TIDE CONSTITUENTS EXTRACTION BY HARMONIC ANALYSIS USING ALTIMETRIC SATELLITE DATA IN THE BRAZILIAN NORTHERN COAST REFINEMENT

LABORATORIO DE METEOROLOGIA APLICADA

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Introduction:

This work has building an harmonic analysis to analyze Sea Surface Height (SSH) dataset from Topex/Poseidon, Jason 1 and Jason 2 satellites for 19-year time series in order to extract the tide harmonic constituents (amplitudes and phases) for the oceanic region nearest Penrod Oil Platform (3°N, 49°17.1'S), located near North mouth of Amazonas river. The harmonic analysis are generally based on Fourier analysis of discrete series, which should attend Nyquist theorem conditions, which state that the sampling frequency should be at least twice higher than the harmonic frequency whose extraction is desired. Presently, the altimetric data available have a frequency of 9.9156 days (or 0.10085/day), which certainly does not fulfill Fourier theory conditions to extract the main tide constituents. On the other hand, Rayleigh Criterion states that two harmonic constituents with close frequencies can be separated depending on the sampling interval and the time series length. Rayleigh's assumptions are attended in this work since a 19-year time series is used and the main diurnal and semidiurnal tide constituents can be properly separately.

Study Area:

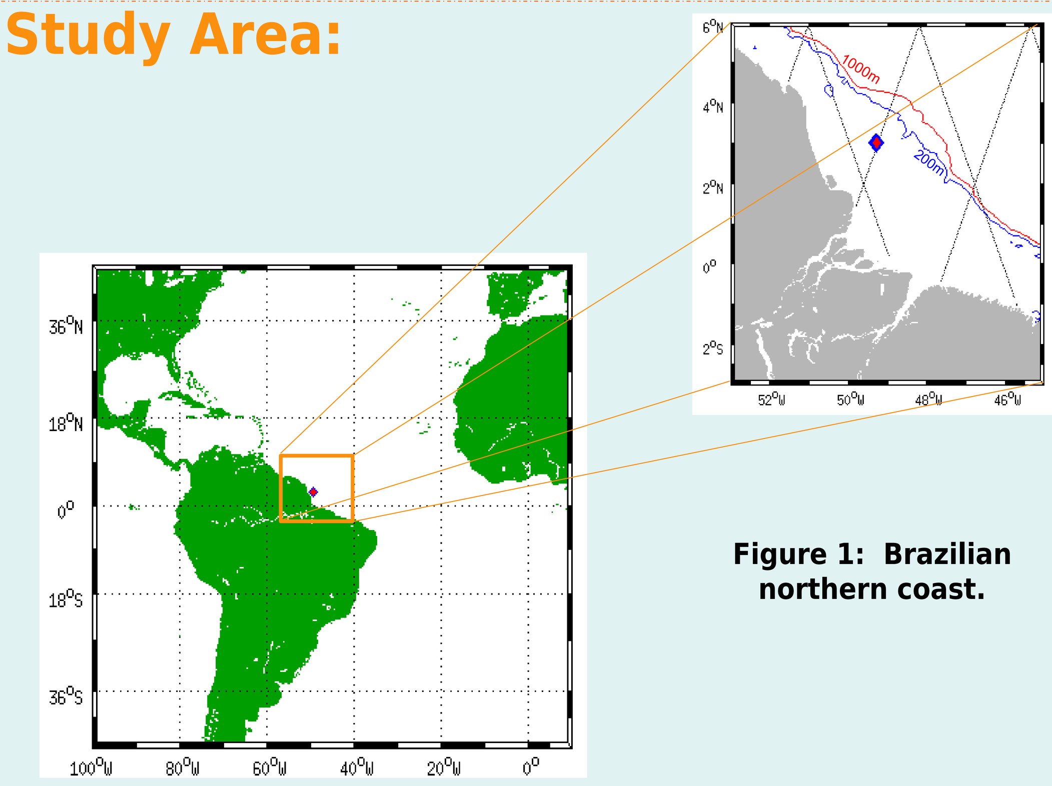


Figure 1: Brazilian northern coast.

Objective:

Use harmonic analysis to extract the tide harmonic constituents (amplitudes and phases) for the oceanic region nearest Penrod Oil Platform, located near North mouth of Amazonas river.

Data:

Sea Surface Height (SSH) and Tide gauge

- SSH : Topex/Poseidon, Jason 1 and Jason 2
  - along-track global coverage;
  - spatial resolution: ~6 km along-track;
  - frequency of 9.9156 days (or 0.10085/day);
  - temporal series: 09/25/1992 to the present.

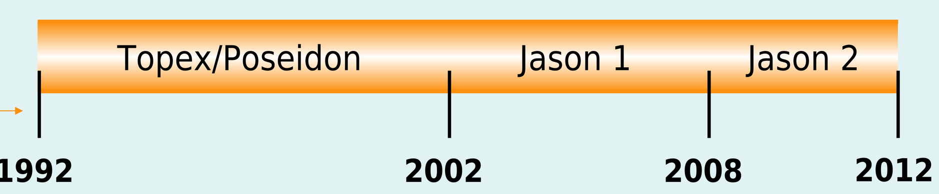
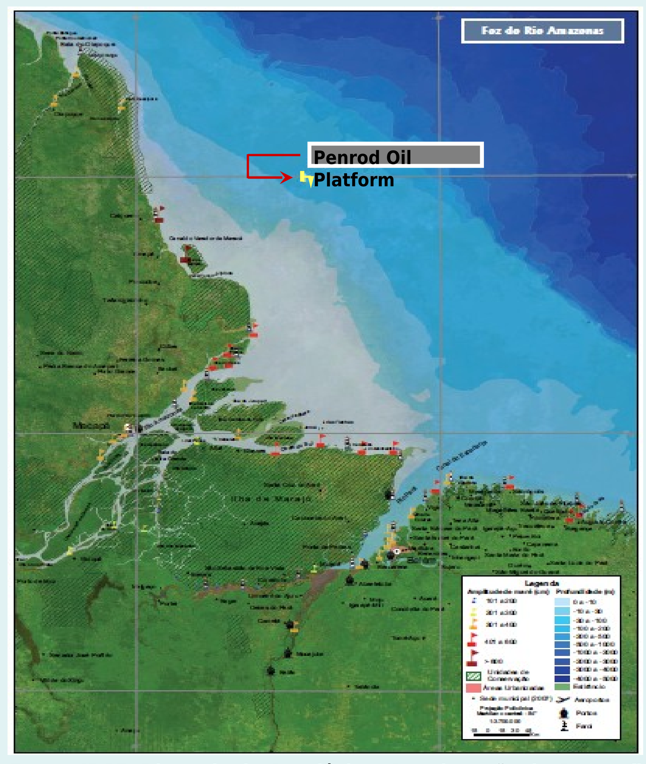


Figure 2: Along track data in the principal orbit of satellites from Poseidon series.

- In situ data: Penrod Oil Platform tide gauge data of the Brazilian Navy;
- 30-day time series;
- Resolution of 60 min.



Fonte: IBGE, Diretoria de Geociêcias, Coordenação de Geografia.

The in situ (tide gauge) and satellite measurements are 5.1446 km apart.

Methodology:

The problem to obtain the harmonic of a wave given is basically to solve a linear equation system, such as:

$$Ax = b,$$

in which in this work A is the coefficient matrix, x is the variable vector to be calculated and b is the vector of SSH obtained from satellite data.

$$\begin{vmatrix} \cos\omega_1 t_1 + \ldots & \mathrm{sen}\,\omega_1 t_1 + \ldots & \cos\omega_n t_1 + \ldots & \mathrm{sen}\,\omega_n t_1 \\ \cos\omega_1 t_m + \ldots & \mathrm{sen}\,\omega_1 t_m + \ldots & \cos\omega_n t_m + \ldots & \mathrm{sen}\,\omega_n t_m \end{vmatrix} * \begin{vmatrix} a_1 \\ b_1 \\ a_n \\ b_n \end{vmatrix} = \begin{vmatrix} \zeta(t_1) \\ \zeta(t_m) \end{vmatrix}$$

where n is the number of constituents and m is the number of meassuremente.

The system is solved for the eight tide constituents using the Singular Values Decomposition (SVD) technique to invert the coefficients matrix.

$$x = A^{-1} b$$

$$A = U . W . VT,$$

where U is the ortogonal matriz with the same dimension of A and W is a matriz of dimension n x n with nulls or positives elements in the diagonal (Singular values) and VT is the transposta of the ortogonal matriz V with dimension n x n.

Compare the preliminary method results with a Penrod Oil Platform tide gauge data (the harmonic constituents of the tide gauge were extracted using Fourier method, done and available by Brazilian Navy). The comparisons have done using the RMSmisfit and forecast.

$$RMSmisfit=(1/N\sum 1/2[(H_1\cos(g_1)-H_2\cos(g_2)]^2+[H_1\sin(g_1)-H_2\sin(g_2)]^2)^{1/2}$$

where N is the number of points used, H1 and g1 are, respectively, the amplitude and Greenwich phase lag obtained from satellite, and H2, g2 are, respectively, the amplitude and Greenwich phase lag provided by the models or TGs.

Results:

The results have shown that the maximum difference between the amplitudes is 6.06 cm for N2 which represents 24% of this constituent amplitude obtained by the tide gauge. The minimum difference is 0.11 cm for K2 which represents 1.4% of amplitude from the tide gauge. Regarding to the phases, the maximum difference is 12.3892o for N2 which represents 7.94% of this constituent phase obtained by the tide gauge. The minimum difference is 3.3623o for M2 constituent which represents 2.1% of the phase from the tide gauge.

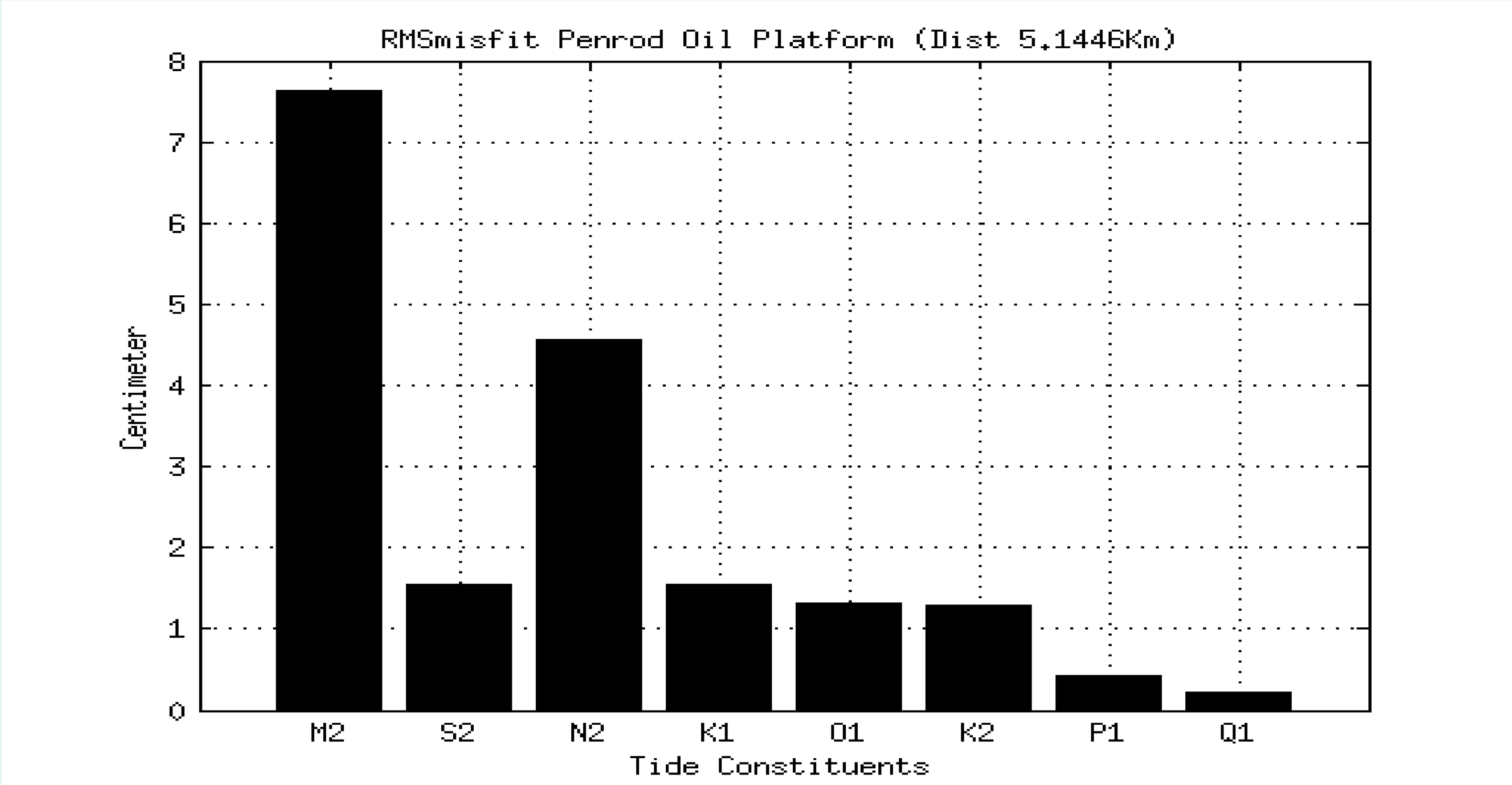


Figure 3:. RMSmisfit between tide constituents extracted from altimetric satellite data and tide gauge.

Table 1:. Amplitudes and phases of the tide constituents extracted from satellite and tide gauge data.

Constituent	Amplitude Satellite	Amplitude Tide Gauge	Fase Satellite	Fase Tide Gauge
Q1	1.780	1.700	177.5700	176.8892
O1	8.370	7.500	223.0800	229.8291
P1	3.100	3.400	260.5200	251.8768
K1	9.030	10.300	263.6700	253.1232
N2	18.780	25.000	228.7800	241.3192
M2	85.880	90.500	250.6700	253.9523
S2	26.080	27.600	270.3800	281.0000
K2	7.170	7.500	288.0400	283.2464

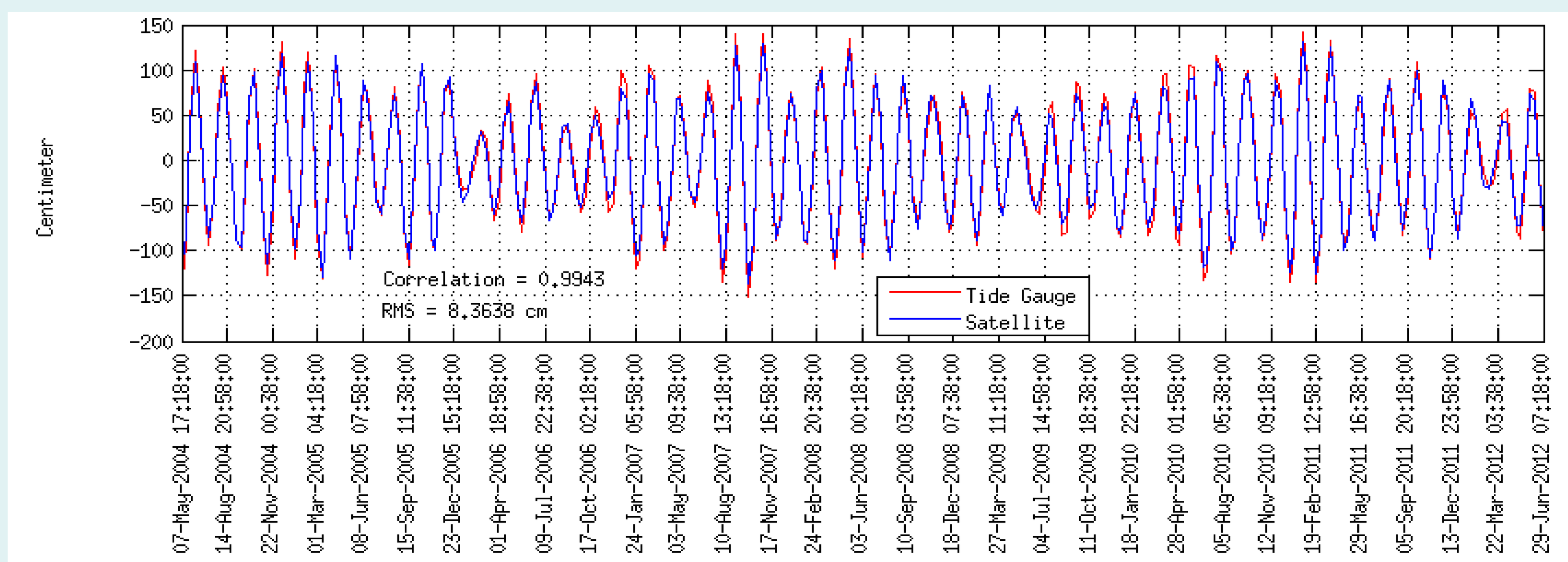


Figure 4:. Tide forecast by tide constituents from altimetric satellite data and Tide gauge.

Conclusions:

The present results suggest that the method could be considered quite efficient to extract tide constituents from altimetric satellite data.