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Comparative study of construction of divergence of wind field based on OLR data obtained from polar orbiting and geostationary satellites

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सार – क्षेत्रीय निदर्शों के लिए पवन क्षेत्र के अपसरण की संरचना के लिए ध्रुव कक्षीय और भू-स्थिर उपग्रहों से प्राप्त बहिर्गामी दीर्घ तरंग विकिरण का मूल्यांकन इस दृष्टि से किया गया कि कौन सा अधिक सुविधाजनक और उपयोगी है। 1979 के दौरान टी आई आर ओ एस-एन (ध्रुव कक्षीय) और जी ओ ई एस-आई ओ (भूस्थिर) उपग्रहों से ओ एल आर आंकड़ों की उपलब्धता ने विश्व परीक्षण आंकड़ा सेटों के विश्लेषण से संरचित 850 और 200 एच पी ए पर पवन क्षेत्र के ओ एल आर आंकड़ा और अपसरण के मध्य सांख्यिकीय संबंध के निर्धारण और अन्वेषण को संभव बनाया है। इस अध्ययन से गहन संवहनी गति विधि के प्रदेश में इन क्षेत्रों के मध्य प्रबल संबंध पाए गए हैं। ध्रुव कक्षीय उपग्रह की अपेक्षा भूस्थिर उपग्रह के लिए ये संबंध भी प्रबल पाए गए हैं। सांख्यिकीय मौसम प्रागुक्ति निदर्शों के लिए विशेषकर आंकड़ा विकीर्ण उष्णकटिबंधीय समुद्री क्षेत्रों में, इस संबंध के प्रयोग का प्रस्ताव रखा गया है।

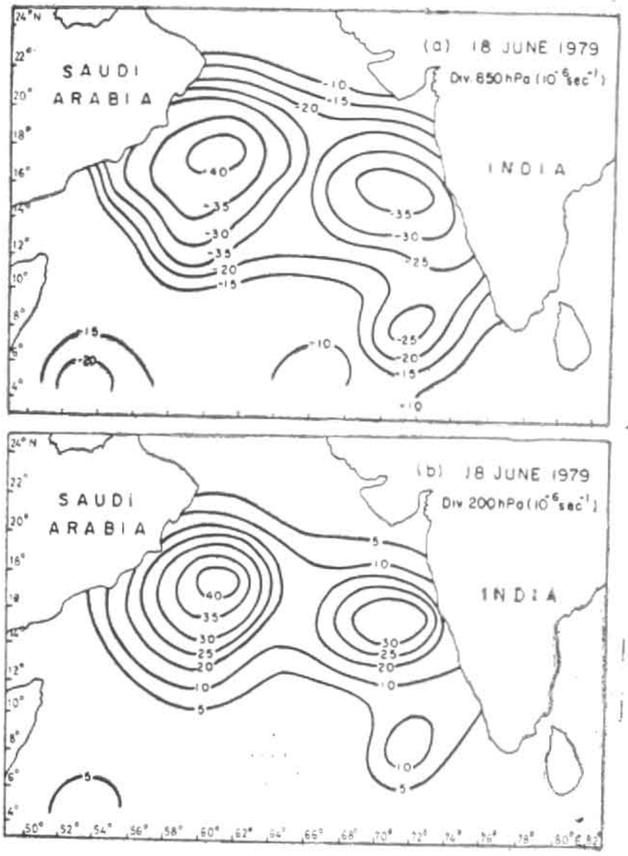
ABSTRACT. An assessment of Outgoing longwave radiation data obtained from polar orbiting and geostationary satellites is made to see which one is more convenient and useful for the construction of divergence of the wind field for regional models. The availability of OLR data from TIROS-N (polar orbiting) and GOES-IO (geostationary) satellites during 1979 made it possible to assess and explore a statistical relationship among the OLR data and divergence of the wind field at 850 and 200 hPa constructed from the analysis of the Global Experiment data sets. This study reveals a very strong relationship between these fields in the region of deep convective activity and this relationship has also been found to be stronger for geostationary satellite than polar orbiting satellite. The use of this relationship especially over data-sparse tropical oceanic regions for NWP models is suggested.

Key words — Divergence of wind fields, OLR data, Numerical weather prediction, Polar orbiting & geostationary satellites, ITCZ, Onset vortex

1. Introduction

Divergence of the wind field is one of the most important factors for describing the major circulation features over the global tropics. Accurate analysis of the divergence of the wind field is rather difficult in the tropics due to the complicated relationship between the mass and velocity fields at low latitudes and due to lack of quality and quantity in observations. Oceanic areas of the global tropics are poorly observed in terms of wind observations and this poses unique problem to analysis schemes. Relatively increased importance of divergent part of the wind field in Numerical Weather Prediction (NWP) models has forced the investigators to explore the spaceborne measurements for obtaining the divergent part of the wind field over the data sparse oceanic regions. Space-borne measurements in the form of radiance data have been used by numerous scientists (Woodley *et al.*, 1980, Richards and Arkin 1981, Martin and Holand 1982) for addressing the definition of various meteorological parameters. OLR (Outgoing Longwave Radiation) data derived from the radiance measurements of the satellite have been considered as a measure of intensity of convection. These data can provide the division between convective and clear sky areas. Therefore, number of investigators (Sumi 1981, Julian 1984, Krishnamurti and Low-Nam 1986; Kasahara *et al.* 1988) have used OLR data obtained from polar orbiting satellite for the construction of divergent wind field. However, these data are rather inconvenient for numerical weather prediction models (Kasahara *et al.* 1988). Polar orbiting satellite data represent those for a given longitude at a local standard time, which is dependent upon the equator-crossing times of a particular space-craft. In order to obtain a data set for a synoptic time of, say 12 UTC, the day time and night time measurement may be linearly weighted according to the time of equator crossing. As the data from polar orbiting satellite is readily available over the global tropics, it is used by number of investigators to formulate the basic algorithm.

Since the OLR data from polar orbiting satellite is inconvenient to use in NWP models we thought of testing OLR data from geostationary satellite. Therefore, a comparison of OLR data obtained from TIROS-N (polar orbiting) and GOES-IO (geostationary) satellites during Summer Monex-79 is made with the divergence of the wind field constructed from one of the best objectively analysed wind data (Krishnamurti *et al.* 1979) over the Indian region. On the basis of comparative study it is shown that OLR data from geostationary



Figs. 1(a & b). Divergence of the wind at 850 and 200 hPa on 18 June 1979

satellite are more convenient and accurate than polar orbiting satellite for the construction of divergence of the wind field, particularly over the deep convection areas of the tropical Indian region.

2. Data

2.1. *Satellite data*

Outgoing longwave radiation data obtained from polar orbiting (TIROS-N) and geostationary (GOES-IO) satellites over the Indian region during Summer Monsoon-1979 have been utilised in the study. TIROS-N provided measurements from a very high resolution radiometer centred at around 11.5 μm band. The net outgoing longwave radiation at local noon (1530 LST) and local midnight (0330 LST) was measured by radiometer on board TIROS-N satellite for earth radiation budget studies. Daily mean values of these observations are used in the study. Daily OLR data is supplied by P. Arkin.

During Summer Monsoon 1979, Indian Ocean geostationary satellite (GOES-IO) of USA was specially brought from South Atlantic Ocean over the Indian Ocean and stationed at about 60°E for the benefit of Monex programme. GOES measurements were ideal because they possessed both high spatial and high temporal resolution (*i.e.,* 1 km in visible, 8 km in infrared and half hourly sampling frequency). Hourly observations of GOES-IO satellite were available for the period 11-20 June 1979 (Virji *et al.* 1982). OLR data at 12 UTC have been used in the study.

TABLE 1

Statistical analysis

Satellite	No. of obs. n	Level (hPa)	c.c. when whole domain is considered 'r'	No. of obs. n	c.c. when only convective region is considered 'r'	RMS error (10^{-6} sec^{-1})	Percentage error
TIROS-N	560	850	0.014	137	0.514	7.22	34.17
(Polar Orbiting)		200	0.012		0.531	6.16	20.63
GOES-IO		850	0.016		0.875	3.18	18.25
(Geostationary)		200	0.019		0.942	2.28	7.34

GOES-IO infrared window (11-12.5 μm) observations were calibrated in terms of total outgoing longwave fluxes using relationship based on simultaneous GOES-IO and TIROS-N multispectral (HIRS) radiometer data. Therefore, there was no variation in quality of OLR data in respect of both the satellites.

2.2. *Objectively analysed wind data*

Objectively analysed wind data at 850 and 200 hPa obtained from *Quick Look Summer Monex Atlas* by Krishnamurti *et al.* (1979) have been utilised for the computation of divergence of the wind field over the Indian region. Those analyses have been considered as standard analyses because they were made very carefully and were based on all available conventional data and additional observations from research ships, aircrafts, dropsonde, constant pressure balloons etc.

3. Methodology

The domain of our study extends from equator to 25°N and 40°-80°E. The data considered over this domain is for 12 UTC and for the period 11-20 June 1979. The main purpose of consideration of above period and domain was that during this particular period number of convective cloud clusters associated with different synoptic systems such as ITCZ, onset vortex, depression and cyclonic storm were prevailing over this domain. Synoptic hour time 12 UTC was considered because it was very close to the equator crossing time (1530 LST) of TIROS-N satellite. OLR values obtained from GOES-IO satellite at 12 UTC in the above domain are picked up from the atlas 'Earth atmosphere radiation balance from geostationary satellite data for the summer monsoon onset region' for the period 11-20 June 1979. Daily OLR values obtained from TIROS-N satellite are plotted at each 2° grid for the same period and domain. Divergence of the wind field at each 2° grid is computed making use of objectively analysed wind field (Krishnamurti *et al.* 1979) at 850 and 200 hPa. Analysis of divergence of the wind field and OLR field are made. As an example a case of 18 June 1979 is depicted in Figs. 1 (a&b). Visible and infrared imageries obtained from GOES-IO satellite are utilised for finding the areas of major convective activity. Here, areas covered by thick cirrostratus plumes which are also associated with low values of OLR and appear in the form of filaments are subjectively eliminated. Comparison of divergence

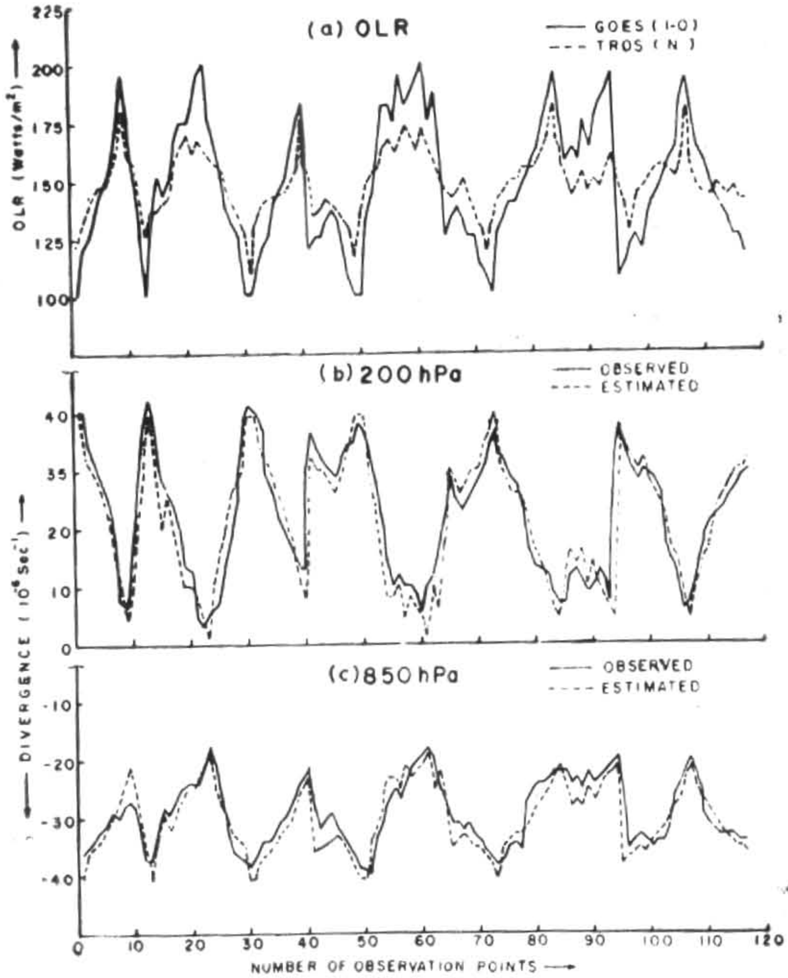


Fig. 2. Comparison of OLR fields (GOES-IO and TIROS-N) with observed and estimated divergence of wind field at 200 and 850 hPa

of the wind fields at 850 and 200 hPa is made with OLR fields of both the satellites. For this purpose an experiments is carried out for the following two cases :

Case A — OLR values at each 2° grid are compared with divergence of the wind field at each 2° grid in the whole domain.

Case B — OLR values enclosed in the area of deep convective activity are compared with the divergence of the wind field in that area.

Table 1 shows the statistical details of the comparison between OLR and divergence of the wind fields. In this table it is observed that correlation coefficients between these two parameters are very poor in case of both the satellites and for both the levels, when OLR values in the whole domain are considered. The values of correlation coefficients are greatly improved for both the satellites and for both the levels, when the values of OLR are considered in the area of deep convective activity. The values of correlation coefficients are found to be quite high for geostationary satellite than polar orbiting satellite. Based on OLR values from geostationary satellite in the region of deep convection, linear regression equations are developed for 850 and 200 hPa. They are as follows :

$$D_{850}=0.21\ x-61.25 \quad (1)$$

$$D_{200}=-0.39\ x-78.56 \quad (2)$$

where,

(*i*) D_{850} and D_{200} are the values of divergence of the wind field at 850 and 200 hPa in 10^{-6} sec^{-1}

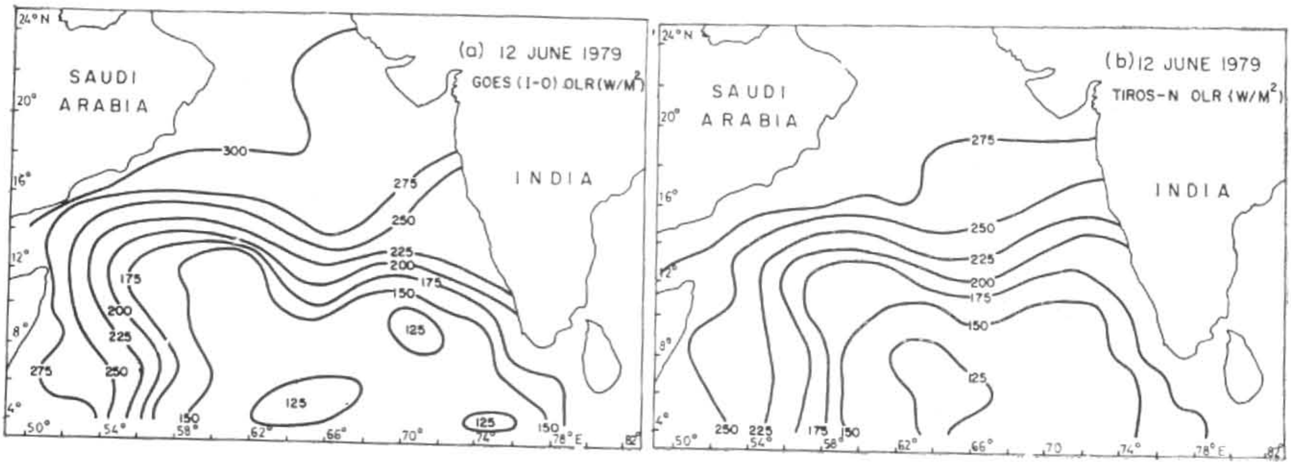
(*ii*) x is the value of OLR in watts/m^2

On the basis of these two equations a series of divergence of the wind field in the area of deep convection is estimated for an independent OLR data set and compared with the observed divergence of the wind field. Fig. 2 depicts the comparison of OLR fields obtained from GOES-IO and TIROS-N satellites in the upper panel and observed and estimated divergence of the wind field for 200 and 850 hPa in the lower panel.

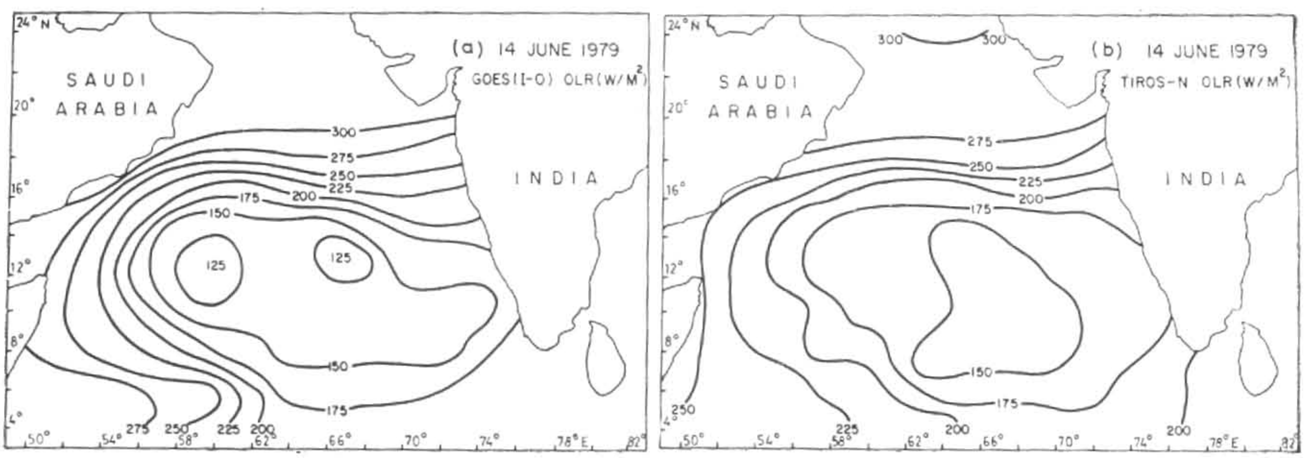
4. Results

Following are the results of the study :

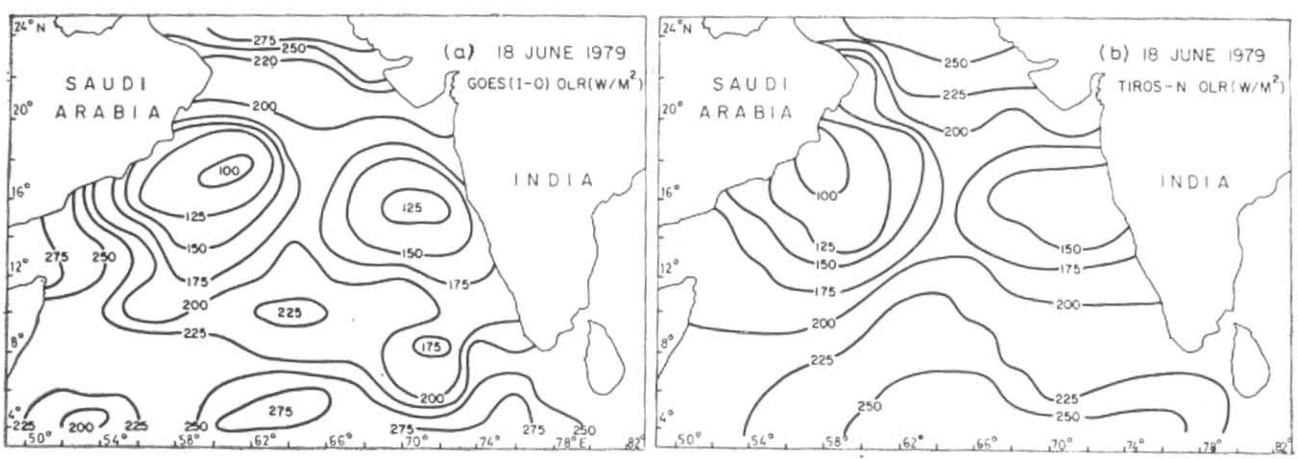
(*i*) A verypoor correlation is obtained between divergence of the wind field and OLR field at 850 and 200 hPa when OLR values in the whole domain are considered.



Figs. 3(a & b). Analysis of OLR field for GOES-IO and TIROS-N satellites on 12 June 1979



Figs. 4 (a & b). Same as Figs. 3 (a & b) but for 14 June 1979



Figs. 5 (a & b). Same as Figs. 3 (a & b) but for 18 June 1979

(*ii*) A highly significant correlation is obtained between divergence of the wind field and OLR field when OLR values in major convective regions are considered.

(*iii*) The above relationship is found to be stronger for geostationary satellite than polar orbiting satellite when OLR values in the region of major convective activity are considered.

(*iv*) A very good coherency between observed and estimated (based on regression equations) divergence of the wind field is obtained at 850 and 200 hPa.

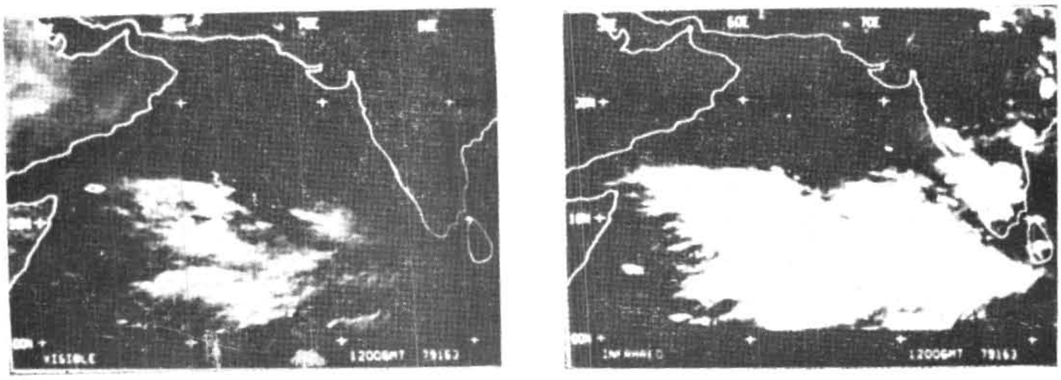


Fig. 6. Visible and infrared picture of GOES-IO satellite at 12 UTC on 12 June 1979

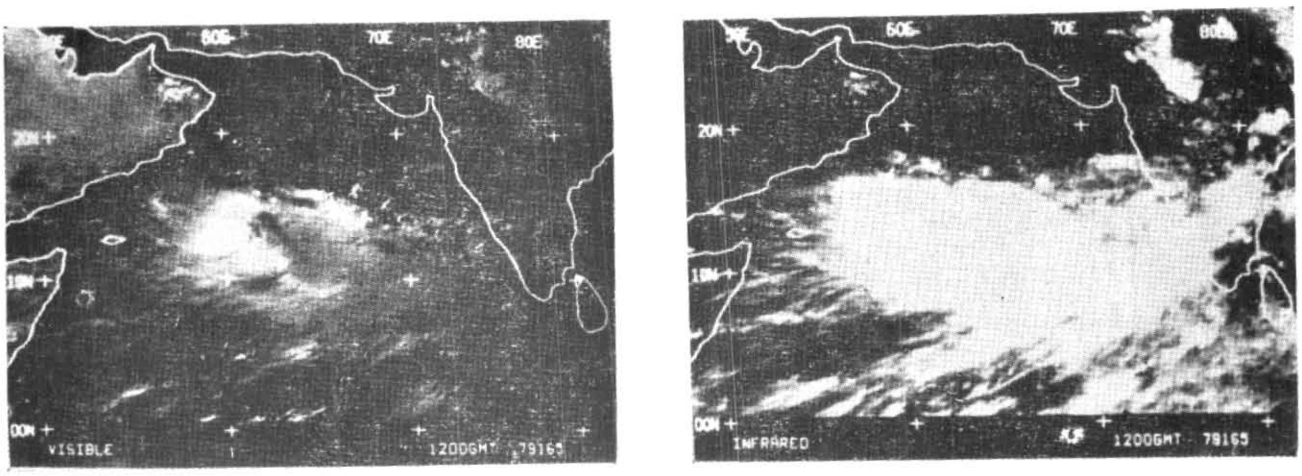


Fig. 7. Same as Fig. 6 but for 14 June 1979

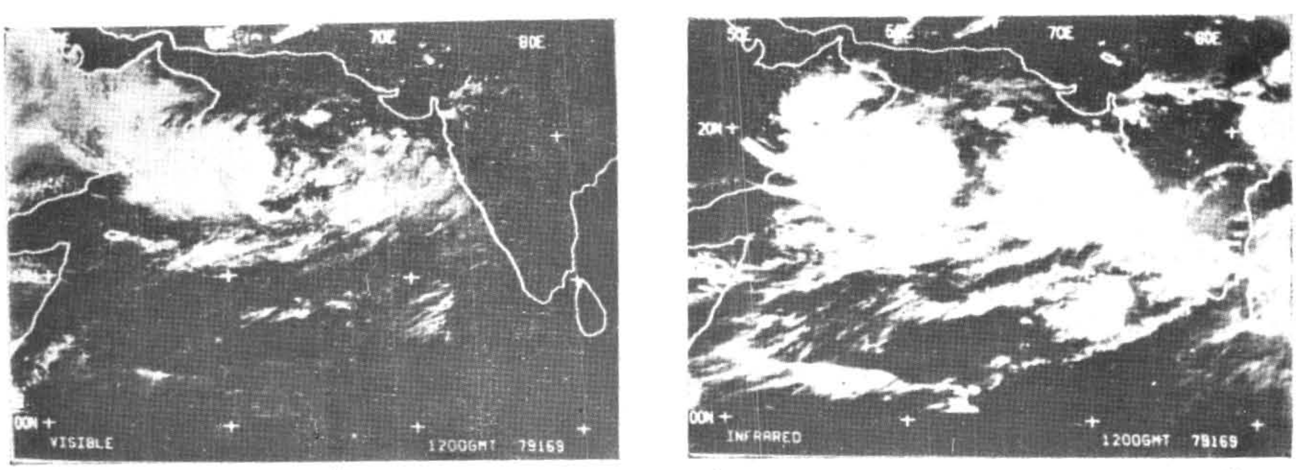


Fig. 8. Same as Fig. 6 but for 18 June 1979

5. Discussions of the results

As shown in Table 1 we could get very poor correlation between OLR field and divergence of the wind field, when OLR values in the non-convective regions are included. This may be due to the fact that some of the areas in the domain are clear skies, some are non-convective and some are convective in nature, and hence we cannot expect a strong relationship between OLR field and divergence of the wind field in all these areas. It is well established fact that strong divergence does exist in the region of major convective activity and hence, we can only expect a strong relationship between OLR values and divergence of the wind field in the area of deep convective activity.

A significant correlation for TIROS-N and very highly significant correlation for GOES-IO satellites are obtained between OLR field and divergence of the wind field, when OLR values only in the area of deep covection are considered. TIROS-N being a polar orbiting satellite, the OLR values represented those for a given longitude at local standard time (1530 and 0330 LST). Moreover, consideration of daily OLR values. *i.e.*, average of day and night time observations might have suppressed the area of deep convection. But in case of GOES-IO satellite the values of OLR were at the exact time of observation. Due to these reasons we could get a significant correlation for TIROS-N satellite and very highly significant correlation for GOES-IO satellite. Figs. 3(a & b), 4(a & b) and 5(a & b) depict analysis of OLR fields obtained from GOES-IO and TIROS-N satellites on 12, 14 and 18 June 1979 respectively, when active ITCZ, onset vortex and depression were formed over the Arabian Sea. Cloudiness pattern at 12 UTC obtained from GOES-IO satellite on 12, 14 and 18 June 1979 in visible and infrared regions are shown in Figs. 6, 7 and 8 respectively.

Comparison of Fig. 3(a) with Fig. 3(b) of 12 June 1979 shows that three cells of lowest values of OLR (125 watts/m^2) seen for GOES-IO satellite associated with major convective activity are not seen for TIROS-N satellite. Instead three cells only one cell is depicted. Comparison of Fig. 4(a) with Fig. 4(b) of 14 June 1979 shows that two cells of lowest values of OLR (125 watts/m^2) field appearing for GOES-IO satellite associated with onset vortex are not seen for TIROS-N satellite. Similarly, comparison of Fig. 5(a) with Fig. 5(b) of 18 June 1979 shows that again two cells of values 125 watts/m^2 and 175 watts/m^2 present for geostationary satellite are absent in polar orbiting satellite. This indicates that while taking daily values of OLR from polar orbiting satellite we are likely to miss a region of intense convection. Further, it is observed that on an average whole OLR field in the region of major convection is suppressed for polar orbiting satellite. In case, we consider day or night time orbital passes over the Indian region and bring these orbital time period to synoptic hour period with some analysis scheme then to some extent we may get reliable information of OLR field. It is rather difficult for any analysis scheme to produce exact OLR field at the synoptic hour observations. Instead of doing all these difficult exercises it is better to consider OLR data obtained from geostationary satellite at a particular synoptic hour. The data from geostationary satellite would give an instantaneous field of view of OLR at that particular synoptic hour.

Data from INSAT series promise to provide wealth of information about clouds, winds, precipitation, sea surface temperature etc. over the Indian sub-continent. Cloud motion vector derivation (Kelkar and Khanna 1986), precipitation estimates (Arkin *et al.* 1989, Kelkar and Rao 1989), sea surface temperature retrieval (Kelkar *et al.* 1989) and OLR derivation have begun recently at Meteorological Data Utilization Centre (MDUC), New Delhi. If we want to have OLR field at any specific time over the Indian region, then it could be easily obtained from INSAT satellite. Therefore, divergence of wind field constructed from OLR data obtained from INSAT satellite would be of potential application for regional models.

6. Conclusion

Construction of divergence of the wind field through OLR data is possible only in the region of major convective activity and for this purpose OLR data obtained from geostationary satellite seems to be more promising than from the polar orbiting satellite for regional circulations.

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