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John G. Gamble M.A. ^a

^a M. Institute, C.E.

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II. *Rainfall of South Africa*.—By John G. Gamble, M. A., M. Institute, C. E.

[Read, 26th June, 1878.]

[NOTE.—The Maps referred to have not been printed, but the table at the end of this paper gives the materials from which the maps were compiled.]

In designing these maps and in exhibiting them to the Philosophical Society I have wished to arouse some interest in rainfall measurement, and to elicit some discussion of the causes of the distribution of rain in South Africa, rather than to set forth any new views of climate or meteorology.

Scantiness of Materials.

It is much to be regretted that there are so few materials for a discussion of the meteorology of South Africa. The only really satisfactory series of observations is that taken at the Royal Observatory, from which we have now thirty-seven continuous years of rainfall measurement. At Port Elizabeth a continuous meteorological record has been kept by Mr. Charles Hammond, the lighthouse-keeper, since 1866 ; and we have rainfall records since 1861 kept at Graaff-Reinet by Mr. Alfred Essex ; as well as good registers from Groote Post near Malmesbury, from Nel's Poort near Beaufort West, from Aliwal North, and from a few other places ; but, as a rule, the information as to the rainfall of the vast districts in the interior of South Africa is sadly deficient. In 1862 the first report of the meteorological commission was published, and subsequently results were printed embracing the years 1861 to 1868 ; but for some reason or other the zeal of the observers flagged, and the commission left off publishing. Since 1875 however, results have again been printed, but the stations are few, and the observations often intermittent. As to the rainfall, which is the matter in which I am specially interested, I have endeavoured to

collect registers for the period between 1868 and 1875 when they were not printed by the commission. Advertisements were put in the papers about a year ago asking all people who had rain-gauge observations to send up copies of their registers to the secretary of the meteorological commission, and intimating that such documents can be sent post free. In consequence I have accumulated from manuscripts, as well as from the available printed records, a large quantity of information, but I have to deplore many notable gaps in the registers. For example, I have not been able to get all the observations from a place so near us as Wynberg, though I have taken some trouble in the matter. At Graham's Town observations were taken as early as 1850, I believe by the Royal Engineers, but I have not been able to get all the statistics. I believe there have been observations taken in Natal which I have not seen: the authorities there have promised to send me a set of the records, but hitherto nothing has arrived. I am indebted to the last book of that diligent collector of authorities, the Rev. J. Croumbie Brown, for a series of nine years' observations taken near Port Natal. Some observations appear to have been taken at Harrismith in the Orange Free State, but I have only got the total of one year. At Motito in Bechuanaland, north of the Diamond-fields, I have the monthly totals for one year, but no more. Whether more observations have been taken or not, I have not yet found out. I need scarcely point out how very valuable any records from such a station would be.

Explanation of the Maps.

The maps exhibited consist of four large wall-diagrams representing the coast-outline of South Africa, with the number of inches of rain at various places during each season of the year, marked in red figures. Each map represents a season, summer being taken as December, January and February, and so on. The five smaller diagrams represent the Cape neighbourhood, and give the rainfall for the same seasons, and also for the whole year. It is an unfortunate but quite unavoidable point with regard to these maps that the red figures at different places do not represent the same period of years. Thus the figure representing the fall at the Royal Observatory is the mean of thirty-six complete years, that at King

William's Town the mean of only nine years and a half, and so on with the others.

Difference between East and West.

One obvious point, that strikes anyone who either examines these maps or travels in this country, is the marked distinction between the East and the West. Natal and the Eastern Province get their rains chiefly in summer when the South-East trade wind blows. The Western portion of the Western Province gets its rain mainly in the winter with the North-West wind. This wind seems to be a similar meteorological phenomenon to the South-West wind of Western Europe, called the return trade by Halley 200 years ago, and, perhaps more correctly, called by Herschel the Anti-trade. We may note that the anti-trade of the Western Province comes apparently from a portion of the equatorial regions that is occupied by sea, while the North-West winds that blow in the Eastern Province, if they really keep their theoretic curvilinear path, and are not interfered with by the height or temperature of the ground, come from a portion of the equator where there is land, and consequently small evaporation. The midland districts seem more connected with the East, getting their principal supply in the summer, but owing their moisture mainly to thunder storms, which, though they occur at a time when the South-East is prevalent on the coast, yet frequently appear to come from a North-West direction. This was pointed out by Mr. Ella, who, when in charge of the Katberg Road, reported that there were three belts of climate: on the coast side of the Katberg, the usual periodic rains of the Eastern Province; on the top of the Katberg* constant rain in summer from the South-East; but to the northward heavy thunder storms from the North-West which swept the northern face of the Winterbergen and Amatolas, and went on in a North-East direction towards Natal. When I was on the Orange River, at Prieska and further down, the thunder storms seemed to come from the westward; but a very grand storm which I witnessed in the Calvinia Hantam

* The top of the Katberg pass is about 5720 feet above sea level. The village of Balfour at the foot of the Katberg on the coast side is about 2160 feet above sea level.

came from the South. These midland storms are often of very small extent, heavy rain falling on one farm while it is dry all round.

It is frequently said that in such and such a year there was a drought in the *colony*, in another year heavy floods in the *colony*. This way of speaking is incorrect, for, in consequence of the very distinct climates of the East and West respectively, which I have already alluded to, it is very rare that a drought occurs all over South Africa at the same time. Mr. Fox Wilson in a paper printed in the Royal Geographical Society's journal for 1865, says there was a drought in the *colony* in 1862. He adds that it was especially severe in Basutoland. On examining the registers we find that there was a severe drought at Graaff-Reinet, only seven inches falling in the year. This is eight below the average. At Uitenhage it was not so marked, twelve inches falling or three below the mean, while at Pietermaritzberg there was an average fall. But when we come to the Western Province we find that on the contrary the fall was superabundant.

The Royal Observatory records give	32	inches or	8	above the mean.
Town House, Cape Town	29	"	3	"
An observer at Sea Point gives	28	"	7	"
An observer at Simon's Town gives	36	"	7	"
An observer at Somerset West gives	29	"	6	"
Mr. Blore at Wynberg marked	68	"	28	"
and even at Worcester there was	21	"	8	"

while from Concordia, in Namaqualand, the almost incredible fall of fourteen inches was reported. On examining the registers we find the explanation of this difference between East and West. The drought at Graaff-Reinet was owing to the failure of the summer rains, and especially of those which are generally expected in February, while the Western Province downpour was owing to the winter rains, as much as forty-five inches of rain being recorded by Mr. Blore at Wynberg for the three months, June, July, August of that year.

The drought of last year 1877 was very severe in the Midlands; only four inches fell in the whole year at Nel's Poort, the smallest yearly total ever registered there. This drought was chiefly, though not entirely, a summer drought; at Graaff-Reinet there was again the failure of the February rains, but the rains in the West were excessive, over twenty-three inches being registered at

Bishopscourt in the month of May alone. The May rain of last year is traceable at Clanwilliam, but not at Frasersburg, Carnarvon, or Amalienstein (near Ladysmith), and is only slightly noticeable at Mossel Bay.

As an instance of the local character of the Midland rains, I find that, though Graaff-Reinet did not get its February rains last year, yet four other observers in that neighbourhood, Mr. Brooke of Goliaad's kraal, Mr. Rubidge of Welwood, Mr. Laharpe of the Glen, and Mr. Watermeyer of Letskraal had an average supply in February.

The entire separation of the Western portion of the Western Province from the rest of South Africa, is shown by Mr. Sidney Jackson of Brakfontein, who says that, when it rains near Cape Town, it very seldom rains in Victoria West, and that the summer rains in Victoria West rarely set in until the Cape South-Easters begin to blow.

We notice that places close to the East Coast do not exhibit the same decided monsoon feature as the interior and the West, or perhaps we should say that the monsoon feature is masked by other causes. Thus at Port Natal March is the wettest month. At both Port Elizabeth and Uitenhage, October and November are the wettest months, while January is dry at both. Is it that the clouds flying higher in summer are able to pass over Port Elizabeth and the coast ranges without depositing moisture?

With regard to the boundary line between the two climates, there are not enough observations to give any satisfactory result. We may, however, expect that the boundary will vary somewhat from year to year, and that it will be a belt rather than a line, over which belt the peculiarities will gradually diminish. Thus at Worcester there was a heavy fall in February, 1863, which is not observable at the Royal observatory, or at the Town Hall. As this February there were heavy rains at Nel's Poort and at Graaff-Reinet, and even at Mossel Bay, we may almost infer that the summer rains came past their usual boundary. The February rains are traceable however in the yearly curve for Wynberg and Worcester, and even in Namaqualand February seems more favoured than January or March. It may be noted that at Amalienstein the winter rains are some-

what in excess of the summer, while the maximum is in autumn. I think that Amalienstein is not far from the average boundary between the two climates.

Effect of height on rainfall.

Another point that is clear to all is that as you go inland you get drier, thus Worcester is drier than Cape Town, Uitenhage than Port Elizabeth, Pietermaritzburg than Port Natal. But there is a law which somewhat interferes with this, and that is that as you go uphill you generally get into a wetter climate. Thus the rainfall on the Katberg is probably as heavy as that of any other place in the Cape Colony. Heavy rainfall is generally found on that slope only of a *very* high mountain chain, which is exposed to the rain-bearing wind, but in the case of *moderately* high hills both slopes have a heavy rainfall. This is seen in India where the South-West monsoon crosses the moderately high Western Ghats and feeds the sources of the Madras rivers ; but is said not to cross the lofty Himalayas. Similarly Table mountain is apparently not high enough to prevent the North-West winds from depositing considerably more rain at Bishopscourt and Wynberg than they do at Sea Point and Cape Town : while at the much higher Katberg the South-East rains penetrate but a short distance beyond the summit. I say purposely as you go *uphill* the fall generally increases, and not as you go *higher*, for it is a well-known and curious fact that, wherever observations have been taken, it has been found the precipitation is greatest near the surface of the ground, and decreases gradually with the height. For example the annual fall of rain on the roof of the Paris Observatory is two inches less than on the ground beside it.

Among the curious points suggested by these maps we note that the summer fall at Brakfontein, Victoria West, is five inches, while that at Nel's Poort, Beaufort West, is only three. When I first saw this I thought it must be owing to the fact that I have only records for four years and eight months at Brakfontein, while I have nearly fourteen years for Nel's Poort. And perhaps in consequence of a rather heavy fall at Nel's Poort, in January, 1876, the figure 5 is rather high, yet on comparing the totals of the four years 1873, '74, '75, '76,

during which the observations were simultaneous at the two stations, I find that in each year there was two inches more rain at Brakfontein than at Nel's Poort. The former is about 1,000 feet higher than the latter; whether this has anything to do with the increased fall I cannot at present say.

Desirability of observing duration of rainfall.

An important point with regard to rainfall is the length of time which each shower or storm lasts. Observations made in France have shown that one inch of drizzling rain lasting seven hours penetrated four and a half inches into the soil, while three inches of heavy rain falling in one hour and a half only penetrated two inches; thus one-third of the quantity penetrated more than twice the depth, because it fell gradually instead of rapidly. This is an important matter for the Karroo farmers, who get most of their meagre allowance in thunderstorms. It is reported that four inches once fell in two hours at Victoria West. Of course only a small portion of this sinks into the ground, the rest passes away rapidly down the river-beds to the sea, and is lost. The new rainfall registers lately issued have columns in which the observer can note down when the rain began and when it left off. I may note in passing that the fact of the rain falling, when it does fall, in heavy showers in a short time, though unfavourable to the actual land it falls upon, is more favourable for the filling of storage reservoirs than a soaking rain.

Sunspot period.

Had the records been ampler it would have been interesting to have examined whether the coincidence between the periodic maxima and minima of sunspots and the maxima and minima of rainfall which Mr. Stone has pointed out for the Royal Observatory here, and which has been noticed in other parts of the world, holds good of up-country stations. If we compare the rainfall of the three minimum sunspot years '65, '66, '67 with that of the maximum years '69, '70, '71, we find that in the three maximum years the rainfall was considerably heavier at Cape Town and Worcester, somewhat heavier

at Uitenhage and Graaff-Reinet, but at Nel's Poort it is the other way, the rainfall of the three minimum years being the greater.

Observations and Observers.

During the last year a large number of new rain-gauges have been distributed over the colony, and we may hope in a few years to add to our knowledge of the climate of this part of the world, climatic questions not requiring such a long period of observations as some others, such for example as the somewhat delicate question of coincidence with the sunspot period.

I have to thank many observers for their readiness in copying out for me, or lending me, their registers. I would not wish to be ungrateful, but it is an unfortunate fact that some observers cannot add up or take means correctly. Hence it is very desirable to have access, where possible, to the original register. Another trouble is that some observers have not distinguished between a month in which there was no rain, and a month during which they were away on a holiday, and took no observation. Of course when an observer is absent he should provide a deputy, but this has not always been done.

Conclusion.

I regret much the small amount of new matter that I have been able to bring before the society; still if I succeed in eliciting an interesting discussion among the many members of the society who, from longer residence in the colony or for other reasons, are better qualified than I am to deal with this question, the labour I have taken in calculating means and designing these maps will not have been spent in vain.

RAINFALL IN SOUTH AFRICA.

Table from which wall diagrams were compiled.

PLACE.	Spring.	Summer.	Autumn.	Winter.	Year.
Royal Observatory, Cape Town	5	2	6	11	24
Town House, Cape Town	4	2	7	13	26
Sea Point	5	2	5	9	21
Bishopscourt	12	6	11	22	47
Wynberg	9	2	6	23	40
Simon's Town	6	3	7	12	29
Somerset West	5	1	5	12	23
Stellenbosch	6	1	7	9	23
Bredasdorp	4	3	5	6	14
Worcester	3	1	3	6	13
Groote Post, Malmesbury	3	2	5	9	19
Glanwilliam	1	1	3	5	10
Concordia, Namaqualand	1	2	2	5	9
Keerom, Namaqualand ...	2	1	1	4	8
Amalienstein	4	3	6	4	18
Nel's Poort, Beaufort West	2	3	3	1	9
Brakfontein, Victoria West	3	5	3	1	13
Graaff-Reinet	4	6	4	2	15
Goliad's Kraal, Graaff-Reinet	3	5	4	2	14
Somerset East	5	6	6	2	19
Uitenhage	6	3	4	3	15
Port Elizabeth	7	5	6	6	25
Graham's Town	8	8	7	4	30
Aliwal North	5	12	6	1	25
Queen's Town	4	11	6	2	24
King William's Town ...	7	11	7	3	29
Pietermaritzburg	10	13	6	1	30
Merebank, near Port Natal	12	13	14	6	44

N.B.—The figures mean inches of rainfall. The annual fall will not be found always to agree with the sum of the seasons, as in some cases I have got yearly totals without monthly totals, and I have preferred to make the yearly mean more accurate by embracing these, than to make the table perfectly symmetrical.

JOHN G. GAMBLE.