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SOME AERIAL EXPLORATIONS OF COASTAL AIRFLOW

By J. FINDLATER

Introduction.—Several descriptive accounts of sea-breeze fronts and their penetration inland have been written, [1,2,3] deduced mainly from analyses of plan-view charts and surface autographic records. Unusual cloud structures associated with the sea-breeze front have been described by sailplane pilots and others [4,5,6] but their explorations have necessarily been confined mainly to the zone of rising air close to the sea-breeze front and, so far as is known, no detailed temperature and moisture content measurements have been made across these zones in this country.

The structure of sea breezes and their associated convergence zones has considerable bearing on a number of important forecasting problems, e.g. formation of showers in the convergence zone,[7] penetration of sea air inland leading to relatively low maximum temperatures, and the amount of cloud in the coastal strip. It was with the aim of exploring the upper structures of sea breezes and, in particular, of their convergence zones that this investigation was undertaken.

Organization.—The plan adopted was to concentrate the maximum observational effort into a small area on a few chosen days rather than to accumulate relatively fragmentary data distributed widely in space and time. The line chosen for the investigation was the 52 nautical mile route from White Waltham to the Owers lightship (50°37'N 00°41'W).

Primary observations were made in the air from a Chipmunk aircraft, equipped with an electrical resistance psychrometer and an aneroid barometer, and manned by a pilot and a meteorologist. The aircraft flew along the selected line between White Waltham and the Owers lightship at varying heights, measured above mean sea level, whilst taking dry- and wet-bulb temperature measurements approximately every two minutes. Cruising air-speed was 85–90 knots. Visual observations of cloud, haze, smoke and smoke drift were also made. On the south-bound leg of the flight the aircraft was flown at 1500 feet until either the sea-breeze convergence zone or the coast was passed, when it gradually descended close to the sea surface to make a near-vertical sounding in the vicinity of the Owers lightship, 10 nautical miles offshore. The flight path followed thereafter was dependent on the position of the sea-breeze front as indicated by readings on the south-bound flight and observations of cloud, haze and smoke drift which might reveal the limit of the sea air. The flight path was also influenced by flight regulations concerning airways and controlled airspace.

The scope of the investigation was planned to contain the more vigorous springtime sea breezes which penetrate more than 35 miles inland and influence developments up to at least 5000 feet, but during investigations in 1961 the organization proved adequate to study the weak and shallow sea breezes in autumn.

The investigation was planned for a maximum of two selected days per month, on week-days only. To supplement the aircraft observations made during the period 1330–1515 GMT, a number of ground stations co-operated by making pilot balloon observations and recording other relevant data. Pilot balloon ascents to 5000 feet at 1300, 1400 and 1500 GMT were made from White Waltham, Farnborough, Odiham, Wormley, Cocking, Thorney Island and Tangmere; in addition the London Weather Centre maintained a radar watch over the route to record precipitation echoes from 1300 to 1700 GMT. The locations of these stations relative to the investigation line are shown in Figures 1 and 2. All the official observing stations listed, and also Wormley,

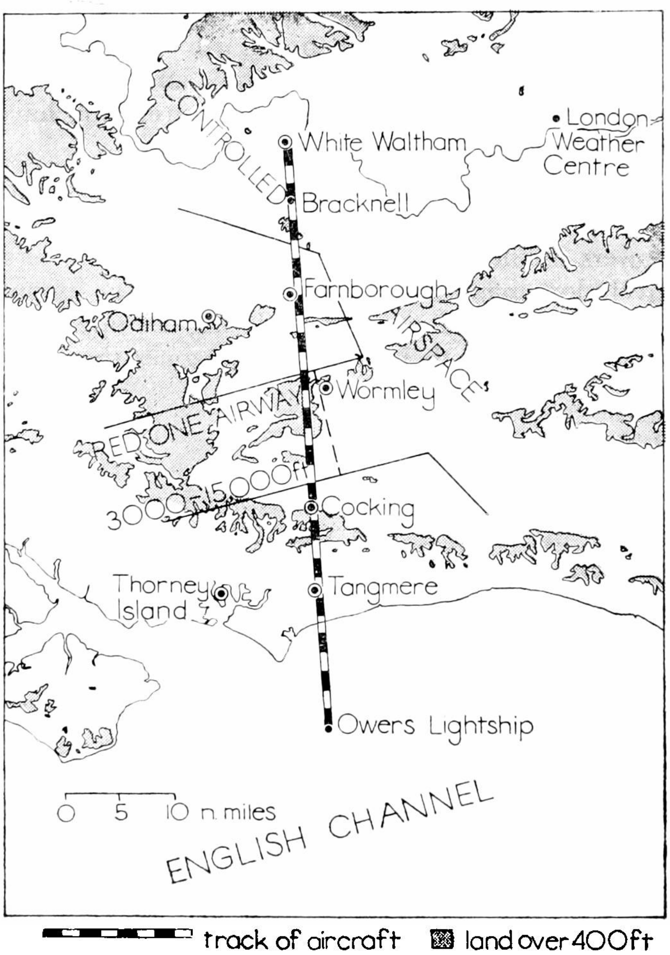

FIGURE 1—LOCATION OF CO-OPERATING STATIONS
Pilot balloon stations are ringed.

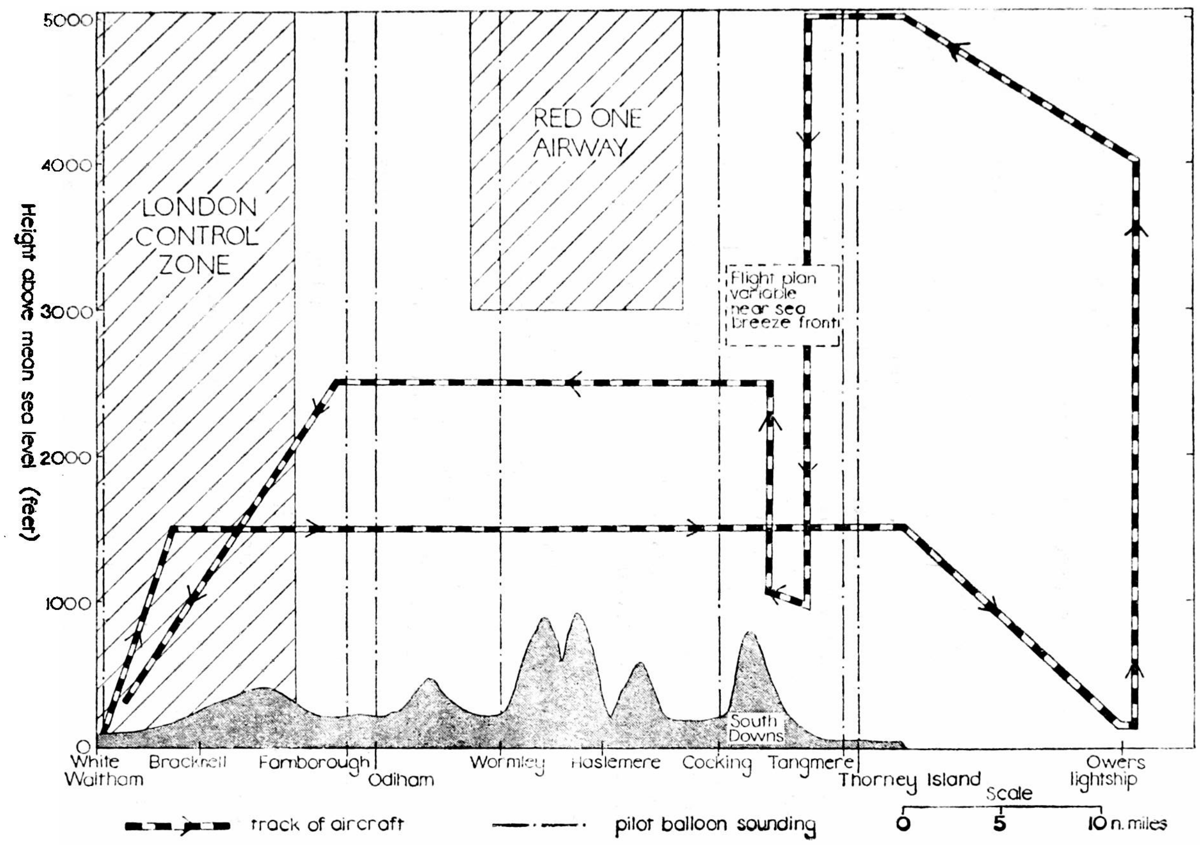

FIGURE 2—FLIGHT PLAN AND POSITIONS OF PILOT BALLOON SOUNDINGS

manned by staff of the National Institute of Oceanography, provided normal hourly observations and autographic records.

On days which were considered suitable for investigation all participants were informed by telephone by 0900 GMT and subsequently carried out the programme noted above. During 1961, operations were only possible during the autumn when sea breezes were weak and fickle; four investigation days were declared and on the first three full programmes were carried out. On the fourth day flight observations were cancelled owing to aircraft unserviceability and only the wind programme was carried out.

Instrumentation.—

Ground stations.—For the surface and pilot balloon observations standard observing equipment was used at the stations listed above and shown in Figure 1.

Aircraft.—The aircraft was equipped with a Meteorological Office aircraft electrical resistance psychrometer Mk 1b calibrated in degrees Fahrenheit and readable to one half degree. Readings from this instrument were corrected for errors due to ambient pressure, speed and position, in addition to the normal instrument errors, and subsequently converted to degrees Celsius. An aircraft aneroid barometer Mk 2b was also carried. Dry- and wet-bulb temperatures were measured against height on an ordinary aircraft altimeter set to sea-level pressure and check readings were taken at various levels.

Aircraft temperature readings taken on take-off and landing were compared with simultaneous measurements made at White Waltham with an Assmann psychrometer. During ascents and descents vertical speeds were limited to 300 feet per minute to prevent errors due to the lag of the instrument.

Analysis.—

Day 1—29 August 1961—hot with south-easterly winds, no sea-breeze development.—The afternoon was hot and cloudless with stable air flowing from the south-east. Surface temperatures exceeded 30°C over the northern part of the investigation route during the afternoon, although a stable layer at 1500-2000 feet limited the penetration of dry thermal convection from the surface. With moderate on-shore winds no sea-breeze effect could be detected—the cool sea air warmed up rapidly within a few miles of the coast. Cross-sections of temperature, moisture content and wind are shown in Figures 3 and 4. Of particular interest is the very warm air over the sea at levels between 500 and 2500 feet, and the cooler air over the South Downs and the hills around Haslemere. A trajectory of the sea air at about 1000 feet showed that the air had been over France some six hours earlier and that the extreme warmth of the air could be accounted for by heating over the continent.

A streamline of the vertical displacement likely to be followed by the sea air is shown in Figure 3 and marked upon it are temperatures which would result from adiabatic changes. These temperatures are consistent with the recorded temperatures and they suggest that the temperature patterns were due to adiabatic changes brought about by topography. The pattern of moisture content lends support to this suggestion.

Each of the pilot balloon stations released balloons at 1300, 1400 and 1500 GMT but of these only those at 1400 GMT are plotted on cross-sections. Little coastal effect is noticeable in this case, but the increase of wind with height up to 1000 feet just north of the South Downs is very well marked.

Day 2—31 *August* 1961—*light east to north-easterly wind, weak sea breeze.*—This day was cloudless also but the surface temperatures were about 5°C cooler than on 29 August in mid-afternoon and the light winds inland were directed mainly offshore. A stable layer was again based at 1500–2000 feet with dry thermal activity below this level. A well marked, although weak, sea breeze set in at Tangmere shortly after 1300 GMT and reached a little to the north of the South Downs before dying out in the evening. At the onset of the sea breeze at Tangmere the surface wind, previously 080 degrees 8 knots, veered to 140 degrees 3 knots and then steadily changed to 160 degrees 10 knots; the dew-point rose by 2°C as the sea air arrived. Cross-sections of temperature, moisture content and wind are shown in Figures 5 and 6.

The sea-breeze convergence zone was made readily visible by a wall of smoke from south-coast towns and numerous field fires. The smoke tracked inland and kept close to the ground in the stable south-easterly sea breeze and changed direction abruptly at the sea-breeze front; easterly to north-easterly winds on the north side of the front sheared the smoke to the west while at the same time it was carried aloft to form a relatively thin wall of about one mile in horizontal extent at 1200 feet. In the stable layer the smoke, considerably thinned, stretched back towards the coast in a tenuous layer eventually overlying the sheet of warm air offshore.

On this day both the temperature and moisture patterns showed that the sea air was twice as deep over Tangmere as it was a few miles out to sea. At 10–12 miles offshore, however, the air was a little cooler and considerably moister up to heights of about 2000 feet than it was just offshore, where subsidence would most probably have been taking place. Wind profiles showed little or no on- or off-shore flow except at Tangmere where the balloon sounding at 1400 GMT showed a marked sea breeze up to 1500 feet with the maximum speed just above the surface, and return flow seawards from 1500 to 3000 feet. Neither of these effects was noticeable at Cocking.

Day 3—19 *September* 1961—*moderate south-westerly winds, weak sea breeze.*—This was a cloudy day with large amounts of altocumulus and altostratus aloft. Temperatures of 22°C produced small cumulus overland at 2000–2500 feet in the fairly moist air spreading in from the south-west. A sea-breeze effect was indicated at Tangmere by the backing of the surface wind to 210 degrees at approximately 1400 GMT and the growth of a zone of deeper cumulus a little way inland. The relevant cross-sections are shown in Figures 7 and 8.

The air over the sea was completely clear of low cloud except for one tenuous lenticular patch of stratus with top at 400 feet lying some 4 nautical miles south-east of Selsey Bill. The position and approximate size and shape of this cloud are shown inserted into Figure 7 as also are the convergence zones indicated by cumulus grouping. The lenticular patch was stationary over the period for which it was observed, about 30 minutes, but it is difficult to visualize the mechanism whereby it persisted. No deviation from course was made to explore this interesting cloud or the surrounding air.

As soon as the air from the sea crossed the coast, fragments of cloud formed at 500 feet and the base lifted rapidly to become 1000 feet over Tangmere, while at the same time the cloud grew into cumulus quite different in size and organization from that inland. Thin veils of pileus cloud overlay the cumulus in the early stages of growth, in a similar fashion to the case reported by

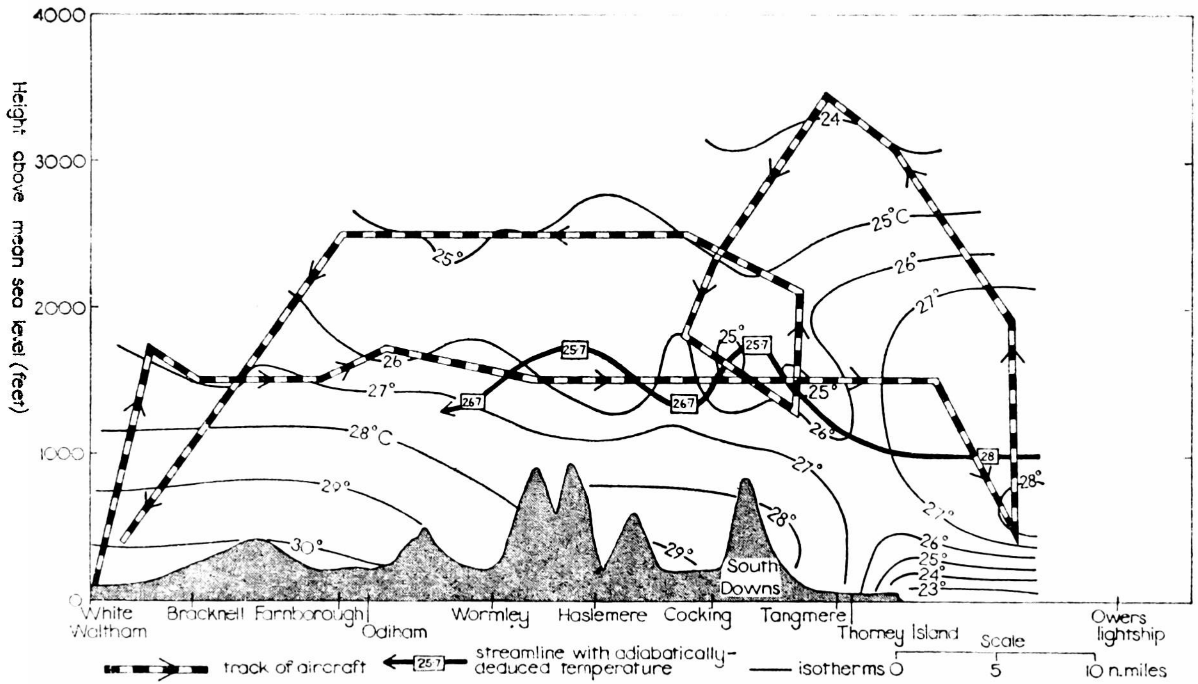

FIGURE 3—ANALYSIS OF DRY-BULB TEMPERATURE, 29 AUGUST 1961, AT APPROXIMATELY 1430 GMT

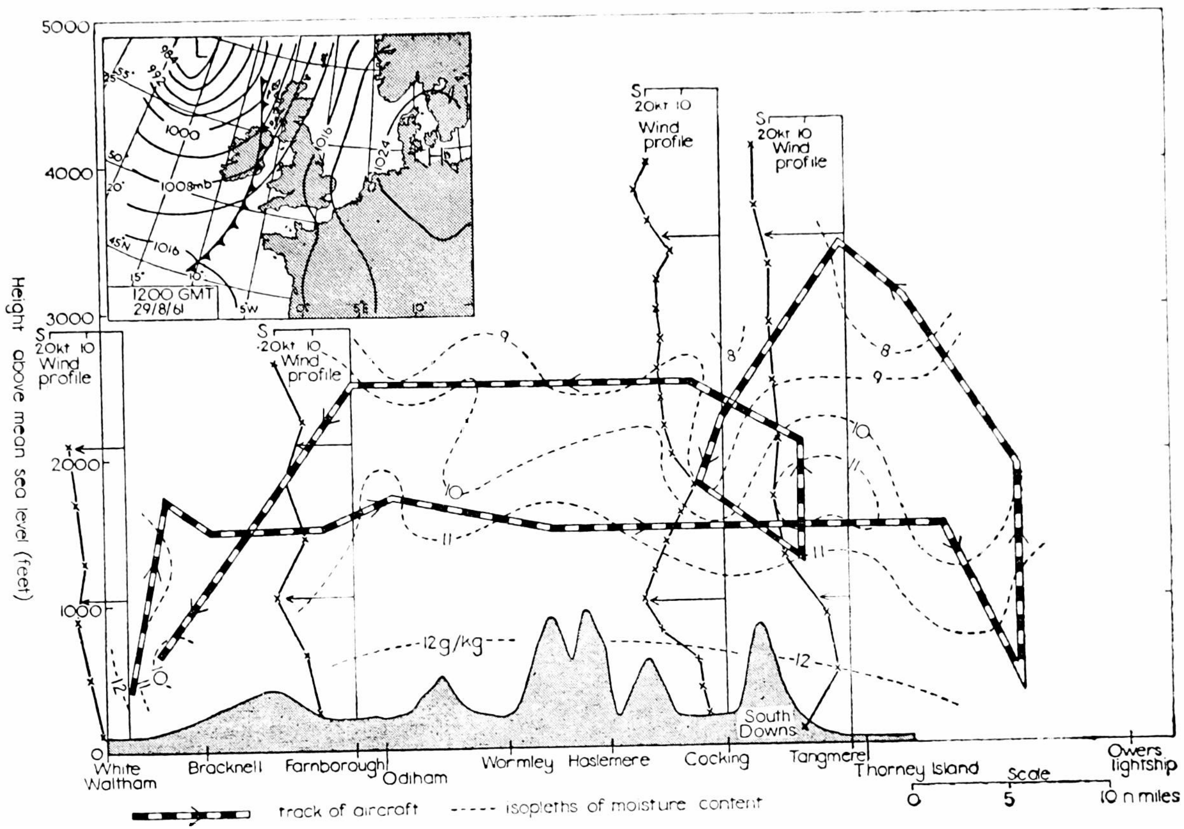

FIGURE 4—WIND PROFILES AND MOISTURE CONTENT ANALYSIS, 29 AUGUST 1961, AT APPROXIMATELY 1430 GMT

Inset shows the synoptic situation at 1200 GMT.

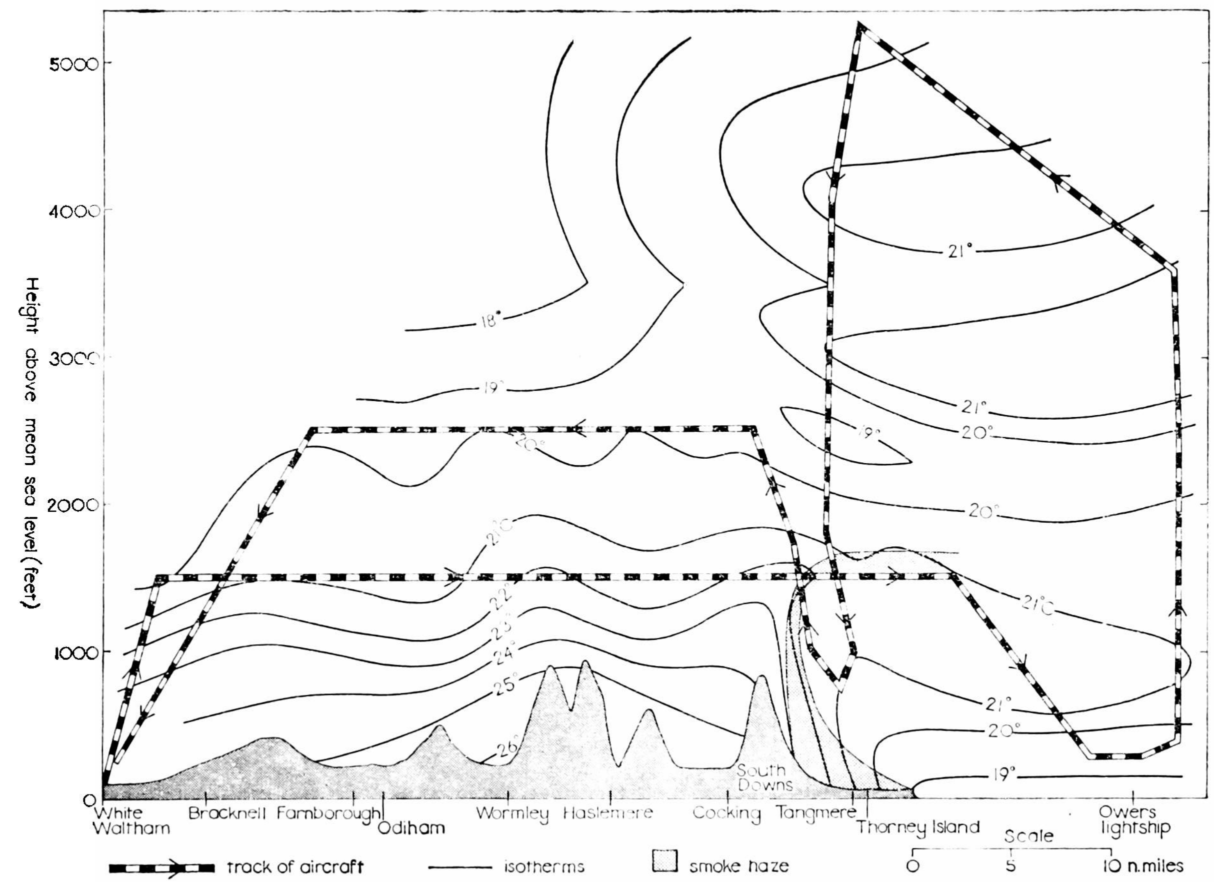

FIGURE 5—ANALYSIS OF DRY-BULB TEMPERATURE, 31 AUGUST 1961, AT APPROXIMATELY 1430 GMT

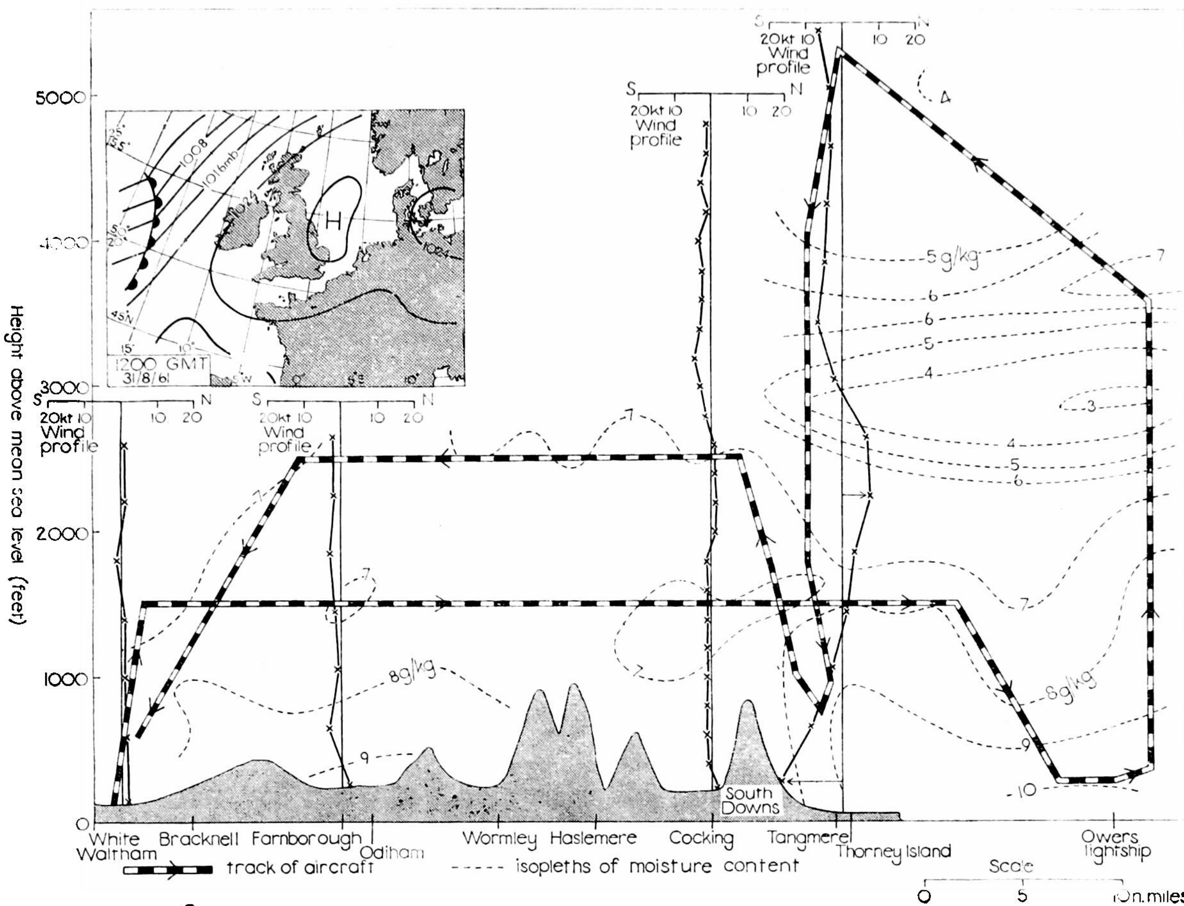

FIGURE 6—WIND PROFILES AND MOISTURE CONTENT ANALYSIS, 31 AUGUST 1961, AT APPROXIMATELY 1430 GMT

Inset shows the synoptic situation at 1200 GMT.

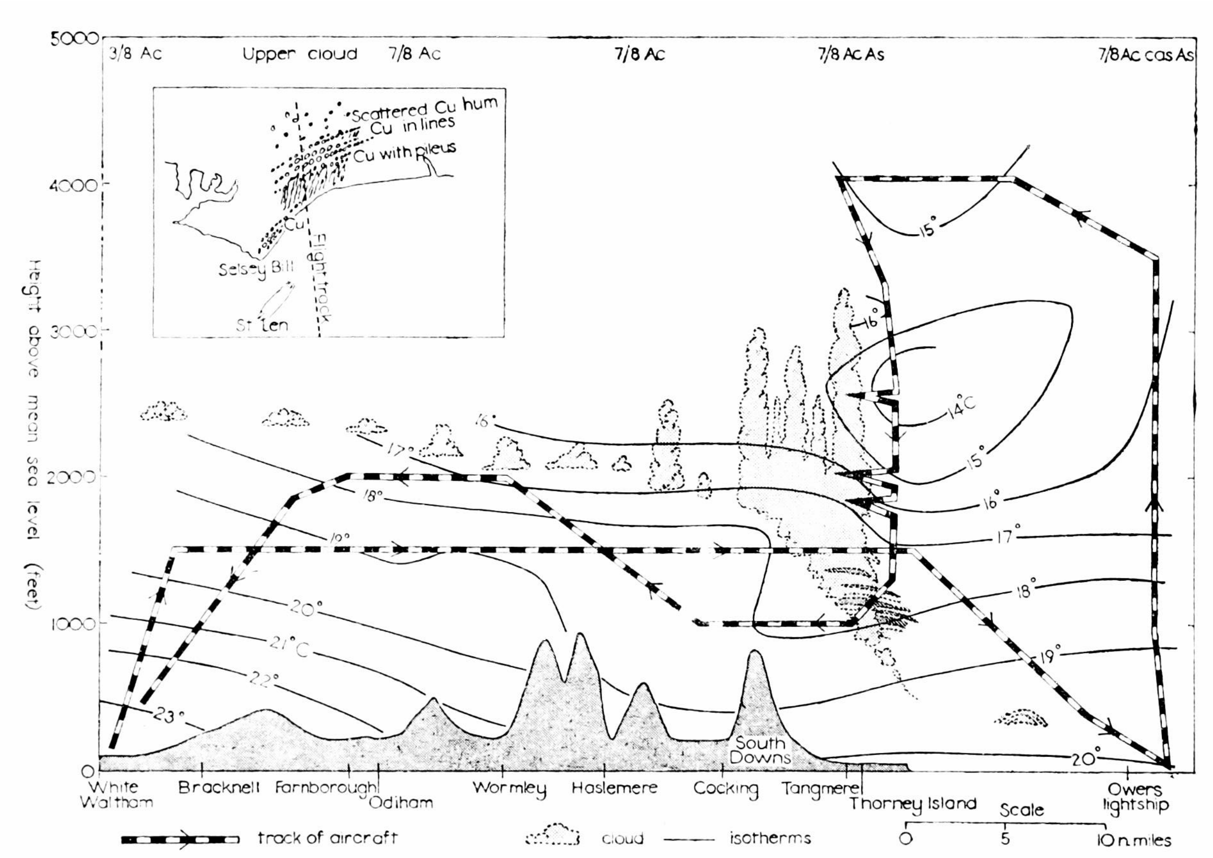

FIGURE 7—ANALYSIS OF DRY-BULB TEMPERATURE, 19 SEPTEMBER 1961, AT APPROXIMATELY 1430 GMT

Inset shows the distribution of cloud at the same time.

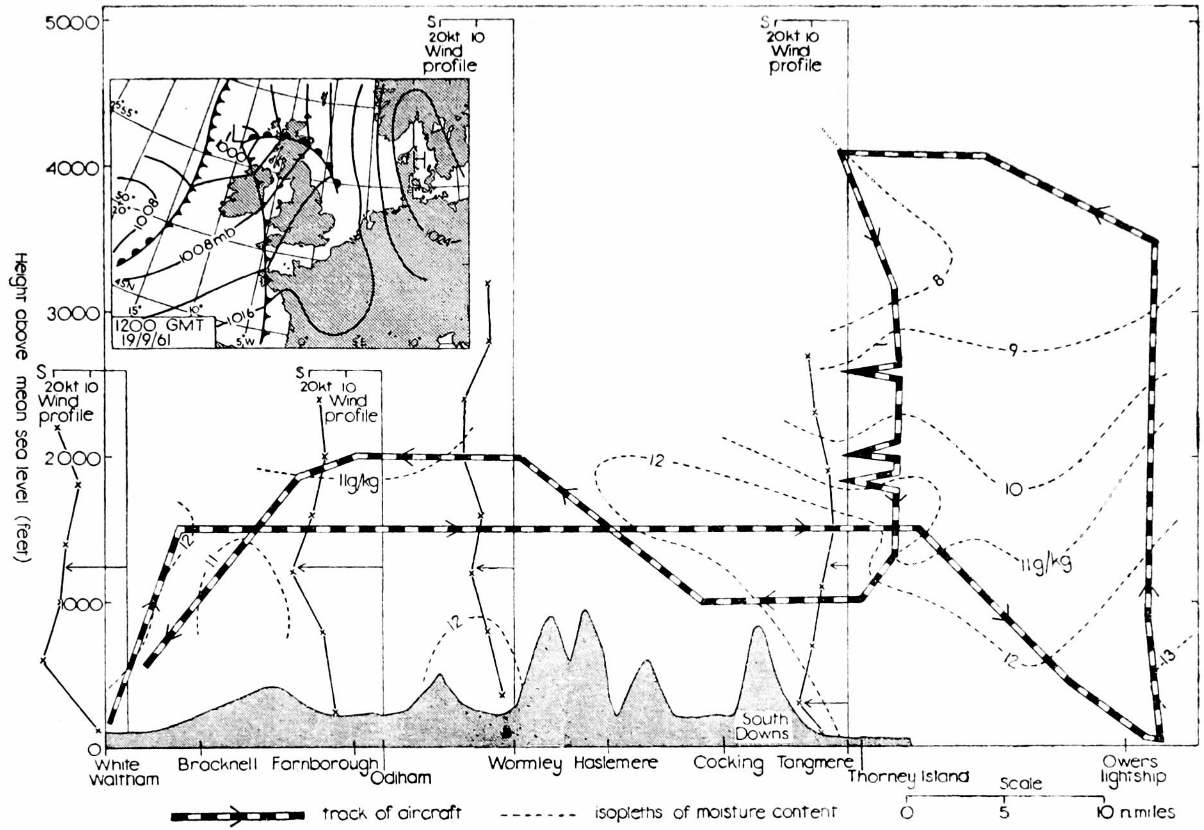

FIGURE 8—WIND PROFILES AND MOISTURE CONTENT ANALYSIS, 19 SEPTEMBER 1961, AT APPROXIMATELY 1430 GMT

Inset shows the synoptic situation at 1200 GMT.

Malkus.[6] Highest tops were at 3300 feet. The temperature pattern showed a region of marked horizontal temperature change in the convergence zone at a height of 2000 feet in association with the presence, or formation, of a cool area at 1500 feet. The most vigorous cumulus clouds were over Tangmere aerodrome and these were probably not due to orographic lifting over the South Downs since the temperature pattern in which they grew could not have been generated by obvious topographical effects.

Another feature of interest was that although the vigorous convergence zone lay over the southern coastal strip, sea air with an almost isothermal lapse rate from 500 to 1500 feet penetrated well to the north of this zone. On the cross-section shown in Figure 7 this stable air had reached the hills around Haslemere. By about 1530 GMT the stable air penetrated to Lasham, some 5 nautical miles south-west of Odiham, and caused the sudden disappearance of good thermal up-currents in which gliders from Lasham were flying.

The cross-section of moisture content shown in Figure 8 shows that the more stable air which penetrated to Haslemere was also more moist and it seems likely that significantly moister sea air, whether or not it was of true sea-breeze origin, had passed through or below the convergence zone marked by the cumulus near Tangmere.

Wind profiles for 1400 GMT are shown in Figure 8. The sounding made at Tangmere reveals an increased on-shore component at low levels which was associated with the backing of the surface wind from 230–240 degrees to 210 degrees for a period of 2 hours. Also the wind component at 1500 feet over Tangmere in the region of cumulus growth is reduced.

Discussion.—The cases of 29 and 31 August 1961, form a useful comparison between a case where a sea-breeze convergence zone did not form and one where it did, both with very stable air above about 1500–2000 feet. The obvious difference is in the wind structure, with no convergence zone forming when the general wind was blowing onshore, but it is probable that if the air had been moist enough to allow condensation in the adiabatically cooled region over the South Downs, the resulting formation of shallow cumulus and the release of latent heat would have accelerated the upward flow of air.

The structure of the sea breeze aloft on 31 August is somewhat surprisingly definite considering the weakness of the surface breeze. The penetration of cool and moist sea air is very well marked up to 1500 feet and, although the breeze itself only moved about 10 miles inland, the patterns of temperature and moisture suggest that the effects of the sea-breeze formation were noticeable 10–12 nautical miles out to sea.

The third case is perhaps the most interesting since there is evidence that moist and stable air was penetrating northwards at low level, although a convergence zone was marked by cloud near the coast.

The cases explored to date are, of course, too few to draw any general conclusions but the analyses of the data gathered reveal a number of interesting features of coastal airflow in relatively stable conditions.

Acknowledgements.—Acknowledgement is made of the ready co-operation and assistance in this investigation of Air Commodore A. G. Dudgeon, C.B.E., D.F.C., F/Lt. Gifford, F/O.'s Patrick and Harris of RAF, White

Waltham; Dr. G. E. R. Deacon, C.B.E., F.R.S. and staff of the National Institute of Oceanography, Wormley; Meteorological Office staff at Tangmere, Thorney Island, Odiham, Farnborough, London Weather Centre and White Waltham.

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551.508.824

AUTOMATIC WEATHER STATION DEVELOPMENT IN THE METEOROLOGICAL OFFICE

By N. E. RIDER

Introduction.—One normally associates the term 'automatic weather station' with a collection of instruments and other equipment which is designed to gather surface meteorological data and to transmit the information from a remote locality where it would be economically unsound to maintain a human observer. Automatic stations are not in any way new to meteorology. The familiar radiosonde is an automatic station, but it must be regarded as of a special type as it is only required to work for a short period although its operational environment is severe. This article will make no reference to upper air observations and will interpret the term 'automatic weather station' in its conventional meaning.

In this country the operational need for automatic stations has to date been only marginal since it has proved generally possible to find people whose normal work requires them to live in the more remote areas and who have been willing to accept the part-time task of observing. However, with the coming of automation to lighthouses and the realization that it might now be possible to fill certain existing gaps in the observing network at permissible cost, interest in automatic weather stations has increased. About two years ago the Instruments Branch of the Office was instructed to undertake a survey of the likely costs of operationally useful systems and to start development on a modest scale. The remainder of this article will give some account of progress to date and of plans for the future.

The development programme.—The aim throughout has been to design and produce a flexible system of automatic weather stations which will provide information of a quality comparable to that which would be expected from a manned station and to do this at a cost which will not be prohibitive to the use of the system. At an early date it was envisaged that the development would proceed in three stages. These stages were not to be distinguished by the quality of the observations to be obtained, but rather by the facilities to be anticipated at the remote observing site. The stage 1 station will require that both land-line facilities and mains power be available at the remote site. At stage 2 mains power will not be used and at stage 3 neither land lines nor mains power will be required. In practice, stages 1 and 2 have largely merged into one as all the meteorological sensors and the transmitting equipment have been designed for low power consumption at low voltage. Radio transmission will only be used in the last stage of development and the length of the radio link will be kept as short as possible. It will probably be used to bridge the gap between the observation point and the nearest convenient telephone line. Wherever possible, land-line connexions are to be preferred to radio links both on the grounds of reliability and cost. This is particularly so when the transmitting and receiving ends can be directly applied to the normal GPO system, that is when both can become normal telephone subscribers.

The present position.—

(*a*) *Meteorological sensors.*—In stages 1 and 2 the telemetering system demands that all parameters to be transmitted be presented in the form of voltages to the voltage/frequency converter which forms the input stage of the telemetering equipment. This is also likely to be so in the stage 3 station. Thus it has been necessary to design what may be regarded as a new generation of meteorological instruments which in themselves could be used together or singly to replace conventional instruments in other applications. Models or design drawings are now available for the sensors for all the conventional parameters with the exception of cloud amount and steps are currently being taken to have a small number of each made. It would be inappropriate here to give a detailed description of each sensor so, as an example, reference will be made to that for sunshine which proved to be one of the most intractable elements to sense in an automatic way. It is well known that the Campbell-Stokes recorder has been adopted as the 'standard' instrument and what was needed was an automatic replacement for this. Plate I is a photograph of the model of the transducer which was developed for this purpose. In effect it is an image discriminator which senses the presence or absence of sharp shadows. A phototransistor is located at the centre of a hemisphere which has alternate opaque and transparent segments. The hemisphere is spun by a small motor so that, in bright sunshine, a series of sharp shadows pass across the phototransistor which in turn provides a train of output pulses. The steepness of the edges of these pulses (the rise-time) is a measure of the sharpness of the shadows and therefore of the directness of the sunshine. A small electronic circuit is used to operate a relay when this pulse rise-time exceeds a certain limit. Adjustments are provided to match the operation of the relay to the definition of bright sunshine provided by the Campbell-Stokes recorder chart. The relay in its turn is used to apply a voltage to an input channel of the telemetering equipment.

(*b*) *The telemetering system.*—This is an audio-frequency transmission system which has been designed to comply with the relevant GPO regulations. A detailed description of its features has been given by Bruley.[1] Here we need only note that it uses a single pair of telephone lines and in its present form is capable of passing information between any two points in the British Isles. It provides 12 information channels and 4 'control' channels and a signal for each meteorological element to be transmitted is passed down one of the information

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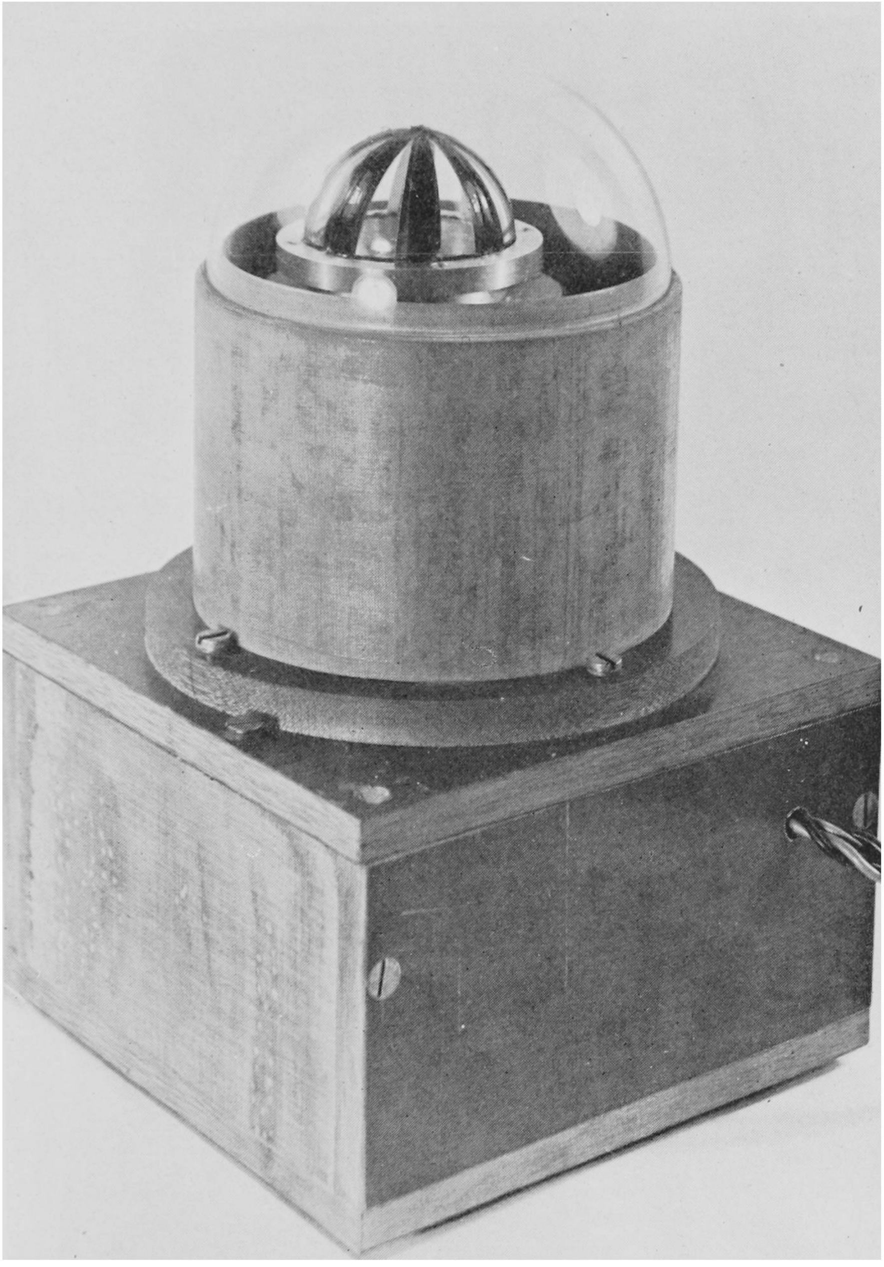

PLATE I—PROTOTYPE SUNSHINE TRANSDUCER TO BE USED AT AN AUTOMATIC WEATHER STATION
(see p. 244)

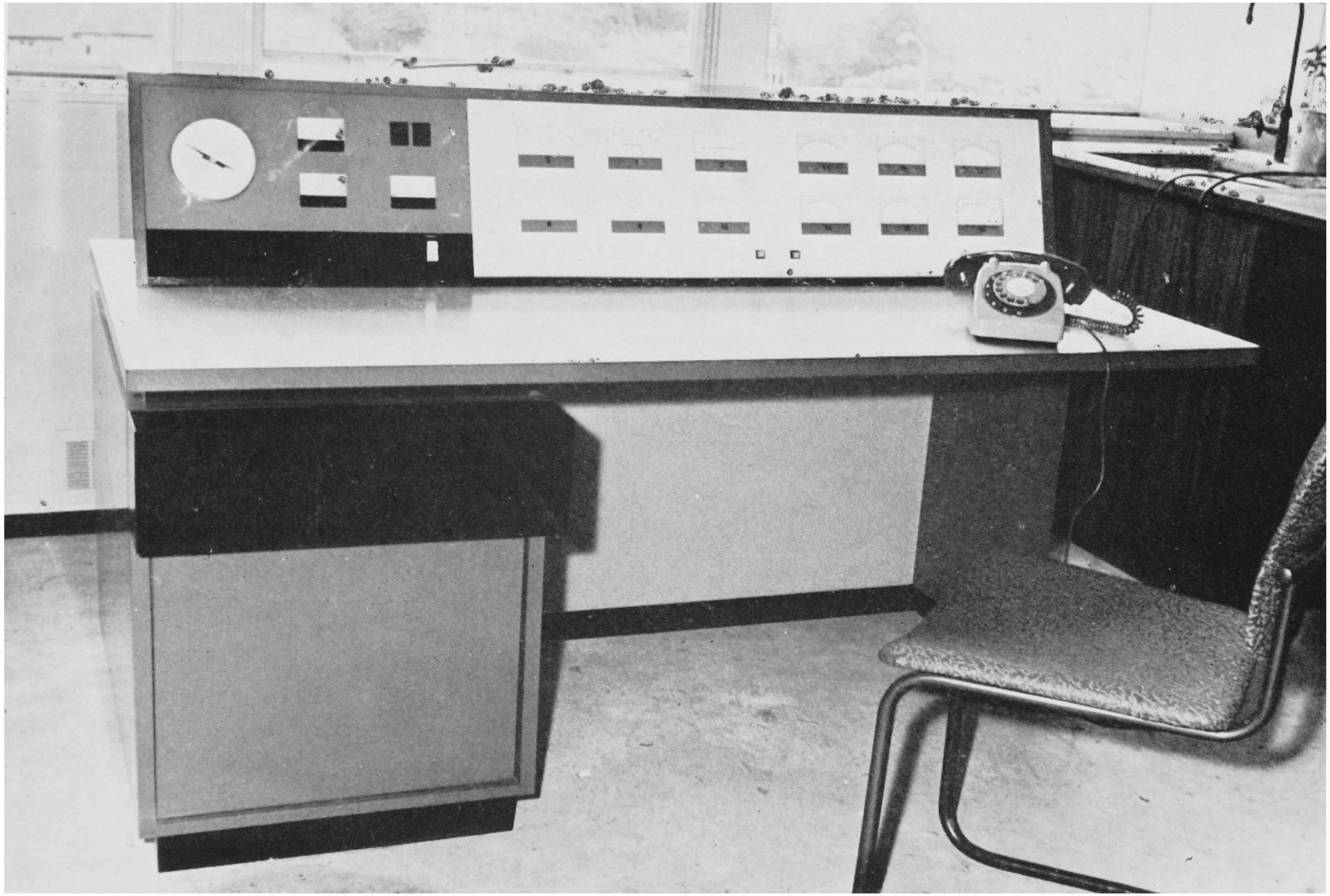

PLATE II—RECEIVING CONSOLE FOR AN AUTOMATIC WEATHER STATION
(see p. 245)

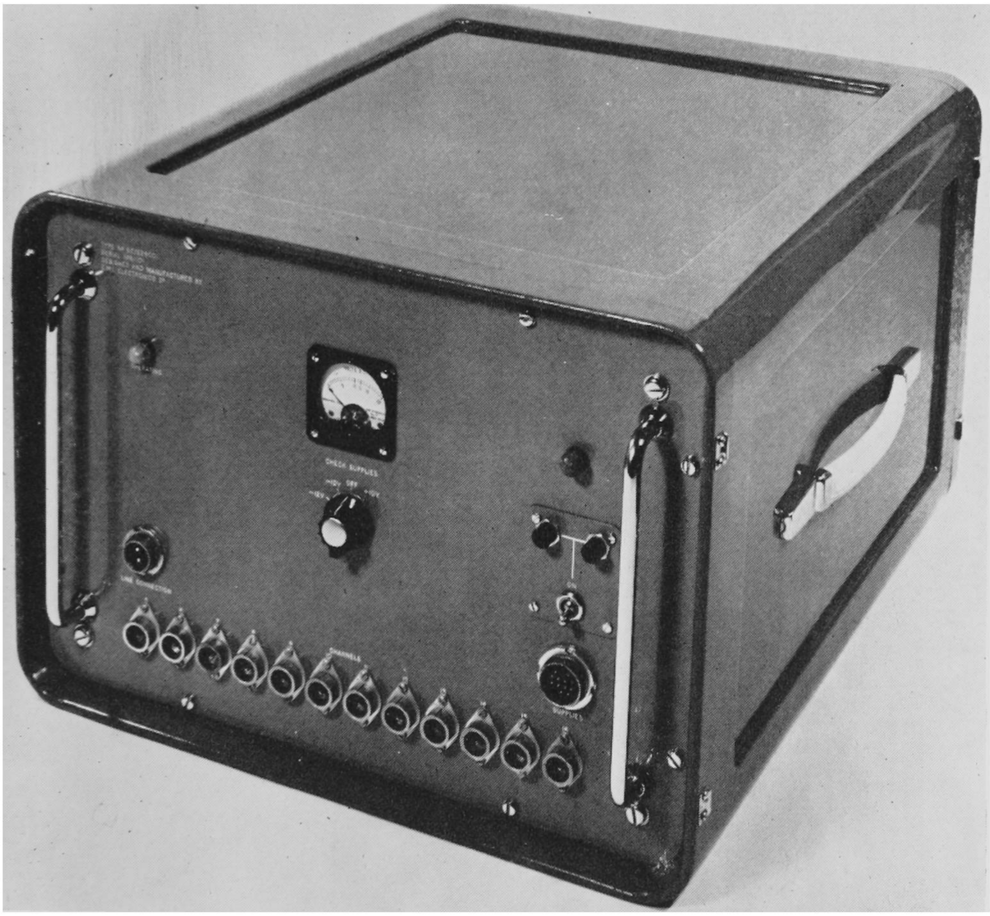

PLATE III—TRANSMITTER TO BE USED AT AN AUTOMATIC WEATHER STATION
(see p. 245)

Photograph by G. J. Jefferson

PLATE IV—PHOTOGRAPH OF THE 'SUB-SUN' OVER THE WESTERN NORTH ATLANTIC
(see p. 254)

The photograph was taken at 1420 GMT, 22 March 1963, at 56°N 51°W, from a height of 35,000 feet, looking in the direction of the sun. Extensive frontal cloud, main top estimated at 15,000–18,000 feet, was present. The sub-sun was produced by reflection of the sun's rays by ice crystals in the higher cirrus cloud.

channels, these being automatically cycled in time sequence. Sixteen seconds are needed to cover one complete cycle and the display at the receiver is in the form of deflections on meters calibrated in terms of the meteorological parameters.

The first information channel may be allocated to pressure in which case the meter scale for the standard station would be calibrated in millibars from 950 to 1050 in steps of 1 millibar. The accuracy of the system is such that pressure will be shown correct to the nearest millibar. Plate II shows a prototype of the receiving console, the final version of which will only differ in minor detail, and Plate III shows the transmitter. The 12 display meters of the receiving console may be clearly seen. These cater for pressure, temperature, wet-bulb depression, rainfall (2 meters), rate of rainfall, sunshine, wind speed (10-minute mean), wind direction and visibility. These elements occupy 10 of the available 12 channels and the remaining 2 may be allocated at a later date to such parameters as net radiation, maximum gust in the last hour, etc. It is hoped that the first complete station will be working at Bracknell before the end of 1963. This will be used for assessment purposes following which the development of the stage 3 station will be started.

Method of operation and alternative arrangements.—Basically, the station may be used in two ways, that is, it may be kept in continuous operation or may be interrogated on demand. Continuous operation will require that a private line be provided between the transmitting and receiving points but interrogation will be carried out over the normal public system. To interrogate the station the appropriate number is dialled or requested and once connexion is made a 10-second delay is followed by a tape recording which identifies the station by name or number. This identification is followed by a series of audio-tones which are shown, in terms of the meteorological elements, on the display meters. The transmitter continues to operate for a preset time, normally two minutes, and a series of readings may be taken. The reading on each meter is held for 15 seconds in each cycle and only falls off 1 second before it is replaced in the next cycle. At the end of the preset time the station shuts down automatically and the last cycle of meter readings is held on until the meters are manually reset to zero at any time after the termination of the call. This type of operation is particularly suitable for collecting data at one central point from a number of observing points. Each remote station may be called up in turn, it only being necessary to meet the cost of the calls in the normal way. Thus, one receiver may then be used to interrogate a chain of automatic stations.

The continuous mode of operation is more appropriate to use on large airfields where the central office cannot be conveniently located near the position where it is desired to take the observations. An obvious example is London (Heathrow) Airport where it is necessary at present to maintain a subsidiary office for the express purpose of observing. It would also be possible to bring to a central office observations from various points on the perimeter of any airfield.

It is worth noting that in either mode of operation continuous recording at the remote observing point is possible and that this recording may also be added to the receiver provided that continuous operation over a private line is maintained. Moreover, at extra cost, the meteorological parameters can be presented in digital form at the receiver and print-out and/or punch facilities added.

A further development, primarily intended for airfield use, will enable the operator to dial, using a preset code, for the parameter required at any time. This parameter would then be presented to him in digital form with an indication that the parameter actually demanded was being displayed. Facilities will be incorporated to enable all available parameters to be displayed in turn if this should be demanded.

Conclusion.—Our experience with automatic weather stations in this country is very limited and the operational requirements are ill defined. There is little doubt that there will be an increasing need for the type of facilities now being developed but at this stage it is impossible to forecast the extent or the exact form of use. Both must depend on the quality of the observations that can be provided as well as the reliability and cost of the various alternative systems.

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551.583.7

PALAEOCLIMATOLOGY

By H. H. LAMB

The beginnings of our knowledge of ancient climates and theories about them go back at least to Robert Hooke, who, in 1686, proceeded from the discoveries of fossil turtles at Portland to the idea that there had been past ages with a much warmer climate in England and that possibly the explanation might lie in shifts of the earth's axis. Active development of work in the field of palaeoclimatology began around 1800–30, with the realization by various observers (John Playfair and the Swiss engineer I. Venetz are the best known) that there had also been at least one great cold epoch in the past when the glaciers were enormously greater in extent than in historical times. Yet palaeoclimatology may rightly be regarded as a new science which is likely to develop significantly in the coming years. New techniques of observation and assessment have, since about 1945, begun to produce a wealth of evidence from many diverse fields of science. This has properly led to the initiation of conferences in several leading countries to bring together the original research workers and interested theorists. Meteorology has been represented as well as geophysics and geology, geomorphology and glaciology, botany, zoology and other disciplines, including sometimes archaeology and history.

The word 'palaeoclimates' (Greek Παλαιος—ancient) means different things to different people. The author has attended two conferences recently under this heading. The first, held in 1962 at Aspen, Colorado under the auspices of the United States National Research Council and National Center for Atmospheric Research, was concerned with the climates of the eleventh and sixteenth centuries A.D., the idea being to test the ability to establish the facts of the past by choosing sample periods not too far back in time. The second conference, sponsored by the North Atlantic Treaty Organization Institute of Advanced Studies, and held in the fine new building of the Department of Physics, Kings College, Newcastle upon Tyne from 7 to 12 January 1963 with Professor S. K. Runcorn as its head, was concerned mainly with the climates of the earth many millions of years ago. The widest range of relevant disciplines was brought together, and a number of applied scientists such as mining engineers were present. Palaeoclimatology is a clear case where knowledge and understanding can only be advanced by interdisciplinary effort. The outcome may soon range from the establishment of a new scientific journal and some organization to maintain regular contacts, to the spreading of beneficial new ideas about where to look (and where not to look) for oil, coal and useful mineral deposits.

When one considers changes of climate over periods of millions of years, there is no doubt that the large-scale geography must be regarded as a variable. There may be interesting lessons for meteorology in this exercise. There is no doubt, for instance, that the land relief has varied and that the positions and arrangement of the main mountain barriers have been quite different in early geological epochs. But when one goes back 200 to 300 million years—a time-span including the Carboniferous, to which the first session at Newcastle was devoted—one encounters phenomena which would be most simply explained if the North Pole at that time lay in the Pacific or near east Asia, with Europe and eastern North America in much lower latitudes than now. Early in the present century Wegener put forward the theory that the continents had also drifted apart and changed their positions relative to the poles during geological time. Within the last ten years these daring theories of pole wandering and continental drift have begun to appear as the simplest (and therefore most plausible) explanation of a mass of heterogeneous evidence, and various geophysical theories have been put forward to account for them. The strongest support comes from measurements of the weak 'fossil magnetism' (remanent magnetization) of rocks serving, as it were, as a very, very weak built-in compass showing the direction and dip of the earth's magnetic field at the time when the rocks were laid down. (The assumption is that, when averaged over any long period of time, the earth's magnetic axis is in line with the axis of rotation, i.e. with the geographical poles. Examination of the observed migration of the north magnetic pole during the last four centuries is enough to lend some support to this idea.) Palaeomagnetic evidence suggests that in the Carboniferous the southern hemisphere continents and India were clustered together around the South Pole. These ideas are in harmony with the apparently tropical character of the vegetation fossilized in most present northern hemisphere coal measures whereas the coals of the southern hemisphere and India appear to show characteristics of a cool temperature vegetation.

The Newcastle meeting was an occasion for sorting out the evidence which fits these constructions and that which still presents difficulties. The warm climate suggested by evidence of flora and fauna over most of the earth in the early Tertiary, 50 or so million years ago, at a time when the North Pole appears to have already arrived near its present position, raises some problems—for instance, the discovery of warmth-loving plants and, recently, of large mammal footprints in Spitsbergen where cold winters with months of darkness must be presumed. At the other end of the time scale, the conference took note of (but refused to grapple with) suggestions of cold climates with glaciers and floating ice over most of the earth in the Pre-Cambrian. Modern techniques of dating make it increasingly possible to treat geological time in numbers rather than as a succession of named epochs, from which the illusion that all geological epochs might be treated as of similar length and presenting *a priori* similar problems can all too easily spring. Since the scattered evidence of glaciation during the Pre-Cambrian may come from times between 500 and 1500 million years ago, it is clearly premature to conclude that we have to develop theories to explain a cold earth in that epoch, i.e. simultaneous cold climates everywhere.

Professor Runcorn himself has been responsible for much of the palaeomagnetic evidence of very ancient climates and very ancient geography, and he is one of its ablest exponents. On this, as on earlier occasions, he appealed to certain directly *climatic* evidence for confirmation of the suggestions about where the poles and continents lay. This climatic evidence is not confined to the traces of former positions of the arid zone (e.g. red sandstones) or of the zones of equatorial and temperate rain-forests. Amongst the sandstones one finds actual fossil sand dunes, from the study of which the ancient wind directions may be deduced. There are puzzles about how a dune becomes fixed and so preserved when desert conditions cease—presumably encroaching subsoil moisture and vegetation play their part—and about why the relatively rarer 'barchan' (transverse) type of dune gets preserved whereas the commoner ones which are set lengthwise in the wind do not. Nevertheless the pattern of wind directions that emerges is quite clear in several important epochs. The Permian sandstones of England and parts of the United States seem to have been laid down in a trade-wind régime. The only surprise is that the north-east to east (palaeo) winds seem to have extended as near the (palaeo) equator (to about 10°N) as deduced by Runcorn. One would have expected some monsoonal disturbance of the wind régime where such big land masses as North America were involved, but the answer may be partly in the probable error of the derived (palaeo) latitudes. In the Triassic desert of South America, in southern Brazil, Dr. J. J. Bigarella of Brazil has found that the fossil sand dunes register an intricate pattern of wind directions remarkably similar to that which prevails at present over the region. (The latitude position in the Triassic should be similar to today's.) He finds the change-over from the northern fringe of the southern hemisphere westerlies to the northerly and north-easterly winds that blow around the cyclonic region over the inner Amazon basin very close to where it is now. Here, then, is an interesting meteorological phenomenon: evidence suggesting a sharpened contrast between the tropical rain-forest and desert in a region where the horizontal arrangement of the atmospheric circulation zones was as it is now. The variables must be sought in other factors—circulation strength (greater persistence of pattern is perhaps unlikely), vertical motion or temperatures and (relative) humidities.

Meteorology can both contribute to, and learn from, these discussions. Moreover, it is vital that any meteorologist who does engage in this field should gain enough acquaintance with the contributions from other disciplines to help him sift fact from fancy. Difficulties abound: the confusions that can arise over attempts to interpret the significance of tree rings are by now well known. This conference heard more of the deposits that can be confused with, and quite wrongly attributed to, glacial drifts (tills) and the difficulties of diagnosis of the origins of soils. There are several approaches that meteorology can use. Professor Sheppard gave the assembly at Newcastle an outline of the present state of our theoretical understanding of the circulation of the atmosphere and of what has been demonstrated by laboratory (simulation) experiments. His opening statement that the problem of climatic variation is the problem of the general circulation of the atmosphere must, however, have seemed to many too bold a claim. It may be largely true for the variations, including ice-ages and interglacials, of the Quaternary, i.e. of the last million years, whilst the geography has remained much as now, and there is a sense in which it must always be true. Even so, it doubtless partly represents the physicist's hope that he has an experiment in which other things remain equal (external conditions constant). The meteorologist's contribution to palaeoclimatology is likely to be along two main roads. Firstly, he must establish both the constant features of the general circulation of the atmosphere and oceans as well as the types and range of variations from short-lived cyclonic and anticyclonic eddies, through changes in the prevailing strength and number of Rossby waves in the upper westerlies up to the scale of climatic fluctuations. This approach was clearly expounded by Professor Sheppard. Secondly, he must go along with the empiricists in other disciplines and identify and map the patterns and sequences of actual climatic changes, both of the recent and the distant past. By gaining a more precise knowledge of the actual nature of some past epochs it may be possible to discover how much of the differences can be attributed to the meanderings of the circulation of atmosphere and oceans and how much evidence there may or may not be of effects due to possible changes of the environment.

551.509.314:551.509.329:551.515.1

FORECASTING THE CENTRAL PRESSURE OF ATLANTIC DEPRESSIONS BY OBJECTIVE METHODS

By J. G. MOORE

Introduction.—The forecasting of visibility at London (Heathrow) Airport 3 and 6 hours ahead during the winter by objective methods has been described by Freeman.[1] The present paper describes the application of similar techniques to the problem of forecasting the central pressure of Atlantic depressions 24 hours ahead. A regression formula has been derived and tested on a year's independent data. The results suggest that the objective methods and the pre-baratics of the Central Forecasting Office (CFO) gave equally good forecasts of central pressures. Both methods are superior to forecasts by persistence.

Data.—Data were extracted for alternate days during 1952–53 for each depression centre found in the area bounded by latitudes 30°N and 70°N and by longitudes 70°W and 5°E, provided the centre was still in the area 24 hours later. Depressions that deepened 20 mb or more on the intermediate days were also recorded. There were 703 depressions in the original sample, but later in the investigation depressions that filled and disappeared while still in the area were included and this brought the number up to 736.

It is important in selecting parameters for use in objective forecasting that they should be physically related to the development of the depressions and they should also be easily obtainable from the synoptic charts in order to make the system operationally practicable. Since the Meteorological Office electronic computer METEOR was used to process the data, it was possible to examine a large number of parameters and retain only the most significant ones.

Parameters extracted from the 500 mb and 300 mb contour charts and from the 1000–500 mb thickness charts included: absolute contour heights at several points relative to the surface centre; the direction, magnitude and components of contour gradients; curvature, vorticity, vorticity advection and a measure of diffluence of the contours; and winds at 300 mb. Another parameter used was the 12-hour change in the 300 mb contour height over the centre. Parameters extracted from the surface chart included: the initial pressure, its change in the previous 3, 6 and 12 hours, the number of closed isobars, the initial latitude and longitude of the centre and the change in the previous 12 hours. The thickness differences 1000–700 mb minus 700–500 mb, and 1000–500 mb minus 500–300 mb, were used as measures of stability.

Preliminary classification of parameters.—Two different methods of objective forecasting using statistical techniques were examined and are described in the next section, but to help determine the most useful parameters each parameter was correlated separately with the central pressure 24 hours later and with the change in central pressure in 24 hours. Using METEOR, a polynomial of the form

$$z = a + bx + cx^2 + dx^3 + \ldots$$

was fitted to the data by the 'least squares' method, taking successively higher powers up to the sixth until no further reduction in the root mean square error (standard error) was obtained. The parameters could now be arranged in descending magnitude of correlation with the pressure 24 hours ahead and the 24-hour pressure change.

The highest correlation, 0.72, was between the future pressure and the initial central pressure. It was also noticeable that for the absolute pressure in 24 hours, absolute values of contour height and surface tendencies were high up on the list, whereas for the changes in pressure, wind speed and contour gradients dominated the top ten.

Methods.—

(*i*) *Graphical correlation.*—Freeman[1] described how with a predictand z and two predictors x and y METEOR had been programmed to fit a surface to the data of the form

$$z = ax^5 + bx^4y + cx^3y^2 + \ldots. + fy^5 + gx^4 + \ldots. + ux + vy + w$$

by the method of least squares.

The fitting of this surface to the data required the formation of 86 sums of the type Σx^7y^3 (each sum in this case comprising over 700 terms) and the solution of 21 simultaneous equations. METEOR carries out the computations and prints out tables from which prediction graphs could be prepared and the actual graphs of the best fitting relation between z and x and y. It also computes the root mean square error of the predicted values. Then for each of the original observations the predicted value Z_1 was computed from the least squares formula and stored within the machine. These values were then used as the x predictor for another diagram, a new predictor being read into the machine as a y parameter. The process described above was then repeated, and a second least squares formula derived with z as the predictand and Z_1 and the new y parameter as predictors. The predicted value at this second stage, Z_2, was, like Z_1, stored within the machine as a new x predictor and the operation described above was repeated.

This process was repeated until the addition of further parameters produced no significant reduction in the standard error. This usually occurred after about the fifth stage.

(ii) *Multiple non-linear regression.*—Alternatively, with a predictand Z and predictors $x_1, x_2 \ldots\ldots x_{24}$ a regression formula of the form

$$Z = a_0 + a_1x_1 + a_2x_1^2 + \ldots b_1x_2 + b_2x_2^2 \ldots$$

could be fitted to the data by the method of least squares. Up to the 15th power of any of the predictors could be included, but not more than 24 terms could be included in the formula at any time. METEOR had again been programmed to carry out the computations and print the coefficients of the regression formula and the root mean square error of the predicted values.

The most significant difference between the methods of graphical correlation and multiple non-linear regression is that the former method includes terms which are the products of the predictors used whereas the latter method does not. Both the programmes described apply significance tests to the regression coefficients and will discard those that are not significant at the 5 per cent level.

Forecasting the central pressure.—With the large number of predictors involved it was not possible to try all possible combinations of them. It seemed highly probable that the initial central pressure would prove an important predictor and this was adopted as the x predictor at the first stage in the graphical correlation method. The next 20 predictors in the ordered list of correlations with future pressure, plus any of the first 20 predictors in the list of correlations with pressure change not already included, were taken as y predictors, the one that yielded the smallest standard error being selected. At the second and third stages the remaining predictors from the first stage were used again as y predictors and the most successful predictors were selected as before. At the fourth and subsequent stages all the remaining predictors from the two lists with correlation coefficient 0.15 or greater were tried as y predictors.

A similar method of selection was used for the multiple non-linear regression method. The first predictor chosen was, as before, central pressure and each of the next 20 predictors in the first list plus any of the first 20 in the second list not included in these was combined with it in turn, taking all powers up to the sixth which were shown to be significant. Keeping the predictor that gave the lowest standard error, other terms were combined until no further significant reduction in the standard error was obtained.

By this method of selection it seems possible that a parameter which could prove to be a useful predictor when taken in conjunction with another or others might, taken singly, be rejected as unimportant. For instance it seemed not improbable that although the latitude and longitude of the depression centre were individually relatively unimportant as predictors, together they would give a precise specification of position and might prove of greater importance. Various combinations of predictors which were thought to be potentially useful in this way and which had not been included in the earlier selection were tried to see if any further reduction in the standard error could be effected. No significant improvement, however, was obtained.

It was found that the results obtained by multiple non-linear regression were slightly superior to those obtained from graphical correlation and since the former method is simpler to use as a forecasting tool, it was decided to use it in preference to the other. Table I lists the predictors used in the final regression equation and shows their effect as they are introduced successively. The independent correlation coefficients are also shown.

TABLE I—FINAL RESULT OF MULTIPLE NON-LINEAR REGRESSION

	Predictors used	Result of adding successive predictors		Independent correlation
		Residual	Correlation	(magnitude)
1. Central pressure initially	1	9.39	0.72	0.72
2. 300 mb contour gradient (knots) measured over 560 n.miles	1 and 2	8.18	0.80	0.29
3. Change in longitude of centre in previous 12 hours	1 to 3	8.03	0.80	0.25
4. Change in central pressure in previous 12 hours	1 to 4	7.90	0.81	0.45
5. Number of closed isobars within 560 n.miles of centre	1 to 5	7.78	0.82	0.39
6. Month	1 to 6	7.73	0.82	0.41

Standard deviation of central pressure after 24 hours 13.52 mb.

Results and discussion.—Table II was derived from the multiple non-linear regression formula and in conjunction with the instructions for estimating the parameters can be used for forecasting the central pressure. The regression method frequently failed to forecast the change in central pressure of depressions which deepened by 20 mb or more. These 'big deepeners' were therefore studied separately. One can say that for 30 of the 35 cases: (1) the 300 mb wind direction over the centre lay between 190° and 290°, (2) the 300 mb contour gradient was large, (3) the initial central pressure of the low was higher than 980 mb and (4) the month was other than June, July and August, but there were also another 100 depressions which satisfied these conditions but did not deepen markedly. These 130 cases were studied separately but no further predictors emerged as being potentially useful and further investigations did not uncover the essential differences between the 'big deepeners' and the others.

One striking feature of the final regression equation is the small part played by the upper-air parameters as predictors. In fact the 300 mb wind speed over the centre is the only upper-air parameter used at all. It is surprising, also, at first sight, that the corresponding wind direction in conjunction with the speed added nothing useful to the regression formula. The correlations between the change in pressure in 24 hours and both 300 mb wind speed and direction arise mainly from larger falls in pressure being associated with high 300 mb wind speeds and wind directions lying between south and west. As was stated earlier, it was found that in nearly all cases of large falls of pressure both these conditions obtained simultaneously. It seems probable that any contribution made by the 300 mb wind direction is largely implicit in the 300 mb wind speed.

The vorticity measurements, using a grid length of about 280 miles, made in this investigation were disappointing as they contributed no more to the regression equation than did more easily derived parameters. There is a suggestion, however, shown by more detailed computations of vorticity fields at 300 mb over open-wave depressions made by Dixon (not yet published) that a centre of high vorticity advection in the cold air is a typical feature of rapidly deepening depressions. It is possible that more accurate measures of vorticity parameters would have improved the forecasts. Probably a measure of the humidity of the air, and a more accurate index of stability would have led to improved results, had these been feasible.

TABLE II—PREDICTION TABLE FOR CENTRAL PRESSURE AFTER 24 HOURS

†Central pressure	$f1$	Central pressure	$f1$	300 mb gradient wind speed over 560 n.miles	$f2$	Change in longitude of centre in previous 12 hours*	$f3$	Change in central pressure in previous 12 hours	$f4$	Change in central pressure in previous 12 hours	$f4$	Number of closed isobars within 560 n.miles of centre, drawn at 4 mb intervals	$f5$	Month	$f6$
millibars		*millibars*		*knots*		*degrees longitude*		*millibars*		*millibars*					
930	3.4	980	42.5	0	20.0	—10	5.2	—25	0.8	25	29.0	0	0.0	Jan.	1.2
932	5.0	982	44.0	5	20.0	—9	5.5	—24	2.0	24	21.0	1	0.1	Feb.	2.3
934	6.5	984	45.6	10	20.0	—8	5.8	—23	3.4	23	15.1	2	0.5	Mar.	3.3
936	8.1	986	47.2	15	19.9	—7	6.0	—22	4.6	22	11.0	3	1.2	Apr.	4.1
938	9.6	988	48.7	20	19.8	—6	6.3	—21	5.7	21	8.4	4	2.1	May	4.6
940	11.2	990	50.3	25	19.7	—5	6.6	—20	6.7	20	6.8	5	3.2	June	4.7
942	12.8	992	51.8	30	19.4	—4	6.8	—19	7.5	19	6.2	6	4.7	July	4.3
944	14.4	994	53.4	35	19.1	—3	7.1	—18	8.1	18	6.2	7	6.3	Aug.	3.6
946	15.9	996	55.0	40	18.7	—2	7.4	—17	8.5	17	6.7	8	8.2	Sept.	2.7
948	17.5	998	56.5	45	18.3	—1	7.6	—16	8.9	16	7.5			Oct.	1.9
950	19.0	1000	58.1	50	17.7	0	7.9	—15	9.1	15	8.4			Nov.	1.7
952	20.6	1002	59.6	55	17.1	1	8.2	—14	9.2	14	9.5			Dec.	2.7
954	22.2	1004	61.2	60	16.3	2	8.4	—13	9.3	13	10.5				
956	23.7	1006	62.8	65	15.5	3	8.7	—12	9.3	12	11.4				
958	25.3	1008	64.3	70	14.7	4	9.0	—11	9.3	11	12.3				
960	26.9	1010	65.9	75	13.7	5	9.2	—10	9.3	10	12.9				
962	28.4	1012	67.5	80	12.7	6	9.5	—9	9.4	9	13.5				
964	30.0	1014	69.0	85	11.7	7	9.8	—8	9.4	8	13.8				
966	31.5	1016	70.6	90	10.6	8	10.0	—7	9.6	7	14.0				
968	33.1	1018	72.1	95	9.6	9	10.3	—6	9.7	6	14.0				
970	34.7	1020	73.7	100	8.5	10	10.6	—5	10.0	5	13.9				
972	36.2			105	7.5			—4	10.3	4	13.7				
974	37.8			110	6.6			—3	10.7	3	13.3				
976	39.3			115	5.7			—2	11.1	2	12.9				
978	40.9			120	4.9			—1	11.5	1	12.5				
				125	4.3					0	12.0				
				130	3.9										

† To nearest whole millibar.
* Eastward movement positive.

Instructions: Read the values of $f1$, $f2$, $f3$, $f4$, $f5$ and $f6$ corresponding to the observed values of the predictors. The forecast value of the central pressure 24 hours later is given by: $900 + f1 + f2 + f3 + f4 + f5 + f6$ mb.

The objective forecasting technique was tested on independent data for alternate days in 1961. There were 302 cases in this period. Standard errors and correlation coefficients for the objective method, for the routine forecasts of the CFO and for persistence forecasts are shown in Table III. These show that the objective and CFO forecasts are very similar in quality and show that they are both superior to persistence forecasts.

TABLE III—RESULTS OF INDEPENDENT TEST FOR 1961 (302 OBSERVATIONS)

	Root mean square error *millibars*	Correlation coefficient
Objective forecast	7.22	0.84
CFO forecast	7.32	0.83
Persistence forecast	8.94	0.73

Standard deviation of central pressure after 24 hours = 13.13 mb.

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

551.593.63 (084.1)

A PHOTOGRAPH OF THE SUB-SUN

By G. J. JEFFERSON M.Sc.

The accompanying photograph (see Plate IV) was taken from an aircraft while flying over the western North Atlantic at 35,000 feet and shows what appears to be a mock sun in cirrus cloud below, seen in the same direction as the sun. It was taken on 22 March 1963 at 1420 GMT at 56°N 51°W. The area was covered by heavy cloud masses associated with a depression in the area. The main cloud top can be seen in the photograph and is estimated at 15,000–18,000 feet while variable but often thick cirrus layers extended above this to an estimated height of 25,000 feet.

Minnaert[1] describes this phenomenon as a sub-sun: ". . . seen only from a mountain or an aeroplane. It is a somewhat oblong, uncoloured reflection; the sun reflected not in a surface of water but in a cloud! A cloud of ice-plates, in fact, which appear to float extremely calmly judging from the comparative sharpness of the image". The phenomenon on this occasion was white without any trace of colour fringing. It was also very bright and elliptical in shape with the major axis vertical thus appearing to fit Minnaert's description.

If indeed it is a direct reflection in plate-shaped ice crystals of cirrus cloud floating horizontally then the angle of depression of the 'sub-sun' will equal the angle of elevation of the sun. The following calculation shows that this was so.

The camera was pointed downwards at a suitable angle to include both the sub-sun and the horizon (cloud top), which can be seen near the top of the photograph. This is illustrated in Figure 1. The length of the negative is shown by AB whose mid-point is E. C is the position of the image of the sub-sun and D that of the horizon. Since the lines DG, EL and CH represent rays passing through the optical centre of the lens, F, they can be represented by straight lines. The angle of depression of the sub-sun below the horizon is angle GFH = angle CFD. Measurements on the negative show that CE = 15.5 and DE = 12.5 millimetres. The focal length of the lens EF = 50 millimetres.

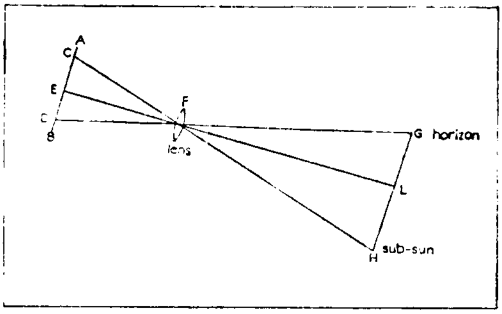

FIGURE 1—DIAGRAM SHOWING THE FORMATION OF A PHOTOGRAPHIC IMAGE OF THE SUB-SUN

$$\text{Angle CFD} = \text{angle CFE} + \text{angle EFD}$$
$$= \tan^{-1}\frac{15\cdot5}{50} + \tan^{-1}\frac{12\cdot5}{50}$$
$$= 17^\circ + 14^\circ = 31^\circ.$$

The horizon was a cloud top whose height was not exactly known. Since there was much cirrus present it was probably not more than 10,000 feet below the aircraft. Assuming the horizon to be 2 miles below the level of the aircraft the angle of depression of the horizon is about 2°. The angle of depression of the sub-sun below the horizontal was therefore about 33°.

The time was about an hour before the local noon when the photograph was taken. At noon on this date the sun's elevation at 56°N is 34°, which shows good agreement with the angle of depression of the sub-sun.

REFERENCE

1. MINNAERT, M.; Light and Colour in the open air, (revised edition). London, G. Bell and Sons, Ltd., 1959.

REVIEW

Meteorologisches Taschenbuch Vol. I, (new series, second edition). Edited by Franz Baur. 8½ in. x 5¾ in., pp. vi + 806, *illus.*, Akademische Verlagsgesellschaft, Geest & Portig K.-G., Leipzig, 1962. Price: D.M. 80.

This is a completely remodelled version of the meteorologist's 'Kaye and Laby' started by Linke in 1930. Linke's *Meteorologisches Taschenbuch* as it was called was not, I think, much used in this country. Professor Baur and his collaborators have however gathered together in Volume I of this new edition so much material which synoptic meteorologists (especially those engaged in medium and long range forecasting and research) and climatologists frequently need that I hope it will not suffer the same fate.

Here is a list of the most useful things in it for which little or no knowledge of German is required:

(i) A list of nearly 4000 meteorological reporting stations in order of block numbers with indicator numbers, position, height above mean sea level and types of observation carried out.
(The 13 ocean weather stations, their code letters and position are listed.)

(ii) Pentad values of 500 mb zonal index for 50°–60°N and from 60°W–60°E for the period from 1948 to 1957 in metres per second.

(iii) Mean pressure maps for each pentad of the year for an area 15°W to 30°E and 40°N to 65°N, complied from pentad pressure means 1883–1944.

(iv) Monthly means of surface pressure, temperature and rainfall for nearly 300 stations distributed over the earth. Height above mean sea level and period of the mean are given in each case. The mean number of rain days (with the particular definitions of a rain day in each case) per month are given for about 150 stations.

(v) Monthly temperature anomalies for central Europe (mean of the values for De Bilt, Potsdam, Basle and Vienna) for the period 1761–1960 and the monthly normal for this period.

(vi) Monthly precipitation anomalies for Germany west of the Oder (mean of 14 stations) for the period 1851–1960.

(vii) Monthly pressure anomalies for Basle (1755–1960), Edinburgh (1770–1960), Copenhagen (1842–1960), Oslo (1816–1959), Upernavik (Greenland) (1875–1958), Jakobshavn (Greenland) (1874–1958) and West Greenland (half Upernavik + half Jakobshavn) (1875–1958).

(viii) Monthly values of *Kp* (the international index of magnetic disturbance) from 1932 to 1961 with annual and monthly means.

(ix) Monthly, yearly and overlapping five-monthly values of the sunspot number (Wolf number) from 1749 to 1960.

(x) Monthly and yearly mean values of a solar-flare index from 1882 to 1957.

Should the German titles of some of these tables not be clear there is a very complete glossary of meteorological terms from German to English and to French, Spanish, Italian and Russian. This glossary is not always as accurate as one would wish. For anyone wanting to write up his work in German there is an English index to the glossary so that the equivalent of a term like *vortex filament*, which would not be in an ordinary dictionary, can be readily found.

To this list could be added a daily-type calendar for the period 1881–1960 based on the occurrence or not of rainfall at four stations, Frankfurt on Main, Gütersloh, Hamburg and Potsdam. It enables the distribution of wet and dry spells over an area about the size of England and Wales to be recognized rapidly in a general way. Again, the explanation of the symbols used can be readily obtained from the lexicon.

Over 100 pages are devoted to the World Meteorological Organization (WMO) codes ranging from FM 11A to FM 83A and the details of the individual symbolic elements. This information and the list of reporting stations under (i) above would normally require reference to be made to two WMO publications.

Among items in the book requiring a good knowledge of German are accounts of chart analysis (surface and upper air) and forecasting by Scherhag, and of the treatment of upper air observations by Zimmerschied. Neither contains anything not readily available in English publications, although in

Scherhag's contribution there is a difference of emphasis which is fairly typical of the somewhat different mental approach of English and German meteorologists. With both sections there is a fairly comprehensive bibliography but it is surprising that Sutcliffe's 1938 paper should have been included and not his 1947 one when reference is being made to his development theory.

Finally there is a list of important dates in meteorological history starting with 600 B.C. They are rather few and far between till the sixteenth century, but from then on they become closer and closer, until by 1939 they are so close that one wonders how much thinning-out they will have experienced by A.D. 2000!

There is an interesting list of meteorological journals and magazines with meteorological contributions, arranged in order of year of first appearance. By what, I am sure, is the purest oversight the *Quarterly Journal of the Royal Meteorological Society* does not appear. Perhaps it is because the proceedings of the Meteorological Society appeared under various titles from 1839 before Volume I of the *Quarterly Journal* appeared for 1871–73.

Professor Baur and his collaborators are to be congratulated on providing such a useful book for their meteorological colleagues. They have gathered together in this one volume material which would otherwise have to be sought for in nearly a score of separate publications. I hope meteorologists will make good use of the fruits of this endeavour.

M. K. MILES

OBITUARY

Mr. R. J. Williams, M.B.E.—It is with very deep regret that we heard of the sudden death of Mr. R. J. Williams on 12 May, only a few months after his retirement. A full appreciation of his many years of service in the Meteorological Office appeared in the February, 1963 issue of this magazine.* Our deepest sympathy is extended to his widow in her sad loss.

METEOROLOGICAL OFFICE NEWS

Academic success.—We offer our congratulations to Mr. W. R. Sparks on obtaining a Diploma in Technology, in Applied Mathematics, at Northampton College of Advanced Technology, London.

Brabazon Trophy.—After a period of 13 years the Meteorological Office at London (Heathrow) Airport has regained the Brabazon Trophy for the best departmental aggregate at the Airport sports held on 8 June 1963. In addition to winning a cup for the men's mile relay, Mr. Miller won the 100 yards sprint cup, while Mr. Burn came first in the 220 yards and Mr. Tucker won the high jump. On the ladies' side, Miss Rundle won the long jump, and also shared the trophy for the best field athlete of the day.

CORRIGENDA

Meteorological Magazine Vol. 92, p. 215, on lines five and seven for "ue" read "u_φ"; on line fifteen for "$u\varphi$" read "u_φ".

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* Meteorological Office News. *Met. Mag.*, **92**. 1963, p. 68.