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NATIONAL CLIMATIC DATA CENTER

TD-9692
WEATHER OBSERVATIONS - CAPE KENNEDY

Documentation Manual

DEPARTMENT OF COMMERCE * UNITED STATES OF AMERICA *

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

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SHEET NUMBER 1.
CAPE WEATHER DATA

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I. DOCUMENTATION ATTACHED? YES X, NO ___. CAPE WX Data

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II. HOW MANY UNIQUE ELEMENTS IN THIS FILE? 28.

III. GEOGRAPHIC COVERAGE region- ___.

IV. PERIOD OF RECORD Dec 1956 - Nov 61.

V IS THIS ORIGINAL OBSERVED DATA? No.

OR COMPUTED STATISTICAL DATA YES.

VI. NUMBER OF TIMES USED DURING PERIOD 7-1-78 THRU 12-2-81 Ø

VII. IMPORTANCE OF USE? LIMITED X, MODERATE ___, VERY ___.

VIII COST TO REPRODUCE DATA SET? TAPE COPY ___, SOME REPROCESSING ___, REP X

IX. NUMBER OF TAPES IN DATA SET AT PRESENT 13.

X. DATA SET SIZE? NO UPDATE/MERGE X, UPDATE/MERGE ___.

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CLOUDS OVER CAPE CANAVERAL

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SECTION I. INTRODUCTION

A. PURPOSE

1. Statement of Problem

There are requirements for visual sighting and camera tracking of space vehicles launched from Cape Canaveral. The requirements are as follows:

a. To help assess the over-all performance of the vehicle.

b. To obtain accurate position data during the early flight period.

c. Range safety.

d. Recovery operations in case of an aborted flight.

B. OBJECTIVES

1. Incidence of opaque cloudiness

a. What are diurnal and monthly empirical probabilities of visual tracking throughout the troposphere classified as:

(1) Favorable - total cloud amount 2/10 or less?

(2) Marginal - total cloud amount 3/10 thru 5/10?

(3) Unfavorable - total cloud amount 6/10 or more?

b. Given the presence of "low" cloud types, what are dirunal and monthly empirical probabilities of visual sighting through the lowest 6,000 feet above ground classified as:

(1) Favorable - low cloud amount 2/10 or less?

(2) Marginal - low cloud amount 3/10 thru 5/10?

(3) Unfavorable - low cloud amount 6/10 or more?

2. Persistence of total opaque cloudiness

a. What are monthly empirical probabilities of spells of unfavorable conditions throughout troposphere—1. a. (3) above?

b. What are monthly empirical probabilities of pre-sunrise to post-sunrise apparent changes in total cloud amount?

c. With what frequency and duration do 7 a.m. Eastern Standard Time total cloud amount conditions continue through forenoon and afternoon?

3. Synoptic situations inducing low opaque cloudiness

a. What are the principal weather map configurations associated with conditions unfavorable for visual tracking through the lowest 6,000 feet--1. b. (3) above?

4. Summary

a. What is the preferred period for vehicle flight tests when visual tracking is required?

SECTION II. ANALYSES

A. DATA SOURCE

The text, tables, and illustrations of this report are largely based on 5 years of "surface" weather observations, period December 1956 through November 1961. Throughout, summaries and discussion refer to 5 Januarys combined, 5 Februarys combined, etc. The analyses are of the cloud observations generally made in complete form only at 3-hourly intervals: 1, 4, 7, 10 a.m. and p.m. Eastern Standard Time (hereafter EST). U.S. Air Weather Service personnel recorded the observations and punched them in 80-column cards. The punched card format is known as WBAN # 1 and National Weather Records Center Card Deck 144.

Centralized verification procedures applied routinely by the Air Weather Service insure consistency of the recorded observations and accuracy of punched cards used for this report. Control and correction of biased visual assessments of cloud amount are largely determined by the experience of and care used by observers at the station site. Recent centralized verification results, however, indicate that Cape Canaveral surface observations are now above average in general quality.

At any location visual observation of cloud amount is difficult at night Uncertainty is greatest when the observer is unaided by moonlight. Therefore daytime total cloudiness and its changes are presented in some detail under the persistence discussion below.

A special limitation of "Low" cloud observations also is briefly explained below.

Empirical probabilities throughout this report are expressed in terms of percentage frequencies computed from the 5 years of around-the-clock observational record available. This relatively short and somewhat serially correlated historical record generally subjects the percentage frequencies herein to statistical sampling error on the order of ± 7 to 9 percent.

As stated above, operating conditions are defined as follows:

Favorable - no clouds through 2-tenths cloud amount.

Marginal - 3-tenths through 5-tenths cloud amount

Unfavorable - 6-tenths through 10-tenths cloud amount (and obscurations other than "thin")

B. INCIDENCE OF OPAQUE CLOUDINESS

1. Empiral Probability Computation

Computational results are displayed in Figures 1 through 7. In each of these figures, percentage frequencies were obtained from the sample available (up to 155 observations) for each month-hour:

$$\text{Percent} = \frac{\text{Frequency of indicated condition}}{\text{No. of observations for month-hour}} \times 100$$

2. Visual Tracking Throughout Troposphere

Figures 1, 2, and 3 show the percentage frequency of favorable, marginal, and unfavorable conditions for each hour by month. Figure 1 indicates that favorable conditions are most likely just before sunrise in July and least likely around noon during the same month. Similarly, unfavorable conditions are least likely just before sunrise in July or August (Fig. 3). The most likely time for unfavorable conditions is indicated as just before sunset in June.

Figure 1 further shows that a 50 percent or better chance of favorable conditions is limited the pre-dawn hours during winter and spring. However, a 50 percent or better chance of marginal or favorable conditions generally prevails; exceptions are: (a) May through September, afternoon and early evening, and (b) March, forenoon and early afternoon (Figure 3 percentages subtracted from 100)

3. Visual Sighting Through the Lowest 6,000 feet above Ground

The initial period of vehicle launch is often accompanied by extra requirements for visual sighting. The presence of "low" clouds may be especially critical depending on extent and position of cloud(s). The punched aviation weather observations available for this study provide no information as to precise location of low clouds. But the tenths of sky covered and the altitude of cloud base above ground is recorded and punched.

Figure 4 shows the high relative frequency with which low clouds (base 6,000 feet or lower) are present in any amount. The figure indicates that low cloud in amount of 1-tenth or more sky coverage is virtually a "sure thing" from 10 a.m. to 4 p.m. during summer. More than 50 percent chance of absence of low clouds is apparently limited to hours of darkness from late fall to spring.

Because: (a) daylight is a normal requirement for effective visual sighting, and (b) "low" clouds are likely to be present in some amount, figures

5 through 7 are presented in terms of the number of observations reporting low clouds:

$$\text{Percent} = \frac{\text{Frequency of indicated condition}}{\text{No. of low cloud observations for month-hour}} \times 100$$

Figure 5 shows that on an annual basis, favorable conditions are least likely at night during winter. Figures 5 and 7 rather clearly show marked effect of convection as a primary "generator" of low clouds over Cape Canaveral, particularly during summer. Favorable conditions are most frequent in summer and at hours around dawn corresponding to the period of minimum surface heating. Favorable conditions during summer are least likely during the "maximum heating" hours of early afternoon. Yet the cellular character of convective clouds "prevents" an increase of unfavorable conditions at this time (Fig. 7). Instead, marginal conditions are at their highest incidence during summer afternoons (Fig. 6).

A low cloud bank on the ground, i.e. fog, is most likely in January (7 percent of all hourly observations) and least likely in July. 6 a.m. and 7 a.m. in January are the hours most favored for fog occurrence. Fog (with visibility 6 miles or less) has been reported in 18 percent of the January observations at each of these hours /1/.

Contrasting with the above 7-percent value for January, fog has been recorded on 1 percent or less of the observations for the months of April through October. During these warmer months, the rare occurrences of fog invariably have terminated (or the fog at least lifted) by 10 a.m. EST.

C. PERSISTENCE OF TOTAL OPAQUE CLOUDINESS

1. Computational Methods

One contingency (frequency) table supplements empirical probabilities presented under this discussion. Use of observations at 3-hourly intervals continues and empirical probabilities are again given in terms of percentage frequencies:

$$\text{Percent (Fig. 8)} = \frac{\text{Frequency of unfavorable spells}}{\text{No. of unfavorable spells for month}} \times 100$$

$$\text{Percent (Table I)} = \frac{\text{Frequency of indicated change}}{\text{No. of 4 a.m. (EST) observations for month}} \times 100$$

Plausible or relatively smooth duration frequency distributions often cannot be realized from a record as short as the 5-year period available for this study. Extensive subjective smoothing during graphical analysis (such as Fig. 8) is required.

To assist in this problem, a rule was employed during tabulation where a single observation indicating favorable or marginal conditions temporarily interrupted an otherwise "continuous" spell of unfavorable conditions. If the intervening single observation indicated a marginal condition, the unfavorable spell was considered to continue without break; if the intervening observation indicated a favorable condition, the unfavorable spell was considered to have terminated with the previous observation while another unfavorable spell began with the next. All spells ran to termination regardless of the calendar, but they were credited to the month in which they began.

2. Around-the-Clock Persistence of Conditions Unfavorable to Visual Tracking Throughout Troposphere

Given the occurrence of unfavorable conditions (Fig. 3), Figure 8 shows percentage frequencies for spells equalling or exceeding the indicated time intervals. For the year, the 12 graphs indicate about a 20 percent chance of unfavorable conditions persisting 24 hours or more and a 5 percent to 10 percent chance of persistence of 48 hours or more. Likelihood for the 24-hour interval ranges from about 30 percent in March to 10-15 percent in midsummer. Percentage frequencies for the 48-hour period vary from 12 percent in March to about 4 percent in July.

Daylight is required for the best visual observation or photography of both clouds and space vehicles. Figure 8, though it provides useful background information, is of limited utility in the practical operational planning problem at hand. The remainder of this section discusses total opaque cloud conditions: (a) around sunrise and (b) as they persist at least 9 hours after 7 a.m. EST.

3. 4 a.m. to 7 a.m. EST Apparent[1] Changes in Total Opaque Sky Cover

Table I gives monthly percentage frequency distributions by class intervals of cloud amount change computed as 7 a.m. minus 4 a.m. The months are divided as to modal (most frequent) class: December through May—no change, June through November—1 to 2 tenths increase. Where a change is observed, an increase is more likely than a decrease in all months. In fact, the table indicates that there is at least a 50 percent chance of some increase after sunrise in all months except February through April, October, and December. The maximum is reached in June when there is a 67 percent chance for some increase in pre-sunrise to post-sunrise total cloud amount.

June is also most likely to have an increase of 3-tenths or more (40 percent chance) while October is the least likely month for such an increase (21 percent chance). Chances of a decrease of similar amounts from 4 a.m. to 7 a.m are less, ranging from 14 percent in April to 3 percent in July.

1 The word apparent is used since observations of high clouds are difficult in the hours preceding dawn, therefore the changes reported may be more apparent than real. However, since there is no way to check the observations all changes have been considered as real.

Table I. Monthly percentage frequency of 4 a.m. to 7 a.m. (EST) change in total opaque sky cover.

	DECREASE			NO CHANGE	INCREASE		
	5 tenths or more	3 or 4 tenths	1 or 2 tenths		1 or 2 tenths	3 or 4 tenths	5 tenths or more
Jan.	6	2	8	34	24	14	12
Feb.	5	3	13	35	21	13	10
Mar.	3	3	14	36	19	14	11
Apr.	5	9	14	25	21	13	13
May	4	4	11	26	22	14	19
June	3	4	7	19	27	20	20
July	2	1	10	24	37	13	13
Aug.	2	2	8	25	36	19	8
Sept.	1	5	15	23	30	15	11
Oct.	3	7	17	25	27	13	8
Nov.	8	4	11	19	29	12	17
Dec.	2	6	13	32	22	13	11

Table I, and its data abstracted for the preceding two paragraphs, is significantly affected by the difficulty of accurately observing clouds during hours of darkness. As indicated above, however, the source data for this station would seem to be of above-average quality, based on indirect evidence pertaining mainly to the more recent half of the 5-year period. In any event, the results are certainly more representative than is obtainable from any other source known at this time.

4. <u>Persistence of 7 a.m. EST Total Opaque Sky Cover</u>

Disregarding weather and photographic requirements, there are other considerations that suggest post-sunrise space vehicle launching in some instances. Table II gives as complete a daylight-hour frequency summary as is practicable using the definitions of this report and the 3-hourly cloud observations available. The table is based on 7 a.m. conditions and indicates the evolution of these conditions as recorded by subsequent cloud observations at 10 a.m., 1 p.m., and 4 p.m.

Table II was compiled by noting the operating conditions at 7 a.m. and at the subsequent observational hours each day. Each day's case was credited once to one of the four categories indicated by the column headings. Where <u>marginal</u> conditions were non-persistent, those that became unfavorable (at 10 a.m.) were noted; resulting frequencies are given in parentheses in an appropriate location for the pertinent month's data.

Table II. Monthly frequency of 7 a.m. (EST) total opaque sky cover and subsequent trend.

Month		Non-Persistent	Persistent at Least 3 hrs.	6 hrs.	9 hrs.	Total	Grand Total
Jan.	Favorable (0-2)	13	11	3	23	37	50
	Marginal (3-5)	21(12)	3	1	6	10	31
	Unfavorable (6-10)	22	7	8	37	52	74
Feb.	Favorable (0-2)	11	9	4	24	37	48
	Marginal (3-5)	19(12)	4	4	4	12	31
	Unfavorable (6-10)	13	13	5	31	49	62
Mar.	Favorable (0-2)	11	11	4	17	32	43
	Marginal (3-5)	22(10)	9	2	1	12	34
	Unfavorable (6-10)	10	8	12	48	68	78
Apr.	Favorable (0-2)	20	5	1	20	26	46
	Marginal (3-5)	25(10)	8	6	1	15	40
	Unfavorable (6-10)	23	6	6	29	41	64
May	Favorable (0-2)	27	6	4	24	34	61
	Marginal (3-5)	20(12)	6	6	2	14	34
	Unfavorable (6-10)	18	4	6	32	42	60
June	Favorable (0-2)	22	4	2	13	19	41
	Marginal (3-5)	22(14)	13	9	4	26	48
	Unfavorable (6-10)	8	7	4	42	53	61

Table II (Cont.)

Month		Non-Persistent	Persistent at Least 3 hrs.	6 hrs.	9 hrs.	Total	Grand Total
July	Favorable (0-2)	32	12	3	8	23	55
	Marginal (3-5)	19(15)	12	6	10	28	47
	Unfavorable (6-10)	16	5	3	29	36	53
Aug.	Favorable (0-2)	34	6	5	6	17	51
	Marginal (3-5)	39(27)	10	4	6	20	59
	Unfavorable (6-10)	12	4	4	25	33	45
Sept.	Favorable (0-2)	24	7	6	3	16	40
	Marginal (3-5)	24(18)	10	9	9	28	52
	Unfavorable (6-10)	13	8	6	31	45	58
Oct.	Favorable (0-2)	18	11	2	17	30	48
	Marginal (3-5)	26(14)	6	6	3	15	41
	Unfavorable (6-10)	13	9	9	35	53	66
Nov.	Favorable (0-2)	16	10	6	18	30	50
	Marginal (3-5)	23(10)	3	5	0	8	31
	Unfavorable (6-10)	13	8	9	39	56	69
Dec.	Favorable (0-2)	20	8	2	23	33	53
	Marginal (3-5)	34(20)	7	0	1	8	42
	Unfavorable (6-10)	13	6	8	33	47	60

For visual tracking throughout the troposphere, 7 a.m. conditions are seen to be predominately unfavorable in nine months of the year ("Grand Total" column). Favorable or marginal conditions prevail only in May, June, and August. Through the 5-year period 7 a.m. conditions, when unfavorable, have persisted at least 3 hours nearly 7 times more often than they have improved (by 10 a.m.) during March and June, and about 2 to 5 times more often in other months.

"Marginal" predominates as the 7 a.m. condition only in August and is the second most frequent condition only in September. Though rare, marginal conditions by their nature are sometimes of special interest. Table II shows that 7 a.m. marginal conditions are more likely to be non-persistent (rather than persistent) in all months except June, July, and September. 7 a.m. non-persistent marginal conditions are more likely to get worse (rather than better) in all months except March, April, and November.

D. SYNOPTIC SITUATIONS INDUCING LOW OPAQUE CLOUDINESS

Synoptic weather map configurations predominately associated with unfavorable conditions vary with the season of the year. In general, maps for the cooler "half" of the year (beginning October or November and ending April or May) contrast with those for the warmer months. Figure 6 shows that, given the existence of low clouds, unfavorable conditions (lowest 6,000 feet) prevail at least 30 percent of the time during the cooler season. Such conditions are typically associated with surface fronts originating in higher latitudes and/or with waves (low pressure centers) developing on these fronts over the Gulf of Mexico. During December and January particularly, a surface frontal system may migrate to the south of Florida and the Gulf of Mexico. In such a case, a long trajectory of cooler moisture-acquiring air from the northeast may follow with subsequent development of extensive low cloud cover along the east coast of northern and central Florida. The surface weather map for this situation typically shows a strong high pressure area centered somewhere to the northeast of a line extending from around Cape Fear, N. C. to near the junction of the Ohio and Mississippi Rivers [2].

Marked contrasts in air masses typically disappear for the warmer season. Then unfavorable conditions in the lower troposphere are less frequent. But when they do occur, any one of three synoptic features may be influential as it approaches Florida: (1) a low pressure trough (surface or aloft) in the westerlies, (2) a trough or wave in the low level easterlies, (3) a tropical cyclone or hurricane. Individual-year predominance of these three patterns varies greatly from summer to summer.

These principal synoptic situations also generally apply to plans for visual tracking throughout the troposphere. However, seasonal contracts are not as great when clouds at any level are considered. Summer remains the preferred season but its superiority for early forenoon launchings is no longer so obvious (Table II).

SECTION III. CONCLUSIONS/RECOMMENDATIONS

A literal reading of the 3-hourly data tabulated for analysis of Figure 1 indicates that 4 a.m. EST in July is the best time of year for visual tracking at Cape Canaveral. But the normal operational necessity for daylight requires, in effect, that we imagine slightly concave "darkness" masks over the right and left ends of Figure 1. Then, considering the basic data's statistical sampling error, we can see that there may be little or no real difference between (a) mid-summer just after sunrise, and (b) mid-winter just before sunset.

Figure 4 offers little help in selecting one preferred time but figure 3 and 7 show the way to proper ordering of the two alternatives. Unfavorable amounts of both total and low clouds have occurred more often on winter afternoons.

<u>Flight tests should be planned for July or August, as near sunrise as possible, when absence of clouds is a primary consideration.</u>

NOTES: 1. The relatively short history of around-the-clock weather records from Cape Canaveral is again stressed. Assuming continuation of the present weather observing program, it is recommended that this report be superseded and updated when punched observations through November 1964 are available for retabulation and reanalysis.

2. Other elements of the atmospheric environment bear upon vehicle development and flight test plans. Another report, in preparation, will deal with total opaque cloudiness in conjunction with wind speeds at the ground and in the upper troposphere.

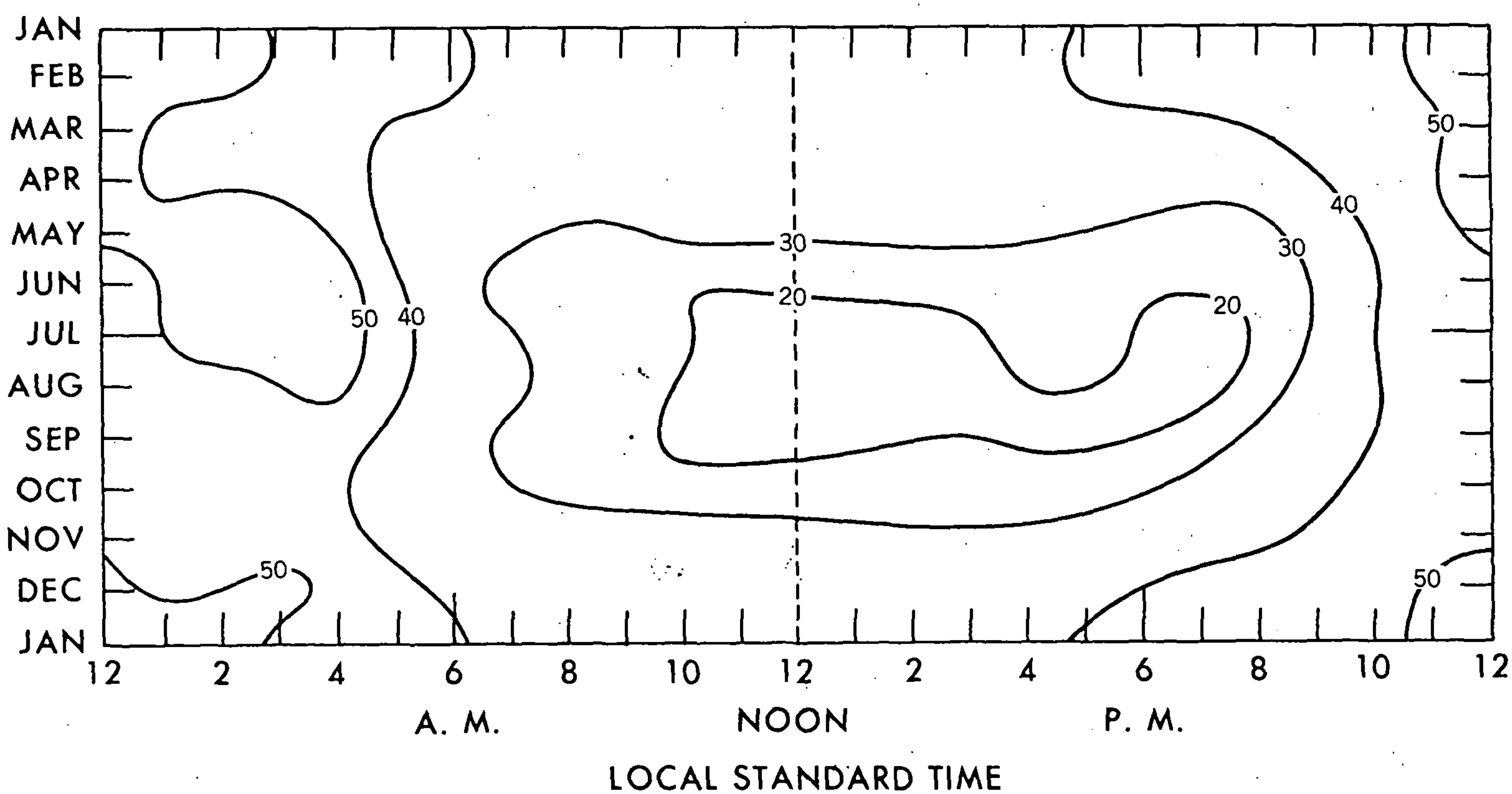

Figure 1. Hourly percentage frequency of total opaque sky cover (cloud amount) ≤ 2-tenths, by month.

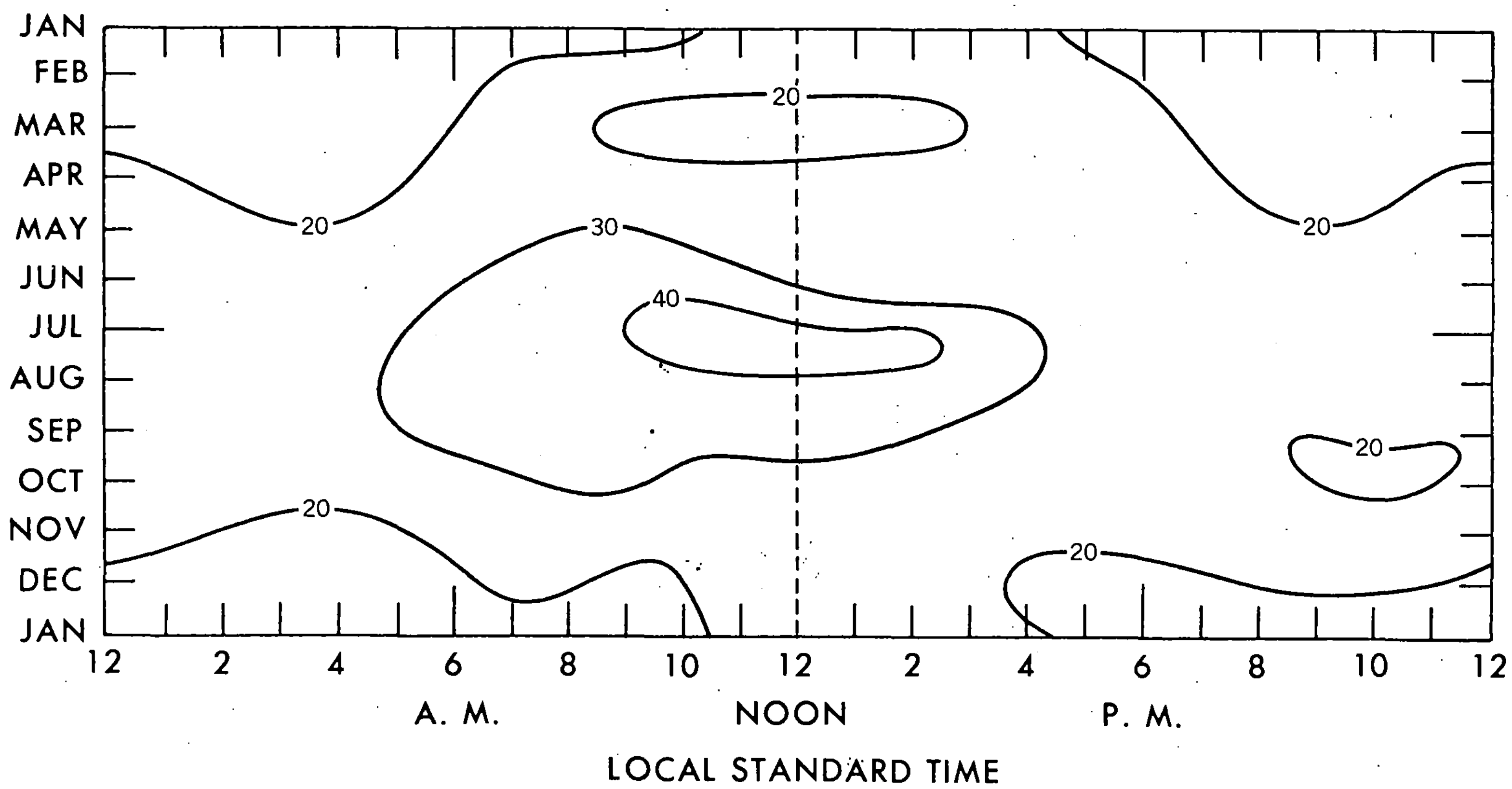

Figure 2. Hourly percentage frequency of total opaque sky cover (cloud amount) 3- through 5-tenths, by month.

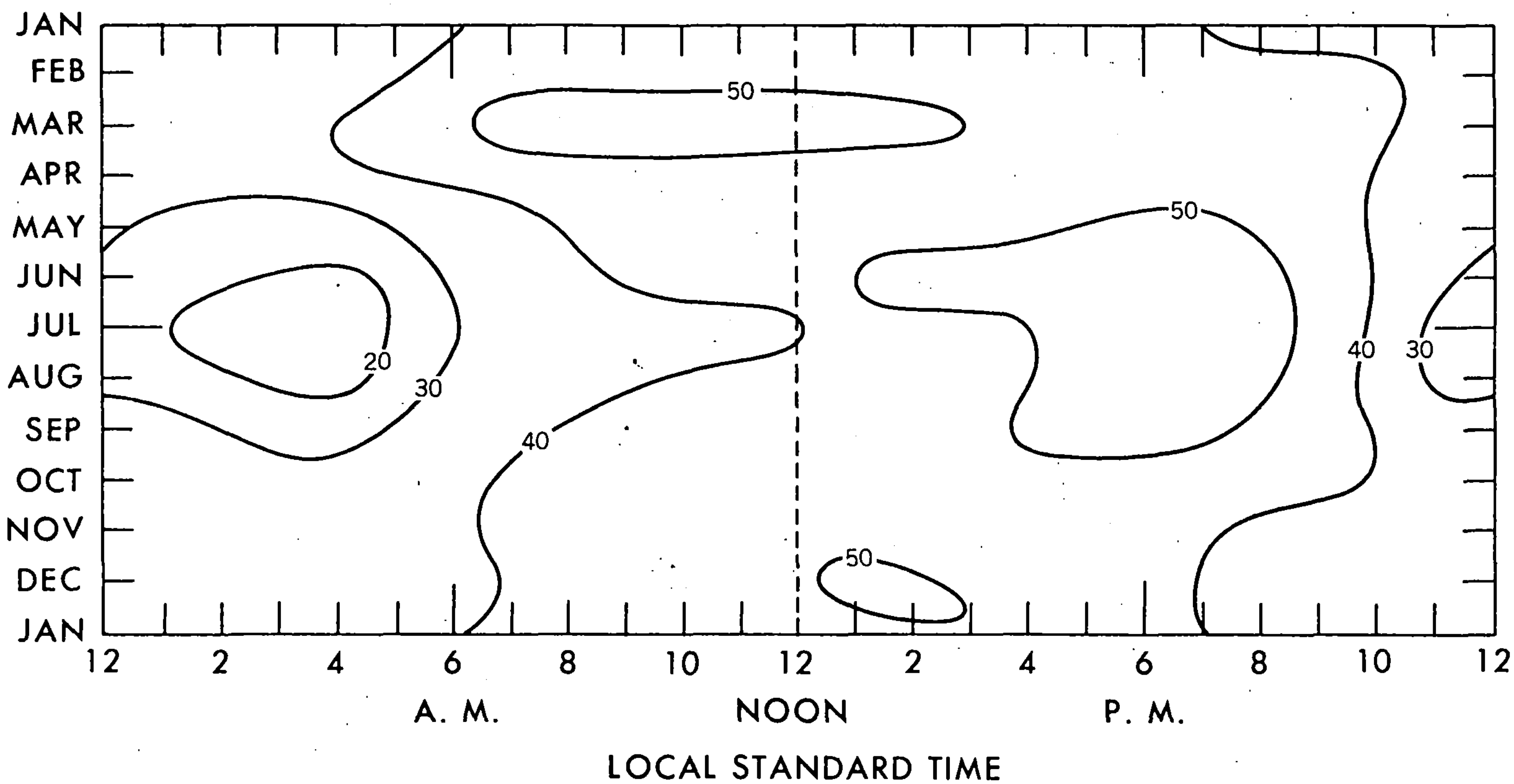

figure 3. Hourly percentage frequency of total opaque sky cover (cloud amount) $\geq$ 3-tenths, by month.

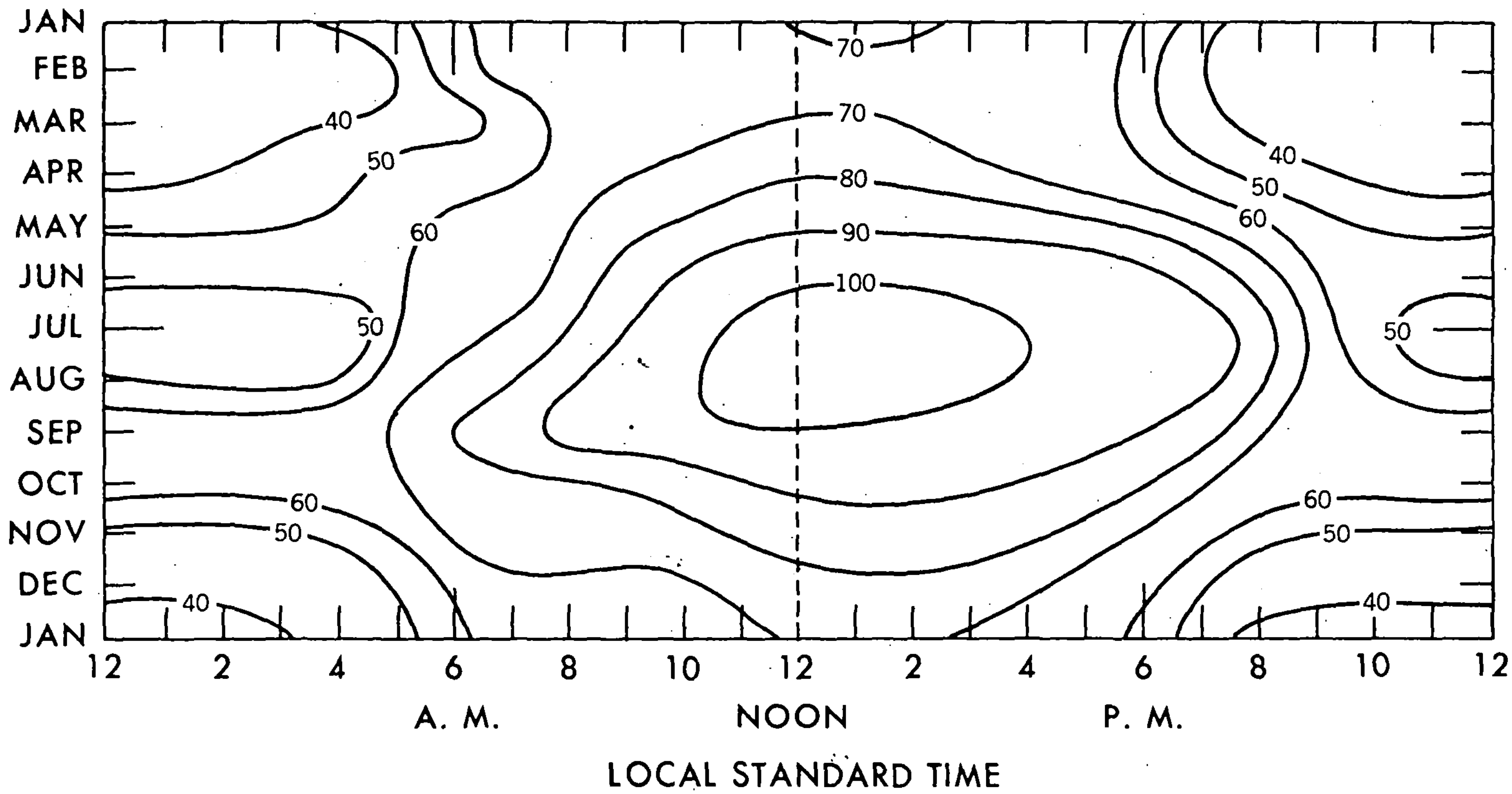

Figure 4. Hourly percentage frequency of observations reporting low clouds (base 3,000 ft. or less) in any amount, by month.

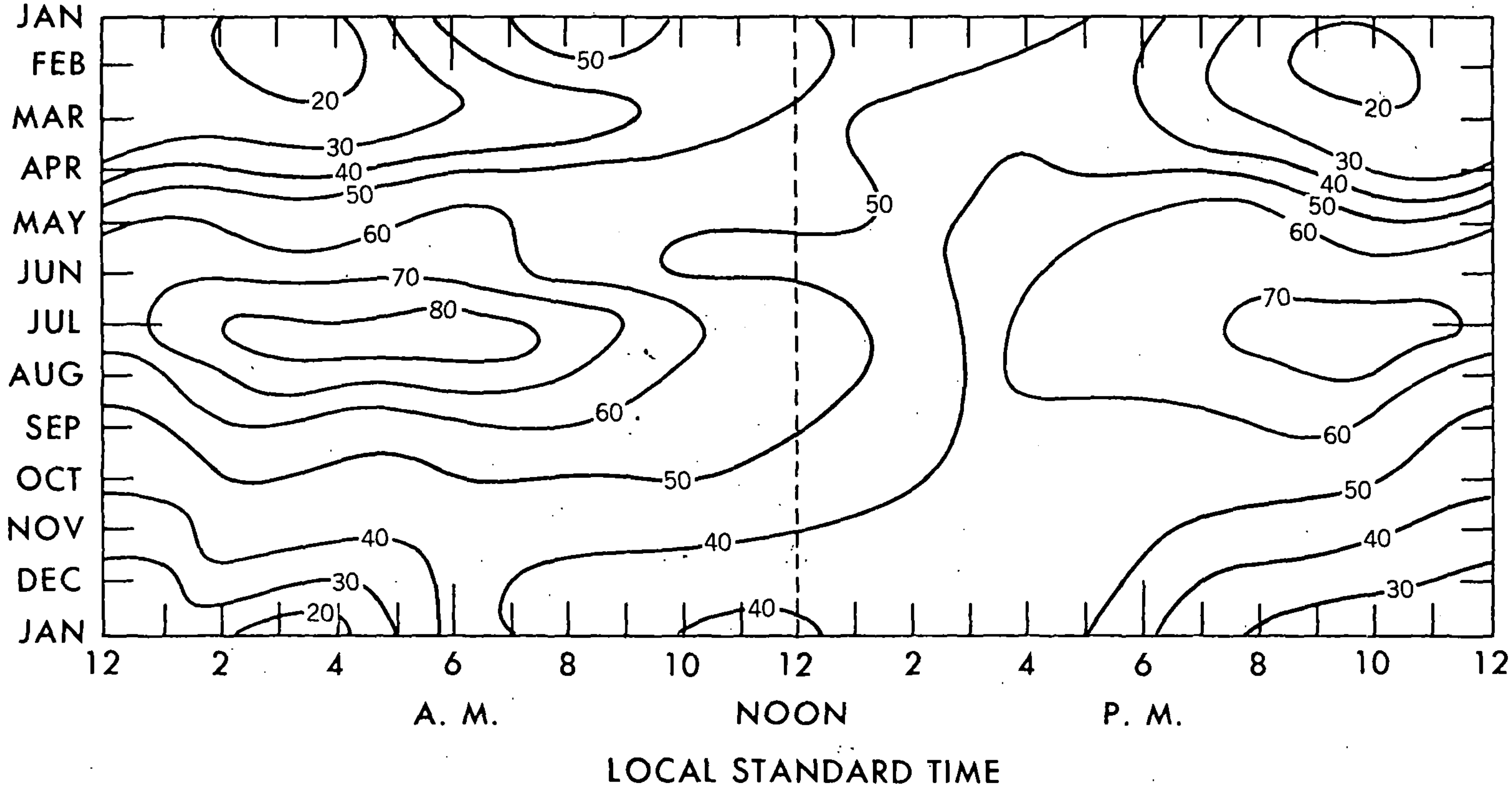

Figure 5. Hourly percentage frequency of low cloud amount $\leq$ 2-tenths, by month.

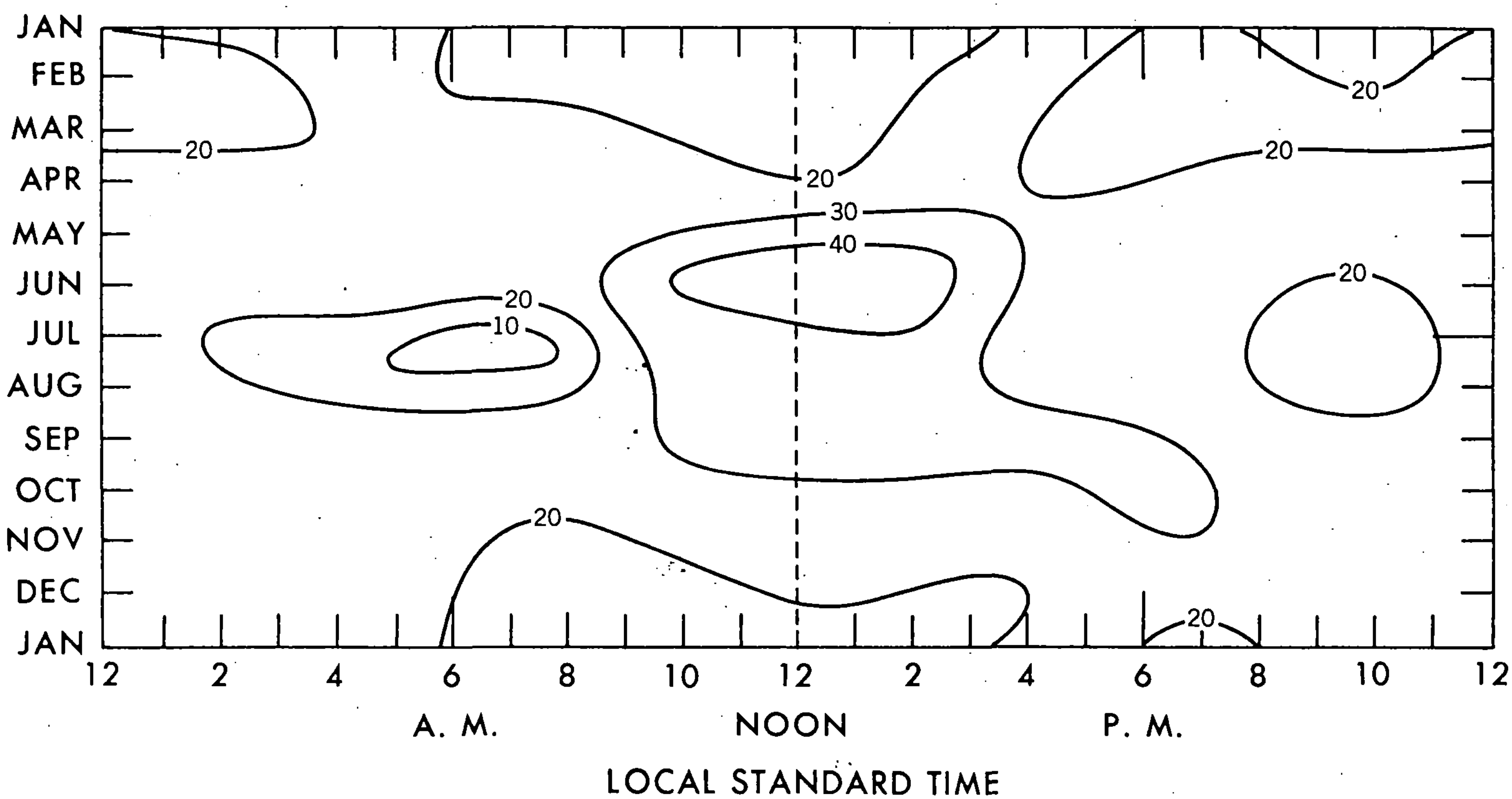

Figure 6. Hourly percentage frequency of low cloud amount 3- through 5-tenths, by month.

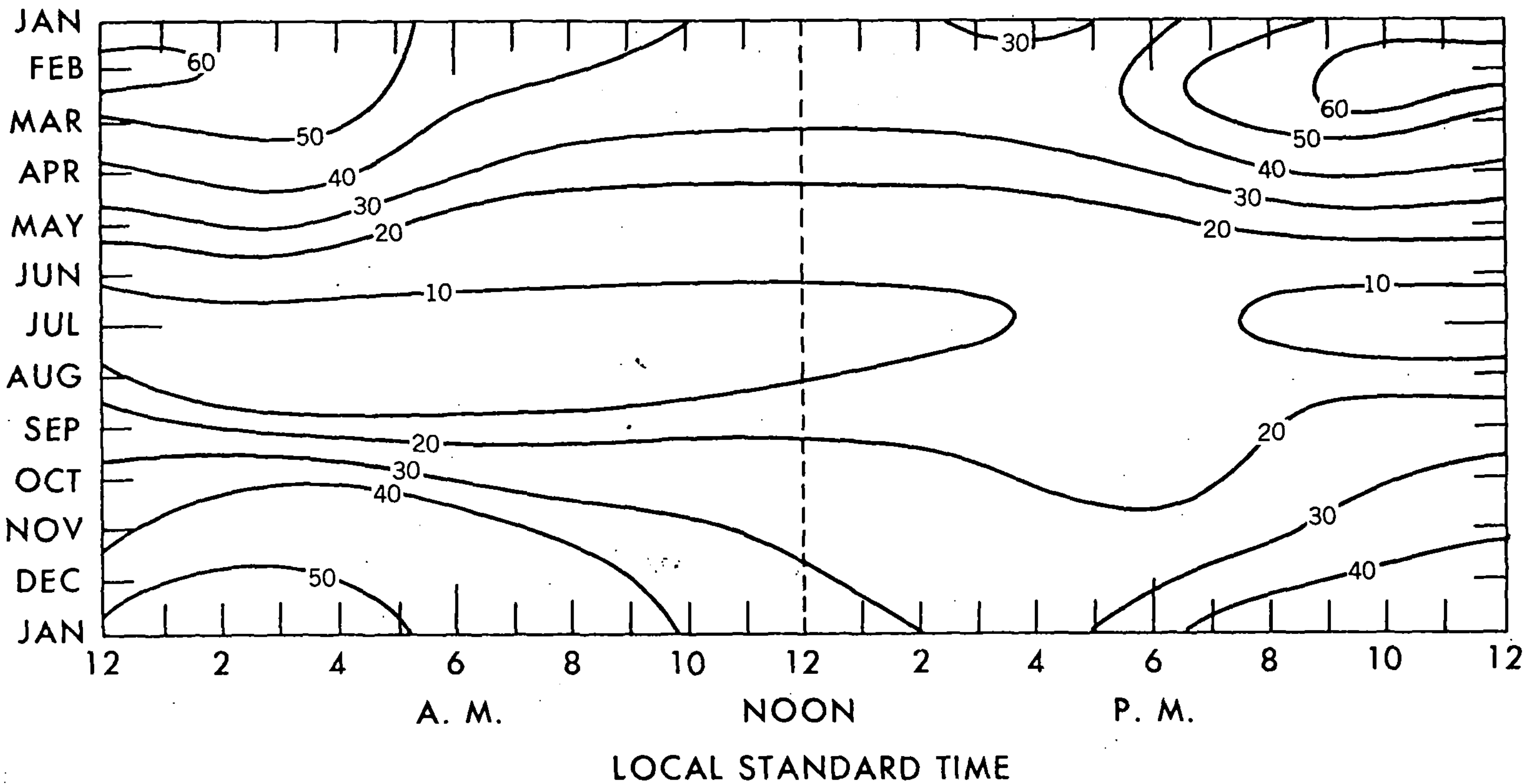

Figure 7. Hourly percentage frequency of low cloud amoung $\geq$ 6-tenths (incl. "obscuration"), by month.

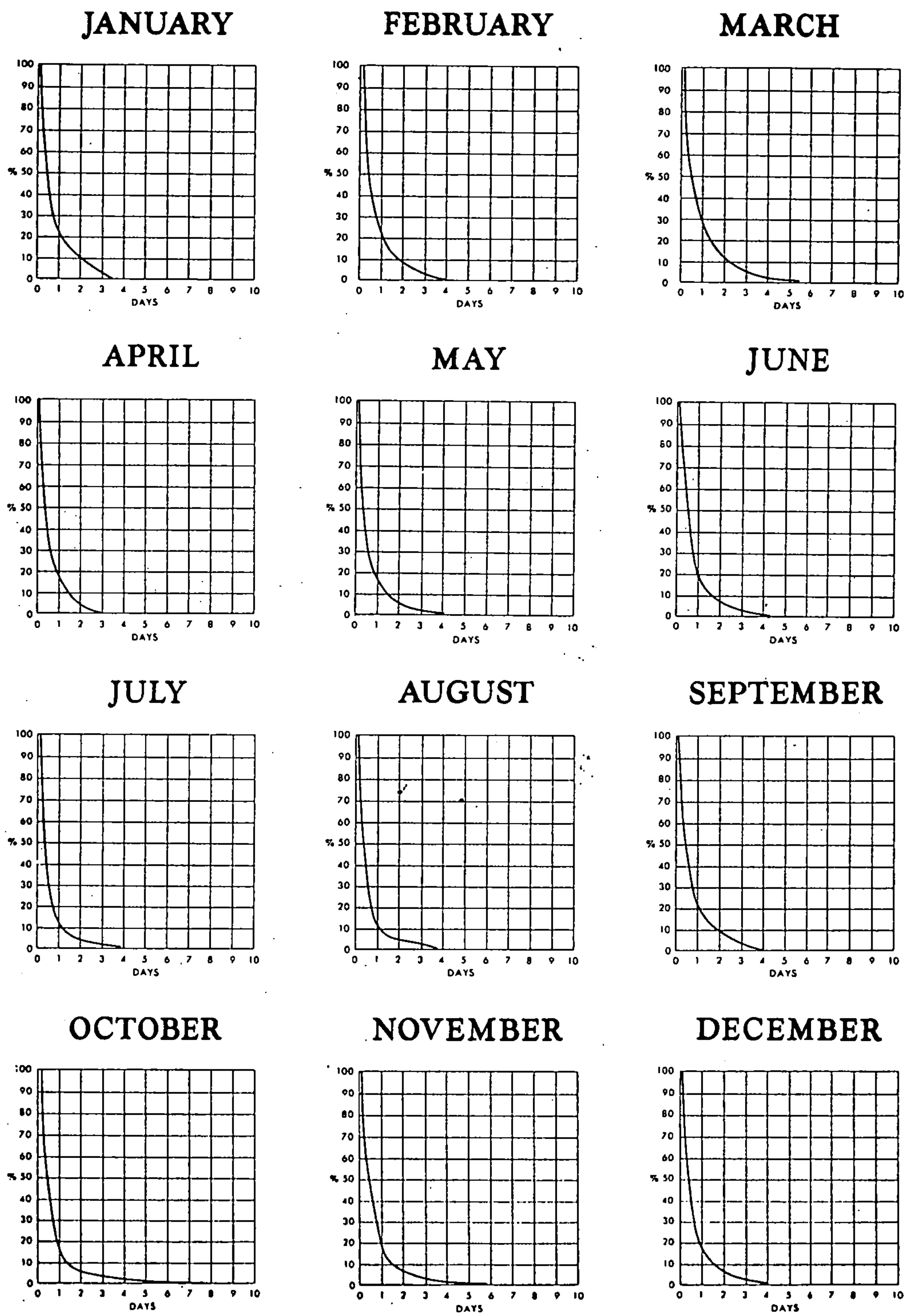

Figure 8. Percentage frequency of spells of total opaque sky cover (cloud amount) $\geq$ 6-tenths, by month of spell beginning.

REFERENCES

1. U.S. Department of Air Force, Air Weather Service, Climatic Center, DPD, "Uniform Summary of Surface Weather Observations, Part A, Cape Canaveral, Florida, June 1950-July 1960."

2. U.S. Department of Commerce, Weather Bureau, Project Mercury Weather Support Group, "Frequency and Causes of Morning Cloudiness at Cape Canaveral."

NOTE: Both references above are undated and unpublished manuscripts.