Preliminary Results of Extreme Sea Level Events from Cananeia, Brazil,
(Lat 25 1' ; Long 47 55)

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Abstract

Sea level data from the station of Cananeia (Lat 25 1'.0 ; 47 55.5' Long) Brazil, were analyzed for the extreme values . Analyses were conducted bearing in mind the determinism of the astronomical tides and the probabilistic nature of the meteorological action on the sea level. Sea level predicted values of astronomical origin were produced to estimate those of meteorological origin. For that, the difference between the predicted and the actually measured sea level were calculated. The difference was taken as a residual of mainly meteorological nature and used to determine its maxima and minima extremes. Estimates of maxima and minima extremes were also made in terms of joint distribution of met and predicted sea level data. The procedures were applied to hourly annual series covering a period of 50 years of Cananeia. This allowed the analysis of the annual and decadal variability of the maxima and minima of met/ocean extreme values. Other analyses were extended, for comparison, to hourly series of sea level data, with other lengths, (series of San Francisco, Honolulu, Atlantic City, Balboa and Vigo) provided by the University of Hawaii Sea Level Center. Results indicate that the great majority of the distributions obey the Gumble, Fréchet and Weibull tails. There were some discrepancy in that tidal staff that appears to be related with the way the tides are filtered from the actual Cananeia data. Fisher test applied to the spectra identified Fourier peaks, in the range of the decadal and intradecadal periods, as compared to results of other known spectral analyses. Average level and period of returns, taken from the joint distribution functions, for the minima and maxima gave values of 20cm and 200 years for the minima and 320 cm (relative to the zero of the tidal staff) and 200 years for the maxima.

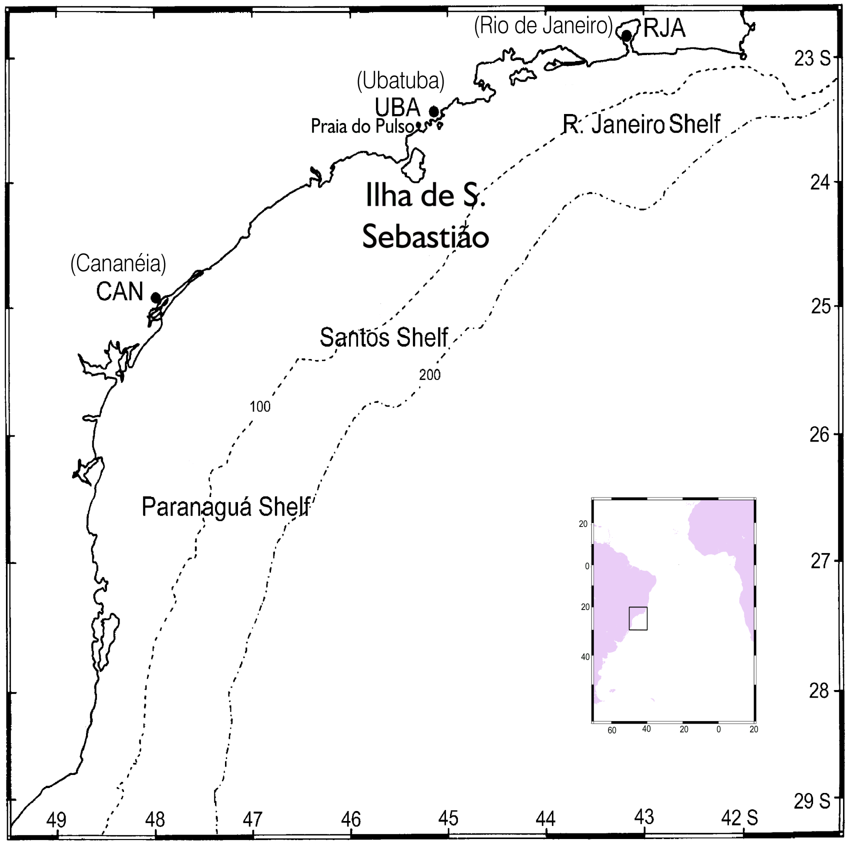
Introduction

. The sea level data of Cananeia (Lat 25 1'.0 ; 47 55.5‘Long), in the Southeastern coast of Brazil (Fig 1), was, in the past, analyzed by several authors for their interaction with the atmospheric and circulation parameters(Miniussi 1958, Johanessen ,1967,Leinebö , 1969,Miao, and Harari 1973), of the estuarine area, where the city is localized.

. Later, using a longer series, analyses, related to the long term variability of sea level, firmly established the decadal and intradecadal periods , as related to the ENSO action (Mesquita,Harari & Franca,1997). Since \then, the laws regulating the use of the Beach (Brazilian Law No 4760), on the sea level limits between the land and the ocean, bearing in mind the rapid Increase of the sea level, consequent to nowadays Global warming, were object of analyses (Mesquita et all, 2001).

. In fact, the increase of the sea level is a worring subject that is threatening the beaches of, perhaps, the entire Brazilian coast, with a rate of 40 cm/cty variation. Needless to say about the threats of the extreme values of the sea level, should the present sea level trend continues. As a follow up, this study deals with use of the early theory of Gumbell , Fréchet and Weibull as outlined in Coles (2001) and more specifically to the studies of Pugh and Vassie (1979) on the extreme values of the sea level. It only covers Cananeia, but it will be, hopefully, extended soon to the other ports of the Brazilian coast.

. Sea level data distributed by the University of Hawaii Center from Honolulu, Atlantic City, San Francisco Balboa and Vigo were other series similarly analyzed, as complementary comparative stations for statistical analyses, in the search for decadal and interdecadal variability of extremes of sea level.



Methods

- Tables I , II and III contains : a) te histogram of the predicted sea level, based on tidal constants estimated by tidal methods (Franco &Rock, 1971), from the actual sea level of each year under analyses; b) the histogram of the residual series obtained by filtering the actual sea level data from the predicted sea level values and c) the joint probability density of the residual series and the predicted sea level.
- The sea residual series is in fact, nowadays, a mixture of various anthropic contributors to sea level variability as : **eustatic variation** (variability of the water volume); the **steric variation** (thermal variation due to global warming); the halosteric variation (**haline variation** due to melting of polar ice), **crustal variation**, (vertical and horizontal motion of the Earth's crust), d) the **astronomical variation** (glaciations) and the **meteorological** nearly randomic variability (atmospheric pressure, wind waves, precipitation....).
- From Tables I, II and III, a Table IV of the extreme values of sea levels and the extreme values of the residual series were exposed for the obtainment of the distribution patterns of extreme values and anlyses for their decadal and intradecadal variability
- Analyses of annual hourly Cananeia data (50 years) were compared with similar analyses made on San Francisco (103),Balboa (92 years), Honolulu (102), Atlantic City (98 years) and Vigo (48 years) sea level data.

TABLE I

TIDAL STATION : CANANEIA LATITUDE: 25 1.0 S
INITIAL DAY: 1/ 1/1980 LONGITUDE: 47 56.0 W

PROBABILITY DENSITY OF THE PREDICTED TIDE

MÍNIMUM: - 89 cm DEVIATION ST : 34.18cm
MÁXIUM: 253 cm ASSIMETRY: 0.06
MEAN: 172.14 cm FLATNESS :-0.77

No.	z	NM+z	p(z)	F(z)	1-F(z)	FREQ.	HISTOGRAM
1	-80	92.14	0.00026	0.00263	0.99737	138	*
2	-70	102.14	0.00134	0.01600	0.98400	703	****
3	-60	112.14	0.00315	0.04747	0.95253	1654	********
4	-50	122.14	0.00554	0.10283	0.89717	2910	***************
5	-40	132.14	0.00751	0.17793	0.82207	3947	********************
6	-30	142.14	0.00836	0.26149	0.73851	4392	**********************
7	-20	152.14	0.00908	0.35228	0.64772	4772	************************
8	-10	162.14	0.01015	0.45382	0.54618	5337	***************************
9	0	172.14	0.01030	0.55681	0.44319	5413	***************************
10	10	182.14	0.01035	0.66031	0.33969	5440	***************************
11	20	192.14	0.00894	0.74975	0.25025	4701	************************
12	30	202.14	0.00728	0.82255	0.17745	3826	*******************
13	40	212.14	0.00605	0.88305	0.11695	3180	****************
14	50	222.14	0.00526	0.93564	0.06436	2764	**************
15	60	232.14	0.00437	0.97930	0.02070	2295	***********
16	70	242.14	0.00188	0.99806	0.00194	986	*****
17	80	252.14	0.00019	1.00000	0.00000	102	*

- Table I contains the histogram of 6 years of hourly **Predicted** sea level of Cananeia data. In this study every 1 year was used to estimate the year's constants .
- **Prediction** was based on tidal constants estimated by tidal analysis methods (Franco & Rock 1971), from the actual sea level series of each year under analyses.
- **Note,** in Table I, the Minimum and Maximum of predicted sea level extremes , the Mean and the Standard Deviation of the actual yearly sea data , which were taken to build the Matrix of Extremes, shown in Table IV.
- No=numer of bins. Z=size fo the bins.NM+z=annual sea level pluz z.P(z)=Probabilty of occurrence. F(z)=distribution.1-F(z)=inverse distribution. Freq.=anually number of occurrences and the Plot of the Histogram

TABLE II

- PROBABILITY DENSITY OF THE RESIDUAL SERIES
- MÍNIMUM : -67 cm DEVIATION: 21.96 cm
- MÁXIMUM: 96 cm ASSIMETRY: 0.63
- MEAN: -0.02 cm FLATNESS : 0.78

No.	z	NM+z	p(z)	F(z)	1-F(z)	FREQ.	HISTOGR
1	-70	-70.02	0.00001	0.00013	0.99987	7	
2	-60	-60.02	0.00016	0.00177	0.99823	86	
3	-50	-50.02	0.00089	0.01071	0.98929	470	
4	-40	-40.02	0.00217	0.03238	0.96762	1139	*
5	-30	-30.02	0.00696	0.10200	0.89800	3659	****
6	-20	-20.02	0.01461	0.24806	0.75194	7677	********
7	-10	-10.02	0.02029	0.45097	0.54903	10665	***********
8	0	-0.02	0.01932	0.6441	0.35586	10153	**********
9	10	9.98	0.01381	0.7822	0.21779	7257	*******
10	20	19.98	0.00858	.86804	0.13196	4511	*****
11	30	29.98	0.00582	0.92626	0.07374	3060	***
12	40	39.98	0.00387	0.96495	0.03505	2034	**
13	50	49.98	0.00183	0.98330	0.01670	964	*
14	60	59.98	0.00090	0.99226	0.00774	471	
15	70	69.98	0.00037	0.99593	0.00407	193	
16	80	79.98	0.00026	0.99850	0.00150	135	
17	90	89.98	0.00014	0.99992	0.00008	75	
18	100	99.98	0.00001	1.00000	0.00000	4	

-**Table II** countains the histogram of the hourly values of the **residual series** obtained by filtering the actual sea level data from the predicted sea level values for a given year (say 1955) over the 50 years actual sea level series of Cananeia .

-The **residual series** is in fact, nowadays, a mixture of various anthropic contributors to sea level variability as :1) **eustatic variation** (variability of the water volume);2) the **steric variation** (thermal variation due to global warming);3) the halosteric variation (**haline variation,** (melting of polar ice), 4) **crustal variation**, (vertical and horizontal motions of the Earth's crust), 5) the **astronomical variation** (glaciations) and 6) the **meteorological** nearly randomic action on sea level (atmospheric pressure, wind, waves, precipitations....)

-**Note** the minimum,maximum,mean, standard deviaton values , which were taken to build the Matrix of Extremes, shown in Table IV.

- # TABLE III

JOINT PROBABILITY DENSITY

No.	z	p(z)	F(z)	1-F(z)	RET.PER	Prob. Density
1	-150	0.000000	0.000000	1.000000	54.409938	
2	-140	0.000001	0.000006	0.999994	2.960293	
3	-130	0.000005	0.000056	0.999944	0.339862	
4	-120	0.000024	0.000291	0.999709	0.065304	
5	-110	0.000085	0.001146	0.998854	0.016603	
6	-100	0.000263	0.003772	0.996228	0.005044	*
7	-90	0.000670	0.010469	0.989531	0.001817	*
8	-80	0.001421	0.024677	0.975323	0.000771	***
9	-70	0.002545	0.050126	0.949874	0.000380	*****
10	-60	0.003923	0.089355	0.910645	0.000213	********
11	-50	0.005341	0.142761	0.857239	0.000133	***********
12	-40	0.006633	0.209092	0.790908	0.000091	*************
13	-30	0.007725	0.286344	0.713656	0.000066	***************
14	-20	0.008578	0.372122	0.627878	0.000051	*****************
15	-10	0.009099	0.463117	0.536883	0.000041	******************
16	0	0.009182	0.554935	0.445065	0.000043	******************
17	10	0.008803	0.642963	0.357037	0.000053	******************
18	20	0.008073	0.723689	0.276311	0.000069	****************
19	30	0.007152	0.795207	0.204793	0.000093	**************
20	40	0.006108	0.856286	0.143714	0.000132	************
21	50	0.004917	0.905451	0.094549	0.000201	**********
22	60	0.003623	0.941680	0.058320	0.000326	*******
23	70	0.002424	0.965922	0.034078	0.000558	*****
24	80	0.001505	0.980971	0.019029	0.001000	***
25	90	0.000897	0.989937	0.010063	0.001891	**
26	100	0.000511	0.995045	0.004955	0.003839	*
27	110	0.000266	0.997700	0.002300	0.008273	*
28	120	0.000127	0.998970	0.001030	0.018470	
29	130	0.000059	0.999561	0.000439	0.043328	
30	140	0.000028	0.999839	0.000161	0.118144	
31	150	0.000012	0.999961	0.000039	0.482636	
32	160	0.000004	0.999996	0.000004	4.379270	
33	170	0.000000	1.000000	0.000	128.823529	

Maximum 170 cm
MInimum: -150 cm

- Table III contains the **joint probability density** of the a) residual series and b) the predicted sea level sea level series for the year, say 1955, of the Cananeia sea level data. **Note** the retturn periods shown in the 6th column and the extreme **jpd** values at the **bottom of Table III**.

- From Tables I, II and III a **Table IV** of the extreme values of sea levels and the extreme values of the residual series were exposed for the obtainment of the distribution patterns of extreme values and analyses for their decadal and intradecadal variability

- Analyses of annual hourly Cananeia data (50 years) were compared with similar analyses made with Balboa (92 years), Honolulu (102years), San Francisco (103 years) Atlantic City (98 years) and Vigo (48 years) sea level data.

Table IV Matrix of Extreme Values of Cananeia

1st	2d	3d	4th	5th	6th	7th	8 th	9th	10th	11th	12th	13th
70	246	158.47	33.69	-51	61	-0.01	18.16	-140	140	50	92	1955
67	244	158.88	33.76	-57	67	0.02	18.58	-150	150	97	13	1956
79	247	158.41	33.66	-67	70	0.01	18.49	-150	150	13	191	1957
73	252	161.51	34.10	-49	63	-0.02	18.48	-140	140	97	11	1958
84	245	162.34	33.86	-52	68	0.00	19.29	-130	140	5	13	1959
75	253	165.34	34.16	-47	77	0.07	18.03	-140	160	50	834	1960
71	249	166.26	34.24	-48	80	0.01	18.08	-150	150	700	14	1961
70	249	164.61	33.71	-61	79	-0.01	20.19	-150	150	63	29	1962
66	259	165.95	33.91	-64	100	0.00	18.44	-160	180	469	119	1963
66	260	165.59	34.30	-54	77	0.02	18.95	-150	160	17	85	1964
67	266	164.95	35.32	-53	63	-0.01	18.87	-150	150	61	12	1965
70	255	162.13	34.96	-60	95	0.01	18.66	-150	180	26	673	1966
76	254	162.34	33.85	-67	84	0.02	20.16	-160	160	1314	64	1967
59	260	159.65	35.45	-68	76	0.02	21.91	-170	170	121	234	1968
68	256	162.51	35.17	-78	70	-0.03	21.04	-170	150	72	16	1969
47	240	158.21	34.58	-76	90	0.07	20.84	-190	160	486	14	1970
52	260	162.90	35.36	-65	90	0.02	19.52	-170	180	14	547	1971
62	253	160.98	34.19	-70	74	0.01	19.02	-170	150	441	15	1972
74	248	163.96	34.24	-75	80	-0.01	17.46	-160	150	102	17	1973
68	250	164.41	35.03	-61	83	-0.02	19.00	-160	160	114	250	1974
56	263	160.42	36.25	-57	70	0.02	19.70	-160	160	40	164	1975
77	244	160.60	34.30	-59	69	0.01	18.81	-140	140	17	8	1976
77	253	163.77	35.45	-61	97	-0.02	19.15	-150	180	142	473	1977
74	253	166.19	35.45	-72	70	-0.01	18.85	-160	150	12	312	1978
73	257	169.70	35.32	-58	72	0.02	17.78	-160	150	1095	364	1979
80	256	172.12	34.77	-58	100	0.00	21.11	-150	170	32	27	1980
82	255	170.06	34.95	-54	80	-0.01	17.97	-140	150	48	16	1981
85	254	171.76	34.62	-71	77	0.00	19.62	-160	150	350	21	1982
87	263	176.34	35.09	-66	79	0.01	19.75	-160	160	772	380	1983
87	267	175.63	35.00	-53	72	-0.01	18.81	-140	150	10	93	1984
81	266	172.05	35.24	-54	83	-0.02	18.98	-140	160	5	12	1985
82	267	174.82	35.21	-53	79	0.00	19.35	-140	160	5	46	1986
78	258	177.48	34.38	-63	84	0.01	19.21	-160	150	32	6	1987
63	259	171.16	35.31	-63	95	-0.01	20.94	-170	170	292	101	1988
66	263	169.71	35.07	-45	90	0.07	18.63	-150	170	398	127	1989
79	266	172.94	34.88	-65	80	0.02	19.10	-160	160	243	43	1990
75	258	169.58	35.06	-63	75	0.02	19.58	-150	150	6	49	1991
79	256	172.80	34.81	-58	86	-0.01	20.41	-150	160	93	46	1992
90	262	175.65	34.74	-60	68	-0.01	19.08	-150	150	604	343	1993
86	269	173.34	35.05	-59	77	0.06	18.79	-150	170	37	51	1994
78	262	172.30	35.50	-56	82	0.03	18.50	-155	171	120	240	1995
75	254	171.23	35.68	-53	98	-0.02	18.13	-150	170	215	14	1996
78	256	172.33	35.12	-67	77	-0.01	19.12	-160	150	31	151	1997
81	265	177.01	35.06	-73	70	0.01	18.01	-170	150	292	224	1998
80	263	176.36	35.04	-92	216	0.00	21.09	-160	155	300	100	1999
90	260	175.78	35.17	-59	79	-0.02	18.30	-150	150	625	11	2000
76	272	176.24	35.72	-57	91	-0.01	18.19	-160	180	324	1877	2001
92	271	179.69	34.81	-81	90	0.02	18.76	-170	170	136	110	2002
97	272	184.98	35.22	-87	144	0.00	21.11	-165	155	200	50	2003
82	265	179.89	35.02	-61	63	-0.01	19.86	-160	140	1501	62	2004

Table IV was built with extreme values of Cananeia given in Tables I, II and III. Each line of the Table reffers to the year shown in the last column.

-In the first, second, third and fourth columns are shown, respectively, the annual values of minima and maxima, (relative of the zero of the rule) of predicted sea level extremes, the mean and the standard deviation of the actual sea level data, taken from the Table I.

-In the fifith, sixth, seventh and eith columns are the annual values of the minima, maxima, mean of the extremes and the standard deviation of the residual series, taken from Table II.

-In the nineth, tenth, eleventh and twelveth columns are shown the annual minima and maxima extremes relative to the mean of the joint probability of sea level, the period of return of the minima and the period of return of the maxima etremes of the residual series, taken from Table III.

Note that although calculated from one year of data the annual minima and maxima values of the return period vary very much from year to year.

Histograms of Extreme Values

- From Table IV the histograms of each column were estimated as shown in the Figure for 50 years of Cananeia hourly data.
- Similar Tables were prepared for the Balboa, Honolulu, Atlantic City, Vigo and San Franciso values of extremes.
- The shape of the tails of similar histograms, as the one seen in the figure, of all ports studied are summarized in Table V.

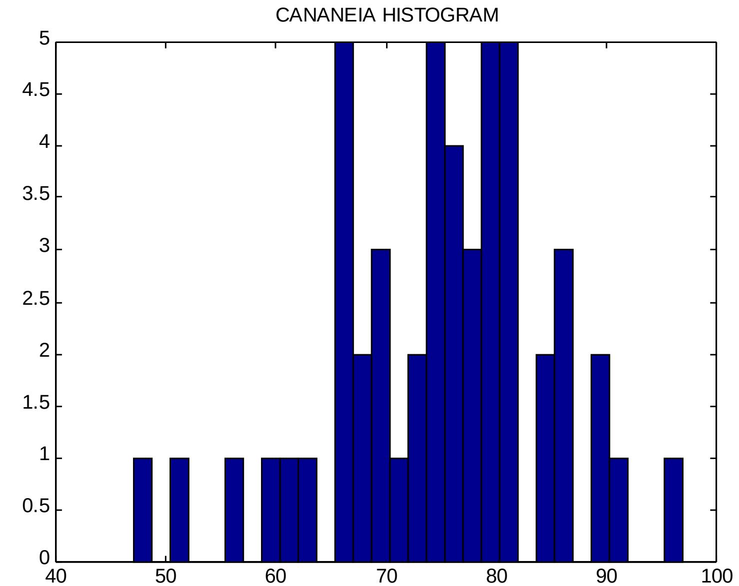


FIG 1 - BINS OF MINIMA EXTREMES OF PREDICTED SEA LEVELS

Table V - Histograms Tails

Port	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th
Balboa	right	left	right	mix	left	right	mix	right	left	right
Cananeia	left	left	right	mix	left	right	mix	right	left	right
S Francisco	right	right	right	mix	left	right	mix	right	left	right
Honolulu	left	left	left	mix	left	right	mix	right	left	right
AtlanCity	left	left	right	mix	left	right	mix	right	left	right
Vigo	right	right	right	mix	left	right	mix	right	right	left

- Table V shows the **visual** aspect of the histograms,regarding their shape, built with data of the Matrix of Extremes for the port of Cananeia, in comparizon with Balboa (Panama), S Francisco (USA), Honolulu(USA), Atlantic City (USA) and Vigo (Spain) data.
-
- The minima and maxima extremes (1st and 2d) , of predicted sea level seem not well repeated by all ports as well as the actual mean sea level (3d) of all places, in which San Francisco is to the right..
- The 4th colum shows that the std deviation of sea level of all ports have a mixed sort of distribution in all ports.
- While the 5th 6th , 7th and 8th columns ,for the minima , maxima, mean and std deviation of extremes of residuals (say meteorological) of all ports are visually very much alike.
- Similar result is obtained for the joint distribution of predicted sea level and meteorology minima and maxima extremes of all ports (9th and 10th),but Vigo, including the port of Cananeia.
- These results are preliminary as they depend on how the tidal constants are calculated.

Series of Extreme Values of all columns of Table VI, for Cananeia, and of all columns of silimar tables of all other ports were spectrally analised for the determination of the most prohiminents periods of variability as in the Figure.

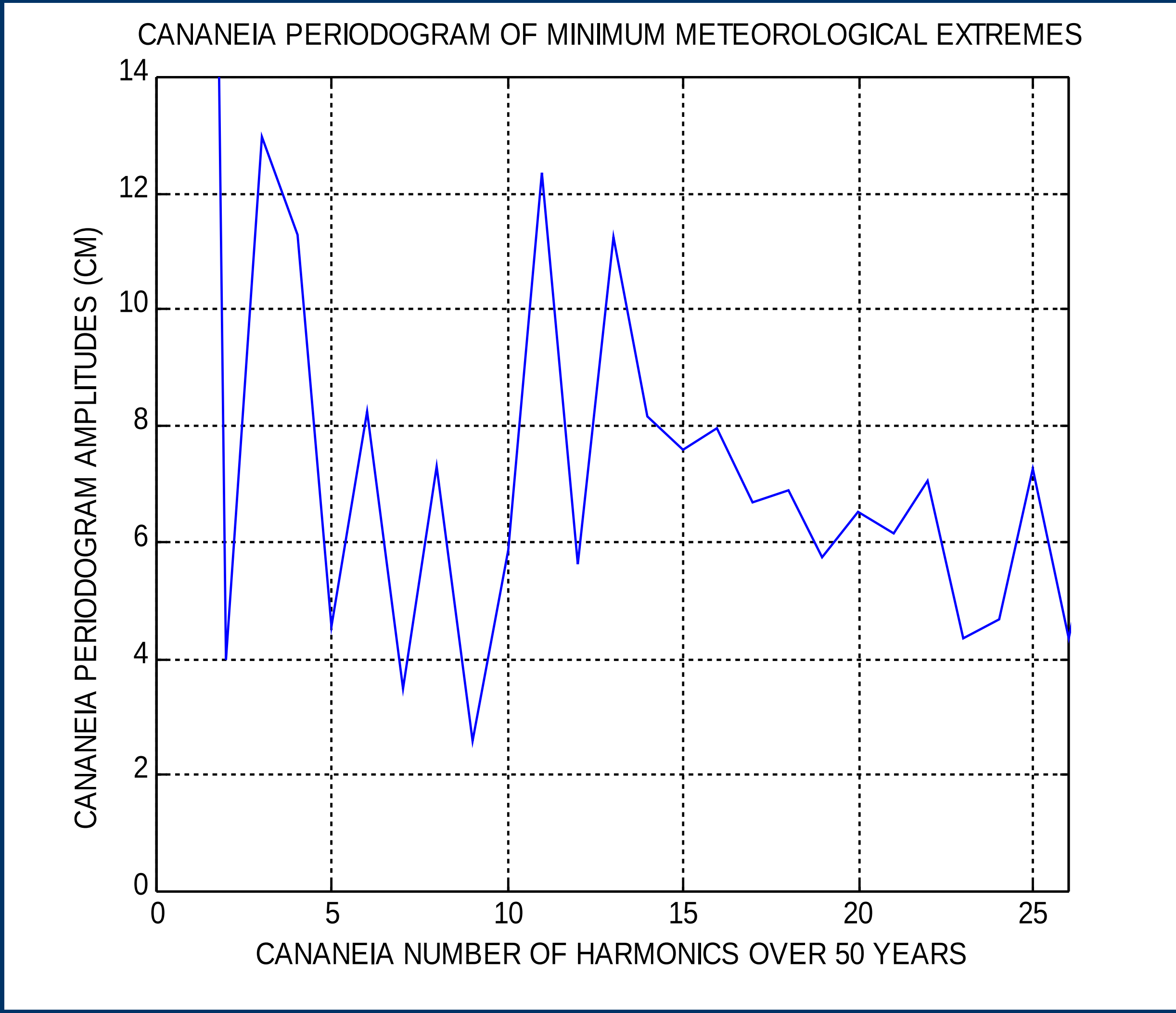


Table VI – Cananeia Harmonics that passed the Test of Fisher

No Har	Period	Amplit	Test	Fisher	
1.0000	50.0000	8.3262	0.3482	0.1259	
2.0000	25.0000	5.1740	0.2063	0.1294	
6.0000	8.3333	4.6240	0.2076	0.1332	First
3.0000	16.6667	3.5430	0.1538	0.1373	
15.000	3.3333	3.5249	0.1799	0.1416	
1.0000	50.0000	5.2521	0.2340	0.1259	
3.000	16.6667	4.7531	0.2502	0.1294	2d
4.0000	12.5000	3.1066	0.1425	0.1332	
1.0000	50.0000	6.9555	0.5439	0.1259	
3.0000	16.6667	3.4762	0.2979	0.1294	
5.0000	10.0000	2.6546	0.2474	0.1332	
4.0000	12.5000	1.8126	0.1533	0.1373	3d
10.0000	5.0000	1.7627	0.1712	0.1416	
6.0000	8.3333	1.5651	0.1628	0.1463	
8.0000	6.2500	1.3919	0.1538	0.1514	
1.0000	50.0000	0.4135	0.2368	0.1259	4th
2.0000	25.0000	0.3580	0.2325	0.1294	
2.0000	25.0000	6.7126	0.2331	0.1259	
10.0000	5.0000	6.1230	0.2530	0.1294	5th
3.0000	16.6667	5.0955	0.2345	0.1332	
12.0000	4.1667	5.0469	0.3005	0.1373	
14.0000	3.5714	12.9254	0.1582	0.1259	6th
13.0000	3.8462	0.0169	0.269	0.1259	7th
0	0	0	0	0	8th
0	0	0	0	0	9th
0	0	0	0	0	10th

Table VI countains the results of application of the periodogram test of Fisher (1929) to the 1st, 2d, 3d, ...,columns of Table IV.The series of annual data of each column were Fourier transformed and the peak amplitudes tested.

-No Har- is the periodogram harmonic number. – Period- is the periodicity of the harmonic (years). – Amplit- is the amplitude of the harmonic (cm). – Test- is the estimated harmonic Fisher value (g*).- Fisher- is the theoretical limiting value (g) of Fisher statistics. - If (g*) is greater than (g) the harmonic passes the test.

Fourier transforms of extreme values of actual sea level series and others similar to Table IV from ports of Honolulu, San Francisco, Atlantic City,Vigo and Balboa were also submmited to the test of Fisher and , contrary to what is seen in Table VI for the port of Cananeia, they all exhibited joint predicted sea level/ meteorological periodicities (9th and 10th blocks) that passed the test.

Table VII – Balboa Harmonics that passed the Test of Fisher

No Har	Period	Amplit	Test	Fisher	
20.0000	4.4000	10.5976	0.3877	0.0844	
1.0000	88.0000	6.7906	0.2599	0.0859	
5.0000	17.6000	4.1854	0.1334	0.0873	
2.0000	44.0000	3.7151	0.1213	0.0889	1st
40.0000	2.2000	3.6654	0.1344	0.0905	
3.0000	29.3333	3.0857	0.1100	0.0921	
21.0000	4.1905	2.8678	0.1068	0.0939	
16.0000	5.5000	2.5881	0.0974	0.0957	
20.0000	4.4000	12.4504	0.5811	0.0844	
19.0000	4.6316	4.1277	0.1525	0.0859	
5.0000	17.6000	3.7293	0.1469	0.0873	
7.0000	12.5714	3.1925	0.1262	0.0889	
6.0000	14.6667	3.0281	0.1299	0.0905	2d
18.0000	4.8889	2.9951	0.1460	0.0921	
11.0000	8.0000	2.3968	0.1095	0.0939	
28.0000	3.1429	2.3655	0.1198	0.0957	
40.0000	2.2000	2.3040	0.1291	0.0976	
32.0000	2.7500	2.0374	0.1159	0.0995	
36.0000	2.4444	1.8129	0.1038	0.1016	
1.0000	88.0000	4.0046	0.3258	0.0844	
2.0000	44.0000	2.0240	0.1234	0.0859	3d
7.0000	12.5714	1.8265	0.1324	0.0889	
5.0000	17.6000	3.9947	0.6809	0.0844	
4.0000	22.0000	1.6677	0.3719	0.0859	
2.0000	44.0000	1.1600	0.2865	0.0873	
1.0000	88.0000	0.9571	0.2733	0.0889	
6.0000	14.6667	0.7659	0.2409	0.0905	
3.0000	29.3333	0.6540	0.2314	0.0921	4th

- Note that series of all columns have decadal and
- Intradecal energy as Balboa is a longer series than
- Cananeia . Period: Years. Ampit: cm. No Har over 92 years

Continued

No Har	Period	Amplit	Test	Fisher	
7.0000	12.5714	0.6296	0.2789	0.0939	4th
9.0000	9.7778	0.4220	0.1739	0.0957	
22.0000	4.0000	0.3216	0.1222	0.0976	
8.0000	11.0000	0.2867	0.1106	0.0995	
23.0000	3.8261	0.2817	0.1201	0.1016	
18.0000	4.8889	0.2657	0.1215	0.1038	
19.0000	4.6316	0.2621	0.1345	0.1061	
16.0000	5.5000	0.2440	0.1347	0.1084	
6.0000	14.6667	7.9415	0.0885	0.0844	5th
23.0000	3.8261	10.2030	0.1535	0.0844	6th
1.0000	88.0000	9.9623	0.1729	0.0859	
42.0000	2.0952	7.1724	0.1083	0.0873	
23.0000	3.8261	0.0568	0.8079	0.0844	
21.0000	4.1905	0.0090	0.1066	0.0859	7th
24.0000	3.6667	0.0079	0.0912	0.0873	
1.0000	88.0000	0.4495	0.1324	0.0844	
4.0000	22.0000	0.4084	0.1260	0.0859	8th
19.0000	4.6316	0.3263	0.0920	0.0873	
2.0000	44.0000	0.3236	0.0997	0.0889	
20.0000	4.4000	10.8397	0.1010	0.0844	
28.0000	3.1429	9.9631	0.0949	0.0859	
3.0000	29.3333	9.1019	0.0875	0.0873	9th
6.0000	14.6667	8.9623	0.0930	0.0889	
5.0000	17.6000	8.4792	0.0917	0.0905	
1.0000	88.0000	10.4333	0.1273	0.0844	
23.0000	3.8261	10.1527	0.1381	0.0859	10th
20.0000	4.4000	7.8058	0.0947	0.0873	

- Note that series of all columns have decadal and
- Intradecal energy as Balboa is a longer series

Discussion

- **The Data**
- The original sea level data of all ports were interpolated by tidal prediction for the missing year of data, in order to produce the Matrix of Extremes from where all the present results were obtained.

- The results are very much dependent on how long is the series from where the tidal constants are calculated.They can be calculated by taken the entire set of years of hourly values of sea level, or for each year of the set. As the series from different ports have different time spans, it was adopted, as a general rule for the comparison, to reduce the computations of the tidal constants to one year basis.

- Other adopted rule was to work with undetrended original series of sea level from all ports, as they all experience a general increase, with different trends, along the years.
-
- **The Histograms**
- The statistical studies of extremes have identified three classes of extreme values distributions known as Gumble, Fréchet and Weibull distributions. The remarkable feature of this result is that the three types of extreme value distributions are the only possible limits , regardless of the distribution of the original data (Coles, 2001). The three types of limits that occorred have distinct forms of tail behaviour depending upon the original data distribution .

- To take this into consideration Table IV was prepared, where one can see that there is an almost similar behaviour of all meteorological series , with a few exceptions . The distribution of minima met extremes (5th column) have all a Fréchet type of tail, while the distribution of maxima extremes (6th column) have a Weibull type . This is also evident from the joint met/sea distributions (9th and 10th columns). The meteorological distributions of all ports for the standard deviations (7th column) have, in general, a sort of mixed profile, although not repeated in all histograms. That does not seem to be attributable to a Gumble type of distribution or Fréchet or Weibull .

- Discussion (continued)

The Fisher Tests

- The test of Fisher only accepts the amplitudes of the periodogram that are best for the Fourier fit to the data. It does not acertain that there is a physical cause of any particular spectral peak which passed the test. The physical causes for the periodicities must be sought by comparison with the results of other studies that have already interpreted them as, for example, in Mesquita, A. R. de. , Harari, J. & Franca, C. A. de S. (1997) for Cananeia.

The Level and Retturn Period of Cananeia

The joint distribution Pugh and Vassie (1979), of predicted sea level and meteorological extremes were calculated for every year. For each year they, sea level and meteorology, separately, originated extreme values of the sea level, which were well within the limits of variation of the sea data , while the joint sea and level return periods were very much variable and higher than expected.

- For that reason a sort of mean of the return period associated with a mean extreme level were calculated from data of columns 11 and 12 of Table IV , giving: 1) 320 cm for the maxima extreme and 200 years for the correspondent return period and 2) 20 cm, relative to the rero of the rule, and 200 years, respectively, for the minima extremes.

Conclusions

- Comparative analyses of extremes from 50 years of Cananeia sea level station and data from stations of Atlantic City (USA) (92), Balboa (Panama),(92), Honolulu (USA) (99), San Francisco (USA) (103)and Vigo (Spain)(48) showed similar Fréchet and Wiebull histograms for the joint sea level/ met distributions and also for the meteorological extremes. There were some difficulty to visually determine the kind of distribution for the standard deviations of the sea level and the std of meteorological distribution, that may be related with the determination of the tidal constants.

- The predicted minima and maxima sea level extremes , the actual sea level extremes of Cananeia and of all ports have variable Fréchet and Weibull distribution, which also seem to be related by the way the tidal constants were determined. This is noteceable in the std of the sea level extremes distribution , which in general is difficult to be certain if it is uniform or other.

- The joint sea/ met distribution of Cananeia extremes (maxima and minima), did not show spectral amplitudes which passed the Fisher text, as well as, the std of the mean meteorological extremes. However the extremes of the other tidal stations have periods that passed the test of Fisher, indicating the occurrence of decadal periodicities in the joint sea/met series of extremes .

- The estimated return periods and the corresponding level of return of Cananeia have average values of 200 years and 20 cm for the minima extreme and 320 cm, relative to the zero of the staff and 200 years for the maxima. The actual mean sea level is about 180cm.

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