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LONG-TERM VARIABILITY OF TIDAL AND MEAN SEA LEVEL COMPONENTS ON THE BRAZILIAN COAST

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ABSTRACT. Recovery and analysis of sea level data from the ports of Belém, Recife, Santos and Cananeia, Brazil, in a decadal time scale, allow determining the seasonal, annual and decadal variability of mean sea level and tidal components, such as M_2 and S_2, which are associated to a probably local phenomena not yet clearly understood and established. On the other hand, trending values of (relative) mean sea level of these ports agree with the variability observed up to now in several ports around the world; the mean sea level trend in Cananeia, about 40 cm/century, may be occurring along the entire Brazilian Coast.

Keywords: Brazilian coast, relative mean sea level, tidal components, decadal trends, Belém, Recife, Santos, Cananeia.

RESUMO. A recuperação e análise de dados de nível do mar dos portos de Belém, Recife, Santos e Cananeia, Brasil, em escala de tempo decadal, permitem determinar variabilidades sazonais, anuais e decadais do nível médio do mar e das componentes de maré, como M_2 e S_2, as quais são associadas a fenômenos, provavelmente locais, ainda não claramente entendidos e estabelecidos. Por outro lado, os valores das tendências de variações do nível médio (relativo) do mar de longo termo desses portos estão em consonância com as variabilidades até agora registradas em vários portos em todo o mundo; a tendência do nível médio do mar no porto de Cananeia, com cerca de 40 cm/século, pode estar ocorrendo em toda costa brasileira.

Palavras-chave: costa brasileira, nível médio relativo do mar, componentes de maré, tendências decadais, Belém, Recife, Santos, Cananeia.

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INTRODUCTION

Sea level measurements have been performed regularly along the Brazilian coast and have provided relevant information about the long-term variability of two main components: mean sea level and tidal waves (Mesquita, 2003).

The mean sea level is calculated through mathematical time series in order to filter short-term fluctuations such as, diurnal tide, semidiurnal, terdiurnal, etc. The special interest lies on determining the mean sea levels monthly, seasonal and annual, which, in general, provide important indications on hydrodynamic seasonal variations and trends over time.

The tidal waves are extracted from the records by determining their amplitudes and phases from the harmonic analysis of the time series of the observations emphasizing tidal frequencies. In this case, there is a special interest on the semidiurnal components, M_2 and S_2, corresponding to the main effects of the sun and the moon, respectively, which are prevalent in the tide-generating potential.

Sea level records of several ports along the Brazilian coast have been regularly edited, filtered and analyzed at the Oceanographic Institute of Universidade de São Paulo (Mesquita & Harari, 1983; Harari & Camargo, 1995). This paper presents the results of interest for two ports on the Northeast/North coast – Recife and Belém (Harari et al., 1994) and, two on the Southeast – Cananeia and Santos (Mesquita et al., 1995; Harari & Camargo, 1995). Cananeia tidal data are from the Oceanographic Institute base, USP, while Santos data were provided by the Companhia Docas do Estado de São Paulo (CODESP) and Belém and Recife data were provided by the Instituto Nacional de Pesquisas Hidroviárias (INPH).

METHODOLOGY

The hourly time series of the sea level in Belém, Recife, Santos and Cananeia were edited after plotting and checking using the harmonic test technique developed by Karunaratne (1980) and Franco (1982). Annual, seasonal, monthly and daily mean levels were calculated using a low pass filter based on moving averages, where A24 is the mean value of 24 observations and the observation series were filtered using the A24A25A25 filter, so that tide oscillations were removed (Godin, 1972).

Annual tidal records were analyzed using the harmonic method, calculating the amplitudes, tidal component phases and main tidal levels (Franco & Harari, 1987; Franco, 1988).

Finally, the mean sea level and tidal analysis results were subjected to statistical and spectral analysis, to determine the most important trends and oscillations (Jenkins & Watts, 1968).

RESULTS

Table 1 shows the results of the analyzed records, the number of years with observations, long-term trends of mean sea level and of amplitudes and phases of the tidal components M_2 and S_2.

DISCUSSION

The most interesting aspects of the above table are the high values for sea level increase, mainly in Recife, where it reached 5.432 cm/decade. On the other hand, these trends should be interpreted carefully, since they are superimposed on oscillations of a large period, as shown in Figure 1, relative to annual variations of mean sea level in Recife. Also in this port, although the amplitudes of tidal components M_2 and S_2 show small decadal trends, their phases display larger variations, with 2.2 and 2.6°/decade. Great variation of mean sea level can be seen for the Port of Belém, 3.5 cm/decade, but in this case M_2 and S_2 amplitudes show significant even though negative trends, –1.10 and –0.29 cm/decade (see Fig. 2, for M_2).

Among the data analyzed of the southeastern Brazilian coast ports, the Port of Cananeia has the highest decadal variability of the mean sea level, with a slightly lower rate compared to Recife of 4.046 cm/decade; however, the increase of M_2 and S_2 amplitudes are more impressive, 0.470 and 0.531 cm/decade, respectively. On the other hand, the Port of Santos is heavily affected by human activity, through frequent dredging, so that the trends calculated above are not the result of essentially natural phenomena, in fact, among the ports analyzed it has the lowest mean sea level increase rate, only 1.132 cm/decade. In this port, the increase rate of the amplitude of the tidal components is also small. Figures 3 and 4 show the annual values of mean sea level in Cananeia and the M_2 amplitude in Santos in order to compare with the ports on the North/Northeast coast and to show again the great oscillations present in the calculated values.

Great effort has been made to interpret displayed variability and to correlate it with other geophysical variables such as, atmospheric temperature on the surface (Mesquita et al., 1995a, 1996). In fact, the rising atmospheric temperature, a result from the greenhouse effect, is considered to be the primary agent that causes the melting of the ice in the polar caps, increased volume of sea water and consequent increase of relative mean sea level in tropical and subtropical latitudes; the variation of the water column, in turn, affects the propagation of tidal waves producing variations of component amplitudes and phases. As a result, other important effects such as changes in the Earth rotation with corresponding changes of day length, are observed.

Table 1 – Decadal trends of mean sea level and the harmonic constants of the tidal components M_2 and S_2, in Recife, Belém, Cananeia and Santos.

	No. years	Mean level (cm/decade)	M_2 amplitude (cm/decade)	M_2 phase (°/decade)	S_2 amplitude (cm/decade)	S_2 phase (°/decade)
Recife (1946-1987)	38	5.432	0.070	2.200	0.090	2.600
Belém (1948-1987)	29	3.500	–1.100	0.600	–0.290	1.000
Cananeia (1954-1990)	37	4.046	0.470	–0.370	0.531	0.160
Santos (1944-1989)	46	1.132	–0.162	0.191	0.130	0.425

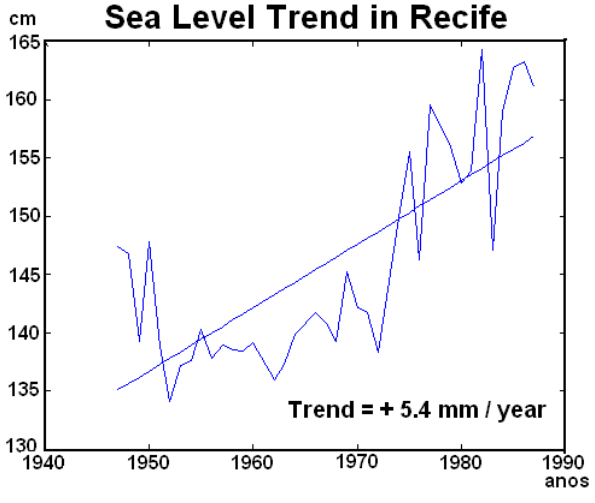

Figure 1 – Mean sea level in Recife.

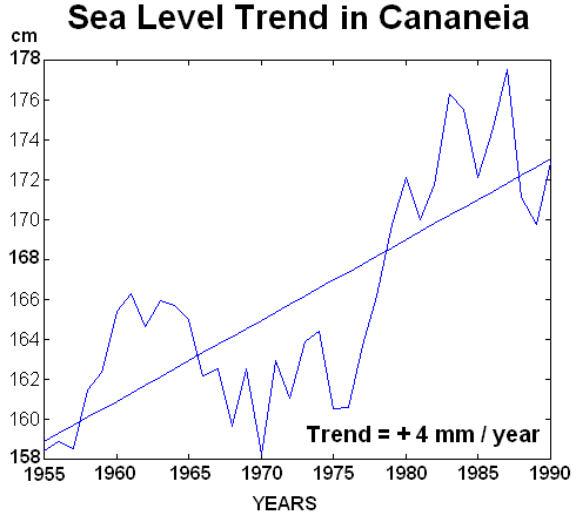

Figure 3 – Mean sea level in Cananeia.

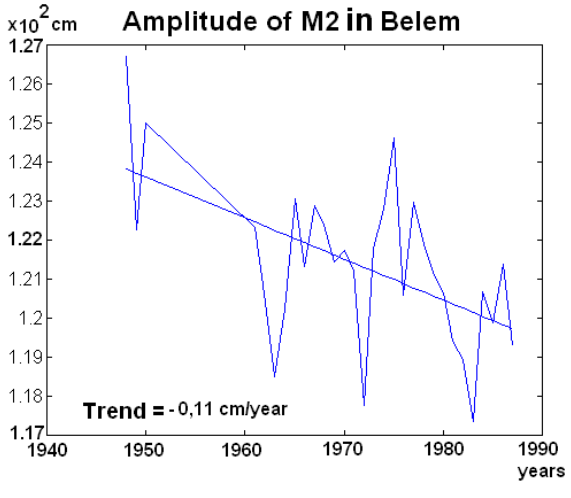

Figure 2 – Values of M_2 amplitude in Belém, from the annual records analysis.

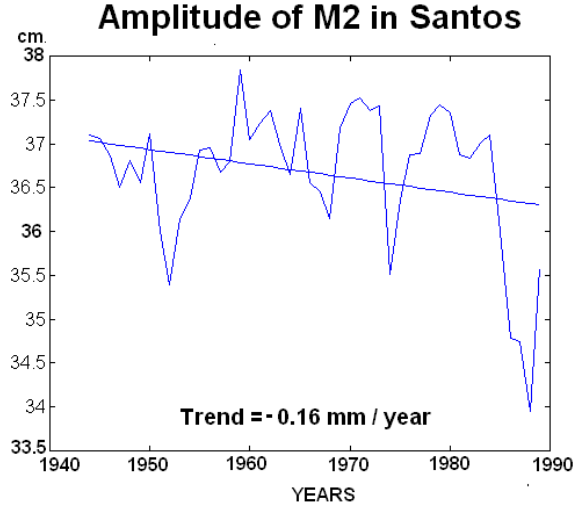

Figure 4 – Values of M_2 amplitude in Santos, from the annual records analysis.

CONCLUSIONS

In conclusion, the observations of sea level over long periods, on the order of decades, along with careful editing, filtering and analysis of the corresponding time series indicate that the components M_2 and S_2 display significant amplitude and phase change in the ports of the Brazilian coast and that the relative mean sea level may be varying along the entire coast at the rate of 40 cm/century. These results may lead to important geophysical information and indicate significant global changes.

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