METEOROLOGICAL OFFICE

FORECASTING TECHNIQUES BRANCH MEMORANDUM

No. 7

FORECASTING METHODS AND TECHNIQUES IN USE AT METEOROLOGICAL OFFICE OUTSTATIONS

by

W.D.S. McCaffery and T.N.S. Harrower

July 1965

F.T.B.M. 7

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P.3042/LG/7/65/175

Forecasting methods and techniques in use at Meteorological Office outstations

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Section

Annexes

P.3042/LG/7/65/175

Forecasting methods and techniques in use at Meteorological Office outstations

1. Introduction In training forecasters in the Meteorological Office it has always been the policy to avoid, where possible, rule of thumb methods of forecasting, while encouraging students to apply basic physical principles in their understanding of atmospheric processes and the application of these principles to their forecast problems. A consequence of this policy is that several different methods of, for example, forecasting fog are explained to the student, as much for the purpose of underlining the physics of fog formation as for the methods of forecasting themselves. The student is afterwards allowed to follow his professional career with the, perhaps somewhat doubtful, advantage of being free to use in his work any forecasting methods and techniques which he has acquired or may in future acquire. We shall return to a discussion of this philosophy later in this report, but it is clear that we can expect a wide variety of techniques to be in current use, especially when it is remembered that UK based forecasters may be forecasting in areas far removed from Britain, as well as for customers with such widely divergent requirements as those of civil and military aviation, agriculture, and public services both national and individual.

During a review of the technical control exercised by Main Meteorological Offices over their dependent outstations it became apparent that a knowledge was desirable of the forecasting techniques actually in use at outstations, particularly techniques in regular use. All forecasting outstations at home and abroad were therefore asked to submit papers on this subject. This report summarises the replies received and, together with the replies themselves, will provide the basis for study of, and further work on, forecasting methods and techniques.

The replies from outstations varied considerably in the amount of information they included when describing techniques in use, but many detailed and exhaustive accounts were returned, including some useful ideas and suggestions. Altogether some 300 pages of typescript, about 170,000 words, were received; forecasters were clearly interested in this exercise in self-analysis, and stimulated into thinking about, discussing with each other, and putting on paper their thoughts and suggestions about forecasting methods in use at their own stations.

2. The raw material

The following questions were posed by headquarters to give guidance as to what might be included in the station report on methods and techniques used in forecasting:-

(1) What techniques are used for area, flight, aerodrome, local and public service forecasting? References should be given to source material, e.g. Handbook of Weather Forecasting, Meteorological Magazine, etc.

(2) What techniques are most popular and useful in the opinion of forecasters?

(3) What techniques would forecasters like to use, but for which time is not normally available?

(4) What techniques have been tried and found wanting?

(5) What suggestions for new techniques would forecasters like developed?

A preliminary analysis of the replies received has been carried out and tabulated at Annexes A and B. This analysis, for home and overseas stations separately, classifies techniques into the following categories:-

(1) technique is in use

(2) technique is in use, popular and helpful

/ (3)

(3) technique is in use, very helpful

(4) technique is in use, but not found satisfactory

(5) technique is in use, but limited applicability

(6) technique tried and found wanting; not now used

(7) station would like to use technique, but time or equipment not available.

These annexes clearly indicate the wide variety of methods and techniques in use even at stations with similar commitments. This variety is also indicated in Annex C which shows a breakdown of the returns made by certain stations which reported by individual forecaster.

Annex B, which analyses techniques used at overseas stations, shows that stations in Germany, as may be expected, use similar methods and techniques to those in use at stations in UK. At other overseas stations methods vary widely with locality.

3. Suggestions for research and development

Suggestions for further research and development contained in the replies from outstations have been tabulated at Annex D to show:-

(1) development requested

(2) development strongly supported

(3) development very strongly supported.

A detailed study of these suggestions has been made in Met.0.8 and each suggestion compared with items in the Meteorological Office programme of research as detailed in MRCP 155 (Meteorological Research Committee, Programme of Research, 1964). Some suggested lines of development are problems of organisation and administration, e.g. increased use of radar, issue of short-term, limited-area prebaratics. Most other suggestions are either covered directly by an item in the research programme, or are specialised aspects of some such item. There remained a number of suggestions for research into subjects which did not seem to be covered, or to be adequately covered, by items in the research programme. Consequently Met.0.8 submitted a list of items (and some amendments to existing items) for possible inclusion in the 1965 programme of research. After study by the Directorate and the Meteorological Research Committee three of these items were accepted for inclusion in MRCP 166 (Meteorological Research Committee, Programme of Research, 1965). These are:

Item 2.1.1.5. The formation, development and movement of non-frontal troughs and polar lows.

Item 2.4.3.1. Conditions (e.g. ground temperature, ground conductivity) under which falling snow may be expected to lie.

Item 2.9.3. Use of satellite pictures and other satellite data as aids for forecasting.

4. Guidance to forecasters

In the introduction to this report a basic philosophy in the training of forecasters was briefly mentioned. A sound training in the scientific principles underlying atmospheric processes and forecasting methods is given at Training School. A knowledge of forecasting techniques is also acquired there, both on initial and subsequent courses. Further techniques are acquired by the forecaster who assiduously reads meteorological literature, attends discussions or colloquia, benefits from the skill of a more experienced

/ colleague

colleague and so on. But little guidance is given as to the relative merits of different techniques for solving the same forecast problem and the practising forecaster is left to select for himself which forecasting technique he will use in any given circumstance. It is therefore not surprising that different techniques are in use at different stations, or that different techniques are used by different forecasters at the same station when making similar types of forecast.

Many things may influence a forecaster in his choice of a technique; available time and facilities for instance can impose severe limitations. But a major obstacle to a sound and reasoned choice is the almost complete lack of adequately controlled comparative tests between techniques, the results of which could enable a forecaster to be more objective in his selection. The increasing use of machine methods and the development of objective techniques of forecasting make it imperative that forecasters should know clearly the likely degree of success to be achieved by using different methods. Again many so-called objective techniques involve the use of parameters which themselves have to be forecast; and the accuracy claimed for a technique is often based on the unreal assumption of high accuracy in forecasting the necessary parameters. Extensive field tests under normal routine operational conditions are thus becoming more and more necessary to aid the forecaster in his choice of methods.

Whenever data from comparative tests are available, or become available, forecasters should be encouraged to use techniques with the highest ratings, unless there are very good reasons, e.g. lack of ancilliary material, for doing otherwise. Instead of leaving forecasters entirely free to choose techniques on a basis of limited experience, possibly combined with rather crude and mainly subjective tests and assessments, the fundamental philosophy would be to offer guidance to forecasters in their choice of techniques, but without mandatory restriction to a "best technique" as indicated by comparative testing.

A mandatory system of methods and techniques in forecasting is hardly possible at this time, certainly not as a complete system, which is in any case to be avoided for several reasons. Not all forecasters always have the time or the material to follow a particular method. But more important, despite the obvious attraction of purely objective methods, comparatively few such methods exist for determining the many details which go to make a finished forecast - particularly detailed local forecasts tailored to customer requirements. And existing methods, employing parameters likely to be the most important, may fail on those occasions when some other parameter becomes important. The forecaster must therefore understand fully, and understand the limitations of, the technique he uses; a fully objective method gives a first approximation to the answer the forecaster is seeking, but he must be left free to modify or reject this answer, or to use another technique, whenever his scientific judgement tells him this is necessary.

A number of forecasting techniques are now (1965) being comprehensively tested at outstations in UK.. Pending the result of these and similar tests which it may be possible to arrange from time to time, an analysis has been made of the replies from outstations to the headquarters questionnaire on methods and techniques of forecasting. The analysis, which is at Annex E to this report, is based on the degree of popularity accorded by stations to particular techniques. It is therefore highly subjective, the more so since not all stations commented in the same way nor to the same extent. Nevertheless, since replies from stations (when not given as from individual forecasters) represent a consensus of opinion based, in many cases, on years of experience, the resultant analysis, though subjective, probably has a real value. At the very least it represents an accumulated weight of experience which it would be difficult to record or pass on to junior staff in any other way.

The analysis at Annex E is based on the material of annexes A and B. It is also convenient to include in this annex a full bibliography; appropriate bibliography reference numbers are listed against techniques in the tables showing the popularity score.

/ 5.

5. Further action

A preliminary report (by T.N.S. Harrower) has already had a limited circulation, chiefly within headquarters, and an advisory group has been set up to consider what further action should be taken. As a result of advice given by the group a programme of work has been formulated. Some of this work has already been completed, for instance that described in the section on "Suggestions for research and development" and in Annex E, while other projects such as the testing of selected techniques and the provision of data from high masts are in hand. Work to be done in the future includes:

(1) A further sifting of station replies and consideration of many ideas put forward.

(2) A study of "most popular" techniques or "best" techniques to see if they could be improved upon.

(3) Outstation forecasters favour simple techniques, and those depending on local parameters, which can be worked out quickly at a station. A study of more complex problems is required to find those which may be solved centrally, the solution being distributed by teleprinter or facsimile.

(4) Investigation of meso-scale phenomena and the preparation of a chapter on Meso-analysis for the Handbook of Weather Forecasting.

(5) Preparation and publication in a form, suitable for ready reference, of "Forecasting Rules". (Considerable progress has already been made with this project).

(6) Continued amendment to the Handbook of Weather Forecasting and the Pocketbook for Forecasters.

/ Annex A

ANNEX A

OUTSTATIONS IN UNITED KINGDOM

Key

Technique is in use. O Technique is in use, popular and helpful. ● Technique is in use, very helpful. + Technique is in use, but not found satisfactory. □ Technique is in use, but limited applicability. ■ Technique tried and found wanting; not now used. ✓

Station would like to use technique but time or equipment not available. –

PRINCIPAL AND MAIN FORECAST OFFICES (1–14)
OTHER FORECAST OFFICES (15–87)

GENERAL ANALYSIS AND FORECASTING

TECHNIQUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Analysed fascimile charts	O		O	O	O			O						O				O		O	O						O		●			O				O						O			O	O									O	O	O	O	O	O					O	O				O	O	O	O						O						O		O
Trajectory charts (various levels)															–																																																–																															
3-front model and Belasco's analysis																																																																													–															
Movement of systems																																			O																																																				
Movement of fronts (Cranwell)																																			O																																																					
Vertical cross-sections				–						–		–		–		–																							–														–			–		–					–														–						–														
Wet-bulb potential temperature analysis																													–																																																											
Cyclonic activity - North Atlantic (George)											■																								●							O																																						✓															
Frontal activity by hodograph (Parker)								●	O			O	O				O	O	O														O			O	O				O	O		O	O	O	O	O			–								–							O	O	✓				O						●			O	O									
Anticyclogenesis (Houseman and Howarth)		–		O																																																																																				
Cold pools (Sumner)					O									O																																																																											
Special upper-air techniques (LAP)		O																																																																																						
Special upper-air techniques (HQBC)	O																																																																																							
500 mb contour patterns (C. V. Smith)				–				O	O																					●																																																										
Rossby wavelength ideas		–						O	O																					□																																																										
Vorticity advection (Sawyer)				–						●				–																																																																										
Isallobar advection with 500 mb wind (Scherhag)										–																																																																													
Tropopause charts										–																																																																													
Isotach analysis																																												–								–																															–							
Relaxing thermal troughs (Miles)								O																																							O																																								
Use of synoptic climatology																		●											+			●				●										●																			●														●									
Weather singularities																												O																																																												

TEMPERATURE

TECHNIQUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Night minimum temperatures (McKenzie)		●		●	O			O	●	□		O	O	●	●			●	●		●	●											●			●	●		O		O	□		●	●	●	●	+	□	●	O	O	O	O		O	O		O	●	●	●				●			O	O	O		O		O	O	●	O		●		O		O				O
Night minimum temperatures (Boyden)										■					O						●				O																							✓	□			O	□													●														O						O	
Night minimum temperatures (Craddock)				●	O		O	O		●		O		●	O			●	O		●	●				●	O	O		O	O	●		O		●		O							O		●	□	□			O	O	O	□	O					O				●		●														●	O	O					O	
Night minimum temperatures (Lewis)																																																																	O																					
Night air and grass minimum temperatures (special formula)																																	O																																																					
1800 and 2100 temperatures																		O																																																																				
Night minimum temperatures - cloudy skies (Summersby)													O																																																																											
Grass minimum temperatures (Saunders)				O				O										O														O				O										O				□																O													O									
Night minimum temperatures - cooling curves (Saunders)		●	+	●	O	O	●	●	●	●		O	●	●	O	O	●	●	●		O	+		O	+	□	O	●		●	O	●	●	●	●	●	●	□		●	●		●	+	●	●	+		●	O	●	●	+	O	O	O	O	+	●	●	●			●	●	●	O	O	●	O	●	O		O	O	●			●	O	O		O			●	O
Night cooling (Cranwell modification)																																		●																																																				
Night minimum temperatures - cooling diagram (H.Q.B.C.)	O			●		●											●										●				●				●	O									●																						●	O														●									
Night minimum temperatures - cooling diagrams (Band)																																																			O																																		
Ground frost (Faust)				O	O			O				O		●				O														O				O										O						O												O														O									
Daily mean temperature from thickness patterns (Boyden)				O														O														O				O										O																					O														O									
Day temperatures - clear or overcast skies (Jefferson)					O				●				O	●					●		O	✓					●			O	O				●					O	O		O	O	O				O		O	O				●			●	●													O		O	O												
Day temperatures - clear days (Cranwell)																																	●																																																						
Day maximum temperatures (Gold)		●		O	O			O	O	■		O	O	●	O		O		●		O	O			O	+		●		●	O		O		●		●	O		O					●		+				O	O							●	●						●	O	O		O				O	O	●	O			O	O		O		+		
Day maximum temperatures (Johnston)									●	●		O	O																			O					●									O					●		O	●		O				●	●	●																											+			O
Extreme maximum temperatures (Redcar)																																																					●																																	
48-hour, 72-hour maximum temperatures																																																					O																																	
Temperatures with winds off the North Sea				O					●	□								O			O							O				O		●		O									O		O	O				O	O			+				●				□		O					O	O	O							O									
Air mass temperature statistics				●														●														●				●										●																			●														●									

VISIBILITY

TECHNIQUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Objective forecasts (Freeman)		O																																																			O																																		
Fog prediction (Saunders)		●	+	●	O	O	●	●	●	●		O	●	●	O	O	●	●	●		O	+		O	+	□	O	●		●	O	●	●	●	●	●	●	□		●	●		●	+	●	●	+		●	O	●	●	+	O	O	O	O	+	●	●	●			●	●	●	O	O	●	O	●	O		O	O	●			●	O	O		O			●	O
Fog prediction (Swinbank)										✓			O	O																																	✓																																								
Fog prediction (Briggs)										O					O																																																				O																					
Cranwell fog point (Modified Briggs)																																		●																																																				
North Sea fogs (haars) (Lamb)									O																																			O																																										
Clearance of fog (Jefferson)					O				●				O	●					●		O	✓					●			O	O				●					O	O		O	O	O				O		O	O				●			●	●													O		O	O												
Clearance of fog (Kennington)												O																		O																																																								

CLOUD

TECHNIQUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Cirrus cloud (James)			O	O	O			O	O	●				O				O	●														O				O				●			O	O	●	O			O								O								O	O				O		O				✓			O								O	
Convective clouds - parcel and slice methods				□		O			O				O																				O						O																O					O											O		O					O	O												
Cumulus cloud (Cranwell method)																																		O																																																			
Turbulence cloud (Forsdyke)																						+																																																																
Stratus cloud near east coast Britain (Bull)					O									O																																																																								
Strato-cumulus layers in anticyclones (Findlater)																																																																			□																			
North Sea haars (Lamb)									O																																			O																																										
Nocturnal dispersal of strato-cumulus overland (James)	O	□		□	O		□	O		✓	■	O	□	O				□	□		O					□		□		O		□				□	□			□				O		□	□		O		□		✓							O	□				□	■			□			O		O					□	✓	O				□	O	
Dispersal of strato-cumulus (Kraus)			O		O			O				O	□	O				□														□				□											□			O											O					□										O				□		O					
Clearance of stratus (Cranwell modification)																																		●																																																				
Nocturnal dispersal of strato-cumulus (Cranwell)																																		●																																																				
Delayed clearance behind cold fronts (Dent)																																																			O																																		
Height of base of cloud (Normand)													O														●																																							O																			
Height of stratus cloud (Kraght)																																			O																																																		
Cloud amount (Poulter)									O																																																																														

PRECIPITATION

TECHNIQUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Instability indices - various	□	□		O				O		●		●	O					O											●		O		O				O						–			O		O	O		O	–	O	O	O													O	●			●			O		O		●	O		O							O		
Thunderstorms - Cranwell modification																																		O																																																			
Thunderstorms - use of isentropic charts (Namias)					O				O				–																																																																										
Precipitation at ana- and kata-fronts			O																									●																																																										
Rain shields (McElmurry)												–																		O																					O																																				
Development of rain ahead of upper trough (Bradbury)												O																																																																										
Hail (Ludlam)								O																																																																														
Precipitation - rain or snow (Lumb)										●																																			O								●																																	
Precipitation - rain or snow (Murray)				O			O			●			O	□				O			O												O				O	O									O	O	●	□		●														O		O	O	O		O				O		O		O		O					

WIND

TECHNIQUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Surface winds					O	O				●				O																					●																					O																					O											
Relationship surface to geostrophic wind (onshore) (Valley)																																																																														O										
Special techniques for lee-waves (Pitreavie)									O																																																																														
Airflow over mountains		O		O					O			O	O				O	O															O				O												O	O	O																			O											–			O						O			
Turbulence in lee-waves		O																																																																																						
Turbulence (affecting aircraft)				O		O			O					O				O								O								O				O					●					O													O							O					O									O									
Sea breezes (Cranwell)																																		O																																																			
Sea breezes (Dyce)									O																																																																														
Variation with height (parachuting)															O																																												●																													
Jet-stream core location		–																																																																																						
Jet-stream core and thickness		✓																																																																																						
Maximum wind and tropopause height		✓																																																																																						

MISCELLANEOUS

TECHNIQUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Airframe icing				O	O	O			O					O				O	O													O				O												O												O						O				O				O			O									
Airframe icing (Preston)										●																																																																													
Radar displays		–		●																				–																										O																																				
Contrails (Helliwell, McKenzie)									O	●			O	O							O				O					O													O															O											O		O							O				O					

ANNEX B OUTSTATIONS OVERSEAS

Key

Technique is in use. O

Technique is in use, very helpful. +

Technique is in use, but limited applicability. ■

Technique is in use, popular and helpful. ●

Technique is in use, but not found satisfactory. □

Technique tried and found wanting; not now used. ✓

Station would like to use technique, but time or equipment not available. –

TECHNIQUE	STATIONS IN GERMANY						OTHER OVERSEAS STATIONS								
GENERAL ANALYSIS AND FORECASTING	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Frontal analysis	O	O				O									
Streamline-isotach analysis, Indian Ocean							O	O	O						
Descriptive notes - various							O	O	+					O	
Seasonal means and climatology										O	O				
24-hour pressure tendencies										✓	+				
Vertical cross-sections, space or time									O		–				
Hodographs	●	O		O											
Isotach-contour charts												●			
Tropopause charts											–				–
Thermal troughs and cut-off lows															–
Diurnal effects - pressure, precipitation, etc.							O								
TEMPERATURE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Night minimum temperatures (McKenzie)		●	O											–	
Night minimum temperatures (Craddock)	●					O								–	
Night minimum termperatures (Gutersloh)				O											
Night minimum temperatures (Nicosia)													●		
Night minimum temperatures – cooling curves (Saunders)	●	□		O										–	
Night cooling and minimum temperatures (H.Q. 1 Gp.)				O											
Night minimum temperatures – cooling diagram (H.Q.B.C.)	●		O			O									
Night minimum temperatures – cooling curves (Laarbruch)	●				●										
Night minimum temperatures – cloudy skies (Summersby)	●														
Night minimum temperatures over snow (Gutersloh)				O											
Ground frost (Faust)				●											
Day temperatures – clear or overcast skies (Jefferson)		●	●		O	●									
Day maximum temperatures (Gold, Johnston)	●	●	O	O											
Day maximum temperature (Cyprus)													●		
VISIBILITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fog prediction (Saunders)	+	●	O	O	+	●					□		●		
Fog prediction (Briggs)	O														
Fog statistics (Gibraltar)															O
Clearance of fog (Jefferson)	O		O	O		□									
CLOUD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cirrus cloud (James)	O		+											O	
Convective clouds – parcel and slice methods	O		O			O				O			●		
Convective clouds – entrainment method (Changi)								O							
Convective-turbulence theory (Ramalingham)						O									
Turbulence in cloud	O	O	O	O	O	O							●	O	
Stratus - tephigram modifications	O														
Stratus - dispersal by insolation (Jefferson)	O				O										
Nocturnal dispersal of strato-cumulus overland (James)	□		O			□									
PRECIPITATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Instability index (Showalter)													●	O	
Instability index (Rackliff)	O	●				●									O
Thunderstorms (George)						O									
Precipitation at ana- and kata-fronts			O												
Movement of precipitation belts (Harper and Biemers)			●												
Diurnal variation of precipitation (in East Africa) (Thompson)							O					●			
Rain and drizzle from stratiform clouds (Mason and Howarth)	O		O												
Precipitation – rain or snow (Murray, Lamb)	O		O												
Hail (local technique – Rheindahlen)	●														
Glazed ice	O														
WIND	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Airflow over mountains	O		●										●		
Pressure difference – Alicante/Casablanca															O
Upper-winds – regression equations															–
MISCELLANEOUS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Airframe icing	O	O	O			●							●	O	
Radar displays, CRDF, aireps									●	O					–
Semi-statistical objective techniques															
Spells of weather (Baur)	■														
Contrails (Helliwell, McKenzie)	O	●	●	●		O							●		

ANNEX C TECHNIQUES USED BY INDIVIDUAL FORECASTERS

Key

Technique is in use. ○ Technique is in use, popular and helpful. ● Technique is in use, very helpful. +

Technique is in use, but not found satisfactory. □ Technique is in use, but limited applicability. ■ Technique tried and found wanting; not now used. ✓

Station would like to use technique, but time or equipment not available. –

TECHNIQUE	Station	9					13								22	25		30		35		41		45			77		81		
GENERAL ANALYSIS AND FORECASTING	Forecaster	1	2	3	4	5	1	2	3	4	5	6	7	8	1	1	2	1	2	1	2	1	2	1	2	3	1	2	1	2	3
Analysed facsimile charts																								○							
Trajectory charts (various levels)																															
3-front model and Belasco's analysis																															
Movement of systems																				○											
Movement of fronts (Cranwell)																															
Vertical cross-sections																															
Wet-bulb potential temperature analysis																															
Cyclonic activity - North Atlantic (George)																						○									
Frontal activity by hodograph (Parker)			○	○	○						○			○						○		○			○						
Anticyclogenesis (Houseman and Howarth)																						○									
Cold pools (Sumner)																															
Special upper-air techniques (LAP)																															
Special upper-air techniques (HQRC)																															
500 mb contour patterns (C. V. Smith)		○																													
Rossby wavelength ideas		○																													
Vorticity advection (Sawyer)		○																													
Isallobar advection with 500 mb wind (Scherhag)																															
Isotach analysis																															
Tropopause charts																															
Relaxing thermal troughs (Miles)																															
Use of synoptic climatology		○																													
Weather singularities																															

TEMPERATURE	Station	9					13								22	25		30		35		41		45			77		81		
	Forecaster	1	2	3	4	5	1	2	3	4	5	6	7	8	1	1	2	1	2	1	2	1	2	1	2	3	1	2	1	2	3
Night minimum temperatures (McKenzie)		●	○	●		○	○		●		○	○		○		○	○				●	□		●	●	+	○				○
Night minimum temperatures (Boyden)															○				○												
Night minimum temperatures (Craddock)																		□											○	○	
Night minimum temperatures (Lewis)																															
Night air and grass minimum temperatures (special formula)																															
1800 and 2100 temperatures																															
Night minimum temperatures - cloudy skies (Summersby)														○																	
Grass minimum temperatures (Saunders)																															
Night minimum temperatures - cooling curves (Saunders)		●	○	●	●	○	+	●	●	○	●	○	○	○	+	+	○	●	○	○	●	●	○	●	●	●			○	○	○
Night cooling (Cranwell modification)																															
Night minimum temperatures - cooling diagram (H.Q.R.C.)																															
Night minimum temperatures - cooling diagrams (Band)																															
Ground frost (Faust)																															
Daily mean temperature from thickness patterns (Boyden)																															
Day temperatures - clear or overcast skies (Jefferson)					●				○					○				○		○	●	○		○					○		
Day temperatures - clear days (Cranwell)																															
Day maximum temperatures (Gold)			●	■		○		○	○				○			○	○	●	○		●			○	●	●	○		○	○	○
Day maximum temperatures (Johnston)			●						●	○		○	○	○				○			●			○							
Extreme maximum temperatures (Redcar)																															
48-hour, 72-hour maximum temperatures																															
Temperatures with winds off the North Sea		●																													
Air mass temperature statistics																															

VISIBILITY	Station	9					13								22	25		30		35		41		45			77		81		
	Forecaster	1	2	3	4	5	1	2	3	4	5	6	7	8	1	1	2	1	2	1	2	1	2	1	2	3	1	2	1	2	3
Objective forecasts (Freeman)																															
Fog prediction (Saunders)		●	○	●	●	○	+	●	●	○	●	○	○	○	+	+	○	●	○	○	●	●	○	●	●	●			○	○	○
Fog prediction (Swinbank)														○																	
Fog prediction (Briggs)																															
Cranwell fog point (Modified Briggs)																															
North Sea fogs (haars) (Lamb)		○																													
Clearance of fog (Jefferson)					●				○					○				○		○	●	○		○					○		
Clearance of fog (Kennington)																		○				○									

CLOUD	Station	9					13								22	25		30		35		41		45			77		81		
	Forecaster	1	2	3	4	5	1	2	3	4	5	6	7	8	1	1	2	1	2	1	2	1	2	1	2	3	1	2	1	2	3
Cirrus cloud (James)			○															○								●					
Convective clouds - parcel and slice methods					○																										
Cumulus cloud (Cranwell method)																															
Turbulence cloud (Forsdyke)																															
Stratus cloud near east coast Britain (Bull)																															
Strato-cumulus layers in anticyclones (Findlater)																															
North Sea haars (Lamb)		○																													
Nocturnal dispersal of strato-cumulus overland (James)								□	□	□	□		○				○											○		
Dispersal of strato-cumulus (Kraus)										□																		○		
Clearance of stratus (Cranwell modification)																															
Nocturnal dispersal of strato-cumulus (Cranwell)																															
Delayed clearance behind cold fronts (Dent)																															
Height of base of cloud (Normand)													○											○							
Height of stratus cloud (Kraght)																				○											
Cloud amount (Poulter)				○																											

PRECIPITATION	Station	9					13								22	25		30		35		41		45			77		81		
	Forecaster	1	2	3	4	5	1	2	3	4	5	6	7	8	1	1	2	1	2	1	2	1	2	1	2	3	1	2	1	2	3
Instability indices - various														○				○				–						○	○		
Thunderstorms - Cranwell modification																															
Thunderstorms - use of isentropic charts (Namias)																															
Precipitation at ana- and kata-fronts																															
Rain shields (McElmurry)																		○													
Development of rain ahead of upper trough (Bradbury)																															
Hail (Ludlam)																															
Precipitation - rain or snow (Lumb)																								○							
Precipitation - rain or snow (Murray)		○	○						○		○		○	□										○			○		○		

WIND	Station	9					13								22	25		30		35		41		45			77		81		
	Forecaster	1	2	3	4	5	1	2	3	4	5	6	7	8	1	1	2	1	2	1	2	1	2	1	2	3	1	2	1	2	3
Surface winds																															
Relationship surface to geostrophic wind (onshore) (Valley)																															
Special techniques for lee-waves (Pitreavie)				○																											
Airflow over mountains		●			○				○																						
Turbulence in lee-waves																															
Turbulence (affecting aircraft)			○													○						●									
Sea breezes (Cranwell)																															
Sea breezes (Dyce)				○																											
Variation with height (parachuting)																															
Jet-stream core location																															
Jet-stream core and thickness																															
Maximum wind and tropopause height																															

MISCELLANEOUS	Station	9					13								22	25		30		35		41		45			77		81		
	Forecaster	1	2	3	4	5	1	2	3	4	5	6	7	8	1	1	2	1	2	1	2	1	2	1	2	3	1	2	1	2	3
Airframe icing			○																												
Airframe icing (Preston)																															
Radar displays																															
Contrails (Helliwell, McKenzie)			○				○	○	○		○		○	○		○											○		○	○	○

Annex D

Suggestions for research and development

KEY Category A Development requested
Category B Development strongly supported
Category C Development very strongly supported

Technique	Number of stations supporting category		
	A	B	C
PREPARATION OF FORECAST CHARTS			
Movement and development of features at surface and aloft	2	1	
Development and movement of non-frontal troughs and polar lows	2		
Acceleration and deceleration of fronts over British Isles	1		
Speed of warm fronts over cold land in winter	1		
"Helmholtz-Cranwell" method for movement of fronts	1		
Short-term limited-area forecast charts - early issue	2	1	1
Analysis of "A" and "C" areas on thickness charts	1		
Thickness change with developing highs and lows	1		
Charts of vertical motion	1		
Vorticity charts	3	1	
Relationship between 300 mb patterns and weather	1		
TEMPERATURE			
Forecasting night minimum temperatures over snow	4		
Modification of air passing from sea to land	2		
Warming and cooling of air passing over the sea	1		
Corrections to above for wind speed and depth of turbulence	1		
Temperature and humidity fine structure in lowest 1000 ft	1	1	
Extension to other places of Belasco's work at Kew	1		
Inland penetration of thaws (warm air advection over snow)	1		
Formula for Chill Factor for public-service forecasts	1		
Meso-scale turbulence - effects on temperature	1		
VISIBILITY			
Fog dispersal using network of low-level soundings	4		
Probability statistics of fog formation	1		
Variation of visibility in fog	2		
Fog clearance during evening or night	1		
Onset and clearance of sea-fog	1		
Meso-scale turbulence - effects on fog	1		
CLOUD			
Stratus dispersal using network of low-level soundings	4		
Meso-scale turbulence - effects on stratus	1		
Relationship between cloud layers and the tephigram plot	3		
Structure and amount of turbulence-cloud (Sc)	11	1	
Formation and dispersal of turbulence-cloud (Sc)	11	1	
Variation of cumulus tops with time	2		
Frontal cloud structure	1		
Amount of instability cloud	1		
Interpretation of satellite pictures	1		
Onset and clearance of stratus	7		
Height of base of stratus	7		
PRECIPITATION			
Frontal rain and the 300-100 mb thickness pattern	1		
Frontal rain - amount in given area	4	1	1
Objective methods for amount, duration and type	1		
Statistical investigation of orographic shelter from rain	1		
Deceleration of frontal rain approaching a blocking anticyclone	1		
Use of radar information	1	2	
Formation of thunderstorms and hail	1		
Instability indices for whole year	2		
Thunderstorms - Similä's method	1		

Suggestions for research and development (contd.)

KEY Category A Development requested
Category B Development strongly supported
Category C Development very strongly supported

Technique	Number of stations supporting category		
	A	B	C
PRECIPITATION (contd.)			
Thunderstorms - Skeib's method	1		
Thunderstorms and hail - Miller and Starrett's method	1		
Early morning showers in coastal areas	1		
Rates of subsidence - effects on showers	1		
Conditions under which falling snow may be expected to lie	1		
Determination of height of snow line - snow over high ground	2		
Relationship between thickness values and snowfall	1		
WIND AND TURBULENCE			
Vertical extent of frictional turbulence over hilly regions		1	
Turbulence near jet-streams - Harrison and George's method	1		
Clear air turbulence in relation to jet-streams	4		
Relationship between winds and topography	1		
Relationship between surface and gradient winds	1		
Sea breezes at specific localities	4		
Short-term, limited-area, upper wind forecasts	3		1
Streamline and isotach charts	1		
LOCAL WEATHER			
Meso- and micro-scale effects of topography of British Isles		1	
Statistics as an aid in local forecasting	2	1	
Objective methods at small stations, e.g. similar to George's	5		
Urban "heat-island" effects	1		
Pollution sources and Clean Air Act	1		
Shower frequency distribution	1		
MEDIUM-RANGE FORECASTING			
Use of 10-day mean-thickness charts	1		
Lowndes' techniques for other parts of Britain	2		
Duration of settled and unsettled spells in various regions	1		
Climatology of thickness patterns and associated weather	1		
SUBTROPICAL AND TROPICAL			
Position, intensity, movement of subtropical jet-stream	1		
Meridional extension in low latitudes	2		
Study of upper-flow patterns in the Eastern Mediterranean	2		
Heavy rainfall at Gibraltar	1		
Wind through Straits of Gibraltar - pressure difference method	1		
Statistics of rainfall according to time of day	1		
Equivalent headwinds - regression equation method	1		
Alternatives to frontal analysis south of 40°N.	1		
Modification to cloud structure on crossing large land masses	1		
Changes in upper easterlies during summer at Bahrain	1		
Movement of semi-permanent trough in Persian Gulf	1		
Wind structure of Inter-tropical Convergence Zone	1		

Annex E

Forecasting techniques - popularity score and bibliography

At Annexes A and B techniques used at home and overseas stations respectively are listed and classified in seven categories. The first six of these categories have been given an arbitrary "popularity rating" as indicated in Table 1. The seventh category (Station would like to use technique, but time or equipment not available) has been omitted from Table 1 as it is not possible to allot to it a realistic popularity rating. It is considered separately below.

Table 1. Forecasting techniques - category popularity rating

	Technique Category	Popularity rating
1.	Technique is in use	2
2.	Technique is in use, popular and helpful	3
3.	Technique is in use, very helpful	5
4.	Technique is in use, but not found satisfactory	0
5.	Technique is in use, but limited applicability	1
6.	Technique tried and found wanting - not used now	-1
7.	Station would like to use technique but time or equipment not available	-

Tables 2 and 3 list those techniques (category 7) which stations at home and overseas respectively would like to use but for which time or equipment is not available. The number of stations placing the technique in category 7 is shown as well as the total number of stations using the technique (sum of the number of stations placing the technique in categories 1, 2 or 3).

From an inspection of these tables it can be seen that several of these techniques, if their effectiveness were adequately proved, are suitable for use at, and the results subsequently distributed by, a central office, e.g. vertical cross-sections, trajectory charts, vorticity advection charts. Others, e.g. forecasting minimum temperatures by McKenzie's method, presumably indicate lack of time for calculating necessary local constants.

/ Table 2.

Table 2. Techniques which outstations in UK would like to use, but for which time or equipment is not available (category 7)

Technique (No. in brackets refers to bibliography)	No. of stations (placing technique in category 7)	No. of stations using technique (categories 1+2+3)
GENERAL ANALYSIS AND FORECASTING		
Trajectory charts (various levels)	2	0
3-front model and Belasco's analysis (1,2)	1	0
Vertical cross-sections	12	1
Wet-bulb potential temperature analysis	1	0
Frontal activity by hodograph (Parker) (7)	1	23
Anticyclogenesis (Houseman and Howarth) (8)	1	1
500 mb contour patterns (C.V. Smith) (12)	1	3
Rossby wavelength ideas (13,14,15)	1	2
Vorticity advection (Sawyer) (16)	2	1
Isallobar advection with 500 mb wind (Scherhag) (17)	1	0
Tropopause charts (18)	1	1
Isotach analysis (19, 4)	3	0
PRECIPITATION		
Use of instability indices - various (58, 59, 60, 61, 62)	3	26
Thunderstorms - use of isentropic charts (Namias) (63,64)	1	2
Rain shields (McElmurry) (66)	1	2
WIND		
Airflow over mountains - Scorer's parameter (73, 74)	1	11
Jet-stream core location (77)	1	0
MISCELLANEOUS		
Radar displays (48)	2	1

Table 3. Techniques which outstations overseas would like to use, but for which time or equipment is not available (category 7)

Technique (Number in brackets refers to bibliography)	No. of stations (placing technique in category 7)	No. of stations using technique (categories 1+2+3)
GENERAL ANALYSIS AND FORECASTING		
24-hour pressure tendencies	1	1
Various upper-air charts and diagrams (thickness, isentropic, trop-max-wind, vertical cross-sections)	2	-
Thermal troughs and cut-off lows (92, 93)	1	0
TEMPERATURE		
Night minimum temperatures (McKenzie) (24)	1	2
Night minimum temperatures (Craddock) (26)	1	2
Night minimum temperatures - cooling curves (Saunders) (28, 29, 30)	1	2
WIND		
Upper-winds - regression equations (72)	1	0

In Tables 4 and 5 techniques have been grouped to facilitate the comparison of the final popularity scores. These final scores were obtained for each technique by multiplying a category rating by the number of stations placing the technique in that category and then adding the totals for the six categories to give a technique popularity score. Though highly subjective, as discussed in the section on Guidance to Forecasters, the results give some indication of the relative merits of various techniques.

Where several techniques exist for making the same forecast the final popularity scores for those techniques can be directly compared. For individual techniques interpretation of the scores is less straight-forward, since a small score may result from the fact that a particular technique may have been developed for one station or only a few stations need to make a particular forecast. Whether this is likely may possibly be judged by considering the nature of the technique concerned and the forecast problem it attempts to solve. In general, however, for individual techniques, a high score indicates a satisfactory and popular technique, while a low score possibly indicates a technique which is not widely regarded as satisfactory. Where a dash appears in the score column the technique has been mentioned only under category 7.

Listed also in Tables 4 and 5 are the bibliography reference numbers appropriate to the various techniques. The bibliography appears after Table 5.

/ Table 4.

Table 4. Popularity score - technique in use at outstations in UK

Technique	Popularity score	Bibliography reference
GENERAL ANALYSIS AND FORECASTING		
Analysed facsimile charts	63	
Trajectory charts (various levels)	-	
3-front model and Belasco's analysis	-	1, 2
Movement of systems	2	3
Movement of fronts (Cranwell)	2	104
Vertical cross-sections	-	4
Wet-bulb potential temperature analysis	-	÷
Cyclonic activity - North Atlantic (George)	5	5, 6
Frontal activity by hodograph (Parker)	47	7
Anticyclogenesis (Houseman and Howarth)	2	8
Cold pools (Sumner)	4	9
Special upper-air techniques (LAP)	2	10, 11, 104
Special upper-air techniques (HQBC)	2	104
500 mb contour patterns (C.V. Smith)	7	12
Rossby wavelength ideas	4	13, 14, 15
Vorticity advection (Sawyer)	3	16
Isallobar advection with 500 mb wind (Scherhag)	-	17
Tropopause charts	-	18
Isotach analysis	-	19, 4
Relaxing thermal troughs (Miles)	4	20
Use of synoptic climatology	23	21
Weather singularities	2	22, 23
TEMPERATURE		
Night minimum temperatures (McKenzie)	120	24
Night minimum temperatures (Boyden)	16	25
Night minimum temperatures (Craddock)	81	26
Night minimum temperatures (Lewis)	2	104
Night air and grass minimum temperatures (special formula)	2	104
1800 and 2100 temperatures	1	104
Night minimum temperatures - cloudy skies (Summersby)	2	27
Grass minimum temperatures (Saunders)	16	28, 29
Night minimum temperatures - cooling curves (Saunders)	197	28, 29, 30
Night cooling (Cranwell modification)	3	104
Night minimum temperatures - cooling diagram (H.Q.B.C.)	33	31, 104
Night minimum temperatures - cooling diagrams (Band)	2	104
Ground frost (Faust)	25	32
Daily mean temperature from thickness patterns (Boyden)	14	33
Day temperatures - clear or overcast skies (Jefferson)	55	34, 35
Day temperatures - clear days (Cranwell)	3	104
Day maximum temperatures (Gold)	104	36
Day maximum temperatures (Johnston)	43	37
Extreme maximum temperatures (Redcar)	3	38
48-hour, 72-hour maximum temperatures	2	2
Temperatures with winds off the North Sea	46	39, 40
Air mass temperature statistics	21	2
VISIBILITY		
Objective forecasts (Freeman)	4	41
Fog prediction (Saunders)	197	28, 29, 42
Fog prediction (Swinbank)	2	43
Fog prediction (Briggs)	6	44
Cranwell fog point (Modified Briggs)	3	104
North Sea fogs (haars) (Lamb)	4	39
Clearance of fog (Jefferson)	55	34, 35
Clearance of fog (Kennington)	4	45
CLOUD		
Cirrus cloud (James)	51	46
Convective clouds - parcel and slice methods	22	47, 48
Cumulus cloud (Cranwell method)	2	104
Turbulence cloud (Forsdyke)	5	49
Stratus cloud near east coast Britain (Bull)	4	50
Strato-cumulus layers in anticyclones (Findlater)	0	51

Table 4 (contd.)

Technique	Popularity score	Bibliography reference
North Sea haars (Lamb)	4	39
Nocturnal dispersal of strato-cumulus overland (James)	27	52
Dispersal of strato-cumulus (Kraus)	18	53
Clearance of stratus (Cranwell modification)	3	104
Nocturnal dispersal of strato-cumulus (Cranwell)	3	104
Delayed clearance behind cold fronts (Dent)	2	54
Height of base of cloud (Normand)	7	55
Height of stratus cloud (Kraght)	2	56
Cloud amount (Poulter)	2	57
PRECIPITATION		
Instability indices - various	58	58, 59, 60, 61, 62
Thunderstorms - Cranwell modification	2	104
Thunderstorms - use of isentropic charts (Namias)	4	63, 64
Precipitation at ana- and kata-fronts	5	65, 7
Rain shields (McElmurry)	4	66
Development of rain ahead of upper trough (Bradbury)	2	67
Hail (Ludlam)	2	68
Precipitation - rain or snow (Lumb)	8	69, 70
Precipitation - rain or snow (Murray)	47	71
WIND		
Surface winds	16	72
Relationship surface to geostrophic wind (onshore) (Valley)	2	104
Special techniques for lee-waves (Pitreavie)	2	104
Airflow over mountains	30	73, 74
Turbulence in lee-waves	2	75
Turbulence (affecting aircraft)	29	76
Sea breezes (Cranwell)	2	104
Sea breezes (Dyce)	2	104
Variation with height (parachuting)	5	104
Jet-stream core location	-	77
Jet-stream core and thickness	-1	18
Maximum wind and tropopause height	-1	18, 78, 79, 104
MISCELLANEOUS		
Airframe icing	30	80
Airframe icing (Preston)	3	104
Radar displays	5	48
Contrails (Helliwell, McKenzie)	27	81

Table 5. Popularity score - techniques in use at outstations overseas

Technique	Popularity score	Bibliography reference
GENERAL ANALYSIS AND FORECASTING		
Frontal analysis	6	82, 83
Streamline-isotach analysis, Indian Ocean	6	84, 85, 104
Descriptive notes - various	13	86, 87, 88, 89, 104
Seasonal means and climatology	4	
24-hour pressure tendencies	4	
Vertical cross-sections, space or time	2	4
Hodographs	7	47
Isotach-contour charts	3	90, 91
Tropopause charts	-	18
Thermal troughs and cut-off lows	-	92, 93
Diurnal effects - pressure, precipitation, etc.	2	
TEMPERATURE		
Night minimum temperatures (McKenzie)	5	24
Night minimum temperatures (Craddock)	5	26
Night minimum temperatures (Gutersloh)	2	104
Night minimum temperatures (Nicosia)	3	104
Night minimum temperatures - cooling curves (Saunders)	5	28, 29, 30
Night cooling and minimum temperatures (H.Q. 1 Gp.)	2	104
Night minimum temperatures - cooling diagram (H.Q.B.C.)	7	31, 104
Night minimum temperatures - cooling curves (Laarbruch)	6	104
Night minimum temperatures - cloudy skies (Summersby)	3	27
Night minimum temperatures over snow (Gutersloh)	2	104
Ground frost (Faust)	3	32
Day temperatures - clear or overcast skies (Jefferson)	11	34, 35
Day maximum temperatures (Gold, Johnston)	10	36, 37
Day maximum temperature (Cyprus)	3	104
VISIBILITY		
Fog prediction (Saunders)	23	28, 29, 42
Fog prediction (Briggs)	2	44
Fog statistics (Gibraltar)	2	94
Clearance of fog (Jefferson)	6	34, 35
CLOUD		
Cirrus cloud (James)	9	46
Convective clouds - parcel and slice methods	11	47, 48
Convective clouds - entrainment method (Changi)	2	104
Convective-turbulence theory (Ramalingham)	2	95
Turbulence in cloud	17	76
Stratus - tephigram modifications	2	48
Stratus - dispersal by insolation (Jefferson)	4	35
Nocturnal dispersal of strato-cumulus overland (James)	2	52
PRECIPITATION		
Instability index (Showalter)	-	96
Instability index (Rackliff)	10	62
Thunderstorms (George)	2	5
Precipitation at ana- and kata-fronts	2	65, 7
Movement of precipitation belts (Harper and Biemers)	3	97
Diurnal variation of precipitation (in East Africa) (Thompson)	5	98
Rain and drizzle from stratiform clouds (Mason and Howarth)	4	99
Precipitation - rain or snow (Murray, Lamb)	4	71, 100
Hail (local techniques - Rheindahlen)	3	104
Glazed ice	2	48
WIND		
Airflow over mountains	8	73, 74
Pressure difference - Alicante/Casablanca	2	104
Upper-winds - regression equations	-	72

Table 5 (contd.)

Technique	Popularity score	Bibliography reference
MISCELLANEOUS		
Airframe icing	14	80
Radar displays, CRDF, aireps	5	48, 101, 102
Semi-statistical objective techniques	-	
Spells of weather (Baur)	1	103
Contrails (Helliwell, McKenzie)	16	81

Bibliography

(Note:- Many of the techniques listed in Tables 4 and 5 of this annex are discussed in the Handbook of weather forecasting. Where the discussion in the handbook may provide the only material readily available to forecasters, reference is made below to the appropriate chapter in the handbook. Otherwise the entries in the bibliography refer to original papers).

1. GALLOWAY, J.L.; The three-front model: its philosophy, nature, construction and use. Weather, London, 13, 1958, p.3.

2. BELASCO, J.E.; Characteristics of air masses over the British Isles. Geophys. Mem., London, 11, No. 87, 1952.

3. HARRISON, H.T.; Results of synoptic tests applied to certain forecasting rules. Bull. Amer. met. Soc., Lancaster, Pa., 32, 1951, p.89.

4. London, Meteorological Office; Handbook of weather forecasting. London, 1962, Chapter 4.

5. GEORGE, J.J.; Forecasting for aeronautics. New York and London. Academic Press, 1960.

6. GEORGE, J.J.; The movement of maritime cyclones. Bur. Aeronautics, Norfolk, Va., Project AROWA Res. Pap., 1956. (Met. Abstract 120)

7. PARKER, A.E.; Relation between upper wind structure and rainfall at fronts. Met. Mag., London, 78, 1949, p.247.

8. HOUSEMAN, J. and HAWORTH, C.; Anticyclones in relation to a particular thickness pattern. Met. Mag., London, 86, 1957, p.321.

9. SUMNER, E.G.; Cold pools: a statistical and synoptic study. Met. Mag., London, 82, 1953, p.291.

10. TREIDAL, R.D.; Thickness-temperature relationships over the north Atlantic. Circ. met. Div. Dep. Transp., Toronto, No. 3138, 289, 1958, (Met. Abstract 171).

11. GORDON, J.C.; A method of deriving 700 mb charts from 500 mb thickness patterns. Met. Mag., London, 90, 1961, p.352.

12. SMITH, C.V.; Synoptic evolution of 500 millibar flow patterns. Met. Rep., London, 3, No. 21, 1959.

13. ROSSBY, C.G.; Relation between variations in the intensity of the zonal circulation of the atmosphere and the displacement of the semi-permanent centres of action. J. mar. Res., New Haven, 2, 1939, p.38.

14. London, Meteorological Office; Handbook of weather forecasting. London, 1961, Chapter 5.

15. London, Meteorological Office; A test of the Rossby formula as applied to the movement of long atmospheric waves at the 500 mb level. Met. Res. Pap., London, No. 605, 1951.

16. SAWYER, J.S.; Vorticity in dynamical meteorology. Met. Mag., London, 80, 1951, p.169.

17. SCHERHAG, R.; Neue Methoden der Wetteranalyse und Wetterprognose. Berlin, 1948, p.324.

18. World Meteorological Organization; Techniques for high-level analysis and forecasting of wind- and temperature-fields. WMO tech. Note, Geneva, No. 35, 1961.

/ 19.

19. ELLSAESSER, H.W.; An investigation of the errors in upper level wind forecasts. Washington, Air Weather Service, Tech. Report 105-104/2. (Met. Abstract 157).

20. MILES, M.K. and WATTS, G.A.; Synoptic factors associated with relaxing thermal troughs and their prediction value. Met. Mag., London, 91, 1962, p.120.

21. London, Meteorological Office; Handbook of weather forecasting. London, 1960, Chapter 12.

22. LAMB, H.H.; Types and spells of weather around the year in the British Isles; annual trends, seasonal structure of the year, singularities. Quart. J. R. met. Soc., London, 76, 1950, p.393.

23. BROOKS, C.E.P.; Annual recurrences of weather. Weather, London, 1, 1946, p.107 and p.130.

24. McKENZIE, P.F.; A method of estimating night minimum temperatures. S.D.T.M., London, No. 68, 1944.

25. BOYDEN, C.J.; A method of predicting night minimum temperatures. Quart. J. R. met. Soc., London, 63, 1937, p.389.

26. CRADDOCK, J.M. and PRITCHARD, D.; Forecasting the formation of radiation fog - a preliminary approach. Met. Res. Pap., London, No. 624, 1951.

27. SUMMERSBY, W.D.; Night cooling under cloudy skies. Met. Mag., London, 82, 1953, p.210.

28. SAUNDERS, W.E.; Night cooling under clear skies. Quart. J. R. met. Soc., London, 78, 1952, p.603.

29. SAUNDERS, W.E.; Some further aspects of night cooling under clear skies. Quart. J. R. met. Soc., London, 78, 1952, p.603.

30. SAUNDERS, W.E.; Night cooling under clear skies at a coastal station. Met. Mag., London, 84, 1955, p.76.

31. BARTHRAM, J.A.; A method of forecasting a radiation night cooling curve. Met. Mag., London, 93, 1964, p.246.

32. FAUST, R.; Ein hilfsmittel zur Nachtfrostvorhersage. Ann. Met., Hamburg, 2, 1949, p.105.

33. BOYDEN, C.J.; The forecasting of daily mean surface temperatures from 1000-500 millibar thickness lines. Met. Mag., London, 87, 1958, p.98.

34. JEFFERSON, G.J.; Temperature rise on clear mornings. Met. Mag., London, 79, 1950, p.33.

35. JEFFERSON, G.J.; Method for forecasting the time of clearance of radiation fog or low stratus. Met. Mag., London, 79, 1950, p.102.

36. GOLD, E.; Maximum day temperatures and the tephigram. Prof. Notes met. Off., London, 5, No. 63, 1933.

37. JOHNSTON, D.W.; The estimation of maximum day temperature from the tephigram. Met. Mag., London, 87, 1958, p.265.

38. HENDERSON, D.C.; The forecasting of high temperatures at Redcar. Met. Mag., London, 93, 1964, p.147.

39. LAMB, H.H. and FROST, R.; Haars or North Sea fogs on the coast of Great Britain. M.O.504, London, 1943.

/ 40.

40. FROST, R.; The influence of the North Sea in winter on temperature and dew point. S.D.T.M., London, No.19, 1941.

41. FREEMAN, M.H.; A graphical method of objective forecasting derived by statistical techniques. Quart. J. R. met. Soc., London, 87, 1961, p.393.

42. SAUNDERS, W.E.; Method of forecasting the temperature of fog formation. Met. Mag., London, 79, 1950, p.213.

43. SWINBANK, W.C.; Prediction diagrams for radiation fog. Prof. Notes met. Off., London, 6, No.100, 1949.

44. BRIGGS, J.; Notes on the temperature at which radiation fog forms. Met. Mag., London, 79, 1950, p.343.

45. KENNINGTON, C.J.; An approach to the problem of the forecasting of fog clearance. Met. Mag., London, 90, 1961, p.70.

46. JAMES, D.G.; Forecasting cirrus cloud over the British Isles. Prof. Notes met. Off., London, 8, No.123.

47. London, Meteorological Office; Handbook of weather forecasting. London, 1960, Chapter 3.

48. London, Meteorological Office; Handbook of weather forecasting. London, 1959, Chapter 16.

49. FORSDYKE, A.G.; Cloud forecasting by means of the tephigram with particular reference to turbulence cloud. Nairobi, E.A.M.S., Memoirs II, No.4, 1948.

50. BULL, G.A.; Stratus cloud near the east coast of Great Britain. Prof. Notes met. Off., London, 7, No.103, 1951.

51. FINDLATER, J.; Thermal structure in the lower layers of anticyclones. Quart. J. R. met. Soc., London, 87, 1961, p.513.

52. JAMES, D.G.; The nocturnal dissipation of strato-cumulus cloud. Met. Mag., London, 85, 1956, p.202.

53. KRAUS, E.; Some contributions to the physics of non-frontal layer clouds. S.D.T.M., London, No.67, 1944.

54. DENT, L.; Delayed clearance of low cloud behind cold fronts at Manchester Airport. Met. Mag., London, 93, 1964, p.202.

55. BRUNT, D.; Physical and dynamical meteorology. Cambridge, 1939, p.89.

56. KRAGHT, P.E.; Temperature and moisture gradients under low stratus cloud. American Airlines, 1951.

57. POULTER, R.M.; Cloud forecasting: the daily use of the tephigram. Quart. J. R. met. Soc., London, 64, 1938.

58. JEFFERSON, G.J.; A modified instability index. Met. Mag., London, 92, 1963, p.92.

59. JEFFERSON, G.J.; A further development of the instability index. Met. Mag., London, 92, 1963, p.313.

60. MULLER, H.G.; The occurrence of shower type precipitation and its relation to values of temperature and humidity in the upper atmosphere. Arch. Met. Geoph. Bioklim., Wien, 8A, 1955, p.237. (Met. Abstract 12).

/ 61.

61. MILLER, R.C. and STARRETT, L.G.; Thunderstorms in Great Britain. Met. Mag., London, 91, 1962, p.247.

62. BACKLIFF, P.G.; Application of an instability index to regional forecasting. Met. Mag., London, 91, 1962, p.113.

63. NAMIAS, J. and SIMMERS, R.G.; Example of isentropic analysis. Cambridge, Mass. (Mass. Institute Technical Meteorology Division), 1938.

64. NAMIAS, J. and others; An introduction to the study of air mass and isentropic analysis. Milton, Mass., 1940.

65. SANSOM, H.W.; A study of cold fronts over the British Isles. Quart. J.R. met. Soc., London, 77, 1951, p.96.

66. McELMURRY, T.M.; Forecasting rain with low stratus in the midlands of England. Bull. Amer. met. Soc., Lancaster, Pa., 42, 1961, p.817. (Met. Abstract 179.)

67. BRADBURY, T.A.M.; Development of rain ahead of an upper trough. Met. Mag., London, 91, 1962, p.71.

68. LUDLAM, F.H.; Cumulonimbus: new ideas on hail-, thunder-, and tropical storms. Munitalp Foundation, New York, Occasional Paper No. 0025, 1957.

69. LUMB, F.E.; The problem of forecasting the downward penetration of snow, Met. Mag., London, 90, 1961, p.310.

70. LUMB, F.E.; Downward penetration of snow in relation to intensity of precipitation. Met. Mag., London, 92, 1963, p.1.

71. MURRAY, R.; Rain and snow in relation to the 1000-700 mb and 1000-500 mb thickness and the freezing level. Met. Mag., London, 81, 1952, p.5.

72. London, Meteorological Office; Handbook of weather forecasting. London, 1960, Chapter 13.

73. CORBY, G.A.; Air flow over mountains. Met. Rep., London, 3, No.18, 1957.

74. SCORER, R.S.; Forecasting mountain and lee waves. Met. Mag., London, 82, 1953, p.232.

75. World Meteorological Organization; The airflow over mountains. WMO tech. Note, Geneva, No.34, 1960.

76. London, Meteorological Office; Handbook of weather forecasting. London, 1962, Chapter 20.

77. BIELINSKI, L.S.; Location of jet maxima. Bull. Amer. met. Soc., Lancaster, Pa., 41, 1960, p.368.

78. LAMB, H.H.; Some interesting properties of the "Nullschicht" or maximum-wind layer. Met. Mag., London, 86, 1957, p.142.

79. AUSTIN, E.E. and BANNON, J.K.; Relation of the height of the maximum wind to the level of the tropopause on occasions of strong wind. Met. Mag., London, 81, 1952, p.321.

80. London, Meteorological Office; Handbook of weather forecasting. London, 1959, Chapter 18.

81. London, Meteorological Office; Handbook of weather forecasting. London, 1960, Chapter 19.

82. London, Meteorological Office; Handbook of weather forecasting. London, 1961, Chapter 6.

/ 83.

83. London, Meteorological Office; Handbook of weather forecasting. London, 1960, Chapter 10.

84. THOMPSON, B.W.; An essay on the general circulation of the atmosphere over South-East Asia and the West Pacific. Quart. J. R. met. Soc., London, 77, 1951, p.569.

85. _____; Discussion on "An essay on the general circulation of the atmosphere over South-East Asia and the West Pacific". Quart. J. R. met. Soc., London, 78, 1952, p.641.

86. FROST, R. and STEPHENSON, P.M.; Mean streamlines and isotachs at standard pressure levels over the Indian and west Pacific Oceans and adjacent land areas. Geophys. Mem., London, No. 109, 1965.

87. KIRK, T.H.; A note on forecasting with reference to the North African and Middle East areas. WMO tech. Note, Geneva, No.64, 1964, p.54.

88. KIRK, T.H.; Discontinuities with reference to Mediterranean and North African meteorology. WMO tech. Note, Geneva, No.64, 1964, p.35.

89. KIRK, T.H.; Commentary on the analysis work relating to North Africa and Middle East areas (series A charts). WMO tech. Note, Geneva, No.64, 1964, p.7.

90. JOHNSON, D.H. and MÖRTH, D.H.T.; Forecasting research in East Africa. Nairobi, E.A.M.D. Memoirs, 3, No.9, 1961.

91. JOHNSON, D.H. and MÖRTH, D.H.T.; Some trans-equatorial contour analyses. Nairobi, E.A.M.D. Memoirs, 3, No.8, 1961,

92. MILES, M.K.; Factors leading to the meridional extension of thermal troughs and some forecasting criteria derived from them. Met. Mag., London, 88, 1959, p.193.

93. SUTCLIFFE, R.C.; The formation of new anticyclones. Met. Mag., London, 82, 1953, p.163.

94. WARD, A.; Fog at North Front, Gibraltar. Met. Mag., London, 81, 1952, p.272.

95. RAMALINGHAM, N.; A convective-turbulence theory of thunderstorms. Nature, London, 185, 1960, p.900.

96. SHOWALTER, A.K.; A stability index for thunderstorm forecasting. Bull. Amer. met. Soc., Lancaster, Pa., 34, 1953, p.250.

97. HARPER, W.G. and BEIMERS, J.G.D.; The movement of precipitation belts as observed by radar. Met. Res. Pap., London, No. 1022, 1956.

98. THOMPSON, B.W.; The diurnal variation of precipitation in British East Africa. Nairobi, E.A.M.D., Tech. Mem., No.8, 1957.

99. MASON, B.J. and HOWARTH, B.P.; Some characteristics of stratiform clouds over North Ireland in relation to their precipitation. Quart. J. R. met. Soc., London, 79, 1952, p.226.

100. LAMB, H.H.; Two-way relationship between the snow or ice limit and 1000-500 mb thickness in the overlying atmosphere. Quart. J. R. met. Soc., London, 81, 1955, p.172.

101. World Meteorological Organization; Atmospherics techniques. WMO tech. Note, Geneva, No.12, 1955.

/ 102.

102. World Meteorological Organization; Utilization of aircraft meteorological reports. WMO tech. Note, Geneva, No.57, 1964.

103. BAUR, F.; Physikalisch-statistische Regeln als Grundlagen fur Wetter-und Witterungsv0rhersagen. Frankfurt A. M. (Akad. Verlagsges), 1956.

104. Various authors. Unpublished MSS.

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