A report on rainfall data analysis over Disdrometer network of Bhopal

Calibration and Validation Division (CVD)
Earth, Ocean, Atmosphere, Planetary Sciences & Applications Area (EPSA)
Space Applications Centre (ISRO)
Ahmedabad – 380 015

&

M.P. Council Of Science and Technology

Document Control Sheet

1. Report No.	SAC/EPSA/CVD/SR/2020-03
2. Publication date	June 2020
3. Title and subtitle	A report on rainfall data analysis over Disdrometer network of Bhopal
4. Type of report	Scientific
5. Number of pages	21
6. Number of references	07
7. Authors	Mahesh C, K.N. Babu, N.M. Suthar, Nithya U., G. D. Bairagi
8. Originating unit	CVD/EPSA/Space Applications Centre, ISRO
9. Abstract	This is an interim report on the analysis of rainfall data obtained from network of optical disdrometer established over Bhopal, Madhya Pradesh. This network of disdrometers established over urban area of Bhopal falls under the central Indian region which is very significant for the monsoon related studies as the monsoon axis passes over the region. This area receives intense rainfall during peak monsoon months. The optical disdrometers are solar powered and work independently. They are nine in number and installed in such a way to cover INSAT-3D/3DR adjacent pixel locations. Due to the instrument malfunctioning very few records of rain data were obtained during 2019 monsoon. This report compiles detailed analysis of the valid rainfall data obtained from the network is carried out over during 2018 monsoon season. The analysis indicates vast scope for the pixel level validation of INSAT-3D/3DR rainfall and studies related to micro scale rainfall characterization over the region.
10. Key words	Optical Disdrometer, Rainfall Analysis, Validation
11. Security classification	Un restricted
12. Distribution statement	Among All Concerned

Contents

List of Figures

List of Tables

Abstract:

This is an interim report on the analysis of rainfall data obtained from network of optical disdrometer established over Bhopal, Madhya Pradesh. This network of disdrometers established over urban area of Bhopal falls under the central Indian region which is very significant for the monsoon related studies as the monsoon axis passes over the region. This area receives intense rainfall during peak monsoon months. The optical disdrometers are solar powered and work independently. They are nine in number and installed in such a way to cover INSAT-3D/3DR adjacent pixel locations. Due to the instrument malfunctioning very few records of rain data were obtained during 2019 monsoon. This report compiles detailed analysis of the valid rainfall data obtained from the network is carried out over during 2018 monsoon season. The analysis indicates vast scope for the pixel level validation of INSAT-3D/3DR rainfall and studies related to micro scale rainfall characterization over the region.

Key words: Optical Disdrometer, Rainfall Analysis, Validation

1. Introduction:

Satellite based rainfall observations are widely used for many atmospheric, oceanographic and agricultural applications. It provides high spatial coverage data compared to other ground-based observations of rain. However, the satellite-based rain data has its own limitation as most of the rain estimation algorithms deduce rain from top of atmosphere brightness temperature observed by sensors mounted on space borne platforms. The brightness temperature-based satellite rain estimates are indirect measurement of rainfall. Hence proper validation of satellite rain estimates become an imperative step before using the data for different application studies. Conventionally, insitu observations such as rain gauges are employed for validation of satellite rain estimates. However, the uneven distribution of gauges introduces inaccuracies in rain measurements over a wider area measurement like satellite rain estimates. More over the data obtained from sparsely distributed gauges cannot be used for micro level characterization of rainfall over a region. Mahesh et al. (2014) and Prakash et al. (2010) has validated INSAT-3D based satellite rainfall using GPCP data and observed the requirement of a dense network of ground observations to make a meaningful validation.

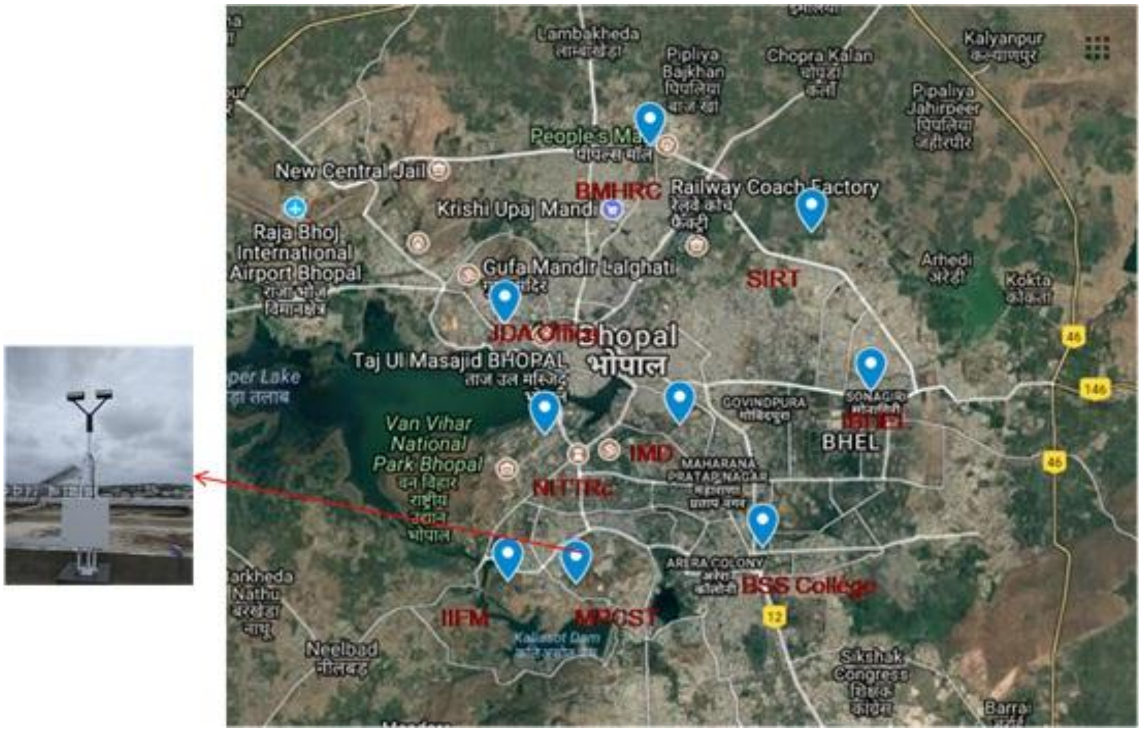
To overcome these problems a network of optical disdrometers are established over Bhopal, Madhya Pradesh. This network encompasses urban area of Bhopal city which falls under the central Indian region. The central Indian region is very significant for the monsoon related studies as the monsoon axis passes over the region. Many large-scale systems pass through this area and receives intense rainfall during peak monsoon months. This report presents an analysis of the valid rainfall data obtained from the network carried out during 2018 monsoon season.

2. Data:

2.1. Optical Disdrometer network:

Nine solar-powered optical disdrometers are installed over the urban area of Bhopal, Madhya Pradesh making 3x3 window of INSAT-3D adjacent pixels and cover ~15 km^2 geographical area. The advantages of the parsivel optical disdrometer is studied by Park et. al. (2017) and the disdrometer is employed for rainfall validation by Zuhang et. al. (2019).

A.



B.

Figure 1: (A)The site locations and the (B)images of nine optical disdrometers installed over the site (a) BHEL (b) BMHRC (c) BSSS (d) IIFM (e) IMD (f) JDA (g) MPCST (h) NITTTR (i) SIRT

2.1.1. Attributes of Optical disdrometer:

Particle size & Velocity	Liquid precipitation: 0.2 to 8mm Solid precipitation: 0.2 to 25mm Particle velocity: 0.2 to 20m/s
Size classification	30
velocity classification	30
Sampling area	$50cm^2$
Precipitation intensity	0.001 to 1000mm/h
Accuracy of precipitation	±5%

2.1.2. Sensor and the working mechanism of the disdrometer:

The main working principle of optical disdrometer is based on attenuation of a laser beam produced by the instrument as a horizontal sheet. The transmitter produces a 5V signal as output. In the absence of hydrometeors, the receiver records all 5V but as hydrometeors pass through the beam the receiver shows drop in voltage which is inferred as rain. The dip in voltage is a function of particle size and velocity (Martin Lo Fler-Manger et. al., 2012). The disdrometer can differentiate particle size from 0.2 to 8 mm with an interval of thirty classes. It can measure hydrometeor velocity from 0.001 to 1000 mm/hr. The accuracy of precipitation accounts for ±5%.

Figure 2: The working principle of OTT parsivel optical disdrometer Parsivel. The signal gets attenuated when pass through the signal (Courtesy: Thies Clima, 2007)

$$R = \frac{\pi}{6} \cdot \frac{3.6}{10^3} \cdot \frac{1}{F \cdot t} \cdot \sum_{i=1}^{20} (n_i \cdot D_i^3)$$

ni : number of drops measured in drop size class i during time interval t

Di : average diameter of the drops in class i mm

F : size of the sensitive surface of the disdrometer m2

F = 0.0050 m2

t : time interval for measurement s

t = 60 s (standard value)

The particle velocity is calculated based on the light thickness and time taken for the particle to enter and leave the light produced by the sensor.

2.2. INSAT-3D-HEM Data:

INSAT-3D HE data with 4 km resolution is used for the present study which is available through MOSDAC.

3. Results and Discussion:

Rain instance is the measure of rainfall intensity for a given minute (temporal sampling interval of instrument). Rain event is defined as the continuous occurrence of two or more rain instances. Among the nine stations, the station which holds maximum record of rain instances and rain events is considered as the master station. The master station is utilized for inter-comparison of rainfall received by the remaining stations and for further analysis. Based on the rain instances, the daily accumulated rainfall is computed for the nine stations. The stations with considerable records (in comparison with master station) are figured and various statistics such as: temporal distribution of rainfall over rainy/non-rainy day, variation of rainfall among these stations etc. are computed. A preliminary comparison between INSAT-3D-DLY data and the rainfall intensity of disdrometer data is done based on the observation of selected disdrometer stations which holds continuous record.

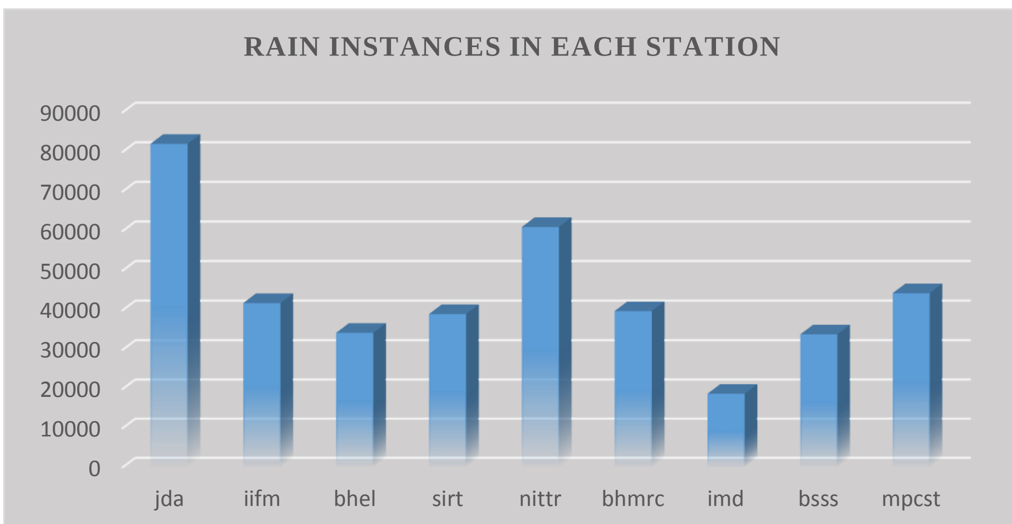


Figure 3: Rain instances recorded on (2018) monsoon season over the stations

The plot (Fig:3) represent number of rain instances occurred over the network of stations. JDA station recorded maximum number of rain instances (~82034) on the 2018 monsoon season. IMD (~2000) observed minimum number of rain instances NITTR recorded ~60000 rain instances. The variation in rain instances can be attributed to natural variations of rainfall across the stations and the performance of instruments. As JDA recorded maximum rain instances it considered as the master station for the present study.

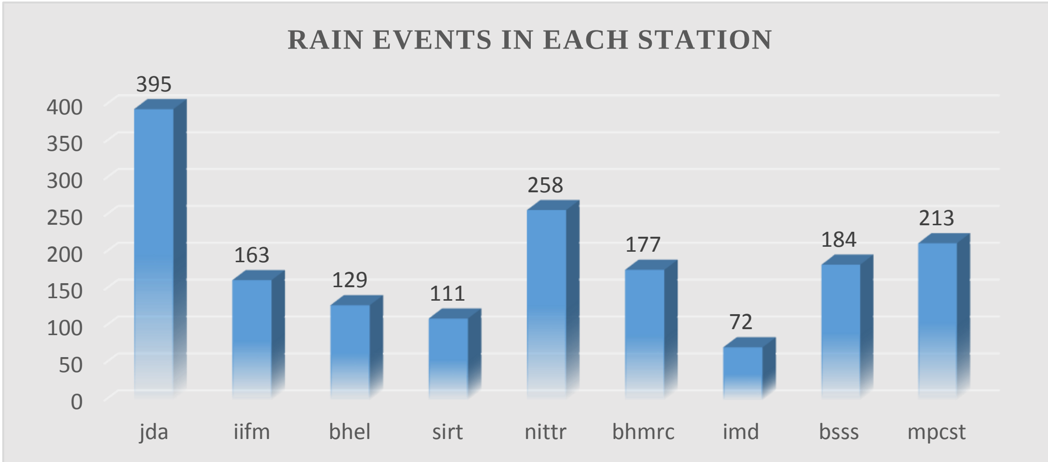


Figure 4: Rain events recorded on (2018) monsoon season over the stations

Similarily rain events recorded over all stations are plotted in Figure 4 . JDA station recorded maximum number of rain events (~385) on the 2018 monsoon season and IMD the minimum of 72 rain events. The trends of rain instances can be observed in the case of rain events also. Based on the rain events also the maximum rain events are recorded in JDA station and it can be treated as the master station.

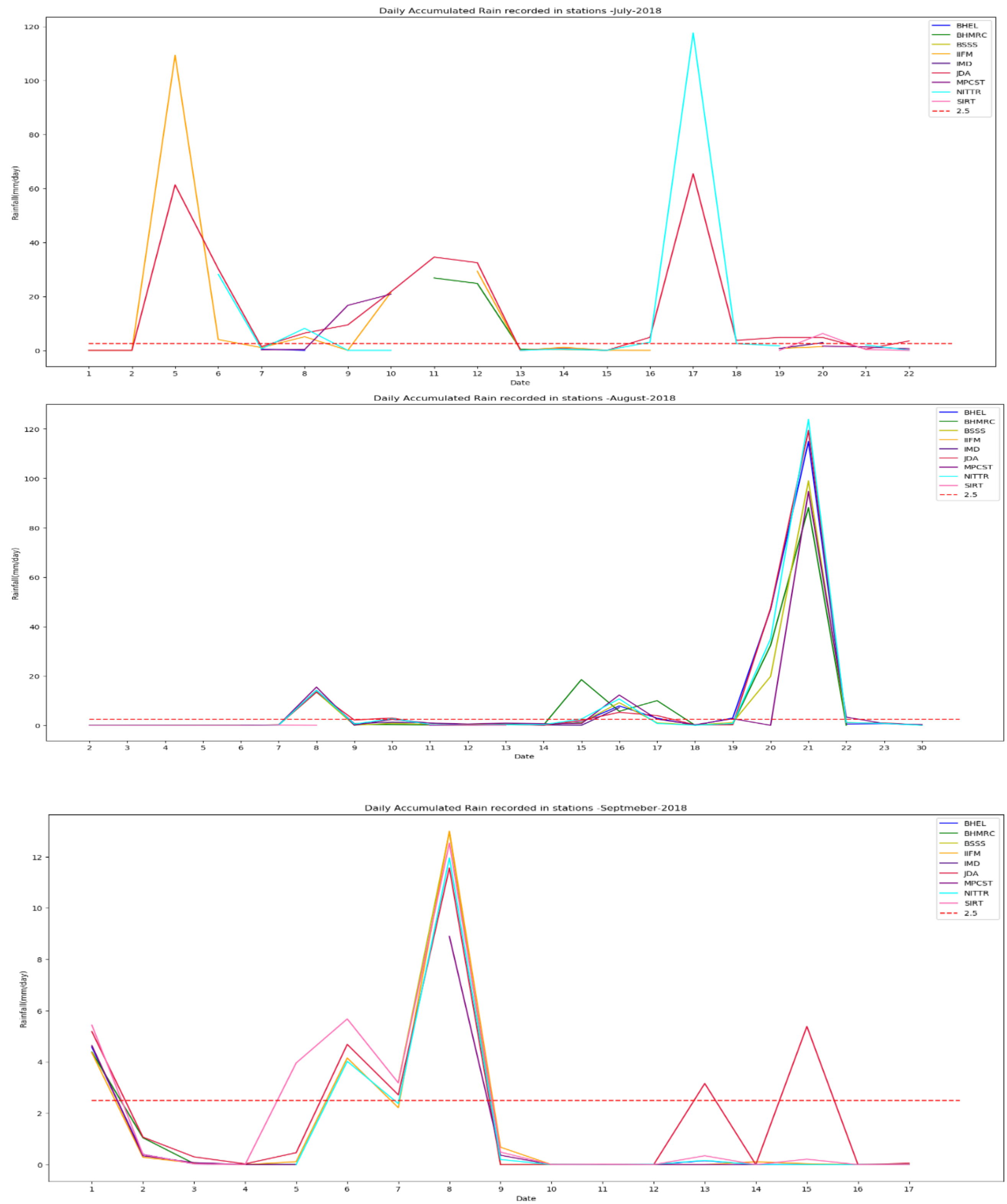


Figure 5: Daily accumulated rainfall recorded across all stations during the monsoon season (mm/day)

The daily rainfall for all the months JAS is computed from the data. According to IMD criterion on a day when >=2.5 mm rain occurs, that day is considered as rainy day. The plot depicts it with dashed line. From the figure it can be observed that all the stations follow overall same rainfall pattern. The breaks are mainly data gaps caused due to various reasons like instrument malfunctioning and non-occurrence of rainfall. From figure 5 it can be observed that in the month of August over the network stations maximum rain occurred during 20th to 25th of the month and all stations recorded nearly equal amount of daily rainfall with a maximum of ~120 mm on August 21. The same trend can be observed on September 8 recording 12mm daily rain on the particular day. It can also be observed from the figure that July and August had heavier rainfall days in comparison to September month. July had three heavy rainfall days: July 5 and July 7, both days recording above 100mm on all stations and July 11 showing 40 mm on the day. August showed one heavy rainfall day recording 120 mm on August 21. In comparison the heaviest rainfall day on September was 8th of the month recording 12 mm on the day. An initial assessment can be made from these cases that major rain events over all the stations show similar trend. Medium and small rain events may be showing variations. However more data sets are required for establishing the fact.

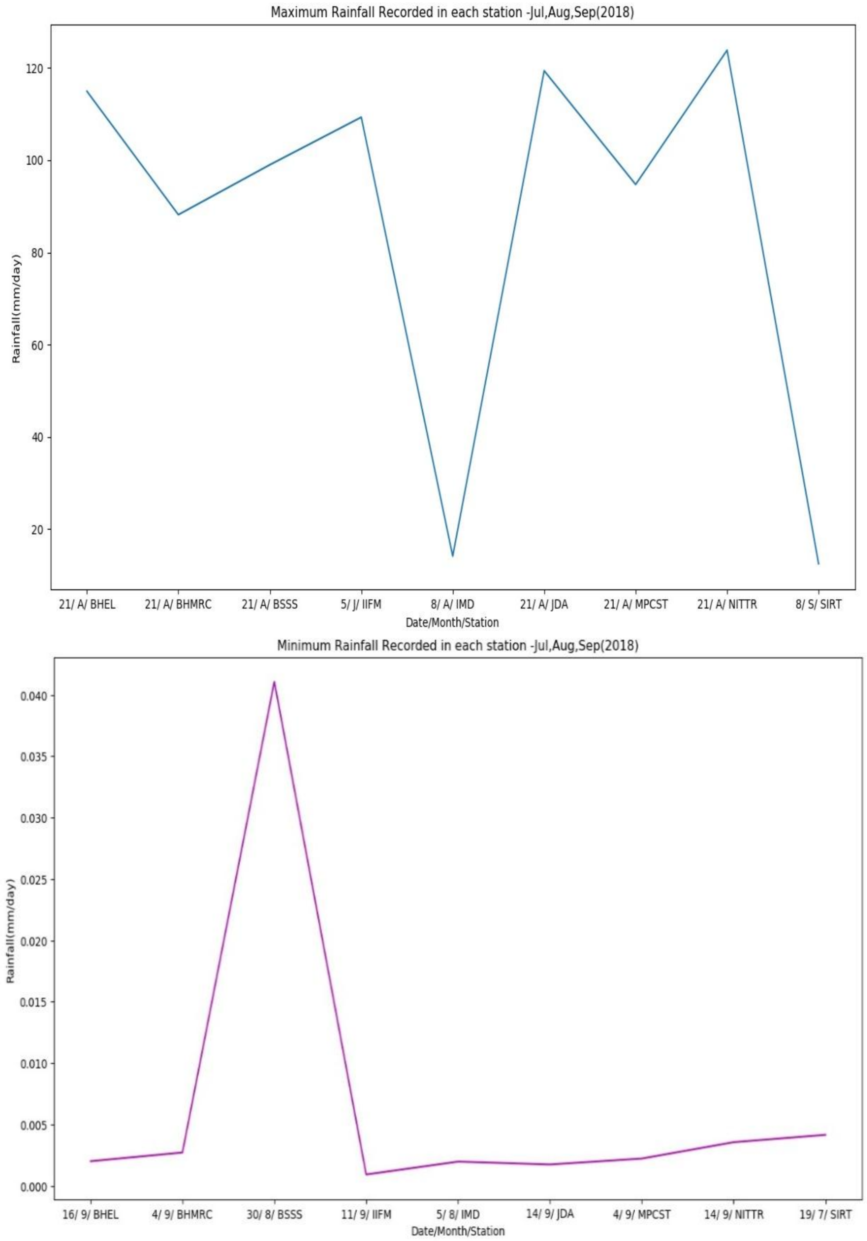


Figure 6: Maximum and Minimum rainfall occurred on each station during the monsoon season (mm/day)

From Fig:6 It can be observed that most of the stations showed >80 mm/day on its heaviest rainfall day except the stations IMD and SIRT. Both the stations showed ~20 mm on the heavy rainfall day. The heaviest rainfall day for majority of the stations on entire monsoon season was 21 August. Similarly, all stations showed < 1mm rain days spanning the whole monsoon season, All nine stations showed different days as their minimum rainfall day.

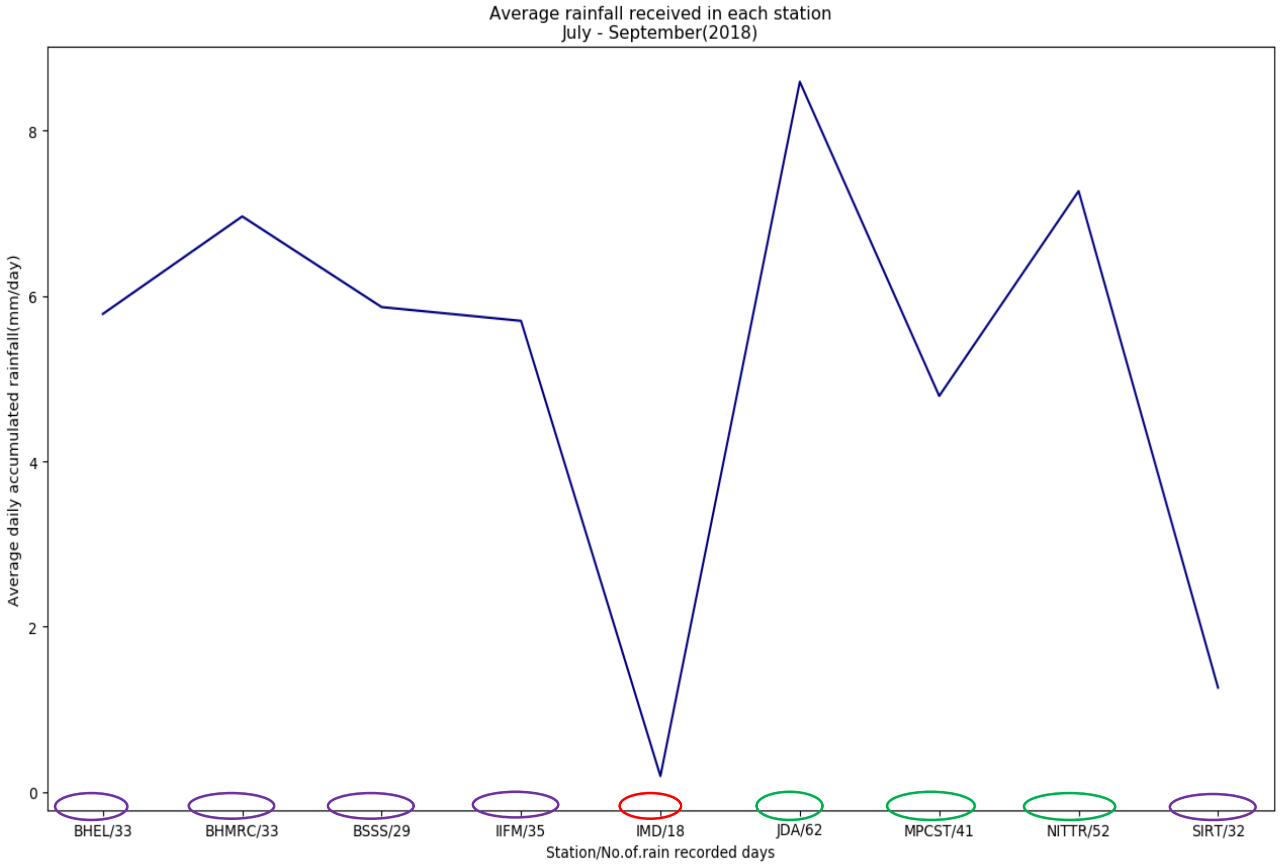


Figure 7: Average daily rainfall (mm/day) during the monsoon with station names and the number of days used for computing the statistics

From Fig 7 it can be inferred that the urban area spanning 15 km^2 show an average 6mm/day during the monsoon season. IMD showed a dip and the days available for the computation also was very less. More data is required for making statistically significant estimate of the average rainfall. Among all the stations NITTR showed maximum number of days (52 days) and show ~ 6.2 mm/day average for the season.

Table 1: Correlation Values of rain instances between nine stations for the 2018 monsoon

Stations/Correlation coefficient	JDA	MPCST	NITTR	IIFM	BSSS	BHMRC	BHEL	IMD	SIRT
JDA	1	-0.03	-0.013	-0.031	-0.015	0.012	-0.005	-0.04	-0.09
MPCST	-0.03	1	0.18	-0.17	0.48	0.26	0.54	0.15	0.08
NITTR	-0.013	0.18	1	-0.17	0.39	-0.061	0.21	0.08	-0.09
IIFM	-0.031	-0.17	-0.17	1	-0.41	-0.43	-0.004	-0.51	0.26
BSSS	-0.015	0.48	0.39	-0.41	1	0.41	0.35	0.36	-0.04
BHMRC	0.012	0.27	-0.06	-0.43	0.41	1	0.26	0.48	-0.13
BHEL	-0.005	0.54	0.21	-0.004	0.35	0.26	1	-0.12	0.04
IMD	-0.04	0.15	0.08	-0.5	0.36	0.48	-0.12	1	0.14
SIRT	-0.09	0.08	-0.09	0.26	-0.04	-0.13	0.04	0.14	1

Table 2: Correlation Values of accumulated rain between nine stations for the 2018 monsoon

Stations/Correlation coefficient	JDA	MPCST	NITTR	IIFM	BSSS	BHMRC	BHEL	IMD	SIRT
JDA	1	0.7	0.8	0.4	0.7	0.8	0.7	0.002	-0.04
MPCST	0.7	1	0.6	-0.03	0.9	0.8	0.8	0.14	0.013
NITTR	0.8	0.6	1	-0.04	0.7	0.6	0.7	0.04	-0.02
IIFM	0.4	-0.03	-0.04	1	-0.03	0.007	-0.03	-0.04	0.05
BSSS	0.7	0.9	0.7	-0.03	1	0.8	0.9	0.1	0.04
BHMRC	0.8	0.8	0.6	0.007	0.8	1	0.9	0.08	-0.07
BHEL	0.7	0.8	0.7	-0.03	0.9	0.9	1	-0.015	-0.016
IMD	0.02	0.14	0.04	-0.04	0.11	0.08	-0.015	1	-0.0009
SIRT	-0.04	0.013	-0.02	0.05	0.04	-0.07	-0.016	-0.0009	1

The tables 1 and 2 show the correlation values between the stations for rain instances and daily accumulated rainfall. It can be observed from the figure that the stations show weaker correlation for rain instances however comparatively better correlation is observed for rainfall data between the stations. From this observation it can be inferred that there is a high variability between the stations for instantaneous rainfall characteristics and show some better correlation for the overall daily rain occurred over the area. To make significant assessment about the characteristics of rainfall the area more data needs to be obtained.

Due to various reasons, continuous records of data were not available. Based on analysis it is observed that continuous data is available from JDA, MPCST and NITTR from 9th August to 4th September. has recorded continuous records from ninth of august to fourth of September based on the above criterion. Computing the correlation and error between the rainfall data of these three stations high correlation was observed for daily accumulated rain. The RMSD is observed to be minimum for JDA and NITTR stations. The reason for high correlation and minimum error between these stations has to be further evaluated.

Table 3: Pearson Corr. Value of accumulated rain between selected three stations for the 2018 monsoon

Station (Corr. Val)	JDA	MPCST	NITTR
JDA	1	0.91	0.98
MPCST	0.91	1	0.95
NITTR	0.98	0.95	1

Table 4: RMSD Value of accumulated rain between selected three stations for the 2018 monsoon

Station (RMSD)	JDA	MPCST	NITTR
JDA	0	11.8	3.47
MPCST	11.8	0	10.23
NITTR	3.47	10.23	0

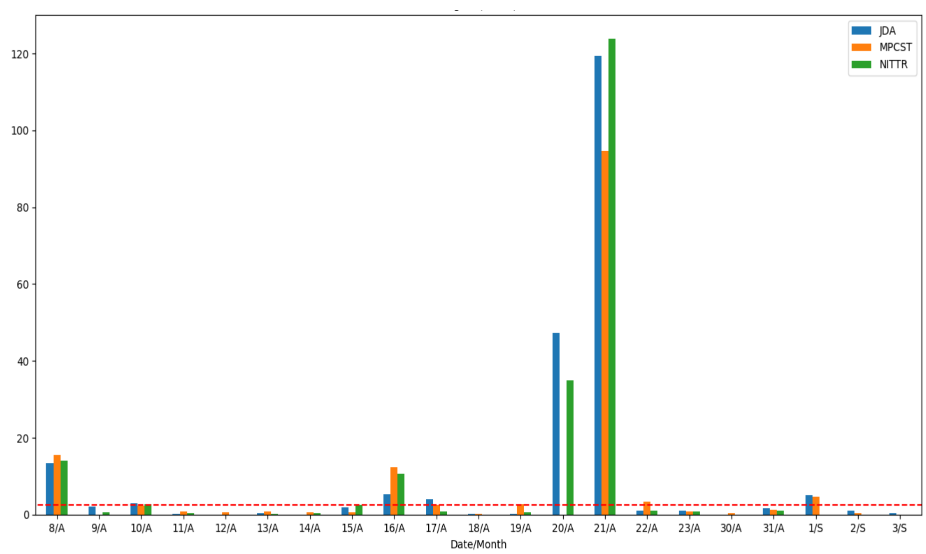


Figure 8: Bar chart of rainfall (mm/day) over the selected three stations during the stipulated continuous record period

The bar chart of daily accumulated rainfall for the stipulated continuous data record period (from 9th August to 4th September) for three stations show close proximity in daily rain values. The heavy rainy-day August 21 is well captured by all three stations with MPCST showing comparatively less rain (~100 mm).

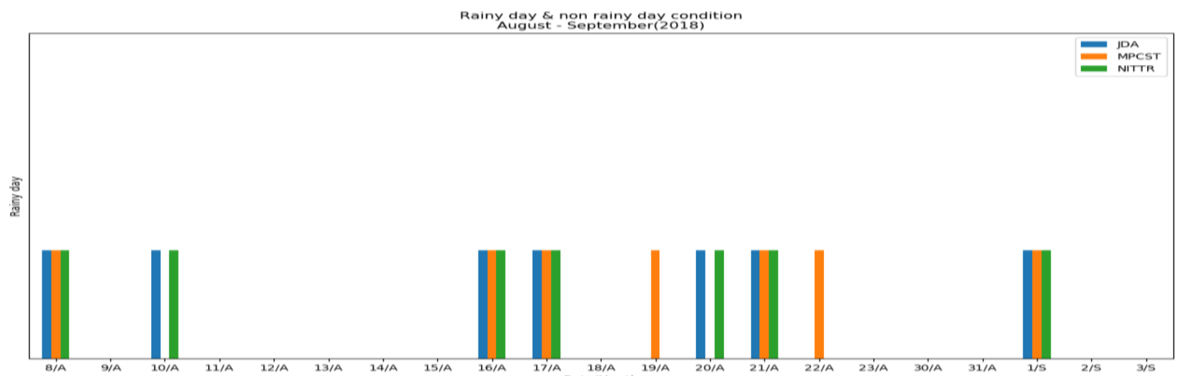


Figure 9: Bar chart representing the rainy/non rainy-day classification based on IMD criterion for the selected three stations

From Fig:9 it can be observed that during continuous data record period of three stations nine days were reported as rainy day by at least one of the stations. JDA and NITTR matched on seven days showing good agreement on the rainy-day classification and all three stations showed mutual agreement on five of the total nine days for rainy day classification.

Comparison with HE rainfall data

The rainfall data obtained from INSAT-3D based hydro estimator (HE) is compared with rain data measured by ground based optical disdrometer. The data is insufficient to make a statistically significant comparison. However, the comparison can suggest the possibilities and scope of validation of satellite measured rainfall data using the disdrometer network-based rain.

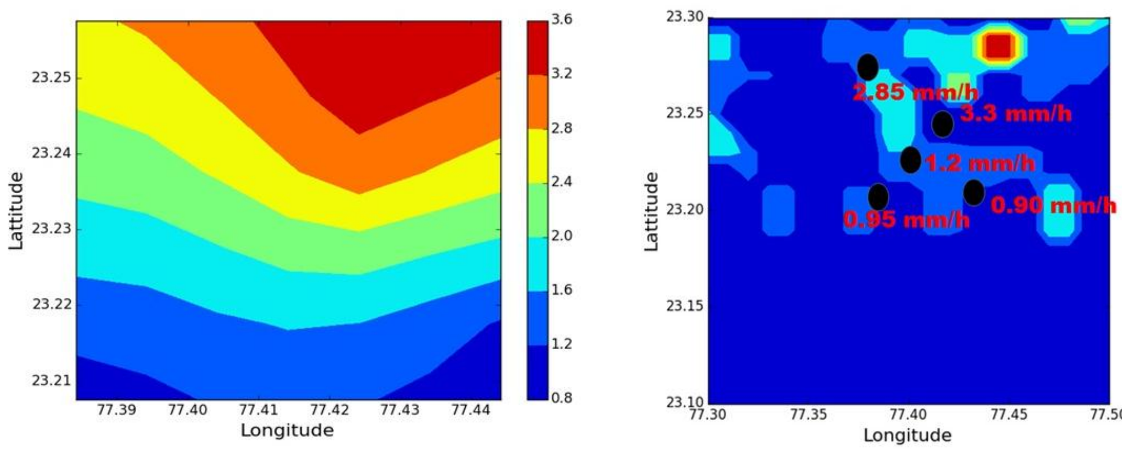


Figure 10: Interpolated rain map of the (a) station network and (b) HE rains data on 19 July 1845 GMT 2018

Figure 10 shows interpolated rainfall map of station network (Fig10a) and the interpolated rain map of INSAT3DR HE data (Fig:10b). A distributed rainfall event happened over the site on 19 July 1845 IST is taken for the case study and Cubic spline interpolation is used as kernel for generating the intensity plot. HE estimated rain is shown in Fig:10b and the black dots represent station location with instantaneous rain marked on the points. From the figure it can be observed that the instantaneous rain varies from 0.90 mm/h to 3.3 mm/h over the stations. Using these values rain value over the space is interpolated and shown in Fig:10a. The HE rains data show closeness to the station recorded rain but doesn't match quantitatively to the intensity values. The satellite estimated rain shows under estimation with respect to station recorded rain.

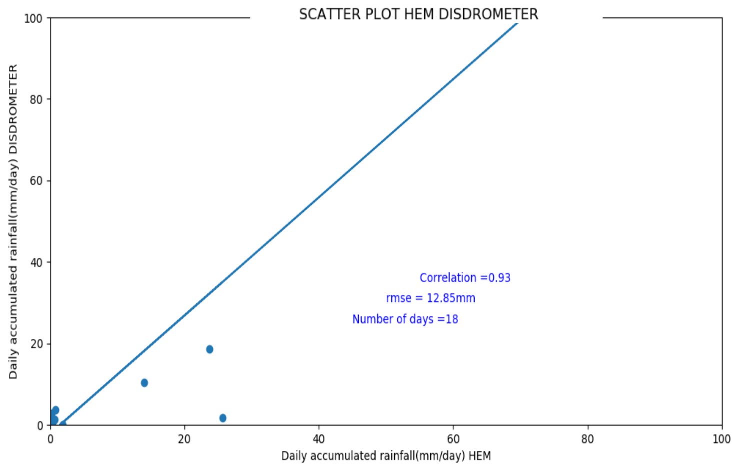


Figure 11 Comparison of daily accumulated HE rain with station average daily accumulated daily rain for August to September.

Figure 11 shows the daily accumulated rain of HE is compared with the average of the daily accumulated rainfall of three stations JDA, MPCST and NITTR (valid rain of August and September). The scatter plot shows very high correlation of 0.93 with a rmse of 12.85mm. However, it has to be noted that correlation and rmse values of the comparison doesn't represent statistically significant figures as the number of available data points are only 18.

4. Conclusions

- This report compiles an analysis of rainfall measurements over a network of nine disdrometer installed over Bhopal urban region. A detailed analysis of rain instances and rain events identified on the basis of time record of rain measurements is carried out
- The rain instances are identified as instantaneous measurements of rain greater than zero by disdrometer and rain event refers to continuous record of rain measurement above zero or no rain condition to the next no rain record.
- From the analysis it is observed that JDA recorded maximum rain instances and events hence identified as the master station for the analysis, which can be used for further analysis and rectification of network.

- Daily accumulated rainfall over all nine stations are carried out and it is observed that the rainfall patterns moreover remains the same with variations in intensity more prominent in low rain days.
- Computing the person correlation between stations for daily accumulated rainfall it is observed that stations, BHEL-BSSS, BHEL- BMHRC shows maximum correlation of 0.9 value and majority of stations showed a correlation value above 0.6. Some stations with less records like IMD showed poor correlation with other stations.
- On the basis of continuous data record JDA, MPCST and NITTR were identified for the rainfall pattern analysis of three weeks spanning August to September. The analysis showed that the three stations showed mutual agreement on seven rainy days (IMD criterion) out of total nine rainy days identified by at least one of the stations.
- An attempt is made to validate hydro estimator daily rainfall with the stations network recorded rain measurement, the comparison showed high correlation with disdrometer recorded rainfall however the value is not statistically significant due to non-availability of data.
- Overall analysis of rainfall data recorded by nine stations network over Bhopal gives encouraging results for validation of satellite based rainfall data at high resolutions and vast scope for meteorological studies of micro scale rainfall characteristics over the urban Bhopal region. Improving the instrument performance and collecting more data becomes an important pre requisite for the afore mentioned goals.

Acknowledgement

We sincerely thank Director, Space Applications Centre, Associate Director, Space Applications Centre, Deputy Director, EPSA for the encouragement and their interest for the research work carried out in present study. We also thank MOSDAC for providing the satellite data. We also sincerely thank Director MPCST and all the HOD's and concern officials of the participating agencies viz. IIFM, NTTTR, Bhopal Commissioner, SIRT, Collage, BSSS, Collage, BHEL and IMD, Bhopal for all the technical/non-technical support provided for this work.

References

Clima, T., 2007, Laser Precipitation Monitor Instruction for Use: 5. 4110.X0.X00; Software Version 1.04; Adolf ThiesGmbH & Co. KG: Göttingen, Germany

Matrin Loffler Mang, Jurg Joss 2012, An optical Disdrometer for Measuring Size and Velocity of Hydrometeors, Journal for atmospheric and Oceanic Technology

Mahesh, C., Prakash, S., Sathiyamoorthy, V. and Gairola, R.M., 2014, An improved approach for rainfall estimation over Indian summer monsoon region using Kalpana-1 data. Advances in Space Research, 54(4), pp.685-693.

Mahesh C. R. P. Prajapati, N.M.Suthar, Aloke Mathur, NithyaSubashini U., G. D. Bairagi,. Madhavi Dubey. Disdrometer network to characterize and validate INSAT-3D/3DR derived rainfall: Installation and preliminary evaluation, SAC/EPSA/CVD/Cal-Val/2019/002

Nithyasubashini Umashankar, Smart program student project on rainfall analaysis: EPSA/MRG/MRTD/SMART/88/2019

Prakash, S., Mahesh, C., Gairola, R.M. and Pal, P.K., 2010. Estimation of Indian summer monsoon rainfall using Kalpana-1 VHRR data and its validation using rain gauge and GPCP data. Meteorology and atmospheric physics, 110(1-2), pp.45-57.

S.-G. Park, Hae-Lim Kim, Young-Woong Ham, and Sung-Hwa Jung, 2017, Comparative Evaluation of the OTT PARSIVEL2 Using a Collocated Two-Dimensional Video Disdrometer Weather Radar Center, Korea Meteorological Administration, Seoul, South Korea

Zuhang Wu, Yun Zhang, Lifeng Zhang , Xiaolong Hao, Hengchi Lei and Hepeng Zheng, 2019 Validation of GPM Precipitation Products by Comparison with Ground-Based Parsivel Disdrometers over Jianghuai Region, Water, 11, 1260; doi:10.3390/w11061260