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A COMPARISON OF TWO METHODS FOR FORECASTING THUNDERSTORMS AT LUKE AIR FORCE BASE, ARIZONA

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A COMPARISON OF TWO METHODS FOR FORECASTING THUNDERSTORMS AT LUKE AIR FORCE BASE, ARIZONA

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I. INTRODUCTION

Thunderstorms with their associated turbulence, precipitation, strong winds, and restricted visibility caused by blowing dust, pose the most significant weather threat to flying at Luke Air Force Base, Arizona, and in the local flying area.

Methods to forecast the occurrence of thunderstorms at Luke Air Force Base have been developed by several different forecasters while stationed there, but none of these methods has been particularly effective. The problems confronted when trying to develop a procedure are compounded at Luke Air Force Base, because the only local measurements routinely recorded are standard surface weather observations at Luke and Williams Air Force Bases and at Sky Harbor Airport in Phoenix. The nearest upper-air soundings stations are Tucson and Winslow, Arizona, San Diego, California, and Albuquerque, New Mexico. Of these, only Tucson is near enough and in the right direction to even be close to representing the same air mass. Although Winslow is about the same distance from Luke, it is on the other side of a mountain range, is in the wrong direction with respect to normal moisture advection, and is generally in a different moisture regime. Therefore, one is faced with using profile data from over 100 miles away, relying on local surface observations, or using recently developed trajectory model forecasts. This report is a summary of two studies for forecasting the occurrence of air-mass thunderstorms for the period 1 June through 30 September. The first is based on twelve years of upper-air data from Tucson and is referred to as the RAOB study. The second is based on three years of trajectory model data and is called the Trajectory study.

II. METHODS USED

RAOB Study. Thunderstorms occur within sight of Luke Air Force Base almost every day during the summer season. However, those that occur at or within five miles of the base are of most concern and are those of interest in verification of the study. The high noise level near the Luke weather station makes it very difficult to hear thunder; therefore, verification was based on (1) thunder being heard by the observer, (2) cumulonimbus clouds and lightning being observed overhead, and (3) observed rainshowers with lightning. Other weather associated with thunderstorms in this area, such as high wind and blowing dust do not themselves verify a thunderstorm forecast. The forecast is based on the 1200Z Tucson RAOB, and is valid for the 24-hour period from 1800Z to 1800Z the following day.

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The parameters used are derived from RAOB plot and consist of: (1) low-level moisture (average surface to 700 millibars), (2) upper-level moisture (average 700 to 400 millibars), (3) low-level stability (850 to 600 millibars), (4) mid-level winds (700-millibar wind direction), and (5) upper-level winds (500-millibar wind direction) (Clark and Cooley, 1966). These parameters were selected from a number tried, as the best descriptures of the factors influencing thunderstorm development. Combinations of these factors were plotted against each other to develop three charts and a weighting system for establishing objective forecasting criteria. The charts are divided into zones of potential thunderstorm occurrence, with the more favorable zones assigned lower numbers.

An explanation of each chart used follows: Chart 1: a plot of the difference in temperature between the 850- and 600-mb levels, against mid-level moisture determined by averaging the moisture between the 700-mb and 400-mb levels. The layer of air between 850 and 600 mb is affected by thermal heating in this area, and the difference in temperature between these levels is a measure of the stability of the layer. The upper-level moisture is determined by subtracting the average dew point from the average free air temperature in the layer between 700 and 400 mb. Both averages are noted at the 550-mb level and the difference between the two is a measure of the saturation of the air layer (Figure 1). Chart 2: a plot of the 700-mb wind direction against the 500-mb wind direction as recorded on the RAOB. This plot tends to indicate those winds which are more likely to steer the thunderstorms over Luke Air Force Base (Figure 2). Chart 3: a plot of the lower-level moisture as expressed by the CCL and the low-level stability index used in Chart 1. The CCL is determined by extending the average saturation mixing ratio curve, between the surface and 700 mb, upward until it intersects the free air temperature curve. The height, in millibars, of this intersection is called the CCL (Figure 3).

In order to obtain a forecast, the following steps should be taken:

(1) Using the five parameters described above, enter the three charts and determine the number value for each chart. The total of the three numbers is used to enter Table 1, which was developed using the first twelve years of data, and shows the relationship between the total number and the observed convective activity using a method suggestion by Wright (1978).

(2) From Table 1, the probability of thunderstorm activity at Luke Air Force Base and in the area, can be determined and indicated in the terminal forecast.

Trajectory Study: Using trajectory data derived from AFGWC's Boundary Layer Model and Six-Level Model (Diercks, 1970; Hammond and Randolph, 1975), a set of forecast criteria was developed by trial, plotting combinations of all moisture, stability, and vertical-motion variables. Individual variables were plotted on either 12- or 24-hour trajectory bulletin time series cross sections, and the vertical scales were adjusted on a light table until the cross-over relationships matched as closely as possible the convective activity at Luke Air Force Base. In addition to the usual cross-over procedures, data for 1975, 1976, and 1977 were used to develop a set of criteria for forecasting thunderstorm activity by using the cross-section charts wherein the individual variables were plotted against each other. The final process was to establish a five-step procedure for determining thunderstorm occurrences as shown in Table 2.

III. EVALUATION OF RESULTS

Evaluation of the two methods using the same criteria is difficult since the parameters on which they were based, the length of database, and the final forecast product are different. Twelve years of data were used to establish the RAOB method, and two years of data were set aside for validation. The Trajectory method was based on three years data, and only one year was set aside for verification. A comparison of the two methods on the same data was possible for 1978 if the RAOB method were modified slightly to provide a yes or no forecast. This was accomplished by considering any probability over 50 percent as a yes forecast. In this case, it was established that a total number score of 6 or less would constitute a forecast of thunderstorm activity, while any number over 6 would constitute a forecast of no thunderstorm activity. Based on the above criteria, the results using the two methods are presented in Table 3, and the skill scores and percent of correct forecasts are shown in Table 4. As shown the RAOB method produced considerably better results, and although less than desirable they are acceptable, especially considering that even those cases that had only a 51 percent probability of occurrence were considered to be a yes forecast for this comparison.

Another way to show the results of the RAOB method is to compare the occurrence of thunderstorms during the two years set aside for verification against the results in Table 1, realizing that only two years data will provide more erratic results than long-term averages. These results are presented in Table 5, and although there is some variation the overall tendency is very similar to that in Table 1.

IV. DISCUSSION

In this study the RAOB method produced considerably better results than the Trajectory model. However, it is based on a longer period of record, and the Trajectory model was changed at least once during the study which could have affected the results. Under the present circumstances (no local observations provide the detailed information necessary), the RAOB method may be the best tool available. It could also be useful to new forecasters both in providing a level of confidence in the forecast, and in helping them to identify which parameters to watch. Since the RAOB method will never provide any better data, and is not based on local factors, it would seem desirable to modify existing models, develop new ones, or improve input data so that the future advances would provide better results.

On that basis, it is suggested that the RAOB method be used as a forecasting aid at the present time, but that the Trajectory model be checked or reevaluated occasionally as a larger database becomes available and as the model itself is improved. This would require saving the data occasionally summarizing and plotting and checking against independent data to see if the relationships can be improved.

V. CONCLUSIONS

At the present time the RAOB method does provide the forecaster an aid to forecasting thunderstorm activity at Luke Air Force Base, and is especially helpful to new forecasters assigned to the base. Its use should be continued until other methods, such as the Trajectory method, are improved or developed to provide better results.

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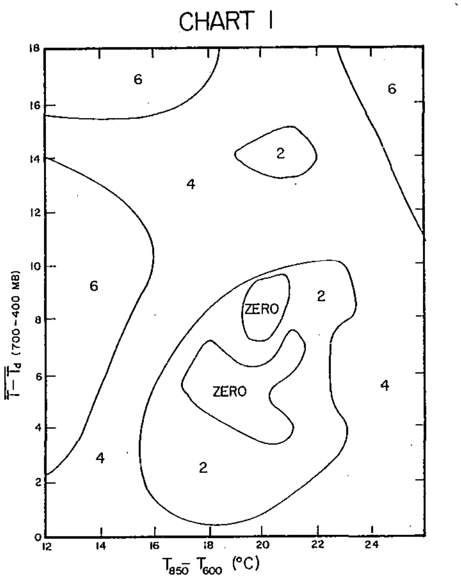

FIGURE I — PLOT OF LOWER LEVEL VS. UPPER LEVEL MOISTURE

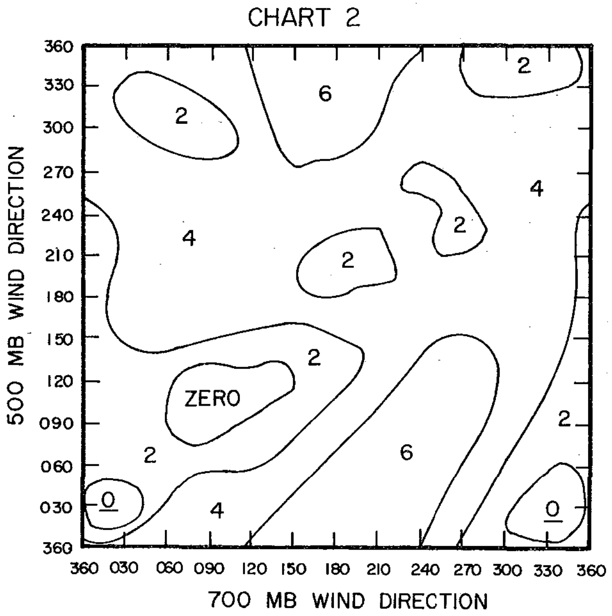

FIGURE 2 - PLOT OF 700MB WIND DIRECTION VS. 500MB WIND DIRECTION

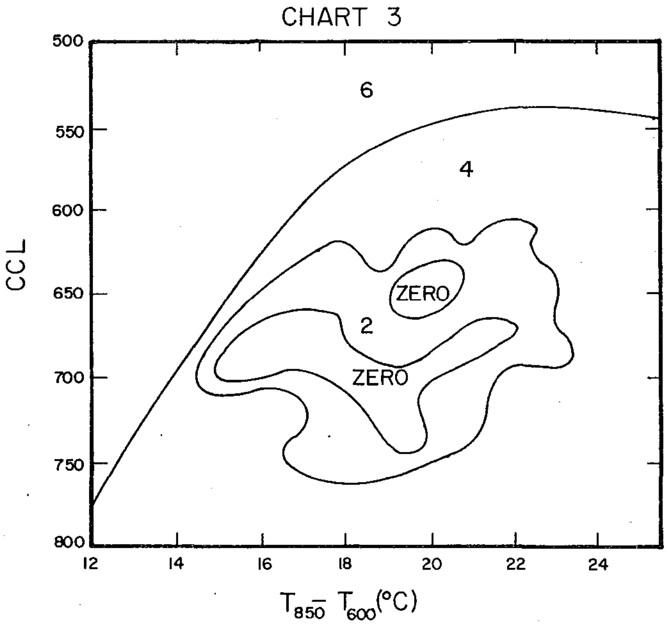

FIGURE 3 - PLOT OF LOWER LEVEL MOISTURE VS. LOWER LEVEL STABILITY

PROBABILITY FACTORS FOR LUKE AFB THUNDERSTORM STUDY

TOTAL POINTS USING CHARTS 1, 2, 3, and TUS 12Z RAOB	CHANCE OF OCCURRENCE IN PERCENT		
	NO CONVECTIVE ACTIVITY	TSTM, CB, RW OR ϟ IN AREA	TSTM OR CB WITH RW and ϟ AT LUKE
0	1	99	99
2	2	98	83
4	3	97	67
6	8	92	51
8	17	83	35
10	32	68	23
12	51	49	13
14	72	28	5
16+	91	9	1

Valid Time of Forecast - 1900Z to 1900Z. Form 10 used for verification.

TABLE 2

FIVE STEP THUNDERSTORM FORECAST PROCEDURE USING TRAJECTORY MODEL

Step 1	Is average of 700 and 500 T-TD ≤15 Yes - Go to Step 2 No - Forecast no thunderstorms
Step 2	Is K ≥22 Yes - Go to Step 3 No - Forecast no thunderstorms
Step 3	Is SI ≤2 Yes - Go to Step 4 No - Forecast no thunderstorms
Step 4	Is 700-mb particle projected to be ≥699 mb Yes - Go to Step 5 No - Forecast no thunderstorms
Step 5	Is 500-mb particle projected to be ≥490 mb Yes - Forecast thunderstorms No - Forecast no thunderstorms

Forecast Valid Time - 22 - 07Z.

TABLE 3

COMPARISON OF FORECAST AND OBSERVED THUNDERSTORM OCCURRENCE AT LUKE AFB, ARIZONA FOR JULY, AUGUST, AND SEPTEMBER 1978

DATE	OBSERVED TSTM ACTIVITY	TRAJECTORY FORECAST	RAOB FORECAST
Jul 1	No	No	No
2	No	No	No
3	No	No	No
4	No	No	No
5	No	No	No
6	No	No	No
7	No	No	No
8	—	—	—
9	Yes	No	No
10	No	No	Yes
11	No	Yes	Yes
12	No	No	Yes
13	No	No	No
14	No	No	No
15	No	No	No
16	No	No	No
17	No	No	No
18	No	Yes	No
19	No	Yes	No
20	No	No	No
21	No	Yes	No
22	Yes	No	Yes
23	—	—	—
24	Yes	Yes	Yes
25	No	Yes	No
26	Yes	Yes	Yes
27	No	Yes	Yes
28	No	Yes	No
29	Yes	Yes	No
30	Yes	No	No
31	No	No	Yes
Aug 1	Yes	Yes	Yes
2	Yes	Yes	Yes
3	Yes	No	Yes
4	No	No	No
5	No	No	No
6	Yes	No	Yes
7	Yes	No	No
Aug 8	Yes	No	No
9	No	No	No
10	No	No	No
11	No	No	No
12	No	No	Yes
13	No	No	No
14	No	No	No
15	No	No	No
16	No	No	No
17	No	No	No
18	—	—	—
19	No	No	Yes
20	Yes	No	No
21	No	Yes	No
22	No	Yes	No
23	No	No	No
24	No	No	Yes
25	No	No	No
26	No	No	No
27	No	No	No
28	No	No	No
29	No	No	No
30	—	—	—
31	No	No	No
Sep 1	No	No	No
2	No	No	No
3	No	No	No
4	No	No	No
5	No	Yes	Yes
6	No	Yes	No
7	No	Yes	No
8	No	Yes	No
9	No	No	Yes
10	No	Yes	No
11	No	No	No
12	No	No	No
13	No	No	No

TABLE 4

SKILL SCORE AND PERCENT OF CORRECT FORECASTS FOR TRAJECTORY AND RAOB METHODS DURING 1978

A - Trajectory Method:

		Forecast Occurrence		
		Yes	No	Total
Observed	Yes	5	8	13
Occurrence	No	14	44	58
	Total	19	52	71

Skill Score = 0.12
Percent of correct forecasts = 69%

B - RAOB Method:

		Forecast Occurrence		
		Yes	No	Total
Observed	Yes	7	6	13
Occurrence	No	10	48	58
	Total	17	54	71

Skill Score = 0.33
Percent of correct forecasts = 78%

TABLE 5

RELATIONSHIP OF TOTAL POINTS FROM CHARTS 1, 2, AND 3 TO PERCENT OCCURRENCE OF CONVECTIVE ACTIVITY AT LUKE AFB, ARIZONA, USING 1976 AND 1978 DATA

TOTAL POINTS USING CHARTS 1, 2, 3, AND TUS 12Z RAOB	OCCURRENCE IN PERCENT		
	NO CONVECTIVE ACTIVITY	TSTM, CB, RW OR ↯ IN AREA	TSTM OR CB WITH RW and ↯ AT LUKE
0	0	100	100
2	0	100	80
4	0	100	53
6	22	78	22
8	8	92	23
10	22	78	31
12	43	57	10
14	80	20	4
16+	100	0	0

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