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GOVERNMENT OF INDIA.
REVENUE AND AGRICULTURAL DEPARTMENT.

Memorandum on the snowfall in the mountain districts bordering Northern India and the abnormal features of the weather in India during the past five months, with a forecast of the probable character of the south-west monsoon rains of 1891. 1891

The present memorandum is drawn up in accordance with the practice of the past eight years, and includes, *first*, a statement of the information received from certain district officers relating to the snowfall of the past winter or cold weather in the Afghan mountains and the Himalayan area; *second*, a statement of the chief peculiarities or abnormal features of the meteorology of India during the past five months; and, *third*, a forecast of the probable character of the approaching south-west monsoon rains based on this information.

The following remarks extracted from the report of the Famine Commission explain succinctly and clearly one of the duties of the Meteorological Department, which it is attempted to carry out in this memorandum:

"Within the last few years a very satisfactory system of meteorological observation has been established all over British India, and in our opinion it is of primary importance that it shall be maintained in complete efficiency, and shall so far be strengthened and improved as to ensure the early and punctual supply of information to the Executive Governments and to the officials in all departments concerned with the agriculture of the country or the preparations required to meet famines as to the actual progress of the periodical seasons of rain in all parts of the Provinces for which those Governments or officers are respectively responsible. *So far as it may become possible with the advance of knowledge to form a forecast of the future, such aids should be made use of, though with due caution.*"

The present forecast is based in part on the snowfall information and on the abnormal features of the weather during the past five months, and in part on a comparison with the meteorology of the previous 25 years, so far as its history is available. The forecast has hence been drawn up carefully after a consideration of all the available information, but it should, to use the words of the Famine Commission report, "*be used with due caution.*"

It appears to be desirable to repeat the brief preliminary statement given last year in order to explain the theory or the principles upon which the forecast is partly based.

At least five-sixths of the rainfall of India occurs during the south-west monsoon, and is brought up by humid winds in the lower atmosphere from the Arabian Sea and Bay of Bengal. The air currents advancing across these two seas into India during this period form the two branches of the monsoon lower air motion or circulation. The current from the Bay of Bengal prevails exclusively in Burma, Bengal and Assam, and the greater portion of Behar, Chutia Nagpur, and the North-Western Provinces. The current from the Arabian Sea obtains wholly in the Peninsula (*i.e.*, the Deccan, Bombay, Madras, the Central Provinces, and the greater part of Central India and Rajputana). During nearly the whole of the south-west monsoon there is a well defined belt of country separating the two areas in which one or other of the currents prevails exclusively, which is characterized by very variable winds and by lower pressure than occurs either to the north or south. This belt is hence meteorologically a trough of low pressure, and usually stretches in a curved line from Orissa to Sind or the South-West Punjab.

It is a feature of great importance, as there is a marked tendency for any cyclonic storms that advance from the Bay in the months of June, July, August, and September to run along it and discharge cyclonic rainfall. Its position varies to some extent from year to year, and apparently depends, in part at least, upon the relative strengths of the two currents. Its probable average position during the monsoon is hence one of the factors that has to be taken into consideration in determining the probable distribution of the monsoon rains.

The south-west monsoon winds are undoubtedly the continuation of the south-east trade winds of the Indian Ocean. During the cold and hot weather months the trade winds usually extend only as far north as the neighbourhood of the Equator. Usually in the last week of May or the first week of June a rapid change occurs, due to the advance of southerly winds (with more or less of westing) from the Equator northwards, which produces an almost complete reversal of the weather conditions in India. The primary cause of this extension of the winds and air movement of the Indian Ocean northward across the Bay of Bengal and Arabian Sea and the land masses of the Indian and Burmese peninsulas is undoubtedly the rapid heating of Central and Northern India in April and May. This cause, however, acts indirectly, and not directly. The air movement does not commence over and near the hot area and extend outwards; nor does it increase gradually in intensity with the increase of temperature during the hot weather months. It is only after hot weather conditions have prevailed for a considerable period in India that the movement commences. It also begins far to the south in the Arabian Sea and Bay of Bengal as a rush of strong winds which advance more or less rapidly northward and eastward according to circumstances.

Previously to the setting in of the south-west monsoon proper very dry hot weather, with cloudless skies, usually much obscured by dust, prevails. The advent of the monsoon gives damp, cloudy weather, with much rain and a moderate and nearly constant temperature. On the West Coast the change is always more or less sudden, and frequently accompanied with very severe thunderstorms, and is usually known as the "burst or setting in of the monsoon." On the Bengal Coast the change is less marked, as the weather is always more or less showery in Bengal and Assam in May.

The motion of the south-west monsoon current is hence a horizontal movement from the Indian Ocean across the Arabian Sea and Bay of Bengal into India and Burma. This vast mass of humid air is impelled northwards by forces due to differences of pressure over the whole tropical region of Southern Asia and the Indian Ocean. It is evident that if there are differences from year to year in the strength of the south-east trades or in the pressure gradients over the sea area to the south of India and Burma due to causes in operation there, they will affect the general strength of the monsoon.

Whether there are such differences from year to year has not been proved in the absence of accurate observations over the sea area, but there are various reasons for believing that they do occur. If this be the case, they form one of the factors which determine the general strength of the monsoon currents.

Again, the conditions in India and Burma before and at the time of the advance of the monsoon differ very largely from one year to another. In one year, for example, little rain may fall in the cold weather, and the hot weather may be prolonged and intense, or may be tempered by frequent series of thunderstorms and dust-storms. In other years excessive rain and snow may have fallen in Upper India and the adjacent mountains, and the cold weather may have been unusually prolonged, and the hot weather conditions necessary to initiate the monsoon may have been feebler than usual, or may have been chiefly exhibited in Burma, North-East India, or Central India. It is evident that these prevailing conditions will modify and determine to some extent at least the extension of the monsoon currents over India at the time of their advance. These conditions must give a certain set to the air currents. Also in virtue of well known laws of air motion or of fluid motion, the currents by their subsequent action and motion will tend during their existence to maintain the peculiarities set up by the conditions in existence at their commencement. The forecast in the final paragraphs is hence partly based on the important principle indicated above, *viz.*, that the meteorological conditions prevailing in India before and at the commencement of the monsoon mainly determine the character and extension of the current, and thus impress upon it features which are more or less permanent throughout its whole period of prevalence, and are largely influential in determining the accompanying rainfall, and may therefore be used as indications of the probable distribution of that rainfall.

It is, however, necessary to point out that such a forecast is a statement of probabilities and not of certainties, and that it is liable to error from the limitation

and uncertainty of part of the data on which it is based. The monsoon forecasts as at present issued necessarily leave out of consideration two important points on which the agricultural value of the monsoon rainfall largely depends, *viz.*:

- (1) The probability of the occurrence of a prolonged break in the rains in July or August;
- (2) The probability of the unusually early termination of the rains in Upper India or Bengal;

and are hence imperfect in every year to that extent.

To sum up: the chief features or conditions which appear to influence and determine the extension and general strength of the south-west monsoon current are as follows:

- 1st.—The amount and time of occurrence of the cold weather snowfall in the mountain districts adjacent to Northern India.
- 2nd.—The local peculiarities of the weather in India itself immediately antecedent to the advance of the monsoon currents across the coast of India into the interior, and which it is found are generally impressed upon it during the hot weather, and are frequently more or less persistent in character. These abnormal features are on the whole best estimated by means of the variations of pressure from its normal value in different parts of India.
- 3rd.—Local peculiarities in the Bay of Bengal and Arabian Sea, over which the monsoon currents pass before they reach India.

The first of these conditions or factors appears to be mainly influential in determining the northern limits of the monsoon rains, heavy and prolonged snowfall in the Western Himalayan area either preventing or delaying the extension of the monsoon current over Upper India during the rainy season. Heavy and untimely snowfall in April and May appears especially to exercise a very powerful influence in this way.

The second factor appears to determine those large local district or provincial variations of rainfall during the monsoon which are evidently due to persistent local conditions or peculiarities, and not to general causes influencing the whole of India more or less. As a recent example may be given the prolonged drought in Ganjam in 1888-89.

The third and last factor is almost certainly of equal importance with the preceding two, but it is that on which information is most difficult to obtain, and as least in amount and longest in being received. In fact, hitherto information respecting the weather conditions in the Arabian Sea or Bay of Bengal has rarely been received in time to be utilized in drawing up the annual forecasts.

Snowfall information.—The whole of the information referring to the snowfall of the past cold weather (up to the end of May) in the mountain districts bordering Northern India which has been received is given in the following paragraphs:

I.—AFGHAN MOUNTAIN DISTRICTS.

(a) HILLS WEST OF DERA ISMAIL KHAN.

The Deputy Commissioner, in a letter dated 25th April, thus describes the weather and snowfall of the past winter in the Suleiman range bordering the Dera Ismail Khan district: "Snow began to fall in the early part of the season, *i.e.*, about the end of November, and was unusually heavy. Towards the end of December the Nave Fizha, Sapreza, Bushta and Kaisargarh peaks of the Takht-i-Suleiman and the Pirghal range in the Mahsud country were well covered with snow, which continued to fall at intervals until the middle of March. In the lower ranges, such as Kashmir Kar, the snow disappeared in February. The total fall is said to have been between 5 and 6 feet in depth, and on some of the ranges the snow still remains unmelted. Rain fell in abundance, and the season was a severe one, with great cold. Snow fell on the sanitarium of Shekh-budin for the first time for many years, and the low Bhattani mountains of Ghabbar received some at the end of December."

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(b) MOUNTAINS WEST OF KOHAT.

The Deputy Commissioner has forwarded the following information received from the Assistant Commissioner, Thall Outpost, respecting the snowfall on the Sufed Koh and neighbouring mountains:

January.—There was heavy snow in the mountains near the Kohat frontier in January.

The following gives the approximate depth of snow that fell on the 15th, 16th and 17th, on which days heavy snow was received:

	JANUARY.			Total fall.
	15th.	16th.	17th.	
	Ft.	Ft.	Ft.	
Samana	3½	2½	3½	8½ feet.
Forghar	3	2	3	8 "
Hangu village	...	...	½	½ foot.

February.—There was an unusually heavy fall on the 1st and 2nd, on both of which days snow fell low down at Thall and Hangu. This fall was succeeded by rain in the plains and lower hills, which quickly melted away the snow.

The following is the approximate depth of the snowfall during the month:

Spinghar (Sufed Koh)	10 to 15 feet.
Dandoghar	2 " 3 "
Zawa mountain	3 " 4 "
Samana	2 " 3 "
Mastura	3 " 4 "

The depth of snow on the highest peaks of the Sufed Koh has not been ascertained, but is undoubtedly large.

The snowfall of the month was exceptionally heavy.

March.—Snow fell on the 10th and 17th on the Spinghar and other high mountains. The snowfall during the month is estimated as follows:

Spinghar	9 to 12 feet.
Dandoghar	½ foot.
Forghar	½ "

The snow melted away almost entirely by the end of the month from all except the higher peaks of the Sufed Koh, on which there was at the end of the month from 6 to 9 feet of snow still lying.

The reports for April and May have not yet been received, but it is probable no further snow has fallen.

(c) MOUNTAIN DISTRICTS WEST OF PESHAWAR.

The whole of the following information was sent by the Deputy Commissioner of Peshawar:

I.—KHYBER AND TIRAH HILLS.

January.—Heavy rain and snow fell on two occasions on these hills during the month. The first fall of snow was preceded by heavy and continuous rain, and amounted to 2½ feet in the Shinwari hills. On the Tirah hills the first fall measured 6 feet and the second 4½ feet. Also unprecedentedly heavy snow fell on the Cherat Range and the Khyber Pass hills, and the winter up to the end of the month was very severe and trying.

February.—Snow fell in the beginning of the month. The following give the estimated amounts on different hills:

Khyber hills	1 foot.
Lakka hills	3 feet.
Forsapper	2 "
Tirah	3 "
Bazar Valley	½ to 1 foot.

The snowfall of the 4th on the higher parts of the Cherat Range was 4 feet, and lower down about 2½ feet. The greater part of this melted away during the next fortnight.

The following statement gives the snowfall for the months of January and March in the hills to the north and west of the Yusafzai division of the Peshawar District (the statement for February has not been received):

Name of Hill.	APPROXIMATE DEPTH OF SNOWFALL IN					
	January.		February.		March.	
	Ft.	in.	Ft.	in.	Ft.	in.
Maha Ban hills	15	6	...	...	1	6
Bagooch	4	...	...	...	1	...
Ban	2	6	...	...	...	Nil
Tanga	1	...	...	...	...	Nil
Nal	1	6	...	...	...	Nil
Sakra	4	6	...	...	...	Nil
China Tangi	1	...	...	...	...	Nil

No later accounts have been received of snowfall in these districts, and it is probable that no snow has fallen during the past two months.

II.—THE HIMALAYAS.

I.—THE PUNJAB AND KASHMIR HIMALAYAS.

(a) *Ladakh.*—The Reverend Mr. Redslob, Superintendent of the Observatory at Leh, writing on the 3rd May, describes the weather in Ladakh during the past winter in the following terms: "The amount of snow which fell at any time during the winter was not large, never exceeding ½ foot. We had, however, far more frequent falls than usual, and the whole valley was white with snow for over a fortnight, which is a very rare thing with us. On the adjacent higher hills heavy snow has fallen. Some people tried to cross the Karakorum pass in February, but found so much snow lying (over 9 feet) that they had to return. The snow is unusually low down on the neighbouring hills, and the cold at night is still severe. The villagers in the Upper Sutlej Valley near the Chinese frontier were not able to begin ploughing until nearly the end of March, over a month after the usual time."

(b) *Lahoul.*—The Reverend Mr. Heyde, Superintendent of the Observatory at Kailong, sends full information of the weather in Lahoul. In his first letter, dated 14th March, he writes: "The winter set in unusually early at the end of November, and has been so far a very severe one. The chief characteristic of the present winter was the strong and almost storm-like winds which accompanied the heavier falls of snow. This was especially the case on the 25th December, 16th and 17th of January, and 1st, 2nd, 26th, and 27th of February. Clear sunny days were very rare, and hence the fallen snow has not melted away in the intervals between the storms, as is usually the case, and there is at present upwards of 4 feet of snow lying in the valley."

The letter was written on the 14th March in the hope that the passes into Kulu would open at the usual time. It was not possible to send it off until the

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second week of April, and Mr. Heyde adds in a postscript that 4 feet more of snow had fallen during that interval.

In his second letter of the 23rd May he states that the passes by which communication is kept open with Kulu had been twice closed after the despatch of the previous letter. They are usually open for the season from the middle of March, but this year they were passable for the first time in the second week of April. They were closed again from the 21st of April to the 8th of May in consequence of heavy snowfall, and again from the 10th to the 20th of May, on which day the second dak of this season was sent across. Snow, however, began to fall again on the 21st, and fell steadily for over forty-eight hours. This fall has probably added at least 5 feet of snow to the past winter's accumulation on the higher mountains.

The ploughing of the fields, which was begun a fortnight later than usual, has been interrupted by this heavy fall, and it is feared the season will now be too short to permit of the ripening of the crops.

(c) *Murree*.—The following statement of the snowfall at Murree and on the hills adjacent to Kahuta is based on information supplied by the Deputy Commissioner of the Rawal Pindi District:

District.	APPROXIMATE DEPTH OF SNOWFALL IN			TOTAL FALL FROM JANUARY TO MARCH				
	January 1891.	February 1891.	March 1891.	1891.	1890.	1889.	1888.	1887.
	ft. in.	ft. in.	ft. in.	ft.	ft.	ft.	ft.	ft.
Murree	13 8	12 6	2 10	29	3½	7½	6½	4½
Kahuta	2 9	2 6	Nil	5½	½	4½	6	2½

(d) *Kulu*.—The Assistant Commissioner, Kulu, has sent very full and interesting information of the weather during the past winter in his district. The following gives all the more important facts:

January.—The weather was very cold during the month. From the 15th to the end of the month the sky was more or less clouded. A heavy fall of snow on the 16th and 17th completely closed all the passes. They had also been previously closed by a heavy fall of snow on the 20th and 21st of December, but before the storm of the 16th and 17th some people crossed the Rotang pass, though with some difficulty.

February.—The weather was very cold and much damper than usual, and the sky was more or less clouded throughout the whole month. Snow or rain fell at frequent intervals, and the passes were closed throughout the whole month.

March.—The weather was cold, damp, and cloudy throughout the month. Frequent snow or rain fell, and in some parts of the district hailstorms occurred, but did no serious damage. The passes were closed throughout the month.

April.—The snow melted steadily throughout the month, but there were falls of snow on the higher elevations on the 7th, 8th, 11th, 12th, 15th, 22nd, and 28th. On the 28th snow fell down to 10,000 feet. The Hamta pass is still closed. The Rotang pass is practically closed, although several natives of Lahoul crossed it at the end of the month, but with much difficulty. These facts and the data given in the following table show that there was much more snow lying on the mountains at the end of April 1891 than there has ever been at the same time of year since the systematic reports of snowfall were commenced (in 1883). The winter is, according to popular opinion, the latest and most severe that has been experienced for many years.

Kulu District.

Name of Pass.	Height.	APPROXIMATE DEPTH OF SNOW ON					DEPTH OF SNOW ON APRIL 25TH.			
		January 25th.	February 25th.	March 25th.	April 25th.	May 25th.	1891.	1890.	1889.	1888.
		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Rotang	13,000	15	19	13	10	9	10	6	15½	4
Hamta	14,500	18	16	13	?	12	?	8	13	3
Chandar Khani	?	14	15	14	10	8	10	3	7	5
Barsai	?	11	9	9	5	5	5	3	1½	1
Bujadhar	?	13½	13	10	4	2	4	3½	1	2
Lori Achri	?	9	10	8	3	Nil	3	2	3	3
Pushtari	?	7	8	9	3	Nil	3	½	1	Nil
Bhubhu	10,000	9	9	9	5	Nil	5	1½	2	4
Majang	?	5	6	5	Nil	Nil	Nil	½	Nil	Nil

Plach District.

Name of Pass.	Height.	APPROXIMATE DEPTH OF SNOW ON					DEPTH OF SNOW ON APRIL 25TH.			
		January 25th.	February 25th.	March 25th.	April 25th.	May 25th.	1891.	1890.	1889.	1888.
		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Chul	?	10	13	9½	4	Nil	4	2	1	1
Sirikand	15,000	25	35	39	36	32	36	17	55	14
Maghian	?	8	11	11	4	1	4	2	2	1
Tikkar	?	7½	11	9	4	1	...	...	...	...
Dundku	?	11	15	15	7	2	7	4	2	3½
Ramgarh	?	2	1	½	?	...	...	...	...	...
Nunu	?	7	7	7	2	Nil	2	Nil	Nil	Nil
Jalori	10,500	7	10	7	4	1	4	1	1	Nil
Raghopur	?	8	11	8	5	2	5	2	1	Nil
Himri	?	6	11	8	4	1	4	1	1	Nil
Sakiran	?	10	12	13	5	Nil	5	1	?	?
Suphakun	?	13	17	23	12	4	12	5	1	5
Gargarasan	17,000	16	21	28	12	4	12	8	2	7
Bashleo	11,000	8	12	9	4	1	4	2	2	1
Plach	?	10	14	11	7	2	7	6	?	2
Tirath	?	10	14	15	10	2	10	7	11	7

Upper Sutlej Valley.—The Deputy Conservator of Forests, Bushahir Division, wrote on the 16th May that the valley of the Buspa was blocked by snow, and that it was not possible to launch any timber at present, and hence that a much smaller quantity of timber will be sent down this year than usual.

II.—THE NORTH-WESTERN PROVINCES HIMALAYAS.

Garhwal.—The Senior Assistant Commissioner, Garhwal, states that from the information obtained from hill men, it appears that the snowfall during the past

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winter in the northern parts of Garhwal is at least four times the usual amount. Painkhanda is the most northern pargana of the district, and from Painkhanda the Niti and Manā passes lead into Tibet. These passes have been closed since the 16th September, and not a week has passed without snow falling on the higher mountains. It is not expected that these passes will be open before August next.

No snowfall reports have been received from the district officers of Kumaon in the North-Western Provinces and Darjeeling in Bengal.

III.—ASSAM HIMALAYAS.

The Assistant Political Officer, Sadiya, states that the snowfall in the neighbouring Himalayas was later than usual, but was about the same in amount as in the preceding year.

The Extra Assistant Commissioner, Darrang District, Tezpur, states that, as far as he can ascertain from the various hill tribes to the north of his district, there was less snowfall this year than in the previous year. This is further confirmed by the Chardner Bhutia Sub-Rajas, who said unusually heavy showers of rain were received, and there was in consequence a good harvest, but that there was less snow than usual.

The Subdivisional Officer of Koriapara also states that the snowfall to the north of his district was somewhat less than usual.

The Deputy Commissioner of Kamrup states that there were so few Bhutias in Durranga this year that he did not make much enquiry about the snowfall. The men whom he asked said that there had been a good deal of snow, and; so far as he could understand, above the average.

Summary of the snowfall information.—The following gives the chief facts respecting the snowfall of the past winter in Central Asia and the Himalayan and Afghan mountain districts:

(a) The past winter has been unusually severe and prolonged over nearly the whole of the Temperate Zone, extending across from the United States through Central Europe into Central Asia. Statements have been published to the effect that over a large part of Central Asia at least, as well as over the greater part of England, France, Germany, Switzerland, and Central Russia, the season has been an exceptionally severe one, and the snowfall everywhere much above the average.

(b) The snowfall in the mountain regions of Baluchistan and Afghanistan was very much above the average. The winter began early in November and continued unusually late, and snow fell at frequent intervals and in large amounts during the whole of that period.

(c) The winter has been exceptionally severe and prolonged in the Western Himalayas (bordering the Punjab and North-Western Provinces). The first considerable snowfall occurred in November, and snow has since fallen more or less steadily throughout the whole season up to nearly the end of May. The amount received in the lower ranges was generally (except in the North Punjab) not much greater than usual, but on the higher interior ranges it has been very excessive, and over the greater part of the area at least heavier than the snowfall of 1885, and also than that of 1877 and of 1878. So far as it can be judged from the reports, it appears to be almost certain that an average fall of 40 feet, if not considerably more, must have occurred over all the higher ranges from Murree eastwards to Garhwal, and perhaps to Central Nepal. This is equivalent to a fall of between 40 and 50 inches of rain over an area 800 miles in length and upwards of 50 miles in breadth. It is hence evident that there must be at the present time a very great accumulation of snow in the mountain districts to the north and north-west of Upper India. In this respect the conditions of the present year differ entirely from those of the previous three years, in every one of which the snowfall was below the average, but resemble more or less closely those of the years 1885, 1878, 1877, and perhaps 1868.

(d) The snowfall in the Eastern Himalayas was over a considerable part of it certainly less than usual, and over the whole area was either normal or in

defect. As the fall of last year was also below the normal in that area, it is certain the snow accumulation in the Eastern Himalayas is at present decreasing in amount, and is below the average. Hence the conditions with respect to the amount and accumulation of snow in the Eastern and Western Himalayas are this year opposite in character.

Abnormal features of the weather of the past six months.—The south-west monsoon currents of last year were unusually vigorous, and gave heavy rain over the greater part of India. The rains were especially heavy along the foot of the hills from Dhubri to Sialkot. The currents withdrew from Upper India unusually early in September.

The pressure was at that time and throughout October locally in excess in the Deccan and the Bombay Coast districts. Weather was very unsettled in the Bay in October, and three cyclonic storms formed in it during the month, one of which passed into Bengal and the other two into Madras. Although the north-east monsoon did not set in strongly or steadily, the Carnatic, Mysore, and Hyderabad received moderate rain in that month from these storms. Madras continued to receive moderate rain during the first fortnight of November, when a remarkable change occurred in the weather. Weather cleared and rain ceased in Southern India, and it became disturbed with more or less frequent rain in Baluchistan and Afghanistan and North-Western India, more especially the North and West Punjab, and unusually early and heavy snow fell on the higher elevations. The Carnatic received an average of only 5.15 inches, during the month of November (its normal amount being 10 inches). The drought in Southern India continued during the whole of December. The Carnatic, for example, had an average fall during that month of only .85 inch, its normal fall being 4.1 inches. Disturbed weather continued in North-Western India throughout December, and unusually heavy snow fell on the Western Himalayas and the Afghan mountains, and heavy rain in the Punjab. Thus the West Punjab received an average of 3.6 inches, its normal average in December being only .3 inch. The following gives a somewhat fuller account of the most important features of the weather in India from January to May 1891:

January.—The weather was unusually disturbed in Upper India. Three disturbances appeared in or passed across North-Western India, and gave heavy rain in Northern India and much snow in the mountain districts to the north and north-west. The Punjab, the North-West Provinces, and Behar received from 25 to 200 per cent. in excess of the normal fall. The mean pressure of the whole of India was .005 inch above the normal. Relatively to the general state pressure was locally in defect in Burma and North-Eastern India and in excess in North-Western India. The excess was greatest in the Indus Valley and the deficiency greatest in Assam and Burma. The mean temperature of the month was below the normal in North-Western and Central India, and above it in North-Eastern India and Burma. The contrast between the meteorological conditions of the western and eastern halves of Northern India and Burma was hence even at this stage very clearly marked.

February.—The weather in February was on the whole somewhat less disturbed than in January. Two large disturbances, the first extending over the 1st to the 5th, and the second from the 19th to the 22nd, gave heavy rain to the plains of Northern India and very heavy snow in the North-Western Himalayas. In the interval between these two disturbances there was a period of unsettled weather in Madras and Southern India, during which numerous thunderstorms occurred, which gave rain in many districts where it was urgently required after the prolonged drought of December and January.

The variations of the meteorological conditions from the normal were similar in character, but generally larger in amount, than the corresponding variations of the month of January. Thus the mean pressure of the whole of India for the month was .022 inch in excess. Pressure was locally in excess in North-Western and Central India, and was in defect in Assam, Burma, and Southern India. The temperature of the month was below the normal over the whole of Northern and Central India. The deficiency ranged from 3° to 5° over the greater part of the North-West Provinces and the Punjab, and was absolutely greatest in the hills at Murree (6½°) and in the plains at Peshawar (5½°). It was,

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on the other hand, in moderate excess in Assam, Burma, and the Peninsula to the south of Lat. 18° N. The deficiency in the temperature in Northern India was chiefly due to unusually low day temperature.

March.—The conditions were even more abnormal than in the preceding two months. A depression appeared in North-West India on the 10th and gave much rain in the Punjab. It was immediately after followed by a very remarkable disturbance in Bengal, Behar, and the North-West Provinces, which gave a very unusual and general burst of rain on the 12th, 13th, and 14th. During this period an average amount of about 3 inches fell in Behar and West Bengal, in which the average rainfall of the whole month is less than half an inch.

The mean pressure of the whole of India for the month was $0.15''$ above the normal. Relatively to this general condition pressure was in excess in Northern India. The excess was greatest in the Indus Valley at Jacobabad, where it was $0.5''$. Pressure was locally in defect in Assam, Burma, and the Peninsula. The deficiency exceeded $0.2''$ in Burma and the Peninsula to the south of Lat. 18° . It was absolutely greatest in Lower Pegu and South India, and at several stations amounted to nearly $0.4''$. The month was remarkably cool over the whole of Northern and Central India. The mean temperature in Northern India was below the normal by amounts varying from 3° in East Bengal to $8\frac{1}{2}^{\circ}$ at Lahore. It was in slight excess in Burma and Southern India.

April was a month of frequent slight disturbance. During the first three weeks of the month the weather was very dry in Burma, Bengal, and Assam, whilst frequent thunderstorms or duststorms occurred in Upper India and South Madras. From the 22nd to the end of the month rain, chiefly as thunder-showers, fell daily in Bengal and Assam. The 27th and 28th were also disturbed periods in Upper India, with duststorms in the plains and rain or snow on the hills. Temperature increased somewhat more rapidly than usual, and was below the normal by smaller amounts than in the preceding month. The deficiency was only in the North and East Punjab, and was greatest at Lahore (4.7°). On the other hand, it was nearly 3° above the normal in East and Central Burma. The mean pressure of the month for the whole of India was $0.28''$ above the normal. Pressure was locally in excess over the whole of Northern and Central India. The positive anomalies were largest in the West Punjab and Baluchistan at Peshawar ($+0.40''$) and Quetta ($+0.41''$). Pressure was in relative defect in Southern India, Burma, and Assam. The deficiency was very large in Assam at Sibsagar ($-0.65''$) and Dhubri ($-0.21''$). A remarkable and important feature of the meteorology of the month was the predominance of north-westerly winds along the West Coast of India as far south as Cochin, and also in Rajputana, Central India, and Berar. The Punjab, Bengal, and Southern India received heavier rain than usual. Elsewhere the rainfall was very small in amount and unimportant.

May.—The weather was slightly disturbed throughout the whole month. From the 1st to the 16th frequent thunderstorms occurred in Bengal. On the 7th, 8th, 12th, and 13th duststorms and thunderstorms visited Upper India and the hill stations. Heavy rain commenced to fall at Colombo on the 16th, and shortly afterwards a depression formed in the south-west of the Bay, which drifted very slowly northwards. This depression gave moderate rain to Southern India on the 21st and 22nd, and afterwards chiefly to Burma, Assam, and Bengal. This gave a preliminary burst of the monsoon up the Bay of Bengal, but at the end of the month rain was very light at Colombo, and there were no indications of the immediate advance of the monsoon up the Malabar and Bombay Coasts.

The variation of the mean pressure of India from the normal was $+0.15''$. Pressure was locally in excess in North-Western and Central India, the excess being greatest in the Indus Valley at Peshawar ($+0.52''$), Mooltan ($+0.41''$), and Jacobabad ($+0.46''$), and at Quetta ($+0.49''$). Pressure was relatively in defect in Assam, Burma, and Southern India. The negative anomalies were greatest at Calicut ($-0.40''$), Madura ($-0.30''$), and Sibsagar ($-0.31''$). The mean temperature of the month was below the normal in Northern and Central India. The deficiency was greatest in the Punjab at the following stations:—Peshawar (-3.2°), Lahore (-3.3°), and Rawalpindi (-3.7°). It was, on the

other hand, excessive in Burma and the Peninsula. The following gives the largest variations in those two areas:

Burma	...	Rangoon	...	$+5.6^{\circ}$ (?)
		Moulmein	...	$+4.4^{\circ}$
		Toungbo	...	$+4.1^{\circ}$
Southern India	...	Salem	...	$+3.3^{\circ}$
		Bangalore	...	$+2.5^{\circ}$

The extraordinary character of the rainfall during the past seven months is shown by the following data:

District.	Station.	Actual from 1st November to 31st May 1891.	Average from 1st November to 31st May.	Ratio of actual to average.
Punjab Hills	Quetta	19.38	7.56	2.5
	Murree	51.51	17.52	2.9
	Simla	19.42	15.15	1.3
Punjab Plains	Peshawar	17.99	7.86	2.4
	Sialkot	16.18	6.99	2.3
	Lahore	10.47	4.24	2.4
North-West Provinces Hills	Dera Ismail Khan	9.58	2.79	3.4
	Mussoorie	15.96	13.64	1.2
	Ranikhet	13.94	11.56	1.2
North-West Provinces Plains	Roorkee	6.00	5.72	1.1
	Lucknow	8.59	2.95	2.8
	Allahabad	3.47	2.32	1.5
Bengal Hills	Gorakhpur	6.20	3.32	1.9
	Darjeeling	22.58	17.52	1.3
	Patna	7.22	4.10	1.7
Bengal and Assam Plains	Purneah	15.05	7.54	2.0
	Dhubri	24.53	22.51	1.1
	Calcutta	9.61	11.66	.8
	Dacca	28.91	19.35	1.5
	Sibsagar	30.59	29.71	1.1

This return indicates that the precipitation during the past winter and spring months has been excessive over the whole of Northern India. It was most excessive in Baluchistan and the Punjab, where from two to three times the normal amount of the season fell. The excess relatively to the normal decreased eastwards, and in Assam the rainfall was very slightly in excess, and this was chiefly due to the rainfall of the months of April and May. The data for Quetta and Murree support very strongly the statement of the Assistant Commissioner of Garhwal that in the northern portion of his district four times the usual amount of snow has fallen. Considering the whole of the evidence, it is almost certain that over the Afghan mountains and the western half of the Himalayas the past winter snowfall has been very largely in excess, and probably at least from three to five times the normal amount has been received.

The preceding remarks show that the following abnormal features have been remarkably persistent from January to the end of May:

1st.—General excess of pressure over the Indian area, viz.,—

Excess in January	+ '005"
" February	+ '022"
" March	+ '015
" April	+ '028"
" May	+ '015"

The excess was hence not very large, but was a permanent feature throughout the whole period.

2nd.—Local excess of pressure relative to the general condition during the whole period in Northern India (excepting Bengal and Assam) and Central India, greatest in amount in the Indus Valley and Baluchistan, and decreasing eastwards and southwards. This excess has not only been a permanent feature, but has steadily increased in amount from the beginning of January up to the end of May. One example will suffice:

	January.	February.	March.	April.	May.
Peshawar ...	+ '024	+ '016	+ '038	+ '040	+ '052

3rd.—Local deficiency of pressure in North-Eastern India, Burma, and the Peninsula (south of Lat. 18° N.). This deficiency in April and May was greatest and most marked in Assam and Southern India, and was as persistent a feature as the excessive pressure in North-Western India.

4th.—The temperature conditions have been throughout as marked as the pressure conditions. Temperature has been steadily below the average in Northern and Central India, and above it in Burma and the Peninsula. The deficiency in Northern India increased until the month of March, in which month it was 6° in defect over the greater part of North-Western India. It has decreased throughout April and May, and at the end of the latter month temperature was slightly above the average in North-Western India and increasing rapidly. The excessive temperature was most marked in Burma and increased until May, when the mean of the month was upwards of 4° above the normal over the greater part of that province.

5th.—South-easterly winds have been unusually prevalent in Bengal and Behar during the months of April and May, and north-westerly and northerly winds on the West Coast of India as far south as Cochin. The unusual prevalence of north-westerly winds on the Bombay Coast in the month of May was one of the features of the weather in 1876, 1883, and 1885, in which years the monsoon was greatly retarded on that coast.

All these abnormal features are satisfactorily explained by the heavy snowfall of the winter in the Himalayan and Afghan areas, and hence further confirm the conclusions respecting the character of the snowfall based on the snowfall reports.

Comparison with previous years.

During the past twenty-five years the snowfall in the Himalayas was most excessive in the years 1868, 1877, 1878, 1883, and 1885. The following gives a very brief summary of the chief features of the meteorology of these years for comparison with the present year:

1868.—The information for that year is very scanty. Heavy snow is stated to have fallen in the Punjab Himalayas. Pressure was throughout the pre-monsoon period locally in excess in North-Western India, and in defect in Burma, Assam, and Orissa. So far as can be judged from the rainfall data, the snowfall in the hills and the rain on the plains were excessive in the months of February, March, and April. May was on the whole a dry month. The whole pre-monsoon

period was somewhat drier than usual in North-Eastern India. Bengal and Burma received very heavy rain during the monsoon. The rains were retarded on the West Coast, and were very deficient in Rajputana and the adjacent portions of the Punjab, the North-West Provinces, and Central India. The drought caused an intense famine in Rajputana in 1869.

1877.—There was heavy snowfall during the months of January, February, March, and April in the Western Himalayas. It appears to have been very excessive only in the Garhwal and Kumaon Himalayas. Pressure was steadily in excess at this period in India. It was during the pre-monsoon period locally in defect in Bombay and the Deccan, and was locally in excess in Northern and Central India, more especially the Punjab, Rajputana, and Central India. Temperature was very considerably below the normal in North-Western India from February to May, the deficiency being very large in April (when it averaged 6° in the Punjab). The monsoon rains were very late in the Peninsula, but were on the whole abundant, and brought the Madras famine of 1876-77 to a close. They were very largely deficient in the North-West Provinces, and considerably in defect in the Punjab, Rajputana, Behar, and the Central Provinces. There was, on the other hand, a large excess in Bengal and Burma.

1878.—Very heavy snow fell in the Kashmir and Punjab Himalayas in January, February, April, and May, and there was an enormous accumulation of snow in the Kashmir Himalayas at the end of May. Temperature in North-Western India was above the normal in February and March, and was slightly below it in April, and very largely below in May (4° to 7° in the Punjab). The chief feature of the cold weather was undoubtedly the excessive snowfall in Kashmir in the latter part of May, which occurred during a period of very stormy weather generally in Upper India. Pressure was steadily in defect in the Peninsula, Central India, Rajputana, and Sind during the pre-monsoon period, the deficiency being greatest on the West Coast, and was considerably in excess locally in Bengal and Assam.

The rains were much later than usual on the Bombay Coast. The rainfall was generally above the average in Northern India (except the southern districts of the North-West Provinces and Bundelkand) and the Peninsula, but was considerably in defect in Burma. The rains terminated slightly earlier than usual in North-Western India.

1883.—Very heavy snow fell in the Punjab and Kashmir in January, and again in the last week of May, but little in February, March, and April. Temperature was in excess in January, April, and May, and slightly in defect in January and March in Upper India. The pre-monsoon pressure variations were neither large nor persistent. The monsoon was considerably retarded on the West Coast, and did not set in strongly at Bombay until the 24th June.

The Peninsula received normal or abundant rain. There was a more or less general deficiency in Northern India, but the chief features in the rains were a long break in August and their early termination in Northern India in September. The North-West Provinces and Bengal were chiefly affected by this, and the autumn crops in Bengal suffered greatly from drought in October and November.

1885.—There was very heavy snow in the North-Western Himalayas in the months of January, February, April, and May. The whole cold weather season was, on the other hand, drier than usual in North-Eastern India.

Temperature was below the normal in Northern India in January, March, April, and May, the deficiency reaching its maximum in May, when it ranged from 6° to 11° in the Punjab. The pre-monsoon variations of pressure were very similar to those of the present year. Pressure was locally in excess in North-Western and Central India, the excess being greatest on the North-West Frontier, and was in defect in Assam, Burma, and the Peninsula.

The rains were greatly delayed on the Bombay Coast, and did not set in fully until the end of June. They were very deficient in North-Western India in June, July, and September, and were generally excessive in August. The rains were normal or in excess over the greater part of India, excepting the greater

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part of North-Western India, where, moreover, they commenced late and terminated early.

Probable character of the approaching south-west monsoon.—The combination of conditions which have obtained in India with remarkable persistency from the beginning of January to the present time are the results of prolonged—probably the heaviest and most prolonged and extensive—winter snowfall in the Western and Central Himalayan area and Afghan mountains that has occurred during the past twenty-five years at least. The snowfall commenced in November, and has continued more or less steadily from that date until nearly the end of May. It was almost certainly as excessive in the Himalayas of the North-West Provinces as in those of the Punjab and Kashmir, and also, relatively to the normal, even more excessive in the Afghan mountain districts; hence, perhaps, also in Central Asia. In several respects the meteorological conditions strongly resemble those of the pre-monsoon of 1885, and in others those of the pre-monsoon of 1868. They resemble to a less extent those of the pre-monsoon periods of 1877 and 1878. The only favourable feature of the snowfall is that it does not appear to have been very excessive in May, although probably above the normal.

The conditions are such as are almost invariably accompanied by a considerable delay in the progress of the monsoon current up the Bombay Coast, and into the interior of the North Deccan and Central India. They are also frequently accompanied by a weak Bombay current, and occasionally by the early withdrawal of that current from Upper India in the beginning of September.

The low pressure area in Assam and Burma will tend to draw the Bay of Bengal more to the eastward than usual. The relatively high pressure conditions in Upper India as well as the low pressure conditions in Bengal and Burma will tend to deflect the Bombay current in the same direction, and cause it to sweep more directly across the Peninsula than usual. The Bombay current will probably supplement the action of the Bay current to some extent in the North-West Provinces, Chutia Nagpur, and perhaps South Behar. Hence the conditions are such that the Bombay current will very probably be largely diverted from North-Western India, and that Rajputana, Guzerat, and the adjacent districts to the north and east will have dry north-westerly winds to an unusual extent during the monsoon.

The chief meteorological factors of the season are so strongly marked that the minor features will probably have less influence than usual.

So far as can be judged, the trough of low pressure will occupy its normal position from Orissa through the eastern districts of the Central Provinces. Its probable position in North-Western India is very doubtful, but will probably be more easterly than usual.

There has been for some time a small area of deficient pressure in the North-West Provinces extending from Allahabad to Lucknow. It is difficult to judge how far it will influence the distribution of the rains in the present year in Upper India, but it is an unfavourable feature so far as the East Punjab is concerned.

The following is a statement of the chief inferences respecting the probable character of the monsoon rains of the present year drawn from the *known* antecedent conditions:

- (1) Snowfall conditions on the Western Himalayas and Afghan mountains (and probably over a large portion of Central Asia) and the pressure conditions in India are very unfavourable to the establishment of a strong and early monsoon on the Bombay Coast. It is very probable that the monsoon will not be established in full strength on the Bombay Coast before the third or fourth week in June, and it is probable that it will be below its average strength, and may be withdrawn from Upper India earlier than usual in September.
- (2) The snowfall conditions in the Eastern Himalayas and the pressure conditions in North-Eastern India and Burma are favourable to the advance of a moderately strong or strong monsoon in the Bay of Bengal earlier than usual, and to its establishment in Burma and Bengal before or about its normal period.

(3) Pressure and other conditions are very favourable in Burma and North-Eastern India (Bengal and Assam), and it is probable that these Provinces will obtain normal or abundant rain (more or less in excess of the normal).

(4) Conditions are slightly less favourable in Behar and the eastern districts of the North-West Provinces, but it is probable they will obtain about their normal rainfall. The local depression in the North-West Provinces may, if it intensifies (which, however, does not appear, so far as can be judged from the other conditions, to be probable), determine heavy local rain to the central and eastern districts of the North-West Provinces.

(5) Pressure and other conditions are very unfavourable for Rajputana, and also to a somewhat less extent in Guzerat, the southern districts of the Punjab, and the western districts of the North-West Provinces. It is probable the rainfall will be more or less deficient over the whole of that area, and possible that the deficiency may be large and serious. If the Bombay current be strong (in consequence of at present unknown conditions in the Arabian Sea area), these Provinces may receive moderate rain throughout the monsoon. In the East Punjab rainfall will probably be normal or slightly deficient, but may be unfavourably distributed in time, commencing late and terminating early.

(6) Conditions are partly favourable and partly unfavourable in North Bombay and Berar, and the amount of the rainfall in these areas will depend chiefly on the strength of the Bombay current as determined by conditions in the Arabian Sea. The rainfall is on the whole more likely to be slightly deficient than to be up to its normal amount.

(7) Taking into consideration the probable position of the trough of low pressure and the other known conditions, the rainfall in the Central Provinces will probably be fairly normal in character, any tendency to excess being most probable in the eastern districts.

(8) In Southern India the pressure conditions are favourable for heavy rain on the Malabar Coast. There may probably be some slight delay in the establishment of the monsoon on that coast, but the Malabar district and Southern India generally are likely to receive favourable rain during the monsoon.

It should be noted, as was the case last year, that one of the important factors, namely, the pressure conditions in the Arabian Sea, is again of unusual importance, and hence that the inferences stated above, more especially so far as they relate to North-Western India, are uncertain to that extent, and that this element of doubt should be carefully kept in view in judging the probabilities.

It will thus be seen that the conditions are most unfavourable for Rajputana and the districts adjacent to it, including Guzerat, South Punjab, the western districts of the North-West Provinces, and some portions of Central India. The chances that the rains in that area will be more or less deficient are at least 5 to 1, and the chances that they will be largely deficient, at least 2 to 1.

P.S.—The two following interesting statements were received after the previous memorandum was sent to Press. The first, giving an account of the weather in Kulu during the month of May, was sent by the Assistant Commissioner, Kulu. The second is a valuable statement of the snow accumulation in the Upper Sutlej and adjacent valleys at the end of May forwarded by the Deputy Conservator of Forests, Bushahir Division:

Kulu.—The quantity of snow on the mountains has been considerably reduced during the month of May, although the thunderstorms which characterize that month in Kulu have been of more frequent occurrence than usual, and have been attended with falls of snow down to an elevation of 10,000 feet. The Hamta pass Rotang pass has been open for foot traffic during the month. The Hamta pass still continues closed—the first time for many years that it has not been open before the beginning of June.

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Upper Sutlej Valley.—The Deputy Conservator of Forests, Bushahir Division, writing on the 31st May from Sungri, says: "I have just returned from the Upper Sutlej Valley. None of the passes into Thibet, Spiti, Garhwal, or the Paber Valley are open yet, and there is an unusual quantity of snow in the slopes above 10,000 feet. On the north and north-east slopes the snow is 5 to 6 feet in depth at 10,000 feet, and it is said to be as much as 20 feet deep in the valleys below the Barendra, Rupin, Bakch, and Sholarung passes. In the Baspa Valley the torrent beds are full of snow, from 15 to 20 feet deep, and in the Burna Khud below the Barendra pass the snow extends down to 7,000 feet, and there is a snow bridge across the Baspa at that elevation. The villagers say that the snowfall has been the heaviest they remember. From the 3rd to the 10th of May snow fell every day as low down as 9,500 feet, and this has delayed the melting of the snow considerably."

SIMLA, 4th June, 1891.

JOHN ELIOT,

*Meteorological Reporter to the
Government of India.*

E. C. BUCK,

Secretary to the Government of India.

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P. W. DEPARTMENT.

Current No. 7255

From

The Govt. of India

ENCLOS.—

No.

Dated 4-6-91

Received 7-7-91

SUBJECT.

Memorandum on the snow-
-fall in the mountain districts
bordering W India & the ab-
-normal features of the weather
in India during the past five
months, with a forecast of the
probable character of the S W
monsoon rains of 1891 -
Forwards a - by the Meteorologi-
-cal Reports to the Govt -

DISPOSAL.

No. 18915 dated 9 July 1891

⑨

Recorded

S. B.

8.7.91

S. B.

S. B. 14/7