Assessment of Spatio-Temporal and diurnal Urban Heat Island Intensities in Delhi Urban agglomeration using a high resolution Weather Research and Forecasting Model

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Abstract

Urban Heat Island (UHI) is defi ned as increased surface and air temperatures of urban areas ascompared to rural surroundings. Thermal remote sensing data have been used extensively tostudy Surface Urban Heat Island Intensities (SUHII). However, it fails to provide information ondiurnal profi le of UHI as well as information on Canopy Layer Urban Heat Island Intensities(CLUHII). To overcome these limitations, integrated Weather Research and Forecasting (WRF)-Urban model have been employed in this study to downscale meteorological variables to urbanscale (˜500 m) for assessment of spatio-temporal and diurnal profi le of SUHII and CLUHII inDelhi Urban Agglomeration (UA). Delhi UA is third largest UA of the world and largest interstate,densely populated and multi nuclei UA of India. WRF model has been set up with two way nesteddomains of 1.5 km and 0.5 km to take into consideration of local as well as regional weatherphenomenon. Simulations has been carried out for a time period of three days (due tocomputationally intensive simulation) in each season viz. 4-6 June, 2017 in summer season and15-17 January, 2017 in winter season. Evaluation of model performance with ground basedobservations revealed improved RMSE values for Temperature at 2m, wind speed and surfacepressure. Analysis of spatio-temporal and diurnal variability of SUHII in the study region revealedmore UHI during nighttime to morning time (maximum SUHII was observed at 5:30 IST), whereasminimum SUHII value were observed during daytime at 11:30 IST and 14:30 IST in summerseason (Figure 1). As a matter of fact, urban area displayed cool island effect at 11:30 IST.Similar observations were noted while studying the pattern of winter SUHII. Diurnal variability inCLUHII which is computed from model outputs of Temperature at 2m also displayed similarpattern of UHI during winter and summer season as displayed by SUHII. However, in winterCLUHII displayed comparatively more magnitude as compared with winter SUHII. Since, urbanareas displayed lower temperature as compared to its surrounding at 11:30 AM time, the time ofpass of thermal remote sensing satellites (pass time 10:30 AM - 11:30 AM IST) raises concernfor SUHII studies especially in arid and semi-arid regions like Delhi which is surrounded by sand or bare soil that heats up faster than urban built up.

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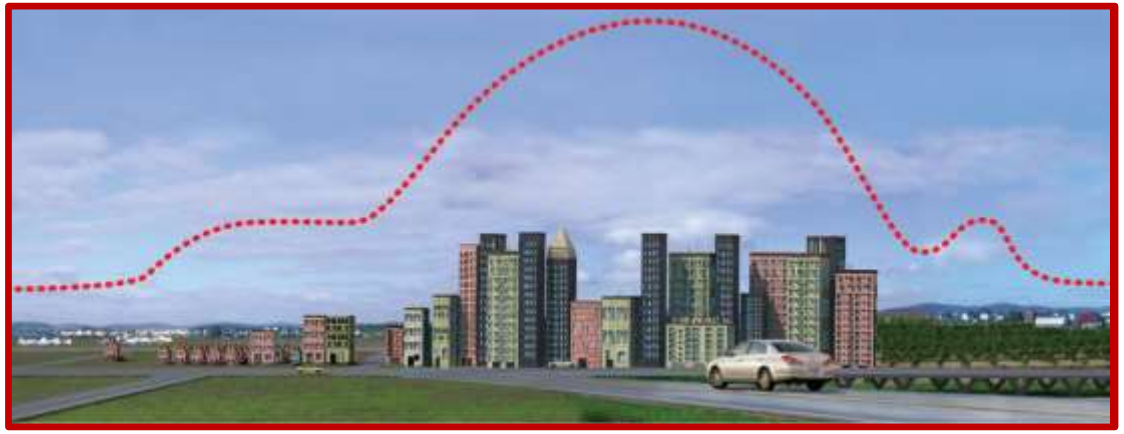
ASSESSMENT OF SPATIO-TEMPORAL AND DIURNAL URBAN HEAT ISLAND INTENSITIES IN DELHI URBAN AGGLOMERATION USING A HIGH RESOLUTION WEATHER RESEARCH AND FORECASTING MODEL

Dr. Kshama Gupta, IIRS/ISRO, India
Dr. Pushplata Garg, IIT Roorkee, India
Dr. Arijit Roy, IIRS/ISRO, India

Monday, 13 December 2021



Credit: NASA

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DR. KSHAMA GUPTA

Scientist/Engr. , Indian Institute of Remote Sensing, Dehradun, India

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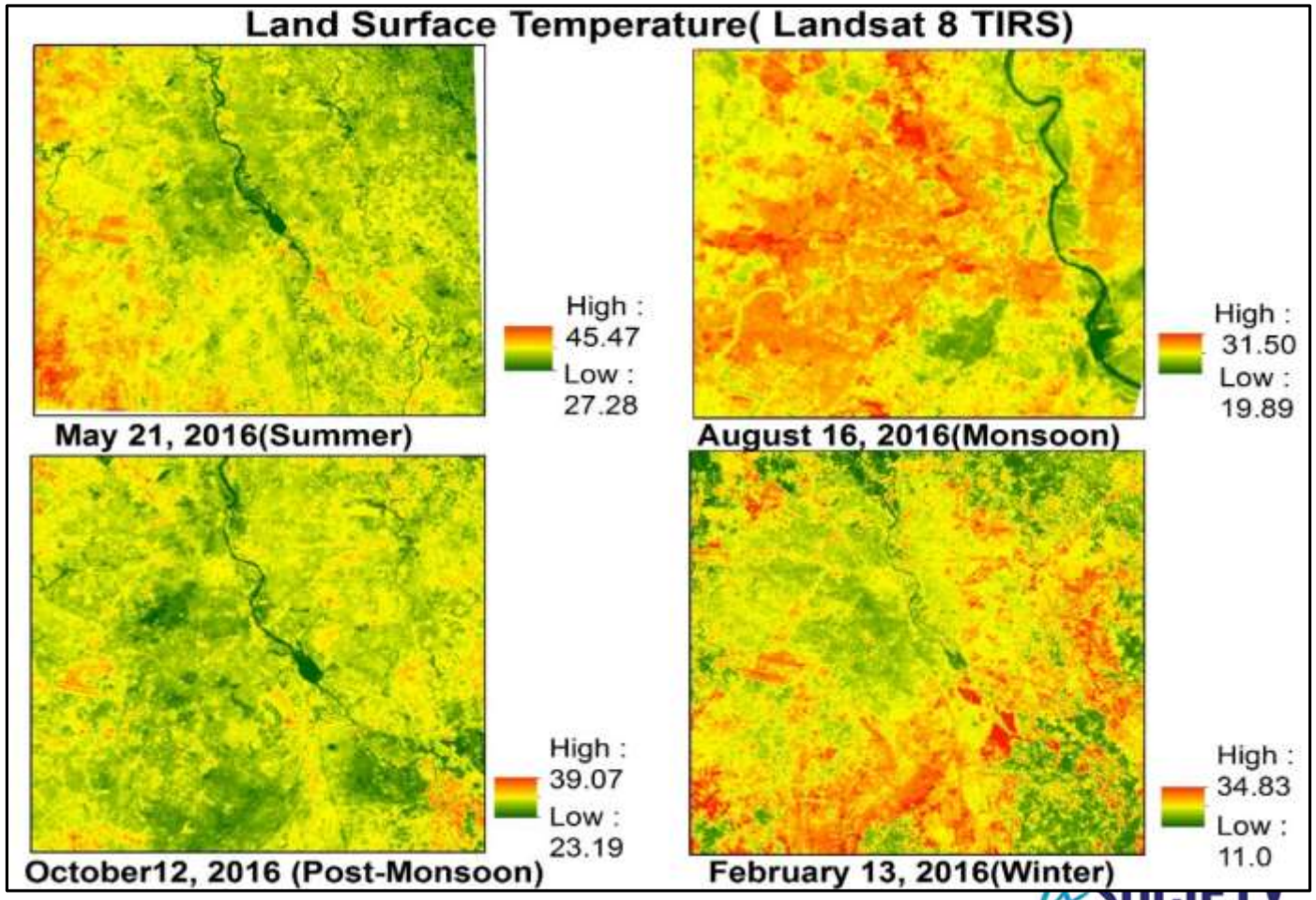
THERMAL REMOTE SENSING

- Data Acquisition time?- usually do not coincide with maximum UHI
- Diurnal Profile ? - Widely used data - Landsat – Day time pass
- Cloud cover? – data gaps- decreases data utility
- High spectral, spatial and temporal resolution with same instrument?



DELHI UA (THIRD LARGEST UA OF THE WORLD) SELECTED FOR IMPLEMENTATION OF HIGH RESOLUTION INTEGRATED WRF-URBAN MODEL SIMULATIONS FOR UHI STUDIES

Resourcesat-2 LISS IV (5.8 m resolution)

3- Class Urban LULC

High resolution updated Land Surface Parameters (Downloaded from web)

NCEP GFS Data (0.25˚)

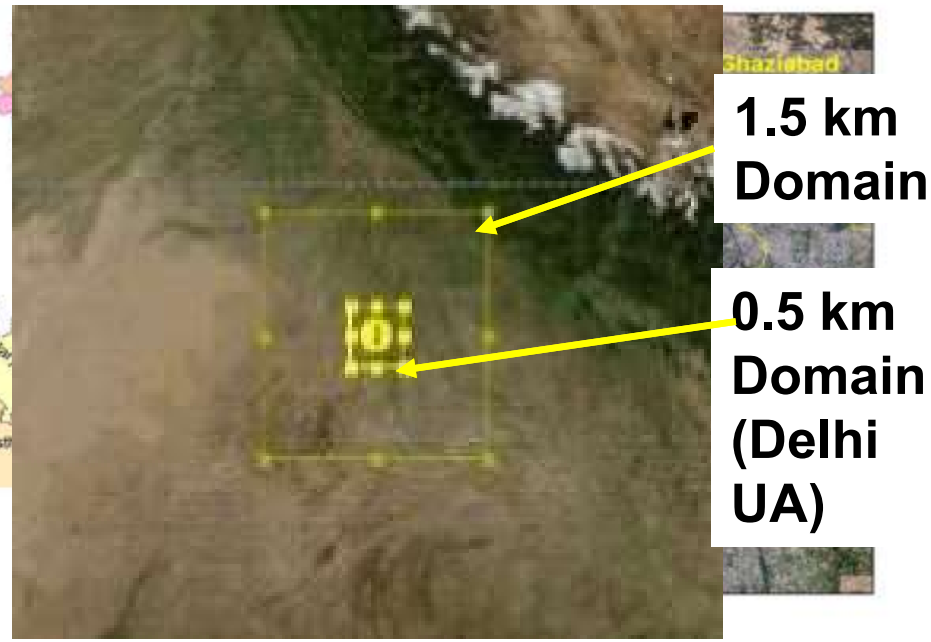
Integration in WRF Model

Downscaling of meteorological parameters

Ground Observations (IMD)

Validation of WRF outputs

MODIS LST



Season	Date of simulation
Summer	June 04-06, 2017
Monsoon	August 08-10, 2017
Winter	December 15-17, 2017

DELHI UA IS SURROUNDED BY AGRICULTURE CROP LAND , COMPOSITION OF WHICH CHANGES WITH SEASON.

Resourcesat-2 LISS IV image

Supervised Classification
Water, vegetation, agriculture, built-up, fallow/barren

Vectorization

Overlay of fishnet (100m*100m

Calculation of percentage of area covered by each class in each cell

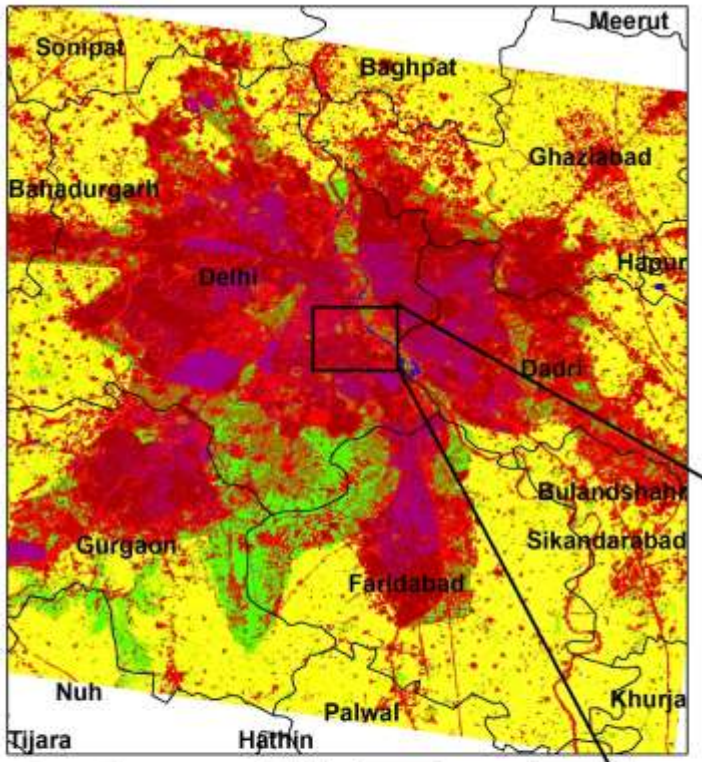
High Intensity Residential
Constructed materials>80%
Vegetation<20%

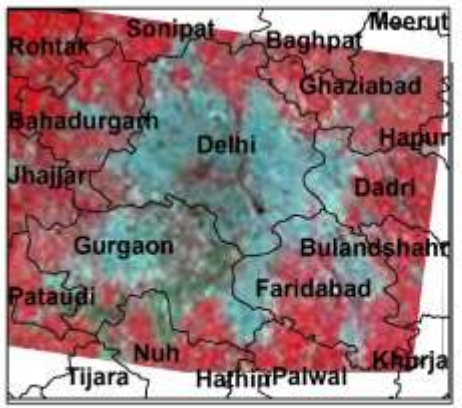
Low Intensity Residential
Constructed materials-30-70%
Vegetation-20-70%

Overlay of Digitized Industrial/Commercial/Transport layer

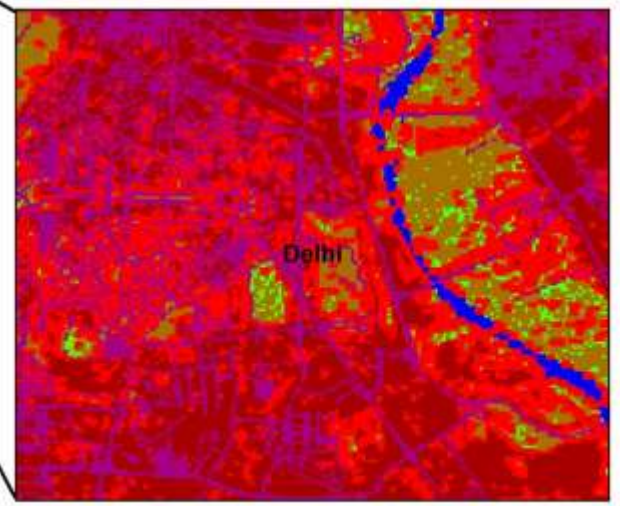
Assigning codes to the classes according to USGS classification

Rasterization of the layer





False Color Composite of Satellite data



Zommed view of Low Density Residential

Source: Gupta et al., 2021

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INTEGRATION OF URBAN LULC IN WRF-URBAN IMPROVES REPRESENTATION OF URBAN AREA IN URBAN CANOPY MODEL, IMPROVED MODEL PERFORMANCE.

Simulations	Pressure (mb)				Temperature at 2m (°C)				Wind Speed (m/s)			
	MAE	RMSE	MEAN	STDV	MAE	RMSE	MEAN	STDV	MAE	RMSE	MEAN	STDV
Simulation 1 (Default LULC + Default LSP)	1.56	1.80	991.54	2.07	1.05	3.77	16.01	2.42	1.98	4.61	6.31	3.39
Simulation 2 (Updated LULC + Default LSP)	1.58	1.82	992.80	1.31	2.07	3.42	14.73	2.44	2.10	3.72	3.10	2.51
Simulation 3 (Default LULC + Updated LSP)	1.22	1.48	991.98	0.93	1.28	2.67	13.68	2.26	0.91	2.83	4.11	2.54
Simulation 4 (Updated LULC+ Updated LSP)	0.30	0.94	991.47	0.85	1.04	2.31	14.12	1.89	0.80	1.79	4.77	2.38

Source: Gupta et al., 2021

RESULTS: EVALUATION OF MODEL PERFORMANCE SHOWS HIGH CORRELATION AND IMPROVED RMSE VALUES FOR MODELED OUTPUTS.

	Temperature at 2m					Relative Humidity at 2m				
Month	Mean	RMSE	MAE	STDV	Correlation	Mean	RMSE	MAE	STDV	Correlation
June (Summer)	38.58	1.44	0.19	3.89	0.95	30.81	3.25	1.5	10.07	0.96
August (Monsoon)	30.24	2.45	1.41	2.68	0.64	88.07	3.56	1.46	13.6	0.9
December (Winter)	14.62	2.31	0.61	4.87	0.86	73.84	2.88	0.16	21.27	0.99

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EVALUATION OF MODEL PERFORMANCE WITH MODIS LAND SURFACE TEMPERATURE DATA (1 KM DAILY PASS) SHOWS SATISFACTORY PERFORMANCE OF MODELED OUTPUTS OF SURFACE TEMPERATURE. ~ 85% OF PIXELS WITH IN -1 TO +1 DEGREE DIFFERENCE RANGE.

RANGE	Urban LULC- June		Urban LULC-August		Urban LULC-December	
	No. of pixels	% of Pixels	No. of pixels	% of Pixels	No. of pixels	% of Pixels
<-2 to -1	27	1.75	291	8.91	201	1.41
-1 to 1	1316	85.51	1053	78.43	1043	84.72
>2	196	12.74	195	12.67	205	12.87
SUM	1539		1539		1539	

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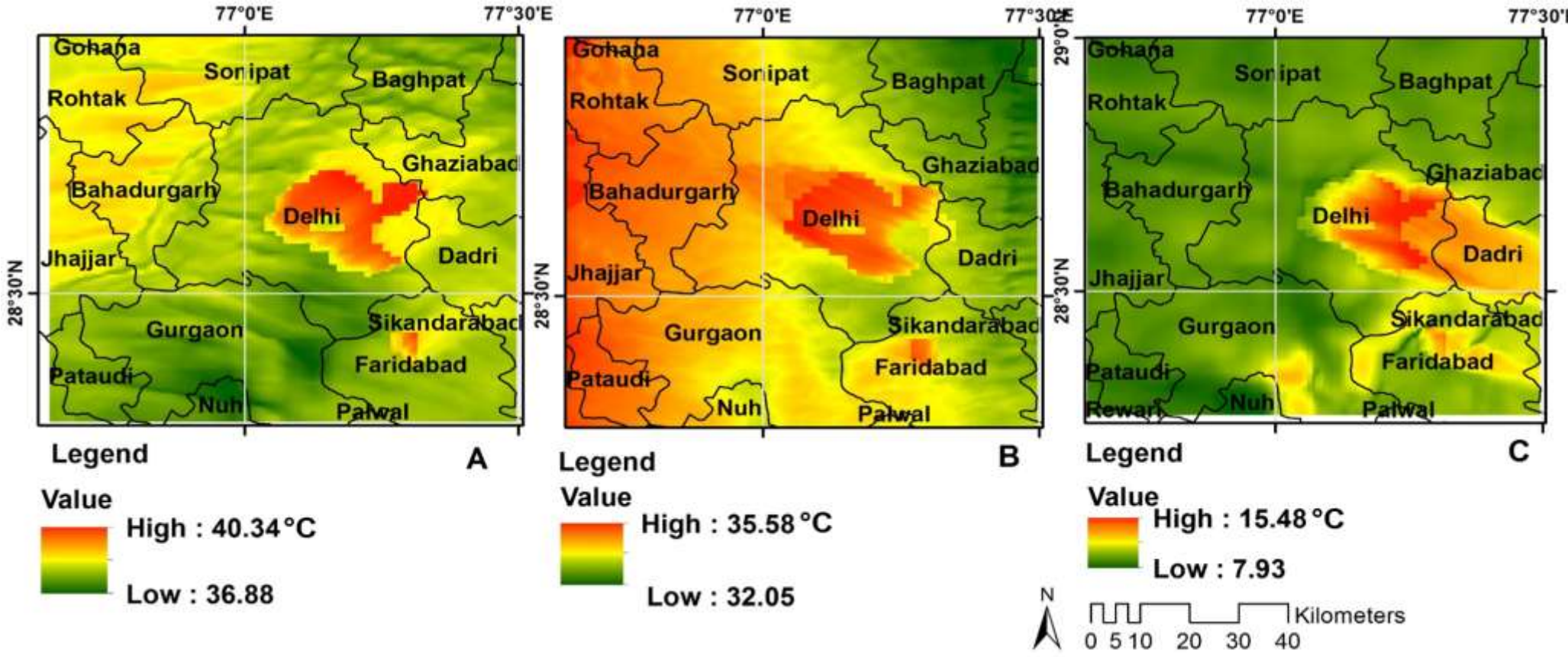
RESULTS: UHI FORMATION CAN BE CLEARLY SEEN OVER DELHI UA ESPECIALLY DURING NIGHT HRS.



Spatial distribution of temperature at 2m (°C) over D02.
A. June 4th, 2017 20:30 IST, B. August 8th, 2017 20:30 IST, C. December 16th, 2017 23:30 IST

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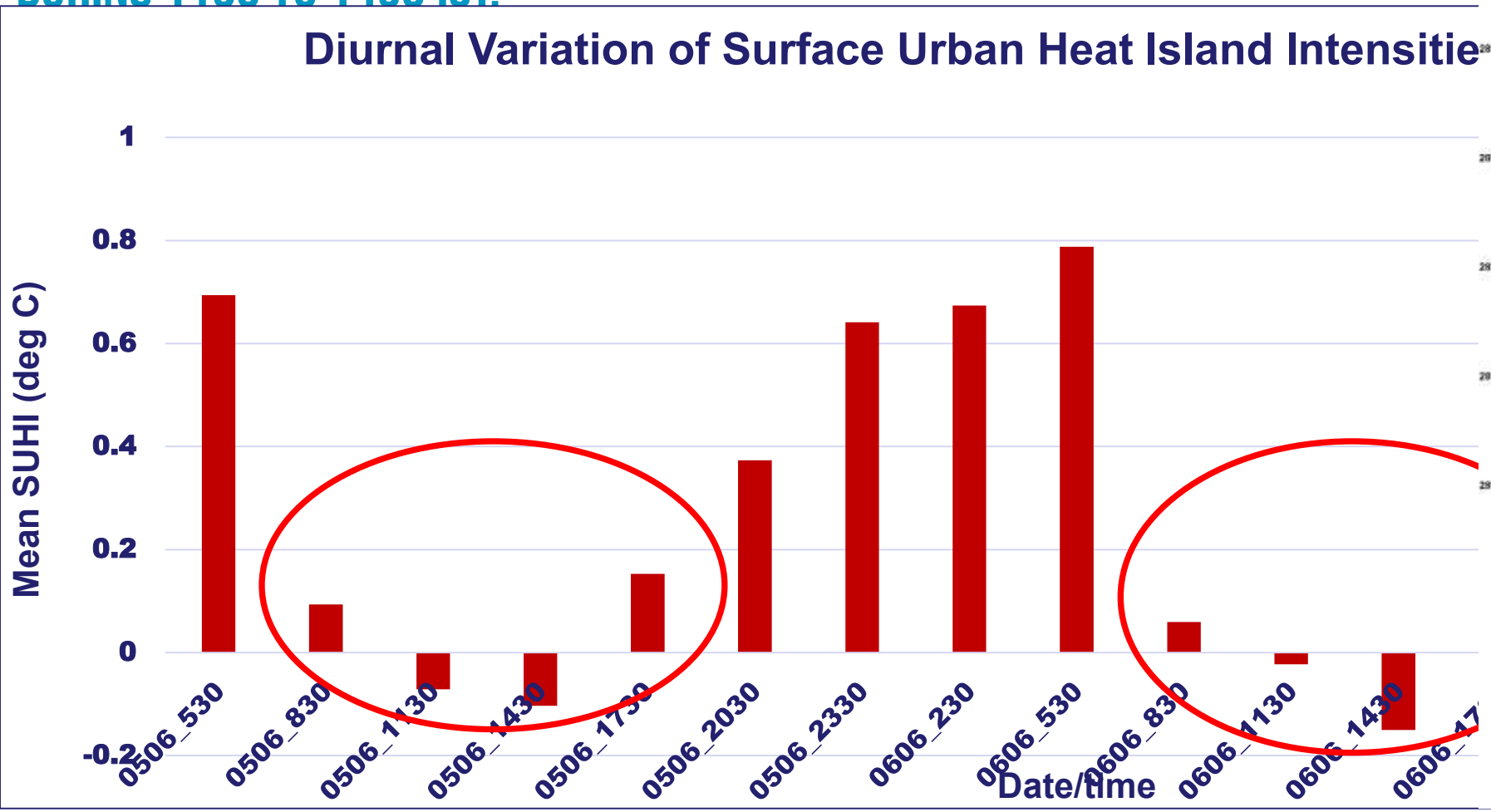
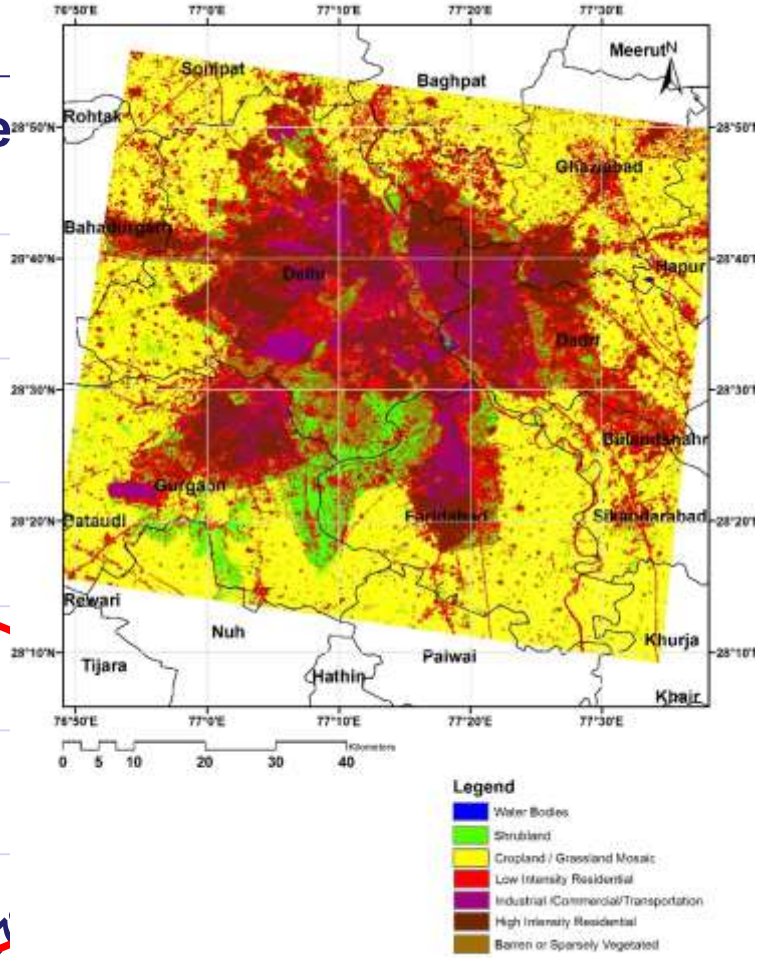
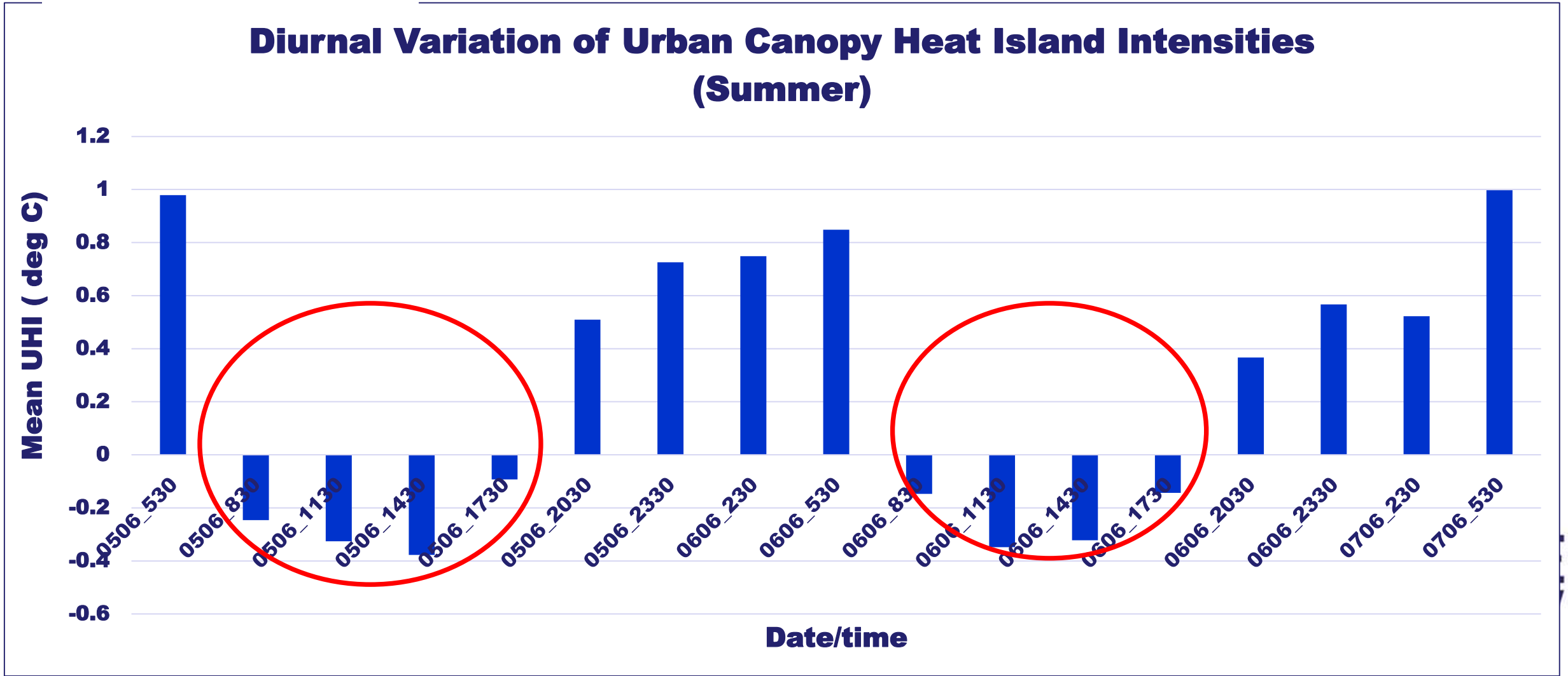
Source: Gupta et al., 2021

RESULTS: FALLOW LAND/ BARE SOIL AREA IN SURROUNDINGS HEATS UP FASTER THAN URBAN AREA (LOW ALBEDO MATERIALS MOSTLY CONCRETE, ASPHALT) IN SUMMER SEASON, DISPLAYED NEGATIVE HEAT ISLAND INTENSITIES DURING 1130 TO 1430 IST.

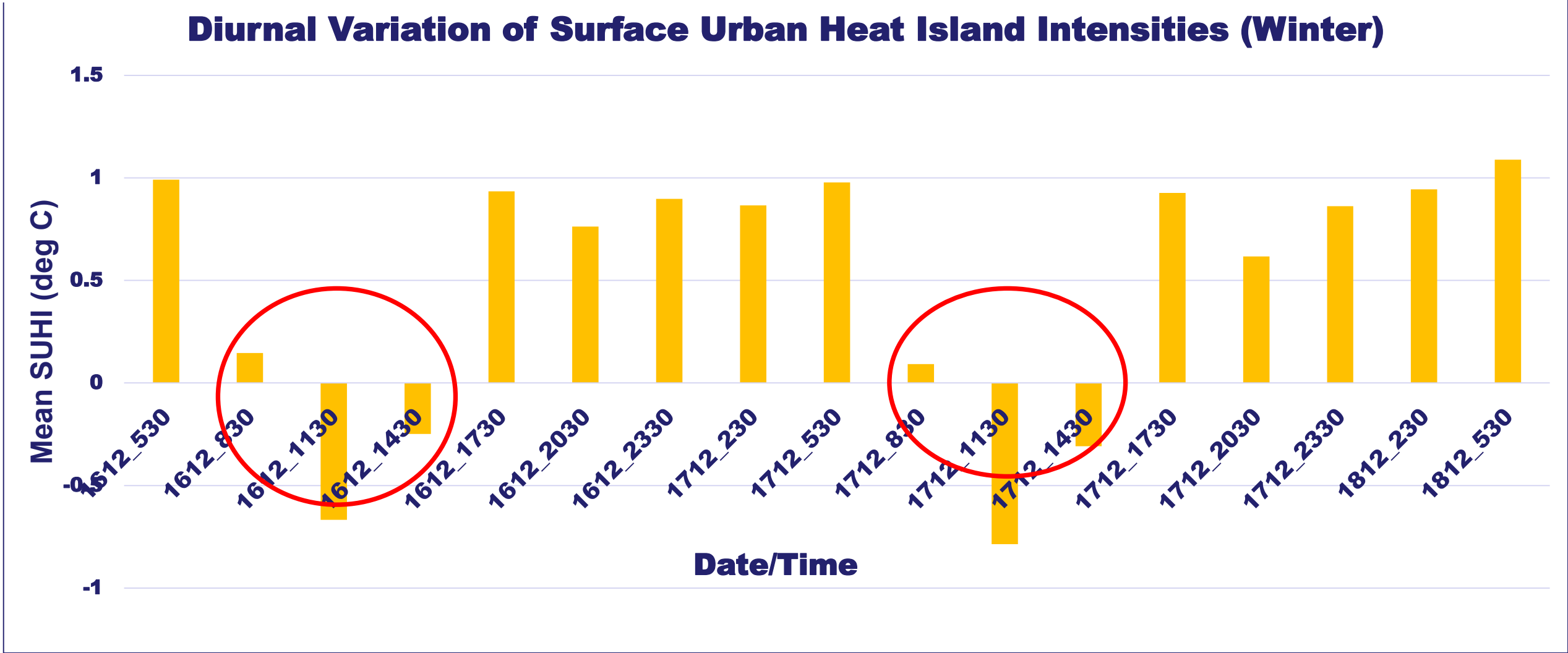




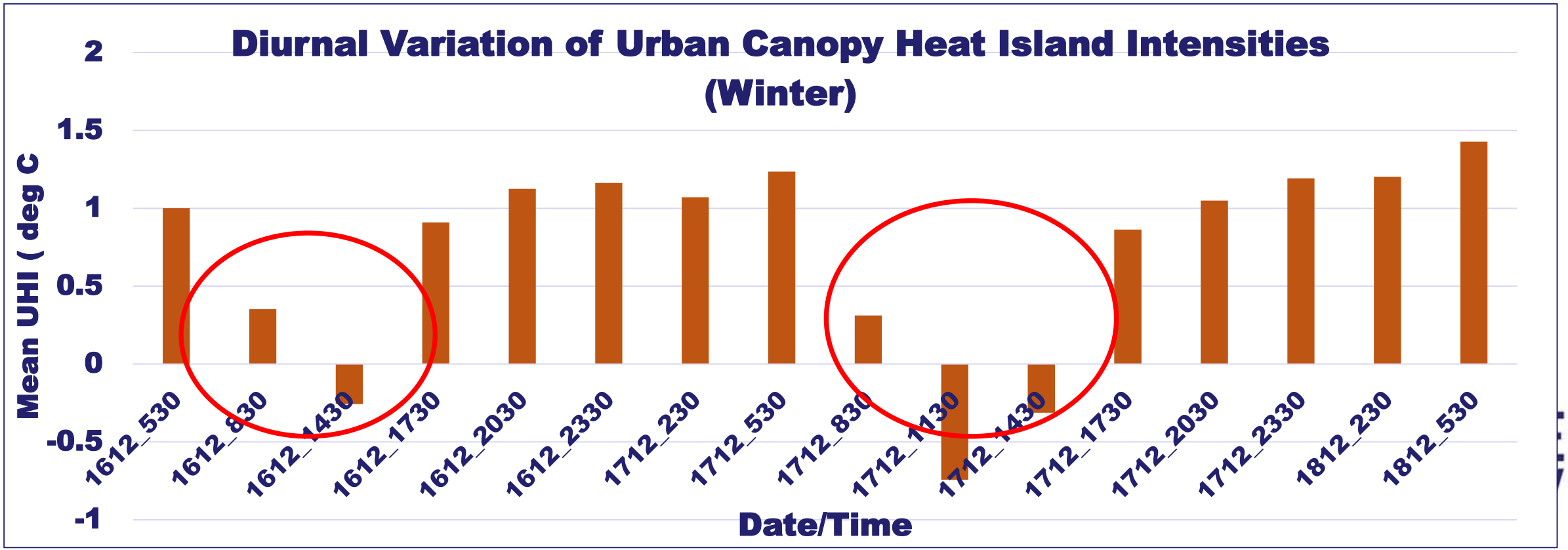
RESULTS: SIMILAR PATTERN OBSERVED FOR CANOPY LAYER HEAT ISLAND INTENSITIES (0830 TO 1730 IST) IN SUMMER SEASON .



RESULTS: IN WINTER SEASON, SHADING DUE TO 3D GEOMETRY OF URBAN AREAS AND INCLINED ELEVATION OF SUN CAUSES URBAN AREAS TO GAIN HEAT SLOWLY AS COMPARED TO SURROUNDING RURAL AREAS.



RESULTS: LOWER SUHII AND CANOPY LAYER HEAT ISLAND INTENSITIES AT 1130 IST RAISES CONCERN FOR USE OF THERMAL REMOTE SENSING SATELLITES (PASS TIME 10:30 AM - 11:30 AM IST) FOR SUHII STUDIES ESPECIALLY IN ARID AND SEMI-ARID REGIONS LIKE DELHI WHICH IS SURROUNDED BY AGRICULTURE CROP LAND/SAND / BARE SOIL.



THANK YOU

Integrated WRF-urban model employed for assessment of SUHI and CLUHI provides complete diurnal profile for UHI studies and shows negative UHI at 1130 IST for Delhi UA, usual time of pass for thermal remote sensing satellites .

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