Some Problems on Time Change of Gravity

Part 4. On Continuous and Precise Gravity Observation during the Period of Annular Eclipse on April 19, 1958

By

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Abstract

The problem of a possible screening effect of gravitation by a third body interposed between two attracting bodies, is an exceedingly interesting one. A solar eclipse is a good opportunity to investigate experimentally this problem. This problem has already been studied by several investigators, but a definite conclusion has not yet been obtained up to the present time. An annular eclipse occured over some scattered islands in the south regions of the Main Land of Japan on April 19, 1958. A continuous and precise observation of gravity change was carried out during a period of the eclipse by means of the Askania gravimeter No. 111 at Naze, situated in the annular eclipse zone.

In the present article, a trial to detect the screening effect of gravitation by the moon from data obtained by the observation, is in detail described. Readings of the records obtained during seven days around the eclipse day, are made at 10-minute intervals up to about 0.25 μgal. After influences of room temperature and atmospheric pressure variations, the instrumental drift and earth tidal effect are eliminated from all the read values, a residual curve is obtained. A detailed investigation is made for its curve thus obtained, and it has come to be established that the screening effect of gravitation, even if it exists, does not exceed 3 μgal.

1. Introduction

The history of an experimental study on absorption of gravitation could be traced back to an early date in the present century. In 1920, Q.

Majorana (**1**) suggested that ‘the force of attraction between any two bodies is directed along the line joining them, but its intensity is less than that given by Newton’s law whenever another body traverses this line, being diminished in accordance with the “law of progressive absorption” which holds good for radiation’. According to his theory, ‘if m_1 and m_2 are the masses of the bodies, r, their distance, and k, the ordinary constant of gravitation, the attractive force f is expressed by

$$f=k\frac{m_1m_2}{r^2}e^{-\int h\theta dr}, \qquad (4.1)$$

where h is a second universal constant, that of absorption of gravitation, and θ the density of matter at any point on the line joining two bodies, and the integral is taken over the whole lengths of this line’ He had obtained an absorption constant such as $h=6.73\times10^{-12}$ in c.g.s. units by some delicate pendulum experiments.

The Majorana’s theory of gravitation was thoroughly discussed and criticized by H. N. Russell in 1921 (**2**). By assuming that Majorana’s theory was correct, he discussed the effect on earth tides of a possible absorption of the gravitational force of the sun or the moon by the earth’s mass.

On the other hand, A. J. Shneiderov (**3**) proposed an exponential theory of gravitation in 1943, being conceptually different from the Majorana’s, and suggested a laboratory experiment to examine the theory (**4**).

A hypothesis on the absorption of gravitation was previously proposed by H. Seeliger in 1909 (**5**). Later in 1912, K. F. Bottlinger (**6**) discussed an irregularity of the lunar motion and obtained the value of 3×10^{-15} in c.g.s. units as an absorption constant by comparing the observational results of the lunar orbit with a theoretical prediction. In order to check its value, he carried out a tiltmetric observation with a horizontal pendulum at the time of the solar eclipse of April 17, 1912, but did not ultimately report his observational results. K. F. Bottlinger (**6**) emphasized that it is advantageous to observe time change of gravity during a solar eclipse rather than to make a tiltmetric observation in order to confirm the hypothesis on absorption of gravitation by an experiment, because disturbances due to the meteorological changes and ground tilt are smaller than screening effect to be expected in a gravimetric observation.

In 1937, R. Tomaschek (**7**) described a possibility to measure the screening effect of the moon on the solar attraction at the time of a total eclipse. However, an actual observation to detect this effect was not made for a long time due to the insufficiency of instrumental accuracy and extremely limited chances of a total eclipse.

By completion of a highly sensitive gravimeter with an automatic recording apparatus and the recent development of measuring technique, the accuracy of observation was largely increased and at last, R. Tomaschek (**8**) and R. Brein (**9**) carried out independently observations of gravity change during the solar eclipse occured on June 30, 1954 in Europe. Speaking in detail, R. Tomaschek (**8**) carried out simultaneous observations with three gravimeters at two stations, several kilometres apart, in Unst (Shetlands) situated in the total eclipse zone. During the eclipse, two Frost gravimeters No. 32 and No. 54 were continuously read by visual observation, and a Worden No. 189 photographically. After correction for pressure variation, the instrumental drift and earth tidal effect were removed, and a residual curve was obtained. The standard deviation of the residual obtained by these observations on the eclipse day was 1.4 μgal in the mean, and thus he concluded that no significant systematic effect exceeding 3 μgal, was observable during the eclipse. On the other hand, R. Brein (**9**) observed a gravity change during the total eclipse of June 30, 1954 at Ula in the Southern Norway. The observation was carried out with a North American gravimeter by automatic recording, and he concluded that a screening effect of gravitation amounted to about 1.3 μgal, was observed during the eclipse.

In Japan, T. Ichinohe (**10**) carried out an observation of gravity change during the partial solar eclipse of December 14, 1955 at Shionomisaki. Since the eclipse occured just before sunset, it was disadvantageous for gravimetric observations. The observation was made at 15-minute intervals by visual reading using a Worden gravimeter No. 127, but no detailed discussion was made.

Furthermore, R. Tomaschek (**11**) suggested possibility of a chance of investigating the screening effect of the moon on the solar gravitational attraction, by tiltmeter or gravimeter, as done at many well-equipped observatories located in the regions from Europe to the Soviet Union at the time of the solar eclipse of February 15, 1961. Observational results obtained at the time of this eclipse have recently been reported by a few investigators (**12**, **13**, **14**). Y. S. Dobrokhotov and others (**12**) carried out observations at Kiev by means of two Askania gravimeters No. 124 and No. 135 with a photographic recording apparatus. Their observations were at least the most substantial ones in such observations ever made. According to their result, the screening effect of gravitation did not exceed 3 μgal during the eclipse. It was in good agreement with Tomaschek's conclusion (8). M. Caputo (**13**) made observations at Trieste with great horizontal pendulums. According to his result, there was no indication of any screening effect beyond the limit of observational error. R. Sigl and O. Eberhard (**14**) detected the screening effect by an observation made at Berchtesgaden with a horizontal pendulum during the solar eclipse of February 15, 1961.

It is an important and attractive problem, which many researchers have shown their keen interest, to investigate whether the attraction force between any two bodies is screened by an interposing third body. In order to investigate it in detail experimentally, it is necessary to increase the observational accuracy and to select an observation room isolated from meteorological disturbances and microseisms. As for the former, it fulfils the purpose to use a highly sensitive gravimeter with an automatic recording apparatus, while as for the latter, to install the instrument at a place as stable and quiet as possible. According to the observational results already obtained by several investigators, the screening effect of gravitation during a solar eclipse seems to be 2~3 μgal, but an experimental and definitive conclusion of this problem is not yet obtained. A solar eclipse is a good opportunity to search for the existence of a screening effect of gravitation. If the screening effect exists, the screening of solar attraction by the moon must take place at the time of a solar eclipse, and therefore it must be looked for on the earth's surface as a disturbance of the tide-generating force. Needless to say that a solar eclipse is usually utilized to study on shape of the earth, but it also offers a good opportunity to investigate experimentally the problem of gravitational absorption.

2. Observations

The annular eclipse of April 19, 1958 was selected as a subject of the present investigation. The central line of this eclipse passed over some scattered islands in the south regions of the Main Land of Japan. Naze situated in the annular eclipse zone, was selected for the present observation station. The position of the observation station and data of the eclipse at the station **(15)** are shown in Table 4.1.

Table 4.1. Observation station and data of the eclipse

Observation station	: Naze (Naze Weather Station)
Latitude	28° 23′ N
Longitude	129° 30′ E
Height above mean sea level	: 3.3 m
Distance from the nearest sea	80 m
First contact	: April 19, 01h 53m 02s, 1958 (UT)
Second contact	03h 44m 20s
Maximum obscuration	03h 46m 37s
Third contact	: 03h 48m 55s
Fourth contact	05h 39m 34s
Duration of annular phase	4m 35s
Magnitude of eclipse	: 0.948
Width of pass of annular phase	226 km
Distance of the station from central line	91 km S

The purpose of the present observation was as follows :

(1) To investigate whether the solar attraction was screened by the moon interposed at the time of the annular eclipse.

(2) To observe the tidal variation of gravity at a singular station such as a solitary island in the far-off ocean.

For the first purpose, it was necessary to select a quiet and stable station as far as possible. The screening effect of gravitation was, if it existed, presumed to be recorded as a disturbance on the recorded curve of gravity change. Since the measuring system of an Askania gravimeter was controlled electrically, an apparent change caused by fluctuation in electric power was sometimes recorded on the registrogram. It was therefore exceedingly difficult to distinguish the real change of gravity from an apparent one. In order to avoid this difficulty, it was important to select as steady an observation station as possible in electric conditions. Taking these matters into consideration, Naze was selected for the present observation station, but it was never a satisfactory one. Among eleven stations where the author selected in Japan in order to observe the tidal variation of gravity **(16)**, to his regret, it must be said that Naze was the wrost station from the standpoint of both microseisms and disturbances attributable to the ground.

The author previously carried out one month's observation of the tidal variation of gravity at each of eleven stations in Japan since the beginning of International Geophysical Year of July 1957. The purpose of that observation was to investigate in detail to what extent various conditions of the observation station affected the tidal variation of gravity. In case of selecting an observation station, two conditions, one oceanic tides and the other geological structure, were especially taken into consideration. Naze was a singular station for both standpoints. In other words, Naze was a singular station for the second purpose mentioned above.

The observation room was an old seismograph room of Naze Weather Station. This room was of concrete building and stood isolated. The gravimeter and recorder were installed on the surface of the concrete block which was used as seismometer's base. The maximum daily variation of room temperature reached about 2°C, but its daily variation was, on an average, less than 0.5°C. The humidity in this room was about 70%. The observation room was about 20 metres from main road that had heavy traffic in the daytime and about 80 metres from the nearest seashore.

An Askania Gs-11 gravimeter No. 111 with automatic recording apparatus was used in the present observation, and its sensitivity was 2.5087 μgal/mm on the registrogram (**17**). The observation was made continuously during a period of about 42 days from March 29 to May 10, 1958, and the annular eclipse occured on April 19 during this period. All electric currents were stabilized with high accuracy and circuits were in good connection with the earth. The rotation speed of the recording paper was usually 8 mm/hour and it was renewed once a day. During one week around the eclipse day, especially, the gravity change was recorded with a speed of 20 mm/hour. Time-marks were recorded at every hour on the recording paper and their accuracy was always held within 30 seconds. In order to avoid artificial disturbances, no one was allowed to enter the observation room during the eclipse day except for renewal of the recording paper.

3. Reduction of data and obtained results

The recorded curve of gravity change obtained during four days around the day of annular eclipse is shown in Fig. 4.1.

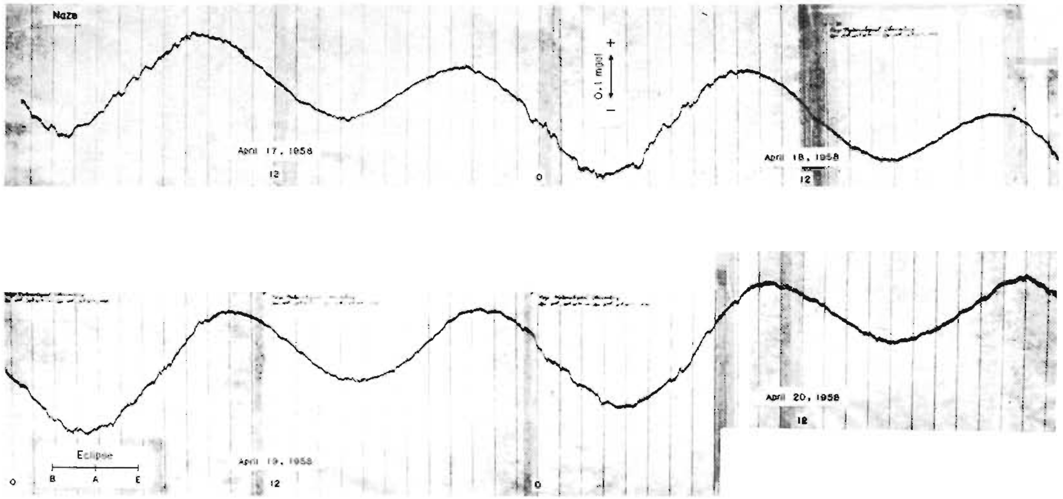

Fig. 4.1. Recorded curve of gravity change obtained at Naze during four days around the eclipse day. (Size about 1/7 of the original record. Hour-marks in UT.)

Notes : B Beginning of the eclipse (01h 53m 02s)
A Maximum obscuration (03h 46m 37s)
E : End of the eclipse (05h 39m 34s)

Readings of the registrograms were made at every hour up to 0.1mm corresponding to about 0.25 μgal in gravity change. Read values obtained were consisted of the instrumental drift, real gravity change, and apparent one caused by meteorological changes and other causes. Therefore, at the first step to enter a harmonic analysis, removals of the instrumental drift and disturbing terms from all the hourly read values were necessitated.

Correction factors of the Askania gravimeter No. 111 for temperature and pressure variations were already obtained by the precise one year's observation (**18**) of the tidal variation of gravity at Kyoto as follows:

Correction factor for room temperature variation : -17 μgal/°C
Correction factor for atmospheric pressure variation : $-$ 3.9 μgal/mmHg.

It was a question whether these factors could be applied to the observed values obtained at Naze as they did at Kyoto. But, since both observations were carried out at the same condition of gravimeter, effects caused by the temperature and pressure variations were first of all excluded from all the hourly read values under an assumption that these factors were also applicable in the present investigation. The maximum value of correction added to or subtracted from the hourly read values was about 65 μgal, and its value was of the same order as the amplitude of M_2-constituent of the tidal gravity variation at Naze.

Next, the drift curve was eliminated from the hourly values thus obtained. As for its method, method (bde) proposed by the author (**19**) was used. After elimination of the drift, hourly values obtained were immediately harmoniously analysed by Lecolazet's method (**20**) to obtain harmonic constants. The actual amplitude R_{obs} and phase ε_{obs} of each gravity constituent obtained by the harmonic analysis are shown in Table 4.2 with epoch of the analysis. In Table 4.2, only the analytical results for six principal tidal constituents —— M_2, S_2, N_2, K_1, O_1 and Q_1 —— were shown. The mean errors of R_{obs} and ε_{obs} shown in this table were values obtained by using error combination introduced by R. Lecolazet (**21**).

On the other hand, theoretical values of the tidal variation of gravity can be calculated by Lecolazet's method (**20**). The theoretical amplitude R_{theor} and phase ε_{theor} for each gravity constituent, corresponding to R_{obs} and ε_{obs}, are shown in Table 4.3.

Thus, the tidal factor of gravity G and phase lag κ are calculated by the formulae

Table 4.2. Values of R_{obs} and ε_{obs}
Epoch of analysis : April 16, 18h, 1958 (UT)

	R (μgal)	ε (degree)
M_2	71.727±0.209	307.53±0.17
S_2	34.289±0.212	256.70±0.37
N_2	14.960±0.217	136.32±0.86
K_1	32.256±0.231	26.75±0.42
O_1	27.215±0.225	139.87±0.49
Q_1	4.110±0.225	16.15±3.21

Table 4.3. Values of R_{theor} and ε_{theor}
Epoch of analysis : April 16, 18h, 1958 (UT)

	R (μgal)	ε (degree)
M_2	60.085	310.92
S_2	29.742	264.45
N_2	12.993	138.22
K_1	28.740	0.74
O_1	20.667	149.08
Q_1	4.430	15.32

$$G=\frac{R_{obs}}{R_{theor}} \quad \text{and} \quad \kappa=\varepsilon_{obs}-\varepsilon_{theor} \qquad (4.2)$$

respectively. The obtained values of G and κ are shown in Table 4.4. Here, the positive sign of κ means that the observed tide advances the theoretical one, while the negative sign means that the former lags behind the latter.

Table 4.4. Values of G and κ
Epoch of analysis : April 16, 18h, 1958 (UT)

	G	κ
M_2	1.194±0.004	− 3.°39±0.°18
S_2	1.153±0.008	− 7.75±0.38
N_2	1.151±0.018	− 1.90±0.86
K_1	1.122±0.009	+26.01±0.43
O_1	1.317±0.012	− 9.21±0.49
Q_1	0.928±0.051	+ 0.83±3.21

Table 4.5. Values of R_{theor}' and ε_{theor}'
Epoch of analysis : April 16, 18h, 1958 (UT)

	R' (μgal)	ε' (degree)
M_2	59.893	310.27
S_2	30.459	262.83
N_2	13.585	133.73
K_1	28.116	356.78
O_1	21.168	150.28
Q_1	3.787	337.35

Now, for the present purpose, it is desirable to investigate in detail the difference between a theoretical and the observed tides. In order to investigate it, it is first of all necessary to calculate the hourly values of theoretical tides. In Lecolazet's method of harmonic analysis, the theoretical amplitude and phase for each tidal constituent of gravity variation, can usually be calculated by an expansion of the tide-generating potential. But they can also be obtained by analysing the hourly theoretical values by the same method as for the observed ones, when the hourly theoretical values are known.

In the present case, since a tidal curve —— speaking in detail, the tidal curve at Kyoto synthesised by a tide-predictor belonging to the Hydrographic Division of the Maritime Safety Board —— was favourably given, the hourly values of theoretical tides could be obtained from this curve. Namely, readings of the tidal curve were made at every hour up to 0.1 mm. One millimetre on the tidal curve corresponded to 1.5482 μgal in gravity variation. The hourly values read from the tidal curve during the corresponding periods were harmoniously analysed by Lecolazet's method (**20**) as well as the observed values. The theoretical amplitude R_{theor}' and phase ε_{theor}' thus obtained are shown in Table 4.5.

Thus, the tidal factor of gravity G' and phase lag κ' are calculated by the formulae

$$G' = \frac{R_{obs}}{R_{theor}'} \quad \text{and} \quad \kappa' = \varepsilon_{obs} - \varepsilon_{theor}' \tag{4.3}$$

respectively, using Tables 4.2 and 4.5. The obtained values of G' and κ' are shown in Table 4.6.

Table 4.6. Values of G' and κ'

Epoch of analysis :
April 16, 18h, 1958 (UT)

	G'	κ'
M_2	1.198	$-$ 2.°74
S_2	1.126	$-$ 6. 13
N_2	1.101	+ 2. 59
K_1	1.147	+ 29. 97
O_1	1.286	$-$ 10. 41
Q_1	1.085	+ 38. 80

Table 4.7. Mean values of G' and κ'

Epoch of analysis : April 16, 18h, 1958 (UT)

	G'	κ'
Semi-diurnal constituents	1.164±0.029	$-$ 2.°75± 1.°89
Diurnal constituents	1.198±0.052	+ 14. 49±14. 44
All constituents	1.176±0.026	+ 3. 08± 6. 55

(with weights proportional to R_{theor}')

The mean values of G' and κ' for different tidal constituent groups are shown in Table 4.7. As shown in Table 4.7, the mean value of κ' for all constituents is considerably small. Hence, assuming that there is no phase lag between the observed and theoretical tides, the following considerations are continued.

Both observed and theoretical curves are shown in the upper part of Fig. 4.2. The hourly dots are obtained by correcting the influences of meteorological disturbances and instrumental drift on hourly observed values of the tidal variation of gravity, and the curve is drawn magnifying the tidal curve by 1.176. In the middle part of Fig. 4.2, a difference between both curves mentioned above, that is a residual curve, is shown. Although a wave with semi-diurnal period disappears almost perfectly, that with diurnal period remains clearly on the residual curve. If a screening of the solar attraction by the moon occures during a solar eclipse, its effect must be included in this residual. A smoothed residual obtained by applying method (cde) proposed by the author (**19**) to the residual, is shown in the lower part of Fig. 4.2.

As the data to make out Fig. 4.2, hourly observed values were used. Taking into account a duration time of the solar eclipse (about four hours), however, it was suspected that a reading interval was too wide. During seven days before and after the eclipse day, both observed and theoretical curves were read at 10-minute intervals and they were analysed by the same method as for the hourly values. The obtained residual and smoothed residual are shown in Fig. 4.3. As already described above, the readings were made for seven days around the eclipse day. Read values of one day at each end of those periods disappeared in the eliminating process of the drift, and moreover those of one further day at each end disappeared in the smoothing process of the residual. Therefore, results obtained for three days around the eclipse day are shown in Fig. 4.3.

4. Discussion

A screening effect of the gravitational force during a solar eclipse was previously estimated by R. Tomaschek (8) and R. Brein (**9**). According to Brein's conclusion, the screening effect of the gravitational force during a total eclipse reached 2.1 μgal in maximum, when the absorption constant of gravity, 3×10^{-15} in c.g.s. units, determined by K. F. Bottlinger (**6**) was adopted. According to Tomaschek's, it was, applying Majorana's theory (**1**), to be 3 μgal in maximum for an absorption constant of gravitation with less than 10^{-14} which was about one thousandth of the value deduced by Q. Majorana (**1**) from his experiments.

On the other hand, as already described in section 1, observations with a highly sensitive gravimeter to investigate the screening effect of gravitation during a solar eclipse, were carried out earlier by R. Tomaschek (8), R. Brein (**9**) and others, and recently by Y. S. Dobrokhotov and others

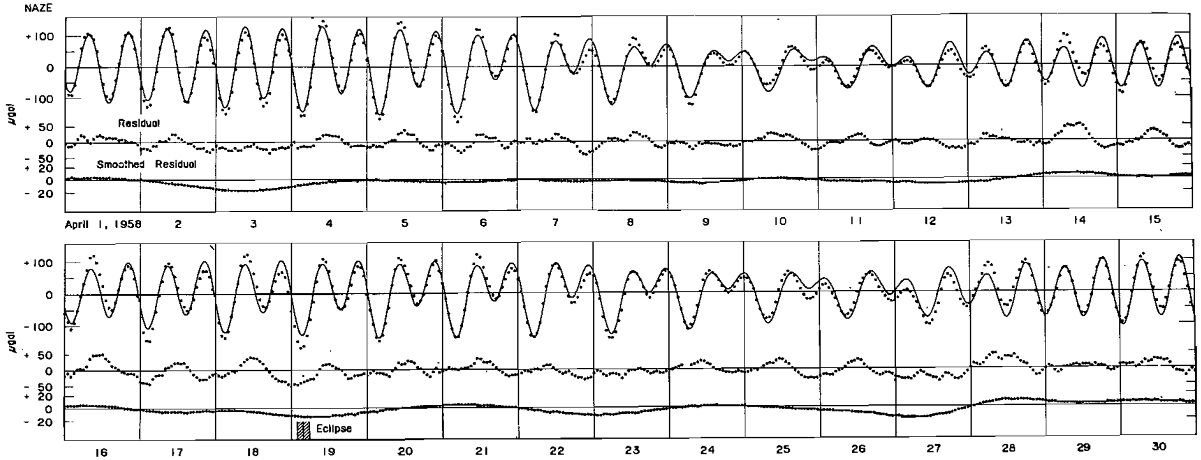

Fig. 4.2. Observed and theoretical curves of the tidal variation of gravity at Naze (Upper part); Deviation of the observed tidal amplitude from the theoretical (Middle part); Smoothed residual (Lower part).

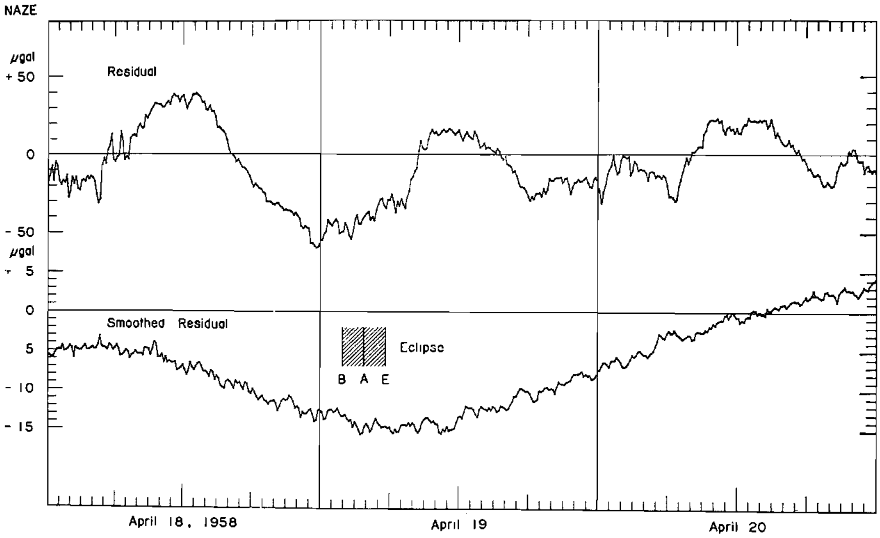

Fig. 4.3. Residual and smoothed residual during three days around the eclipse day.

(**12**). The conclusion obtained by those observations was as follows :

No significant systematic effect was observable during the eclipse (by R. Tomaschek).

The screening effect of gravitation observed during the eclipse was 1.4 μgal (by R. Brein).

The screening effect during the eclipse did not exceed 3 μgal, if it existed (by Y. S. Dobrokhotov and others).

In Tomaschek's observation, the screening effect of gravitation, which was estimated to be about 3 μgal, could not be detected at the time of the solar eclipse, because the accuracy of the gravimeter could not be kept always to 1 μgal, to his regret, due to disturbances caused by violent microseisms. The observation made by Y. S. Dobrokhotov and others (**12**) was the most substantial one ever made, but its detailed result has not yet been reported.

It is concluded by some researchers that the screening effect of gravitation during a solar eclipse is about 2~3 μgal, if it exists. In order to detect this effect by observation, therefore, it is required strongly that the accuracy of gravimeter must always be kept to higher than 1 μgal.

Since the residual shown in Fig. 4.2, is obtained by excluding the effect of meteorological changes, instrumental drift and earth tidal waves from observed values, there must not exist any periodic wave. But, as can easily be seen from Fig. 4.2, there remains a diurnal wave on the residual, and its amplitude is about 30~50 μgal. In this stage, an influence of oceanic tides is included in the residual. As the oceanic tides are mainly represented by an oscillation with semi-diurnal period, the diurnal wave does not vanish from the residual even if their influence is excluded. The residual is not always large when the tidal amplitude is large. In practice, comparing the record of the oceanic tides observed at the port of Naze with the residual, no correlation is found between both curves. If there exists the screening effect of gravitation which is the subject of the present consideration, it must be included in this residual. No significant effect can be found, during the solar eclipse, from both residual and its smoothed curve, shown in Fig. 4.2.

The residual and its smoothed curve during three days around the eclipse day, are also shown in detail in Fig. 4.3. In this figure, there is no obvious difference between the eclipse and ordinary periods. There exist always disturbances with a period of one to three hours on the smoothed residual, and their amplitude amounts to about 2~3 μgal. It is therefore concluded that the screening effect of gravitation during the present solar eclipse does not exceed 3 μgal, if it exists.

As described above, disturbances on the recorded curve were the most violent at Naze, among the recorded curves obtained by the author at eleven stations in Japan. Generally speaking, those disturbances took place frequently in the daytime and rarely at night. It was therefore clear that they were artificial ones. Since there existed disturbances with an amplitude of 2~3 μgal in the ordinary period, it seemed to be insignificant to discuss further on the smoothed residual. But needless to mention, Naze was the most suitable station for the present purpose so far as this eclipse was concerned, and the observation room was the best one available at that place. Further opportunities to elucidate this problem are eagerly awaited.

R. Tomaschek (**11**) reported a possibility of observing the screening effect of gravitation, for the total eclipse occured on February 15, 1961 in Europe, at many stations located in its zone. Since this eclipse occured just after sunrise in Europe, an observation with gravimeter could not be expected and that with horizontal pendulum would be expedient. But in USSR, an observation with gravimeter was possible enough. Observations at that time were carried out by Y. S. Dobrokhotov and others (**12**) with gravimeters and M. Caputo (**13**) and others (**14**) with horizontal pendulums. The conclusion obtained by Y. S. Dobrokhotov and others was, as described above, that the screening effect of gravitation during the eclipse did not exceed 3 μgal, if it existed. It was in good agreement with both the present author's and Tomaschek's conclusions.

R. Tomaschek (**11**) has also described a possibility to elucidate the problem concerning the screening effect of gravitation independently of a solar eclipse, regarding the earth itself as an absorption body. According to his suggestion, a gravitational absorption due to the earth's mass can be detected by observing precisely the gravity change at moonrise or moonset during a period longer than three years. The moon is chosen as a subject of the investigation in spite of its less gravitational field than the sun because of avoiding thermal disturbances. This problem is an important and attractive one and now in progress.

5. Summary

The problem of a screening effect of gravitational force caused of a third body interposing between two attracting bodies, has been discussed both theoretically and experimentally. Since this effect must be very small even if it exists, it is necessary to increase sufficiently accuracy of the instrument and to select as quiet and stable observation station as possible insulated from various disturbances, in order to detect this effect by observation. The opportunity to investigate experimentally the existence of this effect is given only at the time of a solar eclipse, consequently a definitively experimental conclusion for this phenomenon has not yet been obtained up to the present time.

The author carried out one month's observations of the tidal variation of gravity by means of the Askania gravimeter No. 111 with automatic recording apparatus at eleven stations in Japan since July 1957. In those cases, the observation stations were particularly selected from two standpoints of distance from the effective sea and gravity anomaly in order to investigate influences of the oceanic tides and the subterranean structure. As one of the observation stations fulfilling the above-mentioned conditions, Naze located on a solitary island in the Pacific Ocean was selected. An annular eclipse occured over some scattered islands in the south regions of the Main Land of Japan on April 19, 1958, and Naze was situated in the annular eclipse zone. Therefore, the observation at Naze was carried out at that time. In other words, the observation of the time change of gravity at Naze was carried out for two purposes. Namely, one was to observe the tidal variation of gravity on an island and the other to investigate the screening effect of gravitation, if it existed, during a solar eclipse.

The observation was carried out continuously during a period of about 42 days from March 29 to May 10, 1958 by means of the Askania gravimeter No. 111 at an old seismograph room of Naze Weather Station, and an annular eclipse occured during this period. The rotation speed of the recording paper was usually 8 mm/hour, but it was 20 mm/hour during seven days around the eclipse day. The observation room was the best one available there.

Readings of the registrograms were made at every hour up to 0.1 mm corresponding to about 0.25 μgal in gravity change. In particular, they were done at 10-minute intervals for seven days around the eclipse day. After influences of temperature and pressure variations, the instrumental drift and tidal waves were excluded from all the read values, the residual curve and its smoothed one were obtained. Deliberation for these curves resulted in the following conclusions :

(1) Any significant systematic effect which seemed to be related with the gravitational absorption, was not observed during the solar eclipse.

(2) The screening effect of gravitation, if it existed, at the time of the present eclipse, did not exceed 3 μgal.

These conclusions were in perfect agreement with Tomaschek's ones for the total eclipse of June 30, 1954 and also with those obtained by Y. S. Dobrokhotov and others for that of February 15, 1961. Since there were many disturbances caused by changes of the meteorological and other disturbing factors at Naze, a fluctuation of the smoothed residual reached always 2~3 μgal. It was therefore impossible to discuss in further detail the screening effect of gravitation at the time of the present solar eclipse based on these observational data.

In order to elucidate this problem, it is necessary to select a stable station where disturbances are always less than 1 μgal and furthermore to observe simultaneously the gravity change by means of many gravimeters with automatic recording apparatuses, of which accuracy is higher than 1 μgal, during several days at least around a day of solar eclipse. As for the problem concerning the gravitational absorption due to the earth's mass itself, the author is now investigating it and will report in near future.

Acknowledgements

In close of the present article, the author wishes to express his hearty thanks to Prof. E. Nishimura for his kind guidance throughout the present study and also to Master of Sci. M. Funabiki for his willing help in the present observation. Many thanks are extended to Prof. T. Ichinohe who read the manuscript and made many suggestions. The author is also deeply grateful to all members of Naze Weather Station for their help and goodwill. The expense of the present research was defrayed by the Grants in Aid for the International Geophysical Year.

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