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Seasonal and spatial characteristics of QPE errors over Indian region

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सार – इस शोध–पत्र में उपग्रह से प्राप्त की गई विभिन्न प्रकार की परिवर्तनशील सिनॉप्टिक स्थितियों के लिए मात्रात्मक वृष्टि आकलनों (क्यू.पी.ई.) के क्रियाकलापों की जाँच की गई है तथा साथ ही स्थलीय क्षेत्र में हुई वर्षा के प्रेक्षणों के साथ व्यापक रूप से परस्पर तुलना करते हुए भारतीय क्षेत्र में इन त्रुटियों के स्थानिक और मौसमी विशेषताओं के मात्रात्मक मूल्यांकन को भी प्रस्तुत किया गया है। इस अध्ययन से यह पता चलता है कि प्रत्येक मौसम में क्यू.पी.ई. सामान्यतः औसत वर्षा की विभिन्न सिनॉप्टिक स्थितियों के साथ जुड़े वर्षा पैटर्नों का अभिग्रहण करने में सक्षम है। किंतु इसमें मौसमी और स्थानिक बायस सुनिश्चित है। मानूसन ऋतु से पहले की वर्षा के अलावा अक्षांश 30°उ. के दक्षिण में देश के अधिकांश भाग में हुई वर्षा को कम आंका गया है। अंक्षाश 30°उ. के उत्तर के क्षेत्र में जहाँ पश्चिमी विक्षोभ प्रबल होता है वहाँ वर्षा को अधिक आंका गया है। मानसून से पहले की सवंहनी ऋतु में प्रेक्षित वर्षा क्यू.पी.ई. के अनुरूप रहती है।

ABSTRACT. The study examines the performance of INSAT derived quantitative precipitation estimates(QPE) for different varying synoptic conditions and also presents a quantitative assessment of spatial and seasonal characteristics of these errors over Indian region making detailed inter-comparison with land rainfall observations. The study reveals that the QPE, in general, is able to capture rainfall pattern associated with different synoptic conditions and spatial distribution of mean rainfall of each season. But it has certain seasonal and spatial biases. The rainfall over most part of the country south of Lat. 30° N is under-estimated in all seasons except pre-monsoon. For the region north of Lat. 30 ° N where western disturbances are dominant, rainfall is over estimated. In the convective season of pre-monsoon, QPE has got very high degree of correspondence with the observed rainfall.

Key words – INSAT, Quantitative precipitation estimates (QPE), Physical initialization, Synoptic condition, Performance statistics.

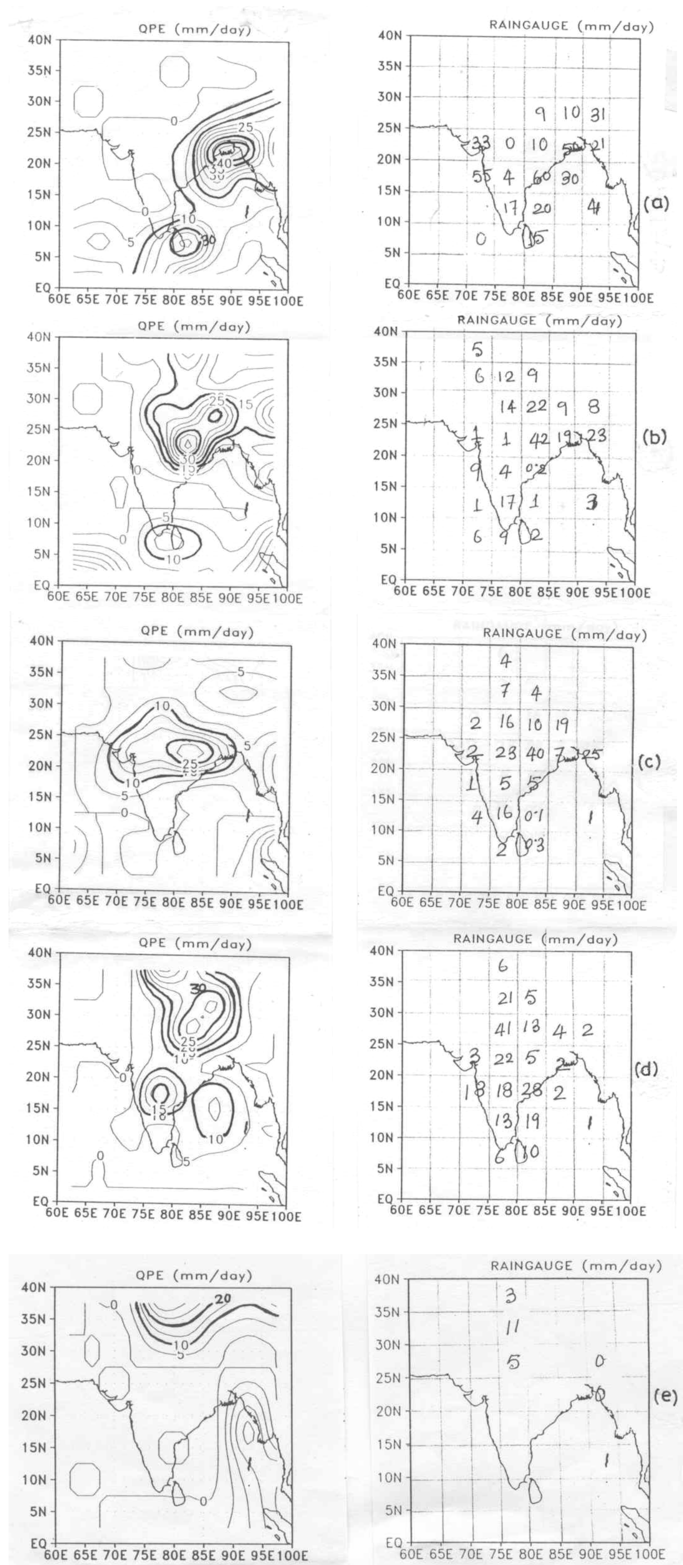
1. Introduction

INSAT derived Quantitative Precipitation Estimates (QPE), promise to provide a very useful input for the physical initialization (Krishnamurti *et al*., 1995; Puri and Devidson, 1992; Heckley *et al*., 1990 etc.) of Numerical Weather Prediction (NWP) models. But the accuracy of the product is limited due to the indirect relationship of the cloud top temperature and precipitation. Before these data are used to aid the initialization of NWP models, an investigation on the performance of these estimates on seasonal and spatial scale is a pre-requisite. Because of this consideration an inter-comparison of GOES data for the global tropics with reference to short range precipitation forecast of NCEP and ECMWF model and for Japan with reference to ground observations is made by Janowiak (1992). Similar study for the Australia region is made by Ebert and Marshall (1995). Arkin *et al*. (1989) examined the performance of INSAT derived precipitation estimates over Indian region for the south-west monsoon season of 1986 utilizing sub-divisional monthly mean rainfall.

In this paper, performance of QPE is examined on daily basis with reference to rain gauge observations for varying synoptic situations. In order to quantify the systematic errors of these estimates the performance statistics such as mean errors and spatial correlation coefficients with reference to land rain gauge observation are also examined for each season .

2. Data and methodology

QPE data from the Indian Geostationary Satellite INSAT are derived at the grid resolution 2.5° × 2.5° Lat./Lon. following the algorithm as described by Arkin *et al*. (1989). The approach is identical with one which



Figs. 1(a-e). Inter-comparison of QPE and land rain gauge rainfall in association with (a) cyclonic storm of 25 September 1997; monsoon depression of (b) 28 July 1999 and (c) 9 August 1999; western disturbance of (d) 8 December 1997 and (e) 28 January 1999. Blank grid indicates no data was used to obtain such estimates for GOES (Arkin and Meisgner, 1987). According to this algorithm the rainfall estimates is given by :

$$R = 3 \times f \times h$$

where R is areal rainfall estimates in mm

f is the fraction of IR pixels with temperature less than 235° K and total number of pixels within the square grid and h is time in hour.

The constant rain-rate of 3 mm/hr provides the best correlation of the regression relation (Richard and Arkin, 1981).

As adequate ground observations are available over the country, rain gauge rainfall observations received on GTS (global telecommunication system) and from DRMS (District wise rainfall monitoring scheme) network of India Meteorological Department (IMD) are used to assess the performance of QPE over the land. Since these data sets are not at uniform resolution, to obtain a comparable data set, both of the data sets are converted into uniform grid resolution of 5° × 5° Lat./Long. computing areal average rainfall for each grid box. Selection of this resolution is also due to the consideration to accommodate more number of ground observations for a reasonable representation of grid box. The performance statistics is based on the data for the period from 1 June 1997 to 30 May 1998.

3. Performance of QPE on daily basis

In this section some case studies on the performance of QPE on daily basis for different varying synoptic situations with reference to land rain gauge observations are illustrated.

Case 1: Bay of Bengal cyclonic storm of 25 September 1997

A depression formed over west central Bay of Bengal on 23 September, 1997. Moving in a northerly direction it intensified into a cyclonic storm by the evening of 24 September. At this time it took north-easterly course and located near Lat. 17.5 ^{o} N and Long. 83.5° E. on 25 September morning. Fig. 1(a) represents corresponding 24 hours rainfall based on QPE and rain gauge observation. Comparison indicates that QPE is able to capture heavy rainfall belts along east coast of India associated with this system. Heavy rainfall belts along western ghats of India is not captured by QPE.

Case 2: Monsoon depression

(a) *Monsoon depression of 28 July 1999*

A monsoon depression developed over northwest Bay of Bengal in the morning of 27 July. It crossed Orissa - West Bengal coast in the early morning of 28 July and lay as deep depression in the morning of 28 July near Lat. 23° N and Long. 86.5° E. Fig. 1(b) represents corresponding 24 hours rainfall distribution observed in the morning of the day. The comparison reveals that QPE could capture the heavy rainfall zone associated with the system. Orographic rainfall along western ghats is not captured by QPE.

(b) *Monsoon depression of 9 August 1999*

A depression lay centered near Lat. 22.5°N/Long. 86° E on the morning of 7 August 1999. Moving in a westnorthwesterly direction it was located on 8 morning near Lat. 22.5°/ Long. 85° E. Fig. 1(c) represents corresponding 24 hours rainfall distribution observed in the morning of the day. In this case east-west oriented heavy rainfall belt is well captured by QPE.

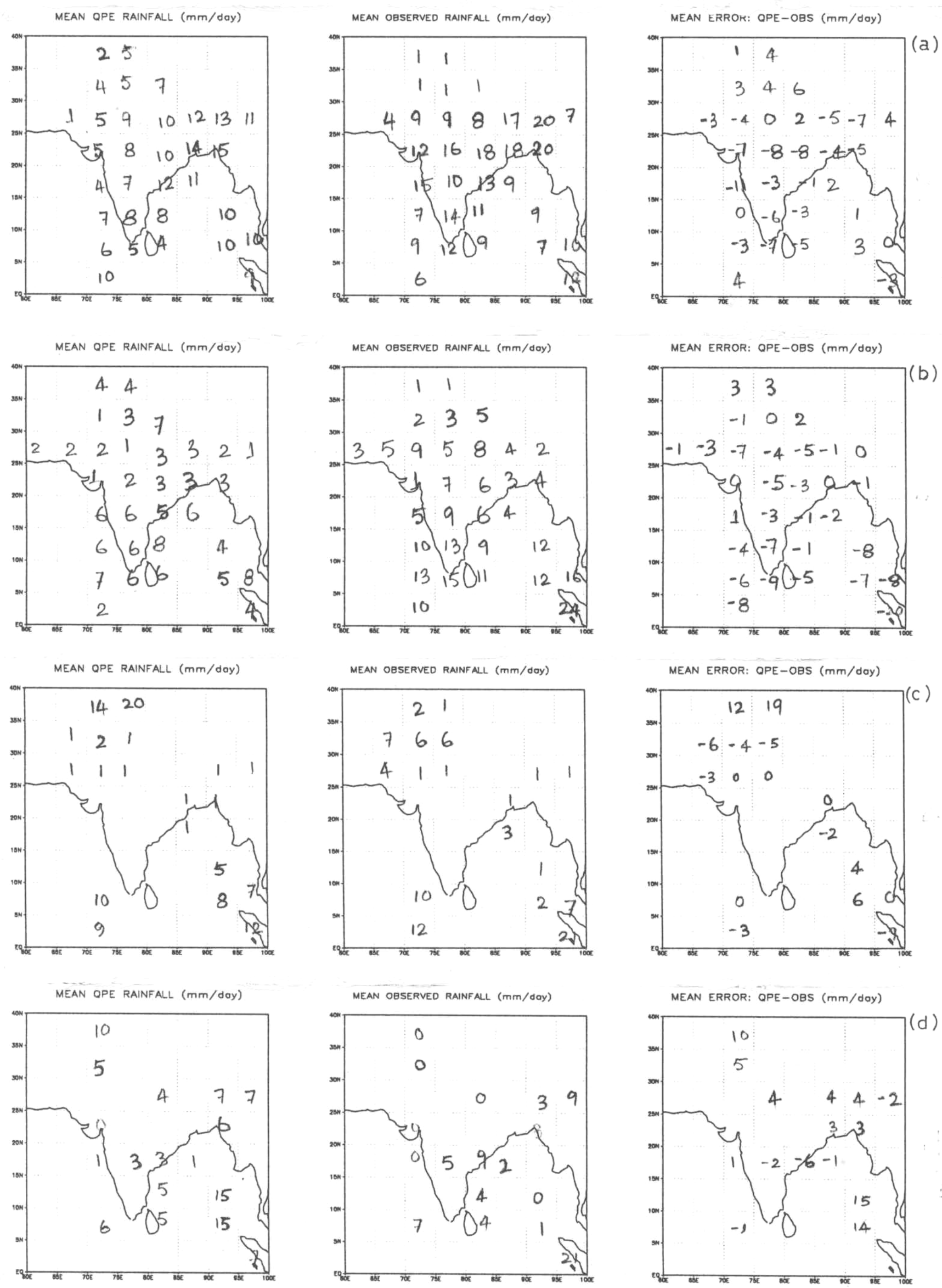
Case 3: Western disturbance

(a) *Western disturbance of 8 December 1997*

An active western disturbance was located over north Pakistan and adjoining Jammu and Kashmir on 7 December 1997 as an upper air system. Associated with this an induced cyclonic circulation lay over central parts of Rajasthan extending upto 3.1 km a.s.l. A trough in mid upper tropospheric westerlies with axis at 9.5 km a.s.l lay along Long. 67° E and north of Lat. 15° N. Under the influence of these system most parts of the country received widespread rainfall activities. Fig. 1(d) which represents corresponding 24 hours rainfall distribution observed in the morning of 8 December, shows that associated north-south oriented heavy rainfall belts over the country is well captured by QPE.

(b) *Western disturbance of 28 January 1999*

A western disturbance as an upper air system lay over north Pakistan and adjoining Jammu and Kashmir with an induced cyclonic circulation extending upto 3.1 km a.s.l. over Punjab and neighbourhood on 27 January 1999. Fig. 1(e) represents corresponding 24 hours rainfall distribution observed in the morning of 28 January. In this case, rainfall activity as reported north of 30° N is well captured by QPE, but the amount of rainfall is over predicted.



Figs. 2(a-d). Comparison between QPE and observed rainfall of (a) south-west monsoon season (for the year 1997), (b) post-monsoon season (year 1997), (c) Winter season (year 1998) and (d) pre-monsoon season (year 1998)

4. Performance statistics

Fig. 2(a) shows the spatial pattern of south-west monsoon based on QPE, rain gauge-observations and the mean errors (QPE-land rain gauge rainfall). Both QPE and ground rainfall observations are characterized by a maximum rainfall zone over Gangetic West Bengal and neighbourhood, but QPE under estimates the seasonal rainfall over most parts of the country. The maximum under estimation occurs over the central parts of the country (8 mm/day). QPE shows heaviest rainfall of amount 13-16 mm/day,

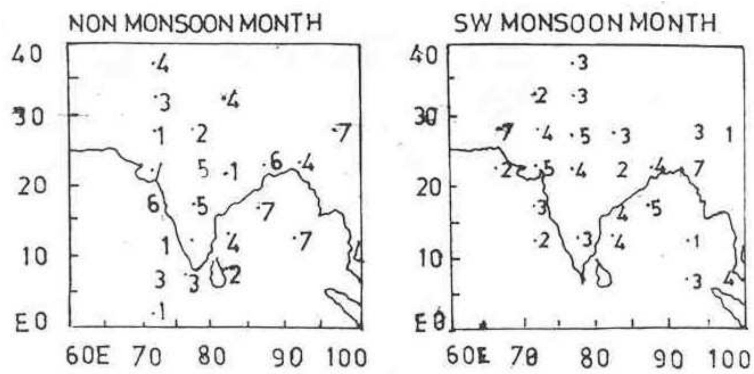


Fig. 3. Spatial pattern of CC between QPE and ground observation rainfall of non-monsoon and southwest monsoon season

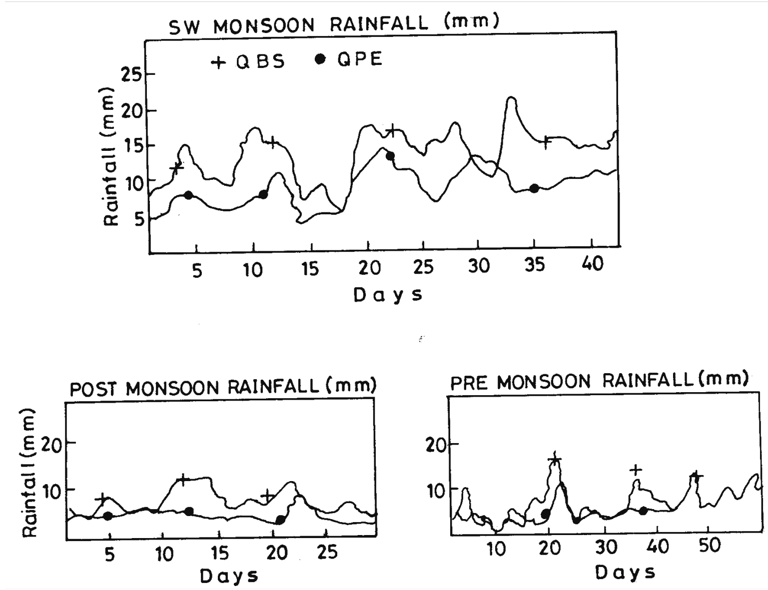


Fig. 4. Time series between QPE and ground observation of southwest monsoon, post-Monsoon of 1997 and pre-monsoon of 1998

where as in the observation the amount is 18-22 mm/day in association with monsoon depression. North of Lat. 30° N rainfall is over estimated. Orographic rainfall over west coast of the country is also not captured by the QPE.

Fig. 2(b) represents spatial pattern for the post- monsoon (October-December) seasons. The QPE could reproduce maximum rainfall zone over the south peninsula, but the rainfall is under estimated by an amount of order 8 mm/day. Observation shows maxima rainfall of amount 12-15 mm/day where as QPE shows about 8 mm/day. To the north of Lat. 35° N there is over-estimation by 3-4 mm/day.

Fig. 2(c) displays the same map for the winter (January-February). Here both QPE and ground data are characterized by mainly two rainfall pockets, one over north-west India and neighborhood- the domain of western disturbances and other over islands of south Indian seas. QPE is higher over Andaman seas and north of lat. 35° N. Otherwise mean error is 0 or negative.

Fig. 2(d) shows the spatial pattern of pre-monsoon season (March-May). Here rain-gauge rainfall and QPE are found to be in well agreement and mean error is very small. However, north of 30° N over estimation continues.

Fig. 3 shows the spatial pattern of correlation co-efficient (CC) between observed rainfall and QPE of non-monsoon months (October,1997 to May, 1998) and south west monsoon season (1997) respectively. The CC is found higher roughly over the domain of mid tropospheric cyclonic circulation (MTC), monsoon depression for southwest monsoon season and over south-central parts of the country during non-monsoon months. Time series of daily space mean rainfall based on QPE and rain gauge observations of three seasons are shown in Fig. 4. The time-series for the winter is not included due to less rainy days over land station for the data period under the study. Though the QPE is able to produce daily ups and downs of daily rainfall, but QPE is always less during southwest monsoon and post-monsoon seasons. The series shows very good correspondence during pre-monsoon season.

5. Concluding remarks

The present study shows that the QPE, in general, is able to reproduce the rainfall pattern associated with different synoptic situations and mean rainfall pattern of each season, but it has certain seasonal and spatial biases. The inter-comparison with ground observations reflects that QPE is lower over most parts of the country south of Lat. 30^{o} N by an order of l2-8 mm/day in all seasons except pre-monsoon.. QPE fails to capture orography rainfall of southwest monsoon season along west coast of India. The time series between space mean QPE and ground observation shows that QPE is able to reproduce daily ups and downs of observed rainfall but QPE is always lower except in pre-monsoon season.

A possible explanation for the behavior of QPE may be rainfall north of 30° N latitude is characterized by mixture of stratiform and convection rainfall in association with Western Disturbance (W.D). QPE which is calibrated for convective rainfall obviously too large for stratiform rainfall that occurs in association with W.D. The under estimation of rainfall south of 30° N latitude is partly due to maximum rainfall rate constant 72 mm/day which is unrealistically low in the context of intense meso-scale convective rainfall in association with monsoon depression/cyclonic storm. This type of seasonal biases of satellite derived rainfall is also observed by Janowiak (1992) over Japan from integrated radar raingauge observations. Arkin *et al.* (1989) utilizing monthly sub-division mean rainfall concluded that 235° K cloud top temperature that QPE uses as threshold for convection is too low in a region where orographic rainfall is predominant. But an encouraging result is the good performance of QPE in pre-monsoon season. During this convective season high degree of correspondence between the time series of QPE and rain-gauge observation is noticed.

Despite these short comings, remotely sensed inferences of precipitation provide very useful information over the ocean and data sparse land region that is not currently available from any conventional source. Further work needs to be aimed at exploring the extent to which model forecast rainfall can complement to enhance INSAT derived rainfall and thereby recalibrating of season, topography and latitude dependent QPE for initialization of convective precipitation applying suitable adjustment between cloud top temperature threshold and rain-rate.

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