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Predicting Heat Dissipation in Urban Areas Using Law of Thermodynamics

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ABSTRACT

The heating of the urban surfaces during the daytime sets the initial temperature, and this overheating is dissipated during the night time through radiation and mean convection motion over the urban surface. The energy balance shows that this cooling effect can be quantified in an exponential decay in time. The minimum temperature reached at the end of this cooling period. For explaining the model temperature data of six major cities of Bangladesh, from 21st January to 23rd January of 2014 was used. The energy balance shows that this cooling effect can be quantified in an exponential decay in time. This can make a relation with the Newton's law of cooling. The temperature decay depends on many natural factors such as wind speed, properties of air in the region, urban length etc. Here in the model it is assumed that the wind speed is constant. Using this model we might be able to predict the temperature at any time at night. This model is not a universal model, but it works well for a specific season. Further this model will be applied under different condition in different regions.

Keywords: *Regional climate, Prediction, urban area, dissipation of heat, WRF model*

1. INTRODUCTION

To explain this process it is necessary to discuss how heat transfer takes place in a medium or without medium. There are three processes, i.e. Conduction, convection and radiation, to transfer heat from one body or place to another. The planet earth gains heat mainly from sun and it come through the process radiation. The heating of the earth surfaces occur during the daytime and dissipated heat during the night. The cooling process in consist of three heat transfer processes. But mainly convection process and radiation is responsible for the cooling process. The elements in our environment radiate heat as infrared ray. The surface of earth and other bodies in our environment heat up its nearest atmosphere. When the air is heated up it becomes less heavy. So it goes up and makes a free space in the atmosphere. The cool air comes from other place and takes the free space do the same as before. This process runs until the environment gain an energy balance with the surrounding areas. Using this concept the heat dissipation process of an urban area can be explained. An urban area surrounded by rural areas, so during the night the temperature of urban area makes thermal balance with rural areas. From Land sat 8 image (Figure 1) it is found that every thermal region surrounded by different thermal region.

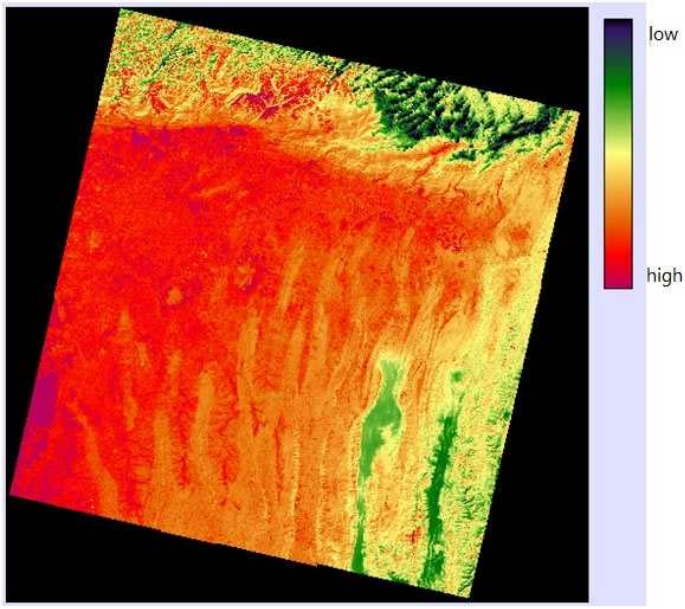

Fig 1: Land sat 8 images showing different thermal region

Given If the convection process is spontaneous than it can be assumed that the urban area act as a hot body surrounded by cool atmosphere. So the cooling system can be explained using the Newton's law of cooling.

$$dT/dt = -k *(T(t)-Tr) \quad \ldots\ldots\ldots\ldots (1)$$

Here in the equation left side represent the change in temperature in time. In right side 'k' is a constant, T(t) is a time dependent function of temp, Tr is represent the temperature of rural area.

Negative sign represents decrease of the temperature. The temperature of six major cities Dhaka, Chittagong, Sylhet, Rajshahi, Khulna and Barishal in Bangladesh were used. The temperature change from 21st January to 23rd February 2014 in the time 6 pm to 6 am was collected. This month was chosen because in this time here spring season exist. So the wind speed mostly remains constant and humidity remains moderated. The data points in graph gave a curve as figure 2.

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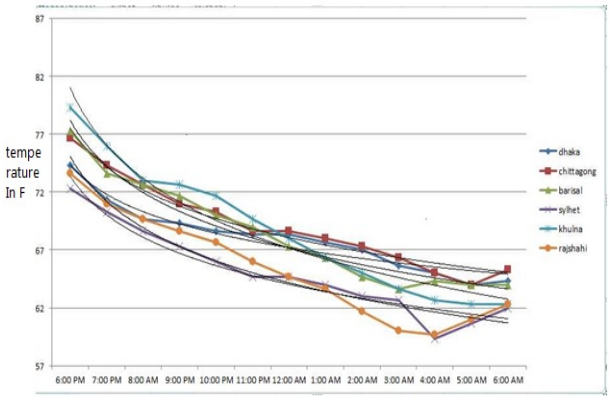

Fig 2: cooling rate of different cities per hour

2. MODEL DESCRIPTION

2.1 Experimental Design and Data

The data used were collected from the weather forecast website i.e. accuweather.com and weathersource.com. The data was collected hourly and then plotted graph temp change versus time change.

The equation (1) defines the Newton's law of dissipation.

$$dT/dt = -k(T(t)-Tr) \ldots\ldots. (1)$$

After some modification,

$$dT/(T(t)-Tr) = -kdt$$

Now integrating both sides,

$$T(t)= Tr +(Tm-Tr) \exp(-k\Delta t) \ldots\ldots\ldots (2)$$

Here Δt represents the change in time.

The graphical presentation can be as like as the figure 3.

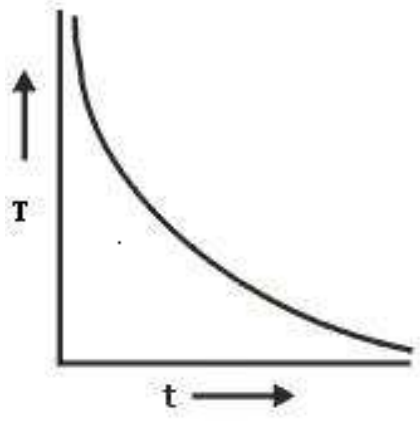

Fig 3: relation of cooling rate with time difference

From observation data the value of "k" was calculated. This value depends on the wind speed, radiation rate and urban length. So for a specific region in a season "k" will be mostly invariant. So it needs to calculate the constant for different region in different seasons.

Simulation 1:

Using the Newton's law of cooling the temperature of the night 25 February 6:00pm to 26 February 6:00am was calculated. Here the observed value of "k" was used. The temperature of Dhaka city and for Dhaka city k is about 0.23. The maximum temperature was 74 degree F and the rural temperature was 61 degree F. Using equation (2) a temperature dissipating graph was found like as figure 4 and it is an exponential decay curve.

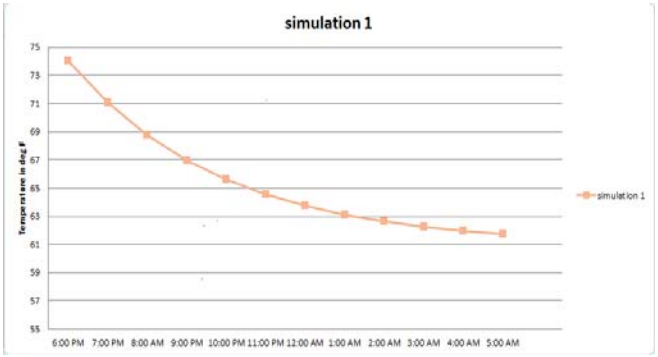

Fig 4: temperature prediction with simulation 1

Simulation 2:

The Weather Research and Forecasting (WRF) Model is a next-generation numerical weather prediction system which is designed to serve operational forecasting needs. For comparing our temperature prediction results with climate model WRF we used NCEP Final Analysis (FNL from GFS) (ds083.2): 1 degree resolution, every 6 hours as input data. Data was taken 25 February 2014 to 28 February 2014 for simulation. A 30km resolution parent domain was used without any nesting domain. For best output we used the configuration below:

Table 1: configuration of WRF simulation

Configuration	**Option used**
WRF model	ARW-WRF 3.4.1
CU	1:KainFritsch
MP	3
PBL	1: YSU Scheme
Vertical levels	35
Data resolution	1 degree
Max domain	1
Domain resolution	30km
Time step	120
Central point of the domain	Latitude 23° 68', Longitude 90° 41'
No of grid points	WE=70 SN=70

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From the surface temperature outputs of WRF model graph of different cities changing temperature per hour is given below. Time showing in the graph is 0-12 as 25 February 2014 6pm to 26 February 2014 5am.

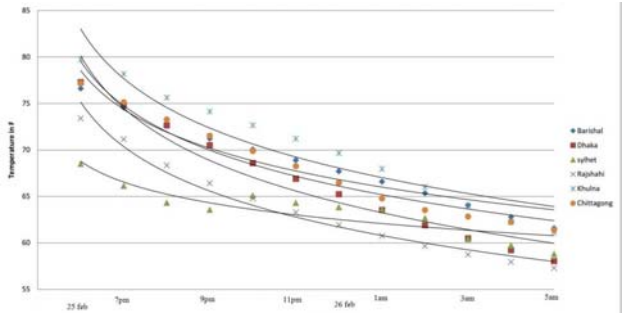

Fig 5: temperature decreasing per hour

We can see that temperature decreasing per hour gives us an exponential curve. Temperature decreasing with changes of time after the sun goes down from 6pm of 25th February to 5am of 26th February shows in figure 6

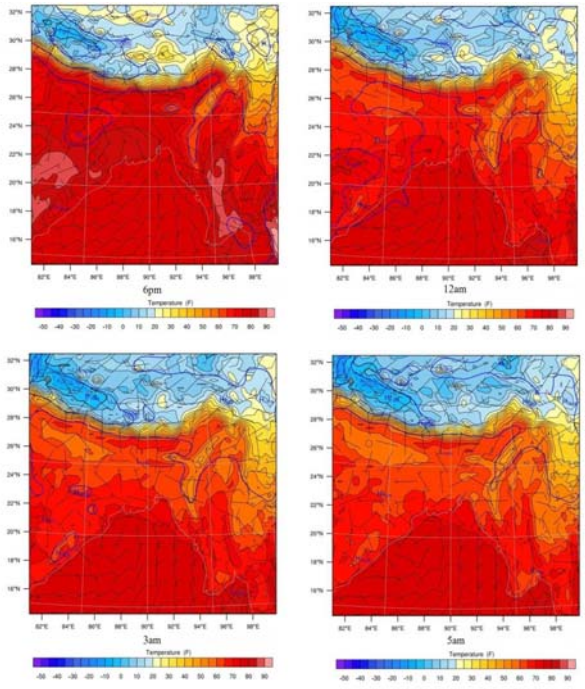

Fig 6: WRF output's showing temperature in different time

3. COMPARISON WITH OBSERVATION

From simulation 1 and simulation 2, two predicted temperature for Dhaka city was found.

The observation time was 6:00pm 25 February to 6:00am 26 February. To compare the three data they were plotted in a same graph and it is shown in adjacent figure.

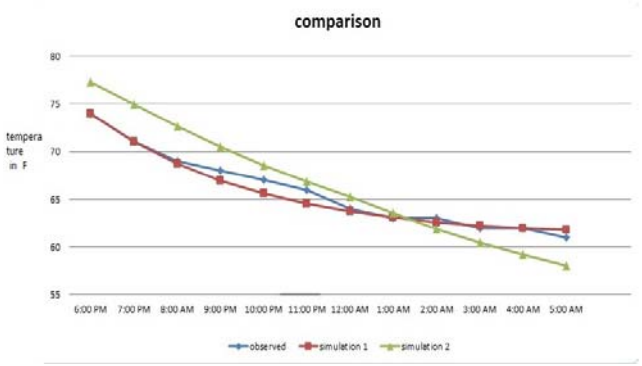

Fig 7: comparison of two simulation and observed data

4. RESULTS AND DISCUSSION

In simulation 1 the temperature was predicted using the Newton's law of cooling. In this process the prediction was made comparing with previous observation. This prediction is mostly same with the observation data. Simulation 2 was the Weather Research and Forecasting (WRF) model. It is a next generation numerical weather prediction system which is designed to serve operational forecasting. This observation is little different from simulation 1 and observation.

The predictions depend on different parameters such as wind speed, thermal radiation, urban length etc. In simulation 1 wind speed and thermal radiation were assumed as invariant. It works well for short urban length in a season. Though Newton's law cannot predict the specific temperature during the whole day but it builds a bridge between thermodynamics and atmospheric physics. Simulation 2 is a next generation weather prediction method. It is a developing method. Till this process works very well and it will be developed well in near future.

The observation data took from 25 February because simulation 1 works well only in a Specific region in a season. From figure 1 we calculated "k" and it is about 0.23. For another season we will have another "k". In future we will work for a universal constant.

In the observation data graph some peaks were found. More than one thermal region can be the reason of the peaks. The urban region make thermal balance through some steps and number of peaks depends on the number of thermal regions it can be explained using satellite images.

REFERENCES

[1] F. Reif, "Fundamentals of Statistical and Thermal Physics", 2008

[2] J Shukla and Y Mintz, "Influence of land surface evapotranspiration on the Earth's climate" 1982

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[3] JR Garratt and RA Brost, "Radiative cooling effects within and above the nocturnal boundary layer , Journal of the Atmospheric Sciences", 1981

[4] S Wakamatsu and T Morikawa and A Ito, "Air Pollution Trends in Japan between 1970 and 2012 and Impact of Urban Air Pollution Countermeasures, Asian Journal of Atmospheric", 2013

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