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ORIGINAL ARTICLE

Understanding the influence of traffic volume on RST (road surface temperature) in Dibrugarh city of India

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Abstract
The basic objective of the study is to analyze the potential role of traffic and transportation volume on RST (road surface temperature) in the streets of Dibrugarh city. Additionally, the study evaluates the role of meteorological parameters on RST of the city. The experiment is accomplished by field measurement using HTC Non-contact IR thermometer over 11 selected streets of Dibrugarh city of Assam for a period of 4 months (August to November 2019). Diurnally, maximum RST is recorded in the mid-afternoon period (1.30–2.00 pm) in the month August and September. But interestingly, peak RST has been noticed in the late morning phase (11.30–12.00 pm) in the subsequent months of October and November. Seasonally, Monsoon acquires maximum positive growth of RST till mid-afternoon and rapid negative growth in the later periods. But post-monsoon reveals negative growth of RST since morning period. The study also found a varying degree of coefficient of correlation between traffic volume and mean RST. The degree of correlation is found as moderately positive in the morning and afternoon episodes during August. While September encountered moderately positive correlation only during afternoon and weaker towards the later part. Evidently, October maintains moderately strong correlation in the morning and evening sections, whereas stronger positive towards the later periods. And finally, November surprisingly displayed weak positive correlation in the morning periods to negative correlation in the successive episodes. Meteorologically, air temperature and relative humidity evidenced strong correlation with RST. Air temperature and RST accounted for a strong positive correlation with r value of 0.80 and 0.77 in monsoon and post-monsoon season, respectively. While relative humidity dominates strong negative correlation with RST with r value of -0.80 and -0.55. Therefore, maximum traffic volume with higher air temperature and lower relative humidity is chiefly accountable for development of RST.

Keywords RST · Traffic volume · Air temperature · Relative humidity · Correlation

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Introduction

The study of road surface temperature (RST) in urban areas has become an integral part to deal with the effects and magnitude of urban heat island, especially for surface heat intensity. Furthermore, RST is useful procedure to predict and detect of the spatial pattern of nocturnal RST over an area (Thornes 1991) and developing thermal mapping of the urban areas. Such thermal mapping using RST data were initially used for detection of cold section of the road surface for deicing policies (Chapman and Thornes 2005). Nowadays, thermal mapping is also used as valuable tool for road weather forecasting and in maintenance of winter road (Todeschini et al. 2016). In addition to these, the thermal mapping is also used to spot the distinctiveness of RST distribution on individual routes. The results of such mapping also help to understand the segment differences

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of RST, even on the same route. Also, the characteristics of such distribution vary usually depending on the time of day or night as well as the weather condition (Tokunaga and Nishiyama 2009). RST can be collected through road weather station (RWS) and vehicle ambient temperature (VAT) sensors (Yang et al. 2019). However, the collection of RST data using IR thermometer is accurate and reliable. RST changes both diurnally and seasonally, and the variations of RST might also result due to different surface materials present therein. The variations of RST are more noticeable during clear and calm night rather than in windy and cloudy weather (Chapman and Thornes 2005). In an urban environment, a major parcel of land use is occupied by road surface which in recent times have paved the way for comparing the prediction of RST with the observation under four different weather conditions, i.e. sunny, cloudy, overcast, rainy (Fenga and Feng 2012). RST is influenced by several geographical factors such as sky view factor (SVF), land use, altitude, topography, road construction and traffic volume (Chapman et al. 2001). More specifically, RST pattern of an area is altered by surface materials, angle of sunlight along with the traffic density (Neog et al. 2019). Various studies on RST including infinite surface temperature with medium periodic variations of heat conduction have been estimated to determine the maximum RST (Barber 1957). There are two common categories of road surfaces found over the urban streets of India, viz. concrete and asphalt road surface. Asphalt black top road surface becomes much hotter in summer season and sunny days causing intense thermal environment. The asphalt pavements cover a high percentage of the urban area and largely affect the development of the urban heat island phenomenon (Higashiyama et al. 2016). However, in the recent period, the influence of traffic and transportation over RST is getting considerable attention. Vehicles are able to generate huge amount of heat and the process of heat dispersion becomes slower in the areas surrounded by high rise buildings and dense road network (Smoliak et al. 2015; Yuan and Chen 2011). Heavy load of traffic with fast speed of vehicles increases the RST (Liu et al. 2018). There are few studies which encountered volume of Traffic along with pattern of RST and thermal mapping using IR thermography (Prusa 2002; Farmer and Tonkinson 1989; Gustavsson et al. 2001; Parmenter and Thornes 1986; Shao 1990; Zhu et al. 2017; Neog et al. 2021). Furthermore, different types of vehicle, have different influence on RST value which can be portrayed in the form of thermal maps in GIS environment using thermal data (Jamaludin 2012). It is also observed that the studies relating to the diurnal and seasonal pattern of RST and its correlation with traffic volume has either been not ascertained or less addressed, mostly in the cities under tropical climate. Therefore, a wise effort has been put forward to understand and analyse the variability pattern of RST at different diurnal and seasonal scale and its correlation to traffic volume.

Limitation of thermal mapping

Thornes (1991) detected several random and systematic errors in thermal mapping of RST related to instrument and road surface. However, additional error of RST can also be ascertained due to different shades of asphalt surface color, surface coverage with dirt and sand particles, and rain and humidity factor in previous period or day, different curvature of the road surface, diverse detection range of the instrument, etc. Apart from these, the angle and distance from the object at which data are being captured also adds to potential errors.

Study area

The study has been demonstrated encircling the Dibrugarh urban agglomeration (Fig. 1). The city is situated in the south bank of river Brahmaputra in upper Assam (Neog et al. 2020). The city agglomeration accommodates a population size of 154,296, while the Municipality area with a total population of 138,661 (census of India, 2011) and a total geographical area of 1550 hectares distributed over 22 nos. of municipal wards. The city is located at an altitude of 104 m above the mean sea level, approximately 340 km away eastward from the Guwahati metropolitan in Assam. The city enjoys tropical monsoon climate with maximum mean temperature of 27.9 °C in the month of August and minimum mean temperature of 16.2 °C in the month of January.

Materials and methods

The experiment has been carried out using HTC MT4 non-contact Infra Red Thermometer over 11 major streets of Dibrugarh city. Three sample locations in a single street have been considered for study incorporating average of three reading at each of these locations to maximize accuracy of the study. Therefore, a total 33 sample locations were considered for selected 11 urban streets. The number, location and name of the selected streets of the Dibrugarh city are depicted in Fig. 1 and Table 1. The reading has been made at a distance of 30 cm from each targeted locations over asphalt surface. The emissivity value of the IR Thermometer has been calibrated as 0.93 for all locations. The data have been collected for 12 days, considering 3 days for each month. The study covered both monsoon (i.e. the month of August and September) and post-monsoon season (i.e. the month of October and November). Moreover, to address diurnal pattern, the study is further subdivided into six time frames, i.e. 9.30–10 am, 11.30–12 pm, 1.30–2 pm,

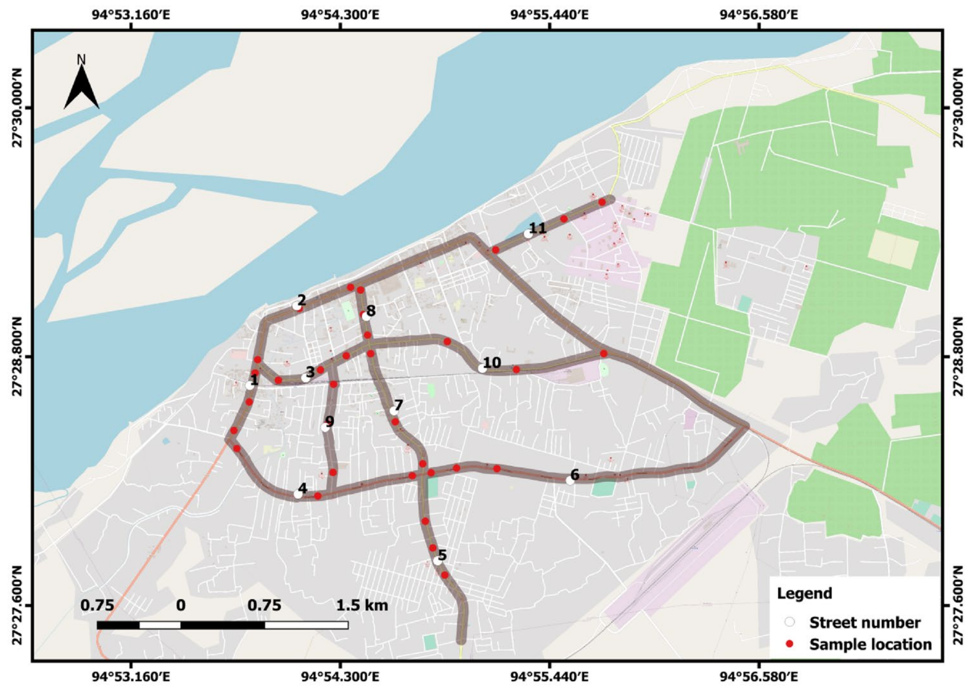

Fig. 1 Location map of the study area

Table 1 Name of the streets, Dibrugarh town, 2019

Street number	Name of the street	Location
1	Amolapatty to Kalibari Road	Urban
2	Kalibari to Phoolbagan	Urban
3	Kalibari to Thana Chariali	Urban
4	Amolapatty to Chowkidingee	Urban
5	Chowkidingee to Milan Nagar	Sub-Urban
6	Chowkidingee to Boiragimoth	Urban
7	Chowkidingee to Thana Chariali	Urban
8	Thana Chariali to Phoolbagan	Urban
9	P.N. Road to Santipara	Urban
10	Thana Chariali to Naliapool	Urban
11	Graham Bazar to Paltan Bazar	Urban

3.30–4 pm, 5.30–6 pm and 7.30–8 pm. The coordinates of the location is accessed by Garmin Etrex 30 Handheld GPS. The mean temperature of three locations for each road/street is considered for final analysis of the thermal data. Similarly, at the same time frames, the volume of Traffic movement (aggregate movement of two, three, four wheelers and others) over the selected streets/roads has been measured using video recording. Additionally, air temperature and relative humidity condition of the study area during the selected days and time frame is collected using Microlite Data Logger with celebrated record interval of 1 min. The accuracy of the HTC MT4 IR Thermometer is ± 2 °C and resolution is 0.1 °C within the temperature range of – 30 to 550 °C (Neog et al. 2020). Accuracy of Microlite Data logger is 0.3 °C for air temperature and 2% for relative humidity. While the resolution of Data logger is 0.1 °C for air temperature and 0.1% for relative humidity. The RST (road surface temperature) data have been correlated individually with traffic volume to analyze the impact of traffic volume over RST. Additionally, air temperature and relative humidity is individually correlated with RST to portray the impact of these variables upon the dynamics of RST. The spatio-temporal nature of RST over the study area is displayed in thermal maps developed using IDW method in QGIS. Finally, the validation of field data has been done with power data access viewer of NASA [POWER Data Access Viewer (nasa.gov)] for the selected days. The description of methodology is represented in Fig. 2.

Results and analysis

Validation of the data

The collected primary data have been validated by correlation with different surface temperature and meteorological data from official sources of nasa.gov. The climatological data such as Thermal Infra Red Radiative flux (TIR), Earth skin surface temperature (TS), and air temperature up to 2 m (AT2M) including relative humidity up to 2 m (RH2M) have been accessed from the power data access viewer of NASA [(POWER Data Access Viewer (nasa.gov)] for a total of 12 days selected over the study area. The data acquired from the official source of NASA have been individually

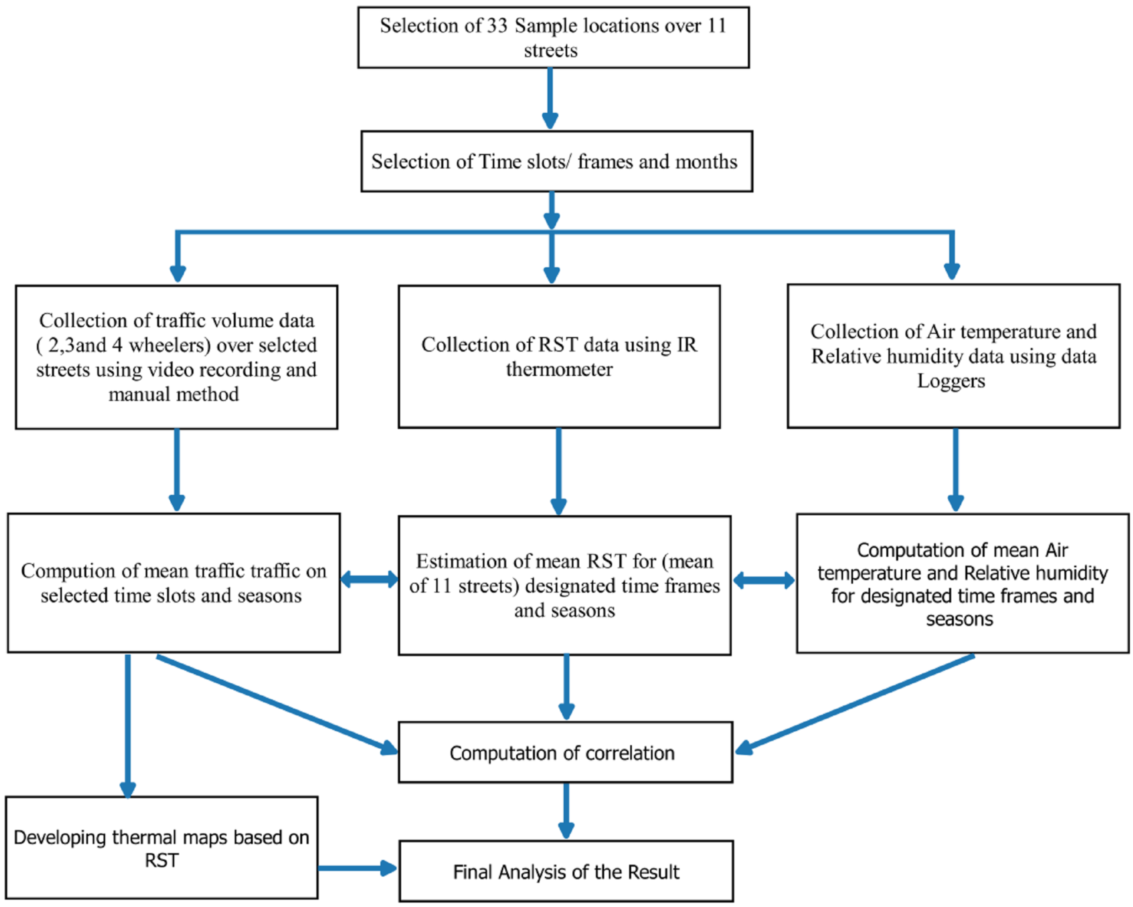

Fig. 2 Flow chart of the methodology

correlated with field surveyed data. The results have shown a very high positive correlation between TIR and RST, RST and TS and AT2M and air temperature with *r* value of 0.91, 0.98 and 0.97 and comparatively low positive correlation between relative humidity and RH2M with *r* value of 0.36, respectively. The nature of relationship between data already stated above is represented in the form of scatter plot in Fig. 3.

Diurnal pattern of road surface temperature

Diurnal pattern of road surface temperature (RST) over the city is estimated for the month of August, September, October and November (Tables 2, 3, 4 and 5). Mean RST is calculated for pre-defined time frame considering the RST of selected roads/streets of the city. Interestingly, at diurnal scale peak RST (considering mean RST of all roads) is recorded during 1.30 pm in the month of August and September and 11.30 during the month of October and November. Thus, slight shift of peak RST is noticed from afternoon to morning time. Though, minimum RST is more profound at 7.30 pm during each month. While in case of range of temperature (considering the maximum and minimum RST during the selected time slot) for the month of August showed a maximum range followed by October, September and December with 18.73 °C, 17.96 °C, 17.58 °C and 13.87 °C, respectively.

As per the rate of RST change during the mentioned time frames, a sharp increment of RST is noticed during the period of 9.30–11.30 am with maximum change or increase in the month of August with 6.10 °C with considerable decline in the succeeding month of September, October and November accounting for 3.31 °C, 3.02 °C and 1.74 °C, respectively. Apart from the study produced, it is noticed that stable RST is noticed during the selected time slot from 11.30 am to 1.30 pm in the month of August with a very insignificant change of 0.01 °C, followed by remarkable increment of RST during September and surprisingly declining trend in October and November with RST of 1.12 °C, − 1.31 °C and − 0.53 °C, respectively. While the remaining selected time slots i.e. 1.30–3.30 pm, 3.30–5.30 pm and 5.30–7.30 pm portrayed declining trend of RST with quite similar rate of change. Moreover, while analyzing and correlating the standard deviation (SD) and coefficient

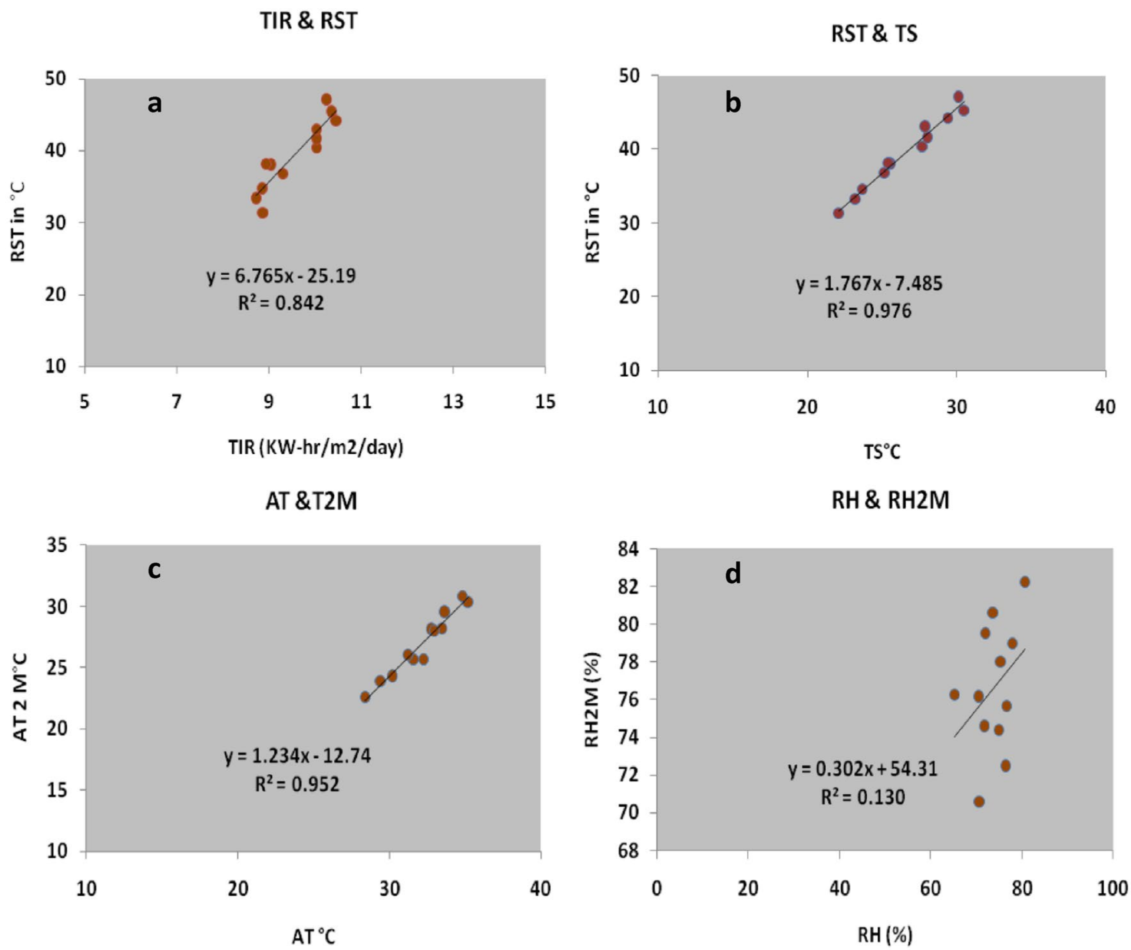

Fig. 3 Scatter plot showing relationship between different parameters. **a** Thermal Infra Red Radiative flux (TIR) and RST, **b** RST and TS (Earth skin surface temperature), **c** air temperature (AT) and air temperature up to 2 m (T2M), **d** relative humidity (RH) and relative humidity up to 2 m (RH2M)

Table 2 Diurnal variation of RST over different road in Dibrugarh city, August 2019

Road/street no	Time/temperature in °C					
	9.30 am	11.30 am	1.30 pm	3.30 pm	5.30 pm	7.30 pm
1	49.02	53.48	55.22	46.01	35.9	33.32
2	47.4	53.72	53.56	44.04	36.7	34.32
3	53.84	61.29	59.56	52.68	40.47	36.77
4	46.11	51.55	52.49	47.62	39.90	36.81
5	45.86	50.15	47.39	43.50	33.80	32.75
6	43.51	49.85	50.32	44.36	35.34	33.68
7	49.12	55.92	53.64	47.74	37.28	34.8
8	48.93	54.14	54.61	48.70	37.47	34.89
9	44.39	52.54	54.13	45.11	36.01	34.34
10	48.09	55.27	55.45	49.05	40.43	37.13
11	45.4	50.82	52.51	44.32	36.47	33.97
Mean	47.42	53.52	53.53	46.65	37.25	34.80
SD	2.87	3.26	3.08	2.80	2.18	1.49
CV	6.04	6.10	5.74	6.01	5.84	4.28

Table 3 Diurnal variation of RST over different road in Dibrugarh city, September 2019

Road/street no	Time/temperature in °C					
	9.30 am	11.30 am	1.30 pm	3.30 pm	5.30 pm	7.30 pm
1	44.31	50.78	50.96	41.1	32.83	30.9
2	46.33	49.95	52.52	41.30	34.35	32.19
3	47.46	34.86	53.86	43.76	32.26	33.41
4	43.37	48.19	48.96	42.73	35.69	33.38
5	42.95	46.85	40.61	35.74	35.45	31.9
6	38.93	47.03	46.64	36.48	30.10	29.18
7	47.73	51.41	50.29	40.95	31.78	30.15
8	46.34	52.01	51.16	39.40	34.68	31.1
9	42.2	49.38	48.1	39.77	33.18	31.24
10	49.55	52.57	51.17	44.48	35.80	33.48
11	43.81	46.4	47.5	39.88	33.64	31.43
Mean	44.82	48.13	49.25	40.51	33.61	31.67
SD	3.01	4.89	3.59	2.71	1.80	1.39
CV	6.73	10.17	7.30	6.70	5.36	4.38

Table 4 Diurnal variation of RST over different road in Dibrugarh city, October 2019

Road/street no	Time/temperature in °C					
	9.30 am	11.30 am	1.30 pm	3.30 pm	5.30 pm	7.30 pm
1	45.18	47	44.41	35.19	30.84	27.44
2	44.14	47.66	46.33	38.36	31.43	29.16
3	45.03	50.39	49.78	39.07	32.83	30.13
4	41.72	42.88	44.15	36.5	31.37	26.73
5	39.18	43.39	39.39	29.68	27.82	26.42
6	40.71	41.16	38.73	30.6	27.22	25.88
7	43.24	47.04	44.42	33.7	29.68	27.53
8	44.53	50.03	46.93	33.68	29.18	27.31
9	39.62	44.02	44.86	31.87	29.54	28.06
10	47.74	48.14	47.58	36.78	32	29.64
11	39.87	42.52	43.24	35.79	30.67	28.37
Mean	42.81	45.84	44.53	34.66	30.23	27.88
SD	2.78	3.17	3.28	3.06	1.73	1.35
CV	6.50	6.92	7.38	8.82	5.72	4.83

of variability (CV) of RST (considering mean RST of all roads), maximum relation strength is observed during 11.30 am in all months except for the month of October. Whereas minimum is detected during the time frame 7.30 pm for all month (Tables 2, 3, 4 and 5). The spatial pattern of RST over different time frames is depicted in the Figs. 4, 5, 6 and 7.

Seasonal pattern of RST

On seasonal basis, a comparison has been made between monsoon and post-monsoon to portray RST (Tables 6 and 7). During monsoon season, peak RST in noticed at 1.30 pm while lowest at 7.30 pm with RST of 51.22 °C and 33.34 °C, respectively. But on the other hand, post-monsoon depicted quite different picture with maximum and minimum RST for the time frame 11.30 am and 7.30 pm at 42.24 °C and 26.52 °C correspondingly. Similarly, the rate of RST change between the mentioned time frames also exhibited a different scenario seasonally. The rate of change exhibited rapid increment with 4.58 °C during 9.30–11.30 am with subsequently meager rise of 0.53 °C during the period of 11.30 am to 1.30 pm in the monsoon season. At the same time, relatively gradual increment at 2.18 °C is observed between 9.30 and 11.30 am followed by subsequent diminishing rate with −0.71 °C in the post-monsoon season, respectively. Thus, rate of change of RST (between diurnal slots) was quite rapid and mostly positive till early afternoon period (till 1.30 pm) in monsoon season with mean rate of 2.55 °C due to intense sunlight and high temperature and while it is only 0.73 in post-monsoonal period. While taking into account

Table 5 Diurnal variation of RST over different road in Dibrugarh city, November 2019

Road/street no	Time/temperature in °C					
	9.30 am	11.30 am	1.30 pm	3.30 pm	5.30 pm	7.30 pm
1	37.43	41.36	38.79	30.79	26.3	27.66
2	37.55	32.1	40.54	33.65	27.71	24.87
3	38.51	42.39	39.66	33.31	28.79	24.37
4	36.4	38.98	39.32	29.94	26.97	26.77
5	36.18	38.03	39.12	27.63	25.07	23.69
6	34.29	34.01	31.6	26.46	23.57	22.43
7	37.93	40.93	36.07	29.27	25.07	22.76
8	40.24	41.24	40.48	29.72	26.58	24.15
9	34.75	38.29	37.71	28.40	25.95	25.07
10	42	43.23	40.43	31.80	28.05	25.86
11	35.09	38.98	39.97	34.07	32.4	29.38
Mean	37.31	39.05	38.52	30.46	26.95	25.18
SD	2.35	3.43	2.66	2.52	2.34	2.10
CV	6.30	8.78	6.90	8.29	8.70	8.35

the succeeding time slots (i.e. from 3.30 to 7.30 pm) for both monsoon and post-monsoon season showed rapid mean rate of decline at − 5.96 °C for the former and at − 5.0 °C for the later season. However, the overall mean rate of change of RST for time slot from 9.30 am to 7.30 pm is observed as − 2.55 for monsoon and − 2.77 for post-monsoonal season. This signifies dominance of both higher positive and higher negative growth of RST at before noon and afternoon session in the monsoon season, becoming quite gradual than post-monsoon. Overall mean RST of the city (considering mean of all time and roads) during monsoon is 43.45 °C and post-monsoon is 35.36 °C. The distributional pattern of RST over different time and seasons are represented in Fig. 8.

Impact of traffic and transportation over RST

The influence of traffic over RST is analyzed through inclusion of the method—coefficient of correlation and scatter plot. The relationship is examined for all diurnal sets of the selected months. The results suggested quite dissimilar pattern. The correlations are quite stronger in the morning as well afternoon session in the month of August with r value of 0.48, 0.40, 0.38 and 0.40 during 9.30 am, 11.30 am, 1.30 pm and 3.30 pm, respectively. However, correlation seems to be weak in the early and late evening period with *r* value of 0.18 and 0.23 during 5.30 pm and 7.30 pm. While, a different scenario is observed for the month of September portraying relatively weaker correlation between traffic volume and RST particularly in the morning session with *r* value of 0.30 and 0.18 at 9.30 am and 11.30 am, leaving apart moderately stronger correlation during the afternoon period with *r* value of 0.45 and 0.49, followed by again weaker trend in the early and late evening period supported by *r* value of 0.11 and 0.25, respectively. For the month of October, it is correlated low to moderately positive during morning and afternoon with *r* value of 0.26, 0.56, 0.42 and 0.34 at the same time slot whereas strongly correlated in the evening with *r* value of 0.82 and 0.73 at 5.30 pm and 7.30 pm, respectively. The month of November witnessed a weaker correlation in the morning epoch with *r* value of 0.37 and 0.22 and negative correlation in early afternoon and evening period with *r* value of − 0.32, − 0.38 and − 0.38 at 1.30 pm, 5.30 pm and 7.30 pm followed by low positive correlation with *r* value of 0.31 during 3.30 pm. The overall estimation points out that there are moderate positive correlation between mean traffic volume and mean RST in the month of August, September and October with *r* value of 0.56, 0.60 and 0.51 alongside a very weak positive correlation witnessed by *r* value of 0.11 in the month of November. Furthermore, the monsoon season overall showed weaker positive correlation than post-monsoonal season in terms of mean traffic volume and RST asserted by *r* value of 0.54 and 0.68, respectively. While considering mean volume of the traffic for selected 12 days (considering mean traffic of two, three and four wheeler at the designate day) is correlated to mean RST. The results appeared as positively strong relation in almost all days expect day 1 and 2, where *r* value is negative with − 0.52 and − 0.36 and weakly positive in day 4 and day 6 with *r* value of 0.31 and 0.22, respectively.

Types of traffic and its impact of RST

The influence of different classes of traffic volume has been individually correlated with RST for selected time and month (Table 8). The results revealed were quite dynamic in terms of two-wheeler, three-wheeler and four-wheeler traffic volume including its influence over the RST development in varied temporal direction. In terms of two

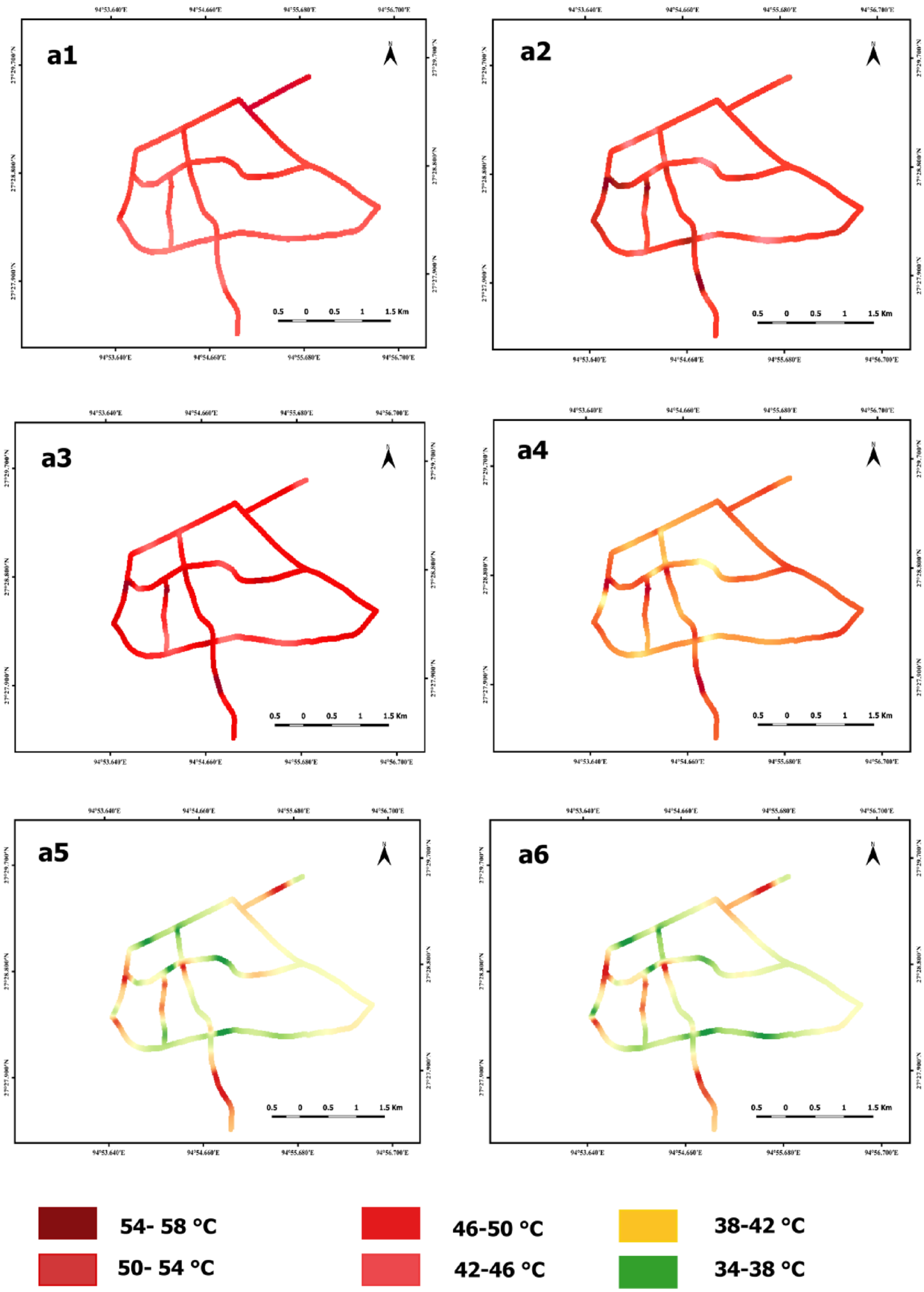

Fig. 4 Spatio-temporal pattern of RST (road surface temperature) in August, Dibrugarh, 2019 (**a**—August, **1** = 9.30–10 am, **2** = 11.30–12 pm, **3** = 1.30–2 pm, **4** = 3.30–4 pm, **5** = 5.30–6 pm, **6** = 7.30–8 pm)

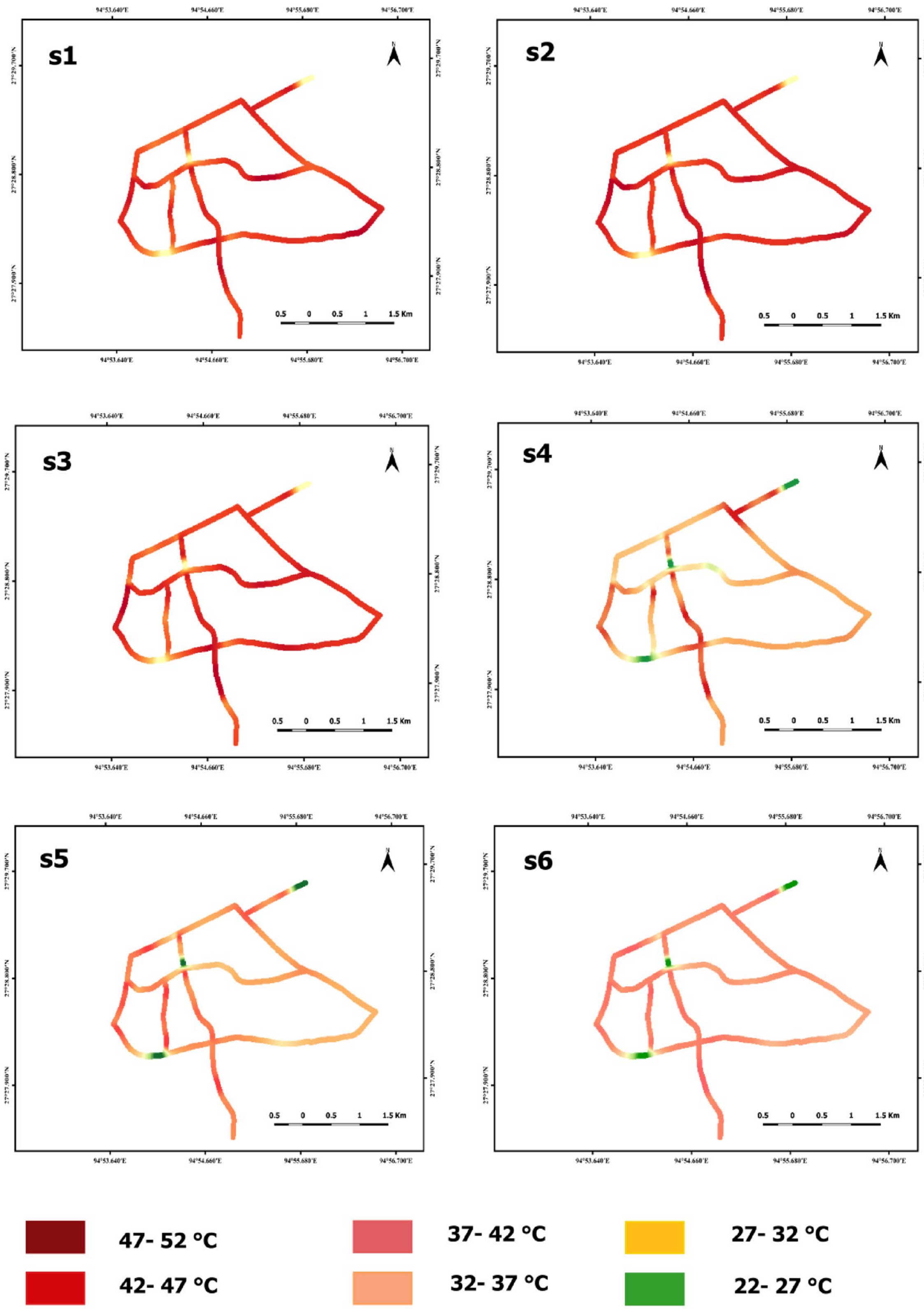

Fig. 5 Spatio-temporal pattern of RST (road surface temperature) in September, Dibrugarh, 2019 (**s**—September, **1** = 9.30–10 am, **2** = 11.30–12 pm, **3** = 1.30–2 pm, **4** = 3.30–4 pm, **5** = 5.30–6 pm, **6** = 7.30–8 pm)

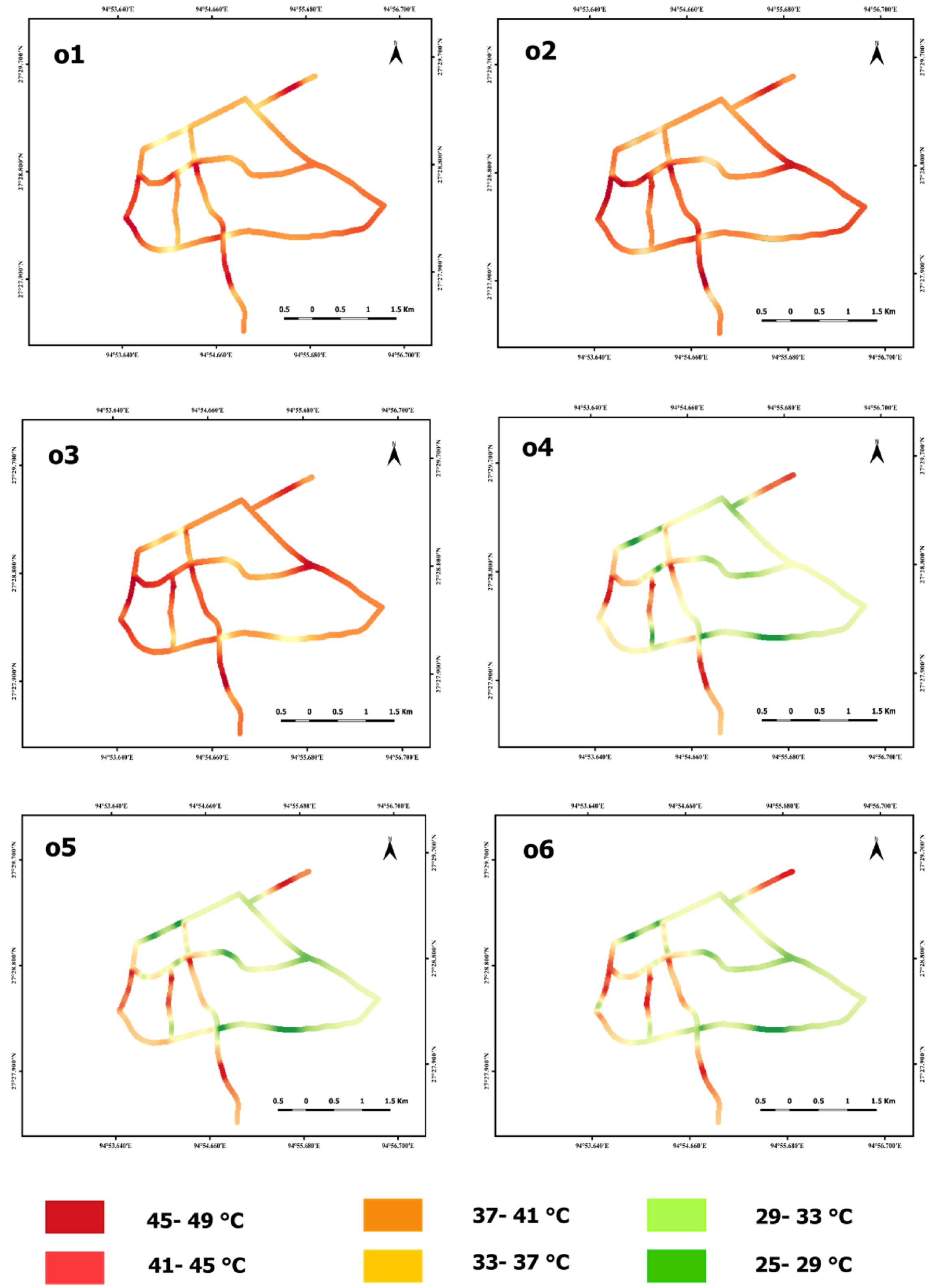

Fig. 6 Spatio-temporal pattern of RST (road surface temperature) in October, Dibrugarh, 2019 (**o**—October, **1** = 9.30–10 am, **2** = 11.30–12 pm, **3** = 1.30–2 pm, **4** = 3.30–4 pm, **5** = 5.30–6 pm, **6** = 7.30–8 pm)

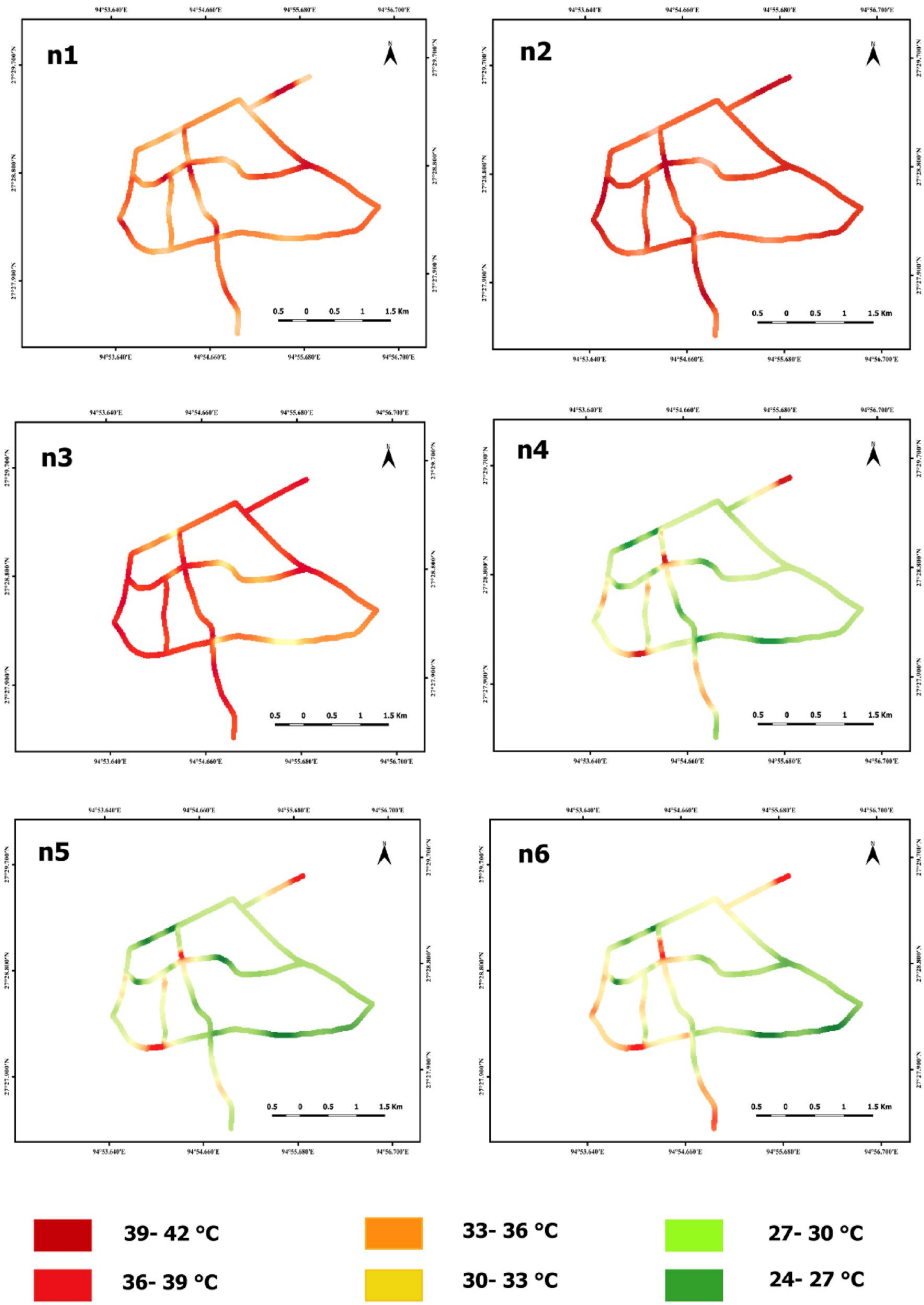

Fig. 7 Spatio-temporal pattern of RST (road surface temperature) in November, Dibrugarh, 2019 (**n**—August, **1** = 9.30–10 am, **2** = 11.30–12 pm, **3** = 1.30–2 pm, **4** = 3.30–4 pm, **5** = 5.30–6 pm, **6** = 7.30–8 pm)

Table 6 Pattern of RST (road surface temperature) over different roads in Dibrugarh city, Monsoon Season, 2019

Road/street no	Time/temperature in °C					
	9.30 am	11.30 am	1.30 pm	3.30 pm	5.30 pm	7.30 pm
1	46.66	52.13	53.09	43.55	34.36	32.11
2	46.85	51.83	53.04	42.67	35.52	33.25
3	50.65	48.07	56.71	48.22	36.36	35.09
4	44.74	49.87	50.72	45.17	37.79	35.09
5	44.4	48.5	44	39.62	34.62	32.32
6	41.22	48.44	48.48	40.42	32.72	31.43
7	48.42	53.66	51.96	44.34	34.53	32.47
8	47.63	53.07	52.88	44.05	36.07	32.99
9	43.29	50.96	51.11	42.44	34.59	32.79
10	48.82	53.92	53.31	46.76	40.11	35.3
11	44.6	48.61	50	42.10	35.05	32.7
Mean	46.12	50.69	51.22	43.58	35.74	33.34
SD	2.89	2.31	3.37	2.69	2.04	1.34
CV	6.26	4.56	6.59	6.16	5.71	4.03

Table 7 Pattern of RST (road surface temperature) over different roads in Dibrugarh city, post-monsoon season, 2019

Road/street no	Time/temperature in °C					
	9. am	11.30 am	1.30 pm	3.30 pm	5.30 pm	7.30 pm
1	41.30	44.18	41.6	32.99	28.57	27.55
2	40.84	39.88	43.41	36.00	29.57	27.01
3	41.77	46.39	44.72	36.19	30.81	27.25
4	39.06	40.93	41.73	33.22	29.17	26.75
5	37.68	40.71	39.35	28.64	26.44	25.05
6	37.5	37.80	35.16	28.53	25.39	24.15
7	40.58	41.55	40.24	31.48	28.13	25.14
8	42.38	45.63	43.7	31.70	27.88	25.73
9	37.18	41.15	41.28	30.13	27.74	26.56
10	44.87	45.68	44	34.29	30.03	27.75
11	37.48	40.75	41.6	34.93	31.53	28.83
Mean	40.06	42.24	41.53	32.55	28.66	26.52
SD	2.49	2.78	2.68	2.71	1.82	1.38
CV	6.22	6.59	6.44	8.34	6.36	5.20

wheeler, the correlation seems to be stronger mostly in the morning, noon and afternoon section (9.30–10 am, 11.30–12 pm, 1.30–2 pm and 3.30–4 pm) while weaker in the later periods for almost all month. Similarly, three wheeler also witnessed similar pattern almost for all the month except for the month of august, which depicted maximum correlation in the noon and afternoon period. Contrary four-wheeler traffic demarcates a dissimilar pattern by incorporating stronger correlation particularly in the morning, noon and late afternoon section (i.e. 9.30–10 am, 11.30–12 pm and 5.30–6 pm) for all selected months. The distributional pattern of traffic in the Dibrugarh city in different roads and time slots are represented in the Fig. 9.

Influence of air temperature and relative humidity on RST

Air temperature and relative humidity play an important role in modifying as well as understanding the RST. The air temperature is strongly positive while relative humidity has weaker positive to negative relationship with RST. The relationship is analyzed for monthly, seasonal and diurnal pattern. Diurnal pattern of relationship is examined by considering the day wise mean air temperature, relative humidity and RST fragmented in the pre-defined time slots. Diurnal air temperature has a very strong positive correlation with RST with computed *r* value of 0.92.0.94, 0.96, 0.95, 0.96 and 0.94 for the selected time frames, respectively. While relative humidity seems

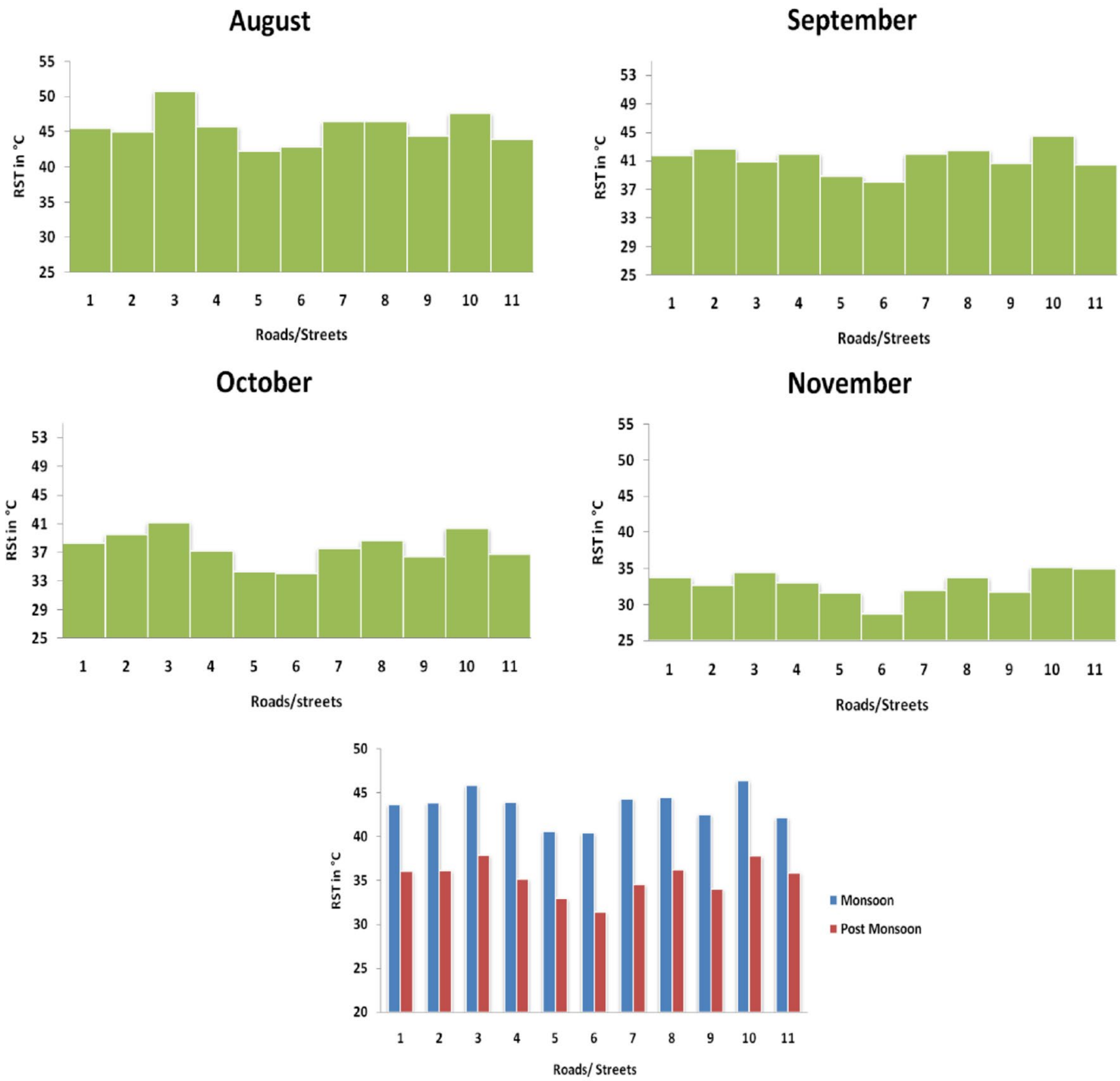

Fig. 8 Monthly and seasonal pattern of mean RST (road surface temperature) in different streets of Dibrugarh, 2019

Table 8 Correlation of two-wheeler, three-wheeler and four-wheeler traffic with RST for all month, Dibrugarh, 2019

Time	August			September			October			November		
	2 W	3 W	4 W	2 W	3 W	4 W	2 W	3 W	4 W	2 W	3 W	4 W
9.30–10 am	0.14	0.37	0.29	0.50	0.47	0.21	0.41	0.21	0.25	0.58	0.49	0.23
11.30–12 pm	0.33	0.23	0.03	0.08	−0.18	0.15	0.61	0.47	0.41	0.65	0.49	0.25
1.30–2 pm	0.34	0.11	−0.05	0.04	−0.04	0.04	0.34	0.23	−0.05	0.22	0.31	0.27
3.30–4 pm	0.72	0.46	0.15	0.28	−0.05	0.30	0.15	0.07	0.34	0.13	0.10	0.16
5.30–6 pm	0.13	0.15	0.01	0.22	0.08	0.05	0.31	0.10	0.28	−0.13	0.23	−0.07
7.30–8 pm	0.54	0.15	0.27	0.31	0.07	0.11	0.24	−0.06	0.01	−0.27	−0.11	−0.13

W wheeler

to be less dominating for RST modification with *r* value of −0.15 in the early morning, whereas 0.25, 0.06, 0.50 in the succeeding time slots and quite interestingly moderately negative with *r* value of −0.55 and −0.53 in the early and late evening stage. The presence of both low positive and negative *r* value demonstrate no regular trend of correlation between relative humidity and RST. Thus, proclaimed dominant role of air temperature with weaker role of relative humidity in

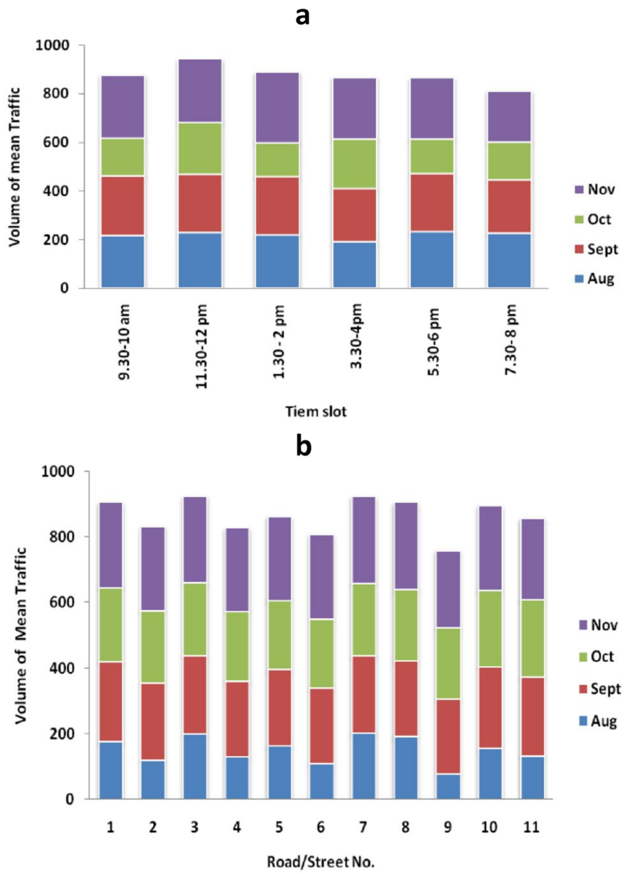

Fig. 9 Volume of traffic in different streets of Dibrugarh city, 2019 (**a** volume of mean traffic at different time slot, **b** volume of mean traffic at different roads/streets)

alteration of RST mostly in its diurnal form where monthly pattern revealed a little different scenario with moderately strong positive correlation between air temperature and RST in August and November with computed r value of 0.67 and 0.73 and strong correlation in September and October month supported by r value of 0.82 and 0.84, respectively. But surprisingly strong negative correlation is witnessed between relative humidity and RST during the aforesaid month chronologically with r value −0.64, −0.36, −0.80 and −0.78 accordingly. While seasonally, in post-monsoon period, strong correlation is acknowledged between air temperature, relative humidity with RST at r value of 0.80 and −0.80, whereas moderately strong correlation is accredited to monsoon season with r value of 0.77 and −0.55, respectively.

Discussion and conclusion

The study finally witnessed an influencing role of traffic volume and count on the alteration of RST. But there seems to be significant variations in pattern of influence of different parameters such as traffic volume, air temperature and relative humidity on RST. Considering the nature of dynamics of RST, there is no regular pattern is noticed in the selected time frames for study months and season except for higher rate of change of RST in the morning session during August and slowly diminishing trend for rest of the months. One of the remarkable differences is noticed in terms of peak RST, which acquired its position in the afternoon time (1.30–2.00 pm) in the monsoon season, whereas before noon (11.30–12.00 pm) time in the post-monsoon season. This is the possible outcome of duration and angle of sunlight on the road surface. Considering the impact of traffic on RST, it has been noticed that the traffic seems to quite governing on morning time during August, afternoon in September and October and finally less effective in November. This evidenced that impact of traffic volume on RST is more on summer, related highly to the intensity of sunlight. Furthermore, the type of traffic also considered to be one of the major factors in dynamics of RST. The two-wheeler vehicles are accounted as more leading on RST rather than three and four wheelers. Thus, overall study incorporated the true nature of RST modification with respect to traffic volume along with air temperature and humidity. It is a fact that appreciable change of RST brings a significant change in the process of urban heat island in a city. The air temperature and humidity always have a considerable influence over RST variability. Nevertheless, the impact of traffic volume and its different type on the alteration of RST development in a city cannot be overlooked. But the observations showed that the impact of traffic and transportation on RST varies with respect to the time as well as seasons. Thus, for an urban planner while dealing with the issue of urban heat more particularly while taking into account the surface urban heat island intensity must also consider the dynamics of RST in the city and its correlation with traffic volume and its types. However, to reduce the intensification of RST, the improvement of green land parcels in alongside the streets as well as in the centerline of the city road is must. The surface urban heating process can be neutralized only through cooling and shading method by incorporation of green areas.

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Declarations

Conflict of interest The authors of the manuscript declare no conflict of interest.

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