Frontispiece]

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CAPTAIN L. G. GARBETT, C.B.E., R.N.
Director of the Naval Meteorological Service

M.O. 482 AIR MINISTRY

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RETIREMENT OF CAPTAIN L. G. GARBETT, C.B.E., R.N.

Captain L. G. Garbett, Director of the Naval Meteorological Service, retired on August 9. He is succeeded by Captain J. W. Josselyn, D.S.C., R.N.

Captain Garbett's association with meteorology goes back for over a quarter of a century. In 1921, on his retirement from the Navy, he was appointed superintendent of Navy Services in the Meteorological Office. His duties consisted chiefly in acting as Liaison Officer between the Meteorological Office and the Admiralty. At first the work was not very arduous and Captain Garbett took the opportunity to increase his technical knowledge by helping with the lectures and classes then being started at the School of Meteorology under Sir Napier Shaw, Professor of Meteorology at the Imperial College of Science. Thus began a very close and happy association which continued until Sir Napier's death in 1945.

From the first Captain Garbett regarded his role as active, and at a very early stage he seems to have visualised what the Naval Service might ultimately become. The *Annual Reports* on the work of the Division show clearly that his efforts were from the first directed towards the definite object of building up an efficient forecast service within the Fleet, and that all the various activities of the Division had that one end in view.

In the early days Captain Garbett spent much of his time finding out what were the needs of the Fleet and how to provide for them. He began by discussions with the Commander-in-Chief of the Atlantic Fleet. Later in 1925 he visited the Mediterranean Fleet at Malta; in 1929–30 he went to China and the East Indies, in the latter part of 1930 to America and the West Indies, and in 1932 to Africa. The object of these visits was " by conference with the officers of the Fleet and with the Meteorological Services to organise the supply of meteorological information to the Fleet and the use of that information within the Fleet ". One of the incidental results of his visit to the West Indies was the formation of a Meteorological Service in Bermuda with a naval officer as Director. The conferences led to much closer co-operation between the local services and the Fleet to their mutual benefit.

One of the landmarks in the organization of the service was the appointment by the Admiralty in 1927 of a Fleet Meteorological Committee to direct and supervise the development of meteorology in the Navy. Captain Garbett was a member of that committee which, in 1934, made certain recommendations for governing the future policy of meteorology in the Navy. The recommendations were based on proposals which had been submitted by Captain Garbett and " embraced internal organization of meteorological work in the Fleet, selection and training of personnel for meteorological duties, meteorological equipment of H.M. ships and meteorological publications for use in the Fleet."

From then onwards the work rapidly expanded but the increased threat of war accentuated the administrative difficulties, and after prolonged discussion the greater part of the work of the Naval Division was transferred to the Admiralty. On August 1, 1937, a new branch of the Hydrographic Department of the Admiralty was formed, known as the Naval Meteorological Branch, with Captain Garbett as Chief Superintendent.

The outbreak of war naturally brought still further expansion and at the end of 1939 meteorological offices, manned by the Navy, were opened at several shore stations. In 1940 the status of the Branch was raised to that of a Directorate and Captain Garbett became Director of the Naval Meteorological Service (D.N.M.S.). The need for more staff was largely met by the enlistment and training of additional officers for meteorological duties in the R.N.V.R. In 1945, when the Branch reached its greatest strength, a total, including W.R.N.S., of no less than 300 officers and 450 ratings were employed in meteorology.

Such, briefly, is the history of the Naval Meteorological Service which grew up under Captain Garbett's guidance and which owes its success chiefly to his patience, courage and initiative.

In the steps by which he reached his end, the first in importance was the provision of adequate training. To begin with, naval officers attended lectures at Portsmouth and Plymouth and also visited the Forecast Division of the Office. Later on special courses of lectures were arranged, first at Calshot and then in London. When the Naval Meteorological Branch was established in 1937, the Admiralty simultaneously assumed responsibility for the training of officers and ratings. Captain Garbett realised that the needs of the Navy were not entirely met by the existing textbooks, and at his request an " Admiralty Weather Manual " was prepared and plans were put in hand for a series of Handbooks of Weather on the different Naval Stations' designed to give an officer the climatic and synoptic background he needed for forecasting in all parts of the world.

In building up a forecast service in the Navy it was also essential to provide for the broadcast of weather data so that ships could construct their own synoptic charts. Captain Garbett worked to ensure that a uniform Fleet Synoptic Message should be broadcast by shore stations for use on board ship. The first messages in this form were broadcast from Malta as the result of Captain Garbett's visit in 1925, and later on similar broadcasts were started in the Far East, South Africa, Australia, Canada and India. He visualised also that in war a ship might have to forecast from nothing but her own observations, so a special study was made of single-observer forecasting. Lt.-Cdr. (now Capt. Beatty was appointed in 1929 for this work. Some of the early work on the relation of cloud forms to fronts was carried out by Lt.-Cdr. (now Capt.) Josselyn, Captain Garbett's successor.

Captain Garbett realised also that the Fleet had its own contribution to make both to synoptic meteorology and to upper air research. In quite early days he arranged that synoptic reports should be broadcast from ships, particularly from those off the regular trade routes, and these reports began to appear in the *Daily Weather Report.* At first they were made only in the Mediterranean, but later they were extended to other regions. Encouraged by Sir Napier Shaw, Captain Garbett also began to take a personal interest in upper air observations at sea. He translated Teisserenc de Bort's instructions for ballon-sonde observations and made experiments with sounding balloons at sea in H.M.S. *Kellett* and H.M.S. *FitzRoy*, himself designing a special anchor for the meteorograph. Arrangements were made for H.M.S. *Hermes* and H.M.S. *Furious* to take upper air temperature observations on international days. He was also active in equipping H.M. ships for pilot-balloon observations and all ships carrying aircraft were so equipped. A chart showing the distribution of observations and later the observations themselves were published.

Although Captain Garbett's own work was chiefly on the administrative side, he was well aware of the help which scientists could give, and at his suggestion several investigations were undertaken, such as the observation of visibility at sea and the design and exposure of instruments on board ship. When the Meteorological Research Committee was formed, Captain Garbett was appointed a member so that he could keep the Admiralty informed of the latest advances in the science, and bring any special requirements of the Navy to the notice of the Committee.

The success of Captain Garbett's work needs no demonstration. The existence of the Naval Meteorological Service itself is its witness, and he has every reason to look back on the past 26 years as years of great achievement. The Admiralty recognised the value of his work by promoting him to the rank of Captain in 1936 in spite of his being on the retired list—a very unusual step—and by advancing the status of the Branch to that of a Directorate in 1940. For his services during the war he was awarded the C.B.E. in 1942.

Our best wishes go to Captain Garbett in his retirement in Herefordshire, and to Captain Josselyn in his task of carrying on the work of the service which Captain Garbett created.

SPECIFICATION OF WATER VAPOUR IN THE ATMOSPHERE

BY G. A. BULL, B.SC.

Introduction.—It has been realised within the last few years by physicists and meteorologists that the nomenclature of atmospheric humidity needed clarification. There has been a tendency for particular industries to use terms unknown to others or, worse, for terms to be used with different meanings by different industries. Here meteorology is included as one of the industries dealing with atmospheric humidity. Other such industries that may be mentioned are heating, ventilating and air conditioning, ceramic manufacture, chemical engineering, gas making.

On this account the British Standards Association in 1945 set up a sub-committee of its technical committee on units and data to prepare a publication on atmospheric humidity to include definitions, formulae, and constants.

The sub-committee contained representatives of the industries mentioned above and of the Physical Society.

The sub-committee met at frequent intervals during 1945 and 1946 and as a result of its work *British Standard* 1339 : 1946 containing recommended definitions formulae and constants was published in December, 1946, by the British Standards Institution.

The Meteorological Office was not able to accept all the decisions of the British Standards humidity sub-committee and reservations on this account are given where necessary in *British Standard* 1339 : 1946. During the discussion in the sub-committee the Meteorological Office prepared a paper, setting out its views on the subject, which has now been submitted to the International Meteorological Organization for examination by the Commission for Instruments and Methods of Observation.

Consideration, from a rather different angle, has been given to humidity matters by the International Joint Committee on Psychrometric Data. The latter committee is mainly American but has participating organizations in Canada and Great Britain. The Meteorological Office, the National Physical Laboratory, the Physical Society and the Institution of Heating and Ventilating Engineers are the British participating organizations. This body is concerned with the compilation of a set of tables of great exactness covering the properties of air and water-vapour mixtures.

The next section of this note is devoted to a detailed consideration of the memorandum on the specification of water vapour in the atmosphere sent to the International Meteorological Organization by the Director of the Meteorological Office, the third section to the British Standard on humidity definitions and constants, and the fourth to the departure of moist air from the perfect gas laws which is the aspect to which the International Joint Committee on Psychrometric Data has particularly given its attention.

Memorandum by the Meteorological Office on the specification of water vapour in the atmosphere.—The memorandum points out that there are seven main terms in meteorological use relating to water vapour, viz. water-vapour pressure, water-vapour density, relative humidity, absolute humidity, specific humidity, moisture content, humidity mixing ratio, which are used to express five different physical quantities. In addition there are the dew-point temperature, the frost-point temperature and the wet-bulb temperature.

Since two of the seven terms are redundant, it is proposed that five of them should be selected, specified and recommended for general use by the International Meteorological Organization.

The terms recommended are, with indicating letters :—

e = vapour pressure,
d = vapour density,
U = relative humidity,
q = moisture content,
x = mixing ratio.

The terms omitted as redundant are "absolute humidity", which is identical with "vapour density", and "specific humidity" which is identical with

" moisture content " as defined below. It is to be noted that " humidity " occurs in only one, " relative humidity ", with the intention that the word humidity in meteorological usage will refer invariably to " relative humidity ".

The specifications are as follows :—

Vapour pressure, e.—The memorandum states that this term is used with its ordinary physical significance. Accepting, as we may for meteorological purposes (see p. 200), the accuracy of Dalton's law of partial pressures, then the vapour pressure is the pressure which the water vapour would exert at the same temperature if the other constituents of the atmosphere were absent. If Dalton's law is not accepted the concept of partial pressure loses its meaning.

Vapour density, d.—This has its ordinary physical definition as the mass of water vapour per unit volume. On the assumption that water vapour is a perfect gas then $e = RdT$ where T is the absolute temperature and R the gas constant for water vapour.

Relative humidity, U.—The memorandum points out that in the past the term relative humidity has been used indiscriminately to mean either of two separate quantities, which, it is true, have almost identical numerical values under conditions occurring in meteorological practice.

These quantities are :—

(i) $U_d = 100\ d/d_t$ where d is the density of water vapour actually in the air, and d_t is the density of saturated water vapour at the temperature t of the air.

(ii) $U_e = 100\ e/e_t$ where e is the partial pressure of the water vapour actually present in the air and e_t is the saturation vapour pressure at temperature t of the air (dry-bulb temperature).

The two ratios are necessarily identical at 0 and 100 per cent., but at intermediate ratios U_e is slightly greater than U_d though the difference is negligibly small at meteorological temperatures. Further information on this matter is given later but we may note here that Callendar's " Steam Tables " show that at a temperature of 126° F. a relative humidity of 50 per cent. on the pressure definition corresponds to a relative humidity of 49·97 per cent. on the density definition, at 153° F. the corresponding value is 49·95 per cent. and at 183° F. it is 49·9 per cent. The discrepancy at a lower temperature than 120° F. is too small for calculation from the tables. For any given temperature the difference is greatest for a relative humidity of 50 per cent.

Clearly the vapour-density definition is the more fundamental since its value can be directly measured by weighing whereas the ratio of the pressures can only be derived indirectly.

The memorandum therefore proposes that the definition of relative humidity should be based on density.

Moisture content, q.—The term moisture content has been used hitherto without any clearly defined meaning. The Meteorological Office memorandum proposes to define it as the mass of water vapour in unit mass of air, i.e., in unit mass of the mixture of dry air and water vapour. The value of q ranges from zero in the case of dry air to unity in the case of steam (water vapour with no air). It is usually expressed in terms of grams per kilogram, and in these units is identical with $1{,}000\ d/d'$ where d' is the density of the air. An expression sometimes used in the past for this quantity was " specific humidity ".

Assuming, as appears to be very nearly the case under meteorological conditions, that Dalton's law holds and that the density of water vapour is 0·622 times that of dry air at the same temperature and pressure then

$$q = \frac{622e}{P - 0{\cdot}378e}$$

where P is the total pressure.

Mixing ratio, x.—This is defined, in agreement with meteorological practice for some years past, as the mass of water vapour which must be mixed with unit mass of dry air to obtain air of the same constitution as the actual air. Like moisture content it is usually expressed in grams per kilogram and in these units is identical with $1{,}000d/(d'-d)$. In terms of pressure

$$x = \frac{622e}{P - e}$$

The value of x ranges from zero for dry air to infinity for steam.

" British Standard 1339 : 1946, Humidity of the air (Definitions, Formulae, and Constants ".—In this section the specification is briefly reviewed with particular attention to terms not used in meteorology or terms recommended for use with different definitions from those proposed in the Meteorological Office memorandum.

The specification begins by referring to the confusion in terminology and recommending the set of definitions based on majority usage given in the specification. Among these definitions are the following :—

Absolute humidity.—This is identical with vapour density.

Humid volume.—This is a term not used in meteorology but much used in industry. It is that volume of the air in cubic feet which contains 1 lb. of dry air. Alternatively it may be given in cubic centimetres per gram of dry air. The term is not very happily chosen since air has a humid volume if it contains no water vapour at all, while its value becomes infinite for steam. The formula for humid volume is

$$V = \frac{RT}{P - e}$$

where R is the gas constant for dry air and T is the absolute temperature.

Moisture content.—The specification defines this as identical with the " mixing ratio " used by meteorologists. The Meteorological Office did not agree with this definition of moisture content. A serious defect is that its value is infinite in the case of steam which is unreasonable for a " content ".

The quantity so defined is important in industrial drying processes since the mass of dry air remains constant as the air passes through the drying apparatus.

Percentage saturation.—This is another industrial term not used by meteorologists. It is the percentage ratio of the actual mixing ratio to the saturation mixing ratio at the same dry-bulb temperature.

The formula for it is

$$\text{Percentage saturation} = 100\,\frac{d}{d_t}\cdot\frac{d'-d_t}{d'-d}$$

where d_t is the saturation vapour density. Assuming the gas laws and Dalton's law this can be written

$$\text{Percentage saturation} = 100\,\frac{e}{e_t}\cdot\frac{P-e}{P-e}$$

The total pressure P is normally taken as 1000 mb. in practice.

When the air is completely saturated its value is 100 per cent. and when the air is completely dry it is 0 per cent. When relative humidity is intermediate between 0 and 100 per cent. the numerical values of relative humidity and percentage saturation are almost identical at low temperatures but above 100° F. the difference is appreciable. The difference between relative humidity and percentage saturation is $U\,(e_t - e)/(P - e)$.

Examples:—

Dry bulb ° F.	Relative humidity %	Percentage saturation %
50	50	49·7
100	50	48
150	50	43

Relative humidity.—The pressure definition of relative humidity was adopted by the sub-committee. The specification points out that the pressure definition is not identical with the mass one, but that the numerical difference between the two is inappreciable at temperatures below 200° F.

The other definitions (dew point, dry- and wet-bulb thermometers, hoar-frost point, saturation vapour pressure, Stevenson screen, total heat and vapour pressure) in the specification do not call for comment.

The notation recommended by the specification differs from the one proposed by the Meteorological Office.

The British Standards Institution (B.S.I.) specification reads :—

P = total atmospheric pressure
t = dry-bulb temperature
t' = wet-bulb temperature
e = actual vapour pressure
e' = saturation vapour pressure at the wet-bulb temperature
e'' = saturation vapour pressure at the dry-bulb temperature
h_W = moisture content
h_V = absolute humidity
ρ = density of moist air (mass of unit volume)
V = humid volume

Formulae with recommended constants are given for the psychrometric relation between vapour pressure and the difference between wet- and dry-bulb thermometers, moisture content (B.S.I. use of term), absolute humidity, density of moist air and humid volume.

The only one of these calling for comment is the value of the constant A in the psychrometric formula $e = e' - A\,P\,(t - t')$ using the notation above. The specification adopts the same values for A as are given in the Meteorological Office "Hygrometric Tables", except that for the wet bulb in the Stevenson screen the value $4{\cdot}4 \times 10^{-4}$ is recommended instead of the value

$4{\cdot}44 \times 10^{-4}$. This appears to be an improvement since the additional ·04 used in the " Hygrometric Tables " can only justifiably be used if account is taken of the variations of pressure, whereas it is normal practice to take P as fixed at 1000 mb. when calculating relative humidity at ground level.

The effect of departure from the perfect gas laws on the humidity elements.—Meteorologists are generally accustomed to accept the accuracy of the laws of a perfect gas or mixture of perfect gases as applied to the atmosphere and but little reference is to be found in meteorological textbooks to the fact that these laws are not quite accurate. The assumption is fully justified under conditions met with in the atmosphere and within the limits of the accuracy possible in meteorological measurement, but it is desirable that meteorologists should appreciate broadly how justifiable it is.

It has been realised for over a century that Avogadro's, Boyle's, and Charles' laws, summarised in the equation $PV = nkT$ (where P = pressure, V = volume, n = number of molecules, k = Boltzmann's constant, T = absolute temperature) are incorrect particularly near the critical points. The perfect gas laws hold in fact only for a collection of infinitesimally small perfectly elastic molecules influencing one another's motion only when in collision. However, molecules are actually of finite size and do exert attractive or repulsive forces upon one another when not in contact. Numerous modifications of the equation of state allowing for these considerations have been put forward.

The most celebrated of the earlier ones, though not the first, is that of Van der Waals,

$$\left(P + \frac{a}{V^2}\right)\left(V - b\right) = R\,T$$

in which a and b are constants for a particular gas. The term a/V^2 added to P is intended to make a rough allowance for the inter-molecular forces of attraction or repulsion while b allows for the finite size of the molecules.

Kammelingh Onnes introduced in 1900 the equation of state of the form $PV = RT + A(T)P + B(T)P^2 + \cdots$, in which $A(T)$, $B(T)$, etc., are functions of T called the second, third, etc., virial coefficients, RT being the first. The second virial coefficient can be found from the mutual potential energy of two unpolarised molecules by means of a formula derived in modern textbooks on the kinetic theory of gases or statistical mechanics.

When there is a mixture of gases a further complication arises from the mutual interaction of unlike molecules. The virial coefficients then become functions of the relative proportions of the different kinds of molecule.

Dry air obeys the gas laws very exactly and water vapour less exactly. The properties of water vapour at high temperatures and pressure are of great importance in steam engineering and much research has been and still is being done on them. Several semi-empirical equations of state have been proposed for water vapour. As a specimen of them we may quote Callendar's equation which is

$$PV = 4611{\cdot}7\ T - P\left\{26{\cdot}3\left(\frac{373{\cdot}1}{T}\right)^{3{\cdot}3} - 1\right\}$$

where V is in cu. cm./gm. and P in mb. Tables of the connexion between the pressure and specific volume of water vapour as functions of temperature based on this formula are available as the Callendar " Steam Tables ". Other more complicated equations, with associated tables, have been published by Keenan and Keys, Linde, and others. Use was made of Callendar's " Steam Tables " in the Meteorological Office memorandum to calculate the difference between the numerical values of the two definitions of relative humidity assuming the accuracy of Dalton's law and neglecting the relatively small extent to which dry air departs from a perfect gas.

The equation of state for a mixture of gases is of the form :—

$$PV = RT + P\left\{ \Sigma A_{ij} (T) \right\} + \cdots$$

where A_{ij} is the second virial corresponding to the gases i and j. This includes the terms depending on the interaction of like molecules which appear as terms such as A_{ij}. R is the value of the gas constant which would be calculated in the ordinary way on the basis of Dalton's law. Clearly, if the equation of state is of this form, the concept of " partial pressures ", the associated Dalton's law, and the pressure definition of relative humidity strictly break down. Research into the properties of moist air on these lines is proceeding at the University of Pennsylvania under the auspices of the American Institution of Heating and Ventilating Engineers and the International Joint Committee on Psychrometric Data. An important paper by J. A. Goff entitled " Thermodynamic Properties of Moist Air ", describing the results so far obtained was published in *Heating, Piping and Air Conditioning*, New York, June, 1945. The results of their researches are reassuring so far as conditions at temperatures occurring in the atmosphere are concerned. Thus, their values of humidity mixing ratio at saturation differ by at most 0·3 per cent., from those of " Hygrometric Tables " over the range from 20° F. to 80° F. At −9° F. the difference has increased to 0·5 per cent. It thus appears that the deviations from the perfect gas laws are very small under meteorological conditions.

ABSOLUTE DROUGHTS AND PARTIAL DROUGHTS OVER THE BRITISH ISLES, 1906—40

BY J. GLASSPOOLE, M.SC., PH.D. AND H. ROWSELL, B.SC.

In *British Rainfall*, 1887, the following definitions of absolute and partial drought were introduced :—

> *Absolute drought* is a period of at least 15 consecutive days, to none of which is credited 0·01 in. of rain or more.
>
> *Partial drought* is a period of at least 29 consecutive days, the mean daily rainfall of which does not exceed 0·01 in.

The absolute and partial droughts recorded at 50 representative stations over the British Isles were initially given in the annual volumes of *British Rainfall*; in 1903 the number of stations was increased to 73 and in 1910 to 100 stations. Although it has not been possible to use the same stations throughout, statistics are therefore available back to 1910 and the series back to 1906 has also been used in order to obtain the mean frequencies for the 35 years 1906–40. The procedure adopted was to prepare maps on which were plotted separately for each year the number of absolute and partial droughts at the individual stations. For each of the 100 places used in recent years the number of droughts was written down from the maps and the mean extracted. Fig. 1 shows the

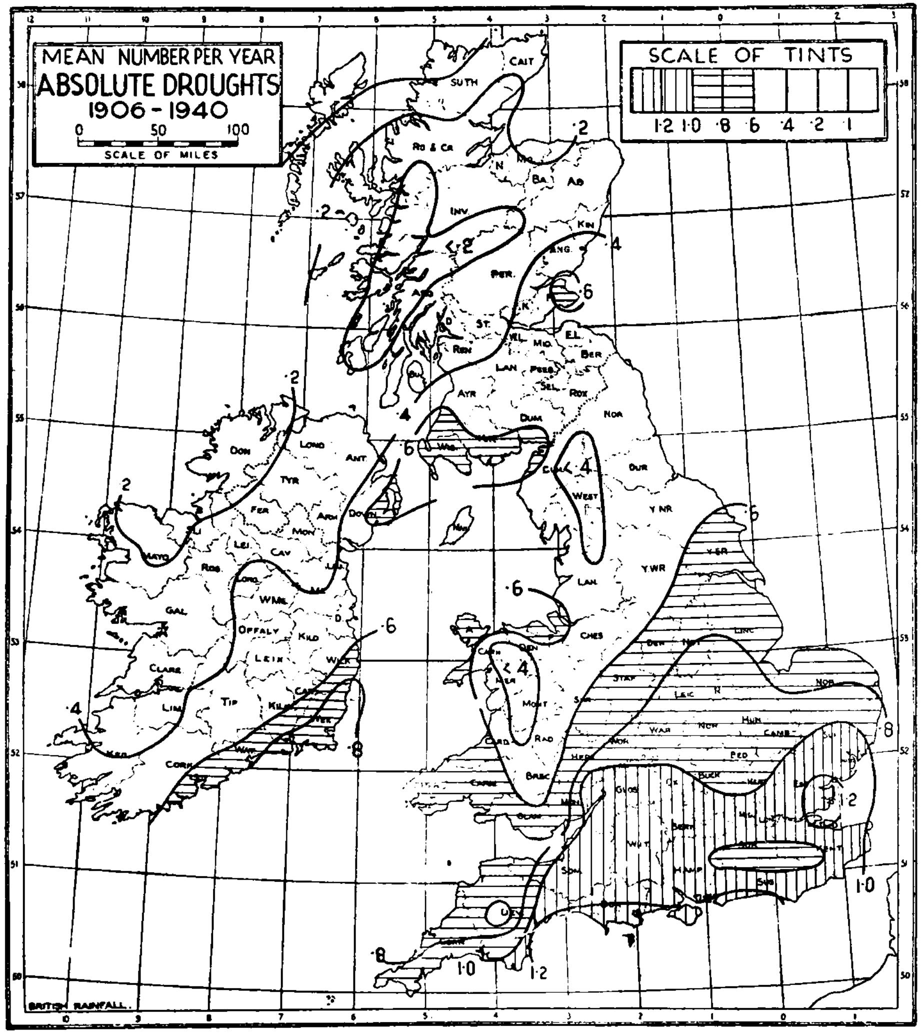

MEAN NUMBER PER YEAR
ABSOLUTE DROUGHTS
1906 - 1940
0 50 100
SCALE OF MILES
SCALE OF TINTS
1·2 1·0 ·8 ·6 ·4 ·2 ·1
BRITISH RAINFALL.

FIG. 1

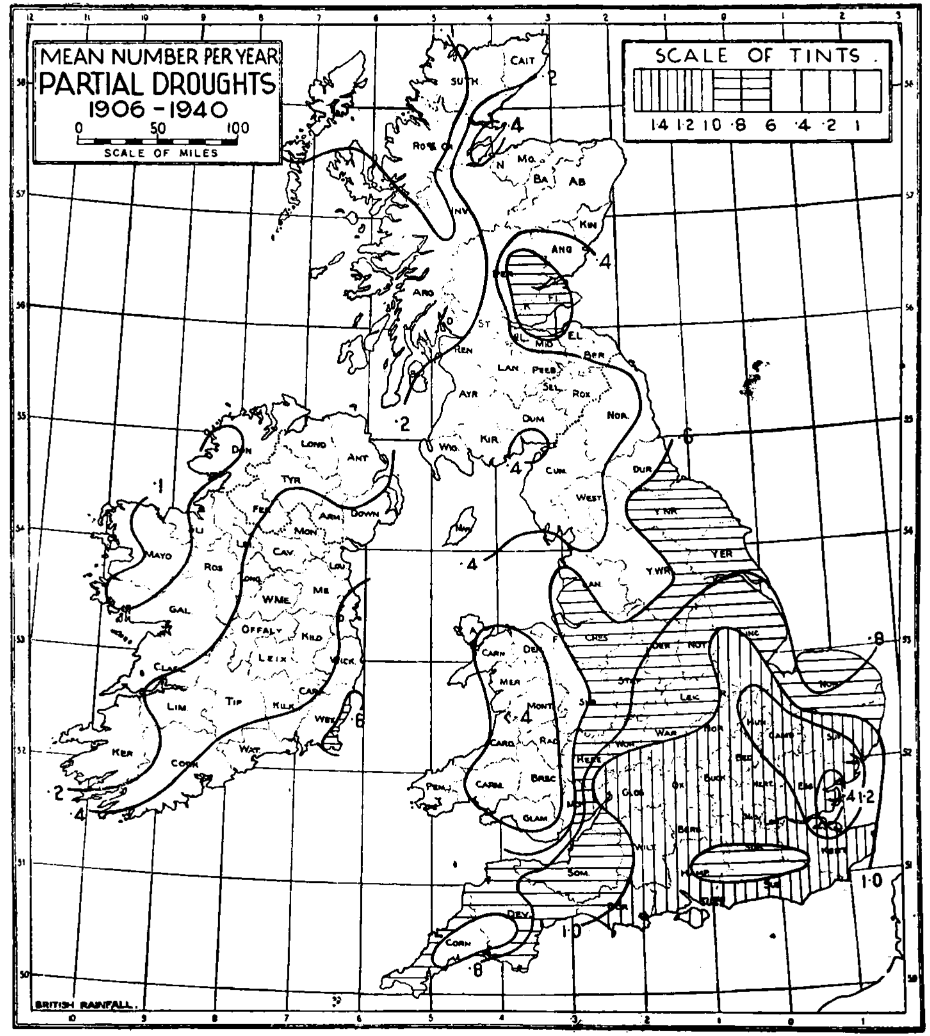

MEAN NUMBER PER YEAR
PARTIAL DROUGHTS
1906 - 1940
0 50 100
SCALE OF MILES
SCALE OF TINTS
1·4 1·2 1·0 ·8 ·6 ·4 ·2 ·1
BRITISH RAINFALL.

FIG. 2

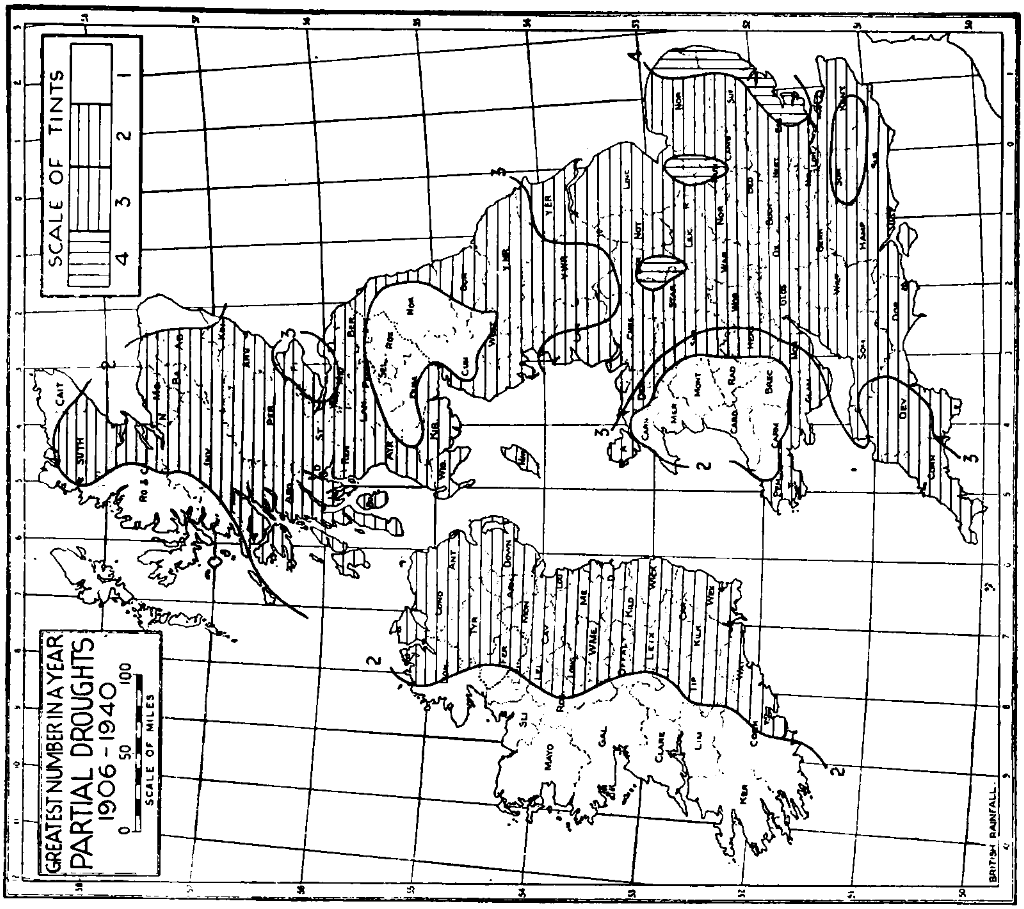

GREATEST NUMBER IN A YEAR
PARTIAL DROUGHTS
1906 - 1940
0 50 100
SCALE OF MILES
SCALE OF TINTS
1 2 3 4
BRITISH RAINFALL.

FIG. 4

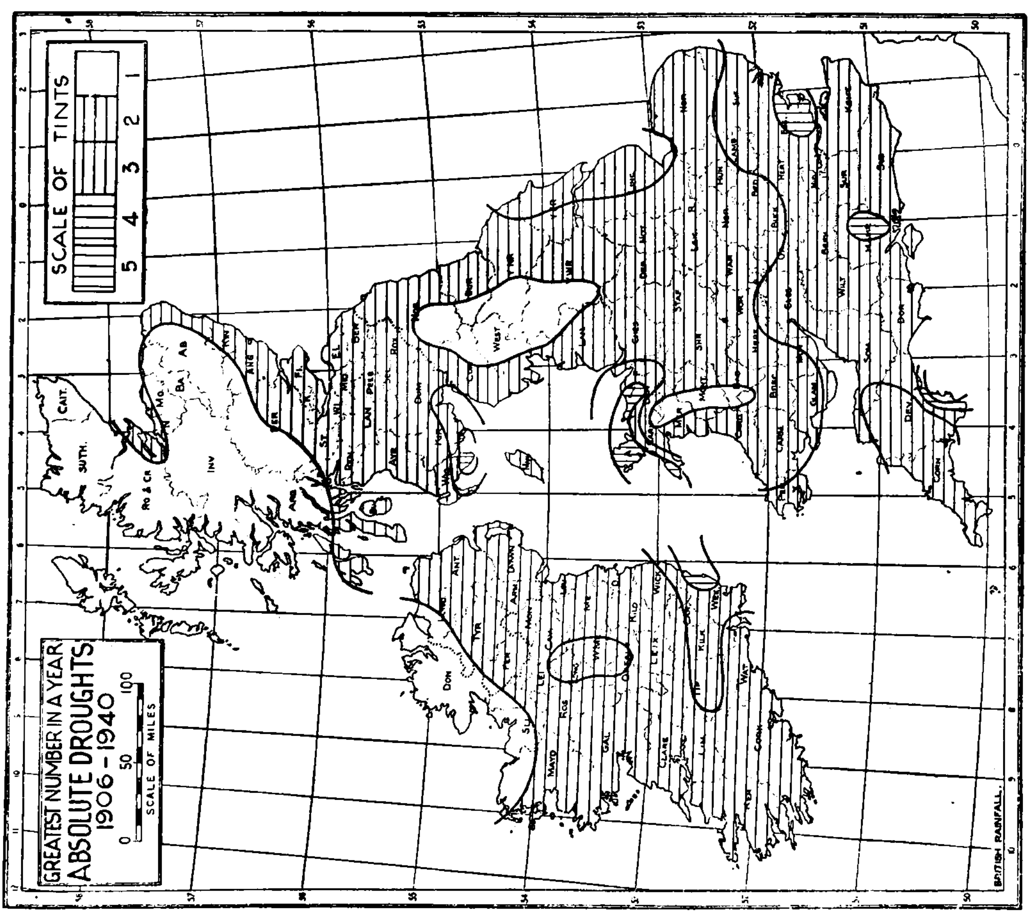

GREATEST NUMBER IN A YEAR
ABSOLUTE DROUGHTS
1906 - 1940
0 50 100
SCALE OF MILES
SCALE OF TINTS
1 2 3 4 5
BRITISH RAINFALL.

FIG. 3

resulting distribution of the mean number of absolute droughts per year and Fig. 2 the corresponding mean number of partial droughts.

It will be seen from Fig. 1 that, on the average, the area south of a line roughly from Ross-on-Wye to Oxford and Bury St. Edmunds records rather more than one absolute drought per year, whereas in the extreme north-west of Scotland the frequency is only one in ten years. The map shows the distribution in greater detail than that first given in the *Quarterly Journal of the Royal Meteorological Society, London,* **65**, 1939, p. 381, which is based on fewer records and for the period 1919–38.

From Fig. 2 it will be seen that the frequency of partial droughts is on the whole very similar to that of absolute droughts, rather more than one per year occurring in the south-east of England and only one in ten years in the north-west of Scotland. The extreme south-east of Essex records three partial droughts in two years, while most of the north-western parts of both Ireland and Scotland give fewer than once in five years.

During the 35 years 1906–40 there was no year (see Fig. 3) with more than one absolute drought over much of the north-west of the British Isles, as well as over the Pennines and the mountainous regions of northern Wales. Over more than half the country the greatest number was two, while three occurred in one year mainly in the south of England. Small areas have recorded as many as four ; and five absolute droughts occurred in 1911 at Ashburton (Druid House) in south Devon. The year 1911 gave the largest number of absolute droughts in the series at the 100 representative stations, viz. 137. The next largest numbers were 112 in 1939 and 110 in 1929. The earlier years 1887 and 1901 gave 160 and 112 respectively, and in 1887 the greatest number at any selected station was four. On the other hand only 11 absolute droughts were recorded at the 100 representative stations in 1923 and 1927. The earlier year 1902 gave 10 only.

All stations (see Fig. 4) have recorded at least one partial drought in a year and a few stations in the Midlands and east of England as many as four. The largest numbers at 100 stations were 156 in 1932, 137 in 1911 and 109 in 1921. Since 1887 the only year to give a comparable number was 1887 with 116. The smallest number in the series occurred in 1918 with 14, although the earlier years 1888, 1890 and 1902, gave 8, 6 and 4 respectively.

Since absolute droughts have been recorded at all stations within the period 1906–40, it is clear that all parts of the country are likely to experience at least 15 consecutive days without measurable rain. The duration of the longest absolute drought experienced at each station has been extracted and the values plotted on a map. Further information is provided by the monthly maps of rainfall which show that no measurable rain has been recorded on a number of occasions in different parts of the country. The list to the end of 1943 of individual months for which no rain was recorded somewhere in the country is:—

February, 1891, 1895, 1932 and 1934
March, 1929 and 1931
April, 1893, 1912 and 1938
June, 1921, 1925 and 1942
July, 1911
August, 1940
September, 1894

In June, 1925, there was no measurable rain over an area of 6,410 sq. miles in southern England and Wales, and in February, 1891, over some 3,290 sq. miles in central and east England and south Wales.

In parts of the north of Scotland and north-west of Ireland the greatest number of consecutive rainless days is between 15 and 20. Over most of Scotland, Ireland and northern England and the mountainous districts in Wales the greatest number has never reached 30 days. In the south-east of England the number has exceeded 40 days and along the south-east coast reached as many as 60 days. The longest well authenticated absolute droughts covered 60 days ~~between~~* March 4 and May 14, 1893 at Hastings, Winchelsea, Lewes and Haywards Heath.

(This note was prepared during the war and is published now for comparison with recent droughts.)

* within the period.

LETTERS TO THE EDITOR

Supercooled water on pond ice

The existence of slush and water on the top of pond ice at a very low temperature in January, 1945, is the subject of a letter in the *Meteorological Magazine* for March, 1947, p. 63. The title was chosen intentionally, as the writer was of the opinion that supercooling was the process responsible for the presence of the water. The Editor has added a note to the effect that it would have been interesting to analyse the slush in view of the possibility of dissolved substances having lowered the freezing point. I admit that I did not conduct the experiment, but it appears most unlikely that this is the explanation.

Taking the well known physico-chemical formula $M = sK/Ld$, where M is the molecular weight of the solute, s its weight in grams, L the weight of the solvent, and d the depression in degrees centigrade below freezing point (in the case of ammonium sulphate, one has to choose at random, $M = 132$, $d = 9^\circ$ C. on the particular occasion) K is a constant ($= 1{,}870$ for water), and taking L as 1,000 gm., it is found that s has to be 635 gm.

Assuming the depth of slush to be 2 in. and that it contained 50 per cent. liquid, and that the area of the pond concerned was $\frac{1}{4}$ acre, the weight of solid needed is about 28 lb./sq. yd. or about 15 tons in all ; this figure is derived by erring on the small side in the calculation. It seems impossible that quantities of soluble substance of this order of magnitude could be deposited on a pond in the country, and particularly over such a limited area, the rest of the pond being free.

Nevertheless, the Editor's remark, though apparently inadequate as an explanation in this case, is interesting, as considerable quantities of dirty-looking solid do get deposited upon snow and ice in winter in places far removed from areas of industrial pollution. On May 26 last, while near the summit of Carnedd Llewelyn examining the last remaining Welsh snow-bed, I found it filthy in appearance, much of it being literally black, as if covered with tar, and the ground around, previously covered by the snow-bed, in the same condition, as I found out after having unwarily sat on it.

S. E. ASHMORE

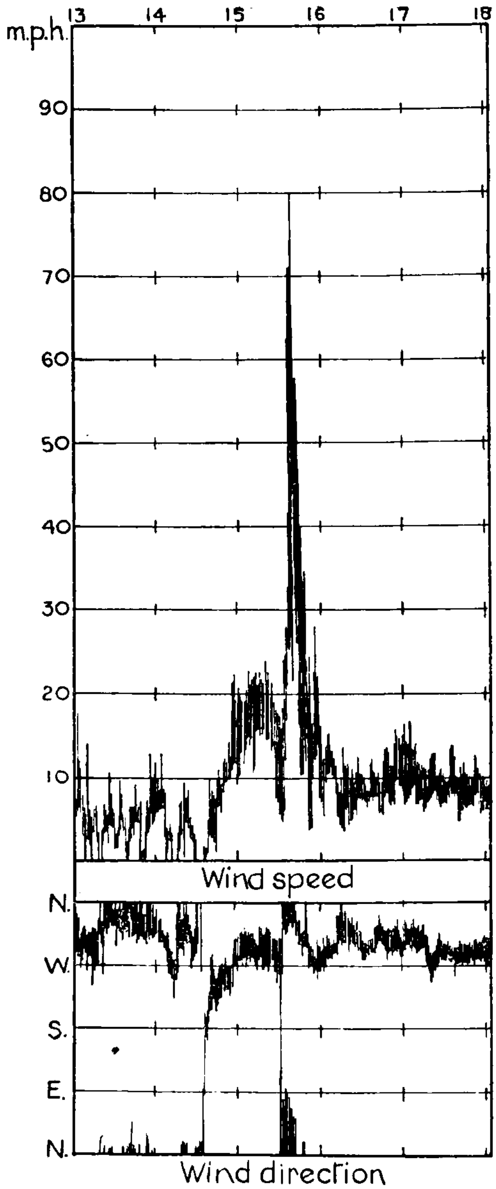
11 *Percy Road, Wrexham.* *June* 13, 1947.

Severe squall at Kano, northern Nigeria

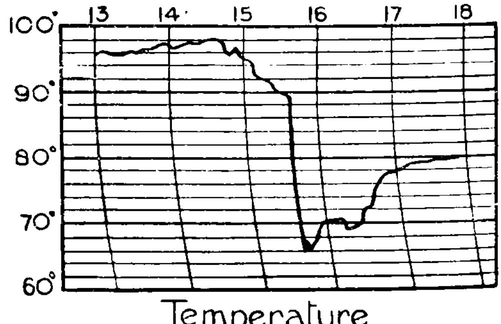
The following notes are on the development of the weather at Kano, on June 12, 1947, culminating in a very severe squall.

Small cumulus began to form at 1100 G.M.T. and had increased to 3 tenths at 4,500–5,000 ft. by 1200. Very rapid development followed, and by 1335, local showers were observed at many points between east and west through south. The shower clouds were isolated, and individually did not cover a large area—6 tenths cumulonimbus were reported at 1400—with base 4,000 ft. and tops in many instances having already reached their maximum vertical development and spreading out to form massive anvils.

At about this time a large isolated cumulus was observed to the north-east, at a distance of some 50 miles. As this cloud, still developing, was borne



SKETCH OF THE OBSERVED CLOUD



AUTOGRAPHIC RECORDS AT KANO DURING THE SQUALL OF JUNE 12, 1947 nearer the airport on the north-easterly upper wind its base was estimated to be at least 5,000 ft. and diameter a little over a mile.

The under surface of the cloud was seen to develop an ominous turbulent annular roll, diameter about half that of the cloud base, and giving to the cloud's under surface an appearance which can be best described as an immense flat-bottomed crater, with the sides of the " crater " protruding downwards from the main base to a distance of between 500 and 1,000 ft. The walls of the " crater " showed evidence of strong downward currents, while the lower edges were swept outwards and upwards.

Surface wind had been light from a westerly point, but shortly before 1500 freshened to SW. 15 to 17 m.p.h. At this time the effects of the cloud were becoming visible to the north-east of the airport, where vast clouds of thick dust were being lifted from the surface. With the closer approach of the cloud, blowing dust arrived at the airport at 1534. The surface wind at this time was still westerly. Six minutes later, at 1540, the squall struck, the wind veering sharply from 300° to 030°, and gusting to 80 m.p.h. Violent gusts were maintained for ten minutes, followed by a rapid moderation and backing, so that by 1600 the wind was again W. 12 m.p.h.

The rain which accompanied the squall was very heavy, but short-lived, soon becoming slight, and ceased at 1630; 0·39 in. were recorded. Thunder occurred, but was not very heavy.

At 1500, when the wind first freshened, the temperature was 96° F., but by 1540 had fallen to 89° F., followed by an almost instantaneous drop to 66° F. as the squall struck.

The path of the squall was narrow, the really heavy squall being contained within a belt of width 200–300 yds. This assumption is based on a survey of the damage caused to buildings in the track of the storm as it passed right across the airport buildings from north-east to south-west. Only in a relatively narrow belt was serious damage caused—corrugated iron roofs, complete with joists, being lifted bodily and carried several hundreds of yards, while similar buildings on each side of the storm track escaped damage.

A. T. DORRELL

Kano airport, Nigeria.

NOTES AND NEWS

First British ocean weather ship—Renaming ceremony

On the afternoon of Thursday, July 31, 1947, in the London Docks, the ceremony of renaming our first ocean weather ship* was performed by the Secretary of State for Air. The ship was the ex-Royal Naval corvette *Marguerite*, and she was to be renamed *Weather Observer*. The extensive work of converting the ship from a war vessel to her new appearance had been carried out at H.M. Dockyard, Sheerness. At about noon on the 30th the ship had arrived up river from that port and had been berthed in Shadwell Basin, London Docks.

The Port of London Authority had kindly allotted, abreast the ship's berth, a large shed in which an exhibition of meteorological instruments was laid out, and where refreshments were arranged for the guests. Decorations were hung round the inside walls of the shed including the national flags of the

* See *Meteorological Magazine*, **76**, 1947, p. 25.

countries interested in the Atlantic ocean weather ship scheme ; Belgium, Canada, Denmark, Eire, France, Holland, Iceland, Norway, Portugal, Sweden, the United Kingdom, and the United States of America. On a flagstaff outside the shed the Union Flag was flown; the ship herself flew masthead flags, a jack, and the Red Ensign, and also her " number " M.P.J.J.

In the forenoon of Thursday, July 31, representatives of the Press visited the ship and were shown the meteorological arrangements in her. A number of photographs were taken, and a radio-sonde balloon was released by the ship's meteorological staff (see photograph facing p. iii of cover). Fortunately the wind was in the right direction to take the balloon and its gear clear of several tall dock cranes and of a near-by church spire. At 11 a.m. Sir Nelson Johnson, Director of the Meteorological Office, addressed a large Press conference in the shed on the quay.

By 3 p.m. a considerable gathering, including many distinguished people, was on the quay. The Secretary of State for Air, Mr. Noel Baker, was introduced by the Director to a number of the guests, and to the Captain and senior officers of the ship. The ship's company had been mustered on the quay alongside their ship, and they were inspected by the Secretary of State, who then made a speech.

After pointing out that the idea of ocean weather ships was not a new one, Mr. Noel Baker went on to mention the International Conference convened by P.I.C.A.O. in London in September, 1946, which resulted in the signing of an agreement by ten countries for providing and maintaining 13 ocean weather ship stations in the North Atlantic. These ships would act as floating " islands " to provide meteorological observations, and to give navigational aid to aircraft in flight. He outlined the work to be done by them, their upper air soundings and other meteorological work, and their use, should occasion unfortunately arise, as air/sea rescue vessels.

The crews of the ocean weather ships would have an arduous and sometimes difficult job, but if their work resulted in improved accuracy of the weather forecasts for the civil air lines operating across the ocean, as well as for shipping, and for agriculture and many other economic purposes ashore, then it would be difficult to estimate the great value of these ships to the peoples of the countries concerned.

At about 3.30 p.m. the Secretary of State, accompanied by the Director and some guests, boarded the ship and the renaming ceremony was performed; this was done by the Secretary of State, after wishing good luck to all who sail in her, pronouncing the ship renamed *Weather Observer* and at the same time cutting a tape which released a Union Flag that had until then covered the vessel's name on her bow.

The party then inspected the ship, being conducted round by the Captain. Other guests visited the exhibition of meteorological instruments in the shed on the quay, while waiting their turn to inspect the ship.

Guests were conducted over the ship in parties of about a dozen. At the end of the inspection by the Secretary of State and party, another radio-sonde balloon was released from the special balloon filling compartment at the after end of the ship. This balloon, like the one launched in the forenoon, also went clear of all obstructions. The successful launching of radio-sonde balloons from a small ship is no easy job; the balloon with its radar target, transmitter aerial and transmitter having about 30 ft. overall length at the launch, requires considerable skill in handling.

Visitors to the ship found plenty to interest them; the navigating bridge with the various "gadgets" in the chartroom and wheelhouse, the motor lifeboats and other rescue arrangements were all interesting. Some found their main interest in the radio and the radar equipment, all of which is of up-to-date Admiralty pattern, or in the engine room with its complicated mass of machinery. The crew's quarters, recreation rooms and cooking arrangements were of interest to others. A large proportion of the visitors were members of the staff of the Meteorological Office, and to them the interest, no doubt, was in the meteorological plotting room, the insrument-preparing room and the balloon-filling compartment.

The ship herself presented quite a striking appearance, with her black hull and with her deck houses, bridge, boats, funnel and masts painted a bright yellow. This colouring is to make the ship conspicuous from the air. Her unusual appearance and rig caused considerable interest in shipping circles on London River.

The vessel's general dimensions are :—

Length O.A. 206 ft., beam 33 ft., draft-loaded, about 16 ft. She is of 725 tons gross, 268 tons net measurement and has a maximum speed of 16 knots, with a single screw, reciprocating steam engines, and oil fired boilers. As a corvette her armament had been one 4-in. gun mounted forward, one two-pounder QF gun mounted aft, six Oerlikon guns (3 either side) and 72 depth charges.

The change in appearance brought about by the conversion from a war-time corvette to an ocean weather ship—truly from "sword into plough-share"—can be seen by comparing the photograph of H.M. corvette *Snowflake*, a sister ship to H.M. Corvette *Marguerite*, facing p. 32 of this year's February issue and the photograph of O.W.S. *Weather Observer* facing p. 216 of this issue.

It can be seen that two specially designed masts have been added, with a radar platform on the lattice-work foremast. The forecastle deck has been carried aft to the mainmast to provide extra cabin accommodation; a deckhouse has been built forward of the bridge, two 30-foot motor lifeboats fitted, and a large balloon-filling compartment built aft. She has also been considerably altered internally.

On Friday, August 1, 1947, the O.W.S. *Weather Observer*, Captain N. F. Israel, D.S.C., sailed from the London Dock at 2 p.m. to complete her radar tests off Portsmouth and then proceed to her station in the Atlantic—Station "J" in latitude 53° 50′ N., longitude 18° 40′ W.

C. H. WILLIAMS

Explosion at Brest

On July 28, one of the seismographs, a short-period vertical-component instrument, and four different types of barograph, including a very sensitive micro-barograph, recorded at Kew Observatory the effects of the explosion of a cargo of nitrate at Brest, some 300 miles away. The whole disturbance lasted about a minute and resembled very closely the observed effects of war-time explosions (bombs, rockets, etc.).

The recordings were simultaneous on all instruments, showing that, as was the case for the most part during the war, the seismograph disturbance was due to the explosion air wave and not to true earth movements. There were no indications of upper air sound waves.

The first pulse recorded by the seismograph was at 16h. 48m. 52s. G.M.T., the largest amplitude at 16h. 49m. 5s. and all four barographs recorded a sudden pulse of about one millibar of very short duration, the mean of the times being 16h. 49m. 6s. ± 15s. It was estimated from these records that the Brest explosion occurred at about 16h. 25m. G.M.T.

Ball lightning

Two accounts of ball lightning have been received recently. The first comes from Mrs. James Carruthers, C.H., reporting that her friend Miss Heron who lives at Castle Douglas, Kirkcudbrightshire, had told her that on July 9, 1947, " it was a close day but with no rain or thunder; about 11 a.m. a nurse, who was looking after an invalid in the house, saw a fire ball apparently running along one of the electric wires outside the house. A moment after, it crashed with a terrific explosion into a very large oak tree in the garden which was shattered and blasted to pieces . . . . Every fuse in the house was smashed, and all the electric communications—telephone, radio, etc.—but no windows were broken."

The second is from Miss B. D. P. Foster who has kept a daily record of rainfall at Penmilder, Liskeard, Cornwall, since August, 1895. She writes:—

" On August 17, about 7 p.m. during a thunderstorm there was a terrifying and apparently simultaneous crash of thunder and a flash of vivid lightning. People in the neighbouring cottages thought their houses had been struck or their chimneys fallen and children were terrified. During the storm a small-holder and his wife (Mr. and Mrs. Coombes) were sheltering by Penmilder gates—they saw a ball, misty coloured, come through the trees and where it touched the trees zigzag lightning shot out. The ball floated on down the hill and hit a telegraph pole . . . the ball was then lost to sight. The trees crackled and the Coombes quite expected to see them on fire, but there was not even any sign of scorching."

[July 9 was a day of widespread thunderstorms in that area of Scotland but no other case of ball lightning has been reported on that date. There were widespread thunderstorms over Cornwall on August 17.—Ed. *M.M.*]

Variations in the frequency of clear and cloudy days with the number of observations

Clear and cloudy days are defined as days on which the mean cloud amount is less than 2 tenths and greater than 8 tenths respectively. As this amount may be based on 2–24 observations, it is of some interest to examine the effect of changing the number of observations on the frequency of clear and cloudy days.

Table I gives the frequencies at 3 stations for some of the more usual combinations of the available observations. Two sets of values are given, based on (*a*) $<$ 2 and $>$ 8 tenths, (*b*) $\leqslant$ 2 and $\geqslant$ 8 tenths. For each station, values are given for one of the clearer and one of the cloudier months. Table II gives the mean cloud amount for the hours used in Table I.

TABLE I—AVERAGE NUMBER OF CLEAR AND CLOUDY DAYS

Station and Period	Times of observations	Clear < 2 (a)	Clear $\leqslant 2$ (b)	Cloudy > 8 (a)	Cloudy $\geqslant 8$ (b)	Clear < 2 (a)	Clear $\leqslant 2$ (b)	Cloudy > 8 (a)	Cloudy $\geqslant 8$ (b)
		July				*May*			
Valencia 1922–31	0700, 0900, 1300, 1500, 1800, 2100	0·6	0·8	17·4	18·7	0·4	0·7	12·1	12·4
	0900, 1500, 2100	0·6	0·8	16·8	19·0	0·3	0·7	12·1	13·9
	0900, 2100	0·7	0·8	18·1	20·5	0·7	1·2	13·4	15·5
	0900	0·8	1·7	18·8	22·2	1·0	2·2	12·8	18·0
		December				*June*			
Potsdam 1924–33	0200, 0800, 1400, 2000	1·9	2·0	16·8	17·4	3·4	3·6	7·5	8·0
	0800, 1400, 2000	2·1	2·4	17·8	18·2	3·3	3·9	7·2	8·2
	0800, 2000	2·8	3·0	18·8	19·5	3·9	4·7	7·3	8·6
	0800	3·6	4·1	21·1	22·2	6·1	8·5	12·1	14·5
		January				*July*			
Batavia 1927–36	0300, 0900, 1500, 2100	0·4	0·5	15·3	16·8	4·0	4·8	2·3	2·7
	0900, 1500, 2100	0·4	0·5	17·5	19·0	4·3	5·3	2·8	3·6
	0900, 2100	0·7	0·8	17·9	19·0	5·7	7·6	3·9	4·8
	0900	1·9	2·7	19·1	20·4	15·3	17·7	4·9	5·9

TABLE II—DIURNAL VARIATION OF CLOUD AMOUNT

	Month	0200	0300	0700	0800	0900	1300	1400	1500	1800	2000	2100
						tenths						
Valencia	July	—	—	8·3	—	8·1	7·9	—	7·6	7·8	—	8·0
	May	—	—	7·5	—	7·3	7·1	—	7·0	7·0	—	7·2
Potsdam	Dec.	7·1	—	—	7·8	—	—	7·4	—	—	7·3	—
	June	5·3	—	—	6·0	—	—	6·6	—	—	5·5	—
Batavia	Jan.	—	6·9	—	—	7·8	—	—	7·9	—	—	8·1
	July	—	4·5	—	—	3·5	—	—	4·7	—	—	6·6

The following causes lead to changes in the frequencies as the number of observations is increased.

(1) The definitions < 2 tenths and > 8 tenths do not refer to a constant cloud amount as the number of observations is changed. For example, on clear days the mean cloud amount is < 2 tenths at n observations, and the maximum possible mean cloudiness c at the hours of observation is given by $(2n - 1)/2$ tenths, thus:—

n	1	2	3	4	6	8	12	24
c	1	1·5	1·67	1·75	1·83	1·87	1·92	1·96

This effect tends to raise the number of clear and cloudy days with additional observations.

(2) The combination of observations leads to a decrease in the standard deviation of the derived values, as compared with the individual values. Thus, provided that the mean cloud amount for the day lies between 2 tenths and 8 tenths, then, as n increases there is less chance that the mean at n observations will be < 2 or > 8 tenths.

(3) It might be expected that the addition of an observation at a comparatively clear time of day would accentuate the decrease in the number of cloudy days and damp down the decrease in the number of clear days.

In Table I the effect of (1) is eliminated in columns (*b*) which show a fall in frequency in almost every case as *n* is increased. While this is generally true also for columns (*a*), there are more occasions on which the expected change does not take place.

Any modifications caused by diurnal variation are most easily seen in columns (*b*). Only at Batavia is the variation sufficiently marked for any effect on the frequencies to be expected. Here, the January 0300 observation is comparatively clear; when this is added to the observations at 0900, 1500 and 2100 the frequency of cloudy days drops from 19·0 to 16·8. Also when the " cloudy " July 2100 observation is added to the " clear " 0900 observation there is a marked drop in the frequency of clear days.

In conclusion it may be stated that the total effects from these three causes are small and that, provided more than one observation a day is used, the variations in frequency are not important from any practical point of view.

W. H. HOGG

REVIEWS

Further researches into the physical reality of some long-periodic cycles in the barometric pressure of Batavia, by H. J. de Boer. Batavia, Koninklijk Magnetisch en Meteorologisch Observatorium. Verh. No. 30. 8vo. $9\frac{1}{2}$ in. × $6\frac{1}{4}$ in. pp. 28. Surabaya, H. van Ingen, 1947.

De Boer has made a new periodic analysis of the pressure curve at Batavia by a method which resembles that of Fulvirch (i.e. auto-correlation) but is much simpler. The mean lengths of the periods so found are

2·34, 3·36, 5·97, 7·32, 8·47, 11·12 and 15·87 years.

The work is then extended to other stations and maps are constructed showing the distribution of the $2\frac{1}{3}$-, 11- and 16-year oscillations over the globe. The author also includes maps of the Brückner cycle of 36 years. His method of presentation is to compute the amplitude and phase of the oscillation by harmonic analysis. To show the relative importance of the oscillations at any particular station he also uses a " development coefficient ", which is the ratio of the amplitude found by harmonic analysis to the standard deviation of the pressure. The pressure oscillations of 11 years and 36 years are found to be similarly distributed over the globe. Both oscillations originate in the tropics and propagate thence in various directions becoming less intense relatively and converging towards the north and south poles. The supposition is that they are both of solar origin.

De Boer regards the 16-year cycle as being a consequence of the interaction of the 11-year and 36-year cycles, and he seeks to derive it by supposing, following Seidel's suggestion, that the amplitude of the 11-year cycle varies in a 36-year rhythm. His map computed on this principle agrees in its main features with the map of the 16-year oscillation which he has earlier derived from the observations themselves, except that there is a discrepancy in phase amounting to 70°.

The paper, which ends with a discussion of errors in harmonic analysis with limited numbers of ordinates, follows on from previous works quoted in the list of references and should be read in conjunction with them.

J. WADSWORTH

Industrial Experimentation, by K. A. Brownlee, London, 2nd edn. 8vo. $9\frac{1}{2}$ in. × 6 in., pp. 151. London, H.M. Stationery Office, 1947. Price 2*s*. 6*d*.

It may seem strange, in a meteorological publication, to recommend a book on the design and interpretation of industrial experiments. The meteorologist, unlike the industrialist, is unable to control the elements he studies. He cannot design experiments; his part is to interpret the results of the experiments conducted by Nature in the atmosphere. " Industrial Experimentation " will enable him to interpret his data and to give quantitative estimates of the correctness of his conclusions.

Two admirable features of the book are the very clear summary of the fundamental concepts of statistics and the attention given to tests of significance. The analysis of variance is treated in much detail, and is applied to correlation and to the planning of experiments. In simple correlation, it is used to check the linearity of the relation between two variables. The chapters on the design of experiments have been considerably amplified in this second edition. Although they do not appear to be of direct application to meteorology, nevertheless some of their contents may be of service; for example the use of logarithms in the analysis of variance and the warnings against the rigid use of significance levels.

The book is concerned only with practical details and no knowledge of mathematics is assumed beyond an acquaintance with algebraic symbols. In the main, the author succeeds in presenting each new idea clearly and separately. He errs, however, in allowing explanations of method to become submerged in numerical computation. Not only is this confusing in a first reading, but it also makes the book less valuable for further (spasmodic) reference. A generalised account, uncomplicated by arithmetic, with the specific examples following, would be a clearer arrangement in the chapters on the " chi-square " test and the analysis of variance. Perhaps this could be remedied in a further edition. In general, the reasonableness of the methods and the similarity of approach to the various problems make up for the lack of theoretical exposition, and instructions are not confused by alternative procedures. An exception to this is found in the treatment of partial regression coefficients. Since no explanation is given for the sets of equations employed, it would seem better to replace these by the easily remembered formulae involving correlation coefficients. Generally, fewer computational errors arise in applying set formulae than in solving simultaneous equations.

The reviewer would like to see specific references to theory where this cannot be found in textbooks of statistics. One interesting example is the use of a modified Poisson series to account for the distribution of time intervals between rare events.

There is much of interest in K. A. Brownlee's book and the advantages of clear print and a well set-out table of contents make it practicable for reference. It is worth possessing if only because of its tables for significance tests. These have been carefully selected and are clear and easy to use.

N. CARRUTHERS

WEATHER OF JULY, 1947

At the beginning of the month a depression approached Iceland from the Atlantic and moved slowly east. On the 4th a depression in mid Atlantic moved rapidly east to the north of Scotland; subsequently it followed a complicated track over Scotland and was associated with rather unsettled cold weather over the British Isles. On the 13th, a wedge of high pressure over the North Sea stretching north from an anticyclone over France moved east and pressure became high in a belt extending from westward of Portugal across England to Scandinavia. Temperature rose considerably and thundery conditions prevailed. From the 20th to 22nd an almost stationary depression was situated west of Ireland, while a trough of low pressure moved slowly north-east across England. Later a weak trough of low pressure associated with a depression over the Azores moved north-east over England becoming almost stationary over central Ireland and northern England. A spell of very warm weather ensued in south-east and east England and heavy rain at times in the vicinity of the trough. Finally an anticyclone developed over the British Isles and the closing days of the month were mainly fine apart from local mist or fog. The average pressure distribution for the month shows a high extending from Bermuda to the west of Portugal (1026 mb. near its centre) with a depression, less than 1010 mb., covering southern Greenland, Iceland and the Faeroes. Pressure was more than 2·5 mb. below the average in a belt from the south of Greenland to the Azores and more than 2·5 mb. above average in an area extending north to Nova Scotia and Newfoundland and east to 40° N. 40° W. Pressure was somewhat above normal over Germany and most of the Baltic.

The weather in the British Isles was distinguished by a cold spell from the 5th to the 11th followed by warm conditions, with frequent and sometimes severe thunderstorms during the remainder of the month. A maximum temperature of 90° F. was registered at Cheltenham on the 27th and in London (Greenwich) on the 28th. The general rainfall was not very different from the average but the distribution was variable owing to heavy local falls during thunderstorms. These were widespread and severe locally on the 15th, 16th and 28th. At Wisley, Surrey, on the 16th, 4 in. of rain fell in about 75 minutes, a "very rare" fall, while hailstones about the size of grapes were observed. In Perthshire two persons were killed by lightning on the 16th and there was considerable flooding and other damage. On the early morning of the 28th, at Ballykelly, Northern Ireland, 1·67 in. fell in 60 minates causing serious flooding. Sunshine was generally below the average except in north-east and east Scotland and locally in eastern districts of England, where it exceeded the average.

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

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	90	40	+ 1·6	95	+ 1	88	34
Scotland	80	36	+ 1·3	99	— 2	105	30
Northern Ireland ..	79	40	0·0	118	+ 2	78	23

RAINFALL OF JULY, 1947

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·78	75	*Glam.*	Cardiff, Penylan ..	2·77	90
Kent	Folkestone, Cherry Gdns.	2·92	139	*Pemb.*	St. Ann's Head ..	3·10	119
,,	Edenb'dg, Falconhurst	1·85	80	*Card.*	Aberystwyth	5·21	171
Sussex	Compton, Compton Ho.	1·59	56	*Radnor*	Bir. W. W., Tyrmynydd	3·42	83
,,	Worthing, Beach Ho. Pk.	1·29	63	*Mont.*	Lake Vyrnwy	4·56	125
Hants.	Ventnor, Roy. Nat. Hos.	1·64	81	*Mer.*	Blaenau Festiniog ..	8·86	104
,,	Fordingb'dg, Oaklands	1·41	71	*Carn.*	Llandudno	1·54	69
,,	Sherborne St. John ..	1·30	58	*Angl.*	Llanerchymedd ..	2·37	83
Herts.	Royston, Therfield Rec.	1·84	73	*I. Man.*	Douglas, Boro' Cem. ..	3·39	111
Bucks.	Slough, Upton ..	2·19	114	*Wigtown*	Pt. William, Monreith..	3·18	113
Oxford	Oxford, Radcliffe ..	1·70	72	*Dumf.*	Dumfries, Crichton R.I.	4·81	147
N'hant	Wellingboro', Swanspool	1·82	79	,,	Eskdalemuir Obsy. ..	4·50	110
Essex	Shoeburyness	1·79	98	*Roxb.*	Kelso, Floors	2·87	109
Suffolk	Campsea Ashe, High Ho.	1·77	77	*Peebles.*	Stobo Castle	2·37	82
,,	Lowestoft Sec. School ..	1·50	66	*Berwick*	Marchmont House ..	2·73	90
,,	Bury St. Ed., Westley H.	2·32	93	*E. Loth.*	North Berwick Res. ..	1·73	67
Norfolk	Sandringham Ho. Gdns.	1·61	63	*Midl'n.*	Edinburgh, Blackf'd. H.	1·92	68
Wilts.	Bishops Cannings ..	1·98	80	*Lanark*	Hamilton W. W., T'nhill	2·20	77
Dorset	Creech Grange.. ..	1·37	56	*Ayr*	Colmonell, Knockdolian	3·43	109
,,	Beaminster, East St. ..	3·11	120	,,	Glen Afton, Ayr San. ..	4·51	107
Devon	Teignmouth, Den Gdns.	1·69	73	*Bute*	Rothesay, Ardencraig ..	3·90	98
,,	Cullompton	1·65	61	*Argyll*	Loch Sunart, G'dale ..	4·87	105
,,	Barnstaple, N. Dev. Ath.	2·49	92	,,	Poltalloch	5·34	129
,,	Okehampton, Uplands	3·13	92	,,	Inveraray Castle ..	8·89	179
Cornwall	Bude School House ..	2·33	95	,,	Islay, Eallabus ..	5·94	174
,,	Penzance, Morrab Gdns.	2·09	77	,,	Tiree	3·50	97
,,	St. Austell, Trevarna ..	3·34	100	*Kinross*	Loch Leven Sluice ..	2·44	85
,,	Scilly, Tresco Abbey ..	2·59	117	*Fife*	Leuchars Airfield ..	1·57	60
Glos.	Cirencester	2·56	99	*Perth*	Loch Dhu	6·90	143
Salop	Church Stretton ..	3·58	136	,,	Crieff, Strathearn Hyd.	4·78	161
,,	Cheswardine Hall ..	5·64	208	,,	Blair Castle Gardens ..	4·66	182
Staffs.	Leek, Wall Grange, P.S.	3·36	105	*Angus*	Montrose, Sunnyside ..	1·51	57
Worcs.	Malvern, Free Library	1·40	61	*Aberd.*	Balmoral Castle Gdns...	2·46	96
Warwick	Birmingham, Edgbaston	3·95	170	,,	Aberdeen Observatory	1·44	51
Leics.	Thornton Reservoir ..	2·69	108	,,	Fyvie Castle	2·06	63
Lincs.	Boston, Skirbeck ..	1·49	68	*Moray*	Gordon Castle	2·41	75
,,	Skegness, Marine Gdns.	1·47	67	*Nairn*	Nairn, Achareidh ..	1·82	71
Notts.	Mansfield, Carr Bank	2·12	81	*Inv's*	Loch Ness, Foyers ..	2·86	95
Ches.	Bidston Observatory ..	4·52	175	,,	Glenquoich	6·51	101
Lancs.	Manchester, Whit. Park	2·85	86	,,	Ft. William, Teviot ..	4·63	95
,,	Stonyhurst College ..	3·56	92	,,	Skye, Duntuilm ..	3·33	89
,,	Blackpool	2·47	85	*R. & C.*	Ullapool	2·01	65
Yorks.	Wakefield, Clarence Pk.	1·80	71	,,	Applecross Gardens ..	3·55	89
,,	Hull, Pearson Park ..	·88	38	,,	Achnashellach	4·74	97
,,	Felixkirk, Mt. St. John	1·61	59	,,	Stornoway Airfield ..	3·06	106
,,	York Museum	2·59	103	*Suth.*	Lairg	2·98	95
,,	Scarborough	1·53	43	,,	Loch More, Achfary ..	3·64	68
,,	Middlesbrough.. ..	2·13	83	*Caith.*	Wick Airfield	·88	33
,,	Baldersdale, Hury Res.	3·64	114	*Shet.*	Lerwick Observatory ..	1·56	68
Norl'd	Newcastle, Leazes Pk.	2·86	112	*Ferm.*	Crom Castle	3·61	104
,,	Bellingham, High Green	4·11	125	*Armagh*	Armagh Observatory ..	3·24	112
,,	Lilburn, Tower Gdns...	2·65	107	*Down*	Seaforde	4·06	127
Cumb.	Geltsdale	5·30	154	*Antrim*	Aldergrove Airfield ..	3·80	136
,,	Keswick, High Hill ..	3·54	92	,,	Ballymena, Harryville..	4·18	122
,,	Ravenglass, The Grove	3·46	92	*Lon.*	Garvagh, Moneydig ..	3·62	112
Mon.	Abergavenny, Larchfield	1·96	79	,,	Londonderry, Creggan	4·37	119
Glam.	Ystaeyfera, Wern Ho. ..	4·85	106	*Tyrone*	Omagh, Edenfel ..	3·76	111

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, MARCH, 1947

Stations	Pressure: Mean of day M.S.L.	Pressure: Diff. from normal	Temperatures: Absolute Max.	Temperatures: Absolute Min.	Temperatures: Mean values Max.	Temperatures: Mean values Min.	Temperatures: Mean values ½ (Max. and Min.)	Temperatures: Mean values Diff. from normal	Temperatures: Mean values Wet bulb	Relative humidity	Mean cloud amount	Precipitation: Total	Precipitation: Diff. from normal	Precipitation: Days	Bright Sunshine: Daily mean	Bright Sunshine: Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hrs.	%
London, Kew Observatory	1002·7	−10·2	58	23	45·9	36·0	40·9	−2·2	38·3	87	7·9	4·66	+2·97	26	1·9	16
Gibraltar	1016·3	−0·8	76	49	67·4	54·9	61·1	+3·5	56·6	84	7·1	5·83	—	15	—	—
Malta	1015·9	+1·7	75	46	66·7	53·7	60·2	+3·1	56·1	63	5·1	0·04	—	1	9·0	76
St. Helena	1014·5	−1·6	74	60	70·2	62·2	66·2	+1·1	62·5	96	9·0	6·39	+2·37	28	—	—
Freetown, Sierra Leone	1010·9	+1·7	90	70	84·5	76·4	80·5	−0·4	75·8	83	5·8	3·50	+2·34	4	8·0	66
Lagos, Nigeria ..	—	—	95	69	91·3	73·5	82·4	+1·0	79·7	83	8·0	7·90	—	7	6·4	53
Kaduna, Nigeria ..	1009·3	—	100	58	95·0	64·5	79·7	−1·9	60·0	22	2·8	0·20	−0·34	1	9·6	80
Zomba, Nyasaland ..																
Salisbury, Rhodesia ..																
Cape Town ..	1015·3	+0·8	99	55	79·9	60·9	70·4	+2·3	61·2	75	3·3	2·53	+1·65	6	—	—
Germiston, South Africa	1015·6	—	83	48	75·8	55·4	65·6	—	56·8	69	4·0	4·70	—	12	8·5	70
Mauritius	1013·9	+2·0	89	66	84·0	72·3	78·1	+0·1	72·0	77	5·8	1·84	−6·75	19	8·4	69
Calcutta, Alipore Obsy.	1010·0	−0·1	100	63	93·2	71·5	82·3	+2·1	72·1	83	3·0	1·30	−0·08	4	8·7	73
Bombay	1010·5	−0·4	92	66	86·8	73·5	80·1	+0·6	71·2	77	2·7	0·00	−0·02	0	8·3	69
Madras	1010·5	−0·4	92	72	90·2	74·7	82·5	+1·4	75·6	81	4·0	0·12	−0·22	1	10·6	88
Colombo, Ceylon ..	1010·6	+0·5	91	71	88·5	74·5	81·5	−0·3	75·1	90	5·8	6·45	+2·17	12	7·6	63
Singapore	1009·2	−0·5	91	72	87·5	74·5	81·0	−0·2	77·6	84	—	17·12	+9·72	20	—	—
Hongkong	1017·6	+1·6	79	50	68·2	58·5	63·3	0·0	59·3	80	6·8	2·85	−0·09	9	4·4	37
Sydney, N.S.W. ..	1016·7	+0·4	87	70	76·3	63·9	70·1	+0·8	64·8	74	5·7	2·55	−2·43	9	7·0	57
Melbourne	1014·5	−2·4	98	47	75·9	56·6	66·3	+1·8	58·2	61	5·8	5·73	+3·55	17	5·9	48
Adelaide	1016.0	−1·1	100	50	79·5	58·2	68·9	−1·0	59·1	50	6·3	2·36	+1·34	9	6·3	52
Perth, W. Australia ..	1014·1	−1·2	98	54	84·6	62·6	73·6	+2·4	62·9	48	2·2	0·48	−0·33	4	9·6	78
Coolgardie	1015·3	+0·4	96	49	84·3	60·1	72·2	+0·3	60·0	59	3·7	0·96	+0·02	5	—	—
Brisbane																
Hobart, Tasmania ..	1012·7	−1·5	85	44	69·6	52·8	61·2	+1·9	54·9	68	7·6	3·21	+1·51	13	5·9	48
Wellington, N.Z. ..	1021·9	+4·7	76	43	65·3	52·9	59·1	−0·2	55·6	78	7·1	1·99	−1·34	8	6·4	52
Suva, Fiji	1010·1	+1·7	90	71	85·1	73·5	79·3	−0·8	75·9	88	8·1	20·99	+6·50	29	4·0	33
Apia, Samoa ..	1010·3	+1·1	91	71	87·3	74·9	81·1	+1·8	78·3	81	6·4	13·40	−0·58	21	6·6	54
Kingston, Jamaica ..	1015·1	+0·2	91	68	87·7	71·3	79·5	+2·4	71·3	66	2·8	0·18	−0·84	3	8·8	73
Grenada, W. Indies ..	1013·8	+0·8	86	71	84·7	75·3	80·0	+2·2	72·7	81	6·8	0·94	−1·72	11	—	—
Toronto	1011·0	−6·3	55	12	37·3	24·5	30·9	+1·3	26·4	—	7·3	2·52	+0·11	14	4·3	36
Winnipeg	1019·1	−0·1	41	−10	26·3	6·2	16·3	+1·3	9·2	—	6·2	0·72	−0·44	13	5·1	43
St. John, N.B. ..	1007·7	−6·4	51	11	39·6	25·3	32·5	+4·1	26·8	—	6·1	2·78	−1·76	12	5·4	45
Victoria, B.C. ..	1016·2	+0·3	65	27	53·3	36·0	44·7	+1·2	38·6	95	5·3	2·24	−0·19	12	5·5	46

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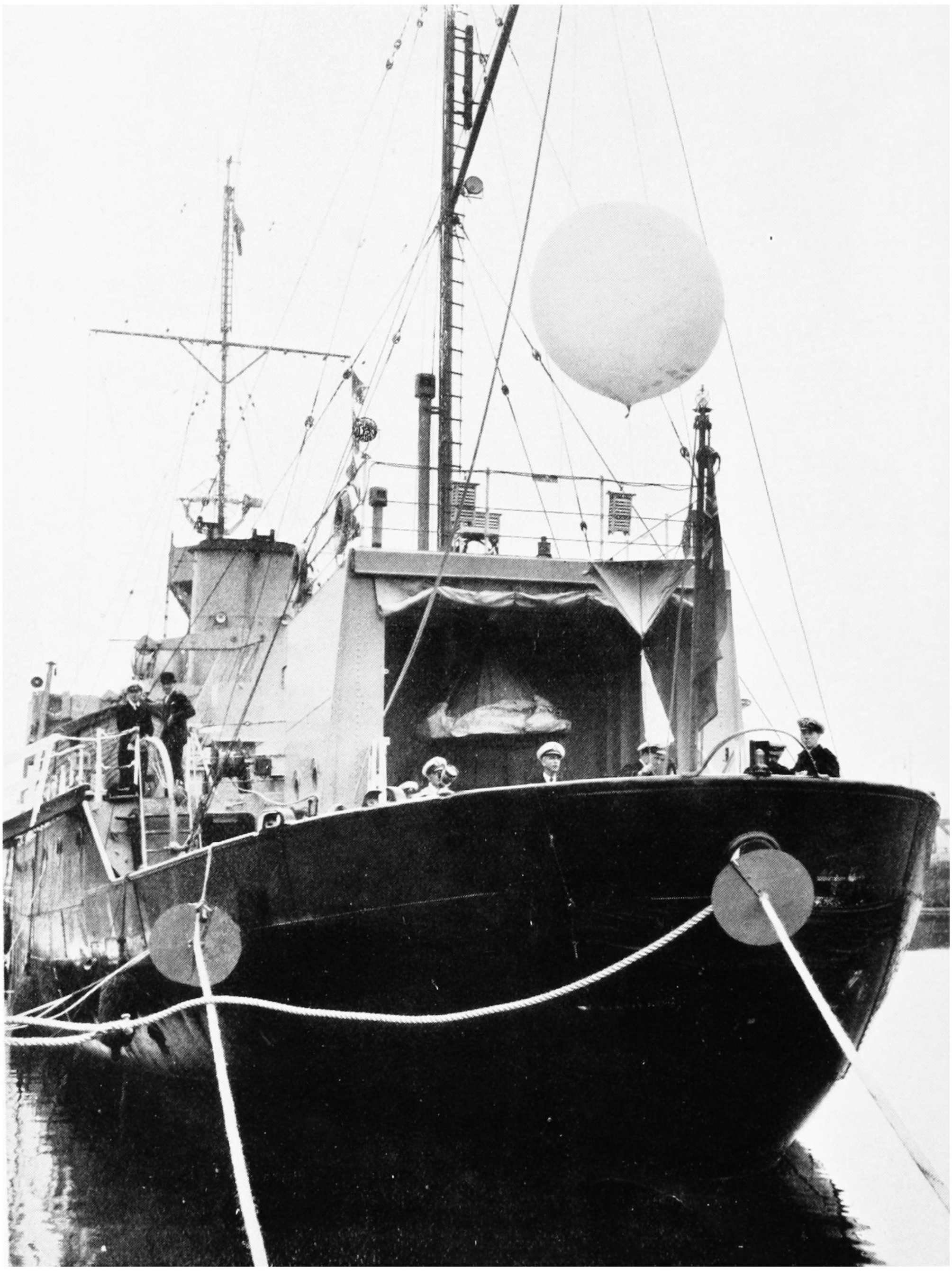

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LAUNCHING OF A RADIO-SONDE BALLOON FROM THE *Weather Observer*

(see p. 208)