I

THE CLIMATE OF GREAT BRITAIN

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CLIMATE, though often described as average weather, should rather be viewed as the sequence and the sum of weather over a long period. It is produced by energy radiated from the Sun working in the Earth's atmosphere, but this process involves so many simultaneous and successive actions and reactions that it can only be made clear by a series of approximations.

The five paragraphs which follow set out with the utmost brevity five stages of approach to the description of British Climate.

(1) If the Earth consisted only of a homogeneous lithosphere with a smooth and rigid surface the temperature of that surface would depend on the latitude only. Temperature would vary from the equator to the poles in strict accord with the astronomical climate produced by the rotation and revolution of the globe and the inclination of its axis to the plane of its orbit. The hot tropical zone with nearly equal day and night would show a great diurnal range of temperature and a small annual range. It would be separated by a gradual transition on each side, the temperate zones, from the two cold polar zones. In the polar zones there would be a great seasonal difference in the length of day and night, allowing feeble heating in summer from a low sun and intense cooling at night in winter by terrestrial radiation; the range of temperature in 24 hours would be slight but the annual range would be great. The heat or cold acquired by the surface in any latitude would be exactly the same from east to west and would not affect contiguous regions to north or south.

(2) The lithosphere's surface is not homogeneous but composed of different rocks differing in thermal conductivity, and so parts of the solid surface in the same latitude are more rapidly heated and cooled than others, and the temperature of the surface is not exactly the same along the same parallel of latitude. The nature of the surface has to be considered.

(3) The surface of the lithosphere is not smooth but ridged into upheavals and depressions. All places in the same latitude are therefore not equally exposed to the sun's rays; the ridges catch the sunlight on one side at a favourable angle for absorption and so are more heated by day on the exposed than on the sheltered

side. Aspect has to be taken into account, and the detailed configuration of mountain and plain exerts a dominant influence on the distribution of local climates.

(4) The Earth does not consist of a lithosphere only; there is a mobile hydrosphere or water envelope, and the chief result of the irregular configuration of the lithosphere is that the water gathers into the deeper hollows and so gives rise to the broad geographical division into land and sea. If the Earth consisted of land and sea alone the astronomical zones of soil-temperature would not be changed on the land; but similar zones would not be established on the sea although solar radiation strikes impartially on both. The heating of the water in the Tropics and the chilling of the water in the polar zones alter the density and set up vertical and horizontal movements resulting in a circulation of warm water towards the polar and of cold water towards the tropical seas. In the northern hemisphere the rotation of the Earth causes these currents constantly to deviate towards the right as they flow on their way, and the edges of the continents guide them in their onward course, so that a warm stream sets eastward and northward towards the coast of northern Europe and a cold current flows southward and westward along the coast of North America. Thus the temperature of the water in the North Atlantic does not increase uniformly from north to south like that of the land surface, but rather from west to east. Heat from the Sun penetrates to a far greater depth in water than in solid land and thus raises the temperature of a far thicker layer to a far less degree. Similarly water cools by conduction and radiation much more slowly than does the land, giving a much smaller diurnal and annual range in the same latitude. Water when it receives heat turns into vapour which rises and accumulates until it is saturated and exerts a certain pressure which is greater as the temperature is higher; but on being cooled saturated vapour returns by degrees to the liquid state. The heat used up in evaporation is restored when the vapour, which may have been carried some distance from its source, condenses as mist or rain. Water, when cooled, solidifies to form ice which tends to accumulate in the polar zones, and the effects of evaporation and freezing greatly complicate the circulation of the sea.

(5) The physical structure of the Earth is completed by an all-embracing atmosphere of air resting in uneasy equilibrium on land and sea and permeated by the vapour of water. Clear dry air allows solar radiation to pass through to the land or sea below it, taking a very small toll of the heat with only a slight rise of temperature, and similarly at night air cools down very little by its own radiation

while allowing radiation from the land or sea to pass through. The presence of water vapour reduces the diathermancy of air, allowing more heat to be absorbed and reducing the heating of the land by day and its cooling by night, the net result being to retain heat in the air near the Earth's surface and to modify extremes. The temperature of the air is raised or lowered mainly by contact with the surface beneath it and always to a greater extent by land than by sea. Being much more mobile than water and expanding more with an equal rise of temperature, air is set into circulation by the gain or loss of heat more actively than the water of the sea, but it follows nearly the same direction at the surface. Under the direct influence of radiation a regular interchange of air takes place between the hot Tropics and the cold polar regions across the temperate zones. Over the North Atlantic the warm air currents from the Tropics flow towards the coasts of Europe from the south-west, while the cold air currents from the polar area flow towards the shores of America. The currents of the air are much less stable than those of the ocean, and in the unceasing conflict of tropical and polar winds Great Britain, though usually in the warm current, is often invaded by polar air and is sometimes in the front where the two streams meet. When polar air meets an opposing current of tropical air the two do not mix except superficially, but the denser air from the north flows under the lighter air from the south which may thus be raised to a considerable height in the atmosphere. This gives rise to a whirling or cyclonic movement affecting the distribution of pressure in the atmosphere.

Gain or loss of heat in air takes place not only by radiation and by contact with things outside; it may result from mechanical changes; thus when air is compressed heat is liberated, and when air is rarefied heat is absorbed. When moist sea winds are forced to ascend by any cause the air expands and is consequently cooled, the water vapour contained in it condenses in clouds which may form a screen nearly stopping radiation of heat to or from the surface below.

The little particles of water in clouds coalesce as they fall to form rain drops, and when a violent upward current is set up through rain the larger drops are shattered into droplets with the separation of electricity which may lead to disruptive discharges in the form of lightning.

The contrast between the thermal characters of land and sea and their influence on the air give rise to the broad distinction between oceanic climates of high rainfall and small range of temperature and continental climates which are very dry and have a great range between the temperature of day and night and of summer and winter. Great Britain enjoys a blend of both climates.

The great scheme of circulation between the Tropics and the polar area is complicated by diurnal and seasonal alternations due to the unequal heating and cooling of land and sea, producing regular breezes blowing from sea to land by day and from land to sea by night, and the system of monsoon winds blowing from sea to land in summer and from land to sea in winter. In the Tropics these effects are powerful enough periodically to slacken or reverse the main circulation; but in Great Britain they only appear feebly in spells of very calm weather. On steep slopes the air chilled by contact with cold land or snow at night may flow downward and displace the warmer air on valley floors or plains. This effect is a powerful agent of air circulation in the polar zones, and in Great Britain it occasionally produces damage to vegetation on low-lying ground in winter. As a rule the temperature of the air at the surface diminishes regularly as the height of the land increases, the rate of fall being about 1° F. in 300 ft. When isothermal maps are made to show the distribution of temperature, the figures are corrected to their value at sea-level before they are plotted. Thus the isotherm of 40° drawn across a mountain 3000 ft. high indicates an actual temperature of 30° on the summit.

Configuration of Great Britain

When dealing with British climate it is desirable to bear in mind the broad lines of the form and relief of the land. Great Britain, an island held in a mesh of the 10-degree net between the parallels of 50° and 60° N. and the meridians of 0° and 10° W., is broad in the south and narrows in a form approaching a triangle towards the north-west as far as the Firth of Forth in 56° N., thence it widens and trends due north in a broken rectangle to the Pentland Firth in 59° N. England is nearly bisected by the meridian of 2° W. which only touches the extreme eastern tips of Scotland, and the mainland of Scotland is nearly bisected by the meridian of 4° W. which traverses only the western peninsulas of Wales and England.

The orographical structure can be understood by dividing the island into two main divisions, the Lower Lands or English Plain, mainly in the south and east but branching westward through Cheshire and Gloucestershire, and the Higher Lands in the north and west, the dividing line running from Axmouth in the south northwards to the Severn estuary and thence in a bold curve to the Humber. In the eastern division the hills are mainly the scarped edges of chalk and limestone rocks rarely reaching much

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above 500 ft. (150 m.)* and nowhere touching 1000 ft. These low hills and plateaux have little practical effect on temperature but they exercise a distinct influence on rainfall. The nature of the soil has a marked effect on local climate. The permeable covering of the Downs and gravel hills allows rain to soak away and the dry ground responds to solar radiation and warms the overlying air. On the other hand, the flat impermeable claylands which alternate with them hold moisture which keeps the air damp and chilly and conduces to the formation of fog. The regions dealt with in ten of the eleven chapters that follow lie wholly or mainly in this division and their climate corresponds to their situation. The division of the Higher Lands contains the South-Western Peninsula (Ch. v) dominated inland by Dartmoor, Exmoor and Bodmin Moor, and enjoying on the coast the most thoroughly oceanic climate of any part of the mainland. On the west there is Wales rising in parts to over 2000 and even 3000 ft. (610 and 910 m.) with steep fronts to the sea on south, west and north, and a less steep face to the lower valleys of the Severn and Dee: a typically mountainous region on a small scale. In the north the backbone of the Pennine Highland is linked westward with the Lake District or Cumbria and includes most of Derbyshire, Yorkshire, and Durham, blending in Northumberland with the Cheviots. In Scotland the Southern Uplands fill the south, merging with the Cheviots: the Midland Valley is a low belt uniting the estuaries of the Clyde, Forth and Tay and seamed with lines of low abrupt hills, and the Highlands fill the north with a great dissected plateau rising over large areas above 3000 ft. and in places touching 4000 (1220 m.). This mass is divided by the Great Glen running north-eastward from the Firth of Lorne to the Moray Firth into two great areas, that to the south in the broadest part of Scotland being largely remote from the influence of ocean air, that in the north less lofty and much more open to sea winds. As a whole Britain faces the Atlantic with a bold front sloping sharply to the ocean and on the other sides it declines much more gradually towards the North Sea into the low plains of the east and south which here and there reach back to the west between the orographic nuclei of the Higher Lands. The contrast between the east and west of Britain is marked by the low level plains which usually border the North Sea in a slightly indented shore and the narrow mountain valleys of the west which front the archipelago of the Hebrides and the Atlantic.

* An explanation of the metric and other numerical equivalents given in this work will be found in the Preface.

The broad lines of configuration explain the distribution of climate by their action on solar radiation and on the wind which carries moderate warmth and abundant vapour from the ocean or extreme temperatures and drought from the continent.

The four conditions of climate, *viz.* latitude, nature of soil, configuration of surface and distribution of land and water, govern the weather-producing power of solar and terrestrial radiation as exemplified in direct sunshine, moving air in the form of wind, temperature changes due to both agencies, evaporation of water and the condensation of water vapour as cloud and its precipitation as dew, rain, snow or hail. These activities form the main elements of climate.

SUNSHINE

In the latitude of Great Britain, the possible duration of sunshine, averaging 12 hours per day, is divided very unequally over the circle of the year. At 50° N. in southern Cornwall the Sun at noon at the summer solstice attains an altitude of 63½°, that is as high as at the winter solstice in 3° N., 200 miles from the equator. It is above the horizon for 16 hours 20 minutes, rising in the NE. by E. and setting in the NW. by W. At the winter solstice the meridian altitude of the Sun in Cornwall is 16½° which is lower than at the North Pole in summer. It is above the horizon for only 8 hours, rising in the SE. by E. and setting in the SW. by W. The altitude of the Sun diminishes exactly as the latitude increases, so at 60° N., north of Orkney, the altitude at the summer solstice is 53½°, but the Sun is above the horizon for 18 hours 40 minutes, rising in the NE. by N. and setting in the NW. by N.; on the other hand, at the winter solstice the noonday altitude of the Sun is only 6½° or 13 times its own diameter above the horizon, an angle so low that radiation is of no account, and the Sun is visible only for 5 hours 40 minutes, rising in the SE. by S. and setting in the SW. by S. Thus the longest summer day is 2¼ hours longer in the north of Scotland than in the south of England; and the shortest winter day is 2¼ hours shorter. The decrease of 10° in the Sun's altitude at all times of the year means a great reduction in the heating power of solar radiation at the surface of the land.

Observations show that, for the country as a whole, cloud, fog and haze allow the Sun to be visible for only about one-third of the time it is above the horizon, that is to say for about 1500 hours in the year out of 4380. The proportion of recorded sunshine diminishes from an average of about 40 per cent. of the possible under the high Sun of Cornwall to about 26 per cent. under the low Sun of

Orkney, and the duration of sunshine is always greater on the coast than in the interior of the country in spite of the wider horizon of the higher land, the effect being assignable to the greater cloudiness over the hills.

In the map of average sunshine duration for the year the brightest region includes the South-Western Peninsula and a belt of about 35 miles (60 km.) wide along the whole south coast and the east coast as far north as the Wash in which the average duration is more than 4½ hours per day; the darkest month, December, has only about 1½ hours of sunshine and the brightest, June, from 7 to 7½ hours per day. Wales, the whole west coast of England and the English Plain enjoy an annual average of 4 hours per day of sunshine, varying from between 1 and 1½ hours in December (when the east coast as far north as Aberdeenshire is equally favoured) to more than 6½ hours in June. England, north of 52° N. and more than 10 miles inland, has an average annual sunshine duration of between 3½ and 4 hours daily, ranging from less than 1 hour per day in December to just under 6 hours per day in June. The Midland Valley of Scotland has about 3½ hours per day of bright sunshine on the average for the year, the Southern Uplands about ¼ hour more, the Highlands about ¼ hour less. In December the only parts of Scotland with over 1 hour a day of sunshine are the extreme south-west and a strip of the east coast extending north to the Moray Firth. In June all Scotland receives on the average more than 5½ hours of sunshine per day while on the Solway Firth and along the east coast south of Peterhead there are over 6 hours per day.

The average duration in December is twice as long on the English Channel as on the Pentland Firth, whereas in June the duration in the south is only 25 per cent. longer than in the north thanks to the difference in the length of the day. The greater altitude of the Sun and the lower level of the land in the English Plain south of the Pennines make that the only part of Great Britain in which local solar radiation is a powerful and sometimes a dominant climatic factor. In other parts of the country near sea-level considerable heating by the Sun may be experienced in clear weather. but it is insignificant everywhere above 1000 ft. (300 m.) although there is much intense cooling by terrestrial radiation on cloudless nights on the higher lands.

Winds and Atmospheric Pressure

The weather and therefore the climate of Great Britain is usually dictated by the vast eddies set up in the air over the North Atlantic somewhere to the south of Iceland. In this centre of action the barometric pressure is low, cloudiness excessive and fog very frequent. Another centre of action situated near the Azores is characterised by clear skies, light winds and high barometric pressure, and as both centres of action swing at times far on either side of their mean positions the conditions which affect the British Isles from the west are infinitely varied, the more so because in winter there is another high-pressure centre and in summer a low-pressure area over the continent, either of which may extend its influence across the North Sea. The Icelandic centre of action gives rise at times to families of secondary depressions which move forward one after another and carry with them a regular sequence of winds, cloud and rain, producing according to the intensity of the barometric gradient gentle breezes and showers or gales and devastating rains.

The most frequent condition of weather is the steady flow of warm moist air from the south-west, and while it is in force the chief agent in shaping regional climates is the configuration of the land. When, however, a depression or one of the active small secondaries crosses Great Britain it brings almost the whole weather-making power with it and distributes it in wind or rain with no apparent regard to local configuration. The distribution of weather in such a case depends on the track of the centre of the depression which is the point of lowest barometer. The most active secondaries seldom carry their rain area farther than 50 (80 km.) or 100 miles from their track, and so the same kind of weather very rarely prevails in the north and south of Britain. The most common track for main Atlantic depressions is north-eastward, parallel to the coasts of Ireland and Scotland. Secondaries cross the country at any point, run in any direction, and the track may curve to right or left, or double on itself. They usually proceed from a westerly to an easterly quarter following a geographical feature, such as that of the English Channel, or the English Plain from the Bristol Channel to the Wash or the Humber, or the Midland Valley of Scotland from the Solway or the Clyde to the Forth, or the Great Glen from the Firth of Lorne to the Moray Firth, or the Pentland Firth. So much of the weather is produced by rapidly moving depressions that the direction and force of the wind at any place change from day to day and often from hour to hour; in every month many instances occur of wind blowing from each point of the compass. For the country as a whole, and there is little variation in the different regions, it is a bold but fair approximation to say that the wind blows on the average from a westerly quarter on half the days of the year, from an easterly quarter on one-quarter of the days of the year, and from north and from south each on one-tenth of the days; on the remaining one-twentieth of the days there is no wind at all. The fact that easterly winds are usually cold and are most felt on the east coast, probably accounts for the common error that such winds predominate on that side of Britain.

The force of the wind at sea is usually steady and varies gradually, whether it is light or rises to a gale, and its direction is steady also, the veering or backing from one direction to another being easy and progressive. The same is true of the free air high above the inequalities of the land surface; but on the ground itself friction against the obstacles round or over which the wind must pass confuses the direction and breaks the steady stream of air into turbulent eddies and irregular gusts. Gales (in which the velocity of the wind exceeds 40 miles an hour) occur twice as frequently on the west, north and north-east coasts as they do on the east and south coasts of England, and strong winds are everywhere most frequent in the winter months, November to February, and least common in the summer months, especially June and July.

The varied configuration of the land gives a bewildering variety of shelter from the wind, the effect being local rather than regional. However, along the whole coast, especially in the west and on wide flat plains such as those of Caithness and the Fenland, the force of the unobstructed wind makes the growth of trees practically impossible without artificial shelter. This is equally true of the moors of the Higher Lands in the north and west, and of the broad ridges of the limestone and chalk downs in the Lower Lands of the south.

The best representation of the true distribution of wind is given by maps showing atmospheric pressure. As the pressure diminishes by about one-tenth of an inch of mercury for every hundred feet of elevation the barometer readings have to be corrected to their value at sea-level before being plotted on maps on which isobars are drawn. The flow of the wind is nearly parallel to the isobars and the direction such that a person standing with his left hand towards the lower pressure and his right towards the higher has the wind on his back. When the average pressure for a month, or a year, is mapped the isobars show which wind-direction prevails on the balance. The average annual isobars run across Great Britain from south-west to north-east with the highest pressure in the south. The gradient of pressure and therefore the mean force of the wind is greatest in January when the barometer oscillates about 1018 millibars in the south of England and 1008 in the north of Scotland. In May and June the gradient, though still for westerly.

winds, is only one-fifth as steep, the pressure varying from 1016 millibars in the south of England to 1014 millibars in the north of Scotland. As the winds in the midwinter months, December and January, are on the average five times as strong as the winds of the early summer months, May and June, it is obvious that the oceanic influence on the climate of Great Britain is five times greater in winter, when the result is to make the climate warmer and damper, than it is in summer, when the result is merely to make the climate a little cooler and moister than it would otherwise be.

Temperature

While solar radiation is important in raising the temperature of the air in the south of Great Britain in summer and terrestrial radiation plays a great part in reducing the air temperature in the north in winter the prevailing south-westerly wind from the ocean is always acting as a modifying agent, and produces for the whole year the warmest and most equable climate which exists in any part of the world between the latitudes of 50° and 60°.

The mean monthly isothermal maps show the seasonal swing of temperature from the coldest period at the winter solstice to the warmest at the summer solstice and back again. It is only possible to refer here to the conditions in the two extreme months and to the average for the whole year. In January the general temperature of Great Britain averages 40° F. (4°·4 C.)* which is the same as that of places 20° farther south on the east coast of North America. On the west side the mean temperature is higher than 40° (with mean daily maximum temperatures above 43° (6°·1) and mean minima about 35° (1°·7)) from Sutherland to Wales, and also over the whole of south-western England from Gloucester to the Isle of Wight. The mean temperature reaches 42° (5°·6) in the Outer Hebrides and the west of Wales and 44° (6°·7) in the south of Cornwall where the mean daily maximum reaches 48° (8°·9) and the night minimum 41° (5°·0): here the winter is mildest, frost is rare and is very seldom severe. The eastern half of Great Britain has a mean January temperature below 38° (3°·3) and often below freezing point in the higher districts, while above 1800 ft. (550 m.) a snow covering is usually found. The mean day maximum in the eastern half is about 43° (6°·1) and the mean night minimum 33° (0°·6) or less, the figures being correspondingly lower on the higher ground. Speaking generally, temperature in January diminishes from the south-west to the north-east in England and

* Temperatures below are given in degrees F., with degrees C. in brackets.