Mausam, (1982), 33, 2, 249–254

551.5 : 551.507

Satellite study of western disturbances

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(*Received 29 March 1979*)

सार — उत्तर-पश्चिम भारत और समीपवर्ती क्षेत्र में शीत काल (नवम्बर-मार्च) में पश्चिम से आने वाली पछुवा हवाओं का अध्ययन भूउपग्रह से ली गई 10 वर्ष की मेघ-बिम्बावलियों की सहायता से किया गया है । इनसे यह दर्शाया गया है कि तीन अलग-अलग प्रकार की मेघ राशियां ज्ञात की जा सकती हैं । इन में से सबसे अधिक वे सामान्य मेघाच्छन्न विशेष आकार रहित मेघ राशियां हैं जो कि 25°-36° उ०, 40°-50° पू० की पेटी में बनती है और पूर्व की ओर चलती हुई उत्तर-पश्चिम में पहुंचती हैं । ये भूमध्यसागर से उ० पू० की ओर गमन करने वाले अतिरिक्त उष्ण कटिबंधीय अवदाबों के द्वितीयकों (गौण अवदाबों) से संबंध होती है । ये द्वितीयक तंत्र सामन्यतः फारस की खाड़ी–कालासागर क्षेत्र में बनते हैं और पू० उ० पू०/ पूर्व की ओर बढ़ते हुए विरल आंकड़े वाले एक क्षेत्र (मध्य पूर्व) से गुजरते हैं । इस प्रकार सिनॉप्टिक चार्टों पर इनसे संबंद्ध कभी कभी इनका अनुसरण करना कठिन हो जाता है । ये अधिकांशतः थोथले तंत्र होते हैं । जो कि 700 मि० बार से ऊपर नहीं बढ़ते । इनसे संबद्ध मेघ राशियों का अध्ययन यह दर्शाते हैं कि वे अच्छी तरह संगठित रहती है और उनका क्रमवद्धरूप से अनुसरण किया जा सकता है । ये फारस की खाड़ी क्षेत्र से इस देश में लगभग 2 दिन में पहुंच जाती है और कभी-कभी उ० पू० भारत पर प्रबल हो जाती है । इसलिए ऐसे तंत्रों के पूर्वानुमान के लिए उपग्रह से लिए गए मेघ छायाचित्र अधिक सहायक प्रतीत होते हैं ।

ABSTRACT. Study of western disturbances approaching NW India and neighbourhood during winter period (November-March) has been made with the help of satellite cloud imageries of 10 years. It has been shown that three distinct types of cloud masses could be detected, of which the most common ones are the overcast shapeless cloud masses forming in the belt 25 deg.-35 deg. N, 40 deg.-50 deg. E and approaching NW India moving eastward. They are associated with the secondaries of the extra-tropical depressions moving NE'ward from the Mediterranean. These secondary systems generally form in the Persian Gulf-Black Sea region and move ENE/E'wards over an area (Middle East) of generally sparse data, thus making it difficult sometimes to follow them on synoptic charts properly. These are mostly shallow systems not extending above 700 mb. The study of cloud masses associated with them shows that they remain well organised and could be followed systematically. They reach the country in about 2 days' time from the Persian Gulf area and sometimes strengthen when over NW India. For the prediction of such systems, therefore, satellite cloud photographs seem to be of great help.

1. Introduction

It is well known that majority of western disturbances affecting NW India approach from the west as weak systems. The lack of data over the Middle-East and the hilly terrain over which they pass, make it very difficult to forecast their movement and strength. Only a few strong ones can be traced on synoptic charts systematically. And even in these cases, the experience is that their organisation changes so fast as to take the forecasters by surprise (Singh *et al.* 1977). A perusal of satellite cloud pictures of western disturbances, however, reveals that clouds show better continuity and indicate the movement and strengh of the system better than the synoptic charts, particularly in those cases where the system is not very strong and organisation on synoptic charts is poor. It is these cases which really cause great problem for the forecasters. Hence in the present paper an attempt has been made to study the approach of weak western disturbances over NW India from the Middle-East with the help of satellite cloud imagery.

Bhaskara Rao and Morey (1971) classified the cloud patterns associated with western disturbances into five broad categories and discussed the synoptic situations generally associated with them. We scrutinised satellite cloud pictures for 10 years and found that cloud imageries can be classified into three broad categories:

1. Organised system (Fig. 1) with banding sructure and vortex which are generally associated with well developed extra-tropical depressions (Anderson 1966).

TABLE 1

Position of first organisation over Middle-East (West Zone) and occurrence over India and neighbourhood (East Zone)

Date	West zone: Cloud mass Lat. (°N)	West zone: Cloud mass Long. (°E)	West zone: Approx. centre Lat. (°N)	West zone: Approx. centre Long. (°E)	Date	East zone: Cloud mass Lat. (°N)	East zone: Cloud mass Long. (°E)	East zone: Approx. centre Lat. (°N)	East zone: Approx. centre Long. (°E)	No. of days
12 Oct '69	35–40	44–55	37	48	14 Oct '69	North of 32 N	East of 70E	North of 32N	East of 70E	2
29 Oct '69	25–32	50–60	28	55	30 Oct '69	35	62–68	35	65	1
18 Nov '69	25–34	38–50	28	44	20 Nov '69	Over west Himalayas		35	68	2
15 Dec '69	28–38	45–52	33	50	16 Dec '69	34–38	60	36	60	1
25 Dec '69	30–35	45–51	33	50	27 Dec '69	30–35	65–75	33	70	2
10 Jan '70	28–33	45–55	30	50	12 Jan '70	Around 30	65–75	30	70	2
21 Jan '70	30–35	45–53	33	48	22 Jan '70	Around 30	65–75	30	70	1
26 Jan '70	25–30	45–55	28	50	28 Jan '70	22–30	65–75	26	70	2
11 Feb '70	30–35	40–50	32	45	13 Feb '70	30–35	67–74	32	72	2
15 Feb '70	28–33	50–59	30	52	17 Feb '70	20–30	70–80	26	75	2
21 Feb '70	25–32	50–60	30	55	22 Feb 70	25–30	65–80	28	72	1
12 Jan '71	28–38	40–50	33	45	14 Jan '71	North of 28 N	70–80	30	75	2
30 Jan '71	30–40	45–52	35	48	1 Feb '71	25–35	65–74	30	70	2
5 Feb '71	30–40	45–55	35	50	7 Feb '71	—	—	30	70	2
16 Feb '71	30–40	42–50	35	46	17 Feb '71	—	—	30	65	1
22 Feb '71	25–31	52–60	28	55	23 Feb '71	—	—	30	65	1
9 Nov'71	30–35	45–55	33	50	11 Nov '71	North of	—	30	70	2
17 Nov '71	30–35	35–45	33	40	20 Nov '71	38–45	65–75	41	70	3
27 Dec '71	—	—	30	50	30 Dec '71	30–40	60–70	35	65	3
10 Jan '72	—	—	30	50	12 Jan '72	—	—	30	70	2
25 Jan '72	—	—	30	40	27 Jan '72	25–30	65–70	28	68	2
13 Feb '72	—	—	35	45	15 Feb '72	above 35N	70	36	70	2
20 Mar '72	—	—	30	50	22 Mar '72	30–35	65–75	33	70	2
5 Dec '72	30–40	48–55	35	51	7 Dec '72	30–40	65–70	35	68	2
1 Jan '73	—	—	25	48	4 Jan '73	20–30	60–70	28	65	3
9 Jan '73	30–35	45–55	32	50	11 Jan '73	30–35	65–75	33	70	2
14 Jan '73	25–35	50–60	30	55	17 Jan '73	30–35	65–75	32	70	3
20 Feb '73	—	—	30	50	22 Feb '73	25–35	60–70	30	65	2
2 Mar '73	25–38	45–55	32	50	4 Mar '73	—	—	30	70	2
15 Mar '73	—	—	30	50	17 Mar '73	25–35	70–80	30	75	2
16 Jan '74	—	—	30	50	18 Jan '74	26–35	65–75	31	70	2
22 Jan '74	—	—	30	50	24 Jan '74	—	—	30	68	2
29 Jan '74	28–32	40–53	30	46	31 Jan '74	28–35	65–75	32	70	2
1 Dec '74	30–35	60–65	33	68	3 Dec '74	25–30	75–85	28	80	2
12 Dec '74	—	—	30	50	14 Dec '74	28–35	70–75	30	72	2
19 Dec '74	—	—	30	57	21 Dec '74	30–35	65–75	31	70	2
24 Jan '75	25–30	50–55	28	52	26 Jan '75	25–30	65–75	28	70	2
28 Jan '75	—	—	30	55	30 Jan '75	25–30	75–80	28	78	2
1 Mar '75	—	—	30	50	3 Mar '75	25–30	70	28	70	2

TABLE 1 (*contd*)

Date	West zone Cloud mass Lat. (°N)	Long. (°E)	Approx. centre Lat. (°N)	Long. (°E)	Date	East zone Cloud mass Lat. (°N)	Long. (°E)	Approx. centre Lat. (°N)	Long. (°E)	No. of days
8 Mar '75	30-35	50	32	50	10 Mar '75	25-30	70	28	70	2
11 Nov '75	30-35	50-55	32	52	13 Nov '75	—	—	30	70	2
29 Nov '75	30-35	50-55	33	52	1 Dec '75	30	65-75	30	70	2
10 Jan '76	25-30	50-55	28	52	12 Jan '76	—	—	30	70	2
21 Jan '76	—	—	30	50	23 Jan '76	—	—	30	68	2
6 Feb '76	—	—	25	55	8 Feb '76	30-35	70-75	33	73	2
10 Feb '76	25-30	55	28	55	12 Feb '76	28-35	70-75	30	72	2
22 Feb '76	25-30	55	28	55	24 Feb '76	25-30	65-75	28	68	2
13 Mar '76	25-30	45-55	28	50	15 Mar '76	30-35	65-75	32	70	2
15 Nov '76	25-30	45-55	28	50	17 Mar '76	25-33	72-80	29	75	2
2 Jan '77	25-35	45-55	30	50	3 Jan '77	25-55	60-80	30	70	1
12 Jan '77	25-35	50-60	30	55	13 Jan '77	30-35	65-80	37	73	1
7 Feb '77	26-33	48-58	30	53	9 Feb '77	32-37	65-70	35	68	2
27 Mar '77	23-33	48-58	28	53	29 Mar '77	25-35	65-75	30	70	2
4 Jan '78	25-32	47-57	28	52	5 Jan '78	30-36	63-70	33	66	1
10 Jan '78	25-33	45-58	29	51	12 Jan '78	31-37	65-75	33	70	2
26 Jan '78	29-36	52-65	33	58	28 Jan '78	30-40	71-80	35	76	2
7 Feb '78	30-38	44-49	34	47	10 Feb '78	20-25	60-75	23	68	3
28 Nov '78	28-33	43-52	30	48	30 Nov '78	31-37	73-80	34	76	2
16 Dec '78	37-44	45-53	40	50	18 Dec '78	33-42	63-80	38	68	2
Total	59 cases		1818.0	2979		59 cases		1834	4132	114
Average			31°N	50°E				31°N	70°E	2

2. Latitudinal bands (Fig. 2) which extend mostly WSW-ENE from Central Arabia to India and progress eastward slowly. They are mostly connected with broad shallow troughs in the upper westerlies (Rao *et al.* 1971).
3. Overcast masses which may sometimes show moderate meridional banding but are mostly shapeless and extensive (Fig. 3). These are by far the most common form of cloudiness approaching the country from the west.

In the present study we have examined in details the formation of these overcast cloud masses (category 3) over the Middle-East and their approach over NW India with the help of satellite cloud over NW India with the help of (1969-1978).

2. Data

The satellite cloud data used in this study were taken from :

(1) Catalogue of Meteorological Satellite Television cloud photograph — published by ESSA upto 1972.

(2) Key to Meteorological Records documentation monthly issue of environmental satellite imagery upto December 1974.

(3) Scanning radiometer data of NOAA satellite from microfilms — upto December 1978.

The period of study was confined to the winter-period, *i.e.*, November through March, for the year 1969 to 1978.

3. Analysis

In all 59 cases of overcast cloud masses (category 3) were found during this period, in which the formation, movement and approach of cloud masses over Indo-Pakistan region could be established with confidence. These cases are listed in Table 1 which shows the date of initial detection of the cloud mass, its extent (Lat.-Long. wise) and its approximate centre. It also shows the date on which this cloud mass reached NW India or neighbourhood, and its approximate centre there. It can be seen from this table that most of the overcast cloud masses which arrive over NW India or neighbourhood are first

TABLE 2

No. of cases of clouds and their location of formation in West Zone (30-55° E) which could be followed up to East-Zone (55-80°E)

Latitude	Favourable positions of organisation over Middle-East (West Zone)				Latitude	Position of occurrence over India and neighbourhood (East Zone)				
	30-40	40-45	45-50	50-55°E		55-60	60-65	65-70	70-75	75-80°E
40-45					40-45			(b) 1		
					35-40			(a) 1	(f) 1	
					30-35			(e) 4		
35-40								(b) 3	(a) 1	(e) 1
								(f) 4		
30-35		(a) 4	(b) 11	(c) 3				(c) 1		
					25-30		(e) 1	(e) 9	(e) 4	
25-30		(d) 1	(e) 1	(f) 14				(b) 6	(f) 3	(f) 1
							(a) 1	(f) 5		
20-25								(c) 2	(a) 1	
					20—25			(b) 1	(d) 1	

NOTE : (a), (b), (c), (d), (e) & (f) indicate position of clouds that formed in West Zone and followed up to East Zone.

noticed between 25 deg. and 40 deg. N, and 40 deg. and 55 deg. E. The approximate centre being 31 deg. N/50 deg. E. They move ENE/eastwards and arrive over the norhern part of Indo-Pakistan region in about 2 days' time. The average position after two days movement is 31 deg. N/70 deg. E. Thus the overcast cloud masses of the type discussed here, move at the rate of about 10 deg. longitude per day from the Middle-East to NW India and neighbourhood, moving in an approximately easterly direction. In individual cases, however, the movement is not only northeasterly but southeasterly also as can be inferred from Table 1 columns 4 and 9 (the approximate centres). It may, however, be noted that the centre and the movement of a cloud mass can be estimated only approximately because its area and shape change all the time due to continuous process of dissipation and formation going on in it. The progress of these cloud masses could not be followed further east because they all entered the Himalayas by the time of next observation and their shape and extent got highly distorted.

Table 2 gives the distribution of these cloud masses (with respect to their centres as in Table 1), in five degree Lat.-Long. squares in the belt 20 deg.-40 deg. N and 35 deg.-80 deg. E. The initial formation area is located to the west of Long. 55 deg. E. The subsequent progress of each of these cloud masses upto which it could be followed, is located to the east of Long. 55 deg. E. Identical suffix in the two zones indicate the movement of the same cloud from west zone (west of 55 deg. E) to east zone (east of 55 deg. E) based on satellite pictures. From this table the following inferences can be drawn:

(*i*) The initial organisation area of the overcast cloud masses studied here, is in the belt 25 deg. N to 35 deg. N and 40 deg. E to 55 deg. E, a large majority of them between 45 deg. E and 50 deg. E.

(*ii*) Most of these move in the same latitude belt eastward and could be tracked upto 75 deg. E, though a greater number of them could be followed upto 70 deg. E only. This is because most of them form fairly north (average Lat. 31 deg. N — Table 1) and their passage beyond 70 deg. E is over the high mountain ranges of Hindukush and the Northern Himalayas. Hence their organisation becomes distorted and cannot be traced with confidence.

(*iii*) As an example of their progress eastward it can be seen that of the four cases marked with suffix 1 in the west zone, one is seen in the square 35-40 deg. N, 65-70 deg. E; another in 30-35 deg. N, 70-75 deg. E; The third in 25-30 deg. N, 70-75 deg. E and fourth in 25-30 deg. N, 60-65 deg. E. This shows that a cloud mass in its passage eastward can move fast or slow, northeast, east of even southeast, and can disorganise before reaching NW India. But it is apparent that a great majority of them reach upto 70 deg. E

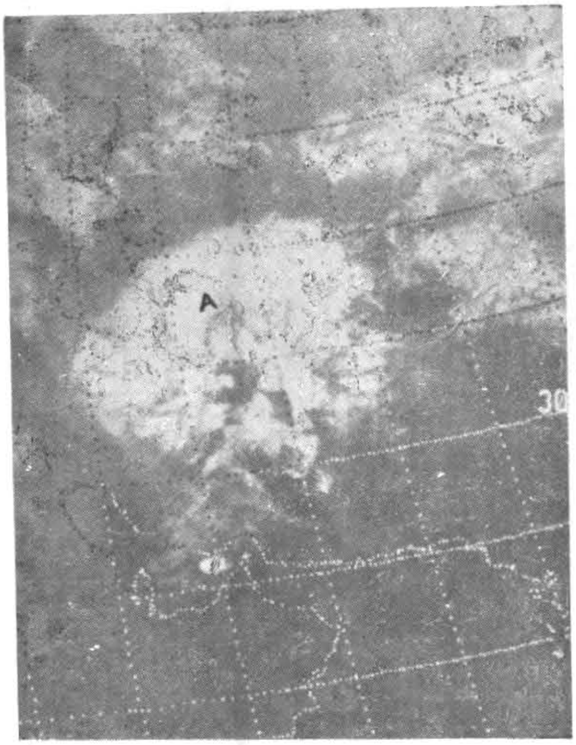

Fig. 1. Satellite picture of 29 November 1975 (VIS) showing a system with banding structures and vortex at 'A'

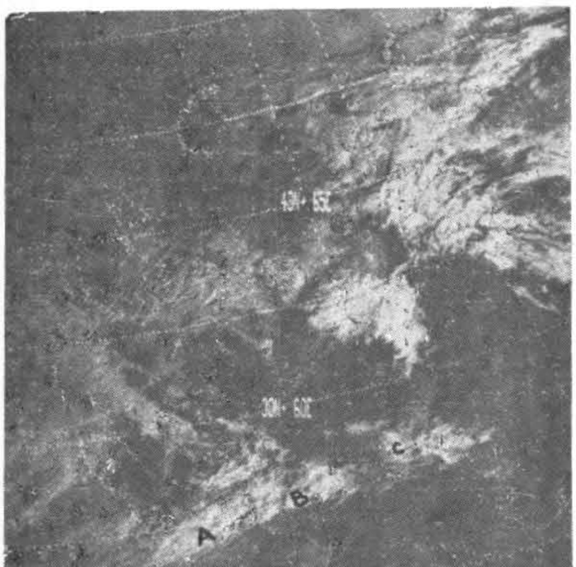

Fig. 2. Satellite picture of 22 January 1974 (VIS) showing latitudinal cloud bands 'A—B—C'

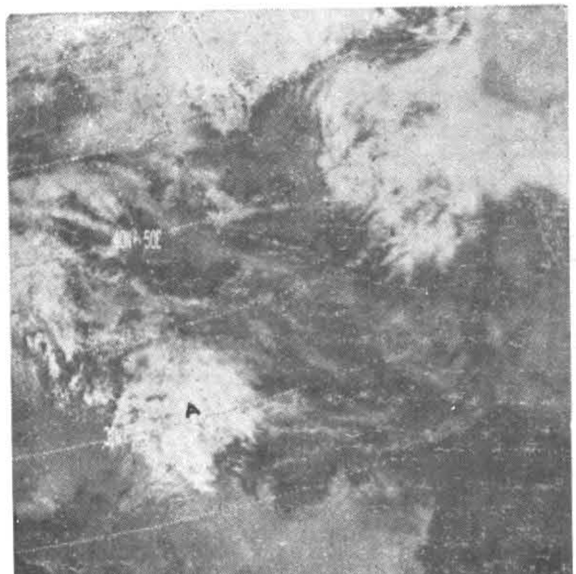

Fig. 3. Satellite picture of 15 March 1973 (VIS) showing overcast cloud mass at 'A'

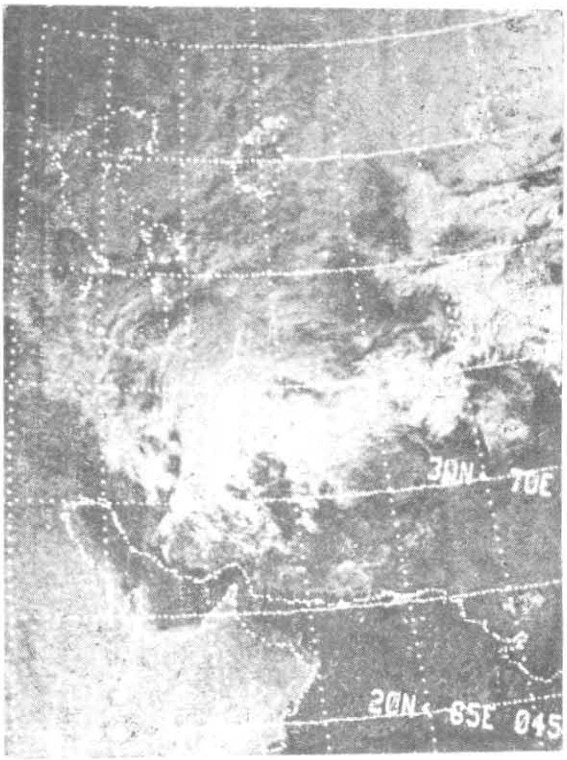

Fig. 4(a). NOAA-4 SR (VIS), Orbit No. 14619; 26 January 1978 at 10-50-47 IST

Fig. 4(b). NOAA-4 SR (VIS), Orbit No. 14631; 27 January 1978 at 09-50-49 IST

Fig. 4(c). NOAA-4 SR (VIS), Orbit No 14643; 28 January 1978 at 08-50-52 IST

TABLE 3

No. of cases of clouds formed in West Zone and moved to East Zone after (A) 24 hr and (B) 48 hr

Lat. (°N)	Cases in West Zone			Cases in East Zone		
	40-45°	45-50°	50-60°E	60-65°	65-70°	70-85°E
30-35	11			(A) 1 (B) 12		
25-30	19	14		(A) 2 (B) 18	(B) 5	

retaining their identity and then break-up over the hills. Similar is the case with all the other groups as can be seen from the Table 2.

(*iv*) It can be seen that the belt of 25-35 deg. N is the most prominent belt as far as the activity of western disturbances of this type is concerned.

Table 3 shows the time required for the cloud masses formed in the west zone to arrive in the east zone. To study their movement individual cloud masses were tracked and their positions after 24 hours, 48 hours and 72 hours were plotted in five degree Lat.-Long. squares. It shows that in almost 80% of the cases a cloud mass took two days to reach the east zone (Indo-Pakistan region).

4. Synoptic situations

Synoptic situation associated with a typical case of this type is discussed below:

Western disturbance of 26-28 January 1978

Figs. 4 (a, b, c) give the organisation and progress of the cloud mass associated with this western disturbance from about Long. 50 deg. E to NW India.

The cloud mass over Iran and Afghanistan, seen in Fig. 4(a), was associated with a well marked low pressure area over central Iran at 26/0000 GMT. The upper air cyclonic circulation associated with this system extended upto 850 mb with a feeble trough at 700 mb. Higher up the trough was not traceable. Fig. 4(b) shows the cloud mass associated with this system the next day when it lay over Afghanistan as a low pressure area with associated upper air circulation extending upto 700 mb (27/0000 GMT).

Fig. 4(c) shows cloud mass associated with this low over Punjab, Himachal Pradesh, J&K and hills of Uttar Pradesh on the 28th. The low lay over the Punjab with associated upper air cyclonic circulation extending upto 700 mb.

From the above discussion it is obvious that the system though well marked at the surface, did not extend beyond 700 mb at any time. The cloud mass associated with it (Fig. 4) was, however, extensive and could be followed systematically.

It appears that the systems causing overcast cloud masses of the type discussed here develop mostly in the Persian Gulf-Black Sea belt as secondaries of extra-tropical depressions from the Mediterranean which move NE'ward. These systems are comparatively shallow, seldom extending beyond 700 mb. At the surface too their organisation is often poor, appearing as a series of weak lows or shallow troughs. It may partly be so because of the general lack of data, over the Middle-East over which they move, making their accurate synoptic analysis rather difficult.

The clouding associated with such systems are typically shapeless overcast masses which are extensive and persistent and their progress can be followed systematically from satellite photographs. Thus these cloud imageries are a great help in the forecasting of the strength and movement of these shallow systems.

5. Conclusion

(1) Overcast cloud masses, studied here, are associated with westerly systems which are first detected generally in the belt 25 deg. to 35 deg. N and 40 deg. to 55 deg. E as secondaries of extra-tropical depressions moving NE'wards from the eastern Mediterranean. They are lower tropospheric systems extending mostly upto 850 mb (or at best 700 mb) and showing rather weak organisation at the surface.

(2) Cloud masses associated with them, however, show better organisation and continuity and can be followed systematically with the help of satellite photographs.

(3) They move generally in an easterly direction at the rate of 10 deg. Long. per day from the Middle-East to NW India and neighbourhood and arrive over the latter area in about two days' time.

(4) They mostly maintain their identity during this period and occasionally strengthen on reaching the Indian region.

(5) Region of 25 deg. N to 35 deg. N is the most active belt for the development and movement of this type of cloud masses.

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