EXPECTED GRAVITY NOISE IN A BASE STATION OF THE VRANCEA GRAVITY NETWORK DUE TO WATER LEVEL CHANGE AT THE SIRIU HYDROPOWER DAM

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Due to the vicinity of the hydropower dam, research has been conducted to clarify whether high accuracy gravity determinations in the Siriu base-station of the Vrancea Dedicated Gravity Network may be distorted by the fluctuation of the water level in the lake of the hydropower dam.

A 3D terrain model was constructed for the area, and numerical simulations for various levels of the water in the lake of the hydropower dam have been performed to assess the gravity change expected at the location of the network base station.

Following the study, it has been concluded that the level of noise may vary in a very narrow range (0 to 10^{-8} ms^{-2}), which may not significantly affect time series recorded in this base station of the network.

Keywords: Vrancea gravity network, gravity observation accuracy, hydro-power dam, water level, Siriu.

1. LOCATION OF THE STUDY AREA

The area subject to research is located in the central part of Romania, in the so-called Vrancea active seismic zone (Fig. 1).

Vrancea lays on the bend of the East Carpathians, where upper mantle intermediate-depth earthquakes (usually met within active subduction zones) may occur within full intra-continental environment. The phenomenon is quite rare and worldwide is known in another two areas only, called seismic nests (e.g., Richter, 1958; Prieto *et al*., 2012; Petrescu *et al*., 2020): Bucaramanga (Colombia), and Hindu Kush (Afghanistan).

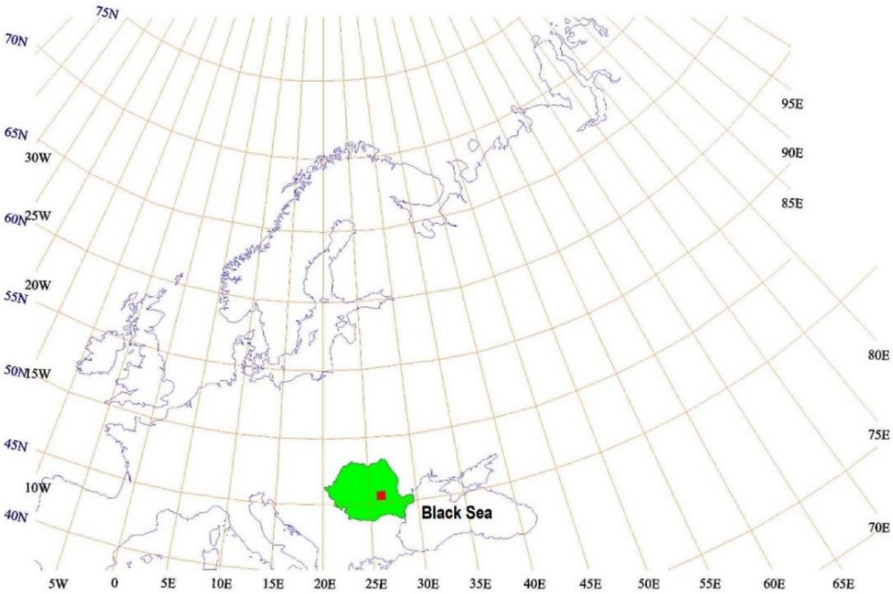

Figure 1 – Location of the study area at the continental scale.

Beside the intermediate-depth events, crust earthquakes are also present within the Vrancea zone, mainly showing vertical extension focal mechanism (e.g., Bălă *et al*, 2003; Radulian *et al*., 2018).

2. RATIONALE BEHIND THE RESEARCH

Despite many years of national and international research (e.g., Radu, 1965; Roman, 1970; McKenzie, 1972; Constantinescu *et al*., 1976; Constantinescu, Enescu, 1985; Wenzel *et al*., 1998; Chalot-Prat & Gîrbacea, 2000; Ismail-Zadeh *et al*., 2000; Beșutiu, 2001; Cloething *et al*., 2004; Knapp *et al*., 2005; Martin *et al*., 2006; Rogozea *et al*., 2007; Lorinczi & Houseman, 2008; Fillerup *et al*., 2010; Bokelmann & Rodler, 2014; Beșutiu *et al*., 2017), the genesis of the intermediate-depth events in the region still remains obscure. However, it is worth mentioning that almost all the above-mentioned research has been mainly based on a seismological approach. That could offer a static image concerning the in-depth structure of the seismically active zone only, with little or no reference to its space-time evolution.

Unlike previous works, the Solid Earth Dynamics Department in the Institute of Geodynamics "Sabba S. Ştefănescu" of the Romanian Academy focused its research efforts on the dynamic aspects of the problem. The Vrancea Dedicated Gravity Network (VDGN) covering the epicentre area of the intermediate earthquakes has been designed and implemented (Beșutiu *et al*., 2006) in an attempt to monitor non-tidal gravity changes related to the dynamics of subsurface masses in connection with the occurrence of seismic events (Fig. 2).

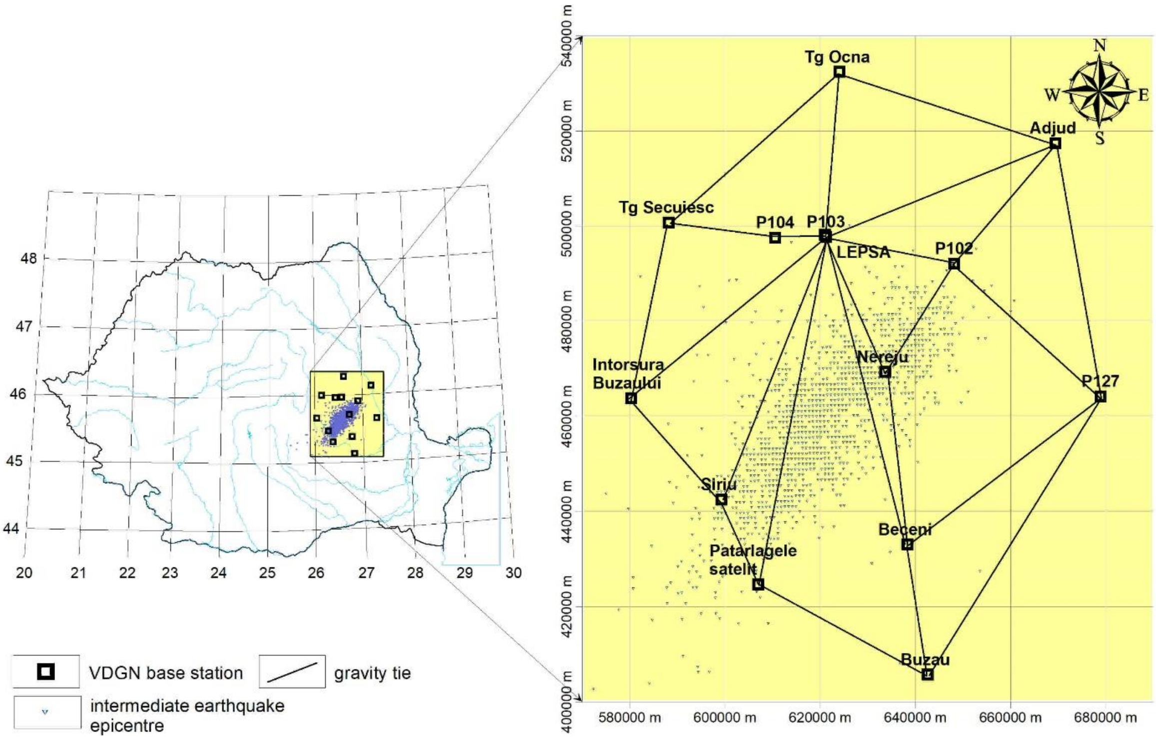

Figure 2 – The design of the Vrancea Dedicated Gravity network.

The network is made of epoch stations for high accuracy repeated observations. They mainly consist of specially designed still-reinforced concrete pillars that allow for both gravity and GPS determinations.

In addition, several base stations belonging to the National 2nd Order Gravity Network of Romania have been included to increase density of the observations, among which is Lunca Jariștei, coded Siriu in the VDGN (see Fig. 2). Details on its location are presented in Fig. 3. As shown in Fig. 3, the VDGN Siriu base station is located in the neighbourhood of the Siriu hydropower dam that is supplying water to the Nehoiașu hydropower plant (42 MW).

Time series recorded in the VDGN (including Siriu base station) have revealed non-tidal gravity changes of a few tens of μGals only (1 μGal = 10^{-8} ms^{-2}), in relation with some significant (Mw>5) earthquakes (e.g., Beșuțiu and Zlăgnean, 2015; Beșuțiu *et al*., 2019), so the accuracy of gravity observations should be carefully controlled in order to get reliable results.

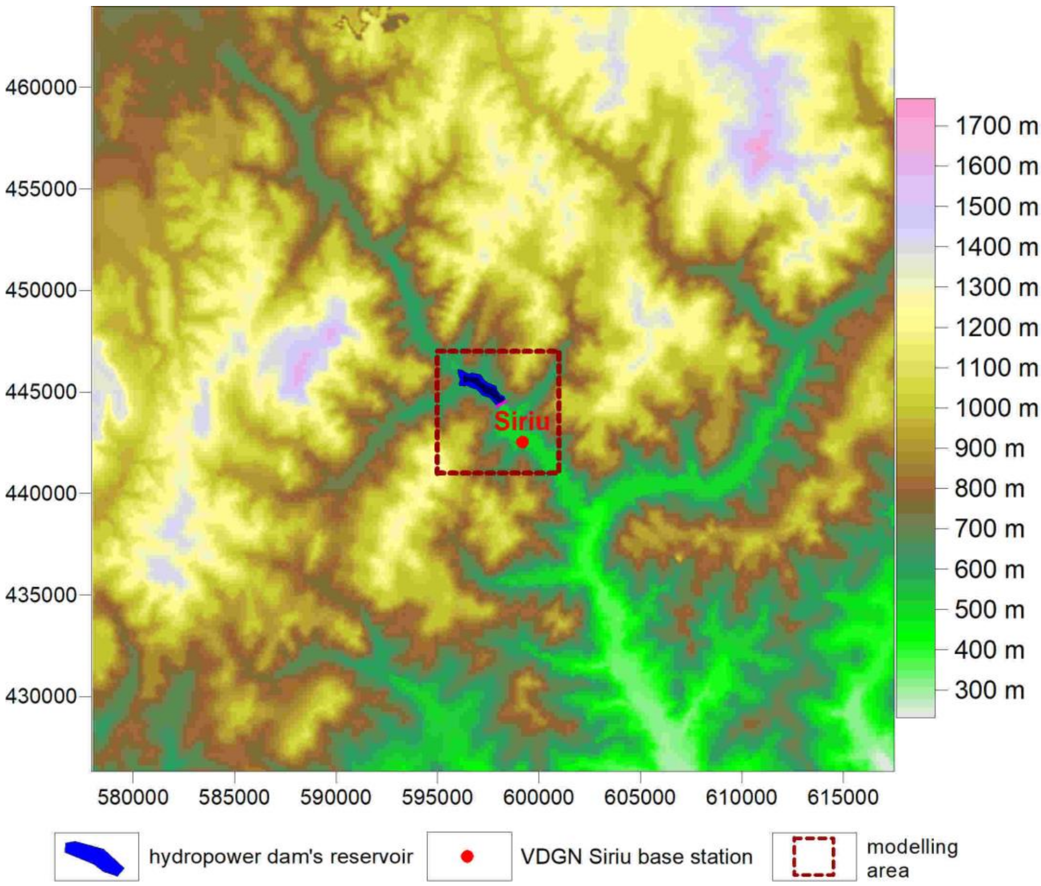

Figure 3 – Digital terrain model of the Siriu hydropower dam area and location of the gravity station.

Consequently, research has been conducted for determining the influence of water level change at the hydropower dam on the gravity observations in the VDGN Siriu base station, and how much could they distort time series recorded within VDGN.

3. THE APPROACH

To solve the problem, the gravity effect of the water accumulated in front of the hydropower dam was assessed by using a 3D forward modelling approach.

The gravity sources, representing various volumes of water as determined by the water level at the hydropower dam, have been determined by constructing a detailed digital model of the topography (Fig. 4), and considering various altitudes of the water from the bottom to the maximum height of the hydropower dam.

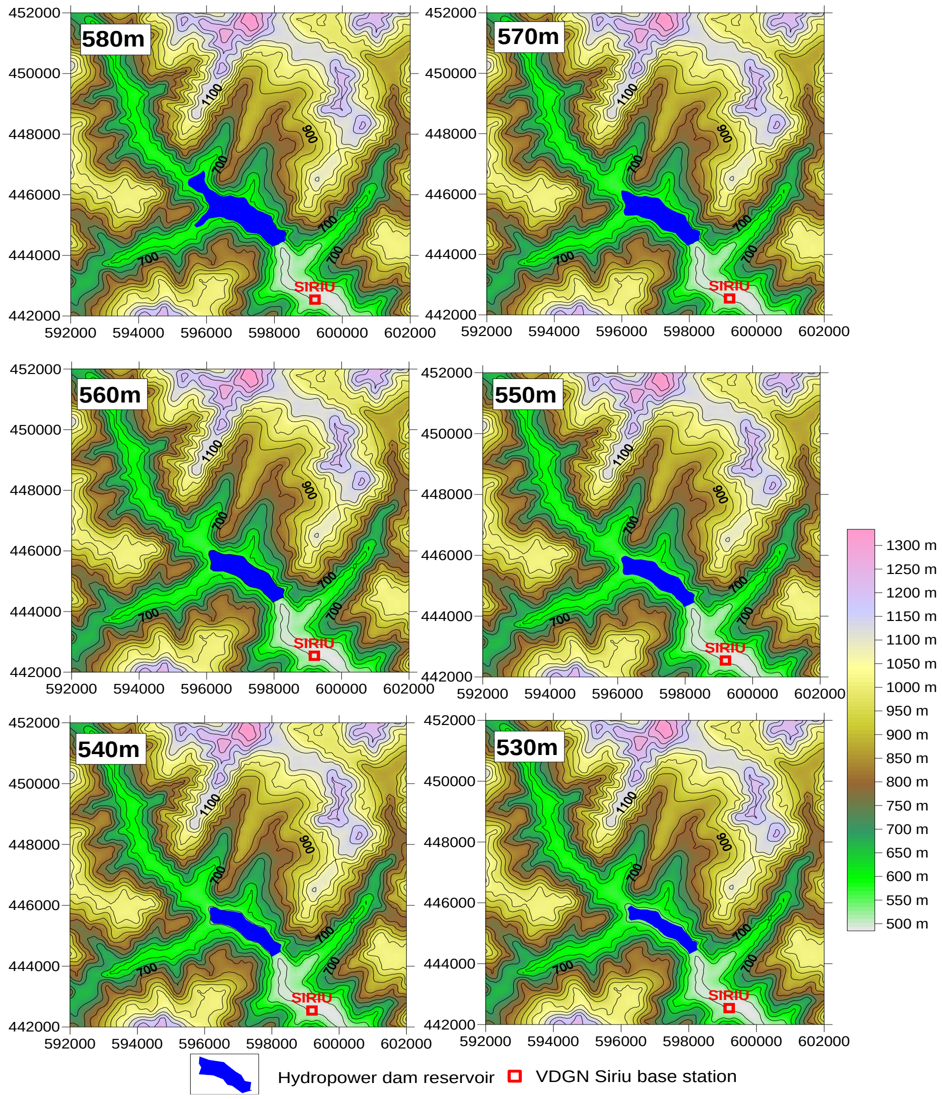

Figure 4 – Digital models including topography and water surface serving as inputs in the simulation of gravity effect of the water level at the Siriu hydropower dam (the altitude of the water level is mentioned in the upper left corner of each map).

3.1. THE ALGORITHM

The gravity effects of the various water volumes were computed by means of GMSYS-3D professional software run on the Oasis platform (© GEOSOFT) (https://files.seequent.com/training/Data/Geosoft/GMSYS-3D).

The GMSYS-3D gravity and magnetic forward modelling is based on the Parker's and Blakely's algorithms in the frequency domain (Parker, 1973; Blakely, 1995). It provides the possibility of computing potential fields produced by inhomogeneous sources delimited by irregular contours, with the help of Fourier transformations (2D-FFT). The software package requires also MAGMAP filtering TM routine.

It's worth mentioning the modelling algorithm for draped surveys. The computing space is divided into two major realms: the layers that extend above the Minimum Survey Elevation (MSE) and are computed as many vertical prism in the space domain (slower); those that are completely below it are calculated using the grid-based FFT routines. (https://my.seequent.com/support/search/knowledgebase).

The surface-oriented models are built by defining a number of stacked (opened or closed surfaces with specific physical properties distributions (e.g. density) specified for the layer bellow or inside the surface: constant value, 1-D variation (a physical property-depth variation), 2D variation (grid) or 3 D distribution (voxel).

3.2 MODEL SETUP

The computing environment extends 10000 m northwards, and 10000 m eastwards. In depth extent has been considered from topography down to the sea level.

The input data consisted of several detailed digital terrain models of the area including the Siriu VDGN base station, and the hydropower water reservoir for various water levels (Fig. 4).

The geometry of the source, representing the water body accumulated in front of the hydropower dam is shown in Figure 5.

All models are GIS based and have been constructed by using the rectangular Stereo70 projection system (e.g. Calistru and Munteanu 1974; Chirila and Mihalache 2011).

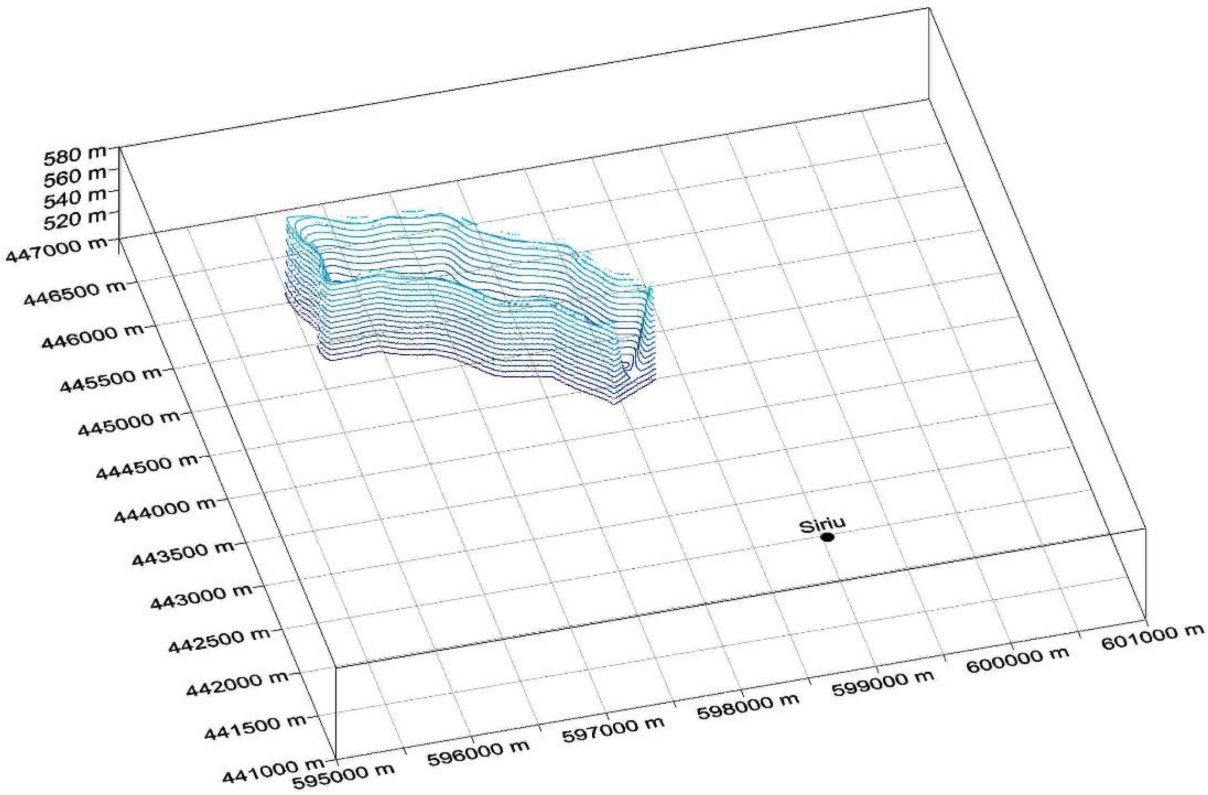

Figure 5 – 3D geometry of the water bodies considered for the simulation of the gravity effect.

The geological environment of the water body, mainly consisting of Paleogene deposits, has been considered homogenous with an average density of 2.50 x 10^3 kg/m^3 (Zlagnean, 2011), while, for the water, a density of 1.0 x 10^3 kg/m^3 has been taken into consideration.

4. RESULTS

The gravity effect induced by the water body is presented in Figure 6 (the altitude of the water level is mentioned in the upper left corner of each map).

It should be mentioned that gravity noise has been computed by subtracting the gravity effect corresponding to the presence of the water body from the gravity synthesized in the absence of the water in the hydropower plant reservoir.

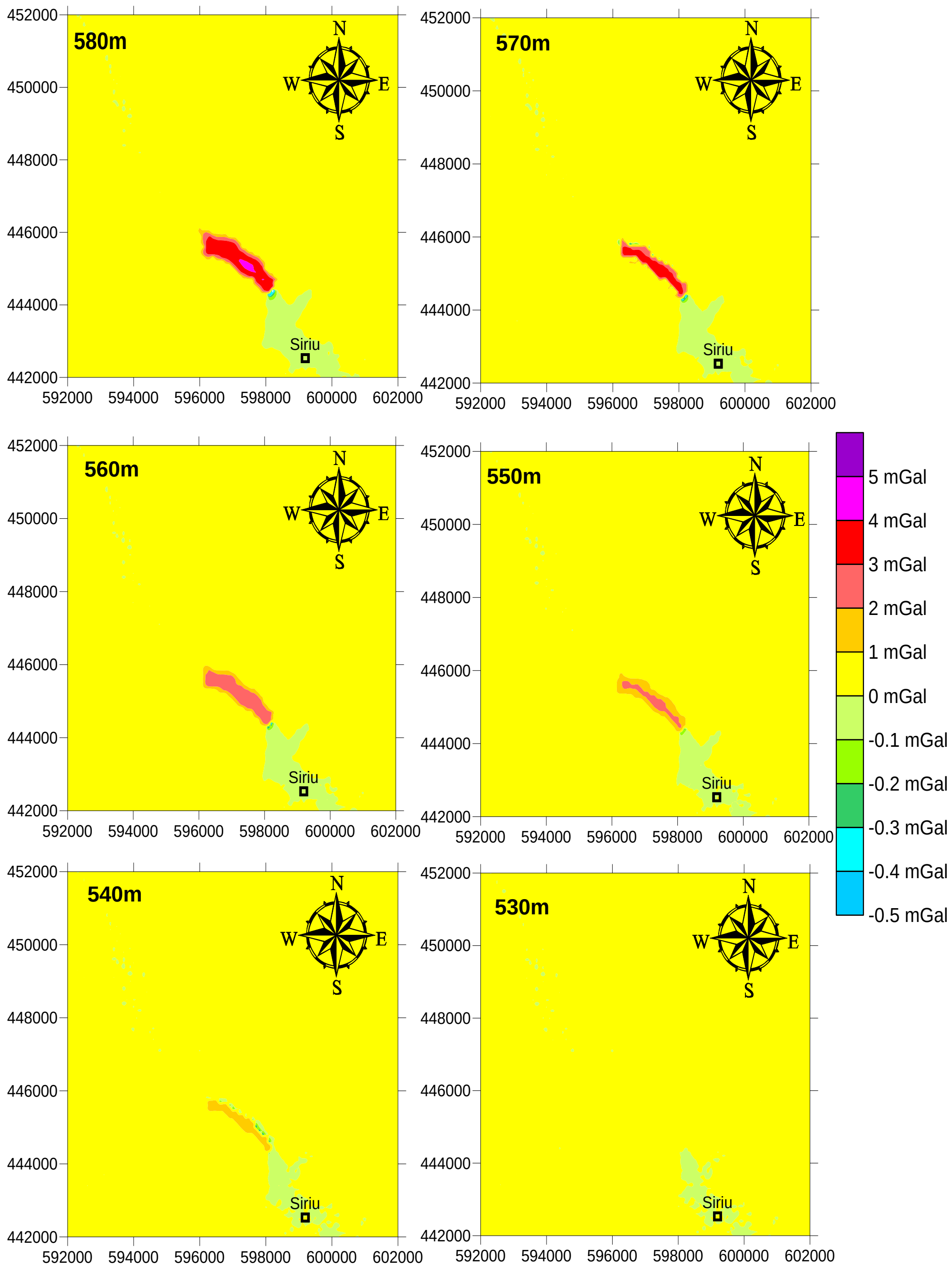

Figure 6 – Gravity noise for various water levels in the Siriu hydropower plant reservoir.

The amplitude of the gravity noise induced by the presence of water in front of the hydropower dam at the VDGN Siriu base station is shown in Figure 7.

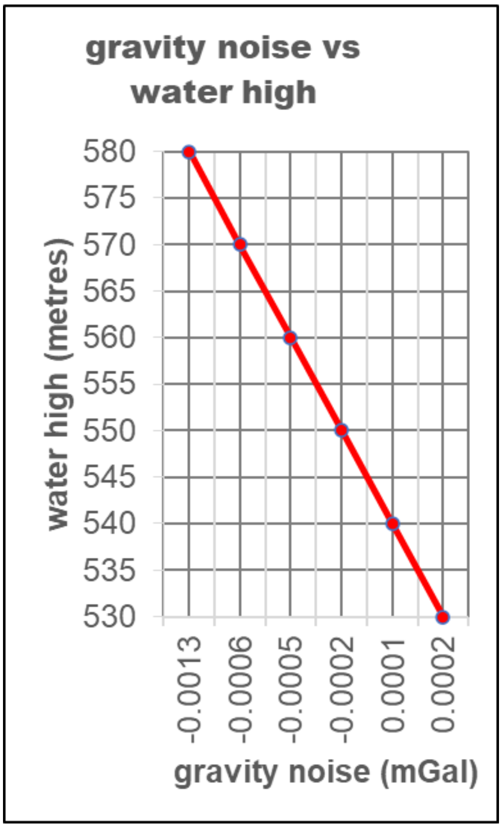

Figure 7 – Potential gravimetric noise induced by various levels of water in the Nehoiașu hydropower plant reservoir at the location of the Siriu VDGN base station.

CONCLUSIONS

Looking at the results of the present research it becomes clear that gravity influence of the presence of the water in the reservoir of the Nehoiașu hydropower plant is fully within the range of the reading errors of the Scintrex CG 5 meter usually employed for determinations within VDGN.

The maximum level of noise would be reached for a completely full reservoir and is slightly above 1×10^{-8} ms^{-2} only, which equals the meter sensitivity and is below the accuracy threshold.

Therefore, it can be considered that time series recorded at the Siriu VDGN base station may not be significantly distorted by any level of water accumulated in front of the hydropower dam.

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