First results using the Microg LaCoste for developping an Earth tide model in São Paulo

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Abstract

The equipment Microg LaCoste, gPhone-103, designed for Earth tide studies, was installed during the year 2012 on the campus of the University of São Paulo, in the building of IAG. The first results of the observation analysis allowed the determination of a preliminary model for the Earth tide in the region of São Paulo. For this purpose the softwares Tsoft and ETERNA were used for the pre-processing and for the referred analysis, respectively. Attention was also addressed to the drift, the behavior of the instrument levels and the influence of the atmospheric pressure during the period.

Introduction

A wide range of geophysical and astronomical phenomena, such as the luni-solar attraction, seismic free oscillations, nutation, changes in the Earth's rotation, movements of plate tectonics, seismic and volcanic processes have to be studied. They are related to masses redistribution in the crust and/or changes in the Earth's shape. Therefore, the Earth’s elastic-gravitational equilibrium is affected, resulting in a slow and small changes of gravity with time. The order of the amplitude is 10^{-8} to 10^{-9}g (between 10μGal and 1μGal), g is the gravity acceleration (mean of 9.8ms^{-2} for Earth). At the level of precision better than a few parts per million, the gravity is sensitive to anomalies caused by subsurface density variation. They represent changes due to natural causes or human activities. For example, those caused by water storage variation, ore, oil and gas deposities; soil moisture; changes manmade excavations; mass flux below active volcanoes.

Method

Aiming to calculate an Earth tide model for the region under study, a gravitymeter LaCoste Microg -103 was installed in the city of São Paulo, USP campus. It is characterized by an improved thermal system - a double-oven - for more precise temperature stability. The instrument also has a true vacuum seal so that it is completely insensitive to buoyancy changes due to atmospheric changes. It employs the Aliod beam nulling system for precise digital measurement of gravity with 0.1 microgal resolution.

The equipment has been installed in an appropriate room of the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG), in a stable pillar, isolated of the building structure. Gmonitor software running in a small computer is used for monitoring the meter and storing the data.

The adjustment of the levels and the sensitivity were undertaken after the installation of the meter and re-evaluate during the period of gravimetric observations, when necessary.

The raw data must be submitted to two phases. First phase is the preprocessing; the aim is to prepare the data for analysis. Tsoft software, created by Paul Vauterin at the Royal Observatory of Belgium, is used in this step. It allows the user to process the data in a fully interactive and graphical way, taking advantage of the extended graphic capabilities of the current computer systems. This approach has a number of important advantages, particularly in the field of error correction of (strongly disturbed) data, and the detection and processing of special events (e.g. free oscillations after Earthquakes). In addition, TSoft offers the possibility to write scripts, which allow to simplify and to speed up routine tasks considerably. The software offers the following tools (http://seismologie.oma.be/TSOFT/tsoft.html):
- Import and export of a variety of file formats;
- Convenient visualization and printing of data channels;
- Arithmetical calculations between different data channels;
- Changing sample rate & sample frame, using anti-aliasing filters;
- Calculation of synthetic tides and residuals, provide tidal parameter sets from the Wahr–Dehant latitude dependent model (Dehant et al., 1999);
- Automatic and interactive correction of spikes, earthquakes, steps, etc;
- Time-dependent, nonlinear calibrations;
- Compensation of varying time shifts & calculation of time delay between channels (correlation);
- A wide range of filters (FFT, LSQ, Butterworth, polynomial);
- Multilinear least squares fit using different drift models;
- Moving-window time dependent least square fit;
- Frequency-dependent admittance determination;

- Calculation of spectra and power spectra, using different data windowings;
- Moving-window time dependent spectra;
- Phase graphs;
- Calculation of transfer function (step response, sine waves);
- Calculation of gravity gradient (multilinear least squares fit).

In the second phase, the ETERNA software undertakes the analysis (Wenzel,1994; Wenzel, 1996). It allows the recording, preprocessing and analysis of Earth tide observations. The final result is the amplitude and the phase of each wave component identified. Indeed, depending on the time of observation, components with longer periods will not have their variables calculated accurately.

Examples

There are ten months of observations (Jan-2012 to Oct-2012) in the university campus, São Paulo. The Figures 1 and 2 show ambient pressure, data survey and model gravity, and residual result of 10 months and January 2012, respectively.

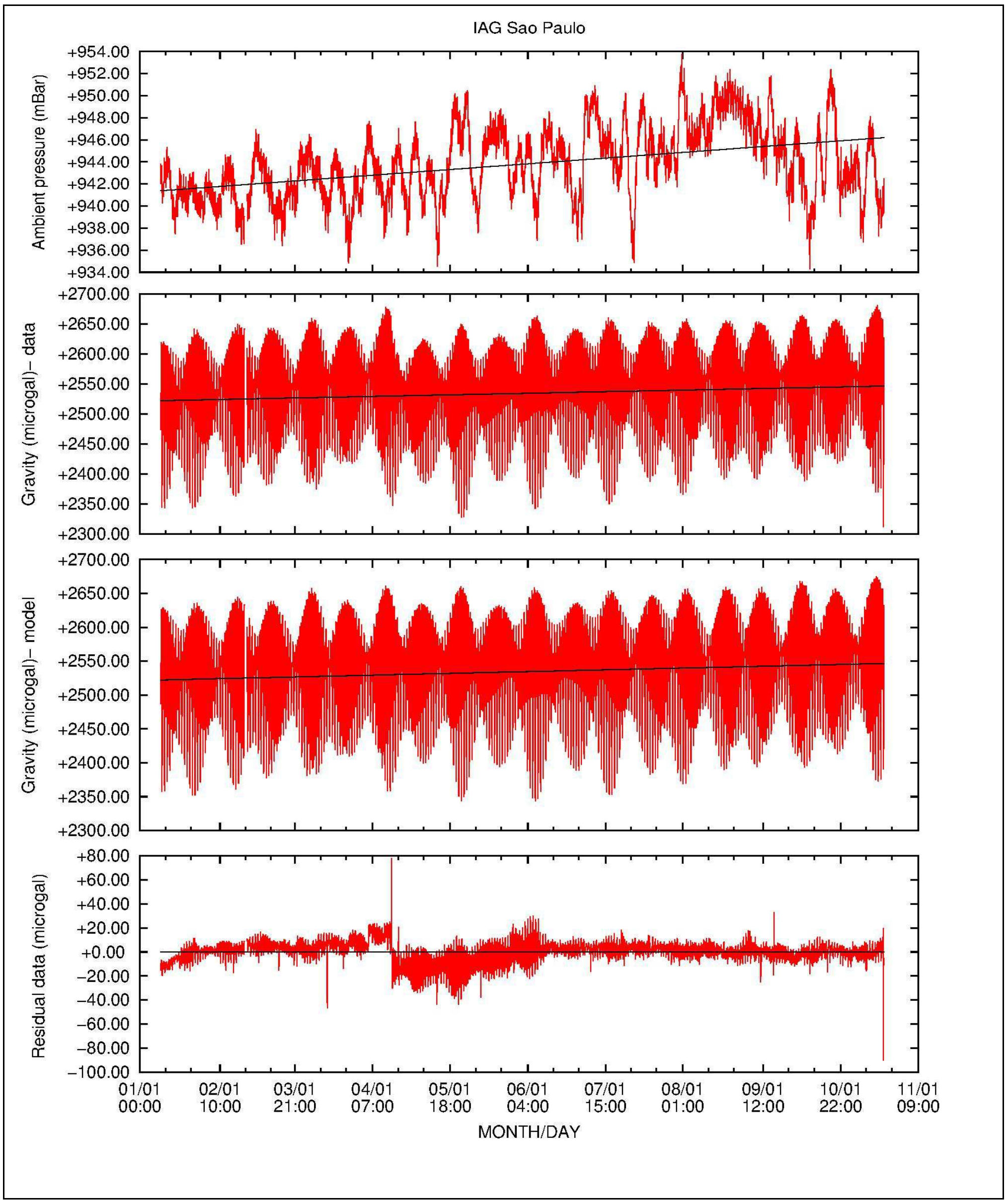

Figure 1 – Ambient pressure, gravity (observation data, model and residual results) of 10 months.

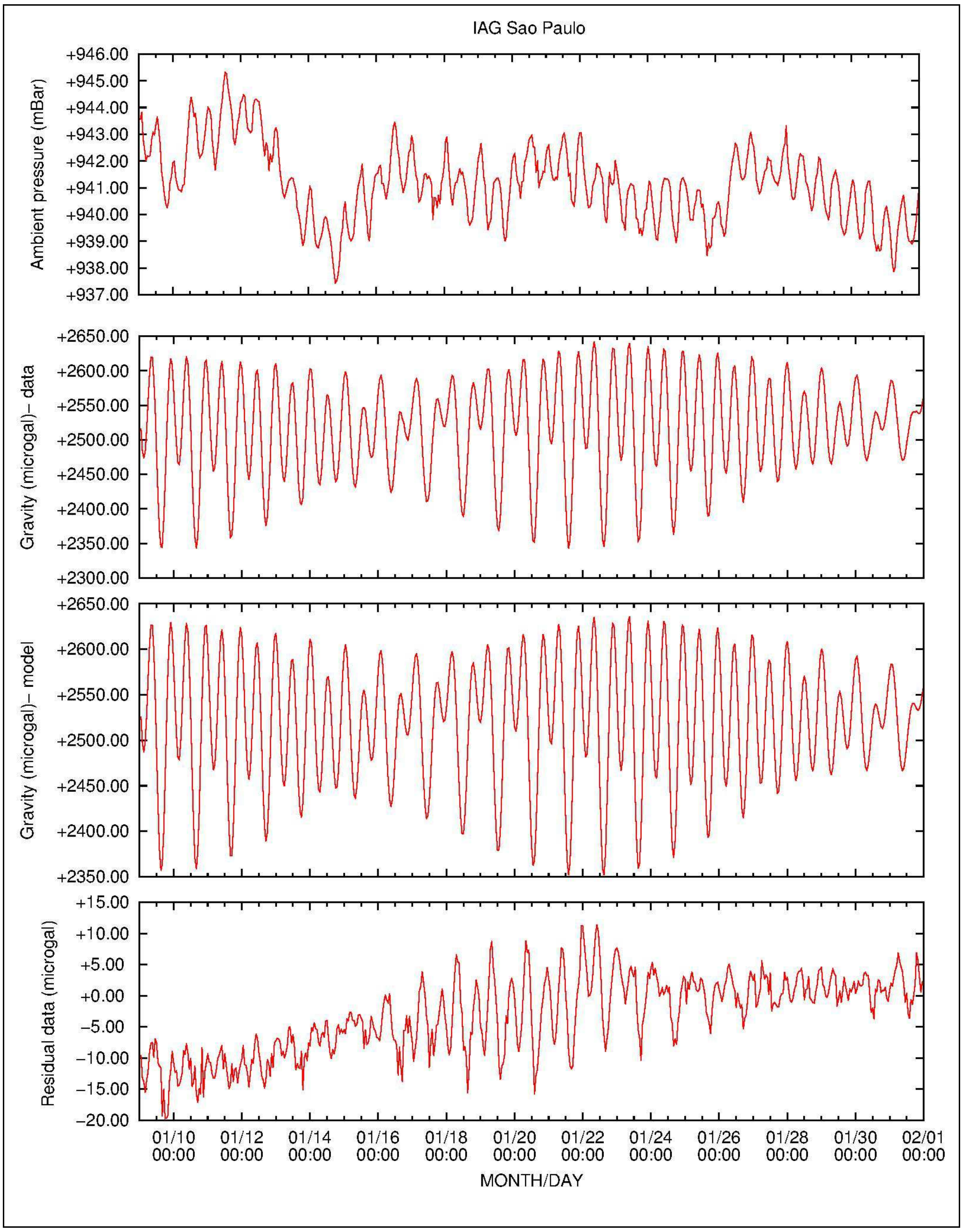

Figure 2 - Ambient pressure, gravity (observation data, model and residual results) of January 2012.

Results

Table 1 presents the results for amplitude and phase related to the diurnal and semi-diurnal components during the mentioned period. It is important to note that the Mean Square Deviations (MSD) is smaller for the semi-diurnal components. It is probably due to the major occurrence of this component.

The Figures 1 and 2, besides the ter-diurnal component, provide a preliminary Earth tide model for the area. In this way, it is possible to estimate the residuals between the gravity observations of the gPhone and the derived model. The maximum difference for the residual was 50 µGal (Figure 1). In the residual signal is included in different phenomena such as ocean loading.

The atmospheric pressure showed a perfect behavior considering that it varies inversely proportional to the gravity. A regression analysis applied to the observed pressure data resulted in a coefficient of 2.69. It is necessary to remove this effect from the gravity data.

The drift of the equipment was practically null. The estimation of the drift by a regression analysis resulted in the following coefficients for the first order linear equation:

y = 5.58158e-13x -0.000224227.

Table 1- Amplitude (microGal) e Phase (degree) related to the main diurnal and semi-diurnal components.

Comp.	Ampl.	MSD	Phase	MSD
Q1	2,6715	1,6597	194,425	35,575
O1	13,1296	1,6045	92,283	6,998
P1	7,8337	1,6135	129,087	12.164
K1	16,0437	2,0643	201,999	7,881
N2	10,8239	0,8419	79,080	4,456
M2	53,0317	0,7584	-39,089	0,819
S2	30,3340	1,4608	2,172	1,587
K2	7,8024	0,8092	42,613	5,934

Conclusions

This new project is starting in Brazil under the coordination of Laboratório de Topografia e Geodesia (LTG), EPUSP, with the objective to establish an Earth tide model in the country. Two Microg LaCoste gravity-meters and one A-10 Absolute Gravitymeter are available for the purpose.

The first phase of the project is intended to achieve the determination of a preliminary model for the Earth tide in São Paulo state. During the year 2012 the two gPhones were installed in the campus of the University of São Paulo and at the Abrahão de Moraes observatory, in São Paulo and Valinhos cities, respectively. The sites belong to Institute of Astronomy, Geophysics and Atmospheric Sciences of the University of São Paulo (IAG-USP).This paper shows the perfect behavior of gPhone observation and first results of the amplitude (microGal) e phase (degree) related to the main diurnal and semi-diurnal components in the campus of the University of São Paulo in 10 months of observations in 2012. The Valinhos data is in the process of analysis.

Presently the two gPhones are set up for operation at Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP), in Presidente Prudente, and in the ocean research base Dr. João de Paiva Carvalho, Oceonographic Institute of the University of São Paulo (IO-USP), located in Cananeia.

The project aims to establish 5 stations well distributed in Brazil, one of long term in Manaus, Amazon, and 4 others in a sequence of one year operation in different places. The A-10 Absolute Gravimeter will work around Brazil establishing fundamental gravity points with high precision and it will be used for controlling de drift of the gPhone are been established.

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