551.501.776(267.37)

SEQUENCE OF FEATURES IN INSAT CLOUD IMAGERIES OF UNUSUAL BEHAVIOUR OF 9-17 OCTOBER 1998 VORTEX IN ARABIAN SEA

A systematic account of features related to intensity and movement, observed in Insat imageries and synoptic charts, of a vortex over Arabian Sea during 9-17 October 1998 was made in this study. It provided a unique opportunity for watching a vortex nearly in the same pattern throughout its life, longer than a vortex normally spans over Arabian Sea.

A vortex formed over east central Arabian Sea on 9 October 1998 centered at 13.0° N / 70.5° E. It moved northward up to 17.4° N and westward up to 60.8° E by 14 October / 2100 UTC, taking about five days. Past climatological tracks show that tropical cyclones over Arabian Sea that moved away to west of 65° E meridian had very rare chance of recurving to northeasterly direction. But this particular vortex did recurve and hit Gujarat Coast on 17 October / 0300 UTC. The NE movement over Arabian Sea was completed in two days- less than half the time taken in NW movement across Arabian Sea. This recurvature is an anomalous behaviour.

Other unusual behaviour observed with this vortex was that it did not intensify more than T2.5 (maximum sustained winds 35 kt) over a period of eight days in the month of October, a duration obviously longer than life of a tropical cyclones normally spanned over Arabian Sea.

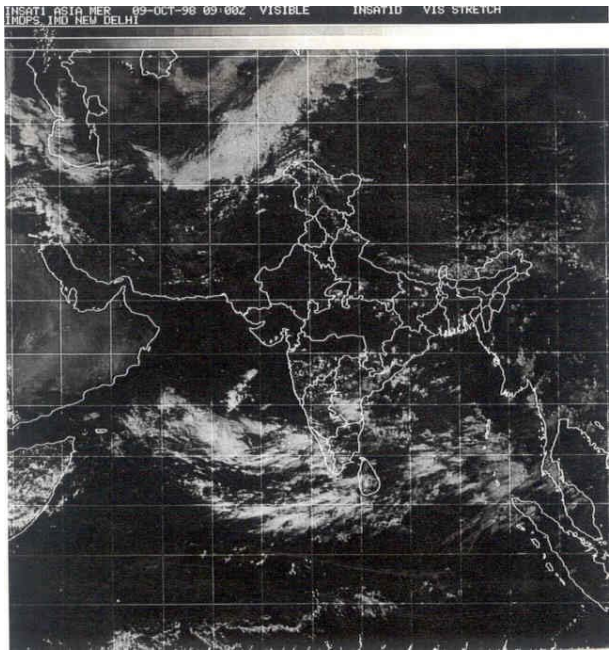

Fig. 1. Vortex in 'band' pattern over east Arabian sea with center at 13.0° N/70.5° E

Present study is to explain these two anomalous behaviour of this vortex using INSAT cloud imageries with the upper level, 500 & 200 hPa, wind circulation analysis maps produced at IMD.

Data and Analysis - (*i*) *Development of Vortex* - A curved band was filled with convective clouds along its entire length by 9 October / 0900 UTC and the associated closed cyclonic circulation was observed to

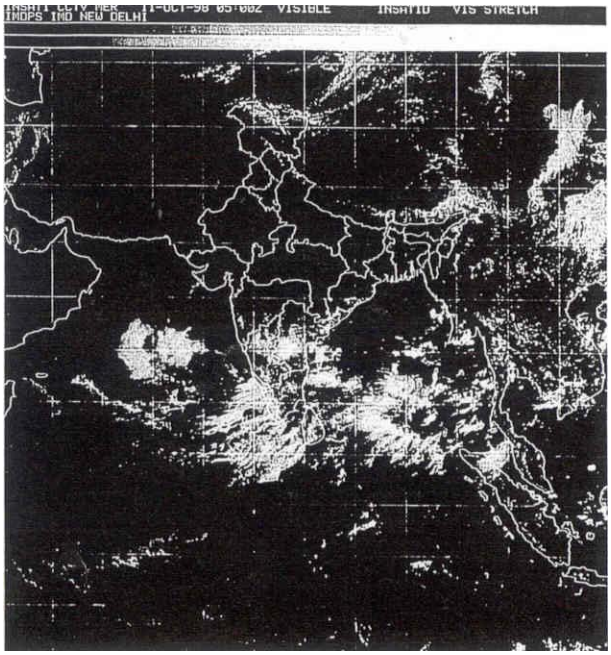

Fig. 2. Vortex in 'shear' pattern having center in low clouds

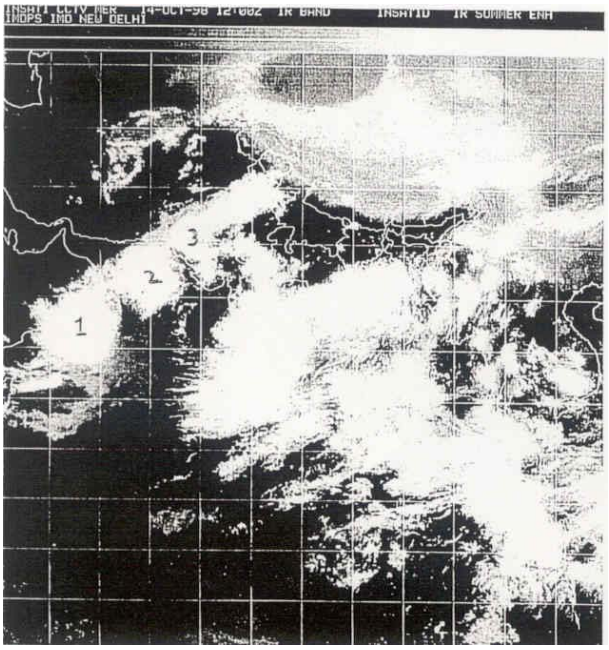

Fig. 3. Vortex as cloud cluster off Saudi Arabia coast. Three clusters aligned along flow ahead of upper westerly trough

have centre near 13° N / 70.5° E and strength T1.0 as estimated by Dvorak Technique (Fig. 1). By 10 October / 1500 UTC the curved band grew organization as shown by the increasing curvature of the band. The convective cloud mass, which was so far located to the south of

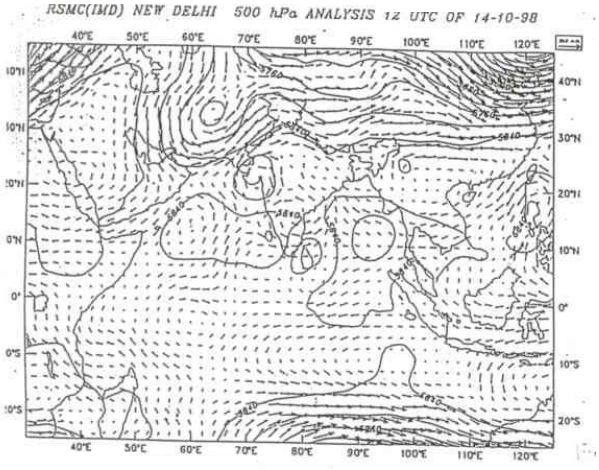

Fig. 4. Vortex over west Arabian Sea close to southern parts of westerly trough

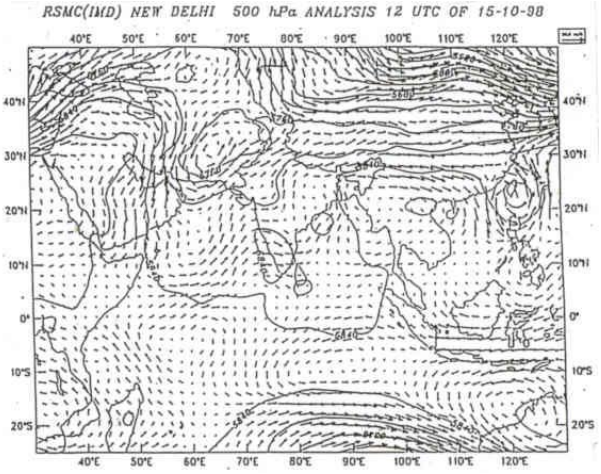

Fig. 5. Vortex forming the southern parts of westerly trough

vortex centre (Fig. 1) shifted to the west on 11 October the amount of convection had decreased and the center of vortex was to the east of convective mass (Fig. 2). Reduction in convective cloud mass was partially due to entrance of the vortex to colder waters, SST lower than 28° C, in the western parts of Arabian Sea. But the convective, cloud mass which was now having circular shape, was closer to centre of vortex amidst low clouds to its east. The centre was at a distance of 1° from the convective cloud mass and hence vortex was of intensity T 2.0 . The organization of various clouds in the vortex region was not of curved band pattern. Obviously there was a change in the organization pattern of 'curved band' type to 'shear' type. The intensity was operationally given as T 2.5 at 12 October / 0900 UTC seeing that the center of vortex amidst low clouds was closer than 0.75° to the convective mass. The vortex was later

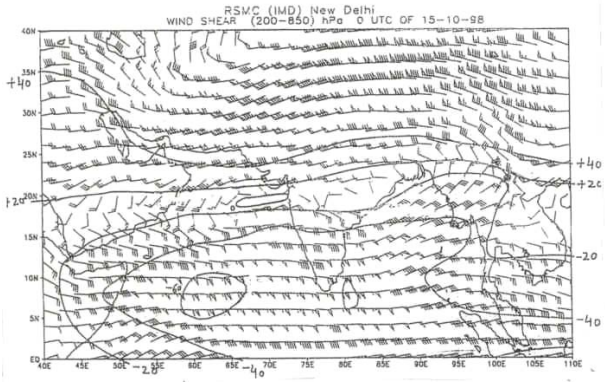

Fig. 6. Wind shear between (200-850) hPa at 0000 UTC of 15 October 1998. Thick lines show isotachs at 20 kt interval. The vortex is amidst wind shears of 20-30 kt over central parts of North Arabian Sea

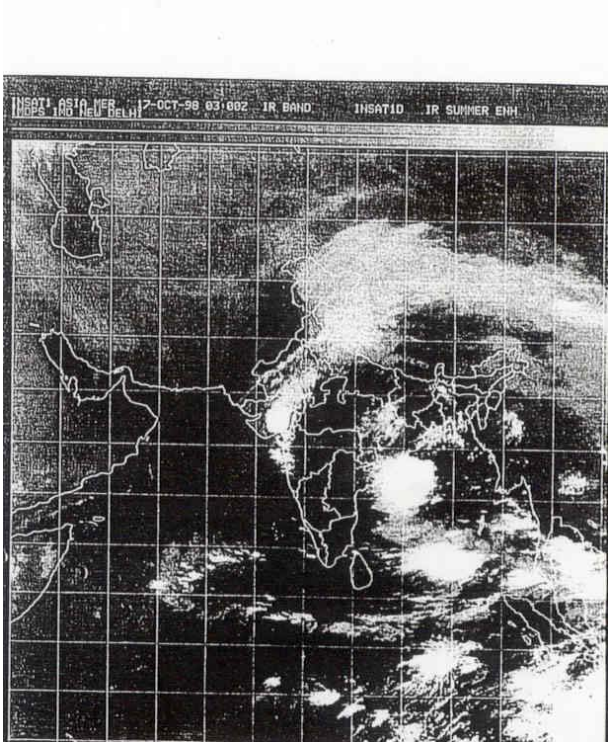

Fig. 7. The cloud cluster over Gujarat shows the vortex with center to the south

operationally estimated weakening from T 2.5 to T 2.0 by 12 October / 1700 UTC. The 'shear' pattern was indicative of strong vertical wind shear over the vortex region and rapid intensification was not favoured neither on 13 nor on 14 October. At 13 October / 1200 UTC the increasing distance, more than 0.75°, between dense overcast and the vortex center, 16.2° N/64.0° E was pointing to further weakening and the vortex was estimated to be of T 1.5 intensity.

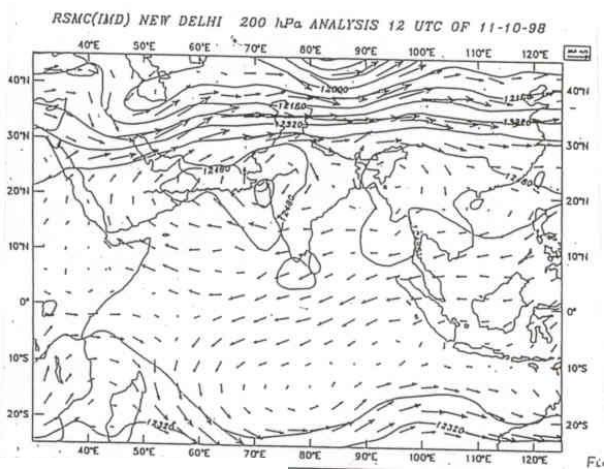

Fig. 8. Winds at 200 hPa level on 11 October 1998 at 1200 UTC. The vortex is beneath the easterly at 14.5° N/66.0° E

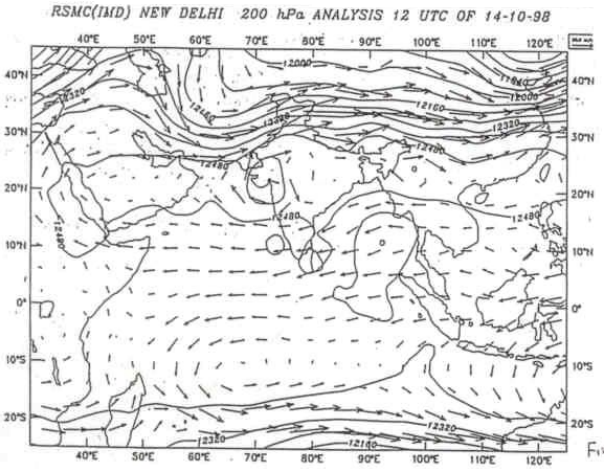

Fig. 9. Trough in westerlies at 200 hPa on 14 October/1200 UTC extending southwards to 26.0° N Lat.

This observation onwards, there was increasing upper level outflow as revealed by cirrus curved bands oriented in NE-SW direction. It was indicative of strong unidirectional upper winds. In addition to cirrus outflow, the weak broken convective band also aligned in NE-SW direction. These features were showing approach of a westerly trough from west. The outflow further increased on 14 October. Under the preponderance of trough in westerlies there appeared a NE-SW oriented band of convective clouds having three clusters in it. The clusters were in the forward part of westerly trough (Fig. 3) which had extended southward and the vortex under study was close to constitute its southern part (Fig. 4). By 15 October / 0300 UTC middle and northern cluster had

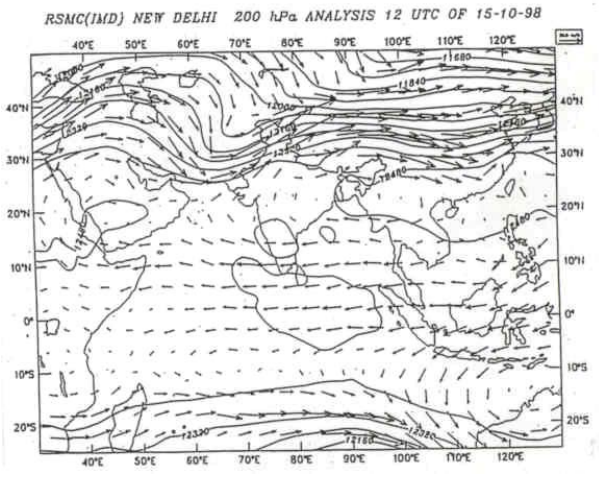

Fig. 10. The trough in westerlies breaking the subtropical high nearly along 60° E Long. at 200 hPa on 15 October/1200 UTC into two cells

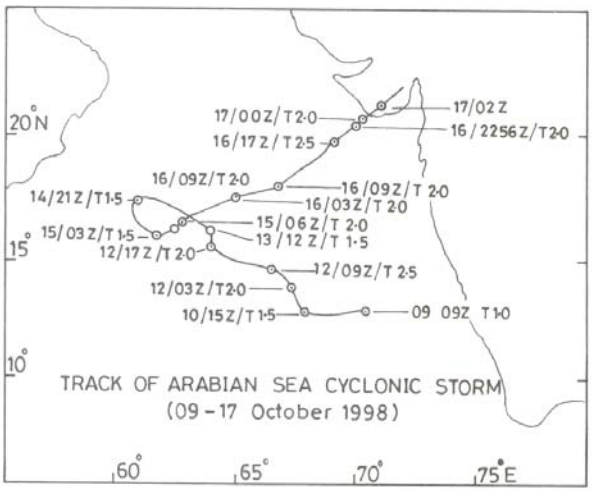

Fig. 11. Track of Arabian Sea cyclonic storm during 9-17 October 1998

merged to form one elongated cluster along the forward part of westerly trough and then vortex was itself constituting the southern part of trough (Fig. 5) . Since the trough in westerlies was moving eastward, the vortex started recurving to NE direction as observed in 0300 UTC imagery of 15 October. As the vortex was being drawn over northern part of Arabian Sea, where vertical wind shears were much less than over southern parts (Fig. 6) the clouds kept their organization in 'shear' pattern with vortex center still at a distance more than 0.75° away to the east of dense overcast. The intensity of vortex increased to T 2.0 at 0600 UTC/ 15 October there was no further intensification of the vortex on 15 October.

The composition of vortex, as regards clouds, did not change on 16 October also except that convective dense overcast shifted from west to the north of vortex center, which was now moving NE wards. This was in conformity with a vortex in 'shear' pattern moving in NE direction. In 16 October / 1400 UTC imageries this convective cloud mass was nearly circular. The size of the circular cloud mass increased from 1400 to 1700 UTC. Whereas the distance between the center, which of course was not very distinct due to poor appearance of non-convective clouds in IR imagery, and the dense overcast to the north was decreasing. At 1700 UTC / 16 October it was inferred that this distance has reduced to less than 0.75°. So the intensity of the vortex was increased to T 2.5. By 0000 UTC / 17 October nearly entire convective cloud mass over Gujarat. But the center of vortex was still over sea near to Veraval. The distance between the center of vortex and dense overcast was estimated to be more than 0.75° and therefore, the intensity of vortex was reduced to T 2.0. Imagery at 17 October / 0300 UTC showed that vortex had made land fall at Veraval on 17 October (Fig. 7) between 0200 & 0300 UTC and further moved in NE direction over land. From the above discussion on development of vortex, it is clear that during most of its life period the vortex had 'shear' type pattern in cloud organization and 'curved band' type pattern only in the beginning. During its movement in NW direction it was flowing through strong wind shear of magnitude about 40 kt. Therefore, the intensification of vortex was not favoured. After recurvature to NE direction the vortex was flowing through westerly vertical wind shear of magnitude over 20 kt. On comparision with normal shear pattern in the month of October, we find that shears of 20 kt were equally detrimental to fast intensification of vortex as the shorter (about 2 days) span over Arabian Sea in its NE movement.

(*ii*) *Movement of vortex* - On 11 October / 1200 UTC the vortex center at 14.5° N/ 66° E was over the central parts of Arabian Sea. The associated cyclonic circulation extended up to middle troposphere with overlying easterly winds at 200 hPa (Fig. 8). The vortex was moving largely in northwesterly direction, seemingly following the steering provided by 200 hPa flow where sub tropical ridge axis was running mainly along 20° N Lat. These conditions prevailed on 12 & 13 October also. In addition, on 13 October a trough in westerlies with axis along 60°E at 200 hPa and extending up to 30° N, appeared. This trough intensified on 14 October / 1200 UTC and one axis was oriented in NNE-SSW direction and extended down to 26° N (Fig. 9). By now the vortex had reached 17.4° N /61.7° E location as the sub tropical ridge was running along 20° N Lat. The vortex center was closer to ridge axis and to the east of southern part of

trough axis at 200 hPa. By 15 October / 1200 UTC (Fig. 10) the trough had further intensified with this extension of trough, the sub tropical high was divided into two cells, one over east Arabian Sea and another over Saudi Arabia & adjoining west Arabian Sea and created a col region over the NW parts of Arabian Sea where the vortex was centred. The vortex recurved in NE direction, under the influence of anticyclonic cell over east Arabian Sea, and merged with the trough in westerlies to become its southern part at 500 hPa (Fig. 11). After this, the vortex was moving eastward along with trough in westerlies. This NE recurvature of the vortex was first observed at 0300 UTC/ 15 October. Before starting its NE movement, the vortex had undergone a looping motion forced, most obviously, by alternate influence of west and east anticyclonic cells over Arabian Sea. With the merge of tropical vortex and the trough in westerlies, the later had gathered large amplitude (Fig. 11). By large this vortex maintained its own closed circulation below 500 hPa and on 17 October / 0300 UTC it reached Gujarat coast to make landfall close to Veraval.

The vortex which was over 70° E meridian (Fig. 11) on 9 October reached its western most meridian 60.8° E by 14 October in its northwest forward journey across Arabian Sea- thus taking five days. While in its northeast backward journey it reached same 70° E meridian by 17 October 1998, thus taking only 2 days. The easterly winds to the south of subtropical ridge at 200 hPa level are of the same magnitude as the westerlies to the north. The forward journey was slower because it was being steered by the easterly winds south of sub tropical ridge of 200 hPa. The backward journey was faster as the vortex became lower part of trough in westerlies. The steering flow south of sub tropical ridge normally provides a speed of movement of the order of 10-20 km/hr whereas troughs in westerlies normally travel about 30-60 km/hr. This is in conformity with the time taken by the vortex under study in its up & down journey over Arabian Sea.

We note from this case study that :

With the sole help of INSAT cloud imageries, we are able to find here that vortex in northwest movement during 9-14 October and in northeast movement during 14-17 October could not intensify due to its passage through strong vertical shear flow. And unusual recurvature from its northwest movement to northeast movement was helped at 60.8° E meridian with the breaking of subtropical ridge into two cells by the deep trough in westerlies. Also after recurvature, the vortex moved very fast because it had become the lower part of westerly trough.

BRIJ BHUSHAN
H. V. GUPTA
A. M. SUD

Meteorological Office, New Delhi - 110 003, India
(9 *November 2001, Modified 11 October 2002*)