Efforts to understand Sea Level variability in the Southeastern Brazilian coast

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1. Introduction

The Tropical and Mid-latitudes South Atlantic is one of the worst sampled oceans of the world for the sea level (Woodworth and Player, 2003). This problem increases the global uncertainties of the estimates for sea level variability and trends. On the other hand, this oceanic region does not present severe tropical storms and has geologically stable coastal boundaries thus a good signal to noise ratio may be achieved for estimating sea level climatic variability. Also, the region connects the two main areas of deep water formation – Weddell Sea and the Norwegian Sea – through the "conveyor belt" (Broecker, 1994). So, it is a particularly suitable region for understanding the global sea level variability.

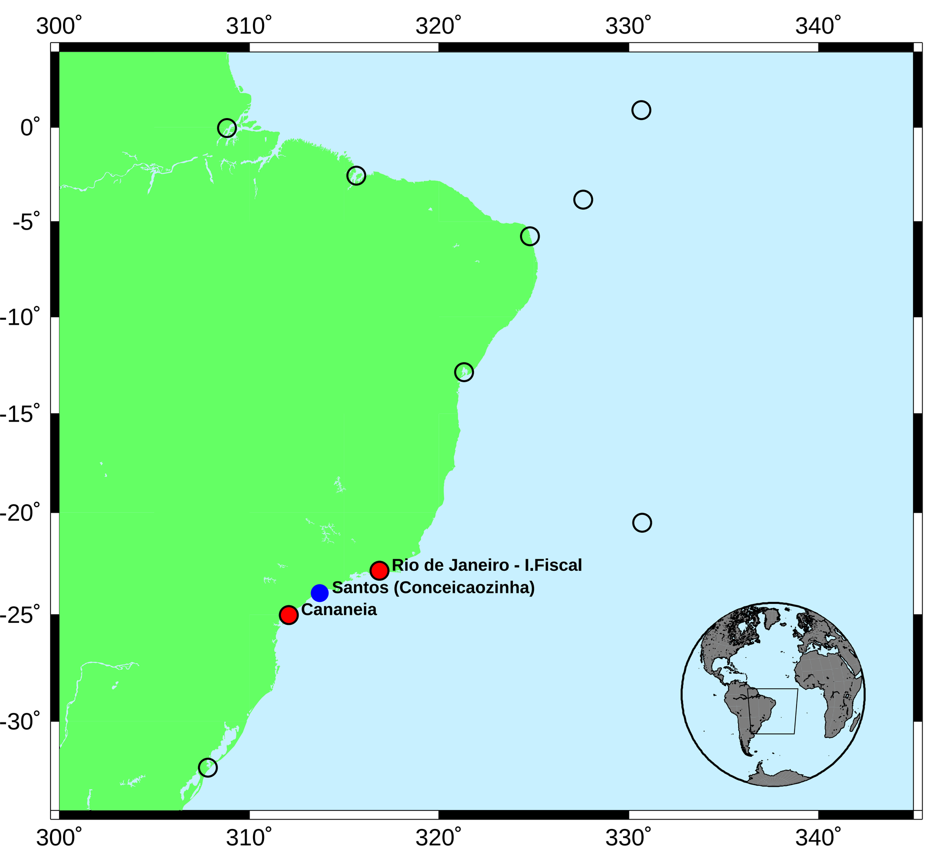

FIGURE 1: *GLOSS ("Global Sea Level Observing System") sea level stations in Brasil (black circles). Only Cananéia, SP, and Rio de Janeiro, RJ, have time series longer than 40 years (red). The recover of Santos data (blue) is underway.*

2. Long term Sea Level Measurements in Brasil

In Brazil, only two sea level records have long enough data to allow climatic estimates: Cananeia, just over 50 years record, and Rio de Janeiro, over 40 years, in the Southeastern coast, both indicating sea level rise (3.2 ± 0.4 and $3.6 \pm 1.1 mm/yr$ respectively) at rates twice as fast as the global upper bounds estimates (Mesquita et al., 1995; Church et al., 2001). To understand this variability, efforts are being made to instrument the Cananeia station with real time tide gauge and permanent GPS records alongside with gravity measurements.

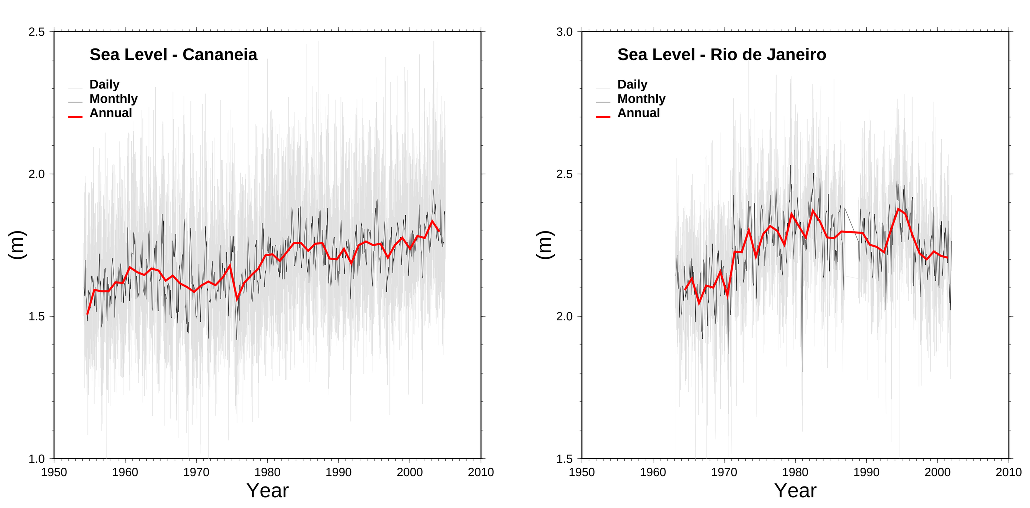

FIGURE 2: *Sea Level measured at Cananéia, SP, and Rio de Janeiro, RJ. Both show sea level rise at rates of 0.42±0.04 cm/year (Cananéia) and 0.36±0.11 cm/year (Rio de Janeiro).*

A radar sea level gauge, sponsored by the Intergovernmental Oceanographic Commission (IOC), was installed at Cananéia and has been tested since April, 2006 (Figure 3). It is expected to be fully operational in a few weeks time producing real time sea level data through the Internet. Continuous GPS measurements at Cananéia are available since 2003 (Figure 4). An interim analysis of this record shows subsidence of $-0.38 cm/year$ (de Mesquita et al., 2005). This result, however, is under scrutiny, since different data processing methodologies produced different results. A gravimeter hut was built at Cananéia in order to obtain yearly absolute gravity measurements. Due to logistics of the instrument the measurements were not taken yet. Meanwhile, relative gravity campaigns have been conducted (Figure 5). Meteorological observations are available for Cananéia since 1956 as paper records. An effort has been conducted to make these observations available in computational media. Automatic observations are available since 2000 (Figure 6).

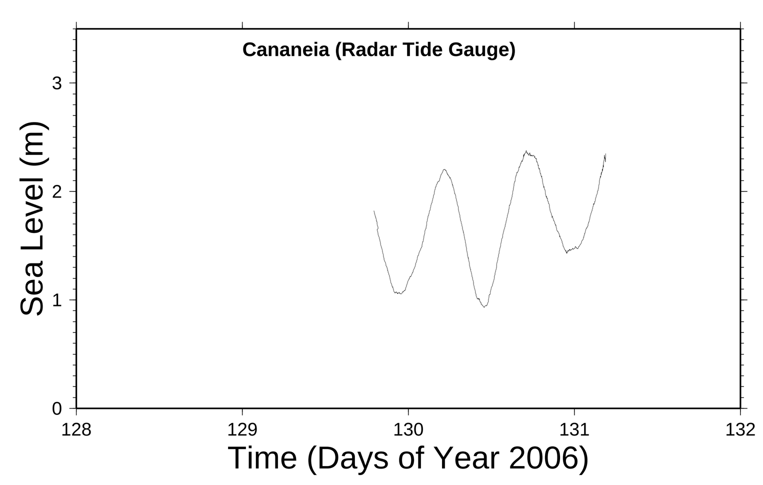

FIGURE 3: *Radar Tide Gauge, sponsored by IOC, installed at Cananeia. Initial hours of measurements are shown.*

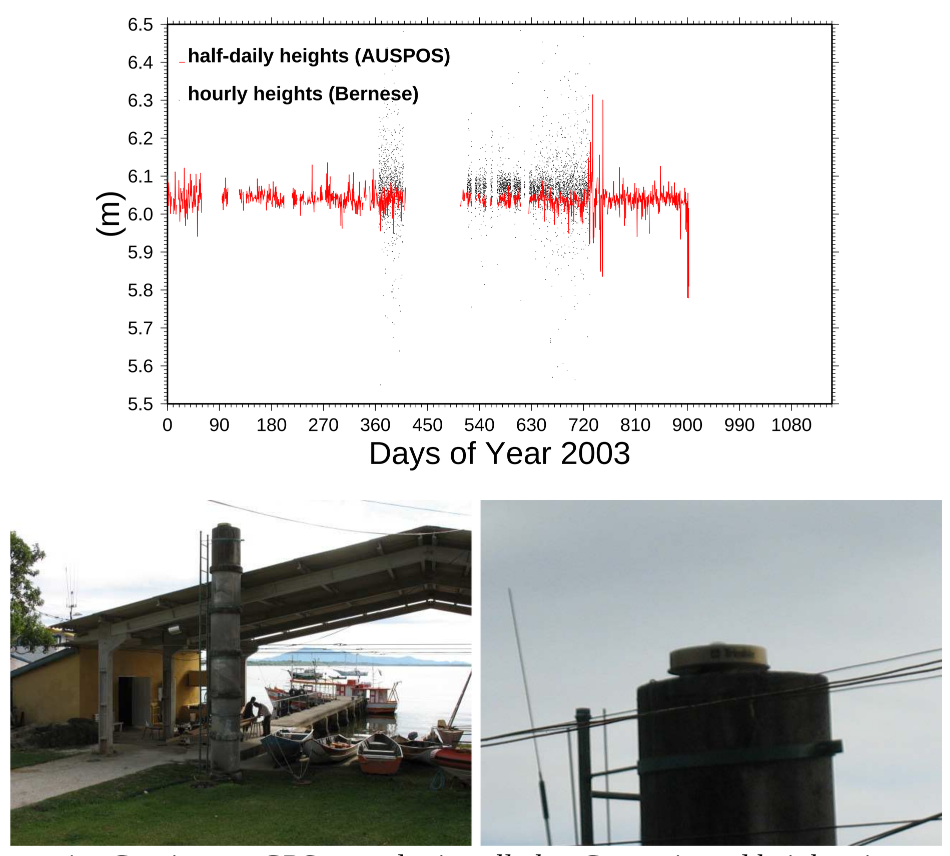

FIGURE 4: *Continuous GPS recorder installed at Cananeia and heights time series.*

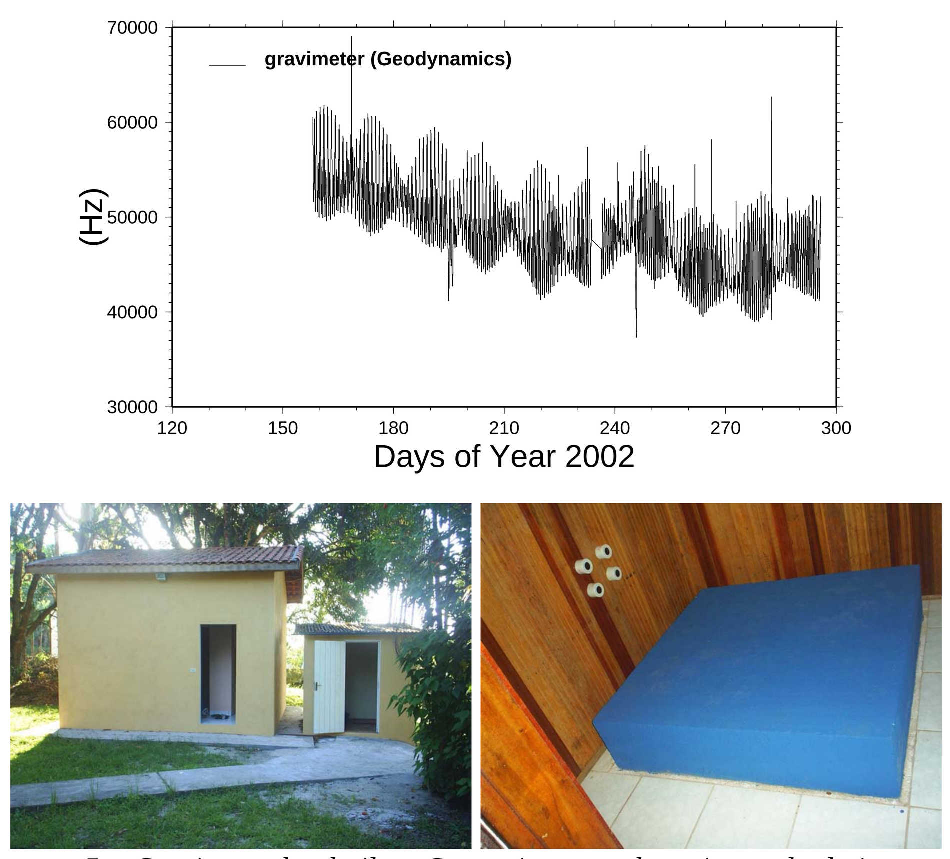

FIGURE 5: *Gravimeter hut built at Cananeia research station and relative gravity measurements.*

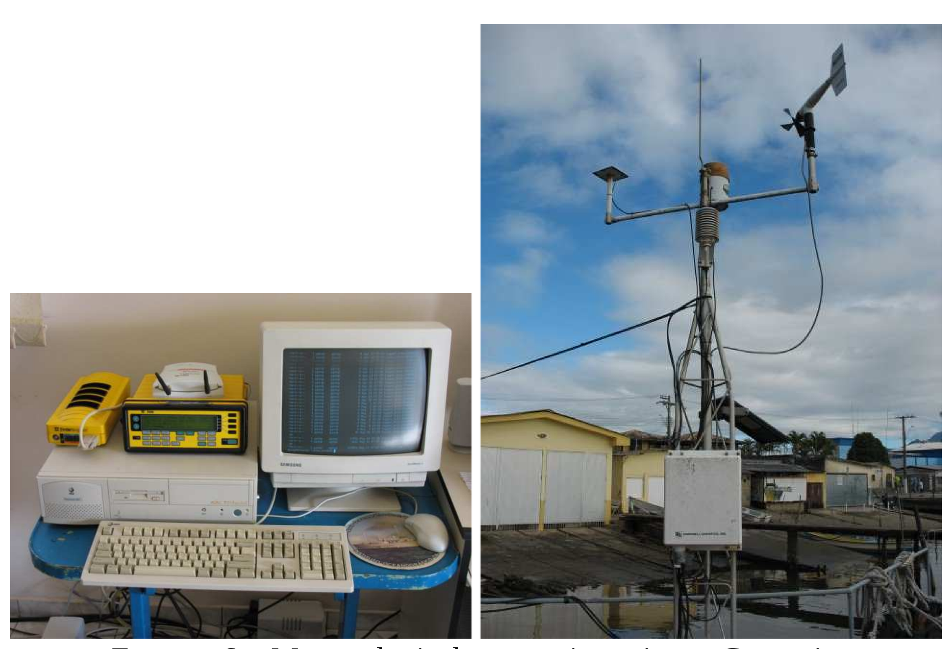

FIGURE 6: *Meteorological automatic station at Cananeia.*

Efforts have also been made towards obtaining a long sea level record from Santos port – the largest port in the South America – where beach erosion, increasing number of extreme events and salinization of the estuary have been reported (Harari and Camargo, 1995), although the 2004 Sumatra tsunami recorded with local 1m amplitudes during high tides (Figure 7) was almost unnoticed. In this port, dredging operations have been performed periodically, so real time tide gauges observations are also necessary to increase navigation security.

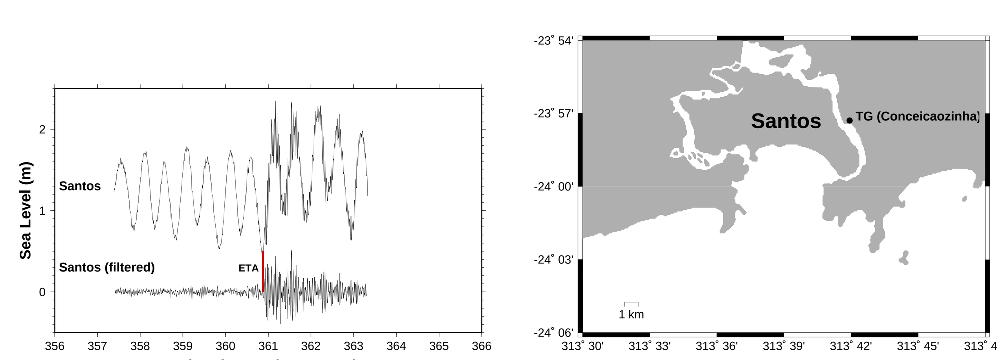

FIGURE 7: *(Left)Sea Level measured at Santos, SP, spanning the period of the 2004 Sumatra tsunami. (Right) Santos bay and estuary. Sea Level has been measured for dredging and navigation operations since 1920. An effort to recover tide gauge benchmarks in the area is being conducted.*

3. Oceanic Measurements

Data from oceanographic stations in the Southeastern Brazilian coast are sparce and not long enough to estimate trends in the dynamic heights, even though it is the most sampled oceanic region along the Brazilian coast. Systematic yearly observations of the entire water column in an oceanographic section through the Brazil deep basin have been proposed (Mesquita, 1989); these observations would give the dynamical thickness of different water masses in the region and their variability, allowing to compare them to the sea level records in the coast.

Temperature and salinity data from oceanographic stations in the Southeastern Brazilian coast ($30^oS - 20^oS$ $50^oW - 40^oW$) are available from the Brazilian National Oceanographic Data Bank (BNDO). The T-S diagram (Figure 8) of the data shows the poor data quality and the absence of deep ocean observations.

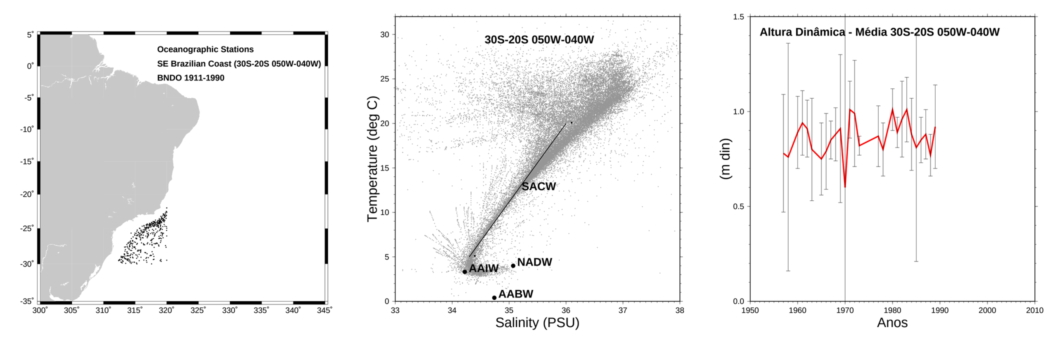

FIGURE 8: *(Left) Positions of the 479 BNDO oceanographic stations in the SE Brazilian coast from 1911 to 1990. (Center) Temperature-Salinity diagram for SE Brazilian coast. The water masses of the area are indicated. SACW - South Atlantic Central Water; AAIW - Antarctic Intermediate Water; NADW - North Atlantic Deep Water; AABW - Antarctic Bottom Water. (Right) Dynamical Heights relative to 1000db annual mean for the Southeastern Brazilian Coast ($30^oS - 20^oS; 050^oW - 040^oW$)*

Annual means of dynamical heights relative to 1000db level in the Southeastern Brazilian coast ($30^oS - 20^oS; 050^oW - 040^oW$) computed from the BNDO data (Figure 8) show data latency of more than 10 years and no data enough before 1950. Smaller regions do not have stations enough for annual estimates. The trend of the mean annual dynamical height is estimated at $0.2 \pm 0.2 cm/year$.

The situation of the oceanographic observations prevents an adequate understanding the sea level variability in the Southeastern Brazilian coast. It is necessary a scientific quality observations of the deep South Atlantic ocean through an annually repeated oceanographic section as planned (Figure 9) allowing to detect climate changes and a better understanding of the regional sea level variability.

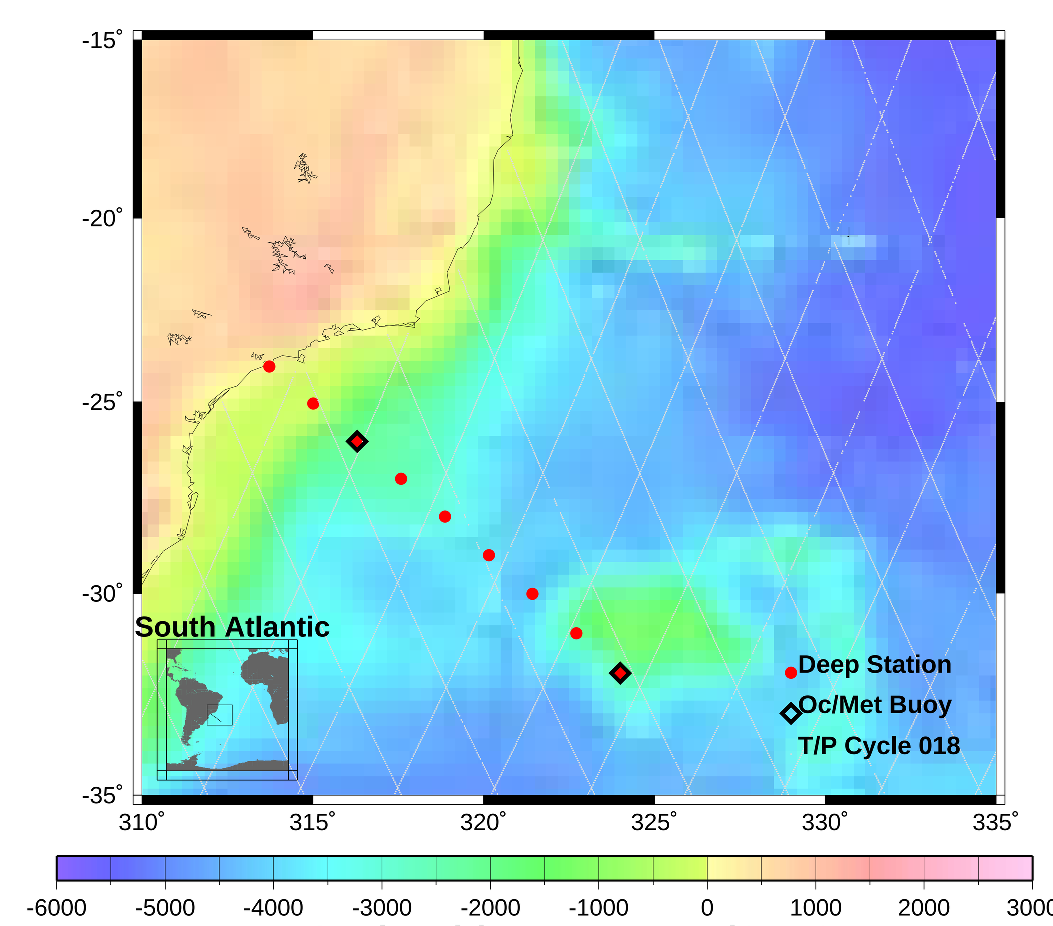

FIGURE 9: *Planned deep-sea oceanographic stations.*

4. Acknowledgements

To FAPESP for grant no. 03/04528-8 and IOC for sponsoring the Cananeia tide gauge.

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