Validation of Regional Weather Forecast for Deep Convection over Indian Subcontinent

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Convection

8:30 am of 16th July 2010

Afternoon 1 pm 16th July 2010

Objectives of WCRG

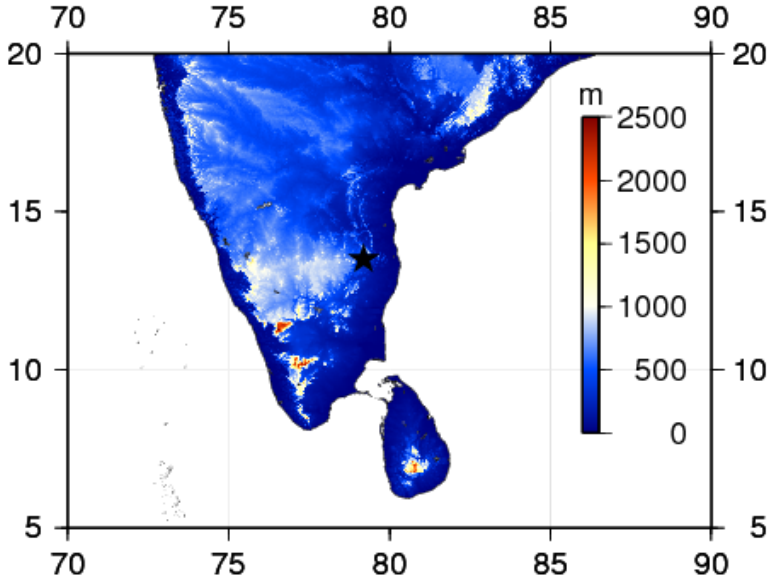
- Research in real time weather forecasting and nowcasting.
- Provide operational weather forecast for SHAR during launching operations.
- Capacity building for forecasting of behaviour of deep convection (thunderstorms / cyclones)

Scientific Objective

To analyze capacity of Mesoscale models to forecast

- Occurrence
- Time of Genesis and duration
- Intensity

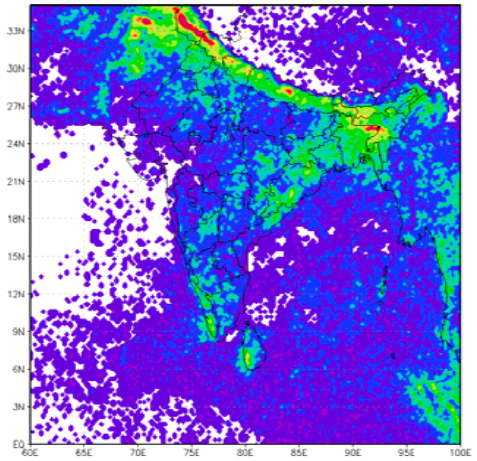
of thunderstorms occurring over SHAR – Gadanki – Chennai Region



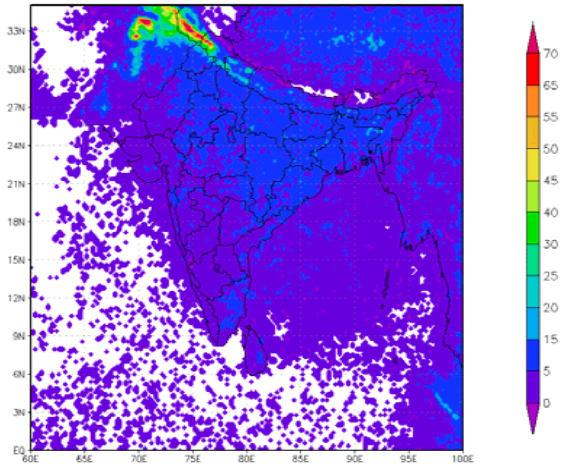
Outline

- Climatology
- Regional Weather Forecasting system
- Deep convective evidences
- Forecast validation
- Conclusions

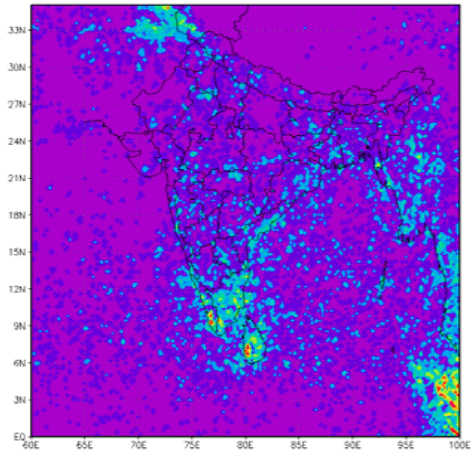
Climatology of Convective Activities



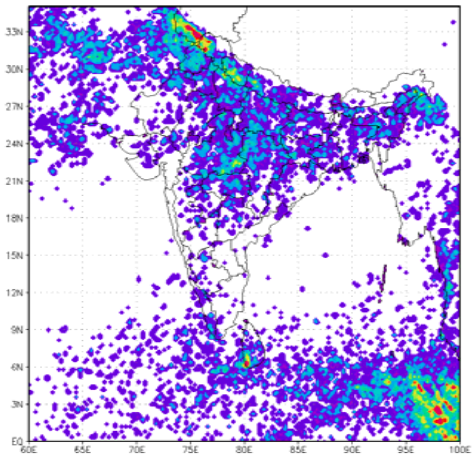
Pre-monsoon (MAM)



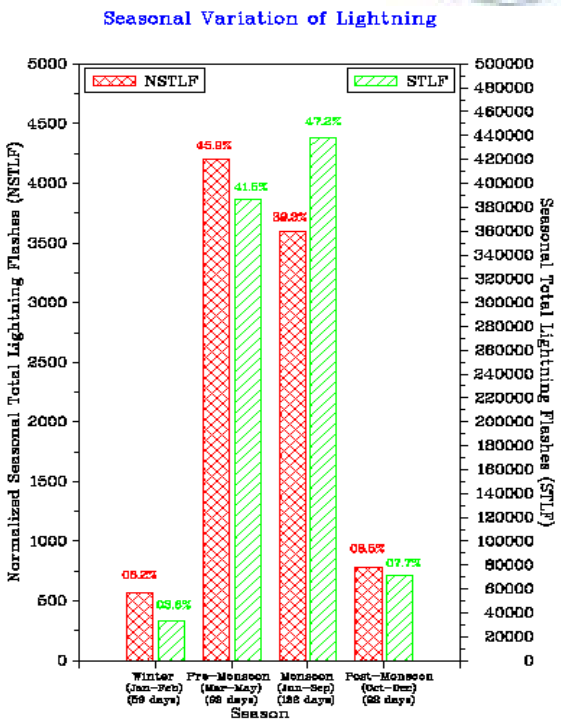
SW monsoon (JJAS)



NE-monsoon (OND)



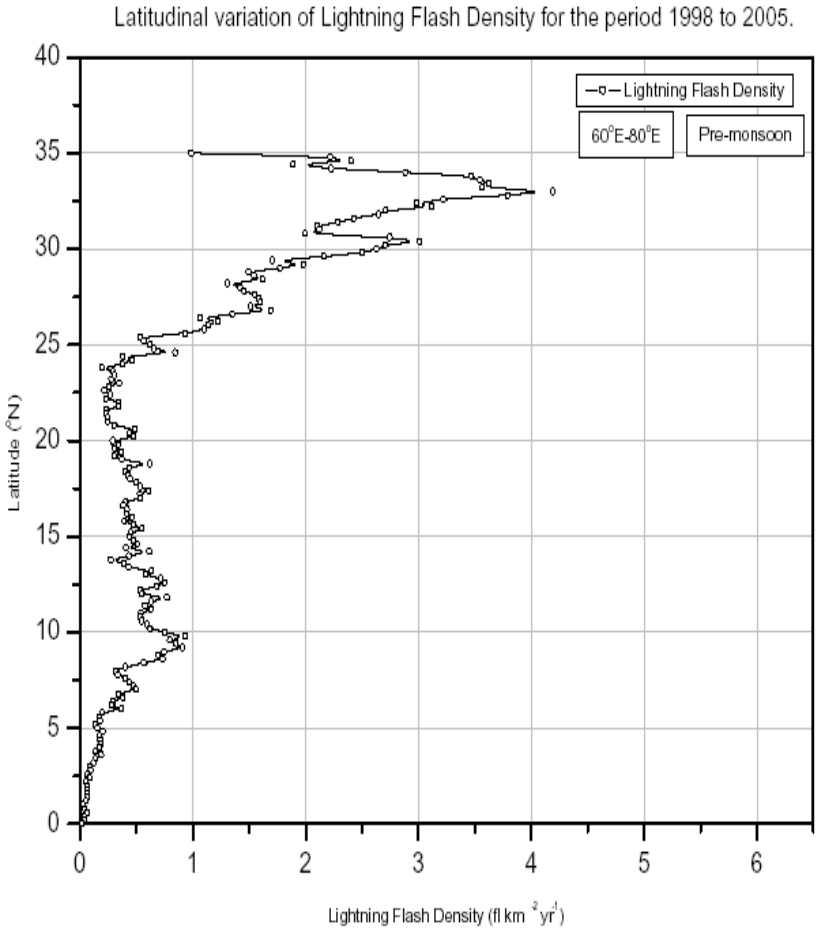
Winter (JF)

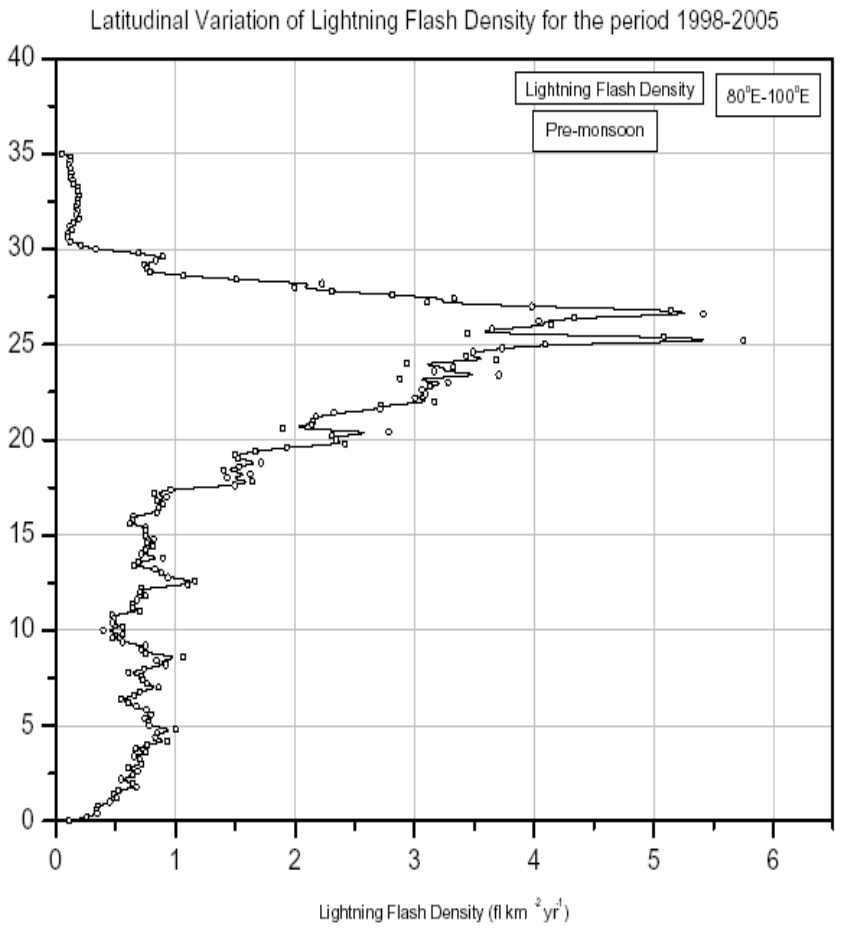


Spatial Distribution of

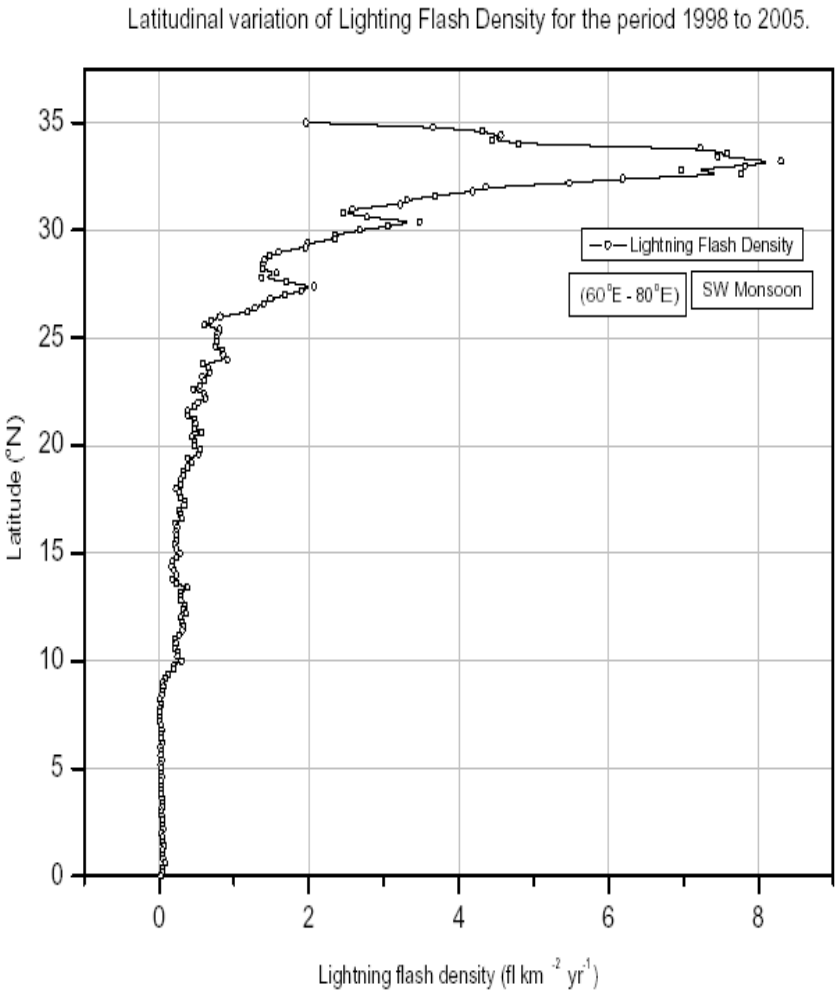
Lightning Flash Density

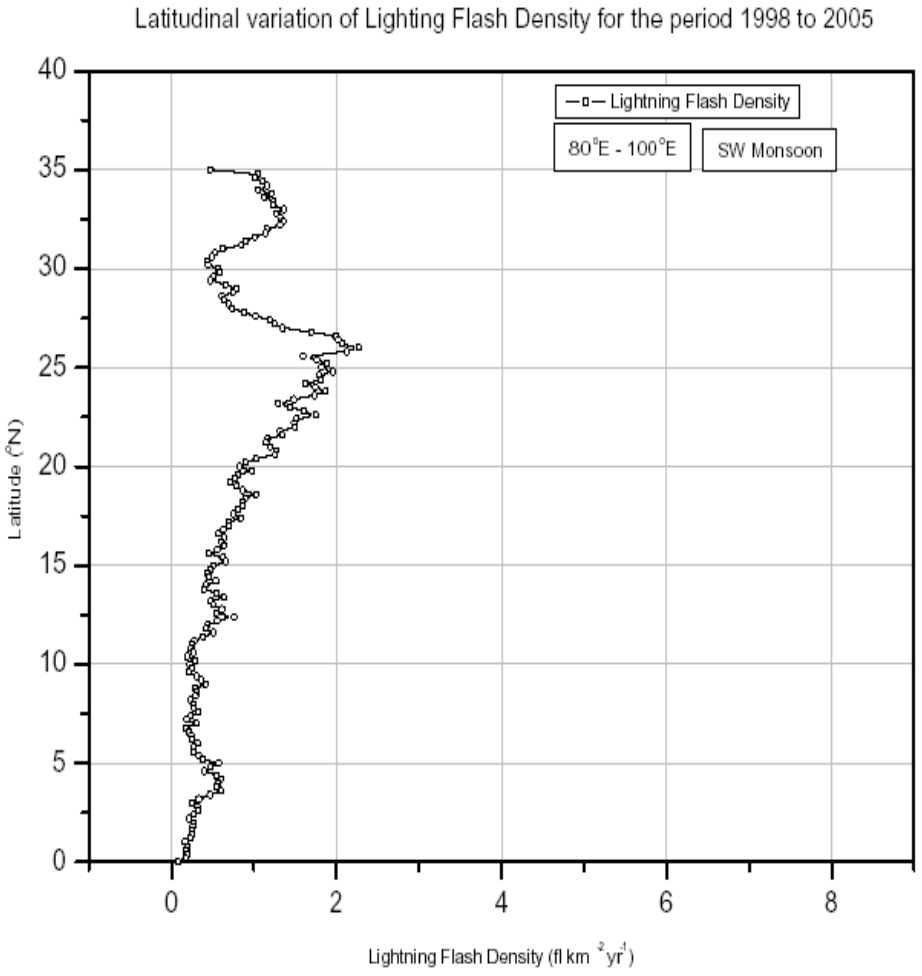
Latitudinal Variations: Premonsoon



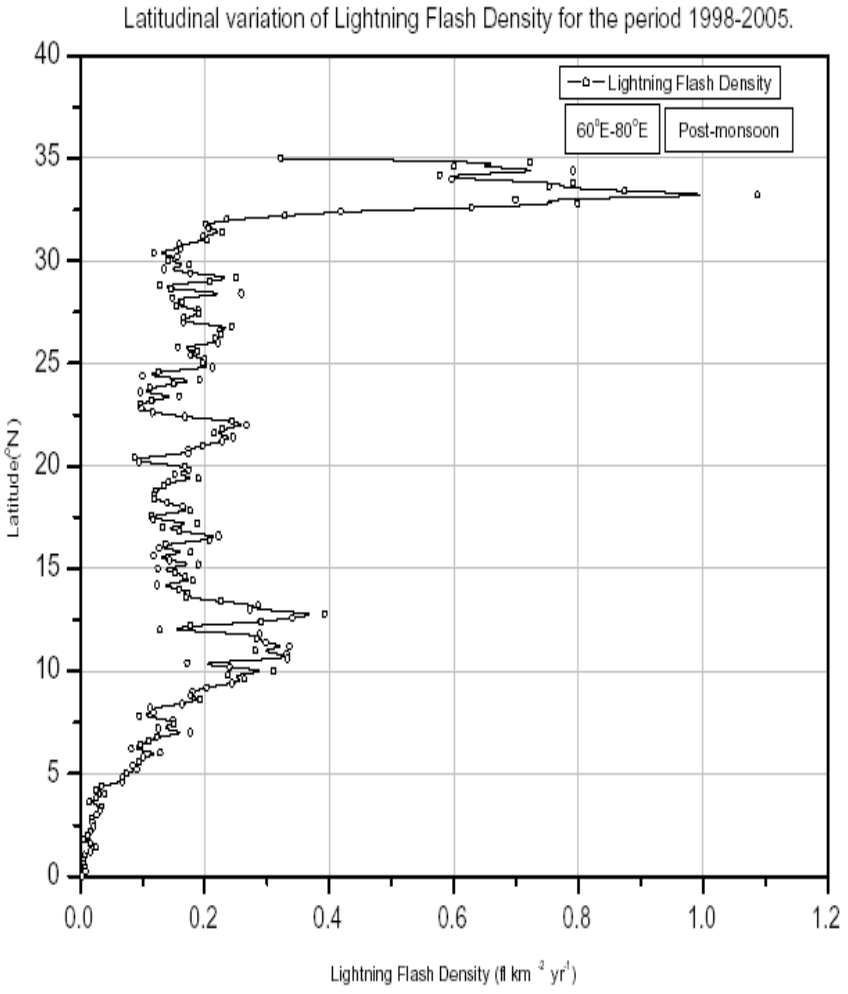


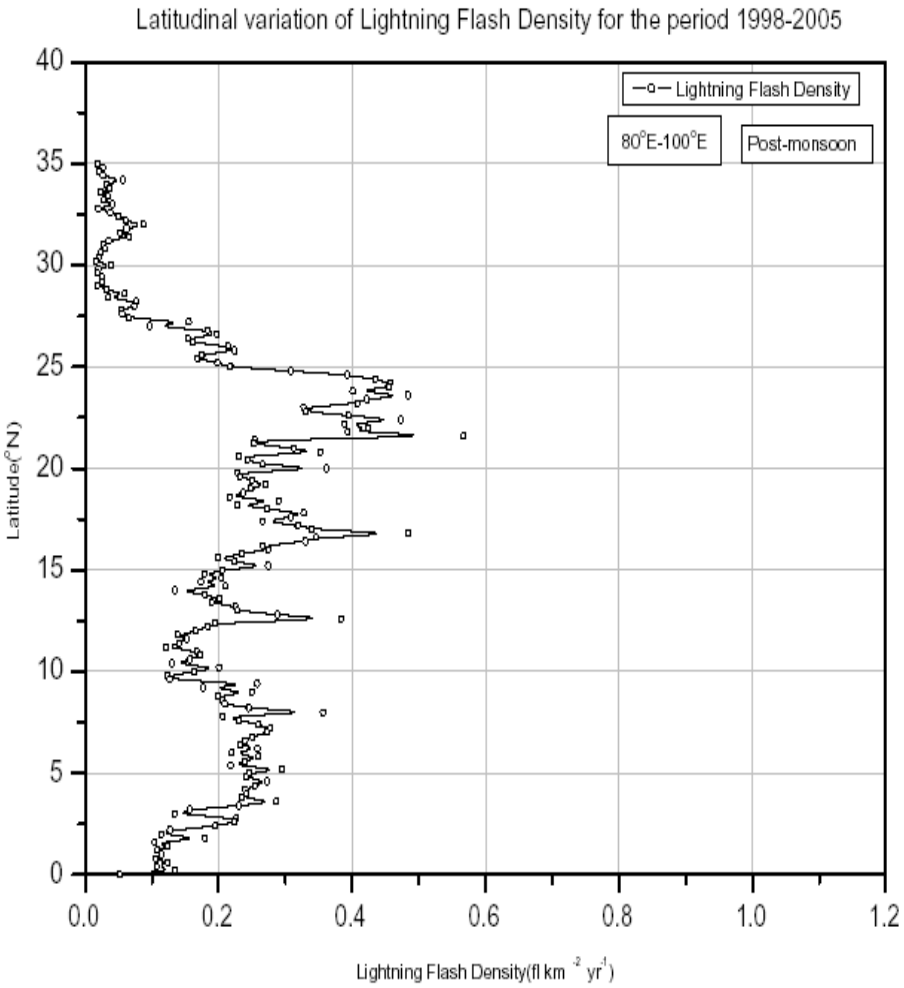
Latitudinal Variations: SW Monsoon



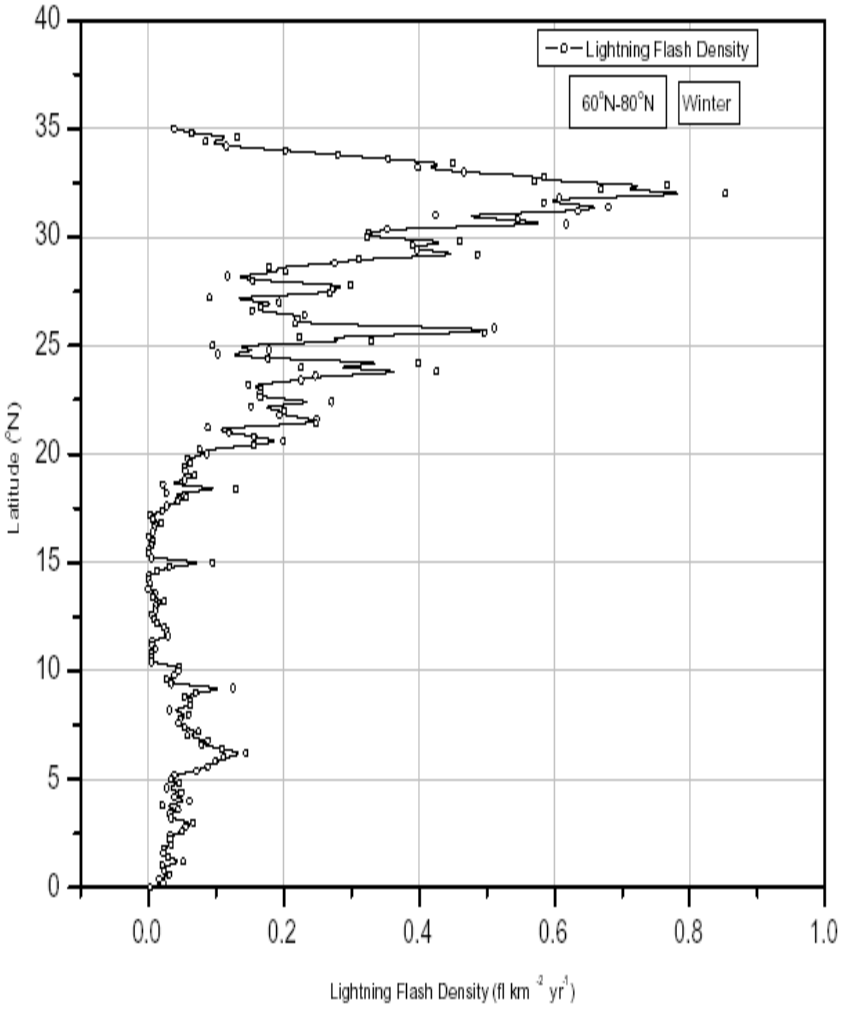


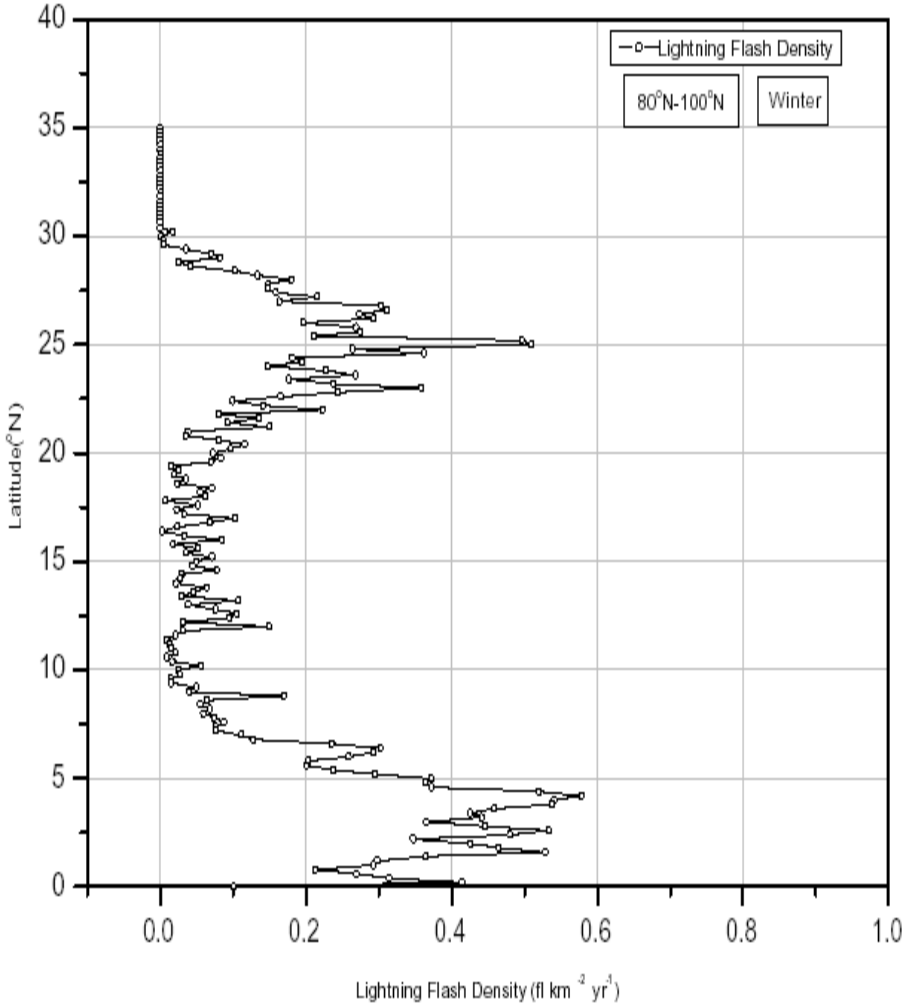
Latitudinal Variations: NE-Monsoon



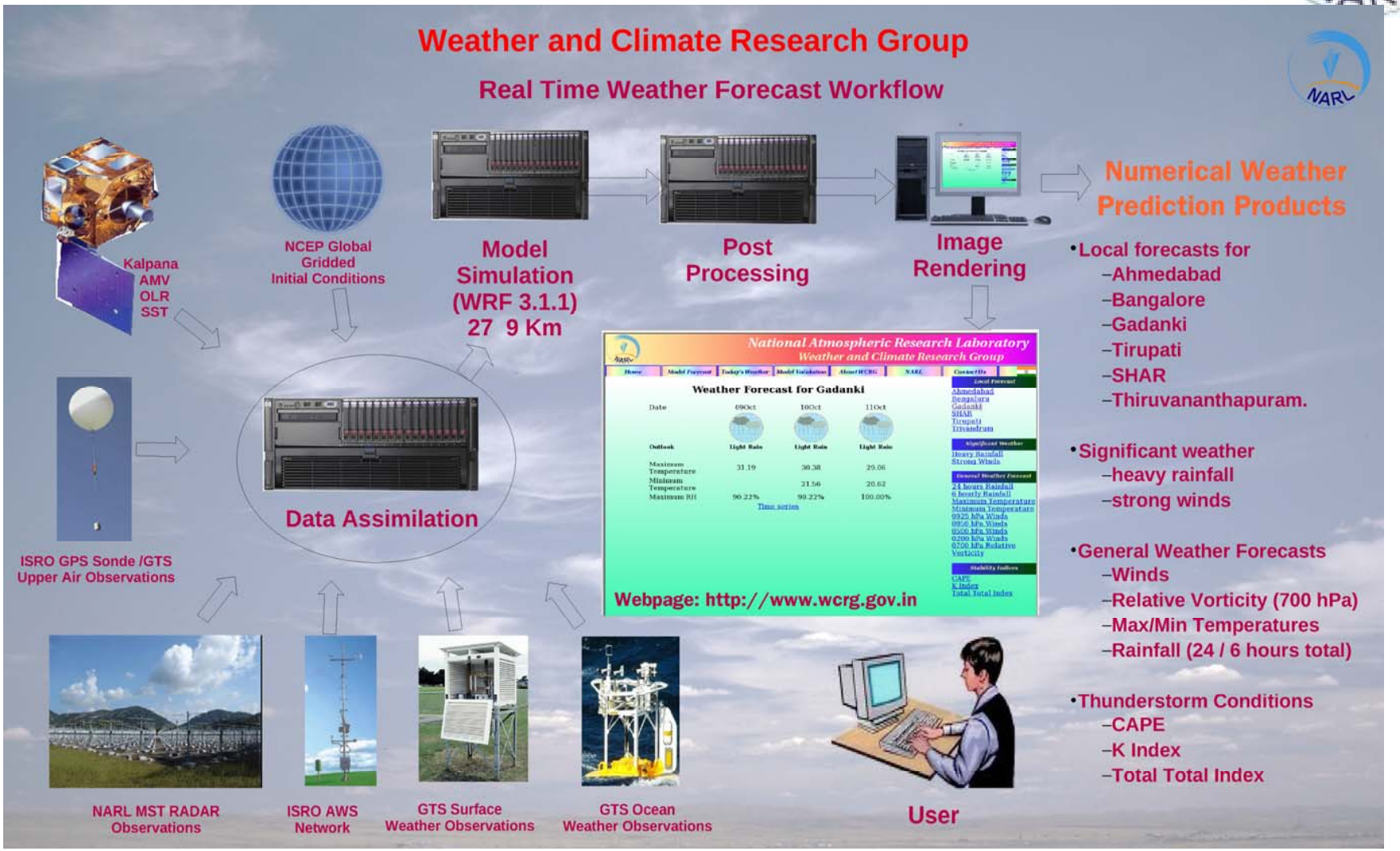


Latitudinal Variations: Winter

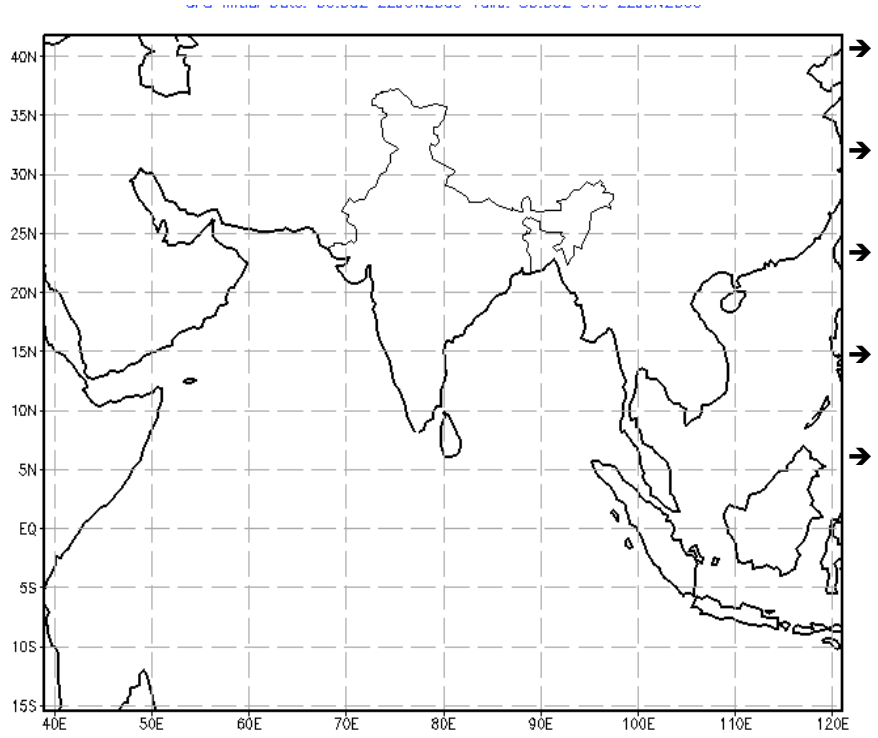




Forecasting System



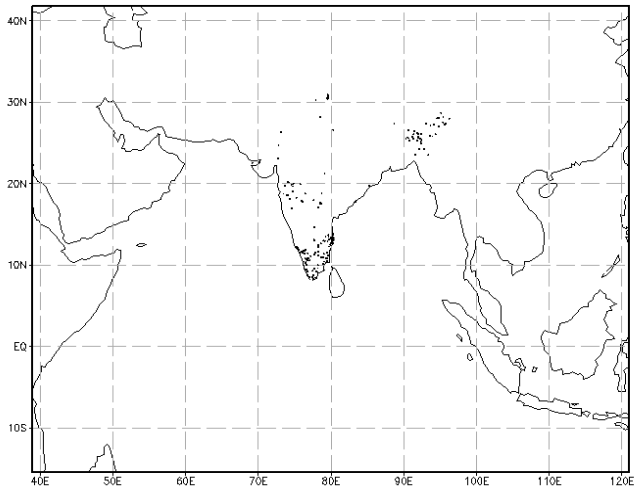
Modeling Domain and Configuration



- Model: WRFV 3.2
- Spatial Resolution 27 Km
- Temporal Resolution: 120 Sec
- Forecasts for 72 hours
- Physics
  - Microphysics: Thompson
  - Cumulus: BMJ
  - PBL: YSU
  - Longwave Radiation: RRTM
  - Shortwave Radiation: Dudhia

Details of Data Assimilation

- Using Objective Analysis
- Multiquardratic Scheme (Nuss and Titley, 1994)
- Most accurate among the other method
  - MST RADAR
  - GTS Data (Internet)
  - ISRO AWS
  - ISRO Kalpana AMV
  - ISRO GPS Sonde
  - ~ 200 vertical profiles from FSL

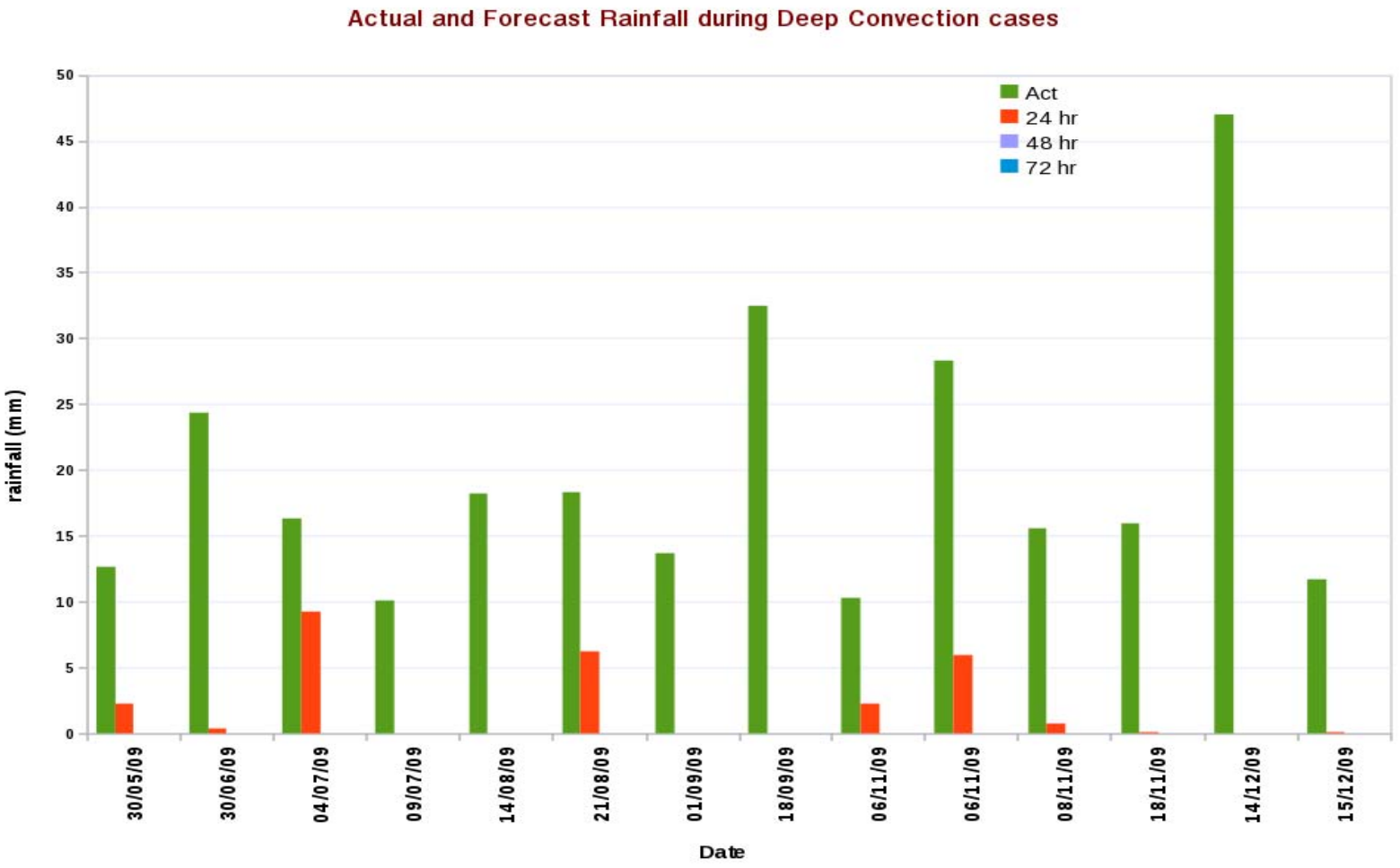


ISRO AWS Network

Severe Deep Convective Evidences

Date	Local Time (IST)	UTC	Accumulated Rain (mm)
30th May 2009	15:32:00 – 16:37:00	10:02:00 – 11:07:00	12.66
30th Jun 2009	18:27:00 – 20:24:00	12:57:00 – 14:54:00	24.37
04th Jul 2009	18:15:00 – 19:47:00	12:45:00 – 14:17:00	16.45
09th Jul 2009	17:14:00 – 18:10:00	11:44:00 -12:40:00	10.14
14th Aug 2009 15th Aug 2009		06:30:00 PM	18.24
	00:00:00 – 09:52:00	04:22:00 AM	
21st Aug 2009	22:40:00 – 23:37:00	17:10:00 – 18:07:00	18.32
01st Sep 2009 02st Sep 2009		19:29:00 – 21:26:00	13.69
	00:59:00 – 02:56:00		
18th Sep 2009	13:19:00 – 14:24:00	07:49:00 – 08:54:00	32.46
06th Nov 2009	22:57:00 – 23:59:00	17:27:00 – 18:29:00	10.29
06th Nov 2009 07th Nov 2009		18:30:00 – 23:04:00	28.32
	00:00:00 – 04:34:00		
08th Nov 2009 09th Nov 2009		18:30:00 – 00:50:00	15.65
	00:00:00 – 06:20:00		
18th Nov 2009	14:35:00 – 18:48:00	09:05:00 – 13:18:00	16.01
14th Dec 2009 15th Dec 2009		22:28:00	47.07
	03:58:00 – 07:33:00	02:03:00 AM	
15th Dec 2009	19:02:00 – 22:56:00	13:32:00 - 17:26:00	11.65

First Validation: Point Rainfall



contingency tables

Category 1: 7.6 – 35.5 mm Moderate rain

	obs yes	obs no	total
fc yes	9	0	9
fc no	4	0	4
total	13	0	13

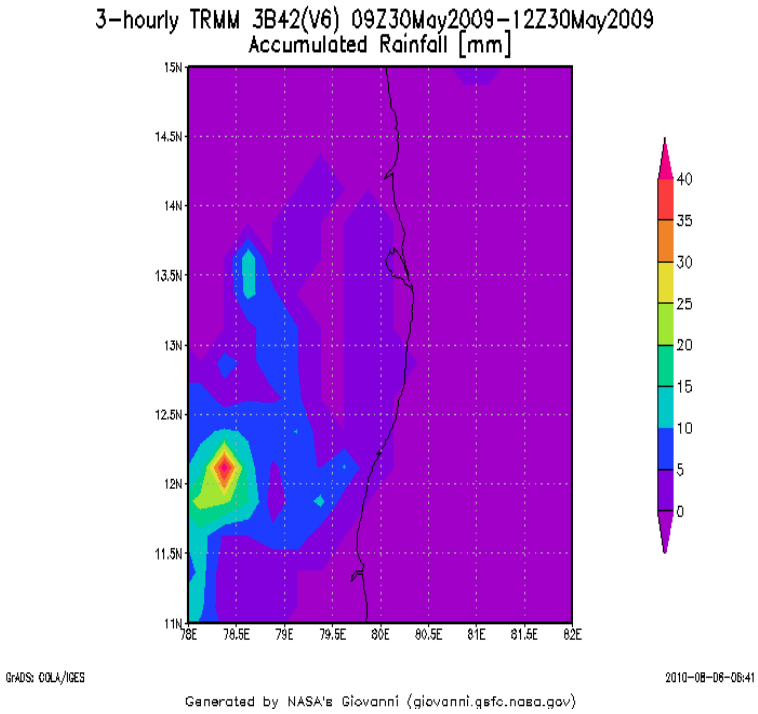
30.77 %

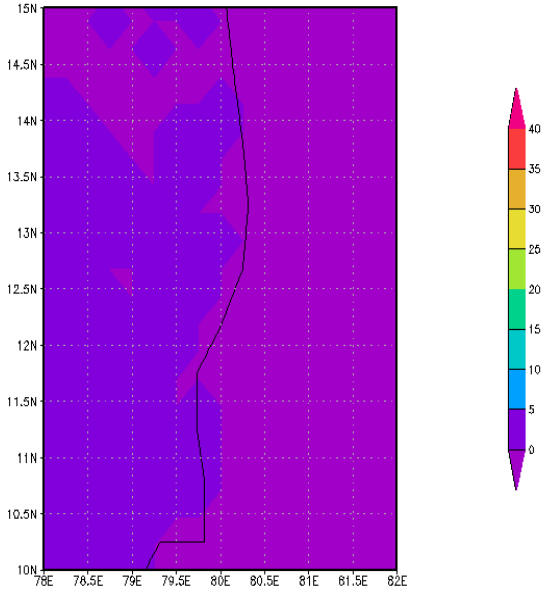
69.23 %

Category 2: 35.6 – 64.4 mm Rather heavy rain

	obs yes	obs no	total
fc yes	0	0	0
fc no	1	0	1
total	0	0	1

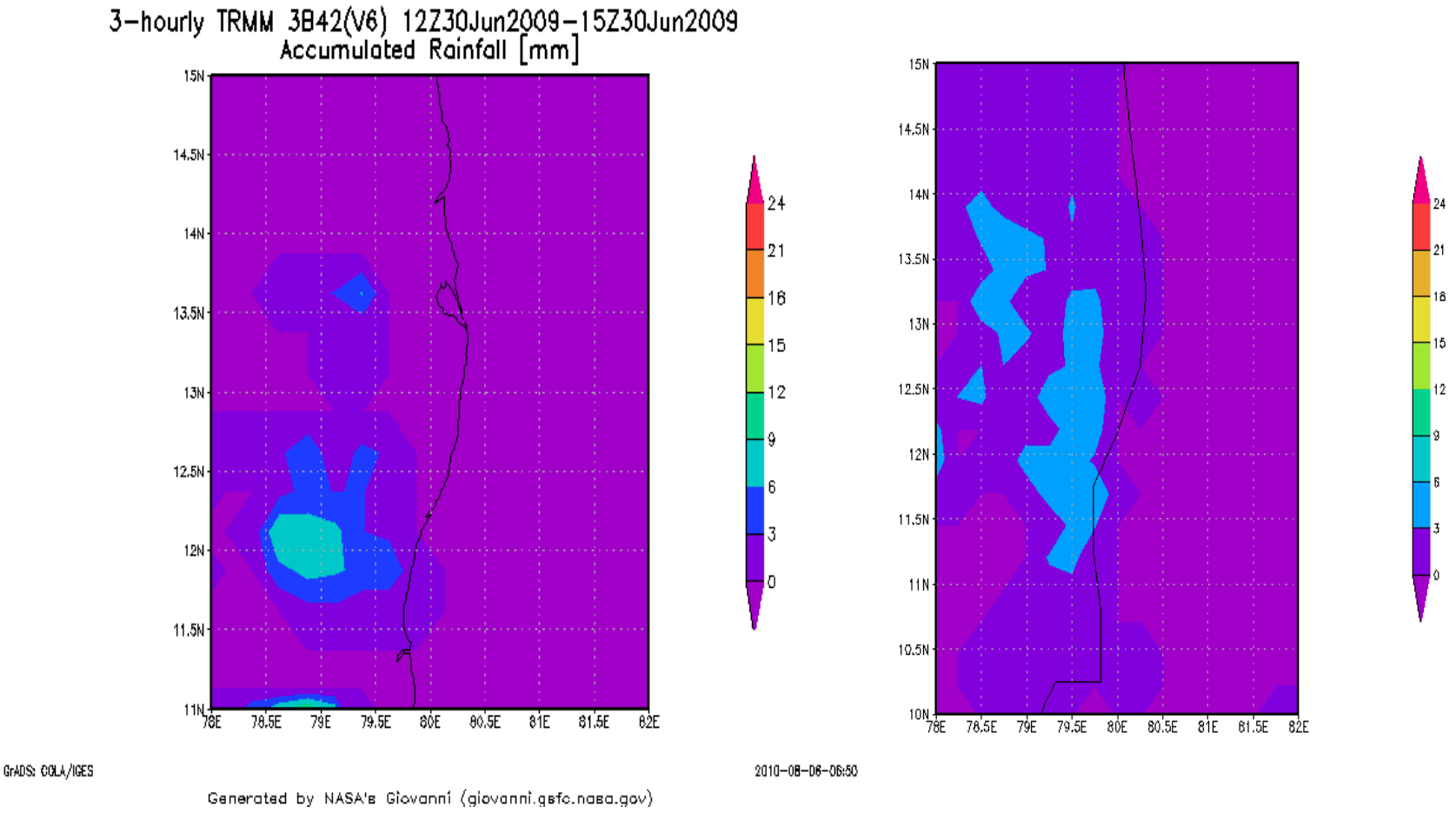
Spatial Rainfall Distribution: May 30th 2009



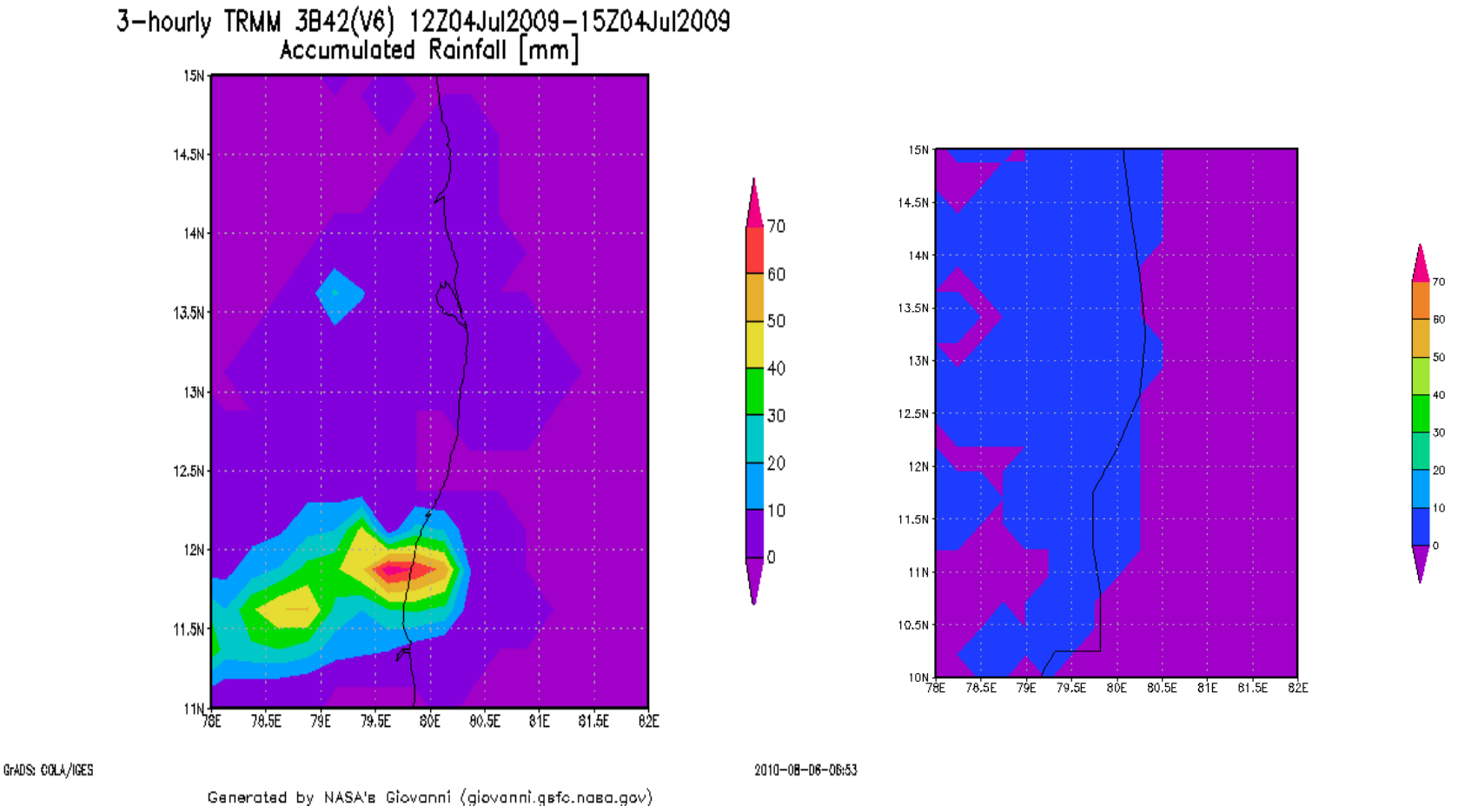


WRF forecast

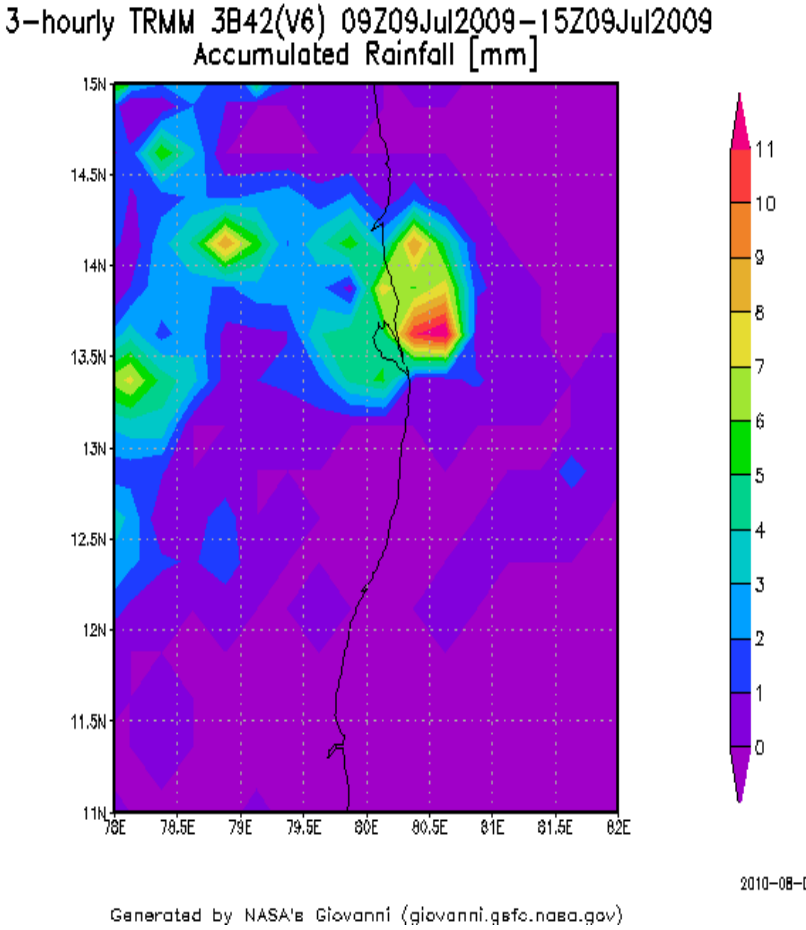
Spatial Rainfall Distribution: Jun 30th 2009

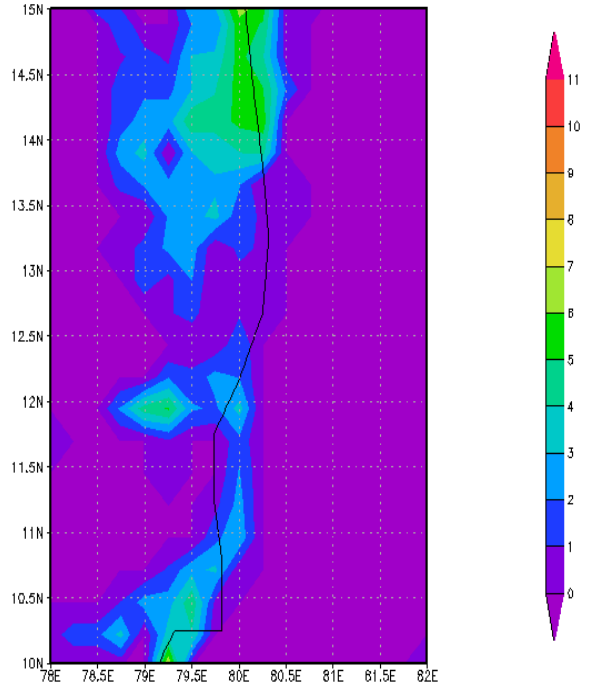


Spatial Rainfall Distribution: Jul 4th 2009

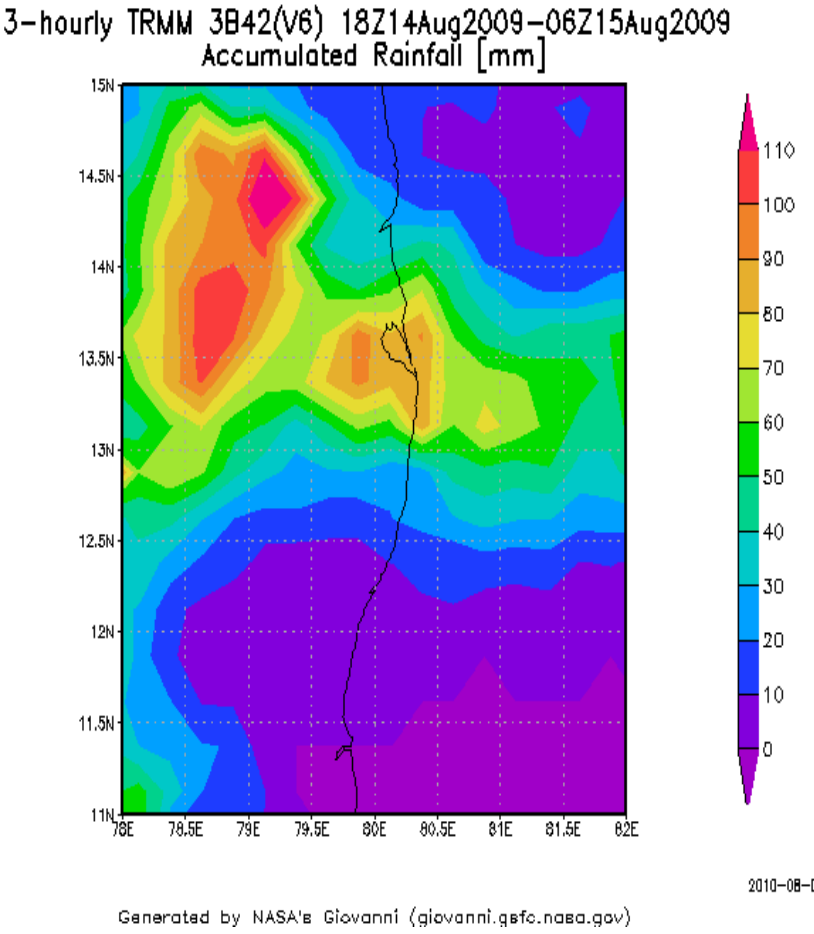


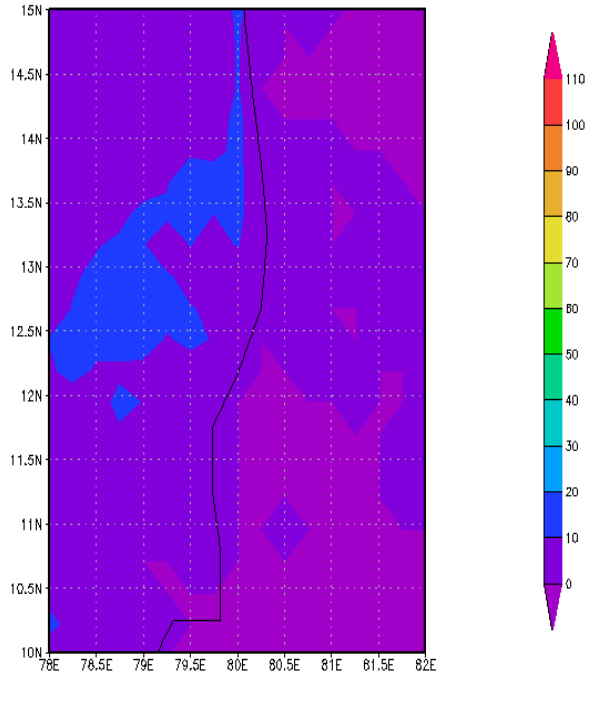
Spatial Rainfall Distribution: Jul 09th 2009



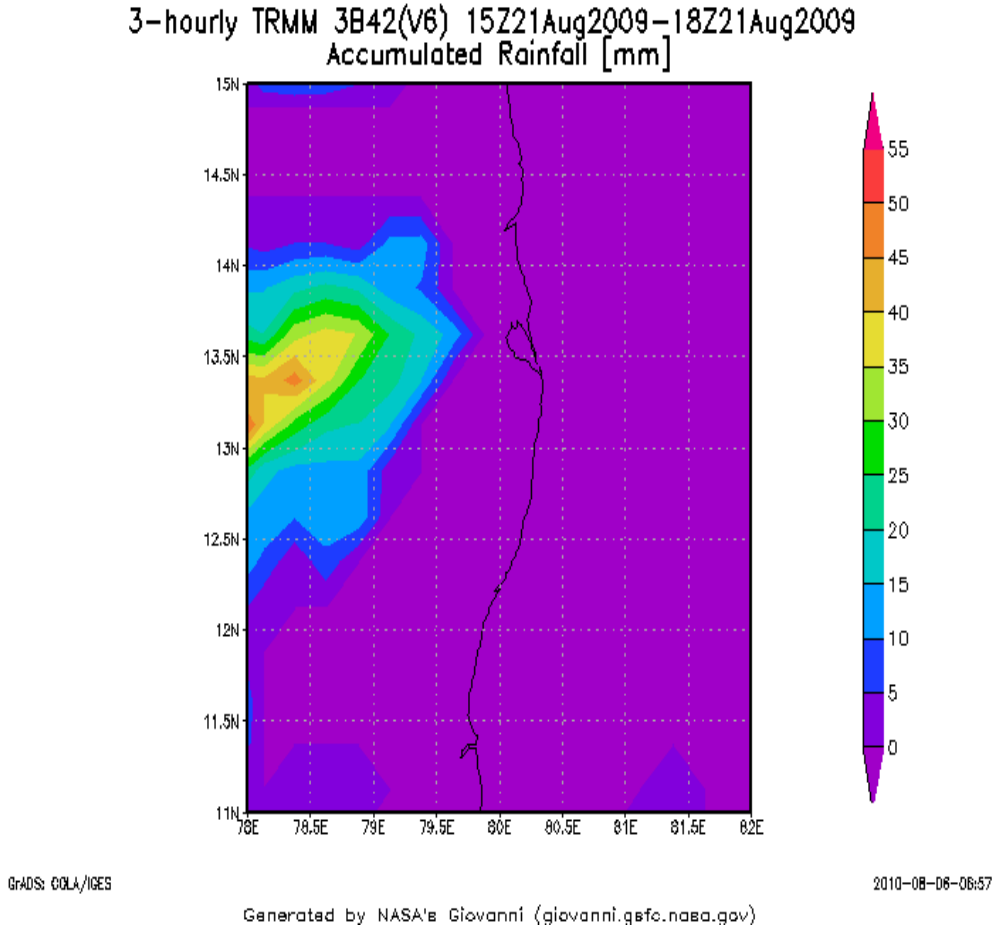


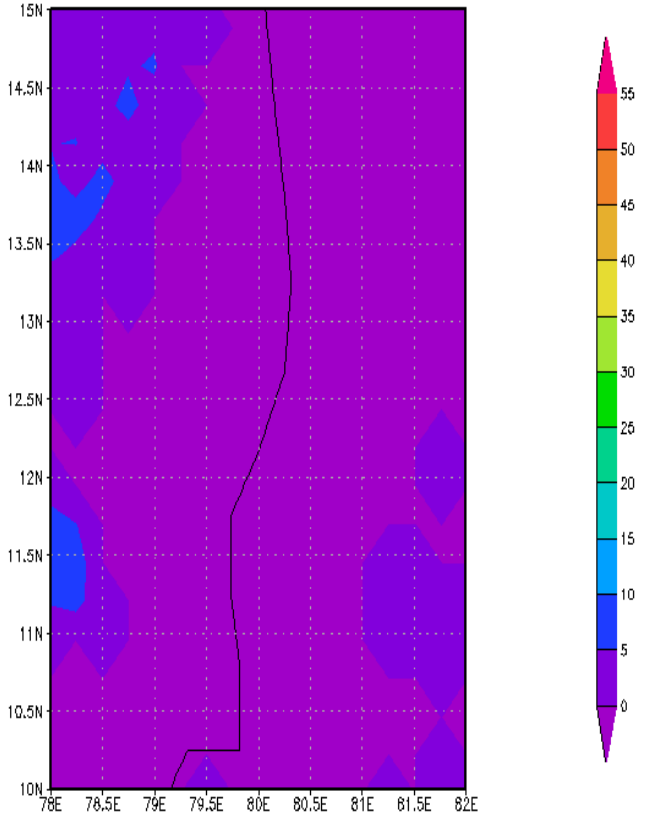
Spatial Rainfall Distribution: Aug 14-15th 2009



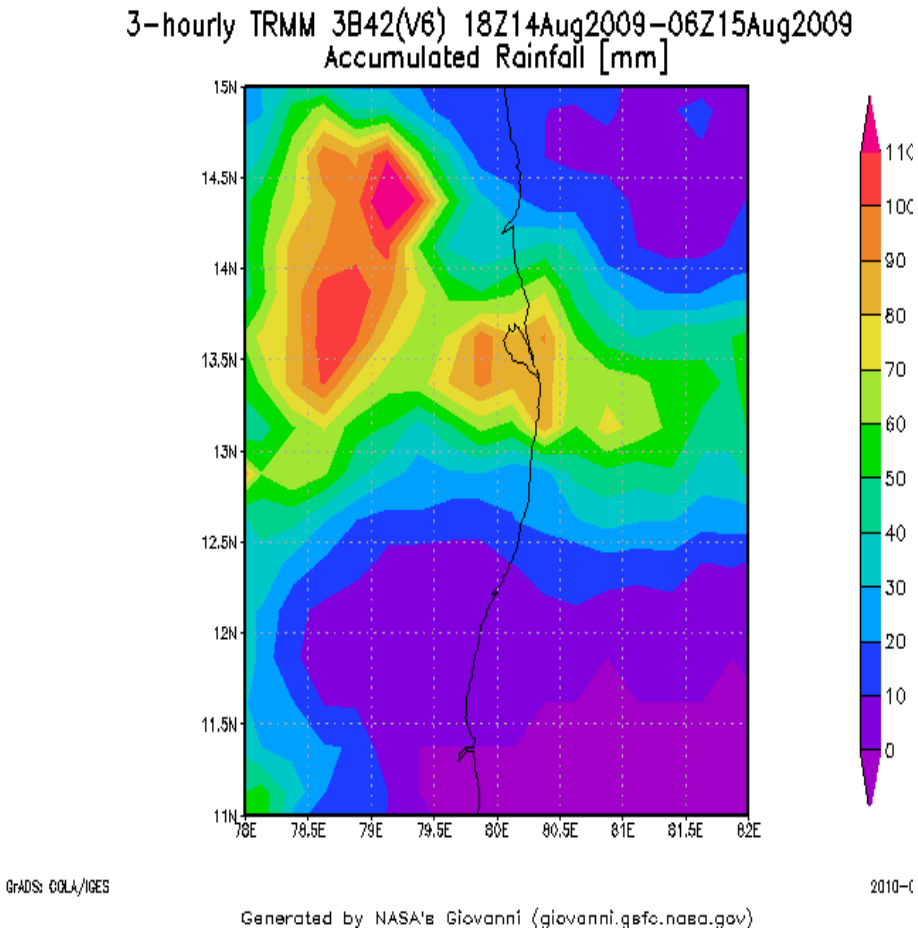


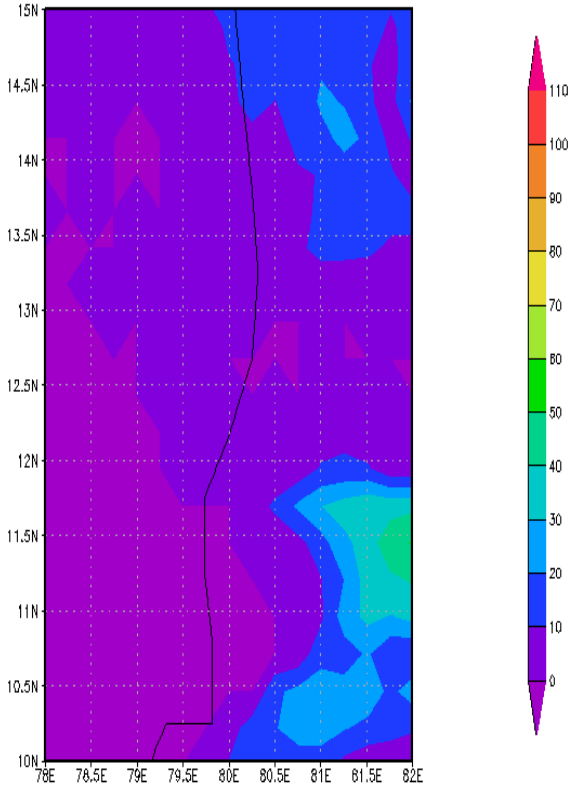
Spatial Rainfall Distribution: Aug 21st 2009



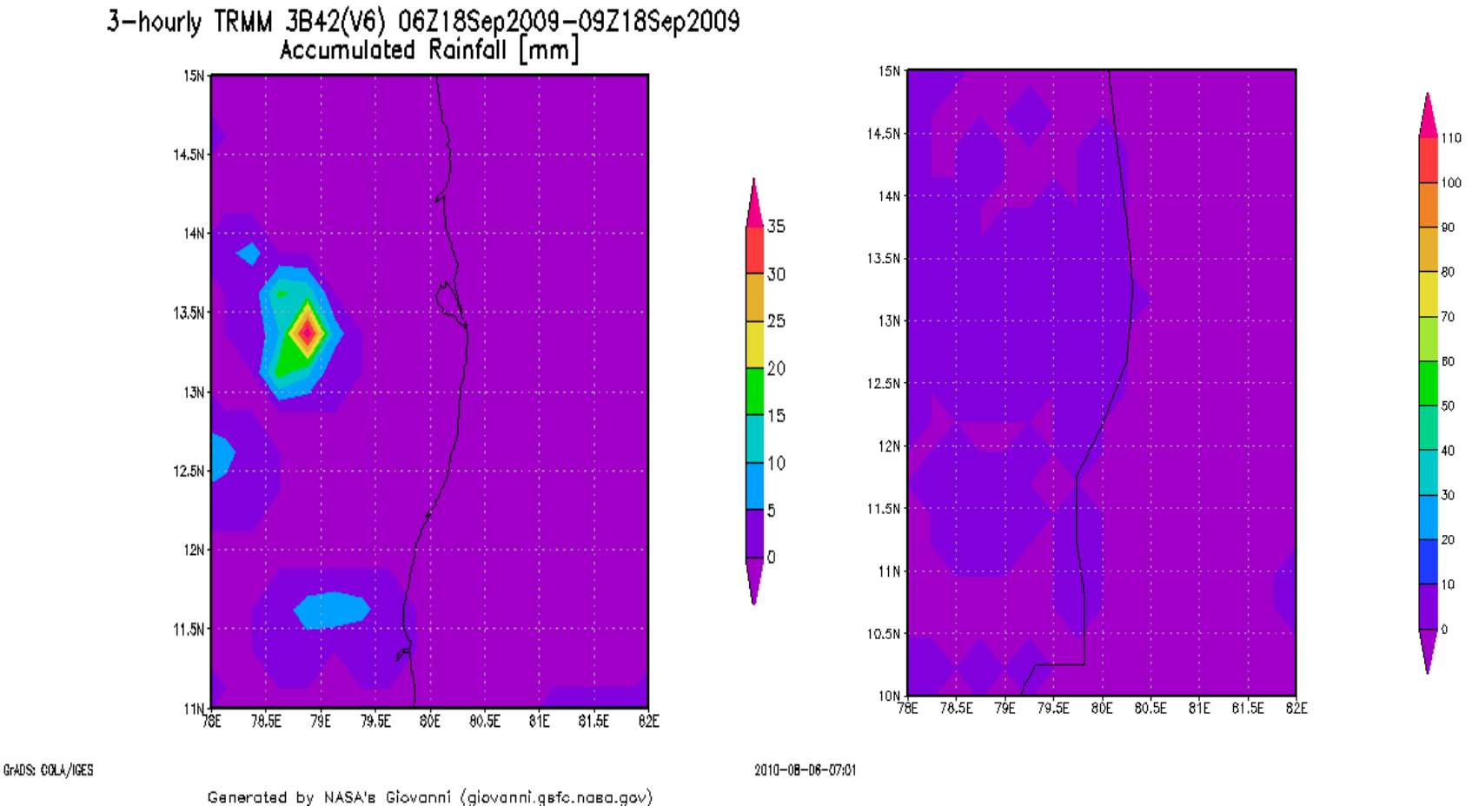


Spatial Rainfall Distribution: Sep 01 – 02st 2009

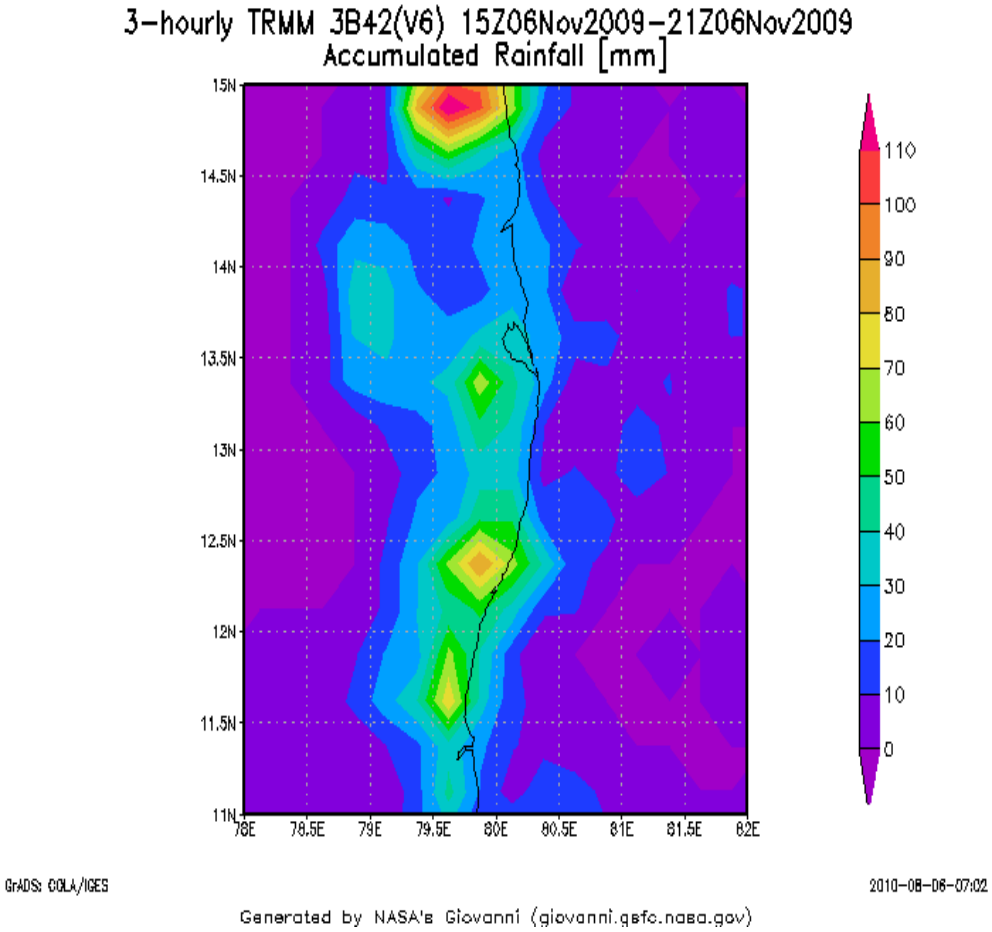


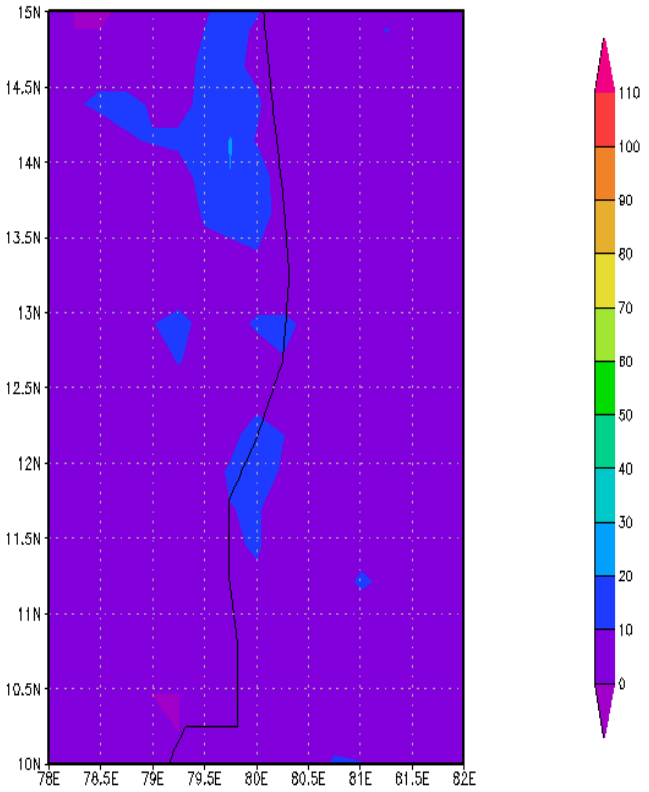


Spatial Rainfall Distribution: Sep 18th 2009

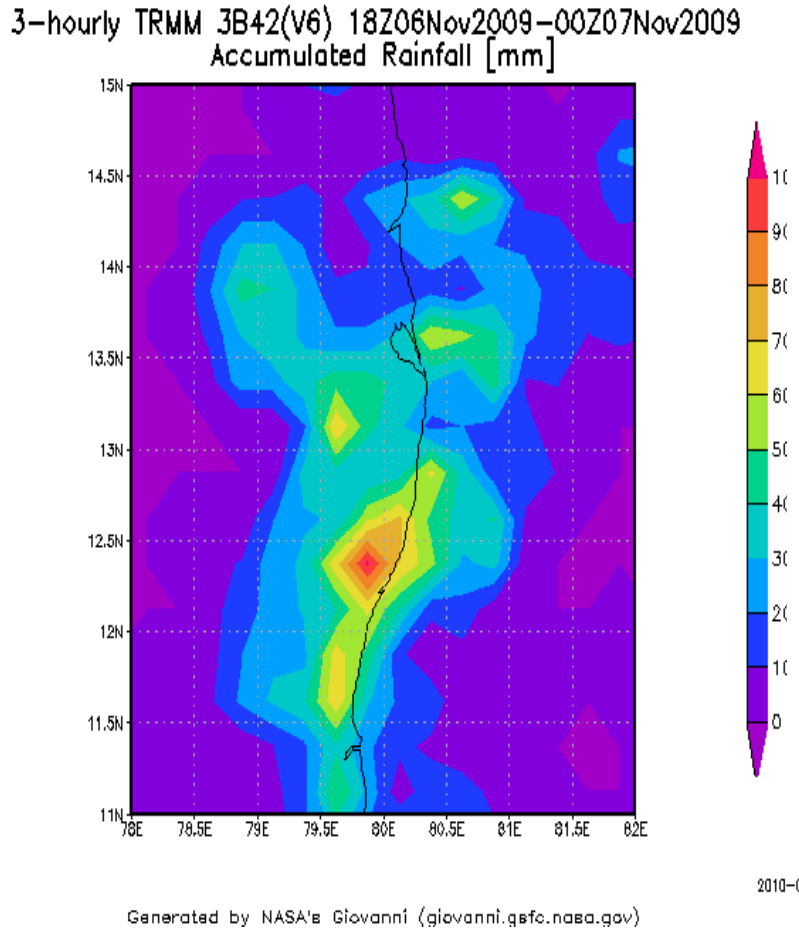


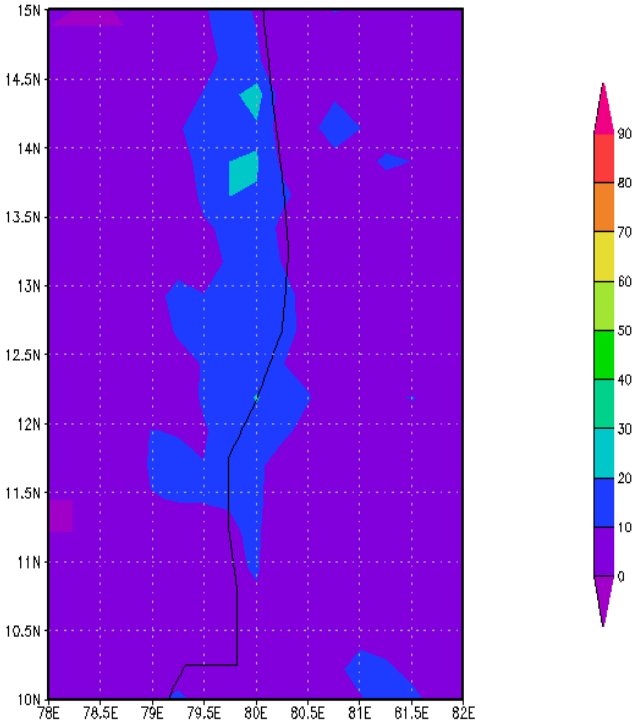
Spatial Rainfall Distribution: Nov 06th 2009



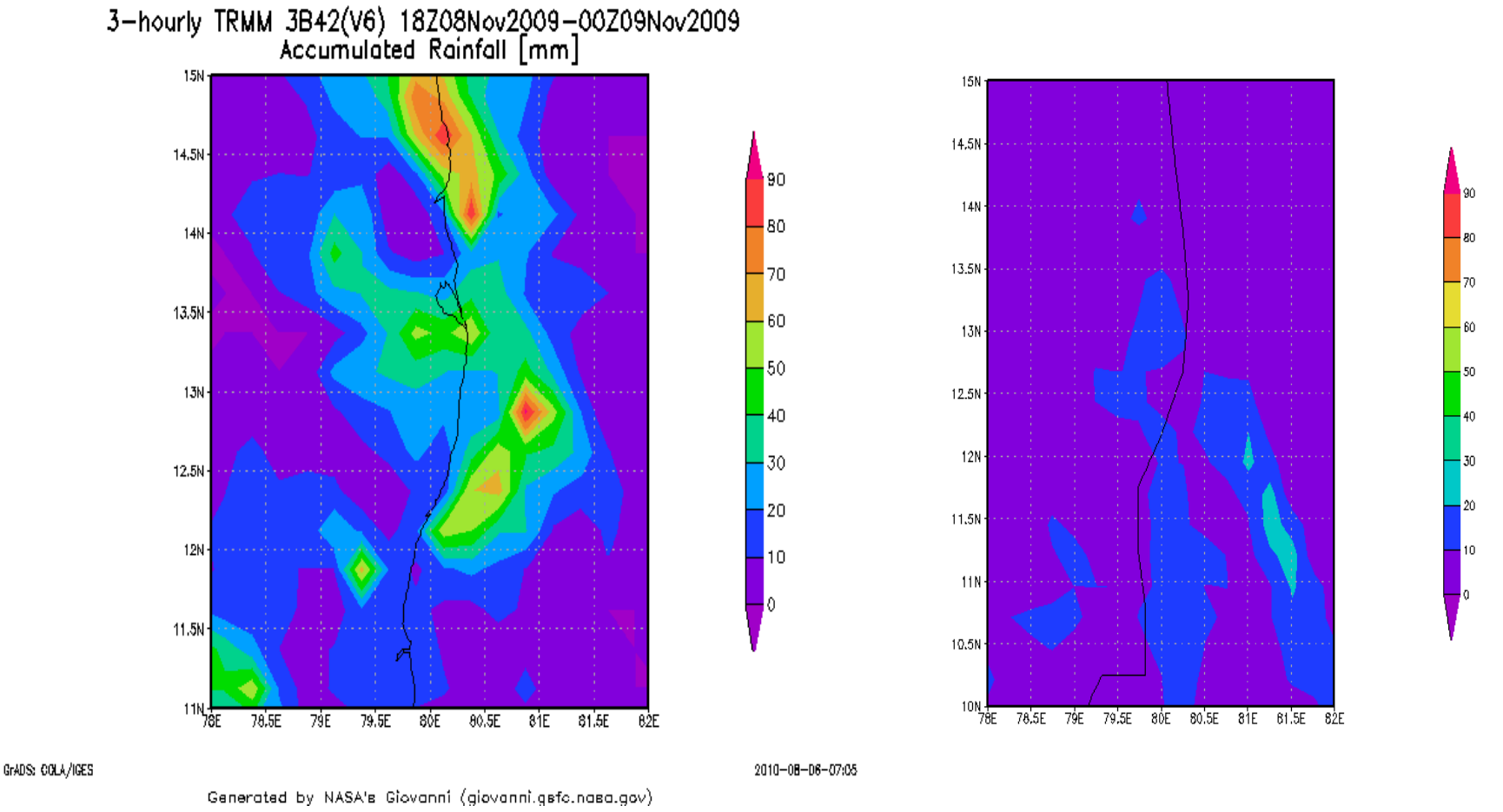


Spatial Rainfall Distribution: Nov 06-07 2009

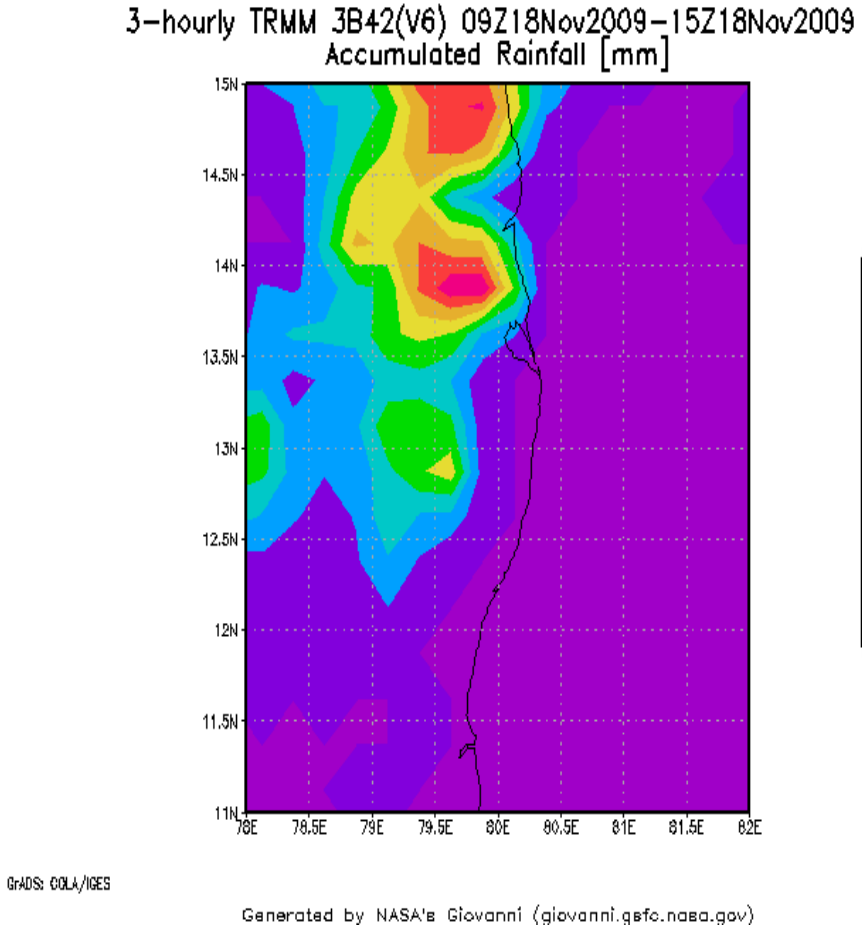


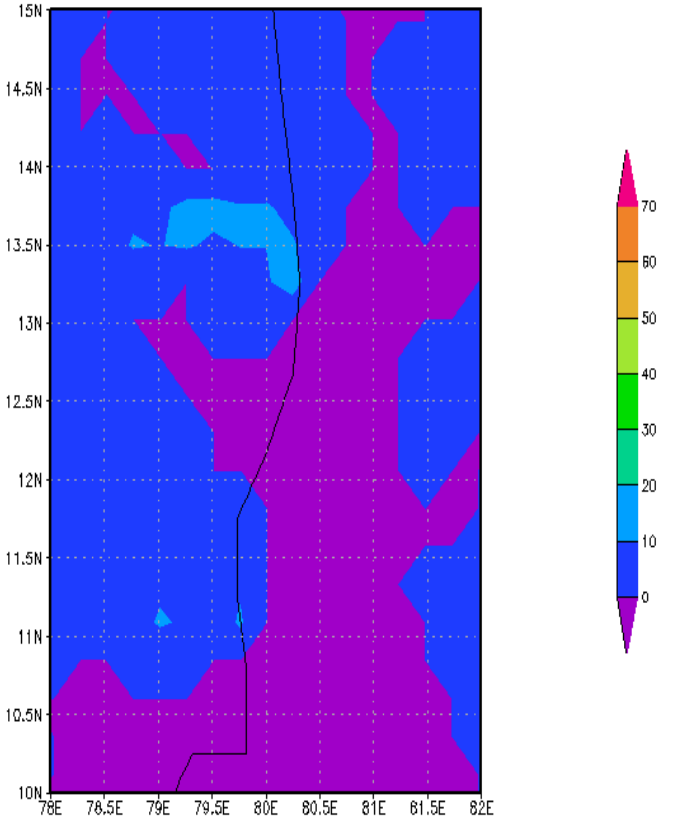


Spatial Rainfall Distribution: Nov 08-09 2009

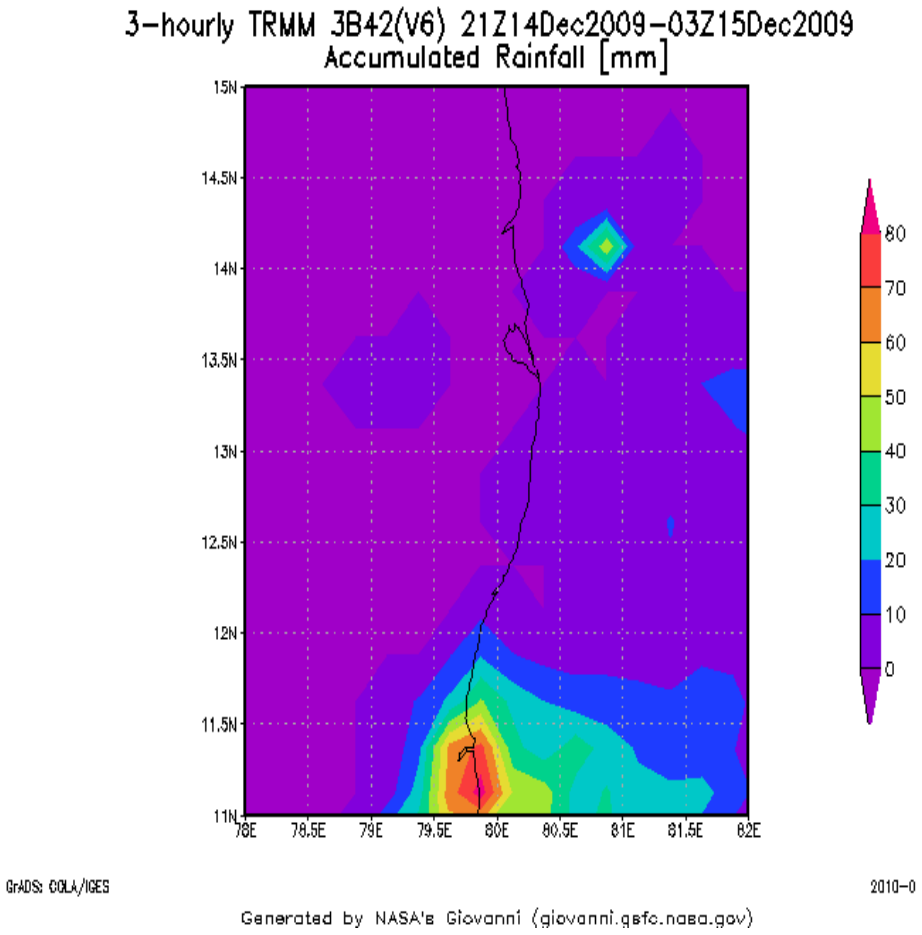


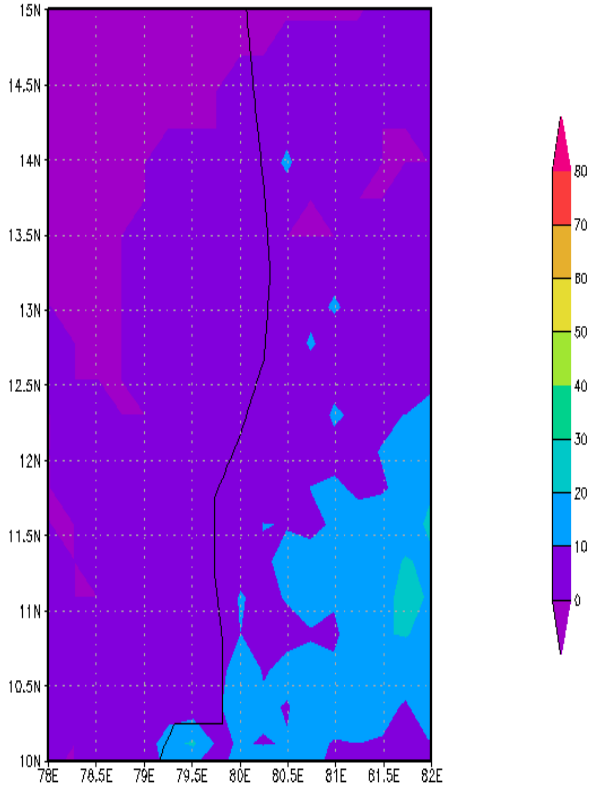
Spatial Rainfall Distribution: Nov 18 2009



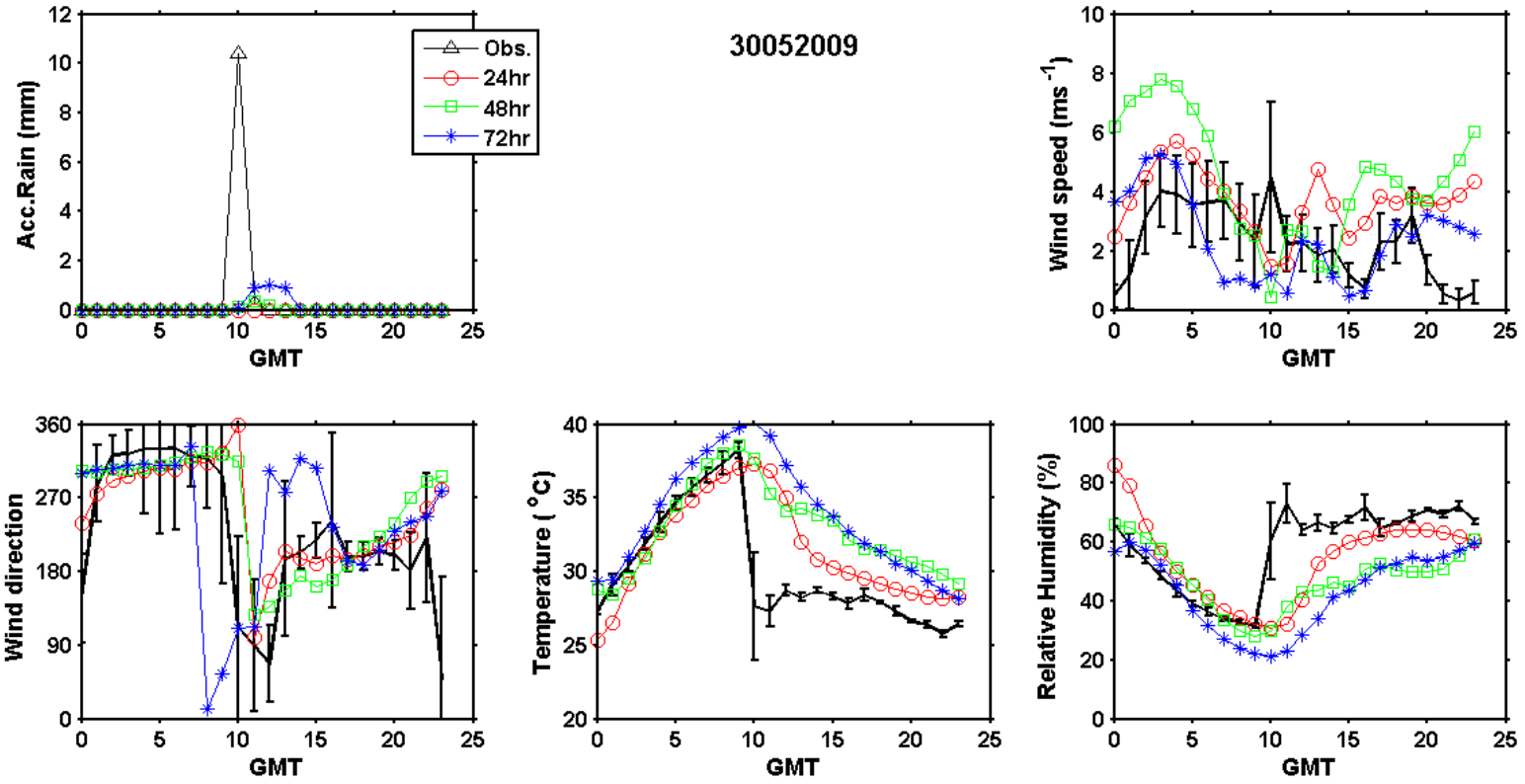


Spatial Rainfall Distribution: Dec 14 - 15 2009

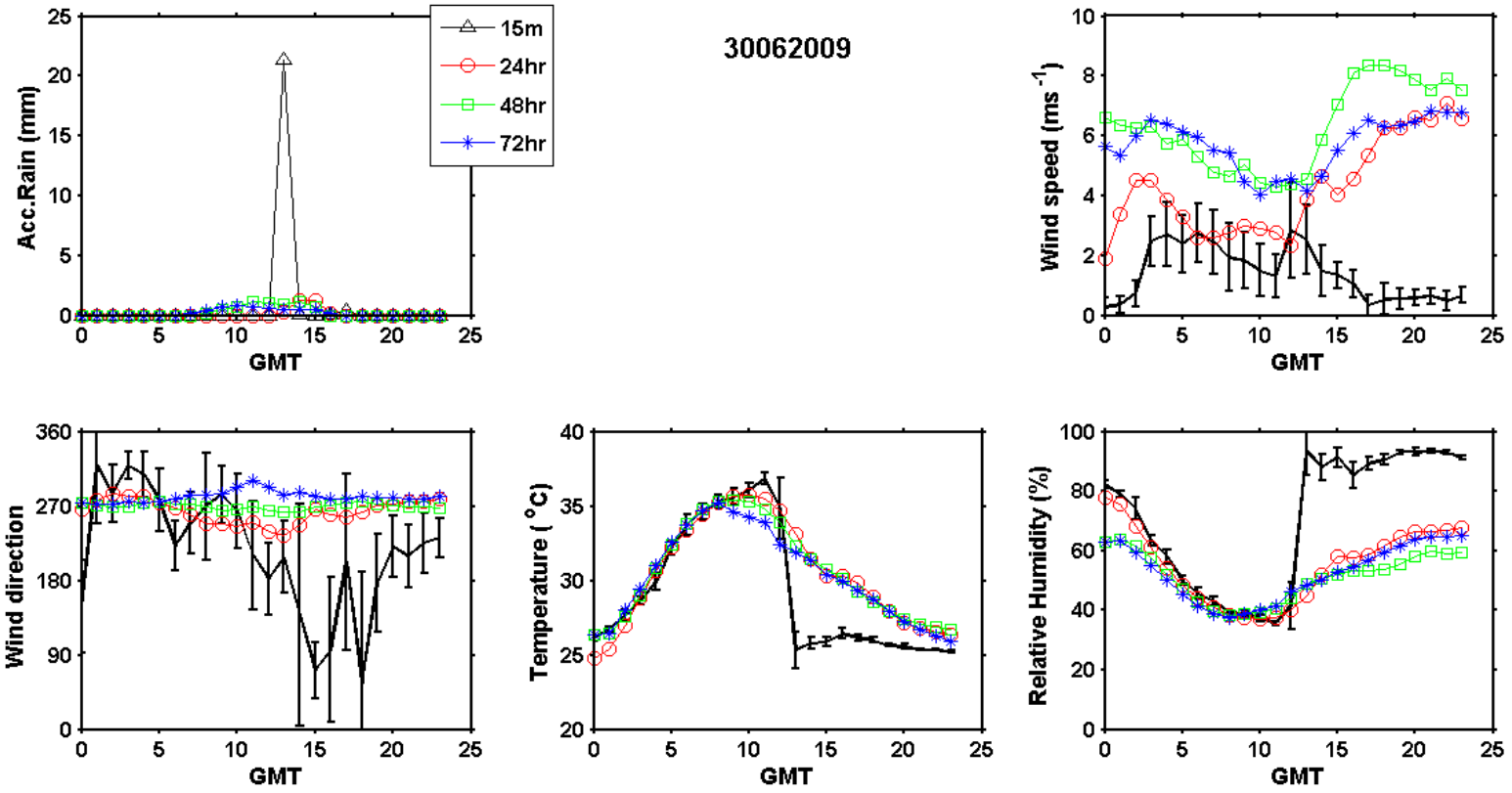




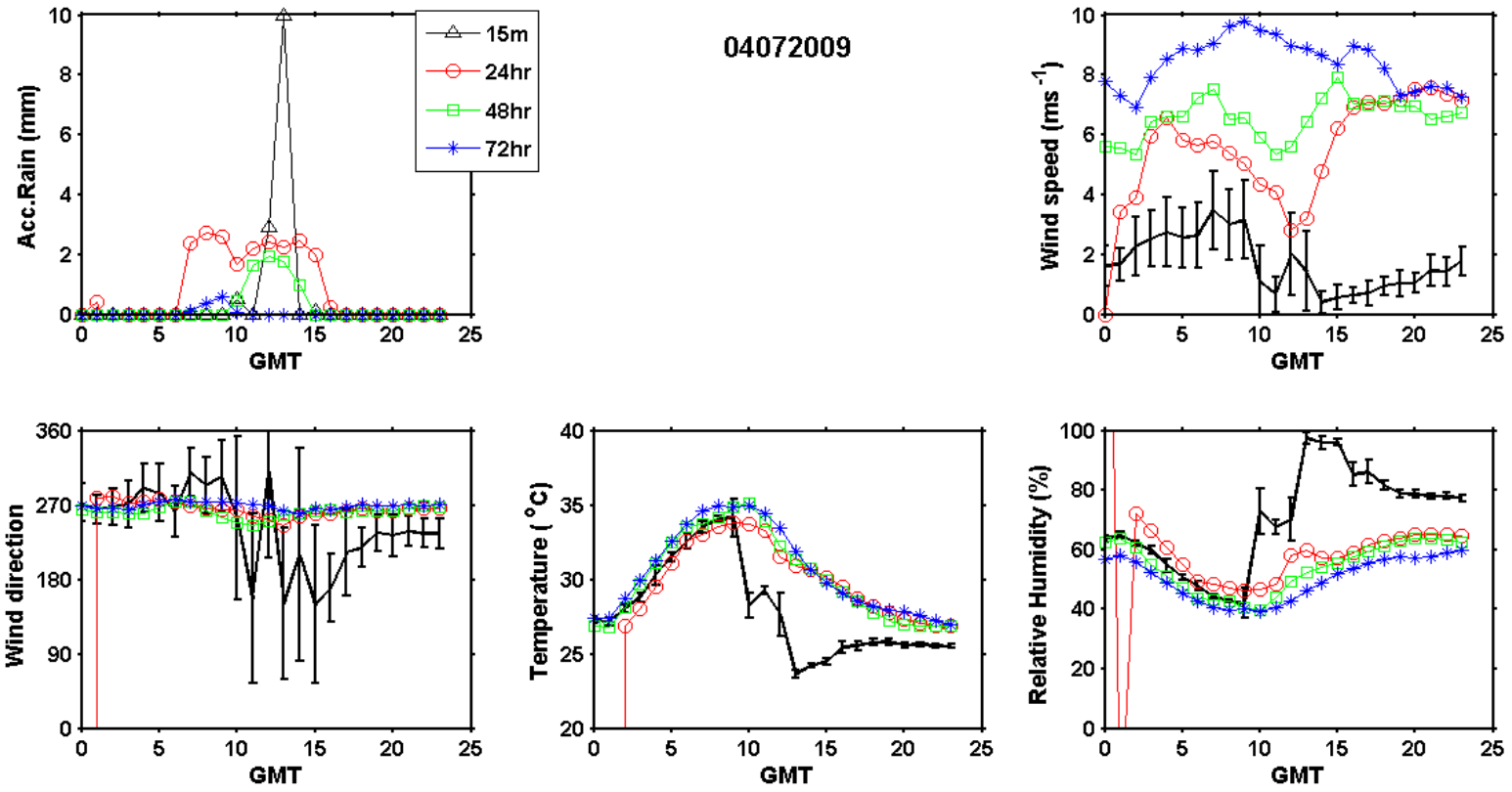
Case 1: May 30, 2009 10:02:00 – 11:07:00 UTC



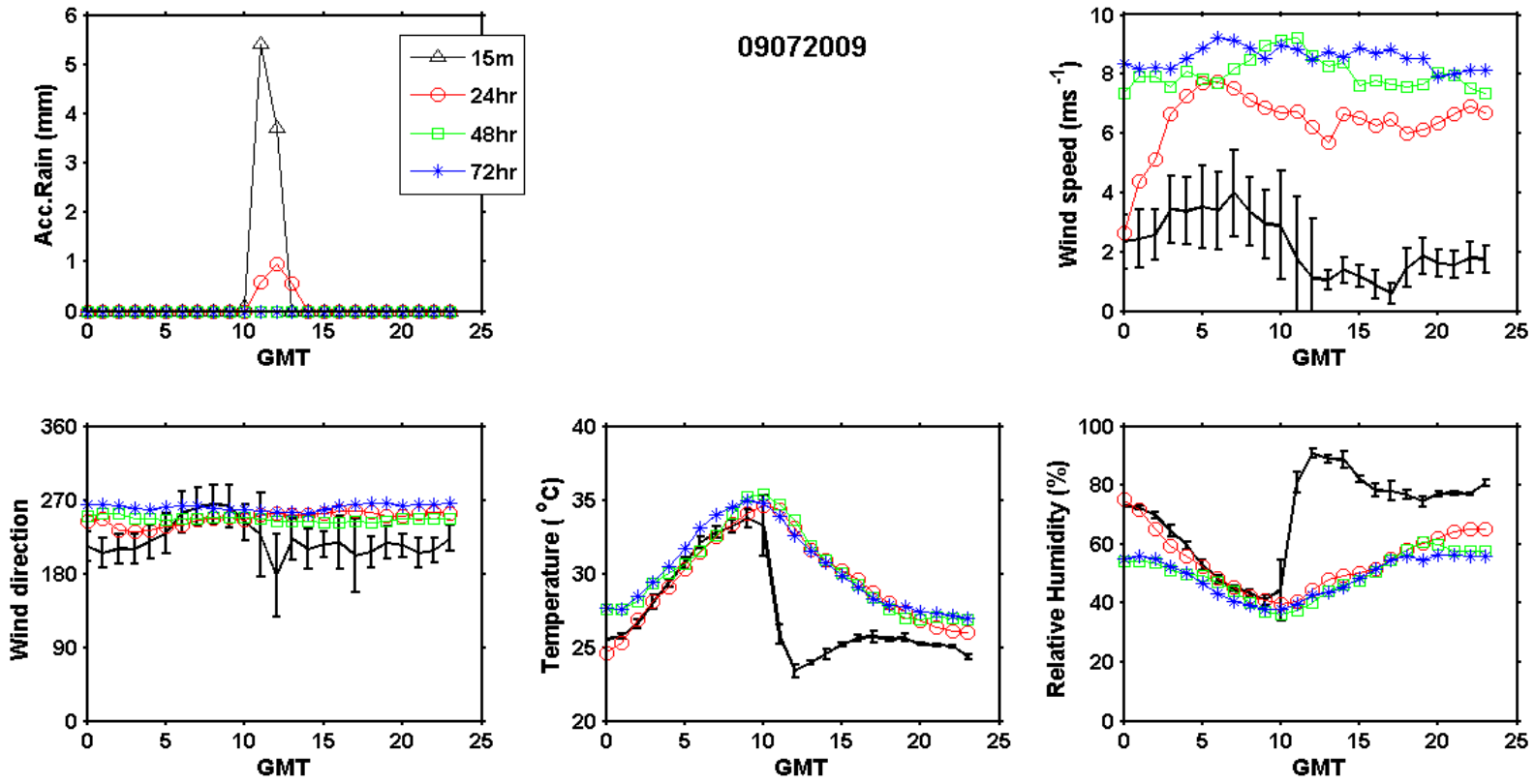
Case 2: Jun 30, 2009 12:57:00 14:54:00 UTC



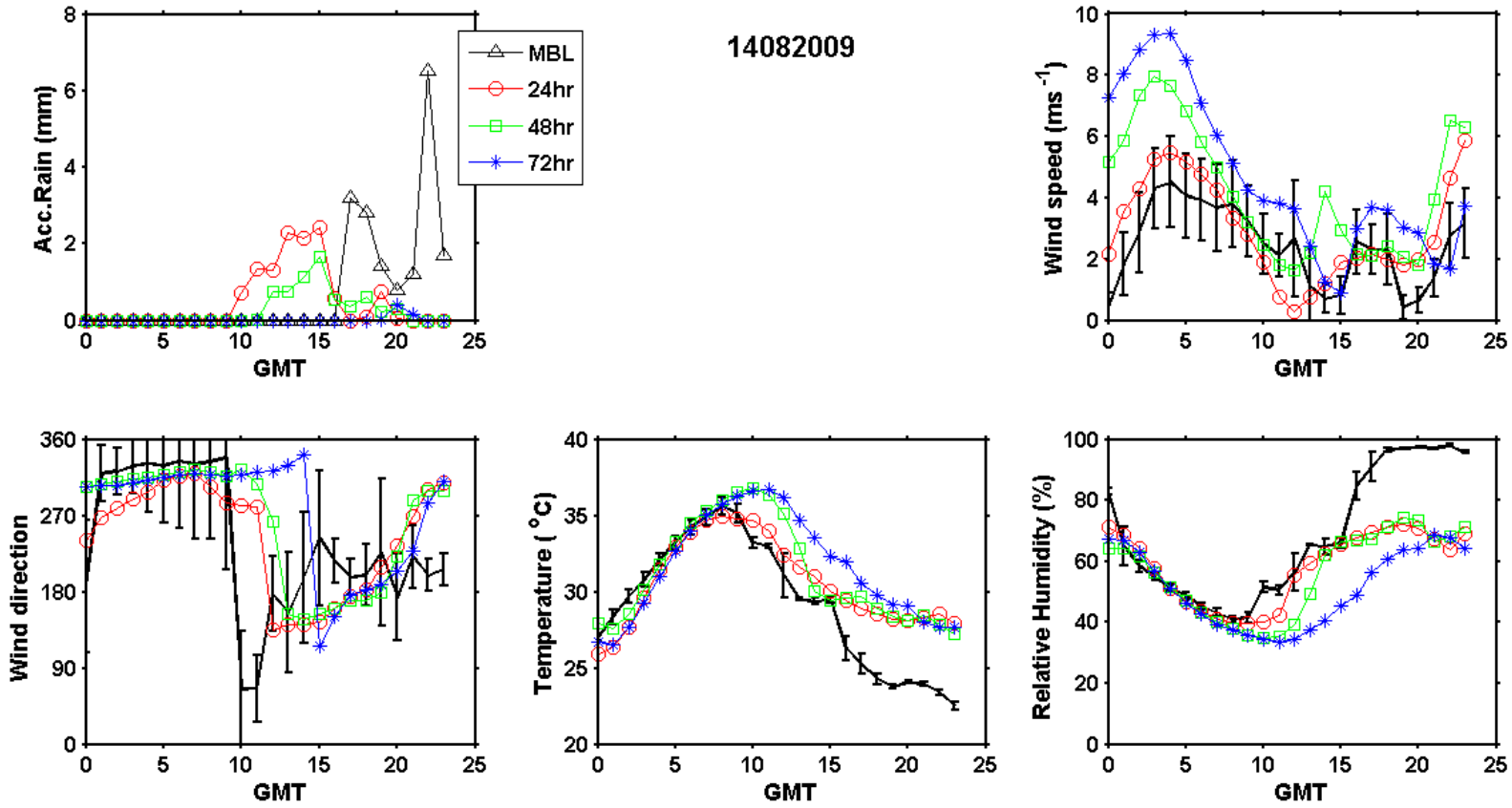
Case 3: Jul 04 2009, 12:45:00 – 14:17:00 UTC



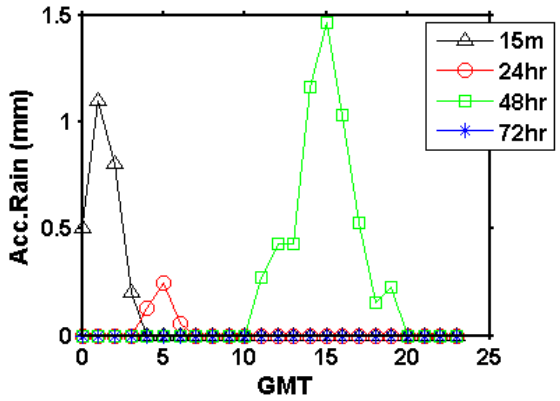
Case 4: Jul 09, 2009 11:44:00 – 12:40:00 UTC



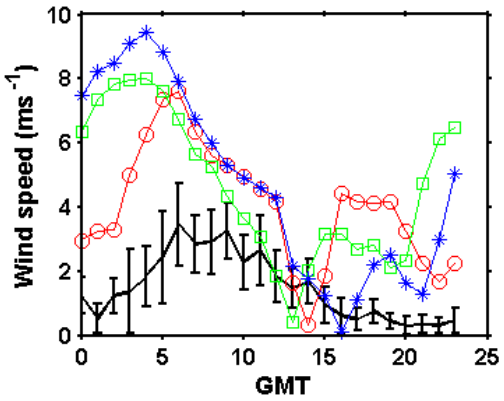
Case 5: 06:30:00 PM 14 Aug 2009 04:22:00 PM 15 Aug 2009

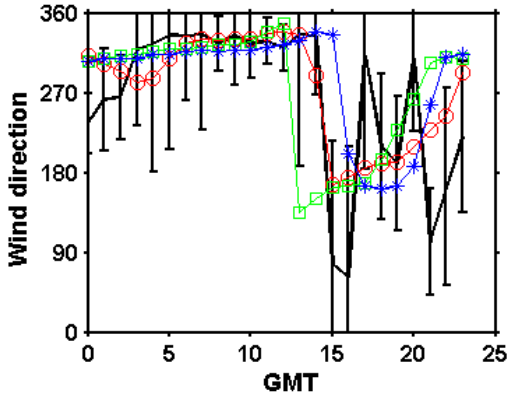


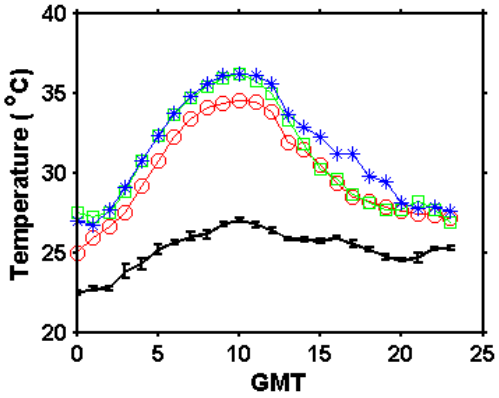
Case 6: 15 Aug 2009 00:00:00 - 04:22:00

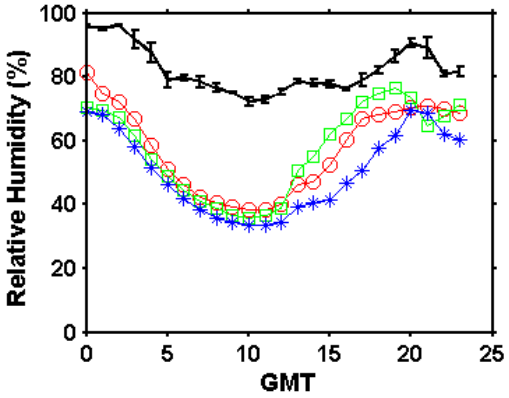


15082009

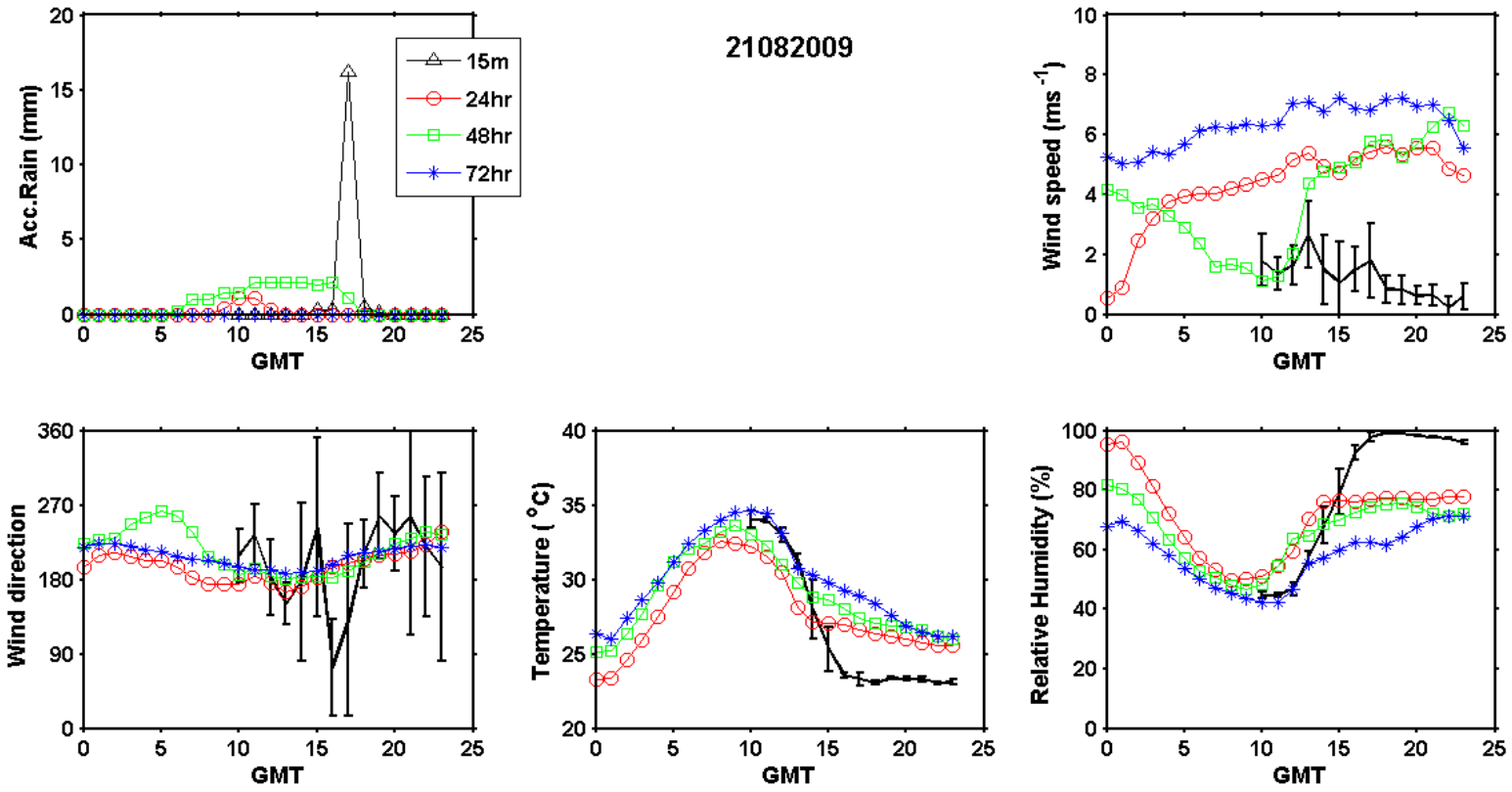




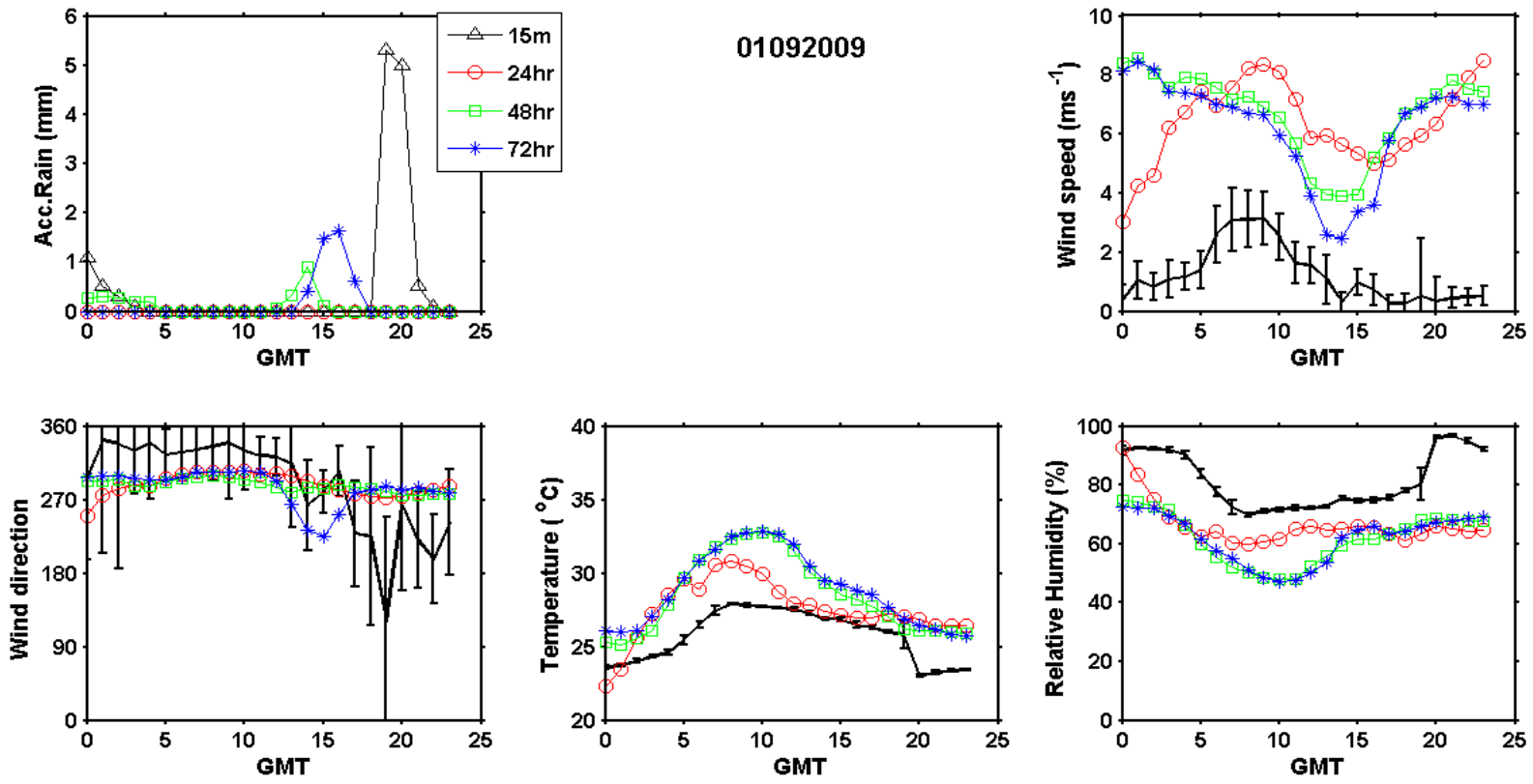




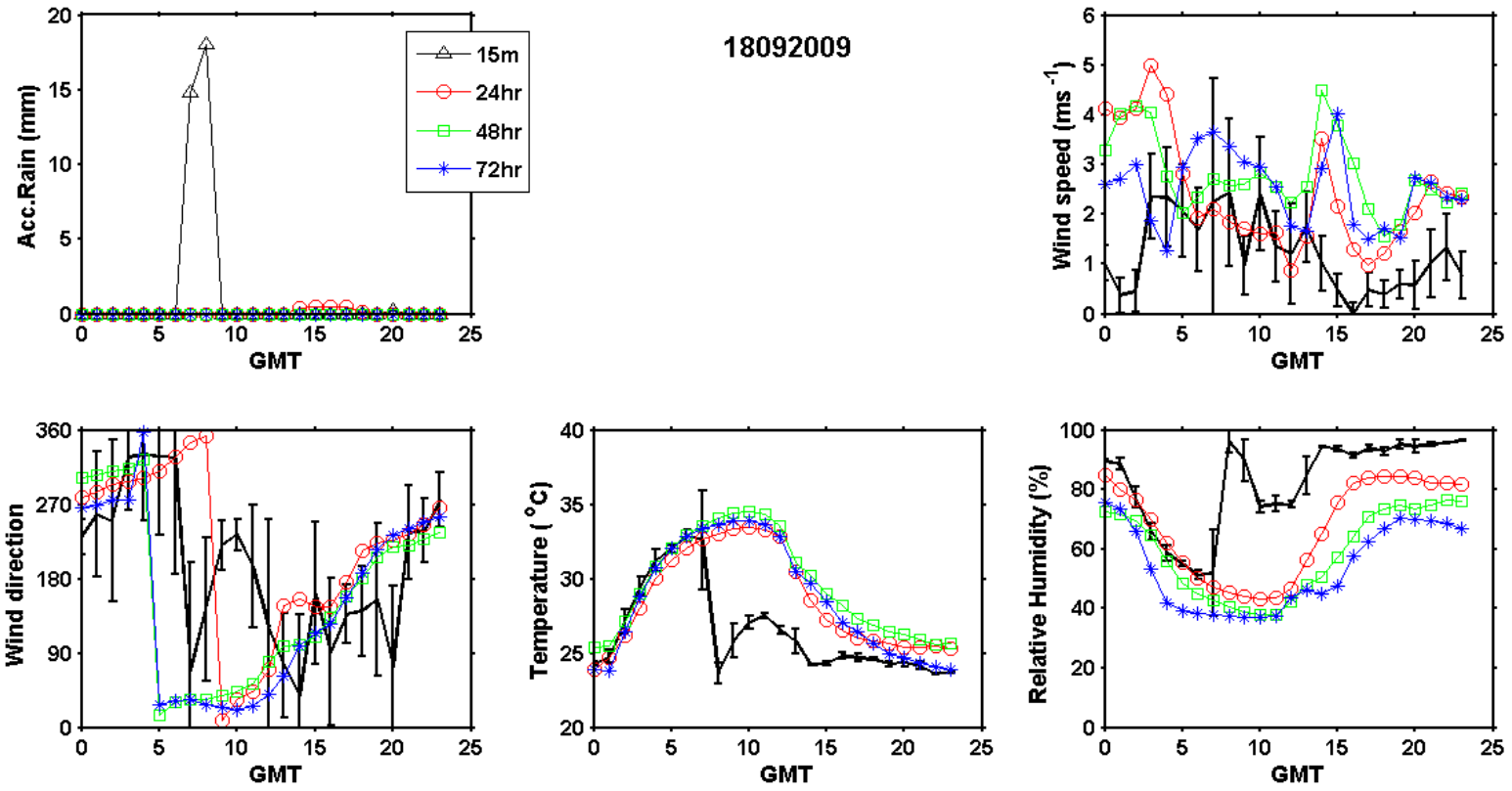
Case 7: Aug 21, 2009 17:10:00 – 18:07:00 UTC



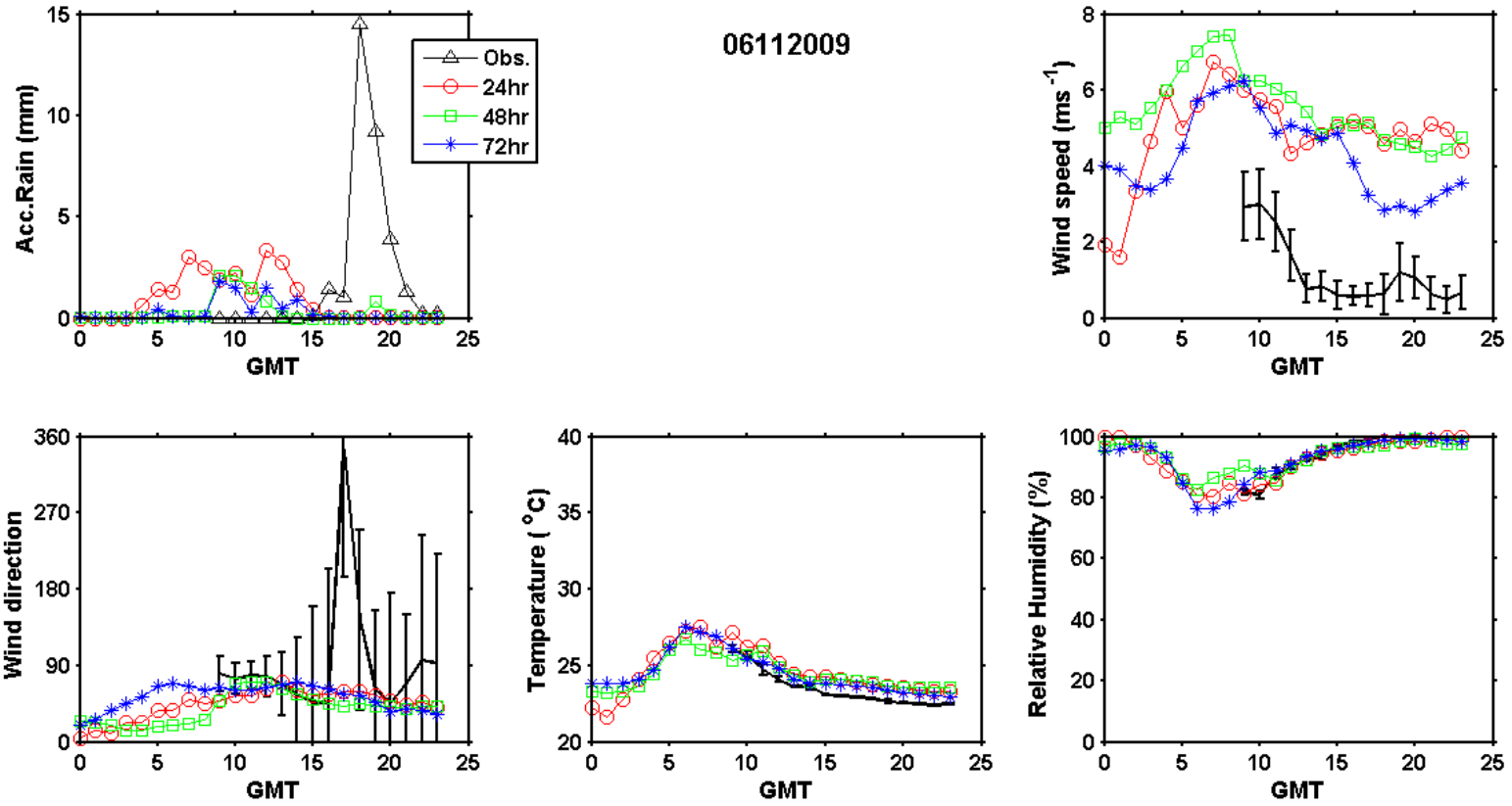
Case 8: Sep 01, 2009 19:29:00 – 21:26:00 UTC



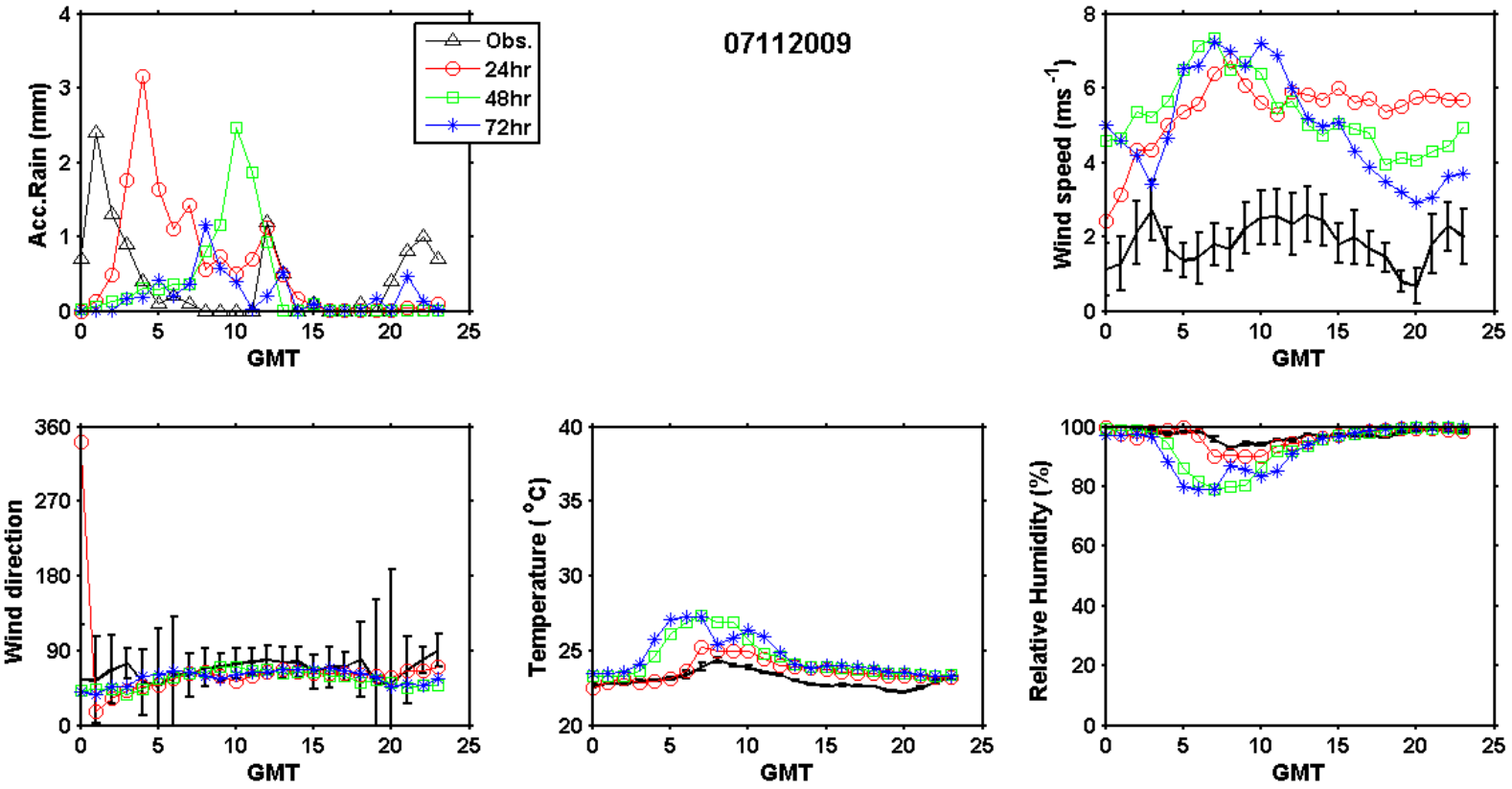
Case 9: Sep 18, 2009 07:49:00 – 08:54:00 UTC



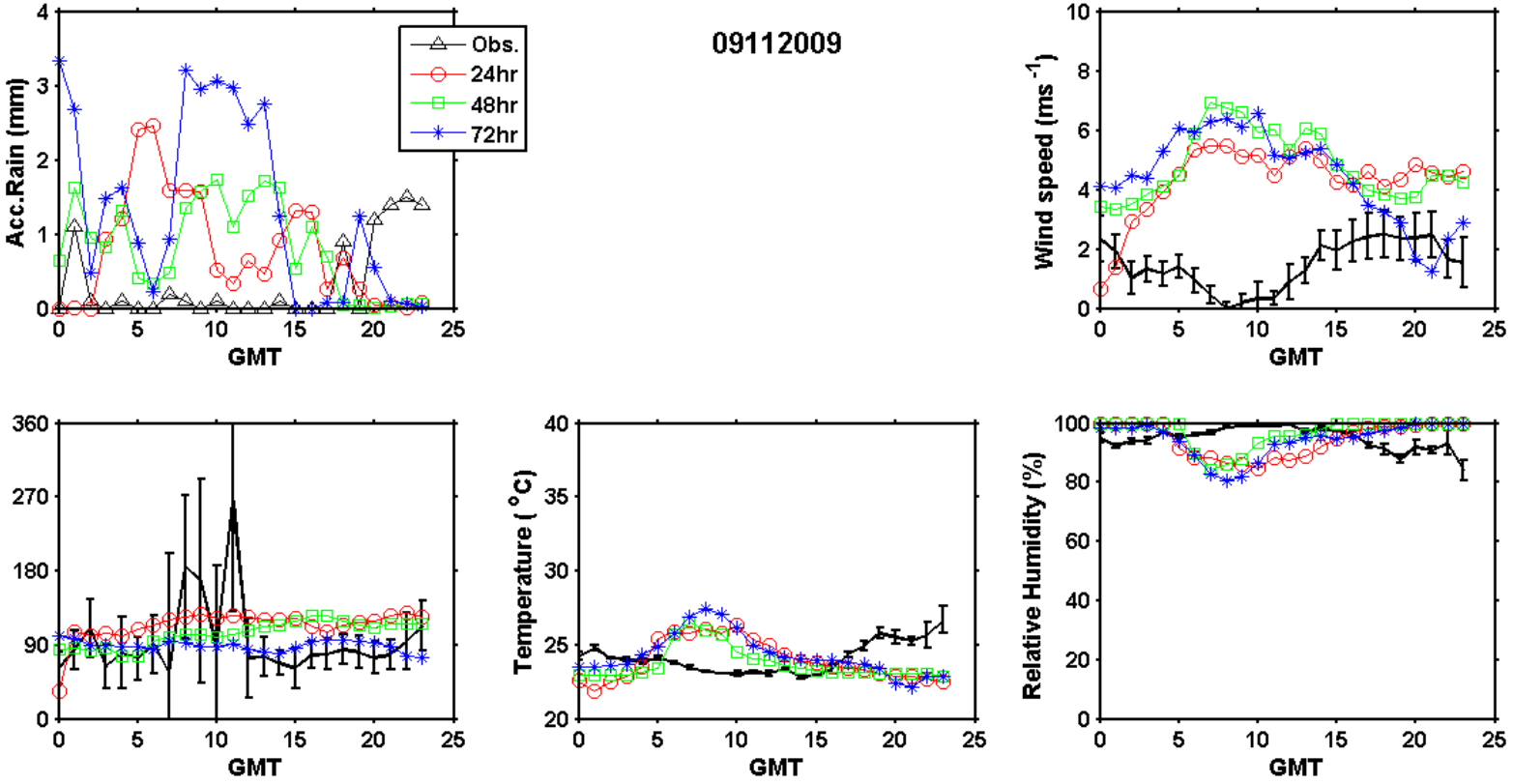
Case 10: Nov 06, 2009 18:30:00 -23:04:00 UTC



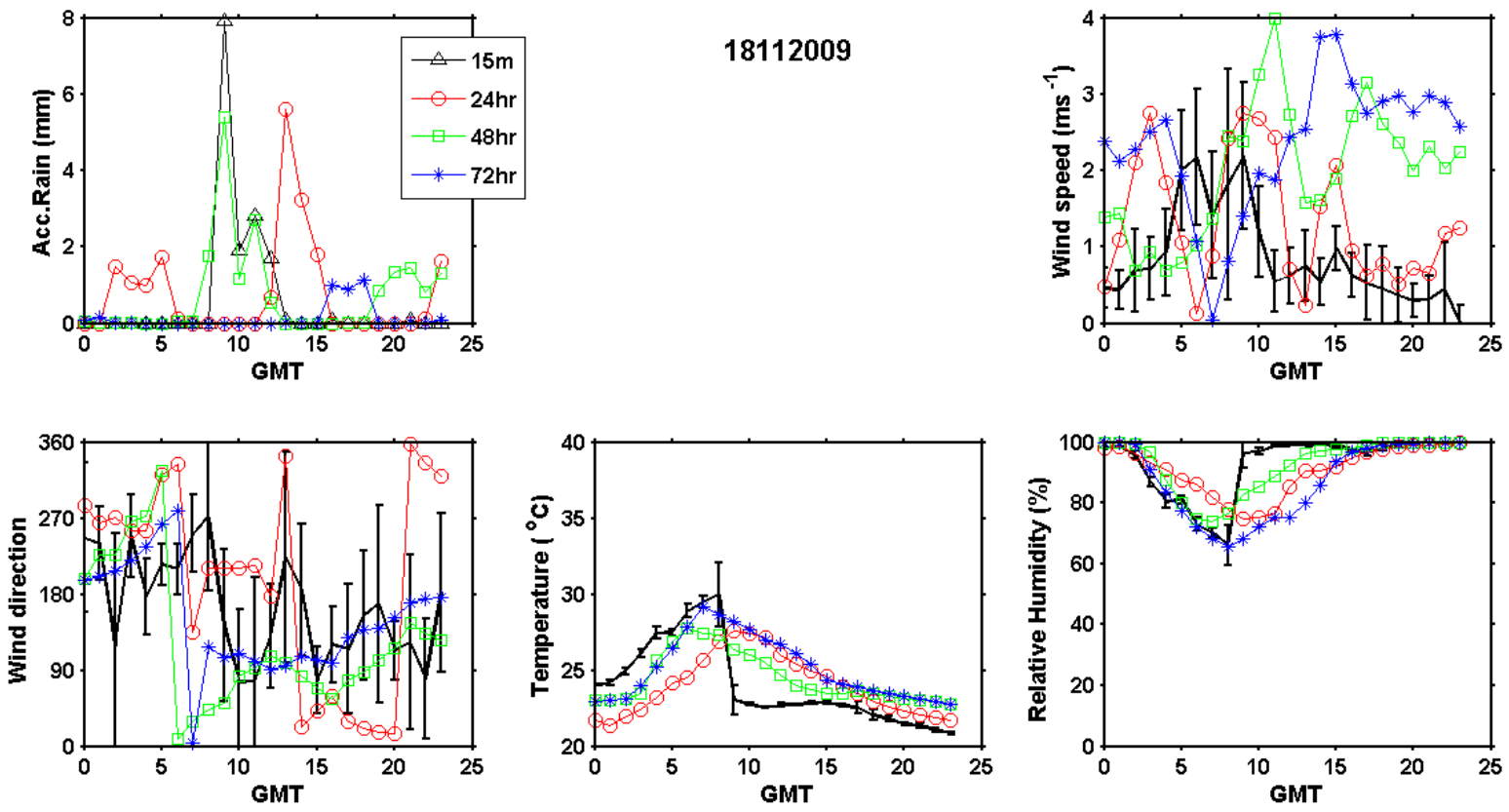
Case 11:


07112009
Obs.
24hr
48hr
72hr
Acc.Rain (mm)
Wind speed (ms-1)
Wind direction
Temperature (°C)
Relative Humidity (%)
GMT

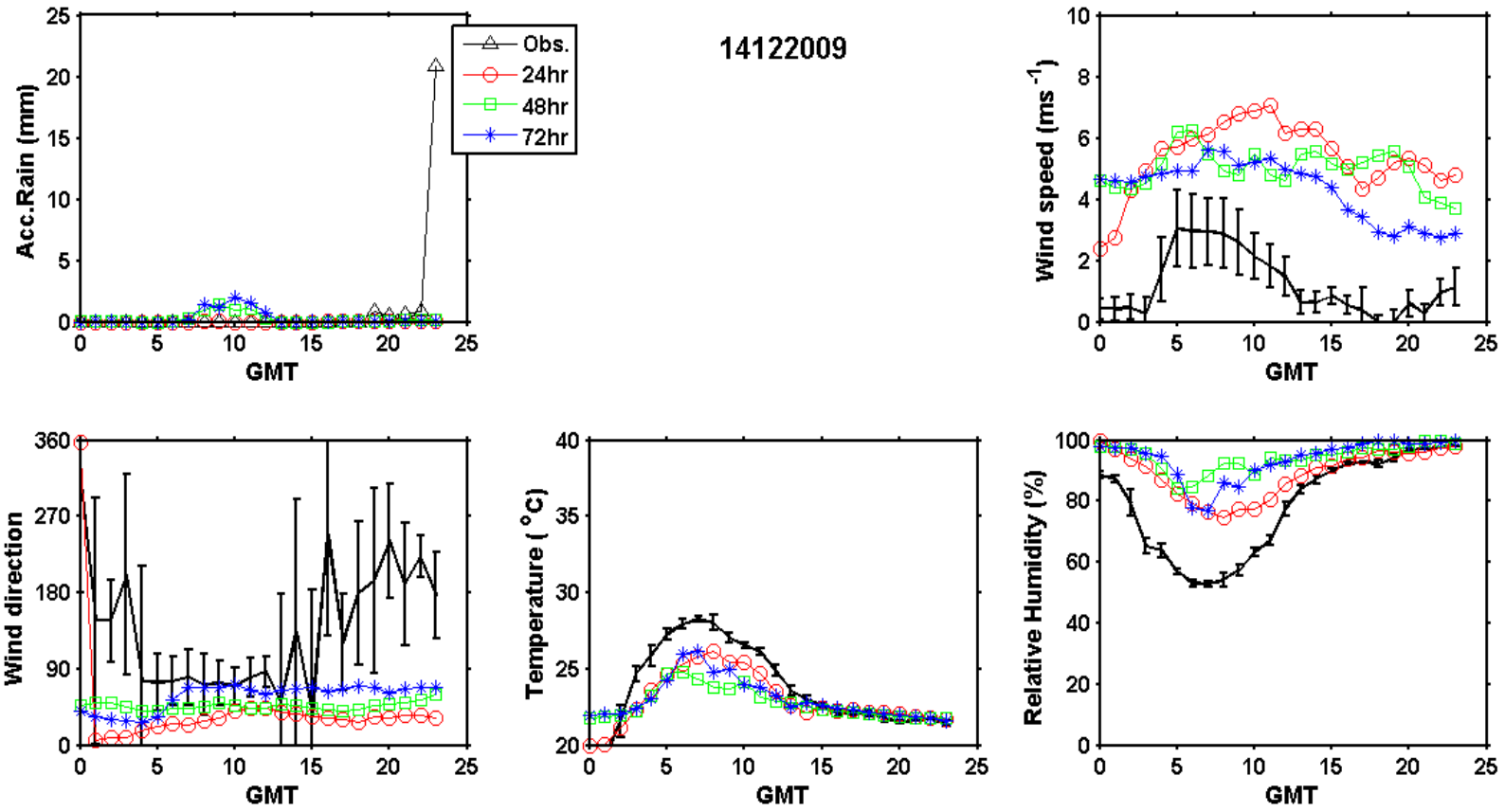
Case 12: Nov 08 18:30:00 UTC – Nov 09 00:50:00 UTC



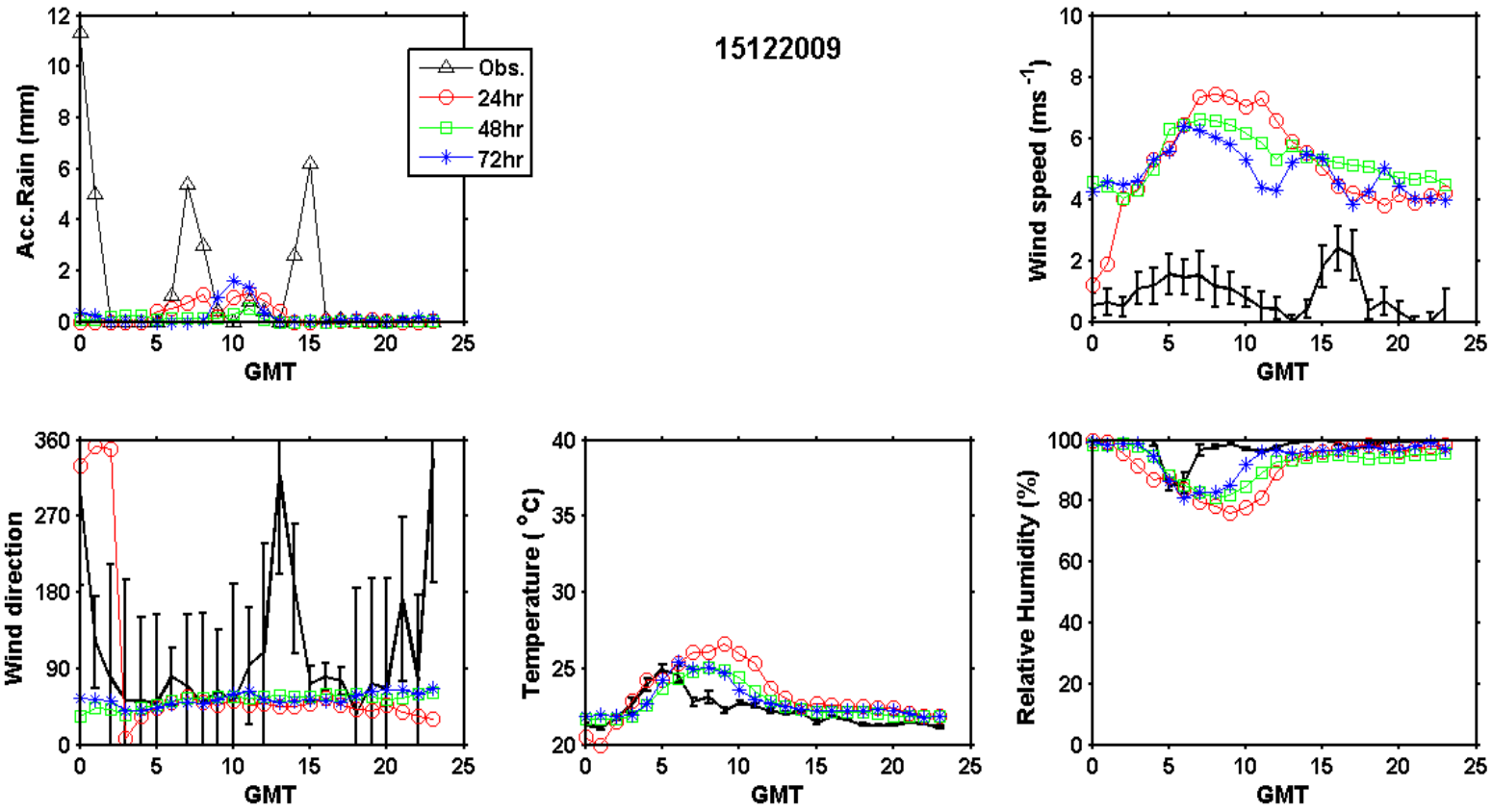
Case 13: Nov 18, 2009 09:05:00 – 13:18:00 UTC



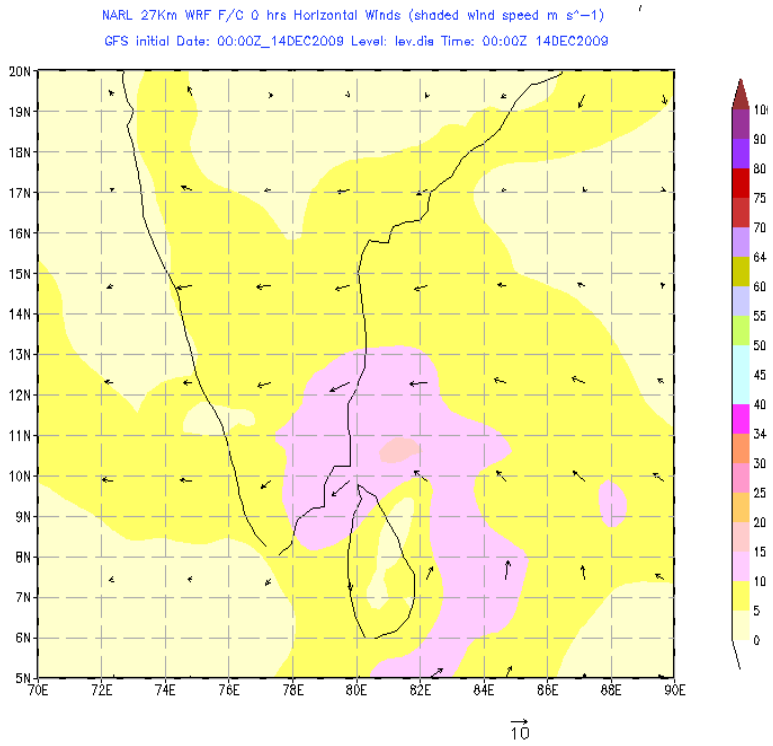
Case 14: 14th Dec 2009 22:28:00 UTC – 15 Dec 2009 02:03:00 UTC

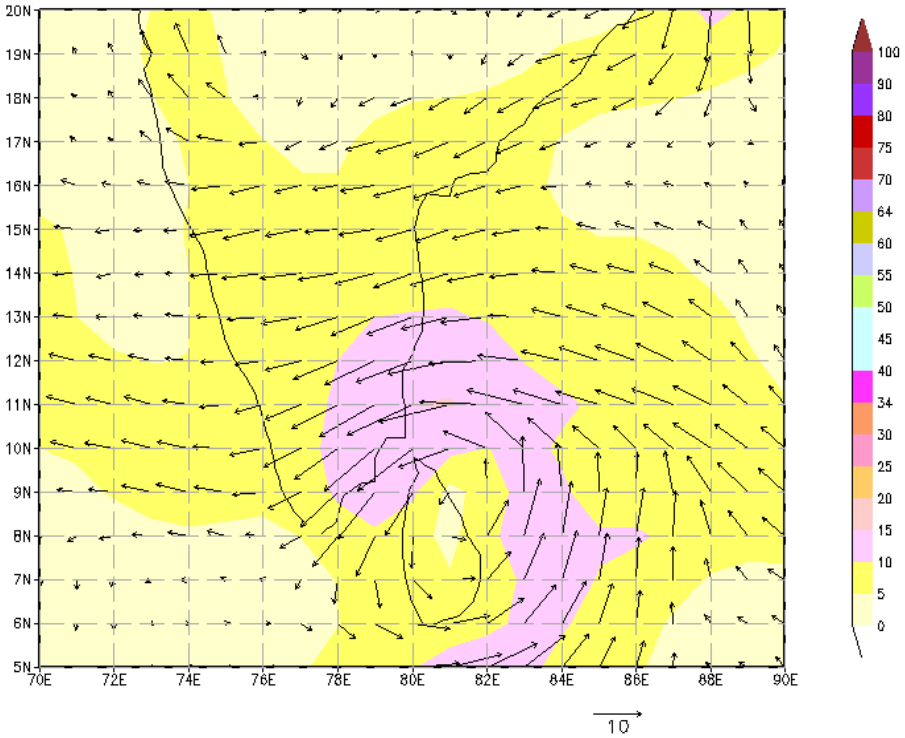


Case 15: Dec 15, 2009 13:32:00 – 17:26:00 UTC

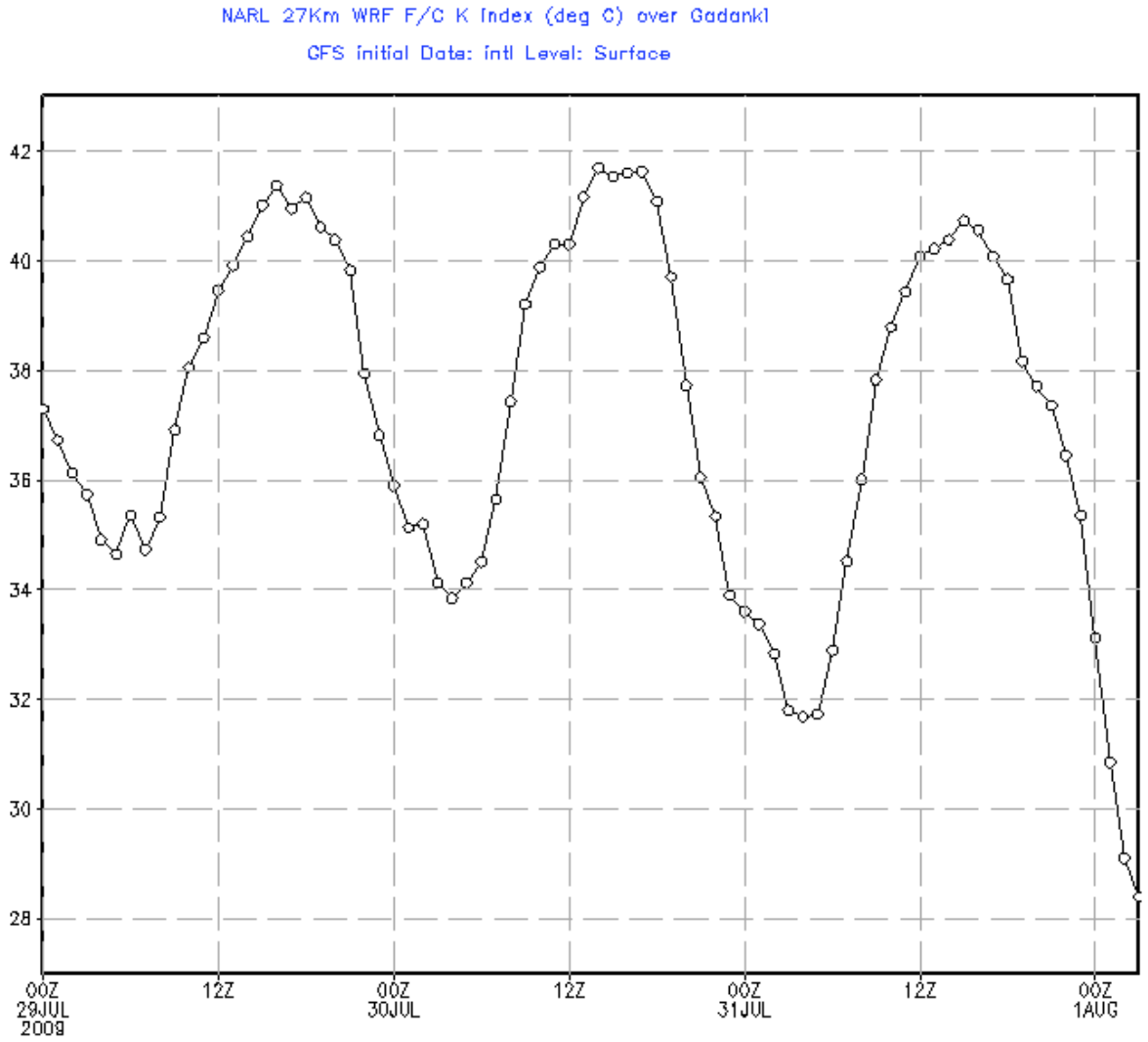


Typical Wind Validation

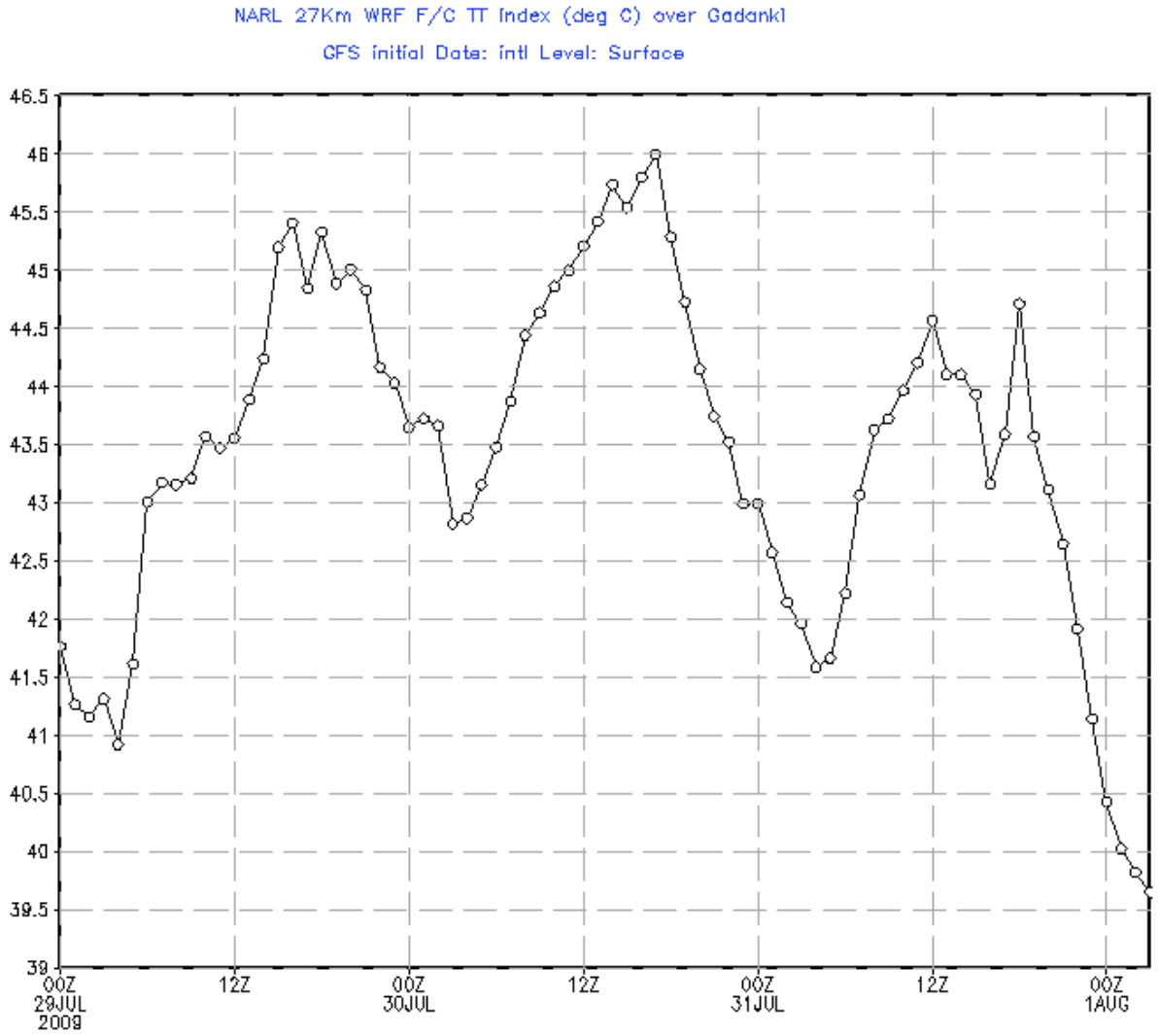




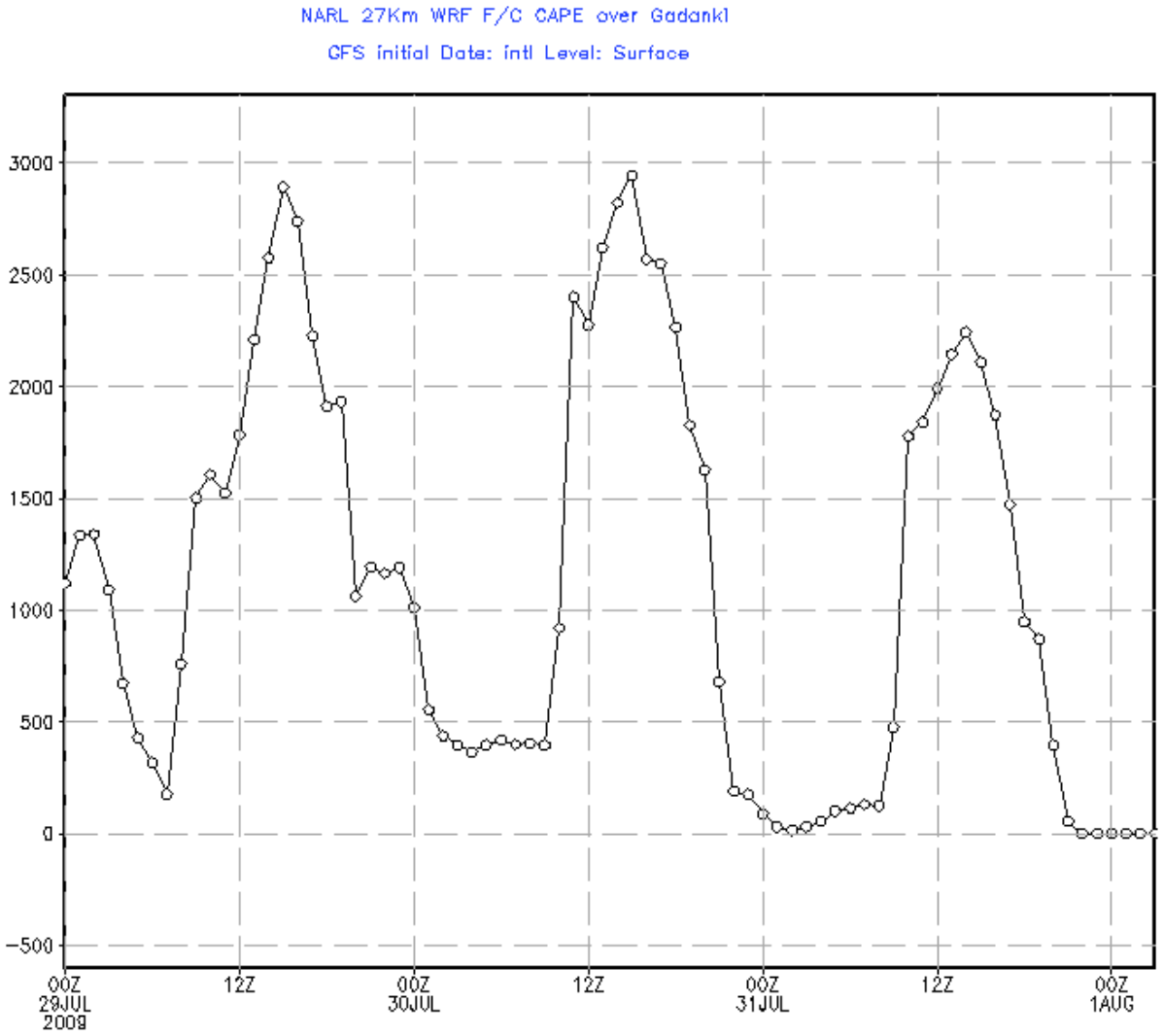
July 29 , 2009:17:30 – 21:30 UTC



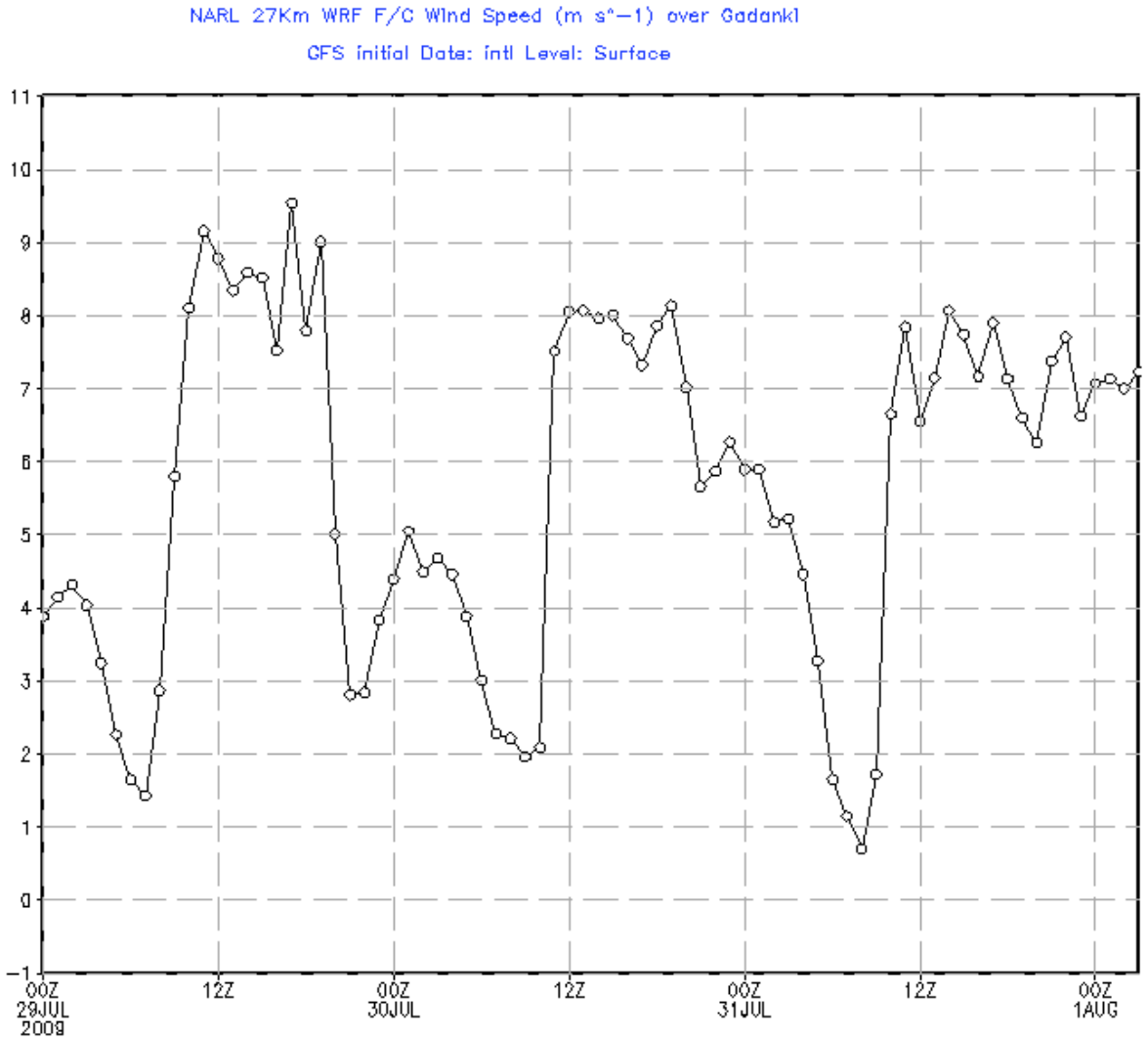
July 29 , 2009:17:30 – 21:30 UTC



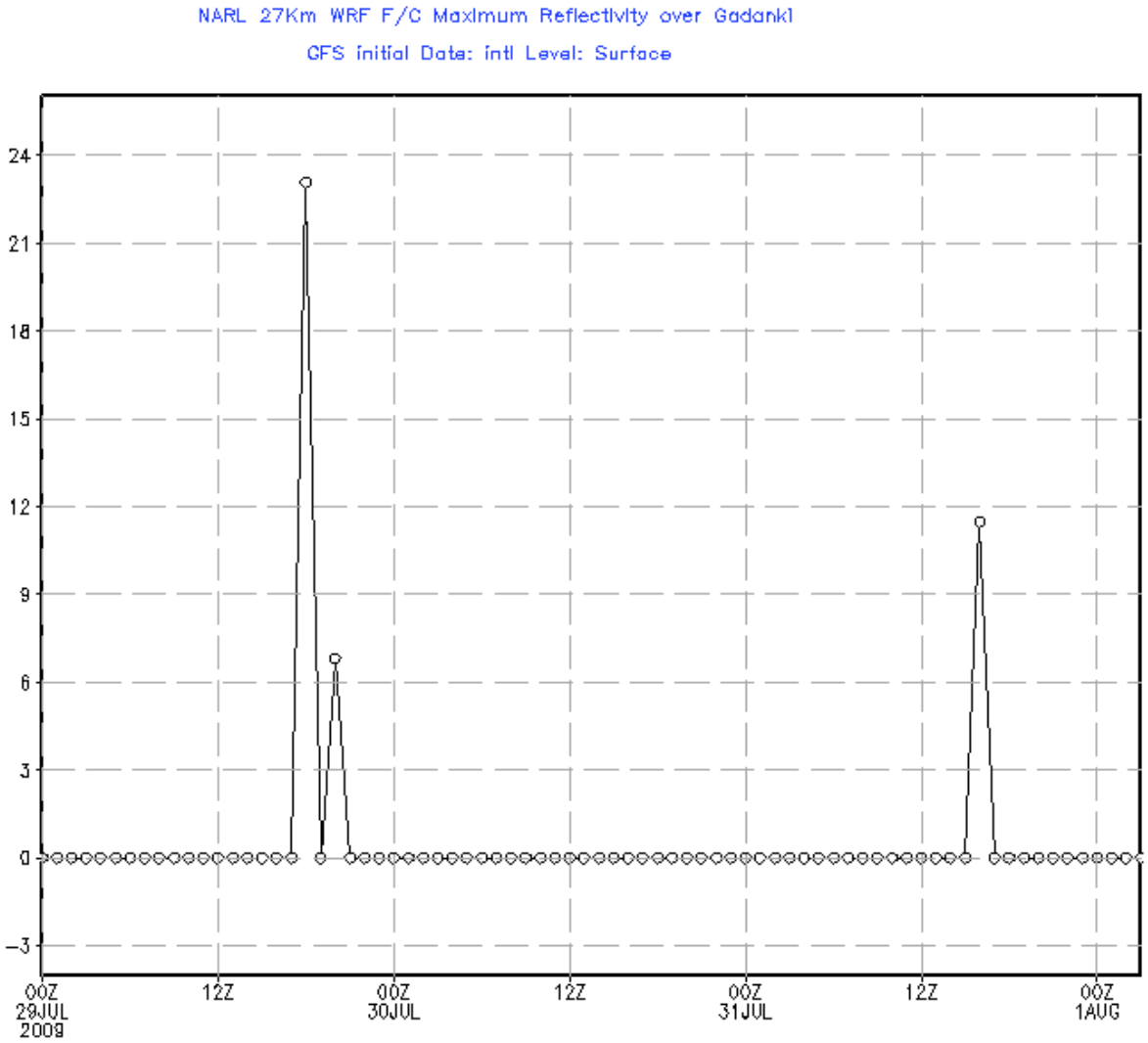
July 29 , 2009:17:30 – 21:30 UTC



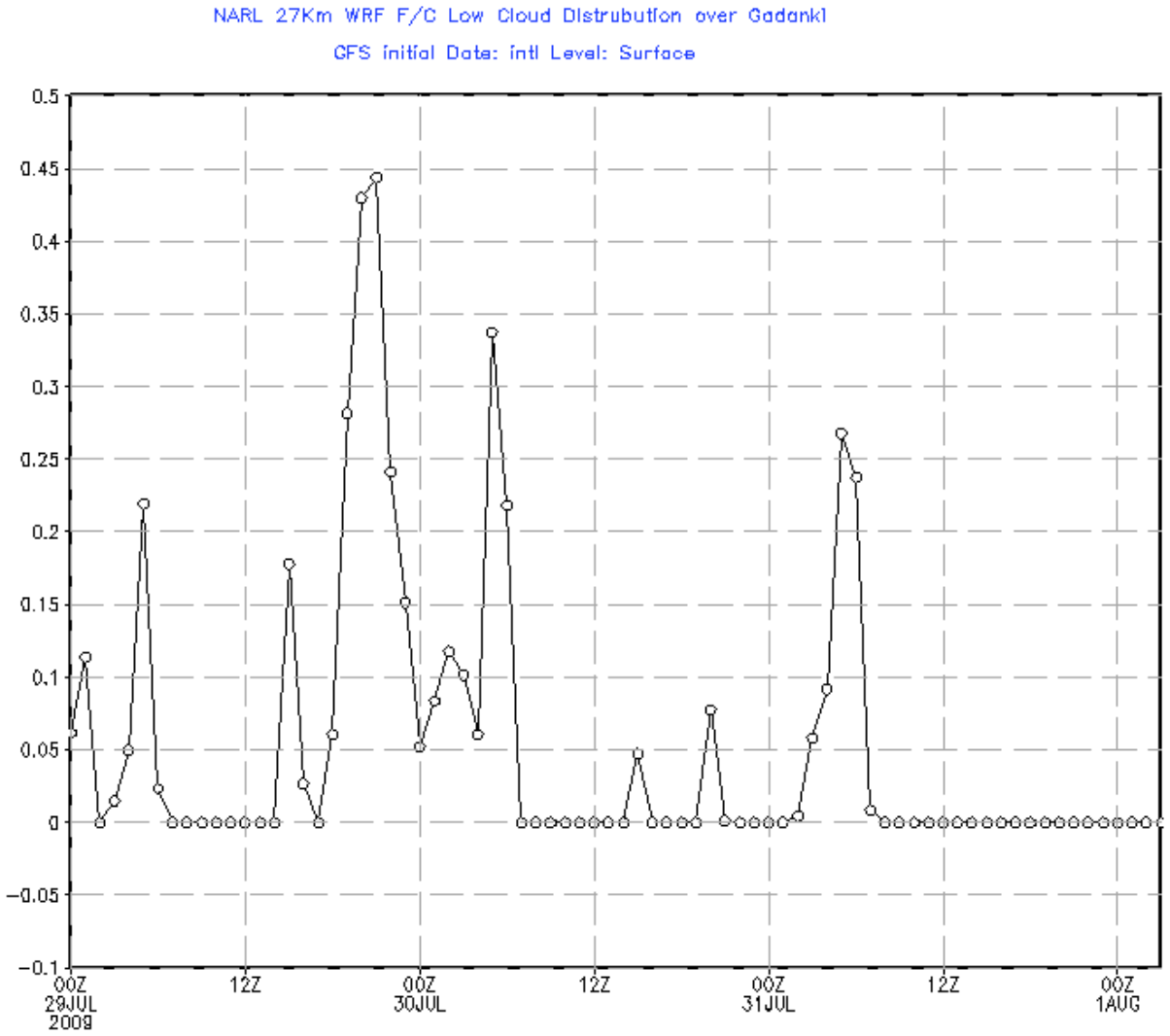
July 29 , 2009:17:30 – 21:30 UTC



July 29 , 2009:17:30 – 21:30 UTC



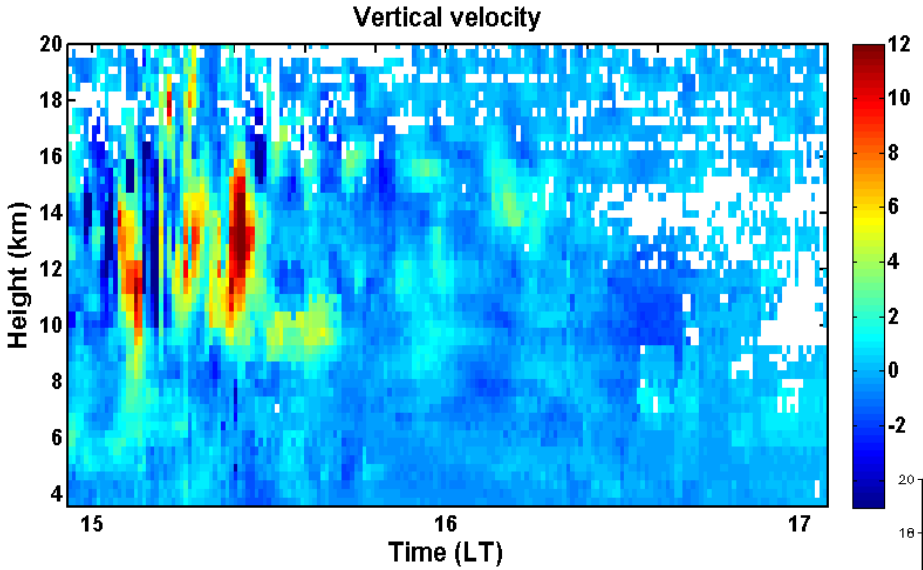
July 29 , 2009:17:30 – 21:30 UTC



Validation of Time of Occurrence and Duration

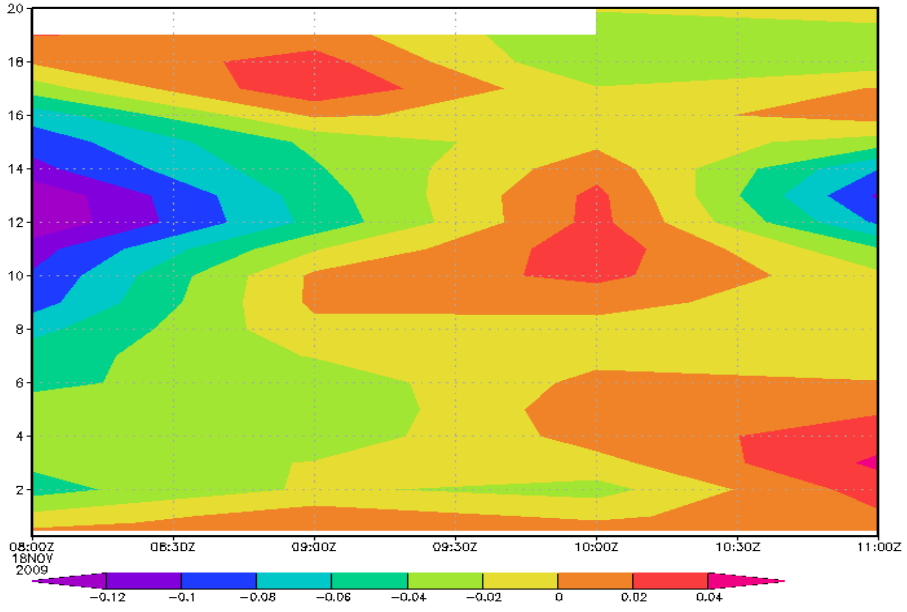
EVENT TIME			MODEL PREDICTION(KI)			MODEL PREDICTION(TTI)			
			48-72 HRS BEFORE	24-48HRS BEFORE	0-24 HRS BEFORE	48-72 HRS BEFORE	24-48HRS BEFORE	0-24 HRS BEFORE	
	IST	GMT	28062009	29062009	30062009	28062009	29062009	30062009	
30/6/2009	18:27	12:00	9:00-12:00	8:00-13:00	8:00-14:00	8:00-15:00	8:00-16:00	**7:00-14:00**	
	20:24	14:00							
			2072009	**3072009**	**4072009**	**2072009**	**3072009**	**4072009**	
4/7/2009	18:15	12:00	8:00-14:00	9:00-12:00	8:00-11:00	6:00-18:00	7:00-14:00	7:00-13:00	
	19:47	13:00							
			7072009	**8072009**		**7072009**	**8072009**	**9072009**	
9/7/2009	17:14	11:00	11:00	11:00		6:00-16:00	4:00-22:00	6:00-11:00	
	18:10	12:00							
			13082009	**14082009**	**15082009**	**13082009**	**14082009**	**15082009**	
15/8/2009	0:00	19:00	11:00-18:00	10:00-19:00	16:00-18:00	10:00-23:00	0:00-3:00	0:00-4:00	
	9:52	5:00					7:00-23:00		
						19082009	**20082009**	**21082009**	**22082009**
21/8/2009	22:40	17:00				0:00	8:00-9:00	0:00-2:00	0:00-3:00
	23:37	18:00				7:00-22:00	17:00-23:00	5:00-23:00	
			31082009	**1092009**	**2092009**	**31082009**	**1092009**	**2092009**	
2/9/2009	0:59	19:00	13:00-23:00	0:00-2:00	13:00-16:00	0:00-23:00	0:00-23:00	0:00-2:00	
	2:56	22:00		8:00-20:00				13:00-16:00	
						16092009			
18/9/2009	13:19	11:00				0:00-1:00			
	14:24	12:00				14:00-22:00			
						16112009	**17112009**	**18112009**	**19112009**
18/11/2009	14:35	9:00				7:00-8:00	8:00-17:00	7:00-23:00	0:00-1:00
	18:48	13:00							

Validation of Vertical Velocity

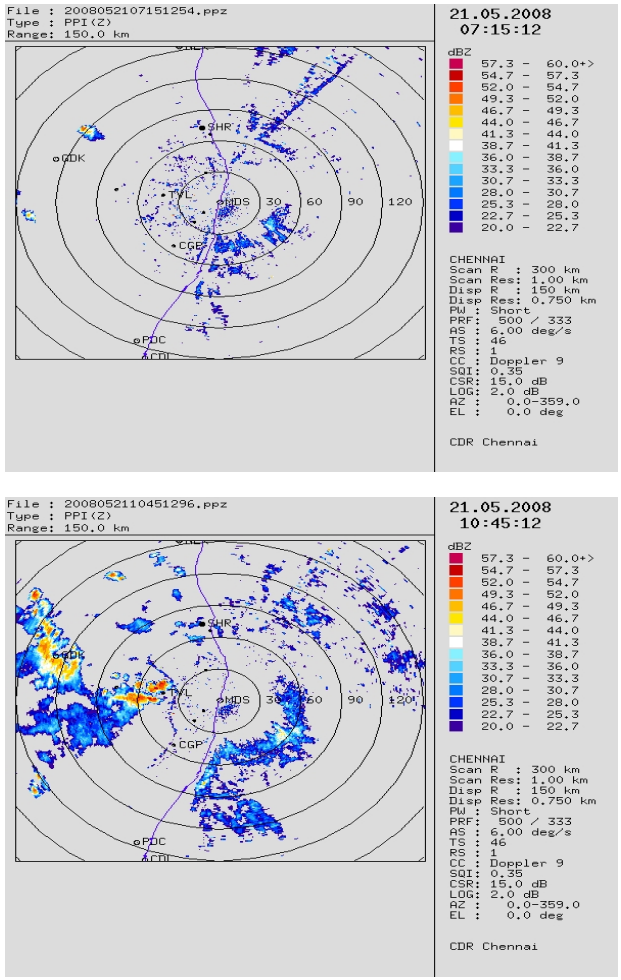


Vertical Velocity Observed by MST RADAR on 18th November 2009

Vertical Velocity Simulated by WRF based on GFS initial conditions of 18th November 2009



The Thunderstorm : 21 May 2008



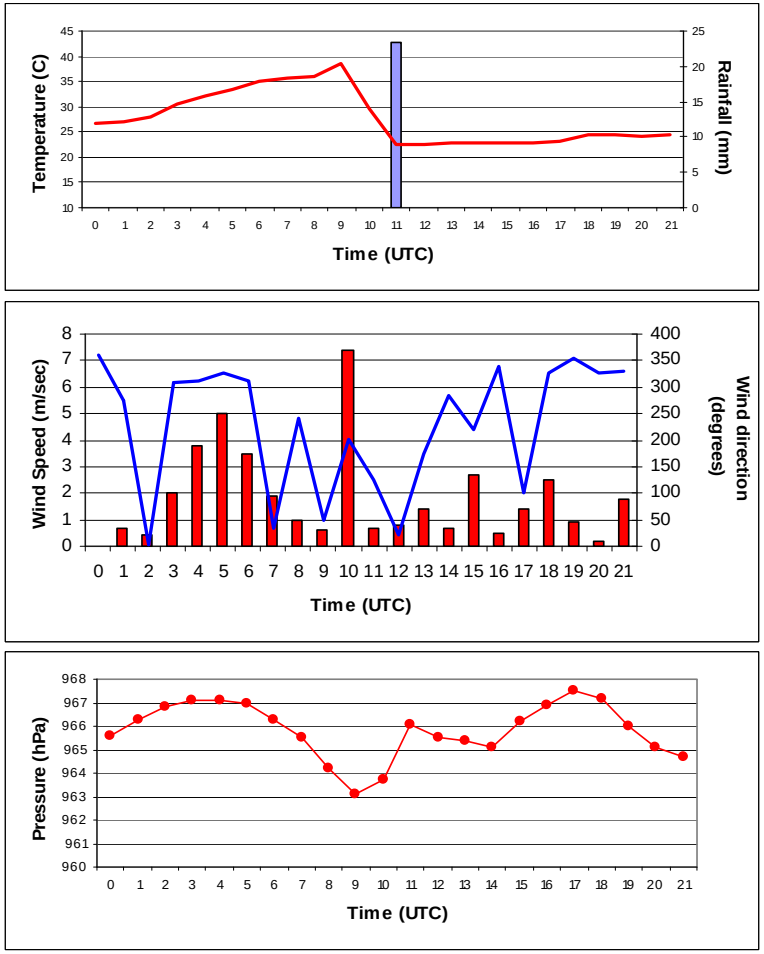


Fig.Details of the thunderstorm observed over Gadanki on 21 May 2008. Left panels show the Doppler Radar reflectivity maps taken at 0715 hrs UTC (top) and 1045 hrs UTC (below). The right panels show the variation of meteorological parameters associated with the passage of the thunderstorm. The top panel shows the variation of dry bulb temperature (line) and rainfall in mm (vertical bar). The middle panel shows variation of wind direction (line) and wind speed (vertical bars). The bottom panel shows the variation of surface pressure on 21 May 2008.

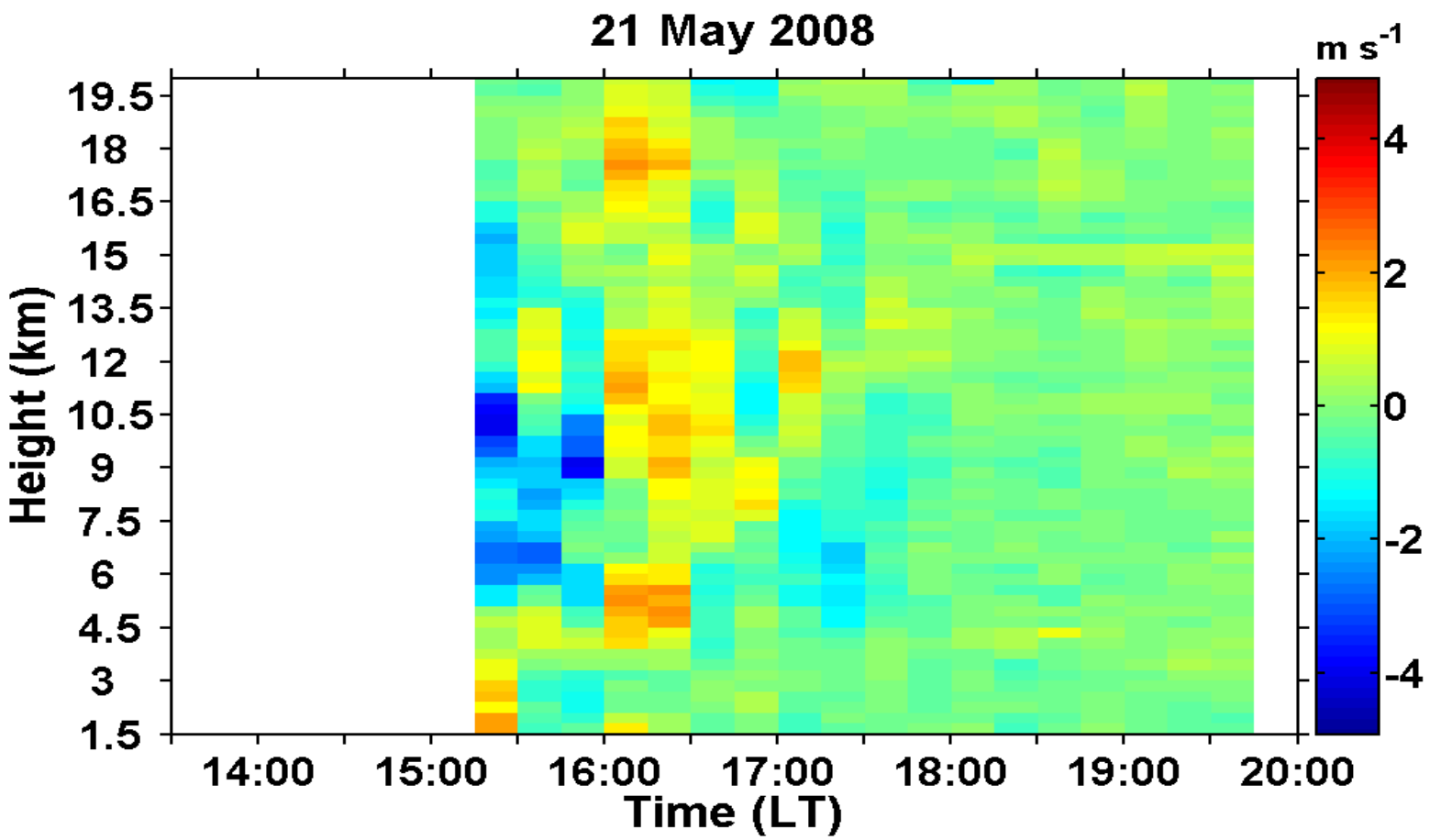
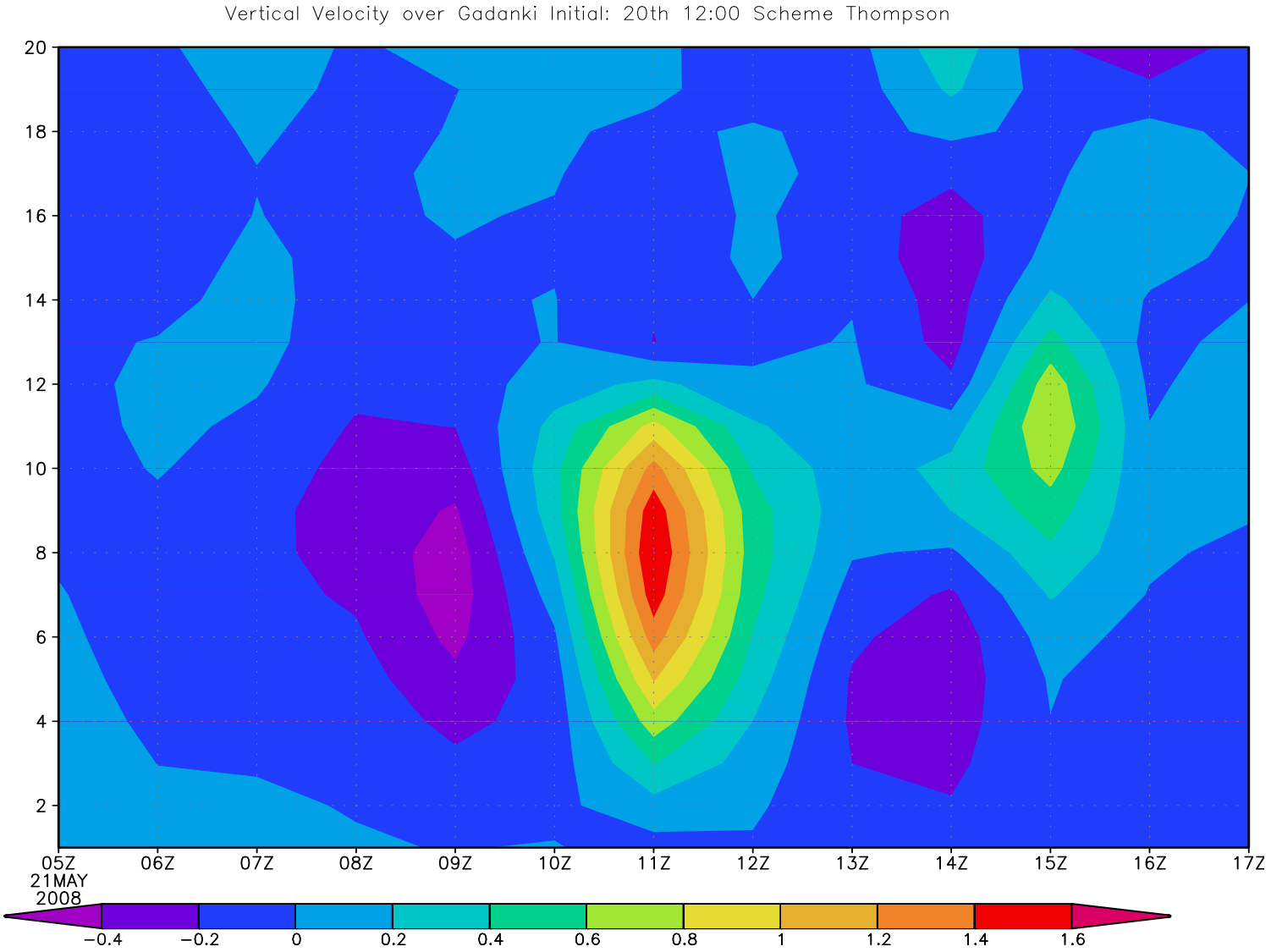
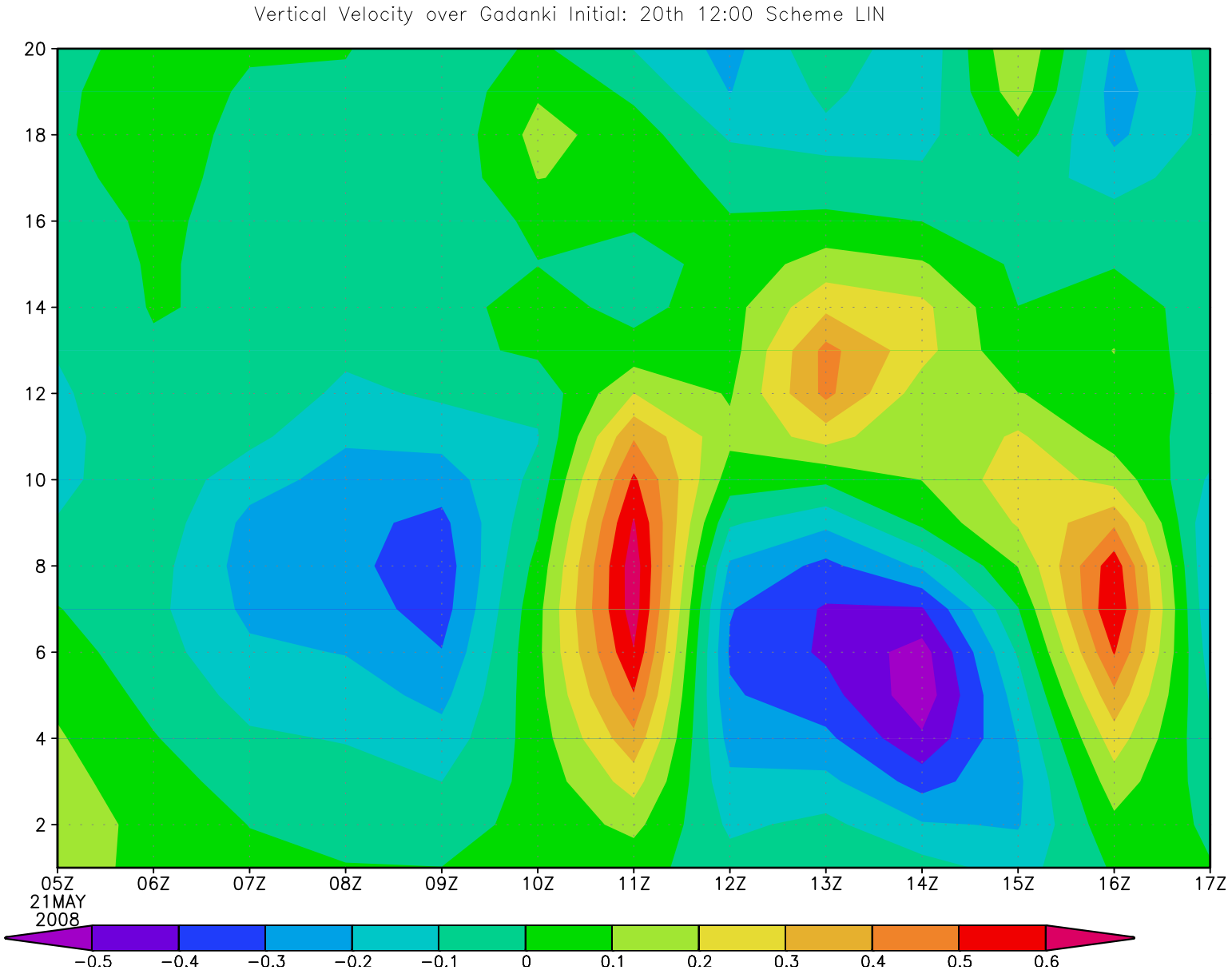
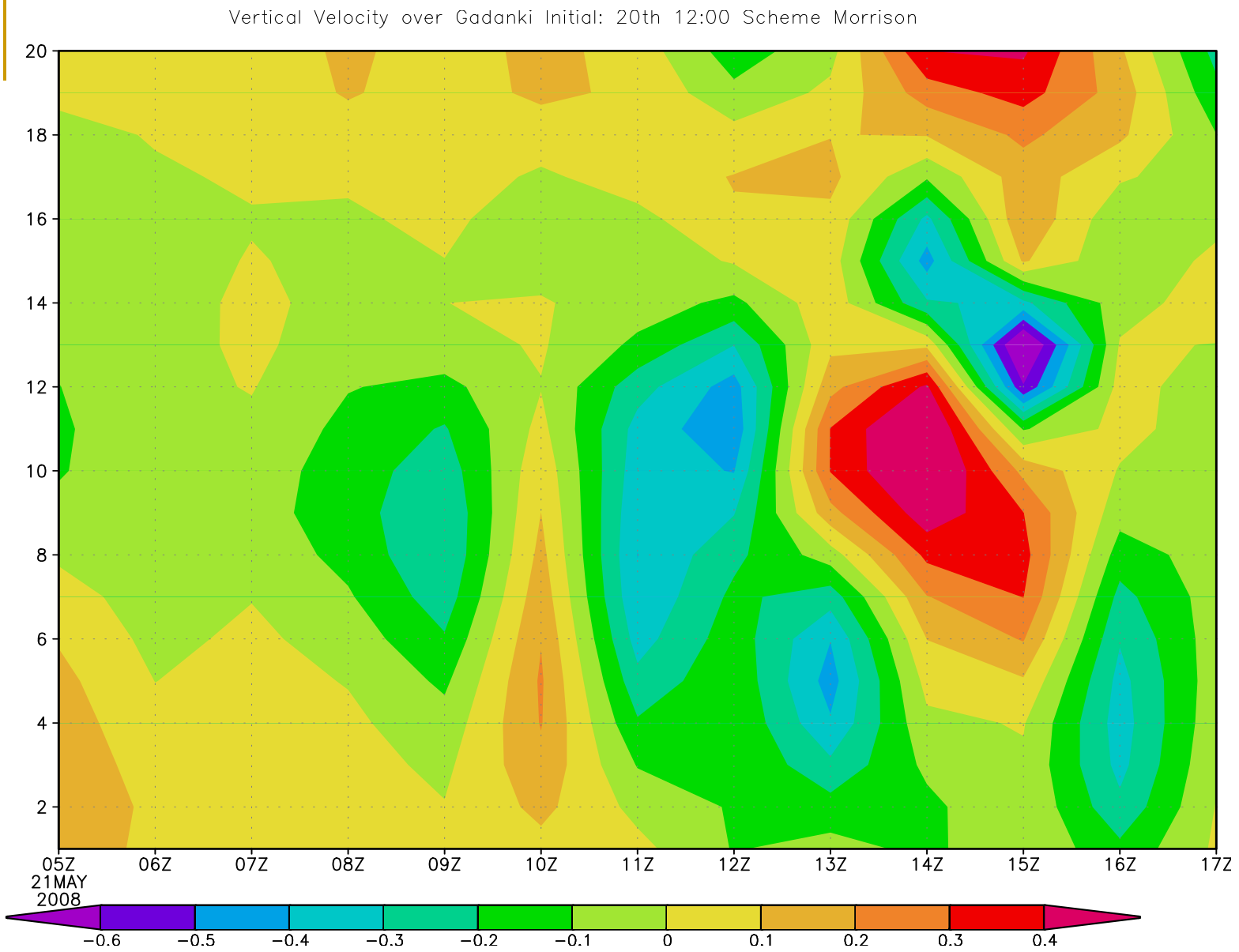
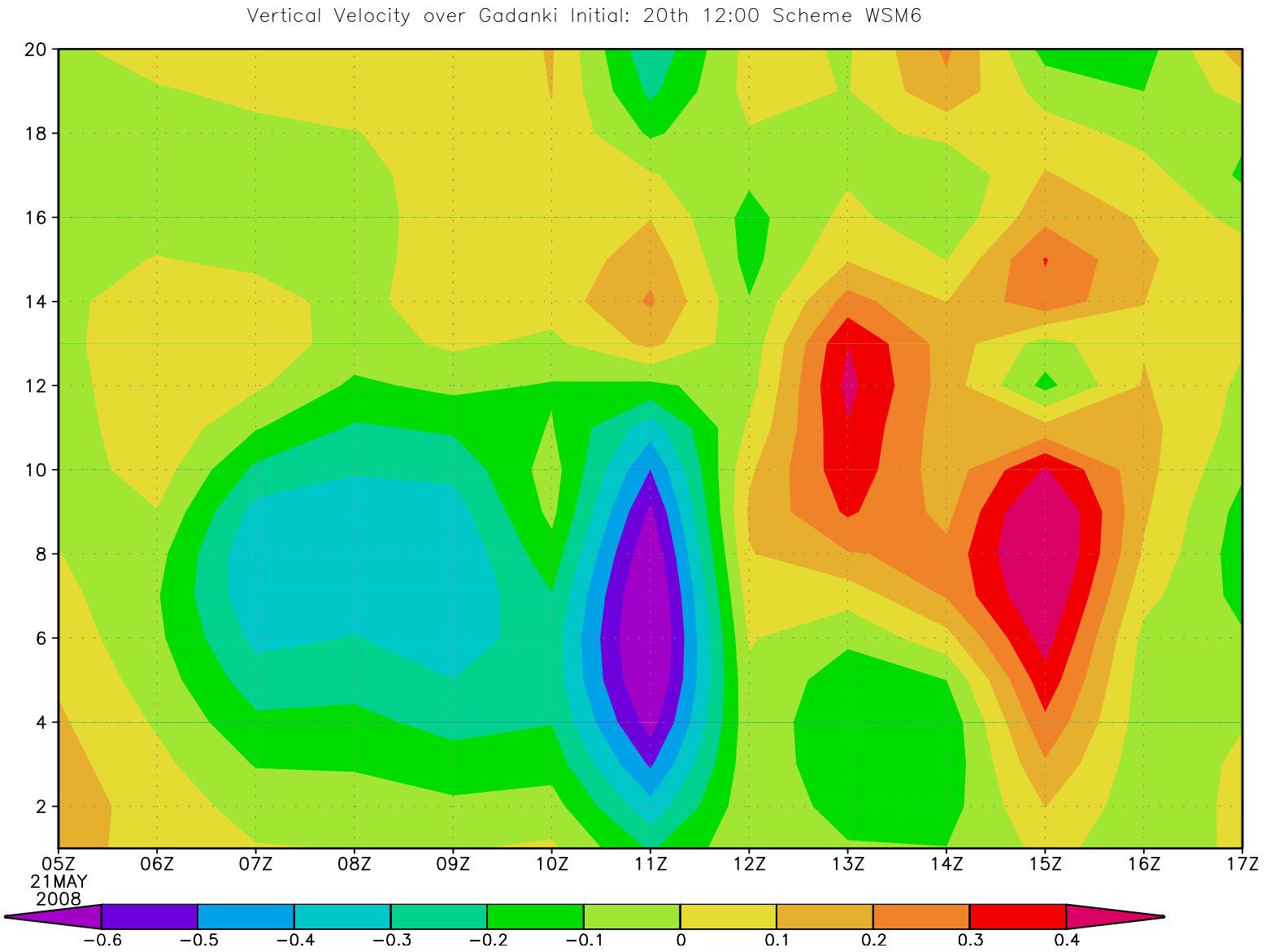


Fig.3 Vertical velocity (m/sec) derived from the MST radar data on 21 May 2008. The top panel shows wind speed averaged over a minute and the bottom panel shows the same averaged over 15 minutes.


Vertical Velocity over Gadanki Initial: 20th 12:00 Scheme Thompson
20
18
16
14
12
10
8
6
4
2
05Z
21MAY
2008
06Z
07Z
08Z
09Z
10Z
11Z
12Z
13Z
14Z
15Z
16Z
17Z
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6


Vertical Velocity over Gadanki Initial: 20th 12:00 Scheme LIN
20
18
16
14
12
10
8
6
4
2
05Z
21MAY
2008
06Z
07Z
08Z
09Z
10Z
11Z
12Z
13Z
14Z
15Z
16Z
17Z
−0.5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
0.4
0.5
0.6


Vertical Velocity over Gadanki Initial: 20th 12:00 Scheme Morrison
20
18
16
14
12
10
8
6
4
2
05Z
21MAY
2008
06Z
07Z
08Z
09Z
10Z
11Z
12Z
13Z
14Z
15Z
16Z
17Z
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
0.4


Vertical Velocity over Gadanki Initial: 20th 12:00 Scheme WSM6
20
18
16
14
12
10
8
6
4
2
05Z
21MAY
2008
06Z
07Z
08Z
09Z
10Z
11Z
12Z
13Z
14Z
15Z
16Z
17Z
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
0.4

Conclusions

WRF is successful in simulating dynamics of dduring deep convection needs lot of attention to Atmospheric Physics representation

Underestimates rainfall however in moderate category of rainfall most of the deep convection cases

WRF does not simulate fall in temperature and changes in other surface parameters after occurence of deep convection

Use of thermodynamic indices helpful in estimating time and duration of deep convective events

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K Index

$$K = t_{850} - t_{500} + t_{d850} - t_{700} + t_{d700}$$

K value	T-Storm Probability
<15	0%
15-20	<20%
21-25	20-40%
26-30	40-60%
31-35	60-80%

Total Totals (TT)

$$TT = VT + CT = T_{850} + T_{d850} - 2\,T_{500}$$

TT	T-Storm Potential
44-45	Isolated to few moderate
46-47	scattered moderate, a few heavy
48-49	scattered moderate, a few heavy and isolated severe
50-51	scattered heavy, a few severe; isolated tornados
52-55	scattered to numerous heavy, few to scattered severe, a few tornados