UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NOAA Technical Memorandum NWS ER-46

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

AN OBJECTIVE METHOD OF FORECASTING SUMMERTIME THUNDERSTORMS

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Eastern Region
Garden City, N.Y.

May 1972

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE EASTERN REGION
Garden City, New York

NOAA TECHNICAL MEMORANDUM NWS ER-46

AN OBJECTIVE METHOD OF FORECASTING SUMMERTIME THUNDERSTORMS

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SCIENTIFIC SERVICES DIVISION
Eastern Region Headquarters
May 1972

AN OBJECTIVE METHOD OF FORECASTING SUMMERTIME THUNDERSTORMS

INTRODUCTION

This study was conducted to develop and test an objective method of forecasting summertime thunderstorm activity using as predictors numerical model output which are normally available at National Weather Service field offices. The technique was developed specifically for Washington, DC, but may be applicable at other areas. A thunderstorm forecast index, valid at 0000Z, was first developed, and this index was then related to the frequency of occurrence of thunderstorms between 1800Z and 0600Z. The objective forecast is intended as guidance for the preparation of the public weather forecast that is released near 0900Z. To serve this purpose, it must be available by 0800Z. The skill of the objective thunderstorm forecast is compared to the skill of forecasts obtained by using lifted index (1) and K-index values (2) available for use at 0800Z.

PROCEDURE

In an unpublished study, Younkin developed a summertime thunderstorm index that empirically relates observed 1000-500 mb. thickness, surface maximum temperature and surface dewpoint at time of maximum temperature to thunderstorm activity. The Younkin thunderstorm index is:

$$[Z_5 - 8 (P - 1000)] - 2.5X - 5030,$$

where Z_5 is the 500 mb. height in meters, P is sea level pressure in millibars, and X has a value equal to (T max + $3T_d$ max). T max is the afternoon maximum surface temperature and Td max is the surface dewpoint at time of T max. The term 8 (P - 1000) approximates the 1000 mb. height in meters. Therefore, $[Z_5 - 8 (P - 1000)]$ approximates the 1000-500 mb. thickness. Younkin developed this index for use in the area of the United States east of about 95° west longitude.

Younkin found that his index values are related to thunderstorm activity as follows:

9 to -10	Few thunderstorms in mountains only.
-10 to -25	Few to scattered thunderstorms.
Less than -25	Scattered to numerous thunderstorms.

The Younkin Index can be modified to accept numerical forecast predictors available at a Weather Service Forecast Office. The equation for the Modified Younkin Index (MYI) becomes:

$$MYI = H_5 - 5030 - 2.5\ (T\ max + 3Td\ max),$$

where H_5 is the 24-hour forecast of 1000-500 mb. thickness in meters, valid at 0000Z, T max is the Klein maximum temperature forecast (3), and Td max is an objective dewpoint forecast for the afternoon (valid at time of T max) derived as explained below.

The H_5 term is available at 0700Z on the FOUS printout of PE model (4) predictions based on 0000Z data. The Klein temperature forecast is available at about 0800Z. Originally, the Td max term was to be computed using the Klein maximum temperature forecast and the PE model 24-hour forecast (valid 0000Z) of mean boundary layer relative humidity. Klein forecasts of T max have significant skill, but the PE model boundary layer relative humidity forecasts for Washington, DC, were found to be too poor for use. The trajectory model(5) forecasts of dewpoint were also considered but they, too, were not sufficiently accurate. Trial and error experimentation with several different variables led to an objective method of predicting Td max using as predictors the observed 0600Z dewpoint at Washington National Airport (DCA) and 24-hour PE model forecasts of mean boundary layer wind direction (valid at 0000Z). Summer data for 1970 were used to develop a Td max forecast relationship (Figure 1). The relationship presented in Figure 1 is intended for use only in the Washington area. Td max forecasts for other areas would have to be obtained by the most accurate objective method, determined by testing. Independent summer data for 1971, used to test Td max forecasts, showed a mean forecast error of 2.3°F.

The MYI was computed daily during the 1970 summer (June 15 to September 15) using observed data. The frequency of occurrence of thunderstorms was determined for different ranges of observed values of the MYI (Table 1). In this study, a thunderstorm is considered to have occurred if it was observed between 1800Z and 0600Z at IAD (Dulles International Airport), DCA, or BAL (Friendship International Airport) as a thunderstorm at the station or a cumulonimbus cloud in the vicinity. A thunderstorm was also considered to have occurred if it were reported by any of the large network of Washington area cooperative observers. The purpose of using this definition of thunderstorm activity is to provide the forecaster with guidance as to whether thunderstorms will occur anywhere in the Washington metropolitan area. Severity of thunderstorm activity is not considered.

RESULTS

Tests were conducted using independent data from June 1 through September 15, 1971 in the Washington metropolitan area. From these tests the skill of forecast values of MYI as an indicator of thunderstorm activity was determined. Comparative skill was also determined for K-index persistence forecast values, computed from observed data (0000Z previous evening), and forecast lifted index values computed from 24-hour PE model forecasts (valid at 0000Z). The frequency of thunderstorms for ranges of the different indices compared are presented in Table 2. To determine the skill of the different indices in indicating a categorical forecast of thunderstorms, it is first necessary to determine index threshold values at or above which thunderstorms are to be expected. From observed 1970 data (Table 1) the threshold value for the MYI was established to be -50. For the lifted index and K-index, several threshold values are used to show the optimum results that can be obtained from these indices. Threat scores for thunderstorm forecasts based on the three different indices are shown in Table 3. The threat score is equal to the ratio:

$$\frac{\text{No. Correct Forecasts}}{\text{No. Forecasts + No. Occurrences - No. Correct Forecasts}}$$

The higher the threat score, the greater the skill. Therefore, it can be seen (Table 3) that the MYI, using a threshold value of -50, has skill comparable to the other two indices, no matter what threshold value is used for these other indices.

It would be interesting to know how the indices examined would have performed in 1971 as a thunderstorm indicator, given perfect forecasts of these indices. Again using -50 as a threshold value for the MYI and using a variable threshold value for the other indices, perfect forecasts of the MYI would have produced a higher threat score for forecasts of thunderstorms than perfect forecasts of the other two indices (Table 4). In fact, imperfect forecasts of MYI outperformed perfect forecasts of the other two indices as indicators of thunderstorms.

It may be of greater utility to equate observed or forecast values of the MYI to probability of occurrence of thunderstorms, rather than categorical yes and no forecasts. Data for 1970 and 1971 were combined to determine the frequency of occurrence of thunderstorms for ranges of observed values of the MYI. The results were then subjectively smoothed to arrive at an objective technique for determining the probability of thunderstorms, given a perfect MYI forecast (Table 5). The frequency of thunderstorms, unsmoothed, versus forecast values of MYI for 1971, is presented in Table 2. Unfortunately, forecast values of MYI for 1970 were not conveniently available.

CONCLUSIONS

A thunderstorm forecast index, the MYI, has been introduced and related to the frequency of thunderstorms in the Washington metropolitan area. Forecast values of the MYI can be determined objectively. Tests on independent data show greater skill, as indicated by the threat score, obtained with forecast values of the MYI, than that obtained with either observed or forecast values of the lifted index and K-index. The MYI may be suitable for use at other locations, but tests should first be conducted to determine this. Although the emphasis in this paper has been to relate the MYI to the frequency of thunderstorms within an area, this same MYI can be related to the frequency of occurrence of thunderstorms at a point. Obviously, the point frequency would be less than the area frequency.

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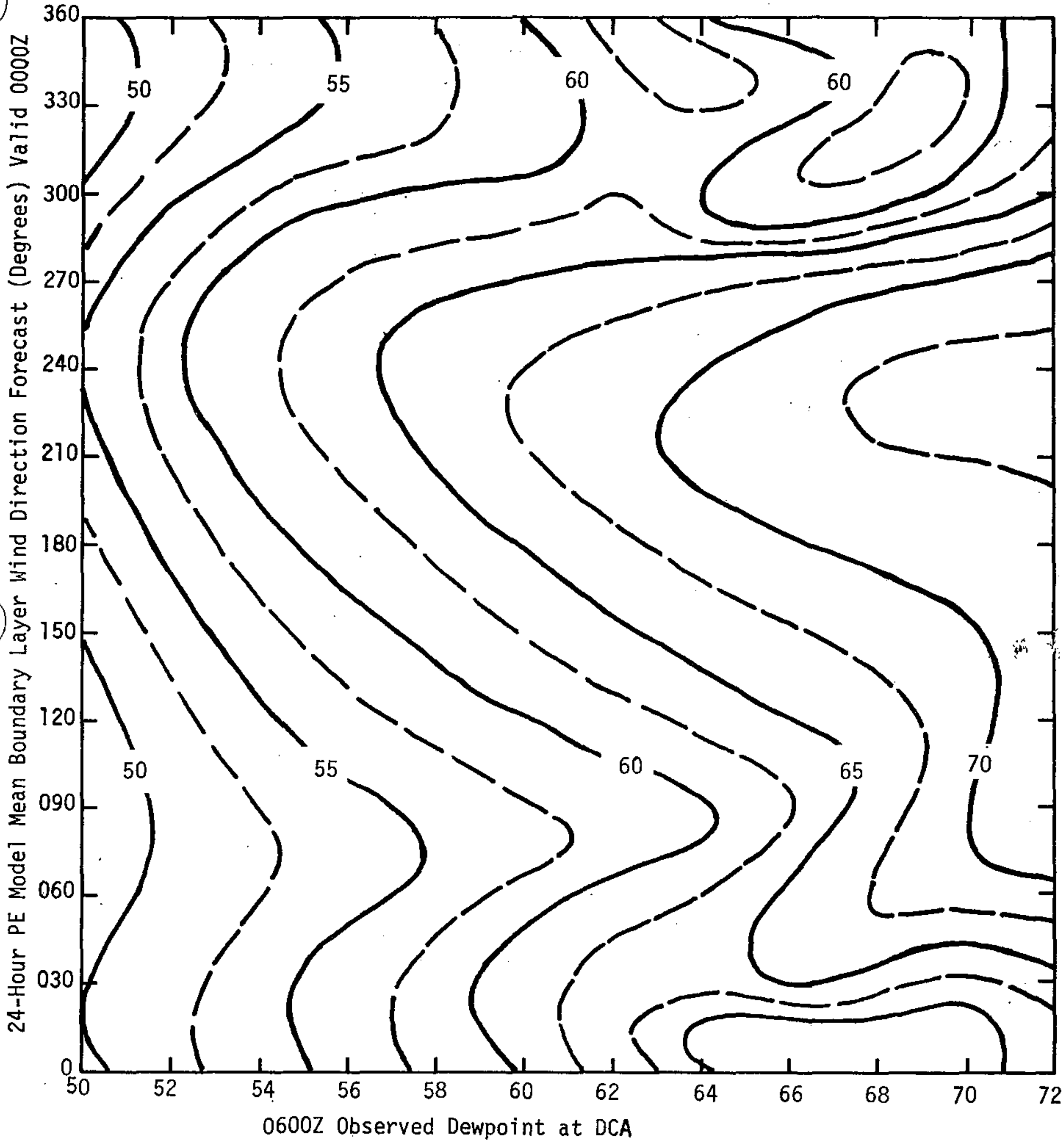

FIGURE 1. *Isopleths of afternoon dewpoint (Td max) as a function of the 0600Z observed dewpoint at DCA and the 24-hour PE model mean boundary layer wind direction forecast, valid at 0000Z at DCA. Dewpoints are in degrees Fahrenheit.*

OBSERVED MYI	TOTAL CASES	TOTAL THUNDERSTORM CASES	RELATIVE FREQUENCY OF THUNDERSTORMS
80 to 60	5	0	0
59 to 40	5	0	0
39 to 20	10	0	0
19 to 1	11	0	0
0 to -9	9	0	0
-10 to -19	8	0	0
-20 to -29	9	0	0
-30 to -39	7	2	.29
-40 to -49	9	4	.44
-50 to -59	4	3	.75
-60 to -69	3	2	.67
-70 to -79	6	5	.83
-80 to -89	4	4	1.00
-90 to -99	2	2	1.00

TABLE 1. *Frequency of thunderstorms between 18Z and 06Z for different ranges of observed values of 00Z MYI. Data are for June 15 to September 15, 1970.*

STABILITY INDEX FORECAST VALUE	PE MODEL LIFTED INDEX			K-INDEX			MYI FORECAST		
	TOTAL CASES	TOTAL THUNDER-STORM CASES	%FREQUENCY THUNDER-STORMS	TOTAL CASES	TOTAL THUNDER-STORM CASES	%FREQUENCY THUNDER-STORMS	TOTAL CASES	TOTAL THUNDER-STORM CASES	%FREQUENCY THUNDER-STORMS
80 to 60							2	0	0%
59 to 50							2	0	0
49 to 45							0	0	0
44 to 40				2	1	50%	0	0	0
39 to 35				7	4	57	2	0	0
34 to 30				24	6	25	3	0	0
29 to 25				16	5	31	6	0	0
24 to 20				9	2	33	4	0	0
19 to 15	1	0	0%	6	3	50	4	1	25
14 to 10	7	0	0	3	0	0	5	0	0
9 to 5	23	2	9	13	1	8	1	0	0
4 to 1	20	6	30	5	2	40	4	1	25
0 to -4	35	18	51	4	0	0	2	0	0
-5 to -9	1	1	100	2	0	0	4	0	0
-10 to -14				3	0	0	2	0	0
-15 to -19				5	1	20	2	0	0
-20 to -24				0	0	0	3	1	33
-25 to -29				1	1	100	6	0	0
-30 to -34							8	3	38
-35 to -39							5	1	20
-40 to -49							12	3	25
-50 to -59							6	3	50
-60 to -69							14	9	64
-70 to -79							3	3	100
-80 to -99							3	3	100

TABLE 2. *Percent frequency of thunderstorms between 1800Z and 0600Z as a function of 24-hour stability index forecasts valid at 0000Z. 24-hour persistence lag is assumed for K-index. Data are for Washington, DC, June 1, 1971, to September 15, 1971.*

PE MODEL LIFTED INDEX FORECAST		K-INDEX FORECAST		MYI FORECAST	
TSTM FCST FOR VALUES AT OR BELOW:	TSTM FCST THREAT SCORE IS:	TSTM FCST FOR VALUES AT OR ABOVE	TSTM FCST THREAT SCORE IS:	TSTM FCST FOR VALUES AT OR BELOW:	TSTM FCST THREAT SCORE IS:
+6	.39	+36	.09		
+5	.41	+35	.15	-50	.50
+4	.43	+34	.22		
+3	.45	+33	.26		
+2	.49	+32	.24		
+1	.42	+31	.23		
0	.45	+30	.26		
-1	.36	+29	.29		
-2	.23	+28	.28		
-3	.04	+27	.27		
-4	.04				

TABLE 3. *Threat scores for 1800Z to 0600Z thunderstorm forecasts. Thunderstorm forecasts are a function of threshold values of 24-hour stability index forecasts, valid at 0000Z. 24-hour persistence is assumed for K-index. Data are for Washington, DC, June 1, 1971, to September 15, 1971.*

OBSERVED LIFTED INDEX		OBSERVED K-INDEX		OBSERVED MYI	
TSTM FCST FOR VALUES AT OR BELOW:	TSTM FCST THREAT SCORE IS:	TSTM FCST FOR VALUES AT OR ABOVE	TSTM FCST THREAT SCORE IS:	TSTM FCST FOR VALUES AT OR BELOW:	TSTM FCST THREAT SCORE IS:
+5	.40	+35	.15	-50	.69
+4	.43	+34	.29		
+3	.46	+33	.41		
+2	.45	+32	.42		
+1	.37	+31	.46		
0	.38	+30	.43		
-1	.35	+29	.46		
-2	.24	+28	.44		
-3	.17	+27	.44		
-4	.09	+26	.47		
		+25	.47		
		+24	.49		
		+23	.48		
		+22	.49		
		+21	.49		
		+20	.48		
		+19	.49		
		+18	.49		
		+17	.47		
		+16	.45		

TABLE 4. *Threat scores for 1800Z to 0600Z thunderstorm forecasts. Thunderstorm forecasts are a function of threshold values of stability index observed at 0000Z. Data are for Washington, DC, June 1, 1971, to September 15, 1971.*

OBSERVED MYI	TOTAL CASES	TOTAL THUNDER-STORM CASES	FREQUENCY OF THUNDERSTORMS	
			Unsmoothed	Smoothed
80 to 60	7	0	0	0
59 to 40	7	0	0	0
39 to 20	25	0	0	0
19 to 1	25	2	.08	0
0 to -9	15	0	0	0
-10 to -19	12	0	0	0
-20 to -29	18	1	.06	.10
-30 to -39	20	6	.30	.25
-40 to -49	21	7	.33	.40
-50 to -59	10	6	.60	.60
-60 to -69	17	11	.65	.70
-70 to -79	9	8	.89	.85
-80 to -89	6	6	1.00	1.00
-90 to -99	3	3	1.00	1.00

TABLE 5. *Frequency of thunderstorms between 18Z and 06Z for different ranges of observed values of 00Z MYI. Data are for summers of 1970 and 1971 combined.*

LIST OF EASTERN REGION TECHNICAL MEMORANDA

(Continued from inside front cover)

NWS ER 40 Use of Detailed Radar Intensity Data in Mesoscale Surface Analysis. Robert E. Hamilton. March 1971 (COM-71-00573)

NWS ER 41 A Relationship Between Snow Accumulation and Snow Intensity as Determined from Visibility. Stanley E. Wasserman and Daniel J. Monte. May 1971 (COM-71-00763)

NWS ER 42 A Case Study of Radar Determined Rainfall as Compared to Rain Gage Measurements. Martin Ross. July 1971 (COM-71-00897)

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NWS ER 44 Forecasting Precipitation Type at Greer, South Carolina. John C. Purvis. December 1971 (COM-72-10332)

NWS ER 45 Forecasting Type of Precipitation. Stanley E. Wasserman. January 1972 (COM-72-10316)