THE METEOROLOGICAL MAGAZINE

HER MAJESTY'S STATIONERY OFFICE

November 1985

Met.O.967 No. 1360 Vol. 114

METEOROLOGICAL OFFICE Met.O.967

THE METEOROLOGICAL MAGAZINE

No. 1360, November 1985, Vol. 114

551.501.81:551.507.362.2:551.515.4(261.27)

The use of satellite and radar imagery to identify persistent shower bands downwind of the North Channel*

By K. A. Browning†, A. J. Eccleston‡ and G. A. Monk§

(Meteorological Office Radar Research Laboratory, Royal Signals and Radar Establishment, Malvern)

Summary

Organized bands of showers downwind of the North Channel often occur during cold north-westerly or northerly outbreaks in autumn and winter. Examples are given which show the value of satellite and radar imagery in identifying such bands and in tracking individual showers over periods of several hours.

1. Introduction

A band of convective showers can often be observed during unstable north-westerly or northerly outbreaks, extending downwind of the stretch of sea between Scotland and Northern Ireland known as the North Channel. The bands, which occur mainly in autumn and winter, are often hundreds of kilometres long. Sometimes they are isolated, and frequently they persist for many hours. They can lead to notable local weather anomalies. Places only 20 km apart can experience persistently different weather conditions when such a band remains stationary. Thus on one such occasion we have observed small hail accumulating in drifts near Manchester and on other occasions sustained snowfalls have occurred over the Preseli Mountains in south-west Wales at times when most other areas had none. Although the bands can take different orientations, one of the commonest is such as to cause showers to reach the Midlands by way of the Cheshire Gap.

The occurrence of significant shower activity downwind of the North Channel in unstable conditions is well known. Evidence of this can be found in *Aerodrome weather diagrams and characteristics*

*No. 1 in the series *The use and interpretation of satellite and radar imagery in weather forecasting.*
†Now Deputy Director (Physical Research) Meteorological Office, Bracknell.
‡Now at the Computer Department, 73 Church St, Malvern.
§Now at Meteorological Office, Bracknell.

(Meteorological Office)* for airfields at Blackpool, Manchester, Shawbury and Brawdy. In particular, the characteristics for Blackpool state that 'most showers, except those associated with troughs, occur in unstable north-westerly airstreams which reach Blackpool via the North Channel'. Farther away at Brawdy in south-west Wales no specific mention is made of the North Channel, but instability in airstreams coming from the general direction of the North Channel is clearly important since it is stated that 'frequent showers can occur from the north in autumn and winter by day and night' and, although thunderstorms occur on average only 9 days per year, these occur 'mostly in northerly airstreams in winter'. Despite the local experience accumulated at these stations, however, the well-defined and persistent nature of these shower bands did not become really obvious until the advent of frequent imagery from satellites and radars. In fact the shower bands are often quite narrow and composed of sequences of individual convective cells and so they are not well described by the conventional surface observational network alone.

2. The nature of North Channel shower bands

Infra-red satellite photographs for five cases of shower bands originating from the North Channel are shown in Figs 1(a), 2(a), 3(a), 4(a) and 5(a). The corresponding surface analyses are given in Figs 1(b), 2(b), 3(b), 4(b) and 5(b). The characteristics of these and other cases we have studied may be summarized as follows:

(i) The shower bands occur in situations of strong north-westerly or northerly polar airstreams with convective instability from the surface to typically 700–600 mb. Maximum temperature excesses assuming parcel theory are about 2 °C.

(ii) The bands may be well defined and isolated, particularly at night. However, during the day in the more strongly unstable conditions, showers are likely to be more widely distributed, especially over hills.

(iii) The bands consist of successions of fast-moving convective showers each of which produces a short heavy burst of precipitation as it passes over a given location. Averaged over a 1-hour period a typical rainfall amount near the axis of a band would be about 1 mm.

(iv) Suitable synoptic patterns can be persistent with showers following almost identical tracks downwind of the North Channel for many hours. Accumulations of precipitation will then be confined to a narrow swath, with a half-width of perhaps a few tens of kilometres.

(v) The shower cells travel at the speed of the wind over a well-mixed layer between 900 and 700 mb. Their direction of travel tends to be close to (actually a few degrees to the right of) the corresponding wind direction.

(vi) Individual shower cells are long lived and can be tracked for a period of 4 to 5 hours as they travel downwind from the region between the North Channel and the Isle of Man.

(vii) With a north-westerly wind the showers can penetrate inland over the Midlands to give a band up to 400 km long. They can survive passage over the southern end of the Pennines but tend to die out if they cross the Pennines farther north where the hills are higher. With a northerly wind showers originating near the North Channel tend to travel down the Irish Sea, only occasionally encountering land. The resulting shower bands can be twice as long as those forming with a north-westerly wind.

*Meteorological Office; *Aerodrome weather diagrams and characteristics*. (Unpublished, copy available in the National Meteorological Library, Bracknell.)

Figures 1–5. (a) NOAA satellite infra-red photographs (*by courtesy of University of Dundee*) showing a band of shower clouds extending downwind of the North Channel and (b) corresponding surface analyses (mb). Times and dates are as shown.

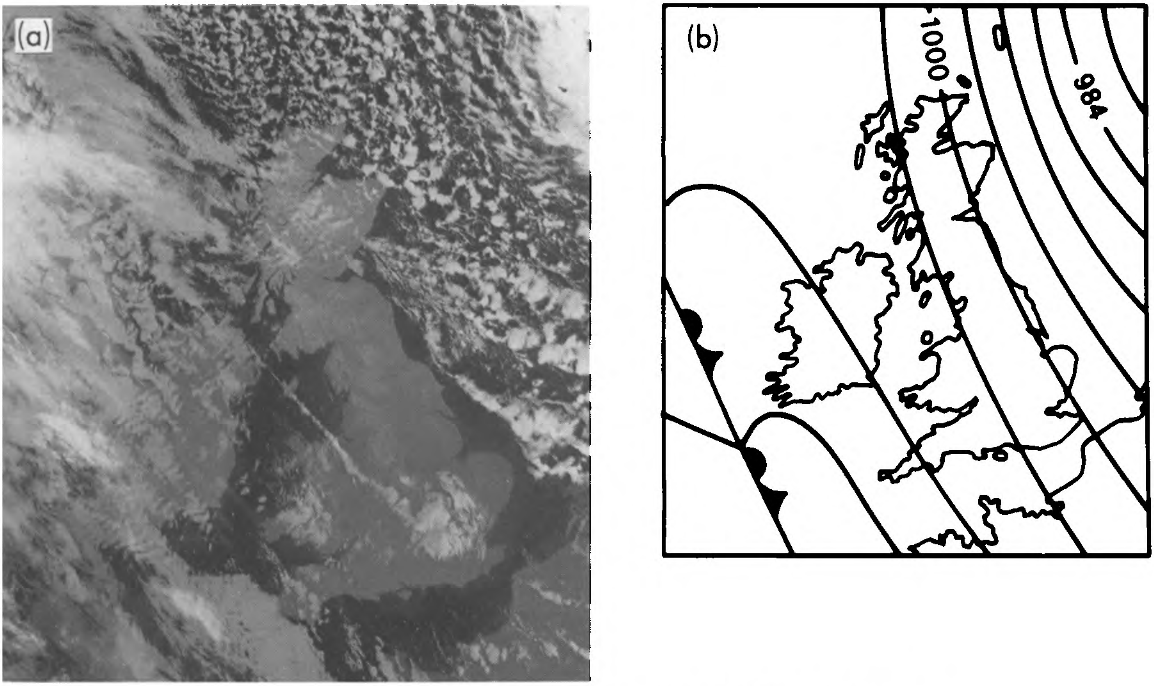


Figure 1. (a) 1903 GMT on 15 January 1981, (b) 1800 GMT on same date.

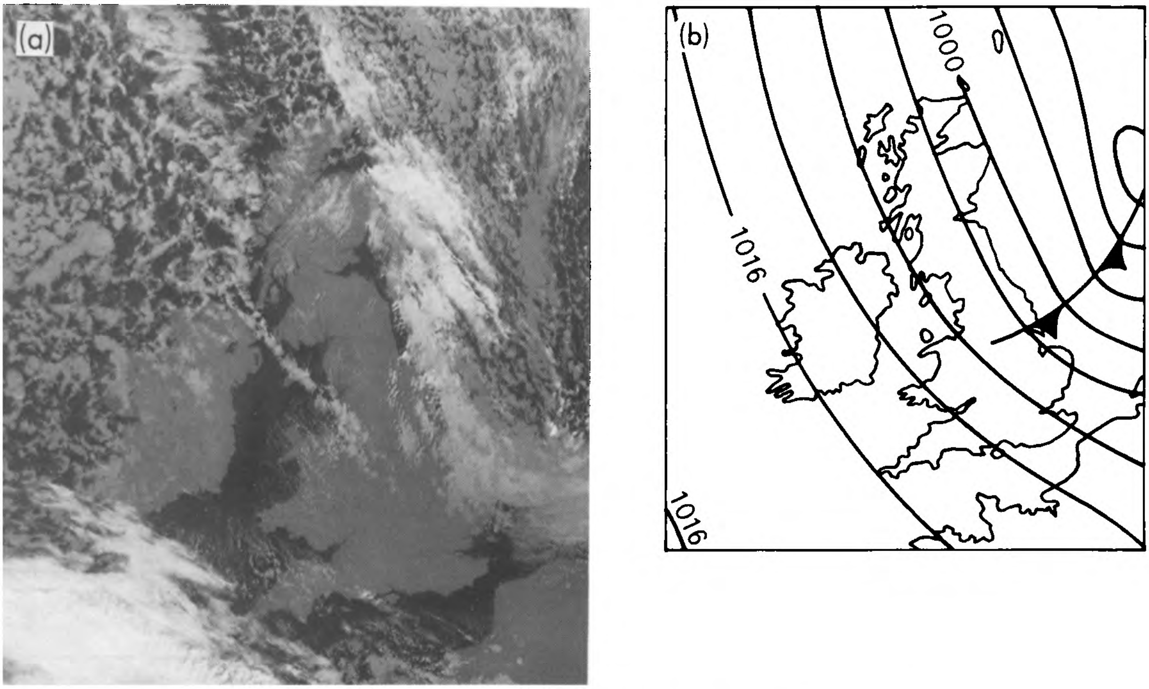


Figure 2. (a) 0301 GMT on 13 October 1981, (b) 0000 GMT on same date.

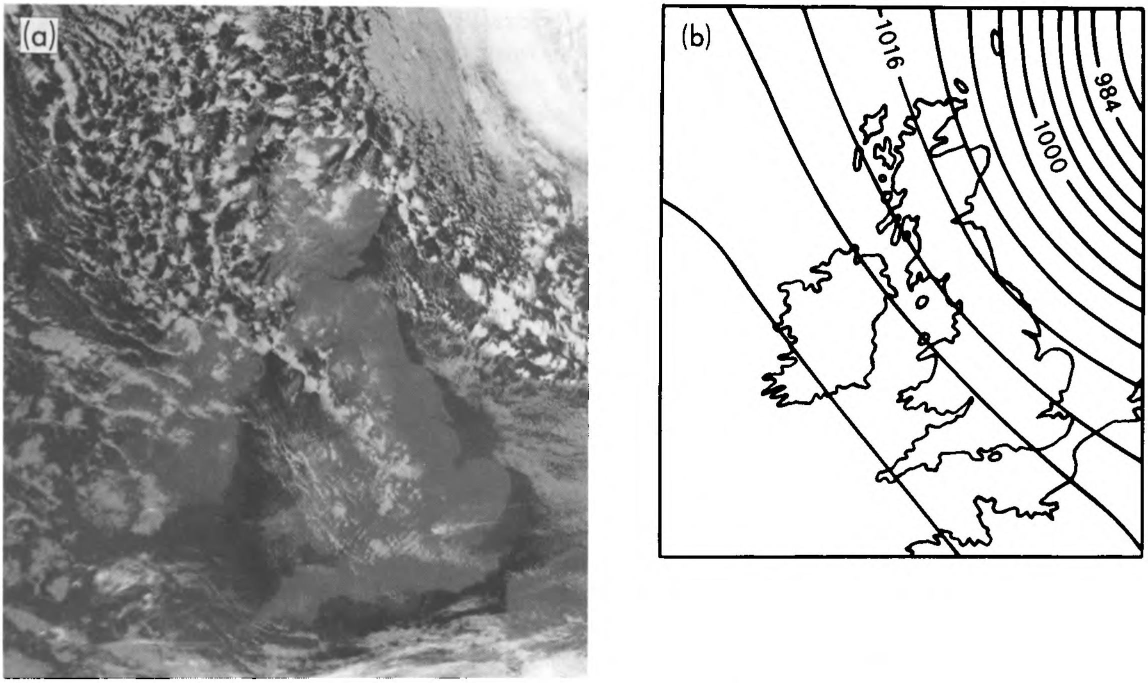


Figure 3. (a) 1314 GMT on 24 November 1981, (b) 1200 GMT on same date.

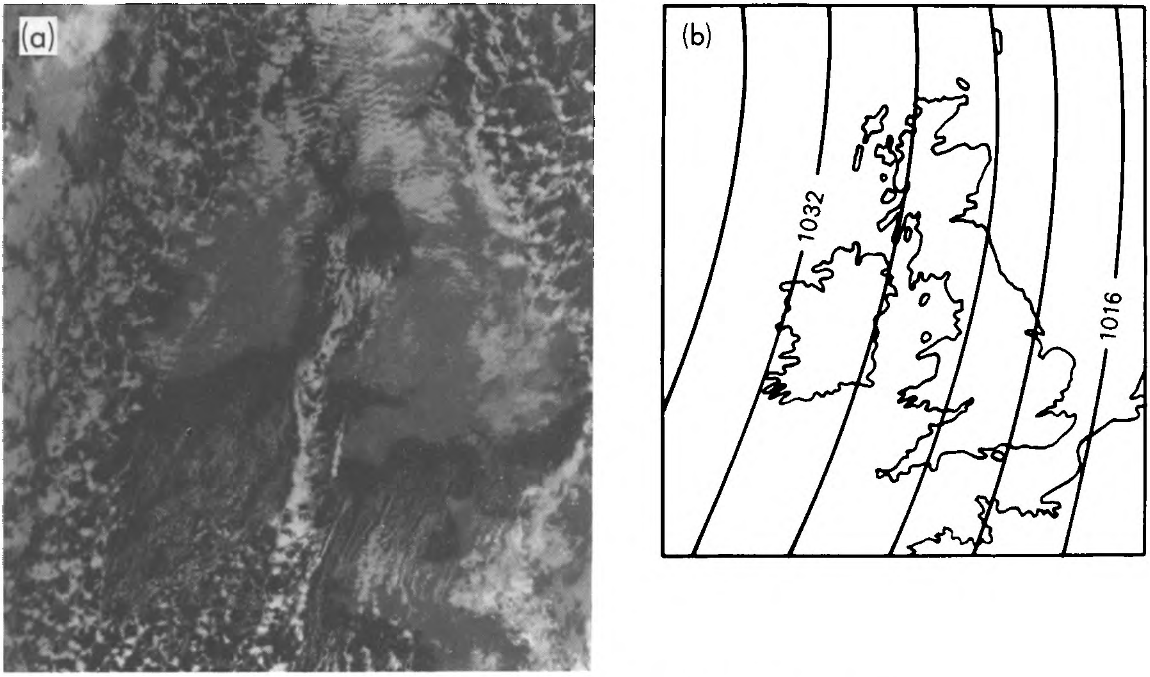


Figure 4. (a) 1430 GMT on 19 December 1979, (b) 1200 GMT on same date.

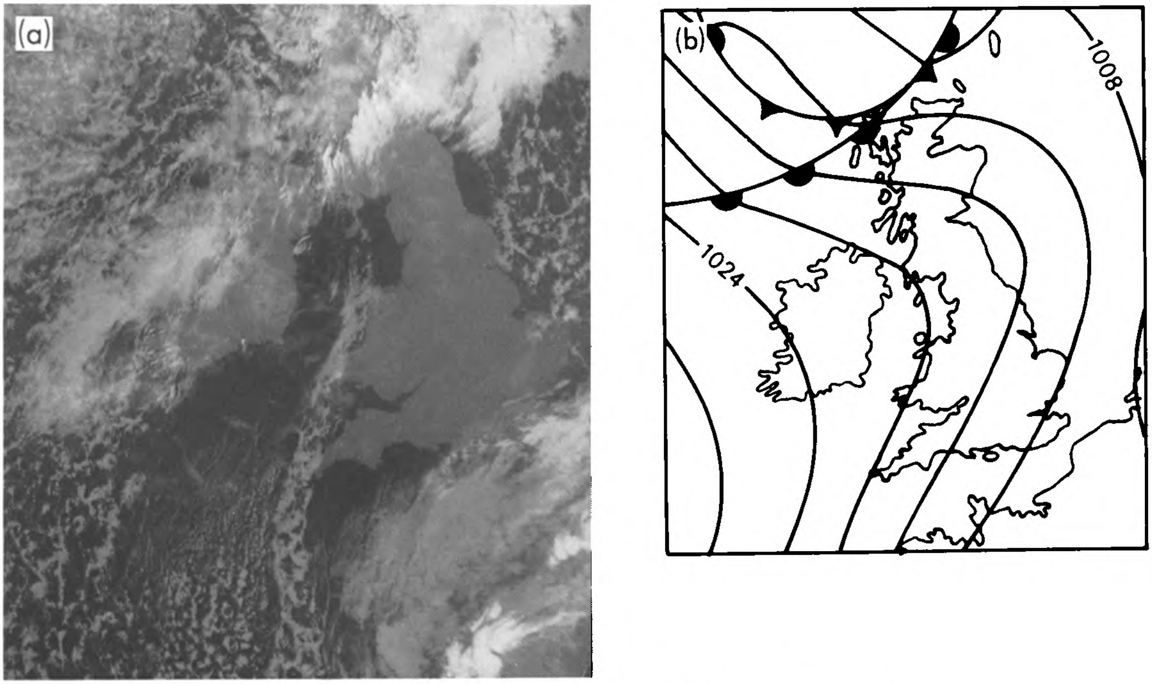


Figure 5. (a) 0928 GMT on 26 November 1980, (b) 0600 GMT on same date.

(viii) Most of the well-defined shower bands observed so far have occurred during the autumn and winter when the sea surface temperature was high compared with the surface temperature over land.

3. Mode of generation of North Channel shower bands

In each of the examples shown in Figs 1 to 5, it appears that the North Channel led to a mesoscale region of ascent, tens of kilometres wide and extending some hundreds of kilometres downwind, within which convection was preferentially maintained. There are two principal ways in which this kind of mesoscale circulation might arise:

(i) the convection might be generated from scratch in the North Channel gap, as seems to be the case in Fig. 1(a), owing to differential heating and frictional effects between land and sea; or

(ii) the North Channel might merely allow pre-existing convective activity to pass through it, albeit with a change in organization from open cells to a longitudinal line of shower cells, as appears to be the case in Figs 2(a) and 3(a).

In some cases both these mechanisms seem to be at work. Fig. 6(a) shows a North Channel shower band during a winter-time north-westerly outbreak as detected by the weather radar network, with the corresponding surface analysis in Fig. 6(b). The radar network does not yet extend far enough upwind to detect the origin of the showers. However, the shower clouds have been tracked using the half-hourly imagery from the European weather satellite, Meteosat.* The tracks of four of the individual shower

*Image sequences from Meteosat can be displayed on a television monitor in the same format as the weather radar network pictures. Although radar network pictures are being received at an increasing number of forecast outstations, the only outstation receiving the Meteosat imagery in this format at present is RAF Lyneham.

551.506.3(423):551.582.2:551.524.36

Exeter temperatures: monthly means from 1840 to 1984

By R. F. M. Hay

(Burnham Market, Norfolk)

Summary

A table of monthly mean temperatures representative of the vicinity of Exeter has been derived for the period from 1840 to 1984. From 1840 to 1879 the long daily record kept at the Devon and Exeter Institution (DEI) in Exeter was the most valuable source, supplemented until 1853 by the Heberden record (also for Exeter), and, from 1865 onwards, by a number of stations — Sidmouth, Cullompton, Killerton and others. From 1880 until 1941 the DEI record appears to be homogeneous and almost unbroken; while the record from Exeter Airport, which was started in 1942, continues unbroken up to the present time. A few short breaks in the DEI record, mainly during 1937 to 1939, were filled using the appropriate data from stations nearby at Cullompton and Killerton.

Introduction

In two papers Manley (1953, 1974) has derived monthly mean temperatures (MMTs) for central England for 1659 to 1973. Following his suggestion made a few years ago that the derivation of a homogeneous record of temperature for south-west England would be valuable, a table is presented here of MMTs for Exeter for 1840 to 1984. The choice of Exeter was suggested by Professor Manley since extensive temperature records were already known to be available from stations in Exeter and its vicinity, while details of these records were kindly provided by him personally to the present writer on several occasions (Transactions n.d., Glaisher n.d., Heberden n.d., Shapter 1862).

Derivation of the record

No problems were encountered in the period going back from the present (1984) as far as 1899. The Exeter Airport series goes back to 1942; before this date the long record kept in Exeter under the auspices of the Devon and Exeter Institution (DEI) provides the main source of data back as far as 1840 and earlier (Devon and Exeter Institution n.d.). Daily values of maximum and minimum temperatures are available for Exeter DEI throughout this period, and for other stations included in Table I for shorter periods. All monthly means were obtained initially as means of daily values of ½ (maximum + minimum); subsequently corrections as described in the text here were applied to obtain as

Table I. *Corrections used for derivation of Exeter monthly temperatures*

Station	Distance from Exeter (DEI) *miles*	Height *feet*	Height *metres*	Temperature correction *degrees Celsius*
Tiverton	12.5	230	70	0.1
Cullompton	11.5	202	62	0.1
Sidmouth (Sidmount)	12.5	30	9	0.1
Whimple	8	160	49	0.0
Killerton	7	159	48	0.0
Exeter (DEI)	0	155	47	0.0
Brampford Speke	4	140	43	0.0
Exeter (Devon and Exeter Hospital)	0.5	112	34	−0.1
Exeter Airport	5	100	30	−0.1

homogeneous a series as possible. For the period from 1942 back to 1840 it is understood that the maximum and minimum thermometers were exposed out of doors near the north-east corner of a small building facing a garden on the north side of the DEI building. Fuller details are given at the end of Table II. Exeter Cathedral and its close are situated nearby to the south of the Institution. Reference to a publication (Sharp 1946) that includes maps of the city boundaries for several dates shows that, whereas the city appears to have more than doubled in area between 1740 and 1840, the increase in area between 1840 and 1919 was quite small. In the 20 years up to 1940 the area of Exeter more than doubled again, and some further increase has presumably taken place since then. The maps also show that the growth of Exeter has been mainly to the east and less extensively to the south-west of the medieval city surrounding the cathedral and its close, which are situated on relatively high ground. These facts suggest that the effect of urbanization upon the Exeter temperature record, during the period covered here, should probably have been less than upon the corresponding temperature records kept at places such as Greenwich, Kew or Oxford (Chandler 1964, Knox-Shaw and Balk 1932).

There was one gap in this period, for 1937 to 1939 inclusive, when records were not available for any station in Exeter itself. After scrutiny of the *Monthly weather report* (Meteorological Office 1937, 1938,

Table II. *Details of principal stations used for analysis of Exeter temperatures*

Exeter Airport (Meteorological Office), 50° 44'N, 03° 25'W, height 100 ft amsl

Period used	1942 until the present
Observing practices	World Meteorological Organization standard practices
Times of observation	Standard procedures
Max. and min. observed	Standard procedures
Exposure	Good. Open country nearby although some building has taken place adjacent to the enclosure in recent years.
Thermometers	Standard

Exeter, Devon and Exeter Institution, 50° 43'N, 03° 32'W, height 155 ft amsl

Period used	1840 to 1941
Observing practices	Not known
Times of observation	Around 0930 (clock time)
Max. and min. observed	Around 0930 (clock time)
Exposure	The thermometers were exposed about 5 ft above ground level on the north-facing side of a vertical wooden frame* which was fixed near to the corner formed at the meeting of the north and east walls of a small house. It is understood that this position of the thermometers has been unchanged throughout the period. In this position the thermometers were completely sheltered from direct sunshine at all times of the year. Before about 1950 a small garden and an orchard existed to the north of the site, but after that date some new buildings were erected where the orchard had been, leaving only a small garden. There is a rather high (13–14 ft) wall of red sandstone, running north-north-east to south-south-west about 6 ft east of the former thermometer frame, which was built (probably) around 1500. The site has, therefore, always been somewhat obstructed for easterly and southerly winds but until about 1950 the exposure was tolerably good for westerly and northerly winds.
Thermometers	According to staff of the DEI Library, at least between about 1940, or earlier, and 1975, the thermometers used were standard ones made by Negretti and Zambra and were bought from a 'good shop in Exeter'. It appears that no corrections were applied. No records remain regarding thermometers used during earlier periods. It can be reasonably assumed that some members of the DEI, physicians, geophysicists, etc., were concerned to maintain as good standards of observation as were possible at the time.

*The vertical wooden frame was about 15 inches high by 12 inches broad, and was surrounded by a thin wooden edge some 4 inches wide all around (horizontal at top and bottom, vertical at the sides). It was probably stained many years ago, but was not painted and had no louvers at any time.

1939), and some comparisons with other years, it was found that monthly temperatures for Exeter for this period could be represented satisfactorily by taking the mean of Cullompton and Killerton and hence these values have been utilized for Exeter for 1937 to 1939.

Table I shows distances from Exeter DEI and heights of all stations in the vicinity that have been utilized in deriving this series. Initially all monthly temperatures were corrected to the height of the DEI (155 ft above mean sea level (amsl)) as shown here. However, in the tables presented in the Appendix the whole series from 1840 to 1984 has been corrected to the height of Exeter Airport (100 ft amsl) to enable direct comparisons to be made with readings in the future.

Between 1881 and 1898 the record for Cullompton appears to have been accepted for publication by Transactions of the Devon Association (Transactions n.d.), with the exception of 1887, in preference to the Exeter DEI record.

For 1887 a record is also available for the Devon and Exeter Hospital. However, a comparison made between the respective monthly mean values and ranges (maximum – minimum) for Exeter DEI and Exeter Hospital for 1887 suggested that the DEI values were the more reliable and consistent, so these values were adopted and Exeter DEI is retained for 1887, while Cullompton is used from 1881 to 1886 and 1888 to 1898 for the series in the Appendix.

A comparison made of the difference between monthly mean maxima and monthly mean minima found in July at Exeter DEI and Cullompton, for the 11 years that are available at each station between 1870 and 1894, showed a good agreement (Exeter DEI 8.8 °C, Cullompton 9.3 °C). This suggests Cullompton readings can be used with confidence for periods when values for Exeter are not available, or were not published by Transactions of the Devon and Exeter Association.

Before 1881 the derived series depends mainly upon the DEI record with some support from other stations in various years mainly as shown in Table III.

Table III. *Supporting stations also used for analysis of Exeter temperatures*

Station	Latitude	Longitude	Periods used here
Devon and Exeter Hospital	50° 43′N	03° 32′W	—
Brampford Speke	50° 47′N	03° 32′W	1878–79
Killerton	50° 48′N	03° 27′W	1936–39
Whimple	50° 46′N	03° 21′W	—
Tiverton	50° 54′N	03° 28′W	1876–78
Cullompton	50° 52′N	03° 23′W	1881–98, 1936–39
Sidmouth (Sidmount)	50° 41′N	03° 14′W	1865–72, 1875–79
Truro	50° 16′N	05° 02′W	1840–44
Falmouth	50° 08′W	05° 04′W	1840–44
Scilly	49° 55′N	06° 19′W	1840–44
Oxford	51° 46′N	01° 16′W	See text

Details of site, exposure and instruments for Oxford are given in Knox-Shaw and Balk (1932). Details for remaining stations above are not available.

Inspection of the DEI monthly data showed too high maxima in spring and summer and similarly low minima in autumn and winter before 1881 when compared with those of later years. This discrepancy has been largely removed by the following simple procedure. For a long period before 1879 the sole observations available for comparison with Exeter are those made at Sidmouth, which are complete for 12 of the years between 1865 and 1879. Information available regarding the sites at both places, and scrutiny of the two records, suggested that thermometers at the more urban site at Exeter were reading rather too high in summer months and a little too low in winter months respectively.

The modern values for the corrections of monthly means of Exeter temperatures to those of Sidmouth for each month January to December are readily obtained from the respective monthly means for 1941 to 1970. These values of Exeter minus Sidmouth in °C have been called 'correction A' and represent a correction to be applied to Exeter to obtain Sidmouth values of MMT on account of geographical and climatological factors (see Table IV, column 1).

Values for the corrections of monthly means (Exeter minus Sidmouth) were similarly obtained for January to December using the 12 years of complete observations available at both stations between 1865 and 1879. These values were denoted by 'correction B' (see Table IV, column 2).

Table IV. *Monthly mean temperature differences (°C)*

Month	Exeter Airport minus Sidmouth (uncorrected) 1941–70 averages (correction A)	Exeter (DEI) minus Sidmouth (uncorrected) 1865–72, 1876–79 averages (correction B)	Temperature differences due to exposure	
			Unsmoothed (correction C)	Smoothed (correction C)
Jan.	-0.3	-0.3	0.0	0.0
Feb.	-0.4	0.0	-0.4	-0.2
Mar.	0.1	0.2	-0.1	-0.3
Apr.	0.2	0.8	-0.6	-0.6
May	0.2	1.2	-1.0	-1.0
June	0.3	1.7	-1.4	-1.2
July	0.3	1.2	-0.9	-1.1
Aug.	0.1	1.1	-1.0	-0.8
Sept.	-0.2	0.2	-0.4	-0.5
Oct.	-0.5	-0.1	-0.4	-0.3
Nov.	-0.5	-0.4	-0.1	-0.1
Dec.	-0.4	-0.7	0.3	0.1
Year	-0.1	0.4	-0.5	-0.5

Correction A minus correction B is defined as correction C, and represents the correction to be applied to Exeter DEI on account of the urban site and exposure.

On the reasonable assumption that the differences of differences in temperature due to climatological and geographical factors between Exeter and Sidmouth were very small as between 1941 to 1970 and 1865 to 1879, it follows that the monthly values of 'correction A minus correction B' give approximately the differences between instrumental errors (and site errors) at the two places, since the climatological and geographical differences have been largely eliminated. If we can assume that instrumental errors were broadly the same at both stations, it follows that 'correction A minus correction B' broadly represents the differences between the urban site at Exeter and the better, more rural and coastal, site at Sidmouth. This difference will be denoted by 'correction C' from now on. Using this argument the Exeter values before 1879 have all been corrected back to 1840 by the appropriate (smoothed) monthly values of 'correction C' in each instance (see Table IV, column 4). These corrections in column 4 have then been applied to the values given in the DEI record from 1879 back to 1840 to derive the results given for these years in the finalized series of Exeter MMTs set out in the Appendix. Some indication that this correction goes far to eliminate errors in the exposure at Exeter DEI is provided by a statistical comparison made between the differences of the decadal means of May minus March and August minus October MMTs at Exeter DEI, as between earlier decades when the results have been 'corrected' as suggested by Table IV and the similar differences during recent decades. The differences between the effects of overexposure to daytime sunshine and night-time radiation under clear skies should be nearly at a maximum as between March and May and again August to October. But a comparison of these differences between decadal means during the overall periods from 1901 to 1980 and 1851 to 1900 by means of the 'Student's' t-test shows no evidence that these decadal MMT differences are significantly different in magnitude as between 1851 to 1900 and 1901 to 1980.

Further evidence that the monthly corrections given under the heading 'correction C' in Table IV are satisfactory was provided by a comparison made between values of Exeter DEI (with corrections applied as in Table IV) with MMTs derived as the mean of Bradford Speke, Sidmouth and Tiverton for the period from 1876 to 1879 when these data were available. In only 4 of these 48 months was the difference between Exeter DEI and the mean of Bradford Speke, Sidmouth and Tiverton greater than 0.6 °C and the largest individual difference was 0.8 °C.

When it was subsequently found that the DEI record had overlapped for more than 20 years after temperature observations were started at Exeter Airport, it became possible to make a comparison between the two records. This is shown here as Table V.

Table V. *Differences (rounded down) between means of monthly means (°C), Exeter DEI minus Exeter Airport for the period 1943–64*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Differences of monthly means as above 'M'	0.0	0.2	0.4	0.8	1.2	1.2	1.2	0.9	0.7	0.4	0.1	-0.1
Correction C* (see Table IV, col. 4)	0.0	0.2	0.3	0.6	1.0	1.2	1.1	0.8	0.5	0.3	0.1	-0.1
M-C	0.0	0.0	0.1	0.2	0.2	0.0	0.1	0.1	0.2	0.1	0.1	0.0

*Correction C is here expressed as the difference Exeter DEI minus Sidmouth for comparability with 'M' in Table V.

Monthly values of correction C are also shown in Table V together with the differences between the two comparisons. These results afford confidence in the accuracy of the corrections C based on differences between Sidmouth and Exeter DEI which were derived and used at a much earlier stage of the work (see Table IV). In the course of revising the data in the Appendix, the corrections C have thus been applied to all periods between 1840 and 1941 when Exeter DEI was unsupported by data from another station (see Table I).

Before 1865, when Sidmouth temperatures begin, there were no other temperature records available in the region. Some reliance was therefore put on the Oxford record (Knox-Shaw and Balk 1932). Oxford monthly temperatures were 'corrected' for normal climatological temperature differences by subtracting the respective MMTs for the period 1941 to 1970 from each other and assuming, as above, that the same 'climatological difference' in temperature prevailed in the mid-19th century as during 1941 to 1970. (This assumption seems justifiable when, as here, it is made for the purposes of comparison and not for any systematic adjustment of actual monthly means.) From these Oxford temperatures, corrected to Exeter values for climatological factors, values of Exeter DEI minus 'Oxford corrected' were derived for the period 1840 to 1864. It was found that for 1840 to 1844 the differences were much larger than for subsequent years. For 1844 to 1864 the mean monthly differences (°C) Exeter DEI minus 'Oxford corrected' were as follows:

Jan.	−0.3	July	0.1
Feb.	0.0	Aug.	0.1
Mar.	−0.1	Sept.	0.4
Apr.	0.4	Oct.	0.1
May	0.3	Nov.	0.2
June	−0.3	Dec.	−0.1

The small value of these differences is considered satisfactory.

For the years from 1840 to 1844 short records of MMTs were available for one or more stations simultaneously selected from Truro, Falmouth and Scilly (Royal Cornwall Polytechnic Society n.d.). Use was also made of Oxford temperatures as these five stations (including Exeter) lie roughly aligned along the great circle through Scilly and Oxford. Climatological 'corrections' were applied (as previously for Oxford using averages for 1941 to 1970) to each station to 'correct' it to the Exeter location and the residual differences Exeter DEI minus Scilly, etc., corrected, were obtained. The results were set out in a table (not given here), and after careful scrutiny, all the means derived for Exeter DEI (after correction C was applied) were found to be in satisfactory agreement with the differences from the supporting stations. These early results for Exeter DEI are therefore included in the Appendix with reasonable confidence in their accuracy.

References

Chandler, T. J. 1964 North-wall and Stevenson screen temperatures at Kew Observatory. *Q J R Meteorol Soc*, **90**, 332–333.

Devon and Exeter Institution n.d. Meteorological observations kept daily in observation books at the Devon and Exeter Institution in Exeter, 1840–1975 and a few earlier years.

Glaisher, J. n.d. Meteorology of England, 1851–1862. London, Eyre and Spottiswoode for HMSO.

Heberden, T. n.d. Weather record of the Rev. Thomas Heberden, 1785–1855. (Original manuscript available in the Devon Record Office, Central Library, Exeter.)

Knox-Shaw, H. and Balk, J. 1932 Radcliffe observations, **55**.

Manley, G. 1953 The mean temperature of central England, 1698 to 1952. *QJR Meteorol Soc*, **79**, 242–261.

1974 Central England temperatures: monthly means 1659 to 1973. *QJR Meteorol Soc*, **100**, 389–405.

Meteorological Office 1937 Monthly weather report.

1938 Monthly weather report.

1939 Monthly weather report.

Royal Cornwall Polytechnic Society n.d. Meteorological observations for Scilly, Falmouth, Truro. 7th Annual Report, 1839 *et seq*.

Shapter, T. 1862 The climate of the south of Devon, 2nd edition. London, John Churchill.

Sharp, T. 1946 Exeter Phoenix. London, Architectural Press.

Transactions n.d. Devon Association, 1862 to 1871, volumes 1 to 4, then yearly volumes 1872 to 1941.

Appendix

Table A.I. *Monthly mean and yearly temperatures (°C) for Exeter, 1840–1984, together with extreme values for each month and year of occurrence*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1839	—	—	—	—	—	—	—	—	—	—	—	5.7	
1840	6.0	4.2	4.3	9.8	12.7	14.4	14.8	17.0	12.5	9.4	7.8	2.4	9.6
1841	3.4	2.4	7.7	8.3	13.0	13.4	14.6	15.3	14.5	10.0	6.9	6.2	9.6
1842	2.7	5.3	7.3	7.9	11.5	16.7	15.7	17.7	14.2	8.3	7.5	9.1	10.3
1843	6.8	3.2	6.8	9.5	10.8	13.0	15.8	16.4	16.3	10.2	7.5	8.4	10.4
1844	5.9	4.0	6.1	10.4	11.3	15.5	15.2	13.7	14.2	10.3	8.0	2.5	9.8
1845	5.2	2.6	3.0	8.8	10.4	14.4	14.4	13.5	12.4	10.5	8.4	6.4	9.2
1846	7.6	7.5	7.0	8.9	11.7	17.1	16.1	17.0	15.0	10.4	8.4	2.7	10.8
1847	4.8	4.3	5.9	7.5	11.5	13.8	17.0	15.7	12.9	11.7	9.0	6.7	10.1
1848	2.9	6.9	6.7	8.9	13.3	13.4	15.5	14.5	13.2	10.4	7.3	7.4	10.0
1849	6.1	6.4	6.3	7.0	11.9	13.9	15.3	15.9	13.6	11.4	8.2	4.9	10.1
1850	2.0	7.9	4.9	9.7	9.8	14.6	15.5	15.0	13.0	8.4	8.8	6.4	9.7
1851	7.4	5.5	6.9	7.9	10.4	13.9	14.9	16.0	12.4	11.3	4.2	5.4	9.7
1852	5.9	4.7	5.2	7.5	10.9	12.7	17.9	15.7	13.0	8.6	9.0	8.6	10.0
1853	5.7	1.3	4.3	8.7	11.4	14.2	15.5	15.2	13.0	10.6	6.9	2.7	9.1
1854	5.2	4.9	7.0	9.3	9.9	12.4	14.9	15.2	14.3	9.9	5.7	6.4	9.6
1855	2.8	-0.4	4.1	7.6	9.3	12.9	15.9	15.9	14.0	10.3	6.0	4.8	8.6
1856	4.9	6.5	4.9	8.3	9.7	13.9	16.1	16.9	12.9	11.5	6.8	6.2	9.9
1857	3.9	5.8	5.5	7.8	10.8	14.6	16.4	17.0	14.9	11.2	7.4	8.0	10.3
1858	4.7	3.7	5.9	8.8	10.8	15.8	14.8	15.7	15.4	10.3	5.1	6.7	9.8
1859	6.2	6.4	7.8	8.5	11.6	14.9	18.0	16.2	13.8	11.2	7.2	3.5	10.4
1860	5.6	2.9	6.5	7.0	12.2	12.0	14.9	14.3	11.8	10.7	6.2	3.2	8.9
1861	2.5	6.0	6.5	7.8	11.5	14.3	13.8	15.8	13.2	11.5	4.8	4.8	9.4
1862	5.3	5.5	6.4	10.0	11.6	12.4	14.1	15.0	13.9	12.0	5.4	7.8	10.0
1863	5.4	6.5	6.9	10.3	11.9	12.0	16.6	15.7	12.8	10.6	8.8	7.7	10.4
1864	3.9	3.2	6.3	9.4	12.4	13.8	16.0	15.0	14.0	10.0	6.2	3.9	9.5
1865	2.9	4.0	3.8	11.3	12.3	15.9	16.3	14.9	16.3	10.9	8.0	6.5	10.3
1866	6.9	5.3	5.7	9.0	9.7	14.9	15.9	15.1	13.0	11.2	8.9	7.9	10.3
1867	2.7	8.0	3.8	10.1	10.9	13.9	15.2	16.0	13.7	10.6	5.8	4.3	9.6
1868	4.7	6.8	7.8	9.5	12.8	15.2	18.7	17.3	14.5	9.7	6.5	8.6	11.0
1869	7.3	8.3	4.5	10.2	10.3	13.3	16.1	15.9	14.2	11.0	7.5	4.0	10.2
1870	4.7	3.4	5.4	9.0	11.3	14.9	17.4	16.0	13.9	10.6	6.2	1.7	9.5
1871	2.2	7.2	7.5	9.9	11.2	13.0	15.0	17.2	13.2	11.7	5.1	4.0	9.8
1872	6.4	8.0	7.8	8.5	9.8	13.7	16.4	15.7	14.0	9.0	8.0	6.9	10.4
1873	6.4	3.0	6.3	8.5	10.8	14.4	15.7	16.1	12.3	9.7	7.7	5.6	9.7
1874	6.6	6.1	7.8	10.2	11.1	14.4	17.1	15.5	13.7	11.2	8.3	2.9	10.4
1875	8.0	3.4	6.1	7.8	12.2	14.0	14.6	16.4	15.7	10.2	6.9	5.0	10.0
1876	4.2	6.7	5.5	8.5	9.7	14.2	17.9	16.7	13.9	11.8	6.5	7.5	10.3
1877	7.0	7.7	6.2	7.9	9.4	15.3	15.0	15.7	12.0	10.5	8.3	5.9	10.1
1878	5.9	6.4	6.7	9.2	12.0	14.8	17.0	16.5	13.9	10.9	4.8	1.9	10.0
1879	1.5	5.1	5.7	5.8	9.3	13.0	14.2	15.0	13.2	10.6	4.9	1.9	8.4
1880	1.8	7.0	7.8	8.9	12.2	14.8	16.7	16.6	15.4	8.2	6.7	7.3	10.3
1881	-0.6	4.5	6.7	8.7	12.4	13.6	16.9	14.7	12.9	8.1	9.6	5.1	9.4
1882	5.8	6.4	7.9	9.1	11.7	13.0	15.1	15.4	11.8	10.0	6.9	5.3	9.9
1883	6.2	6.4	3.3	8.3	10.8	14.1	14.5	15.5	14.0	10.4	6.8	5.3	9.6
1884	7.1	6.1	6.8	6.9	11.6	14.4	15.9	16.5	15.1	9.9	6.4	5.5	10.2
1885	4.3	7.0	5.3	7.5	9.4	14.6	16.5	14.5	12.8	8.5	7.5	3.9	9.3
1886	2.8	2.0	5.0	8.7	11.3	14.4	16.4	16.3	14.3	12.0	7.1	3.3	9.5
1887	3.9	4.5	4.0	6.6	10.4	15.6	17.5	16.6	12.3	7.6	5.3	4.4	9.1
1888	3.6	2.2	4.4	7.1	11.1	13.9	14.6	14.6	12.8	8.9	8.8	5.7	9.0
1889	4.0	4.4	5.6	7.9	12.9	15.7	15.5	14.6	13.4	8.8	8.1	3.6	9.5
1890	6.7	4.1	6.7	8.3	12.3	14.4	15.0	15.0	14.6	10.7	6.6	0.2	9.6

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1891	2.0	4.5	4.7	7.0	9.9	15.0	14.8	14.5	14.4	9.8	6.1	5.9	9.0
1892	3.2	4.5	3.7	8.9	11.9	13.7	15.3	15.9	12.9	7.6	7.4	3.9	9.1
1893	3.9	6.1	8.0	11.6	13.7	16.0	16.8	17.2	13.4	10.1	6.2	5.3	10.7
1894	4.1	6.2	7.3	10.1	10.0	14.8	15.7	15.4	12.6	10.6	8.4	6.4	10.1
1895	1.4	−1.3	6.4	9.4	13.0	15.4	15.8	15.4	16.0	7.9	9.0	5.5	9.5
1896	5.3	5.0	8.3	10.1	13.4	16.4	16.9	15.4	14.1	7.9	4.1	4.8	10.1
1897	2.7	8.0	8.1	8.8	11.5	16.1	17.6	16.2	12.9	11.4	8.3	6.1	10.6
1898	7.0	5.6	4.9	9.0	11.6	14.6	16.4	17.2	15.5	12.0	7.9	8.1	10.8
1899	6.1	6.2	6.0	8.8	10.7	15.2	17.3	18.0	14.7	10.4	9.2	4.2	10.6
1900	6.3	4.7	4.0	8.8	10.8	14.9	17.4	15.0	14.0	11.0	7.8	7.4	10.2
1901	4.6	3.7	4.6	8.6	12.3	14.0	17.8	15.8	14.5	10.1	5.4	4.4	9.7
1902	5.9	2.5	7.6	8.2	9.9	13.6	15.6	15.8	13.5	10.6	8.9	5.9	9.8
1903	6.2	7.8	8.1	7.8	11.5	13.2	15.7	15.3	14.0	11.8	7.9	4.8	10.3
1904	5.5	4.8	5.4	9.6	11.5	14.0	16.4	15.7	13.5	11.1	6.8	6.8	10.1
1905	5.1	6.5	7.9	9.0	11.5	15.0	17.6	14.9	13.3	8.5	5.3	6.4	10.1
1906	6.8	4.2	6.3	7.9	11.5	14.4	16.3	17.2	14.4	11.1	7.9	5.2	10.3
1907	5.3	3.6	7.0	8.1	11.3	13.3	15.1	15.6	14.4	10.5	8.6	6.6	9.9
1908	4.4	6.7	5.1	7.5	12.9	14.8	16.3	15.6	13.4	12.4	8.9	6.4	10.4
1909	4.8	4.0	4.9	9.3	11.4	12.7	15.5	16.5	13.3	11.5	5.9	4.7	9.5
1910	5.2	6.5	6.9	8.2	11.7	14.6	14.8	16.0	13.9	11.6	5.6	7.5	10.2
1911	4.4	6.2	6.7	8.7	13.4	15.0	18.6	18.5	13.6	11.0	6.8	7.8	10.9
1912	5.3	6.7	8.5	9.8	12.8	14.0	16.2	13.5	12.2	8.7	7.6	8.4	10.3
1913	6.4	5.6	7.2	8.7	11.9	14.1	15.8	16.3	14.5	11.7	9.3	6.0	10.6
1914	4.7	7.4	7.5	10.3	11.4	14.9	16.2	16.4	13.5	10.9	7.1	5.6	10.5
1915	5.3	5.1	6.1	9.2	12.0	14.4	14.8	15.9	13.1	10.2	3.9	7.3	9.8
1916	8.4	4.7	3.6	8.8	12.0	11.8	16.0	16.9	14.1	12.1	6.9	3.0	9.9
1917	2.3	2.6	4.8	6.6	12.5	14.9	16.1	15.7	14.5	8.8	9.4	3.3	9.3
1918	5.2	7.7	6.7	7.8	12.9	14.1	16.3	16.4	13.3	10.2	7.4	8.6	10.5
1919	4.1	4.1	5.5	8.2	13.2	14.4	15.1	17.2	13.7	8.1	4.3	7.1	9.6
1920	6.4	7.2	7.4	9.4	12.3	14.6	14.6	13.9	13.9	11.5	7.8	5.6	10.4
1921	9.0	5.6	8.0	8.9	12.2	16.1	19.7	16.5	15.8	13.7	7.9	7.9	11.8
1922	5.7	6.2	5.7	6.8	14.0	15.0	14.3	14.6	13.2	8.9	6.7	6.8	9.8
1923	6.5	7.7	7.7	8.8	10.5	13.5	17.6	15.9	13.3	11.0	4.3	6.1	10.2
1924	6.5	4.0	5.2	8.3	11.7	12.3	15.2	14.9	13.9	11.0	7.7	7.8	9.9
1925	6.6	6.3	6.1	8.5	11.3	16.0	17.2	16.4	12.5	11.6	4.7	5.2	10.2
1926	6.3	8.3	7.6	9.6	11.0	13.6	17.6	17.6	16.2	9.7	7.3	5.5	10.9
1927	6.0	6.1	8.6	8.9	13.0	13.3	16.5	16.0	13.5	11.2	7.6	4.5	10.4
1928	6.9	7.5	7.1	9.0	12.0	13.7	16.9	15.6	13.4	11.5	9.2	5.7	10.7
1929	2.9	2.5	6.6	7.8	11.4	13.6	16.2	15.6	16.1	10.5	7.8	6.9	9.8
1930	6.4	3.2	6.4	8.9	11.7	15.9	15.6	16.0	14.7	11.9	7.6	6.2	10.4
1931	4.9	5.0	4.9	8.5	11.5	14.8	15.5	15.1	12.8	10.5	9.1	7.0	10.0
1932	8.4	5.2	6.2	7.9	10.9	14.6	16.1	18.1	14.8	9.7	8.1	6.8	10.6
1933	3.7	5.6	8.4	9.2	13.3	15.0	17.4	17.9	16.1	11.2	6.8	2.0	10.5
1934	5.7	3.8	6.3	8.7	12.2	15.9	18.4	15.4	15.9	11.7	7.8	9.5	10.9
1935	6.3	7.2	6.2	9.1	12.3	14.7	17.9	16.7	12.9	10.9	7.4	5.4	10.6
1936	5.9	4.6	7.9	7.1	11.6	14.7	15.3	16.4	15.1	10.5	7.2	6.9	10.3
1937	6.2	7.0	5.2	10.7	12.6	15.0	16.4	16.9	14.0	10.7	5.7	3.8	10.4
1938	6.7	5.5	9.3	8.4	10.9	14.8	15.6	16.4	14.1	11.5	9.7	5.2	10.7
1939	5.7	6.4	7.5	9.4	12.7	15.5	15.6	17.0	14.6	9.3	9.9	3.7	10.6
1940	0.9	5.2	7.1	9.7	13.4	16.5	15.3	16.7	14.2	10.9	8.3	5.3	10.3
1941	3.0	5.2	7.2	7.7	12.7	15.3	17.1	15.4	14.9	11.7	8.2	7.0	10.5
1942	3.3	1.4	6.7	9.9	11.1	14.1	15.6	15.9	14.1	11.2	5.5	8.3	9.7
1943	7.0	6.6	7.1	10.9	12.1	14.3	15.8	16.1	13.1	10.9	7.4	4.7	10.5
1944	7.6	4.4	5.8	9.9	11.4	14.4	16.3	17.7	13.3	9.7	7.8	4.8	10.3
1945	1.4	8.1	7.6	10.4	12.4	14.4	15.8	16.2	14.9	12.5	8.1	6.9	10.7

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1946	4.5	7.4	5.8	9.7	11.3	12.9	16.0	14.9	14.2	11.2	9.4	3.5	10.1
1947	3.6	−0.4	5.7	9.1	12.1	14.5	16.5	18.7	14.6	10.9	8.9	6.4	10.0
1948	6.7	5.6	8.7	9.2	12.1	14.1	15.9	15.2	14.4	10.9	9.7	7.1	10.8
1949	6.5	6.3	8.2	10.1	11.1	15.4	17.8	17.2	16.4	12.6	7.8	6.8	11.3
1950	5.3	7.1	8.3	8.5	11.8	16.1	16.1	15.5	13.9	10.6	7.1	2.6	10.2
1951	5.8	5.0	5.6	7.6	10.1	13.8	16.7	14.9	14.4	10.5	9.6	7.3	10.1
1952	4.4	4.3	7.6	9.5	12.9	14.5	17.3	16.6	11.6	10.5	5.7	5.1	10.0
1953	4.2	4.9	6.2	8.6	12.5	14.5	16.3	16.4	14.2	10.6	9.6	8.4	10.5
1954	4.3	4.5	7.2	8.2	11.3	13.7	14.5	15.1	13.7	12.9	8.2	7.9	10.1
1955	4.8	2.6	3.6	9.5	10.3	14.5	18.1	18.2	14.4	10.1	7.6	7.9	10.1
1956	5.3	0.2	7.1	7.4	11.9	14.2	16.7	14.3	14.9	10.6	7.1	7.5	9.8
1957	6.2	6.8	10.1	9.6	11.2	15.7	17.1	16.1	14.1	11.6	6.7	5.5	10.9
1958	4.6	7.2	5.0	7.7	11.3	13.7	15.9	16.3	15.4	11.8	7.5	5.7	10.2
1959	4.1	5.4	7.8	9.6	12.6	15.2	17.1	17.0	15.3	13.1	8.2	7.5	11.1
1960	5.5	5.3	7.6	9.4	12.8	15.9	15.7	15.4	13.7	11.0	8.7	4.7	10.5
1961	5.5	8.3	8.1	10.9	11.5	14.9	16.0	16.0	15.4	11.4	7.3	4.3	10.8
1962	6.1	5.7	3.8	8.5	10.4	13.7	15.4	15.0	13.1	11.3	6.3	4.0	9.4
1963	−2.4	1.1	6.9	9.3	10.9	15.5	15.3	15.2	13.9	12.1	9.7	3.5	9.3
1964	4.6	5.5	5.9	9.0	13.1	14.6	16.7	15.9	14.9	9.9	8.8	5.1	10.3
1965	4.8	3.7	6.4	8.9	11.5	14.5	14.8	15.5	12.4	12.0	6.4	6.5	9.8
1966	4.7	7.9	7.5	8.9	11.5	15.5	15.7	15.7	14.9	11.1	6.0	7.5	10.6
1967	5.7	6.5	7.7	8.9	10.8	14.9	16.5	15.9	14.5	11.9	6.5	5.8	10.4
1968	6.5	3.2	7.0	7.7	10.5	15.1	15.6	16.1	14.5	13.5	8.1	5.3	10.3
1969	7.1	2.3	5.6	8.9	11.3	14.4	16.7	16.1	14.5	13.3	6.7	4.7	10.1
1970	5.7	5.0	5.1	7.9	12.7	16.4	15.9	16.1	14.8	11.3	9.5	4.9	10.4
1971	6.1	5.4	5.9	8.2	11.8	13.2	17.5	16.6	15.3	12.4	6.7	7.6	10.6
1972	5.1	5.9	7.5	9.2	10.5	11.5	16.1	15.5	12.1	11.3	7.1	7.7	9.9
1973	5.5	5.5	6.3	7.9	11.7	14.7	15.5	17.1	15.1	10.1	8.1	6.3	10.3
1974	7.5	6.7	6.5	8.6	10.9	14.1	15.9	15.3	12.4	8.7	8.3	9.1	10.3
1975	7.9	6.4	5.8	8.8	11.1	15.1	17.9	18.4	13.7	11.1	7.8	5.6	10.8
1976	7.0	5.4	5.9	8.3	11.9	17.3	18.5	17.9	14.1	11.3	7.7	3.5	10.7
1977	4.3	7.0	8.1	8.2	11.3	12.9	16.7	15.9	13.6	12.6	7.3	7.7	10.5
1978	5.1	3.9	7.4	7.3	11.9	14.0	15.3	15.5	14.5	12.9	9.5	6.4	10.3
1979	1.3	2.9	6.1	8.6	9.9	14.0	16.9	15.2	13.9	12.3	8.3	7.2	9.7
1980	3.2	7.7	6.0	9.3	11.6	13.9	14.8	16.4	15.4	10.1	7.4	6.8	10.2
1981	6.3	4.3	9.3	8.7	11.5	14.1	16.5	17.1	14.8	9.6	9.1	3.7	10.4
1982	5.1	6.7	6.9	9.3	11.6	15.6	16.9	16.2	15.2	11.1	9.3	5.9	10.8
1983	7.9	3.4	7.6	7.4	10.5	15.2	19.9	18.1	14.9	11.3	8.8	6.9	11.0
1984	5.6	5.3	5.5	8.7	10.7	15.7	16.9	17.7	14.5	12.2	8.7	6.5	10.7

Extreme values for each month and year of occurrence

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Highest	9.0	8.3	10.1	11.6	14.0	17.3	19.9	18.7	16.4	13.7	9.9	9.5	11.8
	1921	1869 1926 1961	1957	1893	1922	1976	1983	1947	1949	1921	1939	1934	1921
Lowest	−2.4	−1.3	3.0	5.8	9.3	11.5	13.8	13.5	11.6	7.6	3.9	0.2	8.4
	1963	1895	1845	1879	1855 1879	1972	1861	1845 1912	1952	1887 1892	1915	1890	1879
Overall means 1841–1980	5.0	5.2	6.4	8.7	11.5	14.4	16.1	16.0	14.0	10.7	7.4	5.8	10.1

Table A.II. *Decadal monthly mean temperatures (°C) for Exeter, 1841–1984*

Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1841–50	4.7	5.1	6.2	8.7	11.5	14.6	15.5	15.5	13.9	10.2	8.0	6.1	10.0
1851–60	5.2	4.1	5.8	8.1	10.7	13.7	15.9	15.8	13.5	10.6	6.5	5.5	9.6
1861–70	4.6	5.7	5.7	9.7	11.5	14.1	16.0	15.7	13.9	10.8	6.8	5.7	10.0
1871–80	5.0	6.1	6.7	8.5	10.8	14.2	16.0	16.1	13.7	10.4	6.7	4.9	9.9
1881–90	4.4	4.8	5.6	7.9	11.4	14.4	15.8	15.4	13.4	9.5	7.3	4.2	9.5
1891–1900	4.2	4.9	6.1	9.3	11.7	15.2	16.4	16.0	14.1	9.9	7.4	5.8	10.1
1901–10	5.4	5.0	6.4	8.4	11.5	14.0	16.1	15.8	13.8	10.9	7.1	5.9	10.0
1911–20	5.3	5.7	6.4	8.7	12.4	14.2	16.0	16.1	13.6	10.3	7.1	6.3	10.2
1921–30	6.3	5.7	6.9	8.5	11.9	14.3	16.7	15.9	14.3	11.1	7.1	6.3	10.4
1931–40	5.4	5.5	6.9	8.9	12.1	15.1	16.3	16.7	14.5	10.7	8.0	5.6	10.5
1941–50	4.9	5.2	7.1	9.5	11.8	14.5	16.3	16.3	14.4	11.2	8.0	5.8	10.4
1951–60	4.9	4.6	6.8	8.7	11.7	14.6	16.5	16.0	14.2	11.3	7.9	6.7	10.3
1961–70	4.8	4.9	6.4	8.9	11.4	14.9	15.9	15.7	14.3	11.8	7.5	5.2	10.1
1971–80	5.3	5.7	6.5	8.4	11.3	14.1	16.5	16.4	14.0	11.3	7.8	6.8	10.3
1981–84 (4 years)	6.2	4.9	7.3	8.5	11.1	15.1	17.5	17.3	14.9	11.1	9.0	5.7	10.7
Overall means 1841–1980	5.0	5.2	6.4	8.7	11.5	14.4	16.1	16.0	14.0	10.7	7.4	5.8	10.1

Table A.III. *Seasonal mean temperatures (°C) for Exeter, 1840–1984*

	Winter	Spring	Summer	Autumn		Winter	Spring	Summer	Autumn
1840	5.3	8.9	15.4	9.9					
1841	2.7	9.7	14.4	10.5	1871	3.7	9.5	15.1	10.0
1842	4.7	8.9	16.7	10.0	1872	6.1	8.7	15.3	10.3
1843	6.4	9.0	15.1	11.3	1873	5.4	8.5	15.4	9.9
1844	6.1	9.3	14.8	10.8	1874	6.1	9.7	15.7	11.1
1845	3.4	7.4	14.1	10.4	1875	4.8	8.7	15.0	10.9
1846	7.2	9.2	16.7	11.3	1876	5.3	7.9	16.3	10.7
1847	3.9	8.3	15.5	11.2	1877	7.4	7.8	15.3	10.3
1848	5.5	9.6	14.5	10.3	1878	6.1	9.3	16.1	9.9
1849	6.6	8.4	15.0	11.1	1879	2.8	6.9	14.1	9.6
1850	4.9	8.1	15.0	10.1	1880	3.6	9.6	16.0	10.1
1851	6.4	8.4	14.9	9.3	1881	3.7	9.3	15.1	10.2
1852	5.3	7.9	15.4	10.2	1882	5.8	9.6	14.5	9.6
1853	5.2	8.1	15.0	10.2	1883	6.0	7.5	14.7	10.4
1854	4.3	8.7	14.2	10.0	1884	6.2	8.4	15.6	10.5
1855	2.9	7.0	14.9	10.1	1885	5.6	7.4	15.2	9.6
1856	5.4	7.6	15.6	10.4	1886	2.9	8.3	15.7	11.1
1857	5.3	8.0	16.0	11.2	1887	3.9	7.0	16.6	8.4
1858	5.5	8.5	15.4	10.3	1888	3.4	7.5	14.4	10.2
1859	6.4	9.3	16.4	10.7	1889	4.7	8.8	15.3	10.1
1860	4.0	8.6	13.7	9.6	1890	4.8	9.1	14.8	10.6
1861	3.9	8.6	14.6	9.8	1891	2.2	7.2	14.8	10.1
1862	5.2	9.3	13.8	10.4	1892	4.5	8.2	15.0	9.3
1863	6.6	9.7	14.8	10.7	1893	4.6	11.1	16.7	9.9
1864	4.9	9.4	14.9	10.1	1894	5.2	9.1	15.3	10.5
1865	3.6	9.1	15.7	11.7	1895	2.2	9.6	15.5	11.0
1866	6.2	8.1	15.3	11.0	1896	5.3	10.6	16.2	8.7
1867	6.2	8.3	15.0	10.0	1897	5.2	9.5	16.6	10.9
1868	5.3	10.0	17.1	10.2	1898	6.2	8.5	16.1	11.8
1869	8.1	8.3	15.1	10.9	1899	6.8	8.5	16.8	11.4
1870	4.0	8.6	16.1	10.2	1900	5.1	7.9	15.8	10.9

	Winter	Spring	Summer	Autumn
1901	5.2	8.5	15.9	10.0
1902	4.3	8.6	15.0	11.0
1903	6.6	9.1	14.7	11.2
1904	5.0	8.8	15.4	10.5
1905	6.1	9.5	15.8	9.0
1906	5.8	8.6	16.0	11.1
1907	4.7	8.8	14.7	11.2
1908	5.9	8.5	15.6	11.6
1909	5.1	8.5	14.9	10.2
1910	5.5	8.9	15.1	10.4
1911	6.0	9.6	17.4	10.5
1912	6.6	10.4	14.6	9.5
1913	6.8	9.3	15.4	11.8
1914	6.0	9.7	15.8	10.5
1915	5.3	9.1	15.0	9.1
1916	6.8	8.1	14.9	11.0
1917	2.6	8.0	15.6	10.9
1918	5.4	9.1	15.6	10.3
1919	5.6	9.0	15.6	8.7
1920	6.9	9.7	14.4	11.1
1921	6.7	9.7	17.4	12.5
1922	6.6	8.8	14.6	9.6
1923	7.0	9.0	15.7	9.5
1924	5.5	8.4	14.1	10.9
1925	6.9	8.6	16.5	9.6
1926	6.6	9.4	16.3	11.1
1927	5.9	10.2	15.3	10.8
1928	6.3	9.4	15.4	11.4
1929	3.7	8.6	15.1	11.5
1930	5.5	9.0	15.8	11.4
1931	5.4	8.3	15.1	10.8
1932	6.9	8.3	16.3	10.9
1933	5.4	10.3	16.8	11.4
1934	3.8	9.1	16.6	11.8
1935	7.7	9.2	16.4	10.4
1936	5.3	8.9	15.5	10.9
1937	6.7	9.5	16.1	10.1
1938	5.3	9.5	15.6	11.8
1939	5.8	9.9	16.0	11.3
1940	3.3	10.1	16.2	11.1
1941	4.5	9.2	15.9	11.6
1942	3.9	9.2	15.2	10.3
1943	7.3	10.0	15.3	10.5
1944	5.6	9.0	16.1	10.3
1945	4.8	10.1	15.5	11.8
1946	6.3	8.9	14.6	11.6
1947	2.2	9.0	16.6	11.5
1948	6.2	10.0	15.1	11.7
1949	6.6	9.8	16.8	12.3
1950	6.4	9.5	15.9	10.5
1951	4.5	7.8	15.1	11.5
1952	5.3	10.0	16.1	9.3
1953	4.7	9.1	15.7	11.5
1954	5.7	8.9	14.4	11.6
1955	5.1	7.8	16.9	10.7
1956	4.5	8.8	15.1	10.9
1957	6.8	10.3	16.3	10.8
1958	5.8	8.0	15.3	11.6
1959	5.1	10.0	16.4	12.2
1960	6.1	9.9	15.7	11.1
1961	6.2	10.2	15.6	11.4
1962	5.4	7.6	14.7	10.2
1963	0.9	9.0	15.3	11.9
1964	4.5	9.3	15.7	11.2
1965	4.5	8.9	14.9	10.3
1966	6.4	9.3	15.6	10.7
1967	6.6	9.1	15.8	11.0
1968	5.2	8.4	15.6	12.0
1969	4.9	8.6	15.7	11.5
1970	5.1	8.6	16.1	11.9
1971	5.5	8.6	15.8	11.5
1972	6.2	9.1	14.4	10.2
1973	6.2	8.6	15.8	11.1
1974	6.8	8.7	15.1	9.8
1975	7.8	8.6	17.1	10.9
1976	6.0	8.7	17.9	11.0
1977	4.9	9.2	15.2	11.2
1978	5.6	8.9	14.9	12.3
1979	3.5	8.2	15.4	11.5
1980	6.0	9.0	15.0	11.0
1981	5.8	9.8	15.9	11.2
1982	5.2	9.3	16.2	11.9
1983	5.7	8.5	17.7	11.7
1984	5.9	8.3	16.8	11.8

Table A.IV. *Decadal seasonal mean temperatures (°C) for Exeter, 1841–1984*

Years	Winter	Spring	Summer	Autumn
1841–50	5.1	8.8	15.2	10.7
1851–60	5.1	8.2	15.1	10.2
1861–70	5.4	8.9	15.2	10.5
1871–80	5.1	8.7	15.4	10.3
1881–90	4.7	8.3	15.2	10.1
1891–1900	4.7	9.0	15.9	10.5
1901–10	5.4	8.8	15.3	10.6
1911–20	5.8	9.2	15.4	10.3
1921–30	6.1	9.1	15.6	10.8
1931–40	5.6	9.3	16.1	11.1
1941–50	5.4	9.5	15.7	11.2
1951–60	5.4	9.1	15.7	11.1
1961–70	5.0	8.9	15.5	11.2
1971–80	5.9	8.8	15.7	11.1
1981–84 (4 years)	5.7	9.0	16.7	11.7
Overall means 1841–1980	5.3	8.9	15.5	10.7

551.5(09):551.501.9(468.2)

The history of the Meteorological Office at Gibraltar

By D. Hyde*

Summary

The Meteorological Office at Gibraltar was opened in November 1935. To celebrate its 50th anniversary an account is given of meteorological observing and forecasting work at Gibraltar over the last two centuries, with more detailed attention being given to the activities of Meteorological Office staff since 1935. Most of these were concerned with aviation, but more general public service work has been increasing in recent years.

Introduction

One of the earliest events to concentrate the minds of Gibraltar's citizens on the weather occurred on 31 January 1776 when 50 people were killed in a great deluge of unrecorded intensity. The siege of Gibraltar commenced in 1779 and a climatological account (Drinkwater 1905) refers to 'heavy rains, high winds and most tremendous thunder, with dreadful vivid lightning'. In 1790 the Royal Engineers introduced their 'pluviometer' to commence a virtually continuous record of rainfall over nearly 200 years. In 1862 responsibility for weather records was handed over to the Colonial Government who assigned the rather grand title of Government Observatory to a stone hut at South Bastion where observations were made. As instrumentation on the Rock evolved, rain-gauges and anemometers became rather like wandering minstrels jostled by the populace at large as space became a valuable commodity. Even the police became involved in making observations. In 1923 one officer struggling

*Formerly of the Main Meteorological Office, Royal Air Force Gibraltar.

with a strange instrument at a remote site reported 'it is impossible to see the vane of the anemometer at 9.0 p.m. owing to the darkness'. In 1929 the South Bastion station moved to Alameda Gardens in the charge of the head gardener (one Harry Bently) and his two deputies. No doubt they were relieved to see a direction dial fitted to the anemometer a year later, thus avoiding the police officer's dilemma. Hurst (1959) provides an excellent review of early observations together with a map of meteorological stations at Gibraltar.

In the early part of this century aviation was starting to emerge as a force to be reckoned with. Soon after the Wright brothers made their first flight, the Balloon Section of the Royal Engineers sampled Gibraltar in 1904–5 but it is suspected that wind and weather proved too much for them. The racecourse was used to operate military aircraft on a small scale during the First World War and a few seaplanes were also used. Forthcoming dependence on meteorological services was revealed in some of the remarks of pilots at that time — 'dropping 600 feet in one act' near the Rock did not impress them.

In 1931 Gibraltar Airways Limited was formed to provide a service to Tangier. This first attempt proved abortive but it did set the scene for years of discussion on Gibraltar's airfield of the future. It was in 1935 that the Meteorological Office interest in the ancient fortress came to fruition with the arrival of British staff.

1935 to 1955

In 1935 the observing site was moved from Alameda Gardens (just south of the city) to Windmill Hill near the southern extremity of the Rock. The new office occupied a commanding position at about 400 feet above sea level overlooking the Strait. Naval ratings supervised by Air Ministry meteorologists got the office established and began the new sequence of observations. In 1938 the Air Ministry formally took over the station using locally employed staff in the observer role. At about that time General Ironside took over as Governor and started to press for facilities to make the Rock viable as a base for air operations. The outbreak of war in 1939 meant rapid expansion at Windmill Hill with 24-hour observing and forecasting services. External communications became very difficult with cable exchanges with London replacing earlier radio messages. By the early 1940s it was obvious that something had to be done to provide close meteorological support to the joint military staffs and the aircrews. Early in 1942 the forecast service was moved to New Camp (the flying boat base); from there the forecasters served both the newly formed Combined HQ and RAF North Front by motorcycle and side-car. In the meantime the provision of a runway at North Front, between the Rock and nearby Spain (see Figs 1 and 2) was going ahead, ably pushed and prodded by the Governor, Lord Gort. Later in 1942 the Combined HQ together with the forecast section moved into secure accommodation in the centre of the Rock. The external exchange of meteorological information was going more smoothly by using encyphered radio messages. On 2 November 1942 the first meteorological reconnaissance Hudson aircraft took off from the new runway. All this activity culminated in Operation Torch, the allied landings at Algiers, Oran and Casablanca. A third Meteorological Office had to be opened at North Front during the build-up and it became Gibraltar's Main Meteorological Office north of the runway in the post-war years.

Although Gibraltar's weather was regarded as relatively reliable, the aircrews quickly found out that it was not a factor to be trifled with (Dyer 1976). Heavy rain flooded the runway during a vital stage of Operation Torch. In October 1942 five Hudson aircraft of 233 Squadron circled above the fog-bound runway for three hours — one aircraft was forced to ditch but the remaining four landed safely. During the 1946/47 winter, the author witnessed an extraordinary landing by an American transport aircraft. In a south-westerly gale with heavy rain, the pilot elected to make his approach to runway 27 from the north over La Linea thus avoiding the severe turbulence in the lee of the Rock. On arrival over the

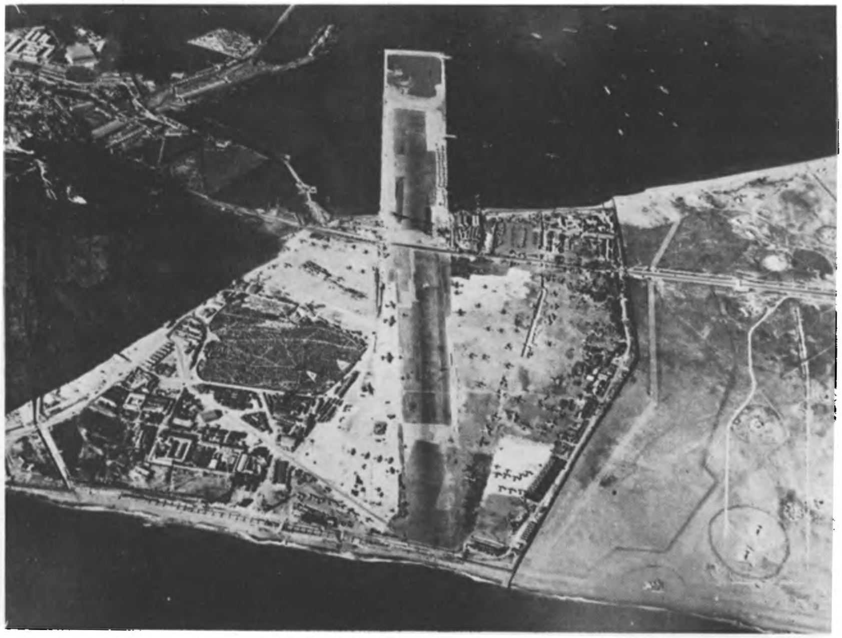


Figure 1. Royal Air Force, North Front, Gibraltar February 1943; looking westwards.

Figure 2. Royal Air Force, Gibraltar today; looking eastwards, Main Meteorological Office in Control Tower — middle distance left of runway.

runway with the Rock dead ahead he executed a steeply banked turn to starboard a few feet above the surface and landed safely — a superb feat of airmanship.

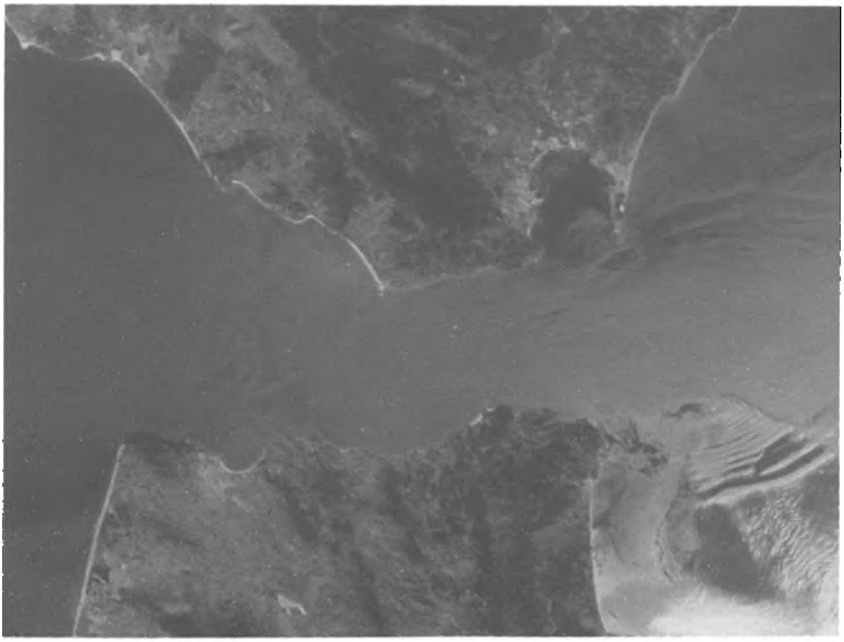
The military activity gave impetus to solving the problem of providing adequate data for the forecasters to work with. Using Halifax aircraft 520 Squadron made regular daily meteorological reconnaissance flights (code-named Nocturnal) from 1944 to 1951. Gladiator aircraft carried out vertical temperature soundings in 1943 and 1944 but the program was later replaced by the radiosonde unit formed by the author in 1946 (Fig. 3). The unit was housed in temporary accommodation north of the runway some distance from the North Front Meteorological Office. Surface observations based on adequate exposure and a wide range of instruments commenced at North Front in 1944 and the Windmill Hill station was closed in 1948. Apart from minor changes, notably in radiosonde, the years of upheaval ended in 1955 when the Main Meteorological Office moved into the new air traffic control building.

1955 to 1985

In a more stable operational environment, and with the winding down of military requirements, the Office was able to use part of its resources to tackle some of the meteorological problems arising from Gibraltar's unique location and orography (see Fig. 4). A concerted effort was made in the 1960s and 1970s to evaluate turbulence in the vicinity of the Rock, potentially the worst problem in the light of earlier wartime experience (Briggs 1963, Barnham and Spavins 1965, Cook 1976). For this purpose the Meteorological Office and the Royal Air Force secured the co-operation of the Royal Aircraft Establishment and the Building Research Advisory Service. Using in-flight observations and wind-tunnel data it was possible to correlate turbulence patterns and intensities with measured surface winds at North Front. A related problem was the forecasting of surface wind not only for turbulence but for a wider selection of elements. The orography of the Strait area imposed either westerlies or easterlies with a few (significant) variations. The weather associated with each regime was surprisingly different and effective forecasting of surface wind opened the door to success in other fields. McKay (1977) developed useful relationships between low-level winds and the pressure difference between Alicante and Casablanca which had been used subjectively in earlier years. In the 1980s the main effort in local investigations has been directed towards numerical products, especially the evaluation and verification of fine-mesh pressure and rainfall forecasts which are received at Gibraltar in the form of grid-point values.

When the Meteorological Office became centred on North Front in 1955 civilian staff had replaced service radio operators in a new cell dedicated entirely to reception of meteorological data on four channels with a further channel for transmission. In 1974 the RAF again took over the meteorological communications role. Since then channels were provided on the Defence communication network and in the 1980s most data are received by teleprinter direct from the automated telecommunication centre at Bracknell. There have been some changes in weather observing and monitoring as well. In 1963 the main instrument enclosure at North Front was removed from the immediate vicinity of the Main Meteorological Office to a site on British Lines Road adjacent to the border fence and near the present radiosonde unit. The standard recording anemometer at the Main Meteorological Office was supplemented by installations at both ends of the runway in addition to one at Rock Gun (near the Rock top at 390 metres, overlooking the runway). In 1972 automatic picture transmission equipment was added and is currently awaiting replacement by a more advanced station. At the radiosonde unit technical enhancement continued, the main highlights being the replacement of the old Army gun-laying radar with Cossor equipment in 1973 and the introduction of the Grawsonde in 1979 to replace the earlier Meteorological Office system.

Figure 3. One of the first radiosonde launches from Gibraltar, June 1946; author — middle distance centre, Halifax meteorological reconnaissance aircraft — middle distance right.



Photograph by courtesy of NASA Johnson Spaceflight Center

Figure 4. Satellite photograph showing location and orography of Gibraltar.

It is to be expected that this article reveals preoccupation with aviation matters but this is not to say that other customers have been neglected in satisfying the general thirst of the Gibraltarians for meteorological information. Radio and television broadcasts for the general public were developed steadily with special attention being given to the large sailing community. A mini-studio was installed by the British Forces Broadcasting Service in 1979 to enable the forecasters to make personal radio presentations either live or on tape. The Gibraltar Broadcasting Corporation provided both radio and television outlets. It is perhaps not generally appreciated that the audience included many thousands of English-speaking people on the Costa del Sol. More specialist services were provided to the Army, Navy, Property Services Agency, local government and the private sector. Even a local hotelier received a special warning service to help protect his guests from the vagaries of the weather. Fig. 5 shows the hotel in question with damage to water catchments above it caused by powerful lifting forces associated with lee turbulence. On the debit side, there is no doubt that smugglers took heed of meteorological advice to their advantage — the tables were turned on more than one occasion when the prosecution secured convictions in court using meteorological evidence in support. Oceanographers have always shown a great deal of interest in the seas around Gibraltar. In 1982 an international field experiment named 'Donde Va' examined the many aspects of sea water behaviour in the Strait and the Alboran Sea. Although the United Kingdom did not participate directly, the Main Meteorological Office was able to give useful support which was much appreciated. Local climatological services developed apace. Monthly and annual statistics were given a wide circulation within Gibraltar and usually received suitable attention in the media.

Meteorological observers, amateur and professional, are a dedicated breed the world over. None of the achievements in the long history of meteorology at Gibraltar would have been possible without a similar response from those who pioneered in the early days and the locally employed staff who have

Figure 5. Damage to east-facing water catchments at Gibraltar, March 1975.

carried on ever since. Initially the forecasters faced an almost impossible task in times of crisis but local investigations have slowly eroded the areas of uncertainty. Unlike the Meteorological Office at home, Main Meteorological Office Gibraltar is unlikely to reap the benefits of advanced communications and computer technology (but see Briggs 1963) in the near future — with the probable exception of better satellite imagery. Nevertheless there is every reason to predict a promising future, one hopes in the dawn of a new era of good relations with nearby Spain.

References

Briggs, J. 1963 Airflow around a model of the Rock of Gibraltar. *Meteorol Off Sci Pap* No. 18.

Barnham, J. and Spavins, C. S. 1965 Gusts on the approach at Gibraltar Airfield. RAE Technical Report No. 65099.

Cook, N. J. 1976 Aircraft flightpaths at RAF Gibraltar. Building Research Advisory Service Report of special investigation No. 3072. London, Department of the Environment.

Drinkwater, J. 1905 A history of the Siege of Gibraltar (1779–1783). Spilsbury.

Dyer, P. C. 1976 Flying from the Rock. The story of aviation at Gibraltar (1901–1945). (Unpublished RAF document, copy available in the RAF Library, Gibraltar.)

Hurst, G. W. 1959 A brief history of meteorology in Gibraltar. *Weather*, **14**, 41–46.

McKay, W. 1977 Surface and low level winds at Gibraltar in relation to surface pressure differences between Casablanca and Alicante. (Unpublished note, copy available in the Main Meteorological Office Library, Gibraltar.)

551.593.653

Noctilucent clouds over western Europe during 1984

By D. M. Gavine

(Leith Nautical College, Edinburgh)

Table I summarizes the noctilucent cloud (NLC) reports received by the Aurora Section of the British Astronomical Association (BAA) during 1984, from observers in Great Britain, Belgium, Denmark and Finland.

Times (UT) in the second column are of sightings, not necessarily the durations, of displays. Maximum elevations and, where possible, limiting azimuths are included. Coordinates of the observing stations are given to the nearest half-degree.

No routine hourly sky reports were received from British meteorological stations. All known 'negative' nights (i.e. clear sky but with no visible NLC) are based on the reports of regular, experienced observers in Great Britain (G), Belgium (B) and Finland (F). Positive reports were received from 16 British amateurs and 5 meteorological stations, Mr van Loo (Itegem, Belgium), Mr Olesen and Mr Persson (Denmark), and the highly organized team of 16 observers throughout Finland co-ordinated by Mr V. Mäkelä, whose excellent report forms the bulk of this summary. In Finland 31 positive NLC sightings were made between 2/3 May and 24/25 August, of which only one was seen in June; but only 11 were made in Britain which, despite a dry summer, experienced a great deal of night tropospheric cloud, especially in the north. Many of our regular observers, including the staff at Sumburgh, saw nothing over the entire season. Seven NLC were observed in Denmark, one in Belgium. A positive NLC sighting on 10/11 August by Mr Frydman at Wembley and Meteorological Office staff at Bedford, and four by Finnish observers in the second half of August, suggest a careful watch beyond the expected 'season' (Simmons and McIntosh 1983).*

Dr M. Gadsden (Aberdeen) carried out polarimetric work on the brilliant display of June 28/29 but cloud cover rendered parallactic photography by fixed-bracket cameras unsuccessful.

Thanks are due to all observers, amateur and professional, for their efforts, to Mr N. M. Bone, Director of the Aurora Section, Junior Astronomical Society, for helpful collaboration, and to Drs Gadsden and McIntosh for their advice and encouragement. The BAA Aurora Section carries out routine observation of aurora and noctilucent cloud to provide data for possible future research and its activities are almost entirely in the hands of amateurs. We would like to see a network of voluntary observers spread widely throughout north-west Europe, as was organized by James Paton during the International Geophysical Year. Information on the Section and observing instructions may be obtained from the Director, Mr R. J. Livesey, 46 Paidmyre Crescent, Newton Mearns, Glasgow G77 5AQ.

Table I. *Displays of noctilucent clouds over western Europe during 1984*

Date — night of	Times UT	Notes	Station position (to nearest 0.5 degree)	Time UT	Max elev. (degrees)	Limiting azimuths (degrees)
30 Apr/ 1 May		No NLC (F)				
1/2 May		No NLC (F)				
2/3	1915–2130	At Vaasa, poorly defined band. No NLC at Helsinki and Toivala.	63°N 21.5°E	2105–2130	15	355–030
3/4		No NLC (F)				
5/6 to 11/12		No NLC (F)				
12/13	1940–2250	Suspect small patch of bands and veil at Lapua, but no NLC seen by 8 other Finnish stations.	63°N 23°E	2145	50	350–045
				2155–2210	90	180–000
13/14 to 5/6 June		No NLC (F)				
6/7 June	2145–2300	Bluish faint bands at Helsinki. No NLC (G).	60°N 25°E	2230–2300	15	340–010
			61°N 29°E	2145–2200	No NLC	
7/8		No NLC (G)				
8/9		No NLC (F, G)				
9/10	2256–0210	Weak parallel bands at Edinburgh and Morpeth, photographed at Petworth. No NLC (B, F).	56°N 03°W	2256	40	320–040
				2304	45?	
				2308	22	–025
				2315	13?	–030
				2330	22	345–005
			55°N 01.5°W	2300	30	300–008
				2315	40	320–030
				2330	48	317–020
				2345	37	332–017
				0000	No NLC	
				0045	15	005–020

*Simmons, D. A. R. and McIntosh, D. H.; An analysis of noctilucent cloud over western Europe during the period 1966 to 1982, *Meteorol Mag*, **112**, 1983, 289–298.

Date — night of	Times UT	Notes	Station position (to nearest 0.5 degree)	Time UT	Max elev.	Limiting azimuths
					degrees	
9/10 (contd)			51°N 00.5°W	0145	3	
				0200	4	020–045
10/11	2150–2300	Medium-bright bands at Morpeth. No NLC (F).	55°N 01.5°W	2150	7	290–300
				2200	8	292–351
				2215	11?	Faint veil
				2230	No NLC	
11/12		No NLC (F)				
13/14		No NLC (G)				
14/15		No NLC (F, G)				
15/16 to 24/25		No NLC (F); also 15/16, 21/22 no NLC (B); no NLC (G) on 18/19, 23/24. Suspect band at Herstmonceux 22/23, 0120.				
27/28	2150–2324	Greenish NLC at Rönne.	55°N 14.5°E	2150–2324		NE
28/29	2115–0250	Brilliant display visible as far S as Yorkshire, and in Denmark. Intense gold-blue area in NE, strong waves parallel to horizon, fainter waves and bands N. From 0115 large-scale irregularities and whirl structure. Display illuminated rapidly from low in NE to high in N from 0130. Veil, bands and waves in tropospheric cloud at Rönne.	57°N 02°W	2210	No NLC	
				2230	30	000–030
				2255	20	000–045
				0145	Zenith and SE	
			56.5°N 03°W	2300	10	045–090
				2315	15	000–090
				2330	20	000–090
			56°N 03°W	2345	NLC in cloud	
				0000	9	027–065
				0015	11	012–070
				0030	11	000–070
				0045	12	012–074
				0100	11	-080
				0115	13	006–080
				0130	30	-070
				0145	40	356–072
				0200	42	
				0215	NLC visible	
			55°N 01.5°W	2300	Bands visible	
				2315	16	342–023
				2330	11	340–025
				2345	9	340–018
				0000	7	342–070
				0015	6	345–080
				0030	11	350–082
				0045	12	353–095
				0100	20	356–095
				0115	22	355–095
				0130	32	344–083
				0145	38	340–065
				0200	20	340–070
				0215	Traces	
				0230	No NLC	
			55°N 14.5°E	2115	30	315–045
				2200	Cloud	
			54.5°N 01°W	2330	8	Cloud
			54°N 01°W	2240	7	345–015
				2345	8	340–080
				0000	8	340–080
				0100	7	350–070
				0200	15	350–060
				0250	No NLC	
29/30	2200–0230	Extensive but fairly weak display of bands, slight wave structure, becoming lower in altitude. Visible as far S as Exeter.	56°N 03°W	2325	15?	Cloud
				2350	11?	-005
				0017	10?	330–030
				0030	NLC in cloud	
			55°N 01.5°W	2220	40	000
				2250	17	330–030
				2305	17	340–010
				2315	18	335–005
				2320	6	317–000
				2330	5	304–000
				0015	4	000–017
				0030	4	036–062
				0045	5	000–060

Date — night of	Times UT	Notes	Station position (to nearest 0.5 degree)	Time UT	Max elev. (degrees)	Limiting azimuths (degrees)
29/30 (contd)			54.5°N 03.5°W	0030	15	310–010
			52.5°N 00.5°E	2215	30	320–015
				2300	30	Cloud
				2315	Cloud	
			52°N 02°W	2200	35	320–000
				2250	25	315–010
			50.5°N 03.5°W	0200	4	010–
				0218	6	010–
				0228	8	
				0230	No NLC	
30 June/ 1 July	2150–2240	Very small faint veil at Turku. No NLC (B, G).	60.5°N 22.5°E	2150–2240	65	290
1/2 July		No NLC (F)				
2/3	2150–2210	Faint, poorly defined bands, central Finland. No NLC (G).	60.5°N 22.5°E	2150–2210	30	005–040
3/4	2140–2300	Faint blue-white veil and bands, S Finland. No NLC (G).	60.5°N 22.5°E	2215–2300	90	
			60°N 25°E	2140	35	300–000
4/5	2100–2325	Bands over W coast of Finland, veil to S. Waves over Helsinki. Veil suspected at Cockermouth despite moon. (a) Mr Parviainen, (b) Mr Frydman.	60.5°N 22.5°E	2200–2300	45	300–050
			60°N 25°E(a)	2100	Cloud	
				2125	25	000
				2140	60	315–095
				2200	100	315–090
				2215	70	330–180
				2230	40	330–045
			60°N 25°E(b)	2151	30	290–015
				2220	50	300–010
				2230	30	300–010
				2245	20	320–000
				2300	Cloud	
			54.5°N 03.5°W	2250–2325	25	350–040
5/6	2100–0050	Well-defined bands along Finnish–Soviet border, moving NE to SW. NLC visible in cloud at Morpeth.	63°N 27.5°E	No NLC		
			62.5°N 27°E	2210	18	080–140
				2220	24	095–150
				2235	20	110–170
				2245	18	130–170
				2255	18	145–180
			61°N 29°E	2215–2245	100	040–050
			60.5°N 22.5°E	0000–2215	No NLC	
			60°N 25°E	2150	11	Trace NW?
				2215	20	290–055
				2240	NLC in cloud NW	
			55°N 01.5°W	2320	26	350–060
				0020	35	In cloud
				0035	28	–038
				0050	Cloud	
6/7	2100–2343	Bands NNE–SSW with waves and whirls over central Finland. Faint bands at Itegem.	62.5°N 27°E	2220	145	
				2230	145	Cloud
			62°N 25°E	2145–2245	40	010–050
			60.5°N 22.5°E	2100	No NLC	
				2140	16	030–080
				2200	16	030–075
				2215	15	030–080
				2230	13	030–080
			60°N 25°E	2152	70	330–080
				2215	60?	340–015
				2222	20	330–015
				2240	20	340–015
				2300	20	310–015?
				2315	40	300–015
				2330	62	275–005
				2343	60	280–000
			51°N 04.5°E	2144	23	312–010
7/8	2120–2248	Bands and ripples low in NW. Blue-green, eastward drift, at Birkeröd. No NLC (F).	56°N 12.5°E	2120		315
				2143	Low	
				2248	No NLC	

Date — night of	Times UT	Notes	Station position (to nearest 0.5 degree)	Time UT	Max elev.	Limiting azimuths
					degrees	
8/9	2045–0003	Faint bands and ripples at Helsinki, in tropospheric cloud. At Rönne, bands with rapid changes in whirl structure from 2223, westward drift. NLC seen in Sweden — no details. No NLC (B).	62°N 25°E	2200–2245	No NLC	
			60°N 25°E	2222	20	In cirrus
				2245	20	340–010
				2305	30	330–010
				2335	50	285–005
				2345–0003	NLC?	
			55°N 14.5°E	2045	13	045
				2130	13	045
				2210	10	340–020
				2223	10	
				2320	NLC	
9/10	2100–0000	Veil and bands over Gulf of Bothnia and Sweden. Brilliant bands and billows up to 30° drifting W at Rönne. Mr Olesen photographed panorama of display. (a) Mr Manner, (b) Mr Frydman.	61°N 29°E	No NLC		
			60.5°N 22.5°E	2100	No NLC	
				2150	NLC	305
				2200	20	300–350
				2215	30	290–030
				2230	35	270–005
			60°N 25°E(a)	2200–2300	15	270–340
			60°N 25°E(b)	2143	10	240–315
				2209	18	265–315
				2221	16	260–335
				2230	15	260–345
				2245	18	257–355
				2300	18	258–342
				2315	22	260–002
				2330	27	260–000
				2345	14	290–345
				0000	12	295
			55°N 14.5°E	2110	30	340–045
				2130	30	315–135
				2145	30	315–135
				2230	13	315–135
				2320	10	
10/11		No NLC (F)				
11/12		No NLC (F)				
12/13	2105–2300	Veil and bands over SW Finland, Gulf of Bothnia and central Sweden. Thin bands seen at Morpeth and S Shields. No NLC (B).	63°N 27.5°E	No NLC		
			60.5°N 22.5°E	2105	30	015–045
				2200	90	280–120
				2215	110	250–130
				2230	105	250–090
			60°N 25°E	2238	28	350–080
				2240	35	350–015
				2300	Cloud	
			55°N 01.5°W (Morpeth)	2155–2200	40	260–000
				2300	No NLC	
			(S Shields)	2234	25	340
13/14		No NLC (B). Possible trace of NLC at Helsinki 2230–2240, no NLC at Imatra.				
15/16		No NLC (F, B)				
16/17		No NLC (F)				
17/18	2212–0005	Very faint NLC trace at Helsinki, faint band at Edinburgh.	60°N 25°E	2212	No NLC	
				2308	13	345
				2313	Cloud	
			56°N 03°W	2345	11	020–060
				0000	14	050–060
				0005	Cloud	
18/19	2200–2355	Weak bands, gradually brightening, at Alrö. No NLC (F).	56°N 10°E	2200	5	000
				2300	10	
				2355	NLC	
19/20		No NLC (F)				
21/22		No NLC (F)				

Date — night of	Times UT	Notes	Station position (to nearest 0.5 degree)	Time UT	Max elev.	Limiting azimuths
					degrees	
22/23	2130–2300	Poorly defined bands over E Finnish border. No NLC (G).	62.5°N 27°E	2130	No NLC	
				2205	10	010–070
				2230	15	040–085
				2245–2300	16	050–080
23/24	2045–2250	Bands and waves observed in a cloudy sky in E Finland. Mr Frydman (Helsinki) describes intense 'corkscrew' form 2237, NLC in NW sky. Faint NLC in cloud Alrö, no NLC (G).	63°N 23°E	No NLC		
			62.5°N 27°E	2220	24	050–100
				0145–0150	50	070–120
			61°N 29°E	No NLC? cirrus		
			60°N 25°E	2103	NLC suspected	
				2130	30	270–000
				2150	Cloud	
				2210	NLC in cloud	
				2228		355–015
				2237	30	
				2245	Cloud	
			56°N 10°E	2145	NLC in cloud	
24/25	2015–2247	Bands over USSR–Finnish border. No NLC (G).	63°N 27.5°E	2015–2100	No NLC	
			62.5°N 27°E	2130	No NLC	
				2205	56	000–058
				2215	56	000–058
				2225	66	038–068
				2235	66	042–062
				2242	66	066–122
25/26		No NLC (F, B, G)				
26/27	2045–2130	Veil over W Bothnia, observed from Turku. No NLC (G).	60.5°N 22.5°E	2045	NLC present	
				2100	18	315–000
				2130	8	315–010
27/28	2045–2250	Bands over USSR E of Finland. (a) Mr Koistinen, (b) Mr Heikkinen, (c) Mr Nousiainen, (d) Mr Pekkola.	62.5°N 29.5°E	2030–2130	No NLC	
			62.5°N 27°E(a)	2111	11	046–070
				2140	19	038–068
				2157	15	040–080
			62.5°N 27°E(b)	2112	10	040–070
				2218–2240	12	010–080
			62.5°N 27°E(c)	2120	12	040–070
				2215–2230	12	040–095
			62.5°N 27°E(d)	2140	13	045–085
				2210	10	040–095
				2225	9	030–095
				2245	9	050–085
28/29	2045–0015	Bright and extensive display covering almost all Finland. All forms visible, bands and waves aligned mainly NNE–SSW and ENE–WSW. Most observers in patchy tropospheric cloud ((a), (b), (c), (d) as before).	66°N 24.5°E	2215–2231	45	036–090
			63°N 23°E	2040	20	040–080
			62.5°N 27°E(a)	2313	100	250–090
				2340–0000	30	010–100 (In cloud)
			62.5°N 27°E(b)	2100	14	350–060
				2150–2200	20	025–080? (In cloud)
			62.5°N 27°E(c)	2100–2130	28	320–065
			62.5°N 27°E(d)	2115	26	010–070
				2145	40	030–080
				2318	100	260–090
				2340	30	000–130
				0005	28	090–170
29/30	2015–0315	Extensive display over most of Finland, long bands, waves, large whirls over Vaasa. Waves aligned NNW–SSE. Bands visible in Carlisle and Bedford ((b), (c), (d) as before).	63°N 21.5°E	2210–2240	80	275–080
			63°N 23°E	2100–2130	90	260–330
			62.5°N 27°E(b)	2140	100	300–040
				2225	14	350–065
			62.5°N 27°E(c), (d)	2150	100	300–040
				2225	14	350–065
			61°N 29°E	2015	60	270–000
			60.5°N 22.5°E	2025	20	020
				2045	50	320–070
				2100	55	315–070
				2115	40	330–040
				2130	28	300–050
				2145	25	335–045
				2200	20	330–045

Date — night of	Times UT	Notes	Station position (to nearest 0.5 degree)	Time UT	Max elev. (degrees)	Limiting azimuths (degrees)
29/30 (contd)			55°N 03°W	0300–0315	30	045
			53°N 00.5°W	0250	10	000–030
30/31		No NLC (F)				
31 July/ 1 Aug	2000–2240	Poorly defined areas in N and central Finland not seen S of 62°N. All forms seen in N, bands and veil farther S. Possible drift SE. No NLC (G).	63°N 27.5°E	2130–2220	12	000–060
			63°N 23°E	2140–2200	50	030–040
			62.5°N 27°E	2135	No NLC	
				2150	8	010–070
				2200	8	010–060
			62°N 25°E	2040–2245	15	015–030
1/2 Aug	2000–2315	Small areas of veil, waves and whirls in central Finland? Most observers negative, one suspects aurora — fast drift of forms.	63°N 23°E	2150	10	030–040
			63°N 27.5°E	2100–2115	40	330–040
			62.5°N 27°E	2205	46	320–355 Aurora?
2/3	2030–2230	Bright display, all forms with long bands, over N Finland and Sweden. In tropospheric cloud gaps ((b), (c) as before).	63°N 27.5°E(b)	2100	20	330–060
				2130	18	000–065
			63°N 27.5°E(c)	2100	20	320–060
				2150	18	340–040
			62.5°N 27°E	2150	12	340–050
			(Kutunjarvi)	2213	16	005–035
				2225	16	340–070
			62.5°N 27°E	2125	14	350–010
			(Rautalampi)	2130	16	340–050
				2220	12	345–050
			62°N 25°E	2030–2100	20	020–060
3/4	2000–2230	Veil, bands and whirls over N central Finland.	63°N 27.5°E (Kuopio)	2115–2140	45	300–025
			63°N 27.5°E (Toivala)	2300	No NLC	
			62.5°N 29.5°E	2000–2200	40	315–012
4/5	2000–2300	Large bright NLC area over N Finland and Sweden, all forms, mainly E–W bands. Bands seen in Campbeltown and Paisley.	63°N 21.5°E	2155	20	310–000
				2250	10	315–010
			63°N 27.5°E	2035	45	270–020
				2045–2115	30	270–030
			63°N 23°E	2100–2120	40	340–030
			62.5°N 29.5°E	2000–2300	Bands	
			62.5°N 27°E	2032	32	300–024
				2110	25	300–010
			61°N 29°E	2045	25	310–010
				2115	20	310–010
			60.5°N 22.5°E	2000–2050	No NLC	
			56°N 04.5°W	2130–2145	10	045
			55.5°N 05.5°W	2210	12	355–015
5/6 to 8/9		No NLC (F)				
9/10	2215–2300	Bluish veil and bands over Lapland.	66°N 24.5°E	2215–2300	45	350–085
10/11	2000–0402	Long bands, waves and whirls over Gulf of Bothnia. Thin bands and ripples seen at Bedford and photographed near London.	62°N 25°E	2030–2100	40	315–040
				2130	25	320–030
				2215–2300	20	340–010
			53°N 00.5°W	0245	4	000–050
				0310	9	000
				0330	Low NLC	
			51.5°N 00°	0323	10	350–020
				0334	9	340–020
				0345	8	345–010
				0354	5	355
				0402	No NLC	
11/12 to 13/14		No NLC (F)				
15/16		No NLC (F)				
16/17	2120–2130	Veil and bands over extreme N of Scandinavia.	63°N 21.5°E	2120–2130	5	350–015

Date — night of	Times UT	Notes	Station position (to nearest 0.5 degree)	Time UT	Max elev.	Limiting azimuths
					degrees	
17/18	1830–2225	Poorly defined patches of veil over Lapland and central Finland.	63°N 23°E	2200–2225	50	120–140
			63°N 21.5°E	2035–2050	5	355–010
			61°N 29°E	No NLC		
18/19	1900–2130	Veil, E Bothnia.	62°N 25°E	1930–2130	15	000–025
			61°N 29°E	No NLC		
20/21		No NLC (F)				
22/23		No NLC (F)				
23/24		No NLC (F)				
24/25	1900–0030	Poorly defined veil over Lapland.	66°N 24.5°E	2230–2315	4	000–015
			63°N 23°E	No NLC		
			62°N 25°E	1900–0030	10	320–010
25/26		No NLC (F)				
26/27		No NLC (F)				
28/29		No NLC (F)				
31 Aug/ 1 Sept		No NLC (F)				

Photographs

9/10 June	0145–0200	Petworth	D. Strachan
27/28	2314–16, 2324	Rönne	J. O. Olesen
28/29	2330–0155	Aberdeen	M. Gadsden
	0000	Aviemore	D. McConnell
	2300, 0020	Dundee	G. Young
	0000–0143	Edinburgh (Joppa)	D. Gavine
	0050–0140	Edinburgh	J. Shepherd
	2322–0148	Morpeth	A. McBeath
8/9 July	2223, 2232	Rönne	J. O. Olesen
9/10	2135–2240	Rönne	J. O. Olesen
18/19	2355	Alrö	J. O. Olesen
10/11 Aug	0329–0332	Wembley	D. Frydman

551.5:06(a):556.02

HOMS — The World Meteorological Organization Commission for Hydrology Operational Multipurpose Sub-programme

By B. R. May

(Meteorological Office, Bracknell)

One of the World Meteorological Organization's (WMO's) major programmes of work is the Hydrology and Water Resources Programme (HWRP) which, in these days of increasing flood demand, drought and flood hazard, assumes a particular importance. The developing countries are most likely to be affected by water resource problems, whereas at least some experience of tackling these problems resides in the developed countries so that some means of promoting the international exchange of hydrological and hydrometeorological techniques is required.

The WMO Commission for Hydrology which supports the HWRP through its Operational Hydrology Programme decided that an effective way of promoting this exchange of technical experience would be through the Hydrological Operational Multipurpose Sub-programme (HOMS). HOMS has involved the preparation of a reference manual giving brief but comprehensive descriptions of a large number of items (called 'components') of practical interest to hydrologists and hydrometeorologists. These components are subdivided into 12 broad sections:

A policy, planning and organization,
B network design,
C instruments and equipment,
D remote sensing,
E methods of observation,
F data transmission,
G data storage, retrieval and dissemination,
H primary data processing,
I secondary data processing,
J hydrological models for forecasting and design,
K analysis of data for planning, design and operation of water resource systems, and
X mathematical and statistical computation.

Within each of these sections there are further subject subdivisions. For example, within section I these are: general water quality, sediment transport data, precipitation data, evaporation (general), evaporation (computation from meteorological measurements), snow data, ground water, and river discharge data.

The individual components consist of, for instance, descriptions of instruments and their use, advice on networks of instruments and the design of data sets, recommendations for observing standards, and computer programs to meet a wide range of data-processing and modelling requirements.

There are now over 330 HOMS components summarized in the reference manual. Each summary is arranged to a uniform format with information under these headings: purpose and objectives, description, input, output, operational requirements and restrictions, form of presentation, operational experience, originator and technical support, availability, and conditions on use.

The components are largely independent but some, usually from different sections, are designed to be used together to perform a logical progression of operations — these are arranged in sequences of which there are now 11 specified in the manual. For instance a particular sequence entitled 'Catchment potential evaporation using synoptic data' contains six individual components, the first of which deals

Within GARP and the GWE considerable emphasis was given to tropical meteorology, and papers presented at the conference showed how this had borne fruit in improved understanding of tropical weather systems. Some improvement has also been achieved in predictive capabilities in the tropics, but more experience is needed in the application of global model results to tropical forecasting and, if possible, in the use of tropical fine-mesh models. Given the special features of tropical weather systems, coupled with the difficulties in establishing adequate computing and telecommunication facilities in many regions, the tangible benefits of the GWE to date are effective mainly in the technologically more advanced parts of the world. One of the major challenges which follows from the success of the GWE is to maintain a steady progress towards an enhanced WWW — known within WMO as WWW 2000 — which by the end of the century will permit further substantial progress in forecasting skill, with demonstrable benefits in all parts of the world.

551.58:69:019.941

An international seminar on building climatology

By M. J. Prior

(Meteorological Office, Bracknell)

The National Swedish Institute for Building Research (SIB) hosted a seminar from 28 to 31 May 1985 for the working commission of the International Council for Building Research Studies and Documentation responsible for building climatology (CIB-W71). Seventeen delegates from meteorological services, building research institutes and university departments attended, representing the four Nordic countries, the United Kingdom, Austria, Italy and Israel.

The seminar opened with a visit to the SIB laboratories at Gävle, where a 28-metre wind-tunnel, a mobile laboratory for microclimate studies and a computer-controlled thermal mannikin (for studies of the effects of the environments of buildings upon their occupants) were examined with interest.

The main part of the seminar was held in the 'think-tank' atmosphere of an 18th century manor house at Österbybruk. Energy conservation, test reference years, human comfort, standards for presenting climatic data and the use of microcomputers for manipulating data were among the topics covered during presentations of the work of the delegates, which were followed by a business session of W71. It was resolved that links with the relevant groups within the World Meteorological Organization (WMO) and the International Federation for Housing and Planning should be strengthened so that, for example, at least one representative of each group is present at the various meetings of these groups. The revision of the 1972 CIB/WMO report 15 — *Survey of meteorological information for architecture and building* — and arrangements for future symposia and working commission meetings were also discussed.

On the last day a visit was made to the Swedish housing exhibition at Upplands Väsby near Stockholm, where new housing designs and rehabilitation work by a housing association on 30-year old apartment blocks were seen. A common feature was the use of extensive glazing for conservatories and shared courtyards for energy conservation and amenity reasons.

The SIB is to be congratulated for arranging such an interesting and stimulating three days.

Notes and news

Mr P. Goldsmith

Mr P. Goldsmith, Director of Research in the Meteorological Office, has been granted special leave from 13 August 1985 to take up the appointment of Director of Earth Observations and Microgravity at the European Space Agency.

Mr Goldsmith's post in the Meteorological Office has been filled by Mr A. Gilchrist, previously Deputy Director (Dynamical Research).

Reviews

Nuclear winter, by Mark A. Harwell. 150 mm × 235 mm, pp. xxi + 179, *illus.* Springer-Verlag, Berlin, Heidelberg, New York, Tokyo, 1984. Price DM 54.00.

This book is concerned with an evaluation of the long-term impact of nuclear warfare on man and his environment. The short-term effects (which include blast damage, heat radiation and nuclear radiation) have been known about since the first nuclear weapon was exploded in July 1945. Concern as to longer-term effects focused first on radioactive fall-out and, in the 1970s, on possible destruction of the ozone layer (with subsequent enhancement of biologically damaging ultraviolet radiation at the surface) by the oxides of nitrogen injected into the stratosphere in the fireballs of the high-yield weapons then being developed. More recent research suggests that ozone reductions would be smaller, in part because there has been a trend towards smaller warheads. However, the possibility that mass fires would liberate large amounts of highly absorbing smoke, which would prevent solar radiation from reaching the surface and thus lead to a 'nuclear winter', has received a great deal of attention (and considerable publicity) in the last three years. It is in this area that the present book places much (but by no means all) of its emphasis.

The spectre of nuclear winter was first raised in 1982 in an article by Crutzen and Birks in a special issue of the journal *Ambio*, published by the Swedish Academy of Sciences, which was devoted to the environmental effects of nuclear war. This created a great deal of interest in the United States, where several groups began research projects and various committees were set up to produce reports. The first results were presented at a Conference on the Long-Term Biological Consequences of Nuclear War, which took place in Washington in late 1983. A paper by Turco and others (later published in *Science* and often known as TTAPS after the initials of its five authors) developed a range of war scenarios and through a chain of calculations (which they stressed were subject to great uncertainties) arrived at mean atmospheric smoke and dust loadings as a function of time. The climatic response was assessed using a one-dimensional radiative-convective model. The TTAPS results were used as input to a study of the environmental consequences by a team of biologists. Harwell's book began life as a technical support document for this part of the meeting.

This is both a complex and an emotive subject, so it is important that the uncertainties in the predictions are understood. A major fault in this book is that the TTAPS results are accepted virtually without qualification and the impression is given that firm projections are being made. It is worth summarizing here the chain of events which is supposed to lead to nuclear winter in order to bring out these uncertainties.

It is widely believed that a limited nuclear war is very unlikely and that there would be rapid escalation to a large-scale exchange, though this depends on assumptions which (one hopes) cannot be checked fully. Likely targets include military (bases, command centres, missile silos, etc.), strategic (industrial, communications and transport centres) and civilian (large cities). There is a wide range of possible scenarios for the number and nature of the targets and for the size of the warhead used on each. The thermal pulse from a nuclear explosion can ignite combustible materials over a wide area, so that extensive city, industrial and forest fires would be expected, depending on many factors such as the nature of the target and the ambient weather. In such fires, some fraction of the burning material would create smoke and a proportion of this would be elemental carbon. The smoke particles would initially be expected to be much smaller than 0.1 μm, but would grow by coagulation and would ultimately be removed by gravitational settling and by incorporation into precipitation. The exact size, shape, physical and chemical composition of the aerosol from a large fire are very uncertain. Central to the nuclear winter hypothesis is that sufficient carbonaceous aerosol would remain in the crucial size range around 0.1 μm radius to alter radically the radiation balance. Such an aerosol has unusual optical properties; it strongly absorbs solar radiation but is too small to have an appreciable influence on long-wave radiation. If sufficient quantities were lofted, one would therefore expect strong atmospheric heating while at the same time the surface would cool. Merging of smoke plumes and spreading by the winds is supposed to lead to most of the northern hemisphere being covered by smoke, with land surface temperatures up to several tens of degrees Celsius below normal for several weeks. This projection depends on an enormous extrapolation of current knowledge. The aerosol would have to run the gauntlet of scavenging by precipitation, which may be very important as large fires often lead to cumulonimbus clouds. At Hiroshima, for example, such a cloud formed and 'black rain' fell.

By varying the assumptions one can predict any response from surface warming to a cooling so severe that some authors have even raised the possibility that the next ice age would be initiated. Atmospheric scientists expecting to find a discussion of these uncertainties will be disappointed by this book. Nevertheless, it is worth reading if only to see what biologists get up to when presented with such possibilities and to enjoy some of the pretentious conclusions on the jacket cover and in the foreword and summary of consequences. For what should be a more careful review of the current status of this subject I recommend the report of the SCOPE-ENUWAR project, due to be published this September.

It is easy to pour scorn on the projections of a nuclear winter, but the uncertainties will only be reduced if scientists are prepared to spend time studying them. As with many other environmental issues, by focusing attention on areas of atmospheric science which are poorly understood, research may be stimulated which has wider application and thus enriches the science. However, even if these projections were shown to be incorrect, nuclear war would still be an appalling prospect. It is a terrible indictment of our age that such weapons are considered necessary as the ultimate deterrent, or to provide the ultimate solution, in the resolution of conflicts between nations.

A. Slingo

Recent advances in planetary meteorology, edited by Garry E. Hunt. 178 mm × 252 mm, pp. xiv + 161, *illus.* Cambridge University Press, Cambridge, London, New York, New Rochelle, Melbourne, Sydney, 1985. Price £20.00, US $39.50.

Recent spacecraft missions and other improved observational techniques have, over several years, led to the collection of a body of data concerning the structure, composition and dynamics of planetary atmospheres. These observations present the meteorologist with a challenge and an opportunity to test ideas developed by analysing data from our own atmosphere which, although extensive in coverage, are obtained under a limited range of conditions. This book contains a selection of reviews of several aspects of planetary meteorology which will be of interest to many. The seven contributions were originally prepared as keynote lectures at sessions of an International Union of Geodesy and Geophysics meeting on planetary meteorology held in Hamburg in 1983. The session was dedicated to the memory of

Seymour Hess whose contributions to this field of meteorology and to the success of the Viking missions to Mars are well known.

The seven papers fall into three groups. The first two papers are concerned with aspects of the chemical composition and chemical evolution of the atmospheres of Venus, Jupiter, Saturn and Uranus. The next two papers are concerned with particular aspects of the local atmospheric conditions or 'weather' on Mars, and the final three papers address aspects of the dynamical structure of the atmospheres of Jupiter and Saturn and the way in which planetary atmospheres provide tests of theories developed for explaining the observed circulation of the Earth's atmosphere.

In the first paper Prinn describes the chemistry of the atmosphere of Venus emphasizing the reactions involving the radiatively important sulphur compounds. The complex chemistry is presented in a way which may be followed by the non-specialist. The chemical reactions can be classified by three time-scales but, although these are clearly distinguished, a more quantitative assessment of the rate-determining steps in complex systems of reactions would have been useful. A minor deficiency of this paper is the lack of figure captions although the diagrams are described in the text.

The chemistry of the outer planets is described by Atreya and Romani who provide a comprehensive review of the many reactions which are important at the temperatures and pressures experienced on these planets. Unfortunately the rather brief discussion of the observations of the chemical structure of the atmospheres makes it difficult to critically evaluate the different reactions. The calculation of the cloud structure and the effects of the formation of solution droplets are clearly presented and the results showing the clouds expected at different heights are particularly interesting.

Leovy *et al.* describe the meteorological data obtained from the Viking 'landers' on Mars and it is this and subsequent papers that many meteorologists will find of most interest; despite the relative lack of observations compared with the observing systems with which we are more familiar, much has been deduced concerning the Martian 'weather'. Although conditions are relatively settled in summer (the landers were at subtropical and mid-latitudes) with alternating upslope and downslope winds, the winters are more disturbed and fall into two groups. The importance of dust in the atmosphere is stressed and the observations show that baroclinic activity is suppressed when major global dust storms occur. The circulations associated with baroclinic waves produce limited dust storms which are confined to the lower layers of the atmosphere. It is suggested that the differences between those years in which global dust storms occur and those in which they do not, represent the differences between two pseudo-equilibrium states between which transitions may be triggered by small random fluctuations.

Martian dust storms are discussed in more detail by James, making use of the Viking orbiter data. The similarities and differences between dust storms on Earth and Mars are clearly described and the relevance of particle size and air density demonstrated. The relationship between the different climatic types and the small-scale processes leading to dust raising is also described. Both this paper and the preceding one are largely descriptive and, although presenting a considerable body of information, are very readable.

Hunt *et al.* provide a comprehensive description of the atmospheres of Jupiter and Saturn using data from many sources. Theoretical explanations of the observations are presented although the discussion is largely qualitative. The importance of the internal energy source for these circulations, which implies that the incoming and outgoing radiative fluxes need not balance, is demonstrated. Naturally, in the discussion of Jupiter's atmosphere, theories of the Great Red Spot receive attention and the current ideas concerning soliton and baroclinic theories are briefly but adequately described. It is perhaps a reflection on our understanding of atmospheric dynamics that such gross and long-lived features are still not fully understood.

The conversion between different forms of energy is important in determining the forms of atmospheric circulations as well as in maintaining features such as the Great Red Spot against dissipation. Conversion processes are discussed in general terms by Gierasch and Conrath who draw attention to the energy sources which are important in some planetary atmospheres if not in the Earth's atmosphere. While the terrestrial meteorologist is only concerned with changes of phase involving water, latent heating or cooling during phase changes involving silicon and magnesium compounds is significant at the high temperatures deep in some planetary atmospheres.

A brief concluding paper by Leovy and Hunt presents observations of planetary circulations and indicates how these may be used to extend theories of the Earth's atmosphere. While some of the material summarizes that in earlier papers, attention is drawn to the theoretical ideas and to areas where no adequate explanations exist.

These invited papers are clearly written and will be understood by a non-specialist readership; a uniform standard has been achieved despite the number of contributing authors. The material presented is both up to date and comprehensive. The text (typescript) and figures are clear and there is little duplication between the papers. While the general reader will probably be content to accept the material as presented, extensive additional references are provided and the short subject index should enable the book to be used for reference. The book, although short, will serve to bring the reader up to date in this rapidly developing field and should help encourage some to see the circulation of the atmosphere of the Earth as but one example of an atmospheric circulation.

P. R. Jonas

New views on an old planet: continental drift and the history of the earth, by Tjeerd H. van Andel. 182 mm × 258 mm, pp. xii + 324, *illus.* Cambridge University Press, Cambridge, London, New York, New Rochelle, Melbourne, Sydney, 1985. Price £15.00, US $19.95.

Professor van Andel is a geologist at Stanford University and a member of the Royal Netherlands Academy of Sciences. He is also a skilful writer of lucid and elegant English prose who has produced an excellent introductory book designed for anyone who has an interest in the history of the earth but no prior knowledge of geology. The book arose from an undergraduate course at Stanford, taught mainly to students who did not intend to become geologists, and contains no mathematics. Anyone, therefore, with an interest in modern scientific advances can read it with profit and enjoyment, an enjoyment enhanced by the quotations introducing each major section which are culled from a wide range of scientific and imaginative literature and the illustrations that accompany them which come from 18th and 19th century scientific books.

This book covers basic geological principles and how we may read the record of the rocks; past and present climates; continental drift and plate tectonics; oceanic circulations and the ice ages; the dawn of life and its development and evolution; and the various crises and catastrophes for which there is evidence including the Permian marine collapse and the great Cretaceous extinction of the dinosaurs. Professor van Andel refers to all the main hypotheses and theories put forward to account for climatic change (the main topic of professional interest to meteorologists in the book) and explains the fundamental ideas behind them. He also points out the difficulties and anomalies in the evidence which none of the theories as yet fully account for; his sober appraisal of our knowledge (certainly increasing) and our ignorance (still very great) is a salutary corrective to many more sensational accounts.

There is a useful glossary of technical terms at the end, but there is at least one omission; few non-geologists know that the sea nymph Tethys gave her name to the Mesozoic sea that stretched across the mid-Atlantic and the Mediterranean out into the Indian Ocean.

R. P. W. Lewis

THE METEOROLOGICAL MAGAZINE

No. 1360 November 1985 Vol. 114

CONTENTS

NOTICE

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire RG12 2SZ and marked 'For Meteorological Magazine'.

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

Authors wishing to retain copyright for themselves or for their sponsors should inform the Editor when they submit contributions which will otherwise become UK Crown copyright by right of first publication.

Applications for postal subscriptions should be made to HMSO, PO Box 276, London SW8 5DT.

Complete volumes of 'Meteorological Magazine' beginning with Volume 54 are now available in microfilm form from University Microfilms International, 18 Bedford Row, London WC1R 4EJ, England.

Full-size reprints of Vols 1–75 (1866–1940) are obtainable from Johnson Reprint Co. Ltd, 24–28 Oval Road, London NW1 7DX, England.

Please write to Kraus Microfiche, Rte 100, Millwood, NY 10546, USA, for information concerning microfiche issues.

HMSO Subscription enquiries 01 211 8667.

Printed in England for HMSO and published by
Her Majesty's Stationery Office

£2.30 monthly **Annual subscription £27.00 including postage**

Dd. 736047 C15 11/85

ISBN 0 11 727565 4
ISSN 0026–1149