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# METEOROLOGICAL DATA SUMMARY
# INTEROCEANIC CANAL ROUTE 17, PANAMA
# FINAL REPORT

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This report presents summaries of meteorological data collected along Route 17 in the Darien region of Panama as part of the Interoceanic Canal Studies to determine the feasibility of constructing a new sea-level canal across the American Isthmus. Surface weather and upper-air wind data are summarized for the period July 1966 to December 1967.

## 1. INTRODUCTION

In September 1964, Congress authorized a study to determine the feasibility of constructing a sea-level canal across the American Isthmus. The overall study considers converting the present Panama Canal to a sea-level canal by conventional means and the use of nuclear or conventional excavation along two possible routes in remote jungle areas: Route 17 in the Darien region of Panama and Route 25 in northwest Colombia. Safety studies relating to nuclear excavation are assigned to the Nevada Operations Office (NVOO) of the Atomic Energy Commission. Required meteorological studies are being performed for NVOO by the Interoceanic Canal Project of the Environmental Science Services Administration (ESSA), which is staffed by personnel from the ESSA Research Laboratories (Air Resources Laboratories) and the Weather Bureau (Overseas Operations Division).

This report supersedes Preliminary Meteorological Data Summary-Route 17 (IOCS Memorandum ESSA-1) and summarizes the surface weather and winds aloft data for Route 17 during the period of operations from July 1966 through December 1967. Other project reports will present precipitation data obtained by the weather radars, tetroon studies, Route 25 weather data, and radiation safety studies for both routes.

## 1.1 Objectives

The meteorological program was designed primarily to answer two basic questions related to radiological safety: (a) What is the optimum size and orientation of the area that will have to be evacuated around each proposed canal route in order to insure the safety of the surrounding population? (b) What is the frequency of occurrence of wind and weather conditions that would confine the radiation hazard to the evacuated area?

## 1.2 Data Collection Program

Four manned weather stations, one near each end of each route, and six remote instrumented towers, three located along each route, were established to carry out the meteorological observation program. The locations of the weather stations are shown in figure 1.

The manned stations on Route 17 began operations during the summer of 1966; Pidiaque on July 1 and Soskatupu on August 1. The instrumented towers were installed early in 1967. A 2-year period of data collection was planned for all stations. However, all weather observations along Route 17 were terminated on December 31, 1967, due to lack of funds.

The manned stations on Route 25 began operations during the summer of 1967; Alto Curiche on June 1 and Loma Teguerre

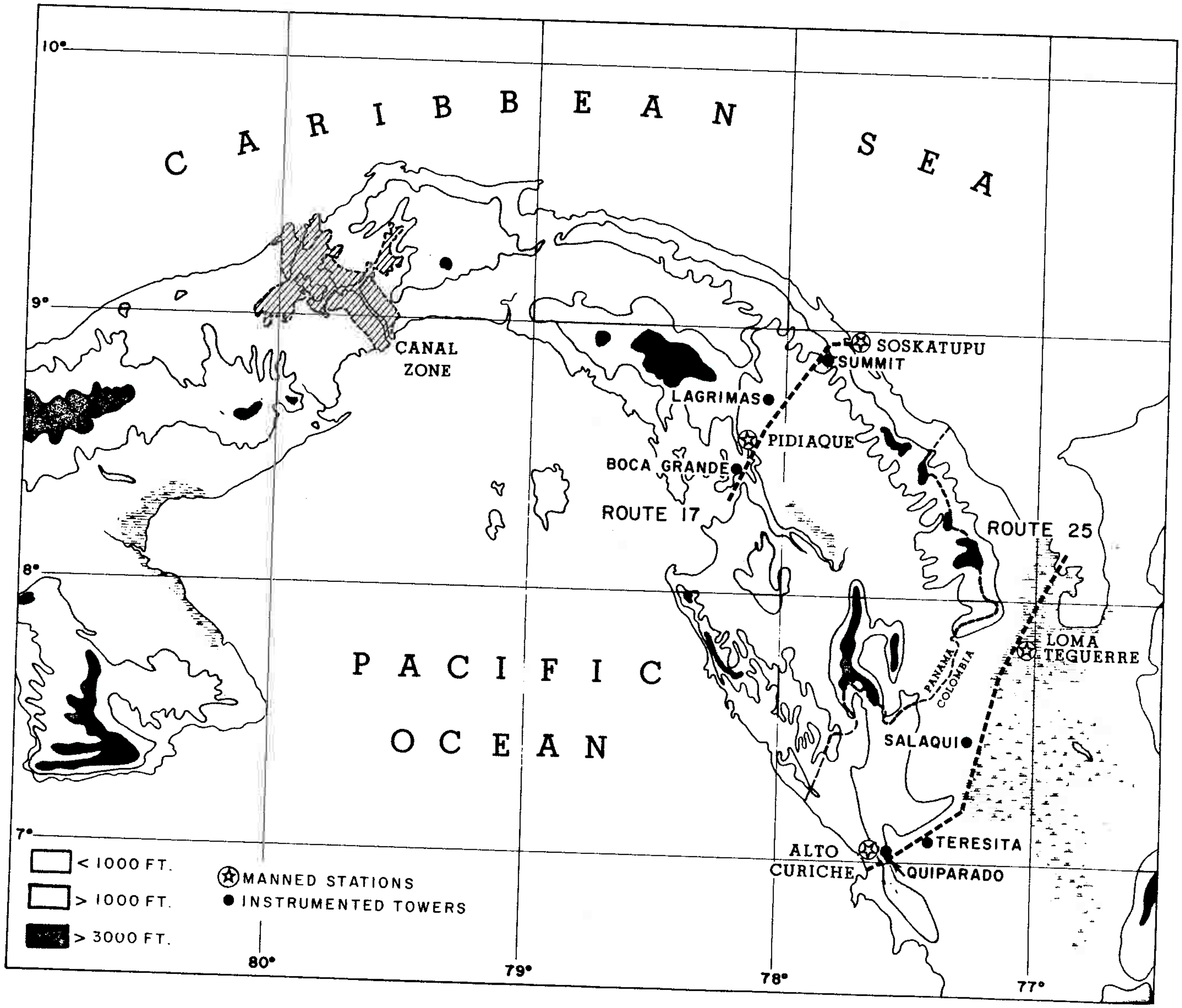



*Figure 1. Location of weather stations.*

on July 1. The instrumented towers were installed during November 1967. The Loma Teguerre station was closed on February 29, 1968. Observations at Alto Curiche and the three instrumented towers along Route 25 continued through June 10, 1969 when the facilities were turned over to the Colombian Meteorology and Hydrology Service.

The programs on both routes included standard observations of surface weather and radar measurements of winds aloft to 60,000 feet at 6-hour intervals. Air trajectories at altitudes below 15,000 feet were studied by radar tracking of constant-volume balloons (tetroons) that can float for many hours at approximately constant altitude. Routine weather radar observations of the areal distribution of rainfall and the heights to which rain storms extend were made.

The three remote instrumented towers along each route provided continuous records of wind, precipitation and temperature. The wind and temperature sensors were located on the towers just above the jungle canopy to aid in the study of low-level wind circulations. Precipitation measurements were made at ground level, a short distance from the base of the towers.

## 2. ROUTE 17 CLIMATOLOGY

Route 17 crosses the Darien Province of the Republic of Panama between $8^{\circ}$N and $9^{\circ}$N. Beginning on the Caribbean coast, it runs across the Continental Divide (at an elevation of about 1000 feet) about 5 miles inland and then across the Chucunaque Valley and Pacific highlands into the Gulf of San Miguel.

Route 17 lies in a region under the influence of the southern part of the circulation around the Atlantic cell of the high-pressure belt that encircles the earth at about $30^{\circ}$N and moves equatorward in winter and toward higher latitude in summer. A comparable high-pressure belt exists in the southern hemisphere with similar seasonal displacements. A broad band of easterly winds, the well-known trade winds, characterizes the equatorward side of both belts. Between the two lies the equatorial trough, an ill-defined region of low pressure with light and variable winds, commonly referred to as the doldrums. The equatorial trough is usually in the vicinity of Route 17 from May to November, shifting south of the area from December through April. One or more bands of bad weather are usually distinguishable within the equatorial trough zone. These bands mark the "intertropical convergence zone" (ITC), characterized by maximum cloudiness, heavy showers, and thunderstorms. The ITC zone appears in satellite photographs of this region of the tropics as a band of cloudiness generally oriented east-west, which persists throughout the year, although its size and intensity changes from day to day as it oscillates north or south of its mean seasonal position.

The climatic conditions along Route 17 may best be described as tropical - hot and humid throughout the year, with a rainy season and a dry season. The rainy season, with its depressingly humid conditions, fog, frequent thunderstorms, and torrential rains usually begins in April and ends abruptly in late December. The dry season, with somewhat less humid conditions, little rain or fog, and steady trade winds prevails through the remainder of the year.

### 2.1 Air Mass Characteristics

There is a marked difference in the structure of the atmosphere prevailing over Route 17 during the two seasons. In the dry season moist air is confined to the lowest layer of the atmosphere with drier air aloft, while in the rainy season there is moist unstable air to much greater heights. In the dry season, subsiding air aloft associated with the warm subtropical high over the route produces the so-called trade-wind inversion. In the tropics this inversion is discernible as a sharp decrease in humidity and increase in temperature with height at some altitude between 4000 and 10,000 feet. No vertical temperature and humidity profiles are available for Route 17, but vertical wind profiles for Pidiaque and Soskatupu from January through April show a marked anticyclonic wind shear at the 6,000-foot level. This suggests that 6000 feet is the average height of the base of the trade wind inversion in the route area. Below the inversion the air is moist and unstable, but the inversion arrests vertical development of clouds and showers. The trades weaken in April, and there is an increase of convective activity, which adds latent heat to the lower atmosphere. As more clouds penetrate the inversion and transport moisture into the dry air aloft, the inversion is weakened and raised. The transport of moist unstable air through the weakened inversion heralds the onset of the rainy season.

## 2.2 Surface Weather Conditions

Surface weather conditions along Route 17 are fairly uniform. However, the Caribbean side of the Continental Divide has more rainfall and much less fog than the rest of the route. Large departures from normal conditions are expected to be rare, except for rainfall, which can be quite variable.

### 2.2.1 Temperature

The temperatures along Route 17 show little seasonal or day-to-day variation. The mean monthly temperatures differ only $2^{\circ}F$ to $3^{\circ}F$ from an annual mean of $78^{\circ}F$. The diurnal temperature range is much greater. During the wet season the diurnal range is about $15^{\circ}F$ along the entire route. During the dry season the diurnal range decreases to 8°F on the Caribbean side, while it increases to 17°F on the Pacific side.

### 2.2.2 Humidity

The mean monthly relative humidity ranges from about 80 percent in the dry season to near 90 percent in the wet season. Diurnally, the relative humidity varies inversely with air temperature. Maximum relative humidity occurs near daybreak and the minimum occurs in midafternoon.

### 2.2.3 Rainfall

Annual rainfalls of 100 to 130 inches are common along the Caribbean coast and Atlantic highlands, while 70 to 100 inches are typical of the interior and Pacific side of the route. Less than 5 percent of the mean annual rainfall is in the dry season. Most of the precipitation is associated with convective showers or thunderstorms during both seasons of the year.

### 2.2.4 Severe Weather

Although thunderstorms occur in the vicinity of the route on most days during the rainy season, severe storms accompanied by damaging winds or hail are rare. No hurricanes or tornadoes have been recorded in the area, but strong sea swells and heavy rains connected with the outer perimeter of hurricanes passing north of the route through the western Caribbean have extended southward to the Caribbean side of the route.

### 2.2.5 Fog

During the rainy season fog is common over the entire route except for the Caribbean coast. The fog usually forms a few hours after sunset and continues until midmorning. Fog is not common during the dry season anywhere along the route.

### 2.2.6 Surface Winds

The trade winds, which tend to be northerly in the region, persist from December through April with little or no diurnal variation. From May through November, when the route lies in the doldrums, surface winds are light and variable, favor a southerly direction, and show a pronounced diurnal variation. Over both the Pacific and Atlantic ends of the route, there is a land breeze (offshore) during the early morning hours and a stronger sea breeze (onshore) during the afternoon. The land and sea breezes extend inland to the Continental Divide on the Caribbean side and up the Sabana River valley past Pidiaque but not as far as Lagrimas on the Pacific side of the route.

### 2.2.7 Upper Winds

The period from November through April is characterized by north or northeast winds near the ground, east winds in the lower troposphere, and westerlies in the upper troposphere, reversing to easterlies again near the tropopause. May and October are transitional months. October shows the greatest wind variability through most of the troposphere and also the highest frequency of southwesterly flow in the lowest 5000 feet. June through September is characterized by persistent easterly winds in the entire layer from 5000 to 60,000 feet. Northerly winds still predominate in the lowest 5000 feet. However, Pidiaque shows a secondary maximum of winds from the southwest below 5000 feet that appears to reflect a sea breeze that frequently develops in the afternoons during this season when the northeasterly trade wind flow tends to be weak.

## 2.3 Data Reliability

The seasonal and diurnal variations in weather conditions are based on the meteorological data collected along Route 17 from July 1966 through December 1967. The fact that the data cover only this relatively short period undoubtedly influences our conclusions, but since the route lies wholly within a tropical environment the variation of weather conditions from year to year should be small. Short-period and limited area anomalies may go undetected because of the limited data sample, but this should not greatly impair its value in examining the safety feasibility of nuclear excavation of Route 17.

## 3. SURFACE WEATHER PROGRAM

### 3.1 Route 17 Station Locations and Equipment

The meteorological program on Route 17 included two manned weather stations at Pidiaque and Soskatupu and instrumented towers at Boca Grande, Summit, and Lagrimas (see fig. 1). Table 1 lists location, station elevation, and the date on which data collection began at each site. All observations terminated on December 31, 1967.

The Pidiaque station was located on the crest of a 985-foot ridge, the northernmost of a line of hills that parallel the Sabana River. In the north and east quadrants from the

*Table 1. Surface Weather Observation Stations.*

| Station | Location (Lat.-Long.) | Station Elevation (Feet-MSL) | Tower Height (Feet) | Date Observations Began |
|---|---|---|---|---|
| Soskatupu | 8°56'N 77°44'W | 7 | - | 8/1/66 |
| Pidiaque | 8°36'N 78°8'W | 921 | - | 7/1/66 |
| Boca Grande | 8°28'N 78°10.1'W | 200 | 60 | 2/1/67 |
| Summit | 8°54.9'N 77°50.9'W | 1060 | 120 | 3/8/67 |
| Lagrimas | 8°44.2'W 78°4.9'W | 274 | 140 | 2/8/67 |

station, the area is forested with elevations roughly from 100 to 300 feet above sea level. The Sabana River Valley, extending from just west of the station southward to Darien Harbor, is near sea level, with tides extending up-river past the station. The area west of the river is also forested and hilly, with elevations generally ranging from 300 to 1000 feet. The station is approximately 10 miles north of Darien Harbor, but it is 21 miles to the Pacific coast toward the southwest. The Caribbean Sea is 32 miles to the northeast. Weather conditions at Pidiaque are fairly representative of the Pacific coast and interior portions of the route area.

The station was constructed on the cleared ridge whose surface consists of soft rock and clay. The radar was located on the highest point of the ridge at an elevation of about 985 feet. The office and surface weather observing equipment were located at a lower level with a ground elevation of 916 feet. The height of the barometer (official station elevation) was 921 feet.

The surface wind equipment was a Bendix Aerovane mounted on the office building 23 feet above the ground. The data were recorded on a Bendix recorder model 141. An instrument shelter housed a manually aspirated psychrometer and maximum and minimum thermometers. Precipitation was measured, at 6-hour intervals, with a standard 8-inch nonrecording rain gage.

Pidiaque also had an M-33 radar system, including S-band (10 cm) and X-band (3 cm) components used for precipitation observations and upper air wind measurements respectively. Other instruments at the station included a mercurial barometer, a microbarograph, and a theodolite for upper wind observations when the X-band radar was not operational.

The other manned station on Route 17 was on Soskatupu Island, about 1 mile off the Caribbean Coast. The island parallels the coast and is about 1/2 mile wide and 2 miles long; it is only a few feet above sea level, except for one hill that has an elevation of 145 feet. The station was located in a palm grove near the beach on the Caribbean side side of the island. The ground elevation at the station site was 2 feet. The height of the barometer (official station elevation) was 7 feet.

The meteorological instruments at Soskatupu were identical with those of Pidiaque, except that Soskatupu did not have an S-band radar. The X-band radar was located atop the 145-foot hill, and the height of the radar antenna was 161 feet.

Areas were cleared and instrumented towers erected at three other sites:

(a) Boca Grande - Ground elevation 200 feet. The instruments on the towers were 60 feet above ground; the station was located on the crest of a hill a few hundred feet inland from the northern end of Darien Harbor.

(b) Lagrimas - Ground elevation 274 feet. The instruments on the tower were 140 feet above ground; dense jungle surrounds the Lagrimas tower site, with only slight variation in elevation of the surrounding terrain.

(c) Summit - Ground elevation 1,060 feet. The instruments on the tower were 120 feet above ground; the tower was located near the crest of the Continental Divide about 5 miles inland from the Caribbean coast.

The equipment at each power site consisted of wind, temperature, and precipitation measuring and recording devices manufactured by Meteorology Research, Incorporated. The wind and temperature instruments were installed on each tower approximately 20 feet above the top of the jungle canopy. Wind speed was measured by a three-cup anemometer and the direction determined by a single-blade aluminum vane. The temperature sensor was a spiral bimetallic element. A tipping bucket rain gage that records rainfall in 0.01-inch increments was located at the ground approximately 50 feet from the base of the tower. All data were recorded on battery-wound, spring-driven, strip-chart recorders supposedly designed for 60-day unattended operation. The chart recorder was mounted on the tower just below the wind sensor.

Meteorological records from the instrumented tower stations were frequently incomplete because of equipment malfunctions. Tables 2 and 3 list the number of days of observations of the different weather parameters obtained per month for each tower along Route 17. Surface weather summaries of precipitation were made only for those months for which there were more than 10 days of record.

*Table 2. Number of Days of Precipitation Observations per Month in 1967.*

| | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Boca Grande | 28 | 1 | 25 | 30 | 30 | 31 | 18 | 18 | 12 | 14 | 13 |
| Lagrimas | 21 | 2 | 25 | 22 | 0 | 0 | 6 | 17 | 4 | 30 | 7 |
| Summit | | 24 | 17 | 14 | 28 | 14 | 10 | 0 | 23 | 30 | 31 |

*Table 3. Number of Days of Temperature and Wind Observations per Month in 1967.*

| | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Boca Grande | 28 | 0 | 26 | 30 | 30 | 31 | 31 | 18 | 12 | 30 | 31 |
| Lagrimas | 21 | 0 | 25 | 22 | 0 | 14 | 21 | 17 | 5 | 30 | 8 |
| Summit | | 24 | 17 | 14 | 28 | 15 | 10 | 0 | 22 | 30 | 31 |

### 3.2 Frequency and Type of Observations

Routine surface synoptic weather observations at the manned stations were made daily at 0100, 0700, 1300, and 1900 local standard time (0600, 1200, 1800, 0000 GMT). These were complete 6-hourly synoptic observations that contained the following atmospheric measurements:

(a) Cloud layers.

(b) Sky (amount of sky covered by clouds or obscuring phenomena).

(c) Visibility.

(d) Weather (rain, fog, thunderstorms, etc.).

(e) Sea-level pressure.

(f) Temperature.

(g) Dew point and relative humidity.

(h) Wind direction and speed.

(i) Precipitation amount (6-hour total).

(j) State of ground.

A summary of the daily record also lists the beginning and ending time of rain, fog, and thunderstorms; the maximum and minimum daily temperature; the speed and time of occurrence of peak wind gust; and total amount of daily (midnight to midnight) precipitation.

### 3.3 Data Processing

Before July 1, 1967, the surface weather summaries for manned and instrumented tower stations were compiled manually. After that date, the data were sent to the National Weather Records Center (NWRC) at Asheville, North Carolina, where they were entered on punched cards and summarized by computer.

The following types of monthly summaries were prepared for the stations along Route 17:

Manned stations (Pidiaque and Soskatupu)

(1) Fog and Thunderstorms

- (a) Tabulation of occurrence by date and hour.
- (b) Number of occurrences each day and each month.
- (c) Number of hours of occurrence each day and each month.
- (d) Monthly percent frequency of occurrence for each hour of the day.

(2) Cloud Ceiling

- (a) Monthly percent frequency of various cloud ceiling ranges for 0100, 0700, 1300, and 1900 local standard time.

(3) Visibility

- (a) Monthly percent frequency of various visibility ranges for 0100, 0700, 1300, and 1900 local standard time.

(4) Humidity

- (a) Monthly mean maximum and minimum relative humidity.
- (b) Monthly absolute maximum and minimum relative humidity.

Manned stations and instrumented towers (Boca Grande, Lagrimas, and Summit)

(1) Rainfall

(a) Tabulation of occurrence by date and hour.

(b) Number of occurrences each day (including trace occurrences at manned stations) and each month.

(c) Number of hours of occurrence each day and sum for the month.

(d) Monthly percent frequency of occurrence for each hour of the day.

(e) Total rainfall for each 6-hour and 24-hour period for each month.

(2) Surface Wind

Monthly percent frequency of surface winds in direction increments of 10° and various speed categories (increments of 3 to 5 knots). Summarized for every 3 hours at tower stations and every 6 hours for manned stations beginning at 0100 LST. Also summarized for all hours combined.

(3) Temperature

(a) Monthly mean maximum and minimum temperature.

(b) Absolute maximum and minimum temperature for each month.

3.4 Surface Weather Data Summary and Discussion

Summaries of the surface weather data collected on Route 17 from July 1966 through December 1967 are presented in figures 2 through 15. Explanatory notes and a brief interpretation of the data appear on the page preceding each figure.

*Figure 2. -Summary of temperature and humidity for Soskatupu and Pidiaque and temperature for tower stations.*

The mean annual temperature varies from about 80°F along the Caribbean coast to about 75°F on the Continental Divide and increases again to 78°F in the interior region. There is little seasonal change in temperature, and diurnal changes are greater than the variation of the monthly means. The diurnal variation on the Caribbean side is less than in the interior region, particularly during the dry season. The average diurnal variation at Soskatupu (Caribbean) ranges from 8°F in the dry season to 14°F during the wet season, whereas Pidiaque (interior) shows an average diurnal difference of about 17°F in the dry season and about 15°F in the wet season. The absolute maximum temperature recorded along the route was 94°F and the absolute minimum temperature was 65°F.

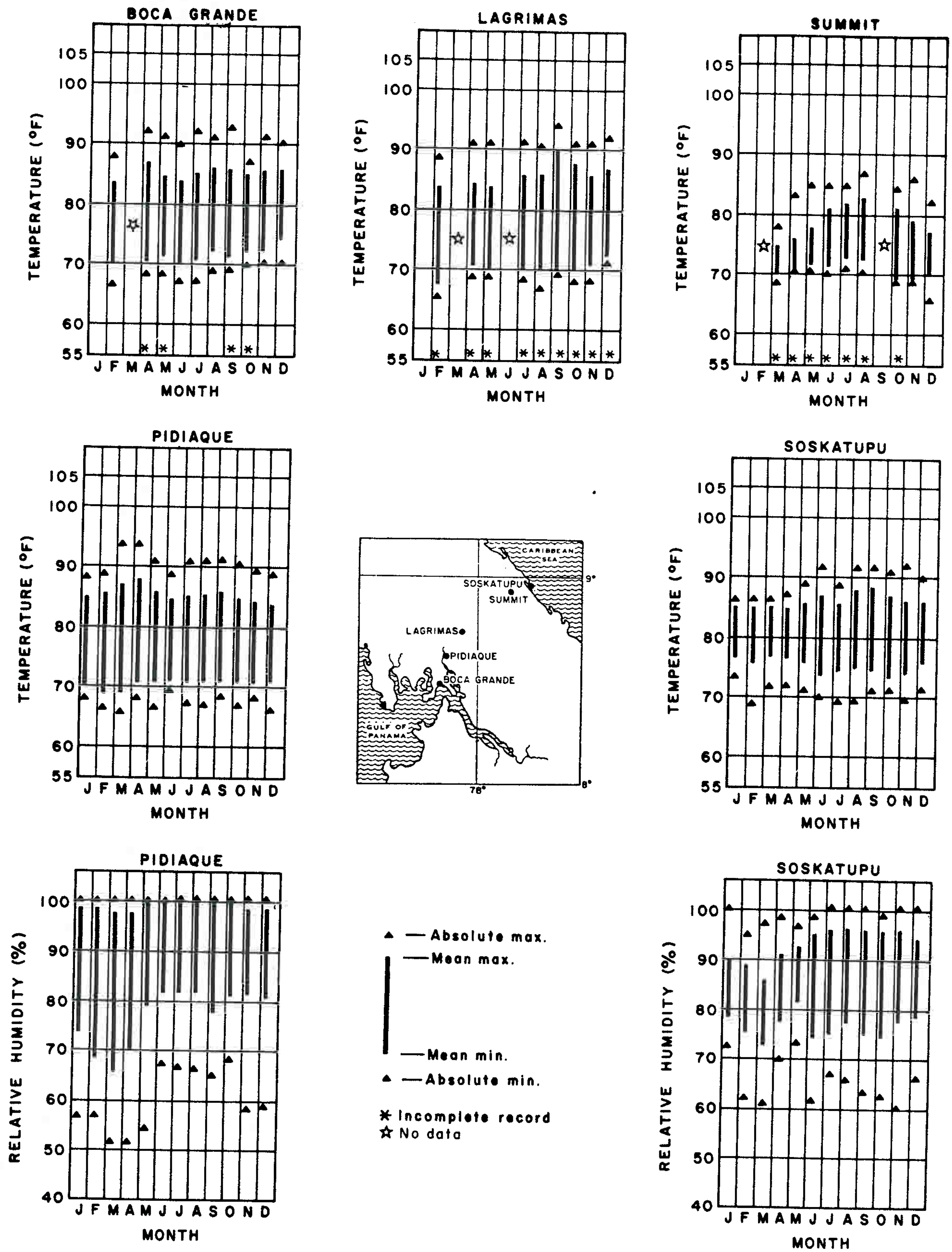
Humidity is high throughout the year, but there is a small decrease during the dry season. The mean monthly humidities are generally between 80 and 90 percent. It is somewhat less humid on the Caribbean Coast than over the interior.

Explanatory Notes:

The humidity summaries were made from observations taken at 0100, 0700, 1300, and 1900 local standard time. Daily maximum and minimum temperatures were obtained from 24-hour per day observations.

Table 3 (page 13) gives the number of days with observations per month for the tower stations.

Temperatures and humidities for the same months during 1966 and 1967 have been averaged, i.e., Pidiaque - July through December; Soskatupu - August through December.




MONTHLY MAXIMUM AND MINIMUM TEMPERATURES AND HUMIDITIES

*Figure 2.*

*Figure 3. Percent frequency distribution of cloud ceilings for Soskatupu and Pidiaque.*

Over the interior during the rainy season the early morning is heavily overcast or fog shrouded, with cloud ceilings frequently less than 700 feet. The low clouds or fog dissipate around midmorning. By noon, clouds with bases of 2000 to 3000 feet form, building rapidly into towering cumulus and cumulonimbus during the afternoon, and dissipating around sunset. Fog usually sets in a few hours after sunset, and ceilings lower during the night. During the dry season skies are mostly clear throughout the day except for cumulus clouds that form in the moist unstable air below the trade inversion during late morning or early afternoon. Cloud bases are at 2000 to 3000 feet. However, vertical development of the cumulus during this season is inhibited by the strong trade wind inversion.

The Caribbean coast has a high incidence of cloud ceilings of about 2000 feet throughout the year. These clouds are more prevalent in the dry season when the strong flow of moist air below the trade inversion is lifted by the Atlantic highland barrier. Cloud ceilings below 1500 feet are rare along the Caribbean coast.

Explanatory Notes:

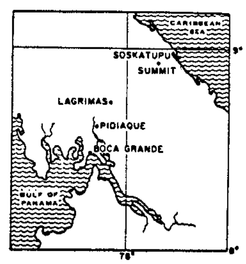
The cloud ceiling observations are summarized for each calendar quarter of the year for each of the four observation times.

Cloud ceilings for the third and fourth quarters are an average of both 1966 and 1967 observations.

SOSKATUPU

| LOCAL TIME | 0100 | | | | 0700 | | | | 1300 | | | | 1900 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUARTER | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **CEILING HEIGHT (HUNDREDS OF FEET)** | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8-9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10-14 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15-19 | 0 | 7 | 4 | 1 | 2 | 8 | 4 | 1 | 3 | 1 | 0 | 1 | 0 | 8 | 1 | 2 |
| 20-29 | 36 | 27 | 17 | 12 | 59 | 33 | 22 | 30 | 31 | 21 | 7 | 17 | 41 | 32 | 15 | 13 |
| 30-49 | 1 | 7 | 5 | 1 | 6 | 10 | 4 | 2 | 1 | 7 | 1 | 0 | 1 | 3 | 1 | 0 |
| 50-95 | 1 | 3 | 1 | 4 | 4 | 8 | 6 | 4 | 1 | 10 | 2 | 4 | 3 | 9 | 1 | 5 |
| > 95 | 62 | 55 | 73 | 82 | 29 | 40 | 64 | 62 | 64 | 60 | 90 | 78 | 54 | 49 | 82 | 80 |

Quarter 1 : Jan - Mar
Quarter 2 : Apr - Jun
Quarter 3 : Jul - Sep
Quarter 4 : Oct - Dec




PIDIAQUE

| LOCAL TIME | 0100 | | | | 0700 | | | | 1300 | | | | 1900 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUARTER | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **CEILING HEIGHT (HUNDREDS OF FEET)** | | | | | | | | | | | | | | | | |
| 0 | 0 | 1 | 5 | 0 | 0 | 1 | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 3 | 1 | 0 | 1 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 2 | 0 | 4 | 5 | 3 | 0 | 2 | 7 | 7 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| 3 | 0 | 1 | 1 | 3 | 0 | 7 | 6 | 8 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 4 | 0 | 1 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-7 | 0 | 3 | 2 | 2 | 1 | 4 | 5 | 8 | 1 | 1 | 1 | 1 | 0 | 2 | 6 | 1 |
| 8-9 | 0 | 0 | 1 | 1 | 0 | 1 | 3 | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 1 |
| 10-14 | 0 | 1 | 3 | 3 | 0 | 2 | 4 | 4 | 0 | 7 | 6 | 4 | 0 | 4 | 3 | 6 |
| 15-19 | 0 | 4 | 2 | 5 | 2 | 5 | 3 | 4 | 1 | 7 | 13 | 14 | 0 | 7 | 4 | 3 |
| 20-29 | 1 | 4 | 6 | 3 | 4 | 15 | 4 | 5 | 36 | 43 | 20 | 24 | 6 | 11 | 10 | 9 |
| 30-49 | 1 | 3 | 8 | 2 | 4 | 5 | 2 | 3 | 13 | 10 | 6 | 5 | 3 | 8 | 6 | 4 |
| 50-95 | 6 | 7 | 6 | 5 | 3 | 11 | 14 | 6 | 3 | 5 | 4 | 6 | 1 | 3 | 10 | 8 |
| > 95 | 92 | 69 | 58 | 71 | 85 | 43 | 39 | 45 | 46 | 26 | 47 | 45 | 89 | 61 | 57 | 66 |

FREQUENCY DISTRIBUTION OF CLOUD CEILINGS (percent)
*Figure 3.*

*Figure 4. Percent frequency distribution of visibility for Soskatupu and Pidiaque.*

Visibility below 3 miles is rare along the Caribbean coast during all seasons of the year. Visibilities may lower to near 1 mile in a shower or a rare fog during the rainy season, but on the average visibilities of 7 miles or greater prevail.

Over the interior region in the rainy season visibilities are frequently restricted by fog to less than 3/8 mile during the night and early morning hours. Visibilities associated with showers and thunderstorms often lower to 1 mile. During the dry season, visibility over the interior region is greater than 7 miles, except for an isolated thunderstorm or fog occurrence, which could reduce visibility to 1 mile or less.

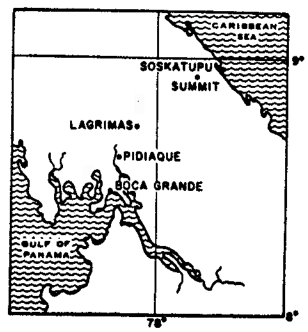
Explanatory Notes:

The visibility observations are summarized for each calendar quarter of the year for each of the four observation times. The two samples (1966 and 1967) obtained for the third and fourth quarters have been averaged.

SOSKATUPU

| LOCAL | | 0100 | | | | 0700 | | | | 1300 | | | | 1900 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUARTER | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| VISIBILITY (MILES) | 0-1/8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3/16-3/8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1/2-3/4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1-1 3/4 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2-2 1/2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3-6 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| | 7-15 | 73 | 91 | 49 | 54 | 60 | 85 | 56 | 53 | 30 | 67 | 41 | 45 | 50 | 84 | 42 | 55 |
| | > 15 | 27 | 9 | 51 | 45 | 40 | 10 | 44 | 46 | 70 | 31 | 59 | 54 | 50 | 15 | 57 | 45 |

Quarter 1 : Jan - Mar
Quarter 2 : Apr - Jun
Quarter 3 : Jul Sep
Quarter 4 : Oct Dec




PIDIAQUE

| LOCAL TIME | | 0100 | | | | 0700 | | | | 1300 | | | | 1900 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUARTER | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| VISIBILITY (MILES) | 0-1/8 | 0 | 3 | 11 | 7 | 1 | 8 | 27 | 18 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 3/16-3/8 | 0 | 5 | 8 | 5 | 0 | 13 | 15 | 12 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| | 1/2-3/4 | 0 | 3 | 2 | 6 | 0 | 4 | 5 | 10 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 2 |
| | 1-1 3/4 | 0 | 1 | 3 | 0 | 0 | 4 | 6 | 3 | 0 | 2 | 2 | 1 | 0 | 1 | 0 | 1 |
| | 2-2 1/2 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| | 3-6 | 2 | 8 | 7 | 7 | 2 | 2 | 5 | 6 | 0 | 3 | 2 | 2 | 1 | 3 | 10 | 2 |
| | 7-15 | 69 | 75 | 49 | 61 | 88 | 65 | 28 | 42 | 64 | 84 | 62 | 66 | 84 | 85 | 62 | 67 |
| | > 15 | 28 | 3 | 19 | 14 | 9 | 2 | 12 | 6 | 34 | 11 | 34 | 29 | 14 | 5 | 23 | 23 |

FREQUENCY DISTRIBUTION OF VISIBILITY RANGES (percent)

*Figure 4.*

*Figure 5. Monthly rainfall amounts.*

The Caribbean coast and Continental Divide receive the highest annual rainfall. Yearly totals average about 100 to 130 inches, with larger amounts likely over the higher elevations. Annual rainfall averages from 70 to 100 inches elsewhere over Route 17.

The average monthly rainfall during the dry season (January through March) ranges from about 1/2 inch over the Caribbean coast to 1 inch elsewhere along the route.

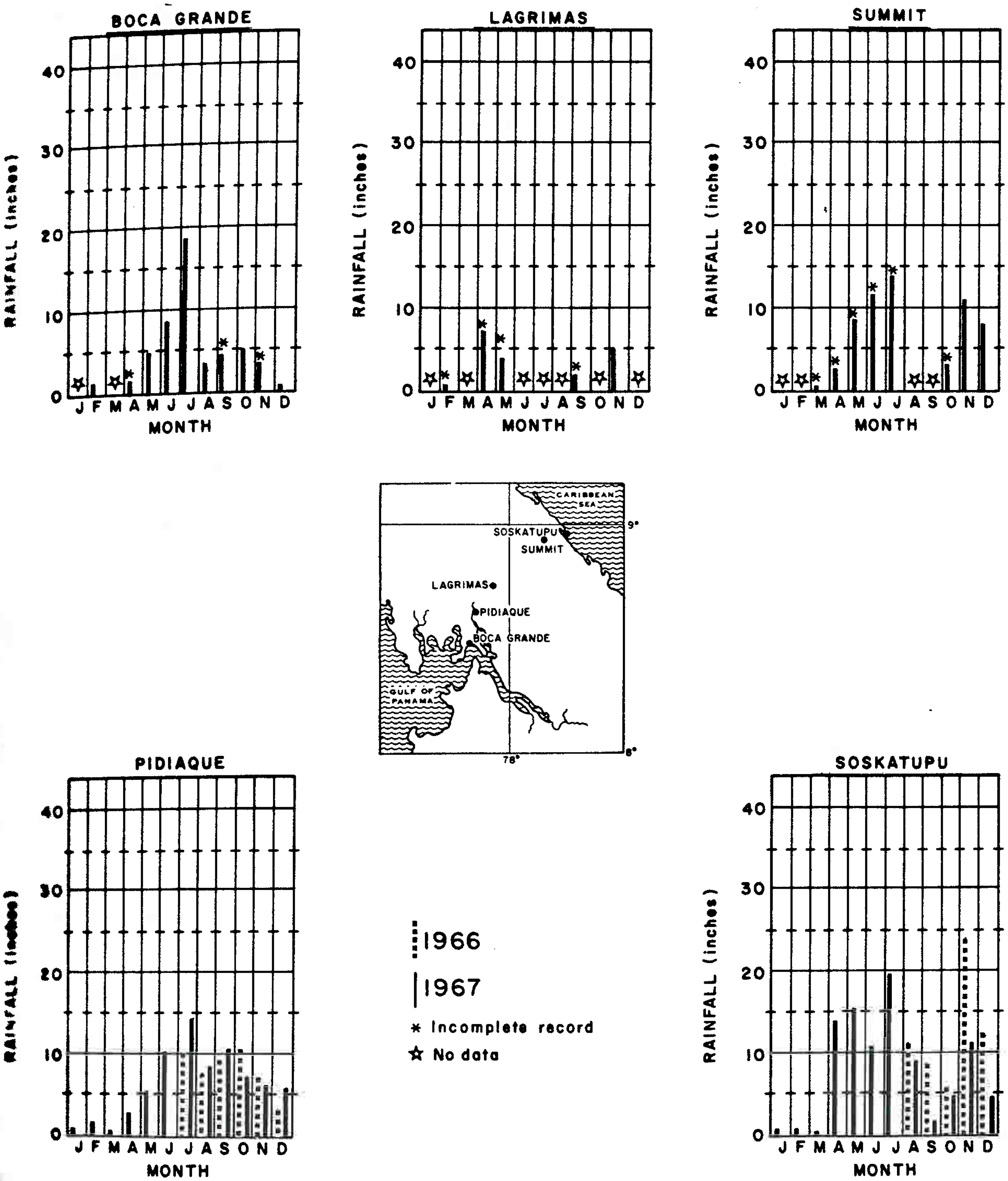
The average monthly rainfall during the wet season (April through December) was about 8 inches at Pidiaque and about 11 inches at Soskatupu. During the rainy season, precipitation varies greatly as shown by the monthly rainfall totals at Pidiaque and Soskatupu given in the table below. Note that rainfall totals may differ greatly from one month to the next, or for a given month from one year to another, or at the two stations for the same month.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pidiaque | | | | | | | | | | | | |
| 1966 | | | | | | | 10.0 | 7.1 | 9.7 | 10.2 | 7.0 | 3.4 |
| 1967 | 1.0 | 1.7 | 0.4 | 2.7 | 5.2 | 10.1 | 14.8 | 8.1 | 10.4 | 7.5 | 6.1 | 6.2 |
| Soskatupu | | | | | | | | | | | | |
| 1966 | | | | | | | | 11.0 | 8.6 | 5.6 | 23.8 | 12.3 |
| 1967 | 0.6 | 0.6 | 0.2 | 13.6 | 15.0 | 10.6 | 19.6 | 9.2 | 1.7 | 4.7 | 11.0 | 4.2 |

Explanatory Notes:

Months with a rainfall record for fewer than 11 days have been considered to have "no data".

Months with more than 11 days of record but less than a complete month have been marked as "incomplete record".




MONTHLY RAINFALL AMOUNTS

*Figure 5.*

*Figure 6. Frequency of rain by hour of day and season of year at Pidiaque and Soskatupu.*

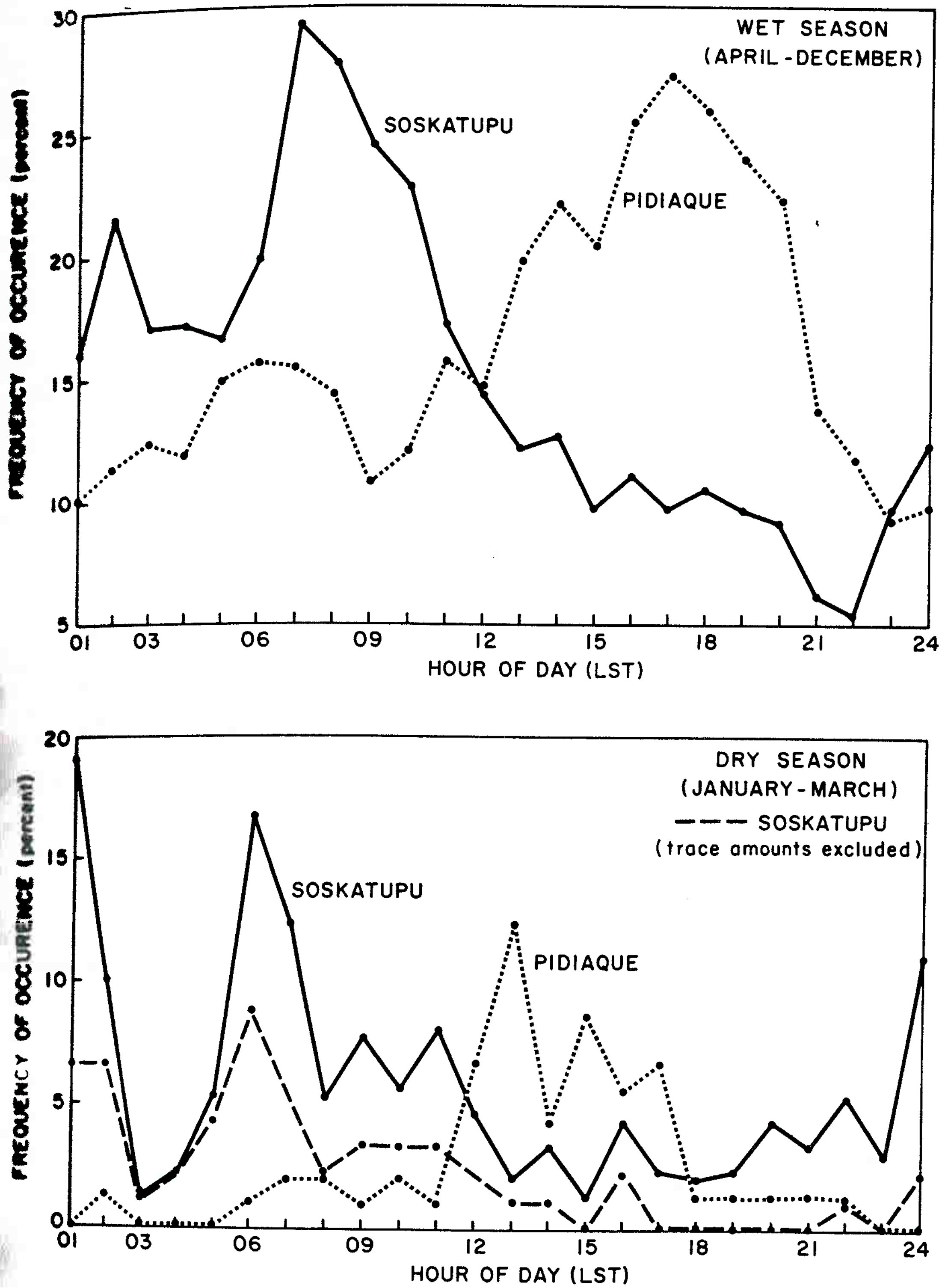
The diurnal distributions of rainfall are significantly different on the Caribbean coast (Soskatupu) and in the interior (Pidiaque). In the wet season, Soskatupu has a precipitation maximum shortly after sunrise and a secondary maximum shortly after midnight. Pidiaque shows almost an opposite diurnal distribution, with the principal maximum occurring in the late afternoon and a lesser maximum around daybreak.

The diurnal distributions of rainfall are similar in the dry and wet seasons. At Soskatupu there are many showers during the night and early morning hours, but they rarely produce more than a trace of precipitation. A dashed curve has been added for Soskatupu to show the frequency of precipitation when trace amounts are eliminated.

Explanatory Notes:

The percent frequency listed for any hour represents the period 30 min before to 30 min after the hour. A minimum of 5 min of continuous rain during this period was established as a criterion for the inclusion of a rain occurrence in the statistic.

The observations for the same months during 1966 and 1967 have been averaged.




FREQUENCY OF RAIN BY HOUR OF DAY AND SEASON

*Figure 6.*

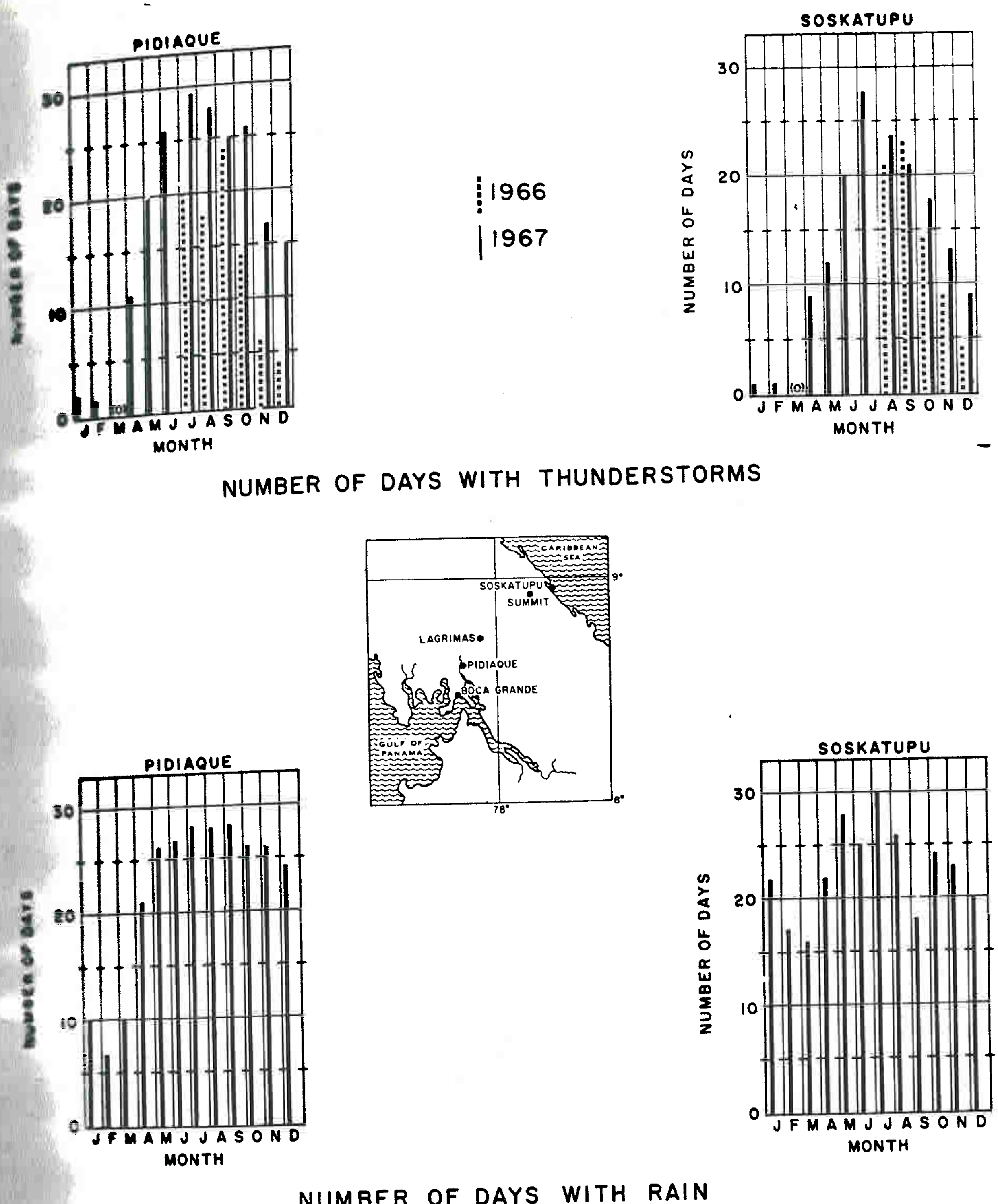
*Figure 7. Number of days per month with rain and thunderstorms.*

The interior region shows a low number of days with rain from January through March with an increase in rainy days in April, and the frequency stays high through December. The average number of days with rain varies from 9 per month during the dry season to 26 per month during the wet season. If trace amounts of rain are excluded, the average number of rainy days per month drops to 4 during the dry season and 22 in the wet season. In contrast, on the Caribbean coast the number of days with rain remains high throughout the year. The average number of days with rain for the Caribbean coast ranges from 18 days during the dry season months to 24 days in the wet season. However, when trace amounts are excluded, only 7 rainy days per month in the dry season and 19 per month in the wet season remain.

The days per month with thunderstorms increases rapidly in April and are maximum from June through October. Thunderstorms are rare from January through March.

Explanatory Notes:

The days with rain summary includes trace amounts and the data for the same months during 1966 and 1967 have been averaged.



PIDIAQUE
SOSKATUPU
1966
1967
NUMBER OF DAYS
MONTH
J F M A M J J A S O N D
0
10
20
30
(0)
NUMBER OF DAYS WITH THUNDERSTORMS
CARIBBEAN SEA
SOSKATUPU
SUMMIT
LAGRIMAS
PIDIAQUE
BOCA GRANDE
GULF OF PANAMA
9°
8°
78°
PIDIAQUE
SOSKATUPU
NUMBER OF DAYS
MONTH
J F M A M J J A S O N D
NUMBER OF DAYS WITH RAIN


*Figure 7.*

*Figure 8. Frequency distribution of 6-hour and daily midnight-to-midnight rainfall amounts.*

The 6-hour and daily (midnight-to-midnight) precipitation amounts are about the same for all stations, except for fewer cases of high intensity rainfalls over the interior region. Several cases of 6-hour rainfall of 3 inches or more were recorded.

Both Boca Grande and Pidiaque recorded one incident of a daily rainfall amount in excess of 3 inches; Summit recorded 2 cases, and Soskatupu reported 8 cases.

Explanatory Notes:

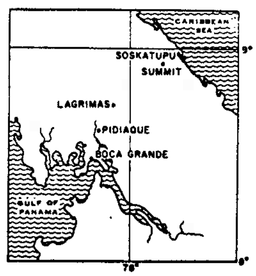
The summaries show an asterisk to indicate incomplete record for the quarters when the data are considered unreliable because of insufficient data. At Pidiaque and Soskatupu, two data samples were obtained for the third and fourth quarters (1966 and 1967). The tables show average values for these quarters.

PERCENT FREQUENCY OF 6 HOUR AMOUNTS

| LOCATION | BOCA GRANDE | | | | PIDIAQUE | | | | LAGRIMAS | | | | SUMMIT | | | | SOSKATUPU | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUARTER | 1* | 2* | 3* | 4* | 1 | 2 | 3 | 4 | 1* | 2* | 3* | 4* | 1* | 2* | 3* | 4* | 1 | 2 | 3 | 4 |
| RAINFALL (INCHES) 0 | 97 | 77 | 70 | 78 | 89 | 58 | 58 | 57 | 95 | 82 | 76 | 68 | 78 | 60 | 54 | 63 | 79 | 59 | 64 | 65 |
| T-.01 | 0 | 6 | 7 | 5 | 7 | 20 | 18 | 20 | 3 | 5 | 7 | 5 | 7 | 9 | 10 | 12 | 17 | 21 | 16 | 15 |
| .02-.09 | 2 | 7 | 11 | 7 | 2 | 12 | 10 | 12 | .9 | 5 | 13 | 15 | 14 | 16 | 17 | 12 | 3 | 8 | 8 | 8 |
| .1-.24 | 0 | 5 | 5 | 3 | 1 | 5 | 6 | 6 | 0 | 2 | 0 | 8 | 0 | 6 | 4 | 7 | 1 | 4 | 7 | 4 |
| .25-.49 | 0 | 3 | 3 | 3 | 0 | 2 | 2 | 2 | 0 | 2 | 1 | 1 | 1 | 3 | 6 | 2 | .3 | 3 | 3 | 4 |
| .50-.99 | .8 | 2 | 3 | 3 | .3 | 2 | 4 | 1 | .9 | 1 | 2 | 1 | 0 | 3 | 3 | 3 | 0 | 3 | 2 | 3 |
| 1.0-1.99 | 0 | 0 | .6 | 1 | .3 | .8 | 1 | 1 | 0 | 3 | 1 | 2 | 0 | 3 | 1 | 1 | 0 | .8 | 2 | 2 |
| 2.0-2.99 | 0 | .3 | 0 | 0 | 0 | .3 | .4 | .4 | 0 | 0 | 0 | 0 | 0 | .4 | 3 | .2 | 0 | .3 | .6 | .5 |
| 3.0-5.0 | 0 | 0 | 0 | 0 | 0 | 0 | .3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | .5 | 0 | .2 |
| > 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .2 | 0 |

* Incomplete record

Quarter 1 : Jan - Mar
Quarter 2 : Apr - Jun
Quarter 3 : Jul - Sep
Quarter 4 : Oct - Dec




PERCENT FREQUENCY OF DAILY AMOUNTS

| LOCATION | BOCA GRANDE | | | | PIDIAQUE | | | | LAGRIMAS | | | | SUMMIT | | | | SOSKATUPU | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUARTER | 1* | 2* | 3* | 4* | 1 | 2 | 3 | 4 | 1* | 2* | 3* | 4* | 1* | 2* | 3* | 4* | 1 | 2 | 3 | 4 |
| RAINFALL (INCHES) 0 | 94 | 41 | 20 | 44 | 71 | 10 | 10 | 18 | 84 | 49 | 35 | 17 | 55 | 16 | 4 | 15 | 38 | 17 | 23 | 26 |
| T-.01 | 3 | 11 | 10 | 5 | 18 | 23 | 20 | 23 | 8 | 11 | 13 | 5 | 0 | 8 | 0 | 19 | 48 | 29 | 16 | 23 |
| .02-.09 | 0 | 16 | 24 | 18 | 7 | 21 | 24 | 18 | 4 | 15 | 35 | 34 | 37 | 27 | 33 | 21 | 9 | 18 | 13 | 14 |
| .1-.24 | 0 | 11 | 16 | 13 | 3 | 16 | 13 | 16 | 0 | 4 | 4 | 22 | 4 | 19 | 13 | 20 | 3 | 8 | 15 | 7 |
| .25-.49 | 0 | 7 | 9 | 8 | 0 | 8 | 10 | 13 | 0 | 6 | 4 | 7 | 4 | 5 | 13 | 10 | 2 | 9 | 12 | 9 |
| .50-.99 | 0 | 11 | 11 | 8 | 1 | 3 | 13 | 6 | 4 | 4 | 4 | 7 | 0 | 12 | 17 | 6 | 0 | 9 | 11 | 10 |
| 1.0-1.99 | 3 | 2 | 5 | 3 | 1 | 4 | 7 | 5 | 0 | 11 | 4 | 7 | 0 | 8 | 4 | 5 | 0 | 3 | 7 | 4 |
| 2.0-2.99 | 0 | 1 | 5 | 0 | 0 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 13 | 4 | 0 | 2 | 2 | 5 |
| 3.0-5.0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 4 | 1 | 1 |
| > 5.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 1 |

FREQUENCY DISTRIBUTION OF RAINFALL AMOUNTS

*Figure 8.*

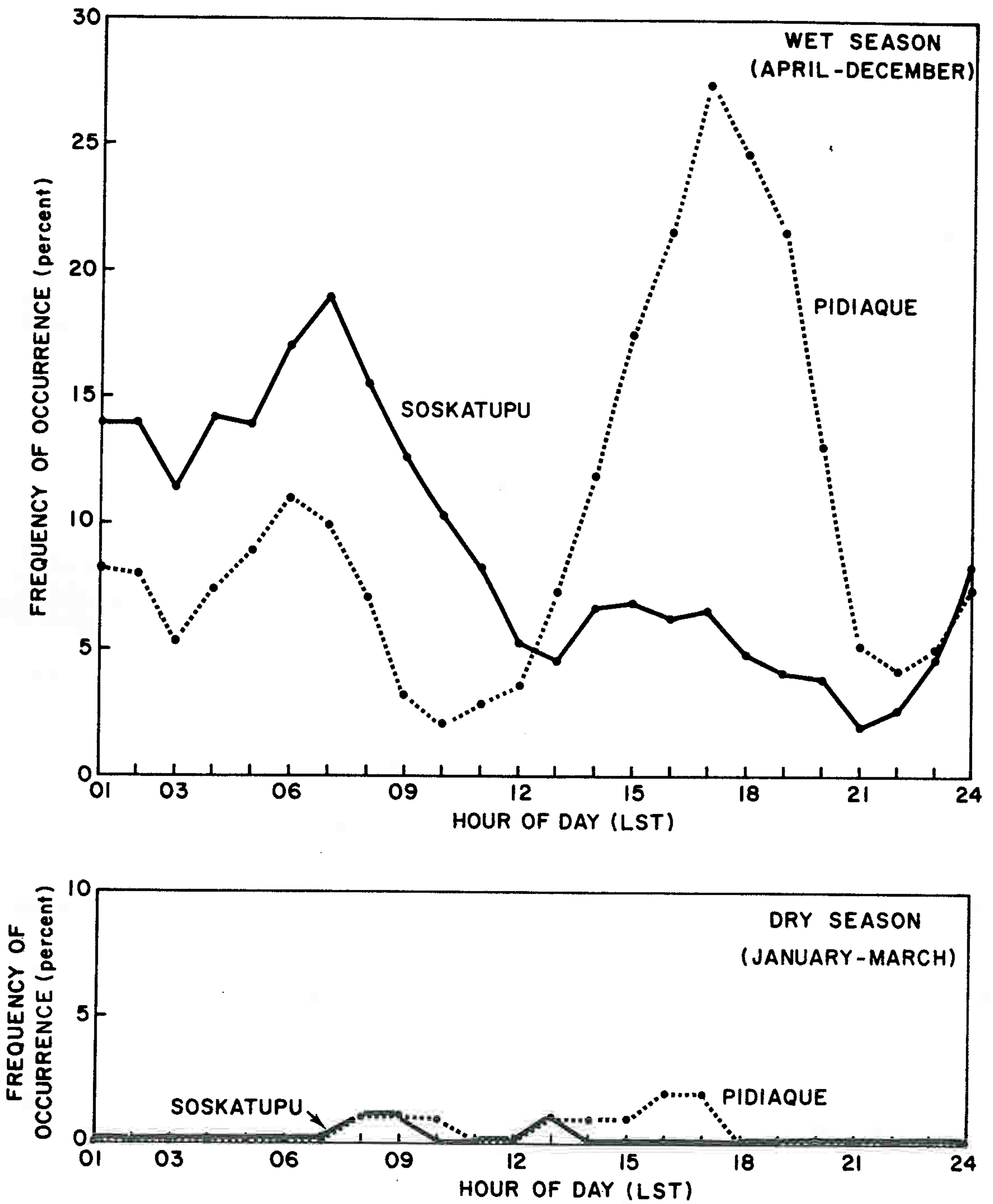
*Figure 9. Frequency distribution of thunderstorms by hour of day and by season for Soskatupu and Pidiaque.*

Since most of the precipitation occurs from convective activity, it is not surprising that the diurnal distribution of thunderstorms is similar to the rainfall distribution (compare with fig. 6).

Explanatory Notes:

A thunderstorm was recorded when thunder was heard at the station or when overhead lightning was observed and the local noise level was such as might prevent hearing thunder.

The percent frequency for each hour represents the period 30 min before to 30 min after the hour.




FREQUENCY OF OCCURRENCE OF THUNDERSTORMS BY HOUR OF DAY AND SEASON

*Figure 9.*

*Figure 10. Frequency distribution of fog by hour of day and number of days with fog per month.*

Although fog rarely occurs along the Caribbean coast, it can occur during all months of the year elsewhere over the route. Fog is frequent over the interior from May through December, when it usually forms about 2 to 3 hours after sunset and dissipates about 2 to 3 hours after sunrise. During the dry season, fog is infrequent and does not last long, usually forming after midnight and dissipating around sunrise. During the rainy season, fog was reported on an average of 25 days per month at Pidiaque, whereas Soskatupu reported only one incidence of fog during 17 months of observations. The frequency of fog over the interior during the dry season drops to 5 days or less per month; it is usually caused by rapid radiational cooling of the land mass after sunset. Afternoon cloudiness dissipates around sunset, creating favorable conditions for rapid radiation of heat from the surface and causing the moisture-laden air near the ground to cool and condense its moisture in the form of fog or low stratus. Comparison of fog observations at Pidiaque (hilltop station) to a limited sample of such observations taken at nearby Santa Fe (valley station) indicate that the frequency and hours of fog occurrence are compatible; thus we can assume that the fog that forms over the interior is widespread, covering valleys as well as surrounding hilltops. The lower moisture content the air and strong trade-wind flow tend to reduce the frequency of fog formation during the dry seasons.

Explanatory Notes:

The percent frequency distributions were compiled based on criterion stated in the explanatory note for figure 6.

The statistic includes the occurrence of "fog" and "ground fog".

The percent frequency distributions for Soskatupu have not been included, because only one occurrence was observed during the entire recording period. This was on June 14, 1967, between 1730 and 1945 (EST).

The observations for the same months during 1966 and 1967 have been averaged.

PIDIAQUE

FREQUENCY OF FOG BY HOUR OF THE DAY (PERCENT)

| | HOUR OF DAY (LST) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Jan | 6 | 3 | 3 | 3 | 6 | 6 | 6 | 6 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 6 |
| Feb | 4 | 4 | 11 | 14 | 7 | 11 | 14 | 4 | 4 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 4 | 0 | 4 | 4 | 4 | 4 | 4 | 4 |
| Mar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apr. | 7 | 7 | 7 | 10 | 10 | 13 | 20 | 13 | 10 | 7 | 7 | 7 | 3 | 3 | 7 | 10 | 10 | 7 | 7 | 7 | 7 | 10 | 10 | 10 |
| May | 23 | 29 | 10 | 16 | 29 | 42 | 45 | 32 | 23 | 23 | 16 | 3 | 3 | 0 | 0 | 3 | 3 | 3 | 6 | 10 | 10 | 19 | 16 | 19 |
| Jun | 53 | 53 | 57 | 63 | 63 | 76 | 63 | 86 | 86 | 63 | 20 | 3 | 7 | 10 | 10 | 17 | 20 | 27 | 27 | 23 | 33 | 33 | 43 | 53 |
| Jul | 24 | 29 | 36 | 37 | 36 | 56 | 58 | 58 | 52 | 28 | 22 | 10 | 4 | 3 | 3 | 6 | 11 | 10 | 6 | 13 | 13 | 13 | 13 | 26 |
| Aug | 28 | 29 | 28 | 32 | 40 | 50 | 60 | 52 | 47 | 42 | 29 | 14 | 6 | 5 | 2 | 3 | 3 | 6 | 6 | 6 | 4 | 14 | 14 | 16 |
| Sep | 45 | 44 | 50 | 38 | 65 | 76 | 73 | 82 | 67 | 24 | 7 | 0 | 0 | 5 | 6 | 8 | 15 | 20 | 24 | 16 | 10 | 16 | 26 | 42 |
| Oct | 42 | 48 | 53 | 58 | 68 | 76 | 82 | 81 | 66 | 24 | 14 | 4 | 0 | 6 | 8 | 12 | 13 | 18 | 18 | 12 | 13 | 16 | 22 | 32 |
| Nov | 32 | 36 | 42 | 40 | 53 | 60 | 64 | 66 | 64 | 33 | 14 | 8 | 8 | 8 | 7 | 12 | 12 | 7 | 15 | 20 | 13 | 12 | 12 | 20 |
| Dec | 11 | 14 | 26 | 16 | 24 | 32 | 37 | 37 | 37 | 24 | 18 | 14 | 12 | 6 | 6 | 3 | 4 | 6 | 3 | 3 | 3 | 3 | 6 | 16 |

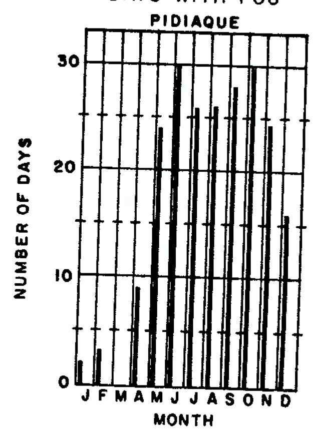



*Figure 10.*

*Figures 11, 12, 13, 14, and 15. Frequency distribution of surface winds.*

Each of these diagrams is a composite analysis by month of the frequency distribution of surface wind direction and speed. The statistics were compiled from the combined wind observations at 0100, 0700, 1300, and 1900 local standard time. The percent frequency of occurrence of winds in 30° sectors centered at the indicated direction (direction from which the wind is blowing) is shown. The two curves on the right side of each figure show the wind speeds, which include 50 percent and 97 percent of all cases.

The diurnal variations of the surface wind discussed in connection with each diagram were determined from monthly wind data summarized for each of the four daily observation times. These summaries are not included in this report.

The number of days with observations per month at the tower stations is given in table 3.

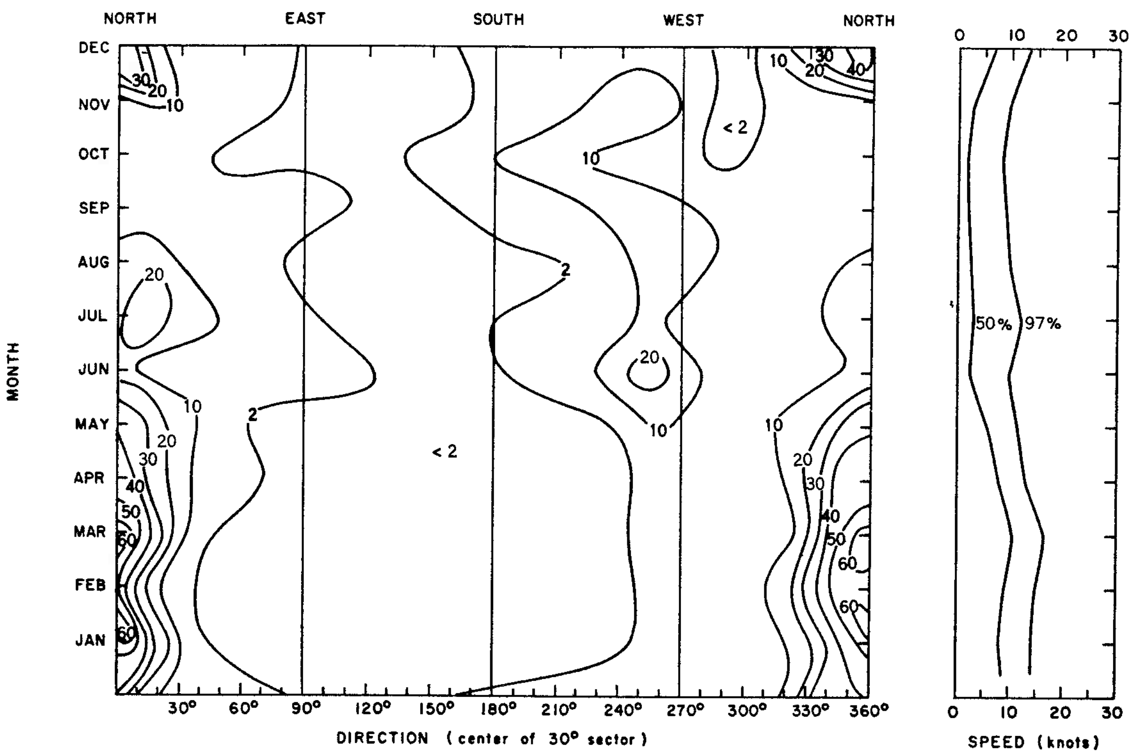



*Figure 11. Frequency distribution of surface winds (percent). Soskatupu*

The summary of surface wind frequency at Soskatupu (August 1966 through December 1967 data) shows a steady flow from the north from December through May. From June through November calm conditions are frequent; when the wind blows, it tends to be either from the southwest or north. Strongest wind speeds were observed in March, and the month with most frequent calms was October. The diurnal distribution of surface winds from June through November shows onshore (northerly) flow beginning around daybreak, reaching its peak during the early afternoon, then diminishing by dark. The surface wind frequently blows offshore (from the southwest) during the night. From December through April the strong northerly trades inhibit the development of the offshore flow. Highest wind speeds occur in the afternoon during all months of the year.

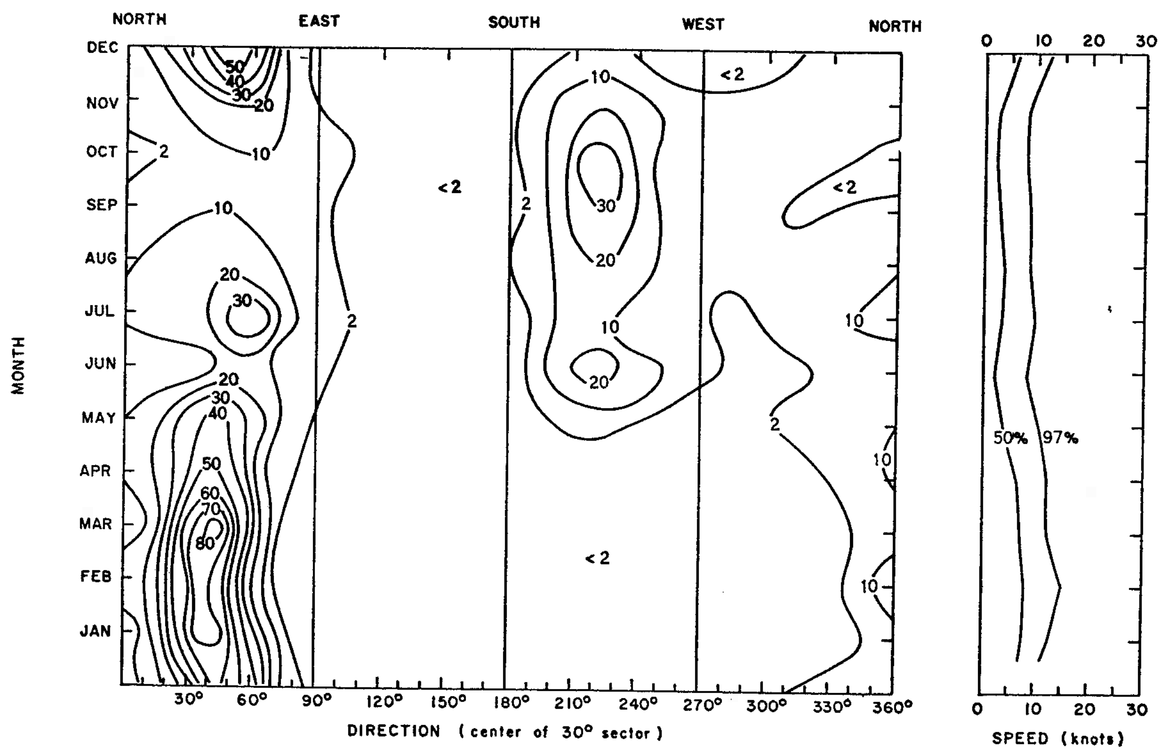



*Figure 12. Frequency distribution of surface winds (percent). Pidiaque*

The summary of surface wind frequency for Pidiaque (July 1966 through December 1967 data) indicates a persistent north-easterly flow from December through May. From June through November winds are light and come from either the southwest or northeast, favoring the southwest in all months except July. Strongest wind velocities were observed in February; the calmest month was September. The diurnal variation of surface winds from May through November shows strong onshore flow (southwest) beginning by midafternoon, reaching peak speed by late afternoon, then diminishing during evening. There is a general offshore (northeast) wind flow during the remaining hours, which is most frequent around daybreak and continues until late morning. From December through April the strong northerly trades inhibit the development of the afternoon onshore surface wind flow. The highest wind speeds occur in the afternoon during all months of the year.

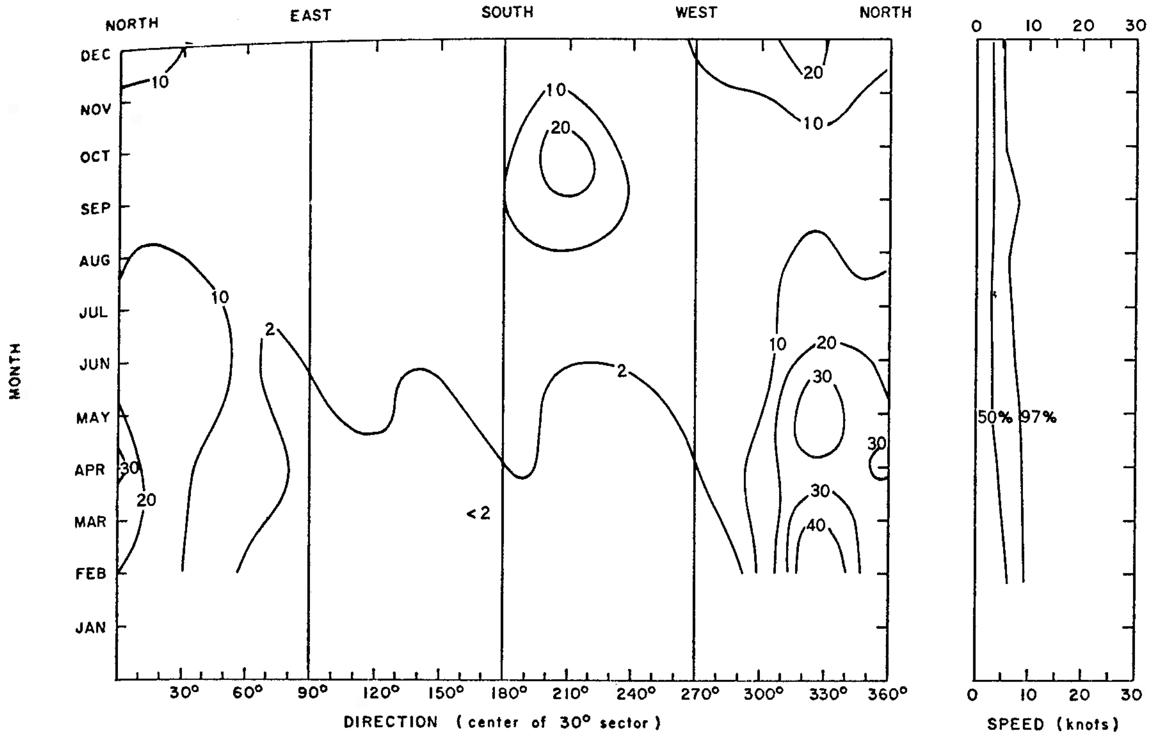



*Figure 13. Frequency distribution of surface winds (percent). Lagrimas*

The summary of surface wind frequency at Lagrimas (February through December) is difficult to interpret because of the large amount of missing data. In general, however, northwest flow prevailed in December and from February to May. From July through November (June data missing) the winds were light and varied greatly, blowing from either the northeast or northwest in July and August with south-southwest winds predominant in September and October. October appears to be the month with the most frequent calms, although winds were light throughout the year. There does not appear to be any clear diurnal pattern in the surface wind during any month of the year; the Pidiaque pattern does not hold as far inland as Lagrimas.

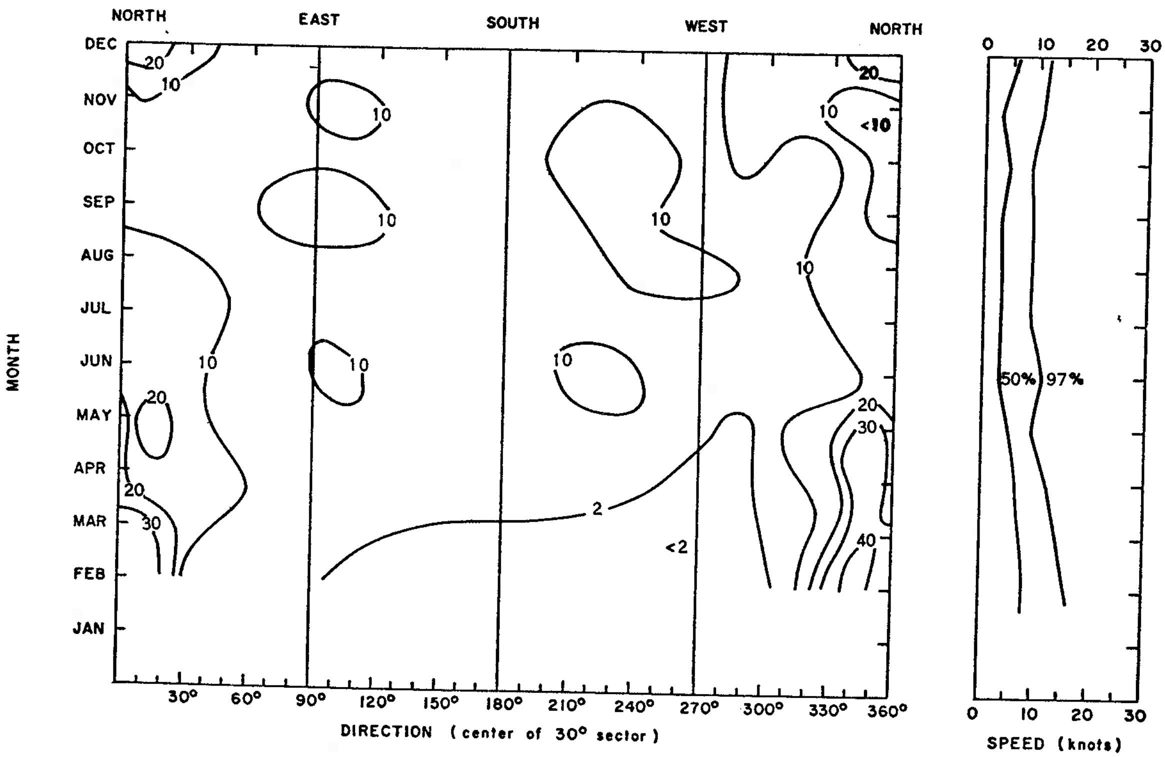



*Figure 14. Frequency distribution of surface winds (percent). Boca Grande*

The summary of surface wind frequency at Boca Grande (February through December 1967) shows northerly wind flow in December and from February through May. Winds are light and extremely variable from June through November. The great variations in wind direction may be attributed to local land and sea breeze effects. Boca Grande is seaward from Pidiaque and shows similar diurnal wind changes, except that the offshore (east-southeast) and onshore (southwest) peak frequencies occur about 3 hours earlier. The strongest winds were observed in February, while the month of most frequent calms was November.

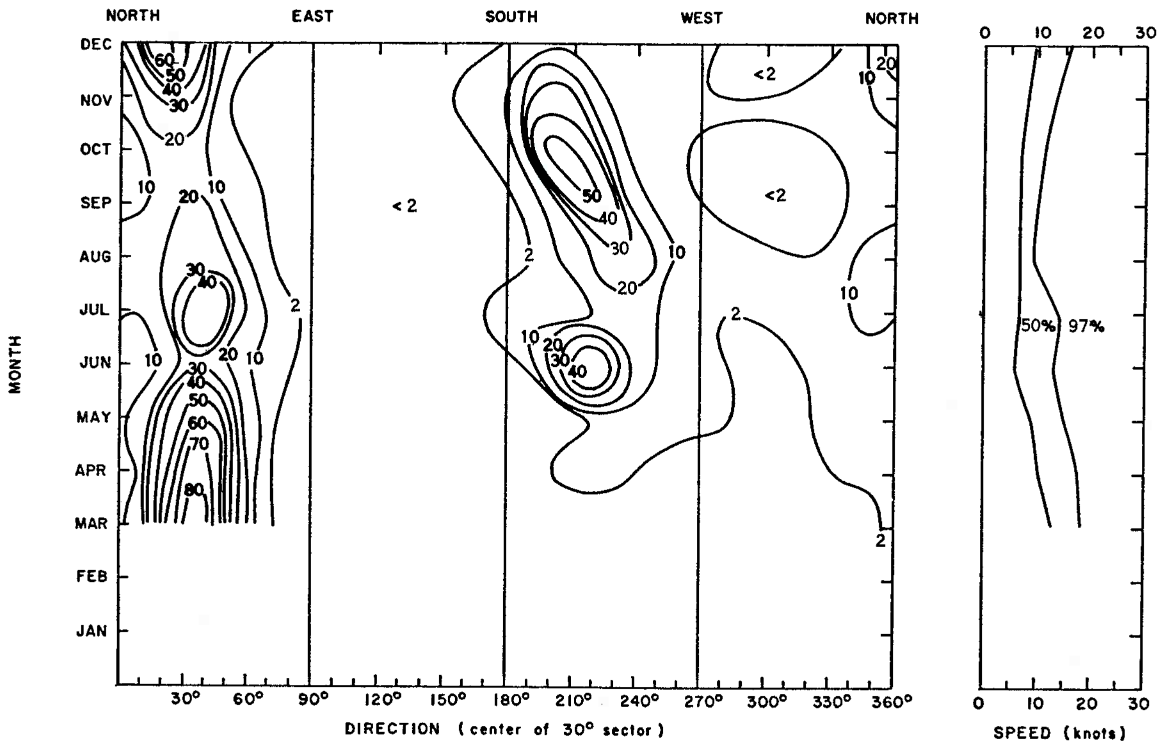



*Figure 15. Frequency distribution of surface winds (percent).*

*Summit*

The summary of surface wind frequency for Summit (March through December 1967) shows persistent northeasterly flow in December and from March through May, which undoubtedly prevails through January and February as well. During the remaining months, the winds vary between southwest and northeast, favoring the southwest in all months except July. The strongest winds were in March; the month with the most frequent calms was October. Summit, on the Continental Divide, shows about the same diurnal surface wind changes as Soskatupu, except that the onshore (northeast) peak frequency comes a few hours later and the southwest flow is stronger and more frequent.

# 4. UPPER-AIR WIND PROGRAM

Upper-air winds were measured with radar-tracked balloons every 6 hours (0100, 0700, 1300, and 1900 local standard time) at the two manned weather stations on each route. This program began on Route 17 in July 1966 at Pidiaque and in August 1966 at Soskatupu. The basic data from these four daily soundings have been processed in three different forms: winds aloft, mean layer winds and fallout vectors.

These data are available on punched cards at the National Weather Records Center (NWRC), Asheville, North Carolina.

## 4.1 Winds Aloft

These data consist of the direction (degrees) and speed (knots) of winds at specified altitudes above mean sea level. Winds were determined every 1000 feet up to 20,000 feet, at 23,000 feet, and 25,000 feet, and then every 5000 feet up to 60,000 feet.

## 4.2 Mean Layer Winds

Mean winds through layers of the atmosphere were also determined directly from the radar-tracked balloon positions. From each wind sounding, mean winds were determined for the layer from the surface to 2000 feet (MSL), for 2000 to 5000 feet, and then for each 5000-foot layer up to 60,000 feet. These data are easier to use and are more representative than the winds aloft data for fallout calculations.

## 4.3 Fallout Vector Data

Derived from the mean layer wind data from each sounding, the fallout vector data indicate the direction along which particles will reach the ground from various altitudes in the atmosphere. The vector speed represents the rate at which fallout deposition will advance in the indicated direction. The fallout vector is obtained from the vector sum of the mean layer winds (weighted according to the relative particle fall rates in each layer) from the ground to the altitude from which the particle falls. Hence, it represents a weighted mean wind from the surface to the indicated altitude. Note that, by convention, wind direction indicates the direction from which the wind blows, while fallout vectors indicate the direction toward which the fallout is carried. Fallout vectors were calculated for the following layers: Surface-2000, sfc-5000, sfc-10,000, sfc-15,000, sfc-20,000, sfc-25,000, sfc-30,000, sfc-40,000, sfc-50,000, and sfc-60,000 feet.

### 4.4 Wind Data Summaries

Monthly summaries of the frequency distribution of the mean layer winds and fallout vectors have been computed and stored on magnetic tape. A computer printout can be obtained for any desired altitude layer for any month or combination of months, for any or all observation times. The summaries record the percent frequency of occurrence for each $10^{\circ}$ sector for various wind speed ranges. Frequencies are also shown for all 30, 50, 70 and $90^{\circ}$ sectors centered at $10^{\circ}$ increments.

Monthly summaries of the variability of the fallout vectors are also available on magnetic tape. One set of statistics was compiled on the directional change of the fallout vectors as a function of initial speed and time (6-, 12-, 18-, and 24-hour intervals). Another set summarizes the directional differences between fallout vectors at Pidiaque and Soskatupu as a function of speed and fallout sector.

These summaries are available at NWRC as Job No. 7648 in the following tabulations:

- Table I - Percentage Frequency of Mean Layer Winds.
- Table II - Percentage Frequency of Fallout Winds.
- Table III - Percentage Frequency of Fallout Wind Variability (time variability of fallout vectors).
- Table IV - Percentage Frequency of Fallout Wind Variability (directional differences between stations).

## 4.5 Wind Frequency Charts

The monthly summaries of the mean layer wind data and the fallout vector data (NWRC Tables I and II) were used to prepare figures 16 through 54, which illustrate the frequency distributions of the mean layer winds and fallout vectors at Pidiaque and Soskatupu from August 1966 through December 1967. Data for all four observation times were combined in each chart.

### 4.5.1 Mean Layer Wind Frequency Charts

Figures 16 through 35 show the frequency of occurrence of winds in 30° sectors centered at the direction indicated at the bottom of the charts, the direction from which the wind is blowing. To smooth the data, the frequencies were determined for overlapping 30° sectors taken every 10°. The right side of each chart gives information on the frequency distribution of wind speeds in each layer. The two curves indicate the wind speeds which include 50 percent and 97 percent of all cases.

Figure 16 shows the distribution of winds at Pidiaque during August-September 1966. This period is characterized by easterly winds throughout the troposphere except for the lowest 5000 feet, which are influenced by the surface topography. In this layer the winds most frequently veer with altitude from north-northeast to east. Winds in the surface to 2000-foot layer show a secondary maximum from the west-southwest.

The upper wind data obtained at Soskatupu during August 1966 are considered unreliable because of difficulties in the installation and operation of the radar. Therefore, figure 17 shows the distribution of winds at Soskatupu for September only. The picture is similar to that at Pidiaque, with easterlies predominating in all layers above 2000 feet.

Figures 18 and 19 summarize the wind frequencies at Pidiaque and Soskatupu during October 1966. In this transitional month the winds throughout the troposphere are generally more variable than in any other month. Southwesterly winds in the lowest 10,000 feet seem to prevail in October over other months. Note that at Soskatupu the maximum frequency in the lowest 2000 feet occurs in the sector centered at 210°, while at Pidiaque it is centered at 235°. In general, throughout the year, the significant differences between the wind frequencies at Soskatupu and Pidiaque are confined to the layer from the surface to 5000 feet, where a wind shift of about 10 to 30° from Soskatupu to Pidiaque usually occurs.

Another feature, noted on most charts, is the tendency for the frequency maxima to be more marked at Pidiaque than at Soskatupu.

Figures 20 and 21 show the wind frequencies during November-December 1966. Northeasterly winds predominate from the surface to about 30,000 feet. From about 30,000 to 45,000 feet, southerly winds predominate, while easterly and westerly components occur with about equal frequency. From 45,000 to 55,000 feet, westerlies are dominant, and in the layer from 55,000 to 60,000 feet easterlies and westerlies occur with about equal frequency.

The January-February 1967 period (figs. 22 and 23) was similar to November-December 1966, but the regimes of easterly and westerlies were more sharply defined, and the intervening layer of southerlies was no longer evident. Both stations show predominant easterlies from 5000 to 30,000 feet, westerlies between 30,000 and 55,000 feet, and easterlies above 55,000 feet. In the lowest 5000 feet, northeast winds predominate at Pidiaque; north winds at Soskatupu. Soskatupu shows a much higher frequency of northwest winds than Pidiaque in this layer.

The March-April period (figs. 24 and 25) shows distributions very similar to January-February. In the mean, the entire period from November through April, which includes the dry season in Panama, is characterized by north or northeast winds near the ground, east winds in the lower troposphere, and west winds in the upper troposphere that reverse to easterlies again near the tropopause.

The wind distributions in May (figs. 26 and 27) begin to show a transition toward the summer wind pattern in the mid-troposphere. The dry-season westerlies have been replaced by southeasterly winds.

The wind distributions during June-July 1967 are very similar to those during August-September 1966 and are characterized by persistent easterly winds from about 5000 feet to 60,000 feet. However, figures 28 and 29 show relatively high frequencies of westerly winds between 45,000 and 55,000 feet which occurred in June. In the layer from the surface to 2000 feet, Pidiaque shows predominant north-northeast winds with a secondary maximum of winds from the southwest. At Soskatupu there is a high frequency of northwest winds in this layer.

The Pidiaque radar was inoperative for 3 weeks in September, and Soskatupu wind data were substituted for this period in the computation of the August-September 1967 frequency distribution for Pidiaque. Figures 30 and 31 show easterly winds throughout the troposphere, except for the lowest 5000 feet where the winds generally veer with altitude from north to east. Winds from the surface to 2000 feet again show a secondary maximum from the west-southwest at Pidiaque. These characteristics were also apparent during August-September 1966 (figs. 16 and 17).

The transitional month of October shows considerable variation between 1966 (figs. 18 and 19) and 1967 (figs. 32 and 33). In 1966 southwest winds tended to predominate from the surface to about 45,000 feet, with northeasterly winds above that level. In 1967 the southwest winds are dominant only in the lowest 5000 feet with east or northeast winds dominant through most of the troposphere. Westerlies prevailed in the layer from 50,000 to 60,000 feet.

Figures 34 and 35 show the wind frequencies during the November-December 1967 period. These charts are very similar to those for November-December 1966 (figs. 21 and 22). However, in 1967 easterlies are predominant in the vicinity of the tropopause (55,000 to 60,000 feet).

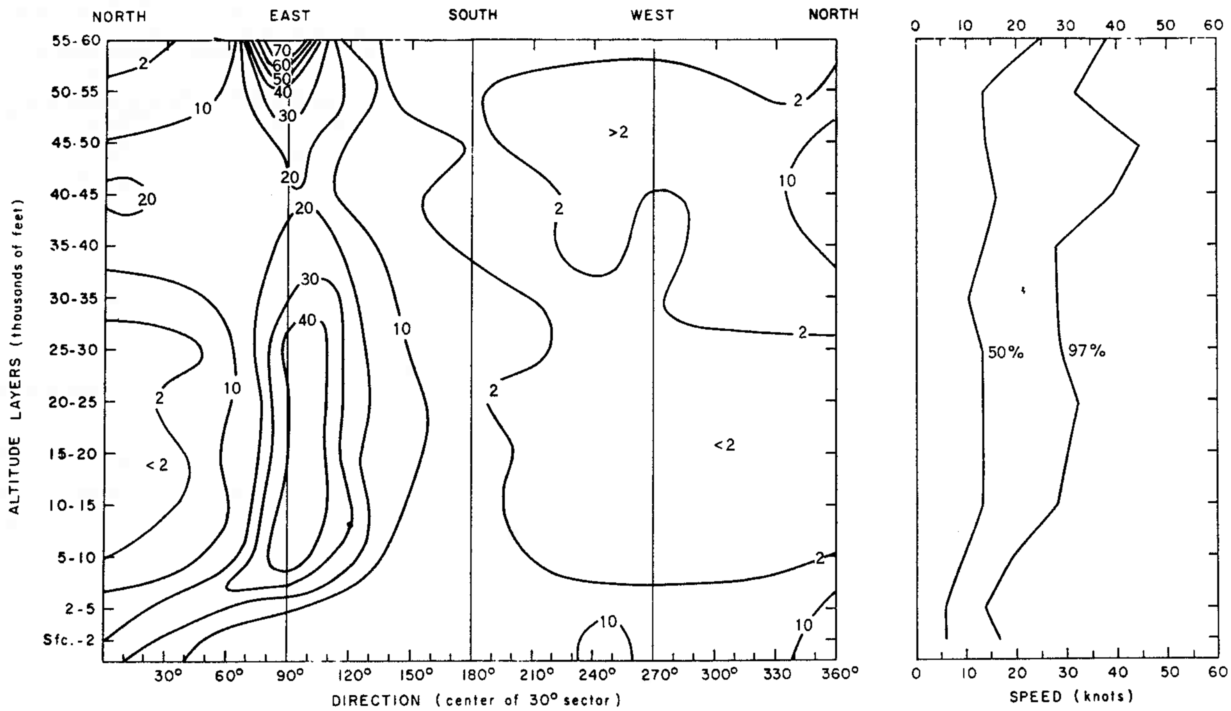



*Figure 16. Frequency distribution of mean layer winds (percent). Pidiaque Aug-Sep 1966*

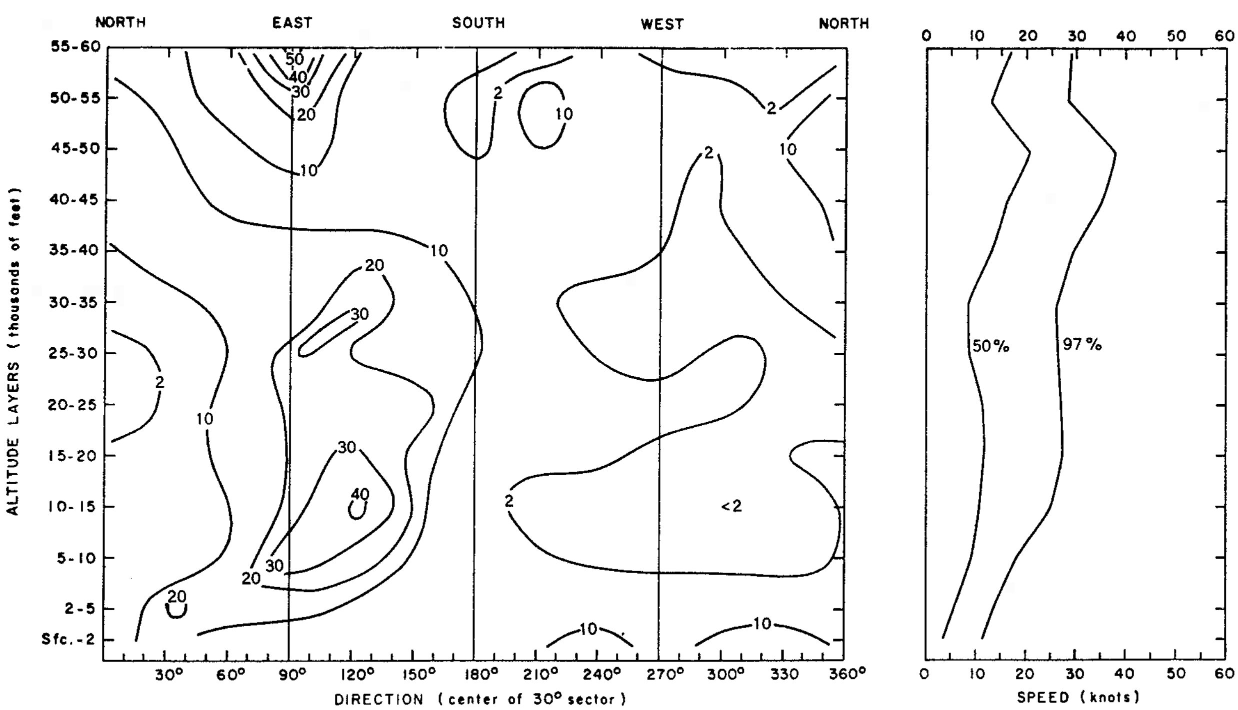



*Figure 17. Frequency distribution of mean layer winds (percent). Soskatupu Sep 1966*

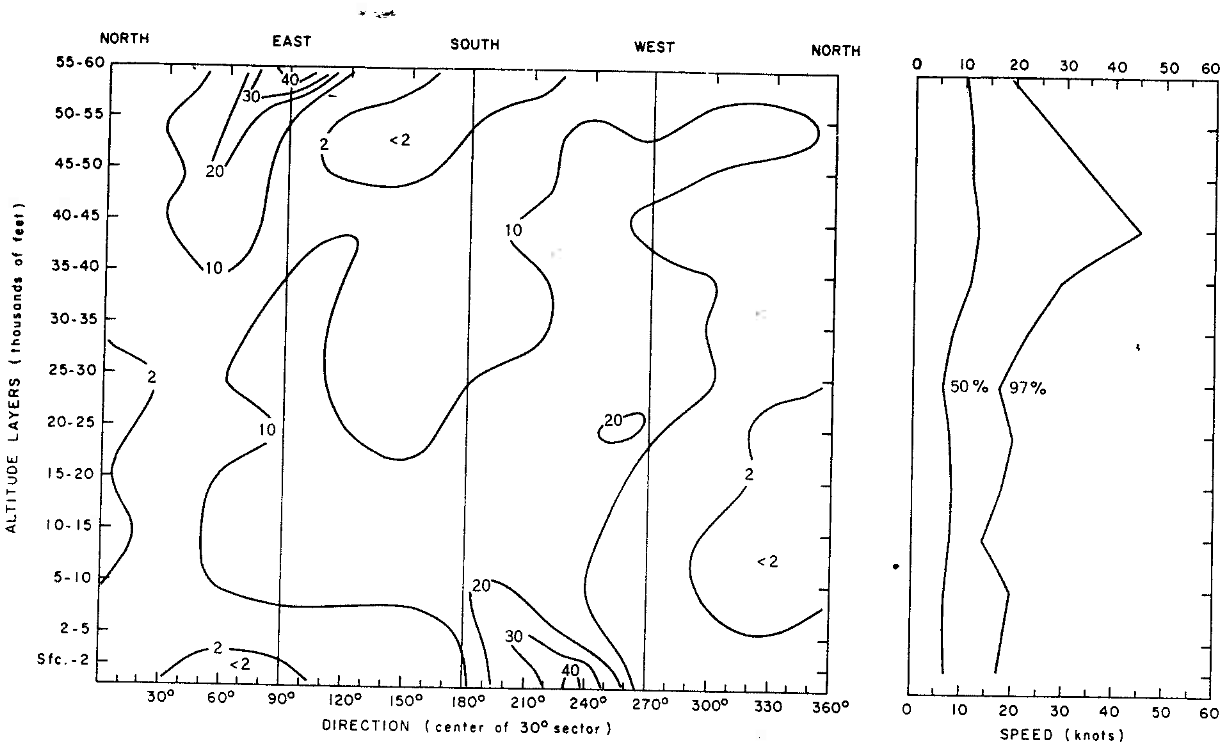



*Figure 18. Frequency distribution of mean layer winds (percent).*
*Pidiaque Oct 1966*

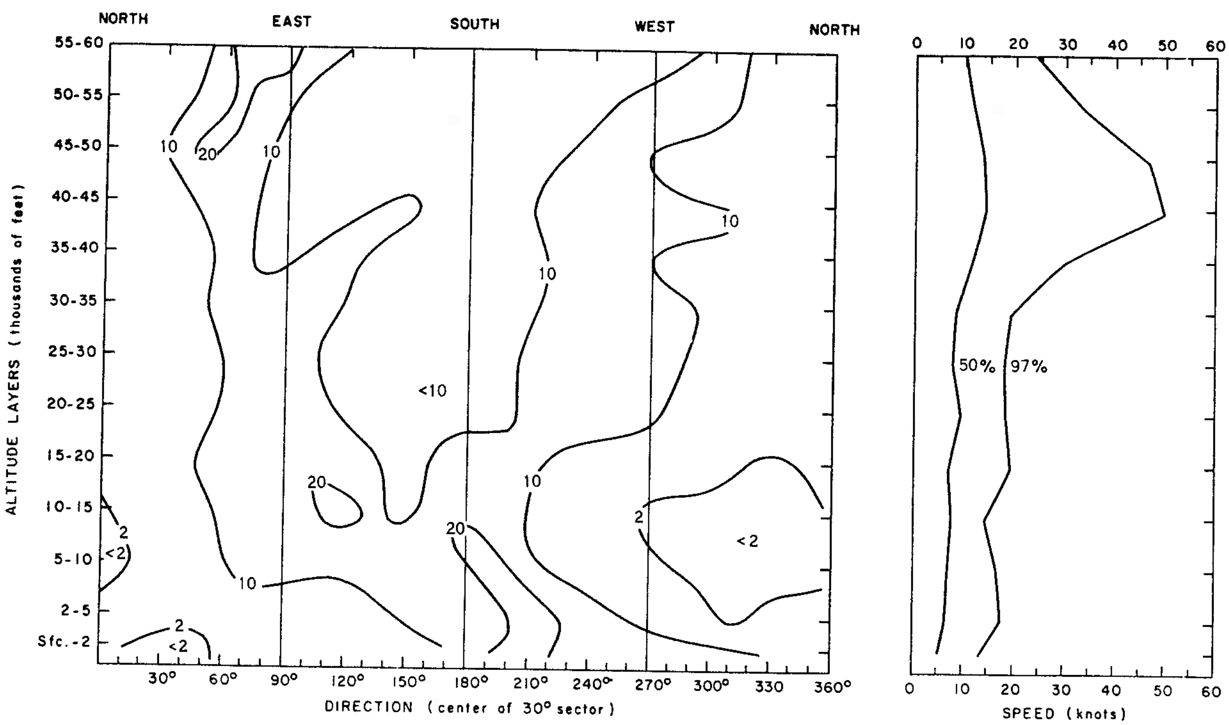



*Figure 19. Frequency distribution of mean layer winds (percent).*
*Soskatupu Oct 1966*

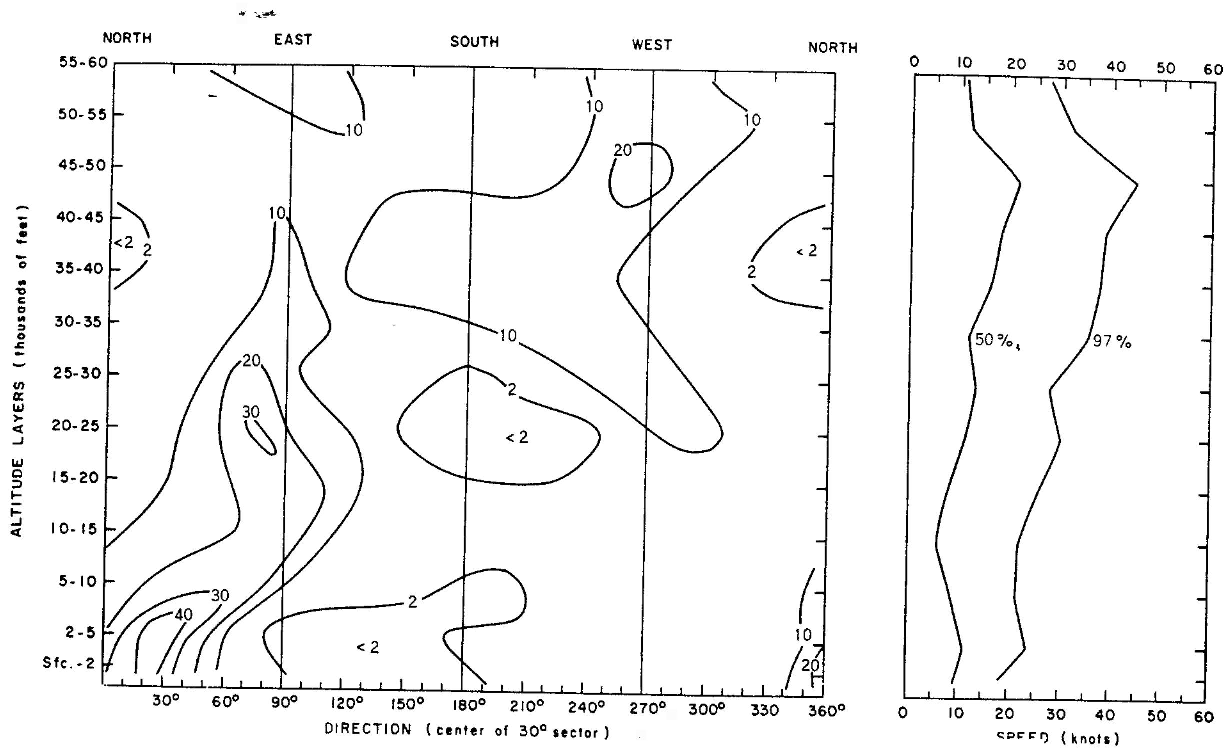



*Figure 20. Frequency distribution of mean layer winds (percent).*
*Pidiaque Nov-Dec 1966*

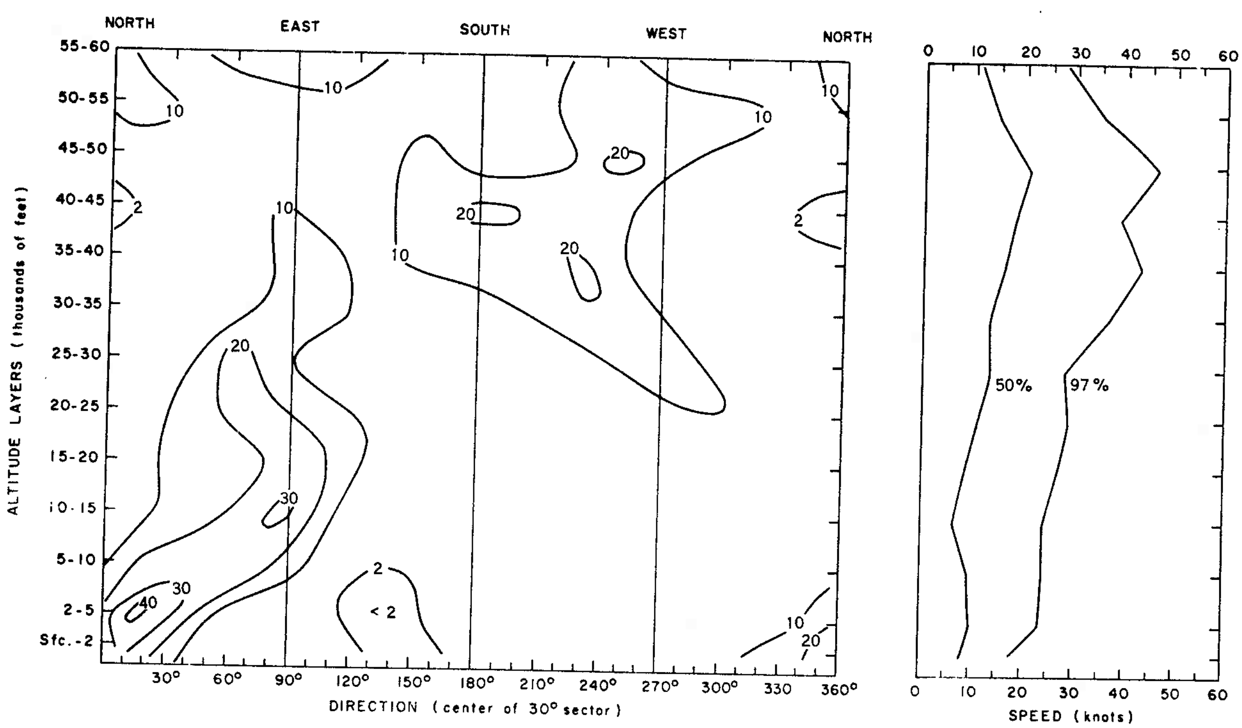



*Figure 21. Frequency distribution of mean layer winds (percent).*
*Soskatupu Nov-Dec 1966*

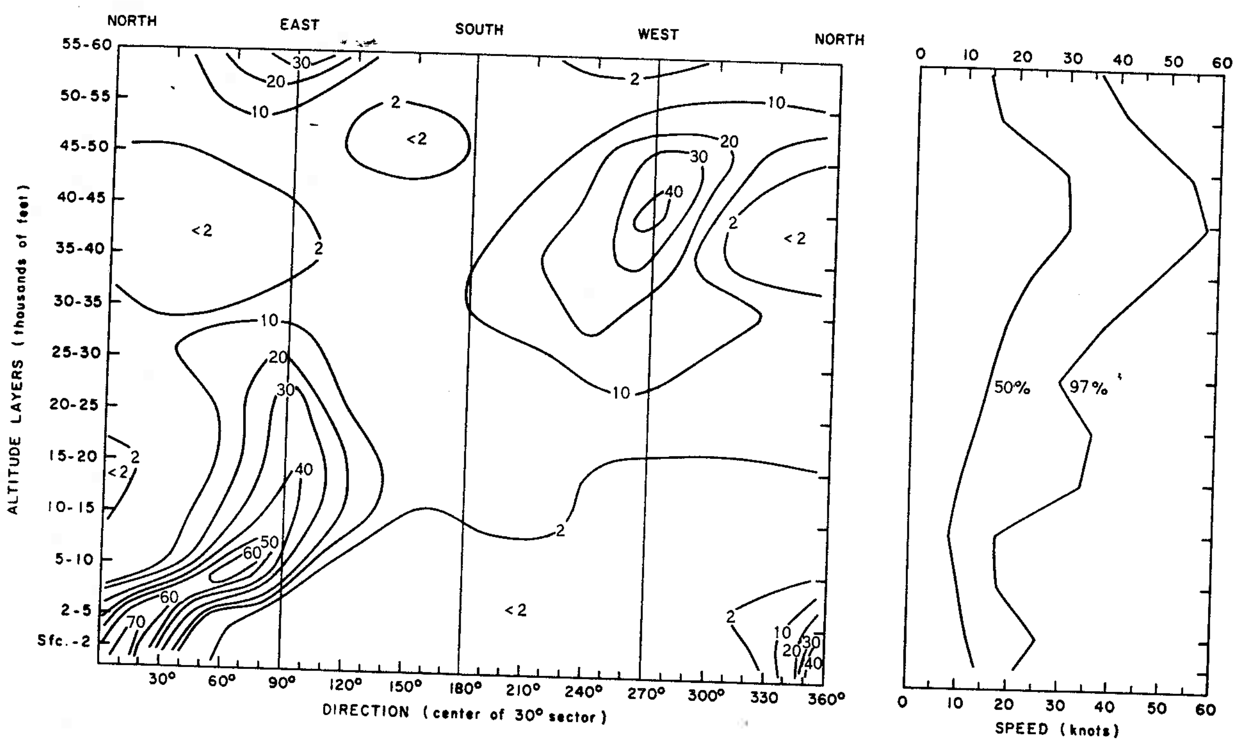



*Figure 22. Frequency distribution of mean layer winds (percent). Pidiaque Jan-Feb 1967*

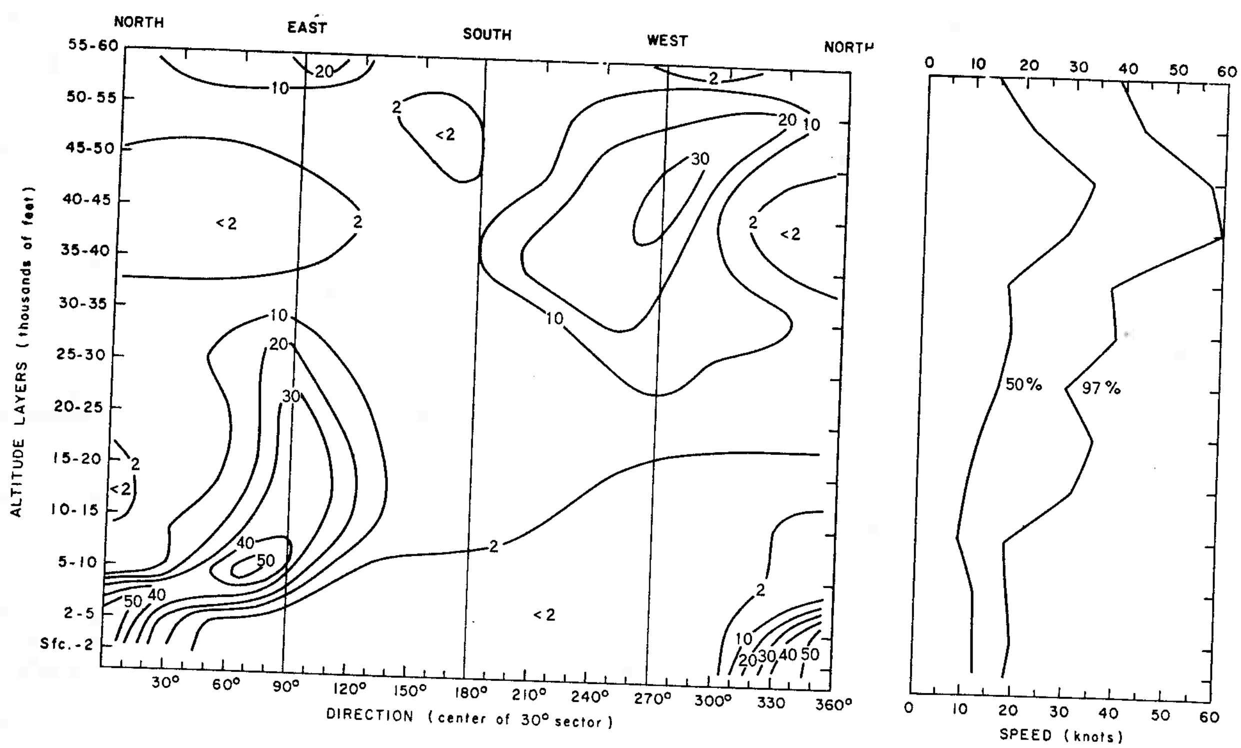



*Figure 23. Frequency distribution of mean layer winds (percent). Soskatupu Jan-Feb 1967*

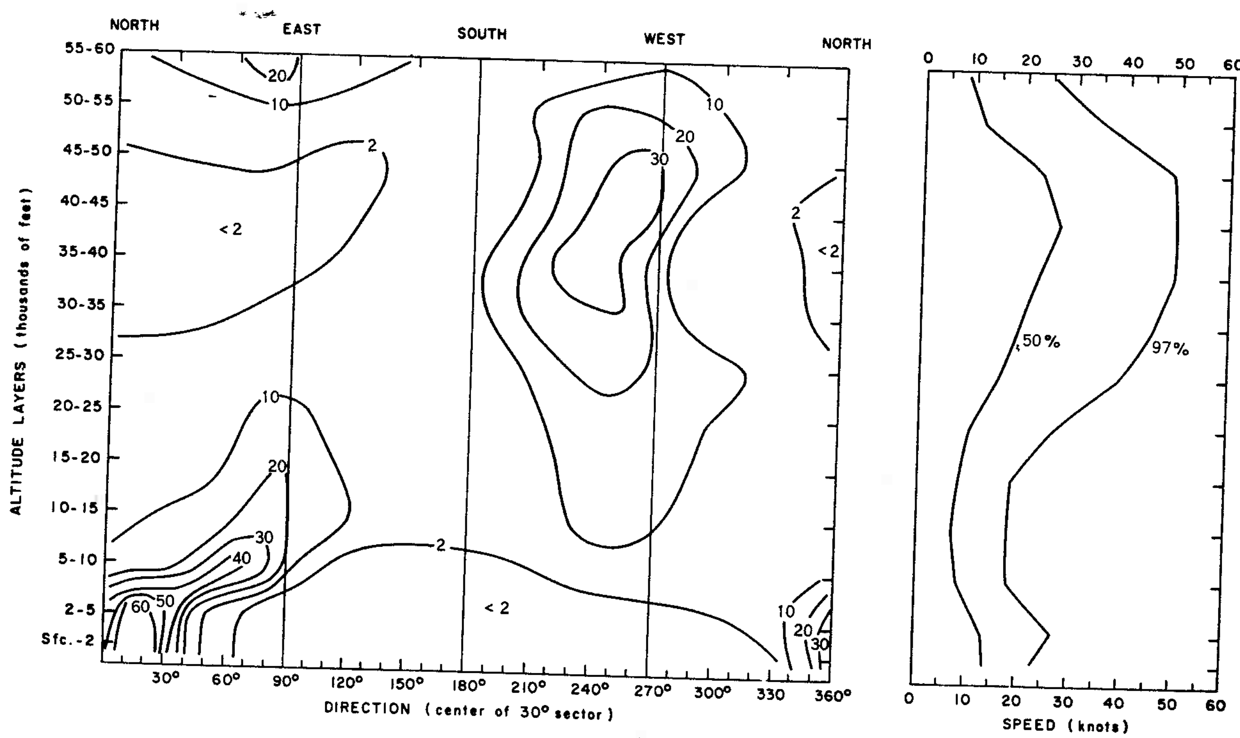



*Figure 24. Frequency distribution of mean layer winds (percent).*
*Pidiaque Mar-Apr 1967*

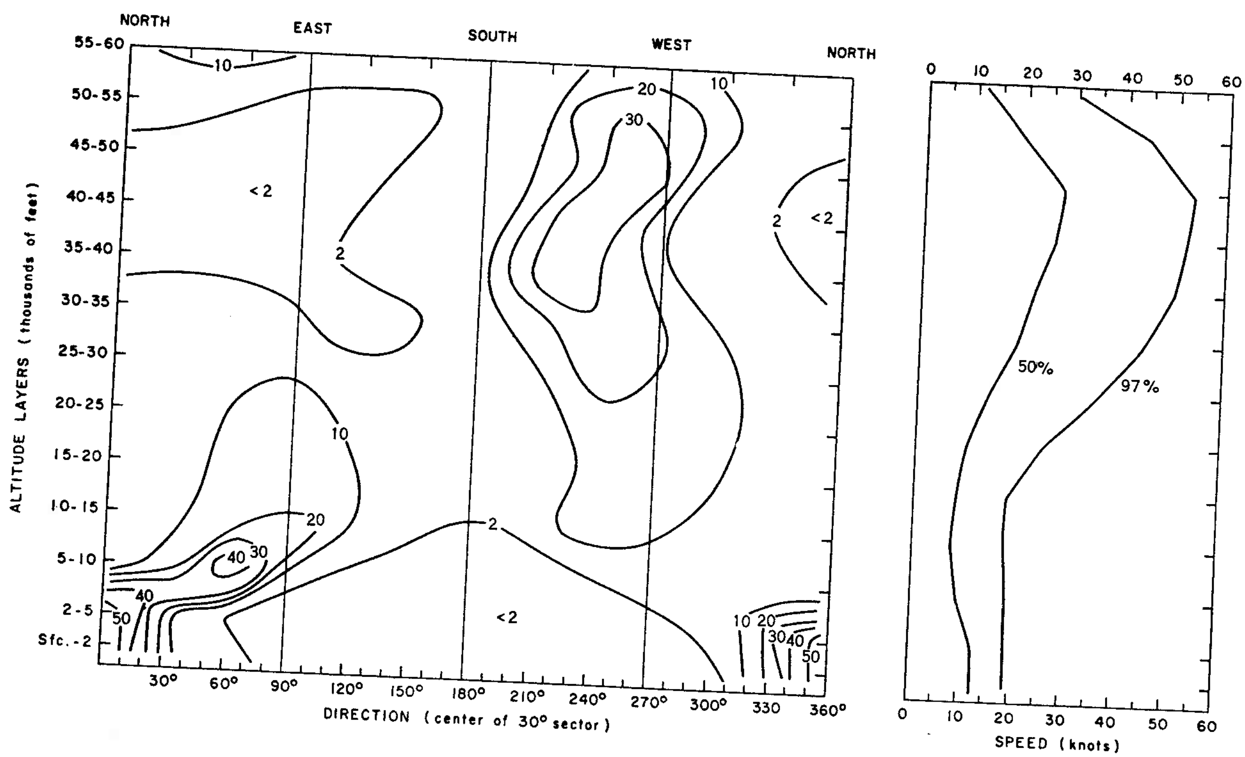



*Figure 25. Frequency distribution of mean layer winds (percent).*
*Soskatupu Mar-Apr 1967*

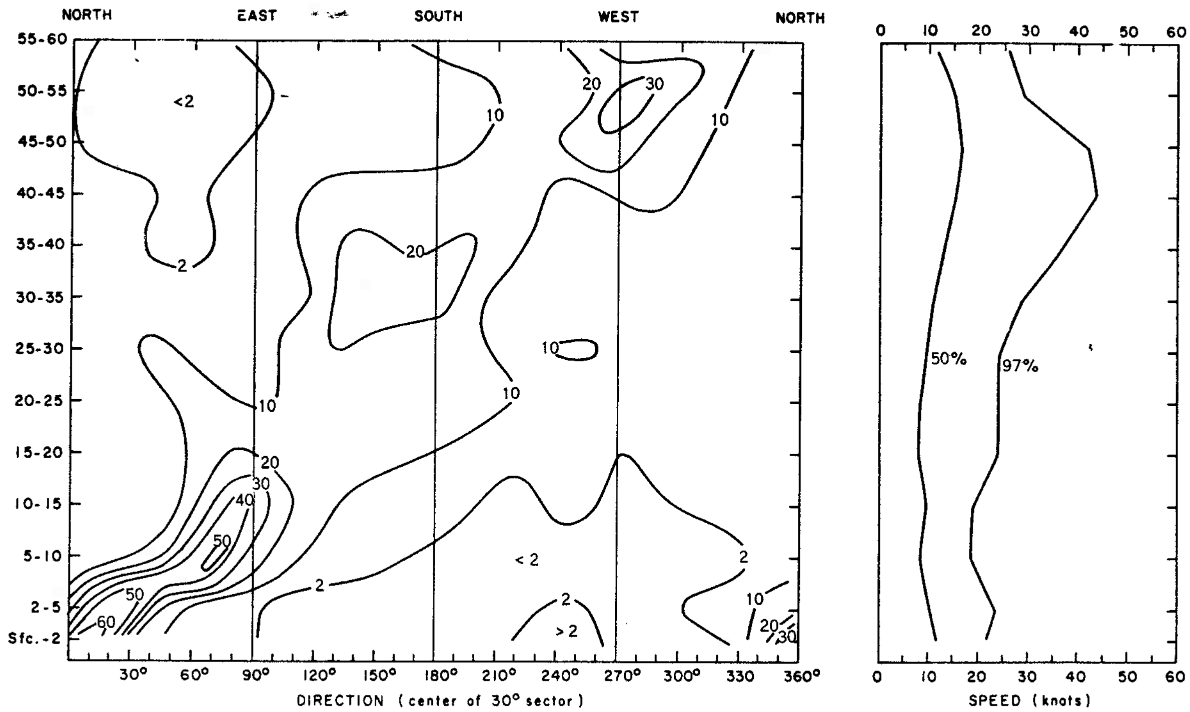



*Figure 26. Frequency distribution of mean layer winds (percent).*
*Pidiaque May 1967*

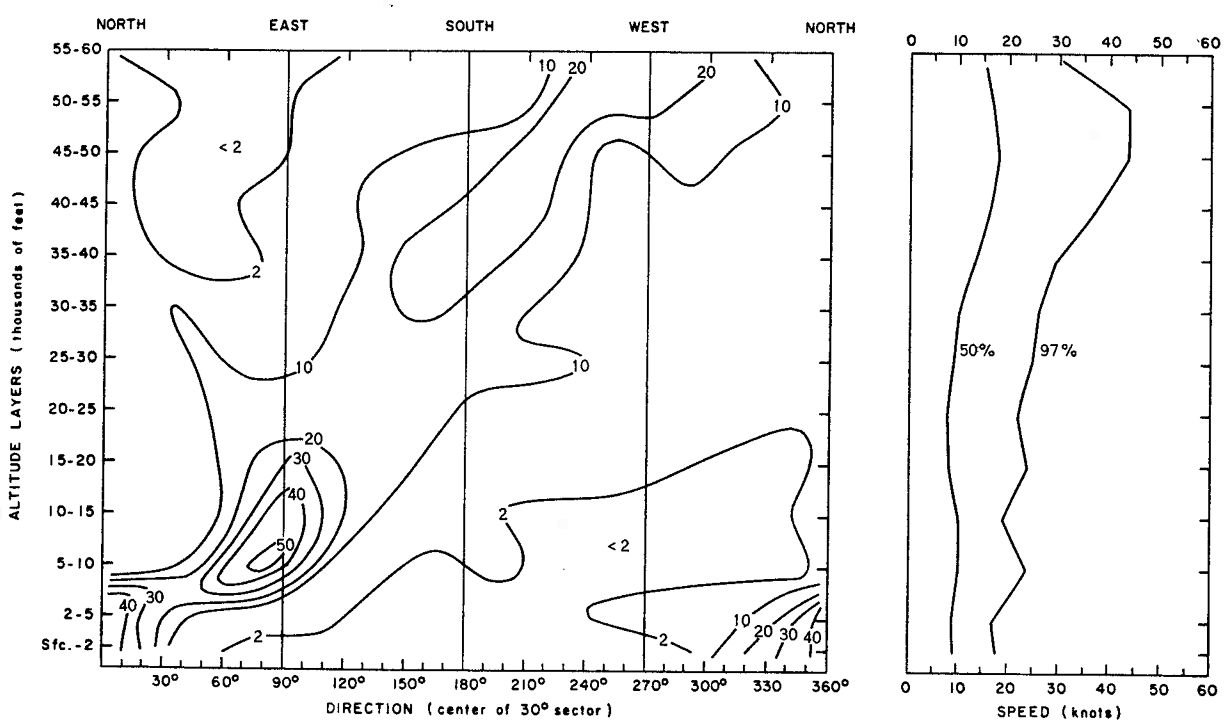



*Figure 27. Frequency distribution of mean layer winds (percent).*
*Soskatupu May 1967*

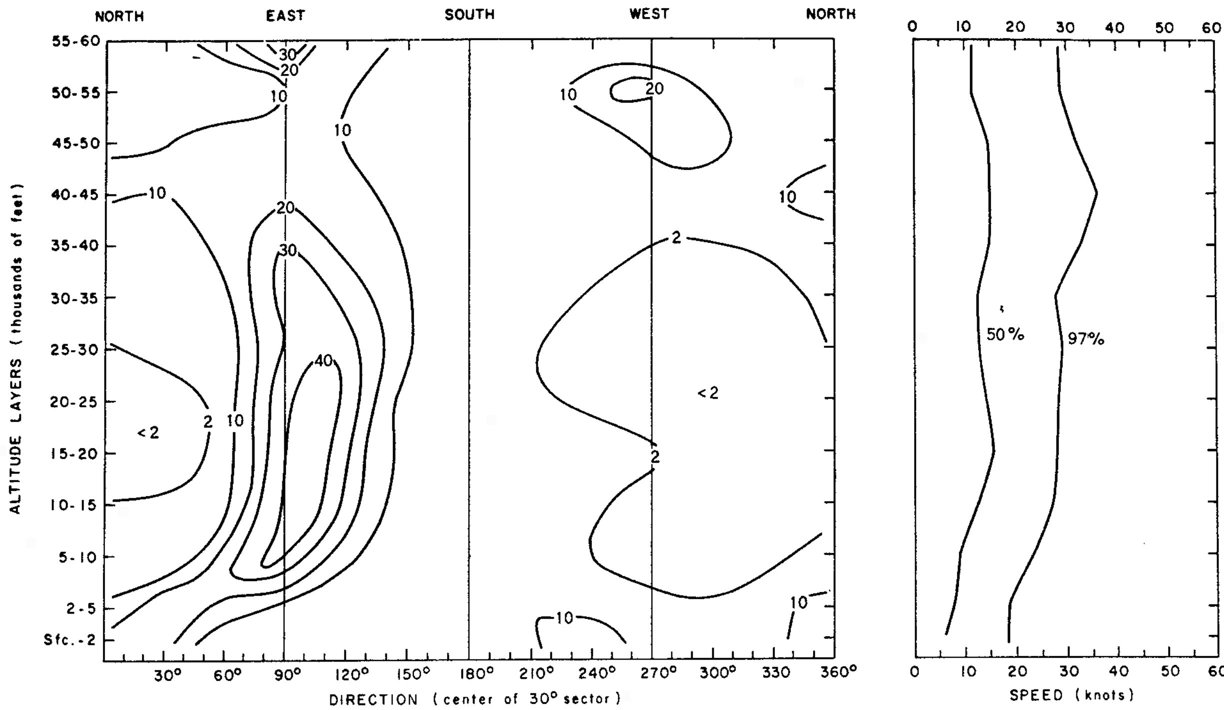



*Figure 28. Frequency distribution of mean layer winds (percent).*
*Pidiaque Jun-Jul 1967*

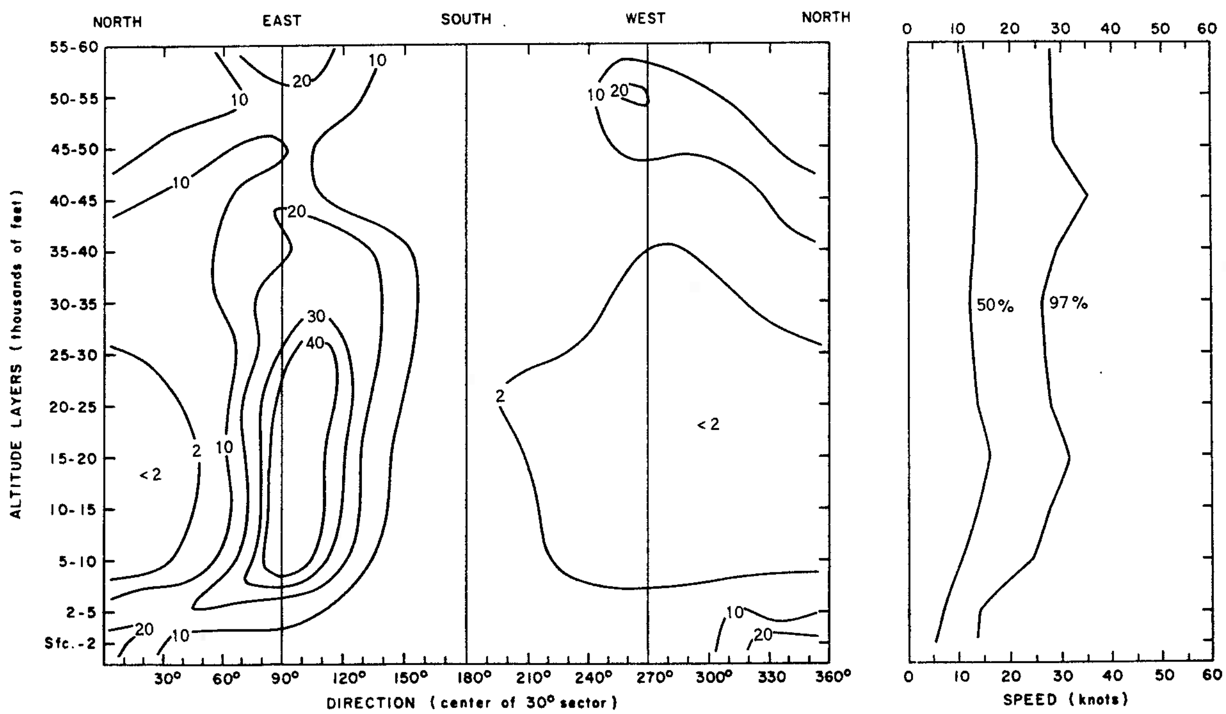



*Figure 29. Frequency distribution of mean layer winds (percent).*
*Soskatupu Jun-Jul 1967*

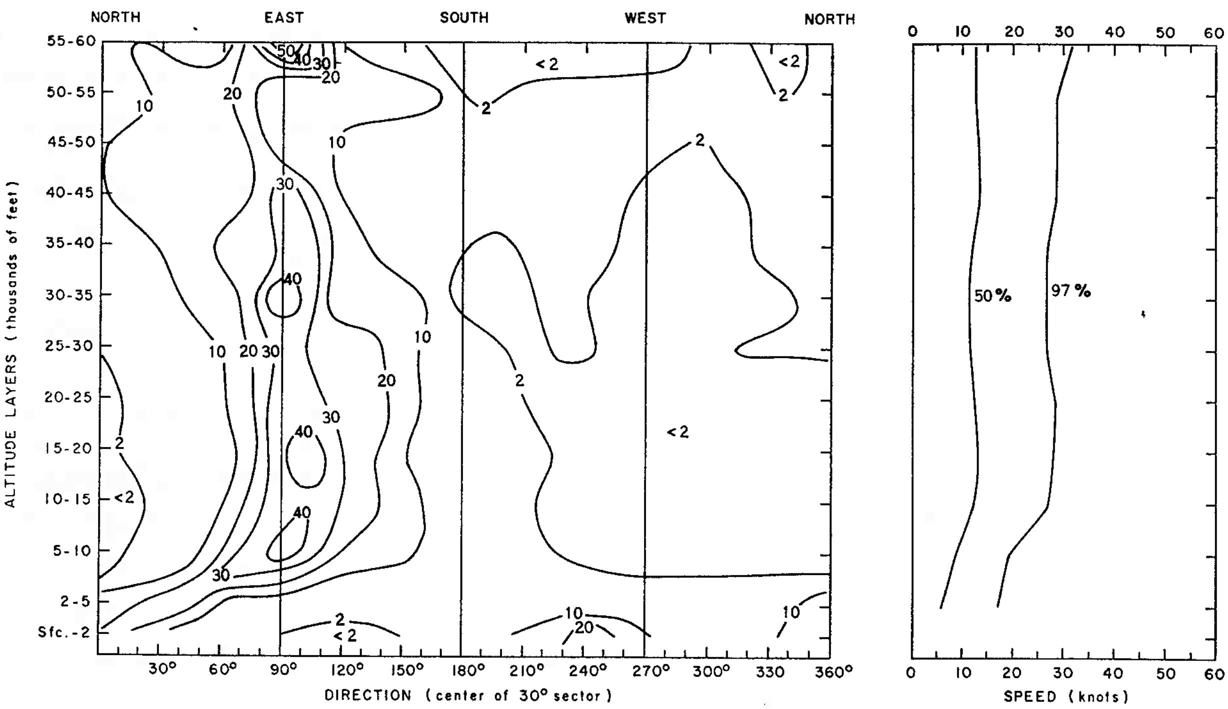



*Figure 30. Frequency distribution of mean layer winds (percent).*
*Pidiaque Aug-Sep 1967*

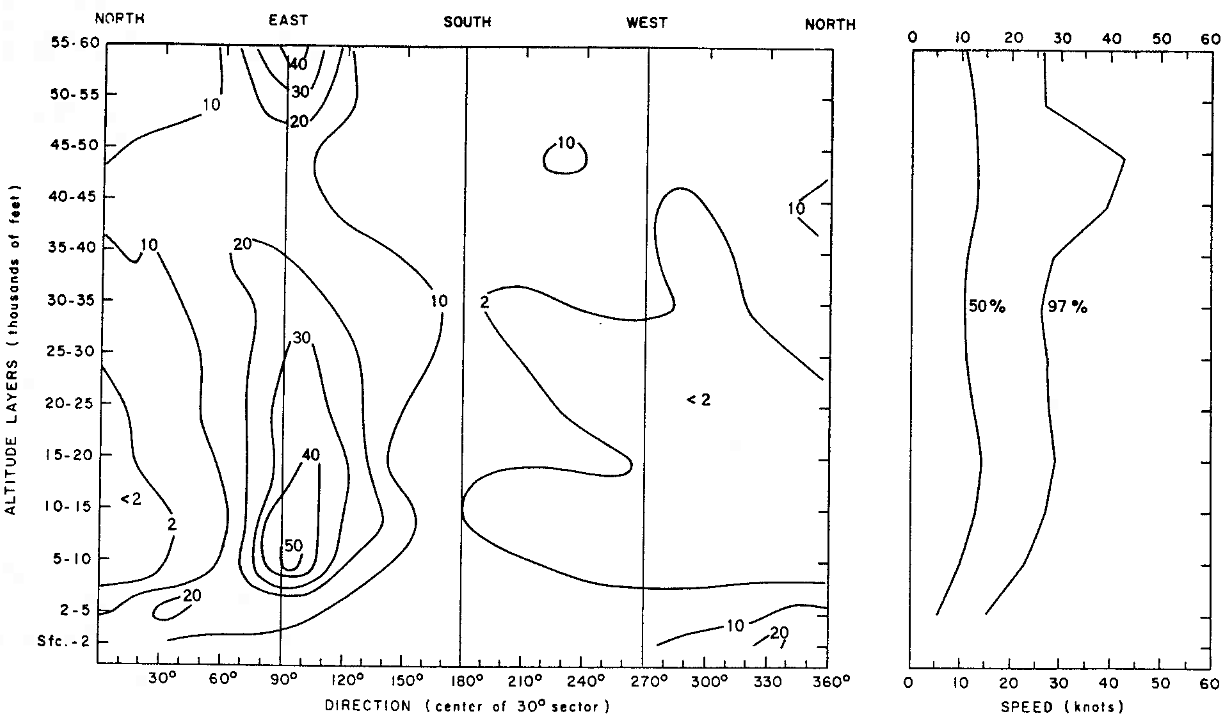



*Figure 31. Frequency distribution of mean layer winds (percent).*
*Soskatupu Aug-Sep 1967*

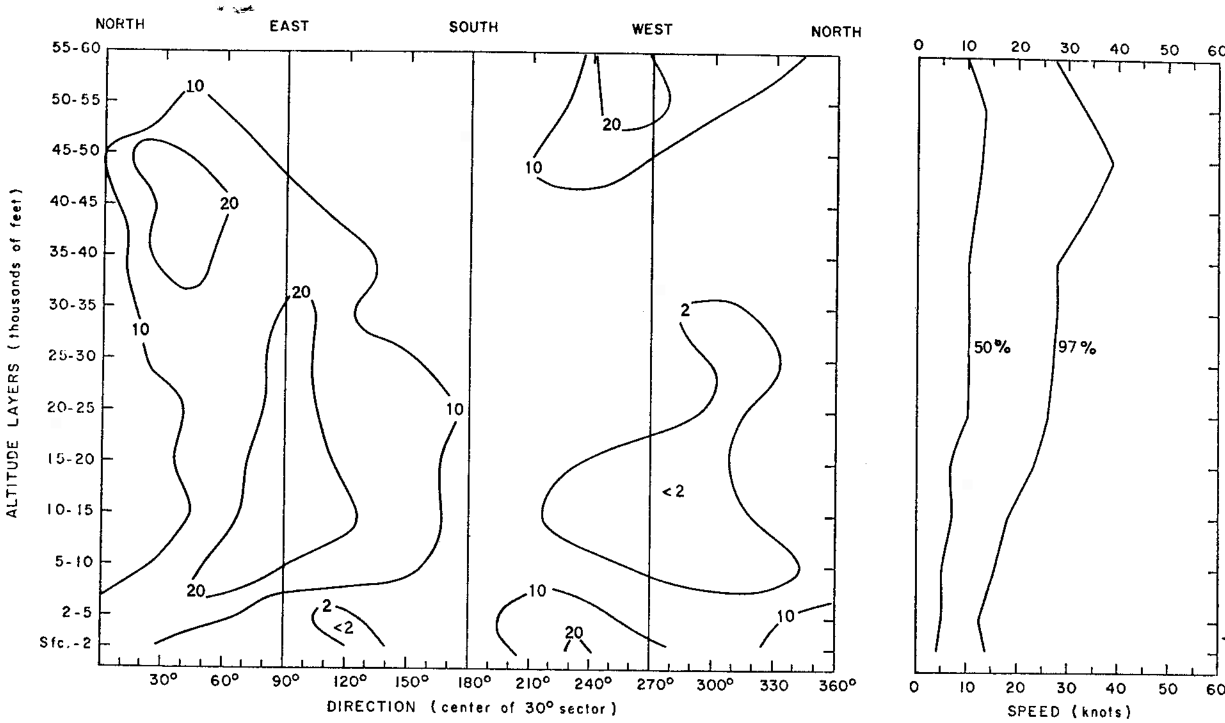



*Figure 32. Frequency distribution of mean layer winds (percent).*
*Pidiaque Oct 1967*

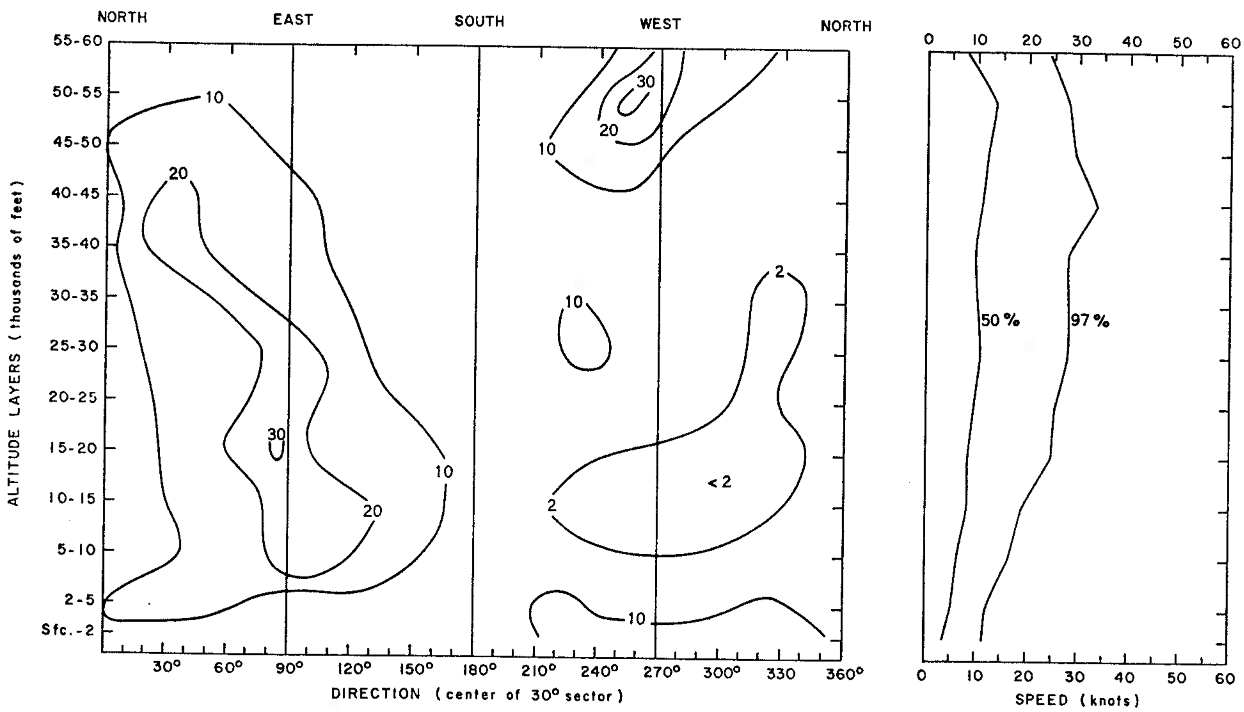



*Figure 33. Frequency distribution of mean layer winds (percent).*
*Soskatupu Oct 1967*

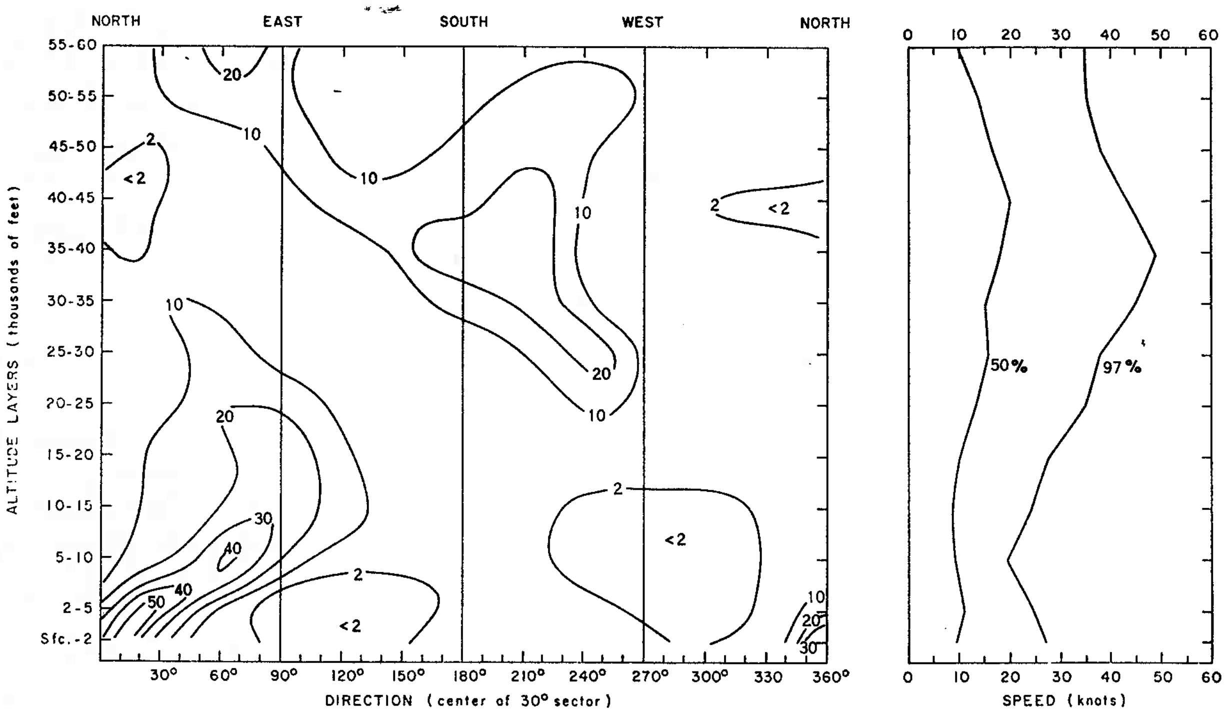



*Figure 34. Frequency distribution of mean layer winds (percent).*
*Pidiaque Nov-Dec 1967*

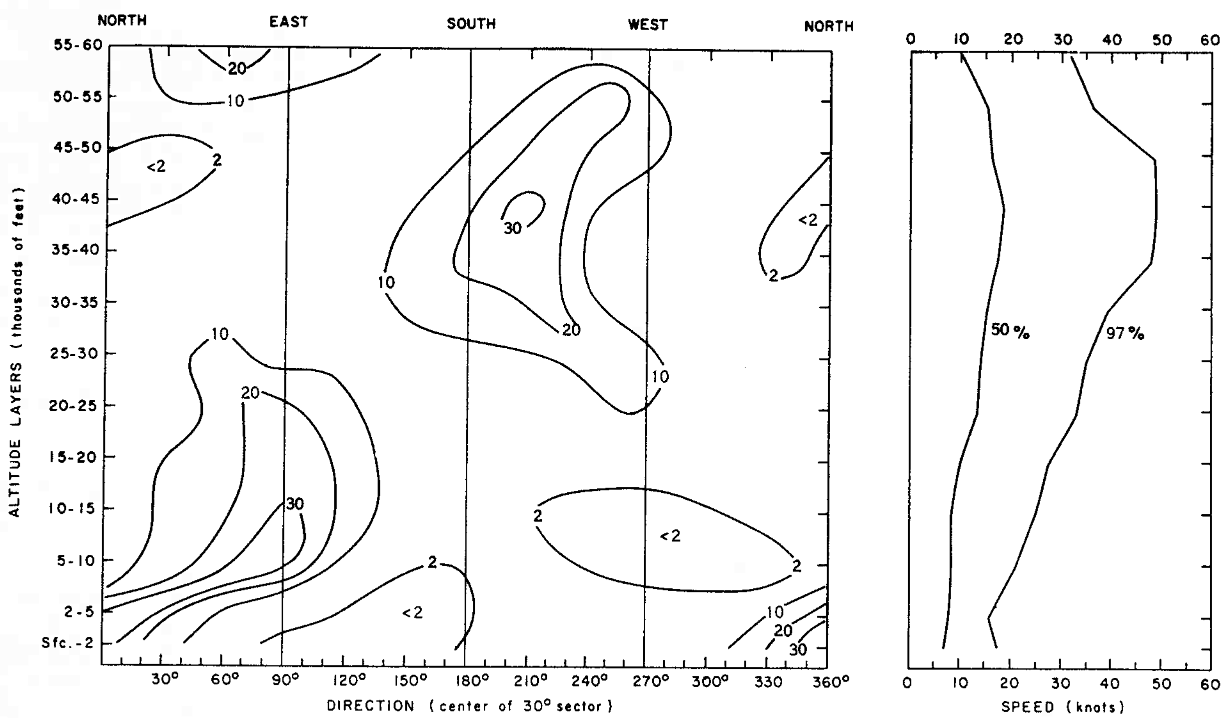



*Figure 35. Frequency distribution of mean layer winds (percent).*
*Soskatupu Nov-Dec 1967*

4.5.2 Fallout Wind Vector Frequency Charts

These charts (figs. 36 through 54) indicate the direction toward which fallout from specified altitudes would be deposited. The percentage frequencies are shown for $30^{\circ}$ sectors centered at the indicated directions. The fallout wind vectors represent the integrated effects of all the mean layer winds from the specified altitude to the ground, weighting each wind for the relative amount of time required for a fallout particle to fall through each layer. The right side of each chart indicates the fallout vector speed that includes 50 percent and 97 percent of all cases.

Figure 36 shows the percent frequency distribution of fallout wind vectors at Pidiaque during August-September 1966. This picture is typical of the entire period from June through September, which is characterized by predominantly easterly winds above 5000 feet. As a result, fallout particles originating above about 15,000 feet would be deposited toward the west a great percentage of the time. The chart shows a maximum toward the southwest for debris below 15,000 feet and a secondary maximum toward the northeast below about 5000 feet. Note that the fallout vector speeds on these charts are almost always below 20 knots and more than half of the speeds are below 10 knots. A similar chart is not shown for Soskatupu because reliable data were not obtained until September.

Figures 37 and 38 show the fallout vector frequency distributions for Pidiaque and Soskatupu for October 1966. Wind variability is greatest during October, and both stations show comparatively weak maxima of fallout vectors toward the northeast. Fallout vectors from above 10,000 feet show a second maximum toward the west. Note that the fallout vector speeds are very light and tend to decrease with altitude.

Figures 39 and 40 show the fallout vector distributions for November-December 1966. Both stations show frequency maxima toward the southwest which are strongest in the lower layers. The vectors extending above about 40,000 feet show a secondary maximum toward the east-northeast.

Figures 41 and 42 show the January-February 1967 period to be very similar to November-December. The frequency maximum in the southwest sector is even stronger at this time of year. Note that there is a difference of about 20° between the two stations in the direction of the maximum frequencies in the lowest 5000 feet, a characteristic that can be seen in most of the charts.

The March-April period (figs. 43 and 44) again shows a strong frequency maximum toward the southwest below 30,000 feet, but there is a secondary maximum toward the southeast above 20,000 feet, and vectors from above 35,000 feet show a strong maximum toward the east-northeast, due to the relatively strong westerlies in the upper troposphere overcoming the easterlies in the lower layers.

Figures 45 and 46 show the fallout vector distribution in May 1967. There is a frequency maximum toward the southwest in the lower layers, veering to the northwest from the layers extending above 35,000 feet.

Figures 47 and 48 show the fallout vector frequencies for June-July 1967. Note that the distribution at Pidiaque is almost identical to that for August-September 1966 (fig. 36). The distributions above 5000 feet at the two stations are very similar. In the lowest layers, the Soskatupu fallout vectors veer with altitude from south-southeast to southwest.

The August-September 1967 fallout vector distribution is shown in figures 49 and 50. Because the Pidiaque radar was inoperative for 3 weeks in September, Soskatupu wind data were substituted for this period in the computation of fallout vectors for this station. The patterns are essentially the same as those observed in August-September 1966 and in June-July 1967.

The fallout vector distributions in October 1967 (figs. 51 and 52) are somewhat different from the previous October (figs. 37 and 38). In 1966 there was a maximum toward the northeast throughout the troposphere and a somewhat weaker maximum toward the west from the layers extending above 10,000 feet. In 1967 the maximum toward the west is somewhat stronger, but the one toward the northeast is barely discernible.

Figures 53 and 54 show the November-December 1967 fallout vector distribution. Both stations show frequency maxima toward the southwest that are strongest in the lowest layers. The distribution is similar to that observed in 1966 (figs. 39 and 40).

It must be emphasized that the frequency distributions of fallout vectors do not necessarily reflect the distribution of fallout that would result from nuclear excavation of a canal. In practice, detonations would be conducted only under weather conditions that would serve to deposit the fallout patterns in desired sectors. The statistics presented in these charts are useful in determining the frequency of occurrence of favorable wind conditions.

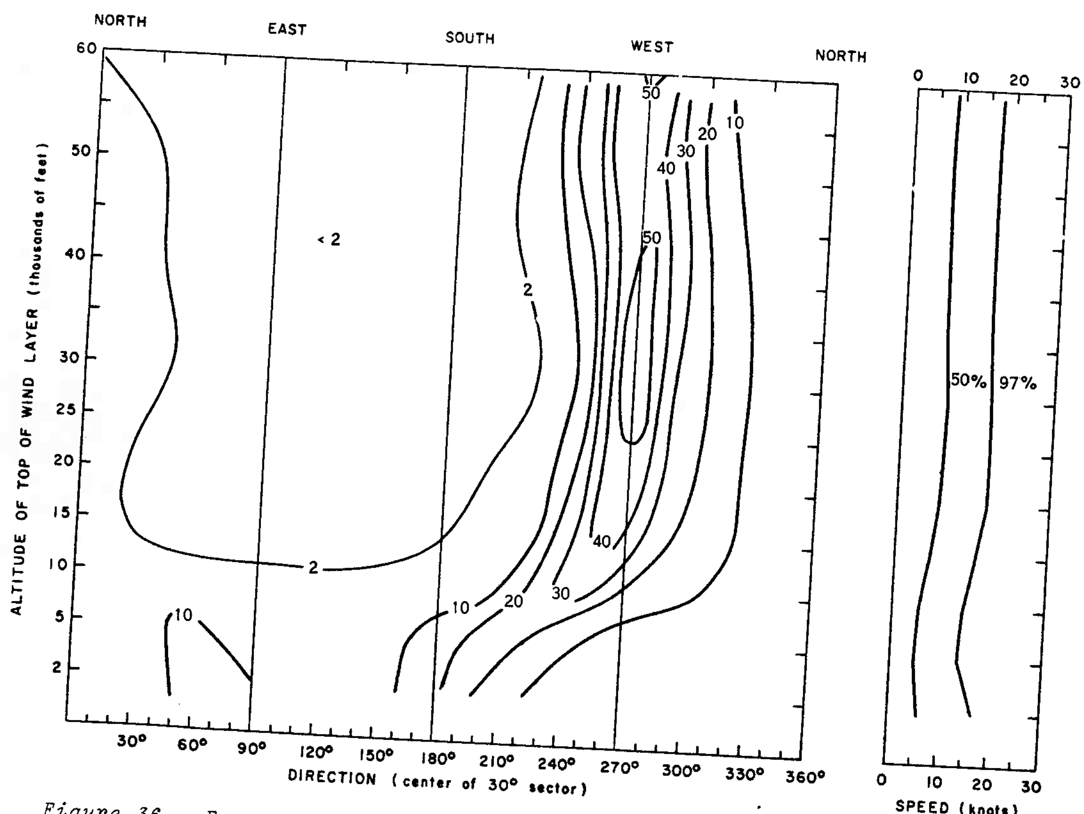



*Figure 36. Frequency distribution of fallout wind vectors (percent).*
*Pidiaque Aug-Sep 1966*

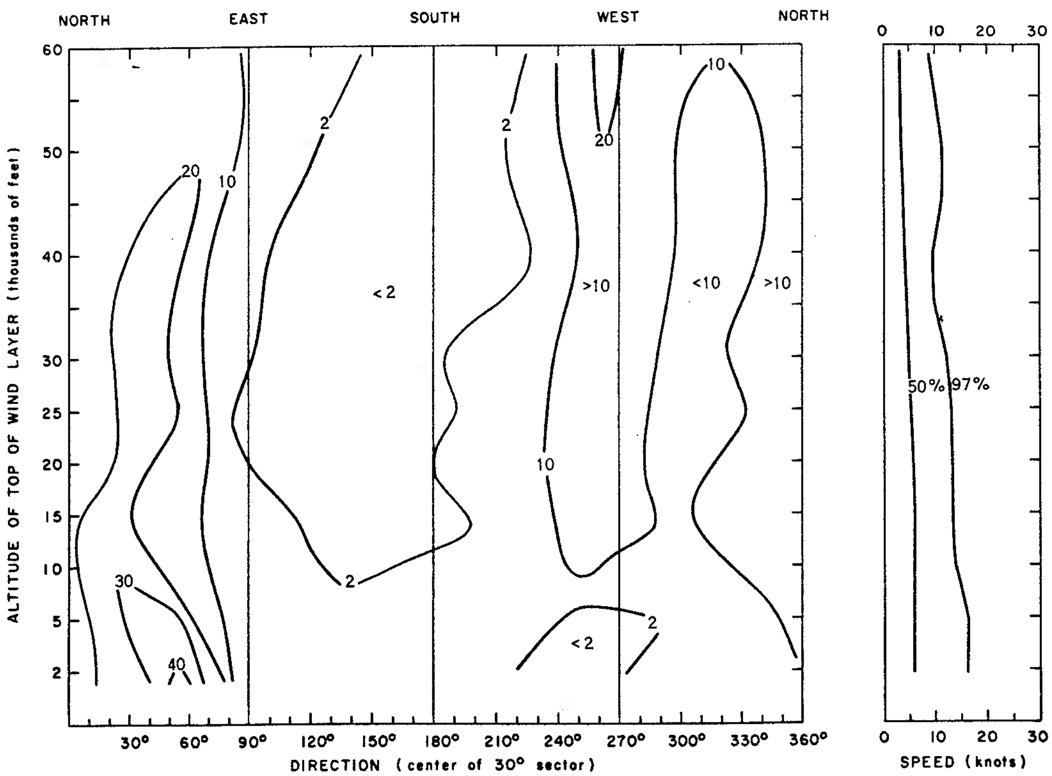



*Figure 37. Frequency distribution of fallout wind vectors (percent).*
*Pidiaque Oct 1966*

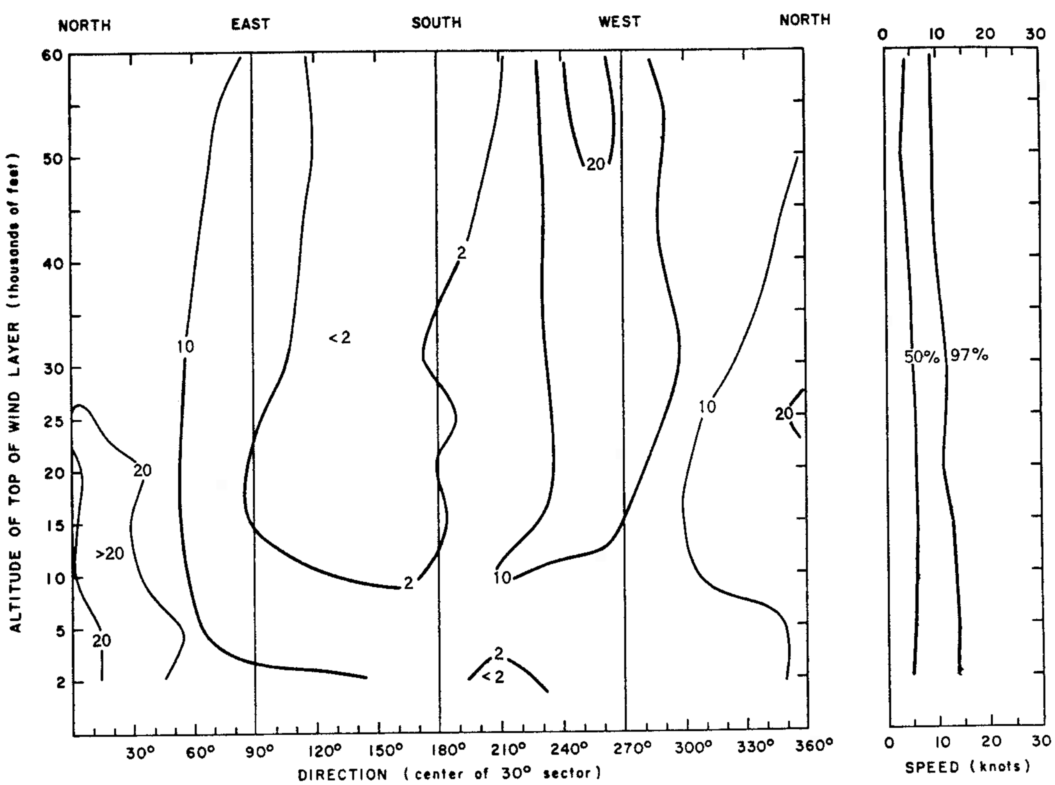



*Figure 38. Frequency distribution of fallout wind vectors (percent).*
*Soskatupu Oct 1966*

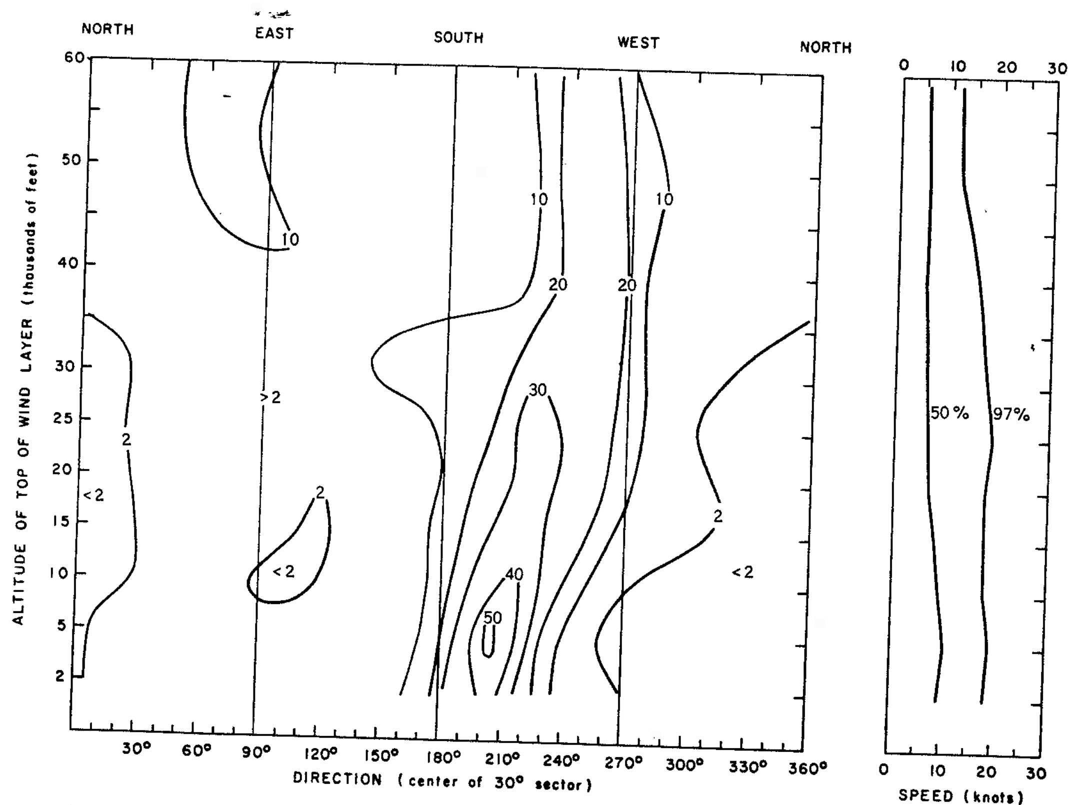



*Figure 39. Frequency distribution of fallout wind vectors (percent). Pidiaque Nov-Dec 1966*

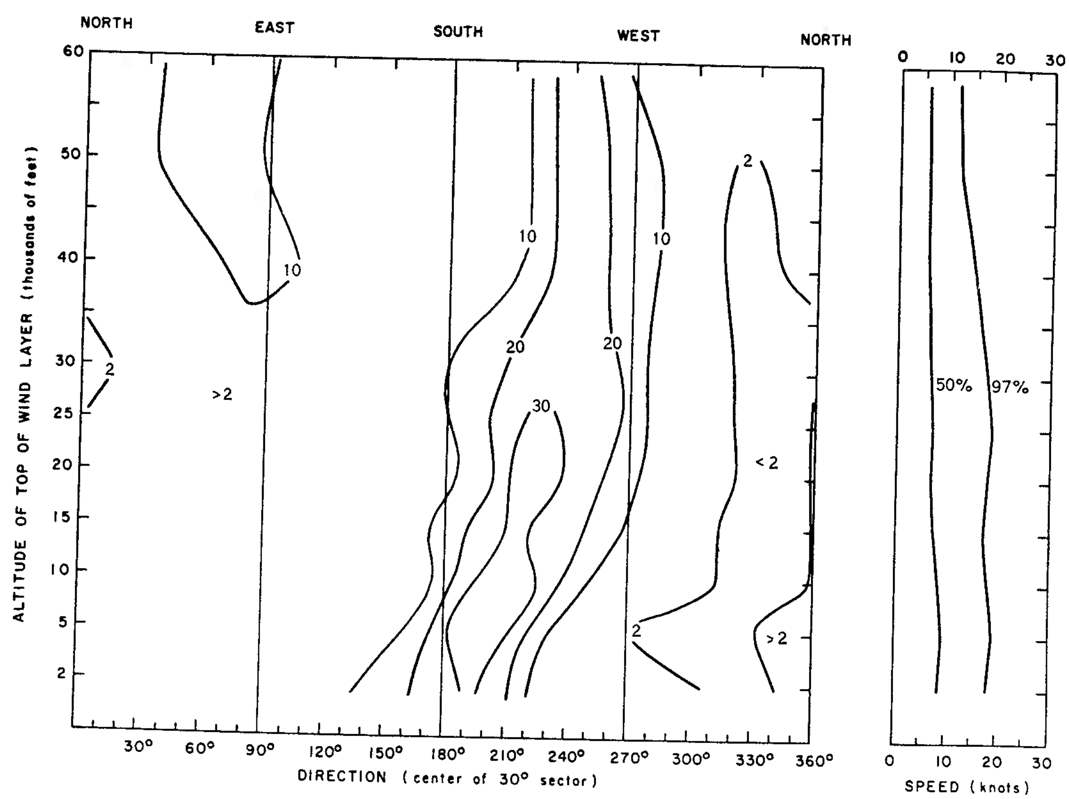



*Figure 40. Frequency distribution of fallout wind vectors (percent). Soskatupu Nov-Dec 1966*

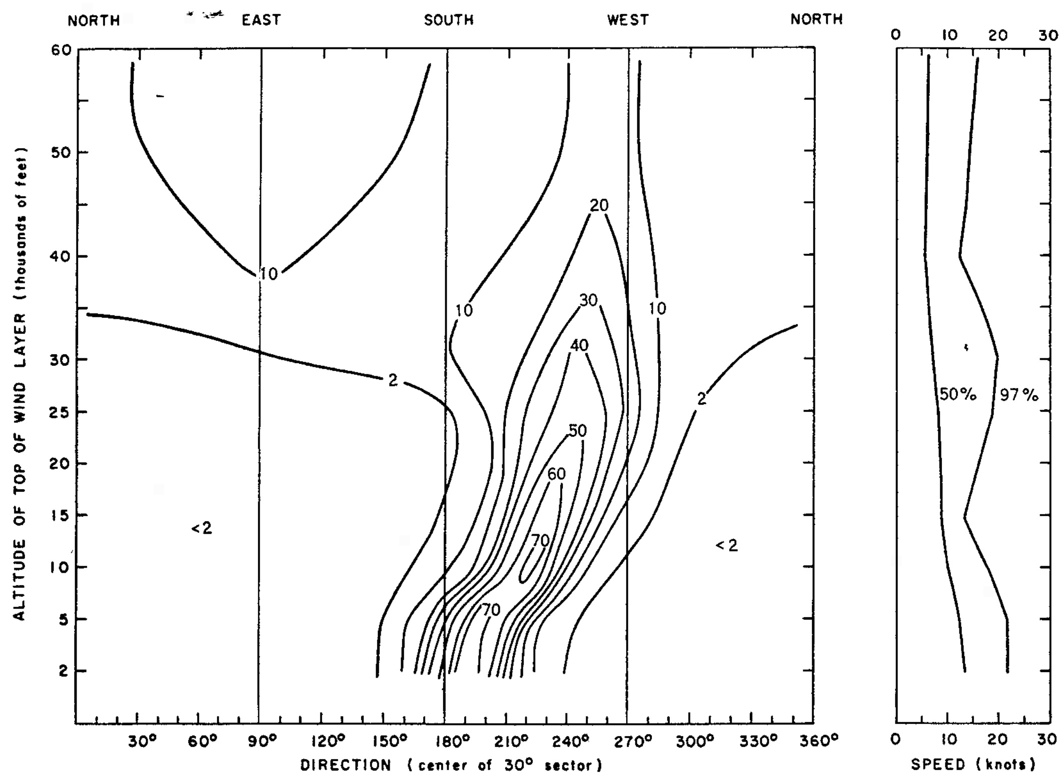



*Figure 41. Frequency distribution of fallout wind vectors (percent). Pidiaque Jan-Feb 1967*

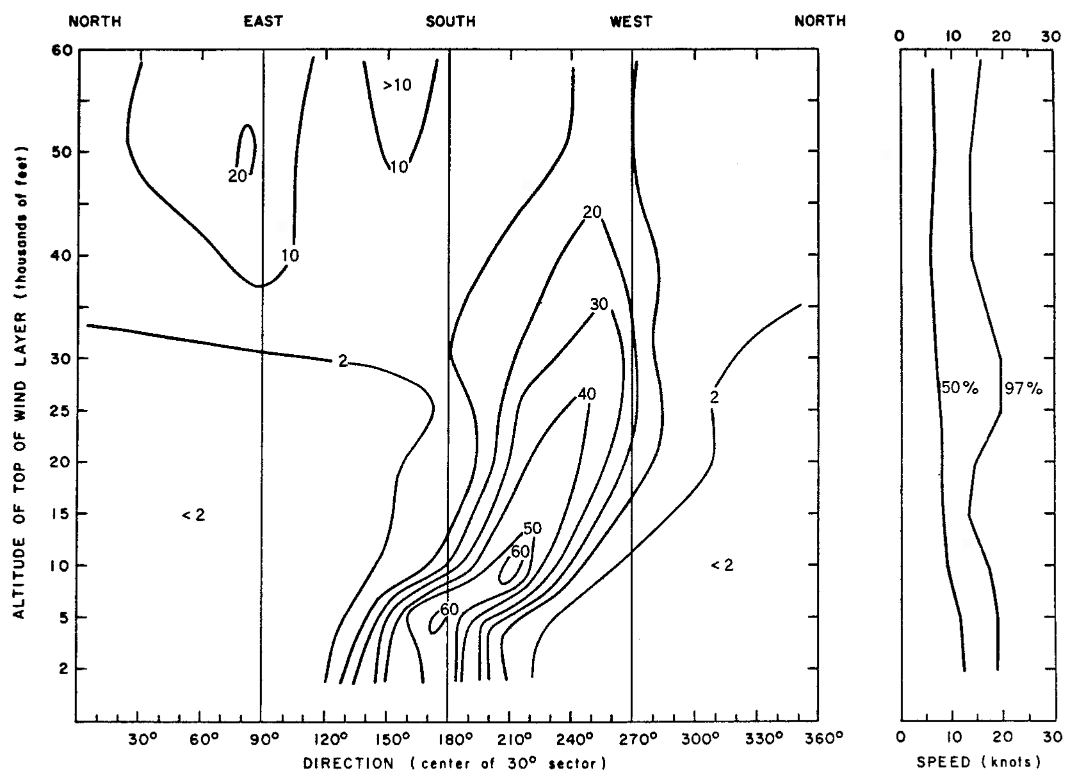



*Figure 42. Frequency distribution of fallout wind vectors (percent). Soskatupu Jan-Feb 1967*

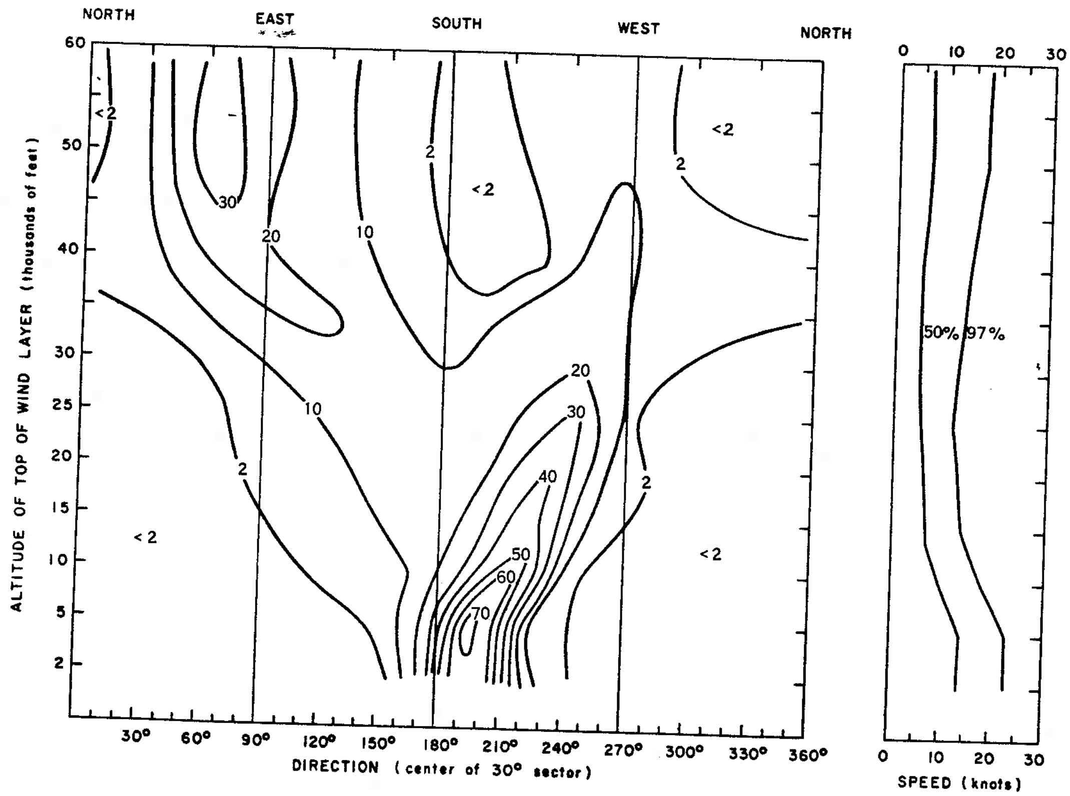



*Figure 43. Frequency distribution of fallout wind vectors (percent).*
*Pidiaque Mar-Apr 1967*

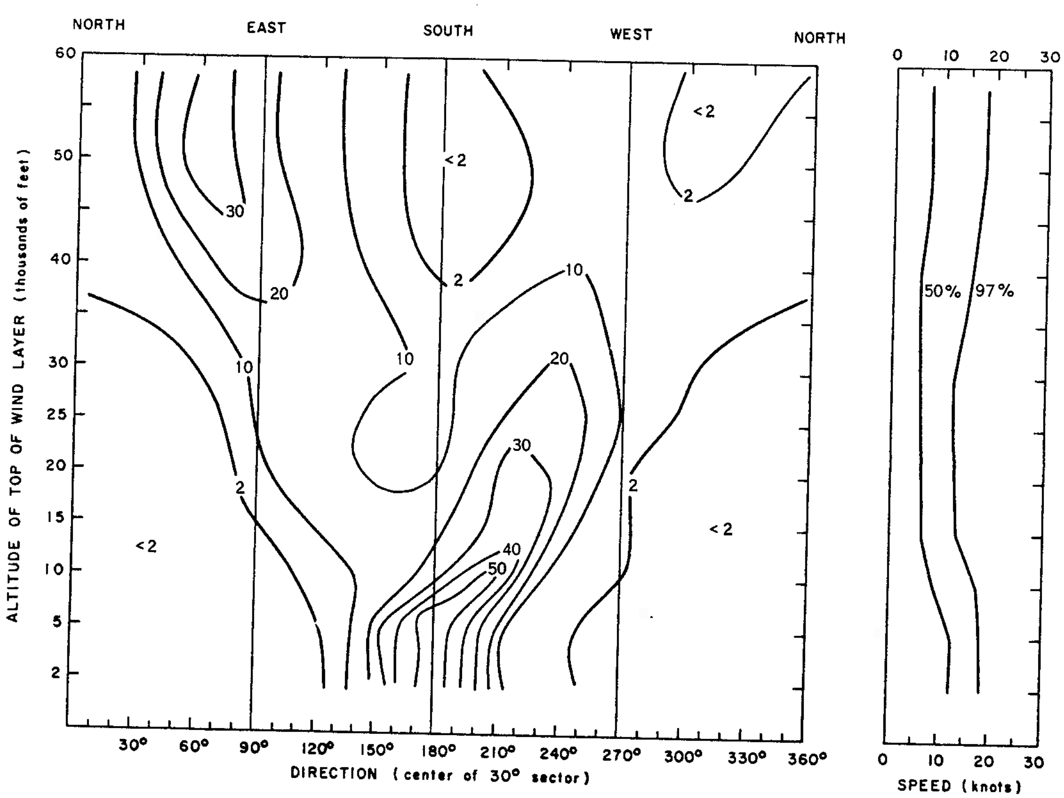



*Figure 44. Frequency distribution of fallout wind vectors (percent).*
*Soskatupu Mar-Apr 1967*

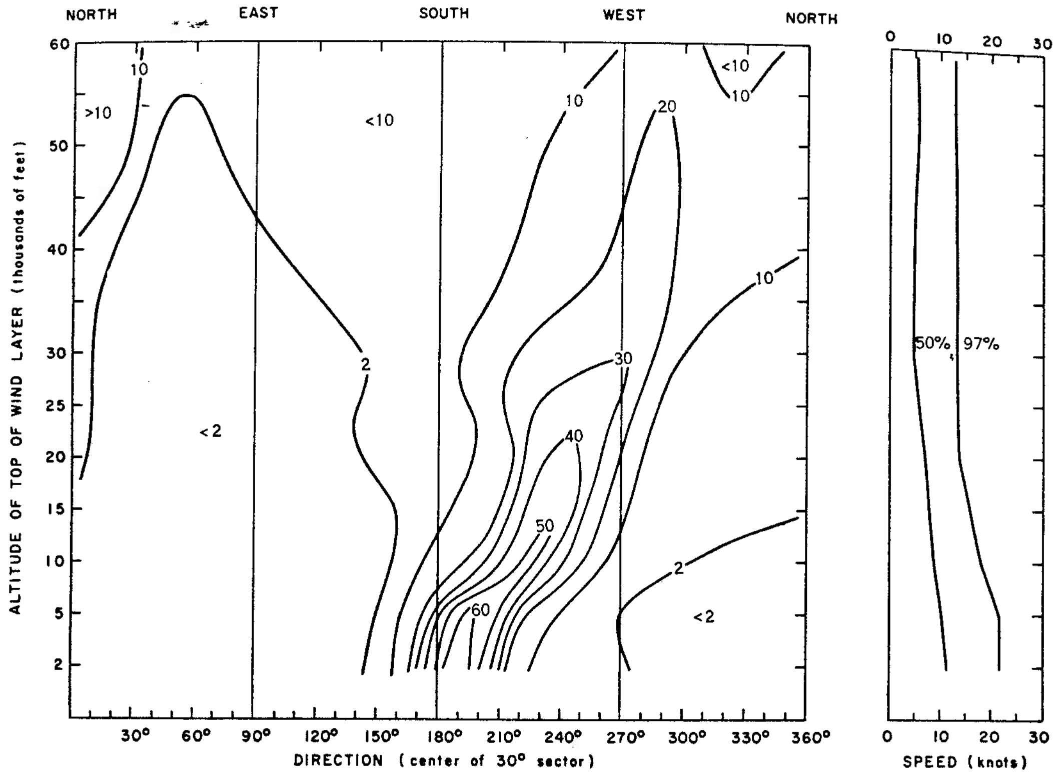



*Figure 45. Frequency distribution of fallout wind vectors (percent). Pidiaque May 1967*

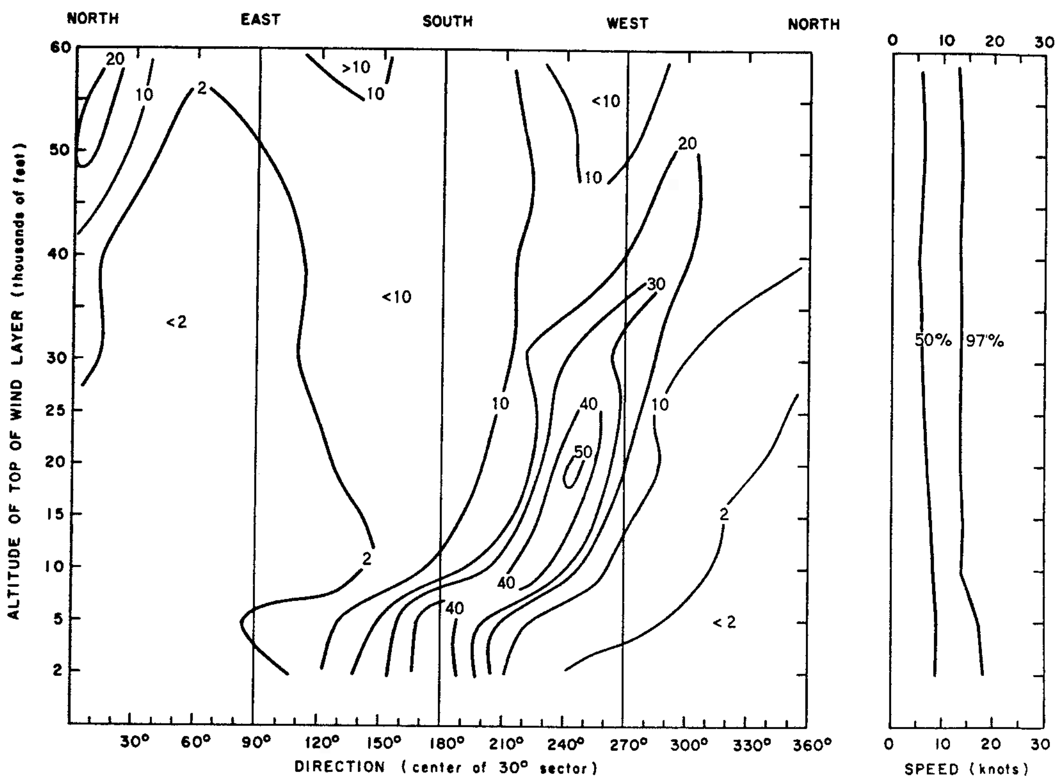



*Figure 46. Frequency distribution of fallout wind vectors (percent). Soskatupu May 1967*

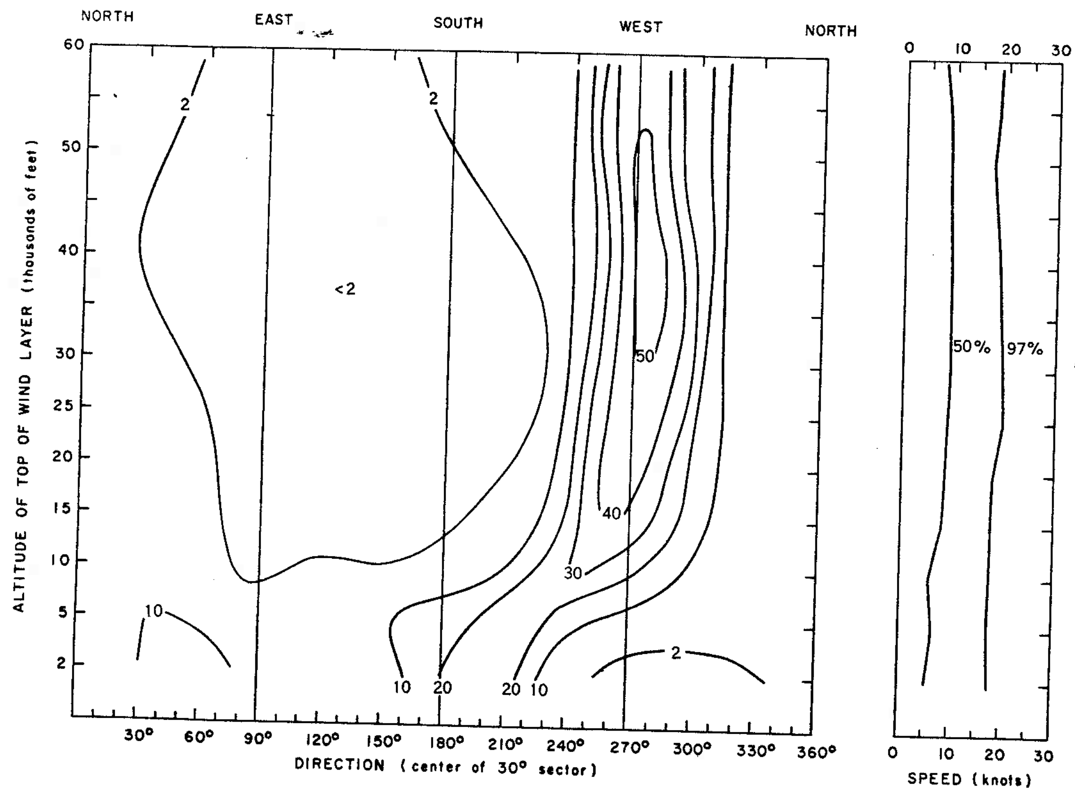



*Figure 47. Frequency distribution of fallout wind vectors (percent). Pidiaque Jun-Jul 1967*

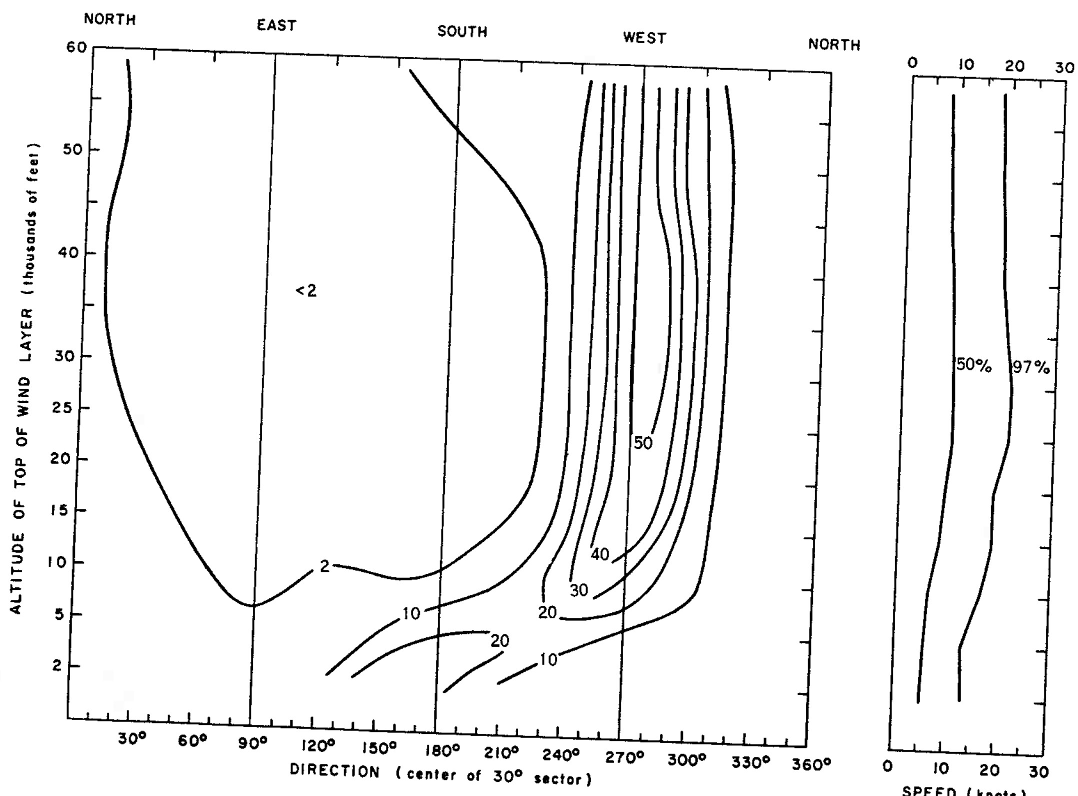



*Figure 48. Frequency distribution of fallout wind vectors (percent). Soskatupu Jun-Jul 1967*

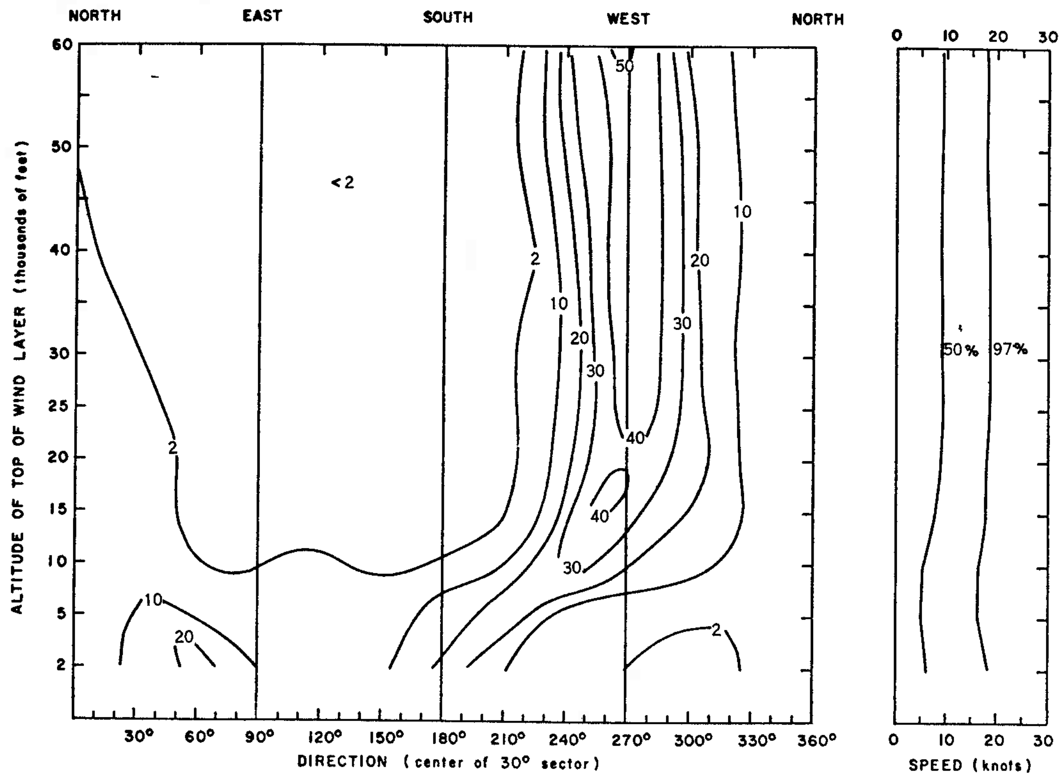



*Figure 49. Frequency distribution of fallout wind vectors (percent).*
*Pidiaque Aug-Sep 1967*

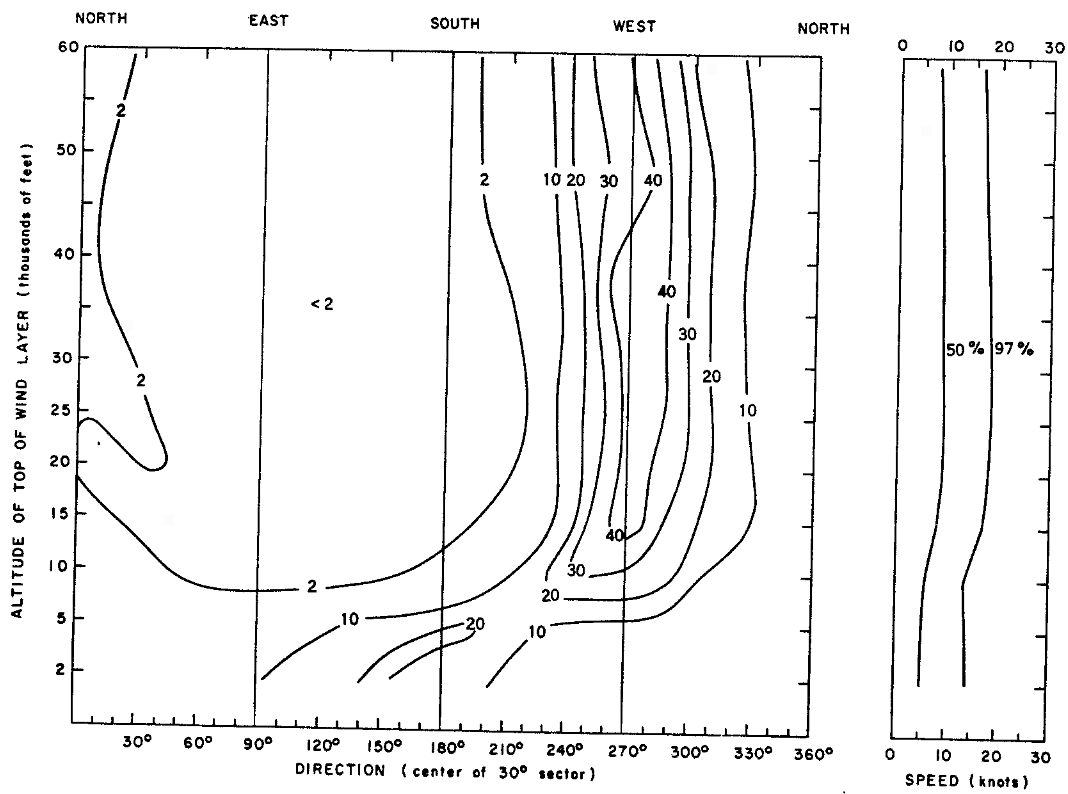



*Figure 50. Frequency distribution of fallout wind vectors (percent).*
*Soskatupu Aug-Sept 1967*

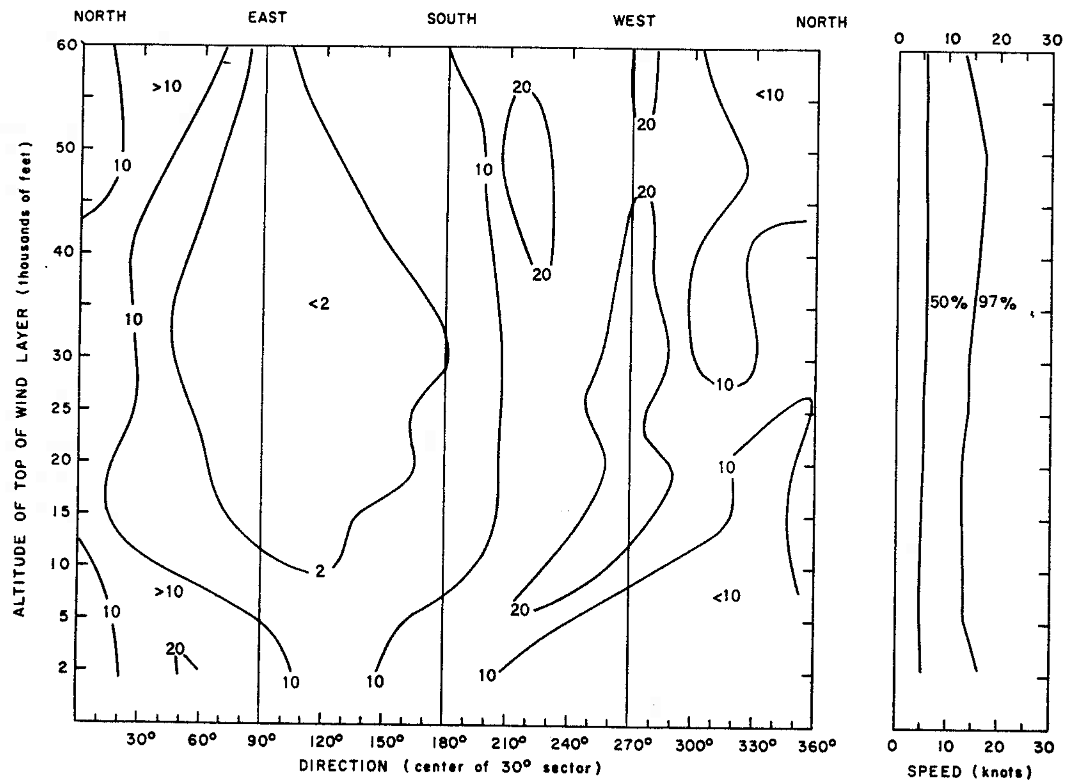



*Figure 51. Frequency distribution of fallout wind vectors (percent).*
*Pidiaque Oct 1967*

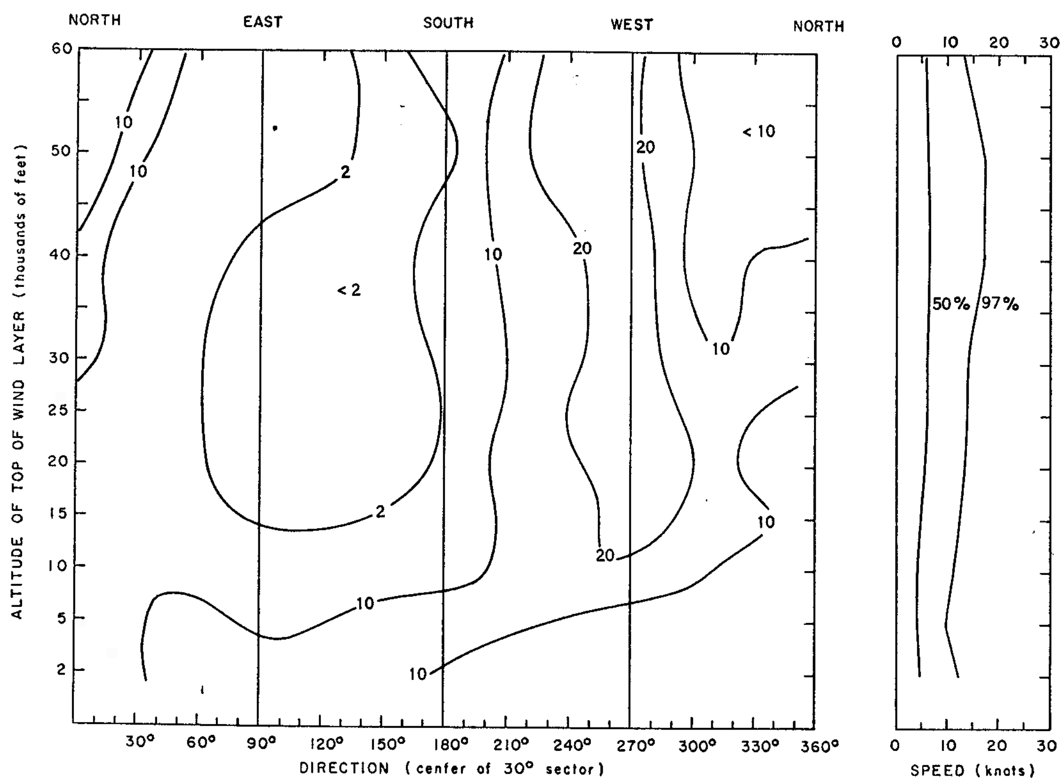



*Figure 52. Frequency distribution of fallout wind vectors (percent).*
*Soskatupu Oct 1967*

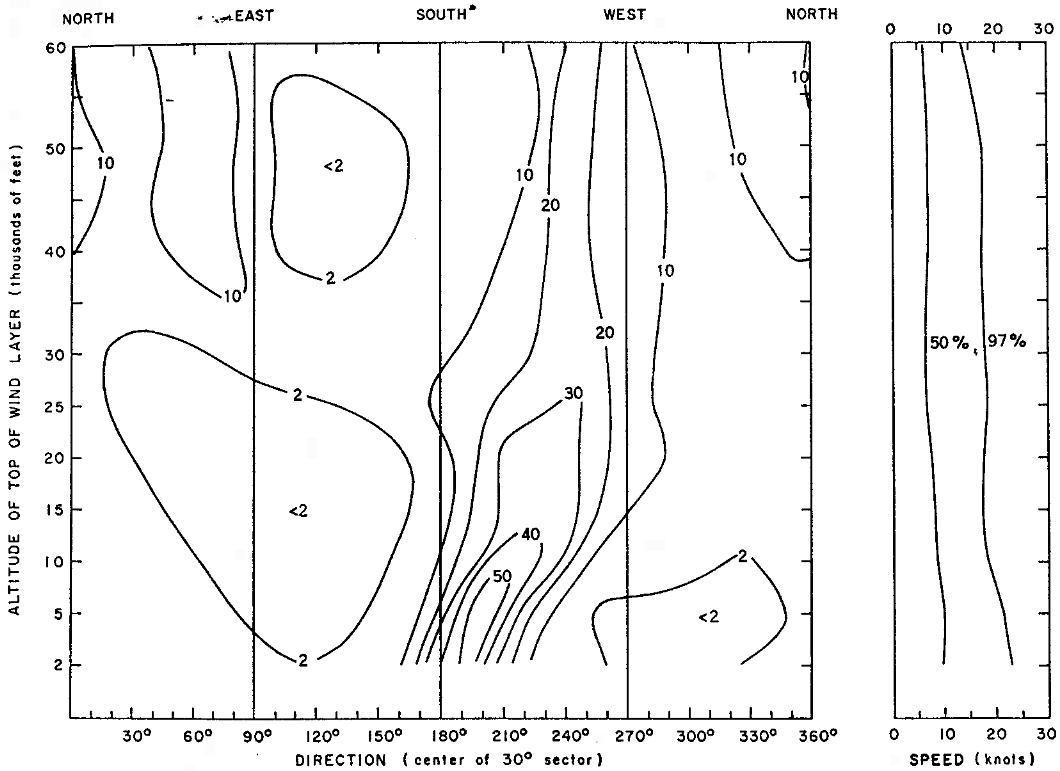



*Figure 53. Frequency distribution of fallout wind vectors (percent).*
*Pidiaque Nov-Dec 1967*

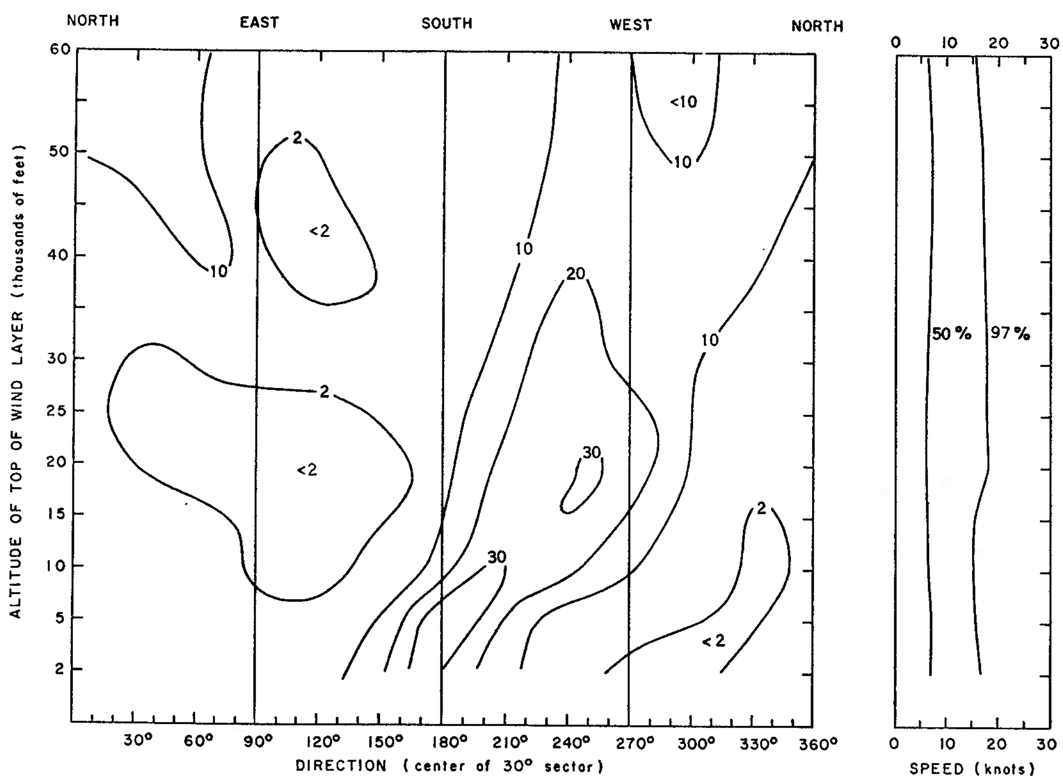



*Figure 54. Frequency distribution of fallout wind vectors (percent).*
*Soskatupu Nov-Dec 1967*

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