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IOAA Technical Memorandum NWS CR-54

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

OBJECTIVE PROBABILITIES OF SEVERE THUNDERSTORMS USING PREDICTORS FROM FOUS AND OBSERVED SURFACE DATA

Clarence L. David

Central Region
Kansas City, Mo.
MAY 1974



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(Continued on back inside cover)

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USING PREDICTORS FROM FOUS AND OBSERVED SURFACE DATA

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Kansas City, Missouri
May 1974



OBJECTIVE PROBABILITIES OF SEVERE THUNDERSTORMS USING PREDICTORS FROM FOUS AND OBSERVED SURFACE DATA

Clarence L. David
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Kansas City, Missouri

ABSTRACT

Model Output Statistics and screening regression are used to derive equations for estimating the probability of severe thunderstorm occurrences. The predictors screened were the PE model forecast data transmitted on the FOUS teletype message and the latest observed surface data. The predictand is the occurrence of severe thunderstorms during a 12-hour period in an area 120 nm centered on a station. Two equations are derived from the 00Z FOUS data and two from the 12Z FOUS data. One is for the period 12 to 24 hours after the FOUS data time and the other is for the period 24 to 36 hours after the data time.

I. Introduction

One of the forecast problems of the Severe Local Storms Unit (SELS) and of National Weather Service Offices is to determine in the early morning what the possibility of severe thunderstorms is for the day. The convective outlook transmitted by SELS at 09Z gives the expected areas of severe thunderstorms for the two twelve hour periods, 12Z to 00Z and 00Z to 12Z. The following describes an aid that has been developed to help prepare the convective outlook.

II. The Method

Model Output Statistics (MOS), together with screening regression, has been recently applied to the prediction of various weather events. Precipitation probability forecasting by Glahn (1969) and severe thunderstorm forecasting by Bonner (1971) are two recent applications. The screening regression technique was applied to observed data by Miller and David (1971) to forecast severe thunderstorms. Both MOS and screening regression are discussed fully by Glahn and Lowry (1972).

III. The Predictors and the Predictand

The predictand is the occurrence of severe thunderstorms during a 12-hour period in an area 120 nm on a side centered on a station. An occurrence of severe thunderstorm is defined as one or more reports of any of the following: surface wind 50 knots or greater, surface hail three-fourths inch or larger, or tornadoes. Predictors are the PE model forecast data transmitted on the FOUS teletype message* at 0644Z (from 00Z data) or 1844Z (from 12Z data) and the observed 06Z or 18Z surface data, respectively.

For the first period equations, 12, 18, and 24 hour forecasts from the PE model for each of the following were screened:

- mean relative humidity for each of the three layers
- 6 hourly quantitative precipitation totals
- vertical velocity at 700 mb
- lifted index
- 1000-500 mb thickness
- U and V components of the mean wind of the boundary layer
- mean potential temperature of the boundary layer
- mean pressure of the boundary layer (converted to sea level using standard atmospheric conditions)

The surface predictors which were screened are given below:

- temperature
- dew point
- sea level pressure
- wind direction and speed (U and V components)
- cloudiness
- visibility
- cloud height

For the second period the same predictors were screened except the 24, 30, and 36 hour forecasts from the PE model were used. Data for 1971 and 1972 for the 32 stations shown in figure 1 were the sample for developing equations.

*This message, consisting of PE model forecast output interpolated to a number of cities over the U.S. for 6-hour periods from 12 hours out to 48 hours, is described by Ostby (1972).

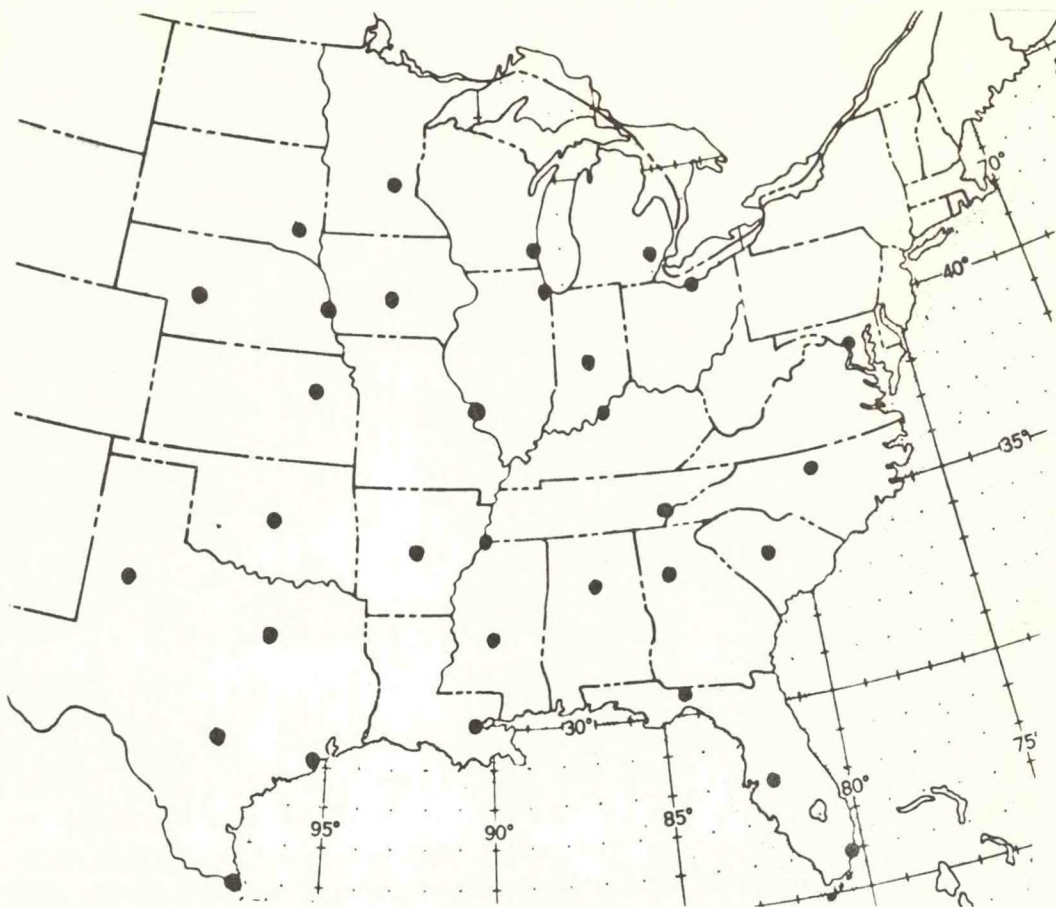


Figure 1. Stations used in developing equations.

IV. The Equations

Four equations were developed, two from the 00Z FOUS and the 06Z surface data, and two from the 12Z FOUS and the 18Z surface data. The first period equation from each FOUS data time covers the period 12-24 hours from FOUS data time, and the second period equation is for the succeeding 12 hours. Predictors selected, along with their contribution to the probability and the cumulative reductions of variance, are given in Tables 1 through 4. The predictors all are binary (except for day of year), that is, the predictor takes the value either zero or one and the coefficient will contribute zero or its full value.

For those persons wishing to compute the probability according to the method herein, a worksheet is given in the Appendix for each FOUS data time, along with a list of definitions and units.

Predictor	Contribution to equation (percent)	Cumulative reduction of variance (percent)
1. Constant	18.8	
2. 24 hour LI ≤ 0	4.7	3.8
3. 06Z SLP ≤ 1011	2.7	5.3
4. 18 hour VV ≤ 20	-7.7	6.1
5. 24 hour LI ≤ -4	4.3	6.4
6. 18 hour FOUS pressure ≤ 1005	4.8	6.8
7. 06Z surface dew point ≤ 45	-2.1	7.1
8. 06Z surface V component ≤ 15	-7.5	7.4
9. 12 hour VV ≤ 10	-2.5	7.6
10. 06Z SLP ≤ 1014	2.3	7.7
11. 24 hour LI ≤ -2	3.6	7.9
12. 24 hour LI ≤ 4	1.8	8.0
13. 06Z surface wind V component ≤ 10	-1.4	8.1

Maximum probability 43.0%

Table 1. Regression equation for severe thunderstorm occurrence 12-24 hours from FOUS data time from 00Z FOUS data and 06Z surface data. LI is PE model lifted index $^{\circ}\text{C}$. VV is 700 mb vertical motion from PE model (tenths of a microbar per second), SLP sea level pressure (mb), FOUS pressure is converted to sea level (mb) using Standard Atmosphere conditions, surface dew point $^{\circ}\text{F}$ and surface wind V component is in kt.

Predictor	Contribution to equation (percent)	Cumulative reduction of variance (percent)
1. Constant	1.6	
2. 30 hour LI ≤ -6	2.9	
3. 24 hour FOUS pressure ≤ 1011	1.1	1.2
4. 30 hour VV ≤ 10	-3.1	2.3
5. 06Z SLP ≤ 1011	2.2	2.9
6. 30 hour second level relative humidity ≤ 70	1.9	3.2
7. 30 hour LI ≤ 4	1.7	3.5
8. 30 hour LI ≤ 0	4.4	3.7
9. 36 hour VV ≤ 10	-1.1	3.8
10. 24 hour FOUS pressure ≤ 1008	1.4	3.9
		4.0

Maximum probability 17.2%

Table 2. Same as table 1 but for 24-36 hours from FOUS data time. Relative Humidity is in percent.

Predictor	Contribution to equation (percent)	Cumulative reduction of variance (percent)
1. Constant	3.2	
2. 12 hour FOUS pressure ≤ 1008	3.8	2.0
3. 18 hour LI ≤ 4	2.1	3.2
4. 12 hour LI ≤ -4	7.2	3.6
5. 18Z surface SLP ≤ 1011	2.4	4.0
6. 18 hour FOUS VV ≤ 10	-2.4	4.4
7. 18 hour FOUS R2 ≤ 70	2.0	4.6
8. 12 hour FOUS VV ≤ 10	-2.3	4.9
9. 18Z surface wind V component ≤ 5	-1.3	5.1
10. Day of the year	-.8xCos day	5.2
11. 18 hour LI ≤ 0	1.7	5.4
12. 12 hour FOUS pressure ≤ 1002	3.4	5.5
Maximum probability 26.6%		

Table 3. Same as Table 1 but from 12Z FOUS and 18Z surface data.

Predictor	Contribution to equation (percent)	Cumulative reduction of variance (percent)
1. Constant	6.4	
2. 36 hour LI ≤ 4	2.2	2.0
3. 36 hour LI ≤ -2	4.4	2.8
4. 36 hour VV ≤ 10	-1.4	3.1
5. Day of year	-1.1xCos day	3.4
6. 18Z surface SLP ≤ 1011	1.7	3.6
7. 36 hour FOUS wind V component ≤ 5	-1.0	3.7
8. 36 hour VV ≤ 20	-2.1	3.8
9. 24 hour VV ≤ 20	-1.7	3.9
10. 18Z surface wind V component ≤ 5	-.7	3.9
11. 36 hour LI ≤ 0	1.2	4.0
Maximum probability 17.0%		

Table 4. Same as Table 2 but from 12Z FOUS and 18Z surface data.

V. TEST ON INDEPENDENT DATA

A test on independent data for January thru May 1973 was made and the results are given in tables 5 thru 8. During the first period (Table 5), 24 percent of the severe occurrences are with probability of 18 or greater and 60 percent with values of 10 or greater. For the second period (Table 6) 14 percent of the severe occurrences are with probability values of 10 or greater and 38 percent with values of 7 or greater. For the 12Z first period (Table 7) about 32 percent of the severe occurrences are with values of 8 or greater. Table 8 (12Z second period) shows that about 14 percent of the severe occurrences are with values of 8 or greater. For comparison, SELS verification over the years show that about 35 percent of the severe reports occur in watch areas and about 55 percent are in or close to watch areas. The skill scores (percent improvement over climatology of the Brier score) on independent data are nearly equal to the reductions of variance for the corresponding equations on dependent data, thus indicating stability of the equations since the skill score and the reduction of variance are nearly the same thing (for a demonstration of this, see Scientific Services Division, 1970). The average forecast probabilities are roughly equal to the corresponding observed frequencies of severe occurrences, another good sign.

P%	N	FS	RFS(%)	CRFS(%)
$P \geq 18$	94	24	25.5	24.2
$18 > P \geq 10$	308	35	11.4	59.6
$10 > P \geq 6$	527	23	4.4	82.8
$6 > P \geq 1$	916	16	1.7	99.0
$1 > P$	1739	1	0.1	100.0
ALL	3584	99	2.8	
AVG. FCST PROB. = 4.0%			SKILL SCORE = 7.4%	

Table 5. Verification results from the first period equation as given in Table 1 (independent data Jan. through May 1973) with class interval (P%), number of cases (N), frequency of severe occurrence (FS), relative frequency of occurrence (RFS%), and cumulative percent of total severe occurrences (CRFS%) for each class.

	P%	N	FS	RFS(%)	CRFS(%)
	P \geq 10	44	12	27.3	14.4
10 >	P \geq 7	178	20	11.2	38.4
7 >	P \geq 4	448	26	5.8	69.7
4 >	P	3008	25	0.8	100.0
	ALL	3678	83	2.3	
AVG. FCST PROB. = 2.0%				SKILL SCORE = 5.2%	

Table 6. Same as Table 5 but for second period equation as given in Table 2.

	P%	N	FS	RFS(%)	CRFS(%)
	P \geq 16	11	4	36.4	4.9
16 >	P \geq 8	190	22	11.6	31.8
8 >	P \geq 3	530	40	6.3	80.6
3 >	P \geq 1	502	13	2.6	96.4
1 >	P	2194	3	0.1	100.0
	ALL	3427	82	2.4	
AVG. FCST PROB. = 2.1%				SKILL SCORE = 5.9%	

Table 7. Same as Table 5 but for first period equation given in Table 3.

	P%	N	FS	RFS(%)	CRFS(%)
	P \geq 8	56	13	23.2	13.9
8 >	P \geq 4	421	40	9.5	57.0
4 >	P \geq 1	1517	35	2.3	94.7
1 >	P	1438	5	0.3	100.0
	ALL	3432	93	2.7	
AVG. FCST PROB. = 2.2%				SKILL SCORE = 4.0%	

Table 8. Same as Table 5 but for second period equation as given in Table 4.

VI. CONCLUSIONS

The 00Z equations were developed early in 1973 and were available at the NSSFC for most of the 1973 severe storms season. In using the equations, forecasters have found that there are some subjective modifications that can be made to the equations, some of these are:

1. The area to the east of a maximum is more likely to have severe thunderstorms than the area to the west.
2. Severe thunderstorms are more likely when there is a maximum on the first period map which apparently moves eastward as shown by the second period map, than when a maximum remains nearly stationary.
3. Severe storms are less likely when there are high values on the first map and the second map has very low values.

Stations using the work sheets may want to work up more than their own stations. The 12Z equations were developed late in 1973 and have had little operational testing.

The equations are useful because they relate to time periods which are the same as those of the fax convective outlook. They cannot be compared directly with the Techniques Development Laboratory equations (FAX F040C) because the TDL equations are for a shorter time period around 00Z. The SELS watch areas are of higher skills, but the equations should not be compared with them because the watches are for smaller areas and have shorter lead times. The convective outlooks at the NSSFC have never been verified and there is no direct way to compare the equations with the convective outlooks, but the equations have been found to be an aid in preparing the outlook, and should be an aid to field stations in understanding and using the outlook.

In summary, predictors from the PE model are very useful in forecasting areas of expected severe thunderstorms. When combined with observed surface data the first period equation of Table 1 has a greater reduction of variance than a similar equation developed by Miller and David (1971) using observed 12Z surface and radiosonde data.

VII. ACKNOWLEDGEMENTS

The author wishes to thank Dr. Harry R. Glahn of the National Weather Service Techniques Development Laboratory for furnishing the screening regression program, the members of the computer operating staff of the NSSFC for their efforts and patience in the computer operations necessary for this type of study, and Dr. Wayne E. Sangster of Central Region Headquarters for his help and comments.

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May 1974

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Weather Service

WORKSHEET FOR SEVERE THUNDERSTORM PROBABILITIES
FROM 00Z FOUS AND 06Z SURFACE DATA

Enter in the blank spaced the probability increment first encountered, scanning from top to bottom, that meets the conditions specified for the data at hand. LE means "less than or equal to". GT means "greater than". The final probability is the sum of all the increments.

<u>FIRST PERIOD 12-24Z</u>	<u>SECOND PERIOD 00-12Z</u>
<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">↑</div> <div> 12 Hr VV <div style="display: flex; justify-content: space-between; width: 100%;"> LE 10 -2 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 10 0 </div> </div> </div>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; margin-right: 5px;">↑</div> <div> 24 Hr SLP <div style="display: flex; justify-content: space-between; width: 100%;"> LE 1008 3 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> LE 1011 1 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 1011 0 </div> </div> </div>
<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">↑</div> <div> 18 Hr VV <div style="display: flex; justify-content: space-between; width: 100%;"> LE 20 0 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 20 8 </div> </div> </div>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; margin-right: 5px;">↑</div> <div> 30 Hr R2 <div style="display: flex; justify-content: space-between; width: 100%;"> LE 70 2 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 70 0 </div> </div> </div>
<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">↑</div> <div> 18 Hr SLP <div style="display: flex; justify-content: space-between; width: 100%;"> LE 1005 5 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 1005 0 </div> </div> </div>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; margin-right: 5px;">↑</div> <div> 30 Hr VV <div style="display: flex; justify-content: space-between; width: 100%;"> LE 10 -3 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 10 0 </div> </div> </div>
<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">↑</div> <div> 24 Hr LI <div style="display: flex; justify-content: space-between; width: 100%;"> LE -4 14 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> LE -2 10 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> LE 0 7 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> LE 4 2 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 4 0 </div> </div> </div>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; margin-right: 5px;">↑</div> <div> 30 Hr LI <div style="display: flex; justify-content: space-between; width: 100%;"> LE -6 9 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> LE 0 5 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> LE 4 2 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 4 0 </div> </div> </div>
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<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">↑</div> <div> 06Z Dew Point <div style="display: flex; justify-content: space-between; width: 100%;"> LE 45 0 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 45 2 </div> </div> </div>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; margin-right: 5px;">↑</div> <div> 06Z SLP <div style="display: flex; justify-content: space-between; width: 100%;"> LE 1011 2 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 1011 0 </div> </div> </div>
<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">↑</div> <div> 06Z V Component of wind <div style="display: flex; justify-content: space-between; width: 100%;"> LE 10 0 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> LE 15 1 </div> <div style="display: flex; justify-content: space-between; width: 100%;"> GT 15 9 </div> </div> </div>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; margin-right: 5px;">↑</div> <div> Sum of Increments (Maximum 17%) </div> </div>
<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">↑</div> <div> Sum of Increments (Maximum 43%) </div> </div>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; margin-right: 5px;">↑</div> <div> Sum of Increments (Maximum 17%) </div> </div>

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Weather ServiceWORKSHEET FOR SEVERE THUNDERSTORM PROBABILITIES
FROM 12Z FOUS AND 18Z SURFACE DATA

Enter in the blank spaces the probability increment first encountered, scanning from top to bottom, that meets the conditions specified for the data at hand. LE means "less than or equal to". GT means "greater than". The final probability is the sum of all the increments.

<u>FIRST PERIOD 00-12Z</u>				<u>SECOND PERIOD 12-24Z</u>			
↑ 12Z FOUS ↓	12 Hr VV			↑ 12Z FOUS ↓	24 Hr VV		
	LE 5	-2			LE 20	0	
	GT 5	0	_____		GT 20	2	_____
	12 Hr LI				36 Hr VV		
	LE -4	7			LE 10	0	
	GT -4	0	_____		LE 20	1	
	12 Hr SLP				GT 20	4	_____
	LE 1002	7			36 Hr LI		
	LE 1008	4			LE -2	8	
	GT 1008	0	_____		LE 0	3	
↑ 12Z FOUS ↓	18 Hr R2			↑ 12Z FOUS ↓	LE 4	2	
	LE 70	2			GT 4	0	_____
	GT 70	0	_____		36 Hr V component of DDFF		
	18 Hr VV				LE 5	0	
	LE 10	0			GT 5	1	_____
	GT 10	2	_____		18Z SLP		
	18 Hr LI				LE 1011	2	
	LE 0	4			GT 1011	0	_____
	LE 4	2			18Z V component of wind		
	GT 4	0	_____		LE 5	-1	
↑ OBSVD SFC ↓	18Z SLP			↑ OBSVD SFC ↓	GT 5	0	_____
	LE 1011	3			(Day of Year)		
	GT 1011	0	_____				
	18Z V Component of wind						
	LE 5	-1					
	GT 5	0	_____				
	Day of Year						
	Sum of increments		_____		Sum of increments		_____
	(Maximum 26%)				(Maximum 18%)		

DEFINITIONS AND UNITS

- R2 -- Mean relative humidity of the lowest tropospheric layer, in percent.
- VV -- Vertical Velocity at 700 mb, in tenths of a microbar per second.
- LI -- Lifted index, in degrees Celsius. Negative values are designated by subtracting from 100: e. g. -4 = 96.
- DDFF- Direction, in tens of degrees, and speed, in knots, of the mean wind in the boundary layer of the PE model.
- PB -- Mean pressure of the boundary layer, in millibars, with the hundreds position omitted.
- SLP - Sea Level Pressure, either observed from surface chart or obtained by adding correction in Table 1A to PB if FOUS data are being used.

Dew Point is in degrees Fahrenheit.

V component of the wind is the south component (a northerly wind has a negative V component). Use Table 2A to find its value.

Day of the Year Increment

<u>First period 00-12Z</u>	<u>Second period 12-24Z</u>
May 22 to Aug. 19 1	Apr. 27 to Aug. 31 1
Nov. 25 to Feb. 20 -1	Oct. 24 to Mar. 4 -1
Remainder of year 0	Remainder of year 0

TABLE 1A. Pressure (mb) to add to FOUS pressure to get the FOUS SLP used in the work sheet.

BGR 47	BUF 65	OMA 83	CLE 61	ELP 213	ALB 65
DSM 67	IND 52	BRO 49	FSD 87	ORD 52	DDC 134
BOS 53	MSP 66	SAT 61	RAP 145	MKE 54	BIS 104
GSW 58	DAY 55	MIA 25	CAE 56	LBB 133	DRT 96
LAL 26	LIT 45	MEM 40	IPT 55	ABQ 254	BHM 38
HAT 33	TLH 31	ATL 51	PIT 72	DEN 243	HOU 35
JFK 54	TYS 82	JAN 33	PHL 58	CYS 238	OKC 83
RDU 61	INL 66	STL 53	BIL 155	SSM 49	TOP 78
CRW 72	BTV 71	LBF 141	NEW 27	DCA 58	SDF 55
DET 54					

V (SOUTH) WIND COMPONENT

A-4

(continued from front inside cover)

- NWS CR 48 Manual of Great Lakes Ice Forecasting. C. Robert Snider -
December 1971 (COM-72-10143)
- NWS CR 49 A Preliminary Transport Wind and Mixing Height Climatology
St. Louis, Missouri Donald E. Wuerch, Albert J. Courtois,
Carl Ewald, Gary Ernst June 1972 (COM-72-10859)
- NWS CR 50 An Objective Forecast Technique for Colorado Downslope Winds
Wayne E. Sangster December 1972 (COM-73-10280)
- NWS CR 51 Effect on Temperature and Precipitation of Observation Site
Change at Columbia, Missouri March 1973 (COM-73-10734)
- NWS CR 52 Cold Air Funnels. Jack R. Cooley and Marshall E. Soderberg
September 1973 (COM-73-11753)
- NWS CR 53 The Frequency of Potentially Unfavorable Temperature
Conditions in St. Louis, Missouri October 1973