



**Administration Report of the India
Meteorological Department for the
year 1924-25 and A History
of the Department during
the half century
1875-1924**

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METEOROLOGICAL DEPARTMENT, HALF-CENTENARY, 1925.

DIRECTORS-GENERAL OF INDIAN OBSERVATORIES.



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1875-1880



SIR JOHN ELIOT, K.C.I.E., F.R.S.,
1880-1903



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1904-1924

Report on the Administration of the Meteorological Department of the Government of India in 1924-25, and a General Survey of half a century's Work since the Establishment of the De- partment.

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THIS is the fiftieth Administration Report of the India Meteorological Department and records the completion of the first half century of systematic observations on weather in India, by uniform methods. It would have been pleasant to have been able to call 1925 a Jubilee year, but that would imply not only a 50 years' course of work, but a prosperous condition of the department at its close, with adequate staff and resources: it will be safer to call this year the half-centenary, and regard it as a fitting time to review the progress made, to take stock of the present and consider the future.

HISTORY.

2. In a country where extremes of climate—temperature, dryness and torrential rainfall—have always added to the difficulties of life, there must often have been a natural instinct to set up a collection of private meteorological instruments and take at least occasional readings. Even in the earliest days of British interest in India this was evidenced, for among the less unsystematic work of this kind there have been records by Colonel Pearse in Calcutta, 1785, and by other officers sprinkled about the country. But the difference is radical between any collection of short series of unordered observations and the work of a centrally controlled system on uniform lines, so that although before 1865 provincial authorities occasionally issued instructions to district administrative and medical officers to note temperatures, rainfall and air pressure, these old observations as actually taken have since been found to be of little value.

Sets of instruments were then issued, but without previous comparison with standards for determination of their errors, and commonly without instructions

for the guidance of observers. Little was known in those days of correct methods of exposing thermometers, and the instruments were frequently hung in rooms of public buildings or placed against the walls of verandahs, convenience for the observer and security from unofficial curiosity having been regarded, perhaps, as the main conditions to be satisfied; comparatively seldom were the thermometers located in open-sided sheds, where they could indicate more correctly the temperature of the open air. Sheristadars, writers, compounders or hospital assistants were told off to take the observations, and being generally untrained, realised no need for accuracy or punctuality. Little attempt apparently was made to turn the data to account, or even to ascertain whether they were of any scientific value. They were, as a rule, forwarded to the Boards of Revenue or Medical Boards in the Presidencies, where they were allowed to accumulate without examination, and remained practically inaccessible for the purposes of scientific enquiry. During the years of the Sepoy Mutiny (1857 to 1860) the collection of meteorological statistics naturally ceased over nearly the whole of India, even at those stations in which rainfall observations then went back some 10, 20 or 30 years.

In these general circumstances it was natural that the records should later be regarded with suspicion, and when ultimately they were examined by Mr. H. F. Blanford, this suspicion was found to be well grounded. Many of the records were at that time in the hands of the Messrs. Von Schlagintweit, who had been sent out by the English Government in 1861, at the instance of Prince Albert, on a scientific mission to India and High Asia. An application for the return of the registers was practically declined except on monetary conditions which were held to be unreasonable. But so important was it considered to examine the records that eventually Blanford, while on furlough in Europe, took the opportunity to visit Munich, went through the registers and obtained copies of parts of them. In the result it seemed to him certain that the meteorological observations taken during this early period at sadar and other stations in obedience to orders from Revenue or Medical Boards and any discussions based on them, were of little or no value from the scientific point of view, however interesting they might be historically in throwing more light upon the meteorological conditions accompanying the droughts and famines of the years 1837-38, 1853-54 and 1866-67 in India.

3. Fortunately, however, observations of very great value were recorded at a few observatories of the first rank, established, chiefly by the East India Company, for purely scientific purposes. Thus, the Madras Astronomical Observatory, which was built and started in 1792, began meteorological observations in 1796, and from that date to the present time a continuous series of observations is available, though only a part has been published. The Colaba Observatory, projected about 1821 for astronomical and other purposes, had its building completed in 1826, but did not begin meteorological work until 1841. The observations were apparently unsatisfactory; for the Government of Bombay in 1864 appointed a committee of enquiry to determine what improvements were needed and, as a result, obtained new magnetic and meteorological instruments and appointed a qualified Director to ensure continuous critical examination and discussion of the data, and frequent publication of the results. This was followed by the creation of a meteorological office for the Bombay Government in 1875, and by the printing of a daily weather report for western India from 1889. The Bombay Observatory, which was till 1898 under the control of the local Government, was placed under the Director-General of Observatories in that year, while both the observatory and the meteorological office were amalgamated under a meteorologist in 1923. The East India Company also had accurate meteorological observations taken from 1847 to 1855 by a trained observer on the summit of Dodabetta, a high peak near Ootacamund.

The Trivandrum Observatory owed its origin in 1836 to the enlightened interest of His Highness Rama Vurmah, the then reigning Raja of Travancore. Meteorological observations began there in 1842, were carried on with increased activity from 1852 to 1864 and, though then threatened with complete stoppage, have in fact continued with more or less regularity up to the present time. In Calcutta an observatory was maintained from 1853 in the compound of the Survey Office buildings in Park Street, where observations were recorded until the completion of Alipore Observatory in 1875.

4. In 1857, Sir Richard Strachey called the attention of the Asiatic Society of Bengal to the uselessness of the desultory attempts that had, up to that time, been made to acquire a knowledge of Indian meteorology, and to the urgent need of a controlling authority capable of directing and utilising the work of observers in India. A committee was accordingly appointed with this object, but shortly afterwards came the outbreak of the Mutiny, when men had little leisure or taste for scientific pursuits. Further consideration of improvement in scientific work remained in abeyance for 5 years, and it was not until 1862 that the Committee drew up a report to Government, and were asked in reply to formulate a scheme for giving practical effect to their recommendations.

Various delays supervened, and, meanwhile, Mr. H. F. Blanford who, after 7 years' service in the Geological Department, had been appointed Professor of Science in the Presidency College, Calcutta, became in 1864 one of the honorary secretaries of the Asiatic Society and in this connection had his attention directed to Meteorology. He was partly responsible for the report drawn up by the Society and laid before Government in the beginning of 1865.

Almost simultaneously Government were pressed on other sides to take action. In October 1864 Calcutta was visited by one of the most destructive cyclones on record; a storm-wave rushed up the Hooghly River and flooded the neighbouring lowlands; upwards of 80,000 human beings were drowned or died of exposure, and a great part of the shipping in the river was wrecked. This cyclone was followed within few weeks by another, which passed over Masulipatam, and the storm wave again cost the lives of about 40,000 persons. The attention of the mercantile and shipping community was naturally aroused, and the Bengal Chamber of Commerce called the attention of Government to the inefficiency of a system under which no warning was given to ships of the approach of one of the most disastrous storms on record. About the same time the Secretary of State for India urged upon Government the necessity of a systematic record of meteorological phenomena in order to furnish data for the investigation of the relations of climate and weather with disease in India, and the further necessity to collect data of value for sanitary improvements and projects. To the Sanitary Commission, then appointed, was referred the whole question of meteorological enquiry in India; and in accordance with its recommendations, provincial meteorological systems were established in the Punjab and North-West Provinces in 1865, Madras in 1866, Bengal in 1867, the Central Provinces in 1868 and in Bombay in 1871. The Bengal meteorological department was established with a twofold purpose, to give cyclone warnings for the protection of shipping and to collect and record systematic meteorological observations throughout the Presidency. Blanford became the Meteorological Reporter of Bengal, while still retaining his professorship in the Presidency College. In his admirable hands the new department at once took a very high position and became known for the accuracy of its data and the thoroughness of its work, while his annual reports on the meteorology of Bengal increased in importance from year to year. Blanford also published, during the eight years for which he held the post of Reporter.

series of original papers in the publications of the Asiatic Society of Bengal and the Royal Society of London. In one of the latter papers "The Winds of Northern India" he was able, by the use of data collected in Bengal, the North-West Provinces and the Punjab, to recognize the causes of the prevailing air-currents of northern India, and to detect the general relations of the two seasonal monsoons to each other and to the temperature conditions of the country. This paper was particularly valuable, for not only was it the first attempt to discuss this important question by the aid of fairly accurate data, but it was also the earliest essay on Indian meteorology as a whole; and the subject was, for the first time, treated as a problem of dynamic meteorology.

5. While the new system was thus being developed with such success in Bengal, less progress was made elsewhere, and no attempt was made to begin systematic observations in Burma or the native states of India. In fact, the result of the efforts of Government during this decade—1865 to 1874—was to cover and deal with only about one-third of the total area of India, and that by means of 5 entirely independent organisations of work. There was no attempt to co-ordinate the separate systems, nor unity of aim and direction. This parochial system of dealing with the meteorology of a well-defined meteorological area like the Indian monsoon region, though a valuable innovation on past want of foresight, was self-condemned from the first. The commission of enquiry into the Orissa and Bengal famine in 1866 even urged that Professor Tyndall should be invited to come to India to develop meteorological enquiry. After prolonged consideration by the Government of India and the Secretary of State, it was finally determined to reorganise and extend the work of meteorological observation, and to engage a Meteorological Reporter to consolidate the organisation for the whole of India. This appointment was offered to Blanford, and his preparatory report and scheme, in July 1875, form virtually the foundation of the present system of meteorological work in India. The chief object of his proposals was the systematic study of the climate and weather of India as a whole, and the application of the knowledge thus acquired to the issue of storm and other warnings and daily weather forecasts; and subsequent history shows how fully these aims were kept in view and how well they were achieved. The whole of the proposals were approved and sanctioned by Government: and the evolution of the new organisation from those of provincial departments took place smoothly and without hiatus in the work of observation as previously established. While local meteorological reporters were retained in Bengal, the North-West Provinces, the Punjab and Madras, and a further reporter was appointed for Bombay and Rajputana, each was now subordinate to the Imperial Reporter. The chief improvements lay in the adoption of uniform methods of observation, the collection and discussion of all data at a central headquarters and the establishment of a central observatory at Calcutta, which made possible the comparison with standards of every instrument used by the department. The number of observatories was increased immediately from 77 to 94, special attention being paid to filling as far as possible the larger gaps in the net-work of the observing stations over the land area. A preliminary essay in the preparation of daily weather reports was made in 1877, when the Meteorological Office in Calcutta began to collect reports daily by post from all observatories, and to chart all barometric, wind, temperature and rainfall data on daily charts. A study of these soon threw considerable light on the sequence of day-to-day changes in the weather situation, and also proved of high value in enabling the reporter to exercise a close and strict supervision over the daily work of each observer. But as ten days or a fortnight necessarily elapsed before the information was brought

H. F. BLANFORD:
Imperial Reporter,
1875-89.

together, the system still lacked the power to give current information to the public or to serve for daily forecast purposes. As a conscious step towards the transmission of weather reports, daily by telegraph the new departure was important, and a further stage was soon reached. After the droughts and famines of 1876 and 1877, Government's anxiety for the earliest possible information about the progress of the monsoon of 1878 led, in June of that year, to the institution of the Indian Daily Weather Report for which the 10 A. M. observations, 51 in all, were gathered by telegraph. The printed report was circulated to Government officials in Simla each following morning. This service, as originally sanctioned, was to terminate at the end of the rainy season, but it was found to be of such value that it received various temporary extensions, until in 1881 its permanent establishment was sanctioned in an improved and still more useful form. The improvements were intended partly to give effect to the recommendations of the Madras Famine Commission of 1881, which also prompted various fresh activities, among them the institution of the daily weather telegraphic summary, still circulated from Simla each day throughout the country; the collection at Calcutta and Bombay of current information on weather in the Indian seas as gathered from ships' logs, and the working out of a valuable series of observations collected by the English Meteorological Office from vessels sailing in Indian Seas and made over to the Indian Meteorological Department for discussion. These additional duties necessitated further staff, and a new officer, Mr. Dallas, was recruited from London mainly to reduce and discuss the marine observations, which were later embodied in monthly weather charts of the Bay of Bengal and of the Arabian Sea for the benefit of shipping. A few years later the first Indian officer of the department was appointed and trained to prepare the daily weather reports.

6. Meanwhile improvements were also being effected in the work of the provincial offices. A storm signal service was established for the Bombay coast in 1880; extensions were made in the Calcutta storm-signal service in 1881; and from 1883 two Daily Weather Reports, one for the Bay of Bengal and the other for the Presidency, were published regularly by the Bengal Reporter.

A fresh duty of practical value devolved upon the central office in 1885. This resulted from the destructive floods in the lower valleys of the Nerbudda and Tapti rivers in July of the previous year, of which the district officers received no warning in the absence of any organization to that end. The floods in these rivers, it may be noted, are usually the result of excessive rainfall accompanying the passage of cyclonic depressions in their westerly course from the Bay of Bengal. It is almost always possible to send ample premonitory advice of their approach, while immediate notice of actual heavy rain in the catchment areas also serves later as a warning for floods in the lower reaches of the rivers. Telegraphic warnings of probable and actual heavy rainfall to the district officers and political officers of Surat, Baroda, etc., were therefore arranged for in that year, and have continued ever since.

At this stage also, the first of the long and continuous series of Indian Monsoon forecasts was issued and published in the *Gazette of India*. Previously, tentative forecasts had been made by Wilson in 1874, by Eliot in June 1878 and by Blanford in 1882 to 1884. In 1885 the indications on which Blanford's forecast was based were more pronounced than in either of the preceding years, and the prediction which they seemed to justify, that the influx of the monsoon rains on the west coast and in southern and western India, generally, would be considerably retarded, was so fully borne out by the subsequent history of the season that confidence in the general validity of the method was much strengthened. The basis of the forecast was the connection which Blanford has discovered between snowfall on the Himalayas

and the incidence of the monsoon, a connection of sufficient interest to form the subject of a valuable paper by Blanford in the Proceedings of the Royal Society of London.

7. Blanford's most important work at this time was undoubtedly the series of annual reports on the meteorology of India (from 1876 to 1885), but he was also contributing many scientific papers to the departmental memoirs and other publications. The subjects of these papers show how largely his mind was occupied with the regular diurnal and annual meteorological changes in India. He considered that a full knowledge of these matters was of primary importance at that stage of development, and would throw valuable light on some of the most important features of Indian weather. He had at an earlier date written and published the "Indian Meteorologist's Vade Mecum", which was particularly intended to inform Indian observers what and how they were to observe. In order, however, to arouse an intelligent interest in their work, Blanford added, in Part II of that book, a most readable account of all the chief features of Indian meteorology so far as they were then known, with explanations based on the ideas of recent advances in physical science. The "Vade Mecum" was, indeed, practically the first treatise to place the ideas of the modern school of dynamical meteorology in an easily accessible form before ordinary readers. It was for many years the best book on modern meteorology, and was the forerunner of the numerous treatises on the science which have been published in the United States, Germany, and England. Blanford's last and most important work of investigation was the monograph on "The rainfall of India", published in the Memoirs of the India Meteorological Department. It was the outcome of years of labour spent in obtaining all the available data, and sifting out the doubtful from the trustworthy. The result of this investigation was to secure an accurate knowledge of all the broader features of the distribution of rainfall in India, and of the chief factors determining the law of that distribution.

Blanford left India on long leave in 1887 and retired on pension in 1889; but despite failing health, he continued, until his death in 1893, to devote himself with unwearied zeal to the discussion of problems in this his favourite subject. He presented, shortly before his death the chief results of his own and his co-workers' investigations to the English-reading public, in his very interesting book 'Climates and weather of India'. European meteorologists recognised almost from the first the great value of Blanford's papers and the high level of his scientific work: and his name will always be associated with the beginnings and development of scientific meteorology in India, while the rapid rise of the department under him furnishes eloquent testimony to his sound judgment, zeal and untiring energy.

8. John Eliot, who had been Blanford's successor, in the professorship of Science in Calcutta and in the post of Meteorological Reporter to the Government of Bengal, now succeeded also to the Imperial post. He had already acted in the appointment on one or two

JOHN ELIOT:
Imperial Reporter,
1889-1903.

occasions, and had been largely responsible for extensions in the Bengal meteorological system. His investigations into cyclones in the Bay of Bengal were well-known. In one of the earliest of these, a "Report on the Vizagapatam and Backergunj Cyclones of October 1876", in which latter cyclone about two hundred thousand people were drowned in a single half hour by a huge storm wave sweeping over the Island of Sandip, Eliot largely developed and extended the theory of the formation of cyclones. The publication excited unusual attention both in India and England; so much so, indeed, that a request was made in the House of Commons for the report to be produced and laid on the table. In connection,

also with his study of cyclones, Eliot had started the systematic collection in India of weather observations made by ships in the Indian Seas.

The pioneer stages in the development of the department on an imperial basis were by that time complete and Eliot was able to make rapid progress in consolidating the position and applying to practical ends the knowledge already gained. One of the first changes was the adoption of 8 A. M. in place of 10 A. M. as the hour for observations to be sent by telegram to Simla, Calcutta and Bombay, and by this change the publication of all daily weather reports was correspondingly accelerated. He discontinued in 1889 the 10 and 16 hrs. observations at 88 stations where careless work or imperfect instruments had been vitiating previous records; and thereafter these fuller records were maintained at only 69 stations where examination indicated the returns to be accurate and to form a reliable basis for scientific discussion in the annual report.

Important improvements were now effected in the methods of rainfall registration. Before 1887 the records of only 497 rainfall stations were received by the Imperial Government, while those maintained for Provincial Governments, totalled 1,390. Further, the measurements at these stations had been started provincially under the revenue authorities, and had never been systematised for India as a whole; so that there resulted a lack of uniformity in the hours and methods of observation as well as in the publication of results. A striking instance of the difficulty and inconvenience of dealing with unsystematised observations had cropped up earlier in connection with a question about the influence of forests upon rainfall. The rainfall statistics of the Central Provinces for the previous 20 years, if they could have been accepted as true, would have established most conclusively that the extension of forests had been accompanied by a marked increase in the average rainfall of the forest districts. But when Blanford made further enquiry into the value of these rainfall returns, the Chief Commissioner for the Central Provinces had to acknowledge that uncertainties about the gauges used in past years, and inaccuracies in registration, made the records quite unreliable. Unsystematic registration thus postponed a decision about the influence of forests on rainfall until, some 20 years later, the question was again tackled with records of undoubted value.

A uniform system of registration, inspection and publication was now introduced throughout India; all gauges had to be of standard pattern and were tested by the Meteorological Department before issue. Further, uniformity in method of publication by provincial Governments enabled the Meteorological Department to collect the rainfall data for the whole of India in annual volumes which have been of great service to irrigation and other engineering and sanitary officers, as well as to meteorologists throughout the world.

9. Up to this time no effort had been made to secure the co-operation of the larger Native States in meteorological work. Eliot visited Hyderabad in 1890 for that purpose and his suggestions received a ready response from His Exalted Highness the Nizam's Government, which established seven observatories within a year. The Mysore State also arranged about the same time to establish a local battery of stations. A first-class observatory, supplied with photographic self-registering instruments, was established at Bangalore, and smaller observatories at three other stations. A few years later the Kashmir Durbar cordially agreed to the establishment of four observatories, in addition to that at Srinagar, and these have furnished most valuable observations for an area where meteorology presents many unique features. The net-work of reporting stations was also extended in Upper Burma and into Persia. The Persian observatories were founded in the expectation, since completely

substantiated, that they would throw light upon the origin and march of the cold-weather depressions which bring winter rainfall to northern India and snowfall to the Himalayas.

The issue of a daily weather report in Bombay, the need of which had for long been pressed by the commercial public there and was prominently suggested during the enquiry into the loss of the Shepherds' steamer *Vaitarna*, was made feasible in 1889 by considerable annual contributions from the Chamber of Commerce and the Port Trust to cover part of the actual increased expenditure for staff. Four years later the unsatisfactory seasons and partial failures of the crops of 1892 and 1893 in the Madras Presidency quickened the interest of the Madras authorities and public in the subject of daily weather reports, and both the Government and the press expressed dissatisfaction with the meagre published statement on rainfall and weather in Madras, which was all that could be incorporated in the daily telegraphic summaries issued from Simla. The result was the institution from October 1893 of a Madras daily weather report, similar to those of Calcutta and Bombay.

Another series of published daily weather charts began in this year and was continued till 1899. In these was embodied information from the whole Indian Monsoon area, including land observations from India, Burma, Persia, Arabia, and several islands such as the Seychelles, with ships' observations for all parts of the Indian Ocean to the north of latitude 12° S. While found to be of considerable use to shipping firms and mariners, these charts were intended mainly for the study by meteorologists of the relations between the weather of India and that of the adjacent seas, and they have furnished important information regarding the advance of the great monsoon currents from the equatorial belt to their goal in north India, as well as of the perturbations at sea which are followed by "breaks" in the rains inland. Though publication ceased in 1899, the charts themselves were continued till 1904 for the internal use of the department.

Various improvements were made at different times in the storm signal systems (one in 1888 on the recommendation of the Court of Enquiry on the loss of the S. S. Sir John Lawrence), and ultimately in 1898 a single uniform system of signals was adopted at all the major Indian ports; from this system, which was rather too extensive and complicated for small ports and fishing towns, a set of three signals (modified since into the present "brief system") was chosen, as adequate for these smaller ports needing warnings only of storms likely to affect them directly. The efficiency of the storm-warning service was increased in 1896 by more rapid transmission of all telegraphic weather messages, special priority being then accorded to "storm" messages.

A large extension of the flood warning system was called for as a result of a remarkable series of floods during the southwest monsoon of 1889. The Public Works Department issued a circular to all its officers, as a result of which there was received a large number of applications for information of heavy rainfall and warnings of floods, chiefly in upper India. The flood warning system has continued further to expand until there are now some 200 officers, or more, on the warning lists.

Seismological observations by Milne instruments were begun at the major observatories in 1898 at the request of the Earthquake Committee of the British Association.

Eliot was greatly interested in the subject of solar physics and was instrumental in starting the Solar Physics Observatory at Kodaikanal, which in recent years, under the able directorship of Mr. Evershed, has contributed so largely to our knowledge of the 'meteorology' of the sun.

10. On the purely scientific side also Eliot was an indefatigable worker and contributed largely to the furtherance of the science of weather. During his connection with the Department he wrote no less than 50 original papers on various meteorological subjects. His early researches, as mentioned above, were largely concerned with extending our knowledge of the origin and progress of cyclones in the Bay of Bengal. The results of these investigations were embodied in a handbook which dealt in a comprehensive manner with the various features of these storms. The book was greatly read by mariners, went through two editions and has in all probability been the mean of saving many vessels—possibly from destruction and certainly from damage—by enabling their navigators to avoid the more dangerous parts of these cyclones. Of his later papers, possibly those on (a) the cold-weather storms of northern India, (b) oscillatory changes of long period and of short period in India, and (c) the hourly observations recorded at 29 stations, were the most important. The first of these discussed in an exhaustive manner the varying characteristics of the cold-weather storms and associated phenomena, and was described in "Nature" as "a model of scientific investigation". An interesting result of this research was the outline of a method, and the beginning of the practice, of forecasting the winter rains. The connection then found between the winter rains and certain previous barometric measurements (technically known as the vertical pressure anomalies) had been found, by an examination of available data, to hold good in four years out of five; but this relationship has not been confirmed by later experience. The second memoir indicated and discussed some possible methods of seasonal forecasting, while the third investigated the relations of the diurnal variations of the air pressure with those of other meteorological elements, and showed how far seasonal and local geographical conditions modify the amplitudes and periods of the diurnal oscillation.

11. Eliot's strenuous efforts to increase, as far as possible, the efficiency and usefulness of the department had thus met with considerable success, and had brought it into line with the best of meteorological organisations in other countries. He retired from service at the end of 1903 and was gazetted K.C.I.E. in that year.

After his retirement he was able to see through the press his last publication and the most valuable of all his works, "The Climatological Atlas of India," which a European review described as "a unique storehouse of the climatology of a great unit of tropical land, a magnificent acquisition, a very mine of meteorological relationships, for which we cannot be too grateful to the enlightenment of the Indian Government and the patient labour of Sir John Eliot and his assistants." Unhappily Sir John Eliot's death in 1908 prevented the completion of the "Handbook of Indian Meteorology" which he had planned as a companion volume to the Atlas.

12. Gilbert Thomas Walker, Fellow and mathematical lecturer of Trinity College, Cambridge, and Senior Wrangler in the Mathematical Tripos of 1889, succeeded Sir John Eliot on the 1st January 1904 as head of the department. In England Sir Gilbert's original work had been almost entirely in two fields, dynamics and electro-magnetism. His papers on *The Motion of Elongated Projectiles* (Proc. Roy. Artill. Inst. 1892), on *Dynamical Tops* (Quart. Journ. Math. 1896) and his paper *On Boomerangs* (Phil. Trans., Royal Society), had given him the reputation of an authority on this branch of dynamics, and led to his being invited to write the article "Spiel und Sport" for the great *Encyclopädie der Math. Wissenschaften*. His electrical papers began with a substantial memoir *Repulsion and Rotation produced by Alternating Electric Currents* occupying 50 pages of the Phil. Trans., Royal Society, for 1892. In 1900 he was awarded the Adams Prize by the University of Cambridge for an essay on *Aberration and*

other problems connected with the electromagnetic field, which was published later in book form; this was followed by a paper in the *Camb. Phil. Trans.* of 1881 *Some Problems in Electric Convection* and one on *The Optical properties of thin metal plates* in the *Annalen der Physik* for 1903.

Shortly after Sir Gilbert assumed charge of the department, the Secretary of State decided that the scientific activities should be widened and the staff increased. In place of one meteorologist at Simla and a second at Calcutta there were, from the beginning of 1905, three such officers at Simla. With this increased staff a more careful and critical examination of all telegraphic observations became possible, and soon led to considerable improvements both in the accuracy of the work of the ordinary observers and in the condition of the observatories. While the production of the Indian Daily Weather Report was thus accelerated, the telegraphic summary was made the chief mode of publication; it is now issued at noon as an urgent press message, to be posted up at telegraph offices in all the large towns of India, and is delivered as a telegram to subscribers of Rs. 10 monthly, now numbering some 50 or more in the monsoon season.

Changes were made in the routine work connected with the study of marine meteorology. It had been the practice to issue each month pilot charts of the Indian Seas, showing the mean pressure, wind and surface ocean currents as far beyond the equator as 12° S., and about 160 copies were commonly sold at 4 annas each. It was now decided to bind these monthly charts once for all in atlas form, with additional charts illustrating historical storm tracks in the several months, and some selected actual storms in detail; and Messrs. Bartholomew of Edinburgh undertook production. On publication in 1908 the atlas appeared to be greatly appreciated by the shipping community.

It has previously been mentioned that routine charts of the whole monsoon area—land and sea down to 12°, were drawn up daily from 1893 to 1904 by using observations extracted from logs of ocean-going ships. In the latter year it was felt that an attempt should be made to extend the area down, if possible, to the Kerguelen Islands, or in any case to include the far southern high pressure region where monsoon winds might originate. The meteorological offices in London, Hamburg and Mauritius were already collecting logs from many ships sailing through those regions, and arrangements were accordingly made for copies of the logs to be sent to India. To make use of this material, it was necessary to try weekly means instead of daily observations, as parts of the regions dealt with were but sparsely crossed by ships; this practice continued with poor results till 1906 when improvement was sought by adopting monthly means. An essential feature of the charts was to be the pressure distribution, and it is well known that ships' readings of the barometer tend to be bad unless a close touch with ships' officers can be maintained, and interest in accuracy induced. Such 'touch' was necessarily absent with the weakness of meteorological staff; and in the result this work, with all its potential usefulness in seasonal forecasting, had to be relinquished.

13. At about this time there was a rapid growth in the departmental correspondence. Requests for information of a general or statistical character began to come in from officers interested in the relation of weather and disease, weather and agriculture, and such other practical matters, as well as from firms wishing to start factories under special conditions; while enquiries about meteorological subjects, books, instruments and methods of observation became very numerous. The work involved in answering such questions is sometimes very considerable.

As a result of the great Dharamsala earthquake, the seismographs which had been put up at major observatories in 1898 were supplemented in 1905 in Simla by an *Cimori-Ewina* instrument loaned by Professor Cimori; and subsequently others

of this type were obtained and set up in Colaba, Calcutta and Simla. Schedules of all instrumental measurements have since then been supplied regularly to the Seismological Committee of the British Association, and a systematic collection of notes on earthquakes, as felt by observers in India, has been made for the Geological Survey of India.

Original investigations were now begun on various new problems, and many of them were dealt with by Sir Gilbert himself. An account of these is given below as a review of his contributions to meteorological knowledge.

Research work was undertaken on the experimental side of meteorology. A small laboratory and workshop had been provided in Simla, and two mechanics were regularly employed. Dr. Simpson investigated the electric potential gradient in Simla and carried on systematic observations on the electricity of rainfall, which led to valuable results. For he found the long-sought cause of thunderstorm formation, and showed that it lay in the breaking up of drops of rain carried upwards by air currents, and the consequent formation of a strong positive charge on the rain, with a negative charge in the air. His memoir on this subject (Indian Meteorological Memoirs, Vol. XX, part 8) is now regarded the world over as a classic.

14. A beginning was now made on meteorological measurements in the upper air. As early as 1877, H. F. Blanford had clearly recognised the need of enlarging the scope of measurement by freely employing small observation balloons, and had published his view that with such means in India, a few years would suffice to place our knowledge of meteorological laws on a very advanced footing. For this work he considered India to be the one country in the world most suitable; the northern boundary of the high Himalayas, and the southern boundary of flat and unvarying barometric pressure in the equatorial zone forming almost impassable meteorological limits to the immense range of 30° of latitude under a nearly vertical sun.

Later, his successor, Sir John Eliot expressed similar views on the necessity to undertake such work, and indeed was instrumental at his retirement in making provision for this object. A very strong advocate was C. Little, the official meteorologist in Bengal, who in a series of papers in the Journal of the Asiatic Society of Bengal, 1903-04, insisted with the greatest vigour on the immediate need to work with balloons, and elaborated his reasoning for attributing the want of departmental success in seasonal forecasts to the practical neglect of what Blanford had laid down 20 years earlier as a *sine qua non*. Little himself had sent up some small balloons in Calcutta, and had at once found them helpful in verifying points on air circulation in Bengal, to account for weather variations.

In 1905, then, such work was definitely begun, though as yet without any allocation of funds for systematic study. A kite-wire winding machine and kites of various shapes were made, and first tested in action during August and September 1905 at Karachi. Their purpose was to lift recording meteorographs, light instruments which registered on a diagram the varying pressure, temperature and humidity of all the air layers they passed through. They were either fixed within the kite itself, or made to run up and down the kite wire during the flight. The kites were used again the following year at Belgaum during May and August, when information was obtained of the air conditions in the Peninsula previous to and during the monsoon, from the ground level up to a height of 11,000 feet above the sea. Similar observations were made at Belgaum in the monsoon of 1907, and from a ship in the Bay of Bengal and the Arabian Sea in August and September 1907.

Another type of light recording instrument for attachment to free balloons was copied by Indian mechanics, with minor changes, from the excellent model developed in England by Mr. W. H. Dines. The class of recorder which had been used till

then in Europe was a comparatively heavy and very expensive instrument, unsuitable for use in India where a large proportion of total losses was expected; the light Dines' model was then the only one that could be made at a cost to suit this country. In a first trial of these in September and October 1908, in Jhang (Punjab), 11 were recovered out of 17 released. All but one contained good records, the greatest height reached being 65,000 feet above sea level; and there were in three cases thought to be signs, perhaps a little doubtful, that the strange upper region of constant temperature, found first in Europe and now looked for in India, was penetrated three times. In the following year, 17 balloons with instruments were liberated at Jhang during the monsoon months, June and July, and 7 in December, of the first set more than half were recovered, but only one of those in December. The heights reached during the monsoon ranged up to 12 miles, with a lowest temperature of about -107°F . and the descents occurred at short distances from Jhang, in several cases within 10 miles of the starting point. The balloons in December all travelled eastward, and their horizontal velocities indicated very strong winds a few miles above the ground surface. The one instrument recovered had only reached the 6 mile level, with a lowest temperature of -35°F ., but it came down as far away as Lahore. With the knowledge which we now possess of the strong upper-air winds in the cold weather, we may be certain that the remaining instruments were carried into the Himalayas or Tibet, and that, but for some defect in the balloon which touched ground in Lahore, no one of the seven instruments would have been heard of again.

A feature of the ascents in the monsoon was the liberation on two occasions of a pair of instruments together on the same balloon, in order to contrast the records of an associated couple and ascertain to how great an extent the traces could be relied upon to represent actual conditions. This question had assumed some importance in consequence of doubts which had been expressed by scientists at home as to the capabilities of instruments constructed so lightly as these must necessarily be. One pair was recovered, and the two independent records were found to agree as well as could reasonably be expected.

15. All these were preliminary essays in upper-air work, the funds available having been inadequate for any serious tackling of the problems in view. But in 1912, on the insistence of the Secretary of State, to whom the Royal Society had sent a protest on the department's lack of means, a real, if small, allotment was definitely made, and very rapidly used to build and start Agra Upper-air Observatory, and begin work there and at several outstations, with observation and instrument-carrying balloons. Electrical plant was put down for the making of hydrogen, and its compression into cylinders for transport about country, and has been kept working continuously since. The greater part of the observational work has been on free pilot balloons, of 2' or 3' diameter, watched by measuring theodolites, and a very great deal of useful information has by now been gathered as to the prevailing currents at all heights up to 30,000', and in all seasons, over the northern half of India and at one station, Bangalore, in S. India by the valued assistance of the Government of Mysore. Some thousands of these simple observation balloons have been made and sent up, and this work has already gone a long way towards establishing definite normals of wind data, and showing reasons, not observable at ground levels, for the character of coming winter rains, of breaks in the monsoon rains, and even (though at present to a less extent) of the character of a coming southwest monsoon. The daily results up to 20,000' are telegraphed to Simla from 7 selected stations, and much used in daily weather forecasting. The memoirs that have been published on this work (I. M. M., Vol. 20, parts 1, 2, 7; Vol. 22, parts 4, 5; Vol. 23, part 3; Vol. 24, parts 5, 6, 7, 8) will give an idea of how earnestly the

small facilities available have been used, and how fruitful have been the immediate results. A critical review in "Nature" (Sept. 1924) of the later ones of this series of memoirs ended with the remark:—

"Dr. Harwood finds a very noticeable coincidence between the track of storms and depressions, as shown in the Climatological Atlas of India and in the Meteorological Atlas of the Indian Seas, and the monthly mean directions of the upper winds at the cirrus level. If this be more than a coincidence, and it seems to be so, it has an important bearing on the formation and propagation of cyclones, and shows that their source must be sought for in the upper winds rather than in the surface conditions.

The four Memoirs form a very valuable contribution, not to Indian meteorology only, but also to meteorology in general."

It will be seen that a new point is recognised as possibly emerging from this upper-air work, that of the cause and amount of a cyclone's recurving in its destructive course at sea.

A second review of these papers by the American Meteorological Society, in December 1924, draws public attention to the very remarkable results found for temperature distribution in the upper air of the monsoon: in any future method of forecasting the rainfall amount and distribution during the course of a monsoon, it is fairly certain that the essential measurements will be temperature and humidity distribution upwards to some 4 miles height. These measures are so far only being taken systematically at Agra: it remains to extend them to several other stations in India.

16. Reverting now to the period 1905 to 1909, it has been shown that the appointment of new scientific staff was productive of much new knowledge of importance, and that the work of those years set a standard for India in fields of new activities. But unfortunately the maintenance of these promising beginnings was thereafter handicapped for one reason or another, and has continued so right up to the present time. The departure of Dr. Simpson on Scott's South Polar Expedition in 1910 and the subsequent resignation of Mr. Patterson, followed by illness among the remaining officers, led in a period when routine work was with difficulty kept up to date and research work became impossible. Pressure from the financial side then threatened to make the temporary shortness of staff a permanency, and necessitated the cutting down of the routine work to the very lowest limits consistent with efficiency in the principal objects of immediate utility. Observatories were reduced, or abolished wherever possible, and only a barely sufficient network of stations maintained over the country to provide information of the major changes in the weather situation from day to day. The more purely scientific work suffered grievously, and all attempts at improving methods of forecasting and storm warning, or gaining more insight into Indian weather were temporarily abandoned. It seemed, in fact, that any scientific enquiries with the object of improving practical methods would be rendered impossible, and that the work of the department would be confined to the mere supervision and publication of meteorological statistics. Happily, this disaster was averted, and at the overruling instance of the Secretary of State sanction was given in 1912 for a return to the original number of officers' posts and at the same time the systematic scheme of enquiry into the meteorology of the upper-air, which has been briefly described above, was considered and sanctioned. A dole of three lakhs was granted to cover 10 years' work under the charge of two officers whose services were to be devoted entirely to this purpose. The scheme was to be put into operation

in the financial year 1913-14, when the two officers, transferred their headquarters to Agra and began work in the new upper-air observatory there. By the beginning of 1914, therefore, the outlook for the department was again, perhaps showing some glimmerings of hope. But, no sooner had the staff settled down to the new regime than the Great War called for officers, and the years 1916 to 1919 formed a period in which part of the routine work, e.g., the preparation of *Monthly Weather Reviews* and *Annual Summaries*, as well as the examination and compilation of upper air results, had to be allowed to fall into arrears. Practically the only attempt at scientific work, at this time was the engagement of part of the clerical staff on a programme of computation, which Sir Gilbert Walker was later able to utilise in a series of important papers, to be referred to later. In 1920, when some recovery from the effects of the war was hoped for, the department suffered a serious double loss in the death of Rai Bahadur Hem Raj, who possessed a unique knowledge of Indian weather, and in the resignation of Dr. Simpson, who had been appointed Director of the British Meteorological Office under the Air Ministry. In the following year, two more officers resigned, namely, Dr. Harwood, who was offered and accepted a post under the English Meteorological Office, and Mr. Chinmaynandam, who reverted to the Accounts Department. Both of these resignations resulted from dissatisfaction with inadequate pay and prospects. In a scientific department the efficiency of which is so completely dependent on the maintenance of trained staff, these losses were serious and disheartening, and it was with the greatest difficulty at times that the skeleton routine work of the department could be carried on.

17. Hitherto all the gazetted officers of the department had been recruited on personal rates of pay; there was no cadre of officers on a uniform pay scale as in other services. This was now remedied by the institution of a Meteorological Service, Government at the same time deciding that it should be Indianised as far as possible, and suitable Indian officers were appointed in 1922 to the four existing vacancies. All difficulties were not yet over, however. Financial stringency was by now dictating a policy of retrenchment on all departments of Government and, despite the already restricted activities of the meteorological department, and without regard to the fact that for several years complete collapse had barely been escaped, the department also was instructed to fall into line. Although the main items of expenditure, telegraphic costs and pay of establishment, had been burdened by a doubling of the telegraphic rates and establishment costs since 1914 yet the departmental budget, which stood at 5 lakhs in that earlier year was limited, to 6.2 lakhs in 1923-24. One of the gazetted officers' posts at Kodaikanal was abolished, a proceeding which has imposed on the output of research work from that observatory a restriction which is quite out of proportion to the savings effected. It was possible also to make a few retrenchments in establishment, and by drastic reductions in the free distribution lists of the various weather reports; but the main curtailment of expenditure had to be effected in telegraphic charges. In consequence the periods of issue of the Calcutta, Bombay and Madras reports were shortened to 10, 6 and 9 months respectively, and the number of stations reporting daily to Calcutta and Madras was greatly curtailed. Vigorous protests against many of these measures have been made by the Press, and by various associations such as the Chambers of Commerce of Bengal, Bombay, Madras and Narayanganj, the Associated Chambers of Commerce for India and the Association of Marine Insurance Agents. The Committee of Inquiry on the loss of the S. S. "Okara" also criticised the new retrenchment arrangements in so far as they involved the issue of storm warnings for the Bay from Simla instead of from Calcutta. One by one, most of these retrenchments have been found to have been mistakes, and there is now no question that the blind application of general instructions to reduce expenditure, to a department which has always lived at the lower limit of outlay, was a very ill-advised step.

During all this period, 1909 to 1923, comparatively little change except reduction, had taken place in the routine work of the department, and the main new activity lay in research work at the Agra upper-air observatory as outlined above. But one other matter deserves notice. In the years 1913 to 1915, the storm warning service for ports and ships at sea had been thoroughly discussed, and a new uniform and simplified code of signals applicable to all Indian and Burman ports had been introduced. At the same time regular transmission of weather bulletins by wireless to ships at sea was arranged for, and a start was made in the early part of 1914 with the receipt from ships at sea of coded weather messages in the hope that the accuracy of our warnings in the case of storms far out at sea would be improved. This was another line of activities necessarily stopped by the War, but the scheme was taken up again in 1920 and, although the response from ships has not been as frequent as the department would wish, it is steadily increasing and there is every likelihood of a really active co-operation in the near future between the department and the shipping community, which will result in a very efficient warning service.

18. A review of Sir Gilbert Walker's contributions to meteorological knowledge will form a fitting finish to this fifty years' history; and in view of his recent retirement his work may be dealt with more fully than that of his predecessors.

At the request of Government he prepared a report in January 1908 dealing, on purely meteorological evidence, with the question of supposed changes of climate in India. The comparative weakness of the monsoon in northwest India after 1894 had from time to time given rise to conjectures that the climate in that region had altered permanently, and various hypotheses such as increase of irrigation or diminution of forests had been put forward to account for the change. An analysis of the evidence led Sir Gilbert to the conclusion that the spell of deficient monsoon rainfall in central and northwestern India ought to be attributed to something abnormal in the larger movements of the atmosphere and not to human agency in India; the deficiency had not lasted long enough to justify a verdict of permanent change of climate; and there were marked indications of an impending return to good seasons. The years since 1908 have fully supported these conclusions.

Another interesting report was presented to Government in 1910 on the question of the liability to drought in India as compared with other countries.

19. But the main problem which faced him was that which had faced his predecessors—the problem of forecasting the monsoon rain fall. He soon noted that the graphical methods which had hitherto been employed for estimating the relationship between monsoon rainfall and other factors were open to objection, because, when disturbing factors are numerous or the connection sought is slight, the same curves may be variously interpreted by different authors. Sir Gilbert therefore brought to bear upon his problem the statistical method of what is known as the “co-efficient of correlation”, a method that gives quantitative instead of merely qualitative results and is free from subjective influences. He also considered it necessary not to limit his enquiries to the Indian monsoon region but to take the whole world for his field of search for correlated factors, and was content to leave for subsequent work any attempts to obtain physical explanations for the relationships that should be found. In 1910 there appeared the first of a series of departmental memoirs on the statistical examination of such relationships. Though barometric pressure in India was found to be strongly correlated contemporaneously with the amount of monsoon rainfall, the connection with Indian pressure in May or in earlier months was found to be very slight. The association with Indian temperature in May was also examined. Since the heating up of the lands of south Asia is a fundamental portion of the mechanism that brings the moisture-bearing winds northward over

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the equator to India, it was popularly believed that years of high temperatures in May would be years of abundant rain, and *vice versa*. But the data do not confirm any conclusion of the kind, either when the temperatures over India as a whole or when those of the northwestern regions only are considered; and Sir Gilbert concluded that the paradox might be ascribed to our ignorance of temperatures in the upper layers of the atmosphere.

When at a loss for an explanation of failures in the Indian rains, several writers had put forward the suggestion that an abundance of icebergs in the south Indian ocean would probably have a marked effect on the sea temperatures and so have a determining influence upon the monsoon. An examination of the information about ice as recorded by ships, did not however support the suggestion. On the other hand, the ice data of the south Atlantic ocean were much more promising, for they emphatically suggested that years of much ice off South America tended to be years of high pressure in the Argentine and Chili and of good rainfall in India.

The origin of monsoon forecasting, as already noted, lay in Blanford's discovery that late and heavy snowfall in the mountains to the north and northwest of India was prejudicial to rainfall in northwest India; Blanford had also recognised that associated with late snowfall were high pressure in the neighbourhood of Gujarat, and northwesterly winds over northwest India. With the data which had accumulated since Blanford's time, Sir Gilbert was able to subject this question to a critical statistical examination and conclusively showed that the snowfall accumulation at the end of May, and not the amount which actually falls in May, is the important factor. Turning his attention now to extra-Indian factors Sir Gilbert considered that the connections with pressure at Mauritius and rainfall at Zanzibar in May, and with pressure in South America in April and May, were sufficiently pronounced to justify their use, along with the snowfall factor, in a forecast of the monsoon. The relative importance to be attached to each factor was assessed statistically and expressed in the form of an equation, which could be applied by anyone and was free from personal bias. It was recognised that by no means all the factors affecting the monsoon had been discovered; other potent factors, unknown and unassessed, might upset the forecasts. All the more interesting therefore was it to find, on examination 13 years later, that the indications given by the 1910 formula had been fairly definite in eight years and been of the right sign in seven of these eight years. In these early memoirs similar methods were applied to determine the relationship of the Nile flood and Australian summer rainfall with other meteorological factors; and statistical formulæ were given as guides for rough forecasts of these two phenomena.

In later years further progress in the solution of the monsoon problem was made by considering the local distribution of monsoon rainfall. Excessive rain in April and May at Zanzibar, which is close to the path of the Indian monsoon winds, appears to be prejudicial to the rain from the Arabian Sea monsoon; but, like snowfall, it has no influence on the rains of Burma and N. E. India, which come from the Bay monsoon. Similarly excessive rain at Seychelles in the path of the Bay monsoon is prejudicial to the rainfall brought by that monsoon. Improvements in forecasting were attained by considering Burma, N. E. India and S. Madras separately, and dividing the bulk of India into two areas, the north-west region and the Peninsula, each fairly homogeneous in its dependence on external factors. By 1924 several other important relationships were discovered, notably the favourable effects of low pressure at the Cape in the previous spring months, deficient rainfall in the preceding rainy seasons in Rhodesia and Java, and low winter temperatures in the Aleutian Islands.

The problem of forecasting at the beginning of January the subsequent winter precipitation of northwest India was tackled in a similar manner; the factors ultimately adopted for use for this purpose being the preceding precipitation in northern India, Persia, the Anlamans and Zanzibar, and barometric pressure and rain at the Seychelles. In short, before his retirement Sir Gilbert had examined most of the available meteorological data from all corners of the earth for the light they could throw on the Indian monsoon and winter rains; and it is clear that any considerable further improvement in such methods of forecasting must await the tabulation of the rainfall of large areas like Australia, America and Africa and the accumulation of data from Antarctica and the upper air.

20. While the investigation of the relationships between the Indian monsoon rainfall and extra-Indian factors aimed primarily at improving the monsoon forecasts, it also led incidentally to the accumulation of a great deal of information concerning world-wide variations of weather. On collecting these together, since all weather operations may be ascribed ultimately to energy from the sun, it was natural in the first place to consider how far the variations were controlled by variations in numbers of sunspots. In the year 1915 three memoirs were published dealing with the connection of sunspots with rainfall, temperature and pressure all over the earth; and the question of the effect of the sun as a direct control of weather was again reviewed in a paper in 1923. Authorities are agreed that increased spottedness of the sun is generally accompanied by increased solar radiation. It is remarkable therefore that a period of sunspot maximum is accompanied, on the average, by a fall of temperature, particularly in tropical regions. The relationship between sunspots and pressure turned out to be very slight, and not in the same sense for the whole earth, increased spottedness leading on the average to increased pressure over the Western hemisphere and decreased pressure over the Eastern. Rainfall is affected irregularly but in general the relationships of sunspots with rain are opposed to those with pressure. On Indian cloud, sunspots exert apparently a slight stimulation except in the hot weather months, April and May. For the sunspot-temperature relationship a plausible explanation is afforded by supposing sunspots to cause higher temperatures in the upper air over land areas, inducing indraught of sea winds with increased humidity and cloud and so producing a lowering of temperature at lower levels. The increase in humidity, however, would also call for either increased temperature or increased wind velocity over the oceans, and neither of these results appears to be specially associated with sunspot maxima. Further, the negative correlation between temperature and sunspots is found to persist even when the effect of rainfall on temperature is allowed for. We are forced therefore to imagine that an increase of sunspots somehow causes greater opacity to heat in the atmosphere through some agency not associated with rainfall. On the other hand, the correlation between the American solar radiation measures and temperature is generally positive, but small. The whole discussion finally led to the verdict that the widely prevalent idea of seasonal weather variations being directly controlled by variations in solar radiations is erroneous. As a definite example, there is nothing obvious in solar physics to explain, without reference to previous terrestrial conditions, the contrast between the biggest Indian monsoon on record in 1917 and the monsoon in 1918 which has only been surpassed in scantiness twice in the last sixty years.

The key to the variations of terrestrial weather must therefore be sought within the atmosphere itself in the previous distribution of weather abnormalities. Sir Gilbert's study of world weather from this point of view has been described in two departmental memoirs, both rich in suggestion and so concisely full of facts that they hardly bear condensing into a short description. The quarterly means of pressure and rainfall at some 20 centres over the earth were all correlated one with another, not only for the same season but for one quarter and two quarters

before and after. In all, over three thousand correlation coefficients were worked out and tabulated, so that the papers laid down a thorough foundation for long range weather forecasting in all parts of the world. The generalisation which emerges from the mass of detailed information is that

“ there is a swaying of pressure on a big scale backwards and forwards between the Indian Ocean and the Pacific Ocean, and there are swayings on a much smaller scale between the Azores and Iceland and between the areas of high and low pressure in the North Pacific; further, there is marked tendency for the ‘ highs ’ of the last two swayings to be accentuated when pressure in the Pacific is raised and that in the Indian Ocean lowered.”

Attention has frequently been devoted by European meteorologists to the mechanism of the oscillation in the north Atlantic where an accentuated pressure difference between the Azores and Iceland in autumn and winter is associated with a strong circulation of winds in the Atlantic, a strong Gulf stream, high temperatures in winter and spring in Scandinavia and the east coast of the United States, and with lower temperatures on the east coast of Canada and the west of Greenland. The larger scale oscillation between the Pacific and Indian oceans, briefly named the “ southern oscillation ”, is shown by the tendency of pressure at stations in the Pacific from Tokio to South America, and of rainfall in India and Java (presumably also in Australia and Abyssinia) to increase, while pressure in the region of the Indian Ocean diminishes.

The mechanism of this oscillation is difficult to understand. It was noticed that the opposing areas in the oscillations were strongly reminiscent of the areas of positive and negative correlation coefficients shown on the chart in the earlier memoir on sunspots and pressure, already referred to. Since the influence of the sun as a direct control has already been ruled out of account, the meaning of this similarity must be that “ variations of world-weather tend to occur in a definite manner, i.e., to be associated with definite swayings or surges of pressure, and that changes in solar conditions tend to favour or check these weather changes.”

In the search for the cause of these slow swayings of pressure, the most suggestive relationships are those of winter pressure in south America, the changes in which usually precede changes elsewhere; and the natural inference is that south America is either one of the original controls or is connected directly with it. After an exhaustive examination of the possibility of the relation depending on a sea current, sometimes comparatively warm, at others comparatively cold, leaving south America in winter, Sir Gilbert finally summarises his discussion thus—

“ The natural view is that positive departures in the first group and negative in the second suggest an increase in the general circulation; but this theory is not free from difficulty, and the fuller information now available shows that the explanation of the reversal between the S. Pacific and the Indian Oceans does not lie wholly in the cold currents from the Weddell Sea to the Cape; for there are controls of South America in the first half-year by previous pressure conditions at San Francisco, the Cape and probably in India, and these controls include reversals just as those exercised by South America. Conditions in the area of the Indian Ocean affect each other closely, but they exercise comparatively little influence on the region of the Pacific Ocean. It may be that the solution of the general problem will not be found until we have a score of years of monthly means of Antarctic and upper air data available.

"There are however grounds for satisfaction in the consistency of the relationships ascertained. If we examine the 150 significant coefficients between the 11 representative centres we shall find that the classification just given directly explains the sign of 149 of them. The solitary exception is the negative effect of Java rain (October to February) upon the Peninsula rain of the succeeding monsoon. This consistency is very remarkable and supports the view that seasonal forecasting is capable of wider application than at present. For the amount that appears capricious in the relationships is materially less than might have been anticipated; so that when the departures from normal of different regions used in forecasting the rainfall of a country point in the same direction and are strongly marked, there is the greater reason for expecting that the conclusion indicated will be realised. To this argument may be added that the rainfalls of Java, India and Rhodesia appear to have far-reaching influence, largely independent of that of the pressures in these areas; and there is every reason for hoping that the tabulation and publication of reliable series of the rainfall of other large areas, in Australia, America and Africa, will have important results".

21. This note on Sir Gilbert's contributions to Indian and world meteorology may conclude with an extract from an appreciation of his work by Captain Brunt, a meteorologist in the British service.—

"Dr. Walker's discussion of the seasonal variations of world-weather form the most complete discussion of the subject which is available at the present day. In the future it will be possible to supplement this work by the investigation of observations made at other places where observations have not been hitherto available.

"The value of the papers, which represent many years of continuous and strenuous work on the part of Dr. Walker, can scarcely be over-estimated. Quite apart from their direct application to the forecasting of the monsoon rainfall and the light which they throw on the physical causes of variations of weather in India, they establish some very interesting and important relationships between the seasonal changes of weather in different parts of the globe. Whether these changes should be regarded as pure oscillations of the general circulation of the atmosphere in the ordinary sense of the word oscillation, is doubtful. They are possibly oscillations which after a time are damped out and may later be brought back into being with a different phase. And it is on account of this possibility of a change of phase that the method of correlation coefficients adopted by Dr. Walker is superior to the method of harmonic analysis at the present stage of our knowledge. Dr. Walker has shown, as no one else has ever done, how very powerful an instrument for scientific investigation of the earth's atmosphere is afforded by the method of correlation. He has now brought his investigation to a stage at which it is profitable to discuss the results from a purely physical standpoint, as opposed to the statistical method, and the last paper by him to which reference is made above is the beginning of this stage".

22. The foregoing history of the department in Sir Gilbert Walker's time has shown that despite many handicaps, a very material advance has been made during the last 20 years in most branches of our knowledge of Indian and world meteorology.

Indeed it may confidently be claimed that in the face of much that *some years ago* resembled official discouragement, a very high "yield" has been returned for *outlay* and opportunities which were totally inadequate considering the importance of the objects in view.

Sir Gilbert retired from service in December last; he was gazetted C.S.I., in 1911 and Kt., in 1924. For him personally the whole department retains the liveliest affection and regard: his kindly sympathy *tided over* many a period of depression in work, and his enthusiasm, strong sense of reason, and grasp of the true bearings of emerging results were responsible for the noteworthy advances which marked his régime.

23. This short survey brings the department up to the present time, and it is advantageous to summarise the position as it now stands, and to define what is necessary for the future if the department is to make progress in matters ripe for attention.

With existing strength of headquarters staff little more is possible than to keep up mere routine work in a scrambling and unsatisfactory manner. No time is left to officers for such progress as in other countries is regarded as essential in these times. We have to look forward to the certainty that aerial transport is coming east to stay, and India is to reap the immense advantage of being on the direct Empire route to Australia. It is imperative not to be caught unready with upper-air data when that time arrives within the next few years, but the present provision of balloon stations shows poor recognition of this point. In this connection it may be mentioned that in 1918 the balloon station at Lahore was started with the foresight that frontier flying would shortly demand upper-air normals; and fortunate indeed it proved, within a few years, that this had been done. Immediate steps are called for now to set these fresh matters right, and the undertaking is not expensive in comparison with the value of the work to be done. Representations on both staff strength and increase of balloon stations in India are before Government, and it is hoped that the remedies suggested will be found practicable.

Then again there is the difficulty of headquarters location. For 50 years the department has been bundled through a series of temporary quarters in Simla, and is now packed into a building totally unsuited to many of the new activities demanded: the need is to remove headquarters from Simla to the plains, to some place in the direct line of the monsoon where officers can, as they cannot now, get personally busy on research to improve knowledge of upper-air monsoon conditions with a view to accurate forecasting. Proposals on this point are before Government. As regards the actual location Poona suggests itself as suitable, and with the present Agra observatory continuing to speak for the upper-air conditions of northern India, and Poona for the south, it will only be necessary later to adopt a third, but quite subsidiary, experimental station in northeast India for a triangle of major observation to have been obtained, and a great advance to have been secured.

REPORT ON THE ADMINISTRATION OF THE METEOROLOGICAL DEPARTMENT OF THE GOVERNMENT OF INDIA IN 1924-25.

CHIEF FEATURES OF THE YEAR.

The present year completes a half century since the department was constituted on a centralised system, from the originally independent and fragmentary services in provincial areas : and it has seen the retirement of Sir Gilbert Walker, who for some 21 years has very ably directed the policy and work of the department. To mark this stage in the department's history and development, the ordinary annual report has been prefaced by a historical review up to the year 1924.

2. The year under review was marked by considerable activity, made possible by a budget allowing of liberal inspection tours, which have been out of the question on any adequate scale for many years past, and by the relief afforded by the growing acquaintance of our Indian officers with the administration of the department.

3. The measures which were taken in 1922-23 to share in the scheme of severe retrenchment required by the Government of India have not in all cases turned out happily, and it appears now, in the light of experience, that more was attempted than was advisable. So many and vigorous were the protests from public and other bodies in regard to the reduction of reporting stations for the Bengal Daily Weather Report, the stoppage of the Report itself for a part of the year, and the transfer of cyclone-warning duties from Calcutta to Simla, that it was found necessary materially to reduce the measure of retrenchment intended by reverting in some cases to prior practice and expenditure. Perhaps the strongest protests came from the Chamber of Commerce of Bengal, who objected to nearly every step which has affected non-official Bengal ; and in addition to securing acceptance of certain of their minor points, continued to urge Government to reconsider their most insistent demand that the work of cyclone-warning shall be returned from Simla to Calcutta.

4. Such incidents draw attention to the public utility of the department, a utility seldom realised outside the ranks of those who immediately benefit, and only perhaps by them when the benefits are themselves threatened with foreclosure. It is certain that the functions of cyclone and flood-warning alone, though not directly of a revenue producing type, are from time to time the means of saving immense sums to the country, and by themselves constitute a claim to adequate financial treatment, when lines of meteorological advance affecting them are being hampered by lack of funds.

5. During the past year the services of cyclone warning to ports and shipping, and of flood warnings to officers in the irrigation, railway and other departments, were carried out as well as present conditions allow.

The period was marked by heavy localised rainfall causing destructive floods from time to time in various parts of India, but the sea areas were unusually free from severe storms. Warnings for the Arabian Sea were issued during the year on 21 occasions. No storm occurred in this sea area and the warnings were generally for squally weather due to advances of monsoon, and for western depressions which, in passing through Baluchistan and Rajputana, caused rough weather on the coasts.

For the Bay of Bengal warnings were issued for 35 periods of disturbed weather ; the disturbances developed into storms during 5 of these periods, and into a cyclone during one.

6. An outstanding need for improving accuracy of cyclone-warning is to secure co-operation of ship commanders at sea in the matter of wireless communication of certain standardised sets of meteorological observations. The wide distribution of the printed codes of the department for this purpose has been found ineffective in the absence of such goodwill as can only be secured by suitable resident representation in Calcutta.

With a view, however, to make the best of the present crippled condition of the department, a beginning was made during the year under review with the policy of interesting individual ship commanders by supplying on personal loan reliable instruments for shipboard use, in return for regular weather messages and for special observations when called for by the department. Two good barographs have thus been supplied to the two mail steamers on the Madras-Rangoon run, and the results obtained show that the expenditure has been justified. Any considerable or really effective extension of this policy cannot, unfortunately, be undertaken unless the gazetted staff in Calcutta and Simla is increased.

7. Work continued throughout the year on precise measurements in high-level winds at the Agra headquarters of the upper-air system and the eight outstations of India and Burma; and an expedition of three observers and equipment worked in Jask, on the southern coastline of Persia, during the monsoon and winter months.

The Agra Upper-air Observatory was started in 1913 on a temporary basis with sanction for 10 years, and as a result of the very solid advantages gained from its investigations, was made permanent, with part of its staff, in 1924.

A branch of its utility lies in association with Army Headquarters to provide for the needs of Artillery and Royal Air Force. This connection becomes closer year by year, and involves, therefore, an increasing amount of incidental work outside the purely meteorological objects of the observatory. Thus as a result of a request by the Royal Air Force reading:—

“I have recently flown round from Delhi to Peshawar, Quetta and Delhi and have used 3 of your forecasts.

All 3 were remarkably correct in every detail. Please allow me to congratulate you on these results.

I want the Royal Air Force to use your forecasts much more freely both for travelling flights and for operational work. Can you let me know whether you can supply these as required?”

such forecasts on demand were promised by the Simla Meteorological office, to be based partly on regular or extra observations at upper air stations.

The character of the co-operation of Agra with the Artillery has been mentioned in previous annual reports, and with regard to the Royal Air Force, consideration was given by Government to questions of relative incidence of work and expenditure between the Royal Air Force and the meteorological department in a scheme for satisfactory co-operation on the frontier.

8. Assistance from our Simla and Agra offices and their upper-air outstations was asked for, given, and gratefully acknowledged on the occasion of the U. S. A. flight and Squadron Leader Maclaren's flight through India. The acknowledgments indeed, were couched in terms which increased even the Department's own realisation of the essential necessity of current upper-air information in any flying service in the East.

9. In general it may be said that such physical experimental work as Agra undertakes on upper-air conditions is now regarded the world over as the next essential to meteorological advance. In India especially it is necessary; and, given

proper facilities, it is likely to form in future the most active part of the programme of this department. On this account there has for some time past been a realisation that a really live headquarters of this department must in future be stationed in the plains, at some place where typical conditions of Indian weather prevail, and that a move from Simla was called for. Northern India, with its hazardous contact with the monsoon, is well represented in this matter by Agra, and a proposal to move headquarters from Simla to Poona, in the direct path of the more vigorous monsoon fresh from the Arabian Sea, and there to provide adequate means for this newer type of work, was put before Government.

10. In matters of research and publication we had the work of Sir Gilbert Walker, now issued in the departmental Memoirs,

Correlation in seasonal variations of weather, IX—A further study of world weather.

Correlation in seasonal variations of weather, X—Applications to seasonal forecasting in India.

Monthly and annual normals of rainfall and of rainy days, (from records up to 1920), and

Frequency of heavy rain in India.

In the press, also, was an atlas by Dr. Normand, of storm tracks in the Bay of Bengal, brought up to 1923 inclusive.

LEAVE AND APPOINTMENTS.

11. Sir Gilbert Walker went on 6 months' leave preparatory to retirement, from 14th June 1924, Dr. C. W. B. Normand officiating as Director-General up to the 9th October and Mr. J. H. Field, on return from leave, up to the 13th December 1924.

Mr. J. H. Field returned from leave on the 10th October 1924 and was later appointed Director-General of Observatories in succession to Sir Gilbert Walker, from the 14th December 1924.

Mr. V. V. Sohoni went on one month's leave on the 20th March 1925.

Mr. V. Doraiswamy Iyer was appointed Assistant Meteorologist from the 14th April 1924, and was granted leave for 3 months and 12 days from the 27th February 1925. Mr. Mukand V. Unakar acted as Assistant Meteorologist during his absence.

Mr. M. G. Subrahmanyam returned to duty after 3 months' leave on 12th April 1924. Mr. Hans Raj Puri acted for him during his absence.

Mr. Barkat Ali was appointed Assistant Meteorologist on probation from the 16th April 1924.

Dr. T. Royds went on combined leave for 13 months from the 24th November 1924, and during his absence Mr. A. A. Narayana Ayyar, Assistant, was placed in charge of the duties of Director, Kodaikanal Observatory.

Mr. S. Sita-amayya who had been granted combined leave for 28 months from 9th September 1922 was allowed to return from leave; he joined duty at Agra on the 16th April 1924.

THE SYSTEM OF STORM WARNING FOR PORTS AND SHIPPING.

12. The work of warning ports and shipping in the Arabian Sea and the Bay of Bengal of the approach of cyclonic storms or of bad weather was done throughout the year from Simla. Thirty-one ports are on the warning list for storms in the Arabian Sea, and thirty-nine ports, fourteen River Police Stations and 40 District

Police stations for storms in the Bay; of the Bay ports, twelve get additional information regarding the particular areas in which weather is disturbed, a special system of 'locality signals' being in use for this purpose. Shipping at sea is also supplied with the latest weather information by means of wireless bulletins, which are broadcasted twice daily, or more frequently if the occasion demands it, from the radio stations at Bombay, Karachi, Calcutta, Rangoon, Madras, Matara (Ceylon) and Aden. The weather bulletins from Matara and Aden were started in March 1920 at the request of the Admiralty. A complete account of the warning system may be found in the "Code of Storm Warning Signals for use at Indian Ports," obtainable at Calcutta from the Superintendent of Government Printing, India.

Warnings to Ports and Shipping in the Bay of Bengal.

13. During the year warnings were issued for thirty-five periods of disturbed weather; the disturbances developed into moderate storms during five of these periods, and into a severe storm once. The last mentioned storm was generated to the southwest of the Andamans on the 15th November, moved at first west-north-west and later almost north to cross the Madras coast near Gopelpur on the morning of the 19th. It thus threatened a long stretch of coast line before actually passing inland. The warnings issued for this storm, as well as for most of the other periods of disturbed weather, were satisfactory.

14. As an instance of the usefulness of the warnings it may be mentioned that in the cyclone of November last, the S. S. "Bame", lying in Cocozzda, telegraphed to Simla to know whether she should proceed, and decided on receipt of reply to lie up for 36 hours, and then steam south in her passage to Rangoon to dodge the cyclone position. In the same cyclone, three of the Asiatic S. N. Co.'s steamers marked time at the head of the Bay until the Simla broadcasts showed that it was safe to move on.

15. Two important criticisms, however, were received. One from the Deputy Port Conservator at Calcutta, dated the 4th August 1924, made the following statements:—

- (1) "Yesterday it was obvious to everyone that weather was very unsettled at the head of the Bay but no warning of any description was received either from Simla or locally".
- (2) "At 2-20 p. m. a telegram was received from Simla reading as follows—" Deep depression with centre near Sandheads moving west-north-west winds comparatively weak at present neighbourhood centre, but unusually strong remainder of Bay hoist distant cautionary signal No. 1".
- (3) "3 P.M. telephoned to the local Meteorological Office; was informed by head clerk that Meteorologist was not in office. Was told that the storm centre was 50 miles at least from Saugor Island. Head Clerk stated that his office could take no further action without instructions from Simla".
- (4) "4 P.M. Telephoned to Meteorological Office again. Was informed by head clerk that Meteorologist had gone to the Presidency College, and was not expected back before the evening. He communicated telegram received from s. s. *Yam* Saug, at 13 hours, reading as follows—" Position 91°.30' E. 16°.30' N. wind southwesterly gale force, sea very rough, weather becoming worse". On being questioned head clerk stated that his office was taking no steps as regards further local observations.
- (5) "Under the circumstances Signal No. 1 is valueless both to ocean going vessels, and to local craft. Should the storm develop in intensity, and should it be necessary for us to place small craft in shelter, approximately 12 hours must elapse before this can be carried out completely".
- (6) "I take a very strong view of the manner in which warnings are being issued, and feel that the matter should be strongly represented to Government".
- (7) "On our own responsibility we have hoisted No. 4 Storm Signal".

16. This letter was discussed at a meeting of a committee of the Bengal Chamber of Commerce with the officiating Director-General, who pointed out that the second part of (1) was incorrect, inasmuch as special telegrams about weather at the head of

the Bay had been sent both at noon and at 9 P. M. on the 3rd August to Calcutta port officials, who had received these messages. With regard to (2), (5), (6), (7) it was explained that the telegram sent at noon on the 4th purposely used the term "depression" and not "storm", because ships and ports near or to the north of the centre of the depression were not considered to be in danger; consequently the "cautionary" and not the "storm" signal was ordered to be hoisted; and, it may be noted, the next day's observations showed that the depression had moved west-north-west, exactly as forecasted, without causing stormy weather at the Hooghly ports. With regard to (4) and (5), the Calcutta Daily Weather Report's mention of a small storm near Saugor Island was unfortunate, while the Head Clerk's reply to the Deputy Port Conservator over the telephone was quite misleading, inasmuch as Simla was getting special observations from Calcutta every 8 hours and the Superintendent at Calcutta was examining frequently the records of the self-recording instruments and would have sent Simla a priority telegram in the event of any unexpected change. Thus the Simla warnings to Calcutta, though not trusted, were in fact good, but the telephonic information given by the Calcutta Head Clerk was misleading.

17. From the Deputy Port Conservatory at Rangoon a criticism was received regarding the warnings issued on 1st September 1924. His letter read as follows—

"On the 1st September 1924, a storm of moderate intensity struck the Port at about 3-30 P.M. The weather telegram intimating the formation of a depression with squally weather between the Andamans and Diamond Island that might develop into a storm, together with cautionary weather signals to be hoisted for the information of shipping, was only despatched from Simla at 12-35 P.M. on the 1st September and reached this office at 3 P.M. on the same afternoon. This gave very little time to warn local shipping of the approaching bad weather and, while no report of damage to sea-going vessels that arrived in the Port after the 1st September 1924 was received in this office, damage to river craft was fairly general. I presume that in this instance the depression formed so quickly in the Bay that it was not possible to acquaint this office any earlier than was done of the approaching bad weather".

The weather situation in the Andaman Sea became slightly suspicious on the morning of the 31st August, and special observations were called for from the coast stations that evening. Neither the morning nor the evening observations seemed, however, to justify the hoisting of any signals at Rangoon. By the next morning a depression had formed with centre some 60 miles east of Prepara Island, and later developed into a storm, which moved west-north-west during the next three days, but its centre was at no time within two hundred miles of Rangoon. In view of this distance of the depression centre the force of the squalls at Rangoon on the afternoon of the 1st was unexpectedly great; and the failure to hoist the local cautionary signal at an earlier hour was not due to neglect but to the definite belief that it was not justifiable.

Warnings to Ports and shipping in the Arabian Sea.

18. The west coast ports are warned not only for storms but also for squally weather, especially at the beginning of the monsoon. There were 21 periods of disturbed weather for which warnings were issued: during 16 of these the warnings were for squally weather or strong winds connected with the monsoon, and during the remaining 5 for rough weather off the Mekran coast due to the passage of western depressions through Baluchistan. There was no cyclonic storm in the Arabian sea during the year.

FLOOD AND STORM WARNING, AND WEATHER FORECASTS TO DISTRICT IRRIGATION, RAILWAY AND OTHER OFFICERS.

19. This work was done wholly by the Simla Meteorological Office. The arrangements have been made at various times and differ considerably in character, according to the nature and extent of the flood or weather warnings required by those concerned. In most cases the officers require telegrams either warning them of

advancing storms likely to give heavy rain or informing them of the actual occurrence of heavy rainfall likely to cause severe floods which might injure railways or canal works ; and in other cases, they require warnings or forecasts of the weather for as long a period beforehand as possible.

20. At the end of the year the listed number of district officers and officers in the irrigation, railway and other departments to whom flood warnings, weather forecasts or intimations of the likelihood of rain during the dry season were to be sent by this department was 205. There were also 19 officers of the Telegraphic Department requiring warnings, mostly for strong winds.

In order to provide against serious loss of life and property in inland Bengal when a cyclone from the Bay crosses the coast, 461 officers were added in 1921 to the warning list ; of these officers 40 hoist the signals shown in Appendix D of the " Code of Storm Warning Signals " whenever instructed to do so.

21. The number of special forecasts and warning messages issued by the Department during the year was 1616, and in addition 702 telegrams of actual heavy rainfall were sent by meteorological observers direct to various officers.

Reports were received from 54 of the officers on the warning lists. Of these 40 stated that the warnings were satisfactory, 7 gave no remarks, and the remaining 7 offered suggestions or minor criticism, which have received consideration.

On the whole a comparison of the warnings with the actual subsequent rainfall, or the tracks of storms inland, show that the system is working satisfactorily and that most of the warnings issued were of value to the recipients.

Warnings to Military Authorities.

22. Telegraphic forecasts of the likelihood of bad weather were sent throughout the year to Headquarters, Waziristan and the Officer Commanding, Royal Air Force, Dardoni, and were stated " to be timely, accurate and most useful ". Special warnings were issued to the General Officer Commanding, United Provinces District, Meerut, as well as to the General Staff Branch of the Army Headquarters, in connection with the Eastern Command Manoeuvres which took place between the 15th and the 21st January 1925 ; the General Staff Branch reported that the forecasts had been very helpful to all concerned. Warnings were also issued to the Officer Commanding, 4th Infantry Brigade, Nowshera, in connection with Brigade training during the later part of January ; the Officer Commanding, in asking for earliest news of approaching rains during the 10 days beginning on the 22nd January expressed gratitude for the accuracy of the forecasts made to him previous to that date.

Warnings to Aviators.

23. From time to time telegraphic weather warnings were supplied to various aviators, and it is satisfactory to note that almost invariably the forecasts were reported to have been correct and useful. The American aviators who flew round the world were supplied with such information, in a series of some 200 telegrams from meteorological stations between the Persian Gulf and south Burma, as well as from Simla headquarters.

24. The following appreciations of the department's warnings are of interest :—

The Aeronautical Engineer, Air station, Monkey Point, Rangoon says :—

" There is no doubt whatever your telegraphic weather reports both from local stations between Calcutta and Rangoon, and also Rangoon and

Tavoy, as well as your more general report from Simla, sent at the time the world flights were passing over this part, were of the utmost utility.

The United States flight and Major Maclaren both passed over the Rangoon-Akyab section on the same day. On the following day the United States flight continued to Calcutta and one day later Major Maclaren left for Bangkok but made a halt at Tavoy.

All these flights were started on these particular days, owing to the improved weather conditions along the routes as shown by your reports.
 Upper air reports were of course the most useful".

The American Consul, Calcutta, wrote as follows :—

" On behalf of the American Aviators and Naval Officers recently in Calcutta I desire to extend to you my hearty and cordial thanks for the very valuable assistance which you and the members of your staff rendered to them in promptly and regularly transmitting reports on weather conditions.

Flight Commander Lieutenant Smith asked me particularly to tell you of his appreciation of your unusually fine co-operation and of the high quality of the reports submitted. They have contributed largely to the success of the flight throughout India."

25. Royal Air Force, Headquarters, in a note on operations in Waziristan intimated that :—

" The air staff would like to express to you their gratitude for the trouble you have taken in this matter.

The reports have been of the greatest value, and I have heard from the pilots how much they have appreciated them".

26. The Chief Staff Officer of Royal Air Force, Headquarters wrote on the 21st February 1925, that :—

" I have recently flown round from Delhi to Peshawar Quetta and Delhi and have used 3 of your forecasts.

The first said that the weather at Peshawar would break on Tuesday 10th ; the second that there would be fine weather over the Zhob on Thursday 12th and Friday 13th ; the third that the weather would be fine with poor visibility on Wednesday 18th and Thursday 19th in Rajputana. All 3 were remarkably correct—in every detail. Please allow me to congratulate you on these results.

I want the Royal Air Force, to use your forecasts much more freely both for travelling flights and for operational work".

27. In the near future there is the probability of closer co-operation of the department with the Royal Air Force as the development of civil and military aviation progresses ; and plans about appointment of forecasting meteorologists at centres like Quetta, Peshawar and Karachi were discussed during the year.

SUPPLY OF METEOROLOGICAL INFORMATION.

28. From time to time special information is supplied to the meteorological departments of England, Australia and Egypt. Climatological and other data, at times involving special calculations are also provided for sanitary and other

officers of Government as well as for those private firms who are willing to pay for the service. The extent to which the department was utilized in this manner during the last year will be seen from the curves B and C in the graph at the end of this report.

UPPER AIR WORK.

29. Exploration of the free atmosphere in India has been recognised as indispensable in the interests of aviation, general meteorology, and both daily and seasonal forecasting. This recognition found its expression in Government's order of April 1924, placing the Agra observatory on a permanent footing and establishing the nucleus of a permanent staff there. The principal routine work of the year at that observatory consisted as before of

- (a) supplying material and equipment to the upper air stations at Quetta, Peshawar, Lahore, Simla, Diamond Harbour, Akyab, Bangalore and Bombay.
- (b) exercising close supervision over work at outstations.
- (c) tabulation of pilot balloon results and of cloud observations.
- (d) flights of instrument balloons—69 were sent up, and 41 recovered.
- (e) repair to barometers and anemometers.
- (f) construction of Stevenson screens—65 were made and sent to various observatories.

The new engine house, begun in November 1923, was completed in February 1925 and the erection of plant was taken in hand.

30. An interesting activity of the year, was an expedition of 3 observers to Jask on the Persian Gulf for a year's series of pilot balloon observations, beginning on 4th June 1924. The expedition was undertaken to collect upper-air data in an unsurveyed part of the Imperial air route, and also to throw some light on the physical causes of breaks in the monsoon.

31. The Agra observatory as usual supplied equipment for pilot balloon work at 8 artillery practice camps during the winter.

At the request of Royal Air Force, a batch of 6 Royal Air Force wireless operators was trained in Agra in pilot balloon observation, in August 1924; some of these keep in touch with the work, by helping the department's observers at Quetta and Peshawar.

His Excellency the Governor of the United Provinces visited the Agra observatory on the 15th August 1924.

OBSERVATORIES.

32. *Bombay.*—The routine activities of the observatory and the Meteorological Office consist of registering continuous records of magnetical, meteorological and seismographic instruments, taking numerous eye observations, reduction and tabulation of these data, publication of a Daily Weather Report (for 6 months—May to October—under present arrangements), taking star or sun observations for time determination, rating a large number of chronometers belonging to the Royal Indian Marine and the Royal Navy, directing the local time-ball service for the harbour and collecting extracts from weather logs of ships. All these were satisfactorily carried out during the year; about 60 chronometers were rated and issued, and 950 weather logs from ships were collected. Some headway was made in preparing hourly normals of meteorological elements based on data for 1846-1920.

The Alibag Magnetic Observatory, where the leaky condition of the roof was causing great anxiety last year, was fully overhauled at a cost of over Rs. 7,000 before the monsoon rains of 1924 began.

33. *Calcutta, Alipore.*—In addition to the issue of the Daily Weather Report for northeast India, the Calcutta office and observatory have the important duties of supplying all the Indian observatories with instruments and stores, keeping a stock of tested instruments, checking and computing a portion of the data accumulated from observatories, supplying mean local time to the Port of Calcutta and by wireless to shipping at sea; distributing the departmental publications and attending to some of the routine correspondence of the department as a whole.

34. The insistent protests from the commercial public of Calcutta led to the restoration of the Daily Weather Report to its pre-retrenchment form from the 7th April 1924, with resumption of continuous publication throughout the year. A new system of issuing early weather information by telephone was introduced from 19th July 1924 for subscribers to this local service. In connection with the warning service, for storms at sea it had been found necessary for Simla, when the work is done, to keep Calcutta observatory informed on all special observations received, by sending coded messages to communicate their substance. This arrangement, however, was not found fully satisfactory, and it was subsequently decided that the Calcutta office should receive duplicate telegrams of all special observations direct from the observatories, and be thus enabled to supply the public fairly rapidly with the latest information about storms or disturbed weather.

35. The determination of time from transit circle observations of stars improved considerably during the year. In April the times of transmission of the wireless time-signals were changed from 7 A.M. and 7 P.M. (I. S. T.) to 2 P.M. and 10 P.M. (I. S. T.); the electric diffuser was generally used for this transmission.

36. The Meteorologist, as a member of the North Bengal Flood Enquiry Committee, undertook the preparation of statistics on rainfall from data of the period 1870 to 1921, obtained from various sources. A fairly exhaustive piece of work on excessive rainfall and its relation to floods was carried through and a report submitted to the Government of Bengal in January 1925.

37. *Madras.*—The most important routine work, the supply of time to the local shipping and the whole country generally was carried on well. The issue of the Daily Weather Report was limited as in the previous year, to the 9 months from April to December.

38. *Kodaikanal.*—The Director of the Solar Physics Observatory published a report on the astronomical work of 1924. The collection of spectroheliograms from other observatories, for days on which complete observations at Kodaikanal were impossible, continued as a part of the programme of the International Astronomical Union.

39. *Agra.*—The Aerological Observatory continued its most important and fruitful activities. A full report may be found on page 28.

40. *Other Observatories.*—A number of observatories keep continuous instrumental records of certain meteorological elements; 6 stations record wind by Beckley anemographs, 4 by Dines' anemograph, 6 record hours of sunshine, 15 deal with air pressure, 7 with air temperature, 9 with terrestrial radiation, 2 with underground temperatures, and 1 with solar radiation.

41. Of the purely meteorological observatories under the department's care 47 were non-departmental and 214 were maintained by the Government of India; these include stations as far afield as Tehran, Kashgar, Aden and Seychelles. According to the classification given in the report for 1918-19, the departmental observatories consisted this year of 5 of the first class, 180 of the third class, 6 of the fourth class and 23 of the fifth class. The maintenance of these observatories the supply to them of tested instruments, and the careful scrutiny of their observations naturally entail much work of a routine character at headquarters. The

correctness of observations depends upon the continuance of good exposure and good condition of instruments at observatories, and upon the accuracy of reading by observers. The former point can only be ensured by visits of inspection by trained officers. The latter point can to some extent be estimated at headquarters from the number of mistakes detected in the data for the Indian Daily Weather Report. The stations of great reliability in which no mistake or at most one has been detected, numbered 32 and the number at which more than 50 mistakes were made was 5. The average number of mistakes during the year at the remaining stations was 10

Inspection of Observatories.

42. One of the essentials for continued accuracy of meteorological observations is frequent inspection of observatories. This feature had been neglected for many years owing either to want of funds or to inadequate staff: but a marked improvement had taken place during 1923-24 with the inspection of about 50 observatories, chiefly those on the coast lines between Rangoon and Karachi. During 1924-25 the previous year's record was maintained, thanks to sufficient travelling grants, and 80 observatories from the western frontier to Burma, and 8 in south India, were inspected by Meteorologists and others. The Director-General visited the principal observatories at Bombay, Agra and Alipore (Calcutta).

MARINE METEOROLOGY.

43. Wireless weather messages from ships at sea, and extracts from weather logs of ships calling at the principal ports on the Indian seaboard, are the chief sources of marine data collected by the department.

44. The object of the system of radio-messages from ships is mainly to supplement the coast observations in cyclone-warning work. In the absence of observations from sea areas it is not always easy to draw correct conclusions about the position, movement and intensity of storms; this is the case particularly with disturbances in the Arabian Sea for which inferences had in the past to be drawn from very insufficient observations from the west coast line of India. The system of wireless weather messages which was started in 1914, but which was necessarily suspended during the war, was resumed in 1921. It showed improvement over preceding years during the year under report: thus the number of ships' messages from the Bay and the Arabian Sea totalled 3,633, in comparison with 2,237 in the previous year and 956 in 1921-22. The department gratefully acknowledges the assistance given by commanders of ships who took part in this service, and would especially mention the following steamers from whom more than 40 weather messages were received during the year.

S.S. <i>Angora</i> .. 104	S.S. <i>Ethiopia</i> .. 48	S.S. <i>Narwab</i> .. 65
„ <i>Arankola</i> .. 59	„ <i>Ellora</i> .. 53	„ <i>Nurjehan</i> .. 53
„ <i>Begum</i> .. 61	„ <i>Egra</i> .. 105	„ <i>Ormara</i> .. 53
„ <i>Badarpur</i> .. 77	„ <i>Goalpara</i> .. 50	„ <i>Orna</i> .. 59
„ <i>City of London</i> 55	„ <i>Havildar</i> .. 45	„ <i>Pasha</i> .. 44
R.I.M.S. <i>Clive</i> .. 103	„ <i>Manipur</i> .. 63	„ <i>Shahjehan</i> .. 64
S.S. <i>Chindwara</i> .. 44	„ <i>Maharaja</i> .. 175	„ <i>Shakada</i> .. 86
„ <i>Chyebassa</i> .. 53	„ <i>Namsang</i> .. 43	„ <i>Varsora</i> .. 43
		„ <i>Warialda</i> .. 46

This is a gratifying increase, but even yet the department's warning officers frequently lack, at critical times, ships' observations from the vicinity of a storm at sea and find themselves compelled to draw their inferences and base their broadcast messages on coast observations alone. It is hoped that as more ships come to

co-operate with the warning service the number of such occasions will steadily diminish. It would be most helpful if co operating captains would induce others to take a share in this service of information from sea.

45 The Madras-Rangoon mail boats were provided with two good barographs, in accordance with the policy of issuing instruments on loan to ships' commanders. The results have been satisfactory and this policy if extended, would certainly be fruitful in increasing a knowledge of the meteorology of the Indian Seas ; but lack of sufficient gazetted staff does not at present allow of an extension in this direction.

46. Apart from ships' wireless messages, an important source of data is the log extracts taken by clerks in Calcutta and Bombay. In this connection a new opening was created in Rangoon, where, through the helpfulness of the Port authorities, the observers of the Time-Ball and Tidal observatory of the Port Commissioners are entrusted with the collection of ships' data. Occasionally, in special cases, logs of steamers with experience of disturbed weather are collected at Madras ; and the Colombo Port authorities also help us similarly whenever requested. A total of over 2,000 logs was recorded at the end of the year.

The data thus obtained are entered on charts of disturbances in the Bay of Bengal and the Arabian Sea, and kept for reference in the storm-warning work of the department, and in drawing up an account of the storms of the year for publication in the India Weather Review (Annual Summary).

An atlas of Storm Tracks in the Bay of Bengal during the period 1891 to 1923 was prepared, and was on the point of publication at the end of the year.

RAINFALL REGISTRATION.

47. The registration of rainfall in India has always been carried out under the control of provincial authorities. In 1889 a uniform system was introduced by the Government of India, and the Director-General of Observatories was made consulting officer in connection with this work. His advice is sought regarding the starting of new rain-gauge stations, and he receives annual reports upon the efficiency of the work from the local controlling officers, who are in most of the provinces the Directors of Agriculture or of Land Records.

48. The following is a statement of the number of raingauge stations, totalling nearly 3,000, which supply data for publication in the " Rainfall of India " as they stood in January 1925 :—

Province.	Number of stations.	Province.	Number of stations.
Burma	240	Baluchistan	79
Assam	125	Sind	14
Bengal	251	Rajputana	145
Bihar and Orissa	316	Bombay	274
United Provinces	275	Central India	85
Punjab	191	Central Provinces	188
Kashmir	41	Hyderabad	18
North-West Frontier Province	33	Mysore (excluding raingauges in taluks).	77
		Madras (including Foudatory states)	524

49. In 1920 the necessity of frequent inspections of raingauges was brought to the notice of the officers in charge of rainfall registration, and subsequent reports have shown a decided improvement in this respect.

The following notes are based on the reports for 1924-25 of these officers:—

Burma.—There were 241 stations as against 239 last year; 18 were meteorological observatories, 30 under the Public Works Department, 2 belonging to the Agricultural Department and the rest under the supervision of civil officers. 217 raingauges were inspected as against 194 in the previous year, out of which almost all were reported to be in good condition; the main defects were, as usual, nearness to buildings and trees.

Assam.—There were 125 stations at the end of the year. The number of raingauges inspected was 114, against 105 in the preceding year. The districts are generally well equipped with raingauges and their accessories.

Bengal.—The number of raingauges at the end of the year was 251. The number of stations inspected was 197 as against 202 in the preceding year. The condition of the raingauges in the provinces is reported to be good on the whole, defects pointed out by inspecting officers being remedied very promptly.

Bihar and Orissa.—There were 316 raingauges (including 30 in the Feudatory and Tributary Mahals of Orissa) out of which 256 were inspected.

United Provinces.—There were 286 rain-reporting stations, including the meteorological observatories, as against 288 last year. Out of 270 stations under District and Canal Officers 78 per cent. were inspected during the year as compared with 75 per cent. in the previous year.

The Punjab.—There were 191 rainauge stations at the end of the year 1924 as against 180 in the previous year. Of these 130 gauges were inspected during the year 1924.

North-West Frontier Province.—There were 34 raingauges; out of these 30 were inspected and reported to be in good working order, except that at Kohat with regard to which necessary action was being taken.

Baluchistan.—There were 79 raingauges as in the previous year in addition to 9 meteorological observatories. Eighteen raingauges in charge of Civil Department were inspected by District Officers, while the railway raingauges were frequently inspected by the officers of the railway department.

Bombay.—There were 277 stations in the Presidency proper of which 242 were inspected as against 237 in the previous year; while out of the 61 raingauges in the Indian States 40 were inspected. In the previous year there were 54 inspections of raingauges in the States: the decrease is due to the transference of the gauges in Cutch and Kathiawar to the control of the Government of India. The maintenance of the rainfall registration system was quite satisfactory.

Rajputana.—Reports on the rainfall registration were received from all the States. In all there were 328 rainauge stations, out of which 290 were inspected as against 308 last year.

Central India.—Reports on the rainfall registration were received from almost all the States in the Central India Agency with the exception of Indore.

There were 148 raingauges in all the States and Agencies, out of which 142 stations were inspected as against 139 last year. The condition reported was on the whole good.

Jammu and Kashmir State.—There were 41 stations altogether, out of which 8 are meteorological observatories. The number of rainauge stations inspected during the year was 21 against 15 last year. "Every endeavour is being made to have all the raingauges inspected at least once a year."

Central Provinces.—The number of raingauges in the Central Provinces was 125 and those in Berar 43, the number of inspections in the former being 309 and in the latter 115 against 292 and 97 respectively in the previous year.

Hyderabad.—No report has been received.

Mysore.—The number of rainauge stations remained unchanged, i.e., 226. Of these 77 are at district and taluk headquarters and the rest in villages. 203 stations were inspected in 1924-25 as compared with 196 in the previous year; no less than 117 stations were inspected more than once.

Coorg.—7 out of the 10 raingauges were inspected and found to be in good order.

Madras.—There were 492 rainauge stations in the Madras Presidency and feudatory states on 31st March 1925. The number of stations inspected during the year was 470. The condition of the raingauges was generally good.

A general review of the report shows the satisfactory fact that in practically all the divisions over 75 per cent. of the raingauges were inspected, while in some the percentage was as high as 90.

50. *Heavy Rainfall Reports.*—Heavy rainfall is occasionally so very local that small areas can have as much as 10" of rain without the Daily Weather Report conveying the least suggestion of it. With a view to have such useful data promptly available for the Daily Weather Report it was arranged in 1921, with the approval of the Government of India, that reports of 5 inches or more of rainfall should be

telegraphed to Simla from rain-gauge stations at district headquarters throughout the country. The number of such telegrams was 180 during 1924-25 as compared with 218 in the previous year.

Snowfall Registration in the Mountain Districts to the North and West of India.

51. Information as to the amount, distribution and time of occurrence of the snowfall in the Himalayan and Afghan mountain areas was on the whole tolerably complete, and the thanks of the department are due to the various officers who collected and forwarded it.

SEISMOLOGICAL OBSERVATIONS.

52. Seismological observations were recorded throughout the year by two Omori-Ewing seismographs at Simla, two at Calcutta and one at Bombay, and a Milne seismograph at Kodaikanal. At Bombay (Colaba) the new Milne-Shaw machine has worked excellently since its installation in 1922-23 and the Meteorologist there has undertaken a study of the microseisms that appear just before the setting in of the monsoon. All the seismic data collected at these places are sent to the Seismological Committee of the British Association.

TIME SIGNALS.

53. The observatories at Madras, Calcutta and Bombay determine time from star and sun observations and communicate it to the local ports by time-ball signals. The distribution of time over the country generally is made from the Madras Observatory by a signal transmitted daily at 16 hours I. S. T. over the Indian telegraph system; considerable errors are inevitably introduced into the signal at stations where retransmission is effected by hand. A wireless time signal for the use of ships was broadcasted automatically twice daily from the Alipore Observatory at 2 P.M. and 10 P.M. I. S. T. through the Calcutta radio station.

A wireless receiver was put up at the Bombay Observatory and was used regularly from November 1924 for a comparison of the local time determination with the time signals transmitted from Calcutta, Eiffel Tower and Nauen.

The time work was satisfactory throughout the year.

PUBLICATIONS AND LIBRARY.

54. The routine publications of the departments are mentioned in the Administration Report for 1922-23. The Calcutta Daily Weather Report was restored to its original form from the 7th April 1924.

The Daily Weather Telegram was despatched to subscribers daily about noon, and the weekly rainfall summary was supplied to the *Gazette of India*. The Weekly Weather Report, containing matter similar to the Weekly Summary published in the *Gazette of India*, was published during the monsoon period, and supplied to about 75 subscribers and also to the Press.

The quinquennial volume for 1916-20 of the Bombay Observatory was sent to press and was about to issue at the end of the year. The Annual Volume for 1921 was also sent to press, while the manuscripts for the Annual Volume for 1922 were almost ready for printing.

Orders were received about the abolition of the free exchange of publications between the department and officials of provincial Governments from the next official year and appreciable reduction of the distribution lists was accordingly anticipated. The number of institutions etc., on the distribution lists of the department was 410 at the end of the year.

The following memoirs of the Indian Meteorological Department were published during the year :—

Volume XXIII, Part VIII, "Frequency of heavy rain in India," by Sir Gilbert T. Walker.

Volume XXIV, Part IX. "Correlation in seasonal variations of weather, IX, A further study of world-weather", by Sir Gilbert T. Walker.

Volume XXIV, Part X, "Correlation in seasonal variations of weather, X, Applications to seasonal forecasting in India", by Sir Gilbert T. Walker.

55. Books, periodicals and pamphlets, either purchased or received as presentation copies in the department's libraries at Simla and Calcutta during the year numbered 779. In the library at headquarters the longstanding arrears in classification were cleared up, and in addition 178 current books and pamphlets and 522 periodicals and publications containing data were catalogued and indexed.

CONCLUDING REMARKS.

56. The Meteorological Department owes a large part of its usefulness to the sympathetic assistance it receives from other departments. Civil Surgeons and other officers of Government departments, as honorary superintendents of observatories and in other capacities, help in the meteorological work ; the Posts and Telegraphs Department assists in the rapid transmission of meteorological information ; at the same time they allow their employees to act as observers. The Indo-European Telegraph Department, also, by giving free transit to the daily messages from the Persian observatories, places a large amount of most useful information at the disposal of the Meteorological Department. Weekly telegrams are received from April to September from the Director, Royal Alfred Observatory, Mauritius, and from April to October from the departmental observatories at Zanzibar and Seychelles. These telegrams give valuable information of the weather conditions in the Indian Ocean, and the department is indebted to the officers indicated for the punctual transmission of the information. Thanks are due to the Director of the Royal Alfred Observatory also for his courtesy in placing the meteorological data of that observatory at our disposal.

The department is greatly indebted for important information on meteorological conditions prevailing before and during the south-west monsoon to the Controller, Physical Department, Cairo ; the Directors of the Observatories at Buenos Ayres Santiago and Batavia ; the Astronomer Royal, Cape Town ; Director, L'Observatoire Physique Central, Leningrad ; the Secretary, Friends' Industrial Mission, Banani Pemba, Zanzibar ; the Principal Medical Officer, Tanganyika Territory, Dar-es-Salaam ; the Commonwealth Meteorologist, Melbourne ; Director of Agriculture, Salisbury, Rhodesia ; Chief of the Weather Bureau, Washington ; and to the various officers around the Indian frontiers who have collected and supplied valuable snowfall information.

The thanks of the Department are due to Mr. A. J. Bamford, Superintendent of Colombo Observatory, for the very useful help he has rendered from time to time in connection with storm warning work. The department is also grateful to the Director, Koninklijk Magnetisch en Meteorologisch Observatorium, Batavia, Java who has arranged for taking and telegraphing to Simla daily observations from Sabang in Sumatra during the cyclone months April, May and October to December.

SIMLA ;

J. H. FIELD,

The 12th August 1925.

Director-General of Observatories.

