6117 Radford Dr.
Seattle 15, Wash.

February 28, 1958

Mr. Grote Reber
Wailuke, Maui
Hawaii

Dear Grote:

I was very glad to hear from you again and to hear that you are back on Maui for awhile. It will be wonderful if you will be able to continue and extend your fine work on the diurnal pressure wave.

Grote, I am sorry to report that I do not have your missing barograph charts. Sometime in 1955 I had photostatic copies made of all the charts and then returned the originals to their owners. I believe that Wendell Mordy was not around at that time, and my best recollection is that Dave Johnson was the person to whom I returned your charts. As you know, PRI's Meteorology Department was in the process of closing its operations at that time, and it is possible that the charts were filed somewhere else without being put with the rest of the series. Yesterday I searched all of my material just to be sure, and I am certain that I no longer have them.

I do have good photostatic copies of your barograph charts for the period June 7 to July 5, 1954, which you are welcome to fall back on if you can't locate your originals over there. I also have photostats of your hygrothermograph charts for exactly the same period. Since my records indicate that your hygrothermograph also belonged to PRI, it's probable that both sets of original charts were returned to PRI at the same time.

Thanks a lot for your reprints of your earlier pressure results. Your values of the 12, 24 and 8 hourly components for June, 1954, agree well with my values. I did not compute the 6 hourly component; however I am curious about your Fig. 5 which depicts this component. For June, 1954, you show a 6 a.m. maximum which seems way out of line with the preceeding and following months. Being a 6 hourly wave, there must also have been a maximum occurring at noon and another at 6 p.m., either of which would fit in well with the other months. Why did you choose to plot the maximum at 6 a.m. rather than at noon or 6 p.m.? The same situation occurs for the anomalous months in 1953. I agree with you that the 6 hourly comppnent is too small to be determined accurately, but I also believe your Fig. 5 makes the phase appear much more erratic than it really is.

I am sending separately a copy of my report on the Maui observations. It is one of my last copies, but there is no one more entitled to it than you. However, if you should want any additional copies, I have penciled a note on the cover giving the address where the main stock is kept.

Here at school I am working hard on my thesis, which is an attempt to explain theoretically the diurnal pressure wave on Haleakala by using the hydrodynamic equations for air flow over a heated obstacle. With good luck I may be able to finish this summer. However, if you do get to the mainland while we are still here, I certainly hope you can get up here for a visit. Meahwhile, best wishes for continued success in your Haleakala observations, and don't hesitate to let me know if there is anything else I can do for you.

Sincerely, Bob

Robert L. Pyle

Reprint arrived 31 March 58

OAHU RESEARCH CENTER

INSTITUTE OF GEOPHYSICS

UNIVERSITY OF CALIFORNIA

Scientific Report No. 15

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The 24-Hour Component of the Diurnal Pressure Oscillation on Haleakala Mountain, Hawaii

by
Robert L. Pyle

November 1955

The Contracting Officer
Air Force Cambridge Research Center
224 Albany Street
Cambridge 39, Massachusetts

Sir:

The research reported in this document represents a continuation of the work reported in Scientific Report No. 2. The same techniques as were applied to Oahu pressure observations in 1953 have been used on a wider scale on the island of Maui.

Respectively submitted:

Clarence E. Palmer

Clarence E. Palmer
Professor of Geophysics

ABSTRACT

The 24-hour component of the diurnal pressure oscillation was measured at eleven stations between sea level and 10,000 ft., and was found to vary greatly with altitude and with orographic exposure. An abrupt shift of phase occurs near 2,000 ft. elevation, with the time of maximum occurring in the early morning hours at low level stations and in the early afternoon at higher levels. Near sea level, the amplitude is smallest at the station exposed directly to fresh oceanic air, and is ten times larger at the station farthest removed from the ocean. At higher elevations the amplitude is largest just above the level of phase shift. It decreases markedly to a minimum at the base of the tradewind inversion near 6,000 ft., but is larger again above 7,000 ft.

A possible physical explanation of these variations in terms of daily solar heating is discussed. Two main influences are suggested: an "orographic effect" arising from differential heating of land and water surfaces, and a "worldwide effect" which is independent of the character of the underlying surface.

TABLE OF CONTENTS

THE 24-HOUR COMPONENT OF THE DIURNAL PRESSURE OSCILLATION ON HALEAKALA MOUNTAIN, HAWAII

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PART I - INTRODUCTION

Atmospheric pressure at the earth's surface is one of the most accurately measured quantities among the many meteorological variables customarily observed in routine practice. Not only are pressure-measuring instruments capable of greater precision, but the pressure itself is less affected by local exposure. Unlike temperature, rainfall, wind and humidity, a pressure measurement may be considered representative regardless of whether it was made in sunlight or shade, indoors or out. Moreover, at stations in tropical and sub-tropical areas, the day-to-day pressure changes caused by moving synoptic features are small and gradual. Cyclic oscillations in the pressure resulting from the familiar semi-diurnal and higher order components are quite regular. Pressure variations arising from these factors may be easily computed and deleted from the data.

Thus the high precision of pressure measurements and their freedom from unrepresentative influences make it possible to measure and study the small diurnal oscillations of 24-hour period. This component, having one maximum and one minimum every 24 hours, varies markedly from day to day and from place to place according to elevation and orographic exposure. It is apparently linked to daily solar heating and resulting vertical displacements in the air, so that additional information on these phenomena may eventually be gained from a close study of the 24-hour pressure cycle and its variations.

In June 1953 a pilot project was conducted to measure the 24-hour pressure component at various locations on Oahu Island, Hawaii.* The data obtained from this project demonstrated that two weeks of continuous pressure observations are quite sufficient to determine the characteristics of the 24-, 12-, and 8-hour components of the diurnal pressure oscillation. Procedures were developed for eliminating the longer period synoptic trend from the pressure record, and for isolating the 24-hour component for each day. The variation of the observed 24-hour component according to orographic exposure was discussed, and underlying causes suggested. However, data were only available from two elevations: sea level and 2671 ft; and it was evident that measurements were needed from a greater range of elevations.

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* Pyle, R. L., 1954: "Pressure Variations on Oahu Island," Oahu Research Center Scientific Report No. 2, Contract No. AF 19(604)-546.

Haleakala Mountain on nearby Maui Island was selected as the site of a second project to obtain pressure data for this purpose. Haleakala is a relatively smooth-sided mountain cone rising out of the Pacific Ocean to a peak elevation of 10,000 ft. It has an ocean shoreline around more than 90% of its base, and is connected to the remainder of Maui Island by a narrow flat isthmus lying well below 200 ft elevation (Fig. 1, map). Moreover, Haleakala lies up-wind from this isthmus, so that the prevailing tradewinds have a fetch of thousands of miles without obstacle until they strike this very regular cone-shaped mountain. Ideally, in order to get pressure measurements above sea level that are free from gross orographic effects, one should mount recording instruments on a mast which offers no resistance to the wind and which rises as high as desired above a flat surface of infinite extent. Lacking any artificial device of this kind, it is suggested that Haleakala comes as close to this ideal as any other natural feature likely to be found.

PART II - DATA

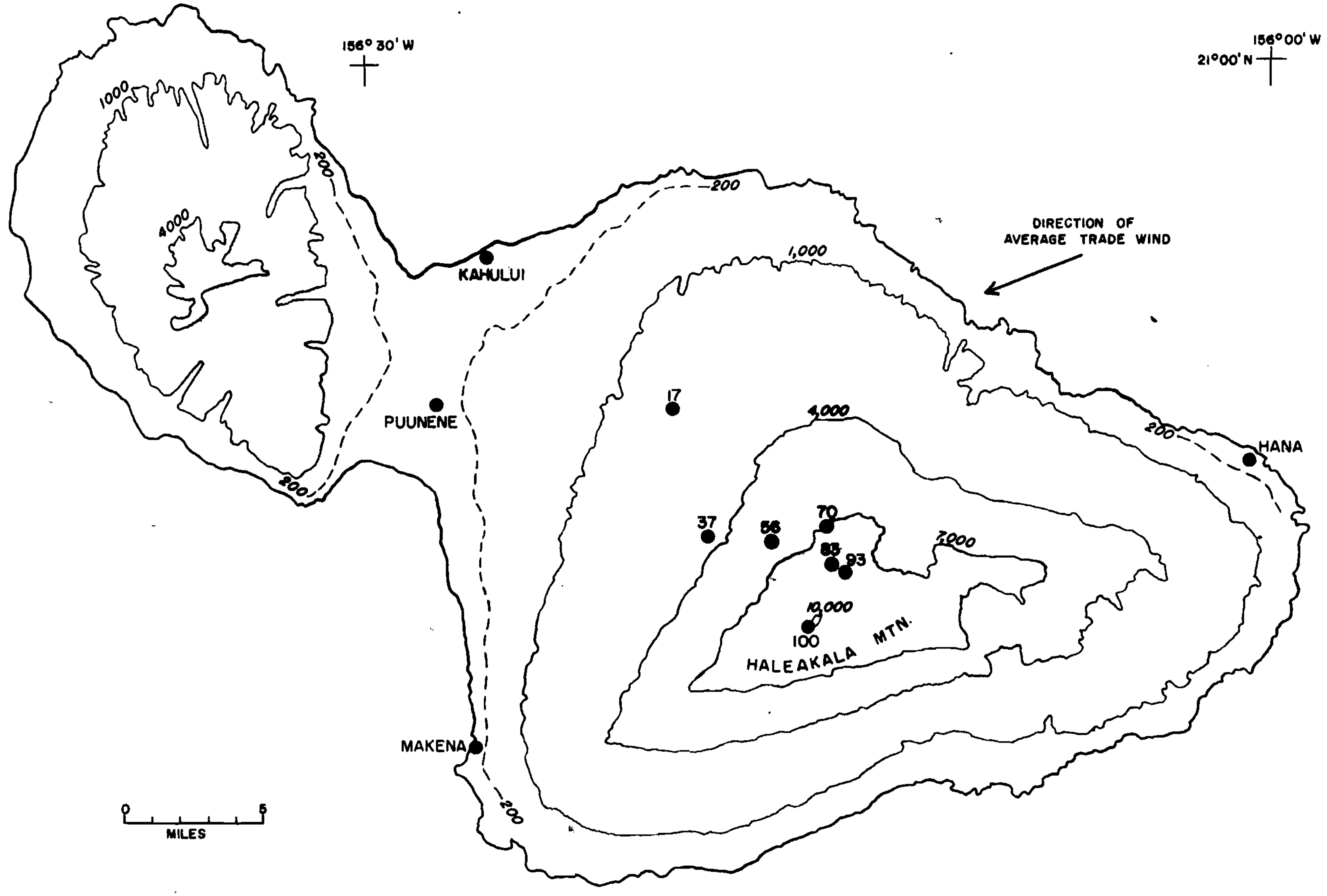
Continuously recording micro-barographs were in operation at eleven stations on Haleakala during the period June 10 to July 5, 1954. Four of these stations were around the base of the mountain close to sea level, and seven were at various elevations up the mountainside (Fig. 1). For convenience, the mountainside stations will hereafter be referred to by the first two digits of their elevations, e.g., station 17 for the one at 1761 ft, station 37 for the one at 3728 ft., etc. A paved road leads up the northwest slope to the peak, and the instruments were placed along this road, most of them at climatological stations already in existence. For a detailed discussion of the pressure instrumentation, see the Appendix.

Hourly temperature and wet-bulb readings were taken throughout the day and night at Puunene, and during the daytime hours at Kahului. Continuously recording thermographs were in operation at Hana and station 17. At all other stations, continuously recording hygro-thermographs were installed in the shelters with the barographs.

The stations were visited frequently during the period to check the recording instruments and to compare them with readings of portable barometers and thermometers taken on the spot. Dry and wet-bulb temperature observations were taken at each visit using a standard sling psychrometer. Many of the stations had maximum and minimum thermometers which were read and reset on each visit.

PART III - ANALYSIS

The mean pressure during each hour of the observation period was read from the barograms. For the purposes of this study, mean pressures for one-hour periods are much preferred to spot readings taken at one-



MAUI ISLAND, HAWAII

CONTOURS LABELED IN FEET
● LOCATION OF BAROGRAPH STATION

FIG. 1

hour intervals, especially when dealing with barograph traces. When time corrections were necessary, they were incorporated in the reading procedure so that the value obtained is the mean for that section of the barogram actually traced during the hour to which the mean applies. These values are means for one-hour periods centered on the half hour in Hawaiian (150th meridian) time. Since Haleakala lies at about 156°15' West Longitude, local solar time at the instrument sites is around 25 minutes behind Hawaiian time. Thus the means are for periods centered very nearly on the hour in local solar time.

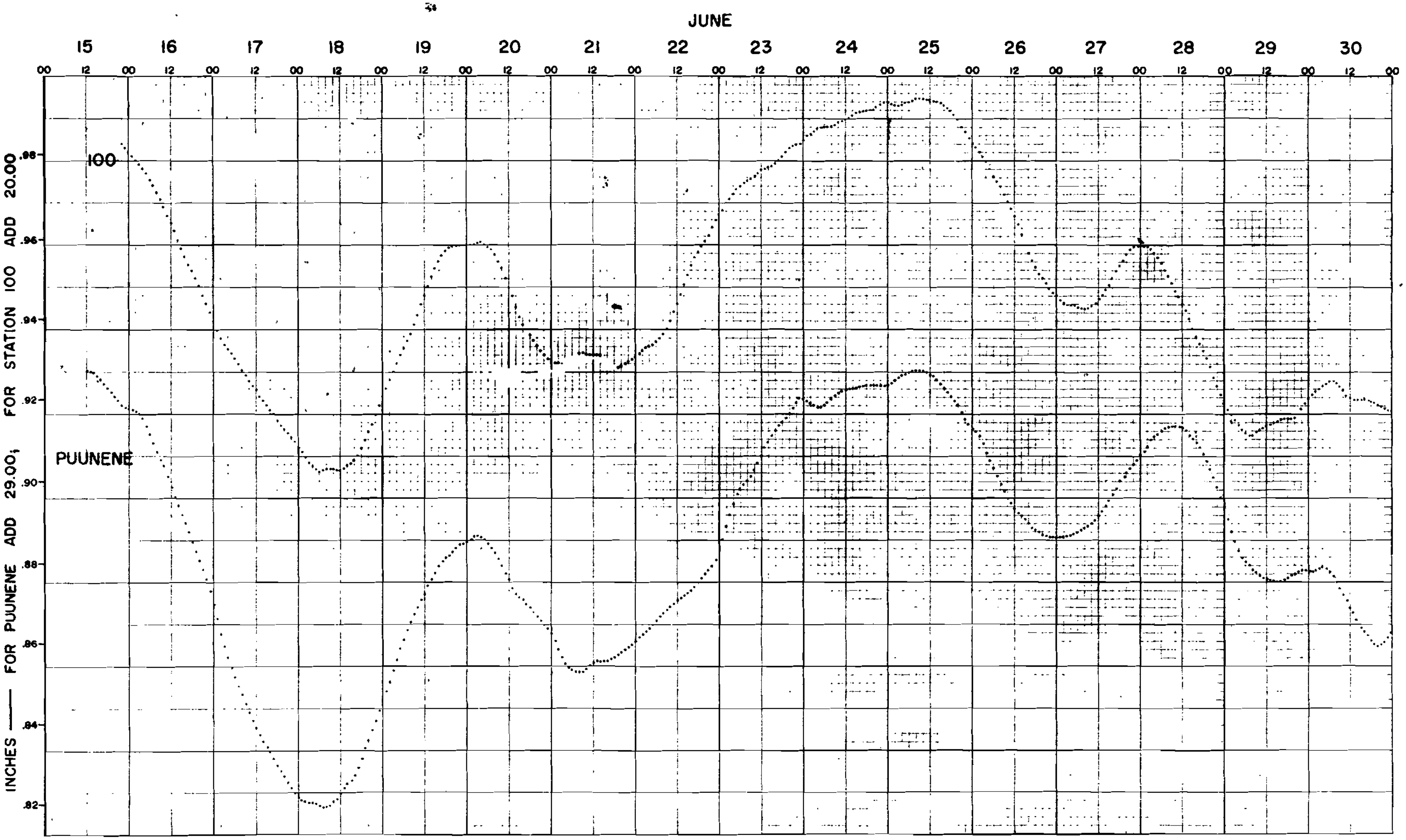
The width of the trace line is of the order of .005 inch on the pressure scale of the printed chart, but with the aid of a template the mean value of the central axis of this line could be determined to the nearest .005 inch with little difficulty. The values were read directly from the printed grid on the chart, and any necessary pressure corrections were then applied. These corrected hourly pressure values comprise the basic data for this study.

The fifteen days from June 15 to July 1 were selected as the period of study. Overlapping 24-hour means centered exactly on each hourly value throughout this period were computed for all eleven stations. Figure 2 shows a time graph of these running means for Puunene and Station 100. The graphs for all stations were very similar in their major features and in many cases corresponding minor features appeared at several stations. For stations in the sub-tropics, these graphs seem to offer the closest approach to the true "synoptic" pressure trend which is normally masked by the larger diurnal oscillations.

Using standard harmonic analysis methods the 24-, 12-, and 8-hour components of the diurnal pressure oscillation were computed for each station. In order to do this, the pressure observation at each hour was expressed as a deviation from the 24-hour mean centered at that hour. For each hour of the day, the average deviation during the 15-day period was computed, and this set of 24 average values was used for the harmonic analysis computations, at each station.

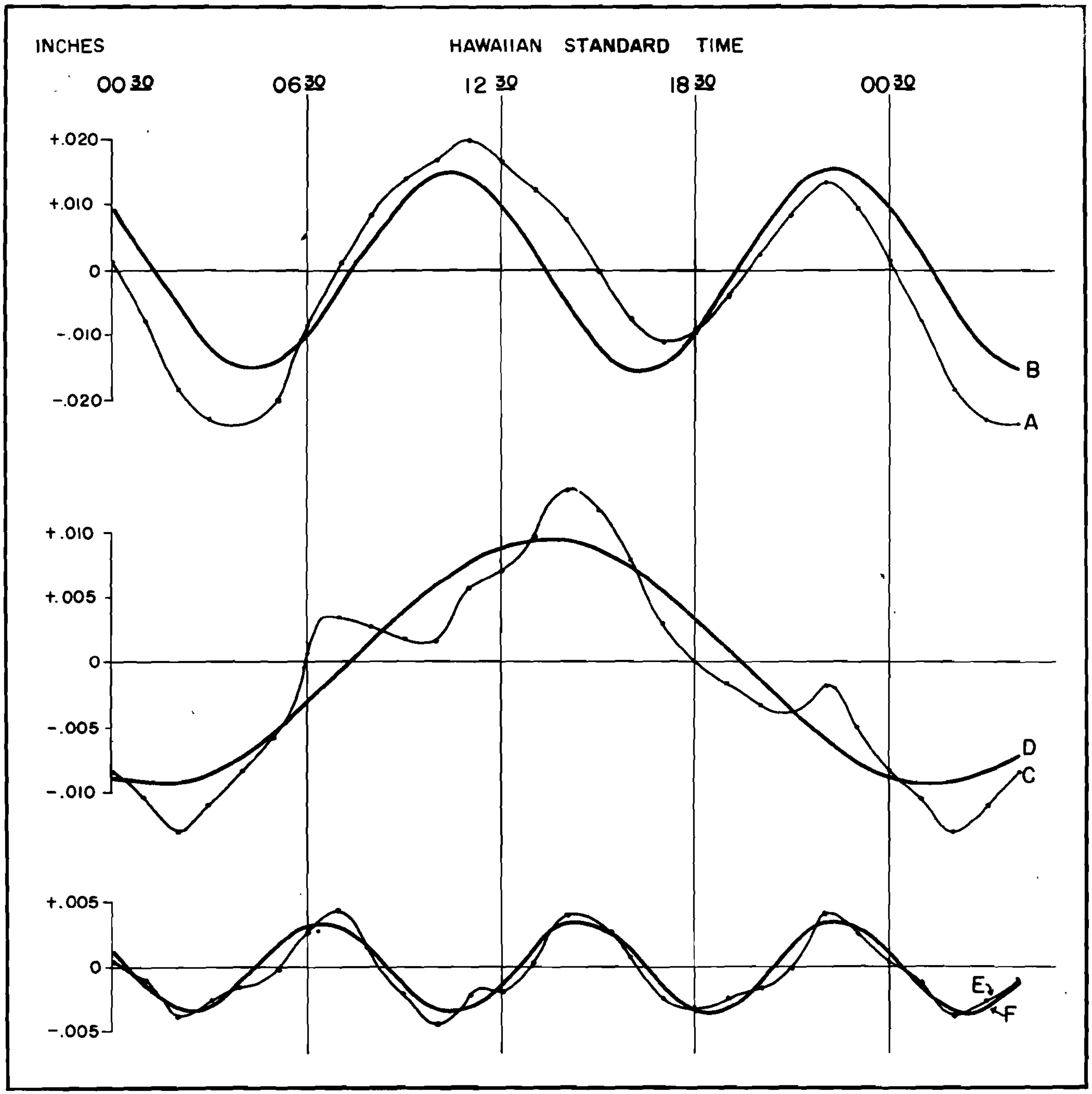
After the components of 24-, 12- and 8-hour periods had been extracted, the residual amounts at each hour were reduced to less than 0.0025 inch. Figure 3 illustrates the three components for station 70, and the degree to which they account for almost all of the observed departure from the running 24-hour mean. The computed components for all stations are shown in Fig. 4, and the phase and amplitude values are given in Table 1. The 24-hour components are shown in a harmonic dial in Fig. 4A. For comparison, the corresponding data for 1953 from four locations on Oahu Island have been added in Table 1, and the 24-hour components have been added to Figs. 4 and 4A.

In Fig. 4 the three computed components for all stations have been entered on a graph of amplitude versus phase. The data from Station 83 are considered to be inaccurate (see Appendix), but for comparison they are entered in parentheses on the graph. Referring to the 12-hour components appearing at the upper center of the diagram, it can be seen that the amplitude



TIME GRAPHS OF RUNNING 24-HOUR MEAN PRESSURES AT PUUNENE AND STATION 100.

FIG. 2



COMPONENTS OF THE DIURNAL PRESSURE OSCILLATION AT STATION 70

CURVE A: DEPARTURE OF HOURLY PRESSURE FROM RUNNING 24-HOUR MEAN (AVERAGE FOR 15 DAYS)

CURVE B: COMPUTED 12-HOUR COMPONENT

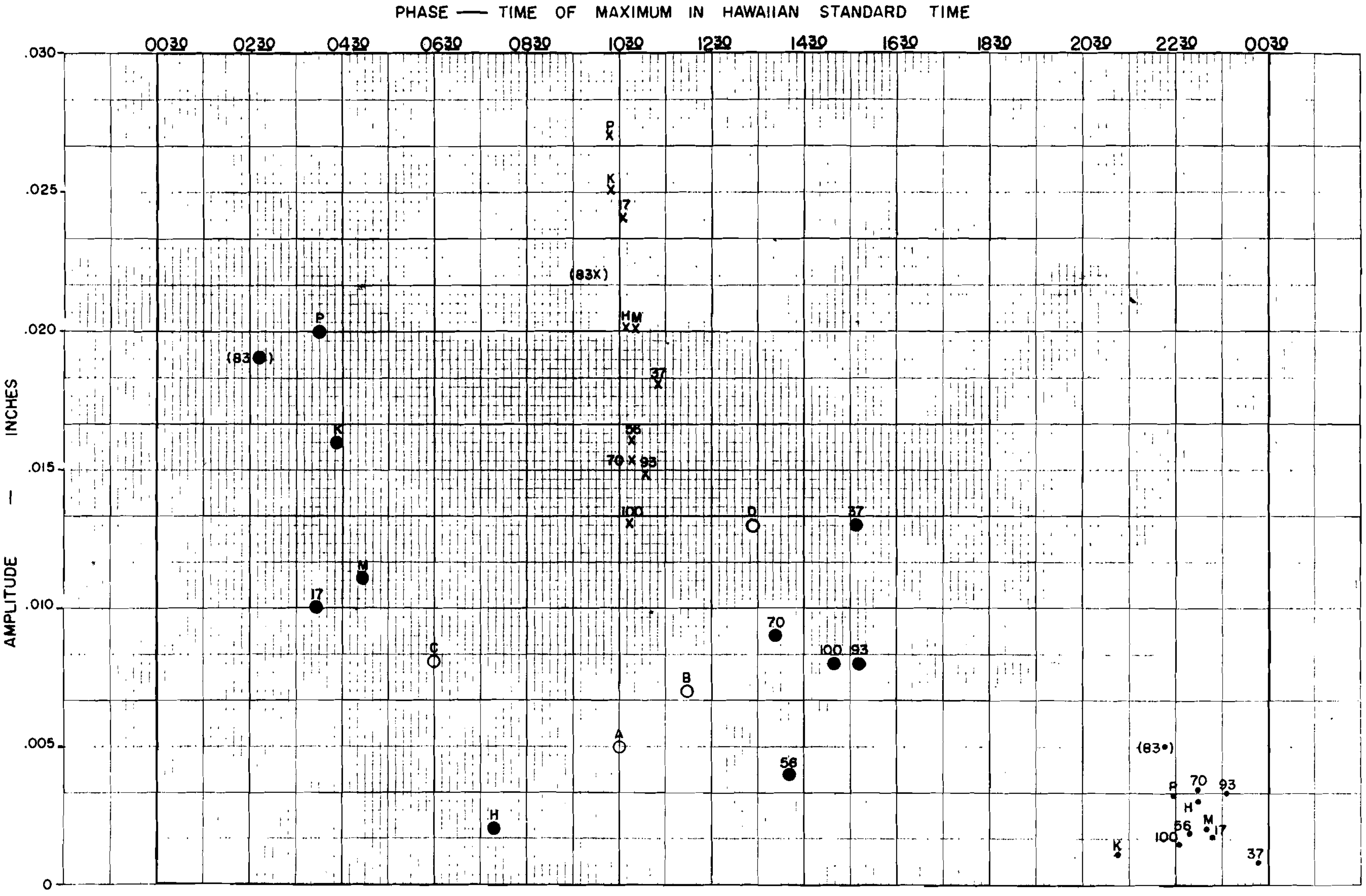
CURVE C: DEPARTURE OF CURVE A FROM CURVE B

CURVE D: COMPUTED 24-HOUR COMPONENT

CURVE E: DEPARTURE OF CURVE C FROM CURVE D

CURVE F: COMPUTED 8-HOUR COMPONENT

FIG. 3



COMPONENTS OF THE DIURNAL PRESSURE OSCILLATION MEASURED AT HALEAKALA AND OAHU

HALEAKALA

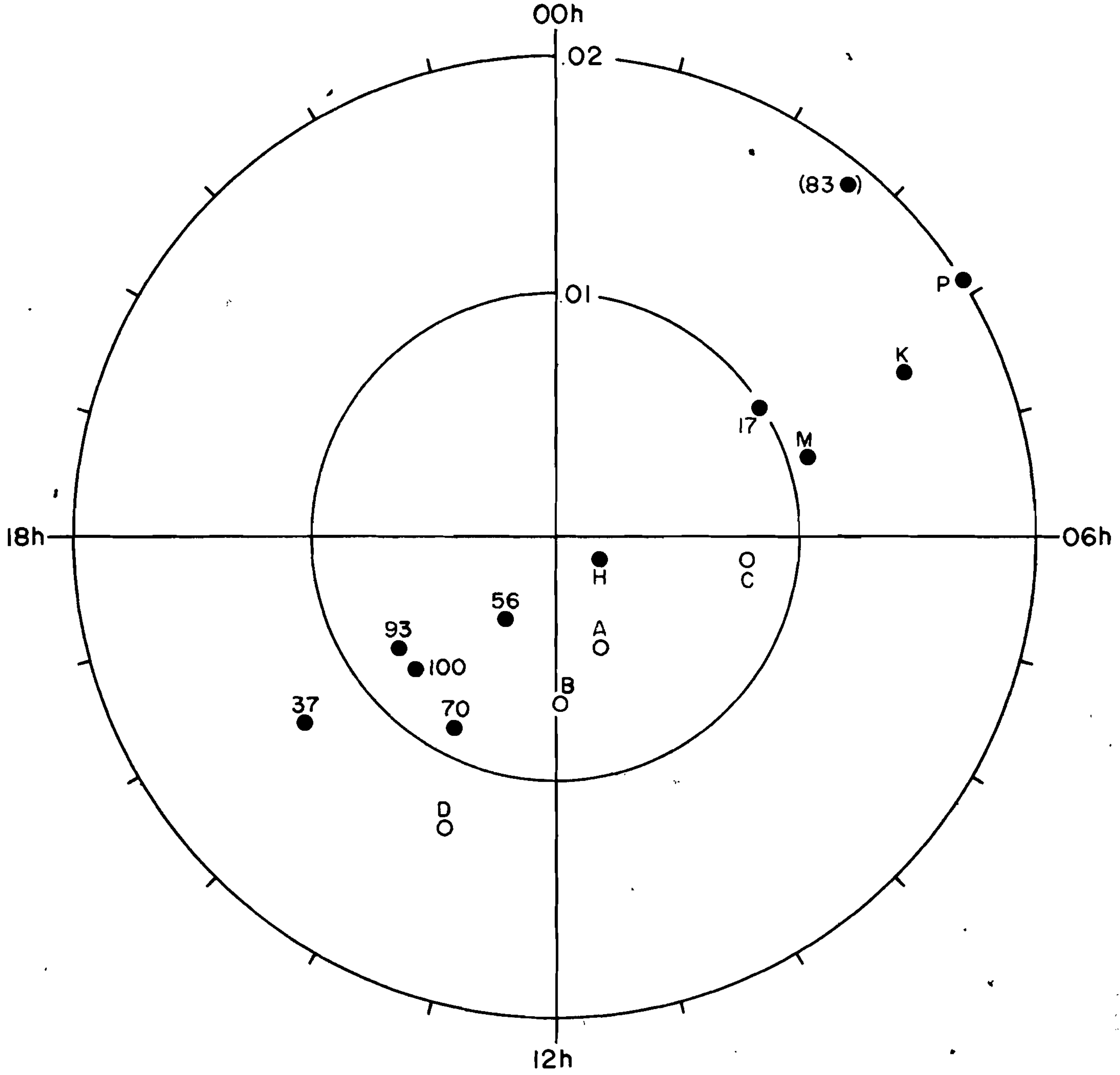
FIGURES ARE ELEVATIONS OF STATIONS IN HUNDREDS OF FEET. LETTERS ARE INITIALS OF STATIONS CLOSE TO SEA LEVEL.

● - 24-HOUR COMPONENT
X - 12-HOUR COMPONENT
• - 8-HOUR COMPONENT

O – OAHU – 24-HOUR COMPONENT

A - SEA LEVEL, WINDWARD
B - 2671 FEET, WINDWARD
C - SEA LEVEL, LEEWARD
D - 2671 FEET, LEEWARD

FIG. 4



HARMONIC DIAL FOR THE 24-HOUR COMPONENT

HALEAKALA AND OAHU OBSERVATIONS AS IN FIG. 4

AMPLITUDE IN INCHES OF MERCURY

FIG. 4A

of this component decreases with elevation in an orderly fashion. The time of morning maximum remains fairly constant at about 10 o'clock, although there is a tendency for the phase to be slightly delayed at stations with smaller amplitudes.

TABLE 1

Amplitude and Phase of components of diurnal pressure oscillation.
A = Amplitude in inches of mercury
P = Phase expressed by time of maximum, Hawaiian Standard Time.

	24-Hr Component		12-Hr Component		8-Hr Component	
	A	P	A	P	A	P
Haleakala						
Hana	0.002	07:45	0.020	10:33	0.0030	22:58
Makena	.011	04:51	.020	10:49	.0020	23:08
Kahului	.016	04:20	.025	10:16	.0011	21:13
Puunene	.020	03:56	.027	10:15	.0032	22:26
Station 17	.010	03:52	.024	10:31	.0017	23:15
Station 37	.013	15:33	.018	11:17	.0008	00:17
Station 56	.004	14:09	.016	10:45	.0018	22:47
Station 70	.009	13:50	.0153	10:48	.0034	22:59
(Station 83*)	(.019	02:40)	(.022	10:01)	(.0050	22:15)
Station 93	.008	15:39	.0148	11:03	.0032	23:33
Station 100	.008	15:06	.013	10:40	.0014	22:32
Oahu						
Sea-Level-Windward	.005	10:31	.022	10:44	.0035	23:11
Sea Level-Leeward	.008	06:27	.024	10:38	.0035	22:45
2671 ft - Windward	.007	11:55	.019	10:50	.0026	23:21
2671 ft - Leeward	.013	13:23	.018	11:26	.0019	23:48

* Station 83 data are considered to be inaccurate (see Appendix) but are included for comparison.

The 8-hour components are grouped in the lower right corner of the diagram and are uniformly small and regularly timed. No regular variation with elevation is detectable, although this component has such small amplitude that accurate measurement probably requires a longer series of data. On Oahu, both the 12- and 8-hour components agree very well with the Haleakala measurements.

In the lower center and left portions of the diagram are scattered the points representing the 24-hour components. Both the amplitude and phase of this component vary greatly from station to station, but there is a definite pattern to this variation. Considering the Haleakala data, the stations above 2,000 ft. show the daily maximum in the early afternoon, but below 2,000 ft. the maximum occurs in the early morning hours. The amplitude is quite small at lowland stations on the windward side of Oahu and Haleakala, and is quite large on the leeward side.

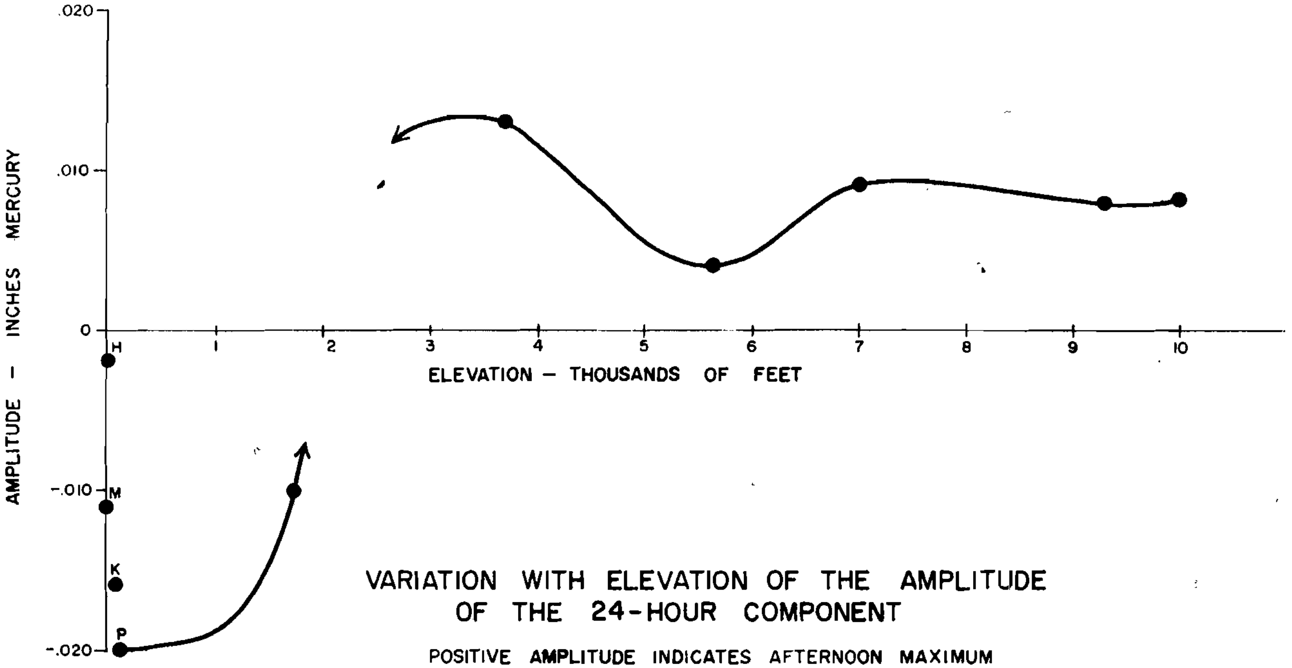
Although the component of 12-hour period is usually considered to be the strongly dominant one, it is interesting to note that the 24-hour component at Puunene equals the 12-hour component at Hana and Makena and is larger than the 12-hour component at all stations above 2000 ft.

The amplitude of the 24-hour component is graphed against elevation in Fig. 5A. For the purposes of this diagram, the components with morning maximums are arbitrarily considered to have "negative" amplitude, while those with afternoon maximums are considered to have "positive" amplitude. The switch from negative to positive amplitude at about 2,000 ft. elevation is well marked. Because of the arbitrary convention separating negative from positive amplitudes, the region of rapid phase shift constitutes an indeterminant section of the graph in Fig. 5A. More observations near 2,000 ft. are needed in order to determine specifically whether the amplitude passes through zero at the level of phase shift; or whether, on the other hand, the amplitude remains finite while the time of maximum shifts rapidly but continuously from morning to afternoon.

The largest positive amplitudes are observed immediately above 2,000 ft., and above that the amplitude decreases gradually. The great difference in amplitudes observed at the sea level stations is related to varying orographic exposure and will be discussed in the following section.

There is a curious anomalous dip in the graph at the 5600 ft. level which requires further discussion. The tradewind inversion is normally found at about 6000 to 8000 ft. and station 56 was often in or at the base of the stratocumulus clouds that formed under this inversion. A preliminary examination of the thermograph records indicates that on the average the diurnal temperature cycle had a significantly smaller amplitude at this station than was observed at stations 37 and 70. It is tempting to suggest that the barograph instruments were not properly compensated for temperature and that smaller amplitude of the pressure component at station 56 compared to neighboring stations is thus a direct result of the smaller diurnal temperature changes observed inside the instrument shelter. Such reasoning must imply that it is not just one instrument at fault, but rather that this temperature compensation defect is inherent in several if not all of the instruments.

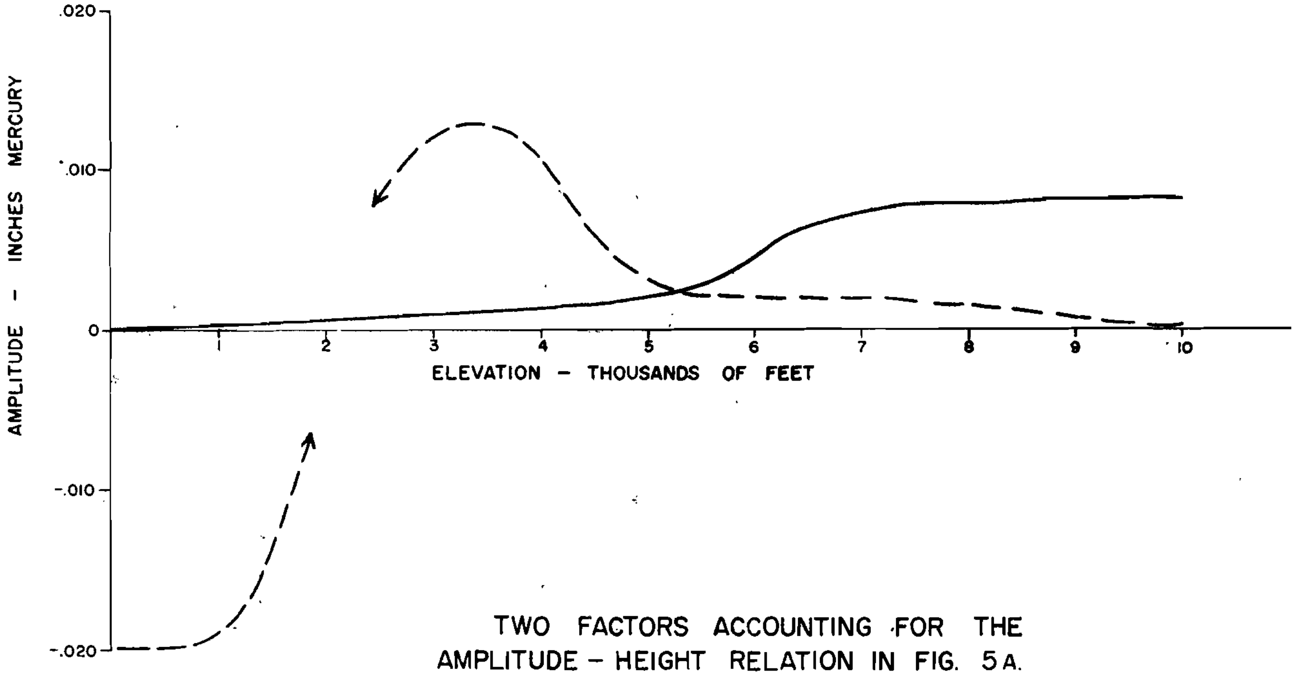
However, all stations below 2,000 ft. showed a complete reversal of phase of the 24-hour pressure component, even though the temperature regimes there were essentially the same as those above 2,000 ft. It seems quite unlikely that by coincidence all barographs above 2,000 ft. would have a certain temperature defect and all those below 2,000 ft. have no defect or one of opposite sense. It also seems unlikely that a 70% decrease in amplitude from station 37 to station 56 can be attributed to a slightly smaller temperature oscillation, when a complete reversal of phase of the pressure component occurs between stations 37 and 17 with practically no change in temperature oscillation.



VARIATION WITH ELEVATION OF THE AMPLITUDE OF THE 24-HOUR COMPONENT

POSITIVE AMPLITUDE INDICATES AFTERNOON MAXIMUM
NEGATIVE AMPLITUDE INDICATES MORNING MAXIMUM

5A



TWO FACTORS ACCOUNTING FOR THE AMPLITUDE - HEIGHT RELATION IN FIG. 5A.

– – – – OROGRAPHIC EFFECT
——— WORLDWIDE EFFECT

5B

FIG. 5

It is not a question of the 15-day average amplitude being lowered at station 56 by greater day-to-day variation in timing of the component. The 24-hour components of the pressure oscillation for each day individually were computed and graphed and it is quite evident that the amplitude each day is significantly smaller at station 56.

Other types of instrumental error in the station 56 barograph seem just as unlikely, since it is only the 24-hour component which is affected. The much larger 12-hour oscillation and the smaller 8-hour component are in complete agreement with those at other stations. This is in contrast to the situation at station 83 where all components appear to be inaccurate (see Fig. 4 and Appendix). Also unlike station 83, the frequent checks of the station 56 barograph against the aneroid barometer showed no diurnal pattern in the difference between the two instruments. Thus, while there is good reason for discarding the data from station 83, there is no readily apparent reason for discarding the station 56 data.

PART IV - DISCUSSION

The great variation in the average 24-hour pressure component as measured at various sites on Haleakala is directly related to the differences in elevation and orographic exposure of the stations. The switch in phase timing near 2,000 ft. seems to be well substantiated as a fundamental feature of this component. If the anomalously small amplitude measured at station 56 is physically real and representative of the component at that elevation, then it is evident that at least two separate influences must be at work. Bjerknes has pointed out* that the observed 24-hour component is closely connected with the thermal sea-and land-breeze and valley-mountain circulations, and that it also includes a very small "global" oscillation which is independent of local influences. The Haleakala measurements provide the data for a close study of these effects, particularly their variation in the vertical, since the 24-hour component is measured directly at a number of elevations up to 10,000 ft, over a relatively small horizontal distance, and in a region of unusually simple topography.

A simplified hypothesis is now proposed, based on two factors which together could account for the observed variation with height of the 24-hour component. The first factor is absorption of long-wave radiation from the underlying earth during its daily cycle of warming and cooling, which will be called the "orographic effect." The second factor is independent of the character of the underlying surface, and will be called the "worldwide effect".

The Orographic Effect: This effect is a form of the well-known sea-breeze regime. We may imagine an area of large diurnal heating and cooling, such

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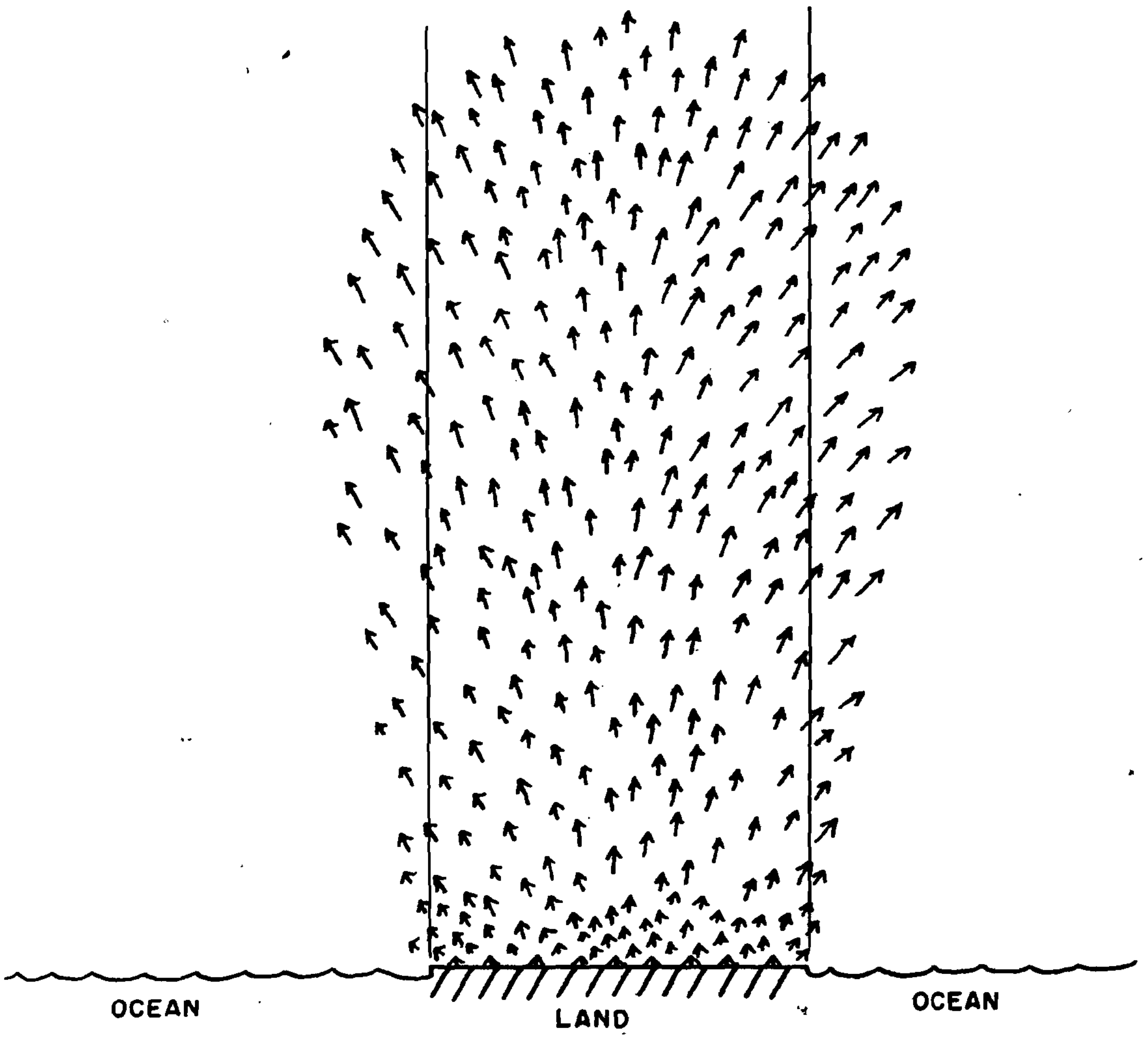
* Bjerknes, J., 1948: "Atmospheric Tides", Sears Found. Journ. Mar. Res. Vol 7, p 154.

as the low flat isthmus of Maui Island, lying adjacent to an area of less or no diurnal heating and cooling, such as the Pacific Ocean. During the late morning as the air over the isthmus is heated, there is a gradual expansion both outward over the unheated ocean and upward. This process is shown schematically in Fig. 6. It should be emphasized that no large-scale currents are implied, but rather a small displacement of each air parcel produces the overall effect as shown. Over the isthmus itself, there is a depletion of air and a consequent lowering of surface pressure during the hot part of the day. Above the ground surface, however, this lowering of pressure is counteracted by the slight upward displacement which tends to increase the pressure measured at a fixed level. Above some critical level the upward displacement over-balances the outward expansion, producing a net increase of air and a consequent rising of pressure at fixed levels. The critical level at which this over-balancing occurs will of course vary from day to day because of the many factors involved. During this 15-day period of study on Maui it was found on the average somewhere around 2,000 ft. elevation, as shown in Fig. 5A.

The effect of this upward displacement appears to be largest around 3,000 to 4,000 ft. elevation where the largest positive amplitude of the 24-hour pressure component is observed. Going to higher levels, the effect of this upward displacement begins to taper off and is eventually reduced to an insignificant amount. The much lower amplitude of the 24-hour pressure component at Station 56 indicates that the orographic effect has already diminished greatly by the time this elevation is reached.

The orographic effect on the amplitude of the 24-hour pressure component is shown schematically by the dashed line in Fig. 5B. This curve of course is a result of the orographic conditions peculiar to Maui, and we should not necessarily expect to find this same amplitude-height relation at other places. Even on nearby Oahu, the 24-hour components may be expected to differ considerably from corresponding ones on Maui because of differences in orography and size of the two islands. For this reason the Oahu data have not been entered on Fig. 5A, although they do indicate that the same general shift in phase also occurs there at some level below 2,600 ft.

The maximum height at which the upward displacement is felt probably varies considerably from day to day. Reber has observed that daily weather regimes at station 100 fall into two distinct types. There are days when the wind is light, the normal daytime temperature rise is accompanied by a rise in relative humidity, and wisps of cloud often drift around the station. On other days, the wind is strong, there is no daytime rise in relative humidity and no clouds about the station. There are many days on which the regime is confused and thus not clearly assignable to either type. These two types are based on a year of records and first hand observation, and probably represent the two cases of the upward displacement of most air either reaching or not reaching to the 10,000 ft. level.



SCHEMATIC ILLUSTRATION OF UPWARD AND OUTWARD EXPANSION OF AIR DURING LATE MORNING AS LAND SURFACE IS HEATED.

FIG. 6

During the nighttime, the process described above is reversed. Cooling occurs over the isthmus accompanied by some contraction and subsidence, and replacement of the heated daytime air by fresh oceanic air that is no longer heated by its passage over the land surface. The presence of the two large mountain masses, Haleakala and West Maui, complicates this simplified picture, but in the main these heat and cold sources at significant elevations above sea level probably augment both the daytime and nighttime portions of the cycle over the isthmus.

There is another aspect of the orographic effect which must be considered. The stations above sea level are all on the northwest slope of Haleakala and thus have about the same exposure to the prevailing tradewinds. The coastal stations, however, definitely do not have similar exposures. At Hana, on the windward coast, the air is newly arrived after lengthy travel over the ocean. The heating processes described above have little chance to operate directly over the station as the air is being continuously replaced by fresh oceanic air. We thus find a very small amplitude in the 24-hour pressure component. At Puunene, on the other hand, the air reaches the station after having passed over a considerable amount of heated land surface, and the 24-hour component has a correspondingly large amplitude. The trade wind current, upon reaching the windward coast, divides and flows around Haleakala, so that at Kahului and Makena the air has had intermediate exposure to the land surface and the amplitudes of the 24-hour components are intermediate between those at Puunene and Hana. In Fig. 5A, therefore, the large scatter of points from coastal stations may be directly related to varying orographic exposures. This same effect is found in the Oahu data, where the amplitude at windward stations is significantly smaller than at leeward stations at both sea level and 2,671 ft. elevation.

The Worldwide Effect: It is suggested that this effect stems from some direct influence from the sun during the daytime hours. As the sun passes overhead, air exposed to the sun is affected without regard for whether the underlying surface is ocean or land. This seems to cause a worldwide pulsating of the atmosphere: a slight expansion and upward swelling in the daytime and a shrinking and downward subsiding at night. Since at any level all of the air over a wide area is affected more or less uniformly, the resulting expansion is primarily upward, rather than outward, and the effect on the pressure measured at the earth's surface is small. But at levels above the surface, the upward swelling produces a small rise in pressure during the daytime, and the amount of this rise increases with increasing elevation. The contribution of this worldwide effect to the amplitude of the 24-hour pressure oscillation is shown schematically by the solid line in Fig. 5B.

One possible cause of this pulsating might be the direct absorption of solar radiation by the atmosphere. The actual amount of pressure rise that could be produced in this manner is difficult to estimate quantitatively. Crude computations using the hydrostratic equation indicate that a uniform warming of 1°C throughout an air column from sea level to 10,000 ft. would produce a pressure rise at 10,000 ft. on the order of 1 mb or 0.03 inch, if surface pressure is unchanged. In the absence of other effects, the range (twice the amplitude) of .016 inch actually observed at station 100 would correspond to a uniform night-to-day warming of about 0.5°C throughout the column. It would be reasonable to expect, however, that rather than being uniform, the warming would be greatest in the upper layers of the moist air just under the trade wind inversion. Thus the worldwide curve in Fig. 5B is shown to have a steeper slope at levels near 6,000 ft.

While Fig. 5B is intended to show the orographic and worldwide effects in schematic form, the two curves have been carefully drawn so that when added together they will nearly equal the observed curve in Fig. 5A. This latter curve, based on average values for only 15 days, is of course very crude and for various reasons the plotted points should not be considered precise measurements of the representative amplitude existing at each level. Nevertheless, the main features of this curve may be explained to a first approximation by the two effects shown in Fig. 5B.

ACKNOWLEDGEMENTS

This study was carried on under the direction of Professor C.E. Palmer, whose helpful advice and suggestions are greatly appreciated. The field work on Maui could not have been accomplished without the generous help and cooperation of Mr. James Nicholson; Mr. Grote Reber; Mr. Saul Price of the U. S. Weather Bureau; Assistant Superintendent Eugene Barton of Hawaii National Park; Mr. Carl Thornton of the U. S. Geological Survey; Mr Ray Miyabara of the Oriental Fruit Fly Investigations, U. S. Department of Agriculture; Mr. David Chun of the Maui Pineapple Co.; the Hawaiian Commercial and Sugar Co.; the C. A. A. radio station at Puunene; and the Hawaiian Airlines Station Managers at Hana and Kahului.

APPENDIX

Pressure Instrumentation

Standard double-cell microbarographs were used at all stations. At most stations, the dashpots were emptied of fluid and the plungers dismantled so that the instruments were completely undamped. At Hana, Kahului and Puunene the instruments were permanently installed in airport weather stations and the damping mechanisms remained in operation. At Station 93, the pumping resulting from strong winds was so great that the dashpot plungers had to be re-assembled on June 20, and the instrument was damped for the remainder of the period. The undamped instruments were placed on one-inch foam rubber mats. The clock drums on all instruments were geared to make one revolution in 4 days, and the chart paper was changed each fourth day.

At Station 100, the barograph was inside a concrete blockhouse protected from the strong winds. All others except those at airport stations were housed in standard U. S. Weather Bureau type instrument shelters, standing four feet above the ground, and surrounded by grass or low bushes limited to five feet in height. At Makena, the shelter was in a small clearing surrounded by tall trees, and was shaded by these trees during parts of the day. The other shelters were completely unshaded.

Prior to the project, the barographs used at Makena and Stations 17, 37, 56, 83 and 93 were checked in a pressure chamber at the U. S. Navy Fleet Weather Central, Pearl Harbor. Each was found to operate within the expected limits of accuracy within the range of pressures it was to experience in the field.

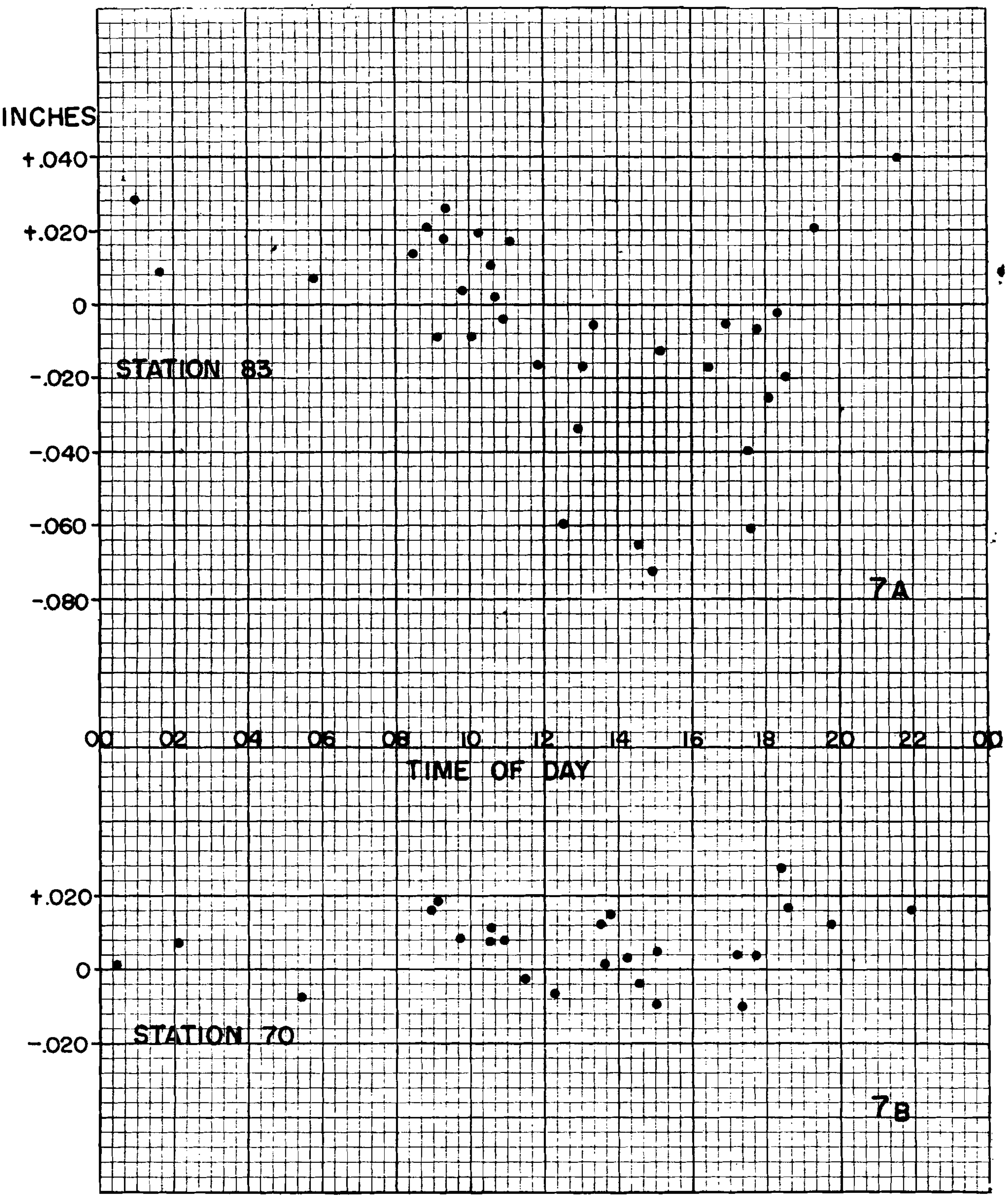
During the project, the accuracy of the barographs was checked by comparison with two portable precision aneroid barometers. These aneroids were both Wallace & Tiernan models, one with a scale marked in whole millibars from 10 to 1060, and the other with a scale marked in half millibars from 745 to 1065. When they were transported up and down the mountain road, a quite noticeable error appeared in their readings because of the lag in response of the instruments to the changes in elevation. However, the mountainside barographs were checked quite often while enroute both up and down the mountain and the lag was found to be fairly regular. During each visit to Hana, Kahului and Puunene, the aneroids were checked against mercurial barometers, and the readings were found to be consistent throughout the period.

At the time of installation, each barograph was compared directly with the aneroid and the position of the pen arm adjusted to agree with the aneroid reading. Thereafter, no further adjustments to the position of the pen arm were made.

During the project period, the barograph reading was checked against the aneroids at irregular intervals ranging from every fourth day at Makena to about once or twice a day at Stations 17 and 56. The position of the drum was adjusted to the correct time at the beginning of each chart, and at intervening visits the time was checked against a good watch. Time discrepencies were small and consistent. The departures of the barograph readings from the aneroid readings were in general small and within the limits of the aneroids' hysterisis described above. Except for Station 83, the departures were quite random and the barographs appeared to operate consistently.

The barograph at Station 83 unfortunately showed a pronounced inconsistency in its record. The departure of the barograph reading from the aneroid reading, at times of direct comparison, are plotted in Fig. 7A against the time of day when the comparison was made. There is definite evidence of a diurnal pattern to those departures in the sense of the barograph registering too low during the hot part of the day. In contrast, Fig. 7B shows the corresponding data for Station 70, which is quite typical of other stations, and no such diurnal pattern is present. This is not an effect of hysterisis in the aneroid, since afternoon visits to Station 83 were made both while enroute up and while enroute down the mountain road. Furthermore, the departures at Station 83 were much larger than those observed at any other station. On most days, there was a noticeable anomaly in the barograph trace in that the afternoon minimum of the normal semi-diurnal pressure cycle was greatly exaggerated and extended until about sundown. It was followed invariably by an abrupt rise. Harmonic analysis of the pressure record at Station 83 showed the various diurnal components to be incompatible with the components at neighboring stations.

There seems to be no plausible way in which such a diurnal phenomenon, if physically real, could affect the barograph at this one station alone but not affect the aneroid barometers. Consequently, this discrepancy in the Station 83 pressure record has been tentatively attributed to instrumental defect, possibly a faulty temperature compensation mechanism.



DEPARTURE OF BAROGRAPH FROM ANEROID READING AT TIMES OF DIRECT COMPARISON

FIG. 7