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Climatic variations at Trieste during the last century*

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The time series of the annual values of eight climatic elements (atmospheric pressure, air temperature, relative humidity, precipitations, „bora" and southerly winds frequencies, sunshine duration and sea level) recorded at Trieste, northern Adriatic, in the years 1871–1985 are reported and analysed. The characteristic spectra are computed by means of least squares method: the most significant periods are 50, 24, 18.3, 12.7, 10.9, 7.80, 4.96, 4.62, 3.67, 3.42, 2.97 and 2.25 years, the last one corresponding to the quasi-biennial oscillation of 27 months.

The linear trends show an almost stationary pressure, an increase of the air temperature (+ 0.003°C/a), a decreasing relative humidity (– 0.03 %/a), decreasing precipitations (– 1.5 mm/a), a reduction of „bora" and an increase of southerly winds (– 0.3 and + 0.3 days per year respectively), a reduction of the sunshine duration (– 1.6 h/a) and an increase of the sea level (+ 0.13 cm/a).

Klimatske varijacije u Trstu tijekom proteklog stoljeća

U članku se analiziraju nizovi godišnjih vrijednosti osam klimatskih elemenata (tlak zraka, temperatura zraka, relativna vlažnost, oborina, čestina bure i južnih vjetrova, insolacija i razina mora), registriranih u Trstu u periodu od 1871. do 1985. godine. Karakteristični spektri određeni su metodom najmanjih kvadrata: najznačajniji periodi su 50, 24, 18,3, 12,7, 10,9, 7,80, 4,96, 4,62, 3,67, 3,42, 2,97 i 2,25 godine, od kojih posljednji odgovara približno dvogodišnjoj oscilaciji perioda 27 mjeseci.

Linearni trendovi ukazuju na gotovo stacionaran tlak, na porast temperature zraka (+ 0,003°C/g), opadanje relativne vlažnosti (– 0,03%/g), opadanje količine oborine (– 1,5 mm/g), opadanje čestine bure i porast čestine južnih vjetrova (– 0,3 odnosno + 0,3 dana/g), opadanje insolacije (– 1,6 sati/g) te uzdizanje razine mora (+ 0,13 cm/g).

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1. The climatic data

A regular series of meteorological observations began in Trieste in 1819 (Stravisi and Zorzenon, 1986) at the local Nautical and Commerce Academy. Nowadays, all the existing original hand-written reports, starting in 1841, are conserved in the archives of the Thalassographic Institute of the National Research Council. A hystorical review of the meteorological stations and instruments at Trieste is given by Polli (1942, 1946, 1948, 1951); annual data reports have been published by the Trieste Maritime Observatory and by the Thalassographic Institute (ITTS). The time series of annual data considered in this paper are taken from Stravisi (1976), from ITTS (1977–1980), from Stravisi et al. (1986), from Stravisi (1986 b) and from Stravisi and Ferraro (1986).

(1) The atmospheric pressure p (unit: hectopascal; 1 hPa = 1 mbar) is reduced at the sea level; (2) the air temperature ϑ (unit: degree Celsius, °C) is reduced at the actual

Table 1. Annual climatic data for Trieste, Italy. (1) Atmospheric pressure (hPa), (2) air temperature (°C), (3) relative humidity (%), (4) precipitations (mm/d), (5) „bora" frequency (%), (6) southerly winds frequency (%), (7) sunshine duration (%) and (8) sea level (cm).

	1	2	3	4	5	6	7	8
1871	1015.4	13.3	67	2.3				
1872	1014.8	15.0	71	3.8				
1873	1016.2	14.6	68	3.0				
1874	1016.0	13.6	67	2.5				
1875	1016.0	13.1	70	2.7				
1876	1014.7	13.5	73	4.0				
1877	1015.0	14.0	70	3.2				
1878	1014.5	13.9	71	3.6				
1879	1014.6	13.7	70	2.8				
1880	1016.8	14.1	73	3.4				
1881	1016.0	13.4	68	2.6				
1882	1016.8	14.6	66	3.1				
1883	1015.7	13.6	63	2.2				
1884	1016.7	13.7	66	2.6				
1885	1014.7	13.9	69	4.0				
1886	1015.0	14.2	64	3.0			48.9	
1887	1015.9	13.5	65	3.0			50.7	
1888	1016.0	13.4	74	2.6			46.8	
1889	1014.8	13.6	66	3.7			49.8	
1890	1015.6	13.7	63	2.2			54.6	145.1
1891	1016.4	13.7	67	2.6			54.2	146.2
1892	1014.6	13.9	67	3.3			51.6	151.7
1893	1015.8	13.7	67	2.4			52.0	147.4
1894	1016.2	14.2	65	2.3			54.4	145.2
1895	1014.0	13.9	66	2.3			48.6	155.6
1896	1015.9	13.8	66	3.8			50.9	147.2
1897	1016.0	14.5	67	2.5			51.1	150.7
1898	1016.0	15.1	67	2.4			47.3	150.3
1899	1016.5	14.0	68	2.9			44.4	147.4
1900	1014.2	14.8	67	3.6			46.4	154.9
1901	1014.9	13.7	67	3.1			47.1	153.4
1902	1015.6	13.7	65	2.5			48.2	154.2
1903	1016.4	14.3	66	2.8	44.4	17.4	44.9	150.3
1904	1015.8	15.0	65	2.3	54.2	13.7	46.0	151.9
1905	1016.1	13.7	66	3.4	48.3	16.3	47.1	151.7
1906	1015.3	13.9	65	2.7	45.2	17.1	49.1	152.9
1907	1015.9	14.0	65	2.7	48.0	14.7	47.9	146.4
1908	1016.8	13.7	63	1.9	47.0	14.7	52.9	148.5
1909	1014.5	13.7	65	2.9	42.1	20.2	49.3	151.2
1910	1013.9	14.1	69	3.8	42.7	20.4	45.1	160.8
1911	1017.0	14.6	66	2.5	43.1	18.2	52.0	150.0
1912	1015.8	13.5	68	2.8	40.4	19.0	40.3	152.1
1913	1017.0	13.9	70	3.0	41.9	16.4	48.4	151.6
1914	1015.6	13.9	69	3.1	43.2	18.3	49.5	154.9
1915	1013.3	13.9	70	4.4	44.6	18.8	46.7	162.0
1916	1013.7	15.0	72	3.9	37.8	24.3	48.4	161.2
1917	1014.9	14.1	64	3.2	49.8	18.0	53.9	152.7
1918	1016.8	13.8	69	3.5	41.1	23.0	50.7	151.3
1919	1014.2	13.6	69	3.5	40.2	25.4	49.6	155.4
1920	1017.3	14.4	67	2.0	39.6	20.0	50.2	155.0
1921	1018.4	14.6	61	1.8	43.1	20.6	49.9	148.8
1922	1015.1	13.7	62	2.7	36.3	26.7	44.0	156.5
1923	1014.3	14.6	61	2.9	38.6	25.1	45.5	157.0
1924	1015.3	14.0	63	2.8	40.5	25.2	43.2	152.6
1925	1015.3	14.1	64	2.9	30.8	29.9	43.2	154.8
1926	1015.2	14.6	63	3.6	36.5	28.2	38.2	157.5
1927	1014.8	14.9	61	2.6	36.2	28.5	49.9	157.7
1928	1015.8	14.4	61	3.2	42.9	25.7	48.8	155.0
1929	1016.3	13.8	60	2.4	44.0	24.6	49.9	150.5
1930	1014.6	14.7	63	3.6	37.5	27.7	44.9	157.7
1931	1014.8	13.9	61	2.8	40.8	26.8	44.9	157.8
1932	1016.9	13.8	62	3.1	38.2	29.7	47.4	153.3
1933	1014.9	13.3	62	3.4	47.3	23.2	42.4	155.0
1934	1015.5	15.0	62	3.5	40.9	26.7	49.3	156.0
1935	1013.9	14.3	59	2.2	43.9	22.7	49.9	156.3
1936	1014.2	14.8	63	2.5	43.3	22.9	46.9	162.1
1937	1013.7	14.7	65	3.5	45.9	21.5	42.6	163.8
1938	1017.4	14.2	61	1.7	47.5	18.1	54.2	153.2
1939	1014.7	14.1	61	2.5	53.1	14.2	49.2	158.7
1940	1015.0	12.8	63	3.1	58.2	15.5	45.7	158.8
1941	1014.9	13.0	65	2.5	51.7	19.2	46.1	161.9
1942	1015.8	14.0	65	1.6	51.3	19.0	50.7	157.1
1943	1017.6	15.0	65	2.3	43.6	13.9	54.6	152.2
1944	1015.2	13.9	63	2.1	50.7	17.0	48.5	153.6
1945	1016.9	14.8	63	1.6	41.3	15.0	55.4	156.1
1946	1016.1	14.8	60	2.1	45.4	18.2	54.4	157.2
1947	1015.6	14.7	64	2.6	48.8	20.8	48.9	160.4
1948	1018.0	14.5	68	3.2	52.8	17.4	48.7	155.9
1949	1017.8	14.8	68	2.3	52.1	15.0	53.7	150.3
1950	1015.0	15.2	71	2.7	45.1	19.9	50.4	156.9
1951	1014.7	15.1	72	2.9	38.4	24.6	44.8	165.1
1952	1014.2	14.3	66	2.9	35.4	24.4	46.2	160.3
1953	1018.0	14.4	65	2.3	48.5	15.2	48.4	154.6
1954	1014.3	13.7	66	2.2	39.6	20.9	44.7	155.8
1955	1014.4	13.7	69	2.6	43.7	15.5	43.5	161.8
1956	1016.0	13.1	67	2.7	45.1	20.6	45.3	157.7
1957	1016.2	14.3	65	2.1	42.1	23.8	50.0	156.0
1958	1014.8	14.5	65	2.5	37.7	23.3	50.6	161.9
1959	1016.0	14.5	66	2.8	44.8	17.6	47.2	155.2
1960	1013.7	14.3	69	3.7	40.5	22.6	45.6	166.1
1961	1016.5	15.0	65	3.1	38.2	22.5	55.0	160.3
1962	1015.2	13.8	61	2.9	47.3	19.3	52.4	159.8
1963	1014.5	13.9	65	3.3	39.2	25.1	50.9	165.0
1964	1016.9	14.2	65	2.7	39.4	25.5	51.6	157.2
1965	1014.3	13.7	67	3.8	32.8	29.7	48.1	162.9
1966	1013.9	14.7	66	2.8	36.5	24.6	43.6	165.3
1967	1016.6	14.7	64	2.2	34.3	27.4	46.4	158.7
1968	1015.2	14.3	65	3.1	36.6	26.5	46.1	160.7
1969	1014.2	14.2	63	3.0	39.7	24.0	43.9	164.6
1970	1015.2	14.0	66	2.9	30.9	29.4	44.1	163.1
1971	1016.1	14.2	62	2.4	38.5	25.1	48.1	160.9
1972	1016.1	14.1	65	2.8	39.5	25.7	39.9	159.8
1973	1016.4	14.3	62	2.3	39.4	23.7	45.9	156.3
1974	1015.5	14.4	67	2.8	38.3	28.9	42.6	159.8
1975	1016.6	14.8	66	3.2	36.9	30.7	45.6	158.3
1976	1015.5	14.0	64	2.7	40.1	23.3	44.0	159.0
1977	1015.9	14.3	68	3.3	31.3	31.6	41.5	161.4
1978	1014.9	13.5	66	3.2	33.2	30.3	42.6	163.4
1979	1014.8	14.2	65	2.9	39.2	26.7	45.8	165.3
1980	1015.2	13.2	66	3.1	41.3	25.2	40.3	162.6
1981	1015.5	14.0	65	2.8	37.5	25.4	44.3	163.2
1982	1016.9	14.6	64	2.6	42.7	23.1	47.2	161.0
1983	1017.5	14.4	64	1.9	36.1	29.5	50.8	160.5
1984	1015.6	13.8	66	2.8	37.8	31.2	43.9	163.7
1985	1015.6	14.0	65	2.4	33.6	32.4	48.3	161.2

height (10 m) of the ITTS meteorological screen, as well as (3) the relative humidity r (unit: percent of saturation. %). (4) Precipitations P are expressed in millimeters per day or in millimeters per year (mm/d and mm/a respectively). (5) The term "bora" frequency B here denotes the annual duration of the wind from NNE, NE, ENE, E; units are days per year (d/a) or the percentual ratio of bora to the total windy time. (6) In the same way, the frequency of southerly winds S refers to directions SE, SSE, S, SW. Bora descents from the continent and S winds in the Adriatic Sea are generally synoptic scale phenomena which strongly affect the Trieste climate; durations and not velocities have been considered, since, owing to changes both of the site and of the type of anemographs, these do not represent homogeneous time series. The initial year for wind data is 1903, since wind distributions before this time were computed according to eight instead of sixteen directions. (7) The sunshine duration is given in hours per year (h/a) or in percent of the astronomical daylight, which at Trieste is 4401 hours per year, 4412 hours per leap year (Stravisi, 1986 a). A Campbell-Stokes sunshine recorder began to work in 1886. (8) The annual mean sea level height η at Trieste above the conventional ITTS datum ("Zero Istituto Talassografico", ZIT; Stravisi and Ferraro, 1986) is given in centimeters.

In this study we considered the time series (1–8) above starting 1871 (or later), since preceding data must be taken at present with some care. Data are given in Table 1. The aim now is to investigate preliminarily the trend of the climatic series and the main components of their spectra.

2. The amplitude spectra

An appropriate technique to estimate the spectral characteristics of short time series (about one hundred annual values in our case) is given by the least squares method. Detrended data are fitted by means of harmonic components (HC) of variable frequency; the HC amplitude as a function of frequency gives the amplitude spectrum.

The climatic time series of Trieste (Table 1) have been analysed in this way, by scanning the frequency domain between 0.05 and 3.12 rad/a (126 and 2 years respectively) with a frequency interval equal to 0.01 rad/a. The resulting spectra are represented in Figs. 1 to 8; amplitudes have been normalized with respect to the standard deviation of the data sets. Large amplitude HC are found in relative humidity, sunshine and most of all in the time series of the characteristic winds frequency. The root mean power spectrum (the square root of the average of the eight power spectra, Fig. 9) has been computed in order to point out the common "characteristic geophysical periods" between the climatic elements. The periods in years corresponding to spectral peaks exceeding 0.25 σ are listed in Table 2; in the case of the root mean square power spectrum, the limit is 0.2 σ.

The longer emerging period is 50 a; this is found both in the bora and southerly winds spectra and in the precipitation spectrum: precipitations at Trieste are indeed generally related, at least during the cold season, to meridional winds. A period of 24.1 a is found both in sunshine and in the air temperature. Other periods are 18.3 a, 12.7 a

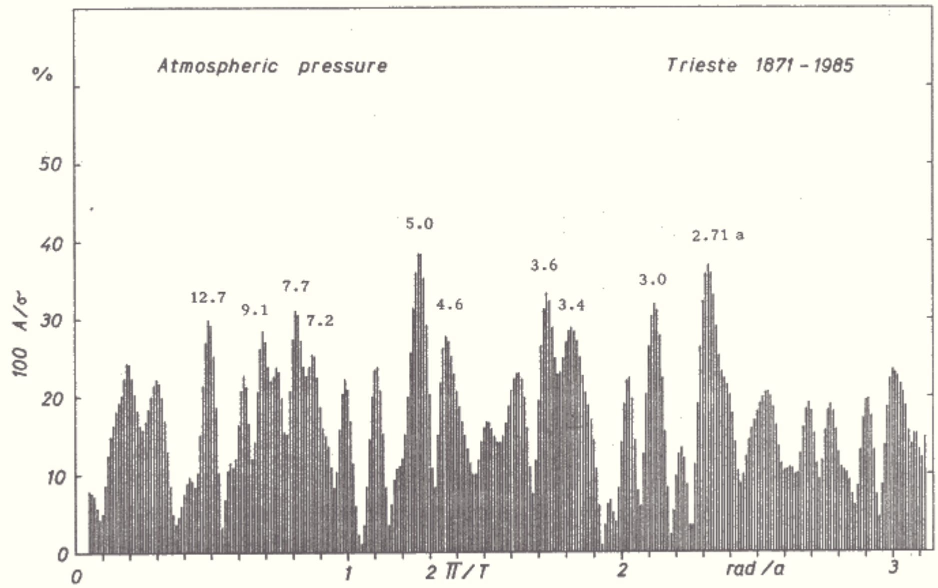

Figure 1. Amplitude spectrum of the atmospheric pressure at Trieste (1871–1985). Periods in years exceeding 0.25 σ.

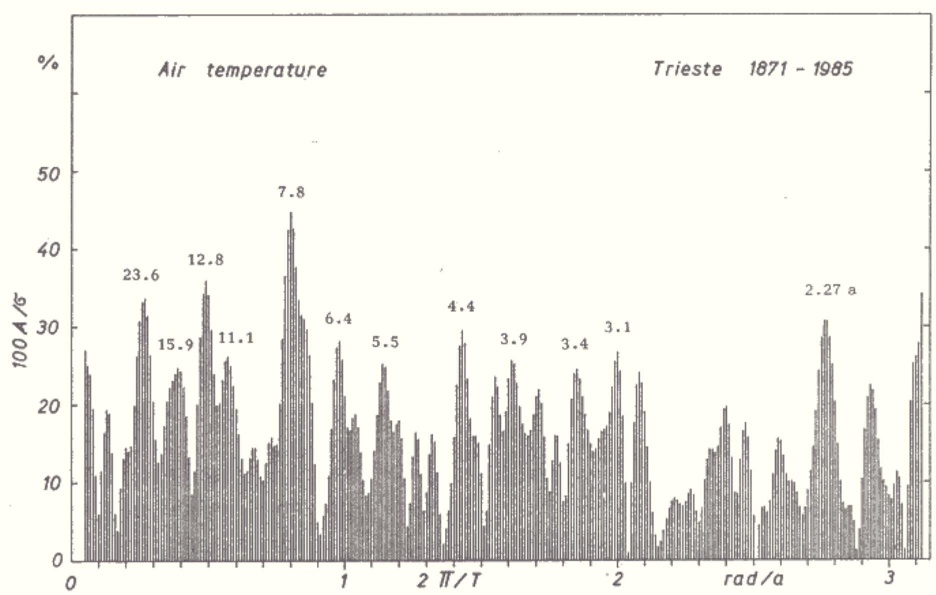

Figure 2. Amplitude spectrum of the air temperature at Trieste (1871–1985). Periods in years exceeding 0.25 σ.

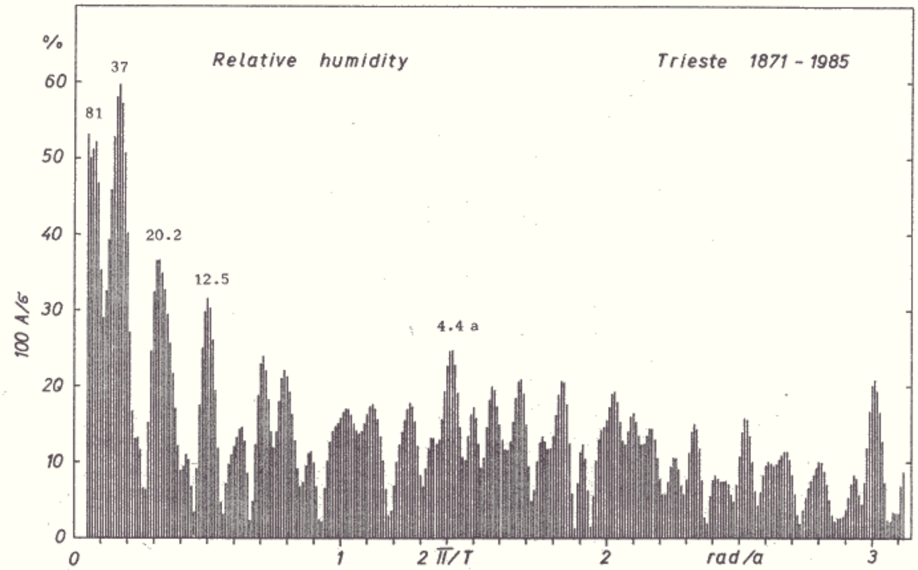

Figure 3. Amplitude spectrum of the relative humidity at Trieste (1871–1985). Periods in years exceeding 0.25 σ.

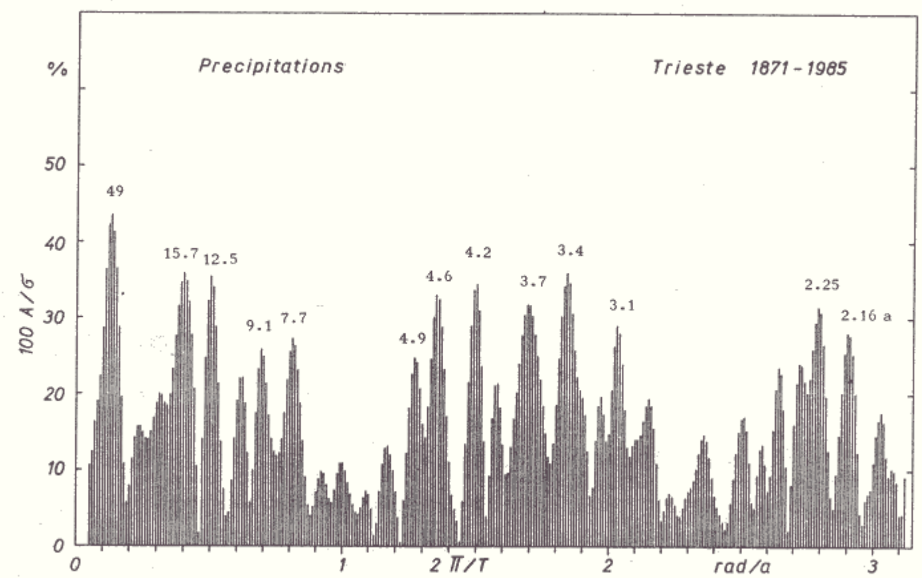

Figure 4. Amplitude spectrum of the precipitations at Trieste (1871–1985). Periods in years exceeding 0.25 σ.

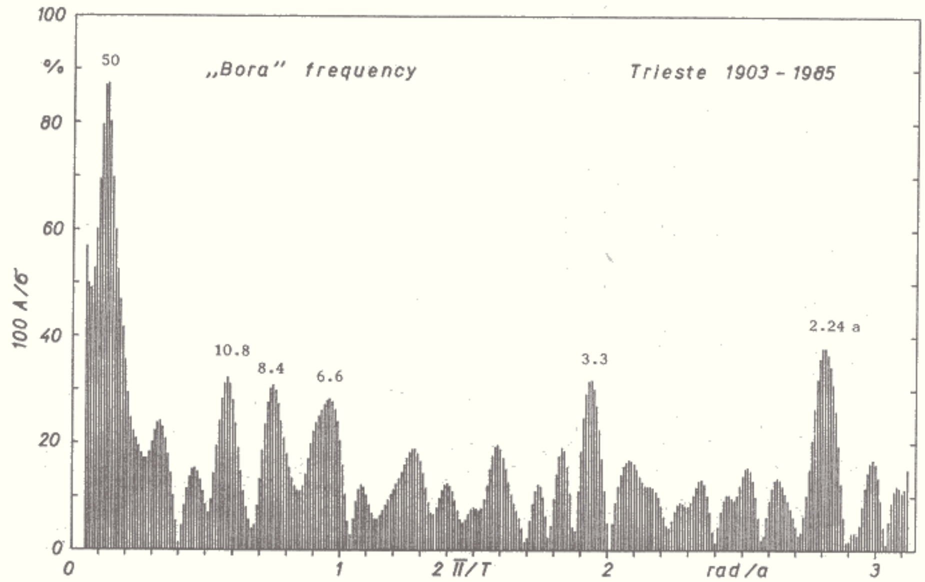

Figure 5. Amplitude spectrum of the „bora" frequency at Trieste (1903–1985). Periods in years exceeding 0.25 σ.

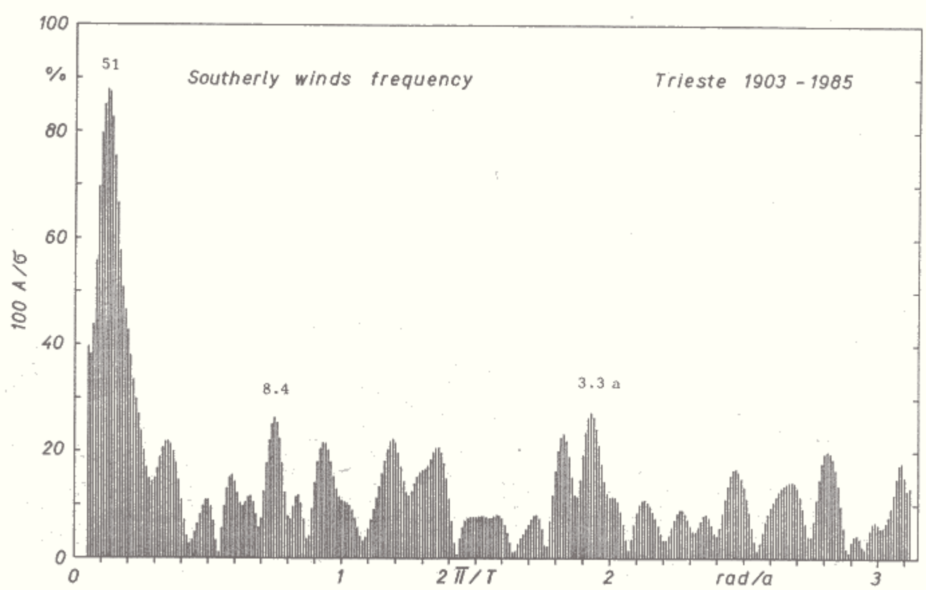

Figure 6. Amplitude spectrum of the southerly winds frequency at Trieste (1903–1985). Periods in years exceeding 0.25 σ.

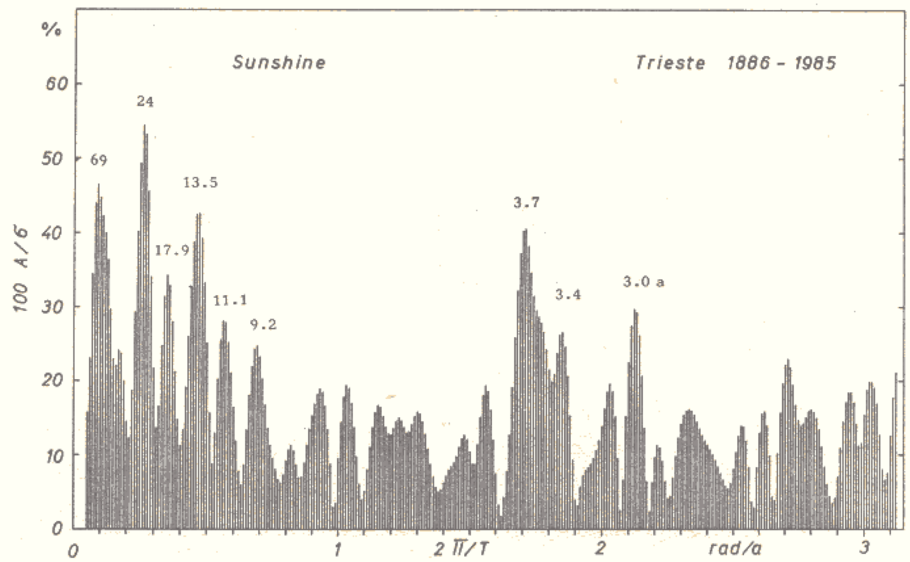

Figure 7. Amplitude spectrum of the sunshine duration at Trieste (1886–1985). Periods in years exceeding 0.25 σ.

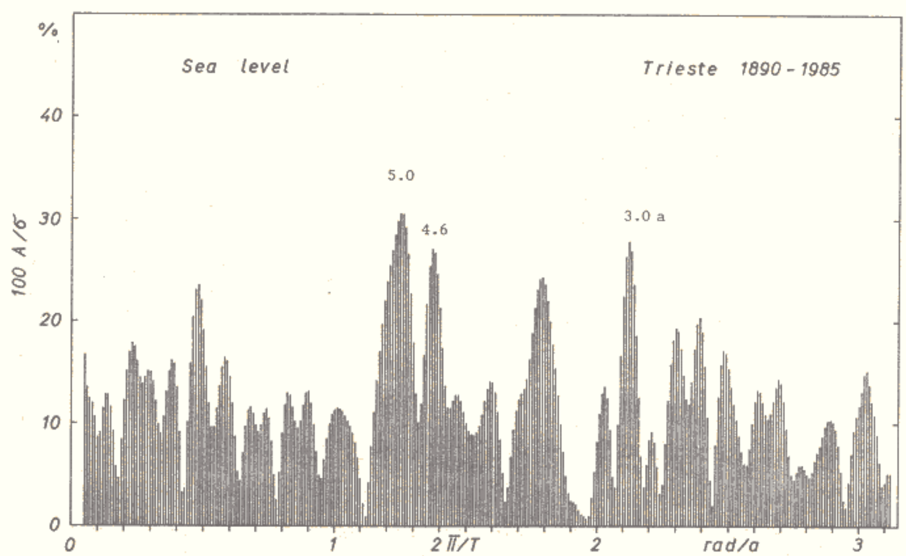

Figure 8. Amplitude spectrum of the sea level at Trieste (1890–1985). Periods in years exceeding 0.25 σ.

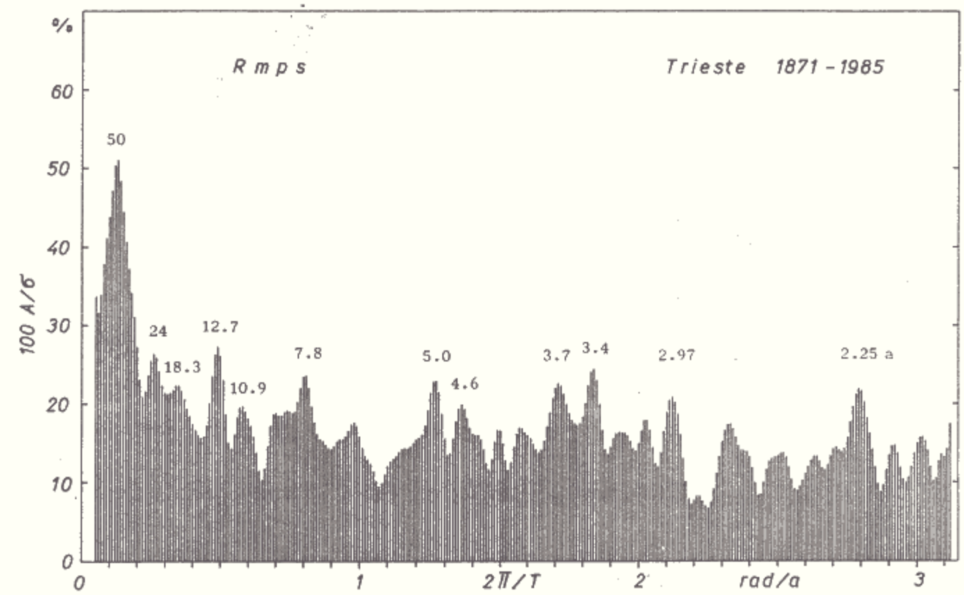

Figure 9. Root mean power spectrum of the climatic elements (1–8) of Trieste (1871–1985). Periods in years exceeding 0.20 σ.

(pressure, temperature, humidity and precipitations), 10.9 a (temperature, sunshine and bora), 7.8 a (pressure, temperature and precipitations), 4.96 and 4.62 a (pressure, precipitations and sea level), 3.67 a, 3.42 a (temperature, precipitations and sunshine) 2.97 a (36–37 months), mainly in pressure, sunshine and sea level and, finally, 2.25 a (27 months), mainly present in precipitations and bora.

These characteristic periods of course resemble those commonly found by several authors in geophysical records. We report, for example, periods found by Brier (1979) by analysing sunspot numbers: 11.08, 24.07, 59.03 and 83.1 years. Mörth and Schlamminger (1979) computed the synodic periods of pairs and couples of pairs of planets affecting the distribution of angular momentum in the solar system; synodic periods are 45.36 a (between Saturn and Uranus), 22.46 a (Jupiter-Saturn and Uranus-Neptune), 19.85 a (Jupiter-Saturn), 3.79 a (Mars-Ceres and Jupiter-Saturn), 3.22 a (Venus-Earth and Mars-Ceres), 3.18 a (Mars-Ceres) and 2.13 a (Earth-Mars). Remember that the moon nodal period, well known in tidal analysis, is 18.61 a.

Periods about 2.16–2.27 a (26–27 months) are known in the literature as "quasi-biennial oscillations". These have been found by Reed et al. (1961) in the stratosphere, by Shah and Godson (1966) in zonal wind and temperature and by Hamilton (1983) in the atmospheric pressure. Quasi-biennial periods in the climatic series of Trieste are particularly evident for air temperature, precipitations and bora duration.

Table 2. Periods in years of the spectral peaks exceeding 0.25 σ (climatic elements 1–8) and 0.20 σ (root mean power spectrum).

1	2	3	4	5	6	7	8	rmps
		81				69		
			49	50	51			50
		37						
	23.6					24.0		24.1
		20.2						
						17.9		18.3
	15.9		15.7					
						13.5		
12.7	12.8	12.5	12.5					12.7
	11.1			10.8		11.1		10.9
9.1			9.1			9.2		
				8.4	8.4			
7.7	7.8		7.7					7.8
7.21								
				6.57				
	6.44							
	5.49							
4.97			4.94				5.02	4.96
4.62			4.64				4.58	4.62
	4.39	4.44						
			4.20					
	3.89							
			3.71					
						3.68		3.67
3.63								
3.45								
	3.40		3.41			3.40		3.42
				3.25	3.26			
	3.15							
			3.09					
2.96						2.96	2.96	2.97
2.71								
	2.27							
			2.25	2.24				2.25
			2.16					

3. The linear trends

The computation of the linear trend of a time series is biased by the presence of cyclic components, mainly by those with longer periods. In order to avoid this, the set of all significant harmonic components has been subtracted from the climatic series (1–8) before applying the linear regression.

The procedure is the same as that adopted by Stravisi and Ferraro (1986) for the analysis of the sea level at Trieste.

The climatic series is fitted by a linear trend (α, λ) plus N harmonic components:

$$\varphi(t) = \lambda + \alpha t + \sum_{n=1}^{N} A_n \cos\ 2\pi\,(t - f_n)/T_n. \tag{1}$$

With the aid of the amplitude spectra represented in Fig. 1–8 and working on detrended data, the amplitude and phase (A_1, f_1) of the HC of larger period T_1 are computed by means of least squares best fits (Stravisi 1986 c) with a resolution of 0.01 a; the first HC is removed, the second HC is fitted on the residual series and so on. The procedure stops when the root mean square difference between the original data and the best fit becomes smaller than the desired value. At this point, the synthesis of N HC is subtracted from the observed data and the linear trend (α, λ) is computed. This method is to some extent subjective, but the rms difference between the climatic series and (1) is known and can be reduced by adding more HC. Table 3 reports, for each climatic element (1–8), the

Table 3. Standard deviations σ of the time series (1–8) and results of the best fits by means of harmonic components: number N of HC (number of HC with period greater than 10 a); minimum and maximum amplitudes A_n, A_x; period in years of the larger HC; root mean square error of the best fit.

Climatic element		σ	N	A_n	A_x	A_x/σ	T/a	rmse	rmse/σ
1) Pressure	hPa	1.06	39 (9)	0.08	0.42	0.40	2.71	0.19	0.18
2) Temperature	C	0.52	33 (6)	0.06	0.22	0.42	7.81	0.15	0.30
3) Rel. humidity	%	3.0	17 (5)	0.5	1.9	0.64	37.99	1.3	0.41
4) Precipitations	mm/d	0.55	27 (6)	0.07	0.25	0.44	50.18	0.16	0.29
5) Bora frequency	%	5.6	26 (6)	0.5	5.0	0.89	50.06	0.9	0.16
6) S winds freq.	%	4.9	22 (5)	0.4	4.6	0.92	49.62	0.8	0.17
7) Sunshine	%	3.7	29 (6)	0.4	1.9	0.50	23.52	0.9	0.23
8) Sea level	cm	5.2	26 (7)	0.6	1.6	0.31	4.99	0.9	0.17

standard deviation σ, the number N of HC (in parentheses the number of HC with periods greater than ten years), the minimum and maximum HC amplitudes, the period in years of the major component and the root mean square error of the best fit. The climatic series are represented in Figs. 10–16: the linear trends and the best fits (1), in which HC with periods less than ten years have been removed, are shown.

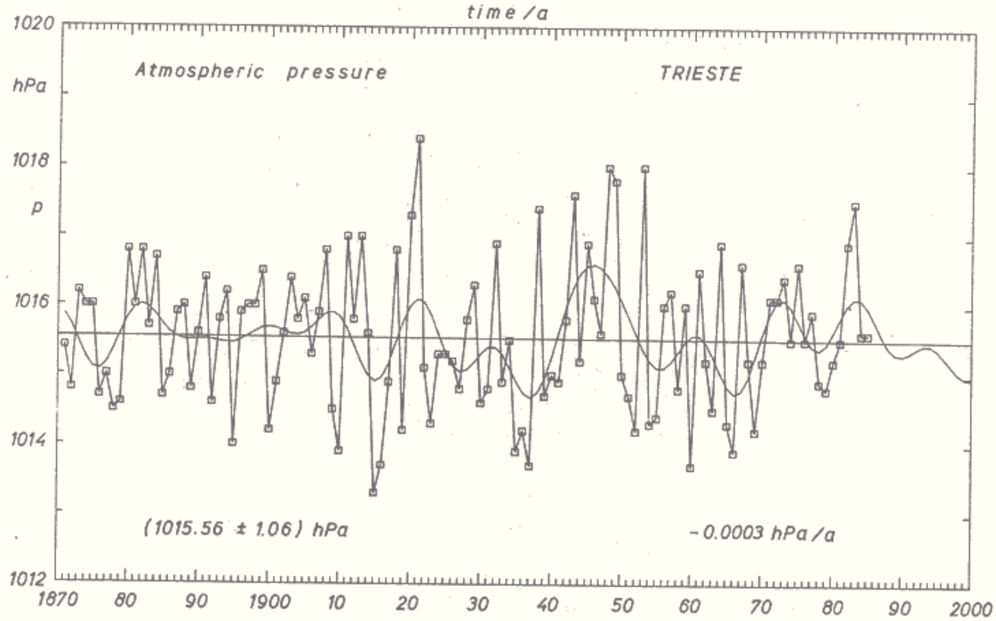

Figure 10. Time series of the atmospheric pressure at Trieste (1871–1985). Linear trend and best fit with harmonic components with periods greater than ten years.

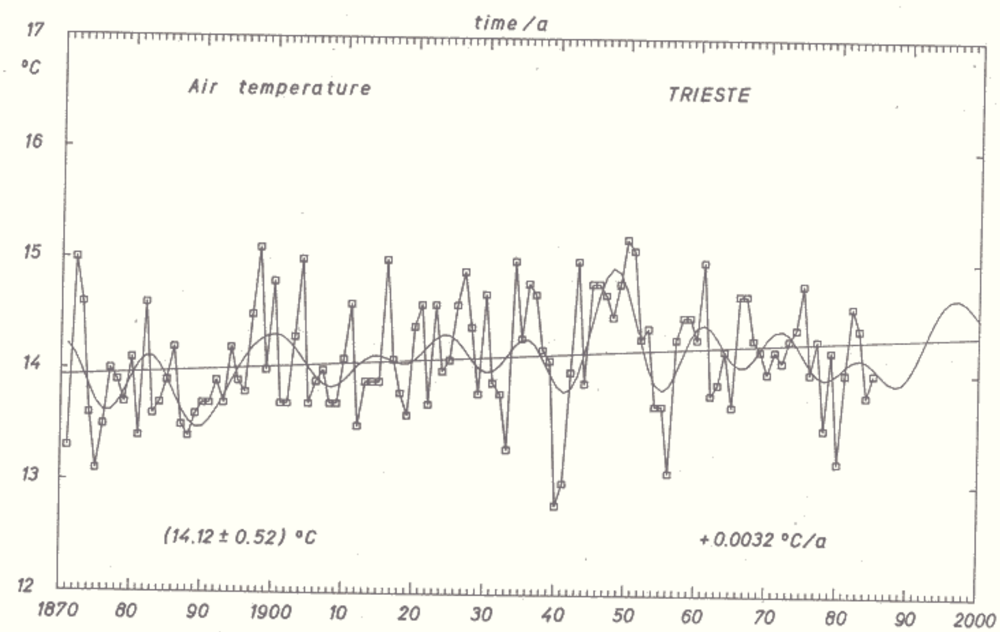

Figure 11 Time series of the air temperature at Trieste (1871–1985). Linear trend and best fit with harmonic components with periods greater than ten years.

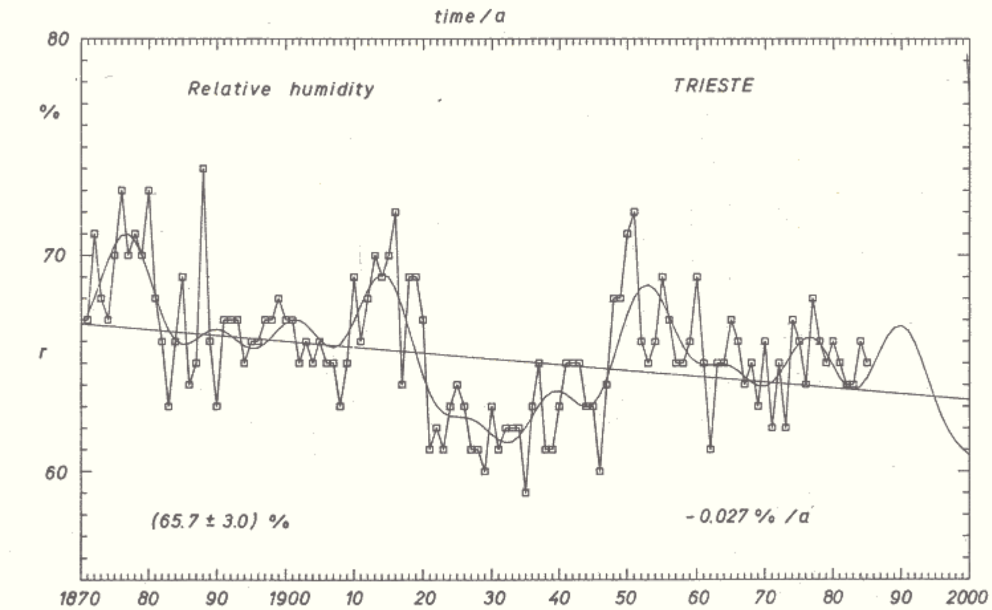

Figure 12. Time series of the relative humidity at Trieste (1871–1985). Linear trend and best fit with harmonic components with periods greater than ten years.

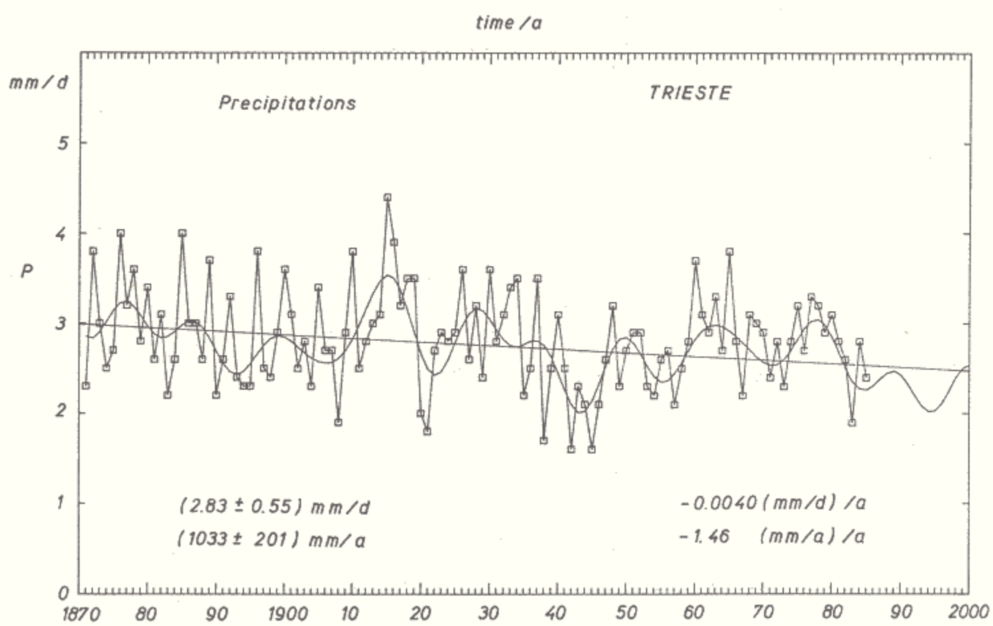

Figure 13. Time series of the precipitations at Trieste (1871–1985). Linear trend and best fit with harmonic components with periods greater than ten years.

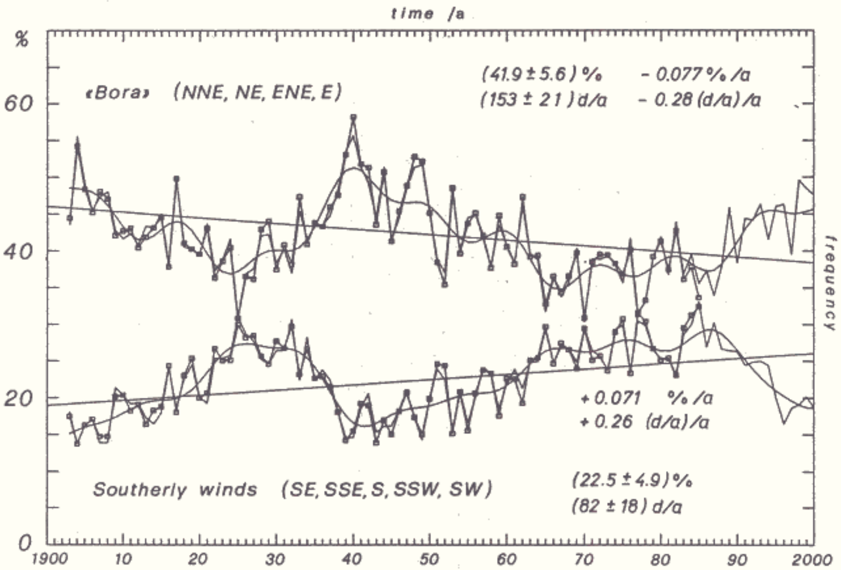

Figure 14. Time series of the „bora" and southerly winds frequencies at Trieste (1903–1985). Linear trends and best fits with harmonic components with periods greater than ten years.

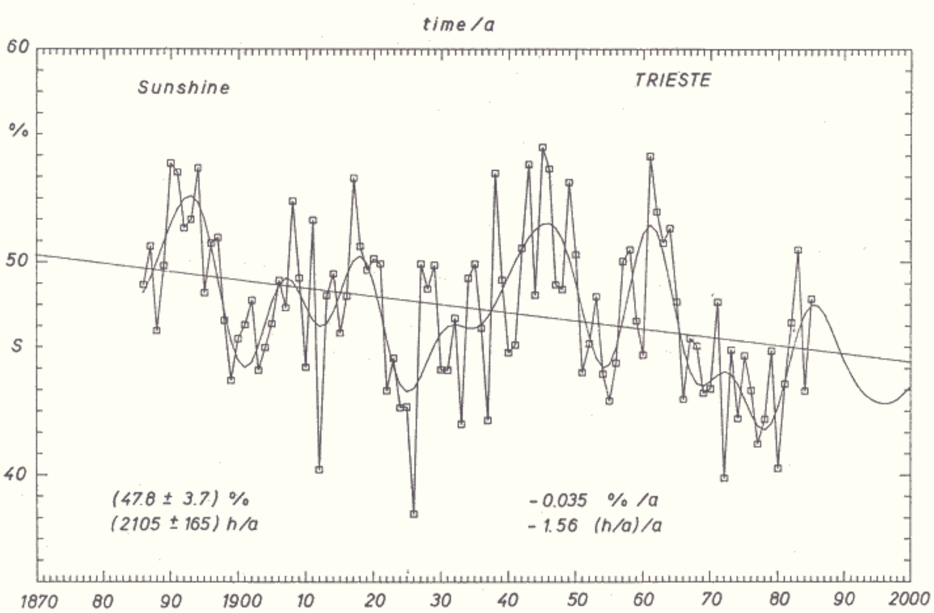

Figure 15. Time series of the sunshine at Trieste (1886–1985). Linear trend and best fit with harmonic components with periods greater than ten years.

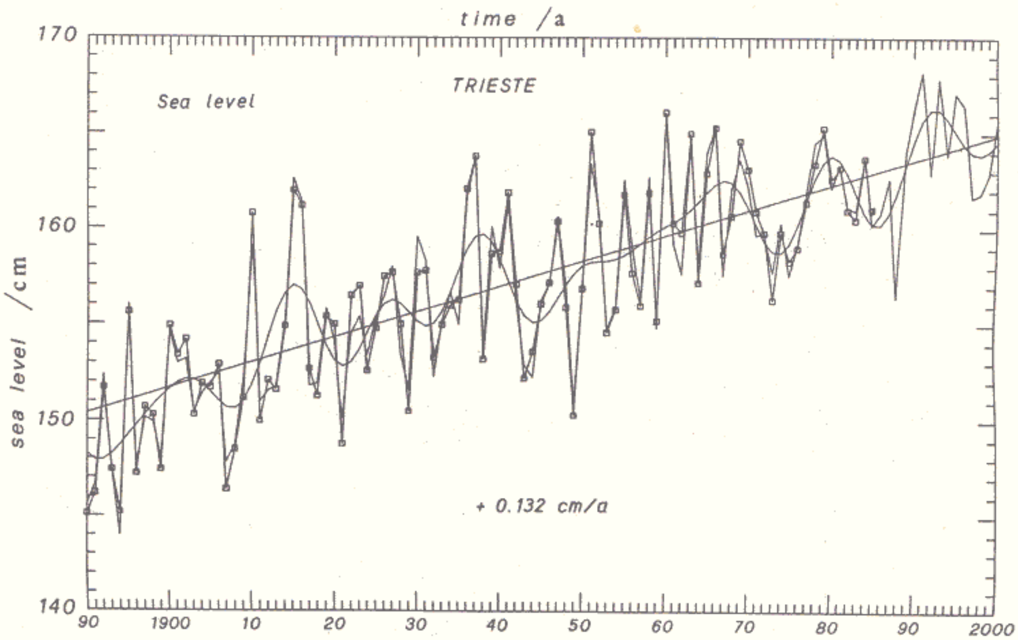

Figure 16. Time series of the sea level at Trieste (1890–1985). Linear trend and best fit with harmonic components with periods greater than ten years. (From: Stravisi and Ferraro, 1986).

The fitting functions are prosecuted till 2000 AD in order to help approximate "forecast" of each climatic element. The time rates of change λ, together with the mean values and the standard deviations of the climatic series, are indicated.

4. Comments

The main results concerning the climatic changes at Trieste during the past century can be summarized as follows.

1) The atmospheric pressure (1015.56 ± 1.06 hPa) is almost stationary; components with periods of 5.0 and 2.71 years have amplitudes greater than 0.4 hPa.

2) The air temperature (14.12 ± 0.52°C) increased at the rate of + 0.32°C/100 a; there is one component, 7.8 a, exceeding 0.2°C.

3) The relative humidity (65.7 ± 3.0%) decreased at the rate of – 2.7%/100 a: long period components (81 and 38 years) with rather large amplitudes (1.6 and 1.9% respectively) are present.

4) Precipitations (2.83 ± 0.55 mm/d, or 1033 ± 201 mm/a) decreased at the rate of – 0.40 mm/d = – 146 mm/a per century; main periodicities, exceeding 0.2 mm/d, are 50, 16, 4.2 and 3.7 years.

5, 6) The "bora" and southerly winds frequencies (41.9 ± 5.6% and 22.5 ± 4.9%, corresponding to 153 ± 21 d/a and 82 ± 18 d/a respectively) present almost opposite variations: linear trends are respectively – 7.7 and + 7.1%/100 a corresponding to – 28 and + 26 d/a per century. A harmonic wave with a period of 50 years, an amplitude of about 5% (18 d/a) characterizes, with opposite phases, the main wind flows at Trieste.

7) The sunshine duration (47.8 ± 3.7%, corresponding to 2105 ± 165 h/a) decreased at the rate of – 3.5%/100 a (– 156 h/a per century), with main periodicities of 70, 24, 13.6 and 3.7 a and amplitudes 1.7, 1.9, 1.6 and 1.5% (76, 82, 71, 67 h/a) respectively.

8) The sea level (156.5 ± 5.2 cm above ZIT) increased 13.2 cm/100 a, slightly less than the world ocean (+15.9 cm/100 a, as computed by Mosetti, 1975); main periods are 5.0 and 3.0 years (1.6 and 1.4 cm).

Comments to the results above are the following. More sophisticated statistical techniques should be used, as a rule, in order to detect trends and periodicities; the length of the time series does not represent a problem, in the case of Trieste, because monthly, daily or even hourly values are at disposal. A simple method, based on annual values, has been used here because, in our opinion, it is sufficient to depict, at this stage, the main characteristics of the climatic changes at Trieste during the last century. Further improvements shall necessary pass through (i) a digitalization of large data sets and (ii) a thorough and extensive revision of each time series.

The statistical significance of the spectral peaks should be better discussed. From a geophysical point of view, the "reality" of some peaks can be inferred a posteriori, since almost the same periods are found in different climatic elements and also in the planetary motions.

Future research should point toward a better comprehension of the solar system as a whole. There are indeed indications that the planetary motions, producing changes in the gravitational field and in the distribution of angular momentum, affect the earth climate both directly and through a modulation of the solar activity.

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