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Research Article

Wavelet & Correlation Analysis of Weather Data

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Abstract

This paper deals with the wavelet and correlation analysis of meteorological parameters for various meteorological stations of India. Discrete wavelet using Daubechies wavelet at level 5 (Db_5) and Continuous wavelet using Mexican Hat wavelet of meteorological parameters have been discussed. Discrete wavelet decomposition of each parameter presented in seven parts namely s, a_5, d_1, d_2, d_3, d_4 and d_5. The first part "s" represents the signal or raw data and the second part "a_5" corresponds to the amplitude of the signal. The next five parts d_1, d_2, d_3, d_4 and d_5 represent details of the signal or raw data at five different levels. 1-D continuous wavelet decomposition of each parameter has four parts; first part on top represents the analyzed signal or raw data, second part contains the scalogram value. The third part shows the daily variation of coefficients. The fourth part depicts the local maximums of related parameters. It has been observed that maximum and minimum temperature have positive correlation for all the years and at all stations except for Shimla. All stations for all years have negative correlation between rainfall and maximum temperature; rainfall and minimum temperature.

Keywords: *Wavelets, Correlation, meteorology, temperature, rainfall*

1. Introduction

Wavelet analysis is a tool for analyzing localized variations in power by decomposing a trace into time frequency space to determine both the dominant modes of variability and how those modes vary in time. This method is appropriate for analysis of non-stationary traces, i.e. where the variance does not remain constant with increasing length of the data set. The wavelet method is based on the property that wavelet transforms of the self-affine traces have self-affine properties. Kurnaz (2004) discussed model based predictions about climate change and the application of de-trended fluctuation analysis to monthly average of the maximum daily temperatures to resolve different climates. Rangarajanet. al. (2004) studied the fractal and multi-fractal analysis of Indian climate dynamics. Nature provides different forms of data which can be converted to climatic data but wavelet based multi-fractal formalism will be used for better understanding the climatic changes. The combined behavior of pressure, temperature, and relative humidity, which defines the refractivity, is very critical for radar coverage of an area adjacent to the earth as studied by Ochotta and Gebhart (2006). Wavelet transforms of Meteorological parameters and gravity waves have been studied by Can, Aslan and Siddiqi (2005). Wavelet based analysis of meteorological parameters like temperature, relative humidity and total rainfall was performed in terms of decomposition, approximation, compression and de-noising of the original signals as studied by Vincent et. al. (2006).Wavelet and wavelet based multi-fractal formalism is studied by Can et al (2005).

Statistical Analysis

India situated between 8º N and 37º N Latitude, it occupies a large area of South Asia. The **climate of India** comprises a wide range of weather conditions across a large geographic scale and varied topography. India's unique geography and geology strongly influence its climate; this is particularly true of the Himalayas in the north and the Thar Desert in the northwest. The Himalayas act as a barrier to the frigid katabatic winds flowing down from Central Asia. Thus, North India is kept warm or only mildly cold during winter; in summer, the same phenomenon makes India relatively hot. Although the Tropic of Cancer—the boundary between the tropics and subtropics—passes through the middle of India, the whole country is considered to be tropical. It varies from The Tropical monsoon in south India to temperate in north India.

Daily average values of meteorological data for 11 meteorological stations Ahmadabad, Amritsar, Bikaner, Dehradun, Delhi, Gwalior, Hissar, Jaipur, Lucknow, Ludhiana and Shimla for a period of 3 years between 2008 and 2010 has been used to study the climatic

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dynamics through modern wavelet and wavelet based techniques. Temperature (TP) and total daily rain (Rain) values for accurate range, erroneous values and missing data have been used. The range of each region is dictated by the long term behaviour of the data. The meteorological data includes daily minimum temperature, daily maximum temperature and daily total rain for all 11 meteorological stations. Table 1 summarizes the latitudes, longitudes, data period and number of daily record for each location.

Table1 Details of latitudes, longitudes, data period and number of records for each location

Station	Latitude	Longitude	Period	Records
Ahmedabad	23.04N	72.38E	2008-2010	1096
Amritsar	31.38N	74.52E	2008-2010	1096
Bikaner	28.00N	73.18E	2008-2010	1096
Dehradun	30.19N	78.02E	2008-2010	1096
Delhi	28.35N	77.12E	2008-2010	1096
Gwalior	26.14N	78.15E	2008-2010	1096
Hissar	29.10N	75.44E	2008-2010	1096
Jaipur	26.49N	75.48E	2008-2010	1096
Lucknow	26.45N	80.53E	2008-2010	1096
Ludhiana	30.52N	75.56E	2008-2010	1096
Shimla	31.06N	77.10E	2008-2010	1096

The cross-correlation coefficient (*r*), is a measure of the strength of the linear relationship between two variables and values ranging between -1 and +1 is defined as,

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 \sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

Table 2, Table 3 and Table 4 describes the correlation coefficient between rainfall and maximum temperature, rainfall and minimum temperature and maximum and minimum temperature of all the 11 meteorological stations for the period of three years from 2008-2010 respectively.

Table 2 Correlation coefficient between Rainfall and Maximum Temperature

Stations	2008-2010	2008	2009	2010
Ahmedabad	-0.06457	-0.10031	-0.3836	0.025519
Amritsar	-0.25992	-0.31528	-0.3153	-0.0825
Bikaner	-0.04282	0.01663	0.01663	-0.20607
Dehradun	-0.18781	-0.32682	-0.314	-0.14368
Delhi	-0.11253	-0.12092	-0.3586	-0.07112
Gwalior	0.03525	0.08092	-0.0127	0.04891
Hissar	-0.18141	-0.39397	-0.3579	-0.07812
Jaipur	-0.29858	-0.34495	-0.1637	-0.34725
Lucknow	-0.21579	-0.30656	-0.0855	-0.25754
Ludhiana	-0.12641	-0.16765	-0.2736	-0.11517
Shimla	-0.20904	-0.2852	-0.1984	-0.12783

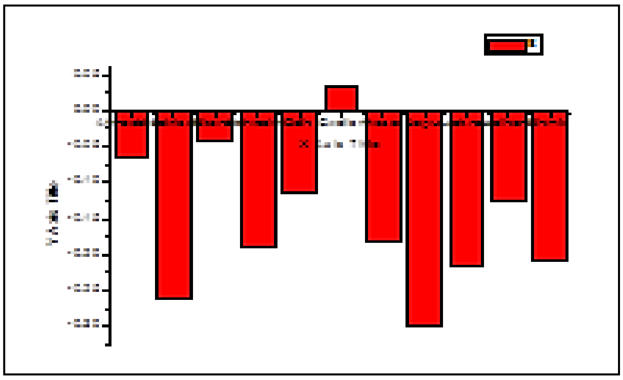
Table 3 Correlation coefficient between Rainfall and Minimum Temperature

Stations	2008-2010	2008	2009	2010
Ahmedabad	-0.04875	0.1072	-0.5038	-0.13739
Amritsar	-0.21708	-0.28513	-0.28513	-0.05032
Bikaner	-0.10308	-0.29353	-0.29353	-0.10917
Dehradun	-0.10587	-0.23529	0.01194	-0.16892
Delhi	-0.11557	-0.16409	-0.30199	-0.08627
Gwalior	-0.11175	-0.12611	-0.17356	-0.15339
Hissar	-0.10982	-0.12446	-0.31616	-0.12261
Jaipur	-0.14414	-0.2898	-0.3245	-0.13491
Lucknow	-0.11067	-0.35977	-0.30102	-0.15055
Ludhiana	-0.09075	-0.02687	-0.23515	-0.14819
Shimla	-0.10008	-0.12116	0.0492	-0.11587

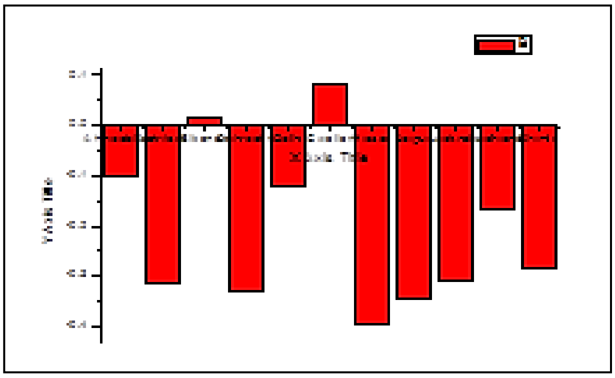
Table 4 Correlation coefficient between Maximum and Minimum Temperatures

Stations	2008-2010	2008	2009	2010
Ahmedabad	0.09132	0.01865	0.75623	0.07666
Amritsar	0.36974	0.36974	0.36974	0.36974
Bikaner	0.10599	0.63713	0.63713	-0.0133
Dehradun	0.40247	0.46932	0.00994	0.42483
Delhi	0.039196	-0.01437	0.16978	0.05402
Gwalior	0.04286	-0.04039	0.57388	0.00184
Hissar	0.42401	0.13612	0.59504	0.53627
Jaipur	0.2849	0.72193	0.58243	0.22659
Lucknow	0.12988	0.65595	0.45711	0.10973
Ludhiana	0.56582	0.37937	0.41108	0.5788
Shimla	-0.03158	-0.10741	0.3041	-0.024

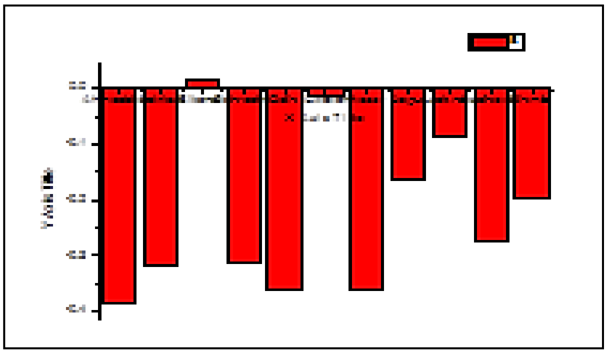
The long term variation of daily mean values of temperature and rainfall of all the 11 meteorological stations for the period of three years from 2008-2010 are shown in Figures 1-3 respectively. In these figures, the correlation coefficient between rainfall and maximum temperature, rainfall and minimum temperature and maximum and minimum temperature of all the 11 meteorological stations for the period of three years from 2008-2010 respectively have been plotted.



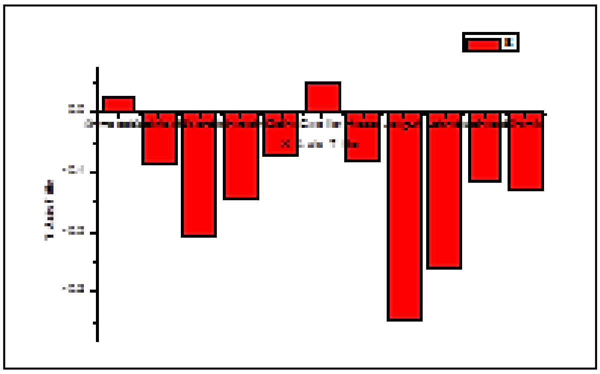
1(a)



1(b)

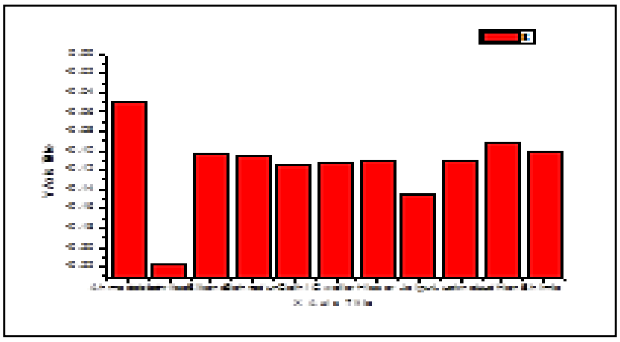


1(c)

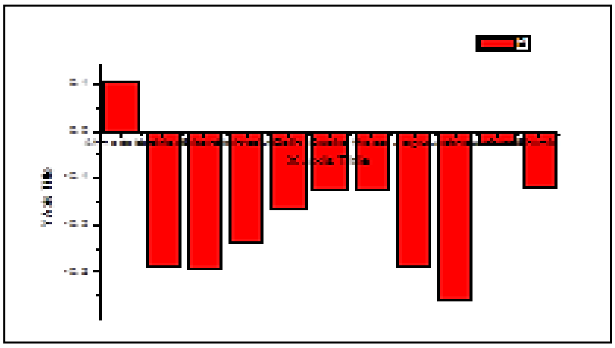


1(d)

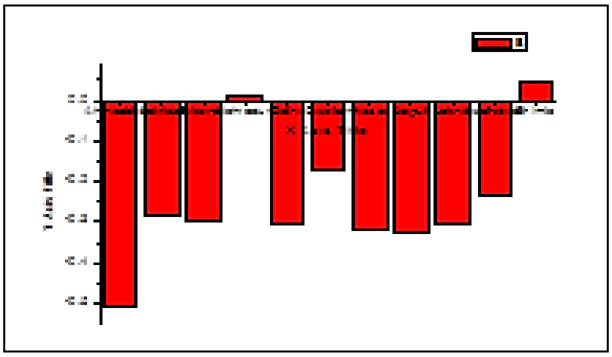
Fig.1Correlation Analysis between rainfall and maximum temperature of 11 meteorological stations for the period (a) 2008-2010 (b) 2008 (c) 2009 (d) 2010



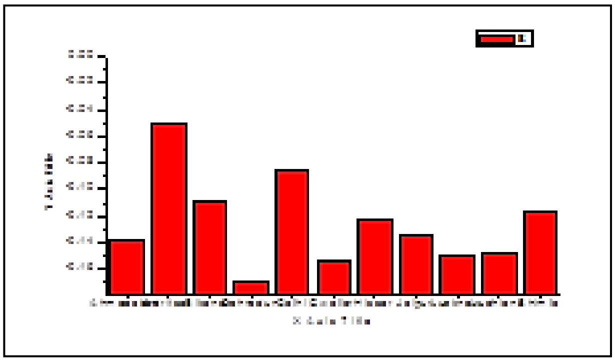
2(a)



2(b)

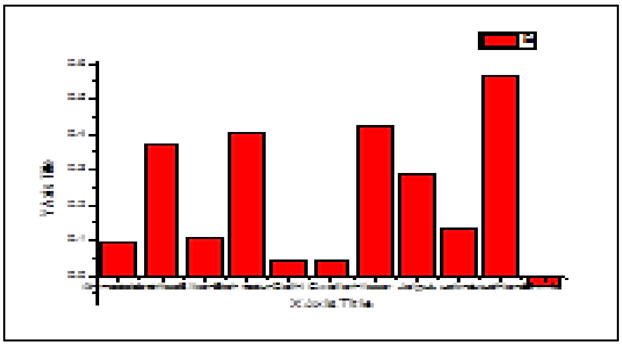


2(c)

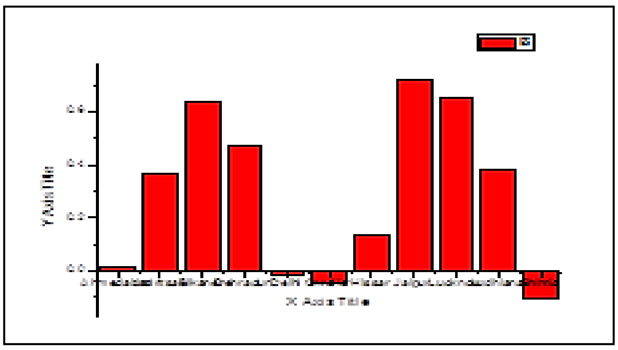


2(d)

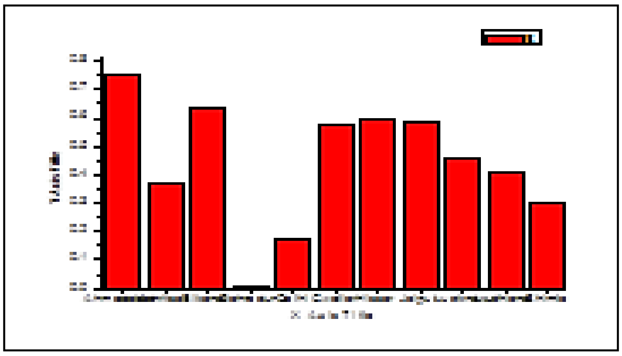
Fig. 2Correlation Analysis between rainfall and minimum temperature of 11meteorological stations for the period (a) 2008-2010(b) 2008 (c) 2009(d) 2010



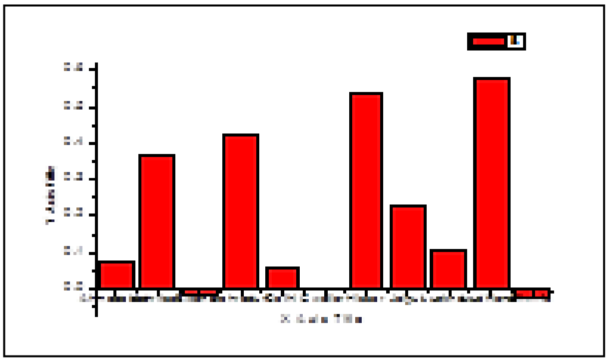
3(a)



3(b)



3(c)



3(d)

Fig. 3 Correlation Analysis between minimum and maximum temperature of 11meteorological stations for the period (a) 2008-2010 (b) 2008 (c) 2009 (d) 2010

The positive value of the correlation coefficient *r* indicates that as one value increases other tend to increase and the negative value of the correlation coefficient r indicates that as one value increases other tend to decrease. It has been observed that maximum and minimum temperature have positive correlation for all the years and at all stations except for Shimla. All stations for all years have negative correlation between rainfall and maximum temperature; rainfall and minimum temperature.

Discrete Wavelet Analysis of Meteorological Data

Discrete wavelet analysis of meteorological parameters such as maximum temperature, minimum temperature and total daily rainfall for 11 meteorological stations Ahmadabad, Amritsar, Bikaner, Dehradun, Delhi, Gwalior, Hissar, Jaipur, Lucknow, Ludhiana and Shimla for a period of 3 years between 2008 and 2010 have been studied for climatic dynamics. The discrete wavelet analysis of meteorological parameters are performed in terms of decomposition, approximation, compression and de-noising of the original signal. The decomposition analysis of maximum temperature, minimum temperature and total daily rainfall for the above meteorological stations have been performed using discrete wavelets. Figures 4- Figure 6 shows 1D Discrete wavelet decomposition of rainfall, minimum temperature, maximum temperature using Db5 (Daubechie) Wavelet for Delhi station respectively. In these figures, the x-axis shows the number of days of the entire data period used in this study and each of these figures have seven parts. The first part 's' represents the signal or raw data and the second part 'a_5' corresponds to the amplitude of the signal for Daubechies wavelet (Db) at level 5. The last five parts i.e. d_1, d_2, d_3, d_4 and d_5 of these figures represent details of the signal or raw data at five different levels.

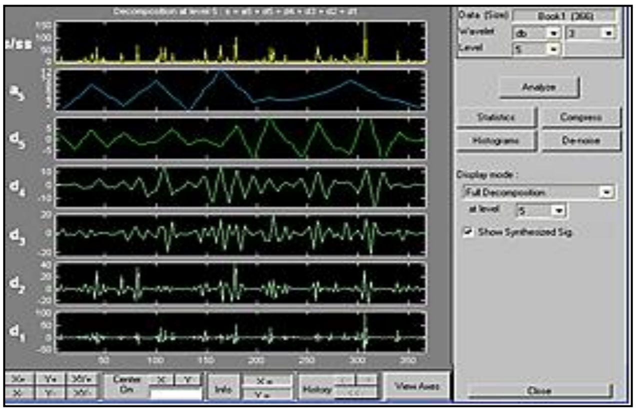


Fig. 4 Decomposition of Rainfall time series data for Delhi using DB5

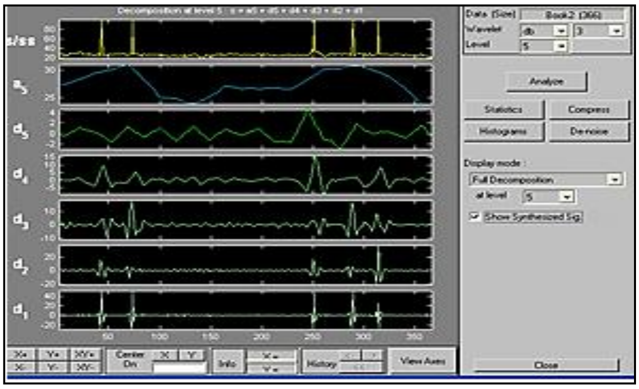


Fig. 5 Decomposition of Minimum Temperature for Delhi using DB5

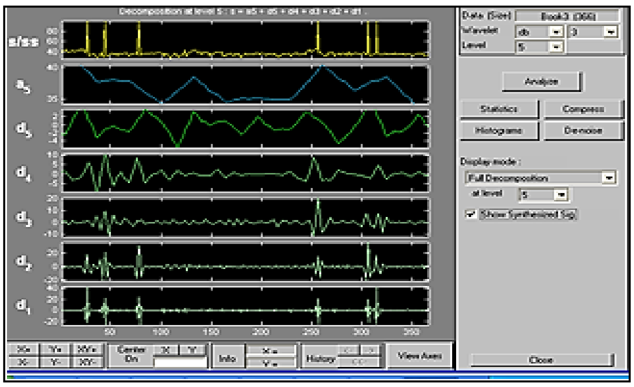


Fig. 6 Decomposition of Maximum Temperature for Delhi using DB5

Continuous Wavelet Analysis of Meteorological Data

1- Dimensional Mexican continuous wavelet analysis of meteorological parameters such as maximum temperature, minimum temperature and total daily rainfall for 11 meteorological stations Ahmadabad, Amritsar, Bikaner, Dehradun, Delhi, Gwalior, Hissar, Jaipur, Lucknow, Ludhiana and Shimla for a period of 3 years between 2008 and 2010 have been analyzed. Figures 7- fignre 9 discussed the Meteorological data of rainfall, minimum temperature, maximum temperature using Mexican continuous wavelet decomposition for Delhi respectively. Each of these figures havefour parts. The first part on the top of the figure represents the analyzed signal or the raw data. The second part of these figures shows scalogram. The scale of colors changes from minimum (dark colors) to maximum (light colors). The vertical axis shows the frequency values while the horizontal axis represents the number of days. The third part shows the daily variation of coefficients. The last part of the figure explains the local maximums of related parameters.

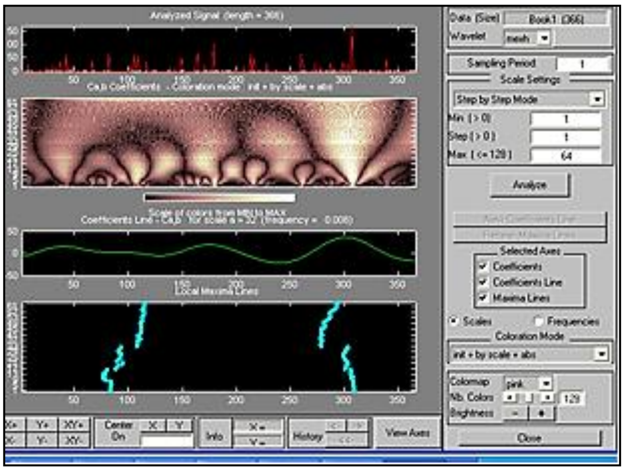


Fig. 7 Mexican hat Continuous Wavelet analysis of Rainfall for Delhi

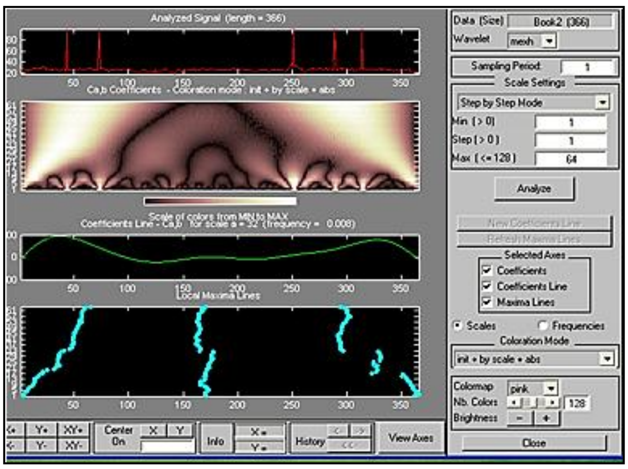


Fig. 8 Mexican hat Continuous Wavelet analysis of Minimum Temperature for Delhi

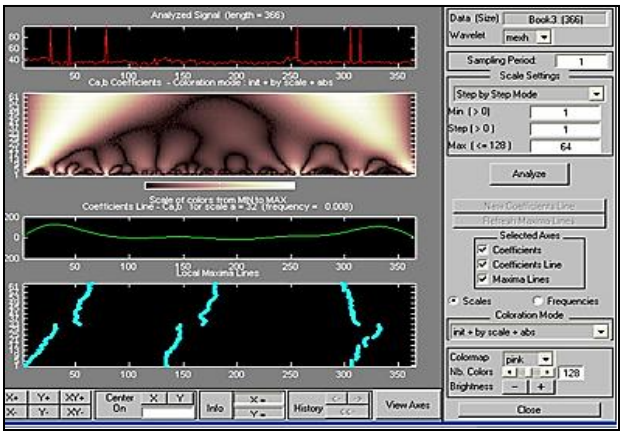


Fig. 9 Mexican hat Continuous Wavelet analysis of Maximum Temperature for Delhi

Conclusion

It has been observed that maximum and minimum temperature have positive correlation for all the years and at all stations except for Shimla. All stations for all years have negative correlation between rainfall and maximum temperature; rainfall and minimum temperature. The same results have been confirmed with the help of Discrete and Continuous wavelet analysis.

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