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STUDY ON SENSITIVITY OF MICROPHYSICS FOR THE SIMULATION OF RAINFALL FOR THE MONTH OF MAY 2015 OVER BANGLADESH USING HIGH RESOLUTION WRF-ARW MODEL

Md. Salman Khan and M. M. Alam

Department of Physics, Khulna University of Engineering & Technology, Khulna - 9203, Bangladesh

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ABSTRACT

In this research the Advanced Research WRF (ARW) model v3.8.1 has been used to simulate the rainfall of May 2015 all over Bangladesh. The model was configured in nested domain with 18 and 6 km horizontal grid spacing with 100×96 *and* 103×127 *grids in the east-west and north-south directions, respectively with 30 vertical levels. The Lin et al., WSM6, Thomson, Morrison Double-Moment (M-2Mom), Stony Brook University (SBU), and WDM6 microphysics schemes coupling with Kain-Fritsch (KF) cumulus parameterization (CP) scheme have been used to simulate the monthly total rainfall, heavy rainfall, monthly rainy days and heavy rainy days for the month of May 2015 at all meteorological stations of Bangladesh. The simulated results are compared with the observed results of 33 meteorological stations of Bangladesh Meteorological Department (BMD) and Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) output. Relative standard deviation of all observed, PERSIANN and model simulated parameters have been analyzed and compared.*

The maximum monthly observed rain in May 2015 at Sylhet was 752 mm but WSM6, M-2Mom and WDM6 schemes have simulated 831, 788 and 742 mm for day 1 prediction; WSM6, WDM6 and SBU-Lin schemes have simulated 757, 916 and 981 mm for day 2 prediction and WSM6 and WDM6 schemes have simulated 741 and 925 mm for day 3 prediction, respectively and all other MPs have simulated much higher rainfall at domain (D1). The WDM6, M-2Mom and Lin et al. schemes have simulated 744, 807 and 923 mm for day 1 prediction, WSM6 and WDM6 schemes have simulated 714 and 877 mm for day 2 predictions and WSM6, SBU-Lin and Lin et al. schemes have simulated 802 and 913 and 998 mm, respectively for day 3 predictions at domain (D2). The relative standard deviation (RSD) has minimum at D1 and D2 for WDM6 scheme for day 1 prediction and WSM6 scheme for day 2 and day 3 predictions for the monthly total rainfall and heavy rainfall of May 2015. The results suggest that as the forecast time increased the amount of total rain and also heavy rain is increased. As a result RSD is also increased for all MPs. WDM6 scheme gives the better performance of rainfall and rainy days all over the country.

Keywords: *Pre-monsoon; PERSIANN; Relative standard deviation; Microphysics; Cumulus parameterization.*

1. INTRODUCTION

The mean temperature of Bangladesh during the summer months varies between 23-30°C. April and May are the hottest months (Khatun *et al.,* 2016). The maximum temperature of 36-40°C was attained in the southwestern (SW) and northwestern (NW) districts. When the maximum temperature goes above 36°C, heat wave situation occurs over Bangladesh. Due to heavy rainfall associated with severe thunderstorm in the northeastern (NE) part of Bangladesh and adjoining NE states of India flash flood occurs in the NE part of Bangladesh. Only 19 % of the total annual rainfall occurs in this season. Matsumoto (1997) studied the onset of rainy season by the index of precipitation over the Asian summer monsoon region, and indicated that the Assam region of India is earliest region where the onset of rainy season starts.

Ahasan *et al*. (2013) conducted research on simulation of high impact rainfall events over southeastern hilly region of Bangladesh using MM5 model. The model suggests that the highly localized high impact rainfall was the result of an interaction of the mesoscale severe convective processes with the large scale active monsoon system. Shahid (2010) studied rainfall variability and the trends of wet and dry periods in Bangladesh. The result shows a significant increase in the average annual and pre-monsoon rainfall of Bangladesh. Alam (2013) studied the impact of cloud microphysics and cumulus parameterization schemes for the prediction of heavy rainfall event during 15-16 October 2007 over Bangladesh. The study showed that the microphysical schemes have a major impact on time and location of rainfall intensity. All MPs coupled with BMJ schemes fails to simulate heavy rainfall in Sitakundu-Sandwip-Chittagong region but they simulate heavy rainfall in the north-northeastern parts of the country, which does not match with the observation during 15–16 October 2007. Alam (2014) have studied the impact of cloud microphysics and cumulus parameterization on simulation of heavy rainfall event during 7–9 October 2007 over Bangladesh using 9 and 3 km nested domain. To examine the

* Corresponding Author: malam@phy.kuet.ac.bd https://www2.kuet.ac.bd/JES/
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sensitivity of the simulations of six different microphysical schemes and Kain–Fritsch (KF) and Betts–Miller–Janjic (BMJ) schemes were considered.

Cumulus parameterization (CP) schemes must estimate the rate of subgrid-scale convective precipitation, release of latent heat, and the distribution of heat, moisture, and momentum in the vertical due to convection (Kain and Fritsch, 1993). Cumulus convection modifies the large-scale temperature and moisture fields through detrainment and cumulus-induced subsidence in the environment. The detrainment causes large-scale cooling and moistening, and the cumulus-induced subsidence causes large-scale warming and drying (Arakawa and Schubert, 1974). Precipitation is recognized as one of the most difficult parameters to forecast in numerical weather prediction despite the fact that the accuracy of numerical models has increased during the past several decades (Wang and Seaman, 1997). Prior studies have shown that a model's microphysical parameterization scheme can strongly influence the magnitude of predicted precipitation (Otkin *et al*., 2006). Litta *et al.,* (2012) illustrates that the microphysics scheme can significantly impact the accuracy of quantitative precipitation forecasts during the pre-monsoon season. Fihir (2018) has simulated the heavy rainfall events in the southeastern regions of Bangladesh during May 2013 using four different MPs i.e., Lin *et al*., WSM6, Thompson and WDM6 and four different CPs i.e., KF, Tiedtke (TD), Zhang-McFarlane (ZM) and Multi-Scale KF (MSKF). The research also suggests that WSM6 and WDM6 schemes coupling with ZM and MSKF schemes give the better performance on the basis of Threat Score, Equivalent Threat Score and Bias Score during May 2013.

Haney *et al.* (2018) has been used to simulate the heavy rainfall event in the southeastern regions of Bangladesh during 23-26 June 2015 using 12 different MPs in WRF-ARW model. The microphysics schemes are Kessler, Lin *et al*., WSM3, Ferrier, WSM6, Thomson graupel, MYDM, M-2Mom, CAM V5.12-Moment 5 class, SBU, WDM6 and NSSL2. Country averaged rainfall suggests that among 12 MPs, the schemes Thompson, SBU, WSM6 and WDM6 have simulated almost similar amount of rainfall as observed during the study period during 23-26 June 2015. The model has also simulated similar amounts of rainfall in the heavy rainfall(HR) area of 5 s i.e., in the SE region by SBU, WDM6, Lin, TH and WSM6 schemes during 23-26 June 2015. Saifullah *et al.* (2018) studied on the simulation of Heavy Rainfall Event (HRE) over the south and southeastern part of Bangladesh due to monsoon depression using WRF Model. Their results suggested that, from the enormous area of the Bay of Bengal a large amount of moisture carried by a strong southwesterly flow towards the southeastern part of Bangladesh and the adjoining area and so the HRE over these regions might be characterized by the positive vorticity and strong vertical wind shear between 850 to 200 hPa. Sumon and Alam (2019) studied the impact on environmental moisture during the intensification and movement of tropical cyclone Hudhud in the Bay of Bengal using WRF-ARW Model. They studied WSM6-class graupel, Thomson graupel, WDM6-class graupel and NSSL mom-1 microphysics schemes with four different initial conditions. Their results suggests that the average track error was minimum for WDM6 schemes with the initial conditions at 7-9 October, which gives the better performance of WDM6 among all used MPs.

In the present study, WRF-ARWv3.8.1 model has been used to simulate the total rainfall, heavy rainfall (HR), total rainy days and HR days for the month of May 2015 all over Bangladesh. Six MPs schemes i.e. Lin *et al*., WSM6, Thomson, Morrison Double-Moment (M-2Mom), SBU and WDM6-class and KF scheme have been considered to study the monthly rainfall and rainy days of May 2015 and tried to identify the performances of different MP schemes. The primary objectives of this study are to examine which microphysics schemes are suitable for the prediction of monthly rain in the pre-monsoon season. The simulated results have been compared with the observed rainfall of Bangladesh Meteorological Department (BMD) and PERSIANN rainfall.

2. METHODOLOGY

2.1 Model Domain and Configuration

The Weather Research and Forecast (WRF-ARW Version 3.8.1) model has been used to simulate the pre-monsoon rainfall all over Bangladesh. The model has different microphysics options but in this research 6 microphysics schemes are utilized for the simulation of daily rainfall for the month of May 2015. The model has used initial and lateral boundary conditions (LBCs) from NCEP-FNL analysis at six hourly intervals. The model has been configured in double domain, 18 km and 6 km horizontal grid spacing with 103×127 and 100×96 grids in the east-west and north-south directions and 30 vertical levels. The double domain is used to identify, which domain produces more accurate monthly rainfall. Time step of integration is set to 30 and 90 seconds for maintaining computational stability as the model uses third-order Runge-Kutta time integration scheme. The detail of the model and domain configuration is given in Table 1. The model domain is given in Figure 1 and different physics options are given in Table 1:

Table 1: WRF Model and Domain Configurations

Dynamics	Non-hydrostatic
Number of domain	2
Horizontal grid distance	6 km and 18 km
Integration time step	30 s and 90 s
Number of grid points	X-direction 96 and 103 points, Y-direction 100 and 127 points
Initial conditions	Three-dimensional real-data (FNL: 1° × 1°)
Microphysics	(1) Lin *et al*., (2) WSM6-class graupel, (3) Thomson graupel, (4) Morrison Double-Moment, (5) SBU and (6) WDM6-class
Radiation scheme	Dudhia (1989) for short wave radiation/ RRTM long wave Mlawer *et al.* (1997)
Surface layer	Monin-Obukhov similarity theory scheme (Hong and Pan, 1996)
Land surface parameterization	5 Layer Thermal diffusion scheme (Ek *et al*., 2003)
Cumulus parameterization schemes	Kain-Fritsch (KF) scheme, (Kain and Fritsch, 1990, 1993; Kain, 2004)
PBL parameterization	Yonsei University Scheme (YSU) (Hong *et al*., 2006)

Lin *et al.* scheme: Lin *et al.* scheme has ice, snow and graupel processes, suitable for real-data high-resolution simulations. In this scheme six classes of hydrometeors are included: water vapor, cloud water, rain water, cloud ice, snow, and graupel. All parameterization production terms are based on Lin *et al*. (1983). The scheme is taken from Purdue cloud model and the details can be found in Chen and Sun (2002) 2-D microphysics scheme. This is one of the first schemes to parameterize snow, graupel, and mixed-phase processes and it includes ice sedimentation and time-split fall terms. It has been extensively used in research studies and in mesoscale NWP Model.

WRF Single-moment 6-class (WSM6) microphysics scheme: This scheme predicts the mixing ratios for water vapor, cloud water, cloud ice, snow, rain, and graupel in six different arrays. The characteristics of the cold rain process in the WSM6 scheme follow the revised ice microphysics process (Hong *et al.*, 2004), whereas the warm rain processes are primarily based on the works of Lin *et al.* (1983) and the auto conversion process from Tropoli and Cotton (1980). A new method for representing mixed-phase particle fall speeds for the snow and graupel processes suitable for high-resolution simulations by assigning a single fall speed to both sedimentation and accumulation processes is introduced. This method uses a large eddy simulation (LES)-based approach (Khairoutdinov and Kogan, 2000) to determine the auto conversion rates and allow for a more sophisticated coupling between cloud field and number concentrations of warm species. Double-moment prediction for the warm species in WSM6 scheme will allow more flexibility of the size distribution enabling the mean diameter to evolve in contrast to the one-moment scheme.

Thompson Scheme: Thompson Scheme is a bulk microphysical parameterization scheme developed to use with WRF or other mesoscale models. The snow size distribution depends on both ice water content and temperature and is represented as a sum of exponential and gamma distribution functions. Furthermore, snow assumes a non-spherical shape with a bulk density that varies inversely with diameter. A new scheme with ice, snow and graupel processes suitable for high-resolution simulations.

Morrison Double-Moment (M-2Mom) Scheme: The Morrison scheme predicts the mass concentration of cloud water, cloud ice, rain, snow and graupel. The physics are based on the full double-moment version described in Morrison *et al*. (2009). The auto conversion process from cloud ice to snow is triggered when cloud ice mass exceeds a specified threshold related to the maximum permitted size of cloud ice crystals, but it does not require a corresponding minimum size for the snow category. Truncation at larger particle sizes would lead to a greater reduction as additional counts of small particles are eliminated. Morrison scheme prediction of provided a good fit to aircraft estimates with a mean profile and range that is within the bulk of aircraft estimates below 4 km and also represented the general decrease from cloud top to cloud base associated with continued aggregation.

Stony Brook University (SBU) scheme: Stony Brook University scheme is a 5-class scheme with riming intensity predicted to account for the mixed-phase processes. In this scheme the ice microphysics is presented, which considers both temperature and riming effects on ice properties. The five prognostic mixing ratios are water vapor, cloud ice, precipitating ice (PI), cloud liquid water, and rain. Dry snow, rimed snow, and graupel are included in the PI category through the introduction of a varying riming intensity parameter. The new scheme allows for physically based representation of the ice particles with temperature and riming intensity–dependent properties, such as the mass, cross-sectional area, and fall velocity relationships. Riming intensity is diagnosed from liquid water content (LWC), PI mass, and temperature.

WRF Double-Moment 6-class (WDM6) scheme: The WDM6 implements a double-moment bulk micro physical parameterization of clouds and precipitation and is applicable in mesoscale and general circulation models. The WDM6 scheme enables the investigation of the aerosol effects on cloud properties and precipitation processes with the prognostic variables of cloud condensation nuclei (CCN), cloud water and rain number concentrations. WDM6 extends the WRF single-moment 6-class microphysics scheme (WSM6) by incorporating the number concentrations for cloud and rainwater along with a prognostic variable of CCN number concentration. Moreover, it predicts the mixing ratios of six water species similar to WSM6. Prognostic water substance variables include water vapor, clouds, rain, ice, snow, and graupel for both the WDM6 and WSM6 schemes. Additionally, the prognostic number concentrations of cloud and rain waters, together with the CCN, are considered in the WDM6 scheme. The number concentrations of ice species such as graupel, snow, and ice are diagnosed following the ice-phase microphysics of Hong *et al*. (2004).

2.2 Data

Final Reanalysis (FNL) data (1^{o} x1^{o}) from National Centre for Environment Prediction (NCEP) is used as initial and lateral boundary conditions (LBCs) which is updated at six hourly interval i.e. the model will be initialized with 0000, 0600, 1200 and 1800 UTC initial field of corresponding date. The NCEP FNL data will be interpolated to the model horizontal and vertical grids. Bangladesh Meteorological Department (BMD) observed rainfall and Precipitation estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) data will be used for verification. In the present study, the Weather Research and Forecast (WRF-ARW Version 3.8.1) model has been used to simulate the rainfall of May 2015 over Bangladesh. In this research, six different MP schemes and Kain-Fritsch cumulus parameterization scheme have been used to simulate the monthly rainfall of May 2015. 3-hourly rain gauge data of 33 meteorological stations have been collected from Bangladesh Meteorological Department (BMD) all over Bangladesh.

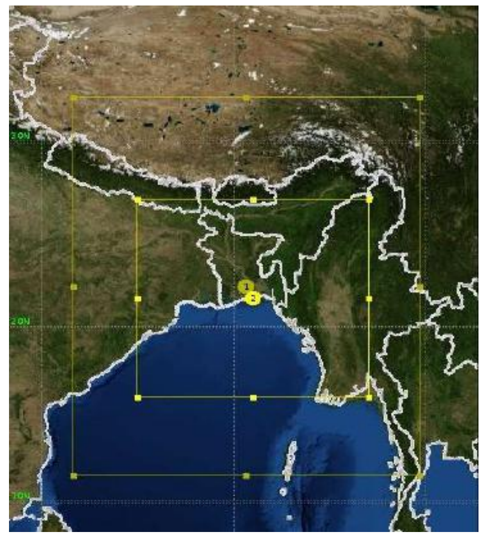

Figure 1: WRF Model Domain for the prediction rainfall in Bangladesh

In probability theory and statistics, the coefficient of variation (CV), also known as relative standard deviation (RSD) is a standardized measure of dispersion of a probability distribution or frequency distribution. Relative Standard Deviation (RSD) = (Standard Deviation (SD) / Mean) $\times 100 = \frac{\sigma \times 100}{\bar{X}}$

RSD gives the variability of a parameter. If the value is less it is less variable and vice-versa.

3. RESULTS AND DISCUSSION

3.1 Observed Rainfall and PERSIANN satellite precipitation for the month of May 2015

Special distribution of observed total rainfall and heavy rainfall of May 2015 all over Bangladesh is presented in Figures 2(a-b). The maximum rain is observed at Sylhet (752 mm) and minimum rain at Satkhira (16 mm). It is also seen from the spatial distribution pattern that the rainfall increased continuously from southwestern (SW) to northeastern (NE) region of Bangladesh. The minimum rainfall is also observed at Barishal, Bhola, Khepupara and Patuakhali and is 72, 71, 39 and 38 mm respectively. The second maximum of rainfall is seen at Dinajpur region (375 mm). From the spatial distribution pattern it is observed that 100 to 200 mm rainfall is seen in the central to western region of the country and Dhaka gets 185 mm of rainfall during this month. From the distribution pattern, the maximum amount of HR is observed at Sylhet (379 mm) and minimum in the southern region of Bangladesh. The amount of monthly HR of 231 mm is also found at Srimangal region.

PERSIANN total rainfall and heavy rainfall distribution of May 2015 all over Bangladesh is presented in Figure 2(c-d). The total rain (Figure 2c) is observed maximum at Sylhet (556 mm) and minimum at Khepupara (48 mm). The PERSIANN rainfall increased continuously from SW to NE and northwestern (NW) regions of Bangladesh. The second and third maxima of rainfall are seen at Srimangal (446 mm) and Rangpur (376 mm) region of Bangladesh. The distribution pattern is almost similar to that of BMD observed rainfall. From the distribution pattern, the highest HR (Figure 2d) was found at Srimangal and its amount is 213 mm. The PERSIANN HR observed at Dhaka was 56 mm at the same time the BMD observed rain was 185 mm, which is much higher than that of PERSIANN. The PERSIANN distribution of HR indicated that maximum region of the country has no HR. The PERSIANN HR is much lower than that of BMD observed HR.

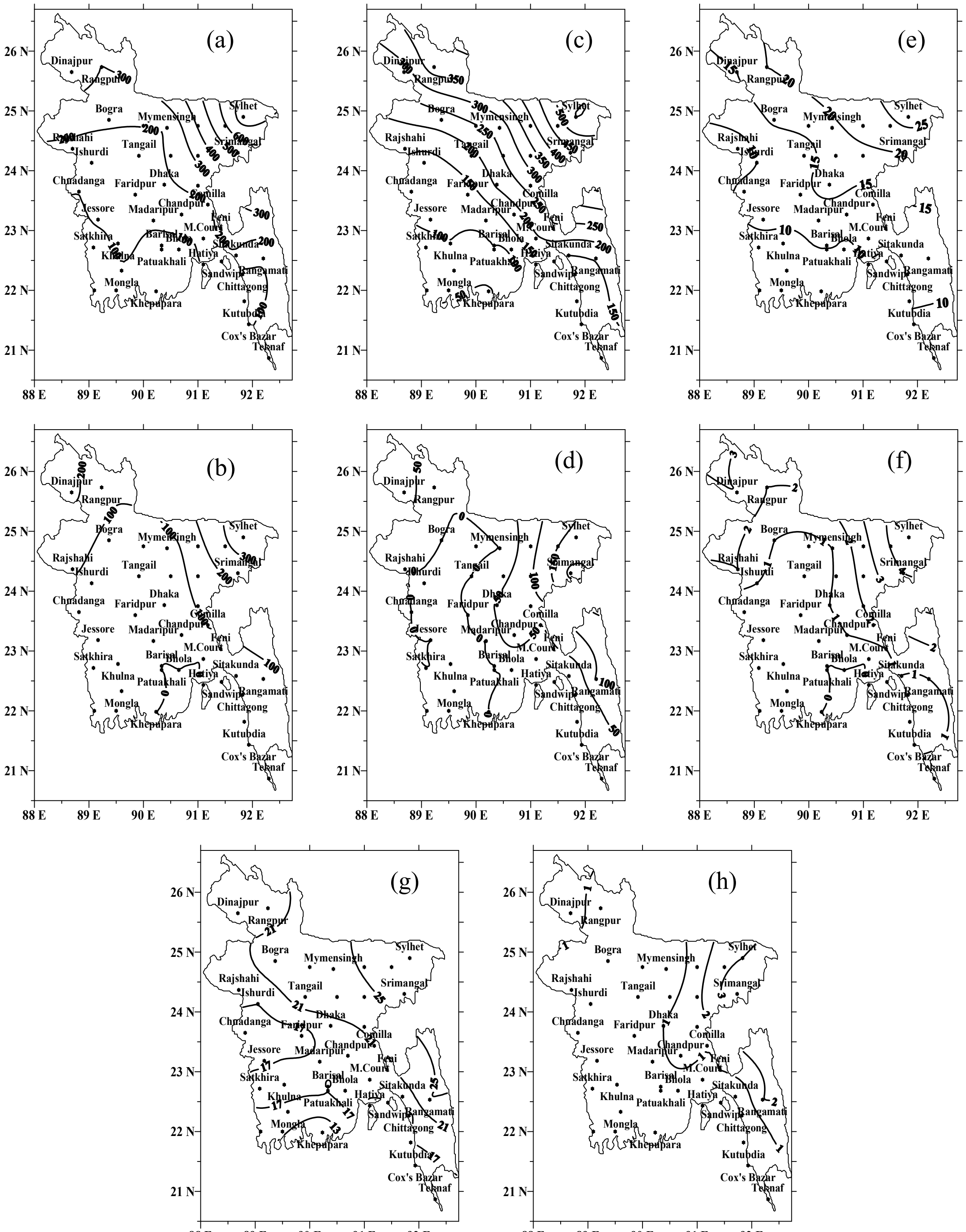

Figure 2: (a-b) BMD Observed and (c-d) PERSIANN total rainfall and heavy rainfall respectively, (e-f) BMD Observed and (g-h) PERSIANN total rainy days and heavy rainy days respectively all over Bangladesh for the month of May 2015

3.2 BMD and PERSIANN Observed rainy days and heavy rainy days for the month of May 2015

Special distribution of observed and PERSIANN total rainy days and heavy rainy days for the month of May 2015 all over Bangladesh is presented in Figures 2(e-h). The maximum and minimum rainy days (Figure 2e) are 27 and 5 days, respectively observed at Sylhet and Khepupara. It is seen from the spatial distribution pattern that the rainy days increased continuously from SW to N-NE region of Bangladesh due to orography of NE hilly region. The significant number of rainy days is also observed at Rangpur (20 days), Dhaka (19 days) and Mymensingh (19 days) region.

The maximum and minimum numbers of PERSIANN total rainy days of 28 and 10 (Figure 2f) are observed at Sylhet and Khepupara, respectively. It is seen from the spatial distribution pattern that the rainy days increased continuously from SW to N-NE region of Bangladesh. The maximum rainy days are also observed at Bhola, Rajshahi, Rangamati, Satkhira and Sitakunda and are 19 days and Madaripur and M.Court are 18 days and Ishwardi, Kutubdia and Patuakhali regions are 17 days and Chittagong and Jashore are 16 days. The maximum number of BMD observed HR days (Figure 2g) is found at Sylhet and no HR days are found at central to south, SE, SW and western region of the country. It is also seen from the spatial distribution pattern that the HR days increased continuously from SW to NE region of Bangladesh. The second peak of HR days are also observed at Dinajpur. The maximum PERSIANN distribution of HR days (Figure 2h) is observed at Srimangal (4 days) and no HR days are found at maximum region of the country. In the NW and SE regions of Bangladesh i.e., Rangpur and Rangamati observed only 2 HR days.

3.3 Model simulated monthly total rainfall at D1 for Day 1 prediction

The spatial distributions of simulated monthly 24 hourly rainfalls in domain 1 (D1) of May 2015 for different MP schemes in combination with KF CP scheme with the initial conditions of 0000 UTC of everyday for the month of May are presented in Figures 3(a-f). Lin *et al.* scheme (Figure 3a) has simulated maximum rainfall at Sylhet (861 mm) and minimum rainfall at Bhola (45 mm). The distribution pattern shows that the rainfall increased continuously from SW to north-NE region of Bangladesh. The second maximum simulated rainfall is at Dinajpur region and the third maximum rainfall is at Madaripur region. The minimum rainfall is simulated in the southeastern regions of Bangladesh. The amounts of minimum rainfall are 113, 115, 133, 134 and 135 mm at Rangamati, Feni, Sitakunda, Teknaf and Cox-Bazar, respectively. The simulated rainfall at Dhaka is 393 mm. The model simulated rainfall is matched with the observed rainfall in the northeastern region.

WSM6 scheme (Figure 3b) has simulated maximum rainfall of 831 mm at Sylhet and minimum rainfall of 44 mm at Bhola. The second maximum rainfall is seen at Srimangal region of Bangladesh. It is also seen from the spatial distribution pattern that the rainfall increased continuously from SW to NE region of Bangladesh. The simulated rainfall at Tangail is 430 mm. The minimum rainfall is seen at Teknaf, Chuadanga, Rangamati, Feni, Cox-Bazar and Kutubdia and the amounts are 108, 112, 112, 125, 128 and 131 mm, respectively. The distribution pattern of simulated rainfall in the SE and NE region is similar to that of observed rain but the WSM6 scheme has simulated much higher rainfall in the central to southern and western region of the country. Thompson scheme (Figure 3c) has simulated maximum rainfall of 939 mm at Sylhet and minimum rainfall of 50 mm at Bhola. From the spatial distribution pattern of rainfall it is found that the rainfall increased continuously from SW to NE region of Bangladesh. In the central region of Bangladesh i.e., Dhaka-Tangail regions the simulated rainfall is greater than 300 mm but the observed rain was less than 200 mm. The distribution pattern of simulated rainfall in the SE region is similar to that of observed rain but all other region Thompson scheme has simulated much higher rainfall.

M-2Mom scheme (Figure 3d) has simulated maximum rainfall of 788 mm at Sylhet and minimum rainfall of 33 mm at Bhola. It is seen from the spatial distribution pattern that the rainfall increased continuously from south SW to NE region of Bangladesh. The rainfall simulated at Dhaka is 409 mm. The minimum rainfall also seen at Chittagong and Cox-Bazar is 91 and 93 mm, respectively. The distribution pattern is similar but the scheme has simulated much higher rainfall in the central region. The distribution pattern of simulated rainfall in the SE and NE region is similar to that of observed rain but M-2Mom scheme has simulated much higher rainfall in the central to southern, west and northwestern (NW) region of the country. SBU-YLin scheme (Figure 3e) has simulated maximum rainfall of 941 mm at Sylhet and minimum rainfall of 40 mm at Bhola. The spatial distribution pattern shows that the rainfall increased continuously from SW to NE and NW regions of Bangladesh. The simulated rainfall at Dhaka is 325 mm. The minimum rainfall is seen at Chittagong, Cox-Bazar and Chandpur and are 86, 92 and 98 mm, respectively. The distribution pattern of simulated rainfall in the SE region is similar to that of observed rain but all other region SBU-YLin scheme has simulated much higher rainfall. WDM6 scheme (Figure 3f) has simulated maximum rainfall of 742 mm at Sylhet and minimum rainfall of 46 mm at Bhola. The spatial distribution pattern shows that the rainfall increased continuously from SW to NE region of Bangladesh. The significant amounts of rainfall equal to 450 and 329 mm have also been simulated in the central and NW regions i.e., Tangail and Bogura, respectively. The minimum rainfall is also seen in the south SE regions of the country. The simulated rainfall is found to match with observed rainfall in the NE region i.e., highest rain regions. The errors of monthly total all BMD stations rainfall have simulated 41, 40, 31, 35, 22 and 40% for day 1 prediction; 47, 31, 34, 49, 27 and 38% for day 2 prediction and 42, 37, 29, 50, 28 and 45% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D1.

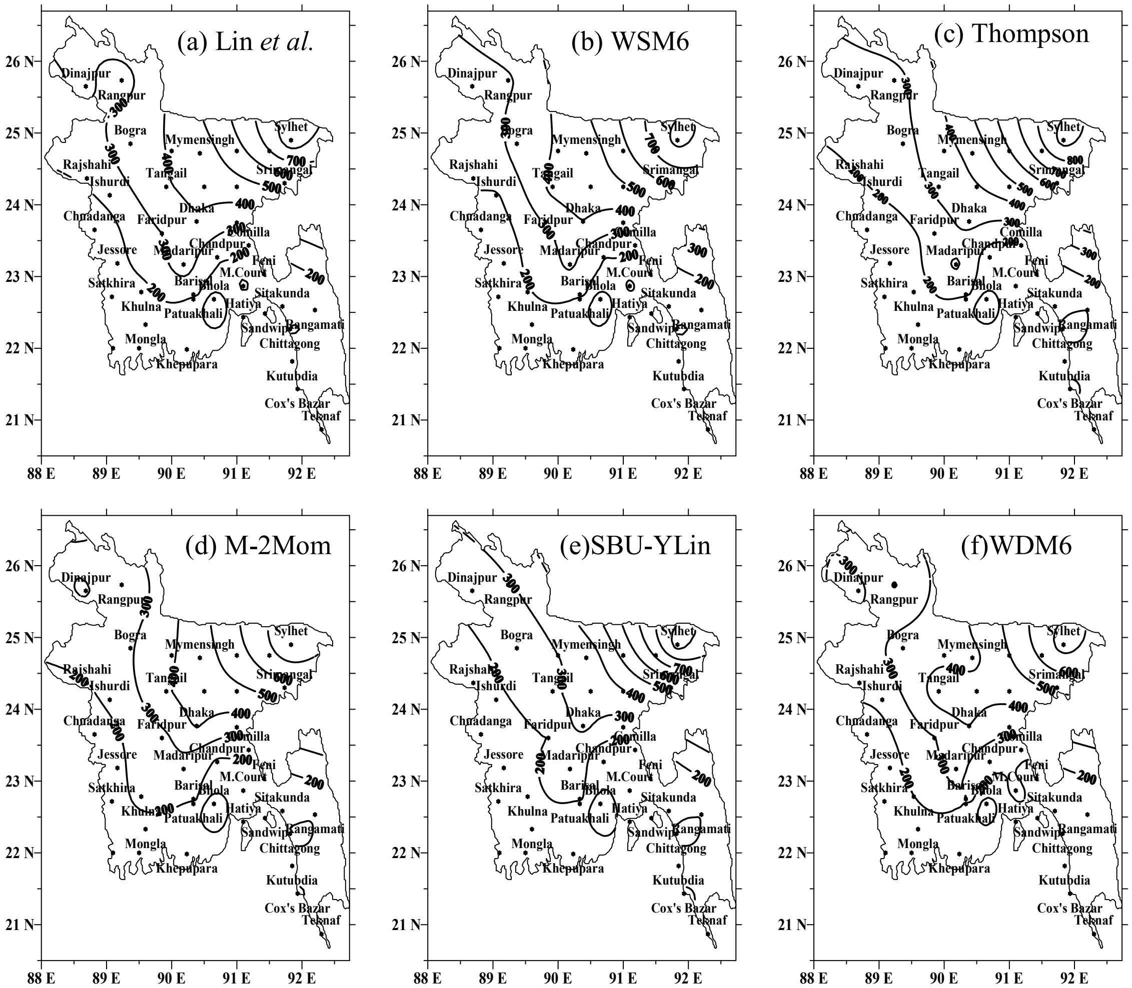

Figure 3: Model simulated spatial distribution of monthly total rainfall of May 2015 for day 1 prediction in D1 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.4 Model simulated monthly total rainfall at D2 for Day 1 prediction

The simulated monthly rainfall distributions of domain 2 (D2) for different MP schemes with the everyday initial conditions for the month of May 2015 are presented in Figures 4(a-f). From the spatial distribution it is observed that all MP schemes have simulated maximum rainfall in the NE region and minimum rainfall in the south SW regions. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the highest rainfall at Sylhet and the amounts are 923, 999, 1000, 807, 950 and 744 mm and Bhola has the lowest rainfall of 33, 25, 47, 30, 22 and 58 mm, respectively and observed rainfall at Sylhet is 752 mm and at Bhola it is 71 mm.

The Lin *et al.* scheme has simulated significant amount of rainfall at Dhaka and Bogura having 440 and 315 mm (Figure 4a), respectively. The minimum rainfall is also seen at Teknaf and Cox-Bazar where the amounts are 107 and 106 mm, respectively. Lin *et al.* scheme has simulated 16 to 18% higher rainfall all over the country in D2 for day 1 prediction. The WSM6 scheme has simulated significant amount of rainfall at Dhaka and Bogura and the amounts are 423 and 391 mm (Figure 4b), respectively. The minimum rainfall of 74 mm is also seen at Teknaf. WSM6 scheme has simulated 9 to 24 % higher rainfall all over the country in D2 for day 1 prediction. The Thompson scheme has simulated significant amount of rainfall at Dhaka and Dinajpur where the amounts are 412 and 310 mm (Figure 4c), respectively. The minimum rainfall is also seen at Teknaf and Cox-Bazar regions are 104 and 95 mm, respectively. Thompson scheme has simulated 24 to 31% higher rainfall all over the country than that observed in D2 for day 1 prediction.

The M-2Mom scheme has simulated significant amount of rainfall of 446 and 317 mm at Dhaka and Dinajpur (Figure 4d), respectively. The minimum rainfall of 109 and 82 mm is also seen in Teknaf and Cox-Bazar, respectively. The SBU-YLin scheme has simulated significant amount of rainfall at Dhaka and Dinajpur where the amounts are 390 and 267 mm (Figure 4e), respectively. The minimum rainfall of 108, 86 and 73 mm is also seen at Teknaf, Cox-Bazar and Chandpur, respectively. The SBU-YLin scheme has simulated 6 to 20 % higher rainfall all over the country than that observed rainfall in D2 for day 1 prediction. The WDM6 scheme has simulated significant amount of rainfall of 415 and 375 mm (Figure 4f) at Tangail and Bogura, respectively. The minimum rainfall of 128, 116 and 90 mm is also seen at Chandpur, Mongla and Teknaf regions, respectively. The rainfall simulated by WDM6 scheme is almost matched with the observed rainfall except in the central region where the scheme has simulated higher rainfall. The errors of monthly total all BMD stations rainfall have simulated 49, 46, 37, 38, 22 and 41% for day 1 prediction; 49, 42, 26, 48, 28 and 33% for day 2 prediction and 58, 41, 27, 61, 31 and 44% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D2.

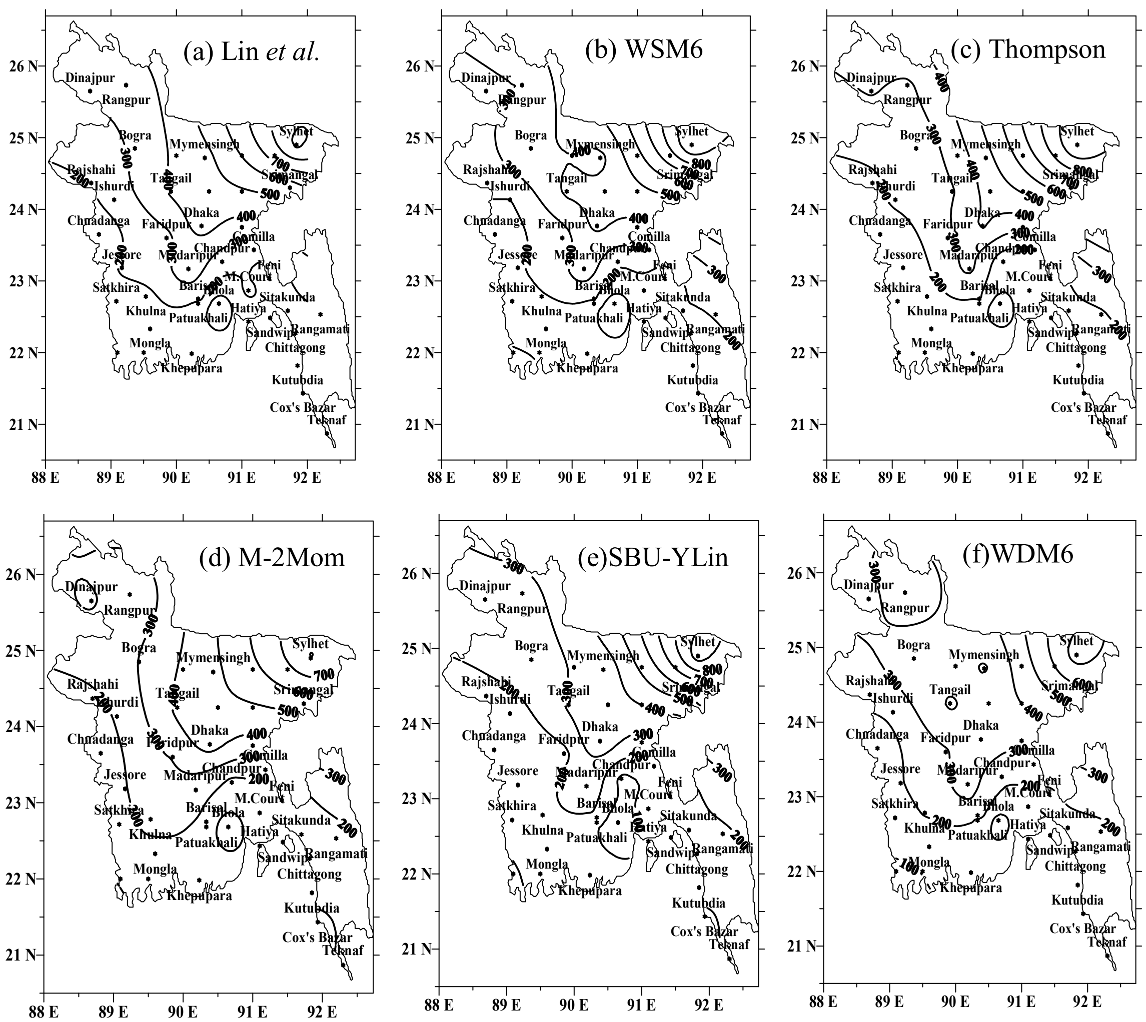

Figure 4: Model simulated spatial distribution of monthly total rainfall of May 2015 for day 1 prediction in D2 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.5 Model simulated monthly heavy rainfall at D1 for Day 1 prediction

The monthly distributions of model simulated heavy rainfall (HR) for day 1 in D1 for different MP schemes with the initial conditions of 0000 UTC of everyday for the month of May 2015 are presented in Figures 5(a-f). All studied MP schemes have simulated maximum HR in the NE region and no HR in the central to S-SE, SW and NW regions of Bangladesh. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the highest rainfall at Sylhet and the amounts are 654, 499, 619, 523, 781 and 445 mm, respectively and observed rainfall at Sylhet is 379 mm. WSM6, M-2Mom and WDM6 schemes have also simulated significant amount of HR at Bogura having100, 92 and 104 mm, respectively and the observed rain is 73 mm. The distribution pattern of HR for Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes are similar to that of observed HR all over the country except in the central and NW region. Lin *et al.* (Figure 5a), Thompson (Figure 5c) and SBU-YLin (Figure 5e) schemes have not simulated HR in the NW region and WSM6 (Figure 5b), M-2Mom (Figure 5d), and WDM6 (Figure 5f) schemes have simulated higher HR in Bogura but lower in Dinajpur. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have also simulated similar rainfall at Srimangal and the amounts are 204, 185, 383, 249, 270 and 135 mm, respectively and that of observed rainfall is 231 mm. The errors of monthly all BMD stations heavy rainfall have simulated 35, 39, 37, 34, 34 and 46% for day 1 prediction; 03, 14, 5, 15, 21 and 27% for day 2 prediction and 3, 31, 12, 13, 13 and 22% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D1.

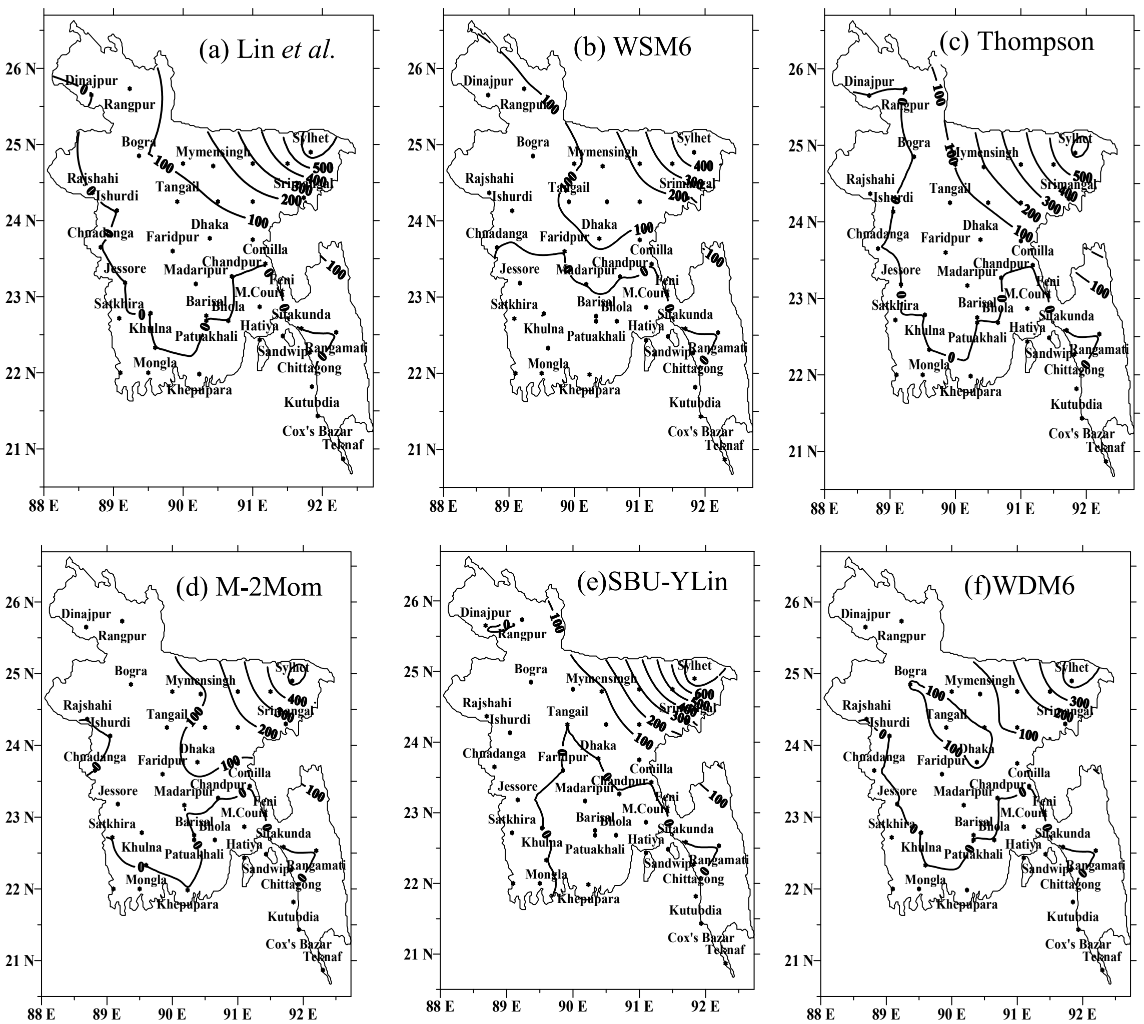

Figure 5: Model simulated spatial distribution of monthly HR of May 2015 for day 1 prediction in D1 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.6 Model simulated monthly total heavy rainfall at D2 for Day 1 prediction

The monthly distributions of model simulated heavy rainfall (HR) for day 1 in D1 for different MP schemes in combination with KF scheme with the initial conditions of 0000 UTC of everyday for the month of May 2015 are presented in Figures 6(a-f). All studied MP schemes have simulated maximum HR in the NE region and no HR in the S-SE, SW and western regions of Bangladesh. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the highest rainfall at Sylhet and the amounts are 687, 681, 780, 503, 808 and 386 mm, respectively and the observed rainfall at Sylhet is 379 mm. Lin e*t al.,* WSM6, M-2Mom, SBU-Lin and WDM6 schemes have also been simulated significant amount of HR at Bogura and it is 69, 138, 190, 80 and 123 mm, respectively and the observed rain is 73 mm. The distribution pattern of HR for Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes are similar to that of observed HR all over the country but all the studied schemes have simulated higher rain from central region to north-NE region. Lin *et al.* (Figure 6a), WSM6 (Figure 6b), Thompson (Figure 6c), M-2Mom (Figure 6d), SBU-YLin (Figure 6e) and WDM6 (Figure 6f) schemes have also simulated similar rainfall at Srimangal and the amounts are 251, 236, 362, 270, 256 and 214 mm, respectively and that of observed rainfall is 231 mm. All schemes have simulated lower rainfall at Dinajpur region. Lin *et al.,* WSM6, Thompson and SBU-YLin schemes have simulated higher rainfall and M-2Mom and WDM6 schemes simulated lower rainfall at Sylhet in D2 than that of D1. The errors of monthly all BMD stations heavy rainfall have simulated 7, 4, 15, 9, 25 and 35% for day 1 prediction; 8, 13, 5, 35, 14 and 26% for day 2 prediction and 44, 6, 0, 58, 8 and 11% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D2.

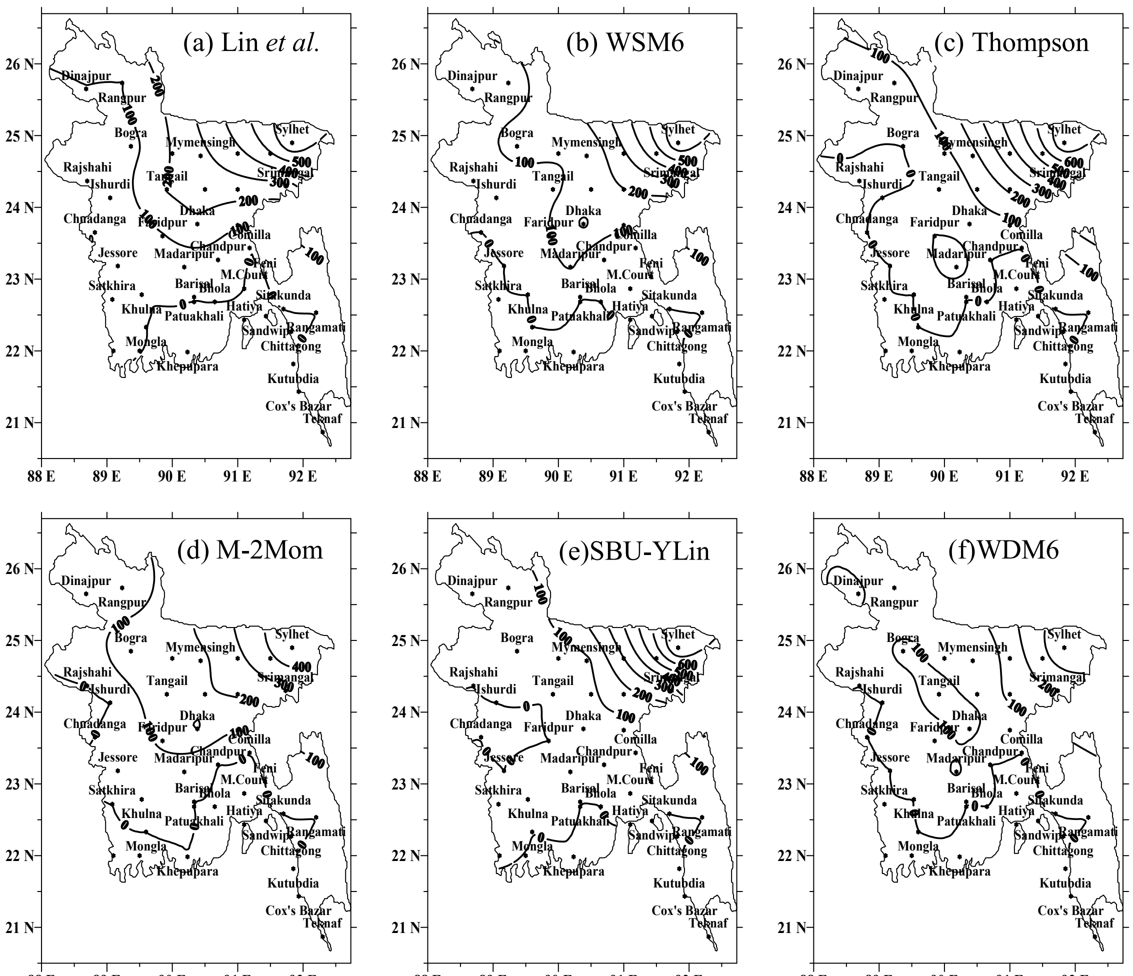

Figure 6: Model simulated spatial distribution of monthly HR of May 2015 for day 1 prediction in D2 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.7 Simulated rainy days at D1 for Day 1 prediction

The monthly distributions of model simulated total rainy days for day 1 prediction in D1 for different MP schemes in combination with KF scheme with the initial conditions of 0000 UTC of everyday for the month of May 2015 are presented in Figures 7(a-f). All studied MP schemes have simulated highest number of rainy days at Barishal-Madaripur region and next higher number of rainy days have simulated at Sylhet region. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the number of rainy days at Sylhet having 26, 25 23, 27, 27 and 25 days, respectively and observed is 27 days and at Barishal it is 28, 29, 28, 29, 28 and 29 days, respectively and observed is 12 days. The number of rainy days at Sylhet is almost matched with the observed rainy days but in the south-SE, SW and western region all the MP schemes have simulated much higher rainy days. Lin *et al.* (Figure 7a), WSM6 (Figure 7b), M-2Mom (Figure 7d) and WDM6 (Figure 7f) schemes have simulated minimum number of rainy days at Bhola are 14, 12, 12 and 13, respectively and Thompson (Figure 7c) and SBU-YLin (Figure 7e) schemes at Jashore it is 13 days. It is also seen that Lin *et al.*, WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated number of rainy days at Sylhet having 28, 28, 29, 28, 28 and 28, respectively for day 2 (Figure not shown) prediction and 28, 26, 28, 29, 28 and 27, respectively for day 3 (Figure not shown) prediction. The distribution of simulated number of rainy days for all studied MP schemes in day 2 and day 3 (Figure not shown) predictions are almost similar but slightly higher than that of day 1. The errors of monthly all BMD stations rainy days have simulated 90, 96, 83, 87, 83 and 92% for day 1 prediction; 94, 87, 92, 82, 84 and 91% for day 2 prediction and 83, 83, 74, 76, 73 and 84% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D1.

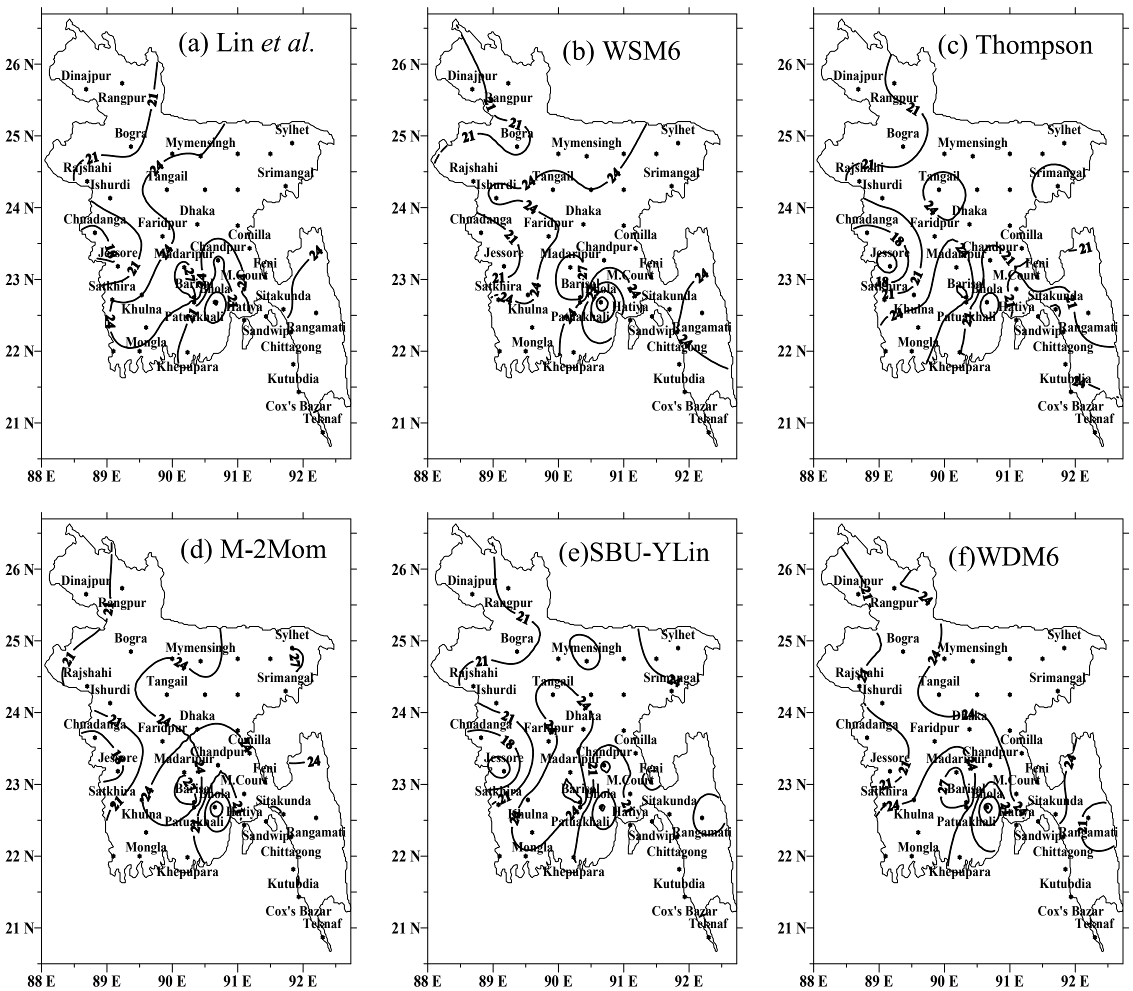

Figure 7: Model simulated spatial distribution of monthly total rainy days of May 2015 for day 1 prediction in D1 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.8 Simulated rainy days at D2 for Day 1 prediction

The monthly distributions of model simulated total rainy days for day 1 prediction in D2 for different MP schemes in combination with KF scheme with the initial conditions of 0000 UTC of everyday for the month of May 2015 are presented in Figures 8(a-f). Lin *et al.* (Figure 8a), WSM6 (Figure 8b), Thompson (Figure 8c), M-2Mom (Figure 8d), SBU-YLin (Figure 8e) and WDM6 (Figure 8f) schemes have simulated maximum rainy days in the central to NE regions and minimum in the south-SW regions of Bangladesh. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the monthly highest number of rainy days at Dhaka, Madaripur, Cumilla, Sylhet, Sylhet and Sandwip having 27, 26, 25, 26, 26 and 26, respectively. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the number of rainy days at Sylhet having 26, 25, 23, 26, 26 and 24, respectively and observed is 27 and at Barishal it is 24, 23, 21, 21, 19 and 25, respectively and observed is 12 days. The number of rainy days simulated by different MP schemes at Sylhet is almost matched with the observed rainy days but the schemes have simulated much higher rainy days in the south-SE, SW and western region. Lin *et al.*, WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated minimum number of rainy days at Bhola having 12, 10, 13, 10, 9 and 13, respectively for day 1 prediction and observed is 9 days. It is also seen that Lin *et al.*, WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the number of rainy days at Bhola having 9, 11, 14, 7, 9 and 12, respectively for day 2 (Figure not shown) prediction and 11, 8, 10, 7, 8 and 8, respectively for day 3 (Figure not shown) prediction. The distribution of simulated number of rainy days for all studied MP schemes in day 2 and day 3 predictions are almost similar but slightly lower than that of day 1.The errors of monthly all BMD stations rainy days have simulated 73, 73, 67, 69, 60 and 74% for day 1 prediction; 74, 74, 69, 60, 60 and 69% for day 2 prediction and 71, 69, 55, 60, 53 and 68% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D2.

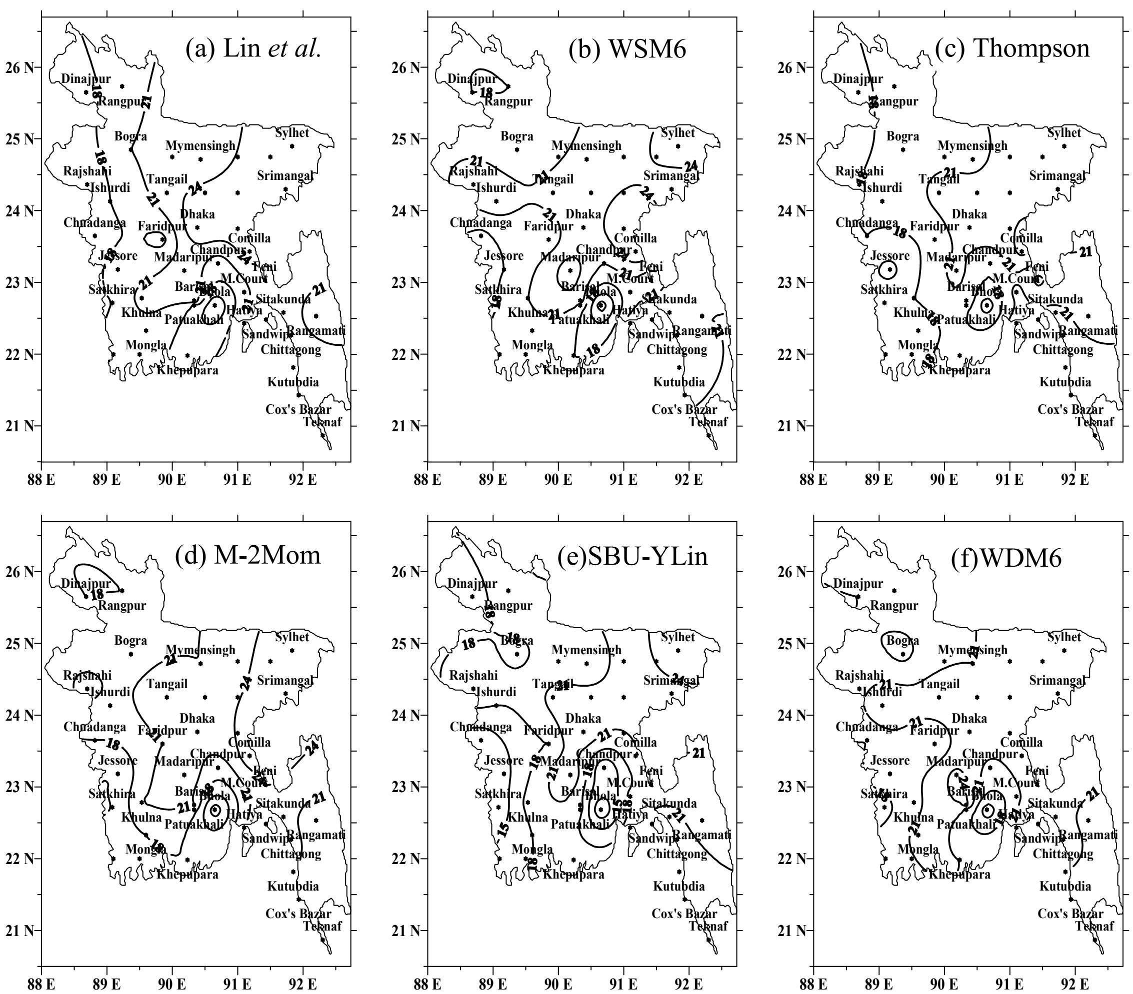

Figure 8: Model simulated spatial distribution of monthly total rainy days of May 2015 for day 1 prediction in D2 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.9 Simulated heavy rainy days at D1 for Day 1 prediction

The monthly distributions of model simulated HR days for day 1 prediction in D1 for different MP schemes in combination with KF scheme with the initial conditions of 0000 UTC of everyday for the month of May 2015 are presented in Figures 9(a-f). Lin *et al.* (Figure 9a), WSM6 (Figure 9b), Thompson (Figure 9c), M-2Mom (Figure 9d), SBU-YLin (Figure 9e) and WDM6 (Figure 9f) schemes have simulated maximum HR days in the central to NE regions and almost zero all other regions of Bangladesh. Observed HR days is found to increase from central to NE and NW regions but almost all studied MP schemes have simulated HR days from central to NE regions of Bangladesh. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the monthly highest number of HR days are 9, 6, 8, 8, 11 and 6, respectively at Sylhet and next higher HR days 3, 3, 5, 4, 4 and 2 respectively at Srimangal. The observed HR days are 5 and 4 at Sylhet and Srimangal respectively. WSM6 and WDM6 schemes have simulated almost similar HR days at Sylhet but it was less in Srimangal. Lin *et al.*, WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated number of HR days 10, 7, 11, 13, 9 and 7, respectively for day 2 (Figure not shown) prediction and 8, 5, 8, 10, 9 and 7 days, respectively for day 3 (Figure not shown) prediction at Sylhet. The distribution of simulated number of rainy days for all studied MPs in day 2 is higher and day 3 predictions are almost similar to that of day 1. The errors of monthly all BMD stations heavy rainy days have simulated 36, 45, 45, 33, 36 and 52% for day 1 prediction; 3, 9, 15, 3, 24 and 33% for day 2 prediction and 3, 27, 24, 9, 18 and 27% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D1.

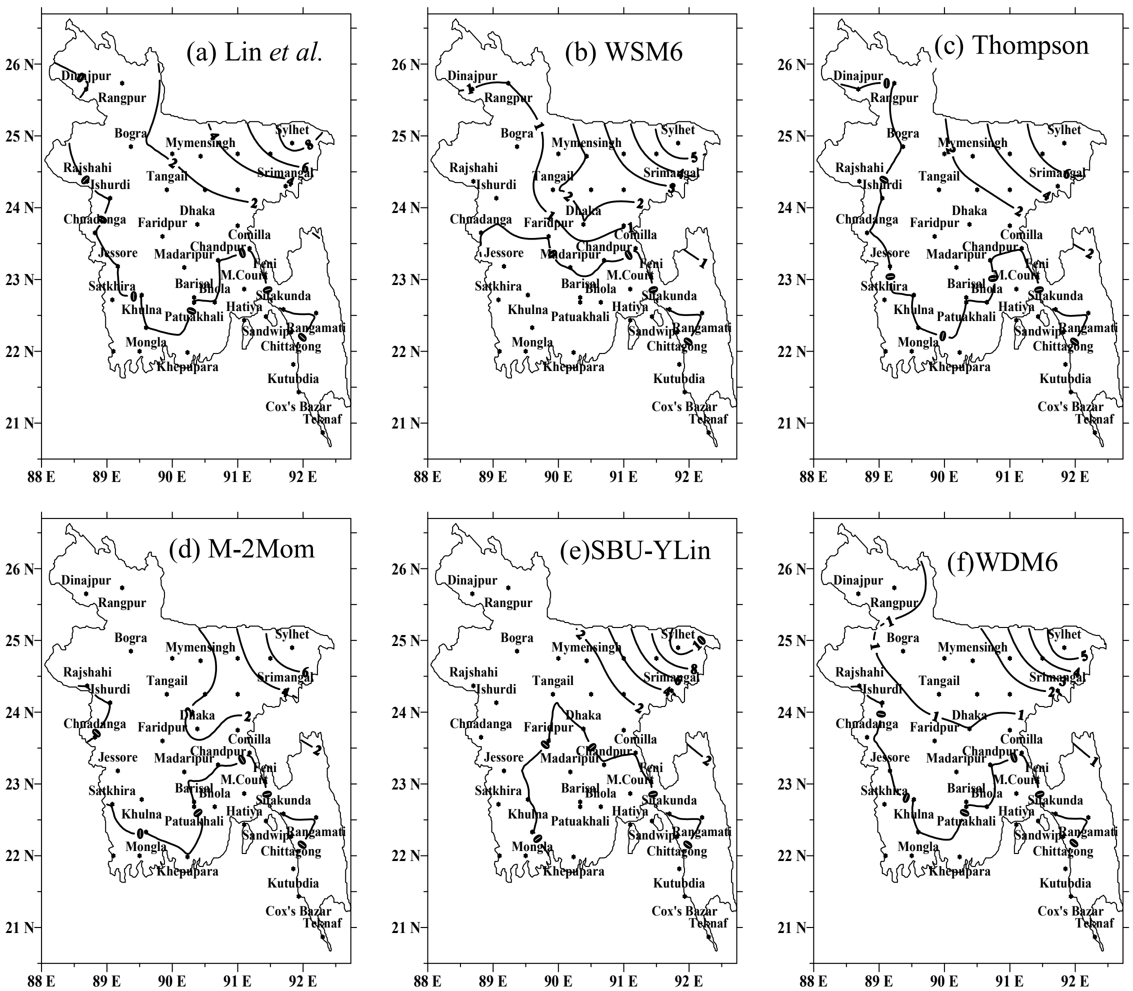

Figure 9: Model simulated spatial distribution of monthly HR days of May 2015 for day 1 prediction in D1 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.10 Simulated heavy rainy days at D2 for Day 1 prediction

The monthly distributions of model simulated HR days for day 1 prediction in D2 for different MP schemes in combination with KF scheme with the initial conditions of 0000 UTC of everyday for the month of May 2015 are presented in Figures 10(a-f). Lin *et al.* (Figure 10a), WSM6 (Figure 10b), Thompson (Figure 10c), M-2Mom (Figure 10d), SBU-YLin (Figure 10e) and WDM6 (Figure 10f) schemes have simulated maximum HR days in the NE region and increased from central to north-NE and NW regions and almost zero in the south-SE and western regions of Bangladesh. Observed HR days is found to increase from central to north-NE and NW regions and almost similar pattern is simulated for all studied MP schemes. Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated the monthly highest number of HR days having 9, 6, 9, 8, 12 and 4, respectively at Sylhet and next higher HR days at Srimangal having 4, 4, 5, 4, 5 and 3 respectively. The observed HR days are 5 and 4 at Sylhet and Srimangal respectively. Lin *et al.*, WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated number of HR days 9, 5, 10, 11, 9 and 5, for day 2 (Figure not shown) and 7, 6, 7, 12, 9 and 6, respectively for day 3 (Figure not shown) prediction at Sylhet. WSM6 and WDM6 schemes have simulated almost similar HR days at Sylhet and Srimangal and all other MPs have simulated higher number of HR days for day 1, day 2 and day 3 predictions. Similar HR days are also simulated at D2 and less at D1to that of observed. The errors of monthly all BMD stations heavy rainy days have simulated 12, 15, 24, 3, 21 and 45% for day 1 prediction; 6, 21, 3, 21, 9 and 36% for day 2 prediction and 24, 6, 15, 45, 3 and 3% for day 3 prediction by Lin *et al.,* WSM6, Thompson, M-2Mom, SBU and WDM6 schemes, respectively at D2.

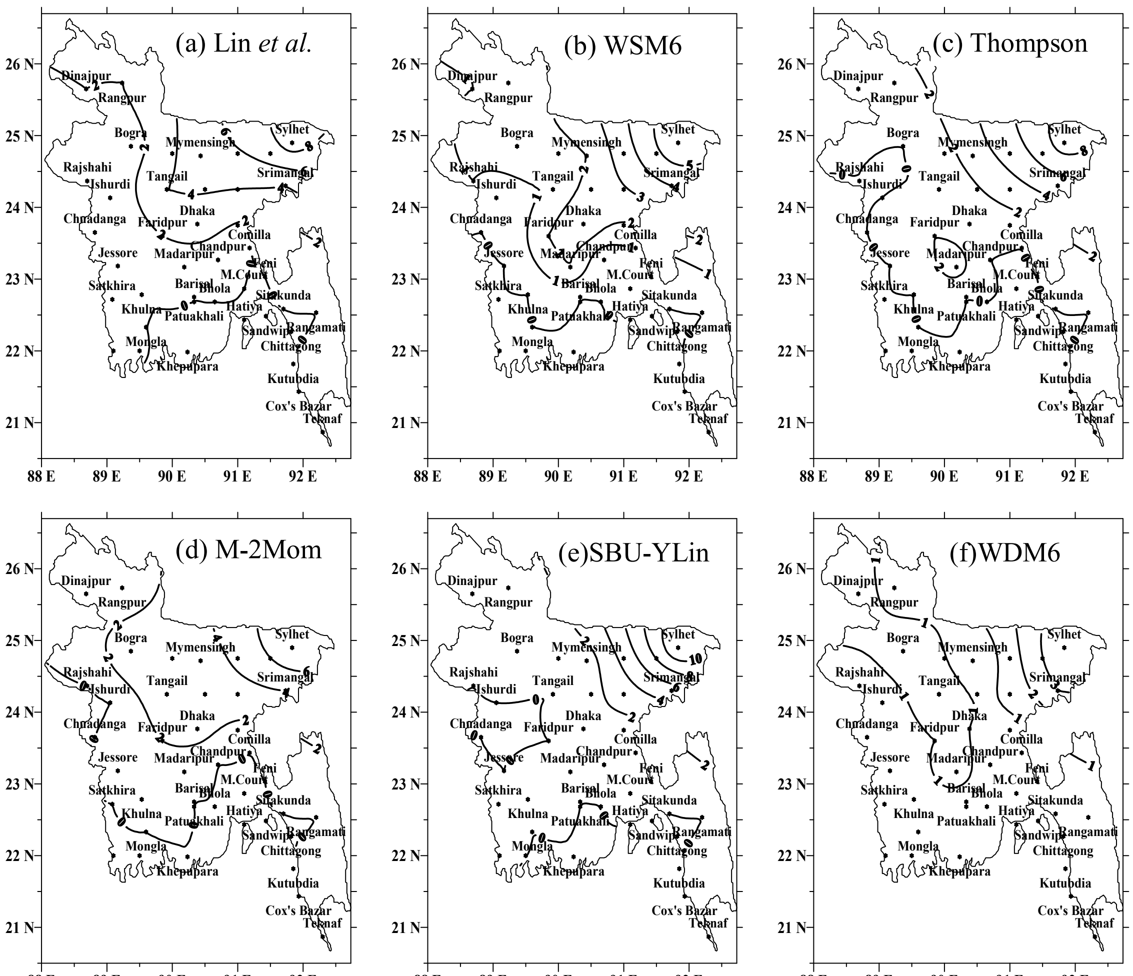

Figure 10: Model simulated spatial distribution of monthly HR days of May 2015 for day 1 prediction in D2 using a) Lin, b) WSM6, c) Thompson, d) M-2Mom, e) SBU-YLin and f) WDM6 schemes coupling with KF scheme all over Bangladesh.

3.11 Relative Standard deviation of rainfall and rainy days for the month of May 2015

The coefficient of variation (CV), also known as relative standard deviation (RSD), is a standardized measure of dispersion of a probability distribution or frequency distribution. RSD gives the variability of a parameter. If the value is less it is less variable and vice-versa. The RSD for monthly total rainfall and heavy rainfall of May 2015 is presented in Figure 11(a-d). The highest and lowest values of RSD for day 1 prediction are found 78 & 59% for in D1 and 79 & 57% in D2 for Thompson & WDM6 schemes respectively and for day 2 prediction 94 & 71% for Thompson & WSM6 in D1 and 98 & 65% for SBU & WSM6 in D2 and for day 3 prediction 106 & 60% in D1 and 101 & 65% in D2 for Thompson & WSM6 schemes, respectively.

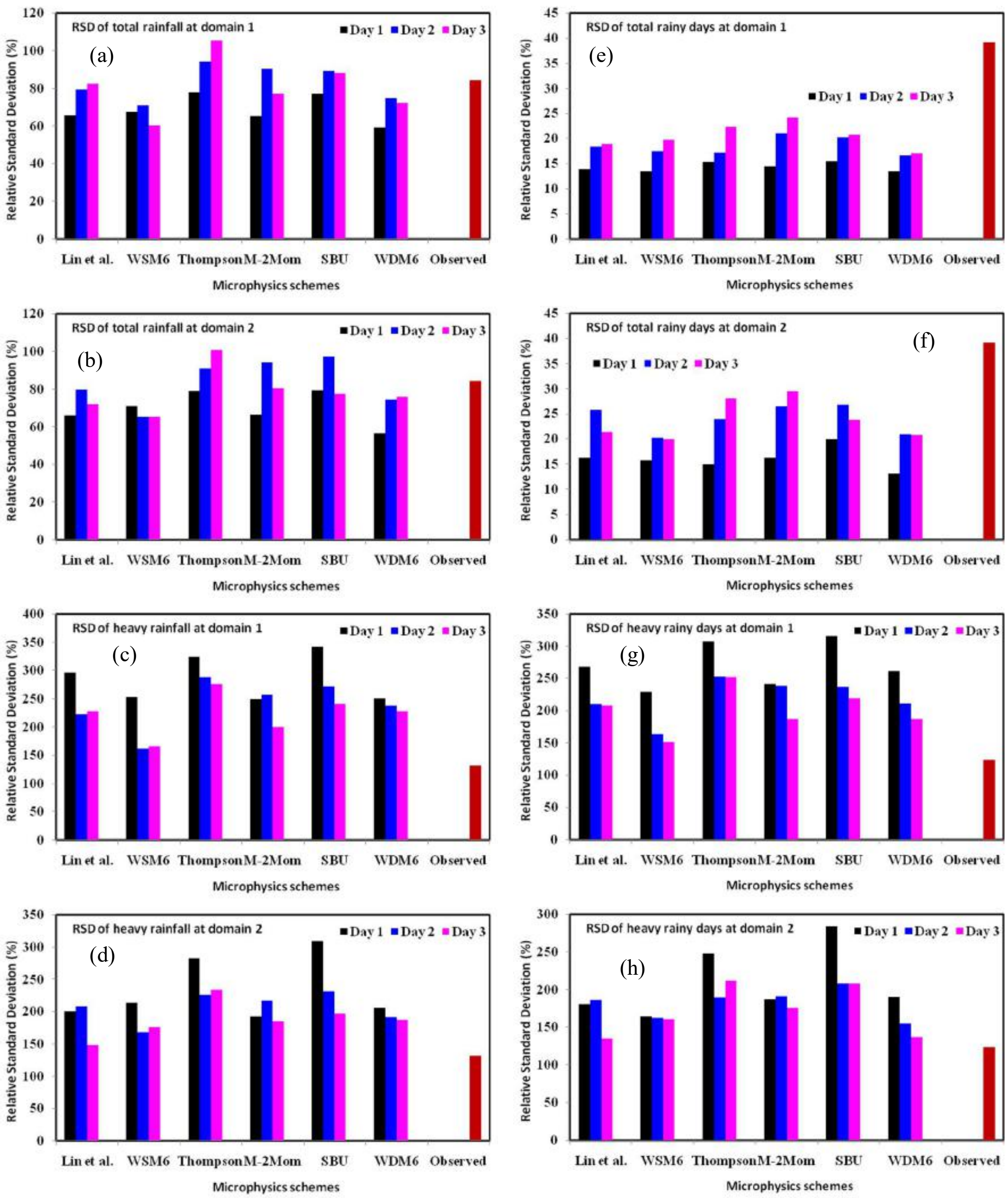

Figure 11: RSD for all Bangladesh meteorological stations monthly (a-b) total rainfall, (c-d) heavy rainfall, (e-f) total rainy days and (g-h) heavy rainy days in D1 and D2 respectively for different microphysics schemes of May 2015

The RSD for day 1, day 2 and day 3 prediction in D1 & D2 is almost similar to that of observed rainfall. The observed SD of all BMD stations heavy rainfall is 84%. It is found that the rainfall is less variable in day 1 and it increases with the increase in forecasting period (day 2 and day 3) at domain 1 (Figure 11a) and domain 2 (Figure 11b). The highest and lowest values of RSD of HR is found for day 1 prediction 342 & 249 mm for SBU & M-2Mom in D1 and 310 & 192 % for SBU& M-2Mom in D2 and for day 2 prediction 288 & 162% for Thompson & WSM6 in D1 and 231 & 167 mm for SBU & WSM6 in D2 and for day 3 prediction 277 & 166% for Thompson & WSM6 in D1 and 234 & 149% for Thompson & Lin *et al.* schemes in D2. The variability of heavy rainfall for day 1 prediction is less variable for M-2Mom and WDM6 schemes in D1 & also in D2, for day 2 prediction WSM6 in D1 & D2 and for day 3 prediction WSM6 and Lin *et al.* schemes in D1 & D2 respectively. The observed RSD of all BMD stations heavy rainfall is 131%. It can be seen that in case of heavy rainfall, RSD decreases with the increase of forecasting period at domain 1 (Figure 11c) and domain 2 (Figure 11d).

The RSD of total rainy days and HR days for the month of May 2015 is presented in Table 3 and Figure 11(e-h). The RSD of total rainy days is found for day 1, day 2 and day 3 predictions are 13, 17 and 20% for WSM6 scheme, 14, 18 and 19% for Lin *et al.* scheme, 15, 17 and 22% for Thompson scheme, 14, 21 and 24% for M-2Mom scheme, 15, 20 and 21% for SBU scheme and 14, 17 and 17% for WDM6 scheme at D1. On the basis of the findings it is found that the WDM6 scheme is less variable than the other MP schemes in D1. The RSD of total rainy days is found for day 1, day 2 and day 3 predictions are 16, 20 and 20% for WSM6 scheme, 16, 26and 21% for Lin *et al.* scheme, 15, 24 and 28% for Thompson scheme, 16, 27 and 30% for M-2Mom scheme, 20, 27 and 24% for SBU scheme and 13, 21 and 21% for WDM6 scheme at D2. On the basis of the findings it is found that the WDM6 scheme is less variable than the other MP schemes in D2 also. The observed RSD is found 39% for total rainy days all over Bangladesh. It is found that the total rainy days is less variable in day 1 and it increases with the increase in forecasting period (day 2 and day 3) at domain 1 (Figure 11e) and domain 2 (Figure 11f).

The RSD of heavy rainy days is found for day 1, day 2 and day 3 predictions are 229, 164 and 151% for WSM6 scheme, 269, 210 and 208% for Lin *et al.* scheme, 242, 239 and 187% for Thompson scheme, 242, 239 and 187% for M-2Mom scheme, 316, 236 and 219% for SBU scheme and 262, 212 and 187% for WDM6 scheme at D1. On the basis of the findings it is found that the WSM6 scheme is less variable than the other MP schemes in D1. The RSD of heavy rainy days is found for day 1, day 2 and day 3 predictions are 164, 162 and 161% for WSM6 scheme, 181, 186 and 135% for Lin *et al.* scheme, 248, 189 and 212% for Thompson scheme, 187, 191 and 175% for M-2Mom scheme, 284, 208 and 208% for SBU scheme and 191, 156 and 137% for WDM6 scheme at D2. On the basis of the findings it is found that the WDM6 scheme is less variable than the other MP schemes in D2 also. The observed RSD is found 123% for heavy rainy days all over Bangladesh. The RSD decreases with the increase of forecasting period at domain 1 (Figure 11g) and domain 2 (Figure 11h).

4. CONCLUSIONS

On the basis of our findings the following the conclusions have been drawn:

- The maximum monthly observed rain of May 2015 at Sylhet is 752 mm but WSM6, M-2Mom and WDM6 schemes have simulated rainfall of 831, 788 and 742 mm for day 1 prediction WSM6, WDM6 and SBU-Lin schemes have simulated rainfall of 757, 916 and 981 mm for day 2 prediction whereas WSM6 and WDM6 schemes have simulated 741 and 925 mm for day 3 prediction, respectively and all other MPs have simulated much higher rainfall at D1.
- The WDM6, M-2Mom and Lin *et al.* schemes have simulated rainfall of 744, 807 and 923 mm for day 1 prediction whereas WSM6 and WDM6 schemes have simulated 714 and 877 mm for day 2 predictions and WSM6, SBU-Lin and Lin *et al.* schemes have simulated 802 and 913 and 998 mm, respectively for day 3 prediction at D2.
- The maximum monthly observed HR of May 2015 at Sylhet is 379 mm but WDM6, WSM6 and M-2Mom have simulated 445, 499 and 523 mm for day 1 prediction, WSM6 and WDM6 schemes have simulated 398 & 558 mm and 364 & 619 mm for day 2 and day 3 predictions, respectively at D1.
- The WDM6 and M-2Mom schemes have simulated 383 and 503 mm HR at Sylhet for day 1 prediction, WSM6 and WDM6 schemes have simulated 334 and 476 mm for day 2 predictions and WSM6 and SBU-Lin schemes have simulated 507 and 614 mm for day 3 predictions at D2.
- The simulated number of total rainy days at Sylhet and Bhola for all MPs is almost matched with the observed total rainy days. All MPs have simulated much higher total rainy days for day 1, day 2 and day 3 predictions with little exceptions all over the country for the month of May 2015. The number of observed rainy days in the south-southeastern regions is very few but different MPs have simulated much higher rainy days in those regions. The distribution pattern of HR days for different MPs is similar in the central to NE, S-SE and SW regions but in the NW regions the number of HR days is insignificant.

- Lin *et al.,* WSM6, Thompson, M-2Mom, SBU-YLin and WDM6 schemes have simulated much higher rain at domain 1 (308, 292, 257, 271, 264 and 310%) and at domain 2 (298, 273, 258, 259, 214, and 283%) at Dhaka, Faridpur, Barishal, Patuakhali, Khepupara, Madaripur, Satkhira and Tangail and all other stations have simulated 25, 24, 13, 21, 7 and 26% higher at domain 1 and 34, 31, 20, 25, 8 and 31% higher rainfall at domain 2 than that of observed rain at day 1.
- The RSD is minimum at D1 and D2 for WDM6 scheme for day 1 prediction and WSM6 scheme for day 2 and day 3 predictions for the monthly total rainfall and total heavy rainfall of May 2015.
- The RSD is minimum at D2 for WDM6 scheme for day 1, day 2 and day 3 predictions for the monthly total rainy days and total HR days of May 2015.

On the basis of above discussion WDM6 scheme gives the better performance of rainfall and rainy days all over the country.

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