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NOAA Technical Memorandum NWSTM PR-21

THE ESTIMATION OF CIRRUS CLOUD OVER OAHU

MICHAEL J. MORROW

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Weather Service

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- Continued on inside back cover -

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

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I. Purpose

The phenomenal growth of the astronomical community in the Hawaiian Islands and the glaring absence of climatological data on cirrus cloudiness prompted the writing of this short paper.

Optical astronomy is vitally affected by meteorological parameters. One very important parameter to the astronomer observing from the high mountain tops of Hawaii (Mauna Kea, Mauna Loa, and Haleakala) in infra-red wavelengths, as well as visible wavelengths, is the amount of water in the atmosphere above him. This water is mainly in the form of ice crystals in cirrus clouds.

While this study deals with and presents a climatology of cirrus as observed from Oahu, its results will, with some modification, be useful on the Big Island and Maui. Satellite pictures indicate more cirrus cloudiness over the southern islands than over Oahu.

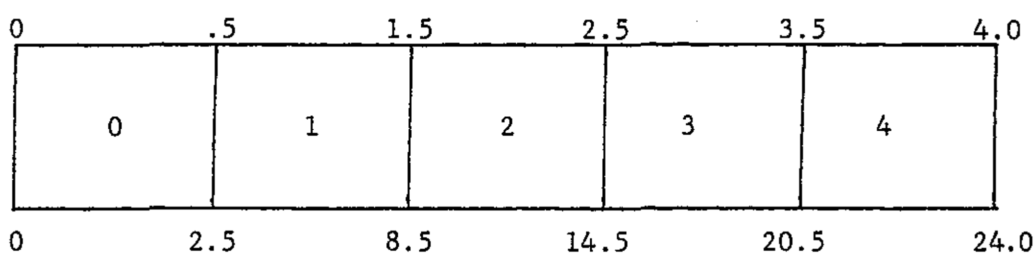
II. Procedure

Observations used in this study were taken at the Weather Service Forecast Office (WSFO) Honolulu. Hourly observations over a period of fifteen years form the data base. Each day has been given a value or class dependent on the total number of hours of cirrus of any type and any amount observed at WSFO Honolulu.

The classes used are as follows:

Class	No. of Hours of Cirrus Observed
0	0 to 2
1	3 to 8
2	9 to 14
3	15 to 20
4	21 to 24

After the data had been collected, it was deemed necessary to revert to hours instead of continuing the use of class intervals to obtain the most useful information. Therefore, formulae had to be devised to convert intervals to hours. This was done by means of the use of mid-point of each interval as shown below.



Now, using the figures on the bottom of the boxes, the reader will note the values become

0	-	1.25
1	-	5.5
2	-	11.5
3	-	17.5
4	-	22.25

and, if x is an average class interval value for a day, then, for

$x < .5$ the number of hours equal $5x$ (1)

$.5 \leq x \leq 3.5$ the number of hours equal $6x - .5$ (2)

$x > 3.5$ the number of hours equal $7x - 4$ (3)

As an example, January 1 had an average class interval x of 1.6. Placing this value in the appropriate equation, number two above yields the number of hours of cirrus cloudiness that might be observed for any average January 1, in this case, approximately nine hours.

A further step, giving more meaning to the value of nine hours, is the standard deviation which on January 1 is ten hours. Hence, an average of nine hours of cirrus cloud with a range of no cirrus to nineteen hours of cirrus might occur on any January 1.

Table 1 is the result of extending the January 1 example to each day of the year. The reader will note, perhaps with horror, the standard deviation (SD) is at times equal to or larger than the average. This is true of the January 1 example and many other entries. The explanation is that the day is a "block" consisting of twenty-four hours, while cirrus cloudiness is not "blocked" but extends from one day to another without regard to arbitrary time units. Furthermore, the SD is computed with respect to a normal curve, not the partial gamma function which appears to fit cirrus variability fairly well, at least on a monthly basis.

Finally, the SD is smaller than the average during periods of high cirrus occurrence as opposed to large SD during low incidence of cirrus.

Random trials of the data presented in Table 1 have shown the table to be useful. Amounts of cirrus cloud were needed for planning purposes for a project encompassing both Oahu and Molokai islands. Table 1 indicated that cirrus would not be a problem on day one of the project but would be present on day two and day three. The actual results followed the table's estimate very well.

Table 2 has been derived by taking the number of days each calendar date with 1) no cirrus, and 2) all day cirrus over the 15-year period of record. Probabilities of the occurrence or non-occurrence of cirrus on a given date were then computed.

For instance, we may ask "What is the probability of NO CIRRUS on a particular day, say, January 1?"

$$P(\text{no cirrus}) = 7/15 \text{ or } .47 \qquad (4)$$

or, what is the probability of ALL-DAY CIRRUS on January 1?

P(all-day cirrus) - 4/15 or .27 (5)

Equations (4) and (5) are the basis for Table 2. In Table 2 the probability has been changed to per cent.

Equation (4) tells us that in the fifteen years of data used seven January 1's had no cirrus, while equation (5) says that four January 1's had all-day cirrus. Therefore, on January 1 there is a 47 per cent chance of not observing cirrus and from equation (5) we find a 27 per cent chance of all-day cirrus. By subtracting from 100 per cent the result obtained in equation (4), the per cent of January 1's with some cirrus is found, (100-47 = 53).

Returning to Table 2, these values are presented as 47/27 for January 1. The values are the per cent chance of no cirrus on the day indicated followed by the per cent chance of all-day cirrus.

III. Average Monthly Cirrus Occurrence

The question arises, "What may one expect on a monthly basis for the occurrence of cirrus cloud?" The graph presented gives the answer to the question in a simple easy manner. The reader must be cautioned that the graph is only an estimate, but it is the best estimate available at this time.

The graph has been computed by taking the total number of hours with cirrus in each month over the 15 years and expressing this as a percentage of the total number of hours in each month.

Taking January as an example, enter the graph at January and move up to the plotted line, then over to the left where the percentage is found to be 26 per cent. Follow the same procedure for the other months.

Another function of the graph is it allows the user to see the annual variation of cirrus cloud at a glance. The major peaks very nearly coincide with the subtropical jet stream's movement over the islands. The single major minimum is when the subtropical jet is the greatest distance south of the islands.

The following additional facts can be gleaned by statistical methods.

1. Testing for differences of monthly averages for different months, one way analysis of variance rejected the hypothesis of constant monthly means. Hence, it was concluded the monthly means were significantly different at the one per cent level.

2. Tests for differences in monthly variance for different months were made. Bartlett's test for homogeniety of variances did not reject the hypothesis of constant variance. Therefore, monthly variances is not significantly different.

3. Month-to-month serial correlation were run. There is slight month-to-month serial correlation, but for estimating purposes it only gives about five per cent reduction in variance (2.5% reduction in SD), so it is of little practical importance.

4. Likelihood tests showed that the gamma distribution fits better than the normal distribution.

TABLE 1

Estimated Daily Duration of Cirrus in Hours

Left hand entry is average daily duration. Right hand entry (in parenthesis) is the standard deviation of the average.

JANUARY		FEBRUARY		MARCH		APRIL	
1	9(10)	1	4(7)	1	8(10)	1	12(9)
2	8(10)	2	3(6)	2	9(7)	2	12(10)
3	10(10)	3	4(8)	3	6(8)	3	11(11)
4	13(9)	4	5(7)	4	6(7)	4	10(10)
5	9(9)	5	6(9)	5	4(8)	5	13(10)
6	7(7)	6	8(10)	6	5(7)	6	11(9)
7	4(7)	7	4(8)	7	4(4)	7	10(10)
8	6(7)	8	4(7)	8	5(6)	8	10(11)
9	7(7)	9	6(8)	9	6(9)	9	7(8)
10	4(7)	10	5(8)	10	9(10)	10	10(9)
11	4(7)	11	4(8)	11	8(9)	11	12(9)
12	6(9)	12	5(9)	12	9(9)	12	12(10)
13	7(9)	13	7(10)	13	6(7)	13	11(9)
14	7(9)	14	7(9)	14	7(9)	14	11(8)
15	9(9)	15	6(9)	15	9(9)	15	13(7)
16	8(8)	16	7(9)	16	7(9)	16	16(7)
17	6(7)	17	5(7)	17	12(9)	17	13(9)
18	3(5)	18	5(8)	18	13(10)	18	15(9)
19	4(6)	19	7(7)	19	10(9)	19	13(9)
20	6(8)	20	4(7)	20	11(9)	20	12(9)
21	4(9)	21	6(8)	21	10(9)	21	10(9)
22	7(7)	22	7(7)	22	10(8)	22	12(10)
23	5(6)	23	3(5)	23	10(8)	23	11(9)
24	4(7)	24	6(7)	24	11(9)	24	12(10)
25	5(7)	25	10(6)	25	12(8)	25	12(10)
26	3(4)	26	4(7)	26	12(10)	26	13(10)
27	6(9)	27	6(9)	27	11(10)	27	12(9)
28	4(7)	28	7(10)	28	10(9)	28	13(8)
29	6(9)	29	9(9)	29	10(8)	29	10(8)
30	4(5)			30	7(10)	30	7(10)
31	6(9)			31	12(9)		

TABLE 1 (Continued)

MAY		JUNE		JULY		AUGUST	
1	16(9)	1	9(9)	1	6(7)	1	13(10)
2	12(9)	2	14(8)	2	11(9)	2	10(9)
3	12(9)	3	12(8)	3	12(7)	3	7(10)
4	11(9)	4	12(10)	4	7(10)	4	12(9)
5	10(9)	5	9(9)	5	7(8)	5	12(10)
6	12(9)	6	11(10)	6	12(9)	6	10(10)
7	10(11)	7	9(9)	7	12(10)	7	12(10)
8	10(8)	8	9(9)	8	10(10)	8	9(8)
9	11(7)	9	10(9)	9	6(7)	9	12(9)
10	16(6)	10	6(9)	10	6(9)	10	13(9)
11	13(9)	11	8(9)	11	10(8)	11	10(9)
12	13(9)	12	9(9)	12	10(10)	12	9(9)
13	15(9)	13	9(7)	13	9(9)	13	10(10)
14	13(9)	14	9(9)	14	11(10)	14	9(9)
15	12(8)	15	7(7)	15	13(10)	15	7(9)
16	12(10)	16	7(7)	16	6(7)	16	11(8)
17	13(9)	17	10(8)	17	4(7)	17	12(9)
18	12(10)	18	10(10)	18	7(8)	18	9(8)
19	8(9)	19	6(8)	19	9(9)	19	9(9)
20	10(9)	20	7(9)	20	7(7)	20	9(9)
21	11(9)	21	9(10)	21	7(7)	21	9(9)
22	8(9)	22	9(9)	22	9(9)	22	7(8)
23	7(8)	23	7(7)	23	12(9)	23	7(8)
24	9(9)	24	6(7)	24	14(8)	24	7(9)
25	12(9)	25	9(9)	25	15(9)	25	9(8)
26	10(8)	26	11(9)	26	11(10)	26	7(9)
27	12(7)	27	11(10)	27	13(9)	27	10(8)
28	12(9)	28	7(7)	28	9(9)	28	10(7)
29	12(9)	29	6(8)	29	9(9)	29	7(7)
30	12(9)	30	9(9)	30	10(9)	30	6(8)
31	12(10)			31	13(9)	31	9(9)

TABLE 1 (Continued)

SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	10(9)	1	11(7)	1	10(10)	1	10(8)
2	9(7)	2	9(3)	2	11(9)	2	14(7)
3	7(7)	3	9(9)	3	10(8)	3	12(10)
4	7(7)	4	11(9)	4	9(9)	4	7(8)
5	7(9)	5	11(7)	5	11(9)	5	9(9)
6	10(10)	6	9(9)	6	13(9)	6	7(10)
7	11(9)	7	11(9)	7	8(9)	7	12(7)
8	9(9)	8	10(9)	8	7(9)	8	9(10)
9	12(9)	9	12(9)	9	8(9)	9	9(9)
10	11(8)	10	10(9)	10	8(10)	10	7(9)
11	9(8)	11	10(9)	11	10(9)	11	9(9)
12	8(9)	12	12(9)	12	13(10)	12	6(7)
13	7(9)	13	11(9)	13	15(8)	13	6(8)
14	7(8)	14	8(9)	14	10(8)	14	7(9)
15	9(6)	15	11(9)	15	10(6)	15	9(8)
16	11(10)	16	12(9)	16	11(7)	16	5(8)
17	9(7)	17	12(9)	17	12(7)	17	7(7)
18	10(7)	18	13(9)	18	12(9)	18	5(9)
19	9(9)	19	17(9)	19	10(10)	19	7(9)
20	12(9)	20	15(9)	20	10(10)	20	4(7)
21	10(9)	21	16(10)	21	7(8)	21	7(9)
22	12(8)	22	12(8)	22	6(9)	22	7(9)
23	11(8)	23	12(8)	23	11(10)	23	8(6)
24	9(9)	24	9(7)	24	11(10)	24	7(7)
25	11(7)	25	6(7)	25	11(9)	25	7(7)
26	15(6)	26	7(8)	26	11(9)	26	6(9)
27	13(7)	27	10(9)	27	10(9)	27	5(7)
28	10(7)	28	13(9)	28	8(8)	28	7(10)
29	10(12)	29	12(9)	29	6(9)	29	6(7)
30	12(8)	30	13(9)	30	7(8)	30	9(9)
		31	12(9)			31	7(9)

TABLE 2

In each case the figure on the left of solidus is the probability of no cirrus; the figure on the right of the solidus is the probability of all-day cirrus. 00 indicates little chance of cirrus.

JANUARY		FEBRUARY		MARCH		APRIL	
1	47/27	1	60/00	1	53/20	1	27/33
2	53/27	2	67/00	2	33/00	2	33/27
3	40/20	3	73/13	3	53/07	3	40/40
4	20/33	4	73/07	4	47/07	4	40/20
5	27/20	5	53/13	5	53/00	5	27/33
6	40/07	6	47/20	6	53/07	6	20/33
7	67/07	7	67/00	7	40/20	7	47/20
8	47/07	8	67/00	8	47/00	8	47/33
9	40/07	9	53/07	9	60/13	9	47/13
10	73/00	10	60/07	10	40/27	10	27/20
11	73/07	11	73/07	11	40/07	11	20/20
12	60/13	12	67/13	12	40/07	12	33/20
13	40/20	13	60/13	13	40/07	13	33/20
14	47/13	14	53/20	14	47/13	14	20/07
15	33/13	15	53/13	15	53/20	15	07/27
16	40/13	16	60/13	16	40/27	16	07/27
17	53/13	17	53/13	17	20/33	17	27/27
18	67/00	18	67/07	18	27/33	18	27/40
19	60/00	19	33/20	19	27/27	19	20/33
20	53/07	20	73/13	20	27/20	20	20/27
21	67/07	21	60/13	21	27/20	21	27/13
22	40/07	22	40/00	22	13/20	22	40/33
23	47/00	23	67/07	23	27/13	23	20/20
24	60/07	24	47/00	24	27/13	24	33/27
25	60/07	25	13/00	25	13/20	25	33/27
26	60/00	26	60/07	26	33/40	26	27/33
27	53/20	27	67/13	27	33/27	27	27/33
28	60/07	28	60/20	28	20/20	28	13/20
29	67/13	29	50/07	29	20/13	29	20/27
30	53/00			30	60/20	30	07/47
31	53/13			31	20/20		

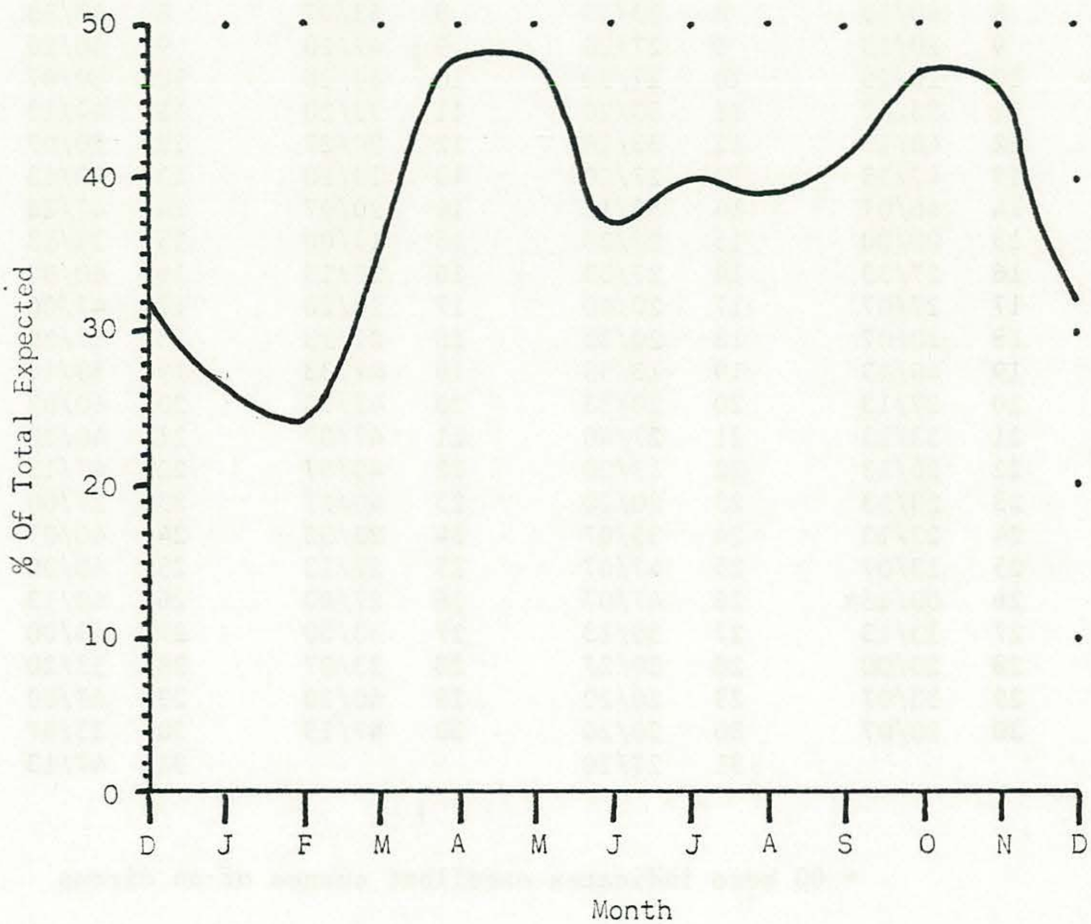
TABLE 2 (Continued)

MAY		JUNE		JULY		AUGUST	
1	20/40	1	40/20	1	53/00	1	33/33
2	20/27	2	20/20	2	33/13	2	33/20
3	13/27	3	13/20	3	33/13	3	53/27
4	33/20	4	47/33	4	60/20	4	27/20
5	33/20	5	33/20	5	47/13	5	27/27
6	20/13	6	40/33	6	27/13	6	33/20
7	47/40	7	40/13	7	20/40	7	27/33
8	27/13	8	40/13	8	40/20	8	27/13
9	13/13	9	40/13	9	40/07	9	33/27
10	07/27	10	60/13	10	53/07	10	27/27
11	20/33	11	40/07	11	27/13	11	27/20
12	20/33	12	40/07	12	40/20	12	40/20
13	07/33	13	20/13	13	33/07	13	40/27
14	07/27	14	40/13	14	40/27	14	33/00
15	20/13	15	33/07	15	27/33	15	53/13
16	33/53	16	40/00	16	40/00	16	27/13
17	20/33	17	33/07	17	67/07	17	20/27
18	47/40	18	40/20	18	40/07	18	27/13
19	53/13	19	60/00	19	40/13	19	27/13
20	53/13	20	47/13	20	47/00	20	33/13
21	20/13	21	40/13	21	40/07	21	40/07
22	33/13	22	40/07	22	40/13	22	40/13
23	47/07	23	40/00	23	20/27	23	40/13
24	33/13	24	47/07	24	13/33	24	60/13
25	27/13	25	40/20	25	20/33	25	40/00
26	20/07	26	27/20	26	20/13	26	47/13
27	13/13	27	40/20	27	27/27	27	33/07
28	20/20	28	40/13	28	33/07	28	33/00
29	13/20	29	53/07	29	40/13	29	33/00
30	33/33	30	40/07	30	27/13	30	47/00
31	33/27			31	27/27	31	40/13

TABLE 2 (Continued)

SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	33/13	1	20/20	1	33/27	1	27/13
2	33/13	2	27/20	2	27/13	2	13/20
3	40/27	3	33/13	3	33/07	3	33/33
4	40/00	4	27/13	4	33/13	4	40/13
5	47/13	5	13/13	5	27/20	5	40/13
6	33/27	6	33/13	6	13/27	6	33/13
7	33/20	7	33/20	7	40/13	7	20/13
8	40/13	8	33/13	8	53/07	8	47/33
9	20/13	9	27/20	9	47/20	9	40/20
10	20/20	10	27/20	10	60/20	10	60/07
11	33/07	11	33/20	11	33/20	11	47/13
12	40/13	12	33/20	12	20/27	12	50/07
13	47/13	13	27/20	13	13/20	13	40/13
14	40/07	14	53/13	14	20/07	14	47/20
15	20/00	15	27/20	15	13/00	15	33/13
16	27/33	16	27/33	16	20/13	16	60/07
17	27/07	17	20/40	17	20/20	17	47/00
18	20/07	18	20/33	18	27/33	18	67/20
19	40/13	19	13/53	19	47/33	19	53/13
20	27/13	20	20/53	20	47/33	20	60/07
21	33/13	21	27/40	21	47/07	21	40/20
22	20/13	22	13/20	22	40/07	22	47/13
23	20/13	23	20/20	23	40/27	23	27/00
24	27/13	24	33/07	24	33/33	24	40/07
25	13/07	25	47/07	25	27/13	25	40/00
26	00/13*	26	47/07	26	27/20	26	60/13
27	13/13	27	33/13	27	33/20	27	53/00
28	20/00	28	20/27	28	33/07	28	53/20
29	33/07	29	20/20	29	60/20	29	47/00
30	20/07	30	20/20	30	47/13	30	33/07
		31	27/20			31	47/13

* 00 here indicates excellent chance of no cirrus


50
40
30
20
10
0
% Of Total Expected
D
J
F
M
A
M
J
J
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O
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Month

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