CAUSES OF ARIDITY AND INVERSION OVER THE DESERT AREAS OF WEST PAKISTAN AND NEIGHBOURHOOD DURING THE SOUTH-WEST MONSOON SEASON

By B. N. Desai, F.A.Sc.

(173, *Swami Vivekananda Road, Vile Parle—West, Bombay*-56)

Received February 21, 1968

Abstract

Views of Flohn (1965, 1966) and of Ramage (1966) regarding the causes of aridity and inversion over the desert areas of West Pakistan and neighbourhood have been examined. It is shown on the basis of climatic features of the area that the inversion is due to air masses and *not* due to subsidence; the aridity of the region is due to absence usually of a mechanism which can break up the inversion and *not* due to the restricted depth of the moist current.

Introduction

It has hitherto been considered that the inversion over West Pakistan during the monsoon season is due to different air masses, deflected trades or moist monsoon air in the lower levels and warmer drier air from Baluchistan plateau side above (Desai, 1966—1, 2; 1967—1, 2); the aridity of the desert area has been taken as being due to inability of the convective clouds to penetrate the inversion.

Flohn (1965, 1966) has expressed the view that the aridity of the desert region is due to subsidence caused by divergence. Ramage (1966) has stated that the inversion over the desert area is due to large-scale subsidence which restricts the depth of the moist current and is responsible for scanty rainfall over that area.

It is proposed to examine in this paper the various facts of observations over the area with a view to decide which of the two causes—air masses considered valid upto 1963 or subsidence (Flohn and Ramage) is responsible for the inversion between about 1·0 and 2·0 km. and scanty rainfall over the desert area of West Pakistan and neighbourhood.

DISCUSSION

Climatic features.—It has been found on analysis of aeroplane ascents over Karachi (Hariharan, 1932) that during a typical monsoon month like July, an inversion usually occurs over Karachi at a height of about 1·0 km. and it is about 500 meter thick, the rise in temperature in the inversion being about 4° C. on an average. The lapse rate below the inversion was adiabatic and above it in the dry air about 6 to 8° C. per km. The winds over Karachi are moderate to strong and mainly from west upto 1·0 km., veer with height and at 3·0 km. are light to moderate between north and east, being somewhat stronger but from about the same direction at 6·0 km. Light rain occurs at times in the mornings from the stratiform clouds below the inversion, but the clouds dissipate as the insolation effect increases. It is also noticed that when above about 3·0 km. the north-easterly to easterly air is a continuation of the moist air from the east, the humidity increases (Hariharan, 1932; Mal and Desai, 1938; Desai and Mal, 1940), the convergence zone between the dry continental air (west to north-west veered to north-east) and the moist easterly air being also over the area.

View-point of Flohn.—Flohn (1965) has considered that the aridity of the desert region is due to the monsoon current becoming divergent as a result of the heat-low over West Pakistan and, therefore, subject to large-scale subsidence, reducing the vertical extent of the moist layer to about 1·5 to 2·0 km. In his comments on Desai's paper (1966—2) Flohn (1966) has also stated that average vertical wind components at altitudes of 1·5 and 2·1 km. computed on the basis of low-level mass divergence, were evidently strongly correlated with the average rainfall map. The following remarks might be made regarding Flohn's conclusions:

(*a*) While there will be divergence of the monsoon current under the influence of the heat-low resulting into subsidence, this effect will decrease with height as it (heat-low) is shallow (Ramage, 1966). Further, as a result of insolation vertical currents would be set up and these will considerably decrease the subsidence effect if not completely obliterate it in the lower levels upto about 2·0 km. if not more. The inversion occurs only between about 1·0 and 2·0 km. This would also show little effect of subsidence in the moist layer, *i.e.*, below about 1·0 km. Computation of the divergence of the mean resultant winds at standard pressure levels over the eastern portion of the heat-low over Indo-Pakistan border area by Bellamy (1949) indicated net ascent below 700 mb. associated with the heat-low circulation and net descent above 700 mb. associated with the convergent easterlies (Ramage, 1966). Thus the computations of Flohn would not appear to be supported by those of Bellamy for levels below 700 mb.

(*b*) The depth of the monsoon current (deflected trades) over the Arabian Sea to the west of about 68° E. is also only about 1·0 to 1·5 km. as over the desert area. It cannot be more than 1·0 to 1·5 km. over the desert area because the current extends north-eastwards from the equator (west of about 60° E. where it is deepest about 2·0 to 3·0 km. according to Fig. 2 of Ramage, 1966) as a wedge below the warmer and drier continental air.

(*c*) The inversion generally disappears only when the upper drier air is replaced by easterly moist air (Hariharan, 1932; Mal and Desai, 1938; Desai and Mal, 1940). As the south-westerly to westerly moist current persists in the lower levels and so also the heat-low, it can be assumed that the inversion between 1·0 and 2·0 km. is due to air masses and not due to subsidence as a result of divergence.

Under the circumstances one is justified to consider that the inversion over the desert area is due to hot air from Baluchistan plateau spreading over the cooler moist air.

View-point of Ramage.—(*a*) Desai (1967—1) has given the mean wind at different levels at Karachi and discussed the weather conditions during August 1963, the period of temperature and humidity data given in Fig. 4 of the paper of Ramage (1966). The Karachi data during August 1963 were generally similar to average monsoon conditions. Humidity increase from 41% at 700 mb. to 75% at 500 mb. would appear to be associated with the close proximity of the boundary between the continental and moist north-easterlies to easterlies. The high humidity at 500 mb. during August 1963 would thus not appear to be due to subsidence of warm moist air from the rain systems from the east and south (Desai, 1967—1).

(*b*) Ramage (1966) has stated that descending motion is generally above 700 mb. and ascending motion below that level. As the inversion is only between about 900 and 825 mb., it cannot be considered as being due to subsidence. The ascending motion below 700 mb. would not appear to be sufficiently strong as the inversion between 1·0 and 2·0 km. is not destroyed.

(*c*) Regarding the temperature differences of 2–6° C. in the middle and upper troposphere between monsoon rain (30–6–1964, 12 GMT) and monsoon lull (15–7–1964, 12 GMT) situations studied by Dixit and Jones

(1964) and referred to by Ramage (1966), the following differences worked out from temperatures obtained from the Met. Office, Poona, are significant:

Temperature differences in ° C.—Temperature of 30–6–1964 minus *Temperature of* 15–7–1964

Level mb. \ Station	Bombay	Ahmedabad	Jodhpur	New Delhi	Srinagar
500	+5·0 (+1·0)	+0·7	+4·6 (+3·6)	−0·4 (+0·6)	+6·6
300	+9·8 (+3·0)	+6·9	+1·4 (+4·7)	.. (+3·3)	+4·4
200	+2·9 (+0·9)	+8·4	+5·8 (+5·8)	.. (+1·7)	+4·9

The values in bracket are taken from Fig. 16 of Dixit and Jones' paper. They have not considered data for Ahmedabad and Srinagar and given values for New Delhi for 300 and 200 mb. for which data are not complete. Further, even where they have given values, they are different in all the cases except for Jodhpur for 200 mb. where they are the same. From the above table it would appear that the highest difference was at Srinagar at 500 mb., at Bombay at 300 mb. and at Ahmedabad at 200 mb. Thus one does not find highest differences at any level at Jodhpur near the area of heat-low. Ramage would not, therefore, appear justified in using Dixit and Jones' Fig. 16 to support his hypothesis about subsidence in the middle and upper troposphere over the heat-low over West Pakistan.

CONCLUDING REMARKS

From the foregoing discussion it would appear that the views of Flohn regarding low-level divergence giving rise to subsidence and of Ramage regarding subsidence over the heat-low above 700 mb. level cannot explain presence of the inversion between about 1·0 and 2·0 km. over the desert area. While Flohn considers subsidence due to divergence taking place in the lower levels, Ramage considers that there is net ascent below about 700 mb. There is also no question of the depth of the moist layer being restricted to 1·0 to 1·5 km. due to subsidence. According to Fig. 2 of Ramage's paper there is inversion even over the east Arabian Sea with base at 2·0 to 3·0 km. near about 70° E. Large depth of moist current (about 6·0 km.) over the west coast without an inversion is not due to absence of subsidence over there, but mostly due to the presence of the Western Ghats across the path of the deflected trades as suggested by Desai (1966—1, 2, 1967, 1—2) in contrast to the Sind Kutch and West Saurashtra coasts where there is absence of such barriers. Further, the depth of the deflected trades over the desert area and the Arabian Sea west of about 68° E is only about 1·0 to 1·5 km. as they advance as a wedge north-east to eastwards below warmer and drier continental air. Thus the view hitherto held that the inversion over the desert area is an air mass one and that its persistence is responsible for the aridity of the region would appear to be substantially valid even today.

References

Bellamy, J. C. .. *Bull. Amer. Meteor. Soc.*, 1949, **30**, 4[illegible]

Desai, B. N. .. *Ind. J. Meteor. and Geophys.*, 1966, **17**, 1 [illegible]

——— . *J. Atmos. Sci.*, 1967 (1), **24**, 21[illegible]

——— . *Proc. Ind. Acad. Sci.*, 1967 (2), **66** [illegible]

——— and Mal, S. *Ind. Met. Dept. Sci. Notes*, 1938, **8**, No. [illegible]

Dixit, C. M. and Jones, D. R. .. "A kinematic and dynamical study of active and weak monsoon conditions over India during June and July 1964," *Report issued by International Met. Centre, Bombay*, 1965.

Flohn, H. . *B.M.O. Tech. Note*, 1965, No. 69, [illegible]

——— . *Ind. J. Meteor. and Geophys.*, 1966, **17**, [illegible]

Hariharan, A. S. . *Indian Met. Dept. Sci. Notes*, 193[illegible], **4**, No. [illegible]

Mal, S. and Desai, B. N. .. *Q. J. Royal Met. Soc.*, 1938, **64**, 52[illegible]

Ramage, C. S. .. *J. Atmos. Sci.*, 1966, **23**, 144.

387-68. Printed at The Bangalore Press, Bangalore City, by M. S. Narayanamurthy, Secretary and Published by B. S. Venkatachar, Editor, "Proceedings of the Indian Academy of Sciences," Bangalore