

42. Free Oscillation of the Earth Observed by Gravimeters Installed in Kyoto, Japan

By Yasuo SATÔ,

Earthquake Research Institute;

Hitoshi TAKEUCHI,

Geophysical Institute, the University of Tokyo;

Eiichi NISHIMURA and Ichiro NAKAGAWA,

Geophysical Institute, Kyoto University.

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Abstract

The earth's free oscillation excited by the Chilean earthquake of May 22, 1960 was observed by two gravimeters installed in Kyoto, Japan. The spectrum analysis gives marked peaks within 6 and 30 minutes, which are in good coincidence with the theoretical periods of spheroidal oscillation of the Gutenberg earth's model. Q value around the period 12 minutes came out between 200 and 300.

1. Introduction

In the case of the Chilean earthquake of May 1960 the free oscillation of the earth was observed at various stations and reports are pointed in geophysical journals.^{1), 2), 3), 4), 5), 6)} In Japan also, two gravimeters were working at the International Gravity Reference Station in

1) H. BENIOFF, F. PRESS and S. SMITH, "Excitation of the Free Oscillations of the Earth by Earthquakes," *Journ. Geophys. Res.*, **66** (1961), 605.

2) N. F. NESS, J. C. HARRISON and L. B. SLICHTER, "Observations of the Free Oscillations of the Earth," *Journ. Geophys. Res.*, **66** (1961), 621.

3) L. E. ALSOP, G. H. SUTTON and M. EWING, "Free Oscillation of the Earth Observed on Strain and Pendulum Seismographs," *Journ. Geophys. Res.*, **66** (1961), 631.

4) B. P. BOGERT, "An Observation of Free Oscillations of the Earth," *Journ. Geophys. Res.*, **66** (1961), 643.

5) C. L. PEKERIS, Z. ALTERMAN and H. JAROSCH, "Comparison of Theoretical with Observed Values of the Periods of Free Oscillation of the Earth," *Proc. National Acad. Sci.*, **47** (1961), 91.

6) J. CONNES, P. A. BLUM and N. JOBERT, "Observation des oscillations propres de la terre," *Annales de Geophysique*, **18** (1962), 260.

a basement of the Geophysical Institute, Kyoto University. This room is kept at constant temperature and humidity, the location of the standard point being $135^{\circ}47'.2E$, $35^{\circ}01'.8N$, the altitude 59.8 m. The epicenter is located at $\lambda=38^{\circ}.0S$, $\phi=73^{\circ}.5W$, therefore the epicentral distance is $\Delta=138^{\circ}.0$. The room temperature at the time of observation was $19^{\circ}.6C \pm 0^{\circ}.2C$.

The instruments are ;

Askania Gs-11, No. 105 and No. 111,

Pendulum $T=12$ sec, $h=1.0$,

Galvanometer $T=20$ sec, $h=60$,

which belong to Geographical Survey Institute and Kyoto University respectively. The statical sensitivity is ;

$$\Delta g = 3.086 \times 10^{-6} a \text{ gal,}$$

where $a(\text{cm})$ is the variation of altitude at the surface of the earth.

The following report is an attempt to find the free oscillation period of the earth using the record obtained by the gravimeter No. 111. A similar study was reported twice by Nishimura, Takeuchi and others.^{7),8)}

2. Data and method of analysis

The readings commenced at 4^h00^m (U.T.) on May 23, 1960 with an interval of 2 minutes, the total number of readings being 1480. In order to remove the disturbance caused by the earth tide we employed the following method.

1) Readings $u_j (j=1, \dots, 148)$ were chosen every 20 minutes.

2) Five kinds of tide periods

TM2 (745 min.), TS1 (1440 min.),

TS2 (720 min.), TO1 (1549 min.),

TN2 (759 min.), and a constant

were assumed and employing the observation equation

$$\begin{aligned} u_j = & AM2 \cdot \cos(t_j \cdot (2\pi/TM2)) + BM2 \cdot \sin(t_j \cdot (2\pi/TM2)) \\ & + AS1 \cdot \cos(t_j \cdot (2\pi/TS1)) + BS1 \cdot \sin(t_j \cdot (2\pi/TS1)) \\ & + \dots + C \end{aligned} \quad (j=1, \dots, 148)$$

7) E. NISHIMURA, I. NAKAGAWA, K. HOSIYAMA, M. SAITO and H. TAKEUCHI, "Free Oscillations of the Earth Observed on Gravimeters," *Journ. Seismol. Soc. Japan*, [ii], 14 (1961), 103.

8) H. TAKEUCHI, M. SAITO, N. KOBAYASHI and I. NAKAGAWA, "Free Oscillations of the Earth Observed on Gravimeters," *Journ. Seismol. Soc. Japan*, [ii], 15 (1962), 122. In this paper the original readings are given.

11 constants AM2, BM2; AS1, BS1; ...; C were calculated by the method of least squares.

3) Using these constants, the tide prediction

$$\begin{aligned}\bar{u}_k = & \text{AM2} \cdot \cos(t_k \cdot (2\pi/\text{TM2})) + \text{BM2} \cdot \sin(t_k \cdot (2\pi/\text{TM2})) \\ & + \text{AS1} \cdot \cos(t_k \cdot (2\pi/\text{TS1})) + \dots + C \quad (k=1, \dots, 1480)\end{aligned}$$

was calculated.

4) Finally, the deviation from the prediction, or the residual

$$w_k = u_k - \bar{u}_k,$$

was calculated and Fourier analysed. Several first and last values of w_k were discarded, and the range of analysis was assumed to be exactly 48 hours starting from 4^h30^m (U. T.).

3. Result of analysis

The tide constants determined by the above method are ;

	cos term	sin term	amplitude
M2	-29.9 μgal	-44.2 μgal	50.8 μgal
S1	-3.8	-0.8	3.9
S2	-1.4	20.8	20.8
O1	0.3	2.8	2.8
N2	23.2	27.4	35.8

This analysis is aimed at removing the effect of tide, therefore too many constants are assumed compared with the short range of observation. Consequently each value in the above table may not have good reliability by itself.

The spectrum calculated using the method given above is shown in Fig. 1, from which we can draw several conclusions.

1) Peaks with periods longer than 20 minutes are not very clear, although there are some which are not identified with any of the known free oscillation periods.

2) There are several remarkable peaks with periods between 6 and 20 minutes, which are all identified with the spheroidal oscillation period.

3) Theoretical periods of the Gutenberg earth model fit the above calculated values well.

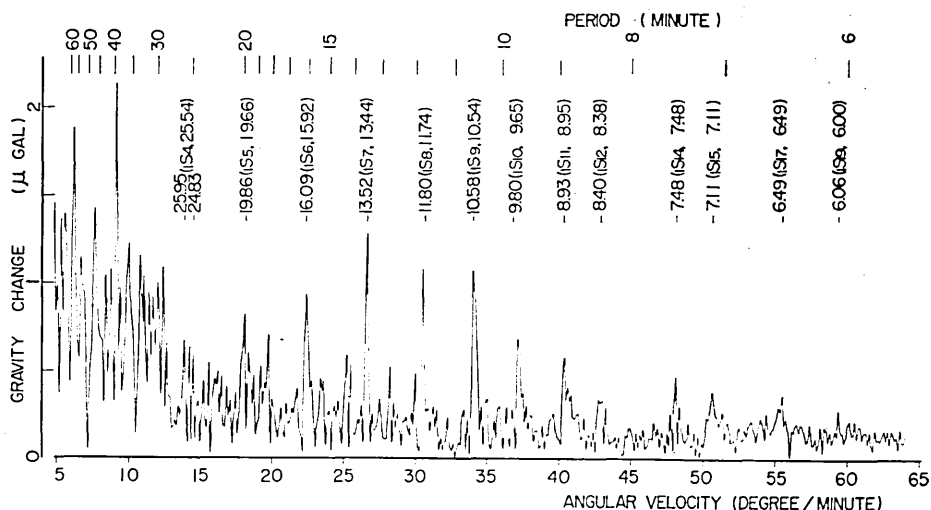


Fig. 1. Spectrum analysis of the disturbance excited by the Chilean earthquake May 22, 1960. The record was obtained by a gravimeter installed in Kyoto, Japan. In the parentheses, the mode of oscillation (S_n) and the theoretical period based on Gutenberg earth model are given. Numbers left of the parentheses are the periods corresponding to the peaks of the spectrum.

4) Some of the peaks (corresponding to $n=13$, 16 and 18) are missing. This might be caused by the focus mechanism or the geographical location of the station. Since the observation was done by a gravimeter the disturbance should be proportional to the vertical displacement, which is expressed by $P_n^m(\cos \Delta) \cdot (\cos \text{ or } \sin m\phi)$. Introducing the epicentral distance $\Delta=138^\circ.0$, the zero points of the above function is⁹⁾ for various values of m are:

$$m=0 ; n=2.4, 6.1, 9.7, 13.3, 17.2$$

$$m=1 ; n=4.2, 7.8, 11.5, 15.3, 19.1$$

$$m=2 ; n=5.7, 9.6, 13.3, 17.2$$

None of the above assumptions do not explain the missing spectrum lines.

Dividing the observation range, 48 hours, into two 24 hour periods,

9) Y. SATÔ and T. USAMI, "Method of Determining the Degree of Free Oscillation of a Radially Heterogeneous Elastic Sphere," *Bull. Earthq. Res. Inst.*, **41** (1963), 331-342.

and comparing the spectrum amplitude of both ranges, the attenuation is calculated for three marked peaks.

Mode	Period (min.)	Gravity amplitude (μgal)		Q
		1st 24 hours	2nd 24 hours	
${}_1S_7$	13.57	1.12	0.194	192
${}_1S_8$	11.80	0.97	0.277	306
${}_1S_9$	10.58	1.11	0.153	216

The data is not sufficient for discussing the dependence of Q on the period. We can only deduce that the Q value around the period 12 minutes is between 200 and 300.

Acknowledgments

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42. 重力計によつて観測された地球振動

地 震 研 究 所 佐 藤 泰 夫
理 学 部 地 球 物 理 学 教 室 竹 内 均
京都大学理学部地球物理学教室 { 西 村 英 一
中 川 一 郎

1960年5月のチリ地震の際に、京都大学地球物理学教室に設置されていた二台の重力計はいずれも大きな振動を記録した。これを2分おきに読み取り、最小二乗法によつて潮汐の常数を定めた。つぎに、この常数を用いて潮汐の影響を取り除いたものを、フーリエ解析して地球振動をとり出すことを試みた。その結果6分ないし20分の周期を持つ振動はよく現われたが、これらはグーテンベルグによる地球モデルの理論的な周期とよくあつている。 $n=13, 16, 18$ に対してはスペクトルの山が見えない。また、観測の区間を二分して24時間ずつの二つとし、両者を独立にフーリエ解析して得られるスペクトルの大きさの比較から減衰を求めると、12分前後の周期のところでQは200~300とでてくる。