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# THERMAL ANOMALY AND HEAT INDEX DURING MECCA PILGRIMAGE (1982-2010)

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## ABSTRACT

*The Hajj or Mecca Pilgrimage falls during the month of Dhulhijjah, i.e. the last month of the Islamic calendar. Nowadays, more than 2 million people performed Hajj and officials have been forced in recent years to limit the number of pilgrims. There are an increasing number of cases associated with sudden death due to extreme heat within the period of pilgrimage in Saudi Arabia. In general, this study attempts to examine the changes in the thermal anomaly and the heat index in city of Mecca, particularly during the Hajj period. This study uses a scientific approach and applies quantitative analysis of secondary information on climatology of Mecca from 1982 to 2012. The study found that almost 48.3% of pilgrimage took place in summer, during which the heat index was categorized as Extreme Danger. About 24% of pilgrimage season was considered as Danger. There is a potential existence of heat stroke within the hajj season between the months of April to September. Local meteorological analysis has also established that Medina has experienced less extreme temperature conditions within 1982-2012, if compared to other cities. The study also found that the next future hajj seasons (2018-2030) is expected fall within months of April to August, which associated with dry and hot period.*

**KEYWORDS:** *thermal anomaly, heat stroke, hajj, Mecca, Medina, heat index*

## INTRODUCTION

Disaster caused by thermal anomaly or extreme change in temperature has been widely studied especially in arid and semi-arid environment. The research related to sudden death due heat stroke to human kind not only driven through medical approach, but it also done through intra and inter-discipline approaches. In Saudi Arabia, the climate is generally dry and hot climate and prone to exhibit extreme thermal anomaly especially in summer. Heat stroke and heat wave phenomena are common in the country. Many of hajj pilgrims suffered from heat stroke annually. The death toll due to extreme temperature disturbances has increasing through time and still stand as an important issue to the Saudi management (Gabal & Salem 2003). Global climatic change has reinforced this extreme situation and probably gives cascading impact to Mecca's pilgrims in future. Apart of that, catastrophic urban climate due to urbanization such as heat island phenomenon will lessen the quality of life among urban dwellers. According to Ahmed (1988) and Abderahman (2008), rapid urbanization in the Saudi region is due to the influx of large-scale international migration following the labor force demand for the region's development. In general, this study attempts to examine changes in meteorological conditions in three major cities, namely Makkah, Medina and Jeddah as well as to study heat anomaly especially during the Hajj season.

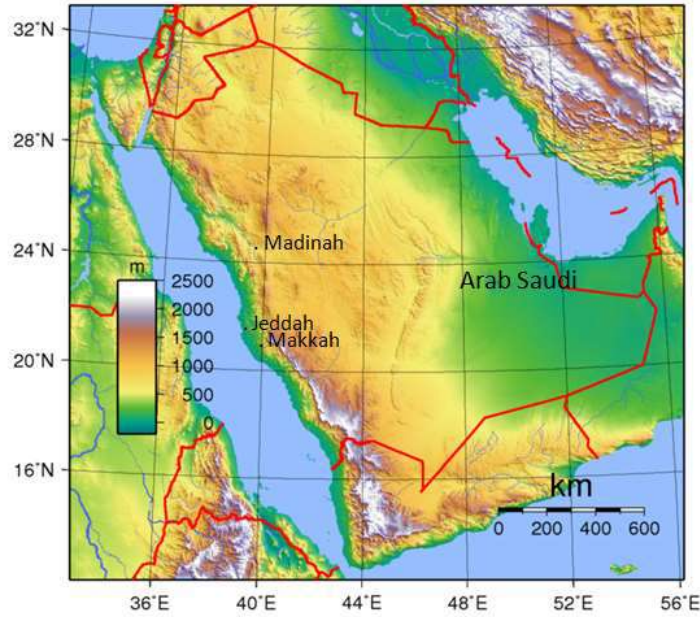
Generally, the heat wave is a situation where local weather experiencing prolonged overheated period with high relative humidity (Collins 2009). From the urban climate aspect, this heat wave is defined as a period (whether in the day or hour count) the surrounding temperature is capable of causing catastrophic exposure to humans (Mehta and Jaswal

2003). Hence, it can be within a few hours or several days resulting in thermal discomfort, disease and even death.

Given today's uncertain global climate change, the heat wave does not only exist in a desert country like Saudi Arabia, but it also happens around the world. The occurrence of reported deaths occurs worldwide due to this heat wave. The hyperthermia phenomenon is a condition in which the human body is no longer capable of controlling body temperature until the body temperature increases dramatically and results in loss of heart function and leads to sudden death. Heat wave not only causes heat stress, but in some cases, it leads to loss of property and death. A study done by Gabe and Salem (2003) in Saudi Arabia showed that the elderly hajjajs (hajj performer) were much affected to heat stroke. Their research also found that hajjajs who experienced excessive heat problems also led to the death of pilgrims. Heat wave event in Europe in 2003 was considered a 'USD1 billion disaster' (EPI 2006) clearly showed the level of catastrophic severity to the human economy just in a few days.

## METHODOLOGY AND STUDY AREA

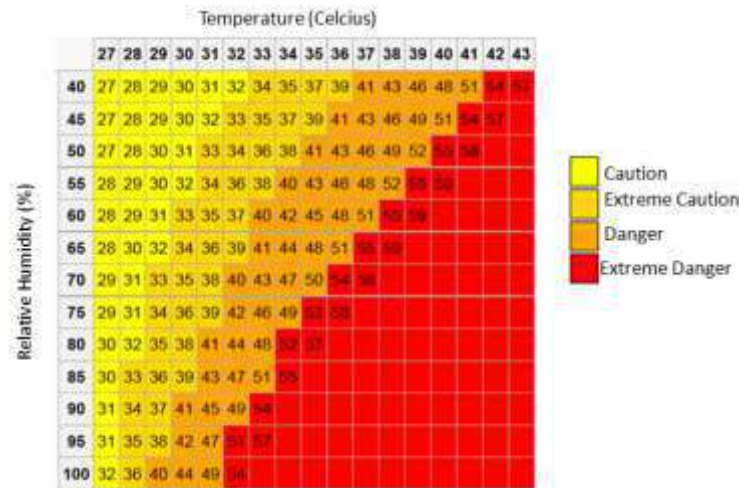
Generally, this study is based on quantitative analysis using secondary data provided by several agencies in Saudi Arabia. Among agencies involved were National Meteorological and Environment Centre of Saudi Arabia and the Ministry Hajj and Umrah. Among the data quoted for the purpose of climatological analysis include several major stations, mainly 3 cities - Makkah, Medina and Jeddah (Figure 1). Long-term meteorological information for the three cities is carefully studied. The relevant meteorological information is from 1984 to 2012, which is a period of 29 years.



**Figure 1. Location of Makkah, Medina and Jeddah, Saudi Arabia**

To measure the effect of heat on human, a heat index table published by the National Oceanic and Atmospheric Administration (NOAA) was used (Figure 2). NOAA is a United States government body that focuses to the changing pattern of ocean and atmospheric conditions. Full information regarding this

index can be accessed online through the website <http://www.nws.noaa.gov/os/heat/index.shtml>. The heat index is a measure of how hot it really feels when relative humidity is factored in with the actual ambient air temperature.



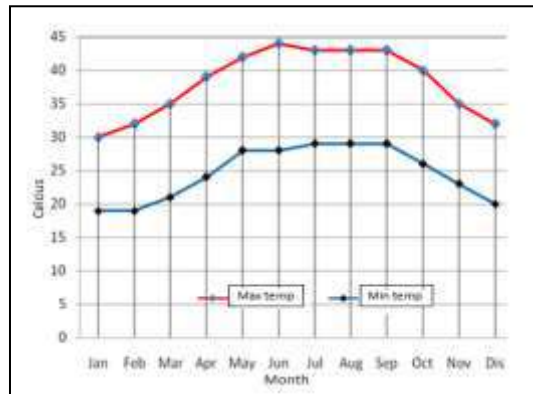
**Figure 2. NOAA's heat index**

Source: [www.hpc.ncep.noaa.gov/html/heatindex.shtml](http://www.hpc.ncep.noaa.gov/html/heatindex.shtml)

## RESULT AND DISCUSSION

There is a significant difference in climate from coastal to the inland (desert area) in Saudi Arabia. The coastal area has a high humidity and the temperature is considered normal (i.e. below 38°C) while the interior is very dry, hot and the ambient temperature is high compared to the coastal area

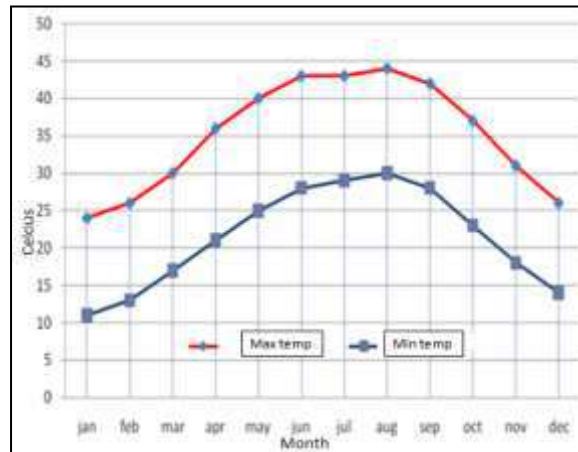
(average 45°C in the summer) sometimes reaching maximum temperature up to 54 °C. The annual amount of rainfall is usually less than 100 mm, but there is extreme wet conditions leading to flash flood phenomenon in urban areas such as Riyadh and Jeddah. Rainy periods are usually between May and October.



**Figure 3. Temperature variation at Makkah (1984-2012)**  
 Source: National Meteorological and Environment Centre of Saudi Arabia

In Makkah, summer usually runs from May 7 to October 10 with a high daily average temperature above 41°C (Figure 3). The warmest days in the period (1984-2012) were June 12, with an average of 43°C. Winter runs from December 5 to February 24 with a high daily average temperature below 32°C. The coldest day of the year (1984-2012) was on January 19,

with an average low of 19°C. In Makkah, June 21 was regarded as the clearest day in the period (1984-2012) where the sky was clear while on January 2, the cloudiest day. In Makkah, the relative humidity is usually between 19% (dry) to 80% (damp) throughout the year, but it rarely drops below 12% (very dry), or above 91% (very moist).



**Figure 4. Temperature variation at Jeddah (1984-2012)**  
 Source: National Meteorological and Environment Centre of Saudi Arabia

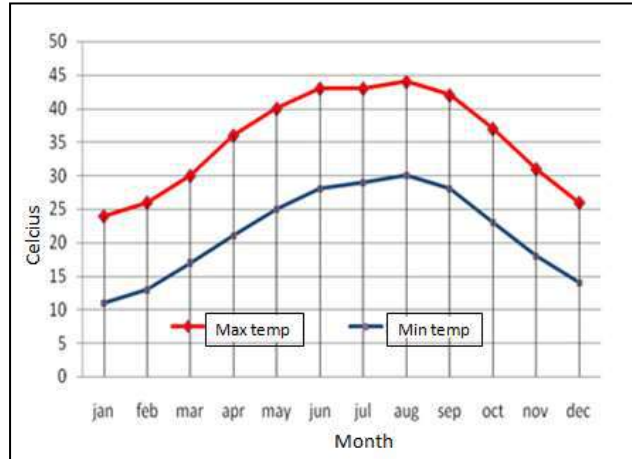
Months from December to February are considered the most comfortable months in Makkah from the aspect of relative humidity and surface temperatures, which are expected lesser heat stroke problems for visitors or pilgrims. While the months of May to October are considered the most challenging months due to the extreme heat and the most extreme unheated temperatures in Makkah. In Jeddah, the summer runs from May 17 to October 10 in that period (1984-2012) with a daily average temperature above 37°C (Figure 4). The warmest day in the period (1984-2012) was July 7, with an average level of 39°C. Winter takes place between 13 December and 28

February with a daily average temperature below 30°C. The coldest day in that period (1984-2012) was February 12, with an average low of 18°C.

The relative humidity in Jeddah is usually between 30% (dry) to 89% (very moist) within that period (1984-2012) and rarely less than 17% (dry) or reaches as high as 96% (very moist). The air was dry around July 7, where at humidity falls below 39% while the average time was around October 3 which is over 84%. In Medina Al Munawarrah, throughout the year the temperature varies from 12°C to 43°C and very rare less than 8°C or above 46°C (Figure 5). Summer usually from May 16 to October 4 with a daily

average high temperature above 39°C. The warmest day in the period (1984-2012) was on August 19, with an average temperature of 43°C and a minimum temperature of 30°C. The winter runs from November 30 to February 24 with a daily average temperature below 27°C. The coldest day of the year was in January 16, with an average temperature of 12°C.

Relative humidity in Medina Al Munawwarrah was usually between 6% (very dry) to 63% (slightly wet) within that period (1984-2012), falling as lowest as 3% (very dry) and reaching as highest as 98% (very damp). The air extremely dried around June 14, where the relative humidity fell below 7%, while the extremely wet conditions experienced around January 1, exceeding 48%.



**Figure 5. Temperature variation at Medina (1984-2012)**  
 Source: National Meteorological and Environment Centre of Saudi Arabia

Table 1 shows highest temperature, relative humidity and heat index during the haj season 1982-2010. Date of wuqf for 29 years from 1982 to 2010 shown the hajj practices have been performed almost 48% during the summer and composite values between surface temperature and relative humidity have been

categorized as Extreme Danger (ED), where the reading index exceeded 54 °C. Only 24% of the Hajj season in the category of Danger (D), while the Caution state (C) and Extreme Caution (EC) zone of 23% and 5% respectively (Figure 6).

**Table 1. Highest temperature, Relative humidity and heat index during the Hajj season 1982-2010**

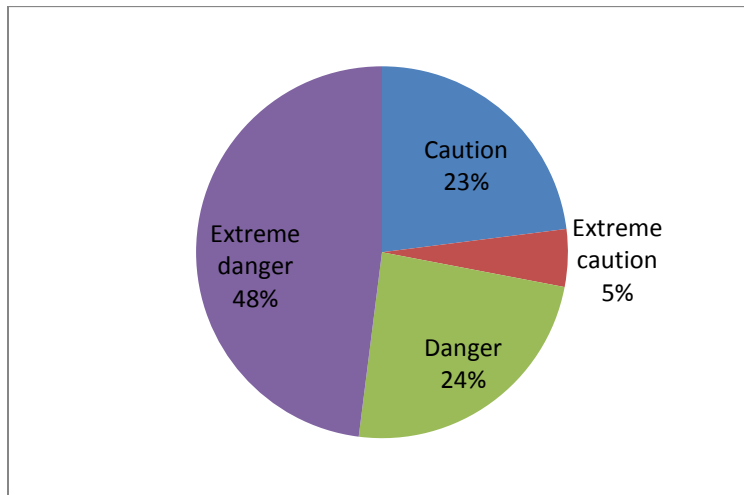
Year	Total visitor	Wuqf date at Arafah	Highest Temp. (°C)	Relative Humidity (%)	Heat Index
1982	2,011,555	27 Sept 1982	38	50	D
1983	2,501,706	16 Sept 1983	39.5	52	D
1984	1,664,478	5 Sept 1984	43	65	ED
1985	1,589,776	25 Aug 1985	44.5	85	ED
1986	1,600,475	14 Aug 1986	43	56	ED
1987	1,619,324	3 Aug 1987	43.2	37	ED
1988	1,379,556	21 Jul 1988	42	65	ED
1989	1466,995	12 Jul 1989	49.8	77	ED
1990	1,644,470	1 Jul 1990	41.8	58	ED
1991	1,628,186	21 June 1991	43.2	62	ED
1992	2,178,141	10 June 1992	42.7	47	ED
1993	2,035,375	30 May 1993	40.8	57	ED
1994	1,533,506	18 May 1994	47	76	ED
1995	1,537,168	8 May 1995	41.2	37	D
1996	1,609,423	27 April 1996	39.0	62	ED

1997	1,688,500	15 April 1997	40.2	50	ED
1998	1,718,186	6 April 1998	22.4	88	C
1999	1,831,998	26 Mac 1999	35.2	59	D
2000	1,733,785	15 Mac2000	37.2	76	ED
2001	1,913,263	4 Mac 2001	36.4	70	D
2002	1,944,760	22 Feb 2002	35.3	62	D
2003	2,041,129	11 Feb 2003	32.2	53	EC
2004	2,012,074	2 Feb 2004	27.4	54	C
2005	2,164,469	17 Jan 2005	27.2	44	C
2006	2,130,594	9 Jan 2006	31.5	49	EC
2007	2,454,325	30 Dis 2007	34.3	60	D
2008	2,483,344	7 Dis 2008	33.2	20	C
2009	2,521,000	27 Nov 2009	28.1	68	C
2010	2,800,000	17 Nov 2010	40.2	49	D

Note:

Heat Index Level

- Caution (C) : Level 1
- Extreme Caution (EC) : Level 2
- Danger (D) : Level 3
- Extreme Danger (ED) : Level 4



**Fig 6 Heat index level in hajj season (1982-2012)**

The information has shown that the potential for heat stroke due to the presence of heat wave is higher during the hajj season from April to September, which is earlier than the summer peak time Saudi Arabia, which is in month of May. The finding of the local meteorological analysis also proven that the city of Medina is a city with less extreme surface temperature condition between 1982-2012, compared to other cities. The findings also found that Jeddah and Makkah cities are two major cities which are included in uncomfortable zone bands (extreme heat waves). However, what is more alarming is that of the city of Mecca, especially during the Hajj season as most of the pilgrims and pilgrims and pilgrims are located at the site.

Generally, the population is higher in the port city of Jeddah, compared to Makkah and Medina. This is because the city of Jeddah is considered a major transportation city and is also the prime location for the service and commercial system in Saudi Arabia. Hence, there is an overflow of migration into the port city of Jeddah which provides continuous employment opportunities. As shown in Table 2, it concluded that the next future hajj seasons (2018-2030) is expected fall within months of April to August, which associated with dry and hot period.

**Table 2. Date of the next Hajj Event**

2018	2019	2020	2021	2022
19 Aug	9 Aug	28 July	17 July	7 July
2023	2024	2025	2026	2027
June 26	June 14	June 4	May 24	May 14
2028	2029	2030		
May 5	April 23	April 12		

**CONCLUSION**

Among the major factors of increased visitor attendance during the haj season after 1994 was due to weather factors, where the haj season that lasted between 1995 and 2012 was in winter condition. There was only 4 years in which the index was regarded as Extreme Danger (ED) between 1994-2010, while the rest (11 years) had a ED index in that period (1982-1994). The result of the correlation analysis between the number of pilgrims and the highest temperature at Arafah during the haj season showed negative relationships ( $r = -0.46, p < 0.05$ ), but significance at the confidence level of 0.05. This shows a significant inverse relationship between the highest temperature in Arafah and the number of pilgrims from 1982 to 1994. The result of this study confirmed that the number of pilgrims (whether coming from overseas or from the Gulf region) is heavily dependent on weather condition and the presence of heat waves that may lead to discomfort and death to the visitors.

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