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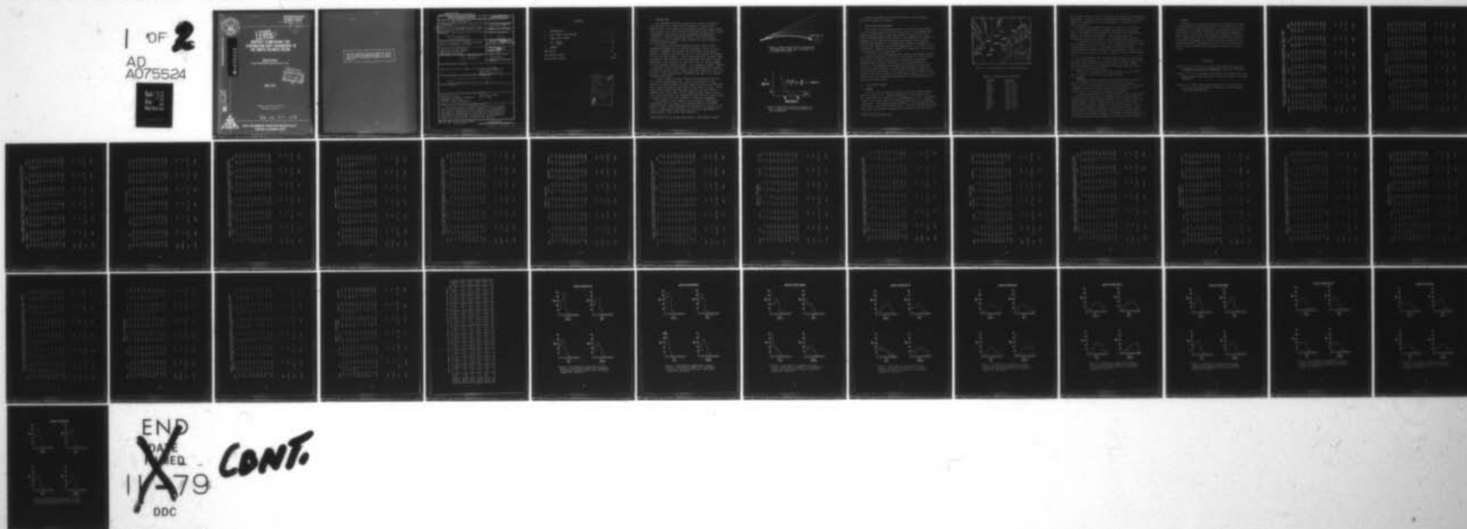

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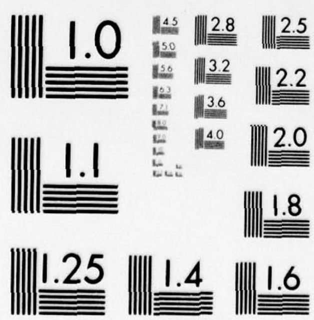


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NAVENVPREDRSCHFAC
TECHNICAL REPORT
TR 79-01



# MONTHLY CLIMATOLOGY FOR EVAPORATION DUCT OCCURRENCE IN THE NORTH ATLANTIC OCEAN

**Wayne Sweet**
Naval Environmental Prediction Research Facility



JUNE 1979





NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY
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**20. ABSTRACT (Continue on reverse side if necessary and identify by block number)**

Evaporation duct climatologies are given for 10 North Atlantic Ocean weather stations. Statistics for evaporation duct height, a measure of duct intensity, are presented in the forms of frequencies of occurrence for each month and histograms of percentages of occurrence for mid-months of each of the four seasons. These data can be used both for operational planning and as input to war gaming.



407 279 Gm

CONTENTS

## 1. INTRODUCTION

The atmosphere adjacent to the ocean surface is generally characterized by a strong vertical gradient in water vapor pressure due to the process of evaporation from the ocean surface. This gradient can cause trapping of microwave energy under certain combinations of microwave system parameters and atmospheric conditions. Known as evaporation ducts, these near-surface trapping regions are nearly always present in varying depths in the maritime environment.

The degree to which an evaporation duct affects signal propagation depends not only on duct thickness, but also on the emitter's frequency and antenna and the height of the target. Generally, however, the thicker the duct, the greater the bending of the rays (wave fronts) -- hence the greater the tracking range. Knowledge of the thickness of the evaporation duct gives a great advantage to any surface unit that uses radar or radio equipment in the microwave frequency region. As an example, Figure 1 depicts a situation in which the presence of an evaporation duct greatly extends the smaller vessel's radar detection capability, while the carrier's radar experiences no extended range due to its antenna frequency and height.

Figure 2 shows a typical refractivity profile for the case of a shallow evaporation duct. This is the region of sharp decrease in N with height in which radar/radio rays are refracted with a curvature greater than that of the earth's surface. After they reflect upward from the ocean surface, the rays refract downward until they again reflect upward off the ocean surface -- this cycle continues until attenuation diminishes the signal below a usable value, or the ray escapes*, or the duct disappears.

The purpose of this report is to provide a climatology of evaporation duct occurrence for selected regions in the North Atlantic Ocean. This information is expected to be useful to the Fleet in operational planning as well as in the development of meteorological input to war game scenarios.

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*These ducts are not perfect wave guides; some energy escapes.

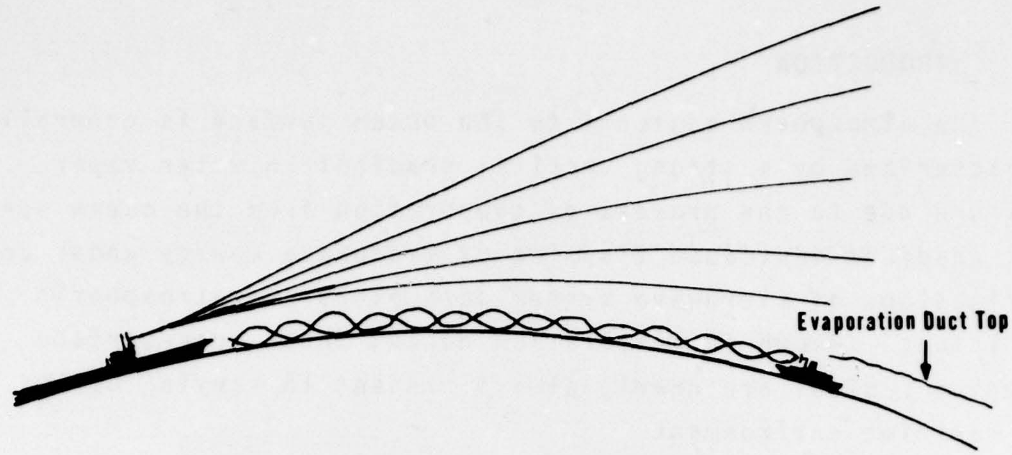


Figure 1. Near-surface emitter experiences extended radar range due to presence of an evaporation duct.

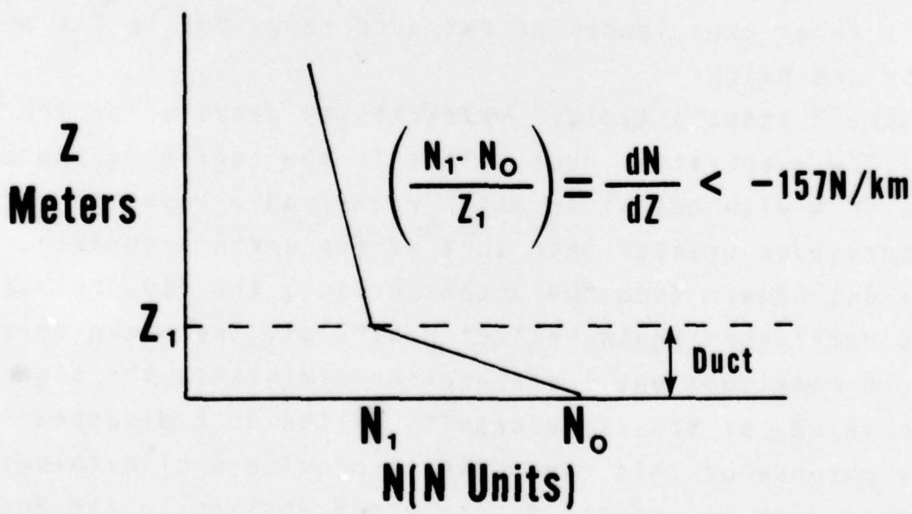


Figure 2. Typical refractivity profile of N vs. height when a shallow evaporation duct is present.

Data are provided for 10 ocean stations at the locations defined in Figure 3 and Table 1.

## 2. DUCT HEIGHT CALCULATIONS

The height of an evaporation duct is the calculated distance from the ocean surface to the top of the duct. The procedure for determining duct height, based on a method originated by Jeske (1971) and modified by Hitney (1975), uses boundary layer theory to parameterize the physical processes and requires four surface-observed measurements -- air temperature, dew point temperature, surface wind speed, and sea surface temperature -- as inputs to the calculation. (Because of their number and complexity, the calculation equations are not given here.)

As given in this memorandum, duct height calculations used all the surface observations except for those nearest to 1200 and 1500 local time. In these latter cases, preliminary computations revealed that a diurnal variation in duct height resulted if statistics were generated from observations during the warm part of the day; these diurnal variations were generally strong and statistically significant.* Such diurnal variations appear to be caused by the mass of the ship itself, which, acting like an island, tends to bias air temperature measurements by warming during the day and cooling at night.

## 3. TABLES AND FIGURES

### 3.1 Tables

Data for the 10 ocean stations are listed by station and by month in Tables 2-11. Grouped frequencies of occurrence (in %) are given for duct heights in 3 m increments up to 21 m; the larger heights 21-30 m and >30 m are given to contain the less frequent occurrences. The undefined group (UNDEF) is for those observations with zero or nearly zero surface winds. The first column under each month gives the percent frequency distribution of the particular

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*Based on a Chi-Square test.

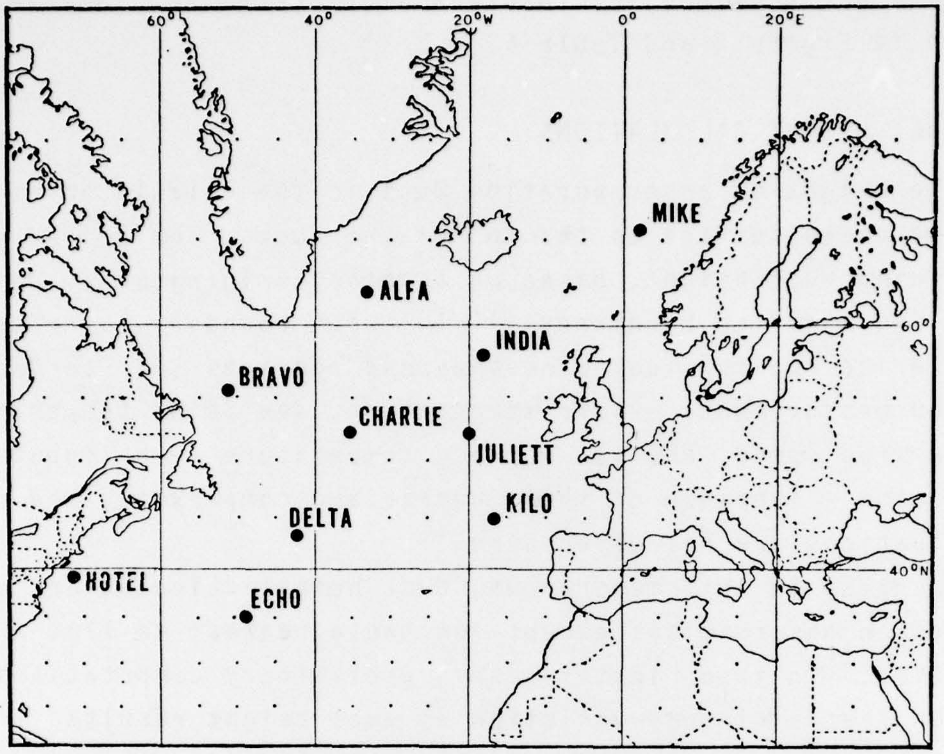


Figure 3. Ocean stations in the North Atlantic.

Table 1. Ocean station locations.

| Station | Location |
|---|---|
| ALFA | 62°N, 33°W |
| BRAVO | 56°N, 51°W |
| CHARLIE | 52°N, 35°W |
| DELTA | 44°N, 41°W |
| ECHO | 35°N, 48°W |
| HOTEL | 39°N, 71°W |
| INDIA | 58°N, 19°W |
| JULIETT | 52°N, 20°W |
| KILO | 45°N, 18°W |
| MIKE | 66°N, 2°E |

duct height, and the second column gives the cumulative distribution percentage. The mean, median, interquartile range (IQR), and total number of observations for the month appear in descending order under each month.

The mean is the average of the duct heights for the given month, and therefore can be strongly influenced by a few high ducts. The median is the height value at which half of the duct heights are below and half above. The median value, less influenced by such rare events, is a more meaningful statistic.

For example, July of ocean station ECHO shows a mean of 20.7 m and a median of 14.7 m (Table 6). The frequency distribution shows a mode between 9 and 15 m. The median therefore is a more representative indicator (statistic) than the mean in this case (notice also the relatively higher frequency of duct heights above 30 m).

The IQR represents the lower and upper bounds for the middle 50% of the duct heights, i.e., 25% of the ducts have heights below the lower number and 75% have heights below the upper number. Therefore, the IQR can be viewed as an indicator of the spread, or variation, of the duct height.

Table 12 is a summary of the median values of duct heights for each month at each of the 10 ocean stations.

### 3.2 Figures

Histograms of duct occurrence for the mid-months of each of the four seasons at each of the ocean stations are shown in Figures 4-13. The horizontal axis gives duct heights in the nine increments (from 0-3 through >30 m) used in Tables 2-11; the vertical axis is percentage frequency of occurrence.

The mode (group that occurs most frequently) can be determined easily from the histograms; for example, ocean station CHARLIE (Figure 6) has a winter/January mode of 6-9 m, nearly a dual mode. The histograms provide a quick-look overview of distribution shapes and the seasonal changes in these distributions. Using the single mid-month to represent a season gives greater accent to the shift in the distribution from season to season, moreso than would a three-month average. The tables of distributions can be used directly for those months not plotted on the histograms.

## 4. SUMMARY

Evaporation duct height statistics were generated for the 10 ocean stations in the North Atlantic. The objective of this climatology is to provide guidance to operational planners and data input to war gaming, regarding the expected evaporation duct heights in the ocean areas addressed. Seasonal variations can be determined from the histograms (Figures 4-13) showing mid-months' percentages of occurrence of duct heights for the 10 ocean stations. The information given in this report can be used as input to NOSC TD-144 to determine effects on specific radars.

## REFERENCES

Jeske, H., 1971: The state of radar range prediction over sea. Tropospheric Radio Wave Propagation - Part II. NATO-AGARD.

Hitney, H.V., 1975: Propagation modeling in the evaporation duct. NELC TR 1947. Naval Electronics Laboratory Center, San Diego, CA 92152.

Hitney, H.V., 1978: Surface duct effects on fleet radars (U). Naval Ocean Systems Center, San Diego, CA 92152. (Report classified CONFIDENTIAL)

Table 2. Monthly percentage frequencies of occurrence of duct heights, ocean station ALFA. Data presentation discussed in text, Para. 3.1.

| HT(M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 12.9 | 12.9 | 16.4 | 16.4 | 18.2 | 18.2 | 21.7 | 21.7 | 26.1 | 26.1 | 33.4 | 33.4 |
| 3-6 | 31.9 | 44.8 | 30.6 | 46.9 | 31.0 | 49.1 | 31.9 | 53.5 | 36.5 | 62.6 | 32.4 | 65.8 |
| 6-9 | 38.0 | 82.8 | 36.5 | 83.4 | 37.7 | 86.8 | 32.6 | 86.1 | 26.0 | 88.6 | 23.2 | 89.0 |
| 9-12 | 14.9 | 97.8 | 14.0 | 97.4 | 11.3 | 98.2 | 10.7 | 96.8 | 7.3 | 95.9 | 6.1 | 95.1 |
| 12-15 | 1.2 | 99.0 | 1.4 | 98.8 | .8 | 99.0 | 1.2 | 98.0 | 1.0 | 96.9 | .9 | 96.0 |
| 15-18 | .0 | 99.1 | .1 | 98.9 | .1 | 99.1 | .2 | 98.2 | .4 | 97.3 | .2 | 96.2 |
| 18-21 | 0.0 | 99.1 | 0.0 | 98.9 | 0.0 | 99.1 | .1 | 98.2 | .1 | 97.4 | .2 | 96.3 |
| 21-30 | 0.0 | 99.1 | 0.0 | 98.9 | .0 | 99.1 | .1 | 98.3 | .1 | 97.5 | .2 | 96.6 |
| >30 | 0.0 | 99.1 | 0.0 | 98.9 | .0 | 99.1 | .3 | 98.6 | .5 | 98.0 | .9 | 97.4 |
| UNDEF | .9 | 100.0 | 1.1 | 100.0 | .9 | 100.0 | 1.4 | 100.0 | 2.0 | 100.0 | 2.6 | 100.0 |
| MEAN | | 6.2 | | 5.9 | | 5.7 | | 5.6 | | 5.1 | | 4.9 |
| MEDIAN | | 6.4 | | 6.3 | | 6.1 | | 5.7 | | 5.0 | | 4.5 |
| IQR | 4.1- 8.4 | | 3.8- 8.3 | | 3.7- 8.1 | | 3.3- 8.0 | | 2.9- 7.4 | | 2.2- 7.2 | |
| TOTAL | 4091. | | 3577. | | 3915. | | 3996. | | 4016. | | 3805. | |

Table 2, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 26.7 | 26.7 | 20.6 | 20.6 | 16.2 | 16.2 | 15.6 | 15.6 | 16.2 | 16.2 | 12.0 | 12.0 |
| 3-6 | 38.1 | 64.8 | 33.2 | 53.8 | 26.5 | 42.7 | 26.4 | 42.1 | 28.0 | 44.2 | 27.1 | 39.0 |
| 6-9 | 22.7 | 87.5 | 27.4 | 81.2 | 31.0 | 73.6 | 32.3 | 74.4 | 35.1 | 79.3 | 36.4 | 75.5 |
| 9-12 | 6.2 | 93.7 | 12.0 | 93.2 | 18.7 | 92.4 | 18.7 | 93.1 | 15.5 | 94.8 | 19.4 | 94.9 |
| 12-15 | 1.1 | 94.8 | 3.3 | 96.5 | 4.9 | 97.2 | 4.2 | 97.4 | 3.4 | 98.2 | 3.2 | 98.1 |
| 15-18 | .4 | 95.2 | .5 | 96.9 | .9 | 98.1 | .8 | 98.2 | .4 | 98.6 | .1 | 98.2 |
| 18-21 | .2 | 95.3 | .3 | 97.2 | .1 | 98.2 | .2 | 98.4 | 0.0 | 98.6 | 0.0 | 98.2 |
| 21-30 | .3 | 95.6 | .2 | 97.4 | .1 | 98.2 | .0 | 98.4 | .1 | 98.7 | 0.0 | 98.2 |
| >30 | .6 | 96.2 | .5 | 97.9 | .2 | 98.4 | .0 | 98.4 | .0 | 98.7 | 0.0 | 98.2 |
| UNDEF | 3.8 | 100.0 | 2.1 | 100.0 | 1.6 | 100.0 | 1.6 | 100.0 | 1.3 | 100.0 | 1.8 | 100.0 |
| MEAN | | 5.0 | | 5.9 | | 6.6 | | 6.5 | | 6.2 | | 6.6 |
| MEDIAN | | 4.8 | | 5.7 | | 6.7 | | 5.7 | | 6.5 | | 6.9 |
| IQR | 2.8- 7.3 | | 3.4- 8.3 | | 4.0- 9.2 | | 4.1- 9.1 | | 3.9- 8.6 | | 4.4- 9.0 | |
| TOTAL | 3977. | | 3933. | | 3811. | | 4128. | | 3828. | | 3969. | |

Table 3. Monthly percentage frequencies of occurrence of duct heights, ocean station BRAVO. Data presentation discussed in text, Para. 3.1.

| HT (M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 13.2 | 13.2 | 16.5 | 16.5 | 19.4 | 19.4 | 22.1 | 22.1 | 35.2 | 35.2 | 44.3 | 44.3 |
| 3-6 | 44.4 | 57.6 | 46.8 | 63.3 | 40.8 | 60.2 | 41.4 | 63.5 | 39.7 | 74.9 | 36.4 | 80.7 |
| 6-9 | 37.0 | 94.6 | 32.4 | 95.7 | 34.2 | 94.4 | 29.8 | 93.3 | 18.9 | 93.8 | 13.4 | 94.0 |
| 9-12 | 4.7 | 99.3 | 3.3 | 99.0 | 4.5 | 98.9 | 4.7 | 98.0 | 3.7 | 97.5 | 2.5 | 96.5 |
| 12-15 | .1 | 99.4 | .1 | 99.1 | .2 | 99.1 | .6 | 98.6 | .3 | 97.8 | .5 | 97.0 |
| 15-18 | .0 | 99.5 | .1 | 99.2 | .0 | 99.1 | .1 | 98.7 | .1 | 97.9 | .4 | 97.4 |
| 18-21 | 0.0 | 99.5 | 0.0 | 99.2 | .1 | 99.2 | .1 | 98.8 | .1 | 98.0 | .1 | 97.5 |
| 21-30 | .0 | 99.5 | 0.0 | 99.2 | 0.0 | 99.2 | .1 | 98.9 | .2 | 98.1 | .3 | 97.8 |
| >30 | 0.0 | 99.5 | .0 | 99.2 | .1 | 99.3 | .3 | 99.2 | .4 | 98.5 | .3 | 98.1 |
| UNDEF | .5 | 100.0 | .8 | 100.0 | .7 | 100.0 | .8 | 100.0 | 1.5 | 100.0 | 1.9 | 100.0 |
| MEAN | | 5.5 | | 5.1 | | 5.2 | | 5.2 | | 4.3 | | 3.8 |
| MEDIAN | | 5.5 | | 5.1 | | 5.3 | | 5.0 | | 4.1 | | 3.5 |
| IQR | 3.8- 7.4 | | 3.5- 7.1 | | 3.4- 7.3 | | 3.2- 7.2 | | 2.1- 6.0 | | 1.7- 5.5 | |
| TOTAL | 4410. | | 3891. | | 4328. | | 4349. | | 4346. | | 4260. | |

Table 3, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 58.4 | 58.4 | 38.3 | 38.3 | 18.7 | 18.7 | 12.7 | 12.7 | 14.4 | 14.4 | 12.1 | 12.1 |
| 3-6 | 27.9 | 86.4 | 32.5 | 70.9 | 26.8 | 45.5 | 26.5 | 39.2 | 34.7 | 49.1 | 35.9 | 48.0 |
| 6-9 | 8.0 | 94.3 | 18.6 | 89.5 | 29.7 | 75.1 | 34.6 | 73.8 | 37.7 | 86.8 | 42.9 | 90.9 |
| 9-12 | 1.4 | 95.8 | 5.9 | 95.4 | 18.6 | 93.7 | 21.3 | 95.1 | 11.4 | 98.3 | 8.1 | 99.0 |
| 12-15 | .5 | 96.3 | 1.2 | 96.6 | 4.4 | 98.2 | 3.5 | 98.7 | 1.0 | 99.2 | .3 | 99.3 |
| 15-18 | .2 | 96.5 | .1 | 96.6 | .3 | 98.5 | .2 | 98.8 | 0.0 | 99.2 | .0 | 99.3 |
| 18-21 | .1 | 96.5 | .3 | 96.9 | .1 | 98.6 | .0 | 98.9 | 0.0 | 99.2 | 0.0 | 99.3 |
| 21-30 | .4 | 96.9 | .3 | 97.3 | .1 | 98.7 | .0 | 98.9 | 0.0 | 99.2 | .0 | 99.3 |
| >30 | .4 | 97.3 | .4 | 97.7 | .3 | 99.0 | .2 | 99.1 | .1 | 99.3 | .0 | 99.4 |
| UNDEF | 2.7 | 100.0 | 2.3 | 100.0 | 1.0 | 100.0 | .9 | 100.0 | .7 | 100.0 | .5 | 100.0 |
| MEAN | 3.0 | | 4.4 | | 6.5 | | 6.8 | | 5.9 | | 5.9 | |
| MEDIAN | 2.6 | | 4.1 | | 6.5 | | 6.9 | | 6.1 | | 6.1 | |
| IQR | 1.3- 4.8 | | 2.0- 6.7 | | 3.7- 9.0 | | 4.4- 9.2 | | 3.9- 8.1 | | 4.1- 7.9 | |
| TOTAL | 4442. | | 4262. | | 4235. | | 4473. | | 4175. | | 4153. | |

Table 4. Monthly percentage frequencies of occurrence of duct heights, ocean station CHARLIE. Data presentation discussed in text, Para. 3.1.

| HT (M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 18.2 | 18.2 | 20.9 | 20.9 | 26.5 | 26.5 | 31.0 | 31.0 | 34.3 | 34.3 | 39.3 | 39.3 |
| 3-6 | 21.5 | 39.7 | 24.2 | 45.1 | 22.0 | 48.5 | 22.3 | 53.3 | 22.6 | 57.3 | 25.9 | 55.2 |
| 6-9 | 30.6 | 70.3 | 29.6 | 74.7 | 26.1 | 74.7 | 24.3 | 77.6 | 22.2 | 79.5 | 19.2 | 84.4 |
| 9-12 | 22.4 | 92.8 | 19.4 | 94.1 | 17.9 | 92.6 | 15.9 | 93.5 | 13.9 | 93.4 | 9.5 | 93.9 |
| 12-15 | 6.0 | 98.8 | 4.5 | 98.6 | 5.6 | 98.2 | 4.3 | 97.8 | 3.1 | 96.5 | 2.1 | 96.0 |
| 15-18 | .5 | 99.3 | .4 | 99.0 | .7 | 98.9 | .4 | 98.2 | .6 | 97.0 | .5 | 96.6 |
| 18-21 | .0 | 99.3 | .0 | 99.0 | .1 | 99.0 | .1 | 98.3 | .2 | 97.2 | .3 | 96.9 |
| 21-30 | .1 | 99.5 | .1 | 99.1 | .2 | 99.1 | .1 | 98.5 | .4 | 97.6 | .5 | 97.3 |
| >30 | .2 | 99.7 | .3 | 99.3 | .2 | 99.4 | .5 | 99.0 | 1.0 | 98.6 | 1.1 | 98.4 |
| UNDEF | .3 | 100.0 | .7 | 100.0 | .6 | 100.0 | 1.0 | 100.0 | 1.4 | 100.0 | 1.6 | 100.0 |
| MEAN | | 6.3 | | 6.3 | | 6.1 | | 5.7 | | 5.6 | | 5.0 |
| MEDIAN | | 7.0 | | 6.5 | | 6.2 | | 5.6 | | 5.0 | | 4.2 |
| IQR | 3.9- | 9.6 | 3.5- | 9.1 | 2.8- | 9.1 | 2.4- | 8.7 | 2.2- | 8.4 | 1.9- | 7.5 |
| TOTAL | | 4634. | | 4374. | | 4532. | | 4630. | | 4841. | | 4748. |

Table 4, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 46.2 | 46.2 | 33.2 | 33.2 | 25.1 | 25.1 | 20.7 | 20.7 | 22.4 | 22.4 | 21.9 | 21.9 |
| 3-6 | 21.4 | 67.6 | 20.8 | 54.0 | 17.4 | 42.6 | 16.0 | 36.6 | 17.1 | 39.5 | 15.9 | 37.8 |
| 6-9 | 16.8 | 84.4 | 20.2 | 74.2 | 18.6 | 61.1 | 22.5 | 59.1 | 24.1 | 63.6 | 26.3 | 64.1 |
| 9-12 | 7.6 | 92.0 | 14.4 | 88.6 | 18.6 | 79.7 | 23.8 | 82.9 | 23.5 | 87.2 | 23.9 | 88.0 |
| 12-15 | 2.7 | 94.7 | 6.3 | 94.9 | 13.1 | 92.8 | 12.7 | 95.6 | 9.8 | 97.0 | 9.8 | 97.8 |
| 15-18 | .8 | 95.5 | 1.6 | 96.5 | 4.4 | 97.2 | 2.8 | 98.4 | 1.8 | 98.8 | 1.0 | 98.8 |
| 18-21 | .3 | 95.8 | .6 | 97.2 | .6 | 97.9 | .4 | 98.8 | .0 | 98.8 | .2 | 98.9 |
| 21-30 | .6 | 96.5 | .5 | 97.7 | .4 | 98.3 | .2 | 99.0 | .2 | 99.1 | .1 | 99.1 |
| >30 | 1.7 | 98.1 | 1.0 | 98.6 | .7 | 99.0 | .4 | 99.4 | .3 | 99.4 | .5 | 99.5 |
| UNDEF | 1.9 | 100.0 | 1.4 | 100.0 | 1.0 | 100.0 | .6 | 100.0 | .6 | 100.0 | .5 | 100.0 |
| MEAN | | 4.9 | | 6.1 | | 7.5 | | 7.6 | | 7.0 | | 7.2 |
| MEDIAN | | 3.5 | | 5.4 | | 7.2 | | 7.5 | | 7.3 | | 7.4 |
| IQR | | 1.6- 7.3 | | 2.3- 9.2 | | 3.0-11.2 | | 3.8-11.0 | | 3.5-10.4 | | 3.6-10.4 |
| TOTAL | | 4940. | | 4913. | | 4601. | | 4757. | | 4669. | | 4607. |

Table 5. Monthly percentage frequencies of occurrence of duct heights, ocean station DELTA. Data presentation discussed in text, Para. 3.1.

| HT(M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 3.7 | 3.7 | 4.3 | 4.3 | 4.9 | 4.9 | 11.5 | 11.5 | 15.9 | 15.9 | 30.0 | 30.0 |
| 3-6 | 7.0 | 10.7 | 7.9 | 12.2 | 8.8 | 13.7 | 12.2 | 23.8 | 13.8 | 29.7 | 15.0 | 45.0 |
| 6-9 | 11.0 | 21.7 | 13.5 | 25.7 | 16.2 | 29.9 | 15.2 | 39.0 | 18.2 | 47.9 | 15.3 | 60.3 |
| 9-12 | 18.6 | 40.3 | 19.5 | 45.2 | 22.2 | 52.1 | 21.4 | 60.5 | 18.3 | 66.2 | 15.6 | 75.9 |
| 12-15 | 24.4 | 64.8 | 24.8 | 70.0 | 23.0 | 75.2 | 19.8 | 80.2 | 16.3 | 82.5 | 11.6 | 87.5 |
| 15-18 | 20.2 | 85.0 | 19.3 | 89.3 | 16.3 | 91.5 | 12.7 | 92.9 | 10.3 | 92.8 | 6.4 | 93.9 |
| 18-21 | 11.0 | 96.0 | 8.0 | 97.3 | 6.3 | 97.8 | 4.5 | 97.4 | 3.5 | 96.3 | 2.8 | 96.6 |
| 21-30 | 3.2 | 99.2 | 1.6 | 98.9 | 1.3 | 99.1 | 1.3 | 98.6 | 1.1 | 97.4 | 1.1 | 97.7 |
| >30 | .1 | 99.4 | .3 | 99.2 | .2 | 99.3 | .6 | 99.3 | 1.0 | 98.3 | 1.0 | 98.7 |
| UNDEF | .6 | 100.0 | .8 | 100.0 | .7 | 100.0 | .7 | 100.0 | 1.7 | 100.0 | 1.3 | 10 .0 |
| MEAN | 12.7 | | 12.1 | | 11.5 | | 10.3 | | 9.6 | | 7.7 | |
| MEDIAN | 13.2 | | 12.6 | | 11.7 | | 10.5 | | 9.3 | | 7.0 | |
| IQR | 9.5-16.5 | | 8.8-15.8 | | 8.1-15.0 | | 6.2-14.2 | | 5.0-13.6 | | 2.5-11.8 | |
| TOTAL | 4038. | | 3856. | | 4252. | | 4145. | | 4281. | | 4083. | |

Table 5, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 25.6 | 25.6 | 13.2 | 13.2 | 9.8 | 9.8 | 10.4 | 10.4 | 8.0 | 8.0 | 7.0 | 7.0 |
| 3-6 | 14.7 | 40.3 | 11.7 | 24.9 | 8.4 | 18.2 | 7.6 | 18.0 | 7.7 | 15.6 | 7.5 | 14.5 |
| 6-9 | 18.4 | 58.7 | 16.2 | 41.1 | 11.7 | 29.9 | 9.8 | 27.8 | 10.5 | 26.2 | 12.2 | 26.7 |
| 9-12 | 15.3 | 74.0 | 16.5 | 57.6 | 14.4 | 44.3 | 13.6 | 41.4 | 14.9 | 41.0 | 16.3 | 43.1 |
| 12-15 | 11.9 | 85.9 | 14.6 | 72.1 | 16.9 | 61.3 | 18.4 | 59.8 | 19.1 | 60.2 | 21.5 | 64.6 |
| 15-18 | 5.8 | 91.7 | 12.3 | 84.5 | 15.6 | 76.9 | 16.9 | 76.6 | 19.6 | 79.8 | 19.0 | 83.6 |
| 18-21 | 3.1 | 94.8 | 6.9 | 91.4 | 10.7 | 87.6 | 12.2 | 88.9 | 12.6 | 92.4 | 10.8 | 94.4 |
| 21-30 | 1.7 | 96.5 | 5.8 | 97.2 | 9.7 | 97.3 | 8.5 | 97.4 | 6.6 | 98.9 | 5.0 | 99.5 |
| >30 | 1.7 | 98.3 | 1.5 | 98.7 | 1.4 | 98.7 | 1.5 | 98.9 | .4 | 99.3 | .1 | 99.5 |
| UNDEF | 1.7 | 100.0 | 1.3 | 100.0 | 1.3 | 100.0 | 1.1 | 100.0 | .7 | 100.0 | .5 | 100.0 |
| MEAN | 8.7 | | 11.4 | | 13.1 | | 13.2 | | 12.8 | | 12.4 | |
| MEDIAN | 7.6 | | 10.6 | | 13.0 | | 13.4 | | 13.4 | | 13.0 | |
| IQR | 2.9-12.2 | | 6.0-15.7 | | 7.7-17.6 | | 8.1-17.7 | | 8.7-17.3 | | 8.6-16.6 | |
| TOTAL | 4133. | | 4222. | | 4085. | | 4316. | | 4095. | | 4106. | |

Table 6. Monthly percentage frequencies of occurrence of duct heights, ocean station ECHO. Data presentation discussed in text, Para. 3.1.

| HT (M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 1.9 | 1.9 | 2.1 | 2.1 | 4.1 | 4.1 | 4.8 | 4.8 | 6.1 | 6.1 | 7.3 | 7.3 |
| 3-6 | 4.4 | 6.3 | 5.9 | 8.0 | 6.8 | 10.9 | 11.0 | 15.8 | 12.9 | 19.1 | 10.1 | 17.4 |
| 6-9 | 10.4 | 16.7 | 12.9 | 21.0 | 11.0 | 21.9 | 16.5 | 32.2 | 19.7 | 38.8 | 17.5 | 34.8 |
| 9-12 | 16.2 | 32.9 | 17.9 | 38.9 | 15.4 | 37.4 | 18.1 | 50.3 | 19.2 | 58.0 | 20.5 | 55.4 |
| 12-15 | 18.6 | 51.5 | 16.9 | 55.8 | 17.0 | 54.4 | 17.5 | 67.8 | 14.0 | 72.1 | 17.0 | 72.3 |
| 15-18 | 18.3 | 69.8 | 16.7 | 72.5 | 17.4 | 71.7 | 15.1 | 83.0 | 10.3 | 82.3 | 9.9 | 82.2 |
| 18-21 | 14.7 | 84.5 | 14.1 | 86.6 | 14.0 | 85.7 | 9.1 | 92.0 | 6.2 | 88.5 | 5.7 | 87.9 |
| 21-30 | 13.7 | 98.2 | 11.4 | 98.0 | 10.9 | 96.7 | 5.0 | 97.0 | 5.2 | 93.8 | 4.3 | 92.2 |
| >30 | .6 | 98.8 | .6 | 98.6 | 2.0 | 98.7 | 1.8 | 98.8 | 4.0 | 97.8 | 4.8 | 97.0 |
| UNDEF | 1.2 | 100.0 | 1.4 | 100.0 | 1.3 | 100.0 | 1.2 | 100.0 | 2.2 | 100.0 | 3.0 | 100.0 |
| MEAN | 14.7 | | 14.1 | | 14.6 | | 12.7 | | 13.2 | | 13.4 | |
| MEDIAN | 14.3 | | 14.0 | | 14.2 | | 12.0 | | 10.7 | | 11.2 | |
| IQR | 10.5-19.1 | | 9.7-18.5 | | 9.6-18.7 | | 7.7-16.4 | | 6.9-15.9 | | 7.3-15.8 | |
| TOTAL | 3872. | | 3587. | | 3924. | | 3877. | | 3983. | | 3987. | |

Table 6, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | .6 | .6 | .0 | .0 | .1 | .1 | .7 | .7 | .5 | .5 | 1.3 | 1.3 |
| 3-6 | 2.4 | 3.0 | .3 | .3 | .8 | .9 | 2.0 | 2.7 | 3.1 | 3.6 | 4.5 | 5.8 |
| 6-9 | 10.0 | 13.0 | 3.5 | 3.8 | 5.0 | 5.9 | 6.9 | 9.6 | 9.1 | 12.6 | 11.3 | 17.2 |
| 9-12 | 19.5 | 32.5 | 14.2 | 18.0 | 12.4 | 18.3 | 14.2 | 23.8 | 14.5 | 27.1 | 15.7 | 32.9 |
| 12-15 | 19.5 | 52.0 | 20.3 | 38.3 | 19.0 | 37.4 | 19.2 | 43.0 | 15.8 | 42.9 | 17.1 | 50.0 |
| 15-18 | 13.7 | 65.7 | 19.0 | 57.3 | 18.3 | 55.7 | 17.2 | 60.2 | 16.8 | 59.7 | 17.2 | 67.2 |
| 18-21 | 10.7 | 76.4 | 14.8 | 72.2 | 15.6 | 71.3 | 14.8 | 74.9 | 14.0 | 73.7 | 13.6 | 80.8 |
| 21-30 | 9.5 | 85.9 | 15.5 | 87.6 | 20.4 | 91.7 | 19.8 | 94.6 | 22.1 | 95.8 | 16.6 | 97.4 |
| >30 | 9.5 | 95.4 | 8.4 | 96.0 | 5.2 | 96.9 | 3.3 | 98.1 | 3.1 | 98.9 | 1.4 | 98.8 |
| UNDEF | 4.6 | 100.0 | 4.0 | 100.0 | 3.1 | 100.0 | 1.9 | 100.0 | 1.1 | 100.0 | 1.2 | 100.0 |
| MEAN | 20.7 | | 22.5 | | 19.3 | | 17.2 | | 17.3 | | 15.1 | |
| MEDIAN | 14.7 | | 16.8 | | 17.1 | | 16.2 | | 16.3 | | 15.0 | |
| IQR | 10.9-20.6 | | 13.0-21.5 | | 13.1-21.5 | | 12.2-21.0 | | 11.6-21.2 | | 10.5-19.7 | |
| TOTAL | 3998. | | 4075. | | 3959. | | 4142. | | 3953. | | 3991. | |

Table 7. Monthly percentage frequencies of occurrence of duct heights, ocean station HOTEL. Data presentation discussed in text, Para. 3.1.

| HT(M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 3.2 | 3.2 | 2.8 | 2.8 | 3.4 | 3.4 | 1.1 | 1.1 | 2.2 | 2.2 | 9.3 | 9.3 |
| 3-6 | 4.5 | 7.7 | 3.9 | 6.7 | 5.5 | 9.0 | 3.4 | 4.5 | 6.1 | 8.3 | 6.2 | 15.5 |
| 6-9 | 11.9 | 19.6 | 7.8 | 14.5 | 9.6 | 18.5 | 10.3 | 14.8 | 12.7 | 21.0 | 13.2 | 28.7 |
| 9-12 | 15.7 | 35.3 | 19.5 | 34.0 | 16.5 | 35.1 | 14.8 | 29.6 | 18.4 | 39.4 | 17.4 | 46.1 |
| 12-15 | 21.0 | 56.3 | 21.6 | 55.6 | 22.1 | 57.1 | 20.8 | 50.4 | 19.0 | 58.4 | 16.9 | 63.0 |
| 15-18 | 19.2 | 75.5 | 18.4 | 74.0 | 17.1 | 74.3 | 20.5 | 70.9 | 14.9 | 73.3 | 11.2 | 74.2 |
| 18-21 | 13.0 | 88.5 | 13.3 | 87.3 | 14.5 | 88.8 | 16.0 | 86.9 | 8.9 | 82.2 | 8.5 | 82.8 |
| 21-30 | 10.2 | 98.7 | 12.0 | 99.3 | 10.3 | 99.1 | 11.7 | 98.6 | 11.5 | 93.7 | 10.5 | 93.2 |
| >30 | .3 | 99.0 | .4 | 99.6 | .1 | 99.2 | 1.4 | 100.0 | 5.3 | 99.0 | 6.4 | 99.6 |
| UNDEF | 1.0 | 100.0 | .4 | 100.0 | .8 | 100.0 | 0.0 | 100.0 | 1.0 | 100.0 | .4 | 100.0 |
| MEAN | 13.8 | | 14.5 | | 13.8 | | 15.6 | | 16.8 | | 16.4 | |
| MEDIAN | 14.1 | | 14.2 | | 14.0 | | 14.9 | | 13.7 | | 12.7 | |
| IQR | 10.0-17.9 | | 10.5-18.2 | | 10.2-18.2 | | 11.1-18.8 | | 9.7-18.6 | | 8.2-18.3 | |
| TOTAL | 1000. | | 850. | | 347. | | 351. | | 495. | | 516. | |

Table 7, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | .3 | .3 | .4 | .4 | 0.0 | 0.0 | .2 | .2 | .6 | .6 | 2.7 | 2.7 |
| 3-6 | 3.3 | 3.6 | .7 | 1.2 | .2 | .2 | 2.0 | 2.2 | 2.1 | 2.7 | 3.4 | 6.1 |
| 6-9 | 11.6 | 15.2 | 6.9 | 8.1 | 3.5 | 3.7 | 5.5 | 7.7 | 7.7 | 10.5 | 7.5 | 13.5 |
| 9-12 | 19.2 | 34.4 | 17.2 | 25.3 | 10.3 | 14.1 | 10.2 | 17.9 | 13.1 | 23.6 | 11.6 | 25.1 |
| 12-15 | 25.5 | 59.9 | 20.6 | 45.8 | 17.4 | 31.5 | 15.4 | 33.2 | 16.2 | 39.8 | 19.8 | 44.9 |
| 15-18 | 11.9 | 71.0 | 18.1 | 64.0 | 19.4 | 50.9 | 20.5 | 53.7 | 20.7 | 60.5 | 20.0 | 64.9 |
| 18-21 | 12.1 | 83.9 | 16.0 | 80.0 | 19.0 | 70.0 | 19.7 | 73.4 | 15.2 | 75.7 | 17.6 | 82.5 |
| 21-30 | 7.8 | 91.7 | 13.9 | 93.9 | 24.4 | 94.4 | 23.0 | 96.4 | 21.5 | 97.2 | 16.0 | 98.5 |
| >30 | 6.3 | 98.0 | 4.4 | 98.2 | 3.9 | 98.3 | 2.3 | 98.8 | 1.6 | 98.7 | .9 | 99.4 |
| UNDEF | 2.0 | 100.0 | 1.8 | 100.0 | 1.7 | 100.0 | 1.2 | 100.0 | 1.3 | 100.0 | .6 | 100.0 |
| MEAN | 16.9 | | 17.3 | | 18.5 | | 17.9 | | 16.6 | | 15.6 | |
| MEDIAN | 13.8 | | 15.7 | | 17.9 | | 17.5 | | 16.5 | | 15.8 | |
| IQR | 10.5-18.8 | | 12.0-20.1 | | 13.9-21.6 | | 13.4-21.2 | | 12.3-20.9 | | 12.0-19.7 | |
| TOTAL | 663. | | 1124. | | 1015. | | 1068. | | 955. | | 100 [illegible] | |

Table 8. Monthly percentage frequencies of occurrence of duct heights, ocean station INDIA. Data presentation discussed in text, Para. 3.1.

| HT(M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 10.3 | 10.3 | 10.3 | 10.3 | 9.9 | 9.9 | 12.5 | 12.5 | 17.5 | 17.5 | 21.6 | 21.6 |
| 3-6 | 19.8 | 30.1 | 20.1 | 30.4 | 21.2 | 31.1 | 21.0 | 33.4 | 25.9 | 43.3 | 24.5 | 46.1 |
| 6-9 | 36.7 | 66.8 | 36.1 | 66.5 | 31.7 | 62.8 | 30.5 | 63.9 | 29.7 | 73.1 | 27.9 | 74.0 |
| 9-12 | 25.6 | 92.3 | 24.4 | 90.9 | 26.2 | 89.0 | 25.4 | 89.4 | 18.9 | 92.0 | 18.3 | 92.2 |
| 12-15 | 6.4 | 98.7 | 7.5 | 98.4 | 8.7 | 97.7 | 8.2 | 97.5 | 4.8 | 96.7 | 4.1 | 96.3 |
| 15-18 | .6 | 99.4 | .7 | 99.1 | 1.2 | 98.9 | 1.0 | 98.5 | .6 | 97.3 | .5 | 96.8 |
| 18-21 | 0.0 | 99.4 | .0 | 99.2 | .0 | 99.0 | 0.0 | 98.5 | .1 | 97.4 | .1 | 96.9 |
| 21-30 | 0.0 | 99.4 | 0.0 | 99.2 | 0.0 | 99.0 | .1 | 98.6 | .3 | 97.7 | .2 | 97.1 |
| >30 | .0 | 99.4 | 0.0 | 99.2 | 0.0 | 99.0 | .1 | 98.7 | .6 | 98.4 | .6 | 97.7 |
| UNDEF | .6 | 100.0 | .8 | 100.0 | 1.0 | 100.0 | 1.3 | 100.0 | 1.6 | 100.0 | 2.3 | 100.0 |
| MEAN | | 7.4 | | 7.4 | | 7.6 | | 7.4 | | 6.9 | | 6.4 |
| MEDIAN | | 7.6 | | 7.6 | | 7.8 | | 7.6 | | 6.7 | | 6.4 |
| IQR | | 5.2-10.0 | | 5.2-10.0 | | 5.1-10.4 | | 4.8-10.3 | | 3.9- 9.3 | | 3.4- 9.2 |
| TOTAL | | 3447. | | 3141. | | 3555. | | 3627. | | 3721. | | 3697. |

Table 8, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 18.4 | 18.4 | 15.1 | 15.1 | 15.4 | 15.4 | 17.5 | 17.5 | 11.8 | 11.8 | 9.0 | 9.0 |
| 3-6 | 27.4 | 5.7 | [illegible] | 40.3 | 22.5 | 37.9 | 17.5 | 35.1 | 18.5 | 30.2 | 17.8 | 26.8 |
| 6-9 | 29.8 | 75.5 | 29.3 | 69.6 | 24.9 | 62.9 | 25.0 | 60.1 | 31.1 | 61.3 | 33.9 | 60.7 |
| 9-12 | 16.3 | 91.8 | 19.4 | 89.0 | 20.8 | 83.7 | 24.1 | 84.1 | 26.4 | 87.7 | 28.4 | 89.0 |
| 12-15 | 4.2 | 96.0 | 6.2 | 95.2 | 11.1 | 94.3 | 11.9 | 96.0 | 10.3 | 98.0 | 8.7 | 97.8 |
| 15-18 | 1.1 | 97.1 | 1.5 | 96.7 | 2.5 | 97.3 | 2.3 | 98.3 | 1.1 | 99.1 | .8 | 98.6 |
| 18-21 | .2 | 97.3 | .2 | 97.0 | .3 | 97.6 | .2 | 98.5 | .1 | 99.2 | 0.0 | 98.6 |
| 21-30 | .2 | 97.5 | .2 | 97.2 | .1 | 97.7 | .1 | 98.5 | 0.0 | 99.2 | .0 | 98.6 |
| >30 | .6 | 98.0 | .6 | 97.8 | .2 | 97.9 | .1 | 98.6 | .1 | 99.2 | 0.0 | 98.6 |
| UNDEF | 2.0 | 100.0 | 2.2 | 100.0 | 2.1 | 100.0 | 1.4 | 100.0 | .8 | 100.0 | 1.4 | 100.0 |
| MEAN | 6.6 | | 7.1 | | 7.3 | | 7.4 | | 7.7 | | 7.7 | |
| MEDIAN | 6.4 | | 7.0 | | 7.5 | | 7.8 | | 7.9 | | 8.1 | |
| IQR | 3.7- 8.9 | | 4.2- 9.8 | | 4.3-10.7 | | 4.3-10.9 | | 5.2-10.6 | | 5.7-10.5 | |
| TOTAL | 3929. | | 3767. | | 3557. | | 3710. | | 3455. | | 3441. | |

Table 9. Monthly percentage frequencies of occurrence of duct heights, ocean station JULIETT. Data presentation discussed in text, Para. 3.1.

| HT(M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 15.2 | 15.2 | 12.4 | 12.4 | 17.4 | 17.4 | 18.4 | 18.4 | 17.1 | 17.1 | 27.3 | 27.3 |
| 3-6 | 16.7 | 31.9 | 15.7 | 28.1 | 22.9 | 40.3 | 19.4 | 37.8 | 20.9 | 37.9 | 20.8 | 48.1 |
| 6-9 | 24.9 | 56.8 | 26.1 | 54.3 | 26.0 | 66.3 | 26.1 | 63.9 | 23.0 | 60.9 | 20.2 | 68.3 |
| 9-12 | 26.0 | 82.8 | 26.3 | 80.6 | 22.3 | 88.5 | 22.8 | 86.7 | 22.8 | 83.8 | 18.2 | 86.5 |
| 12-15 | 13.6 | 96.4 | 15.3 | 96.0 | 9.2 | 97.7 | 9.3 | 96.0 | 11.0 | 94.8 | 8.6 | 95.1 |
| 15-18 | 2.7 | 99.1 | 3.2 | 99.2 | 1.1 | 98.8 | 1.7 | 97.7 | 2.2 | 97.0 | 1.9 | 97.0 |
| 18-21 | .3 | 99.3 | .2 | 99.3 | .2 | 99.0 | .3 | 97.9 | .4 | 97.4 | .4 | 97.4 |
| 21-30 | 0.0 | 99.3 | 0.0 | 99.3 | .1 | 99.1 | .1 | 98.0 | .3 | 97.7 | .2 | 97.6 |
| >30 | .0 | 99.3 | .0 | 99.4 | .1 | 99.2 | .4 | 98.4 | .3 | 98.1 | .6 | 98.2 |
| UNDEF | .7 | 100.0 | .6 | 100.0 | .8 | 100.0 | 1.6 | 100.0 | 1.9 | 100.0 | 1.8 | 100.0 |
| MEAN | | 7.8 | | 8.2 | | 7.0 | | 7.2 | | 7.5 | | 6.6 |
| MEDIAN | | 8.2 | | 8.5 | | 7.1 | | 7.4 | | 7.6 | | 6.3 |
| IQR | | 4.8-11.1 | | 5.4-11.4 | | 4.0-10.2 | | 4.0-10.5 | | 4.1-10.8 | | 2.7-10.1 |
| TOTAL | | 3991. | | 3561. | | 3912. | | 3755. | | 3774. | | 3742. |

Table 9, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMB R | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 23.7 | 23.7 | 18.7 | 18.7 | 20.9 | 20.9 | 19.7 | 19.7 | 12.3 | 12.3 | 15.9 | 15.9 |
| 3-6 | 19.4 | 43.1 | 16.0 | 35.7 | 17.3 | 38.2 | 15.5 | 35.2 | 16.5 | 28.8 | 16.8 | 32.7 |
| 6-9 | 22.8 | 65.9 | 22.4 | 58.1 | 18.8 | 57.0 | 19.6 | 54.7 | 22.3 | 51.0 | 23.0 | 55.7 |
| 9-12 | 18.2 | 84.1 | 20.2 | 78.4 | 18.1 | 75.1 | 21.3 | 76.0 | 25.5 | 76.5 | 26.2 | 81.9 |
| 12-15 | 10.0 | 94.1 | 13.1 | 91.4 | 14.6 | 89.7 | 15.3 | 91.3 | 16.2 | 92.8 | 14.3 | 96.2 |
| 15-18 | 1.8 | 95.9 | 4.3 | 95.7 | 6.3 | 96.1 | 6.4 | 97.7 | 5.3 | 98.1 | 3.0 | 99.3 |
| 18-21 | .6 | 96.5 | 1.0 | 96.7 | 1.9 | 97.9 | .7 | 98.4 | .8 | 99.0 | .2 | 99.5 |
| 21-30 | .5 | 97.0 | .5 | 97.2 | .3 | 98.3 | .1 | 98.6 | .1 | 99.1 | 0.0 | 9 .5 |
| >30 | .9 | 97.9 | .7 | 97.9 | .3 | 98.6 | .2 | 98.8 | .0 | 99.1 | 0.0 | 99.5 |
| UNDEF | 2.1 | 100.0 | 2.1 | 100.0 | 1.4 | 100.0 | 1.2 | 100.0 | .9 | 100.0 | .5 | 100.0 |
| MEAN | 7.2 | | 8.0 | | 7.9 | | 8.0 | | 8.5 | | 7.8 | |
| MEDIAN | 6.9 | | 7.9 | | 7.9 | | 8.3 | | 8.9 | | 8.3 | |
| IQR | 3.2-10.5 | | 4.1-11.5 | | 3.7-12.0 | | 4.0-11.9 | | 5.3-11.8 | | 4.6-11.2 | |
| TOTAL | 3877. | | 3788. | | 3834. | | 3664. | | 3828. | | 3734. | |

Table 10. Monthly percentage frequencies of occurrence of duct heights, ocean station KILO. Data presentation discussed in text, Para. 3.1.

| HT(M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 17.1 | 17.1 | 8.9 | 8.9 | 14.3 | 14.3 | 12.9 | 12.9 | 16.5 | 16.5 | 13.1 | 13.1 |
| 3-6 | 16.4 | 33.5 | 14.8 | 23.7 | 20.5 | 34.9 | 17.7 | 30.6 | 18.6 | 35.1 | 21.9 | 35.0 |
| 6-9 | 16.9 | 50.4 | 19.5 | 43.1 | 20.7 | 55.5 | 21.2 | 51.7 | 22.7 | 57.8 | 22.5 | 57.6 |
| 9-12 | 18.0 | 68.4 | 22.4 | 65.6 | 19.8 | 75.3 | 24.0 | 75.8 | 19.4 | 77.2 | 17.0 | 74.6 |
| 12-15 | 15.4 | 83.8 | 19.2 | 84.7 | 15.0 | 90.3 | 13.6 | 89.4 | 13.5 | 90.7 | 12.8 | 87.4 |
| 15-18 | 11.3 | 95.1 | 11.2 | 95.9 | 6.8 | 97.1 | 6.7 | 96.0 | 5.1 | 95.8 | 5.2 | 92.6 |
| 18-21 | 2.9 | 97.9 | 2.0 | 97.9 | 1.2 | 98.3 | 1.2 | 97.2 | 1.1 | 96.9 | 2.0 | 94.6 |
| 21-30 | .7 | 98.6 | .5 | 98.4 | .4 | 98.7 | .3 | 97.5 | .5 | 97.4 | 1.3 | 95.9 |
| >30 | .2 | 98.8 | .2 | 98.6 | .1 | 98.9 | .5 | 98.0 | .9 | 98.3 | 1.6 | 97.5 |
| UNDEF | 1.2 | 100.0 | 1.4 | 100.0 | 1.1 | 100.0 | 2.0 | 100.0 | 1.7 | 100.0 | 2.5 | 100.0 |
| MEAN | 8.8 | | 9.7 | | 8.2 | | 8.5 | | 8.2 | | 9.0 | |
| MEDIAN | 8.9 | | 9.9 | | 8.2 | | 8.8 | | 8.0 | | 8.0 | |
| IQR | 4.4-13.3 | | 6.2-13.6 | | 4.6-12.0 | | 5.1-11.9 | | 4.4-11.7 | | 4.6-12.1 | |
| TOTAL | 2912. | | 2816. | | 2906. | | 2850. | | 2908. | | 2480. | |

Table 10, continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 10.4 | 10.4 | 7.8 | 7.8 | 9.3 | 9.3 | 8.4 | 8.4 | 7.7 | 7.7 | 14.6 | 14.6 |
| 3-6 | 14.3 | 24.7 | 11.2 | 19.1 | 11.4 | 20.7 | 10.8 | 19.2 | 10.6 | 18.3 | 15.3 | 29.9 |
| 6-9 | 20.6 | 45.4 | 19.2 | 38.2 | 16.9 | 37.6 | 16.8 | 36.1 | 15.2 | 33.5 | 19.9 | 49.8 |
| 9-12 | 21.5 | 66.8 | 19.7 | 58.0 | 17.9 | 55.5 | 17.3 | 53.4 | 18.8 | 52.3 | 18.6 | 68.4 |
| 12-15 | 15.1 | 81.9 | 18.9 | 76.9 | 16.7 | 72.2 | 19.8 | 73.2 | 21.7 | 74.0 | 15.0 | 83.4 |
| 15-18 | 8.0 | 89.9 | 10.9 | 87.8 | 12.0 | 84.2 | 13.7 | 86.9 | 15.4 | 89.4 | 10.3 | 93.7 |
| 18-21 | 2.9 | 92.8 | 5.2 | 93.0 | 6.5 | 90.7 | 6.8 | 93.7 | 6.5 | 95.9 | 3.6 | 97.3 |
| 21-30 | 1.9 | 94.7 | 3.1 | 96.1 | 4.6 | 95.3 | 3.0 | 96.8 | 2.5 | 98.4 | 1.0 | 98.3 |
| >30 | 2.5 | 97.2 | 1.1 | 97.3 | 2.0 | 97.3 | 1.1 | 97.8 | .5 | 98.9 | .6 | 98.9 |
| UNDEF | 2.8 | 100.0 | 2.7 | 100.0 | 2.7 | 100.0 | 2.2 | 100.0 | 1.1 | 100.0 | 1.1 | 100.0 |
| MEAN | 10.8 | | 11.1 | | 11.8 | | 11.3 | | 11.4 | | 9.2 | |
| MEDIAN | 9.6 | | 10.8 | | 11.1 | | 11.4 | | 11.6 | | 9.0 | |
| IQR | 6.0-13.6 | | 6.9-14.7 | | 6.8-15.7 | | 7.0-15.4 | | 7.3-15.2 | | 5.0-13.3 | |
| TOTAL | 2873. | | 2787. | | 2740. | | 3108. | | 2352. | | 2600. | |

Table 11. Monthly percentage frequencies of occurrence of duct heights, ocean station MIKE. Data presentation discussed in text, Para. 3.1.

| HT(M) | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 6.2 | 6.2 | 5.1 | 5.1 | 7.9 | 7.9 | 11.4 | 11.4 | 14.0 | 14.0 | 21.3 | 21.3 |
| 3-6 | 25.8 | 32.0 | 23.2 | 28.3 | 27.8 | 35.7 | 32.0 | 43.4 | 33.5 | 47.5 | 28.2 | 49.5 |
| 6-9 | 42.3 | 74.3 | 44.9 | 73.3 | 40.3 | 76.0 | 38.1 | 81.5 | 36.0 | 83.5 | 33.2 | 82.7 |
| 9-12 | 21.4 | 95.7 | 21.9 | 95.1 | 20.1 | 96.1 | 15.1 | 96.6 | 12.3 | 95.8 | 11.3 | 94.0 |
| 12-15 | 2.7 | 98.5 | 3.1 | 98.3 | 2.0 | 98.1 | .9 | 97.5 | .9 | 96.7 | 1.1 | 95.2 |
| 15-18 | .1 | 98.6 | .1 | 98.3 | .1 | 98.2 | .0 | 97.5 | .0 | 96.8 | .1 | 95.2 |
| 18-21 | 0.0 | 98.6 | 0.0 | 98.3 | .0 | 98.2 | .1 | 97.6 | 0.0 | 96.8 | .1 | 95.4 |
| 21-30 | 0.0 | 98.6 | 0.0 | 98.3 | 0.0 | 98.2 | 0.0 | 97.6 | .1 | 96.8 | .2 | 95.6 |
| >30 | 0.0 | 98.6 | 0.0 | 98.3 | .1 | 98.3 | .1 | 97.7 | .2 | 97.0 | .1 | 95.6 |
| UNDEF | 1.4 | 100.0 | 1.7 | 100.0 | 1.7 | 100.0 | 2.3 | 100.0 | 3.0 | 100.0 | 4.4 | 100.0 |
| MEAN | | 7.1 | | 7.2 | | 6.9 | | 6.3 | | 5.9 | | 5.5 |
| MEDIAN | | 7.3 | | 7.4 | | 7.1 | | 6.5 | | 6.2 | | 6.0 |
| IQR | 5.2- 9.1 | | 5.6- 9.2 | | 4.8- 8.9 | | 4.3- 8.5 | | 4.0- 8.3 | | 3.4- 8.3 | |
| TOTAL | 3637. | | 3212. | | 3574. | | 3400. | | 3635. | | 3488. | |

Table 11. continued.

| HT(M) | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | 18.6 | 18.6 | 18.1 | 18.1 | 15.7 | 15.7 | 14.4 | 14.4 | 10.4 | 10.4 | 6.1 | 6.1 |
| 3-6 | 31.0 | 49.6 | 27.0 | 45.1 | 25.8 | 41.5 | 22.8 | 37.2 | 24.3 | 34.7 | 23.4 | 29.5 |
| 6-9 | 32.5 | 82.0 | 31.0 | 76.1 | 29.3 | 70.8 | 34.0 | 71.1 | 36.0 | 70.7 | 40.4 | 69.9 |
| 9-12 | 12.1 | 94.1 | 16.1 | 92.2 | 20.9 | 91.6 | 21.2 | 92.3 | 22.9 | 93.6 | 24.2 | 94.1 |
| 12-15 | 1.9 | 95.9 | 4.0 | 96.2 | 5.0 | 96.5 | 5.7 | 98.0 | 4.8 | 98.4 | 4.0 | 98.1 |
| 15-18 | .1 | 96.0 | .4 | 96.6 | .6 | 97.2 | .7 | 98.7 | .2 | 98.6 | .2 | 98.3 |
| 18-21 | .1 | 96.1 | .1 | 96.7 | 0.0 | 97.2 | 0.0 | 98.7 | .0 | 98.7 | 0.0 | 98.3 |
| 21-30 | .2 | 96.3 | .2 | 96.8 | .0 | 97.3 | .0 | 98.7 | 0.0 | 98.7 | 0.0 | 98.3 |
| >30 | .2 | 96.5 | .1 | 97.0 | .0 | 97.3 | 0.0 | 98.7 | .1 | 98.7 | .0 | 98.3 |
| UNDEF | 3.5 | 100.0 | 3.0 | 100.0 | 2.7 | 100.0 | 1.3 | 100.0 | 1.3 | 100.0 | 1.7 | 100.0 |
| MEAN | 5.7 | | 6.1 | | 6.5 | | 6.9 | | 7.1 | | 7.3 | |
| MEDIAN | 6.0 | | 6.5 | | 6.9 | | 7.1 | | 7.3 | | 7.5 | |
| IQR | 3.6- 8.4 | | 3.8- 8.9 | | 4.1- 9.6 | | 4.4- 9.5 | | 4.8- 9.6 | | 5.4- 9.5 | |
| TOTAL | 3576. | | 3818. | | 3675. | | 3722. | | 3602. | | 3308. | |

Table 12. Median values of duct heights (in meters) by month by ocean station.

| Ocean Station | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALFA | 6.4 | 6.3 | 6.1 | 5.7 | 5.0 | 4.5 | 4.8 | 5.7 | 6.7 | 6.7 | 6.5 | 6.9 |
| BRAVO | 5.5 | 5.1 | 5.3 | 5.0 | 4.1 | 3.5 | 2.6 | 4.1 | 6.5 | 6.9 | 6.1 | 6.1 |
| CHARLIE | 7.0 | 6.5 | 6.2 | 5.6 | 5.0 | 4.2 | 3.5 | 5.4 | 7.2 | 7.8 | 7.3 | 7.4 |
| DELTA | 13.2 | 12.6 | 11.7 | 10.5 | 9.3 | 7.0 | 7.6 | 10.6 | 13.0 | 13.4 | 13.4 | 13.0 |
| ECHO | 14.8 | 14.0 | 14.2 | 12.0 | 10.7 | 11.2 | 14.7 | 16.8 | 17.1 | 16.2 | 16.3 | 15.0 |
| HOTEL | 14.1 | 14.2 | 14.0 | 14.9 | 13.7 | 12.7 | 13.8 | 15.7 | 18.9 | 17.5 | 16.5 | 15.8 |
| INDIA | 7.6 | 7.6 | 7.8 | 7.6 | 7.6 | 6.7 | 6.4 | 7.0 | 7.5 | 7.8 | 7.9 | 8.1 |
| JULIETT | 8.2 | 8.5 | 7.1 | 7.4 | 7.6 | 6.3 | 6.9 | 7.9 | 7.9 | 8.3 | 8.9 | 8.3 |
| KILO | 8.9 | 9.9 | 8.2 | 8.8 | 8.0 | 8.0 | 9.6 | 10.8 | 11.1 | 11.4 | 11.6 | 9.0 |
| MIKE | 7.3 | 7.4 | 7.1 | 6.5 | 6.2 | 6.0 | 6.0 | 6.5 | 6.9 | 7.1 | 7.3 | 7.5 |

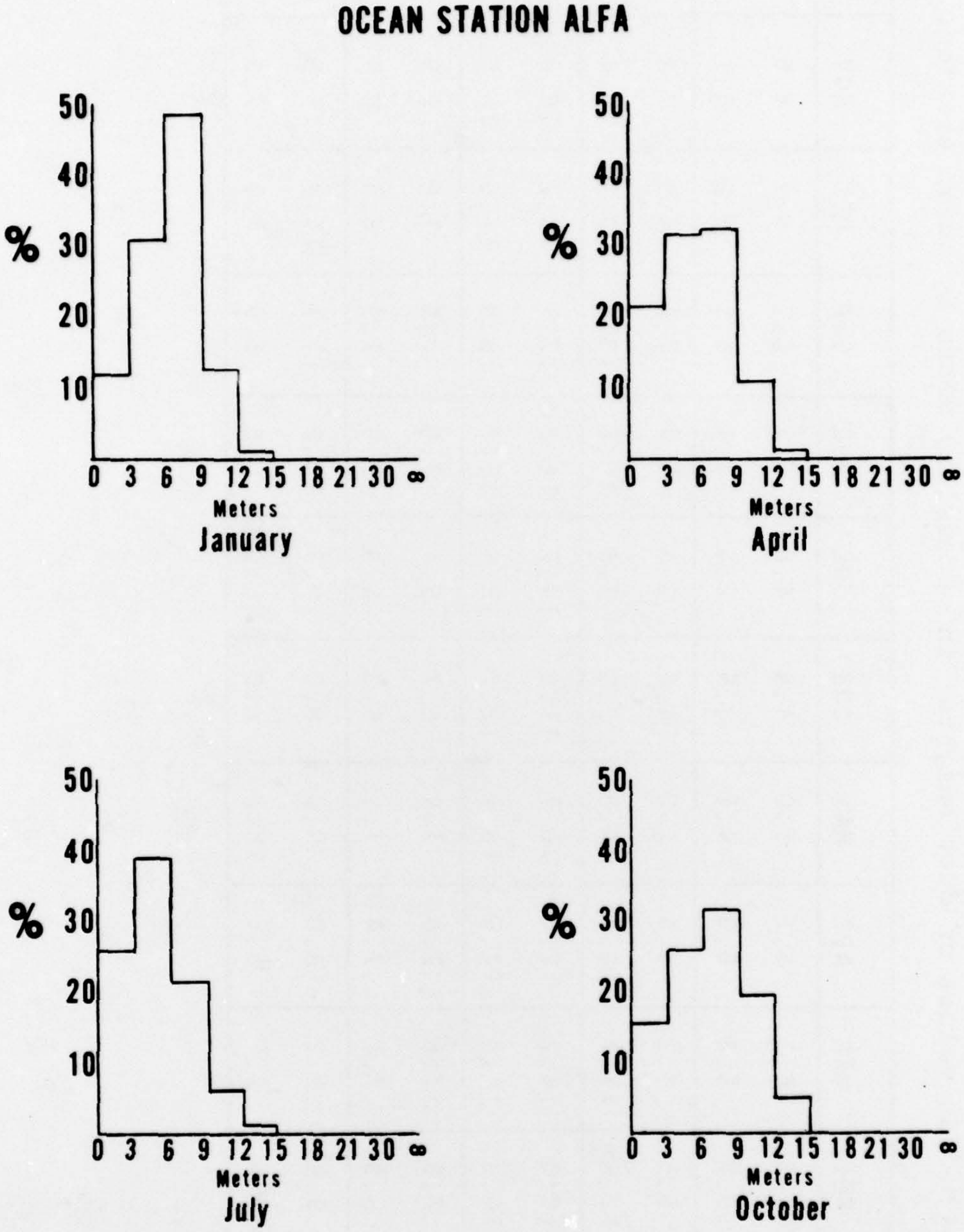


Figure 4. Percentages of occurrence of duct heights, ocean station ALFA, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

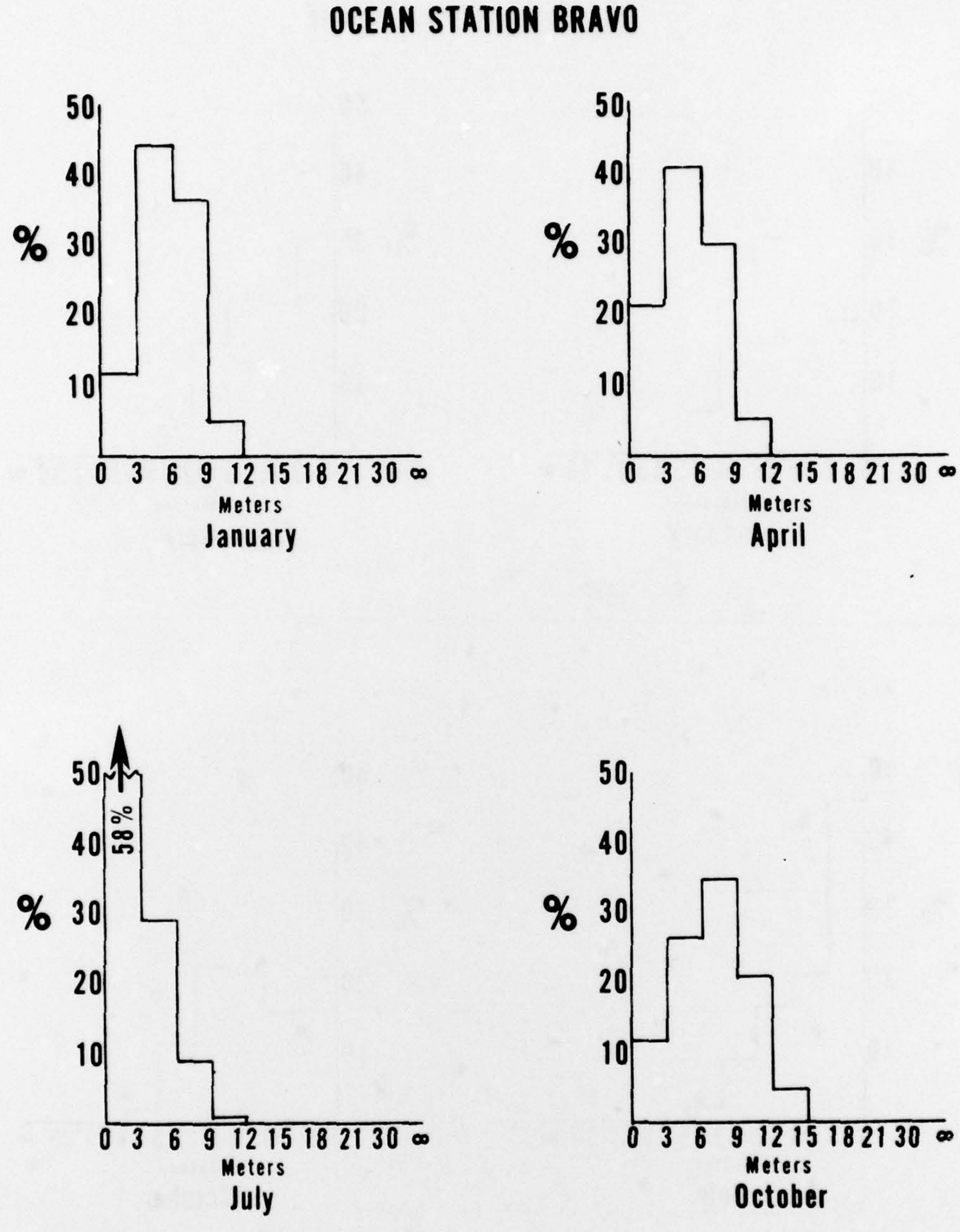


Figure 5. Percentages of occurrence of duct heights, *ocean station BRAVO, for mid-months* of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

OCEAN STATION CHARLIE

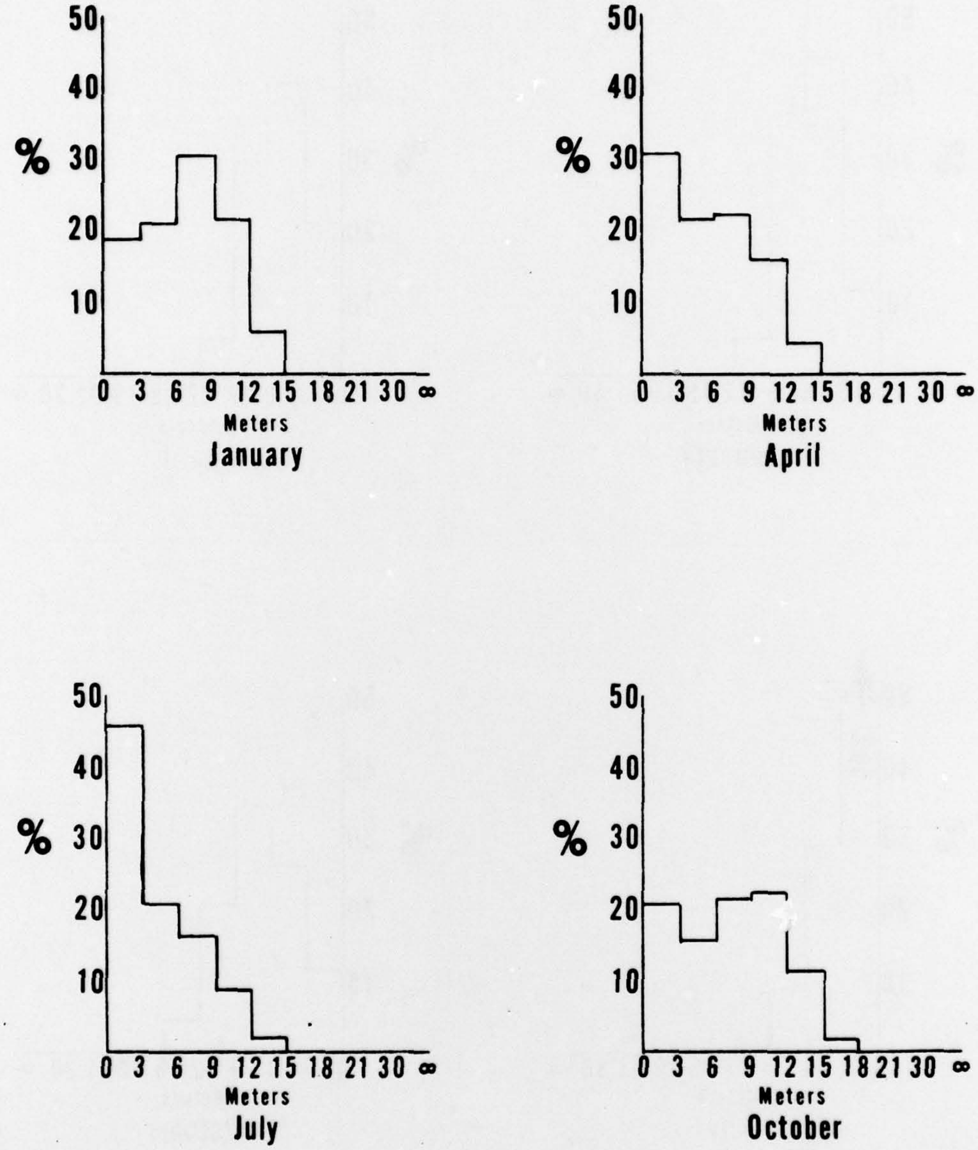


Figure 6. Percentages of occurrence of duct heights, ocean station CHARLIE, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

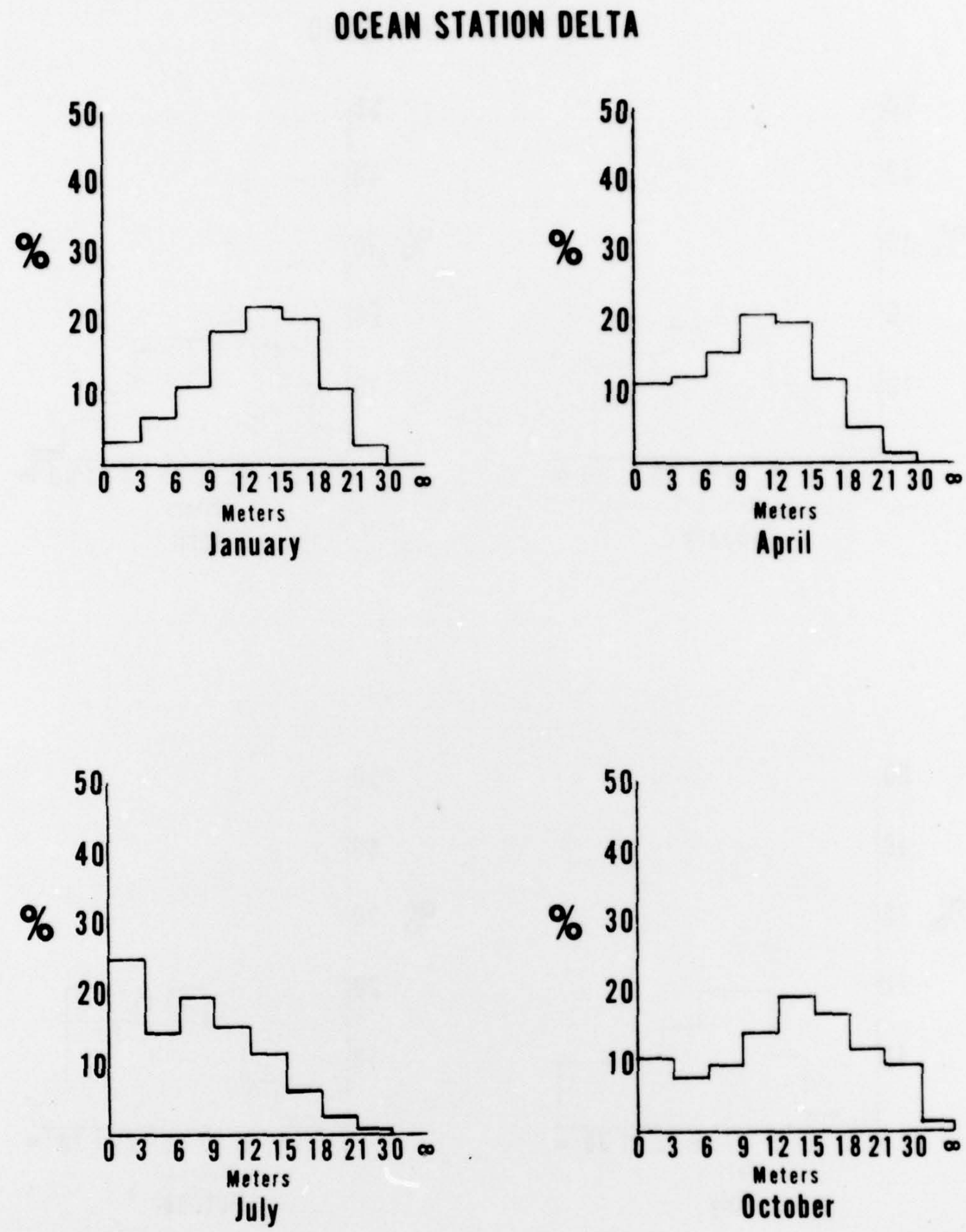


Figure 7. Percentages of occurrence of duct heights, ocean station DELTA, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

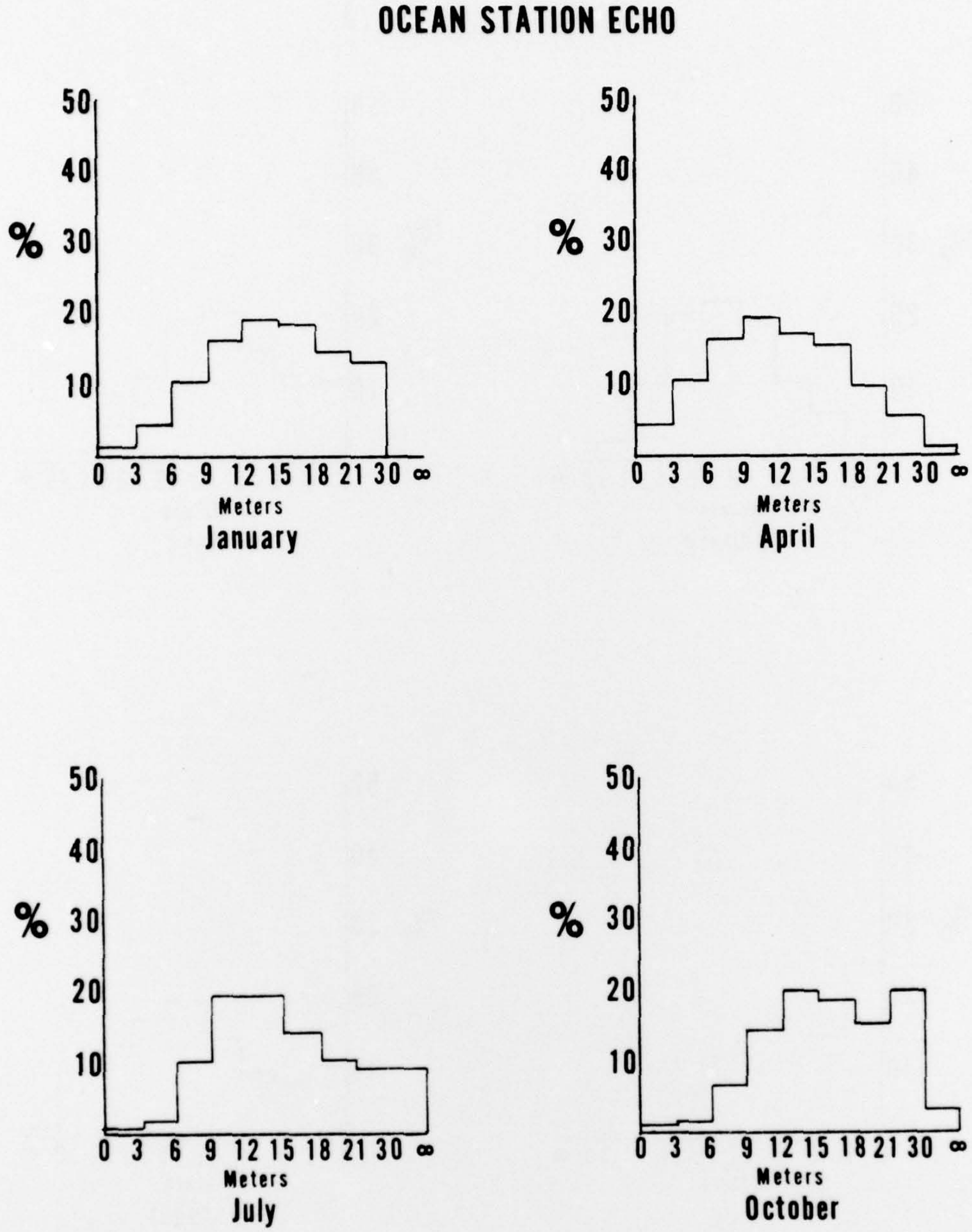


Figure 8. Percentages of occurrence of duct heights, ocean station ECHO, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

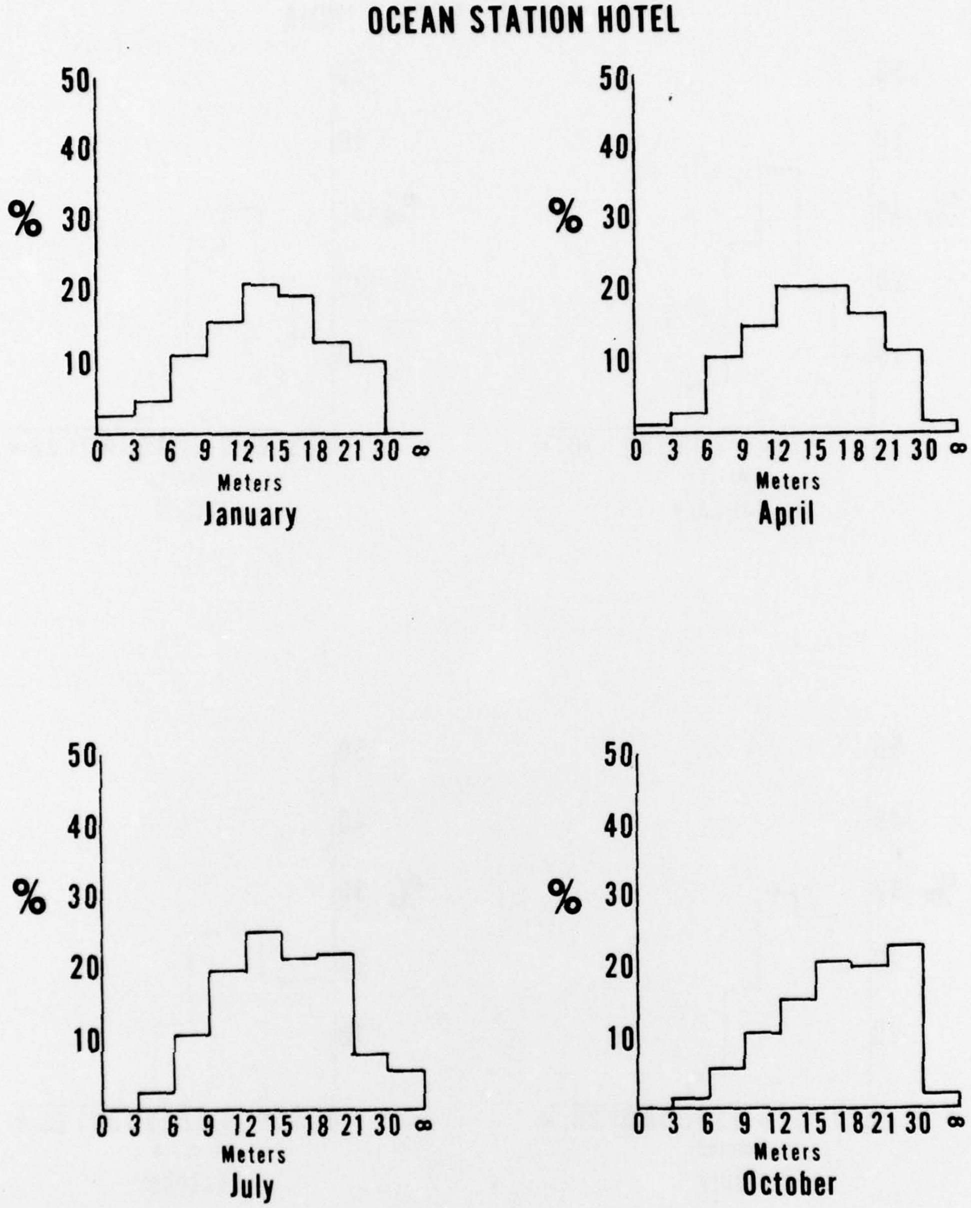


Figure 9. Percentages of occurrence of duct heights, ocean station HOTEL, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

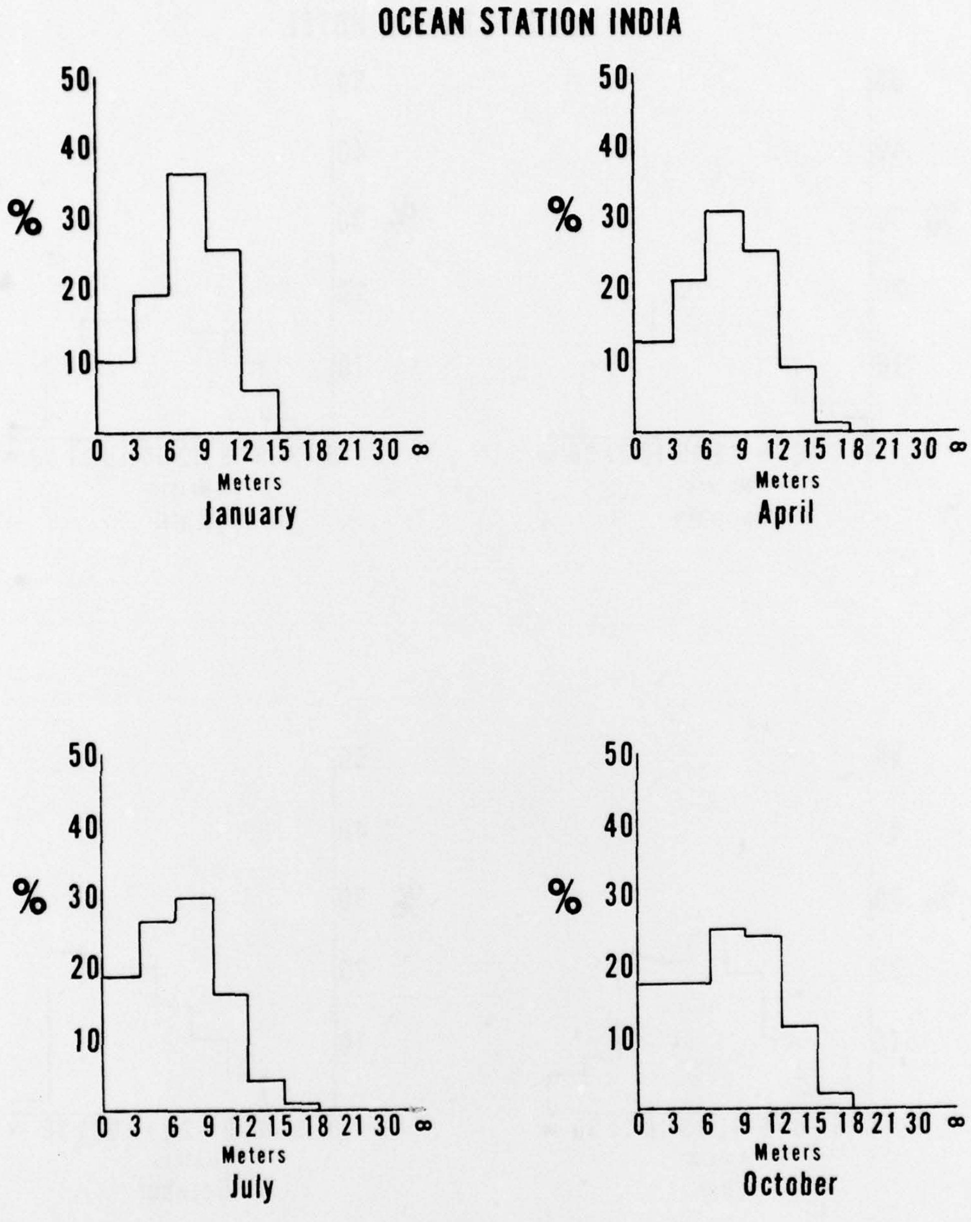


Figure 10. Percentages of occurrence of duct heights, ocean station INDIA, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

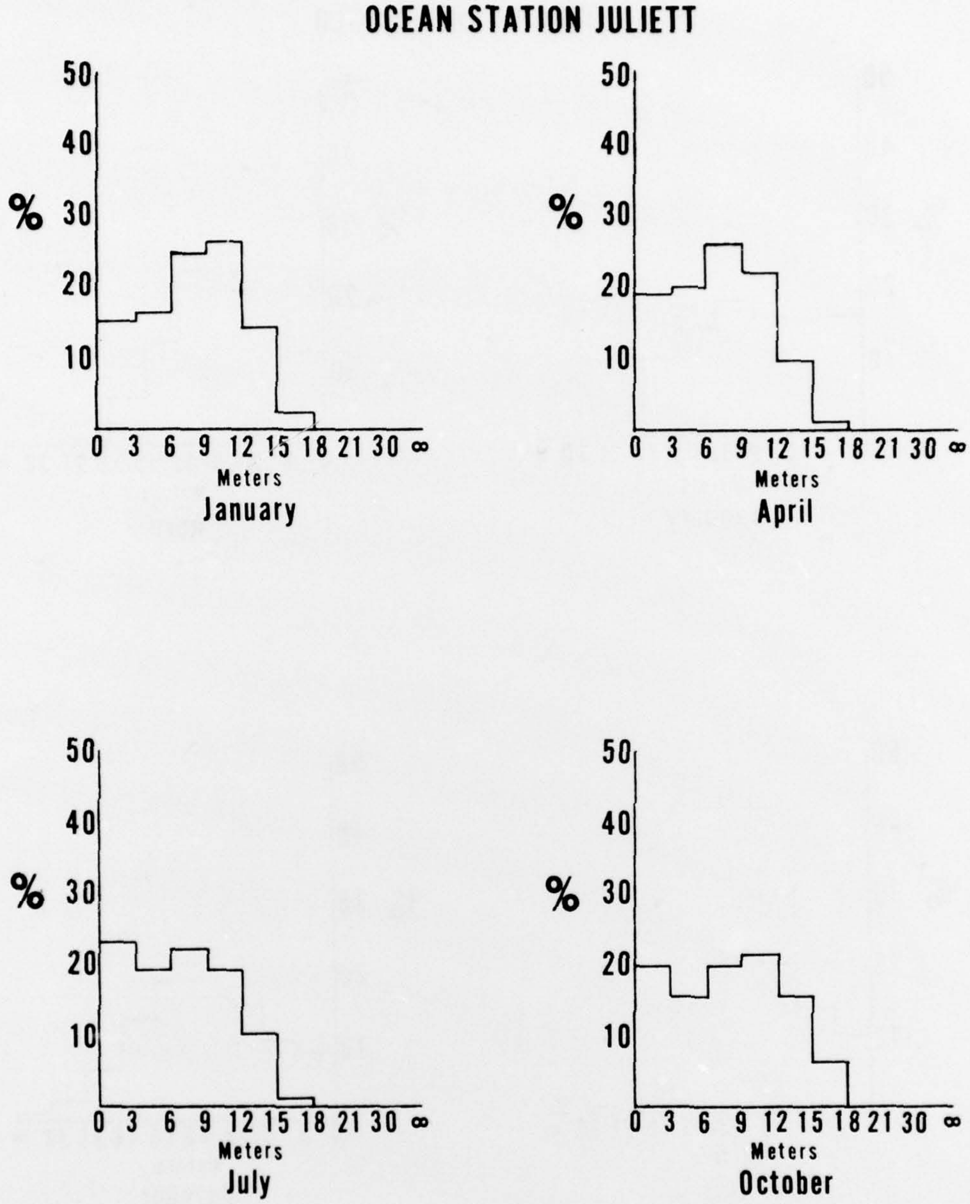


Figure 11. Percentages of occurrence of duct heights, ocean station JULIETT, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

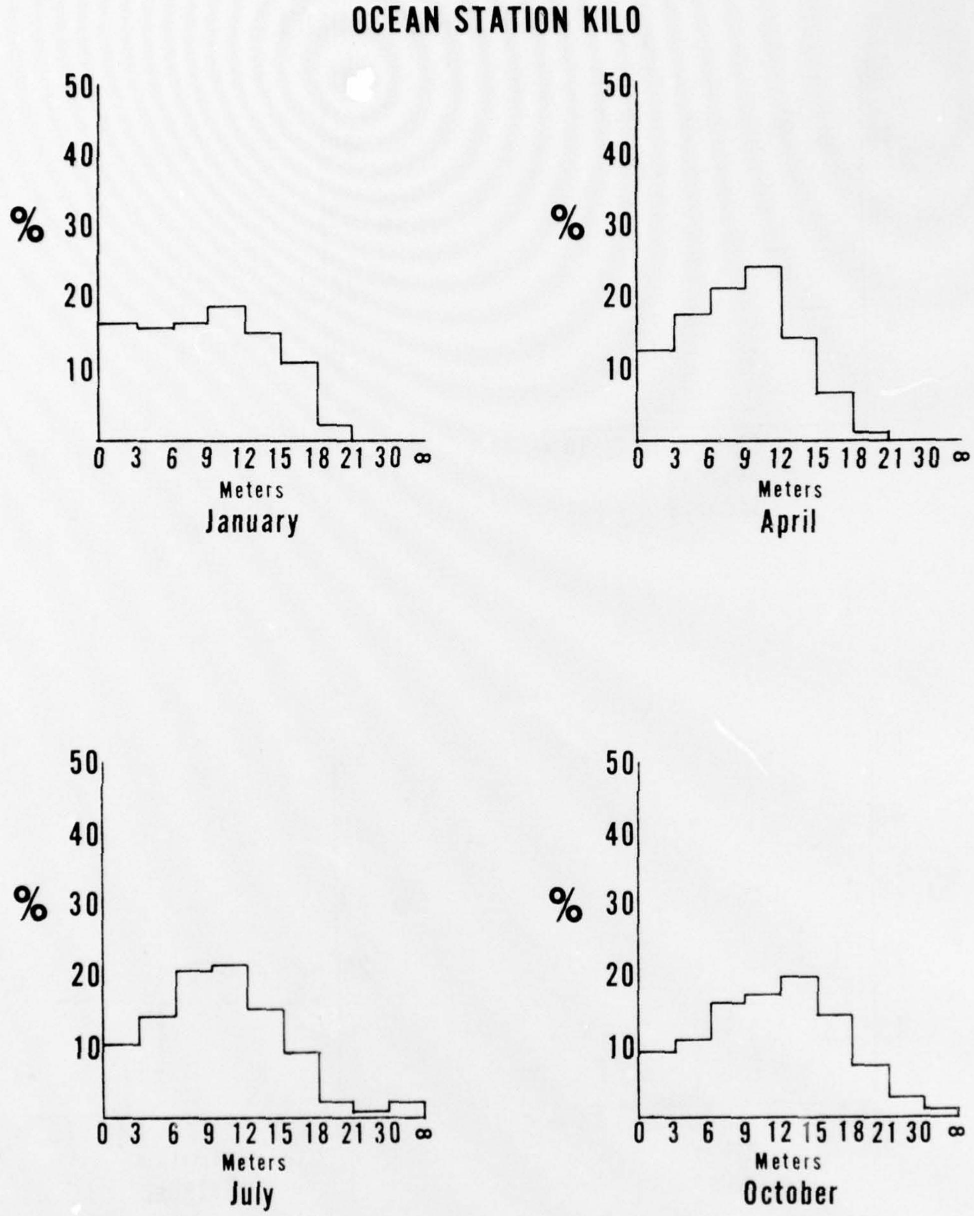


Figure 12. Percentages of occurrence of duct heights, ocean station KILO, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

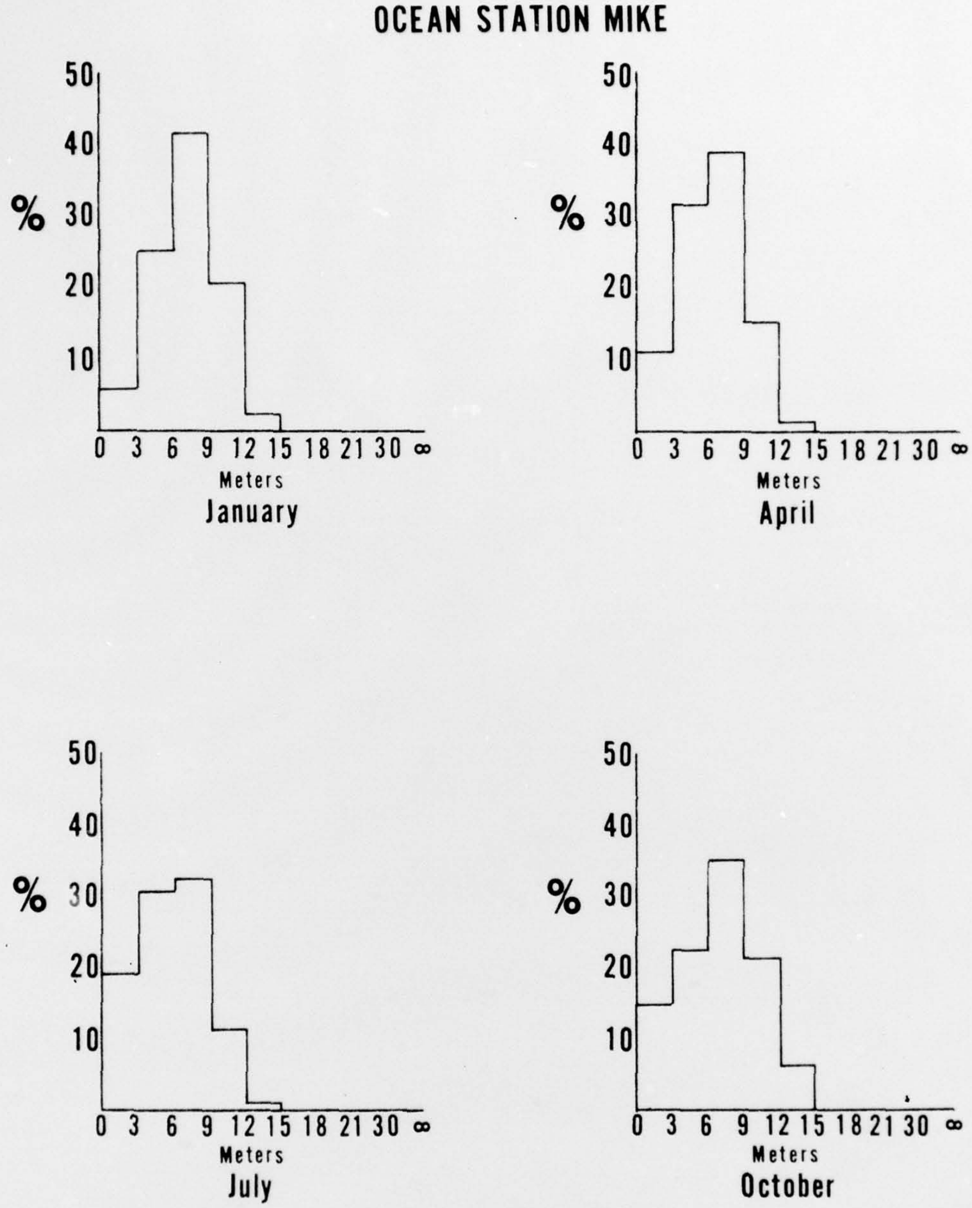


Figure 13. Percentages of occurrence of duct heights, ocean station MIKE, for mid-months of the four seasons (winter-Jan, spring-Apr, summer-Jul, fall-Oct).

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MONTHLY CLIMATOLOGY FOR EVAPORATION DUCT OCCURRENCE IN THE NORT--ETC(U)
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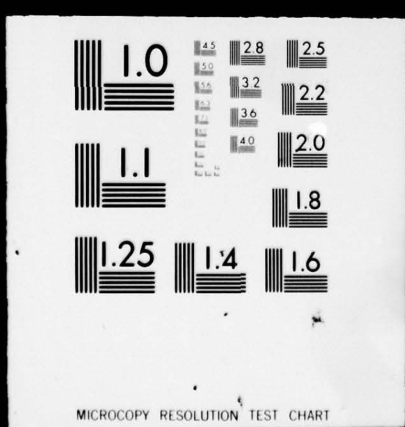

SUPPLEMENTARY

INFORMATION

NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY
MONTEREY, CALIFORNIA 93940

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22 May 1981

From: Commanding Officer
To: Distribution

Subj: NAVENVPREDRSCHFAC Technical Reports; changes in

1. Subject reports in which pen and ink changes should be made are:

D-A075524 a. TR 79-01, June 1979: Monthly climatology for evaporation duct occurrence in the North Atlantic Ocean

b. TR 79-02, July 1979: Summary of an EASTPAC refractive structure climatology

c. TR 80-01, February 1980: Anomalous microwave propagation assessment in the lower troposphere using a bulk meteorological parameter

d. TR 80-02, July 1980: Meteorological factors affecting evaporation duct height climatologies

e. TR 80-05, October 1980: Assessment/forecasting of anomalous microwave propagation in the troposphere using model output

2. On DD Forms 1473 of all subject reports listed in Para. 1 above,

Block 10 should read . . . PE62759N
Block 11 should read . . . Naval Ocean Systems Center
San Diego, CA 92152
Block 14 should read . . . Naval Material Command
Department of the Navy
Washington, DC 20360

3. On p. 5 of TR 80-05,

Eq. (1) should read $\Delta N = N_w(Ta) - N_w(Td)$

Eq. (2) should read $\Delta N = B[\frac{e(Ta)}{Ta^2} - \frac{e(Td)}{Td^2}] \approx \frac{B\Delta e}{Ta^2}$

adding $\Delta$ in Eq. (1), and deleting repeated expression $-\frac{e(Ta)}{Ta^2}$ in Eq. (2).

Gustave Gold

GUSTAVE GOLD
By direction