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

Clarence L. David

Central Region
Kansas City, Mo.
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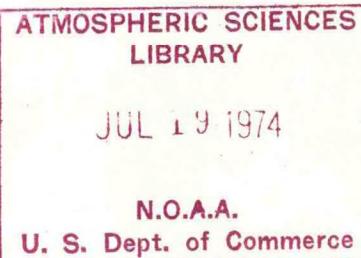
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CENTRAL REGION

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

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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 predict-and 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.

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*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).

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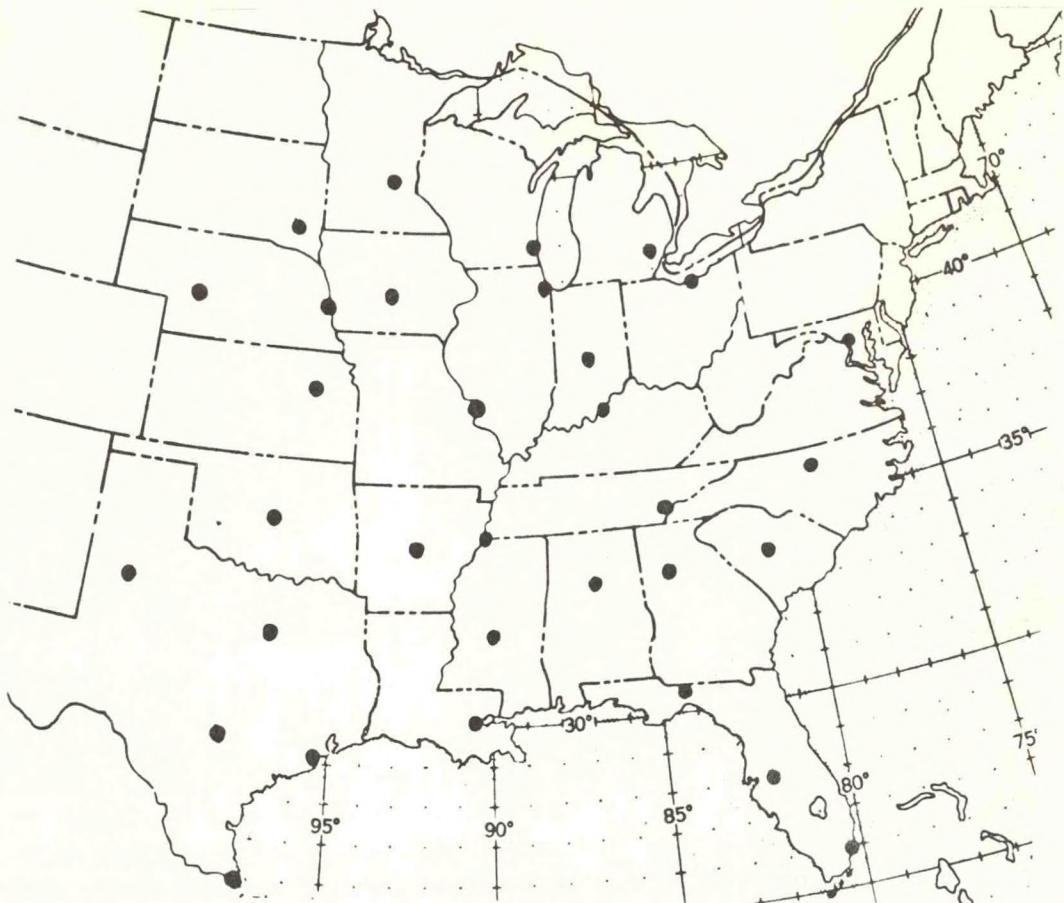
Figure 1.   Stations used in developing equations.

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.

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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 ^{o}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 ^{o}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	1.2
3. 24 hour FOUS pressure ≤1011	1.1	2.3
4. 30 hour VV≤10	-3.1	2.9
5. 06Z SLP≤1011	2.2	3.2
6. 30 hour second level relative humidity ≤70	1.9	3.5
7. 30 hour LI≤4	1.7	3.7
8. 30 hour LI≤0	4.4	3.8
9. 36 hour VV≤10	-1.1	3.9
10. 24 hour FOUS pressure ≤1008	1.4	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 $\leq$ 1008	3.8	2.0
3. 18 hour LI $\leq$ 4	2.1	3.2
4. 12 hour LI $\leq$ -4	7.2	3.6
5. 18Z surface SLP $\leq$ 1011	2.4	4.0
6. 18 hour FOUS VV $\leq$ 10	-2.4	4.4
7. 18 hour FOUS R2 $\leq$ 70	2.0	4.6
8. 12 hour FOUS VV $\leq$ 10	-2.3	4.9
9. 18Z surface wind V component $\leq$ 5	-1.3	5.1
10. Day of the year	-.8 x Cos day	5.2
11. 18 hour LI $\leq$ 0	1.7	5.4
12. 12 hour FOUS pressure $\leq$ 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 $\leq$ 4	2.2	2.0
3. 36 hour LI $\leq$ -2	4.4	2.8
4. 36 hour VV $\leq$ 10	-1.4	3.1
5. Day of year	-1.1 x Cos day	3.4
6. 18Z surface SLP $\leq$ 1011	1.7	3.6
7. 36 hour FOUS wind V component $\leq$ 5	-1.0	3.7
8. 36 hour VV $\leq$ 20	-2.1	3.8
9. 24 hour VV $\leq$ 20	-1.7	3.9
10. 18Z surface wind V component $\leq$ 5	-.7	3.9
11. 36 hour LI $\leq$ 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≧18	94	24	25.5	24.2
18 > P≧10	308	35	11.4	59.6
10 > P≧6	527	23	4.4	82.8
6 > P≧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 <u>more</u> likely to have severe thunderstorms than the area to the west.

2. Severe thunderstorms are <u>more</u> 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 <u>less</u> 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

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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 <u>first</u> 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.

FIRST PERIOD 12-24Z

00Z FOUS

12 Hr VV
LE 10	-2
GT 10	0

18 Hr VV
LE 20	0
GT 20	8

18 Hr SLP
LE 1005	5
GT 1005	0

24 Hr LI
LE -4	14
LE -2	10
LE 0	7
LE 4	2
GT 4	0

OBSVD SFC

06Z SLP
LE 1011	5
LE 1014	2
GT 1014	0

06Z Dew Point
LE 45	0
GT 45	2

06Z V Component of wind
LE 10	0
LE 15	1
GT 15	9

Sum of Increments ____
(Maximun 43%)

SECOND PERIOD 00-12Z

00Z FOUS

24 Hr SLP
LE 1008	3
LE 1011	1
GT 1011	0

30 Hr R2
LE 70	2
GT 70	0

30 Hr VV
LE 10	-3
GT 10	0

30 Hr LI
LE -6	9
LE 0	5
LE 4	2
GT 4	0

36 Hr VV
LE 10	0
GT 10	1

OBSVD SFC

06Z SLP
LE 1011	2
GT 1011	0

Sum of Increments ____
(Maximum 17%)

A-1

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Weather Service

WORKSHEET 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 pro-
bability is the sum of all the increments.

FIRST PERIOD 00-12Z

12 Hr VV
    LE 5   -2 ____
    GT 5   0 ____

12 Hr LI
    LE -4   7 ____
    GT -4   0 ____

12 Hr SLP
    LE 1002   7
    LE 1008   4
    GT 1008   0 ____

18 Hr R2
    LE 70   2
    GT 70   0 ____

18 Hr VV
    LE 10   0
    GT 10   2 ____

18 Hr LI
    LE 0   4
    LE 4   2
    GT 4   0 ____

18Z SLP
    LE 1011   3
    GT 1011   0 ____
18Z V Component of wind
    LE 5   -1
    GT 5   0 ____
Day of Year
                    ____

Sum of increments ____
(Maximum 26%)

SECOND PERIOD 12-24Z

24 Hr VV
    LE 20   0
    GT 20   2 ____

36 Hr VV
    LE 10   0
    LE 20   1
    GT 20   4 ____

36 Hr LI
    LE -2   8
    LE 0   3
    LE 4   2
    GT 4   0 ____

36 Hr V component of DDFF
    LE 5   0
    GT 5   1 ____

18Z SLP
    LE 1011   2
    GT 1011   0 ____

18Z V component of wind
    LE 5   -1
    GT 5   0 ____

(Day of Year)
                    ____

Sum of increments ____
(Maximum 18%)

12Z FOUS · OBSVD SFC · 12Z FOUS · OBSVD SFC

A-2

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

First period 00-12Z		Second period 12-24Z	
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										

TABLE 2A

V (SOUTH) WIND COMPONENT

DIRECTION — speeds 0–29

SPEED	180/180	190/170	200/160	210/150	220/140	230/130	240/120	250/110	260/100
0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	0	0
2	2	2	2	2	2	1	1	1	0
3	3	3	3	3	2	2	2	1	1
4	4	4	4	3	3	3	2	1	1
5	5	5	5	4	4	3	3	2	1
6	6	6	6	5	5	4	3	2	1
7	7	7	7	6	5	5	4	2	1
8	8	8	8	7	6	5	4	3	1
9	9	9	8	8	7	6	5	3	2
10	10	10	9	9	8	6	5	3	2
11	11	11	10	10	8	7	6	4	2
12	12	12	11	10	9	8	6	4	2
13	13	13	12	11	10	8	7	4	2
14	14	14	13	12	11	9	7	5	2
15	15	15	14	13	11	10	8	5	3
16	16	16	15	14	12	10	8	5	3
17	17	17	16	15	13	11	9	6	3
18	18	18	17	16	14	12	9	6	3
19	19	19	18	16	15	12	10	6	3
20	20	20	19	17	15	13	10	7	3
21	21	21	20	18	16	14	11	7	4
22	22	22	21	19	17	14	11	8	4
23	23	23	22	20	18	15	12	8	4
24	24	24	23	21	18	15	12	8	4
25	25	25	23	22	19	16	13	9	4
26	26	26	24	23	20	17	13	9	5
27	27	27	25	23	21	17	14	9	5
28	28	28	26	24	21	18	14	10	5
29	29	29	27	25	22	19	15	10	5

DIRECTION — speeds 30–59

SPEED	180/180	190/170	200/160	210/150	220/140	230/130	240/120	250/110	260/100
30	30	30	28	26	23	19	15	10	5
31	31	31	29	27	24	20	16	11	5
32	32	32	30	28	25	21	16	11	6
33	33	32	31	29	25	21	17	11	6
34	34	33	32	29	26	22	17	12	6
35	35	34	33	30	27	23	18	12	6
36	36	35	34	31	28	23	18	12	6
37	37	36	35	32	28	24	19	13	6
38	38	37	36	33	29	24	19	13	7
39	39	38	37	34	30	25	20	13	7
40	40	39	38	35	31	26	20	14	7
41	41	40	39	36	31	26	21	14	7
42	42	41	39	36	32	27	21	14	7
43	43	42	40	37	33	28	22	15	7
44	44	43	41	38	34	28	22	15	8
45	45	44	42	39	34	29	23	15	8
46	46	45	43	40	35	30	23	16	8
47	47	46	44	41	36	30	24	16	8
48	48	47	45	42	37	31	24	16	8
49	49	48	46	42	38	32	25	17	9
50	50	49	47	43	38	32	25	17	9
51	51	50	48	44	39	33	26	17	9
52	52	51	49	45	40	33	26	18	9
53	53	52	50	46	41	34	27	18	9
54	54	53	51	47	41	35	27	18	9
55	55	54	52	48	42	35	28	19	10
56	56	55	53	49	43	36	28	19	10
57	57	56	54	49	44	37	29	20	10
58	58	57	55	50	44	37	29	20	10
59	59	58	55	51	45	38	30	20	10

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