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Climate and Work in Australian New Guinea.[1]

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Of the open spaces of the world New Guinea is one of the least known and least developed. Although ever since its discovery in 1525, its luxuriant vegetation and rumors of abundance of spices and of gold had attracted explorers and adventurers, New Guinea remained outside the mainstream of European colonial expansion in the South Pacific. Only in the latter part of the Nineteenth century did New Guinea begin to acquire political and economic importance to the western world, in particular to Germany and Australia. The annexation of southeastern New Guinea by Queensland in November 1885 and that of northeastern New Guinea by Germany in the following month were successive moves in the rivalry for control of the Pacific between Germany and Great Britain. This rivalry ended ultimately in the expulsion of Germany from New Guinea after the First World War. Subsequently Japanese expansion in Southeast Asia and in the South Pacific, which reached its peak during the Second World War, demonstrated the strategic importance of New Guinea to Australia: "it became for the Japanese an insurmountable barrier; for the allies a heaven sent springboard" (1).

The rise of New Guinea into political and strategic importance was accompanied by an increase in its economic value. In the early years of this century numerous coconut plantations were established in both the Territory of Papua and in Kaiser Wilhelmsland, as the German possession was called. Copra became the most important economic product, and the yearly output amounted to as much as eighty percent of the entire annual production of copra in the South Seas (2). Furthermore, intensified prospecting for gold, which was discovered first in Papua, culminated in the strike of 1926 at Edie Creek, a tributary of the Bulolo River, in the present Trusteeship Territory.

Nevertheless, New Guinea has continued to remain an economically and politically backward region. Before the last war Eu-

[1] The term Australian New Guinea includes the Trusteeship Territory of New Guinea and the Territory of Papua.

ropean colonization and native participation in the economic and political life of both the Territory of Papua and the Mandated Territory were insignificant. In neither territories did the government initiate a consistent and reasoned policy for economic development and for promoting the wellbeing of the natives. Whatever were the merits that the administration of Papua possessed, they were largely the achievments of Lieutenant Governor Sir HUBERT MURRAY, whose long rule has been described as no more than a well organized and benevolent police rule (3). And in the Mandated Territory the administration directed its efforts to furthering European commercial interests rather than to the needs of the indigenous population. In general economic and political conditions in Australian New Guinea reflected the outlook of a government lacking traditional experience and devoid of interest in the conduct of native affairs, and of a native population not sufficiently sophisticated to make its needs felt by the ruling power.

The Second World War changed the attitude of Australia towards New Guinea and that of the natives towards their rulers. The experience of health, of climate and of the general environment, which fell to the lot of the Australian troops in this region; the measures for economic reconstruction initiated by the Australian New Guinea Administrative Unit; and the belated realization that this region might be a land offering vast opportunities for economic development have brought about a new point of view in Australia on its responsibility towards New Guinea. As a result the government established the policy of giving to the indigenous population the largest opportunities for improving their standard of living and for building a healthy and prosperous community. At the same time those groups of the native population which have become participants in the political and economic activities of this region fully expect the administrative authority to raise them to a comparatively high level of economic and social progress, and they have placed their trust in this authority (4).

Economic and social progress, however, are attainable only within the framework of a given environment and within the limits of its modifiability. The environment can either hinder or facilitate human activity. Thus the mountain ranges, which traverse the island in all directions, the extensive swamps and the dense forests have presented obstacles to communication. They have contributed to the isolation of the native population, and they have retarded the extension of political control, economic development and cultural penetration by the administering authority. By themselves alone these physical factors could have been responsible for the cultural backwardness of the natives and they might hamper future progress. Yet the obviousness of the hindrances offered by terrain has not prevented the humid tropical climate, which prevails in the lowlands, from being singled out as a major cause of the primitive state of the native population and of the failure of the island to have been successfully colonized by Europeans. Hence, those features of the climate of New Guinea, especially those parameters which influence the loss and gain of heat by the body and the physiological tolerance of the climate, must be examined before the climatic suitability of Australian New Guinea can be evaluated.

The suitability of humid tropical climates for settlement by Europeans and their compatibility with the development and existences of societies enjoying a high standard of living have long been matters of theoretical debate as well as of practical importance. The general opinion, expressed most clearly by the late ELLSWORTH HUNTINGTON, is that the climates of the humid tropics are inimical to the normal physiological functioning of human beings, in particular of members of the white race, and hence prevent physiological and psychological efficiency, which are fundamental prerequisites for carrying on activities leading to a high degree of human welfare. This conclusion, however, has not been attained by means of experimental evidence, since human beings, and even to a greater degree human societies, cannot be subjected to direct experimentation for protracted intervals of time. Instead this evaluation of humid tropical climates is the result of an inadequate analysis of historical, biological and economic characteristics presented by communities of the humid tropics, and is based upon reasoning, which has failed to distinguish between cause and effect and which has oversimplified the relationship between man and his environment.

However, the need for a scientific answer to the question whether the combinations of high temperature and humidity prevailing in the humid tropics are immediate causes of physiological and psychological deterioration has become a matter of pressing importance. Thus such newly established nations as Ceylon, Burma and Indonesia, for example, are striving for higher standards of living, which require a higher level of productive efficiency, the Point Four Program of the United States is assisting these nations to attain their economic goals, and the governments administering Trusteeships are pledged to promote the welfare of their Trusts.

Fortunately data and techniques capable of providing a rational even though approximate and tentative answer to this question have become available. During the Second World War large numbers of troops, natives of temperate climates, were engaged in combat in the humid tropics, and the successful maintenance of their health and efficiency demanded precise information on the results of exposure to humid tropical climates. Accordingly numerous investigations on the effects of various combinations of temperature and humidity upon the physiological processes involved in maintaining the thermal balance of resting and working individuals under controlled experimental conditions were carried out in the United States, England and Australia. Approximate, tolerable combinations of atmospheric temperature and humidity were established and these were used to assess the severity of the climate of a particular region. Therefore, with the aid of these experimental limits of climatic tolerance this study will attempt to evaluate provisionally the suitability of Australian New Guinea for habitation by white Europeans and the possibility of attaining a standard of living comparable to that prevailing in Queensland, for example.

The Climate of Australian New Guinea and its Parameters.

The climate of New Guinea is determined by its geographical position and by its topography. Its equatorial location accounts for the seasonally uniform and elevated atmospheric temperature and humidity, and its position between Asia and Australia subjects it to a monsoonal regime with the resulting seasonal variability of wind direction and precipitation, which is generally high throughout the year. However, the vertical extension of the terrain with the consequent decrease of atmospheric temperature and humidity with elevation counteracts the climatic uniformity in time and causes climatic variability in space. As a result the climate can be regarded as comprised of two broad types, namely a seasonally uniform warm and humid climate which is characteristic of the lowlands, and a seasonally uniform almost temperate climate, which prevails on the interior plateau, at an elevation of about 5000 feet (1700 m.) above sea level. And owing to the spatial juxtaposition of these distinct climatic regions seasonal diversity can be experienced by progress in space rather than in time.

In order to determine the severity of the stress which the climate exerts upon the physiological processes of human beings only the parameters of atmospheric temperature, atmospheric humidity, radiation and wind velocity need be considered, since these are the only climatic factors that influence heat exchange between the body and its surroundings and are constituents of the heat balance equation. However, no radiation data are available for New Guinea.

The Lowland Climate.

Atmospheric temperature. The general characteristics of atmospheric temperature are illustrated in Table 1.

TABLE 1 (5).

Mean Annual, Mean Monthly Maxima and Minima, Absolute Temperatures and Annual Range in Australian New Guinea.

Locality	Height A.S.L. ft.	° F.					
		Mean Annual	Mean Monthly Max.	Mean Monthly Min.	Abs. Max.	Abs. Min.	Annual Range
Hatzfeldt Harbor	10	81	91	69	96	67	3
Madang	20	81	88	74	98	62	2
Salamaua		79	89	70	93	65	4
Kikori	80	79	90	72			6
Upoia		81	94	73			5
Kerema	65	80	90	72			4
Buna Bay	6	80	90	69	97	62	2
Cape Nelson	214	80	88	74	96	60	4
Daru	25	80	88	73	98	63	5
Port Moresby	126	81	89	73	97	69	5
Rigo	100	81	92	70			4
Baniari		82	92	74			4
Abau	140	79	88	71			5
Orangerie Bay		77	89	68			6
Samarai	20	80	89	73	102	64	6
Kemp Welch	125	79	92	67			6

The spatial uniformity in atmospheric temperature in the coastal lowlands is indicated by the fact that it varies between 82° F. and 77° F. The seasonal uniformity is reflected in the difference between the warmest and coldest months, which ranges between 6° F. and 8° F. On the other hand, the atmospheric temperature does not attain extreme values; the mean monthly maximum is 94° F. and the highest absolute maximum is 102° F.

The seasonal uniformity of atmospheric temperature, which is a consequence of the slight interdiurnal variability, contrasts markedly with the intradiurnal variation. The latter has considerable bioclimatic importance for human beings, since it facilitates the loss of heat from the body and thereby helps to maintain thermal balance. The annual average of the daily range of atmospheric temperatures in the coastal lowlands varies between 10° F. and 18° F. An intradiurnal range of as much as 22° F. and 24° F. is found during the southern summer at Kemp Welch and Hatzfeldt Harbor respectively, and as little as 6° F. and 8° F. during the winter at Samarai and Kikori respectively.

Atmospheric humidity. Atmospheric vapor pressure is a fundamental factor influencing the thermal balance, since it controls the loss of heat by the evaporation of sweat from the surface of the skin. Evaporative cooling can take place only when a difference of vapor pressure exists between the evaporating surface and the ambient atmosphere. If the vapor pressure gradient is small then the atmosphere becomes quickly saturated; evaporation into it ceases so that the cooling of the body by the evaporation of sweat cannot take place. The result is heat storage within the body and consequent heat strain in the organism.

The degree of spatial and seasonal variability of atmospheric humidity in the coastal lowlands is illustrated in Table 2.

TABLE 2 (6).

Spatial and Seasonal Variability of Vapor Pressure in the Coastal Lowlands [2].

Locality	Elevation ft.	vapor pressure mm Hg.			
		Mean annual	Seasonal max.	Seasonal min.	Annual range
Hatzfeldt Harbor	10	20.0	21.4	20.0	1.4
Madang	20	23.0	23.6	22.5	1.1
Salamaua		21.6	23.6	20.5	3.1
Kikori	80	22.3	23.3	20.8	2.5
Upoia		23.0	23.7	21.1	2.6
Kerema	65	21.8	22.7	20.8	1.9
Buna Bay	6	22.3	21.7	19.2	2.5
Cape Nelson	214	21.8	23.4	19.8	3.6
Daru	25	21.5	22.2	20.0	2.2
Port Moresby	126	21.1	22.4	19.4	3.0
Rigo	100	20.6	21.6	20.4	1.2
Baniari		21.2	22.8	19.0	3.8
Kemp Welch	125	20.3	21.3	18.6	2.7
Abau	140	21.3	23.2	20.0	3.2
Orangerie Bay		22.5	23.7	20.4	3.3
Samarai	20	22.0	23.6	20.1	3.5

Atmospheric vapor pressure manifests thus a spatial and temporal uniformity similar to that of atmospheric temperature. The mean annual vapor pressure at localities approximately at sea level varies between 20.3 and 23.0 mm. Hg; the mean annual range is 2.5 and the maximum annual range is 3.8 mm. Hg.

Daily march of vapor pressure. Owing to the inadequate climatic data available for New Guinea it is impossible to present a detailed account of the diurnal course of vapor pressure. However, some idea of its regime can be obtained from the few 09.00 and 15.00 o'clock observations and from a continuous hourly record of dry bulb temperature and relative humidity made at Lae during January and July 1948. The diurnal march of vapor pressure was calculated from the latter data and it is shown in Table 3.

[2] 09.00 o'clock.

TABLE 3 (7).

Daily March of Vapor Pressure at Lae in mm. Hg.

Season	hours											
	2	4	6	8	10	12	14	16	18	20	22	24
Summer	21.1	20.4	19.9	20.1	20.9	21.4	20.0	20.4	20.9	20.3	20.0	21.0
Winter	21.0	20.7	20.5	21.4	22.3	22.8	22.3	21.6	21.2	21.5	21.9	21.7

Wind velocity. From the point of view of the physiological suitability of a climate and the maintenance of thermal balance the daily and seasonal march of wind velocity are very important factors influencing heat loss from the body. A favorable daily and seasonal variability of wind velocity can reduce heat stress upon the body and ameliorate the effect of high temperature and humidity, since the loss of heat by evaporation and convection increases as air movement increases.

The mean seasonal wind velocities in those coastal localities for which data are available are given in Table 4.

TABLE 4 (8).

Seasonal Wind Velocity mi./hr.

Locality	Latitude	Mean Annual Wind Velocity mi./hr.	Winter S.E. Season Wind Velocity mi. hr.	Summer N.W. Season Wind Velocity mi. hr.	Annual Range mi./hr.
Hatzfeldt Harbor					
(09.00)	4 24′S	0.61	0.61	0.81	0.20
(14.00)		4.90	8.40	7.60	0.80
Madang					
(09.00)	5 13′S	3.30	2.70	3.30	0.60
(14.00)		7.00	6.50	7.50	1.00
Kikori	7 24′S	3.70	3.70	3.70	0.00
Cape Nelson	8 59′S	6.60	10.00	4.00	6.00
Port Moresby	9 29′S	9.50	12.00	7.00	5.00
Samarai					
(09.00)	10 37′S	3.50	3.50	3.50	0.00

Plateau and Mountain Climate.

Atmospheric temperature. Climatic data for the interior uplands are almost entirely lacking. Nevertheless, the general characteristics of the plateau climate can be deduced from the meager data available with the aid of general principles.

The characteristics of atmospheric temperature at elevations from 400 to 3200 feet above sea level are illustrated in Table 5. The decline in atmospheric temperature with elevation is clearly evident. At an elevation of 3200 feet (1100 m.) above sea level the mean annual temperature is already 70° F. as compared with 20° F. at sea level. Assuming a lapse rate of 0.75° F. per 300 feet (100 m.), the mean annual temperature on the Central Plateau, which is approximately 6000 feet (2000 m.) above sea level, is around 56° F.

TABLE 5.

Atmospheric Temperatures at Elevations Exceeding 400 Feet above Sea Level [3].

Locality [4]	Elevation ft.	° F. Mean Annual	Annual Range	Mean Monthly Max.	Mean Monthly Min.	Abs. Max.	Abs. Min.
Bei Malu	400	83	3	93	73	101	67
Ioma	400	81	3	91	71		
Nepa	800	80	3	90	70		
Kokoda	1200	78	4	90	67	98	54
Hombron Bluff [4]	1800	74	2	82			
Bulolo	2300	77	4		64		
Sattelberg Kuppe [4]	3200	70	9	81	63	88	60

As in the coastal lowlands the daily range of temperature exceeds the seasonal range and it is greater in the summer than in the winter. The mean daily range varies between 9° F. at Sattelberg Kuppe and 20° F. at Kokoda, and the mean monthly range in January is 17° F. as compared with 15° F. in July.

Atmospheric vapor pressure. Like atmospheric temperature atmospheric humidity also declines with elevation. This phenomenon is illustrated in Table 6. Thus at Sattelberg Kuppe, which is situated 3200 feet (1100 m.) above sea level, the mean annual vapor pressure is 16.0 mm. Hg as compared with a mean annual vapor pressure of 22 mm. Hg at sea level. Furthermore, by means of an empirical formula [5], which relates vapor pressure to elevation, a mean annual vapor pressure of 13 mm. Hg is calculated for the Central Plateau (about 5000 feet [1700 m.] above sea level).

TABLE 6 (10).

Spatial and Seasonal Variations in Atmospheric Vapor Pressure at Elevations Exceeding 400 Feet above Sea Level [3].

Locality	Elevation ft.	mm. Hg Mean Annual	Seasonal Max.	Seasonal Min.	Annual Range
Bei Malu	400	20.5	23.2	22.8	0.5
Nepa	800	21.9	22.2	20.4	1.8
Kokoda	1200	19.6	20.4	18.4	2.0
Hombron Bluff	1800	16.2	17.7	15.4	2.3
Bulolo	2300	17.6	18.5	17.1	1.4
Sattelberg Kuppe	3200	16.0	17.5	15.4	2.3

[3] 09.00 hours.

[4] These localities are fairly close to the coast and hence are subject to the moderating action of the sea breeze.

[5] $E_h = E_o \ (1\text{-}0.00025\,h)$; h = meters.

Wind pattern in the Central Plateau. Data on the wind regime of the Central Plateau are lacking. However, as in other hilly or mountainous regions wind direction and velocity can be assumed to vary with exposure and topography. Moreover, the nature of the terrain suggests that both mountain or downslope winds and valley or upslope winds must be a common phenomenon.

The Physiological Climatology of New Guinea.

Given now the approximate climatic parameters of New Guinea there remains the problem of assessing its compatibility with normal physiological functioning of working and resting individuals. A provisional estimate can be made by examining the climatic variables in the light of the limits of climatic tolerance established experimentally for individuals resting and working under atmospheric conditions simulating a humid tropical climate.

Upper limits of tolerance of various combinations of atmospheric temperature and humidity have been established experimentally for acclimatized resting and working white men. To be sure these limits of tolerance are not very realistic. They were obtained under laboratory conditions involving highly specialized activities, lasting for relatively brief periods of time and accompanied by very artificial motivation. Nevertheless, these limits do provide an objectively founded notion of the upper range of atmospheric conditions which white men can withstand without physiological impairment and under which they can work efficiently. Among the most realistic limits of tolerance are those established by SID ROBINSON et al. (11), since the subjects were exposed daily for six hours, the approximate equivalent of a normal working day, for a period of three weeks, to various combinations of extreme temperature and humidity. For clothed resting acclimatized white men these tolerance limits were 122° F. D.B. with 31.6 mm. Hg vapor pressure at an air movement of 180 feet per minute; for clothed individuals working at a rate of 188 kg. cal. per m^2 per hour [6], they were 93.2° F. D.B. with 36.2 mm. Hg vapor pressure and 122° F. D.B. with 19.4 mm. Hg vapor pressure at an air movement of 180 feet per minute.

Furthermore, critical combinations of atmospheric temperature and humidity above which the psychomotor and mental performance of acclimatized white men begins to deteriorate significantly have been established experimentally by MACKWORTH (12). These are given in Table 7.

[6] 188 kg. cal./m^2/hr. corresponds to work performed while walking at the rate of 3.4 mi./hr. up a 2.5% grade or to fairly heavy carpentry work.

TABLE 7.

Critical Atmospheric Conditions for Various Physical and Mental Activities.

Type of Work	Air Tem. ^{0} F. D.B.	Vapor Press. mm. Hg	Wind Velocity	Effective Temperat. F
Heavy pursuitmeter	95	27.7	100 ft./min. (1 mi./hr.)	87.5
Wireless telegraph operation				
Competent operators	95	27.5	»	87.5
Very good operators	100	34.8	»	92.0
Exceptionally skilled operators	105	39.4	»	97.0
Coding	95	27.5	»	87.5

These limits of climatic tolerance are applicable only to the execution of specific psychomotor and mental tasks for brief periods of time by specially trained individuals. At best they can serve only as a rough guide for assessing the suitability of a climate for comparable human activities.

Finally the Committee on Atmospheric Comfort of the American Public Health Association (13) has established limiting combinations of atmospheric temperature, humidity and wind velocity that can be tolerated in daily work by healthy, white American males, wearing winter clothing. A metabolic rate of 240 kg. cal. per hour was regarded as a practical performance that can be maintained over a regular working day of eight hours without difficulty by physically fit men. These atmospheric conditions are given in Table 8.

TABLE 8.

Limiting Combinations of Dry Bulb Temperatures and Atmospheric Vapor Pressures that can be Tolerated by Healthy Acclimatized White Men Wearing Warm Clothes.

Air Movement 15-25 ft./min.		100 ft./min.		300 ft./min.	
Dry-bulb ^{0} F.	Vapor pressure mm. Hg	Dry-bulb ^{0} F.	Vapor pressure mm. Hg	Dry-bulb ^{0} F.	Vapor pressure mm. Hg
Summer season. Light sedentary activities (Effective Temperature 85^0 F.)					
89	28.0	91	29.8	93	31.7
94	24.5	96	26.1	98	27.7
100	19.6	101	20.2	103	21.5
Summer season. Heavy work. Metabolic rate 240 kg. cal./hr. (Effective Temperature 80^0 F.)					
83	23.1	86	25.5	89	28.0
88	20.3	90	21.7	93	23.8
93	15.0	95	16.9	97	19.7

Thus at an air movement of 100 feet per minute (approximately one mile per hour) heavy work, involving a metabolic rate of 240 kg. cal./hr., can be performed at 86^0 F. D.B. with 26 mm. Hg vapor pressure (80^0 F. E.T.) and at 90^0 F. D.B. with 21.7 mm. Hg vapor pressure (80^0 F. E.T.). At an air movement of 300 feet per minute (three miles per hour) similar work can be performed in a state of thermal balance at 89^0 F. D.B. with 28 mm. Hg vapor pressure (85^0 F. E.T.) and at 90^0 F. D.B. with 23.8 mm. Hg vapor pressure (85^0 F. E.T.).

These extreme limits of tolerability at which acclimatized men can work at a rate of 240 kg. cal. per hour are characterized by the Committee on Ventilation as conditions of minimum comfort. However, the habitability of any region requires more than a mere minimum of comfort compatible with the absence of physiological strain. Moreover, a difference exists between atmospheric conditions under which individuals can work without experiencing physiological strain and those which they regard as comfortable. Comfort is a complex sensation that reflects the degree of strain imposed upon the heat regulating mechanism of the body by the thermal state of the ambient climate. A state of comfort prevails when heat regulation is accomplished with a minimum of physiological adjustment and with complete unawareness of sensations of heat or cold.

TABLE 9.

Comfort limits and Zones of Effective Temperature.

Activity	Zone of Comfort	Upper limits of Effective Temperature above which Thermal Comfort Ceases	Comfort Line
320 kg. cal./hr.	53-64^0	64^0	—
209 kg. cal./hr.		74^0	—
165 kg. cal./hr.		79^0	—
Summer: non-basal resting state; normally clothed men	66-75^0	75^0	72^0
Entire year: non-basal; resting and stripped to waist: men	66-82^0	82^0	72.5^0

Assessment of the Climate of New Guinea.

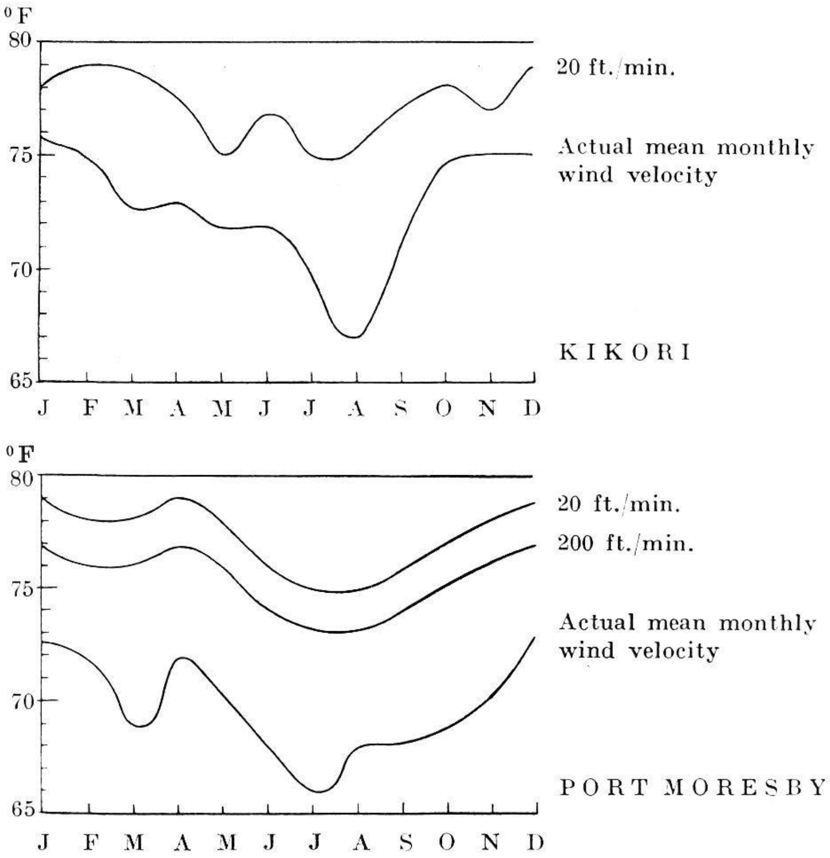
By means of the effective temperature scale we shall attempt to assess the heat stress imposed by the climate of New Guinea upon human beings. Effective temperature can be used as an approximate index of the habitability of a region, since it manifests a high positive correlation with subjective sensations of physical comfort, and pulse rate.

The effective temperature scale, however, has definite limitations. Under atmospheric conditions of high temperature and humidity it gives more weight to dry bulb than to wet bulb temperature, while at these high levels of warmth bodily reactions are influenced more by the latter than by the former. Effective temperatures are valid for atmospheres in which the heat load due to radiation is insignificant, for example in rooms in which the wall temperatures are equal to the air temperature. Finally it is based upon a highly selected group of individuals, namely white American males, acclimatized to a temperate climate, either stripped to the waist or lightly clothed and engaged in light activity.

The extent to which the climatic conditions prevailing in the coastal lowlands of New Guinea are suitable for human habitation in the light of the limiting atmospheric tolerances and comfort zones discussed above, can be gaged by determining the annual and daily march of effective temperatures at the various localities for which climatic data are available. However, the climatic statistics for New Guinea consist primarily of the mean monthly, mean monthly maximum and mean monthly minimum dry bulb temperature and mean monthly relative humidity. Mean monthly maximum and minimum relative humidity and wind velocity data are available for only a few localities.

Nevertheless, some idea of the effective temperatures prevailing in lowland New Guinea can be obtained by using the mean monthly temperatures and mean monthly relative humidities at almost still air (20 feet per minute) and at moderate air movement (200 feet per minute or one mile per hour). In cases where data of the annual march of wind velocities are available the actual mean monthly wind velocity will be used. By using effective temperature to integrate air temperature, relative humidity and air movement it is possible to indicate the climatic conditions in terma of the effective temperature scale. Effective temperature will be used to assess the habitability of any locality in terma of the standards established by the Committee on Ventilation for individuals working at a metabolic rate of 240 kg. cal./hour and in terms of the various comfort zones which are characterized by complete thermal balance.

The mean annual effective temperature ranges between 79° F. E.T. and 76° F. E.T. at almost still air and between 76° F. E.T. and 72° F. E.T. at an air movement of 200 ft./min. However, as seen in Figs. 1 and 2, which show the annual variation of effective temperature for several representative localities for which actual mean monthly wind velocities are available, the effective temperature may attain values that are considerably below those just cited.



Fig, 1. Mean monthly march of effective temperature °F.

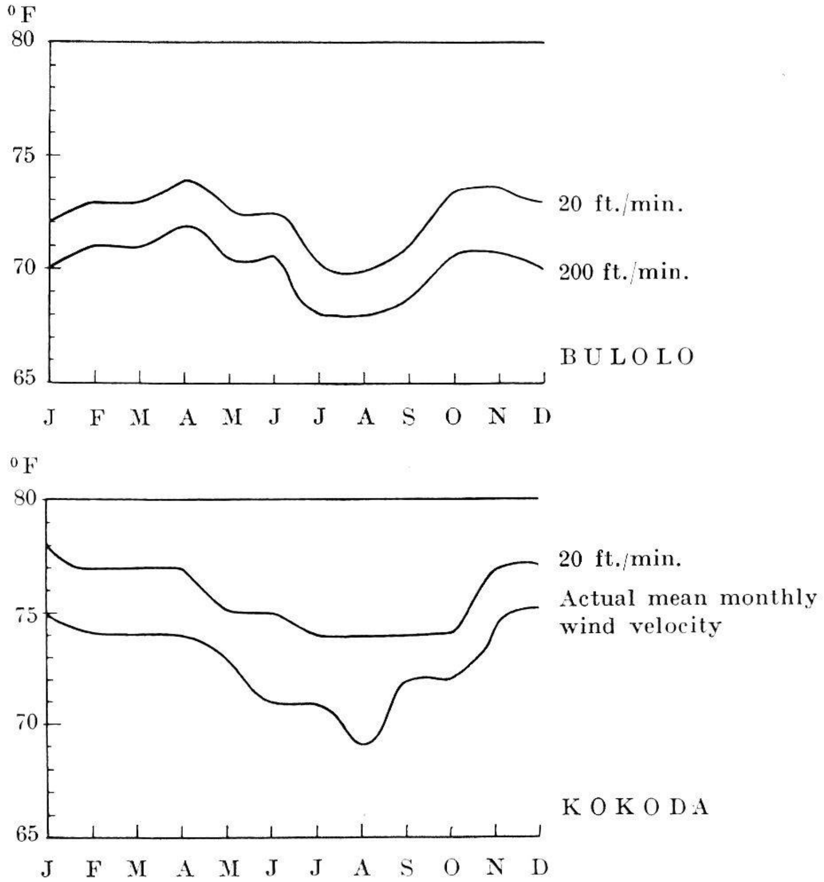


Fig. 2. Mean monthly march of effective temperature °F.

TABLE 10.

Distribution of Mean Annual Effective Temperature in Lowland New Guinea.

Locality	Air Movement 20 ft./min. °F.	200 ft./min. °F.
Abau	75	72
Baniari	79	76
Buna Bay	78	75
Cape Nelson	75	72
Daru	78	75
Hatzfeldt Harbor	79	76
Kemp Welch	76	73
Kerema	78	75
Kikori	78	75
Madang	75	72
Orangerie Bay	76	73
Port Moresby	79	76
Rigo	79	76
Salamaua	76	72
Samarai	77.5	74
Upoia	79	76

By comparing the prevailing effective temperature of the coastal lowlands with the atmospheric limits of tolerance established by the Committee on Atmospheric Comfort of the American Public Health Association (Table 8) and with the range of the comfort zone as formulated by YAGLOU and DRINKER (Table 9) it becomes possible to arrive at a tentative evaluation of the suitability of the climate of New Guinea for the development and existence of societies having a high standard of living. Since the limit of tolerance for light sedentary activity is 85° F. E.T. and for heavy work it is 80° F. E.T., the mean annual temperature of the coastal lowlands is considerably below the former limit and, depending upon the degree of air movement, it may approach but not exceed the latter. In relation to a comfort zone of 66-75° F. E.T. (Table 9) the mean annual effective temperature exceeds the upper limit at an air movement of 20 ft./min., approaches the upper limit at air movement of 200 ft./min. and may lie well within the comfort zone in those localities where the actual wind velocities are sufficiently high (Fig. 3).

In relation to the limits of atmospheric tolerance of working white men and to the comfort zone the climate of the lowlands manifests considerable variability and, on the whole, a tendency not to exceed these limits. Moreover, since the limits of tolerance established by the Committee on Atmospheric Tolerance refer to accli-

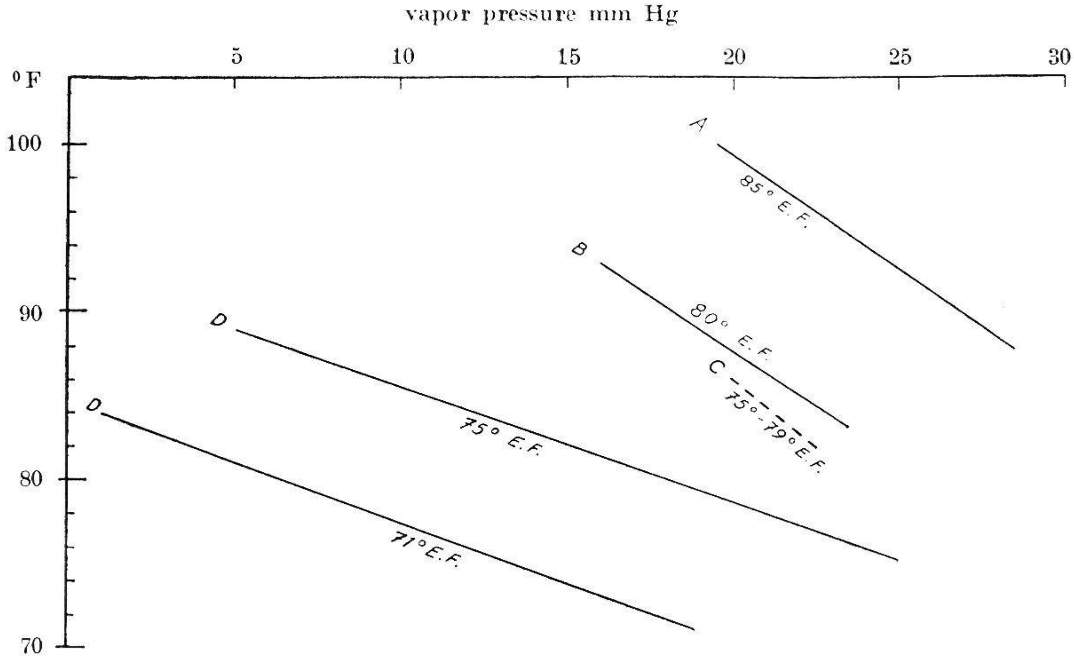


Fig. 3. Limits of Effective Temperature for Rest and Work (20 ft./min.). A = Light Sedentary Work. B = Work at a Rate of 240 kg. cal./hour. C = Mean Annual Range of Effective Temperature in the Coastal Lowlands (20 ft./min.). D = Comfort Limits (20 ft./min.).

matized men dressed in winter clothing it stands to reason that with lighter clothing the limiting atmospheric temperatures would be higher. Consequently the effective temperature of lowland New Guinea lies even farther below the atmospheric tolerance limits so that the climate is probably less difficult than it appears to be from the comparison that has just been made. Additional evidence for the latter conclusion is provided by the findings of MACKWORTH (Table 7) on the limiting atmospheric conditions for the performance of specialized mental and physical tasks. Not only do they indicate limits of atmospheric tolerance that are higher than the effective temperatures prevailing in the lowlands but they show clearly that exceptionally competent individuals can perform efficiently complicated mental activities at atmospheric conditions which exceed the limits set for less capable individuals.

Accordingly the climate of lowland New Guinea appears to be compatible with the efficient performance of severe physical and complex mental activities by acclimatized white men. It is certainly not an intolerable, excessively uncomfortable or impossible climate inherently unfit for white men. However, the fitness of the climate may be considered to be a border-line fitness, for occasionally the limits of atmospheric tolerance may be exceeded. Therefore the climate cannot be accepted passively; its aggression must be countered by various cultural measures which civilized man has developed.

The Plateau Climate.

The climate of New Guinea at higher elevations is characterized by lower atmospheric temperature and humidity. Thus the effective temperatures at Kokoda, which is 1200 feet above sea level, and at Bulolo, which is 2300 feet above sea level, lie entirely within the comfort range of 66-75° F. E.T. and below the upper limit of atmospheric tolerance for severe physical exertion. Accordingly the climate of the interior highlands cannot be regarded as an aggressive climate and does not pose any special problems of physiological acclimatization and cultural adaptation.

Adaptation of the Natives to the Lowland Climate.

This assessment of the suitability of the climate of New Guinea is valid only for members of the white race. Its suitability for the native inhabitants is at present merely a matter of conjecture, since the effect of a humid tropical climate upon the heat tolerance of the native colored peoples of the tropics in general and upon that of the natives of New Guinea in particular has, to the writer's knowledge, never been investigated. On the basis of a-priori reasoning we may assume that as a result of racial acclimatization, of natural selection and of cultural adaptation the natives' tolerance of the humid heat is greater than that of the whites.

However, as the natives become acculturated and adapt themselves to European habits of work and standards of productivity their heat tolerance might conceivably be reduced, for acclimatization is specific for particular activities at given climatic conditions. Accordingly climatic amelioration will be necessary for the natives as their cultural patterns approach that of the whites.

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Résumé.

Le bien-être des habitants de la Nouvelle-Guinée Australienne dépend, entre autres, de la capacité productive des êtres humains qui vivent et travaillent sous un climat tropical humide. Le climat de la Nouvelle-Guinée est tropical et humide dans la plaine, tandis qu'il est presque tempéré sur le plateau central à une altitude d'environ 5000 pieds. Dans la plaine la température annuelle moyenne oscille entre 82⁰ et 77⁰ F et la pression atmosphérique entre 23 et 20 mm. Hg; dans les régions plus élevées la température annuelle moyenne peut atteindre 55⁰ F.

La compatibilité du climat chaud et humide de la plaine avec des fonctions physiologiques et une capacité productive normales peut être estimée à l'aide des limites de tolérance atmosphérique, déterminées expérimentalement par le « Committee on Industrial Ventilation of the American Public Health Association ». Les conditions atmosphériques, sous lesquelles des blancs sains, vêtus d'habits chauds, peuvent accomplir des efforts physiques de 240 kg. cal./h. et des activités sédentaires demandant peu d'efforts, sont limitées à 80⁰ et 85⁰ F température effective respectivement (vitesse du vent 20 pieds/min.).

Comme la température effective dans la plaine, à une vitesse du vent de 20 pieds/min., s'élève à 74⁰-79⁰ F, le climat de la Nouvelle-Guinée est au-dessous de la limite de tolérance atmosphérique, qui serait plus élevée pour des individus habillés légèrement ou à torse nu. On peut en conclure que le climat de la Nouvelle-Guinée ne présente pas de difficultés insurmontables au fonctionnement physiologique et à la capacité productive normales.

Zusammenfassung.

Das Wohlbefinden der Bewohner von Australisch-Neuguinea hängt u. a. von der Leistungsfähigkeit der im feucht-tropischen Klima lebenden und arbeitenden Menschen ab. Das Klima von Neuguinea ist in den Niederungen tropisch-feucht, im Zentralplateau, auf einer Höhe von ca. 5000 Fuß, jedoch nahezu gemäßigt. In den Niederungen beträgt die mittlere jährliche Temperatur zwischen 82⁰ und

77^0 F und der Dampfdruck zwischen 23 und 20 mm Hg; in höheren Lagen kann die jährliche mittlere Temperatur ca. 55^0 F betragen.

Die Vereinbarkeit des warm-feuchten Klimas der Niederungen mit normaler körperlicher Tätigkeit und Leistungsfähigkeit kann mit Hilfe der vom «Committee on Industrial Ventilation of the American Public Health Association» experimentell festgestellten Grenzen der atmosphärischen Toleranz beurteilt werden. Die Grenzen der atmosphärischen Bedingungen, unter welchen gesunde Weiße, warm gekleidet, schwere Arbeit von 240 kg cal/h verrichten können, liegen bei einer Windgeschwindigkeit von 20 ft/min [7] 80^0 F effektive Temperatur; für leichtere sitzende Tätigkeit ohne körperliche Anstrengung liegen sie bei 85^0 F E.T.

Da in den Niederungen Neuguineas die E.T. bei einer Windgeschwindigkeit von 20 ft/min zwischen 74^0 und 79^0 F schwankt, liegt das Klima dieses Landes unter der Grenze atmosphärischer Toleranz; diese Grenze läge für Personen in leichter Kleidung oder mit nacktem Oberkörper noch höher. Daraus kann geschlossen werden, daß das Klima von Neuguinea in bezug auf normale Arbeitsfähigkeit und körperliche Leistung keine unüberwindlichen Schwierigkeiten bietet.

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[7] ft = englischer Fuß (0,304 m).