# The Praia Grande Sea Level Limits

A.   R. de Mesquita*, J. L. A. Trabanco**, M. Q. Monteiro*,R . A. de Carvalho* & M. B. Galzarano**.
Oceanographic Institute  of  University of  São Paulo, ** Faculty  of Civil Engineer of-UNICAMP.
mail: ardmesqu@usp.br.  ** E-mail : jorgetrabanco@gmail.com
Praga, IUGG/IAPSO,  22/06/2015 to 02/07/2015

## Abstract

The 1831 sea level of "Praia Grande" (PG), (Lat  24º 00' S; Long  46º 24' W ), in the shores of the State of São Paulo, as established by the Brazilian Law Number 9760 of 1946, has been estimated and materialized. The 5 days sea level data at PG  was obtained by continuous, day and night  pressure measurements, recorded in a data logger and  also, by discrete visual  readings during the day time,  against a tide staff fixed on a pier.  The estim**a**tes followed three plausible hypotheses, about  the global relative sea level variation, since 1831 until  the present, on the known rate of sea level changes as measured: a)- in the port of Brest, France, b)- rate in the port of Cananeia, Brazil, and c)-global rate given by  the global estimates of Intergovernmental Panel for Climate Change (IPCC) of the United Nations Organization (UN). These rates, allowed the demarcation of the "Terrenos de Marinha" (Union Sea Land Limits, or Marine Land) of PG, along the terms of the Law. The procedures, were based on the assumption of the same sea level of the geoid, and that the  tidal constants are invariant, for transferring the long term sea level trend of Cananeia to Praia Grande. Geometrical leveling was used to refer the  PG sea level values to the national geodetic of Imbituba Datum and the network levels of the Brazilian Institute of Geography and Statistics (IBGE). Results indicate that the limits in Praia Grande, are within the beach, and are according to the terms of the 1946 Federal Law.

## Introduction

This work is a follow up of  previous contributions  for  Barra do Una and Praia do Pulso  by Mesquita et al (1996)  and by Mesquita et al (2011, 2013) and so, it is also related to the Brazilian Law 9.760 of 1946, SPU(1999). As in these contributions, there is the  need to comply "ipsis litteris", with the terms of the Federal Law and, for that, it is necessary to know  where is, in the present,  the line in the ground of the relative sea level of year 1831 at "Praia Grande". Fig. **1.**



Fig 1 - View of "Praia Grande" (PG). On the right side of the Figure is shown the position (Lat=24º01'13''S; Long 046º26'37''W) , where sea level measurements were taken at  Praia Grande (CAPRI), referred to IBGE´s RN 2141D. The data were all referred to the IBGE  Datum  of the port of Imbituba, located at (Lat 28° 13' S ; Long  48º39' W). The reference  level used was  the  IBGE  RN 2813D, for Cananeia and for Praia Grande (CAPRI) the  IBGE RN 2141D of a nearby City of São Vicente .

If one knows where is, in the beach, the line of relative mean sea level value of  1831 at BG, its altitude, relative to the datum of Imbituba, can be determined. However,  the problem to comply with the Law  is of difficult solution, because although the records of sea level  of 1831 in Rio de Janeiro, is in the museum of the Directory of Hydrography and Navigation of the Brazilian Navy (DHN), in the city of Niteroi, State of Rio de Janeiro, there is no information about the "datum", relative to which, the sea levels of 1831 were referred to . For this reason, to fix the Sea land limits at PG (Marine Land), based on the mean sea level of 1831, is impossible  and the methods used in Barra do Una (Mesquita et al 2011) and  Praia do Pulso (Mesquita et al 2013), for solving  similar  difficulty, were also used in the present work.

Sea Level Measurements in Praia Grande (PG)

Measurements in PG were taken during the days 05 to 11 of November of 2014, with an AANDERAA continuous pressure recorder and also by visual reading at 15 minutes interval, of the tidal staff, with readings in meters, decimeters and centimeters. For 10 hours of each day, from 8 hours,  in the morning, to 17hs in the afternoon as shown in Figure 2.
Simultaneous sea level measurements, for the same period, were also taken with KALESTO at the Research Station of Cananeia. Figure 3 also shows the facility available of the Meteorological  data measurements.



Figure 2 Sea Level Measurements taken with a bottom pressure record (BPR)  AANDERAA  and visual readings of the tidal staff taken at Praia Gran
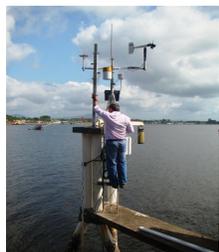


Figure 3 – Sea Level measurements for the year 2014  taken with (KALESTO) and also the sea surface Meteorology Station at Cananéia.

## Results

By assuming that the sea level of, PG and Cananeia,are physically the same , (i.e. would not differ from the geometrical levelling), which is reasonable to accept,  bearing in mind that they  are relatively close places, as Cananeia positioning is,  Lat. 25º01'S - Long. 47º54'W, which is close to PG's positioning at Lat=24º01'13''S: Long =046º26'37''W.

The mean Sea level of Cananeia is (0,058±0,01 m) for the same 5 days of measurements, which  gives by adding  0,016 m (1,6 cm), the value of the PG mean sea level which is (0,074±0,01) m.

As the rate of sea levels (correlation), of PG and CAN is **nearly 1, this is used to estimate** the mean sea level for the year 183, from the knowledge of the sea level heights of the *Sizyges* at PG.
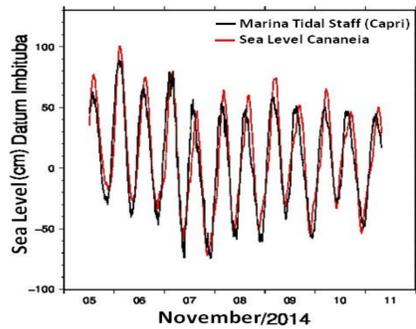


Fig 4 - Sea Level at PG and at Cananeia Research Station, reduced to altitudes relative to the Imbituba datum. Note that the mean altitudes of both places are referred to equal to zero.

Sea level of Cananeia is  (0,058±0,01 m) for the same 5 days of measurements, which  gives by adding  0,016 m (1,6 cm), the value of the PG mean sea level  value of , (0,074±0,01) m.

The ratio of the amplitudes of CAN and PG, relative to Imbituba, shown in Fig 4, gave the value of 0.994. This value, for any practical work, corresponds to a correlation of amplitudes with value almost equal 1, which means that there is an almost coincidence between the curves.

As the rate of sea levels (correlation), of PG and CAN is nearly 1, this is used to estimate the mean sea level for the year 1831, from the knowledge of the sea level heights of the *Sizyges* at PG.
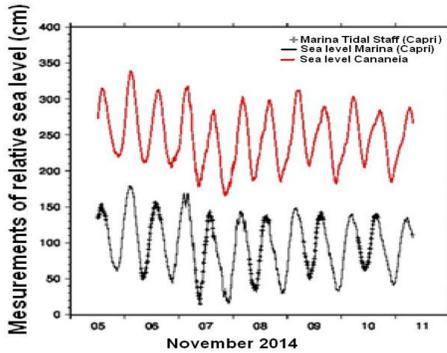


Figure 05 .Measurements taken at Marina Capri during days 05 to  11 of November of 2014, compared  to similar measurements  taken at Cananeia (red color). The Crosses indicate the measurements taken by visual readings at the tidal staff. Mean High Water Tide (*Sizyges*) of 1831

To estimate the long term value of the altitudes relative to Imbituba of the mean sea level of 1831 in PG, is necessary to estimate first, how far from the coast, using the measurements of November 2014, in the beach, is the altitude of the mean sigyses sea level, nowadays, and from this line to measure the 33 m towards the PG and see, where are in the beach,  the limiting  borders  of the Marine Land, shown in Fig 07.

The  Imbituba altitudes of the mean sea level  of the places, during the period of the measurements, were respectively, 0,058±0,01 m for PG and  0.074 ± 0.01 m  for CAN, producing  a difference of 0.016 m in their altitude  relative to Imbituba, or of only 1.6 centimetres in a period of 5 days. And for this reason it is possible to

It is well known (Peltier 2000), that the relative global sea level has risen since 1831 in the tropics, i.e., the tropical and subtropical areas of the globe, which  includes the southern coast of Brazil.

IPCC Global rate of  1,8 mm/year = 180mm/100 years , which acting during 183 years (from 1831 to 2014),  produce a  global increase of  180mm/100 years X (183 years) = (32940) mm /100)  = 32,9 mm = 0,0329 metres, relative to the Imbituba datum. Similar calculation for  Brest -France gives 0.017 metres and similar calculation for Cananeia gives 0,023 metres
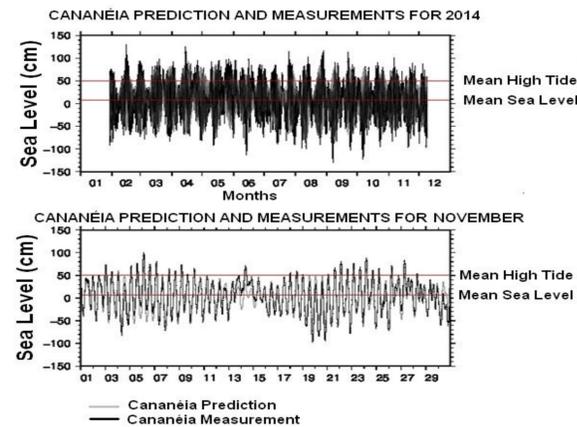


Figure 06. The upper part of the Figure shows the line of  Mean High Tides (*Sizyges*) and Mean Sea Level  Line for the  entire year of 2014 and in the second part the corresponding month of November 1831, obtained  by Retro-Prediction, with the actual data obtained by KALESTO for the Research Station of Cananeia.

The effectiveness of the procedure was tested, by making the prediction of the sea level of CAN,  recorded during the 5 days  period of the field work, from the known tidal constants (Mesquita & Harari 1983) and by plotting their values, as shown in Fig 07.

Measured values of sea level are in the darker curve, and the lighter curve indicates the predicted values of sea level. From the comparison of the curves one sees that they are  very well synchronous  and that the differences in amplitude in some periods may be due to the  action of the atmospheric tides.

## The Praia Grande  Sea Level Limits
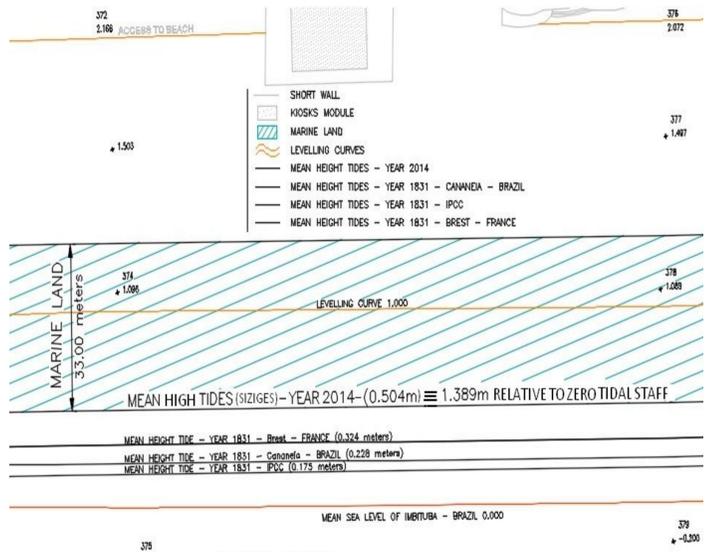


Fig 07 – Mean Sea Level Heights of Sizyges of "Praia Grande" . Marine Land relative to the year 2014. Sea level lines of the year 1831, estimated  according to the rates of variation of sea level of Cananéia, Brazil, from the IPCC global estimates and the rate of Brest, France.

From the above Figure  one can see that the leveling line relative to Imbituba of Mean Sea Level Heights of year 2014 was obtained with the radar  measurements by KALESTO  in Cananeia Station. The  corresponding lines of 1831 were drawn according to the hypotheses on the long term rate of variation of Brest, Cananeia and IPCC.

The resulting estimative for Praia Grande by applying, the known rate of variation of the sea level at Brest- France (0.96 cm/ 100 years),(which includes the year of 1831 mentioned by the Law), the Global sea  level  rate of variation estimated by the  IPCC (18 cm/100 years) and the estimated rate of variation of sea level of Cananeia (12 cm/100years), reduced to the datum of Imbituba.

As depicted by the hachured  lines in green color, the 33 metres of  Marine Land defined by the Federal Law  Nº 9760 of 1946 (SPU 2001),  measured according  the Mean Tidal Heigts altitudes of the year 2014, relative to Imbituba,  is entirely within the Praia Grande Beach.

For all  lines in green of the Marine Land, Cananeia-Brazil, in blue for IPCC,  or  dark blue Brest – France, the 33 m limits of PG Beach would yet be within the Beach. They do not invade the Kiosks located along the access to the Beach of Praia Grande shown in Figure 07.

## Discussion

The period of 1820 to 1840, which includes the year 1831 referred as the relative sea level of long term (sea level measured along the regression line of the period),  was a period of time, when the  relative sea level  remained constant and the year 1831, established as a reference, complied satisfactorily with the function of a geodetic mark for the application of the Law 9.760.

The continuous increase in temperature, since 1850s,  heated the air over the poles, producing the melting of the ice and consequent increase in relative sea level rise in the polar areas, as pointed by Peltier (2000) and Chao (1999) for  the tropical of Capricorn and Tropical of Cancer insights.

In spite the uncertainties, it is very much probable that the relative sea level, not only in Cananeia, but all over the Brazilian coast may be rising at 41 cm/cty Mesquita, Harari & França (1996), following Pelier's  theory of global isostatic adjustment.

The procedures adopted in the present work admit the  long term mobility of sea level , through the variation of the relative sea level, based upon  the hypotheses on the rates of variation of Brest, IPCC and Cananeia.

 It was also necessary to certify that the seasonal, daily and diurnal variations Franco & Mesquita ( 1986), of the sea level of the area where PG is in, Mesquita,(2003). (See also www. mares.io.usp.br Icon "Praias Arenosas" - Sandy Beaches).

Nowadays the national reference for geodesic measurements is no longer  the 1831 sea level of the port of Rio de Janeiro. The port of Imbituba, in the State of Santa Catarina, used in Figures 04, 05,06 and 07, is the reference taken by the IBGE for the purpose.

## Conclusion

The measurement of the relative sea level in PG, referred to the mean relative sea level heights of sygizes of the year 1831, as established by the Brazilian Law Number 9.760 of 1946, through plausible hypothesis of the variation of global relative sea level from 1831 to the present days, allowed the demarcation of the "Terrenos de Marinha"(Union Sea Land Property) in PG.

By assuming that tidal constants have not varied  and remained constant since 1831 until  present days at Cananeia,  the sea level retro-prediction of the mean of high water for 1831, allowed its materialization along the terms of the Law. The accuracy of the procedures of sea level transference, from CAN research station to PG, based on the  geographical proximity of the localities, were also assessed by parallel work of geometrical leveling.

Three plausible and measurable hypotheses were used as follows: 1) that the rate of relative sea level in PG varied in the period of 1831 to 2014 at the same rate as the rate of variation of the relative sea level of the port of Brest, France; 2) that the relative sea level of PG varied at the same rate, as the global relative sea level of long term  presently estimated by the Intergovernmental Panel for Climatic Changes (IPCC) and: 3) that the rate of long term variation is equal to the rate of variation registered, so far, in the relative sea level at the research Station of  Cananeia.

## Acknowledgements

## References

-Chao, B F. (1999). Concrete testimony to Milankovitch Cycle in Earth's Changing Obliquity. EOS Transactions Am. Geophys.Union. Vol (77). Number 44:433.
-Franco, A.S & Mesquita, A. R. de. (1986). On Practical Uses of filtered Daily Sea Level. IHR v62n.2, p 133-141.
-IGBP. (1996). Global Network for Isotopes in Precipitation. (GNIPG). International Geosphere Biosphere Programme/ World Meteorological Organisation. 48p.
- IPCC, (2001). Intergovernmental Panel for Climatic Changes. IPCC, WGI, Third Assessment Report. Shangai, China, 2001. 18 p.
-Mesquita, A R de e Harari, J. (1983) Tides and Tide Gauges of Cananeia and Ubatuba - Brasil (Lat 24 50) Relat. Int.Inst. Oceanogr., Univ. S Paulo. SP.11, 1-12.
-Mesquita, A R de, Harari, J. and França, C A S. (1996). Global Change in the South Atlantic: Decadal and Intradecadal Scales. An. Acad. Bras.Ci.,Vol (68) Supl I: 117-128.
-Mesquita, A. R. de. (2003) Sea Level Variations along the Brazilian Coast: A  Short Review. Edtrs Klein, A. H. F. et al. In Proceedings of the Brazilian Symposium on Sandy Beaches. Sl, Vol (35):21-31.. See also www.mares.io.usp.br  AAGN.
Mesquita, A. R. de ; Franca, C. A. S. ; Blitzkow, D ; Correa, M. A. ; Monteiro, M Q ; Trabanco J. L. (2011). Sea Land Limits: a Study Case.. Anais da Academia Brasileira de Ciências (Impresso) v. 83, p. 1221-1230,.See also www.mares.io.usp.br
- Mesquita, A. R. de ; França, C. A. S. ; Blitzkow, D ; Correa, M. A. ; Monteiro, M Q ; Trabanco J. L, A, (2013).  The Brazilian 'Terrenos de Marinha' and the Relative Sea Level of the Year 1831 at 'Praia do Pulso'. Revista Brasileira de Geofisica. v. 31, p.1-15, See also http://www.mares.io.usp. br/aagn/51/una/una.htm.
-Peltier, W. R. (2000). Global Glacial Isostatic Adjustment and Modern Instrumental records of Relative Sea Level History. In Global Sea Level Rise. J. Geophys. Res. 96, No C4.
- PSMSL (Permanent Service for the Mean Sea Level) Inglaterra. http://www.pol.ac. uk/psmsl/programmes/gloss/info.html - IAPSO (International Association for the Physical Sciences of the Oceans). Bidston, Birkenhead. POL (Proudman Oceanographic Laboratory). Inglaterra.
- SPU (1999). Serviço do Patrimônio da União. Ministério da Fazenda da República do Brasil. Cronologia Básica da Legislação Patrimonial. (Basic Chronology of the Patrimonial Legislation). 1p.