

Letters to the Editor

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REMARKS ON THE NATURE AND ORIGIN OF THE LOW-LEVEL JET OFF SOMALIA AND OVER THE INDIAN PENINSULA DURING THE SOUTHWEST MONSOON

1. Strong surface winds off Somalia during the southwest monsoon season were known from ships' reports. The IIOE observations as reported by Colon (1964) and Bunker (1965) showed that they extended even to 500 and 1000 m. Bunker called these strong winds a low-level jet. The jet was traced to the central portion of the Arabian Sea and further east to the coast line of India, maximum values decreasing progressively from 25 to 30m/sec off Somalia to 15m/sec or less towards the coast of the Indian Peninsula. To the north no jet could be detected and maximum speeds occurred near the surface. At 4°N both in the western and the eastern Arabian Sea no sign of a low-level jet was found. Bunker has presented cross-section of potential temperature for 30 August 1964 from the Gulf of Aden to 4°N, 56°E in the north Indian Ocean on the basis of dropsondes data over the region on that day (these have been given in Figs. 1a and 1b of Desai 1968); he has stated that horizontal temperature gradient applied to the thermal wind equation would show that the velocity should increase by about 10 m/sec through the lowest 600m of air; temperature gradient was found to be reversed above the layer of cool air, thereby indicating decrease of wind speed with height. Bunker considered that the low-level jet off Somalia had developed due to thermal causes. Acceleration of jet winds in the western Arabian Sea would, according to him, indicate subsidence and little rain and explain the low-level inversion; deceleration of the jet winds in the eastern Arabian Sea would mean convergence and showers.

Low-level jet over the Indian Peninsula has also been reported by Joseph and Raman (1966)—(also see Desai 1968); it occurs at about 1.5 km, there being also a secondary jet higher up; the jet persists for a few days at a time and moves northwards and southwards and is associated with heavy rain on the coast and also over the Peninsula when there is a depression. The low-level jet occurs with or without the presence of a depression. According to Joseph and Raman

the low-level jet might be even due to thermal causes.

2. Findlater (1969) has given maximum wind speeds which are known to have been recorded in the layer 600-2,400 m above m.s.l. during the northern summer over the western Indian Ocean and the adjoining areas of East Africa and over India and some typical low-level jet profiles. It would appear from the data presented by him and his discussions that the high speeds are associated with the concentration of the cross-equatorial airflow between 38°E to 45°E. The high speed current flows intermittently from the vicinity of Mauritius through Madagascar, Kenya, eastern Ethiopia, Somalia and thence across the Indian Ocean to the west coast of India and beyond. The stream is occasionally reinforced or replaced by northward flow through the Mozambique Channel, presumably in connection with the rear of the extratropical troughs in the westerlies of the southern hemisphere. The jet-speed current off Somalia and over the Peninsula and western India would appear to be a part of the circulation pattern in lower levels across the equator between 38° and 45°E.

The jet current is made up of a series of segments and may be at different levels at different places and not as one continuous stream over the entire area. There might thus be falling off of wind speeds between different segments of the jet current. Absence of jet in the north Arabian Sea and maximum wind speeds occurring near the surface there was presumably due to depth of the monsoon current being less than about 1.0 km over that area (Desai 1968). No low-level jet could be found near 4°N in the western and eastern Arabian Sea. It is seen that winds there are not a part of the jet-pattern circulation; winds between about 45° and 75°E and between about 5° north and south of the equator are apparently of speeds less than 50 kt often much lower. This equatorial area of low speeds is to the east of the equatorial low-level jet current between 38° and 45°E.

The low-level jet over the Indian peninsula is associated with good rainfall on the west coast and even in the interior if there is a depression to its north. The lapse rate in this westerly moist

current of about 6.0 km depth over the Peninsula is near saturation adiabatic. Thus the westerly moist current over there is presumably a continuation of the southerly jet stream about 4.5 km deep, bulk of which crosses the equator between about 38° and 45°E.

Bunker has stated that the strong low-level jet is formed off Somalia due to the thermal causes as judged from study of soundings from 12°N, 50°E in the Gulf of Aden southeastwards to 4°N, 56°E. From wind profiles presented by Findlater (1969), it is clear that the low-level jets over different areas are of the same type although the maximum speed and level of its occurrence might be different. It is also clear that the low-level jet off Somalia and over the western Arabian Sea, the Peninsula and western India is apparently a continuation of the jet from across the equator as mentioned earlier. The marked upwelling off Somalia does not extend to all the areas where Findlater has now found the low-level jet stream. The mechanism of the development of this jet stream may be the same all over its extent, including off Somalia. Hence it would appear that the low-level jet off Somalia noticed by Bunker may not have a thermal origin as presumed by him.

Findlater has given temperature and dew point data of Dar-es-Salaam in the area of the low-level jet. The strong southerly winds there are overlain by warmer northeasterly winds, an inversion separating the two airmasses. There was unstable moist airmass upto about 850 mb and less moist airmass with nearly saturation adiabatic lapse above upto 700 mb. According to Findlater the inversion base is highest—3,700 to 4,300 m when the southerly monsoon is strongest. It is seen from the study of soundings over the Arabian Sea during the IIOE period that there are two types of airmass stratifications (Desai 1968); in both the cases there is moist unstable airmass in the lower layer, but above it there is drier unstable airmass with an inversion between the two in one case and less moist airmass with nearly saturation adiabatic lapse with or without an inversion in the other case. The airmass stratification of the second type was apparently present at 11°N, 60°E (Desai 1968) when a low-level jet was detected at 11°N, 58°E on 1 September 1964 by Bunker; this would mean moist unstable airmass in the surface layers and less moist airmass with nearly saturation adiabatic lapse above in the layers of jet speeds both over Dar-es-Salaam and off Somalia. Over the Peninsula there is moist airmass with nearly saturation adiabatic lapse in the layers of jet speeds. It may be mentioned that in the first type of airmass stratification over

the Arabian Sea no low-level jet might occur, the depth of the moist layer being 0.5 to 1.5 km west of about 68°E and north of about 10°N, the core of the low-level jet being above that level and there is drier unstable airmass above about 1.5 km.

In view of the above it would appear that it is not necessary to put forward the idea of subsidence to account for the low-level inversion in the west Arabian Sea as has been done by Bunker (1965) and Ramage (1966). Acceleration of jet winds in the western Arabian Sea is not due to subsidence, the jet being not of thermal origin; it is characteristic of the low-level jet stream both to the south and north of the equator as seen from wind profiles of Findlater. Little or no rain in the western Arabian Sea can also be explained as being due to the presence of low-level airmass inversion there as mentioned by Desai (1968, 1969). Showers in the eastern Arabian Sea within about 500 km of the west coast of the Peninsula are due to the various causes stated by Desai (1969), the influence of the Ghats being of primary importance. It is doubtful if heavy rain would occur over the west coast if the jet current there was produced in the manner contemplated by Bunker and had not its origin across the equator.

3. From the foregoing discussions it would appear that the low-level jet off Somalia and over the Peninsula which is associated with good rainfall on the west coast, is not due to thermal causes. The low-level jet current is a continuation of the southerly jet current from the southern hemisphere which crosses the equator between about 38° and 45°E in levels from the surface to about 4.5 km, the bulk of it in levels about 0.5 to 3.0 km. Variations of the longitudinal extent of the jet along the equator may determine strengthening of the monsoon at different latitudes along the west coast of the Peninsula. The inversion in the western Arabian Sea is not due to subsidence but is an airmass one. There would not appear any difficulty in explaining little or no rain in the western Arabian Sea without the presence of subsidence there, as the airmass inversion can also prevent precipitation due to absence ordinarily of any mechanism to break up the inversion.

The summer monsoon current over the Arabian Sea and the Peninsula has its roots in the southern hemisphere as hitherto believed by the bulk of

the Indian Meteorologists and it is not of northern hemisphere origin as considered by some.

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