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Is it possible to increase rainfall in the semi-arid regions of Rajasthan by reducing quantity of dust suspended in the atmosphere? — No

B. N. DESAI

173, Swami Vivekananda Road, Vile Parle (West), Bombay

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ABSTRACT. The nature of air masses during the monsoon season and the causes responsible for (1) small rainfall and (2) desert conditions over west Rajasthan have been discussed. It is shown that reduction in the quantity of dust suspended in the atmosphere can increase neither the depth of the moist layer nor the rainfall over the area as suggested by Bryson and co-workers (1964, 1967); stable conditions between about 1·0 and 2·0 km are not considered as being due to subsidence which can ordinarily occur over the area only above about 3·0 km.

1. Introduction

Das (1962) has stated on the basis of his computations that during the monsoon season there was pronounced ascent of air over northeast India (source) and a zone of descent over northwest India (sink). Further, it is shown by him that cooling at the rate of 2·4°C per day would be required over northwest India to maintain a steady circulation. Considering water vapour and carbon dioxide as radiators, Das found that cooling of only 1·8°C per day could be accounted for. Bryson *et al.* (1964) have found from their radiation-sonde measurements over northwest India that the observed rate of cooling was 2·4°C per day, closely agreeing with the computed value of Das; their estimated rate of cooling by radiative divergence was 1·6°C per day also very near Das's computed rate.

To account for difference of about 1°C between the observed and computed rates of cooling per day to maintain the observed rate of subsidence, Bryson *et al.* considered that the additional cooling could be provided by the presence of dust particles over the arid regions of northwest India. Considerable amounts of suspended dust were also found during their flights. Bryson and Baerreis (1967) have stated that it appeared that the desert coincided with the extent of the divergent sinking air at about 10,000 ft. Further, according to them if the atmospheric subsidence over the area was less, the moist monsoon layer which is ordinarily shallow, would be deeper and the slight summer rainfall maximum would be considerably larger. Their discussion incline one to the view that if subsidence could be reduced by reduction of the quantity of dust suspended in the atmosphere, it may be possible to increase rainfall in the desert areas of northwest India.

Discussions given in papers of Das (1962) and Bryson and co-workers (1964, 1967) are important from the point of forecasters and it is proposed to discuss them with reference to the weather, climatic and topographical features of the desert and its surrounding areas.

2. Discussion

From the computations of Das (1962) it is seen that there is a region of subsidence near the western periphery of the Himalayas and further to their west at 900 mb and that the maximum subsidence at 500 mb is near 34°N, 68°E. In this connection, it may be stated that as seen from the normal isohyets for July, there is considerable rainfall over the western periphery of the Himalayas and that it decreases westwards towards the plains. It is thus difficult to reconcile the normal rainfall with subsidence conclusions of Das for 900-mb level. Computations of divergence by Bellamy (1949) of the mean resultant winds at standard pressure levels over the eastern portion of the West Pakistan heat low indicated net ascent below 700 mb associated with the heat low circulation and net descent above that level associated with the convergent easterlies (Ramage 1966); these results for levels below 700 mb would not appear to support computations of Das.

The subsidence areas for 500-mb level would be supported by observations of Sawyer (1947) who has stated that there are surges in the continental air which enters India across Afghanistan and Iran and they are associated with lowering of temperatures over the Punjab at levels between 10,000 and 20,000 ft; the warming which follows a cold burst would suggest that subsidence takes place above about 10,000 ft in the continental air over northern India. This according to Sawyer

appeared to be confirmed by some of the soundings in the vicinity of the partitions between the continental air and the moist (monsoon) air which showed presence of air above 10,000 ft with temperatures similar to those of the monsoon current but with humidities too low for the monsoon airmass.

Regarding the role of dust suspended in the atmosphere acting as radiator to produce cooling as suggested by Bryson *et al.* (1964, 1967), it can also be argued that the presence of dust might actually produce heating. If there is a haze layer, there will be cooling at the top, but the same effect might not be produced by dust below that layer. During day time dust will help transmission downwards of long wave radiation; at night the suspended dust will prevent cooling of the surface. It is well-known that in Delhi when there is plenty of dust suspended in the atmosphere, the minimum temperature is high and the diurnal range of temperature is reduced. It will be difficult to decide the extent to which the presence of dust would help subsidence due to cooling.

Bryson *et al*'s inference that if subsidence could be decreased by reduction of dust, the depth of the monsoon layer would increase may now be considered. The airmasses ordinarily present over the semi-arid regions of northwest India during the southwest monsoon season are (Desai 1966, 1967):

(*a*) Southwesterly to westerly moist air from the surface upto 1·0 to 1·5 km.

(*b*) Drier continental air from west to north between 1·0 to 1·5 and 4·0 km.

(*c*) Drier continental air from a direction between north and east over the northern portions and moist air from the east over the southern portions between 4·0 and 6·0 km.

Between (*a*) and (*b*), there is a transition layer of air 0·5 to 1·0 km thick with stable conditions; at Karachi this layer extends from about 1·0 to 2·0 km (Ramage 1966). The dry and warm continental air in (*b*) is from areas between west and north Baluchistan plateau and the neighbouring northwest frontier hills. The humidity of the moist monsoon air as it enters the coast is very high, but decreases as it moves over the semi-arid or desert areas with higher temperatures. As such, even if the monsoon air rises due to convection currents, it has to rise much higher in the interior than over the coast to form large *Cu* and *Cb* clouds and rain. But before the moist air can reach such a height, it encounters the layer with stable conditions and the drier air and whatever clouds have formed, dissolve. Thus convective processes are ordinarily not able to cause rainfall over the area although they might succeed in raising dust in the atmosphere.

There are no mountain ranges on or near the coast over Saurashtra, Kutch and Sind across the path of the monsoon current to force the moist air to rise and cause large towering clouds and rain and to break up the stable layer of air. The Aravalli range extends southwest to northeast and divides Rajasthan into two parts, the western part, *i.e.*, area to the west of the hills being semi-arid. This range is too far away from the coast where the monsoon current enters inland. Even when the monsoon air reaches the Aravalli range, it flows practically parallel to it and there is little ascent. As such, no orographic rain ordinarily falls on the western windward side of the range.

The above conditions are in marked contrast to those prevailing on the west coast south of Surat. According to the results of the International Indian Ocean Expedition (IIOE) during 1963–64, over the Arabian Sea west of about 68°E, the monsoon current extends only to about 1·0 to 1·5 km above the sea surface and above it, there is on some occasions drier continental air upto about 4·0 km with a stable air layer between the two air currents. Thus the air currents over the Arabian Sea at some distance to the west of the Ghats, are of about the same type as over the desert regions of northwest India. There is *no* question of dust being convected up above the sea surface in contrast to conditions over the desert area. But according to the IIOE results, little rain ordinarily falls over the west and north Arabian Sea also as over the semi-arid areas of Rajasthan and Sind.

The Western Ghats where the monsoon air strikes almost at right angle, force the cool moist air with high humidity as it approaches them, to rise giving large towering clouds and considerable rain; this cloud activity and rain on a large scale, lead to breaking up or weakening of the stable air-layer and mixing of the lower moist air and upper relatively dry air, and there comes into existance moist current about 6·0 km deep over the Peninsula instead of 1·0 to 1·5 km deep over the Arabian Sea about 500 km west of the Ghats. The depth of the moist current, however, does not change on the Sind-Kutch-Saurashtra coast due to absence of orographic barrier across the path of the moist air.

Rainfall can, therefore, occur over the semi-arid regions of northwest India only if there is convergence between the moist and other air currents present with or without a depression or with warm front conditions with an approaching depression. Most of the rainfall over the northwest India desert region during the monsoon season occurs in association with the movement to or across it of depressions from the Bay and in a few cases from the Arabian Sea. These disturbances besides producing convergence also effect changes in the distribution of airmasses, the upper drier air being replaced by moist easterly current and the stable layer above the lower westerly monsoon air disappearing. Rainfall due to convergence is considerable; it is light with warm front conditions as the front is present only above about 3·0 km where the moist air becomes warmer than the drier air (which is warmer than the moist air below that level) as a result of a difference in the lapse rates in the two currents (Sawyer 1947).

The stable layer of air between the moist and relatively dry air currents is very important from the point of occurrence of rainfall as will appear from the foregoing discussions. If the stable layer was due to subsidence as a result of cooling of the suspended dust in the atmosphere, reduction or removal of dust would certainly cause increased rainfall. But the stable layer is due to the differences in the nature of the moist and drier air currents which are present over the region. The dust suspended in the atmosphere would affect temperatures (and not rainfall) due to its effect on the incoming and outgoing radiation.

Over the Sahara desert, there are persistent anticyclonic conditions. The Gobi desert has peculiar topographical features as a result of which moisture bearing winds are shut out from the region. The desert over Peru is due to persistence of cold current of the Andes. The desert region of northwest India does not owe its existence to any of these mechanisms. During the winter months dry northwesterly winds ordinarily blow over the region as a result of the prevailing pressure distribution although on some occasions light rain occurs there in association with the passage of the western disturbances eastwards across northern India or of the secondaries which develop over the north Arabian Sea or Gujarat and move northeast to east. During the summer and monsoon seasons the region becomes a low pressure region as a result of high temperatures; the topographical features—the mountains to the west and northwest and to the northeast and east, help location of the lowest pressure region over upper Sind and neighbourhood of the Indo-Pakistan sub-continent. The moist monsoon winds enter this low region in the lower levels, but due to the mechanism stated earlier, little rain falls over and around the low pressure region during the monsoon season. The low is maintained by clear skies and intense insolation.

The statement of Bryson *et al.* (1964) that if there was absence of dust and consequently less subsidence, there would be a deeper layer of moist air is also not tenable. Even over the Arabian Sea west of about 68°E, the depth of the moist current is only 1·0 to 1·5 km and it becomes about 6·0 km over the west coast south of 20°N due to the presence of the Western Ghats as mentioned earlier. Further, it is shown by the IIOE results that the depth of the moist current is 2·0 to 3·0 km near the equator west of 60°E; the cold moist current moves northeast to eastwards as a wedge towards the west coast of the sub-continent. Under the circumstances, its depth on the Sind-Kutch-Saurashtra coast cannot be more than 1·0 to 1·5 km. The inversion above the layer of moist air whether its origin is due to subsidence or airmasses has, therefore, it is felt, nothing to do with the shallow depth of the moist current over the semi-arid areas of northwest India. Moreover, as mentioned earlier, marked subsidence occurs over northwest India only above about 3·0 km (Sawyer 1947), while the inversion over lower Sind is between about 1·0 and 2·0 km as shown by Karachi data.

Similarly the statement of Bryson and Baerreis (1967) that if the source of the dust is the desert itself, the desert would appear to be self-sustaining, would also not appear justified. From the foregoing discussions it would be clear that the desert of northwest India is the result of peculiar climatic and topographical features. Presence of vegetative cover would certainly inhibit the raising of dust by wind and affect micro-climate of the surface layers, but it will not be able to change either the topographical features or the nature of airmasses or depth of the moist current over the area.

It is difficult to appreciate the statement of Trewartha (1961) that the northeastern and northwestern extremities of the sub-continent exhibit impressive contrasts regarding rainfall amounts in spite of the two regions having so many similar climatic controls. As discussed earlier, the depth of the moist current over the desert area is only 1·0 to 1·5 km and there is a stable layer above, while its depth over the eastern area is

about 6·0 km and there is ordinarily no stable layer. Further, over the eastern area there is considerable convergence due to nearness of the trough axis, while such convergence does noto ccur over the northwestern area. The former area is subjected to the activity of a large number of depressions from the Bay of Bengal or those which form over land, while only a few such disturbances affect the desert area west of the Aravalli range. The southwesterly to westerly moist monsoon air is deflected northwestwards by the Arakan and Assam mountains and the Himalayas; this influence is absent over the desert area. Thus the climatic and topographical controls for rainfall are substantially different in the northeastern and northwestern extremities of the sub-continent.

In view of the foregoing discussions it can be stated that it is *not possible* to increase rainfall in the semi-arid regions of Rajasthan by reducing quantity of dust suspended in the atmosphere, although the same may affect the micro-climate of the surface layers so vital for the crops.

REFERENCES

Bellamy, J. C.	1949	*Bull. Amer. met. Soc.*, **30**, 45.
Bryson, R. A. and Baerreis, D. A.	1967	*Ibid.*, **48**, 136.
Bryson, R. A., Wilson, C. A. and Kuhn, P. M.	1964	*Proc. Symp. Tropical Meteorology*, Rotorus, New Zealand, 737.
Das, P. K.	1962	*Tellus*, **14**, 212.
Desai, B. N.	1966(a)	*Indian J. Met. Geophys.*, **17**, 399.
	1966(b)	*Ibid.*, **17**, 575.
	1967(a)	*J. atmos. Sci.*, **24**, 216.
	1967(b)	*Proc. Indian Acad. Sci.*, **66A**, 306.
Ramage, C. S.	1966	*J. atmos. Sci.*, **23**, 144.
Sawyer, J. S.	1947	*Quart. J. R. met. Soc.*, **73**, 346.
Trewartha, G.	1961	The earth's problem climates. Madison, University of Wisconsin Proc., 151-170.