An unusual hot summer in Kolkata in last 10 years and prediction of probability of discomfort applying numerical method

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सार – यह सर्वविदित तथ्य है कि ग्रीष्म काल उच्च तापमान और उच्च आर्द्रता का समय होता है। प्रत्येक ग्रीष्म ऋतु में कोलकाता में लोग उच्च आर्द्रता और तापमान के कारण बहुत असहज महसूस करते हैं। कोलकाता में अन्य ग्रीष्म काल की तुलना में पिछले 10 वर्षों में असहजता की भावना अधिक हुई है। इस अध्ययन में यह दिखाया गया है कि पिछले दशक में लंबे समय तक लोगों ने कोलकाता में मौसम के कारण असहजता महसूस की। विश्व भर में असहज मौसम का अध्ययन करने के लिए औसत तापमान, सापेक्ष आर्द्रता और पवन गति के आधार पर ग्रीष्म काल में विभिन्न जलवायु सूचकांकों जैसे - नेट इफेक्टिव टेम्परेचर (NET), वेदर स्ट्रेस इंडेक्स (WSI), डिस्कमफर्ट इंडेक्स (DI), टेम्परेचर ह्यूमिडिटी इंडेक्स (THI) आदि का उपयोग किया जाता है। मार्च से मई तक कोलकाता में औसत तापमान, आर्द्रता और पवन गति के आधार पर NET, WSI, DI की गणना की जाती है। कोलकाता के इस ग्रीष्म काल की औसत ग्रीष्म काल की स्थिति से तुलना करने के लिए औसत तापमान, औसत आर्द्रता, पवन गति को ध्यान में रखते हुए, NET और WSI के 30 वर्ष के थ्रेसहोल्ड मानों की गणना की गई। पिछले 10 वर्षों से डिस्कमफर्ट इंडेक्स (DI) का अध्ययन किया गया है और बहुत ही असहज, अत्यंत असहज और स्वास्थ्य स्थितियों के लिए खतरनाक की प्रतिशतता का महीने के अनुसार उल्लेख किया गया है। सामान्य से अधिकतम तापमान के प्रत्यंतर और सामान्य से आर्द्रता के प्रत्यंतर के आधार पर असहजता की संभावना की गणना करने के लिए एक संख्यात्मक समीकरण स्थापित किया गया है।

ABSTRACT. It is a well known fact that summer period is a time for high temperature and high humidity. In every summer people in Kolkata feel very discomfort due to high humidity and temperature. In last 10 years, feeling of discomfort is more in Kolkata than other summers. In this study it is shown that last decade people felt discomfort weather for a long time in Kolkata. Different climatologically indices in summer such as Net Effective Temperature (NET), Weather Stress Index (WSI), Discomfort Index (DI), Temperature Humidity Index (THI), etc. based on average temperature, relative humidity and wind speed   are used to study discomfort weather throughout the world. NET, WSI, DI based on average temperature, humidity and wind speed are calculated in Kolkata from March to May. Considering average temperature, average humidity, wind speed for 30 years threshold values of NET & WSI have been calculated for comparing this hot summer in Kolkata with average summer conditions. Discomfort Index (DI) for last 10 years has been studied and percentage of very uncomfortable, extremely uncomfortable and hazardous to health conditions has been mentioned month wise. A numerical equation for calculating probability of discomfort on the basis of departure of maximum temperature from normal and departure of humidity from normal has been established.

Key words – Net effective temperature, Weather stress index, Discomfort index, Degree of discomfort, Departure from normal, Maximum temperature, Relative humidity, Wind speed, Probability of discomfort.

1. Introduction

Over the past several years, a large portion of climate research has been devoted to the development and improvement of Indices which directly indicate day's weather condition as well as its impact on human. Evaluation of the impact of heat stress on the individual and measuring comfort/discomfort from different parameters of a day's weather is an important task for weather forecasting. Discomfort from a day's weather condition is measured taking into account temperature, humidity or combination of these two. Thom, 1959 studies on effective temperature and it would serve to indicate the amount of human discomfort. In Steadman, 1979 studied and attempt to measure human discomfort by Index number. In Quale and Doehring, 1981 focused on the utility in evaluating human discomfort. Ellis, 1972, discussed heat-aggravated illness in United States. Kilbourne *et al.*, 1982, studied on risk factors for heat illness. Laurance *et al.*, 1986, evaluated discomfort in the United States. Vekiteshwaran and Swaminathan, 1967, estimated thermal comfort at some stations in India.

Lakshman, 1984, calculated discomfort Index over India in different months of the year. Talukdar *et al.*, 2017 evaluated thermal discomfort in Mymensingh, Bangladesh applying Discomfort Index. Li and Chun, 2000 discussed Weather Stress Index for alerting the Public to stressful weather in Hong Kong. Outcome of these researches were different Index numbers such as Humidex, Apparent temperature, Weather Stress Index, Discomfort Index, Temperature- humidity index etc.

In the different part of tropical and subtropical countries in the whole if day's dry bulb temperature exceed 40 degree centigrade then the impact on human behavioural and daily activity changed significantly and with the increase of Relative humidity it developed a tremendous impact and create several Summer diseases. India is mainly a Sub tropical country and three months before Monsoon start, *i.e.*, pre monsoon season in the months of March, April and May due to rapid increase of dry bulb temperature and significant change in relative humidity "Heat Wave "developed. Heat Wave is a significant weather phenomenon which caused death of many people in India in every year. Moreover many people suffer from Sun-stoke and other diseases caused due to hot air flow, *i.e.*, "Loo". Conditions which are responsible for human stress in extreme weather situation should be forecasted in advance. It is clear that the contention that human behavioural response to weather is more often relative rather than absolute. Awareness of the people based on weather forecast is very important and weather forecasting should be more precise to develop confident among people.

2.   Data and methodology

Three months data from 2008 to 2017 of Alipore, Kolkata (latitude 22.57° N, longitude 88.37° E) from March to May have been collected from IMD at 0600 UTC and 1200 UTC observations. Average dry bulb temperature and average humidity for 30 years of 0600 UTC and 1200 UTC observations are calculated taking data from IMD. Normal data of maximum temperature and humidity have also been collected from IMD.

3.   Development of index number

Net effective temperature (NET) incorporates ambient temperature, wind speed and relative humidity. It is used in both hot and cold situations. The extreme values of NET uses as a gauge. Assessment of Summer thermal comfort is effectively done using the NET.

The weather Stress Index (WSI) is developed for wide-spread application and necessary impact on human

on the date and it is easily obtainable from weather observations. This Index is easy to understand and it permits utilization by professional who are intended in weather impacts. Steadman, 1979 who evaluated physiological human responses to various weather conditions first developed WSI. Discomfort depends on human ventilation rate, surface radiation, convection, moisture transfer and clothing resistance to heat. WSI is defined after development of apparent temperature and it is the perceived air temperature for an individual. Apparent temperature is measured using meteorological parameters such as temperature, vapor pressure, wind speed for indoor locations, shaded locations and sunny locations. Other index numbers used for denoting weather conditions are (*i*) Temperature humidity Index (THI) (*ii*) Humiture or wind chill Index. Advantages of WSI are (a) The WSI considers temperature, relative humidity and wind speed while other indices evaluate on only two of the above parameters. (b) WSI distinguished discomfort on human behaviour from place to place though weather parameters are same at those places. (c) WSI can be used in summer for measuring discomfort from heat flow and also in winter for measuring discomfort from chilly condition.

where, T = Dry bulb temperature in degree centigrade, V = Wind speed in m/s, RH = Relative humidity in percentage.

In hot weather NET increases with increase in temperature, humidity and decrease in wind speed. In Winter season NET decreases with decrease in temperature, humidity and increase in wind speed. WSI is derived from NET as is 99% which means 1% of days in the study period exceed NET, but if WSI = 1% it means that only 1% of days had a NET below that threshold extreme values of WSI. WSI are related to physiological value of great discomfort. From meteorological data of Kolkata NET value from 01.3.12 to 31.5.12 are calculated and from those values WSI of the days are calculated.

Thermal comfort is considered very important in aspects of risk assessment and summer time morbidity. Discomfort index (DI) to assess the trend of outdoor thermal discomfort.

4.   Calculation of WSI

In this study in the Summer season from 2008 to 2017, WSI for 92 days (March to May) have been calculated based on average data of Alipore, Kolkata for 0600 UTC (1130 IST) and 1200 UTC (1730 IST) because mostly at these times of the day people realized the

TABLE 1

Net effective temperature

Date	On the basis of 0600 UTC observation				On the basis of 1200 UTC observation			
	March	April	May	Threshold Value	March	April	May	Threshold Value
1	34.713	38.081	39.428		35.503	35.503	33.067	
2	34.186	39.885	38.111		35.169	35.169	33.182	
3	33.401	36.203	37.949		35.611	35.611	34.048	
4	36.887	37.002	41.837		37.493	37.493	34.822	
5	34.401	33.024	25.277		31.266	31.266	25.277	
6	39.644	27.258	37.595	Mar : 37.052	33.939	33.939	36.711	Mar : 35.945
7	36.711	28.962	40.591		32.241	32.241	37.981	
8	32.489	33.312	41.698	April : 37.262	29.671	29.671	39.781	April : 35.085
9	34.572	36.274	39.784		35.338	35.338	39.006	
10	38.701	31.409	38.358	May : 39.784	35.691	35.691	35.031	May : 37.178
11	38.745	34.358	39.869		36.978	36.978	36.258	
12	37.084	39.591	39.353		36.681	36.681	35.451	
13	30.851	33.926	37.888		35.597	35.597	33.165	
14	35.063	39.151	38.011		36.184	36.184	35.451	
15	36.749	39.396	41.185		38.045	38.045	35.426	
16	34.244	36.489	37.733		37.387	37.387	33.378	
17	36.903	41.793	42.258		32.375	32.375	42.654	
18	39.796	40.418	42.043		34.477	34.477	37.665	
19	37.794	38.144	40.273		37.497	37.497	38.541	
20	37.715	39.564	42.901		36.292	36.292	39.891	
21	37.106	40.528	40.829		38.484	38.484	34.048	
22	39.228	46.159	38.451		38.414	42.425	38.369	
23	37.233	40.035	38.811		39.567	38.071	36.146	
24	41.929	43.615	39.457		39.885	37.451	36.452	
25	37.702	37.159	41.837		39.088	34.117	37.744	
26	40.061	35.678	39.825		38.157	33.102	38.864	
27	41.934	38.542	40.051		37.307	37.315	37.245	
28	42.229	39.149	37.691		41.315	36.597	37.421	
29	37.558	40.093	37.838		38.291	37.209	36.337	
30	36.678	42.863	36.897		36.711	36.381	36.541	
31	35.674	-	36.152		35.282	-	36.332	

discomfort prominently and also most of the tropical and subtropical countries WSI measured based on the data of 0600 UTC and 1200 UTC. Net Effective Temperature (NET of these hours varies from the mean Net Effective Temperature (NET) of these hour on each day and also standard deviation of Net Effective Temperature (NET) of the day is significant in stressful day.

The WSI is also based on Net Effective Temperature (NET). The input parameters to NET calculation are temperature, humidity and wind speed.

$$NET = 37-[(37-T)/(0.68-0.0014RH) + (1.76+1.4*V^{0.75})^{(-1)}]-0.29*T (1-0.01RH) \tag{1}$$

TABLE 2

Weather stress index

| Date	On the basis of 0600 UTC observation				On the basis of 1200 UTC observation			
	March	April	May	Maximum/Minimum value	March	April	May	Maximum/Minimum value
1	0.319	0.666	0.587		0.757	0.879	0.149	
2	0.255	0.794	0.409		0.532	0.869	0.156	
3	0.176	0.512	0.378		0.591	0.705	0.236	
4	0.614	0.564	0.848		0.092	0.456	0.326	
5	0.281	0.245	0.021	March : 0.985/0.034	0.811	0.816	0.729	March : 0.986/0.092
6	0.896	0.027	0.334		0.363	0.371	0.571	
7	0.591	0.059	0.719	April : 0.983/0.027	0.176	0.181	0.013	April : 0.947/0.056
8	0.106	0.488	0.829		0.134	0.056	0.889	
9	0.301	0.149	0.622	May : 0.913/0.021	0.556	0.168	0.829	May : 0.985/0.013
10	0.834	0.341	0.433		0.603	0.187	0.352	
11	0.826	0.761	0.633		0.758	0.129	0.508	
12	0.641	0.732	0.371		0.712	0.688	0.405	
13	0.034	0.749	0.386		0.591	0.123	0.156	
14	0.363	0.516	0.782		0.666	0.705	0.405	
15	0.596	0.881	0.352		0.858	0.929	0.985	
16	0.264	0.813	0.873		0.799	0.811	0.166	
17	0.615	0.663	0.858		0.186	0.947	0.401	
18	0.905	0.761	0.681		0.436	0.460	0.688	
19	0.429	0.819	0.913		0.921	0.824	0.785	
20	0.719	0.983	0.745		0.677	0.935	0.894	
21	0.644	0.791	0.444		0.811	0.083	0.239	
22	0.873	0.942	0.492		0.429	0.938	0.770	
23	0.659	0.575	0.579		0.944	0.836	0.504	
24	0.980	0.448	0.844		0.913	0.797	0.536	
25	0.719	0.688	0.626		0.924	0.504	0.702	
26	0.921	0.482	0.652		0.866	0.405	0.816	
27	0.980	0.685	0.345		0.986	0.785	0.641	
28	0.985	0.732	0.363		0.939	0.732	0.663	
29	0.702	0.794	0.251		0.723	0.779	0.519	
30	0.587	0.921	0.179		0.729	0.712	0.549.	
31	0.448	-	0.229		0.548	-	0.517	

where, consider normal body temperature is 37 degree centigrade.

Taking 0600 UTC and 1200 UTC data of Alipore, Kolkata observatory of three parameters temperature, humidity and wind speed are used to calculate Net Effective Temperature (NET) daily two times at 1130 IST and 1730 IST. Mean NET values calculated from 30 years average data of dry bulb temperature, humidity and wind speed at 0600 UTC and 1200 UTC observations. Standard deviation of daily NET with mean value has been calculated & Weather Stress Index (WSI) values are found
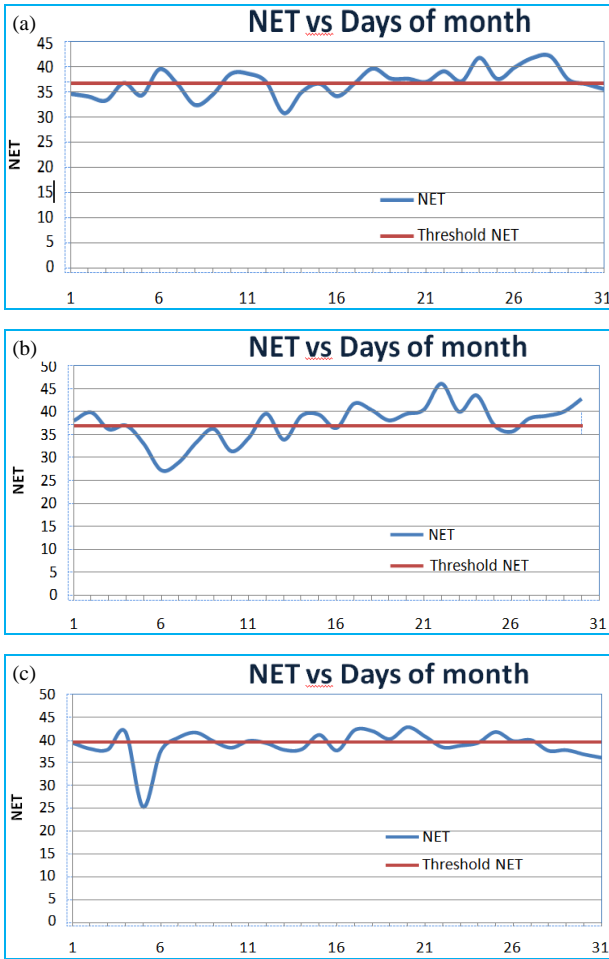
Figs. 1(a-c). Graph of NET & Threshold NET based on 0600 UTC data of (a) March, (b) April and (c) May
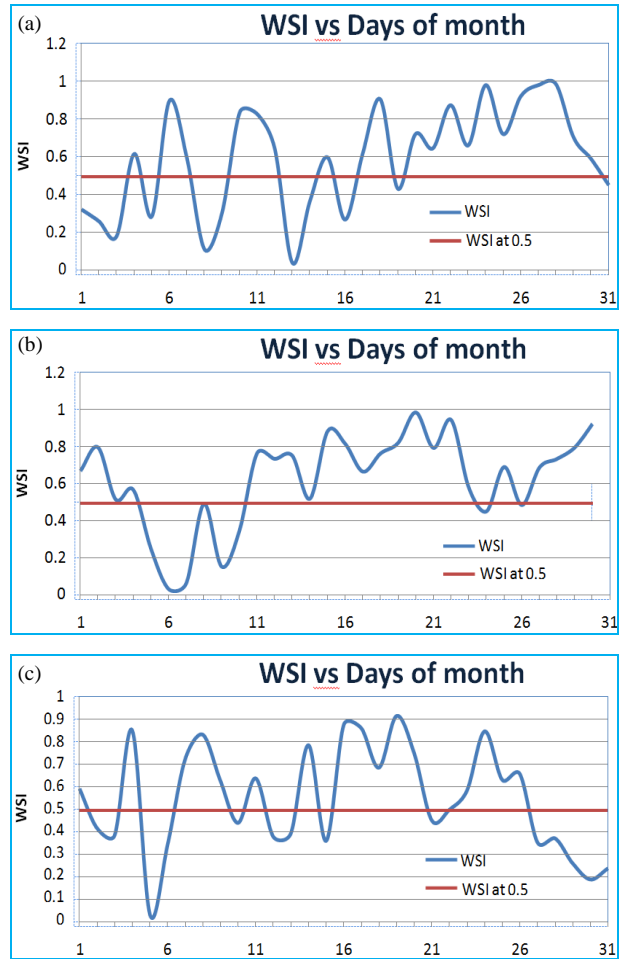
Figs. 2(a-c). Graph of WSI & WSI of 0.500 level based on 0600 UTC data of (a) March, (b) April and (c) May

considering Normal distribution of NET values and from standard normal distribution values of WSI are calculated.

Discomfort Index are calculated considering dry bulb temperature and relative humidity at 0600 UTC and 1200 UTC observation using equation,

$$\text{Discomfort Index} = 2*T + RH *T/100 +24 \qquad (2)$$

From discomfort values Degree of Discomfort are sorted out as follows:

S. No.	Discomfort Index	Condition
1.	90 to 100	Very discomfort
2.	101 to 110	Extremely uncomfortable
3.	> 110	Hazardous to health

Equations used for Normalized variable NET (*X*),

$$Z = X\text{-}m/s, \text{ where } m = \sum X_i /n \text{ and } s^2 \sum (X-m)^2 /n$$

In This study a mathematical prediction equation has been developed to calculate Probability of Discomfort (POD) using equation,

$$\text{POD} = [1+ \text{EXP} (a\text{-}b*DRH + c*DMT)] ^ {(-1)} \qquad (3)$$

Applying Maximum Likelihood Method values of a, b, c, are calculated. where, a = 0.2512, b = 1.1409 and c = 0.5705, DRH = Departure of relative humidity from Normal data, DMT = Departure of Maximum temperature from Normal.

5. Results and discussion

(*i*)   Net Effective Temperature (NET) for 92 days from March to May on the basis of 0600 UTC and 1200 UTC average data is mentioned in Table 1. Threshold values for each month are mentioned. From Table 1. On the basis of 0600 UTC observation NET values in March, April and

TABLE 3

Discomfort index

Date	On the basis of 0600 UTC observation				On the basis of 1200 UTC observation			
	March	April	May	Maximum / Minimum Value	March	April	May	Maximum / Minimum Value
1	95.732	101.76	116.21		98.701	104.85	112.23	
2	94.061	108.70	115.35		95.248	107.31	112.02	
3	104.53	108.33	114.65		94.760	106.29	108.36	
4	95.604	104.14	94.216		93.100	108.16	109.60	
5	104.45	105.43	104.50	March : 108.73/94.061	103.67	115.87	107.39	March : 107.49/93.100
6	103.56	93.618	109.61		102.55	99.51	110.83	
7	102.35	105.10	111.71	April : 118.68/93.618	101.44	95.55	99.60	April : 115.87/95.55
8	96.534	110.08	113.56		98.052	106.03	111.78	
9	105.15	111.02	115.01	May : 120.57/94.216	103.65	107.84	109.32	May : 117.87/99.60
10	103.95	103.43	112.04		102.69	106.98	110.46	
11	094.06	106.88	113.78		98.101	103.67	112.45	
12	97.350	105.98	113.29		99.640	105.13	114.72	
13	97.141	104.49	117.63		98.976	106.75	115.73	
14	97.081	106.62	120.57		98.401	107.16	112.67	
15	99.521	113.41	117.45		91.836	111.35	117.87	
16	106.16	113.91	116.87		97.320	111.17	116.22	
17	105.18	112.56	117.61		101.74	113.65	115.34	
18	104.52	115.80	117.76		103.95	113.22	113.21	
19	107.49	115.70	114.65		107.49	114.10	113.27	
20	104.45	118.68	117.03		105.13	113.11	114.78	
21	110.21	116.88	118.43		103.67	108.41	117.49	
22	106.51	106.28	118.38		102.73	110.41	115.52	
23	95.732	111.29	119.04		94.990	112.22	115.17	
24	104.85	113.65	121.87		99.168	114.99	113.26	
25	102.78	113.95	117.60		101.55	109.01	114.13	
26	110.36	114.13	118.06		104.19	110.72	113.66	
27	109.41	105.92	111.38		107.48	110.19	114.13	
28	105.77	111.35	117.80		106.01	111.88	112.45	
29	108.73	117.24	118.68		106.02	111.38	114.63	
30	108.01	116.26	117.21		105.67	110.69	113.04	
31	107.99	-	115.52		107.39	-	113.87	

May exceed threshold values by 21 days, 20 days, 19 days, respectively. From Table 1 on the basis of 1200 UTC observation, NET values exceed threshold values by 25 days, 20 days and 18 days, respectively in March, April and May. Figs 1(a-c) were drawn on the basis of NET values at 0600 UTC data and their threshold values for the months of March, April and May respectively. Graphs are shown higher NET values than threshold values. Maximum and Minimum values of NET values are mentioned in Table 1.

TABLE 4

Condition of discomfort

On the basis of 0600 UTC data			On the basis of 1200 UTC data		
Condition	Days	Percentage	Condition	Days	Percentage
March					
Very Uncomfortable	10	32%	Very Uncomfortable	13	42%
Extremely Uncomfortable	19	61%	Extremely Uncomfortable	18	58%
Hazardous to health	2	7%	Hazardous to health	NIL	NIL
April					
Very Uncomfortable	01	3%	Very Uncomfortable	2	7%
Extremely Uncomfortable	13	44%	Extremely Uncomfortable	12	40%
Hazardous to health	16	53%	Hazardous to health	16	53%
May					
Very Uncomfortable	1	32%	Very Uncomfortable	13	42%
Extremely Uncomfortable		61%	Extremely Uncomfortable	18	58%
Hazardous to health	2	7%	Hazardous to health	NIL	NIL

(*ii*) Weather Stress Index (WSI) for 92 days from March to May on the basis of 0600 UTC and 1200 UTC average data mentioned in Table 2. WSI are calculated from NET values of 0600 UTC and 1200 UTC using Standard Normal Distribution function. According to the Table 2. WSI exceeds 0.5 (50%) normal level by 21 days, 21 days and 17 days in March, April and May respectively. From the Table 2. Considering 1200 UTC data WSI exceed 0.50 (50%) normal level by 23 days, 20 days and 19 days respectively in March, April and May. Maximum and Minimum values of WSI are mentioned in Table 2. More over graph of WSI are shown in Figs 2(a-c) on the basis of 0600 UTC observations. From graphs it is clear that in this Summer WSI values above the value 0.500 in maximum numbers of days in both observations.

(*iii*) Discomfort Index (DI) on the basis of 0600 UTC data are mentioned in Table 3. And also on the basis of 1200 UTC average data it is mentioned in Table 3. Three categorical discomfort conditions: (a) Very Uncomfortable (b) Extremely Uncomfortable and (c) Hazardous to health are mentioned in the Table 4. Percentage of days covering three conditions for March, April and May mentioned. It is shown that on the basis of 0600 UTC and 1200 UTC observations in March, 61% days and 58% days extremely uncomfortable condition prevailed. In April on the basis of 0600 UTC and 1200 UTC data Hazardous to health condition prevailed on 53% days both cases. In May Extremely Uncomfortable condition prevailed on 61% with respect to 0600 UTC data and 58% with respect to

1200 UTC data. These results indicated that discomfort weather prevailed over Kolkata in all three months of last 10 years.

(*iv*) Graphs of WSI and WSI of 50% level for the months of March, April and May of last 10 years are shown in Fig 2. Form the graphs it is also clear that WSI values crossed threshold value of the month on maximum numbers of days.

(*v*) Probability of discomfort on the basis of departure of maximum temperature from Normal maximum temperature and Departure of relative humidity from Normal values of relative humidity are mentioned in Table 5. From the table maximum values probability of discomfort on the basis of 1200 UTC data 0.842 on 19th March, 0.865 on 17th April and 0.731 on 15th May and minimum values of probability of discomfort on the basis of 1200 UTC observation are 0.026 on 4th March, 0.039 on 21st April and 0.093 on 7th May.

(*vi*) Maximum Probability of Discomfort calculated on 19th March, 17th April and 15th May. Discomfort Index on those days are 104.26, 111.65 and 117.87, respectively. Weather Stress Index calculated on those days are 0.889, 0.947 and 0.985, respectively. From Table3 and Table2 maximum Discomfort Index and maximum Weather Stress Index are related with maximum Probability of Discomfort. Similarly, minimum Probability of Discomfort Index calculated on 4th March,
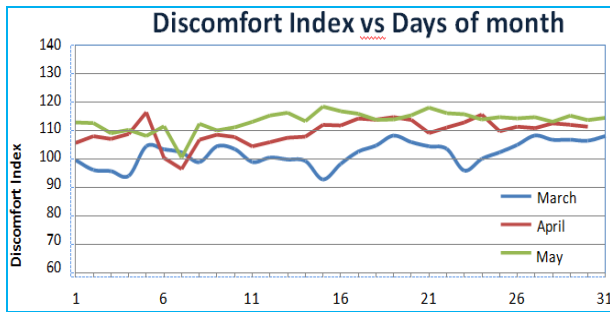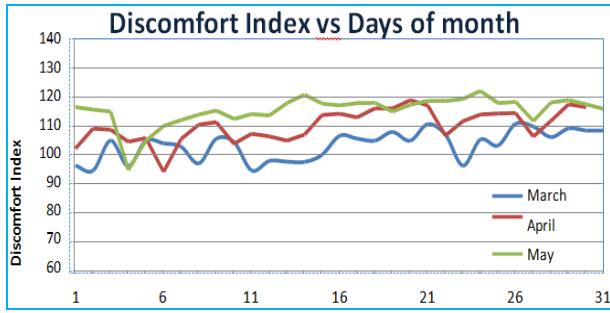
Figs. 3(a&b). Discomfort index based on (a) 0600 UTC data of March, April and May and (b) 1200 UTC data of March, April and May

21st April and 7th May. Discomfort Index on those days are 93.100, 108.41 and 110.02, respectively. Weather Stress Index on those days are 0.102, 0.532 and 0.013, respectively. From Table 3 and Table 2 minimum Discomfort Index and minimum Weather Stress Index are also related with minimum Probability of Discomforts. So results are satisfied by the derived equation.

(*vii*) For prediction of probability of Discomfort (predict ant) on the basis of previous days data the equation is developed. Predictors of the equation are Departure of maximum temperature from normal temperature of the day (1200 UTC) and it is denoted by DMT and Departure of relative humidity observed from the Normal Relative Humidity of the day (1200 UTC) and it is denoted by DRH. Parameters of the predict ant and predictors equation are calculated by Maximum likelihood method. Values of Probability of Discomfort calculated from the equation are tallying with values of WSI and Discomfort Index (DI).

(*viii*) Curves of Discomfort Index are shown in Figs 3(a&b). From curves it is clear that Discomfort Index in May is higher than March & April. That is why weather in May was intolerable. In May 61% days and 58% days weather conditions were Extremely Uncomfortable on the basis 0600 UTC and 1200 UTC data. Details of weather condition in three months are shown in Table 4. In Table 4 it is mentioned that weather condition in April was mostly

TABLE 5

Calculated probability of discomfort from derived equation using 1200 UTC data

Date	March	April	May	Remarks
1	0.291	0.179	0.648	
2	0.811	0.166	0.534	
3	0.112	0.379	0.332	
4	0.026	0.622	0.628	
5	0.612	0.681	0.272	
6	0.354	0.697	0.229	
7	0.298	0.795	0.093	
8	0.278	0.817	0.066	Maximum/minimum probability
9	0.745	0.859	0.461	of discomfort:
10	0.749	0.856	0.186	March : 0.842/0.026
11	0.405	0.753	0.274	
12	0.315	0.312	0.569	April : 0.865/0.039
13	0.145	0.806	0.084	
14	0.448	0.234	0.536	May : 0.731/0.093
15	0.136	0.207	0.731	
16	0.148	0.121	0.096	
17	0.429	0.865	0.347	
18	0.831	0.476	0.383	
19	0.842	0.615	0.167	
20	0.663	0.082	0.672	
21	0.464	0.039	0.191	
22	0.193	0.506	0.369	
23	0.047	0.355	0.502	
24	0.066	0.421	0.272	
25	0.085	0.549	0.201	
26	0.179	0.159	0.193	
27	0.148	0.178	0.262	
28	0.808	0.224	0.348	
29	0.675	0.171	0.446	
30	0.274	0.642	0.271	
31	0.543	-	0.452	

Hazardous to health because 53% in both cases, *i.e.*, on the basis of 0600 UTC and 1200 UTC observations it was Hazardous to health.

6.   **Conclusions**

(*i*)   In these three pre Monsoon months NET values exceeded threshold value 70% days in March, 65% days

in April and 59% days in May on 0600 UTC observation. More over NET values on 1200 UTC observation exceeded threshold values 80% days in March, 67% days in April and 60% days in May. This result indicates unusual hot condition prevailed in this summer.

(*ii*) From WSI analysis it is shown that 23 days in March, 21 days in April and 20 days in May Weather Stress Index calculated from 1200 UTC data exceeded 0.50 level. WSI calculated from 0600 UTC data weather stress index crossed 0.50 level on 21 days in March, 21 days in April and 19 days in May. Both results proved that weather stresses over Kolkata were more intolerable.

(*iii*) Form Table4, according to discomfort index on the basis of 0600 UTC data Extremely Uncomfortable weather conditions prevailed 61%, 44% and 61% days in the month of March, April and May, respectively. In the month of April in 53% days weather condition Hazardous to health prevailed. This type of summer weather is unprecedented in Kolkata.

(*iv*) The numerical equation has been developed for calculation of Probability of Discomfort (POD) and values of POD are tallying with NET, WSI and values of Discomfort Index of corresponding days. Using predicted maximum temperature and humidity and their departures from Normals, the equation has been established, the developed equation can be used to forecast probable discomfort weather condition in next days.

(*v*) Due to synoptic conditions over Jharkhand, Bihar and central part of India hot air from North West and Central part of India entered over Gangetic West Bengal.

(*vi*) In this study it is found out that causes of unusual discomfort conditions in last 10 summers   due to, (a) Higher temperatures dry bulb, maximum and minimum. Maximum temperature exceeded Normal maximum temperature on 26 days in March, 20 days in April and 27 days in May. Minimum temperature exceeded Normal values on 25 days in March, 18 days in April and 24 days in May. Difference of maximum and minimum values of a day is less. (b) Moisture contents of air were low. Departure of relative humidity from Normal values is negative on maximum numbers of days. Negative relative humidity departure was 20 days in March, 16 days in April and 20 days in May.

(*vii*) Direction of wind except calm wind mainly from Westerly, North Westerly and West South Westerly and average wind speed in March was 3.6 kmph, April 3.4 kmph and May 3.8 kmph on the basis of 0600 UTC observation. On the basis of 1200 UTC observation direction of wind except calm wind observed mainly from
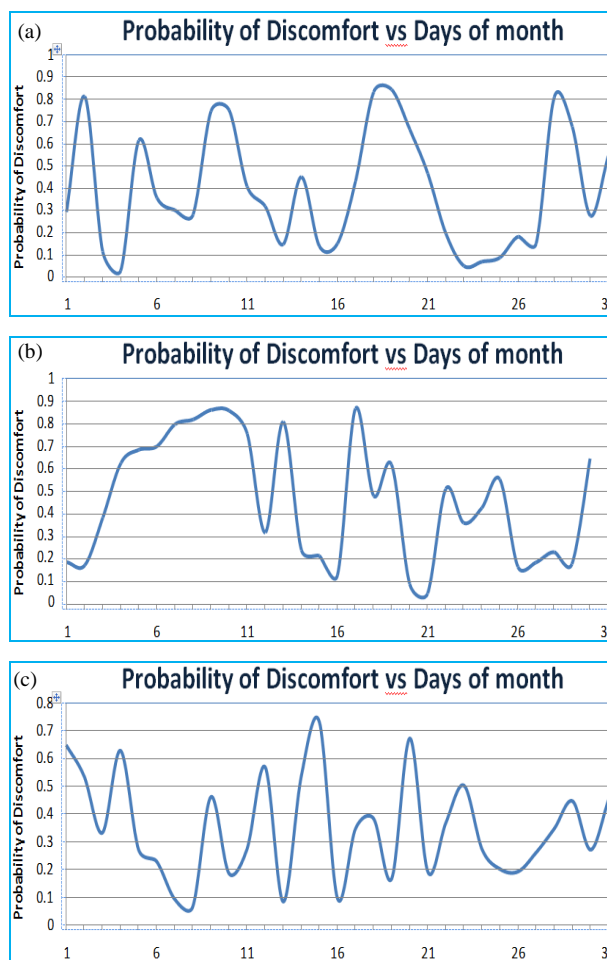

Figs. 4(a-c). Graph of calculated probability of discomfort for (a) March, (b) April and (c) May

Westerly and South Westerly and average wind speed were 1.2 kmph, 3.8 kmph and 3.4 kmph in March, April and May respectively. So, conditions are favourable for entering hot air from Central part of India and Bihar, Jharkhand to Gangetic West Bengal.

(*viii*) (a) It is observed from the results that in last decade NET, WSI and DI values exceeded normal or threshold values for 30 years data more numbers of days in the month of March, April and May. (b) Graphical presentation (year wise) for NET Vs Days for the month of March to May denoted increasing trend of NET compare with threshold NET values in last decade. (c)WSI also exceeded threshold values more numbers of days in the month of March to May in last decade compare with 30 years data.

(*ix*) It is very importance to derive an equation for prediction of the probability of discomfort in the next days on the basis of the available data before 24 hrs or 48 hrs. It

is observed that main factors for discomfort are : (a) Maximum and minimum temperature of the day, (b) Maximum and minimum percentage of humidity, (c) Wind speed and director of the day, (d) Heat wave condition mainly depends on the departure of maximum temperature from that day's normal maximum temperature and dryness (less relative humidity) of the air. Normal maximum temperature data and normal relative humidity at 1200 UTC are available. On the basis of one day's maximum temperature and relative humidity, maximum temperature and relative humidity of next two/ three days can be predicated. So, on the basis of (*i*) DMT, *i.e.*, departure of maximum temperature from normal maximum temperature and (*ii*) DRH, *i.e.*, departure of relative humidity from normal relative humidity data an equation has been developed for prediction of Probability of Discomfort. Parameters of the derived equation have been calculated by using Maximum likely hood Method. Probability of Discomfort for each day from 1st March to 31st May has been calculated and mentioned in Table5 and Figs 4(a-c) shown curves of Probability of Discomfort from 1st March to 31st May.

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