FORECASTING DROUGHTS IN THE SUBCONTINENT OF INDIA

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INTRODUCTION

It is well known that wide-spread rainfall is a consequence of extensive ascending motion of relatively moist air. Hence a drought over an extensive area is a consequence of either:

(*a*) sustained extensive descending motion of air over the area in question over a period of about a couple of months, or

(*b*) lack of moisture in the prevailing air over the area.

India (and the neighbouring S.E. Asian countries like Bangladesh and Burma) receives its main quota of rainfall during the S.W. Monsoon Season—June to September. A significant deficiency of rainfall during this period over any part of the country in any year, makes that year a year of drought. An examination (Ramaswamy 1958) of the day-to-day as well as the mean monthly representative tephigrams over the drought area during such years reveals no significant decrease in the total precipitable content below that of a normal monsoon year. One is therefore tempted to infer that the rainfall deficiency is a consequence of the changes in the dynamical conditions during that monsoon period over that area, rather than a deficiency in the moisture content* of the air over the area. The dynamic conditions in question should be leading to a general sinking motion over the area suffering drought during the major part of the monsoon period—June to September. Meteorologists commonly associate such drought conditions over India with synoptic features like:

(*i*) lack of a well developed monsoon-trough over the Indo-Gangetic Valley over most of the monsoon period,

(*ii*) a large decrease in the number of monsoon-depressions moving west-north-westwards along the Gangetic Valley,

(*iii*) weakness of the south to north pressure gradient over the country,

(*iv*) lack of easterly winds in the Assam and the Northern part of the Indo-Gangetic Valley, and generally weak easterlies over the upper troposphere over the whole of North India,

(*v*) Proximity of the eastern half of the axis of the monsoon trough to the Himalayas, etc.

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*I am discounting the possibility that a large deficit in the condensation nuclei is responsible for a seasonal drought and that the drought can be broken by artificially providing an adequate supply of the requisite nuclei—silver iodide or common salt. Such a nucleation can perhaps only augment natural precipitation over a given locality, and that too only on those days when natural precipitation may occur in the immediate neighbourhood, if not at that locality itself.

Of these only (*ii*)—the lack of monsoon depressions—does directly refer to the dynamics of the monsoon system.

MERIDIONAL MONSOON CELLS

Recent studies (Koteswaram 1960; and Keshavamurty 1971) have shown that there is a direct Hadley type circulation associated with the southwest monsoon in which warm air over the thermal equator (along the Indo-Gangetic Valley), rises, moves towards the equator in the upper troposphere and sinks in the equatorial troposphere. The cell is completed with a northward return current in the lower troposphere. Obviously this circulation exists even during the years of weak monsoon as we do have the westerlies of the lower troposphere, perhaps weaker than in the normal years. Similarly the easterly winds in the upper troposphere are also weak in these years, indicating a weaker meridional circulation.

Obviously such a meridional circulation does not exist in the same latitudinal belt over all the longitudinal zone. This meridional circulation of the monsoon region is perhaps confined to the longitudinal belt 75°E to 100°E, but not eastward of this belt nor westward of it, where the thermal equator of the northern summer is much less displaced from the geographical equator. The meridional cells of those longitudinal belts are not likely to have *any rising* limb at latitudes north of 15°N; instead their feeble sinking limbs would extend north of 15°N, with the sinking component increasing with latitude.

ZONAL CELLS

Bjerknes (1969) has recently demonstrated the existence of zonal cells in the equatorial and near equatorial latitudes with the rising limbs in one longitudinal belt and the sinking limb in another longitudinal belt 40° or 50° west or east of the rising limb. He has given evidence of the existence of such a cell over the equatorial Pacific with the rising limb located over areas of warm equatorial waters and the sinking limb over areas of comparatively cold equatorial waters. Evidence also has been produced about changes in the location of such zonal cells from one year to another. Das (1962) has shown that during the normal monsoon, one has to infer indirectly, a zonal cell roughly between Bengal and Rajasthan, with its rising limb over Northeast India (Assam–Bengal), and its sinking limb over Northwest India (Rajasthan–Sind).

HYPOTHESIS REGARDING INDIAN DROUGHT AND THE ZONAL CELL

It would be reasonable to assume that the zonal cells envisaged by Bjerknes over the Pacific are apparently along the thermal equator. The one over the Indian Region would then be normally between 95°E and 65°E in the *longitudinal belt* 20°N–28°N, with the rising limb over the eastern half and the sinking limb over the western half. Continuing the argument, one may say that during the drought years over India, the zonal cell is displaced eastwards by about twenty or thirty degrees of longitude so that the *sinking limb* is over India and the rising limb over Burma and Indo-China.

If we get evidence for the occurrence of such features, which are necessarily persistent, one can make an attempt to foreshadow drought areas. Mooley (1970) has shown that droughts over North India are generally associated with excess rainfall over Indo-China, and above normal pressures over North India. It is reasonable to associate the sinking limb of a zonal vertical circulation cell with an above normal pressure. Hence Mooley's findings are in support of the hypothesis outlined in the previous para. The next question is whether such an eastward shift of the monsoon zonal cell is associated with a simultaneous and similar eastward shift of the equatorial zonal Pacific cell studied by Bjerknes. Instead of examining the ultimate causes of such a shift, it would be useful to identify, if we can, the quasi-persistent parameters associated with an eastward shift of the zonal monsoonal cell. The possible nearly antecedent parameters are:—

(*i*) A lower value of the sea temperature over the north Bay of Bengal, by a couple of degrees, in May-June, below the normal value.

(*ii*) An eastward displacement of the Pacific zonal cell called "Walker Circulation" by Bjerknes, evidenced by the increased annual rainfall recorded at Canton Island, during the winter months. It may be recalled that this station has an average rainfall of 732 mm. When the Pacific zonal cell was in its eastward location as in the winters of 1957–58 and 1965–66, the annual rainfall was 1350 mm.

(*iii*) The eastward displacement of the Pacific Cell may also be indicated (or caused) by the above average sea temperatures in the equatorial belt between the longitudes 160°E and 160°W, as pointed out by Bjerknes.

A schematic picture of the thermal equatorial zonal cells is given in Fig. 1.

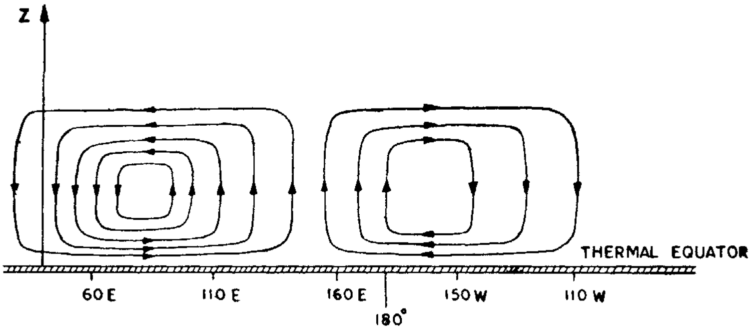

FIG. 1. A Schematic Diagram of Zonal Cells along the Thermal Equator

During the drought years over India, one should expect on this hypothesis, the equatorial seas around 170°E, warmer than normal by a couple of degrees. Ocean surface temperatures being more persistent than most of the atmospheric phenomena can be of use in long term prognostics. Using parameters pertaining only to the atmosphere, numerical prediction methods have provided sufficient evidence (Smagorinsky 1969) that the predictability is hardly three weeks at the best. A significant increase in predictability can occur only when oceanic parameters like ocean currents, water temperature etc. are taken into consideration. Instead of taking normal ocean surface temperatures for the initial state, one can use a distribution of temperature, sinusoidally varying along the thermal equator as the initial state and numerically simulate the consequences with a multi-layer model.

Appendix

From October to May there is practically no rain over many parts of India like: Maharashtra, Madhya Pradesh, Gujarat, interior Andhra Pradesh etc. In a sense this is a climatological drought for eight months of every year.

Obviously it is necessary to store the rainwater for eight months. The amount of water stored in reservoirs created by dams across rivers, is about a week's normal monsoon rainfall over the catchment areas. Hence it is necessary to adopt some other method of storing all the rain water. The water than runs off is about 50 per cent of the rainfall, the annual potential evaporation is about 1½ metres of water, while the amount that percolates into the soil is about 30 per cent.

Suppose steps are taken to collect practically all the runoff in small tanks at the rate of one or two for every village. Let the catchment area of each tank be about 20 times its surface area. Then in any region where the mean annual rainfall is 50 cm or more, the tank would collect water at least to a depth of 5 metres, assuming a 50 per cent run-off. If the tank is 10 metres deep, two years annual rainfall, minus the evaporation of 3 metres of water can be stored in the tank. The tank thus would offer a buffer stock of water for a lean year.

To my mind this type of Tank or Talab culture appears to be a necessary proposition in a land like ours where the precipitation is not in the form of snow, is not distributed throughout the year, and varies significantly from one year to another. There is no need to enumerate the favourable ecological and sociological effects of such a Talab Culture.

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