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On the Influence of Intense Thunderstorm Activity on High-Precision Gravimetric Observations

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Abstract—The influence of thunderstorm activity on gravimetric observations has not been considered previously. Based on long-term high-precision gravimetric observations, we have found that thunderstorm activity induces a systematic error in the measured value of gravity acceleration. The measurements were conducted by CG-5 relative gravimeters with a root-mean-square error of 1 mcGal, installed on a pedestal of a dedicated geophysical observatory. The revealed effect should be considered nongravitational changes. The magnitude of this effect is at most 3 mcGal. It has been reliably identified against the graph of tidal observations.

Keywords: gravimetry, geophysical observatory, CG-5 gravimeter, non-gravitational changes, thunderstorm activity and its influence on the nontidal gravity variations

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INTRODUCTION

The sensing element of a seismometer, gravimeter, or accelerometer typically consists of a mass suspended on the end of a string oriented along one a measurement axis. In the gravimeter, this axis is aligned with the direction of action of gravity acceleration. The influence of various factors on the sensing element of geophysical instruments can be used for studying the character of the errors of these instruments.

Identifying the factors responsible for nontidal variations in gravity and estimating their intensity is one of the purposes of high-precision gravimetric observations. The measurements conducted make it possible to investigate the redistribution of masses on the surface, in the subsurface layer, and in the Earth's interior (Veselov, 1986; Malovichko et al., 1979; Slepak, 2005). Gravimetric monitoring is efficient in regions of volcanoes in cases where intruding magma has a significant density contrast or where large amounts of volcanic gases are accumulated near the surface (Yuzefovich et al., 1978). Nontidal changes in gravity include impacts from atmospheric pressure.

At the same time, the problem of local and high-frequency nontidal gravity variations caused by the other factors has not been considered in the literature. In the present paper, it is shown that such changes may occur during the passage of a powerful thunderstorm front.

THE INSTRUMENTS AND MEASUREMENT STAND

A CG-5 relative gravimeter has a sensing element in the form of a quartz string, which has inherent peculiarities. Multiyear experience in the operation of two CG-5 gravimeters as part of the geophysical equipment installed at the geophysical observatory revealed a number of factors affecting error in gravity measurements (Abramov et al., 2011; Koneshov et al., 2011). This not only enabled us to elaborate the procedure for refining the delta factor for a gravity measurement site (Abramov et al., 2013a), but also to more thoroughly estimate effects arising in the errors of gravity measurements in response to seismic events, cyclones, and anticyclones even in remote regions (Abramov et al., 2013b; Drobyshev and Koneshov, 2013). Long-term measurements showed that seismic and weather factors do not affect the value of gravity acceleration but only increase the root-mean-square (rms) error of gravity measurements. This highlighted the absence of nontidal changes in gravity caused by the factors described above. It is expected that these nontidal changes could manifest themselves in the form of systematic deviations from the graph of tidal functions obtained during measurements by the CG-5 gravimeter.

The developed geophysical observatory has one design feature that is worthy of a particular note here. For eliminating the effects associated with the changes in the ground water level, a two-level drainage system was laid out in the foundation pit of the future observatory. This system has been operating efficiently throughout the entire lifetime of the observatory. It

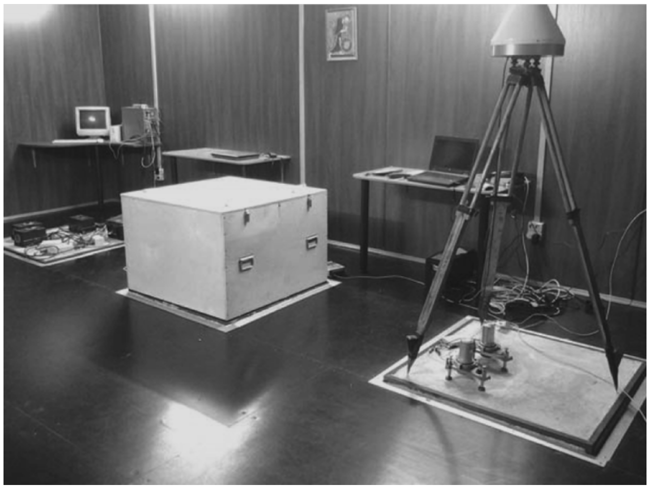

Fig. 1. Positions of instruments of the geophysical measurement complex on the pedestals of the seismogravimetric observatory.

enables the ground water level to be maintained constant all the year round. This constancy is supported by the absence of seasonal variations in gravity acceleration caused by seasonal changes in the ground water level.

Special efforts were made to temperature control the observatory rooms. Although each gravimeter is equipped with a dual-circuit temperature-control system, it is placed into a room with a constant temperature since it is sensitive to thermal impact (e.g., an opened door). Above the ground, a shelter building with a three-circuit thermal protection system was constructed above the pedestals. This building has a radio transparent roof, which enables high-precision geodetic GPS measurements. In addition to the main purpose, GPS signals are also used for synchronizing all the geophysical, meteorological, and geodetic measurements. The weather station makes real-time measurements of pressure, outdoor and indoor temperature, and air humidity. The layout of the geophysical instruments on the pedestals of the observatory is illustrated in Fig. 1.

THE RESULTS OF THE MEASUREMENTS

Typically, gravity-acceleration sampling in practical observations is rather rare (once per one minute or even rarer), and the presence of an operator at the geophysical observatory is impractical since this enhances microseismic noise. During observations on June 10–11, 2014, we applied a nonstandard recording mode of the gravimeters with a sampling frequency of 6 Hz. The purpose of these measurements was to more accurately determine the spectral content of microseismic noise in the vertical channel in the pass band of the gravimeter.

Detailed analysis carried out by the operator disclosed an interesting fact illustrated in Fig. 2. During observations conducted from 15 to 24 UT on June 10, an intense thunderstorm front was passing above the observation point. It rained alternately heavily and lightly, but continuously, for nine hours. During this interval, the tidal effect in the gravimeter readings decreased by up to 3 mcGal. The thin solid red line in the figure shows the calculated tidal effect for the observation point, and the two thick solid green lines depict the filtered readings of two CG-5 gravimeters. As seen in Fig. 2, gravity acceleration caused by the tidal effect dropped by 2–3 mcGal during the nine-hour period of the thunderstorm. Almost synchronous deviations with identical amplitude are detected by the two CG-5 gravimeters. The observed effect is probably due to the large mass of the rain clouds against the relatively low thunderstorm cloudiness of the atmospheric thunderstorm front.

The geophysical observatory and the designed complex of the instruments make it possible to estimate the errors of gravity measurements. In the case described in the present paper, variations in gravity acceleration measured by the given type of the

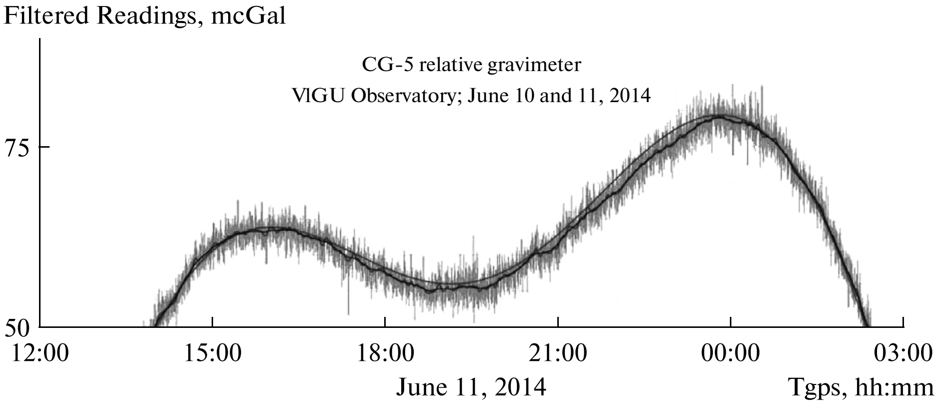

Fig. 2. Graphs of variations in gravity acceleration. Thin gray line shows tidal curve, and thick black lines show curves measured by gravimeters.

gravimeters can only be attributed to the passage of the thunderstorm front.

CONCLUSIONS

The revealed effect should be treated as one of the probable types of nontidal variations in gravity acceleration. The intensity of this effect is estimated for the first time and has not been reported previously.

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