CLIMATIC NOTES ON NEW GUINEA.

By B. G. Challis.

It is noted that throughout the Territory an increasing interest is being taken in the weather and climate of New Guinea, and for the information of residents generally it is proposed to supplement the attached climatological tables with a few notes on the subject of meteorology as it affects the Territory.

Meteorology may be defined as a study of the atmospheric conditions and its various changes, or, being a branch of the wider science Physics, it is sometimes referred to as the science of the earth's atmosphere, embracing both weather and climate. The study of the latter, however, is separately designated climatology. Climate implies the degree of heat, light and moisture, and affects the suitability or otherwise of a country for vegetable, human or animal life.

With the introduction of scientific methods in industry and commerce, applied meteorology is, of recent years, rapidly coming to the fore and, thus, we have sub-divisions as agricultural, marine, aeronautical and insurance meteorology. From time to time, as circumstances permit, these branches of meteorology will be dealt with through the medium of this *Gazette*.

The following notes, however, deal in a general way only with climatic conditions as met with in the Territory of New Guinea, and readers are cordially invited to communicate with the Department of Agriculture, Rabaul, regarding the weather conditions which they may experience from time to time, so that more detailed information may be collected and more accurate climatological data be made available for the benefit and interest of the Territory generally.

The Mandated Territory of New Guinea is situated 141° to 156° east longitude, and approximately 0°–8° south of the equator and, as its latitudes imply, a typically tropical climate in the narrower sense is experienced, although nothing like the climatic fluctuations which occur between 8° south and 23° south.

To those who have never lived in the tropics, the word "tropics" very often conveys a wrong impression of the actual conditions to be expected. This is perhaps due to the term "temperate climate" applied to the intermediate zones either north or south of the equator, where extremes of temperature, ranging from as low as 0° Fahrenheit to as high as 125° F. are liable to occur. (125° F has been registered at Bourke in New South Wales.)

The tropics are generally defined as ranging from 23° north on the tropic of Cancer to the tropic of Capricorn at 23° south of the equator, but, from a practical geographic point of view, the "tropics" may better be regarded as lying between 10° north and 10° south of the equator, and in these latitudes within which New Guinea lies in the Southern Hemisphere, the temperatures at sea level seldom rise higher than 95° F. or rarely sink below 70° F.—figures which indicate a more temperate climate than those experienced in the more popularly recognized temperate zones with their extreme range of weather conditions. However, as in temperate climates, the temperatures in the tropics are affected by elevation by a drop or lapse rate of about 3° F. in every 1,000 feet of altitude; Humboldt,[4] the great German explorer, discovered that the thermometer fell 1° for every 343 feet of elevation, a fact which is evident by comparing the 1938 tables of climatological stations at Bulolo, 2,200 feet, Aiyura Agricultural

Station, 5,875 feet, and those of the coastal districts capital stations. It is interesting to note that aviators have reported ice accretions on aircraft at 16,000 feet when in flight over the mainland of our Territory, but on descending to about 14,500 feet such ice formation disappeared. Falls of snow have been reported on Mount William (approximately 15,000 feet).

The situation of the many islands which comprise the Territory permits of a free circulation of air so that, from a general point of view, the climate resembles that of the ocean near the equator, i.e., with high average temperature and stable atmospheric conditions, and thus we have along the coastal belts, a maximum isothermic average of about 88° F. and a minimum average of 75° F. and a mean of 82° F. It will be observed that there is little seasonal variation between the cooler and warmer months. The range being about 3°.

In the Territory there is no winter with its short days and long nights, or summer days of a converse nature. The sun daily ascends and descends almost perpendicularly with the horizon, so that dawn and twilight are of short duration. There is but little apparent change in the sun's position daily at noon, when the sun stands practically overhead, and, in consequence, there is only a small daily temperature variation, and only about half an hour difference between extreme times of sunrise and sunset, during the course of a year.

Slight variations in temperature become distinctly noticeable to acclimatized tropical residents, despite the small temperature range. There are other atmospheric conditions, such as humidity, which affect the human senses, but there is no fear of heat wave visitations such as were experienced in Australia during the last summer, when high record temperature registrations were reported in most States.

Actually New Guinea, with its widespread area of 93,000 square miles ranging from the large mainland area with mountain peaks of about 15,000 feet to numerous islands of diversified shapes and sizes, presents many climatic variations, but broadly regarded, along the coastal belts, where most Europeans are settled either in business or agriculture, the climate is hot and moist; whereas in the mining settlements of the highlands weather conditions are cooler and more pleasant. In the plain country, there is a greater range of the minima and maxima temperatures which is doubtless due to greater radiation. There is, however, that "everlasting sameness" which has an enervating effect on the populace, but this can be combated with attention to suitable diet and a moderate amount of exercise.

Weather conditions as affecting man in the tropics have been comprehensively dealt with by Dr. Douglas H. K. Lee[5] in a series of articles, entitled *The Tropics and Man* which appeared last year in the *Queensland Agricultural Journal*, and these observations are applicable to New Guinea.

Generally speaking, our calendar year is divided into two seasons which correspond to the periods in which the south-east trade winds or the north-west monsoons prevail. Fortunately, New Guinea is outside the hurricane zone. Squalls are often experienced, especially during the north-west monsoon period, but it is thought that there is a tendency to exaggerate their intensity by European residents who are accustomed to more open-air housing conditions than they may have known in other countries.

WINDS.

Changes in Weather Conditions.

Although New Guinea has nothing that can be described as summer or winter, there are changes in weather conditions, due sometimes to general and sometimes to local causes.

Local Causes.

Land and Sea Breezes.—The local cause is attributed to gravity winds, sea and land breezes. Land and sea breezes are felt only along the coastal areas of the larger land masses throughout the islands.

The explanation of the local breeze is that as the day progresses and the sun shows itself above the horizon, the land becomes warmer more rapidly than the adjacent sea, owing to the sun pouring down a stream of radiant energy or insolation, which on contact with the land manifests as heat and causes a rise in temperature. The land surface being a better absorber than the sea surface, it is naturally a better radiator of heat when subject to the same amount of insolation, so that in the mornings the air above the land becomes warmer than the air above the water. The warm air then rises, and is replaced by damp and denser air flowing in from the sea, and this particular indraft of air is known as a sea breeze. As this incoming air in its turn rises, it cools and its moisture condenses to form heavy cumulus clouds. Towards sunset, the reverse process of air flow takes place through the sea losing its radiation more slowly than that of the land. This results in upward convection currents over the sea due to its lessened density, thus setting up a land breeze, and the cooler air from the mountains descends to the sea where it becomes warmed again, thus preserving the equilibrium unless the monsoonal or trade winds cause a change in this sequence.

The configuration and vegetation of the land in some portions of the Territory have a marked effect on the development of land breezes and, unless a considerable land mass is adjacent from which radiation can emanate, it is unlikely that local winds will form to any extent.

Land and sea breezes are most noticeable off the mainland, and the islands of New Britain, Manus, New Ireland and Kieta.

Land and sea breezes seldom reach a height beyond 1,500 feet or attain a velocity above 10-15 miles per hour, nor do they extend their influence inland, nor beyond about 12 miles or 10 miles out to sea.

Gravity Winds.

Gravity winds are perhaps best known in the Markham Valley and other parts of the mainland ranges, but they are also prevalent in other parts of the Territory where high mountain ranges are also in evidence, such as Kieta, which has Mount Balbi, 10,170 feet, New Britain–Ulawun (The Father), 7,546 feet, and Mount Bamus (South Son), 7,376 feet. The intensity of these winds will of course be influenced by the relief features of the land.

The gravity winds are purely local winds and often bear no relation to the distribution of the general atmospheric pressures.

During the day, the sun warms the ground in the valleys and an upward flow of air is commenced due to the convection of heated air. As the air in the valleys becomes warmed, its density decreases and as heated air rises, it flows up the valleys of mountain slopes in the form of an *Anabatic* wind.

At night the reverse process occurs, and a different wind called *Katabatic* is experienced in the hills.

Particularly on clear nights, the radiation from the ground is greater on the mountain tops than in the valleys, because at the higher altitudes there are less dust particles and water vapour particles in the air to intercept the radiation and thus to absorb or reflect it. Hence, we find that the air on the surface of a hill is colder than the air at some distance from the surface, and as it is colder air, and, therefore, denser at the tops of the ranges, a flow of air will gravitate in the direction of the slopes to form a *Katabatic* wind. Under favorable conditions, such as the augmentation of the seasonal winds, these gravity winds develop quite high velocities, but generally they are quite mild.

Upper Winds.

At present no data is available on the upper winds of New Guinea, although experiments in this respect are now being conducted by the aid of pilot balloons at Salamaua and Rabaul.

The opinion at present held is that above the local winds, the trades and monsoons prevail, whilst above the seasonal winds, the direction of the winds is reversed to preserve the general atmospheric wind equilibrium.

Lull of Wind at Night.

Normally, we experience a lull in the wind after sunset and until sunrise. This drop in the force of the wind is not in evidence far out to sea nor above about 1,000 feet.

The lighter winds in the evening are a result of lack of heating from the sun's radiation. This does not allow for convective rising and mingling of the lower layers with the upper, and these lower layers therefore do not receive any impulsive force from above.

During the day the opposite effect is in operation. The sun's radiation heats the lower layers of the atmosphere by convection, and these rise and become connected up with the upper layers, which exert a driving force on them thus increasing their velocity which, were it not for the friction of the ground, would approximate closely to the velocities in the upper layers.

It is of course assumed that there is a steady wind blowing in the upper layers, which is not always the case as in the months of change of season, but it is true for the major parts of the year, during the north-west monsoon and south-east trades.

This lull in the wind is more noticeable during nights of clear sky when the clouds cannot cause a blanketing effect, and prevent free radiation from the earth's surface. On clear nights, radiation from the earth is greatest and thus cooling off is greatest. Under such conditions, the density of the air in contact with the earth's surface increases, and this greater density means a greater lulling of the wind.

The velocity of the wind at the earth's surface is usually greatest in the early afternoon, and least before dawn, but, at the tops of hills, the reverse conditions generally operate.

Seasonal Winds.

Whereas land, sea and gravity winds are local in origin and develop daily within confined, limited areas, the seasonal winds of New Guinea are felt more generally. They divide the year into two seasons and are classified as the north-west monsoon which blows intermittently from December to April, and the south-east trades which prevail from about the end of April to early November,

Sometimes these seasonal winds are referred to as monsoons.[6] "Monsoon" is derived from the Arabic "season", but strictly speaking, monsoons are restricted to Southern Asia and the East Indies where the word monsoon is often used to denote the "rains", more especially the rains which accompany the south-west seasonal winds in those parts.

Monsoons are caused by the seasonal difference of variation of temperature between land and sea areas, and change with the summer and winter of the temperate zones of Southern Asia, where exceptionally high and low barometric pressures operate in summer and winter respectively. In New Guinea, there is very little variation in temperature or barometric pressure throughout the year, and the only monsoonal wind felt is when the north-east monsoon off Southern Asia is deflected into a north-west wind during its passage across the equator, and blows intermittently until its strength is lost in the doldrums—the zone of calms and light variable winds which move north and south of the equator with the annual change of the sun's declination.

The change in the direction of this north-east monsoon off Southern Asia is accounted for by the fact that the earth's velocity at the equator is about 1,000 miles per hour from west to east with an easing off to zero at the North and South Poles. This action gives effect to Professor Buys Ballot's[1] Law which states that—"If in the Northern Hemisphere you stand with your back to the wind, the wind pressure is lower on your left hand, but if in the Southern Hemisphere you stand with your back to the wind, pressure is lower on your right hand".

The more prevalent seasonal wind in New Guinea is the south-east trade—a name originating in the days of sail "to blow trade", meaning to blow constantly in the same direction. This nautical phrase was subsequently shortened to the word "trade".

It is of interest to note that the monsoons were formerly grouped with the trades.

The trades circulate from the great permanent oceanic high pressures at 30° north and 30° south of the equator, and these characteristically regular trades encountered in this Territory sweep up from about latitude 30° south during the winter season of the Southern Hemisphere. Similar trades blow from the north during the winter of the North Hemisphere, but the Indian Ocean and China Seas are exceptions to this general rule and it is from the last-named direction that our north-west monsoons are derived.

The trades are supposed to be constant in force, but closer observations reveal that they are variable when interrupted by contact with the land masses with their local winds and other atmospheric influences. It is generally recognized

in meteorological circles that although throughout the Pacific Oceans, the south-east crosses the equator during the summer of the Northern Hemisphere the north-east trade does not extend to the south of the equator. As New Guinea lies in the southern latitudes, the names given to our seasonal winds are the north-west monsoon (December to April) and south-east trade (May to November).

Both of these seasonal winds carry moisture but the degree of precipitation which occurs is regulated by the height and situation of the land which they strike en route. The rains very often fall in more violent showers than in the more temperate latitudes. The physical features of New Guinea being so varied they account for the diverse monthly and annual rainfall averages shown on the rainfall map. While the seasonal winds are blowing strongly, they overcome the land and sea breezes, but if only blowing moderately, the land and sea breezes will cause a small daily variation in the strength and direction of the seasonal winds near the coasts.

South-East Trades.

As previously mentioned, the south-east trades prevail throughout the Territory from May to November. They make their appearance about the end of April, and gradually increase and freshen in force until July, when the winds continue with marked regularity until October. Their force is then abated by the presence of the north-west monsoon which at this period begins to assert itself against the trade in the upper layers, thus causing the calms experienced during November and correspondingly around April with the change of seasons.

Wind roses have not been prepared to indicate the strength and direction from which the various winds blow, but it is recognized from general observations that in the Admiralty Group and along the north coast of the mainland, so far as the south-east trade is concerned, its strength is more intermittent in character while its course is deflected in such places as St. George's Channel, Dampier and Vitiaz Straits, where it follows the trend of the land, which thus gives it a more southerly direction.

Where the orographical features permit, as in the Huon Gulf and south coast of New Britain, there is a particularly heavy rainfall during the period in which the south-east trade prevails.

In July, when the south-east reaches its maximum intensity, the wind sometimes blows strongly for stretches up to a fortnight. In crossing the New Britain ranges much of the moisture content is lost on the southern side of the island, but the wind continues with but little lessening in force as far as the Admiralty Islands. It merges in the Doldrums, just north of the equator.

The weather is perhaps a little more hazy during the south-east season.

North-West Monsoon.

The north-west monsoon is of a more intermittent character than the south-east trade and blows with more sudden squalls, and often brings more rain, although it will be noted that in the more exposed islands, the rainfall is fairly regular in most months of the year.

The presence of the north-west monsoon is first felt in the northern part of the Territory in November, and its influence is gradually extended southwards until about Christmas time when it may be considered to be general throughout

the islands. There is considerable variation in the strength and direction of the winds during January to March and unsettled conditions and heavy rains are frequently the order of the day. It should be noted, however, that along the Finisterre Range south-east from Madang, in the Huon Gulf and on the south coast of New Britain, this is considered to be the dry season, because in these parts it is found that the north-west monsoon is less effective.

Change in Seasons.

The change in seasons usually covers a period of five or six weeks between April-May and November-December when either the monsoon or trade wind is losing its force, and neither wind has full charge of the higher atmospheric movement. At such times the weather is generally more humid and oppressive, and thunderstorms in the afternoon often occur.

Along the coastal areas the early morning skies are often clear or have high cirrus clouds. By about 9 a.m. to 10 a.m. cumulus or cauliflower-shaped clouds form and continue to develop until the afternoon, when very often thunderstorms are likely to occur. Thunderstorms also occur out to sea, and are more generally found to occur in the early hours of the morning, due to night radiation from the cloud tops, but are usually later in breaking out than over the land.

It has been found that the electrical potential in the region of lofty mountain peaks is often very high. Increase in electrical potential is recorded where the warm air from the sea coast, carrying dense masses of water vapour from the sea, is forced up the high mountain slopes, and the electrical charge increases with condensation. Thus there would be more liability to lightning near very high mountains (e.g. lightning strike in coco-nuts is particularly severe at the foot of Mt. Balbi, 10,170 feet, Bougainville Island). Although under moist conditions, the potential need not be so great as in a dry atmosphere, the exaggerated causes here due to altitude are more pronounced in the tropics. Of course, other factors may cause particular areas to be liable to severe lightning storms.

Frequently between 9 a.m. to 10 a.m., the seasonal winds which have abated during the night, begin to blow again to some degree, although it should be noted that they often blow throughout the upper air layers during the night. Where there is so often a comparatively clear sky in the mornings, as already mentioned, places with an eastern exposure receive more sunshine compared with a similar position to the west.

Pressure.

In the winter of the Northern Hemisphere the average pressure is very high over Asia and the North Pacific while at the same time there is a corresponding low in Australia. In the summer of the Northern Hemisphere the pressure distribution is reversed. New Guinea lies practically between these defined pressure zones, but being subject to tropical oceanic conditions, there is very little isobaric change along the coast, although a slight increase is noticeable in the transition periods of the Asiatic and Australian pressure zones.

At mean sea level within the Territory the average pressure differs little from about 1008.5 millibars or 29.78 inches and 3.5 millibars would cover the range between highest and lowest monthly average values.

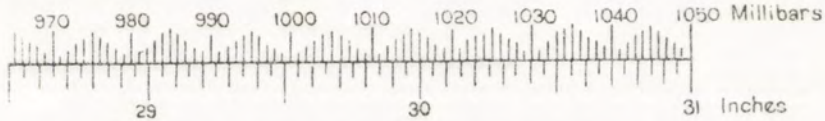
Twice daily there are rises and falls in the barometer. At 9 a.m. and 10 p.m. it reaches its highest and at 4 a.m. and 4 p.m. isobaric pressure is lowest. Any departure from this diurnal variation may indicate a change of weather.

Where there is a defined wet and dry season, as in Rabaul, the average monthly pressure is higher in the dry season than in the wet. It will be noticed that the morning maximum is often higher in the dry season while in the wet season the evening maximum shows a tendency to be more pronounced.

The greatest difference between highest and lowest barometer readings for Rabaul last year was 10.2 millibars or 3/10ths of an inch.[8] With such small variations it will be seen that aneroid barometers are of little assistance to weather observers in this Territory and that extreme accuracy is necessary in reading mercurial barometers if any value is to be placed on such registrations.

Pressure and Winds—Barometer.

The accompanying diagram shows the equivalent of millibars in inches, and vice versa:—



Humidity.

Frequently this office is called upon for an explanation of humidity. Apparently the relative humidity figures which are published each week in the local press are often the cause of comment on this subject.

Humidity is commonly expressed in relative figures, hence the term *relative humidity*, by which is meant the amount of moisture or water vapour actually in the air to the amount it would have if saturated at a given temperature, or in other words, the air is a certain percentage saturated with moisture. This amount is determined from the readings of the thermometers known as the "dry and wet" bulbs, erected in the shade 4 feet above the surface of the ground, where there is free circulation of air.[3]

The dry bulb (an ordinary thermometer) shows the internal shade temperature of the air, while the wet bulb indicates the external shade temperature of evaporation. The wet bulb is an ordinary thermometer kept covered by wet muslin (changed at least once weekly) attached to a reservoir of distilled or rain water by strands of absorbent cotton thread, which keeps the muslin supplied by capillary attraction. Since evaporation causes cooling, the reading of the wet bulb is lower than that of the dry bulb, unless the air is saturated, or it is raining, in either of which cases evaporation is no longer possible.

If the wet bulb records over 80° F. the weather is exceedingly trying and should it reach up to 88° F., it is regarded as prejudicial to life.

Wet bulb registration above 80° F. may be regarded with suspicion, and correct readings over 88° F. are practically impossible.

The drier the atmosphere the greater will be the difference between the readings of the wet and dry bulbs. It may be as much as 30°, if there is very little moisture in the air, but if the air is fully charged to saturation point, there will be no evaporation, and both dry and wet bulb readings will be the same.

Mathematical tables are available by which from readings of the two thermometers humidities can be calculated, i.e. the percentage ratio between the amount of moisture present and the amount required to saturate the air at the prevailing dry bulb temperature.

Absolute Humidity.

The adjective "absolute" is less commonly used to qualify the humidity. This is also calculated from the readings of the wet and dry bulbs, and refers to the mass or actual amount of water vapour present in each unit volume of air. It is expressed in either so many grains per cubic foot or so many grammes per cubic metre of air, but no such statistical references are made in the attached tables under the humidity columns.

The warmer the air is, the more water vapour it will absorb and hold, and, for this reason, it will be noticed that, on the average, the New Guinea humidity figures are much higher than in cooler climates. The temperature to which unsaturated air is reduced before it becomes saturated, is termed the dew point or the temperature at which moisture forms in visible drops. This is usually the lowest temperature of the night.

Dew readily collects on grass, metals or any good radiating surface and frequently appears on clear nights. Heavy dew is often a sign of good weather and the greater the difference between the wet and dry bulb thermometers, the greater are the chances of the weather being fine. It might be mentioned that the moisture which forms the dew is sometimes derived from the transpiration of plants, and thus in the mornings slight moisture may be seen condensed on the leaves of plants. Many New Guinea plants have particular adaptions for transpiration of moisture, while their flowers are so formed as to protect them from the effects of excessive moisture.

The average relative humidity is a most important factor in the growth of plant life and especially for such crops as sugar, tobacco, &c.

Observation of the behaviour of humidity is of importance to planters when drying their copra. For instance, where copra driers are situated near, or in, a valley the saturated cool night breeze drifting down the valleys makes drying extremely difficult.

Copra may have been thoroughly dried, but where the humidity is high, the copra will absorb a certain amount of moisture during the night and dry out during the heat of the day. In such situations, it is better to bag the copra later in the day when the atmosphere is usually drier than in the early morning when humidity is often greatest.

From observations taken over a period of years at five main coastal stations throughout the Territory, the average relative humidity is 81 per cent. at 9 a.m., 75 per cent. at 3 p.m. and 88 per cent. for 9 p.m. readings.

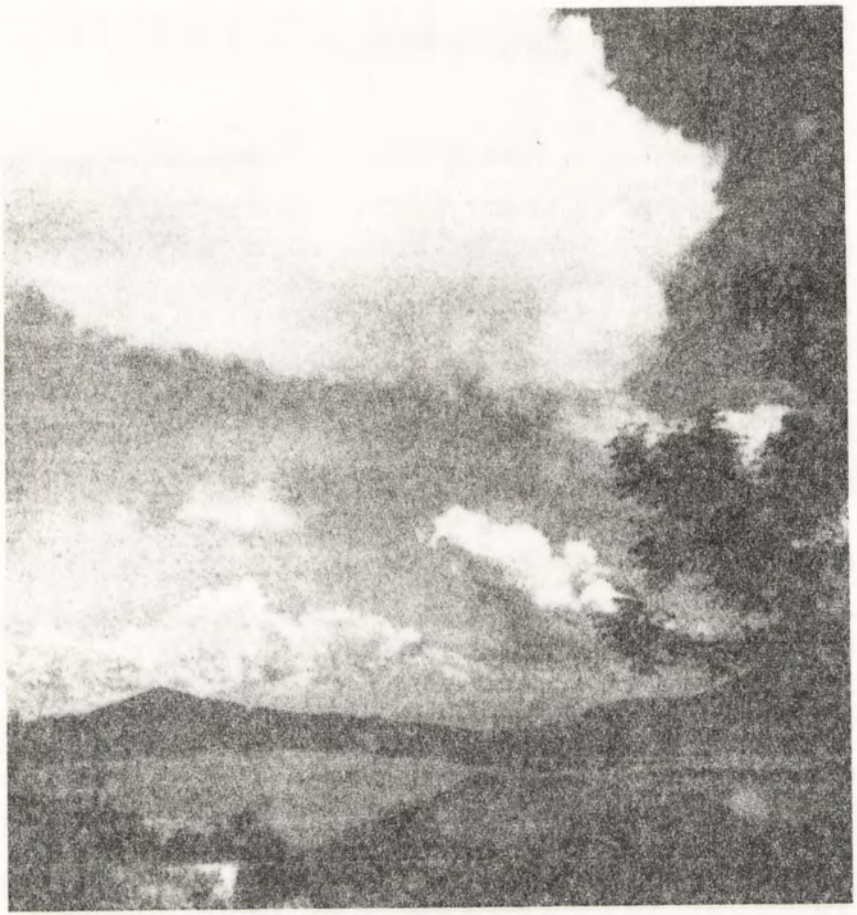
When the air movement is held in check by the dense virgin bush or jungle as in many parts of the Territory, the relative humidity is likely to be higher

than the previously quoted humidity figures, and on the highlands and plain country, it would doubtless be lower on the average.

Other Local Climatic Influences.

Forests.

Forests exert a marked local effect on climate as the sun's rays cannot reach the ground through the dense foliage which attracts the cool and denser vapours.



Cumulus Clouds over Rabaul taken from Taliligap.

If the forests are cleared, the atmosphere in such recently exposed places becomes warmer and drier. This fact was pointed out in this *Gazette* (vol. 4, No. 1), when discussing rainfall and forests.[2] Of course a similar warming and drying effect is noticeable after the drainage of swampy land; should the soil be of a sandy nature, it will be noticeably hotter than in clay country.

Aspect.

A southern and eastern aspect is usually cooler and more moist than a situation with a northerly and western one—a feature with which architects and horticulturists are often concerned.

In hilly country the lie of the land will have a marked effect on the climate. In the narrow valleys the side having the most shade may be cool and moist, while the opposite side would probably be warm and dry, thus causing an appreciable difference in climatic conditions between places relatively nearby.(7)

Some plantations and parts of plantations, for instance, have been suspected of receiving too much rainfall and too little sunshine to be payable propositions.

Sheltered situations will have a different climate from places exposed to the wind and weather, but if desired this defect can usually be controlled by the use of wind-breaks, as explained in previous notes on rainfall, which appeared in Vol. 4, No. 1 of this *Gazette*.(2)

Changes in climate are presumed to occur in isolated instances. History shows for instance the change in the eastern portion of the Sahara where the orchards and cereal fields of Carthage at one time covered hundreds of square miles; now there is only desert.

The department is grateful to those stations that have regularly submitted rainfall figures which have enabled the compilation of the rainfall map appearing in this issue.

This office would welcome, in addition to rainfall statistics, such particulars as pressures, temperature, moisture, cloudiness, sunshine, wind direction and velocity and visibility. It is the state of these meteorological elements over a considerable period of time which is required to complete a picture of the climate of any particular place and region. In fact, without a statistical treatment of such collated information, the latest science of long-range forecasting will be impossible.

As illustration of usefulness of an isolated type of information, weather bureaux have co-opted the services of air liners to give weather conditions and especially temperatures encountered at various heights to assist in forecasting, and the spread of existing weather conditions. From both an agricultural and health point of view, actual climatic conditions have a great bearing on the incidence of disease, whether of humans, animals or plants. In short, the principal factor controlling all growth life is climate.

Apart from illuminating statistical facts such as compiled from the attached climatological tables, observers who care to follow this subject will obtain an aesthetic delight from a study of changing weather phenomena, and to cite Ruskin—

> It (meteorology) is a science of the pure air, and the bright heaven; its thoughts are amidst the loveliest of creation; it leads the mind, as well as the eye, to the morning mist, and the noon-day glory and the twilight cloud—to the purple peace of the mountain heaven—to the cloudy repose of the green valley; now expiating in the silence of the stormless aether—now on the rushing of the wings of the wind. It is indeed a knowledge, which must be felt to be, in its very essence, full of the soul of the beautiful.

REFERENCES.

(1) Ballot, Professor Buys, quoted by the *Meteorological Glossary*, Meteorological Office, London.
(2) Challis, B., Rainfall Notes. *New Guinea Agricultural Gazette*, vol. 4, No. 1, p. 39.
(3) *Australian Meteorological Observer's Hand-book*, 1925.
(4) Humboldt—Quoted by Nicholls and Holland—*A Text Book of Tropical Agriculture*.
(5) Lee, D. H. K., *Queensland Agricultural Journal—The Tropics and Man*.
(6) The *Meteorological Glossary*, Meteorological Office, London.
(7) *A Text Book of Tropical Agriculture*, by Nicholls, H. A., and Holland, J. H., Pub. Macmillan and Co., Ltd., London, 1929.
(8) *New Guinea Agricultural Gazette*, vol. 5, No. 1, p. 66 (Rabaul Climatological Data).