The Climatic Amelioration in Southern California: 1955 to 1960

ROBERT E. STEVENSON[1]

Allan Hancock Foundation, University of Southern California

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ABSTRACT

Climatic variations influential in modifying the Southern California sea are considered in relation to the strong warming trend observed from 1956 to 1959 both for surface-water temperatures and for air temperatures at coastal stations. Although the rise in air temperatures might commonly be attributed to warmer water, it is concluded in this case that the higher temperatures in both media resulted from the same changes in general circulation pattern.

1. Introduction

Distinct climatic types with small areal extents can be recognized along the coast and over the offshore waters of southern California. All are associated with warm and cold water at or near the coast (Fig. 1). Cold water along the coast is mainly the result of local upwelling, although in particular locations unequal tidal stirring is important (Leipper, 1955; Stevenson and Gorsline, 1956). Warm water is mainly concentrated where wind-driven surface water is trapped in an em-

[1] Now at the Texas A. and M. Marine Laboratory, Fort Crockett, Galveston, Tex.

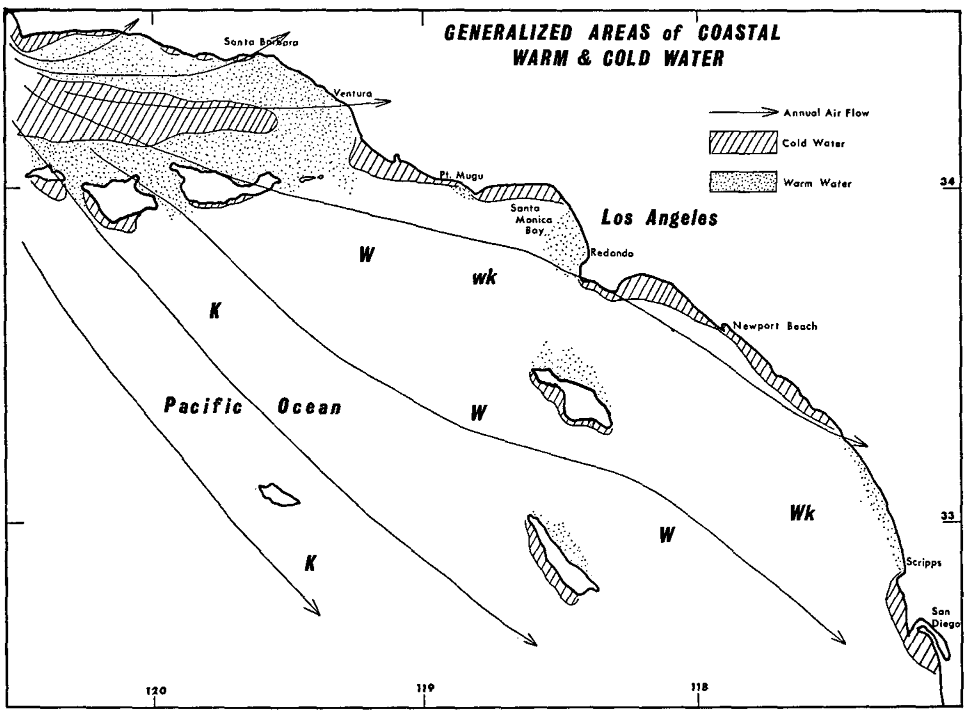

FIG. 1. Annual air-flow streamlines and relative areas of warm and cold water of the southern California Sea. The large letters "K" and "W" indicate general cold and warm surface waters. The smaller letters represent the relative effectiveness of the corresponding water temperatures. Cooler water in the Santa Barbara Channel is the result of the wind-driven surface divergence. Other Coastal cold water is from upwelling.

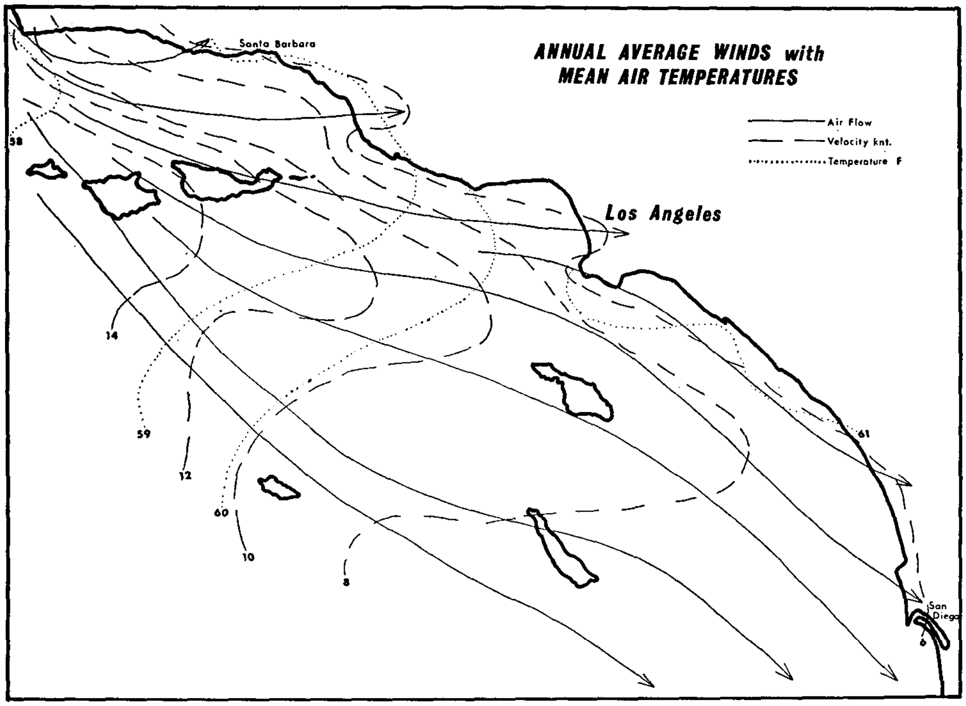

FIG. 2. Annual streamlines, wind velocity and mean air temperatures (deg F) over the sea off southern California. The divergence in the air flow over the Santa Barbara Channel can be readily noted.

bayment, as in Santa Monica Bay. This effect, plus the introduction of water heated in the south, combines to produce the warm area off the Ventura Coast.

In the Santa Barbara Channel, the diverging air flow (Fig. 2) develops a wind drift which results in a surface-water divergence in the center of the channel. Along the mainland coast, warm water is driven into the Ventura Embayment, but offshore it moves seaward and against the channel islands. A typical water distribution is shown in Fig. 3. The vertical distribution of water temperatures indicated that the cooler water (54F) rose from depths near 100 ft.

All of the various warm- and cool-water surfaces significantly influence the temperature and moisture characteristics of the marine air layer (Leavastu, 1960; Stevenson, 1961). As a consequence, parts of the southern California coast have greater frequencies of fog and low clouds (Point Mugu) than other sections (Ventura and Redondo) under the same initial air mass conditions.

It is not the purpose of this paper to describe the meso-climates of southern California in further detail. More complete data may be found in reports by Stevenson (1958, 1960) and from U. S. Weather Bureau summaries. The significance of the brief outline presented here is to aid the reader in understanding climatic variations which are influential in modifying the southern California sea.

2. The warming period of 1956 to 1959

In 1948, air temperatures in southern California were the lowest since the mid-1930's. Los Angeles had an annual mean temperature which was 1.3F below the long-term mean (59.6 as compared with 60.9F), and San Diego experienced annual temperatures which were 1.2F below the mean.

From 1948 to 1959 the annual temperatures became increasingly warmer. The long-term means for land

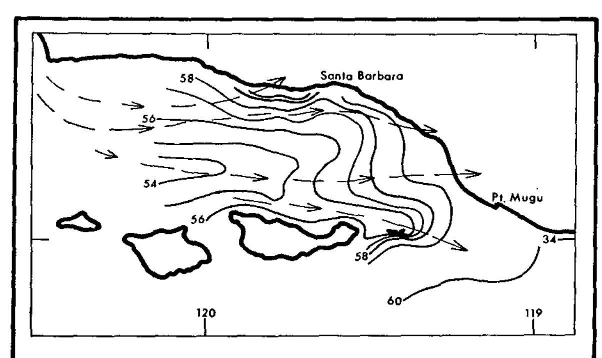

FIG. 3. Air flow and surface water temperature distribution (deg F) in the Santa Barbara Channel, 12–15 April 1961. The axis of the wind-driven divergence extends eastward from the center of the channel to the south of Point Mugu.

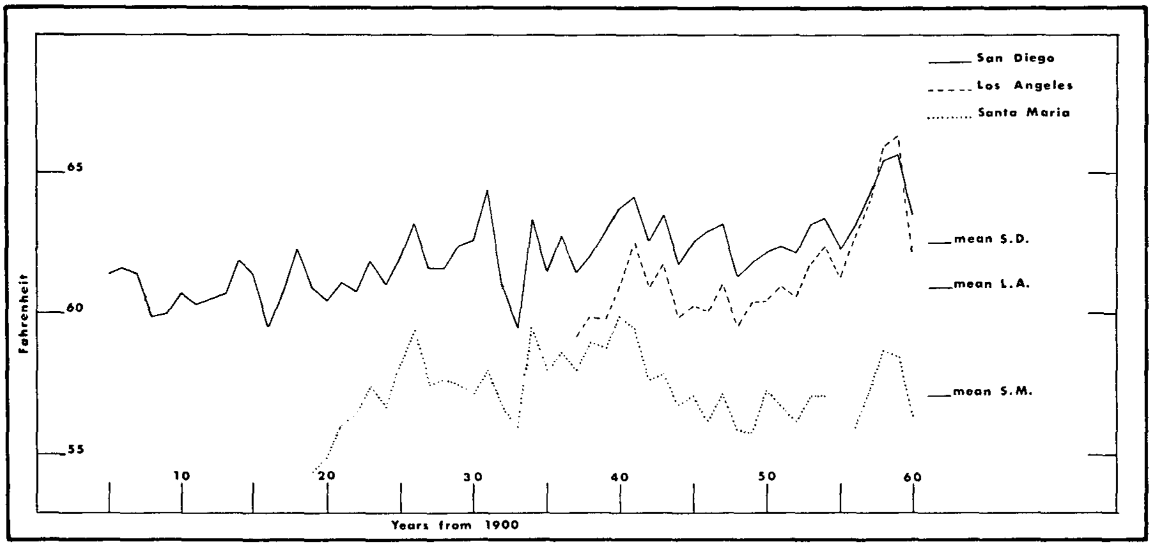

FIG. 4. Annual mean temperatures in degrees Fahrenheit at Lindbergh Field, San Diego; Los Angeles International Airport; and Santa Maria Airport.

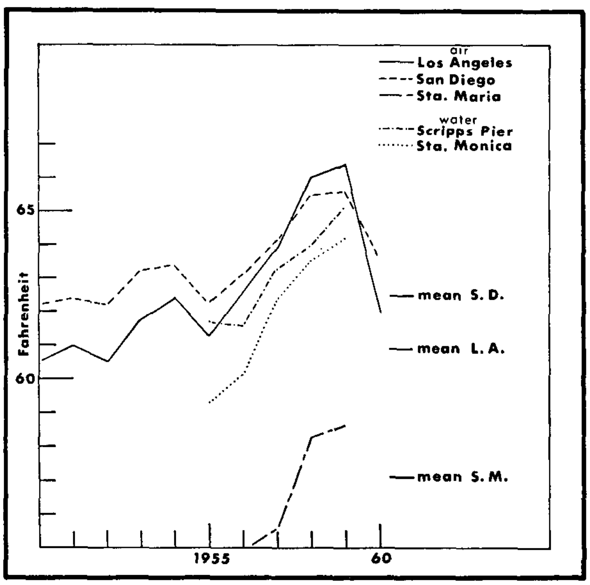

FIG. 5. Annual mean air temperature (deg F), 1950 through 1960, at Lindbergh Field, San Diego; Los Angeles International Airport; and Santa Maria Airport; and, mean annual surface water temperatures at the piers of the Scripps Institution of Oceanography and the City of Santa Monica.

stations were surpassed in 1953, followed by a deterioration in 1955. However, from the latter year, the annual temperatures rose rapidly to a maximum in 1959 (Fig. 4). This period was the warmest ever recorded in southern California. In 1959 the positive anomaly at the Los Angeles International Airport was 5.5F (66.4F) for the year, and in San Diego, the anomaly was 3.1F. The highest previously recorded annual means in San Diego were 64.4 deg (1931) and 65.5F (1958). In Los Angeles an annual mean of 62.5F was experienced in 1941 and this was not exceeded until the 1956–1959 period (Fig. 5).

The rate of temperature increase was greatest from 1955 through 1958 (1.4F per year at Los Angeles and 1.1F per year at San Diego). Following 1959, the annual temperatures dropped rapidly in 1960 (4.5 deg at Los Angeles and 2.0 deg in San Diego). The latter trend continued in 1961, when temperatures from March through June were several degrees lower than those in the same months in 1960.

The air temperature increase in the latter 1950's was accompanied by similar increases in the water temperatures along the coast (Fig. 5). Using the annual means of the temperature of surface water at Santa Monica and Scripps piers as comparisons, the water temperatures increased at Santa Monica by 4.9F (5.1F in the air at the Los Angeles International Airport) and at Scripps Institution of Oceanography by 3.4F (3.3F in the air at San Diego). The compatibility of air and water temperatures is not necessarily surprising, for all stations where the flow of air is from the sea have temperatures close to those of the sea.

In Fig. 6, the differences between the monthly means of air temperatures at Los Angeles Airport and water temperatures at the Santa Monica Pier have been plotted, for the years 1955 to 1959. The annual average difference is also shown. In only the winter months was the air temperature less than that of the adjacent sea (air temperatures over the water would show a positive difference in every month). The large positive air-sea anomaly in December of 1956 was the result of a se-

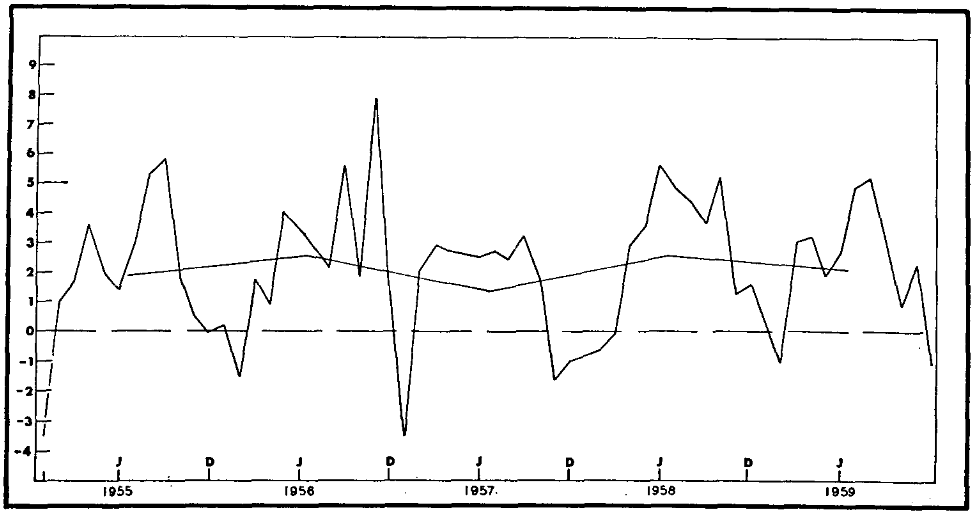

FIG. 6. Monthly difference between the mean air temperatures (deg F) at Los Angeles International Airport and the surface water temperatures at Santa Monica Pier, 1955–1959. The average annual difference is also shown.

quence of hot, dry winds from the interior. The annual average difference was positive each year with the lowest being in 1957. This was the year when the water-temperature increase was the most rapid.

The sequence of the warming period may be followed by the monthly mean anomalies from the Los Angeles International Airport (Fig. 7). In 1955 temperatures were close to or below the mean. Water temperatures along the Pacific coast were also lower than normal (Rodewald, 1957). The cool period continued through the spring of 1956 when temperatures began to increase. The last months of 1957 were cool, but such low temperatures were not experienced again until 1960. Maximum anomalies occurred in the fall of 1958 and in the spring and summer of 1959. With the rapidly decreasing anomalies in 1961, it would appear that a half cycle of warming has been completed.

3. Discussion

It is not the plan here to analyze in detail the causes of the warm years of 1957 to 1959. It should be of interest to the reader, however, to recognize that short-term modifications of the water and air climates can take place and that the causes are not unusual.

Rodewald (1958) has described the atmospheric conditions in 1955 which led to the cool water temperatures in the eastern Pacific Ocean. In that year and through the early months of 1957, the East Pacific High Pressure Center was intensified with pressures well above the mean (Fig. 8). There was a strong northerly air flow over the western part of North America and the adjacent ocean which brought cool air into the southwest. In addition, the great movement of air influenced the water motion, producing an augmented flow south along the west coast (Fig. 9).

By the middle of 1957 the pressures in the East Pacific High began to subside, decreasing the northerly component of the wind, perhaps to the extent of allowing a southerly ebb (Namais, 1960). The weakened high and somewhat deepened Aleutian Trough continued through 1958 (Fig. 10). This change in the pressure patterns was followed by a significant shift in the California Current (Fig. 11), with an indication of an increased flow from the south along the California coast (Reid, 1960; Stewart, 1960). The warmer water and air temperatures were not, however, restricted to the coast. They covered the greater part of the northeast Pacific Ocean (McGary, 1960), indicating the intensity of the system.

Tropical marine animals increased in numbers along the west coast, particularly off southern California, but biologists are reticent to say that the species traveled from the south (Balech, 1960). Rather, they concluded that the higher water temperatures supplied a more favorable environment for the increased productivity of southern species which are always present in small numbers.

By mid-1959, pressures in the East Pacific High had returned to a normal level (Fig. 12), and in 1960 the high had intensified to the 1956 level. Northern water re-entered the southern California Sea almost as a surge and by the spring of 1960 it had reached as far south as La Jolla.

An interesting side effect of the warming water was the rise in sea level along the west coast. Stewart (1960) has calculated the departures from sea level and noted that, as an example, Port Hueneme near Ventura, had a +0.5-ft anomaly in the last months of 1958. This

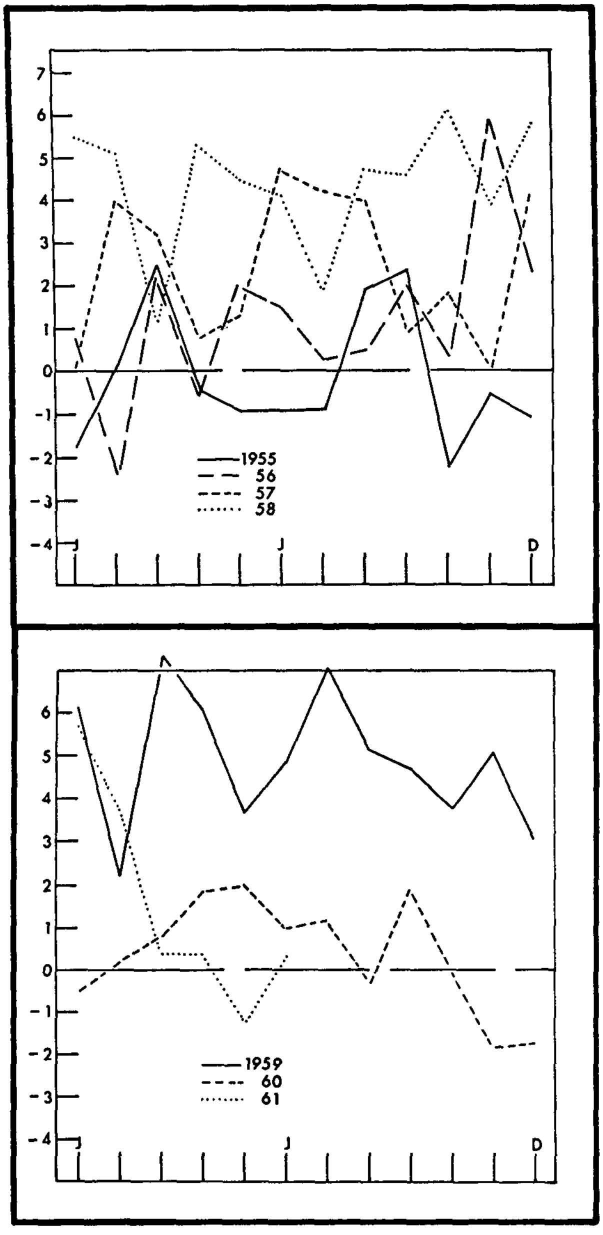

Fig. 7. Monthly anomalies of air temperature (deg F) at Los Angeles International Airport, January 1955–July 1961. The extremes of 1958 and 1959 are easily noted, as is the marked return to the mean in 1960.

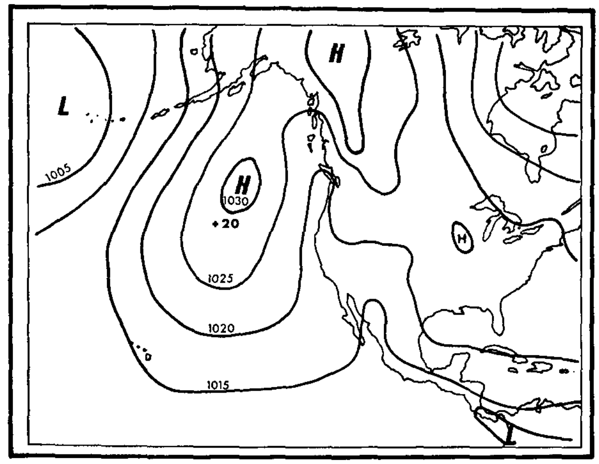

Fig. 8. Monthly mean pressure pattern and anomalies in millibars, January 1957 (from charts published by the Seewetteramt, Deutscher Wetterdienst). The Aleutian low pressure area was at the mean level, whereas the Icelandic low, the edge of which extended over Hudson Bay, had a negative anomaly of 16.

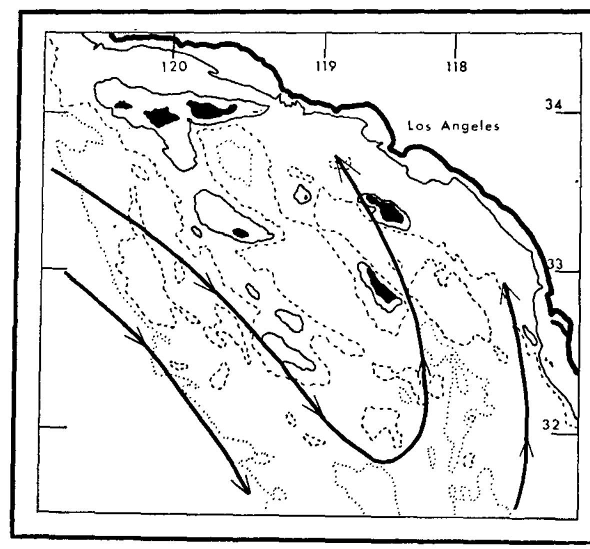

Fig. 9. Surface current flow in the waters off southern California in August 1955 (after Reid, 1960). This current pattern continued through the early months of 1957.

condition was, no doubt, the result of the lessening northerly component of the prevailing winds, as explained by Jacobs (1939). The northwest airflow, moving with the coast on the left, tends to move the surface water away from shore. Nearshore upwelling and the generally cool waters along the coast are results of this seaward surface flow. As the northwesterly winds lessened in force, the seaward wind drift also decreased causing a relative resurgence of water toward shore.

There may be a general impression that because of the comparable rise of water and air temperatures that the air temperatures were the result of the warmer water. Such an impression could be gained from contemplating the well-known influence of the sea on climatic moderation. In this case, it is more apparent that the higher temperatures in both media were the result, rather than having a cause-and-effect relationship (Namais, 1960). Both warm air and warm water moved

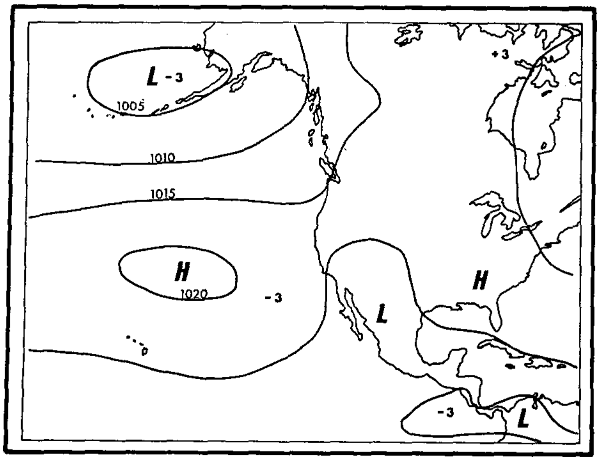

FIG. 10. Annual mean pressure pattern and anomalies in millibars, 1958 (from charts published by the Seewetteramt, Deutscher Wetterdienst).

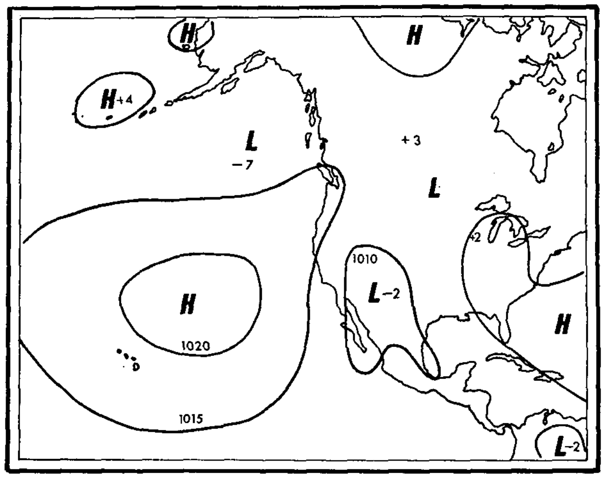

FIG. 12. Monthly mean pressure patterns and anomalies in millibars, June 1959 (from charts published by the Seewetteramt, Deutscher Wetterdienst). The East Pacific high was at the mean level at this time.

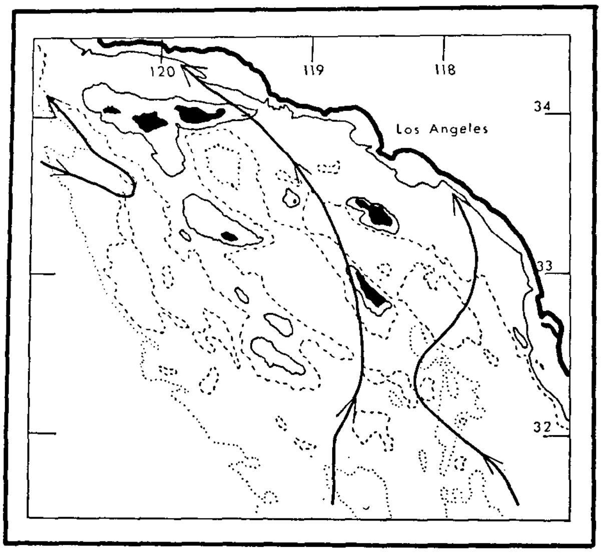

FIG. 11. Surface current flow in the waters off southern California in January 1958 (after Reid, 1960). Note the greater northerly flow near shore as compared with that in August 1955.

in from more southerly areas, or at least there was a decrease from the north in each medium.

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