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METEOROLOGICAL OFFICE

FORECASTING TECHNIQUES MEMORANDUM

Nº 19

THIRD REPORT ON TESTS OF THUNDERSTORM FORECASTING METHODS

by

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G04684/PH/2/70/200

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1. Introduction

A number of thunderstorm forecasting techniques were tested at forecasting offices under the author's control in 1965[1] and 1966[2]. The tests were then discontinued for a time, because it appeared that little more could be done with the methods then available, but were resumed in the summer of 1969 to include methods published since the earlier tests.

2. Methods tested

Methods dealt with in 1969 include those found most useful in earlier years, those of Rackliff[3], modified Jefferson[4] and Boyden[5]. New methods tried were those of Peskov[6], Fateev[7] and Cox[8]. As before, the normal forecasting of Manby forecasters was included under the designation "general practice". Critical values used in the older methods were those found best in this area, namely:-

Rackliff	29/30
modified Jefferson	27/28 (but 26/27 in returning polar maritime (RPM) air)
Boyden	94/95

Peskov's paper suggests use of a "non-adiabatic index", which allows for dew-point depression at 700 and 500 mb., as well as for the magnitude of air influx at these levels. This index, using afternoon data, was stated by Peskov to give a general correctness of 71%. The general practice accuracy of yes/no forecasts, based on early morning data, is in the range 79-88% for a large area, and 94% for a single aerodrome[1,2]. It therefore seemed unlikely that the non-adiabatic index would lead to much improvement, and it was not included. Peskov also provided two diagrams which give the distribution of thunderstorms in relation to (a) dew-point depression at 700 and 500 mb levels, and (b) deviation of the process curve from the environmental curve at 700 and 500 mb. The probabilities (P_1, P_2) of thunderstorms from these two diagrams were combined on a single diagram to give a thunderstorm probability (P_3). This simultaneous allowance for four parameters (again using afternoon data) raised the general accuracy to 83%. Peskov then provided a further table giving the lowest values of P_3 for which thunderstorms occurred with different 700 mb contour patterns. This table shows that

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considerably differing thermodynamic conditions are required for thunderstorm development in different types of distribution at 700 mb. Use of this table is said to increase the general accuracy to 90%.

Fateev proposed an instability index given by:-

$$A = (T_{850} - T_{500}) - \sum_{i=1}^{4} \Delta i$$

where T_{850} = temperature at 850 mb (deg.C)

T_{500} = temperature at 500 mb

$\sum_{i=1}^{4} \Delta i$ = sum of dew-point depressions (T - Td) at 850, 700, 600 and 500 mb.

When $A \geqslant 0$ thunderstorms are forecast. If $(T_{850} - T_{500}) \leqslant 22^\circ$, or at any of the levels $(T - Td) \geqslant 12^\circ$, calculation of the index is not carried out: it is taken to be negative.

Index A was plotted on the 700 mb contour chart, together with the positions of surface fronts. Fronts and isopleths of A = 0 were advected at speed 0.8 times the wind speed at 700 mb, and positions found for 15 - 18 hours ahead. Thunderstorms were forecast for zones where $A \geqslant 0$, with the following restrictions:-

(i) Thunderstorms were not expected in the zone 100 - 400 km behind a cold front, even with A positive.

(ii) At warm fronts, thunderstorms were not predicted between the surface front and 50 km on the warm side of it.

(iii) On occlusions, thunderstorms were forecast depending on the type of front and index A.

(iv) If the base of a jet stream zone (undefined) lay below a height of 7 km, then independently of the value of A and fronts, no thunderstorms were forecast.

Fateev reported that in 197 test forecasts, thunderstorms occurred on more than 90% of occasions when $A \geqslant 0$.

In Cox's method the representative upper air ascent is analysed for four parameters, as follows:-

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(i) A modified version of the Severe Weather Warning Centre Stability Index is found by raising the mean wet-bulb temperature of the lowest 100 mb layer moist adiabatically to 500 mb, and then subtracting the temperature thus found from the reported 500 mb temperature.

(ii) The temperature dew-point difference (T - Td) at 700 mb. This is used as a quantitative value of the available middle level moisture.

(iii) The "C" stability value. This is found by descending dry adiabatically from the dry-bulb temperature at 850 mb to 1000 mb, then ascending moist adiabatically to 600 mb. The C value is the difference in the temperature thus found and the reported 600 mb temperatures. A table of values of C as a function of the 850 and 600 mb temperatures is provided.

(iv) The Lifting Condensation Level is found by the intersection of the surface mixing ratio curve with the surface dry adiabatic.

The parameters are combined into two forecast graphs. If both graphs indicate "YES", thunderstorms are forecast. If both indicate "NO", thunderstorms are not forecast. In marginal cases, one diagram indicating "YES" and the other "NO", thunderstorms are forecast only if there is surface cyclonic curvature in the area.

Cox reported that in tests covering 149 days in eastern Virginia, forecasts based on 1200 GMT data were successful on 92% of occasions, with skill score 0.86.

3. The current tests

As in earlier tests, the work was confined to Mondays to Fridays in the period 1st April to 30th September.

Forecasters were asked to use early morning upper air data with the chosen technique, to allow for effects of advection and surface heating as appropriate, and record a simple "yes" or "no" forecast for thunderstorms in the Manby Group Area in the period 1200-2400 GMT. At the same time, forecasts for individual aerodromes, in this case Leeming, Linton and Manby, were included.

In marking the results, SFLOC reports were counted as positive.

4. Discussion of results

The results for area forecasts are presented in Tables I to VII, on the same basis as for earlier tests. The main features of interest seem to be as follows:

(i) Overall accuracy (Table I) showed a slight decrease from 1966 in General Practice, and in use of the Jefferson index, while remaining better than in 1965. There was a more pronounced decline in accuracy using the Rackliff and Boyden indices.

(ii) General Practice continued to give better results than any individual technique.

(iii) Tables IV and VII show that the decrease in accuracy was most pronounced in occasions classified as in RPM air masses. There is no apparent explanation for this.

(iv) Among the individual techniques, that due to Peskov seems to be the most promising for future work and further development.

Time taken in use of the Peskov method at Topcliffe was on average 8 minutes per day, with a maximum of 30 minutes. Peskov's table relating the thunderstorm probability P_3 to the 700 mb contour distribution was found a little difficult to apply. His "breaking up" case was taken to refer to a rapid change from cyclonic to anticyclonic type. A 50% threshold value for straight contours was used. On further consideration this was reduced to 35%, so that Peskov's table would become as below:-

700 mb pattern	(i) Marked troughing	(ii) Cyclonic curvature	(iii) Straight Contours	(iv) Marked ridge	(v) Anticyclonic curvature	(vi) Change from (i) or (ii) to (iv) or (v)
Threshold value (%)	10	25	35	45	60	75

Fateev's method occupied on average 5 minutes per day, with a maximum of 20 minutes. It includes use of 600 mb data, which is not directly available from coded messages. It appears to lean heavily on humidity.

Table VIII gives the accuracy of forecasting for individual aerodromes by general practice. It confirms a point noted in the 1966 tests - that it is more difficult to forecast thunderstorms near a coast than it is well inland. It shows that quite a good standard of accuracy is obtained at inland stations - see especially the results for Linton.

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5. Conclusions

It remains true that none of the older techniques tested seem likely to improve upon general practice. The current round of tests suggest that the Jefferson index is the most useful, but if the three series of tests are taken together it appears there is little to choose between this and the Rackliff and Boyden indices.

Among more recent approaches, the method of Peskov seems the most promising, and is perhaps the one best suited for further development and adaption for use in the UK.

6. Acknowledgments

Thanks are due to the forecasting staff at Manby and outstations for their efforts in this further round of tests.

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Method	Testing Station	Accuracy of "Yes/No" forecasts (1969)			Accuracy of "Yes" forecasts (1969)			Accuracy of "No" forecasts (1969)			Skill Score		
		Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	1969	1966	1965
General Practice	Manby	123	106	86	34	26	76	89	80	90	0.66	0.73	0.54
Boyden 94/95	Leeming	95	67	71	31	14	45	64	53	83	0.29	0.61	-
Peskov	Topcliffe	123	100	81	38	25	66	85	75	88	0.55	-	-
Fateev	Topcliffe	123	97	79	31	20	65	92	77	84	0.46	-	-
Cox	Linton	121	86	71	3	1	33	118	85	72	0.01	-	-
Jefferson 27/28 (or 26/27 in RPM)	Strubby	116	92	79	26	17	65	90	75	83	0.45	0.51	0.36
Rackliff 29/30	Syerston	122	91	75	33	18	55	89	73	82	0.36	0.57	0.46

T A B L E I

Overall accuracy of thunderstorm forecasts

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Method	Accuracy of "Yes/No" forecasts (1969)			Accuracy of "Yes" forecasts (1969)			Accuracy of "No" forecasts (1969)			Skill Score		
	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	1969	1966	1965
General Practice	39	32	82	17	13	76	22	19	86	0.63	0.71	0.45
Boyden 94/95	29	17	59	10	5	50	19	12	63	0.13	0.50	–
Peskov	39	30	77	17	12	71	22	18	82	0.53	–	–
Fateev	39	28	72	13	9	69	26	19	73	0.40	–	–
Cox	38	22	58	1	0	0	37	22	59	–	–	–
Jefferson 27/28 (26/27 in RPM)	36	28	78	12	9	75	24	19	79	0.52	0.28	0.47
Rackliff 29/30	39	25	64	20	11	55	19	14	74	0.29	0.47	0.34

<u>T A B L E II</u>

<u>Accuracy of thunderstorm forecasts for frontal or trough occasions</u>

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Method	Accuracy of "Yes/No" forecasts (1969)			Accuracy of "Yes" forecasts (1969)			Accuracy of "No" forecasts (1969)			Skill Score	
	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	1969	1966
General Practice	32	31	97	8	7	87	24	24	100	0.91	0.65
Boyden 94/95	27	23	85	8	4	50	19	19	100	0.59	0.52
Peskov	32	29	91	8	6	75	24	23	96	0.74	-
Fateev	32	28	87	7	5	71	25	23	92	0.63	-
Cox	32	25	78	0	0	0	32	25	78	-	-
Jefferson 27/28	31	27	87	5	4	80	26	23	88	0.59	0.52
Rackliff 29/30	31	28	90	7	5	71	24	23	96	0.71	0.56

TABLE III

Accuracy of thunderstorm forecasts for polar maritime air masses

Method	Accuracy of "Yes/No" forecasts (1969)			Accuracy of "Yes" forecasts (1969)			Accuracy of "No" forecasts (1969)			Skill Score	
	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	1969	1966
General Practice	31	21	68	12	8	67	19	13	68	0.34	0.80
Boyden 94/95	24	12	50	9	4	44	15	8	53	–	0.67
Peskov	31	20	65	15	9	60	16	11	69	0.29	–
Fateev	31	19	61	14	8	57	17	11	65	0.22	–
Cox	30	16	53	1	0	0	29	16	55	–	–
Jefferson 26/27	30	19	63	10	6	60	20	13	65	0.23	0.56
Rackliff 29/30	31	19	61	16	9	56	15	10	67	0.23	0.63

TABLE IV

Accuracy of thunderstorm forecasts for returning polar maritime air masses

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Method	Accuracy of "Yes/No" forecasts (1969)			Accuracy of "Yes" forecasts (1969)			Accuracy of "No" forecasts (1969)			Skill Score	
	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	1969	1966
General Practice	60	54	90	14	11	79	46	43	93	0.72	0.46
Boyden 94/95	44	32	73	14	6	43	30	26	87	0.32	–
Peskov	60	51	85	15	10	67	45	41	91	0.59	–
Fateev	60	50	83	10	7	70	50	43	86	0.48	–
Cox	59	45	76	2	1	50	57	44	77	0.07	–
Jefferson 27/28	55	46	84	11	7	64	44	39	89	0.51	–
Rackliff 29/30	60	44	73	10	4	40	50	40	80	0.17	–

T A B L E V

Accuracy of thunderstorm forecasts for warm and miscellaneous air masses

Method	All occasions					Frontal or trough days					Convection days				
	Number of thunderstorms (1969)	Number forecast correctly	% correct			Number of thunderstorms (1969)	Number forecast correctly	% correct			Number of thunderstorms (1969)	Number forecast correctly	% correct		
			1969	1966	1965			1969	1966	1965			1969	1966	1965
General Practice	35	26	74	87	72	16	13	91	89	65	19	13	68	83	76
Boyden 94/95	25	14	56	75	–	12	5	42	64	–	13	9	69	100	–
Peskov	35	25	71	–	–	16	12	75	–	–	19	13	68	–	–
Fateev	35	20	57	–	–	16	9	56	–	–	19	11	58	–	–
Cox	34	1	3	–	–	15	0	0	–	–	19	1	5	–	–
Jefferson 27/28 (26/27 in RPM)	32	17	53	65	62	14	9	64	57	76	18	8	44	83	54
Rackliff 29/30	34	18	53	67	56	16	11	69	61	44	18	7	39	82	63

T A B L E VI

Accuracy of forecasts on thunderstorm days: frontal or trough days and convection days

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Method	Polar Maritime Air Masses				Returning Polar Maritime Air Masses				Warm and Miscellaneous Air Masses			
	Number of thunder-storms (1969)	Number forecast correctly	% correct		Number of thunder-storms (1969)	Number forecast correctly	% correct		Number of thunder-storms (1969)	Number forecast correctly	% correct	
			1969	1966			1969	1966			1969	1966
General Practice	7	7	100	75	14	8	57	96	14	11	79	100
Boyden 94/95	4	4	100	69	11	4	36	83	10	6	60	0
Peskov	7	6	86	–	14	9	64	–	14	10	71	–
Fateev	7	5	71	–	14	8	57	–	14	7	50	–
Cox	7	0	0	–	13	0	0	–	14	1	7	–
Jefferson 27/28 (26/27 in RPM)	7	4	57	56	13	6	46	74	12	7	58	0
Rackliff 29/30	6	5	83	60	14	9	64	74	14	4	29	0

T A B L E VII

Accuracy of forecasts on thunderstorm days related to air mass

	Accuracy of "Yes/No" forecasts (1969)			Accuracy of "Yes" forecasts (1969)			Accuracy of "No" forecasts (1969)			Skill Score	
Station	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	Number of forecasts	Number correct	% correct	1969	1966
Manby	123	111	90	16	8	50	107	103	96	0.52	-
Linton	121	118	98	13	11	85	108	107	99	0.87	-
Leeming	123	116	94	10	5	50	113	111	98	0.56	0.64

T A B L E VIII

Accuracy of general practice forecasts for individual aerodromes

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