TROPICAL NATURE,

AND OTHER ESSAYS.

I.

THE CLIMATE AND PHYSICAL ASPECTS OF THE EQUATORIAL ZONE.

The three Climatal Zones of the Earth—Temperature of the Equatorial Zone—Causes of the Uniform High Temperature near the Equator—Influence of the Heat of the Soil—Influence of the Aqueous Vapour of the Atmosphere—Influence of Winds on the Temperature of the Equator—Heat due to the Condensation of Atmospheric Vapour—General features of the Equatorial Climate—Uniformity of the Equatorial Climate in all parts of the globe—Effects of Vegetation on Climate—Short Twilight of the Equatorial Zone—The aspect of the Equatorial Heavens—Intensity of meteorological phenomena at the Equator—Concluding Remarks.

It is difficult for an inhabitant of our temperate land to realize either the sudden and violent contrasts of the arctic seasons or the wonderful uniformity of the equatorial climate. The lengthening or the shortening days, the ever-changing tints of spring, summer, and autumn, succeeded by the leafless boughs of winter, are constantly recurring phenomena which represent to us the established course of nature. At the equator none of these changes occur; there is a perpetual equinox and

a perpetual summer, and were it not for variations in the quantity of rain, in the direction and strength of the winds, and in the amount of sunshine, accompanied by corresponding slight changes in the development of vegetable and animal life, the monotony of nature would be extreme.

In the present chapter it is proposed to describe the chief peculiarities which distinguish the equatorial from the temperate climate, and to explain the causes of the difference between them,—causes which are by no means of so simple a nature as are usually imagined.

The three great divisions of the earth—the tropical, the temperate, and the frigid zones, may be briefly defined as the regions of uniform, of variable, and of extreme physical conditions respectively. They are primarily determined by the circumstance of the earth's axis not being perpendicular to the plane in which it moves round the sun; whence it follows that during one half of its revolution the north pole, and during the other half the south pole, is turned at a considerable angle towards the source of light and heat. This inclination of the axis on which the earth rotates is usually defined by the inclination of the equator to the plane of the orbit, termed the obliquity of the ecliptic. The amount of this obliquity is $23\frac{1}{2}$ degrees, and this measures the extent on each side of the equator of what are called the tropics, because within these limits the sun becomes vertical at noon twice a year, and at the extreme limit once a year, while beyond this distance it is never vertical. It will be evident, however, from the nature of the case, that the two lines which mark the limits of the geographical "tropics" will not define any abrupt

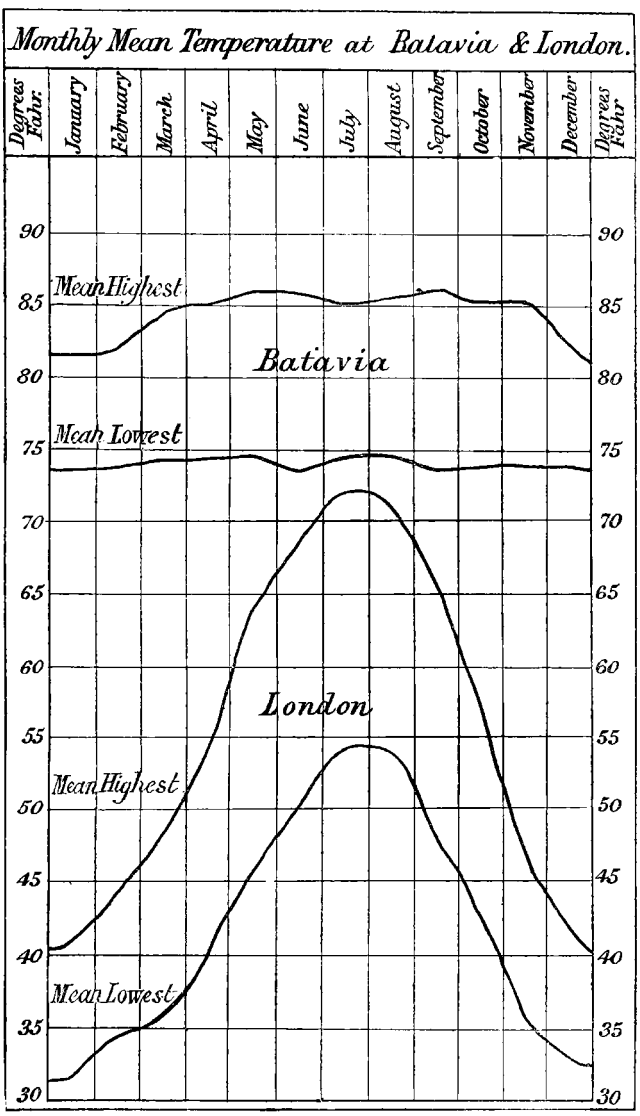
change of climate or physical conditions, such as characterise the tropical and temperate zones in their full development. There will be a gradual transition from one to the other, and in order to study them separately and contrast their special features we must only take into account the portion of each in which these are most fully exhibited. For the temperate zone we may take all countries situated between 35° and 60° of latitude, which in Europe will include every place between Christiana and Algiers, the districts further south forming a transitional belt in which temperate and tropical features are combined. In order to study the special features of tropical nature, on the other hand, it will be advisable to confine our attention mainly to that portion of the globe which extends for about twelve degrees on each side of the equator, in which all the chief tropical phenomena dependent on astronomical causes are most fully manifested, and which we may distinguish as the "equatorial zone." In the debateable ground between these two well contrasted belts local causes have a preponderating influence; and it would not be difficult to point out localities within the temperate zone of our maps, which exhibit all the chief characteristics of tropical nature to a greater degree than other localities which are, as regards geographical position, tropical.

Temperature of the Equatorial Zone.—The most characteristic, as it is the most important feature in the physical conditions of the great equatorial zone is the wonderful uniformity of its temperature, alike throughout the changes of day and night, and from one part of the year to another. As a general rule, the greatest heat of the day does not exceed 90° or 91°

Fahr., while it seldom falls during the night below 74° Fahr. It has been found by hourly observations carried on for three years at the meteorological observatory established by the Dutch government at Batavia, that the extreme range of temperature in that period was only 27° Fahr., the maximum being 95° and the minimum 68°. But this is, of course, very much beyond the usual daily range of the thermometer, which is, on the average, only a little more than 11° Fahr.; being 12·6° in September when it is greatest, and only 8·1° in January, when it is least.

Batavia, being situated between six and seven degrees south of the equator, may be taken as affording a fair example of the climate of the equatorial zone; though, being in an island, it is somewhat less extreme than many continental localities. Observations made at Para, which is continental and close to the equator, agree however very closely with those at Batavia; but at the latter place all the observations were made with extreme care and with the best instruments, and are therefore preferred as being thoroughly trustworthy.[1] The accompanying diagram, showing by curves the monthly means of the highest and lowest daily temperatures at Batavia and London, is very instructive; more especially when we consider that the maximum of temperature is by no means remarkably different in the two places, 90° Fahr. being sometimes reached with us and not being often very much exceeded at Batavia.

[1] "Observations Made at the Magnetical and Meteorological Observa at Batavia. Published by order of the Government of Netherlands I Vol. I. Meteorological, from Jan. 1866 to Dec. 1868; and Magnetical, July 1867 to June 1870. By Dr. P. A. Bergsma. Batavia, 1871." fine work is entirely in English.



Causes of the Uniform High Temperature near the Equator.—It is popularly supposed that the uniform high temperature of the tropics is sufficiently explained by the greater altitude, and therefore greater heating-power, of the midday sun; but a little consideration will show that this alone by no means accounts for the phenomenon. The island of Java is situated in from six and a half to eight and a half degrees of south latitude, and in the month of June the sun's altitude at noon will not be more than from 58° to 60°. In the same month at London, which is fifty-two and a half degrees of north latitude, the sun's noonday altitude is 62°. But besides this difference of altitude in favour of London there is a still more important difference; for in Java the day is only about eleven and a half hours long in the month of June, while at London it is sixteen hours long, so that the total amount of sun-heat received by the earth must be then very much greater at London than at Batavia. Yet at the former place the mean temperature of the day and night is under 60° Fahr., while in the latter place it is 80° Fahr., the daily maximum being on the average in the one case about 68° and in the other about 89°.

Neither does the temperature at the same place depend upon the height of the sun at noon; for at Batavia it is nearly vertical during October and February, but these are far from being the hottest months, which are May, June, and September; while December, January, and February are the coldest months, although then the sun attains nearly its greatest altitude. It is evident, therefore, that a difference of 30° in the altitude of the sun at noon has no apparent influence in raising the temperature of a place near the equator, and we must

therefore conclude that other agencies are at work which often completely neutralise the effect which increased altitude must undoubtedly exert.

There is another important difference between the temperate and tropical zones, in the direct heating effect of the sun's rays independently of altitude. In England the noonday sun in the month of June rarely inconveniences us or produces any burning of the skin; while in the tropics, at almost any hour of the day, and when the sun has an elevation of only 40° or 50°, exposure to to it for a few minutes will scorch a European so that the skin turns red, becomes painful, and often blisters or peels off. Almost every visitor to the tropics suffers from incautious exposure of the neck, the leg, or some other part of the body to the sun's rays, which there possess a power as new, as it is at first sight inexplicable, for it is not accompanied by any extraordinary increase in the temperature of the air.

These very different effects, produced by the same amount of sun-heat poured upon the earth in different latitudes is due to a combination of causes. The most important of these are, probably,—the constant high temperature of the soil and of the surface-waters of the ocean,—the great amount of aqueous vapour in the atmosphere,—the great extent of the intertropical regions which cause the winds that reach the equatorial zone to be always warm,—and the latent heat given out during the formation of rain and dew. We will briefly consider the manner in which each of these causes contributes to the degree and the uniformity of the equatorial temperature.

Influence of the Heat of the Soil.—It is well known that at a very moderate depth the soil maintains a uniform temperature during the twenty-four hours; while at a greater depth even the annual inequalities disappear, and a uniform temperature, which is almost exactly the mean temperature of the locality, is constantly maintained throughout the year. The depth at which this uniform temperature is reached is greater as the annual range of temperature is greater, so that it is least near the equator, and greatest in localities near the arctic circle where the greatest difference between summer and winter temperature prevails. In the vicinity of the equator, where the annual range of the thermometer is so small as we have seen that it is at Batavia, the mean temperature of about 80° Fahr. is reached at a depth of four or five feet. The surplus heat received during the day is therefore conducted downwards very slowly, the surface soil becomes greatly superheated, and a large portion of this heat is given out at night and thus keeps up the high temperature of the air when the sun has ceased to warm the earth. In the temperate zones, on the other hand, the stratum of uniform earth-temperature lies very deep. At Geneva it is not less than from thirty to forty feet, and with us it is probably fifty or sixty feet, and the temperature found there is nearly forty degrees lower than at the equator. This great body of cool earth absorbs a large portion of the surface heat during the summer, and conducts it downwards with comparative rapidity, and it is only late in the year (in July and August) when the upper layers of the soil have accumulated a surplus store of solar heat that a sufficient quantity is radiated at

night to keep up a high temperature in the absence of the sun. At the equator, on the other hand, this radiation is always going on, and earth-heat is one of the most important of the agencies which tend to equalise the equatorial climate.

Influence of the Aqueous Vapour of the Atmosphere.—The aqueous vapour which is always present in considerable quantities in the atmosphere, exhibits a singular and very important relation to solar and terrestrial heat. The rays of the sun pass through it unobstructed to the earth; but the warmth given off by the heated earth is very largely absorbed by it, thus raising the temperature of the air; and as it is the lower strata of air which contain most vapour these act as a blanket to the earth, preventing it from losing heat at night by radiation into space. During a large part of the year the air in the equatorial zone is nearly saturated with vapour, so that, notwithstanding the heat, salt and sugar become liquid, and all articles of iron get thickly coated with rust. Complete saturation being represented by 100, the daily average of greatest humidity at Batavia reaches 96 in January and 92 in December. In January, which is the dampest month, the range of humidity is small (77 to 96), and at this time the range of temperature is also least; while in September, with a greater daily range of humidity (62 to 92) the range of temperature is the greatest, and the lowest temperatures are recorded in this and the preceding month. It is a curious fact, that in many parts of England the degree of humidity as measured by the comparative saturation of the air, is as great as that of Batavia or even greater. A register kept at Clifton

during the years 1853—1862 shows a mean humidity in January of 90, while the highest monthly mean for the four years at Batavia was 88; and while the lowest of the monthly means at Clifton was 79·1, the lowest at Batavia was 78·9. These figures however represent an immense difference in the *quantity* of vapour in every cubic foot of air. In January at Clifton, with a temperature of 35° to 40° Fahr., there would be only about 4 to 4½ grains of vapour per cubic foot of air, while at Batavia, with a temperature from 80° to 90° Fahr., there would be about 20 grains in the same quantity of air. The most important fact however is, that the capacity of air for holding vapour in suspension increases more rapidly than temperature increases, so that a fall of ten degrees at 50° Fahr. will lead to the condensation of about 1½ grains of vapour, while a similar fall at 90° Fahr. will set free 6½ grains. We can thus understand how it is that the very moderate fall of the thermometer during a tropical night causes heavier dews and a greater amount of sensible moisture than are ever experienced during much greater variations of temperature in the temperate zone. It is this large quantity of vapour in the equatorial atmosphere that keeps up a genial warmth throughout the night by preventing the radiation into space of the heat absorbed by the surface soil during the day. That this is really the case is strikingly proved by what occurs in the plains of Northern India, where the daily maximum of heat is far beyond anything experienced near the equator, yet, owing to the extreme dryness of the atmosphere, the clear nights are very cold, radiation being sometimes so rapid that water placed in shallow pans becomes frozen over.