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Spatial and temporal homogeneity in a half-hourly sequence of satellite-derived upper winds

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सार — 2 जून 1985 को ग्री.मा.स. 0300 तथा 1030 बजे के बीच भारतीय प्रायद्वीप के आसपास सात इनसैट-। बी प्रतिबिम्बों द्वारा तीन महासागरीय सैक्टरों में मेघ के गति मार्ग ज्ञात किए गए हैं। इस थोड़े से समय में प्राप्त मेघ गतिसदिश (सी एम वीस) की स्थानिक व अस्थायी एकरूपता की जांच की गई है।

पवन वेग के रूप में 2° वर्गों पर आंकड़ों के विश्लेषण से 42 प्रतिशत वर्गों पर श्रेष्ठ दिशापूरक सम्बद्धता प्राप्त होती है। तथा इसका अभाव केवल 13 प्रतिशत है। कुछ चुने हुए वर्गों की आगे और जांच करने पर ज्ञात होता है कि जहां पवन दिशा अनुकूल होती है, वहां पवन की गति तथा ऊंचाई भी अनुकूल पाई जाती है।

कुछ चुने हुए स्थानों पर मेघगति मार्ग के समय अनुक्रम से यह तथ्य और अधिक स्पष्ट होता है कि मेघ क. गतिमार्ग सिनॉप्टिक प्रवाह का प्रतिनिधित्व करता है या नहीं।

ABSTRACT. Cloud motion vectors were derived over three oceanic sectors around the Indian Peninsula with seven INSAT-1B image pairs on 2 June 1985 between 0300 and 1030 GMT. The spatial and temporal homogeneity of the CMVs obtained over this small period is examined. Analysis of data over 2° squares in the form of wind roses shows excellent directional coherence in 42% of squares, and a lack of it in only 13%. A further examination of selected squares shows that where the wind directions agree well, the wind speeds and heights also tend to agree. Time series of CMVs at selected grid points throw further light on whether a CMV is representative of the synoptic flow or not.

1. Introduction

An automated procedure for the extraction of Cloud Motion Vectors (CMV) from two successive INSAT-1B images was introduced at the Meteorological Data Utilization Centre (MDUC), New Delhi on 1 November 1984. Since then, CMVs are being derived on an operational basis at 0300 and 0600 GMT daily over three oceanic sectors around the Indian Peninsula, *viz.*,

Arabian Sea (AS)	24°-10°N, 59°-73°E
Bay of Bengal (BB)	21.5°-8°N, 80°-93.5°E
Indian Ocean (IO)	10°N-3°S, 72°-85°E

The pattern-matching technique and related procedural details have been discussed by Kelkar and Khanna (1986) who have found the INSAT CMVs to be in general agreement with the upper wind flow pattens drawn on the basis of conventional observations.

A rigorous inter-comparison between CMVs and radiosonde winds is not possible because of an almost total absence of 'ground' truth over the oceans. The radiosonde winds may not themselves be regarded as entirely error-free. The question which then arises is how representative in terms of time and space is a cloud motion vector derived at a given place, time and heights ? In the present exercise, which attempts to seek an answer, CMVs were derived for the sectors AS, BB and IO with the following seven pairs of INSAT-1B images of 2 June 1985; 0300/0330, 0530/0600, 0800/0830, 0830/0900, 0900/0930, 0930/1000 and 1000/1030 GMT. The spatial and temporal homogeneity of the CMVs obtained over a small span of seven and a half hours, has been examined critically.

It must be noted here that it is not the practice at MDUC to subject the CMV field to any kind of smoothing. The automated procedure does not also have any bias towards the selection of tracers in areas where uniform characteristics are present and the exclusion of areas where chaotic cloud motions exist, as in methods used elsewhere (Wylie and Hinton 1981). The present paper is, therefore, not limited to considerations of wind variability of the synpotic scale, but applies also to that of the mesoscale. This approach to the problem of time and space variability of winds is much simpler and easier than conducting an experiment involving the launch and tracking of several hundred balloons at 30-minutes intervals from closely located sites (Jasperson 1982).

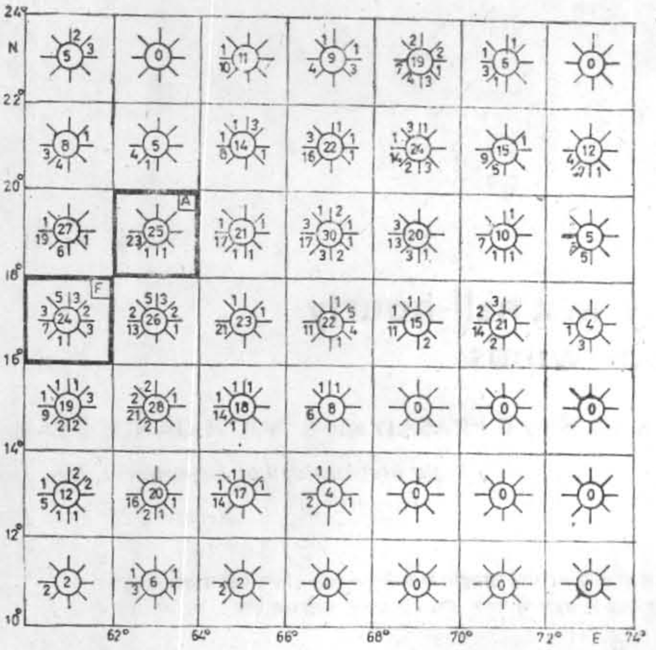

Fig. 1. Distribution of CMVs over sector 'AS' at 850 mb with respect to direction

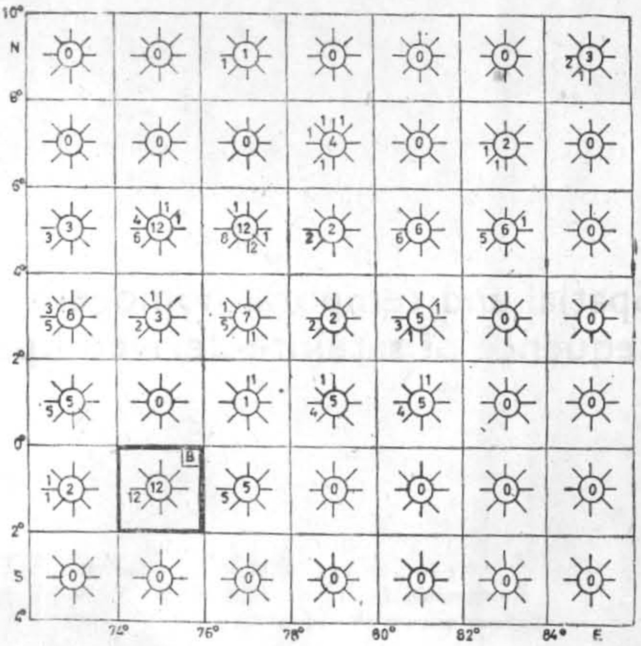

Fig. 2. Distribution of CMVs over sector 'IO' at 850 mb with respect to direction

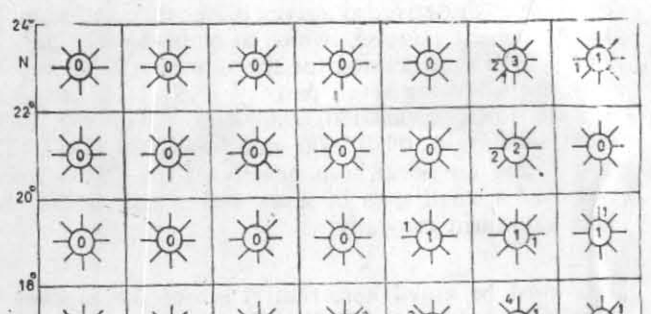

Fig. 3. Distribution of CMVs over sector 'AS' at 500 mb with respect to direction

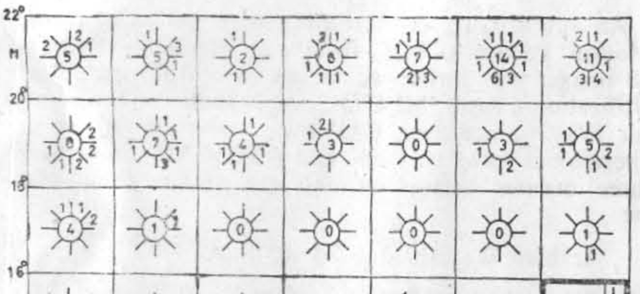

Fig. 4. Distribution of CMVs over sector 'BB' at 500 mb with respect to direction

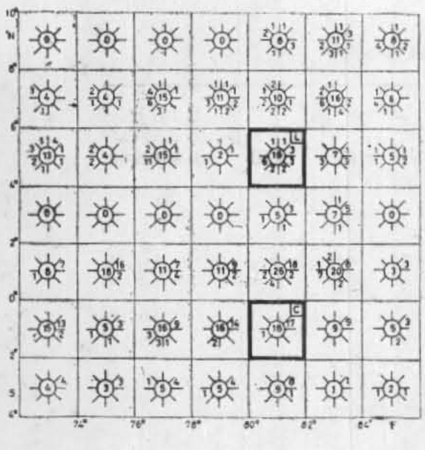

Fig. 5. Distribution of CMVs over sector 'IO' at 500 mb with respect to direction

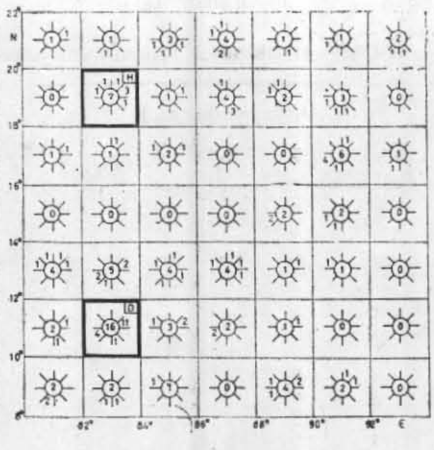

Fig. 6. Distribution of CMVs over sector 'BB' at 200 mb with respect to direction

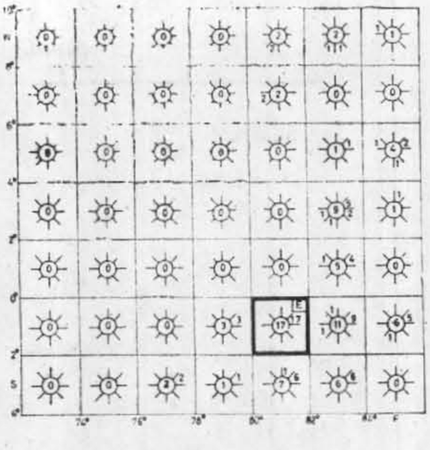

Fig. 7. Distribution of CMVs over sector 'IO' at 200 mb with respect to direction

2. Circulation pattern of 2 June 1985

On 2 June 1985, the conventional 850 mb wind analysis showed a cyclonic circulation in the neighbourhood of Bangladesh. A trough from this circulation extended south-southwestwards into the central Bay of Bengal. A seasonal trough-line lay in the northeast to southwest direction over Arabian Sea. There was a westerly flow south of Sri Lanka.

At the 500 mb level, the mid-tropospheric shear line ran across the Peninsula along 14°N and east-northeastwards into the east-central Bay. There was anticyclonic flow to the north of it and westerly to southwesterly monsoon flow to the south of it.

Strong easterlies of jet strength prevailed over the tip of the Indian Peninsula at 200 mb. The speeds were seen to decrease northwards, to light winds in the ridge across north India.

3. Directional coherence

As per the prevailing practice at MDUC, the CMVs were assigned to 850, 500 or 200 mb levels depending upon whether their heights fell in one of the ranges, <3, 3 to 8, or >8 km. Thus, a three-level CMV pattern was generated for each sector. The seven CMV data sets (one for each image pair) for a particular level and sector were then considered together and analysed over two-degree latitude-longitude squares. It is to be expected that where the spatial variation within a 2° square is small and there is little temporal variation over the 7½-hour period, all the CMVs in that square would be nearly identical. Wind direction was analysed in detail because it is the primary input to streamline analysis. For each square, a simplified 45° wind rose-like distribution was derived, disregarding the wind speed. Figs. 1-7 show the wind roses for each sector and level separately, except for AS-200 mb and BB-850 mb, over which the tracers were insufficient for such analysis. The total number of CMVs in a square, classified into the wind rose, is written at the centre of the pattern. The number of the CMVs falling in the eight different classes of direction, *viz.,* N-NE, NE-E, E-SE......etc are wirtten in the corresponding sectors of the wind rose.

A significant feature of Figs. 1-7 is that in a large number of squares, the CMVs show a certain preferred direction. For example, over sector IO at 500 mb (Fig. 5), most CMVs are northeasterly to easterly in the area south of 4°N latitude and they are southwesterly to westerly in the region to the north of it. Over the same sector, but at 200 mb (Fig. 7) the CMV field is predominantly northeasterly to easterly. Over sector AS at 850 mb (Fig. 1), and over Sector IO at the same level (Fig. 2), the flow is seen to be generally southwesterly everywhere. This is characteristic of the wind patterns prevailing around the neighbourhood of India at the time of the arrival of the southwest monsoon into the country.

A coherent wind-rose pattern is indicative of a high degree of spatial as well as temporal homogeneity of the CMVs. On the other hand, a diffused wind-rose pattern could be attributed to either a veering or backing of the wind at a given point with time, or to sharp curvature of the streamlines within the 2° square area. A third possibility is the presence of mesoscale circulations which are not representative of the large-scale flow.

The CMVs of 12 typical 2° squares, showing a wide variety of wind-rose patterns, were chosen for a closer scrutiny from these points of view. The squares are designated by the letters A to L for convenience.

TABLE 1

Distribution of CMVs in selected 2° squares with respect to height

Square	Height range (km)											Total No. of CMVs in squares
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9.10	>10	
A	—	25	—	—	—	—	—	—	—	—	—	25
B	—	7	5	—	—	—	—	—	—	—	—	12
C	—	—	—	—	—	2	7	9	—	—	—	18
D	—	—	—	—	—	—	—	—	13	3	—	16
E	—	—	—	—	—	—	—	—	17	—	—	17
F	4	18	2	—	—	—	—	—	—	—	—	24
G	—	—	—	4	3	2	—	—	—	—	—	9
H	—	—	—	—	—	—	—	—	4	1	2	7
I	—	—	—	2	3	4	3	1	—	—	—	13
J	—	—	—	7	8	5	3	2	—	—	—	25
K	—	—	—	3	1	4	6	3	—	—	—	17
L	—	—	—	7	8	3	—	—	—	—	—	18

4. Homogeneity of CMV speeds and heights

Squares A to E (Figs. 1, 2, 5-7) are characterised by the fact that most CMVs within them lie in one octant, the proportions being 23 out of 25, 12/12, 17/18, 11/16 and 17/17 respectively.

Table 1 shows for squares A to L the distribution of CMVs with respect to their assigned heights. In square A, all the 25 CMVs had a height of 1-2 km. In square B, 7 out of 12 had 1-2 km height. In square C, 16 out of 18 CMVs were in the 6-8 km height range. Square D had 13 out of 16 CMVs with 8-9 km height and square E had all the 17 with 8-9 km height.

In Table 2 is shown the squarewise distribution with regard to wind speed. In square A, 19 out of 25 CMVs had speeds of 10-20 knots, while in square B all the CMVs were in this speed range. In square C, 14 out of 18 had a speed of 30-40 knots. In square D, 9 out of 16 CMVs had speeds of 40-50 knots. In square E, 12 out of 17 were in the 30-40 knots speed range.

The above statistics show that the cloud tracers in square A to E constituted a homogeneous set in each square, resulting in the extraction of CMVs with largely similar properties and representative of the synoptic wind flow. Of all the wind roses shown in Figs. 1-7, 42% were of this type.

In contrast with the squares A to E, discussed above, three squares, *viz.*, F, G and H (Figs. 1, 3 and 6) are characterised by an absence of any preferred wind direction. Only 13% of the wind roses were of this type. Squares designated I to L (Figs. 3, 4 and 5) are intermediate cases showing a weak tendency of the CMVs to get grouped within one octant.

TABLE 2

Distribution of CMVs in selected 2° squares with respect to speed

Square	Wind speed range (kt)					Total No. of CMVs in squares
	0-10	10-20	20-30	30-40	40-50	
A	2	19	4	—	—	25
B	—	12	—	—	—	12
C	—	—	4	14	—	18
D	—	—	1	5	9	16
E	—	—	5	12	—	17
F	1	7	16	—	—	24
G	2	1	5	1	—	9
H	6	—	—	—	1	7
I	—	9	3	1	—	13
J	3	4	9	8	1	25
K	3	6	2	6	—	17
L	6	4	3	5	—	18

Table 1 shows that in these squares, the tracer heights have a large scatter except in F and L. From Table 2, it is seen that correspondingly, the wind speeds also lack uniformity here except in square I.

It should be remembered here that what are called 500 mb CMVs actually relate to a set of tracers drifting at various heights ranging from 3 to 8 km. This is the region of changeover from low level westerlies to high level easterlies in the monsoon regime. The non-uniform characteristics of the CMVs within the squares, G, I, J and K are thus due to a clubbing together of CMVs on either side of the level of non-divergence, which is around 500 mb.

5. Temporal continuity

In the automated procedure used by MDUC, the possibility of CMV extraction is considered at 225 points (15×15 grid) over an oceanic image sector AS, BB or IO. The likelihood of a CMV being derived repeatedly at a given grid point in a sequence of half-hourly images, depends upon the type, life-time and speed of movement of the tracer.

The temporal homogeneity of CMVs in the 7½-hour period under consideration was examined at certain grid points within the squares A to L with the exception of J which did not have suitable data. The results are plotted in Fig. 8. Quite evidently, the grid-points in squares A to E have a high degree of continuity from one observation time to another in respect of speed, direction as well as height.

The presence of a mesoscale circulation in square F is also indicated by the time series of CMV at two different grid points within it. Other squares show sudden changes in CMV height suggesting that either the tracers underwent a development or dissipation processs or that the tracers tracked at different times were of different type (*e.g.*, G and I). Such a possibility is also associated with a strengthening or weakening of winds with time at certain grid points (*e.g.*, J, K and L).

6. Concluding remarks

The present analysis of half-hourly INSAT CMVs has shown that over a 7½-hour period, 42% of the 2° square areas had a space and time homogeneity of CMVs of a very high order. Only 13% of the squares did not exhibit any homogeneity, and these are mostly at the 500 mb level. If, for the purposes of synoptic analysis, mesoscale features need to be filtered out, it would be desirable to derive CMVs with two or more successive image pairs and reject those which are discontinuous in time.

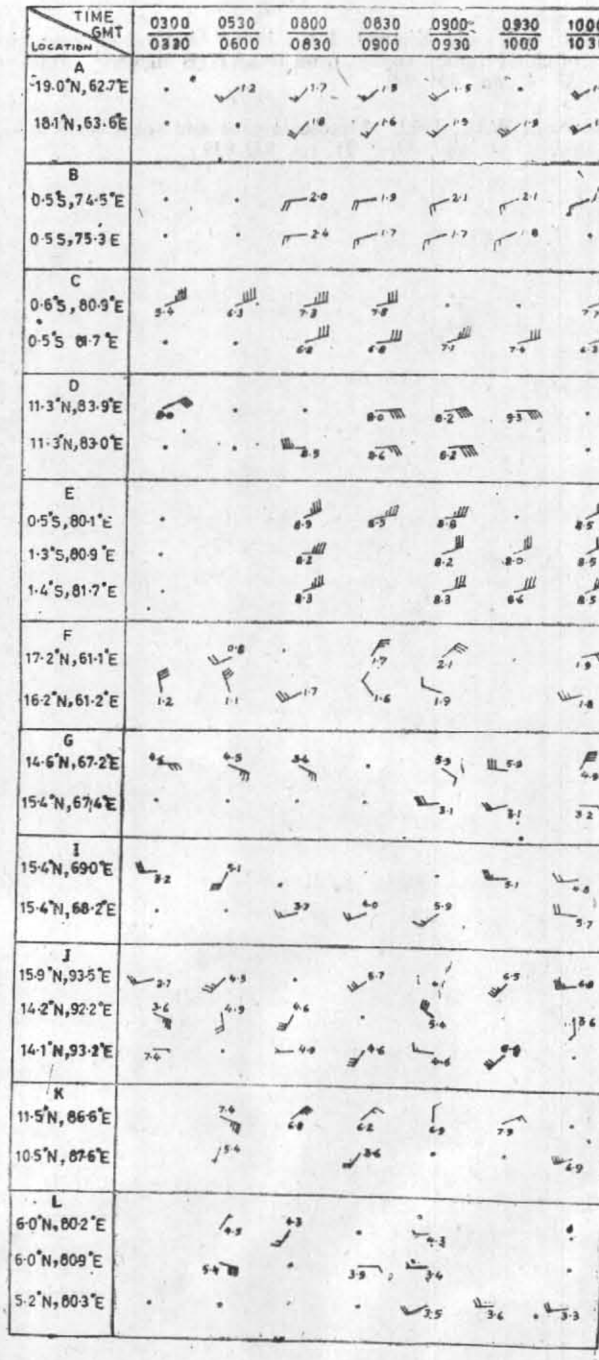

Fig. 8. Temporal variation of CMVs in selected squares (height is given in km)

Low-level CMVs (700 mb), over the Indian Ocean area computed from GOES-IO imagery during the FGGE and MONEX period were studied by Wylie and Hinton (1981, 1982) and compared with ship observations. They estimated that during May-July, surface winds over the ocean deduced from CMVs would have accuracies of 22° in direction and 2.6 m sec^{-1} in speed after removal of the mean shear. They also found that autocorrelations between CMVs were 0.85 and 0.66 in the u and v components respectively for a separation of 3° Lat./Long., and as low as 0.69 and 0.50 respectively for a separation of 6°. This result also strongly supports the need for a judicious decision on whether a given CMV is representative of the synoptic-scale flow or not.

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