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Calculation of rainfall from satellite data in and around Bangladesh

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सार — इस शोध पत्र में 0.5 ° × 0.5 °, 1° × 1°, 2° × 2° के स्थानिक विभेदन और एक दिवसीय, तीन दिवसीय, सात दिवसीय तथा मासिक औसतों के कालिक मानों के लिए बंगलादेश और निकटवर्ती क्षेत्रों के जी.एम. एस. - 5 से प्राप्त किए गए तीन घंटेवार आई. आर. आँकड़े का प्रयोग करते हुए जी. एम. एस. वर्षा सूचकांक (जी. पी. आई., उपग्रह वर्षा) का आंकलन किया। भूमि धरातल पर 0.5 ° अथवा 1° मेश के स्थानिक औसत मान के मध्य कोई विशेष अंतर नहीं पाया गया है। जी. पी. आई. की कंटूररेखाएँ 0.5° के मेश के पास पास थी और उनका जी. पी. आई. के उतार चढ़ाव के साथ भली भाँति तालमेल पाया गया है। जून से जुलाई के मानसून महीनों में अधिकतम और न्यूनतम जी. पी. आई. के आरम्भिक स्थान में परिवर्तन का पता चला है। अधिकतम और न्यूनतम दोनों जी. पी. आई. उत्तर की ओर खिसक जाते हैं। उत्तर से दक्षिण की ओर बढ़ते हुए, जी. पी. आई. में वृद्धि का पता चला है। जहाँ वर्षा के उतार चढ़ाव कम क्षैतिज दूरी पर पाए गए हैं वहाँ भू-क्षेत्रों की अपेक्षा समुद्र और अपतट के क्षेत्रों में अधिकांशतः एक समान जी. पी. आई. प्राप्त किए गए हैं। इस अध्ययन में यह देखा गया है कि वास्तविक वर्षा जी. पी. आई. के 88% थी।

ABSTRACT. We calculated GMS Precipitation Index (GPI, satellite rainfall) using three hourly IR data from GMS-5 over Bangladesh and adjoining areas for spatial resolution of 0.5°× 0.5°, 1°× 1°, 2°× 2° and temporal scales of 1-day, 3-day, and 7-day and monthly averages. There was no special difference between the spatial averaging scale of 0.5° or 1° mesh on land. The GPI contours were closely spaced in 0.5° mesh and better to comprehend the GPI fluctuation. From the monsoon month of June to July the GPI maxima and minima shift from their original (starting) location. Both the GPI maxima and minima shifted toward north. There was an increase in GPI as one moved from north to south. Sea and offshore areas received almost uniform GPI compared to land areas where rain fluctuations occurred with little horizontal distance. It was found that actual rainfall was 88% of the GPI in this study.

Key words- Rainfall, GMS Precipitation Index (GPI), Spatial, Temporal, Contour, Grid cell.

1. Introduction

Tropical convective precipitation with the release of latent heat is one of the major forcing mechanisms of the general circulation of the atmosphere. Knowledge of the actual precipitation averaged over large areas of potentially great importance for both numerical weather prediction and simulations of the climate using general circulations models (Arkin, 1979); also crop assessment and large basin flood forecasting can be easily envisioned. Flood is a common phenomenon in Bangladesh.

In an average year about one-fifth of the country gets flooded (Rahman *et al.* 1997). So estimation of precipitation may play an important role in flood forecasting.

There are two fundamental methods of measuring rainfall. One is to catch the rain directly by a raingauge. Despite problems associated with the shape of the container its exposure, the wind and evaporation between measurements raingauges provide the best available estimates of precipitation at any given point (Arkin and Meissner, 1987). However, a dense network of raingauges is required to produce

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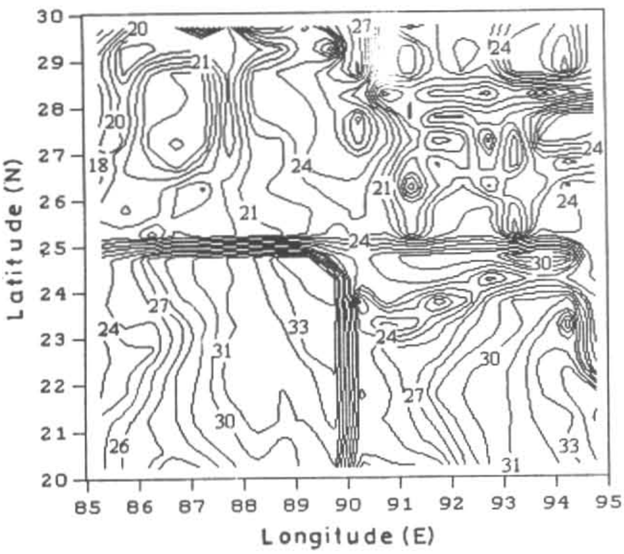

Fig. 1. Daily average GPI (mm) for 0.5° mesh from June-July 1996. Contours are at 1 mm interval

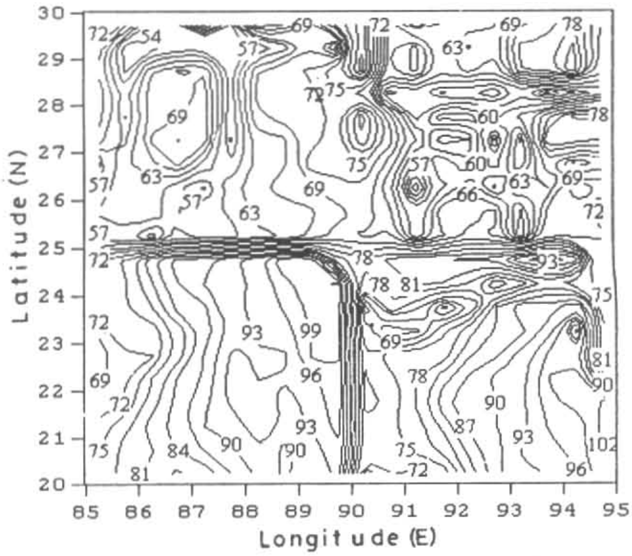

Fig. 2. Same as Fig. 1 except for 3-day accumulated value. Contours are at 3 mm interval

accurate estimates of a really averaged precipitation, which is impossible over ocean and inaccessible areas. Some remote sensors make the second category of rainfall measurements. They may be direct (radar) or indirect (satellite). Despite problems such as variation in the reflectivity rainfall relation varying droplet size spectra and beam attenuation among others good estimates of a really averaged rainfall can be obtained using suitable calibrated digital radars (Hudlow and Patterson, 1979). However radar ranges are rather small (100-500 km approximately) and its deployment is impracticable over the ocean and it would be very expensive to have a large radar network on land. So the solution to overcome the difficulties of land based equipment is to make use of satellite based remote sensing devices. Satellite data become useful when averaged over large space and or time scales and then only when carefully calibrated for the region and monsoon in question (Petty and Krajewski, 1996). In recent times, researchers are trying to estimate rainfall using satellite data. Adler and Negri (1988) developed a method named Convective Stratiform Technique (CST) to estimate rainfall from satellite data. Goldenberg *et al.* (1990) modified CST for the south China sea region. Islam *et al.* (1998) adapted CST for the tropical region.

The GOES Precipitation Index (GPI; Arkin and Meissner, 1987; hereafter GPI 87) is one of the simplest and widely used one parameter technique to estimate average precipitation over a large area for a period of time. GPI 87 technique is being successfully used on an operational mode with US geo-stationary satellites. Recently this technique is used to estimate precipitation using INSAT-1B data. Though very important still now there is no standard method to estimate rainfall using satellite data. Therefore, it is interesting to estimate rainfall using Geo-stationary Meteorological Satellite (GMS) data. In this paper we calculated GMS Precipitation Index (GPI) using three hourly IR data from Japanese GMS-5 over Bangladesh and adjoining area for spatial resolutions of 0.5°× 0.5°, 1°× 1° and 2°× 2° and temporal scales of 1-day, 3-day, 7-day and monthly averages.

2. Data

We used three hourly satellite infrared (IR) data, provided by the Institute of Flood Control and Drainage Research (IFCDR), Bangladesh University of Engineering and Technology (BUET), Dhaka, from the Japanese Geo-stationary Meteorological Satellite (GMS-5).

3. Procedure

Three hourly full resolution IR data from GMS-5 were used to estimate GPI for the monsoon months June and July 1966. Digital images from GMS-5 consist of IR counts of pixels, which vary from 0 to 63 gray shade values. The gray shade value of each pixel is read and converted into its corresponding temperature (equivalent black body temperature) by a lookup table prepared by the Japan Meteorological Department.

To obtain GPI from GMS-5 data the steps are as follows:-

Step 1 – Our study area extends from 20°N- 30°N and 85°E-95°E covering whole Bangladesh and some portion of

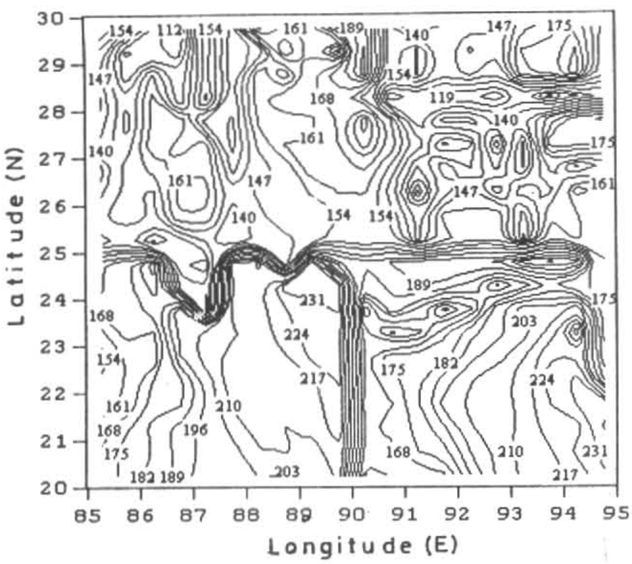

Fig. 3. Same as Fig. 1 except for 7-day accumulated value. Contours are at 7 mm interval

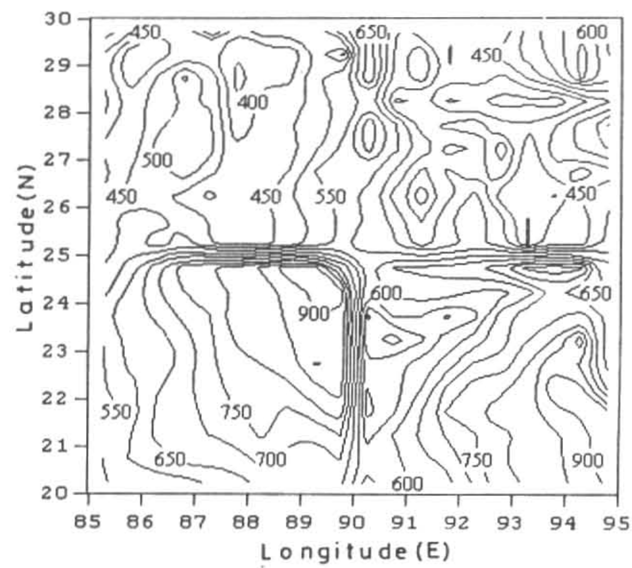

Fig. 4. Total GPI (mm) for 0.5° mesh for the month of June 1996. Contours are at 50 mm interval

the Bay of Bengal and India. The whole area was divided into 0.5°×0.5° grid cells. Each cell contains 30 pixels, while each pixel was 11 km × 9 km.

Step 2 – The fractional coverage of cloud ' F_c' was calculated for each 0.5°×0.5° grid cell. "F_c" was defined as for each 0.5°×0.5° cell covered by clouds whose cloud top temperatures are colder than 253°K. The threshold so chosen to include all kind of precipitating clouds. The same was used by Shih (1990) who defined cloud area having the threshold value of 253°K. According to the definition.

$$F_c = \frac{\text{Total number of cloudy pixels}}{\text{total pixels}} \tag{1}$$

Step 3 – Estimation of large space and time scale precipitation is carried out using a linear model (Arkin and Meissner, 1987). The rainfall estimates are referred to as GMS-5 Precipitation Index (GPI).

The linear form of GPI is,

$$\text{GPI (mm)} = K \times F_c \times T \tag{2}$$

Where 'F_c' is the fractional coverage of cloud and 'K' is a constant related to rain rate and is taken as 3 mm/h as by Arkin and Meissner (1987). And 'T ' is the length of averaging period in hour.

Step 1 to step 3 were repeated for each 8 images of the day. Then the total number of pixels for the day was calculated by simple addition. The daily GPI values were averaged for 3-days and 7-days to produce 3-day and 7-day average GPI for each 0.5°×0.5° grid cell. The average GPI for the monsoon months June-July 1996 was also calculated.

Step 4 – We took the sum of four adjacent 0.5°×0.5° cells to get the accumulated GPI for an area of 1°×1°. Again the sum of GPI of four 1°×1° boxes were converted into the GPI for an area of 2°×2°.

4. Results and discussion

4.1. *GPI for 0.5° mesh*

Fig.1 shows the daily average GPI (mm) for the month of June and July 1966. The GPI was calculated for a grid cell of 0.5°× 0.5° Lat./Long. area. In this study GPI is the technical name of satellite rainfall. A peak rain of 34 mm showed the areas 89.5°E, 24°N and 95°E, 20-22.5°N experienced highest average rain during the months of June-July 1996. Rain decreased from south to north. There was a minimum rain (16 mm) region located around 26°N, 91°E. The contour represents that there was a GPI in an average 19 mm/day. It is clear that although the GPI varies from region to region. The 1996 monsoon (June-July) rain has small spatial differences. Fig. 1 also implies that it rained almost uniformly from 20° - 29°N and 85° - 95°E.

Fig. 2 shows that the average 3-day accumulated rain for a grid cell of 0.5°×0.5° Lat./Long. for the month of June-July 1996. The region 22°N, 94.5°E experienced the highest GPI, which was 100 mm/3-day. The region of lowest GPI experienced 50 mm/3-day rain and there were two such

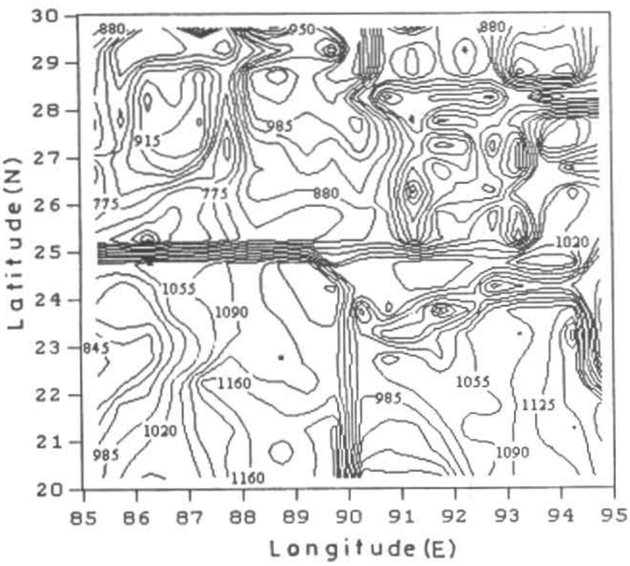

Fig. 5. Same as Fig. 4 except for the month of July 1996. Contours are at 35 mm interval

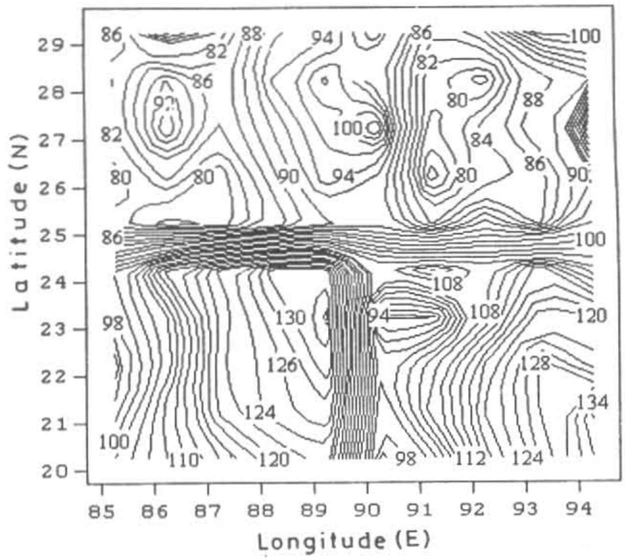

Fig. 6. Same as Fig. 1 except for 1° mesh. Contours are at 2 mm interval

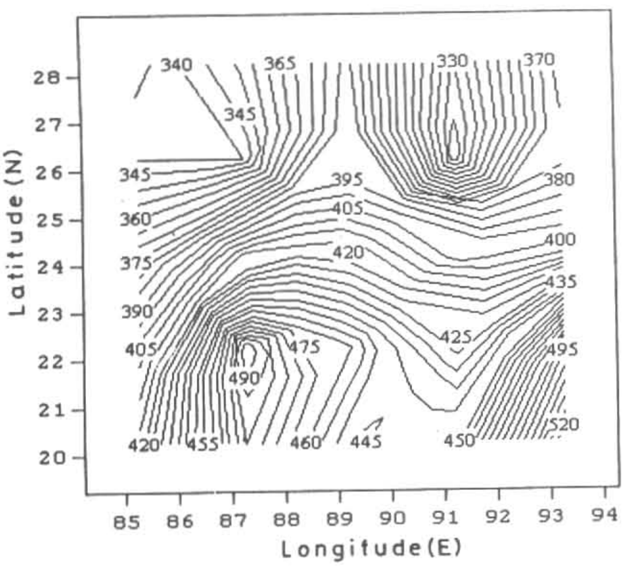

Fig. 7. Same as Fig. 1 except for 2° mesh. Contours are at 5 mm interval

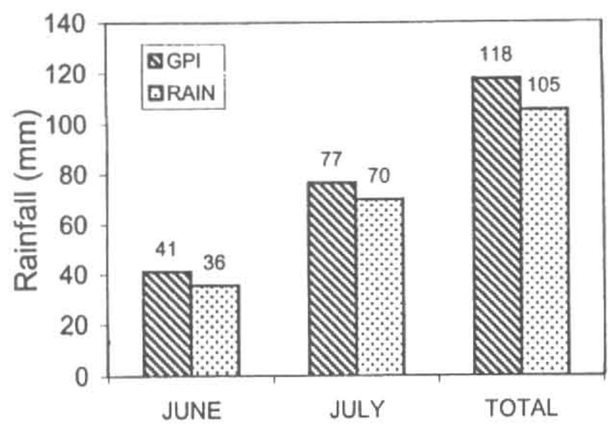

Fig. 8. Comparison between satellite rainfall (GPI) and the actual rainfall (RAIN) for June-July 1996

locations: one at 29°-30°N, 87°-88°E while another one at 28°N, 94°E. Fig. 2 also shows that the 25°N line may divide the analysis area into two regions: northern region having average GPI almost above 70 mm/3-day, while the southern region experienced over 85 mm/3- day rain in an average. There was a closely spaced rain contours extending from west to east at 25°N represents that rain varies here with small distances. Such another area extends from south to north at 90°E.

There were some "*T*" shaped closely spaced GPI contours, which show the large variation of GPI for 1° or less horizontal extent. The vertical arms of "*T*" show the rapid spatial variation, while the horizontal region has less difference. The vertical areas were situated on land and sea. On land local orography wind temperature humidity and even woods has their effect on GPI amount. In contrast on ocean these parameters are rather uniform at least at small regions. So that over land the GPI amount may change rapidly but over the ocean this is not so drastic.

Fig. 3 shows the estimated GPI (mm) for an averaging scale of week. The maximum and minimum GPI was 235 mm/week and 123 mm/week located at 21°N, 95°E and 29.5°N, 86.5°E respectively. Again here we notice some closely spaced "*T*" shaped contours. However the horizontal area was deformed to a zigzag. Here precipitation varied from 138-168 mm/7-day. In the vertical arm of the "*T*" precipitation varied from 213-160 mm/7-day. There was less rain as one move toward east.

Fig. 4 shows the total GPI (mm) for the month of June 1996. The average GPI was ~ 500 mm/month, but GPI ranges from 350- 900 mm/month. Maximum rain area was located at 21.25°N, 94.75°E and 24.5°N, 89.5°E. The total amount was not so high because in 1996 the monsoon was set on the 13 June. So almost half of the month was rainless. Therefore this figure well agreed with empirical data. Here we observed a "*T*" shaped pattern where GPI varied sharply with small spatial change. The horizontal arm of the "*T*" was located at 25°N actually divided the total area into two parts: in one part (upper part) GPI ranged from 350-650 mm/month whereas in the lower part GPI varied from 450-900 mm/month. This area (below 25°N) was mainly the Bay of Bengal and its coastal areas, which usually received more GPI than other areas.

Fig. 5 shows the total GPI in the month of July. The total rain varied from 700 mm to over 1200 mm/month. There was a wide variety of GPI in July 1996. There was a less rainy area located at 28°N, from 90.75° - 92.75°E. The area below 25°N received enough rain during July, the maximum rain area was located at 21°N, 94.75°E. On July Bhutan (28°N, 90°E) and adjoining South China (30°N, 90°E) experienced heaviest GPI about 35-40 mm in a day. There is enough rain also over Assam and Myanmar.

Comparing the GPI between June and July 1966, we found that there was a gradual shift in GPI maxima toward south; however the GPI minima moved northward. The general trend of the GPI patterns is an increase in precipitation as one move from north to south. Both in June and in July the GPI contours were closely spaced over land than over sea.

4.2. *GPI for 1° mesh*

Fig. 6 shows average daily GPI distribution for an area of 10° × 10° Lat./Long. GPI was calculated for a box of 1° × 1° area. So that there were 100 small boxes. The highest rain area was located at 94°E, 20°-21°N. This is same as Fig. 1 where we calculated precipitation for an area of 0.5°× 0.5° grid cell. Again here appeared a " *T*" shaped closely spaced GPI contours. In the left part of the vertical arm, GPI (mm) varied from 82-100 mm/day, where in the right part it was 120-98 mm/day. Here lowest GPI areas were situated at different locations.

4.3. *GPI for 2° mesh*

Fig. 7 shows 1-day average GPI for a grid cell of area 2°×2° Lat./Long. The maximum GPI area received a GPI over 520 mm/day. This area was located at 20.5°N, 93°E. The minimum GPI area that was located at 26.5°N, 91°E received 325 mm GPI a day.

Fig. 8 shows the comparison between GPI and the actual rainfall (RAIN) for the months of June-July 1996. It is seen that GPI calculated 41 mm and 77 mm for June and July respectively while actual rainfall was 36 mm and 70 mm for the corresponding months. In total GPI calculated 118 mm and raingauge calculated 105 mm for these two months. This represents that actual rainfall was 88% of the satellite rain (GPI) that encouraged calculating rainfall from satellite data.

5. Conclusions

In this study we found that there was no special difference in the spatial averaging scale of 0.5° or 1° mesh on land areas. However, the GPI contours were closely spaced in a 0.5° mesh and so enabled us better comprehend the GPI fluctuations. From the monsoon month of June to July the GPI maxima and minima shift from their original (starting) location. Both the GPI maxima and minima shifted toward north. There was an increase in GPI as one moved from north to south. Sea and offshore areas received almost uniform GPI compared to land areas where rain fluctuations occurred with little horizontal distance. The actual rainfall was 88% of the GPI value calculated from satellite data.

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