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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Survey

Trends and Variability of Yearly Mean Sea Level 1893-1971

KVILLE, MD.
March 1973

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TRENDS AND VARIABILITY OF YEARLY MEAN SEA LEVEL 1893-1971

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March 1973

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.1	Sea level data
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"1893-1971"	1893-1971

TRENDS AND VARIABILITY OF YEARLY MEAN SEA LEVEL, 1893-1971

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ABSTRACT. Sea-level trends, their standard errors, and variability are presented in tabular form for 43 locations along the coasts of the United States. The values are given for the entire series length at each station, the oldest dating from 1893 at New York. For intrastation comparisons, values also are given for the longest length of series common to all stations, 1940-71. Graphs of yearly mean sea level, upon which the calculations were performed, are plotted for each station.

1. INTRODUCTION

This Technical Memorandum is directed to the needs of the coastal zone manager, coastal engineer, physical and geological oceanographer, geologist, tectonophysicist, climatologist, and conservationist. Since the uses of the calculations may vary greatly, no interpretive text is included. It is anticipated that this publication will be issued annually; each issue will incorporate the new yearly mean sea level values in each tabulated calculation and graph.

2. EXPLANATION OF TRENDS AND VARIABILITY

Yearly mean sea level is the arithmetic mean of hourly sea level heights obtained from an analog tide gage over a period of one calendar year. The tide gage, often located on a pier,

continuously measures sea-level heights relative to the land adjacent to the station location. The gage is connected to bench marks on the adjacent land by precise first-order leveling. If possible, the bench marks are located in bedrock.

One table and nine illustrations show the trends and variability of yearly mean sea level at permanent continuous tide stations operated by the National Ocean Survey (NOS). Column 1 of the table lists all of the NOS-operated stations that were in operation by 1939 and that had very few and short breaks in their series. The inclusive dates of each station series are given in column 2. Where the length of a break in the series is sufficient to invalidate a yearly mean, the missing year is shown in column 3.

If a series of yearly mean sea level values is plotted on a graph of height against date, an apparent secular trend and yearly variability become evident. "Secular" means nonperiodic; "apparent" means it is not known whether the trend is nonperiodic or is merely a segment of a very long oscillation. Apparent secular trends in sea level result from glacial-eustatic, tectonic, and climatological and oceanographic apparent secular trend effects. Columns 4 and 7 show the apparent secular trend as the slope of a straight line mathematically fitted through the yearly mean sea level values (see note *b* on table). About two-thirds of repeated calculations of the apparent secular trend will differ from the true apparent secular trend by less than the standard error of slope listed in columns 5 and 8 (see note *c* on table). About 95% of repeated calculations of the apparent secular trend will differ by less than two times the standard error of slope, and practically all repeated calculations will differ by less than three times the standard error of slope.

Yearly variability is caused by variations in the meteorological and oceanographic parameters of wind, direct atmospheric pressure, river discharge, currents, salinity, and water temperature. About two-thirds of the yearly mean sea level values will differ from the straight line slope by less than the variability given in columns 6 and 9 (see note *d* on table). About 95% of the yearly mean sea level values will differ from the line by less than two times the variability, and practically all the values will differ by less than three times the variability.

Trends and variability of yearly mean sea level through 1971[a]

(1) Location	(2) Date series began	(3) Dates of missing data	(4) Trend[b]	(5) Standard error of trend[c]	(6) Variability[d]	(7) 1940-71 Trend	(8) Standard error of trend	(9) Variability
			ft yr^{-1}	± ft yr^{-1}	± ft	ft yr^{-1}	± ft yr^{-1}	± ft
Atlantic Coast								
1. Eastport, Me.	1930	1957,58,70,71	.0104	.0010	.0711	.0111	.0016	.0771
2. Portland, Me.	1912	1970,71	.0067	.0007	.0905	.0053	.0019	.0892
3. Portsmouth, N. H.	1927	1935-39	.0078	.0009	.0721	.0057	.0013	.0688
4. Boston, Mass.	1922		.0093	.0008	.0833	.0039	.0014	.0731
5. Woods Hole, Mass.	1933	1965,67-69	.0110	.0011	.0696	.0096	.0015	.0679
6. Newport, R. I.	1931		.0096	.0009	.0694	.0074	.0013	.0666
7. New London, Conn.	1939		.0082	.0013	.0700	.0079	.0014	.0708
8. Willets Pt., N. Y.	1932		.0100	.0011	.0839	.0082	.0016	.0847
9. New York, N. Y.[e]	1893		.0093	.0004	.0888	.0096	.0014	.0708
10. Sandy Hook, N. J.	1933		.0155	.0011	.0758	.0155	.0015	.0777
11. Atlantic City, N. J.	1912	1921,22,70,71	.0125	.0007	.0901	.0094	.0017	.0829
12. Baltimore, Md.	1903		.0109	.0005	.0841	.0088	.0015	.0804
13. Annapolis, Md.	1929	1969,70	.0135	.0010	.0798	.0105	.0015	.0747
14. Washington, D. C.	1932		.0096	.0013	.0985	.0089	.0019	.0995
15. Solomons, Md.	1938	1970	.0118	.0014	.0775	.0115	.0016	.0798
16. Hampton Roads, Va.	1928		.0146	.0011	.0950	.0112	.0017	.0880
17. Portsmouth, Va.	1936		.0117	.0013	.0831	.0117	.0017	.0866
18. Charleston, S. C.	1922		.0116	.0011	.1150	.0063	.0022	.1156
19. Fort Pulaski, Ga.	1936		.0079	.0017	.1040	.0067	.0020	.1058
20. Fernandina, Fla.	1939		.0049	.0020	.1078	.0042	.0021	.1071
21. Mayport, Fla.	1929		.0084	.0013	.1069	.0051	.0020	.1058
22. Miami Beach, Fla.	1932	1951, 53, 54	.0080	.0010	.0740	.0061	.0014	.0746
Gulf Coast								
23. Key West, Fla.	1913		.0068	.0006	.0845	.0025	.0016	.0830
24. Cedar Key, Fla.	1915	1926-38	.0066	.0008	.0962	.0024	.0019	.0978
25. Pensacola, Fla.	1924		.0075	.0012	.1184	.0017	.0021	.1076
26. Eugene I., La.	1940	1967,71	.0302	.0024	.1194	.0302	.0024	.1194
27. Galveston, Tex.	1909		.0188	.0011	.1539	.0133	.0027	.1411
West Coast								
28. San Diego, Calif.	1906		.0064	.0005	.0817	.0043	.0017	.0901
29. La Jolla, Calif.	1925	1954,55	.0060	.0009	.0874	.0056	.0018	.0962
30. Los Angeles, Calif.	1924		.0020	.0009	.0883	-.0017	.0016	.0860
31. Alameda, Calif.	1940		.0014	.0023	.1203	.0014	.0023	.1203
32. San Francisco, Calif.	1898		.0064	.0006	.1030	.0054	.0022	.1140
33. Crescent City, Calif.	1933		-.0020	.0014	.1012	-.0052	.0019	.0982
34. Astoria, Oreg.	1925		-.0003	.0014	.1328	-.0025	.0024	.1271
35. Seattle, Wash.	1899		.0062	.0006	.0997	.0081	.0018	.0948

Trends and variability of yearly mean sea level through 1971[a] (continued)

(1) Location	(2) Date series began	(3) Dates of missing data	(4) Trend[b]	(5) Standard error of trend[c]	(6) Variability[d]	(7) Trend	(8) Standard error of trend	(9) Variability
			ft yr^{-1}	± ft yr^{-1}	± ft	ft yr^{-1}	± ft yr^{-1}	± ft
36. Neah Bay, Wash.	1935	1959	-.0029	.0016	.1006	-.0047	.0020	.1021
37. Friday Harbor, Wash.	1934	1970	.0034	.0015	.0997	.0020	.0019	.1018
38. Ketchikan, Alaska	1919		.0002	.0011	.1181	-.0000	.0026	.1371
39. Sitka, Alaska	1938		-.0073	.0017	.0970	-.0073	.0019	.1001
40. Juneau, Alaska	1936		-.0440	.0019	.1206	-.0442	.0024	.1271
41. Yakutat, Alaska	1940		-.0171	.0022	.1143	-.0171	.0022	.1143
42. Honolulu, Hawaii	1905		.0053	.0007	.1173	.0004	.0019	.0988
43. Cristobal, C. Z.	1909		.0037	.0005	.0677	.0008	.0010	.0506

[a] Columns 4 - 6: entire series. Columns 7 - 9: 1940-71.

[b] Slope of a least-squares line of regression:

$$b = \frac{\Sigma xy - \frac{(\Sigma x)(\Sigma y)}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}$$

Where y = height of yearly mean sea level,
x = date, and
n = number of yearly mean sea-level values.

[c] Standard Error of Slope:

$$s_b = \frac{s_{y.x}}{\sqrt{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}}$$

Where $s_{y.x}$ = Standard Error of Estimate.

[d] Standard Error of Estimate (standard deviation from line of regression):

$$s_{y.x} = \sqrt{\frac{\Sigma y^2 - \frac{(\Sigma y)^2}{n} - b\left(\Sigma xy - \frac{(\Sigma x)(\Sigma y)}{n}\right)}{n - 2}}$$

[e] 1893-1920, Ft. Hamilton; 1921-71, The Battery.

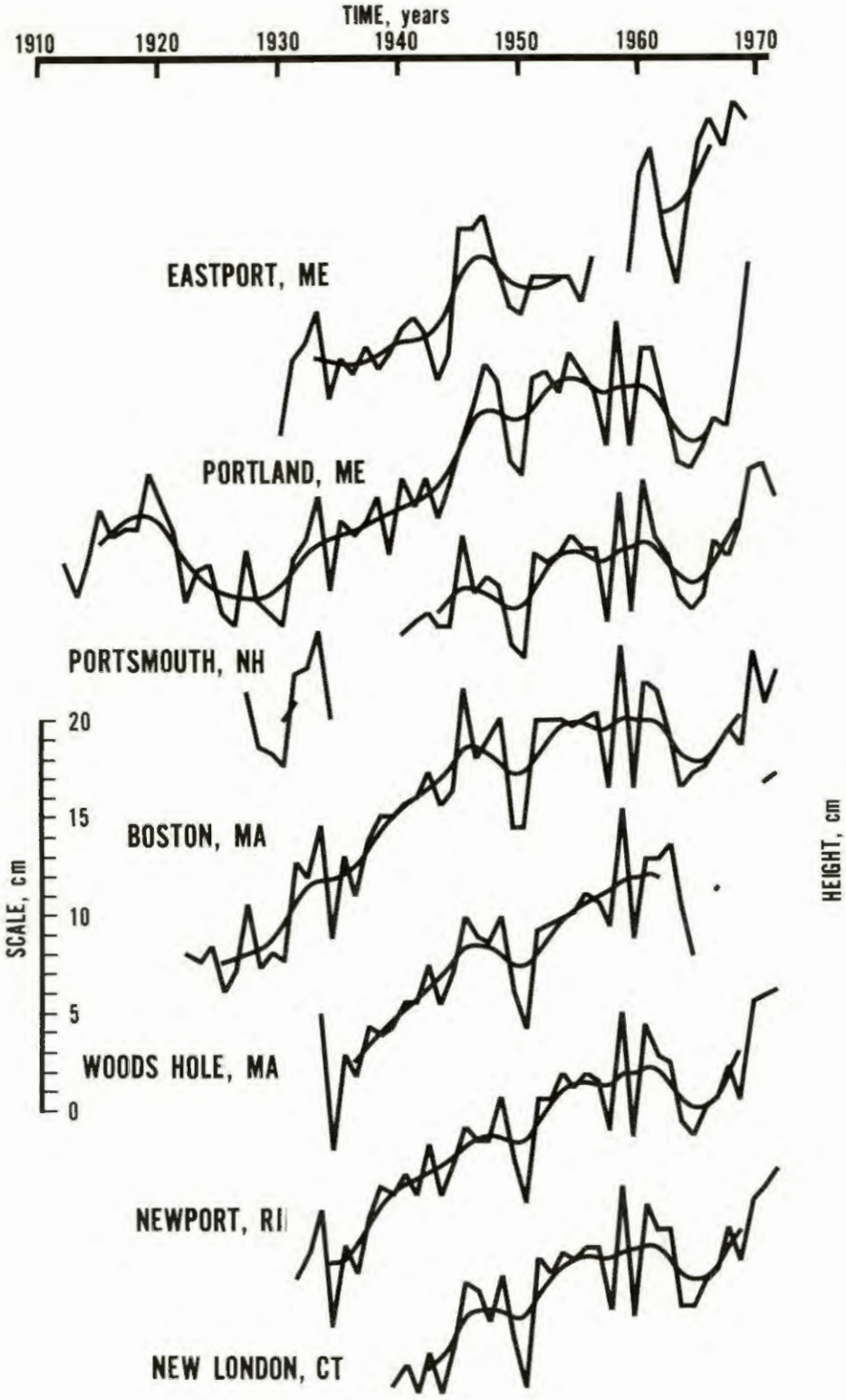

Figure 1.--Change in sea level with respect to adjacent land for stations from Maine to Connecticut. Straight-line segments connect yearly mean sea level values. Curved lines connect yearly values smoothed by weighting array.

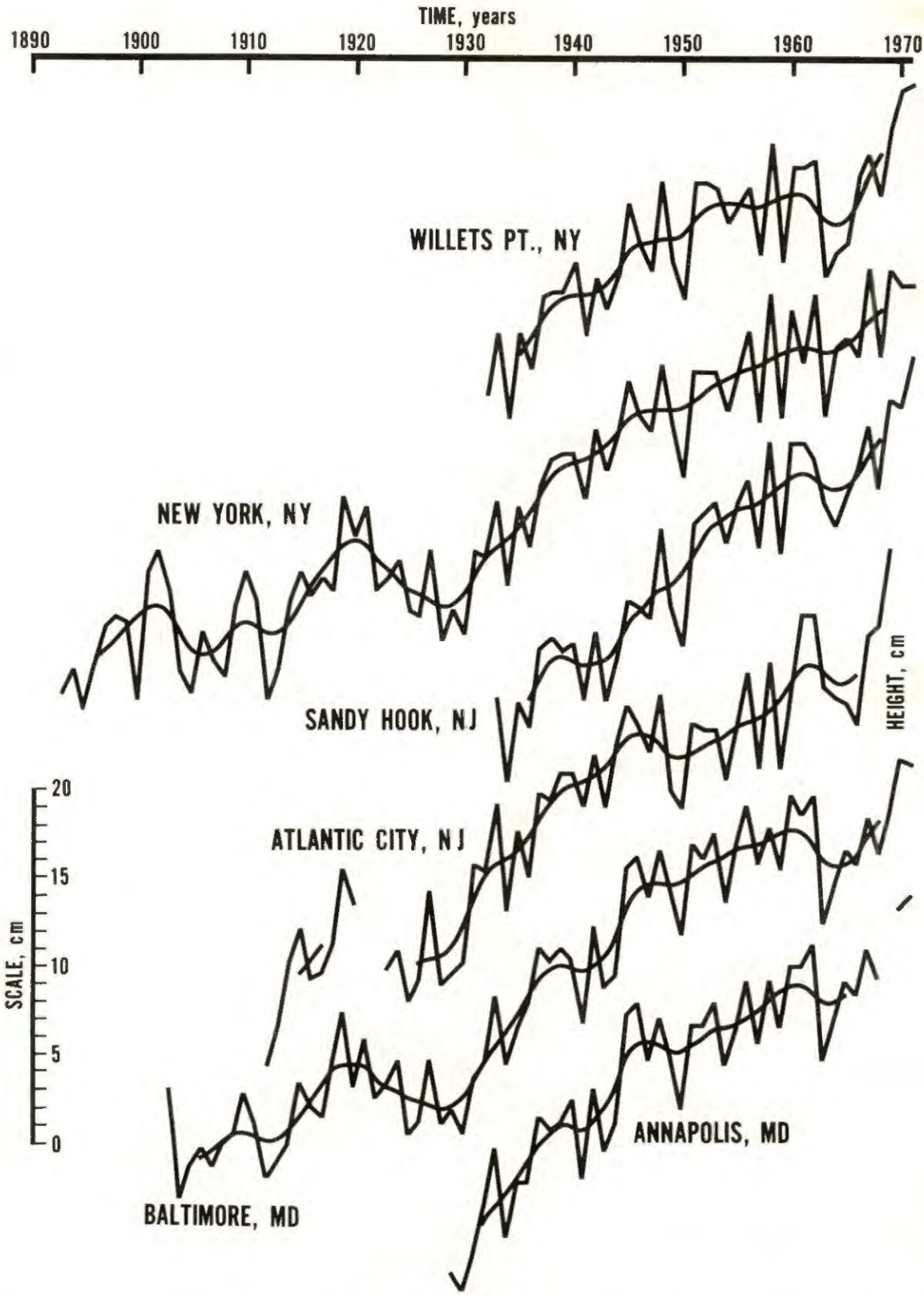

Figure 2.--Change in sea level with respect to adjacent land for stations from New York to Maryland.

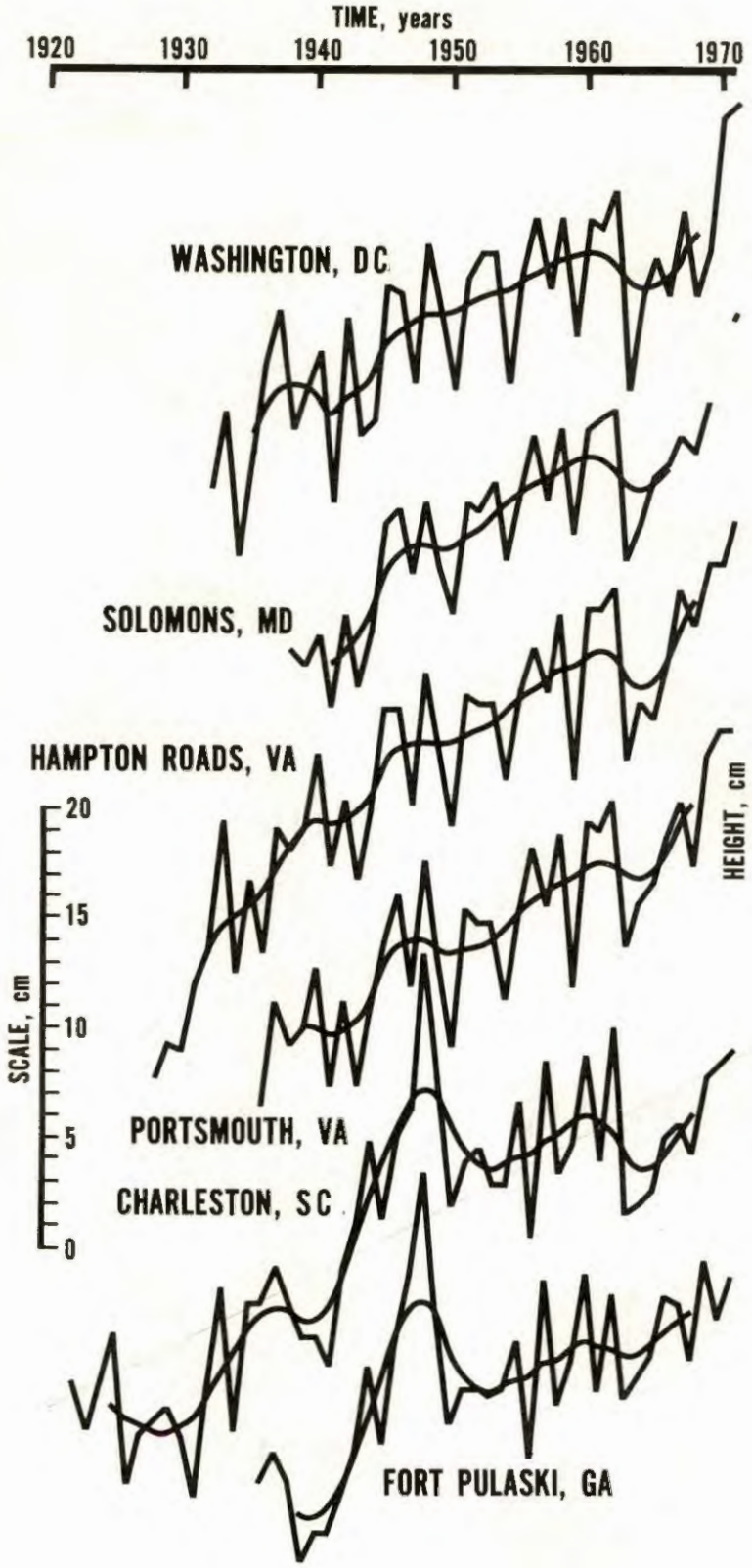

Figure 3.--Change in sea level with respect to adjacent land for stations from the District of Columbia to Georgia.

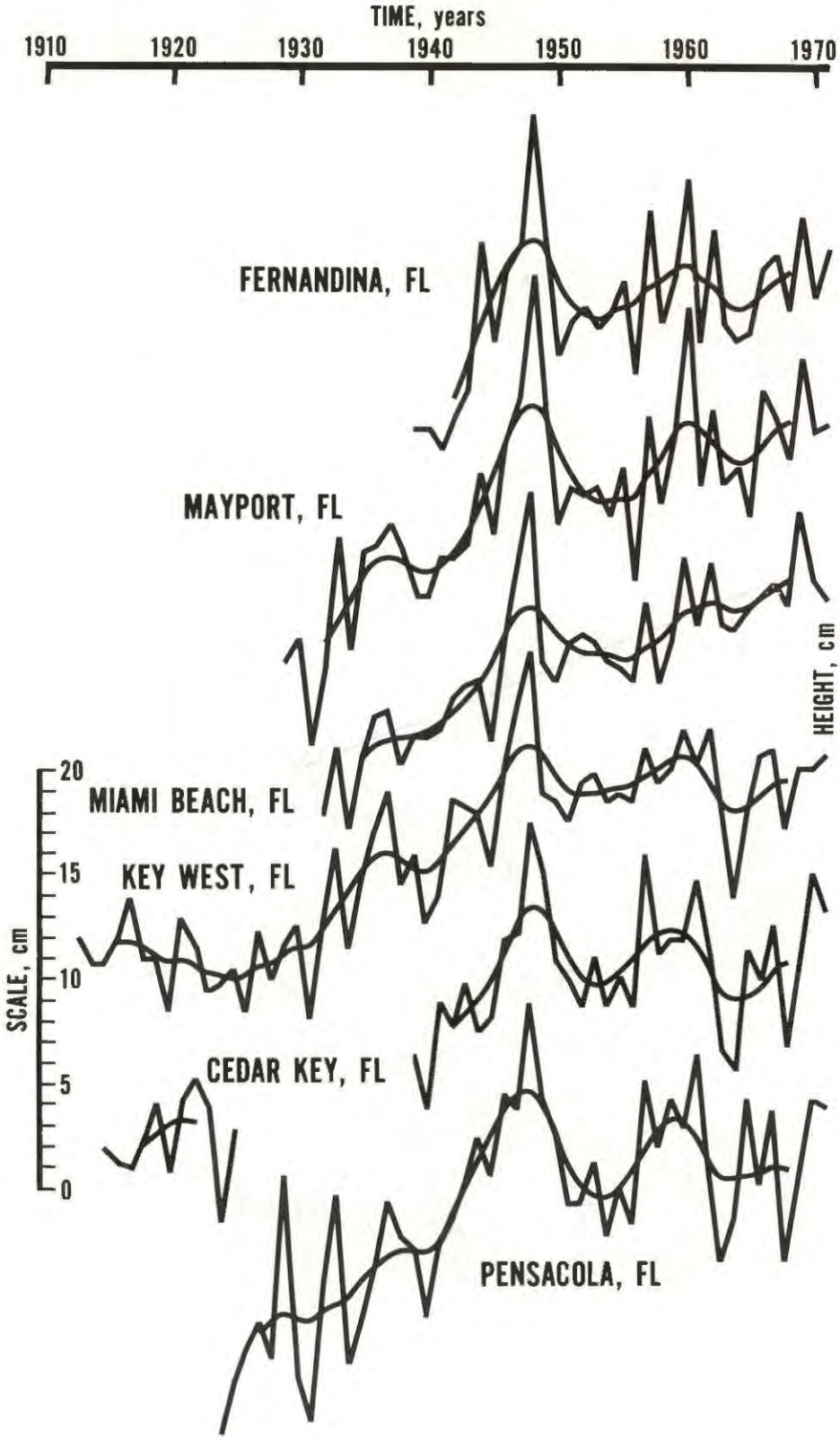

Figure 4.--Change in sea level with respect to adjacent land for stations in Florida.

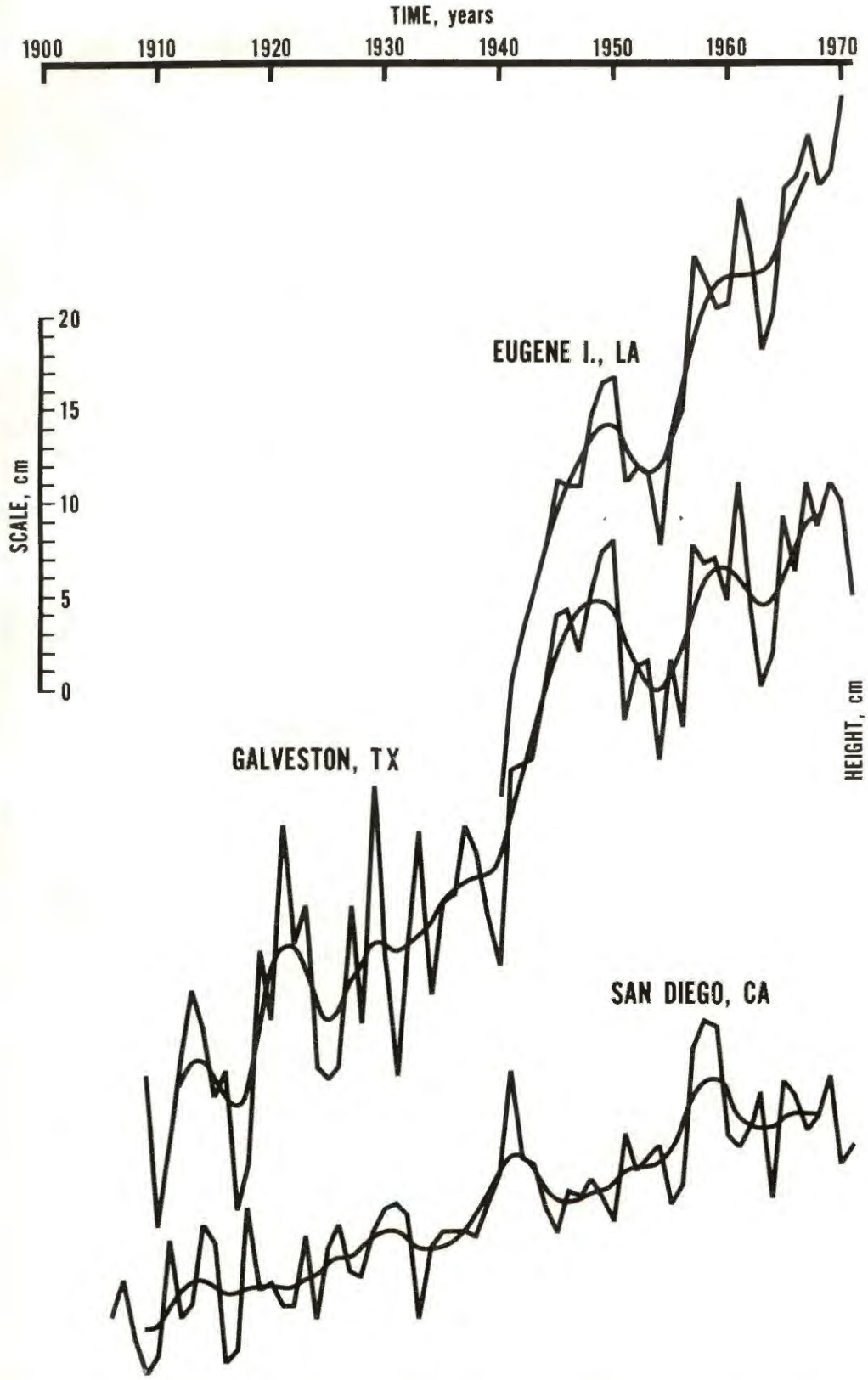

Figure 5.--Change in sea level with respect to adjacent land for stations from Louisiana to California.

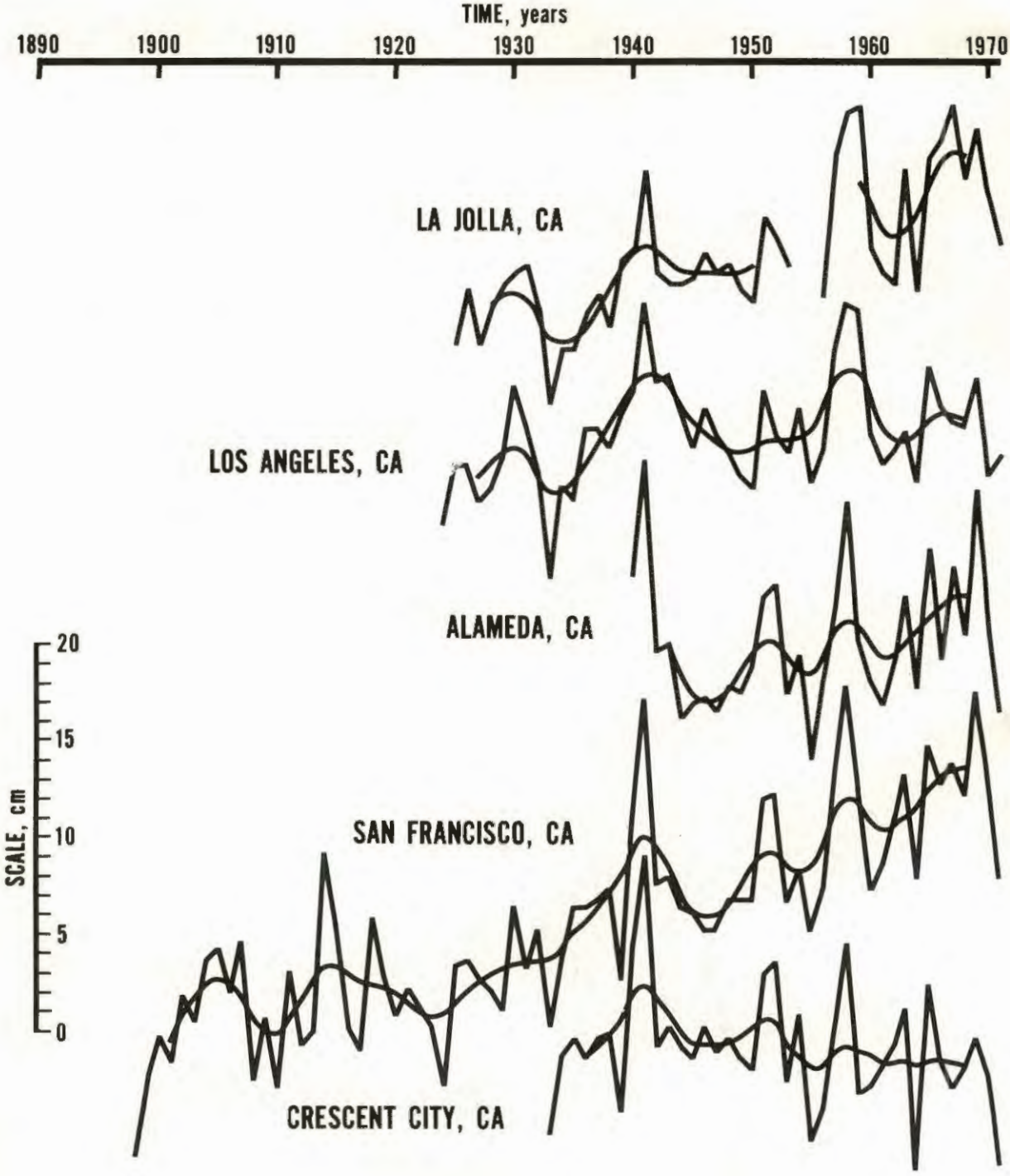

Figure 6.--Change in sea level with respect to adjacent land for stations in California.

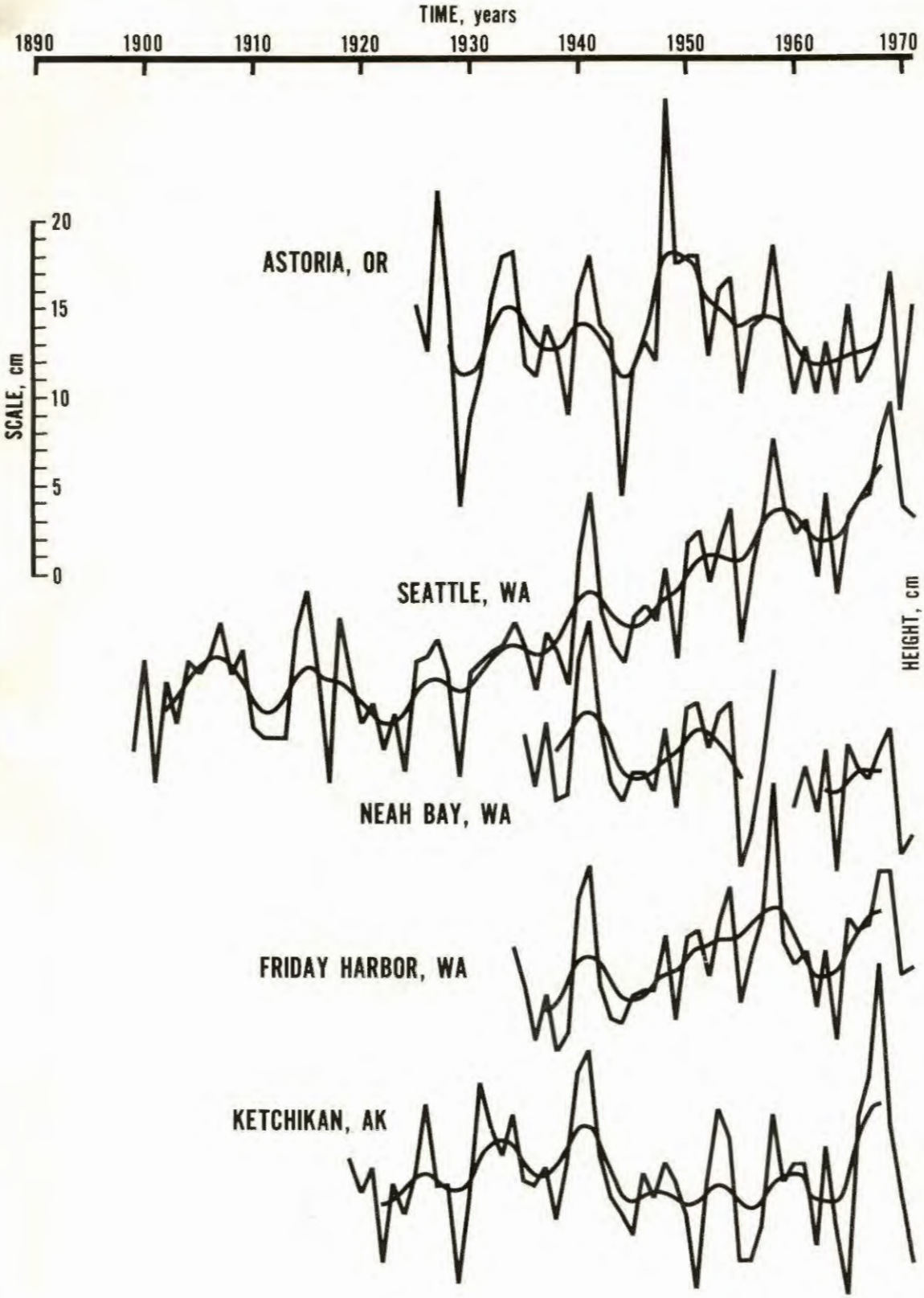

Figure 7.--Change in sea level with respect to adjacent land for stations from Oregon to Alaska.

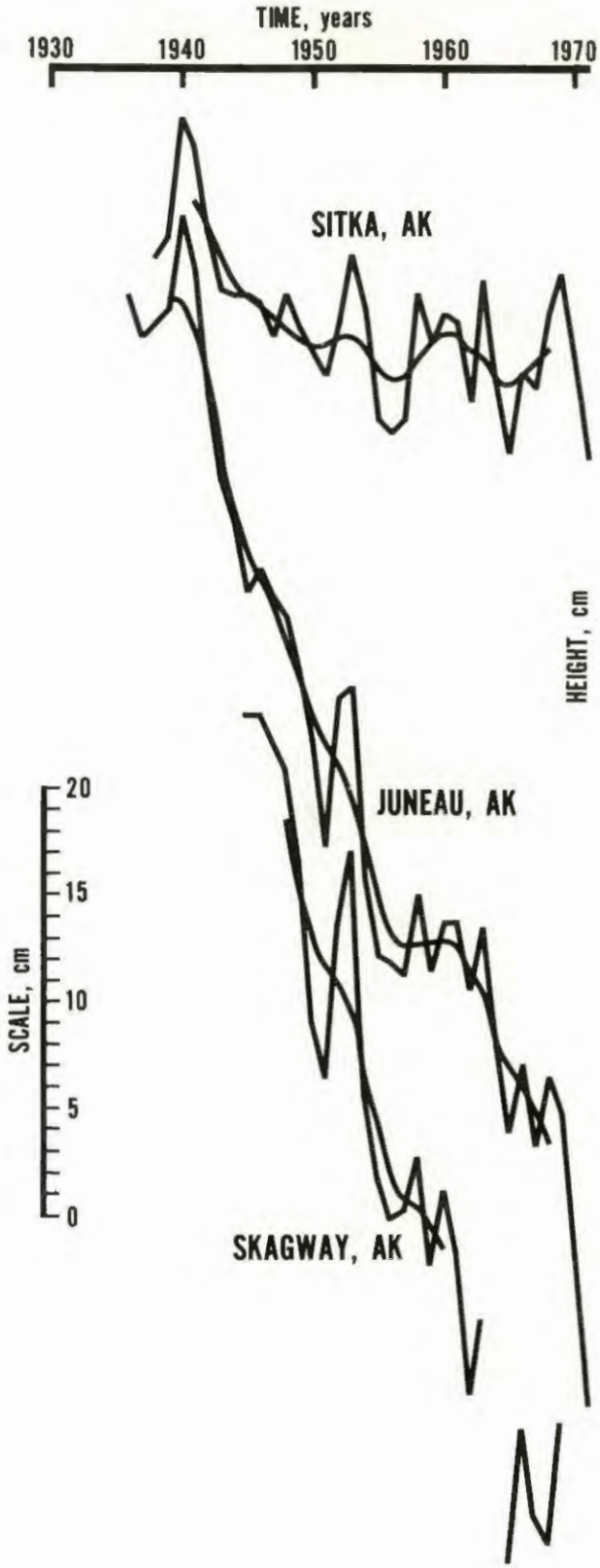

Figure 8.--Change in sea level with respect to adjacent land for stations in Alaska.

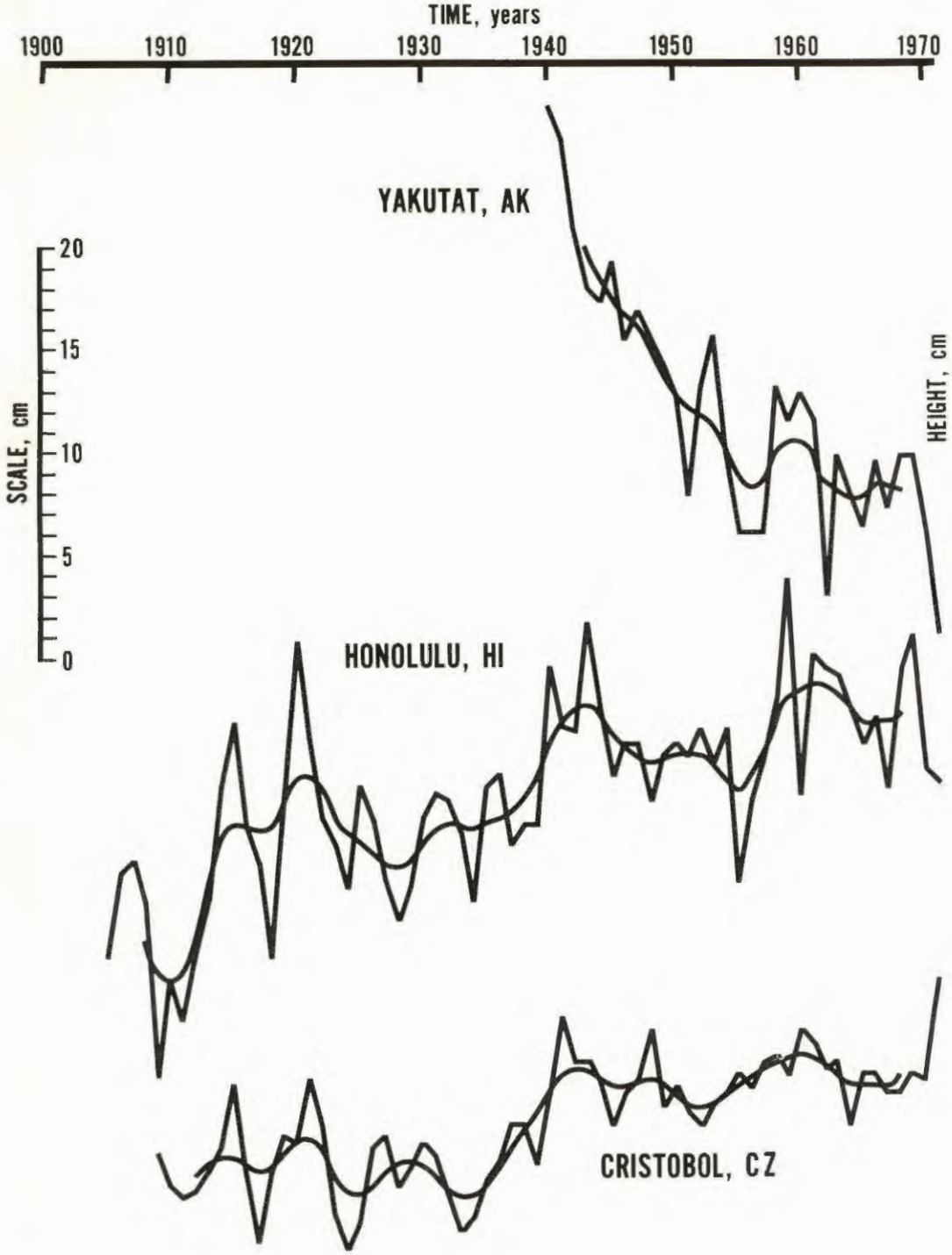

Figure 9.--Change in sea level with respect to adjacent land for Yakutat, Ak., Honolulu, Hi., and Cristobal, C.Z.