

METEOROLOGICAL OFFICE

# THE METEOROLOGICAL MAGAZINE

VOL. 83, No. 984, JUNE 1954

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## SOME REMINISCENCES OF THE METEOROLOGICAL OFFICE OF THE YEAR 1902

By R. G. K. LEMPFERT, C.B.E., M.A.

I joined the staff of the Meteorological Office on May 1, 1902, and it has been suggested to me that some account of the Office and its work in those days may be of interest to meteorologists of the present day.

The Royal Society was responsible for the administration which it carried out through a Council, of which Sir Richard Strachey was Chairman. Mr. W. N. Shaw, as he then was, had succeeded R. H. Scott as Secretary of the Council about two years earlier. A Parliamentary Grant-in-Aid of £15,300 provided the necessary finance. The staff on the payroll numbered about 40. I was the first graduate to be appointed to it. We were not on the telephone and I seem to remember one single typewriter in the "office". Outgoing letters were written autograph in copying ink and press-copied before dispatch. Copy for the printer was supplied in long-hand.

The Office was housed in Westminster, at No. 63 Victoria Street, the corner building at the junction with Strutton Ground. The passer-by could recognize it by a display of notice-boards on the first-floor balcony giving the latest reports of the weather and state of the sea in the Strait of Dover. The ground floor was occupied by a piano shop, and we had the four floors above and also the basement for storage. The piano shop and the itinerant musicians of Strutton Ground saw to it that we did not lack for musical entertainment.

On the first floor was the office-keeper's den, which later became my room as Superintendent of Statistics. A large but extremely low room which ran from front to back of the building housed the Statistics Division. I was told that originally it had been two rooms but the dividing partition had been removed and replaced by an iron girder to support the ever-increasing weight of the records accumulating on the floors above. The instrument store was also on this floor.

On the next floor were the rooms of the Secretary and the Marine Superintendent, the "office" and the main working room of the Marine Division. The Secretary's room was a large pleasant room, facing south. It was used for the fortnightly meetings of the Council, and, later on, also for the Monday-evening discussions inaugurated by Mr. Shaw on the model of the *colloquia* which J. J. Thomson held at the Cavendish Laboratory in Cambridge. The room also housed the library which even then had begun to overflow into other parts of the building.

On the third floor two rooms were allotted to the Forecast Division of which more anon. The Observatory Division had the large front room and the Marine Division the remaining small one. On the top floor I had my room. The front room was occupied by four ladies attached to the Marine Division, the only women in an otherwise all-male staff. The best room on this floor, that over the Secretary's room, was tenanted by Mr. and Mrs. Drane, the resident caretaker and his wife. It combined the functions of bedroom, sitting-room, kitchen and scullery. Before her marriage Mrs. Drane had been cook in Mr. Scott's family, and she continued these professional activities by providing for those members of the staff who wanted it (and most of them did) a substantial lunch for 1s. 2d. The lunches were sent to the recipients on trays and eaten at their desks. Another domestic detail that sticks in my memory is that at about 6 p.m. the cleaners arrived, the fires, if still smouldering, were doused with water (imagine the dust), relaid for lighting next morning, and the rooms swept and garnished.

I saw little of the work of the Marine Division in those early days. Captain Campbell Hepworth was Marine Superintendent with Charles Harding as his principal assistant. Another member of the staff was a retired sea captain, William Allingham, who revised and enlarged the 15th edition of Lecky's "Wrinkles in practical navigation", which enjoyed a considerable sale in its day. Then, as now, the Division's task was to collect and discuss observations from the sea, the purpose for which the Office had been founded in 1854. It had agents in Southampton, Liverpool and other ports, but Port Meteorological Officers had not been thought of. Its current output was *Monthly pilot charts of the North Atlantic and Mediterranean*, which gave the average distribution of the meteorological elements and a lot of interesting miscellaneous information. The *magnum opus* then in hand was "Monthly wind charts of the South Atlantic", which was published by the Admiralty in 1903. The Instrument Division was at this time part of the Marine Division. It was in the main an instrument store for the supply of instruments to the navy, the mercantile marine and the telegraphic reporting stations. Questions of design or of testing new types, when they arose, were mostly farmed to outside bodies for study and report.

In 1902 John Curtis was the head of the Statistics Division with Duncan Bell under him as librarian, in which capacity he was personally responsible for the meteorological section of the Royal Society's "International catalogue of scientific literature". A few years later Curtis succeeded James Harding as Chief Clerk and Cashier and I became the Division's superintendent with Duncan Bell as my principal assistant. Both Curtis and Bell gave much of their private time to municipal politics. Curtis became Mayor of Fulham and Bell an alderman of his borough.

*Meteorological observations at stations of the second order* was perhaps the Division's most important task. This was a publication issued to comply with a resolution of the International Meteorological Committee which aimed to bring uniformity into the presentation of climatological data. It contained daily observations at 9 a.m. and 9 p.m., under the headings suggested by the committee, for a selection of stations, and monthly summaries for a larger number. No doubt the committee hoped that the data would be published promptly, but in most countries there was a lag of several years and we were no exception. We did however manage to clear off the arrears during the next five years.

The *Weekly Weather Report* was another important part of the Division's work. It gave a statistical resumé of the weather over the country by district values (means for up to ten stations in each district), the week being the time unit. The week ended with the Sunday morning observation, and the returns from most contributing stations reached the Office by first or second post on Monday. Copy for the printer had to be ready by Tuesday afternoon. Proofs came in on Thursday at midday and were returned the same afternoon so that the report might reach subscribers by the end of the week. Weekly publication ceased on the outbreak of war in 1914, but the computation of the district values was continued. They were subsequently published in annual volumes. The *Monthly Weather Report*, at the time I am writing about, was a very slender affair, confined almost entirely to summaries for the telegraphic stations. It grew rapidly during the next few years when it became Office policy to devote a line of print in the report to a summary of all approved observations received. The report formed as it were an index of the information available. The new policy was a result of the transfer to the Office of the supervision of the network of stations supplying information for the Registrar-General's *Quarterly Reports*, which had been run by James Glaisher from Greenwich. This enlargement of the *Monthly Weather Report* rendered the volumes of *Meteorological observations at stations of the second order* redundant as regards monthly summaries, and they came to an end with the volume for 1907.

The Observatories Division, under Richard Curtis, took charge of all records from self-recording instruments, tabulating a selection and scrutinizing the rest. Richard Curtis was the Office expert on anemometry. He and W. H. Dines were the moving spirits on the Wind Force Committee of the Royal Meteorological Society. The stock job of the Division was the tabulation of the records from the six observatories, Kew, Aberdeen, Stonyhurst, Oxford, Falmouth and Valentia, the last the only place outside London where the Office had whole-time staff of its own. The enlistment of these institutions into the service of meteorology and their equipment with similar instruments (photographic recorders of pressure and temperature, Beckley rain-gauge and Robinson cup anemometer) had been one of the first actions of the Meteorological Council when it took charge after Fitzroy's death. The Division had carried through the reproduction of their records in the now defunct *Quarterly Weather Report*. It was a beautiful piece of engraving and the copper plates were kept for many years until they were requisitioned for scrap in 1915. The Division had also carried out the harmonic analysis of the records on Galton's Harmonic Analyser which, its task completed, was on show at the entrance to the Meteorological Office in South Kensington and ultimately found its way to the Science Museum. I never saw the machine in use.

There were not many recording instruments apart from those at the observatories. The cards from a considerable number of Campbell-Stokes sunshine recorders had to be scrutinized and their evaluations checked. There were Robinson cup anemometers at Deerness, Scilly, Yarmouth and Kingstown. The Dines pressure-tube anemograph was a new invention. It had been installed experimentally at Kew, Pendennis Castle (Falmouth) and Scilly. Barographs were not general. They were not issued to the telegraphic stations until barometric tendency became included in the synoptic code some ten years later. When preparing the hourly maps used in "The life history of surface air currents" we had to borrow records from wherever we could get them.

No part of the Office has seen greater changes than the Forecast Division. When I set foot in it Frederic Gaster was still the senior member of its staff. He was then close on the retiring age, and if my information that he joined the Office as a boy is correct he must have been there when telegraphic weather reporting started under Fitzroy in 1865. For the greater part of his life he had been principal forecaster. He was in failing health and took little or no part in the daily routine but he was still, nominally at any rate, the London observer. The London observations given in the *Daily Weather Report* were taken in his garden at Brixton and telegraphed to Victoria Street twice a day.

F. J. Brodie and R. Sargeant were the two forecasters, with G. G. Francis and A. R. Simpkins as their principal assistants. All four had years of experience in plotting synoptic charts and watching the vagaries of British weather which they revealed. Looking back on those days I cannot help wondering how they carried on, for I don't remember any reserve of experienced man-power in the Division to provide for sickness or leave or public holidays. After I had been in the Office for a year I was called on to take a share in forecasting, and about the same time Henry Harries was transferred from the Marine Division. Though the routine of that Division was mainly concerned with statistical work he had had plenty of synoptic experience. The contribution of the Office to the International Polar Year 1881-82 had taken the form of publishing daily synoptic charts of the North Atlantic Ocean from all available information that could be collected, not only from British ships but also from those of other co-operating nations. That task had been assigned to the Marine Division. It was a big job as all data had to be extracted from the logs.

The forecasting was carried on in two rooms on the third floor which were used turn about, morning and evening, to give the cleaners an opportunity for sweeping and dusting. All information was received by Post Office telegram. The messages were paid for at normal rates and had no priority over those of the general public. Liaison with the Post Office was by private wire from Victoria Street to the Central Telegraph Office, but that represented no concession to the importance of meteorology. Anybody doing much business by telegram could hire a private line but had to operate his own end of it himself. That meant that the forecast staff had to be proficient in sending and receiving morse. Teleprinters had not yet been invented.

The hour for opening local post offices, 8 a.m., was the hour for the morning observations. At that hour the morning staff, three strong—forecaster, telegraphist and boy clerk—came on duty and soon after the reports began to trickle in. We received 25 from the British Isles and 30 from the Continent (Norway 4, Sweden 5, Germany 4, Denmark 2, France 10, Holland, Belgium, Spain, Portugal and the Azores each 1) but the latter were very often incomplete as the gaps in the *Daily Weather Report* of those days show. All messages were in the international code which had remained practically unchanged since its adoption by the International Meteorological Committee in 1874. There was, of course, no upper air information, but it is rather surprising that there was no provision for reporting cloud motion or form. Only one figure, ten possibilities, was allotted to "present weather" and "past weather" was ignored. Our own observers were instructed to supplement the code figures by adding groups of Beaufort letters to their inland messages, and they were encouraged to add short notes such as "cirrus rapidly from west" though my recollection is that little use was made of that discretion.



As the reports were received by the telegraphist they were called out by the junior, after conversion of the foreign ones to British units (pressure was still given in inches or millimetres) for the forecaster to plot them on the working chart. The chart was usually reasonably complete by 9.30 a.m. or soon after. If it was not that was unfortunate, but one just had to do one's best. Storm warnings were the first consideration. In doubtful cases one could call on stations for "special reports". A reply to a telegram dispatched about 9.15 might be expected before 11. That disposed of, telegrams were drafted for certain Admiralty addresses and then came the "General inference" and the district forecasts for eleven districts. They were written by the forecaster in the Forecast Book. The instruction was that the inference should indicate the reasons for the district forecasts. The assistants then wrote them out in violet ink on special forms for manifolding by what we called "jellygraph". These press issues were collected by messengers from the news agencies and evening papers soon after 10 a.m.

In the meantime the staff had been reinforced by staff on normal hours of duty, some lent from other divisions, and the preparation of the transfer for the *Daily Weather Report* had been put in hand. There were no typewriters, and everything had to be written and drawn on the transfers in lithographic ink. In addition to being expert telegraphists the staff had therefore to be competent draughtsmen and calligraphists. Fortunately such demands were not made on me or on other graduates who took a hand in forecasting in later years. The transfers had to be ready by 11 a.m. for dispatch by special messenger to Weller and Graham, the lithographers, whose works were somewhere in the City or East End. The reports were delivered at the Office, again by special messenger, during the afternoon. Those for dispatch by post were got away in time for the 5 p.m. collection at the South-Western District Office.

The routine for the evening reports (6 p.m.) followed much the same course. Only a selection of stations reported, and the continental information was very meagre. As there was no *Daily Weather Report* to be prepared, the staff of three could cope with the work even though a map had to be drawn for *The Times*. Incidentally I should mention that that newspaper had started the evening service in 1876, and for several years its cost was shared by *The Times*, the *Standard* and the *Daily News*. It was not until 1880 that the parliamentary grant was increased to enable the Office to provide the service from its own resources.

A few stations reported throughout the year at 2 p.m. as a check on developments for the issue of warnings. During the summer (June to September) the number was increased, and special harvest forecasts were issued for farmers. Anticipations of spells of fine weather were a feature of these forecasts, the forerunners of the "Further outlook".

On Sunday mornings, when press forecasts were not required, two members of the staff attended at the Central Telegraph Office to plot the observations and issue any necessary warnings or special forecasts.

In conclusion, a word about the training of forecasters in those early days. The staff I met on entering the Office had all climbed the ladder—assistant—telegraphist—forecaster, a slow process of evolution over 15, 20, or more years, and until Sir Napier Shaw joined the Council it does not seem to have been thought that anything more expeditious would ever be required. The general principles that had emerged from the scrutiny of synoptic charts over some 30

years were admirably set out in Abercromby's "Weather" and Clement Ley's "Aids to the study and forecast of weather" and that was all the specialized literature I was offered. For more general reading there was Hann's "Lehrbuch" and some American textbooks, and of course the collection of original papers in the Office volumes of pamphlets. However, all forecasts were carefully checked, district by district, by reference to the observations set out in the *Daily Weather Report* supplemented by those contributed for the *Weekly Weather Report*. For checking storm warnings the wind observations recorded at light-houses were used, the logs being lent to the Office for the purpose. The summarized results were given each year in the *Annual Reports* presented to Parliament. During my first year I spent a considerable time on this checking, and no doubt I learned a lot from it. It was not until the war of 1914 brought a sudden demand for forecasters that anything formal was attempted.

## FURTHER INVESTIGATIONS OF HIGH-LEVEL CLEAR-AIR TURBULENCE

By D. C. E. JONES, B.Sc.

**Introduction.**—There is a considerable amount of statistical information now available concerning the frequency, vertical and horizontal extent, and levels of occurrence of high-level clear-air turbulence over the British Isles and western Europe up to a height of about 40,000 ft.<sup>1,2</sup> This kind of turbulence has been observed in almost all weather situations, though it is fairly certain that there are two factors, one or other or both of which are usually associated with its occurrence, namely strong shear of wind in the vertical and in the horizontal.

In previous papers<sup>3,4</sup> accounts have been given of attempts made to correlate severe incidents of turbulence with various meteorological situations. It was found that they occurred mostly in the vicinity of jet streams or very strong winds, and to a much lesser extent near upper troughs and lows. This note describes a further analysis of a large number of casual reports of severe turbulence received in the Meteorological Office from various sources during the last two years. An account is also given of some special flights made by jet aircraft of the Royal Air Force and Royal Aircraft Establishment, Farnborough, to investigate further details of turbulence near jet streams.

**Method of reporting.**—The Royal Aircraft Establishment reports were based on accelerometer readings, but all those from Royal Air Force aircraft were qualitative assessments because none of the aircraft carried an accelerometer. It is difficult to know with certainty whether all pilots adopt the same standard of severity when reporting qualitatively, and there is always the risk that an incident may be described as severe simply because it is severe compared with the usual turbulence at high levels, and not on an absolute scale. In order to try to overcome this possible human error and in an endeavour to achieve consistency and uniformity, all pilots were asked to classify the severity as either "perceptible", "moderate" or "severe" in accordance with the following rough guide which is substantially the same as that recommended by the International Civil Aviation Organization:—

Perceptible ( $\pm 0.05g$  to  $\pm 0.2g$ )—perceptible difference from steady flying conditions

Moderate ( $\pm 0.2g$  to  $\pm 0.5g$ )—uncomfortable, slight tendency to be lifted out of seat

Severe (more than  $\pm 0.5g$ )—difficulty in observing flying instruments and/or maintaining aircraft heading; marked tendency to be thrown from seat.

**Casual reports of severe turbulence.**—147 reports of turbulence encountered over the British Isles and classed as “severe” were examined. Some of the incidents were of unusual severity and the two examples given below may be of interest:—

“Aircraft was pitching and tossing about the sky and one of its instruments was shaken from the instrument panel.”

“Crew were lifted from their seats. Aircraft suffered structural damage and several rivets were dislodged.”

Most of the reports were received from operational Royal Air Force jet aircraft but some were also received from Royal Navy and civil aircraft. The true speed of the aircraft at the time when the turbulence was encountered varied between about 250 and 450 kt.

Each report was studied in conjunction with the information given in the *Daily Aerological Record*, and an attempt was made to associate the turbulence with broad features of the relevant 300-mb. contour chart, that is with jet streams, strong winds, lows, and troughs, etc. A summary of the cases occurring in various situations is given in Table I.

TABLE I—WEATHER SITUATIONS ASSOCIATED WITH OCCASIONS OF SEVERE TURBULENCE IN CLEAR AIR AT HIGH ALTITUDE

WEATHER SITUATION										NO. OF CASES
Near jet stream	...	...	...	...	...	...	...	...	...	98
Probably near jet stream (i.e. jet stream almost certainly present but details of wind speed, breadth, etc., not available)	...	...	...	...	...	...	...	...	...	7
Upper trough	...	...	...	...	...	...	...	...	...	19
Upper low	...	...	...	...	...	...	...	...	...	3
Discontinuity in tropopause surface at same level as turbulence and within 100 miles of it	...	...	...	...	...	...	...	...	...	1
Discontinuity in tropopause surface at same level as turbulence, within 100 miles of it and near upper trough	...	...	...	...	...	...	...	...	...	2
Discontinuity in tropopause surface at same level as turbulence, within 100 miles of it and near upper low	...	...	...	...	...	...	...	...	...	0
Strong upper winds but no evidence of a well defined jet stream...	...	...	...	...	...	...	...	...	...	4
Unclassified	...	...	...	...	...	...	...	...	...	13
Total	...	...	...	...	...	...	...	...	...	147

Of the 147 cases, 21 occurred in the stratosphere, 2 were almost at the tropopause level and the remainder were in the upper troposphere. The 13 unclassified cases occurred in situations that could not be classed as any one of the above types. A few of them were in the middle of upper ridges and no evidence of vertical or horizontal wind shear could be found, nor a discontinuity of any kind.

As regards the height at which the severe turbulence was encountered, the majority of cases were between 25,000 and 35,000 ft., 25 between 35,000 and 40,000 ft., 7 between 40,000 and 45,000 ft. and 1 was above 45,000 ft. It is not safe to conclude from the above figures that the incidence is less in the lower stratosphere because in all probability the amount of flying at these levels was considerably less than at those below 40,000 ft.

Reports of severe turbulence in the vicinity of jet streams were further analysed with regard to their position relative to the axis of the jet. The

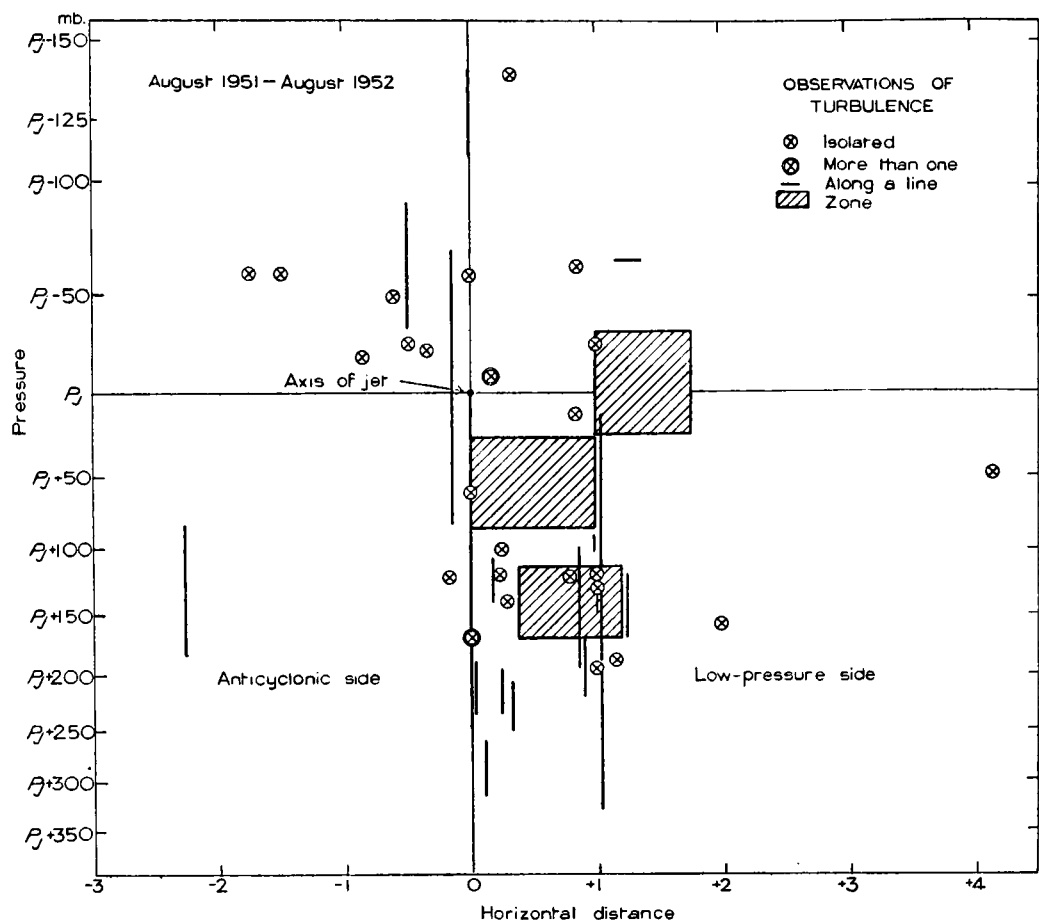
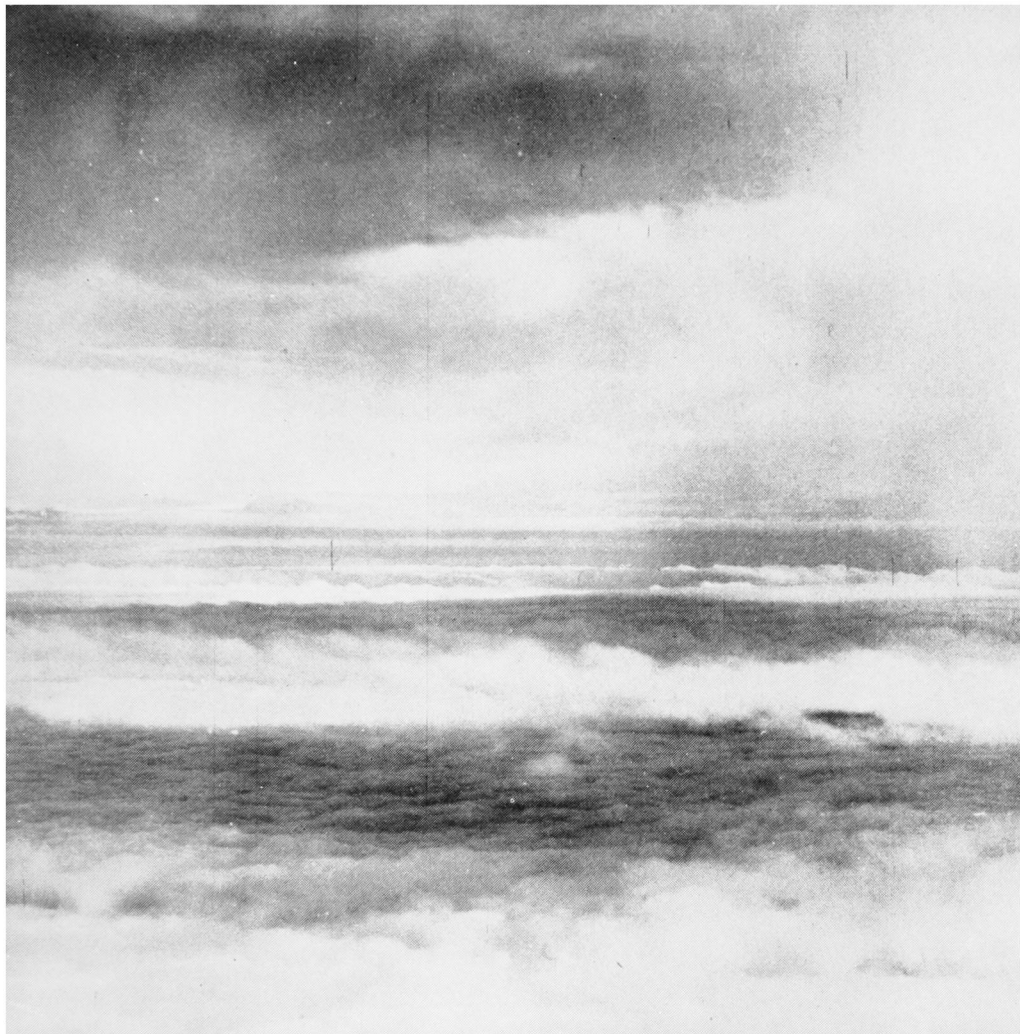


FIG. 1—POSITIONS OF OCCURRENCE OF SEVERE TURBULENCE RELATIVE TO THE JET-STREAM AXIS, AUGUST 1951–AUGUST 1952

method used was the same as that employed in previous work<sup>3,4</sup>. By inspection of the 300-mb. charts and the wind reports given in the *Daily Aerological Record*, the position, orientation and height of the axis of the jet were estimated at the time the turbulence was reported. For this purpose it was assumed that the jet stream had approximately straight and parallel contours with a maximum wind speed of 80 kt. or more. The level of the jet stream was taken as the level of the maximum wind reported in the upper air soundings in the vicinity of the jet and this wind report was taken as the nearest approximation to the maximum speed of the jet. When a report of turbulence did not coincide with the time of routine upper air soundings an allowance was made for movement of the jet axis by using continuity considerations of space and time.

The horizontal unit of measurement was taken as the distance from the centre of the jet stream, on the low-pressure side, over which the wind velocity at the same level as the axis of the jet fell to half the maximum value. The vertical co-ordinate was taken as the difference between the international standard atmosphere pressure equivalent of the reported height and the pressure,  $P_j$ , at the axis of the jet.

This method of analysis is rather subjective because the jet stream could not always be placed with a great degree of reliance. However, in view of the fairly large number of cases examined the accuracy obtained should be sufficient to



#### WEATHER CONDITIONS NEAR THE CENTRE OF A DEPRESSION

The photograph above shows the conditions obtaining near the centre of a depression in the North Sea on July 17, 1942, as seen from a meteorological reconnaissance aircraft in  $54^{\circ} 50' \text{N.}$ ,  $2^{\circ} 30' \text{E.}$  at 0610 G.M.T. The clouds, as reported by observer in the aircraft, were 7-8 tenths of stratocumulus, base 900 ft., top about 2,500 ft.; there was some cirrostratus above. The depression was formed on the polar front south of Newfoundland on July 12; it moved rapidly across the Atlantic Ocean on the 14th-16th and the centre passed to the north of Scotland reaching the North Sea on the 17th. Rain was reported by the aircraft over the first 50 miles of its route from base at Bircham Newton and also near  $56^{\circ} \text{N.}$ ,  $4^{\circ} \text{E.}$ , but nowhere else on its course.



*Reproduced by courtesy of Miss V. Hoare*

**PRECIPITATION VIRGAE ON A SHOWERY DAY**

This photograph was taken from the top of Ben Vrackie near Blair Atholl in Perthshire soon after midday on July 28, 1953. An old depression remained more or less stationary just to the north of Scotland for several days, bringing unstable air with very showery weather to the whole of the country.

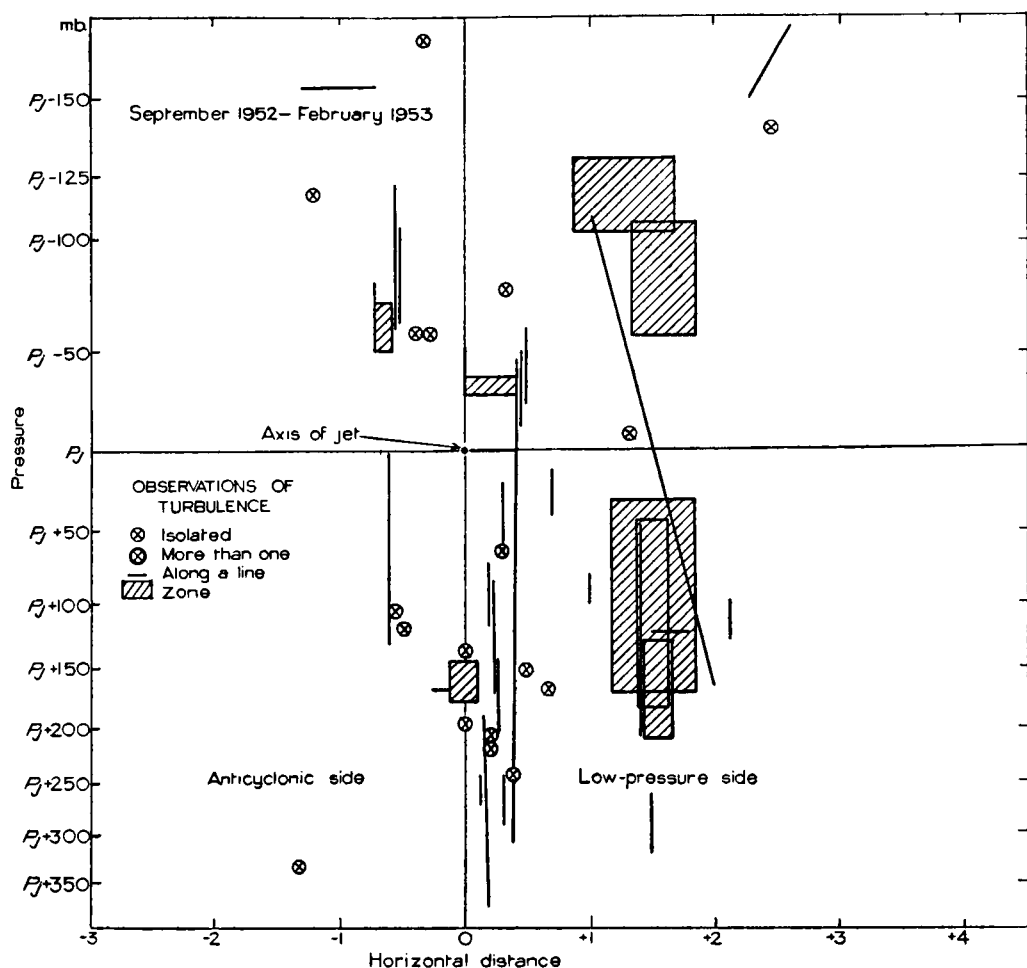


FIG. 2—POSITIONS OF OCCURRENCE OF SEVERE TURBULENCE RELATIVE TO THE JET-STREAM AXIS, SEPTEMBER 1952—FEBRUARY 1953

show the main features, although there may be some uncertainty in any one particular case.

The co-ordinates thus obtained for the positions of the 98 reports (mentioned in Table I) with respect to the jet stream were plotted in Figs. 1 and 2 which show all the cases examined for the periods August 1951—August 1952 and September 1952—February 1953 respectively. Details regarding certain parameters of the jet streams are given in Table II.

TABLE II—MEAN VALUES AND EXTREMES OF VARIOUS PARAMETERS OF JET STREAMS IN WHICH 98 SEVERE TURBULENCE INCIDENTS WERE REPORTED

		Wind speed at jet axis	Pressure at jet axis, $P_j$	Scale of hori- zontal units*
		kt.	mb.	nautical miles
August 1951—August 1952	Maximum	170	...	300
	Minimum	80	...	50
	Mean	115	283	147
September 1952—February 1953	Maximum	165	...	360
	Minimum	87	...	70
	Mean	122	315	162

\* The horizontal unit is the distance from the axis, at the same level on the low-pressure side, at which the wind speed is half the value at the axis.

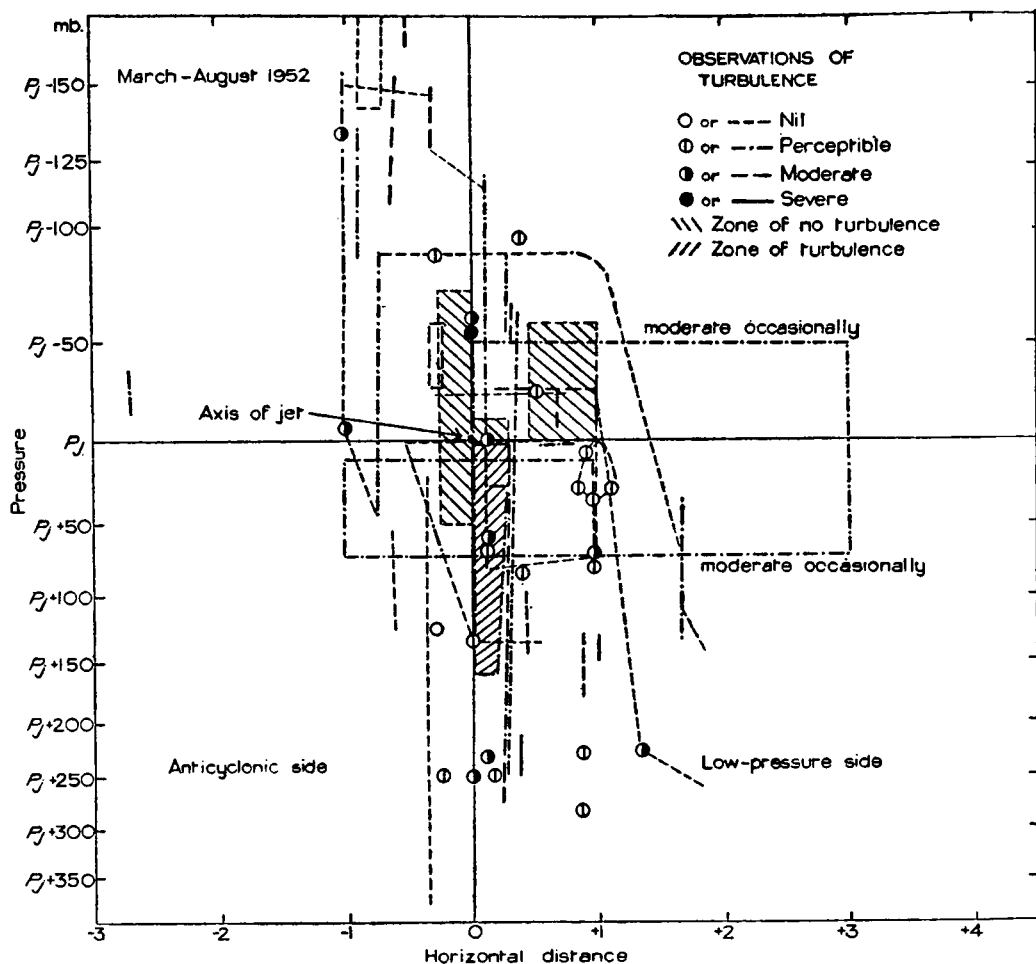


FIG. 3—POSITIONS RELATIVE TO THE AXES OF JET STREAMS OF FLIGHTS MADE BY THE ROYAL AIR FORCE  
14 jet streams

The most striking result is that severe turbulence was encountered on less than 10 per cent. of occasions in the quadrant below and on the anticyclonic side of the axis, and 75 per cent. were in the two quadrants on the low-pressure side.

An attempt was made to study any variations with respect to position along the jet stream, but only 3 cases occurred near the entrance and 11 near the exit of a jet stream, and these numbers are too small for any particular significance to be attached to them.

**Special investigational flights.**—In order to study further the occurrence of turbulence near jet streams it was arranged for the Royal Air Force to carry out special investigational flights. These were made by the dispatch of a special aircraft or by diverting an aircraft already airborne, and at times they were made in conjunction with the normal flying programme. In addition, aircraft of the Royal Aircraft Establishment Flight, Farnborough, also made a similar but rather limited series of investigational flights.

The pilot was expected to note the position and severity of turbulence throughout each flight, observations from heights above 20,000 ft. being the main interest. Reports of no turbulence were regarded as being just as important



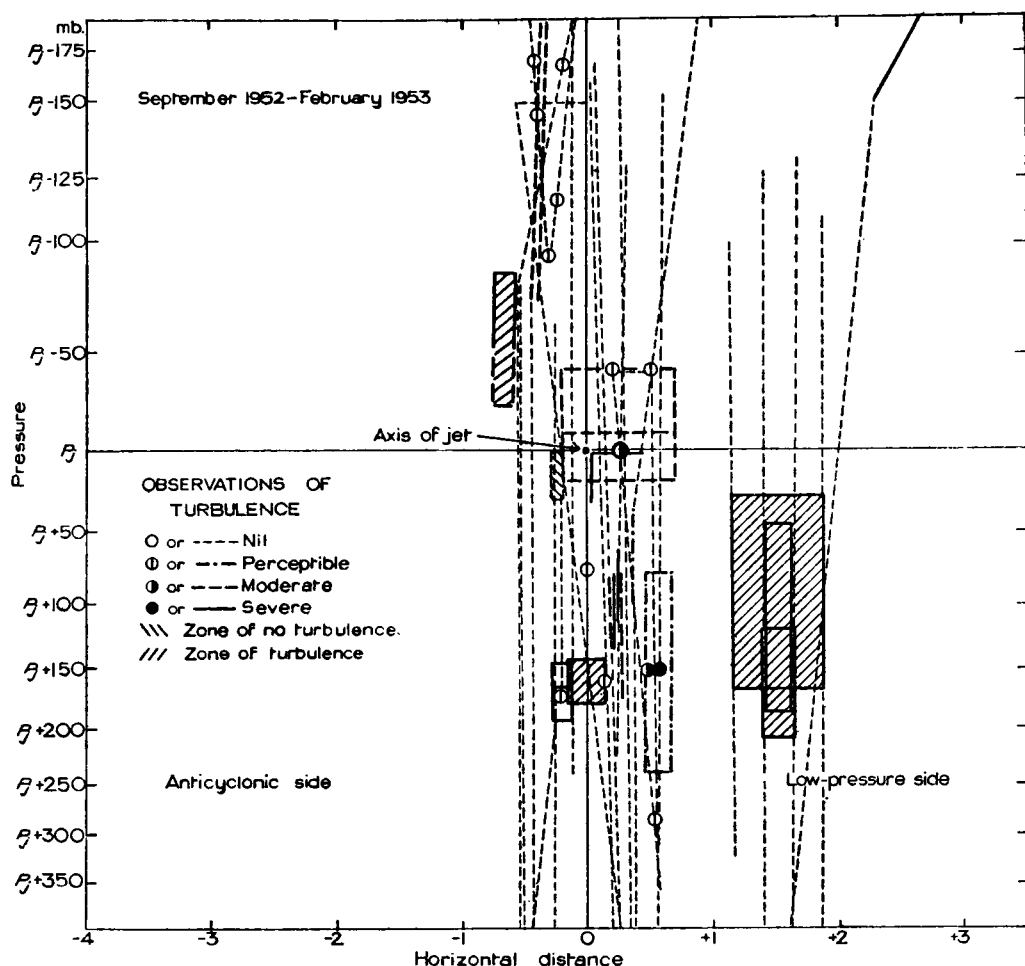


FIG. 4—POSITIONS RELATIVE TO THE AXES OF JET STREAMS OF SPECIAL FLIGHTS MADE BY THE ROYAL AIR FORCE  
9 jet streams

as positive reports. Pilots were also encouraged to note and report any special or unusual features of the turbulence and to state if any action was taken either by climbing, or descending, or altering course or speed, to fly out of the turbulent areas. No attempt was made to investigate the variations along the jet streams; only cross-sections of the jets were explored.

A total of 30 jet streams over the British Isles were investigated in this way—23 by the Royal Air Force and 7 by the Royal Aircraft Establishment aircraft. The number of flights made either across or in particular regions of jet streams varied from 1 to 12 per jet stream, the average being about 3.

The track of each flight was plotted on a graph showing the position of the flight relative to that of the jet stream using the same method as that employed in Figs. 1 and 2. Figs. 3 and 4 show diagrammatically all flights by the Royal Air Force during the periods March–August 1952 and September 1952–February 1953 respectively, and Fig. 5 shows the Royal Aircraft Establishment flights.

An attempt was made to classify each jet stream according to vertical and horizontal shear and to ascertain if there was any correlation between these

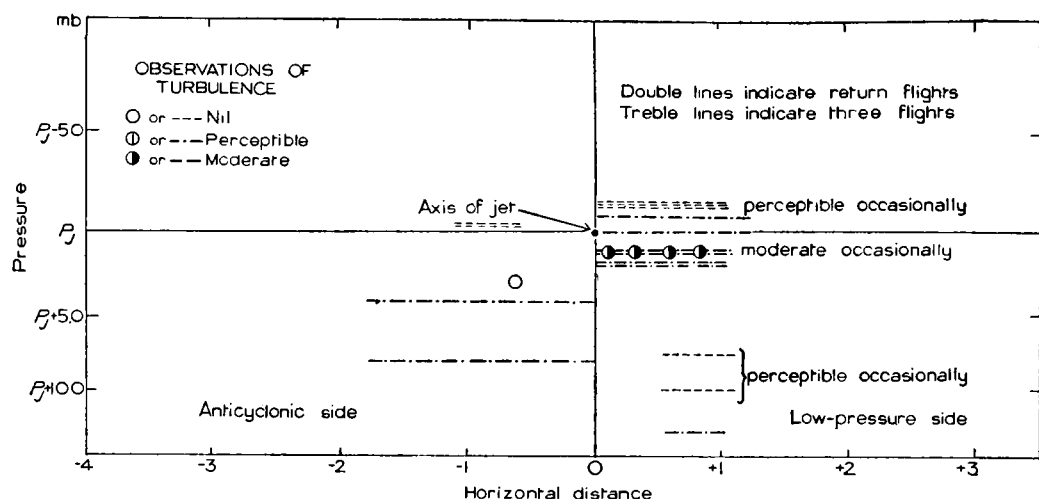


FIG. 5—POSITIONS RELATIVE TO THE AXES OF JET STREAMS OF SPECIAL FLIGHTS  
MADE BY AERO FLIGHT, ROYAL AIRCRAFT ESTABLISHMENT  
7 jet streams

parameters and the intensity of the turbulence experienced. The vertical shear was taken as the shear between the 500-mb. and 300-mb. levels of the jet. These levels were chosen because they are standard levels used for constructing contour charts, and it was thought desirable in this investigation to choose a parameter which is a characteristic of the individual jet stream rather than the actual position where the turbulence was observed. This method of evaluating vertical shear, however, suffers from the disadvantage that it does not give a representative value when the axis of the jet lies about half way between the two levels, but fortunately such cases were few. The horizontal shear was estimated on the low-pressure side of the jet and at the same level as the axis of the jet. The value obtained refers to the average wind shear over the distance which the wind takes to fall to half its maximum value at the axis of the jet. In order to ascertain whether a relationship exists between the shear (both vertical and horizontal) and the severity of turbulence, Fig. 6 was constructed to show the most severe turbulence encountered near each jet stream plotted against the appropriate values of the horizontal and vertical shear.

The worst turbulence encountered near any of the 30 jets investigated is given in Table III.

TABLE III

		NO. OF CASES
Severe turbulence ...	...	9
Moderate turbulence ...	...	10
Perceptible turbulence ...	...	9
No turbulence ...	...	2
Total ...	...	30

**Conclusions.**—Although in the special flights described in the last section the amount of flying varied considerably with different jet streams, and in some of them the flights may not have been made in the most turbulent part of the jet, it can be tentatively deduced that near a jet stream there is an approximately equal probability that the worst bumpiness encountered will be severe or moderate or perceptible in intensity. No decisive result was obtained from the study of

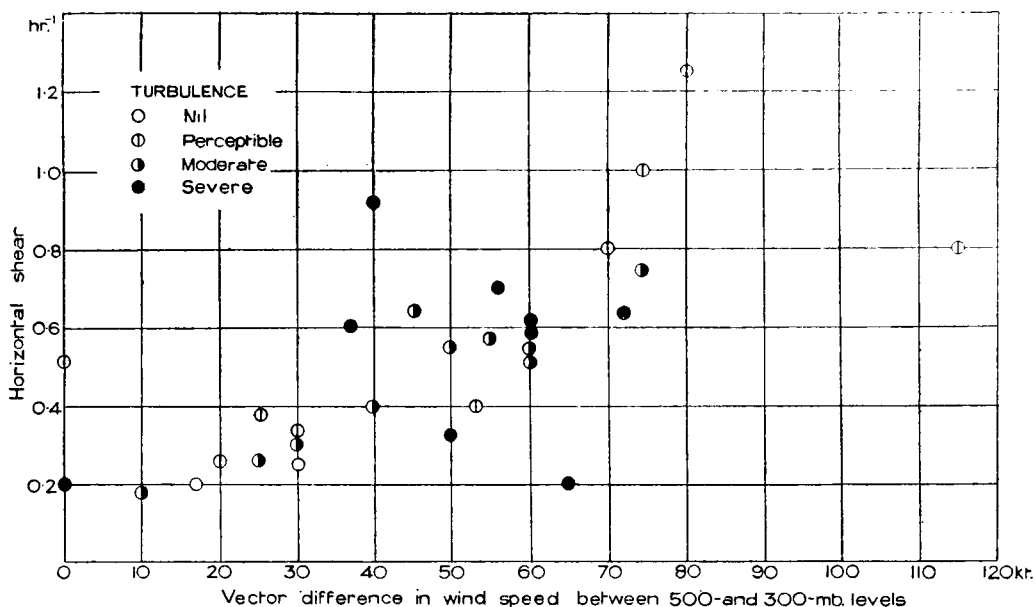


FIG. 6—MOST SEVERE TURBULENCE ENCOUNTERED NEAR THE 30 JET STREAMS

the variation in the severity of the turbulence with the horizontal and vertical shear in the vicinity of the jet streams (Fig. 6). But, in general, it would appear that severe turbulence occurred when the vector difference between the wind at the 500-mb. and 300-mb. levels exceeded 35 kt. and the horizontal shear exceeded  $0.2 \text{ hr.}^{-1}$

The analysis of the positions of all reports relative to the axis of the jet confirms previous finds on the subject<sup>4</sup>. With only a few exceptions the moderate and severe incidents occurred on the low-pressure side of the jet and to a lesser extent on the anticyclonic side above the axis; there were very few on the anticyclonic side below the axis.

Little further progress has been made in this investigation towards formulating rigid rules to assist the practical forecaster in this task of predicting the occurrence of high-level turbulence in clear air. Turbulence is a state in which the air undergoes rapid and random local fluctuations, and it appears very probable, at this stage, that it is only the statistical properties that can be recognized and subjected to analysis. Recent reports from jet aircraft indicate that severe turbulence can be experienced in practically any weather situation up to a height of about 50,000 ft. and well above the tropopause. But, nevertheless, the results obtained in these investigations should be of some help to the forecaster in recognizing the regions of the high atmosphere where aircraft flying at speeds between 250 and 450 kt. stand the greatest risk of encountering patches of severe bumpiness.

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## UPPER WINDS FROM NEPHOSCOPE OBSERVATIONS

By A. F. JENKINSON, B.A.

In 1903 Hildebrandsson<sup>1</sup> published for the International Meteorological Committee an historical survey giving average directions of cirrus-cloud motion from all available cloud observations; and in 1905 he summarized<sup>1</sup> the results of the special photometric and nephoscope observations made by stations during the International Cloud Year 1896-97. In this he gave mean winter and summer directions and scalar wind speeds of the motion of various cloud types.

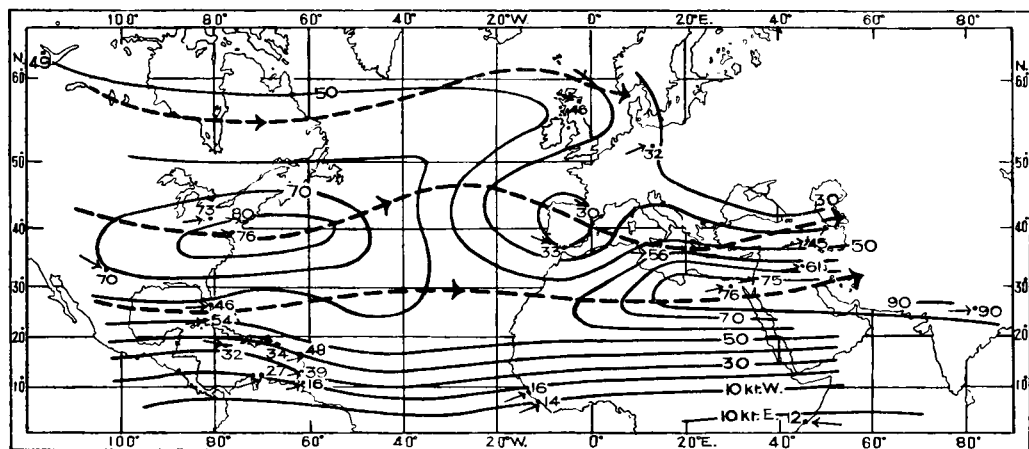


FIG. 1—ISOTACHS AND STREAM-LINES AT CIRRUS LEVEL DURING WINTER  
(DECEMBER-FEBRUARY)

Resultant vector winds from nephoscope observations are plotted.

Isotachs ——— Stream-lines - - - - -

In 1904, Bigelow<sup>2</sup> published monthly average vector winds derived from nephoscope observations on various cloud types, including cirrus and cirro-stratus, for stations in the United States and the Caribbean area, and he strongly recommended that similar work should be done all over the world to enable world maps of the average vector winds at cirrus and other levels to be drawn.

Unfortunately, the attention of meteorologists was largely drawn away from research on clouds and winds at high levels to the lower levels, where the needs of aircraft were then more pressing. The winds at these levels could be investigated fairly satisfactorily by pilot-balloon observations; and although nephoscope observations continued to be made no world-wide analysis of the vector resultants of cloud motions of the kind envisaged by Bigelow was ever made. Mention should however be made of the papers by Hildebrandsson<sup>3</sup>, van Bemmelen<sup>4</sup> and Harwood<sup>5</sup> giving data of directions of cloud motion and some stream-line maps of cirrus motion.

In recent years the measurement of upper winds by radar seems to have thrown the use of nephoscope observations into further disfavour, although C. F. Brooks<sup>6</sup> has made an eloquent appeal for the reporting of nephoscope observations from all synoptic stations.

In preparing seasonal maps of the average vector-wind distribution at various levels, the present author<sup>7</sup> found that average vector winds computed from nephoscope observations were of very great value.

The value of nephoscope winds as an ancillary aid to radar winds may perhaps be made more plain by showing how useful they are even on their own.

Vector winds from nephoscope observations at cirrus level for the season December to February have been plotted, and using these alone, average isotachs and stream-lines have been drawn for the northern hemisphere south of 60°N. between longitudes 100°W. and 60°E. They are shown in Fig. 1.

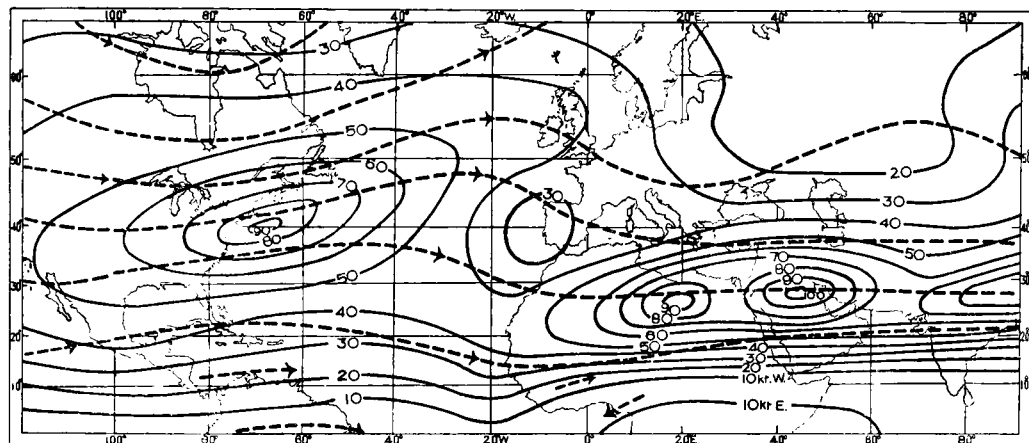


FIG. 2—ISOTACHS AND STREAM-LINES FOR JANUARY AT 300 MB.

Isotachs ——— Stream-lines - - - - -

The reliability of the nephoscope vector winds may be seen by comparison of Fig. 1 with the vector winds at 300 mb. for January for the same area<sup>7</sup>, reproduced in Fig. 2.

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## METEOROLOGICAL OFFICE DISCUSSION

### Dynamical forecasting by numerical methods

The discussion on Monday, February 17, 1954, held at the Royal Society of Arts, was opened by Mr. F. H. Bushby who gave a brief history of the subject and then described the research by staff of the Forecasting Research Division, Dunstable into numerical methods of forecasting.

In spite of the advent of modern electronic computing machinery it is still not practicable to solve directly the fundamental equations of motion, continuity

and state in order to compute the future condition of the atmosphere from its known condition at a given instant. These equations refer to gravity waves in addition to the meteorologically important large-scale disturbances, and it would be necessary to proceed in time steps of 10 min. using a 400-Km. grid-length in order that the finite-difference approximation to the equations of motion should converge to the correct answer. Also, it would be necessary to evaluate directly the horizontal divergence of the velocity field, and it frequently happens that the divergence of the large-scale pattern is masked by the divergence of the small-scale disturbances.

Charney<sup>1</sup> points out that the use of the geostrophic approximation effectively filters out these small-scale disturbances, but this approximation cannot be made until the horizontal divergence has been eliminated from the equations. Charney, using the geostrophic approximation and also assuming that the wind was unidirectional with respect to height and that the increase of wind with height was constant along a vertical, derived an equation for predicting the height of an isobaric surface in mid troposphere. He called this surface the "equivalent barotropic level".

As a result of tests at Dunstable and elsewhere it became apparent that although the barotropic model does account for some part of the atmospheric motion it is not an adequate forecasting tool. The equations derived by Sawyer and Bushby<sup>2</sup> combine the ideas of Charney with those of Sutcliffe<sup>3</sup> in an attempt to find a more realistic atmospheric model. Quite independent research by Eady<sup>4</sup>, Eliassen<sup>5</sup> and Thompson<sup>6</sup> has led to the derivation of similar sets of results. Meanwhile, Charney and Phillips<sup>7</sup> have been exploring the possibilities of using multi-layer barotropic models. Phillips<sup>8</sup>, using two homogeneous incompressible fluids superimposed one upon the other, derives a set of equations which, with suitable interpretation of the dependent variables, is analogous to the set derived by Sawyer and Bushby.

The model of the atmosphere adopted by Sawyer and Bushby consists of a baroclinic fluid in which the thermal wind is constant in direction in any vertical column, but not necessarily parallel to the wind direction at any level, and in which the thermal wind is proportional to the pressure difference through the layer considered. It is also assumed that the atmosphere is bounded by two pressure surfaces corresponding to the upper limit of the troposphere and to a level near the ground, and that the movement across these surfaces is negligible. The geostrophic approximations to the vertical vorticity component and to the horizontal velocity components are made after the elimination of the horizontal divergence. Since the geostrophic wind closely approximates to the actual wind, the state of the model atmosphere is adequately specified by the height of some isobaric surface together with the thickness of a selected layer. The height  $h_m$  of the 500-mb. contour surface and the thickness  $h'$  of the 1000-500-mb. layer are being used in the present experiments at Dunstable. The terms involving transfer of the horizontal components of vorticity to the vertical component have been omitted from the vorticity equation and the effects of surface friction are neglected. Radiation and convection are not considered in deriving the equation for the thickness tendency, the change of thickness being attributed to a combination of advection and vertical motion. For the purpose of evaluating certain integrals involving the vertical motion as a function of pressure the vertical motion was assumed to be parabolic with respect to pressure, having a maximum in mid troposphere and being zero at the ground and at the tropopause.

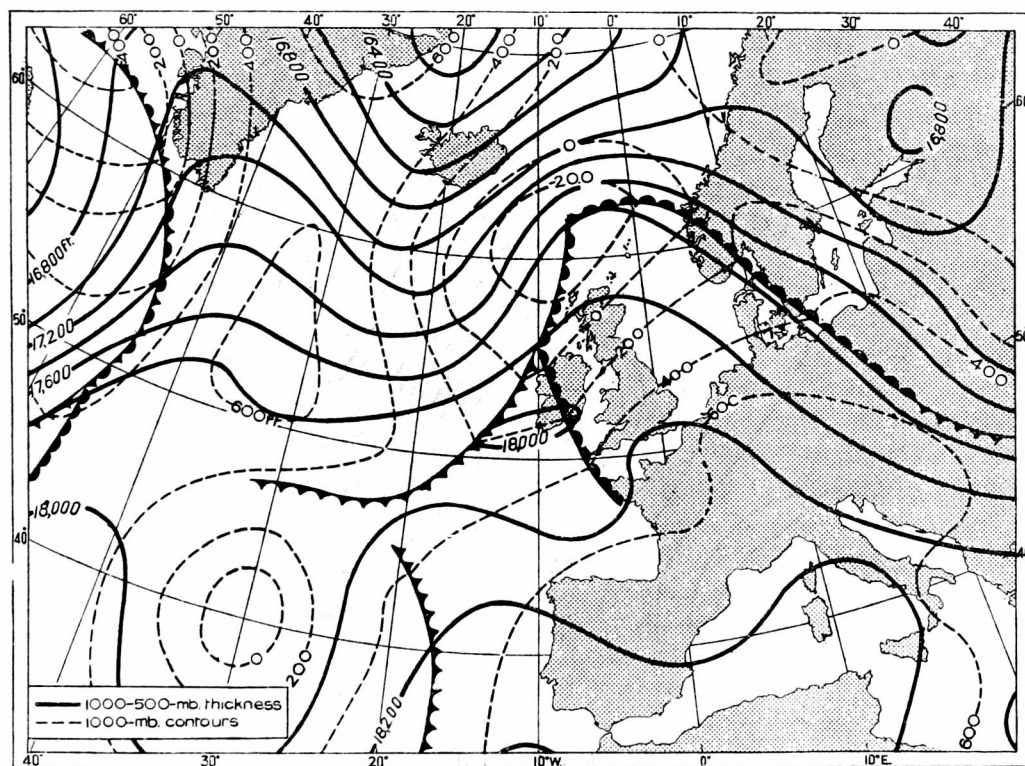
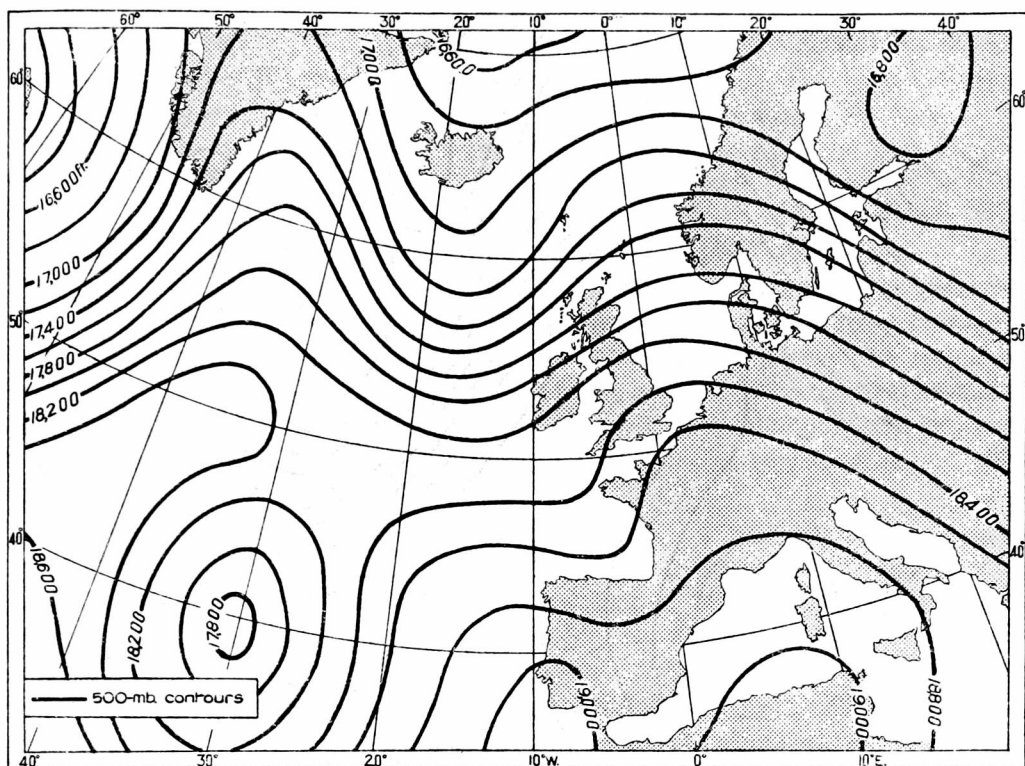
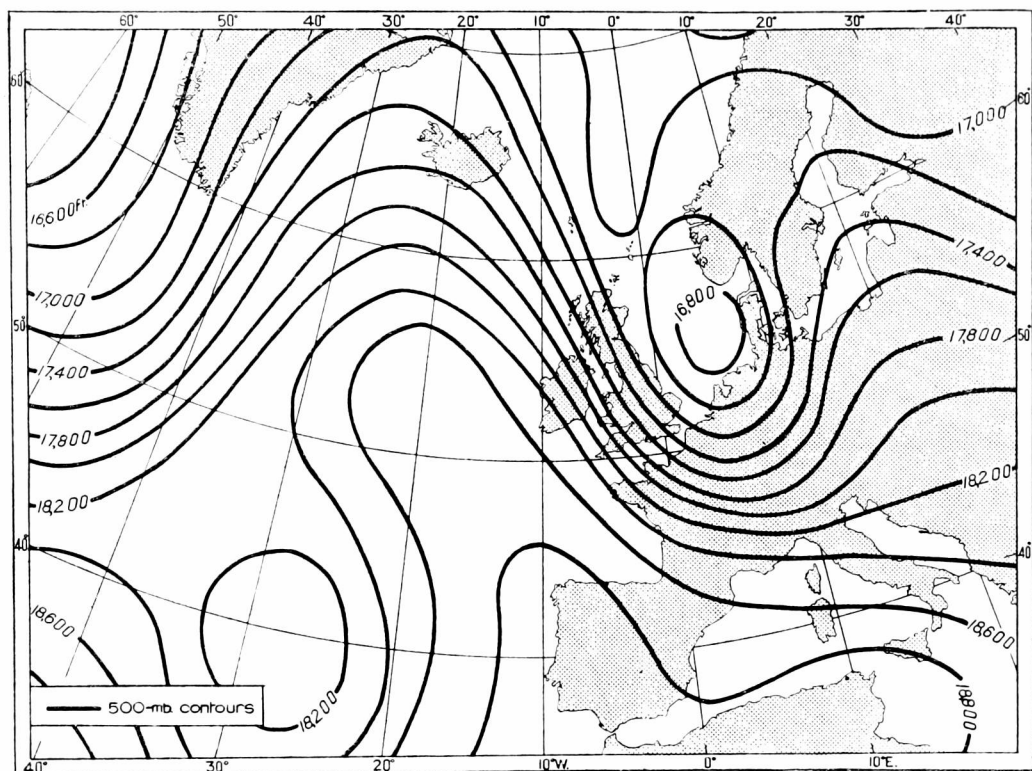
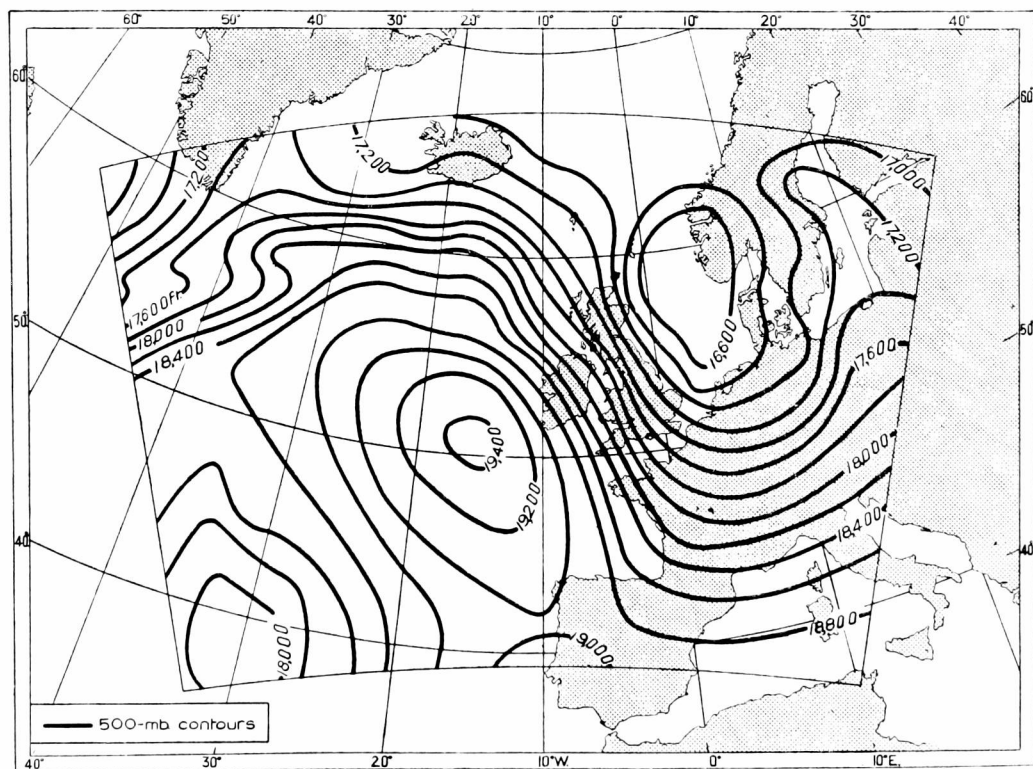


FIG. 1—ACTUAL CHARTS, 1500 G.M.T., JANUARY 30, 1953



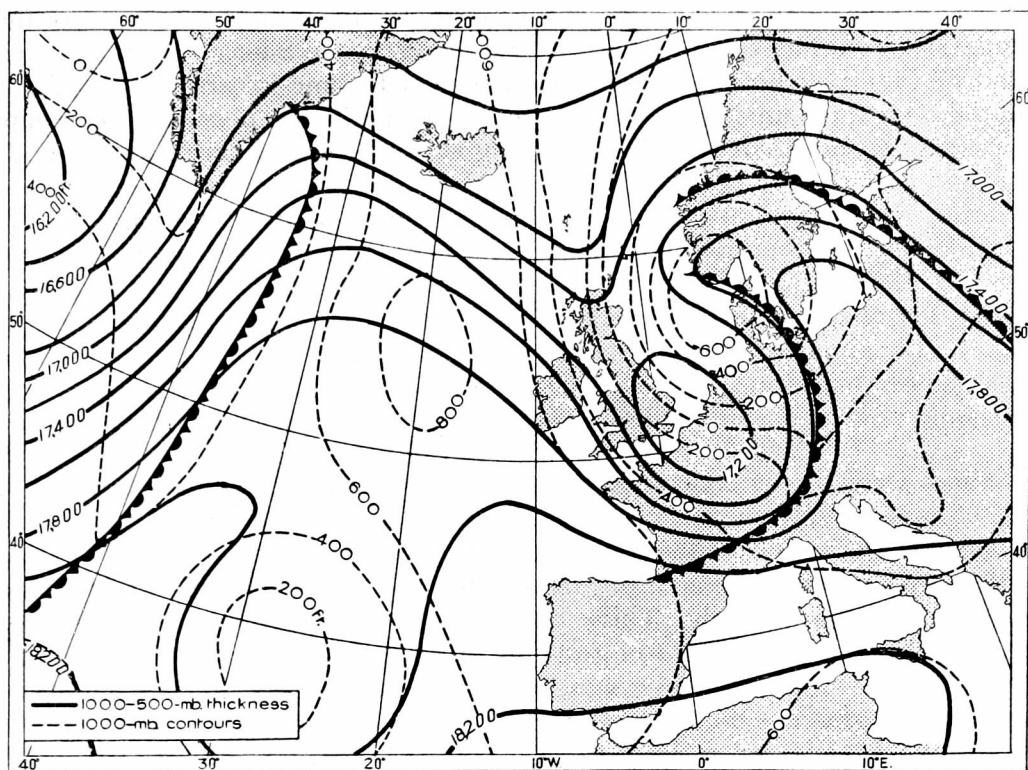
(a) Actual



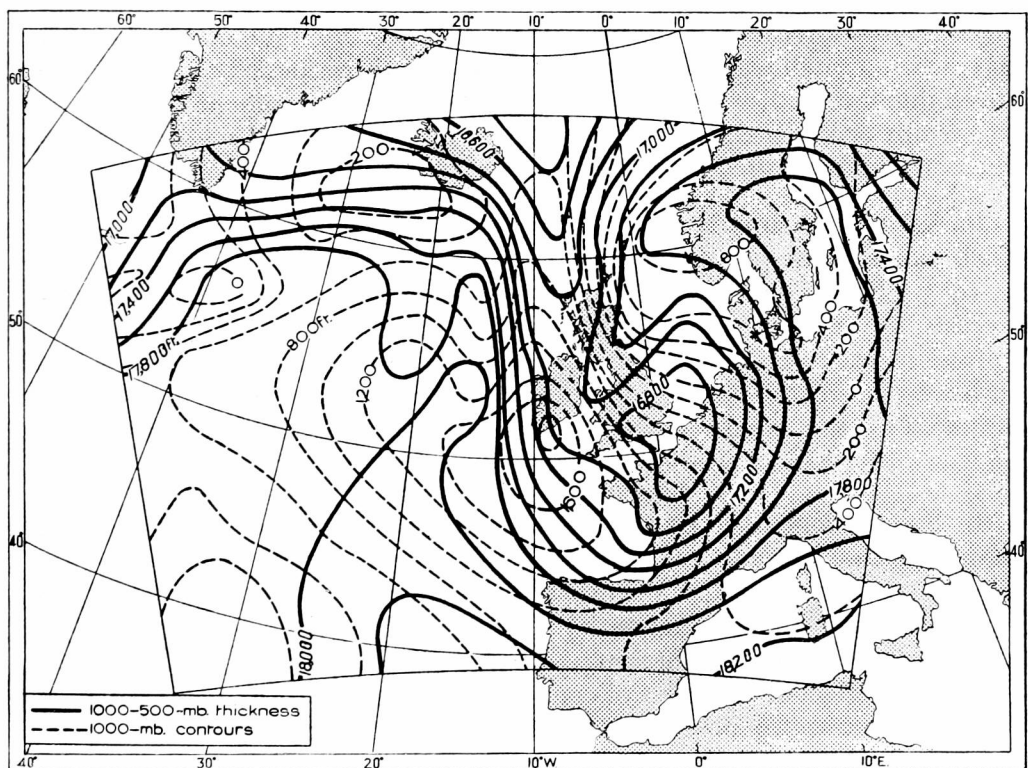
(b) Computed

FIG. 2—500-MB. CONTOUR CHARTS, 1500 G.M.T., JANUARY 31, 1953





(a) Actual



(b) Computed

FIG. 3—1000-MB. CONTOUR AND 1000-500-MB. THICKNESS CHARTS, 1500 G.M.T., JANUARY 31, 1953

Mr. Bushby then gave a brief outline of the mathematical derivation of the equations used for computing  $\partial h_m / \partial t$  and  $\partial h' / \partial t$  in the Sawyer-Bushby model, and he indicated how integration with respect to time is carried out. Using initial data for points of a rectangular  $18 \times 14$  grid, it is possible to compute values for  $h_m$  and  $h'$  for some future instant at points of the interior  $14 \times 10$  grid, but the variations of  $h_m$  and  $h'$  with time have to be postulated along the two exterior rings of points of the  $18 \times 14$  grid. A grid-length of 260 Km. is being used for the present series of computations. The computations have been done on two electronic computing machines, LEO owned by Messrs. J. Lyons & Co., and a Ferranti machine installed at Manchester University. A 24-hr. forecast takes approximately 4 hr. of machine time if 1-hr. time steps are used in the integration procedure. However, faster machines are already being built, and it should now be possible to reduce considerably the computing time.

Slides were shown comparing the 12-hr. and 24-hr. computed forecasts of  $h_m$ ,  $h'$  and  $(h_m - h')$  for five synoptic situations with the actual conditions that occurred. In four of the five situations there was good agreement between the computed and actual charts, but there was a tendency to overdo anticyclonic development considerably. This could be due to the fact that in anticyclonic regions the two assumptions of geostrophic motion and the neglect of friction both cause errors of the same sign, but this is not the case in cyclonic areas. It was also apparent that in certain areas the 1000–500-mb. thickness was less than the minimum value that had occurred in that region at that time of year during the previous five years. This is probably due to the neglect of the convective processes in cold air over warm sea. A bad result was obtained for the computed forecast starting from the initial data for 1500 G.M.T., January 8, 1951, when a small wave depression in mid Atlantic deepened considerably and moved into the south-western approaches. No such development was computed, but on this occasion the forecast produced by conventional methods was very similar to the computed forecast.

One of the five situations for which forecasts have been computed was that which caused widespread flooding in eastern districts of England on January 31, 1953. The initial and final conditions, together with the computed 24-hr. forecasts, are reproduced in Figs. 1–3. It can be seen that the behaviour of the depression was forecast reasonably well, but unnaturally high pressure to the south-west of Ireland caused much stronger winds than actually occurred to be computed for the vicinity of the British Isles. The cold trough over the North Sea was in the correct position but was too intense.

Mr. Bushby concluded by emphasizing that in this project it was intended to obtain ten 24-hr. computed forecasts, and examine them carefully to see if one could deduce what fundamental assumptions were the most restrictive, and, if possible, remove them. From the results so far obtained it would seem that, although there is an encouraging agreement between computed and actual charts, the neglect of the effect of convective heating over the sea and the use of the geostrophic approximation are two sources of error. Errors of a lesser extent are introduced by the arbitrary choice of boundary conditions and by the effects of topography. There is hope that some of these deficiencies of the two-parameter model can be removed, thus opening a way for operational numerical weather prediction.

*Prof. Rossby* (Sweden) congratulated the Meteorological Office on being the first official weather service to experiment with numerical forecasting. He mentioned that the electronic computing machine BESK at Stockholm was being used for some forecasts using the simple barotropic model. Three forecasts had so far been made, each relating to a mobile 500-mb. pattern with little development, and in these cases correlation coefficients between 0.8 and 0.9 had been obtained between the actual and computed 24-hr. 500-mb. height change.

*Dr. Smagorinsky* (United States) said that the United States Weather Bureau were arranging trials to find the most suitable electronic computing machine for meteorological computations based on the three-layer model. He stressed that it was important that most of the information should be taken from the lowest part of the atmosphere, e.g. by using pressure squared as the vertical co-ordinate, as this is the region where most potential energy is available.

*Mr. Jenkinson* criticized the basic assumptions of the Sawyer-Bushby model regarding the vertical wind structure and the independence of static stability and pressure. He suggested that there were large areas where the thermal wind was not constant in direction with respect to height, especially in the region of jet streams and fronts. He also thought there was a need to compute surface pressure directly and not obtain it from the difference of the 500-mb. height and 1000–500-mb. thickness. In reply, *Mr. Bushby* said that he did not think that the thermal-wind approximation was frequently a bad one over a large area, but that there certainly were limited regions where this approximation was not good.

*Mr. Ludlam* inquired how much additional data was needed for perfect forecasts. *Mr. Bushby* said that it was difficult to give an exact reply, but certainly more rather than fewer ocean weather ships would be of great assistance.

*Mr. Eldridge* asked whether a new depression could be predicted; *Mr. Bushby* said that it certainly could if it were caused by local concentrations of vorticity, but not if it were caused by some local instability.

*Dr. Scorer* asked if *Mr. Bushby* had anything to say about fronts.

*Mr. Douglas* said that it was immaterial that fronts were not taken into account. The need was to make a better forecast of the pressure distribution, and very good progress has so far been made.

*Mr. Sawyer* thought that it was better to try to account for the missing physical factors than to use more parameters.

*Mr. Bradbury* inquired whether any attempt had been made to compute the development of a blocking high. *Mr. Bushby* said that such developments usually took much longer than 24 hours.

*Prof. Rossby* agreed, but said he thought that numerical forecasting would probably be used for forecasting the movement of large-scale features over 2–3 days before it was used for detailed 24-hr. forecasting. *Mr. Bushby*, in reply, said that as the equations were non-linear it was not obvious that detail could be neglected in preparing a medium-range forecast.

*Mr. Veryard* said it was important to consider the latent heat of condensation if one was considering convective processes.

*Mr. Lumb* suggested that once the thermal pattern had been computed, it might be better to fix the centres of depressions and anticyclones by placing

them in the most appropriate part of the thermal field. In his opinion this would have given a better forecast for the position of the flood depression.

*Dr. Stagg* concluded the discussion by saying that the subject of numerical forecasting was still in its infancy, but that considerable progress was being made.

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#### OFFICIAL PUBLICATION

The following publication has recently been issued:—

##### PROFESSIONAL NOTES

*No. 109—Radar echoes from and turbulence within cumulus and cumulonimbus clouds.*  
By R. F. Jones, B.A.

Accelerometer records obtained on traverses of cumulus and cumulonimbus clouds by Spitfire aircraft have been analysed to give the frequency of gusts encountered of specified magnitudes. It appears that turbulence increases slowly with height in a cumulonimbus cloud until rather less than half way up the cloud, and thereafter remains at or near its maximum value until the top third of the cloud is reached. In the top third of the cloud the turbulence steadily decreases with height to a minimum value near the top of the cloud. The readings obtained are shown not to be inconsistent with statistics of American observations made in Florida and Ohio.

Radar observations, made at the same time as the accelerometer records were obtained, make it possible to relate the turbulence to the characteristics of the radar echo received from the part of the cloud traversed. It is found that the radar-echo characteristics, as shown on a height-range display tube, can be used to indicate the places in a cloud where turbulence is likely to be the most severe. Edges of the echoing volume in particular are shown to be regions of severe turbulence. Severe gusts frequently occur in sequences with the distance between individual gusts less than 400 yd.

Although most of the severe gusts occurred in the echo-producing regions of the clouds there was nevertheless a substantial number of severe gusts experienced in clouds, or parts of a cloud, which failed to give a detectable radar echo.

#### METEOROLOGICAL RESEARCH COMMITTEE

The Synoptic and Dynamical Sub-Committee met on January 28, the Physical Sub-Committee on February 4, the Instruments Sub-Committee on February 11, and the Main Committee on March 24, 1954.

At the meeting on January 28 the Synoptic and Dynamical Sub-Committee considered a paper by Mr. Lamb<sup>1</sup> which discussed two-way relationships between the snow or ice limit and 1000–500-mb. thicknesses in the overlying atmosphere, a paper by Mr. Sumner<sup>2</sup> on the annual and geographical distribution of cold pools, and a paper by Mr. Sawyer<sup>3</sup> on the rainfall of depressions which move eastward across Scotland.

At the meeting of the Physical Sub-Committee there was a discussion on post-war research in micrometeorology within the Meteorological Office at which the opening speakers were Dr. Robinson, Mr. Rider and Dr. Stewart.

At the meeting on February 11 the Instruments Sub-Committee considered a paper by Dr. Scrase<sup>4</sup> on radiation and lag errors of the Meteorological Office radio-sonde and the diurnal variation of upper air temperature. There was also a discussion on the meteorological elements for radio-sondes at which the opening speakers were Dr. Harrison, Mr. Grant and Mr. Almond.

At these three meetings the Annual Reports to the Meteorological Research Committee from the chairmen of the various sub-committees were discussed and recommendations formulated for the revision of the research programme.

At the 67th meeting of the Meteorological Research Committee the Annual Reports from the chairmen of the various sub-committees were received, the research programme for the following 12 months was approved, and the Annual Report to the Secretary of State for Air was agreed. Mr. L. P. Smith also gave an interesting summary of the application of meteorological research to agricultural problems.

#### ABSTRACTS

1. LAMB, H. H.; Two-way relationships between the snow or ice limit and 1000–500-mb. thicknesses in the overlying atmosphere. *Met. Res. Pap., London*, No. 834, S.C. II/159, 1953.

Deals first with relations between 1000–500-mb. thickness in British Isles, east Atlantic and north-west Europe and temperature at surface, 850, 700 and 500 mb. Change from rain to snow occurs with thickness about 17,150 ft. (oceanic) or 17,400 ft. (continental). The limit of a snow- or ice-covered surface in Europe had a mean thickness of 17,260 ft.; at normal 0°C. M.S.L. isotherm it was 17,500 ft. Encroachments of greater thickness (up to 18,000 ft.) over snow-covered areas were short-lived; this favours persistence of snow cover. High ground is an effective barrier. Effect of an extensive snow cover on severity of winter is considered.

2. SUMNER, E. J.; The annual and geographical distribution of cold pools. *Met. Res. Pap., London*, No. 837, S.C. II/160, 1953.

In continuation of *Meteorological Research Paper* No. 764 frequency of all cold pools with one or more closed lines in 1000–500-mb. charts is tabulated for annual and geographical distribution. Results are shown graphically and discussed.

3. SAWYER, J. S.; The rainfall of depressions which move eastward across Scotland. *Met. Res. Pap., London*, No. 843, S.C. II/164, 1953.

In continuation of previous *Meteorological Research Papers* rainfall charts were drawn for 49 depressions crossing Scotland in 1941–50. Figures show average rainfall, relation to distance from track, percentage giving no rain, and frequency diagrams for selected stations.

4. SCRASE, F. J.; Radiation and lag errors of the Meteorological Office radio-sonde and the diurnal variation of upper air temperature. *Met. Res. Pap., London*, No. 836, S.C. I/81, 1953.

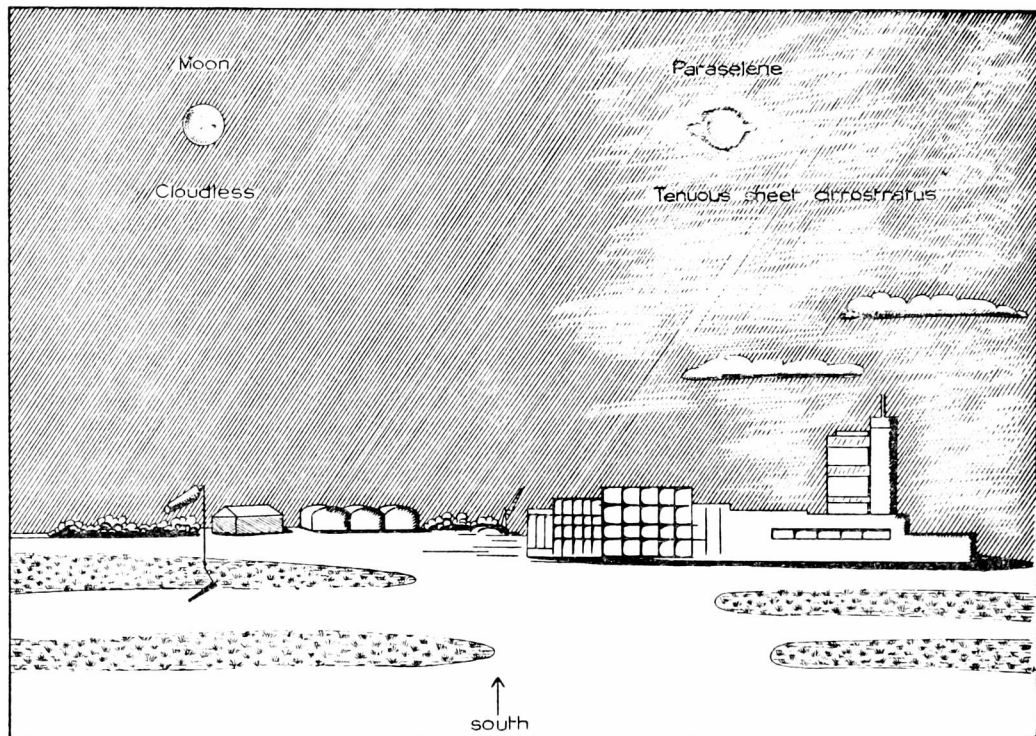
The shielded thermo-element of the radio-sonde may be affected by radiation (direct and reflected from the inner shield) and by air warmed by the shield. The heat transfer for a radio-sonde ascending at 6 m./sec. and swinging through 60° and the absorption of radiation for different solar altitudes, are calculated. In 50°N. the total error varies from 0.7°C. at ground level to 17.3°C. at 30 Km., where heating of the air in the shield accounts for 65 per cent. The error due to lag is also calculated and found to be generally less than 1°C. These results are confirmed by comparison of temperatures during ascent and much faster descent. Some experimental modifications were tried, but the only one which showed appreciable improvement was the substitution of white card for aluminium for the inner shield. The results show that up to 15 Km. radiation errors can account for the whole observed difference between day and night temperatures, but that there is a true diurnal range of about 1.5°C. at 20 Km. and 3°C. at 25 Km.

## LETTERS TO THE EDITOR

### Paraselenae observed at London Airport

A well defined paraselenae (mock moon) was observed at London Airport between 2338 and 2345 G.M.T. on Saturday, March 20, 1954. At the time of the observation the moon was one day after full and very bright. The altitude was about  $28^\circ$  and at a bearing  $160^\circ$  from true north.

Prior to the observation the sky had been almost cloudless but a sheet of very tenuous cirrostratus had spread in from the north-west with small amounts of stratocumulus cloud. As this cirrostratus spread towards the position of the moon, a bright paraselenae was observed at the position on the paraselenic circle to the west of the moon and at an angular distance of about  $28^\circ$  from the moon. Very small parts of the paraselenic circle were evident as projections on the equator of the paraselenae. The edge of the paraselenae nearest to the moon had a reddish tinge. There was no trace of any part of the  $22^\circ$  halo or any other halo phenomena.



The paraselenae was visible for about seven minutes when it was obscured by increasing low cloud.

An examination of the available upper air data indicates that the tenuous cirrostratus sheet was probably at a height of 29,000 ft. with a temperature of  $-50^\circ\text{C}$ . The maximum vertical wind shear was in the belt between 350 and 300 mb. with the wind velocity at the cirrostratus level about  $284^\circ$  35 kt.

T. N. S. HARROWER

D. C. EVANS

*London Airport, March 22, 1954*

[There is nothing unusual in theory about paraselenae but in practice well defined ones are rarely observed. The absence of a  $22^\circ$  halo indicates that the axes of the hexagonal ice crystals were mainly vertical.—Ed., *M.M.*]





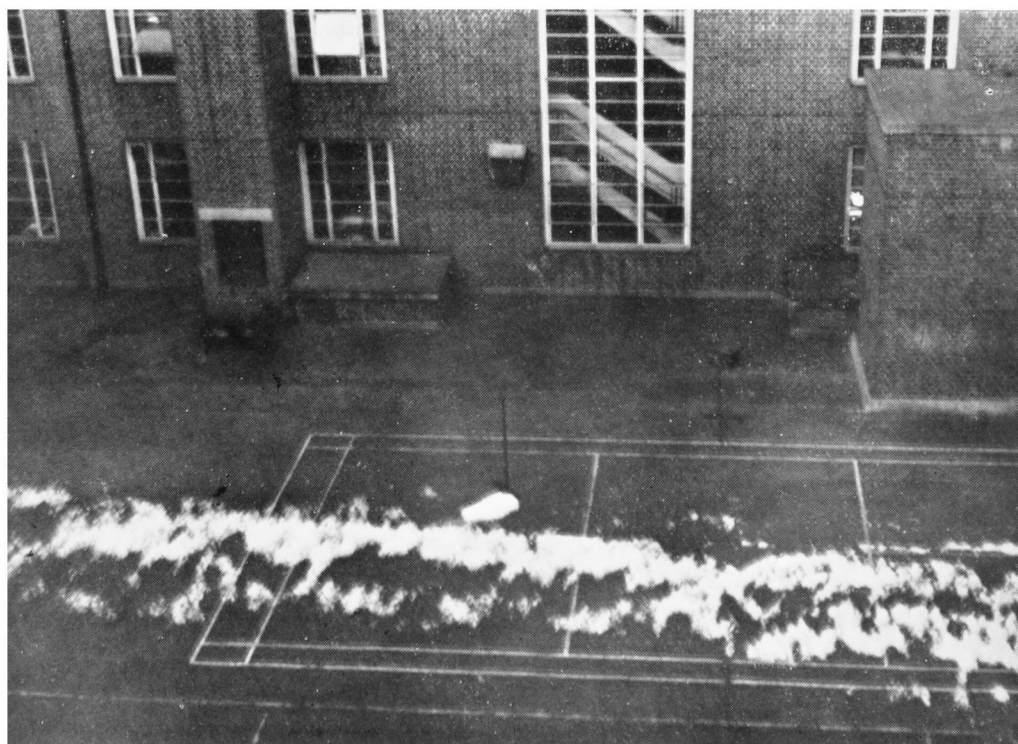
*Reproduced by courtesy of the late Mr. W. J. Day*

A CORONA TOWARDS SUNSET



*Reproduced by courtesy of the late Mr. W. J. Day*

ALTOSTRATUS AND CIRROSTRATUS NEAR SUNSET



QUADRANGLE OF METEOROLOGICAL OFFICE, HARROW, FEBRUARY 1, 1954, 1650 G.M.T.  
Looking north-east



## Low range for a long period

The thermograph trace for the Nether Park station at Alston, Cumberland, for January 20–23, 1954, showed an almost horizontal line extending across 57 hr. The maximum temperature during this time was 35°F. and the minimum about 33·5°F. The range of only 1·5°F. between 1800 G.M.T. on the 20th and 0300 G.M.T. on the 23rd offered something unique in the Alston record, but whether this is really unusual I cannot say.

The validity of the trace is substantiated by the readings at the Alston climatological station where 2·9°F. was the range recorded on thermometers. The almost invariably lower maxima at Nether Park gives support to the slightly lower range registered by the thermograph.

W. E. RICHARDSON

*Alston Climatological Station, The Grove, Alston, Cumberland, February 10, 1954.*

## NOTES AND NEWS

### Eddies unusually defined by snow

The lower photograph opposite shows the distribution of dry snow at approximately 1700 G.M.T. on February 1, 1954, in the quadrangle of the Meteorological Office building at Harrow. The anemograph wind was east-north-easterly, 10–15 kt. A plan of the surroundings is shown in Fig. 1; the snow was in the

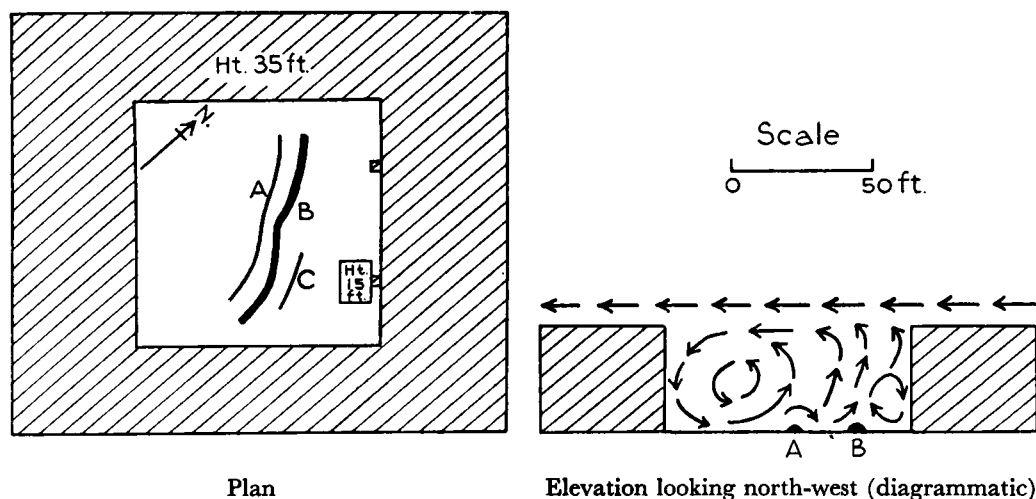


FIG. 1—METEOROLOGICAL OFFICE, HARROW

form of two lanes, one of which, at B, was distinctly larger and contained more snow than the other at A. The snow lanes were parallel to the main windward face of the building but curved at one end towards the second most windward face. Snow was restricted to the “lee” side of the quadrangle; and on objects in this region, snow piled up on the side facing the returning “eddy” wind. The double lane suggests that the eddy flow gave an extra “bounce”. Assuming this to be the case and that snow accumulated in areas of little wind, the air flow would be roughly as illustrated in Fig. 1. The larger deposition is presumably in the more sheltered region, nearer to the building. In the photograph, there is a slight suggestion of a third snow lane (at C in Fig. 1), particularly where the eddy flow has a longer (that is, more diagonal) path. The number of waves would appear to be a function of this length of path, and of the strength of the general air flow and height of the obstruction.

A further point of interest is that the small building in the quadrangle appears to have caused an irregularity in the snow lanes. The direction of this irregularity from the small building probably indicates the direction of the returning eddy wind.

E. N. LAWRENCE

### Halo complex, March 2, 1954

A brilliant halo display, which as seen from some places included phenomena rarely observed, occurred over England, south Scotland and Wales on the afternoon of March 2, 1954. The halo complex was particularly well developed over East Anglia and Lincolnshire. Mr. G. D. Alcock of Farcet, Peterborough, Northamptonshire has sent the following description of his observations and the figure reproduced at Fig. 1:—

An unusual halo phenomenon was seen here on the afternoon of Tuesday, March 2, between 1340 and 1515 G.M.T. A uniform sheet of cirrostratus spread over rapidly from the west. This cloud sheet was quite devoid of any detail, being a uniform milky white, and gradually thickened during the period of observation.

A conspicuous coloured normal  $23^\circ$  halo was first seen with mock suns on either side placed just outside the arc. These mock suns became very brilliant and highly coloured. By 1345 the extreme upper segment of the  $46^\circ$  halo was visible with its upper arc of contact with all spectrum colours brilliantly visible. The mock-sun ring spread equally quickly right round the sky with conspicuous white mock suns at  $329^\circ$  and  $90^\circ$  true bearing (a prismatic compass was used). Then the anthelion became gradually visible. All these three had white arcs through them.

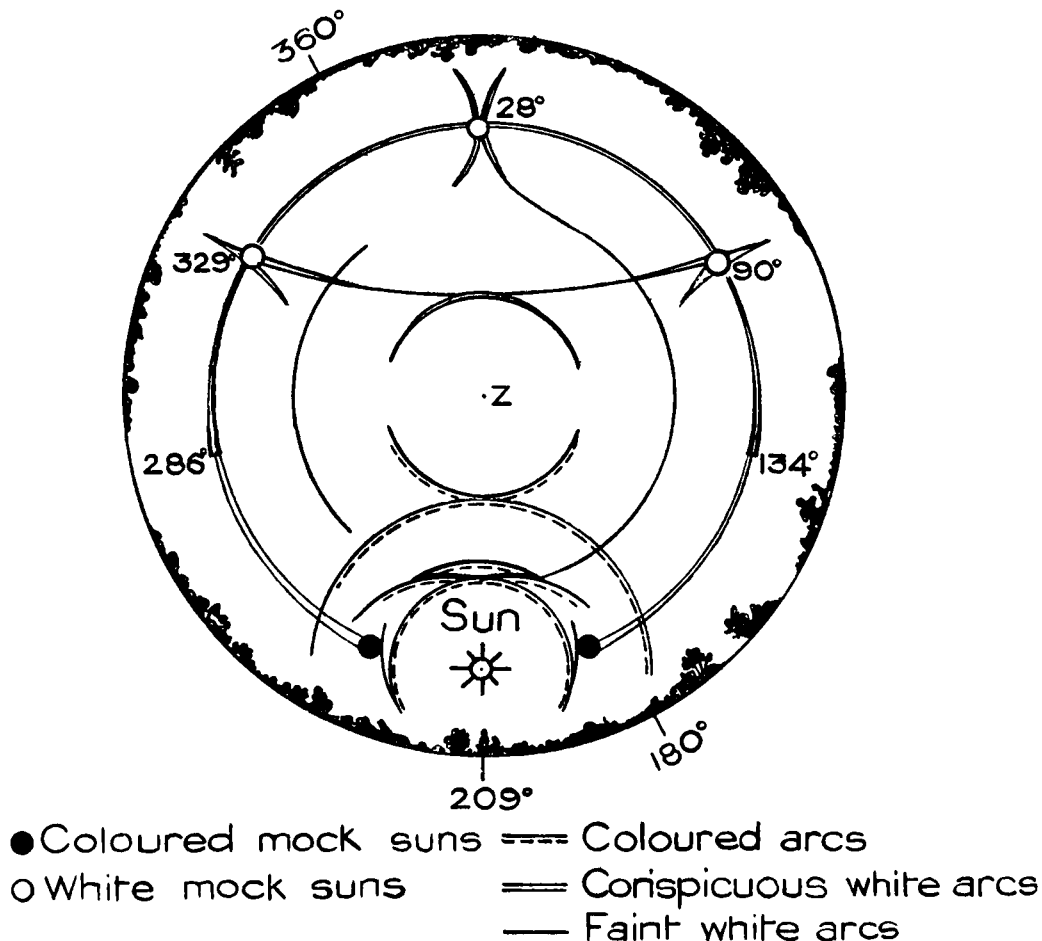


FIG. 1—HALO PHENOMENON, FARCET, PETERBOROUGH  
 1340-1515 G.M.T., MARCH 2, 1954

From 1415 to 1430 a faint arc connected the mock suns and just touched a white segment of zenithal arc opposite the sun. The  $46^\circ$  halo was now very conspicuous especially to the east of the sun and near the southern horizon, where it looked like a bright very narrow rainbow. The phenomenon was most brilliant at 1422 when all arcs shown on the sketch were visible, including one from above the  $23^\circ$  halo to the anthelion. This dipped in an arc as it approached the anthelion as shown in the sketch.

At positions  $286^\circ$  and  $134^\circ$  on the mock-sun ring were clear-cut lines of brilliance from which the mock-sun ring streamed brilliantly away from the sun like comet tails. There were no mock suns at  $286^\circ$  and  $134^\circ$  true bearing.

I have watched for such phenomena since 1933, and this is quite the most uncommon I have so far witnessed.

Mr. A. Blackham of the Meteorological Office, Cranwell, Lincolnshire has represented the phenomena seen by himself and other members of the Cranwell staff in Fig. 2.

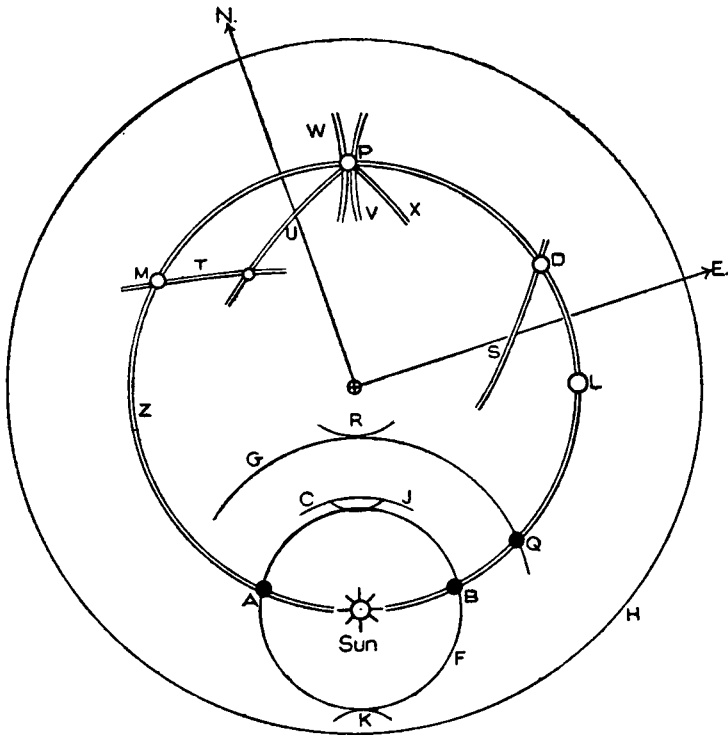


FIG. 2—HALO PHENOMENON, CRANWELL, MARCH 2, 1954

- H horizon
- A, B mock suns at the intersection of the  $22^\circ$  halo and the parhelic circle, containing the spectrum colours, red nearest the sun
- Q mock sun, coloured, at the intersection of the  $46^\circ$  halo and the parhelic circle
- P anthelion, white
- L mock sun, white,  $90^\circ$  from the sun
- D mock sun, white,  $120^\circ$  from the sun
- M mock sun, white,  $240^\circ$  from the sun
- Z parhelic circle, distinct and white and a complete circle
- F  $22^\circ$  halo, complete and faintly coloured
- G  $46^\circ$  halo, faintly coloured, but incomplete
- R arc of contact of  $46^\circ$  halo, brightly coloured
- K lower arc of contact of  $22^\circ$  halo, distinct, faintly coloured
- CJ arc of upper contact, appearing to consist of a concave and a convex arc, both coloured, giving a distorted effect to the curve

S, T, U, } arcs cutting the parhelic circle, all white and quite distinct.  
V, W, X }

All colours were spectrum colours, red nearest the sun in all cases. All angles were measured in azimuth round the parhelic circle, from the sun through east.

Mr. S. E. Ashmore reports that at Wrexham about 1000 he observed a halo complex rivalling the Danzig phenomenon of February 20, 1661 as follows:—

22° halo	Small sun pillar
Two parhelia of the 22° halo	Circumzenithal arc
Most of the circumscribed ellipse	Parhelic circle, nearly complete
Upper Parry arc	One parheliion of 90° with part of the
Partial halo 9–11°	90° halo going through it
46° halo unbroken	One paranthelion with an oblique
Infralateral arcs of the 46° halo	arc through it.

The halo phenomena were also observed at Dunstable by Meteorological Office staff. As the upper protruding parts of the arc of contact with the 22° halo faded, the combination of this arc with the Parry arc appeared to take a sinuous shape, likened by Mr. A. P. Taylor to a “cupid’s bow”.

A large number of other reports have also been received; it is impossible to mention all the individual observers to whom we are indebted for information on the display.

Rare phenomena reported were:—

- (i) The Parry arc above and concave to the sun bridging the arc of contact to the 22° halo seen by several observers including those at Peterborough, Wrexham, Dunstable and Cranwell.
- (ii) Mock suns at 120° and 90° along the parhelic circle on either side of the sun. These were reported by several observers.
- (iii) The anthelion and associated arcs. Mr. Alcock saw two nearly closed anthelic arcs running from the arc of contact to the 22° halo to the anthelion on either side of the zenith.
- (iv) The rare Kern’s arc at the same altitude as the circumzenithal arc above the sun but on the opposite side of the zenith seen by Mr. Alcock.
- (v) The rare Lowitz arcs from the parhelia just outside the 22° halo joining the 22° halo in cusps near the horizon as seen by Mr. Alcock.
- (vi) The arc seen by Mr. Alcock joining the 120° mock suns. Arcs through the two 120° mock suns are seen rarely, and it is rare for them to join. This continuous arc was, however, seen at Ternhill, Shropshire on March 6, 1941\*, and in south Finland on March 10, 1920†. According to Humphreys‡, the arcs through the 120° parhelia are produced by total internal reflections at surfaces inclined at 120° in the same manner as the 120° parhelia. The crystals responsible produce 120° parhelia if their axes are horizontal and arcs if tilted out of the horizontal.

### The Napier Shaw Memorial Prize

The Royal Meteorological Society announces the first competition for the Napier Shaw Prize which has been instituted to commemorate the recent centenary of the birth of Sir Napier Shaw. The competition will be open to anyone without restriction of nationality. The prize of £100 is offered on this occasion for an original essay on “The energetics of the general circulation”.

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\* London, Meteorological Office. Typescript, *Met. Mag.*, London, April, 1941, p. 1.

† MEYER, R.; Die Haloerscheinungen. *Probl. Kosm. Phys.*, Hamburg, 12, 1929, p. 4.

‡ HUMPHREY, W. J.; Physics of the air. New York, 3rd edn, 1940, p. 542.

The essay will be expected to treat of the energy transformations of the circulation as a general theme or any particular aspects of that theme. It may be an essay in which the author describes and discusses the salient and essential features of the general circulation and the energy transformations involved; it may be an essay which attempts an adequate synopsis and discussion of the observations, or a study of the thermodynamics and hydrodynamics of the circulation; or the essay may treat of any combination of these within the general theme.

Further particulars can be obtained from the Assistant Secretary, Royal Meteorological Society, 49 Cromwell Road, London, S.W.7. Essays for the competition must be received at the Society's Offices not later than March 4, 1956. All correspondence should be marked clearly "Napier Shaw Prize".

### REVIEW

*Climatology*. By A. Austin Miller. 8 $\frac{3}{4}$  in.  $\times$  5 $\frac{3}{4}$  in., pp. x + 318, *Illus.*, Methuen & Co. Ltd, London, 8th edition, 1954. Price: 21s.

When the third edition of this well known textbook appeared in January 1944 it was pleasing to find that the author had revised his work by adding a chapter on the concept of air masses and fronts. He thus modified, in part, what was originally a mainly statistical approach to the subject by a more dynamical approach. In the latest (1954) edition one finds that there has been further revision, but that this consists chiefly of the refinement of a regional system of climatic classification and an overhaul of the chapter dealing with changes of climate. One could have wished that the author had extended the dynamical approach by including some discussion of the mechanism of climate in the light of studies which have been made in recent years on the general circulation of the atmosphere. However, as is clearly stated in the Preface, the book is intended primarily for geographers who no doubt are more concerned with physical rather than with dynamic climatology, and on the basis of climatic types the author aims at giving a descriptive but reasoned account of the world's climate with special reference to the human aspect.

Although a smaller type has been used the number of pages is about the same and the general layout remains unchanged. After an introductory chapter on the meaning and scope of climatology there follow chapters dealing with the elements and factors of climate. Next there is the chapter on air masses and then the "key" chapter on the classification of climates. Many workers have toyed with the classification of climates and have produced different criteria varying according to the factors considered and the requirements of the user. In this case the intention is to define geographical regions. From a study of types of vegetation and applying specified threshold values for plant growth the author examines, in conjunction with the distribution of surface winds, the available data for the seasonal distribution of rainfall and temperature with particular reference to the length of dry and cold seasons and thereby defines a number of main and subsidiary types of climate. These types are discussed in greater detail, and on a regional basis, in the ten following chapters which include tables of monthly temperature and rainfall for nearly 300 stations. In the light of new knowledge arising, in particular, from the increasing amount of upper air data a meteorologist, especially one with experience in the regions concerned, might differ from the author here and there especially in regard to the causes of various phenomena—but then meteorologists may not yet be able to agree among themselves!

The final chapter relates to changes of climate and gives an outline of the more important work on the subject and a tentative account of the evolution of climate. No mention is made, however, of recent studies, e.g. by H. C. Willett, on the periodic fluctuations of the general circulation of the atmosphere, or of the ocean-bed research described by J. D. H. Wiseman and Hans Petterson, or of the technique of radio-carbon dating as employed by W. D. Urey. In fact in the "Suggestions for further reading" at the end of each chapter—an excellent idea if the references given are up to date—it would appear that some of the interesting publications of recent times have been overlooked, e.g. "Climate in everyday life" by C. E. P. Brooks. Nevertheless it can be said that the author has a right to feel that, in general, he has succeeded in his task.

Apart from one or two slips in the spelling of names and an incorrect reference to Fig. 33 on page 98 the reproduction of text and diagrams is good. It would appear that the index needs bringing up to date. For example, it does not include the name of H. W. von Ahlmann whose glaciological investigations are mentioned on page 303.

R. G. VERYARD

### OBITUARIES

*John Nelson Bennett.*—We regret to announce the death of Mr. J. N. Bennett (Scientific Assistant) on April 22, 1954 as a result of a climbing accident on Sergeants Crag, Langstrath, Cumberland. Mr. Bennett joined the Office in 1947 and practically the whole of his service was spent at radio-sonde stations. At the time of his death he was stationed at Fazakerley.

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*Leonard William Dolley.*—We also regret to announce the sudden death of Mr. L. W. Dolley, Executive Officer at the Ocean Weather Ship Base, Greenock, which occurred at Gourock on March 30, 1954. Mr. Dolley was posted to the Ocean Weather Ship Base in 1948 where he carried out the duties of Base Accountant and assistant to the Shore Captain.

### METEOROLOGICAL OFFICE NEWS

**Studentships at the Royal Military College of Science, Shrivenham.**—We congratulate Mr. J. R. Grundy, Assistant Experimental Officer, Little Rissington, on his selection for an award of a studentship at the Royal Military College, Shrivenham, to be taken up in the autumn of 1954.

**Sports Activities.**—*Motoring.*—Mr. C. H. R. Lane, Scientific Assistant, London Airport, received a first-class award in the Navigation Rally held by the Civil Service Motoring Association on February 28 last. The navigator was Mr. P. J. Cutting, Scientific Assistant, Kew Observatory.

*Football.*—The Meteorological Office "A" team defeated the Directorate General of Organization by 6 goals to nil in the final of the competition for the Air Ministry Football Cup at Northolt on May 4. This is the seventh consecutive occasion on which the Office has won the competition. It was unfortunate that the Meteorological Office "B" team from Harrow and Uxbridge were drawn to play the "A" team in an early round of the competition.

### WEATHER OF APRIL 1954

Mean pressure was above normal over the whole of Europe, including the Mediterranean and the greatest excess occurred in the west of this region; the mean pressure exceeded 1020 mb. in the north and west of France where it was

as much as 9 mb. above normal. The mean pressure at the Azores, 1024 mb., was 1 mb. above normal and it was also above normal over most of North America.

The mean temperature over most of Europe was 4°F. below normal; this was associated with the gradient for north-easterly winds corresponding to the mean pressure distribution. The mean temperature over much of the United States was 5°F. above normal.

In the British Isles the weather was sunny and very dry; mean temperature was about or slightly above the average in Scotland and somewhat below the average in England and Wales; night frost was unusually frequent and there were no notably warm days. A changeable westerly type of weather prevailed for the first few days but afterwards conditions were mainly anticyclonic.

In the opening days Atlantic depressions moved along our north-west seaboard and associated fronts crossed the British Isles; rain fell generally. On the 3rd a deep depression near the north-west coast of Scotland gave rain generally and gales at exposed places on the coasts of north-west Ireland and north Scotland. The depression moved away north-east and in its rear a north-westerly air stream spread over the British Isles and showers occurred with hail, sleet and thunder in places, mainly in the north and west on the 4th and more generally on the 5th. Snow fell on some of the high ground, including Dartmoor, later on the 5th when a small disturbance moved from north-west Ireland to Brittany. A wedge of high pressure moved in over the British Isles from the west on the 6th and later became part of a belt of high pressure from the Azores across England to Scandinavia, which lasted until the 11th. Weak fronts moved east across the country on the 12th but another anticyclone approached south-west Ireland on the 13th and dominated conditions over most of the country until the 19th. Subsequently pressure became high to the north of Scotland, with a ridge extending southward over the British Isles; persistent NE. winds gave cold weather on the east coast up to the 28th but there were sunny periods generally and much sunshine in the west. The dry spell began over England and Wales on the 6th and lasted with small local interruptions until the 29th, amounting to an absolute drought over a substantial area. In Scotland and Ireland, rainfall was not large from the 6th to the 17th, and from the 18th to the 28th the weather was almost entirely dry. On the 29th a slow-moving cold front moved southward over northern districts, with some rain, considerable in amount locally in east Scotland. Snow fell locally in Scotland and thunderstorms occurred at some places in the Midlands and east of England on the 30th.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Per-centage of average	No. of days difference from average	Per-centage of average
	°F.	°F.	°F.	%		%
England and Wales ...	67	20	—1·4	29	—8	121
Scotland ...	66	20	+0·5	66	—6	127
Northern Ireland ...	61	27	—0·1	35	—8	117

# RAINFALL OF APRIL 1954

## Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
<i>London</i>	Camden Square ...	0·29	19	<i>Glam.</i>	Cardiff, Penylan ...	0·88	35
<i>Kent</i>	Dover ...	0·22	14	<i>Pemb.</i>	Tenby, The Priory ...	0·87	38
<i>„</i>	Edenbridge, Falconhurst ...	0·52	28	<i>Radnor</i>	Tyrmynydd ...	1·20	33
<i>Sussex</i>	Compton, Compton Ho. ...	0·38	19	<i>Mont.</i>	Lake Vyrnwy ...	1·96	62
<i>„</i>	Worthing, Beach Ho. Pk. ...	0·42	27	<i>Mer.</i>	Blaenau Festiniog ...	4·57	74
<i>Hants.</i>	Ventnor Cemetery ...	0·41	24	<i>„</i>	Aberdovey ...	1·68	65
<i>„</i>	Southampton, East Pk. ...	0·24	13	<i>Carn.</i>	Llandudno ...	1·37	81
<i>„</i>	South Farnborough ...	0·25	16	<i>Angl.</i>	Llanerchymedd ...	1·12	51
<i>Herts.</i>	Royston, Therfield Rec. ...	0·22	14	<i>I. Man</i>	Douglas, Borough Cem. ...	0·57	23
<i>Bucks.</i>	Slough, Upton ...	0·36	25	<i>Wigtown</i>	Newton Stewart ...	1·45	57
<i>Oxford</i>	Oxford, Radcliffe ...	0·39	24	<i>Dumf.</i>	Dumfries, Crichton R.I. ...	0·89	38
<i>N'hants.</i>	Wellingboro' Swanspool ...	0·22	15	<i>„</i>	Eskdalemuir Obsy. ...	1·40	41
<i>Essex</i>	Shoeburyness ...	0·26	21	<i>Roxb.</i>	Crailling ...	0·72	45
<i>„</i>	Dovercourt ...	0·23	18	<i>Peebles</i>	Stobo Castle ...	0·90	43
<i>Suffolk</i>	Lowestoft Sec. School ...	0·37	25	<i>Berwick</i>	Marchmont House ...	0·70	35
<i>„</i>	Bury St. Ed., Westley H. ...	0·41	27	<i>E. Loth.</i>	North Berwick Res. ...	1·60	114
<i>Norfolk</i>	Sandringham Ho. Gdns. ...	0·43	28	<i>Mid'l'n.</i>	Edinburgh, Blackf'd. H. ...	1·22	83
<i>Wilts.</i>	Aldbourn ...	0·40	22	<i>Lanark</i>	Hamilton W. W., T'nhill ...	1·57	84
<i>Dorset</i>	Creech Grange ...	0·19	9	<i>Ayr</i>	Colmonell, Knockdolian ...	1·11	44
<i>„</i>	Beaminster, East St. ...	0·32	14	<i>„</i>	Glen Afton, Ayr San. ...	2·36	79
<i>Devon</i>	Teignmouth, Den Gdns. ...	0·12	6	<i>Renfrew</i>	Greenock, Prospect Hill ...	2·88	84
<i>„</i>	Ilfracombe ...	0·70	33	<i>Bute</i>	Rothesay, Ardenraig ...	2·19	73
<i>„</i>	Princetown ...	1·61	32	<i>Argyll</i>	Morven, Drimnin ...	..	..
<i>Cornwall</i>	Bude, School House ...	0·79	42	<i>„</i>	Poltalloch ...	2·47	82
<i>„</i>	Penzance, Morrab Gdns. ...	0·84	35	<i>„</i>	Inveraray Castle ...	4·23	92
<i>„</i>	St. Austell ...	0·85	30	<i>„</i>	Islay, Eallabus ...	1·65	57
<i>„</i>	Scilly, Tresco Abbey ...	0·57	29	<i>„</i>	Tiree ...	1·41	57
<i>Somerset</i>	Taunton ...	0·14	8	<i>Kinross</i>	Loch Leven Sluice ...	1·36	71
<i>Glos.</i>	Cirencester ...	0·45	24	<i>Fife</i>	Leuchars Airfield ...	1·69	106
<i>Salop</i>	Church Stretton ...	0·74	34	<i>Perth</i>	Loch Dhu ...	3·54	75
<i>„</i>	Shrewsbury, Monkmore ...	0·46	31	<i>„</i>	Crieff, Strathearn Hyd. ...	1·38	63
<i>Worcs.</i>	Malvern, Free Library ...	0·45	25	<i>„</i>	Pitlochry, Fincastle ...	0·96	43
<i>Warwick</i>	Birmingham, Edgbaston ...	0·62	36	<i>Angus</i>	Montrose, Sunnyside ...	0·94	52
<i>Leics.</i>	Thornton Reservoir ...	0·47	28	<i>Aberd.</i>	Braemar ...	0·96	41
<i>Lincs.</i>	Boston, Skirbeck ...	0·32	24	<i>„</i>	Dyce, Craibstone ...	1·53	74
<i>„</i>	Skegness, Marine Gdns. ...	0·44	33	<i>„</i>	New Deer School House ...	1·18	59
<i>Notts.</i>	Mansfield, Carr Bank ...	0·36	21	<i>Moray</i>	Gordon Castle ...	0·81	46
<i>Derby</i>	Buxton, Terrace Slopes ...	0·88	30	<i>Nairn</i>	Nairn, Achareidh ...	0·86	61
<i>Ches.</i>	Bidston Observatory ...	0·65	40	<i>Inverness</i>	Loch Ness, Garthbeg ...	1·72	75
<i>„</i>	Manchester, Ringway ...	0·58	32	<i>„</i>	Glenquoich ...	4·42	68
<i>Lancs.</i>	Stonyhurst College ...	1·47	54	<i>„</i>	Fort William, Teviot ...	3·12	69
<i>„</i>	Squires Gate ...	1·06	60	<i>„</i>	Skye, Broadford ...	2·43	54
<i>Yorks.</i>	Wakefield, Clarence Pk. ...	0·28	17	<i>„</i>	Skye, Duntuilim ...	2·12	65
<i>„</i>	Hull, Pearson Park ...	0·19	12	<i>R. &amp; C.</i>	Tain, Mayfield ...	0·90	49
<i>„</i>	Felixkirk, Mt. St. John ...	0·25	15	<i>„</i>	Inverbroom, Glackour ...	2·50	67
<i>„</i>	York Museum ...	0·22	14	<i>„</i>	Achnashellach ...	4·10	77
<i>„</i>	Scarborough ...	0·20	13	<i>Suth.</i>	Lochinver, Bank Ho. ...	1·83	64
<i>„</i>	Middlesbrough ...	0·16	12	<i>Caith.</i>	Wick Airfield ...	1·10	55
<i>„</i>	Baldersdale, Hury Res. ...	0·73	33	<i>Shetland</i>	Lerwick Observatory ...	2·14	93
<i>Nor'l'd.</i>	Newcastle, Leazes Pk. ...	0·52	33	<i>Ferm.</i>	Crom Castle ...	0·82	32
<i>„</i>	Bellingham, High Green ...	0·53	25	<i>Armagh</i>	Armagh Observatory ...	0·50	24
<i>„</i>	Lilburn Tower Gdns. ...	0·63	32	<i>Down</i>	Seaford ...	0·60	23
<i>Cumb.</i>	Geltsdale ...	0·82	38	<i>Antrim</i>	Aldergrove Airfield ...	0·38	18
<i>„</i>	Keswick, High Hill ...	1·16	38	<i>„</i>	Ballymena, Harryville ...	0·61	23
<i>„</i>	Ravenglass, The Grove ...	0·86	35	<i>L'derry</i>	Garvagh, Moneydig ...	1·08	44
<i>Mon.</i>	A'gavenny, Plas Derwen ...	0·17	6	<i>„</i>	Londonderry, Creggan ...	1·51	59
<i>Glam.</i>	Ystalyfera, Wern House ...	1·88	49	<i>Tyrone</i>	Omagh, Edenfel ...	1·40	53