Microbarograph for investigation of geodynamical phenomena caused by atmospheric pressure variations influenced by lunisolar effects

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Abstract

The air pressure variations due to lunisolar effects cause the deformation of the Earth and therefore directly and indirectly influence several geodynamical phenomena. For a better understanding of these effects a microbarograph of high sensitivity was developed in the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences in 1991. In this paper the construction of the instrument and the calibration method are described and the measured data are presented. The microbarograph data can be used to study atmospheric tides, the connection between air pressure variations and relevant geodynamical phenomena, the relationship between barometric pressure and instrumental effects. The results of the first data analyses are also given.

1. Introduction

Earth tide measurements are influenced by several environmental disturbances that must be taken into account before these records are used to obtain information on physical properties or geodynamics of the solid Earth. One of such phenomena is the barometric pressure variation on the surface. The influence of pressure variation on Earth tide measurements - gravitational and other types (extensometric, tilt, etc.) - consists of two main parts:

- direct attraction of the atmospheric mass,
- indirect effect due to elastic deformation of the Earth which causes change in gravity due to vertical displacement of the Earth's crust and due to redistribution inside the Earth.

The dominant part is the direct attraction. According to investigations the total effect of air pressure variations cause a gravity response of 0.3-0.4 Gal/mbar in the case of local pressure fluctuations (responsible for a part of the random fluctuations of gravity records) while the response to the global atmospheric tides is significantly larger (0.66 Gal/mbar for S_1 and 0.47 Gal/mbar for S_2, for the two main pressure tide waves) according to the results published by Warburton and Goodkind [1977]. For these reasons it is very important to correct Earth tide measurements for atmospheric variations. To provide appropriate corrections air tide parameters must be determined for the given location and response effects have to be investigated.

Another reason for monitoring of air pressure variations is that there are a lot of connections between atmospheric tides and different geodynamical phenomena of the solid Earth. To study these relationships high sensitive barographs are needed. The difficulty of such investigation lies in the fact that the magnitude of the air pressure variations is much higher than the one caused by lunisolar effects. For that reason a very sensitive microbarograph with a broad measuring range was developed at the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences (GGRI) in 1991.

2. Construction of the microbarograph

The principle of the microbarograph is shown in Fig.1. The pressure sensor is a very sensitive closed diaphragm applied in conventional mechanically recording barographs used for meteorological measurements. The bottom of the closed diaphragm is firmly fixed to a rigid frame. The displacements of the top of the closed diaphragm due to air-pressure variations are sensed by a differential condenser. The moving plate of the transducer is fastened to the middle point of the top of the diaphragm and the fix plates are fastened to the rigid frame isolated electrically from it. The capacitance changes of the transducer are measured in a bridge circuit developed at the GGRI (Mentes, 1983, 1994).

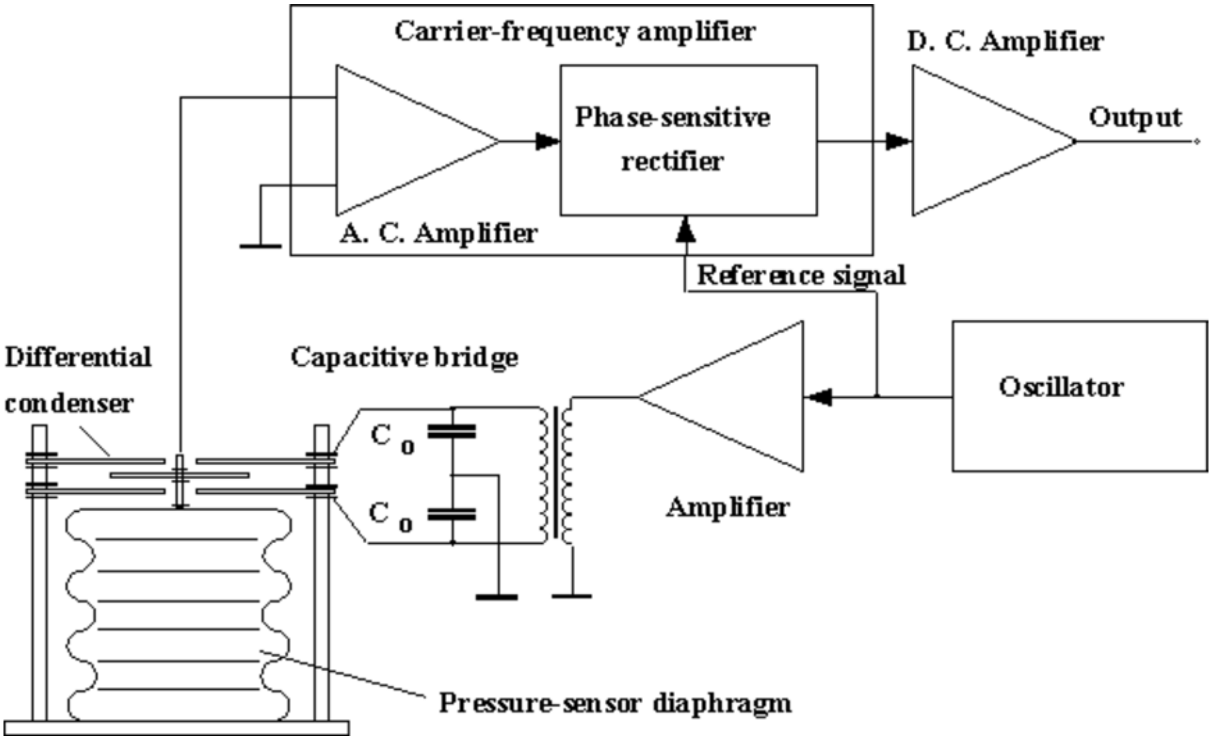

Fig.1. The construction of the high sensitive microbarograph

3. Calibration of the microbarograph

At first the calibration of the microbarograph was made by comparision of its output signal with the air pressure measured by other precision barometers during large barometric pressure changes. This solution had a limited accuracy and was not suitable for the exact determination of the characteristics of the microbarograph. For regular in-situ calibration of the instrument a calibration equipment shown in Fig. 2. was constructed. The microbarograph is placed in a vessel, in which the air pressure can be increased or decreased in relation to the actual air pressure by means of air pumps. During recording air pressure valve 1 is open and valves 2, 3 are closed. During the calibration valve 1 is closed. In this case an additional pressure can be added to the external air pressure by means of the compressor if valve 3 is open and the compressor is working (valves 1, 2 are closed). The air pressure in the vessel can be decreased in relation to the external air pressure by the vacuum pump when valves 1, 3 are closed and 2 is open. The air pressure differences can be measured manually by means of an U-gauge filled with water. In this case the measurement of the pressure is made on a clear physical principle and therefore the measurements are not affected by the errors of other electrical pressure sensors. Figures 3 and 4 show the inner part of the microbarograph and the calibration equipment respectively.

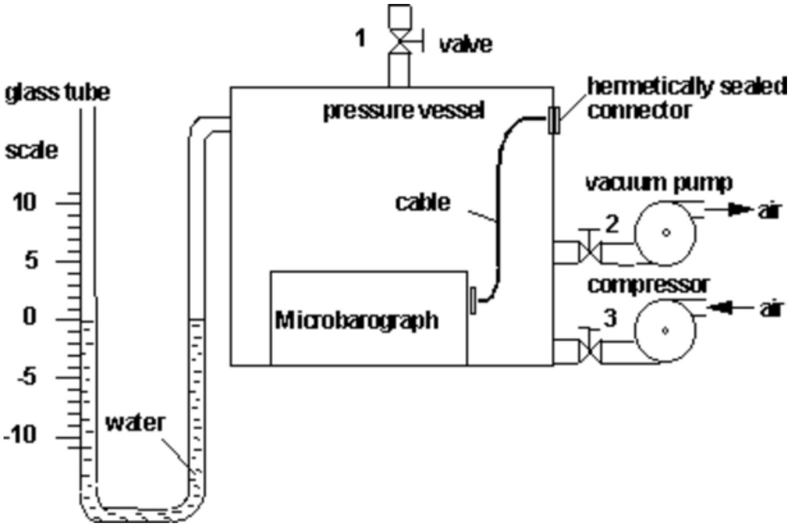

Figure 2. Equipment for the calibration of the microbarograph

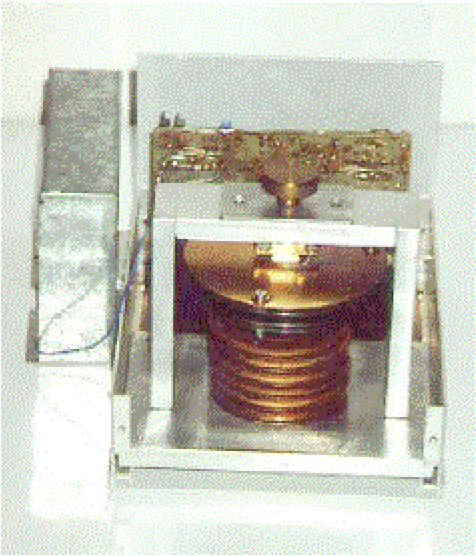

Fig. 5. The inner part of the microbarograph

Fig. 6. The calibration equipment of the microbarograph

The scale factor of the microbarograph obtained by several calibrations is 0.3 V/hPa. The characteristics of the instrument and its linearity errors are shown in Fig. 5. The highest linearity error of the instrument in the investigated measurement range (approx. 65 hPa) is less than 1%. The instrument must have a lower linearity error because one part of the errors arises from the calibration method.

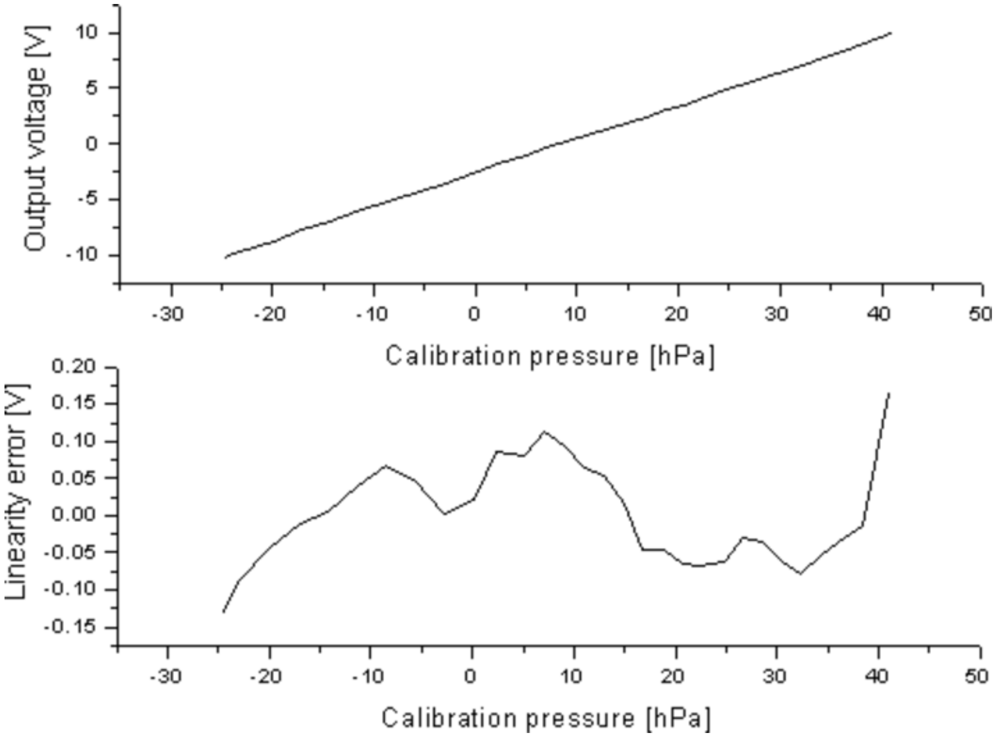

Fig. 5. Characteristics of the microbarograph and its linearity errors

4. Results of the atmospheric tide measurements

The microbarograph was installed at the Geodynamical Observatory of the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences in Sopron for recording air pressure variations in the vicinity of the long quartz tube extensometer. The annual temperature variation in the recording room is less than 0.5 C. The constant temperature is very important because the sensor membrane of the microbarograph is sensitive to temperature variations.

Since 1992 several series of experimental analogous recordings have been made. This time for the calibration of the instrument a conventional high precision pointer barometer was used and its pressure values were regularly compared with the signal of the microbarograph. From the recorded data three continuous data series and their amplitude spectra are shown in Fig. 6. The recorded data show how strongly depends the barometric record on the weather, especially on the daily temperature variations. Regarding the construction of the microbarograph it means that the instrument must have high resolution and a high dynamic range simultaneously because the weather effect is much greater than the tidal one.

The Fourier representation of the raw data series was produced to detect atmospheric tidal variations covered by much larger pressure changes caused by weather system variations. To enhance the tidal peaks in the spectrum the raw data (sampling rate: 10 min.) were filtered by a moving average filter which replaces raw data by the average calculated of the data being in question and of 12-12 data before and after it.

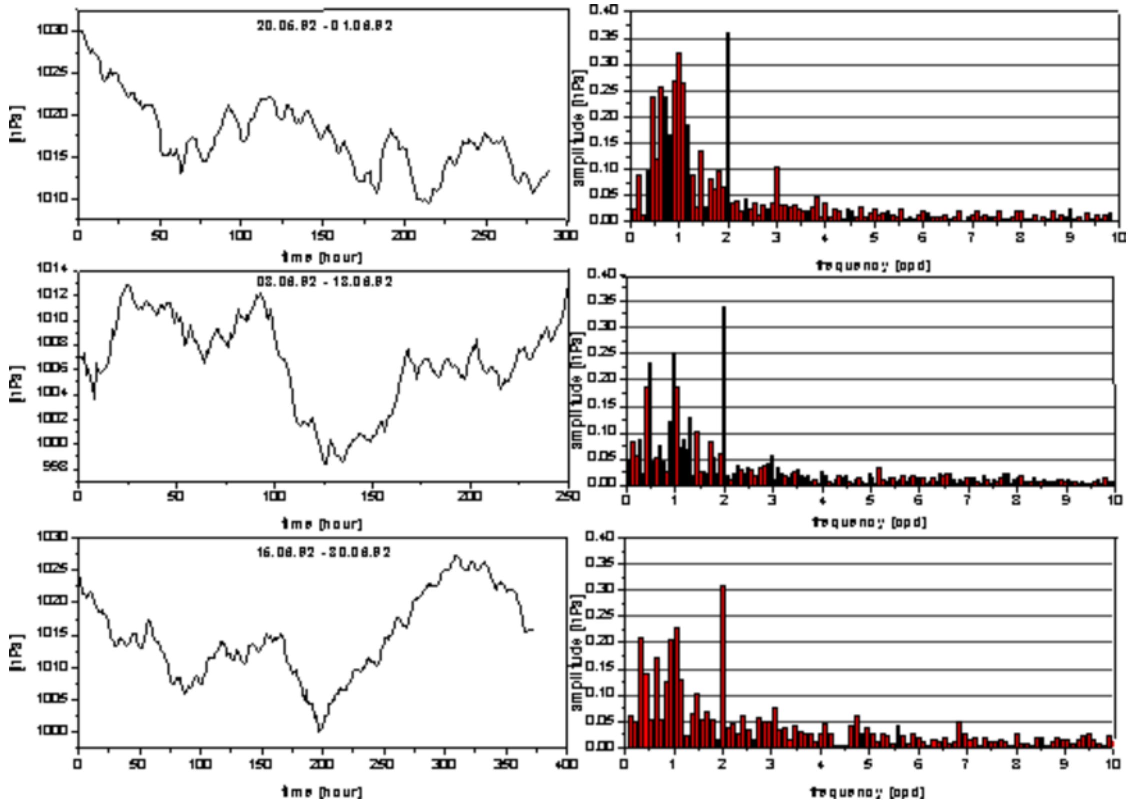

Fig. 6. Air pressure recorded by the microbarograph in the time interval: 20.05.92. - 01.06.92.

To investigate the temperature dependence of the instrument we placed it in the institute in a room where the temperature variation was high. The air pressure and temperature pressure variations were measured simultaneously. Figure 7. shows the raw data measured from 01.01.2001 till 28.08.2001. The large amplitudes are cut by the datalogger at ± 2500 mV. The drift of the microbarograph is very low and has no correlation with the trend of the temperature. It means that the direct temperature effect on the instrument is negligible and the sensitivity of the instrument can be further increased if we apply a datalogger with a greater input range and a higher resolution. This will make possible to detect smaller components of the barometric tides. The correlation between pressure variations and the short periodic temperature variations is obvious. This is due to the dependence of the air pressure on the temperature variations.

Figure 8 shows only the variations of the air pressure and the amplitude spectrum of the data presented in Fig. 7. These data series are longer than the ones shown in Fig. 6. Therefore the amplitude spectrum of the later one is much more disturbed in the long periodic range than the one of the shorter data series. The reason is the seasonal variation of the air pressure.

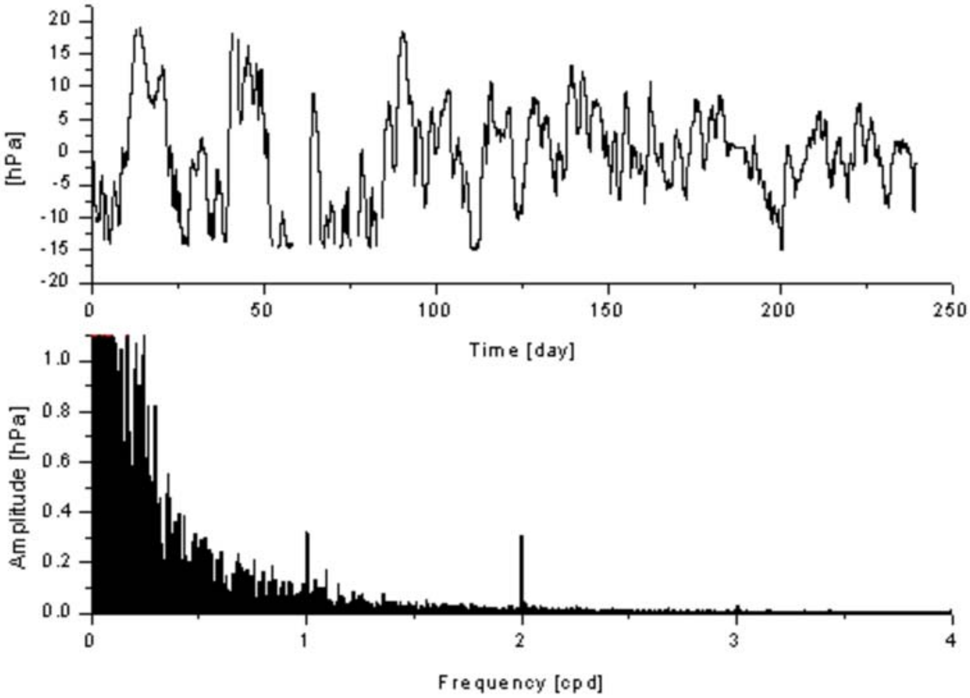

Fig. 8. Variation of the air pressure recorded by the microbarograph from 01.01.2001 till 28.08.2001 and the amplitude spectrum of the pressure variations

There are small periodic oscillations in the Earth's atmospheric pressure variations. These worldwide coherent waves are excited thermally and gravitationally, where the gravitational part is in general much weaker. One type of air tide waves is solar waves driven thermally with frequencies of one solar day and integer multiples ($S_1(p)$, $S_2(p)$, $S_3(p)$, $S_4(p)$). In this case the most important sources of excitation are the insolation and the absorption by ozon and water vapor. The other type is the lunar air tide waves with frequencies of one lunar day having significantly smaller amplitudes. The main components of the measured barometric tidal variations are the solar semidiurnal (dominant) and diurnal waves. The S-type waves are larger at equatorial regions, than at middle latitudes. They reach an amplitude of approx. 0.4 hPa.

The amplitude spectra calculated from the data measured by the microbarograph show the S-type waves very clearly. These are the diurnal, semidiurnal and terdiurnal peaks (Figs 6 and 8). The peaks S_4 apear also but they are very small. Table 1. summarizes the amplitudes of the detected S-type main atmospheric tidal waves. In spite of the analyzed short data series (especially data series 1-3. shown in Fig. 6.) the obtained amplitudes of the diurnal (S_1), semidiurnal (S_2) and terdiurnal (S_3) waves approximate rather well the values published by others (Chapman and Lindzen, 1970). The published annual mean amplitude of S_1 is 0.23 -0.24 mbar and the one of S_2 is 0.41 -0.42 mbar at the latitude of 45. The air tide has also a seasonal variation. Therefore the mean values of the different type waves are given in special groupings. For example in the group J-season S_1 is 0.33 -0.34 mbar and S_2 is 0.4 mbar.

Table 1. Amplitudes of the different S-type waves measured by the microbarograph

Waves	Amplitudes [hPa]				Mean value [hPa]	RMS error [hPa]
	Data series 1.	Data series 2.	Data series 3.	Data series 4.		
S_1	0.322	0.249	0.229	0.313	0.278	0.026

S_2	0.358	0.337	0.309	0.302	0.327	0.015
S_3	0.106	0.057	0.070	0.031	0.066	0.018
S_4	0.037	0.0086	0.026	0.0046	0.019	0.011

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