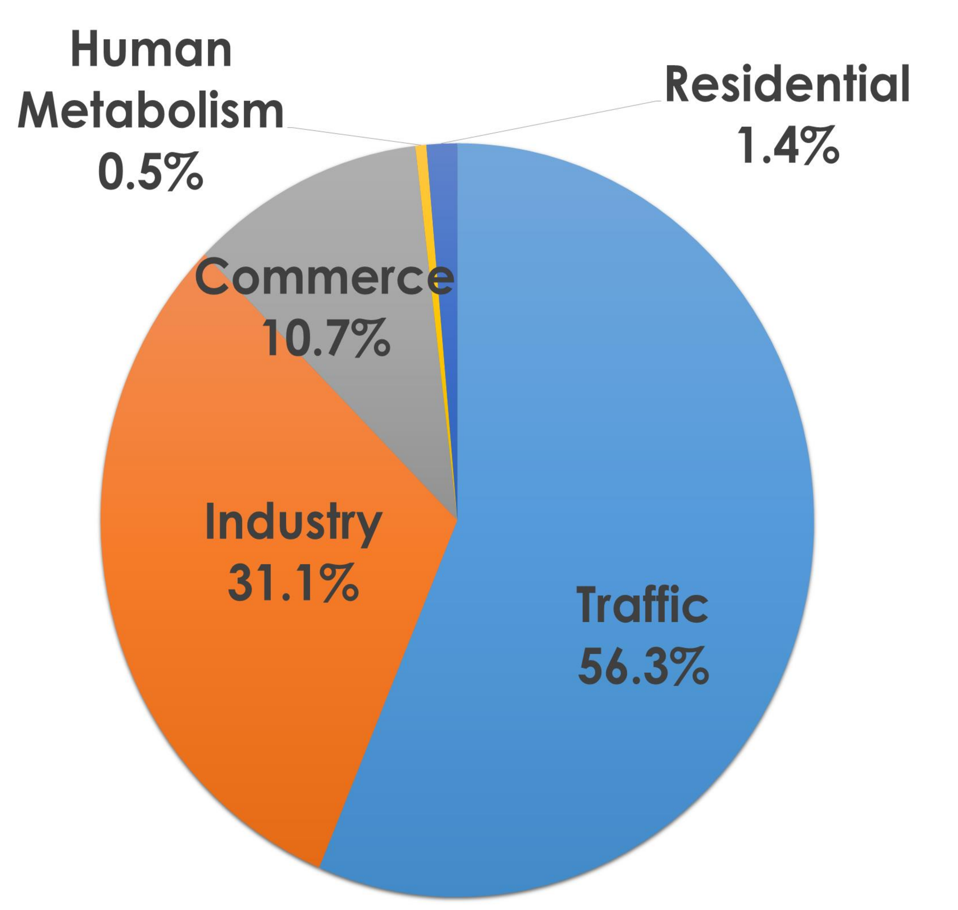

Figure 2: Sectoral contributions to the anthropogenic heat emissions of Durban.

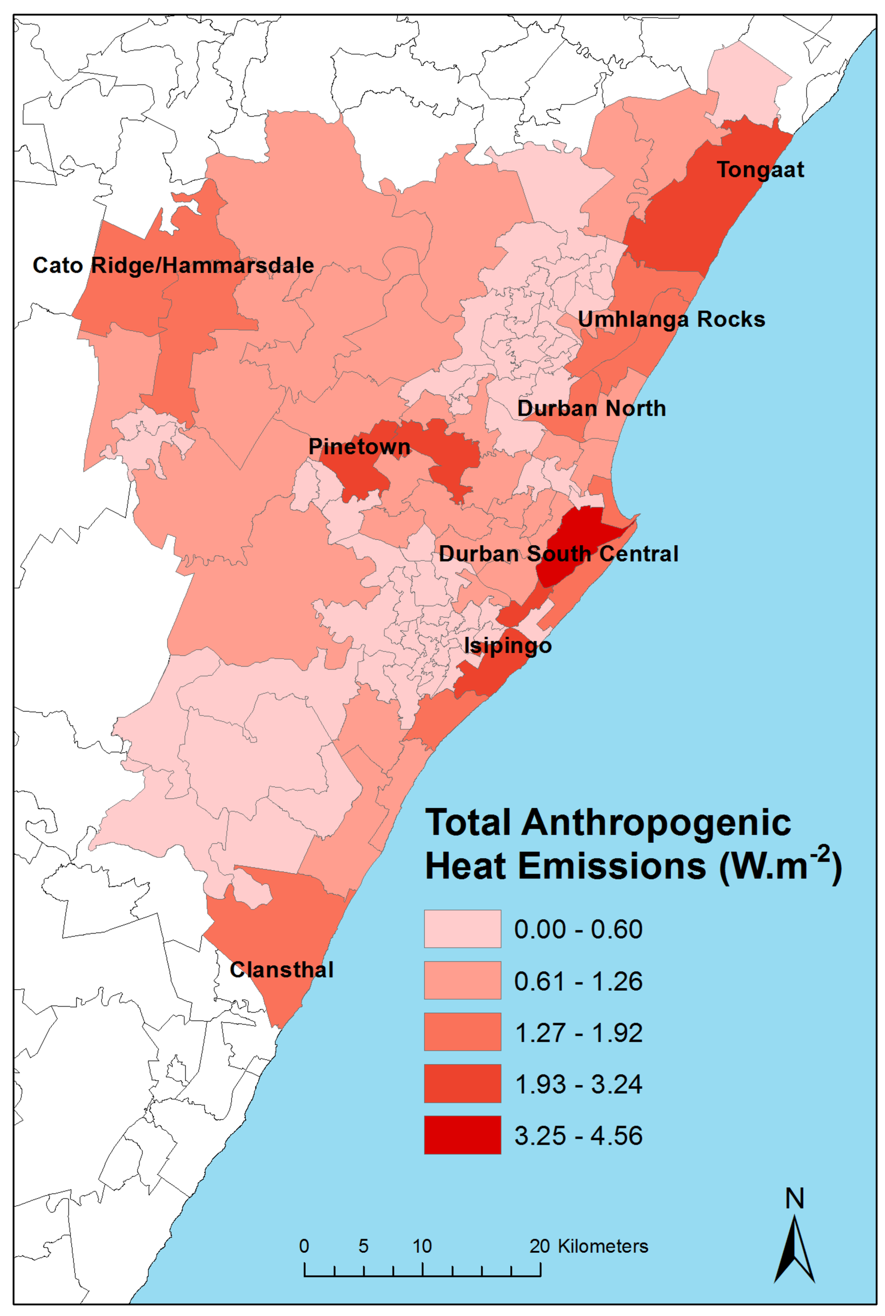

Figure 3: Total anthropogenic heat emissions of Durban .

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