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

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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 to 100 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.
The sea level data of Cananeia (Lat 25°1.0’; Long 47°55.5’), 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 al., 2001). In fact, the increase of the sea level is a worrying 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 the use of the early theory of Gumbell, Fréchet, and Weibull as outlined in Colles (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 and Balboa were longer series similarly analysed, as complementary comparative stations for statistical analyses, in the search for decadal and interdecadal variability of extremes of 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.


• 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.

HAWAIIAN Series

Hourly Sea Level Data
### Table A - Matrix of Extreme Values of Cananeia

Table A was built with extreme values of Cananeia and ........ Each line of the Table refers 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 fifth, 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 return of the minima and the period of return 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 return 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 Francisco 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
Table B-Histogram Tails

Table B shows the visual aspect of the histograms, regarding their shape, built with data of the Matrix of Extremes for the port of Cananeia, in comparison with Balboa (Panama), S Francisco (USA), Honolulu (USA) and Atlantic City (USA), 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 column 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.

<table>
<thead>
<tr>
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<th>Meteorology</th>
<th>Joint Distr</th>
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<td>Port</td>
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</tr>
<tr>
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<tr>
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<td>S Fran</td>
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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 analysed 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

Table C contains 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.

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<tr>
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7th

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<th>Fisher</th>
</tr>
</thead>
</table>
| 8th
| 9th
| 10th

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 submitted 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 periodocities (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 Matrix 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 adopted, as a general rule for the comparison, to reduce the computations of the 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 along the years.

- **The Histograms**
  - The statistical 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 ascertain 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 interpreted them.

The Level and Return 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 return level of the sea level, which were well within the limits of variation of the data, while the return periods were very much 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) 260 cm for the maxima extreme and 200 years for the correspondent return period and 2) 70 cm and 200 years, respectively, for the minima extremes.
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 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, 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 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 test 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 return 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. (ο Nearly zero, ox High negative, + High positive)
Trends of all series seem to be well distributed along the Longitudes.
Trends of all series seem to be well distributed along the Latitudes
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 \( (F = \rho \cdot l) \), 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.
For the longest series with more than 60 to 100 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.
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- 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 to 100 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.
References