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INTERNATIONAL GEOPHYSICAL YEAR

By H. W. L. ABSALOM

The normal good international co-operation in astronomy and the sciences of the earth and its atmosphere is enhanced and sharpened by the preparations in progress for the International Geophysical Year, July 1, 1957 to December 31, 1958. During that period some 40 nations acting in concert will engage in an agreed, extended, intensified world-wide programme of concurrent measurements and observations directed to the investigation of selected problems, in the different sciences concerned, which call for maximum practicable international effort widely based. In earlier international years, 1882–83 and 1932–33, attention was specially given to observations in the north-polar regions, whereas the International Geophysical Year programmes, more comprehensive in character, are concerned with all latitudes—so far as resources permit—and indeed place special emphasis on the tropical regions as well as on areas from which systematic geophysical data are not normally obtained. The improvement in techniques of observations in recent decades, especially in ionospheric physics and aerology, and the increased—if still incomplete—understanding of many problems make peculiarly desirable a major general effort only 25 years after the last international year. Moreover, 1957–58 is at or near the next maximum in the sun-spot cycle, whereas 1932–33 was at a minimum, and is therefore of special interest in studies of solar activity, the ionosphere, aurora and geomagnetism.

This notable undertaking is sponsored by the International Council of Scientific Unions which has appointed a Special Committee for the International Geophysical Year consisting of representatives of the international organizations concerned. This Committee has Prof. S. Chapman as Chairman and Prof. M. Nicolet as Secretary-General, and includes Dr. W. J. G. Beynon, Sir Harold Spencer Jones and Mr. J. M. Wordie of the United Kingdom. In the last three years the Special Committee, with the assistance of national proposals and recommendations from international scientific organizations, has developed International Geophysical Year programmes of work in meteorology, geomagnetism, aurora and air glow, ionospheric physics, solar activity, cosmic rays, the determination of longitudes and latitudes, glaciology, oceanography, seismology, gravity, and the exploration of the high atmosphere by rockets. Throughout, the aim is to concentrate effort on main problems. It is for participating nations to comply as fully as practicable with the recommendations of the Special Committee. In most of the countries concerned a special committee has been set up to initiate and co-ordinate their national activities during the International Geophysical Year both within and outside their national boundaries. The

British Royal Society Committee, with Mr. J. M. Wordie as Chairman, includes Sir Graham Sutton and Dr. J. M. Stagg as national correspondents for meteorology and geomagnetism respectively.

In addition to establishing in considerable detail the programmes of work, subject by subject, to be undertaken, the Special Committee has recommended on the distribution of observing stations, and in particular as to the setting up of special stations in places from which observations are needed to provide adequate general coverage, e.g. on ocean islands, in the tropics and subtropics including desert areas, in the Arctic and Antarctic. Two other measures, designed to ensure maximum use of the facilities made available during the International Geophysical Year and of the information obtained, may be mentioned. A plan has been made for World Days of different categories on which there shall be special concentration of effort in the appropriate disciplines. Three or four days each month are specified as Regular World Days; they include days at new moon and quarter moon, days with enhanced meteoric activity, and solar eclipses. Special World Days or Intervals will be announced when, from solar or other indications, a period of solar and geophysical disturbance is expected. World Meteorological Intervals are specified 10-day periods at each equinox and solstice, starting in June 1957. The other and very important measure of co-ordination relates to the form of presentation, exchange and publication of data, and envisages main collecting centres for information obtained during the International Geophysical Year.

In regard to the scientific programmes, it is natural in this article to restrict attention mainly to meteorology, though in doing so it is not implied that meteorologists are not conscious of the interrelations between their science, oceanography and glaciology, and that the increase in knowledge of atmospheric motions and other characteristics above 50 Km. by the use of radio and rockets is of no meteorological interest. Reference may be made to articles by Prof. S. Chapman[1,2] for a survey of the whole field, and (until a later publication is available) to the International Union of Geodesy and Geophysics News Letters No. 9 and No. 11 for more detail on the several subject programmes.

Meteorology.—The Special Committee's plan for meteorology was largely determined by the World Meteorological Organization and the International Association of Meteorology. Briefly stated, the prime objective is the investigation of the large-scale physical, dynamical and thermodynamical processes of the general circulation of the atmosphere the world over. To this end it is proposed that the network of upper air observing stations shall be suitably improved to permit the preparation of aerological cross-sections along the whole or specified major portions of the meridians 10°E., 30°E. (from 30°N. to 30°S.), 75°E., 110°E., 140°E., 180°, 80°W. (north pole to 20°S.) and 70°W. (20°S. to the south pole), 20°W., and also along 5°S., the equator, 5°N., 15°N., 40°N. in North America and a parallel through the Andes. It is recommended, firstly, that all upper air stations (not only those for the vertical sections) shall make two radio-sonde and four radar-wind soundings daily, with an increase to four combined temperature-wind soundings on the 10 consecutive days of the seven World Meteorological Intervals; and secondly, that soundings should attain the 50-mb. level on each day, and that every effort be made to attain the 10-mb. level especially in the tropics and in the four daily ascents on World Meteorological Interval days. Moreover, it is suggested that the World

Meteorological Intervals at the equinoxes shall be extended, as may be necessary, so that the soundings to high levels may cover the occurrence of the directional change in the zonal circulation in the stratosphere at those seasons.

As the thermal economy of the atmosphere is an important item in the central problem of the general circulation there is need for additional stations, preferably aerological stations, to carry out systematic measurements of solar, atmospheric and terrestrial radiation. It is suggested that astronomical observatories shall determine the earth's albedo (and so the total solar energy absorbed by the earth and its atmosphere) by using Danjon's method of observing the earth radiation reflected from the moon. A further requirement is for measurements of atmospheric ozone to be made at certain stations on selected meridians, at points near subtropical anticyclones between 15° and 40°N. and near the subtropical jet stream. Among the subjects of other recommendations are networks of nephoscope observations in areas where upper wind measurements by balloon are impracticable or scarce, accurate measurement of humidity in aerological soundings, good observations of cloud (especially at sea), the importance of upper air observations on ocean islands and whaling or other ships, and representative measurements of temperature at depths below the earth's surface, at the surface, and at heights near the surface.

Participation by the United Kingdom.—The Meteorological Office operates aerological stations at the four ocean weather stations (shared with other countries) A, I, J and K, at 15 stations in the United Kingdom, Mediterranean and Middle East (Lerwick, Stornoway, Leuchars, Aldergrove, Liverpool, Hemsby, Crawley, Camborne, Gibraltar, Malta, Benina, Cyprus, Aden, Bahrain, Habbaniya), and at Stanley (Falkland Islands). The ocean weather stations I, J and K qualify for the 20°W. vertical section, Malta qualifies for the 10°E. and Aden for the 15°N. zonal sections. At almost all these stations two radio-sonde and either two or four radar-wind soundings are made as daily routine. It is intended on ordinary days in the International Geophysical Year to make the normal number of soundings, but that in one of the combined temperature-wind ascents daily a large balloon (perhaps 1,250 gm.) shall be used to attain greater height, and on World Meteorological Interval days to make four combined temperature-wind ascents with large balloons at the three 20°W. ocean weather stations and at three well distributed stations in the United Kingdom, and also to increase the radar-wind ascents (with large balloons) to four daily at stations in the Mediterranean and Middle East.

The current programmes in radiation will be maintained at Kew Observatory, Cambridge, Aberporth, and Eskdalemuir and Lerwick Observatories. Each of these stations will therefore obtain during the International Geophysical Year continuous records of the total and diffuse radiation received on a horizontal surface, while in addition Kew will record the solar intensity normal to the beam, daylight illumination, the vertical flux of total radiation near the ground, and perhaps solar-infra-red radiation. Arrangements are being made to record solar radiation on a horizontal surface and also the vertical flux of total radiation near the earth's surface at Malta, Aden and Port Stanley (Falkland Islands); it is hoped that the vertical-flux measurements at Malta will be made over the sea. A recent study by G. D. Robinson[3] indicates that the international plan for radiation measurements during the International Geophysical Year if carried out with care should make a considerable contribution to the more general meteorological problem, though measurements of the flux of radiation at all attainable heights in the atmosphere are greatly to be desired. It is proposed that the Meteorological Research Flight, in collaboration with Kew, shall measure the flux of long-wave radiation and the albedo of the earth's surface and of cloud at heights up to about 16 Km. over southern England.

In the United Kingdom, measurements of the total amount of atmospheric ozone, using the Dobson spectro-photometer, will be made as at present at the Ozone Commission Centre at Oxford by Prof. G. M. B. Dobson and Sir Charles Normand and at the Meteorological Office upper air stations at Lerwick, Aldergrove, and Camborne. It is hoped that further determinations of the ozone concentration (using a chemical absorption method), together with simultaneous readings of air temperature and humidity, will be made by the Meteorological Research Flight to heights of about 16 Km. To assist the investigation of relationships between ozone amount, the subtropical jet stream, and the occurrence of the double tropopause structure of the atmosphere, it is intended to make ozone measurements at two of the upper air stations maintained at Aden, Bahrain and Habbaniya.

The British sferics network—Leuchars, Irvinestown, Hemsby and Camborne—linked to the Central Forecasting Office, Dunstable, meets several of the international recommendations on the location of thunderstorms by radio direction-finding.

It is scarcely necessary to emphasize that meteorology will be by no means the only field of United Kingdom participation in the International Geophysical Year. Indeed, a significant part is to be taken in the programme of the other subjects.

The usual geomagnetic measurements obtained at the Eskdalemuir and Lerwick Observatories of the Meteorological Office and the Abinger and Hartland Point Observatories of the Royal Greenwich Observatory will contribute to the basis of the international programme in this field. It is intended to operate magnetic recording equipment at two points about 10–15 miles west and north of Lerwick to determine the horizontal space-gradients in the earth's magnetic field in that locality; it is hoped that these and similar measurements at other stations in the auroral region will contribute to knowledge of the intense electric-current systems located at heights of 100 Km. or more. An auroral survey organized by Mr. J. Paton, University of Edinburgh, has operated for some years. In addition, photographic and spectrographic studies of aurora will be made in Scotland by members of the Universities of Edinburgh and St. Andrews, and air glow will be investigated in Northern Ireland in conjunction with members of Queen's University, Belfast. Radio echo recording of aurora, not confined to darkness, will be undertaken at the Jodrell Bank radio astronomical station (University of Manchester). A widespread programme of ionospheric measurements and investigations will be operated by the Radio Research Organization of the Department of Scientific and Industrial Research in the United Kingdom, Falkland Islands, Singapore, and at Ibadan, British West Africa (with the University College); also by the University of Edinburgh, Jodrell Bank, Cavendish Laboratory, University College of Swansea and, it is understood, colleges in east and west Africa. Programmes in various aspects of solar activity will be carried out by the Royal Observatory at Edinburgh, the Cavendish Laboratory, Jodrell Bank, the Royal Greenwich Observatory, and the Royal Observatory at the Cape of Good Hope. Cosmic-ray measurements will be made by the Royal Greenwich Observatory, Imperial College (London), University of Bristol and Makerere College (British East Africa). Preparations are being made for work in glaciology and oceanography. At the time of writing it is too early to say whether British rocket flights to explore the high atmosphere will be made to supplement the series planned by the United States and France.

Arrangements for the International Geophysical Year corresponding to those outlined above are being made by other members of the British Commonwealth, in varying degree according to circumstances. Few of the recommended aerological meridians and parallels listed earlier are everywhere remote from Commonwealth territory. It is to be regretted that other Commonwealth commitments will preclude the setting up of special stations on certain isolated islands in the southern hemisphere from which upper air observations would be very valuable.

Polar regions.—In the past 20 years or so there has been a marked increase in the number of places in the Arctic regions at which meteorological and other geophysical observations are made. Nevertheless, countries bordering or otherwise interested in these regions are preparing to amplify the current programmes, and where practicable to establish additional special stations during the International Geophysical Year.

Probably the most striking feature in the preparations for the International Geophysical Year is the effort being made to develop a good geophysical coverage in the Antarctic. Apart from the permanent British bases in the Falkland Islands Dependencies and bases occupied by Argentina and Chile in that territory, some 20 special geophysical stations, reasonably well distributed, are to be operated on and in the vicinity of the main Antarctic mass by the United Kingdom, Australia, New Zealand, France, Norway, United States, U.S.S.R., Japan and possibly Belgium and Spain. Six stations are planned by the United States (one at the South Pole), three by the U.S.S.R. (probably one at the geomagnetic pole), two by Australia, possibly two by New Zealand, and two by France. An Antarctic Weather Central is to be set up at the main American base in the Ross Sea area for the collection of weather reports from Antarctic stations and neighbouring areas, and the dissemination of reports, analyses and other information. Arrangements for codes and communications are under active discussion between the United States Weather Bureau, the World Meteorological Organization and the countries immediately concerned.

The United Kingdom contribution in the First and Second International Polar Years of an expedition to Fort Rae, north-west Canada, with a party for ionospheric studies at Tromsø in 1932–33, is to be followed by a British (Royal Society) International Geophysical Year expedition to Coats Land (75°36′S. 26°45′W.) in the Weddell Sea to undertake programmes in meteorology, geomagnetism, aurora, ionospheric measurements, glaciology, seismology and, possibly, gravity. The meteorological work will include two radio-sonde and probably radar-wind ascents daily, measurements of atmospheric ozone and the recording of solar radiation on a horizontal surface and of the vertical flux of total radiation. Regular measurements of the components of the earth's magnetic field will be made and continuous photographic records of variations in the geomagnetic field maintained. This base is situated in or very near to the zone of maximum auroral frequency, and the auroral, geomagnetic and ionospheric observations obtained at the station will be of special interest. As is generally known, an advance party of the Royal Society expedition left England for the Weddell Sea in November 1955 to establish the base and to initiate a limited scientific programme of surface meteorological observations, solar radiation and ozone measurements, photographic and visual observations of aurora, ionospheric noise measurements and human physiology. Mr. D. W. S. Limbert of the Meteorological Office is a member of the advance party. The main party, about 18 strong and including five members to deal primarily with meteorology and geomagnetism, will arrive at Coats Land early in 1957 to carry out the extended programme until the end of 1958.

A valuable additional contribution to meteorological knowledge of the Weddell Sea area is expected from the Commonwealth Transantarctic Expedition, led by Dr. V. E. Fuchs. The advance party of this expedition, which also left England in November 1955, plan to carry out surface meteorological observations, radiation measurements and daily radio-sonde ascents at their main base—to be known as "Shackleton"—from as early as possible in 1956 until 1957. Mr. R. H. A. Stewart, formerly of the Meteorological Office, and Mr. P. H. Jeffries, a present member of the staff, are included in this advance party.

At the Argentine Islands base (65°S. 64°W.) of the Falkland Islands Dependencies Survey, the newly inaugurated long-term programme of radio-sonde soundings, and in radiation ozone and geomagnetism, will yield valuable results for International Geophysical Year purposes.

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AN UNUSUALLY SMOOTH WAVE PATTERN IN A CONDENSATION TRAIL

By W. G. HARPER, M.Sc.

An unusually smooth wave pattern was seen in a condensation trail from East Hill near Dunstable just before sunset on March 10, 1955. When the wave pattern was first seen at 1755 G.M.T., about a minute after the passage of the aircraft, the waves were almost uniform in amplitude, but at 1758, when the sketch (Fig. 1) was made, their amplitude showed a definite decrease towards the north-east, the direction in which the aircraft was flying. Waves were not formed outside this zone.

The aircraft was picked up on the East Hill height-range radar, which gave its height as 37,000 ft., track 40° and ground speed 310 kt. The trail itself gave no radar echo. This radar height, and elevation and azimuth measurements made with an 8-in. protractor as an alidade, located the wave pattern in space and gave a value for the wave-length of 1½ miles. The waves were still visible at 1805 G.M.T. but by then had almost dissipated and were in sunset shadow.

Synoptic situation.—An anticyclone of central pressure 1032 mb. was stationary over the British Isles with its centre over southern Scotland, giving

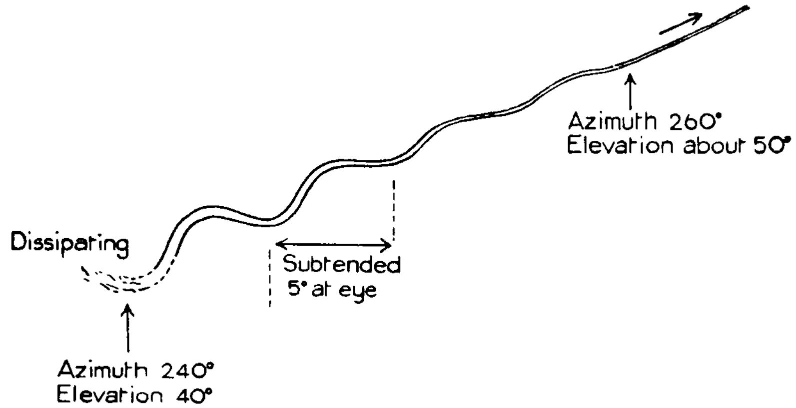

FIG. 1—CONDENSATION-TRAIL PATTERN AS SEEN OBLIQUELY FROM THE GROUND
1758 G.M.T., March 10, 1955

clear skies and cold NE. winds over England. Upper air soundings at Hemsby must on this occasion have been closely representative of conditions along the track of the aircraft. The 1400 G.M.T. temperature sounding (Fig. 2) shows an isothermal layer from 5,000 to 9,000 ft. The tropopause at 35,700 ft. places the aircraft just in the stratosphere. The upper winds, also given in Fig. 2, were north-easterly at all levels up to 50,000 ft. It can be seen that the trail was formed in a region of considerable wind shear in the vertical above a north-easterly jet stream centred at the 32,000-ft. level. The wind at 37,000 ft. was 50° 70 kt.

Cause of wave pattern.—If the wave pattern had been moving with the 70-kt. wind it would have changed in azimuth by more than 20° in the period in which it was observed. This would have been detected readily even though the pattern was not watched continuously, and certainly did not occur. This excludes the possibility that the waves were due to aerobatic motion or to perturbations in the wind field moving with the wind.

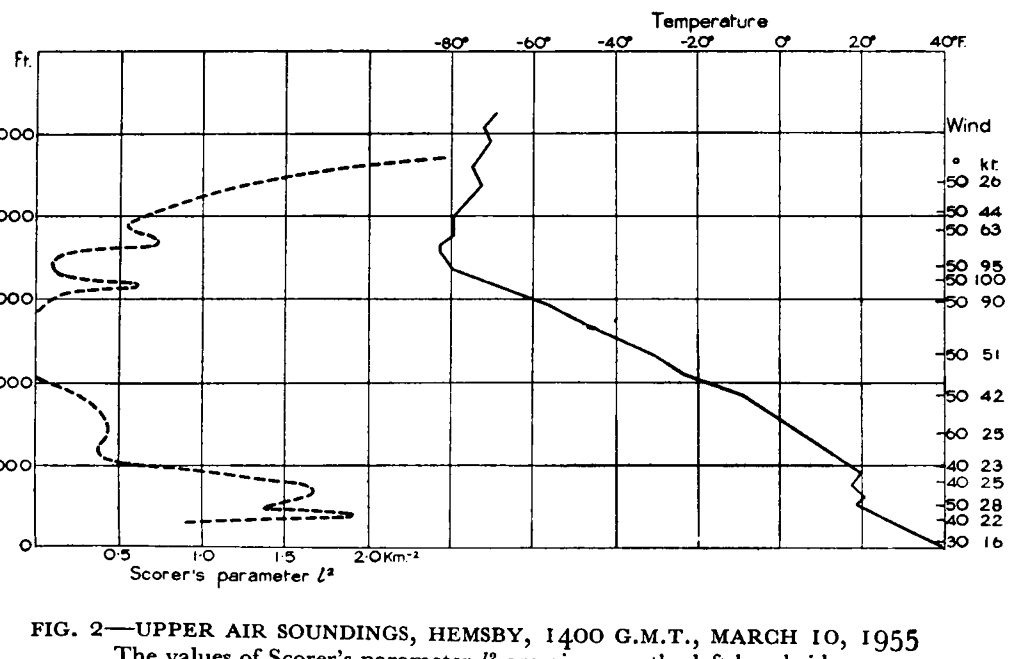

FIG. 2—UPPER AIR SOUNDINGS, HEMSBY, 1400 G.M.T., MARCH 10, 1955
The values of Scorer's parameter l^2 are given on the left-hand side.

There is no certainty that the waves were not due to some sort of horizontal wind shear or formed at an interface between two fluids, but there is some evidence to suggest that they were of standing-wave origin.

Standing waves.—There is increasing evidence that orographic standing-wave effects can occur at considerable heights. They are quite readily demonstrable in the upper troposphere as orographic cirrus. Ludlam[1] has studied orographic cirrus which formed at levels around 30,000 ft. to leeward of the ridges of the Cotswolds and Chilterns, but in the present case the aircraft track was not across the main ridge of the Chilterns, but parallel to it and a short distance to the south-east. It did however cross a well defined spur of the Chilterns rising to 500 ft. above mean sea level which has an obstruction height of 300 ft. (Fig. 3). If orographic cirrus can be formed by the 500–600-ft. obstruction of the Chilterns it cannot be ruled out that in favourable conditions orographic effects from an obstruction of 300 ft. could extend to 37,000 ft.

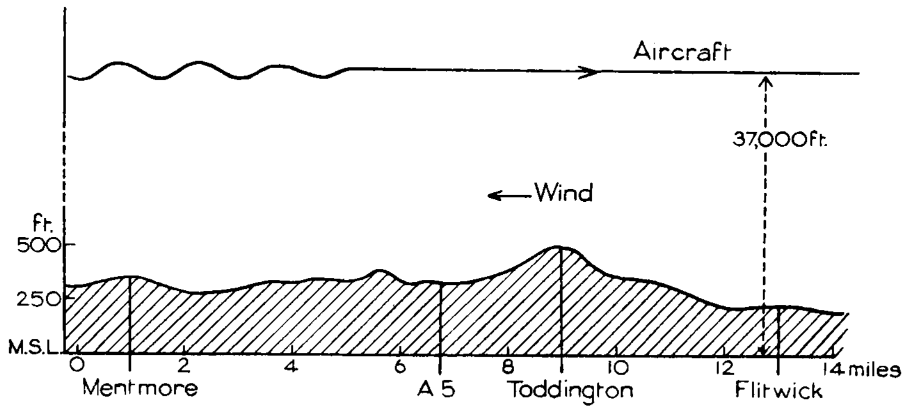

FIG. 3—SURFACE CONTOURS IN RELATION TO WAVE PATTERN

The wave pattern, the height of aircraft and the ground contours are not drawn on the same vertical scale.

Corby[2] quotes the wave-length of hill and ridge waves in Great Britain as being commonly in the range 1–10 miles, and has summarized a study by Turner of aircraft reports of standing waves which indicates that increase of wind with height in the lower layers of the air stream and the presence of a deep isothermal layer are very favourable for their development. These conditions can be seen to be present on March 10 (Fig. 2). It is also of interest to consider the profile of the parameter l^2 which Scorer[3] has shown to be significant in the occurrence of standing waves; l^2 is seen to have a broad maximum between 4,000 and 8,000 ft. In this the amplitude of standing waves should be a maximum, but it should be noted that a subsidiary maximum occurs at 37,000 ft.

In most standing waves the amplitude decreases down wind, and some explanation is desirable for the decrease in amplitude of the wave pattern up wind between 1755 and 1758 G.M.T.

A straight-line condensation trail moving with the wind into a standing-wave zone will of course take up the standing-wave stream-line; but a condensation trail formed in a standing-wave zone will not. Not only is a wave motion imposed on the aircraft itself by the standing waves but each element of the condensation trail is formed in a different stream-line and will move with the wind along that particular stream-line. The effect can be conveniently shown graphically if the standing-wave stream-line is assumed to be sinusoidal and of uniform amplitude, and the horizontal component of the wind equal to the free-air wind speed at every point. Taking wind speed as 75 kt., and ground speed 300 kt., an aircraft heading into wind will traverse one wave-length of the standing wave in exactly 16 sec. for wave-length 1·53 miles. These values are convenient and close to those measured. If the mean horizontal speed of the air in the wave is U, the amplitude (maximum departure from the mean position) of wave-motion a, and wave-length L, the vertical component of air motion in a standing wave of form $z = a \sin (2\pi x/L)$ is $(2\pi aU/L) \cos (2\pi x/L)$.

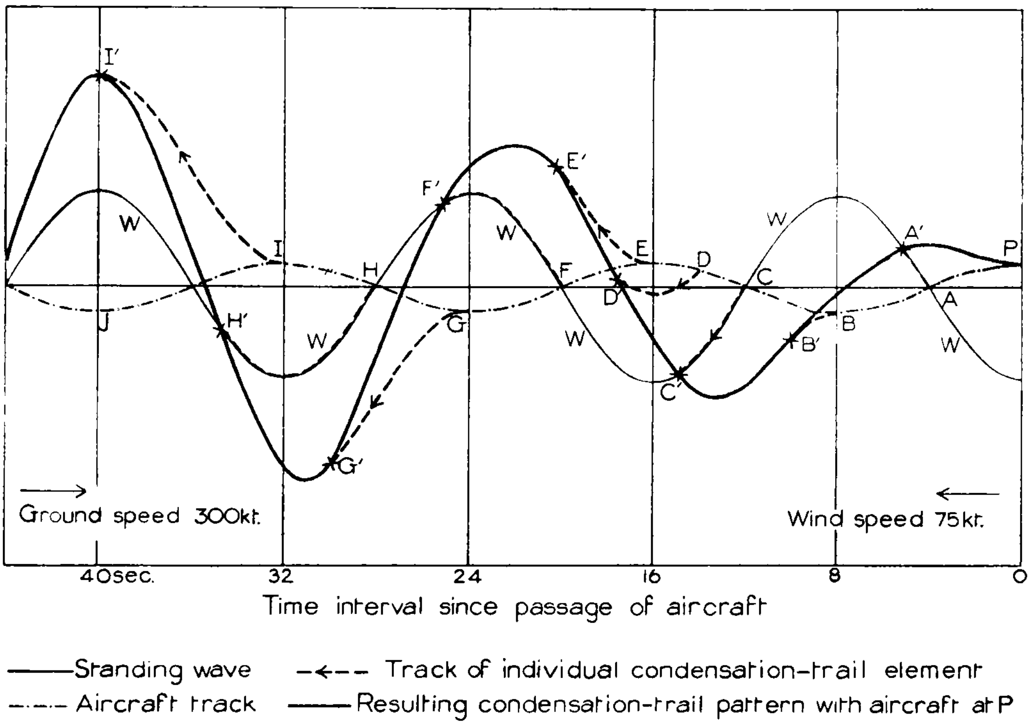

FIG. 4—GRAPHICAL CONSTRUCTION OF CONDENSATION-TRAIL PATTERN

If the attitude of the aircraft relative to the air is unchanged the aircraft will have this vertical component of air motion imparted to it at every point. For an aircraft flying up wind with airspeed V we find, on combining the ground speed $-V+U$ with the vertical component of air motion, that the trajectory of the aircraft is given by

$$z = -\frac{aU}{V-U} \sin \frac{2\pi x}{L}.$$

The track of the aircraft is thus sinusoidal 180° out of phase with the air motion, and for the numerical values of U and V chosen its amplitude is one quarter the amplitude of the standing waves.

In Fig. 4 WWW . . . is the standing-wave stream-line, and JIH . . . the resulting aircraft track. When the aircraft is at P the condensation-trail element formed 16 sec. earlier at E will have been lifted on the standing wave to E′; that at B will in 8 sec. have descended to B′, etc.; so that A′B′C′ . . . . is

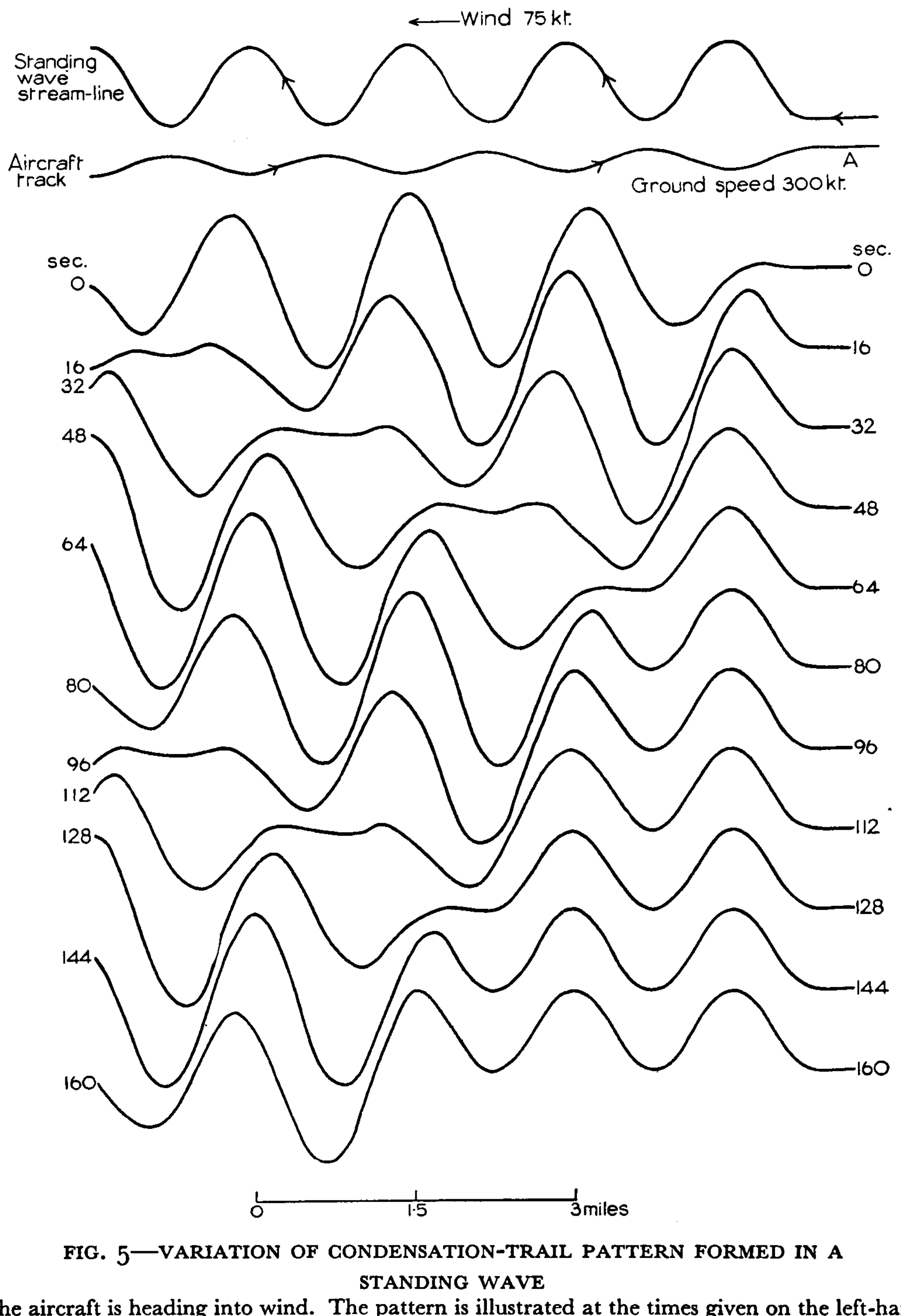

FIG. 5—VARIATION OF CONDENSATION-TRAIL PATTERN FORMED IN A STANDING WAVE

The aircraft is heading into wind. The pattern is illustrated at the times given on the left-hand side since the aircraft left the standing-wave zone at point A.

the condensation-trail pattern at this time. The interesting feature is that a wave with amplitude roughly twice that of the aircraft motion developed within ½ min. of the passage of the aircraft. The changes in the pattern from the time the aircraft leaves the standing-wave zone (Fig. 5) show how the true standing waves gradually take over from the large-amplitude waves. To an observer at the ground the whole pattern would effectively appear stationary although the early stages are not strictly so.

The graphical construction leads readily to the equation of the pattern. For an aircraft of airspeed V passing through the origin at time $t = 0$ the vertical displacement z of the condensation-trail is given by

$$z = a \sin \frac{2\pi x}{L} - \frac{V}{V-U} a \sin \left\{ \frac{2\pi}{L}\left(\frac{V-U}{V}\right)(x + Ut) \right\}.$$

For flight down wind the sign of the wind speed U must be reversed. The first term represents the standing wave, on which is superposed a sine wave with a different amplitude and wave-length moving with the wind. z has a maximum value $(2V-U)a/(V-U)$, from which it can be seen that large-amplitude waves are formed over a wide range of airspeeds for both up-wind and down-wind flight. In the example chosen $V = 375$ kt., $U = 75$ kt., z_{max} is $2 \cdot 25a$. An example of this is I′ in Fig. 4.

The pattern at the time the aircraft leaves the standing-wave zone consists of waves of approximately uniform amplitude and corresponds to the condensation-trail appearance at 1755 G.M.T., while the pattern 144 and 160 sec. later corresponds reasonably to the sketch made at 1758 G.M.T. (Fig. 1). This lends some support to the view that the waves were of standing-wave origin.

The argument above neglects the variation with height in the vertical component and the periodic part of the horizontal component of the air motion in the standing wave. It can be shown that the effects of neglecting these terms are of the second order in the amplitude.

Vertical currents.—The assumption that the wave pattern was in a vertical plane and was due to standing waves leads to a value for the standing-wave amplitude of about 350 ft. As the wind traversed one wave-length in 64 sec. this gives a mean value for the up-draughts and down-draughts of 1,200 ft./min. Bigger vertical currents than this have been reported in standing waves over the Pennines and over Scotland, but none as large over the south of England. It must be remembered however that the amplitude of the aircraft track would have been less than 100 ft., and a pilot would be unlikely to report rate of climb for this type of motion.

It is hoped that, with the steady increase of high-altitude flying, reports from pilots will show clearly whether or not orographic waves can extend to the stratosphere and will throw more light on the frequency of their occurrence.

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LEE WAVES OVER GREEN I AIR ROUTE LONDON TO SOUTH-EAST IRELAND

By E. CHAMBERS, M.A.
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B.O.A.C. Stratocruiser GAKGK, under the command of Capt. P. C. Fair, departed from London Airport at 1518 G.M.T. on December 23, 1954 and arrived at Shannon at 1735 G.M.T. on the first leg of a charter flight to Bermuda. The aircraft was flown at a pressure altitude of 10,500 ft. over the Green I Airway and the track is shown in Figs. 1 and 2. The airway extends westwards from Compton, which is 8 miles north of Newbury (Berkshire), and thence to Stockwood, Bristol, Newport, Strumble and Tuskar Rock, which is off Carnsore Point.

The following is an extract from Capt. Fair's voyage report:—

Between Compton beacon and the coast of Ireland a curious phenomenon was observed. A few minutes after passing Compton the airspeed fell back almost 25 kt. from 200 to 175 kt., while the aircraft maintained a constant altitude of 10,500 ft., the altitude control of the gyro-pilot being in use. I flew the aircraft by hand for about 5 min. and was able to get the airspeed back to 200 kt. Shortly afterwards the airspeed fell again. The aircraft was trimmed normally and flew in a stable manner. There was no turbulence. The airspeed again dropped about 25 kt. but gradually returned to normal. All engine instruments gave normal readings and there was no indication of overheating or loss of power. All gills, flaps and undercarriage were checked visually as far as possible and were in normal positions. All doors were checked. This loss of airspeed occurred at least four times between Compton and the Irish coast at Tuskar Rock, and each cycle of loss and build-up lasted about 6 min. There was a strong north-westerly air stream and the temperature at 10,500 ft. was about −6°C. The aircraft was flying in clear air, but all anti-ice heaters were kept on in case the loss of speed was caused by some form of clear ice. There was no indication of any form of icing. The aircraft take-off at London Airport was normal and the landing at Shannon was normal as regards airspeeds for power settings.

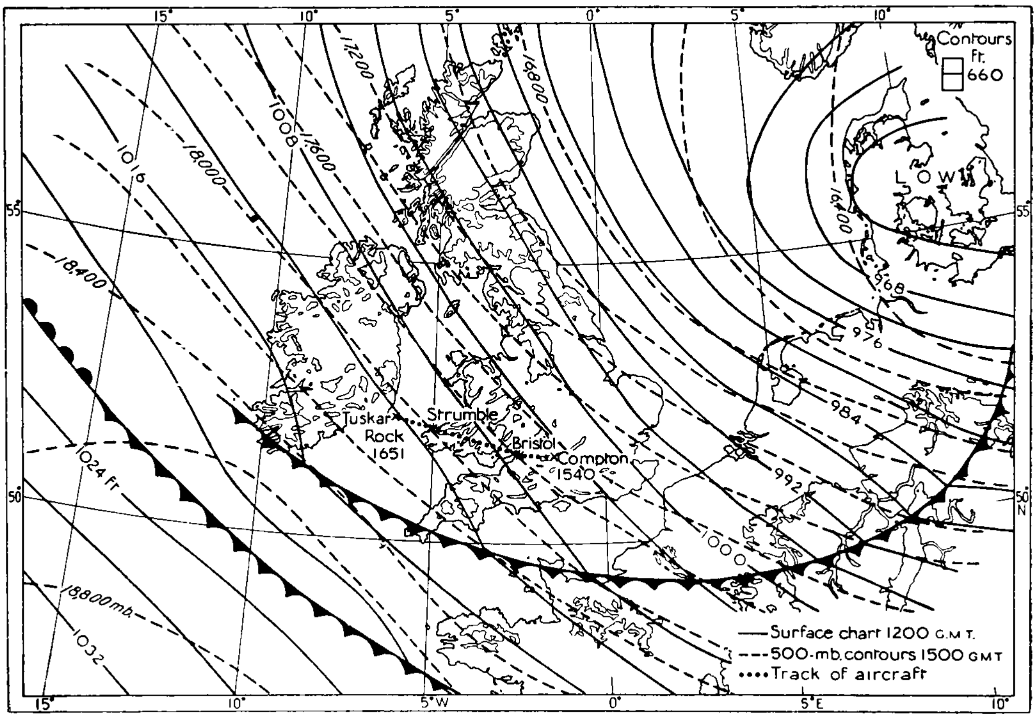


FIG. 1—SYNOPTIC CHART, DECEMBER 23, 1954

The report is interesting in the sense that there were cycles of loss of airspeed with a gradual return to normal but no corresponding increase of airspeed to above normal, and so it was not obvious to the pilots that the effect was due to atmospheric wave motion. It was thought worth while, therefore, to examine the meteorological situation in some detail, and, in particular, to apply Scorer's theory[1,2] to find out if the air-stream characteristics were favourable for the occurrence of lee waves.

Fig. 1 shows the 1200 G.M.T. surface chart and the 1500 G.M.T. contour chart for the 500-mb. level on December 23, 1954 as drawn by the meteorological office at London Airport. Pressure was low over Denmark and high north-east of the Azores and there was a cold north-westerly air stream over the whole of the British Isles. A stream of warm air flowing around the Azores anticyclone was approaching the British Isles from the Atlantic and, as would be expected, there was a well marked jet stream in the north-westerly current ahead of the warm front. Fig. 2 shows a cross-section of the wind and temperature structure of this jet stream normal to the general air flow of 310° true, and was constructed from the 1400 G.M.T. upper air reports obtained from the *Daily aerological record* and other sources.

Strong winds and high values of vertical wind shear, especially in the 750–550-mb. altitude band, were reported at various places and it is unfortunate that the French observations in Table I were restricted to

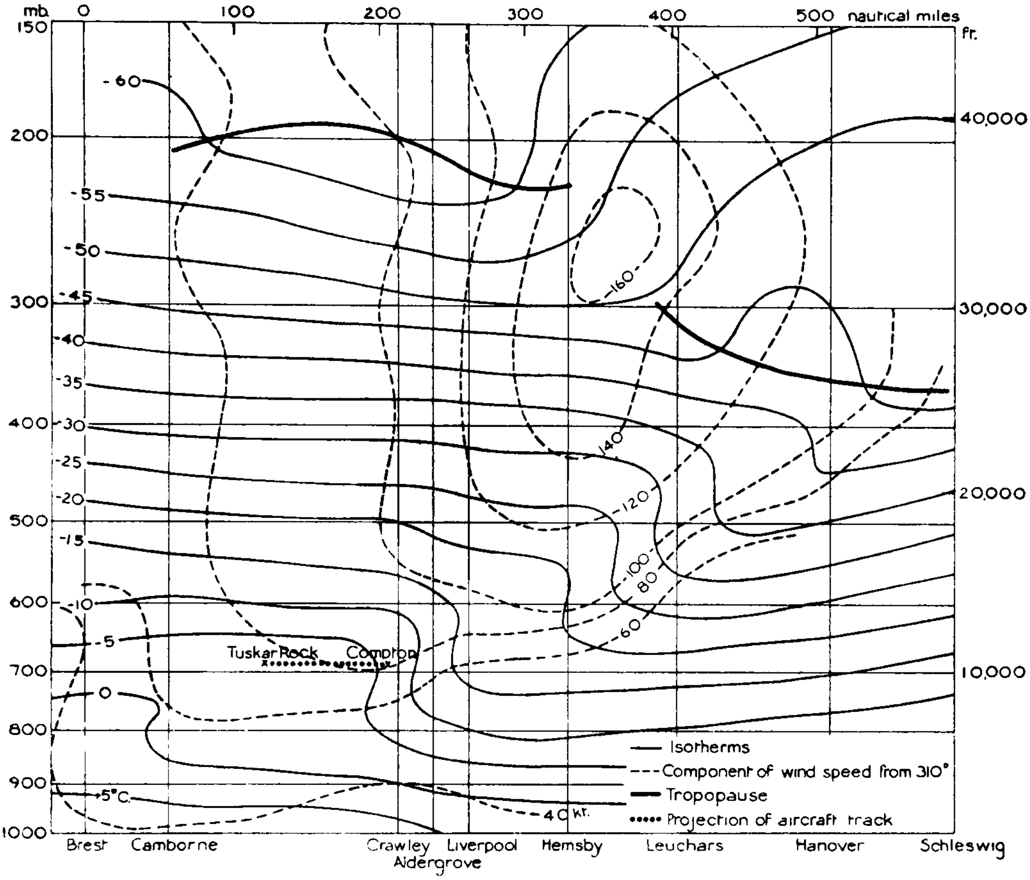


FIG. 2—VERTICAL CROSS-SECTION AT RIGHT ANGLES TO 310°, 1400, DECEMBER 23, 1954

comparatively low altitudes. The flight appears to have been made in the warm air just above the frontal surface of the cold front which is shown in Fig. 1 through Valentia and Cherbourg and it is interesting to note that there was no turbulence.

Wind-speed (component from 310°) and temperature profiles for Aldergrove and Crawley for 1400 G.M.T. are shown in Fig. 3, and it will be seen that these are essentially similar so it seems fair to assume that the Crawley data may be taken as being representative of the air mass in its undisturbed form.

Scorer[1,2] has shown that lee waves can only occur in an air stream if the parameter l^2 has lower values through a fairly deep upper layer than in the

TABLE I—UPPER AIR OBSERVATIONS, 1400 G.M.T., DECEMBER 23, 1954

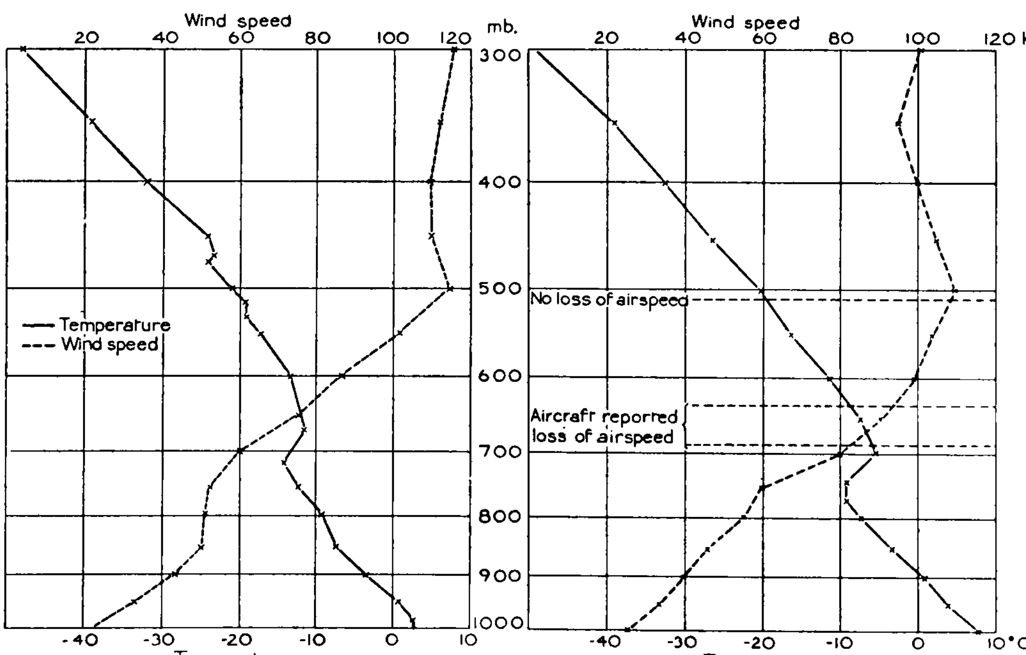
	Brest		Trappes	
mb.	°	kt.	°	kt.
519	290	142	...	...
543	300	130	...	...
553	300	124	...	...
600	300	45	...	...
650	300	41	...	...
671	...	...	300	159
700	300	39	300	124
712	...	...	300	95
750	300	45	300	66

layer below where

$$l^2 = \left(\frac{B}{U}\right)^2 - \frac{1}{U}\frac{\partial^2 U}{\partial z^2}, \quad B^2 = g\beta = \frac{g}{\theta}\frac{\partial \theta}{\partial z},$$

U is the wind speed, z the height, β the static stability and θ the potential temperature. He has also shown that the reduction in l^2 must exceed a critical value for waves to be possible and the greater the reduction of l^2 with height the greater the likelihood of waves.

A first approximation to the value of l^2 has been calculated from the Crawley data for 1400 G.M.T. on December 23, 1954, using the method of Wallington[3] and the results are given in Table II. From the surface to 950 mb. the lapse rate was adiabatic but Scorer[2] has constructed stream-lines to show the occurrence of lee waves for a three-layer model with an adiabatic layer near the surface, a layer with comparatively large l^2 above and an upper layer of small l^2. It will be seen from Table II that the inversion of temperature from 740 to 700 mb. produced large values of l^2 whilst the strong forward wind



Aldergrove Crawley

FIG. 3—WIND-SPEED (COMPONENT FROM 310°) AND TEMPERATURE PROFILES, 1400 G.M.T., DECEMBER 23, 1954

shear was the dominant factor in producing very small values of l^2 above 650 mb.

TABLE II—VALUES USED IN CALCULATION OF SCORER'S PARAMETER l^2

	B	U	B^2/U^2
mb.	hr.$^{-1}$	kt.	Km.$^{-2}$
350	42	95	0·06
400	42	99	0·05
450	35	105	0·03
500	50	110	0·06
550	32	103	0·03
600	32	99	0·03
650	62	90	0·14
700	78	79	0·28
720	110	72	0·68
750	70	59	0·41
770	37	58	0·12
800	42	55	0·17
850	17	45	0·04
900	35	39	0·23

Conditions appeared to be very favourable, therefore, for the occurrence of lee waves, and there seems to be little doubt that the Stratocruiser's loss of airspeed was due to flight at constant altitude in the descending portions of waves set up in the lee of the Welsh Mountains and probably also of the Wicklow Mountains and Cotswold Hills. It would be expected that the waves would attain maximum amplitude somewhere in the layer 750–650 mb. where the value of l^2 was a maximum, and it is interesting to note that an hour or so later two other commercial aircraft, flying at 10,500 ft. and 12,500 ft. respectively, also experienced a loss of airspeed of about 20 kt. in the region of Bristol but with no repetition of the cycle, whilst a third, at 17,500 ft., had nothing to report.

Another case worthy of mention occurred on January 16, 1955 when a B.O.A.C. Constellation aircraft flying at approximately 17,000 ft. along the east coast of Italy on a flight from Beirut to Zurich encountered standing waves continuously throughout the period 2100–2230 G.M.T. The Captain stated that, although he had flown through standing waves on previous occasions, he had never flown for so long a period in waves of such well defined regions of lift and sink. The flight was largely smooth but there were occasional short periods of moderate clear-air turbulence. As in the previous case, the waves occurred in an air stream containing strong forward wind shear on the warm side of a well developed jet stream. Very high values of vertical wind shear were reported at various places near the jet stream; Hemsby at 1400 G.M.T. on January 17, 1955 reported winds of 280° 42 kt. at 500 mb. and 280° 154 kt. at 300 mb., whilst Brindisi reported 20 kt. at 700 mb. and 110 kt. at 300 mb. The flow over Italy was south-westerly, i.e. more or less at right angles to the Apennines.

There now appears to be ample evidence to show that lee waves are very likely to occur in an air stream where the wind speed shows a marked increase with height and where there is a low stable layer, preferably an inversion, so that the parameter l^2 is large in the low layer and small above that layer. Such conditions often exist on the warm-air side of jet streams or perhaps on the cold side if subsidence has occurred in the cold air. Regions of jet streams of high values of wind shear also have a high incidence of clear-air turbulence, and it is not surprising therefore that Jones[4] has suggested a possible connexion between clear-air turbulence and standing waves. The fact remains, however, that the majority of flights in well developed standing waves are quite smooth, and the degeneration of waves into turbulent motion is difficult to substantiate.

Owing to the effect on aircraft performance, it is obviously important that pilots should be warned whenever standing waves are thought to be probable, and Scorer's l^2 criterion might profitably be used by forecasters for the purpose of providing such advice.

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METEOROLOGICAL OFFICE DISCUSSION

Winds in the outer atmosphere

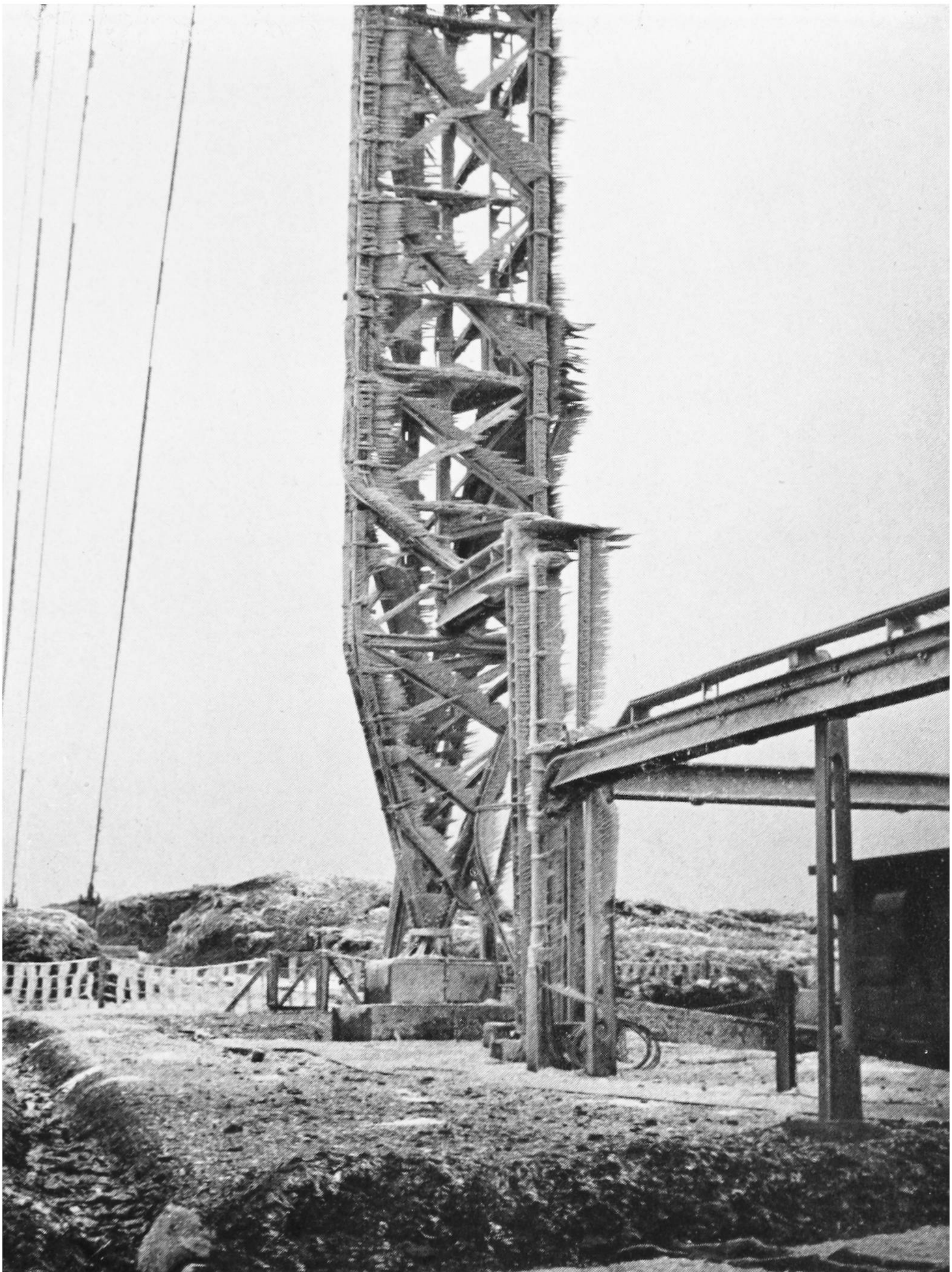
The discussion at the Royal Society of Arts on Monday, November 21, 1955, on winds in the outer atmosphere was opened by Mr. P. Graystone.

Mr. Graystone defined the outer atmosphere, in this instance, as the region above 30 Km., i.e. beyond the normal present limit of radar wind observation. The variation of temperature with height was first briefly discussed. A temperature increase with height has set in by 30 Km. in most latitudes, and a peak value, somewhat above that at the surface, is reached near the top of the ozone layer. Following a temperature lapse to a temperature at 80 Km. similar to that at the tropopause, there is a further rise, possibly to very high values in the ionosphere.

The physical structure of the atmosphere was portrayed, with reference to phenomena relevant to the measurement of upper winds. The E- and F-layers, bases about 100 and 250 Km. respectively, are the principle ionospheric regions, both showing considerable diurnal fluctuation. Other phenomena indicated were sporadic E, or "clouds" of more intense ionization occurring in the lower E-layer, noctilucent clouds, usually about 80 Km., and meteors, visible at heights ranging from 50 to 150 Km.

A few other points of interest were mentioned. The composition of the atmosphere remains roughly constant, apart from minor gases, to great heights, though above 80 Km. oxygen molecules are dissociated into the atomic form, and at higher levels dissociation of nitrogen also occurs. The atmospheric pressure is approximately 10 mb. at 30 Km., 10^{-3} mb. at 100 Km. and 10^{-6} mb. at 400 Km. The mean molecular free path is of the order of 1 cm. at 100 Km. and perhaps 1 Km. at the top of the F-layer.

A fair number of measurements of wind at and just above 30 Km. have been made by the normal radar wind technique, either using very large balloons, or a double-balloon method, the maximum height so far reached being just over



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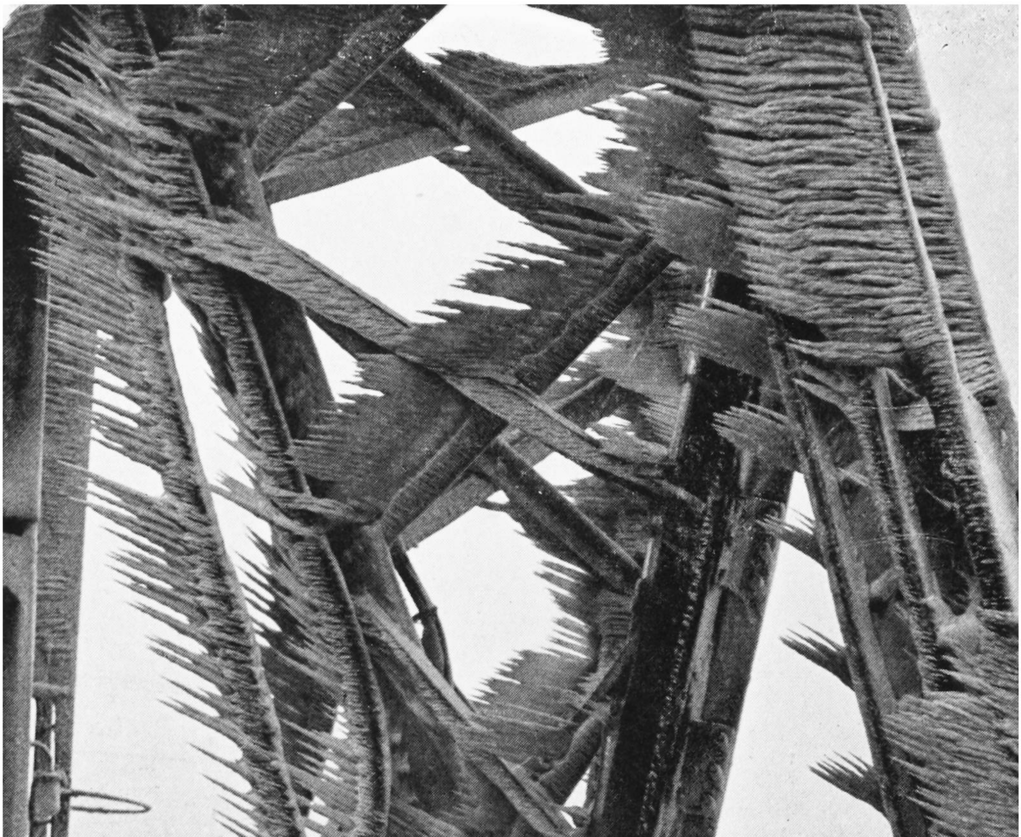
RIME ACCRETION AT B.B.C. TRANSMITTING STATION, HOLME MOSS

Base of main transmitting mast

(see p. 57)



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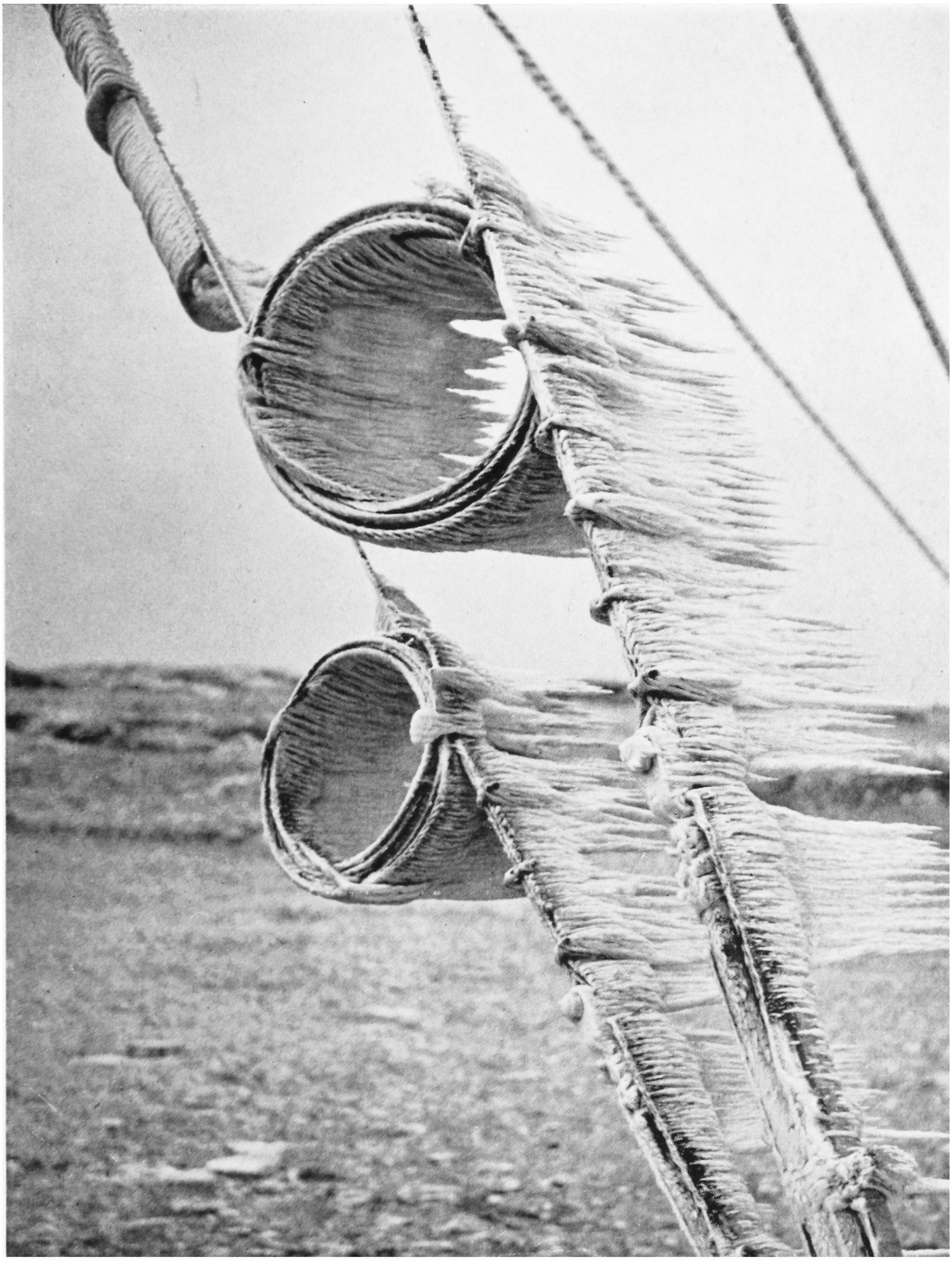

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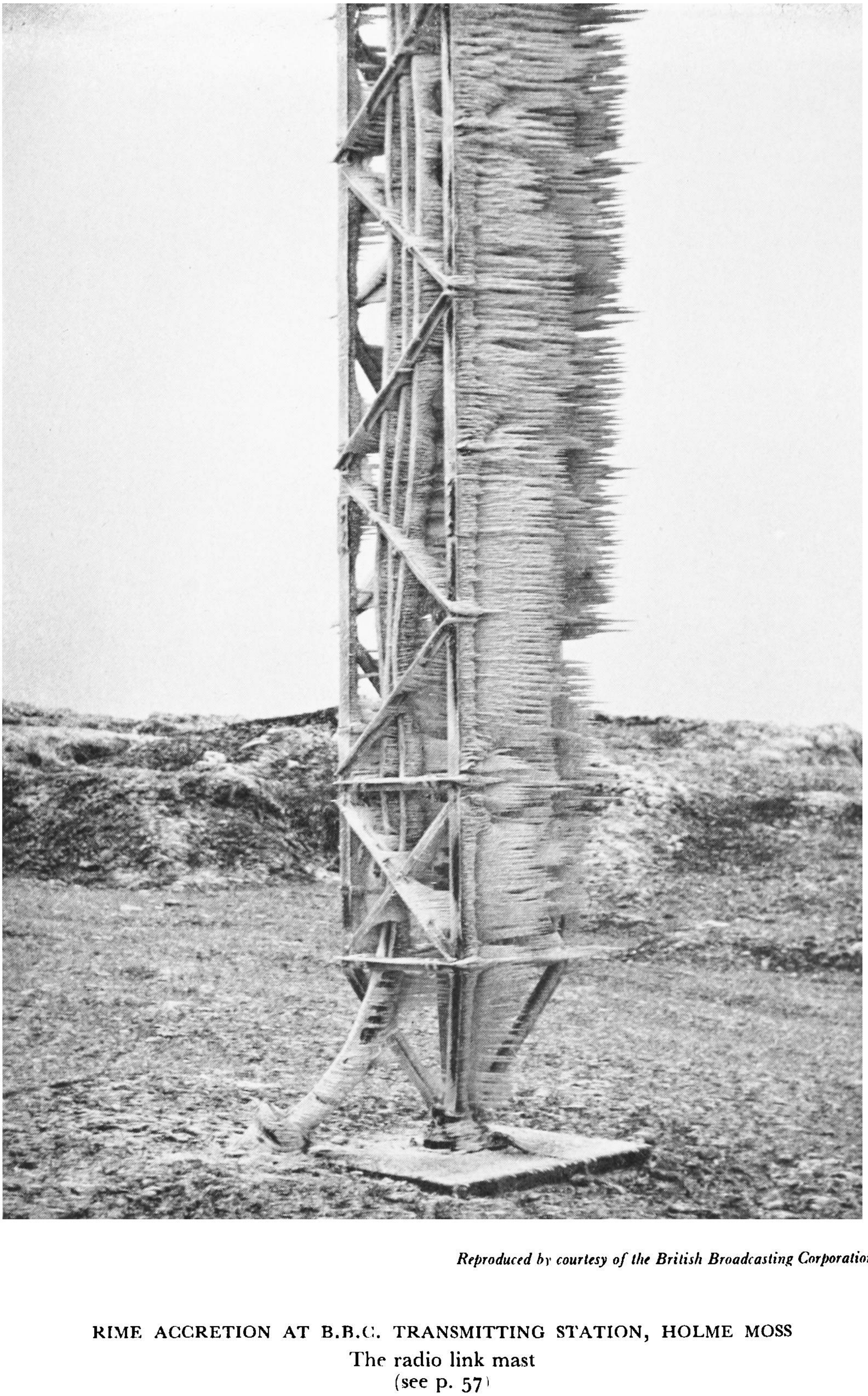

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RIME ACCRETION AT B.B.C. TRANSMITTING STATION, HOLME MOSS
The radio link mast
(see p. 57)

40 Km. Further data at 30 Km. are available from the programme carried out in this country during the last war, when the movements of smoke puffs from high-level shell bursts were recorded[1]. But at higher levels information largely depends on the movements of natural phenomena, observed visually or by radio.

The principal visual method is the observation of meteor trails. Some of these give a luminosity persisting for several seconds, and in rare cases a few hours, and observations of long-persisting trails, dating back over many years, have been tabulated by Olivier[2,3] and others. Though this is a chance method, observations compiled over a long period could be very useful, and it is unfortunate that there is doubt as to the accuracy of some of the observations. A modern variation on this method is the photography of meteor trails at intervals of a second or two. The other visual method is the observation of movements of noctilucent clouds, rather uncommon phenomena chiefly seen in summer in high latitudes when the sun is just below the horizon.

Radio techniques, however, provide the principal tool for wind measurement on a regular basis. Two quite distinct ones have been developed during the past few years. The first uses the fact that meteor trails are highly ionized, and hence that their movements at right angles to their orientation can be recorded, either by the Doppler technique, or by the variation in range. Since meteor trails can be tracked at the rate of a hundred an hour or more, a continuous record can be maintained of the mean wind over a wide area.

The other radio method uses the fact that irregularities of electron density exist throughout the ionosphere and can be recorded at ground receivers, both by reflection from the E and lower F regions, and in the upper F region by recording the "scintillation" of radio stars. Three receivers located at the corners of a right-angled triangle are used, and the "fading pattern" is normally found to be similar at each, with a time-lag of a second or two. This is taken as a measure of the velocity of the irregularity pattern, and the use of three receivers enables two wind components to be evaluated. There are doubts as to the reliability of these wind-measurement methods. The height of the irregularities recorded is uncertain, casting doubt on the F-layer velocities, and there is also the question of whether a true air movement is being recorded. Two other possibilities exist—there may be a form of redistribution of ionization occurring, or there may be a separation of the motion of ionized and neutral air. The ionized air is subject to electric and magnetic forces, and in a very rarified gas there could be a separation of velocities. This effect, unlikely in the E-layer, is a distinct possibility in the F-layer.

Sporadic E affords another method of wind measurement, principally used by Gerson[4] assisted by a large body of radio amateurs in North America. Over a period of four years, they have carried out experiments in tracking sporadic E by observing when radio contact was established and broken off between two amateurs. Lack of knowledge as to the origin and nature of sporadic E, however, make it uncertain whether true air movements can be measured in this way.

The method of acoustical propagation is one other way of recording high-level winds on a systematic basis. The marked temperature inversion in the ozonosphere assists the refraction of sound waves, so that sound waves from an explosive source can be recorded at the surface at ranges of 100–200 miles.

Observations of the time of travel of the sound wave, and of the orientation of the wave front at the receivers, enable estimates to be made of the temperature and wind structure to the top of the ozonosphere. Despite the technical difficulties involved, the fact that temperature and wind effects have to be separated and that some form of variation with height has to be postulated, the results are basically reliable, and are the only ones available for this level.

Fig. 1 illustrates the normal heights over which these methods of wind measurement are operative. It will be seen that there is a gap between 60 and 80 Km., with little information available—all the information above about 120 Km. is doubtful, if considered as air movements.

Results for the level 30–60 Km. fit into a coherent pattern, and the estimated zonal flow for summer and winter is illustrated in Fig. 2. The outstanding feature is the reversal in nearly all latitudes from westerly in winter to easterly in summer. The position of the westerly maximum in winter is uncertain—it may extend down to much lower latitudes than those indicated in the diagram. In summer there is some slight evidence that the easterly winds decrease, or even become westerly in the upper ozonosphere in high latitudes.

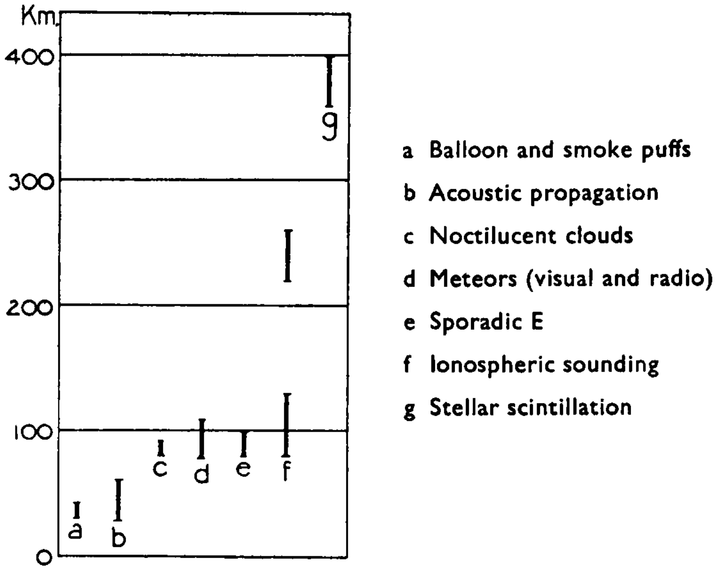
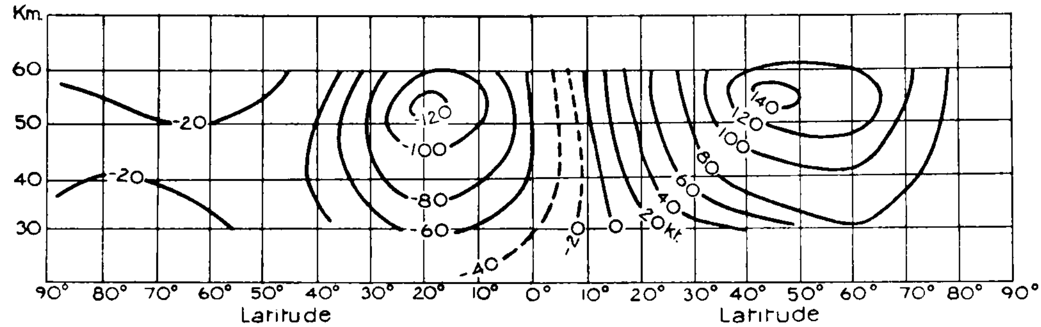


FIG. 1—HEIGHTS FOR WHICH WIND ESTIMATES ARE AVAILABLE

At higher levels no definite flow pattern has yet emerged. In and below the E-layer, there is agreement on the order of magnitude of the velocities, which has a modal value of 100–150 kt. and occasionally reaches 400–600 kt. Seasonal trends have been identified by individual workers, but it would be unrealistic at this stage to attempt to deduce a circulation pattern. Similar considerations apply to the F-layer, where velocities are similar in magnitude but occasionally reach very high values, these being apparently highly correlated with the intensity of geomagnetic activity.

Several observers have noted the existence of periodic oscillations at or near the E level, the most pronounced being a semi-diurnal variation of large amplitude representable by a wind vector rotating through 360° twice in 24 hr. Such an oscillation at the surface is readily explicable in terms of the surface semi-diurnal pressure wave; by applying the equations of motion for small perturbations, and using an empirical formula for the pressure variation, it can be shown that this entails a wind component, rotating every 12 hr., in a clockwise direction in the northern hemisphere and counter-clockwise in the southern, with an amplitude in middle latitudes of around 1 kt. On the resonance theory of the surface pressure wave, Taylor[5] and Pekeris[6] have shown that for an idealized atmosphere possessing a temperature structure similar to that now known to exist, a free period of oscillation of 12 hr. is possible, and that the resulting wind variation would undergo a 180° change of phase at 30 Km. and subsequently increase rapidly in amplitude. The observed results for the ionosphere fit the theory quite well, though the change in phase differs somewhat. Results obtained by Johnson[7] at 100 mb. fit the theory well, showing a rotation of about 1 kt. amplitude in phase with the surface oscillation.

The radio methods of wind measurement are capable of yielding much information about the spatial and temporal variations of wind in the ionosphere. The radio-fading technique usually shows rapid velocity fluctuations over a minute or two, but the interpretation of these is open to doubt. Meteor trails likewise indicate rapid velocity fluctuations, the vertical shear apparently predominating. Visual observations and the photography of meteor trails illustrate this vividly. Results in general indicate that wind variability with height and time are as great as, if not greater than, in the troposphere.



Summer hemisphere   Winter hemisphere

FIG. 2—ISOPLETHS OF WESTERLY WIND COMPONENT

In conclusion, Mr. Graystone mentioned the possibility of connexions between high-level phenomena and meteorological conditions near the surface. No relation has been noticed as far as upper level winds are concerned, apart from the diurnal oscillation, but claims have been made of the existence of relationships between ionospheric intensity and various surface parameters.

Mr. Waldo Lewis, opening the general discussion, described the relation of the transient small-scale fluctuations of the earth's magnetic field to winds in the high atmosphere. During a magnetic "quiet" period, the fluctuations are regular and of small amplitude, and have components periodic in the solar and lunar day. By analysing the distribution of these fluctuations over the earth's surface, it is possible to construct a hypothetical current sheet at about 100 Km., which in turn can be explained by the dynamo action of the solar and lunar atmospheric tides, a current being induced in the conducting air by the earth's magnetic field. The currents deduced from the observed tidal flow agree reasonably well with those deduced from the magnetic observations, and direct evidence of the existence of a current sheet has now been derived from rocket observations. The magnetic variation in disturbed conditions cannot as yet be closely linked with high-level winds.

Mr. Murgatroyd described briefly an attempt he had made to explain the temperature structure below 100 Km. in terms of the absorption of solar ultra-violet radiation by oxygen and ozone. It is possible to calculate the heating if the solar spectrum outside the earth's atmosphere, the concentration of oxygen and ozone, and the absorption coefficients of these gases are known, a good deal of data about them now being available from American rocket experiments. Some preliminary unpublished calculations by Dr. R. M. Goody, Department of Meteorology, Imperial College, have been extended to all zenith angles, and hence to different seasons and latitudes, assuming constant oxygen and ozone conditions at any given height. Calculated heating rates for different solar zenith angles, and the corresponding values for summer and winter for different latitudes are given in Tables I and II. There is a

TABLE I—HEATING RATES FOR DIFFERENT SOLAR ZENITH ANGLES

Zenith angle	Height (kilometres) 30	40	45	50	60	70	80	90	100
°				degrees Celsius per day					
0	5	21	26	21	8	3	2	6	40
40	5	16	23	21	8	3	2	4	31
60	4	10	18	18	8	3	2	3	21
80	3	4	6	10	7	3	2	1	6

TABLE II—HEATING RATES FOR DIFFERENT LATITUDES

Latitude	Height (kilometres) 30	40	50	60	70	80	90	100
°				degrees Celsius per day				
				SUMMER				
0	2	6	8	3	1	1	2	10
20	2	6	9	4	2	1	3	13
40	2	7	11	3	2	1	4	15
60	3	7	12	4	2	1	3	15
80	2	8	17	8	4	1	3	16
				WINTER				
0	2	6	9	4	2	1	2	11
20	2	4	8	4	2	1	1	8
40	1	2	5	3	1	0	1	4
60	0	1	1	1	0	0	0	1
80	0	0	0	0	0	0	0	0

reversal of temperature gradient with season in the ozonosphere, the maximum heating in the hemisphere occurring at 50 Km. near the pole in summer and at 48 Km. near the equator in winter. This would produce westerly winds in winter and easterly in summer, the winter type including both mid-seasonal months, March and September. At 100 Km. there is a positive gradient of heating rate from pole to equator in winter, but an irregular one in summer, though the results here are less reliable than for the ozonosphere. Similar calculations can be made for temperature from the formula $\partial T/\partial t = KT^4$, where K, a constant of assumed grey-body radiation, is obtained from a single assumed temperature structure and then taken as constant at a given altitude. Results from this indicate a much greater gradient of "solar radiation temperature", and hence stronger thermal winds, in winter than in summer.

Mr. Bannon queried the sensitivity of these calculations to variations in ozone distribution. Mr. Murgatroyd replying considered that these were not very critical; Pressman[8], who has recently published calculations giving results similar in form though with slightly differing magnitudes, found that the variation of ozone distribution with latitude was comparatively unimportant compared with the effect of the sun's changing declination.

Mr. Graystone observed that the computed seasonal variations of temperature in the ozonosphere would result in winds many times stronger than those reported. Mr. Murgatroyd emphasized that estimations of wind and temperature gradients were qualitative at this stage. When more was known about the long-wave components of radiation and about the detailed composition of the upper atmosphere, we should have a circulation problem in terms of unequally heated air masses.

Mr. Gold referring to the relation between the surface pressure wave and upper wind variations, asked if the lag in phase of the pressure variation at high-level stations was consistent with theory. Mr. Graystone replied that the surface pressure oscillation itself differed in phase from that resulting from a solar tide, the difference presumably being attributable to thermal effects. He thought that variations in the latter might explain the phase lag with height, pointing out, however, that the observed lag might not occur in the free atmosphere. Replying to another question from Mr. Gold, Mr. Waldo Lewis said that the phase of magnetic variations agreed as well as could be expected with that of the wind variations.

Mr. G. M. Brown (University College of Swansea) spoke of ionospheric research carried out under Dr. Beynon at the University College of Swansea. There is now considerable evidence suggesting that the currents responsible for the solar "quiet day" magnetic variations flow in the E region of the ionosphere. The electrodynamics of this "dynamo" region is complicated, but it appears that vertical transport of ionization is important. Except at latitude 30–40°, corresponding to the foci of these current systems, there is an east–west component of current overhead at all stations. This current, acting across the horizontal south–north force of the earth's magnetic field, results in a vertical force, directed upwards for places on the equator side of the foci, and downwards for places on the polar side. This vertical force may be expected to lead to a distortion of the ionization in the dynamo region. From E-region studies at Swansea it had been concluded that the so-called anomalies of this region can be attributed to the influence of this vertical drift. It was possible to locate the foci along a line of longitude, while at a given station the varying influence of drift over the day could be detected, showing a maximum east–west current at about 1100 G.M.T., and a minimum about 1500 G.M.T. Mr. Brown also referred to the difference in length observed between the two cycles of wind variation, the day cycle being completed in 9 hr. and the night in 15 hr. Mr. Graystone said that this variation had been noticed by two or three observers; it did not fit the resonance theory, and if real, it would indicate that some other effect is operating. Referring to Mr. Brown's references to vertical transport of ionization, he pointed out that this would affect the validity of wind observation by the ionospheric reflection method.

Dr. Stagg inquired to what extent we were justified in talking of "winds" at all, in the ionosphere.

Mr. G. M. Brown said that ionospheric workers were concerned only with the ions and electrons, and preferred to speak of "motions" rather than winds.

Mr. Absalom said that movements of meteor trails were generally considered to represent true air movements.

Mr. Graystone thought that the frequency of collisions at 100 Km. was sufficient to talk of real "winds".

The Director doubted whether hydrodynamicists could deal with motion when the mean free path became too great, and drew attention to the importance of momentum, rather than wind velocity.

Mr. H. H. Lamb asked if the decrease in wind velocity indicated at the top of the ozonosphere was real, pointing out that this meant a reversal of temperature gradient. Mr. Graystone said it was unfortunate that information for the very interesting levels 60–80 Km. was almost totally lacking. If the results obtained from meteor-trail observations at 80–90 Km. were accepted, it would certainly mean a reversal of thermal gradient at some level below 80 Km.

Mr. Beimers, on the question of a relation between the ionosphere and surface parameters, suggested a connexion between sporadic E and thunderstorms, adding that this might mean that the movements of the two are related. Mr. Murgatroyd argued that the directions and velocities of sporadic E movements recorded by Gerson were against this.

Mr. Gold considered that the upper wind might be related to the movement of areas of thundery activity rather than of individual storms.

Dr. Sutcliffe suggested that thunderstorms could initiate sporadic E, which would then move with the wind.

Another speaker referred to the work of Fr Gherzi in relating ionospheric intensity to surface parameters.

Dr. Scrase, in answer to a question of the possibility of more accurate wind measurements at very high levels, considered that 35–40 Km. was about the limit we could reach by radar wind sounding, and thought that rockets offered the only prospect of readings at higher levels.

Mr. Oddie asked what forces were available for the maintenance of large velocity gradients at very high levels. Mr. Graystone said that there was no difficulty about the forces responsible for high velocities; the energy available from the ionization and dissociation processes had been shown to be greater than from the evaporation and condensation of water vapour at low levels. The magnitudes of the velocity gradients were however surprising.

Dr. Sutcliffe wondered what had occasioned the interest shown in very high-level winds, and asked whether it was envisaged that they would have practical importance for the Meteorological Office.

Mr. Murgatroyd argued forcibly that the whole of the atmosphere was the concern of the meteorologist. In particular he expressed his disappointment that the high-level rocket research programme should be the responsibility of the Gassiot Committee, rather than of the Meteorological Office.

Mr. Graystone drew attention to the over-statistical approach adopted by ionospheric physicists in dealing with upper winds, and called for a more synoptic investigation. He also regretted the lack of co-ordination of different methods of wind measurement.

Mr. Gold likewise held that meteorologists should not restrict themselves to that part of the atmosphere attainable by radio-soundings, and thought that ionospheric workers might expect the Meteorological Office to give information on high-level winds.

Dr. Stagg, reverting to the validity of wind observations at high levels, drew attention to the fact that aurora "pencils" extending out to about 1,000 Km. remained straight, while meteor trails were rapidly distorted. Mr. Graystone thought the two phenomena were of quite a different nature; insufficient was known about the aurora to explain the mechanism of the auroral rays. The bodily motions of these rays had been measured, and had, mistakenly he thought, been classified as winds.

Mr. G. M. Brown referred to the complexity of the problem of motions in the ionosphere, where we were concerned with electrodynamics rather than hydrodynamics.

The Director, in conclusion, agreed that the Meteorological Office need not consider itself restricted to the lower atmosphere. In thanking the visitors for their contributions to the discussion, he referred in particular to Mr. Gold's pioneer work on radiation in the high atmosphere.

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OFFICIAL PUBLICATION

The following publication has recently been issued:—

METEOROLOGICAL REPORTS

No. 16—Winds between 300 and 100 mb. in the tropics and subtropics. By A. Gilchrist, M.A.

Charts showing the mean winds at 300, 200, 150 and 100 mb. for stations in the tropics and subtropics and mean atmospheric cross-sections at 80°W., 45°E., 140°E. and 165°E. are presented for January, April, July and October 1951. A strong westerly wind belt, which is strongest in winter, exists near latitude 30° in winter and at higher latitudes in summer. This belt may be distinct from the polar jet stream; cross-sections at 80°W. for individual occasions indicate its structure. The easterly winds on the equatorial side of the westerlies reach their maximum extent in summer when a strong easterly current stretches from the Pacific across southern Asia to Africa.

ROYAL ASTRONOMICAL SOCIETY

A discussion held by the Royal Astronomical Society on Friday, November 25, 1955, on the subject of irregularities and horizontal movements of electrons in the upper atmosphere, was attended by several prominent ionospheric physicists.

The chairman, Mr. J. A. Ratcliffe, F.R.S., opened with a brief survey of existing knowledge of ionospheric irregularities and their movements, and suggested several problems for general discussion. Dr. Briggs and Dr. Greenhow presented observations of mean flow obtained by radio reflection from the E-layer and by meteor-trail operations respectively, while Dr. Beynon and Mr. Dagg illustrated results for the F-layer, using ionospheric reflection and the stellar-scintillation techniques. Mr. Jones gave results indicating an advance of phase and an increase of amplitude with height in the E-layer semi-diurnal wind rotation. Dr. Weekes considered these to be consistent with theory, but the large reported seasonal variation in phase could not be explained. A mean velocity gradient of 2 kt./Km. was found by Dr. Beynon for the F-layer.

Dr. Clemmow discussed the relation of the electron movements to air movements, and it was generally agreed that, in the case of ionized meteor trails at least, true air movements were being recorded. No simultaneous observations, using different methods at the same height, had yet been made, and Dr. Scorer urged the use of visual observations of noctilucent clouds which could be correlated with meteor-trail movements.

The nature of ionospheric irregularities was discussed, particularly interesting being the F-layer "ripples", 100–200 miles across, which moved over considerable horizontal distances. The small-scale F-layer irregularities had been found to have a similar diurnal variation over widely separated geographical locations, though this was not considered to be due to the maintenance of the irregularity pattern over long distances.

LETTER TO THE EDITOR

Use of Esperanto by meteorologists

In the course of his article, "Second Congress of the World Meteorological Organization" in the September 1955 number of this Magazine, Mr. Durward writes "It will be appreciated that one source of difficulty is that of language—translation too often alters the sense". In this connexion I should like to draw attention to a Resolution passed by the General Conference of UNESCO in December 1954, which reads as follows: The General Conference

(i) takes note of the results attained by Esperanto in the field of international intellectual relations and in the *rapprochement* of the peoples of the world

(ii) recognizes that these results correspond with the aims and ideals of UNESCO

(iii) authorizes the Director-General to follow current developments in the use of Esperanto in education, science and culture, and to this end to co-operate with the Universal Esperanto Association in matters concerning both organizations

(iv) takes note that several Member States have announced their readiness to introduce, or expand, the teaching of Esperanto in their schools and higher educational establishments, and requests these Member States to keep the Director-General informed of the results attained in this field.

In meteorological circles we have been living with the difficulty mentioned by Mr. Durward for at least a quarter of a century, and it is strange that, whilst great advances have been made in finding solutions to scientific problems connected with the weather, as far as I am aware, no serious attempts have been made even to encourage the younger generation of meteorologists to familiarize themselves with a universal language. Opinions, often based on hearsay, that Esperanto is not practicable or that something else, like basic English, would probably be better, are only too familiar but lead nowhere. I suggest the World Meteorological Organization could give a lead in this matter by following up the UNESCO resolution and fostering the use of Esperanto for a trial period of, say, 3 or 5 yr. It is in line with the best scientific traditions to conduct such an experiment, and arrive at a conclusion, either to continue or abandon the project, in the light of results. For instance, a page in the *WMO Bulletin* devoted to letters on meteorological topics and written in Esperanto would stimulate interest.

Esperanto cannot be said to be a perfect international language, but if we wait for perfection we may wait for ever. As far back as 1907 it was the most widely known and used of its numerous competitors, and the fact that it has survived 50 yr., and is now the subject of a UNESCO resolution, indicates that it is the most reasonable and practical artificial language that has yet appeared. To the meteorologist it can perhaps best be regarded as a code language, and to any one who masters the international codes contained in the World Meteorological Organization Publication No. 9, Volume A, and who also has a knowledge of French, the acquisition of a working knowledge of Esperanto is a relatively simple matter and can be a fascinating relaxation. It is entirely phonetic, and according to the "Encyclopaedia Britannica" the grammar can be learned in half an hour. In 1929, Mr. Gold, then President of the International Meteorological Organization Commission for Synoptic Information, wrote:* "I have been frequently concerned by the difficulties which are experienced in our Commission owing to differences of language . . . I do not think it is practicable for the difficulty to be satisfactorily resolved in our generation; it can only be met by the adoption of one standard language for our discussions, and this language ought to be one which is taught as part of the education of youth". The Conference of Directors in the same year adopted a resolution* which recommended "that the League of Nations should be notified of the importance for the work of the Conference and all its Commissions of an international agreement on a standard language to be used generally for international meetings and eventually taught to the youth of all nations".

Doubtless there are many readers who share the belief that the use of a universal language would be of great benefit to the science of meteorology, the advancement of which depends so much on international co-operation, but who have thought it too idealistic, or too difficult, or not worth-while. This has been the view of the majority of nationals up to now, but the minority of "pioneers" who urge otherwise and consider it is a practical proposition may, after all, be proved to be correct.

Dunstable, October 18, 1955. C. V. OCKENDEN

[The Report of the Tateno Aerological Observatory, Japan, was published wholly in Esperanto from 1926 to 1939.—Ed. *M.M.*]

NOTES AND NEWS

Rime at Holme Moss

The photographs in the centre of this magazine were taken on March 17, 1954, at Holme Moss the site of the B.B.C. television transmitter nine miles south-south-west of Huddersfield. They illustrate the formation of rime in an easterly wind during the previous few days. Holme Moss is at a height of 1,750 ft. above sea level and the main mast of the transmitter extends 750 ft. above that.

A large anticyclone covered the whole of Russia and southern Siberia on March 11, 1954, and began to spread westwards, a separate circulation splitting off the main anticyclone and settling over Scandinavia on the 12th. This new anticyclone then spread further west and became persistent over the region

* Secrétariat du Comité Météorologique International No. 3. Procès-verbaux des séances de la conférence internationale des Directeurs du Comité Météorologique International et de diverses commissions à Copenhague Septembre 1929. Utrecht 1929.

from Iceland to Scotland on the 15th; it finally retreated eastwards on the 18th. During the period from the 12th the wind at low-level stations in Yorkshire was persistently easterly or east-north-easterly with a strength between 5 and 15 kt. During the same period over Liverpool radar wind measurements at 950 mb. (about the height of Holme Moss) gave east-south-easterly winds with speed decreasing from 25–30 kt. on the 12th–13th to 10–15 kt. on the 18th.

Air temperature on the Yorkshire coast was almost constant at 37–40°F. and at Huddersfield (Oaks), at a height of 762 ft., the temperature never rose above 38°F. until the 17th when a maximum temperature of 41°F. was recorded; the mean of the temperatures at 950 mb. over Leuchars and Hemsby varied between 28½° and 31½°F. from the afternoon of the 13th until the morning of the 17th; the temperature at Holme Moss was continuously below freezing for at least four days before the photographs were taken (the temperature at 950 mb. over Liverpool was sometimes above freezing but there, in the lee of the hills, there would be a föhn effect).

The air mass was typically polar continental with an inversion of 10–15°F. extending from 2,500–3,000 ft. to about 4,500 ft. where the temperature was 38–40°F.—warmer than at sea level. Beneath this inversion was a continuous sheet of North Sea stratus with base normally at about 800 ft. but occasionally lifting during the day to 1,000–1,200 ft. Not until the 16th did the cloud lift to 2,000 ft. or higher when it began to break in the afternoon.

At Holme Moss the cloud was down to the surface until the 17th, and with temperature a few degrees below freezing rime formed on all surfaces exposed to the wind. Rime builds up into the wind as each supercooled cloud particle strikes and freezes on to any exposed object. The characteristic horizontal feathery "icicles" illustrated in the photographs are then formed, each pointing into the local wind direction. In this connexion the "icicles" near the base of the large transmitter mast (on the north-north-west side of the buildings) are particularly interesting because they show a consistent down-draught in the lee of the buildings almost free from eddies. The smaller radio-link mast, illustrated in the photograph facing p. 49, is clear of the buildings (north-east of the main mast) and only shows horizontal "icicles"; close to the ground these "icicles" are shorter as would be expected with the lower wind speed (and therefore lower number of passing cloud particles) at that level. The ground itself shows only slight accumulations of ice for the same reason, but moorland grass was reported to be exhibiting the "icicles" in miniature. These would be more pronounced on the crests of hillocks as can be seen by the increased whiteness on some of the photographs.

There was no snow during this period, and therefore the "icicles" are not smothered and concealed as was the ice on the radio-telephone towers on Great Dun Fell, Cumberland, illustrated in the October 1951 *Meteorological Magazine.*

During March 17 (maximum temperature of 41°F. at Huddersfield), the stratus cloud lifted and the air became warmer. Whilst the photographs were being taken some of the "icicles" broke off and fell in great masses, deluging the photographer in a rain of ice.

Despite the accumulation of ice on the transmitting aerials there was no effect on transmission from Holme Moss.

P. B. SARSON

Extension of area forecasts for shipping and a new service for ships sailing from London

From November 1, the Atlantic weather bulletin for shipping transmitted from Portishead Radio Station has included forecasts for the areas "Denmark Strait" and "North Iceland" covering a period of 24 hr. from the time of issue.

Forecasts for these two areas give surface-wind force and direction with the addition of air temperature when this is expected to be below freezing. The importance of these additional forecasts to the large number of trawlers which fish in this area is considerable. The British trawlers *Lorella* and *Roderigo* were both lost on January 26, 1955, with no survivors, within a few miles of each other in an approximate position 67½°N. 21°W. The court of inquiry, which held an investigation into this disaster, found that "the vessels capsized and foundered due to the unusual and unpredictable combination of a heavy gale, high seas and the loss of stability due to the heavy accumulation of ice on the upper structures", and stress was laid on the fact that the disaster occurred, not as a result of a prolonged north-easterly gale alone but because it was associated with persistent low temperatures. Thus for the benefit of trawlers operating in this area the importance of including air temperature when this is expected to be below freezing, as well as wind force and direction, becomes obvious.

The "Denmark Strait" area extends to the middle of that Strait (about 100 miles from the Icelandic coast); its southern limit is the parallel of 65°N. extending from the Icelandic coast to the meridian of 30°W., and its eastern limit the meridian of 19° W. extending from the Icelandic shore to 68°N.

The "North Iceland" area also embraces an area about 100 miles off the coast. Its western limit will be the meridian of 19°W. extending from the Icelandic shore to 68°N. and its south-eastern limit will be along the northern limit of the "South-East Iceland" area extending from the Icelandic shore to the position 64°N. 10°W.

Another new service provided by the Meteorological Office for shipping with the co-operation of the Elder Brethren of Trinity House and British Railways began on November 21; ships sailing from London are now provided with a prebaratic chart which is taken aboard by the pilot when he joins the ship at Gravesend. The chart is prepared at the Meteorological Office in Victory House, London, in sufficient time to catch the 9 a.m. train to Gravesend, and it is thus available to the pilots by about 11 a.m. each day, Sundays included. The information on the chart includes a brief statement about the general synoptic situation, a forecast (prebaratic) chart for "midnight tonight" showing the North Sea, Iceland, Greenland and the Atlantic as far as 40°W., and a statement of the sea-area forecasts for 24 hr. from 0600 G.M.T. for the "Thames estuary", "North Sea", "south coast" and "south-west approaches to the English Channel".

Charts of standard vector deviation of wind

It was stated in the *Meteorological Magazine* for May 1955, that a limited number of charts of average vector wind distribution over the world at 500, 300, 200 and 100 mb. for the four seasons were available for purchase.

Corresponding charts of standard vector deviation of wind at 300, 200 and 100 mb. have now been reproduced, representing revisions of those published in *Geophysical Memoirs* No. 85 (which gives values at 130 mb. not 100 mb.).

Combined sets of the two charts (16 average vector wind and 12 standard vector deviation) size approximately 13 in. × 16 in. are now available for purchase, price £1 8*s.* 0*d.* plus postage (6½*d.* in the United Kingdom) on application to the Director, Meteorological Office, Kingsway, London, W.C.2.

REVIEWS

Theoretische Hydromechanik. Band II. By N. J. Kotschin, I. A. Kibel and N. W. Rose. Translated from the Russian and technically edited by K. Krienes. 9½ in. × 6¾ in., pp. viii + 569, *Illus.*, Akademie-Verlag, Berlin, 1955. Price: *DM* 48.

The first volume of this work, dealing with inviscid fluids, was reviewed in the *Meteorological Magazine**. The present volume, which presumably completes the work, is devoted to the study of gas dynamics (compressible flow), viscous fluids and turbulence.

"Gas dynamics" is not a very happy term, and here it is taken, as usual, to imply the study of fluids of relatively small volume moving at high speed. It thus embraces those aspects of fluid dynamics that are of importance in ballistics, turbine design, rocket construction, etc., and as such does not often concern the meteorologist. Much of the text also relates to problems arising in high-speed flight and, as might be expected, there is considerable use of the method of characteristics which has found application also in the meteorological field. This section of the book, written by Kibel and occupying the first 240 pages, is a very good and clear account of the main features of compressible flow that have yielded to analysis.

The second chapter deals with viscous flow. This takes up about 260 pages and is mainly written by Kotschin. It covers the ground adequately, beginning with a full discussion of the Navier-Stokes equations in their various forms (rectilinear, cylindrical and spherical co-ordinates), the vorticity equation, similarity relations (Reynolds and Froude numbers), and the conduction of heat. After this come the various well known applications, such as Poiseuille's law and the diffusion of vorticity. The two limiting cases of small Reynolds number (influence of viscosity dominant as in Stokes law for a sphere) and of large Reynolds number are then discussed. The case of small friction (large Reynolds number) introduces the boundary-layer theory, which is also dealt with thoroughly.

The final section of the book, written by Kibel, deals with turbulence. It is refreshing to find that at last there is a textbook which is prepared to devote some space to a mathematical discussion of Reynolds's rules for forming mean values and the conditions under which these are valid. The subsequent discussion of technical problems is somewhat brief, but most of the techniques that have proved fruitful, such as the mixing-length concept and the statistical-mechanics approach of Taylor, are included, and there is a mention of the work of Kolmogoroff. Meteorological applications do not receive much attention, but this is not unexpected in a book that is intended to cover fluid mechanics in general.

The impression left on the reviewer is that this volume, like the first, is a very workmanlike job, and can be thoroughly recommended. It is to be doubted if there is a book of similar length in English that covers the ground as well, and

* *Met. Mag., London,* **84**, 1955, p. 27.

one is filled with admiration for the way in which the topics have been selected and discussed. Anyone who seeks to become proficient in this difficult field of mathematical physics could hardly do better than to study this treatise. Finally, the text, possibly because it is a translation, is written in a style that offers few difficulties even to those who (like the present reviewer) learned to read scientific German rather late in life. In this respect it is a welcome relief from the average *Handbuch.*

O. G. SUTTON

Degree of wintriness. By B. D. Kyriazopoulos. *Meteorologica* No. 1. $9\frac{1}{2}$ in. $\times 6\frac{1}{2}$ in., pp. 25, *Illus.*, University of Salonika, 1954.

This little paper, written in English, contains a reasoned presentation of an index of wintriness in Thessaloniki (Salonika) obtained by adding together

(i) the sum of all minimum temperatures $\leqslant$ 0°C.

(ii) the sum of all minimum temperatures $\leqslant$ −4°C.

(iii) the number of observations with temperature $\leqslant$ +3°C. at the observation hour

(iv) the number of days with average cloud cover at the three observations $\geqslant$ 8 tenths

(v) the number of days with precipitation (> 0·0 mm.)

(vi) twice the number of days with snow-cover

In 45 winters (1891–1910, 1928–1954) the resulting index varied from 98 in 1901–02 ("mild") to 457 in 1941–42 ("severe"). The temperature contribution, items (i)–(iii), ranged from 9·5 to 367·5; the contribution due to cloudiness, rain and snow-cover, items (iv)–(vi), was always between 50 and 176.

The severer two thirds of the winters were all so rated mainly on account of high values of the low-temperature contribution; only one of these winters (1953–54) had a "humidity" contribution higher than in the mild winters. The winter of 1953–54 seems to have been of a highly unusual type in this respect, dull, wet, snowy and severe. Other severe winters were generally dry, though the numbers of cloudy days were subject to a good deal of variation; the average winter rainfall in the 16 milder winters was 176 mm. as against 143 mm. in the remaining (normal and severe) winters.

In the reviewer's opinion this paper is chiefly of interest for its statement of the different make-up of different winters, whereas an index which adds up, and purports to measure, all these unlike characteristics on a single scale is meaningless.

H. H. LAMB

Meteorologia por correspondencia. Nos. 3 and 4. $9\frac{1}{4}$ in. $\times$ $5\frac{1}{4}$ in., pp. 4, *Illus.*, Instituto de Estudios Superior, Sociedad Meteorológica, Montevideo, 1954.

The Meteorological Society of Uruguay is publishing a series of folders entitled "Meteorologia por correspondencia" giving elementary lessons in meteorology. Nos. 3 and 4 have been sent to us. The first of these contains short articles on the qualities needed in a meteorological observer, on the questions he should ask himself when making an observation, and on the sun. Accompanying them are sheets giving graphical methods of recording observations and a climatological record form for the month.

G. A. BULL

Fish rain in Western Macedonia. By G. C. Livadas. 9½ in. × 6¾ in., pp. 12, *Illus.*, University of Salonica, Meteorological Institute, Salonica, 1954.

This publication of the Meteorological Institute of the University of Salonica describes the circumstances attending the fall of a large number of fish at the village of Alona in northern Greece (about 90 miles west of Salonica).

The fish were found on the morning of October 15, 1951, scattered in groups on the ground and in trees over an area of about ½ square mile. Samples examined by an ichthyologist showed that some at least of the fish came from a lake about 25 miles to the east of Alona. A strong NE. wind blew during the night with showers. The author concludes that a waterspout formed over the lake sucking up the fish which were then dropped to the westward.

G. A. BULL

ERRATA

September 1955, PAGE 295, line 29; *for* "On the islands and coasts of north and west Scotland sea fog and low cloud kept temperatures in the fifties for most of the month." *read* "Over north and west Scotland there were many gloriously sunny days on which temperature rose to over 70°F. but fog and low cloud restricted bright sunshine on some days in coastal districts, especially in the mornings."

November 1955, PAGE 349, equation (3) and both parts of equation (4); *for* "U_{gr}" *read* "U_{gs}".

METEOROLOGICAL OFFICE NEWS

Retirement.—Mr. E. D. Dent, Experimental Officer, retired on December 31, 1955. He joined the Office in January 1927 and during his service has worked both at Headquarters and outstations. Since 1948 he has served in three branches at Harrow. Mr. Dent saw military service during the whole of the First World War, 1914–18, and during the latter part he served with the Royal Air Force.

Ocean weather ships.—The following is an extract from the report of the Meteorological Officer-in-Charge aboard the *Weather Recorder* during voyage 64 (October 27 to November 30, 1955) when the ship was on duty at Station A.

"A fund was inaugurated this voyage whereby the staff filling balloons were fined ½*d.*/ft. by which the rate of ascent was outside the required limits, the proceeds to go towards a pre-sailing Christmas party for the meteorological staff. An interesting result was the fact that no improvement in rate of ascent evolved, hard as the staff tried! Dinner and a visit to a show in Glasgow are now envisaged, the night before sailing."

WEATHER OF DECEMBER 1955

The main Atlantic depression track was further south than normal and the depressions largely travelled due east between 50° and 60°N., passing across or near to the British Isles and over Europe, though there were also some deep centres off the coast of north Norway. One depression from the Atlantic became rejuvenated and had a depth of 976 mb. over central Russia on the 14th. The Azores and continental anticyclones were both weaker and farther from Europe than usual. As in recent months the anticyclone over the polar ice was again prominent and unusually intense (monthly mean pressures 6–10 mb. above normal on the Arctic coasts of north-east Siberia and Alaska, monthly mean pressure 1028 mb. north of the New Siberian Islands at approximately 77°N. 160°E.). Maximum pressure anomalies in the Atlantic–European sector were −13 mb. off the Norwegian coast in 65°N. 5°E., −12 mb. near Stockholm and −10 mb. in mid ocean at about 45–50°N. 35–40°W.

The distribution of temperature anomalies was very similar to the previous month with cold areas dominating the Canadian Rockies (greatest anomaly −8°C.) and the broadest part of North America south-east thereof, also a less extensive but even bigger negative anomaly over northern Europe (−10°C. over central Finland). Europe south of 55°N. was a little milder than usual thanks to the prevailing westerly winds. Northern Siberia, north of about 55°N., was colder than usual in December. After a relatively mild November, most stations around the fringe of the polar ice again registered negative anomalies of 1° or 2°C.

The month had above-normal precipitation over most of northern, central and south-western Europe but was dry in the Balkans and most of the Mediterranean. Two or three times the normal precipitation was measured in western Spain, the eastern Alps, eastern Germany, Sweden and central Norway.

In the British Isles the main feature of the month was the large variations of temperature due to the frequent incursion of polar or arctic air from the north. This affected much of the country during the 7th, 10th–12th, 17th–22nd and 30th–31st, but otherwise the weather was mild and changeable.

During the first week the weather was of a mild westerly type, though slight air frost occurred in places at night. Fog was fairly frequent night and morning, and persisted locally until late afternoon on the 2nd. There were occasional rain and showers, heavy at times, in the north and west, with thunder on the 2nd and 3rd in north Scotland and the Hebrides. On the 7th, an anticyclone over Greenland intensified, and cold arctic air subsequently swept southward to the English Channel, but on the 9th a large and complex depression crossed Scotland bringing mild air back over the country; there was widespread rain preceded in the north by snow; 1½ in. fell at Leuchars in the 24 hr. ending 0900 on the 10th. Arctic air again broke through to much of the British Isles on the 10th, and the following day a ridge of high pressure developed south-eastwards from Greenland giving a south-easterly air stream over England. Fronts, which were held quasi-stationary by this air stream, gave considerable rain and sleet over the south and south-west of the country; at 2100 on the 11th Aberporth measured over 1 in. of rain which had fallen in 12 hr. A deep depression on the Atlantic brought mild cloudy weather slowly back over the country on the 13th, the warm air being preceded by fog and rather prolonged rain and snow; there was widespread rain, heavy at times, also on the 14th and 15th. On the 16th, the near freezing temperatures, which had persisted in the Shetlands since the 10th, began to spread southwards as a ridge from the Greenland anticyclone developed over the British Isles, and early on the 19th there was keen or hard frost over most of the country; Elmdon recorded a screen temperature of 16°F. with 5°F. on the grass. For several nights very low temperatures were reported from parts of Scotland including 8°F. at Dyce on the 21st–22nd with 2°F. on the grass. A depression moved across southern England on the 20th giving widespread rain or sleet in the south and snow further north; there were prolonged and heavy falls east of the Pennines, and in many parts of Yorkshire snow lay to a depth of more than 12 in. It was not until the 22nd that the weather reverted to a mild westerly type which, once established, persisted until after Christmas. Christmas-day was generally fine in the east but rain spread to western districts during the afternoon, and thereafter troughs from a complex depression near Iceland maintained widespread and locally heavy rain over the country for the next two days with a gradually rising temperature. Temperature did not fall below 50°F. over most of England and Wales on the night of the 27th–28th, and 55°F. at Ross-on-Wye was a record high minimum for a December night. On the 28th temperature reached 59°F. in East Anglia and in Yorkshire, and the maximum, 58°F., recorded on the Air Ministry roof at Kingsway London had not been exceeded in late December since records began there in 1940. On the night of the 29th–30th there was heavy rain over south England and south Wales as a secondary depression moved along the English Channel, but thereafter weather became progressively colder as squally north-westerly winds with occasional showers became established over the country.

Mean temperature varied from 4°F. above the average in the south to 4°F. below average in the north, and while sunshine was about average over the country as a whole there was an excess in Scotland and eastern England and a deficit in the west. Rainfall was above average in Scotland and northern England but was below in much of East Anglia, the Midlands, north Wales and Northern Ireland. In spite of the rain, some of the heaviest land is still not ploughing easily, but most seed beds have been good with quick germination. Farm work has gone on without hindrance and is more forward than it has been at this date for a considerable number of years. Most winter cereals look well and the sugar-beet harvest is virtually complete. Supplies of winter fodder remain good and seem adequate to withstand a hard winter.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	60	9	+2·3	109	+2	104
Scotland	58	−4	−0·8	146	+2	120
Northern Ireland ...	57	18	+1·0	117	−1	83

RAINFALL OF DECEMBER 1955

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	2·03	85	*Glam.*	Cardiff, Penylan	5·96	119
Kent	Dover	2·36	77	*Pemb.*	Tenby	6·43	129
,,	Edenbridge, Falconhurst	3·12	95	*Radnor*	Tyrmynydd	7·37	90
Sussex	Compton, Compton Ho.	4·88	116	*Mont.*	Lake Vyrnwy	8·58	122
,,	Worthing, Beach Ho. Pk.	3·67	122	*Mer.*	Blaenau Festiniog	14·64	116
Hants.	St. Catherine's L'thouse	5·23	165	,,	Aberdovey	4·49	94
,,	Southampton (East Pk.)	4·20	115	*Carn.*	Llandudno	3·52	121
,,	South Farnborough	2·58	89	*Angl.*	Llanerchymedd	4·56	104
Herts.	Harpenden, Rothamsted	2·44	86	*I. Man*	Douglas, Borough Cem.	6·34	128
Bucks.	Slough, Upton	2·13	85	*Wigtown*	Newton Stewart	5·70	105
Oxford	Oxford, Radcliffe	3·09	126	*Dumf.*	Dumfries, Crichton R.I.	5·56	130
N'hants.	Wellingboro' Swanspool	2·01	86	,,	Eskdalemuir Obsy.	8·07	115
Essex	Southend, W. W.	1·43	72	*Roxb.*	Crailing	3·69	137
Suffolk	Felixstowe	1·48	71	*Peebles*	Stobo Castle	5·15	136
,,	Lowestoft Sec. School	1·24	53	*Berwick*	Marchmont House	3·95	141
,,	Bury St. Ed., Westley H.	1·48	61	*E. Loth.*	North Berwick Gas Wks.	3·55	166
Norfolk	Sandringham Ho. Gdns.	1·87	74	*Midl'n.*	Edinburgh, Blackf'd. H.	4·02	172
Wilts.	Aldbourne	3·51	109	*Lanark*	Hamilton W. W., T'nhill	5·95	138
Dorset	Creech Grange	6·48	147	*Ayr*	Prestwick	4·34	124
,,	Beaminster, East St.	6·08	127	,,	Glen Afton, Ayr San.	9·41	147
Devon	Teignmouth, Den Gdns.	5·27	125	*Renfrew*	Greenock, Prospect Hill	9·19	123
,,	Ilfracombe	5·99	124	*Bute*	Rothesay, Ardencraig	8·11	149
,,	Princetown	13·89	120	*Argyll*	Morven, Drimnin	8·34	106
Cornwall	Bude, School House	5·68	130	,,	Poltalloch	8·39	132
,,	Penzance	8·19	144	,,	Inveraray Castle	14·03	141
,,	St. Austell	6·95	114	,,	Islay, Eallabus	7·02	118
,,	Scilly, Tresco Abbey	4·46	95	,,	Tiree	6·29	120
Somerset	Taunton	5·17	156	*Kinross*	Loch Leven Sluice	6·60	168
Glos.	Cirencester	3·86	111	*Fife*	Leuchars Airfield	4·35	176
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