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Synoptic aspects relating to the development of widespread heavy rainfall over southern England on 30 May 1979

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Summary

A small low moving north-north-eastwards across the English Channel and south-east England on 30 May 1979 brought heavy and prolonged rain to much of southern England, accompanied by thunderstorms and a tornado. Synoptic aspects of the development are now examined, with emphasis on the contribution of low-level convergence.

Introduction

May 1979 was a wet month over much of southern England, and in a number of areas the soil moisture deficit for grassland was at or close to zero near the end of the month. On 30 May a small low moved north-north-east from near south-west France, reaching the Channel Islands by midday, where for a time it became multi-centred, with the main depression crossing south-east England in the evening. The associated fronts brought prolonged heavy rainfall to western areas, with falls exceeding 50 mm in some places and flooding, notably around the Dorset, Wiltshire and Somerset border area. A well-marked line-squall and tornado was observed, and thunderstorms developed over southern and eastern England during the afternoon and evening. In this paper the synoptic factors are considered in some detail, in order to explain the apparent rapid development of an area of heavy rain and thunderstorms.

Synoptic developments

A major upper trough developed in mid-Atlantic towards the end of May and a deepening surface low moved north-eastwards to become centred near western Ireland. A warm and moist airflow was advected over the British Isles and near-continent with dew-points of 17 °C being reported in parts of western France. During 29 May the surface fronts moved east across the country, giving only occasional light rain over southern England. The upper trough continued to move slowly east and by 00 GMT on 30 May, the surface fronts had become quasi-stationary over south-east England and the near-continent with a marked baroclinic zone extending from the Bay of Biscay, through Cornwall, to south-west Norway. An analysis of wet-bulb potential temperature (θ_w) at 850 mb (Bradbury 1977), Fig. 1, showed the fronts to be well marked, with a gradient of 1 °C in 50 km. The places used for this analysis or subsequently mentioned in this paper are given in Fig. 2. On the morning of 30 May, the surface anticyclone over central Europe began extending a ridge westwards across central Britain as the upper trough became disrupted by upper-air developments over mid-Atlantic. The corresponding decline of Low P created an easterly geostrophic component of about 10 m s^{-1} along the surface fronts, some 150 km to 450 km ahead of the low, and gave a westward movement of around 6 m s^{-1} to the fronts.

Isolated outbreaks of rain occurred early in the day over southern counties of England, the Channel Islands and Brittany. This rain area expanded quickly into a wide band of moderate or heavy precipitation, which moved north-north-eastwards at about 6·5 m s^{-1}, reaching the Manchester area around 12 GMT. Some areas of western England experienced almost 12 hours of continuous rain, much of

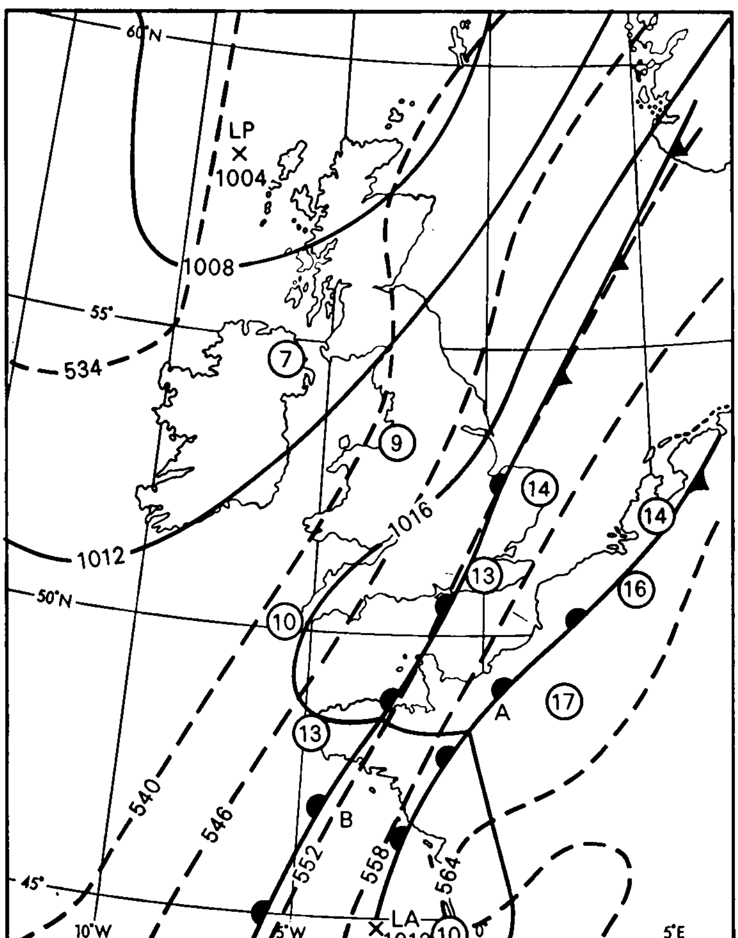


Figure 1. Surface and 1000–500 mb thickness analysis at 00 GMT on 30 May 1979. Figures within circles are wet-bulb potential temperatures at 850 mb. Pressures in millibars. Thicknesses in decageopotential metres.

it heavy, and by early afternoon, telephone inquirers from parts of eastern Somerset were speaking of rivers overflowing and flood water threatening property. The Wessex Water Authority, to whom the Main Meteorological Office at Upavon is responsible for rainfall warnings, later reported that rainfall totals in their area exceeded 30 mm in a number of places, with Yeovilton (Somerset) recording 57 mm. It will be seen later that the main area of rain was closely related to the surface fronts and the area of easterly geostrophic wind flow, whereas the precipitation close to the main low centre was generally caused by thunderstorms triggered by daytime heating.

The principles of the use of radar data for determining rainfall rates over a wide area have been reported in several publications, and the development of a system of linked radars is described by Taylor and Browning (1974). A rainfall radar system was installed at Upavon early in 1979 as part of the Meteorological Office short-period weather forecasting pilot project (Browning 1979), and the system proved invaluable on this occasion. The first indication of thundery activity came from a

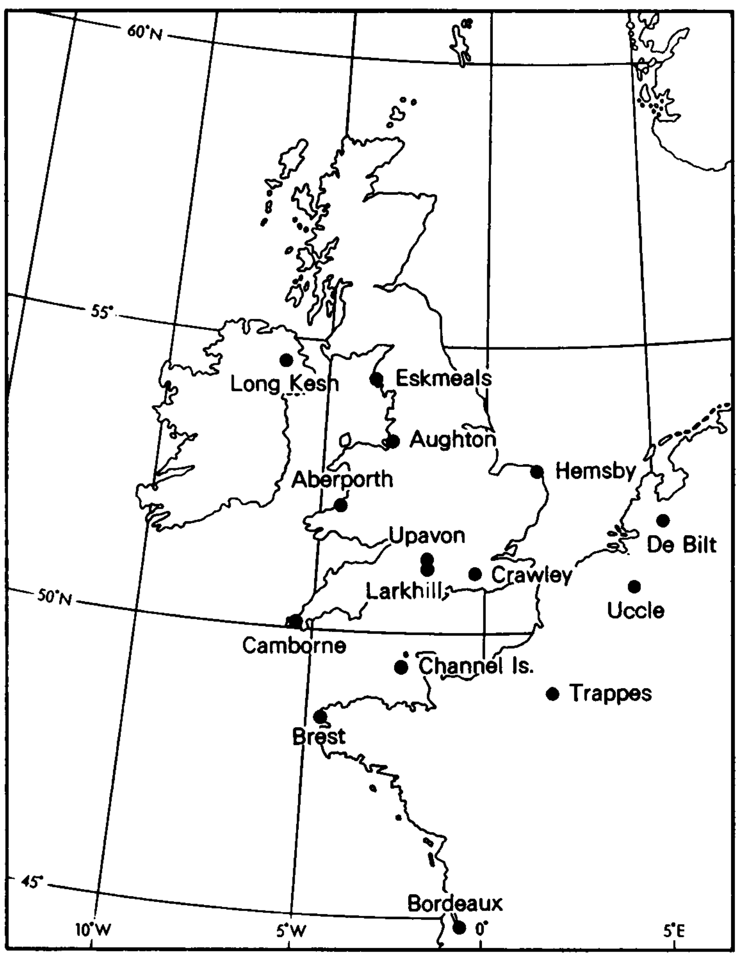


Figure 2. Location of places mentioned in article.

SFLOC report over central Brittany at 0800 GMT. Subsequent reports showed the area of activity moving north-north-eastwards at 17 m s^{-1} with thunder being heard at the Portland Bill Coastguard station at 11 GMT. This storm weakened as it moved inland, but a further thunderstorm reported at Portland Bill the following hour was later identified as part of a developing system which moved inland across east Dorset and Wiltshire to give a particularly active line-squall and tornado over Salisbury Plain (Smith 1980) between 1315 and 1330 GMT.

Fig. 3 shows the areas of precipitation, nominally* 1 mm h^{-1} and 4 mm h^{-1}, within a 50 km radius of Upavon, and derived from the computed raw radar data. The sequence of patterns shows clearly the south-west to north-east movement of the thunderstorm/squall front at about 50 degrees to the right of the backing mid-tropospheric wind flow (Figs (4a) and (b)). Plate I shows clearly the rainfall pattern depicted by the Upavon radar over a 210 km radius at 1403 GMT with its two distinct bands. The cellular cluster just to the north of Cherbourg is probably a newly formed thunderstorm cell, which moved into east Hampshire about one hour later. Further thunderstorms occurred during the afternoon over south-east England, later becoming widespread as the low moved north-north-east across the home counties. Drier weather which spread into south-west England behind the second rainfall band later extended to most parts of southern England by midnight.

Factors relating to the development of heavy rain

The development of the widespread heavy rainfall on the 30th was not, even with hindsight, immediately apparent from a study of the synoptic situation. Though the data at 00 GMT pointed towards cloud and rain moving from the south, none of the available data suggested the likelihood of copious rainfall.

The 00 GMT upper-air ascents from Crawley, Hemsby, and Camborne showed layers of cloud between 8000 ft and 18 000 ft, some of which were unstable, but the ascent for Brest, however, was rather more stable with moist layers to at least 24 000 ft. The radiosonde ascents from De Bilt, Uccle, Trappes, and Bordeaux, (see Fig. 2), revealed marked potential instability between 3000 ft and 20 000 ft, and infra-red pictures taken by the METEOSAT and NOAA 6 satellite systems showed this cloud belt to extend north-north-east from north-west Spain, across south-west England, and then, with breaks, to south-west Norway. A sequence of METEOSAT photographs covering part of 29 and 30 May has previously been published (Moore 1980).

Fig. 5 shows the 00 GMT analysis of the 14 °C θ_w surface following work by Harrold and Nicholls (1968), and Browning and Harrold (1969), and vertical motion (w) of about + 30 cm s^{-1} at Brest may be deduced from the diagram, although without upper-wind data from Bordeaux, the analysis over northern France is in some doubt. The absence of reports of moderate or heavy rain in Brittany at midnight supports the view that the deduced value of w at Brest is too high. Two further methods were therefore used to calculate the vertical motion more accurately.

The first used the sharp increase in θ_w—where the radiosonde sounding intersects the frontal zone—and the vertical wind shear to obtain the height of the frontal surface and hence the slope from the position of the front at the surface. A rate of vertical motion may thus be calculated using a simple formula (Appendix 1). This method will not give a detailed description of the bands of ascending and descending motion, but it will provide an indication of the activity of the front. Table I shows an analysis of the frontal surfaces at various radiosonde stations and the calculated rate of vertical motion.

* At that time the radar had not been calibrated against the check rain-gauges: the best available estimate was that the radar was under-reading by a factor of 2.

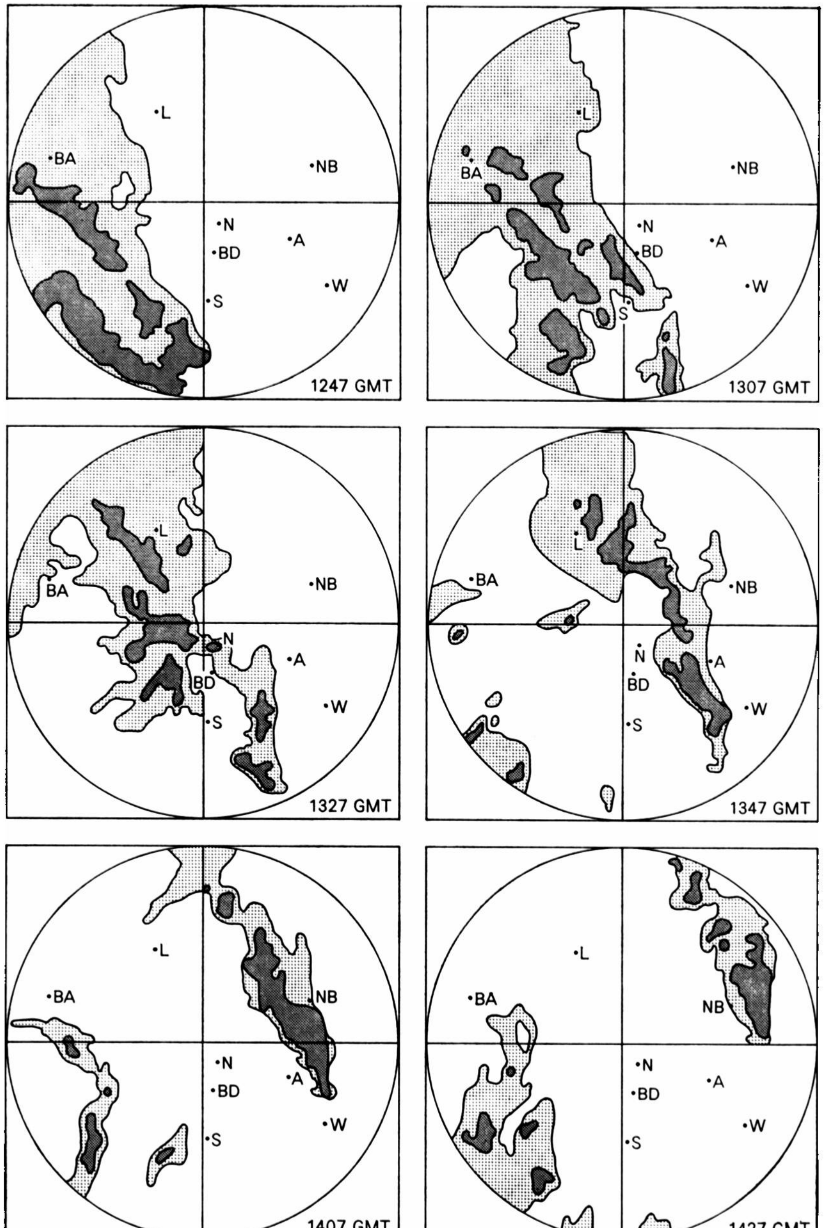
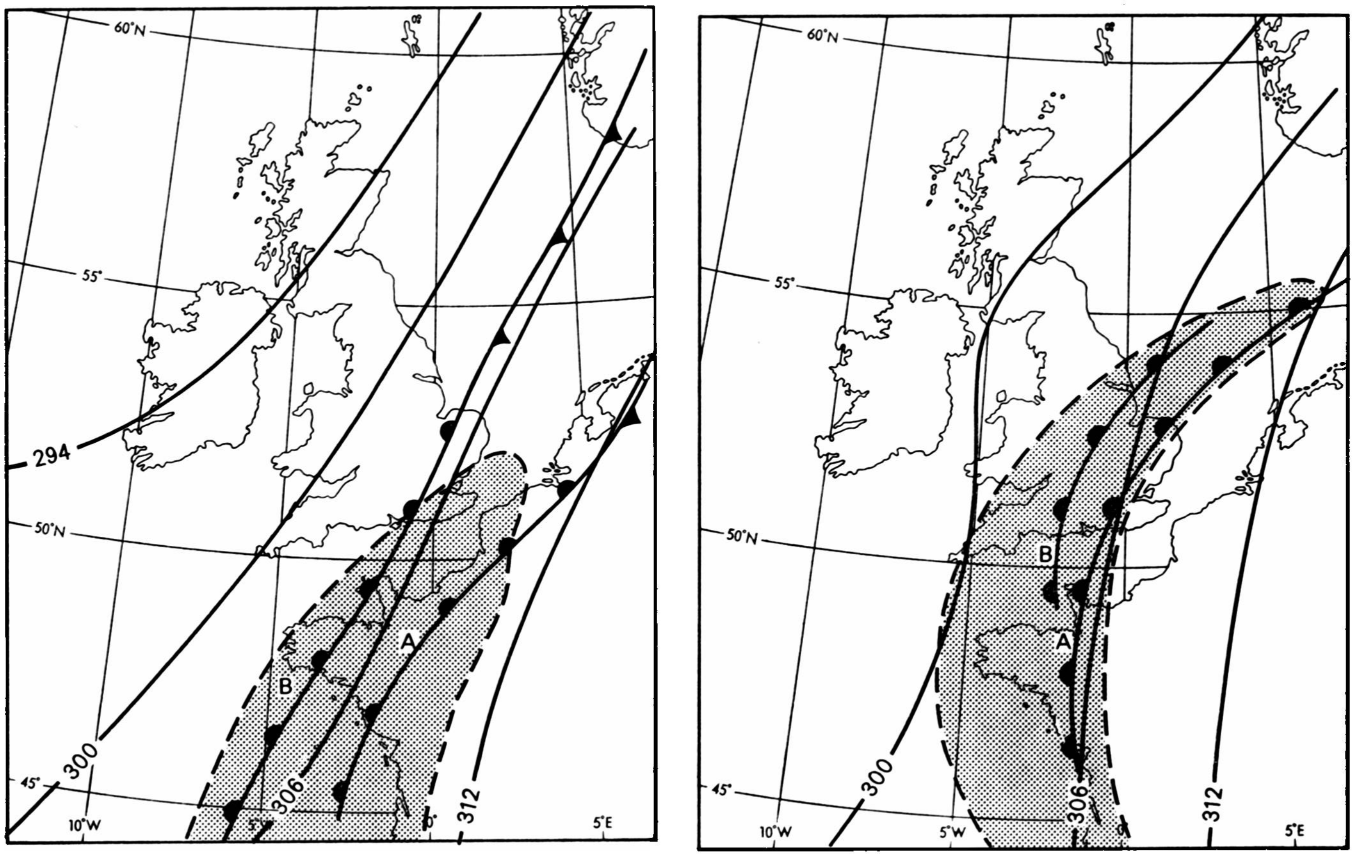


Figure 3. Precipitation patterns within a 50 km radius of Upavon at elevations of 0·5° or 0·9°. Light stipple indicates areas with precipitation nominally equalling or exceeding 1 mm h^{-1}, and dark stipple areas with nominal precipitation ⩾ 4 mm h^{-1}.

Key to locations: BA = Bath, L = Lyneham, NB = Newbury, N = Netheravon, BD = Boscombe Down, A = Andover, W = Winchester, S = Salisbury.



00 GMT

12 GMT

Figure 4. 700 mb geopotentials in decageopotential metres. Surface fronts shown conventionally. Shaded area indicates dew-point depression ⩽ 2 °C. (a) 00 GMT, (b) 12 GMT.

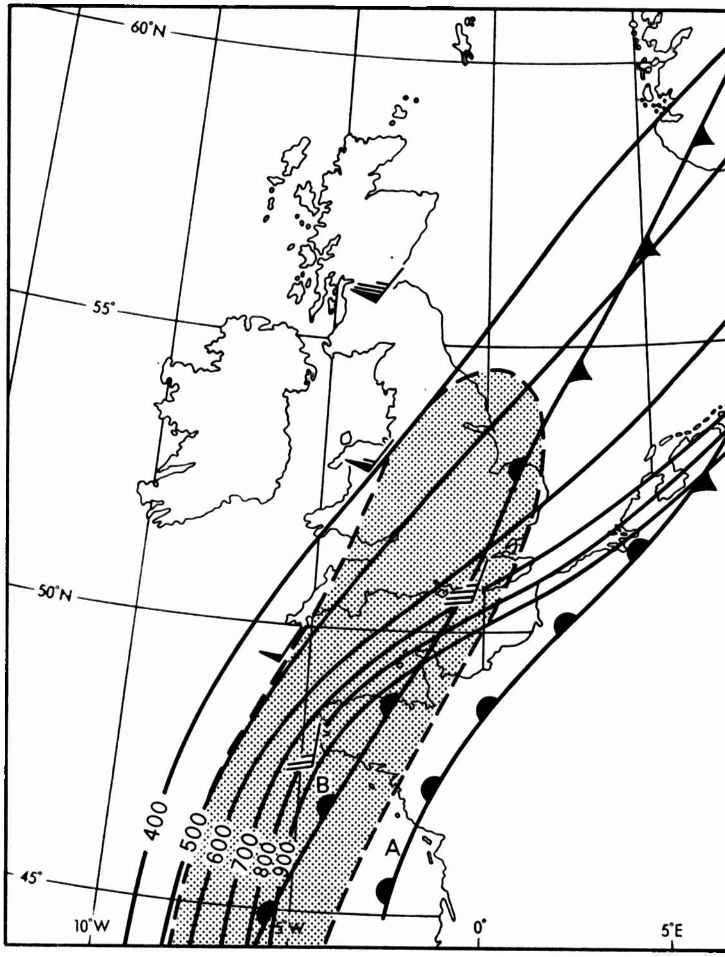
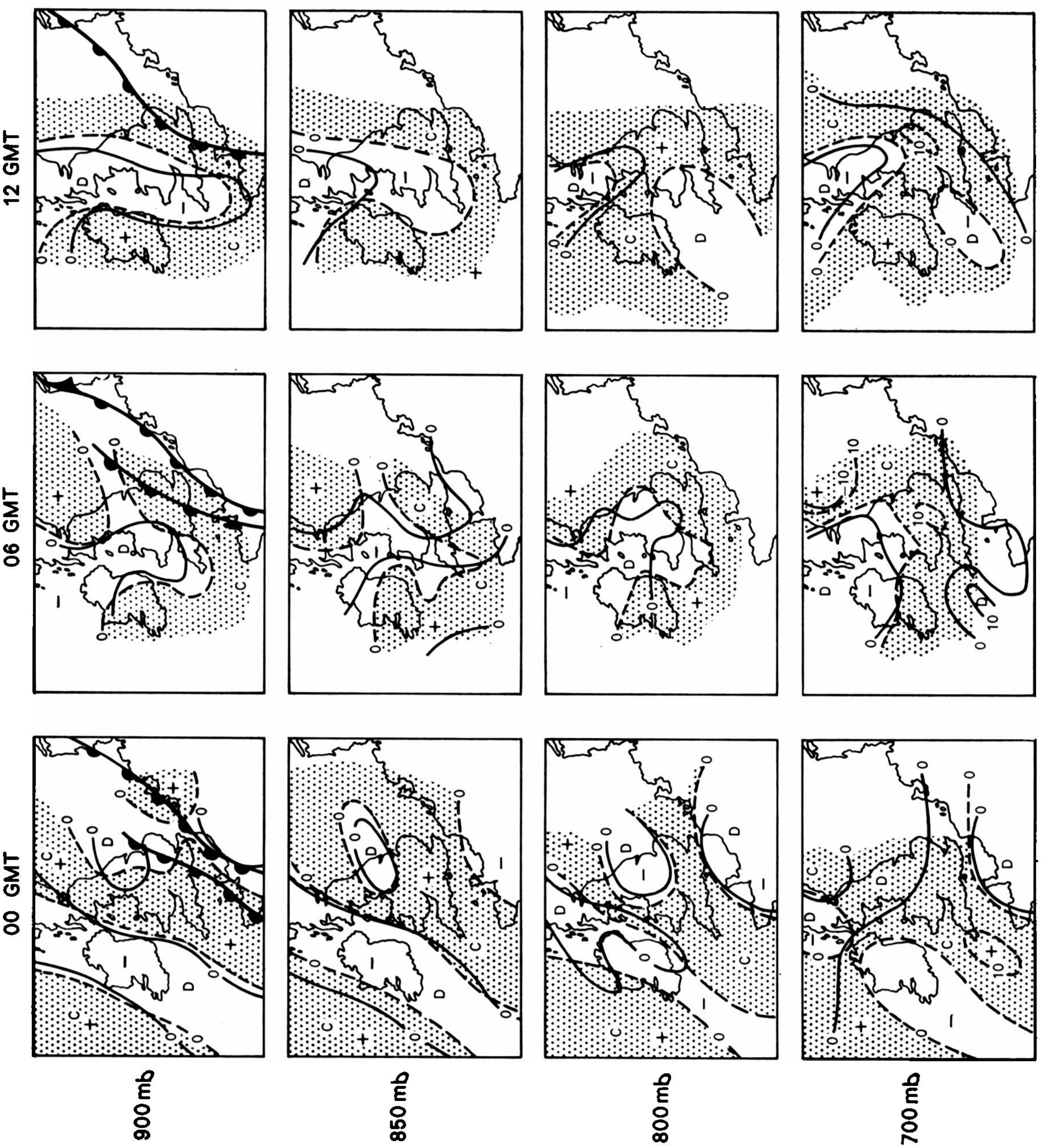


Figure 5. Analysis of 14 °C wet-bulb potential temperature surface at 00 GMT on 30 May 1979. Solid lines are isobars. Relative winds indicated by wind arrows: each full feather denotes 5 m s^{-1} and triangles 25 m s^{-1}. Shading indicates area with dew-point depression < 5 °C.

No assessment was made for warm front B at Brest, because the front was within the surface friction layer.

The second method was based on the technique used by Bellamy (1949) and Poulter (1949). Briefly, a triangular system is devised between radiosonde stations, and by calculating the line integrals around the triangles, the horizontal divergence fields are calculated for the centroid of each triangle for each upper-air level, including an initial divergence field at the surface. From these values w may be computed using the method described by Holton (1972), for an incompressible fluid. Here the difference in w at the top and bottom of a column may be determined by multiplying the mean horizontal divergence of that layer by the thickness of the layer. Therefore with $w = 0$, at the surface of the earth, w may be computed for sequential layers in the vertical. The results for seven layers are shown in Fig. 6. The data are incomplete because upper-wind information was missing or unavailable at some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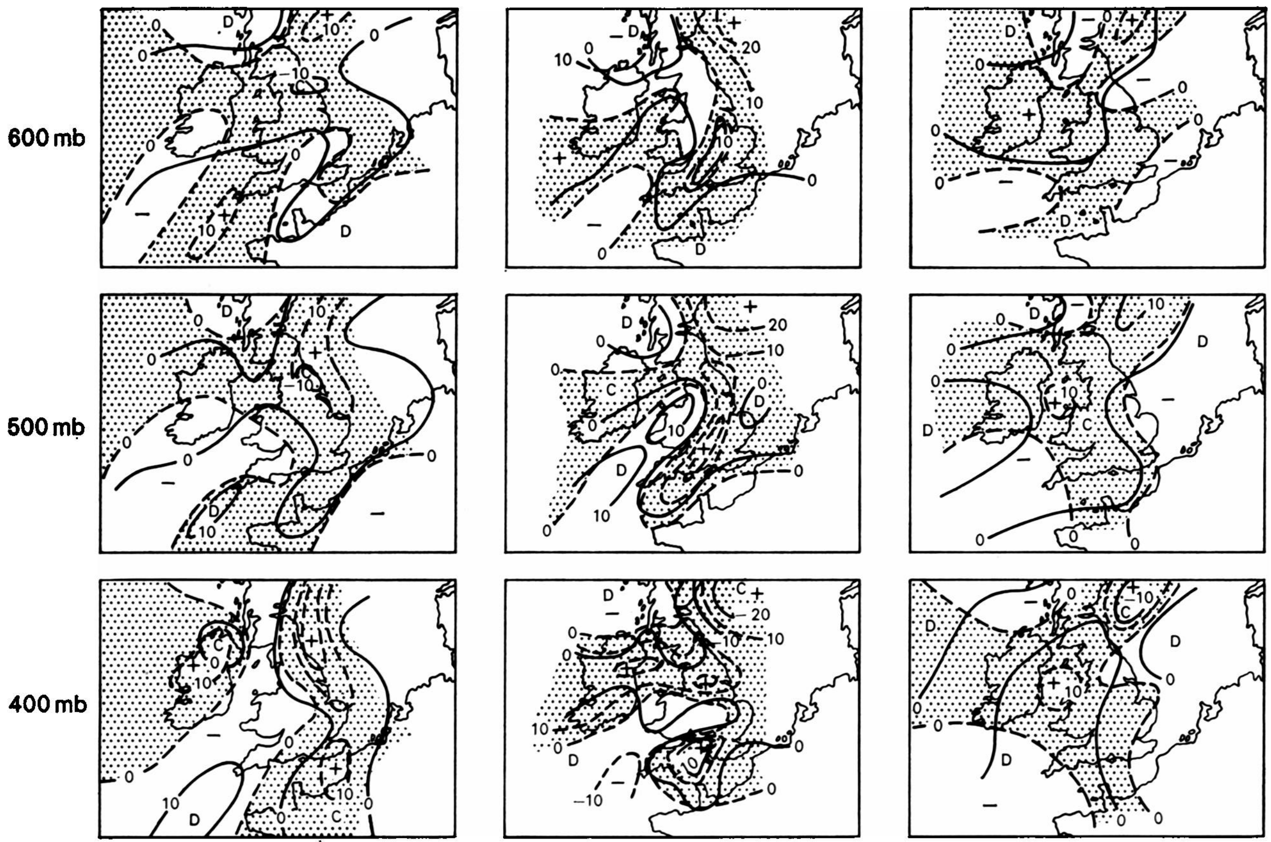

Figure 6. Divergence and vertical velocity on 30 May 1979. Divergence in full lines in units of $10^{-6}\ s^{-1}$. Vertical motion in dashed lines in units of $1\ cm\ s^{-1}$. Areas of ascent are shaded and indicated by +; areas of descent are indicated by —. D = Divergence, C = Convergence. Surface fronts are superimposed at 900 mb level.

Table I. *Analyses of frontal surfaces on* 30 *May* 1979

Station	Time GMT	Height mb	Height km	θ_w °C	Wind degrees/m s^{-1}	Resultant wind degrees/m s^{-1}	Horizontal distance from surface front km	Slope degrees	Orientation of surface front degrees	w cm s^{-1}	ω mb h^{-1}
(a) Warm Front A		Details of frontal zone (top T and bottom B)									
Camborne	00	T 535	5·06	14	210/40*	205/27·5	315	0·92	210	3·85	—9
		B 550	4·86	12	205/35*	200/23		0·88			
Brest	00	T 805	1·91	14	200/16	195/13·5	185	0·59	210	3·60	—13
		B 850	1·46	11	230/6·5	210/08		0·46			
	12	T 700	3·01	15	170/14·5	180/11	189	0·91	190	3·03	—9
		B 745	2·52	13	—	—		0·76			
Crawley	00	T 595	4·43	15	220/24	210/17	149	1·70	210	0·0	0·0
		B 605	4·24	13	215/20	205/16		1·62			
Larkhill	05	T 460	6·23	15	205/32	200/22	203	1·75	210	11·67	—30
		B 475	6·10	13	205/26	200/19		1·72			
	09	T 540	5·06	14	180/29	185/20	102	2·84	200	25·6	—68
		B 625	3·95	12	180/20	185/15		2·21			
(b) Warm front B											
Long Kesh	12	T 560	4·69	11	185/20	190/15	463	0·58	230	9·75	—28
		B 575	4·49	8	185/12·5*	190/11		0·55			
Aughton	00	T 620	3·91	11	205/29	200/21	231	0·97	210	6·17	—17
		B 680	3·22	9	210/14	200/12		0·80			
	12	T 700	3·02	12	170/12	180/11	212	0·82	230	12·05	—38
		B 720	2·80	8	Calm	190/05		0·76			
Aberporth	07	T 575	4·53	12	200/27·5*	195/19	315	0·82	210	7·04	—19
		B 600	4·21	10	205/21·5	200/16		0·76			
Camborne	00	T 640	3·70	12	205/27·5	200/20	250	0·85	210	5·15	—15
		B 720	2·78	10	200/16·5	195/14		0·63			
	12	T 730	2·66	12	190/10*	190/10	198	0·77	190	0·0	0·0
		B 850	1·44	9	140/03	180/06		0·42			
Larkhill	05	T 780	2·17	12	195/14*	190/12	93	1·33	210	9·53	—35
		B 810	1·87	10	205/08	195/09		1·15			
	09	T 855	1·41	12	155/13	160/11	22	3·36	200	41·44	—145
		B 930	0·72	10	070/09	150/05		1·71			

* Wind values are 'best estimates' at that level assuming the continuation of a marked shear in speed above the frontal surface.

Note. The height (in kilometres) of the frontal surface was obtained from the WMO table of geopotential altitude as a function of pressure and proportionally adjusted to fit the reported height of the standard reporting level above the frontal surface. Geometric height was assumed equal to geopotential altitude.

stations, at some or all levels. This method of calculation can be used with advantage where upper-air stations are fairly close together; however, small errors in the reported winds, or marked wind shears, can cause large errors in the horizontal divergence values.

Discussion of results

The diagrams in Fig. 6 show clearly the effect of increasing convergence along warm front B, with the largest values of w occurring over central southern England, at 06 GMT. Comparison of the results of Table I with these diagrams show a reasonable measure of agreement. The value of $w = 41{\cdot}44$ cm s^{-1} at Larkhill at 855 mb gives a clear indication of the marked increase in the convergence effect by 0900 GMT: it is consistent with the intensification of the main rain area over south-west and western England, and also with the probable values of w ahead of a developing line-squall and tornado system. The apparent decrease in values of w for midday is also consistent with the main squall front being confined to parts of Wiltshire, Hampshire, and possibly parts of west Berkshire.

The radiosonde soundings (Fig. 7) at Larkhill for 0500 GMT and 0920 GMT are of particular interest. If the ascents are modified to take account of w, the air mass becomes potentially unstable with considerable entrainment of moist air to high levels. This modification will also enable the analyst to calculate a new precipitable water content. Using the method developed by Benwell (1965), the precipitable water content, was, chronologically, 19 mm and 18 mm, for Larkhill. Modified, these figures become 22 mm and 24 mm respectively. Though Larkhill itself experienced less than 10 mm precipitation, the revised figures are nearer to the general level of rainfall in the area.

The criteria associated with the development of the tornadic storm are similar to those reported at the time of the Wokingham storm (Browning and Ludlam 1962) and the 1973 tornadoes (Whyte 1974). They are:

(a) a frontal zone across southern England, with south-south-westerly upper winds;

(b) development of the first storm over Brittany, probably over the Côtes du Nord where the land rises in places to over 350 m;

(c) movement of the storm to the right of the mid-tropospheric wind flow (Fig. 8);

(d) a marked vertical wind shear, i.e. a wind veer with height;

(e) a surface wind directly opposed to the path of the storm;

(f) a marked squall or gust front ahead of the storm; and

(g) a sharp veer in the surface wind behind the main storm.

Clearly these events demonstrate that the storm system contained a supercell, and can be classified as a 'severe right local storm' (see Browning 1968). It was unusual in that severe storms generally require θ_w values of around 20 °C. An analysis of the computer printout of the rainfall radar data, plus SFLOC reports, show that the thundery system could be tracked from 0800 GMT to 1450 GMT, and that from 1150 GMT onwards it probably consisted of a supercell with other smaller cells nearby. The rainfall radar system proved to be of considerable value to the forecasting staff at Main Meteorological Office, Upavon in showing the cellular structure of the rainfall pattern and the well-defined boundary marking the spread of clearer weather from the south-south-west.

Conclusions

The frontal storms were triggered off by the forced ascent of moist air over Brittany, and in moving across the English Channel encountered increasingly favourable conditions for development. The

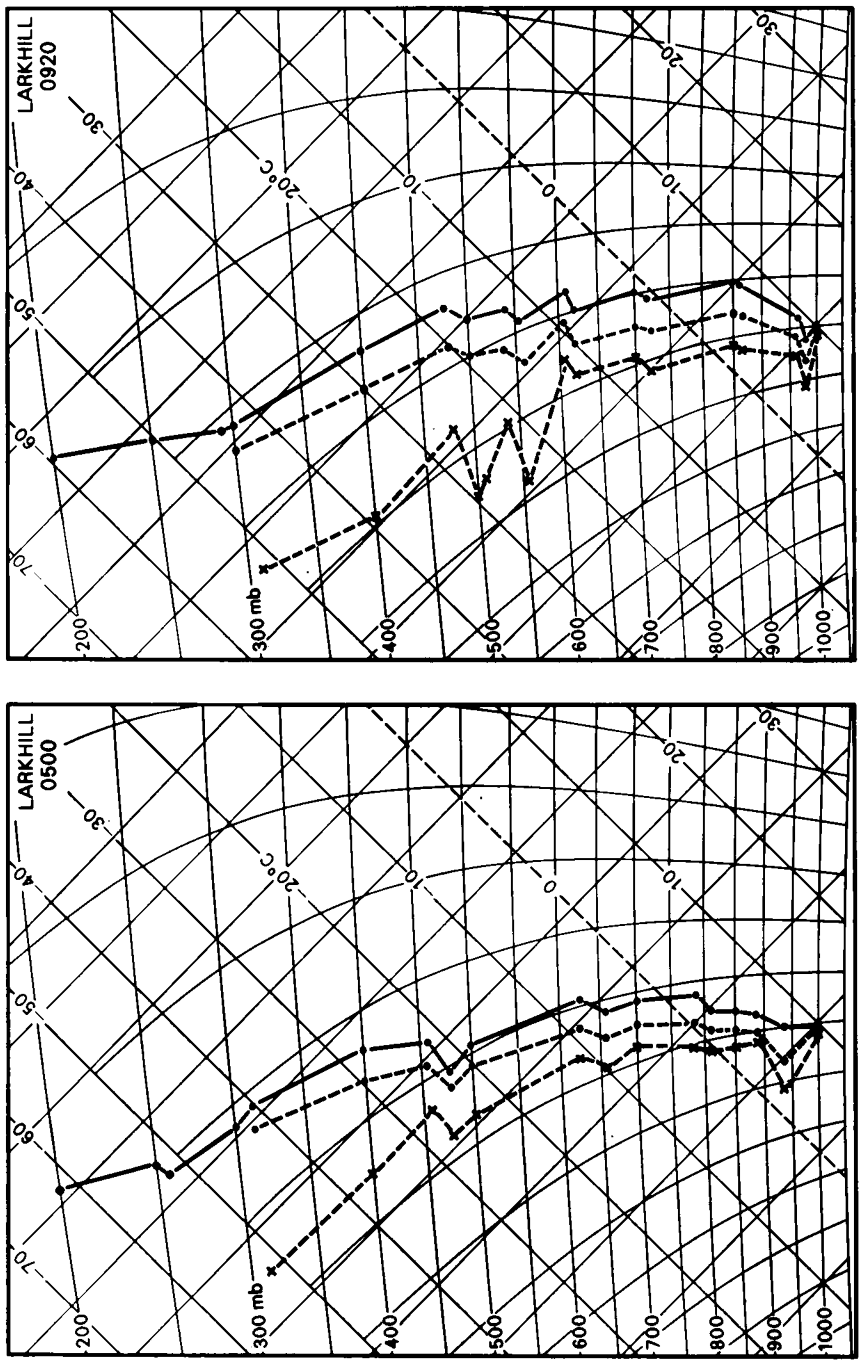

Figure 7. Radiosonde ascents at Larkhill on 30 May 1979. ● —— ● Dry bulb ● - - - ● Wet bulb
x - - - x Dew point.

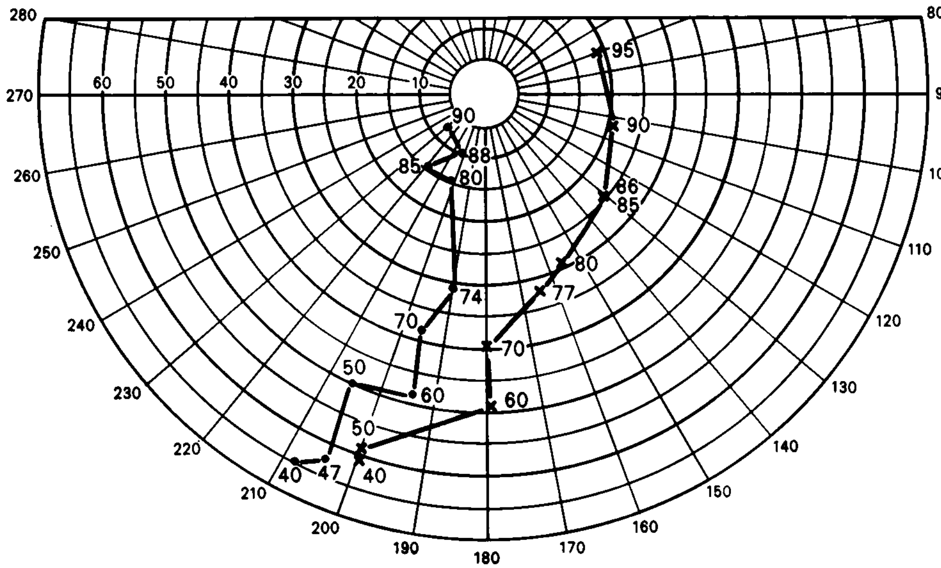

Figure 8. Hodograph of upper winds at Larkhill on 30 May 1979. ● —— ● 05 GMT, × —— × 09 GMT. Speeds in knots. Pressure levels in tens of millibars.

convergence, associated with the warm fronts, was responsible for the intensification of the rain area over western Britain, and the development of a supercell near the Dorset coast. Other storms were brought about by the effects of daytime surface heating over France, and the backing of the upper winds advected the storms across south-east and east England. Undoubtedly the key factor was the development of a surface ridge some 400 km to the north of Low A, brought about by a combination of anticyclonic disruption of the mid-Atlantic upper trough, and favourable dynamic factors in the baroclinic zone. This was responsible for the increased convergence over Britain.

Acknowledgements

Thanks are due to the staff at the Meteorological Office, Royal Signals and Radar Establishment, Malvern for supplying the rainfall radar printout, and to Mr J. D. Perry, Principal Meteorological Officer, 38 Group, for many helpful comments.

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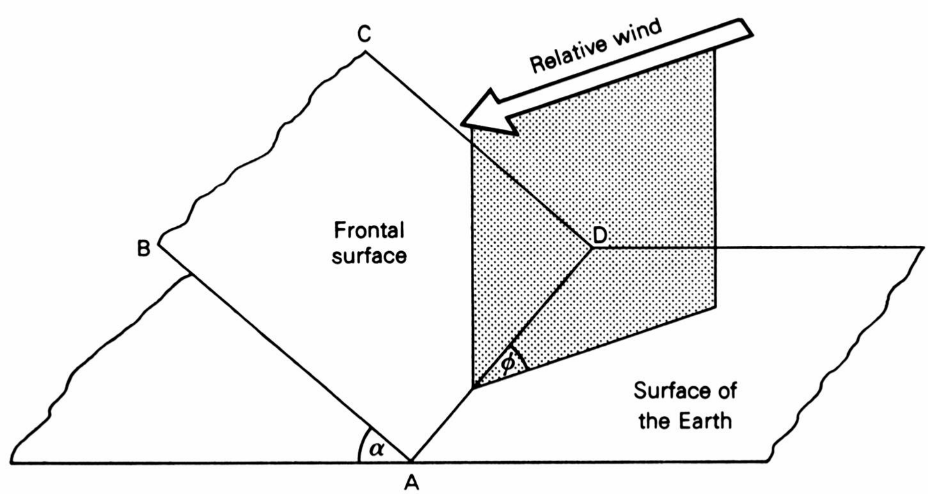
Appendix 1

Let ABCD represent a frontal surface intersecting the surface of the earth at an angle α. Then if the wind relative to the frontal surface is calculated and has magnitude V, the vertical motion can be assessed. If the (relative) wind is blowing parallel to AD (i.e. if $\phi = 0°$ or $180°$) then there is neither ascent nor descent. If the wind is blowing *into* the surface there is ascending motion, and if *away from* the surface there is descending motion. In general, the value w of the induced vertical velocity is given by

$$w = V \sin \phi \sin \alpha.$$



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The founding of the Meteorological Office, 1854–55

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Summary

An account is given of the steps leading to the establishment of the Meteorological Department of the Board of Trade and the appointment of Captain R. FitzRoy, RN as its head in so far as they are ascertainable from contemporary sources.

The present account is intended to amplify, and in certain minor respects to correct, previously published accounts of the history of the Meteorological Office in so far as they are concerned with the actual foundation of that institution in 1854–55 and the appointment of Captain (later Admiral) Robert FitzRoy to be its head. The Office was founded as a department of the Board of Trade, and it is unfortunate that a large number of Board of Trade papers were destroyed towards the end of the last century so that it is possible that some primary documentary sources have disappeared forever; certainly, very little relevant material can be traced today, either in the Public Record Office or elsewhere. However, enough remains for the general course of events to be described clearly enough.

In 1853 the first international marine conference was held in Brussels as a result of the work of Lieutenant M. F. Maury of the United States Navy. (Following an accident which rendered him unfit for further active service, Maury had in 1842 been put in charge of the Depot of Charts and Instruments where he organized a remarkable survey of winds and currents, distributing logbooks to captains and plotting and analysing the results.) As a result of this conference, at which Maury represented the United States, a strong feeling developed in scientific and shipping circles that the British Government should co-operate with the Americans by setting up their own office to collect oceanic and other scientific observations and to tabulate the results. On 26 April 1853 Lord Wrottesley, a senior Fellow of the Royal Society (of which he was to become President in November of the following year) and an expert on astronomy and the observational sciences, made an eloquent speech in the House of Lords; this speech was later reprinted as a pamphlet entitled 'On Lieut. Maury's plan for Improving Navigation, with some remarks upon the advantages arising from the pursuit of abstract science' and makes good reading even now. In February 1854 Captain FitzRoy (as he then was) wrote the following letter[1] to Colonel Sabine*, the Treasurer of the Royal Society:

Febr. 3 1864

My dear Colonel Sabine,

I send a copy of the paper to which I referred yesterday. For the first year it would not be too *difficult* to carry on without a *draughtsman*, but *time* would be lost.

I have made no special allusion to magnetic observations because you are the Magnetic Chief who will say what and how much should be done—and because my "Outline" for Lord Wrottesley was to bear on Maury's plan alone. The more I think about the subject, the more interested I feel in it—and I shall forthwith prepare for regular work—by going to a convenient house—where I shall have air, *room*, and light—and shall be able to work *at home*, as well as in *other* places.

Mr Heywood, in a note *just received* by me, says—"On Monday, I intend to ask Sir James Graham, in the House of Commons, whether an Office will be established to co-operate with Lt Maury, and if the records of surveying ships,

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*General Sir Edward Sabine, K.C.B., F.R.S., 1788–1883; astronomer and geodesist; President of the Royal Society 1861–71.

preserved at the Admiralty, may be rendered accessible to the person in charge of that Office. I am glad to hear, from Lord Wrottesley, that the Office will probably be under the Board of Trade, as it will thus be more easily in communication with the Mercantile Marine".

I remain always
Sincerely and respectfully
Yours
Robt. FitzRoy

(I reserve *other* topics and *private* feelings).

At the same time, FitzRoy wrote a memorandum[2] of eight foolscap pages entitled 'Mode of proceeding in Office' which is reproduced as Appendix 1. The Parliamentary Question referred to in the letter was duly put by Mr Heywood on 6 February 1854 (Appendix 2).

On 3 June 1854 the Board of Trade addressed a letter[3] to the Royal Society in the following terms:

Office of Committee of Privy Council for Trade
Marine Department, 3rd June, 1854.

Sir,—I am directed by the Lords of the Committee of Privy Council for Trade, to acquaint you, that, with the concurrence of the Lords Commissioners of the Treasury, My Lords have determined to submit to Parliament an estimate for an office for the discussion of the Observations on Meteorology which it is proposed shall be made at sea in all parts of the globe in conformity with the recommendation of the conference held at Brussels last year; and they are about to construct a set of forms for the use of that office, in which it is proposed to publish from time to time, and to circulate such statistical results as may be considered most desirable by men learned in the Science of Meteorology in addition to such other information as may be required for the purposes of navigation.

Before doing so, however, they are desirous of having the opinion of the Royal Society as to what are the great desiderata in Meteorology, and as to what forms that Society consider the best calculated to exhibit the great atmospheric laws which it may be most desirable to develope.

I herewith inclose a form of Log which will contain all that it is proposed to execute at sea; but it may possibly happen that observations on land upon an extended scale may hereafter be made and discussed in the same office, and in framing your reply it is desirable that such a contingency should be borne in mind and provided for.

I am, Sir, your obedient Servant,
James Booth

To the Secretary, Royal Society

The Royal Society acknowledged this letter on 24 June in a communication[4] signed by Colonel Sabine which informed the Board of Trade that the President and Council of the Society had 'addressed a letter...to several of the most eminent meteorologists in foreign countries' asking for their comments and advice. (The final reply of the Royal Society was sent to the Board of Trade on 22 February 1855, and is of considerable length. It is reprinted as an Appendix to FitzRoy's Report[5] for 1857 in which it is oddly and probably mistakenly described as a reply to a letter from the Board of Trade dated 15 January 1854, not 3 June; I have not been able to trace any letter for this earlier date, but there was probably a misreading of 15 June (date of Royal Society Council meeting).)

The next undoubted fact is the appointment of Captain FitzRoy to a position in the Board of Trade on 1 August 1854.[6] In the article on FitzRoy written for the 9th Edition of the *Encyclopaedia Britannica* not long after FitzRoy's death it is stated that '...when in 1854 Lord Wrottesley, the President of the Royal Society, was asked by the Board of Trade to recommend a chief for its newly forming meteorological department, he, almost without hesitation, nominated FitzRoy...'. I have not been able to trace any contemporary evidence for this statement, and the Librarian of the Royal Society has informed me that there is no documentary support for it in the Society's archives. However, the article in the *Britannica* was written by John Knox Laughton (1830–1915) who served in the Royal Navy from 1853 to 1885 and then became Professor of Modern History at King's College, London; he was President of the Meteorological Society from 1882 to 1883 (his Presidency covering the time

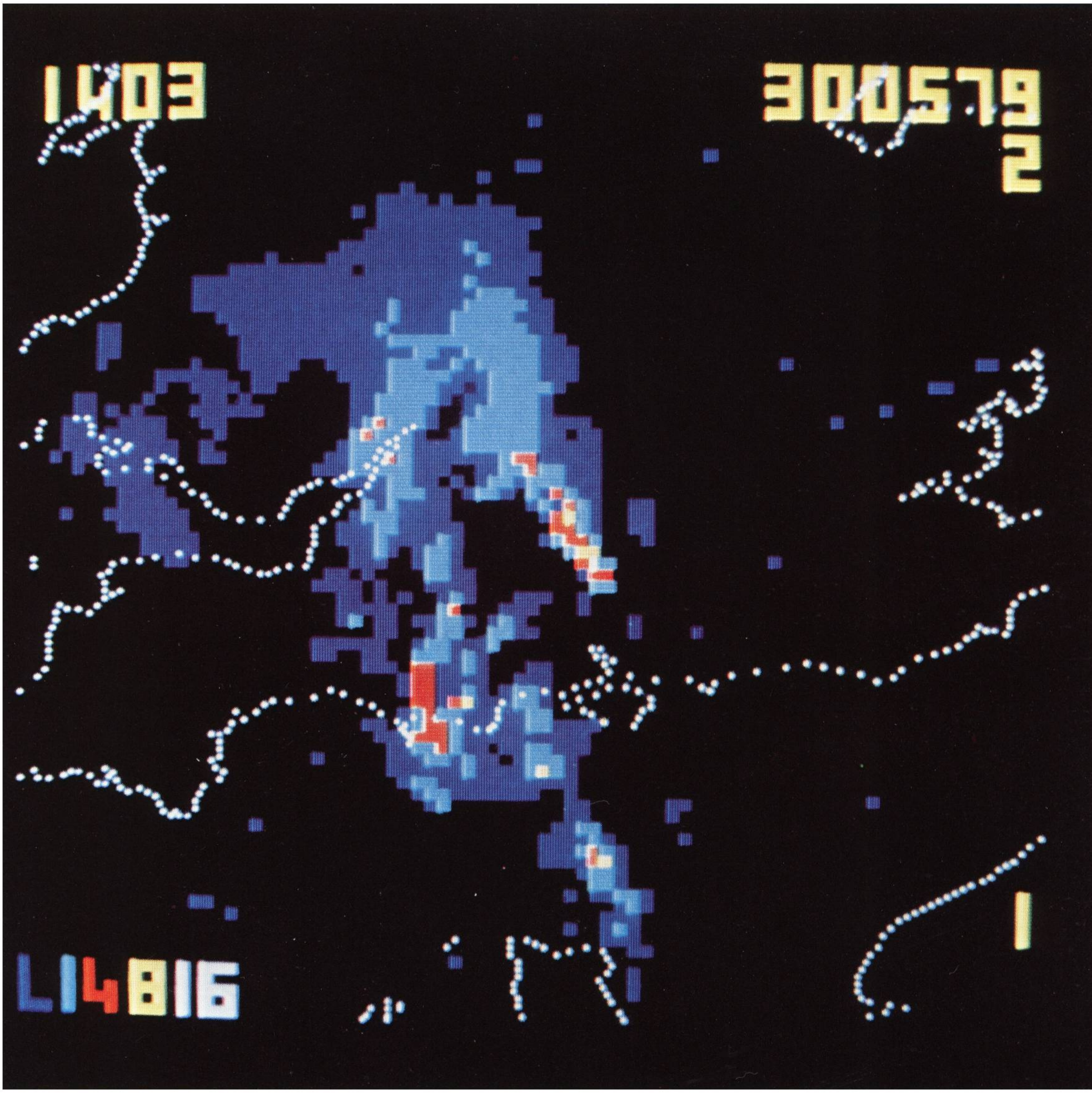

Plate I. Photograph of rainfall radar display at 1403 GMT on 30 May 1979, in 210 km radius of Upavon. (See page 210.)

Plate II. A new river bed caused by the avalanche of rainwater down the hillside on 1 August 1980 at Orra Beg, Co. Antrim. Note the car on the original road location. (See page 227.)

Plate III. Section of road hurled some 200 to 400 metres down the hillside at Orra Beg on 1 August 1980.

Plate IV. Hillside stripped cleanly to bedrock by force of water at Orra Beg on 1 August 1980.

Plate V. Picture shows 'fissures' approximately 3 m deep immediately above old road at Orra Beg on 1 August 1980.

Plate VI. Sunrise at Wokingham, Berkshire at 0718 GMT on 21 November 1980.

Photographs by D. J. Creasy

Plate VII. Sunrise at Wokingham, Berkshire at 0724 GMT on 21 November 1980. These photographs show the effect of the sunrise on the base of a spread of medium cloud in a ridge of high pressure ahead of a weak warm front over the South-west Approaches. Observations from Beaufort Park, Easthampstead around these times gave a light south-westerly wind and medium cloud between 10 000 and 12 000 ft.

that the Society obtained its Royal Charter) and was knighted in 1907. Although a very young man at the time of FitzRoy's appointment, Sir John Knox Laughton would later have been in a position to hear a good deal about it and may have had the opportunity of seeing papers that have since disappeared. (A minor error in the *Encyclopaedia Britannica* article is the description of Lord Wrottesley as the President of the Royal Society, an office he did not assume until several months after FitzRoy's appointment.) It is nevertheless clear from FitzRoy's own letter that he himself, Lord Wrottesley, and Colonel Sabine were in close touch on the matter. FitzRoy's own account,[7] dated 8 February 1855, is uninformative as to the precise steps leading up to his appointment, and is as follows:

> The importance of accumulating meteorological observations, and tabulating them methodically, for the purpose of future, rather than immediate investigation, having been urged by the Royal Society, while the practical benefits arising from such collections, even at the present time, were proved by the direct consequences of Maury's extensive labours, Her Majesty's Ministers agreed to establish an office under the Board of Trade for receiving and tabulating all such observations made at sea.
>
> It was considered that much information might be compiled with respect to currents, as well as winds, which might be made more generally known to those interested in the passages of ships across the ocean; and that the sooner such authentic compilations could be made generally available, the greater would be their value. It was, moreover, pronounced to be necessary that instruments of a reliable and understood nature should be alone employed; that they should be carefully tested and vigilantly guarded from accidental causes of error.
>
> To meet these objects, an estimate of probable expenses was submitted to Parliament, and the sums proposed were voted, namely, 200*l*, for the Mercantile Marine and 1000*l* for Her Majesty's ships.
>
> Soon afterwards an officer was appointed to execute the duties of the Meteorological Office, to be subsequently assisted by a few subordinates; but some time elapsed before instruments of the peculiar kind deemed proper by a Committee of the Royal Society could be finished, and an office appropriated for the object in view. Now the preliminary arrangements are made, and the Meteorological Office of the Board of Trade is open at No 2 Parliament Street...

FitzRoy's official title, as Head of the new office, seems to have varied somewhat, according to the entries in the *Imperial Calendar*. The first mention is in the 1856 edition where he is listed as 'Meteorological Statist', in the 1859 edition this is changed to 'Chief of Meteorological Department' and in 1864 to 'Chief of Meteorological Division'. Nowhere is there any reference to his being called 'Superintendent', which is the title given him in the list of names of Heads of the Meteorological Office inscribed on the wall of the entrance hall of the Meteorological Office Headquarters at Bracknell. The same list also has the letters 'C.B.' (Companion of the Order of the Bath) inscribed after his name. This is a mistake; FitzRoy never received any official honour or decoration for his work.[8]

The staffing and financing of the Office was on a modest scale. FitzRoy's first Report[9] to the President of the Board of Trade contains the following passage:

> The Meteorological Office being but recently established, and not having yet received a large supply of records, only four* persons are at present engaged in it, including the officer in charge.
>
> The sum estimated for 1854–5 was £3,200; but, as no expenses were incurred till half the financial year had expired, a balance remained in hand which may diminish the estimate necessary for 1855–6.

Despite the small number of staff, it is clear from a perusal of FitzRoy's early reports that a very large amount of work was carried out, consisting not only of routine office work and the regular tabulation of data, but of meteorological research and investigation. For example, Appendix No. 6 to the 1863 Report lists 54 'charts, books and pamphlets' published up to 1 April 1863. Although some were brief, and some were merely new editions, others were of considerable length, e.g. the '*Eleventh Number of Papers*' with 280 pages; indeed, the '*Papers*' series averaged 95 pages each.

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*In 1862 the number had risen to ten, but by that time FitzRoy had instituted the collection of daily reports by telegraph, and the issue of storm-warnings.

As to the name of the office, the first four Reports (1855, 1857, 1858 and 1862) called it the 'Meteorological Department of the Board of Trade', and the next two (1863 and 1864) the 'Meteorologic Office of the Board of Trade'; in the body of his first Report FitzRoy occasionally referred to it as the 'Meteorological Office'. The name 'Meteorological Office' was not officially agreed and made permanent until some time after FitzRoy's death. An interesting account of the way the Office worked and of the financial arrangements is given in FitzRoy's Report for 1862 which is reproduced as Appendix 3.

Acknowledgements

I should like to acknowledge the help of Mr R. E. Anslow of the Public Record Office, Kew, and of the Librarian of the Royal Society, Mr N. H. Robinson, who have provided me with copies of certain documents and other useful information. My thanks are also due to Mr David Stanbury who has made a detailed study of the whole life and career of Admiral FitzRoy.

References

1. London, Public Record Office, BJ 3/61.
2. London, Public Record Office, BJ 7/2.
3, 4. Copies in Minutes of the Council of the Royal Society (meeting of 15 June 1854).
5. *Report of the Meteorological Department of the Board of Trade*, 1857.
6. London, Public Record Office, BT 3/50.
7. *Monthly Notices of the Royal Astronomical Society*, **15**, 1855, 165–158.
8. Communication from the Secretary to the Central Chancery of the Orders of Knighthood (Major General P. B. Gillott, C.B., C.V.O., O.B.E.).
9. *Report of the Meteorological Department of the Board of Trade*, 1855.

Appendix 1

On Maury's plan—Ocean Statistics—Mode of proceeding in Office R.F. Feb. 3/54

MEMORANDUM

With reference to Lieut. Maury's project,—It may be assumed that the oceans should be represented by charts or maps, as fully as may be practicable, consistently with clearness. Such charts should shew all the oceanic statistics that can be expressed, at a synoptic view, either by letters, or numbers, or symbolically.

Such statistical information if not all *immediately* useful to Navigation, will be hereafter, if not now, of value to Science.

The following may be a practical method of combining, obtaining and utilising Ocean Statistics.

Employ some nautical man who is interested in such subjects—whose character will guarantee his proceedings, and who will give full time and thought to their pursuing.

Assist him by a draftsman and a clerk. Appropriate an office. Fit it with tables and shelves.

Publish notices of an office being opened by the Government for the reception of Journals, logs, remarkbooks, and other records of nautical information. Issue skeleton forms, and popular instructions, gratuitously, to all proper persons, on condition of the forms being returned, more or less filled.

On the return of each such form, or on the delivery into office of any other acceptable document—a receipt should be given—for the same expressing its character and value, as estimated according to a scale.

Some mode of reward—by honorary distinction,—such as a testimonial, or diploma, or decoration, may be devised—to encourage those who contribute the more valuable observations.

These oceanic charts, in which meteorological facts should be combined with all others affecting the atmosphere, or the bed of the sea, or the ocean itself—these charts should be subdivided into Squares, more or less extending according to the nature of each tract of sea.

For every such space, or square, there should be twelve, or twenty four or even fifty two minutely (48?) subdivided charts—(for the separated data of each month, fortnight, or week) less or more according to the special importance and (varying) natures of each tract, or region. The original drawings should be projected on a large scale, and copied by lithography.

Reduction, and any kind of compilations may be subsequently effected. All factors recorded on the charts should likewise be registered in books, under letters, and numbers, that would correspond to similar distinctions on the squares of the charts (and places of deposit on the shelves of the office?).

While new information is being gathered, and duly entered, as it is received, (with as little delay as may be)—research should be made in every available repository of nautical information—in all the Voyages of every nation that are accessible—in each log, journal, and remarkbook that may contain useful factors bearing on this subject. Such gleanings, when combined, will contribute largely towards this important branch of hydrography—well termed, by Colonel Sabine, "Ocean Statistics".

Much research will be necessary, on the part of the individual charged with the extensive work of which an outline is here sketched. General results should be given by him annually, or from time to time, to [be] subsequently revised as increased knowledge may render advisable.

Libraries—Archives of nautical information, such as those at the Admiralty and India House—and private collections, should be examined, as far as may be practicable, and all facts extracted from such sources, or indeed, from any source, should be forthwith entered in a book—with the particulars necessary for reference to them hereafter, if requisite and for enabling other enquirers to verify any part of the work.

Meanwhile the routine duties of the office, namely receiving, issuing, and copying documents—drawing charts, and entering, or laying down observations, should proceed during the usual, and distinctly specified, hours daily.

From the person charged with these duties will be expected, from time to time, such practical Sailing Directions as may be the earliest return to the Public for their money appropriated for this service.

R.F. Feby 3/54

Appendix 2

Extract from *Hansard's Parliamentary Debates* for 6 February 1854

IMPROVEMENTS IN NAVIGATION—CAPTAIN MAURY'S PLAN—QUESTION.

Mr. HEYWOOD said, he begged to ask the right hon. Baronet the First Lord of the Admiralty whether it was probable that an office would be established to co-operate with Captain Maury and the American Government in oceanic and other scientific observations; and whether the important collections of observations on currents, winds, and temperature, already in possession of the Admiralty, would be rendered accessible to the head of the proposed office?

Sir JAMES GRAHAM said, he was happy to inform his hon. Friend that, amidst more pressing and less peaceful occupations, the subject to which he had adverted had not failed to attract the attention of the Government. The President of the Board of Trade and he (Sir J. Graham) sent Captain Beechy to the Conference at Brussels, and in consequence of his report, it was the intention of the Government to appoint an officer to whom the observations made both on board merchant ships and Queen's ships would be referred. A Vote for this purpose would be taken in the Navy Estimates; and orders had been issued to the commanders of Her Majesty's ships, directing that meteorological observations should be made every four watches—that was, once every four hours—in every part of the world where Queen's ships were employed. An opportunity of making similar observations would also be furnished to a select number of merchant ships—not fewer than one hundred—and the result of all these observations would be returned to the Board of Trade, where they would be digested. They would then be communicated to Captain Maury, as would also the reports already received.

Appendix 3

Extracts from Chapter IX of the '*Report of the Meteorological Department of the Board of Trade*' for 1862, by Admiral FitzRoy.

28. The attendance here is necessarily continuous—between ten and six o'clock daily, for some—from eleven to five for others—of the ten persons employed; only two of whom are yet on the regular establishment of the Board of Trade, namely, Mr Pattrickson and Mr Babington, my zealous and able assistants.

Specially scientific duties are taken principally by the latter, whose Cambridge education and aptitude for meteorology have enabled him to render good public service. General management in the office, with financial business, correspondence, and much valuable aid in drawing and calculating, are Mr Pattrickson's particular business.

29. Meteorological telegraphy is satisfactorily attended to by Mr Simmonds and by Mr Symons, who, also, are assiduously engaged in extracting and reducing various meteorological observations, collected on an extensive scale, therefore needing much time for discussion and preparation for printing.

Mr Harding and his son attend to records, stores, correspondence, and translation. Mr Strachan has charge of the instruments and optician's duties, aided by Mr Gaster. Two youths carry out our weather reports, or telegrams, and are otherwise actively employed in searching for papers, extracting, and copying.

30. Consequent on the progress made, and the results gradually developed, arrangements for weather reporting increased in extensiveness, as has been shown, but the actual time now occupied by meteorological telegraphy is comparatively small, although we are in daily communication with twenty home stations—and with Paris, for six on the Continental coasts.

32. Kew verified instruments were intrusted to the care of clerks in charge of selected telegraph stations, by arrangement with the Directors of the Electric, the Magnetic, and the Submarine Telegraph Companies. Gradually and well those telegraphists acquired the duties asked for, then perfectly new, which are now continued with extremely creditable regularity and precision.

33. From the commencement in September 1860, no break, or interruption, not only of telegraphic but harmonious written intercourse, has occurred. The directors of those great companies have liberally reduced their tariff charges by one-third—in favour of our public communications, and have authorized reasonable precedence for our messages along their lines.

34. Being fully convinced that the importance, nationally considered, of this system of weather reporting—hitherto experimental—deserves support as a permanent institution—I ventured to submit to you, Sir, the following financial estimate.

35. In 1860—for the financial year 1861–2 the sum proposed to be voted by Parliament for "Meteorological Observations" was 2,800*l* which, with 900*l* provided for salaries and printing, under other heads (Board of Trade and Stationery Office), made a total or gross sum of 3,700*l*—for all purposes of this office—including an experimental commencement of meteorological telegraphy.

36. The expense of this new undertaking was first estimated at 100*l* monthly—and that estimate was found to be sufficient until the last quarter of the financial year 1860–1.

37. Nearly at that time (February 1861) the *cautionary signals* were first employed—and so well were they found to answer even on the very limited scale tried during the next few months—that in August following an extension of the system was organised by telegraphic communication from outlying stations—by more extended telegraphic *cautions*, and by daily "*forecasts*" of weather, regularly sent—entirely at the expense of the Board of Trade—to all the principal newspapers—which asked to be supplied with them, besides Lloyd's, Liverpool, and Glasgow Underwriters' associations. Since that time the Admiralty have directed the Coast-guard to co-operate whenever practicable—adding thus about eighty places of storm warning to the fifty previously in communication.

38. These important additions have not caused nearly so great an additional expense as might have been anticipated, because the Telegraph Companies have very liberally reduced their charges on meteorological telegrams for Government, by one-third, in general (and—in the case of Heligoland—one-half), while authorizing procedence on the wires, of all ordinary *private* telegraphy.

39. The result is that the system, at present considered to be working *satisfactorily*—can be continued in a similar manner—without asking for a larger increase to the meteorological vote than 100*l* above *last* year; or 4,600*l* instead of 3,700*l*.

40. The gross sum for meteorological observations in 1862–3 being thus estimated at — — — £4,600
of which is provided for salaries at Board of Trade, 440*l*, and by Stationery Office, for printing forms, books, papers, tables, charts,
&c., 360*l* — — — — — — — — — — — — — — 800

Leaves to be provided	£3,800
Which will be required for–	
Salaries	£800
Agencies	50
Special printing	150
Opticians	100
Carriage, packing, and all contingencies	100
	£1,200
Meteorological telegraphy	2,600
Total	£3,800

1 February 1862

41. This estimate shows the heads under which this sum may be divided; but it is to be said that the great expense of supplying *sets of instruments*, gratis, to merchant ships, has almost ceased; because ample results of that judicious annual expenditure, first authorized in 1854, are now in this office, sufficient to occupy all at present employed here during several years. To continue accumulating would tend to overwhelm.

42. Many of these instruments are now employed at telegraph stations—others are still on board a gradually diminishing number of selected ships, and a few are at maritime positions.

43. In addition to these scientific results, the stimulus that has been given to careful observation and record, the information that has been diffused in the mercantile marine—and the consequent direct advantage—in a national point of view—are now well known to have been very beneficial.

44. But having thus shown the way—and demonstrated its advantages—it may remain for others to follow, for their own advantage chiefly, by supplying themselves similarly with instruments, books, and forms—aided, perhaps, by advice—and occasional publications from this department,—but not otherwise continuing chargeable to the public purse.

45. In a scientific point of view, what has been accumulated here, since 1854, may be fully tabulated, discussed, and utilised—it is respectfully submitted, before overloading our shelves, and our minds, with materials increasing continually without advantage.

46. One of the greatest evils of meteorology hitherto has been the practice of incessantly making observations—without very definite objects in view—with the somewhat vague hope that eventually they might become of value; and the natural consequence has been, voluminous records exceeding the grasp of any genius and industry, however combined in individuals.

551.577.37(416)

Exceptional rainfall of 1 August 1980 over the North Antrim Plateau

By K. E. Woodley

(Meteorological Office, Bracknell)

Summary

An exceptionally severe and localized rainfall which occurred over the North Antrim Plateau on 1 August 1980 caused major damage to tarmacadam roads and swept a fisherman and his boat half a mile out to sea. Eyewitness accounts are given of this event, which has a return period of about 8000 years.

Mr John Young, the meteorological observer at Altnahinch Filters, witnessed and drew attention to an exceptional and very localized fall of rain and hail which occurred on the afternoon of 1 August 1980 in the North Antrim Plateau behind Cushendun in Northern Ireland. This led Mr S. J. G. Partington, Senior Meteorological Officer at the Climatological Services Meteorological Office in Belfast, to interview a number of other witnesses and later to visit the scene.

The downpour commenced at 1630 GMT and ended at 1715 GMT, during which 45 minute period 97·0 mm of precipitation fell at the Orra Beg rainfall station (located at Irish Grid reference iC 143277, altitude 335 m) and 47·0 mm fell at the Orra More, Ballybraddin rainfall station (located at IGR iC 125261, alt. 396 m). Daylight was reduced to virtually night-time conditions and hailstones the size of eggs were observed, with the mountainside white, so dense was the coverage. Some lightning was seen and thunder heard at Altnahinch, but the thundery aspect did not feature in the reports from other witnesses interviewed.

It was fortunate that the fall occurred on the 1st of the month, for the two rain-gauges are read only once a month and had been read and emptied that morning; otherwise the true amount of rainfall would not have been known.

A Mr McNeill, fisherman of Cushendun on the coast, was warned by telephone by some relations living up the valley of the River Dun, that a wall of water was forming, and this prompted him to rush to his boat moored in the estuary so that he might slacken his salmon nets. Whilst he was doing this, he saw this wall of water coming down the river, with an estimated height of between five and ten feet, and when it met the sea, he, in his boat, was swept out to sea about half a mile by the floodwater. This was some time between 1730 and 1800 GMT.

Some 60 metres' length of the Ballymone–Cushendall road was washed away, one end of the section being moved about 200 metres whilst the other end was washed about 400 metres (see Plates II and III). Two policemen in their patrol car were unable to stop before their car drove into the crater created by this landslip.

The area is a peat bog, laid on a solid rock base. The intense rain created fissures some 3 metres or so deep down to bedrock, and some craters appeared about 250 metres wide in which again all the thick peat was washed away, revealing the bedrock surface (see Plates IV and V).

The magnetic-tape rainfall recorder at Orra Beg, Ballybraddin was unserviceable at the time, and the next nearest rain-recorder (of the tilting-siphon pattern) at Altnahinch Filters recorded only a small amount of rainfall, it being on the extreme edge of this storm.

The fall of 97·0 mm in 45 minutes is a United Kingdom record fall for that period. If that information is fed into the return period statistical model developed after the United Kingdom Flood Studies Report, the 97 mm in 45 minutes has a return period for that part of Northern Ireland of around 8000 years.

Movements of peat and other debris from the bogs of Northern Ireland are not all that uncommon. The previous significant one known to the author was on 10 November 1963, again in the Glendun area. A list of bogflows was included in the paper 'Recent bogflows and debris slides in the North of Ireland' by Colhoun, Common and Cruickshank in the *Scientific Proceedings of the Royal Dublin Society*, Series A, Volume 2, No. 10 (1965). Another paper on the subject is 'Composite mudflows on the Antrim coast of North-east Ireland' by Prior, Common and Archer, in *Geografiska Annaler*, Vol. 50, Ser. A, 1968, 2.

We are grateful to Mr Young for his enthusiasm in returning promptly to the Orra More mountain rain-gauge sites to measure the rainfall of this storm: it is largely from such sources that the Meteorological Office and the former British Rainfall Organization have been able to collect reliable and detailed accounts of such localized events that go to make up the rainfall records of the country and are of such value to those who have to design and operate flood control systems.

Correspondence

A review of three long-term cloud-seeding experiments

We wish to comment on the above paper by Sir John Mason, published in the *Meteorological Magazine*, 109, 1980, pp. 335–344. We refer particularly to Mason's remarks concerning the experiment in Tasmania.

Analysis of the rainfall data of a cloud-seeding experiment of this type can only lead to valid statistical conclusions if the analysis is consistent with the design. Mason's 'reanalysis' of the Tasmanian data does not meet this requirement in several respects.

(a) Mason gives prominence to a comparison of the target area rainfalls in seeded periods with those in unseeded periods, making no use of the control area rainfalls. Because the Tasmanian experiment was conducted in an area of variable rainfall this method is insensitive: it would require an experiment conducted over several decades to give a statistically significant result. A rainfall change of reasonable magnitude could not be detected in this way over the four-year duration of the Tasmanian experiment, and it is even less appropriate to apply this method to the results of individual years (as in Mason's Table III).

The design of the experiment included control areas, chosen to have rainfall well correlated with that in the target area. Their use reduces the residual variance by 90% and so allows useful results to be obtained from a four-year experiment: for example they give a reasonable chance of detecting a 20% rainfall change at the 5% significance level.

(b) Mason compares target area rainfalls in seeded periods with those in years (1965, 1967, 1969) when there was no seeding and no randomization. This is not a valid statistical procedure. Moreover, the rain in these three years is known (Smith *et al.* 1977, p. 19) to have been about 27% less than that in the experimental years.

(c) Randomization was by period pairs, and the prespecified design includes stratification by season, pairs of periods being allocated to the season in which the mid-point of the period pair occurs. Mason transfers periods from one season to another in some of the columns of his Tables I and III.

(d) The design specified that results of the east and west halves of the target area should be analysed separately as well as together, because it was thought that results of seeding might differ in the halves, e.g. because of differences in orography. Our results in the halves did indeed differ, so when results for the halves are combined each dilutes the other and results for the whole target area are more difficult to detect than those in the halves. Mason considers only the combined results for the halves together.

We agree with Mason that a limitation of the Tasmanian experiment—designed in the early 1960s—is that there is not enough 'evidence of the structure, evolution and constitution of the clouds'. A body of supporting physical data could clearly answer many questions, including that posed by Mason—namely, to establish what was different about those clouds which appear to have responded to seeding. If a new experiment were planned for Tasmania extensive physical measurements would clearly be desirable; however, the data which could be obtained might well be limited by the hazardous flying conditions in the target area. Nevertheless, and in spite of the lack of physical measurement, the fact remains that the statistical evidence of the Tasmanian experiment clearly demonstrates an association between the seeding and increase in rainfall in the target area in certain seasons.

E. J. Smith

Division of Cloud Physics, CSIRO, Australia

L. G. Veitch
D. E. Shaw
A. J. Miller

Division of Mathematics and Statistics, CSIRO, Australia

Reference

Smith, E. J., Veitch, L. G., Shaw, D. E. and Miller, A. J. 1977 A cloud-seeding experiment in Tasmania—1964–1970. CSIRO Division of Cloud Physics Internal Report CP 183.

Reply by Sir John Mason

Smith *et al.* appear to misunderstand the point and purpose of my critique of the Tasmanian experiment. It was not my intention to criticize their statistical analysis and in particular their use of the double-ratio which may well be a more reliable and sensitive criterion than the single T_s/T_U ratio for the reasons which I acknowledge in my paper. I was concerned mainly with the overall credibility of the results of this and the other two experiments and to point out that one can arrive at quite different conclusions on the outcome of a cloud-seeding experiment depending on the statistical design and criteria adopted. For example, if Smith *et al.* had adopted the single ratio criterion used in the Florida experiment they would have concluded that seeding produced a decrease of rainfall in Tasmania. In the Israeli experiment, however, the single-ratio criterion indicates a distinctly positive seeding response which is confirmed by the double ratio. My real point is that when the magnitudes of both the seeding signal and the signal/noise ratio are low, as is usually the case, one can have little confidence in the statistical results unless there is strongly supporting physical evidence. This is surely the main lesson to be drawn from 30 years of largely fruitless effort.

Looking at the Tasmanian results overall one cannot overlook the fact that, although seeding took place only when the clouds were judged suitable and operational periods were arranged in pairs with one member of each pair being selected for seeding *at random* (the other being used as an unseeded control), the total rainfall in the target area during the 54 seeded periods of the 4-year trial was 8% *less* than in the unseeded periods. Moreover, only 19 of the 54 seeded periods produced more than the average target rainfall for the 108 operational periods and these occurred mainly in the spring rather than in the autumn.

The claim by Smith *et al.* that seeding produced a 25% increase in autumn rainfall therefore rests on the fact that the apparent 16% decrease in the target area rainfall ($T_S/T_U = 0{\cdot}84$) was more than offset by the corresponding ratio for the control areas C_S/C_U being as low as 0·66, i.e. by the rainfall being abnormally low everywhere, especially in the control areas, during the randomly selected seeded periods. This unfortunate bias, which apparently existed over the whole 4 year period, casts doubt on the efficacy of the experimental design and certainly merits investigation and explanation. In the absence of such an explanation, and of strongly supporting physical and dynamical evidence, I hold to my view that the overall evidence for a positive seeding effect, even in autumn, is not strong. The statistical evidence from the Israeli experiment is more convincing because both the single and double ratios were greater than unity (the target area rainfall was 16% higher during the seeded periods) but again supporting physical evidence is lacking.

Smith *et al.* imply that my conclusions are biased by the fact that in calculating double ratios I combined the two halves of the control area and that I would have obtained a different result had I used both halves separately. The following table shows that this is not the case.

Calculated double ratios using control areas

	C_1	C_2	$\frac{1}{2}(C_1+C_2)$
All 4 years	1·04	1·09	1·06
Autumn	1·24	1·27	1·25
Winter	1·02	1·12	1·07
Spring	0·98	1·01	0·99
Summer	0·94	0·91	0·93

B. J. Mason

Meteorological Office
Bracknell
27 *May* 1981

100 years ago*

THE HEAT IN JULY IN THE BRITISH ISLES, AND IN EUROPE GENERALLY.†

The occurrence of a temperature which at Greenwich has not been equalled for at least 40 years, and of a temperature at Brussels which has not been equalled for at least 48 years, naturally claims notice at our hands.

We have made a special effort to place the actual facts before our readers, and we desire in the first place to thank the Directors of nearly all the chief observatories of Europe for the promptitude with which they have supplied the information which we applied for.

We think that it will be convenient to separate the information relating to our own country from that furnished by our Continental friends, and we will therefore dismiss the records from our own little country first.

The British Isles

We might almost dismiss all parts of the British Isles except the South of England, for the exceptional temperatures were very local—a line from Barnstaple in Devonshire, to Peterborough in Northamptonshire would on its S.E. side have all the temperatures which could be regarded as exceptional. July 5th was a hot summer day, temperatures slightly exceeding 90° were recorded at several stations, and over the greater part of England it was the hottest day of the month, but we are not aware that any of the temperatures observed on that day were unprecedented. The remarkable feature of the month was the temperature reached on July 15th, in a belt of country extending from Wiltshire, through the north of Hampshire, north Surrey, west Kent, Middlesex, Essex, Suffolk and Norfolk.

The following tables contain the principal data upon which the foregoing remarks are based. These tables are mainly compiled from letters and returns sent by our own staff, but have been checked and completed by reference to those sent in to the Meteorological Society.

Space is so valuable that we have been obliged to condense much of the information furnished into a very small space; but we print two letters in extenso, one because it shows the evidence upon which we print the excessively high value of 101·0°; the other is inserted in support of the general statement as to the limitation of the phenomenal heat to the southern counties. As regards this, a curious illustration will be found in the Remarks, on page 132, where our correspondent at Portree, in the Isle of Sky, on the N.W. of Scotland, says July was "The coldest July on record." These letters will be found at the end of the article.

Symons's Monthly Meteorological Magazine*, **16, 1881.

†This spell of exceptionally hot weather is well known, and the temperatures recorded in the London area have seldom been exceeded. What makes the spell remarkable if not unique is that it occurred embedded in a summer which was otherwise distinctly on the cool side. Indeed, only two months in 1881 had mean temperatures above average at Kew—July and November; June and August had mean temperatures respectively 1·4 °F and 3·9 °F below average. Most spells of hot weather occur in summers that are as a whole warm, for example 1911, 1947, 1949, 1959 and 1976. The Revd T. A. Preston, in his 'Report on the Phenological Observations for the Year 1881' (*Quarterly Journal of the Meteorological Society*, Vol. VIII, p. 78) remarked that 'the weather of July was most extraordinary'.

MAXIMUM TEMPERATURES ON JULY 15TH, 1881.

Verified Thermometers in Stevenson's Stands.

(Large type indicates that the max. was the absolute max. of the month.)

95·0 Camden Square, Middlesex.
94·9 Eltham Green, Kent.
94·1 South Norwood, Surrey.
93·9 Strathfield Turgiss, Hants.
93·8 Walton-on-Thames, Surrey.
93·5 Regent's Park, Middlesex.
93·2 Beddington, Croydon, Surrey.
92·9 Isleworth, Middlesex.
92·4 Addiscombe, Croydon, Surrey.
92·0 Cranleigh, Surrey.
91·0 Watford, Herts.
90·9 Southend, Essex.
90·3 Tunbridge Wells, Kent.
90·2 Throcking, Buntingford, Herts.
89·4 Swarraton, Alresford, Hants.
89·3 Harestock, Winchester, Hants.
88·5 Somerleyton, Lowestoft, Nrflk.
87·7 Eastbourne, Sussex.
86·8 The Graig, Ross, Hereford.
86·0 Woodway, Teignmouth, Devon.
85·8 Portsmouth, Hants.
85·7 Burghill, Hereford.
85·5 Cullompton, Devon.
85·4 Hodsock Priory, Wrksop, Nots.
85·3 Kenilworth, Warwick.
85·0 Cheltenham, Gloucester.
84·9 Bitton, Teignmouth, Devon.
84·8 Mansfield, Notts.
84·6 Loughboro', Leicester.
84·4 Strelley Park, Nottingham.
83·7 Druid, Ashburton, Devon.
83·3 Ramsgate, Kent.
82·8 Babbacombe, Devon.
81·0 Brampford Speke, Devon.
80·8 Belper, Derby.
80·5 Guernsey.
80·3 Scarborough, York.
79·7 Oakamoor, Stafford.
79·7 Cardiff, Glamorgan.
78·5 Wakefield, Yorks.
78·4 Lowestoft.
78·2 Heath Ho., Cheadle, Stafford.
77·5 Macclesfield, Cheshire.
77·5 Sidmouth, Devon.
71·9 Llandudno, Carnarvon.
71·8 St. Michael's-on-Wyre, Lncsh.
65·9 S. Shore, Blackpool, Lncsh.

Records from Stands of other or unknown patterns.

(D.W.R.—Daily Weather Report of the Meteorological Council.)

101·0 Alton, Hants.
100·0 Alderbury, Salisbury.
97·1 Royal Obs., Greenwich, Kent.
96·7 Foxgrove, Beckenham, Kent.
95·6 Enfield, Middlesex.
95·0 D.W.R., London.
94·6 Camden Square, Middlesex.
94·2 Hornsey, Middlesex.
94·0 Hindringham, Norfolk.
93·8 Addiscombe, Croydon, Surrey.
93·3 Walton-on-Thames, Surrey.
92·0 Merton Villa, Cambridge.
92·0 Ipswich, Suffok.
92·0 Diss, Norfolk.
92·0 Cossey, Norwich, Norfolk.
91·0 Bromley Common, Kent.
91·0 D.W.R., Cambridge Obsvrty.
90·0 D.W.R., Nottingham.
89·0 Ellough, Beccles, Suffolk.
87·0 D.W.R., Oxford Observatory.
85·6 St. Leonards, Sussex.
85·0 Compton Basset, Calne, Wilts.
85·0 D.W.R., Jersey.
83·0 D.W.R., Spurn Head, Yorks.
83·0 Langton Herring, Weymouth.
82·5 Hythe, Kent.
81·0 D.W.R., Hurst Castle, Hants.
80·0 D.W.R., Dover.
80·0 Northampton.

CAMDEN SQUARE.—It was found that the temperature in different parts of the Stevenson stand varied more than a degree—a thermometer near the top recorded 95°·6, or one degree higher than on a Glaisher stand close by. The maximum on the Glaisher stand, 94°·6, is higher than has been recorded since observations commenced in 1858; the highest previously was that on July 21st, 1868, viz., 93°·3.—*G. J. Symons.*

ADDISCOMBE.—Observations have been made here with a Glaisher stand since 1872, hitherto the max. was 13th August, 1876 = 93°·6, but on the 15th July, 1881, it rose to 93°·8 on that stand, and to 92°·4 in the Stevenson.—*E. Mawley.*

GREENWICH.—The maximum temperature (97°·1) on July 15th is higher than any previously recorded in the period 1841-81. On July 22nd, 1868, the maximum temperature was 96°·6.—*G. B. Airy.*

FOXGROVE, BECKENHAM.—The following are all the readings of 90°·0 or upwards on a Glaisher stand since 1867:—1868, July 21st, 91°·9; 22nd, 93°·8; September 7th, 90°·0. 1870, June 22nd, 90°·8. 1871, August 12th, 90°·8; 13th, 90°·0. 1872, July 24th, 90°·0. 1873, July 22nd, 90°·6. 1874, July 9th, 92°·6; 19th, 91°·7. 1876, July 14th, 91°·3; 15th, 94°·1; 16th, 92°·1; 17th, 91°·3; August 13th, 93°·8; 14th, 90°·4; 15th, 90°·1. 1878, June 26th, 90°·1; 27th, 90°·1. 1881, July 5th, 92°·7; 15th, 96°·7.—*P. Bicknell.*

WALTON-ON-THAMES.—It is remarkable that the max. in the Stevenson stand is half-a-degree higher than on the Glaisher. The max. in the louvre screen on the tower, 50 ft. above ground, was only 91°·1, against 93°·8 at 4 ft. above ground.—*G. Dines.*

To the Editor of the Meteorological Magazine.

SIR,—As it was the hottest day I ever knew here yesterday, I thought you would like to be informed that my thermometer in the shade stood at 101°. The thermometers were made by Burrows, of Malvern, are about 4 feet from ground, on a stand made by them, painted white, facing North, with double back to the South; they were compared at Kew and found correct.—I am, yours truly,

FREDERICK CROWLEY.

Ashdell, Alton, Hants, July 16*th,* 1881.

To the Editor of the Meteorological Magazine.

SIR.—So much has been said and written about the almost tropical heat of July in the South, that it may interest you to contrast it with the cool moist weather we have experienced in the North-west of England during the same month.

The mean temperature of July at this station was 57°·7, which is 1°·8 below the average for the month during the previous nineteen years.

The maximum thermometer in the shade reached 70° on only one day during the month, viz., on the 5th, when the reading was 78°·2 (this was just before a thunderstorm). The next highest shade temperature was 68°·4, on the 13th.

Rain fell on 20 days during the month; the total amount being 4·633 inches, and the heaviest fall in 24 hours, 1·680 inches, on the 24th.—I am, Sir, yours truly,

H. DODGSON, M.D., F.R.A.S., &c.

Cockermouth, Cumberland, August 3*rd,* 1881.

Review

Application of remote sensing to agricultural production forecasting, edited by A. Berg. 250 mm × 170 mm, pp. vi + 266, *illus.* A. A. Balkema, Publishers, Rotterdam, The Netherlands, 1981. Price Hfl 120·00, £24.00, US $55·00.

This book describes itself as '18 lectures of a course held at the joint research centre of the Commission of the European Communities in the framework of the Ispra Courses in Ispra, Italy'. It has been printed from the typescript texts which were produced 'under the supervision of the individual authors'. This has had the advantage of providing a 'state of the art' survey of this important topic which is reasonably up to date (the course was held in October 1979) but the disadvantage that the book lacks the coherent structure that greater editorial control would have given. There are 19 authors in all.

As a consequence the reader is not presented with a logical development of the subject (even though no doubt the organizers tried to achieve this when they decided on the subject titles of each lecture and the order in which they were given). There is frequently a repetition of particular topics in different chapters (e.g. the surface radiation balance) but a complete lack of consistency in the use of symbols, subscripts etc. Only two chapters have a summary. There are several obvious errors in the text, most of which are fortunately irritating rather than misleading, and minor editing of the English of some of the authors would have improved their contributions considerably. The quality and comprehensiveness of the different chapters varies enormously.

An introductory chapter or preface describing the aims of the course at Ispra, and giving a short history of the development for agricultural purposes of remote sensing from aircraft and satellites (with a brief summary of the various satellite systems in use at the time and projected) would have been very useful to the non-specialist in the subject, and provided a rapid reference for the bemused reader when lost in some of the jargon of the later chapters.

A considerable part of the book is taken up with the problems and techniques of crop production forecasting from conventionally observed weather data. These chapters are generally interesting, readable and instructive, as would be expected with authors such as Thiede, Frère, Baier, Sakamoto and Nix. Various forms of simplified simulation models for estimating crop production (most of which involve calculation of a soil moisture budget) are described, as also are crop/weather regression models, whose limitations are well documented.

The three chapters on remote sensing techniques using different parts of the electromagnetic spectrum are numbers 5, 15 and 17 covering: (a) reflected radiation in the visible and reflectance infra-red; (b) thermal (emission) infra-red; (c) microwave. These give a general survey of the theory and practical limitations of each technique, and the need to obtain good temporal as well as spatial sampling in order to interpret the data is explained.

The discussion of the use of observations obtainable from remote sensing in crop production forecasting is the least satisfactory aspect of the book. To some extent this is due to the difficulty of the problem, but some of the chapters (excluding those of Berg and Rosema) are very superficial. The chapter by Heiss, Sand and Farley on 'Economic benefits of improved crop information on wheat and cereals for European countries' contains a very detailed mathematical exposition of the economic theory used, which the reviewer is not qualified to judge as to its applicability, and makes the assumption that the European Community is a net importer of cereals; however, Thiede in the first chapter has already made the point that he expects the Community to be self-sufficient in cereals in the near future with a clear surplus by 1985. The chapter by Heiss *et al.* is even more unsatisfactory since it does not give the results of the model, but says that they will be published in a future report.

The final chapter of the book by Walter gives a useful summary of the potential of the Landsat D satellite observations, but is over-optimistic with regard to the resolution which may become possible with geostationary satellites.

At a price of £24 the reader has the right to expect a more complete and accurate account of the present stage of development of this subject than is available in this book. However, there is a good deal of useful information if he is willing to search diligently.

Marjory G. Roy

Notes and news

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Skua meteorological rocket program terminated

The Skua rocket launched from the Royal Artillery Range, South Uist, Outer Hebrides on 14 November 1980 marked the end of the Office's meteorological rocketsonde program. More than 500 Skua rocketsondes had been flown since 1963.

Small inexpensive rockets, which could carry a sonde aloft and deploy it and its parachute at a height of about 65 km, became available in the United States around 1960. These rockets made it possible to measure winds (by tracking the metallized parachute) and temperatures between 20 and 60 km on a regular basis. The Skua system was developed to obtain similar observations in Europe. The project was undertaken by the High Atmosphere branch and led by Dr R. Frith. Bristol Aerojet Ltd and the Rocket Propulsion Establishment, Westcott, developed the 5-inch diameter rocket system, whilst D. D. Clark (1965) and R. Almond (1969) were responsible for the development of the sonde. A coiled tungsten wire of fine gauge was adopted as the temperature-sensing element. By coincidence the first four Skua firings from South Uist (12–23 January 1964) spanned a stratospheric warming (Almond, Farmer and Frith, 1964).

The *Meteorological Magazine* has since carried a number of papers describing the project's progress and presenting some of the results. The Skua system came into regular use at South Uist in 1965 (Almond 1965). Substantial differences were revealed between mean winds and temperatures observed at South Uist in winter and those found at a similar latitude over North America (Farmer 1965). In the following years behaviour of the 20–60 km region in winter was studied by campaigns of firings from South Uist, during which two or three rockets were often fired each week from December to February. Large and rapid changes in temperature and wind were observed in association with stratospheric 'warmings' (Bridge 1971). The second half of December was often a very active period. Those involved were so enthusiastic that firings were maintained throughout the festive season (although no firings took place on Christmas Day). However, the extent to which atmospheric changes observed at South Uist represented advection or development was never clear, since the only other rocket observations, over North America, were too distant. During January 1970 Skua firings were made from both South Uist and ESRANGE (near Kiruna in Sweden), in collaboration with University College, London. This exercise was repeated in January–February 1971, with the addition of some firings from Aberporth. Unfortunately neither of these campaigns was graced by a major stratospheric disturbance over north-west Europe (Bridge 1973).

With the launch, in April 1970, of Oxford and Reading Universities' Selective Chopper Radiometer on board the Nimbus satellite, it was possible to produce global maps of stratospheric temperature. Whilst satellite observations of radiance have provided a much clearer picture of the behaviour of the stratosphere, there are problems in interpreting radiances coupled with slow drifts in instrument characteristics. Flights of rocketsondes at times at which the satellite is passing nearby are an important means for tackling these problems. During the past decade, most Skua firings at South Uist were made for this purpose, in conjunction with the series of Oxford University radiometers on Nimbus 4, 5 and 6 and, since 1978, with the Office's Stratospheric Sounding Units on Tiros N and NOAA 6. Although these firings formed only a small fraction of the total number of rocketsondes flown worldwide, we could control launch times at South Uist to coincide closely with satellite overpasses.

Rocketsondes provide much better vertical resolution than satellite sensors, making them specially suitable for certain investigations. About 70 Skuas were flown between 1969 and 1972 from the island of Gan, in the Indian Ocean, to study the diurnal variation of temperature and wind in the equatorial stratosphere (Shearman 1969, Hamilton and Shearman 1972). During the March 1970 campaign ten Skua rocketsondes were flown from Thumba, India, as a Commonwealth collaborative venture. Observations from two sites provided information on the spatial extent of features in the wind profiles.

Over the years considerable effort was devoted to reducing uncertainty in the corrections for dynamic heating and radiation which had to be applied to the temperatures indicated by the wire element (e.g. Mason and Acres 1972). The Skua system was flown alongside other rocketsonde systems during trials organized by the WMO Commission for Instruments and Methods of Observation (CIMO) at Kourou, French Guiana, in 1973. The performance of the Skua sonde was found to be in close agreement with that of the American sondes. The observations made at Kourou have been used to investigate diurnal variations in temperature and wind (Bridge 1979).

Temperature and wind profiles measured at South Uist have been distributed, as ROCOB messages, on the Global Telecommunication System (GTS) and archived at World Data Center A, Asheville, USA. Observations made up to 1972, including those from Kiruna and Aberporth, were used to produce a climatology of the stratosphere over north-west Europe (Hamilton, Mason and Bridge 1973). Some aspects of this climatology have been extended to include subsequent firings at South Uist (Carruthers and Francis 1981).

The Skua program benefited by co-operation and assistance of many people . Valuable contributions were made by the Commandants and staff of the Royal Artillery Range, Hebrides; Principal Meteorological Officers and staffs at Prestwick and Pitreavie; Senior Meteorological Officer and meteorological and Range staff at Aberporth; staff of the Equipment Provisioning Branch of the Meteorological Office and various contractors. Although the Skua program has ceased, the Office will continue to make a major contribution to the observational system for the stratosphere into the late 1980s, through provision of Stratospheric Sounding Units for the Tiros-N series of satellites. D. E. Miller

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The Society for Underwater Technology to sponsor Oceanology International '82

The Society for Underwater Technology has agreed to sponsor the Oceanology International Exhibition and Conference (Metropole, Brighton, 2–5 March 1982) and will be giving the event its full support. The Society will form a Conference Committee under the chairmanship of John A. Derrington, F. Eng., Director, Sir Robert McAlpine & Sons Ltd, Past President, Institution of Structural Engineers, Vice-President, Institution of Civil Engineers, and Chairman of the National Maritime Institute Board.

The Committee will include corresponding members from equivalent European Societies and organizations and the program will be international in character.

The Conference, which, like the Exhibition, will last for four days, will include sessions on the following subjects:

Geophysics/soil mechanics
Hydrography/sea bed surveys
Marine mining—deep ocean and near-shore
Navigation and position fixing
Dredging and coastal engineering
Underwater research and development
Oceanography/meteorology
Environment/ecology.

The Society has agreed to give the widest possible publicity to the Exhibition and Conference within and beyond its membership at home and abroad, commensurate with the traditional prestige and standing of Oceanology International.

More information about the composition of the Committee and the detailed program headings will be available during summer 1981. The program will consist of between 40 and 50 papers and the Society for Underwater Technology will hold a watching brief over the progress of the conference organization and ensure a high standard of paper presentation within a program having a strong international presence and appeal.

The rights to the title and goodwill of the Oceanology International series of exhibitions and conferences, which have been held in Brighton on five occasions since 1969, were acquired in February 1981 by Spearhead Exhibitions, organizers of the Offshore Europe series of exhibitions and conferences in Aberdeen, as well as the Latin American Oil Show, and the AODC's Underwater Engineering Symposium. Spearhead is also a partner in Offshore South East Asia in Singapore. Further information on Oceanology International '82 is available from Spearhead Exhibitions Ltd, Rowe House, 55–59 Fife Road, Kingston upon Thames, Surrey KT1 1TA. Telephone: 01-549 5831. Telex: 928042 SPEARS G.

Involvement of Meteorological Office with recent foot-and-mouth disease outbreak

The stand-by arrangements for the call-out of the staff of the Agricultural Meteorology section of the Office in connection with foot-and-mouth disease were activated late on Saturday 21 March 1981.

A watching brief and advice to MAFF veterinarians had been undertaken over the previous two weeks.

Computer programs which indicate the down-wind concentration of virus plumes were updated around midnight. A staff member travelled with the computer output to join the veterinary epidemiological team (which sets out to control the outbreak in the field). He was in the Isle of Wight early on Sunday, 22 March.

Several Branches contributed to the information channelled to MAFF through the section (both during the alert and in the development work leading up to the present advisory procedure). MAFF have expressed appreciation of the speed and quality of the advice given.

Last flight of Meteorological Research Flight Canberra

The last flight of Canberra WE 173 of the Meteorological Research Flight (MRF) took place on the afternoon of Tuesday 31 March 1981. The aircraft, the only PR3 still in service, was delivered to MRF in 1964, since when it has carried out a variety of meteorological research projects in the upper troposphere and lower stratosphere both in the United Kingdom and abroad. These included the measurement of stratospheric humidity—extending earlier MRF measurements in the Mosquito aircraft—of disturbed airflow at high levels using accurate winds derived from a combination of stable platform and wind vanes, of upward and downward radiation in a variety of wavelengths and spectral intervals using specially adapted multi-channel radiometers, and more recently of trace gases in the stratosphere above the aircraft using an advanced Michelson interferometer in the sub-millimetre wavelength region. The withdrawal of the Canberra marks the end of more than 30 years of research by the MRF on the atmosphere above the tropopause.

Correction

Meteorological Magazine, **110**, 1981, 139. Several numbers were misplaced in Table VI of 'The accuracy of London Weather Centre forecasts of surface wind and total wave heights and their comparison with computer products' by R. M. Morris. The corrected version is printed below.

Table VI. *Mean modulus errors (in knots) of wind speeds in the ranges* 0–20 *and* 30–39 *knots at* 61° N 2° E *with respect to period of forecast*

Method	Range of wind speeds (kn)	Forecast period T+12	T+24	T+36	T+48	T+72
Rectangle	0–20	4	5	5	—	—
	30–39	9	8	11	—	—
Octagon	0–20	—	—	5	5	6
	30–39	—	—	14	15	18
LWC forecaster	0–20	6	7	—	8	8
	30–39	6	6	—	7	9

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CONTENTS

NOTICES

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