
The Geographical Distribution of Rainfall in the British Isles

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use of spears. A curious custom of theirs, when fighting, is to give quarter to a defeated enemy if the latter catches his opponent's breast in his mouth. The Akamba file their teeth in two ways. Among some of the tribes it is the custom to file all the front teeth to a needle-like point, the effect being extremely repulsive, while among others only the insides of the two middle front teeth are filed. All of them drink enormous quantities of *tembo*, an intoxicating liquor of which there are two varieties—one made from sugar-cane and bananas, while a better kind is made from fermented honey. The old men, according to Captain Aylmer's observations, appeared to be seldom sober, and the spirit is of such bad quality that they soon acquire the most debauched appearance. They have the reputation of being fond of poisoning strangers, and on the whole are a trying people to deal with; but if their assistance can be secured, they will often work hard and willingly, and display a good deal of intelligence.

A plane-table was carried by the expedition, but, owing to the character of the country, it was found impossible to use it effectively. Viewed from any elevation, the country might easily have been mistaken for the sea. There was not a break in the horizon, and nothing to be seen but a shimmering blue haze above miles and miles of dry bush. Compass bearings were taken along the Tiva river, but even in these allowance must be made for a considerable margin of error, owing to the absence of prominent points. The usual difficulty was experienced in ascertaining the native names for particular features, but Captain Aylmer succeeded in compiling a useful list of the general names for "river," "lake," "hill," etc. A collection of rock specimens found by the expedition contained nothing of value. Quartz abounded everywhere, but no shale formation was seen which gave promise of coal.

In its main purpose, to trace the Tiva river throughout its lower course, the expedition failed; but useful experience and knowledge of the country were gained, and Captain Aylmer believes that another attempt made immediately after the rains in a good year would undoubtedly prove successful, and the exact courses of both the Thua and the Tiva rivers would be located.

THE GEOGRAPHICAL DISTRIBUTION OF RAINFALL IN THE BRITISH ISLES.*

By HUGH ROBERT MILL, D.Sc.

In considering the geographical distribution of any condition over a given area, the first essential is a clear view of the position and

* Summary of a course of six lectures delivered at the request of the Council of the Royal Geographical Society, January and February, 1908.

configuration of the area in question. The importance of the position of the British Isles from the point of view of climatology, and especially of rainfall, lies in its relation to the continent on the east and the ocean on the west, in the track of the prevailing south-westerly winds which blow from ocean to continent, carrying warmth and wetness to the land they first encounter. Ireland, standing well to the west of the larger island, and thus enjoying the more oceanic climate, is remarkably open to the sweep of the wind. The central plain is practically continuous, broken only near the edges by the mountain groups of the north-west and the north-east, and by the more compact masses of high land which run through the south of the island from south-west towards north-east, forming a fairly continuous highland belt from Kerry to Wicklow. Great Britain shows a more elaborate vertical relief, the great groups of high land being clearly marked off from one another by plains narrower than that of Ireland, but, like it, stretching in most cases from sea to sea. In order, from north to south, the lofty land-masses include the Highlands and the Southern Uplands of Scotland, each filling nearly the whole breadth of the country and separated by the Lowland Plain, with its lines of low ridges and abrupt bosses of volcanic rocks. Lying, as Scotland does on the whole, to the west as well as to the north of England and Wales, it possesses distinct differences in climatic character from South Britain. The southern and larger part of Great Britain may be best divided into a western and an eastern division. The Western comprises the separate highland masses of (1) the Lake District; (2) the Pennine Chain; (3) Wales; and (4) the western horn of Cornwall and Devon. These four groups of elevations are separated by low plains, over which the rivers, taking their rise in the high ground, pass to the sea. The Eastern Division is, in the main, a plain traversed by long ridges of low hills of well-marked individuality radiating from near the Bristol Channel to the north-east and east. The line commencing with the Cotswold Hills stretches, now higher, now lower, to the moors of the North Riding of Yorkshire. The next line, including the White Horse Downs and the Chiltern Hills, though broken by the flat of the Fenland, rises again in the Wolds of Lincolnshire and the East Riding of Yorkshire; while the third line runs broadly through Salisbury Plain and splits into the curved sweep of the North Downs and the South Downs, with the Forest Ridges between them, each of the members of the system being defined and separated from the others by narrow plains. The river systems of the country emphasize the divisions of the plain, which bounds the masses of high ground and serve as the most natural units of surface for the discussion of rainfall data. Taken as a whole, the vertical relief of the land is the effective agent in directing the action of wind and all climatic conditions arising from the effect of aspect, shelter and direction of movement.

Before bringing into relation the land and the rain, it is necessary to consider the character and causes of the latter. The term "rain," for purposes of measurement, includes all forms of condensation of water from the atmosphere, not merely the fall of liquid drops. The principal agent for the transformation of solar radiation into work is water, which, evaporated from the surface of the hydrosphere, ascends as vapour and is condensed and precipitated whenever it reaches a height where the temperature is below the point of saturation, and when appropriate nuclei are present, upon which condensation of water can take place. These nuclei are usually considered to be supplied by dust; but it is now suggested that the part may be played by electrons also. While it is the lowering of the temperature of air which produces condensation of the aqueous vapour into water, the most usual cause of fall of temperature in masses of air is the ascent of the air either by expansion, due to heat or release of pressure, or by wind blowing along the rising slope of a land surface; ascending air may thus be looked upon as practically the only cause of rain. When condensation takes place in minute globules, the friction exercised by the air retards their fall so greatly that they often appear to float as clouds; but the apparent stability of a cloud is frequently an optical effect due to the formation of fresh cloud above and the simultaneous evaporation of the water globules below when they fall into air which is not saturated. In a cloud formed in saturated air the globules have an opportunity to run together and fall in drops, which sometimes attain a considerable size. In a cyclonic system, and still more in a whirlwind, there is a rapid ascensional movement of air, and these conditions are consequently associated with excessive precipitation; electrification also plays an important part in the production of torrential rainfall. The magnitude of rain as a working power in nature can only be realized when one remembers that all the water of every river is merely rain on its way back to the sea, whence it came.

The method of measuring rainfall is very simple, but many small precautions have gradually been discovered to be necessary in order to secure satisfactory results, and thus it happens that there are few good records of rainfall of any great length. Christopher Wren designed, in 1662, the earliest rain gauge, which has been described; but the first known record was begun at Paris in 1668, and the second at Townley Hall, near Burnley, in 1677. Very few records exist before the commencement of the nineteenth century, and our comprehensive knowledge of the distribution of rain over the British Isles may be said to have started in 1860, when the late Mr. G. J. Symons initiated the British Rainfall Organization, and in 1861 published 507 records for the year. The work of this organization is still carried on in Mr. Symons's old house, 62, Camden Square, London, but now it deals with the records of 4500 stations every year. Experiments were made in the early days to

determine the best form of instrument and the best method of observation, and the outcome was to establish the use of the Snowdon pattern of rain gauge, 5 inches in diameter, or the Meteorological Office pattern, 8 inches in diameter (the two differ only in size), set with the receiving surface 1 foot above the ground, read once daily at 9 a.m., and recorded to the date of the commencement of the twenty-four hours to which the reading refers. Elevation above the surface of the ground or exposure to strong wind causes a loss in the catch of rain, on account of ascending eddies formed round the instrument, and various sheltering devices have been employed in very exposed places to counteract this effect. Rainfall observers in the British Isles belong to all classes of society, and for the most part they do the work voluntarily on account of its interest to themselves; the efforts of the Rainfall Organization—which, unlike the state-supported rainfall services of all other countries, is a private and self-supporting body—being mainly (1) to collect the records and publish them in the annual volumes of 'British Rainfall'; (2) to encourage accuracy and regularity in observers; and (3) as far as is practicable to endeavour to enlist the aid of new observers in the large areas where as yet there are no rain-gauges. New records are urgently wanted in all parts of Ireland and of the Scottish Highlands, but also in many parts of England, such as Northumberland, the East and North Ridings of Yorkshire, in the west of Wales, and in general in all places more than 500 feet above the sea.

The first essential in mapping rainfall is to make sure of the accuracy of the individual records on which the map is based. It is a rule to which the longest experience offers no exception, that rainfall varies gradually from point to point. The gradation may sometimes be very gentle, sometimes almost abrupt; but whatever the period may be for which the rainfall is plotted, an erroneous figure stands out with manifest discordance. A map is thus a valuable means of detecting errors which may usually be corrected by inquiry or by comparison with neighbouring records. The distribution of rainfall may be delineated by means of isohyetal lines similar to isotherms or isobars, and the areas of maximum rainfall may be brought into prominence by the use of deepening tints of colour. The general rainfall or mean depth of rain over a particular area is best obtained by measuring the area between successive isohyets, multiplying the area by the mean rainfall of the zone, adding all such volumes together and dividing by the total area. In this way the difficulty of irregularly distributed stations, which would falsify an arithmetical mean, is practically overcome. In the case of mapping the rainfall of a single day—which is very often the rainfall of the natural unit, a shower—the most important precaution is to make sure that all the observations used were made at the same hour and entered to the same date. This can be done much more readily in the case of heavy than in the case of

light rains. The area enclosed by an agreed-upon isohyet to represent the superficial extent of a shower may conveniently be referred to as a "splash," and such splashes are very sharply defined in the case of thunderstorm rains, or the rain accompanying a line squall. But when the rain accompanies or is produced by a moving depression of the familiar cyclonic type, the result is a series of confluent splashes, which forms a belt across the country, and may be comprehensively termed a "smear." The smear, as a rule, lies mainly to the left of the track of a depression. A heavy shower may dominate the rainfall of a month, but in the course of a year the inequality due to any one shower ceases to appear. The peculiarity of heavy showers due to meteorological causes, such as a thunderstorm, a squall, or a cyclone, is that they depend upon the condition of the air alone, and may fall with equal intensity in any part of the country—on a mountain, on a plain, or over the sea; the configuration of the land seems to exercise no control upon them.

While the rain of a heavy shower shows no trace in its distribution of any effect of configuration or of the elevation of the land, the total rainfall of a year, whether it be relatively a dry year or a wet one, shows so complete a congruence with the configuration that there can be no doubt as to the relation of cause and effect. The highest annual rainfall is always in the neighbourhood of the highest land; the lowest is always on the low and level plains. A map of average rainfall isolates the groups of high land as areas of high rainfall, with nearly the same precision in most cases as a map coloured for elevation. The Highlands of Scotland, the Southern Uplands, the Lake District, the Pennine Chain, Wales, the western horn of Cornwall and Devon, and the mountains of Ireland, all stand out as wet areas, and even the gentle hills of the Eastern Division of England are seen to be wetter than the surrounding plain. It appears probable that after deducting from the annual total the heavy rains due to meteorological causes there remains the bulk of the rain which must be assigned to geographical causes and which is in all probability produced by the cooling of the air consequent on the uplift of the wind blowing over ascending slopes. This very reasonable deduction has not yet been rigidly proved, because it is exceedingly difficult and laborious to separate into meteorological and geographical showers the rainfall for a number of stations sufficient to allow a map of any particular year to be drawn.

The dependence of rainfall on configuration, which is apparent in the rainfall map of any year, is much more marked when the average rainfall of many years is considered. The making of an average rainfall map is beset by special difficulties. The length of the period is important because the total rainfall of one year varies greatly from that of another; and, speaking generally, the wettest year amounts to 150

per cent. and the driest to 65 per cent. of the average, and even a period of ten years may be much in excess or much in defect of the average of a longer period. The rainfall record maintained at Camden Square shows an average of 25.0 inches for fifty years; but the five consecutive decades from its commencement gave averages of 25.5, 25.5, 27.0, 24.0, and 23.5 respectively, the wettest individual year (1903) was 38.10 inches, and the driest (1864) 16.93 inches. A period of thirty-five years is the shortest time which can yield a really satisfactory average rainfall in the British Isles, and probably the rainfall of one period of thirty-five years does not differ from that of any other by more than 2 per cent. As it is impossible to make a map from the small number of thirty-five years' records which exist, it is necessary to apply a correction to the means of shorter records so as to allow for the relative dryness or wetness of the years they comprise. Reinforced by such computed data, the long records suffice for the compilation of a very satisfactory rainfall map of the British Isles to be compiled; but the labour, or, in other words, the expense, of doing so would be very considerable. The best way of making a true average rainfall map would be to prepare a complete map of the rainfall of each year since records were sufficiently numerous, and then to combine these by some mechanical method so as to produce a map on which every individual yearly total would receive due weight. The preparation of annual maps from the current year back to 1870, or perhaps to 1865, is now in progress.

Average rainfall maps of many small districts have been prepared by the method of correcting the shorter records to their equivalent averages for thirty-five years, and such maps of counties on a small scale have been published in the Geological Survey's 'Water Supply Memoirs' for Lincolnshire, Suffolk, East Riding of Yorkshire, Northamptonshire, and Bedfordshire, while they are in preparation for Kent, Sussex, Oxfordshire and Hampshire. In the case of some counties the number of observing stations is so great that it has been possible to plot the data on maps of the large scale of 2 miles to an inch. The result has been to show that the relation of average rainfall to configuration is astonishingly close, and to prove that in bare patches for which no records are available the contour lines of elevation may be taken as guides for the most probable run of the isohyets. The relation is nevertheless not altogether a simple one, as it involves altitude, slope, and exposure to the prevailing wind. It is found, for instance, that while the rainfall gradually increases with altitude on the slope facing the prevailing wind, this increase continues for a short but variable distance down the leeward slope, the suggestion being that the wind forced to rise by the slope of the ground towards the summit continues to ascend for a short distance after the summit is passed, and drops the maximum rainfall from the point where it attains its greatest height.

Reference was made in the last lecture to the economic aspects of rainfall, the damage done by floods and torrential falls, the influence of rainfall in agriculture, the rapidly increasing importance of the question of water supply for consumption in towns, and for the generation of electrical power. The problem of water supply was shown to be one of national and not of merely local importance, and it is in its main lines a geographical question which ought to be dealt with in a far more comprehensive way than the public or even statesmen yet realized.

Some instances of the manner in which rainfall had influenced architecture and processes of agriculture were pointed out and illustrated, as were all the points in the lectures, by lantern slides.

WADE'S METHOD OF DETERMINING LONGITUDE.

By E. J. SCOTT, B.A., F.R.G.S.

MR. E. B. H. WADE, M.A., late of Trinity College, Cambridge, and at present of the Egyptian Survey Department, has devised a new absolute method of determining longitude by observations of the moon. He claims that his new method possesses advantages over the method of occultations, and gives results whose precision is second only to those obtained by telegraphic means. He recently described, at a lecture before the Survey Department at Giza, the instrument he has invented, and has now published a full account of his instrument and method in a report on 'A Field Method of determining Longitude' (Survey Department, Cairo). The accompanying plate is reproduced from that publication by the kind permission of Captain H. G. Lyons, F.R.S., F.R.G.S., F.G.S., late R.E., Director-General, Egyptian Survey Department.

The method is an adaptation of the old method of lunar distances, but no attempt is made to measure actual distances or altitudes. The observations consist in obtaining contacts between a star and the reflected image of the moon, and the only readings required are the clock times (L.M.T.) of the contacts. The principle is the determination of the times at which the moon is a certain (unknown) apparent distance first from one star and afterwards from a second. By the ingenious use of a prism, three distinct contacts of each star with the moon's limb may be timed; thus in comparison with the timing of the single instant of immersion, which alone is available in observing an occultation, there is a great reduction of the risk of error.

The instrument consists of a horizontal $2\frac{1}{2}$ -inch telescope, so mounted on a pedestal or tripod that it may be rotated both in azimuth and about its own optical axis. These rotations are controlled by slow-motion screws, but do not require to be measured. And it is not necessary to level the telescope, the horizontal position being adopted merely for the convenience of the observer.

In front of the object glass of the telescope is a mirror (called the field mirror), whose plane is inclined at an angle of 45° to the optical axis of the telescope, and which is rigidly attached to the telescope. The effect of the field mirror is to reflect the line of sight through the telescope at right angles to its original direction; and it is clear that, though the telescope itself is kept horizontal, the reflected line of sight can be directed to any star by suitably moving the telescope in azimuth

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