The effect of atmospheric pressure on strain measurement at the Sopron Observatory, Hungary

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Abstract

We have investigated the effect of local atmospheric pressure on deformation measurement in Sopron Geodynamical Observatory, western Hungary. The atmospheric pressure variation is measured by a microbarograph and the strain data are measured by a quartz tube extensometer placed in a rock gallery. We found that in the frequency range above 2 days period the strain data has approximately 4 nstr/hPa extension with increasing pressure for 116° azimuthal location. Further we found a negative time shift regarding the best correlation of the time series of the parameters. One possible reason lies in the topography of the rock mass and the placement of the instrument.

1. Introduction

In the Sopron Geodynamical Observatory which is located about 5 km from the town of Sopron, a quartz tube extensometer has been working since 1990. The observatory is an artificial tunnel driven in gneiss, the coordinates are: latitude 47,7° N, longitude 16,5° W. In Fig. 1. the scheme of the observatory and location of the instruments are shown. The total length of the instrument is 22 m, it is situated about 30 m from the entrance and it is thermally insulated by three doors. The annual temperature variation near the instrument is less then 0,5 °C (Mentes, 1991).

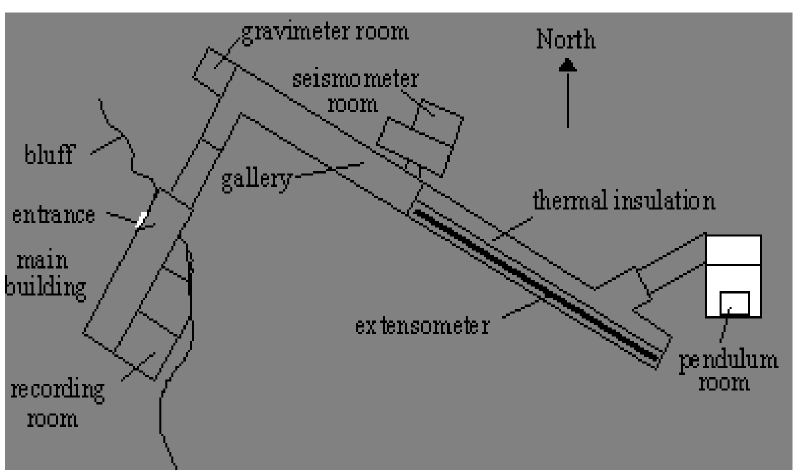

Fig. 1. Scheme of the Geodynamical Observatory of Sopron

A highly sensitive microbarograph was developed in the institute (Mentes, 1994) which is capable of measuring pressure variations and also atmospheric tides with good resolution (Mentes and Eper, 1997). This instrument was installed in the observatory in 1992 and it is working, with breaks for technical reasons, under the same conditions that apply to the extensometer.

When the global deformations of the Earth are measured by means of continuous geodynamical methods it can provide information on periodic deformations (Earth's tides). The long term variations can be related to tectonic forces and these records contain also the exogenic influences such as ocean and atmospheric loading. In the case of deformation measurements the records are influenced by meteorological parameters and by local elastic effects, like cavity, topography and geology depending on the given measurement site. The atmospheric pressure causes the following effects: the gravitational effect which is the direct attraction of the air mass, has no meaning in deformation measurements, and the indirect or deformation effect (vertical displacement of the earth's crust and mass redistribution inside the Earth) causes the deformation of the rock masses around the instrument. In the case of strain measurements the Earth's response to air pressure deviation from the mean pressure is ±10 nstr on the surface (Rabbel and Zschau 1985). In this paper we investigate the influence of local barometric pressure variation on deformation measurements under the conditions of the instrument site.

2. Data analysis

Continuous recording of the extensometric measurement is available since January 1990 and since the end of 1999 we have got digitally recorded data with a sampling interval of 10 minutes. The extensometer is calibrated once a day by a magnetostrictive coil. In the data analysis we have used a four months period: from September to December 2001. Both the extensometric and microbarograph data were filtered to 1 hour sampling interval and calibrated to the proper physical unit of measure.

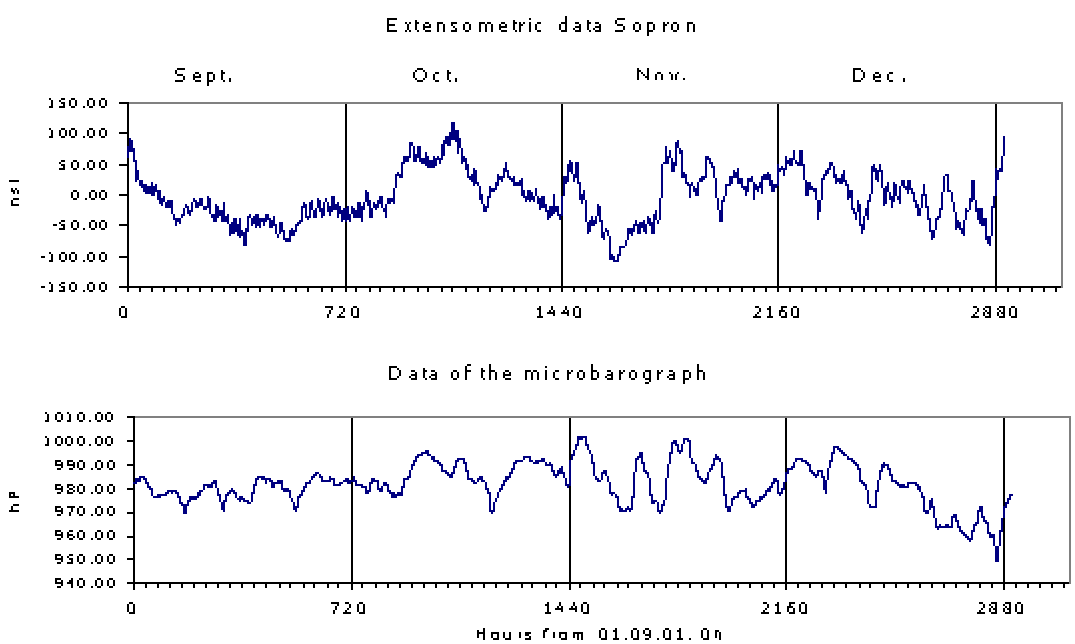

Fig. 2. Data of the extensometer and the microbarograph after preprocessing. Period is Sept.-Dec. 2001

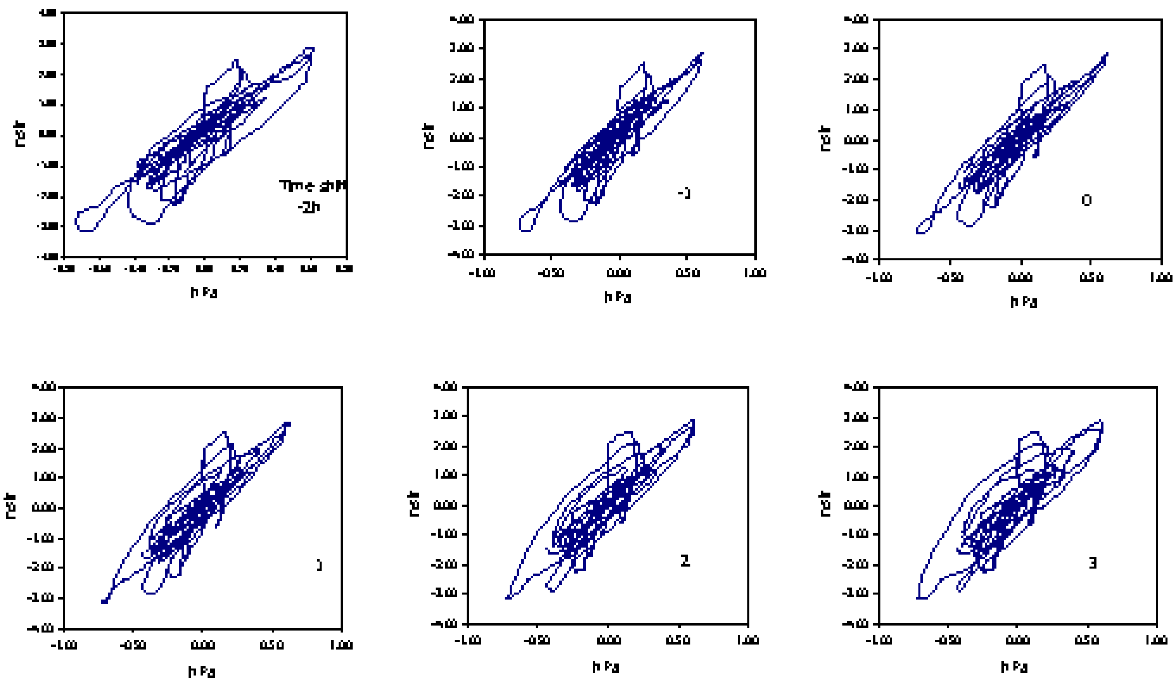

Fig. 3. Relation between strain and atmospheric pressure change data. 0,5 cpd low pass filtering is applied. Time shifts are from –2 to 3 hours.

During the preprocessing operations steps in the data series were corrected, and gaps were interpolated by means of a least square fitting method in the vicinity of the gaps, using theoretical data series which were produced by Eterna 3.3 tidal data processing package. Data are shown in Fig. 2. after preprocessing steps. From the strain data the long term trend was removed by fitting a parabola within the measurement period. In this figure the connection between the strain data and the meteorological parameter is clearly visible.

In this data analysis procedure we investigated the relationship between strain and atmospheric pressure in the non-tidal frequency band. Firstly the long term trend was removed from the extensometric data and the short periods were reduced by low pass filtering with a cut off frequency of 2 days period. In Fig. 3. difference data series of the strain and pressure changes are drawn, with different time shifts between the series. It can be seen that when the atmospheric pressure increases the rock deformation shows extension. We evaluated the average strain change per unit pressure and the time shifts were statistically analysed. The best fit for low pass filtered data is one hour when strain change will be ahead of atmospheric pressure change. The same methods were applied to lower frequency bands. In Fig. 4. similar relation diagrams are drawn for the 2-3 days period band pass filtered data series. In this frequency band the best fit can be revealed also at 1 hour time shifting.

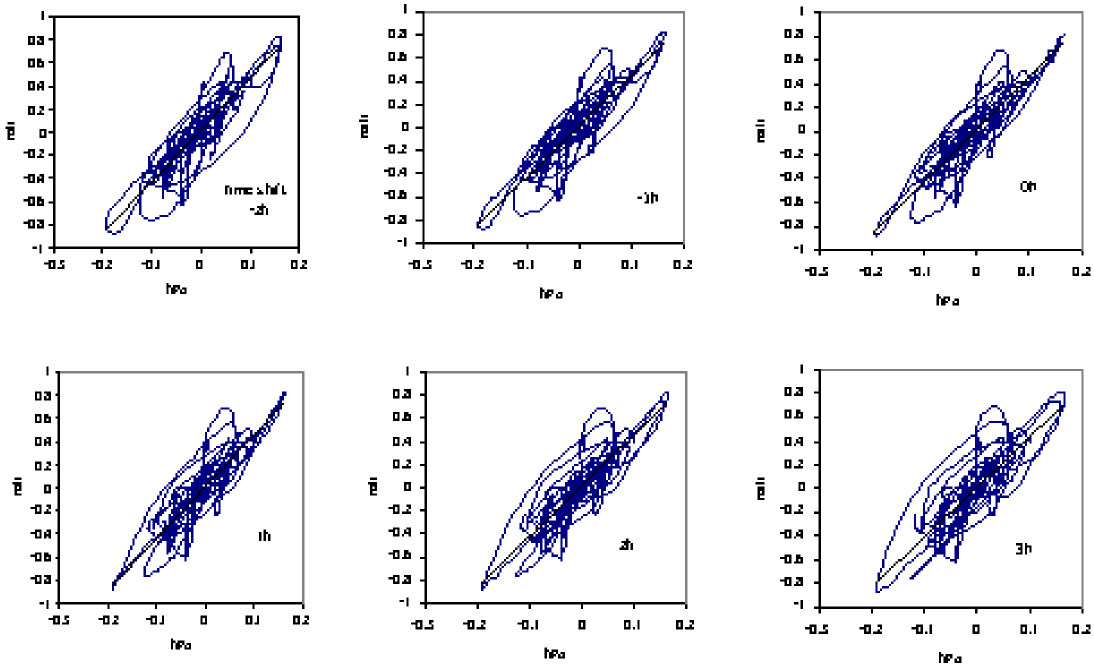

Fig. 4. Relation diagram between strain and atmospheric pressure change data. 0,33-0,5 cpd band pass filtering is applied. Time shifts are from –2 to 3 hours

The same procedure was carried out for lower frequency bands also. The chart in Fig. 5. shows the frequency dependence of the strain change per unit pressure. It can be seen from the values that for these measurement data the relation between strain and atmospheric pressure data depend weakly on frequency, although definite direction can be observed in the frequency function.

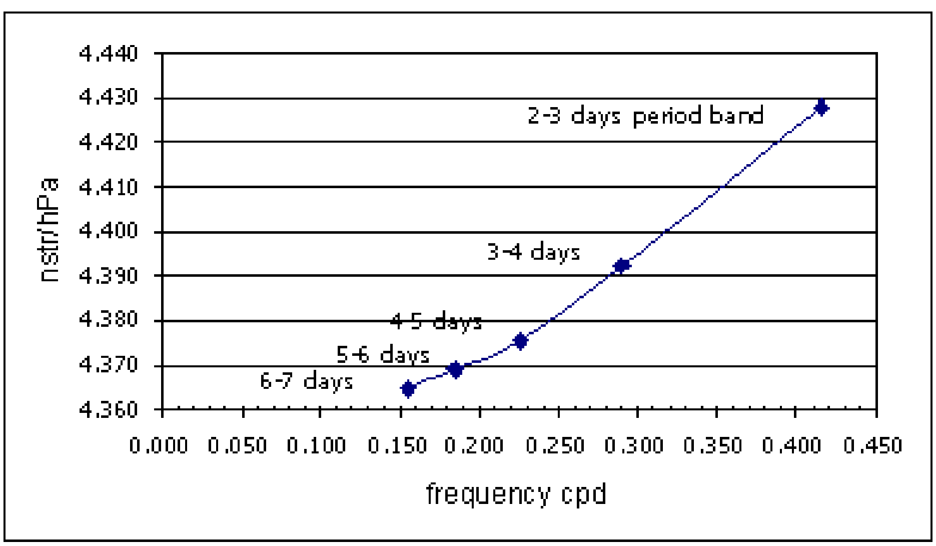

Fig. 5. Strain rate per unit atmospheric pressure change for frequency bands from 0,14-0,17 to 0,33-0,5 cpd

3. Discussion

We investigated the atmospheric pressure effect on extensometric data of Sopron. The relationship between the change of the atmospheric pressure in the gallery where the instruments are placed and the change of the rock deformation is clear. Considerable part of the non-periodic variations of the deformation measurements can be attributed to the pressure changes. It was found that in the frequency range above 0,5 cpd the regression coefficient varies with frequency in a narrow interval of strain per unit pressure, namely the average coefficient is around 4,4 nstr/hPa and the variation is approximately 0,1 nstr/hPa. From other investigations it seems that the influence of the pressure variation on different strain components strongly depends on the topography of the measurement site (Onoue and Takemoto, 1998). In the case of the Sopron Observatory the extensometer is not perpendicular to the high rock wall. Probably it is due to this topographic situation that our results show extension with increasing pressure while the atmospheric loading is dominant in the horizontal direction perpendicular to the wall.

Regarding the time shifts between the data series the strain data can be evaluated 1 hour ahead the local pressure. A possible explanation for this result can be the regional changes of the weather system and the atmospheric pressure, which can cause the outside deformation of the whole rock mass. Although it was found that the extensometric data have low correlation with regional atmospheric pressure variation (Mentes, 2000). It is known that the atmospheric pressure has seasonal characteristics. We intend to investigate the role of seasonal pressure variations in the long term trend of strain data.

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