

## WAVELET ANALYSES OF SOME ATMOSPHERIC PARAMETERS AT BLACK SEA REGION

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**Abstract-** 1D wavelet and continuous wavelet analyses of some atmospheric parameters (annual mean, maximum and minimum air temperature, relative humidity and annual total precipitation) in İle (Northeastern Black Sea Region of Istanbul) between 1939 and 2012 are presented in this paper. The main aim of this study is to extract temporal structure changes of a climatic oscillation of some selected atmospheric parameters. The influence of climatic oscillations based on NO and El-Nino are analyzed for monthly and annual values. Wavelet analyses allowed quantifying both the pattern of variability in the time series and non-stationary associations in general. Mean air temperature values increases associated with decreasing of high frequency (small scale) fluctuations and increasing of low frequency (large scale) fluctuations in the second term. Increasing ratio of maximum air temperatures are more than mean air temperatures. Meso and small scale fluctuations play an important role on increasing of maximum air temperatures in study area. Large scale fluctuations cause increasing trend of minimum air temperature in the second term. Relative humidity increases beginning from 1976 (industrialization) and associates with amplitudes of high frequency fluctuations (small scale evens). Large scale evens have a great importance on this variation at the study area. Annual total rainfall rate values also increase in the second period. Increasing trend of amplitude of high frequency fluctuations are accompany with rainfall increasing. In this period, large scale evens observed every 5 to 20 year periodic modes have a great influence on rainfall increasing. Maximum rainfall rate observations in 1926, 1969-70, 1982-83, 1997-98 and 2009 may be reported strong associations between rainfall and El Nino periodic bands. Warm event matched with increasing values of relative humidity and annual total rainfall rate values.

**Keywords:** Climatic oscillations, wavelet, El Nino

### 1. INTRODUCTION

#### STUDY AREA

İle, 41°10'N latitude and 29° 36' E longitude is one of the province of Istanbul of the Northeastern part of Marmara Sea and of the Black Sea Region (Figure 1).



**Fig. 1.** Study area

#### DATA

Annual mean, maximum and minimum air temperature, relative humidity and annual total precipitation in İle between 1939 and 2012 are archive data of the Turkish State Meteorological Service.

#### METHOD

Wavelet Packet Program covers Morlet, Mexican Hat and Meyer wavelets. These wavelets have generally applied on analyses of atmospheric variables in different scales.

Walker used Daubechies, Coifman, Haar, Gabore Sine, Gabore Cosine and Gabore Complex wavelets by using FAVA software. Wavelet means, small waves. At the initial stage, this method was used analyses of seismic signals by Morlet and Grossmann. Wavelet methodologies, has been used in different fields like; turbulence, ocean waves, seismic data, batimetry, environment, biology, electro cardio data, temperature, global warming.

Liu (1994) analyzed ocean waves by using wavelet spectrum.

Fourier spectrum does not detect some details of high frequency variations. Wavelet methods have more advantages than Fourier spectrum. They have been applied non stationary time series. They detect the details at frequency and time domain simultaneously. Wavelet method has more advantage for diagnostic fluctuations, as SST and climatic systems. Mathematical equations for of wavelet packets of a  $f(t)$  function are given as below, (Aslan et al., 2006; Çal ar et al., 2009) :

$$\int_{-\infty}^{\infty} |f(t)|^2 dt < \infty \quad (1)$$

$\mathbb{E}(t)$  is a continuous wavelet function:

$$\int_{-\infty}^{\infty} |\mathbb{E}(t)|^2 dt = 1 \quad (2)$$

$$\int_{-\infty}^{\infty} \mathbb{E}(t) dt = 0 \quad (3)$$

This paper presents some results of rainfall rate, air temperature and relative humidity variations based on 1D Wavelet Packets and Continuous Wavelet Transforms.

## ANALYSES

### Analyses of Annual Mean Air Temperature (1939-2010)

Mean air temperature values increases at the last term of the study period (Fig 2). Amplitudes of small scale factors decrease, but large scale fluctuations increase in the last period.

In the middle parts, the influence of small and meso scale factors decreases, (Fig 3). Large scale influences increases at the last term.

In the middle part, with the influence of small and meso scale factors, mean air temperatures decrease. Beginning from 1989, they show an increasing trend again (Fig 3).

Frequency histogram of air temperature values show a positive skewness (Fig 4).

### Annual Maximum Air Temperature Analysis (1939-2010)

Increasing trend of maximum air temperature is higher than mean air temperature, (Fig 5).

Meso scale fluctuations result in decreasing air temperature in the middle part of study term (Fig 6).

There is a negative skewness of the histogram for maximum air temperatures, (Fig 7).

### Analyses of Annual Minimum Air Temperature (1939-2010)

Lower level variations show smaller variations at the second part of the period, but higher level (low frequency) variations decrease.

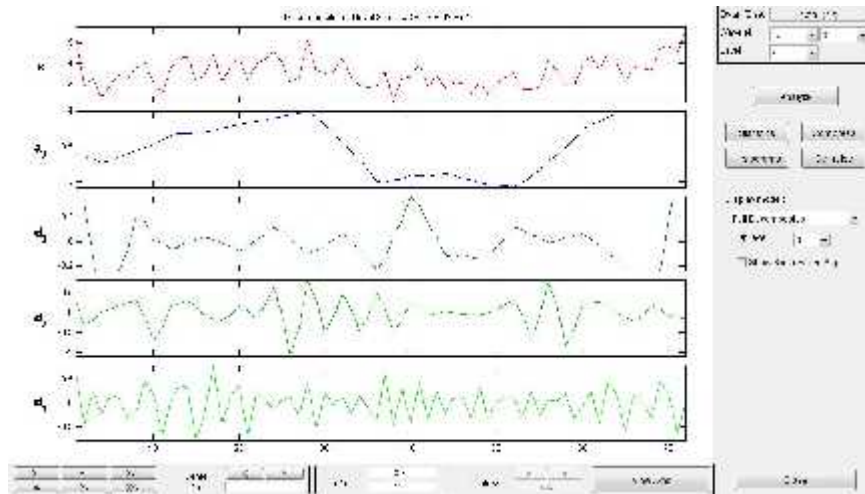


Fig. 2. Mean air temperature 1D Wavelet, ile (1939-2010)

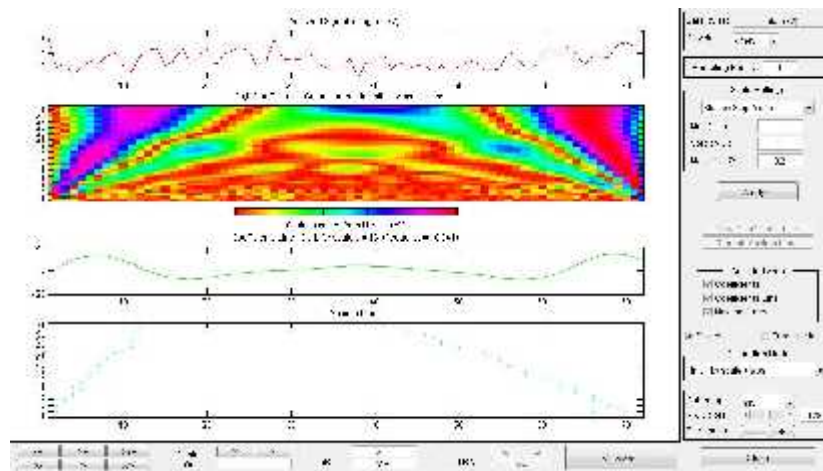


Fig 3. Mean air temperature, 1D Continuous Wavelet, ile

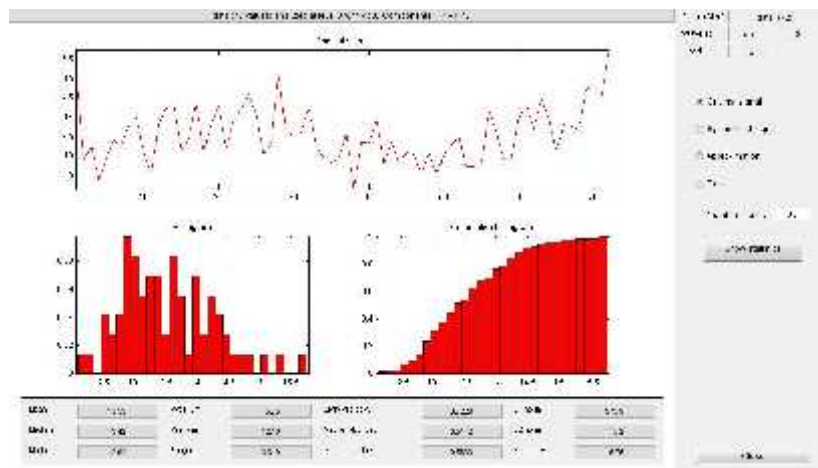


Fig 4. Mean air temperature (Statistical analysis, ile)

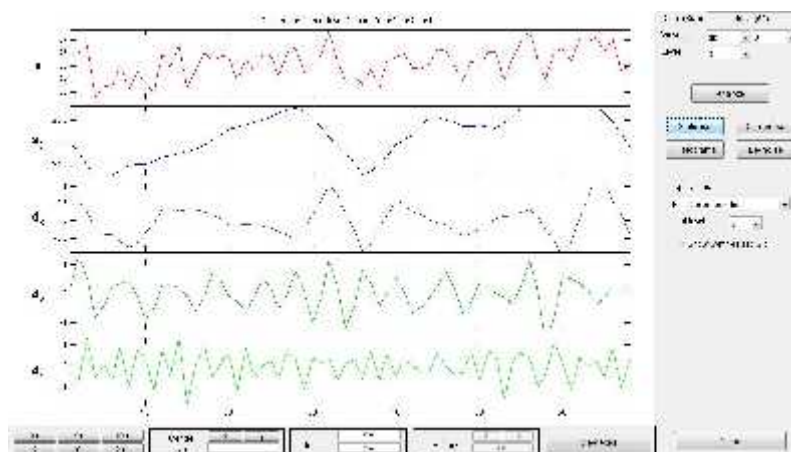
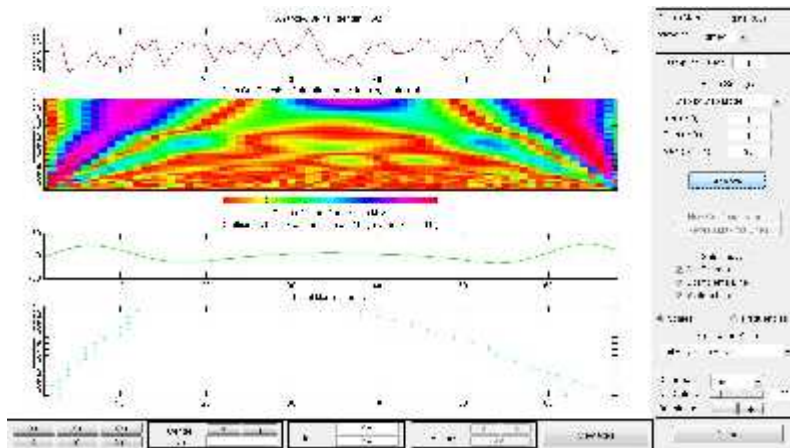
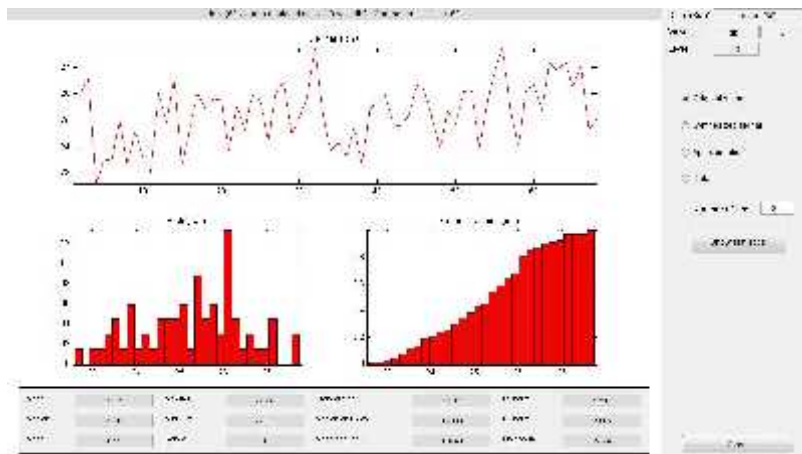


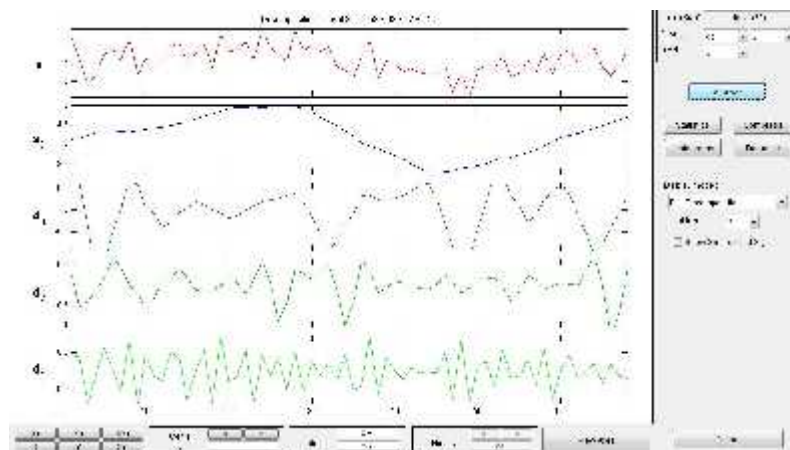
Fig 5. Maximum air temperature 1D Wavelet, ile (1939-2010)



**Fig 6.** Maximum temperature, 1D Continuous Wavelet Analysis ( ile)



**Fig 7.** Maximum air temperature (Statistical analysis, ile)



**Fig 8.** Minimum air temperature 1D Wavelet Analysis, ile , (1939-2010)

Because of the role of large scale fluctuations, lower minimum air temperature values have been observed, (Fig 9).

Frequency analyses show a slightly negative skewness. Frequency of lower level fluctuations is lower than higher ones, (Fig 10).

**Annual Mean Relative Humidity Analyses (1939-2010)**

Relative humidity increases beginning from the second part of the study period. This increasing trend is clearly observed at the amplitude (a3) diagram. All amplitudes at higher and lower frequencies decrease in the second term, (Fig 11).

Lower relative humidity values have a periodicity between 8 to 17 years. Almost in all period, roles of meso and small scale factors have been observed, (Fig12).

Bi-modal frequency distributions have been observed for relative frequency analyses, (Fig.13).

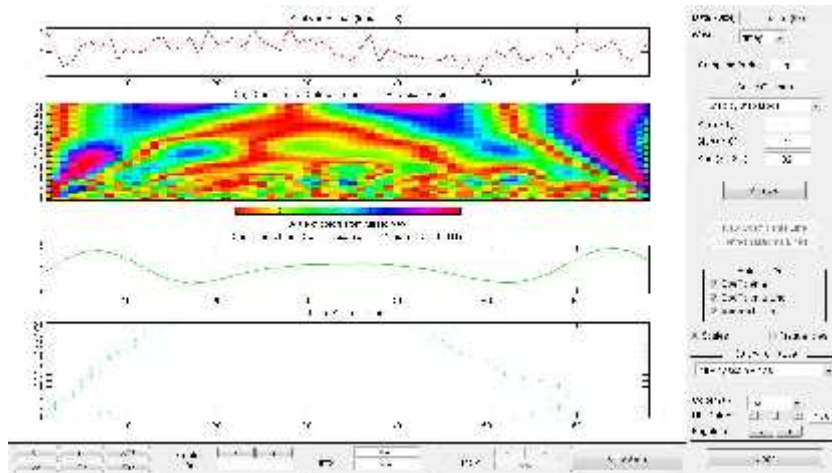
**Annual Total Rainfall Rate Analysis, (1939-2010)**

An increasing trend of air temperature temporal variations in the results in increasing humidity and rainfall rate at the second part of the period. This increasing trend has been associated with an increasing of small scale events, (Fig. 14).

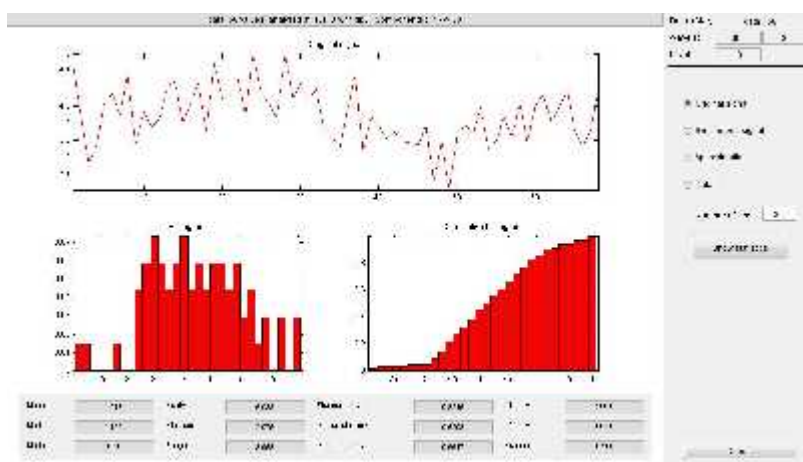
Increasing trend of extreme precipitation is associated with El Nino years 1969-70, 1982-83, 1997-98 and 2009.

Large scale events with 5 to 20 years periodicity are important on rainfall rate variations, (Fig 15).

Statistical analyses present a positive skewness for annual total rainfall rate values, (Fig 16).



**Fig 9.** Minimum air temperature, 1D Continuous Wavelet Analysis (file)



**Fig 10.** Minimum Air Temperature (Statistical analysis, file)



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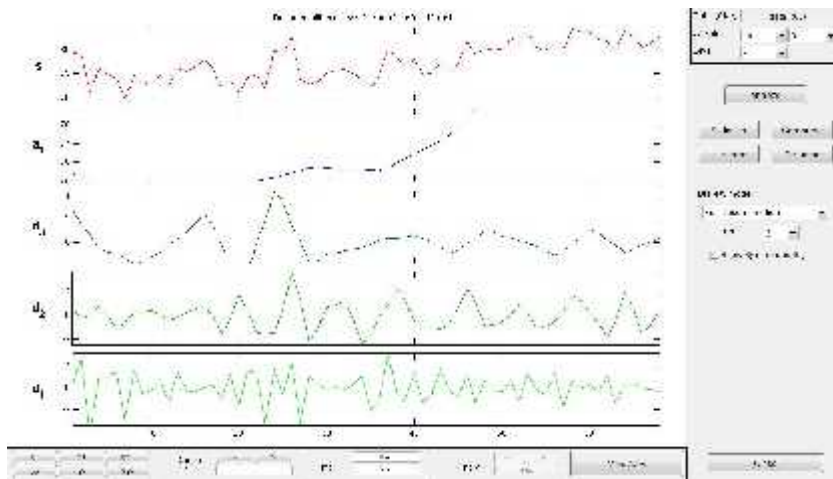


Fig 11. Relative humidity, 1D Wavelet, file , (1939-2010)

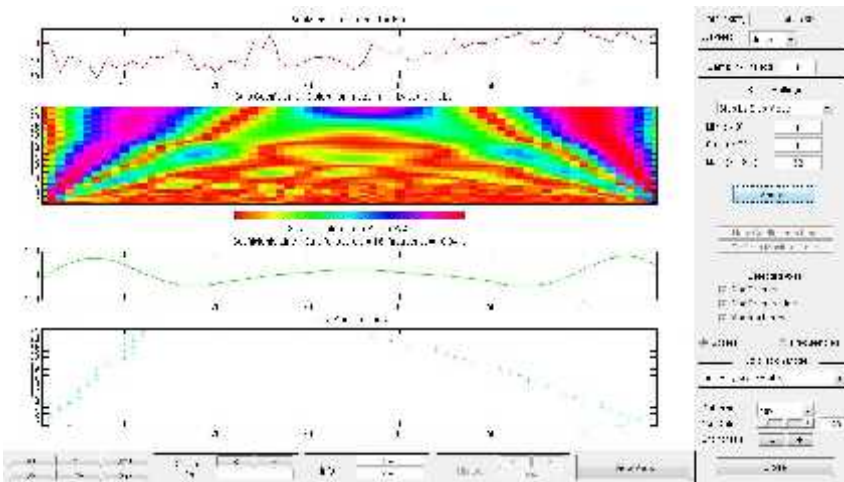


Fig 12. Relative humidity, 1D Continuous Wavelet ( file)

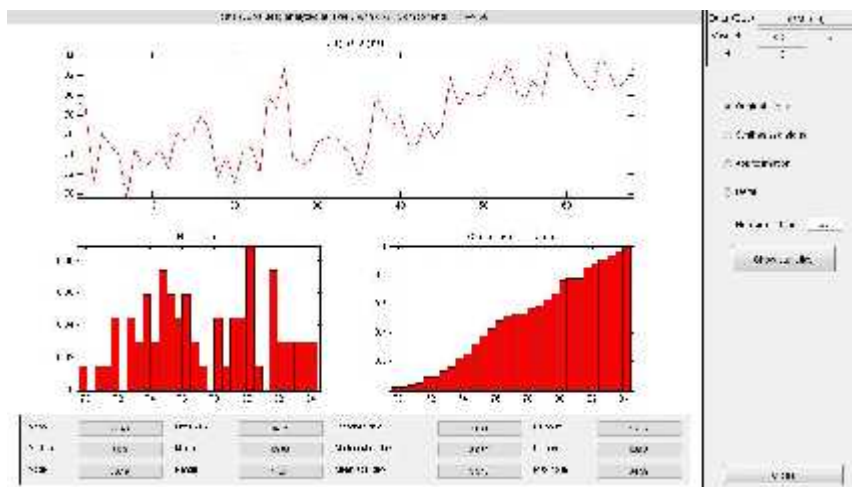


Fig 13. Relative humidity (Statistical analysis, file)

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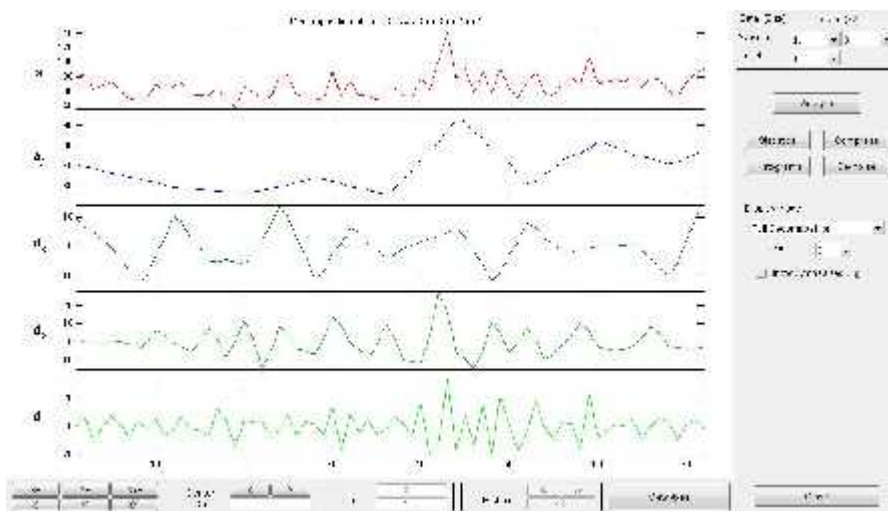


Fig. 14. Annual Rainfall Rate 1D Wavelet Analysis, ile (1939-2010)

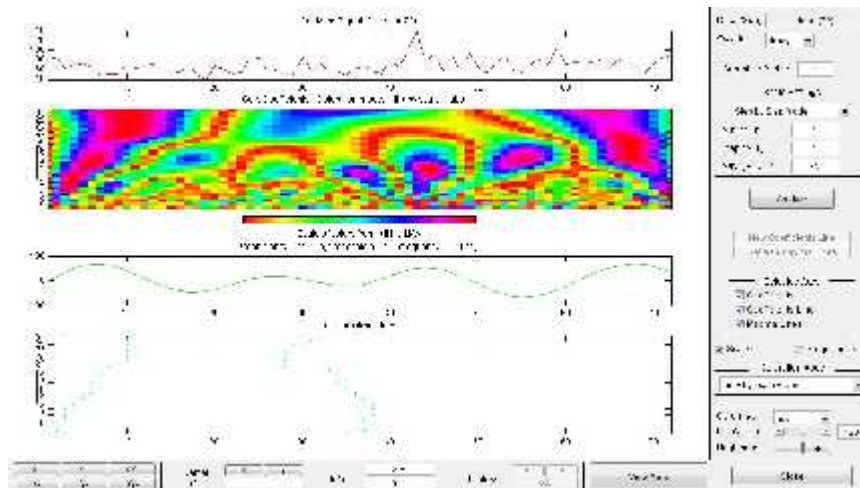


Fig. 15. Annual Rainfall Rate, 1D Continuous Wavelet Analyses ( ile)

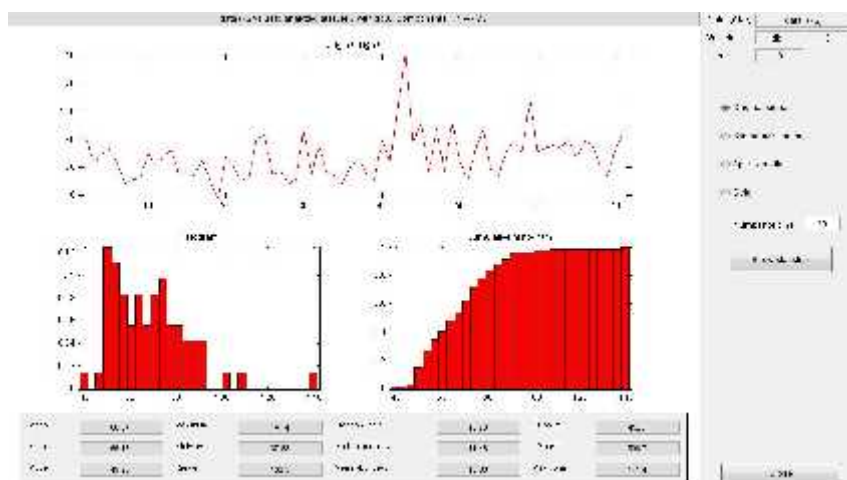


Fig. 16. Annual Rainfall Rate (Statistical analysis, ile)

## RESULTS AND CONCLUSION

Specific results of this study are listed as below:

- Mean air temperature values have been increased since 1989. This increasing trend is associated with large scale events in general,
- Since 1973, maximum air temperature values have been increased. This increasing trend is associated with large amplitudes of long term and meso scale events. In recent year combined role of small and meso scale events have been observed,
- Mean air temperature decreases in the last 20 years, because of large scale factors,
- Relative humidity increases during all study period. It is associated with meso scale events,
- Annual total rainfall rate is under the effects of small and large scale events

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