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8. *On the Changes in the Heights of Mean Sea-levels at Portland, Maine, and at Baltimore, Md., U.S.A.**

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Introduction

The data for the mean sea-levels at Portland, Maine (43°41′ N-lat., 70°15′ W-long), during the period of 47 years from 1912 to 1958, and at Baltimore, Md. (39°16′ N-lat., 76°35′ W-long), during the period of 56 years from 1903 to 1958, were taken from Publication Scientifique, Monthly and Annual Mean Heights of Sea-level.

The changes in the heights of mean sea-levels at the above two stations were investigated similarly as in the cases of San Francisco and of Los Angeles, already reported in the writer's papers[1].

Annual mean sea-levels for each month were calculated first, and the Montly deviations from these, and next, yearly mean sea-levels were calculated and compared with those at San Francisco and at Los Angeles in order to see the tendency, if any, of much increase in the total mass of waters in the North Pacific as well as in the Atlantic Oceans in recent so-called warm years of about 20 in number.

Method of Investigation and Results

At Portland, Maine, the 47 years' mean sea-level for each month, and at Baltimore, Md., the 56 years' mean sea-level for each month, were calculated and compared with those at San Francisco, Los Angeles and at Aburatubo in Japan, plotting against each month in the year as shown in Fig. 1.

The results show that, the first minimum of the curve is seen in January and the second minimum in September at Portland Maine, while at Baltimore, Md., the first minimum is in February, and the second minimum is July. The second minimum in September at Portland Maine

* Communicated by T. Hagiwara.

1) Journal of the Oceanographical Society of Japan, 20th Anniversary Volume 1962, and Journal of the Geodetic Society of Japan.

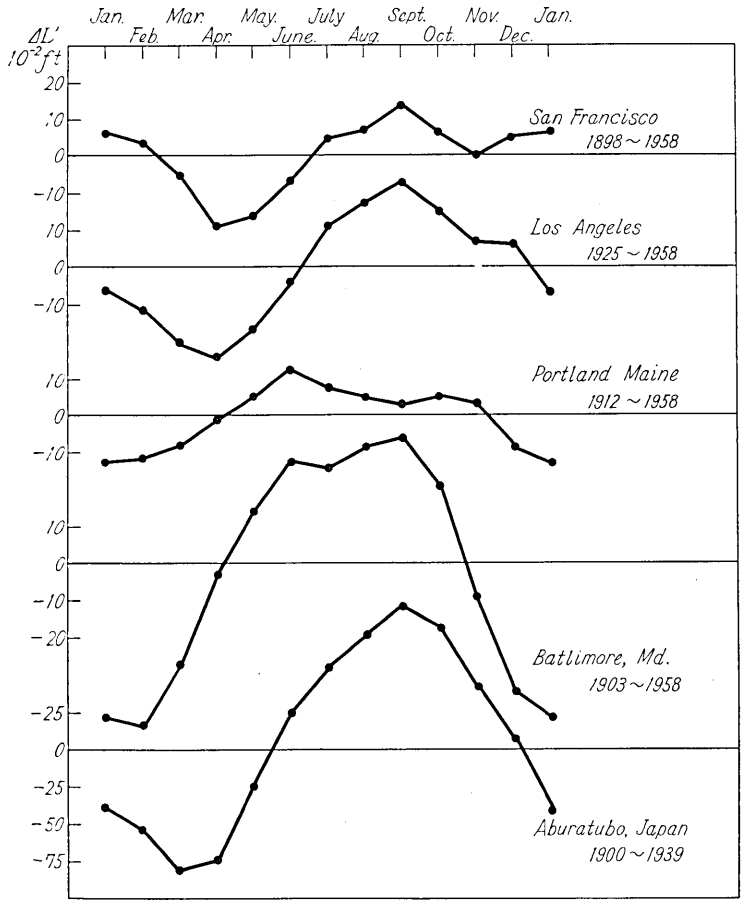

Fig. 1. Annual Mean Sea-levels for many years.

corresponds to the maxima of the curves at all other stations at San Francisco, Los Angeles, Portland Maine and Aburatubo, Japan, the reason of which is not yet clear. The maxima of the curves in June at Portland Maine and at Baltimore, Md., may be due to the greater effect of barometric height on the Atlantic Ocean side than on the Pacific Ocean side, upon annual mean sea-level.

Monthly deviations of sea-levels from the annual mean for each month are calculated and denoted by $\Delta L'$, and tabulated in Table 1 and 2, corresponding to Portland Maine and to Baltimore, Md., respectively.

We have smoothed the values of $\Delta L'$, by taking $\Delta L'_m = \frac{1}{4}(\Delta L'_{n-1} + 2\Delta L'_n + \Delta L'_{n+1})$, instead of $\Delta L'_n$, where n is the order of the month. The values

Table 1. Monthly deviations of sea-levels $\Delta L'$ in 10^{-2} ft from 47 years' mean for each month in an year, at Portland, Maine.

Year / Month	$\Delta L'$ in 10^{-2} ft											
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
Jan.	−34	−19	22	−10	−12	− 5	24	−10	1	19	−44	21
Feb.	−20	−21	−26	− 1	− 5	−10	− 4	10	− 3	6	−22	− 1
Mar.	−38	−47	−11	7	− 4	− 6	− 5	− 3	−31	−21	−11	−10
Apr.	−11	−20	−26	−26	7	−17	− 6	4	20	− 9	0	− 7
May	−10	−24	−17	7	4	18	−19	8	− 9	9	−29	−12
June	− 6	− 9	−29	−18	9	− 2	− 7	− 6	1	− 7	−20	−14
July	6	− 9	− 3	3	−15	− 3	− 8	7	− 3	− 9	−21	−26
Aug.	12	−10	− 5	− 1	3	− 2	−17	8	− 8	−29	−14	−26
Sept.	14	−21	7	− 1	− 6	−14	− 7	7	3	− 6	−18	−33
Oct.	−10	8	− 8	− 7	−26	5	−16	− 4	16	− 2	− 4	−20
Nov.	− 6	−15	−10	0	−14	−11	− 2	33	− 1	− 1	− 4	− 2
Dec.	−25	−10	− 7	22	− 9	− 8	15	0	20	− 6	−14	− 9
Mean	−11	−16	− 9	− 2	− 6	− 5	− 4	5	1	− 4	−17	−12

Year / Month	$\Delta L'$ in 10^{-2} ft											
	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Jan.	−30	− 8	−35	−28	−20	−40	−28	−17	− 4	16	−11	1
Feb.	− 4	−19	− 5	0	−27	−16	−28	−22	− 4	− 7	−31	−23
Mar.	26	−24	−40	−13	−15	− 2	−25	30	1	7	−41	−12
Apr.	− 1	−20	−33	−17	−33	9	−34	− 2	−14	9	− 8	13
May	− 2	−14	−25	−12	−15	−34	−19	−17	−30	2	−25	− 7
June	−12	−20	−25	− 5	−10	− 7	−26	3	−13	4	− 4	8
July	−20	−15	−17	−20	−13	−19	− 1	− 5	5	5	− 2	−11
Aug.	− 6	−25	− 8	−10	− 3	−24	−18	− 9	− 3	− 2	−14	− 7
Sept.	−13	−16	−15	−18	1	−20	−12	4	9	7	− 9	−10
Oct.	−15	−18	− 5	− 1	−17	−23	4	−11	−21	−14	− 1	−20
Nov.	−19	−25	−33	− 2	−17	−24	−42	−39	5	−11	−27	10
Dec.	−28	−22	− 7	19	−34	−30	−21	−25	− 9	−15	− 9	16
Mean	−10	−19	−21	− 9	−17	−19	−21	−10	− 7	0	−14	− 4

(to be continued)

Table 1. (continued)

Year / Month	$\Delta L'$ in 10^{-2} ft											
	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Jan.	10	−18	9	−13	− 1	11	− 8	−22	− 3	6		11
Feb.	− 1	27	0	−20	28	4	19	−10	− 8	− 5		49
Mar.	6	−13	11	−16	4	− 6	12	−28	−18	10		52
Apr.	− 5	− 5	− 5	− 7	6	− 4	11	− 9	1	5		12
May	−14	7	7	− 8	22	7	− 1	−14	−12	22	10	21
June	− 9	− 1	− 7	− 8	12	4	9	1	11	6	12	29
July	9	3	− 6	− 5	− 2	2	5	2	9	1	7	18
Aug.	− 8	−10	5	− 2	−11	4	− 4	15	6	1	22	12
Sept.	− 7	−10	− 6	− 1	− 3	− 2	5	2	6	− 1	15	11
Oct.	− 4	−13	5	− 4	− 5	− 6	− 5	25	− 3	12	19	2
Nov.	−21	− 7	− 7	−23	−10	−14	− 3	17	38	21	24	45
Dec.	−23	− 7	− 6	6	1	− 6	− 3	−14	0	36	17	9
Mean	− 6	− 4	0	− 8	3	− 1	3	− 3	2	10	16	23

Year / Month	$\Delta L'$ in 10^{-2} ft										
	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
Jan.	14	23	− 9	10	31	46	25	41	39	− 8	39
Feb.	9	21	6	5	31	7	36	14	6	2	41
Mar.	17	− 2	−21	53	29	36	28	13	15	29	67
Apr.	5	18	5	28	15	31	2	33	32	− 5	53
May	30	9	−15	25	42	32	49	26	8	9	18
June	25	− 9	− 6	18	24	5	28	26	14	9	10
July	30	8	− 3	14	6	4	23	19	24	22	23
Aug.	17	12	4	21	11	16	14	22	30	7	23
Sept.	12	7	15	15	11	13	26	9	18	11	29
Oct.	23	1	9	21	− 1	11	25	33	0	13	26
Nov.	21	10	33	17	8	14	15	22	14	18	17
Dec.	40	−28	35	16	43	10	21	1	16	11	8
Mean	20	6	4	20	21	19	24	22	18	10	30

Table 2. Monthly deviations of sea-levels $\Delta L'$ in 10^{-2} ft from 56 years' mean for each month in an year, at Baltimore, Md.

Year / Month	$\Delta L'$ in 10^{-2} ft											
	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914
Jan.	−23	−35	−46	3	−15	−23	−15	− 3	−16	−48	−13	12
Feb.	−39	−53	−49	−36	−34	−30	−23	−36	0	−25	−33	−42
Mar.	2	−25	−23	−40	−15	−17	−31	− 2	−29	−28	−50	−48
Apr.	10	−44	−34	−29	−48	−50	−30	16	−18	−37	−32	−13
May	− 7	−27	−33	−35	−30	−20	0	−27	−32	−14	−35	−31
June	21	−22	−25	− 5	−13	−20	−20	−21	−19	−36	−34	−39
July	−16	−27	−11	2	−32	−22	−27	− 6	−34	−34	−35	−15
Aug.	0	−40	−12	− 4	−34	− 6	− 7	−16	−17	−33	−14	−23
Sept.	−13	−27	−24	−26	−38	−12	−17	2	− 3	6	−23	−40
Oct.	−11	−38	−30	−16	−49	− 4	−47	−13	2	−27	− 7	− 4
Nov.	−28	−30	−26	−46	−20	−50	−25	−43	−42	−33	−19	−35
Dec.	−51	−23	−13	−47	2	−21	− 6	−18	−16	−33	−16	6
Mean	−13	−33	−27	−23	−27	−23	−21	−14	−19	−29	−26	−23

Year / Month	$\Delta L'$ in 10^{-2} ft											
	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926
Jan.	12	− 7	−14	− 2	−20	−20	−12	−54	0	−23	2	−42
Feb.	9	−38	−37	−13	− 1	−11	23	− 6	−24	14	17	2
Mar.	−23	−30	3	− 3	−16	−40	2	− 5	3	11	−32	−45
Apr.	−45	− 8	−27	9	−19	11	− 2	−13	− 6	1	−11	−38
May	−20	−26	−11	−26	19	− 4	24	− 6	−10	27	−21	−34
June	−11	4	−23	− 8	20	−17	−13	−16	−44	− 3	−26	−32
July	− 4	− 4	− 8	−15	15	−26	− 7	− 2	−16	−15	−17	−27
Aug.	1	−10	−10	−13	0	−17	−22	−16	−17	− 7	−28	− 1
Sept.	−18	−19	−21	−22	− 9	−19	− 3	− 5	−18	− 6	− 9	10
Oct.	− 8	−16	−18	−12	11	−10	−39	−12	−22	−23	−57	− 5
Nov.	− 7	−12	−21	− 9	28	0	3	−22	6	−12	−30	−10
Dec.	−29	−26	−24	19	− 6	16	3	− 5	9	−51	−42	− 5
Mean	−12	−16	−18	− 8	2	−11	− 4	−14	−12	− 7	−21	−19

(to be continued)

Table 2. (continued)

Year / Month	$\Delta L'$ in 10^{-2} ft											
	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938
Jan.	−40	−49	−61	−11	−17	33	22	− 7	− 8	− 9	48	46
Feb.	26	−15	− 3	8	−13	23	−20	−46	− 8	18	32	23
Mar.	− 3	−17	− 9	−14	11	−47	−21	−14	2	57	−23	28
Apr.	−15	−21	9	−30	−21	−15	24	12	4	− 5	32	4
May	−13	−16	−23	−43	−10	−24	9	−16	−18	−17	14	5
June	−13	− 3	− 8	−33	−10	−16	− 8	5	1	1	5	− 4
July	−14	− 9	−23	−23	4	−24	18	5	2	10	17	1
Aug.	−11	− 2	−21	−11	−20	−14	29	−13	7	− 4	1	−11
Sept.	−14	− 7	−12	−14	18	− 2	18	20	− 3	− 4	− 3	− 9
Oct.	− 1	−22	−23	−14	−14	−17	6	−17	−10	9	14	13
Nov.	− 7	−47	−11	−40	−13	13	−20	−15	27	−26	8	18
Dec.	9	−21	−10	−18	−13	12	0	− 9	−14	6	16	19
Mean	− 8	−19	−16	−20	− 8	− 7	5	− 8	− 2	3	13	11

Year / Month	$\Delta L'$ in 10^{-2} ft											
	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Jan.	13	−17	24	12	19	6	− 5	38	37	1	55	23
Feb.	35	32	−23	−19	16	3	12	21	−16	38	55	30
Mar.	34	6	−29	32	7	19	43	61	10	50	− 3	−30
Apr.	10	11	23	14	− 5	5	20	35	31	25	15	− 2
May	22	30	−17	23	4	18	35	31	14	35	27	8
June	16	9	11	23	12	11	16	25	41	27	26	− 6
July	14	− 2	16	12	15	23	35	31	26	27	25	3
Aug.	4	27	− 8	19	16	5	16	21	30	10	25	12
Sept.	25	− 1	− 3	24	− 6	2	40	19	20	24	3	26
Oct.	− 4	7	− 7	46	11	− 4	23	34	17	27	37	31
Nov.	− 1	− 1	3	16	5	26	47	33	67	52	20	58
Dec.	− 7	36	8	10	−15	−14	63	18	1	55	0	43
Mean	13	11	0	18	7	8	29	31	23	31	24	16

(to be continued)

Table 2. (continued)

Year / Month	$\Delta L'$ in 10^{-2} ft							
	1951	1952	1953	1954	1955	1956	1957	1958
Jan.	28	31	74	22	34	29	13	37
Feb.	22	44	29	48	26	30	50	−11
Mar.	72	44	38	16	16	38	65	63
Apr.	34	27	30	32	45	39	21	77
May	25	41	46	32	28	35	37	33
June	54	9	33	27	23	29	39	34
July	25	19	27	20	28	33	17	24
Aug.	28	18	28	− 1	65	40	16	27
Sept.	29	26	29	23	35	41	26	26
Oct.	34	− 8	34	24	61	58	19	47
Nov.	7	47	31	23	25	45	31	40
Dec.	24	62	16	1	4	52	20	31
Mean	32	30	35	22	33	39	30	36

of $\Delta L'_m$, thus smoothed, are plotted against the months, as shown in Fig. 3.

From these curves the abnormal rise of mean sea-levels during the period from August, 1940 to June, 1941 (which is seen in the cases of San Francisco and Los Angeles) is not seen, which result may be considered to show the particular phenomena on the Pacific Ocean side.

Yearly mean sea-levels, calculated from the values of $\Delta L'$, were plotted against the years, together with those of San Francisco, and Los Angeles, for the sake of comparison as shown in Fig. 2. a. The two curves for Portland, Maine, and for Baltimore Md., show equally a tendency to increase from the year 1912 to 1919 and then a tendency to decrease from the year 1919 to 1930 at the rate of about 6 or 7 mm/year, and again a tendency to increase from the year 1930 to 1958 continuously at the rate of 5 mm/year.

As a pretty good parallelism is seen between the above two curves for Portland, Maine, and Baltimore, Md., we have taken the difference of yearly mean values of sea-levels. The result shows that the amplitude of the curve becomes very small during the period of 23 years from 1912 to 1935, but after the year 1935, it remains pretty large up to the year

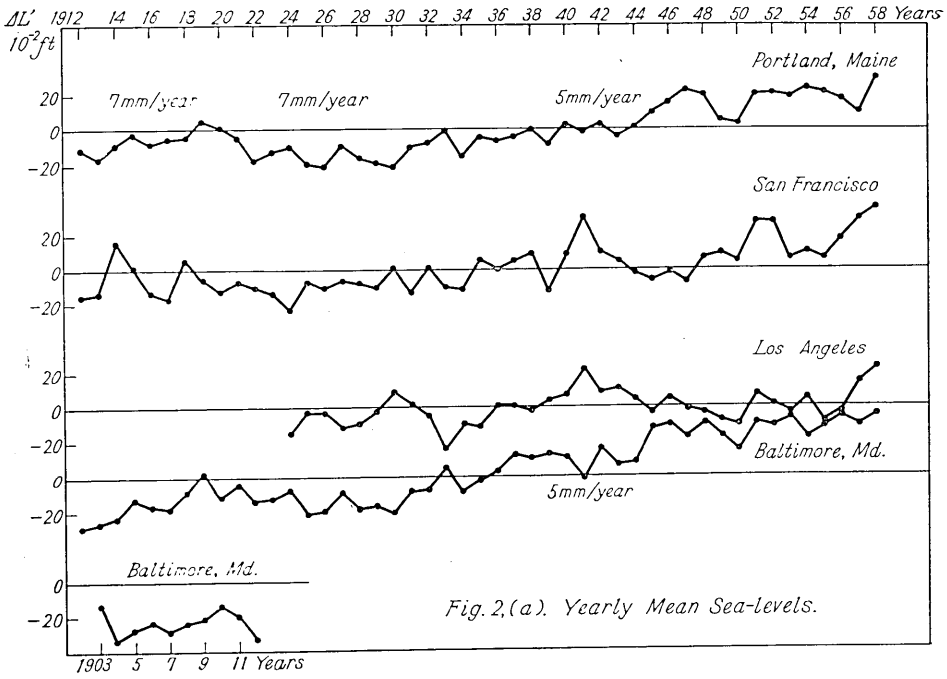

Fig. 2,(a). Yearly Mean Sea-levels.

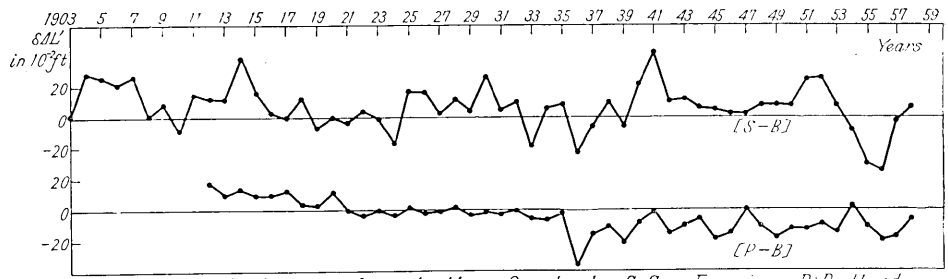

Fig. 2,(b). Differences of yearly Mean Sea-levels. S: San Francisco, P: Portland, Maine, B: Baltimore, Md.

1958. In general, the value of the difference of yearly mean sea-level shows a slightly decreasing tendency during the whole period of 47 years above cited at the rate of about 3 mm/year. The large amplitude of the curve which remains may be considered to show the complexity of oceanic effect upon sea-level, and also the difference of gound movement between the two stations.

The curve for the difference of yearly mean values of sea-levels between San Francisco and Baltimore, Md. shows a very large amplitude, except from 1942 to 1950, and a general trend of decrease at the rate of

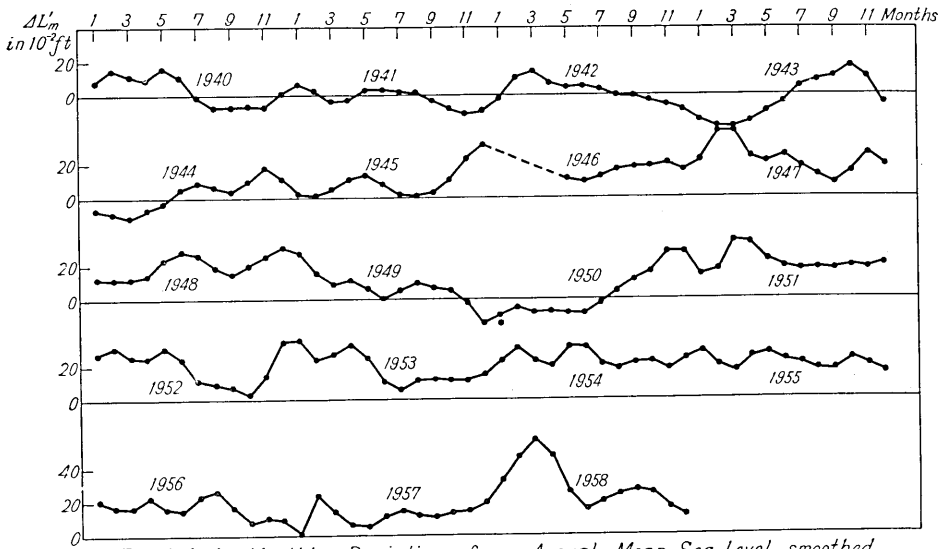

Fig. 3, (a) Monthly Deviations from Annual Mean Sea-level, smoothed, at Portland, Maine. 1940~1958.

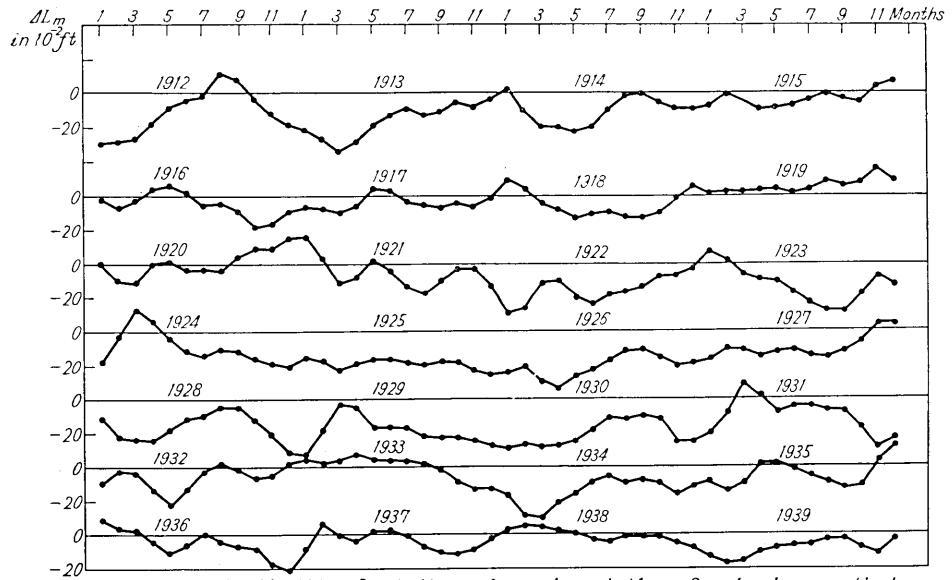

Fig. 3, (a) Monthly Deviations from Annual Mean Sea levels, smoothed, at Portland, Maine. 1912~1939.

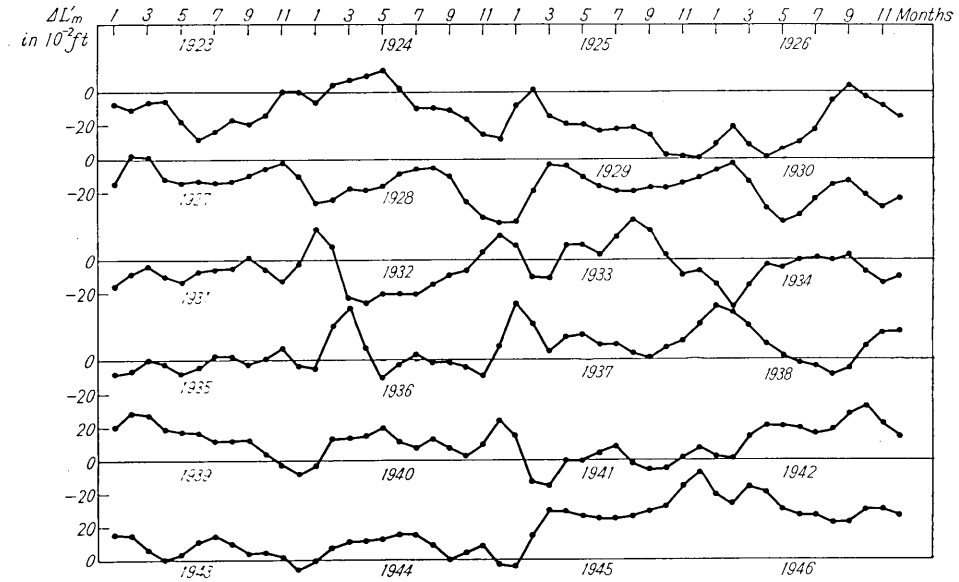

Fig. 3,(b) Monthly deviations from Annual mean Sea-levels, smoothed, at Baltimore, Md. 1923 ~ 1946.

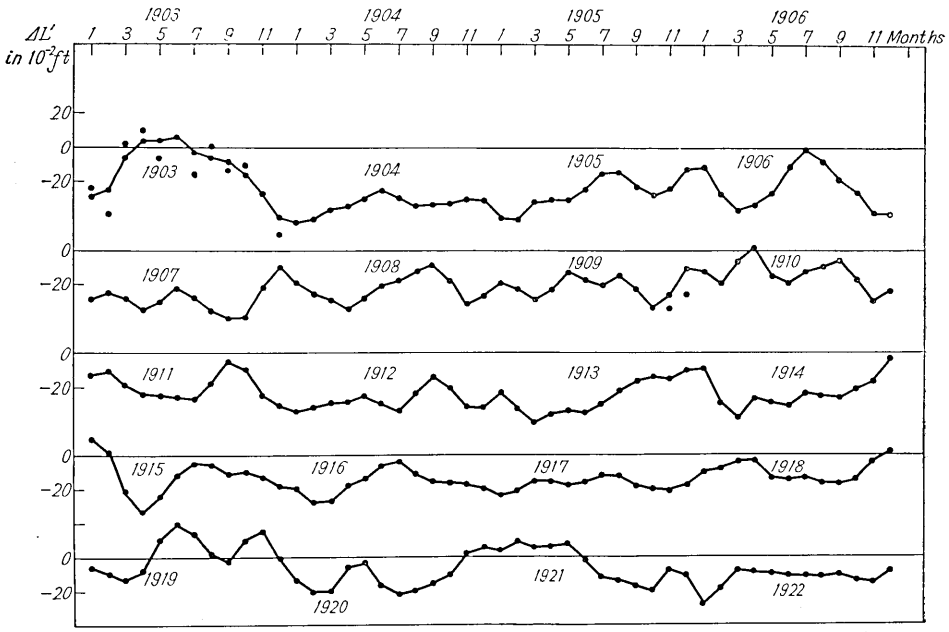

Fig.3,(b). Monthly deviations from Annual Mean Sea-levels, smoothed, at Baltimore, Md. 1903 ~ 1922.

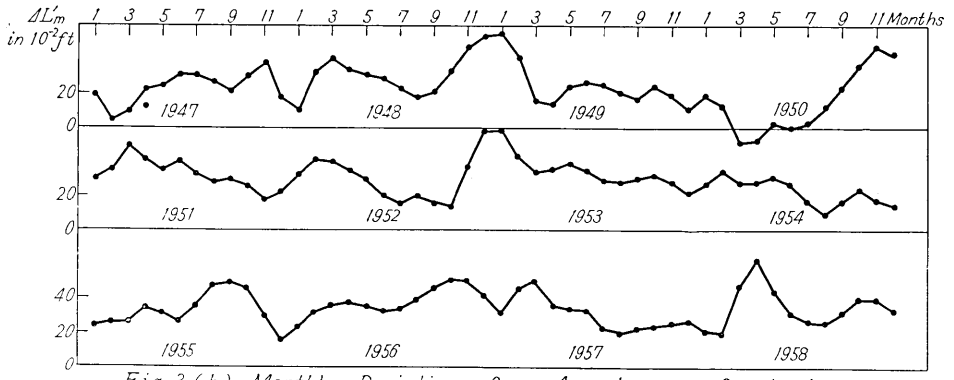

Fig. 3, (b) Monthly Deviations from Annual mean Sea-levels, smoothed, at Baltimore, Md. (1947 ~ 1958)

about 4 mm/year is observed during the whole period of 56 years from 1903 to 1958.

From the various above cited curves no evidence of increase in the total mass of water in the Pacific, and Atlantic Oceans could be found, which rather shows a difference of ground movement or inclination of the ground between the two stations, San Francisco on the Pacific Ocean side, and Portland Maine and Baltimore Md., both on the Atlantic Ocean side. From the curve of yearly mean sea-leves at Aburatubo in Japan, we can discern the up and down motion of the ground with a period of about 18 years, relative to the mean sea-level, which has already been verified as a result of levelling surveys repeatedly carried out through the agency of Geographical Survey Institute, connecting the Standard Bench Mark at Miyakesaka in Tokyo to the Bench Mark inside the mareographic station at Aburatubo[2], no increase of total mass of water in the North Pacific Ocean being shown.

The curves for yearly mean sea-levels at San Francisco as well as at Los Angeles, show a clear tendency from the year 1924 to 1958 to increase continuously at the rate of about 4 or 5 mm/year, and a continuous subsidence of the ground of such an amount relative to the mean sea-level. This result may be considered to coincide approximately with the findings reported by Dr. D. Tocher of U.S. Coast and Geodetic Survery on the occasion of the United States—Japan Conference on Research Related to Earthquake Prediction Problems, held in March, 1964 in Japan, that much of the crustal deformation in coastal California is horizontal, with a slight subsidence of the crust also being observed.

2) S. YAMAGUTI, *Bull. Earthq. Res. Inst.*, **37** (1959), 33-37.

Lastly, if we suppose that the mean sea-levels in the Indian, Pacific and Atlantic Oceans be raised by an amount of 10 cm during the recent period of 20 warm years, then then volume of the melted iceberg from the South Pole Island reaches 3×10^4 km^3, or the blocks, having a base area of 1 km^2 and a height of 300 m for each, amount to 10^5 in number. However, we have no evidence that, so great a number of ice-packs are newly found in a region of the North Pole, or in any other Oceans in the world.

Moreover, before entering into the conclusion of the problem concerning the increase in the total mass of water in the oceans, we must invesigate the problems of precipitation as well as of evaporation from the ocean surface on a worldwide scale. But from the present results of investigations on the changes in the height of mean sea-levels, we may be able to conclude that the continuously increasing tendency of mean sea-levels during the whole period of about 60 years, including the cold years, from 1900 to about 1940, up to 1958 at the rate of about 4 or 5 mm/year, means the slow ground movements relative to the mean sea-levels at such a rate do not indicate the increase of total mass of water in the north Pacific and Atlantic Oceans, it being less warm during years prior to 1940 and after up to recent years.

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8. Portland Maine および Baltimore Md. における平均海水面変化について

神奈川大学　山口生知

日本の Aburatubo や，アメリカの San Francisco, Los Angeles のときと同様な方法で調べてみた．その結果として，

1. 年周変化曲線において，大西洋に面する今回の 2 ヵ所はともに 6 月に maximum があり，特に Portland Maine においては，他はいづれも maximum を示している 9 月に second minimum を示しているのが目立つている．

2. 月平均潮位曲線について 1940～1941 年に太平洋岸の San Francisco や Los Angeles においては異常潮位の上昇があつたが大西洋岸にはそれが見られない．

3. 永年変化曲線については太平洋岸も大西洋岸もいづれも (4～5) mm/year の割合で上昇を続けている．而も温かいといわれる最近 20 年以前の寒い年の頃でも 1900～1940 年の長年月に渡つて殆ぼ同様の割合で上昇を続けている．この結果は日本の国土地理院やアメリカの Coast and Geodetic Survey の測量の結果とも大略一致しているので先ず相対的な地面の動きであると考えられる．而して南極の水が解けて世界的な太洋の水量が増加したという証拠は何一つ見当らない．

4. Portland Maine と Baltimore, Md. との永年変化曲線はよく似ているので，その差をとつてみると，1912 年から 1935 年までは振幅が極めて小となるが，その後 1958 年までの 23 年間はそう小さくならないで，可なり大きな振幅が残つている．これは海洋の平均海水面に及ぼす影響が複雑であることと，今一つは地面の動きがこの期間異なつていることを示すものと思われる．