Cananeia , Brazil - Lat 25, Extreme and Long Term Sea Level Values, Compared to Hawaiian and PSMSL Global Series

Afranio Rubens de Mesquita

Joseph Harari

Institute of Oceanography of University of Sao Paulo .

University City, Butanta . Sao Paulo, Brazil. CEP 05508-900.

ardmesqu@usp.br - http://www.mares.io.usp.br

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Abstract

- Fifty years of sea level data from Cananeia (Lat 25 1'.0 ; 47 55.5' Long) Brazil, were analyzed.
- The variability of the maxima and minima of met/ocean extremes were compared to series of San Francisco, Honolulu, Atlantic City, Balboa and Vigo, provided by the University of Hawaii Sea Level Center.
- The great majority of the sea level distributions have Gumble, Fréchet and Weibull tails. Fisher test identified Fourier decadal and intra decadal periods in all of them.
- Trend analyses of PSMSL series show that all Brazilian ports have positive trends.
- Plots of trends versus correlation bins of all ports, showed small standard deviations close to zero bin, up to the bin and greater absolute values of negative trends, than the positive ones. The highest negative and positive trend values occur geographically in many occasions close to each other.
- Trends of all series seem to be well distributed along the Latitudes and along the Longitudes. The mean distance of the discrete sea level data points, to the regression line, previously calculated, was taken as a measure of proximity of each series.
- An F function, exhibiting the product of these coefficients was defined, which had a tail distribution to the left. Global values of F, series of Cananeia included, in a plot against the trends, exhibited a Christmas Tree aspect and, as the length in years of the series in different plots, started to show two stems, one in the negative and the other in the positive side of the plot.
- For the longest series with more than 60 to100 years, the positive stem showed a straight line, pointing to 18 cm/cty, while the negative stem, along a curved like line, pointed to -58 cm/cty. Further analyses on these odd aspects are underway.

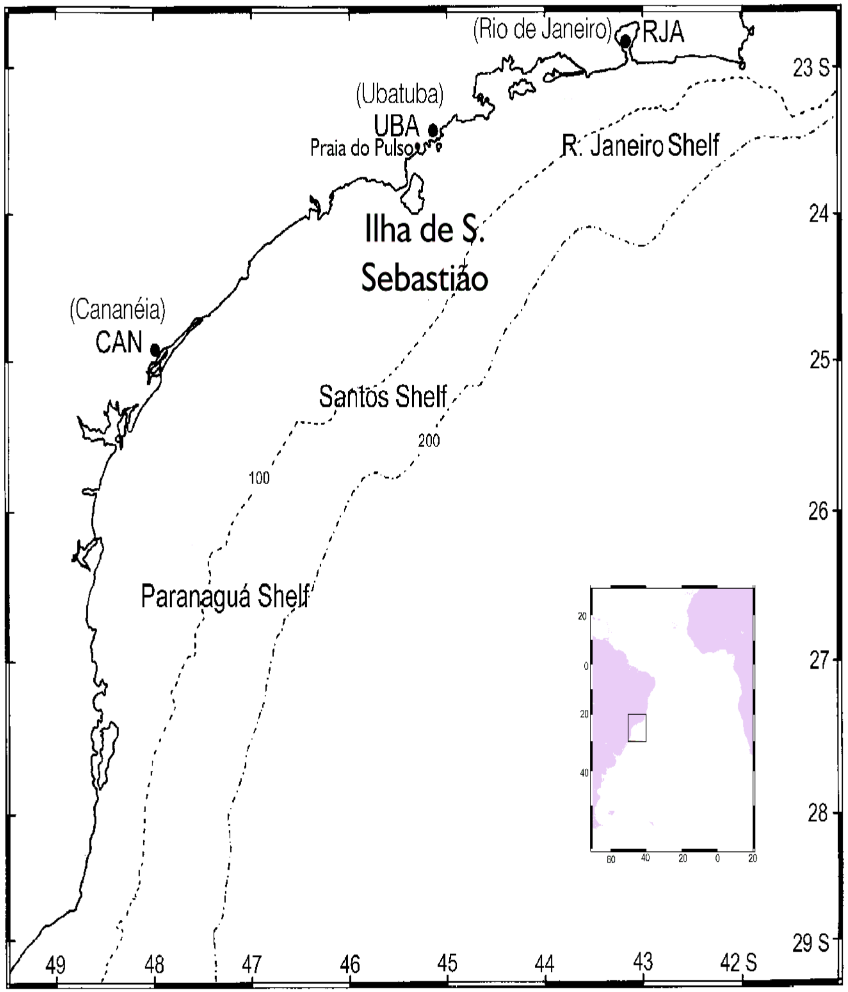
Introduction

.
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, analysed by several authors for their interaction with the atmospheric and circulation parameters (Miniussi 1958, Johanessen ,1967,Leinebö, 1969, Miao, 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 beachs 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



Methods

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

- levels and the extreme values of the residual series were exposed for the obtainement of the distribution patterns of extreme values and analyses for their decadal and intradecadal variability.See: Franco, A. dos S. , Mesquita, A. R. de, Harari, J.& França, C. A. de S. (2007).Preliminary Results of Extreme Sea Level Events from Cananeia Brazil . Afro America GLOSS News (2007).Edição 11(1) :12p. Ver www.mares.io.usp.br

- The sea level series were considered as a mixture of various 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....). See- Mesquita, A. R. de , C. A. de S. França, B. Ducarme, A. Venedikov, D. S. Costa, M. A. de Abreu, R. Vieira Diaz, D. Blitzkow, S. R. C. de Freitas, J. A. L. Trabanco (2005) Analysis of the mean sea level from a 50 years tide gauge record and GPS observations at Cananéia (São Paulo–Brazil .Afro America Gloss News. Edição 9(1). 1p.ver www.mares.io.usp.br – Laboratório MAPTOLAB.

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HAWAIIAN Series

Hourly Sea Level Data

Table A - 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 A was built with extreme values of Cananeia and .... 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, maxima, of predicted sea level extremes, the mean and the standard deviation of the actual sea level data.

-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.

-In the nineth, tenth, eleventh and twelveth columns are shown the annual minima and maxima extremes of the joint probability of sea level, the period of retturn of the minima and the period of retturn of the maxima etremes of the residual series.

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

Histograms of Extreme Values

- From Table A 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 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 B

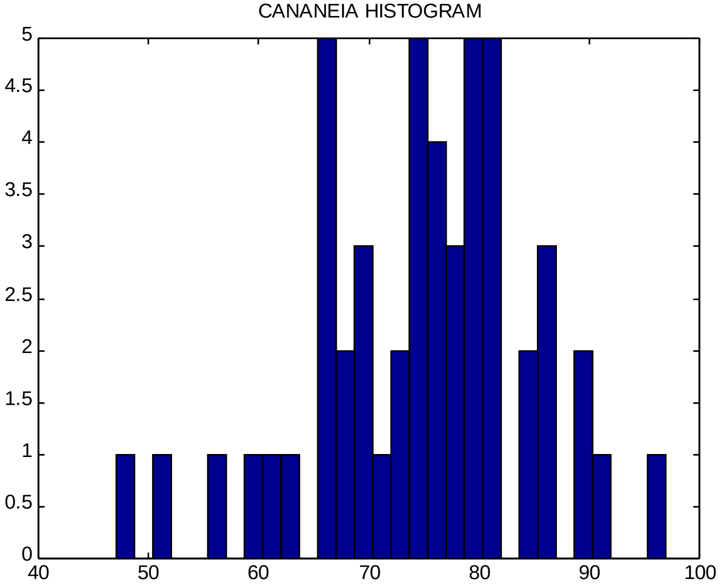

FIG 1 - BINS OF MINIMA EXTREMES OF PREDICTED SEA LEVELS

Table B-Histogram Tails

	Sea Level				Meteorology				Joint Distr	
Port	1st	2d	3d	4th	5th	6th	7th	8h	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 Fran	right	right	right	mix	left	right	mix	right	left	right
Honolulu	left	left	left	mix	left	right	mix	ight	left	right
AtlanCity	left	left	right	mix	left	right	mix	right	left	right

- **Table B shows the visual aspect of the histograms,regarding their shape, built with data of the Matriz of Extremes for the port of Cananeia, in comparizon with Balboa (Panama), S Francisco (USA), Honolulu(USA) and Atlantic City (USA), data.**
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- **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), including the port of Cananeia.**
- **These results are preliminary as they depend on how the tidal constants are determined.**

Spectral Analyses of Extreme Values

Spectral Analyses of Extreme Values of all columns of Table A, for Cananeia,and for all Ports of this study   were produced . The Spectral peaks were analised and tested via Fisher (1929), test for the determination of the significant peaks of variability of the series.

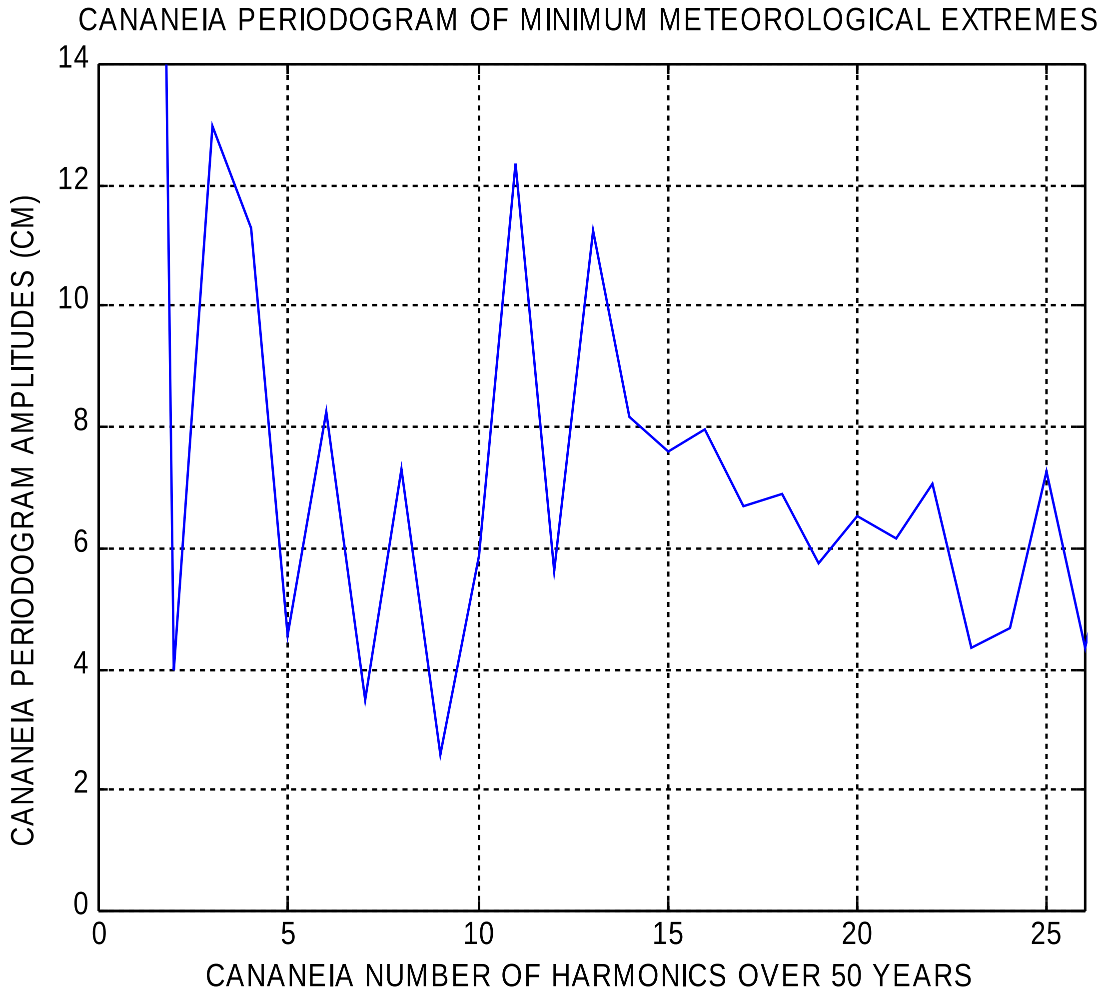

Table C – Cananeia Harmonics that passed the Test of Fisher

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 C countains the results of application of the periodogram test of Fisher (1929) to the 1st, 2d, 3d, ...,columns of Table A.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 A, from ports of Honolulu, San Francisco, Atlantic City and Balboa, were also submmitted to the test of Fisher and , contrary to what is seen in Table C, for the port of Cananeia, they all exhibited joint predicted sea level/meteorological peridocities (8th,9th and 10th blocks), that passed the test.

Discussion: Hawaiian Series

- **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 Matriz of Extremes from where all the present results were obtained.
- The results are very much dependent of how long is the series from 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 addoped, as a general rule for the comparizon, to reduce the computations of the constants to one year basis.
- Other addopted rule was to work with undetrended original series of sea level from all ports as they all experience a general increase along the years.
- **The Histograms**
- The statiscal studies of extremes have identified three classes of extreme values distributions known as Gumble, Fréche 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 arise 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 Fréche 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 Fréche or Weibull .

- Hawaiian Series- Continued

- 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 comparizon with the results of other studies that have interpreted them.

- **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 originated variable values of the retturn level of the sea level, which were well within the limits of variation of the data , while the retturn periods were very much higher than expected.

- For that reazon a sort of mean of the retturn period associated with a mean extreme level were calculated from data of columns 11 and 12 of Table IV , giving: 1) 260 cm for the maxima extreme and 200 years for the correspondent retturn period and 2) 70 cm and 200 years, respectively, for the minima extremes.

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Conclusions: Hawaiian **Series**

. Comparative analyses of extremes from 50 years of Cananeia sea level station and data from stations of Atlantic City (USA) (92), Balboa (Panama),(88), Honolulu (USA) (99), and San Francisco (USA) (103) showed similar Frécht and Wiebull histograms for the joint sea level/met distributions and also for the meteorological extremes. There were some dificulty to visually determine the kind of distribution for the standard deviations of the sea level and the std of meteorological , 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 all ports have variable Fréchet and Weibull distribution, which 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 dificult to be certain if it is uniform or other.

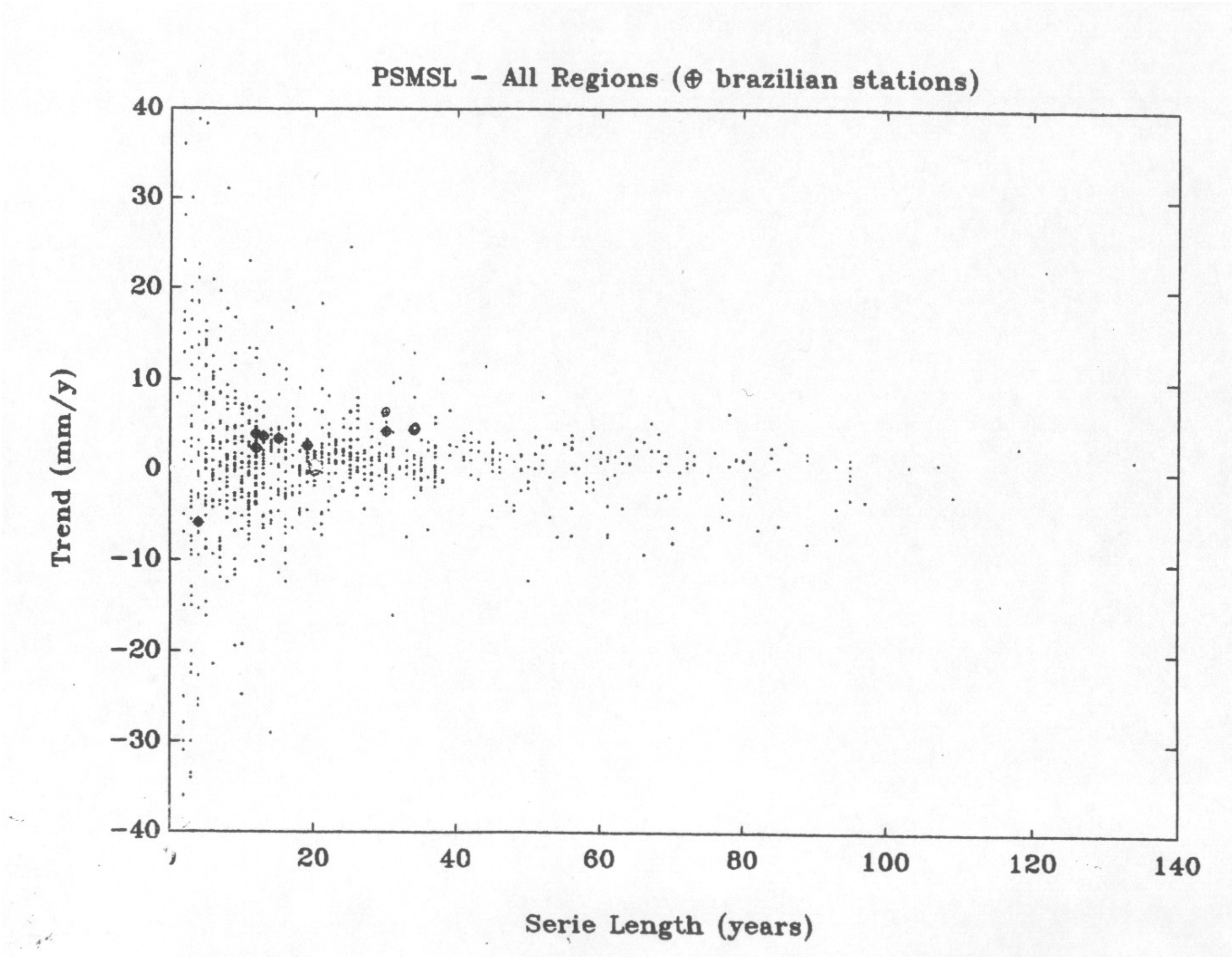
. The joint sea/met distribution of Cananeia extremes (maxima and minima), did not show spectral amplitudes, which passed the Fisher text and also the std of the mean of the meteorological. However the extremes of the other tidal stations have periods that passed the test, indicating the occurrence of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

. The estimated retturn periods and the corresponding level of return of Cananeia have average values of 200 years and 70 cm for the minima extreme and 260 cm and 200 years for the maxima.

PSMSL - Series

Annual Sea Level Data

Trend analyses of PSMSL series show that all Brazilian ports have positive trends



Ports with the highest negative and positive trend values occur geographically, in many occasions, close to each other.(o Nearly zero, ox High negative, + High positive)

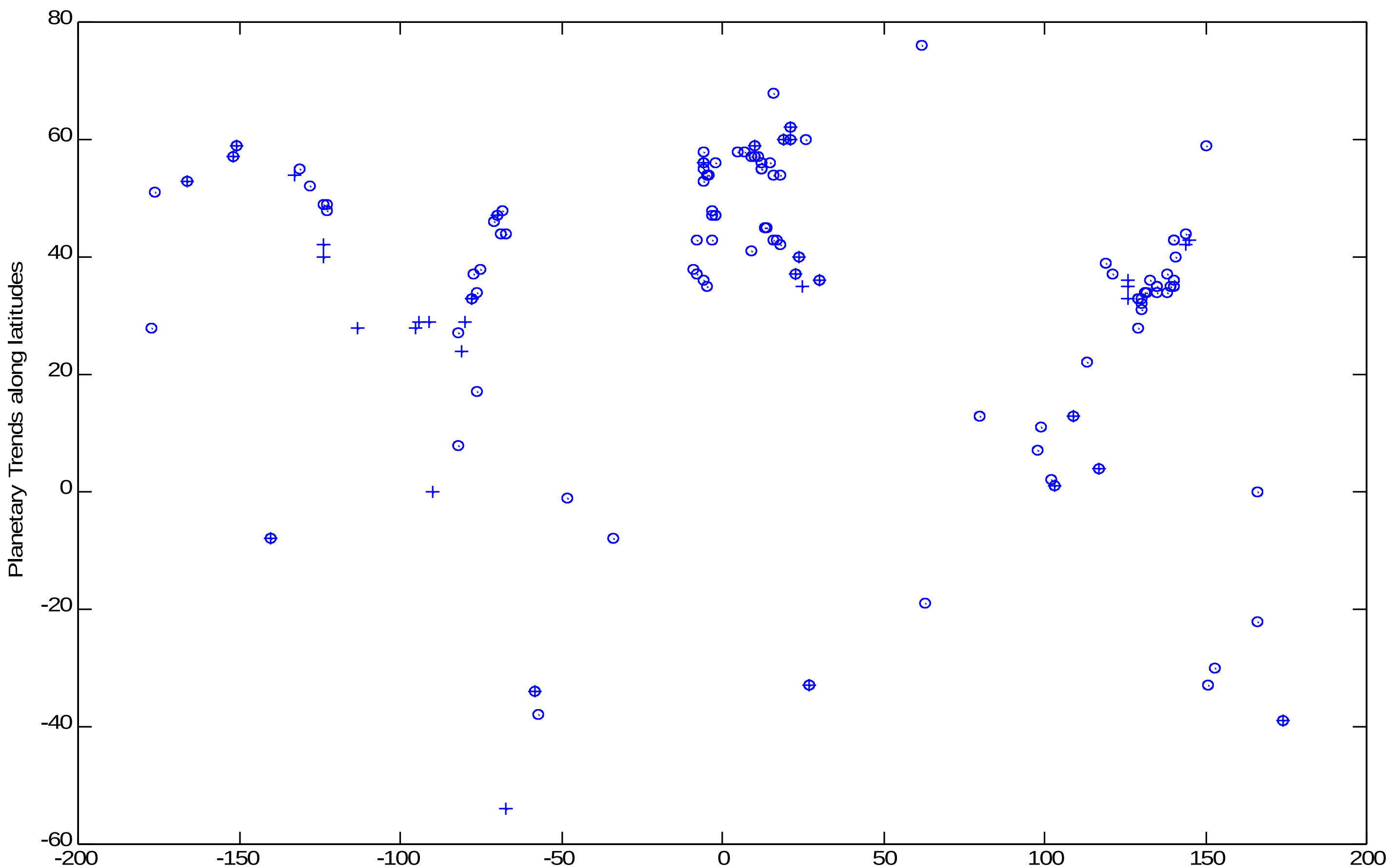


Fig 16 - Trends, nearly stable, maximum negative, maximum positive along longitudes

Trends of all series seem to be well distributed along the Longitudes

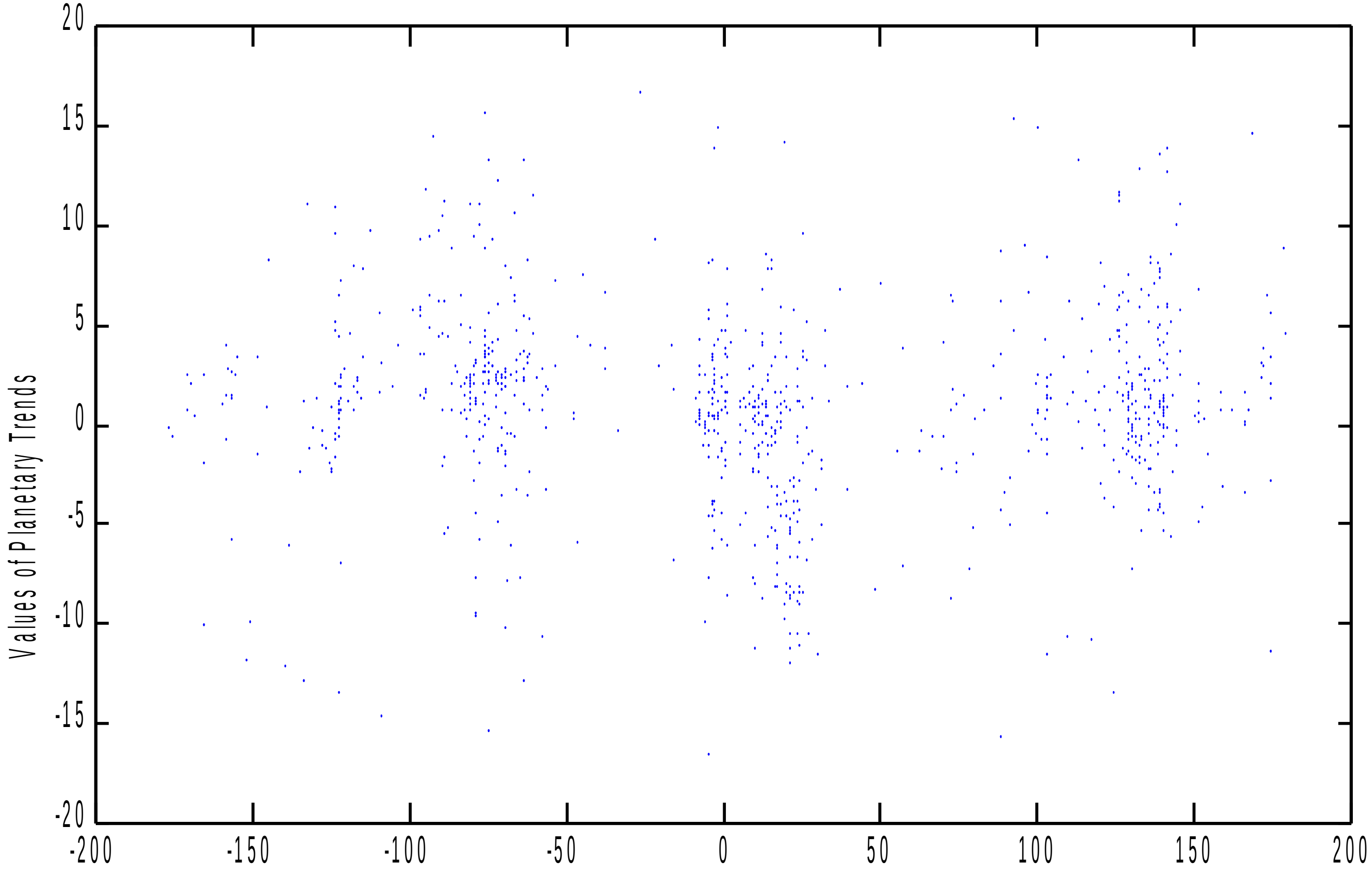


Fig 15 - Distribution along the Longitudes of Planetary Trends

Trends of all series seem to be well distributed along the Latitudes

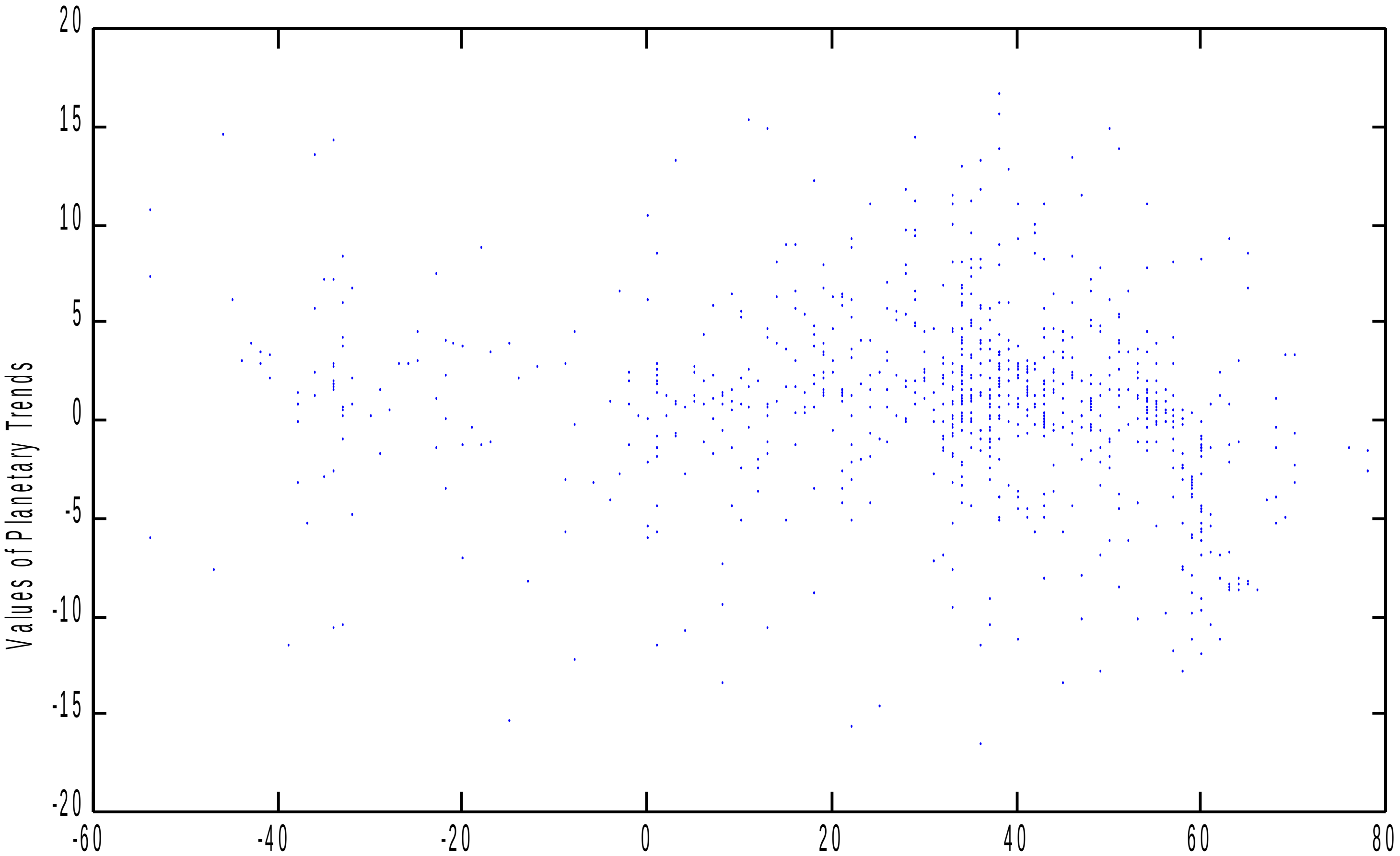
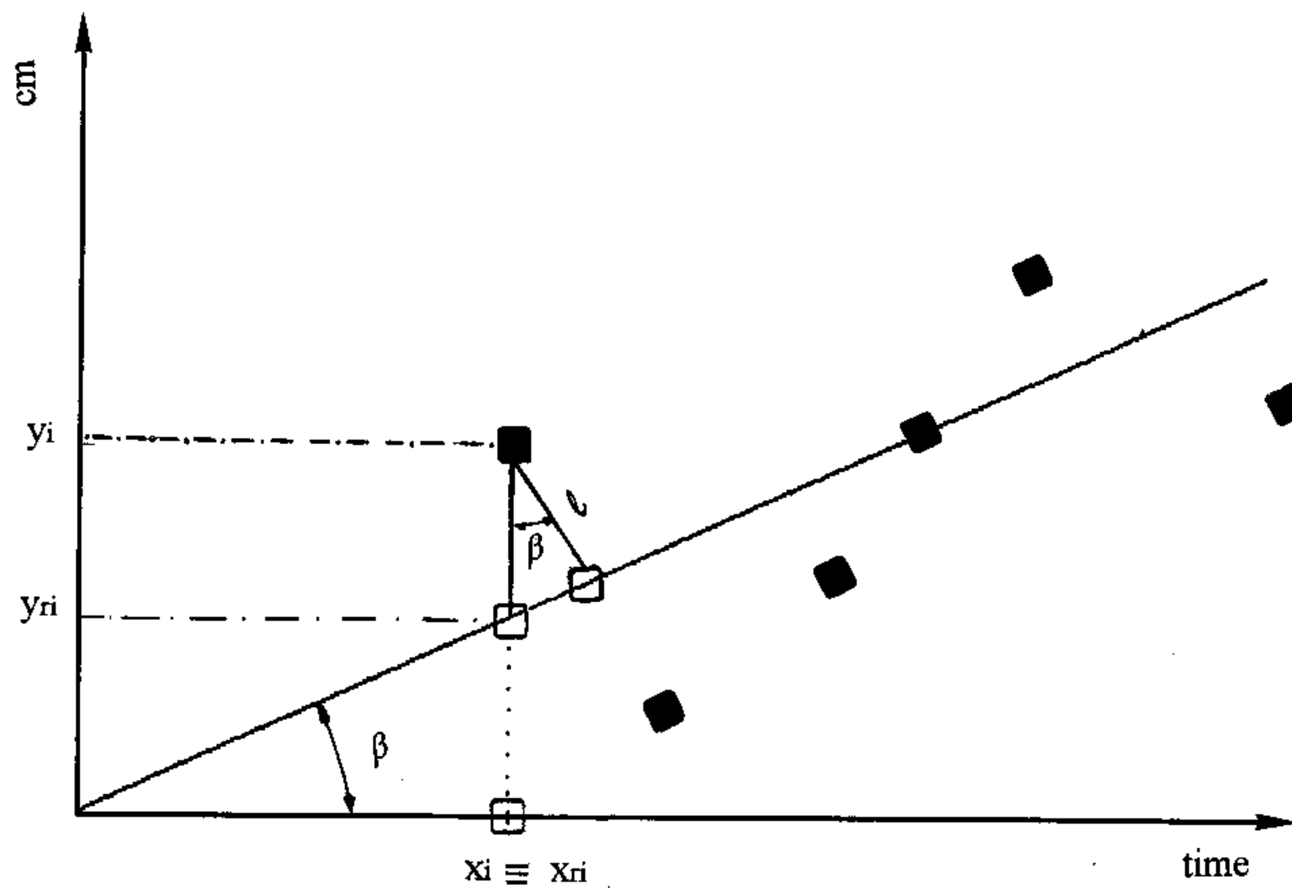
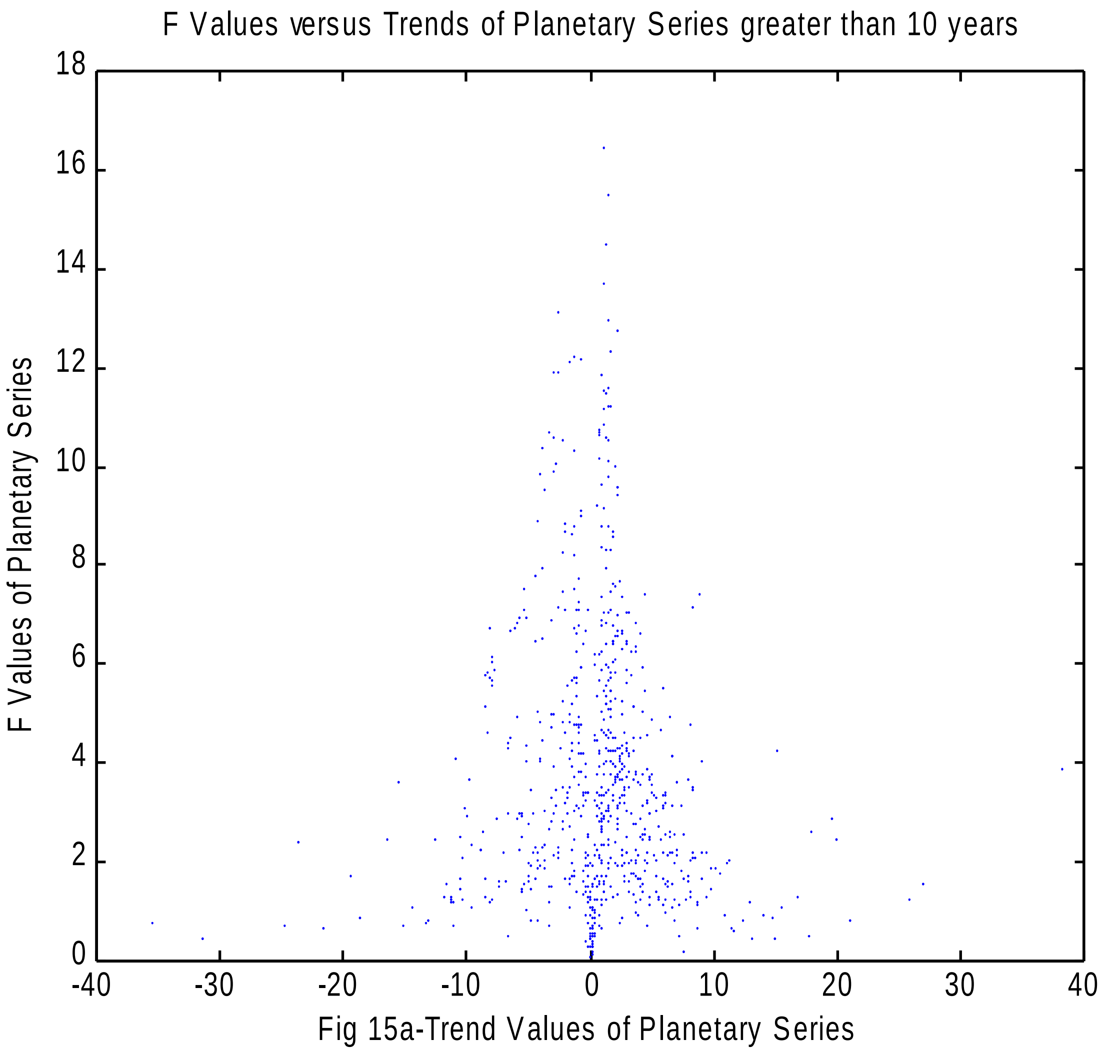


Fig 14 - Distribution along the Latitudes of Planetary Trends

The mean distance of the discrete sea level data points, to the regression line, previously calculated, was taken as a measure of a coefficient of proximity (l) of each series. And a F function, exhibiting the product of this coefficient with the coefficient of correlation (F = ρ.l), was defined .



Global PSMSL (1996) values of F, (series of Cananeia included), in a plot against the trends, exhibited a Christmas Tree aspect and,



as the length, in years, of the series increase (in different plots), started to show two stems, one in the negative and the other, in the positive side of the plot.

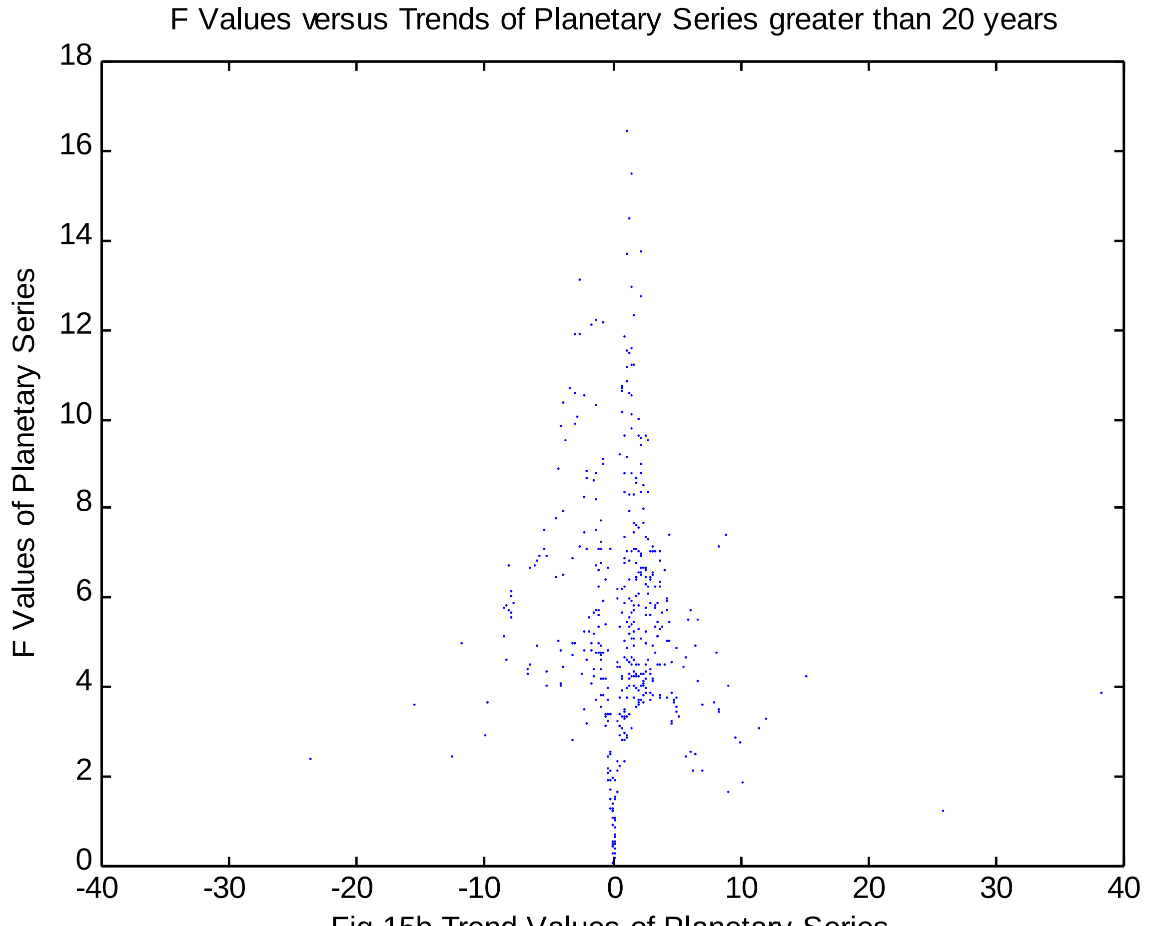


Fig 15b-Trend Values of Planetary Series

For the longest series with more than 60 to100 years, the positive stem showed almost a straight line, pointing to 18 cm/cty, while the negative stem, along a curved like line, pointing_to_58_cm/cty.

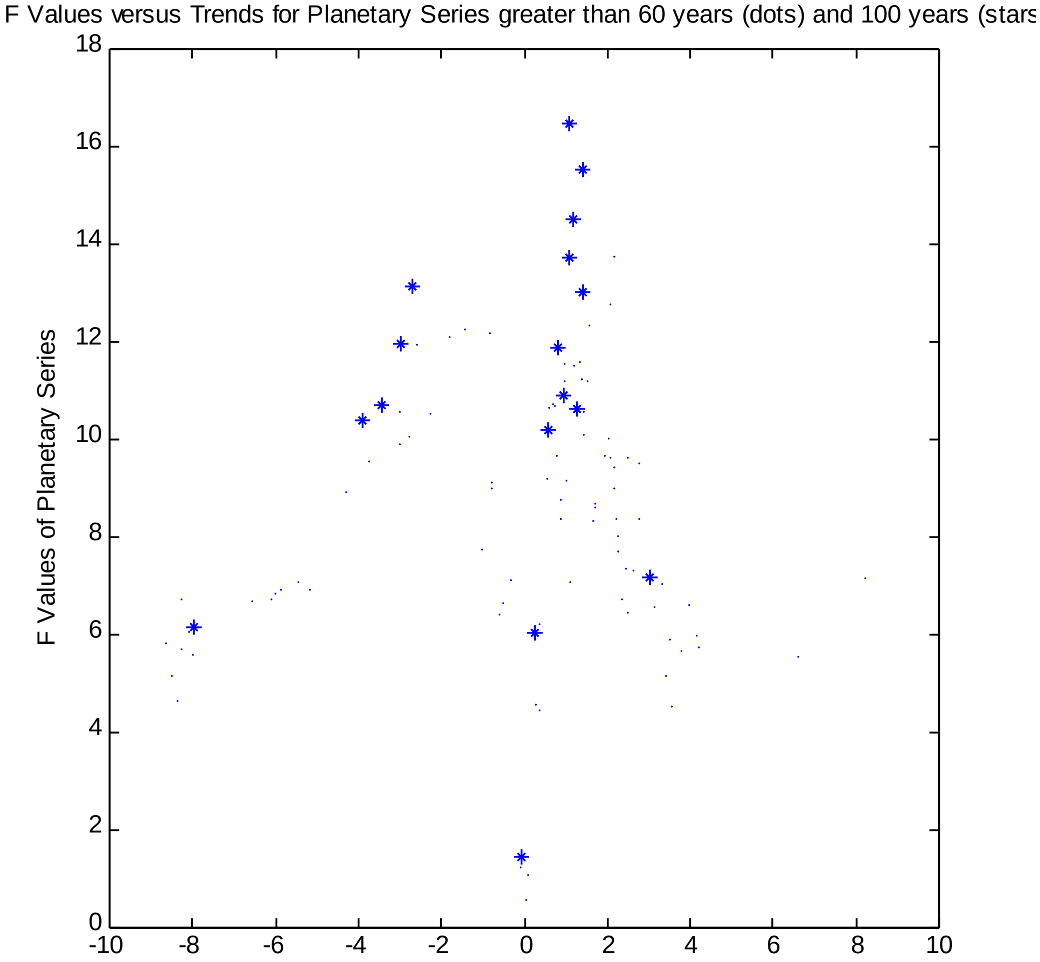


Fig 15c-Trend values of Planetary Series

Conclusions: PSMSL Series

- Trend analyses of PSMSL series show that all Brazilian ports have positive trends.
- Plots of trends versus correlation bins of all ports, showed small standard deviations close to zero bin, up to the bin 0.4 and greater absolute values of negative trends, than the positive ones.
- The highest negative and positive trend values occur geographically in many occasions close to each other.
- Trends of all series seem to be well distributed along the Latitudes and along the Longitudes.
- The mean distance of the discrete sea level data points, to the regression line, previously calculated, was taken as a measure of proximity of each series.
- An F function, exhibiting the product of these coefficients was defined, which had a tail distribution to the left.
- Global values of F, (series of Cananeia included), in a plot against the trends, exhibited a Christmas Tree aspect and,
- as the length in years of the series (in different plots), started to show two stems, one in the negative and the other in the positive side of the plot.
- For the longest series with more than 60 to100 years, the positive stem showed a straight line, pointing to 18 cm/cty, while the negative stem, along a curved like line, pointed to -58 cm/cty. Further analyses on these odd aspects are underway.

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