TIDAL RESEARCH PROGRAMME OF ASTRO-GEODETIC OBSERVATORY IN JOZEFOSLAW

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1. INTRODUCTION

Tidal gravimetric observations in Astro-Geodetic Observatory in Jozefoslaw started in 1993 using LaCoste&Romberg model G gravimeter. Since 2001 Observatory has been equipped with the ET-26 model dedicated to the stationary gravimetric measurements. Tidal research program also encompasses environmental studies to make the results more reliable. This elaboration presents the analyses of the data collected until 2009.

2. GRAVIMETRIC LABORATORY

Gravimetric laboratory is placed in the Observatory's cellar located 5.5 m deep to reduce microseisms. Two independent pillars are placed there. Spring gravimeter LC&R ET-26 is placed into a thermally stabilized chambers with the temperature stability up to 0.2 °C. Computer's clock is synchronised once every hour using internet and time signal from Borowiec Astrogeodynamic Observatory (vega.cbk.poznan.pl). No tilt compensations are introduced. Since 2006 periodic absolute gravity determinations have been made using FG5 No. 230.

3. DATA

The data contains observations collected from 2002 to 2009 by ET-26 meter. The observations are 1-minute sampled and stored to the computer together with some additional data including ambient pressure and temperature, inner gravimeter temperature as well as the electronic levels indications. Fig. 1 presents the raw gravimetric data after the preliminary adjustment (steps, spikes and gaps removing) using TSoft software (Van Camp and Vauterin, 2005):

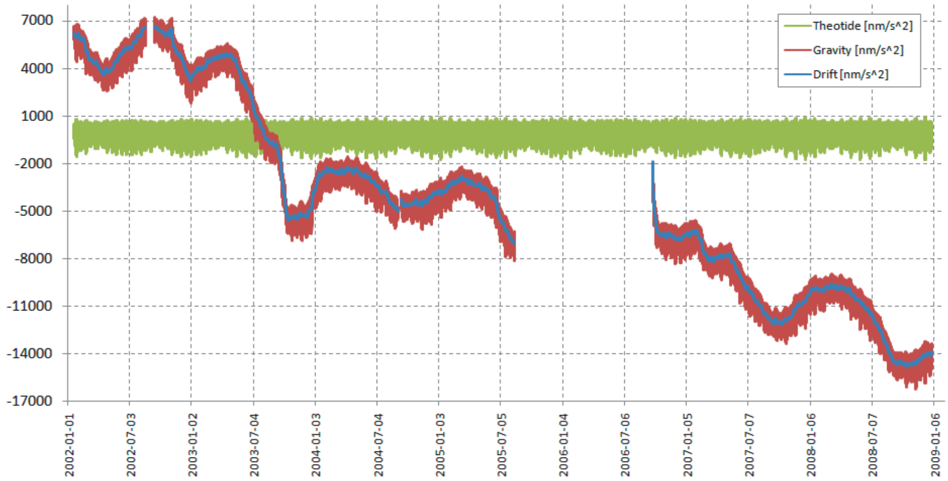

Fig. 1. Tidal gravimetric data.

4. CALIBRATION

The data used for calibration was collected between October 2006 and May 2007. Eight independent absolute gravity determinations were taken into account, consisting of 12 to 28 series each. One series consists of 100 drops, which means single determination of the gravity. Fig. 2 presents data collected during first calibration session. Finally the calibration factor is 1.00059±0.007911.

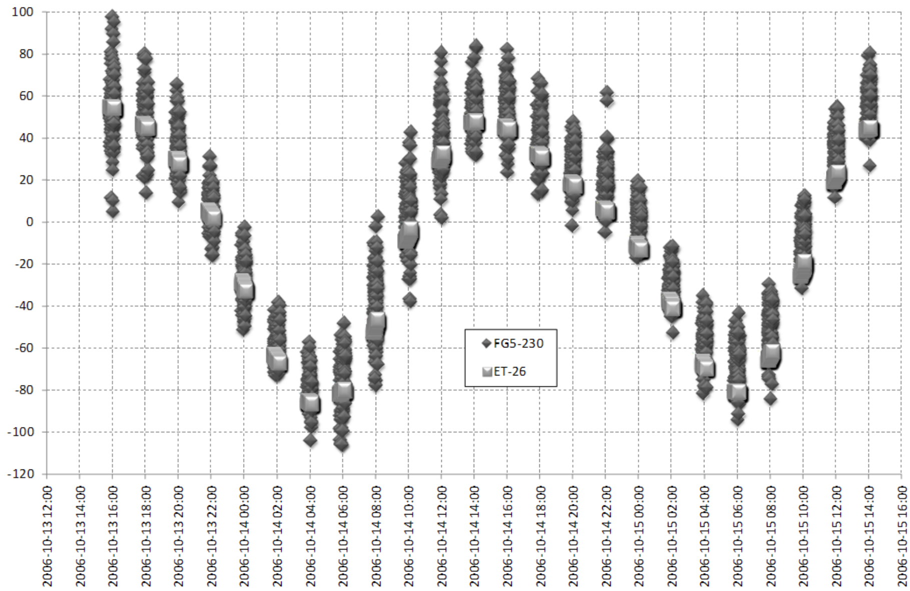

Fig. 2. Absolute and relative gravimetric data [nm/s^2].

5. STABILITY OF THE PILLAR

For the investigation of the pillar's stability the readings of the built-in electronic levels were examined. In the Fourier spectrum the strong yearly signal was discovered so the collected data was divided into the 1-year parts (fig. 3).

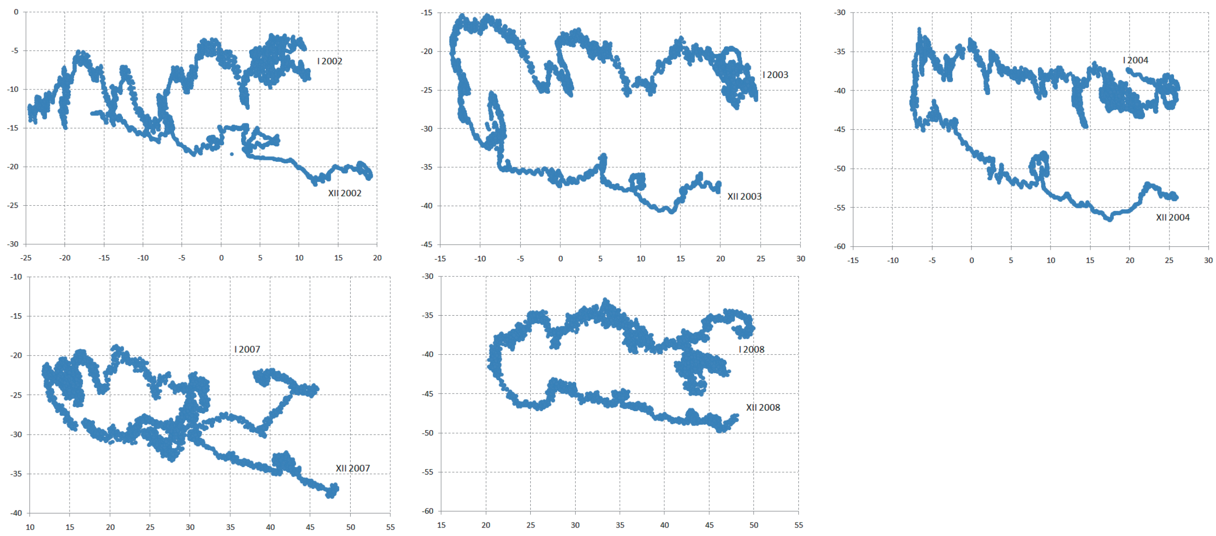

Fig. 3. Changes of the electronic levels (long and cross-level).

The pillar appears to make the movement, which looks like an ellipse with annual cycle. Also diurnal cycle was discovered, which coincidences with tidal frequency. This fact is confirmed in the power spectrum of the level's indications (fig. 4).

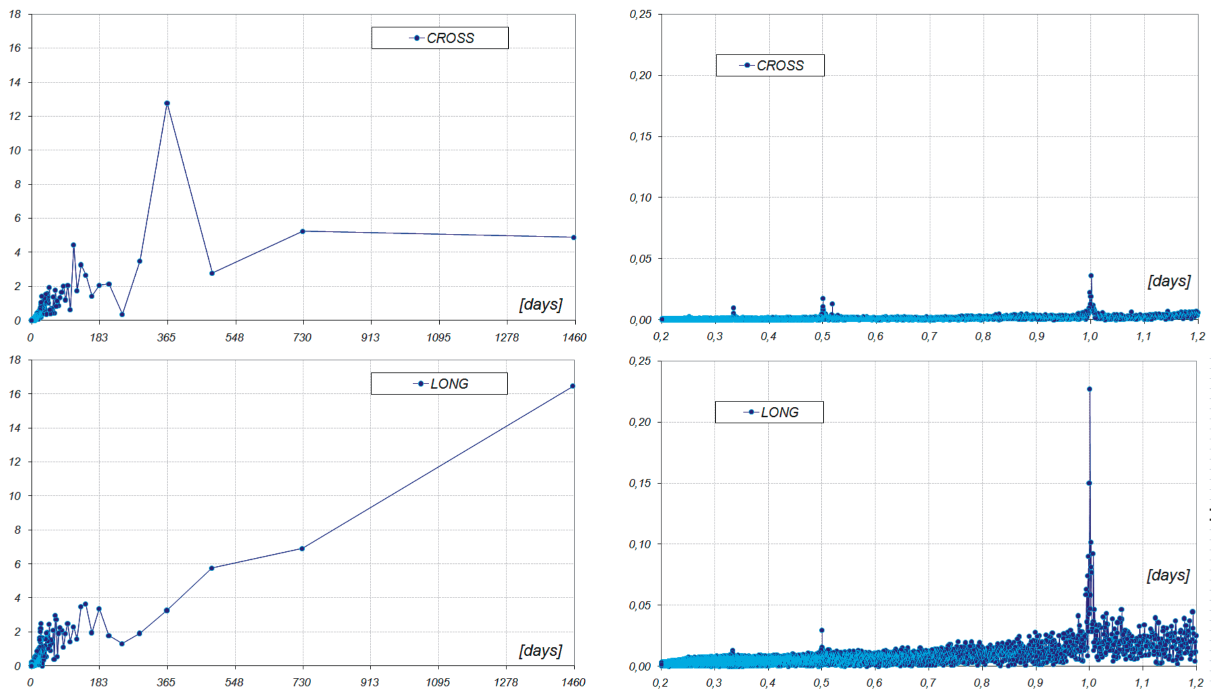

Fig. 4. Power spectrum of the electronic levels indications.

6. ENVIRONMENTAL EFFECTS

In order to obtain accurate and reliable tidal model every kind of environmental effects have to be taken into consideration. They are:

ocean tidal loading;
atmospheric loading and attraction effect;
local hydrological effects.

6.1. Ocean loading effect.

The ocean loading effect was calculated using tide loading provider at www.oso.chalmers.se and TPXO.7.1 model (fig. 5).

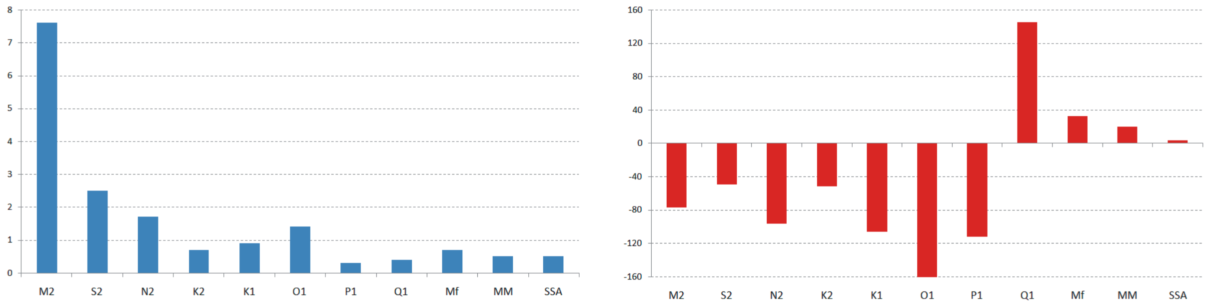

Fig. 5. Amplitudes (left - nm/s^2) and local phases (right - degrees) of the ocean loading effect.

6.2. Local environmental effect.

To introduce the correction for local environmental model several sensors for monitoring atmospheric pressure, temperature, humidity, rainfalls, ground water table and soil moisture were installed. They are presented in fig. 6.

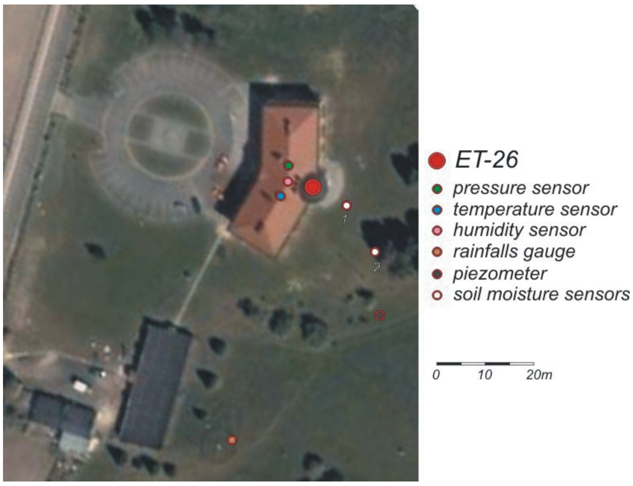

Fig. 6. Sensors for collecting local data.

6.3. Atmospheric effect.

The power spectrum of the pressure changes collected from 2002 to 2009 (fig. 7) indicates small amounts of energy in tidal frequencies (1-terdiurnal, 2-halfdiurnal and 3-diurnal) but also in non-tidal (4-2.2 days, 5-6.5 days and 6-19 days). The power spectrum of the temperature changes (fig. 7) also indicates energy in tidal frequencies (1, 2 and 3 and 5-1-year) and in non-tidal (4-21.6 days).

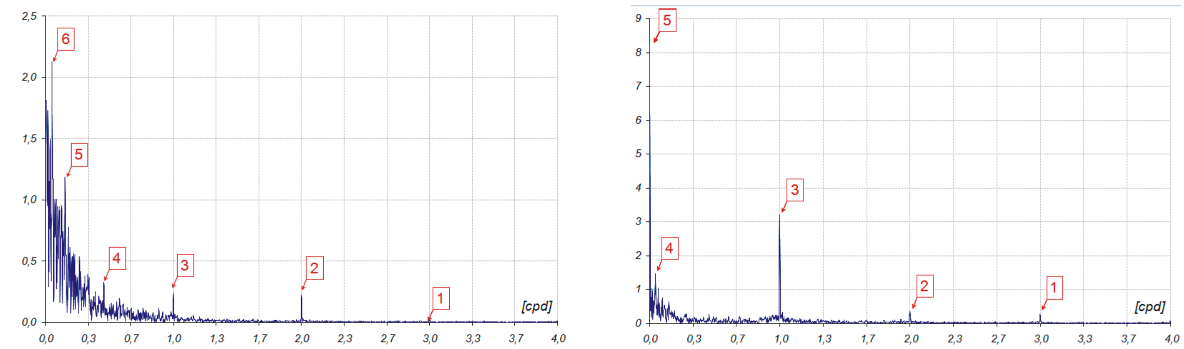

Fig. 7. Power spectrum of the ambient pressure (left) and temperature (right) data.

The power spectrum of the humidity changes (fig. 8) also indicates energy in tidal frequencies (1, 2, 3 and 4-1 year).

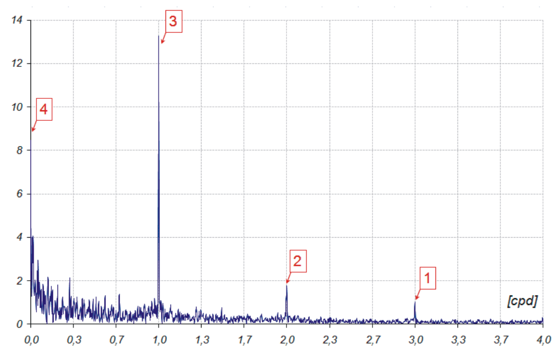

Fig. 8. Power spectrum of the ambient humidity data.

Atmospheric loading and attraction effects were calculated using single regression coefficient (Bogusz, 2000) and is presented in fig. 9.

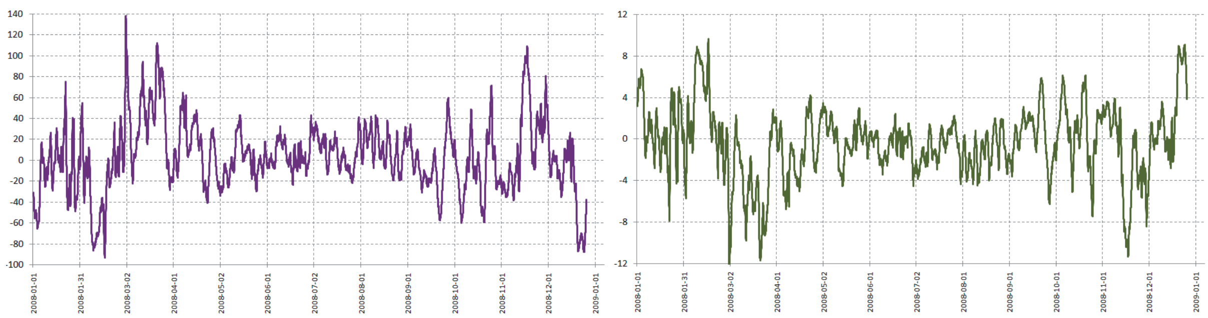

Fig. 9. Changes in gravity (left - nm/s 2) and height (right - mm) due to atmosphere.

Tidal oscillations in atmospheric loading and attraction effect (ETERNA 3.4 data adjustment – Wenzel, 1996) can reach 1.4 nm/s^2 for solar waves S1 and S2, for main tidal constituents (O1 and M2) they have magnitude of about 0.2 nm/s^2 (fig. 10).

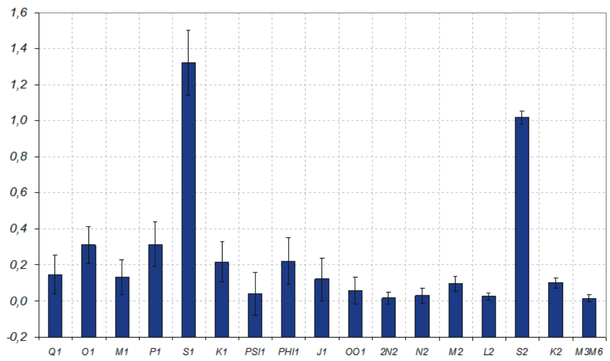

Fig. 10. Tidal oscillations in atmospheric effect [nm/s^2].

6.4. Hydrological model.

The tidal oscillations in the soil moisture, rainfalls and ground water table changes are not expected to be found, but it make sense to reduce these effects from gravity as it leads to a better signal-to-noise ration in the gravity data and thus improves the result of the tidal analysis.

7. TIDAL ANALYSIS

Tidal analysis was made using ETERNA 3.4 software (Wenzel, 1996). Table 1 presents statistics of the data.

Table 1. Statistics of the tidal data.

```
 Program ANALYZE, version 3.40 970921               File:   2002_08
####################################################################
# Gravimetric Earth Tide Station Jozefoslaw no. 909 Poland.        #
# Institute of Geodesy and Geodetic Astronomy,                     #
# Warsaw University of Technology, Poland.                         #
# 52.0973N  21.0316E   H141M   Gravity.                            #
# Gravimeter LaCoste-Romberg no. ET26 electrostatic feedback.      #
# Digital recording with 1 min. interval.                          #
# Installation       J. Bogusz, IGGA.                              #
# 206.5 s instrumental time lag corrected during preprocessing.    #
####################################################################
 Latitude: 52.0973 deg, longitude: 21.0316 deg, azimuth:  0.0000 deg.
 20020120...20081231    11 blocks. Recorded days in total:   2074.708
 Hartmann+Wenzel (1995) TGP, threshold: 0.200E-05      2447 waves.
 WAHR-DEHANT-ZSCHAU inelastic Earth model used.
 UNITY window used for least squares adjustment.
 Sampling interval:     3600. s
 Numerical filter is WENZEL 145   with  145 cœfficients.

 Average noise level at frequency bands in nm/s**2
 0.1 cpd***********       1.0 cpd   0.214953       2.0 cpd   0.132653
 3.0 cpd   0.030390       4.0 cpd   0.024551    white noise   0.064079

 Standard deviation:                         7.938  nm/s**2
 Degree of freedom:                          48147
 Maximum residual:                          44.326  nm/s**2
 Maximum correlation:                       -0.055 X-wave-PHI with X-wave-S1
 Condition number of normal equ.             1.357
```

The results of the tidal data adjustment are the amplitude factor – the amplification of the gravity changes due to elastic response of the Earth and the phase shift – the time lag of the Earth's reaction due to its viscosity. From the described data set 31 constituents were able to be determined (fig. 11 and 12). Final residua after adjustment are presented in fig. 13.

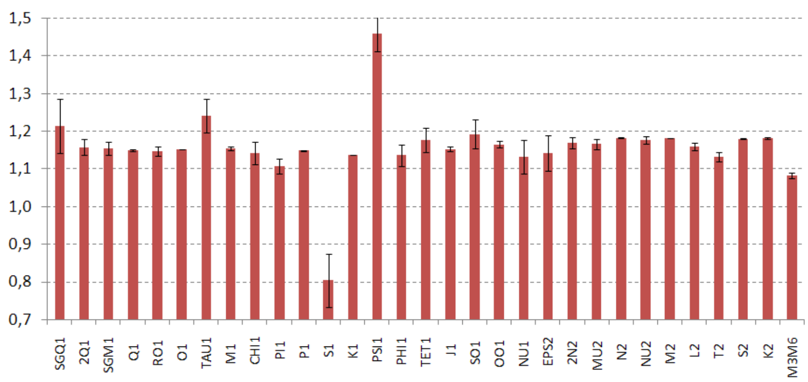

Fig. 11. Amplitude factor.

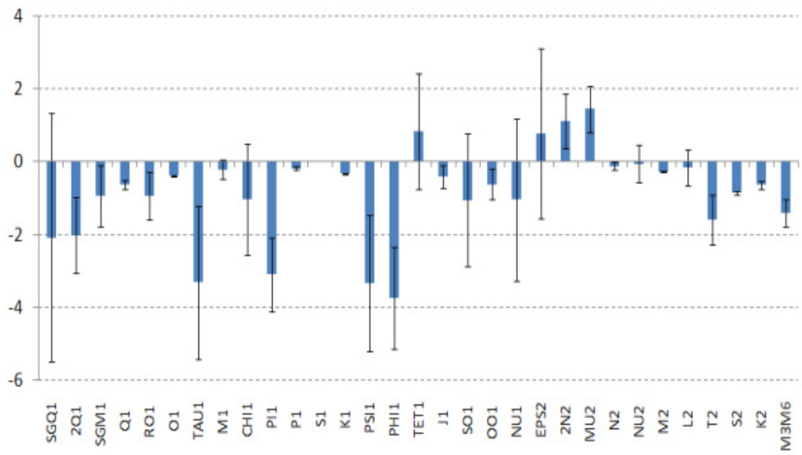

Fig. 12. Phase shift [°].

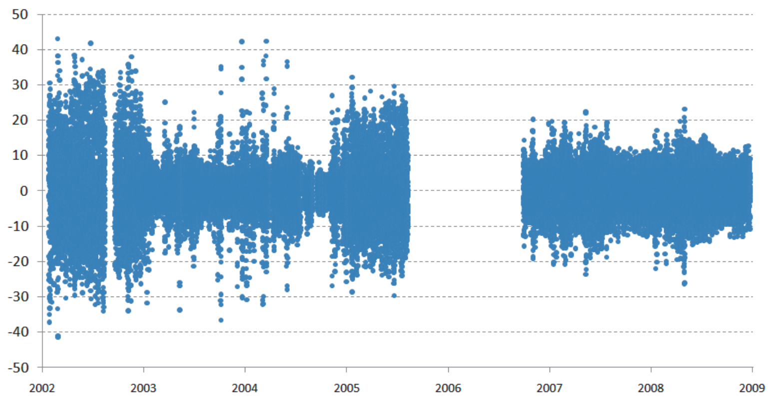

Fig. 13. Final residua after adjustment [nm/s^2].

8. CONCLUSIONS

Maximum peak-to-peak amplitude of the residua indicates that the gravimetric data collected in Jozefoslaw Observatory is very noisy. The reason of this noise could be the unstable site which is placed mostly on the clay. But this set of observations is very promising for obtaining precise and reliable tidal model for the Observatory.

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