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Dimming and Brightening of the Earth's Surface in India: Data for 70 Years

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Abstract

Reversing a decades-long trend toward "global dimming," some parts of the Earth's surface have become brighter since 1990. The brightening means more sunlight; thus, more heat reaches the ground. That could partly explain the record-high global temperatures reported in the late 1990s and accelerate the planet's warming trend. In some places, the brightening of the 1990's has more than offset the dimming. In other places, like Hong Kong, it lost more than a third of its sunlight. The dimming has leveled off, but skies remain darker than in the past. In a few places, like India, the dimming trend continues. Variations in solar radiation incident at Earth's surface affect the human and terrestrial environment. Delhi is dimming, but Kolkata brightened in 2012, according to the report. This report was based on temperature and dew point measurements from 1942 to 2012. Primary pollutants like CO_2 are converted into secondary pollutants, such as carbonic acid, in our atmosphere. These secondary pollutants increased in our atmosphere from 1942 to 2012, affecting sunshine. A mathematical model has been developed from a quantum perspective to determine the causes of the brightening and dimming of Earth's surface.

Key points:

- The capital city of India, Delhi, was dimmer than in 1942.
- The business city of India, Kolkata, was brighter than it had been in 1944.
- The cause of brightening and dimming is due to the presence of volatile and non-volatile pollutants
- This is explained by mixing red, blue, and green colors.

1. Introduction

Reversing a decades-long trend toward "global dimming," some parts of the Earth's surface have become brighter since 1990, as reported by various researchers [**1-4]**. The brightening means more sunlight; thus, more heat reaches the ground. That could partly explain the record-high global temperatures reported in the late 1990s [**5**], and it could accelerate the planet's warming trend. In some places, the brightening of the 1990's has more than offset the dimming, Dr. Wild reported. In other places, like Hong Kong, it lost more than a third of its sunlight. The dimming has leveled off, but skies remain darker than in the past. In a few places, such as India, the dimming trend continues, as studied by several researchers [6]. They included 12 sites in India from 1984 to 2001 in their study and found a decrease in surface solar radiation at all sites, ranging from 1.7 to 14.4 W m^{-2} per decade. No evidence of a change in the dimming trend was also found in a time series constructed from 7 cities in the Canadian Prairies covering the period 1951-2005 [7] and in two sites in Zimbabwe reported by a few researchers [8]. Some researchers, such as Stanhill and Moreshet, have reported that from 1960 to 1990, the amount of sunshine reaching the ground decreased by 2% to 3% per decade [9-10]. Some researchers investigated surface solar radiation at eight sites in Germany and found an average decrease of 10% over the period 1964-1990 [**11**]. Russak reported a 6.8% decrease in surface solar radiation between 1955 and 1986 at the site Toravere in Estonia, and a decrease of 11% to 12% in surface solar radiation between 1964 and 1986 at three sites in the Baltic region: Helsinki, Stockholm, and Kaunas [**12**]. In China, few researchers [13-16] stated that the decreasing trends since the 1960s no longer persist in the 1990s, and that "conditions have improved in the last decade" of the 20^{th} century [**14**], in line with the findings by Wild et al. [**8**] Some researchers quantified this partial recovery in China over the 1990s, at 1.7%, 2.7%, and 3.4% per decade, respectively [**16-18**]. A partial recovery from prior dimming has also been reported at four sites with long-term records in the Southern Hemisphere in New Zealand [19]. These pioneering studies presented the first evidence that solar radiation at the Earth's surface was not constant over time, as previously assumed, but exhibited significant decadal variations. The lack of solar radiation observations has been a persistent problem in land surface-process studies. Accurate solar radiation data are crucial for crop growth, yield simulation, forestry, and the estimation of evaporation and evapotranspiration. The number of surface weather stations recording daily radiation is very small compared with those recording temperatures and dew point data [20]. Various methods have been developed to derive surface solar radiation from these satellite measurements [21]. However, useful satellite information has only been available since the early 1980s. Therefore, satellite-derived SSR cannot be determined for the "dimming period" up to 1980 and can only be determined for the more recent "brightening period". Models for estimating solar radiation based on the diurnal temperature range include algorithms proposed by several researchers [20]. However, no model has been developed so far using temperature and dew point to measure the brightening and dimming of different parts of the Earth. Here, a model was developed to understand the brightening and dimming of the global surface using volatile and non-volatile atmospheric components.

2. Data and Methods

Temperature and dew point data are obtained for different Meteorological stations from the wave site of the NCDC data-sharing service system [**21**]. The relative humidity and actual mixing ratio were calculated using the online system (www.ringbell.co.uk/info/humid.htm). The dew point difference, $T(Temperature) - D(Dew\ point)$, RH (relative humidity)/T-D, RH/T, AMR (Actual Mixing Ratio)/T-D, RH/AMR and RH/D were calculated for each day in Delhi (Safdarjung) and Kolkata (Dum Dum). These data were compared daily throughout the year. Delhi data were collected from January to July up to 2012 and from 1943 onwards, while Kolkata data were collected from January to September up to 2012 and from 1944 onwards.

3. Result and Discussion

3.1 Delhi (Safdarjung station)

In January, the difference in dew point (D) and the ratio of relative humidity with dew point (RH/D) in 1962, 1982, 1991, and 2012 was less than 50%. These graphs, showing Delhi's months from 1943 to 2012, are presented in Figures 1 & 2.

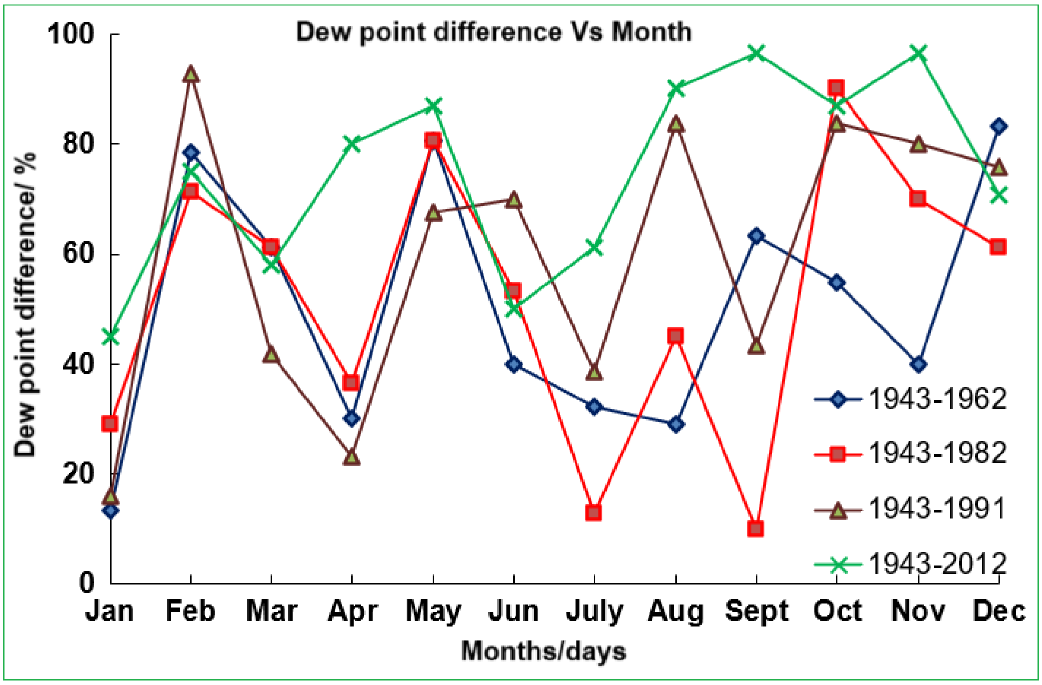

Figure 1. This is the graph between the Dew point difference and the Months from 1943 to 2012.

This was due to a non-volatile compound, water vapor. It is known that the specific heat capacity of water vapor is 1.90 $Jg^{-1}K^{-1}$ at room temperature and pressure, while water is 4.18 $Jg^{-1}K^{-1}$. The C_P of the pollutant SO_2, melting point 197.64 K and boiling point 263.08 K, is 1.35 $Jg^{-1}K^{-1}$ and 0.62 $Jg^{-1}K^{-1}$ at 260.86 K and 298 K, respectively [22-23], pollutant Nitric oxide (NO), melting point 109 K and boiling point 121 K, is

2.61 $Jg^{-1}K^{-1}$ and 0.99 $Jg^{-1}K^{-1}$ at 120.56 K and 298 K, respectively [23-24], and pollutant

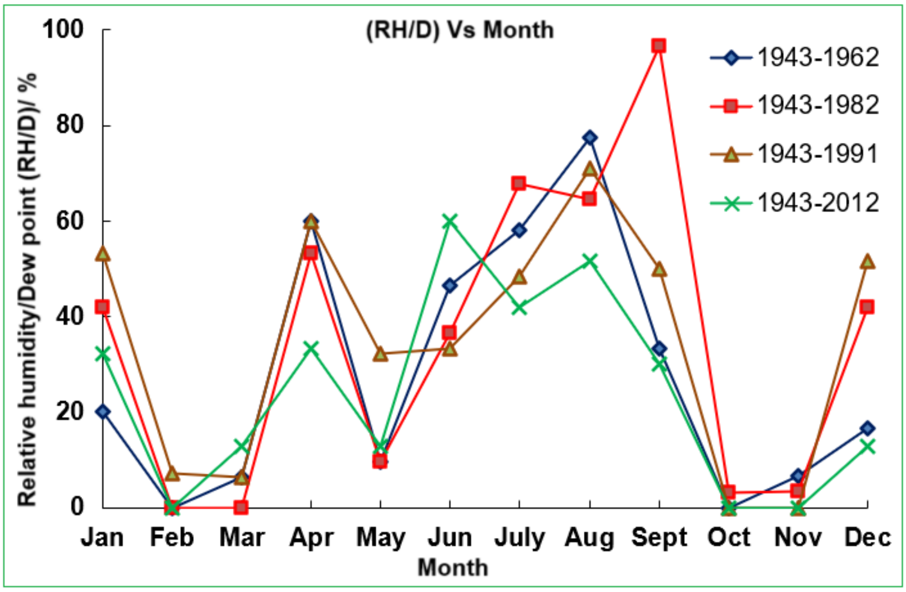

Figure 2. This graph shows the percentage of (RH/D) by month from 1943 to 2012.

CO_2 is 0.84 $Jg^{-1}K^{-1}$ at 298 K [23]. Similarly, the difference between temperature and dew point (T-D) decreased steadily towards 2012, except in 1991, when it was 53%. The (T-D) graph with the months of Delhi from the year 1943 to 2012 is shown in Figure 3.

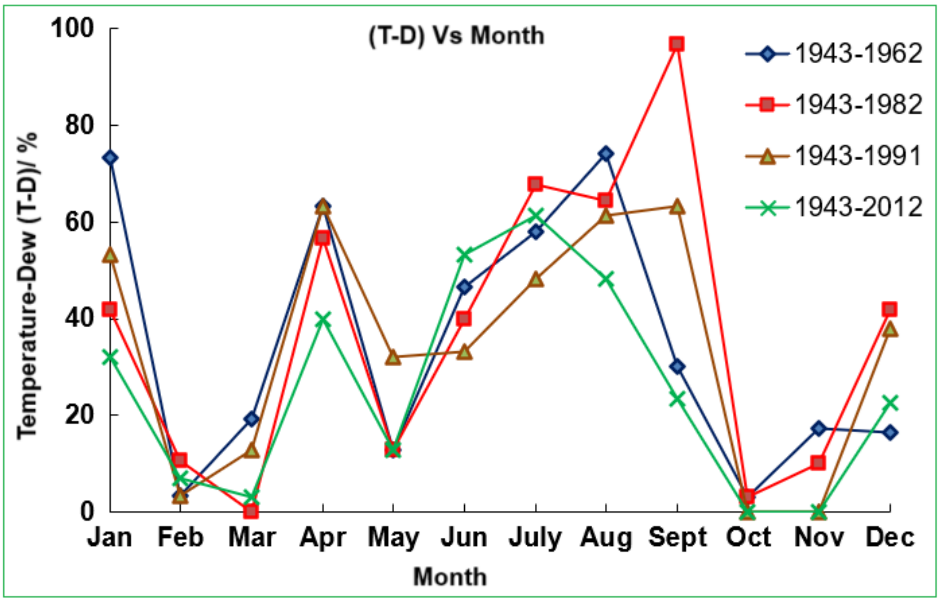

Figure 3. This graph shows the percentage of (T-D) by month from 1943 to 2012.

This was due to non-volatile compounds and particulate matter in the atmosphere. This particulate matter, mixed with water vapor in the atmosphere, increased the water vapor's dew point temperature. Similarly, the ratio of relative humidity with the difference between temperature and dew point, RH/(T-D), the ratio of relative humidity with temperature, RH/T, the ratio of the actual mixing ratio with temperature and dew point difference, AMR/(T-D), and the ratio of relative humidity with actual mixing ratio, RH/AMR, were greater than 50% in 2012. These graphs, showing Delhi's months from 1943 to 2012, are presented in Figures 4-7.

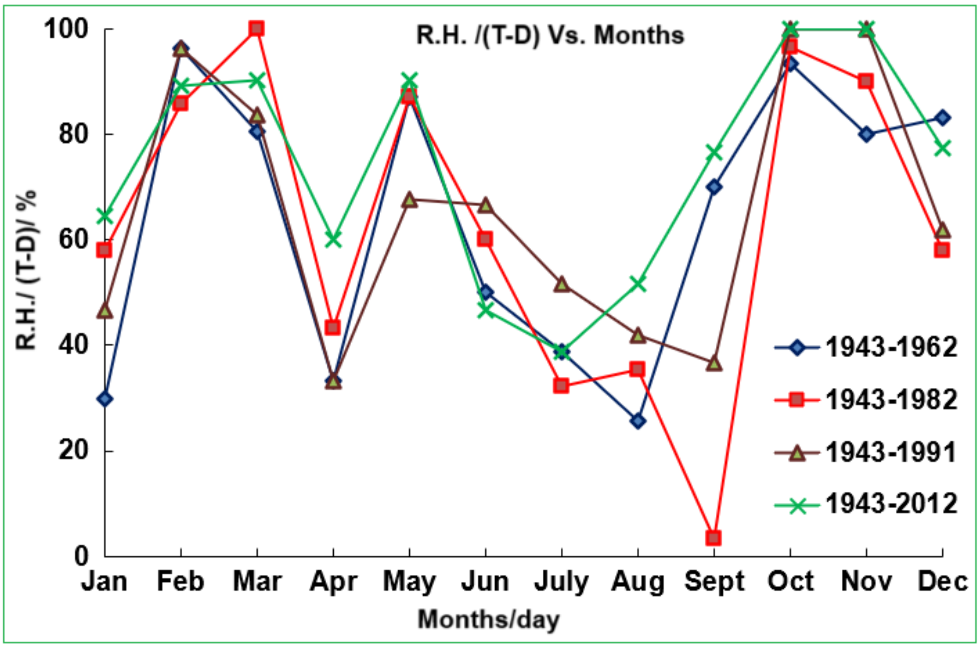

Figure 4. This is the graph between RH/T-D and the months from 1943 to 2012.

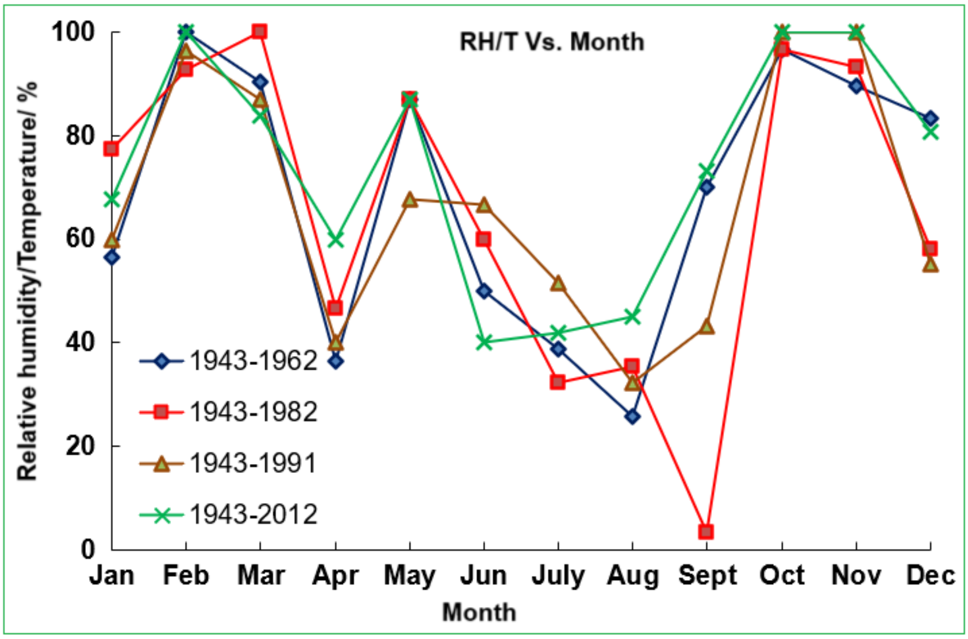

Figure 5. This is the graph between RH/T and the months from 1943 to 2012.

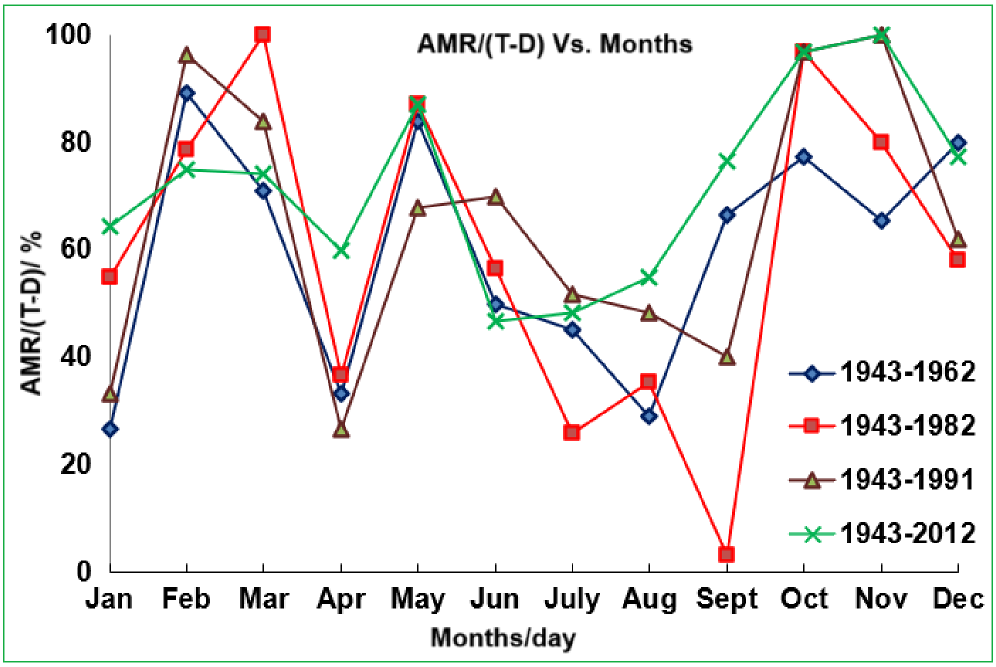

Figure 6. This is the graph between AMR/(T-D) and months from 1943 to 2012

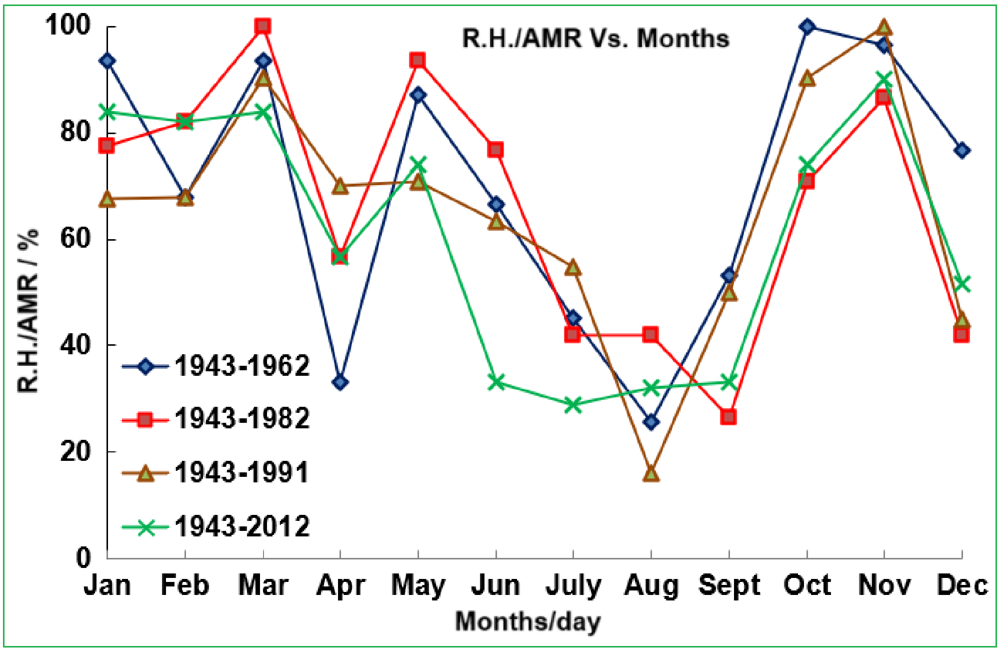

Figure 7. This is the graph between RH/AMR and the months from 1943 to 2012.

The 2012 data were examined more closely due to the presence of volatile pollutants, such as carbonic acid, in the atmosphere, which may be attributable to the use of CNG as a fuel in automobiles. The specific heat capacity of gaseous H_2CO_3 at 284 K and atmospheric pressure is 0.46 $Jg^{-1}K^{-1}$ [**25**]. The atmospheric temperature is reduced by the presence of volatile pollutants. The T-D and RH/D were lower in 2012 than in previous years. This indicated that atmospheric non-volatile pollutants increased. Thus, Delhi was dimmer in 2012 compared to January 1943. This was reported by a few researchers [**6**]. In February, the data were collected in 1943, 1962, 1982, 1990, and 2012. The difference in dew point in 2012 was 75% greater than in previous years. This was due to volatile compounds in the atmosphere. This dew point difference exceeded 50% in all observed years. The RH/D was observed to be lower than in January 2012. Therefore, non-volatile pollutants, such as water vapor, further increased. The T-D decreased in January. That might be due to increased particulate matter in the atmosphere. Similarly, RH/T and RH/AMR were higher than in 1943, but the trend in RH/T-D and AMR/T-D data slightly decreased from 1962. But in all these cases, it was more than 50%. Hence, more volatile pollutants were found in 2012 than in 1943. Hence, Delhi was dimming further this month. The data were collected in March 1943, 1962, 1982, 1993, and 2012. The dew point differences in 2012 (58%) were slightly lower than in the previous years, 1962 and 1982 (62%), but in 1993 the dew point differences were 42%. The T-D data decreased from 19% in 1962 to 3% in 2012. T-D data showed that particulate matter decreased in the atmosphere in January and February. The RH/D data slightly increased from 6% in 1962 to 13% in 2012. So, the non-volatile pollutants, such as water vapor, slightly increased in March compared to February. The other measurements indicated the highest levels of volatile pollutants in the atmosphere this month. In April, all measurements indicated that non-volatile pollutants slightly exceeded those of previous months, while the atmosphere maintained the highest levels of volatile pollutants throughout the month. In May, the volatile pollutants exceeded the non-volatile pollutants for the first three months. In June and July, more non-volatile pollutants than volatile pollutants were found in the atmosphere. In these two months, Delhi was brighter than in the previous months. About 50% of the day in August was dimmed by the presence of almost equal percentages of volatile and non-volatile pollutants in the atmosphere. From September to December, Delhi was dimming for the other four months due to excess volatile pollutants in the atmosphere.

3.2. Kolkata (Dum Dum station)

The data for Kolkata were collected throughout 1944, 1958, 1980, 1992, 2003, and 2012. In January, no conclusion was drawn from the dew point difference over a few decades because the proportions of volatile and non-volatile compounds were nearly equal. The RH/D graph for Kolkata, spanning 1944 to 2012, is shown in Figure 8.

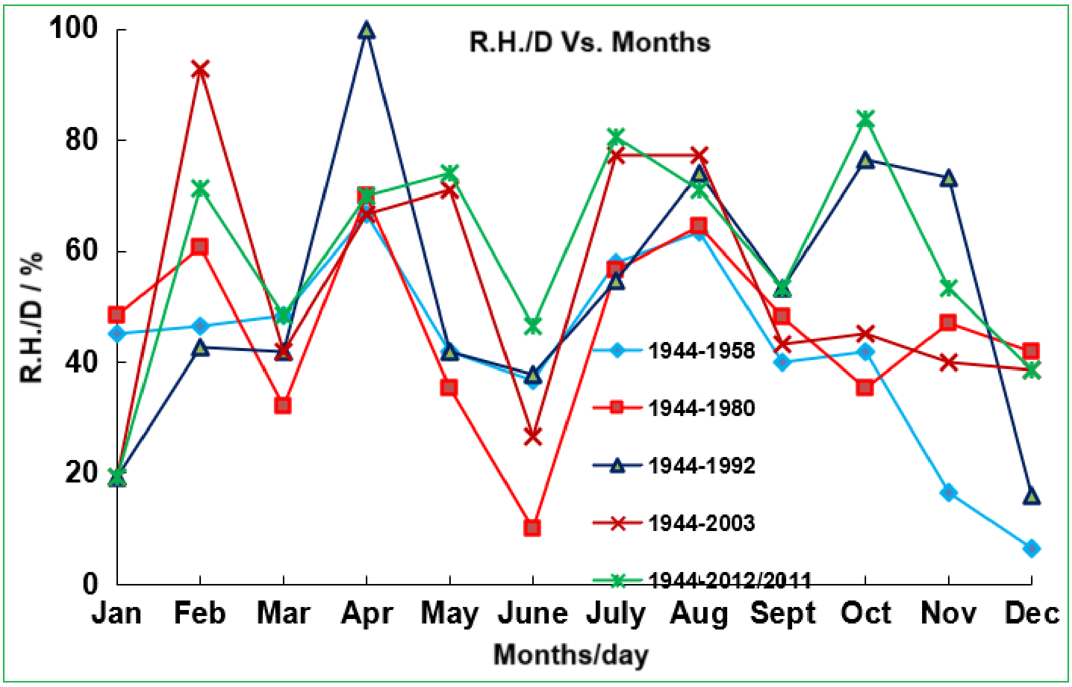

Figure 8. This is the graph between RH/D and the months from 1944 to 2012.

The RH/D in 1958 and 1980 were 45% and 48%, respectively. In all other cases, it was almost 19%. This indicated the presence of the non-volatile compound water in the atmosphere. The graphs of T-D, RH/T-D, RH/Temp, AMR/T-D, and RH/AMR for the months of Kolkata from 1944 to 2012 are shown in Figures 9-13.

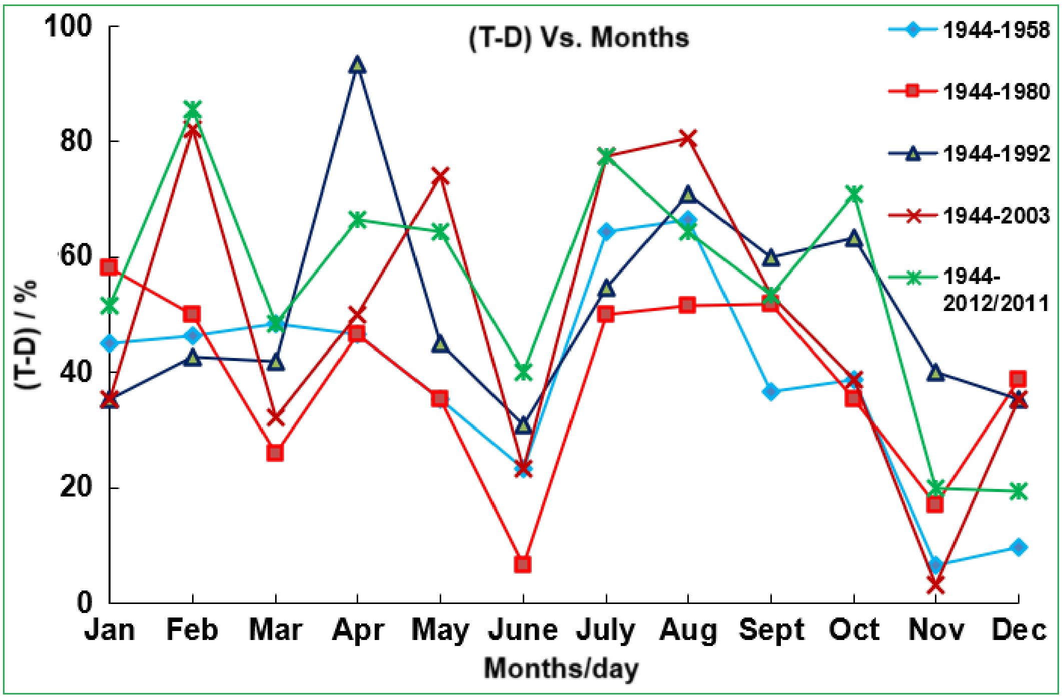

Figure 9. This is the graph between T-D and months from 1944 to 2012

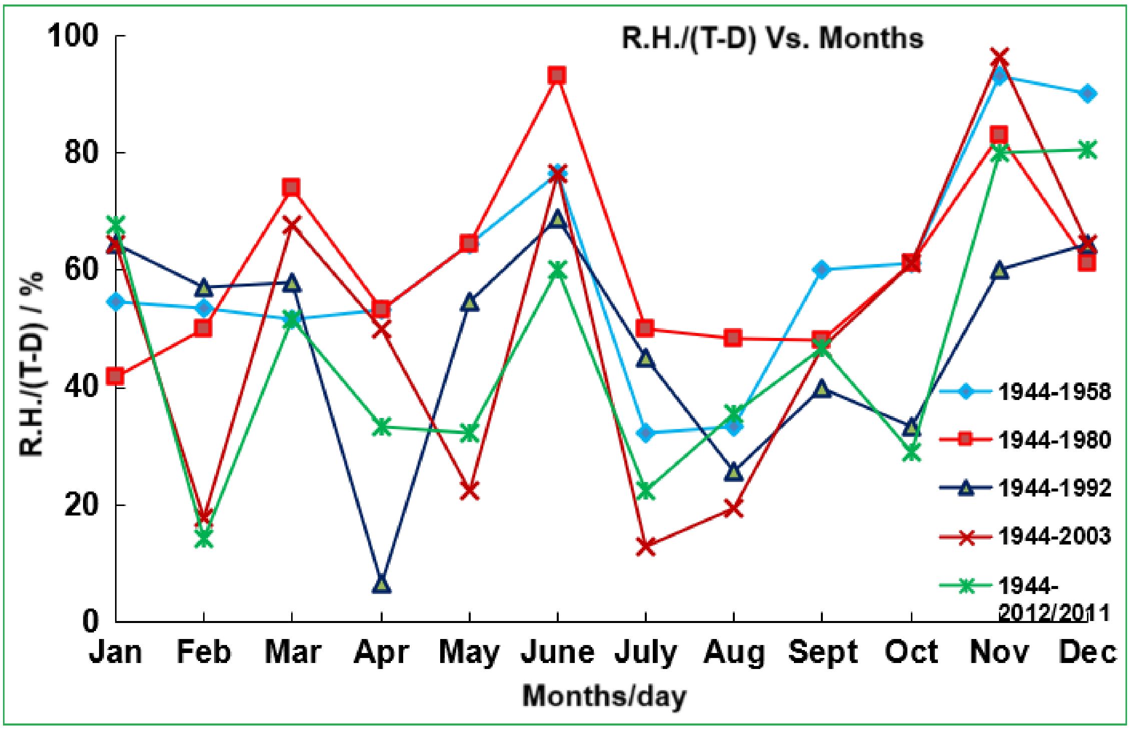

Figure 10. This is the graph between RH/(T-D) and the months from 1944 to 2012.

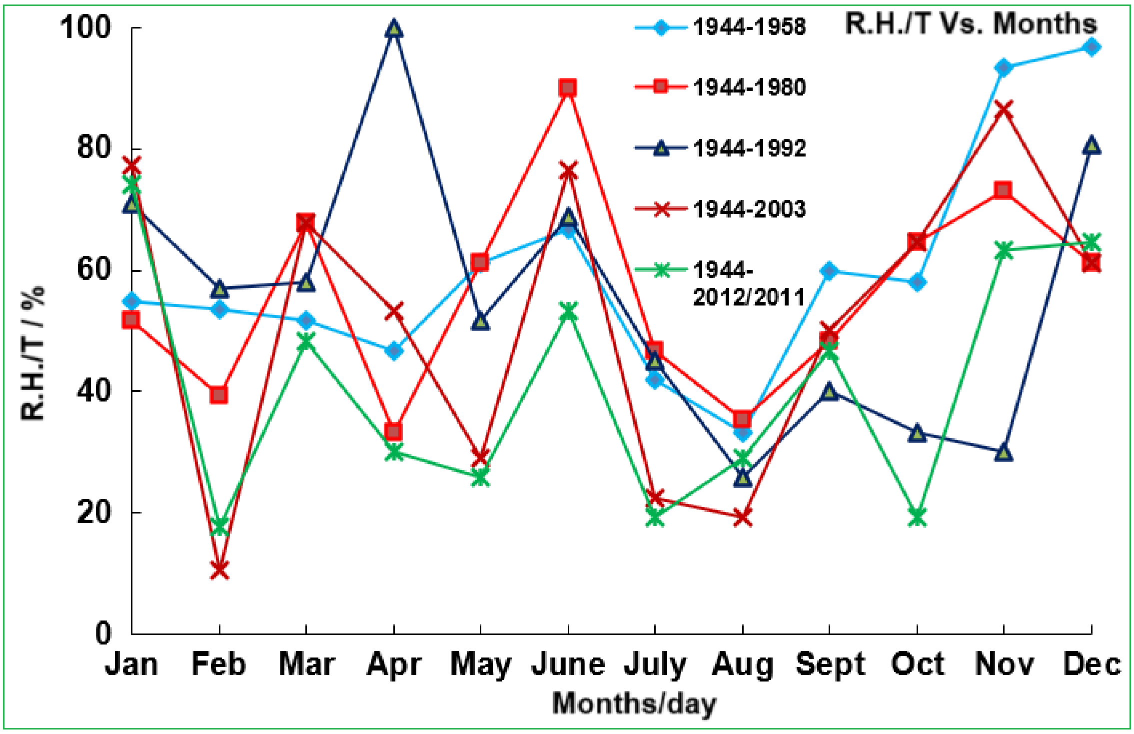

Figure 11. This is the graph between RH/T and the months from 1944 to 2012.

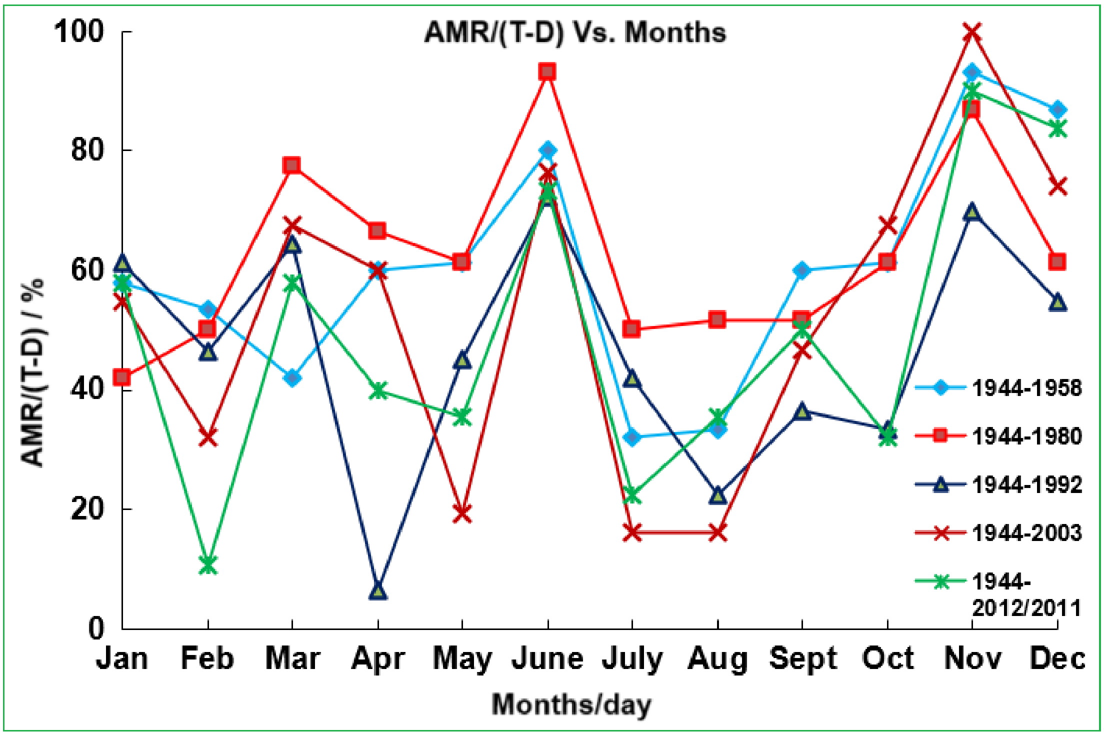

Figure 12. This is the graph between AMR/(T-D) and the months from1944 to 2012

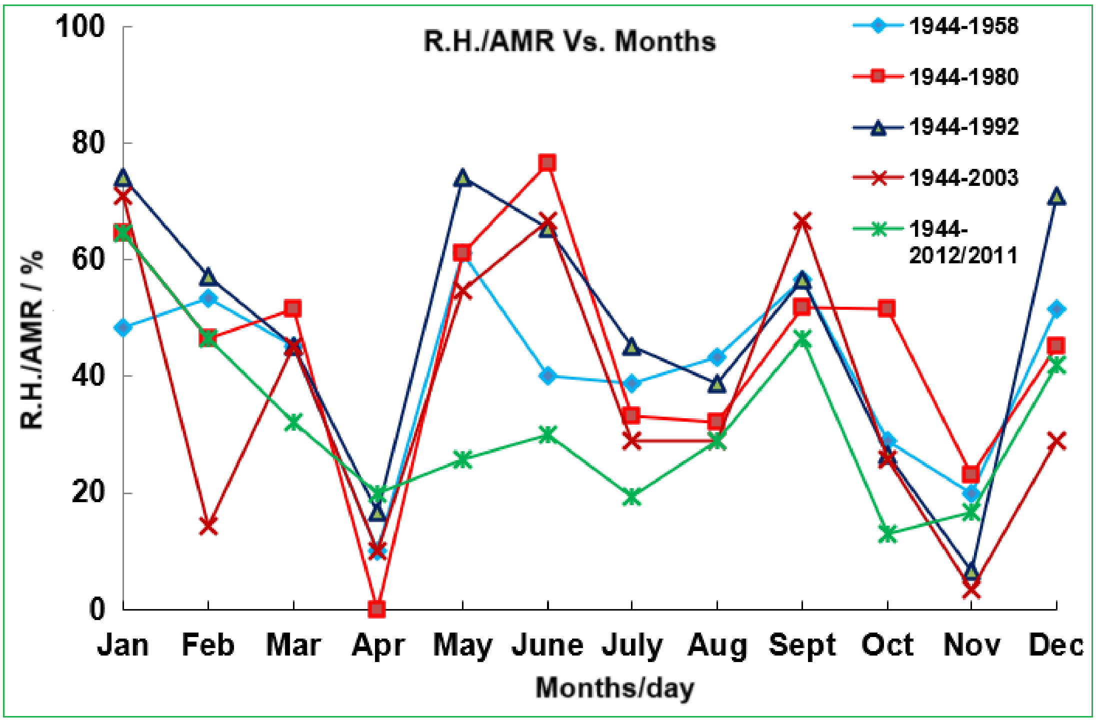

Figure 13. This is the graph between RH/AMR and the months from 1944 to 2012

All data, such as T-D, RH/T-D, RH/Temp, AMR/T-D, and RH/AMR, indicated the presence of excess volatile compounds, as well as carbonic acid formed from the presence of an excess of water vapor and CO_2 at low temperatures in the atmosphere.

So, in January, Kolkata was brightening. In February, the difference in dew point was the lowest in 2012, 25%. The graph of the dew point difference for Kolkata during 1944 to 2012 is shown in Figure 14.

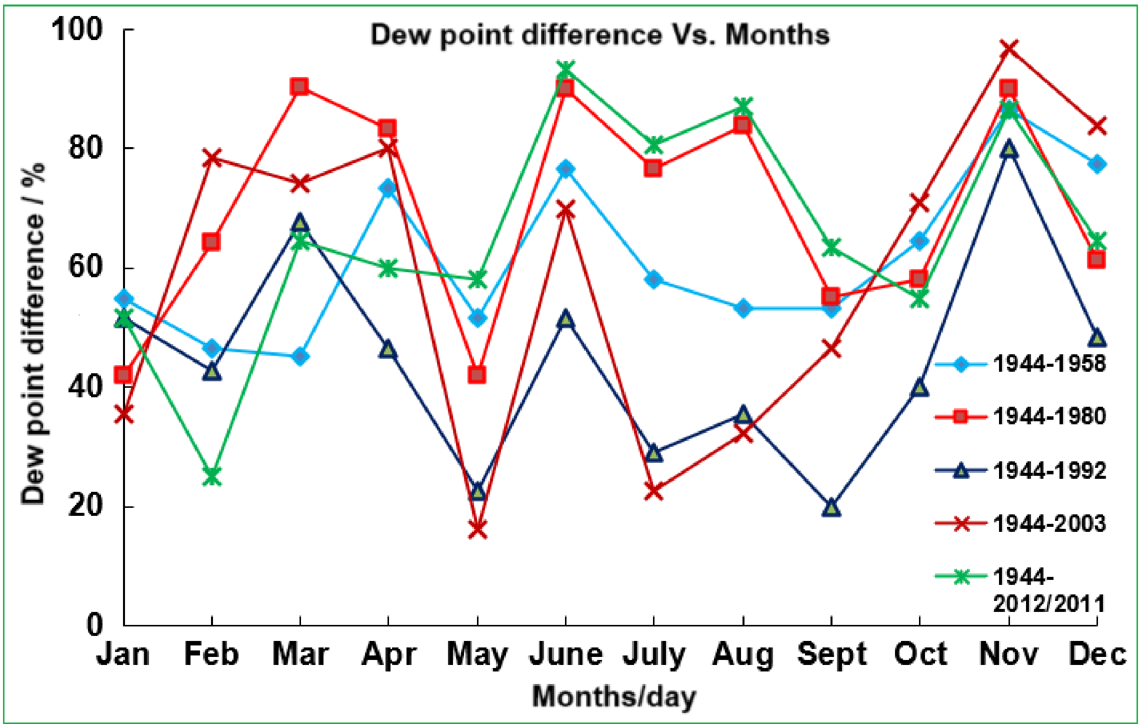

Figure 14. This is the graph between the Dew point difference and the months from 1944 to 2012

This indicates the presence of volatile compounds in the atmosphere. The T-D data, which increased by more than 82% from 2003 onwards, also indicated the presence of non-volatile compounds and particulate matter. According to RH/D data, the atmosphere contained volatile compounds, including carbonic acid, from 1980 onwards, with levels exceeding 60%. These data showed that the increase in water vapor was greater than that of particulate matter in the atmosphere. All other data, such as RH/T-D, RH/Temp, AMR/T-D, and RH/AMR, indicated the presence of non-volatile water vapor compounds in the atmosphere. So, Kolkata was brightening in February. In March, dew point difference data showed that more than 50% indicated the presence of volatile compounds in the atmosphere. The data for T-D was less than 50%, which is lower than in February. So, particulate matter was further reduced from the atmosphere. From the data of RH/D, RH/Temp, RH/AMR, AMR/T-D, and RH/T-D, the non-volatile compounds were greater than the volatile compounds. So, Kolkata was brightening in March. In April and May, dew point differences indicated the presence of volatile compounds in the atmosphere, though at lower levels than in March 2012. The concentration of particulate matter in the atmosphere increased in March. From RH/D data, the non-volatile compound, water vapor, increased in the atmosphere and reached the maximum in April 1992. All other data indicated that this month was brightening due to the presence of a non-volatile compound, water. Based on the dew point difference, there were more volatile compounds in June than in previous months. The non-volatile compounds increased in the atmosphere, as confirmed by T-D, RH/D, RH/Temp, RH/AMR, AMR/T-D, and RH/T-D data. Consequently, Kolkata was brightening in June. In July and August, the dew point difference increased from 22% in 2003 to 80% in 2012. So, the atmosphere contained more volatile compounds. Particulate matter in the atmosphere increased due to higher T-D data values from 1992 onward. From RH/D data, volatile compounds increased in the atmosphere. The RH/Temp, RH/AMR, AMR/T-D, and RH/T-D data indicated the presence of non-volatile compounds in the atmosphere. So, Kolkata was neither brighter nor dimmer this month compared to the previous month. In September and October, the volatile compounds slightly exceeded the non-volatile compounds, as indicated by the dew point difference data. From all other data, it was found that non-volatile compounds increased in the atmosphere. So, Kolkata was brightening. In November and December, the volatile compound increased in the atmosphere due to the formation of carbonic acid, as evidenced by dew point differences. The non-volatile compound water vapor also increased, as evidenced by RH/D data for these two months. Based on the other data, including RH/T-D, RH/Temp, AMR/T-D, and RH/AMR, it was concluded that the atmosphere contained more volatile compounds. So, Kolkata was dimming in the above two months.

4. Mechanism

Through quantum mechanics, global dimming and brightening can be explained as white zones, resulting from the overlap of red, blue, and green light. Volatile and non-volatile compounds in the atmosphere can be compared to the increase or decrease of white zones on Earth. The white zone forms by mixing equal proportions of red, blue, and green. If the number of white zones increases, the Earth appears brighter due to light reflection, and vice versa. The mathematical form of the white zone can be written as below.

Let us consider a cube. The parameters $\left(r_{i_{x\geq 0}} - r_{\infty x}\right)$, $\left(r_{i_{y\geq 0}} - r_{\infty y}\right)$, and $\left(r_{i_{z\geq 0}} - r_{\infty z}\right)$ are the lengths of the box in the X-direction, Y-direction, and Z-direction, respectively.

The volume region of the complete red, blue, and green zones is below.

$$|\psi_R/\psi_B/\psi_G| = \iiint_{i_{(x,y,z)}\geq 0}^{\infty} \psi_x\left(r_{i_{x\geq 0}} - r_{\infty x}\right)\psi_y\left(r_{i_{y\geq 0}} - r_{\infty y}\right)\psi_z\left(r_{i_{z\geq 0}} - r_{\infty z}\right)dxdydz \qquad (1)$$

The white zone is formed by combining all the RGB colors.

The color of an equal proportion of Red and Green is as follows.

$$|\psi_R \cap \psi_G| = \{(\psi_R + \psi_G)^2 - {\psi_R}^2 - {\psi_G}^2\} = 2\psi_R\psi_G$$

The color of equal proportions of Red and Blue is as follows.

$$|\psi_R \cap \psi_B| = \{(\psi_R + \psi_B)^2 - {\psi_R}^2 - {\psi_B}^2\} = 2\psi_R\psi_B$$

The color of equal proportions of Green and Blue is as follows.

$$|\psi_G \cap \psi_B| = \{(\psi_G + \psi_B)^2 - {\psi_G}^2 - {\psi_B}^2\} = 2\psi_G\psi_B$$

The integral equation for the overlap region of any binary color of RGB is as follows

$$|2\psi_R\psi_G/2\psi_R\psi_B/2\psi_G\psi_B| = 2\left(\iiint_{i_{(x,y,z)}\geq 0}^{\infty} {\psi_x}^2(r_{i_{x\geq 0}} - r_{\infty x})\,{\psi_y}^2\left(r_{i_{y\geq 0}} - r_{\infty y}\right){\psi_z}^2(r_{i_{z\geq 0}} - r_{\infty z})dxdydz\right)$$

The medium becomes colorless when the RBG are mixed in equal proportions

$$|\psi_G \cap \psi_B \cap \psi_R| = \{(\psi_G + \psi_B + \psi_R)^2 - {\psi_G}^2 - {\psi_B}^2 - {\psi_R}^2\}$$
$$= 2(\psi_G\psi_B + \psi_R\psi_B + \psi_R\psi_G)$$

This can be written in integral form as

$$|\psi_G \cap \psi_B \cap \psi_R| = 6\left\{\left(\iiint_{i_{(x,y,z)}\geq 0}^{\infty} {\psi_x}^2(r_{i_{x\geq 0}} - r_{\infty x})\,{\psi_y}^2\left(r_{i_{y\geq 0}} - r_{\infty y}\right){\psi_z}^2(r_{i_{z\geq 0}} - r_{\infty z})dxdydz\right)\right\}$$

The mixing of binary and tertiary colours is indicated in **Fig.15**.

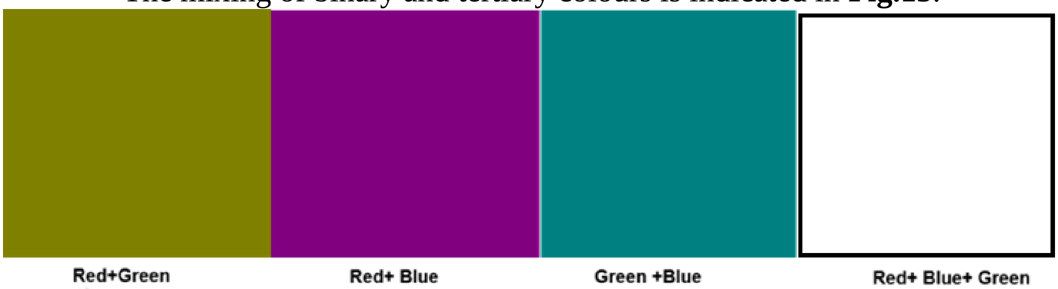

Figure 15. The mixing of binary and tertiary colours of Red, Blue, and Green.

5. Conclusion

From January to July, data were collected from 1943 to 2012 in the Safdarjung area of Delhi. From August onwards, data were collected from 1943 to 2011. From these data, dew point differences (T-D), RH/D, RH/AMR, RH/Temperature, AMR/T-D, and RH/T-D were calculated. The graphs were plotted for dew point differences (T-D), RH/D, RH/AMR, RH/Temperature, AMR/T-D, and RH/T-D against months. From January to September, data were collected from 1944 to 2012 in the Dum Dum area of Kolkata. From October onwards, data were collected from 1944 to 2011. From these data, dew point differences, T-D, RH/D, RH/AMR, RH/Temperature, AMR/T-D and RH/T-D were calculated. The graphs were plotted on dew point differences, T-D, RH/D, RH/AMR, RH/Temperature, AMR/T-D, and RH/T-D against months.

These data showed that Delhi was dimmer than in 1942, while Kolkata was brighter than in 1944 for most of the year.

Data Availability Statement

Datasets for this research are included in this paper (and its supplementary information files). The datasets used for this study were obtained from the National Climatic Data Center's (NCDC) data-sharing service (www7.ncdc.noaa.gov). The data were processed and presented as graphs, with all related graphs presented as figures. The data is available in supplementary files using Excel format. All the processed data is available at https://doi.org/10.5281/zenodo.14610234.

Conflicts of interest

The author, TS, declares no conflicts of interest.

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