Study of Different Cumulus Parameterization Schemes for Simulation of Tornadic and Hailstorm Events in Bangladesh using ARW Model

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Outline:

Introduction

Synoptic Feature

DWR Kolkata

Kalpana-1 Satellite Imagery

WRF ARW

- Model Domain and Resolution
- Cumulus Parameterization

Comparative Study of WRF Model, TRMM and conventional data

Model Diagnosis

Summary

Introduction

This year in 2010, thunderstorms / hailstorms started a bit earlier. Tornadic thunderstorms were reported the southwestern parts (Jhenidah and adjoining area) of Bangladesh on 17 February 2010. Similarly, hailstorm were reported in the middle parts (Dhaka and adjoining area) of the country on 24 February 2010. The events are studied based on field survey, ground and Radar observations.

DWR (Doppler Weather Radar) Kolkata recorded the 17 February 2010 event with hook shaped echoes as Tornado Vortex Signature (TVS). The vertical extent of the 24 February 2010 system was about 14 km, the RADAR reflectivity 60 dBz and the horizontal extent was 40 km as recorded by DWR Kolkata.

The model has been run at 4 km horizontal resolution with 27 vertical levels. For cumulus (CU) parameterization option, the model was run with all the six cu physics schemes which are currently available. Some differences were found while analyzing and comparing model simulated outputs with the radar data and 3 hourly TRMM 3B42RT data. The purpose of this study is to find a suitable CU scheme to improve the accuracy of forecasting of thunderstorms in this region.

Synoptic Feature:

Date	Station	Nature of the squall	Wind Speed Km/hr	Wind blowing from	Occurrence Time (UTC)	24 hrs. Rf (mm)	Comments
17/02/10	Jessore	The Event associated with high wind speed followed gusty and squally weather	N/A	NW	0400-0500	16	Tornadic Storm
24/02/10	Dhaka	Line of Squalls	102	W	1130-1200	48	Mod. NW, Hailstorm (1118-1143Z)
	Dhaka		65	NW	1130-1200		

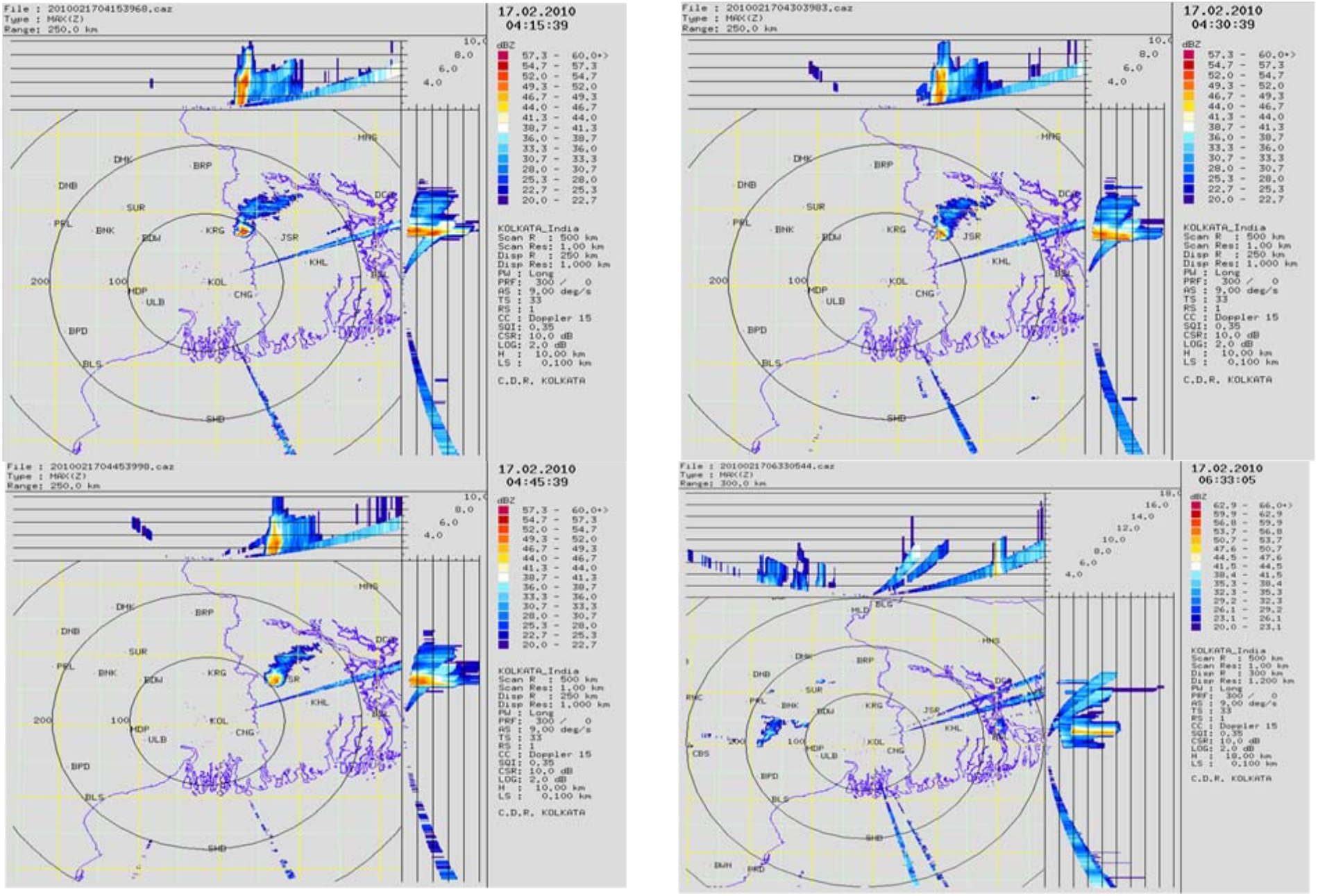
Source: Bangladesh Meteorological Department (BMD)

PHOTO: STAR

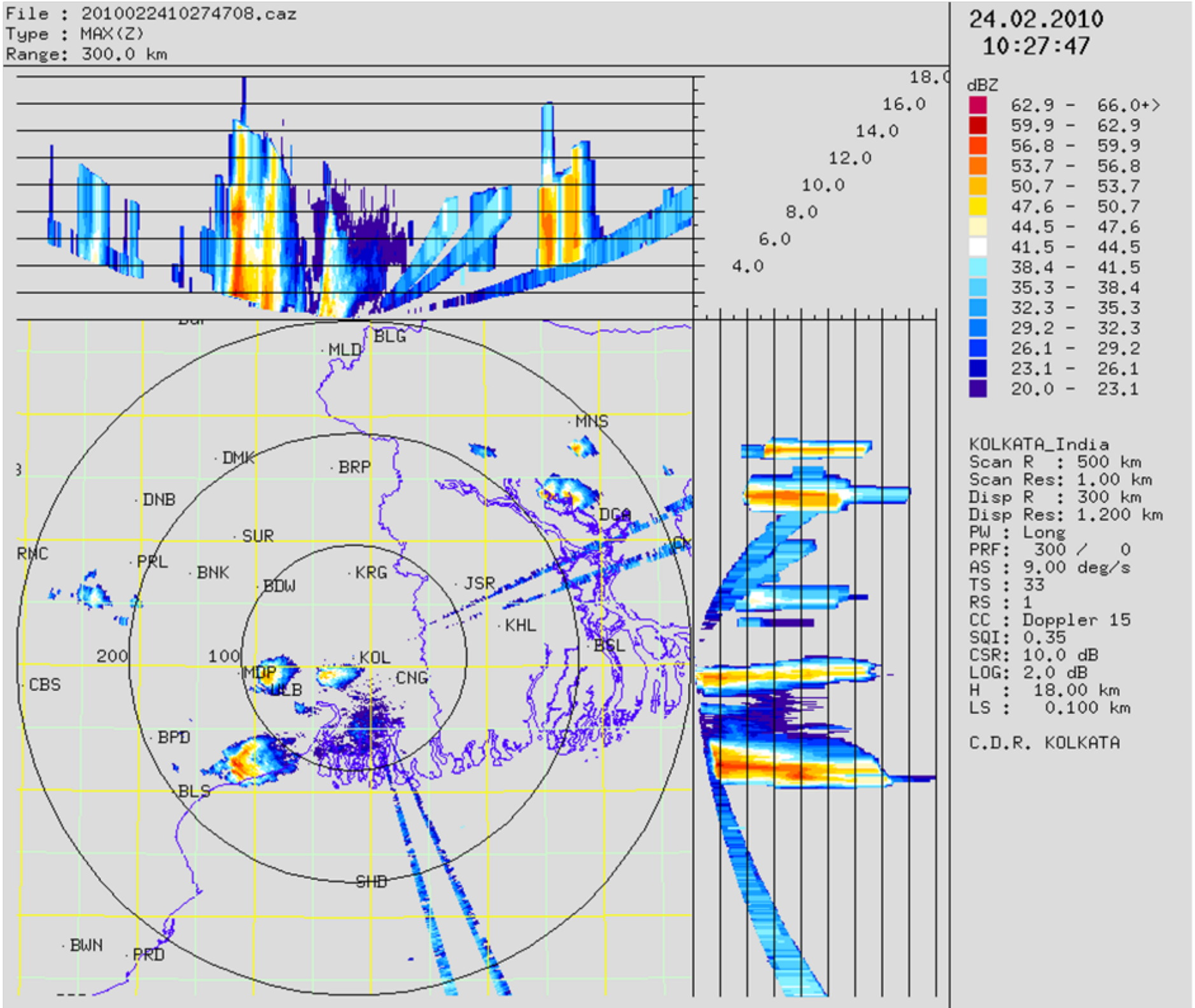
Tornado lashes 22 villages in Moheshpur upazila of Jhenidah district yesterday morning, killing a child and injuring 150 people. Photo shows Pakrail village damaged by the twister.

PHOTO: STAR

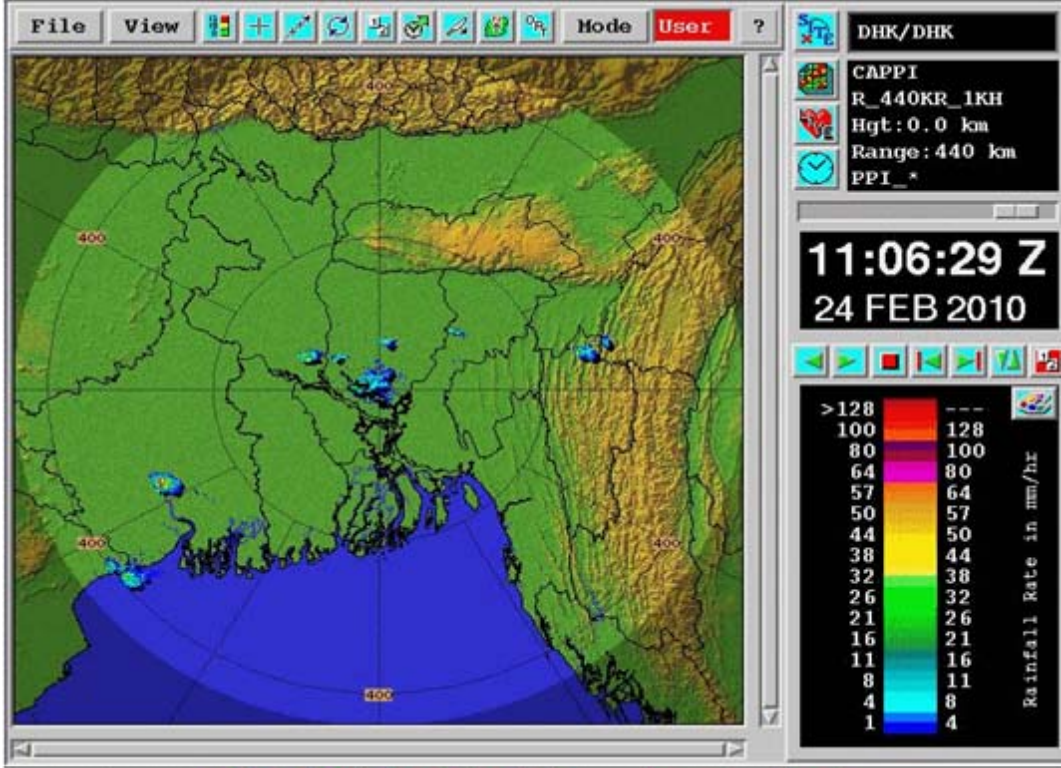
A billboard collapses in the middle of Bijoy Sarani during a hailstorm in the city yesterday. (Story on Page 16)



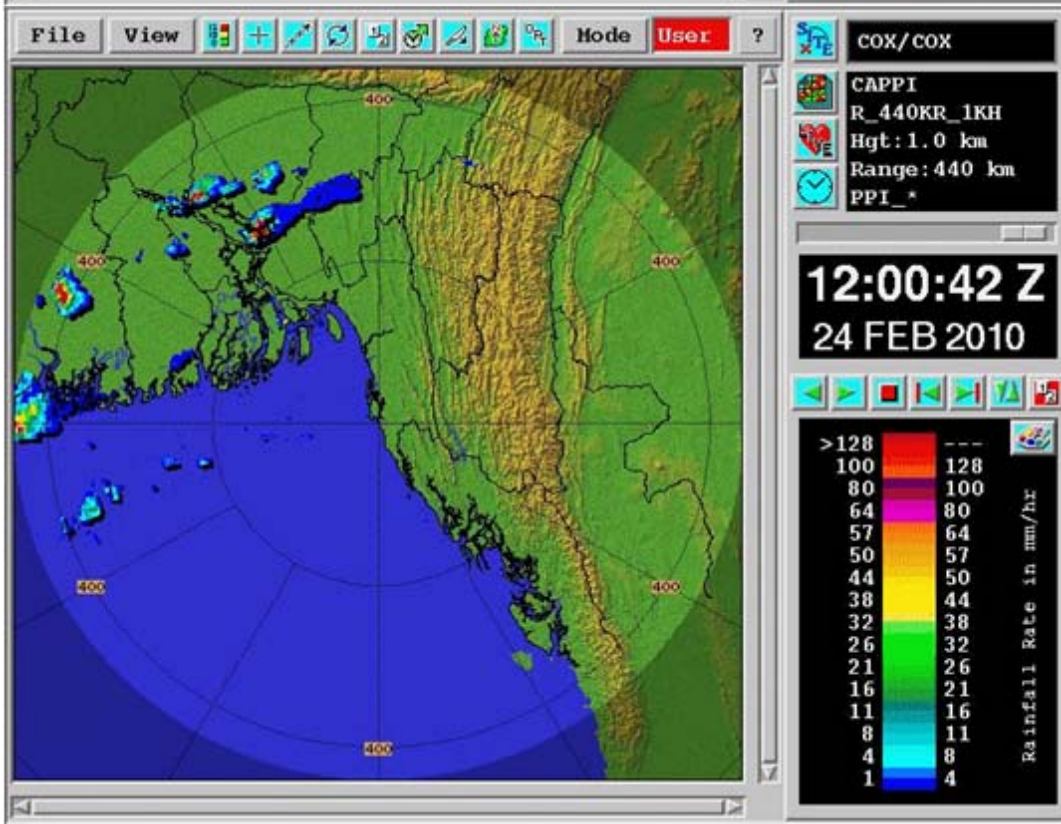
Max (Z)) derived from the DWR Kolkata from 0415 UTC to 0633 UTC of 17 February 2010.

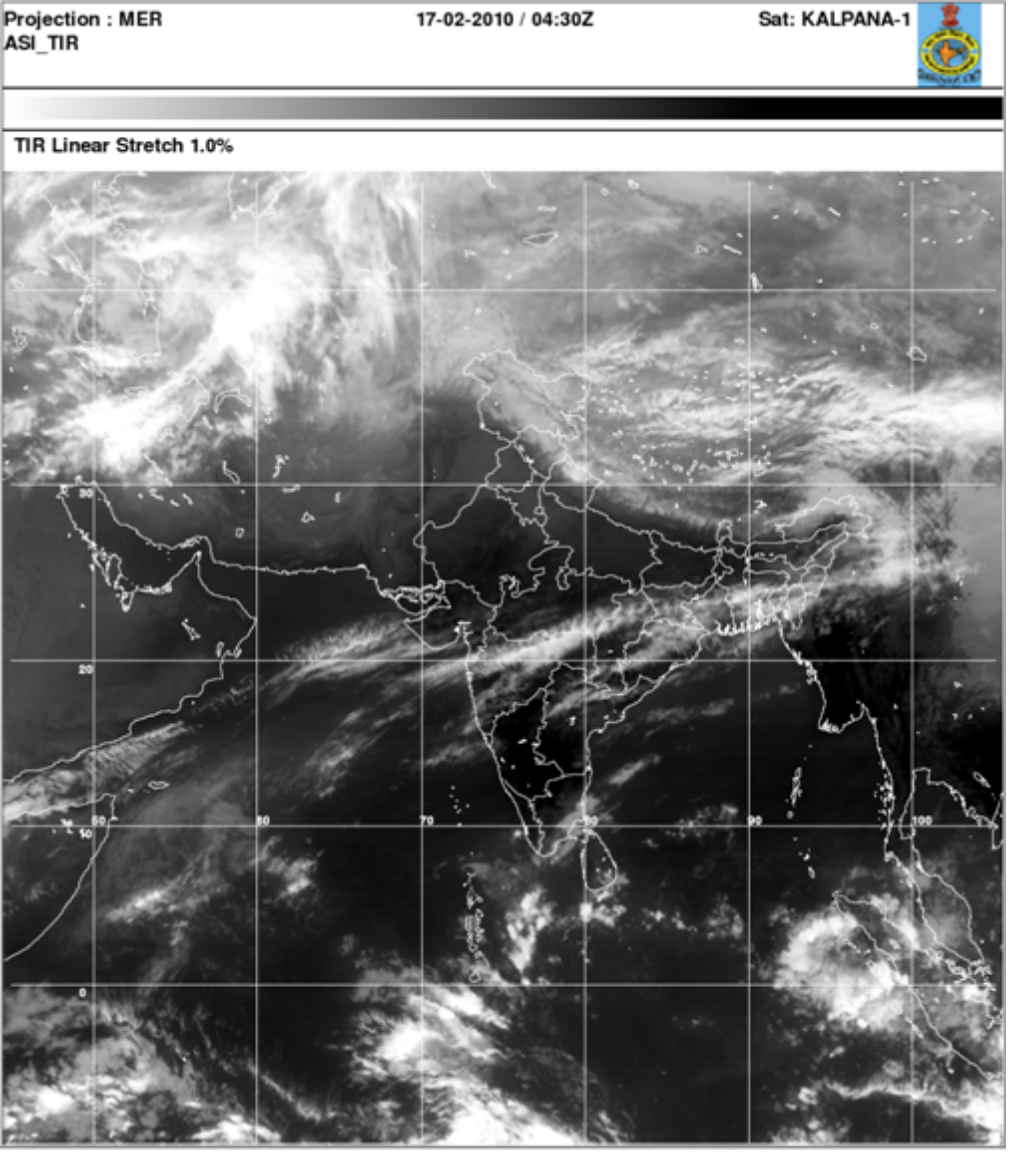

File : 2010022410274708.caz
Type : MAX(Z)
Range: 300.0 km
24.02.2010
10:27:47
dBZ
62.9 - 66.0+>
59.9 - 62.9
56.8 - 59.9
53.7 - 56.8
50.7 - 53.7
47.6 - 50.7
44.5 - 47.6
41.5 - 44.5
38.4 - 41.5
35.3 - 38.4
32.3 - 35.3
29.2 - 32.3
26.1 - 29.2
23.1 - 26.1
20.0 - 23.1
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
MLD
BLG
MNS
DMK
BRP
DNB
SUR
PRL
BNK
BDW
KRG
JSR
KHL
KOL
CNG
MDP
BLB
BSL
CBS
BPD
BLS
SHD
BWN
PRD
200
100
KOLKATA_India
Scan R : 500 km
Scan Res: 1.00 km
Disp R : 300 km
Disp Res: 1.200 km
PW : Long
PRF: 300 / 0
AS : 9.00 deg/s
TS : 33
RS : 1
CC : Doppler 15
SQI: 0.35
CSR: 10.0 dB
LOG: 2.0 dB
H : 18.00 km
LS : 0.100 km
C.D.R. KOLKATA

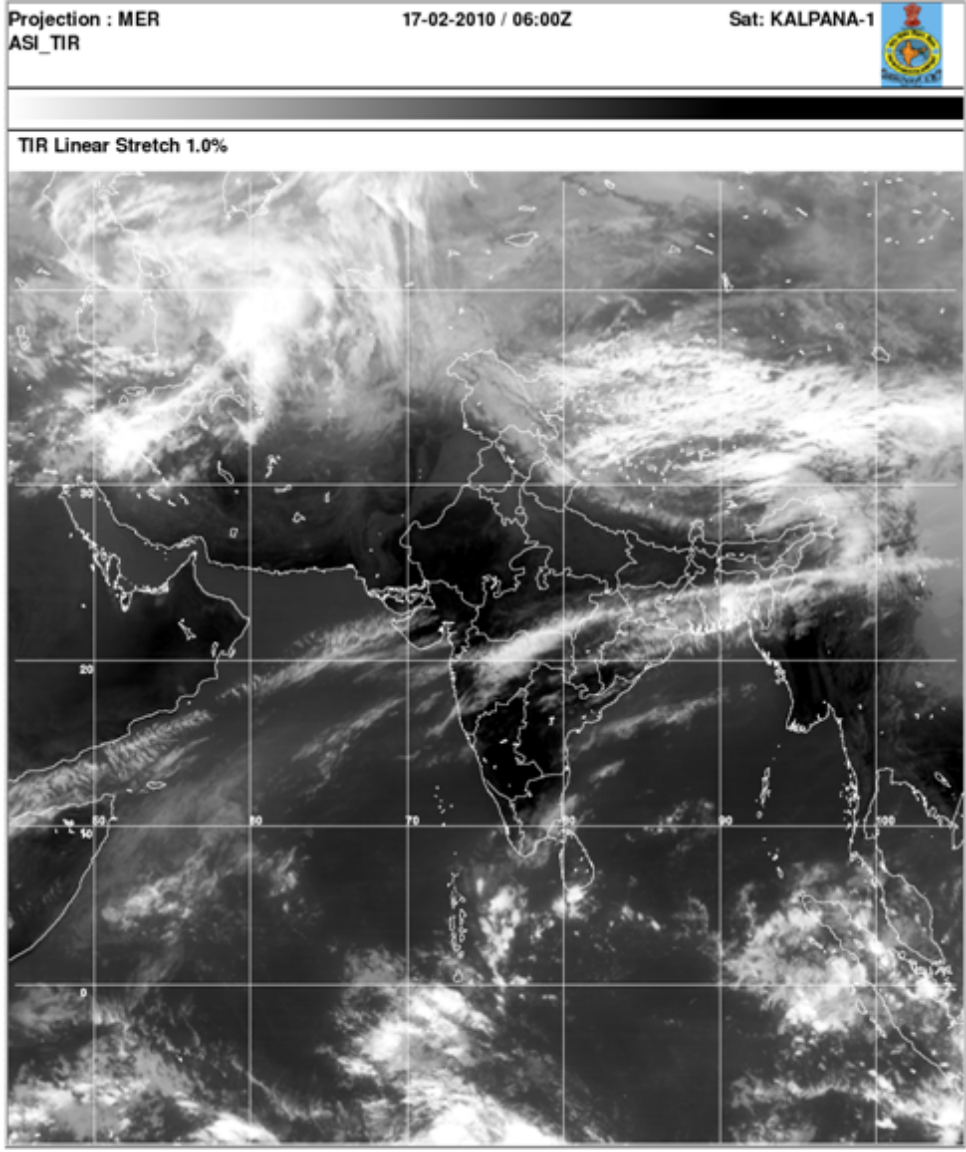
Refectivity derived from the Dhaka S-band Radar from 1023 UTC to 1106 UTC of 24 February 2010.



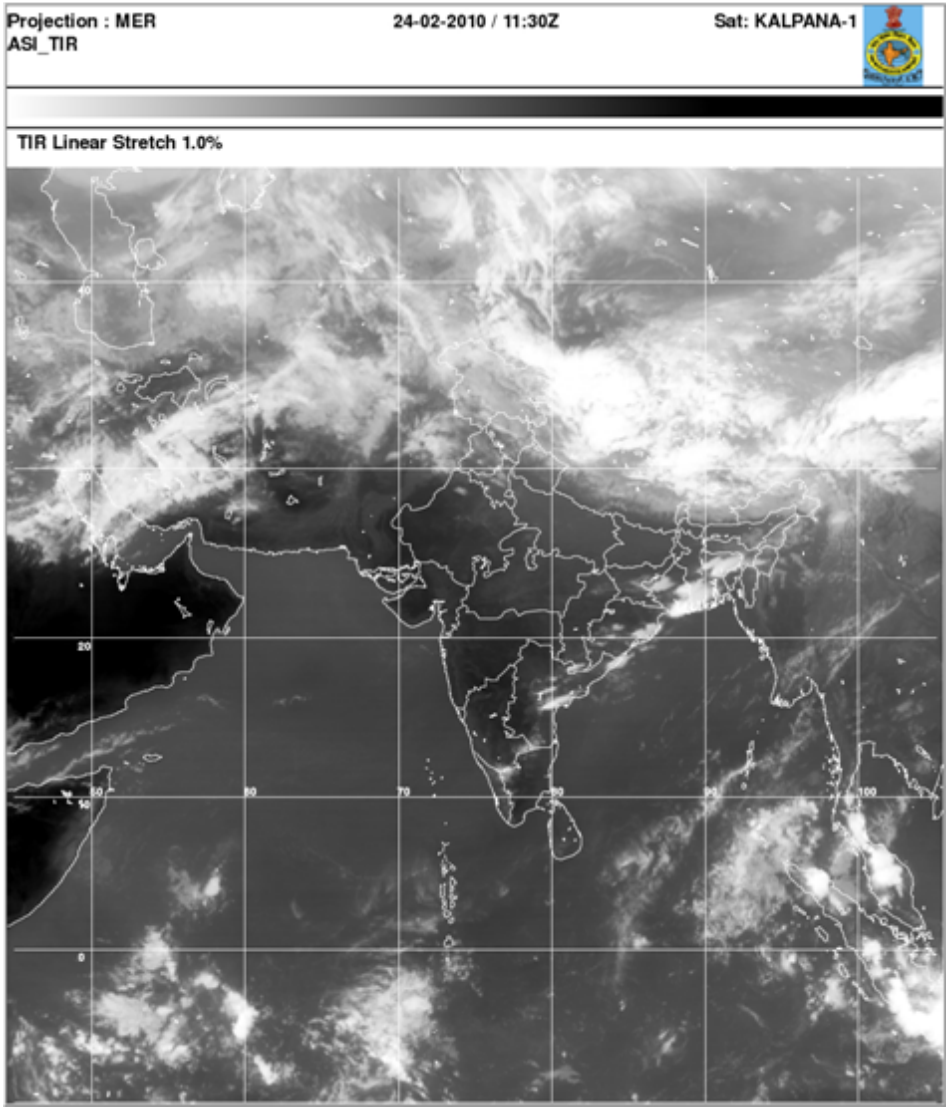
Refectivity derived from the Cox'sbazar DWR from 1115 UTC to 1200 UTC of 24 February 2010.

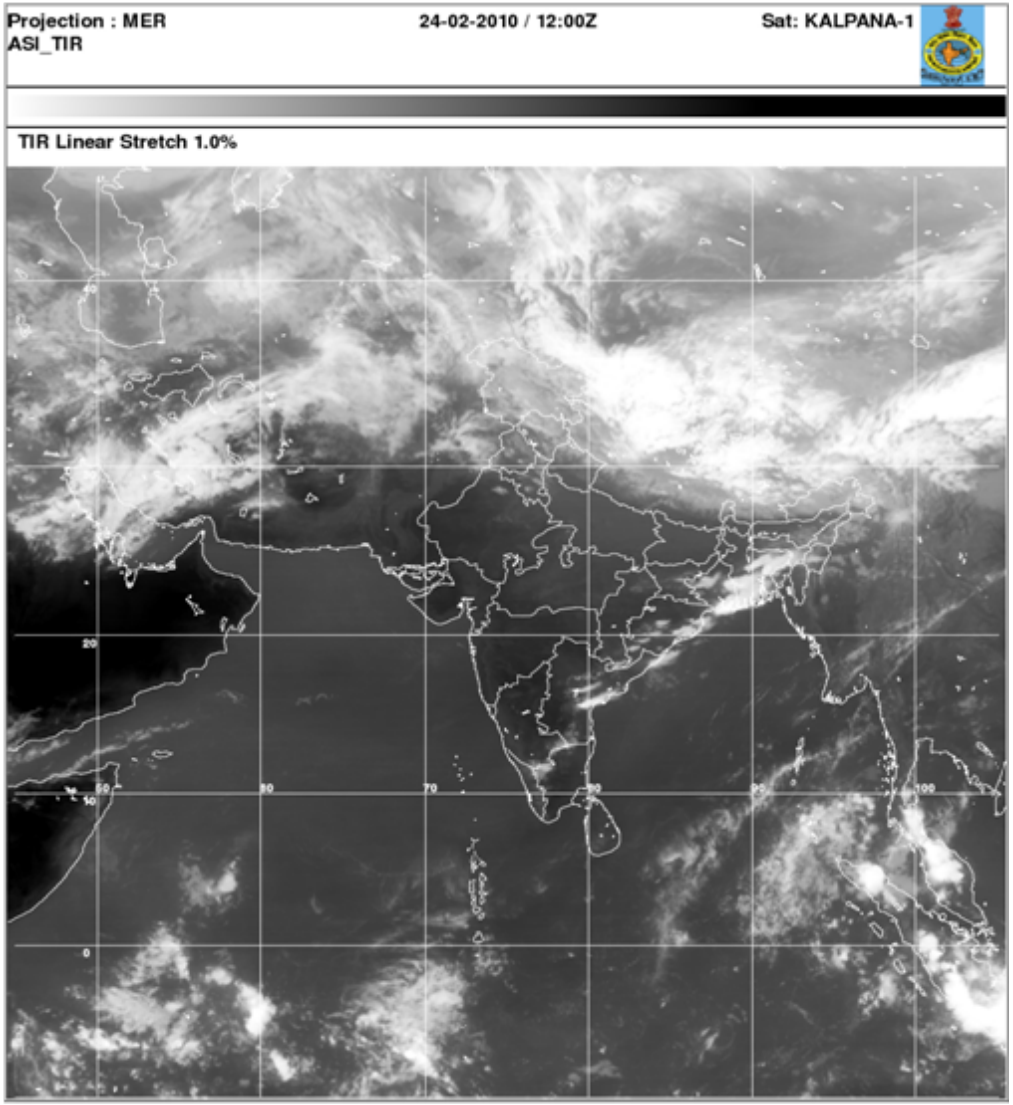




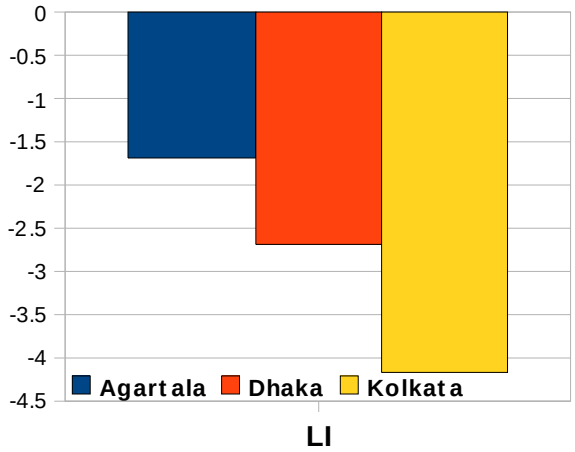


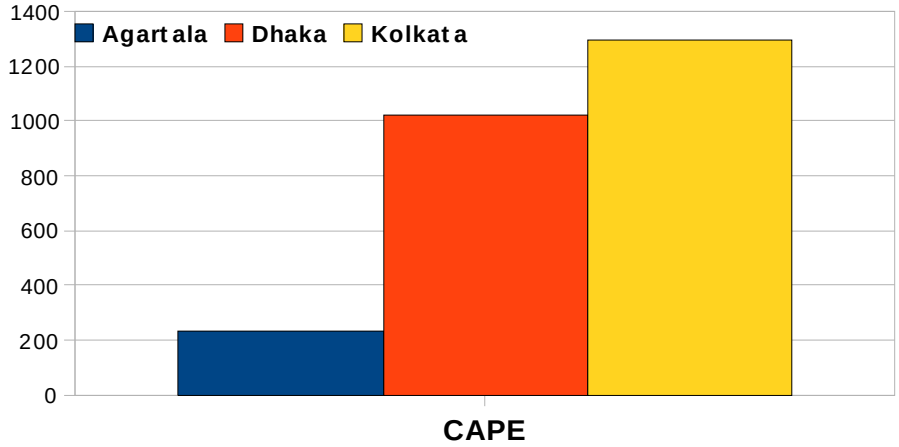
Kalpana-1 Satellite cloud imageries on 17 February 2010 0430 and 0600 UTC.





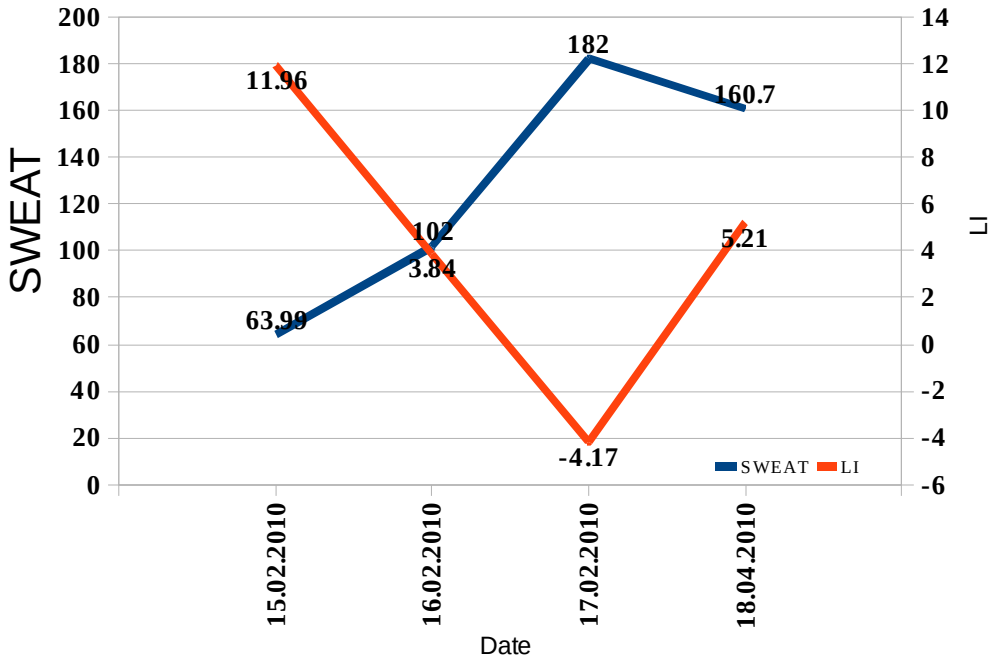
Kalpana-1 Satellite cloud imageries on 24 February 2010 1130 to 1230 UTC.





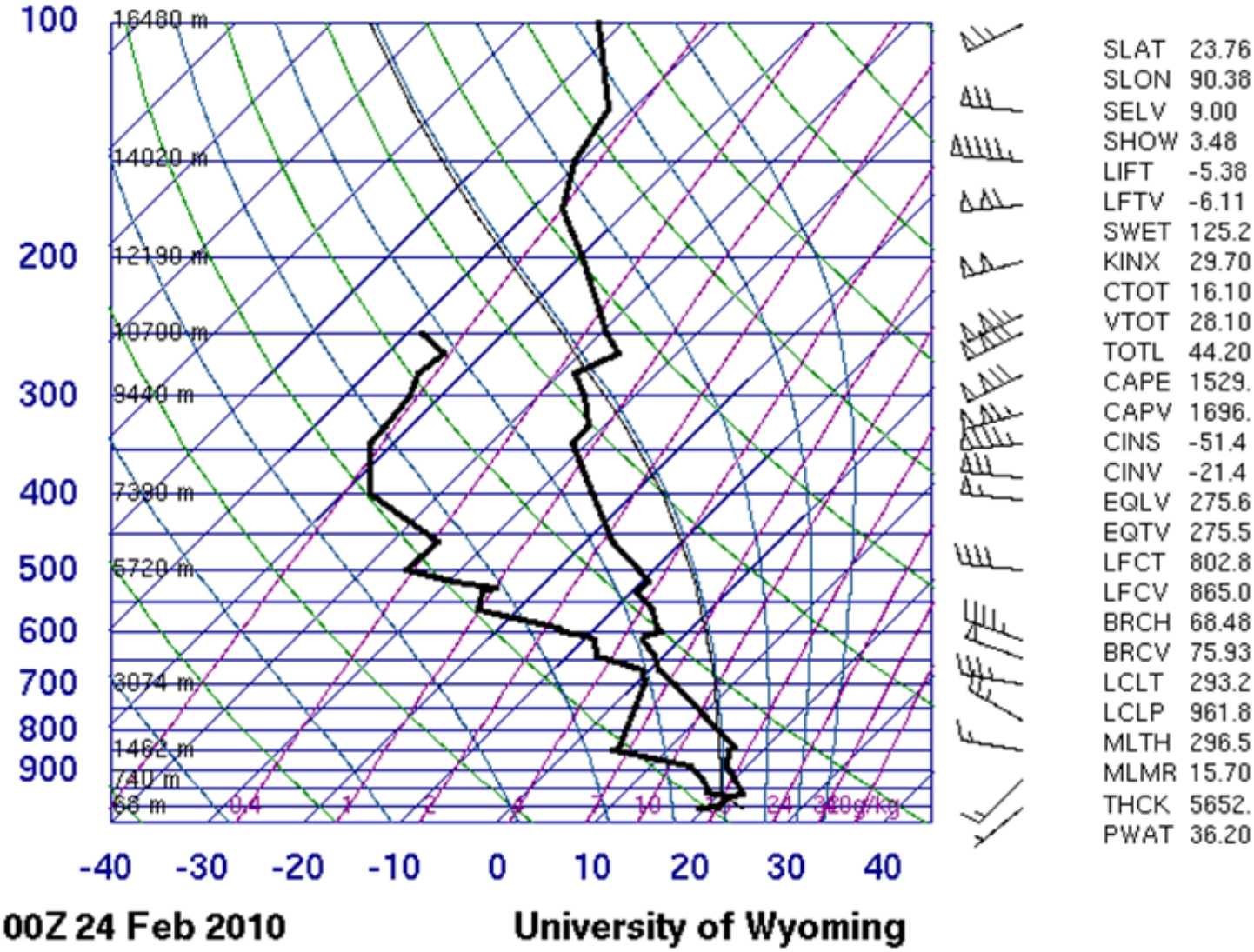
LI **CAPE**

Comparison of LI and CAPE at Different Locations on 17 February 2010, 0000 UTC



SWEAT and LI over Kolkata based on observation at 0000 UTC of 15-18 February 2010

41923 VGTJ Dhaka

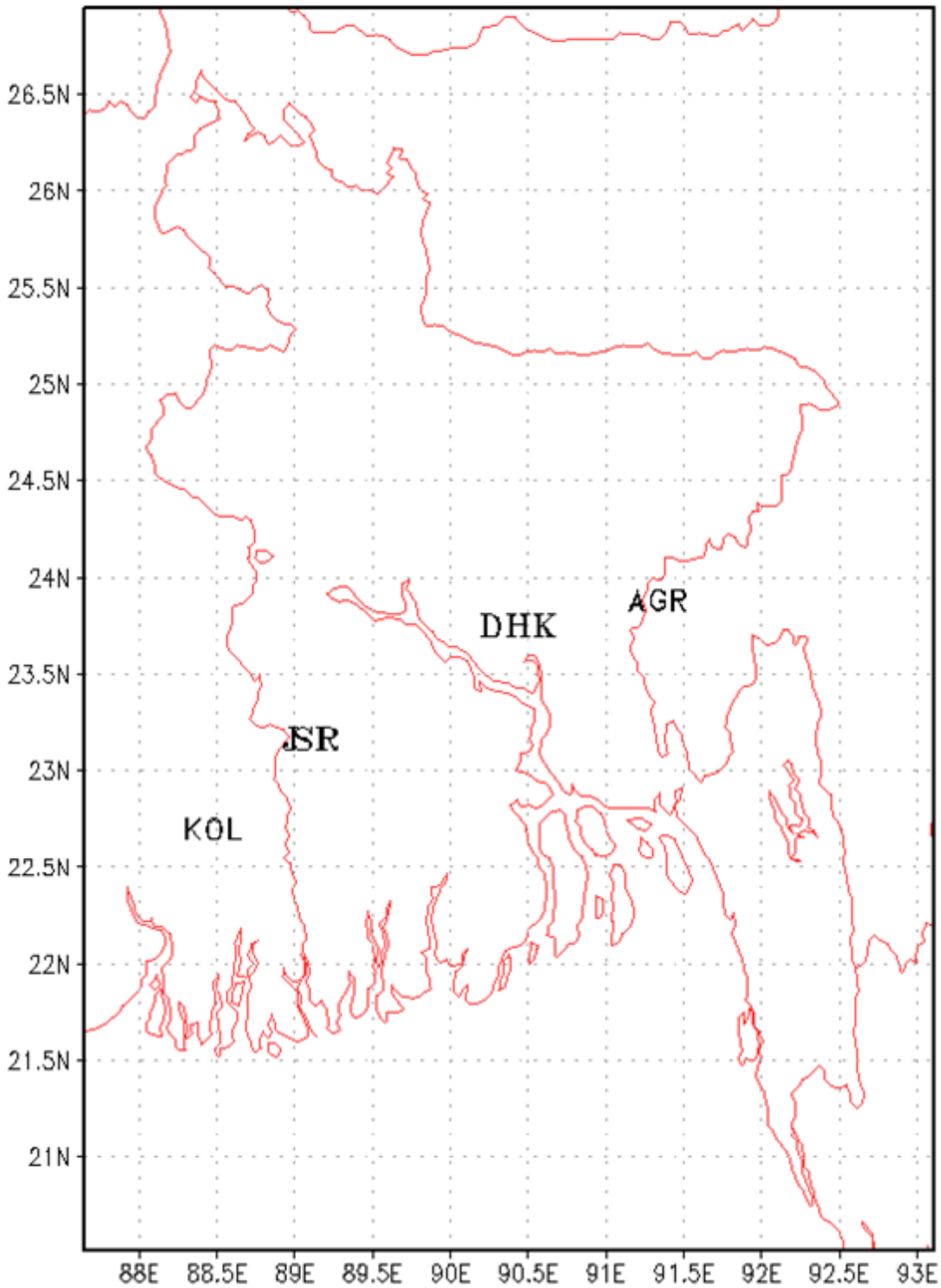


SLAT	23.76
SLON	90.38
SELV	9.00
SHOW	3.48
LIFT	-5.38
LFTV	-6.11
SWET	125.2
KINX	29.70
CTOT	16.10
VTOT	28.10
TOTL	44.20
CAPE	1529.
CAPV	1696.
CINS	-51.4
CINV	-21.4
EQLV	275.6
EQTV	275.5
LFCT	802.8
LFCV	865.0
BRCH	68.48
BRCV	75.93
LCLT	293.2
LCLP	961.8
MLTH	296.5
MLMR	15.70
THCK	5652.
PWAT	36.20

00Z 24 Feb 2010 **University of Wyoming**

Summary of the WRF Model

Model Features	Configurations
Horizontal Resolution	4 km. Single Domain
Vertical Levels	27
Topography	USGS
Dynamics	
Time Integration	Semi Implicit
Time Steps	20 sec.
Vertical Differencing	Arakawa's Energy Conserving Scheme
Time Filtering	Robert's Method
Horizontal Diffusion	2nd order over Quasi-pressure, surface, scale selective
Physics	
Convection	CU Parameterization*
PBL	YSU Scheme
Surface Layer	Monin-Obukhov
Cloud Microphysics	WSM 3-Class Simple Ice
Radiation	RRTM (LW), Dudhia (SW)
Gravity Wave Drag	No
Land Surface Processes	Unified NOAA Land Surface Model


WRF Model 4 km Single Domain
26.5N
26N
25.5N
25N
24.5N
24N
23.5N
23N
22.5N
22N
21.5N
21N
88E
88.5E
89E
89.5E
90E
90.5E
91E
91.5E
92E
92.5E
93E
DHK
AGR
JSR
KOL

*Cumulus Parameterization (cu_physics)

a. Kain-Fritsch scheme **(KFS)**: Deep and shallow convection sub-grid scheme using a mass flux approach with downdrafts and CAPE removal time scale (cu_physics = 1).

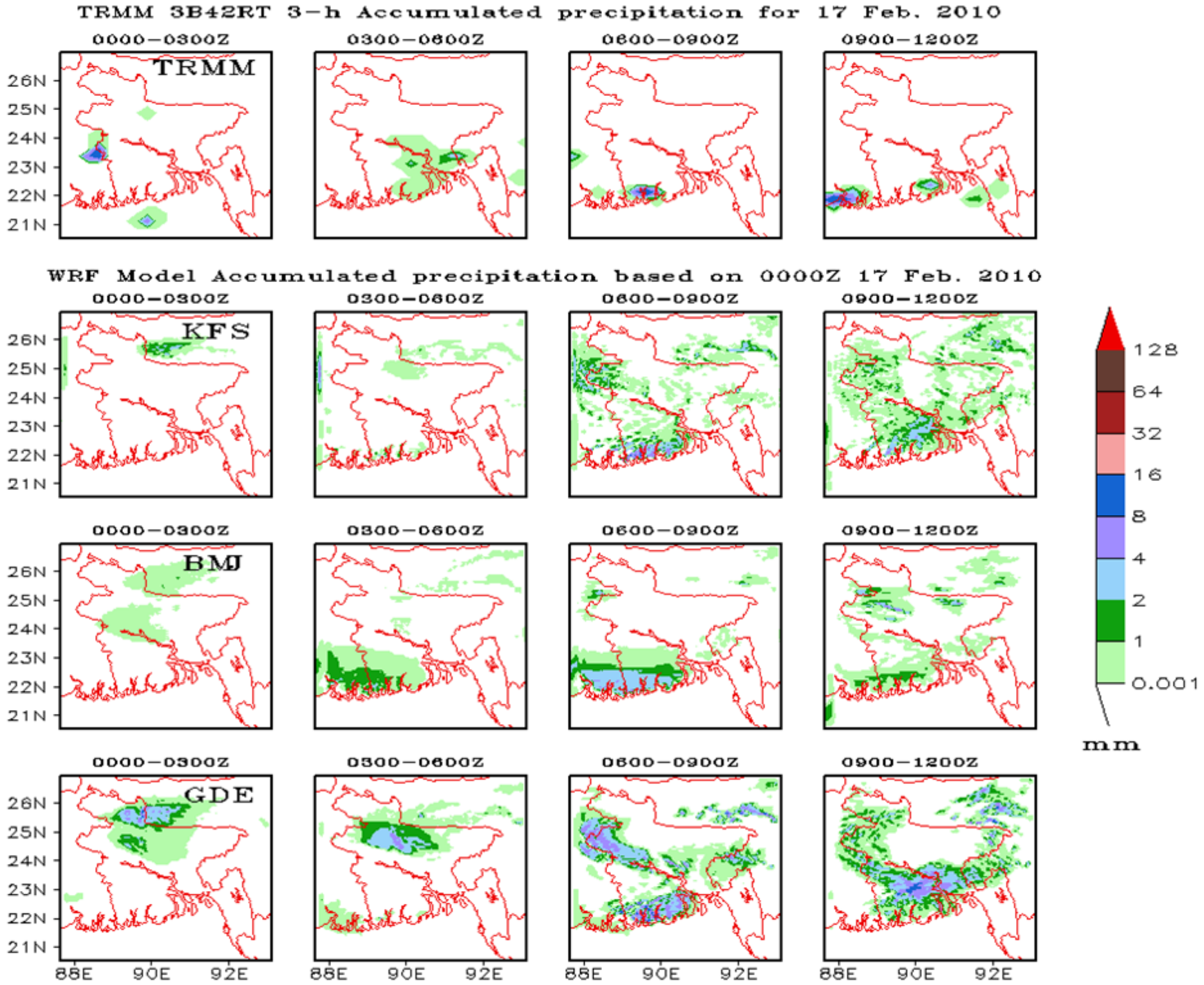
b. Betts-Miller-Janjic scheme **(BMJ)**: Operational Eta scheme. Column moist adjustment scheme relaxing towards a well-mixed profile (2).

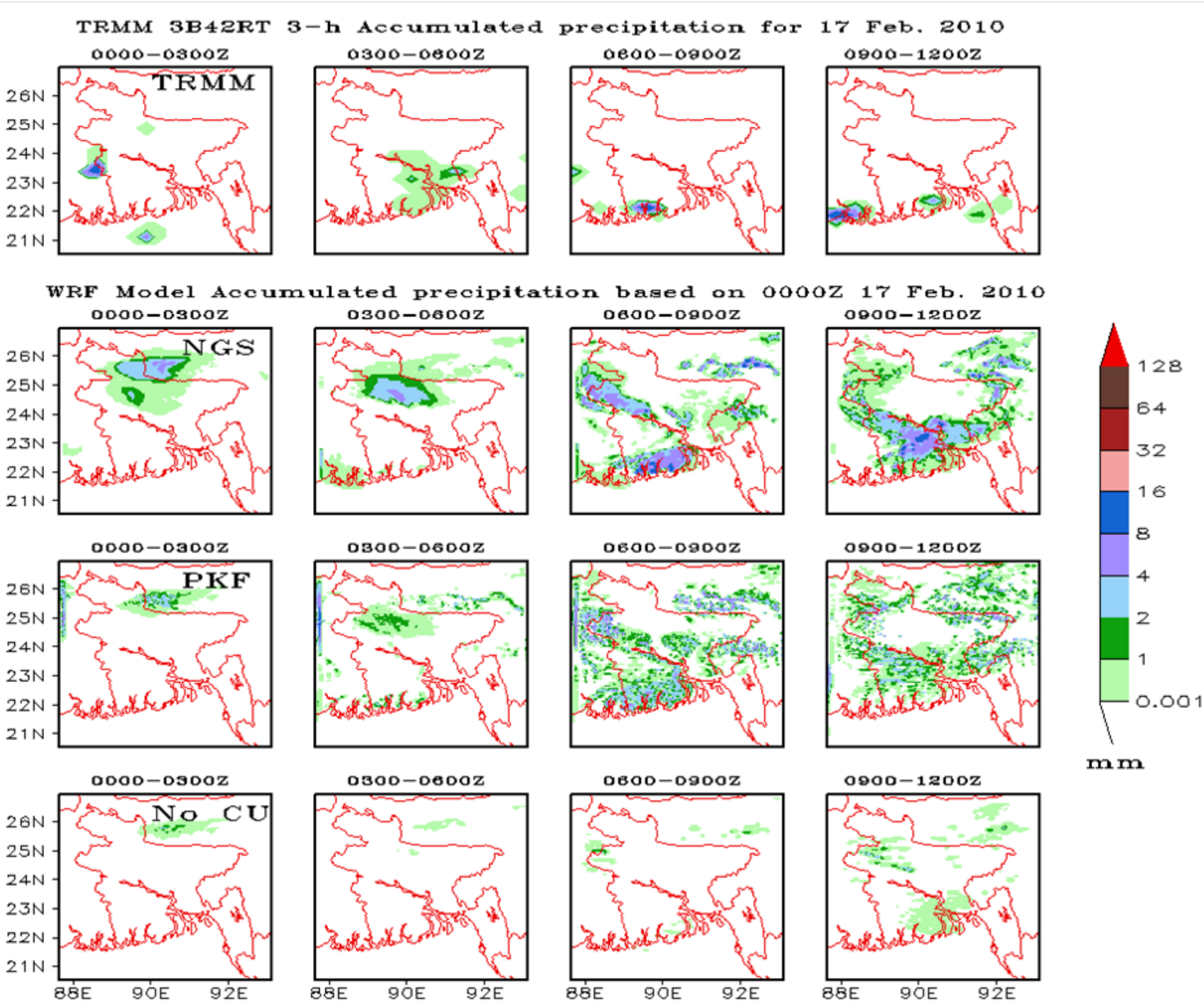
c. Grell-Devenyi ensemble scheme **(GDE)**: Multi-closure, multi-parameter, ensemble method with typically 144 sub-grid members (3).

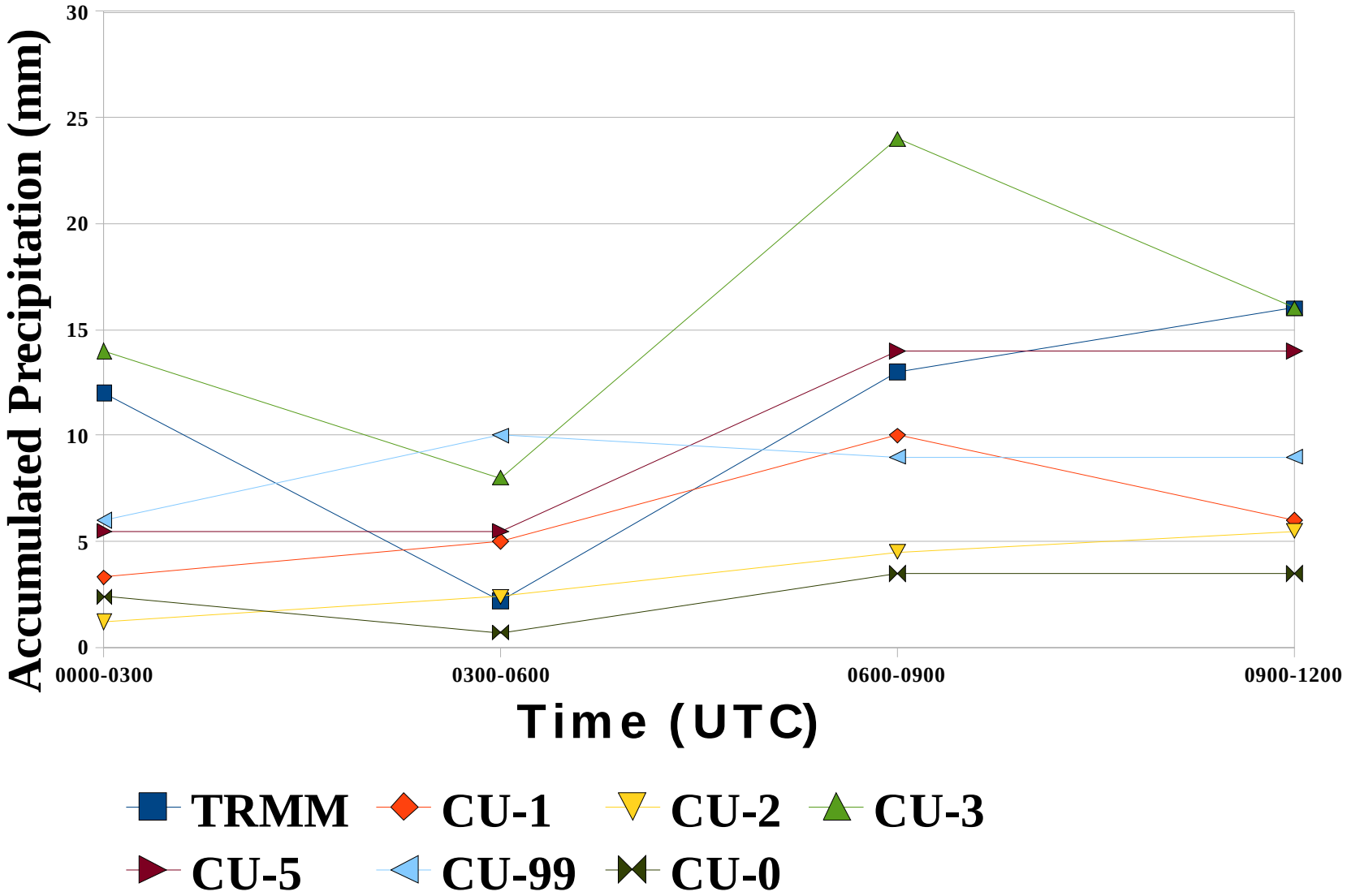
d. New Grell 3d ensemble cumulus scheme **(NGS)**: Scheme for higher resolution domains allowing for subsidence in neighboring columns (5). New in Version 3.0.

e. Previous Kain-Fritsch scheme **(PKF):** Deep convection scheme using a mass flux approach with downdrafts and CAPE removal time scale (99).

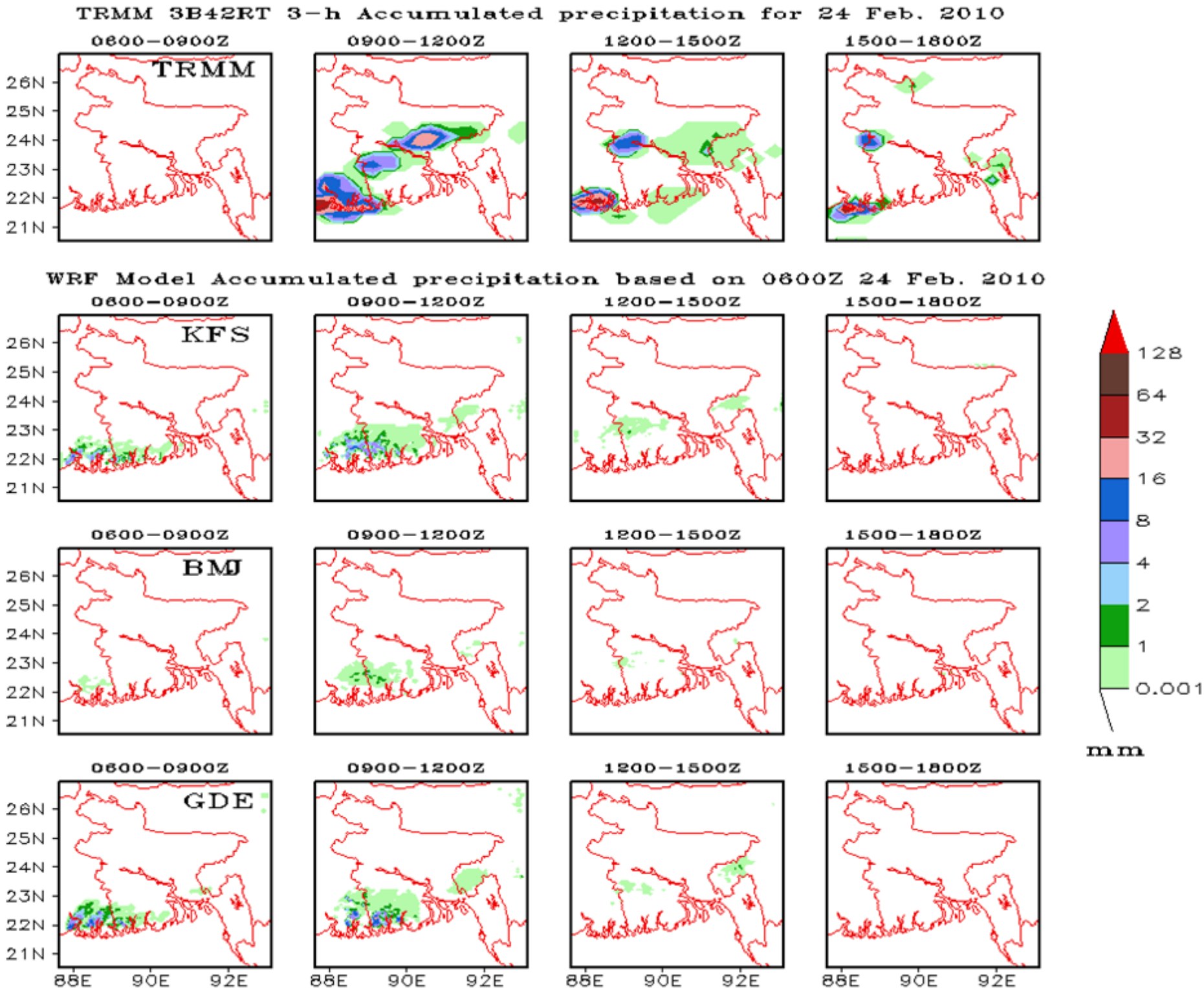
f. **No Cumulus (0)**

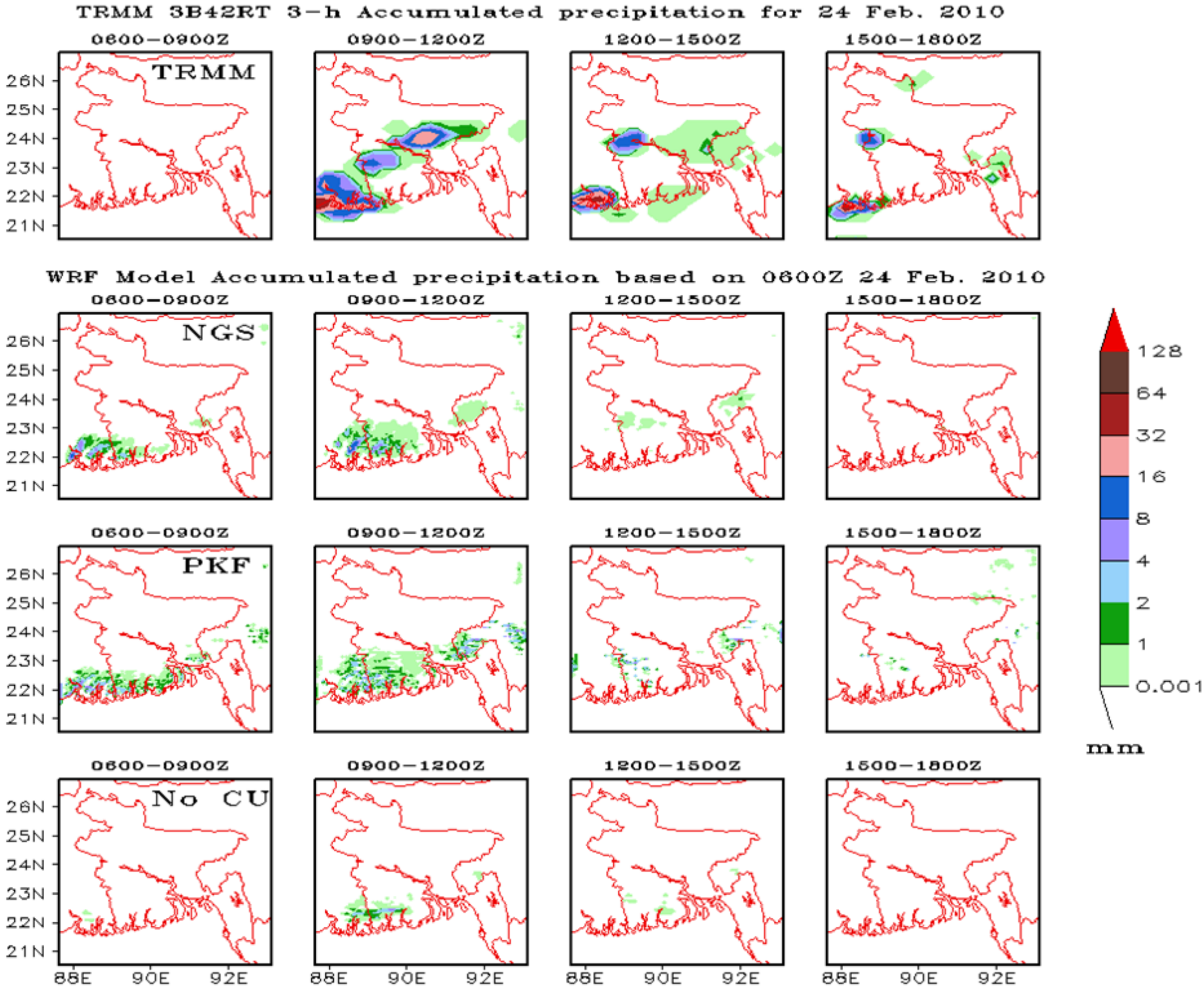

TRMM 3B42RT 3-h Accumulated precipitation for 17 Feb. 2010
0000-0300Z
0300-0600Z
0600-0900Z
0900-1200Z
TRMM
WRF Model Accumulated precipitation based on 0000Z 17 Feb. 2010
KFS
BMJ
GDE
26N
25N
24N
23N
22N
21N
88E
90E
92E
128
64
32
16
8
4
2
1
0.001
mm

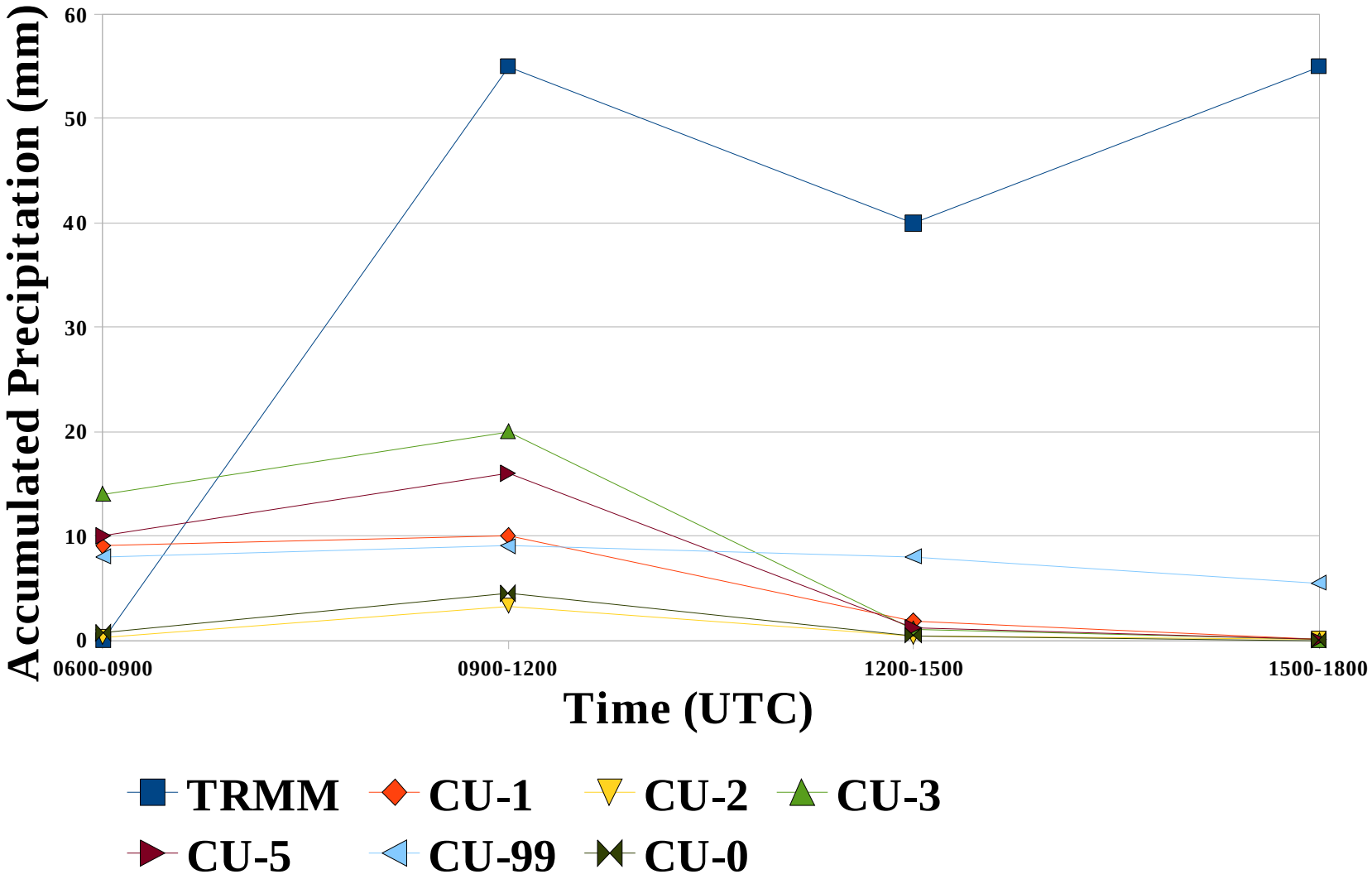

TRMM 3B42RT 3-h Accumulated precipitation for 17 Feb. 2010
0000-0300Z
0300-0600Z
0600-0900Z
0900-1200Z
TRMM
WRF Model Accumulated precipitation based on 0000Z 17 Feb. 2010
NGS
PKF
No CU
26N
25N
24N
23N
22N
21N
88E
90E
92E
128
64
32
16
8
4
2
1
0.001
mm



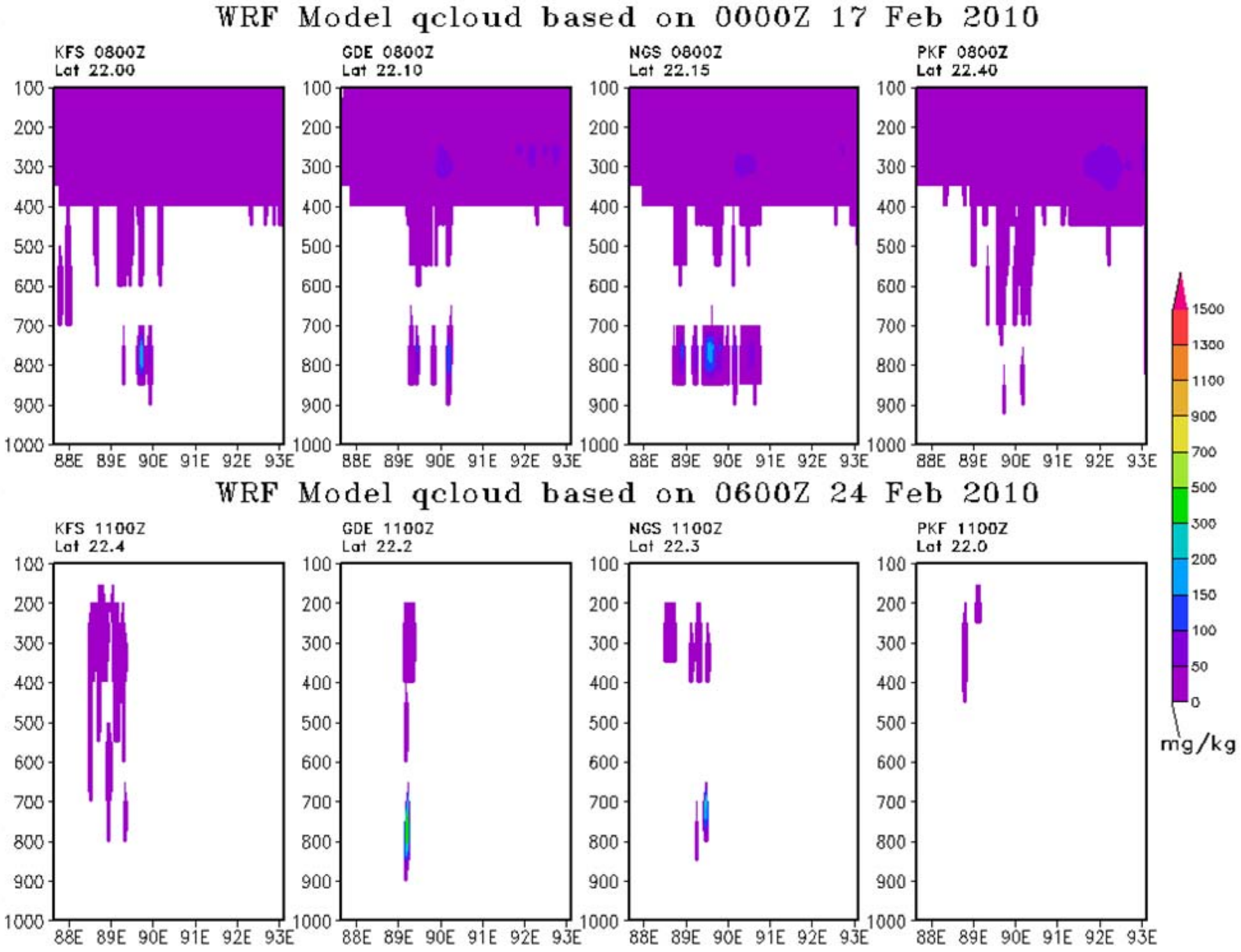
3-h'ly Time Series of Accumulated Precipitation within the Experimental Domain

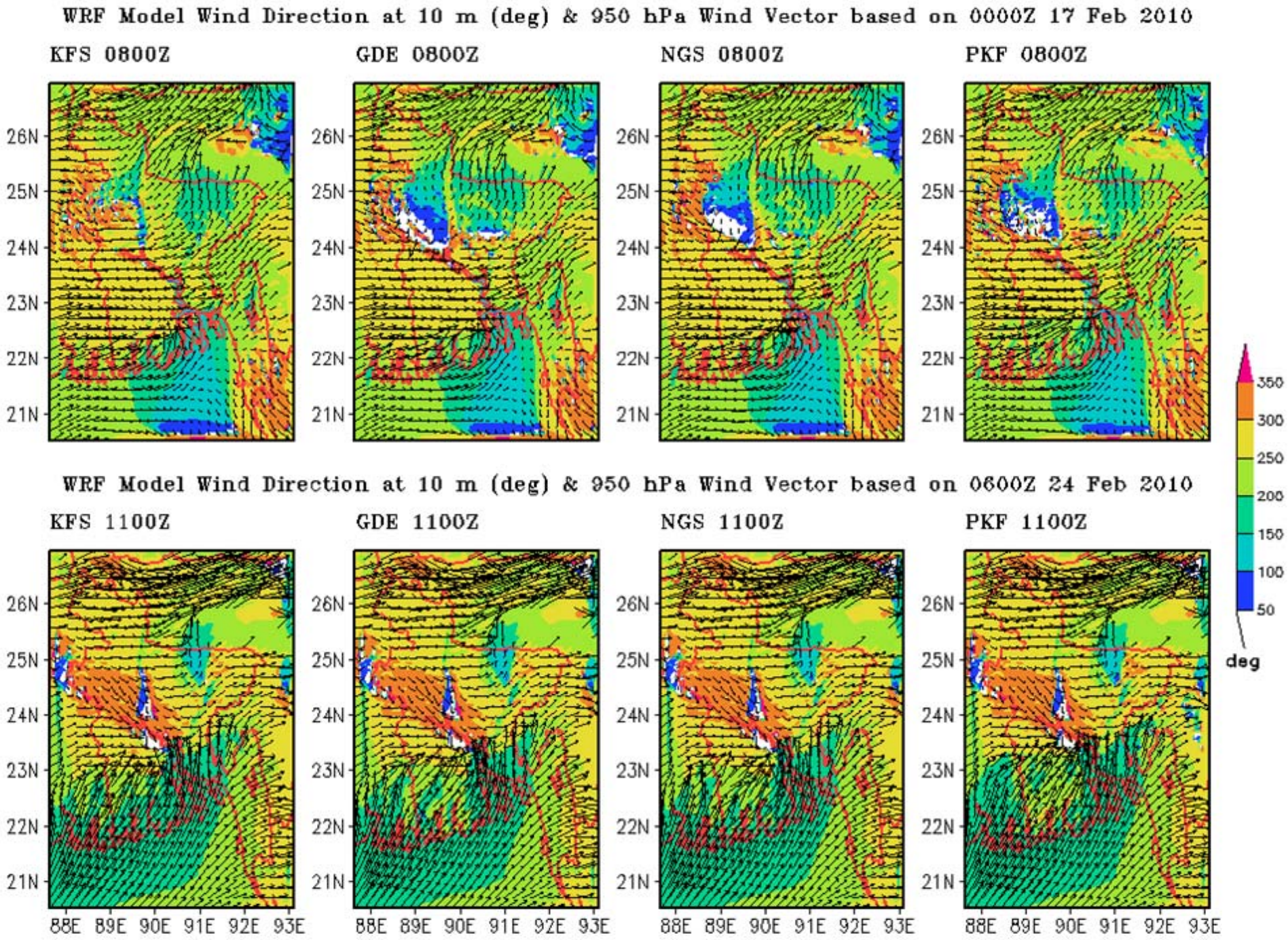

TRMM 3B42RT 3-h Accumulated precipitation for 24 Feb. 2010
0600-0900Z
0900-1200Z
1200-1500Z
1500-1800Z
TRMM
WRF Model Accumulated precipitation based on 0600Z 24 Feb. 2010
KFS
BMJ
GDE
26N
25N
24N
23N
22N
21N
88E
90E
92E
128
64
32
16
8
4
2
1
0.001
mm

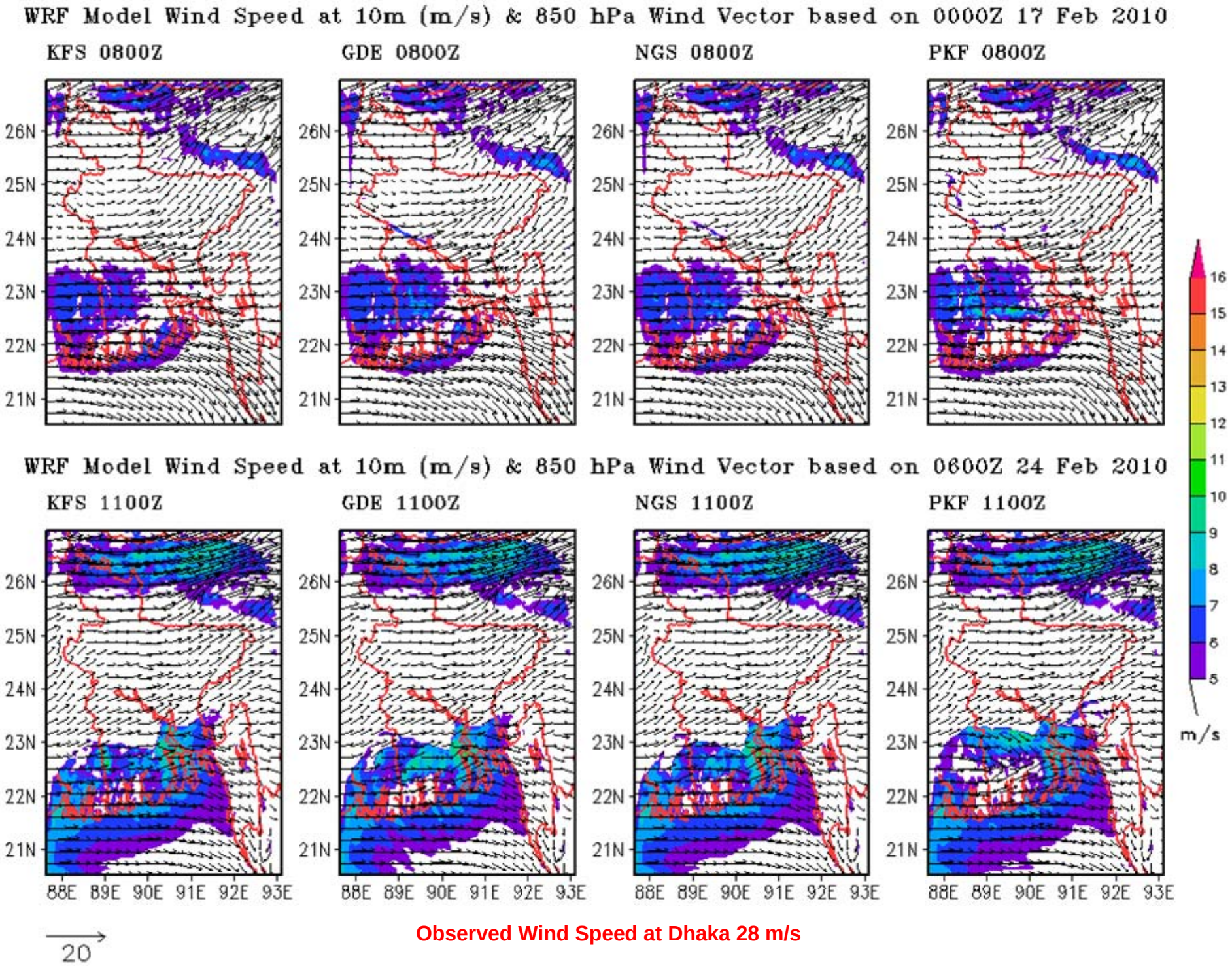

TRMM 3B42RT 3-h Accumulated precipitation for 24 Feb. 2010
0600-0900Z
0900-1200Z
1200-1500Z
1500-1800Z
TRMM
WRF Model Accumulated precipitation based on 0600Z 24 Feb. 2010
NGS
PKF
No CU
26N
25N
24N
23N
22N
21N
88E
90E
92E
128
64
32
16
8
4
2
1
0.001
mm

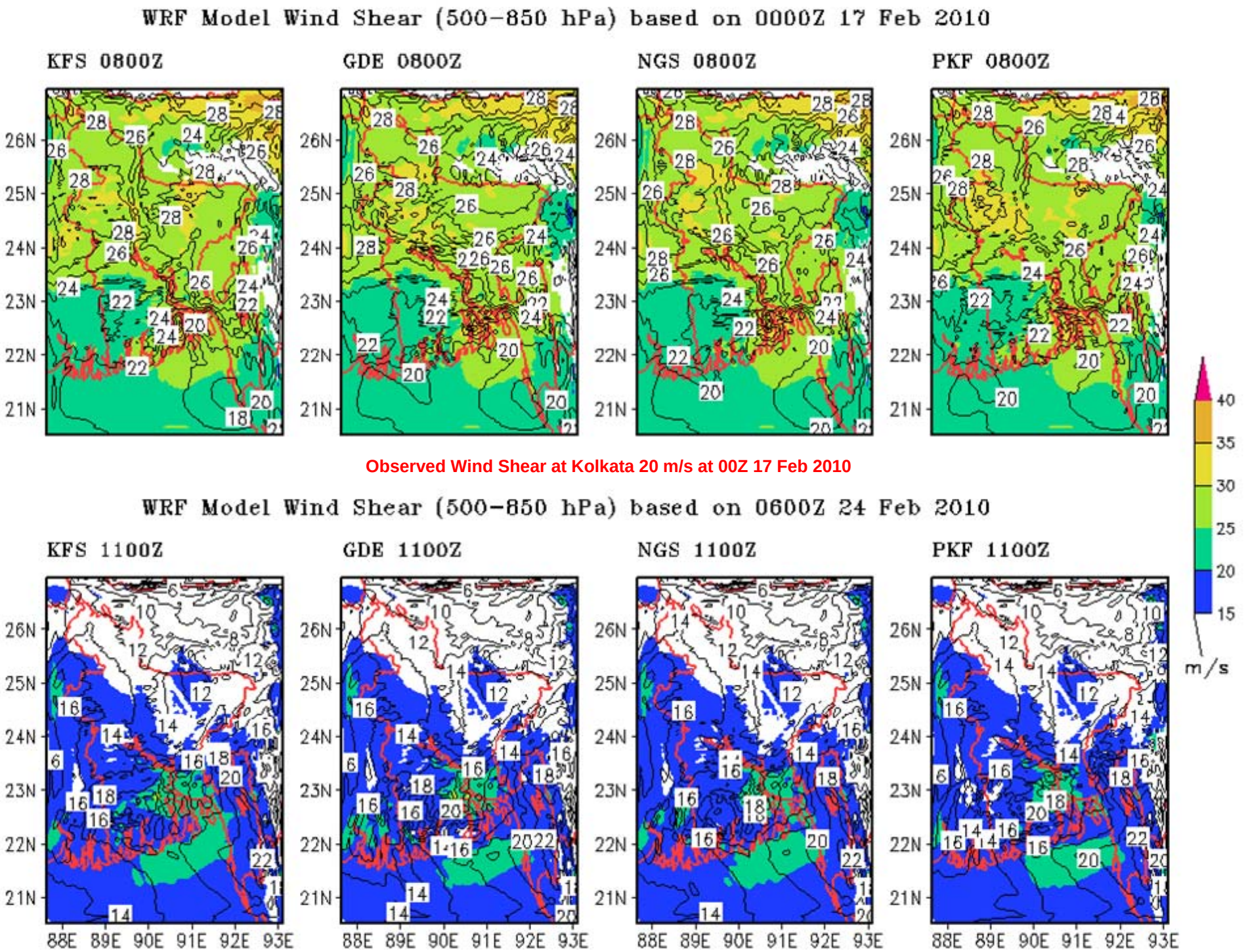


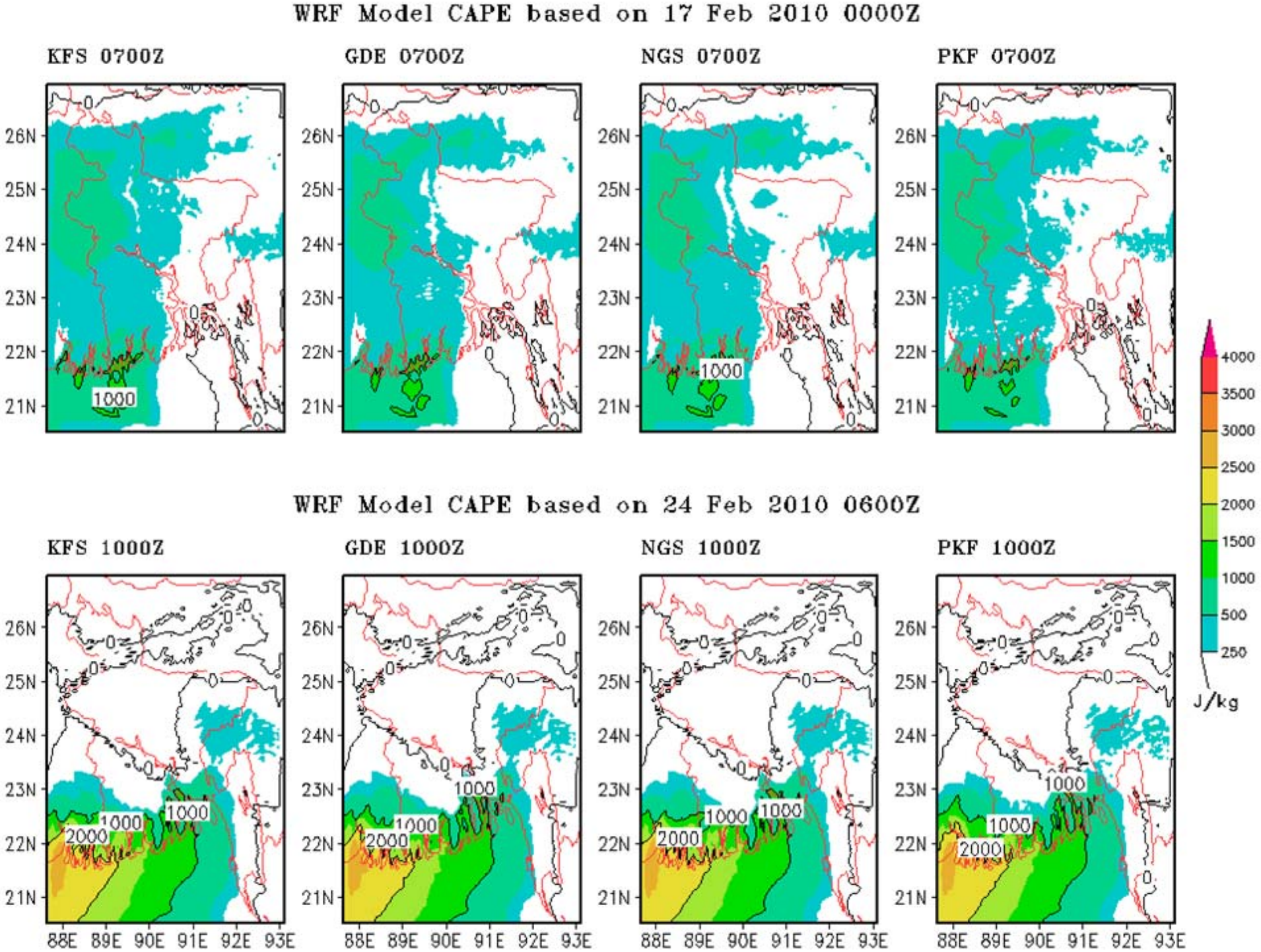
3-h'ly Time Series of Accumulated Precipitation within the Experimental Domain

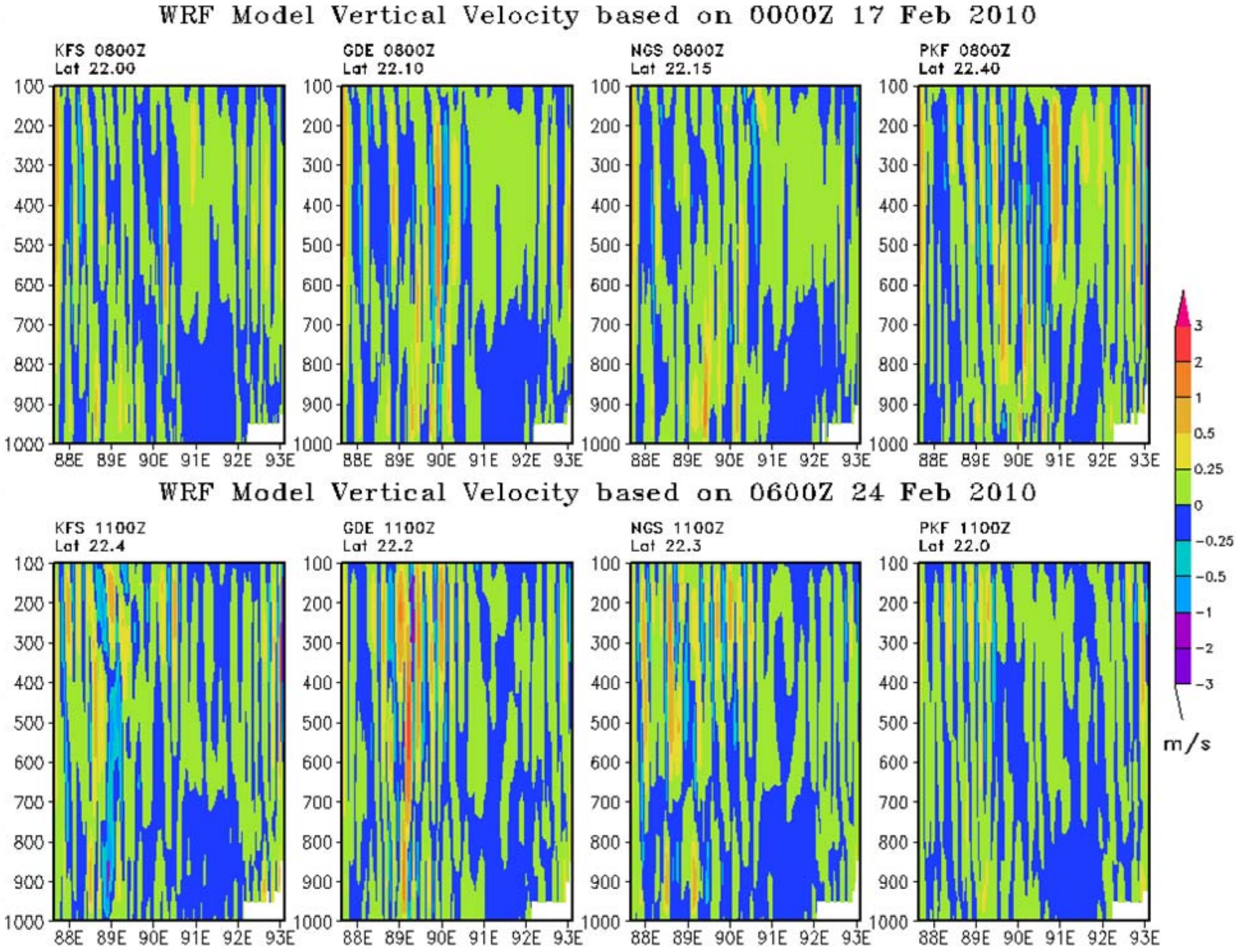

WRF Model qcloud based on 0000Z 17 Feb 2010
KFS 0800Z
Lat 22.00
GDE 0800Z
Lat 22.10
NGS 0800Z
Lat 22.15
PKF 0800Z
Lat 22.40
WRF Model qcloud based on 0600Z 24 Feb 2010
KFS 1100Z
Lat 22.4
GDE 1100Z
Lat 22.2
NGS 1100Z
Lat 22.3
PKF 1100Z
Lat 22.0
100
200
300
400
500
600
700
800
900
1000
88E 89E 90E 91E 92E 93E
1500
1300
1100
900
700
500
300
200
150
100
50
0
mg/kg


WRF Model Wind Direction at 10 m (deg) & 950 hPa Wind Vector based on 0000Z 17 Feb 2010
KFS 0800Z
GDE 0800Z
NGS 0800Z
PKF 0800Z
WRF Model Wind Direction at 10 m (deg) & 950 hPa Wind Vector based on 0600Z 24 Feb 2010
KFS 1100Z
GDE 1100Z
NGS 1100Z
PKF 1100Z
26N
25N
24N
23N
22N
21N
88E 89E 90E 91E 92E 93E
350
300
250
200
150
100
50
deg
20


WRF Model Wind Speed at 10m (m/s) & 850 hPa Wind Vector based on 0000Z 17 Feb 2010
KFS 0800Z
GDE 0800Z
NGS 0800Z
PKF 0800Z
WRF Model Wind Speed at 10m (m/s) & 850 hPa Wind Vector based on 0600Z 24 Feb 2010
KFS 1100Z
GDE 1100Z
NGS 1100Z
PKF 1100Z
26N
25N
24N
23N
22N
21N
88E 89E 90E 91E 92E 93E
16
15
14
13
12
11
10
9
8
7
6
5
m/s
20
Observed Wind Speed at Dhaka 28 m/s


WRF Model Wind Shear (500-850 hPa) based on 0000Z 17 Feb 2010
KFS 0800Z
GDE 0800Z
NGS 0800Z
PKF 0800Z
Observed Wind Shear at Kolkata 20 m/s at 00Z 17 Feb 2010
WRF Model Wind Shear (500-850 hPa) based on 0600Z 24 Feb 2010
KFS 1100Z
GDE 1100Z
NGS 1100Z
PKF 1100Z
Observed Wind Shear at Dhaka 14 m/s at 00Z 24 Feb 2010
26N
25N
24N
23N
22N
21N
88E
89E
90E
91E
92E
93E
40
35
30
25
20
15
m/s


WRF Model CAPE based on 17 Feb 2010 0000Z
KFS 0700Z
GDE 0700Z
NGS 0700Z
PKF 0700Z
WRF Model CAPE based on 24 Feb 2010 0600Z
KFS 1000Z
GDE 1000Z
NGS 1000Z
PKF 1000Z
26N
25N
24N
23N
22N
21N
88E 89E 90E 91E 92E 93E
0
1000
2000
4000
3500
3000
2500
2000
1500
1000
500
250
J/kg


WRF Model Vertical Velocity based on 0000Z 17 Feb 2010
KFS 0800Z
Lat 22.00
GDE 0800Z
Lat 22.10
NGS 0800Z
Lat 22.15
PKF 0800Z
Lat 22.40
WRF Model Vertical Velocity based on 0600Z 24 Feb 2010
KFS 1100Z
Lat 22.4
GDE 1100Z
Lat 22.2
NGS 1100Z
Lat 22.3
PKF 1100Z
Lat 22.0
100
200
300
400
500
600
700
800
900
1000
88E 89E 90E 91E 92E 93E
3
2
1
0.5
0.25
0
-0.25
-0.5
-1
-2
-3
m/s

Summary

NCEP-FNL data are used to simulate the weather events. WRF-ARW model is able to broadly reproduce several features of the hailstorm and Tornadic events, such as spatial pattern and temporal variability.

GDE and NGS performed better than other CU schemes.

If the local data are assimilated into the WRF-ARW Model then the forecast scenario may be improved.

Incorporation of High Resolution Vegetation Data of the region may also improve the quality of forecasts.


Thank You