Analysis of TRMM Precipitation Radar Measurements over Iraq

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Abstract- 'Tropical Rainfall Measuring Mission' (TRMM) satellite was launched in 1997 as a joint mission between the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) to gather rain statistics across the tropics. To date, TRMM has produced a nearly continuous tropical rainfall dataset utilizing several onboard instruments including the TRMM Precipitation Radar (PR), a first-of-its-kind space borne Ku-band (13.8 GHz) meteorological radar based on phased array technology. The aim of this research is to analyze PR measurements over Iraq. Data were downloaded from the University of Utah site of TRMM measurements. Analysis of monthly means of precipitation measurements over Iraq for the period 1998-2011. The results showed that most precipitation falls over Iraq during winter season and it is characterized by very light to light rain and mostly falls over north part of the country. The highest area of precipitation happens during the months of April. The results also indicted that the variations and activities precipitation occur mostly during afternoon and evening times. The vertical structure for diurnal variation showed that the highest contribution of the 20 dBz reflectivity occurred in altitudes between 0.5 and 5 km while for seasonal variation the maximum contribution occurred in altitude from 1.5 to 5 km during rainy season over the zone. The vertical structure for 40 dBz reflectivity showed the maximum contribution for diurnal variation occurred in altitude between 1.5 and 2.5 km for most times of the day, and for the seasonal variation, the month of April showed the highest contribution of 40 dBz reflectivity and occurred in altitude between 1.5 and 3.5 km over the zone.

Index Terms- TRMM, Precipitation, Radar, Iraq.

I. INTRODUCTION

Rainfall comprise the main source of water for the terrestrial hydrological processes, exact measurement and prediction of the spatial and temporal distribution of rainfall is a basic goal in hydrology [1]. Rainfall is measured using rain gages, radar and satellites. The rain gauge networks and ground-based weather radar are covered a limited places and are available only over land. Radar covered areas are larger than when rain gauge covered it, the maximum range of radars coverage is about 300 km. Only satellite instruments are able to make rainfall measurements over remote areas of land or water where data is difficult or impossible to collect [1]. The use of satellite-derived products to estimate precipitation over land is important for monitoring the spatial and temporal distributions of precipitation [2]. The Tropical Rainfall Measuring Mission (TRMM) was launched in November 1997 to understand the global water cycle and for investigation of atmospheric convective systems, cyclonic storms and precipitation processes by observing from space over tropical and subtropical regions [2]. TRMM is the first satellite including the first radar designed specifically for rainfall monitoring to operate from space [3]. There are several researchers are interested with studies and researches about precipitation by using TRMM PR data. Schumacher (2000) [4] explored limitations in the sensitivity and sampling of the TRMM precipitation radar (PR) in tropics. The results showed the regions with very high monthly rainfall have a larger stratiform component and occur at less than maximum sea surface temperature (SST). De Marchi (2006) [5] used methodology for estimating precipitation using information from the satellite-borne precipitation radar of TRMM for Lake Victoria for period 1996-1998. This study showed that precipitation estimate exhibit much lower bias and better correlation with ground data than commonly used methods. Fenta (2010) [6] assess the diurnal cycle of rainfall using TRMM satellite observations, validated TRMM estimates using ground observations and evaluated the spatial pattern of rainfall over Guiana and Blue Nile basin. She found that TRMM estimates showed significant correlation with the ground observations and the spatial pattern showed varying diurnal cycle owing to the high topographic variability of the basin. Prasetia (2010) [7] evaluated the validation and accuracy of prediction of monthly rainfall over

Indonesia based on TRMM PR data. The results showed good agreement of satellite data with rain gauge data on monthly average rainfall. Takahashi et al. (2010) [8] study the diurnal cycle of rainfall during the summer monsoon around the Indochina peninsula by using TRMM PR. They found that nearly half of the total rainfall occurred in the early morning rainfall which indicated that early morning rainfall significantly contributes to the climatological rainfall pattern. Hamada et al. (2014) [9] studied characteristics and global distribution of regional extreme rainfall for 12 years of the TRMM PR measurements. They found good correlations for extreme rainfall rates with corresponding rain-top heights and event sizes over oceans but marginal or no correlation over land. Rapp et al. (2014) [10] analyzed TRMM PR features to understand the role of storm characteristics on the seasonal and diurnal cycles in Costa Rica. They found that the relative importance of convective precipitation increases on the Caribbean side during wintertime cold air surges, but for the coastal Caribbean domain, most regions showed a strong diurnal cycle with an afternoon peak in convection followed by an evening increase in stratiform rain. Yang and Nesbitt (2014) [11] revealed the statistical properties of tropics-subtropics precipitation for 13 years of TRMM PR measurements. They showed that the contributions from large rain intensity events are very importation in total precipitation, especially over land. In addition, the results showed that the statistical properties of precipitation could be utilized as a baseline in the assessment of precipitation from operational numerical weather prediction and climate models.

II. MATERIALS AND METHOD

a) Study area

Iraq liesin the world’s dry belt. It is bounded between 29°5- to 37°15- N latitudes and 38°45- to 48°45- E longitude. Iraq is a country in Western Asia spanning most of the northwestern end of the Zagros mountain range, the eastern part of the Syrian Desert and the northern part of the Arabian Desert. Most of rainfall occurs over the northern part of Iraq while central and southern parts of the country receive low rainfall. Rain falls in October to May but roughly 90 percent of the annual rainfall occurs between November and April, most of it in the winter months from December through March. The remaining six months, particularly the hottest ones of June, July, and August, are dry. Except in the north and northeast, mean annual rainfall ranges between ten and seventeen centimeters. Thunderstorms sometimes accompany the rain, particularly in the spring and they are frequently evening events. Rainfall over Iraq is mainly produced by the depressions travelling from north of Africa and south and east of Mediterranean Sea across the Middle East and southwest of Asia during winter and spring. Sudanese low-pressure thermal systems, which originate from the Red Sea, sometimes combine with Mediterranean troughs in cold seasons, and absorbing more humidity from the Red Sea, and when they reach the south of Iraq they result in heavy rainfalls.

b)Data and Methodology

The Tropical Rainfall Measuring Mission (TRMM) is a joint effort of the National Aeronautics and Space Administration (NASA) of the United States and the Japan Aerospace Exploration Agency (JAXA) of Japan to understand the global water cycle and for investigation of atmospheric convective systems, cyclonic storms and precipitation processes by observing from space over tropical and subtropical regions [2]. Among many observing instruments, TRMM satellite borne a Ku band radar (13.8 GHz). The TRMM precipitation radar (PR) is the first spaceborne rain radar and the only instrument on TRMM that can directly observe vertical distributions of rain. The data used in this study was downloaded from University of Utah TRMM database for a zone bounded by longitude 38-50^{o}E and latitude 28-36o N. The data set covers the period from 1998 to 2011. The domain of Utah TRMM database is 36^{o}S – 36^{o}N and -180^o – 180^o.Data extracted include monthly and annual means of precipitation, precipitation area, radar echo top, and precipitation contribution from 20, 30, and 40 dBz radar reflectivity.

III. RESULTS AND DISCUSSION

Figure 1 shows the diurnal distribution of precipitation over the zone. The left side plot illustrates precipitation area, and the right side plot gives radar echo top. It is clear that precipitation between 0.5 and 1.8 mm/hr occupied relatively larger areas (between 104 -105 km2) than areas of smaller amount of precipitation. This is an indication that the majority of precipitation over the zone is between 0.5 to 1.8 mm/hr. The right side plot indicates that the precipitation radar echo top ranging between 6-12 km for almost the same range of precipitation (0.5-1.8 mm/hr). The radar echo top in the afternoon and evening times is higher than that during other times of the day, this is expected since strong convection usually occurs in the afternoon over the zone under consideration.

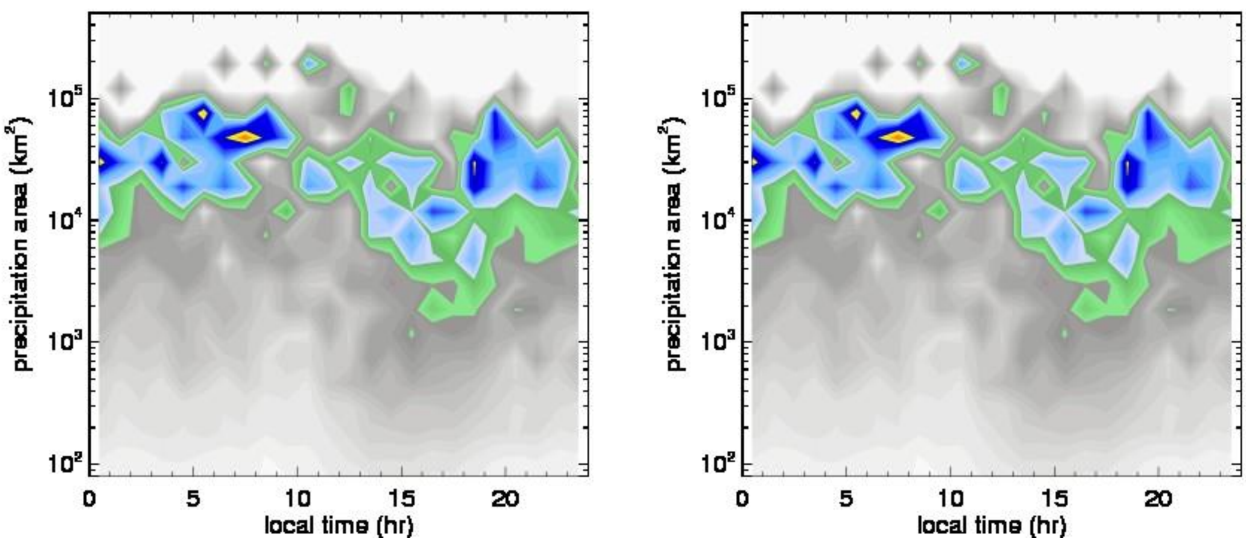

Figure 1. Distribution of hourly precipitation (mm/hr). Left plot represents precipitation area (km2), Right plot represents radar echo top (km) over zone of Lon 38-50oE, Lat 28-36oN for period 1998-2011.

Figure2 illustrates the seasonal distribution of precipitation over the zone. It is obvious that the precipitation occurred over Iraq concentrated in north, and east parts of the country. The amount of precipitation during winter season (Dec to Feb) is more than that during other seasons. The maximum amount of precipitation over Iraq was 224 mm/season in the north eastern part of the country. The maximum value of precipitation occurred in the spring season (Mar to May) over Iraq is located in the north eastern part. Summer season (Jun-Aug) has no precipitation activities over the zone. Autumn season (Sep-Nov) is characterize by an amount of precipitation less than 100 mm/season in the north and eastern part of Iraq. An area near the northern border of Iraq with Iran may receive more than 100 mm/season precipitation.

Figure 3 shows the monthly distribution of precipitation, left side plot indicates the precipitation area and the right side plot indicates the radar echo top over the zone. The left side plot illustrates that the area of more than 1 mm/month is between 103-105 km2 during the rainy season over the zone (Oct-May). It is clear that more than 5 mm/month occurred during the month of Apr. The right side plot shows that the radar echo top of more than 1 mm/month precipitation is between 4-12 km and occurs during the rainy season. The highest echo top occurred in the months of Feb and Apr due to the strong convection during these months. In addition, its notable that in both of plots there was no precipitation activities during the months of Jun to Sep.

Figure 4 gives the distribution of annual hourly precipitation over the zone. It is seen that higher intensity of precipitation occurs in the northern, and eastern regions of Iraq during all times of the day. It is notable that the times of 6-9, 12-15, 15-18, and 18-21 hr have intensity of precipitation more than the other times and the maximum value of precipitation was approximately 5 mm/day occurred in time of 15-18 hr in the north of Iraq.

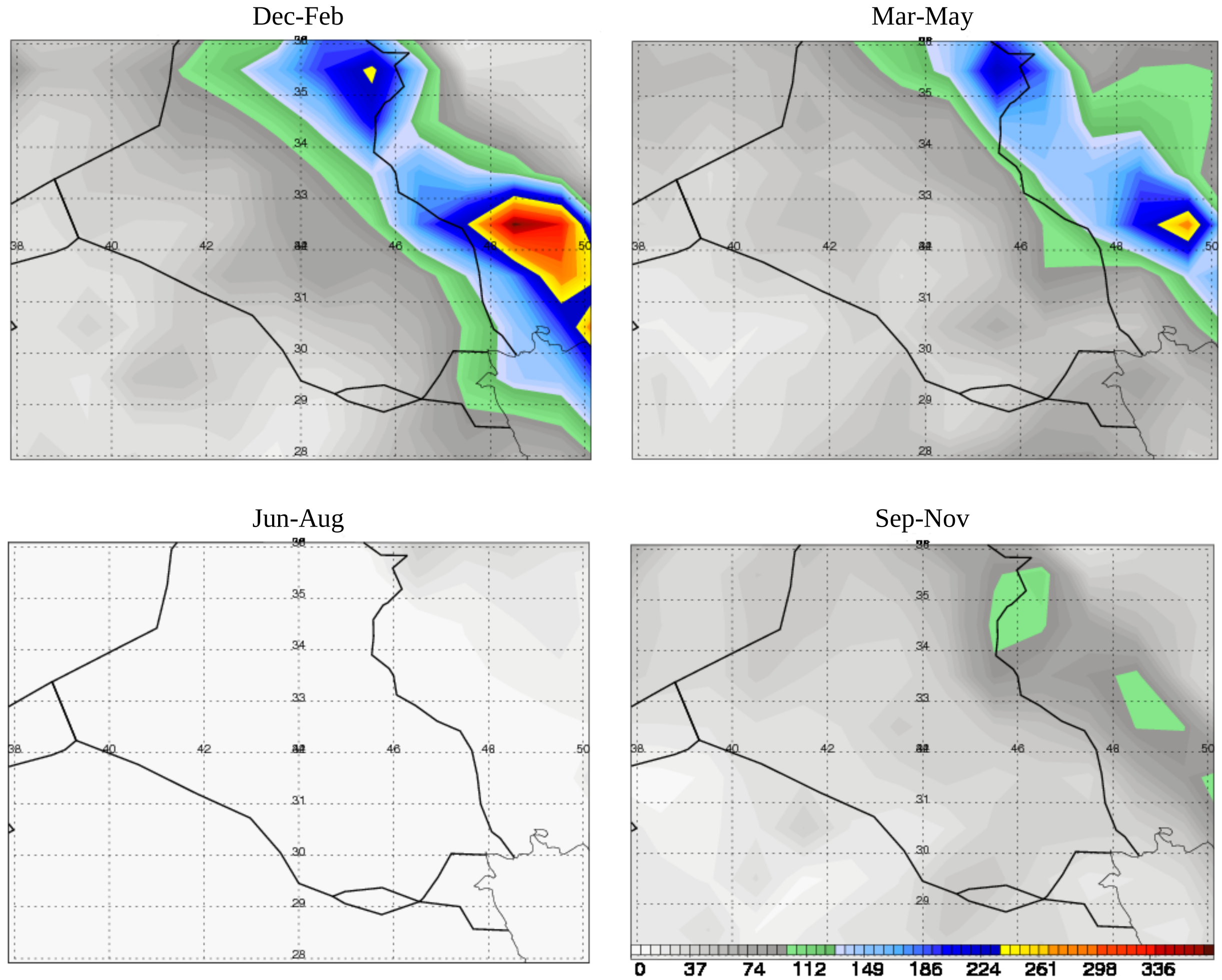

Figure 2. Seasonal distribution of precipitation (mm/season) over zone of Lon 38-50^{o}E, Lat 28-36^{o}N for period 1998-2011.

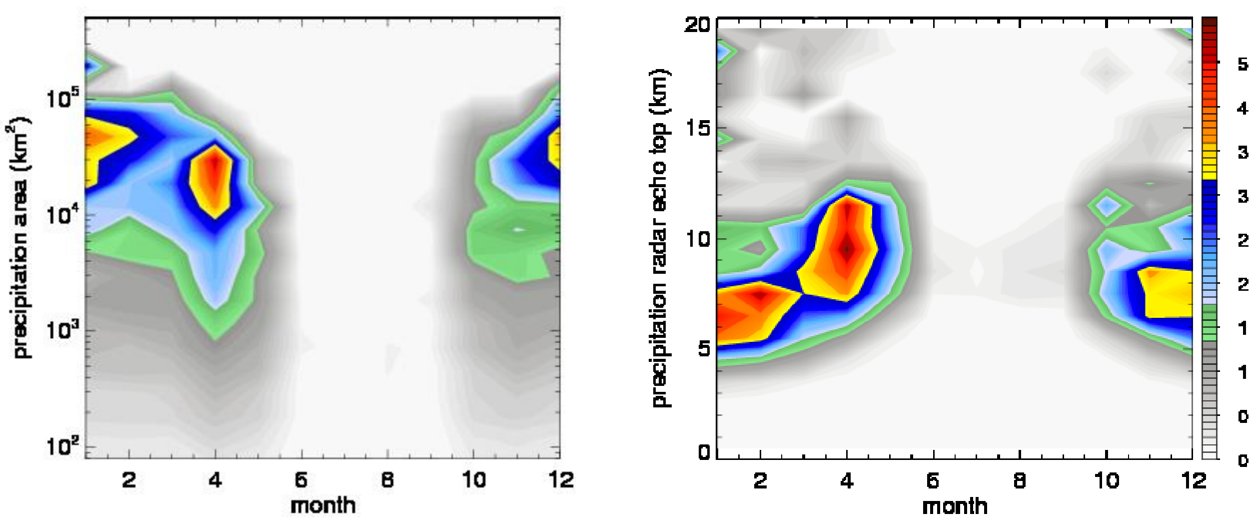

Figure 3. Distribution of monthly precipitation (mm/month). Left plot represents precipitation area (km2), Right plot represents radar echo top (km) over zone of Lon 38-50oE, Lat 28-36oN for period 1998-2011.

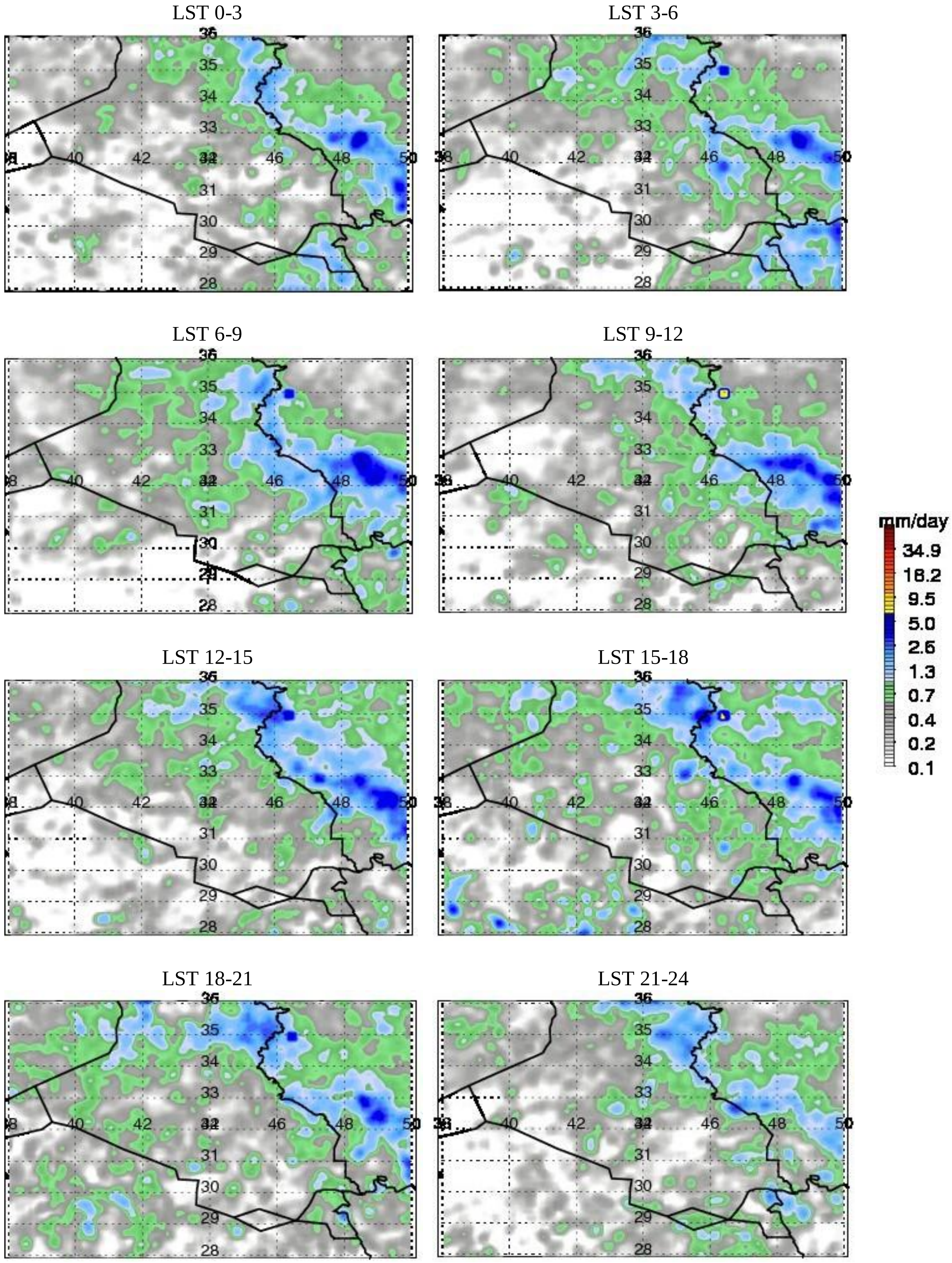

Figure 4. Annual hourly distribution of precipitation mm/day over zone of Lon 38- 50°E, Lat 28-36°N for period 1998-2011.

Figure 5, and 6 illustrate the annual diurnal and seasonal variations of precipitation over the zone. Figure 5 shows that the behavior of diurnal variation of precipitation distribution. It is seen that the lowest precipitation, less than 7 mm/year occurs in the times 2-3 and 9-10 LTC while highest precipitation, more than 10 mm/year, occurs in the times 15-16 and 18-19 LTC and less than 9 mm/year occurs during other times of the day. Figure 6 indicates that the major contribution of annual precipitation, more than 30 mm/month, comes from the storms occurring during the months of Dec, Jan, Mar, and Apr. It is also seen than months of Jun to Sep are characterized by almost close to 0 mm/month.

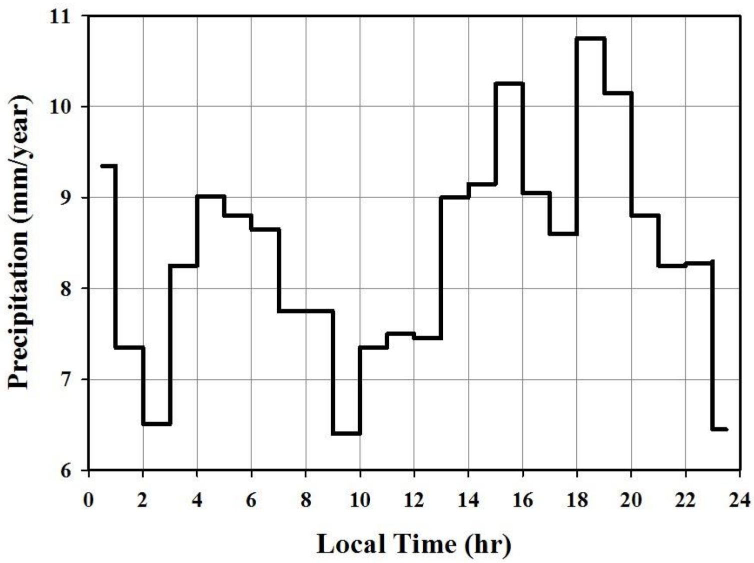

Figure 5.Annual diurnal variations of precipitation (mm/year) over zone of Lon 38-50oE, Lat 28-36oN for period 1998-2011.

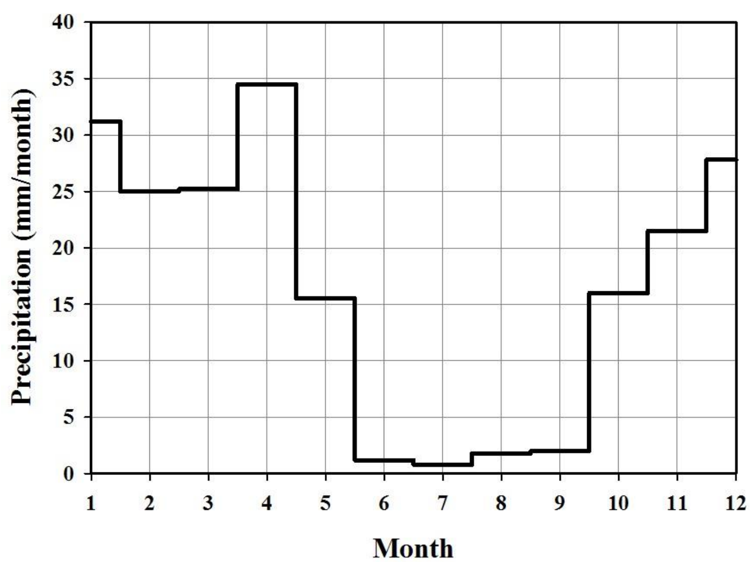

Figure 6.Annual seasonal variations of precipitation (mm/month) over zone of Lon 38-50oE, Lat 28-36oN for period 1998-2011.

Figure 7 displays the mean annual distribution of precipitation over the zone. It is clear that the north part of Iraq and a strip along the eastern borders with Iran receives larger annual precipitation, more than 400 mm. The annual precipitation is gradually decreasing as one goes from north and north-east towards west and south-west areas, i.e. moving from mountains areas towards desert areas. Deserts are caused by the shortage of rain. It is seen that the maximum value of precipitation, more than 583 mm/year occurs over two distinct areas, one in the north-eastern part of Iraq just near the city of Sulymaniyah and the other area in Iran just close to the Iranian city of Kerminsha.

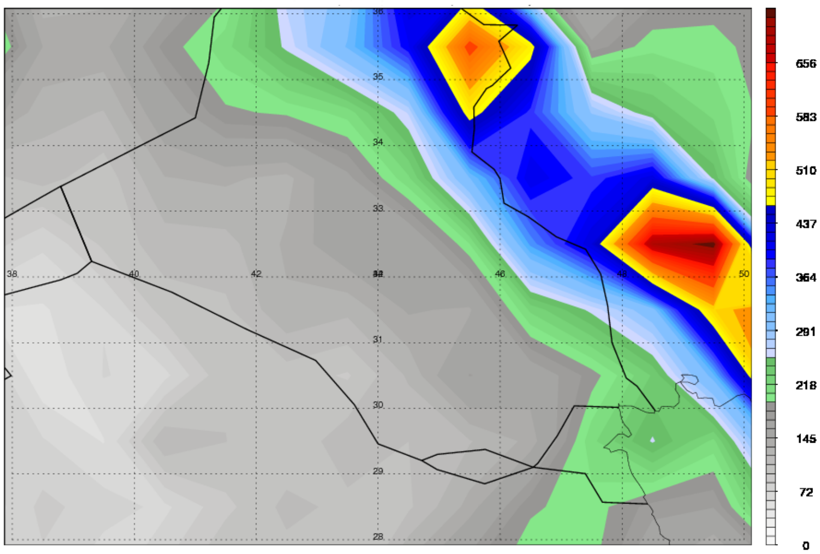

Figure 7.Mean annual distribution of precipitation (mm/year) over zone of Lon 38-50oE, Lat 28-36oN for period 1998-2011.

Figure 8 gives the diurnal (left diagram), and seasonal (right diagram) variations of 20 dBz precipitation reflectivity fractional occurrences for different altitudes over the zone. It is clear that for all times of the day and for altitudes between 0.5 and 5 km, the highest contribution of the 20 dBz reflectivity lays between 1 to 2% and outside these altitudes, the contribution is less than 1%. For the seasonal variations, it is obvious that the maximum contribution of precipitation 20 dBz reflectivity was more than 2% in the altitudes from 1.5 to 5 km during the months from Oct to May, while the other months the contribution 20 dBz reflectivity less than 0.4%. It is also noted that the 20 dBz contribute by less than 0.1% at altitudes higher than 10 km.

Figure 9 reflects the diurnal, and seasonal variations of precipitation 40 dBz reflectivity fractional occurrences for different altitudes over the zone. It is seen that the maximum value of precipitation 40 dBz reflectivity contribution was 0.04% and laid in altitudes between 1.5 and 2.5 km from most times of the day. During the time 15 to 20 LTC the contribution extends to 3.5 km. Just above and below this layer the contribution of the 40 dBz reflectivity is about 0.01%. Above 5 km height, the contribution decreases with increasing height. The seasonal variation of the contribution of precipitation 40 dBz reflectivity. It is clear that the contribution of 40 dBz was about 0.04 within a layer of 1.5 to 2.5 km during rainy season. It is notable that contribution in Apr is relatively higher than that during other months and the layer extends to 3.5 km. During the months from June to Sep the contribution of 40 dBz reflectivity is less than 0.01%.

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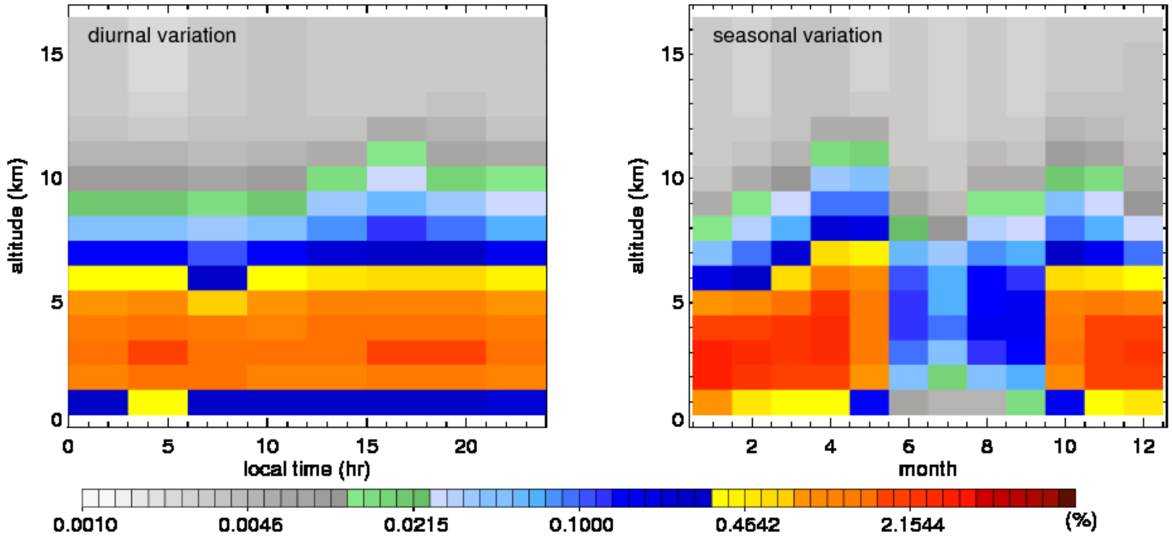

Figure 8. Diurnal and seasonal variations of precipitation reflectivity contribution 20 dBz at different latitudes over zone of Lon 38-50oE, Lat 28-36oN for period 1998-2011.

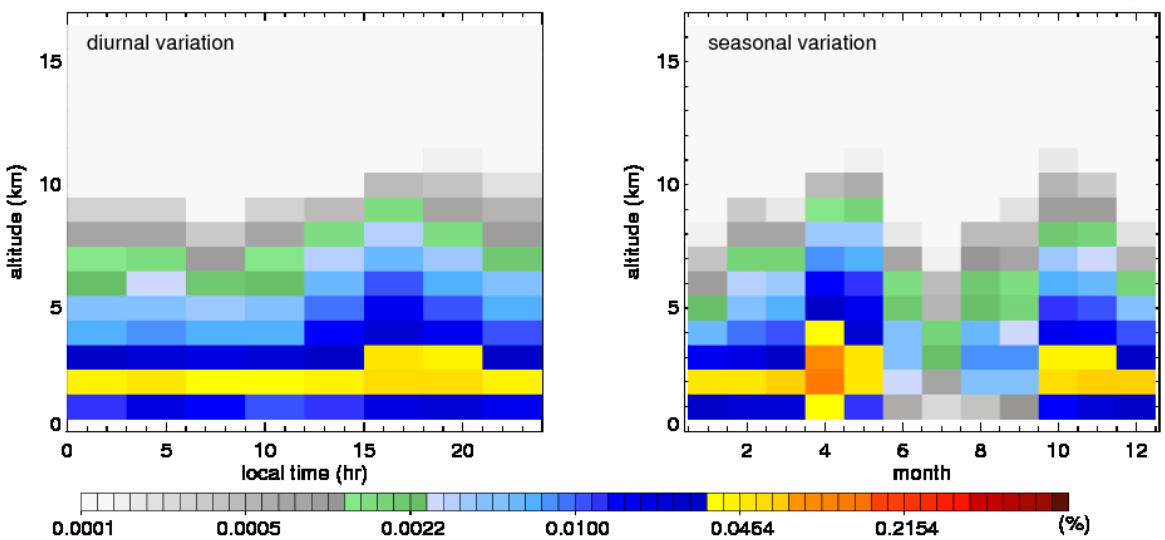

Figure 9. Diurnal and seasonal variations of precipitation reflectivity contribution 40 dBz at different latitudes over zone of Lon 38-50oE, Lat 28-36oN for period 1998-2011.

IV. Conclusion

In this research, TRMM Precipitation radar data were analyzed over Iraq. Analysis of 14 years' monthly means of precipitation suggested that precipitation activities over Iraq occur during the months of October through May and mostly fall over northern and north eastern parts of the country. The majority of precipitation lies between 0.5 to 1.8 mm/hr and the highest area receives monthly precipitation of these amount is between 104-105 km2 during the month of April. Diurnal variations indicated that the maximum value of precipitation occurred in the afternoon time and the diurnal variation of precipitation in the morning times was lowest than that during the night time The vertical profile of radar reflectivity factor showed the contribution to total precipitation from 20 dBz is higher than that from 40 dBz.

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