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PREDICTION OF DROUGHTS IN INDIA

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4.—THE PREDICTION OF DROUGHTS IN INDIA.

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The following gives an account of the method employed in India for the preparation of the seasonal forecasts issued by the India Meteorological Department, the chief object of which is to give warning of the probable occurrence of severe drought in any large area in India.

In northern India there are two distinct periods of rainfall of importance for agricultural operations. The first is the period of the southwest monsoon rains from June to October. They are heaviest in the coast districts and at the foot of the Himalayas, and are most intermittent and irregular in the more interior districts of northern India. The second period is that of the cold weather rains from December to March, when light to moderate showers are received during the passage of feeble cyclonic storms across northern India.

The chief causes of failure of crops in northern India are:

1st. Deficiency of rainfall, more especially in the southwest monsoon period.

2d. Early termination of the southwest monsoon rains.

Under these circumstances the great rice crop in the parts of northeastern India affected withers away and is a more or less complete failure. In northwestern India it prevents the cold weather crops being sown, except in low-lying or irrigated districts.

In southern India, the Deccan, and Burmah, the only period of regular rains of value for the crops is that of the southwest monsoon from May to November or December. In the Deccan and southern India it is moderate in May and June, light from July to September, and moderate to very heavy in October, November, and December.

In these districts the rains may fail more or less completely during a part or whole of the period. The most serious partial fail when the rainfall of the second maximum (October to Dece light and irregular.

Hence, in northern India the most serious droughts are due to the combination of a more or less complete failure of the southwest monsoon rains followed by a failure of the cold weather rains. In this case both crops, the *kharif* and *rabi*, fail.

In southern India failure of the crops and consequent famine is

due to a more or less serious and large failure of the rains of a complete southwest monsoon period. The intensity of the scarcity or famine consequent on the failure of the crops under either of these conditions depends largely upon the character of the previous seasons. If the preceding two or three seasons have been unsatisfactory, so that the accumulated food stocks have been depleted, the famine may be of the most intense character.

The preceding remarks have shown that the most important factor in determining the character of the crops is the rainfall of the southwest monsoon, and hence long period forecasts in India have been chiefly confined to the prevision of the southwest monsoon distribution of rainfall.

These forecasts are usually issued in the first week of June, and attempt to give a rough estimate of the general character of the rainfall of the next four months in the larger provinces of India, and more especially to indicate any area in which there is a strong probability the rainfall will be seriously below the normal, or to point out when there is a probability of unusual delay in the commencement of the rains or of their abnormally early termination in northern or central India.

Rainfall in Europe occurs chiefly during the passage of cyclonic storms, and hence is apparently fortuitous in its occurrence.

In India at least four-fifths of the rainfall occurs as a normal feature of the southwest monsoon circulation. The lower air currents of that circulation advance into India from the adjacent sea areas, determined by the regular periodic pressure and temperature changes in India and central Asia. The circulation is mainly maintained and continued by its internal energy, or rather by that of the energy set free on the condensation of the aqueous vapor brought up in it over India. It varies to some slight degree in intensity from year to year, and its extension also varies in different years, dependent upon the antecedent meteorological conditions.

It is this fact, that the rainfall of this period is due to the prevalence of a massive and steady current, and not to local cyclonic disturbances in a region of irregular winds, that makes it probable long prevision can be successfully attempted and carried out in India.

In order that the attempt to forecast the character and distribution of the monsoon rainfall from the meteorological conditions prevailing anterior to the advance of the rain giving southwest monsoon currents, it is essential that there should be uniform and direct relations between the former as results and the latter as conditions.

It is immaterial for the purposes of forecasting whether they are based upon experience or upon theory. It is most satisfactory, of course, that relations emperically obtained should be proved to be in strict accordance with a rational theory.

The following gives a statement of some of the more important uniformities or relations utilized in preparing the long period forecasts in India:

A most important feature is that the general character of the distribution of the rainfall during the southwest monsoon is fairly constant during the whole period, and hence that an area of largely deficient rainfall has usually deficient rainfall throughout the whole season. Similarly for excessive rainfall. The annual reports of the meteorology of India give numerous examples of the persistency of the seasonal characteristics throughout the whole monsoon period. It will suffice to give one example. The southwest monsoon of 1890 gave abundant rain to northern and central India and the north Deccan, and as usually happens when the humid currents are more largely determined to northern India than usual, the rainfall of the same season was in defect in Burmah and southern India. The following gives data:

Percentage variation of rainfall from normal.

District.	1890.				Total for period.
	June.	July.	Aug.	Sept.	
Areas of excessive rainfall:					
Orissa	+ 33	+ 10	+ 1	+ 16	+ 11
Assam and east Bengal	+ 28	+ 10	+ 13	− 35	+ 9
Lower Bengal	+ 22	+ 10	− 11	0	+ 13
Bihar	+ 66	+ 65	+ 31	− 10	+ 34
Northwestern Provinces and Oudh	+110	+ 45	− 8	+ 14	+ 28
Punjab	+ 33	+ 28	+ 35	− 73	+ 15
Central Provinces	− 13	+ 9	− 3	+ 24	nil.
Hyderabad	+ 43	+ 10	− 7	+ 15	+ 6
Konkan	+ 20	+ 27	+ 18	− 37	+ 12
Areas of decreased rainfall:					
Mysore	− 19	− 12	− 1	− 4	.....
Carnatic	− 15	− 2	− 27	− 49	.....
Arakan	− 19	+ 24	− 20	− 24	.....
Pegu	− 16	+ 10	− 10	− 21	.....
Tenasserim	− 6	− 9	− 27	0	.....
Upper Burmah	− 41	− 39	− 30	− 17	.....

Hence, the steady tendency to increased rainfall in the former areas was as strongly marked as the large deficiency in the latter areas throughout the whole season.

The above example is very interesting on one account, as it shows persistent opposite tendencies and variations in areas of which the meteorological relations to the monsoon currents are more or less opposed or inverse to each other.

The persistent variations in the distribution of the monsoon rainfall are related to persistent variations in the strength and extension and other characteristics of the great currents of the period. It will suffice to give one case. The monsoon rainfall was very largely in excess in Burmah in 1891. The following table gives the deflection of the mean winds at three representative stations in that area during each month of the season:

Westerly deflection, 1891.

Station.	June.	July.	Aug.	Sept.
	°	°	°	°
Port Blair	+ 25	+ 15	+ 18	+ 25
Diamond Island	+ 25	+ 8	+ 3	+ 29
Rangoon	+ 20	+ 28	+ 12	+ 36

The winds at these stations during the southwest monsoon are from directions between south and west, and increased westing ardently indicates a greater determination of the Bay monsoon current to Burmah and Tenasserim than usual.

Again, the monsoon currents were both stronger than usual in 1892 during the period July to September. The following data will show that the increased strength was marked throughout the whole of the period, more especially in the case of the strongest current in that year, viz., the Bengal current:

Percentage variation of strength.

Name of current.	June.	July.	Aug.	Sept.
Bengal	+ 30	+ 27	+ 15	+ 32
Bombay	− 30	+ 7	+ 10	+ 15

The relations of the variations of the strength and direction of the lower air currents during the southwest monsoon to the rainfall variations require further investigation, but sufficient data have already been accumulated to establish that there are marked differences in the strength and extension of the monsoon currents and in the distribution of the rainfall from year to year, and that these are directly related to each other.

These relations might have been inferred from the fact that the monsoon rainfall is not due to the passage of cyclonic storms, but to the continued prevalence of a steady, strong current charged with vast supplies of aqueous vapor. Assuming that the character of the distribution of the rainfall is fairly persistent throughout each season, and that the rainfall is due to the advance and prevalence of a strong sea current into the Indian land area, it is evident that the extension of this current will be to some degree determined by any abnormal meteorological conditions present before or during its advance. The following gives a brief statement of some of these determining conditions:

(1) Unusually heavy and prolonged snowfall in the Himalayan Mountain area has been shown by Mr. Blanford to exercise a very powerful influence. It modifies the pressure and temperature conditions in northern India, and usually not only retards the commencement of the monsoon but modifies its intensity. The manner in which snowfall modifies the hot weather conditions and the sub-

sequent rains has been investigated and is fairly well known. Abnormally deficient snowfall and its usual correlative, more intense hot weather conditions than usual, on the other hand are found to precede almost invariably stronger and steadier monsoon than usual.

(2) The abnormal pressure conditions established during the hot weather, more especially if they are marked, exercise a large influence in modifying the set of the monsoon currents. The general rule in India is that the hot weather tends to exaggerate and develop local pecularities of pressure, and the rains to smooth them away. Thus, if the hot weather develop a local deficiency of pressure in any area it tends to become a sink to which the monsoon current is more largely directed than usual, and hence also affects the rainfall in neighboring districts. If, on the other hand, a local excess of pressure is formed, as occasionally happens in Guzerat, northwest Rajputana, etc., it usually accompanies a considerable or large diminution of the rainfall in Rajputana or northwestern India. Much remains to be done to work out fully the influence exerted by high and low abnormal pressure areas in modifying the distribution of the monsoon rainfall, but several useful relations have been established and are used in drawing up these long-period forecasts.

Similarly, the consideration of the temperature conditions of India during the hot weather throws light on the causes of the general and local pressure conditions obtaining before the setting in of the monsoon, and hence enables their probable importance to be estimated.

An important point to be taken into consideration is the relative strength of the two currents, as upon this depends largely the position of the monsoon trough of low pressure, and hence also the mean tracks of the cyclonic storms of the rains and of the heavy rainfall that accompanies these storms. A strong Bombay monsoon tends to displace it northward and a strong Bengal monsoon southward.

Another important point is based on the results of Mr. Blanford's investigations (given in the "Rainfall of India") of the relations between the rainfall variations in different parts of India. He has worked out very fully the areas in which the rainfall variations are usually similar or opposite in character, and the measure of the probability of similar or opposite variations occurring for any given year.

The previous gives a few of the more important principles and facts upon which the forecasts of the distribution of the monsoon rainfall are based.

A consideration of the snowfall data of the cold weather, of the meteorological conditions prevailing during the hot weather, and more especially the character and persistency of the pressure variations, usually enables a rough estimate of the general strength of the monsoon currents and the distribution of the rainfall to be made. This is first done and afterwards a comparison is made with previous

years in which similar conditions are known to have obtained. By taking into consideration the actual conditions, the relations established by Mr. Blanford between the rainfall variations in different areas, and the rainfall distribution of previous years of similar meteorological conditions, not only the probable character of the rainfall can be estimated, but also the probability of the occurrence of, deficiency or excess of rainfall in any area as dependent upon or resulting from these conditions. This is what is now attempted to be done in the forecasts issued annually in June by the department, and which have had a fair measure of success. For example, a full warning was given in June, 1891, of the drought in Rajputana during the monsoon rains of that year.

It is hardly necessary to point out that the methods employed and sketched above are practically identical with those employed in giving warning of the approach of storms, and I may again point out that these long-period forecasts in India are rendered possible by the peculiar features of the southwest monsoon air motion over India, and by the remarkable persistency of many of the abnormal conditions of the meteorology of that current.