

## VARIATIONS IN YEARLY SEA LEVEL

by

PAUL SCHUREMAN, SENIOR MATHEMATICIAN, U. S. C. & G. SURVEY.

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The variation in sea level from year to year is a matter of considerable interest to the geodesist. At some of the tide-gauge stations maintained by the Coast and Geodetic Survey observations have been continued over many years thus affording an opportunity for a study of these variations. Accompanying tables give average sea-level values for the principal long series tide observations taken in the United States and Alaska. There are included the results from the tide station at Honolulu, Hawaiian Islands, and also yearly averages for Cristobal and Balboa, Canal Zone, furnished by the Chief of Surveys of the Panama Canal.

The observations by the Coast and Geodetic Survey were taken by means of the standard automatic tide gauge such as described in Special Publication No 196, "Manual of Tide Observations". The record from this gauge is referred to a fixed staff or tape-gauge zero through daily comparative readings, while the constancy of the staff or tape-gauge zero is checked from time to time by levels to a system of benchmarks. Corrections are applied for any changes in the elevation of the zero.

The datum or zero to which the tabular heights at each station are referred is an arbitrary one, and in general the datums for the different stations have no particular relation to each other. In most cases, original tide staff zero was adopted as the datum for the tabulations. The datum used for Fort Hamilton and Whitehall Street, N. Y., is a plane 5 feet below the Sandy Hook sea-level datum, the latter being the standard reference plane for first-order levelling in this area. The heights at Cristobal are referred to a plane 0.138 foot below the "final precise level datum" of the Canal Zone, and the heights at Balboa to a plane 0.036 foot above the same datum.

The tide observations at Atlantic City, N. J., were taken at the Million Dollar pier during the years 1912 to 1920, and at the Steel pier from 1923 to the present time. The results from both series have been referred to a common datum through spirit-levelling connections. At Key West, Fla., the sea-level values for the years 1913 to 1925 inclusive, are from a gauge located at Curry's wharf, and the values for the subsequent years from a gauge at the naval base, all heights being referred to the tide staff at the latter place. For Galveston, Tex., the results are based upon observations at Fort Point from January 1, 1903, to June 30, 1908, and upon observations at the foot of Twentieth Street in Galveston Harbor from July 1, 1908, to end of series.

Sea level is derived by averaging the hourly heights of the tide. It is to be distinguished from half-tide level which is obtained from high- and low-water heights. The difference between the two planes is generally small. At Fort Hamilton, the tabular sea-level values for the years 1921 to 1932 were inferred from the half-tide level values by applying the average difference of 0.04 foot to the latter.

An examination of the yearly sea-level elevations shows irregular fluctuations from year to year which at times may amount to several tenths of a foot. Obviously, the meteorological effects are not entirely averaged out even by taking an entire year of observations. Table 3 has been prepared in which sea-level elevations for a number of the longer series are determined from 10-year periods. Even with this length, outstanding irregularities will be found in the tabular means.

It is an interesting question as to whether the average sea level for the entire world varies from year to year. In order to determine this, tide stations should be distributed more or less uniformly over all of the oceans. While the present compilation is inadequate for a study of the sea level as a whole, when taken in connection with similar data which may have been secured by other countries, it offers an opportunity for a more thorough study of the subject.

TABLE 1.—Variations in yearly sea level, Atlantic coast

Year	Port-land, Maine	Boston, Mass.	Fort Hamilton, N. Y.	White-hall Street, New York City	Atlantic City, N. J.	Balti-more, Md.	Charles-ton, S. C.	Fernan-dina, Fla.	Key West, Fla.	Cedar Keys, Fla.	Pensa-cola, Fla.	Galves-ton, Tex.	Cristo-bal, C. Z.
	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
1893			4.94										
1894			4.98										
1895			4.91										
1896			4.99										
1897			5.06										
1898			5.08					6.11					
1899			5.07					6.26					
1900			4.93					6.04					
1901			5.16					6.14					
1902			5.20					6.15					
1903			5.13			4.16		6.34					
1904			4.98			3.96		6.24				3.34	
1905			4.94			4.02		6.20				3.37	
1906			5.05			4.05		6.28				3.38	
1907			5.00			4.02		6.02				3.43	
1908			4.97			4.06		6.22				3.30	
1909			5.10			4.08		6.18				3.48	0.23
1910			5.16			4.15		5.98				3.22	.18
1911			5.11			4.10		6.05				3.35	.16
1912	3.08		4.93		6.01	4.00		6.10				3.51	.17
1913	3.03		4.98		6.08	4.03		6.10	4.94			3.63	.20
1914	3.09		5.11		6.20	4.06		6.16	4.90			3.57	.25
1915	3.17		5.16		6.26	4.17		6.16	4.90	4.77		3.45	.34
1916	3.13		5.12		6.17	4.13		5.99	4.94	4.75		3.50	.30
1917	3.14		5.15		6.18	4.11		5.92	5.00	4.74		3.25	.09
1918	3.14		5.13		6.23	4.21		6.03	4.91	4.79		3.33	.20
1919	3.23		5.30		6.37	4.30		6.33	4.91	4.64		3.70	.26
1920	3.19		5.23		6.31	4.17		6.09	4.83	4.74		3.59	.25
1921	3.14		5.24		6.31	4.25		6.28	4.97	4.85		3.92	.35
1922	3.02	8.09	5.14		6.33	4.15	4.93	6.11	4.93	4.83		3.72	.28
1923	3.07	8.08	5.15		6.19	4.17	4.91	6.08	4.86	4.84		3.78	.14
1924	3.08	8.10	5.10		6.22	4.21	4.98		4.87	4.66	8.40	3.50	.08
1925	3.00	8.03	5.05		6.13	4.08	5.05		4.89	4.80	8.48	3.48	.12
1926	2.98	8.06	5.03		6.17	4.10	4.83		4.83		8.53	3.50	.24
1927	3.10	8.17	5.18		6.33	4.21	4.90		4.95		8.57	3.77	.26
1928	3.02	8.07	5.04	5.05	6.16	4.10	4.92		4.88		8.52	3.88	.18
1929	3.00	8.09	5.00	5.10	6.18	4.12	4.94		4.93		8.80	3.99	.21
1930	2.98	8.09	5.06	5.06	6.20	4.08	4.90		4.96		8.49	3.69	.24
1931	3.09	8.24	5.30	5.21	6.38	4.18	4.81		4.82		8.42	3.49	.22
1932	3.12	8.22	5.30	5.20	6.37	4.21	4.98		4.97		8.64	3.73	.13
1933	3.19	8.30		5.30	6.49	4.33	5.12		6.08		8.77	3.91	.08
1934	3.04	8.12		5.15	6.30	4.21	4.91		4.93		8.51	3.63	.09
1935	3.15	8.25		5.29	6.44	4.27	5.10		5.03		8.58	3.79	

TABLE 2.—Variations in yearly sea level, Pacific coast

Year	Balboa, C. Z.	San Diego, Calif.	La Jolla, Calif.	Los An- geles, Calif.	San Fran- cisco, Calif.	Seattle, Wash.	Ketchi- kan, Alaska	Seward, Alaska	Hono- lulu, Hawaii
	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
1898					8.30				
1899					8.44	3.94			
1900					8.50	4.10			
1901					8.46	3.88			
1902					8.57	4.06			
1903					8.53	3.99			
1904					8.63	4.10			
1905					8.66	4.08			4.14
1906					8.58	4.11			4.27
1907					8.66	4.17			4.29
1908					8.43	4.03			4.23
1909					8.53	4.12			3.95
1910	0.69	6.40			8.42	3.98			4.10
1911	.85	6.63			8.61	3.96			4.04
1912	.60	6.50			8.49	3.96			4.14
1913	.75	6.52			8.51	3.96			4.23
1914	.77	6.66			8.81	4.16			4.41
1915	.79	6.63			8.69	4.23			4.51
1916	.68	6.42			8.52	4.08			4.35
1917	.56	6.44			8.48	3.88			4.29
1918	.82	6.69			8.70	4.18			4.14
1919	.65	6.55			8.61	4.08	4.31		4.40
1920	.74	6.56			8.54	3.99	4.25		4.64
1921	.79	6.52			8.58	4.02	4.29		4.40
1922	.79	6.52			8.55	3.94	4.12		4.36
1923	.77	6.64			8.52	4.00	4.26		4.32
1924	.65	6.50		6.36	8.42	3.90	4.21		4.25
1925	.83	6.62	6.61	6.46	8.62	4.10	4.28		4.41
1926	.58		6.72	6.46	8.63	4.11	4.41	8.30	4.36
1927	.77		6.61	6.40	8.60	4.14	4.26	8.01	4.26
1928	.80		6.67	6.42	8.58	4.08	4.26	8.14	4.20
1929	.81		6.71	6.47	8.55	3.89	4.08	7.95	4.25
1930	.87		6.73	6.60	8.72	4.08	4.24	8.00	4.36
1931	.72		6.74	6.53	8.62	4.10	4.45	8.31	4.40
1932	.87		6.67	6.45	8.68	4.12	4.37	8.10	4.39
1933	.74		6.51	6.27	8.52	4.13	4.32	7.94	4.34
1934	.75		6.60	6.42	8.63	4.17	4.39	8.20	4.23
1935			6.60	6.40	8.72	4.13	4.27	7.94	4.41

TABLE 3.—Sea level for 10-year periods

Period of observations	Portland, Maine	New York Harbor (Fort Hamilton and White- hall Street)	Balti- more, Md.	Key West, Fla.	Galves- ton, Tex.	Cristobal, C. Z.	Balboa, C. Z.	San Fran- cisco, Calif.	Seattle, Wash.	Hono- lulu, Hawaii
	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
1893-1902		5.03								
1894-1903		5.05								
1895-1904		5.05								
1896-1905		5.05								
1897-1906		5.06								
1898-1907		5.05						8.53		
1899-1908		5.04						8.54	4.05	
1900-9		5.05						8.55	4.07	
1901-10		5.07						8.55	4.06	
1902-11		5.06						8.56	4.06	
1903-12		5.04	4.06					8.55	4.06	
1904-13		5.02	4.05					8.55	4.05	
1905-14		5.04	4.06					8.57	4.06	4.18
1906-15		5.06	4.07					8.57	4.07	4.22
1907-16		5.06	4.08					8.57	4.07	4.22
1908-17		5.08	4.09					8.55	4.04	4.22
1909-18		5.10	4.10		3.43	0.20	0.71	8.58	4.05	4.22
1910-19		5.12	4.13		3.45	.20	.71	8.58	4.05	4.26
1911-20		5.12	4.13		3.49	.21	.72	8.60	4.05	4.32
1912-21	3.13	5.14	4.14		3.54	.23	.71	8.59	4.05	4.36
1913-22	3.13	5.16	4.16	4.92	3.57	.24	.73	8.60	4.05	4.38
1914-23	3.13	5.17	4.17	4.92	3.58	.23	.74	8.60	4.06	4.39
1915-24	3.13	5.17	4.19	4.91	3.57	.22	.72	8.56	4.03	4.38
1916-25	3.11	5.16	4.18	4.91	3.58	.20	.73	8.55	4.02	4.36
1917-26	3.10	5.15	4.18	4.90	3.58	.20	.72	8.56	4.02	4.37
1918-27	3.10	5.16	4.18	4.90	3.63	.22	.74	8.58	4.05	4.36
1919-28	3.08	5.15	4.17	4.89	3.65	.22	.74	8.56	4.04	4.37
1920-29	3.06	5.13	4.16	4.89	3.68	.21	.75	8.56	4.02	4.35
1921-30	3.04	5.11	4.15	4.91	3.69	.21	.77	8.58	4.03	4.33
1922-31	3.03	5.11	4.14	4.89	3.65	.20	.76	8.58	4.03	4.32
1923-32	3.04	5.11	4.15	4.90	3.65	.18	.77	8.59	4.05	4.33
1924-33	3.03	5.13	4.16	4.92	3.68	.18	.76	8.59	4.06	4.33
1925-34	3.05	5.13	4.16	4.92	3.68	.18	.78	8.62	4.09	4.33
1926-35	3.07	5.16	4.18	4.94	3.71			8.62	4.10	4.32