



# XXIII. Meteorological observations made during a residence in Colombia between the years 1820 and 1830

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To cite this article: Colonel Francis Hall (1838) XXIII. Meteorological observations made during a residence in Colombia between the years 1820 and 1830, Philosophical Magazine Series 3, 12:73, 148-158, DOI: [10.1080/14786443808649399](https://doi.org/10.1080/14786443808649399)

To link to this article: <http://dx.doi.org/10.1080/14786443808649399>



Published online: 01 Jun 2009.



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minutes it overspreads every part of the field of view, which by this singular process has been metamorphosed from a space almost entirely dark, into a luminous one, mottled with all manner of colours. Should the observer happen to have quitted his instrument in the mean while, and during his absence this change have taken place spontaneously, he would hardly be able to persuade himself that his adjustments had not been deranged, and some new object placed before the microscope.

This very beautiful phænomenon no doubt arises from the following cause, viz. that the crystalline state or arrangement of particles which nitre assumes at the temperature at which it first solidifies after fusion, is no longer suitable to it when grown perfectly cold; so that its condition is then one of unstable equilibrium which the slightest force is capable of subverting. By touching it with a needle a disturbance is produced, which propagates itself from the disturbed point throughout the entire mass.

But even if it is not touched the same change will take place *spontaneously* a few minutes later.

If however we touch it prematurely, as, for instance, during the first minute after it has become solid, this change does not take place.

We may *then* trace lines or letters upon the darkened film with the point of a needle, and these lines will appear luminous, in consequence of the crystalline particles which the needle displaces being thrown into such positions as to depolarize the light. But this does not disturb the rest of the field of view, which remains quiescent for several minutes after, and then changes spontaneously, as I have endeavoured to describe.

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XXIII. *Meteorological Observations made during a residence in Colombia between the Years 1820 and 1830. By the late Colonel FRANCIS HALL.\**

**I**F the materials of science could be gathered only by the scientific, the following collection of observations would be a useless labour; but it frequently happens that in distant countries the opportunity of observing natural phænomena falls to the lot of those very ill-fitted in most respects to profit by it. The genius of a Humboldt, like an incantation of science, descends upon the New World but once in a series of ages. The most that can be done by an ordinary observer is to offer his mite, a single stone towards the pyramid of know-

\* Communicated by Prof. William Jameson, of Quito, to Sir W. J. Hooker, F.R.S., and by him to Phil. Mag.

ledge, in the hope that he may casually prove useful, and with such humble pretensions can scarcely be deemed importunate. Should even this apology barely extenuate the sterility of a ten years' residence in a country so admirably varied and rich in natural phænomena as Colombia, something further may be urged in excuse of the *military* traveller, obliged frequently to hurry through the most interesting parts, and to vegetate whole years in others of minor importance; without books, without instruments, without resources; fettered too often by the chain of his own daily wants and sufferings, and fallen on a time when every species of local or traditional information, every glimmering of philosophic research, had been buried and obliterated amid the storms and struggles of the revolution.

The geographical features of Colombia have been portrayed by Humboldt with an accuracy which renders further description superfluous. It is however impossible to traverse this extensive territory without being struck by the physical phænomena of a country where *height* produces the effects of *latitude*, and where the changes of climate, with all the consequent revolutions of animal and vegetable life, are brought about by localities, to which we find little analogy in Europe. The equatorial seasons, as is well known, are merely the wet and dry; and though the Spaniards, influenced by European recollections, have given the former the name of winter "*invierno*," it is during this period that nature revives from the vegetable torpor which the scorching tropical heats produce in the low-lands, in almost an equal degree with the frosts of northern climates. In the vast plains which extend to the south and east of the great chain of the Andes, the rainy season observes an invariable order. The Orinoco begins to rise in April, and attains its *maximum* of increase in July and August, when the immense savanas which extend to the base of the Andes are converted into the appearance of an inland ocean. It decreases from this period, and the summer is reckoned from October to April. In the mountains, on the contrary, the rains commence about the former month, and predominate, with intervals of fair weather, till May or June. The winter of the low-lands to the west and north of the Cordillera, both on the Pacific and Atlantic coast, is governed by that of the mountains, but with several curious local varieties. Thus, the rainy season of Guayaquil is nearly as regular as that of the plains, being reckoned from the middle of December to the middle of May; while the thick forests which, further to the north, cover the provinces of Esmeraldas, Barbacoas, and Choco, produce by their constant evaporation an almost perpetual deluge. Wherever, on the con-

trary, the Cordillera recedes to some distance from the coast, as is the case with parts of the Venezuelan chain, the intermediate country is parched by a drought often of several years. Maracaybo, and a considerable part of the province of Coro, are instances, where sandy plains, scantily shaded by *Mimosas* and thick plants, afford shelter and subsistence only to flocks of goats and asses. The coast of Rio Hacha is equally dry and sterile till it approaches the foot of the isolated ridge of Santa Marta; while the Goagira territory, interposed between Rio Hacha and Maracaybo, is regularly inundated every year, and consequently, though destitute of streams, maintains considerable herds of cattle and horses, a circumstance to be ascribed to the vicinity of the Ocaña branch of the Andes, which extends, with its clouds and thick forests, almost to the confines of this province. The whole Peruvian coast from Payta to Lima is an additional instance of the same fact, where the recession of the Andes from the coast is marked by sandy deserts, which the industry of the Incas had rendered productive by artificial irrigation. In the valleys, and on the table lands of the mountains themselves, the culminating summits produce great variations in the distribution of moisture. The city of Caraccas, situated at the foot of the Silla, has the benefit of a regular, though mild rainy season; while within a league there are spots which suffer several years of drought. Popayan, placed at the head of the sultry valley of the Cauca, and surrounded by lofty *paramos*, has nine months of continued rains and tempests, attributable to the clouds which are driven in opposite directions from the mountains, till they encounter the hot ascending air of the valley. In that part of the ancient kingdom of Quito now called the Department of the Equator, the mass of Chimborazo interrupts the passage of the clouds from south to north, so that while the western slopes are deluged with rain, the elevated plains of Riobamba to the east recall to the imagination of the traveller the deserts of Arabia Petræa. Following the same mountain-chain towards the city of Quito, we observe the storms arrested between Cotopaxi and Pichincha over the valley of Chillo, while two leagues further to the north the climate of the village of Pomasqui is so dry as to have given it the name of Little Piura.

The manner in which rain is formed and precipitated at various elevations seems to illustrate and confirm the theory of Leslie. In the regions of *paramos*, i. e. from 12,000 feet upwards, the encountering ærial currents, unless in the case of some strong agitation of the mass of the surrounding atmosphere, are of a low and nearly equal temperature. The rains, in consequence, assume the form of thick drizzling mists,

known by the name of *Paramitos*. On the elevated plains we find the showers more or less sudden and violent, according to localities which give rise to a mixture of currents more or less variably heated. Quito, for example, is situated on what may be called a *ledge* of the lofty mountain of Pichincha, and overlooks the valley of Chillo or Guallapamba, furrowing the adjacent table-land, in which the thermometer often rises to  $80^{\circ}$  in the shade. The encounter of portions of the atmosphere thus variously heated produces showers as sudden and heavy as those which generally distinguish tropical climates. On the slopes of the Cordillera the rains are generally violent, for the same reason.

Looking to the hygrometrical state of the atmosphere, as it results from observations made on the table-lands of the Equator and the coast of the Pacific, we find it to vary from  $0^{\circ}$  in the damp forests of Esmeraldas to  $97^{\circ}\cdot 1$  on the elevated plain of Cayambe; the experiments in both places being made during June and July, the summer months both of the coast and mountains. The average medium for the low-lands is  $23^{\circ}\cdot 85$ ; for the Cordillera  $44^{\circ}\cdot 36$  of the hygrometer constructed upon Leslie's principle; but we are in want of sufficient data for those elevations which approach the limit of perpetual snow. To judge however from a small number of observations made on the mountain of Cayambe, at 12,705 and 14,217 feet of elevation; and at the hut of Antisana at 14,520 feet, where the hygrometer was found to give  $16^{\circ}\cdot 5$ ,  $13^{\circ}\cdot 9$ , and  $30^{\circ}\cdot 3$ , it would not seem that the dryness of the atmosphere increases in ratio of the elevation, at least in the neighbourhood of snowy mountains where a continual moisture is exhaled, and heavy mists sweep over the soil towards the evenings even of the fairest days.

To estimate the general distribution of temperatures through the vast territory of Colombia, we may conveniently consider it as divided into five zones. 1. That of the level, or nearly so, of the ocean. 2. That of small elevations, from 500 to 1500 feet. 3. That of the slopes of the Cordillera, from 2000 to 7000 feet. 4. That of the elevated plains, or table-lands, from 8000 to 10,000 feet. 5. That of the *Paramos*, from 11,000 to the limit of perpetual snow.

1. The degree of heat at or near the level of the ocean is modified by a variety of local circumstances, which may be ranged under the following heads: Proximity of the sea; of great rivers or lakes; of lofty ridges of mountains; of extensive forests; of contiguous elevations, which impede the circulation of air and produce reflected heat. The various combinations of these circumstances may be considered as affording a rule of the increase or diminution of temperature.

Thus, La Guayra, situated on a sandy beach backed by a precipitous wall of rocks, has no counterpoise to the excess of heat but the sea breeze, and the remote influence of the ridge of the Silla, which nowhere reaches the limit of perpetual snow. Humboldt considers it in consequence as the hottest place on the shores of the New World, (Personal Narrative, vol. iii. p. 386) the mean annual temperature being  $82^{\circ}6$ ; yet the observations I made during some months' residence in Maracaybo, give an annual mean of  $84^{\circ}63$ ; nor is this surprising, when we consider the localities of both places.

In Maracaybo the sun's rays are reflected from a barren sandy soil, scantily sprinkled with *Mimosas*, and prickly plants; the mountain chains are too remote to have any influence on the atmosphere, so that several years frequently pass without any regular fall of rain. The vicinity of the lake, no doubt, acts slightly as a refrigerant, but the city is built on the border of its outlet to the sea, where it is both narrow and shallowest, and is consequently heated nearly to the temperature of the incumbent atmosphere. Add to this the small sandy elevations to the north, which intercept the partial effect of the sea breezes, so that they are scarcely felt, except in the months of December and January, when the thermometer sometimes sinks to  $73^{\circ}0$ ; yet the medium even of these two months is not less than  $81^{\circ}0$ , while that of La Guayra from November to December at noon is, according to Humboldt,  $75^{\circ}8$ , and at night  $70^{\circ}9$  (Pers. Nar., vol. ii. p. 387). Rio Hacha is situated on a sandy beach; the sea breeze blows with such violence that boats can scarcely land between ten in the morning and four in the afternoon: these winds however, sweeping over the hot plains of Coro and Maracaybo, have but a partial effect in lowering the temperature, the annual mean of which is  $1^{\circ}98$  less than that of Maracaybo. I never saw the thermometer lower than  $75^{\circ}0$ , nor above  $89^{\circ}0$ . In Santa Marta the average of the coolest months is  $82^{\circ}25$ . The thermometer however never rose during my residence there above  $87^{\circ}0$ . The soil is sandy, and the city is surrounded by bare rocky heights to the north and south, which counterpoise the cooling influence of the *Sierra nevada* (snowy mountains), from which it is but a few leagues distant. The temperature of Barranquilla, a village situated on the river Magdalena, about 18 miles from its mouth, is nearly the same with that of Santa Marta; for if on the one hand the air is refreshed by the evaporation from a damp soil covered with luxuriant forests, and the vicinity of a large river; on the other it is beyond the reach of the sea breeze, and the influence of the mountains which operate in Santa Marta. The

annual mean is  $82^{\circ}20$ ; that of Cumanà is, according to Humboldt,  $81^{\circ}0$ . The breezes which sweep from the gulf of Paria over the wooded Birgantine chain probably contribute to lower the temperature.

We have thus, on a calculation of six points on the Atlantic coast of Colombia, a mean annual temperature of  $82^{\circ}56$  \*. The shores of the Pacific, as far as the latitude of Payta, are subjected to other influences, being almost entirely covered by damp luxuriant forests; while the ocean itself is cooled, as Humboldt observes, by the winds which blow constantly from the south. This, however, is more perceptibly the case from latitude  $8^{\circ}$  to  $13^{\circ}$ , where the air is cooled to an average of  $71^{\circ}8$ . Betwixt  $9^{\circ}$  north latitude and  $3^{\circ}$  south latitude, if we may trust to observations made at the five points of Panamá, Esmeraldas, el Morro, the island of Puná and Guayaquil, the annual mean is  $80^{\circ}11$ , being  $2^{\circ}45$  less than the mean of the Atlantic coast. A notable difference also arises from the superior elevation of the Pacific chain of the Andes, and its more immediate vicinity to the coast; while the Venezuelan branch, with the exception of the Santa Marta ridge, is both lower and more inland.

2. On penetrating into the interior of the country and examining the temperature of small elevations, we may take as forming an aggregate specimen of the whole country, 1st, the damp wooded valleys of the Orinoco and Magdalena; 2nd, the forests which border on the Pacific; and, 3rd, the immense plains of Venezuela, alternately flooded and parched with excessive heat. Humboldt assigns to the valley of the Orinoco a mean temperature of  $78^{\circ}2$ . The small number of observations I have made on that of the Magdalena, would give a mean of nearly  $83^{\circ}$ , which I should scarcely think too high, considering the localities of the river, which flowing from south to north, affords no channel to the sea breezes. Its mass of water is also much less considerable than that of the Orinoco, while its numerous sinuosities, and the low ridges which border it in the upper part of its course, contribute to render the air stagnant and suffocating. The temperature of Honda, at 1200 feet of elevation, is as high as that of any part of the coast, except Maracaybo. The unbroken forests which extend from the roots of the Quitenian Andes to the shores of the Pacific have a much lower temperature, caused by the proximity of the snow-capped Cordillera, and the humidity which prevails throughout the year. Accurate observa-

\* I have not included Cartagena, because the number of observations is, perhaps, too limited to draw a conclusion as to the yearly temperature. If we take them into the calculation the annual mean would be  $82^{\circ}86$ , which is probably too high.

tions give an annual mean of  $76^{\circ}78$ , or  $1^{\circ}42$  lower than the valley of the Orinoco, and  $6^{\circ}22$  lower than that of the Magdalena. The mean temperature of the plains of Venezuela is reckoned by Humboldt at  $88^{\circ}4$  (*De Distribut. Geog. Pl.*, p. 92.) yet several reasons may induce the belief that this calculation is excessive. This illustrious traveller performed his journey during the summer season, when the atmosphere is heated by the reverberations from a parched and naked soil. Persons who have resided near the Apure state the climate in rainy weather to be cool, and refreshed by a constant breeze. It is only on the coast of the Pacific that the rainy season is the period of the greatest heat, when the air is still and undisturbed by those electric explosions so common on the mountains and in the interior. The observations I made at Varinas and San Carlos, towards the beginning of the winter season, give a mean of  $81^{\circ}0$ ; and averaging the dry season at  $88^{\circ}4$ , we have a yearly mean of  $84^{\circ}7$ , which is probably the extreme or something beyond it. There is no doubt it is in the plains of the interior that we find the greatest heat during the dry season. In the level country called the valley of Upar, between the mountain ridges of Santa Marta and Ocaña, I found the thermometer in the shade several times above  $100^{\circ}$ , and once as high as  $108^{\circ}0$ . The average of nineteen observations, made at different points of this district, is  $89^{\circ}09$ ; but we must allow a considerable decrease during the months when the soil is covered with thick vegetation, and drenched by continual rains. As a general mean of the interior at small elevations, we may take  $80^{\circ}67$ , or nearly that of Cumaná.

3. The temperate mountain region lies nearly between the elevations of 3000 and 7000 feet. Below this may be considered as a hot climate: such for instance is Valencia and the valleys of Aragua in Venezuela, the height of which is from 1500 to 2000 feet, and its mean temperature  $78^{\circ}$ , or  $0^{\circ}14$  above that of Guayaquil on the Pacific; but the soil, stripped by cultivation of its ancient forests, imbibes freely the solar rays, which are besides reflected from the rocky elevations which everywhere surround the cultivated districts. The temperature of Caraccas (elevation 2904 feet) was fixed by Humboldt in his essay, *De Distribut. Geograph. Pl.*, p. 98. at  $69^{\circ}6$ ; but in his Personal Narrative, b. iv. c. xii. (vol. iii. p. 460) he considers  $17^{\circ}2$  of Reaumur =  $70^{\circ}40$  of Fahrenheit, nearly as the true yearly mean. My own observations during a residence of some months give  $71^{\circ}40$ . The preference would be certainly due to Humboldt's calculation, but for some collateral circumstances deserving of attention. I heard it generally remarked in the city, that the seasons had grown *hotter*



since the earthquake of 1812. It would be difficult to explain how the temporary evolution of volcanic gases, supposing such to have taken place, could operate any permanent change on the surrounding atmosphere; yet other causes may have produced an effect falsely ascribed to the phenomena most impressed on the imagination of the inhabitants. On looking over Humboldt's collection of observations for December and January 1799, we find the thermometer seldom rise to  $75^{\circ}$ , and often sink to  $59^{\circ}$ , so that the mean of these months is about  $68^{\circ}$ . During the same months in 1821 the daily range was from  $65^{\circ}$  to  $76^{\circ}$ . I never observed it lower than  $61\frac{1}{2}^{\circ}$ , and on one occasion at 5 a.m. it stood at  $71^{\circ}$ . The mean of these two months is  $70^{\circ}\cdot21$ , or  $2^{\circ}\cdot21$  higher than the estimate of Humboldt. The clearness and beauty of the sky during almost the whole period of my residence is also a circumstance opposed to Humboldt's "Cœlum sæpe nubibus grave quæ post solis occasum terræ appropinquant." (*De Distrib. Geog. Pl.*, p. 98.) I remember but *once* to have seen a fog in the streets of the city. Future observations will show whether any change of climate has really taken place, or whether the differences observed be only such variations as may be frequently remarked in the same places between one year and another. The mean of the whole temperate mountain region may be reckoned at  $67^{\circ}\cdot80$ , that is if we limit ourselves to the districts partially cultivated and inhabited. The declivities of the Andes, still covered with vast and humid forests, have probably their temperature proportionally lower. Thus the village of Mindo, on the western declivity of Pichincha, embosomed in humid forests, at 3·932 feet of elevation, has a medium temperature of  $65^{\circ}\cdot5$ , the same with that of Popayan.

4. The elevated plains of the Andes between 8000 and 11,000 feet, on which were anciently united the most powerful and civilized indigenous nations beneath the dominion of the Lipas of Tunja and Bogotà, and the Incas of Quito, and where the great mass of Indian population is still to be found, have a general medium temperature of  $59^{\circ}\cdot37$ , modified however by local circumstances, and particularly by the proximity of the *nevados*. Thus the village of Guaranda, placed at the base of Chimborazo, though nearly 500 feet less elevated, is at least  $1^{\circ}\cdot0$  colder than the city of Quito, sheltered on all sides by the ramifications of Pichincha. The city, again, is above  $1^{\circ}\cdot0$  warmer than its suburbs on the plains of Añaquito and Turupamba to the north and south. Riobamba is about 200 feet below Quito; yet its situation in an open plain bordered by the snowy mountains of Chimborazo, Tunguragua, and La Candelaria renders the climate colder and more

variable; while the town of Ambato, only 300 feet lower than Quito, but built in a nook of the river which runs near it, and shut in by dry sandy elevations, has a climate about  $2^{\circ}\text{O}$  milder, so that sugar-cane is cultivated in its immediate vicinity. The general uniformity of temperature, which spreads a certain monotony over tropical regions, is joined, at great elevations, to a daily variability, which must exercise a considerable influence both on vegetable and animal life. The thermometer, which often sinks at night to  $44^{\circ}\text{O}$ , rises in the sun, wherever there is reflected heat, frequently to  $120^{\circ}\text{O}$ , being equal to the heat of Jamaica; while in the shade it seldom exceeds  $65^{\circ}\text{O}$ : so that, on passing from shade to sunshine, one is immediately exposed to a difference of above  $50^{\circ}\text{O}$ , and in the course of twenty-four hours to nearly  $80^{\circ}\text{O}$ . The shade, in consequence, even on the hottest days, imparts a feeling of chilliness, while the solar rays seem to scorch like the vapour of a heated oven. The same difference is perceptible on the *Paramos*. At the foot of the Nevado of Santa Marta, I observed the thermometer at 5 a.m. sink to  $22^{\circ}\text{O}$ , and at 9 a.m. it rose to  $73^{\circ}\text{O}$  in the sun. On the height of Pichan, between Quito and Esmeraldas, elevation 12,986 feet, the thermometer stood at  $53^{\circ}\text{O}$  in the shade, and  $83^{\circ}\text{O}$  in the sun. On Antisana the difference was  $22^{\circ}\text{O}$  at the same time, but  $34^{\circ}\text{O}$  between 6 a.m. and 3 p.m.: when the atmosphere is calm it is much more considerable.

5. Although at great elevations, *i. e.* from 12,000 to 16,000 feet, it is difficult to form a series of meteorological observations, such is the yearly equality of the temperature that a single day may be safely taken as a sample of the whole year. Nay more, a collection of observations made at similar heights, though in different places, will give a similar result to a series taken on the same spot. Thus, in the following table, there is little difference between the result of seven observations, made on seven different mountains, and the six made on that of Antisana.

1.	Paramo of Santa Marta . . . .	15,000 ft.	$22^{\circ}$ $5\frac{1}{2}$ a.m.
2.	Paramo of Cayambe . . . . .	12,705	37 6 "
3.	Paramo of El Altar . . . . .	12,986	42 8 "
4.	Mine of Conderasto . . . . .	14,496	45 12 "
5.	Volcano of Pichincha . . . . .	15,705	46 1 p.m.
6.	Mountain of Atacaso . . . . .	14,820	41 "
7.	Nevado of Cayambe . . . . .	14,217	43 $1\frac{1}{2}$ "
	Mean . . . . .	....	$39^{\circ}\cdot 42$
	Paramo of Antisana . . . . .	14,520	$38\cdot 58$ : six observ.
	General mean..	....	$39\cdot 87$ .

General Table of Temperatures and Elevations.

Elevations.	Places.	Temperature.	Ditto of Humboldt.	Hygrom.	Lat.	Observations.
0	Cumana .....	.....	81°			The Elevations here indicated by Zero are such as are too small to influence the temperature.
0	La Guayra .....	.....	82·6			
0	Maracaybo .....	84°·63				
0	Rio Hacha .....	82·65				
0	Santa Marta .....	82·28				
0	Baranquilla .....	82·21				
	Mean of the Atlantic Coast .....	82·56	81·8			
0	Panama .....	81·14	.....			
0	Esmeraldas .....	79·65	.....	21°·78		
0	Guayaquil .....	77·26	.....	27·01		
	Mean of the Pacific Coast .....	79·35				
500ft.	Valley of the Orinoco.....	78·2	78·2			
650	Valley of the Magdalena .....	83·				
522	Plains of Venezuela	84·7	83·4			
543	San Carlos in ditto	81·15				
600	Canigüe Forests of the Pacific .....	76·78	.....	22·77		
	Mean of the Interior .....	80·61	83·3			
1527	Valencia .....	78·25				
2903	Caracas .....	71·68	70·40			
5823	Popayan .....	65·40	65·6			
6782	Loxa .....	66·6	66·6			
	Temperate Mountain Regions ...	67·71	67·17			
8694	Bogotá .....	60·49	60·8			
9514	Quito .....	60·47	59	40·98		
	Suburbs of ditto ...	58·75	.....	42·03		
9724	Cayambe .....	57·25				
	Elevated Plains ...	59·24	59·9*			
14,520	Antisana Farm ...	38·58	.....	30·3		
12,457	Paramos of Cayambe, El Altar, Pichincha, and Santa Marta .....					
to 15,727						
	Mean Temperature of the Paramos	38·87				

\* Humboldt ascribes to this region a yearly mean temperature of 54°, while the result of the mean temperatures of the various places he has instanced is 60·64°.

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