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FIRST YEAR OF UPPER AIR OBSERVATIONS BY OCEAN WEATHER SHIPS

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Introduction.—The following note deals with the first year's radio-sonde observations made from the British ocean weather stations ITEM and JIG.

Observations were actually started in August 1947 at station JIG (nominal position 53° 50′ N., 18° 40′ W.) and in September 1947 at station ITEM (nominal position 60° N., 20° W.) but there were frequently considerable gaps in the records, owing to the fact that all four weather ships were not then in operation, and for this note the first year has been taken as January–December 1948. The observations used have been restricted to those made when the ships were within ½° of latitude and 1° of longitude of the centre of the I.C.A.O. grid.*

Upper air temperatures.—*Monthly mean and extreme values and extremes for the year.*—Monthly means and extremes for stations JIG and ITEM are given in Table I. As the number of observations falls off rapidly at levels above 300 mb. (30,000 ft.) values have only been given for levels up to 100 mb. (53,000 ft.). Corresponding mean values for Fazakerley (53° 28′ N., 2° 55′ W.) and Lerwick (60° 08′ N., 1° 11′ W.) are also shown in Table I for comparison. Average temperatures for the period 1942–48 are also given for Fazakerley and Lerwick to enable an estimate to be made, if required, of the average temperature over the ocean weather stations.

Graphs of mean monthly temperatures at standard pressure levels are given to make it easier to study the annual variation and differences between the ocean weather stations and the corresponding land stations; these graphs are shown in Fig. 1. Periods when the air was colder over the sea than over the land have been stippled. This stippling shows that, in the troposphere, the upper air was usually colder over station JIG, than over Fazakerley during the winter and warmer during the summer. This was rather surprising as it would have been reasonable to expect the opposite in the lower layers of the troposphere since, in general, the sea is warmer than the land in the winter months and *vice versa* in the summer months. Comparison of the curves for station ITEM with those for Lerwick is more in accordance with expectation, and shows definitely lower upper air temperatures up to 700 mb. from January to March

*An I.C.A.O. grid is a 210-nautical-mile square which is divided into squares with sides 10 nautical miles. The nominal position of the ocean weather station is at the centre of the central square; i.e. the centre of the grid.

TABLE I—MONTHLY MEAN AND EXTREME UPPER AIR TEMPERATURES

Ocean weather station JIG (53° 50′ N., 18° 40′ W.) — Year: 1948

Pressure level	Station JIG Temperature Mean	Max.	Min.	No. of obs.	Fazakerley Mean temperature 1948	1942–48	Station JIG Temperature Mean	Max.	Min.	No. of obs.	Fazakerley Mean temperature 1948	1942–48	Station JIG Temperature Mean	Max.	Min.	No. of obs.	Fazakerley Mean temperature 1948	1942–48	Station JIG Temperature Mean	Max.	Min.	No. of obs.	Fazakerley Mean temperature 1948	1942–48	Pressure level
mb.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	°F.	°F.	°F.		°F.	°F.	mb.
	JANUARY						FEBRUARY						MARCH						APRIL						
100	−66·9	−51	−85	22	−65·4	−72·6	−62·4	−44	−72	14	−65·5	−70·9	−63·1	−54	−74	21	−65·5	−67·5	−58·5	−39	−73	16	−57·9	−64·2	100
150	−62·3	−44	−99	32	−61·7	−70·0	−61·9	−47	−73	21	−62·4	−69·2	−61·7	−38	−79	46	−65·9	−67·3	−56·0	−39	−79	35	−54·0	−63·4	150
200	−60·4	−44	−85	49	−63·5	−72·2	−65·1	−51	−82	34	−62·8	−72·6	−67·9	−35	−86	68	−72·4	−72·4	−60·8	−39	−89	51	−56·5	−67·3	200
300	−60·3	−44	−76	59	−58·5	−58·4	−56·7	−39	−67	52	−53·9	−57·9	−51·6	−36	−62	86	−50·6	−56·4	−49·9	−34	−65	87	−50·8	−52·3	300
400	−38·7	−18	−57	85	−35·9	−35·0	−29·1	−15	−42	67	−32·7	−34·1	−27·2	−15	−48	102	−25·4	−30·5	−27·4	−10	−42	102	−29·7	−27·3	400
500	−18·7	2	−36	90	−14·7	−14·5	−9·1	8	−34	72	−12·7	−13·7	−7·1	6	−29	103	−3·8	−9·4	−8·0	10	−29	102	−9·5	−6·7	500
600	−2·1	16	−18	90	2·2	1·8	6·5	25	−11	73	4·1	2·5	8·6	22	−9	105	11·6	6·7	7·3	25	−12	102	7·3	9·2	600
700	11·4	25	−1	91	15·0	14·9	17·0	33	1	72	16·1	15·0	21·1	35	8	106	24·9	19·1	19·3	35	−1	103	20·1	21·3	700
800	23·0	38	14	91	24·3	24·5	25·5	38	11	72	25·0	24·4	30·3	46	13	106	34·2	28·5	28·3	47	11	103	29·4	30·4	800
850	28·4	41	18	91	29·5	...	29·2	42	19	72	28·1	...	34·3	53	18	106	38·0	...	31·8	52	16	103	33·5	...	850
900	34·6	47	25	91	35·2	32·8	33·6	47	26	73	30·9	31·1	38·6	61	25	106	42·4	35·9	35·9	49	23	103	39·0	39·1	900
	MAY						JUNE						JULY						AUGUST						
100	−60·7	−44	−82	45	−55·5	−59·3	−55·7	−42	−72	41	−54·7	−57·8	−57·3	−42	−76	66	−58·3	−57·5	−52·1	−33	−64	75	−54·8	−57·8	100
150	−60·5	−43	−82	73	−56·3	−59·5	−55·2	−36	−83	58	−52·8	−58·1	−60·2	−45	−78	85	−58·9	−57·6	−53·7	−38	−67	95	−56·1	−58·8	150
200	−63·8	−43	−82	88	−60·3	−62·7	−56·1	−32	−87	74	−56·1	−60·1	−63·0	−41	−76	93	−58·9	−59·8	−55·7	−33	−78	103	−57·9	−59·4	200
300	−49·6	−36	−66	111	−49·5	−50·5	−42·3	−26	−58	98	−43·7	−45·0	−38·9	−23	−52	102	−41·4	−41·8	−44·1	−30	−56	111	−45·1	−42·1	300
400	−24·8	−11	−47	120	−25·7	−26·4	−19·1	1	−43	112	−20·7	−20·7	−12·7	1	−35	114	−15·8	−16·2	−18·6	−7	−37	121	−18·5	−15·9	400
500	−4·6	8	−26	121	−4·8	−5·6	0·1	22	−18	115	−1·4	−0·6	7·3	19	−12	116	4·1	4·1	1·9	11	−16	122	2·0	4·7	500
600	10·8	27	−12	121	12·1	10·8	15·3	33	1	115	14·4	15·1	22·3	33	6	117	19·7	20·0	17·6	28	4	123	17·7	20·2	600
700	22·7	44	1	122	24·7	23·3	27·0	42	13	115	26·6	27·1	34·1	47	18	117	31·7	32·0	29·9	47	17	123	30·0	32·4	700
800	32·3	52	14	122	34·2	33·2	35·5	53	21	115	35·3	36·1	43·0	54	27	117	40·1	41·0	38·7	48	29	123	38·5	41·7	800
850	36·3	56	20	122	39·0	...	38·9	58	25	115	39·8	...	46·3	59	33	117	43·9	...	42·0	52	34	123	43·0	...	850
900	39·7	62	26	122	43·8	42·7	42·6	61	32	115	44·7	45·2	48·3	61	35	117	48·3	49·4	46·4	55	37	123	47·5	50·5	900
	SEPTEMBER						OCTOBER						NOVEMBER						DECEMBER						
100	−65·9	−35	−86	72	−67·5	−63·6	−71·2	−48	−88	51	−70·0	−71·5	−73·2	−59	−88	60	−77·5	−75·6	−69·0	−51	−94	55	−70·5	−74·1	100
150	−67·7	−25	−100	95	−69·3	−64·6	−68·9	−40	−86	77	−70·3	−71·3	−69·9	−54	−91	77	−77·6	−74·0	−65·9	−45	−100	70	−68·5	−73·0	150
200	−64·1	−32	−84	100	−66·1	−63·5	−64·8	−34	−83	89	−66·5	−68·3	−70·1	−52	−96	93	−74·9	−72·6	−66·6	−41	−103	77	−69·5	−74·6	200
300	−37·5	−20	−55	110	−39·7	−43·2	−45·7	−19	−77	107	−46·6	−47·2	−51·4	−36	−69	107	−50·7	−52·8	−55·4	−36	−77	81	−53·9	−56·5	300
400	−12·3	8	−29	115	−13·7	−17·0	−21·9	1	−52	118	−20·8	−21·9	−26·4	−10	−52	117	−24·5	−27·8	−32·1	−15	−51	82	−29·5	−32·1	400
500	7·1	29	−9	115	6·1	3·4	−2·1	18	−28	119	−1·9	−1·3	−5·9	8	−24	117	−3·3	−7·2	−11·4	4	−32	82	−8·5	−11·1	500
600	22·0	40	6	115	21·3	18·2	13·4	30	−12	119	13·5	14·6	10·2	24	−7	117	13·3	8·4	4·9	18	−14	82	8·7	5·2	600
700	33·4	54	20	115	32·4	29·9	24·9	43	1	119	24·9	26·9	23·1	38	8	117	25·7	20·5	18·8	34	3	82	21·7	18·2	700
800	41·3	58	28	115	40·1	38·5	33·3	57	14	119	33·1	35·9	33·0	47	21	117	35·5	30·0	27·9	42	15	82	32·3	27·8	800
850	43·9	60	34	115	42·5	...	36·8	55	21	119	36·9	...	37·2	51	22	117	39·4	...	32·1	47	20	82	36·3	...	850
900	46·4	59	39	115	46·1	46·4	41·3	59	28	119	41·7	43·0	41·8	57	32	117	43·5	37·9	37·2	50	28	82	39·7	35·5	900

Note.—On a number of occasions, observations were missed between 850 and 700 mb.

TABLE I—*continued*

Ocean weather station ITEM (60° N., 20° W.) **Year: 1948**

JANUARY

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−81.2	−72	−91	11	−68.9	−73.4
150	−74.4	−63	−89	30	−64.6	−69.9
200	−72.2	−61	−91	34	−64.1	−71.4
300	−71.2	−57	−82	36	−64.0	−62.2
400	−47.3	−22	−60	38	−45.9	−39.9
500	−25.3	−7	−39	38	−25.1	−20.1
600	−6.5	8	−18	39	−8.3	−4.0
700	9.1	21	0	40	7.1	9.4
800	21.1	27	11	40	18.2	19.6
850	26.5	33	18	40	23.1	...
900	32.6	39	26	40	28.9	28.8

FEBRUARY

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−74.7	−64	−84	10	−66.6	−73.4
150	−73.1	−61	−93	14	−63.4	−70.4
200	−73.3	−60	−93	18	−64.8	−72.1
300	−59.8	−46	−69	24	−60.0	−62.3
400	−33.6	−22	−45	28	−37.0	−40.0
500	−12.4	3	−24	29	−15.8	−20.2
600	4.7	18	−7	29	0.7	−4.0
700	17.4	30	5	29	13.5	9.0
800	27.2	41	16	29	22.7	19.1
850	30.8	43	22	29	25.9	...
900	35.0	45	28	29	29.7	27.9

MARCH

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−61.3	−48	−70	16	−67.2	−68.4
150	−58.8	−40	−72	27	−65.3	−66.3
200	−66.2	−35	−88	32	−70.6	−69.7
300	−52.2	−44	−62	34	−55.5	−59.5
400	−28.9	−18	−51	37	−32.1	−36.5
500	−8.2	4	−32	37	−11.9	−16.6
600	8.0	20	−20	37	4.2	−0.7
700	21.1	32	−2	37	17.5	12.4
800	31.6	45	12	36	28.8	22.3
850	36.1	50	18	36	32.9	...
900	40.1	55	25	37	37.1	30.7

APRIL

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−53.9	−42	−65	41	−54.8	−58.9
150	−51.2	−38	−67	54	−51.7	−57.9
200	−51.3	−36	−81	63	−53.9	−61.5
300	−51.1	−22	−67	81	−51.8	−54.1
400	−33.8	−18	−52	95	−34.4	−32.4
500	−15.9	2	−34	96	−14.8	−12.7
600	−1.7	18	−22	96	1.9	3.0
700	10.3	29	−3	96	14.9	15.4
800	19.6	38	8	96	25.9	25.1
850	23.9	43	14	95	30.3	...
900	29.1	47	20	96	34.8	33.7

MAY

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−56.3	−39	−74	73	−55.2	−54.9
150	−55.8	−36	−76	101	−55.5	−54.8
200	−58.7	−36	−87	109	−60.1	−59.5
300	−51.3	−35	−68	117	−54.5	−51.7
400	−29.1	−8	−52	120	−31.3	−28.0
500	−9.8	7	−37	121	−10.9	−8.0
600	4.7	20	−18	121	5.2	7.7
700	16.8	35	−2	121	18.5	20.1
800	26.0	47	4	121	29.4	29.8
850	30.0	50	13	121	34.3	...
900	34.2	53	19	121	38.4	37.7

JUNE

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−49.3	−29	−63	75	−51.7	−50.9
150	−48.1	−30	−73	96	−50.2	−50.5
200	−49.1	−28	−74	105	−52.8	−51.7
300	−47.7	−36	−58	111	−49.1	−47.0
400	−24.3	−10	−42	118	−26.6	−23.9
500	−4.4	9	−20	118	−5.3	−3.9
600	11.5	24	−2	118	10.7	11.6
700	22.9	34	10	118	23.2	23.9
800	31.5	44	20	118	33.1	33.4
850	35.2	50	25	118	37.1	...
900	38.9	52	29	118	40.8	41.0

JULY

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−48.2	−37	−60	38	−51.6	−50.8
150	−48.8	−35	−68	56	−52.1	−51.0
200	−51.8	−30	−69	61	−53.2	−53.1
300	−45.6	−30	−61	68	−45.7	−44.8
400	−20.1	−2	−37	77	−19.8	−19.4
500	0.3	11	−14	77	0.4	1.0
600	15.3	26	1	77	16.5	16.7
700	26.6	37	16	77	29.1	28.9
800	35.9	47	26	77	39.3	38.5
850	38.9	50	31	77	43.5	...
900	41.1	50	34	77	46.7	46.3

AUGUST

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−50.2	−39	−66	26	−49.6	−52.0
150	−51.7	−35	−69	53	−51.9	−53.8
200	−56.5	−39	−76	66	−57.2	−57.1
300	−47.9	−33	−59	81	−47.7	−45.1
400	−21.8	−11	−40	87	−21.1	−18.8
500	−1.1	10	−18	88	−0.7	1.6
600	14.9	25	0	88	15.2	17.3
700	27.7	39	16	88	27.5	29.5
800	35.9	49	27	88	37.0	38.7
850	39.3	52	29	88	39.3	...
900	42.7	56	35	88	42.3	45.8

SEPTEMBER

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−57.0	−41	−67	32	−57.9	−57.6
150	−55.7	−39	−75	59	−56.7	−57.4
200	−53.2	−35	−75	68	−55.7	−57.6
300	−45.9	−24	−60	93	−44.5	−47.1
400	−22.1	−2	−37	106	−21.8	−23.4
500	−3.4	15	−18	110	−2.4	−3.8
600	10.6	30	−2	110	12.0	11.6
700	21.7	42	9	110	23.5	23.8
800	30.5	42	21	110	32.5	33.2
850	33.4	46	24	110	36.7	...
900	38.9	51	28	110	41.2	41.7

OCTOBER

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−64.3	−50	−75	43	−64.4	−67.9
150	−62.8	−46	−79	61	−63.2	−66.7
200	−63.3	−40	−86	75	−61.7	−65.9
300	−52.6	−35	−75	77	−50.7	−50.7
400	−30.0	−9	−49	83	−29.2	−26.0
500	−10.5	12	−28	83	−10.3	−5.8
600	5.2	27	−9	83	5.3	9.7
700	18.4	35	7	83	17.6	22.2
800	27.9	47	17	83	27.1	31.3
850	32.0	49	21	83	30.8	...
900	36.2	54	29	83	35.6	38.4

NOVEMBER

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−69.8	−52	−85	62	−76.1	−73.5
150	−66.5	−50	−103	81	−74.8	−70.6
200	−65.9	−44	−95	89	−73.0	−69.6
300	−53.3	−27	−70	104	−54.0	−55.9
400	−29.5	−3	−48	117	−28.7	−32.5
500	−8.7	17	−30	117	−7.9	−12.3
600	6.9	27	−15	117	8.0	3.3
700	19.0	36	1	117	20.0	15.5
800	28.1	44	12	117	28.9	25.0
850	32.1	50	18	117	32.6	...
900	36.0	57	26	117	36.6	33.7

DECEMBER

Pressure level (mb.)	Station ITEM Temperature Mean (°F.)	Max. (°F.)	Min. (°F.)	No. of obs.	Lerwick Mean temperature 1948 (°F.)	1942–48 (°F.)
100	−67.0	−49	−84	47	−70.1	−75.2
150	−64.1	−47	−95	77	−69.4	−72.4
200	−63.9	−42	−97	93	−71.2	−73.7
300	−58.3	−37	−77	104	−56.7	−59.2
400	−36.3	−12	−66	114	−32.3	−35.3
500	−16.3	5	−46	114	−11.3	−14.8
600	−0.1	21	−25	114	5.7	1.5
700	13.6	35	−8	114	19.2	14.6
800	23.3	46	6	114	29.5	24.7
850	27.7	46	13	114	32.7	...
900	33.3	49	20	114	35.9	32.5

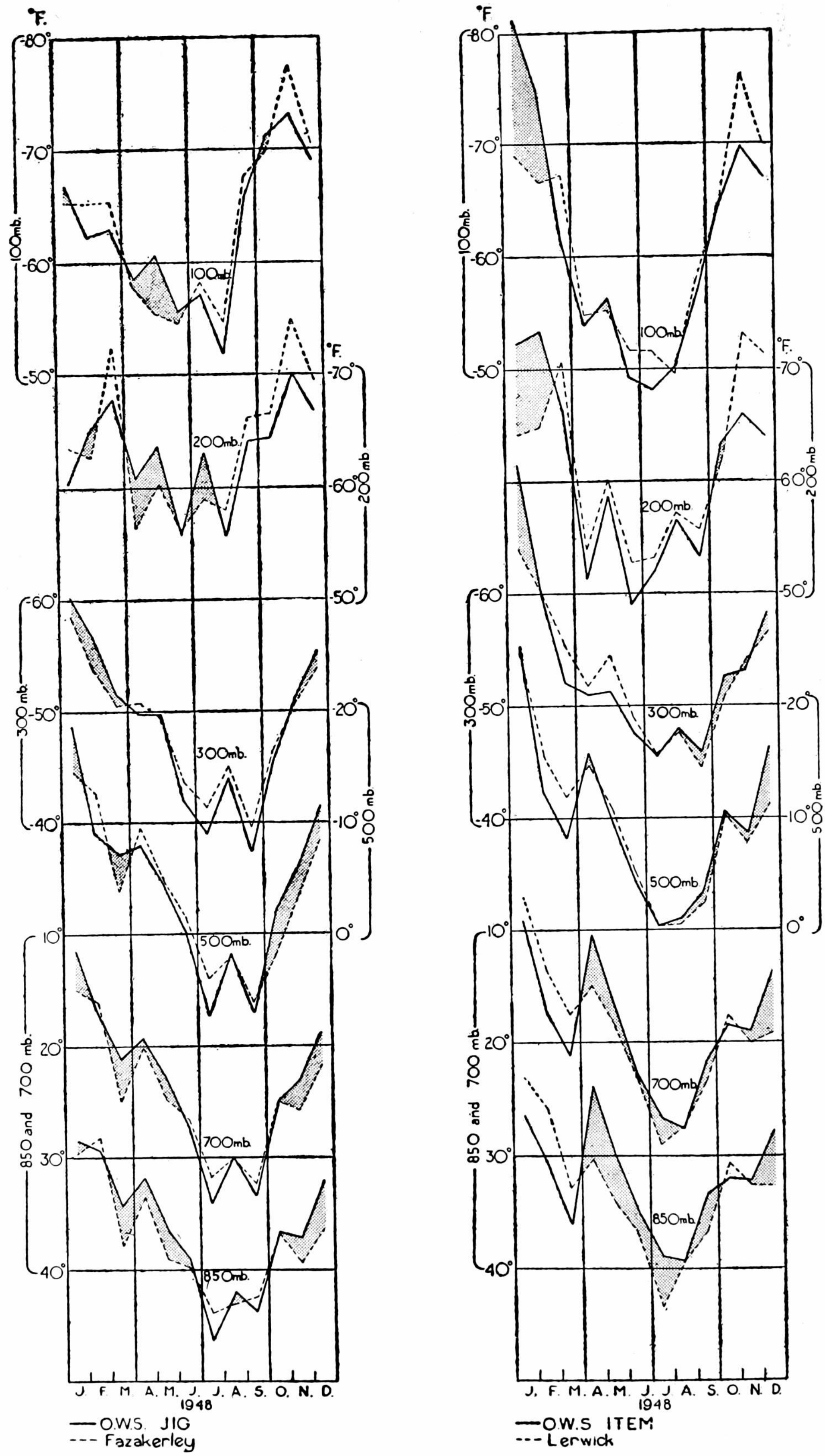

FIG. I—MEAN MONTHLY TEMPERATURES AT STANDARD PRESSURE LEVELS

nearer the main land mass while during the remainder of the year they are higher.

A limited investigation of the peculiarity shown by the JIG values was made by examining a winter month (January) and a summer month (July) in more detail. Differences between the 1400 G.M.T. temperatures for JIG and Fazakerley for individual days of each month were tabulated for those days when there were ascents at both stations. These showed that on the majority of days the sign of the difference was the same as that of the difference of the monthly means. The daily synoptic and upper air charts for each of these days were then examined to find out how these differences arose. The lower mean temperatures over JIG in January may be largely accounted for as follows. This month was comparatively mild over England, and for a considerable part of the month there was a cyclonic circulation around low-pressure systems in the central Atlantic; the air stream over Fazakerley had come from lower latitudes than that over the ship and had probably become appreciably warmer along the southerly part of its track. On the 10th and 16th the predominating effect was reversed, and temperatures were much higher over the ship (more than 20° F. higher at some levels on the 16th) but this was no doubt due to warming associated with subsidence in high-pressure ridges to the west.

The higher mean temperatures over JIG in July were found to be largely due to the persistence of an anticyclone near the ship during the first part of the month; from about 900 to 300 mb. temperatures were considerably higher (frequently 15–20° F.) in the warm subsiding air of the anticyclone. Towards the end of the month Fazakerley came under the influence of an E.–SE. air stream from the Continent while the ship was in an air stream which had come over the Atlantic. This gave higher temperatures (10–20° F.) over Fazakerley in the lower layers but above about 600 mb. the difference largely disappeared. On the 28th the air masses at the 500-mb. level over both stations seem to have been drawn from regions about 50° N., but while the air over Fazakerley had come from Poland that over the ship had come from the Atlantic; it is interesting to note that there was little difference in temperature. It seems, therefore, that 1948 was an exceptional year in this region for most of these months.

The graphs show two interesting features: unusually low troposphere temperatures over both stations in April, particularly so over ITEM, and low temperatures over JIG though not over ITEM in August.

Viewed as a whole, the curves give the impression of similarity of pattern over sea and land at the various levels up to 300 mb., roughly the level of the tropopause, where the pattern changes and is again continued upwards though the resemblance at the upper levels is more marked for ITEM than for JIG. Both stations show, in the stratosphere, a well marked minimum in November, but the minimum over ITEM in January does not occur over JIG.

Extreme temperatures for the year for the two ocean weather stations with the corresponding ranges are given in Table II. The range of temperature increases with height up to about 500 mb. and is then nearly constant up to the tropopause where there is a slight decrease followed by still larger ranges of temperature in the statosphere. In the lower troposphere the range seems to be appreciably smaller at the higher-latitude station but otherwise the range is about the same at both stations.

TABLE II —EXTREME UPPER AIR TEMPERATURES IN 1948

Pressure level	STATION JIG			STATION ITEM		
	Max.	Min.	Range	Max.	Min.	Range
mb.			degrees Fahrenheit			
100	−33	−94	61	−29	−91	62
150	−25	−100	75	−30	−103	73
200	−32	−103	71	−28	−97	69
300	−19	−77	58	−22	−82	60
400	8	−57	65	−2	−66	64
500	29	−36	65	17	−46	63
600	40	−18	58	30	−25	55
700	54	−1	55	42	−8	50
800	58	5	53	49	4	45
850	60	16	44	52	13	39
900	62	23	39	57	19	38

Mean lapse rates.—Mean lapse rates for winter and summer conditions were studied by plotting tephigrams of the mean monthly temperatures (mean of all four hours of observation) for January and July.

The graphs up to 300 mb. are shown in Fig. 2. The curves for January suggest that at both stations the effect of surface warming extends to about 850 mb. (4,000 ft.). Presumably this upward transfer of heat is mainly due to turbulence and it is rather surprising to find that it extends to such a height. Above 850 mb. the curves show stability increasing with height, particularly for station JIG where above 500 mb. the average lapse rate becomes appreciably less than the saturated adiabatic.

In July the curves show a decided difference in the lower layers; the curve for JIG suggests that the ocean has a slight cooling effect extending up to about 850 mb., but the curve for ITEM shows a definite warming up to 900 mb.

Other points of interest shown by the graphs are divergence between the curves for the two stations in January but parallelism in July and the appreciable difference in mean temperature between the stations. With only one year's data there is of course a possibility that these differences are due to exceptional conditions.

Diurnal variation.—Graphs were plotted for JIG, for the four hours of observation separately, for January and July, but it has not been considered worth while to reproduce them. They show, in the troposphere, a negligible variation in January and a difference of about 4° F. between the 0300 and 1500 curves in July. In the stratosphere there is a similar range both in January and July. How much of this variation is real and how much is due to insolation is a question to which it seems no satisfactory answer can at present be given.

Humidity mixing ratios.—Monthly mean humidity mixing ratios and maximum values for the year for the two ocean weather stations are given in Table III. To compare these values with those for an inland station, differences between Larkhill average monthly values for the period 1948–50 and those of Table III have been given in Table IV. Average values for Larkhill are given since means for 1948 were not readily available.

Table III shows that, apart from the winter months, the values at the higher-latitude station are appreciably less than corresponding values at the lower-latitude station.

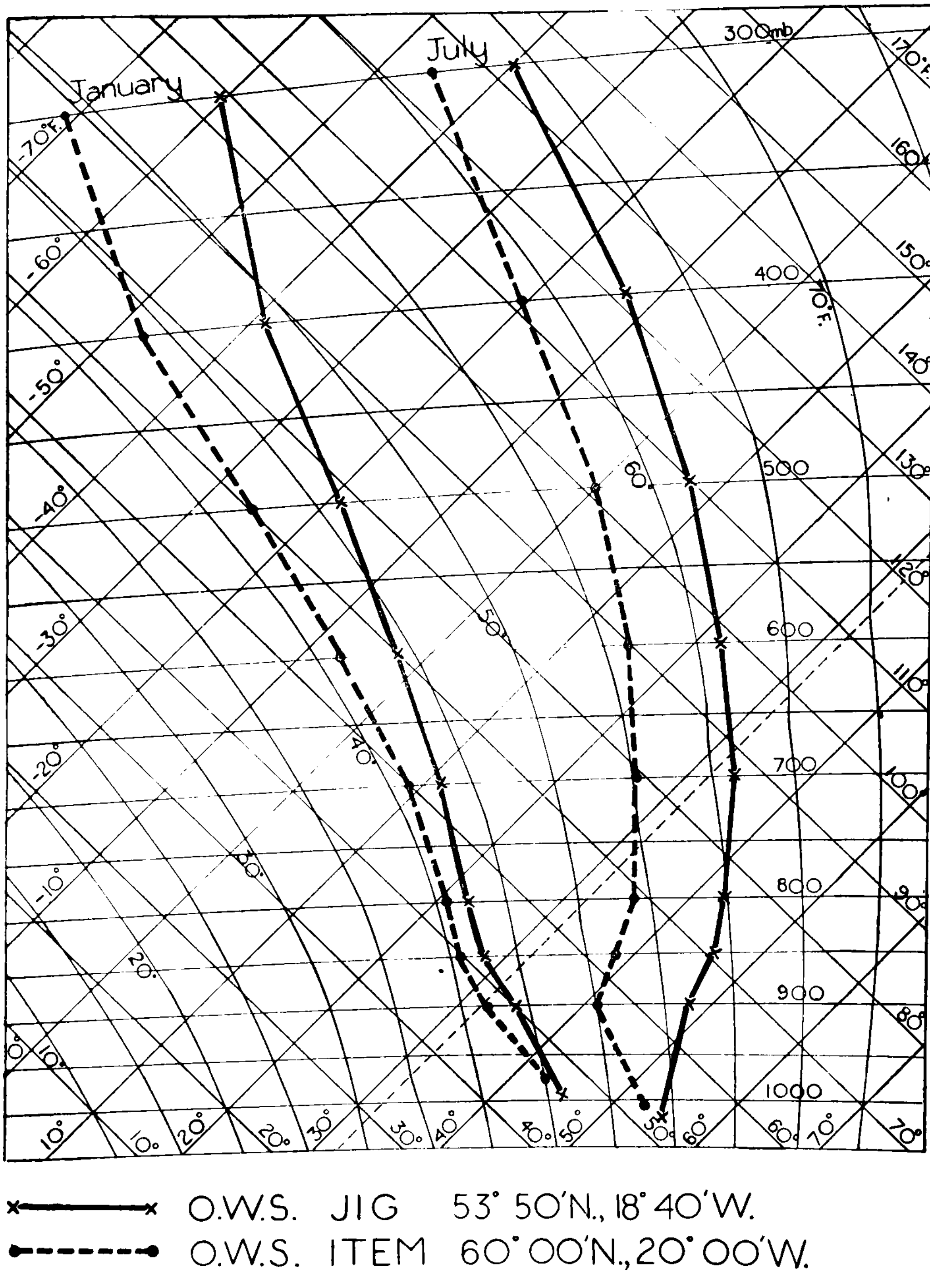

FIG. 2—MEAN MONTHLY UPPER AIR TEMPERATURES

The most remarkable feature however is how well the winter values fit the rough rule that the humidity decreases with decreasing pressure at the rate of about 0·7 gm./Kg./50 mb. from 900 to 800 mb. and about 0·5 gm./Kg./50 mb. from 800 to 700 mb. after which, from 700 to 500 mb. values at successive 100-mb. intervals are about half those at the higher pressure. In the summer months the agreement is only approximate.

TABLE III—MONTHLY MEAN HUMIDITY MIXING RATIOS AND MAXIMUM VALUES FOR 1948

Pressure level	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		YEAR
	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Mean	No. of obs.	Max. daily value
mb.													*grams per kilogram*												
	Ocean weather station JIG (55° 50′ N., 18° 40′ W.)																								
500	0.37	82	0.48	69	0.72	98	0.71	99	0.75	114	1.01	114	1.53	112	1.17	118	1.33	111	0.82	116	0.85	111	0.55	80	5.07
600	0.75	85	0.84	70	1.42	100	1.21	99	1.37	117	1.69	114	2.53	113	2.03	120	2.23	112	1.37	116	1.51	111	0.94	80	6.68
700	1.3	87	1.6	70	2.2	101	1.8	...	2.1	119	2.7	114	3.9	114	3.1	121	3.5	114	2.2	117	2.4	111	1.6	80	9.9
800	2.3	88	2.4	70	3.4	103	2.8	100	3.2	121	4.2	115	5.4	114	4.7	121	4.9	114	3.5	117	3.8	111	2.9	80	10.8
850	3.0	88	3.1	70	4.0	103	3.4	100	3.9	121	4.9	115	6.4	115	5.6	121	5.7	114	4.5	117	4.7	111	3.6	80	12.2
900	3.7	89	3.7	70	4.7	104	4.0	100	4.7	121	5.5	115	7.0	115	6.4	121	6.4	114	5.3	117	5.5	111	4.3	80	13.0
	Ocean weather station ITEM (60° N., 20° W.)																								
500	0.31	38	0.47	29	0.63	36	0.38	96	0.57	121	0.74	115	0.94	74	0.96	85	0.77	107	0.59	80	0.71	112	0.47	111	4.23
600	0.72	39	0.94	29	1.25	36	0.73	96	1.07	121	1.43	115	1.67	74	1.71	86	1.33	110	1.10	81	1.23	113	0.89	111	5.20
700	1.3	40	1.8	29	2.1	36	1.2	96	1.7	121	2.5	117	2.8	75	2.6	86	2.1	110	1.9	81	1.9	113	1.6	112	8.2
800	2.3	40	2.6	29	3.4	35	2.0	96	2.5	121	3.7	117	4.0	76	3.8	86	3.3	110	3.1	81	2.9	113	2.7	112	8.0
850	3.1	40	3.3	29	3.9	35	2.4	95	3.1	121	4.3	117	4.7	76	4.6	86	4.0	110	3.8	81	3.5	113	3.4	112	8.8
900	3.7	40	4.0	29	4.7	36	3.0	96	3.8	121	4.9	117	5.3	76	5.4	86	4.7	110	4.5	81	4.1	114	4.0	112	10.0

TABLE IV—DIFFERENCES BETWEEN LARKHILL AVERAGES (1948–50) AND CORRESPONDING VALUES OF TABLE III

A. Larkhill values minus JIG values   B. Larkhill values minus ITEM values

Pressure level	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
mb.													*grams per kilogram*											
500	0.18	0.24	0.05	0.06	−0.14	−0.05	−0.10	0.23	−0.12	0.06	−0.01	0.26	−0.42	0.17	0.06	0.27	−0.17	0.39	0.15	0.38	−0.27	−0.13	−0.02	0.06
600	0.28	0.31	0.09	−0.01	−0.37	−0.20	−0.07	0.41	−0.18	0.12	0.10	0.36	−0.60	0.26	0.14	0.46	−0.22	0.68	0.34	0.61	−0.48	−0.20	0.03	0.08
700	0.3	0.3	−0.1	−0.3	−0.5	−0.4	0.1	0.7	−0.1	0.3	0.2	0.4	−0.8	0.3	0.3	0.8	−0.3	1.1	0.4	0.7	−0.7	−0.2	−0.1	−0.1
800	0.3	0.3	0.0	−0.2	−0.8	−0.8	0.2	1.0	−0.1	0.6	0.2	0.7	−0.6	0.8	0.4	1.3	−0.1	1.5	0.3	0.7	−1.0	−0.1	−0.5	−0.3
850	0.3	0.2	−0.1	−0.3	−0.9	−0.8	0.1	1.1	0.1	0.9	0.5	1.1	−0.4	1.3	0.4	1.4	0.0	1.7	−0.1	0.6	−1.2	0.0	−0.6	−0.4
900	0.3	0.3	−0.1	−0.4	−0.9	−0.9	0.2	1.2	0.1	1.0	0.9	1.5	−0.1	1.6	0.6	1.6	0.4	2.1	0.0	0.8	−1.3	0.1	−0.6	−0.3

Values have only been given up to 500 mb. in the above tables. Humidity observations are regarded as completely unreliable for temperatures below −40° F. and omission of values for observations when temperature was below −40° F. gives biased means for 400 and 300 mb.

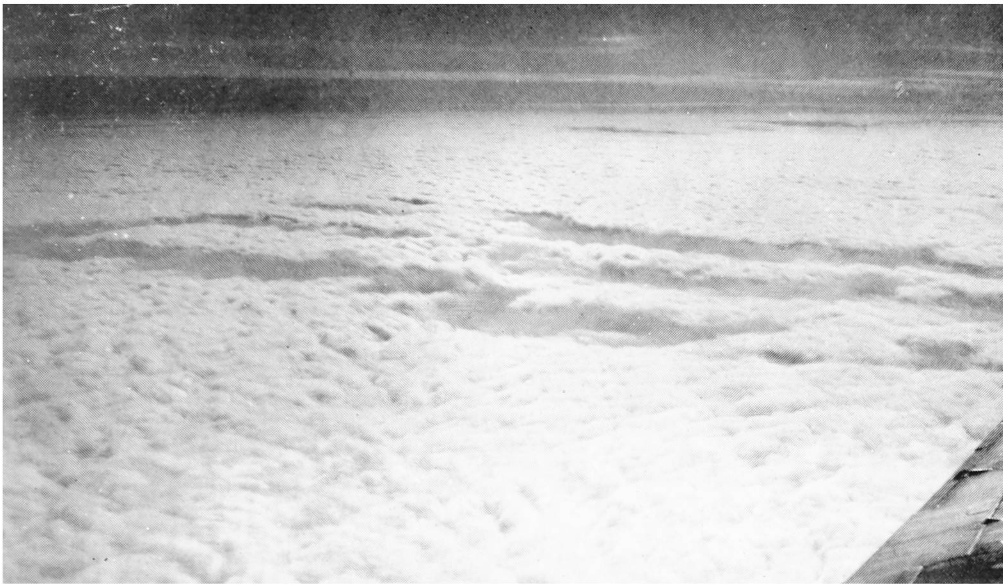

FIG. 1—VIEW OF SEEDED AREA FROM 20,000 FT., 17 MINUTES AFTER COMPLETION OF SEEDING

(see p. 253)

FIG. 2—VIEW FROM 20,000 FT., 40 MINUTES AFTER COMPLETION OF SEEDING

(see p. 253)

To face p. 253]

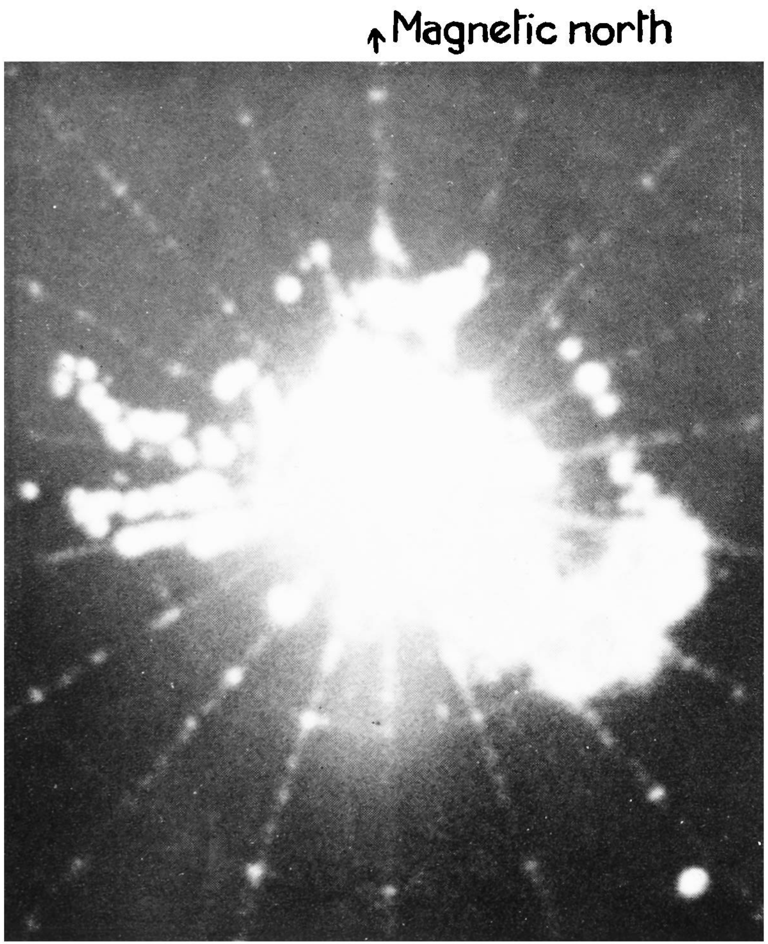

FIG. 3—PHOTOGRAPH OF P.P.I. AT EAST HILL SHOWING ECHO PRODUCED BY FIRST SEEDED LANE, 15 MINUTES AFTER COMPLETION OF SEEDING

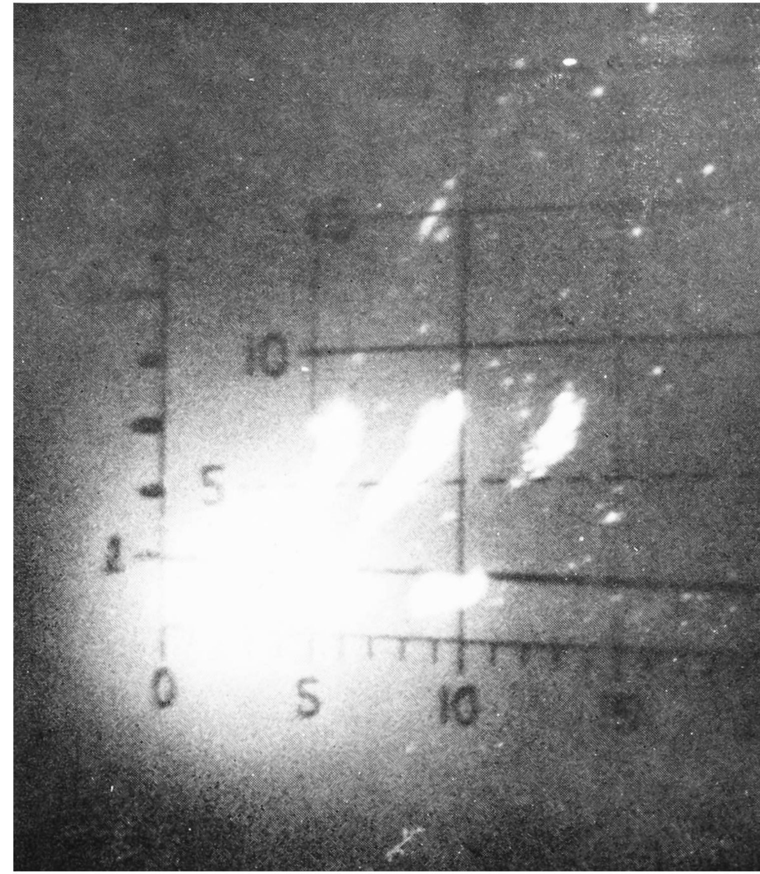

FIG. 4—PHOTOGRAPH OF H.R.T. AT EAST HILL SHOWING ECHOES PRODUCED BY ALL THREE SEEDED LANES, 26 MINUTES AFTER COMPLETION OF SEEDING

The figures of Table IV show that, with the exception of November, there is little difference between JIG and Larkhill, and that from April to October the humidity over ITEM is appreciably less than that over Larkhill though during the months November to February the difference is negligible. From these figures, based on data for one year only, it would seem that the nature of the underlying surface has little effect on the upper air absolute humidity and that latitude is the most important factor.

Tropopause.—Monthly mean values of pressure and temperature at the tropopause for all hours of observation are given in Table V. Very little can be deduced from the values. The usual relation of low pressure and low temperature between tropopause pressure and temperature is shown for most months, but from October to December, though the tropopause pressure increases, the temperature is nearly constant. The pressure curves for both stations are generally similar but that for JIG shows greater fluctuations. In every month except January and February the mean tropopause level is lower at ITEM than at JIG.

TABLE V—MONTHLY MEAN VALUES OF TROPOPAUSE PRESSURE AND TEMPERATURE AT ALL HOURS OF OBSERVATION

	Station JIG			Station ITEM		
	Pressure	Temperature	No. of obs.	Pressure	Temperature	No. of obs.
	mb.	°F.		mb.	°F.	
January	295	−67	55	283	−75	39
February	251	−69	43	251	−75	21
March	235	−71	72	243	−70	31
April	253	−64	81	295	−57	71
May...	239	−68	101	263	−64	110
June...	249	−61	86	265	−58	107
July	213	−68	95	247	−61	63
August	242	−61	108	247	−64	75
September	203	−70	100	265	−58	77
October	217	−71	90	252	−67	68
November	237	−72	95	251	−70	94
December	257	−71	77	269	−70	93
Year...	241	−68	1,003	261	−66	845

The rather erratic values in Table V may be due mainly to the difficulty of identifying the position of the tropopause with any accuracy, and it seems that a much longer period of observations will be required before any significant features can be picked out. It would have been interesting to compare mean monthly tropopause heights at Fazakerley and JIG but data were not readily available.

Upper winds.—No data are given for upper winds in this note as values for both stations are being prepared for publication in *Monthly Frequency Tables.*

RESULTS OF AN ARTIFICIAL NUCLEATION EXPERIMENT

By H. C. SHELLARD, B.Sc. and D. R. GRANT, B.Sc.

Introduction.—On the afternoon of March 9, 1951, a cloud-seeding experiment was carried out from a Hastings aircraft of the Meteorological Research Flight. The cloud chosen was a well defined layer of stratocumulus, base 9,000 ft., top 9,500 ft., with a temperature at its top of +15°F. Below this cloud was a layer of thick stratocumulus from about 1,000 to 7,000 ft., with some patchy cloud between the two layers. Winds taken from the Downham Market radio-sonde ascent for 1400 G.M.T. were 050° 25 kt. at 2,000 ft. veering and decreasing with height to about 090° 10 kt. at 9,500 ft. Seeding commenced just after 1400 G.M.T., at 9,500 ft. and at a point about 080° 15 miles from the Meteorological Office radar station at East Hill. Dry-ice pellets ½–1 cm. in diameter were dropped at a rate of about 1lb./mile; and an S-shaped track, in which the legs (orientated 330–150°) were initially about 10 miles long and 2½ miles apart, was flown. Total seeding time was 11 min.

Visual observations.—The usual effects on the cloud top were noticeable as soon as sufficient height had been gained to see them clearly. The most interesting features were the rates of spread and changes in shape of the seeded lanes. Some 8–10 min. after completion of seeding the effect of a horizontal wind shear approximately at right angles to the lanes was clearly visible. The rate of spread of the lanes was greatest in the region of shear, and, from photographs taken, was deduced as being about 4 m.p.h. there and about 2 m.p.h. elsewhere. As in the experiment* of January 25, 1950, the change in wind took place over a very short distance, which unfortunately cannot be determined from the photographs. Fig. 1, taken from 20,000 ft. 17 min. after seeding in direction 210°, shows the three lanes beginning to join up near the shear line. There is also evidence of some vertical development in the form of cumulus heads just to one side of the line.

Fig. 2 is another view from the north-west taken 40 min. after completion of seeding. The separate lanes were now barely distinguishable and the cloud was completely cleared near the centre of the area.

Radar observations.—During the experiment frequent photographs were taken of the radar echoes obtained from the area on P.P.I. and H.R.T. indicators at East Hill. The first sign of echo appeared about 11 min. after completion of seeding. Fig. 3, a P.P.I. photograph taken 15 min. after seeding, shows an echo extending in a direction 150–330° from a position 100°, range 11 miles, to a position 040°, range 10 miles, from East Hill. This is certainly the first seeded lane and the horizontal wind shear already mentioned is visible at a bearing 080° from East Hill. Later photographs showed this echo drifting towards East Hill until by 1437 it was almost lost in the permanent echoes. It is difficult to explain why no well marked echoes appeared from the other two seeded lanes because as far as possible the rate of seeding was kept constant.

The H.R.T. photographs showed echoes from all three seeded lanes though that from the first was much the most intense. Fig. 4, a good example, was taken 26 min. after completion of seeding. Unless the rate of seeding is completely uniform the H.R.T. will show more pronounced echoes than the P.P.I. because the former is operated on the most favourable azimuth. The H.R.T. photographs also reveal the wind shear in the vertical and, using the Downham Market radio-sonde winds for 1400 G.M.T., the rate of descent of the snow (assumed constant) may be calculated. It was found to be 4·2 ft./sec. in the first lane. Comparison of the shapes of the three columns in Fig.4 shows the rate of fall to be less in the second and third lanes, indicating that the ice crystals were smaller and suggesting that these lanes were overseeded, resulting in many more, and therefore smaller, ice crystals. It seems that the results obtained depend

*FRITH, R.; Wind shear revealed by artificial nucleation. *Quart. J. R. met. Soc., London,* 77, 1951, p. 131.

very critically on the seeding rate. On the H.R.T. photographs there are a few echoes with tops at 2,000–3,000 ft. which were possibly produced by seeding of the lower layer, but this is unlikely as some echoes were present at this height before seeding.

At about 1440 G.M.T. precipitation from the first seeded lane was observed falling to the gound at East Hill. It was of an entirely different nature from the intermittent frozen drizzle which had been falling previously, being quite definitely snow although not in very large flakes.

By about 1500 G.M.T. all the radar echoes had disappeared and the aircraft descended through the gap in the clouds. There were still some *virga* in the vicinity and the optical effects showed that ice crystals were still present in parts of the seeded area.

We are indebted to Mr. R. F. Jones for providing the radar photographs and the ground observations from East Hill.

FOG AT NORTHOLT AIRPORT

By W. E. SAUNDERS, B.Sc. and W. D. SUMMERSBY, B.Sc.

It has been suggested that an analysis of fog at Northolt Airport on similar lines to that recently published by N. E. Davis[1] in regard to London Airport might be of interest to airline operators and to forecasters.

Northolt is six miles north-north-east of London Airport and is 120 ft. above M.S.L. compared with the 82 ft. of London Airport.

In this note, to facilitate comparison, the same four-year period (August 1946–July 1950) has been covered, and the same visibility limits have been used (visibility $\leqslant$220 yd., $\leqslant$440 yd., $\leqslant$880 yd., and $\leqslant$1,100 yd.). Thick fog has been regarded as visibility $\leqslant$220 yd.

The diurnal variation of fog within these ranges is given in Table I, and the percentage frequencies of fog and thick fog in Fig. 1 and Fig. 2 respectively.

The most significant features appear to be as follows:—

(i) The minimum frequency of fog in July.

(ii) The gradually increasing fog frequency in August and September, mainly forming after midnight and clearing at 0600–0900.

(iii) The rapid increase in fog frequency in October, and the tendency to clearance at 0900–1200. But towards the end of the month occasional all-day fogs are experienced.

(iv) The further increase in frequency in November, with marked tendency for the fog to persist all day.

(v) The rapid decrease in frequency from November to December, and the gradual decrease from December to March.

(vi) The relatively low frequency at 0600–0700 in December and January, and December the only month of the year in which the evening maximum fog frequency exceeds the morning maximum.

(vii) The gradually increasing tendency for fog to clear during the forenoon from January to March.

(viii) The rapid decrease in frequency from March to April, and the gradual decrease from April to July.

These features may be explained from a consideration of the nature of the fog at various seasons.

Summer months

TABLE I—DIURNAL VARIATION OF FOG AT NORTHOLT AIRPORT

Time	APRIL				MAY				JUNE				JULY				AUGUST				SEPTEMBER			
	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.
G.M.T.												*number of occasions in four years*												
0000	...	...	...	1	...	...	...	...	...	2	2	3	...	...	...	...	...	...	...	1	...	1	1	1
0100	...	...	...	...	1	1	2	4	1	1	2	2	...	...	...	...	...	...	1	1	...	1	3	4
0200	...	...	...	...	1	2	4	5	1	1	3	4	...	...	...	1	...	2	5	5	3	5	6	7
0300	...	...	...	1	1	1	4	5	1	2	4	5	...	...	1	2	3	3	6	6	3	5	6	8
0400	...	1	1	2	2	2	4	5	2	2	3	4	...	...	1	1	4	4	6	7	5	8	10	11
0500	1	3	5	7	4	5	7	8	3	3	4	5	1	1	1	2	6	9	9	12	5	7	13	14
0600	1	2	4	9	3	5	6	8	1	1	1	2	...	2	2	2	8	10	11	11	7	7	16	19
0700	1	2	3	7	1	3	3	5	1	1	1	1	...	...	...	...	1	2	6	6	3	4	6	10
0800	1	1	4	6	...	...	...	2	...	1	1	1	...	...	...	...	1	1	1	2	3	3	6	7
0900	...	...	...	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	1	1	2
1000	...	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1100	...	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1200	...	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1300	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
1400	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
1500	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1600	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1700	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1800	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
1900	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
2000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
2100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1
2200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1
2300	...	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	1	1
Total	4	9	21	53	13	19	31	43	10	14	22	29	1	3	5	8	23	31	45	53	30	42	70	91
Mean (hr./month)	1	2	5	13	3	5	8	11	3	3	5	7	0	1	1	2	6	8	11	13	7	11	17	23

TABLE I—*continued*

Winter months

Time	OCTOBER				NOVEMBER				DECEMBER				JANUARY				FEBRUARY				MARCH			
	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.	⩽220 yd.	⩽440 yd.	⩽880 yd.	⩽1,100 yd.
G.M.T.	*number of occasions in four years*																							
0000	8	13	21	23	14	16	25	27	8	11	16	19	4	8	13	15	4	5	11	15	5	6	11	17
0100	11	13	18	26	13	17	22	24	10	11	14	18	3	8	10	16	4	5	10	15	6	7	13	17
0200	9	12	20	24	12	17	22	25	9	9	12	15	6	7	10	12	5	6	11	15	4	5	8	14
0300	10	17	24	26	16	20	20	27	8	10	12	15	4	7	10	13	4	7	12	16	6	6	8	14
0400	12	12	19	25	14	18	19	24	7	8	10	13	3	7	8	12	3	4	10	15	5	5	7	13
0500	11	12	20	25	15	18	22	24	6	7	8	14	4	6	8	9	4	5	11	15	5	6	8	13
0600	15	17	22	26	14	20	26	29	5	5	6	9	4	7	9	10	4	5	8	14	6	7	11	16
0700	13	15	24	30	15	21	28	31	5	6	6	7	5	8	9	9	4	5	12	16	9	10	19	23
0800	9	13	23	27	22	23	31	33	5	5	9	14	8	10	13	17	5	8	19	20	8	11	16	21
0900	8	11	21	25	18	23	28	32	5	7	12	17	7	12	15	22	7	9	18	24	8	11	18	20
1000	6	9	15	20	15	19	30	35	5	7	15	19	7	11	16	25	7	8	14	22	4	4	11	14
1100	...	5	9	13	11	14	23	27	6	7	12	18	7	10	13	23	2	5	12	14	3	4	8	11
1200	...	1	4	11	9	10	18	23	5	7	12	17	6	8	11	19	2	3	8	14	...	2	5	9
1300	...	...	2	5	8	11	14	19	5	7	9	15	5	6	10	13	3	3	7	9	...	1	4	5
1400	...	1	2	3	6	7	13	18	6	6	11	15	1	1	6	8	2	3	6	9	...	2	3	3
1500	...	1	2	3	7	8	13	18	6	6	12	15	...	1	6	11	2	4	8	9	1	2	3	4
1600	...	...	2	3	8	10	14	18	5	8	14	18	...	...	11	16	2	3	4	6	1	2	3	4
1700	...	1	3	7	8	10	17	24	6	8	11	20	...	3	12	19	1	2	5	8	1	2	4	9
1800	1	2	6	15	7	10	14	20	7	8	14	19	1	4	9	14	2	2	7	12	1	2	5	10
1900	1	1	5	11	9	11	14	23	6	11	11	20	1	4	10	14	1	4	9	13	2	4	8	13
2000	1	2	10	15	10	13	17	23	8	9	14	19	1	4	12	20	4	4	10	12	3	6	8	14
2100	...	2	9	20	13	15	19	24	8	11	13	22	3	6	11	20	4	6	12	15	3	6	8	12
2200	...	3	11	17	13	15	21	23	8	10	14	19	3	5	12	17	5	8	11	14	4	5	10	14
2300	5	8	16	20	15	17	25	26	7	9	14	17	5	8	14	17	5	6	10	15	3	5	7	11
Total	120	171	308	420	292	363	495	597	156	193	281	394	88	151	258	371	86	120	245	337	88	121	206	301
Mean (hr./month)	30	43	77	107	73	91	124	149	39	48	70	99	22	38	65	93	21	30	61	84	22	40	51	75

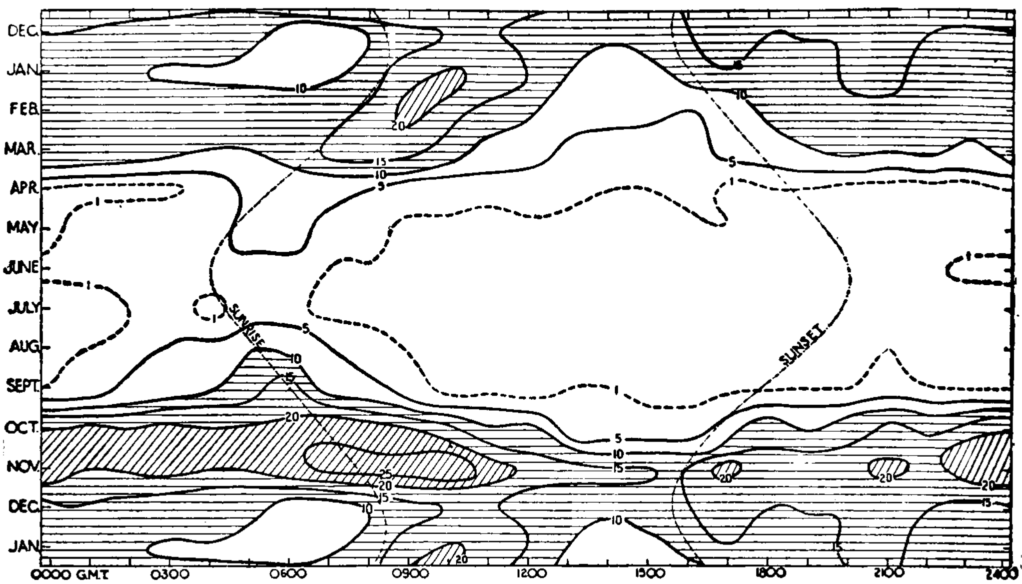

FIG. 1—DIURNAL VARIATION OF FOG AT NORTHOLT AIRPORT

Fog at Northolt is mainly a combination of radiation and smoke fog. Advection fog is very rare, probably occurring on an average less than once a year.

In the summer half year fogs are almost exclusively water fogs. The screen-level temperature at which water fog forms (the fog point) has recently been investigated by Saunders[2]. This temperature has been shown to be conservative within a degree or so at airfields which include Northolt and London Airport. It is approximately proportional to the hydrolapse and to the depression of screen-level dew point below dry-bulb temperature at the time of maximum temperature. In summer and early autumn the fog point is relatively high, mainly within the range of 40–60°F. The gradually increasing fog frequency during this season reflects the greater tendency for the fog point to be reached with the increasing length of night.

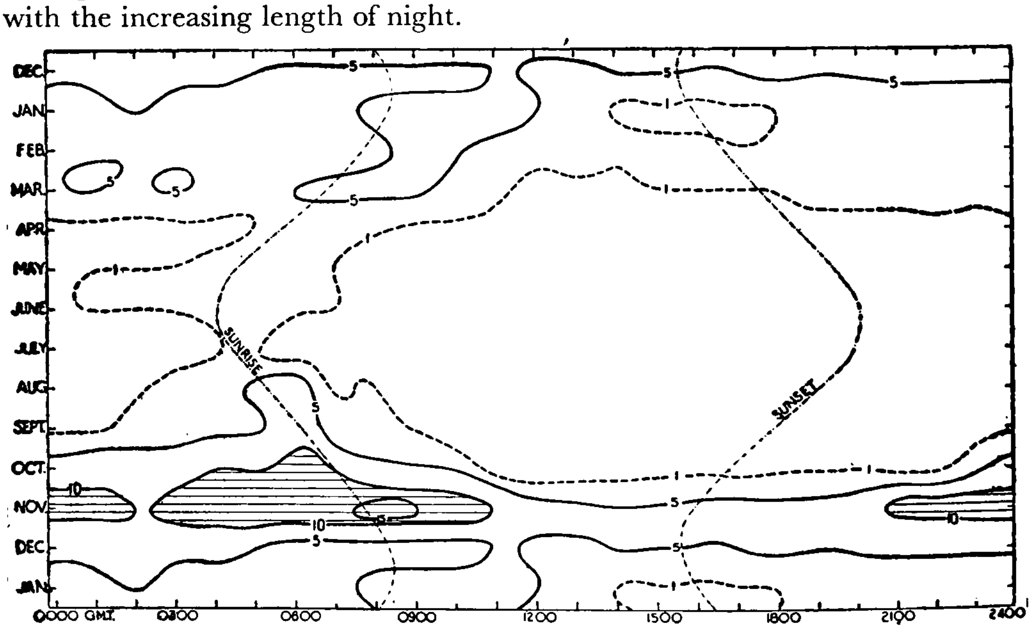

FIG. 2—DIURNAL VARIATION OF THICK FOG AT NORTHOLT AIRPORT

From October smoke becomes significant. Northolt is materially affected by London smoke (a combination of domestic and industrial smoke) when the surface wind is between NE. and SSE., and by domestic smoke from various local sources. It is important to recognize that London smoke will reduce visibility into the fog range with low relative humidity, if other conditions are favourable. Thus occasions have been known with visibility at Northolt below 200 yd. with relative humidity 60–70 per cent., e.g. February 6, 1949, 1600 G.M.T., visibility 180 yd., relative humidity 70 per cent. The local smoke sources are also occasionally sufficient to produce dry fog at Northolt. It follows that water fog and smoke fog must be considered separately until the relative humidity reaches the range 90–100 per cent.

The extent to which the smoke affects visibility at Northolt will depend upon:—

(i) Season of year.
(ii) Time of day.
(iii) Day of week.
(iv) Temperature lapse rate.
(v) Surface wind direction.
(vi) Surface wind speed.

During the summer half year domestic smoke is negligibly slight. Industrial smoke continues, but only very rarely reduces visibility into the fog range. During the winter half year, as Davis points out, domestic fires are burning from 0700–0800 to about 2200 during November to March, and during evenings in October and April. On Sundays and public holidays most fires are lighted later in the mornings, and there is little industrial smoke. For the smoke by itself to reduce visibility into the fog range it must be concentrated beneath a low temperature inversion near the ground. A suitable inversion will develop due to ground cooling on any evening when there is clear sky and light wind. During summer the inversion will break down rapidly after sunrise, but during winter it will remain most of the day, often all day. It follows from these considerations that there is a smoke maximum at 0800–1000 on weekdays, and it has been noted on many occasions that this is delayed until 1100 on Sundays. There is a secondary smoke maximum towards dusk due to the formation or intensification of the ground inversion at this time, accentuated in October and April by smoke from freshly lighted fires. There is a smoke minimum at about 0600 due to smoke having been gradually deposited or carried away during the night. There is a secondary smoke minimum in the early afternoon, when the inversion is most likely to break down, if at all.

The effect of increasing wind speed, at any time, is that the base of the inversion is raised above the ground, and the smoke or fog is distributed through a greater depth. Accordingly, we find that water fog is usually dispersed when the wind speed reaches a critical value in the region of 5–7 kt., and that only the worst cases of smoke fog continue when the wind speed exceeds 10 kt.

In November south-east England is still mainly under the influence of air streams of maritime origin. The water-fog point is still relatively high, mostly in the range 35–45°F. In addition the night is longer and smoke output at the winter level. Hence the November maximum fog frequency for the year. The chance of fog clearing during the day is much decreased by the reduced insolation.

The significant change in December is that south-east England tends to have appreciably drier air of continental origin. Davis has expressed this change in terms of the mean vapour pressure. In terms of the water-fog point it means, on the average, a reduction to the range 25–35°F. with a corresponding decrease in moisture content. On a rural non-smoky site fog will not in general form when the calculated fog point is reached, when this is below 32°F. Hoar-frost or rime will form instead of fog. At Northolt in these circumstances the question whether fog will form will usually depend upon the smoke situation at the time the calculated fog point is reached. The December fog minimum at 0600–0700 is therefore readily explicable from the smoke minimum at this time together with the low water-fog points usually experienced.

During January to March smoke fog continues to predominate. Increased day heating leads to the increasing number of fogs which clear in the forenoon, and all-day fogs are rare by March.

Comparison of the total number of occasions of fog in all the hourly reports shows that the difference between Northolt and London Airport is negligibly small—Northolt had 5 hr. more "fog" and 1 hr. more "thick fog" than London in 4 years. A more detailed comparison is given in Fig. 3 and Table II.

TABLE II—MONTHLY VARIATION IN THE TIME OF MORNING MAXIMUM FOG FREQUENCY AT NORTHOLT AND LONDON AIRPORT

Month	Time of morning maximum London	Time of morning maximum Northolt	Month	Time of morning maximum London	Time of morning maximum Northolt
January	0900	1000	July	0400	0300
February	0900	0900	August	0600	0500
March	0800	0700	September	0600	0600
April	0600	0600	October	0800	0700
May	0500	0500	November	0900	1000
June	0600	0500	December	1000	1000

Fig. 3 shows that there is more fog at Northolt in seasons when water fog predominates, and more at London Airport when smoke fog is common. Table II shows that during the water-fog period the time of fog formation is, on the average, up to 1 hr. earlier at Northolt, while in the late winter months this tendency is to some extent reversed.

These circumstances may readily be explained in terms of the nocturnal cooling, the water-fog point, and the surface wind direction. Owing to differences in soil* between the two airfields early evening cooling is more rapid at Northolt, where it has been noted that the evening temperature discontinuity[3], which is now believed to mark the commencement of dew or hoar-frost formation, is reached up to 1 hr. earlier than at London Airport. This difference is carried forward during the subsequent cooling. It follows that the water-fog point is reached up to 1 hr. earlier at Northolt, and that on some occasions it is just reached at Northolt but not at London Airport. The excess of fog at London Airport during January to March may partly be attributed to the tendency, shown in the wind rose for Greenwich[4], for increasing frequencies of NE. and decreasing frequencies of SE. winds at this season, resulting in rather more London smoke being carried to London Airport than to Northolt.

*Soil types:—*London Airport:* 6–9 in. vegetable soil, then Taplow brick earth down to 3 ft., then gravel down to 10–15 ft. and below that London clay.

Northolt: very little top soil at all, heavy clay from near the surface downwards, no gravel layer.

The general conclusions, as affecting airline operators, are similar to those expressed in Davis' final paragraph, with the addition that during late summer and early autumn London Airport will often be suitable for diversion of aircraft at the time morning fog is forming at Northolt.

The similarity between the two airfields suggests it might be worth obtaining similar figures for an airfield on the opposite side of London. This would show to what extent the greater tendency for instability in N.–WNW. air streams decreases the fog frequency, and might lead to the general conclusion that from this point of view airports should preferably be sited to the south or south-east of large towns.

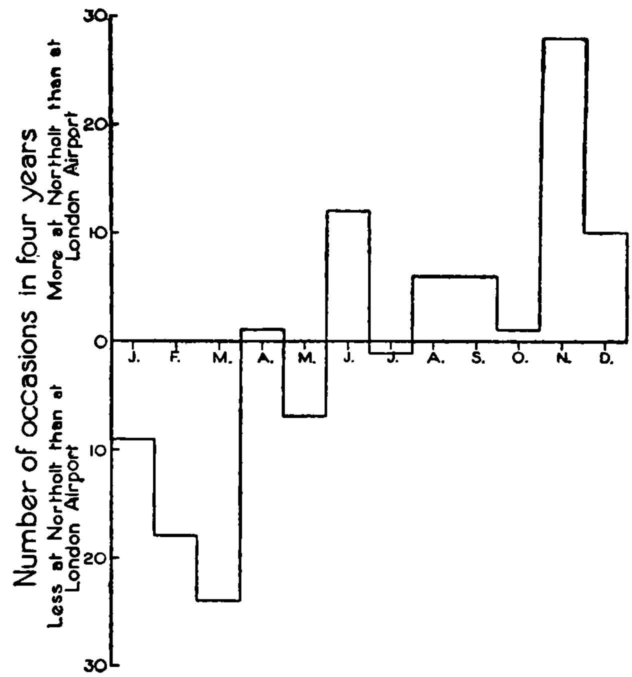

FIG. 3—MONTHLY VARIATION IN THE FREQUENCY OF FOG BETWEEN NORTHOLT AND LONDON AIRPORT

Mr. N. E. Davis comments as follows on the monthly differences between the number of hours of " thick fog " at Northolt and London Airport.

" An even more remarkable result is that the number of hours of ' thick fog ' at London Airport minus the number of hours at Northolt is only 1 hr. over the period of four years. The individual monthly totals vary from 266 hr. thick fog at London Airport and 299 hr. at Northolt in November to 139 hr. at London Airport and 88 hr. at Northolt in January. These figures bear out the statement that Northolt is more subject to water fogs and London Airport to smoke. In January Northolt with a low fog point has less thick fog, the excess moisture being deposited as hoar-frost, but at London Airport, with a greater amount of smoke, excess moisture is deposited on the smoke particles resulting in a thick fog."

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SEVERE TURBULENCE ENCOUNTERED BY AIRCRAFT NEAR JET STREAMS

By J. K. BANNON, B.A.

Introduction.—It is well known that atmospheric turbulence can occasionally have a noticeable effect on the flight of an aircraft even in the cloudless air usually found at high altitudes. The resulting irregular accelerations or " bumps " are usually slight but exceptionally they may be sufficiently developed to be described as severe. Though bumps have been observed between the levels of 20,000 and 40,000 ft. in many varied meteorological situations in temperate latitudes, the neighbourhood of the fast-moving streams of air known as jet streams appears to be favourable for the occurrence of turbulence at high altitude[1]. This note discusses three occasions of jet streams in the upper troposphere when aircraft experienced severe turbulence at heights above 28,000 ft.

Turbulence incidents.—Details of time, place and altitude of the incidents of severe turbulence are given in Table I and also the type of aircraft in which the bumps were experienced.

TABLE I—OCCASIONS OF SEVERE TURBULENCE NEAR JET STREAMS

Incident	Date	Time	Place	Height*	Aircraft
		G.M.T.		ft.	
A_1	14.11.49	1130	York to Durham	35,000	Comet
A_2	14.11.49	1300	Orkneys	35,000–38,000	Comet
A_3	14.11.49	1530	Just east of Felixstowe	35,000–36,000 32,000	Comet Venom
B	2.11.50	1250	Flushing (Holland)	35,000	Comet
C_1	7.11.50	1400	Leicester	28,000–32,000 39,000–41,000	Meteor
C_2	7.11.50	1430	Cromer to Skegness	33,000–38,000	American F.86, Meteor and others
C_3	7.11.50	1345 1500	West Raynham Spalding	28,000–34,000 29,000–31,000†	

* As measured with an I.C.A.N. altimeter. † Maximum intensity.

The case of November 14, 1949, has been described in detail by Hislop[2]; on a long flight by a Comet aircraft, roughly along the track of a well marked jet stream, turbulence of unusual intensity was experienced in several places. A visual accelerometer was fitted in the cockpit of the aircraft but the indications of this instrument are not considered to give a reliable measure of the accelerations experienced at the centre of gravity of the aircraft; however, Hislop[3] has estimated that the maximum equivalent gust velocity* experienced in the York–Durham area (incident A_1, Table I) was about 35 ft./sec. which is comparable with gusts met in cumulonimbus clouds. The turbulence in incidents A_2 and A_3, though giving bumps which most pilots would assess as severe, were much less severe than the exceptional gustiness of incident A_1.

From the readings of the visual accelerometer it is estimated that the equivalent gust velocities experienced on November 2, 1950, (incident B) were about 20 ft./sec. or a little less.

*The equivalent gust velocity[4] is a useful parameter of gustiness as affecting aircraft; it is a calculated equivalent velocity which, if the gust were vertical, of unlimited horizontal extent and built up linearly in a distance of 100 ft., would produce the acceleration experienced by the given aircraft at the same equivalent forward speed.

In the incidents reported on November 7, 1950, the assessments of gustiness were purely qualitative but were variously noted as severe, or violent or very considerable.

Meteorological situation.—Figs. 1, 2 and 3 show diagrammatic synoptic charts for sea level for the three days of severe gustiness, November 14, 1949, November 2 and 7, 1950, respectively. The weather situations at sea level do

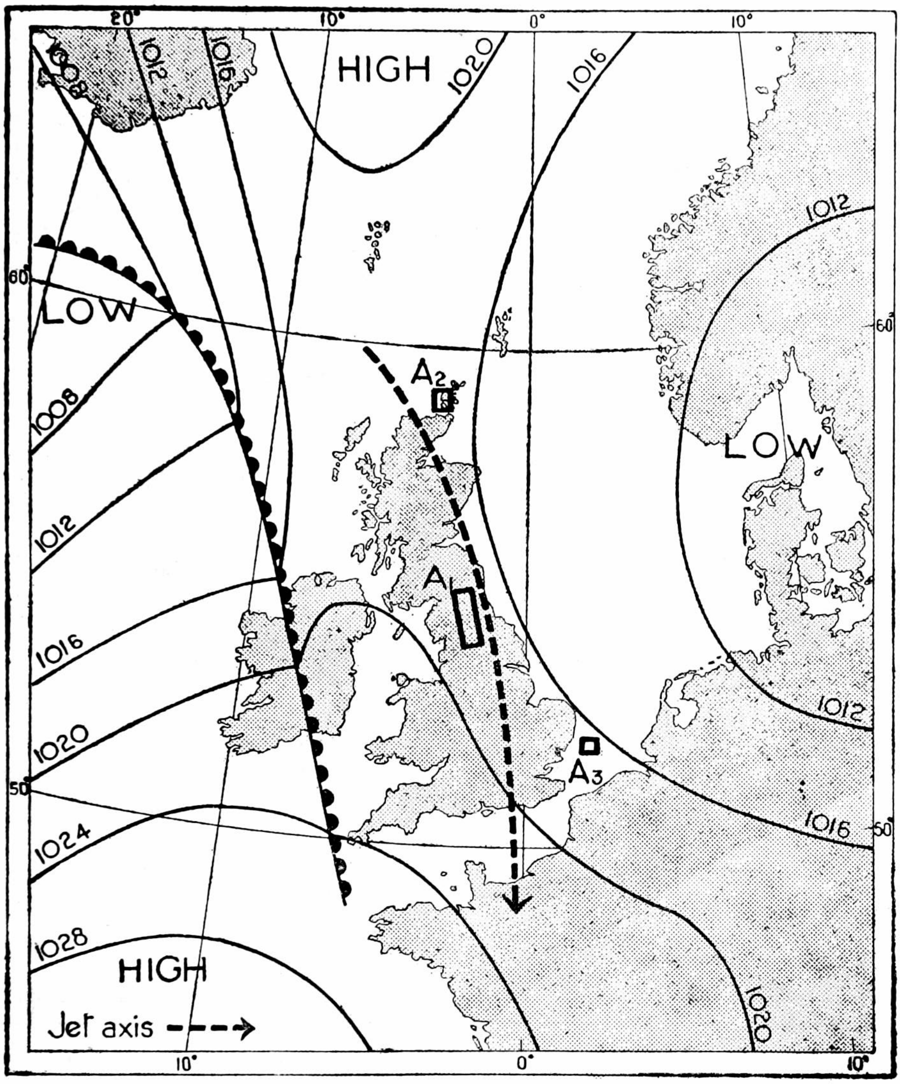

FIG. 1—SYNOPTIC CHART, 1200 G.M.T., NOVEMBER 14, 1949 SHOWING THE REGIONS OF OBSERVED TURBULENCE

not seem to have many points in common. In each case, however, a comparatively narrow zone of fast-moving air or jet stream was present in the upper troposphere in the region where the turbulence was found. (For a description and discussion of jet streams see a paper by Durst and Davis[5].) The axes of these jet streams are indicated in Figs. 1, 2 and 3 and details of some of the characteristics of these jet streams are given in Table II.

The nature of a jet stream is best understood by considering a vertical cross-section at right angles to the general air stream; many examples of cross-sections of jet streams have been published, e.g. by Durst and Davis[5] or by the

University of Chicago[6], and cross-sections of the three cases considered here did not show any unusual features and were in many ways very similar.

To get an idea of which parts of a jet stream are liable to severe turbulence, data for the three occasions were averaged to give a mean cross-section which is

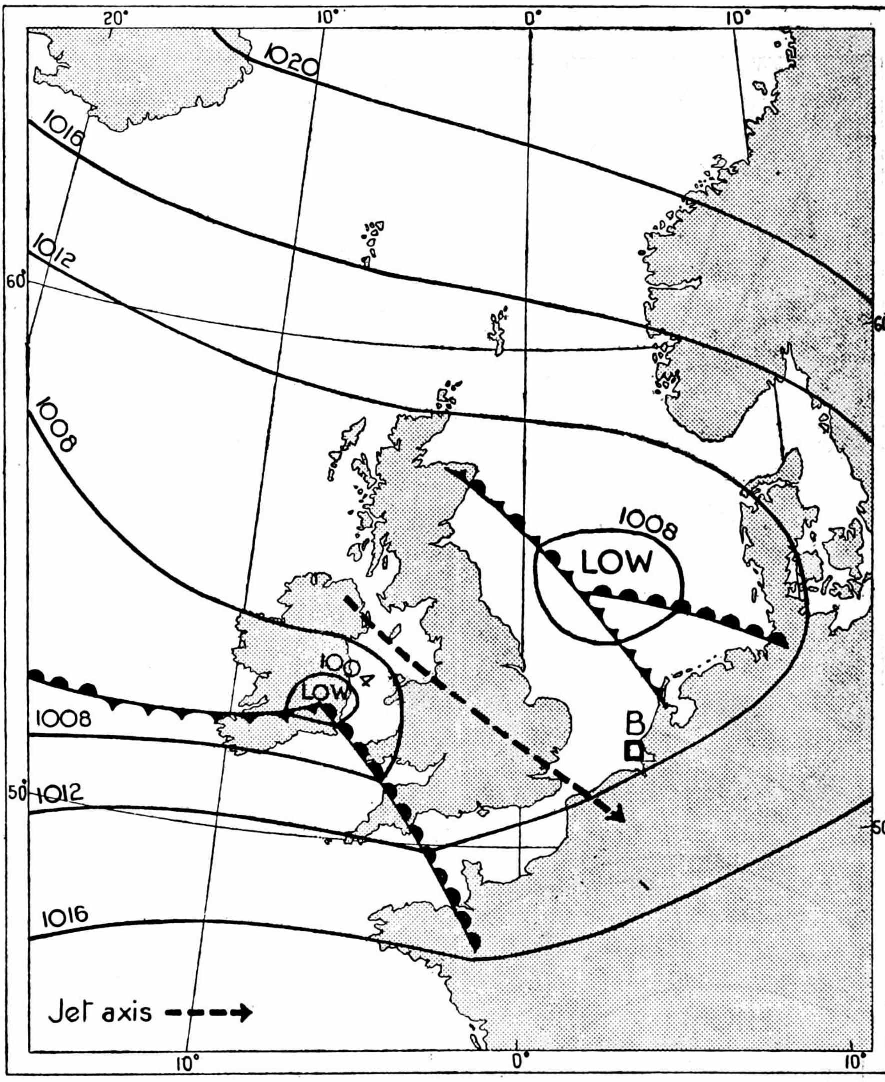

FIG. 2—SYNOPTIC CHART, 1200 G.M.T., NOVEMBER 2, 1950 SHOWING THE REGIONS OF OBSERVED TURBULENCE

TABLE II—CHARACTERISTICS OF THREE JET-STREAM CROSS-SECTIONS

Date	Height* of jet axis	Pressure of jet axis, P_J	Maximum wind speed	Scale of horizontal units in Fig. 4†
	ft.	mb.	kt.	nautical miles
14.11.49	31,600	280	160	113
2.11.50	29,000	315	140	54
7.11.50	32,700	265	130	151
Mean	31,000	287	143	106

* As measured with an I.C.A.N. altimeter.

† The horizontal scale is the distance on the low-pressure side of the jet axis in which the wind speed falls to half its maximum value.

shown in Fig. 4. The positions of the various turbulent incidents relative to the jet stream are shown on this diagram. The mean cross-section was constructed as follows: cross-sections were drawn for each of the jet streams for approximately the same time as the turbulence was observed and for sections as near as possible to the position of the turbulence, using observations of wind and temperature from the British upper air observing stations. Reference lines were then drawn on each cross-section taking the jet centre (point of maximum wind) as origin. Horizontal distances were measured in units of the distance

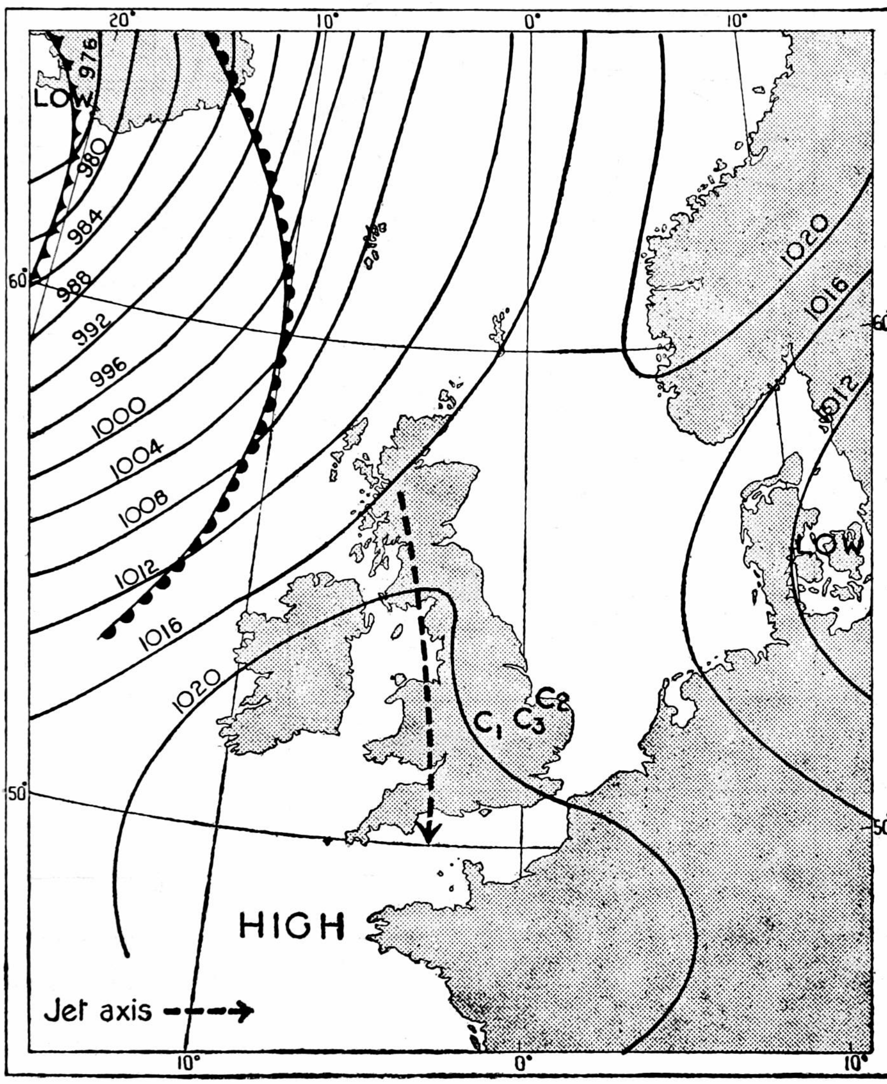

FIG. 3—SYNOPTIC CHART, 1200 G.M.T., NOVEMBER 7, 1950 SHOWING THE REGIONS OF OBSERVED TURBULENCE

from the jet centre to the point, at the same level on the left of the jet looking downwind, at which the wind speed decreased to half its maximum value. Vertical distances were measured in pressure differences as indicated in Fig. 4 where a logarithmic scale is used so that ordinates on the diagram are approximately proportional to true height. Values of temperature, potential temperature and wind speed normal to the cross-section were then read off each diagram for each point of the net of reference lines, wind speed being measured as a percentage of the maximum wind. The readings for corresponding points on the three cross-sections were then meaned and the resulting mean values led to the diagram in Fig. 4. The heights of the axes, the maximum wind speeds and the horizontal-distance scales for the three jet streams are given in Table II.

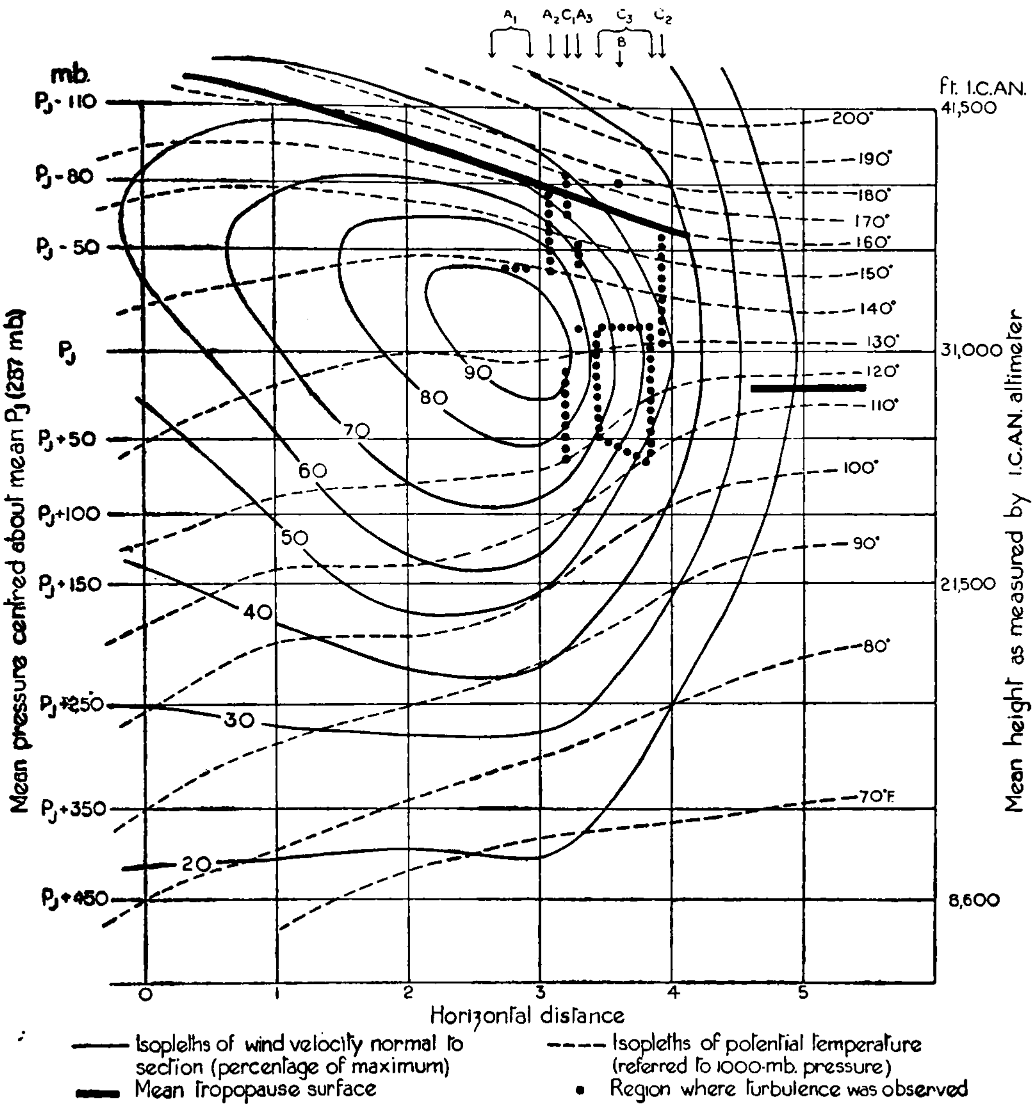

FIG. 4—MEAN CROSS-SECTION OF A JET STREAM SHOWING REGIONS OF TURBULENCE

The scales of units of horizontal distance are given in Table II.

In Fig. 4, isopleths of wind speed normal to the section, expressed as a percentage of the maximum, are given as full lines. The pecked lines show the isopleths of potential temperature which are also isentropes. The only forces opposing motion along isentropic surfaces are frictional so that turbulent transfer along the isentropic surfaces and across the wind (i.e. along the isopleths of potential temperature in the diagram) is easily effected.

A striking feature of Fig. 4 is that with the exception of incident A_1 the reported severe gustiness occurred on the low-pressure side of the jet axis. It must be remembered that only three occasions are considered here and that probably only small portions of the jet region were explored by aircraft on these days. It is not possible, therefore, to deduce with certainty that the low-pressure side of a jet stream is more liable to be turbulent than the anticyclonic side; there is at least one report of severe turbulence occurring on the anticyclonic side (November 30, 1950, over the Wash and Lincolnshire at 40,000 ft.). However, flights above 25,000 ft. are not uncommon so that severe turbulence on the high-pressure side of a jet stream should not go unnoticed for long if it occurs frequently. It is certainly suggestive that the noteworthy cases of severe gustiness in the neighbourhood of jet streams discussed in this note were all just above or on the low-pressure side of the axis. The two cases of severe turbulence encountered near jet streams by the British European Airways high-altitude experimental flights (Hislop[3]; flights VR 4 and VR 60) were also on the low-pressure side of the jet axis.

It is emphasized that this mean cross-section in Fig. 4 has been prepared merely as a convenient way of illustrating the positions of the gustiness observations relative to the jet stream. It is not claimed that this mean jet stream has any properties which can be interpreted physically except in so far as the properties are means of common features.

Probable causes of the gustiness.—In *Professional Notes* No. 104[1] it is shown that high-altitude gustiness is in most cases related to one or both of two meteorological parameters namely shear of wind in the vertical and shear of wind in the horizontal. The physical connexion between vertical wind shear and turbulence is easily visualized as similar to that resulting in turbulence in the shearing layer near the ground. The dimensionless quantity known as the Richardson number, which takes into account the vertical stability of the air as well as the wind shear, appears to be a useful parameter in this connexion. The Richardson number is defined as

$$R_i = \frac{g}{T} \frac{\left(\frac{\partial T}{\partial z} + \Gamma\right)}{\left(\frac{\partial \mathbf{V}}{\partial z}\right)^2}$$

where T is the absolute temperature, z is the height, Γ is the adiabatic lapse rate of temperature (dry- or wet-adiabatic as appropriate), and $\mathbf{V}$ is the wind velocity.

High-altitude turbulence is very often, but not always, associated with small values of R_i of the order 1–5*. In many cases, therefore, it seems reasonable to say that the gustiness encountered by aircraft is caused by abnormal vertical shear of wind.

It is more difficult to see a direct physical connexion between excessive wind shear in the horizontal and the occurrence of gustiness, and the mechanism whereby a horizontal shear of, say, 20 kt./100 nautical miles causes eddies of the order of 200 ft. across is not understood at present. The fact remains that there does appear to be some relation between the occurrence of turbulence at high altitude and abnormal wind shear in the horizontal.

*RICHARDSON[7] deduced theoretically that when Ri is less than 1 turbulence should increase, and should decrease when Ri is greater than 1 but CALDER[8], among others, has shown that the critical value may be less than 1.

In Fig. 4 it is seen that in some cases, (e.g. A_2, A_3, C_1, parts of C_3) the gustiness occurred in regions of large shear in the vertical. Fig. 4 is, however, a composite diagram of three different occasions and the averaging process has probably masked individual peculiarities. Scrutiny of the upper wind data for each particular occasion shows that in every case the wind shear in the vertical was probably large and the Richardson number correspondingly small. On November 14, 1949, the Richardson numbers evaluated from each of the upper air observations made at 1430 G.M.T. at Larkhill, Downham Market and Leuchars were less than 1 at 35,000 ft. (incident A_1), and the Richardson numbers at Lerwick between 35,000 and 38,000 ft. and at Downham Market between 32,000 and 36,000 ft. (incidents A_2 and A_3 respectively) were also less than 1 at 1430. On November 2, 1950, the nearest wind observation to incident B was that made at Downham Market at 1430; there, again, the Richardson number was less than 1. The nearest upper air observations to incidents C_1, C_2 and C_3 on November 7, 1950, (Larkhill and Downham Market), indicated that the Richardson number was less than 1 in the turbulent layers with the exception of the upper layer of C_1 (39,000 to 41,000 ft.) where it had a value of 1·7.

Fig. 4 shows that in almost every case the horizontal shear (or the shear along the isentropic surfaces) was large in the gusty region being 0·2 hr.$^{-1}$ or more and the data for each of the individual cases confirm this.

Thus in these cases of severe gustiness it appears that both meteorological features which are favourable for the occurrence of turbulence were present. There is no way at present of determining which factor was the more important but ease of physical interpretation would point to strong wind shear in the vertical as the main cause of the gustiness.

Conclusions.—There seems little doubt that jet streams are favourable regions for the occurrence of turbulence of such a nature as to cause bumps to an aircraft. Since jet streams often extend as wandering high-speed currents over distances up to 1,000 miles or so they are frequently encountered on flights in the upper troposphere in temperate latitudes, and it is therefore important to discover as much as possible about the occurrence of turbulence in their neighbourhood. The three occasions analysed here, though providing only a limited amount of information, are thought to be useful examples and to form a basis of knowledge to which can be added further information as it becomes available. It is suggested that other interesting incidents of high-altitude gustiness can be added to a diagram such as Fig. 4, and eventually it may be possible to confirm the most turbulent regions of jet streams and whether there is any significant variation in the position of these regions relative to the jet axis, along the length of the jet stream.

Acknowledgment.—Details of the incidents on November 14, 1949, and November 2, 1950, were kindly supplied by the De Havilland Aircraft Company.

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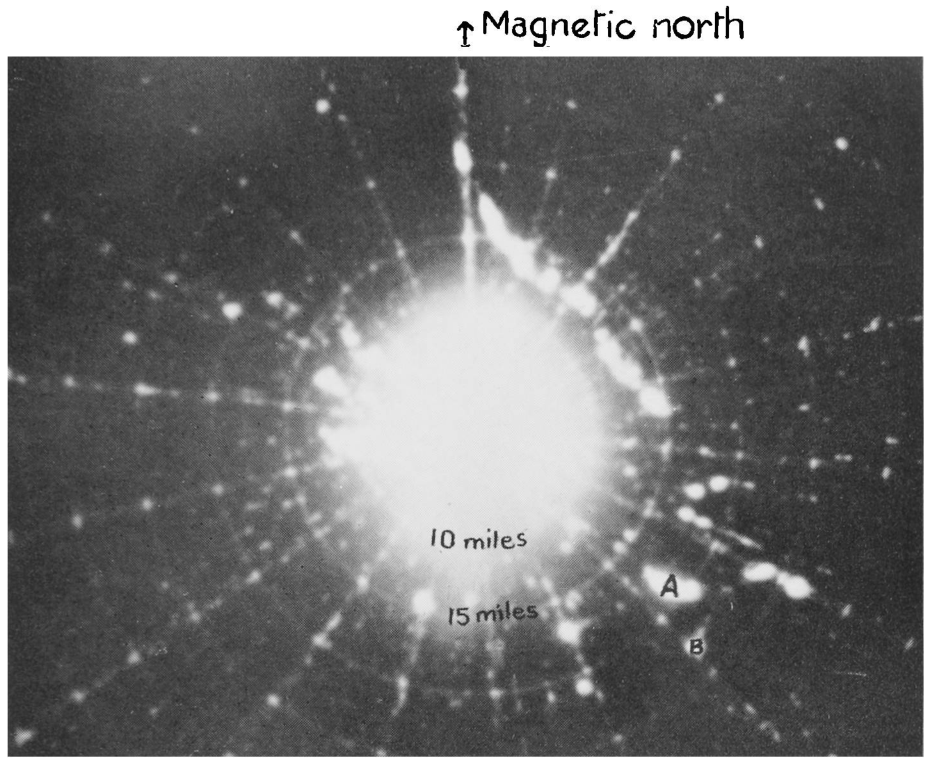


FIG. 1—P.P.I. PHOTOGRAPH OF RAIN ECHOES FROM CLOUD NOT REACHING FREEZING LEVEL

Time of observation: 1501 G.M.T., July 18, 1951

(see p. 273)

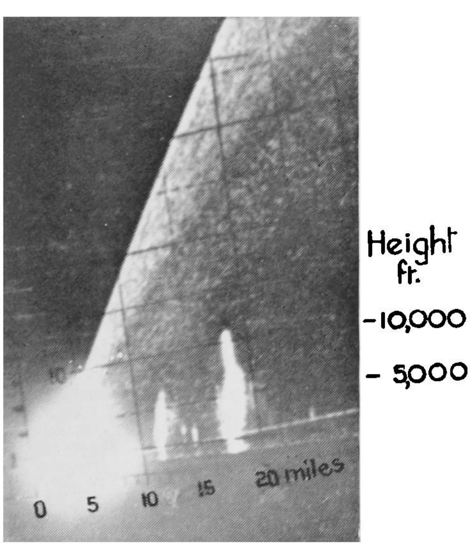


FIG. 2—VERTICAL CROSS-SECTION ON BEARING 134° MAGNETIC

Time of observation: 1459 G.M.T.

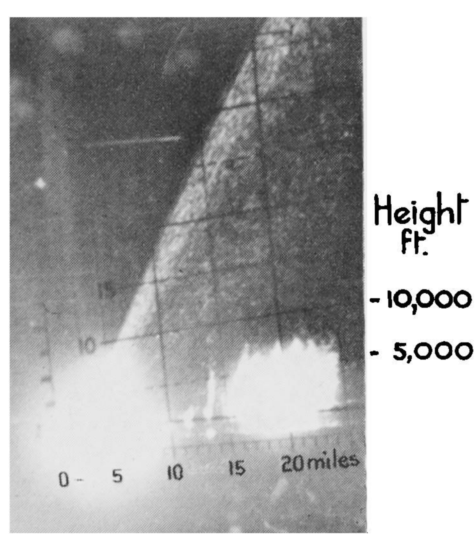
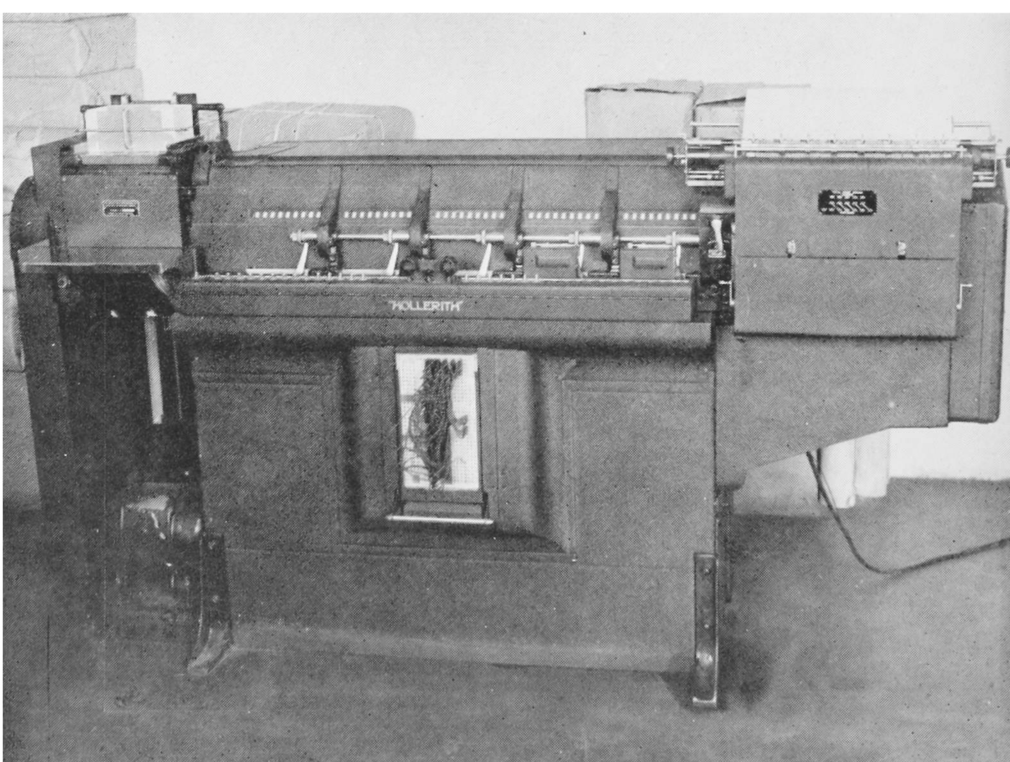


FIG. 3—VERTICAL CROSS-SECTION ON BEARING 125° MAGNETIC

Time of observation: 1346 G.M.T.

PLAIN SORTER AND COUNTER-SORTER MACHINES



TABULATING MACHINE

MECHANICAL SORTING AND TABULATING MACHINES IN THE MARINE BRANCH OF THE METEOROLOGICAL OFFICE

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ADAPTATION OF MECHANICAL SORTING AND TABULATING MACHINES TO RESEARCH IN MARINE METEOROLOGY

By A. H. GORDON, M.S.

Mechanical sorting and tabulating machines are designed for the systematic analysis of large numbers of observations and they may be adapted to many kinds of scientific research problems. They are particularly suitable for the treatment of marine observations, and recent research in marine meteorology has been planned to make good use of the facilities that these machines are able to provide.

The general function and purpose of the machines have been described in a previous article.[1] It is the intention here to outline briefly ways in which the machines may be adapted to meet the requirements of specialized problems in marine meteorological research.

In the Marine Branch of the Meteorological Office there are two plain sorter machines, two counter-sorter machines and a tabulating machine. The plain sorter sorts the punched cards into the groups required, the counter-sorter counts the cards in each group as they are sorted and the tabulator tabulates the data, counts the total number of cards and the sum total of the tabulated values. The simplest analysis of data is the calculation of the mean of all the numerical values of a given meteorological element for a particular area, period or time of day or other boundary condition desired. It is also simple to compute the frequencies of occurrence of various meteorological phenomena or of ranges of values of specified elements, provided the ranges are not too small. The meteorological atlases of the oceans prepared by the Meteorological Office during the late war are based mainly on computations of this nature for two- or five-degree squares, grouped into months of the year.

An example of a more specialized problem is an investigation[2] into the influence of the strength of the wind on the sea and air temperature and the air-sea temperature difference. In this and other similar types of problems the observations are required to be sorted into groups and finally tabulated so that each of a range of values of a particular meteorological element is associated with the corresponding value of another meteorological element for the same observation. If, in the above mentioned problem, the sea and air temperatures were sorted in order from the maximum to the minimum values and these were tabulated for each wind force, a frequency curve of all the sea and air temperatures could be drawn for each wind force, and the mode and median of such a curve obtained. Such a curve could apply to a given area, time of day or time of year and also, if desired, to different wind directions. Each further limiting condition would require additional sortings.

In order to investigate the effect of the wind on the air-sea temperature difference it would be necessary to sort each final wind-force group so that each of the range of values of air temperature from the maximum to the minimum was associated with its corresponding sea temperature for the same observation. The tabulations would then appear in the general form given in the following example:—

Wind force	Air temperature	Sea temperature	Total number of each sea-temperature value for each air-temperature value
1	60	56	1
1		54	1
1	58	54	1
1		52	1
1	55	50	1
1	54	58	
1		58	
1		58	3
1		55	1
1	52	55	1
1		50	1
1	50	48	
1		48	
1		48	3
1		47	
1		47	2
1		46	1

and so forth for each wind-force group throughout the range of air-temperature values. From these tabulations a grid can be prepared which contains the frequency of each air-sea temperature difference (1°, 2°, 3°, etc.) for each air-temperature value. A percentage frequency curve of the whole range of air-sea differences could then be constructed for each wind force and the sets of curves so obtained compared with one another.

Similar types of problems that have been undertaken in marine meteorology are the diurnal variation of sea and air temperature in relation to cloud amount and to the air-sea temperature difference, and the influence of the strength of the wind on the relative humidity. In the latter problem the data would be tabulated as already shown except that wet-bulb observations would replace sea temperatures in the third column. The grid would then contain the frequency of each of the range of relative humidities associated with each value of the air temperature. In this case the curve constructed from the grid would give the percentage frequency of each of the range of relative humidities for each wind force. As before, the sets of curves could be compared with one another and their physical significance studied.

The above examples are only a few of the many problems to which mechanical sorting and tabulating machines may be adapted to convert raw marine data into a form readily used by the research worker. The potentialities of the machines in the furthering of research in marine meteorology are only limited by the ingenuity of the research worker himself.

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OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

PROFESSIONAL NOTES

No. 103—Stratus cloud near the east coast of Great Britain. By G. A. Bull, B.Sc.

Off-sea winds on the east coast of England are frequently accompanied by a sheet of low stratus cloud which is particularly persistent in winter and spring.

In this note the physics and variations of this cloud are examined; and a description is given of methods, tried in the Meteorological Office at Felixstowe, of forecasting the cloud.

No. 104—Meteorological aspects of turbulence affecting aircraft at high altitude. By J. K. Bannon, B.A.

This note describes the results of a meteorological analysis of occasions of turbulence (bumps) experienced by aircraft at high altitude. It is found that noticeable turbulence, which is not associated with cumulonimbus cloud, occurs not infrequently above a height of 20,000 ft. over the British Isles; it is rarely severe.

Statistics of the heights and depths of turbulent layers are given, and it is shown that turbulence occurs most frequently in the neighbourhood of the 30,000-ft. level and that the turbulent layers are usually less than 1,000 ft. thick. Bumps are often found near the tropopause. This turbulence is found to be related to the Richardson number (itself related to wind shear in the vertical and temperature lapse rate) and to the horizontal shear of the wind, but neither of these causes alone can explain all the occurrences of bumpiness and it seems that these two possible causes of turbulence are partly independent.

Well marked jet streams and their margins are regions of large shear in the vertical and in the horizontal, and high-altitude turbulence is frequently experienced in and near such fast-moving streams of air.

ROYAL METEOROLOGICAL SOCIETY

Visit to East Malling Research Station

This year, the annual summer meeting of the Royal Meteorological Society was held at East Malling, near Maidstone in Kent, on July 18.

The Society was welcomed by Dr. Tubbs, Director of the Station, and led at once to an improvised lecture theatre of apple boxes in a nearby orchard. Dr. Tubbs gave a brief talk on the general work of the station: research into the better understanding of fruit-growing and its relation to climate and soil; in this they were greatly helped by the Agricultural Meteorology Branch of the Meteorological Office. Climate had a long-term effect on the soil and this had a cumulative effect on the growth of a tree, and the effect of the weather in one particular year was carried forward to other years. In general, fruit-growing was successful in England south of the 68°F. mean isotherm in August, and the best-quality apples were grown with much sunshine and about 25 in. annual rainfall, very little of which should fall in spring. But growth was much influenced by day-to-day weather changes such as an isolated spring frost, waterlogging or increased attacks by harmful insects and diseases, all of which could affect growth in future years as well as in the present.

Orchards were nowadays planned to avoid frost hollows, but research into the favourable sites near the tops of hills was now necessary. And there was still the problem of the hardiness of individual buds, not the whole tree, and why, after a mild winter, some buds would not produce fruit. In studies of this nature the normal weather measurements were of little use and it was necessary to make accurate microclimatological measurements of the environment of an individual tree or branch or even bud.

Mr. Preston described some efforts that had been made to correlate time of blossoming with various meteorological and other factors, such as the monthly mean temperatures, the accumulation of day degrees above 42°F., the type of fruit and the age of the tree and method of pruning. With some trees the blossoming was a little later every year (after allowing for other factors), with others a little earlier. Eventually it had been possible to make in February a forecast with reasonable accuracy (± 5 days normally, ± 1 day in years of late and early blossoming) of the time of maximum blossoming, and therefore to know beforehand when to prepare for spraying and when to introduce bees. By pruning selectively the blossoming on different branches of the same tree could be arranged to come at different times within the normal blossoming period and so to be sure that some part of the blossom would always escape the effects of frost.

At another part of the station, Mr. Good demonstrated a tensiometer which had been designed by Dr. Rogers to measure the capillary tension of water in the soil. This consisted of a buried porous pot filled with water connected by tubing to a mercury manometer. It was shown being used under various surfaces—clean cultivation, grassing down and straw mulch. When the water content was low the tension was high and the mercury in the tensiometer was low and *vice versa*, the limit of measurement being, of course, 1 atmosphere of pressure. The experiments showed that the straw mulch acted as a blanket to radiation and enabled the water from quite a slight shower to be collected. Also, transpiration from grass in dry weather seemed to be offset by improved penetration of rainfall. While the Society was at the Station the tensiometers were reading about 7 cm. of mercury over the straw mulch and cultivated plots but 60 cm. over the grass plots.

Mr. Ruxton described some experiments on the effect of frost. The temperature of the plants was measured by a fine-wire thermocouple (the wires were so fine they were almost invisible from 15 ft.) which was accurate to approximately 0·1°C. On some occasions of radiational cooling below 0°C. the plant did not freeze, i.e. there was supercooling. The explanation for this supercooling was unknown. A method, still experimental, of preventing the freezing of flowers (or blossoms) during a frosty night was demonstrated in a cold chamber. The flower was sprinkled with a fine shower of water which froze on contact with the flower. This liberated latent heat which was sufficient to maintain the temperature of the flower at only 0·1°C. below freezing. The temperature of a flower in the same chamber but not sprinkled fell to −3°C. and the flower was killed. The method had not, so far, been tested on an orchard scale because of the lack of frost during this spring!

After tea (at which there were home-grown cherries) the Society inspected one of the classical root-stock experimental plots where the root-stocks had been standardized to such an extent that it was now possible to control the size, shape and fruit-bearing qualities of a given root-stock and sire.

Another plot was given over to entomological experiments and Miss Groves gave a short lecture on the character of red-spider-mite migration. If there was any wind at all the tiny red-spider mites clung to the leaves of the trees; in a calm they spun a thread from which they dangled to be blown away by the next breeze.

In the model garden, which the Society visited last, cordon apple trees were on exhibition in all manner of shapes, one of the best (possibly because of its efficiency as a receiver of insolation) being in straight lines at 45° to the horizontal with no real branches at all. A plum tree, growing against a wall, was shown also supplied with a hessian cover for use on radiation nights. This raised the temperature of the plant 5°F. above the air temperature whereas the traditional fish-netting had almost no effect.

Mr. E. L. Hawke, on behalf of the Society, offered sincere gratitude to the staff of the Research Station for the excellent organization and the great amount of work that had been done to make the visit a success.

LETTER TO THE EDITOR

Rain from non-freezing clouds

As rain from non-freezing clouds has not been reported before in England, the following observations may be of interest.

From 1300 to 1630 G.M.T. on July 18, 1951, numerous echoes from precipitation were observed on 10-cm. radar at East Hill on bearings principally between east and south. The maximum top of echo observed was 8,500 ft., and some echoes with tops only 1,000–2,000 ft. were seen to persist for a considerable time. The echoes frequently showed a column structure and were visible, with quite high intensity, at ranges up to 30 miles.

We were able to make contact with a Hastings aircraft of the Meteorological Research Flight and direct it to two of the column-type echoes. The clouds containing the echoes could be distinguished from the aircraft by the domed tops rising about 500 ft. above the general 8 oktas stratocumulus cloud tops. The only cloud above this level was a trace of cirrus. Readings made in the aircraft showed the cloud tops examined to be at 7,500 and 8,800 ft. (I.C.A.N.) and the temperatures of the free air at these heights 45·7° and 44·6°F. respectively. Because these clouds were in the London Control Zone it was not possible to enter them but some distance away the clouds were found to contain a surprising amount of free water with some large drops.

Reports received make it clear that slight rain, in moderately sized drops, did reach the ground in the general area from which echoes were received and there is no doubt that the rain observed fell from non-freezing clouds.

Radar photographs are reproduced facing p. 268.

Fig. 1, a P.P.I. photograph, shows echoes from precipitation visible in a belt from 20 miles range on magnetic north to 15 miles on 090°. There are patches of precipitation echo to the south-east, the one marked A being from the second cloud examined by the aircraft which is at B.

Fig. 2 shows a vertical cross-section on a magnetic bearing of 134°. The echo at 17–19 miles is from the second cloud examined and is echo A of Fig. 1. The top of this echo is at about 8,000 ft. and merges into the echo from the aircraft which was at 8,800 ft. as it flew past the top of the cloud. Fig. 3, a vertical cross-section on a magnetic bearing of 125°, shows a quite extensive echo from 13–25 miles with top not exceeding 8,000 ft.

R. F. JONES

East Hill, near Dunstable, Bedfordshire, July 19, 1951

NOTES AND NEWS

Weather Control Bill

The February 1951 number of *Weatherwise*, organ of the amateur Weathermen of America, received in the Meteorological Office in June contains an article by Senator Clinton P. Anderson (New Mexico) on the Weather Control Bill he has introduced into the United States Congress. A brief summary of this article is published by permission of the Editor of *Weatherwise*.

The Bill is in general based on the United States Atomic Energy Act of 1946. If passed it will place weather modification and control activities in the United States under the exclusive control of the Federal Government. The Senator considers that, though the extent to which measures for weather control may be utilized is still speculative, the possible effects on the national life, economy, and military defence are so large as to call for control by the central government.

The Bill provides for the organization of a Weather Control Commission which would licence and assist institutions engaged in weather control, for work by the armed forces of the United States on the military aspects, and finally for participation by the United States in international measures. The Commission would be specifically authorized to exempt from its licensing requirements such minor aspects of weather control as the protection of fruit trees from frost by " smudging ".

WEATHER OF JULY 1951

Mean pressure was between 1020 and 1025 mb. over the Atlantic between 35°N. and 50°N. Mean pressure over Europe and the Mediterranean was generally between 1015 and 1020 mb., but over Scandinavia, Iceland and Greenland, it was below 1010 mb. Pressure was about 2 mb. above normal over the Atlantic and west Europe and about 2 mb. below normal over Scandinavia. Pressure over North America was generally normal.

Mean temperature over most of the British Isles and Europe including southern Scandinavia was between 60° and 70°F. and reached 75°F. in Spain and the Mediterranean. In west Africa mean temperature was between 75° and 95°F. and exceeded 100°F. at places in the region of the Sahara. Mean temperature was generally about 2°F. above normal over Europe, but 3° to 4°F. below normal over Scandinavia.

In the British Isles the month was rather warm with several fine spells of abundant sunshine, especially in the south. These were interspersed with briefer cool periods and outbreaks of thundery rain. In general, rainfall was on the low side, but irregular in its distribution both in time and space.

From the 1st to the 3rd pressure was high to the south-west with fine warm weather over England and Wales; maximum temperatures in the neighbourhood of 80°F. and bright sunshine exceeding 13 hr. in the day were not uncommon. There were, however, troughs of low pressure over Scotland and one of these moved south with a break-through of polar air which covered the whole country on the 4th and 5th. Weather became cooler and cloudier everywhere, the effect being strikingly shown at Felixstowe with a maximum temperature of 81°F. on the 3rd but only 65°F. on the 4th. A westerly type of weather became established on the 6th bringing cool showery conditions to all districts until the 8th, though rainfall was slight in the south. On the 9th a fairly deep depression approached Ireland and then, gradually filling up, moved slowly across Scotland on the 10th and 11th to reach southern Norway on the 14th. Rain fell in all districts, though it was heaviest in the north where there were widespread thunderstorms on the 10th and 11th. A small secondary disturbance moving north-east along the English Channel brought heavy rain to the south-east and east on the 12th and thundery outbreaks to central districts; 2·04 in. of rain fell at Great Bealings in Suffolk and 2·31 in. at Longfield in Kent. High pressure developed behind the depression on the 13th and became established as an anticyclone centred to the south-west which persisted until the 21st. Though there was somewhat unsettled weather in the north, the south experienced a warm dry period with maximum temperatures again approaching 80°F. and exceeding this value at some places during the last few days. On the 20th the centre of high pressure began to shift towards the east, crossing England on the 21st and reaching central Europe on the 22nd. It was followed by a complex depression which, forming off the south-west coast, moved north-east to reach the North Sea early on the 23rd. Widespread thunderstorms occurred on the 22nd, with special severity in southern England where some deaths from lightning and considerable damage were reported; 2·11 in. of rain fell at Romsey in Hampshire. Polar air in the rear of this depression affected north-west Scotland on the 22nd and covered the whole country on the 23rd, with dull cool weather in most districts; the maximum temperature was 56°F. at Cranfield, Lincolnshire, and exceeded 65°F. at a few places only. High pressure to the south-west again dominated the situation on the 24th and 25th. It was, however, rather unsettled in the north, and these conditions spread south, with some rain in Wales and the Midlands, on the 26th and 27th. Weather in the south was relatively unaffected and became very warm again on the 28th. A further short spell of generally fine weather on the 29th and 30th was associated with the eastward movement of an anticyclone across the country, but a depression moving north from Biscay brought widespread thunderstorms over southern and midland districts on the night of the 30th–31st. There was heavy rainfall followed by lighter falls on the 31st in the north as cloudier conditions spread to all districts.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	86	36	+0·9	67	−3	108
Scotland	79	31	+0·3	116	+1	91
Northern Ireland ...	74	39	+0·1	109	−2	79

RAINFALL OF JULY 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	1·46	61	*Glam.*	Cardiff, Penylan ...	·99	32
Kent	Folkestone, Cherry Gdn.	1·32	63	*Pemb.*	Tenby	1·06	36
„	Edenbridge, Falconhurst	2·56	110	*Card.*	Aberystwyth	4·31	142
Sussex	Compton, Compton Ho.	2·33	82	*Radnor*	Tyrmynydd	2·08	51
„	Worthing, Beach Ho. Pk.	2·77	136	*Mont.*	Lake Vyrnwy	2·71	76
Hants.	Ventnor, Cemetery ...	1·58	77	*Mer.*	Blaenau Festiniog ...	5·24	61
„	Bournemouth	1·19	56	*Carn.*	Llandudno	·85	38
„	Sherborne St. John ...	1·36	61	*Angl.*	Llanerchymedd ...	1·47	72
Herts.	Royston, Therfield Rec.	1·33	53	*I. Man*	Douglas, Borough Cem.	2·06	67
Bucks.	Slough, Upton	1·33	69	*Wigtown*	Port William, Monreith	2·34	83
Oxford	Oxford, Radcliffe ...	1·34	57	*Dumf.*	Dumfries, Crichton R.I.	2·54	78
N'hants.	Wellingboro', Swanspool	·82	36	„	Eskdalemuir Obsy. ...	4·68	114
Essex	Shoeburyness	2·41	132	*Roxb.*	Kelso, Floors	3·26	124
„	Dovercourt	2·02	101	*Peebles*	Stobo Castle	3·18	110
Suffolk	Lowestoft Sec. School ...	3·08	136	*Berwick*	Marchmont House ...	2·57	84
„	Bury St. Ed., Westley H.	1·40	56	*E. Loth.*	North Berwick Res. ...	3·28	127
Norfolk	Sandringham Ho. Gdns.	1·48	58	*Midl'n.*	Edinburgh, Blackf'd. H.	3·50	124
Wilts.	Aldbourne	1·37	58	*Lanark*	Hamilton W. W., T'nhill	2·46	86
Dorset	Creech Grange... ...	1·19	49	*Ayr*	Colmonell, Knockdolian	1·98	63
„	Beaminster, East St. ...	2·79	107	„	Glen Afton, Ayr San ...	2·88	69
Devon	Teignmouth, Den Gdns.	1·82	78	*Bute*	Rothesay, Ardencraig ...	3·69	93
„	Cullompton	1·26	47	*Argyll*	Morvern, Drimnin ...	6·22	141
„	Ilfracombe	1·20	47	„	Poltalloch	5·23	127
„	Okehampton, Uplands	3·54	109	„	Inveraray Castle ...	5·74	115
Cornwall	Bude, School House ...	1·03	42	„	Islay, Eallabus	2·83	83
„	Penzance, Morrab Gdns.	1·07	39	„	Tiree	3·28	91
„	St. Austell	1·72	51	*Kinross*	Loch Leven Sluice ...	5·83	202
„	Scilly, Tresco Abbey ...	·48	22	*Fife*	Leuchars Airfield ...	4·32	166
Glos.	Cirencester	1·94	75	*Perth*	Loch Dhu	4·22	87
Salop	Church Stretton ...	2·36	89	„	Crieff, Strathearn Hyd.	2·92	98
„	Shrewsbury, Monksmore	1·63	78	„	Pitlochry, Fincastle ...	2·30	86
Worcs.	Malvern, Free Library	·98	43	*Angus*	Montrose, Sunnyside ...	3·32	126
Warwick	Birmingham, Edgbaston	1·06	46	*Aberd.*	Braemar	2·24	87
Leics.	Thornton Reservoir ...	1·07	43	„	Dyce, Craibstone ...	5·75	190
Lincs.	Boston, Skirbeck ...	1·08	49	„	Fyvie Castle	4·66	143
„	Skegness, Marine Gdns.	·71	33	*Moray*	Gordon Castle	3·45	108
Notts.	Mansfield, Carr Bank ...	·72	27	*Nairn*	Nairn, Achareidh ...	2·94	115
Derby	Buxton, Terrace Slopes	2·83	72	*Inverness*	Loch Ness, Garthbeg ...	3·38	107
Ches.	Bidston Observatory ...	1·16	45	„	Glenquoich	7·66	119
Lancs.	Manchester, Whit. Park	3·25	98	„	Fort William, Teviot ...	5·52	113
„	Stonyhurst College ...	3·93	102	„	Skye, Duntuilm ...	6·13	163
„	Squires Gate	1·60	57	*R. & C.*	Tain, Tarlogie House ...	2·74	100
Yorks.	Wakefield, Clarence Pk.	2·96	117	„	Inverbroom, Glackour...	3·06	82
„	Hull, Pearson Park ...	1·54	66	„	Applecross Gardens ...	5·43	136
„	Felixkirk, Mt. St. John	3·06	112	„	Achnashellach	7·31	150
„	York Museum	2·23	88	„	Stornoway Airfield ...	3·40	118
„	Scarborough	2·52	104	*Suth.*	Loch More, Achfary ...	7·09	133
„	Middlesbrough... ...	1·89	74	*Caith.*	Wick Airfield	3·71	141
„	Baldersdale, Hury Res.	1·05	33	*Shetland*	Lerwick Observatory ...	3·97	173
Norl'd.	•Newcastle, Leazes Pk....	1·55	61	*Ferm.*	Crom Castle	3·63	104
„	Bellingham, High Green	1·71	52	*Armagh*	Armagh Observatory ...	3·34	116
„	Lilburn Tower Gdns. ...	2·62	106	*Down*	Seaforde	3·21	101
Cumb.	Geltsdale	4·15	120	*Antrim*	Aldergrove Airfield ...	3·31	118
„	Keswick, High Hill ...	3·07	80	„	Ballymena, Harryville...	3·55	104
„	Ravenglass, The Grove	3·14	84	*L'derry*	Garvagh, Moneydig ...	3·79	117
Mon.	Abergavenny, Larchfield	·95	38	„	Londonderry, Creggan	3·49	95
Glam.	Ystalyfera, Wern House	1·37	30	*Tyrone*	Omagh, Edenfel ...	2·94	116