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Urban Heat Island Assessment for a Tropical Urban Air-shed in Bangladesh

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1. Introduction

Urbanization is progressing rapidly in many Asian cities. Capital of Bangladesh, mega city Dhaka has grown by leaps and bounds during past 2 - 3 decades and strongly represents tropical climatic conditions where such studies are practically non-existent. Excessive urbanization has a possibility to induce regional-scale climate change well known as urban heat island (UHI) phenomena. Climate change is projected to compound the pressures on natural resources and the environment, associated with rapid urbanization, industrialization and economic development (IPCC, 2007). Most of the studies on UHI in Dhaka were conducted in late 2000's (Dewan 2009, Khandaker 2003 and Hossain 2008). These studies assessed mean heat island intensities ranging from 0.8 °C to 8 °C. However, there exists a dearth of recent studies regarding urban climatological assessment in Dhaka. The present study considers varying land use/land cover in the grid network also helps in outlining many of the features with UHI in greater details with numerical model.

In order to improve the understanding of processes that are related to neighborhood-scale climate and air quality, the UHI effects, and mesoscale circulation caused by urban-rural land cover differences, the use of mesoscale atmospheric models is increasing (Clarke *et al.*, 2005). Here we employ the Weather Research and Forecasting (WRF) model to simulate the UHI changes. The UHI effect, in turn, can be represented by the surface air temperature at 2 m from the ground surface in the output of WRF model runs. The approach taken in this study will be useful for the prevention and control of UHI effects in association with future city planning and urban development.

2. **WRF simulation**

The WRF model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs (Skamarock *et al.*, 2008). The model has been designed to be a flexible simulation code that is efficient in a parallel computing environment. A modular single source code is maintained that can be configured for both research and operations. It offers a large physical selection, so it is very useful in the modeling community (Skamarock *et al.*, 2008). In this study, the WRF modeling system is applied to the Dhaka City areas to evaluate the influence of urban-scale surface coverage to UHI effects, based on observation of May 2014.

3 Data and Methodology

3.1 NCEP FNL data

National Centers for Environmental Prediction (NCEP) Final (FNL) Operational Global Analysis data provide surface pressure, sea level pressure, geopotential height, temperature, sea surface temperature, soil values, ice cover, relative humidity, u- and v- winds, vertical motion, vorticity and ozone on 1.0 × 1.0 degree grids continuously at every six hours (UCAR, 2010). This product is from the Global Forecast System (GFS) that is operationally run four times a day in near-real time at NCEP. The analyses are available at 26 mandatory (and other pressure) levels from 1000 mb to 10 mb, including the surface boundary layer and some sigma layers. Time period employed in this study is from 30 April 2014 to 01 May 2014, with the benchmark of FNL data in six hour time steps.

3.2 Land use data

A global land use/land cover (LULC) database classified according to the United States Geological Survey (USGS) LULC system is provided with WRF. In this work, the WRF model was set up by using three nests at 3, 1 and 0.3 km horizontal grid spacing for domain 1, 2 and 3, respectively (Fig. 1 a).

3.3 Observational data

The two stations observational data used in this study are the air temperature data from meteorological stations operated by the Bangladesh Meteorological Department. Locations of observation data are Agargaon (23.77 N; 90.38 E), Dhaka and Faridpur (23.6 N; 89.85 E), Dhaka (Fig. 1(b). The period data from 30 April 2014 to 02 May 2014 are used, in synchronization with the time period of model runs.

Table 1 Summary of the WRF Model

Model Features	Configurations
Horizontal Resolution	Nested 3, 1 and 0.3 km
Vertical Levels	40
Topography	USGS
Dynamics	
Time Integration	Semi Implicit
Time Steps	15 s
Vertical Differencing	Arakawa's Energy Conserving Scheme
Time Filtering	Robert's Method
Horizontal Diffusion	2nd order over Quasi-pressure, surface, scale selective
Physics	
Convection	No CU
PBL	YSU
Cloud Microphysics	WSM6
Surface Layer	Monin-Obukhov
Radiation	RRTM (LW) SW (Dudhia 1989)
Gravity Wave Drag	No
Land Surface Processes	Unified NOAH Land Surface Model

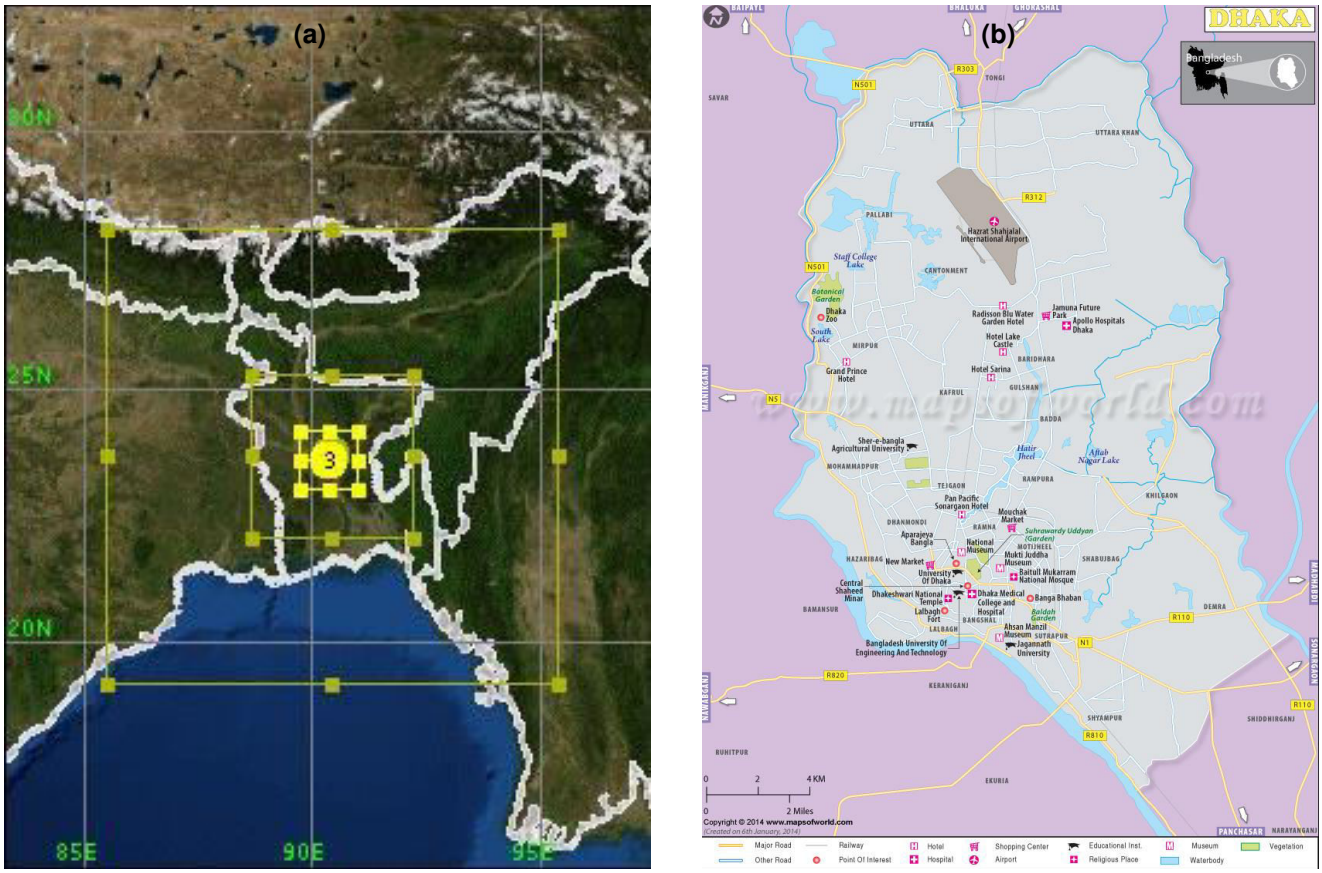

Fig. 1: (a) WRF Model Domain 3 nest and (b) Dhaka City Map.

4. Results and Discussions

4.1 Trend Analysis

Annual temperature trends are studied for mean maximum temperatures. Urban area Dhaka annual mean maximum temperature trend shows more increasing 1961 to 2000 compared to newly urbanized area Fardipur. After 2000 the trend is almost nearer in for the both region due to the urbanization impact (Fig. 2).

To study the temperature distribution over the inner domain, temperature isopleths were constructed for all the times of the experimental for the specific times of 0300 to 1800 UTC. The major UHI zones were observed in commercial centers and densely populated residential areas. The UHI intensity is significant both during daytime as well as night (Fig. 3).

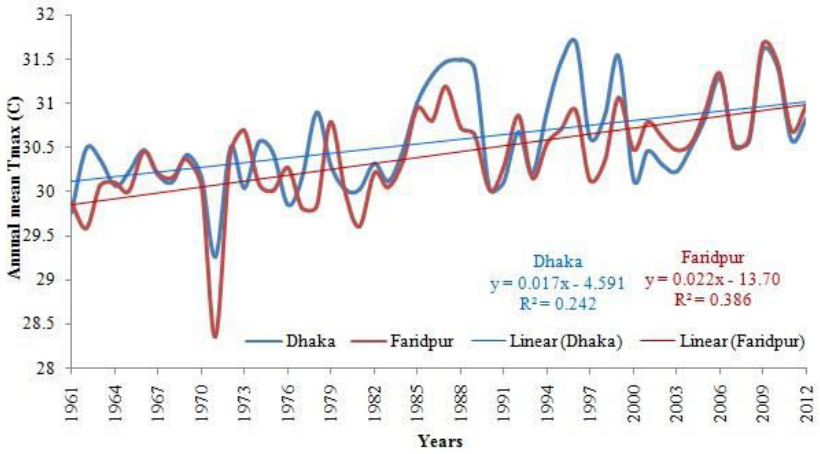

Fig. 2: Annual mean maximum temperature at Agargaon and Faridpur during 1961 - 2012.

4.2 UHI at Different Times of Day across Dhaka

Fig. 3 represents model simulated temperature at 2 m for 0300 to 1800 UTC on 1st May 2014 for every three hours. The heat island intensity at this temperature epoch varies from 2.5 °C to 7.5 °C. All the times depicted the lowest temperatures in the green areas.

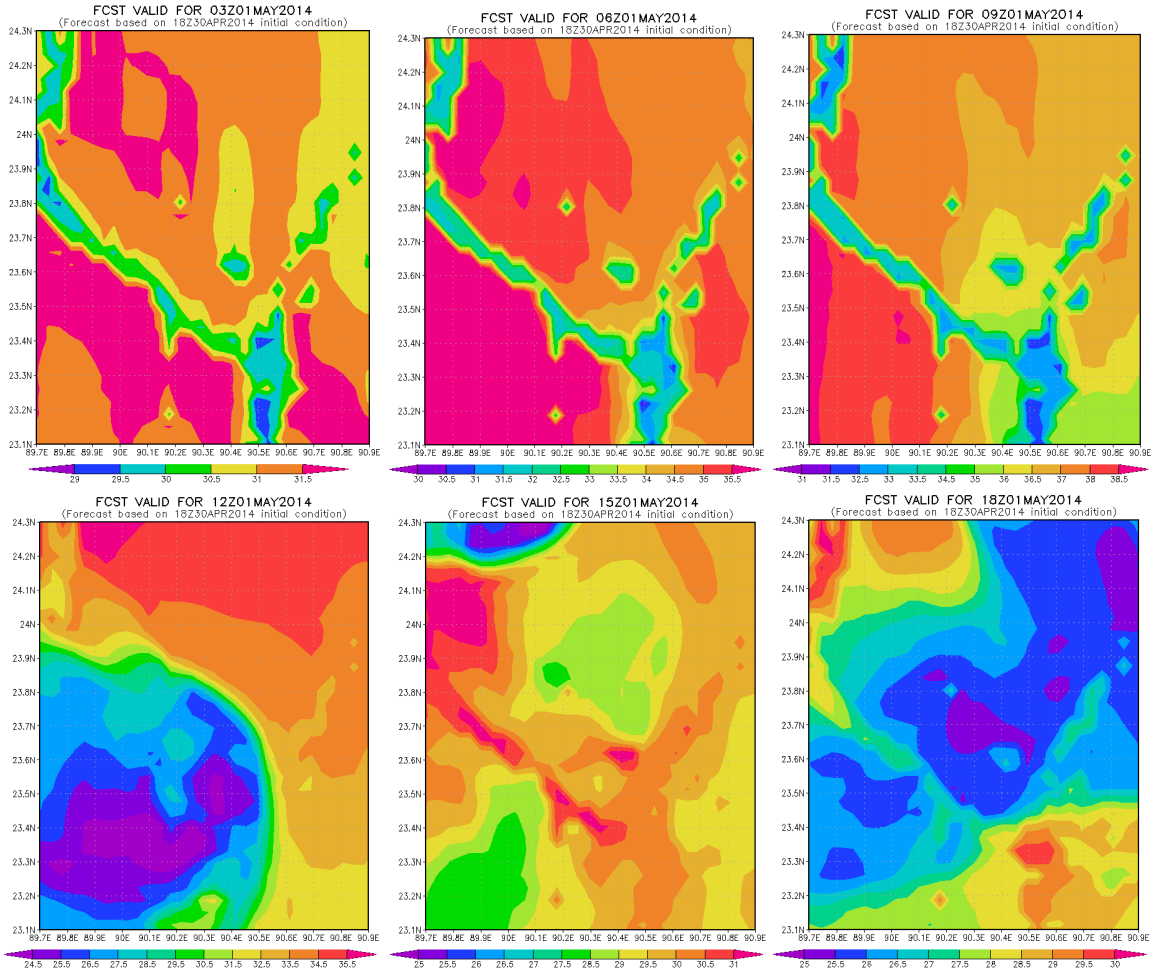

Fig. 3: WRF model simulated temperature at 2 m (°C).

5. Conclusions

The Urban Heat Island (UHI) inside and around Dhaka city as the capital of Bangladesh using the Weather Research and Forecasting (WRF) model has been studied. The UHI intensity in Dhaka is found to be more both in the night and afternoon hours (2.5 °C to 7.5 °C).

This study can be used as reference for good urban design and comfortable environment. The results of this study can still be developed by modification of land use by changing the other land use type, so that the results of running the model will be analyzed further for the sake of a better city planning. The top ranking UHI locations amongst the entire measurement network in the city are all commercial areas namely Mathijhil, Gulshan and Uttara. Green and forest vegetation has a greater impact on lowering heat island effects as compared to a water body such as a river etc. in vicinity.

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