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Review and Application of Methodologies Available for 33 ULBs in Maharashtra, India

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Abstract

The estimation of energy performance is an essential step during the design phase of new buildings to ensure that they comply with regulations and standards, particularly so when the Energy Conservation Building Code (ECBC) is made mandatory and implemented across various states of India. The estimation of energy performance of buildings during the design stage involves simulation, modeling and mathematical calculations of heat transfer over a period time (i.e., a month or a season). This would normally require a quick estimation of the heating or cooling energy consumption of a building, for which it becomes essential that the geographical area of a country is divided in zones with common climatic characteristics. These verity of the climate has an impact on the thermal properties of building components and consequently, the energy performance for new and existing buildings. Furthermore, climate classification can also help to develop a common basis, upon which building products can be designed, evaluated and rated. Within this context and the larger goal of helping to implement the ECBC regulation, this paper attempts to propose climatic zones for 33 ULBs of Maharashtra state.

Keywords

Climate Classification, Energy Performance, Climate Modelling

Introduction

There are three fundamental types of classifications used in climatology. First there are **Empirical systems of classification** that are based on observable features. The Köppen system discussed below is an empirical system based on observations of temperature and precipitation. These are two of the easiest climate characteristics that can be measured, and probably the ones with the longest historical record. It's fairly easy to collect air temperature readings with a thermometer and precipitation with device that

can measure the amount of precipitation. Climates are grouped based on annual averages and seasonal extremes.

Genetic classification systems are those based on the cause of the climate, for example, the Strahler climate classification discussed below. A genetic system relies on information about climate elements like solar radiation, air masses, pressure systems, etc. The important point here is that we assume we know what causes climate. Though atmospheric science is progressing every day, we still have a long way to go before we have a complete understanding of the workings of our climate. These are inherently the most difficult classifications to create and use because of the multitude of variables needed.

Applied classification systems are those created for, or as an outgrowth of, a particular climate-associated problem. The Thornthwaite classification system is one based on potential evapotranspiration and thus groups climates based on water requirements. Research conducted by C.W. Thornthwaite and his associates attempted to formulate a water budget technique that assessed water demand under different environmental conditions. His classification system grew out of the issue of trying to predict the supply and demand for water in different climate regions

Köppen-Geiger Climate Classification

The Köppen climate classification is a vegetation-based empirical climate classification system developed by German botanist-climatologist Wladimir Köppen(Köppen, 1884), and modified by Rudolf Geiger after the death of Köppen(Geiger, 1954). It is the most widely used system for classifying the world's climates. The aim of the Köppen climate classification system was to devise formulas that would define climatic boundaries in such a way as to correspond to those of the vegetation zones (biomes). The first version of the Köppen classification was published in 1884 (Köppen, 1884)and a revised version in 1918(Köppen, 1918) with a final version resulting in it being known as the Köppen-Geiger Climate Classification. Other climatologists (Hantel, 1989)(Essenwanger, 2001)(Bailey & Hogg, 1986)have modified portions of Köppen's procedure on the basis of their experience in various parts of the world.

Today the climate classification of Köppen-Geiger system is assigned to the classical climatology and is called a generic climate classification. Its categories are based on the annual and monthly averages of temperature and precipitation. The Köppen-Geiger system recognizes five major climatic types; each type is represented by the capital letters A, B, C, D, and E (Table 1). Each of these climate types except for 'B' is defined by temperature criteria. Type B designates climates in which the controlling factor on vegetation is dryness (rather than coldness).

TABLE 1. MAJOR CLIMATE GROUPS OF THE KÖPPEN-GEIGER SYSTEM(GEIGER, 1954)

Symbol	Climate group	Characteristics
A	Tropical Rainy Climates	Hot all the year Coldest month > 18°C Winterless climate Annual ppt > Annual evaporation
B	Dry climates	Dry all the year Evaporation > precipitation

		No permanent stream originates in the region
C	Warm Temperate (Mesothermal climates)	Warmest month > 10℃ Coldest month between-3℃to 18℃ Have both summer and winter season
D	Cold Boreal Forest Climates	Warmest month > 10℃ Coldest month < -3 ℃
E	Polar Climates (Ice Climates)	Cold all the year Warmest month < 10 ℃ Have no true summer

A second letter is used to create sub groups of climates to distinguish particular seasonal characteristics of temperature and precipitation (Table 2). The letters S and W are applied only to the dry B climates, yielding two combinations, BS for desert and BS for steppe.

TABLE 2. CLIMATE SUBGROUPSOF THE KÖPPEN-GEIGER SYSTEM(GEIGER, 1954)

Climate Subgroups	**Characteristics**
(f)	It is wet all seasons. This modifier is only applied to A, C, D Groups.
(w)	It is dry in winter of the respective hemisphere
(s)	It is dry in summer of the respective hemisphere
(m)	It is basically the rainforest climates in spite of short dry season. Only applicable in A climate.

Combining the major climate groups and subgroups, 12 climatic regions are distinguished Table 3.

TABLE 3. CLIMATIC REGIONSOF THE KÖPPEN-GEIGER SYSTEM(GEIGER, 1954)

Climatic	**Description**
Af	Tropical rain forest climate
Am	Monsoon variety of Af
Aw	Tropical savanna climate
BS	Steppe climate
BW	Desert Climate
Cf	Temperate rainy climate (moist all the year)
Cw	Temperate rainy climate (dry winter)
Cs	Temperate rainy climate (dry summer)
Df	Cold snowy forest climate, moist in all season
Dw	Cold snowy forest climate, dry winter
ET	Tundra Climate

The advantage of the Köppen classification system is that it is based on data which are readily available – Temperature and precipitation. Therefore, it permits any location to be easily classified. Besides, only a limited number of climatic regions are identified. However, it fails to take account of the causes of the climate described. Furthermore, it neglects the relations between the location of the climatic regions and those of pressure zones and air mass source regions. It has been argued that extreme events, such as a periodic drought or an unusual cold spell, are just as significant in controlling vegetation distributions as the mean conditions upon which Köppen's scheme is based. It also has been pointed out that factors other than those used in the classification, such as sunshine and wind, are important to vegetation. Moreover, it has been contended that natural vegetation can respond only slowly to environmental change, so that the vegetation zones observable today are in part adjusted to past climates. Many critics have drawn attention to the rather poor correspondence between the Köppen zones and the observed vegetation distribution in many areas of the world.

Strahler Climate Classification

A system for describing climates, devised in 1969 by A. N. Strahler, in which world climates are related to the main air masses that produce them, as: (*a*) equatorial/tropical air masses, producing low-latitude climates; (*b*) tropical and polar air masses, producing mid-latitude climates; and (*c*) polar and arctic air masses, producing high-latitude climates. Subsets of these are based on variations in temperature and precipitation to give 14 regional types, plus upland (highland) climates which are regarded as a separate category. See also köppen climate classification; and thornthwaite climate classification.

(*a*) equatorial/tropical air masses, producing low-latitude climates; (*b*) tropical and polar air masses, producing mid-latitude climates; and (*c*) polar and arctic air masses, producing high-latitude climates. Subsets of these are based on variations in temperature and precipitation to give 14 regional types, plus upland (highland) climates which are regarded as a separate category

Thornthwaite Climate Classification

Thornthwaite proposed an applied climate classification system in 1930 and 1948 (Thornthwaite, 1948). He selected effectiveness of precipitation, seasonal precipitation and thermal efficiency as bases for climatic classification Regional variations in precipitation and thermal efficiency result in the grouping of humidity provinces and temperature provinces respectively.

There are thirteen types in three major groups, as well as a more general highland climate (Table 4).

TABLE 4. CLIMATE GROUPS ACCORDING TO THE THORNTHWAITE CLIMATE CLASSIFICATION(THORNTHWAITE, 1948).

Group I Low Latitude Climates	Group II Mid-Latitudes Climates	Group III High-Latitudes Climates
Equatorial rain forest	Humid subtropical	Subarctic
Trade wind littoral	Mediterranean	Tundra
Tropical monsoon	Marine west-coast	Ice cap
Tropical savanna	Dry mid-latitude	
Dry tropical	Humid continental	

Apart from above mentioned classification methods there are many other methods available which are confined to particular region. This paper will discuss and review some of the methodologies available for climate classification which uses temperature, relative humidity and precipitation data provided by International Weather for Energy Calculation (IWEC). The paper will further reinterpret the climate of 33 ULBs or 7 cities of Maharashtra depending upon data availability. The list of 33 ULBs is attached below and 7 ULBs for which IWEC data is available and are among the 33 ULBs are also highlighted.

TABLE 5: LIST OF 33 ULBS

Achalpur	Gondia	Nashik
Aheri	Jalgaon	Parbhani
Ahmadnagar	Kalyan	**Poona**
Akola	Khamgaon	**Ratnagiri**
Amravati	Kolhapur	Satara
Aurangabad	Latur	**Solapur**
Baramati	Malegaon	Sillod
Beed	**Mumbai**	Udgir
Bhadravati	**Nagour Sonegaon**	Uran
Chandrapur	Nanded	Warud
Chiplun	Nandurbar	Yavatmal

The climate classification methods used for the study are:

ASHRAE Climate Classification

The ASHRAE climate classification in based on two parameters: air temperature and precipitation. Relative humidity is not taken into account (ASHRAE, 2007). Cooling Degree Days (CDD) and Heating Degree Days (HDD) are used for defining various climate zones. CDD and HDD are calculated as the sum of differences between daily average temperature and the base temperature. The base temperature for CDD is taken as 10 °C and base temperature for HDD is taken as 18 °C. This method has been used for defining climate zone all over the globe and thus doesn't provide a comprehensive methodology for Indian context. The international climate zone definitions described by ASHRAE are given in Figure 1.

International Climate Zone Definitions

Zone Number	Zone Name	Thermal Criteria (I-P Units)	Thermal Criteria (SI Units)
1A and 1B	Very Hot –Humid (1A) Dry (1B)	9000 < CDD50°F	5000 < CDD10°C
2A and 2B	Hot-Humid (2A) Dry (2B)	6300 < CDD50°F ≤ 9000	3500 < CDD10°C ≤ 5000
3A and 3B	Warm – Humid (3A) Dry (3B)	4500 < CDD50°F ≤ 6300	2500 < CDD10°C < 3500
3C	Warm – Marine (3C)	CDD50°F ≤ 4500 AND HDD65°F ≤ 3600	CDD10°C ≤ 2500 AND HDD18°C ≤ 2000
4A and 4B	Mixed-Humid (4A) Dry (4B)	CDD50°F ≤ 4500 AND 3600 < HDD65°F ≤ 5400	CDD10°C ≤ 2500 AND HDD18°C ≤ 3000
4C	Mixed – Marine (4C)	3600 < HDD65°F ≤ 5400	2000 < HDD18°C ≤ 3000
5A, 5B, and 5C	Cool-Humid (5A) Dry (5B) Marine (5C)	5400 < HDD65°F ≤ 7200	3000 < HDD18°C ≤ 4000
6A and 6B	Cold – Humid (6A) Dry (6B)	7200 < HDD65°F ≤ 9000	4000 < HDD18°C ≤ 5000
7	Very Cold	9000 < HDD65°F ≤ 12600	5000 < HDD18°C ≤ 7000
8	Subarctic	12600 < HDD65°F	7000 < HDD18°C

FIGURE 1. INTERNATIONAL CLIMATE ZONE DEFINITION *(REPRODUCED FROM ASHRAE, 2007)*.

TABLE 6. ASHRAE MAJOR CLIMATE TYPE DEFINITIONS

Marine (C) definition– Locations meeting all four of the following criteria:

1. Mean temperature of coldest month between 27°F (-3°C) and 65°F (18°C)
2. Warmest month mean < 72°F (22°C)
3. At least four months with mean temperatures over 50°F (10°C)
4. Dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

Dry (B) definition – Locations meeting the following criteria:

Not marine and

$P < 0.44 \times (T - 19.5)$ [I-P units]

$P < 2.0 \times (T + 7)$ [SI units]

Where:

P = annual precipitation in inches (cm) and

T = annual mean temperature in °F (°C).

Moist (A) definition– Locations that are not marine and not dry.

For all international locations that are not listed in the ASHRAE 90.1 Standard, ASHRAE prescribes that the international climate zone definitions (given in Figure 1) and the Major Climate Type Definitions given in Table 6 are used to determine both the climate zone letter and number for cities around the world.

On this basis, an attempt was made to classify 33 ULBs of Maharashtra using this system. The CDD and HDD values used are given in Table 7. This resulted in all 33ULBs including the 7 cities lie under category 1A and 1 B of ASHRAE climate zone. This methodology only provides a sketchy picture.

TABLE 7. CDD AND HDD VALUES FOR 33 ULBS OF MAHARASHTRA, USED FOR CLIMATE CLASSIFICATION IN ACCORDANCE WITH THE ASHRAE CLIMATE CLASSIFICATION SYSTEM.

	Achalpur	Aheri	Ahmadnagar	**Akola**	Amravati	**Aurangabad**	Baramati
CDD	6040	6001	5653	6373	6292	5687	5723
HDD	0	0	0	0	0	0	0
	Beed	Bhadravati	Chandrapur	Chiplun	Gondia	Jalgaon	Kalyan
CDD	6010	6324	6375	5665	5886	6228	5583
HDD	0	0	0	0	0	0	0
	Khamgaon	Kolhapur	Latur	Malegaon	**Mumbai**	**Nagpur Sonegaon**	Nanded
CDD	6211	5776	6176	5960	6392	6200	6370
HDD	0	0	0	0	0	0	0
	Nandurbar	Nashik	Parbhani	**Poona**	**Ratnagiri**	Satara	**Solapur**
CDD	6236	5920	6185	5370	6093	5782	6424
HDD	0	0	0	0	0	0	0
	Sillod	Udgir	Uran	Warud	Yavatmal		
CDD	6116	6282	6095	6038	6395		
HDD	0	0	0	0	0		

International Energy Agency Climate Classification

In this model the different climatic conditions are split into 6 different basic climatic zones based on heating and cooling requirements. The base temperature for CDD and HDD both is kept as 18°C. This method also doesn't provide comprehensive methodology for Indian context.

In general, the climates could be described as follows:

	Heating	Cooling
Cold Climate	$2000 \leq$ HDD 18 °C	CDD 18 °C < 500
Heating based	$2000 \leq$ HDD 18 °C	$500 \leq$ CDD 18 °C < 1000
Combined Climate	$2000 \leq$ HDD 18 °C	$1000 \leq$ CDD 18 °C
Moderate Climate	HDD 18 °C < 2000	CDD 18 °C < 1000
Cooling Based	$1000 \leq$ HDD 18 °C < 2000	$1000 \leq$ CDD 18 °C
Hot climate	HDD 18 °C < 1000	$1000 \leq$ CDD 18 °C

FIGURE 2: HEATING AND COOLING DEGREE DAYS. SOURCE (BEHRENDT & CHRISTENSEN, 2013)

Due to non-availability of CDD values at 18°C for 26 ULBs this method is only used to reinterpret climate of 7 cities of Maharashtra. All the 7 cities fall under Hot Climate zone therefore this method also provides a sketchy picture.

TABLE 8: CDD AND HDD VALUES FOR 7 CITIES OF MAHARASHTRA, USED FOR CLIMATE CLASSIFICATION

	Solapur	Ratnagiri	Poona	Nagour-Sonegaon	Bombay-Santacruz	Aurangabad-Chikalth	Akola

CDD (yearly)	3531	3215	2516	3329	3411	2894	3469
HDD (yearly)	0	1	169	89	1	120	61

CEU Climate Classification

In this model the different climatic conditions are split into 5 different basic climatic zones based on heating and cooling requirements. The base temperature for CDD and HDD both is kept as 18°C. This method also doesn't provide comprehensive methodology for Indian context.

In general, the climates could be described as follows:

Zone	Description	Requirements
A	CDD $\geq$ 500 and HDD < 1500	High cooling needs, low heating needs
B	CDD $\geq$ 500 and 1500 $\leq$ HDD < 3000	High cooling needs, medium heating needs
C	CDD < 500 and HDD < 1500	Low cooling needs, low heating needs
D	CDD < 500 and 1500 $\leq$ HDD < 3000	Low cooling needs, medium heating needs
E	CDD < 500 and HDD $\geq$ 3000	Low cooling needs, high heating needs

FIGURE 3: CEU CLIMATE CLASSIFICATION. SOURCE: (TSIKALOUDAKI, LASKOS, & BIKAS, 2011)

Due to non-availability of CDD values at 18°C for 26 ULBs this method is only used to reinterpret climate of 7 cities of Maharashtra. All the 7 cities fall under Hot Climate zone therefore this method also provides a sketchy picture.

TABLE 9: CDD AND HDD VALUES FOR 7 CITIES OF MAHARASHTRA, USED FOR CLIMATE CLASSIFICATION

	Solapur	Ratnagiri	Poona	Nagour-Sonegaon	Bombay-Santacruz	Aurangabad-Chikalth	Akola
CDD (yearly)	3531	3215	2516	3329	3411	2894	3469
HDD (yearly)	0	1	169	89	1	120	61

Bansal and Minke Indian Climate Classification

India possesses a large variety of climates ranging from extremely hot desert regions to high altitude locations with severely cold conditions similar to northern Europe. Within India it is possible to define six regions with distinct climates. The six climates are normally designated as Hot and Dry, Warm and Humid, Moderate, Cold and Sunny, Cold and Cloudy and Composite. The criteria of allocating any location in India to one of the first five climate zones are that the defined conditions prevail for more than six months. In cases where none of these categories can be identified for six months or longer, the climatic zone is called Composite. On this basis, Bansal and Minke (Bansal & Minke, 1988) originally produced the Climatic Zones in India Map by evaluation of the mean monthly data from 233 weather stations, and then delineating the six climatic zones.

The two primary determining factors for this classification system are air temperature and relative humidity. Precipitation and Solar Radiation affect building design and are also considered for climate

classification. The criteria for climate classification for India according to this system are given in Table 100.

TABLE 10. CRITERIA FOR INDIAN CLIMATE CLASSIFICATION(BANSAL & MINKE, 1988)

Climate	Mean Monthly Temperature (°C)	Relative Humidity (%)	Precipitation (mm)	No. of Clear days
Hot & Dry(HD)	>30	<55	<5	>20
Warm & humid (WH)	>30	>55	>5	<20
Moderate (MO)	25-30	<75	<5	<20
Cold & Cloudy (CC)	<25	>55	>5	<20
Cold & Sunny (CS)	<25	<55	<5	>20
Composite (CO)	When six months or more don't fall within any of the above categories			

The Bansal and Minke Indian Climate Classification system has been used to classify the climate for the 33 Urban Local Bodies (ULBs) of Maharashtra, India. Due to unavailability of data on Precipitation and Solar Radiation, the classification has been done based on temperature and relative humidity.The data on temperature and relative humidity was acquired from Rachana Sansad's Institute of Environmental Architecture, Mumbai, India (See Table **11**).

The major outcomes of this study are:

- 24 ULBs of Maharashtra are classified as having a moderate climate
- 9 ULBs are classified as having a composite climate
- The reclassified climate of the ULBs is not similar to the climate classified by Bansal & Minke(Bansal & Minke, 1988).

TABLE 11. THE TEMPERATURE AND RELATIVE HUMIDITY DATA FOR 33 ULBS IS PRESENTED IN THE ATTACHED TABLE (SOURCE: RACHANA SANSAD'S INSTITUTE OF ENVIRONMENTAL ARCHITECTURE, MUMBAI, INDIA).

	Month	1	2	3	4	5	6	7	8	9	10	11	12
City 1	DB	21	24	29.2	32.9	33.7	29.5	26.3	25.6	26.3	25.9	23.5	20.7
Achalpur	RH	43.7	37	27	23	31.8	60.5	76.5	77.4	67.6	50.9	41.9	43
City 2	DB	22.2	25.1	28.9	30	32.3	29.2	26.9	26.2	26.3	25.4	23.5	21.5
Aheri	RH	47.9	43.1	38.3	46.6	44.2	65.4	76	77.6	73.4	63.9	50.1	46.7
City 3	DB	23.1	25.1	28.5	29.8	28.5	25.8	24.4	23.9	24.3	26.1	24.9	23
Ahmadnagar	RH	40.8	35.1	31.3	36.4	53.6	75.5	83.3	83.3	77	53.8	42.4	41
City 4	DB	22.3	24.5	29.2	33.1	35.6	31	27.5	26.6	27.5	26.5	24.1	21.5
Akola	RH	50.6	41.6	29.9	24.6	29.4	57.9	75.8	79.5	71	58.3	48.6	48.4
City 5	DB	22.5	25.3	30.1	33.2	33.8	29.5	26.7	26.1	26.8	26.6	24.4	22
Amravati	RH	43.3	36.4	27.1	24.8	32.6	60.1	73.9	73.9	66.1	52.2	43	52.5

City 6	DB	20.8	23.3	27.9	31.1	32.1	28.4	25.7	24.7	25.4	24.9	22.5	20.1
Aurangabad	RH	54.1	45.3	36.4	36	43.8	67	79.7	82.4	76.8	65.4	59.6	58.5
City 7	DB	23.8	25.7	28.8	29.8	28.3	25.5	24.2	23.7	24.1	25.9	25.2	23.4
Baramati	RH	40.6	35.1	32.2	37.3	54.1	76.6	83.2	83	77	56	42.9	41.1
City 8	DB	23.7	26.1	30	31.7	30.4	26.5	24.8	24.5	25.2	26.6	25.1	23.1
Beed	RH	41.4	33.3	27.5	29.5	43.9	69.6	77.5	77.3	69.6	52	42.8	41.8
City 9	DB	22.3	25.3	29.8	32.6	34.5	30.5	27.3	26.6	27	26.2	24.1	21.7
Bhadravati	RH	44.7	38.9	31.4	32	33.7	59.3	74	75.6	69	56.9	45.5	43.9
City 10	DB	23.2	26	30	31.6	33.6	30	27.5	26.9	27.1	26.4	24.6	22.6
Chandrapur	RH	45.7	40.2	34.5	40	38.5	61.3	72.6	73.8	69.2	59.2	47.1	44.2
City 11	DB	24.6	25.6	27.4	27.7	27	25.4	24.5	24.1	24	25.4	25.8	24.6
Chiplun	RH	45	44.2	46.1	54.3	67	83.1	87	87.1	84.1	67.5	48.5	44.8
City 12	DB	20.2	23.4	28.2	32	33.9	30.2	26.7	25.8	26	25	22.5	19.6
Gondia	RH	46.3	40.7	32.7	30.4	34.2	60.1	77.5	80.2	73.1	58.9	46.4	46.1
City 13	DB	22.4	24.9	29.6	32.5	32.5	28.9	26.5	26	26.8	27.2	25.1	27.1
Jalgaon	RH	40.1	33	25	24.4	37.2	63.7	76.9	76.2	66.9	47	38.5	39.7
City 14	DB	23.6	24.7	27.1	27.6	27	25.6	24.7	24.1	24	25.8	25.5	23.9
Kalyan	RH	43.6	41.4	42.4	51.2	66.3	81.9	87.2	87.5	83.5	61.5	46.1	43.7
City 15	DB	22.6	25.3	30	33	32.8	28.7	26.1	25.7	26.4	26.7	24.7	22.2
Khamgaon	RH	42.1	34.5	25.8	23.7	35.4	62.7	76	75.5	67.3	50.5	41.8	41.7
City 16	DB	24.7	26.6	29.1	29.7	28.2	24.9	23.9	23.5	24	25.6	25.6	24.2
Kolhapur	RH	42.2	36.9	36.6	43.1	57.4	81.1	85.5	85.2	78.9	62.5	46.3	43.8
City 17	DB	23.4	26.3	30.5	32.5	32	27.6	25.7	25.3	26.1	26.4	24.8	22.7
Latur	RH	43.8	34.7	27.8	29.1	38.3	65	73.9	73.7	66.4	53.9	44.8	43.5
City 18	DB	23	25.1	29.1	31	30	27.1	25.3	24.8	25.4	26.8	25.3	23
Malegaon	RH	39.7	33.4	28	31.7	47.8	71.6	81.9	81.4	73.5	50.2	40.4	40
City 19	DB	24.5	24.8	26.9	28.7	30.2	29.2	27.7	27.3	27.7	28.7	28	26.3

Mumbai	RH	60	58.2	62.2	67.6	68.8	76.4	82.2	82	80.2	69.9	59.6	58.2
City 20	DB	20.8	23.2	27.7	32.5	35.1	31.9	27.9	27.1	27.1	26.4	23	20.4
Nagpur	RH	57.9	48	36.2	29.6	32.1	57.9	79.8	83.6	78.6	69.8	61.8	59.2
City 21	DB	23.2	26	30.5	33	33.5	29.2	26.7	26.3	26.9	26.7	24.8	22.7
Nanded	RH	43.8	36.4	28.4	28.7	34.2	60.3	72.1	71.8	65.5	53.8	44.2	42.6
City 22	DB	22.8	25	29.5	32.1	31.7	28.5	26.3	25.8	26.7	27.6	25.7	23.1
Nandurbar	RH	38.4	32	25.1	26.7	41	66.7	79.4	78.5	68.4	46.3	37.2	38.4
City 23	DB	23.6	25.1	28.5	29.7	28.9	26.8	25.3	24.7	25.2	27	26	23.9
Nashik	RH	39.9	35.8	33.4	40.2	56.1	76.8	85.8	85.5	77.6	53.1	41.1	40.5
City 24	DB	23	25.7	30.2	32.9	32.3	28.1	25.8	25.4	26.1	26.6	24.7	22.5
Parbhani	RH	42.8	34.7	26.6	25.5	36.9	63.6	74.8	74.4	67	52.2	43.2	42.2
City 25	DB	20.5	22	25.6	28.8	29.7	27.4	25.3	24.5	25.1	25	22.3	20.2
Poona	RH	61.1	50.9	42	41.7	53.5	73.6	81.7	84.3	80.7	72	65.8	63.8
City 26	DB	24.7	25.1	26.5	28.1	29.3	27.6	26.6	26.2	26.2	27.2	27.1	25.6
Ratnagiri	RH	59.9	61.7	69.7	72.1	73.1	84.7	88.1	88.5	86.5	77.5	62.6	56.5
City 27	DB	24.3	26.3	29.1	29.9	28.4	25.2	24	23.7	24.2	25.9	25.5	23.8
Satara	RH	41.1	35.5	33.7	39.2	55	78.4	83.7	83.4	77	58.4	43.9	42
City 28	DB	24.2	26.6	30.3	32.8	32.9	28.8	26.9	26.3	26.8	26.8	25.3	23.5
Solapur	RH	47.8	38.5	32.8	36.7	46.1	64.5	72.2	71.4	67.7	61.1	52.1	50.5
City 29	DB	22.8	25.3	29.7	32.2	31.5	27.9	25.7	25.3	26	26.9	25	22.6
Sillod	RH	40.8	33.3	25.7	26	40.4	66.2	77.9	77.2	69.1	49.2	40.8	40.8
City 30	DB	23.4	26.3	30.6	32.1	32.8	28.6	26.4	26.1	26.6	26.4	24.6	22.7
Udgir	RH	45.7	37.4	30.5	34.7	37.1	62	71.5	71.3	65.7	56.3	46.8	44.7
City 31	DB	25.6	24.9	25.4	26.1	27.2	27.7	27.2	26.6	26.5	27.9	28.2	27
Uran	RH	56.9	61.7	68.4	73	75.6	79.1	81.2	81.7	78.3	68.8	56.9	54.2
City 32	DB	20.7	23.8	28.9	33	34.2	29.9	26.5	25.8	26.4	25.7	23.2	20.3
Warud	RH	44.7	38.4	28.6	24.1	30.6	58.9	75.9	77.3	68	52.8	43.1	43.9

City 33 Yavatmal	DB	22.6	25.4	30.2	33.3	34.5	30.2	27.2	26.6	27.2	26.6	24.5	22
	RH	43.6	37.3	28.9	27.5	32	58.8	73.1	73.7	66.5	54.2	43.8	42.6

Conclusion

This white paper has presented a review of climate classification methodologies and their application for 33 ULBs in Maharashtra state of India. None of the methodology discussed above help in reinterpretation of climate zone.

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