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A DECADE OF RESEARCH

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The history of any organization such as the Meteorological Office is punctuated by what are called "reorganizations" demanded by changing commitments, by changing views on policy within the organization, and by the changing climate of public policy affecting organizations of a similar kind. Not in all cases does a reorganization, dear though it may be to the authorities who conceive and impose it, seem to those who play a humbler role to be more than a re-deal of the same cards, the game to proceed as before, but in 1948 there was a change of quite major consequence to my present topic in that of three deputy directorates then created in the Office, one was entitled Research.

It would be an interesting exercise to trace the history of research work through the lifetime, more than a century, of our Office, but not an easy one, for the word research was not fashionable in earlier days as it is now and organization tables would give little indication. Certainly from the beginning of the present century when Napier Shaw, as the new Director, began to collect a team of scientists around him, work of high scientific quality has always been in hand. Later, under Sir George Simpson, himself one of the most fertile research scientists in our record, the emphasis was by pressure of events so much on an expanding forecasting service for aviation that research might seem to have been side-tracked, but we must not overlook the steady stream of reports, memoirs and learned society papers from members of the staff, many of whom gained enviable research records and in a few cases scientific eminence of the first rank, largely by work before the Second World War. It was no stagnation period in the Office, as the names Brooks, Brunt, Douglas, Durst, Gold, Goldie, Scrase, Simpson, Stagg, Sutton and Whipple will remind us.

But the pressure of expansion did have an effect which in the long run became very serious scientifically. Instead of the newly recruited staff being assigned to some branch of work calling for organizing skill and research ability, they became a new kind of meteorologist, the general practitioner in forecasting, busy with routine and special daily inquiries, often on roster duties round the clock, with little or no opportunity for the continuous and undisturbed thinking which research has always demanded. So it was that a generation of scientific staff potentially as able as their predecessors gave rise to few names of scientific eminence and, what was much worse, there was no provision for attacking the host of problems which synoptic forecasting was throwing up. The position was, in the view of the forecasters themselves, rapidly becoming intolerable.

No one was more aware of the urgent need for research than Sir Nelson Johnson who, shortly after taking over the directorship, gained the objective which those who knew him were aware was very near to his heart. He put research unequivocally on the map when, for the first time, in 1939, the word appeared in the designation of a senior post. Post-war reorganizations, again under Johnson in 1948 and later under our present Director-General, have all tended towards its greater prominence until today we have a Director of Research side by side with a Director of Services and it may fairly be said that the dual function of the Office, to serve the community and to advance the science, is as fully recognized as it can ever be.

In this trend over many years to a position which is best regarded as the end of a transition period we have been carried along as much by the "changing climate of public policy" as by the convictions of our directors. Scientific research in this mid-twentieth century is widely respected for a glory of intellectual achievement comparing creditably with the creative arts or the scholarship of letters, while those who are uncertain of these values and are happier with practical economics see it as a worthwhile investment. The fight for greater research recognition in our own Office has been carried on as a skirmish in a sweeping tide of successful battle. By looking back over the last ten years since the creation of a deputy directorate of research, a reasonable period over which to review a research enterprise, I wish to show evidence of worthwhile achievement, justification for the policy, proof that in our corner of science we have exploited our opportunities with credit.

The point should not be difficult to make, indeed the task might be thought superfluous, for during the decade the published output of new work is contained in some hundreds of *Meteorological Research Papers*, 22 *Geophysical Memoirs*, 33 *Professional Notes* and 20 *Meteorological Reports* as well as a very large number of papers in the scientific journals. The difficulty lies in summarizing such a wealth of material, avoiding an invidious selection of names where so many have taken part and avoiding also a disjointed cataloguing of contributions. I shall therefore be content to pick out what seem to me to be the highlights of our achievement in the different branches of the science, mentioning in the narrative the names only of those who have been undisputed leaders and originators. Where I begin is arbitrary and perhaps the choice of the oldest branch of meteorology, climatology, is as appropriate as any.

In world climatology the highlight is obvious and bright: the monumental work on upper winds and temperatures over the world. The task was set, with Dr. Goldie's effective backing, so to collect and digest all accessible aerological data as to present the outline of a world climatology of the upper atmosphere. With the late C. E. P. Brooks as the leading author, the first edition of *Upper winds over the world* appeared in 1950[1] giving mean monthly contours and winds (including wind variability) at levels up to 130 millibars for the four seasons. The publication has been in demand ever since, for the aviation interest in upper winds has grown with every extension of air routes and every increase in cruising height. It is now out of print but a new and much improved edition, extending the analysis to greater heights, is well on the way as the outcome of a continuous effort of critical compilation over the intervening years. In addition, temperature is treated in a *Geophysical Memoir* recently published[2]. This incorporates previously published world charts of the average temperature and pressure of the tropopause for the four mid-season months[3]. With J. K. Bannon as the leading contributor there have been many supplementary studies on the upper air including turbulence in clear air at higher altitudes[4], an unexpected trouble for fast high-flying aircraft not yet satisfactorily explained. The world interest is further illustrated by A. G. Forsdyke's surveys of tropical meteorology[5] and H. H. Lamb's studies of polar regions[6], two fields still rich in problems.

British climatology by contrast has been studied for so many years and with such copious data that strikingly new results are unlikely to appear very often. A considerable effort in applied climatology, in relating rainfall and evaporation to hydrology and in analysing agricultural problems has however been fully productive. A specialist from outside the Office remarked on one occasion that if the work of the agricultural branch of the Office had led to nothing more than the arrangements for warnings of conditions conducive to outbreaks of potato blight, the branch would have justified its existence for a generation. Applications of modern theories to the calculation of irrigation needs in different parts of the country have also aroused much interest, while the continued studies of *British Rainfall*, published mainly in the annual volume with that title, have made J. Glasspoole's name a household word amongst water engineers, gracefully recognized by his election as Honorary Member of their Institution. And here also it is most suitable to mention the important textbook by Brooks and Carruthers[7], *Handbook of statistical methods in meteorology*, incorporating amongst other things material which the senior author had accumulated over many years.

In the Marine Division of the Office many contributions have been made both to pure and applied science, and more than twenty significant papers have been published although, since the work has not I think led to major discoveries, I shall shirk the task of picking out names and references. The regular production of the *Marine Observer* under the able editorship of Commander C. E. N. Frankcom has provided a continuous stream of scientific guidance much valued by mariners everywhere and the publication of meteorological and current charts of the oceans is a national service of major importance.

The transition from climatology to synoptic meteorology and forecasting is a natural one and the decade is perhaps most noteworthy in that "forecasting research" was in 1948 at last accepted as a field to be deliberately attacked, so recognizing the urgent need to which I made earlier reference. The new Forecasting Research division had a clear field and with the post-war elaboration of radiosonde and radar wind stations three-dimensional analysis naturally received the major attention. A paper of 1947[8] had presented for the first time a dynamical basis for the discussion of the forecasting problem in terms of divergence and vorticity as inferred from contour and thickness charts. A further paper of 1950[9] discussed the theory and use of thickness charts more fully and as the result of many papers, basic training and routine application, it may justifiably be said that dynamical thinking has permeated the minds of forecasters everywhere. At the same time the basic ideas were found to be remarkably well adapted to the concept of prediction by numerical calculation, a dream of Richardson in 1926 which had become a realistic prospect in America with the invention of the electronic calculating machine. Sawyer and Bushby[10], quickly recognizing the potentialities, presented in 1953 a set of differential equations suited to numerical predictions for a baroclinic atmosphere, using a two-parameter model, and in this way began a programme of research which will be pursued for years to come. By this initiative the Meteorological Office is second only to the United States in its contributions to this revolutionary approach to forecasting. Already one can foresee teleprinted data from observing stations being fed into a calculating machine to be objectively analysed, stored and processed to produce forecast charts taking into account, with some verisimilitude, the baroclinic field, non-geostrophic motion, effects of friction, topography and non-adiabatic processes. The outcome in terms of forecasting guidance will surely be valuable, how precise and accurate may ultimately depend more on the unpredictability inherent in the unstable atmosphere than on the ingenuity of the research workers or the versatility of machines.

At the same time research on more conventional synoptic lines has not been neglected and from many I can mention only three contributions. The first is the study of the structure of fronts and jet streams[11] under Sawyer's leadership revealing, with the supplementary aid of many special frontal sorties performed by the Meteorological Research Flight, not only the instantaneous structure of the jet-stream—frontal complex but also the striking effects of upward motion with the cloud-laden air following a slope steeper than that of the frontal surfaces and separating from them, within the warmer air mass, above heights of about 700 millibars; and revealing also tongues of extreme dryness, the effects of subsidence, extending downwards from the upper troposphere along or near the frontal surfaces themselves. (By frontal surfaces I here imply the two surfaces of first order discontinuity in temperature bounding the sloping zone of hyperbaroclinity, which analysis has established as the most common frontal structure.) The analyses led Sawyer[12] to develop a dynamical theory of frontogenesis which goes a considerable way towards explaining what is observed, while escaping from the limitations imposed by the unsatisfactory classical model of simple upsliding of one air mass over another.

Next I select, also from Sawyer's papers, the series of contributions,[13] empirical and statistical, on the rainfall from various types of depression and finally some practical studies of the forecasting of fog by Saunders[14] as an illustration of what can still be done by the keen operational forecaster—for Saunders was not in a research post and yet he found time to pursue an independent line of research and produce a method of forecasting whose merit is widely recognized.

A special paragraph must be accorded to work by C. S. Durst[15] on the statistical handling of vector winds leading to studies of the forecasting of upper winds by purely statistical methods. This entirely original approach has many possible applications especially when conventional methods of forecasting are difficult to apply.

Forecasting for an extended period of time beyond the 36 hours, more or less, which is regularly attempted has received much attention and lengthy research experiments have led to the introduction of a technique of hemisphere chart analysis and prediction, which at Dunstable is proving useful in the preparation of outlooks for two or three days ahead. In this connection Sumner's[16] studies of blocking have been valuable, but otherwise it can hardly be said that specific new discoveries have been made although the behaviour of the atmosphere on the hemisphere scale has been much described. There is more originality in a recent attack by Craddock[17] on the truly long-range problem of prediction for a month ahead. Started as a study of variability in weather over periods of a few weeks with temperature over a large part of the hemisphere as the parameter chosen for first attention, the work has led to a method of obtaining normal charts by harmonic analysis, to power-spectrum analysis demonstrating the large contribution to variance provided by fluctuations of time-scale some 30–50 days, to the demonstration of the large and persistent features, geographically speaking, of temperature anomalies, and so to the trial of prediction primarily on the basis of analogues (assuming that the behaviour in the forthcoming month would be similar to that in previous years which had showed similar anomaly patterns). Tests have shown success certainly better than chance but whether so much better as to render the forecasts of significant value to anyone remains to be established. But clearly there has been some progress and there is work for a long time ahead in studying, explaining, and perhaps predicting the departures from average expectations which go to make our summers sunny or depressingly wet, our winters mild or arctic as the case may be. One feels that a new break-through has appeared in an old and tantalizingly difficult problem.

Before passing to what, for want of a better term, we call physical meteorology (as though all meteorology were not physics in its wider sense), reference must be made to important studies of wave-motion, on the scale of a few miles, set up in the free atmosphere up to great heights, by orography. The basic theory was developed outside the Office by R. S. Scorer but the studies, particularly by Corby,[18] have done much to advance the subject and to show how synoptic forecasters may apply the theory in daily practice when the demand arises. Ten years ago the phenomena were hardly known and what was known was a theoretical mystery.

We come now to our most valuable tool, other than sondes, for the exploration of the troposphere and lower stratosphere, the Meteorological Research Flight. With three, formerly four, aircraft at the disposal of the Office, a large number of basic data have been collected. The most remarkable discovery of all, perhaps, is the dryness of the lower stratospheric air as established by measurements with the Dobson-Brewer frost-point hygrometer.[19] Recent measurements from the tropics to the arctic indicate little variability about a frost-point of −84°C. and although the result was quite unexpected there seems no reason seriously to doubt the observations. The implications of these results, coupled with other evidence, for example on atmospheric ozone which the Flight has also measured, are far-reaching in the theory of the general circulation of the stratosphere, by no means only an academic issue in these days of nuclear weapons trials.

Outstanding also has been the large amount of work in measuring and counting nuclei of condensation and of freezing, droplets and ice crystals in clouds and drops of precipitation. In this field of basic observing the ingenuity lies in designing and suitably exposing the instruments and a paper by Murgatroyd[20] gives an impression of what has been achieved in this way. On more theoretical aspects of droplets in the atmosphere, A. C. Best[21] contributed a long series of research papers, a few of which are included in the bibliography. In this context the special research with centimetric radar at East Hill, under R. F. Jones[22] and later Harper, is suitably introduced. A great deal has been learnt from the radar echoes from precipitation, about the bright-band due to the melting of falling snow, about the initiation of precipitation by freezing and by coalescence, about the development, travel and decay of rain areas, encouraging the use of weather radar for short-period forecasting and establishing a useful forecasting rule relating travel with wind at 700 millibars, about the association of thunderstorm echoes with severe turbulence, so justifying the use of airborne radar for the avoidance of severe flying conditions. An unexpected outcome was Harper's[23] convincing evidence that many echoes from clear skies, so-called angels, were reflections from flocks of birds, and his work has caused much excitement amongst ornithologists who have seized upon the tool for the study of migration and roosting habits. The provision of a new eye for the bird-watcher is not expected of a meteorologist but his services will still be demanded in relating flight habits to the accompanying conditions of wind and weather.

A service for which the synoptic meteorologists have special reason to be grateful to the M.R.F. has already been mentioned: the provision of data from many flights through fronts and clouds combining visual observations with readings of temperature and humidity on quick-response instruments at intervals of a minute or less. Other flights with recording equipment have provided unique data on the fine structure of the atmosphere.

What of rain-making, the exciting and much-publicized prospect for cloud physicists? In mountainous regions of other countries some success, small but probably real and even economically valuable, has been claimed but similar conditions are not found in these Islands and very careful studies of available knowledge yielded no grounds for optimism. Nevertheless trials of seeding with ground generators of silver iodide particles have been run for three years, thanks to the co-operation of the Chemical Defence Experimental Establishment at Porton. If the results so far are negative they at least confirm the expectations of most specialists and have stimulated other work on large-scale diffusion which is referred to later.

Under the leadership of Robinson,[24] the observing of radiation, solar and terrestrial, and of illumination, has been put on a firm and acceptable basis with new or improved instruments. A ventilated heat-flux plate now serves as an efficient radiation balance meter. Solarimeters have been mounted in ocean weather ships and also on aircraft to provide measures of absorption in cloud and of the albedo of cloud and the earth's surface. Robinson's scheme of observations was the same as that eventually adopted internationally for the I.G.Y. It may truly be said that radiation in the atmosphere is no longer exclusively the concern of specialists but is gradually becoming recognized as a regular climatological factor and one which the synoptic and dynamical meteorologist may hope to take into account quantitatively. This has indeed already been done in making up the heat budgets of stratocumulus cloud[25] and fog,[26] both of which are shown to be in a dynamical condition of near-balance rather than static phenomena. Kew Observatory has been prominent also in the study of exchange by eddy diffusion near the earth's surface, the work having been co-ordinated with that of the research unit attached to the School of Agriculture, Cambridge University. The "aerodynamic method" of estimating evaporation as explored by Rider[27] has indicated large differences in evaporation from cultivated land dependent in part upon the nature of the crop.

Diffusion and turbulence generally were, historically, a pioneer interest of the Meteorological Office and particularly of our present Director-General. Sir Graham Sutton's textbook on micrometeorology[28] appeared in 1953 and if its compilation cannot be claimed as Office work it owed so much to earlier research that it is justifiably recorded in this account. Early in the decade important papers by Calder[29] and by Deacon[30] confirmed the logarithmic profile for neutral conditions and provided generalizations applicable to an unstable atmosphere, while recently mathematical papers have treated convective (buoyancy) transport.[31] Also, in recent years, the problem of larger scale diffusion has been attacked under Pasquill's[32] leadership and led to extensive experimental work with trace substances sampled by aircraft and by instruments mounted on the cables of captive ballons. By combining empiricism with theory, one may now hazard practical estimates of concentrations, at distances up to 100 miles or more, of an airborne contaminant released either at the surface or at an elevated source, in terms of ordinary observables, wind speed, direction and gustiness near the surface, variation of wind with height, the degree of vertical stability or instability and the occurrence of inversions. Realistic problems of this kind occur in considering such diverse questions as pollution from smoke stacks, seeding of cloud by silver iodide smokes, and the improbable but possible dangers due to the accidental release of radioactive matter from Atomic Energy Establishments, as well as to the problems which are the particular field of the Ministry of Supply's Chemical Defence Experimental Establishment where most of the meteorological work has been carried out, and whose invaluable resources for instrument design, air sampling and field experiments have been freely available and are here gratefully acknowledged. Elsewhere mention has been made of the experiments conducted by C.D.E.E. on the release of silver iodide smokes in connexion with rainfall modification.

Finally, I must not forget the efforts of those concerned with the development of instruments, to improve upon standard observations, to yield new data demanded by the service and to assist the research worker, although naturally research physicists must often design and produce their own special tools. A reference to the Assistant Director now in charge provided me with a list of 32 items which might find a place in the ten-year record and my choice for this account is my own. First, under Dr. Scrase's[33] guidance the production of an *Instrument Manual* Part I and, recently finished by Scrase himself, Part II, provides the guidance long awaited to instrument users everywhere, both for surface and upper air observations: this is a major work. A modulated beam cloud searchlight for use in daylight, mainly due to Bibby, and a pulsed-light system due to Almond,[34] both became serviceable although neither fully meets operational needs. Recently a high altitude searchlight, also designed by Bibby and intended to study air density up to heights of 60 kilometres has undergone preliminary trials. A recording transmissometer of Office design has been in use for some years at London Airport. Upper air instruments, radiosonde and wind radar, have been under continuous attention resulting in many minor improvements with gain in accuracy, stability and reliability but radical re-design has been in abeyance pending the outcome of a protracted commercial development of a radarsonde using an airborne transponder (secondary radar). Recently further development on these lines was abandoned owing to high cost and design difficulties and now the Instrument Development division is concentrating its attention once more on the well-tried combination of radiosonde and radar wind with heights of 120,000 feet as the new operational ceiling.

This account has done injustice to many by omission of important successes in special lines and the injustice will be aggravated by the attempt I now make, and for which I freely apologise, to summarize the major items.

In turbulence and diffusion preliminary solutions, useful in practice, to problems of downwind concentrations at all distances from a source to a range of order 100 miles have been made available. Atmospheric radiation, solar and terrestrial in origin, has been developed with theoretical appreciations to the stage of becoming a synoptic and climatological factor, well instrumented with a network of stations. Basic data on cloud physics and atmospheric nuclei have been accumulated by aircraft and radar; the reality of precipitation initiation by coalescence has been established and the water content of clouds is becoming known. The physics of stratocumulus cloud and of fog has been considerably clarified and practical, if empirical, methods of forecasting fog have been improved. The structure of fronts has become much better documented and the vertical motions with the accompanying cloud structure and dry tongues have been incorporated and in part explained by basic dynamics. Rainfall in association with depressions has been statistically analysed and related with the dynamics. Three-dimensional dynamical studies have led to the assimilation of this mode of thinking into routine forecasting practice with a technique of contour and thickness analysis and prediction which is suited to the ideas. With the assistance of electronic computing, hydrodynamical methods, in principle "exact" although in application approximate, have opened up what promises to be the new era of numerical weather prediction. The study of wave motion initiated by topography has been brought to a stage where it can be applied in day-to-day synoptic work. Studies at high levels have revealed the remarkable dryness of the lower stratosphere and so put the general circulation in a new light. The tropopause has been analysed synoptically and climatologically and the world atmosphere up to the lower stratosphere has been mapped in terms of pressure-contours, winds with isotachs, temperatures and in part humidity, so that upper air world climatology is now beyond the early conjectural stage and is a well-developed part of our science. Naturally, ideas and results from British work outside the Office and from other countries have been borrowed with the freedom essential in science but in all the ways mentioned the Office can justly claim to have made major contributions. It is, I feel, a 10-year record in which we may take pride.

The reader, conceding as I hope this claim of achievement, will naturally ask the question: what may we expect from the next decade? But I shall not attempt to conjecture. There are, if we care to examine the record, glaring gaps in progress both on problems of immediate concern to operational meteorologists and on those of scientific meteorology having deep interest if less obvious utility, and future success will depend on planning wisdom, which may or may not fail us, and on the inspiration of British scientists which surely will not.

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A NEW OCEAN WEATHER SHIP

By C. E. N. FRANKCOM.

On 16 May 1958 the former "Castle" class frigate H.M.S. *Oakham Castle* was renamed O.W.S. *Weather Reporter* by Lord Hurcomb, chairman of the Meteorological Committee, thus marking the beginning of her career as an ocean weather ship.

Weather Reporter replaces *Weather Explorer*, which is the first of the earlier British weather ships to be withdrawn from service. *Weather Explorer* and her three sister ships—*Observer*, *Recorder* and *Watcher*—have done over eleven years strenuous service as ocean weather ships in the Atlantic. Prior to that all these ships did a very good job on the exacting duty of convoy escort vessels and it is scarcely surprising that they are now "showing their age", and need replacing by somewhat newer vessels.

It is right to mention that the choice of these ships as ocean weather ships has been amply justified. They have been economical to operate, they have been excellent sea boats and have carried out their duties very effectively. But the "Flower" class corvettes are rather small and their accommodation is inevitably cramped. The "Castle" class frigates being somewhat larger in size (length about 230 feet, compared with 205 feet) can provide much more comfortable accommodation than their predecessors. They also have the advantage of greater fuel capacity, which enables them to operate at either of the ocean stations A, I, J or K without the necessity of refuelling.

Oakham Castle was built at Glasgow by Messrs. A. J. Inglis and launched in July 1944. Her conversion to an ocean weather ship, which involved quite extensive work over about nine months, was carried out by Messrs. James Lamont & Co. at Glasgow.

The renaming ceremony was carried out at Princes Pier in Greenock. About 150 guests were present including the Provost of Greenock and other prominent local citizens, representations of foreign Governments which are signatories of the North Atlantic Ocean Station Agreement, and representatives of British and foreign airlines operating across the Atlantic. Wives of the ship's company of *Weather Reporter* and representatives from other weather ships and from the weather ship base, were also present. Fortunately the weather was fine with a fresh northerly breeze. The ship's white hull and bright yellow upper works, in contrast to the black hull of the earlier ships, gave her a gay and cheerful appearance. At her foremast flew the flags of the other countries which operate weather ships in the North Atlantic—a tribute to her international work.

During the forenoon, Lord Hurcomb had made an unofficial inspection of the ship. Before officially renaming the ship he inspected the ship's company, totalling 57, who were lined up on the pier in front of the ship and he had a few words to say to each man. In his address to the assembled company, Lord Hurcomb emphasized the good work which had been done by the original weather ships since the first North Atlantic Ocean Station Agreement was signed in 1947; he referred to the international nature of the work of these ships for peaceful ends and for the benefit of humanity and pointed out that the observations provided by the weather ships give a regular series of observations at the surface and in the upper atmosphere from fixed points in the Atlantic, which supplement the surface observations provided voluntarily by observers aboard a large number of merchant ships. Lord Hurcomb stressed the good job which had been done by the men serving aboard the weather ships during these eleven years, in carrying out these important duties in all weather in the notoriously stormy North Atlantic Ocean; he drew particular attention to the fact that the meteorologists and some of the radio and radar staff aboard these ships are not professional seamen but have nevertheless stood up to the job admirably. He referred to the difficulties of launching a meteorological balloon in a storm and tracking the balloon by radar in such circumstances, and preparing hot meals in heavy weather—tasks which were regularly carried out no matter what the weather was. Finally Lord Hurcomb expressed a hope that the crew would be happy in their new ship and that she would prove even more successful than her predecessor.

Lord Hurcomb then went aboard the ship, accompanied by the Master, and officially renamed her by releasing a canvas cover which exposed her name painted on the bow and said "I rename this ship *Weather Reporter*—may good fortune attend all those who sail in her".

A meteorological balloon carrying a radiosonde and target was then released for the benefit of the guests; visitors were then invited aboard the ship to inspect her. An exhibition of air/sea rescue equipment—such as inflatable life rafts, immersion suits, first aid equipment, portable radio sets for use in boats and rescue belts—was displayed on the quay alongside the ship.

An inspection of the ship showed that her accommodation was considerably more spacious and better fitted out than that of her predecessors, which were converted soon after the war when almost everything was in short supply. Every officer and petty officer has a well appointed cabin to himself, whereas the ratings are accommodated in 3-berth cabins. The messes and smoke rooms for officers, ratings and petty officers are lined with comfortable cushioned settees and they are attractively furnished generally.

The meteorological office is situated on the upper deck aft, immediately forward of the balloon shelter. It is a bright and cheerful room lighted with four 21-inch portholes. The equipment includes two radiosonde receivers, a plotting table for upper winds, three mercurial barometers and a "precision aneroid", a distant-reading thermograph from the engine room intake, a distant-reading psychrometer from screens on each side of the bridge and a distant-reading anemometer and wind direction dials, the instruments being mounted on a yard each side of the mainmast. For radiosonde reception a special aerial is mounted on top of the balloon shelter. A wave recorder connected to instruments located in the engine room, and a recording potentiometer which records total radiation and net flux of radiation from instruments mounted near the bridge, are also included.

Hydrogen stowage is provided on deck each side of the balloon shelter but for use in very heavy weather a few cylinders are carried inside the shelter. The balloon shelter is provided with a special ventilation system to obviate any risk of a hydrogen explosion and there are no electrical fittings of any kind inside it. Wiring has been installed between the meteorological office and various points in the ship where experimental meteorological equipment may need to be installed, such as the bridge, masts and bow of the ship, so that special investigations can be carried out as necessary. The masts are provided with reasonably spacious platforms from which it will be possible to carry out experimental work aloft more easily.

The radio equipment, which is of a more modern type than that installed in the earlier weather ships, includes HF and MF W/T and R/T, VHF and UHF R/T, a non-directional MF beacon, MF and VHF DF, and "walkie-talkie" sets for use in the lifeboats. A 10-centimetre naval type radar similar to that installed in the earlier ships is provided for radar wind observations and for giving navigational "fixes" to aircraft in flight, as well as a "Decca" radar for navigational purposes. The navigational equipment includes a gyro compass, an echo sounder, Loran and a "clear view" screen.

Weather Reporter is under the command of Captain A. W. Ford, who has served aboard the weather ships since they first came into service in 1947; he was formerly in command of *Weather Recorder.*

A COMPARISON OF RADIOSONDE AND METEOROLOGICAL RESEARCH FLIGHT HUMIDITY MEASUREMENTS

By C. H. HINKEL, B.Sc. and G. B. TUCKER, Ph.D.

Introduction.—Aircraft of the Meteorological Research Flight have measured temperature and humidity (frost-point) in the upper air over southern England since 1943. By the end of 1955, 399 soundings had been made. A preliminary analysis of the data[1] suggested serious discrepancies between the seasonal values of humidity mixing ratio obtained from these ascents and those obtained from radiosonde soundings. The three possible sources of discrepancy were due to differences of sampling, processing the data, and instrumentation. The differences in sampling exist because the results of the preliminary analysis were compared with seasonal averages for Larkhill for the period 1946–50[2] which are based on four radiosonde ascents per day. The M.R.F. seasonal values of humidity mixing ratio were computed from the average of frost-point measurements; this method of processing the data will not give the same answer as that obtained by first converting each frost-point into a humidity mixing ratio and then taking the seasonal average. Instrumentation may be a source of discrepancy because the radiosonde and M.R.F. instruments are different and measure different parameters. The humidity recording instrument on the radiosonde is a gold-beater's skin hygrometer which measures relative humidity—subsequently converted into dew-point by referring to the temperature reading of the bi-metallic thermometer. On the M.R.F. aircraft a frost-point hygrometer was used.

It was decided to analyse the M.R.F. data in more detail and, by eliminating errors due to sampling and processing of data, to attempt a comparison of the humidity measurements obtained from the frost-point hygrometer with those from a radiosonde.

Procedure.—Data were analysed for the 700-millibar and 500-millibar levels. The seasonal classification used was winter (January, February, March), spring (April, May, June), summer (July, August, September), autumn (October, November, December). This conforms to the classification in previous papers on this topic.[1, 3]

Each M.R.F. ascent was paired with a radiosonde sounding made as near as possible in time and place. The frost-point and humidity mixing ratio were computed from both instruments, and mean values at 700 millibars and 500 millibars were computed for each season and the year. There are more observations at 500 millibars than at 700 millibars because before 1950 M.R.F. aircraft made no readings at the lower level.

Results.—Values of the mean seasonal humidity mixing ratio are given in Table I. In all seasons for both the 700-millibar and 500-millibar levels the radiosonde value is much higher than the M.R.F. value, the difference between the two in many cases is more than 50 per cent of the M.R.F. value. The frost-point hygrometer can be regarded as the more accurate instrument, therefore the mean radiosonde humidity mixing ratio is probably a substantial overestimate. Seasonal values of humidity mixing ratio for Larkhill between 1946 and 1950[2] are included in Table I, these are based on four ascents per day. The agreement between these and the radiosonde values suggests that the sampling error of the M.R.F. aircraft ascents is relatively small. The seasonal values of humidity mixing ratio obtained from routine radiosonde soundings (at least over Larkhill) must therefore be regarded as substantially in excess of the true values.

TABLE I—MEAN HUMIDITY MIXING RATIO (H.M.R.) IN GRAMMES/KILOGRAMME

	Winter		Spring		Summer		Autumn		Year	
	H.m.r.	No. of obs.	H.m.r.	No. of obs.	H.m.r.	No. of obs.	H.m.r.	No. of obs.	H.m.r.	No. of obs.
					700 mb.					
(i)	0·83	45	1·64	42	2·12	42	1·36	51	1·47	180
(ii)	1·31	45	2·03	42	2·87	42	2·14	51	2·08	180
(iii)	1·46		1·81		2·98		2·27		2·13	
(iv)	+0·48		+0·39		+0·75		+0·78		+0·61	
					500 mb.					
(i)	0·28	68	0·48	98	0·66	79	0·47	58	0·48	303
(ii)	0·43	68	0·77	98	1·05	79	0·70	58	0·75	303
(iii)	0·48		0·60		1·01		0·78		0·72	
(iv)	+0·15		+0·28		+0·39		+0·23		+0·27	

(i) Meteorological Research Flight. (ii) Radiosonde. (iii) Averages for Larkhill 1946–50. (iv) Difference (ii)–(i).

Values of the mean seasonal frost-point are given in Table II. The radiosonde frost-points are between 4°C. and 8°C. warmer than the M.R.F. frost-points. Individual pairs of frost-point observations were plotted on scatter diagrams (Figure 1), radiosonde value plotted against M.R.F. value. All points would lie on the diagonal line if paired values were identical. Most of the points (nearly 80 per cent of the total) lie on the top-left of the line, that is, the radiosonde systematically gives higher frost-points.

TABLE II—MEAN FROST-POINT (F.P.) IN °C.

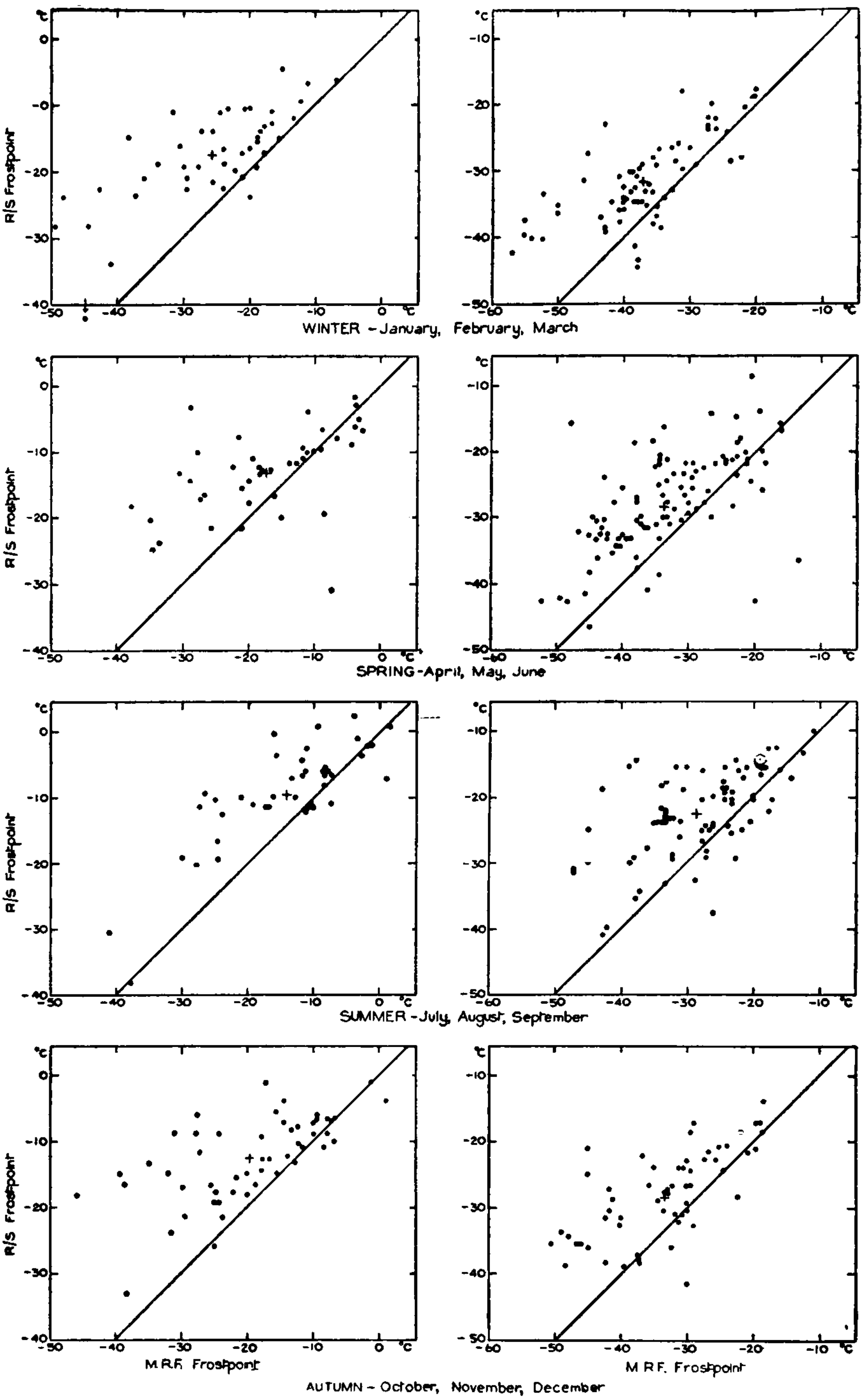
	Winter		Spring		Summer		Autumn		Year	
	F.P.	No. of obs.	F.P.	No. of obs.	F.P.	No. of obs.	F.P.	No. of obs.	F.P.	No. of obs.
					700 mb.					
(i)	−25·7	45	−17·3	42	−14·3	42	−19·8	51	−19·4	180
(ii)	−18·1	45	−13·0	42	− 9·4	42	−12·7	51	−13·3	180
(iii)	+ 7·6		+ 4·3		+ 4·9		+ 7·1		+ 6·1	
					500 mb.					
(i)	−38·2	68	−33·5	98	−29·6	79	−33·3	58	−33·6	303
(ii)	−33·0	68	−28·0	98	−23·9	79	−28·1	58	−28·1	303
(iii)	+ 5·2		+ 5·5		+ 5·7		+ 5·2		+ 5·5	

(i) Meteorological Research Flight. (ii) Radiosonde. (iii) Difference (ii)−(i).

Instrumental considerations. *General.*—The discrepancies between the values of the humidity mixing ratio and frost-points determined by the two methods are caused in the first instance by the over-all accuracy of the instruments and in the second by the conditions under which each set of measurements is made.

The radiosonde and frost-point hygrometer are used under very different conditions. The sonde is ascending at a comparatively slow rate (about 1200 feet per minute) and in general is traversing regions in which there is a hydrolapse. It is therefore to be expected that lag errors will occur. The actual measurement is performed by an observer working in comparative comfort upon the ground. The frost-point hygrometer is mounted inside an aircraft travelling horizontally at 200 knots or more, an observation takes at least half a minute and the aircraft will have travelled over a mile and a half during this time. Lag effects will be relatively unimportant. The instrument requires considerable manipulative skill to operate it in the laboratory and the cramped conditions inside modern military aircraft do not make matters easier.

The two instruments use fundamentally different principles for the measurement of humidity. In the sonde, the detector is a piece of gold-beater's skin[4] which expands or contracts with changing relative humidity. The change of length is converted by means of a suitable transducer into a change of frequency which is transmitted to the ground and after measurement is converted by means of a calibration graph into a relative humidity. In order to obtain either the humidity mixing ratio or the frost-point the temperature of the ambient air must also be known. The frost-point hygrometer[5] measures the temperature at which a deposit of frost forms on a cooled surface (or thimble as it is usually called) as air flows over it, the formation of the deposit being observed by the human eye. The method is thus an absolute determination of the frost-point.



700 mb. 500 mb.

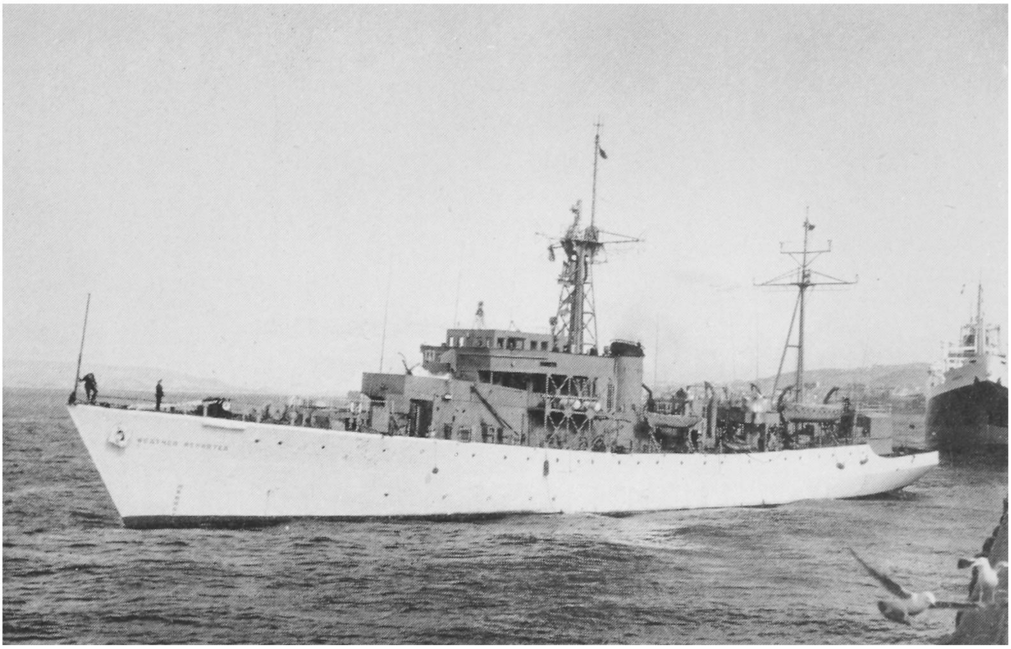
FIGURE 1—SCATTER DIAGRAMS SHOWING THE RELATIONSHIP BETWEEN THE FROST-POINT OVER SOUTHERN ENGLAND AS SAMPLED BY RADIOSONDE AND METEOROLOGICAL RESEARCH FLIGHT INSTRUMENTS

Ushaw College, Durham.

FUNNEL CLOUD AT USHAW COLLEGE, DURHAM

We are indebted to the Rev. A. Pickering, Chief Observer at Ushaw College, Durham, for this photograph of a cloud funnel. The photograph was taken from the College building by one of the students at 0854 G.M.T., 24 June 1958. The cloud funnel did not reach the ground.

On 24 June northern England was in a shallow low pressure area extending from Scandinavia to the Atlantic. A heavy shower fell at Ushaw College at 1100 G.M.T.



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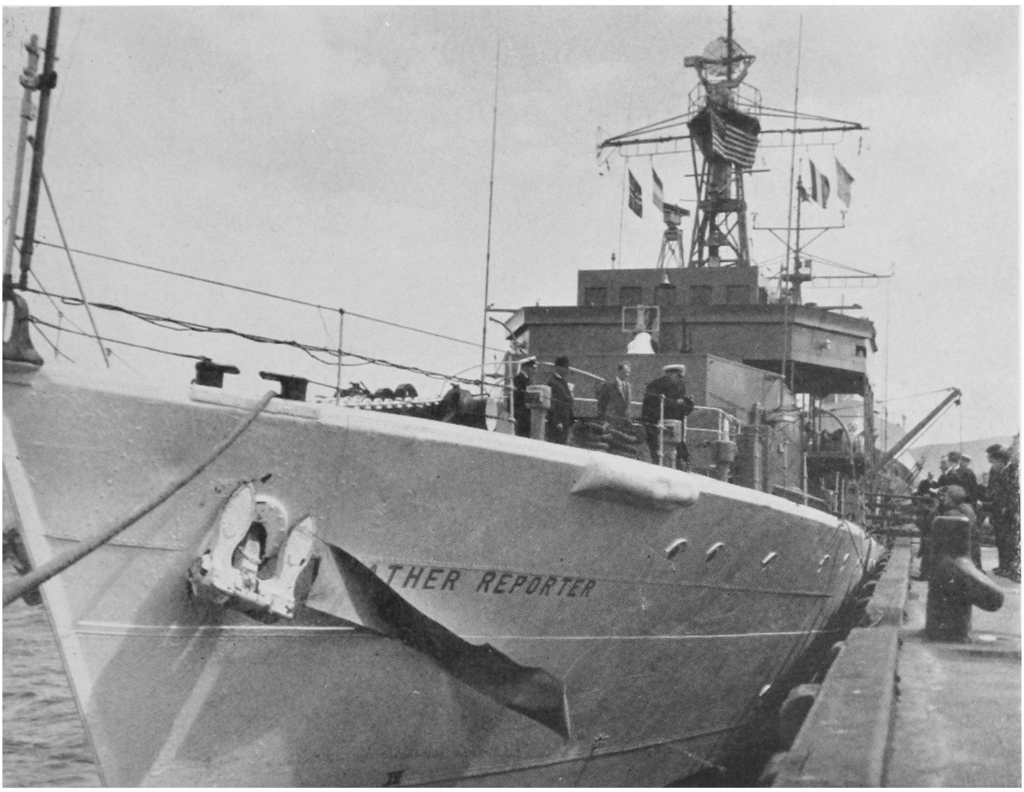

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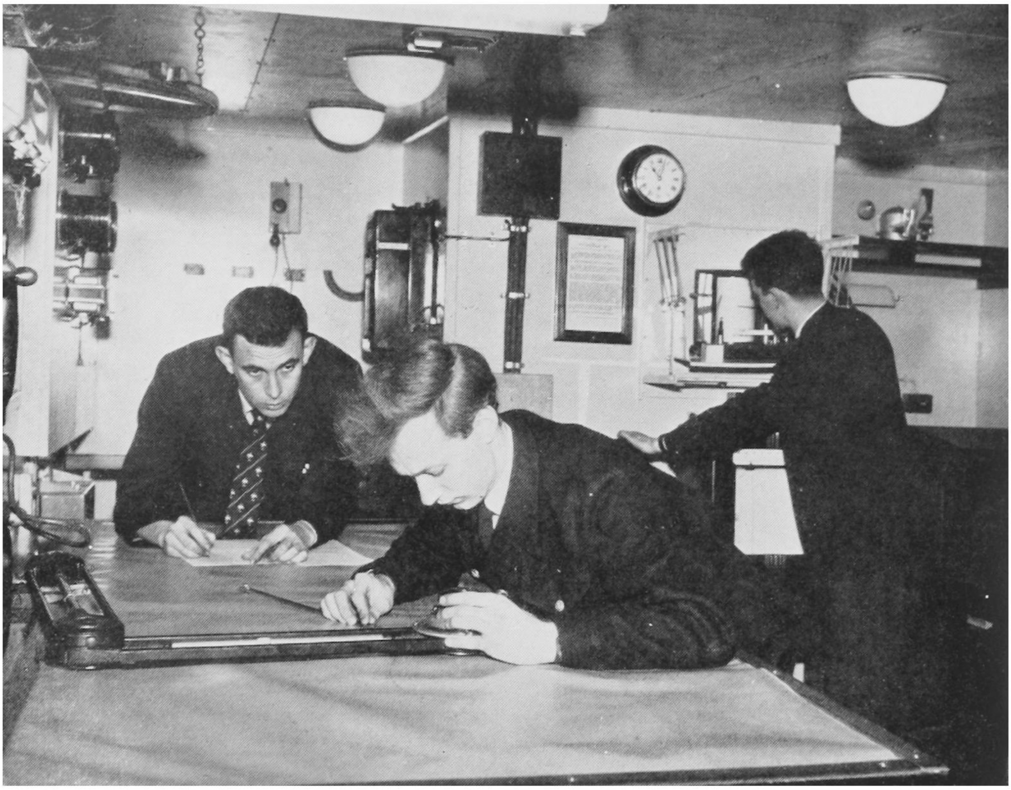

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PLOTTING RADAR WINDS IN THE METEOROLOGICAL OFFICE

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O.W.S. WEATHER REPORTER'S METEOROLOGISTS IN THE PETTY OFFICERS' SMOKEROOM
Left to right: G. Wind, H. J. Matthews (in front), D. W. Griffiths, R. E. Clement, M. Parkin, J. A. Graham, A. B. Smith

(see p. 331)

Errors.—The errors of each instrument will now be considered in greater detail:

(i) *The radiosonde humidity element:*—Each sonde is calibrated in the Instrument Division of the Meteorological Office before issue to the outstations who carry out a spot check at one point only on the calibration curve immediately before flight to test for drift. It is assumed that any drift found to occur has caused no change in the slope of the calibration curve. Gluckauf[6] has shown that the skin extension with humidity exhibits a hysteresis effect when the relative humidity is reduced below 70 per cent. He also states that provided relative humidity with respect to water is plotted against skin extension, the calibration curve is unaffected by temperature, but recent experiments carried out in the Instrument Division point to a variation of the extension of the skin with temperature at a given relative humidity. Another source of error is that the lag is not a constant but increases rapidly with decreasing temperature and is of the order 30 seconds between 700 and 500 millibars. A hydrolapse will cause the sonde to give humidity values that are too large and a humidity inversion will have the opposite effect. The magnitude of the errors from these sources depends upon the conditions at the time of flight and is impossible to assess them accurately. The total effect may be large on one day and small on another, but there is good reason to believe that on average their combined effect gives rise to a reading of the relative humidity that is too high by about 10 per cent or about 2°C. if the frost-point is used as the measure of humidity.

The temperature element is affected by radiation from the sun which causes it to give a higher temperature reading than the true air temperature. Prior to February 1956 no allowance was made for this heating which may amount to about 1·0–1·5°C. at the heights concerned. The measurements discussed above were all made before this time. It is equivalent to a reading of the dew-point that is too high by a similar amount.

(ii) *The frost-point hygrometer:*—The platinum resistance wire thermometer wound round the body of the thimble is connected to a Wheatstone bridge which is calibrated directly in temperature units. The bridge and thimble are calibrated as a single unit before issue. Their combined errors are thus known and the calibration drift of these instruments is very small. A recent check of one particular instrument after five years' use showed that the calibration drift did not exceed 0·75°C. at any part of the scale. A small temperature gradient exists between the thimble surface and that part of the body on which the platinum wire is wound. It is at most 1–2°C. at temperatures above −40°C. and causes the instrument to read low. A loose winding may also contribute a further error whose magnitude cannot easily be assessed but might in extreme cases amount to several degrees. However, in all cases it tends to make the instrument read low.

The frost-point hygrometer has the advantage of giving an absolute measure of the humidity but tends to give values of the frost-point which are about 2°C. too low at temperatures down to −40°C. The sonde element on the other hand does not give an absolute measure of humidity, its range is limited to ambient temperature above −40°C., it is subject to a hysteresis drift and has a considerable lag at sub-zero temperatures. It is extremely difficult to assess all these factors, but it is possible that they cause values of frost-point measurement by the radiosonde to be 3–4°C. high at temperatures down to −40°C. On individual flights the errors may vary considerably on either side of these limits.

Conclusion.—The inaccuracy of the humidity element in the radiosonde is well known to most meteorologists, but there appears to be little quantitative information published concerning the magnitude of the errors involved.

The above discussion of the accuracies of the radiosonde humidity element and the frost-point hygrometer show that the error of each instrument is of opposite sign, their difference therefore could be 5–6°C. The average differences of 4·3–7·6°C. obtained are not therefore surprising. About two-thirds of the discrepancy probably arises from the positive error of the radiosonde and one-third from the negative error of the frost-point hygrometer.

The results of this analysis show that the gold-beater's skin hygrometer of the radiosonde systematically overestimates the humidity. The above allocation of errors implies that the mean humidity mixing ratios at 700 millibars and 500 millibars computed from routine radiosonde soundings are probably 15 to 35 per cent too high.

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ANALYSIS OF WIND AT 300 AND 200 MILLIBARS OVER HONG KONG

By D. S. GILL

Observations and yearly analysis.—Daily radiosonde ascents are made in Hong Kong by the Royal Observatory staff at about 0001 G.M.T. and radar winds form a part of these ascents. The results of the ascents are published by the Royal Observatory[1]. An analysis of these radar winds for the years 1950 and 1951 has already been published[2] and the present work is an extension of this analysis to cover the years 1952, 1953, and 1954.

The observations at 300 millibars (approximately 32,000 geopotential feet) and 200 millibars (approximately 41,000 geopotential feet) have been analysed separately for each month and each year. The mean components V_N and V_E for the months were calculated and from these the vector mean wind $\mathbf{V}_R$ was obtained. The scalar mean wind speed V_S was calculated and from this the constancy q defined as $100V_R/V_S$ was obtained.

Standard deviations of the northerly and easterly components σ_N and σ_E were calculated from the sum of the squares of the differences and a standard vector deviation was obtained from the square root of the sum of the squares of σ_N and σ_E. Computed values of $\mathbf{V}_R$, q, σ_N, σ_E, and standard vector deviations (S.V.D.) are given in Table I.

Effect of missing observations.—Large numbers of observations are missing in some months, a large proportion probably being due to strong winds carrying the sonde balloon beyond radar range. A rough test was made of the skewness of the January observations at 300 and 200 millibars by calculating

TABLE I.—STATISTICS OF MONTHLY MEAN WINDS AT 300 MILLIBARS AND 200 MILLIBARS OVER HONG KONG AT 0001 G.M.T.

		300 mb.						200 mb.					
Month	Year	No. of obs.	$\mathbf{V}_R$ deg/kt	q %	σ_N kt.	σ_E kt.	SVD kt.	No. of obs.	$\mathbf{V}_R$ deg/kt	q %	σ_N kt.	σ_E kt.	SVD kt.
Jan.	1952	22	265/70	99	9·4	21·5	23·4	9	257/69	98	17·0	11·1	20·3
	1953	6	265/72	97	15·3	8·7	17·6	4	250/78	97	20·3	13·6	24·4
	1954	19	261/60	95	19·9	11·4	22·3	9	258/61	92	26·4	11·4	28·6
	1952–54	47	264/65	97	15·6	16·0	22·3	22	256/67	95	22·3	13·6	26·1
Feb.	1952	18	257/56	97	13·9	11·5	18·0	10	258/56	96	14·4	7·8	16·4
	1953	5	248/64	98	14·9	16·9	22·5	NIL					
	1954	16	266/64	99	10·3	18·1	20·8	6	256/52	99	7·8	15·9	17·7
	1952–54	39	260/61	98	15·3	16·3	22·3	16	257/55	98	11·6	13·3	17·6
March	1952	19	256/60	96	15·7	9·0	18·1	12	254/68	98	12·1	8·7	14·9
	1953	15	265/64	97	16·5	11·6	20·1	7	264/61	99	12·2	18·1	20·3
	1954	21	258/58	98	10·1	9·3	14·4	13	255/65	98	12·7	11·7	17·2
	1952–54	55	259/60	97	14·8	10·6	18·3	32	257/65	98	13·4	13·5	19·0
April	1952	20	270/52	95	13·8	14·4	15·8	15	276/60	95	19·6	15·3	25·0
	1953	22	270/51	98	12·1	11·3	16·6	16	266/60	98	12·0	11·1	16·3
	1954	17	266/38	87	18·7	16·6	25·0	14	277/47	90	18·3	19·2	26·6
	1952–54	59	270/47	94	15·2	15·6	21·8	45	272/56	95	17·2	16·9	24·1
May	1952	22	265/17	89	7·5	9·4	12·0	20	301/18	82	10·4	11·4	15·4
	1953	23	265/28	92	8·4	16·6	18·6	22	260/32	87	11·4	23·4	26·0
	1954	24	284/09	63	5·4	13·7	14·7	19	319/13	62	7·8	16·5	18·3
	1952–54	69	273/18	81	7·3	15·5	17·2	61	293/21	74	10·2	20·4	22·8
June	1952	18	345/05	36	9·8	13·9	17·0	15	360/10	44	11·1	22·0	24·6
	1953	22	024/02	10	6·5	15·3	16·6	21	359/04	17	12·0	21·1	24·2
	1954	20	342/03	35	5·4	10·1	11·5	19	041/15	78	7·7	11·8	14·1
	1952–54	60	351/03	23	7·6	13·3	15·3	55	023/09	41	10·9	19·4	22·3
July	1952	26	092/13	75	9·1	10·8	14·1	25	079/22	87	9·5	17·5	19·9
	1953	26	079/21	93	8·3	7·6	11·2	26	077/39	97	9·1	12·4	15·4
	1954	27	079/16	94	6·4	6·7	9·2	18	062/34	97	7·9	14·8	16·8
	1952–54	79	082/17	87	8·2	9·2	12·3	69	073/31	94	10·1	16·4	19·2
Aug.	1952	16	077/13	73	11·3	11·7	16·3	12	056/17	73	13·3	12·7	18·4
	1953	25	090/14	79	6·9	11·8	13·7	24	093/23	88	11·3	11·4	16·1
	1954	22	109/05	33	12·4	10·7	16·4	18	067/12	71	12·6	11·7	17·2
	1952–54	63	089/10	63	10·6	11·8	15·9	54	078/18	79	13·2	13·0	18·6
Sept.	1952	16	068/08	53	10·2	9·2	13·6	8	063/11	51	6·5	20·1	21·1
	1953	18	041/03	29	6·8	10·2	12·3	17	039/07	34	12·5	16·7	20·9
	1954	24	083/09	64	9·6	9·0	13·1	18	090/11	57	13·2	12·6	18·1
	1952–54	58	072/07	50	9·0	9·9	13·4	43	068/09	44	11·3	17·0	20·4
Oct.	1952	21	314/09	59	8·2	11·9	14·4	19	311/13	61	11·9	15·9	19·9
	1953	25	285/12	69	7·0	14·3	15·9	25	281/14	68	8·4	15·6	17·7
	1954	25	287/18	62	9·0	25·4	27·0	23	292/20	59	14·6	26·2	30·0
	1952–54	71	291/13	62	8·2	18·8	20·5	67	293/15	60	12·2	20·1	23·5
Nov.	1952	22	242/15	70	9·9	18·7	21·2	20	244/18	80	9·5	20·2	22·9
	1953	19	241/25	93	7·8	12·7	14·9	16	247/31	88	12·9	15·7	20·3
	1954	25	270/30	83	12·9	26·5	29·5	20	250/29	84	14·0	23·5	27·7
	1952–54	66	255/23	80	11·6	21·2	24·2	56	246/26	86	12·5	20·9	24·4
Dec.	1952	11	267/59	97	15·1	14·6	21·0	8	242/61	99	10·5	10·6	15·0
	1953	20	249/55	97	15·0	17·3	22·9	13	242/60	97	13·5	20·8	24·8
	1954	23	251/44	97	10·7	15·5	18·9	17	240/45	94	15·0	14·5	20·9
	1952–54	54	253/51	97	14·8	17·4	22·8	38	241/54	97	13·5	17·3	21·9

$\sqrt{\beta_1}$ for these observations, $\sqrt{\beta_1}$ being defined as μ_3/σ^3 where μ_3 is the third moment of wind speed and σ is the standard deviation of wind speed[3]. January was chosen as a month with high constancy, high wind speeds and almost equal values of σ_N and σ_E.

The results were:

January 1952	300 mb.	−0·01;	200 mb.	+0·44.
January 1953	300 mb.	−0·50;	200 mb.	−0·08.
January 1954	300 mb.	−0·17;	200 mb.	−1·0.

These values show a tendency for skewness from normal distribution with a larger number of observations less than the true mean, except in the case of January 1952 at 200 millibars.

In view of this it seems that the mean values obtained for wind speed are lower, in most cases, than the true mean. It was found impossible to apply the corrections suggested by Graystone[4] owing to the lack of a full set of observations at a lower level, although Graystone's examples support the suggestion that the uncorrected mean will be too low.

Mean zonal and meridional components.—The mean zonal components (V_E) at 300 and 200 millibars are given in Table II. This table shows a change from a westerly to an easterly component between May and July and the reverse between September and October. The probable error ($\cdot 6745\sigma_E$) and the constancy q are also given and it will be seen that q reaches a minimum during the change-over periods.

The mean meridional component shows a change from southerly in winter to northerly in summer but its values are much lower than those of the zonal component especially in summer, when the northerly component is very small.

TABLE II.—MEAN MONTHLY ZONAL COMPONENT, PROBABLE ERROR, AND CONSTANCY

Month	300 mb.			200 mb.		
	V_E	P.E.	q	V_E	P.E.	q
January	−65·6	10·8	97	−65·4	9·2	95
February	−59·4	11·0	98	−53·1	9·0	98
March	−59·0	7·2	97	−63·3	9·1	98
April	−47·5	10·5	94	−55·8	11·4	95
May...	−17·8	10·5	81	−19·2	13·8	74
June...	− 0·5	9·0	23	+ 3·4	13·1	41
July	+16·5	6·2	87	+30·0	11·1	94
August	+10·4	8·0	63	+17·3	8·8	79
September ...	+ 6·3	16·7	50	+ 8·0	11·5	44
October	−12·2	12·7	62	−14·1	13·6	60
November	−22·2	14·3	80	−23·9	14·1	86
December	−48·5	11·7	97	−47·2	11·7	97

Constancy.—Possibly the most interesting feature of the analysis is the very high values obtained for q, the constancy, during the winter months. These values are as high as those obtained by Clarkson[5] at 50,000 feet over Singapore even at the 300-millibar level. They show a marked drop, as would be expected, in the transitional months of June and September.

Wind speeds.—Table III shows the wind speed which may be expected to be equalled or exceeded on 5 per cent of occasions. It is calculated from the formula[3]

$$V_p = V_R + \text{S.V.D.}\ \sqrt{\log_e (100/p)},\ \text{putting}\ p = 5\ \text{in this case.}$$

TABLE III.—WIND SPEED EQUALLED OR EXCEEDED ON 5 PER CENT OF OCCASIONS

Month	300 mb.			200 mb.		
	Calculated	Observed	Maximum Observed	Calculated	Observed	Maximum Observed
January	104	98	123	112	96	96
February	100	93	93	85		75
March	92	82	93	98		87
April	85	80	81	98	87	95
May...	48	44	47	60	66	68
June...	29	31	46	48	45	45
July...	38	34	46	64	61	69
August	38	40	48	60	49	52
September	30	27	29	46	33	26
October	48	50	57	56	52	62
November	65	70	75	68	65	74
December	90	86	88	92	86	115

TABLE IV.—FREQUENCIES OF WIND SPEED IN WINTER AND SUMMER

Speed kt.	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100	101–110	111–120	121–130
						Winter: December to February							
200 mb.			2	11	9	21	16	8	5	3		1	
300 mb.		3	2	16	19	28	31	22	14	4			1
						Summer: June to August							
200 mb.	23	37	66	23	18	6	4	1					
300 mb.	54	89	47	8	4								

TABLE V.—ACTUAL VALUES OF σ AND VALUES CALCULATED ASSUMING A NORMAL CIRCULAR DISTRIBUTION

Month	300 mb.		200 mb.	
	Calculated	Actual	Calculated	Actual
January	21	22	30	26
February	15	22	14	18
March	20	18	16	19
April	23	22	25	24
May	17	17	24	23
June	14	15	23	22
July	15	12	15	19
August	17	16	17	19
September	14	13	22	20
October	22	20	24	23
November	22	24	19	24
December	17	22	18	22

Where sufficient observations were available the observed wind exceeded on 5 per cent of occasions is given in the table together with the maximum observed wind. The strongest wind observed in the period was 123 knots at 300 millibars on 27 January 1952.

Table IV shows the distribution of wind speed in winter and summer. The most frequent range in winter is 51–60 knots at 200 millibars and 61–70 knots at 300 millibars. In summer the most frequent range is 21–30 knots at 200 millibars and 11–20 knots at 300 millibars.

Distribution of vectors.—For some months the standard deviations of the easterly and northerly components were found to be unequal and it was suggested by Clarkson[5] that this results in a non-circular distribution of winds about the vector mean.

Application of Mauchly's test[3] shows that at the 5 per cent level of significance the wind vectors are not circularly distributed about their mean for the following months:

March, May, June, October, and November at 300 millibars.

May, June, July, October, and November at 200 millibars.

It will be seen from Table I that in all these cases (except March at 300 millibars) the standard deviation of the easterly component is substantially greater, usually 50–100 per cent, than the standard deviation of the northerly component. This is similar to the result obtained by Clarkson for winds at 50,000 ft. in November over Singapore.

It may be noted, however, that the computed values of the standard vector deviation obtained from the approximate relation between q and σ/V_R for a normal circular distribution (given by Brooks and others[6]) are in good agreement with the actual values of the standard vector deviation (see Table V).

Conclusion.—The results obtained from this analysis are similar to those obtained by Hay[2] using more limited data. Strong westerly winds occur over Hong Kong during the winter season (November to April) at 200 and 300 millibars. There is a similar, less marked, tendency for easterlies in summer (June to September). Transition months for the change from west to east and vice versa are June and September-October respectively. The distribution of the winds is non-circular in some months.

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REVIEWS

The Planet Earth. Edited by D. R. Bates, F.R.S. 5½ in. × 8¾ in., pp. vi+312, *illus.*, Pergamon Press, 4 and 5, Fitzroy Square, London. 1957. Price: 35*s.*

It is most appropriate that a book should be written with a background theme of the International Geophysical Year. *The Planet Earth* is a book with such a theme. The vast enterprise of international co-operation in scientific observation and investigation which is now in operation has aroused world-wide interest. This book has been written to meet this interest and to provide the general reader with some knowledge of the various geophysical sciences which make up the story of this world upon which we live. And a fascinating "truth is stranger than fiction" story it is too. It is told in 17 chapters ranging from the astronomical to the atomic scale. Almost every chapter is written by a specialist in his subject, but continuity of the story is readily maintained.

The meteorologist may find the chapters outside his own science a useful introduction to other fields; he will certainly find the chapters on meteorology a refreshing review. The latter are headed "Composition and Structure of the Atmosphere" by Bates, "Climate" and "The General Circulation of the Atmosphere and Oceans" both by Eady and "Meteorology" by Mason. There are also several chapters about the upper atmosphere.

The chapter on "Climate" is perhaps more an essay in methodology than of fact or theory, but the different approach does not make it less interesting. It might have been less confusing to confine Eady's second chapter to the atmospheric circulation. The oceanic circulation is well covered by Deacon earlier in the book. To couple ocean and atmosphere may be useful as an analogue but the general circulation of the atmosphere can be described in its own right.

Mason's chapter is twofold. The first half deals with weather forecasting and the second with the physics of rain clouds. The former is up-to-date but familiar, while the latter subject in the author's specialist field could perhaps have been expanded and given a chapter to itself. Figure 1 in Mason's chapter is not a good example of air-mass analysis. The moist tropical air identifies an easterly current which is blowing from the continent!

A. H. GORDON

Atmospheric electricity. By J. Alan Chalmers. $8\frac{3}{4}$ in. × $5\frac{1}{2}$ in., pp. viii + 327, *illus.*, Pergamon Press, 4 and 5 Fitzroy Square, London, W.1. 1957. Price: 63*s*.

Dr. Chalmers, who over the past twenty-five years or so has devoted his research interests primarily to atmospheric electricity and has initiated many students into its mysteries, is eminently qualified to have written a treatise on the subject. His latest book is, in effect, a greatly expanded and, of course, more up-to-date version of his earlier one (1949) with the same title and practically the same chapter headings. Almost all the chapters are much increased in length, the largest additions being to that on general principles and results and to the list of references. The latter now occupies thirty-one pages instead of six and must surely be one of the most comprehensive bibliographies on the subject ever published. Two other changes have been made; one is the adoption of the m.k.s. system of units in place of the c.g.s. electrostatic system and the other is the avoidance of the term "electric field" and the use of "potential gradient" instead because of the confusion between sign conventions for field in atmospheric electricity and ordinary electrostatics. There can be little objection to these two changes.

The book starts with a brief but interesting historical survey, followed by an outline of fundamental principles, methods and results. Then there are chapters on the usual subdivisions of the subject such as atmospheric ions, potential gradient, precipitation currents, thundercloud electricity and lightning discharges. The book ends with chapters on the separation of charge and on conclusions about the outstanding problems of atmospheric electricity and the possibilities of solving them. The numerous theories of charge separation are described and discussed and the author concludes that some of the questions which still remain unanswered would best be investigated by aircraft flights through storms, with instruments suitable for the measurement of electrical phenomena, air temperature and vertical currents. Perhaps the time is now ripe for a repetition of the "Thunderstorm Project" with more emphasis on the electrical aspects. Dr. Chalmers also suggests that many of the theoretical arguments used to explain atmospheric electrical phenomena assume that a quasi-static state exists, whereas it is often likely that steady conditions will not be reached and that more complex mathematical treatment is needed. Such a suggestion might well apply to a variety of meteorological problems.

The book is undoubtedly much more useful than its predecessor, as, indeed, it should be at the considerably higher price. It is well illustrated and the presentation, as in all of Dr. Chalmers' writings, is concise and lucid. He is, perhaps, more discursive than in his earlier book, devoting more space to assessing the relative merits of conflicting results and views and being more critical in discussions of controversial points. One or two aspects of the subject are dismissed rather too briefly. For example, one would expect to find included in the chapter on the lightning discharge more on atmospherics than a brief paragraph consisting mostly of references.

Probably it will be found that the best use of the book is as a source of reference, since there would appear to be very little published work on the subject which has not received at least a brief mention by the author. It should, therefore, appeal to the research worker who wishes to be relieved of the time-consuming task of searching the very wide field of literature over which the subject spreads. At the same time, the book should be useful to the student in providing him with a good introduction to the subject and a comprehensive review of the present state of knowledge of it. The cost of the book may seem somewhat high in comparison with that of the earlier book, which was about half the length but only one quarter of the price; increases in production costs over the past eight years, however, probably account for the difference.

F. J. SCRASE

The Physics of Clouds. By B. J. Mason. (Oxford monographs on meteorology. Editor P. A. Sheppard) $9\frac{1}{2}$ in. × 6 in., pp. xi + 481, *illus.*, Clarendon Press: Oxford University Press, Amen House, Warwick Square, London, E.C.4. 1957. Price: 70*s.* net.

The discovery by Schaefer and Langmuir, eleven years ago, that super-cooled clouds could in favourable circumstances be precipitated by means of a cooling agent, was one of the most exciting events in the history of meteorology. It seemed that we were no longer to be mere spectators, but actors—we were offered a magic wand which we had only to learn to wave, and the heavens would deliver their floods to order. Alas! when the wand was waved, the deluge which descended consisted of paper. As Dr. Mason says in his preface, "This rapid development" (of research into cloud physics) "along a broad front has produced a large and diverse literature, the growth of which has made life increasingly difficult for the research worker and impossible for the student".

This last is hardly an overstatement: for the literature is not merely large and diverse—is it extraordinarily confused and contradictory. Clouds have not proved an easy subject for study: they are inaccessible and enormously variable. Then, too, the experimenter is driven to the use of aeroplanes, probably the most infuriating working platform any scientist ever had to occupy. In an aeroplane one needs a huge, expensive, temperamental, electronic apparatus even to measure such basic things as one's geographical position or the wind speed: and the accurate measurement of even so simple a quantity as temperature in cloud still defies us. Perhaps some of the trouble was that at first everyone was in too much of a hurry. Success—that is, success in controlling rainfall—was only just round the corner. It seemed better to use the tools that were lying handy than to spend years developing special ones, and, perhaps, be too late.

Whatever the cause, the results of research in cloud physics are extremely discordant and inconclusive. Time and again one finds the same point investigated by half a dozen different investigators, who obtain as many different results. There is remarkably little agreement even on fundamentals. For example, every raindrop that falls on the earth is believed to start either as an ice crystal or by the coalescence of cloud droplets. Yet hitherto a student who wanted to learn what happens when two cloud droplets meet, or in what circumstances ice crystals form, would have found that there was no generally accepted answer, nor even a satisfactory summary of the attempts which have been made to find one. He would have been driven to study the original papers—perhaps a hundred of them in half a dozen languages—and at the end would have been no wiser than when he started. Thus a concise and orderly account of the work that has been done in the past ten years was most urgently needed, both to give the unfortunate student a fighting chance and in order that future research might be intelligently and economically directed. This is the principal object of Dr. Mason's book, the appearance of which will be greeted with a sigh of relief by all workers in this field. He has confined himself to the microphysics of cloud, leaving the large-scale phenomena to a later volume, and, within these limits, has given a notably lucid and comprehensive account of the subject.

He begins with a chapter on the condensation of water vapour in a nucleus-free atmosphere. Like a good deal of the theory in this field, it has no actual contact with cloud physics, but it makes a nice background to the scene. He then deals successively with condensation nuclei, the growth of droplets, ice forming nuclei, the formation of snow crystals, and precipitation processes. These five chapters are the backbone of the work; they are followed by three more dealing with the artificial stimulation of rain, radar studies, and the electrification of clouds, and by two long appendices dealing with the physical behaviour of falling drops. An introduction by Mr. F. H. Ludlam on the large-scale physics of clouds looks like an afterthought: it runs to only seven pages, and is too compressed to be very useful.

Although this is a textbook, and deals comprehensively with each subject, the principal interest, as already noted, lies in the study of the recent literature. All this is hand-picked, set in good order before us, and its results clearly stated and appraised. There is hardly any plot to the story—no grand discoveries, no sweeping progress—almost everything is inconclusive, every chapter asks more questions than it answers. The result might well have been both dull and irritating, and yet is neither. Dr. Mason obviously finds the problems which surround him immensely stimulating and entertaining, and has no difficulty in persuading the reader to share his feelings. This quality, combined with the simplicity and clarity of the language, make the book unusually easy and enjoyable reading.

As a textbook, it has some faults. The author seems too eager to get down to his analysis of recent work, and sometimes hurries over the fundamentals. In particular the mathematical sections (there are very few of them) have a breathless air, and in some cases are condensed to the point of being misleading. Certainly anybody who tries to understand or apply Smoluchowski's equation (for the rate of coalescence of small particles) from the account given here on pp. 68–70, will discover that condensation nuclei can generate more than one kind of fog.

An immense number of papers are digested here: the bibliography contains over six hundred references, and it is apparent that these are by no means all that have been consulted. So far as can be judged, the bibliography is fairly comprehensive up to the year 1955—there are only a few items from 1956. But the flood of research rolls on, and already there are a number of points at which one feels a need for, at least, a footnote. Where so much material has to be considered, some selection is necessary, and probably no two people would agree precisely on this matter. It is a little surprising that there is apparently no reference to Bowen's theory of meteoritic dust as a source of freezing nuclei—which, even if one disbelieves it, has created too much of a stir to be ignored. Some consideration of the general principles of observation and measurement as applied to the study of clouds would likewise have been of great interest, for lack of system in observation is undoubtedly the principal cause of waste and confusion in this field.

The book is excellently printed and bound, in the usual style of the Clarendon Press. It is generously illustrated with twenty-nine photographic plates and a very large number of clear line drawings. Misprints seem to be few. At 70*s.* it is, by modern standards, remarkably good value, and certainly nobody concerned with cloud physics can afford to be without it. B. C. V. ODDIE

Physikalisch-Statistische Regeln als Grundlagen für Wetter- und Witterungsvorhersagen. Band I. By F. Baur. 10¾ in. × 7¾ in., pp. x + 138 *illus.*, Akademische Verlagsgesellschaft. Frankfurt am Main, 1956.

The name of Franz Baur will probably live, like that of Sir Gilbert Walker, as one of the pioneers in the application of statistics to the understanding of the general circulation of the atmosphere and early techniques of medium- and long-range forecasting. Great interest therefore attaches to the publication of a book to record Baur's methods, discoveries and working material.

Baur states the aims of his work in the preface: firstly, to prove the possibility of medium- and long-range forecasting; secondly, to show that, guided by physical considerations, rules can be found regarding connexions between successive weather phenomena or between weather patterns and solar phenomena; and thirdly to provide a better basis than the present universally adopted synoptic analogy methods for short-range forecasting also. The position as regards this last is considerably overstated. Baur's own record of medium- and long-range forecasting may perhaps be regarded as sufficient proof of the first point and demands a thorough study of his "rules" and methods. One gathers, however, that the enormous labour of such approaches as that incorporated in Table 2 (pp. 10–23)—from which the sign of the pressure change at Potsdam during the next 24 hours may be deduced, given the pressure change in the previous 24 hours at the Azores, Brest, Stykkisholm and Heligoland and knowledge of the trend of sky conditions at Potsdam—may result in but a single hard-won step forward: this table which only applies in high summer may be expected to give the right sign of the pressure change with 90 per cent certainty in only about one seventh of the cases arising—the majority of sets of circumstances would suggest no confident forecast. From this point the search goes on for further rules and further criteria to cover other contingencies. Undoubtedly many of Baur's rules work, but each one only covers a minority of special circumstances and for practical application the problem of indexing alone must be formidable.

This volume contains a further selection of rules relating to the forecasting of dry and wet spells of up to five days duration in middle latitudes. Later sections are concerned with defining large-scale circulation types and presenting data of their occurrence and of various measures of circulation intensity over the Northern Hemisphere. Relationships are explored between these data and the 11-year solar cycle.

The second volume is to deal with Baur's derived rules of behaviour of the general circulation affecting long-range forecasting. This reviewer is left with the impression that the work contains material of value both for long-range forecasting and for further research with this aim in view, but that future workers in this field will bend their efforts to clarifying the physical understanding and evolving simpler procedures than those represented by a mass of heterogeneous rules.

The book contains an introductory chapter which is a good four-page philosophical essay on the respective places of experimental and statistical approaches to research in physical science, showing the need for statistical treatment of masses of data in meteorology to be judged in the light of significance tests. In reality, this may be a necessary, but certainly not a sufficient, condition. The aptness and limitations of the concept of numerical measures of significance in solving the practical problems of meteorology may be illustrated by reference to two specific cases. Changes of climate may be defined in terms of the figures (for example, of temperature) alone: the averages and variances in two epochs show differences which have, say, a 5 per cent probability of occurring by chance. This is a useful, but not a high, significance level; yet we may find that the synoptic regimes and effects on living requirements of plants, disease organisms etc. differed notably. Or an association between certain meteorological events and previous conditions elsewhere may attain a higher significance level and clearly demand research, yet still provide an insufficient basis for confident forecasting until further study has revealed a good deal of the physical mechanism and its controls.

It may be that Baur has been successful as a forecaster just in so far as he has gained a real physical insight. His methods seem to point towards a use of statistical approaches at two points in long-range forecasting: first to identify physical mechanisms and secondly in the manner of stating a forecast—for example, that in cases similar to the given circumstances, *A* resulted in, say, 85 per cent of the cases, *B* in, say 9 per cent. of the cases, the remainder being more various. With considerable financial stakes involved for some recipients of the forecast, a presentation along these lines is perhaps the only wise and fair one. Baur's own contribution has been so much on the statistical side, however, that he possibly understates the need to know the physical links in the chains of association. H. H. LAMB

Untersuchungen über die Abhängigkeit der Winterroggenreife von der Witterung. (Veröffentlichungen des Instituts für Agrarmeteorologie der Karl-Marx

Universitat Leipzig, Band 1, Heft 3). By Kurt Müller. 6 in. × 9 in., iv + 53, *illus.*, Akademische Verlagsgesellschaft Geest und Portig K.-G., Leipzig, 1957. Price: *D.M.* 4.60.

This work uses phenological and climatological observations in an attempt to find a relationship between the weather and the ripening period of winter rye. The data are mainly from Germany for the years 1936 and 1937, and the ripening period is defined as the period between the beginning of blossom and crop harvest. Charts of mean daily sunshine in June and July and those for ripening period demonstrate a general inverse relationship between these elements in 1936 and 1937. Long-period means for 28 European stations lead to the regression:

$$R = 87{\cdot}7 - 5{\cdot}32h,$$

where R is mean ripening period and h the mean daily sunshine during this period. When rainfall is considered, the regression for Geisenheim becomes:

$$R = 95{\cdot}6 + 0{\cdot}114N - 8{\cdot}12h,$$

where N is the March–June rainfall (millimetres). The rainfall term is not strictly linear and a graphical adjustment is given for this.

A map of the mean number of hours of sunshine over Europe during ripening period shows a decrease from south to north, which suggests that day-length may also be important in determining ripening period.

The material presented in this paper has no obvious practical value and the author states that it is not possible to use past sunshine to forecast the date of end of harvest.

W. H. HOGG

Combination of observations. By W. M. Smart. $5\frac{1}{2}$ in. × 6 in., pp. xi + 253, *illus.* Cambridge University Press, London. 1958. Price: 35*s.*

The meteorologist as well as the astronomer and other scientists will find much useful information in this book, which is primarily concerned with methods of obtaining the best result from a given series of observations and of estimating the degree of precision of this result. It is not essentially a book on statistics though general statistical theory is discussed in the first introductory chapter and one chapter is devoted to theoretical frequency distributions including Pearson's curves. The main emphasis is on applications of the principle of least squares and the normal law of errors. Thus Chapters 2–6 are:- Errors of observation and the principle of least squares; probability and the normal law; measures of precision; measures of precision for weighted observations; equations of condition in several unknowns.

There are also chapters on the correction of statistics and correlation; normal errors of vectors are discussed briefly. Worked examples of some of the more important techniques are given. There are tables of the error function in an Appendix.

The book is clearly written and forms an excellent introduction to the subject as well as a useful and practical book of reference. Proofs are given of the underlying theory and this will enhance the value of the book to most readers, especially the student preparing for examinations.

It is perhaps strange that there is no mention of the book of the same name by Sir David Brunt, the last edition of which appeared in 1931. The scope of the two books is similar except that the earlier includes a long discussion of harmonic and periodgram analysis (now out of fashion), while Professor Smart dismisses the subject in a few pages. Professor Smart's new book is a worthy successor to the old which served many generations of students well. It is excellently printed (the reviewer found only one misprint) and the price is reasonable by present standards. J. K. BANNON

RAINFALL REPORTS

No readings of rainfall for Lairg, Crask have been received since April 1958.

METEOROLOGICAL OFFICE NEWS

Obituary.—*Mr. Thomas Leslie Hosker.* It is with deep regret that we learn of the death on 22 August of Mr. T. L. Hosker, Assistant (Scientific), at the age of 34 after a long illness. Mr. Hosker joined the Office in December 1941 as a Meteorological Assistant and all his service was spent at aviation outstations. Since 1952 he has served at Squires Gate.

He is survived by a widow, three sons and a daughter to whom the sympathy of all who knew him is extended.

Retirement.—*Mr. A. Stevens,* Senior Assistant (Scientific) retired on 22 August 1958. After service with the Royal Fusiliers in the First World War he was employed in the Ministry of Pensions. In 1926 he entered the Air Ministry and was transferred to the Meteorological Office in March, 1929. All his service in the Office has been at Headquarters in the General Services and Overseas Branches and, from 1955 until his retirement, in the overseas section of the Assistant Directorate Military Services.

WEATHER OF JULY 1958

Northern Hemisphere

For the third consecutive month the sub-polar trough in the Atlantic sector, although of normal intensity, was displaced south of its usual latitude. This displacement amounted to about 10° of latitude, the depression tracks lying across the British Isles instead of further north between Iceland and the Faeroes. Negative pressure anomalies of up to −5 millibars occurred over the Atlantic between approximately 30°N. and 55°N. and over Scandinavia.

The polar anticyclone was about 4 millibars more intense than usual and positive pressure anomalies occurred over Greenland reaching + 8 millibars on the south-east coast. Smaller positive anomalies occurred over most parts of Canada. The Azores high was centred near its normal position but was about 2 millibars weaker than normal. There was more cyclonic activity than usual in the Bering Sea area, giving small negative pressure anomalies there with a maximum value of −5 millibars over the Aleutians. Like the Azores high, the North Pacific high was a little weaker than usual. The Asian monsoon low was slightly deeper than normal and small negative pressure anomalies occurred in India and over the high ground in central and southern Asia.

Mean temperatures over western Europe were very close to the normal. They were 1° or 2°C. below normal over Scandinavia, whilst over eastern Europe and the Balkans the month was slightly warmer than average. Negative temperature anomalies predominated in European Russia, the largest being

-3°C. near the Caspian Sea. Over central regions of the North American continent temperatures were below average, anomalies of -3°C. occurring at some stations. These anomalies resulted from a southward displacement of the polar front and a number of particularly cold northerly outbreaks during the month. Temperature anomalies in Alaska and to the west of the Rockies in Canada and the United States were positive. They reached 3°C. at some stations but were generally about 2°C.

Rainfall totals for the month were above normal in most parts of western Europe. Over central and eastern Europe amounts were generally near normal and in the Balkans and Turkey the month was drier than usual. In all parts of the United States except the south-west, totals were above average. The southward displacement of the polar front gave very changeable weather especially in north-eastern states where many heavy storms and floods were reported. Canada, however, had a dry month, the total rainfall being between 40 per cent and 80 per cent of normal at most places.

WEATHER OF AUGUST 1958

Great Britain and Northern Ireland

The disturbed cyclonic weather of late July continued throughout August. At no time during the month did an anticyclone become established over the British Isles though around the 17th and 26th weather was dominated by ridges of high pressure.

A depression moved eastwards across Scotland on the 1st and thunderstorms were rather widespread over the British Isles on that and the following day. Slight rain or drizzle occurred at most places on the 3rd, but during the next two days there was moderate to heavy rain in many places and strong to gale force winds in the Orkneys and Shetlands associated with a vigorous depression which passed north-eastwards between Scotland and Iceland. Small secondary depressions moving east along the English Channel brought heavy rain with scattered thunderstorms to central and southern districts on the 7th.

On the 8th–10th a deep and slow-moving depression was situated in the eastern Atlantic and warmer air, accompanied by rain and drizzle, gradually spread northward over the British Isles. By the 10th, which was the warmest day of the month, a southerly airstream covered the country and temperature rose into the eighties locally in south-east England and reached 83°F. at London Airport. Thunderstorms broke out at many places during the afternoon and were fairly widespread also on the 11th and 12th. During the next three days there was a good deal of fog in the English Channel and vigorous depressions moving eastward across Scotland gave widespread rain on the 13th and 15th, much of which was heavy.

A break in the wet weather occurred on the 16th when a ridge of high pressure moved slowly eastwards across the country; the following day was also fairly dry and Dishforth recorded over 13 hours of sunshine.

Heavy thunderstorms became widespread on the 19th–22nd as a depression moved slowly from our south-west approaches to Western Europe. Flooding occurred in many areas, particularly in Devon, Cornwall and Yorkshire. On the 19th the village of Coombe Martin, north Devon, was badly damaged by floods and on the same day $1\frac{1}{4}$ inches of rain fell in an hour at Truro, Cornwall. There were widespread floods in the Manchester area on the 22nd where one inch of rain fell in an hour, while at Golder's Green, London, Col. Gold, late of the Meteorological Office, recorded $1\frac{1}{2}$ inches in 46 minutes. A vigorous depression from the Atlantic brought gales to our south-west coasts and prolonged and often heavy rain to many districts on the 24th, as it moved eastward to the North Sea.

On the 26th a ridge of high pressure, associated with a weak anticyclone over France, brought a second break in the generally unsettled weather as it moved eastward across the country and on the following day, although troughs gave rain in the west, the eastern part of the country was dry with over 12 hours of sunshine at many places. During the last two days of the month, a quasi-stationary front in western districts and thundery troughs over France resulted in outbreaks of rain in the west and south-east while central districts had mainly dry weather.

Temperatures were a little below average generally, especially in central and southern districts of England; in Lancashire they were somewhat above average. Sunshine was below average in nearly all parts of the country; at Plymouth and Boscombe Down it was the dullest August since records began in 1921 and 1933 respectively. Most parts of the country had more than average rainfall, the excess being greatest in parts of Sussex, the Isle of Wight and Cornwall where more than twice the average was recorded.

The corn harvest has been seriously delayed by the absence of sun and the heavy rainfall; yields are fully expected to be reduced. The land was too wet to take heavy machinery and in areas where some harvesting was possible the more old-fashioned binder often had to be used in place of the heavier combine-harvester. Potato and sugar-beet crops are also threatened by the continued wet weather. Orchard work has been badly curtailed but yields promise to be good, especially the apple crop, provided that picking can proceed normally.

WEATHER OF SEPTEMBER 1958

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 ...	82	31	+2·2	158	+1	94
Scotland	78	27	+3·5	92	−5	107
Northern Ireland ...	72	40	+3·2	105	−1	86

*1916-1950 †1921-1950

RAINFALL OF SEPTEMBER 1958

Great Britain and Northern Ireland

County	Station	In.	*Per cent of Av.	County	Station	In.	*Per cent of Av.
London	Camden Square ...	3·64	167	*Carm.*	Pontcrynfe	11·07	248
Kent	Dover	2·29	101	*Pemb.*	Maenclochog, Dolwen Br.	10·57	197
„	Edenbridge, Falconhurst	5·83	248	*Radnor*	Llandrindod Wells ...	6·71	214
Sussex	Compton, Compton Ho.	5·16	180	*Mont.*	Lake Vyrnwy	10·32	206
„	Worthing, Beach Ho. Pk.	3·90	181	*Mer.*	Blaenau Festiniog ...	15·01	146
Hants	St. Catherine's L'thouse	3·75	158	„	Aberdovey	8·41	202
„	Southampton, East Pk.	4·87	192	*Carn.*	Llandudno	6·10	224
„	South Farnborough ...	3·79	181	*Angl.*	Llanerchymedd ...	7·66	201
Herts.	Harpenden, Rothamsted	3·41	147	*I. Man*	Douglas, Borough Cem.	4·79	114
Bucks.	Slough, Upton ...	3·31	154	*Wigtown*	Newtown Stewart ...	6·28	146
Oxford	Oxford, Radcliffe ...	3·17	144	*Dumf.*	Dumfries, Crichton R.I.	5·56	149
N'hants.	Wellingboro' Swanspool	2·16	104	„	Eskdalemuir Obsy. ...	6·11	115
Essex	Southend W.W. ...	3·48	217	*Roxb.*	Crailing...	2·50	106
Suffolk	Ipswich, Belstead Hall	2·84	142	*Peebles*	Stobo Castle	3·91	118
„	Lowestoft Sec. School	1·85	89	*Berwick*	Marchmont House ...	2·27	88
„	Bury St. Ed., Westley H.	2·85	123	*E. Loth.*	N. Berwick	2·39	98
Norfolk	Sandringham Ho. Gdns.	2·96	124	*Midl'n.*	Edinburgh, Blackf'd H.	2·29	90
Dorset	Creech Grange... ...	5·14	162	*Lanark*	Hamilton W.W., T'nhill	4·61	128
„	Beaminster, East St. ...	6·11	190	*Ayr*	Prestwick	3·38	102
Devon	Teignmouth, Den Gdns.	3·86	151	„	Glen Afton, Ayr. San ...	5·81	115
„	Ilfracombe	6·36	190	*Renfrew*	Greenock, Prospect Hill	5·41	101
„	Princetown	10·18	153	*Bute*	Rothesay, Ardencraig...	2·87	57
Cornwall	Bude	5·98	202	*Argyll*	Morven, Drimnin ...	5·16	90
„	Penzance	5·74	182	„	Ardrishaig, Canal Office	6·11	96
„	St. Austell	6·94	194	„	Inveraray Castle ...	7·24	89
„	Scilly, St. Mary ...	5·25	213	„	Islay, Eallabus ...	3·03	61
Somerset	Bath	4·81	189	„	Tiree	4·19	101
„	Taunton	4·01	164	*Kinross*	Lock Leven Sluice ...	3·94	120
Glos.	Cirencester	5·36	190	*Fife*	Leuchars Airfield ...	1·87	77
Salop	Church Stretton ...	6·43	236	*Perth*	Loch Dhu	6·30	93
„	Shrewsbury, Monkmore	6·82	319	„	Crieff, Strathearn Hyd.	4·87	144
Worcs.	Worcester, Red Hill ...	5·67	278	„	Pitlochry, Fincastle	4·66	153
Warwick	Birmingham, Edgbaston	3·92	157	*Angus*	Montrose Hospital ...	1·97	75
Leics.	Thornton Reservoir ...	2·68	116	*Aberd.*	Braemar	3·25	109
Lincs.	Cranwell Airfield ...	1·80	90	„	Dyce, Craibstone ...	2·44	80
„	Skegness, Marine Gdns.	2·63	132	„	New Deer School House	2·69	79
Notts.	Mansfield, Carr Bank...	2·51	117	*Moray*	Gordon Castle	2·70	89
Derby	Buxton, Terrace Slopes	5·92	150	*Inverness*	Loch Ness, Garthbeg ...	3·04	84
Ches.	Bidston Observatory ...	4·93	187	„	Fort William	5·10	73
„	Manchester, Airport ...	4·22	157	„	Skye, Duntulm... ...	4·33	86
Lancs.	Stonyhurst College ...	4·95	108	„	Benbecula	4·58	109
„	Squires Gate	3·23	98	R. & C.	Fearn, Geanies ...	2·08	92
Yorks.	Wakefield, Clarence Pk.	2·96	143	„	Inverbroom, Glackour...	2·41	48
„	Hull, Pearson Park ...	2·27	112	„	Loch Duich, Ratagan...	3·87	53
„	Felixkirk, Mt. St. John...	3·16	132	„	Achnashellach	38·6	54
„	York Museum	2·41	116	*Suth.*	Stornoway	3·35	89
„	Scarborough	1·50	72	*Caith.*	Lairg, Crask	...	...
„	Middlesbrough... ...	2·68	133	„	Wick Airfield	0·84	29
„	Baldersdale, Hury Res.	4·24	129	*Shetland*	Lerwick Observatory ...	4·46	119
Nor'l'd	Newcastle, Leazes Pk....	1·63	70	*Ferm.*	Belleek	3·64	80
„	Bellingham, High Green	3·64	113	*Armagh*	Armagh Observatory ...	2·92	100
„	Lilburn Tower Gdns ...	2·66	106	*Down*	Seaforde	7·31	202
Cumb.	Geltsdale	4·13	115	*Antrim*	Aldergrove Airfield ...	4·07	135
„	Keswick, High Hill ...	6·44	115	„	Ballymena, Harryville...	3·90	100
„	Ravenglass, The Grove	4·56	104	*L'derry*	Garvagh, Moneydig ...	3·57	96
Mon.	A'gavenney, Plâs Derwen	7·77	250	„	Londonderry, Creggan	3·26	75
Glam.	Cardiff, Penylan ...	7·01	190	*Tyrone*	Omagh, Edenfel ...	3·99	104

* 1916–1950

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