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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

STRAIGHT LINE WIND VARIABILITY OVER SELECTED STATIONS ON LEEWARD OAHU

MICHAEL J. MORROW

PACIFIC REGION
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National Weather Service, Pacific Region Subseries

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TABLE OF CONTENTS

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I. PURPOSE

The purpose of this short experiment was to find out how the winds over selected stations on leeward Oahu vary under trade wind conditions. While making astronomical observations along the leeward coast with portable instruments, it had been noted that under "normal" trade winds distinct locations of calm or near calm and enhanced wind speed were encountered. It was believed that the Weather Service Forecast Office (WSFO), Honolulu was in an enhanced wind speed area and thus non-representative of the true wind speed of the relatively constant trade winds. While analysis of the data taken is not conclusive, it does show a tendency to support this belief.

II. SITE DESCRIPTIONS

An almost straight line of observation sites was chosen running from Kalihi, a section of Honolulu at the base of the Koolau Mountains, to the western end of Barbers Point Naval Air Station. (See Figure 1 in Appendix II). Intermediate points along this line used as observation sites were the WSFO Honolulu, Bishop Point, and Hale Hoku Observatory. The distance between stations from Kalihi to Hale Hoku is three miles. The distance between Hale Hoku and Barbers Point, five miles. The overall distance is fourteen miles.

All sites were selected to give maximum exposure to trade winds clear of nearby up-wind obstructions. From east to west, the site descriptions are as follows:

1. Kalihi. This site is next to the Likelike Highway, which runs from Honolulu to windward Oahu, in an area known as Kam Park. This park is located on the west side of the highway as well as the west side of Kalihi Valley. The pilot balloon (pibal) release point is located ninety-five feet above sea level.

2. WSFO Honolulu. The pibal site is the standard site at the Honolulu International Airport. Exposure is excellent in all directions. The pibal release point is fifty-two feet above sea level.

3. Bishop Point. This pibal release point is near the channel entrance to Pearl Harbor. Exposure is excellent in all directions. Releases were made from the end of a concrete pier five feet above sea level.

4. Hale Hoku Observatory. To the north of the selected release point there is a stand of one year old sugar cane. Some houses and trees are near the observatory but well clear of the release point on Hanakahi Street in front of the observatory. Pibal releases are made at seventeen feet above sea level.

5. Barbers Point. The site selected is at the Naval Air Station at the end of runway 11/29 at the west end of the runway along Midway Avenue. The site has excellent exposure with only knee high brush in the vicinity. The pibal release point is twenty-five feet above sea level.

III. EQUIPMENT USED AND METHOD OF OBSERVATION

Surface wind speed readings were taken with a hand-held anemometer supplied by the National Weather Service. Pibal readings were made using a clinometer at thirty second intervals up to five and one-half minutes for each run. These observations were made at all stations except WSFO Honolulu where the official readings for surface wind speed were used. Theodolite-obtained pibals from WSFO Honolulu were used for upper level wind speed when regularly scheduled releases occurred within the time span of observations for each run during this experiment. When a regularly scheduled pibal observation fell outside of the time interval involved in one complete observation at each of the selected sites, no upper air data were available for WSFO Honolulu for that particular part of the experiment. This has proved to be the most serious omission in attempting an analysis of the data. (See Appendix I for clinometer-theodolite comparison.)

Each run during the experiment commenced at the Kalihi site and terminated at the Barbers Point site. A truck was used to transport the investigators from point to point. Each run thus took approximately two hours to complete. Runs were only made when trade winds were well established and existed well above the gradient wind level (3000 feet). The six runs comprising the total experiment were broken down into two early day, one mid-day, two early evening, and one mid-evening. Constancy of the wind speed over the two hours necessary to complete a run was a major assumption. Although this is known to be only partially true, even using one minute wind averages, it was a necessary assumption.

IV. RESULTS

It is felt by the writer that no results in absolute terms may be stated; however, implied results as well as apparent trends appear to be meaningful.

The data show that Honolulu International Airport is under the influence of a low level wind maximum and that in forecasting Honolulu winds -- for both downtown and Waikiki -- a scale factor may be needed to bring the forecast and the observed winds into better agreement. Perhaps the winds recorded at Marine Corps Air Station (MCAS) Kaneohe directly exposed to off ocean trade winds would provide more representative information on the true speed of the low level trade winds.

The oscillating minimum (see pages 13-15) found between Bishop Point and Hale Hoku Observatory may be, at least near the surface, due to friction created by tall sugar cane, buildings and tall vegetation. However, a check of Figure 2 (Appendix II) indicates convergence from mountain valleys at Bishop Point. Little divergence or convergence is indicated for Hale Hoku Observatory. Hale Hoku is also about equidistant from both mountain ranges on Oahu.

An interesting point is brought forward for Barbers Point by the average wind speeds for all directions in Figure 3. This map is the result of forty years of wind observations over the sea from boats. Since the trades are so persistent, the map reflects the tradewind conditions in the area. There is a surface minimum in the area, although pibal observations indicate an increase in the wind. Sea breeze effect from two directions about the point is a possible reason for the surface minimum in the area. No closed circulation is indicated. It is not known what effect the Waianae Mountains may have in the Barbers Point area, but it is felt to be small.

Wave action in the wind in the lee of the Koolau Mountains may in part be responsible for regions of calms or enhanced wind speed. (See Figure 4.)

Funneling effects down canyons and valleys in the lee of the Koolaus are known to cause areas of accelerated winds offshore where boats paralleling the shore encounter frequent areas of strong winds followed by areas of little or no wind. Extending a line along the axis of these canyons and valleys implies an acceleration area near WSFO Honolulu and may explain the higher surface wind speeds noted at that location as compared to the other sites.

One side result of the data is the apparent usefulness sugar cane companies could make of the "Clinometer Method" of wind readings prior to burning cane fields. There is no doubt the wind variance is greater in other places on Oahu.

This short study, as with so many studies, is in need of more observations. It is felt that the suggested tendencies indicated by the experiment warrant a more comprehensive study made with enough personnel to allow simultaneous wind measurements.

V. ACKNOWLEDGMENTS

The author wishes to thank the following persons for their assistance in this experiment:

Sylvia K. Graff

Richard Sasaki

Edward M. Carlstead

APPENDIX I

The table below is an actual comparison between clinometer and theodolite readings taken under well established trade winds. Clinometer readings were always rounded to the nearest whole degree, both for the comparison and for the actual data. (All clinometer readings throughout the experiment were taken by the writer.)

MINUTE	CLINOMETER	THEODOLITE
1	26	26.1
2	24	23.7
3	22	22.4
4	23	22.1
5	21	20.1

In the above table only one reading, number four, is much different between the clinometer and the theodolite, yet the difference is not of sufficient magnitude to create false confidence in the overall data obtained by the method used. Clinometer readings are indeed quite comparable to theodolite readings.

A basic assumption made using clinometer readings to calculate wind speed is that the wind direction remains constant with height up to the gradient level. Although this point was not checked with any other instrumentation, all balloons released remained very nearly on the same azimuth from the observer indicating a very small directional change during the time required for each run. For this reason, errors in calculation of wind speed are considered negligible.

A. Normalization of the Wind

An attempt to normalize the surface wind speed was made since surface data were available at all sites. This was done by first determining the average wind speed for thirteen hourly observations centered on the hour nearest the mid-time of each run.

The Kaneohe Marine Corps Air Station (see Figure 1) is considered the most representative station on Oahu of the open ocean trade wind regime. This station reports hourly surface data.

The average taken as stated above was assumed to be the trade wind speed with most fluctuations removed. The average Kaneohe wind speed with most fluctuations removed. The average Kaneohe wind speed for all runs combined was ten knots. This wind speed was used as a base and all runs adjusted to it. Thus, a correction in terms of a percent was applied to each site to adjust the run to the "normal".

Run Number	Mean Wind (knots)	Correction in Percent
1	12	-20
2	12	-20
3	9	+10
4	9	+10
5	11	-10
6	7	+30

APPENDIX II

Figures

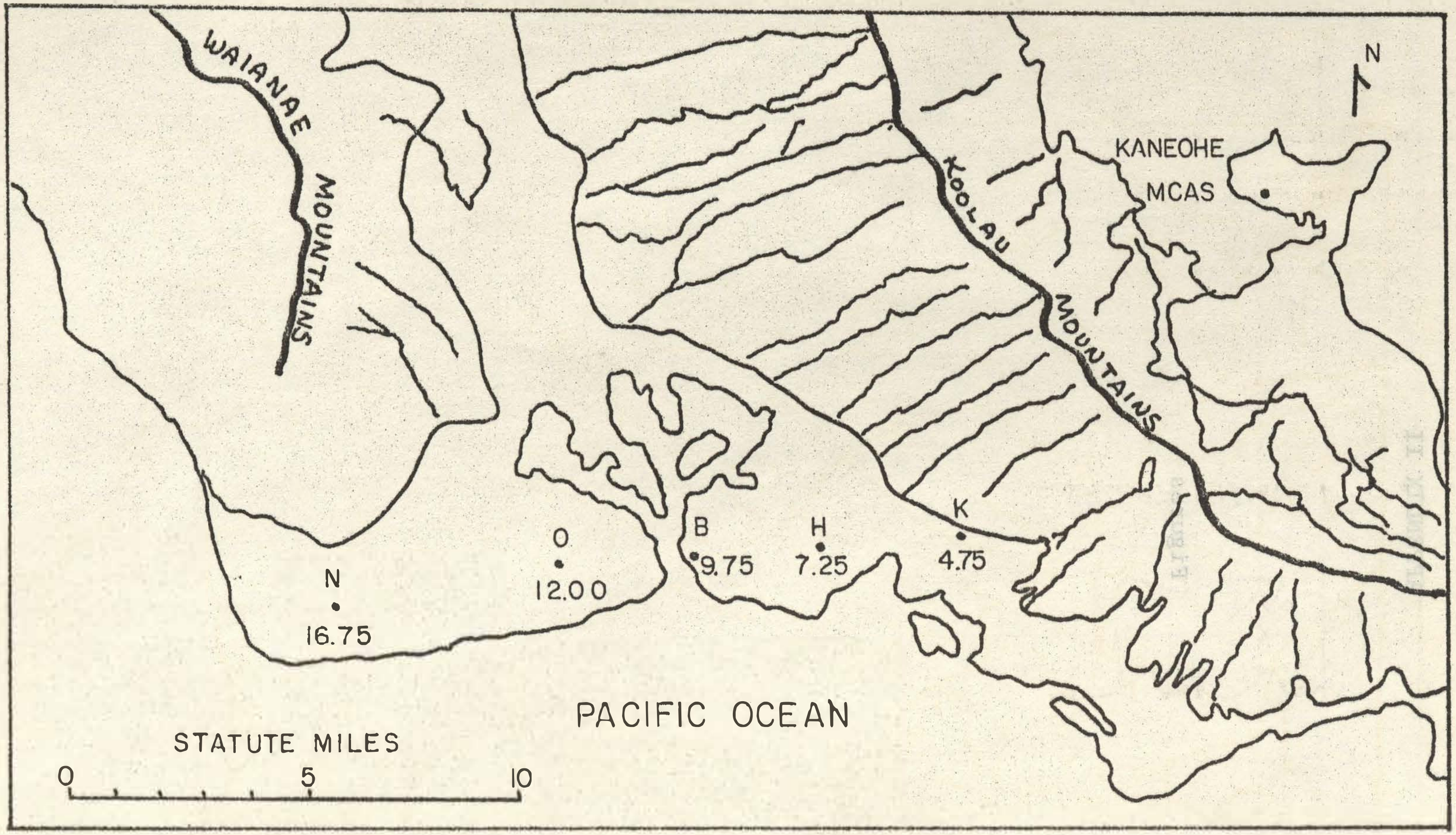


Figure 1

Locations of observing sites on Oahu: K = Kalihi, H = Honolulu International Airport, B = Bishop Point, O = Hale Hoku Observatory, N = Barbers Point Naval Air Station. The figure below each station is the perpendicular distance from the main Koolau Mountain ridge.

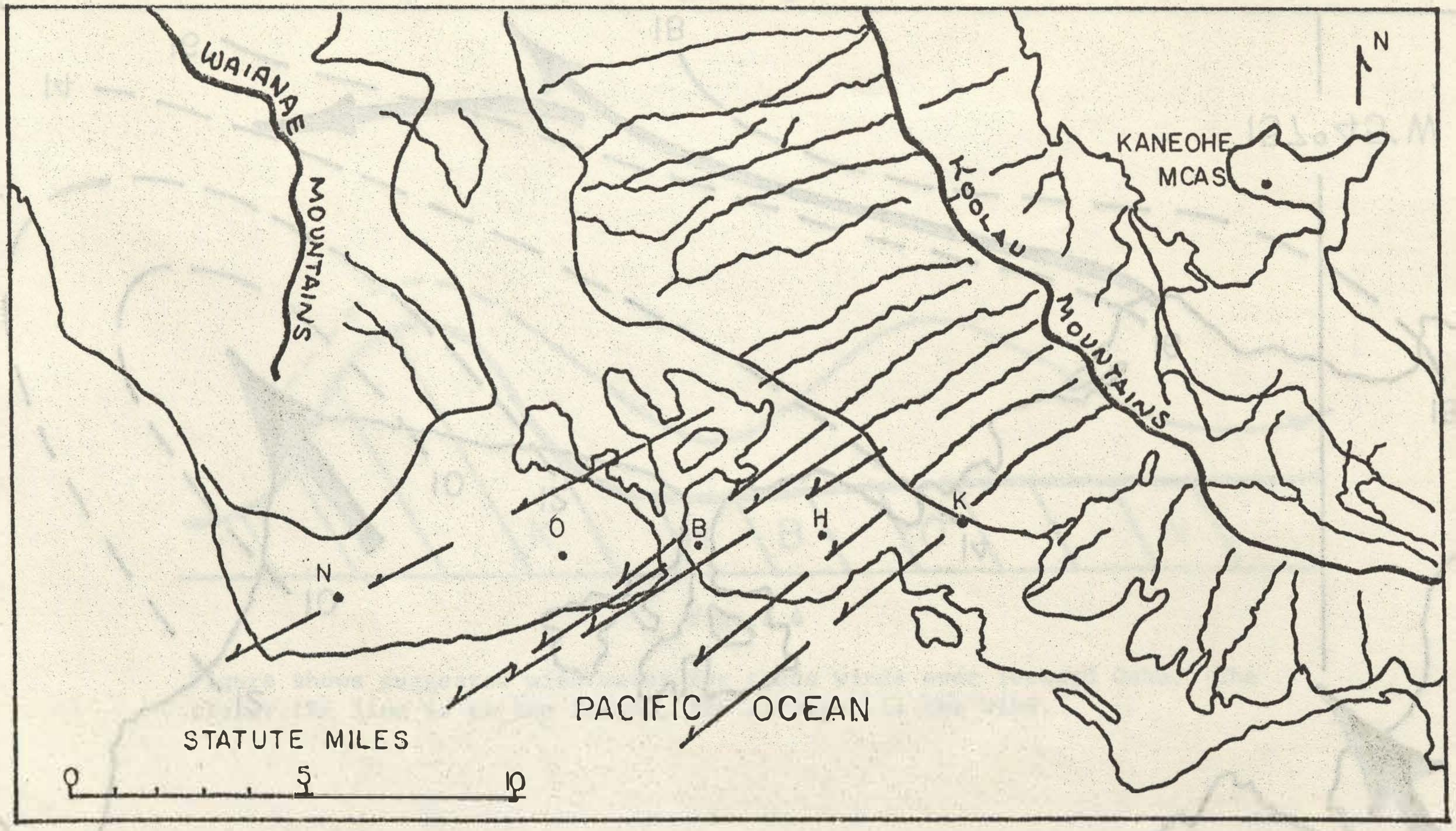


Figure 2

Shows apparent convergence and divergence at observing stations used in the experiment. Note the convergence at the Bishop Point site. Some divergence from mountain valleys is indicated for Barbers Point, Honolulu and Kalihi sites but no apparent convergence or divergence is indicated for Hale Hoku Observatory.

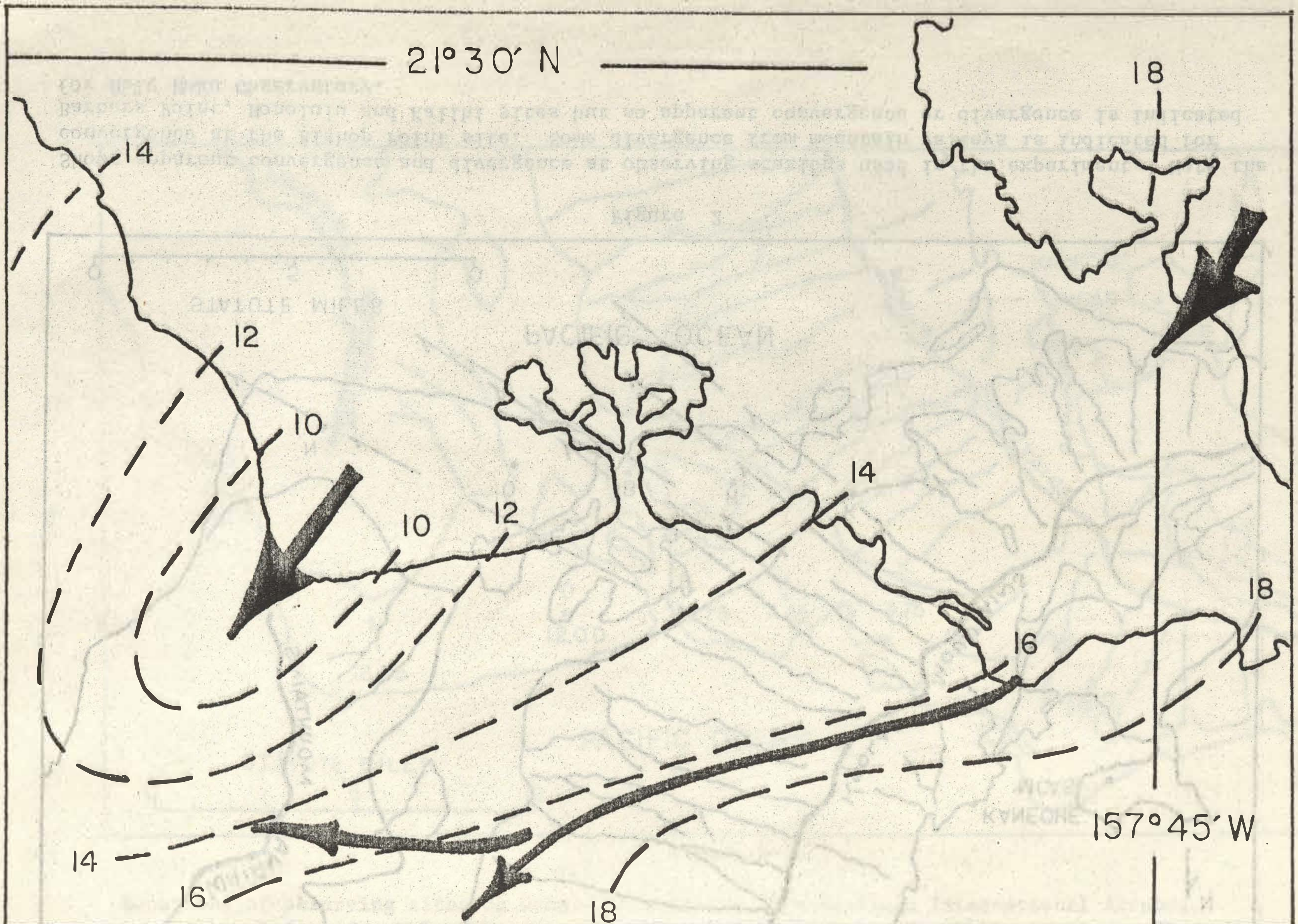


Figure 3

This map shows the result of forty years of wind observations taken from small boats off shore of leeward Oahu. Note the wind minimum off Barbers Point. This minimum is thought to be partially due to sea breeze effect.

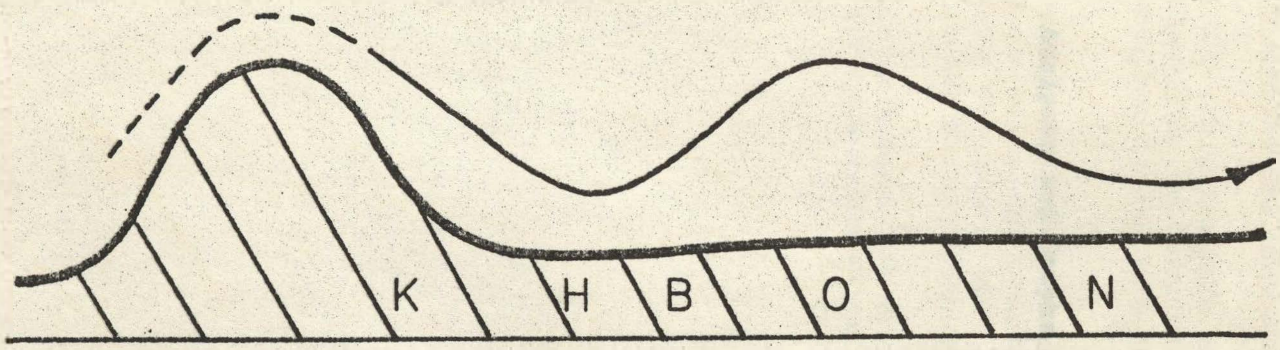


Figure 4

Figure shows suggested wind waves for trade winds over leeward Oahu. The closer the line is to the island, the stronger is the wind.

APPENDIX III

Analyses and Graphs

About the Analyses

The analyses which follow are all normalized in the same manner as the surface wind data to allow a continuous time cross section. Lacking upper wind data for Kaneohe, it has been assumed that the corrections will allow comparison with the surface wind data.

In general, the maxima and minima for the 710 foot and the 2010 foot level occur at the same location, although the shape and size are different. This may be a matter of analysis or the paucity of the data.

There are some differences between the surface analysis and the two upper levels. The greatest differences are noted between the surface and the 710 foot level. The reason for these differences is not readily apparent unless they are as noted above.

Each isotach is labeled with its respective value: 3, 5, 7, 9 knots and so forth. All times are Hawaiian Standard Time. Time runs up the right side of each analysis.

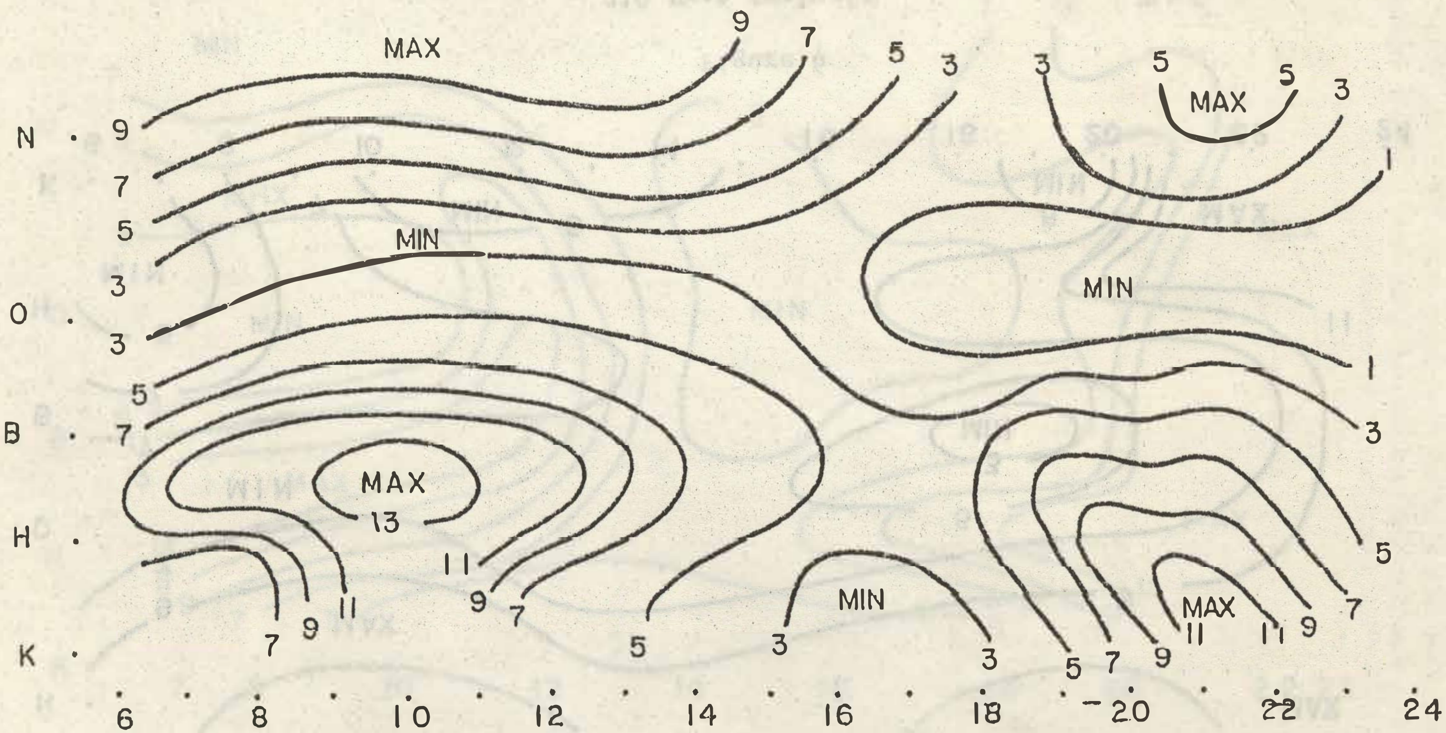


Figure 5

Surface Analysis

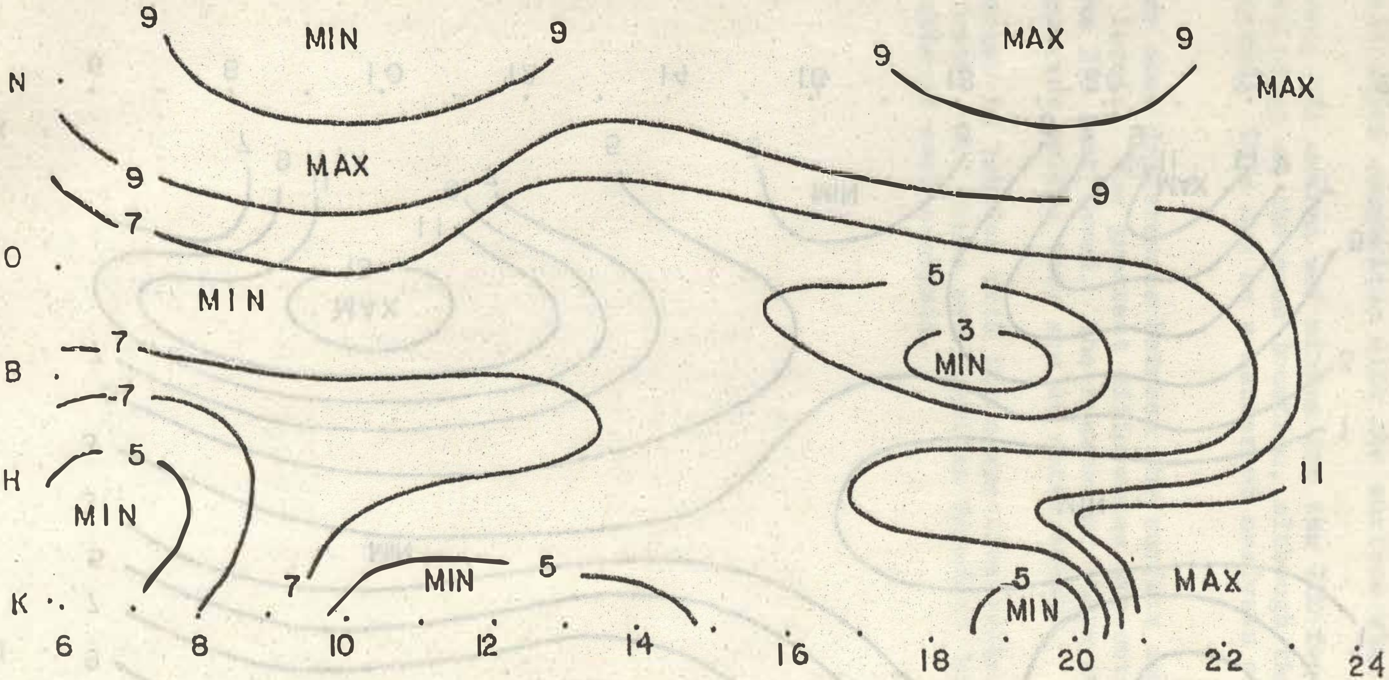


Figure 6

710 Foot Analysis

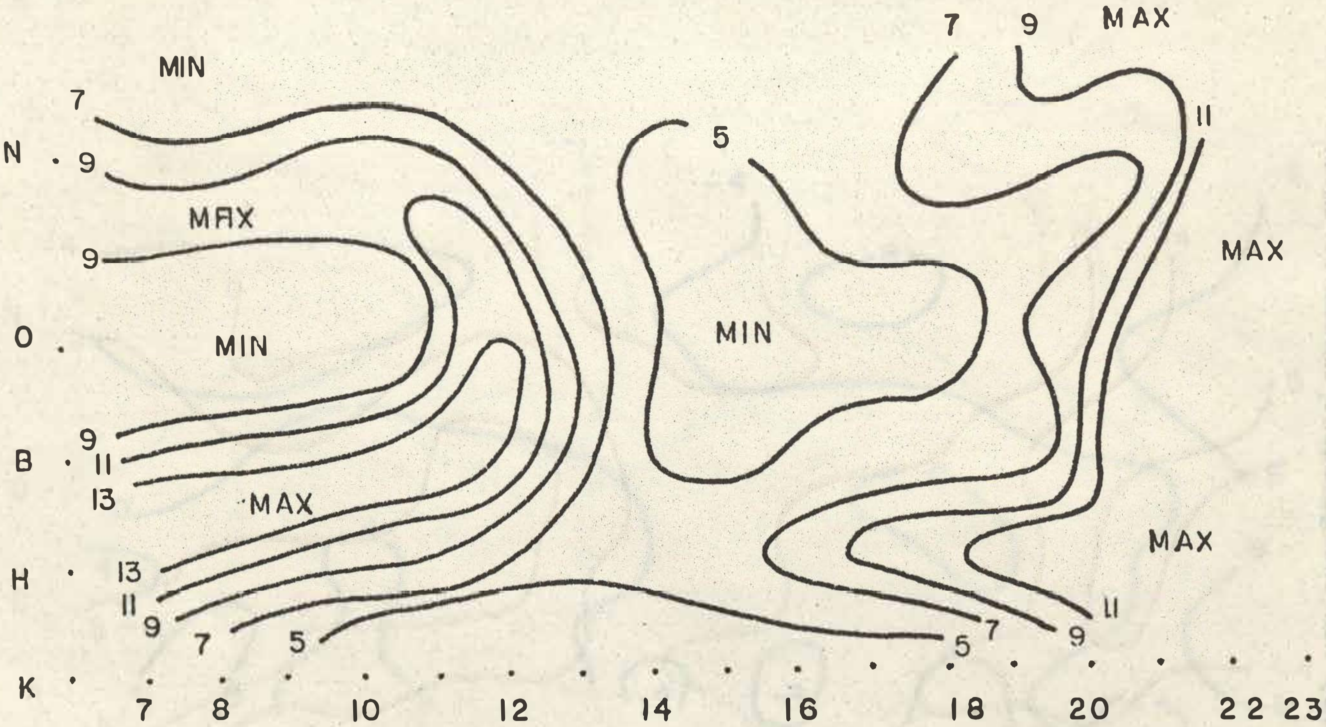


Figure 7

2010 Foot Analysis

Subtraction of Selected Levels

The two analyses which follow are subtractions of the surface level from the 710 foot level and the 710 foot level from the 2010 foot level. These show what might be expected, that is, that turbulent mixing is occurring during the middle of the day. These levels were selected because they had the greatest amount of data.

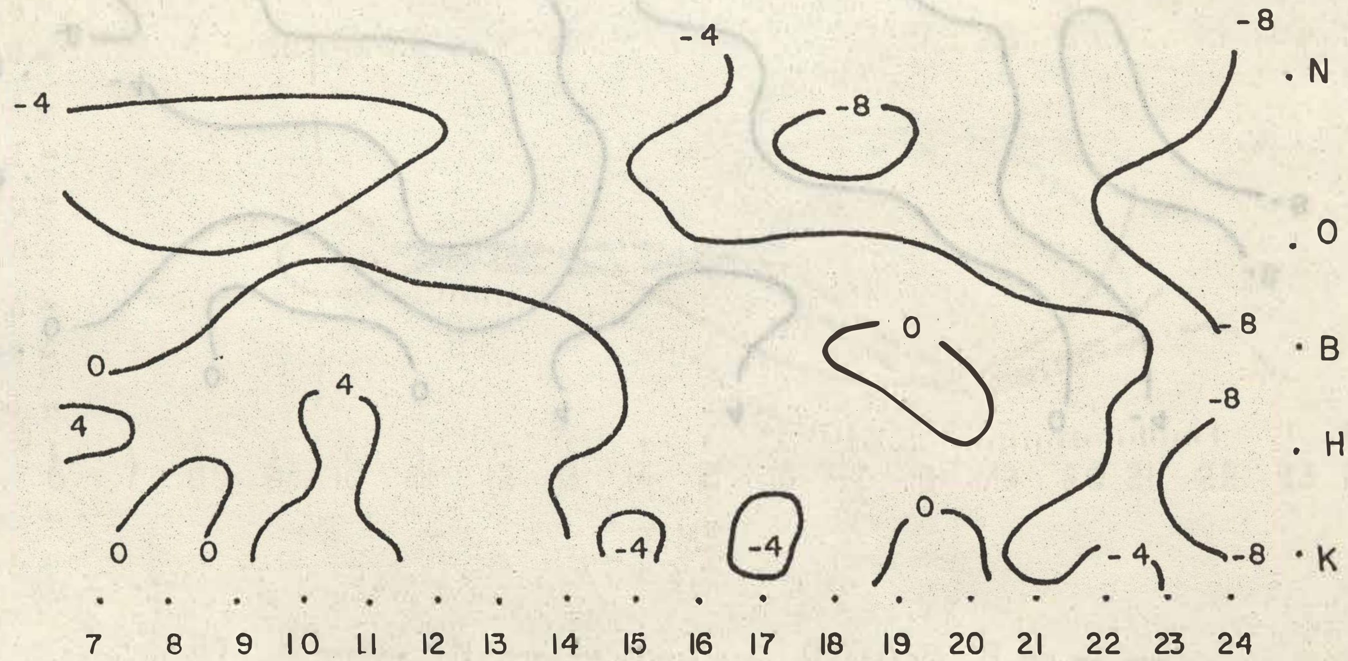


Figure 8

Surface minus 710 foot level

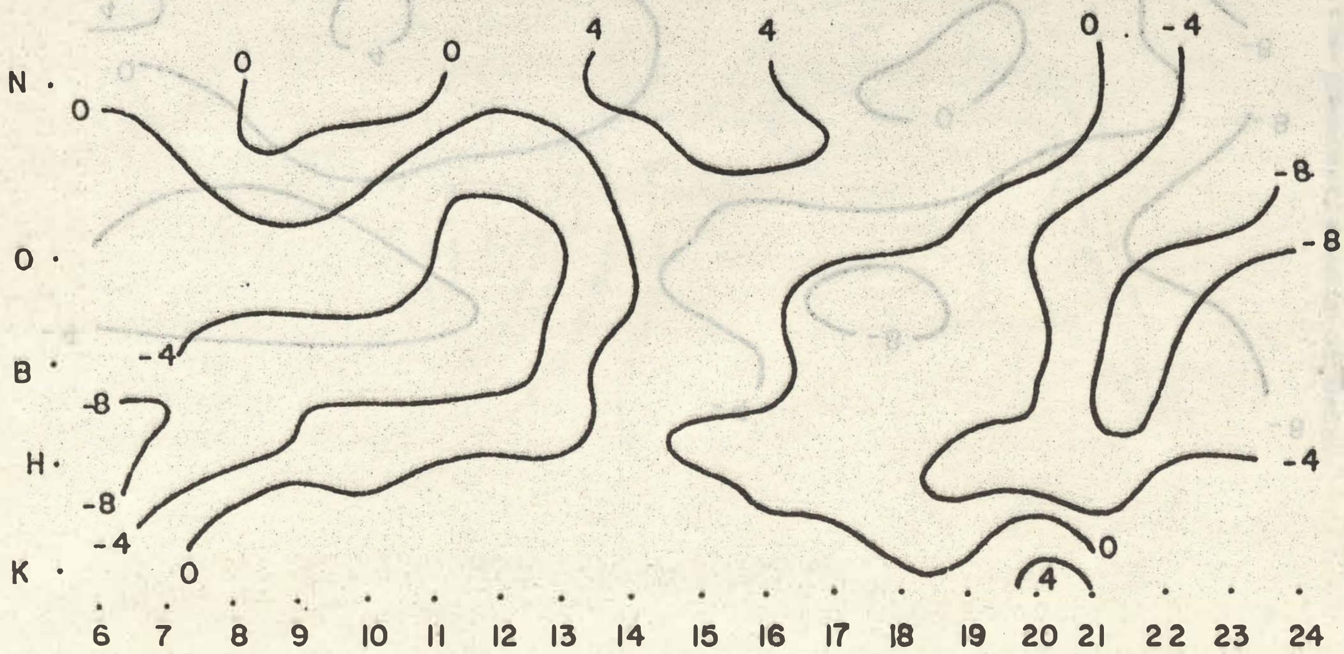


Figure 9

710 foot level minus 2010 foot level

Single Station Analysis

This analysis is the diurnal wind variation for each station. The data for each station has once again been normalized. A night-time maximum at Kalihi shows an enhancement of the trade flow due to down-slope motion.

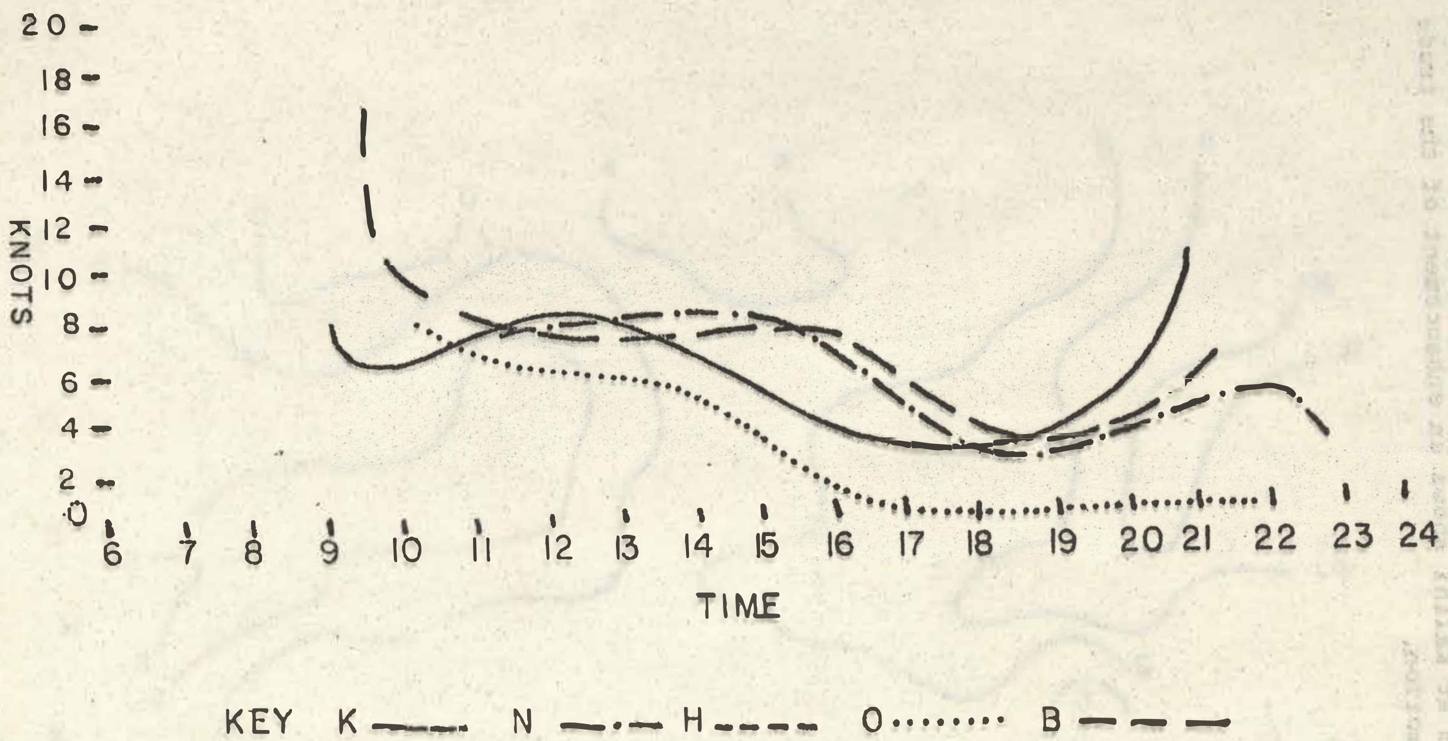
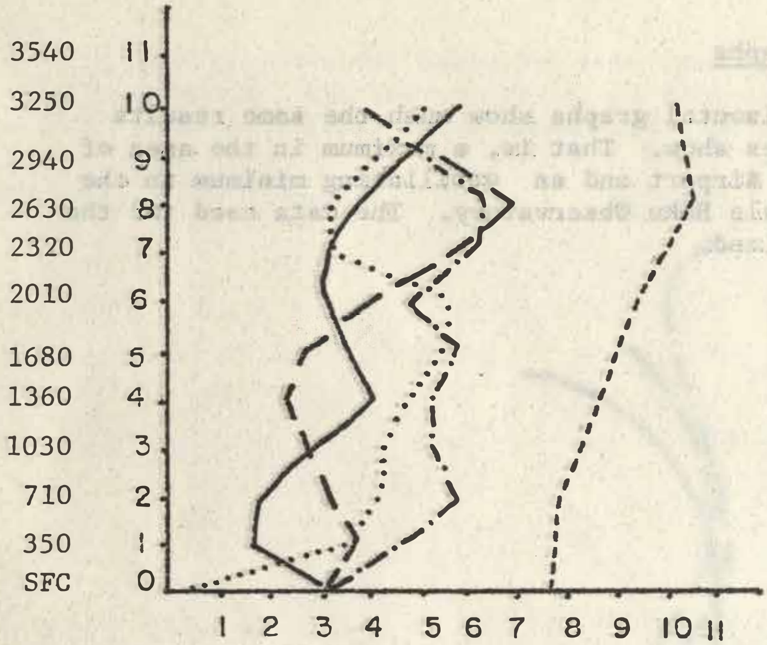


Figure 10

Single Station Analysis

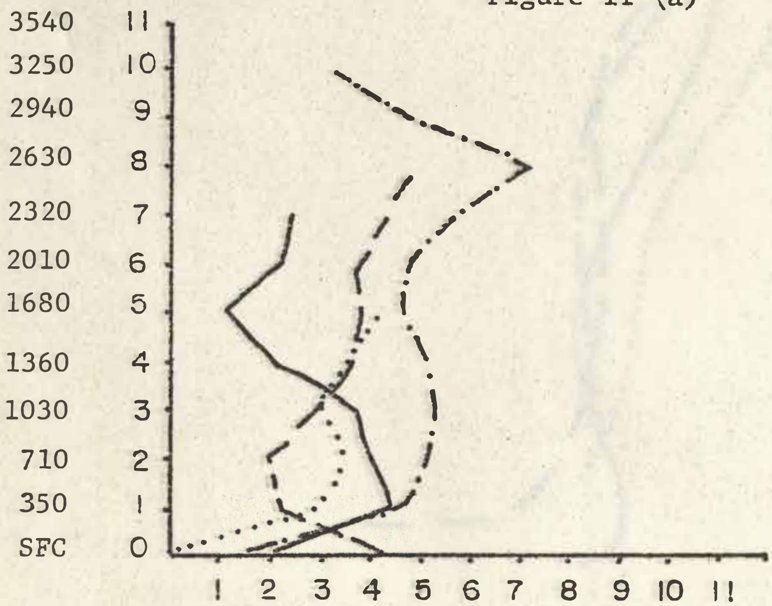
Vertical and Horizontal Graphs

The vertical and horizontal graphs show much the same results that the normalized analyses show. That is, a maximum in the area of the Honolulu International Airport and an oscillating minimum in the area of Bishop Point and Hale Hoku Observatory. The data used for the graphs has not been normalized.



1

Figure 11 (a)



2

KEY K ——— N —·—· H - - - - O ······ B — —

Figure 11 (b)

These graphs correspond to the horizontal graphs, that is, 1 and 1a go together. Vertical scale is altitude and reading number from data sheets. Horizontal scale is meters per second.

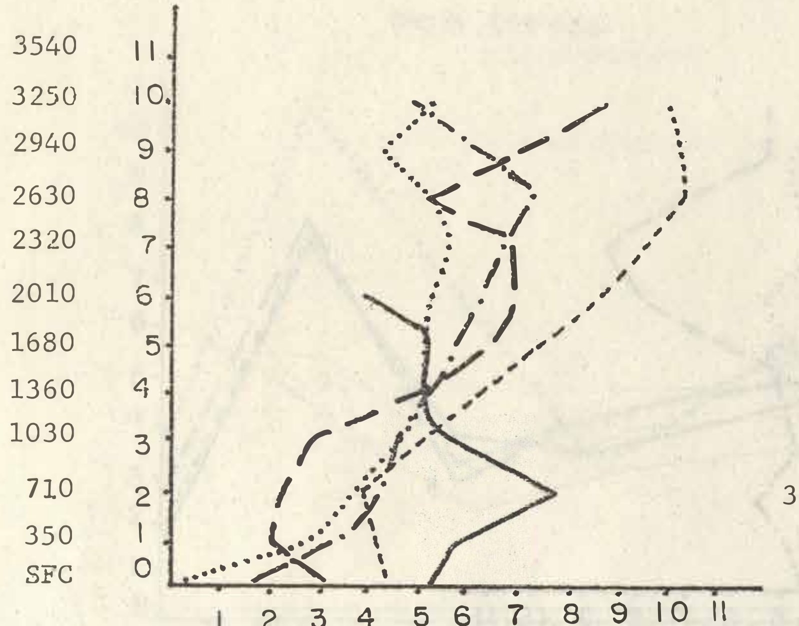


Figure 12 (a)

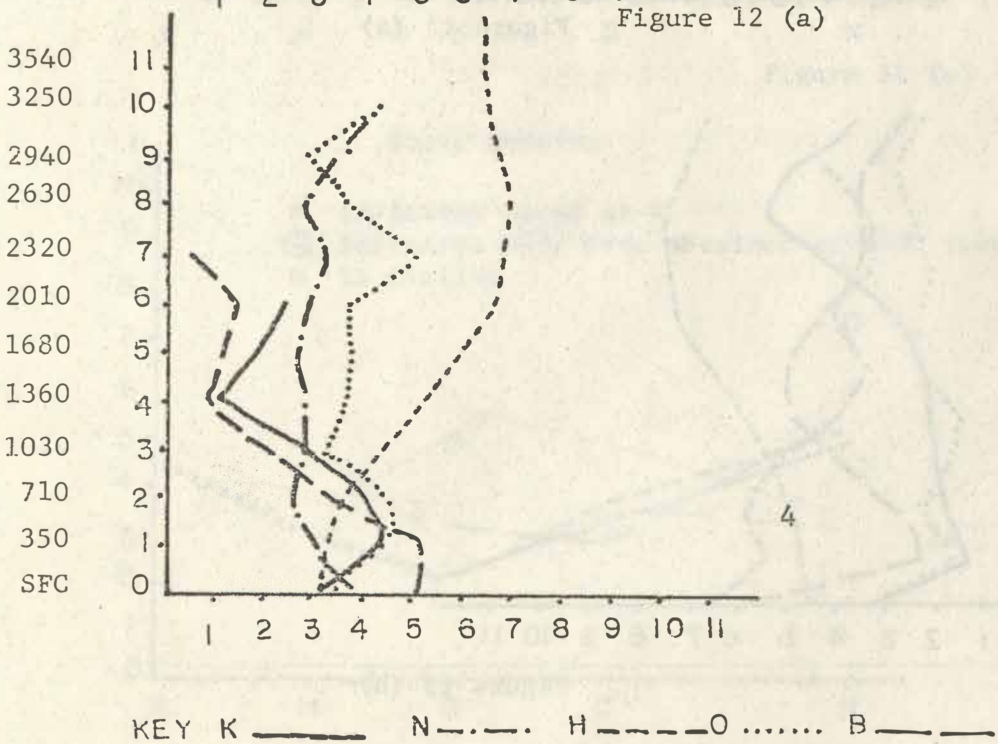


Figure 12 (b)

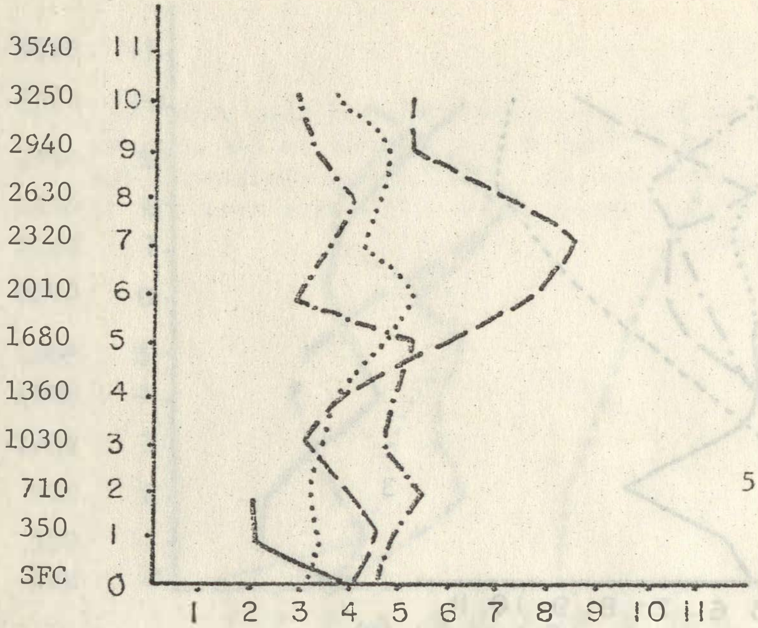


Figure 13 (a)

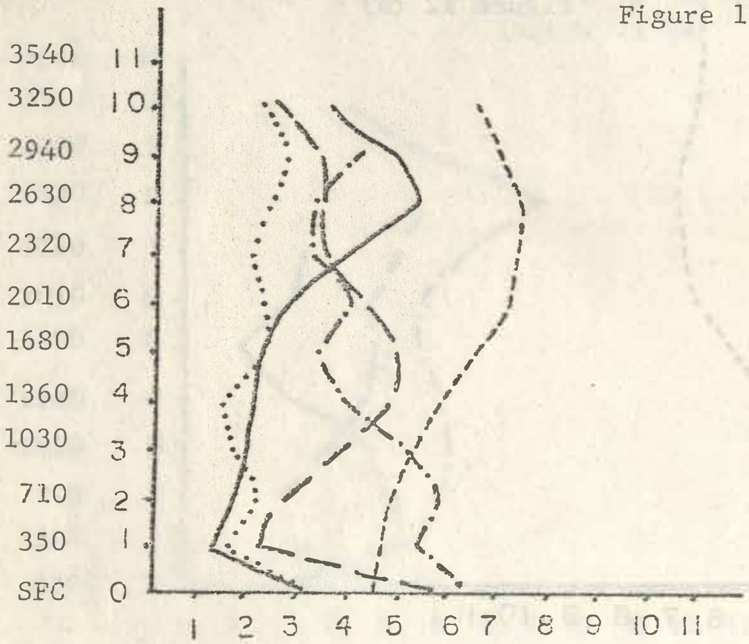


Figure 13 (b)

KEY K——— N —·— H - - - O ···· B — — —

Early Evening

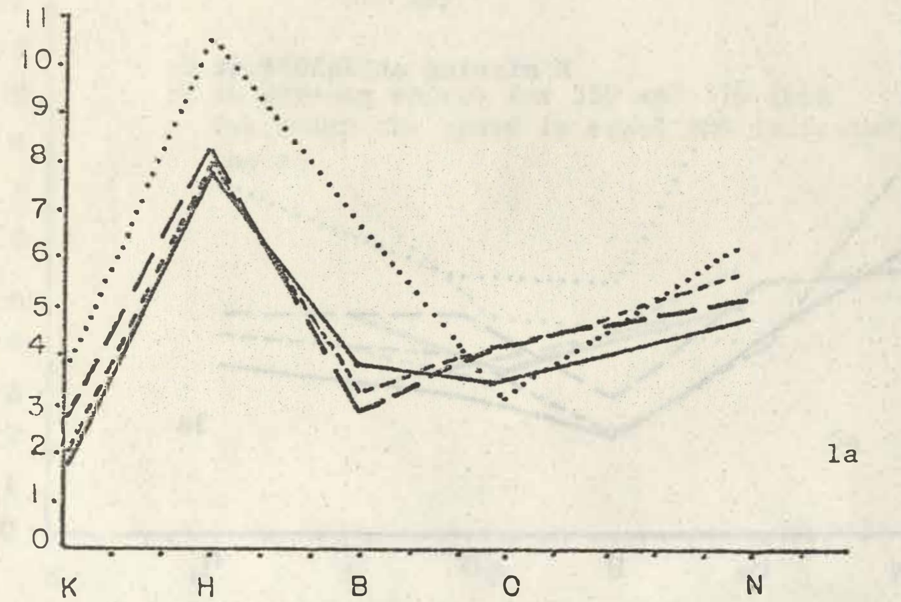
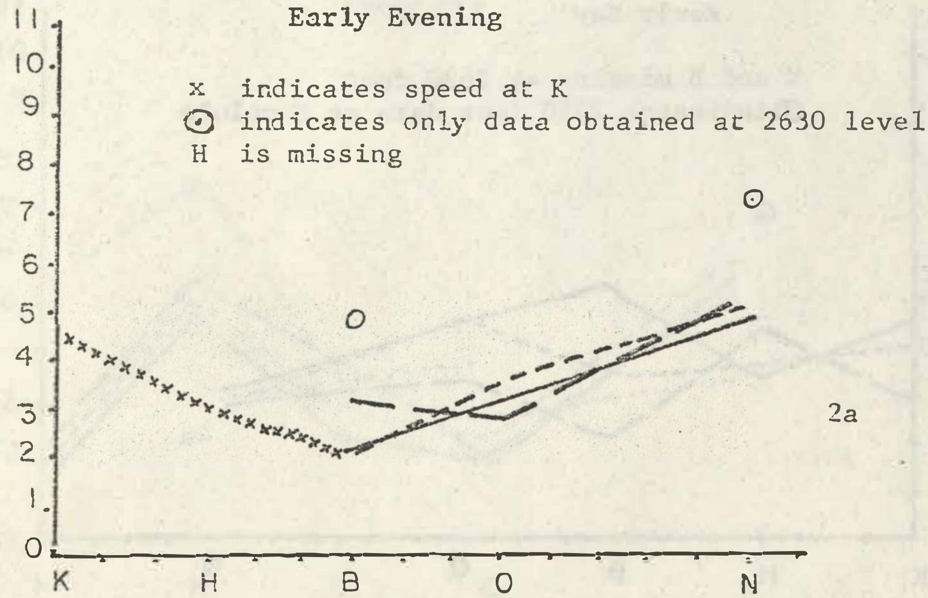


Figure 14 (a)



Altitude in feet

350 ——— 710 — — — 1030 —— —— 2630 ……

Data and vertical scale are in meters per second.
Horizontal scale is station and distance with distance to scale.

Figure 14 (b)

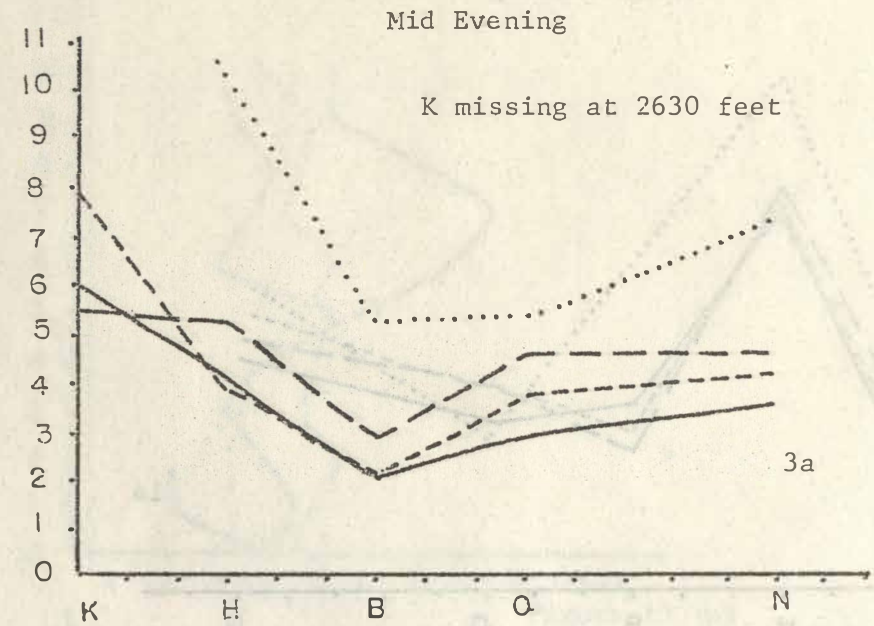


Figure 15 (a)

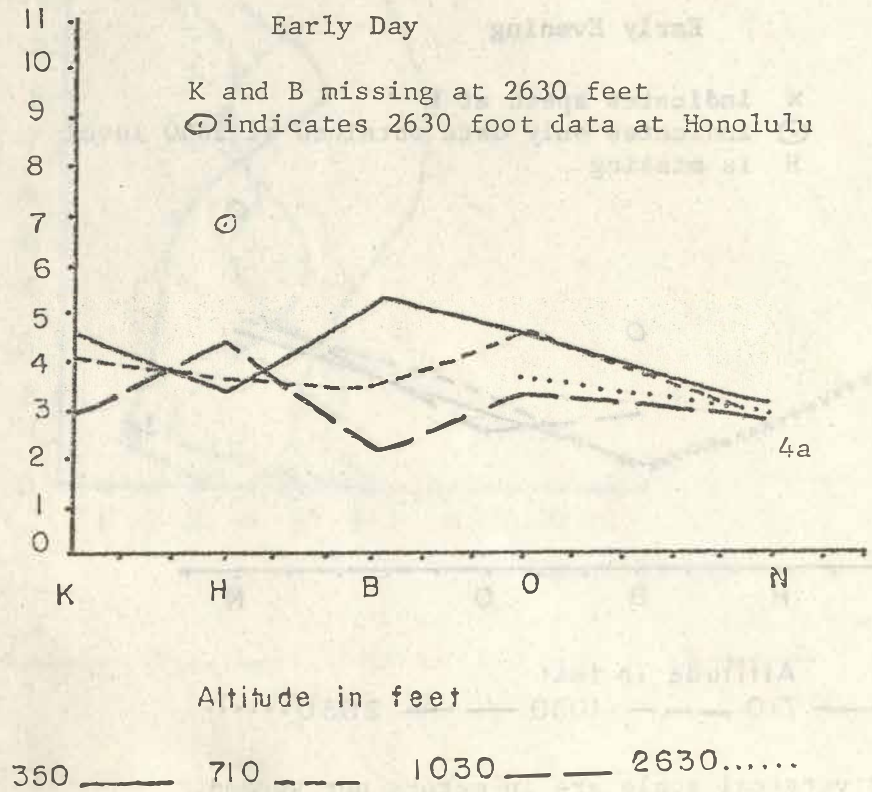


Figure 15 (b)

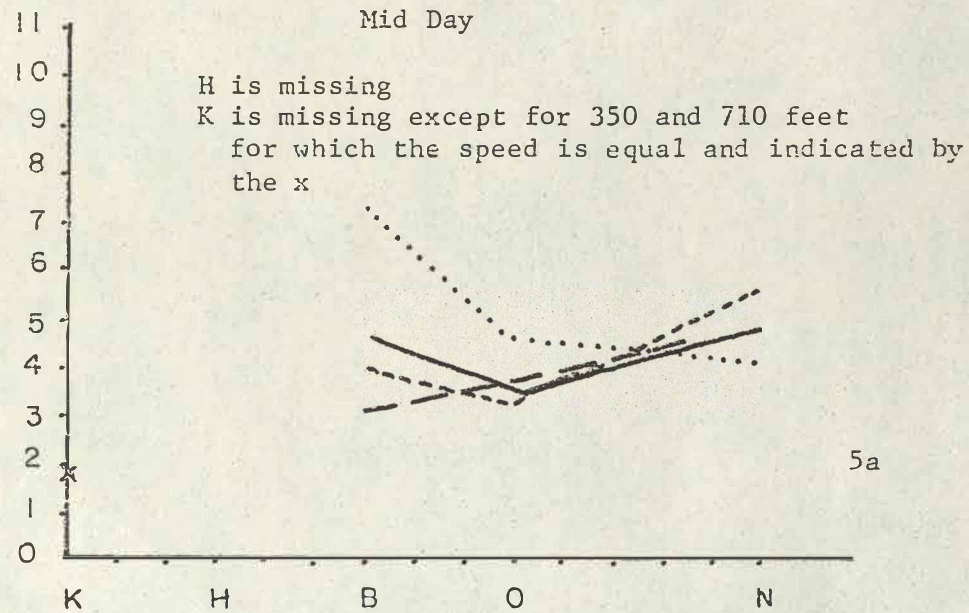


Figure 16 (a)

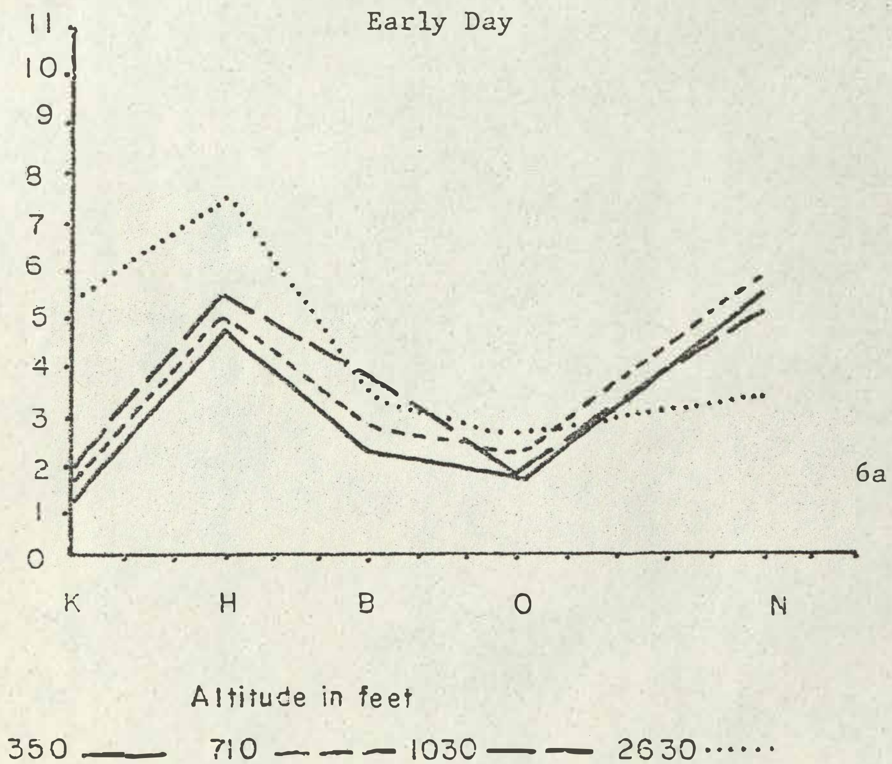


Figure 16 (b)