

NOAA Technical Memorandum NWS WR-163



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

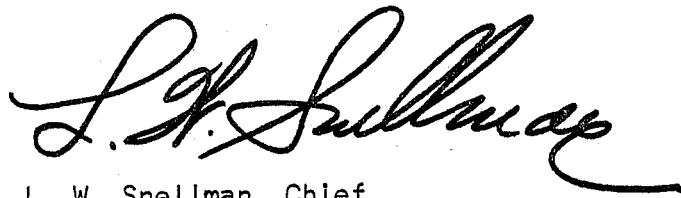
Salt Lake City, Utah
April 1981

**U.S. DEPARTMENT OF
COMMERCE**

National Oceanic and
Atmospheric Administration

National Weather
Service

This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

A handwritten signature in black ink, appearing to read "L. W. Snellman". The signature is written in a cursive style with a long, sweeping tail that extends to the right.

L. W. Snellman, Chief
Scientific Services Division
Western Region Headquarters
Salt Lake City, Utah

CONTENTS

	<u>Page</u>
List of Figures and Tables	iv
I. Introduction	1
II. Methods Used	1
III. Evaluation of Results	4
IV. Discussion	4
V. Conclusions	4
VI. References	5

FIGURES AND TABLES

		<u>Page</u>
Figure 1.	Plot of Lower Level vs Upper Level Moisture	6
Figure 2.	Plot of 700-mb Wind Direction vs 500-mb wind direction	6
Figure 3.	Plot of Lower Level Moisture vs Lower Level Stability	6
Table 1.	Probability Factors for Luke AFB Thunderstorm Study	7
Table 2.	Five Step Thunderstorm Forecast Procedure Using Trajectory Model	7
Table 3.	Comparison of Forecast and Observed Thunderstorm Occurrence at Luke AFB, Arizona, for July, August, and September 1978	8
Table 4.	Skill Score and Percent of Correct Forecasts for Trajectory and RAOB Methods during 1978	9
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	9

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

Lt. Colonel Keith R. Cooley*
Boise, Idaho

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.

*Lt. Colonel Keith R. Cooley, USAFR, Det 15, 25th Weather Squadron,
Luke Air Force Base, Arizona (former affiliation).

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 descriptors 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.

VI. REFERENCES

- Clark, Robert E., and Keith R. Cooley, 1966: An Objective Technique for Forecasting Summer Thunderstorms at Davis-Monthan Air Force Base, Arizona. USAF Pub. DDC No. AD677383, 1 August, 18 pp.
- Diercks, John W., 1970: The Use of Trajectories in Terminal Forecasting (Second Report). Technical Report 237, Air Weather Service (MAC), United States Air Force, November, 29 pp.
- Hammond, Gordon, and Jim Randolph, 1975: AWS/DN, TRAJ/MOS, Trajectory Model; Output Statistics Applications Seminar. AW75-120DN, 10 April, 90 pp.
- Wright, Robert P., 1978: Technical Consultant Visit Report to Det 15, 25WS/CC, Atch 5, 17 March, 2 pp.

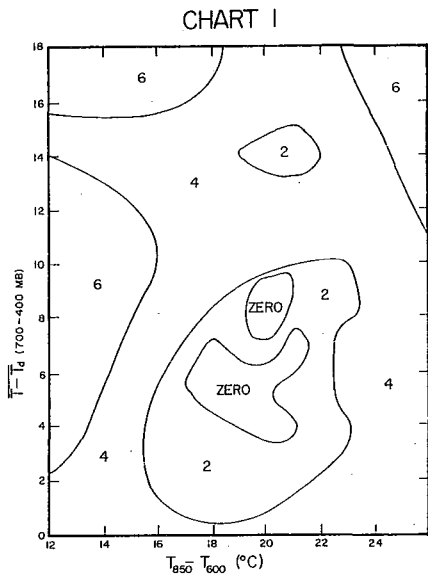


FIGURE 1 - PLOT OF LOWER LEVEL VS. UPPER LEVEL MOISTURE

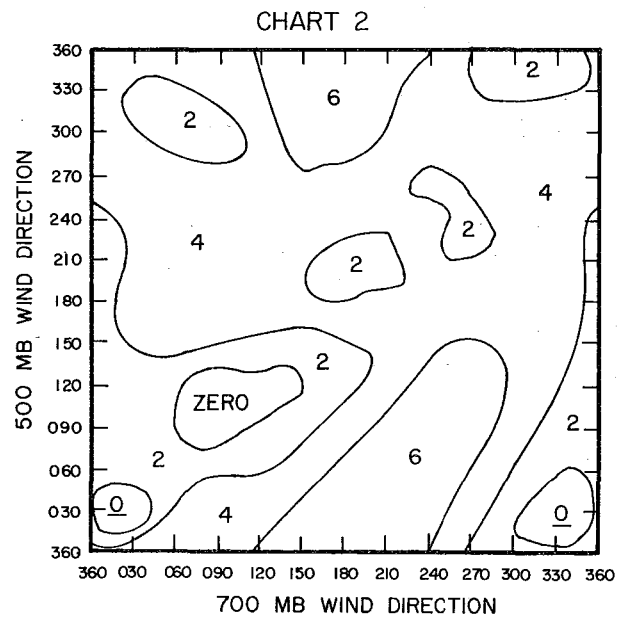


FIGURE 2 - PLOT OF 700MB WIND DIRECTION VS. 500MB WIND DIRECTION

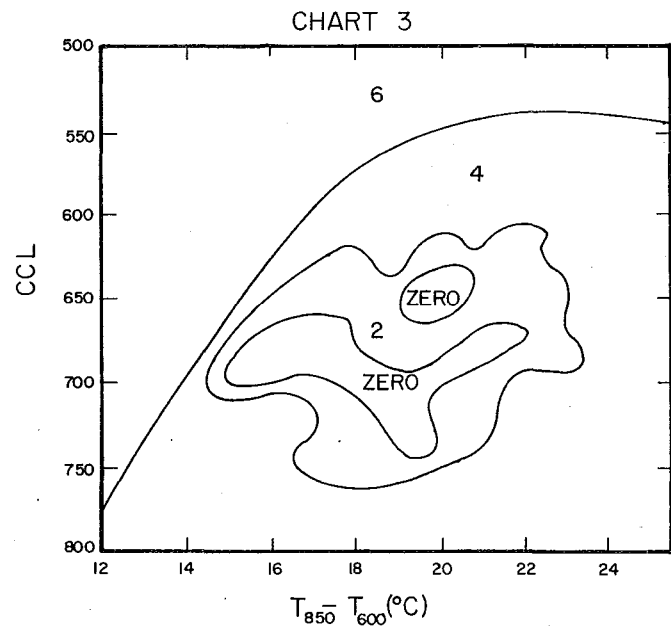


FIGURE 3 - PLOT OF LOWER LEVEL MOISTURE VS. LOWER LEVEL STABILITY

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

NOAA Technical Memoranda NWS WR: (Continued)

- 121 Climatological Prediction of Cumulonimbus Clouds in the Vicinity of the Yucca Flat Weather Station. R. F. Quiring, June 1977. (PB-271-704/AS)
- 122 A Method for Transforming Temperature Distribution to Normality. Morris S. Webb, Jr., June 1977. (PB-271-742/AS)
- 124 Statistical Guidance for Prediction of Eastern North Pacific Tropical Cyclone Motion - Part I. Charles J. Neumann and Preston W. Leftwich, August 1977. (PB-272-661)
- 125 Statistical Guidance on the Prediction of Eastern North Pacific Tropical Cyclone Motion - Part II. Preston W. Leftwich and Charles J. Neumann, August 1977. (PB-273-155/AS)
- 127 Development of a Probability Equation for Winter-Type Precipitation Patterns in Great Falls, Montana. Kenneth B. Mielke, February 1978. (PB-281-387/AS)
- 128 Hand Calculator Program to Compute Parcel Thermal Dynamics. Dan Gudge, April 1978. (PB-283-080/AS)
- 129 Fire Whirls. David W. Goens, May 1978. (PB-283-866/AS)
- 130 Flash-Flood Procedure. Ralph C. Hatch and Gerald Williams, May 1978. (PB-286-014/AS)
- 131 Automated Fire-Weather Forecasts. Mark A. Mollner and David E. Olsen, September 1978. (PB-289-916/AS)
- 132 Estimates of the Effects of Terrain Blocking on the Los Angeles WSR-74C Weather Radar. R. G. Pappas, R. Y. Lee, B. W. Finke, October 1978. (PB289767/AS)
- 133 Spectral Techniques in Ocean Wave Forecasting. John A. Jannuzzi, October 1978. (PB291317/AS)
- 134 Solar Radiation. John A. Jannuzzi, November 1978. (PB291195/AS)
- 135 Application of a Spectrum Analyzer in Forecasting Ocean Swell in Southern California Coastal Waters. Lawrence P. Kierulff, January 1979. (PB292716/AS)
- 136 Basic Hydrologic Principles. Thomas L. Dietrich, January 1979. (PB292247/AS)
- 137 LFM 24-Hour Prediction of Eastern Pacific Cyclones Refined by Satellite Images. John R. Zimmerman and Charles P. Ruscha, Jr., Jan. 1979. (PB294324/AS)
- 138 A Simple Analysis/Diagnosis System for Real Time Evaluation of Vertical Motion. Scott Heflick and James R. Fors, February 1979. (PB294216/AS)
- 139 Aids for Forecasting Minimum Temperature in the Wenatchee Frost District. Robert S. Robinson, April 1979. (PB298339/AS)
- 140 Influence of Cloudiness on Summertime Temperatures in the Eastern Washington Fire Weather District. James Holcomb, April 1979. (PB298674/AS)
- 141 Comparison of LFM and MFM Precipitation Guidance for Nevada During Doreen. Christopher Hill, April 1979. (PB298613/AS)
- 142 The Usefulness of Data from Mountaintop Fire Lookout Stations in Determining Atmospheric Stability. Jonathan W. Corey, April 1979. (PB298899/AS)
- 143 The Depth of the Marine Layer at San Diego as Related to Subsequent Cool Season Precipitation Episodes in Arizona. Ira S. Brenner, May 1979. (PB298817/AS)
- 144 Arizona Cool Season Climatological Surface Wind and Pressure Gradient Study. Ira S. Brenner, May 1979. (PB298900/AS)
- 145 On the Use of Solar Radiation and Temperature Models to Estimate the Snap Bean Maturity Date in the Willamette Valley. Earl M. Bates, August 1979. (PB80-160971)
- 146 The BART Experiment. Morris S. Webb, October 1979. (PB80-155112)
- 147 Occurrence and Distribution of Flash Floods in the Western Region. Thomas L. Dietrich, December 1979. (PB80-160344)
- 149 Misinterpretations of Precipitation Probability Forecasts. Allan H. Murphy, Sarah Lichtenstein, Baruch Fischhoff, and Robert L. Winkler, February 1980. (PB80-174576)
- 150 Annual Data and Verification Tabulation - Eastern and Central North Pacific Tropical Storms and Hurricanes 1979. Emil B. Gunther and Staff, EPHC, April 1980.
- 151 NMC Model Performance in the Northeast Pacific. James E. Overland, PMEL-ERL, April 1980. (PB80-196033)
- 152 Climate of Salt Lake City, Utah. Wilbur E. Figgins, June 1980. (PB80-225493)
- 153 An Automatic Lightning Detection System in Northern California. James E. Rea and Chris E. Fontana, June 1980. (PB80-225592)
- 154 Regression Equation for the Peak Wind Gust 6 to 12 Hours in Advance at Great Falls During Strong Downslope Wind Storms. Michael J. Oard, July 1980. (PB81-108367)
- 155 A Raininess Index for the Arizona Monsoon. John H. TenHarkel, July 1980. (PB81-106494)
- 156 The Effects of Terrain Distribution on Summer Thunderstorm Activity at Reno, Nevada. Christopher Dean Hill, July 1980. (PB81-102501)
- 157 An Operational Evaluation of the Scofield/Oliver Technique for Estimating Precipitation Rates from Satellite Imagery. Richard Ochoa, August 1980. (PB81-108227)
- 158 Hydrology Practicum. Thomas Dietrich, September 1980. (PB81-134033)
- 159 Tropical Cyclone Effects on California. Arnold Court, October 1980. (PB81-133779)
- 160 Eastern North Pacific Tropical Cyclone Occurrences During Intraseasonal Periods. Preston W. Leftwich and Gail M. Brown, February 1981.
- 161 Solar Radiation as a Sole Source of Energy for Photovoltaics in Las Vegas, Nevada, for July and December. Darryl Randerson, April 1981.
- 162 A Systems Approach to Real-Time Runoff Analysis with a Deterministic Rainfall-Runoff Model. Robert J. C. Burnash and R. Larry Ferral, April 1981.

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Department of Commerce on October 3, 1970. The mission responsibilities of NOAA are to assess the socioeconomic impact of natural and technological changes in the environment and to monitor and predict the state of the solid Earth, the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical information in the following kinds of publications:

PROFESSIONAL PAPERS — Important definitive research results, major techniques, and special investigations.

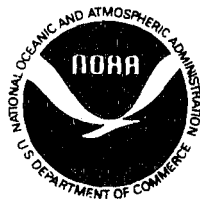
CONTRACT AND GRANT REPORTS — Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS — Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS — Reports containing data, observations, instructions, etc. A partial listing includes data serials; prediction and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS — Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS — Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.



Information on availability of NOAA publications can be obtained from:

**ENVIRONMENTAL SCIENCE INFORMATION CENTER (D822)
ENVIRONMENTAL DATA AND INFORMATION SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE**

**6009 Executive Boulevard
Rockville, MD 20852**