

ON CERTAIN PROTRACTED IRREGULARITIES OF ATMOSPHERIC PRESSURE IN BENGAL IN RELATION TO THE MONSOON RAINFALL OF 1868 AND 1869,—by HENRY F. BLANFORD, *Meteorological Reporter to the Government of Bengal.*

(With plate VIII.)

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When the Meteorological system, recently established in Bengal, began to afford trustworthy results, one of the first objects of enquiry that engaged my attention, was the variation of the monsoon rains. The year 1868 was marked by a rainfall in Lower Bengal (more especially at Calcutta and the S. Western part of the Gangetic delta) of almost unprecedented amount, while in the N. W. Provinces and the Panjab, the deficiency was such as to cause a very considerable failure of the crops and much consequent suffering. This year (1869), the rains have been comparatively light throughout Northern India, including Bengal, except in the districts to the North of the Pudma\* river; and it is fresh in the recollection of all residents in Northern India, that large tracts in the N. W. Provinces, Central India and the Panjab, have been preserved from the imminent horrors of famine only by the timely rains at the very close of the ordinary monsoon season. My object, in the present communication, is to bring to notice certain peculiarities in the distribution of the barometric pressure, which seem to throw some light on the causes, the proximate causes at least, of these notable and important variations.

In watching the daily and monthly reports received from the Meteorological stations in Bengal, I early observed that sometimes for periods of several months, the barometric readings at certain stations, when reduced to the sea-level, shewed an apparently anomalous depression or elevation; anomalous, that is to say, as not conforming to the general law of the barometric gradient for the time of year, as then known. I was at first inclined to suspect that the assigned elevation of certain of the stations might be erroneous, or that, possibly, the barometric registers might be vitiated

\* The name given to the main stream of the Ganges below Rajmahal.



by errors arising from faulty position or manipulation of the instruments. Accordingly I took every means in my power to verify the elevations, and either by personal inspection or otherwise, to satisfy myself that the instruments were properly placed and observed. The barometers had all been compared with the Calcutta standard before they were issued, and the errors thus ascertained had been applied as corrections to their readings. At stations that I visited,\* I repeated the comparison with one or two mountain barometers which I carried with me, and which had been compared with the standard before my departure and were again compared on my return. In no case did the result of the second comparison differ from that of the first by more than a quite trivial amount. Some of the stations,† moreover, have been supplied with duplicate barometers since the peculiarities above noticed first attracted my attention, and in these cases, a comparison was made between the two instruments as soon as possible at the station, and their recorded errors thus made to furnish a check on each other. I mention these details because in this country the barometric variations are so small in comparison with those in Western Europe, that it is of the utmost importance in order that the conclusions based on their readings may be trustworthy, that all merely instrumental errors be most carefully eliminated. Any confidence that my facts may lay claim to, will depend on the assurance that all ascertainable causes of error have been carefully ascertained and allowed for.

These precautions then having been duly observed, and not having afforded any explanation of the observed anomalies,‡ the conclusion became legitimate, that they were real atmospheric phenomena and not apparent and instrumental only: and this conclusion was confirmed by the fact, that in some cases the same peculiarity was shewn by two or more neighbouring stations. Finally during the last cold weather (1868-69) I observed that certain stations which, during the S. W. monsoon, had shewn an excessive barometric depression, now exhibited an opposite tendency, an excess of atmospheric pressure; and that this like the former pecu-

\* Dacca, Chittagong, Shillong and Monghyr.

† Saugor Island, Cuttack and Akyab.

‡ With one exception. The elevation of Chittagong had been erroneously reported, as shewn by my verification.



liarity, affected not one only, but two or three neighbouring stations in different degrees, and lasted for some months.

It was not, however, until another S. W. monsoon had afforded me the means of comparing the barometric features of the same season in two consecutive years, that I could be justified in assuming any correlation between these local peculiarities of atmospheric pressure, and the variations in the rainfall. There has hitherto been very little systematic observation of the barometer in India, that is susceptible of comparative treatment, and very much remains to be done to ascertain the normal distribution of atmospheric pressure during our monsoons. To determine whether any local peculiarity is normal or abnormal, at least two registers for corresponding seasons must be compared. This has now been done for the SW monsoon, and I am justified in concluding, that the local depressions which I shall now describe, and which appear to me to be intimately related to those variations of the rainfall which I have already noticed, are peculiar to the year and not recurrent.

I take first of all the SW monsoon season (May to September) of 1868. The following table (extracted from my official report) gives the mean barometric pressure\* of each of the monsoon months, at all the stations from which I have reports for the period in question. They are reduced to 32° Fahr. and mean sea level.

	May.	June.	July.	Aug.	Sept.
Port Blair, . . . . .	?	29·810*	29·835*	29·819*	29·853*
Madras, . . . . .	29,800	·742*	·756*	·772	·792*
Akyab, . . . . .	·850	·753	·756	·720	·797
False Point, . . . . .	·736	·567	·562	·575	·654
Cuttack, . . . . .	·754	·613	·615	·568	·735
Chittagong, . . . . .	·802	·626	·657	·630	·740
Saugor Island, . . . .	·736	·522	·535	·475	·616
Calcutta, . . . . .	·781	·570	603	·601	699
Hazaribagh, . . . .	·720*	·546*	·509*	?	?

\* The means are obtained from the observations recorded four times daily viz. 4 A. M., 10 A. M., 4 P. M., and 10 P. M. on every day in the month, except those marked with an (\*) which are the means of the 10 A. M. and 4 P. M. observations only. I have shewn, in the Report, that the means thus obtained are comparable to within '01 of an inch.



	May.	June.	July.	Aug.	Sept.
Jessore, .....	·761	·541*	·584*	?	·695*
Berhampore, .....	·777*	·547*	·590*	·590*	·715*
Dacca, .....	·831	·614	·636	·605	·739
Monghyr, .....	·701	·515*	·542*	·564*	·679*
Patna, .....	·740*	·549*	·542*	·574*	·684*
Benares, .....	·747	·570	·573	·621	·710
Roorkí, .....	·694	·491	·517	·523	·658

It will be observed that in June, (with the exception of the comparatively distant stations, Monghyr and Roorkí,) and in August and September, (without exception as far as the table shews, Hazaribaugh being, however, wanting in these months,) Saugor Island shews the lowest mean barometric pressure. False Point also shews a low mean pressure, which is however, 0·1 above that of Saugor Island in August, and 0·03 to 0·04 in the other months after May. The Calcutta mean readings are from 0·045 to 0·12 higher than those of Saugor Island throughout, and those of Cuttack (except in August when this station shews the lower mean pressure,) from 0·018 to 0·08 higher than those of False Point. There was therefore, a persistent barometric relative depression extending from Saugor Island to the SW. It was somewhat changeable both in intensity and position, but the minimum always lay nearer Saugor Island than any other station. The mean barometric gradient between Calcutta and Saugor Island (70 miles) was in

May, one inch in 1555 miles.

June, „ „ 1458 „

July, „ „ 1029 „

Aug. „ „ 555 „

Sept., „ „ 843 „

and it did not finally disappear until December.

There was another area of barometric depression to the NW. and NNW. of the above, (as is shewn by Hazaribaugh and Monghyr) which would seem to be more regularly recurrent than that which lay about the Sand Heads, and is probably due to the elevated and hilly character of the country. In July the mean pressure at Hazaribaugh was lower than at Saugor Island.



Saugor Island as has been already remarked was the lower in June, and in all probability in August also.

Now the rainfall tables shew that the months of June and August were those of the heaviest rainfall in Bengal generally ; but the excessive falls were very local. In June the maximum was at Balasore and Contai ; in August at Hooghly and Kishnagur ; in both cases apparently, (certainly in the latter,) not at the place of greatest mean depression but at some distance (about 100 miles) to the north of it. This is shewn by the following table extracted from the general rainfall table in the official report—

*Rainfall in inches.*

	June.	July.	Aug.	Sept.
Poorí, .....	11·00	10·90	12·90	5·05
Cuttack, .....	17·30	10·12	8·92	9·80
False Point, .....	9·20	12·75	9·95	20·40
Balasore, .....	36·20	5·60	14·30	9·60
Saugor Island, .....	27·40	11·86	16·07	21·50
Contai, .....	34·43	8·76	12·69	17·74
Midnapore, .....	22·80	5·40	19·30	13·20
Calcutta, .....	26·61	11·17	24·83	15·69
Howrah, .....	23·20	14·80	25·30	21·10
Bancoorah, .....	15·25	6·55	15·30	17·10
Hooghly, .....	15·80	9·55	40·50	21·40
Burdwan, .....	8·20	10·80	29·60	14·50
Jessore, .....	16·62	12·24	20·53	9·49
Kishnaghur, .....	10·75	11·50	30·20	7·30
Berhampore, .....	12·71	8·40	18·07	9·36
Soory, .....	8·85	8·85	10·45	9·20
Rampore Beauleah, .....	14·45	13·20	10·75	11·20

Calcutta and Howrah received about the same quantity of rain in June and August, but in the former month they lay to the north, in the latter to the south of the area of greatest rainfall. In June the fall exceeded 20 inches over an area including Balasore, Saugor Island, Contai, Midnapore, Calcutta and Howrah. At Bancoorah, Hooghly and Jessore it was between 15 and 17, and at Cuttack rather more than 17 ins. In August the fall exceeded 20 inches at Jessore, Kishnagur, Hooghly, Burdwan, Calcutta and



Howrah, and was nearly of that amount at Midnapore in one direction and at Berhampore in the other.

In both months there was within these areas a focus of greatest rainfall, around which, the quantity diminished with the distance. This focus was about Contai and Balasore in June, where the quantity registered was between 30 and 40 inches, and in August was situated about Hooghly, where the register exceeds 40 inches for this month.

The resultant directions of the winds at Calcutta, Saugor Island, False Point, Cuttack and Jessore, as calculated from all the observations in each month are given in the following table; comparative prevalence being expressed by a number proportional to the whole number of observations taken as 100.

	May.	June.	July.	August.	Sept.
Jessore, ..	58 S.19E.	56 S. 6W.	74 S.22E.	27 S.16E.	55 S. 12E.
Calcutta, ..	80 S. 5E.	75 S.14W.	88 S .2E.	61 S.24W.	68 S. 18E.
Saugor Id.,	85 S. 5W.	77 S.29W.	72 S.12W.	45 S.37W.	37 S. 12W.
False Pt.,	81 S.24W.	60 S.47W.	68 S.55W.	58 S.87W.	40 N.83W.
Cuttack, ..	70 S.11E.	48 S.35W.	47 S.47W.	42 S.79W.	18 S. 39W.

Now on comparing in this table the mean directions for June and August with those of the other months, it will be observed that the former are characterized by a comparative excess of westerly elements. Thus at Calcutta for example, the wind is East of South in May, July and September, but West of South in June and August. This general characteristic becomes very distinct when the anemometric resultants are laid down on a chart, [see Plate VIII,] as wind arrows, the lengths of which vary as the figures expressing prevalence. At Jessore the August mean is an apparent exception, but the figure expressing prevalence, is so much reduced as to indicate a considerable deficit of Southerly and increase of Northerly elements.\* A similar difference is shewn by the mean of Berhampore.

A comparison of the June and August wind resultants with those of the same stations for any of the monsoon months of 1869 entirely bears out the above inference as to the unusual prevalence of a

\* The detailed table from which the mean resultant is computed shews this to be the case.



Westerly element in the former, in other words of a deflection of the monsoon from its normal course towards the East. The winds do not indeed follow a spiral course around, and in to a place of minimum depression as they would do in a cyclone, but they are deflected from their normal direction to the Eastward, in all probability to feed an ascending current over Lower Bengal. Hence the excessive rainfall already noticed at certain stations in Lower Bengal, and as a consequence, the deficiency experienced by stations to the NW. in the Ganges valley, with the predominance of Westerly winds which characterized the greater part of the monsoon of 1868 in the N. W. Provinces. Of these features the existence of a persistent barometric depression in the head of the Bay seems to offer a consistent explanation.

I now pass to the monsoon of 1869, the barometric features of which differed considerably from those of the previous year, and which brought to the delta of Lower Bengal a rainfall somewhat below the average, while in the NWP. the deficiency of rain up to almost its close, was as marked as in 1868.

	May.	June.	July.	Aug.	Sept.
Port Blair, . . . . .	29·817*	29·770*	29·789*	29·810*	29·829*
Madras, . . . . .	·733*	·673*	·717*	·751*	·777*
Akyab, . . . . .	·782	·656	·701	·724	·804
False Point, . . . .	·763	·609	·626	·719	·748
Cuttack, . . . . .	·710	·572	·626	·716	·733
Chittagong, . . . .	·742	·600	·638	·731	·745
Saugor Island, ..	·705	·548	·566	·668	·704
Calcutta, . . . . .	·680	·531	·566	·666	·708
Hazaribagh, ..	·588	·481	·527	·624	·677
Jessore, . . . . .	·669	·521	·554	·651	·701
Berhampore, . . . .	·665 ?	·517 ?	·562 ?	·668	·709
Dacca, . . . . .	·704	·566	·601	·684	·739
Cachar, . . . . .	·752	·594	·630	·698	·761
Monghyr, . . . . .	?	·482	·527	·596	·644
Patna, . . . . .	·601	·494	·522	·619	·675
Benares, . . . . .	·625	·505	·567	·641	·688
Roorkí, . . . . .	·560	·362	·510	·581	·663



The distribution of atmospheric pressure shown by this table is very different from that shewn by the table for 1868. The Saugor Island means are throughout equal to or higher than those of Calcutta, and those of False Point equal to or higher than those of Cuttack. Of the area of depression in the head of the Bay, which was so marked and constant during the monsoon of 1868, not a trace reappears. This season the seat of minimum pressure is transferred to Hazaribaugh and Monghyr,\* and here it was persistent nearly to the close of the monsoon, deflecting the winds and apparently determining the distribution of the rainfall, just as the Saugor Island depression of the previous year had done in the lower part of the delta.

This depression first became marked in April, in which month the lowest mean readings are those of Hazaribaugh and Patna, Monghyr being wanting. In May the difference was greater and in June these three stations alone lay within the isobaric of 29.5. In June and July the pressure was about the same at Hazaribaugh and Monghyr, but in August and September it rose at the former more rapidly than at the latter station, and the barometric minimum lay above Monghyr.† Throughout the three first months of the rains, and indeed nearly to the end of September, the vapour bearing monsoon was then arrested in its normal course towards the N. W. Provinces by a persistent atmospheric depression in the region of the Curruckpore hills and Hazaribaugh, and it was not

\* In the abstract of the paper given in Proc. As. Soc. for January 1870, it was stated (p. 93) that in March, a slight depression appeared over a region including Berhampore, Monghyr, &c., that in May it was intensified especially over the first named station and reached its lowest point in June, and that there was a mean difference of 0.14 of an inch between Calcutta and Berhampore. On re-examining the registers and laying down their barometric means of the stations for each day in curves, an instrumental error has been detected in the Berhampore register which affected it from the 15th April to the 15th July, and which caused the mean pressure to be recorded as rather more than 0.1 too low. A corresponding correction has been applied to the register in the above table, but since the correction can be determined only for the beginning and end of the period, and is assumed to be the same throughout, the results are marked with a [?]. It results from this that the depression did not move westward as originally stated, but changed as now stated in the text; and that the cyclone of June did not move direct to the place of minimum pressure, though (as I am still of opinion) its course was probably affected by the existence of the local depression.

† Except Roorkí which in this month was lower than any of the Bengal stations, but the barometer has not been compared and there is much reason for the belief that it reads low.



until the end of September that the contraction of this depression allowed the N. W. Provinces to receive their usual rainfall, as it would appear, by leaving the winds from the Bay to follow their normal course across Hazaribaugh and Chota-Nagpoor towards the Upper Provinces.

In June the heaviest rainfall occurred at Julpigori (41.29 ins.) and Rungpore (36.7 ins). At the stations of Dinagepore, Pubna, Malda, Buxa, (Bhotan Doars,) and Goulpara more than 20 inches were registered, while at Darjiling at which the average rainfall for this month is 27.50\* ins., 19.85 inches only fell. At Calcutta the rainfall for the month amounted to 18.84 inches; but of this, 11 inches fell in one day, during the Cyclone of the 9th June, the centre of which passed very near Calcutta. Berhampore received 21.74 inches of which 5.7 fell during the passage of the Cyclone and Rampore Beauleah, which was also near its track, 18.05 inches, in all of which 6 inches fell on the day of the storm. It would appear then that the heaviest fall was to North East of the depression, the maximum being at 150 miles from the seat of greatest depression much as in August of the previous year. In the present case, however, the place of maximum rainfall was probably determined by the proximity of the hills.

That the winds in May and June were greatly influenced by the local barometric depression, and instead of blowing up the Ganges valley, drew in towards the depression with a tendency to circulate round it, is shewn by the following table, which exhibits also the increase of Easterly components in September when the rains reached the Upper Provinces.

It may be noticed, however, that as in the previous year, the influence of the local depression was sufficient only to modify and weaken, not to counteract that of the probably more extensive area of low pressure, which many circumstances lead me to believe must exist in Central India, as a normal phenomenon of the S. W. monsoon.

	May.	June.	July.	Aug.	Sept.
Cuttack, ....	79S 6°E	58S 3°E	58S 49°W	55S 19°W	30S 17°E
False Point,..	63S 15°W	53S 25°E	72S 67°W	63S 56°W	41S 39°W

\* Mean of 7 years.



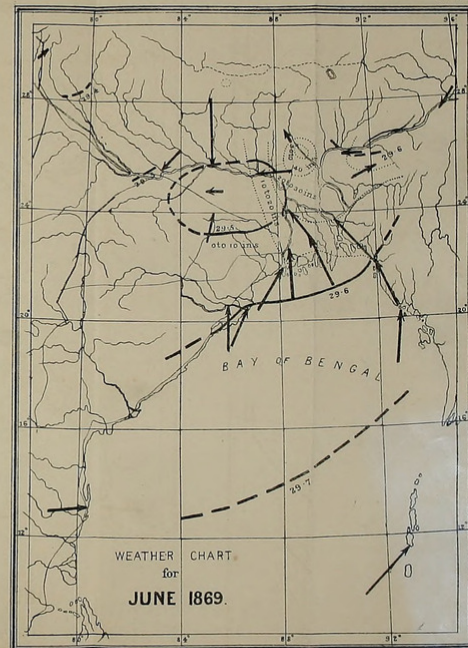
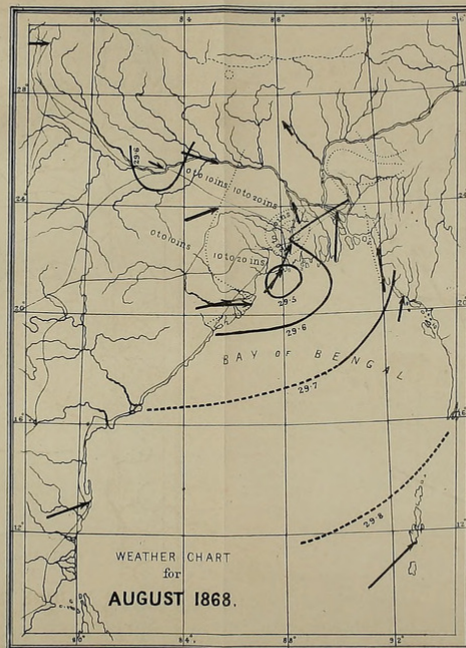
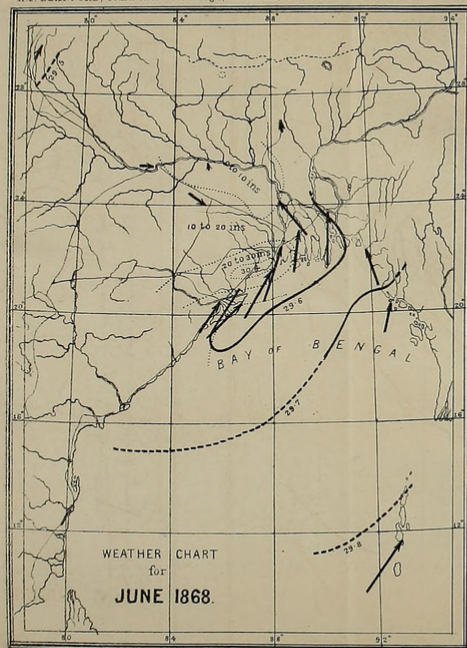
	May.	June.	July.	Aug.	Sept.
Saugor Island,	82S 38°W	65S 32°W	74S 55°W	77S 47°W	68S 11°W
Calcutta, . . . .	82S 7°W	70S 6°E	84S 5°E	85S 1°E	85S 23°E
Jessore, . . . .	55S 11°E	72S 30°E	82S 18°E	70S 7°E	85S 35°E
Dacca, . . . . .	69S 31°E	87S 45°E	93S 37°E	90S 9°E	60S 33°E
Berhampore, ..	63S 43°E	57S 38°E	74S 52°E	64S 23°E	75S 53°E
Monghyr, . . . .	43N 89°E	63N 86°E	61S 89°E	22S 75 E	63S 84°E
Patna, . . . . .	84N 7°W	92N 3°W	71N 6°E	72S 29°E	
Benares, . . . .	58N 5°W	37N 41°E	27 E	14N 48°W	56N 8°E
Gya, . . . . .	?	23S 84°E	42S 77°E	22S 1°E	71S 78°E
Hazaribaugh,	32S 27°W	40S 15°W	32S 18°E	32S 19°W	61S 42°E

To sum up the principal facts brought out in the foregoing discussion.

In the monsoon seasons both of 1868 and 1869, there was an area in or on the borders of Lower Bengal, in which the atmospheric pressure was persistently low, and which was partially or entirely encircled by a region of relatively high barometer. It originated with the general redistribution of barometric pressure at the beginning of the S. W. monsoon in April, and became intensified with the first fall of the rains in June. In 1868 it retained its initial position with a slight variation throughout the monsoon season, the depression being most intense in June and August, after which latter month it gradually decreased in intensity, but did not disappear till December. In 1869 it contracted or retreated northward and as far as can be judged did not entirely disappear, although its influence was diminished until quite the end of the monsoon. Its position was different in the two years, being in the former in the N. W. corner of the Bay of Bengal, in the latter in the hilly country to the west of the delta.

It influenced the vapour bearing winds from the south by deflecting them towards it, and necessarily by determining an ascending current, it produced an excessive rainfall to the north of its position, the maximum fall being at from 50 to 150 miles from the place at which the barometer was lowest. Finally it impeded the passage of the vapour-bearing winds to the N. W. Provinces, and thus deprived that region of a great part of its usual annual supply.









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