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Water Level Phase Shift Relative to Gravity into Georgian Wells

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ABSTRACT

The baytap08 program Is used to study the phase shift of the water level relative to gravity in wells in Georgia. In the extreme east of Georgia (Lagodekhi) and in the west (Kobuleti, Black Sea), the phase shift is <0 (from -25° to -60°). In the central part of the country, the phase shift is ≥ 0: Marneuli (center, south) about 0°; Nakalakevi (center, south, west of Marneuli) from +0.8° to +1.6°; Gori (center) +10°; Oni (center, northwest of Gori) from +15° to +26°. Note that among the specified wells, those with a positive phase shift turned out to be sensitive to remote earthquakes.

Key words: *phase shift, tidal, water level, Georgia*

Introduction

The water level (WL) in the well reacts to gravity force (GF) variation, especially the Z-component. The phase shift between WL and GF can have positive and negative values. If the phase shift value is >0, then the water is ahead of gravity; if the phase shift value is <0, then the water is behind it. Usually, the delay is observed for confined water layers. An advance is typical for shallow unconfined layers.

Results

Using long-term observations, the phase shift between the water level and gravity was calculated for different wells in Georgia (Fig.1). The phase shift was calculated using the baytap08 program. Baytap08 is a modification of the baytap-G program (suggested by D.C. Agnew), developed by M. Ishiguro, Y. Tamura, T. Sato and M. Ooe [1].

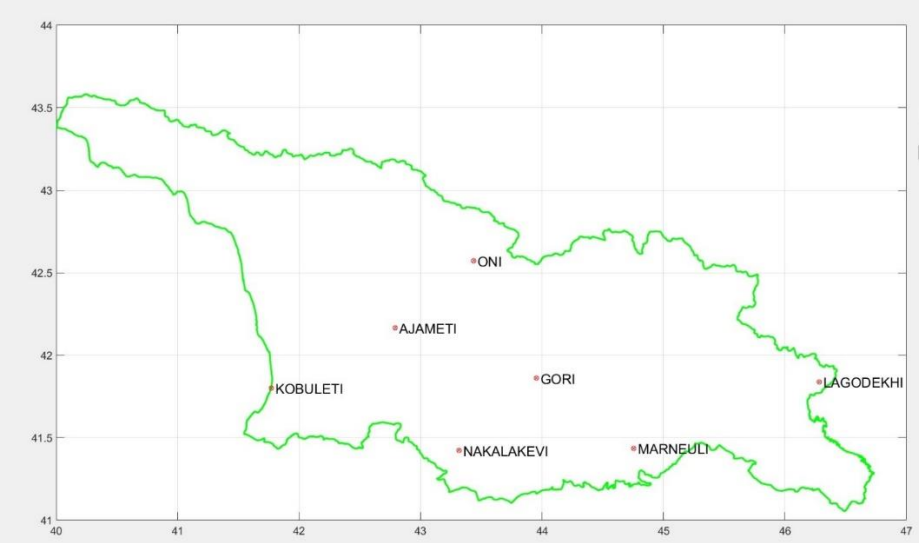

Fig.1. Boreholes in Georgia.

The baytap08 program allows one to estimate the impact of different gravity oscillations, including M_2 and O_1. Recall that M_2 is a semi-diurnal lunar wave and O_1 is the principal lunar declination. For M_2, the period length is 12.42 hours, and speed is 28.98550725 degrees/hour. For O_1, the period length is 25.82 hours, and speed is 13.94268009 degrees/hour.

The initial data in the baytap08 program are: water level in the well, atmospheric values, well coordinates and height. The data frequency is 1 hour.

Phase shift can be converted to a delay or advance in hours using the formula:

$$\text{Time Shift} = \text{Phase Shift} / \text{Speed},$$

where phase shift is measured in degrees and speed in degrees/hour.

Table. Phase shift of water level in wells of Georgia

Name	Time	Phase shift, degrees, M2	Phase shift, degrees, O1
Lagodekhi	2012:	-46.343	-23.746
	2013:	-45.102	-26.147
41.839N, 46.282E	2014:	-47.171	-29.938
H=538; Depth=800	2018:	-55.612	-35.736
	2019:	-61.940	-41.673
	2020:	-62.940	-42.013
	2022:	-65.318	-42.013
	2023:	**-50.638**	**-26.443**
	2024:	-57.227	-35.832
	2025:	-57.981	-39.171
Marneuli	2020, 1 Jan – 1 Jul	3.089	2.051
	2021, 1 Jan – 1 Apr	3.662	2.373
41.436N, 44.755E	1 Apr – 1 Jul	2.946	1.899
H=382;Depth=3505	2022, 1 Apr – 1 Jul	0.488	1.380
	1 Jul – 1 Oct	0.780	0.018
	1 Oct – 31 Dec	0.131	-0.011
Turkey, Feb 2023,	2023, 1 Jan – 1 Apr	**-0.430**	0.093
earthquake M=7.8	1 Apr – 1 Jul	1.641	0.485
	1 Jul – 1 Oct	-0.681	2.077
	2024, 1 Jan – 1 Apr	0.443	0.770
	1 Apr – 1 Jul	-0.145	-0.055
	1 Jul – 1 Oct	-0.995	-0.430
	1 Oct – 31 Dec	-1.269	0.063
	2025, 1 Jan – 1 Apr	-0.117	-0.759
Kobuleti	2019, 1 Jan – 1 Oct	-28.157	-1.358
	2020, 1 Jan -1 Apr	-27.096	-10.276
41.802N, 41.772E	1 Apr – 1 Jul	-26.347	-2.377
H=12; Depth=2000	1 Jul – 1 Oct	-28.837	2.382
	1 Oct -31 Dec	-29.004	-4.637
	2020, all year	-27.613	-3.220
	2021, 1 Jan -1 Apr	-28.164	-3.808
	2025, 1 Jan – 1 May	-28.052	-6.143
Nakalakevi	2019, 1 Jan -1 Aug	1.613	4.630
41.424N, 43.317E	2023, 1 Jun -15 Nov	0.868	6.114
H=1175;Depth=600	2024, 15 Feb – 31 Dec	0.859	5.469
	2025, 1 Jan – 1 May	1.052	6.726
Gori	2018, 1 Apr – 29 Sep	9.327	11.034

Name	Time	Phase shift, degrees, M2	Phase shift, degrees, O1
41.862N, 43.9536E	2021, all year	7.354	5.926
H=1103; D=1500	2025, 9 Mar- 4 May	10.74	1.188
Oni	2020, 1 Jan – 1 Apr	62.043	-33.075
	1 Apr – 1 Jul	15.627	18.318
42.573N, 43.437E	1 Jul – 1 Oct	23.597	34.922
H=798; Depth=255	1 Oct – 31 Dec	26.317	-6.333
	2020, all year	22.313	0.71
	2021, 1 Jan – 1 Apr	24.726	17.619
	1 Apr – 1 Jul	17.661	19.188
	1 Oct – 31 Dec	20.342	49.512
	2022, 1 Jan – 30 Apr	18.796	9.393
atmos not used ->	2023, 1 Jan – 1 Apr	3.404	113.663
Ajameti	2011, 15 May – 1 Oct	-16.648	-8.755
42.187N, 42.791E	2012, 5 May – 25 Oct	-20.782	-9.944
H=102;Depth=1339	2024, 15 Sep – 1 Nov	-17.98	-7.314

Conclusions

A significant delay of WL relative to GF is observed for Lagodekhi and Kobuleti ($\varphi<0$). For Marneuli, the phase shift is approximately 0, with a transition from positive to negative values of the shift. For Nakalakevi, Gori, Oni stations, the phase shift is >0, i.e. water is ahead of gravity.

It may be a coincidence, but at the same time Nakalakevi, Gori, Oni have the property of responding to distant earthquakes. The most sensitive is the Oni well, which has the largest positive phase shift value.

It should be noted that the search for sensitive wells remains a pressing task.

The peculiarity of calculations using the baytap08 program is the duration of the initial data – several months and the frequency of the survey is 1 hour. The result is a single number characterizing the phase shift over an interval of several months.

For a more rapid assessment of the phase shift, another method can be used: the ellipse method. In this case, the amount of data for one day with a polling period of 1 minute may be sufficient to obtain one value of the phase shift [2].

Acknowledgement

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საქართველოს ჭაბურღილებში წყლის დონის ფაზური წანაცვლება გრავიტაციასთან მიმართებაში

გ. კობზევი, თ. ჭელიძე, გ. მელიქაძე, თ. ჯიმშელაძე, თ. ქირია,
ა. ჭანკვეტაძე, ზ. მაღრაძე, ნ. გოგუაძე

რეზიუმე

პროგრამა baytap08-ის საშუალებით ხდება გრავიტაციასთან მიმართებით წყლის დონის ფაზური წანაცვლების შესწავლა საქართველოს ჭაბურღილებში. შედეგი: საქართველოს უკიდურეს აღმოსავლეთში (ლაგოდეხი) და დასავლეთში (ქობულეთი, შავი ზღვა) ფაზური წანაცვლება <0 (მერყეობს -25°-დან -60°-მდე). ქვეყნის ცენტრალურ ნაწილში ფაზური წანაცვლება ≥0: მარნეული (ცენტრი, სამხრეთი) დაახლოებით 0°; ნაქალაქევი (ცენტრ. სამხრეთი, მარნეულიდან დასავლეთით) — +0.8°-დან +1.6°-მდე; გორი (ცენტრი) — +10°; ონი (ცენტრი, გორიდან ჩრდილო-დასავლეთით) — +15°-დან +26°-მდე.

საკვანძო სიტყვები: ფაზური წანაცვლება, გრავიტაცია, წყლის დონე, საქართველო.

Фазовый сдвиг уровня воды относительно гравитации в скважинах Грузии

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Резюме

С помощью программы baytap08 изучается фазовый сдвиг уровня воды по отношению к гравитации в скважинах Грузии. Результат. На крайнем востоке Грузии (Лагодехи) и на западе (Кобулети, Черное море) фазовый сдвиг <0 (от -25° до -60°). В центральной части страны фазовый сдвиг ≥ 0: Марнеули (центр, юг) около 0°; Накалакеви (центр, юг, на запад от Марнеули) от +0.8° до +1.6°; Гори (центр) +10°; Они (центр, северо-запад от Гори) от +15° до +26°.

Ключевые слова: фазовый сдвиг, гравитация, уровень воды, Грузия.