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STUDY OF LOW CLOUD FORMATION AND DURATION AT LITTLE ROCK, ARKANSAS

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1. Introduction

Low cloud ceilings impact both commercial and general aviation. "Go" or "no-go" decisions are based on current and forecast cloud ceilings since additional fuel is required to get to suitable alternate airports. Accurate forecasts of the onset and duration of low ceilings challenge the aviation forecaster in his/her efforts to aid the aviation community. The timing of low ceilings also impacts temperature, forestry, and air pollution mixing height forecasts.

One objective of this study was to look at past cloud ceilings of less than or equal to 610 m (2000 ft) and identify the climatological conditions related to their formation and duration. A second goal was to provide the forecaster with an additional tool to supplement NGM-based MOS guidance which would be:

a. More fine-tuned by season than the warm (April-September) or cool (October-March) two-season MOS approach.

b. More fine-tuned by onset hour.

c. Useful when the NGM synoptic forecast was not performing well.

2. Data Retrieval and Classification

Weather observations taken at Adams Field in Little Rock between 1961 and 1990, recorded on the "Solar and Meteorological Surface Observation Network (SAMSON)" CD-ROM climatological record prepared by NOAA's National Climatic Data Center in Asheville, North Carolina, were scanned visually to select the years with the most frequent occurrence of low ceilings. The ten years selected for this study were 1963, 1964, 1973, 1974, 1975, 1976, 1987, 1988, 1989 and 1990.

To be considered a low cloud event, the ceiling had to form at altitudes between 30-610 m (100-2000 ft). This excluded instances of dense fog events (indefinite ceilings below 30 m) from the data set. However, if a ceiling formed after the dense fog lifted, the observation at the time the ceiling formed was included in this study. If the ceiling formed before midnight and continued into the next day, only one event was counted. During the ten years studied, a total of 1705 low cloud events occurred.

Once an event was identified, the month, day, hour, amount of opaque sky cover, temperature, dewpoint, wind direction, wind speed, ceiling height, and duration were manually recorded. These data were then entered into a Lotus 1-2-3 spreadsheet to be analyzed further.

3. Data Analysis

Standard statistical parameters, such as median and average (mean), are used in this paper. Median values represent the halfway point in the frequency distribution. The median is influenced by the number, but not the value, of extreme members of the frequency distribution. The average (mean) was obtained by the addition of all the variables in a sample and division by the number of cases in the sample.

Either statistic may or may not represent a typical value. The median may be skewed by the number in the sample, and the average may be skewed by the extremes. The average is perhaps a good statistic to start with, but "clustering" of values in the median may be more significant in some cases. In most of the computations for the duration and onset time of the low ceiling, the median and average values were within a value of 0.4 of each other, and in these cases average values were used.

The data were first analyzed for the number of events per month. These numbers were then normalized to a 31-day month to allow a more representative comparison between months. Figures 1 and 2 depict results. Seasonal groupings by month were then selected after considering relative minima/maxima to surrounding months, temperatures, dewpoints (TD), temperature/dewpoint spreads (T-TD), wind speeds, ceiling heights (CIG) and median and average durations. This information is summarized in Table 1. (Note that all times in all tables and figures are in Central Standard Time [CST].) The bold data in Table 1 highlight relative high and low values. When many highs and lows were the same, only the extremes were made bold.

After the monthly data were compiled, seasons were selected. When the average temperatures between adjacent months differed by more than 3 C, a new season was chosen. Average T-TD spreads varied by only 0.5 C, and average wind speeds varied by no more than 1 m/sec between months; so these factors were not used in selecting seasons. When average ceilings were more than 100 m apart, a new season was selected. A cluster analysis on median and average ceiling durations were the final factors considered.

Based on these factors, December, January, and February were grouped together for a winter season, and April and May were combined for a spring season. June, July, and August were grouped as a summer season. Separate "seasons" were selected for the transition months of March, September, October, and November.

After the seasons were selected, the number of events per onset hour were tallied for each season, and the results are summarized in Table 2. Graphical displays of these data are in Figs. 3-9. Sunrise and sunset times were included in Table 2 so the forecaster could relate relative onset frequency to these times. A 1- to 2-hr delay appears to be present in most of the seasons. Bold data highlight relative maxima by month. Figs. 3-9 show not only times with high onset incidence, but also the periods of low incidence. For example, in Fig. 6 for the June to August season, it is unlikely that low ceilings would form from *any wind direction* during the period from 1600 through 2100.

Previous studies from the early 1970s at Little Rock AFB, approximately 8 mi from Adams Field, indicated that, in addition to season and time of day, wind direction was an important factor in low ceiling formation. Because of this, the median and average number of events per hour in this study were calculated for each season and compared. The median duration was selected as most representative to group the most frequent onset hours, since it eliminates undue influence to infrequent extreme events (lasting over 25 hr). The number of cases during these hours was then plotted by wind direction. Figs. 10-20 can be used to determine favorable and unfavorable wind directions for formation. For example, in Fig. 16 for the June to August season, low ceilings would be highly unlikely with winds from 350 deg through 30 deg during the period from 1100 through 1500.

Using a cluster analysis, wind directions were grouped which had at least the median number of events or which produced at least two percent of the total events during the time period. Average onset time, temperature, dewpoint, wind direction, wind speed, ceiling height, duration, T-TD spread, and median and average durations were then calculated for each of these wind groupings. The results are summarized in Table 3. Bold data highlighted in columns 2, 3, and 5 represent the most likely time periods, highest percent of time, and most favorable wind directions for low ceiling onset with at least 9 percent of that time period.

4. Sample Case: February 22, 1996

The following case illustrates how the graphs in this paper might have been used during an extended period of low ceilings at the Little Rock Regional Airport (Adams Field) on February 22, 1996. The aviation forecast issued at 0839 UTC (0239 CST) included no ceiling after 1400 UTC (0800 CST). Each subsequent amendment continued to forecast no ceiling after 1 to 2 hr of the amendment. Few data were available to indicate the ceiling would linger as long as it did. NGM MOS guidance from the previous night (22/0000 UTC) forecast no ceiling. Later data from the morning (23/1200 UTC) NGM run did forecast a ceiling, but of short duration.

By contrast, Table 3 suggests that climatology favored a low ceiling for a longer period. Once the ceiling formed, and with the winds forecast (from the NGM MOS) to be from the northeast (040 deg), the ceiling was not only to remain at a low level, but would potentially continue for a median of 5 hr and an average of 13 hr. Even with calm air, the data illustrate an average of 10 hr of low ceilings, with a median of 6 hr. The low ceiling did, in fact, continue for 13 hr at heights of zero to 1200 ft.

5. Comparison to PP-Tools

Hicks (1995) developed a PC-based climatological forecast aid which utilizes the same CD-ROM data base used in this study. The program, PP-Tools, is also an excellent tool for the aviation forecaster; however, PP-Tools features a forecast of persistence for MOS categories in 3-hr increments, while this study was designed to illustrate the hourly duration after onset for a ceiling of 2000 ft and below.

Additionally, the wind directions in PP-Tools cover at least a 120-deg range and as high as a 150 deg range. In some cases, the ranges included the least likely onset directions. In Table 3, this study includes *only* the most likely wind directions for the onset of a low ceiling, and on average a wind range of 80 deg, up to as high as a 120-deg range.

In general then, PP-Tools offers a broader range of wind directions and 3-hourly MOS categories forecasts.

6. Guidelines for Use of Data

The following are some basic steps toward utilizing the data in this paper for aviation forecasting:

a. The forecaster must first decide whether low ceilings will occur. Low-level moisture must exist either upstream or over the forecast point(s). Little Rock soundings and those from surrounding upper-air stations should be examined for low-level moisture. Have precipitation or low ceilings been reported within the past 24 hr? Are MOS data indicating low ceilings or visibility due to fog?

b. Once the decision is made that low ceilings are possible, the wind direction must be determined. Look at the appropriate figure by season and see if low ceilings are likely/unlikely to form from this direction. If the wind direction is favorable, the time of onset must be forecast. If low ceilings are present upstream, advect them using the wind at ceiling height. The forecaster must now decide whether to use the median or mean duration time, considering what the extent of the moisture field is, whether high clouds are present, and when sufficient heating will break a capping inversion.

c. Often it is best to initially bring the low ceilings in at the average onset hour. The average height, particularly when less than 1100 ft, will help forecast initial ceiling height.

d. Once the low ceiling forms, re-enter Table 3 in columns 2 and 5, and adjust forecast duration by the time decided in step 6b. Fig. 21, Low Ceiling Forecasting Guide, summarizes these steps.

e. When composing a TAF, the duration of a low ceiling may be represented by one or more of the following forms:

(1) For a shorter-term low ceiling (selection of average values that indicate such a scenario):

```
TAF
KLIT 061136Z 061212 18006KT 5SM BR FEW008 OVC030 TEMPO
   1215 1SM -DZ BKN008
  FM1500 14012KT P6SM NSW SCT035 (etc.)
```

(2) For a longer-term ceiling (one slowly increasing in height as indicated by average values):

```
TAF
KLIT 061136Z 061212 18006KT 3SM BR OVC008 TEMPO 1215 1SM
   -DZ
  FM1700 14012KT 5SM BR BKN015 OVC050 BECMG 1920
   16015G25KT P6SM NSW SCT025 (etc.)
```

7. Summary and Conclusions

Regardless of the season, 87 percent of the low cloud ceilings at Little Rock formed with either 9 or 10/10ths opaque coverage. Average winds from 170 to 218 deg were favorable for low ceilings to form in all seasons. During all months except October, average winds from 025 to 076 deg were also favorable directions.

Calm winds accounted for only 6 percent or less of onsets, regardless of time or season, during the most favorable time periods.

The winter season had 28 percent of all low ceilings. Sixty-eight percent began during the nighttime hours, with 32 percent during the day. This is more than a 2 to 1 nighttime preference. This bias toward nighttime onset was evident in each season.

The forecaster can best apply this study by:

a. Using Table 1, and viewing Figs. 1 and 2 to get a broad overview by month for relative maxima and minima.

b. Using Table 2 and viewing Figs. 3 - 9 to see the most and least likely onset hours by month and season.

c. Using Table 3 directly and utilizing Figs. 10- 20 to fine-tune the season, based on the most and least favorable onset periods, most favorable wind directions, and the most likely formation hour, average ceiling height, and durations.

8. Acknowledgement

My sincere thanks go to George Wilken, Science and Operations Officer at NWSFO Little Rock, for his time, technical advice on computer software, and input to this paper.

9. References

Hicks, T., *NOAA Technical Memorandum NWS SR-171 PP-Tools: A Climatological Forecast Aid for Aviation Forecasters*, U.S. Department of Commerce, NOAA, National Weather Service, Southern Region, Fort Worth, TX, 1995.

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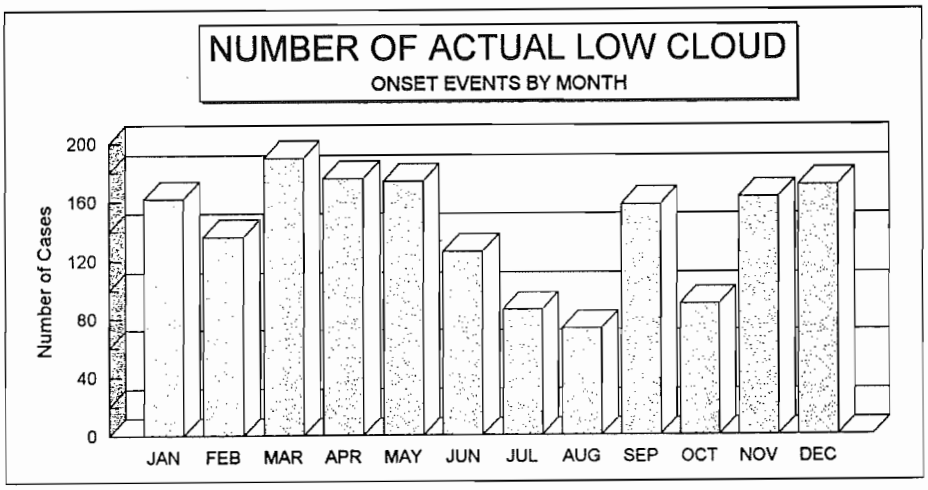
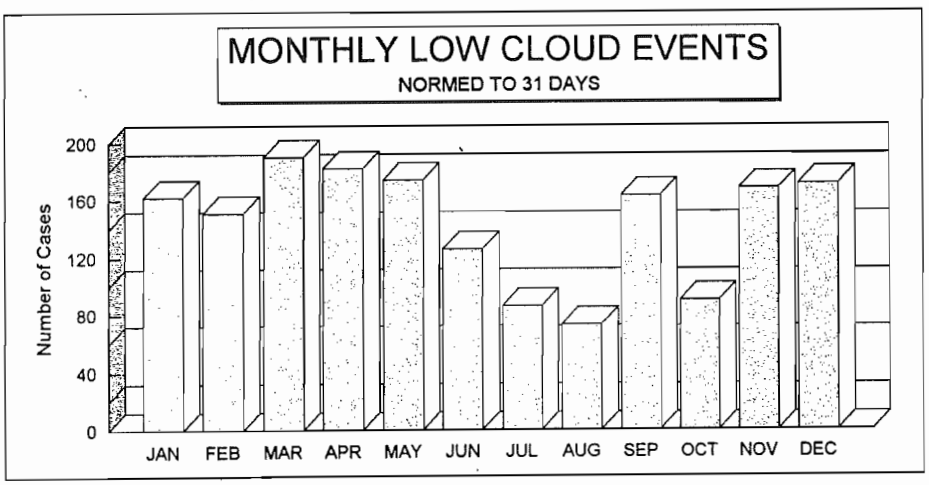
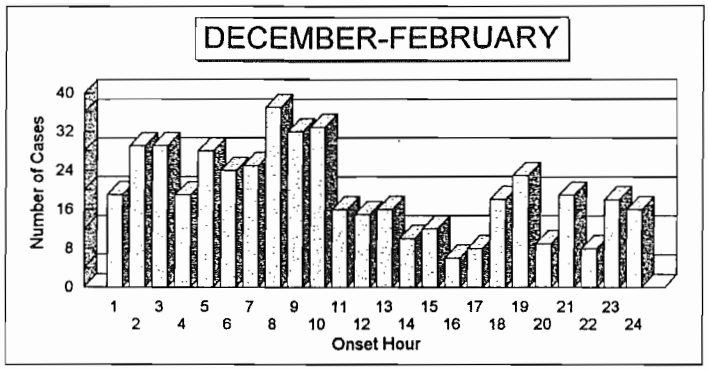
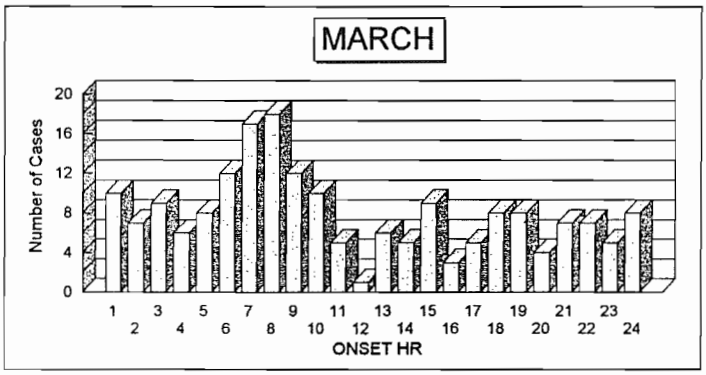
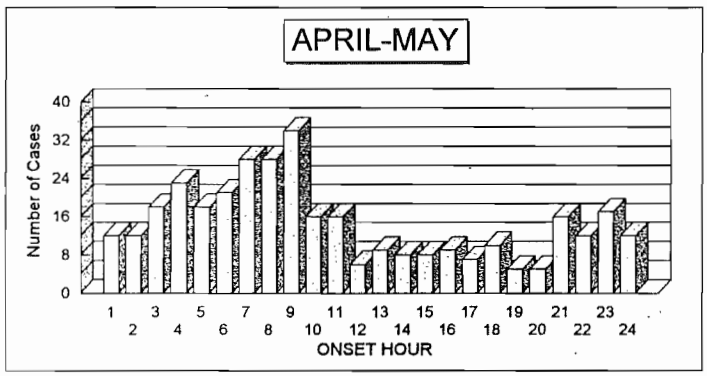




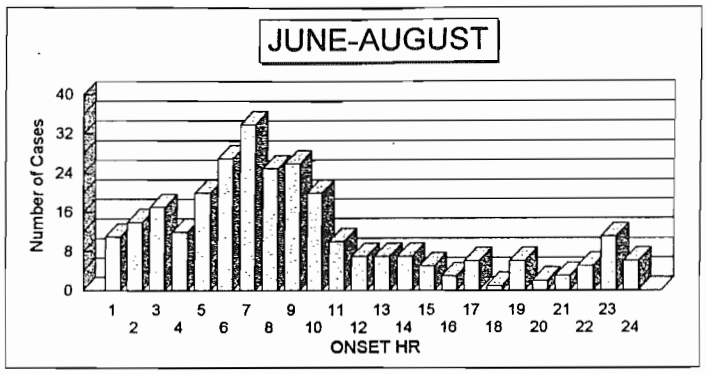
Figures 1 and 2: Frequency of Low Cloud Events
(Actual and Normalized)

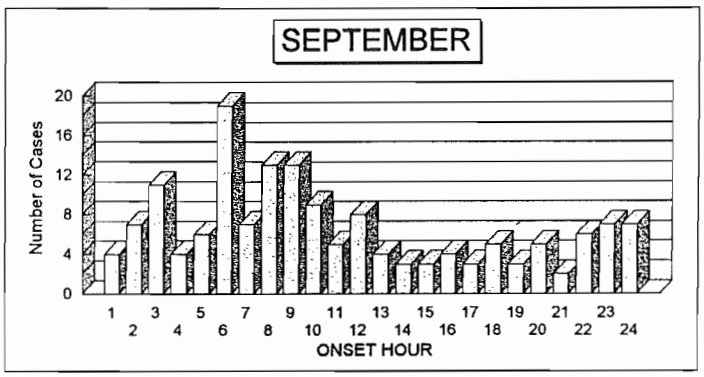


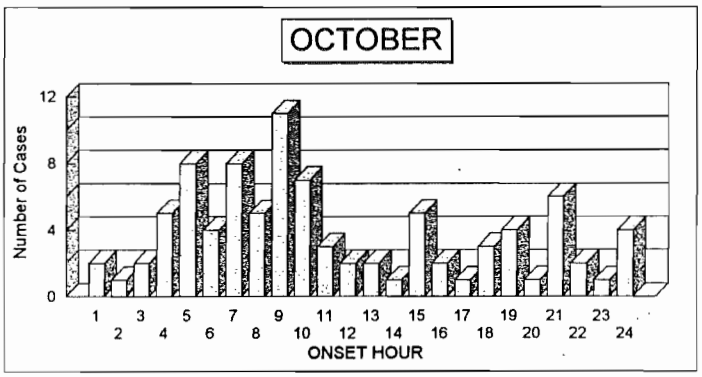




Figures 3-5: Seasonal Onset Hours







Figures 6-8: Seasonal Onset Hours

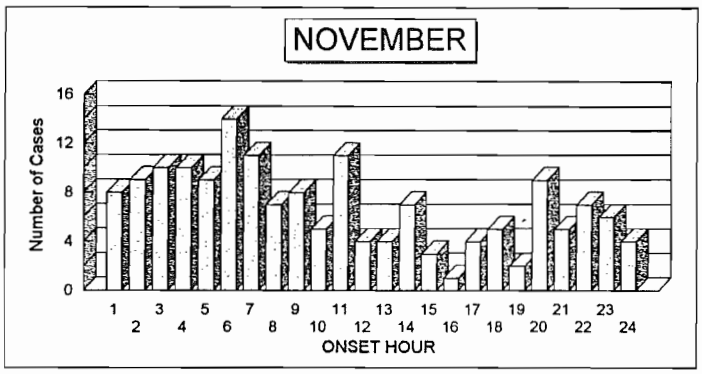


Figure 9: Seasonal Onset Hours

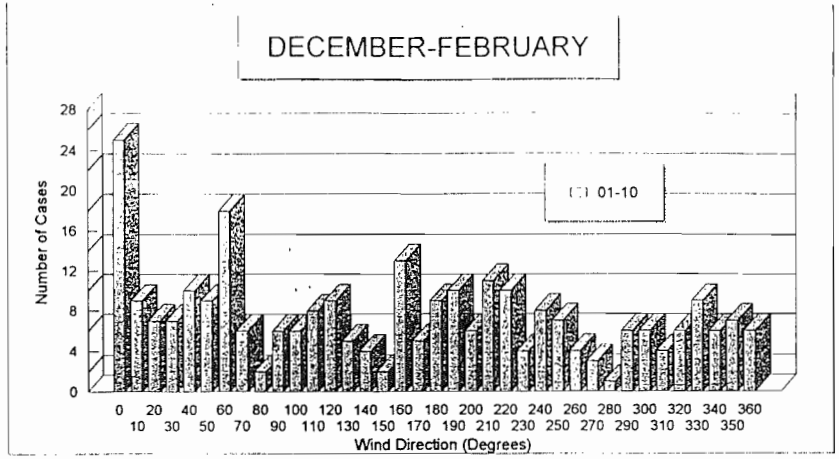


Figure 10 Winter Wind Direction Hours 01-10

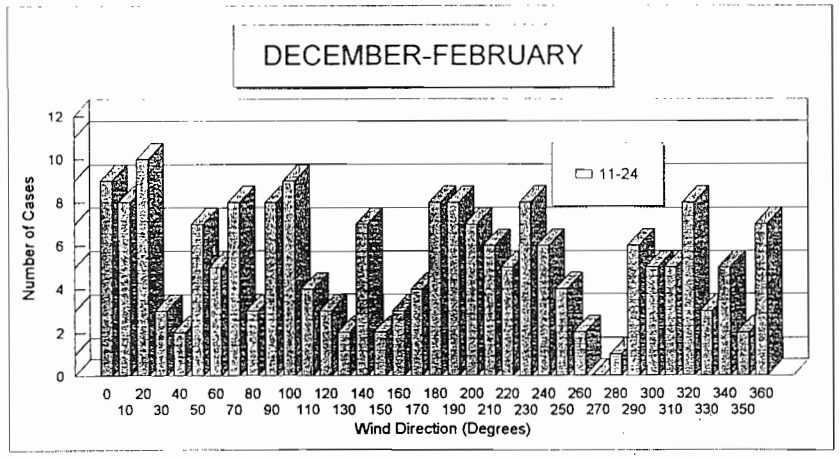


Figure 11 Winter Wind Direction Hours 11-24

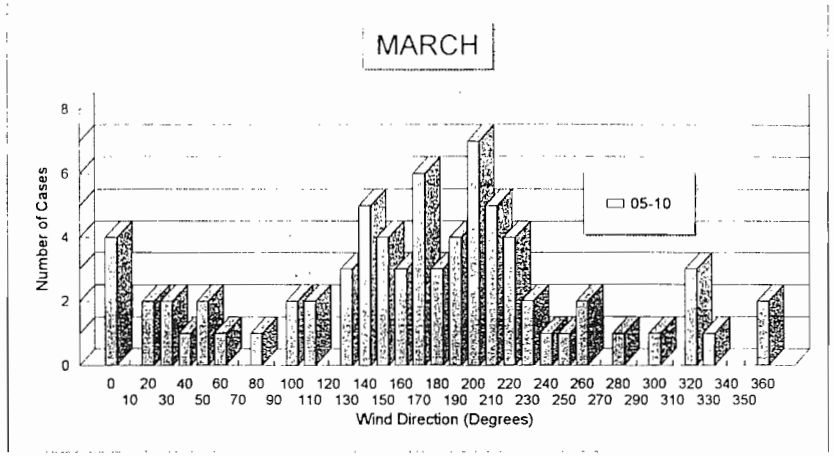


Figure 12 March Wind Direction Hours 05-10

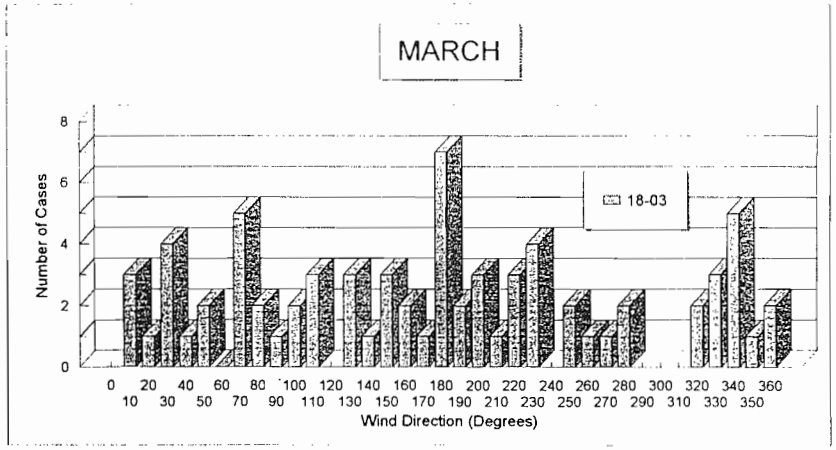


Figure 13 March Wind Direction Hours 18-03

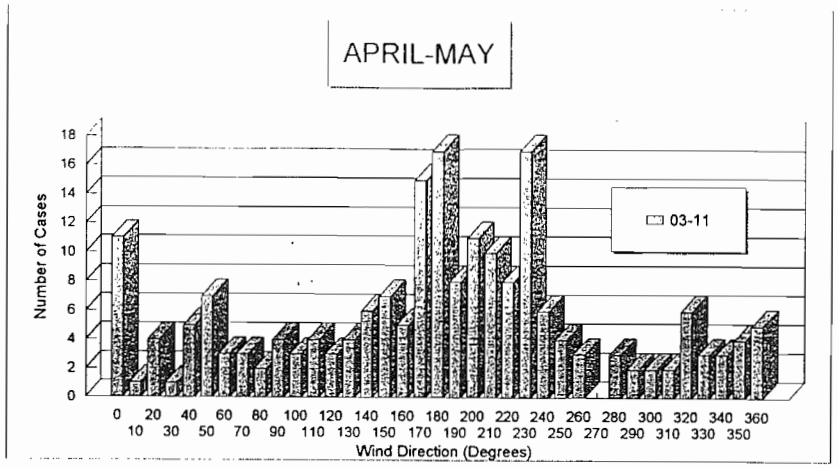


Figure 14 April-May Wind Direction Hours 03-11

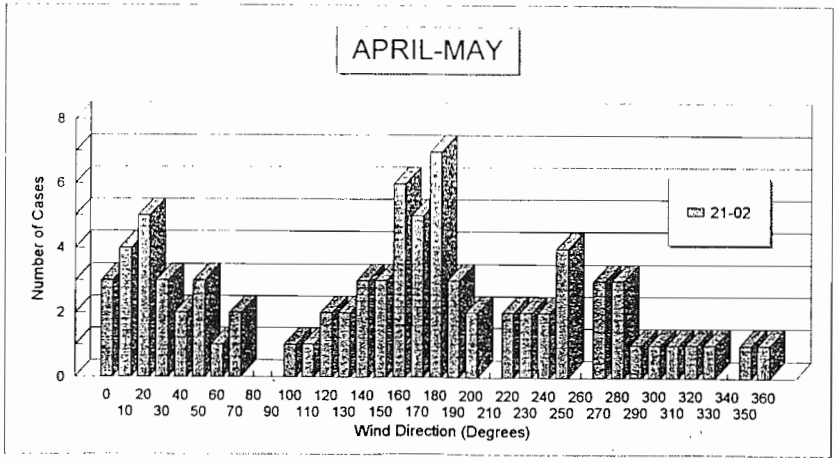


Figure 15 April-May Wind Direction Hours 21-02

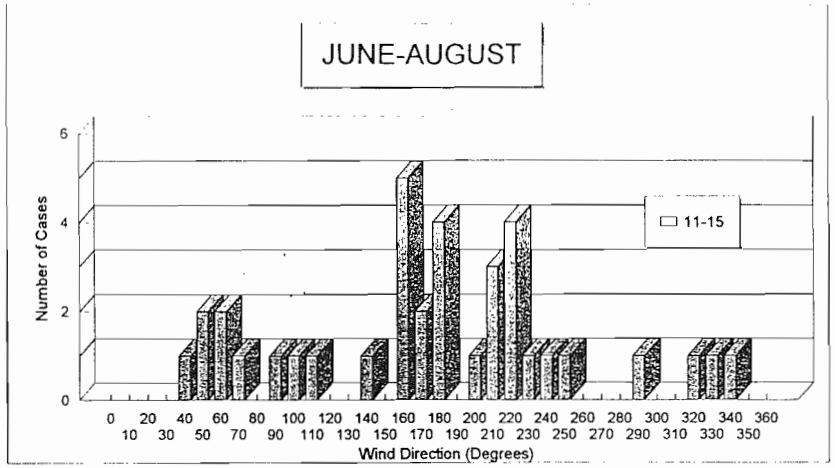


Figure 16 June-August Wind Direction Hours 11-15

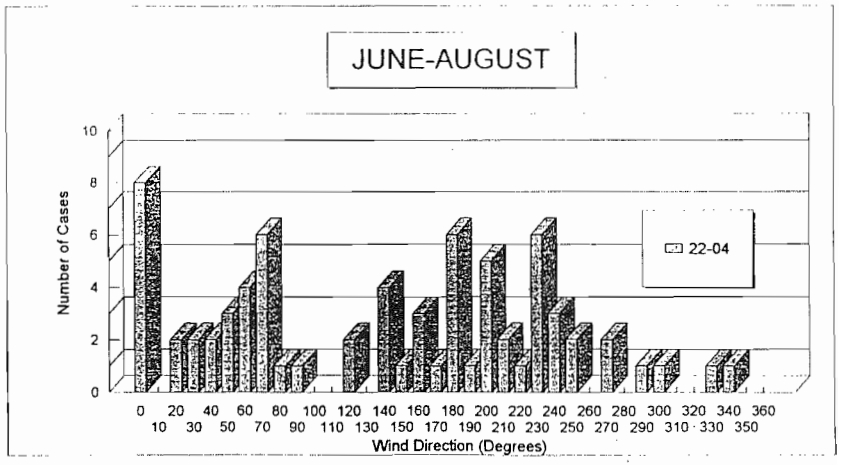
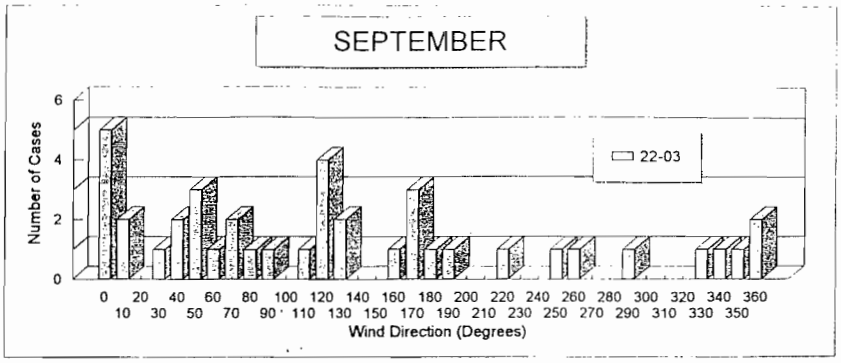
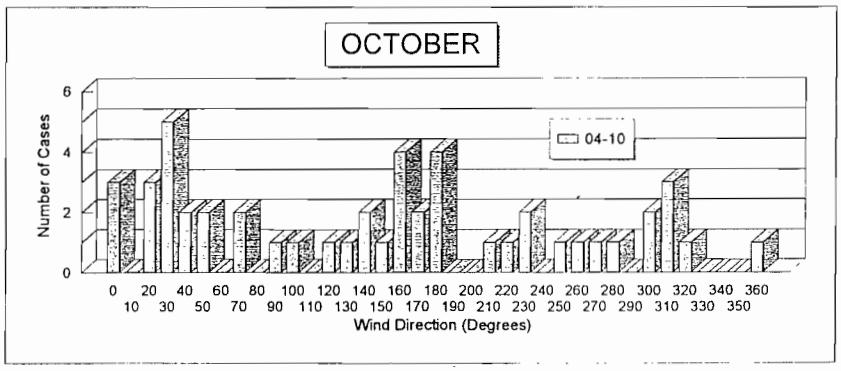
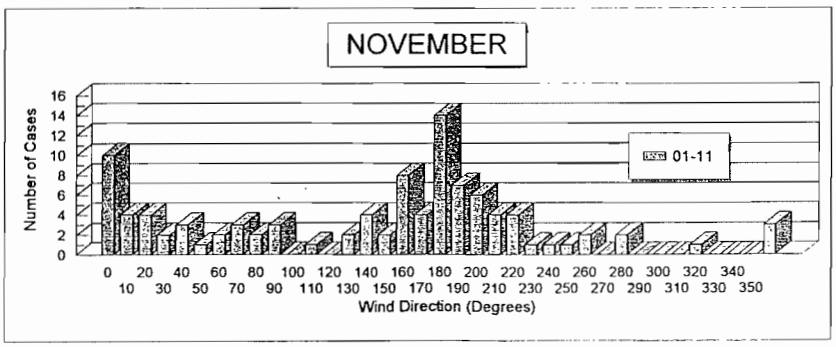


Figure 17 June-August Wind Direction Hours 22-04







Figures 18-20 Wind Direction September 22-03, October 04-10, November 01-11

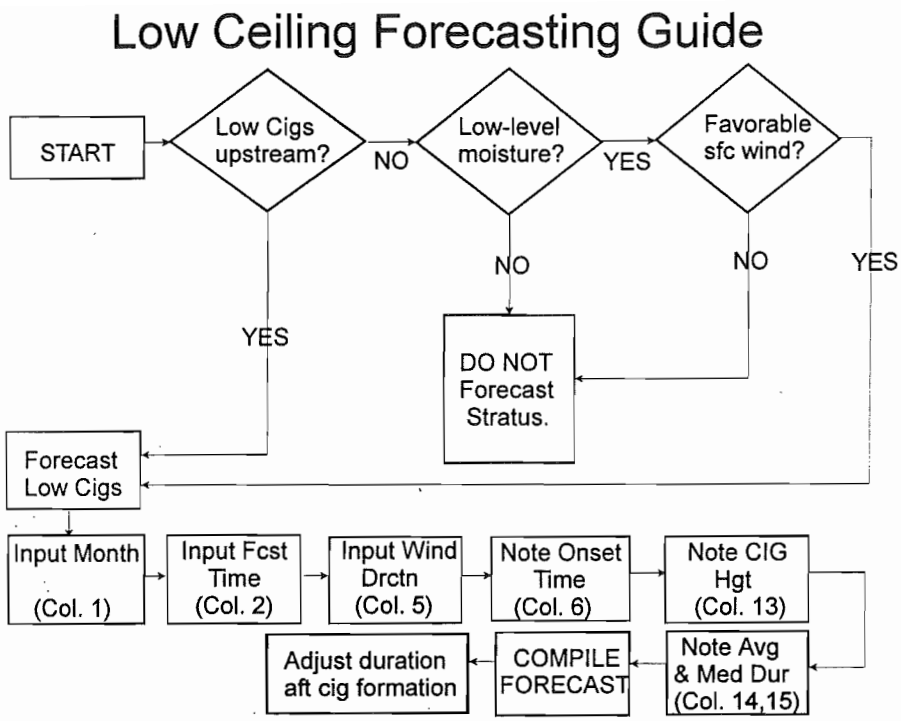


Fig. 21. Low Ceiling Forecasting Guide for Little Rock, Arkansas

TABLE 1		SUMMARY	BY MONTH								
	ACTUAL EVENTS	NORM TO 31 DAYS	PERCENT OF TOTAL	C TEMP	C TD	C T-TD	M/SEC SPEED	M CIG	FT CIG	AVG DUR HRS	MEDIAN DUR HRS
JAN	162	162	9.3	**6.7**	**3.9**	1.7	3.6	460	1500	**10**	**6**
FEB	136	151	8.7	**7.8**	**5.6**	2.2	**4.6**	460	1500	**9**	4
MAR	**190**	**190**	**10.9**	13.9	11.7	2.2	4.1	460	1500	6	4
APR	176	**182**	**10.5**	17.8	16.1	2.2	4.1	460	1500	4	2
MAY	174	174	10.0	20	17.8	2.2	3.6	460	1500	3.5	2
JUN	126	126	7.3	**23.1**	20.6	1.7	3.6	**310**	**1000**	**2.5**	2
JUL	**86**	**86**	**5.0**	**23.3**	**21.7**	1.7	2.9	340	**1100**	**3**	2
AUG	**73**	**73**	**4.2**	**23.3**	**21.7**	2.2	**3.1**	**270**	**900**	3.5	2
SEP	158	163	9.4	22.2	20	1.7	**3.1**	**310**	**1000**	5.5	3
OCT	90	90	5.2	17.2	15	1.7	3.4	340	**1100**	4.5	3
NOV	163	168	9.7	15	13.3	1.7	4.1	460	1500	7	**5**
DEC	171	171	9.9	9.4	7.8	1.7	3.6	430	1400	**9**	4
TOTAL	**1705**										
AVG/YR	142.1			16.6	14.6	1.9	3.7	403	1322	5.6	3.3

Table 1. Monthly Summary of Data for Little Rock, Arkansas

TABLE 2	SUMMARY OF ONSET HOURS (CST)														
	WINTER				T	SPRING			SUMMER				T	T	T
TIME	DEC	JAN	FEB	SUM	MAR	APR	MAY	SUM	JUN	JUL	AUG	SUM	SEP	OCT	NOV
1	4	7	8	19	10	6	6	12	8	2	1	11	4	2	8
2	14	5	10	29	7	4	8	12	4	6	4	14	7	1	9
3	9	15	5	29	9	8	10	18	9	7	1	17	11	2	10
4	6	7	6	19	6	12	11	23	4	5	3	12	4	5	10
5	8	13	7	28	8	10	8	18	6	10	4	20	6	8	9
6	8	7	9	24	12	15	6	21	13	7	7	27	19	4	14
7	9	6	10	25	17	14	14	28	16	6	12	34	7	8	11
8	15	14	8	37	18	11	17	28	12	8	5	25	13	5	7
9	14	9	9	32	12	13	21	34	9	10	7	26	13	11	8
10	7	11	15	33	10	9	7	16	6	6	8	20	9	7	5
11	10	3	3	16	5	8	8	16	5	1	4	10	5	3	11
12	5	4	6	15	1	2	4	6	1	5	1	7	8	2	4
13	7	5	4	16	6	5	4	9	3	2	2	7	4	2	4
14	3	4	3	10	5	5	3	8	5	1	1	7	3	1	7
15	7	4	1	12	9	6	2	8	1	2	2	5	3	5	3
16	2	4	0	6	3	5	4	9	1	1	1	3	4	2	1
17	2	4	2	8	5	5	2	7	5	0	1	6	3	1	4
18	5	6	7	18	8	5	5	10	0	1	0	1	5	3	5
19	13	6	4	23	8	3	2	5	4	0	2	6	3	4	2
20	2	4	3	9	4	1	4	5	1	1	0	2	5	1	9
21	7	6	6	19	7	11	5	16	1	1	1	3	2	6	5
22	2	4	2	8	7	4	8	12	3	1	1	5	6	2	7
23	4	8	6	18	5	8	9	17	5	2	4	11	7	1	6
24	8	6	2	16	8	6	6	12	4	1	1	6	7	4	4
TOTAL	171	162	136	469	190	176	174	350	126	86	73	285	158	90	163
AVE	7.1	6.8	5.7	19.5	7.9	7.3	7.3	14.6	5.3	3.6	3.0	11.9	3.8	3.8	6.8
MEDIAN	7	6	6	18.5	7.5	6	6	12	4.5	2	2	8.5	3	3	7
SUNRISE	707	714	654	705	618	538	508	513	457	508	530	512	553	616	643
SUNSET	1703	1723	1750	1725	1817	1841	1904	1852	1922	1919	1854	1912	1821	1735	1710
T=TRANSTION MONTH															

Table 2. Summary of Ceiling Onset by Month (Season) and Time (CST) for Little Rock, Arkansas

TABLE 3				AVERAGES									DURATIONS	
Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	TIME PERIODS	PERCENT OF PERIOD	NUMBER	WIND DIRECTION	ONSET CST	C TEMP	C TD	C T-TD	DEGREES DIRECTION	M/S WIND	M CIG	FT CIG	HOURS AVERAGE	HOURS MEDIAN
DECEMBER-FEBRUARY			469											
		5	25	CALM	5	8	7	1	0	0	320	1050	10	6
	01-10	19	88	330-060	6	4	2	2	25	4	422	1385	13	5
		14	64	160-250	6	13	10	3	208	4	467	1532	4	3
		38	177											
	11-24	2	9	CALM	20	10	8	2	0	0	438	1437	14	15
		12	57	290-020	18	7	5	2	342	5	390	1280	7	2
		9	40	50-100	18	7	5	2	76	4	358	1175	16	12
		10	48	180-240	16	12	9	3	218	4	434	1424	7	4
		33	154											
MARCH			190											
	05-10	22	42	140-220	8	16	13	3	181	4	437	1434	4	3
	18-03	10	19	330-030	21	7	5	2	357	5	449	1473	8	4
		14	26	150-230	19	16	14	2	191	4	415	1362	5	2
APRIL-MAY			350											
	03-11	3	12	CALM	5	18	17	1	0	0	325	1066	5	6
		31	110	140-240	7	20	17	3	193	4	452	1483	3	2
	21-02	5	18	160-180	23	19	17	2	171	5	381	1250	6	6
TABLE 3				AVERAGES										
	TIME PERIODS	PERCENT OF PERIOD	NUMBER	WIND DIRECTION	ONSET TIME	C TEMP	C TD	C T-TD	DEGREES DIRECTION	M/S WIND	M CIG	FT CIG	DURATIONS (HR) AVERAGE	MEDIAN
JUNE-AUGUST			285											
		3	9	CALM	6	22	21	1	0	0	237	778	3	2
	05-10	9	30	50-110	8	24	22	2	77	4	317	1040	3	2
		30	85	140-250	8	24	21	3	203	4	349	1145	3	2
	11-15	7	19	160-220	13	26	23	3	188	5	421	1381	1	1
	22-04	3	8	CALM	2	22	20	2	0	0	260	853	3	3
		11	32	140-230	2	23	21	2	188	3	275	902	5	5
SEPTEMBER			158											
		12	19	20-90	8	22	19	3	53	3	351	1152	3	2
	05-10	10	16	180-220	7	23	21	2	199	4	291	955	4	3
		7	11	320-360	7	22	19	3	343	4	279	915	3	2
	22-03	9	15	360-70	1	20	18	2	45	4	335	1099	7	7
OCTOBER			90											
	04-10	11	10	160-180	8	21	19	2	170	3	349	1145	5	5
NOVEMBER			163											
		6	10	CALM	5	14	13	1	0	0	331	1086	9	6
	01-11	15	25	360-90	6	12	9	3	61	4	362	1188	8	6
		36	59	140-220	6	17	15	2	181	4	408	1339	5	5

Table 3. Statistical Averages of Data and Ceiling Durations for Little Rock, Arkansas