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Gridding and interpretation of satellite pictures

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ABSTRACT. Cloud photographs from the American weather satellites are being received regularly from the middle of May 1966 at the APT Unit, Bombay. Some of the problems faced in gridding and interpretation of these pictures are presented. A few features noticed in these pictures are enumerated.

1. Reception of pictures

1·1. Cloud photographs are received from U.S. weather satellites with APT (Automatic Picture Transmission) facility from the middle of May 1966. The photographs are taken and transmitted to recipients immediately. Any ground station with proper equipment can receive these pictures. Two to three passes can be tracked daily for each satellite. Pictures are taken during the sunlit portion of the orbit.

1·2. These satellites are launched into near polar sun-synchronous orbits, so that, they come over different parts of earth at the same local time and view each part of earth at least once a day*. Essa satellites take pictures in the north to south leg, Nimbii in the opposite leg of the orbits.

1·3. Before Nimbus 3, the operating technique was to take a photograph and transmit it. Essa pictures are taken at regular intervals so that consecutive frames overlap by about 30 per cent. Nimbus satellites, being at a lower height, take them continuously. There is nearly 50 per cent overlapping between consecutive frames. Nimbus 3 uses a sensor for scanning the earth line by line and photography is dispensed with. The latest satellite ITOS 1 combines both the techniques and comes at about 1500 hours local time, taking pictures in the south to north leg.

1·4. The local time difference between the east and west edges of a picture is two hours or more, hence the illumination is not uniform throughout. The decrease in illumination towards the north and south edges is prevented in Nimbus 3. The north-south extent is reduced by a quarter in the ITOS 1 picture to give better quality. With the sensitivity of the satellite's systems, the quality of pictures is also reduced with age.

2. Gridding

2·1. The centre of the picture, the satellites position, its sub-point on earth, coincide as it is earth-oriented. After calculating the positions individually for each frame, by noting the time of the camera exposure, the corresponding grid is used. The central point and other reference marks are etched on the vidicon tube of the camera system. For Nimbus 3 the principal point is calculated before using the grid. The scanning is done, line by line, from south to north of the satellite's position as it moves, with each line being scanned from east to west. The principal point lies on the scanning line directly below the satellite, and, is in a line with the satellite and the earth's centre. This is a little to the northwest of the centre of the picture display. This is marked with an underlay prepared as per calculations.

2·2. The grids, supplied by NESC (National Environmental Satellite Centre) are prepared mathematically for ideal orbits. The attitude bias—pitch, roll and yaw—if any, give rise to errors. As the scanning in Nimbus 3 involves three motions— the scanning point, the satellite's motion, the earth's rotation—the errors could be more. The grids at the APT Unit are prepared for the mean height of a satellite, and, three grids are prepared for Nimbus 3 to cover its variation in height. Experience shows that in referencing the pictures to the grids in the normal way, Essa pictures generally show good agreement; but, Nimbus pictures present problems with translation and rotation for different pictures. The pictures are

*Essa 4, 6 and Nimbus 2 came later, Essa 8 and Nimbus 3 are coming later and earlier respectively than the scheduled local time. The past tense is used for Essa 4, 6 and Nimbus 2 as they have ceased operating though in orbit. On consecutive orbits, Essa pictures are just contiguous at the equator with increasing overlap towards the poles. In Nimbus the continuity starts at about 25° latitude.

gridded after getting the best fit with all the landmarks available. Landmarks are not prominently seen in Nimbus 3. The cloud masses repeated in consecutive pictures are not exactly in the same location. When good landmarks are available in both the pictures, the mean of the position is generally taken. However, the error is not much. Over ocean areas without landmarks, particularly in the case of Nimbus, the gridding may be fair. It is seen from experience that gridding by this method may bring an error of 0·5° mostly towards the edges.

3. Interpretation

3.1. The working charts at Weather Section Colaba are smaller in area than the total coverage of APT pictures received daily. This imposes a limitation on the interpretation, as the satellite pictures are to be used in conjunction with the working charts. The satellite summaries supplied by Washington are also referred to as a routine measure.

3·2. Normally *StF*, *CuF*, *Ci* and *Cb* are the types of clouds that can be identified, but the differences between large *Cu* and *Cb* are very little. Only a structural view of the clouds is obtained and not their heights. Differentiation between layers of clouds is not possible. The illumination of the Essa satellites is from a side, which may accentuate the sheet clouds and *Ci*. With the Nimbus satellite coming near noon and the illumination being vertical, the cirrus may be penetrated, at least partially, and the sheet clouding reduced. The differences in cloud cover in the respective bulletins may be due to this reason. The clouding which appeared to have decreased in Nimbus, is again seen to be increased in ITOS 1 pictures. Probably the camera system in the Essa satellites may be responsible for increased brightness. At the time of writing (1 March 1970) the ITOS 1 has been in orbit for a short period. The difference in brightness of a cloud mass between consecutive frames may be due to the relative angles of the Sun, the camera and the cloud mass.

3·3. Fog may be interpretated as stratus, but when taken with the charts this may be identified. Sometimes shadows of individual clouds are seen, indicating convective activity, mostly over the ocean areas. Clouds over ice and snow are not easy to locate as the lower cover prevents a clear view and also for want of data in these regions. As the average brightness in each element of scanning is reproduced, fainter reflections may be lost. Fair weather cumulus may come out as a light grey patch and may be missed.

3·4. Centering of storms may bring in some subjectivity except when an eye is visible. There are no means of verifying these positions — like reconnaissance flights or ships' data at the time of the picture.

3·5. Sunlight is seen as a circular bright patch over water surfaces. Qualitative information about the winds over the surface can be obtained from this—the less disturbed the surface, less the dimensions of the patch. Over a completely calm region only a bright spot may be seen. However, no definite conclusions can be drawn from this at this stage.

3·6. The pictures are a two dimensional representation of the three dimensional space below the satellite. As the view is from the top there may be differences in the positions from synoptic charts, if there is a tilt in a pressure system. On several occasions when a good fix is possible from synoptic charts, these differences have been noticed. With the error possible in gridding these differences should not be more than half a degree. On a few occasions the difference noticed could not be satisfactorily explained.

4. Discussion of stages

4·1. The series of stages devised by NESC, for describing disturbances, is based on a study of Pacific and Atlantic storms. The structure of our storms may be different. However, patches of clouds corresponding to stages A and B are frequently seen without any further development. If they are described as such, it may lead to mistakes. So much so, that we usually start mentioning a system only from stage C.

4·2. Considerable difficulty is experienced between the stages C+ and X, Cat 2. The structures are very similar with the qualifying rider, that, the centre should not be more than half a degree inside the cloud mass in the case of C+. With the exaggeration present in Essa pictures this is a serious handicap. When the systems appear near the edges of pictures this difficulty is again experienced. As the storms can intensify rapidly and the satellite pictures are limited to one per day, the continuity in the description of the stages also presents a problem. ITOS 1 will be giving another picture per day and this may help a little. The problem will be overcome when the ATS (Applications Technology Satellite) comes over our region.

4·3. The use of nomograms to determine the wind speeds may not be fully valid. We have, at present, no means of determining the wind speeds except for ships' observations few and far between. A study has to be made with reconnissance flights to get a satisfactory nomogram over our regions.

5. NESC Advisories

The advisories received from NESC on disturbed conditions over our areas are generally found to agree with our conclusions, though on occasions, difference are noticed both in positoning and categorising. This is understandable as the AVCS (Advanced Vidicon Camera System) facility has better definition and a narrow angle view for finer resolution This, however, imposes a handicap on our interpertation. The ITOS satellite coming near about the same time as the satellites used by NESC, presented these differences on a few occasions for recent storms in the southern hemisphere.

6. DRIR data

The APT equipment at Bombay is not, at present, modified to receive DRIR (Direct Readout Infra Red) information from the satellite which correspond to the APT pictures, durings night time. The ITOS 1 satellite also transmits infrared data in the time interval between APT frames during day time. Though meant primarily to obtain the height of clouds from the thermal profile of the atmosphere, these pictures do provide a qualitative distribution of clouds. With our limited data from ships, one or two more observations during the night would be very useful, particularly during disturbed condition. If this facility is provided four to five observations distributed over a day will be available, so that a more continuous watch can be kept over the systems.

7. Features noticed

7.1. *Cyclonic storms* — In most of the storms over the Bay of Bengal a large major cloud band is seen (Fig. 1) from the northeast of the storm, extending to several degrees, separated from the main cloud mass. This band is observed even when the storm stage is X Cat. 4, the maximum in the classification table. The land boundary of the Bay may have some effect on this formation. Eyes are frequently seen. The diameter is frequently less than or equal to four degrees, less than that of the major storms in the Pacific and the Atlantic.

7.2. Our reception normally extends upto about 15°S. As such, we are not able to get full coverage of the southern hemisphere storms. From the pictures received at Bombay, and the few from the Reunion Met. Service, the cloud structures of these storms appear to be more circular and bigger in diameter compared to those in our waters.

7.3. *Extra-tropical system* — Some very good pictures of the extra-tropical systems have been

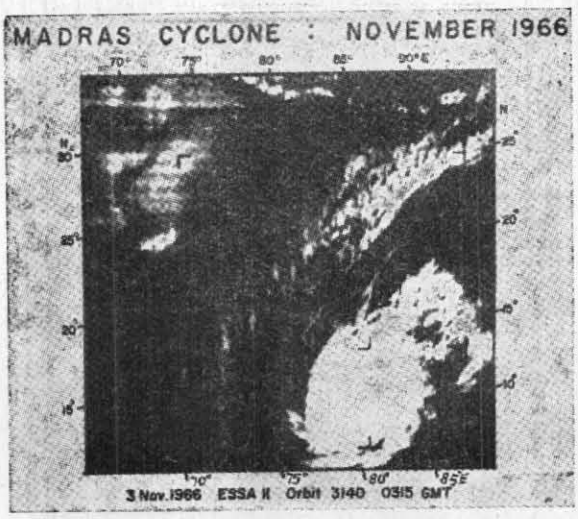

Fig. 1
Cyclonic storm

received, with banded structures, clearing corresponding to cold fronts, and the cellular *Cuf* patterns. In winter, when these systems come to lower latitudes, the illumination is poor and good pictures are not obtained over these latitudes. The position may improve with the ITOS 1 satellite, coming in the afternoon. However, the front cannot be described as such, for want of data from these regions. The movements of these systems are quite fast and at least on two occasions the systems were observed to have retrograde motion.

7.4. *Western disturbances* — These are seen mostly as large cloud masses extending over large areas with indifferent shapes and no organisation. Circulations are practically not seen at all, even though they are seen on the working charts extending to considerable heights. Day to day movement of these cloud masses with associated changes is seen.

7.5. *Jet streams* — The cirrus bands associated with the jet stream have been seen occasionally over India and Arabia. Though the jet stream is a regular feature over the northern parts of the country in winter, it is not regularly seen on the APT pictures. It is not possible to easily distinguish the polar jet stream, but on several occasions a dark line signifying the jet is seen.

7.6. *Mountain waves* — Mountain waves are seen as lenticular clouds, parallel to the mountain ranges, caused by the crests of the damped waves on the leeward side of the mountains. These have been seen on several occasions over the Assam Hills. They have not been noticed, in this pattern, off the Western Ghats, possibly because the clouds produced during the steady

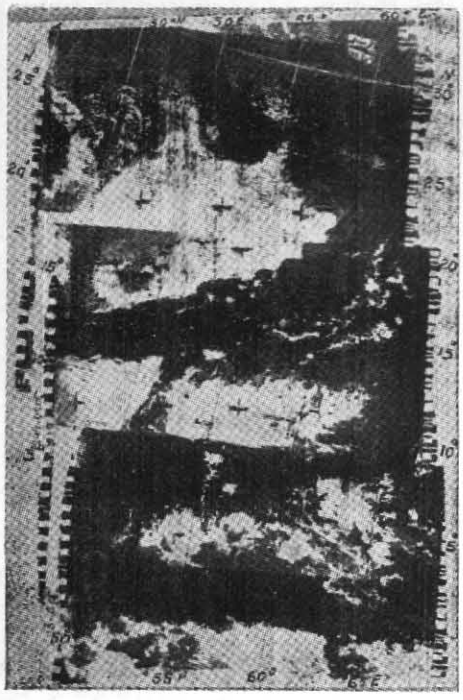

Fig. 2. Clouding off Arabia
Nimbus II APT picture at 13 hr. 19 min. 43 sec IST on 25 Nov 1966

winds mix with the monsoon clouds and are not seen separately.

7.7. *Clouding over South China* — Clouding has been observed practically daily over the Southern China regions. It is seen throughout the year with very little change in structure or in positions. It is not clear whether this is a cloud in reality or some form of reflection. The known reasons do not explain this phenomenon.

7.8. *Clouding off Arabia*—Detached *CuF* cells are seen (Fig. 2) off the south-east coast of Arabia extending nearly five degrees to one side. They persist for a few days and disappear. This has been observed during different seasons and cannot be thought of as a seasonal pattern. This type of clouding is explained as caused by the cold air from the land areas being warmed over the water surfaces. But, this has been observed during the monsoon also when the flow is mostly over the sea, and their alignment shows a southwesterly flow during the monsoons off the Arabian coast. This pattern has been observed during both the strong and the weak monsoon conditions. A gradual extension towards the south, off the coast, is noticed before the pattern collapses.

7.9. *Monsoon clouding* — From the photographs obtained during the last four monsoons, it is seen that there is a pronounced cross equatorial flow agreeing with the two branches of the monsoon. This clouding extends over large regions (ten to twenty degrees) and is persistently seen for several days. Over the country several openings are seen in the clouding. The advance and withdrawal of monsoon is seen characteristically in the pictures. Pronounced shearing is seen in the cirrus cloud corresponding to the easterly jet stream.

8. Advantages of satellite pictures

Satellite pictures are instantaneous, and cover large areas. For studying the systems these pictures depict cloud formation and structure. Though pressure, temperature etc., are not available at present, future sophisticated satellites may provide these also. With the expected development in this field, a complementary study may lead to better anticipation of weather. None of the system can escape detection, as might have happened earlier, for want of data. The objective data from satellites may lead to better climatological studies. The finished product is available and the cause has to be found out. This could be easier than the reverse case, particularly in meteorology, where the variations are too complex for mathematical treatment.

DISCUSSION

SHRI C.R.V. RAMAN : Is there any difficulty in gridding, as the height of the satellite varies?

SHRI B.K. SRIDHAR : Using the same grid magnification, alteration in the height of the satellite gives rise to an error of about half a degree.