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WORLD POPULATION VARIABILITY AND HEAT BIAS PREDICTION: AN APPROACH TO GLOBAL HEAT DISASTER MANAGEMENT

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ABSTRACT

This study examined world population variability and heat bias prediction as an approach to global heat disaster management. Heat bias data were generated from population records of United Nations Department of Economic and Social Affairs, World Population Review and U.S. Census Bureau and International Database using population simulated mathematical model. The world has population of 7,794,798,739 and heat bias of 7.2°C and continental mean of 5.4°C. Asia had the highest heat bias of 7°C, Africa 6.°C, North America 6.4°C, Europe 5.7°C, South America 5.5°C Australia/Oceania 4.8°C and the Antarctica had the least heat bias of 2.2°C ranging 4.8°C. All continents exceeded the recommended +0.5°C-2.5°C human comfort threshold. Countries within the humid tropics had increased heat load. Countries within the subtropics up to the middle latitude had relatively lower heat stress. Population density does not have significant association with heat bias. Heat bias is important in global environmental planning and management.

Contribution/Originality: This study "world population variability and heat bias prediction: an approach to global heat disaster management" contributed to the understanding of the global thermal environment using mathematical population prediction model resulting from limited available studies. Findings showed, Asian continent had highest heat bias of 7°C exceeding +0.5°C-2.5°C human comfort threshold.

1. INTRODUCTION

Globally, the interaction between population and the thermal environment has become a serious issue to be investigated. This is because the health of people across the globe is partly dependent on the thermal environment for their well-being and survival [1-3]. Thus, people in different parts of the world will receive different effects of the heat disaster as provided by their thermal environment because of differential human activities and their use of natural resources available to them [4]. However, with progress in human urbanization and economic activities, the world will continue to face the health effects resulting from rise in temperature of the thermal environment. For instance, the heat waves in Europe caused 70,000 deaths in 2003 and Chicago city recorded 800 deaths in 1995 [5]. Also, the city of Los Angeles budgets over $100 million every year to tackle heat disaster [6]. Heat disaster has affected India to record 384 deaths in 2017 and Japan recorded 80 deaths in 2018, Pakistan recorded 780 deaths in 2015, Telangana 143 deaths in 2016, Canada had 54 death in 2018 [7].

The contribution of population and urbanization has resulted to global heat bias. Thus, thermal bias is a phenomenon resulting from the heat emitted by human activities. The manmade urban fabrics and pavement materials on daily basis generate heat to the ambient air [8]. However, global thermal performance would vary

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from place to place depending on the climate characteristics and anthropogenic modifications. The upsurge of urbanization at a global scale has yielded the phenomenon of population heat bias. Resultantly, the environment is so sensitive to heat emission which is capable of altering the biophysical components of the environment and cause physiological and psychological as well as general health discomfort. Thus, heat as a by-product of industrialization has raised the thermal energy worldwide thereby opening windows to global environmental challenges and general alteration of the global climate pattern, local climate variability and air pollution intensity [9].

When anthropogenic and environmental heats are compromised the inhabitants of the earth will experience rise in pollution, low water quality, alteration of the greenhouse gases, high energy use to cool the ambient air and the general health implication [10]. Globally, many variables have contributed to rise in temperature of the environment cutting across deforestation, industrial emission of green gases, low material albedo, heat properties of urban pavements, urban geometry and morphology, size of city, vehicular gas emission as well as body metabolic processes. The rise in the use of land has exposed different countries to increased temperature of the thermal environment especially those already existing in areas of desert, savanna and low grasslands as well as arid zones [11].

However, increased population will raise the world thermal environment [12, 13]. In the world, little attention is given to the concept of population heat bias at a global scale due to the attention given to general global warming resulting from industrial pollution specifically and most heat related studies concentrate on general urbanization and industrialization consequences as well as their causative factors [14]. Thus, only few studies have been carried out to understand the specific factor of global population to the disaster of heat bias in the thermal environment. Some have only specified attention to a particular region of the world [15]. This study depends on global population variability using mathematical models and extraction of other global heat studies to examine the interactions between population and anthropogenic heat processes across the various continents of the world. Thus, it becomes imperative to carry out this investigation on the variability of global population as it affects the human thermal environment and health for effective sustainable global development planning and management.

2. MATERIALS AND METHODS

This is an investigation of world population variability and heat bias prediction as it applies to global heat disaster management. This investigation covers the entire inhabitable continents and countries of the world with current human population capacity of 7,794,798,739 having growth rate of 1.10% per annum [16]. The world has a global mean rainfall of 990mm and mean temperature of 14.51^{0}C per year [17, 18]. The world has seven continents of Asia, Africa, North America, South America, Europe, Antarctica and Australia/Oceania surrounded by Atlantic, Pacific, Indian and Southern oceans respectively Figure 1. This population data were drawn from world population records from the elaboration of data by World Population Review [16] ; United Nations Department of Economic and Social Affairs [UNDESA] [19]; U.S. Census Bureau [20] with varied annual growth rates. For the heat bias, data were generated from population records using the population mathematical prediction model by Oke [21]. According to the model, the heat bias of a place is tied in the population. Therefore, the heat bias in Degree Celsius will increase with population of the place using the formula:

$$\text{Heat Island} = 0.73 \log 10 \text{ Pop.}$$

Where: Pop denotes population.

The world population data were applied in the formula. According to Oke [21]; an area with 10 persons will have heat bias of 1.46^{0}C and a place with 1000 persons will have 2.2^{o}C and a place with a million people will have heat bias of 4.4^{0}C. Therefor the population mathematical method was adopted to generate heat bias data for all the continents of the world. Descriptive statistics of mean and range were used for the data analysis. Furthermore, the study adapted the global heat load of Gerd and Birger [4] as established in the 2009 ECHAM4/T106-data (2041_2050 and 1971_1980) model stimulation to gain further understanding of the global thermal environment

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across the various continents of the world. The Analysis of Variance (ANOVA) was used to establish whether variation exists between heat bias and population density across the continents.

Figure-1. World Continents.

Source: Maps of the World [22].

3. RESULTS AND DISCUSSION

Population explosion has resulted to rapid urbanization with increased heat bias across different continents of the world. Population and its density can give way to environmental heat bias. In Table 1. The population of Asia was the largest among the continents of the world having 4,436,224,000 persons and landmass of 44,579,000 sq. km with 48 countries. Africa was the second largest continent with population of 1,216,130,000 persons, having a landmass of 30,221,532 sq.km hosting 54 countries. Europe was the third largest populated continent with 738,849,000 persons located in a landmass of 10,180,000 sq. km having 50 countries. The fourth largest populated continent was North America having 579,024,000 persons and landmass of 24,709,000 sq. km and 23 different countries. The fifth largest continent was South America which had population of 422,535,000 persons and land mass of 17,840,000 sq.km with 12 countries respectively. The Australia/Oceania continent had population of 39,901,000 persons and land mass of 8,525,989 sq.km having 23 countries and territories. The Antarctica was the least populated continent with 1,106 persons and known for its low inhabitable landmass of 14,000,000 sq.km due to its extreme cold characteristics Figures 1a and 1b. For the heat bias characteristics of the continents Table 1, Figures 2 and 3, Asia had the highest heat bias of 7^{0}C and population density of 99 persons living per square kilometer. Africa was the second continent with heat bias of 6.6^{0}C and population density of 40 persons per square kilometer. North America had the third heat bias score of 6.4^{0}C and population density of 23 persons per square kilometer. The fourth continent with recorded heat bias was Europe with 5.7^{0}C and population density of 72 persons per square kilometer. The fifth continent with the heat bias regime was Australia/Oceania with 4.8^{0}C and population density of 4 persons per square kilometer. The Antarctica was the least with heat bias of 2.2^{0}C and population density of almost zero persons per square kilometer. The population heat bias of all the continents ranged between 2.2^{0}C to 7^{0}C and population density varied between 0 to 99 persons per square kilometer respectively. The world had heat bias of 7.2^{0}C and a population of over 7,432,664,106 people having mean continental heat bias of 5.4^{0}C respectively. The increased migration of people from one continent to another would accelerate population, urbanization and fluctuation of heat bias among continents. For instance, the 2005 International Organization on Migration [IOM] [23] report estimated that 4.6m Africans were living in the EU and 890,000 in the USA, indicating that heat bias would continue to rise exponentially in both continents. Birth

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regulation and other population control measures would regulate heat bias among the continents of the world. Lemonsu, et al. [24] in their studies established heat bias values of +0.5°C-2.5°C as comfortable threshold for people. Steeneveld, et al. [25] concluded that human comfort was preferred at temperature threshold of 27°C. Ilham [26] unveiled that the heat bias would be acceptable at 1.5°C for human health and comfort.

In this vein, all the continents except Antarctica had exceeded the standard comfort threshold. Thus, Africa and Asia as well as those countries within the tropics would experience severe heat discomfort since they had naturally higher thermal environment. Countries of the temperate regions would relatively experience low impact of the heat bias since their thermal environment was naturally cold. In the global heat load of Gerd and Birger [4] as established in the 2009ECHAM4/T106-data (2041_2050 and 1971_1980) simulation there was further understanding of the thermal environment across the various continents of the world. Countries lying within the humid tropics had limited comfort threshold with continuous heat load and cold stress respectively. Thus, from the subtropical countries up to those of the middle latitudes would experience decline in heat comfort. Heat comfort threshold was limited to areas of moderate population density excluding Southern Scandinavia, some sections of Russia, China, British Columbia of Canada and the northeastern segment of the USA Figure 4. Thus, continents that exceeded the population bias and thermal environmental threshold would be very uncomfortable for inhabitation. The analytical result shows that calculated F-value of 5.35664963 and critical f-value of 4.747225347. This indicates that there is difference between heat bias and population density of the data sets such that population density does not influence heat bias across the globe. This situation could arise because there are other variables affecting heat bias such as the influence of different climatic conditions modifying the thermal environment. Furthermore, it indicates that heat bias across the globe is severely influenced by other biophysical conditions and not only by the number of persons living in the continents. This is in tandem with the previous view that continent such as Europe with population density of 72 persons per square kilometer and heat bias of 5.7°C does not have higher heat bias than Africa with population density of 40 persons per square kilometer and heat bias of 6.6°C.

Table-1. Population, density and heat bias across different continents of the world.

Continent	Size (sq.km)	No. of Countries	Population	Heat Bias (°C)	Population Density
Asia	44,579,000	48	4,436,224,000	7	99
Africa	30,221,532	54	1,216,130,000	6.6	40
Australia/Oceania	8,525,989	3	39,901,000	4.8	4
Antarctica	14,000,000	0	1,106	2.2	0
Europe	10,180,000	50	738,849,000	5.7	72
North America	24,709,000	23	579,024,000	6.4	23
South America	17,840,000	12	422,535,000	5.5	23
	150,055,521	**190**	**7,432,664,106**	**Ave. 5.4**	

Source: Authors adapted and simulated from United Nations Department of Economic and Social Affairs [UNDESA] [19]; World Population Review [16].

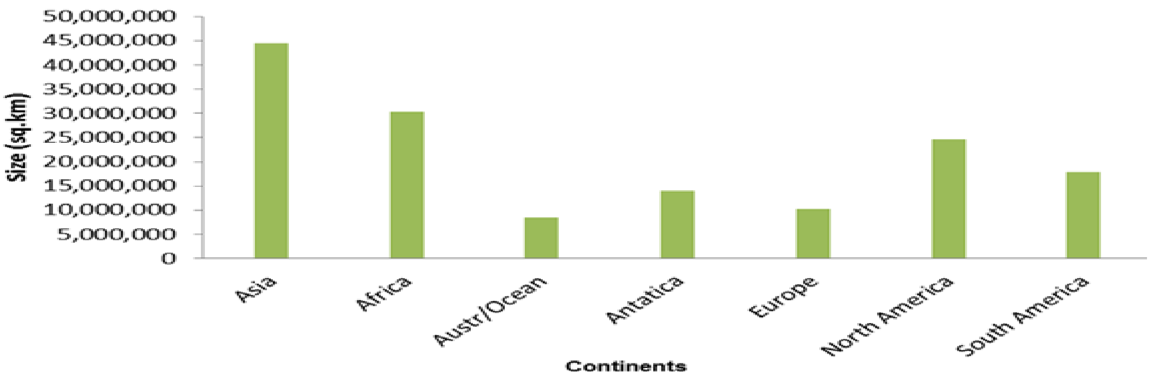

Figure-1a. Landmass of various continents of the world.

Source: Adapted from United Nations Department of Economic and Social Affairs [UNDESA] [19]; World Population Review [16].

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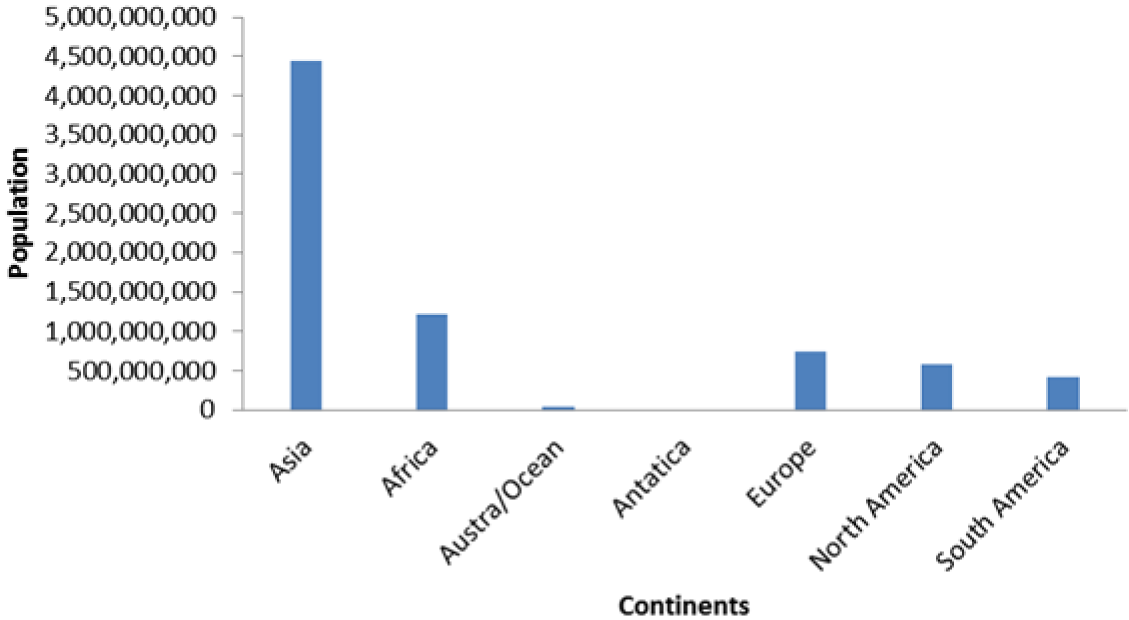

Figure-1b. Population distribution of different continents of the world.

Source: Adapted from World Population Review [16].

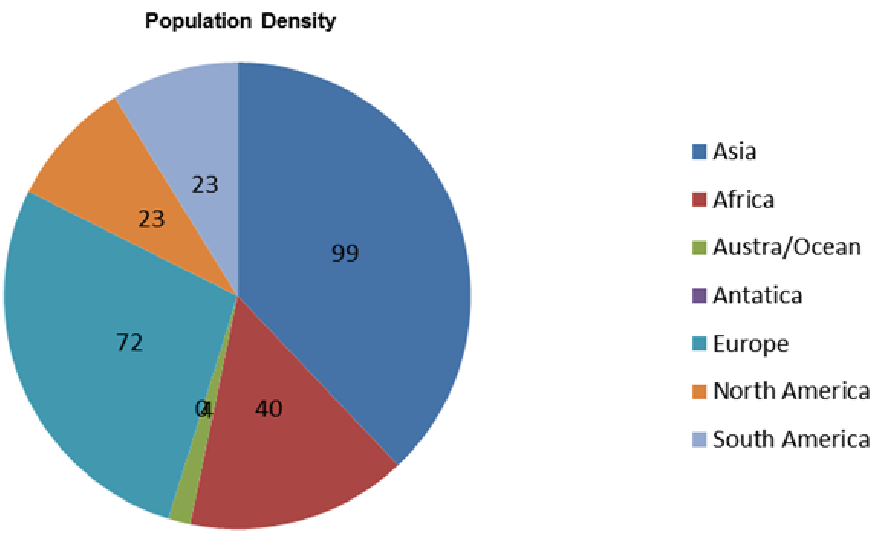

Figure-2. Population density of different continents of the world.

Source: Adapted from World Population Review [16].

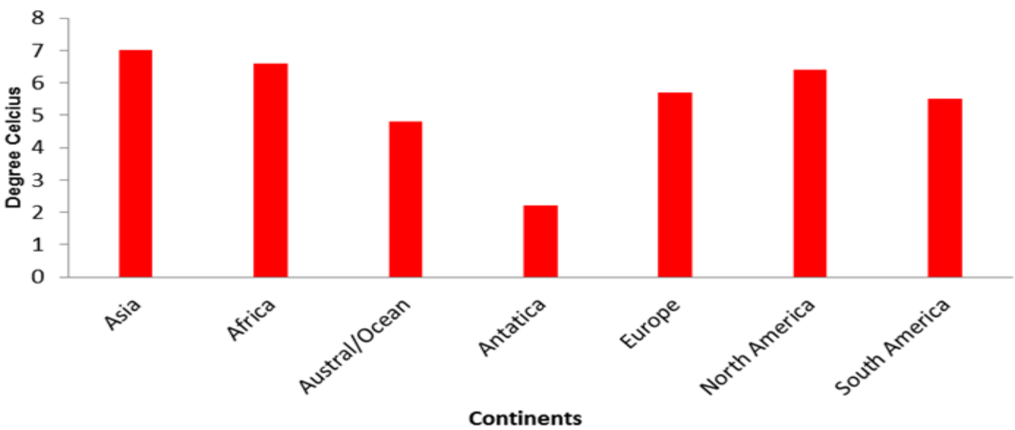

Figure-3. Heat bias of various of continents of the world.

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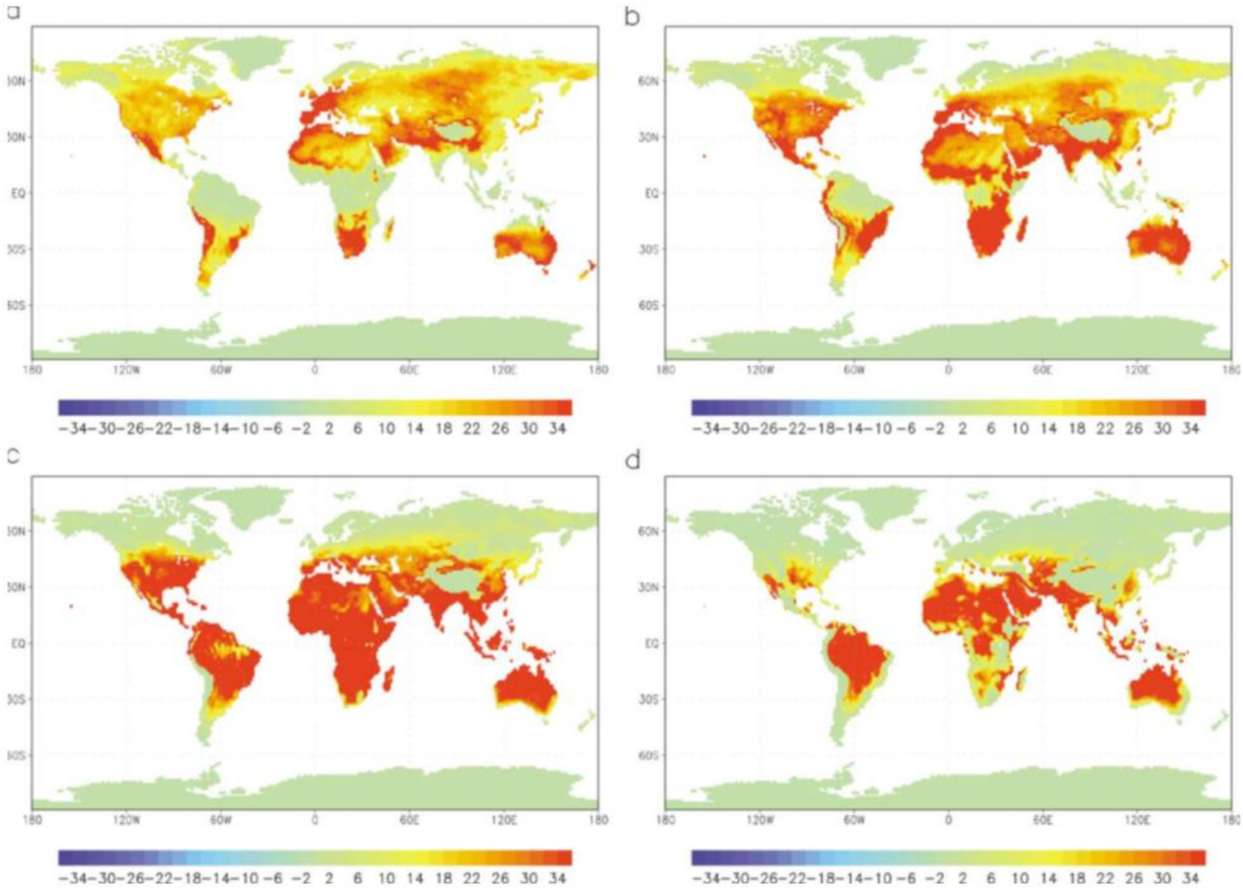

Figure-4. Mean Global Heat Load and Threshold (a) heat load, (b) moderate heat load, (c) strong heat load and (d) extreme heat load at 12 MLT taking acclimatization into account, based on ECHAM4/T106-data.
Source: Adapted from: Gerd and Birger [4].

4. CONCLUSION

This study investigated world population variability and heat bias prediction as an approach to global heat disaster management. The population mathematical model was applied to simulate the heat bias of different continents of the world. Thus, various continents have their special population sizes and heat bias conditions. Asian continent has the highest heat bias and the Antarctica maintains the lowest heat bias. The world has heat bias of 7.2^{0}C and mean heat bias of 5.4^{0}C showing that it has exceeded the global comfort threshold of +0.5-2.5^{0}C. Also, countries within the humid tropics will have a continuous heat load exceeding 27^{0}C and +0.5-2.5^{0}C due to population and influx of direct solar energy. Countries within the subtropics up to the middle latitude as well as those with moderate population will experience relatively lower heat load and heat bias. The rapid migration of people from one continent and country to another will continue to unevenly distribute heat bias across the various places. Therefore, since the excess heat bias and load will result to heat related illness, it is recommended that various governments, planners and decision makers should implement policies that will be capable of mitigating the dangerous effects of population, heat bias and associated health disaster resulting from the human thermal in order to have a sustainable global community free from heat stress.

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