Reports Series No. 96, 117, 129, 147 and 165, IAEA, Vienna, 1984.
12 Raina, A. N., *Geography of Jammu and Kashmir*, National Book Trust, New Delhi, India, 1977, p. 271.
13. Ramesh, R., Bhattacharya, S. K. and Gopalan, K., *J. Geol. Soc. India*, 1985, **27**, 154.

LOW-LEVEL WINDS OVER THE WESTERN INDIAN OCEAN AS OBSERVED BY INDIAN OCEAN SATELLITE (GOES) DURING THE SUMMER MONEX OF 1979

P. N. MAHAJAN, V. R. MUJUMDAR
and S. P. GHANEKAR
Indian Institute of Tropical Meteorology,
Pune 411 005, India.

DURING the months of northern summer, sea-level pressure continuously increases from a heat low over Southern Asia to a subtropical high pressure ridge of the southern hemisphere. This pressure distribution results in a buffer zone straddling the equator between southeast trade-winds and southwest monsoon winds. Thus, the low-level air current circulating over the western Indian ocean is characterized by three different winds: (1) Southwesterly monsoonal flow over the Arabian sea, (2) Cross-equatorial flow along the Somali coast and adjoining ocean and (3) Southeasterly flow in the southern hemisphere. This strong low-level air current, known as Somali jet, however, is a major component of the Asian summer monsoon. The jet originates in the southern hemisphere in the region of small islands near Mauritius. It then penetrates across the northern tip of Madagascar, flat eastern Kenya, Ethiopia, Somalia, Arabian sea and thence flows towards the Indian peninsula. Moisture-laden air current in low-level flows directly over the Indian peninsula during the southwest monsoon season. The southeast trades over the South Indian ocean are deflected by the Coriolis force after crossing the equator to reach the Indian subcontinent as a southwesterly flow. The cross-equatorial flow is not uniform at all longitudes. It is weak over the eastern Indian ocean (east of 60°E) and strong over the western Indian ocean (west of 60°E), particularly along the east African coast. The major low-level current, most pronounced at a height of 1–1.5 km with speeds reaching $\sim 30\,\mathrm{m\,sec^{-1}}$ is one of the most intriguing phenomena of the monsoon system[1]. A correlation has been found between the strength of cross-equatorial flow over Kenya and the amount of rainfall along western coast of India[2]. However, this question deserves careful consideration[3]. It has been observed that the intensity of cross-equatorial flow is greater in good monsoon years than in bad monsoon years[4]. The low-level strong current is forced by low-level divergence in the subtropical high pressure belt (the Mascarene high) and the zone of continental low pressure (the monsoon trough) over northern India[5, 6]. It is seen that wind discontinuity found to the east of Madagascar during eastward propagation of midlatitude depression in the southern hemisphere may be related to the weakening of low-level jet[7].

Use of low-level winds based on the cloud motion vectors in weather analysis has become a regular feature over the Pacific and Atlantic oceans where the geostationary satellites are located. During FGGE year 1979, Indian ocean geostationary satellite (GOES) belonging to the United States was specially brought to a new location (60°E) over the Indian ocean for the benefit of Monex. This gave researchers their first opportunity to view the monsoon circulation over the Indian ocean. This provided exceptional coverage of cloud wind tracers, particularly during summer monsoon months of May–July. GOES measurements are ideal because they possess both high spatial and high temporal resolution (1 km in visible, 8 km in infrared and half-hourly sampling frequency). GOES produces images of the earth and its cloud cover in the spectral bands 0.5–0.9 μm (visible) and 11–12 μm (infrared) respectively. Estimates of low-level wind fields deduced from cloud motions were extracted in LMD (Laboratoire de Meteorologie Dynamique)[8].

Had the satellite been in perfect geostationary orbit, the sequence of images would have shown true cloud motions. Since the orbits are not perfect, the sequence shows apparent motion of earth due to the motion of space craft. The orbit inclination, inclination of spin axis of the satellite relative to the spin axis of the earth and improper alignment of camera axis with the satellite axis all cause image motion and it must be corrected before cloud tracking operations. The basic concept behind cloud drift wind is that some clouds are passive tracers of air motion in the vicinity of clouds. The growth and decay of clouds are related to their size and lifetime which contribute random errors to cloud tracked winds.

GOES satellite imagery of 14 June (figure 1) shows the monsoon cloud cover over the Arabian sea. The low-level clouds are not seen along northern Somalia coast. A well known reason for the lack of cloudiness along the Somali coast is that during southwest monsoon, upwelling along the Somalia coast and the cold Somalia current maintain strong zonal temperature anomaly with cold water in western Indian ocean and warm water in the eastern Indian ocean[9].

Figures 2 and 3 are the examples of raw wind vectors deduced from cloud motions on two days of the 1979 summer Monex (10 and 14 June)[8]. It can be seen that geographic data extends from 30°E–90°E and 30°S–30°N. On 10 June 1979 (before the onset of southwest monsoon) Somali jet is not well established and the strength of cross-equatorial flow is $\sim 10\ \mathrm{m\,sec^{-1}}$. Winds of the order of $5\ \mathrm{m\,sec^{-1}}$ in the Mozambique channel are seen which do not show any specific direction. But on 14 June 1979, suddenly strong southerlies of the order of $\sim 20\ \mathrm{m\,sec^{-1}}$ are noticed in the Mozambique channel. Broad scale forcing of low-level winds in the Mozambique channel may be related to the passage of northward propagating cold fronts observed on 12 and 13 June, to the south of Mozambique channel (around 30°S and 40°E). Increase in the strength of corss-equatorial flow ($\sim 15\ \mathrm{m\,sec^{-1}}$) is noticed. Similarly, a well-established low-level jet (20–25 $\mathrm{m\,sec^{-1}}$) off Somali coast is also noticed. This strengthening of the low-level jet increased cyclonic vorticity over the Arabian sea giving rise to the formation of an onset vortex on 14 June (around 12°N, 70°E). The passage of cold fronts which are mainly accompanied by large amplitude troughs in the middle troposphere lead to a pressure increase and, in some cases, cold air advection equatorward through the Mozambique channel. Such a cold surge leads to

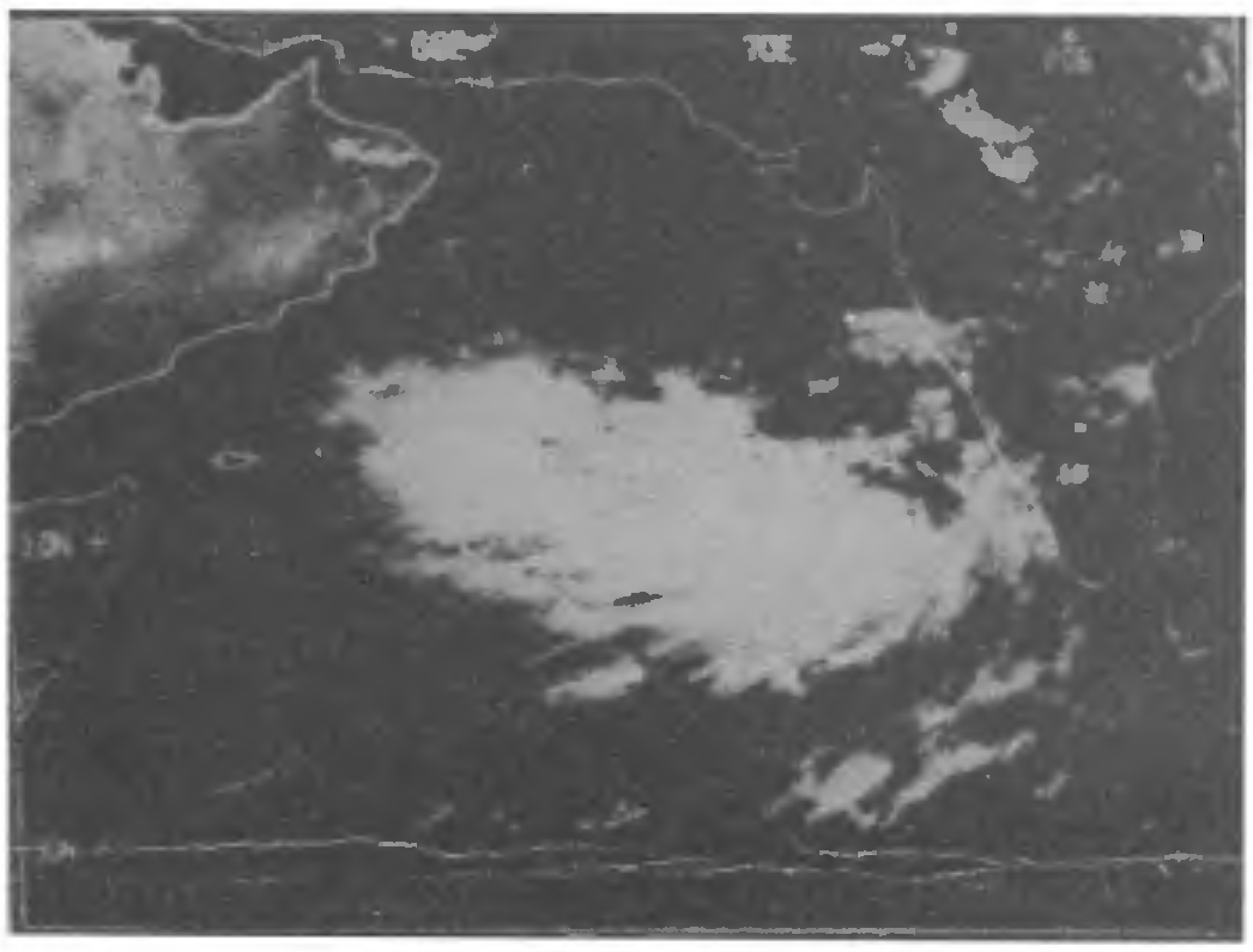
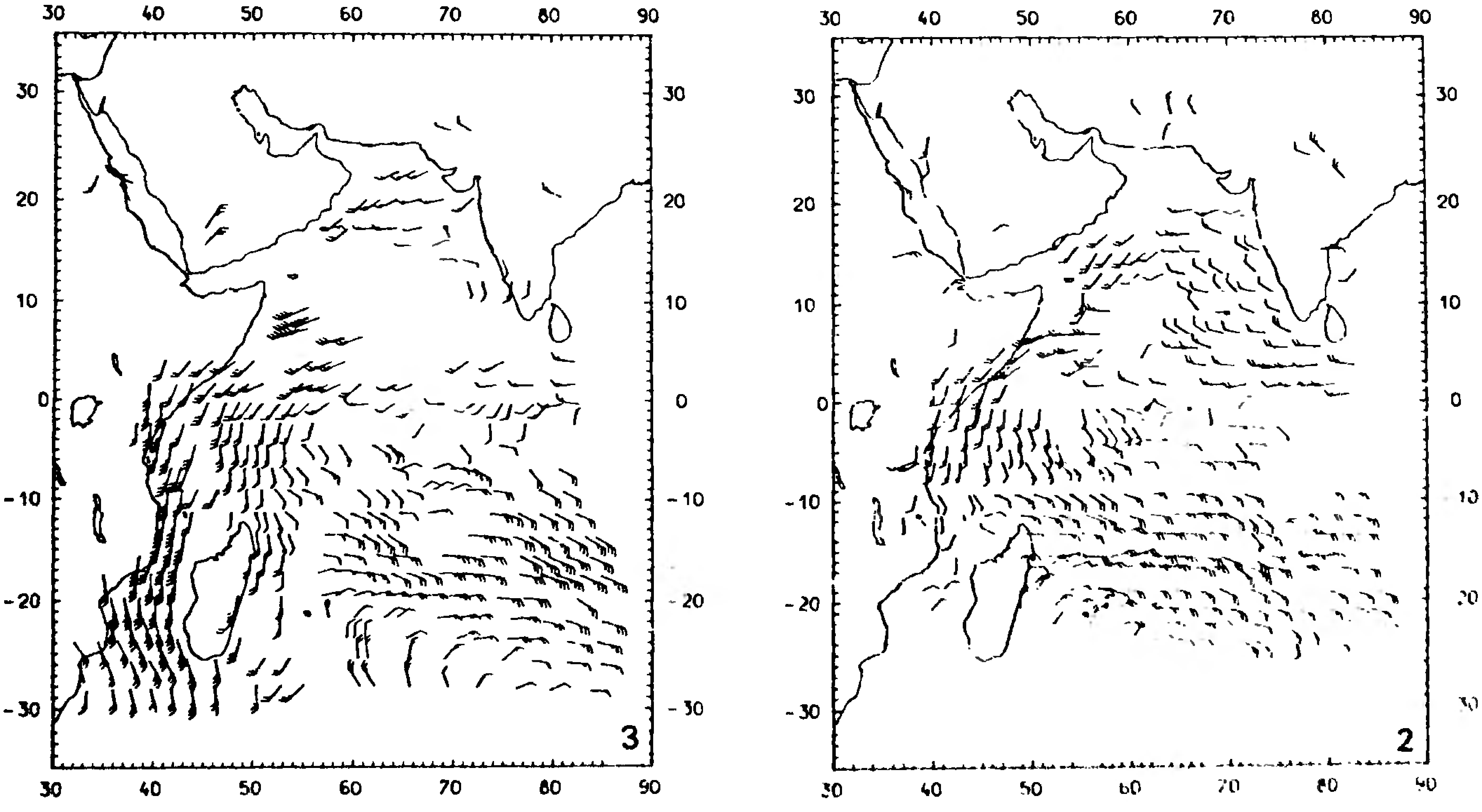


Figure 1. GOES view of Arabian sea on 14 June 1979, at 10.00 GMT.



Figures 2 and 3. 2. Wind vectors determined from cloud displacement on 10 June 1979, at 10.00 GMT. **3.** Wind vectors determined from cloud displacement on 14 June 1979, at 09.30 GMT.

the intensification of cross-equatorial flow and westerlies north of the equator over the Arabian sea thus providing favourable conditions for the formation of tropical disturbance. Intense frontal system as observed on 12 and 13 June over western south Indian ocean played an important role for strengthening of cross-equatorial flow and its spreading towards central and eastern Arabian sea. This provided a favourable environment for the intensification of ITCZ and formation of onset vortex over the Arabian sea which leads to an onset of the monsoon over India[10].

In the present study we have stressed the cause of intensification of the low-level jet, and its effect on the modulation of low-level air circulation over the Arabian sea during onset phase of summer monsoon 1979. It suggests that after the northward passage of cold front to the south of the Mozambique channel, strong southerlies are established in the Mozambique channel within a day or two. It increases the strength of low-level jet and westerlies over the Arabian sea. Thus, strengthening of monsoonal westerlies makes favourable environment for the formation of an onset vortex on the leading edge of the stream. Though an onset vortex is not an indispensible condition for the monsoon's onset, it does form during some of the years and gives onset over India. Thus, satellite-derived low-level winds over the western Indian ocean are useful for monitoring large scale fluctuation of the monsoon circulation over the Arabian sea.

6 December 1985; Revised 1 May 1986

1. Findlater, J., *Q. J. R. Meteor. Soc.*, 1969, **95**, 362.
2. Findlater, J., *Pageoph.*, 1977, **115**, 1251.
3. Raghavan, K., Sikka, D. R. and Gujar, S. V., *Q. J. R. Meteor. Soc.*, 1975, **101**, 1003.
4. Krishnamurti, T. N., Molinari, J. and Hau Lu Pan, *J. Atmos. Sci.*, 1976, **33**, 2350.
5. Anderson, D. L. T., *Mon. Wea. Rev.*, 1976, **104**, 907.
6. Hart, J. E., *Pageoph.*, 1977, **115**, 1263.
7. Cadet, D., Desbois, M., *Mon. Wea. Rev.*, 1981, **109**, 182.
8. Crozet, P., Desbois, M., Semery, A. and Sitbon, P., notes LMD n° 97, 1979.
9. Saha, K. R., *Tellus*, 1970, 22, **4**, 403.
10. Sikka, D.R., Paul, D. K. and Singh, S. V., *FGGE Operations Rep.*, 1980, **9**, 32.

DEVELOPMENT OF KNOCKDOWN RESISTANCE [KDR] AGAINST FENVALERATE IN A DDT-RESISTANT STRAIN OF *ANOPHELES STEPHENSI*

K. V. S. VERMA and S. J. RAHMAN*

Desert Medicine Research Centre, Jaipur Unit,
S.M.S. Medical College, Jaipur 302 004, India.
* *National Institute of Communicable Diseases,*
22-Sham Nath Marg, Delhi 110 054, India.

PYRETHROIDS play an important role in controlling outbreaks of mosquito-borne diseases. The pyrethroids, owing to their fumigant action, cause instant knockdown of the vectors. Synthetic pyrethroids, popularly known as 'emergency insecticides', have been reported to be more effective than natural pyrethroids[1] and can control OP- and OC-resistant strains[2, 3]. These compounds are now being recommended as alternative insecticides in vector control programmes. Keeping in view their high potentiality[2] and quick action[4] selection studies were initiated against an important urban malaria vector *Anopheles stephensi*, using fenvalerate as an experimental compound. While estimating the insecticide susceptibility status of different generations of *A. stephensi* against fenvalerate, it was observed that the test populations of subsequent generations exhibited longer knockdown time against the same concentration of the fenvalerate. This indicated the development of knockdown resistance. To confirm the above observation and generate systematic data on the development of knockdown resistance (KDR) in *A. stephensi* against fenvalerate, the following experimental study was undertaken.

Fourth instar larvae of DDT-resistant strain of *A. stephensi* were taken from NICD insectary and selected against fenvalerate (sumididin) up to 12 generations. The larvae were exposed to 0.5 ppm of fenvalerate. Beyond this concentration, the insecticide got precipitated. At this concentration, the highest mortality (85%) of parent generation (normal generation) was obtained. The insecticide pressure was applied during larval stage in each generation and the development of knockdown resistance was observed in the adults.

Three-day-old freshly fed females of each generation were exposed in 0.5% fenvalerate impregnated papers in the laboratory. Insecticide papers were impregnated using Bushvine method[5]. Knockdown was observed in the exposure tubes, supplied with the W.H.O. test-kit for the estimation of insecticide resistance. The observations were made regularly at 10 min interval till