INVESTIGATION OF TEMPORAL VARIATION OF HUMAN THERMAL DISCOMFORT IN DJIBOUTI

BY

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DECLARATION

I hereby declare that this is my original work and has not been presented for a degree in any other University.

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This project has been submitted for examination for examination whit our approval as University Supervisor

Signature: …………………………… Date ……………………..

Prof N.J.MUTHAMA

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ABSTRACT

Hot weather causes heat stress in dairy humans. Although effects are more severe in hot climates, dairy cattle in areas with relatively moderate climates also are exposed to periods of heat stress.

The objective of the study was to determine the thermal comfort or discomfort of people to the prevailing environmental conditions particularly temperature and relative humidity during the various seasons of the year at Djibouti in terms of thermal discomfort index (DI). The DI was calculated from Thom's formula

The area of study is Djibouti, a small and hot country in the east of Africa. The data for the calculation have been taken from the readings of airt emperature and relative humidity throughout a period of 29 years (1985-2014) in the Djibouti Aerodrome station, Randa, Obock and Ali-Sabieh.

A mass curve method was used for consistency and homogeneity of the data and for missing data, arithmetic methods was used.

The main objective in this study is to make assessment on stress caused by temperature and humidity in order to establish the withal of Djibouti's comfort levels during the various seasons of the year which can be useful in evaluating human discomfort and apply the index on a national level to determine which months possess the most extreme values.

Thom's Table of DI Ranges was used to determine the percentage of the population of Djibouti suffering from discomfort or otherwise. Times series analysis was done to determine the daily and seasonal discomfort level of the population.

This study found that less than 50% of the population experienced the sense of discomfort during January February March April October November and December in the morning time and more than 50% of in the afternoon. But more than 50% of the population suffered from discomfort during May June July August and September in the morning time and almost all the population in the afternoon. The discomfort indices greater than 30 or 32 (indicating 100% of the population feeling discomfort or the condition of medical emergency, respectively) were not attained in Djibouti.

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

The climate and health are two completely different things, and yet there is a close link between them, the first affecting the second. The great change of climate that we experienced and that we still live will have a major impact on the functioning of ecosystems and human health.

Currently one of the most alerting climatic factors for our health is climate change, which affects mostly extreme temperature zones. The impact of climate change was significant enough to threaten human health both directly and indirectly through heat stress, degraded air quality, rising sea levels, food security and the water, extreme weather events. Heat stress due to the High temperature causes a human thermal discomfort. The concept of thermal comfort is most often applied to humans, although it can be applied to any living being. Indeed, life - especially the metabolic activity providing vital functions - is only possible to a certain temperature range, which varies from one species to another. However, there are optimum environmental conditions that will be experienced by the individual as that of a state of thermal comfort. On a physical level, thermal comfort corresponds to a state of thermal equilibrium between the human body and the environmental conditions. It depends on the sensitivity, clothing, metabolism and physical activity of each individual, on one hand, but also the temperature of the environment (air, walls), air movements, of moisture, on the other hand. Beyond a certain level of imbalance, the individual will feel discomfort, especially because it will have to take action to reduce this imbalance. Therefore, the knowledge of human discomfort conditions is necessary because many people especially those living in major cities have more risk for morbidity and mortality due to temperature higher air as the surrounding countryside (Nastos, P. T., &Matzarakis, A. 2006).

The main factor of human discomfort is the thermal component environmental conditions and was calculated by many indexes taking air temperature of the examination, based humidity and wind speed (Thom, E.C. 1959, Steadman, R. G. 1971). The formula for Thom (Thom, E.C. 1959) is one of the most famous formulas used to calculate Discomfort index (DI) based on the temperature and relative humidity.

Djibouti has an arid tropical climate semi-desert type marked by two distinct seasons. The cool season (October to April) is characterized by mild temperatures ranging between 22 ° C and 30 ° C, high relative humidity and sea winds (winds). And warm season (Jun-September), with high temperatures fluctuating between 35 ° C and 45 ° C. The periods May-June and September-October marks a transition season with a very high relative humidity. However Djibouti is among the hottest countries in the planet.

Feeling of discomfort experienced by people to the environmental conditions has been documented in the past through limited studies. In Thessaloniki, Greece, (ANGOURIDAKIS, V.E., AND MAKROGIANNIS, T.J., 1982) found that most people being uncomfortable when DI was greater than 24. In Mexico, United States,(Jauregui, E., and Soto, C., 1963) found that most people experienced the sense of discomfort when DI reached 24 and even in Kenya (Victor Ongoma, John NziokaMuthama, 2014).

No studies on discomfort have been conducted in Djibouti. This study is an attempt to start bridging this gap and will attempt to give more information of human discomfort around the country that somewhat be helpful on evaluating a variety of socioeconomic parameters such as mortality, employee absenteeism, and recreation. The economist and the tourism industry will no doubt benefit a great deal from such information

1.2 Problem Statement

Did you know that an increase in body temperature only a few degrees can affect your mental function? An increase of a few degrees higher can result in serious injury or death?

A healthy human body maintains a constant body temperature of about 37°C. A fluctuation of less than 1°C depending on the time of day, level of physical activity and emotional state is normal. A change of more than 1°C in body temperature occurs only in case of illness or when the body is unable to withstand the environmental conditions, such as extreme heat.

When we are in a hot environment, our body temperature rises. The body should mitigate this effect by removing heat; heat loss is due to evaporation of the sweat produced by the body. If this method does not allow cooling the body, the body temperature increases. In this case, the typical daily functions, such as thinking, concentration and the execution of a task can become difficult depending on the exposure time and environmental conditions. Symptoms of an increase in internal temperature may be, among others, feelings of exhaustion, shortness of breath, dizziness and nausea. These symptoms may be early signs of more serious heat-related hazards.For most people, the comfort temperature range is between 20 and 27 ° C, and when the moisture range is 35 to 60%. When the temperature or the humidity is higher, people feel uncomfortable. As long as the body is able to react and adapt to the heat conditions and ambient humidity, it does not suffer adverse consequences. By cons, very high ambient temperatures can overwhelm the thermoregulatory mechanisms of the body and cause serious problems and even death. This was well by the 1980, 1983 and 1988 heat weaves in USA during which 1700, 556 and 454 deaths respectively were reported. In the year 2003 in France 10000 deaths were reported due to human discomfort caused by heat stress happened in the area.

Throughout the twentieth century and into the twenty first century there has been an active research on: what conditions will produce thermal comfort and how to grade heat stress.
These efforts resulted in various models attempting to describe thermal comfort. These studies have not been conducted only for their scientific merit but rather to establish safety limits and to increase productivity.

1.4 Objective of the study

1.4.1 Main objective

To make assessment on stress caused by temperature and humidity in order to establish the withal of Djibouti's comfort levels during the various seasons of the year which can be useful in evaluating human discomfort and apply the index on a national level to determine which months possess the most extreme values. This can provide knowledge of understanding on how temperature stress can cause human discomfort which can affects human health.

1.4.2 Specific objectives

-Calculate the degree of comfort

-Determine the daily and season discomfort level

1.5 Problem Justification

Control by displacement and the relative action of anticyclones of Arabia and Libya and the movements of the intertropical convergence zone (ITCZ), the climate of the Republic of Djibouti is of tropical arid characterized by annual rainfall of 150 mm (CHA 1982).

We find in Djibouti both seasons of the African sub-tropical climate and they differ essentially in temperature.

The cool season lasts from late October to April when the ITCZ is located south of the country. The Republic of Djibouti has this season a very pleasant climate: the sky is usually clears and temperatures vary between 20 ° C and 30 ° C. The warm season extends from June to September. The ITCZ across Africa and Arabia between 15 ° N and 20 ° N. The SW monsoon circulating on East Africa undergoes a Foehn effect very mark the passage of reliefs from Somalia and Ethiopia and is sweeping the country as a dry westerly wind called Khamsin. The haze and dust hunts are frequent and reduce visibility. Temperatures range from 30 ° C-34 ° C at dawn and 40 ° C-45 ° C in the early afternoon. A transition period from May to June and from September to mid-October between these two seasons. The ITCZ is located at the latitude of the country. The climate is characterized by the absence of wind, relatively high temperatures (28 ° C-36 ° C) and high humidity

So we can say that Djibouti is a hot country in winter and very hot in summer, so the inhabitants of those countries are exposed to the danger of heat stress at all times of the year. Moreover, no study in this area to make entries before visor because the country not being a developing country if that takes seriously the dangers that its population risk.

CHAPTER TWO

LITERATURE REVIEW

Thermal comfort is generally defined as that condition of mind which expresses satisfaction with the thermal environment (e.g. in ISO 1984). Dissatisfaction may be caused by the body being too warm or cold as a whole, or by unwanted heating or cooling of a particular part of the body (local discomfort).

From earlier research (as reported and reviewed in e.g. Fanger 1972, McIntyre 1980, Gagge 1986) we know that thermal comfort is strongly related to the thermal balance of the body. This balance is influenced by:

• Environmental parameters like: air temperature (Ta) and mean radiant temperature (Tr) and relative air velocity (v) and relative humidity (rh)

• Personal parameters like: activity level or metabolic rate (M) (units: 1 met = 58 W/m2.K/W) clothing thermal resistance (Icl) (units: 1 clo = 0.155 m)

Extensive investigations and experiments involving numerous subjects have resulted in methods for predicting the degree of thermal discomfort of people exposed to a still thermal environment.

The most well-known and widely accepted methods are (1) Fanger's "Comfort Equation" and his practical concepts of "Predicted Mean Vote" and "Predicted Percentage of Dissatisfied" (Fanger 1972) and (2) the J.B. Pierce two-node model of human thermoregulation (Gagge 1973, 1986). with these methods several thermal comfort standards (e.g. Fanger 1980, ASHRAE 1981, ISO 1984, Jokl 1987) have been established during the past decade. These standards specify environmental parameter ranges (i.e. comfort zones) in which a large percentage of occupants (generally at least 80%) with given personal parameters will regard the environment as acceptable. Most work related to thermal comfort has concentrated on steady state conditions. This is expressed by the fact that only one of the above standards. (ASHRAE 1981) also specifies limits for changing environmental parameters (for to only).

The factors affecting thermal comfort were explored experimentally in the 1970s. Many of these studies led to the development and refinement of ASHRAE Standard 55 and were performed at Kansas State University by Ole Fanger and others. Perceived comfort was found to be a complex interaction of these variables. It was found that the majority of individuals would be satisfied by an ideal set of values. As the range of values deviated progressively from the ideal, fewer and fewer people were satisfied. This observation could be expressed statistically as the % of individual who expressed satisfaction by comfort conditions and the predicted mean vote (PMV). This approach was challenged by the adaptive comfort model developed from the ASHRAE 884 project which revealed that occupants were comfortable in a broader range of temperature.

CHAPTER THREE

DATA AND METHODOLOGY

3.1 Area of study

Located in the region of the Horn of Africa at the junction between the Red Sea and theGulf of Aden, the Republic of Djibouti extends between latitudes 10 ° 9 'and 12 ° 7'N and longitudes 41 ° 8' 4 'E and 43 °. Sharing common borders with Eritrea, Ethiopia and Somalia, the country covers a land area of 23,000 sq km, has a coastline of 372 km and has an exclusive maritime area of 7.190 km².

Essentially volcanic, the terrain Djibouti territory is home to a unique geological phenomenon in the form of a rift (the Assal Rift) at the junction of plates of Ethiopia, Arabia and Somalia. The activity of this rift that has formed over the last thirty million years of tectonic activity associated with the spacing of the plates, resulting in frequent but moderate seismic events.

This results in very steep terrain and characterized by a succession of massive, plateaus and plains. The territory covered consists mainly of arid shrub-steppe scattered and not concealing that few natural resources or mineral recoverable.

The altitude varies from 155 m below sea level with Lake Assal at 2,021 m at Mount Moussa Ali, the highest point of the country. The line between these two points, oriented in the North-South direction, delimits two distinct morphological sets (PANE, 2000):

♣An East dominates a tormented relief to over 1,000 meters, consisting of ridges and sharp blades along deep ravines

♣A West, an area consisting of plains deepening of East West regularly and depressions where the landscape is marked by a major NW-SE fracture.

A third group is represented by the coastal plains of Obock in the north and south of Djibouti. The rest of the coast is composed of cliffs falling directly into the sea, interspersed with small rocky or sandy beaches

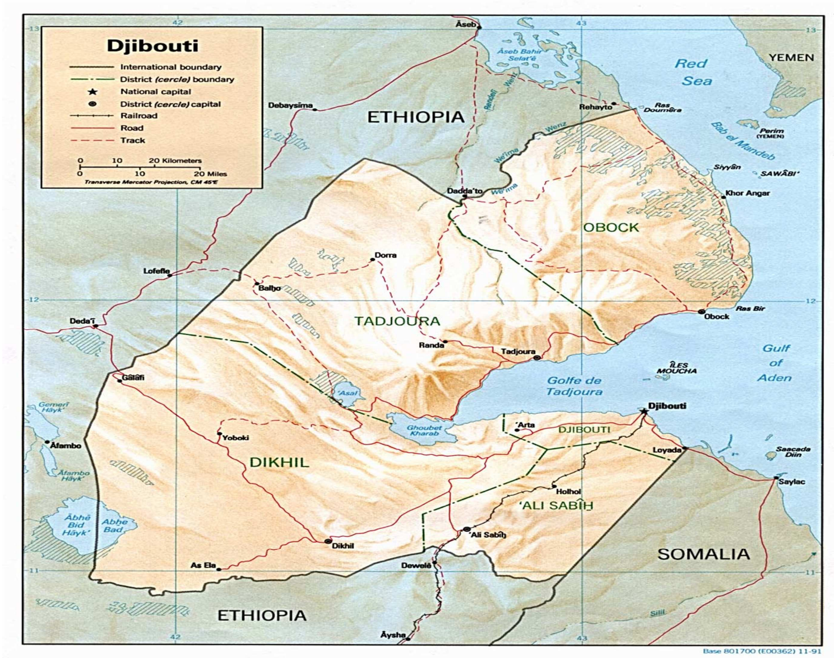

Figure 1: Map of the study area

3.2 Data used

Overall, climate data on the countries are characterized by their dispersion and scarcity due to the closure of most of the meteorological stations in 1978. In these conditions, the climate monitoring cannot be satisfactorily and comprehensively done on whole territory. At present, climate data are mainly collected by the weather station Djibouti Aerodrome. The reste of the data are collected from the satellite.

This study provides comparative information useful in interpreting results because the data used in this study are:

-mean hourly temperatures

-mean hourly relative humidity

The data covered a period of 29 years (from 1985 to 2014)

The followings tables show the main statistical parameters of averages monthly temperatures and relative humidity values for Djibouti Aerodrome station.

Table 1: Averages of temperatures at 06Z over Djibouti Aerodrome from 1985 to 2014

MONTHS	JAN	FEB	MAR	APR	MAI	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Avarege	22.8	23.6	24.9	26.4	28.4	31.0	32.8	31.9	30.3	26.9	24.5	22.3

Table 2: Averages of temperatures at 12Z over Djibouti Aerodrome from 1985 to 2014

MONTHS	JAN	FEB	MAR	APR	MAI	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Average	28.2	28.6	29.7	31.3	34.4	37.9	39.7	39.1	36.2	32.6	30.6	28.2

Table 3: Averages of relative humidity at 06Z over Djibouti Aerodrome from 1985 to 2014

MONTHS	JAN	FEB	MAR	APR	MAI	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Average	83,65	83,77	83,46	85,19	81,48	61,5	51,15	57,13	72,21	78,93	82,34	84,45

Table 4: Averages of relative humidity at 12Z over Djibouti Aerodrome from 1985 to 2014

MONTHS	JAN	FEB	MAR	APR	MAI	JUN	JUL	AUG	SEP	OCT	NOV	DEC
average	61,25	62,3	62,95	63,45	57,02	44,05	32,85	35,51	49,75	56,95	58,88	59,9

3.3 Data quality control

It is often important to determine if a set of data is homogeneous before any statistical technique is applied to it.

The data was subject to exploratory analysis (scattering methods) and mass curve was done for consistency and homogeneity of the data and for missing data, arithmetic mean method was used. Figure 1 to 4 showed that data was consistence and homogenous.

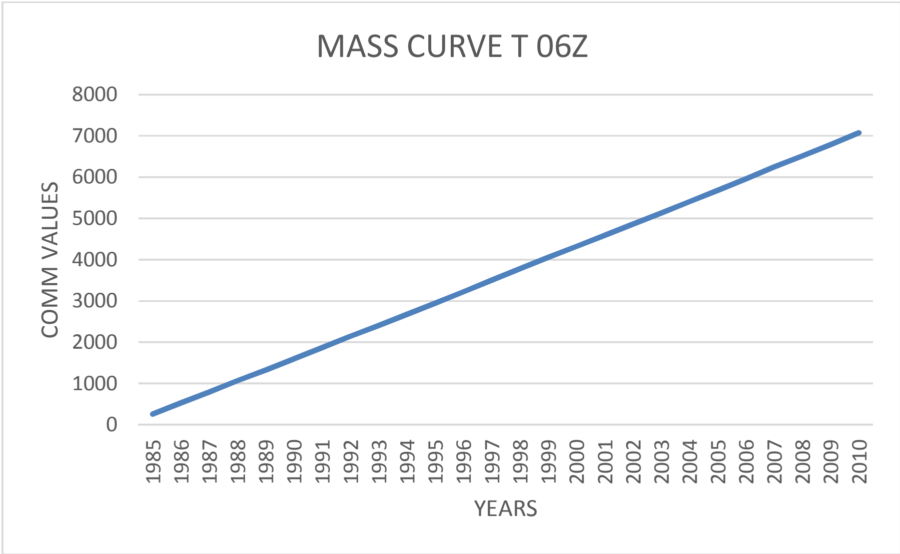

Figure 2 Mass curve for temperature 06Z

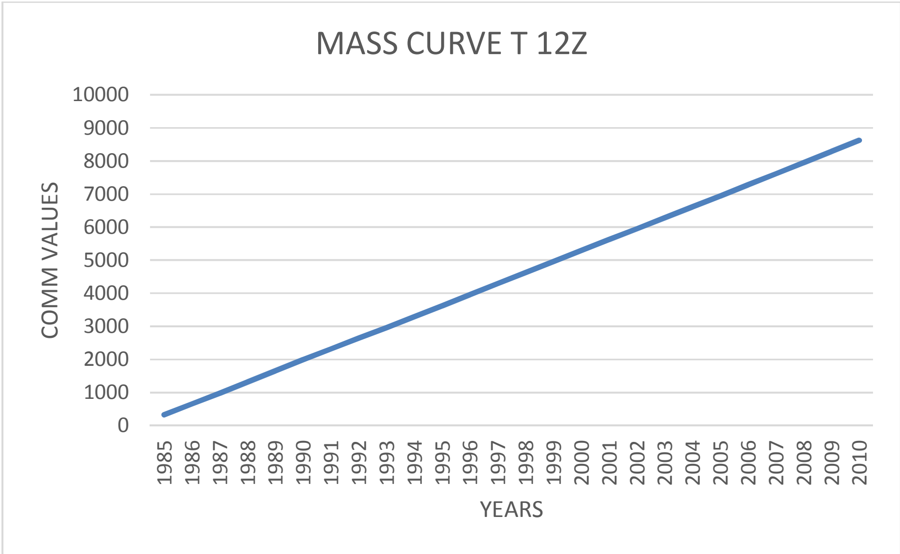

Figure 3 Mass curves for temperature 12Z

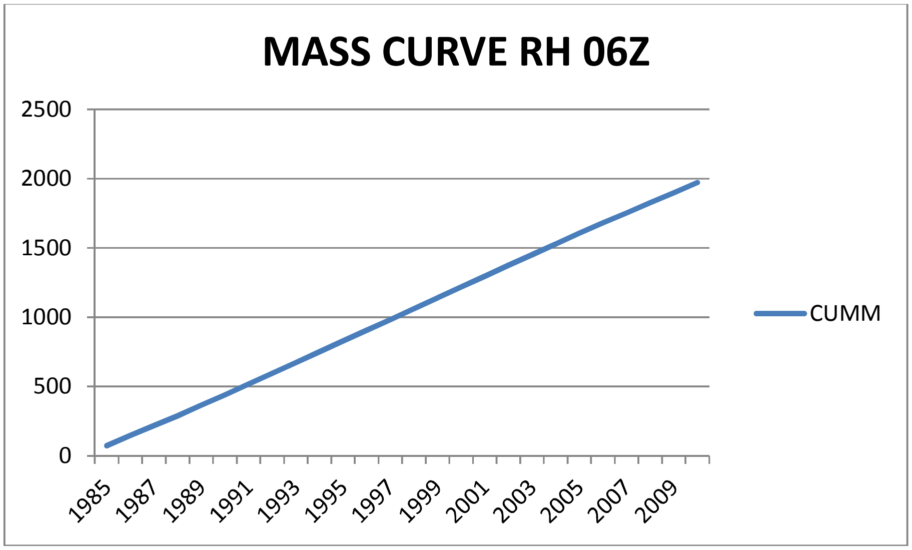

Figure 4 Mass curves for relative humidity 06Z

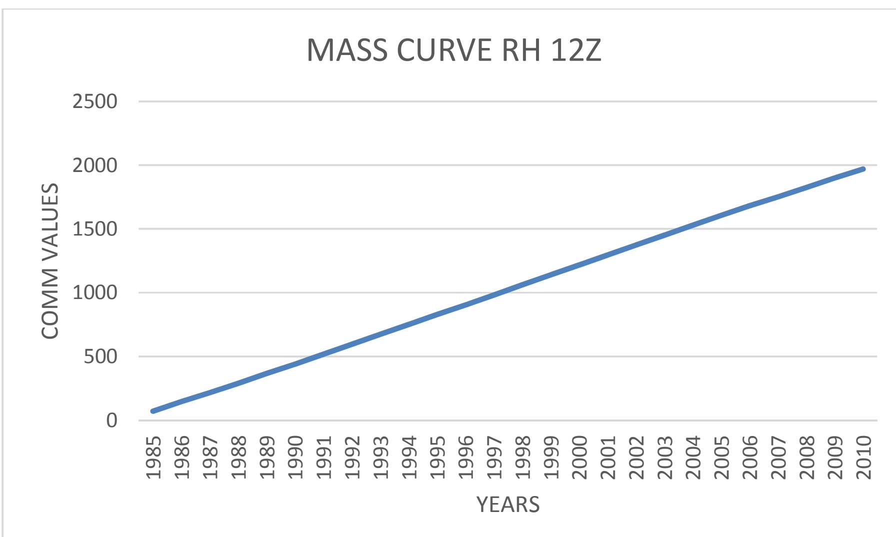

Figure 5Mass curves for relative humidity 12Z

3.4 formulas and techniques used

The combination of atmospheric variables, temperatures and humidity were used in a formula for assessing the causes like

DI= T-0.55 (1-0.01RH) (T-14.5) by GILES et at. 1990

The classifications levels of discomfort conditions used by Thom`s and Giles at. Al, were used in identifying the impact of human discomfort in Djibouti.

Where:

DI= Discomfort Index

T= Main Hourly Air Temperature (in °C)

RH= Main hourly Relative Humidity (in %)

CHAPTER FOUR

RESULTS AND DISCUSSION

Discomfort index is a measure of the heat felt by people. It is for the general public and expresses the combined effect of heat and humidity. It is a number that describes the intense heat felt by the people, just as the wind chill factor describes the intensity of the cold felt by people. Discomfort index is used as a measure of perceived heat resulting from the combined effect of excessive humidity and high temperature.

Discomfort index values are used to inform the general public when conditions of heat and humidity may be uncomfortable. If you know the temperature and relative Discomfort index, the following chart can be used to determine the Discomfort index. For example, if the temperature is 36 ° C and relative humidity is 70%, the Discomfort index is in severe stress range. This level is considered a level of “great discomfort” and may be hazardous to the health of humans.

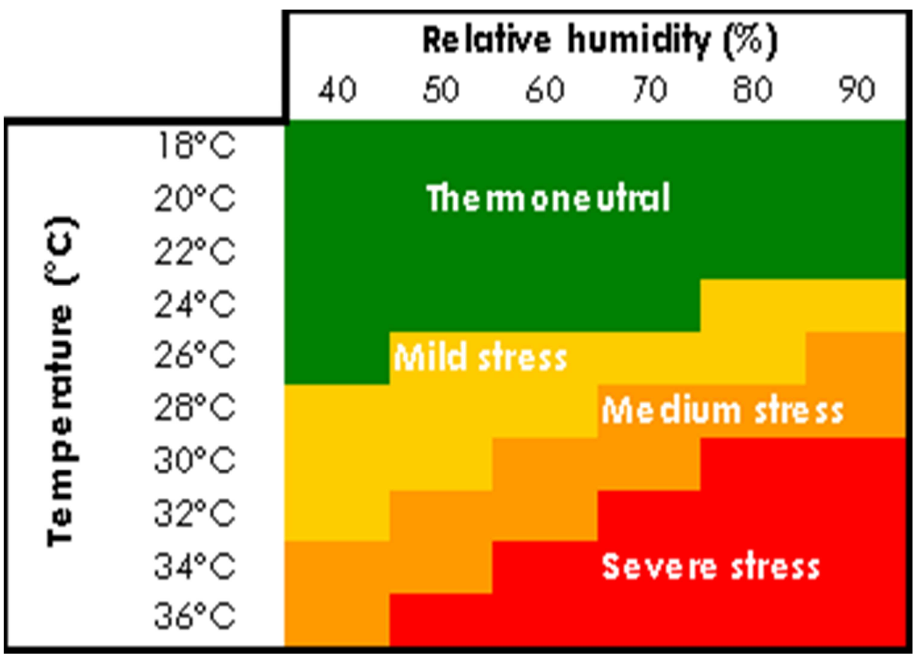

Figure 6chart of Discomfort Index

A criterion was established based on a great number of observations on a wide spectrum of population groups and under different climatic conditions, to characterize the environmental heat stress and the correlate thermal sensation.

Table 5: Criterion of Disconfort index

Condition	DI
No discomfort	< 21
Under 50% of population feels discomfort	21 – 24
Over 50% of population feels discomfort	25 – 27
Most of population suffers discomfort	28 – 29
Everyone feels stress	30 -32
State of medical emergency	>32

Thom, E.C. (1959): The discomfort index. Weather wise, 12: 57–60

Monthly means of the collected data were used for calculating the discomfort indices for the sites of Djibouti Aerodrome, Randa, Obock and Ali-SABIEH station. Pooled data from the 4 sites were used to calculate the discomfort indices for Djibouti State. In all these calculations Thom's formula was used as follows: $DI = T-(0.55-0.0055RH)(T-14.5)$

The following tables shows the main statiscal parameters of the average monthly temperatures, relative humidity and the discomfort index (DI) values for the 4 sites of two different hours (06Z and 12Z) station using Thom`s calculations.

Table 6: discomfort values 06Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Djibouti aerodrome station

MONTHS	TEMPERATURES	RELATIVE HUMIDITY	DI
jan	28.2	61.16	25.27341
feb	28.6	62.19	25.66783
mar	29.7	63.13	26.61767
apr	31.4	63.33	27.99152
may	34.1	57.06	29.47107
jun	37.6	44.4	30.53602
jul	39.7	32.91	30.40133
aug	39	35.38	30.29246
sep	36.3	50.21	30.33018
oct	32.8	56.83	28.45494
nov	30.7	58.54	27.00591
dec	29.1	59.92	25.88158

The chart below shows that in the morning of the DI values are important in the period of May to September (26.8-27.8) after the criterion more than 50% of the population is in a state of discomfort. But this value against the DI becomes less important in the winter period i.e. from January to April and from October to December with values between 21-25. This puts yet less than 50 % of the population in discomfort. These 50% among the most affected are those persons ages 50 and older and those between 0 to 6 years.

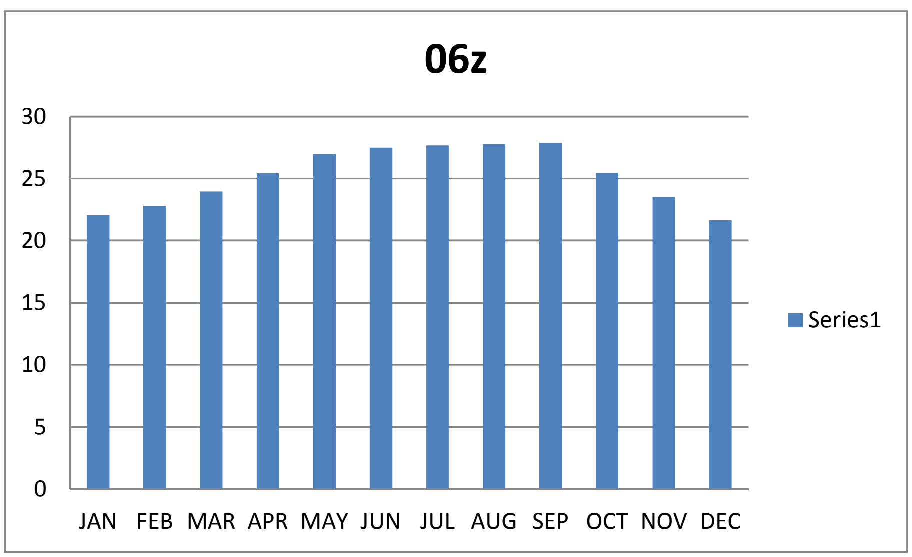

Figure 7: the behaviour of Discomfort Index at 06Z from the formula of Thom's for Djibouti aerodrome station

Table 7: discomfort values 12Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Djibouti aerodrome station

month	T	RH	DI
jan	22.7	84.08	21.98201
feb	23.6	83.85	22.79169
mar	24.9	83.63	23.96364
apr	26.5	85.29	25.52914
may	28.2	81.57	26.8113
jun	30.9	61.63	27.43903
jul	32.6	51.63	27.78477
aug	31.8	57.98	27.8018
sep	30.1	73.47	27.82373
oct	26.9	79.33	25.49031
nov	24.3	82.78	23.37184
dec	23	84.65	22.28239

At this hour of the day , from May to September are the period of summer (June, July, August) and the transition period in the northern hemisphere, the DI values is in critical condition (27.7-30.5) . In conditions like that almost all the people and even all are in a thermal stress. And even in the winter the DI is important (25-28) and thus more than 50 % of the population is in thermal discomfort.

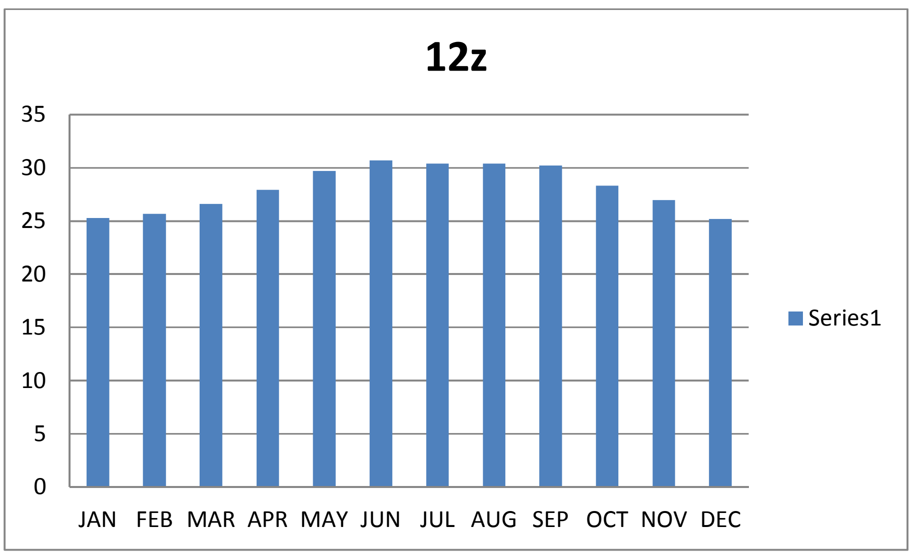

Figure 8: the behaviour of Discomfort Index at 12Z from the formula of Thom's for Djibouti aerodrome station

RANDA

In the part of the country the climate is not very hot and in morning time the people are in discomfort only in summer time.

Table 8: discomfort values 06Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Randa station

Month	T	RH	DI 06
JAN	22.12	52.28	20.12005
FEB	23.6	45.89	20.89179
MAR	25.5	46.9	22.28745
APR	26.9	53.59	23.73484
MAY	28.9	45.6	24.59152
JUN	30.4	40.09	25.16087
JUL	29.23	56.1	25.67344
AUG	28.5	60.29	25.44233
SEP	28.21	57.01	24.96834
OCT	26.33	44.52	22.72019
NOV	24.13	44.33	21.18144
DEC	24.41	50.65	21.72018

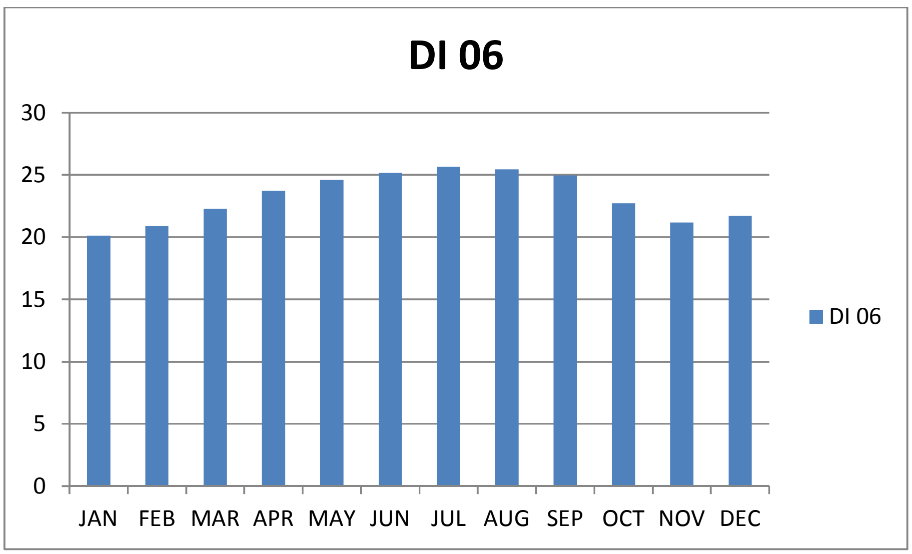

Figure 9: The behaviour of Discomfort Index at 06Z from the formula of Thom's for Randa station

Table 9: Discomfort values 12Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Randa station

month	T	RH	DI 12
JAN	22.3	69.02	20.97096
FEB	23.9	60.26	21.84544
MAR	26.2	57.13	23.44132
APR	27.9	59.61	24.92326
MAY	30.7	48.08	26.07393
JUN	33.3	35.25	26.60485
JUL	31.5	48.75	26.70813
AUG	30.5	55	26.54
SEP	29.8	55.3	26.0385
OCT	27.1	54.4	23.93992
NOV	24.5	59.23	22.25765
DEC	22.6	67.12	21.1352

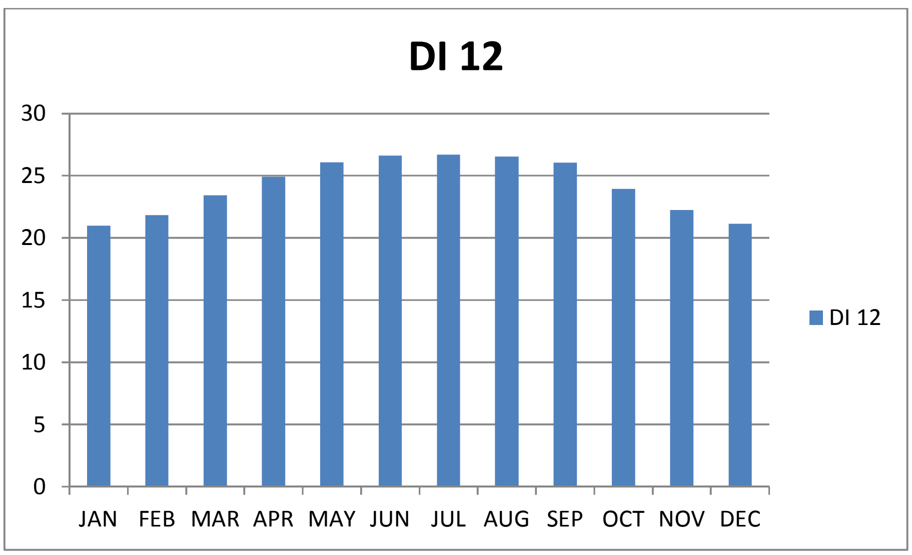

Figure 10: the behaviour of Discomfort Index at 12Z from the formula of Thom's for Randa station

OBOCK

Obock has the same climate of Djibouti and the comment in Djibouti are also available for this area.

Table 10: discomfort values 06Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Obock station

Month	T	RH	DI 06
JAN	21.7	54.35	19.89226
FEB	23.3	46.45	20.70818
MAR	25.3	46.49	22.12151
APR	26.82	52.94	23.63121
MAY	28.9	44.27	24.48618
JUN	30.6	37.41	25.05766
JUL	29.4	53.98	25.62866
AUG	28.7	58.43	25.45338
SEP	28.4	54.45	24.9177
OCT	26.3	43.77	22.65067
NOV	23.8	45.8	21.02767
DEC	22.06	53.16	20.11239

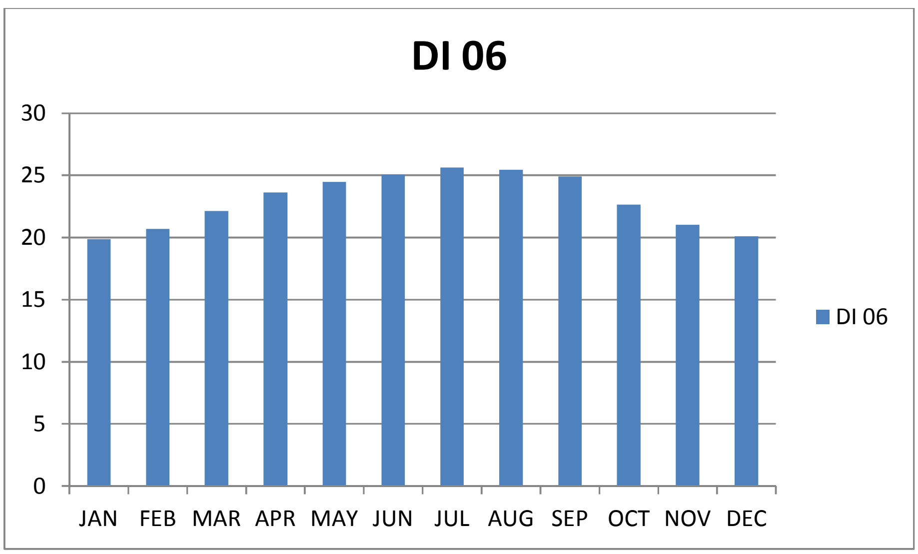

Figure 11: the behaviour of Discomfort Index at 06Z from the formula of Thom's for obock station

Table 11: Discomfort values 12Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Obock station

month	T		RH	DI
JAN	22.7	24.7	54.48	22.146328
FEB	24.4	26.4	55.48	23.486166
MAR	26.4	28.4	46.73	24.3275085
APR	27.8	29.8	51.93	25.7549095
MAY	30.2	32.2	43.54	26.703619
JUN	32.5	34.5	35.62	27.4182
JUL	31.1	33.1	48.82	27.864286
AUG	30.2	32.2	53.86	27.708271
SEP	29.6	31.6	51.15	27.0056575
OCT	27	29	44.57	24.5794575
NOV	24.6	26.6	47.09	23.0788395
DEC	22.9	24.9	52.92	22.207024

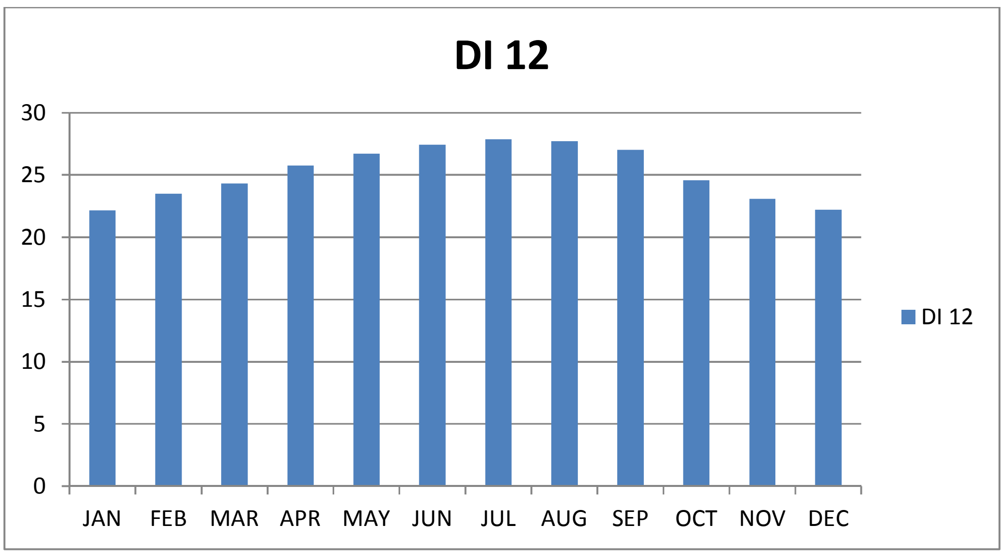

Table 12: the behaviour of Discomfort Index at 12Z from the formula of Thom's for obock station

ALI SABIEH

Table 13: Discomfort values 06Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Ali-Sabieh station

month	T	RH	DI 06
JAN	21.9	54.64	20.05385
FEB	23.4	49.13	20.90991
MAR	25.3	50.27	22.34604
APR	26.6	58.78	23.85681
MAY	28.5	50.61	24.69697
JUN	30.1	44.19	25.3115
JUL	28.9	54.57	25.30194
AUG	28.3	58.33	25.13725
SEP	28	56.81	24.79314
OCT	25.9	48.11	22.6465
NOV	23.8	45.69	21.02204
DEC	22.2	51.66	20.1528

In Ali-Sabieh only under 50% of the people are in discomfort in the summer in the morning time.

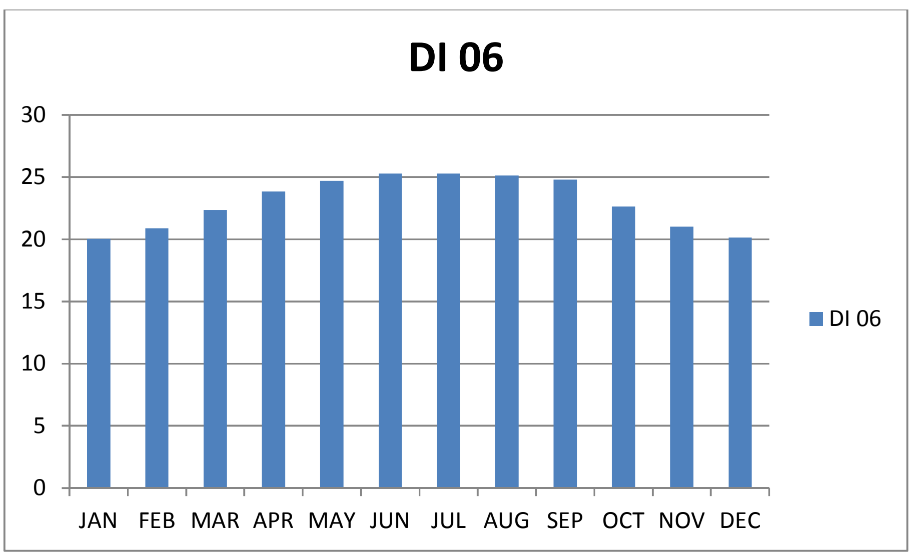

Figure 12: the behaviour of Discomfort Index at 06Z from the formula of Thom's for Ali-Sabieh station

Table 14: Discomfort values 12Z from the formula DI = T-0.55(1-0.01RH) (T-14.5) for Ali-Sabieh station

Month	T	RH	DI 12
JAN	22.8	68.96	21.38302
FEB	24.4	62.09	22.3358
MAR	26.74	59.05	23.98325
APR	28.24	61.58	25.3366
MAY	31.13	46.87	26.27046
JUN	33.67	33.66	26.67544
JUL	32.04	43.81	26.61935
AUG	31.05	49.1	26.41683
SEP	30.51	49.34	26.04913
OCT	27.53	52.96	24.15888
NOV	24.98	58.64	22.59601
DEC	23.12	66.29	21.52181

In the afternoon, under 50% of the population are in discomfort from October to December and over 50% of it from May to June.

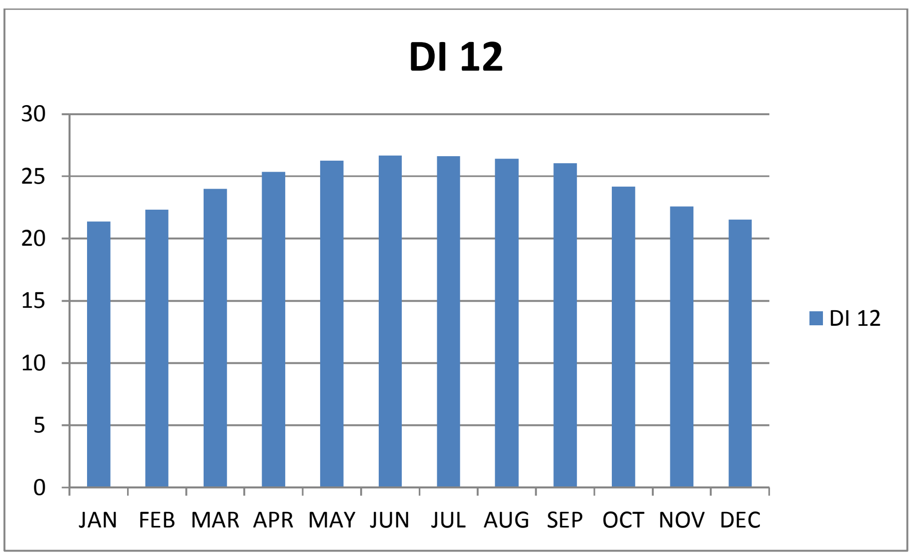

Figure 13: the behaviour of Discomfort Index at 12Z from the formula of Thom's for Ali-Sabieh station

If we make the link between temperature and DI as shown graphic down, we see that the peaks of DI coincide almost perfectly with those of the temperature.

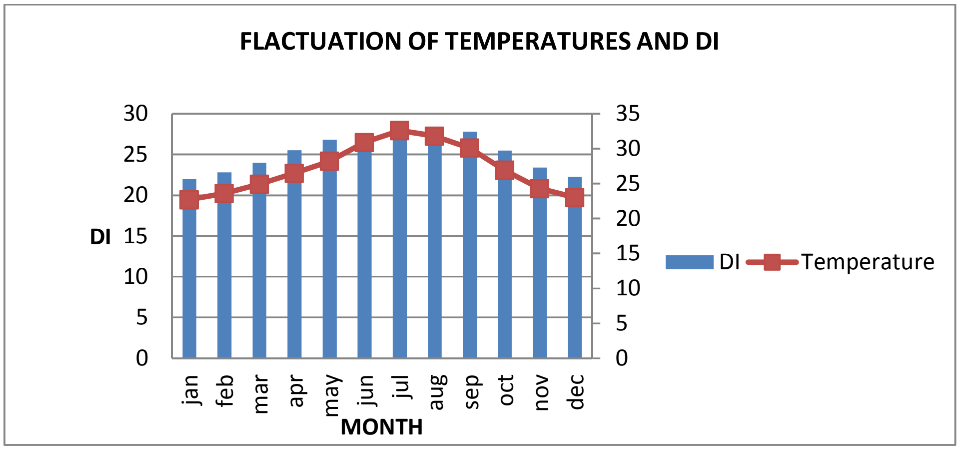

Figure 14: the behaviour of monthly climatic mean temperatures and the discomfort values at 06Z

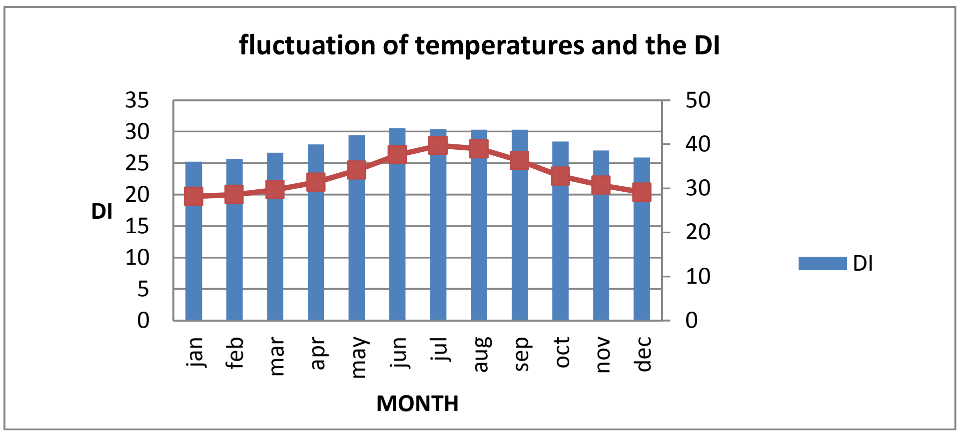

Figure 15: the behaviour of monthly climatic mean temperatures and the discomfort values at 12Z

If combining the two results is clearly Note that the DI values are lower in the morning than in the afternoon as shown in FIG 9

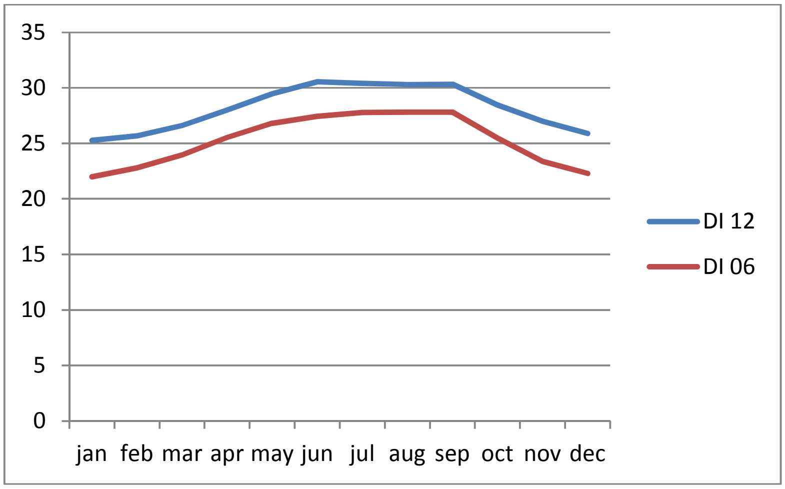

Figure 16: combined 06Z and 12Z of DI

The Northeast Monsoon (known locally as "Gilal") lasts from December through March; Djibouti is under the influence of the trade winds (Alizes) of NE from Arabia peninsula and the Gulf of Aden. During this period, the climate is basically clear Skies with transparent atmosphere and temperatures ranging 20 ° to 30 °C. At this season, in morning times the DI values are between 21 and 25 and less than 50 % of the population are in discomfort. But in the afternoon this values are moderate (25-28) and more than 50 % of the population is in thermal discomfort.

The Southwest Monsoon ("Hagai") lasts from late May through September the ITCZ is between 15° to 20°N. The South-West monsoon as well as the foehn winds is well-marked through the mountains of Somalia and Ethiopia which provides the country with westerly winds (dry and burning). It is called the Khamsin. The temperatures at this time are higher in the morning (between 30 °C to 40 °C) where the DI values are between 26-27 which after the criterion more than 50% of the population is in a state of discomfort. And in the afternoon where the temperatures are very hiegh (43 °C to 45 °C) and the discomfort index is critical (27.7-30.5). In this case almost all the people and even all are in a thermal stress.

The result of the analysis has shown that in almost whole of year summer or winter, morning or afternoon people feel uncomfortable.

Totally of them are in dangerous heat stress situation in summer time and most of half of them in winter time.

Because heat stress, people are more at risk of developing health problems. The elderly, young children and people with cardio respiratory or mental health problems may be more affected by heat stress than the rest of the population because of their health condition can deteriorate this rapidly.

CHAPTER FIVE
CONCLUSIONS

Heat is an environmental and occupational hazard. The prevention of deaths in the community caused by extreme high temperatures (heat waves) is now an issue of public health concern. The risk of heat-related mortality increases with natural aging, but persons with particular social and/or physical vulnerability are also at risk. Important differences in vulnerability exist between populations, depending on climate, culture, infrastructure (housing), and other factors. Public health measures include health promotion and heat wave warning systems, but the effectiveness of acute measures in response to heat waves has not yet been formally evaluated. Climate change will increase the frequency and the intensity of heat waves, and a range of measures, including improvements to housing, management of chronic diseases, and institutional care of the elderly and the vulnerable, will need to be developed to reduce health impacts.

A relative climatological index is developed to evaluate interregional variations in human discomfort and the impacts of weather on a variety of socioeconomic parameters. The "weather stress index" is designed to assess the frequency and magnitude of the most uncomfortable weather conditions, and data inputs are limited to air temperature, dew point, and wind speed. The index is constructed by calculating the apparent temperature using a simple algorithm and comparing how a particular day's apparent temperature varies from the mean for that day at that locale. The index ranges from 0 percent to 100 percent, with the most uncomfortable apparent temperatures exhibiting the highest values.

Over time people adapt to hot conditions by sweating more, and by changing their behavior to try and cool down, eg removing clothing, taking cool drinks, fanning themselves, sitting in the shade or a cool area, and/or reducing their work rate.

It is concluded from this study that some theoretical ranges of DI could be calculated for certain places, depending on actual measurements of air temperature and relative humidity, by the application of Thom’s formula.

Due to THOMS Index 1959, the study shows that, Djibouti have discomfort condition either in morning hours or afternoon. Half of the population feel discomfort in winter and almost all of the population in the summer times.

CHAPTER SIX
RECOMMENDATION

It is probably indispensable to take several steps to lute against this phenomenon that may become increasingly important. Recommendations as of:

-Further human Eco physiological studies are needed in the Djibouti to come out with more realistic results concerning DI.

- Subsequent studies on DI for different parts of the Sudan are needed to prepare a DI map for the country.

- Records the temperature and humidity each fortunes

- Warning and awareness against the risk of heat stress

- provide a break to the people that used to work under the sun , put at their disposal of drinking water and medical supervision if possible.

How can I reduce the risks?

-Control the temperature using engineering solutions eg:

- change the processus
- use fans or air conditioning
- use physical barriers that reduce exposure to radiant heat

-Provide mechanical aids where possible to reduce the work rate. Regulate the length of exposure to hot environments.

-Specialised personal protective clothing is available which incorporates, for example, personal cooling systems or breathable fabrics.

-Provide training, especially new and young employees telling to the population about the risks of heat stress, what symptoms to look out for.

-Allow people to acclimatise to their environment.

-Identify people who are more susceptible to heat stress either because of an illness/condition or medication that may encourage the early onset of heat stress, eg those with heart conditions.

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