Severe Weather and Early Warning System for SAARC Region

S.K. Roy Bhowmik

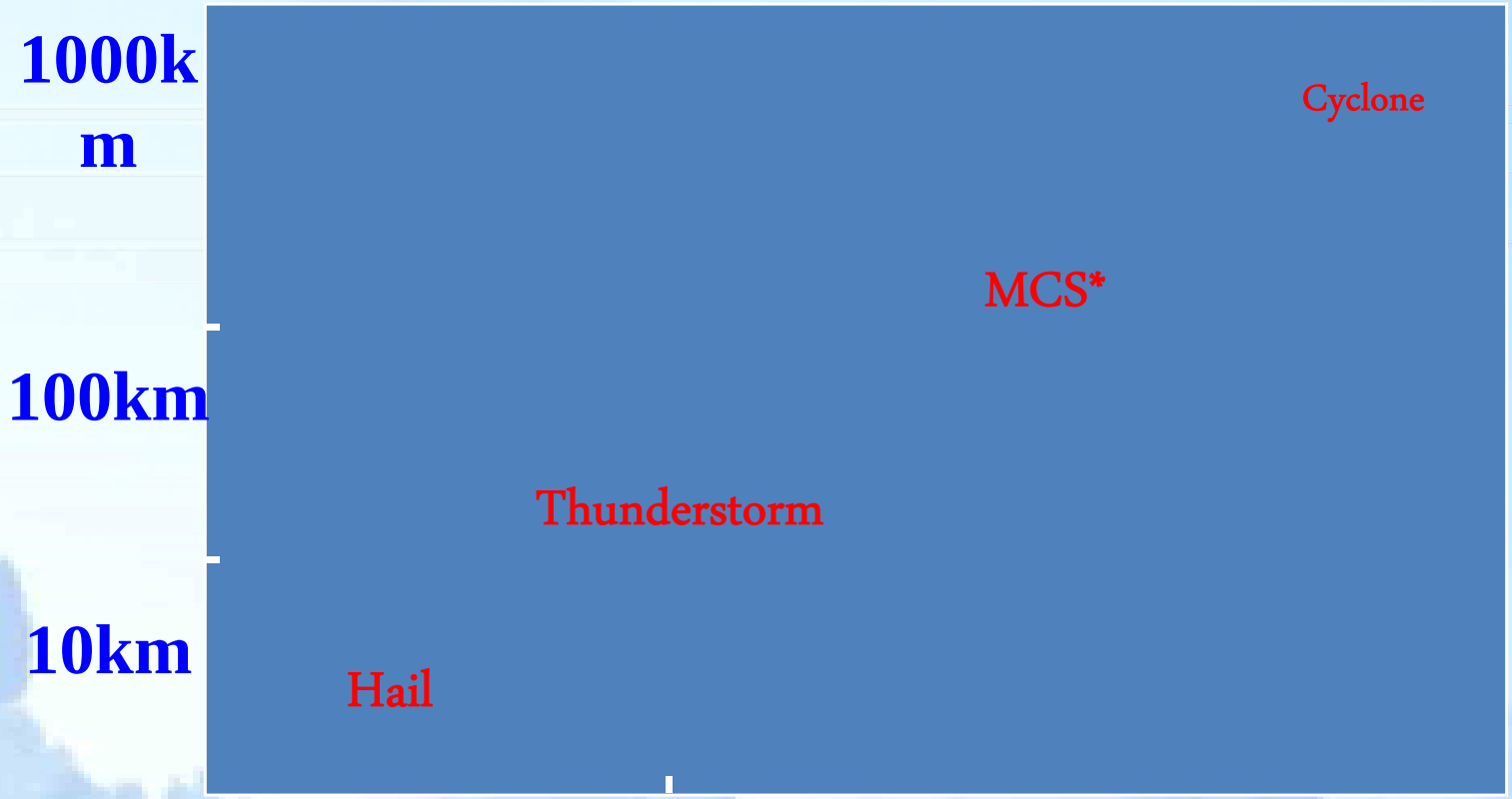
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Out Lines

- Severe weather hazards in SAARC region
- Early Warning System
- Current Operational NWP models
- User specific Forecast Products
- Forecast Performance
- Initiatives at SMRC (1991-2015)
- Future Plan
- Conclusions

Severe Weather: Scales of Motion

* Mesoscale Convective System



Hydro-meteorological Hazards: Season Specific

- **WINTER (JAN-FEB)**
  - WESTERN DISTURBANCES COLD WAVE, FOG
- **PRE-MONSOON (MAR-MAY)**
  - CYCLONIC DISTURBANCES
  - HEAT WAVE
  - THUNDER STORMS, SQUALLS
  - HAIL STORM
  - TORNADO
- **MONSOON (JUN-SEP)**
  - SOUTHWEST MONSOON CIRCULATION
  - MONSOON DISTURBANCES
- **POST-MONSOON (OCT-DEC)**
  - NORTHEAST MONSOON CYCLONIC DISTURBANCES

Spatial and Temporal domains of Forecast

- Nowcast for next few hours(Venue/ location specific)
- Short Range for 24 to 72 hours (Location/District/ State/Met Sub-division)
- Quantitative Medium Range for 3 days to 3-7 days

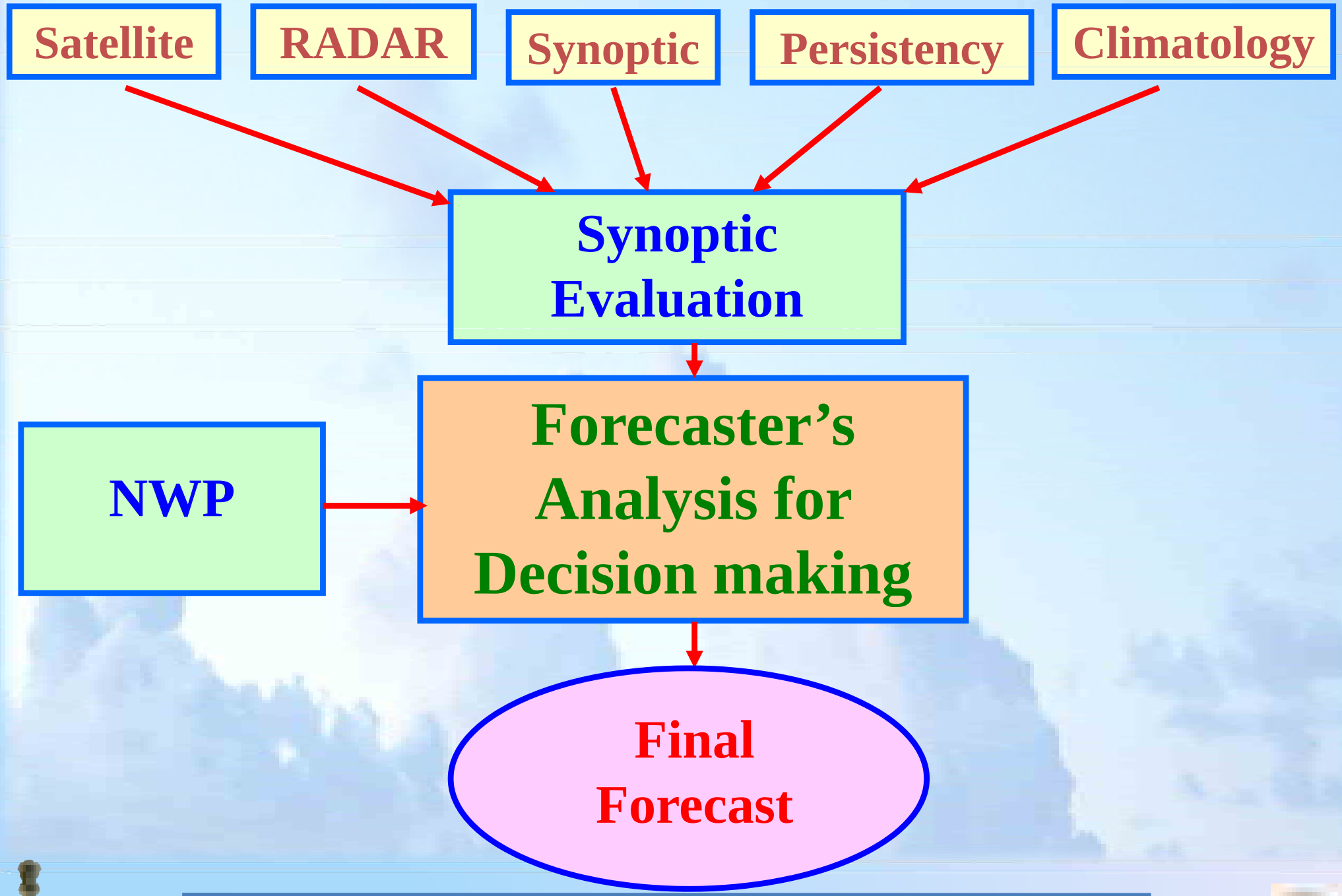
  (City, District, Block)
- Extended range for four weeks

  (Met Subdivision/State/ Homogeneous regions)
- Long range for month/season rainfall

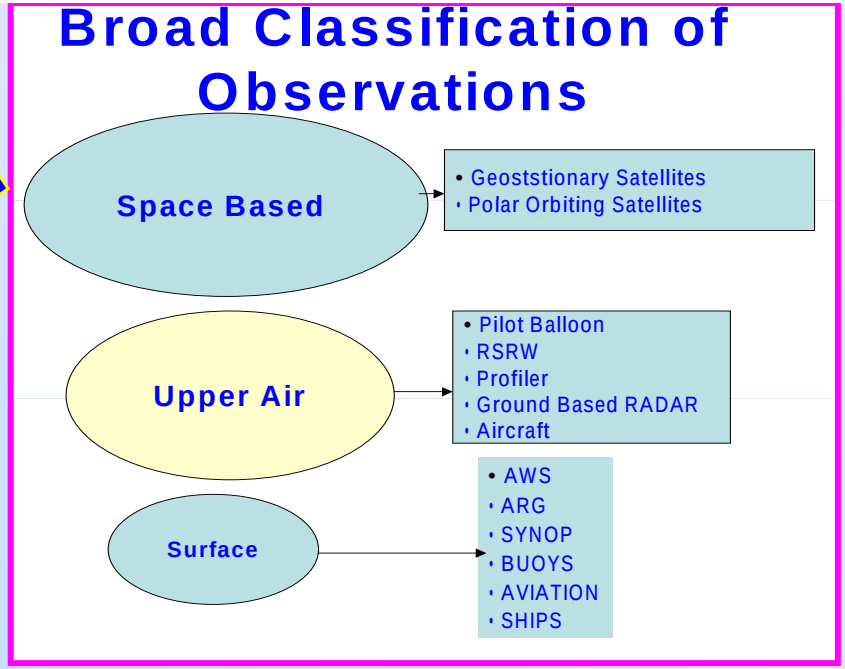
  (Homogeneous regions/country) + India (July and August and temperature for season

Early Warning System

- Atmospheric observation network
  - Surface (AWS, ARG)
  - Upper air
  - Radar
  - Satellite
- Strengthening of computing facilities,
- Data integration
- Model and product generation
- Generation of forecast products
- Dissemination of information to an optimum level.


Satellite
RADAR
Synoptic
Persistency
Climatology
Synoptic Evaluation
NWP
Forecaster's Analysis for Decision making
Final Forecast

Monitoring and Forecast Process



Initial conditions (Observations)

Runs of different Models,

Consecutive runs from the same model,

Ensemble runs ("choosing the best member")

Model runs

Numerical forecasts

Forecaster

End forecast

Decision maker

Action

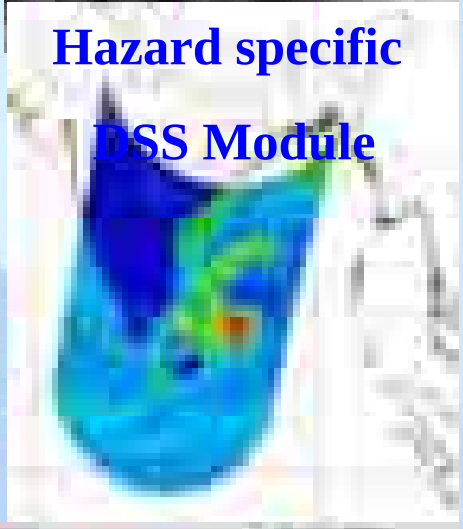
Extreme Weather Monitoring and Forecast Process

Technology for Decision Support System for Early Warning

Global plotting Conditional plotting

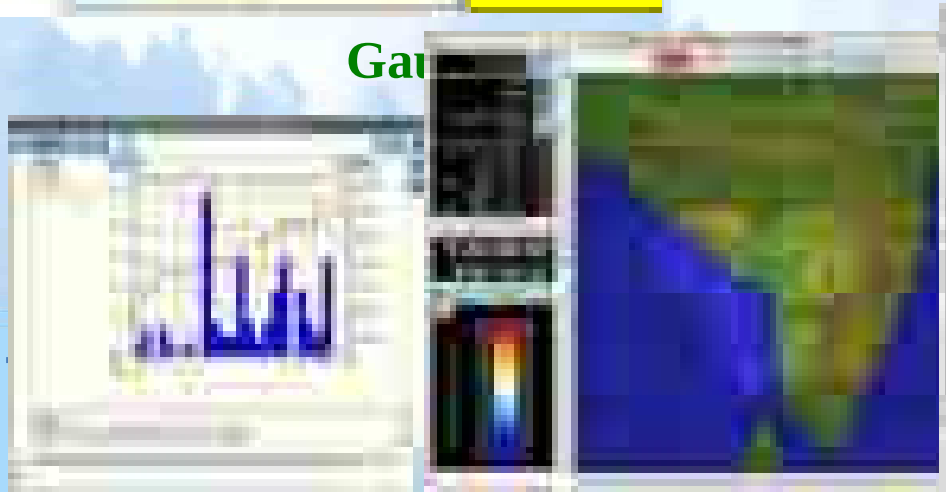
Satellite

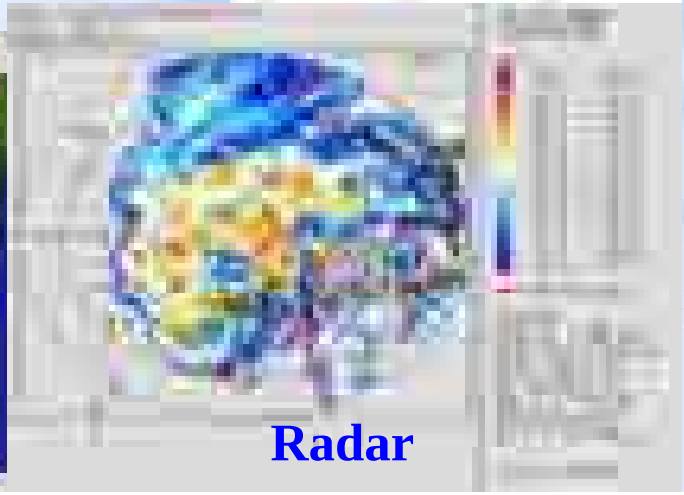
Plane trajectories



Hazard specific DSS Module

Gau





Radar

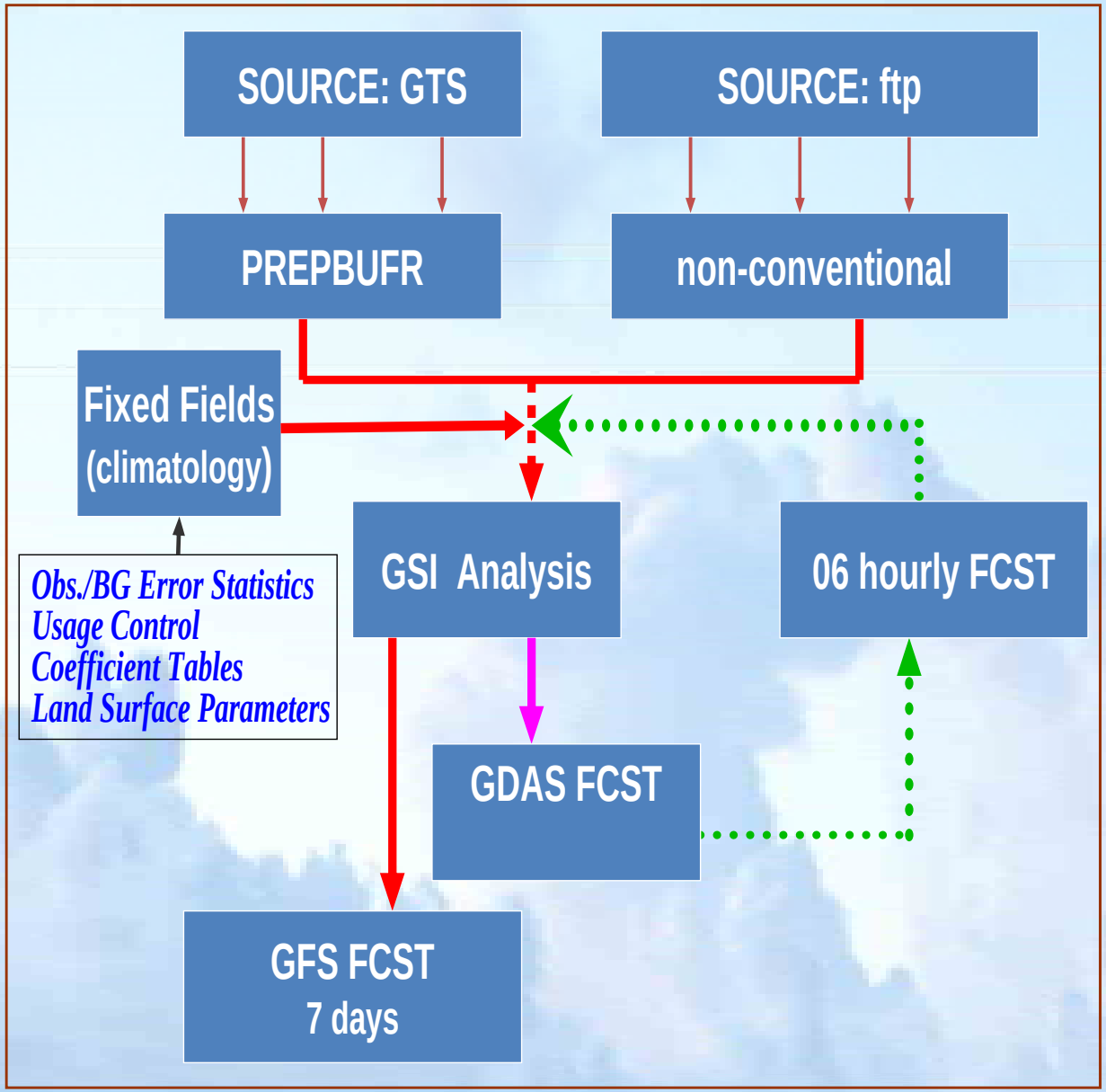
Current Status of Warning System At SAARC NMS

- **India: Observations- Conventional, Satellite and DWR; NWP – Global Regional with data assimilation**
- **Bangladesh, Sri-lanka, Nepal Pakisthan: Observations – conventional, DWR, Regional NWP, NWP Products from Global Centres**
- **Bhutan conventional Observation**
- **Afganisthan only one station**

Operational NWP Models

- **Medium Range Forecast**
  - > GFS (SL) T1574 with ENKF hybrid DA
  - > GEFS T 574 for probabilistic forecast
  - > MME for gridded/district level rainfall F/C
  - > Bias corrected temperature forecast
- **Short Range Forecast**
  - > *WRF (ARW) 3DVAR at 3 km*
  - > *HWRF (18,6,2 km)*
  - > *Polar WRF (at 15 km) for Antarctica*
- **NWP Based Cyclone Forecast**
  - > *Genesis Potential Parameter*
  - > *MME for Track Prediction*
  - > *RI prediction*
  - > *SCIP for Intensity Prediction*
  - > *Decay Prediction at landfall*
- **Nowcast *System WDSSII***

GLOBAL DATA ASSIMILATION



Global Forecast System

- **Global Data Assimilation**

> **NCEP Decoder PREPBUFR**

> **NESDIS Sat Inputs**

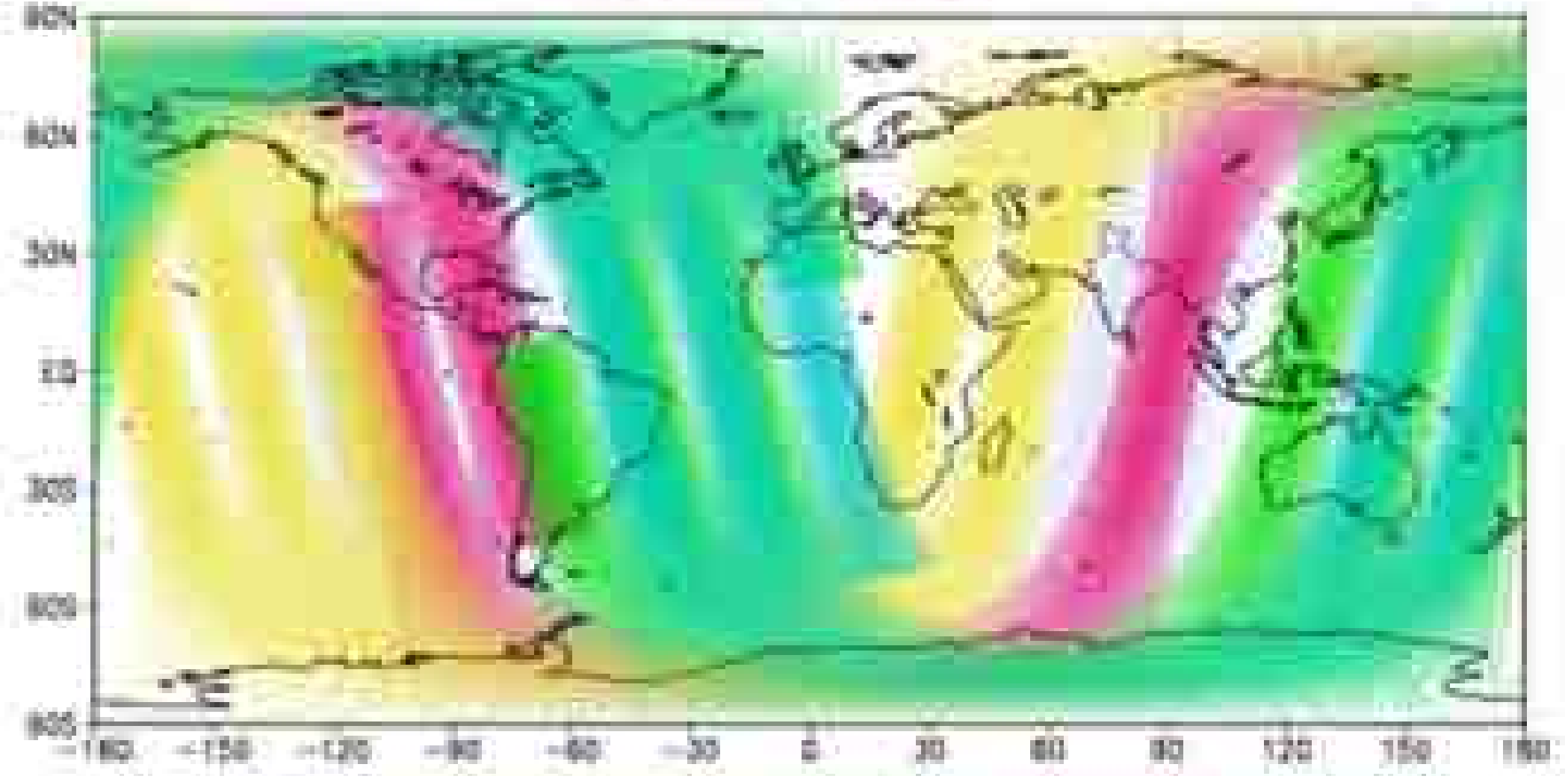
> **Other surface analysis: CEP**

> **Grid Statistical Interpolation**

- **Global Forecast Model GFS T574/L64**

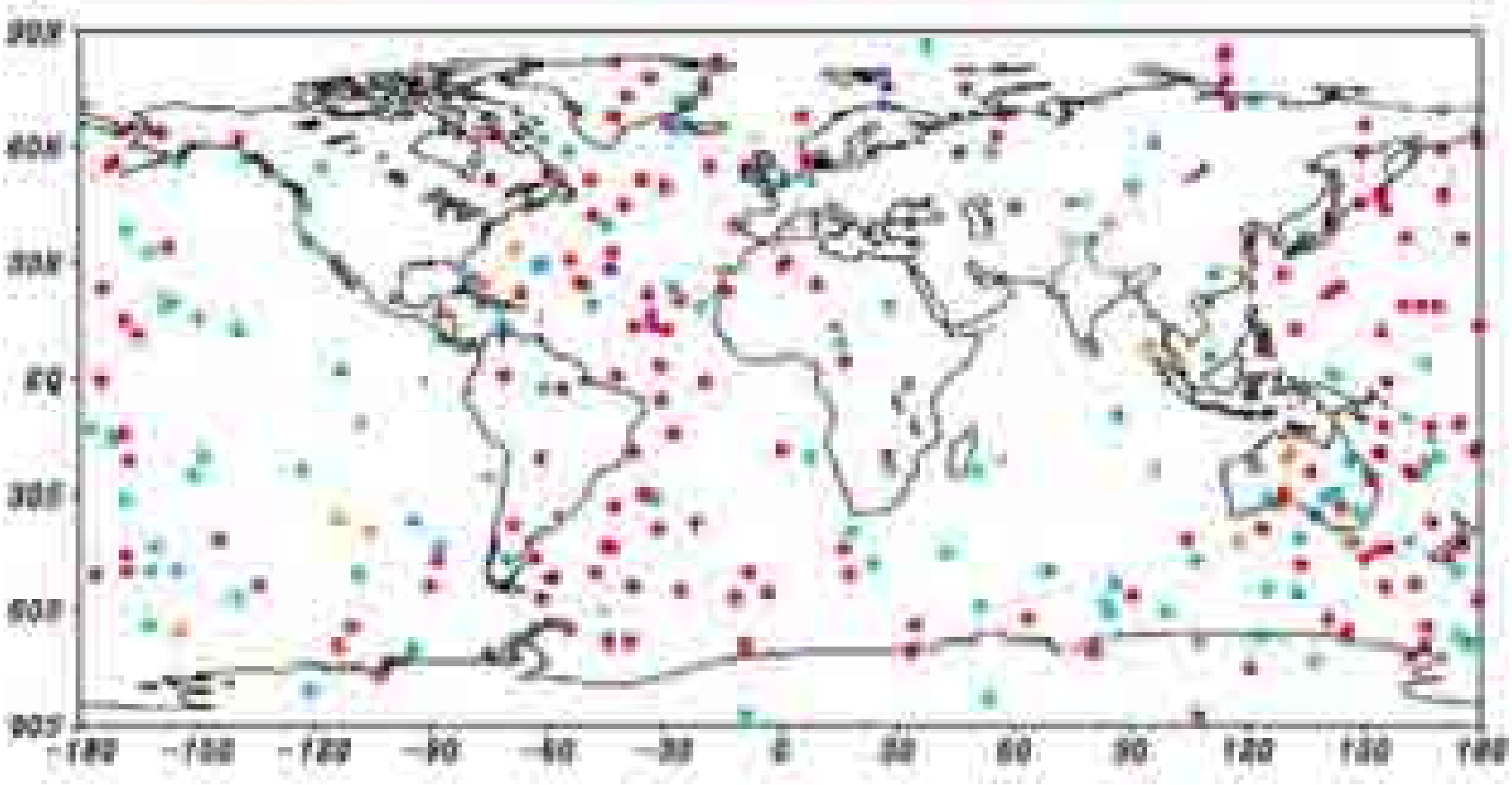
Data Coverage: SAT RADIANCE (19032014 0000UTC +/- 03Hrs)

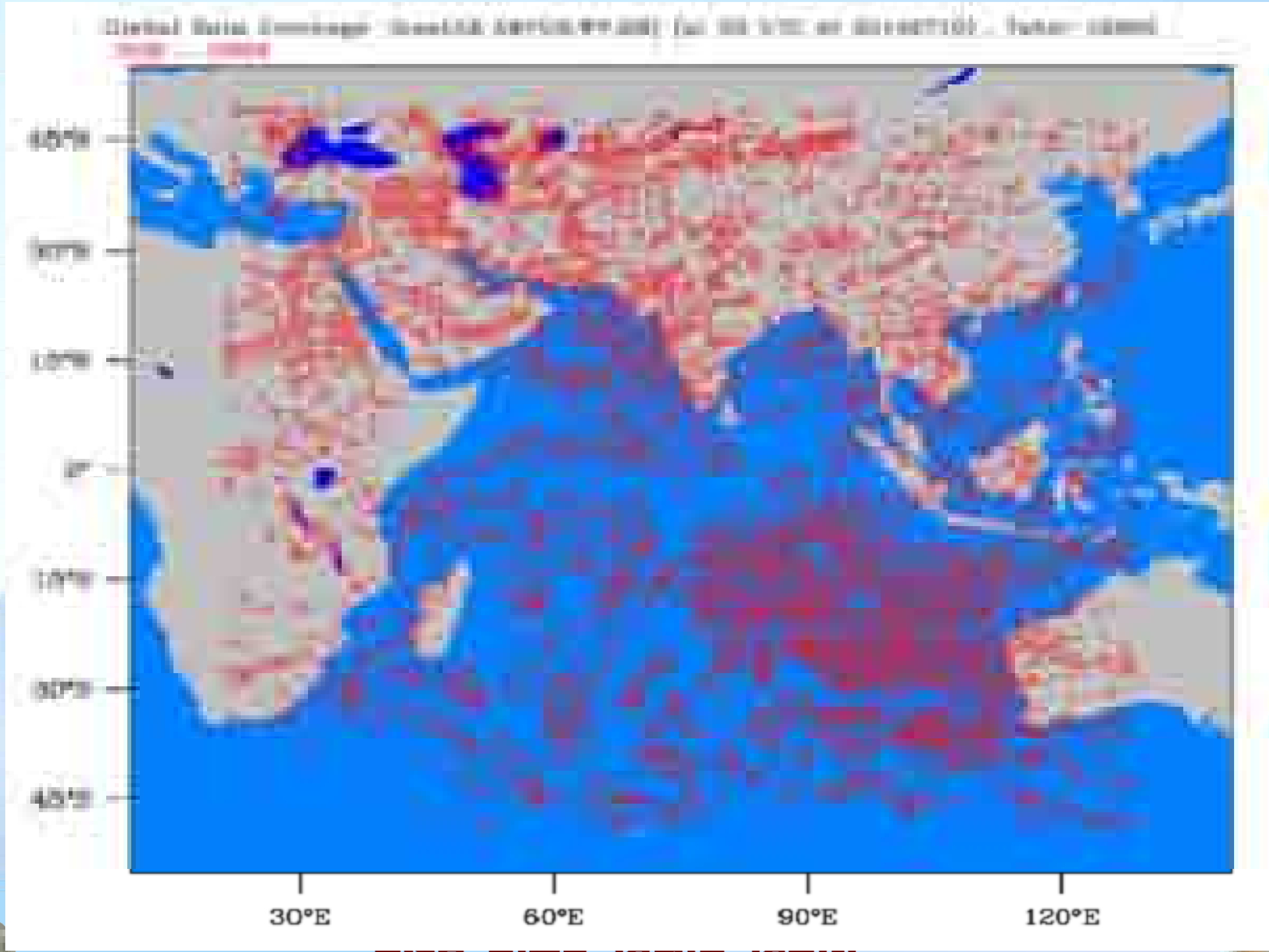
Total Number of Observations Received at IMD: 2058095



Data Coverage:GPSRO (19032014 0000UTC +/-03Hrs)

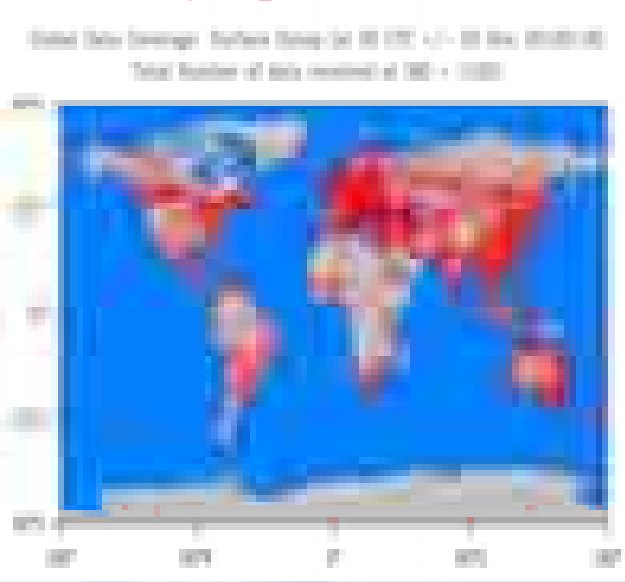
Total Number of Observations Received at IMD: 287



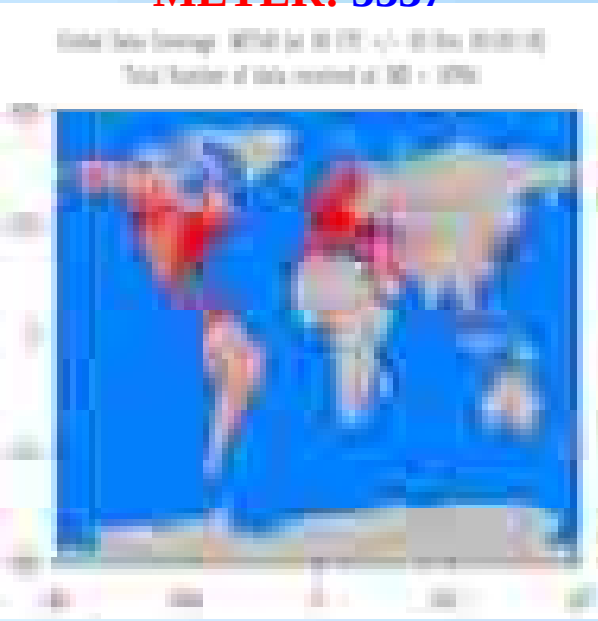

30°E
60°E
90°E
120°E

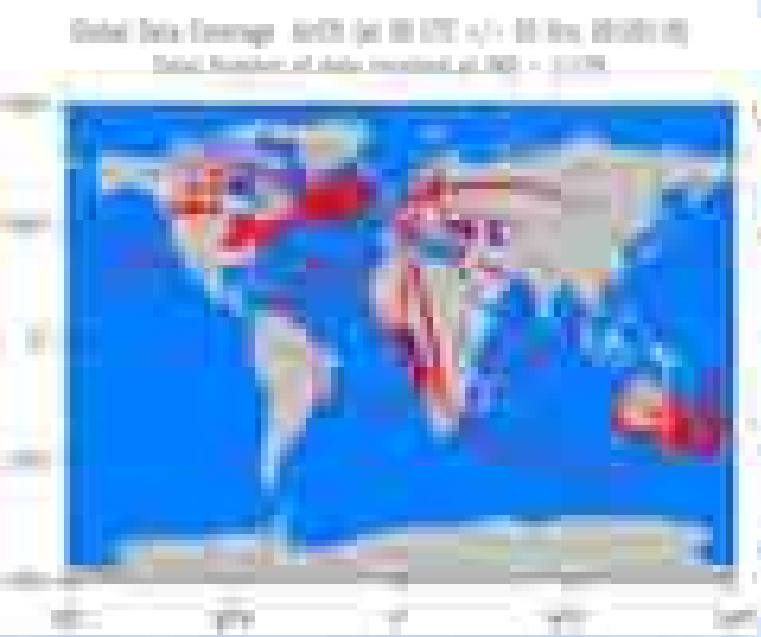
SATOB:1,65000

Synop:11,300



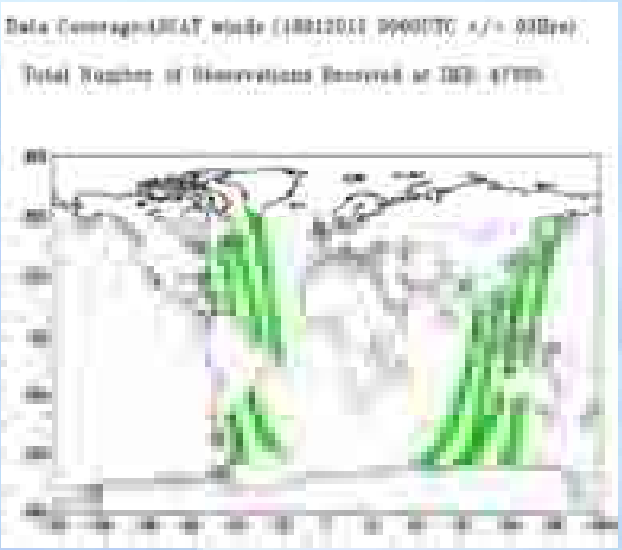
METER: 5337





ACAR:11,1799

AMDAR: 60.229



ASCAT:48,000

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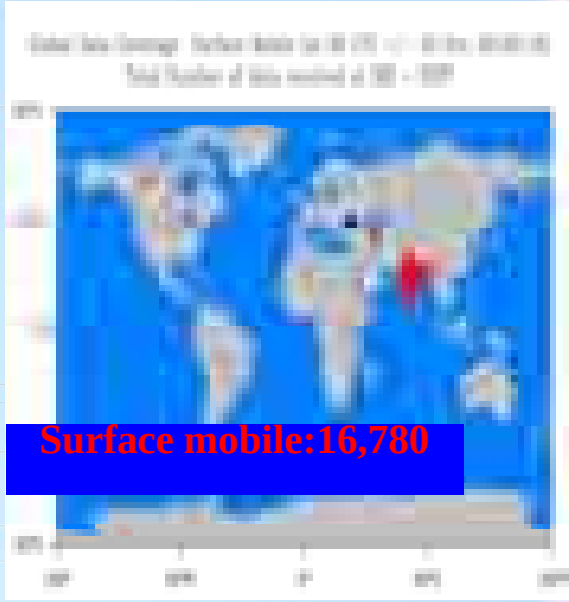
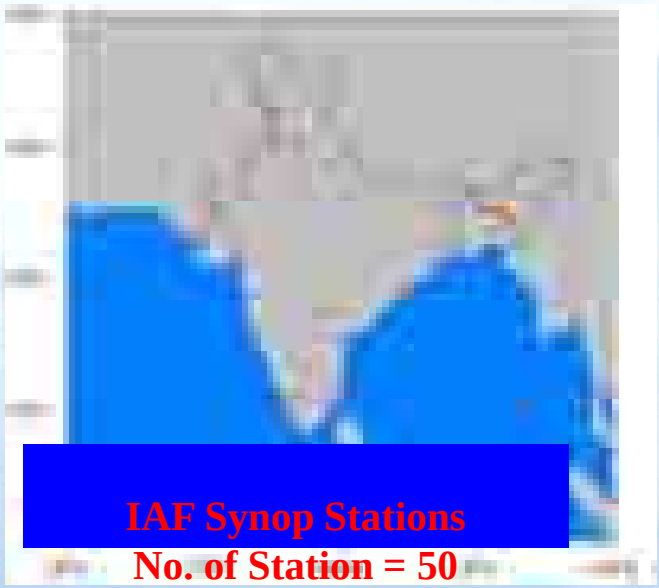
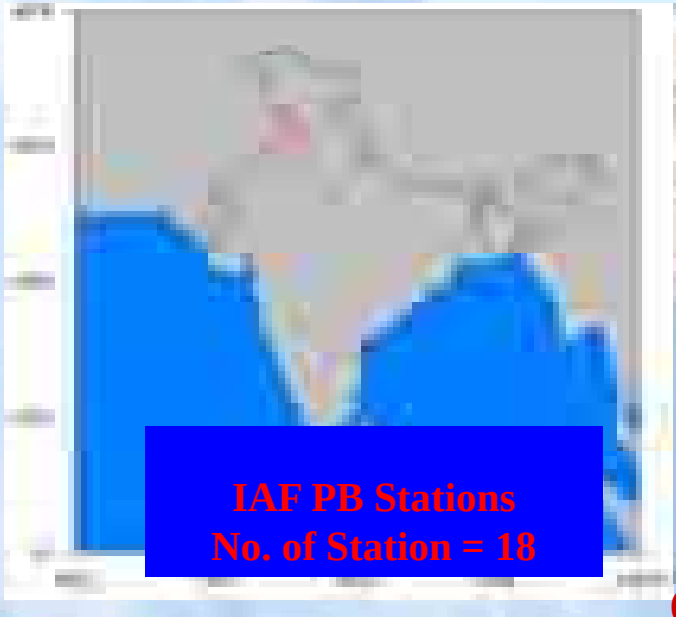
INDIA METEOROLOGICAL DEPARTMENT


Buoy=10,848


Ship: 1095

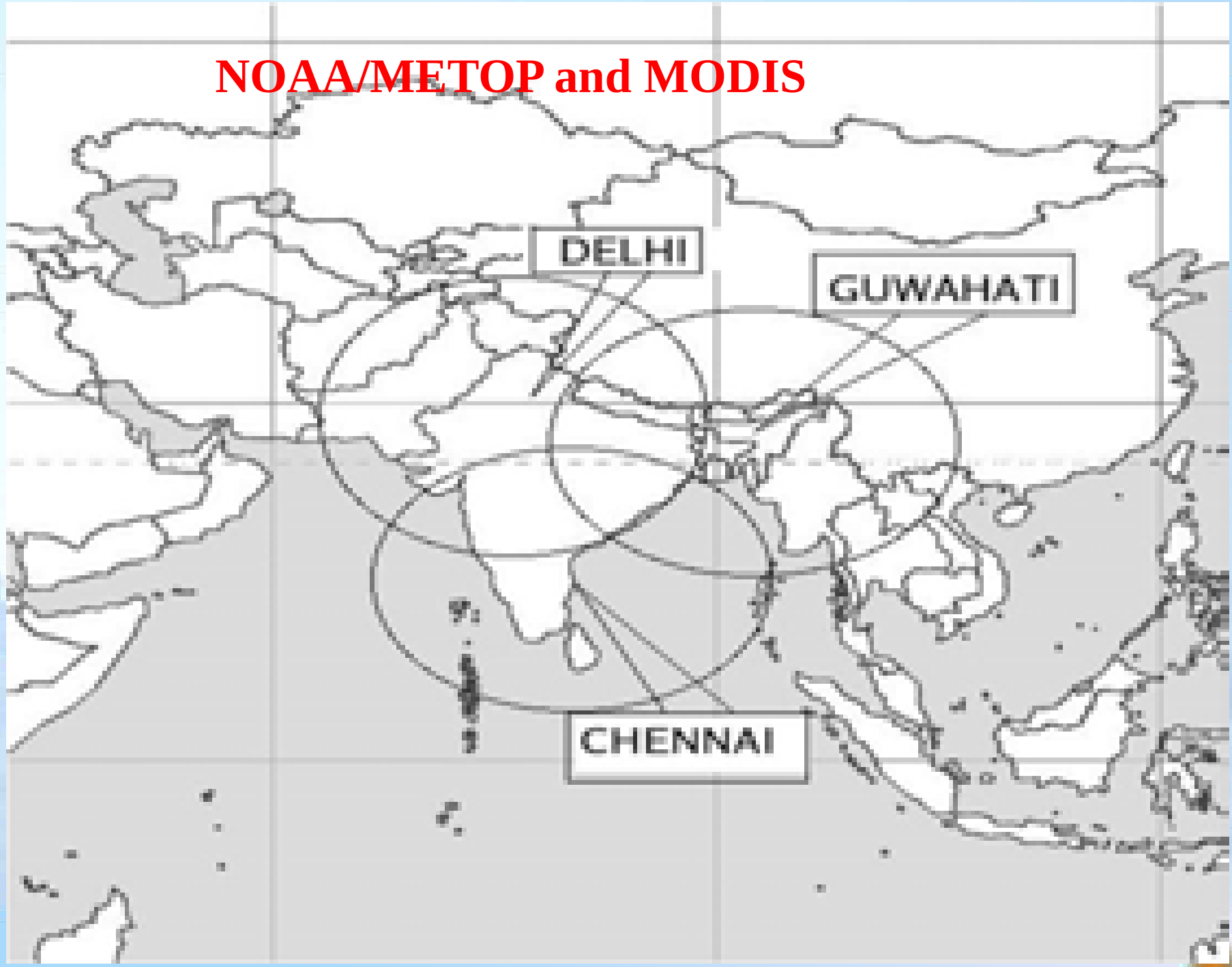

Surface mobile:16,780


IAF Synop Stations
No. of Station = 50


IAF PB Stations
No. of Station = 18


675 Automatic Weather Stations

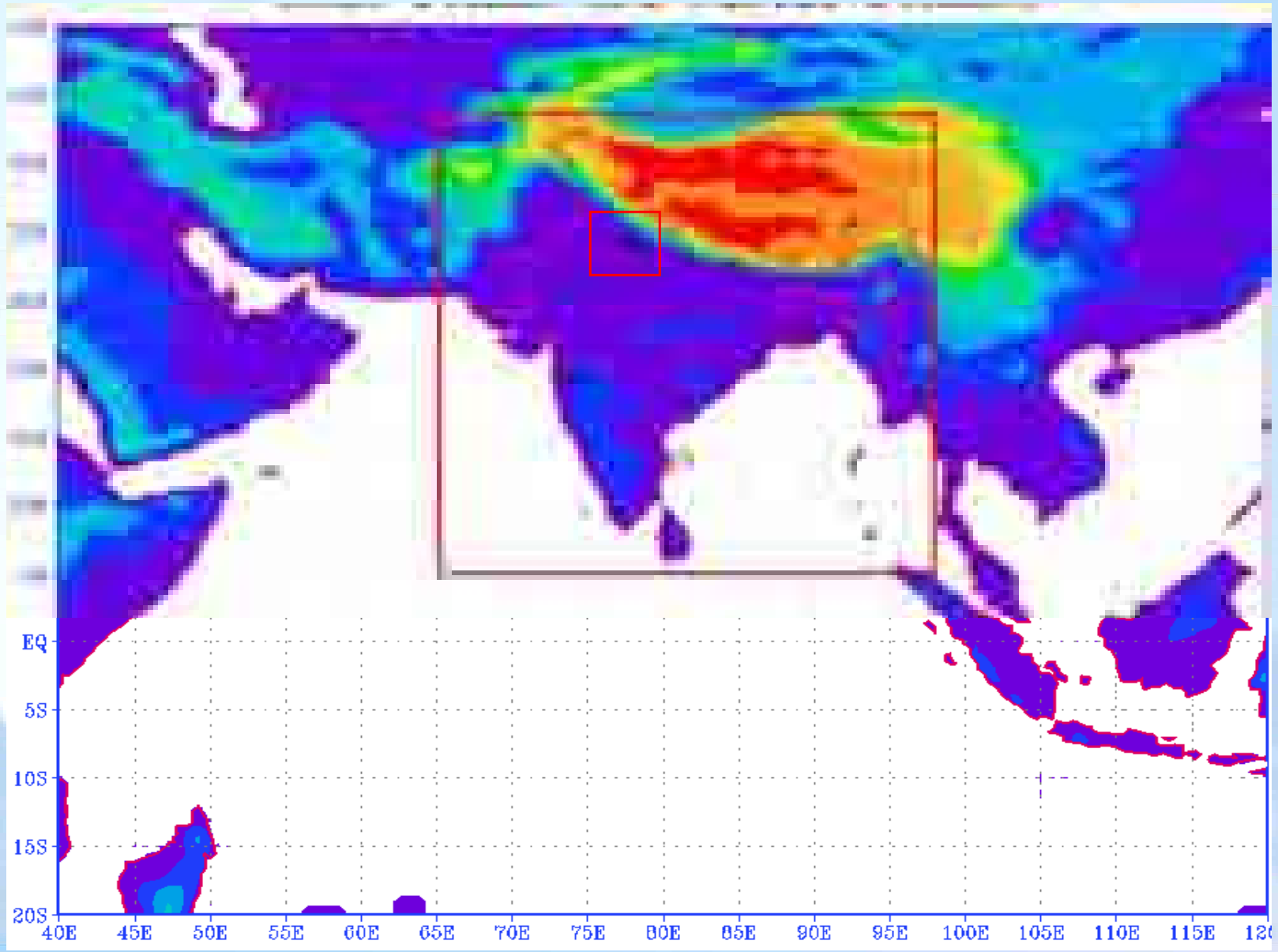
NOAA/METOP and MODIS

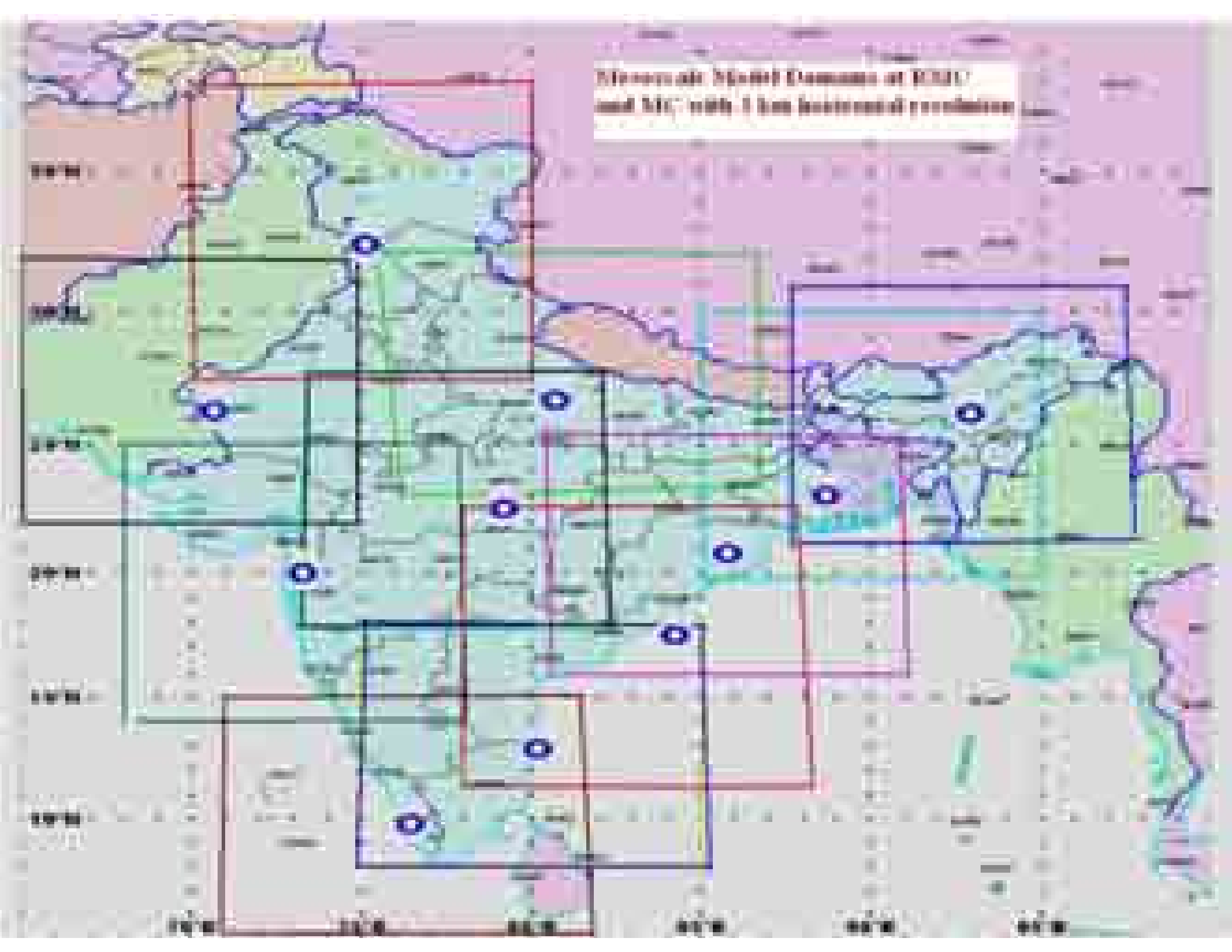


Daily average data statistics in GFS T574L64 for August-2013

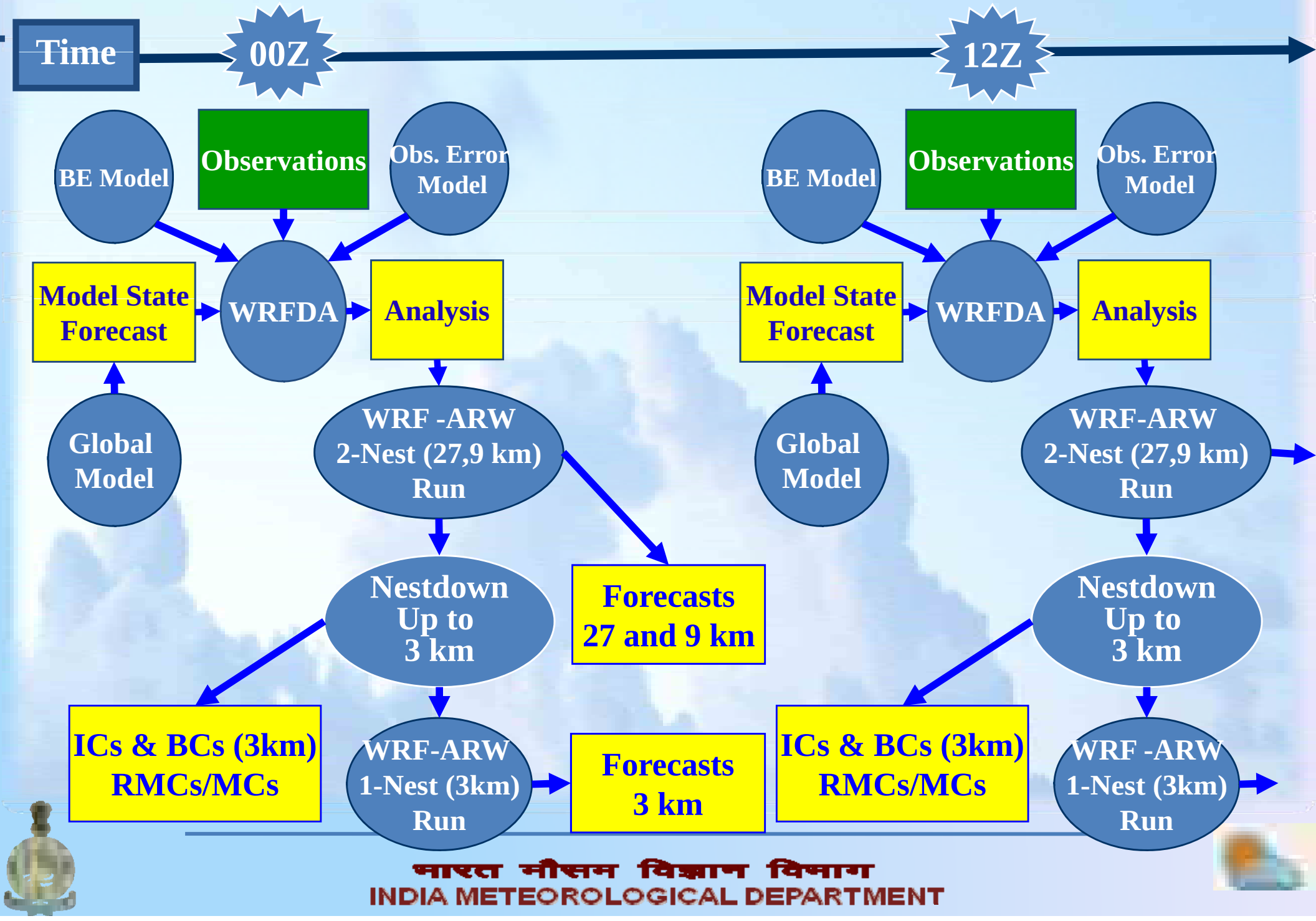
Parameter	*P-surface*	*uv*	*t*	*q*	*Radiance*
Data Received	*29339*	*408147*	*126947*	*51958*	*2982385*
Data Assimilated	*25610*	*292369*	*101473*	*15367*	*744426*
Data Assimilated (%)	*87%*	*71%*	*79%*	*30%*	*29%*

Short-range Forecasting Strategy at HQ

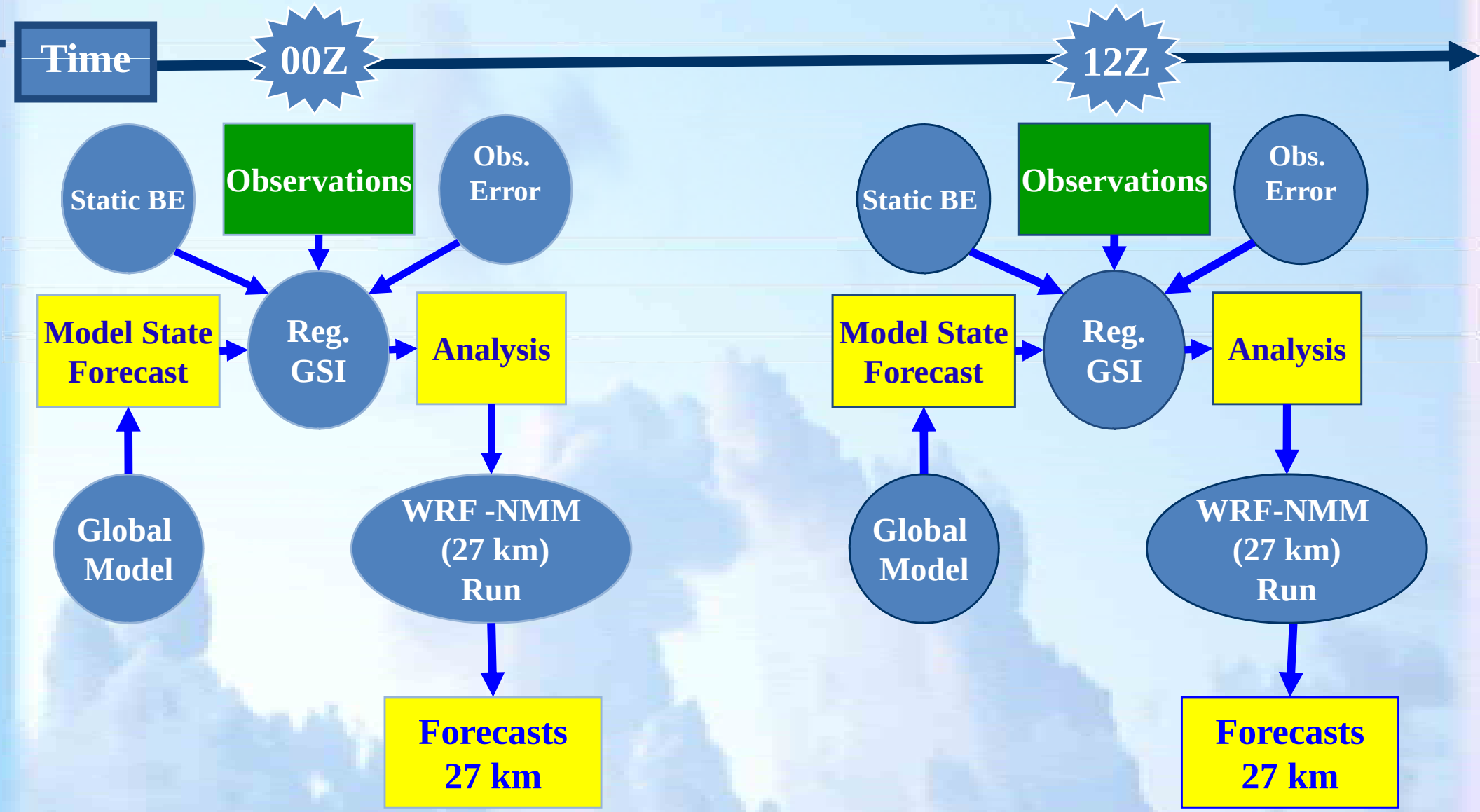




WRF-ARW Forecast with WRFDA Assimilation

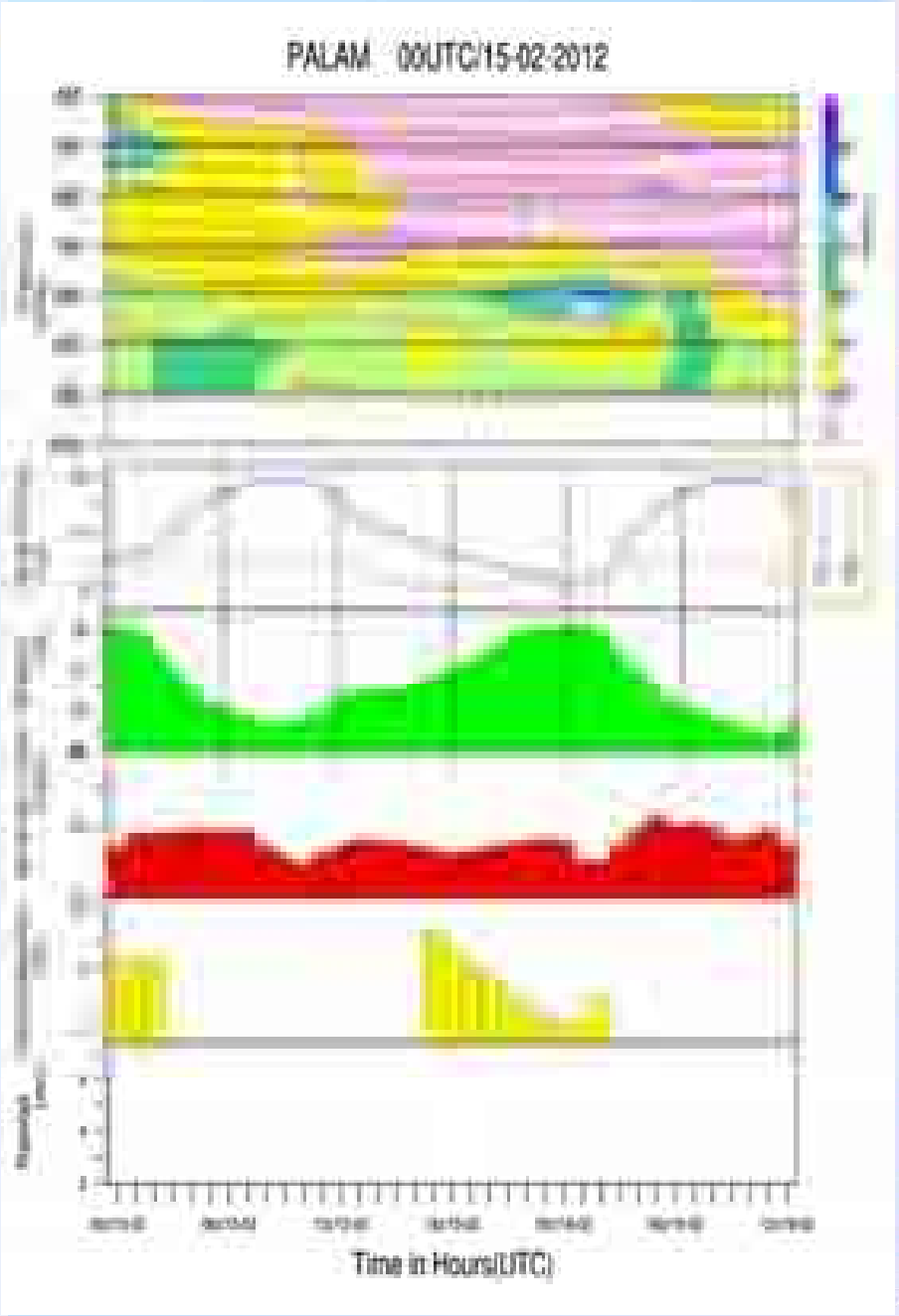


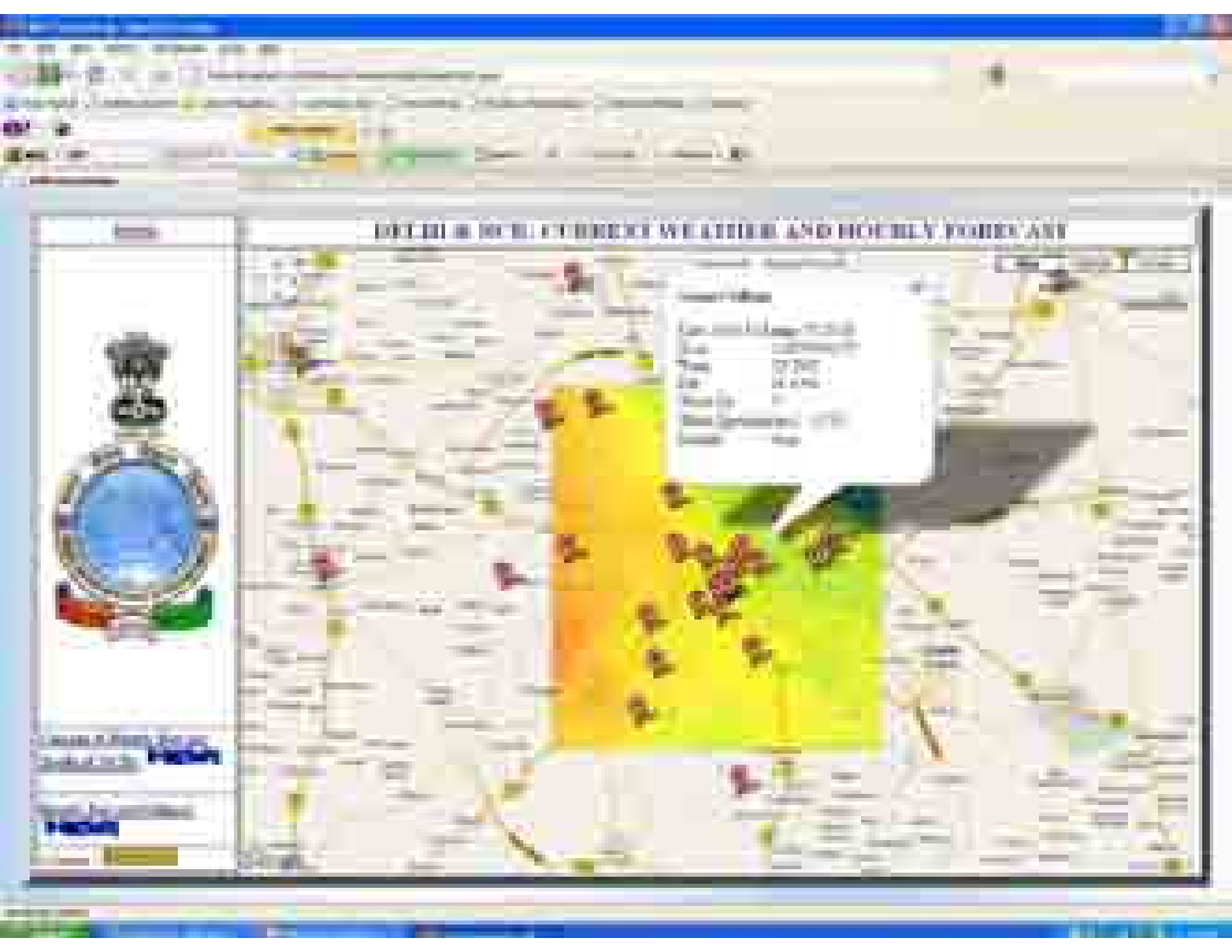
WRF-NMM Forecast with GSI Assimilation



User specific NWP products

S.N	User Name	Type of Forecasts
1	Agro-meteorological Services	Five days quantitative forecasts of rainfall, max and min temperature, cloud cover, surface humidity and winds - District Level, Block Level
2	Cyclone Services for Disaster Management	MME based Cyclone track, genesis potential parameter, intensity and decay prediction up to 3 days
3	Aviation service	Low flying aircraft operator Flight level temperature and wind forecast map, Meteograms for 43 Airports
4	Hydrological Services	MME based gridded rainfall forecasts at 25 km resolution, WRF 9 km
5	PWS, Event Management	City Forecast, Noecast, location specific NWP products

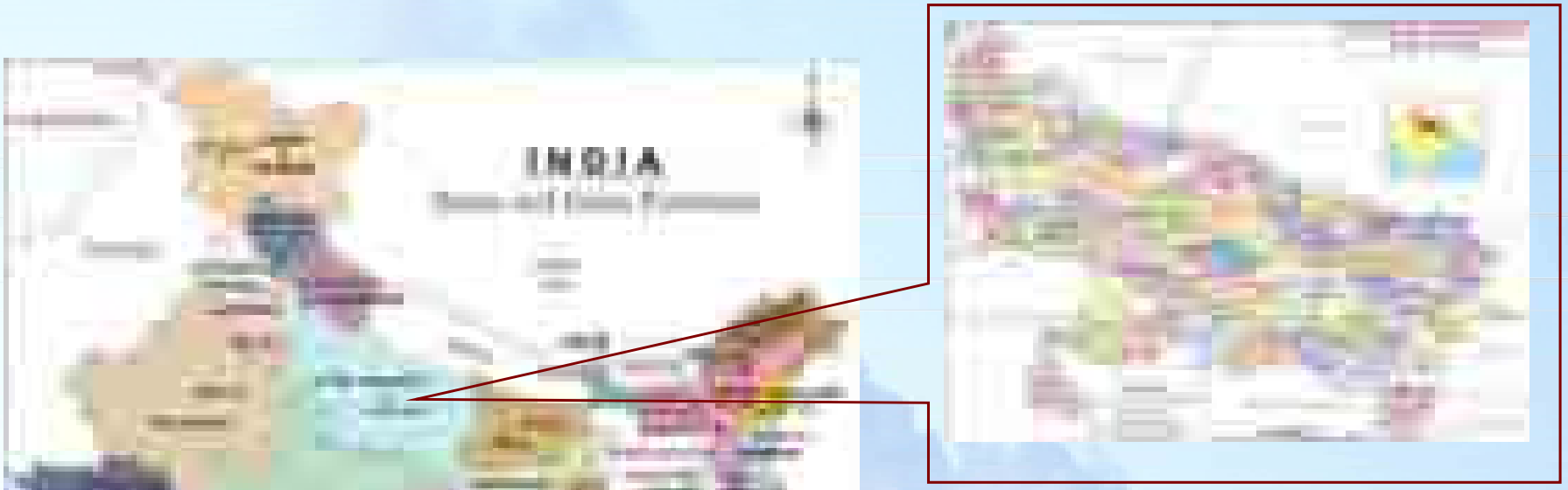

PALAM 00UTC/15-02-2012
Time in Hours(UTC)


DELHI & NCR: CURRENT WEATHER AND HOURLY FORECAST

Aviation charts for low flying aircraft

Upper Mahanadi Basin

IMD Multi-model Ensemble (MME) based District level Forecasts for Integrated Agro Advisory Service of India

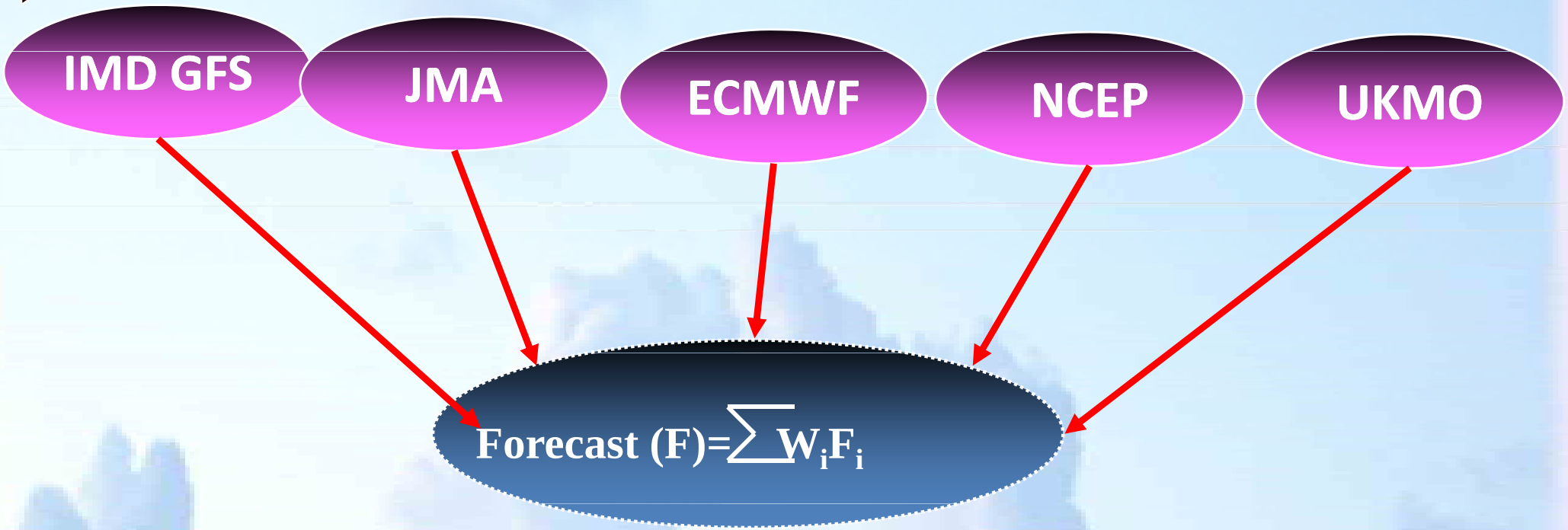


Roy Bhowmik S.K. and Durai V.R., 2010, Application of multi-model ensemble technique for real-time district level forecasts over Indian region in short range time scale, **Meteorl. Atmos. Phy**., 106, 19-35

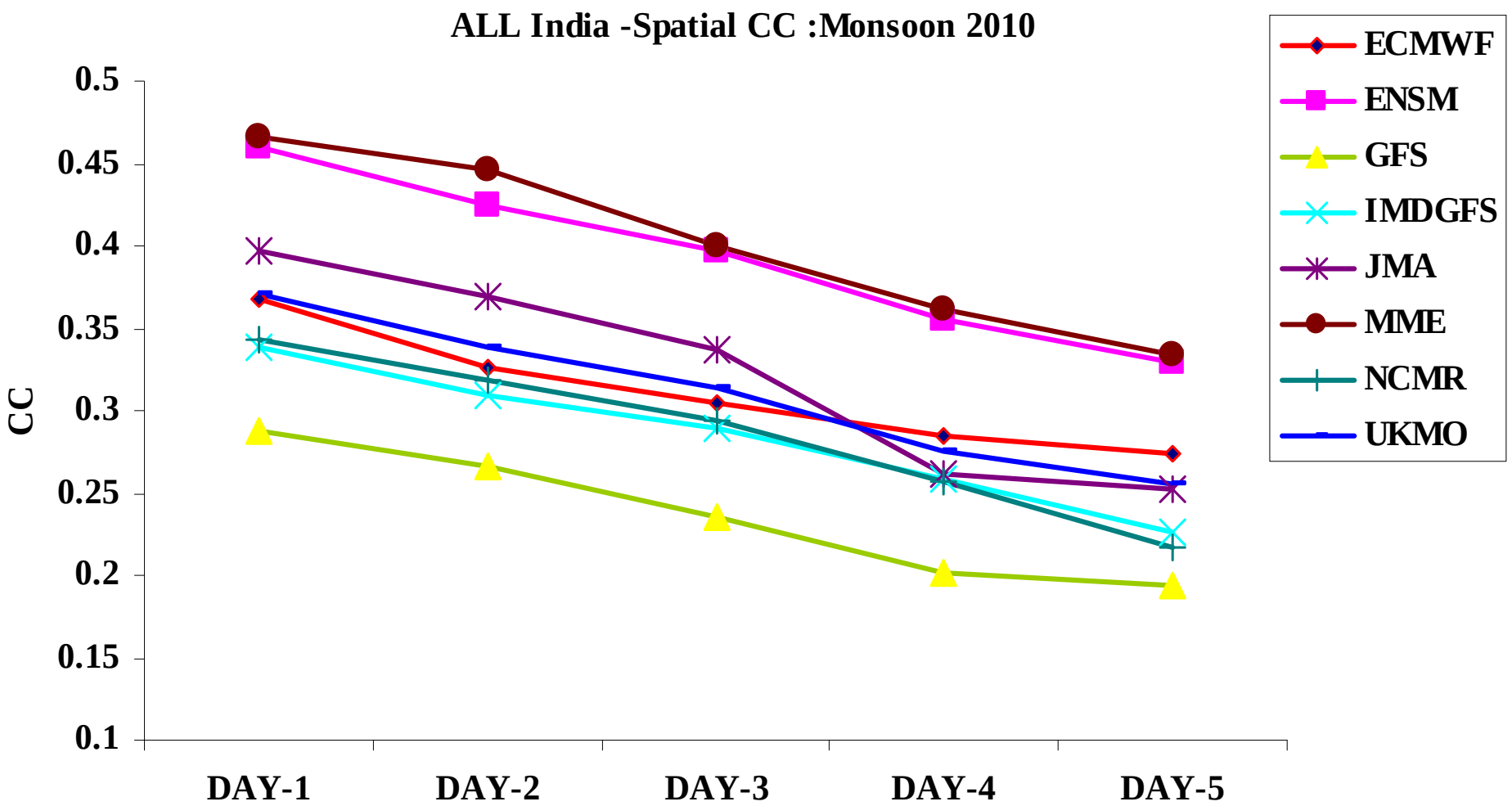
Roy Bhowmik S.K. and Durai V.R., 2012, Development of Multi-model Ensemble based District Level medium range Rainfall Forecast System for Indian region, **JESS,** 121(2)

Step-2

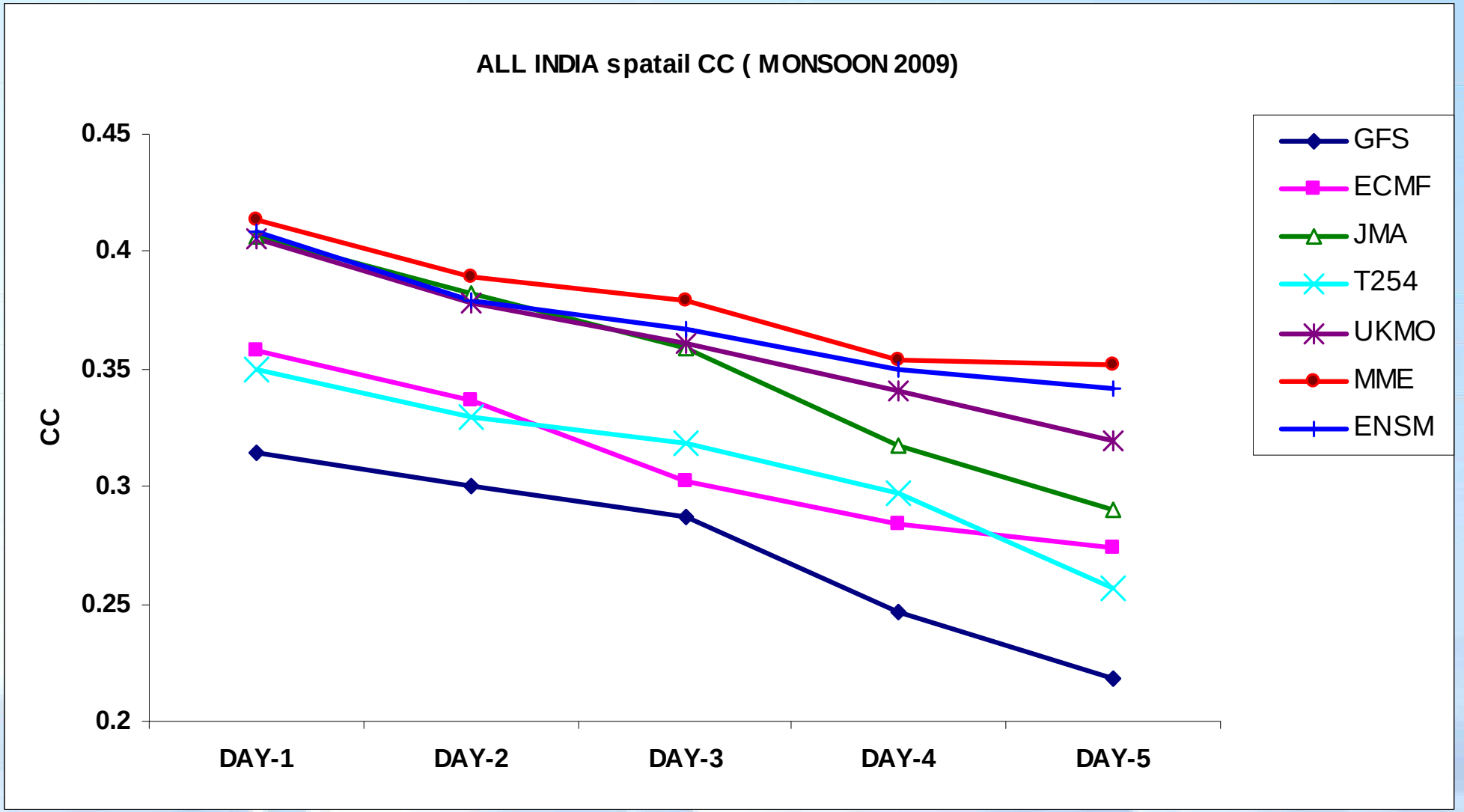
Generation of Multi-model Forecasts



$$W_{i,j,k} = \frac{C_{i,j,k}}{\sum_{k=1}^{5} C_{i,j,k}}, \qquad i = 1, 2, \ldots, 161; \quad j = 1,2,\ldots,161$$

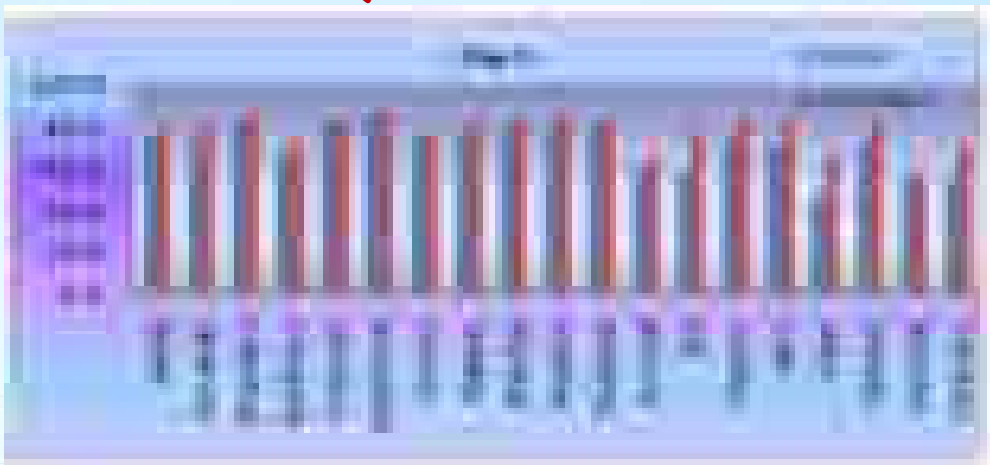


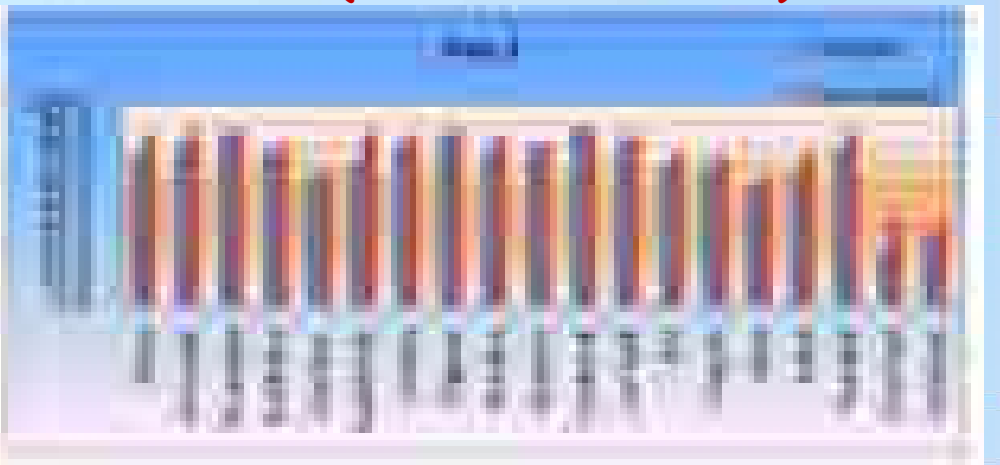
Country mean spatial CC: Ranking order- MME, mean ensemble, JMA (up to day3), UKMO, ECMWF, IMD (non-member),NCMR, NCEP.

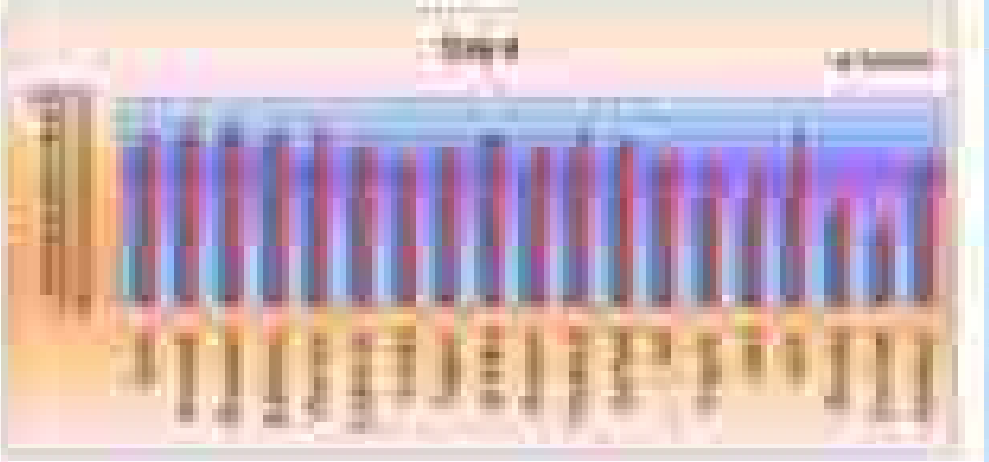


Country mean spatial CC: Ranking order- MME, mean ensemble, UKMO, JMA (up to day3), NCMRWF/ ECMWF, NCEP.

Qualitative verification of Rainfall Forecast (Percent Correct %)





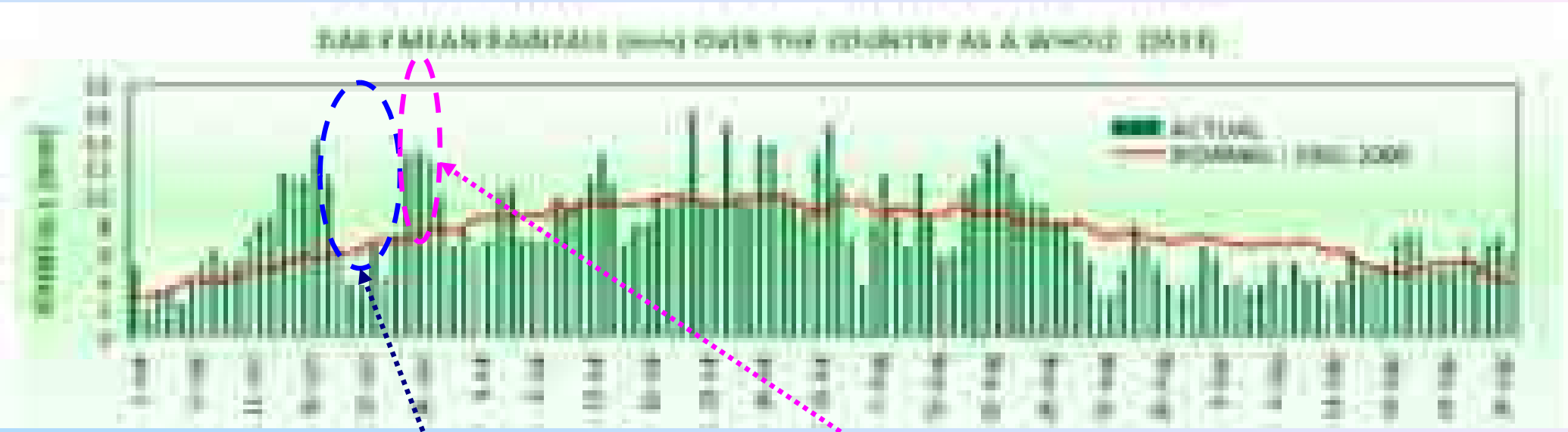


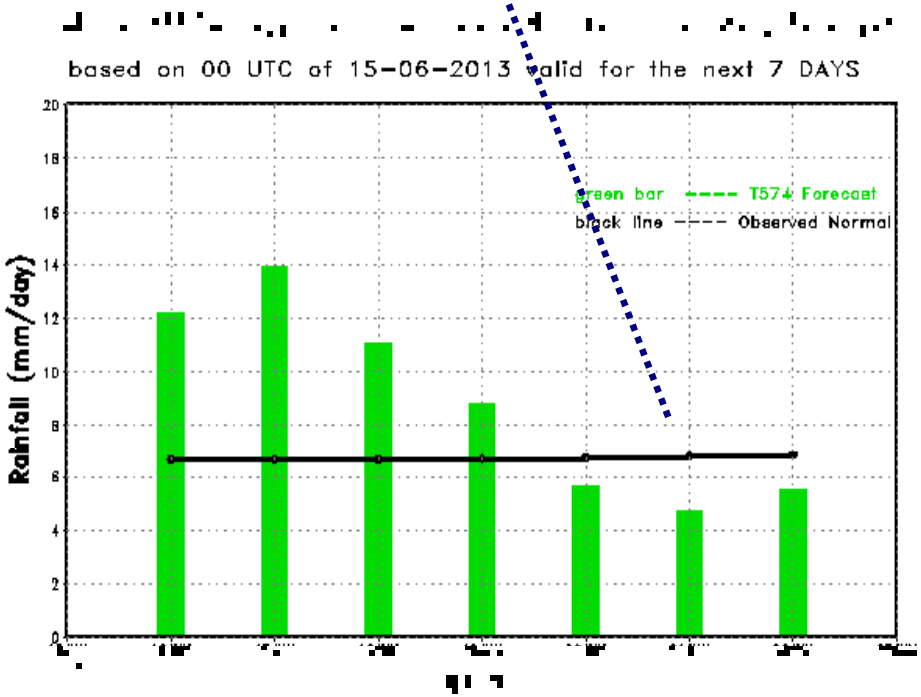
Current Status of Heavy Rainfall Forecast Performance

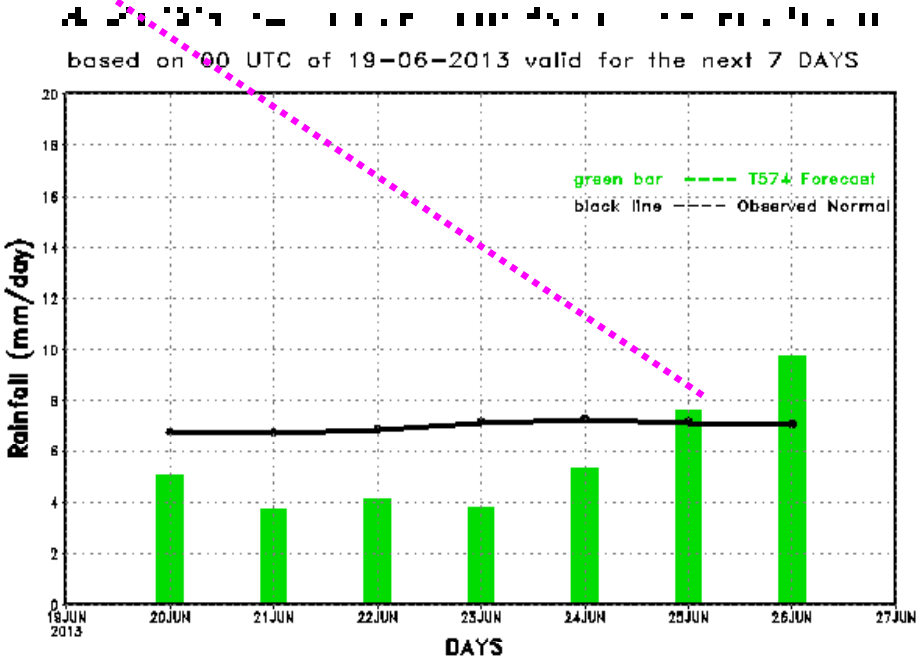
Scores	2002-10	2008-10	2011-13	2013	% improvement In 2011-13 from 2008-10
FAR	0.49	0.47	0.21	0.11	-56%
MR	0.56	0.55	0.30	0.31	-45%
POD	0.44	0.45	0.70	0.69	56%
PC	0.76	0.76	0.87	0.84	14%
HSS	0.32	0.34	0.63	0.59	86%
CSI	0.30	0.32	0.56	0.54	78%

GFS WEEKLY CUMULATIVE RAINFALL (mm) FORECAST

Weak and Active spells: During Monsoon 2013





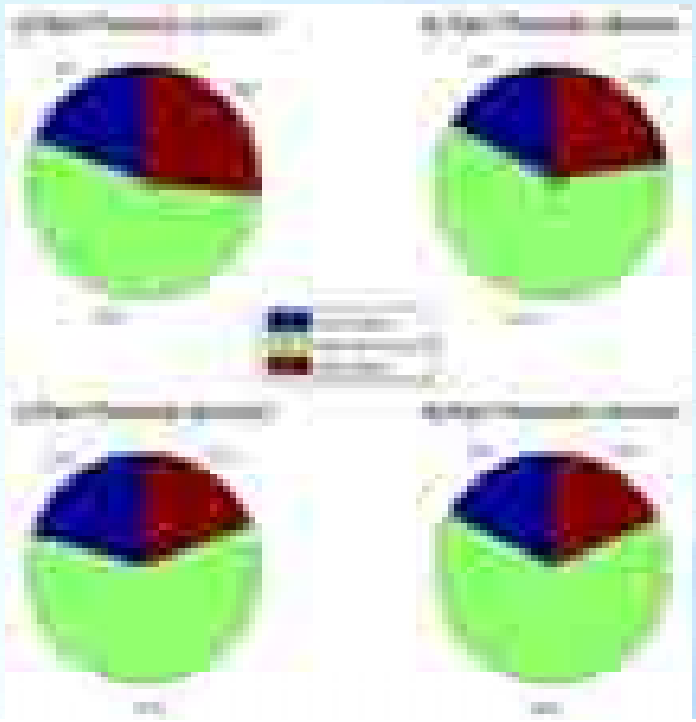


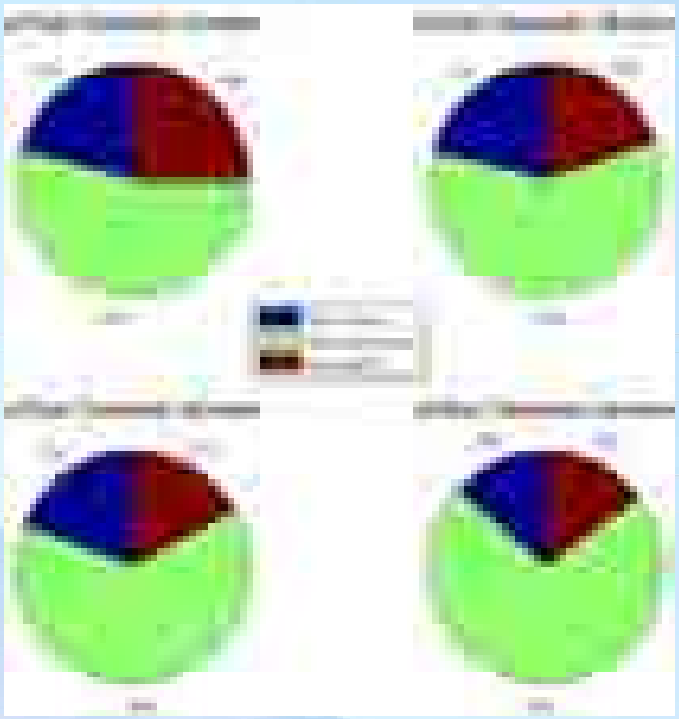
Weak spells followed by Active Spells

Active spells followed by Weak Spells

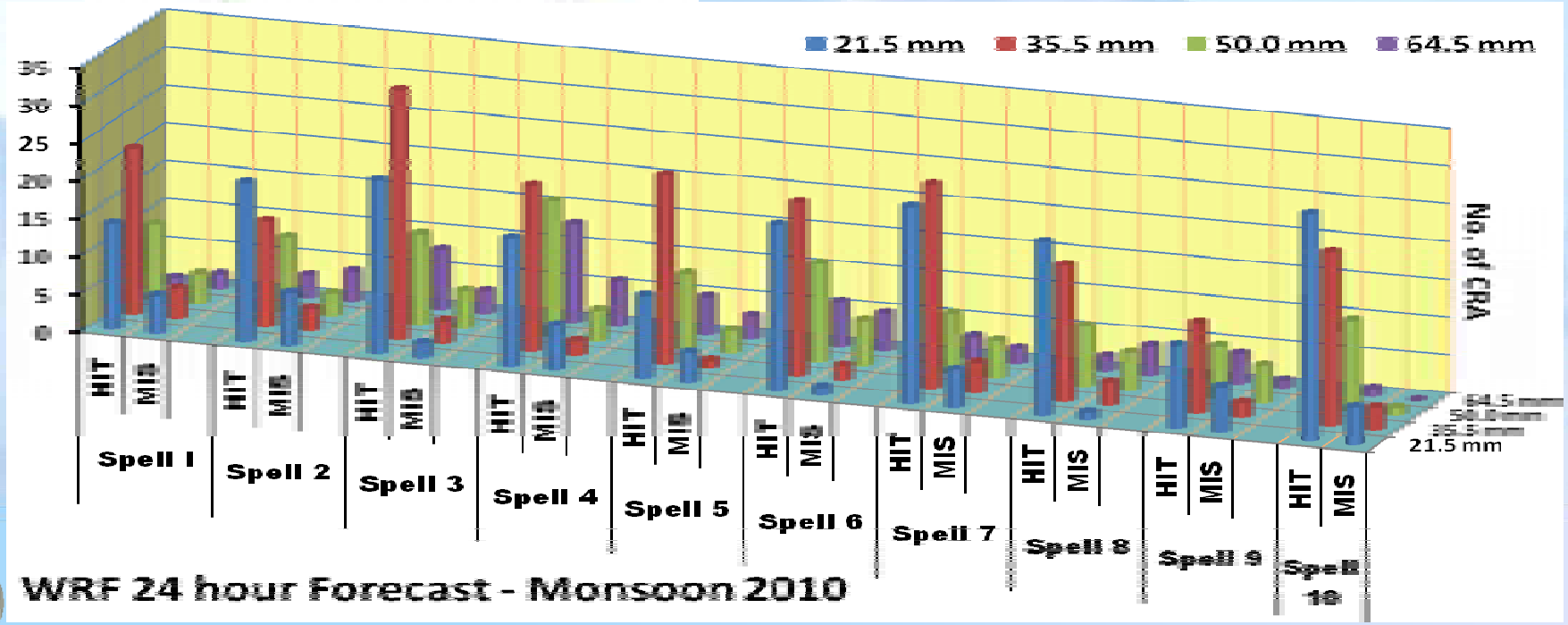
CRA Method of Verification: Monsoon 2010

24 hour WRF Forecast





48 hour WRF Forecast



Meso-scale Applications of Doppler Weather RADAR (DWR) Observations

- **Processing for Nowcasting Applications**
- **Ingest into assimilation cycle of NWP models**

IMD: 22, BMD: 3 PMD: 2

Parameters: radial wind, reflectivity and spectrum width

DWR Stations: Chennai (2002), Machalipatnam (2004), (GEMATRONIK radar, RAINBOW aplication) Vishakapatnam (2006) and Kolkata (2003), (GEMATRONIK radar, RAINBOW software). Sriharikota (ISRO)

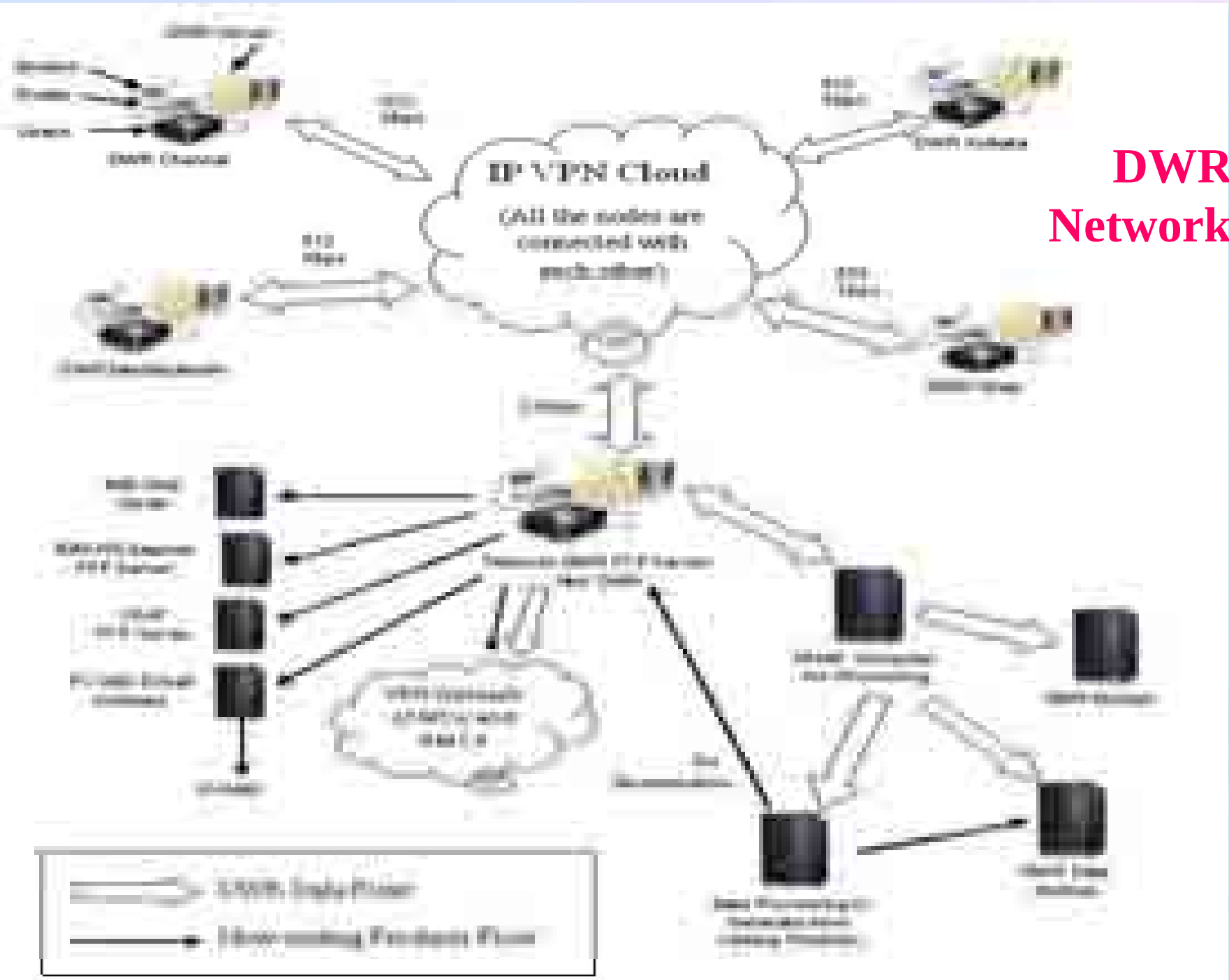
Delhi, Hyderabad, Nagpur, Patna, Agartala, Lucknow, Mohanbari, Patiala, (Beijing Metstar, Sigmet IRIS software) Mumbai (BEL)

Delhi Jaipur Dual Pol radar Vaisala make sigmet IRIS

Technical Challenges of radar data assimilation

- **Optimization of scan strategy**
- **Networking : Real-time data reception**
- **An interface software to convert data files in .VOL and IRIS format to a non-proprietary open source NETCDF format**
- **Quality Control**
- **Assimilation into NWP model**

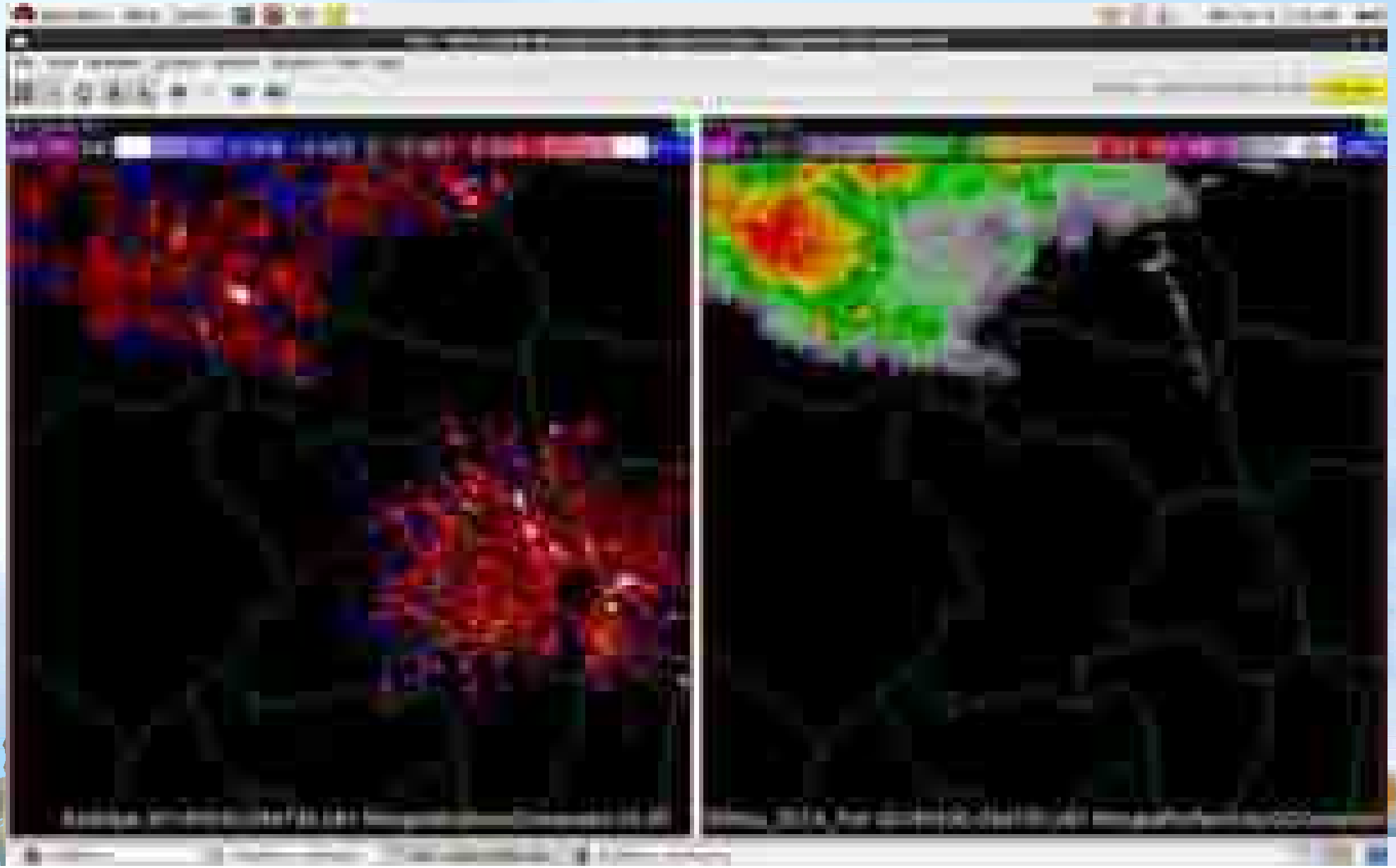
DWR Networking



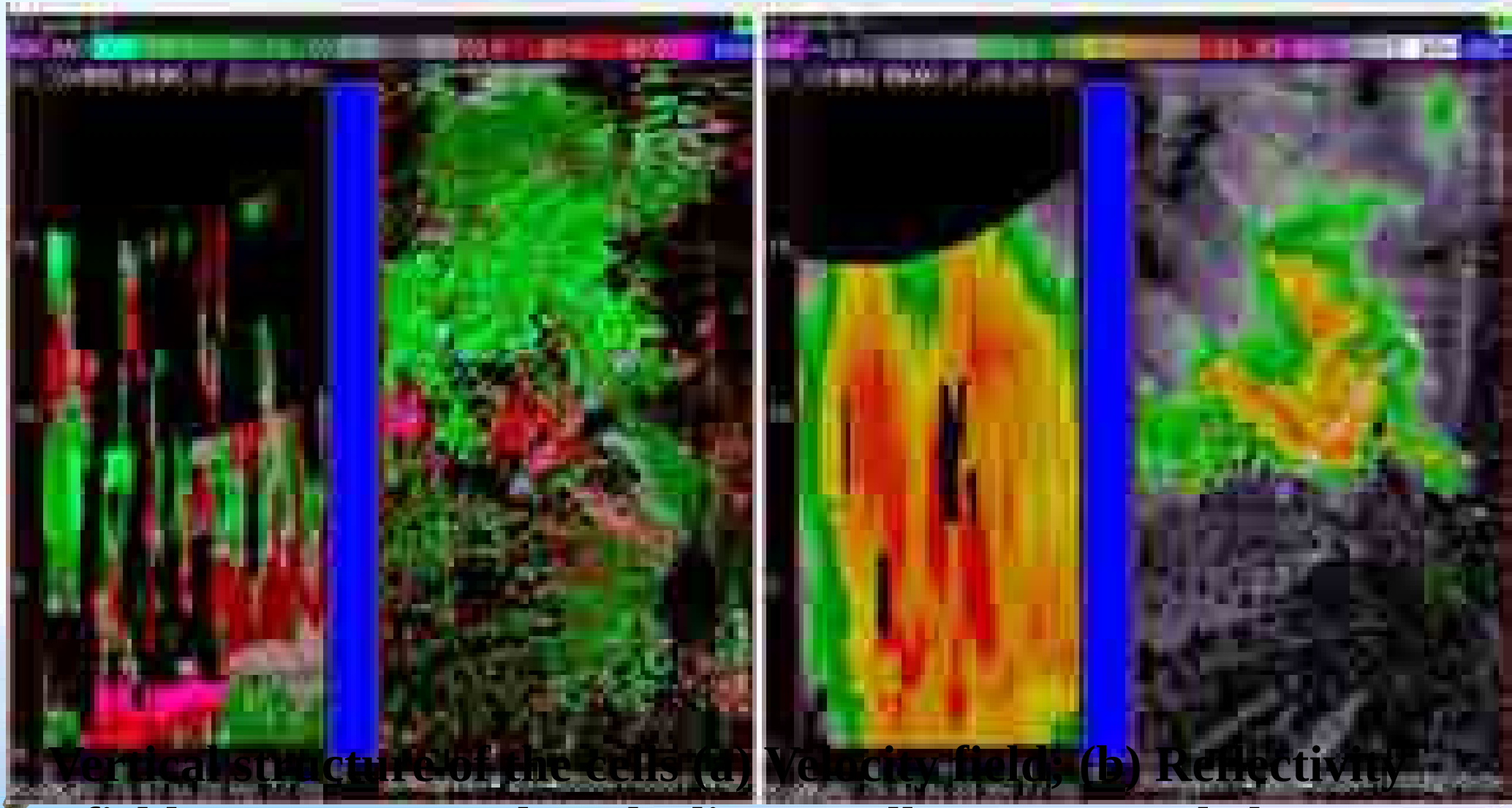
30 May 2014

- In association with the movement of a western disturbance over the North Indian region, a series of thunderstorms passed over Delhi and adjoining regions.
- Downdrafts from the cells resulted in severe line squalls over Delhi.
- Wind squalls of the order of 64 Kt was noted by Palam at 1644 IST (1110 UTC) for 4 minutes.
- Large scale devastation was noted over the Metropolitan area of Delhi.

Observed horizontal azimuth shear and reflectivity for 30 May 2014

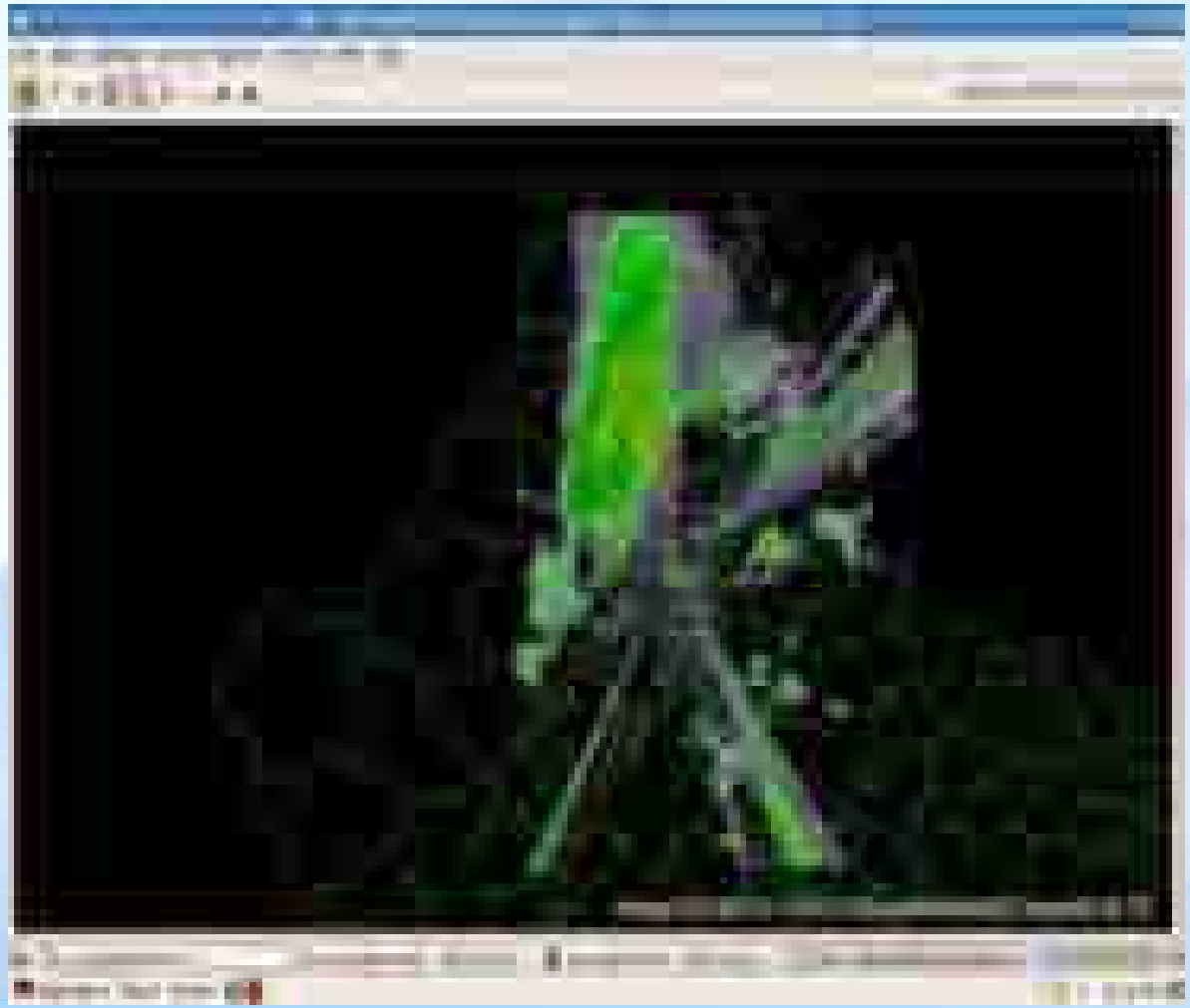


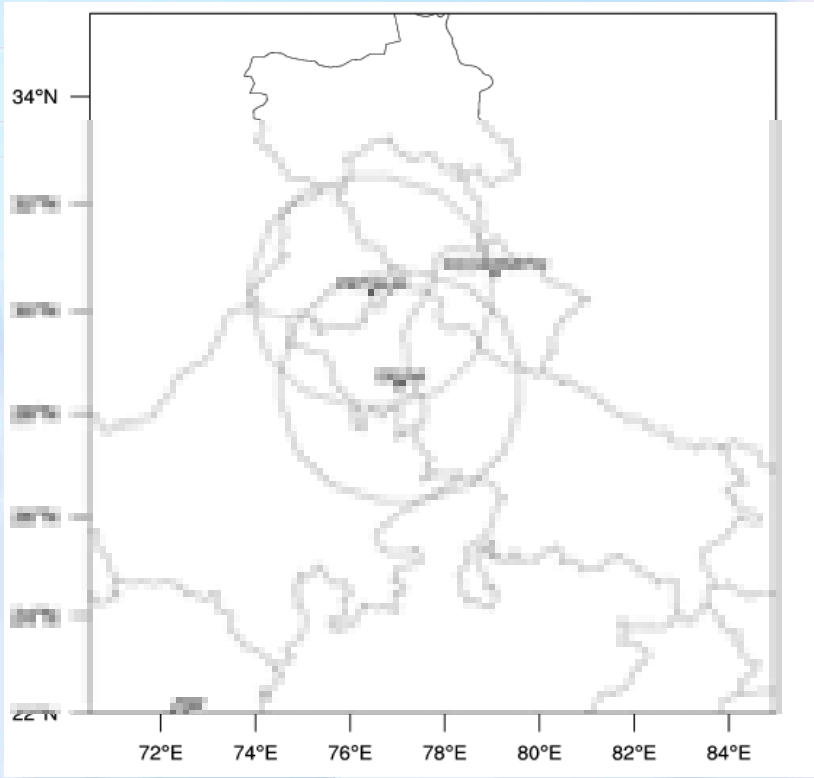
30 May 2014



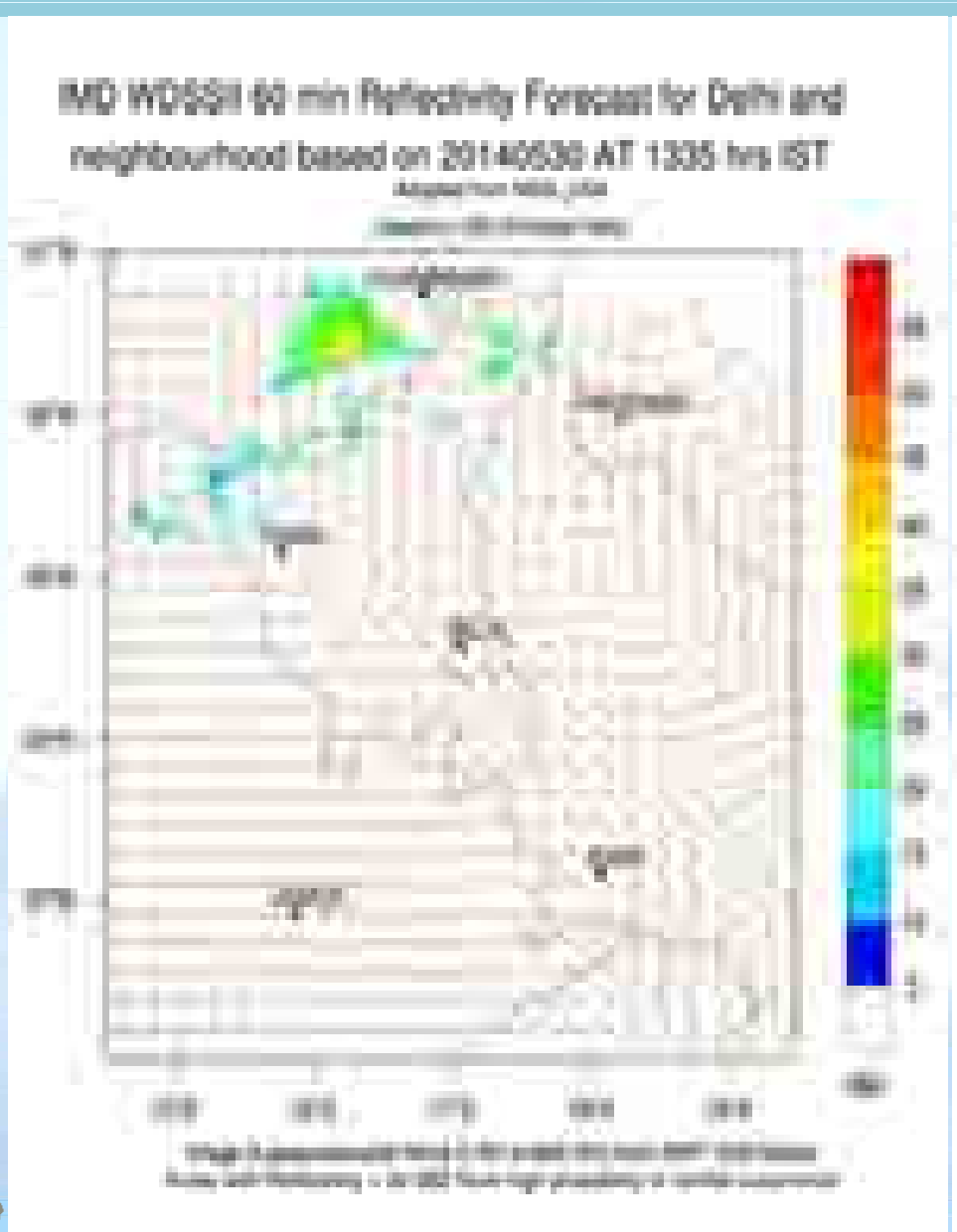
Vertical structure of the cells (a) Velocity field; (b) Reflectivity field at 1110 UTC when the line squalls were recorded over Palam.

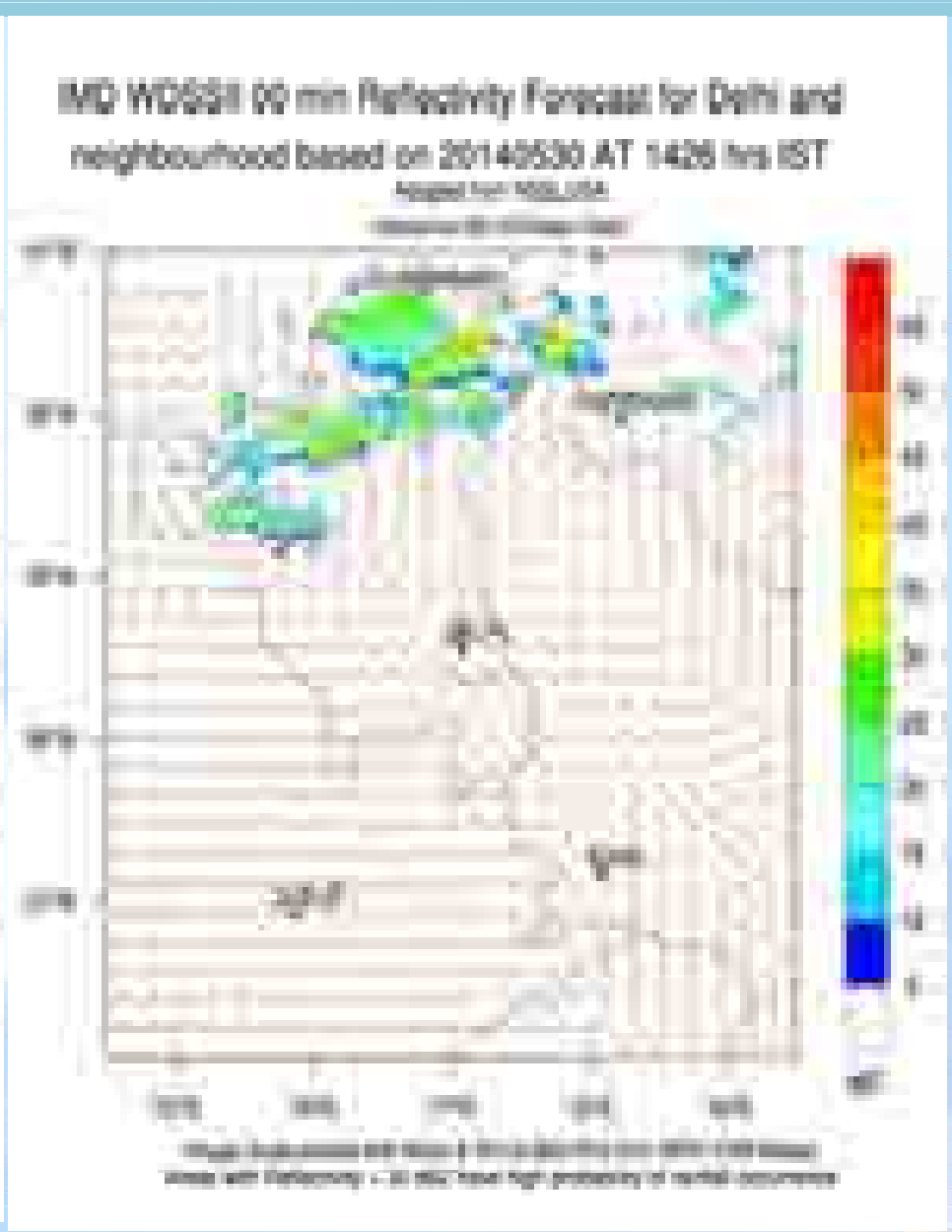
Uttarakhand heavy rainfall episode
15 - 17 June 2013



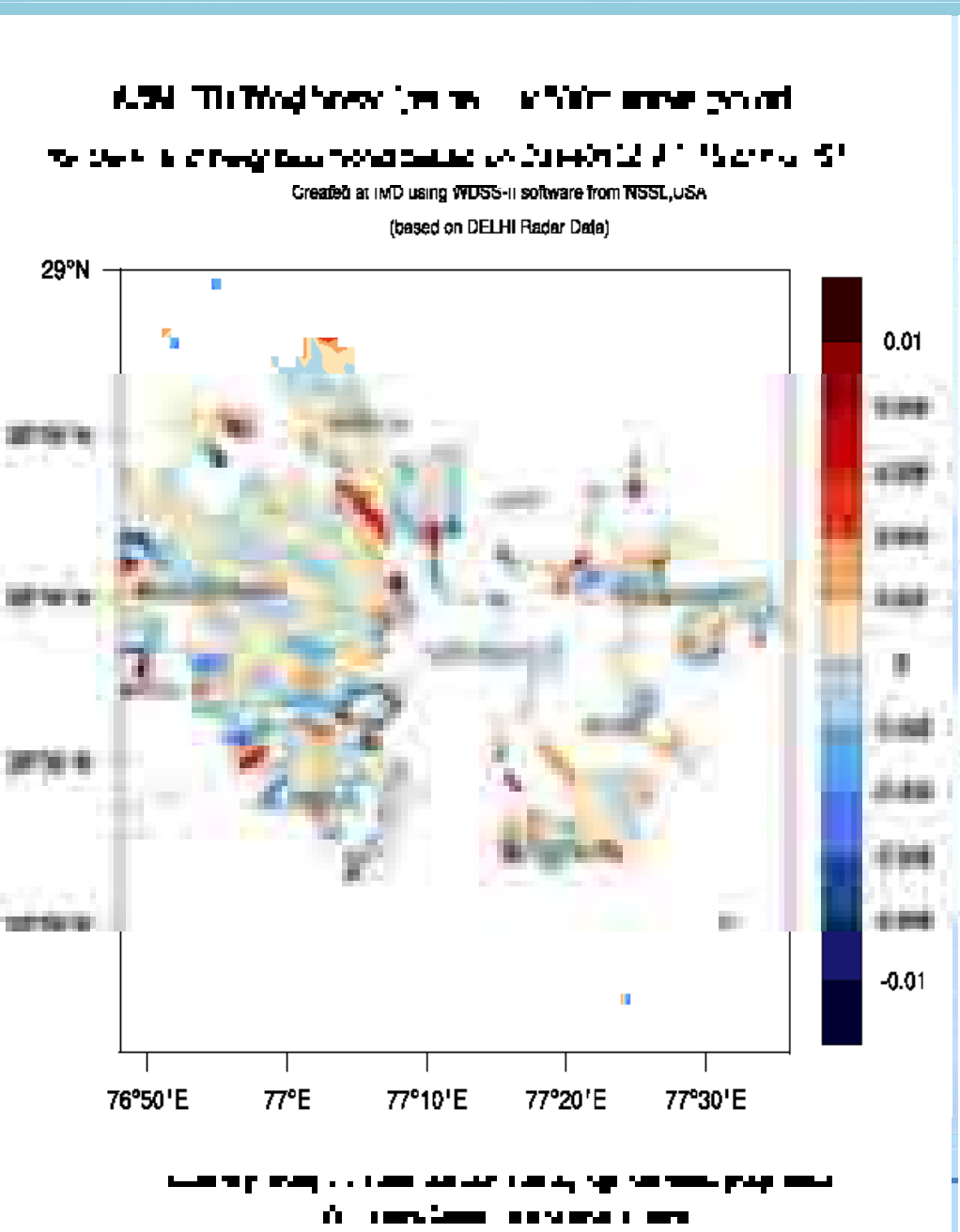


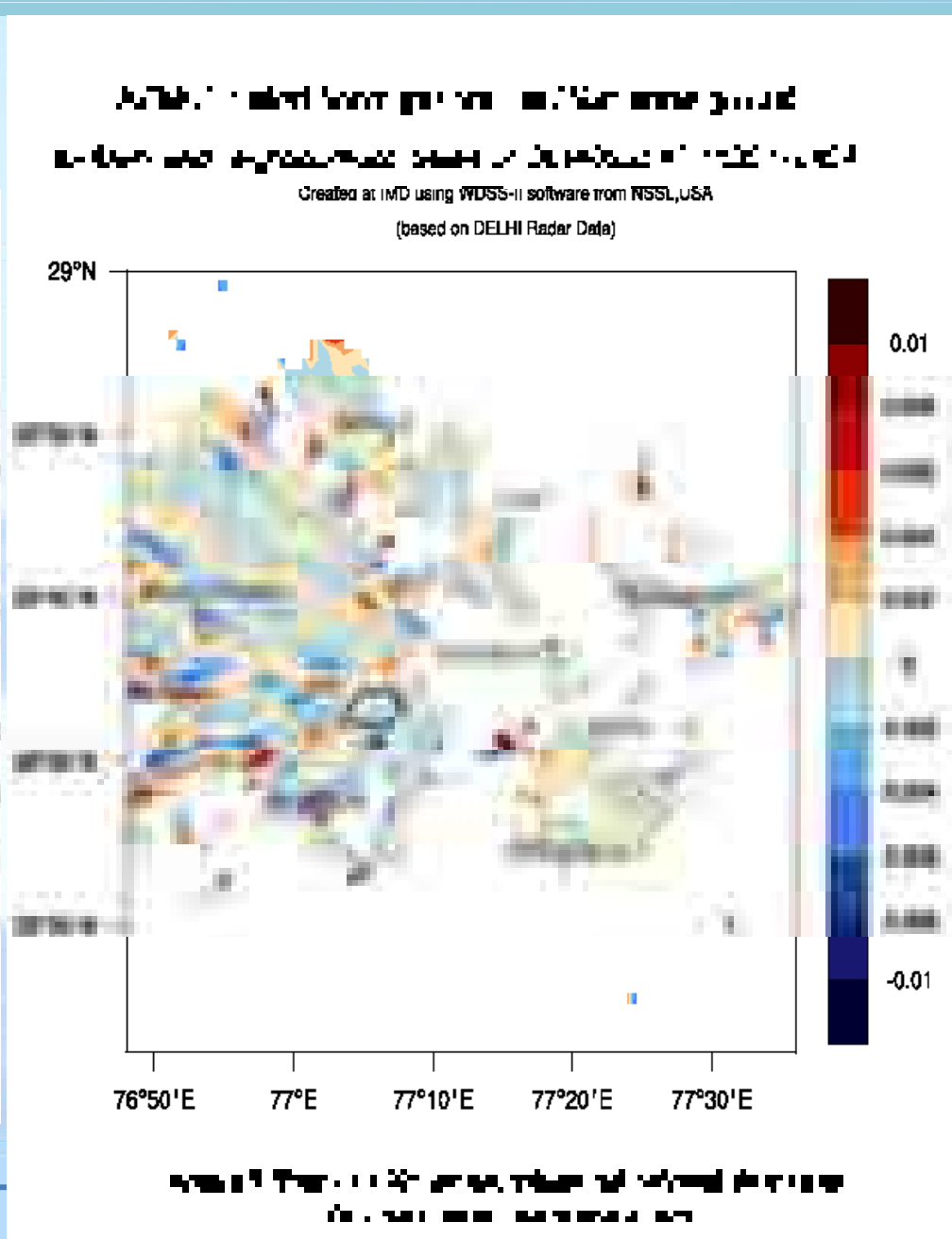
60 minute reflectivity nowcast for 30 May 2014





WDSS-II products for Metropolitan City Forecast and Aviation forecast (Single Radar Products)

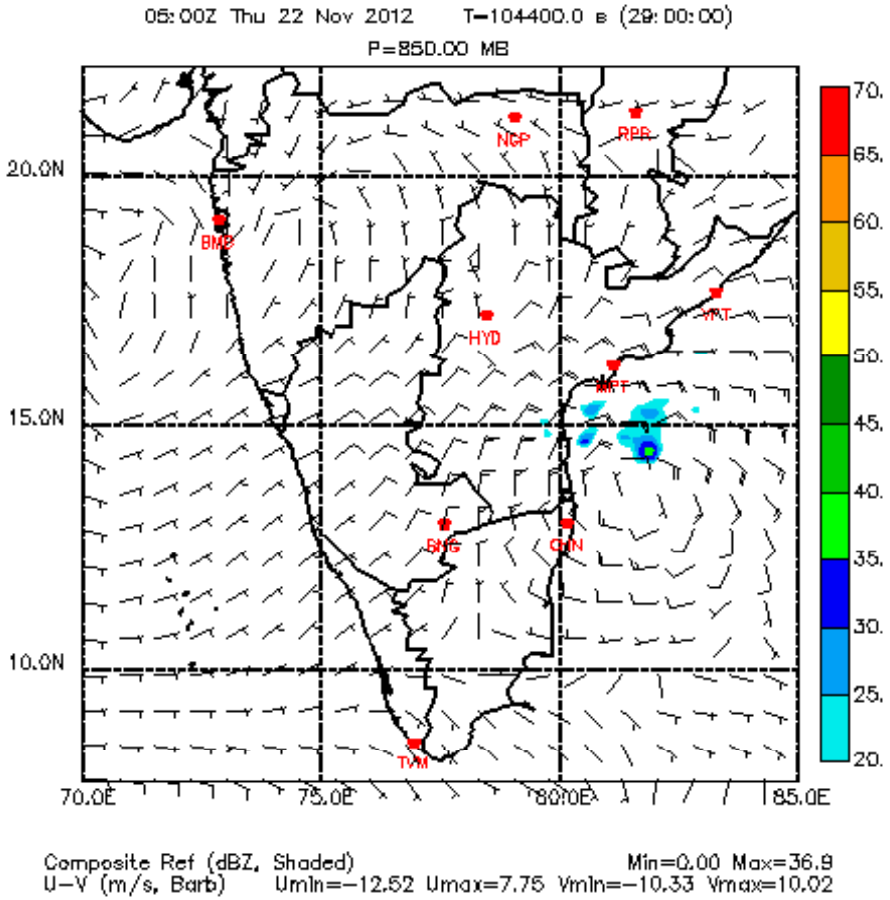




NEXT UPDATE AT 12:15 IST

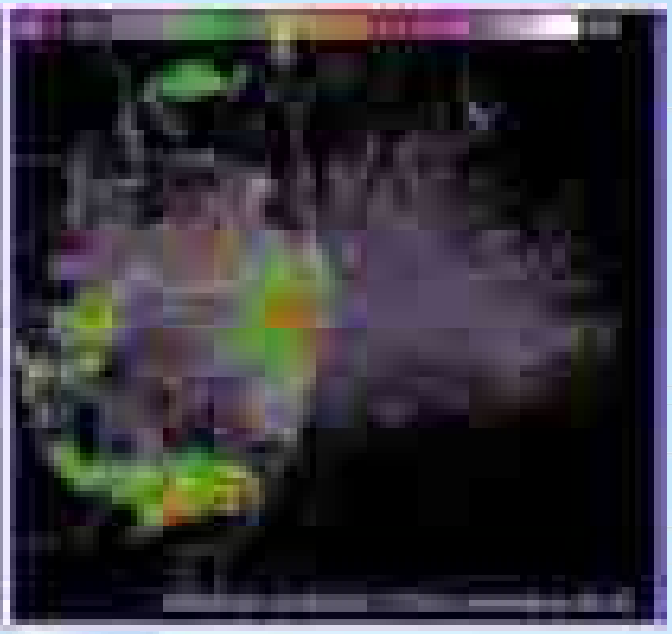
IMD ARPS 850 hPa WIND(kts) & REFLECTIVITY(dBZ) FORECAST

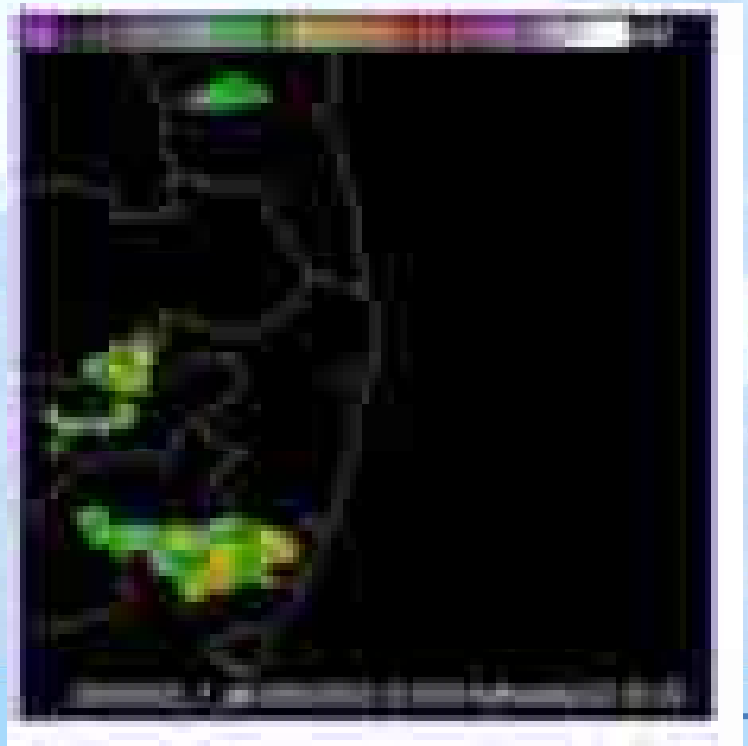
BASED ON 10:30 IST VALID FOR NEXT THREE HOURS



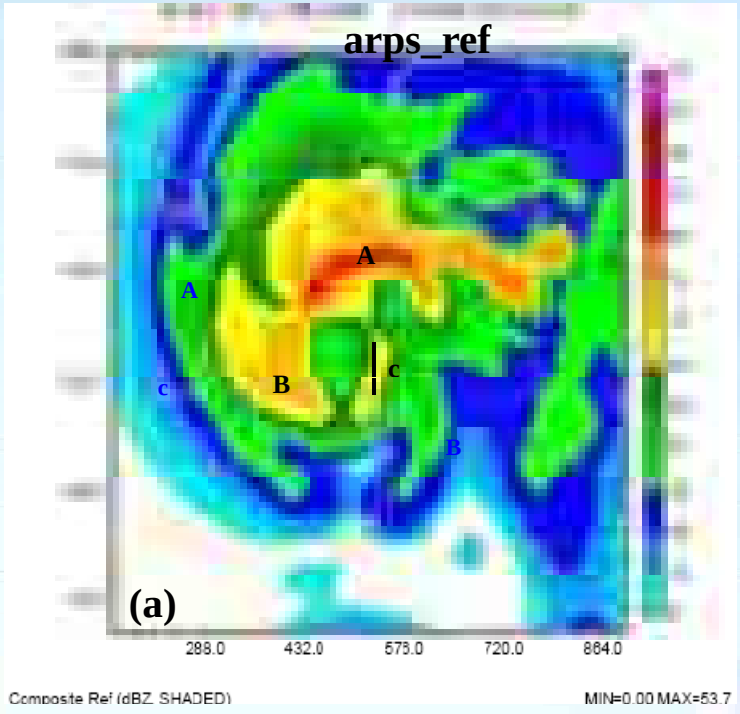
Composite Ref (dBZ, Shaded) Min=0.00 Max=36.9

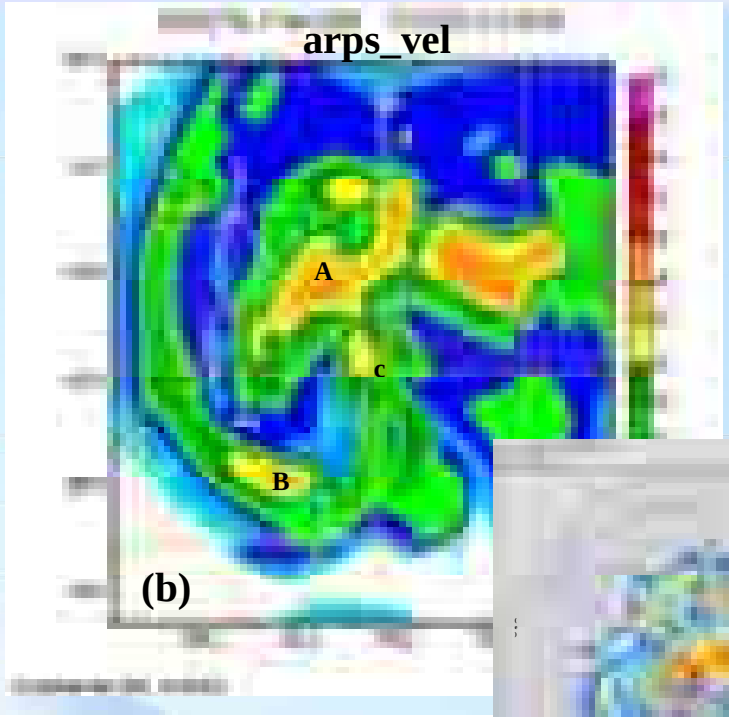
U-V (m/s, Barb) Umin=-12.52 Umax=7.75 Vmin=-10.33 Vmax=10.02

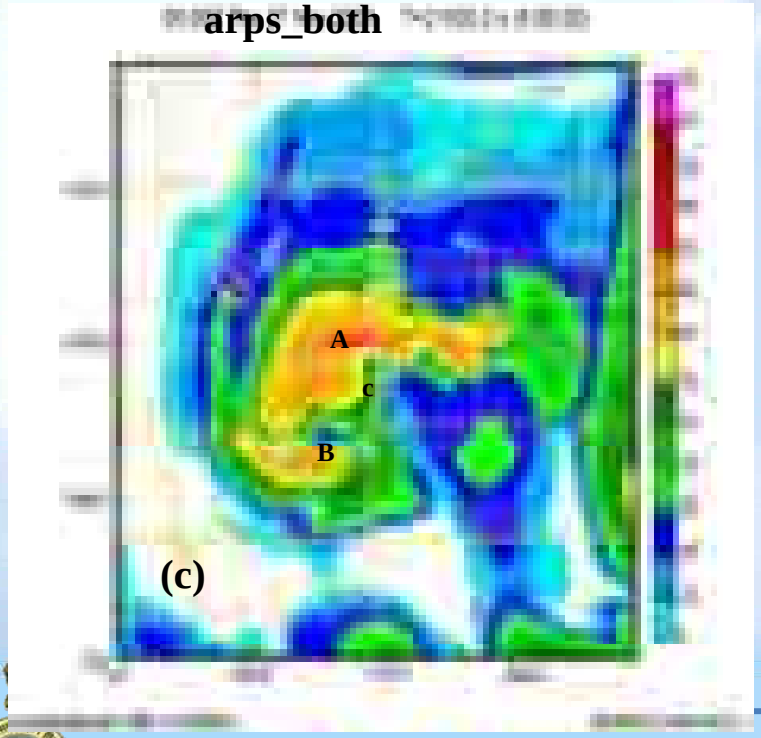


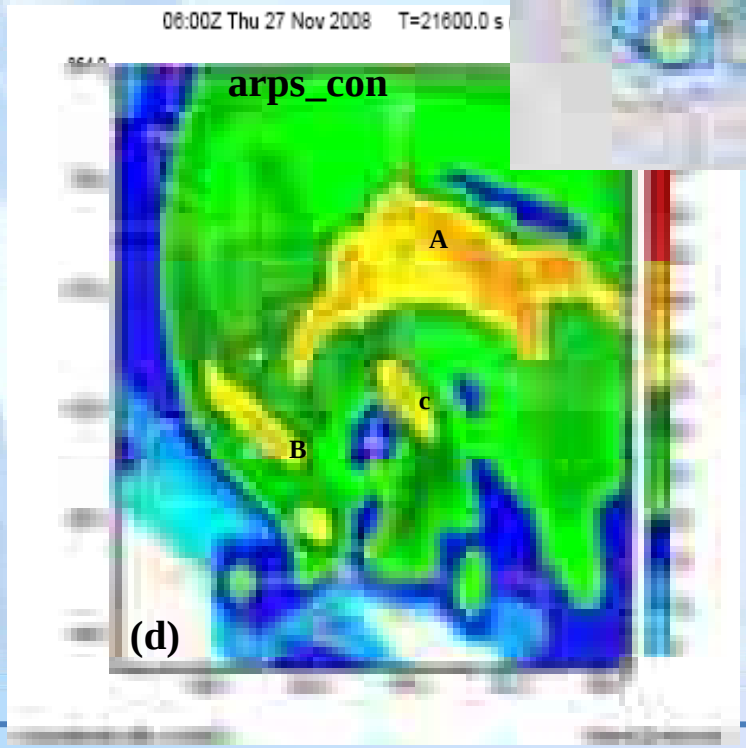


Two reflectivity scans at 1200 UTC and 1210 UTC of 2 September 2005 at 0.2 degree elevation, quality controlled reflectivity scan when anomalous propagation errors and permanent terrain echoes are removed for 1210 UTC scan.


arps_ref
A
A
B
c
c
B
(a)
288.0
432.0
576.0
720.0
864.0
Composite Ref (dBZ, SHADED)
MIN=0.00 MAX=53.7

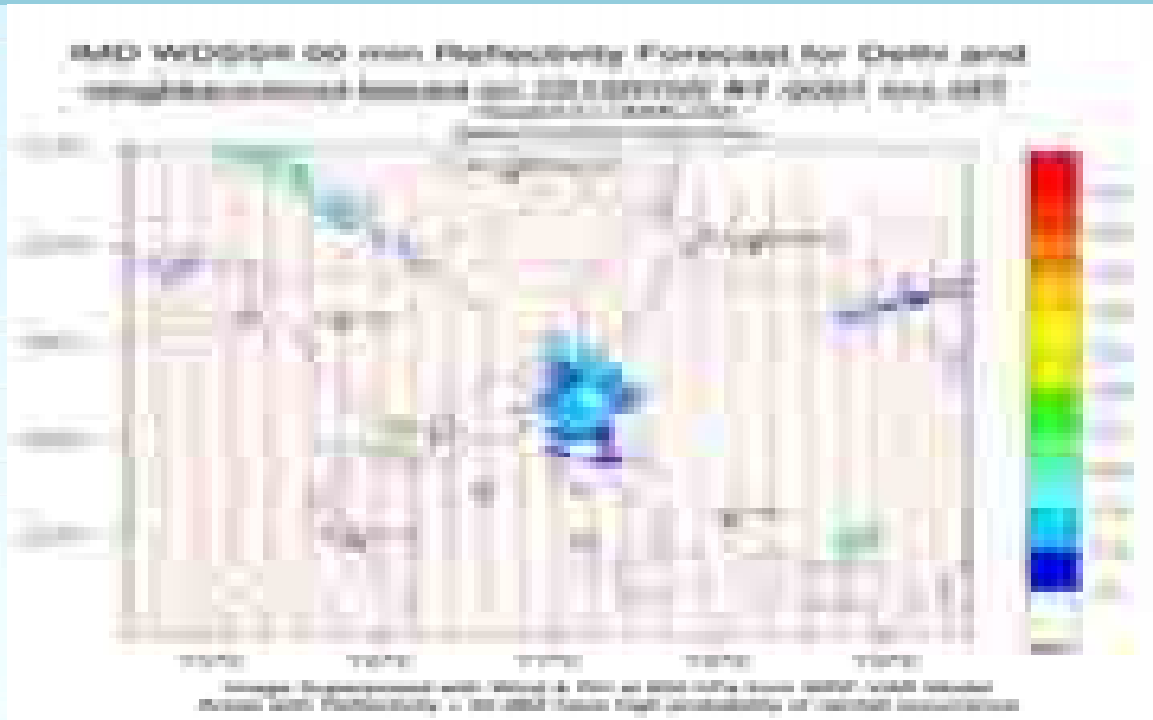

arps_vel
A
c
B
(b)


arps_both
A
c
B
(c)

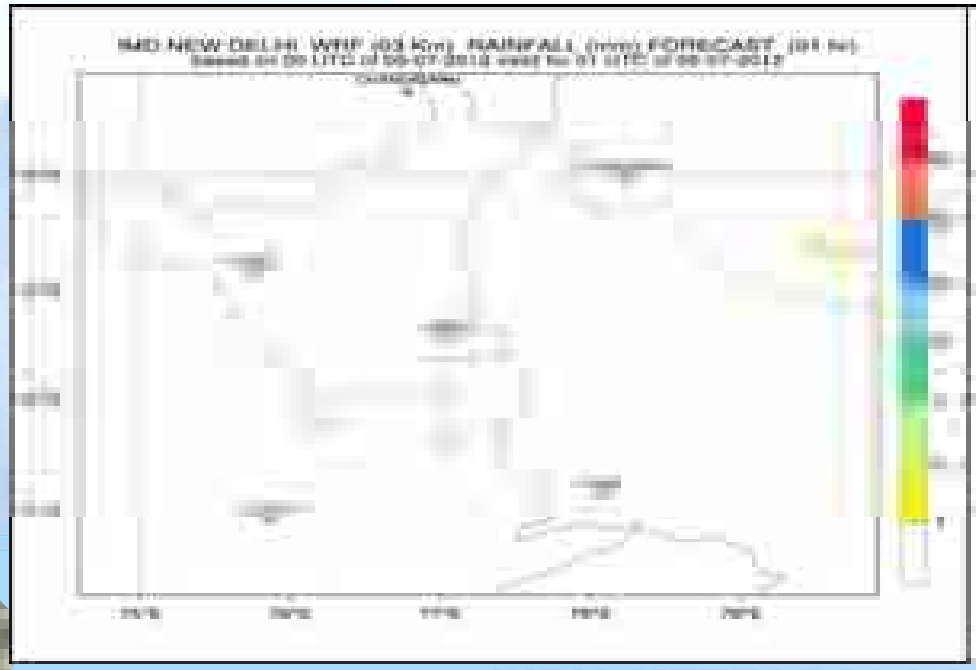

06:00Z Thu 27 Nov 2008
T=21600.0 s
arps_con
A
c
B
(d)

WRF hourly R/F Forecast: Based on 00 UTC 05-07-2012

Observed radar reflectivity



Forecast rainfall without radar assimilation

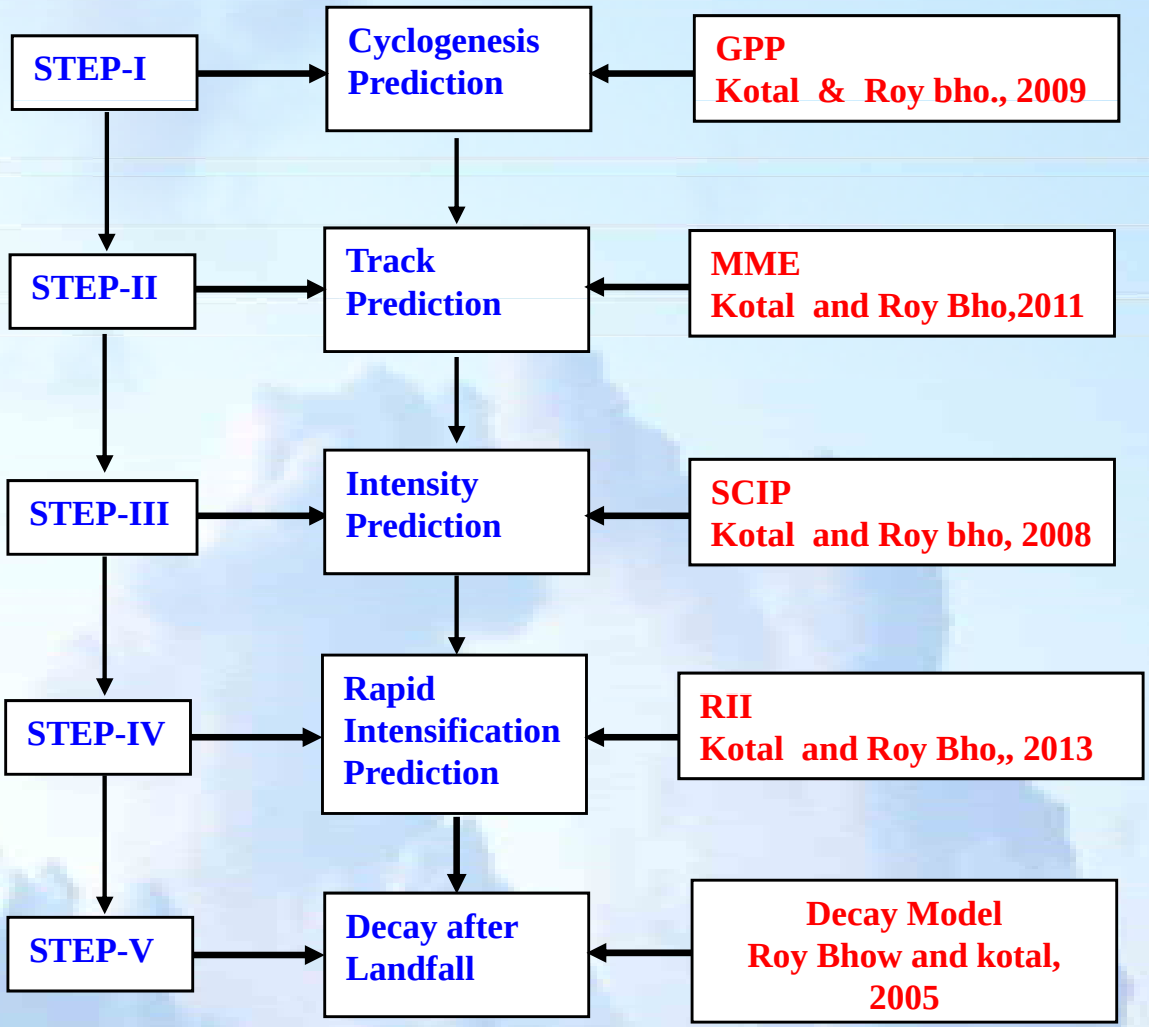


Forecast rainfall with radar assimilation

Forecast Improvement Process

- **Initial Condition**
  - > *Observation*
  - > *Data Assimilation*
- **Model Uncertainty**
  - > *Model Resolution*
  - > *Physical Process*
- **Post Processing**
  - > *Statistical Bias Correction*
  - > *Customization for user specific F/C Product*
  - > *GIS Applications for graphics*

Flow Diagram of Cyclone Prediction System



MME Cyclone Track Prediction

WRF QLM JMA ECMWF IMD GFS

12-hourly forecast latitude (LAT^f) and longitude (LON^f) positions at time t is defined as:

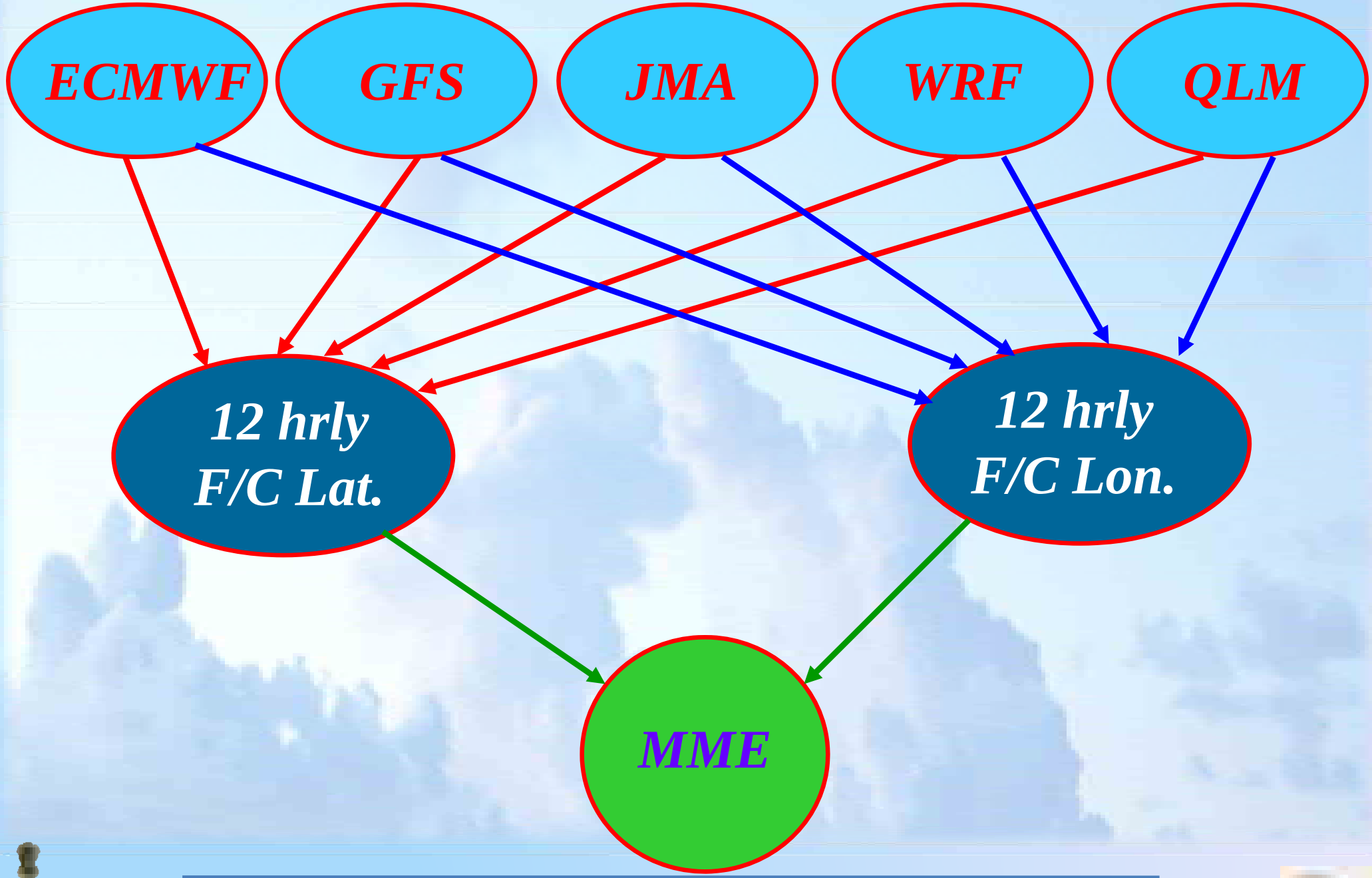
$$LAT^f_t = a_o + a_1 ECMWF_t^{lat} + a_2 GFS_t^{lat} + a_3 JMA_t^{lat} + a_4 WRF_t^{lat} + a_5 QLM_t^{lat}$$

$$LON^f_t = a'_o + a'_1 ECMWF_t^{lon} + a'_2 GFS_t^{lon} + a'_3 JMA_t^{lon} + a'_4 WRF_t^{lon} + a'_5 QLM_t^{lon}$$

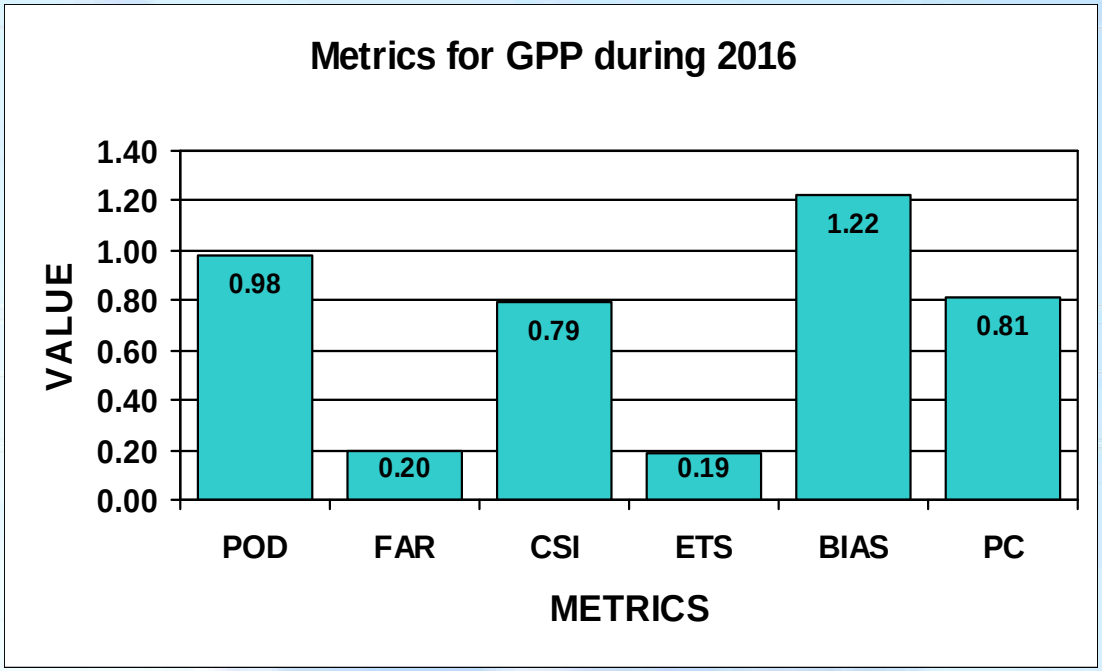
for t = forecast hour 12, 24, 36, 48, 60 and 72

Kotal S.D. and Roy Bhowmik SK, 2011, A multi-model ensemble (MME) technique for cyclone track prediction over the North Indian Sea, **Geofizika, 28, 275-291**

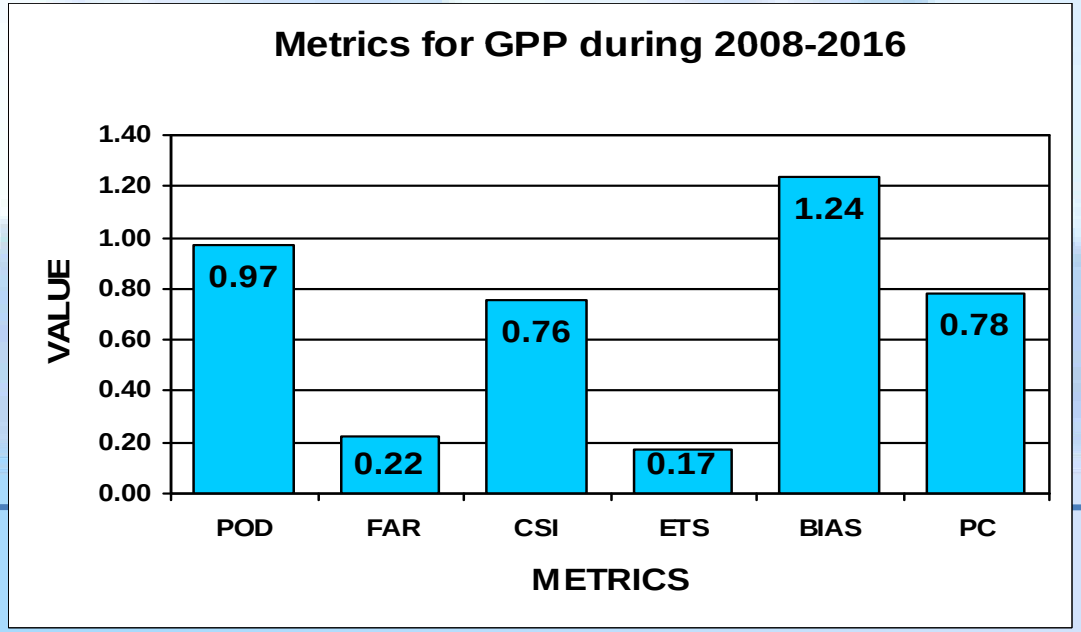
TRACK PREDICTION BY NWP MODELS AND MME



Forecast Skill of Genesis potential parameter (GPP) during 2016



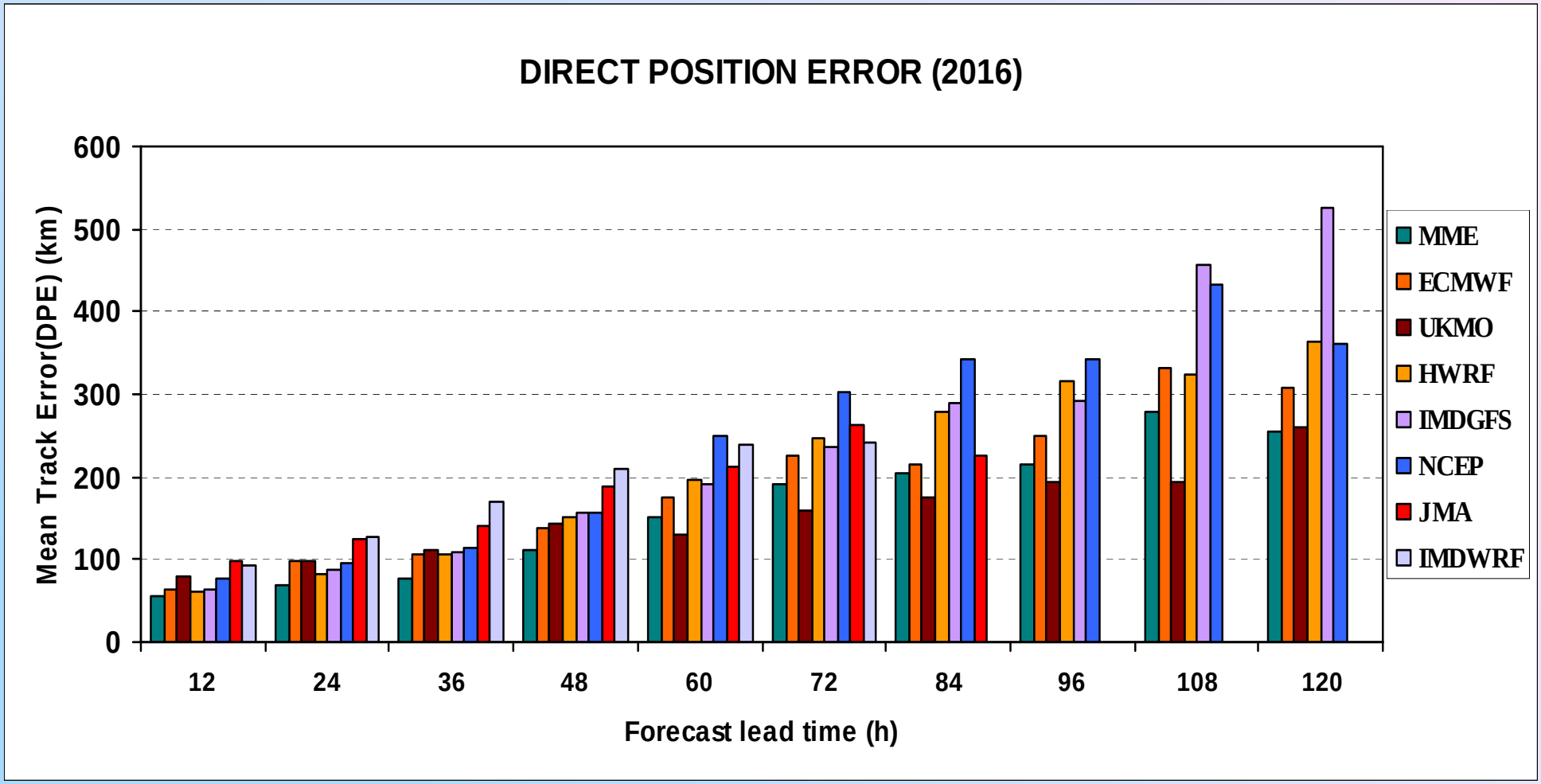
Forecast Skill of Genesis potential parameter (GPP) during 2008-2016



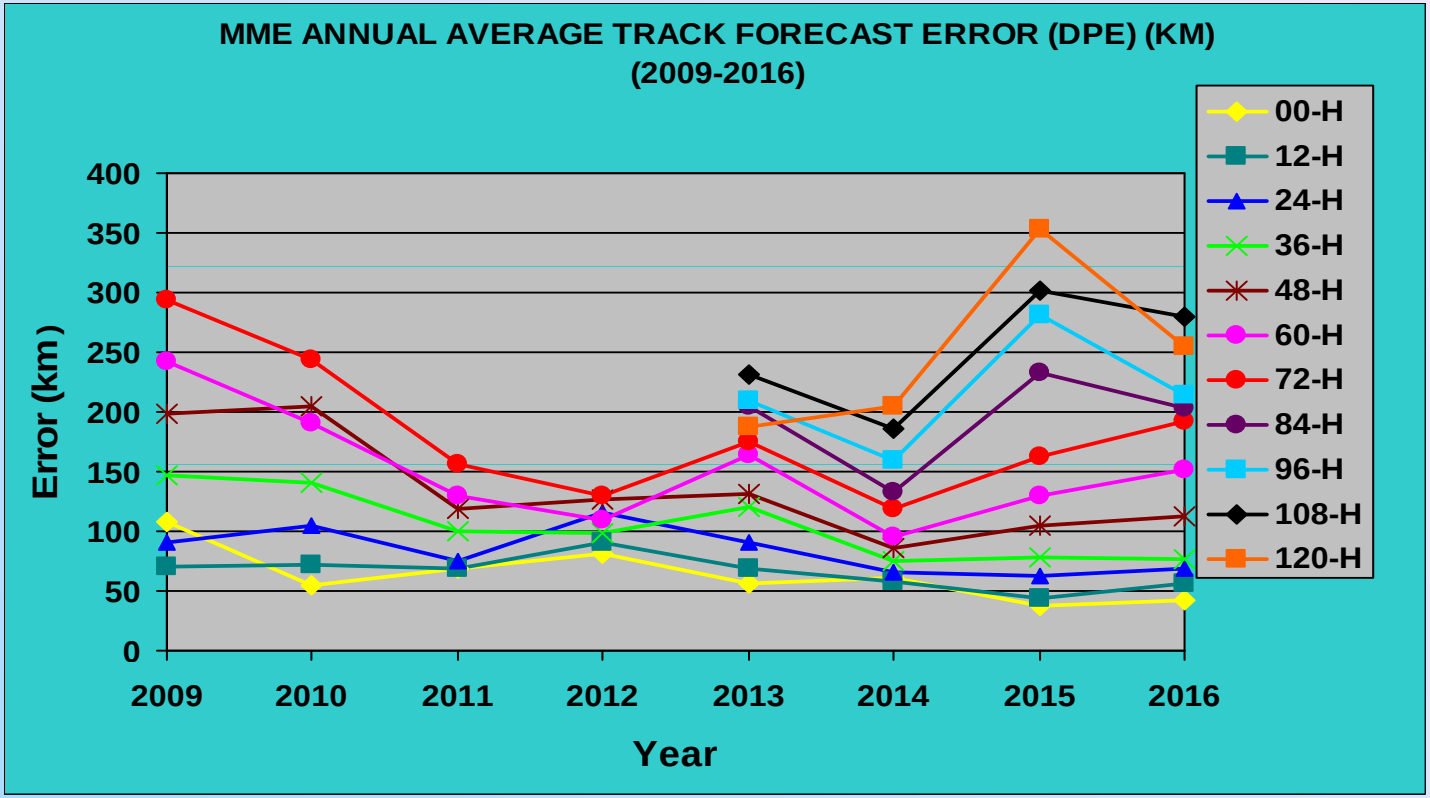
Mean track forecast error (km) - 2016 (Number of forecast verified)

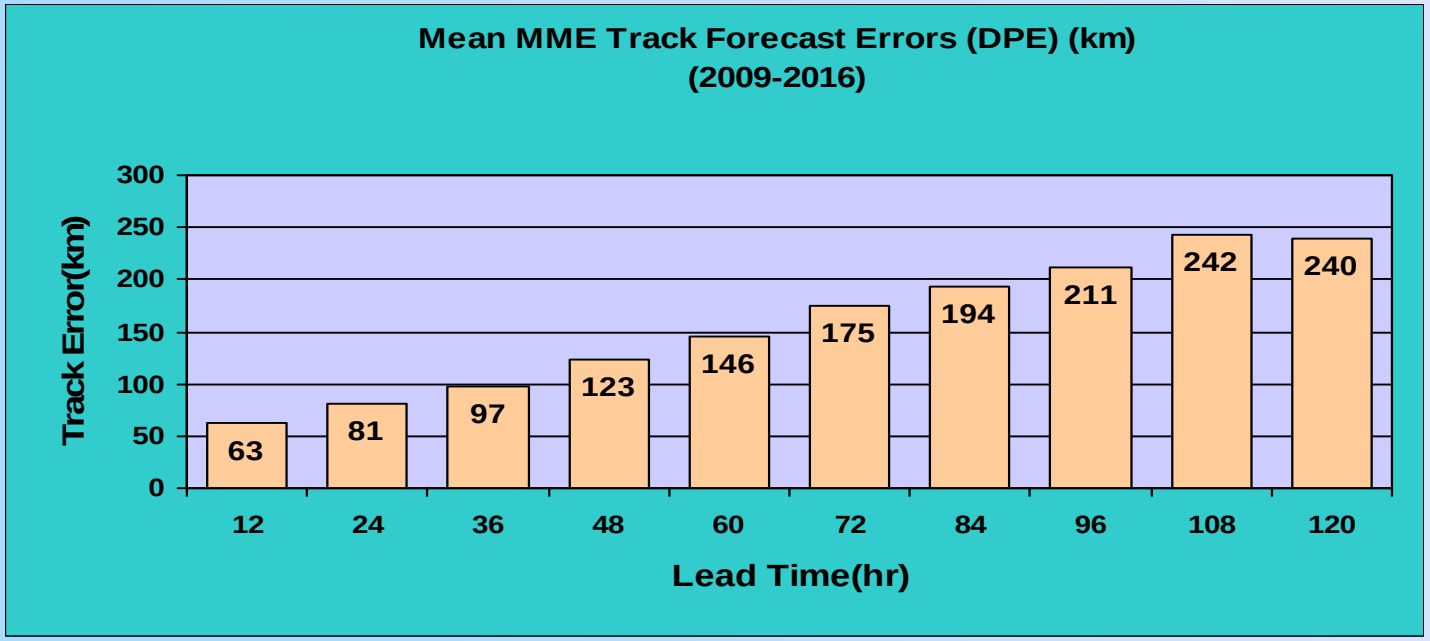
Lead time →	12 hr	24 hr	36 hr	48 hr	60 hr	72 hr	84hr	96hr	108hr	120hr
IMD-GFS	64(33)	87(31)	109(26)	157(23)	190(18)	235(15)	289(11)	293(9)	458(6)	525(4)
IMD-WRF	92(33)	128(32)	169(27)	209(23)	239(17)	242(13)	-	-	-	-
JMA	97(32)	125(31)	142(26)	189(22)	213(17)	264(14)	226(11)	-	-	-
NCEP	77(33)	95(32)	114(27)	157(22)	250(18)	303(15)	343(12)	343(9)	434(6)	361(4)
UKMO	78(33)	99(32)	112(27)	144(23)	130(17)	158(15)	176(12)	194(9)	193(6)	259(4)
ECMWF	64(33)	99(32)	105(27)	139(23)	176(18)	226(15)	216(12)	248(9)	332(6)	307(4)
IMD-HWRF	61(72)	82(64)	107(56)	150(48)	196(41)	246(35)	278(29)	316(23)	323(17)	364(10)
IMD-MME	57(33)	69(32)	76(27)	112(23)	151(18)	192(15)	204(12)	214(9)	279(6)	254(4)

Mean track forecast error (km)-2016

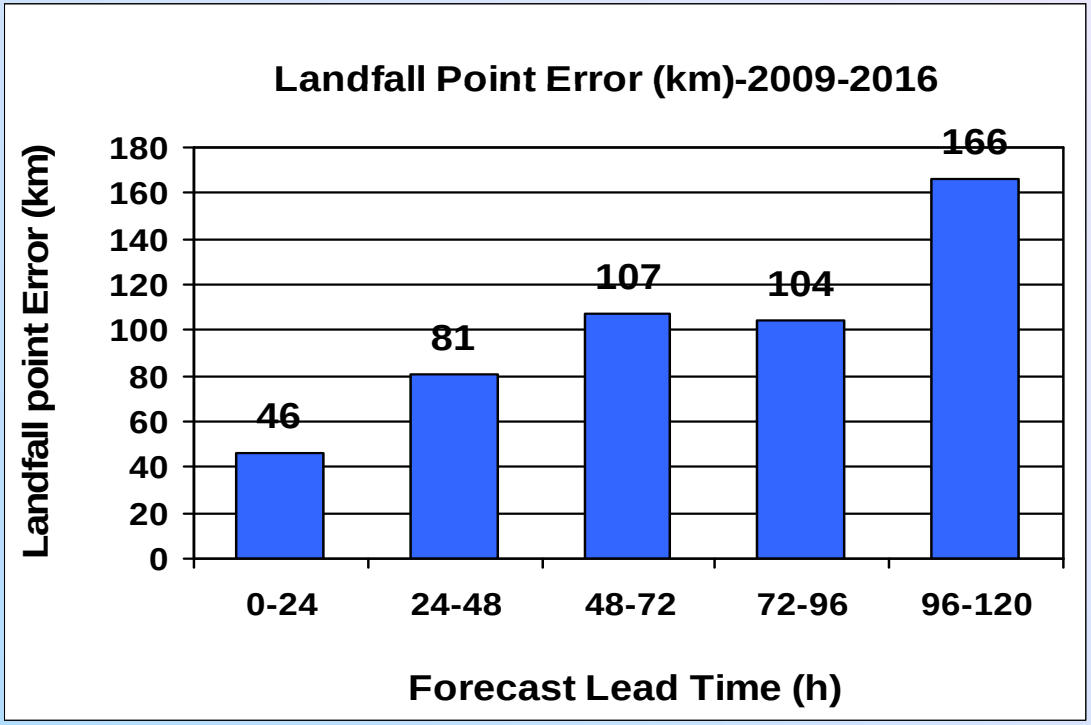


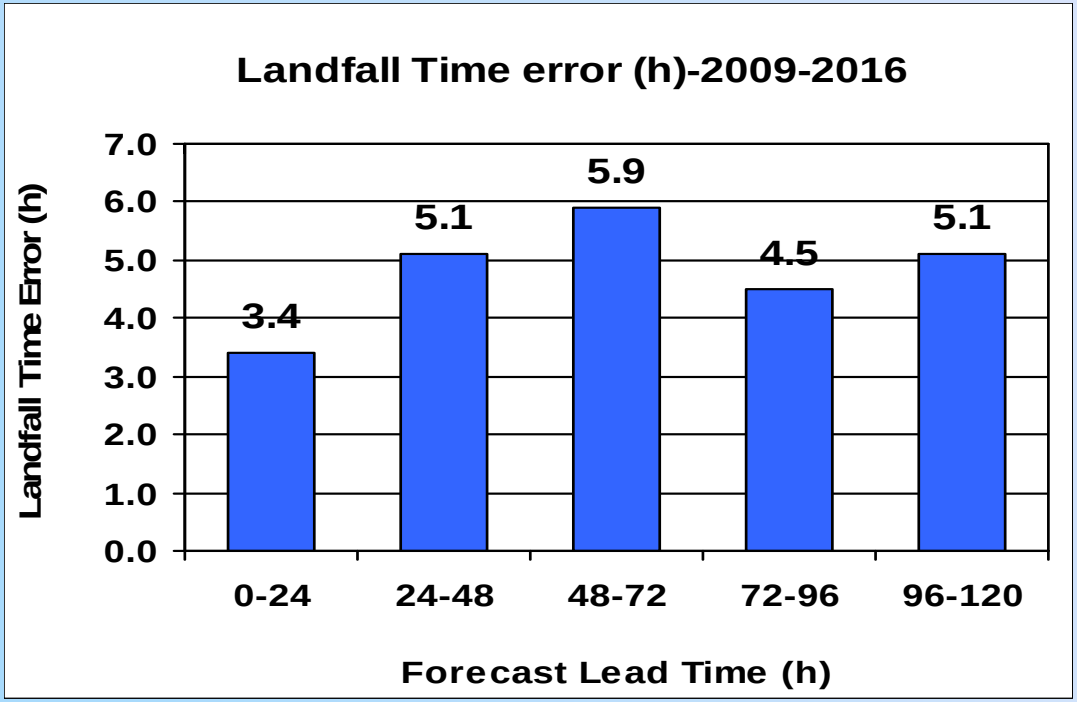
Year wise MME track forecast error (km)





Landfall Point error (km) and Time error (h) of MME (2009-2016)





Mean Intensity forecast error (kt) of SCIP model-2016

SCIP

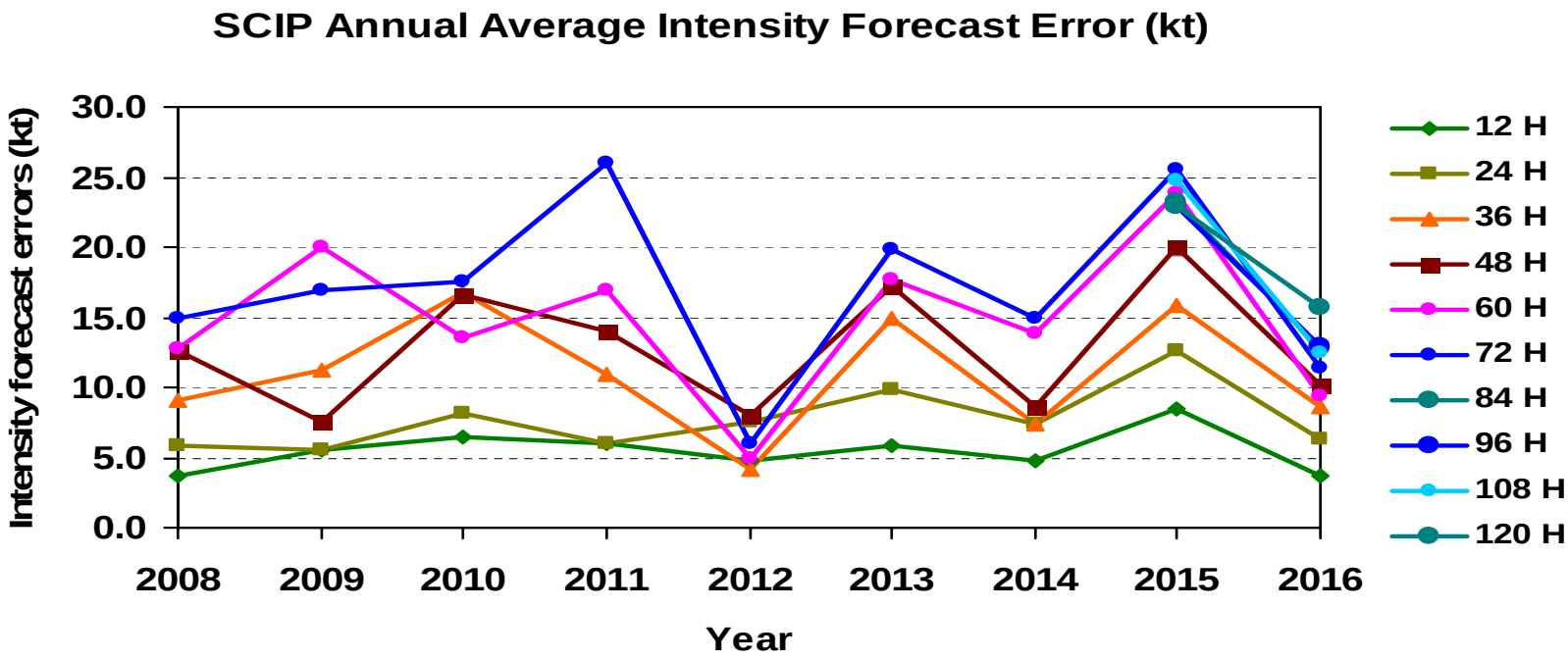
Lead time →	12 hr	24 hr	36 hr	48 hr	60 hr	72 hr	84hr	96hr	108hr	120hr
IMD-SCIP (AAE)	3.7(33)	6.3(30)	8.6(25)	10.1(21)	9.3(16)	11.5(13)	12.7(10)	12.9(7)	12.4(5)	15.7(3)
IMD-SCIP (RMSE)	4.4	7.4	10.0	12.1	12.1	13.7	14.5	16.4	14.9	18.5

Mean Intensity forecast error (kt) of HWRF model-2016

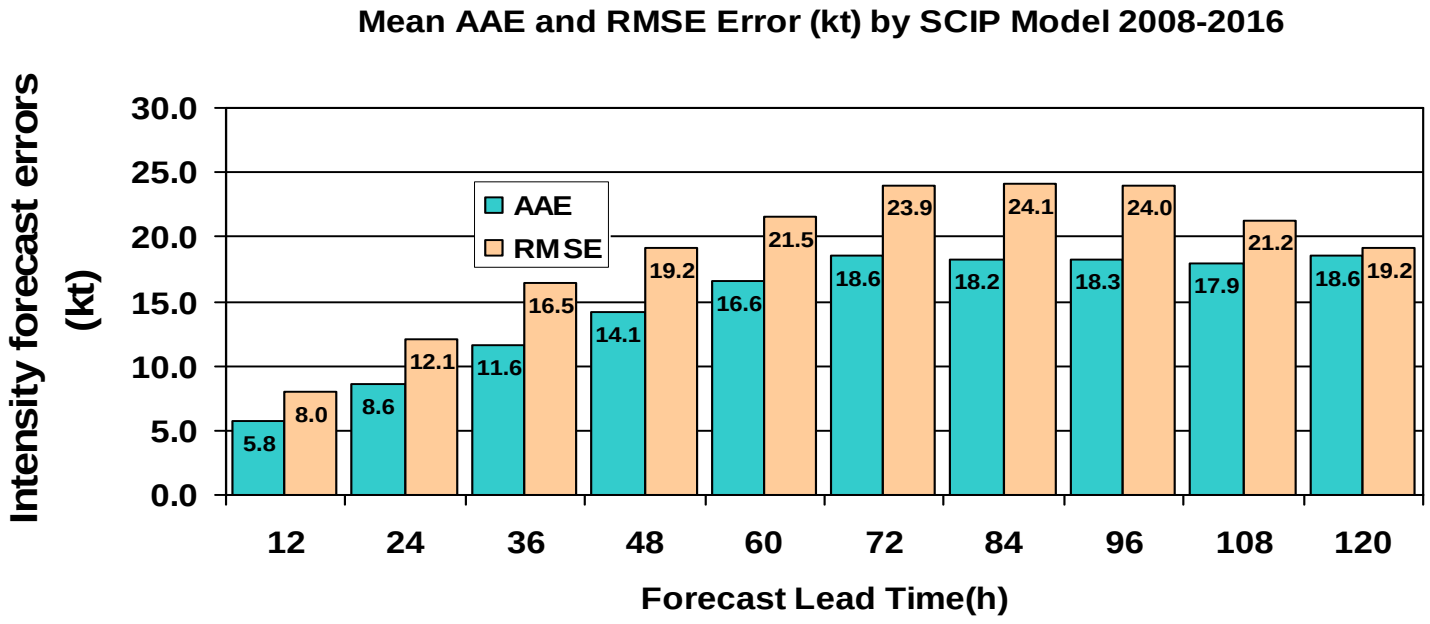
HWRF

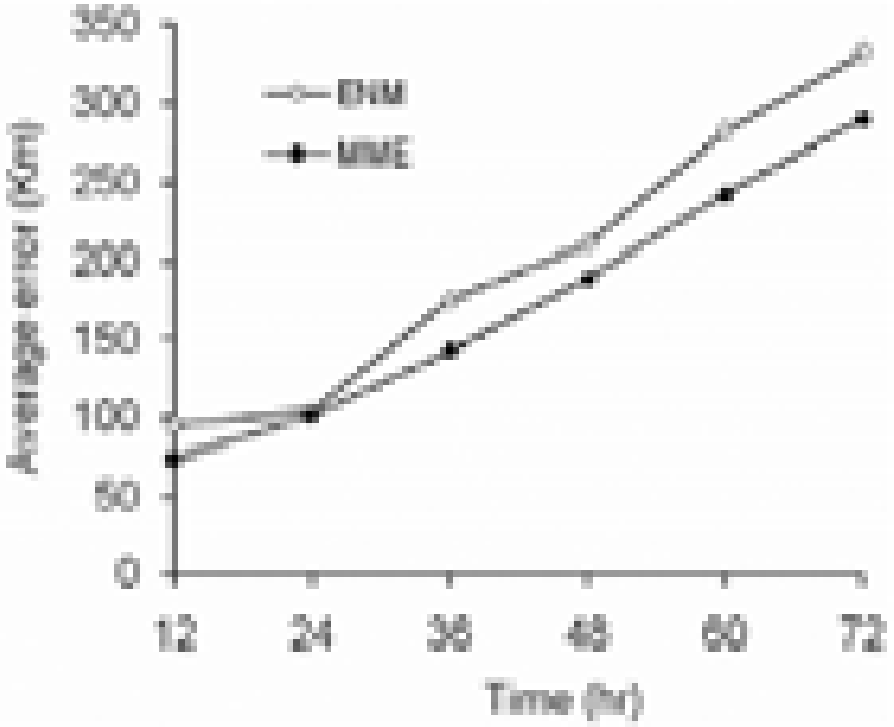
Lead Time	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr	72 Hr	84 Hr	96 Hr	108 Hr	120Hr
AAE	7.8(72)	9.1(64)	9.7(56)	12.8(47)	15.4(41)	20.3(35)	21.6(29)	20.6(23)	24.0(17)	21.9(7)
RMSE	9.7	11.7	12.4	14.9	18.6	21.8	23.5	25.4	27.2	26.1

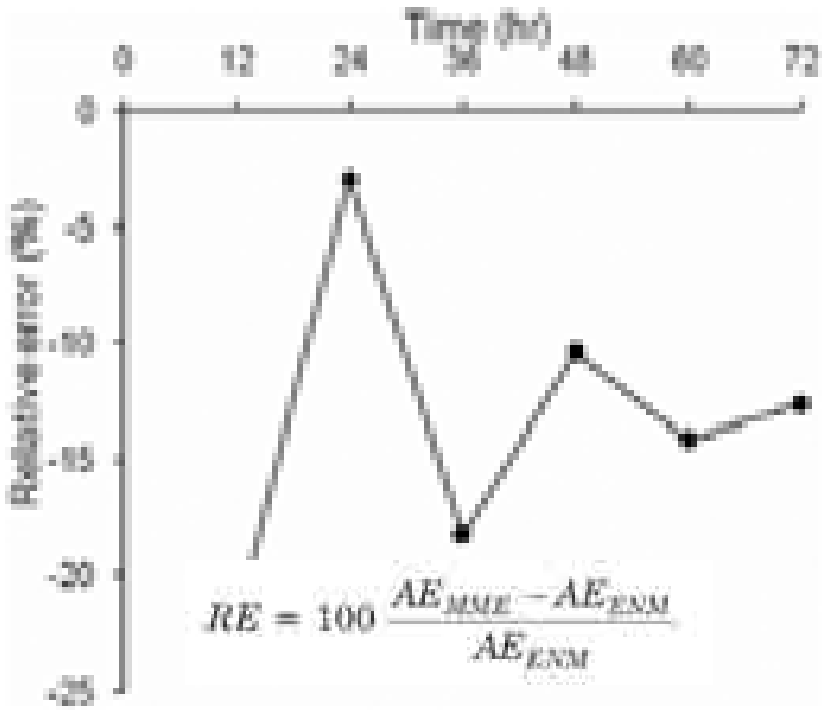
Year wise SCIP intensity forecast error (kt)



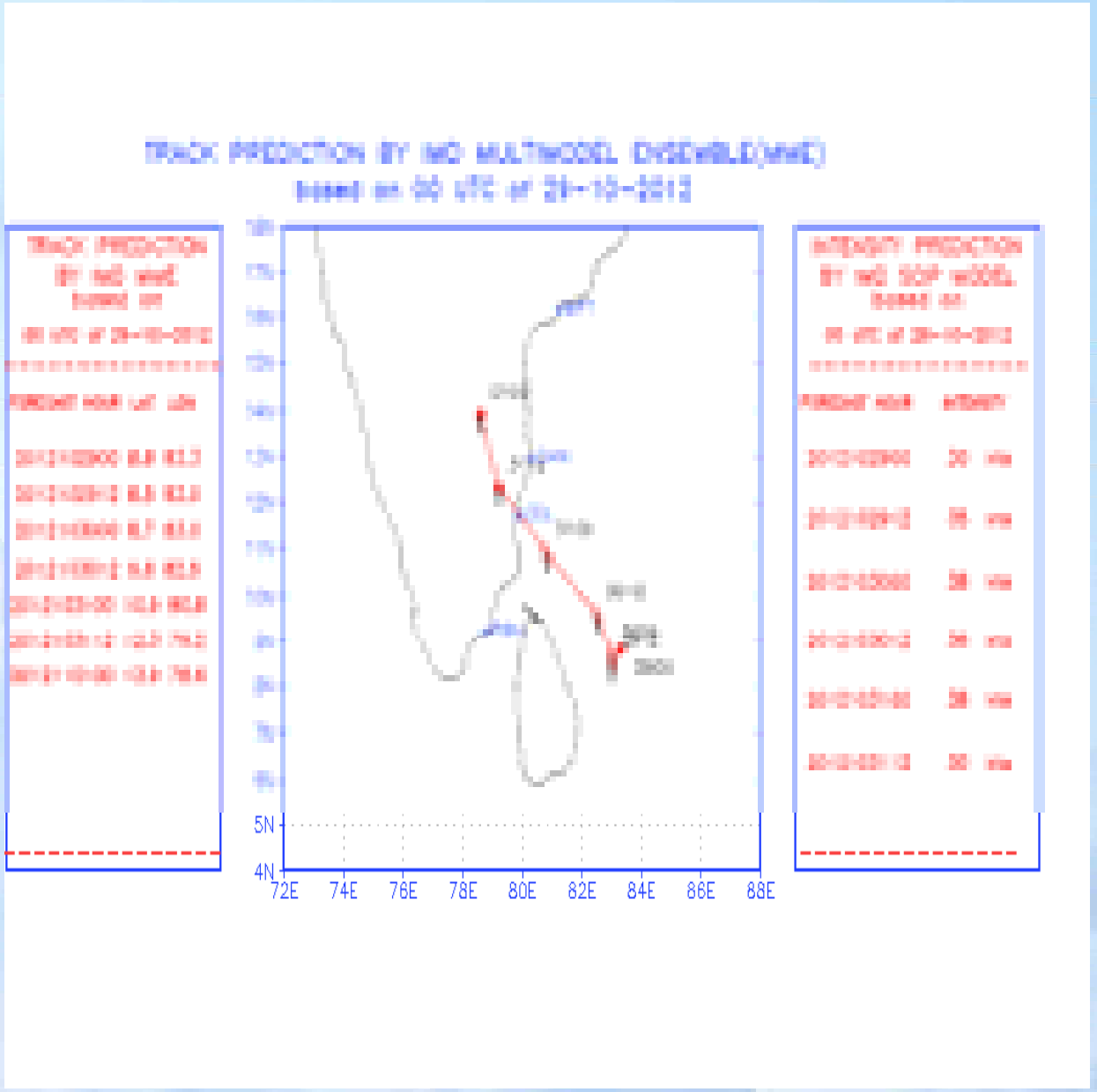
Mean SCIP intensity forecast error (kt)

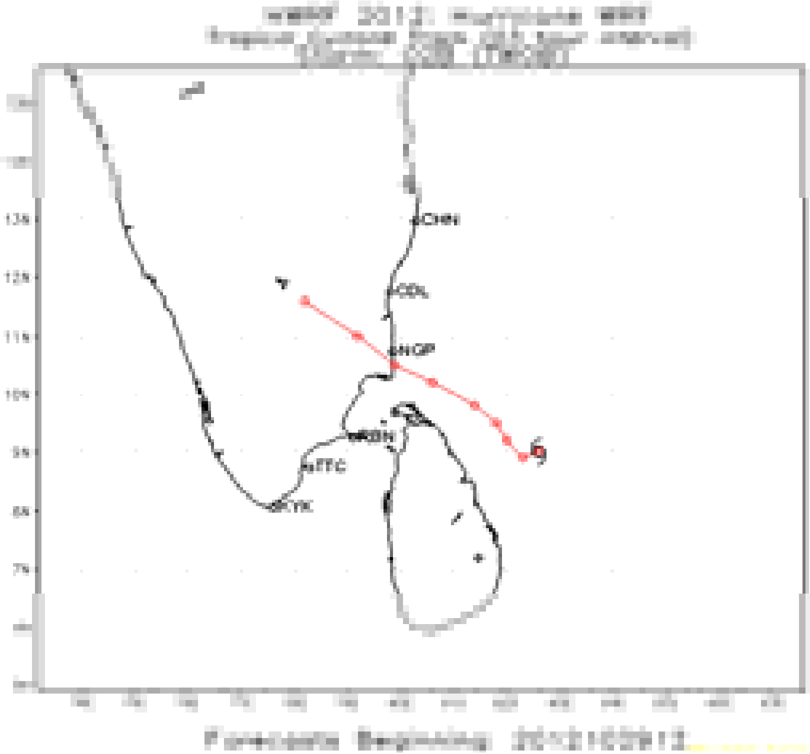


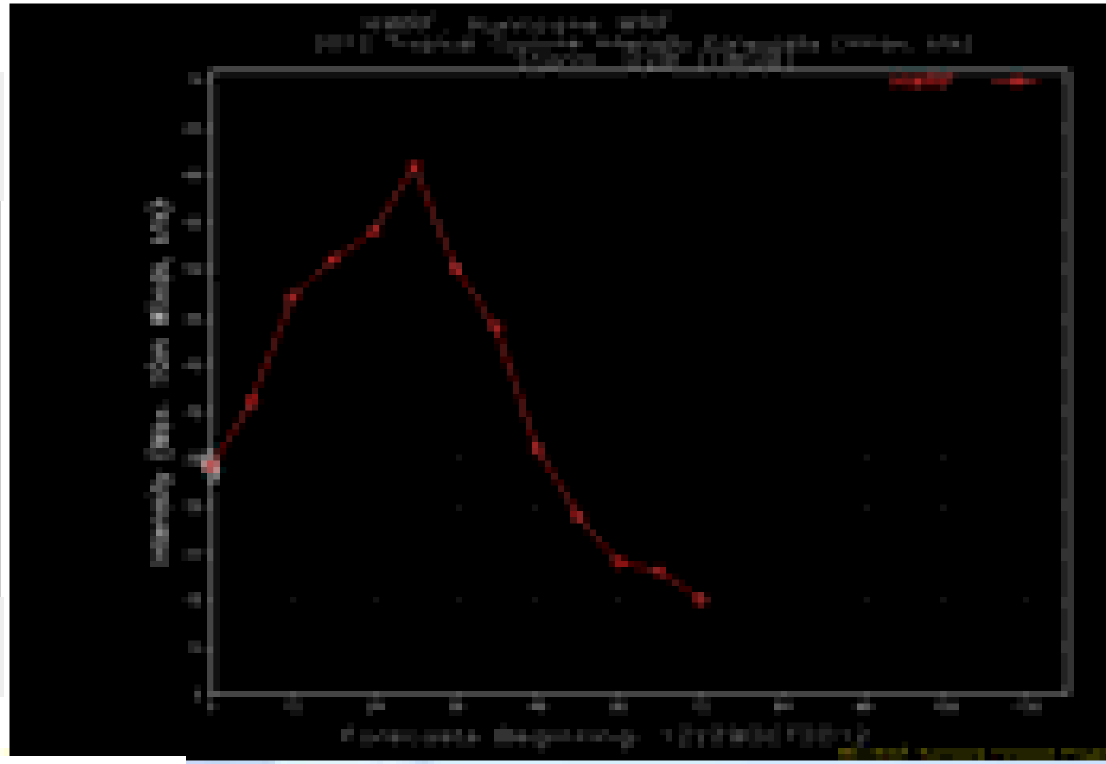


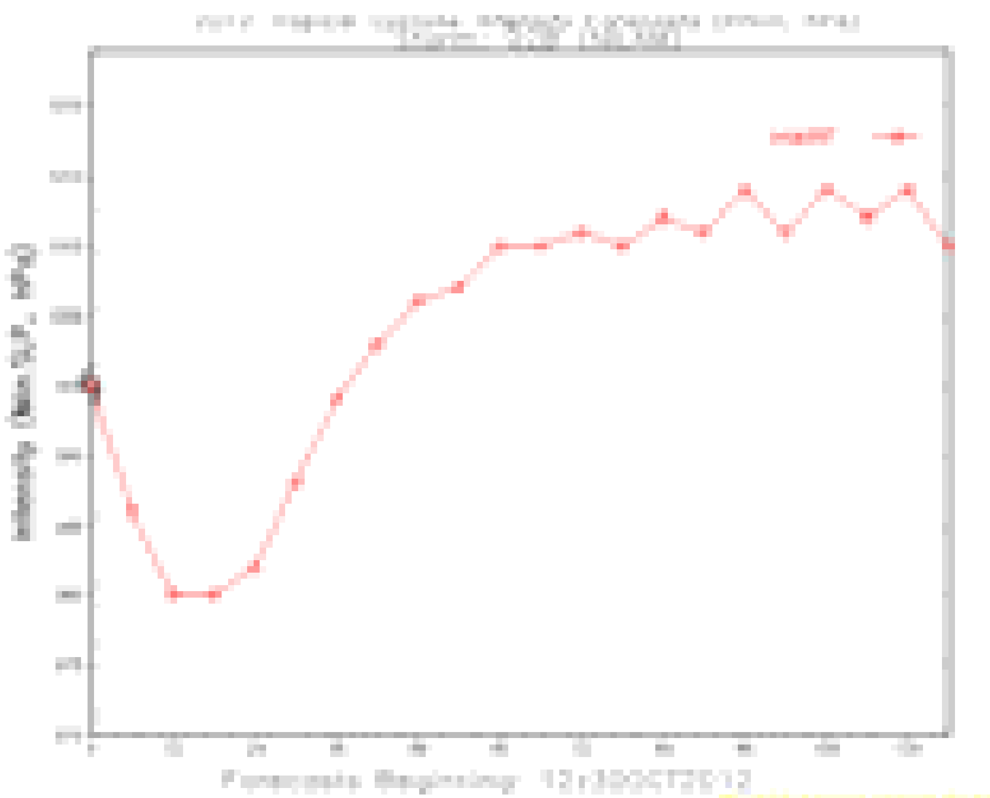


Improvement of MME over ENM 3%-22% during 2009-2010

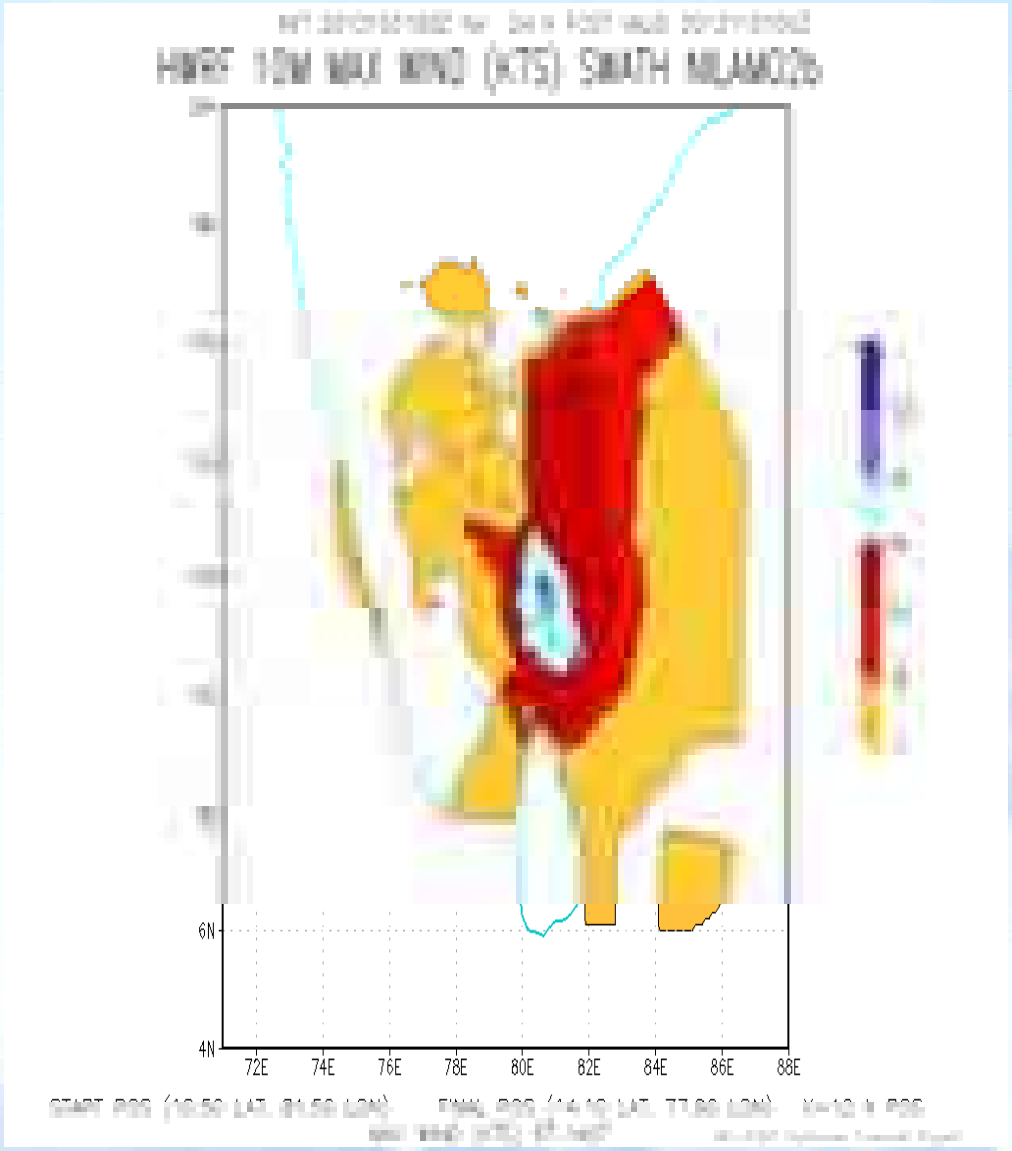

TRACK PREDICTION BY IMD MULTIMODEL ENSEMBLE(MME)
TRACK PREDICTION
INTENSITY PREDICTION
5N
4N
72E
74E
76E
78E
80E
82E
84E
86E
88E

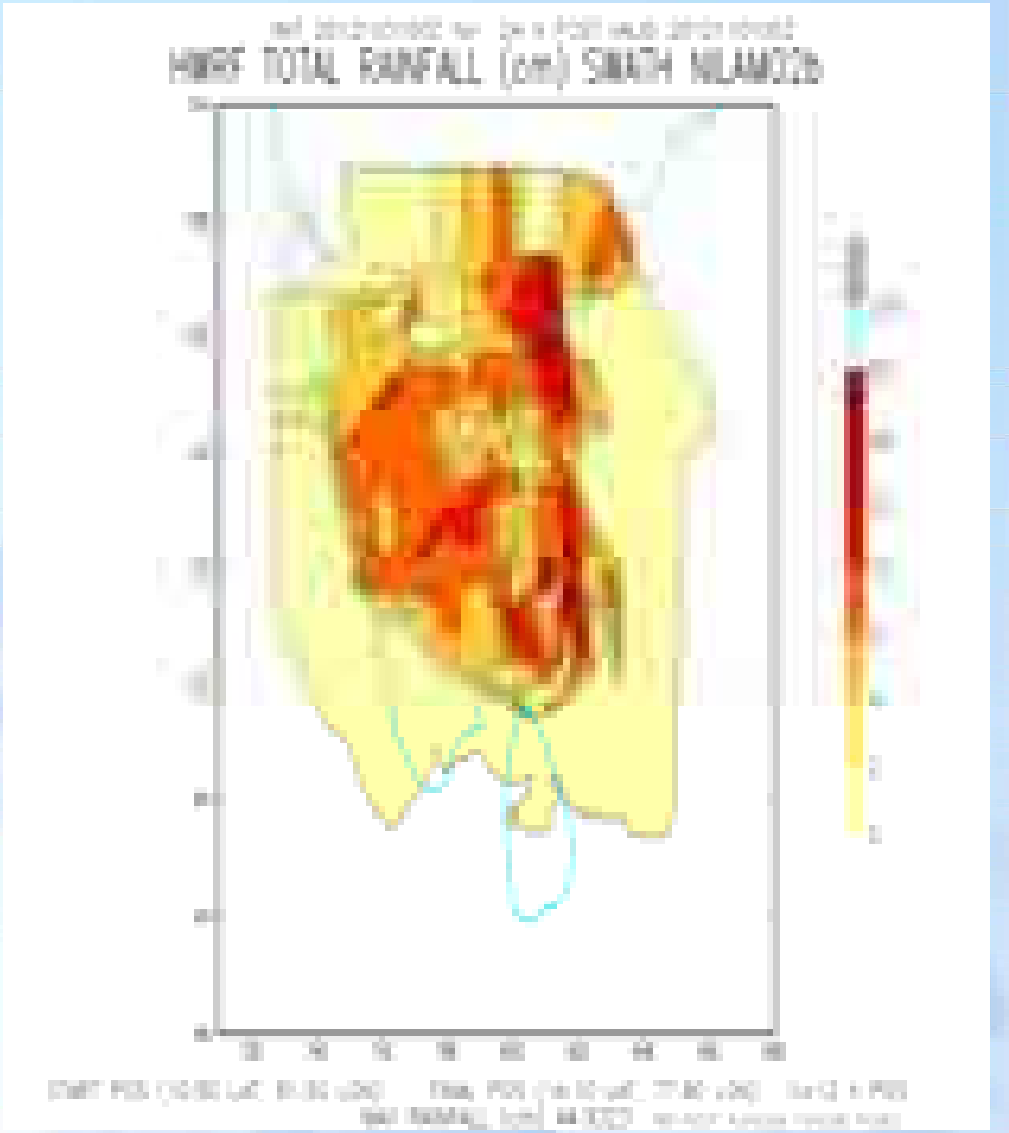






ान विभाग
CAL DEPARTMENT

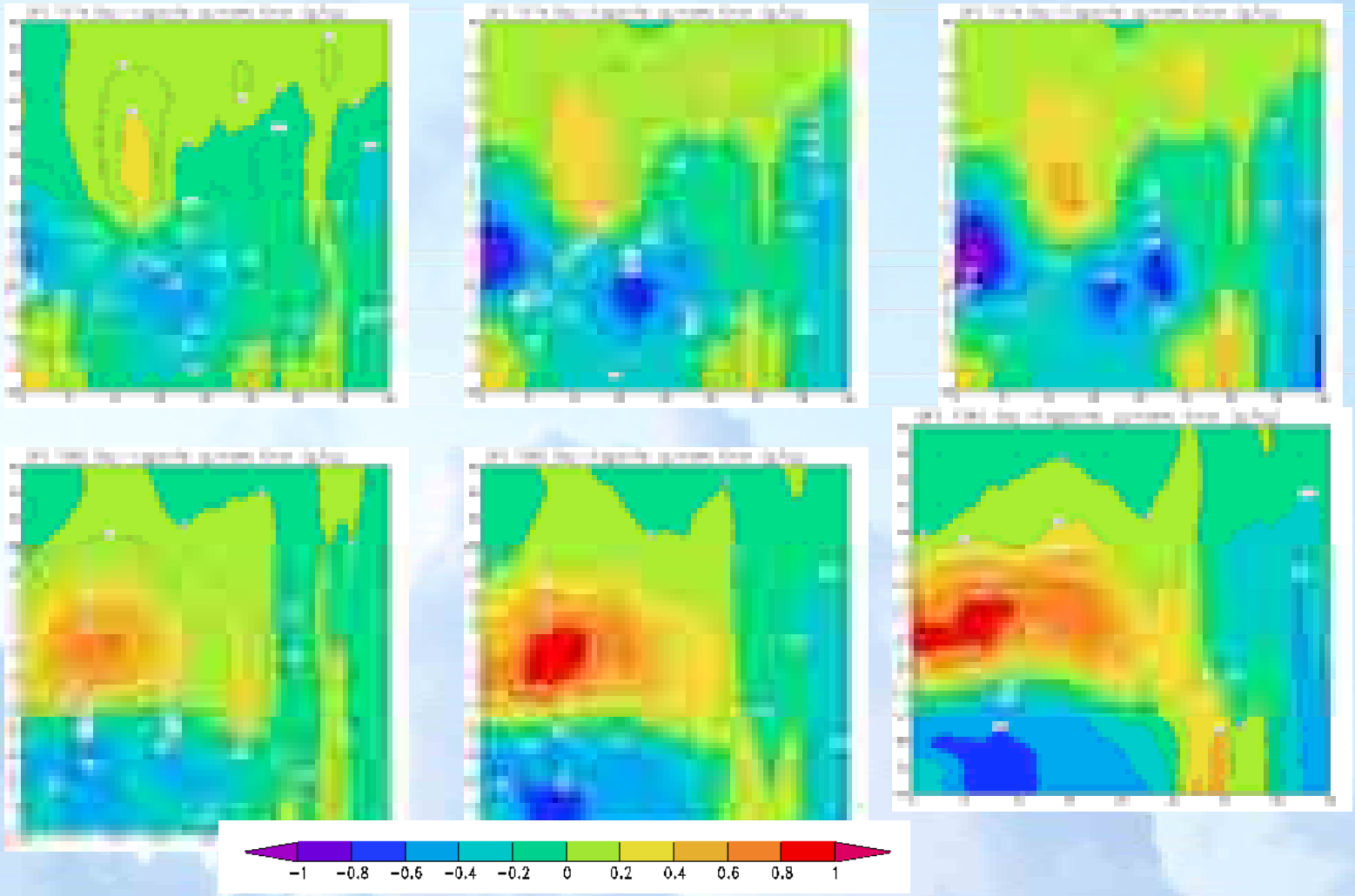

HWRF 10M MAX WIND (KTS) SWATH NILAM2012b
6N
4N
72E
74E
76E
78E
80E
82E
84E
86E
88E


HWRF TOTAL RAINFALL (cm) SWATH NILAM2012b

Results of Model Validation

Validation of GFS T574 and GFS T382 for Monsoon 2011 is done in terms of:

- Rainfall in spatial and temporal scale
- Vertically integrated specific humidity
- Precipitable water content
- Lower troposheric wind circulation
- Monsoon Depression case



Zonally averaged (Long: 60-100E) specific humidity (***g /kg) bias*** (top panel) day-1, day-3 and day-5 for GFS **T574L64,** (bottom panel) for **GFS T382** for monsoon 2011

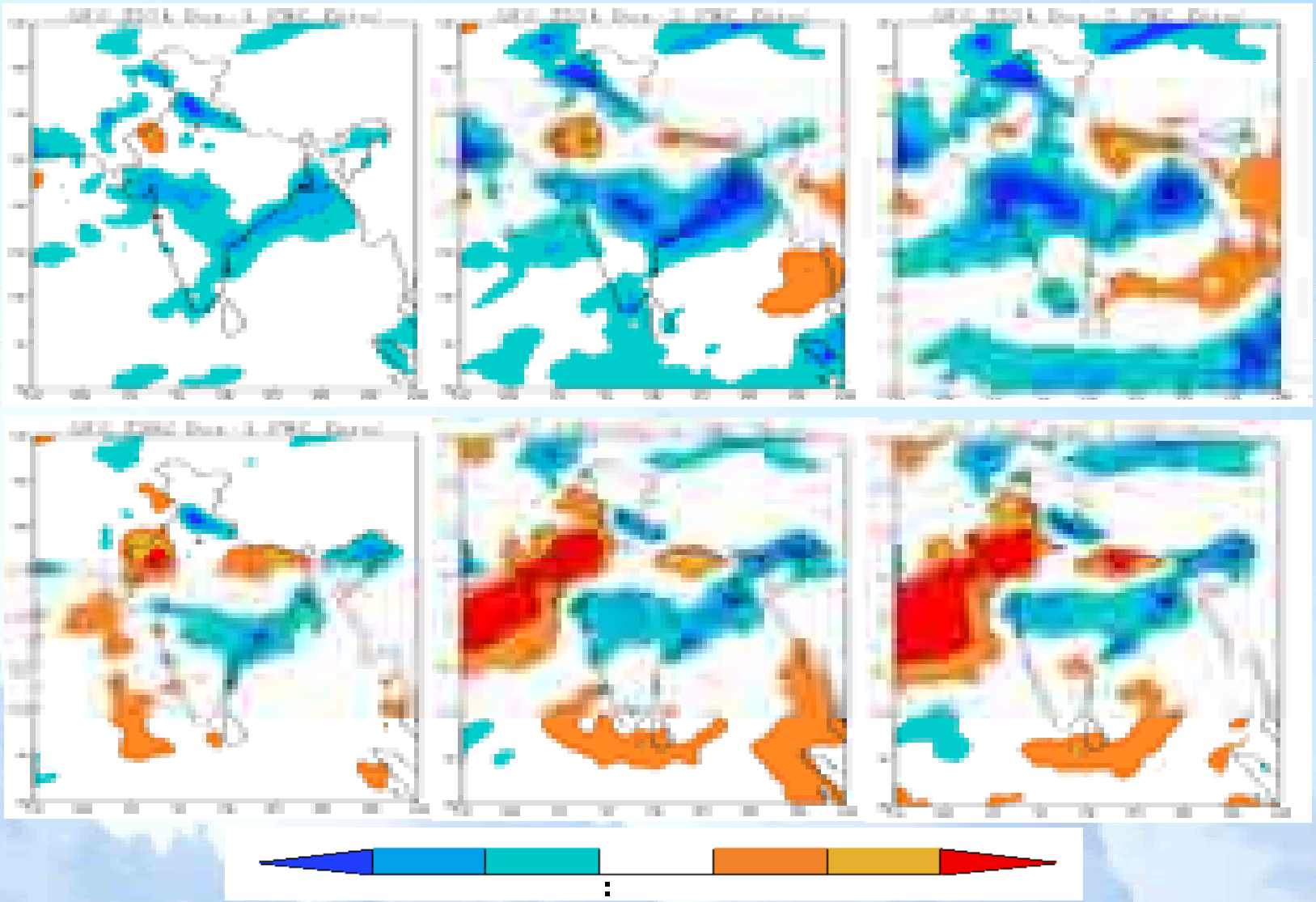


Fig. Seasonal (JJAS) mean precipitable water content (PWC in mm***)*** analysis (top panel) and mean error of day=1, day3 and day-5 forecasts from GFS T574L64 (middle panel) and GFS T382 (bottom panel) for monsoon 2011

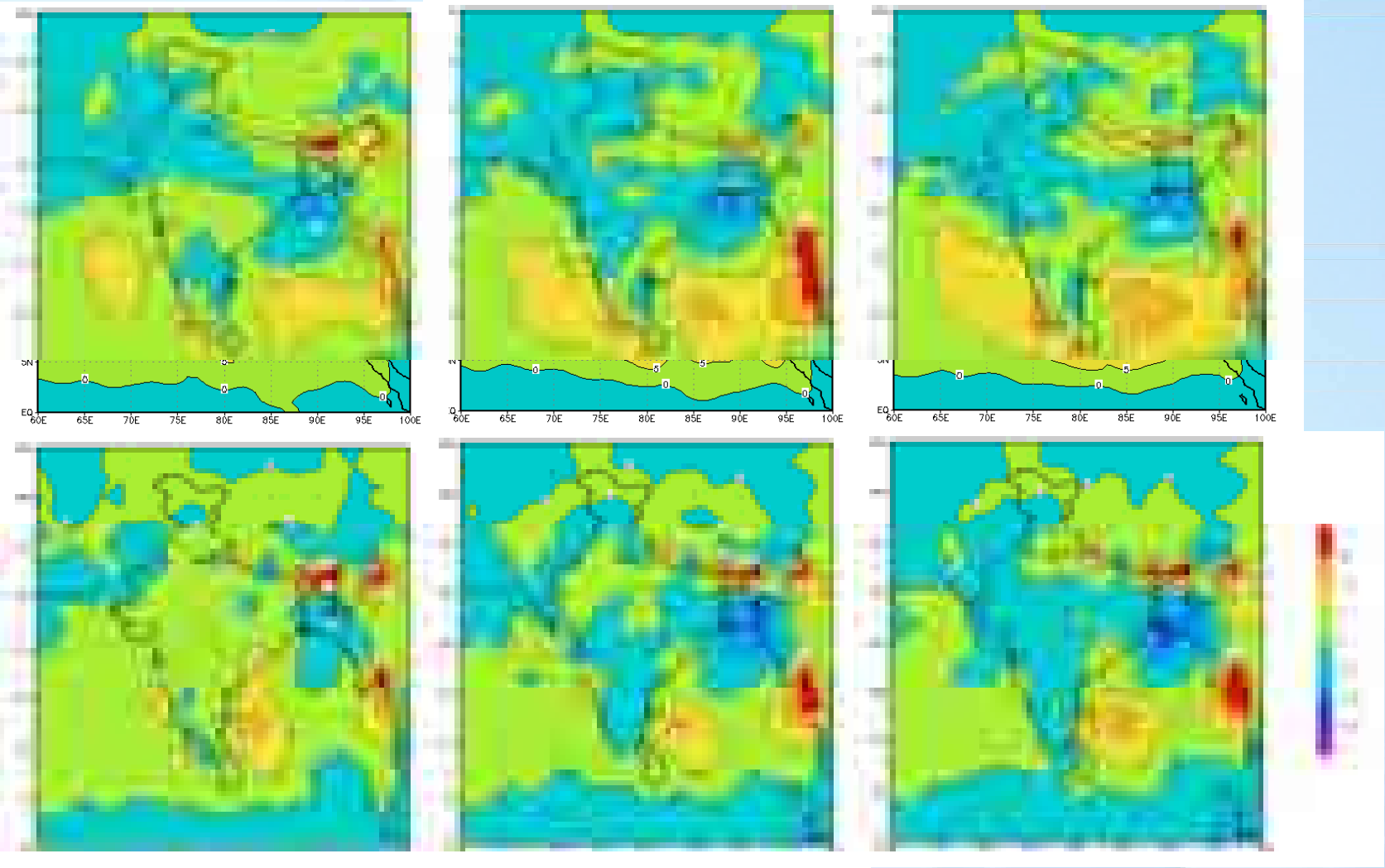


Fig. Spatial distribution of seasonal mean error (forecast-observed) rainfall (mm/day) based on Day-1 to Day-5 forecast of *GFS T382* (top panel) and *GFS T574* (bottom panel) for the period from 1 June to 30 September 2011

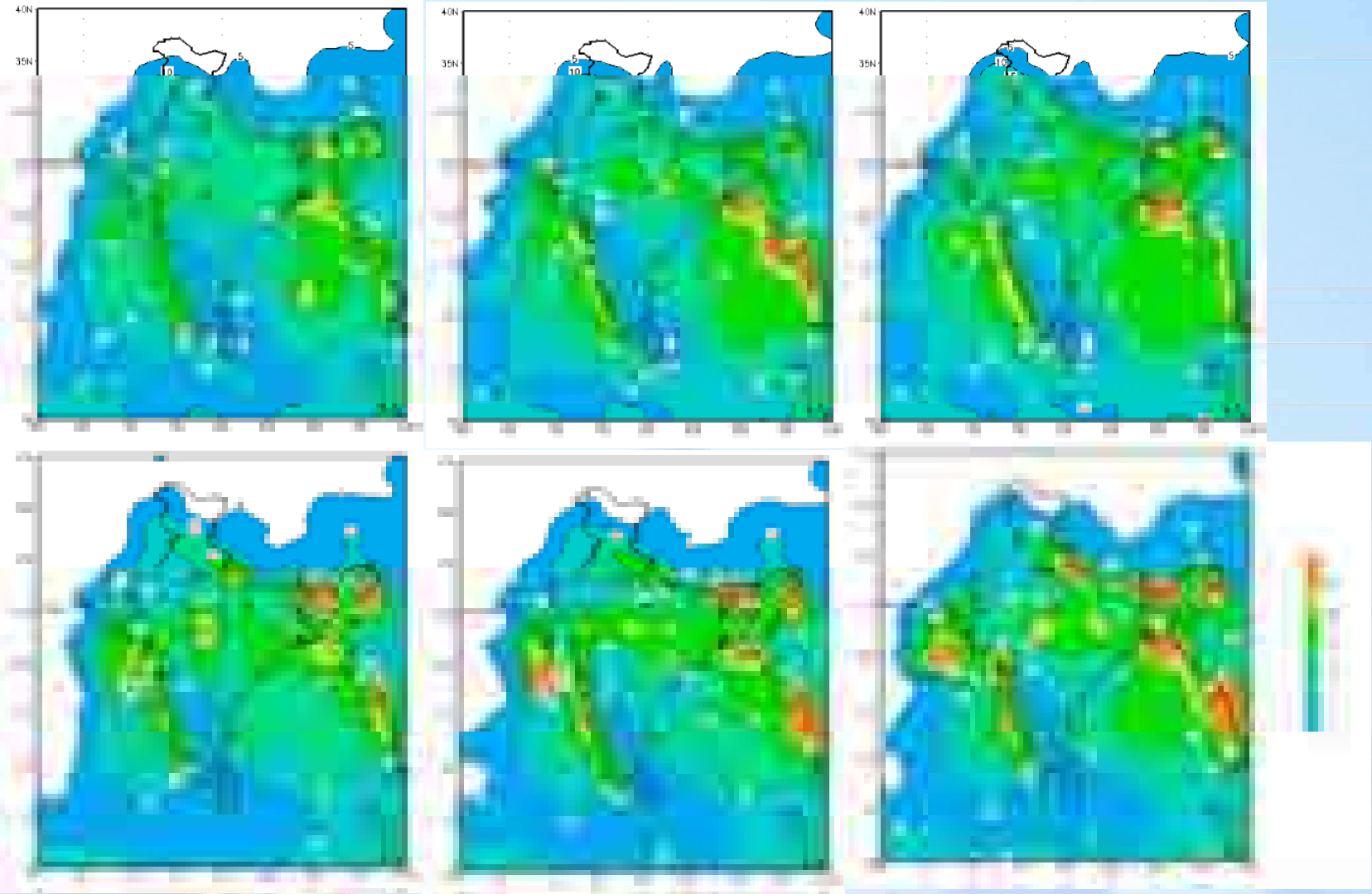
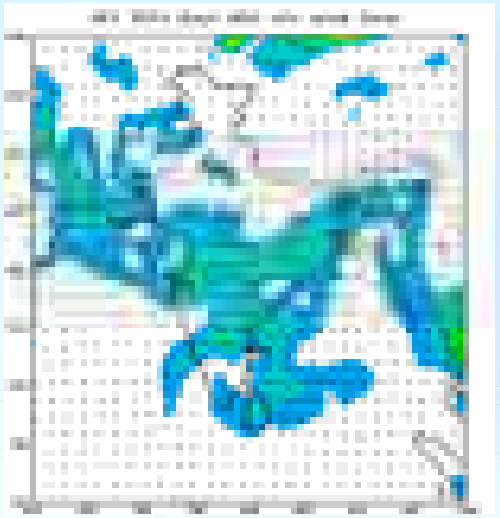
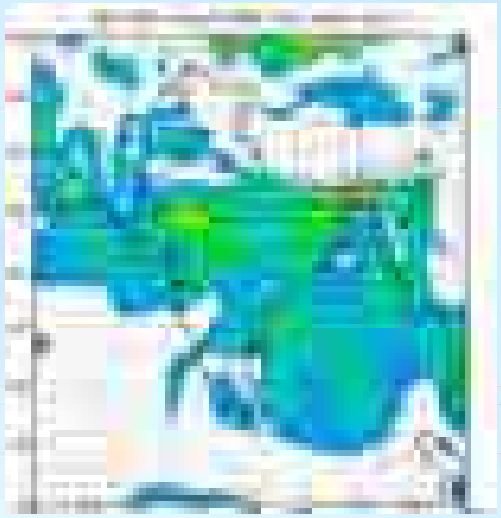
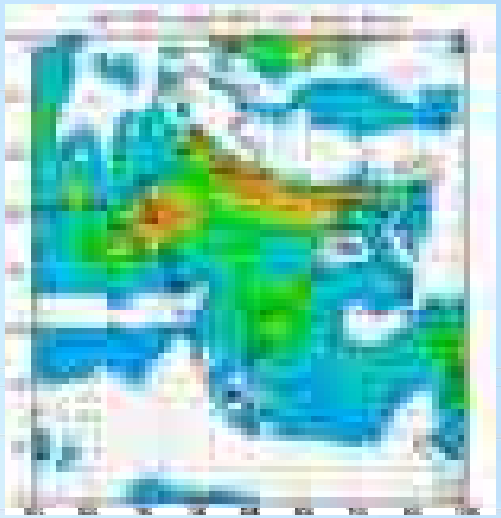
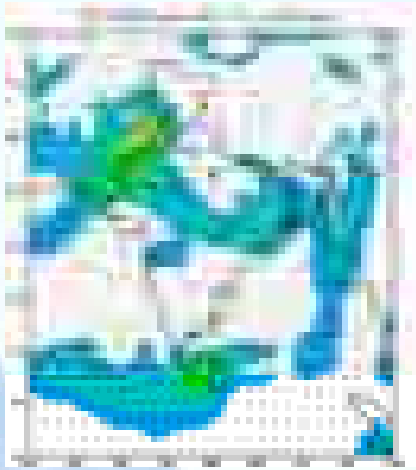
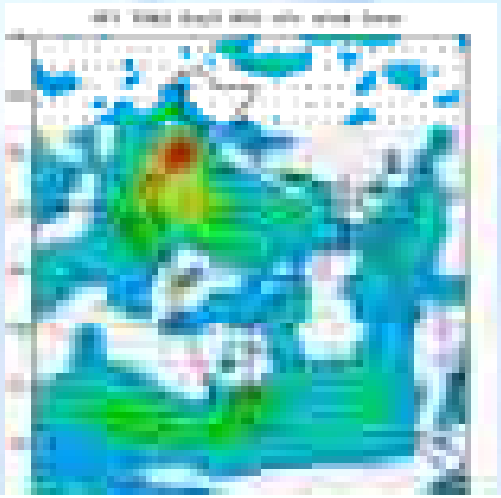
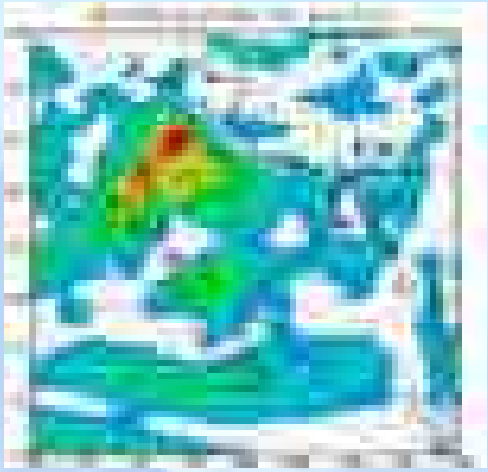
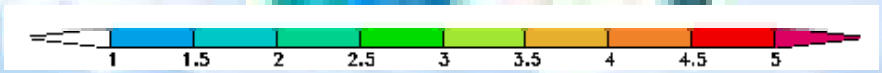


Fig. Spatial distribution of seasonal root mean square error (rmse) rainfall (mm/day) based on day-1, day-3 and day-5 forecast of *GFS T382* (top panel) and *GFS T574* (bottom panel) for the period from 1 June to 30 September 2011

Forecast errosr day-1, day-3 and day-5 from GFS T574L64 (middle panel) and GFS T382 (bottom panel) for monsoon 2011 of wind 850 hPa

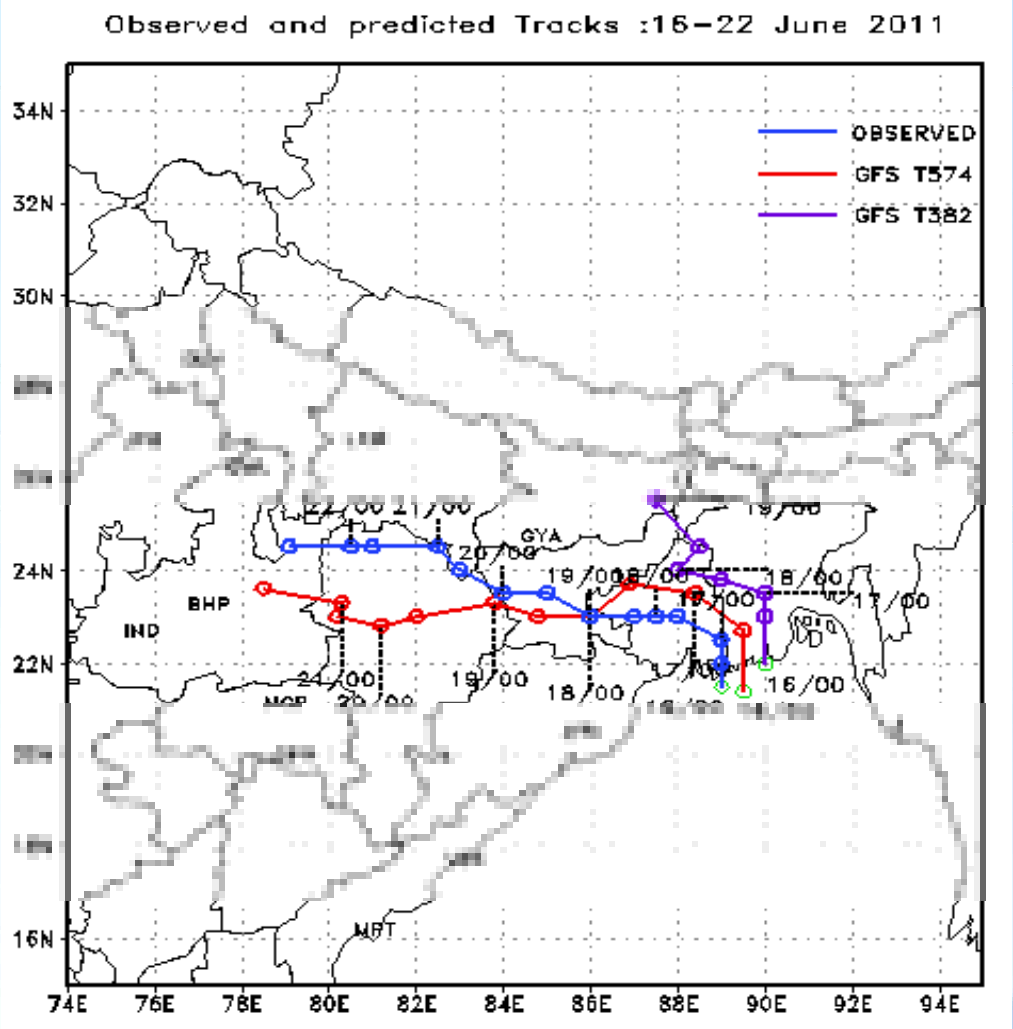


Fig. 17 Observed and model predicted tracks for Deep Depression (16 -22 June 2011) from GFS T574 and GFS T382

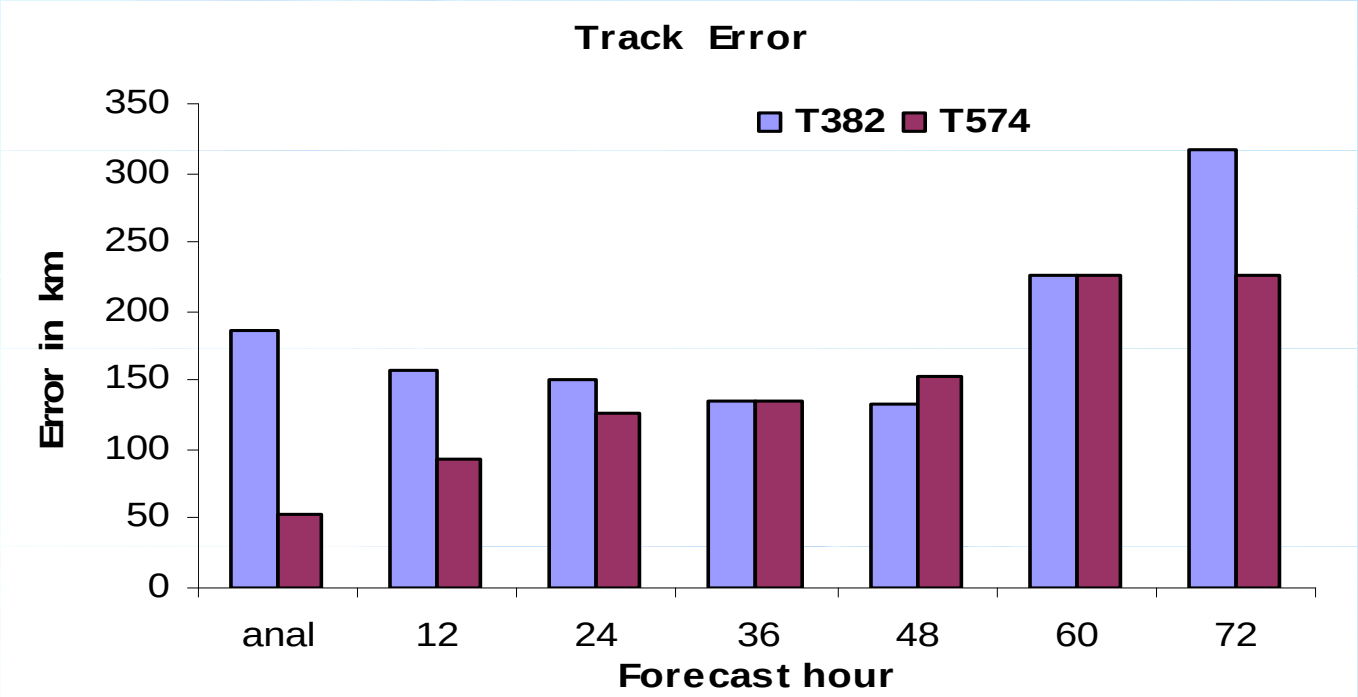
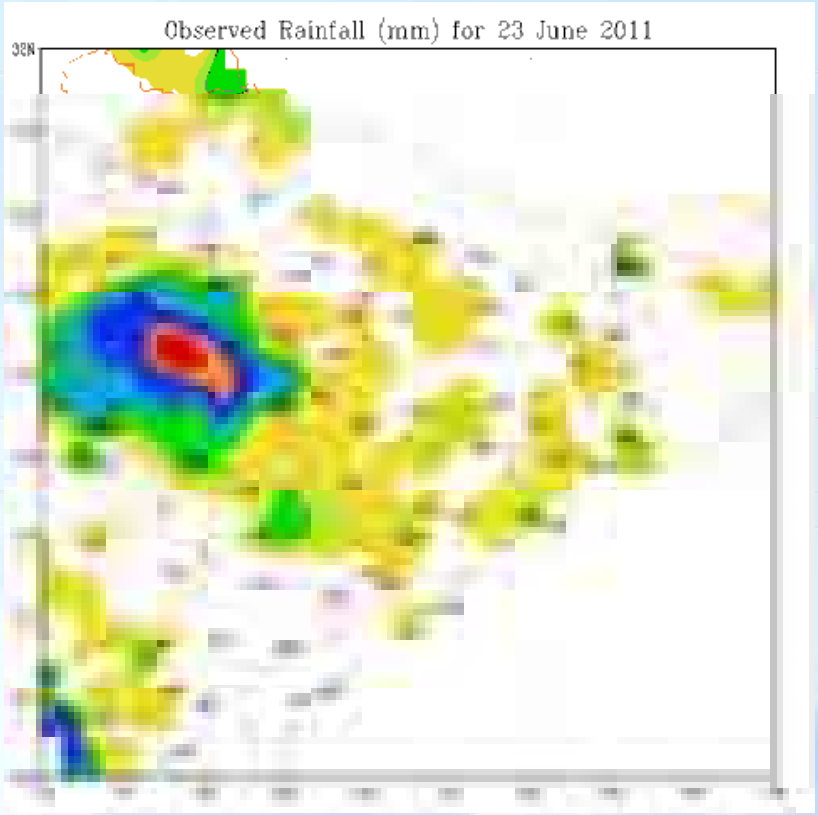
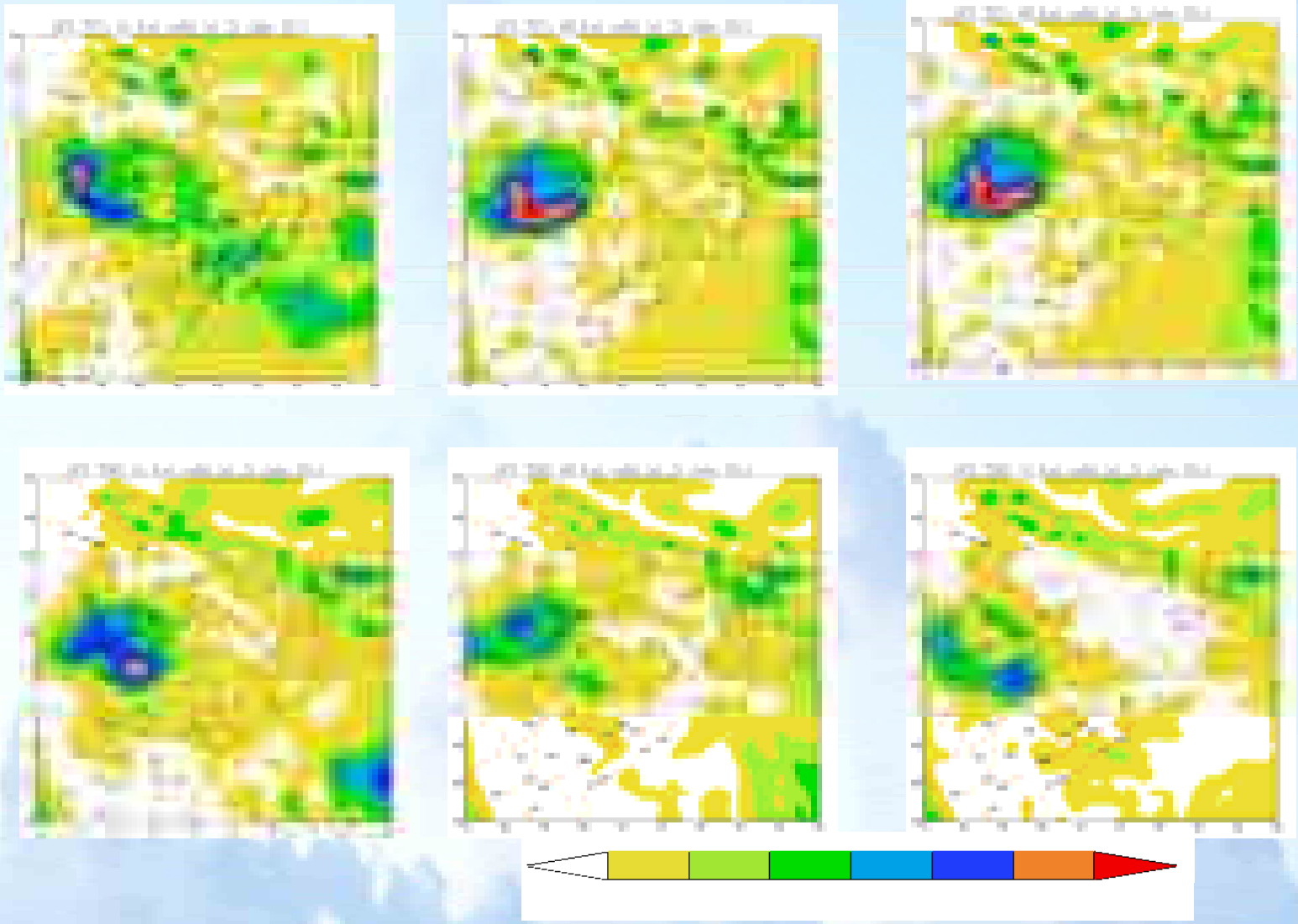


Fig. 18 Track errors of GFS T574 and GFS T382 for Deep Depression over Bay of Bengal (BOB) during 16 -22 June 2011


Observed Rainfall (mm) for 23 June 2011
32N
20
30
40



CC=0.60

CC=0.50

CC=0.52

CC=0.43

CC=0.47

CC=0.28

Fig.20 Observed rainfall and 850 hPa wind analysis (top panel); 24, 48 and 72 hour rainfall forecast from GFS T574L64 (middle panel) and GFS T382 (bottom panel) for heavy rainfall on 23rd, June 2011 over central India.

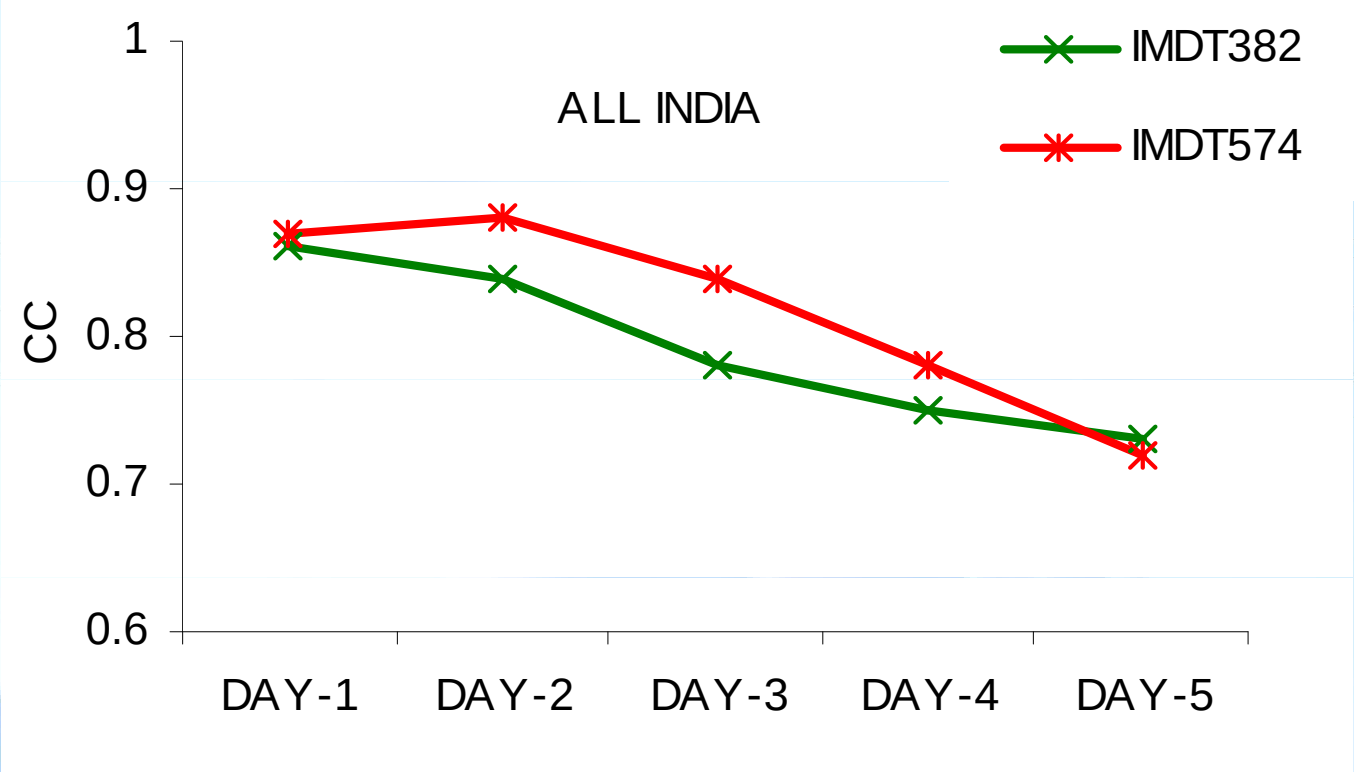


Fig.8 CC of all India daily mean observed and day-1 to day-5 forecasted rainfall of GFS T382 and T574 during monsoon 2011

Problem identified

- GFS shows bias of lower tropospheric drying and upper tropospheric moistening
- Bias anti-cyclonic circulation in the lower troposphere over central India where PWC as well rainfall shows negative bias
- Large RMSE in the rainfall forecast magnitude of bias increases with forecast lead time
- Structure of bias changes with model resolution

BIAS CORRECTION METHODS FOR NWP MODEL

Decaying Weighted Mean (DWM) or Nearest Neighbor (NN)

$$ME = \frac{1}{N} \sum_{k=1}^{N} [F - O]$$

where ... N = 1, 2, ... 15 .days

$$wt(i) = \frac{w(i)}{\sum_{i=1}^{15} w(i)}$$

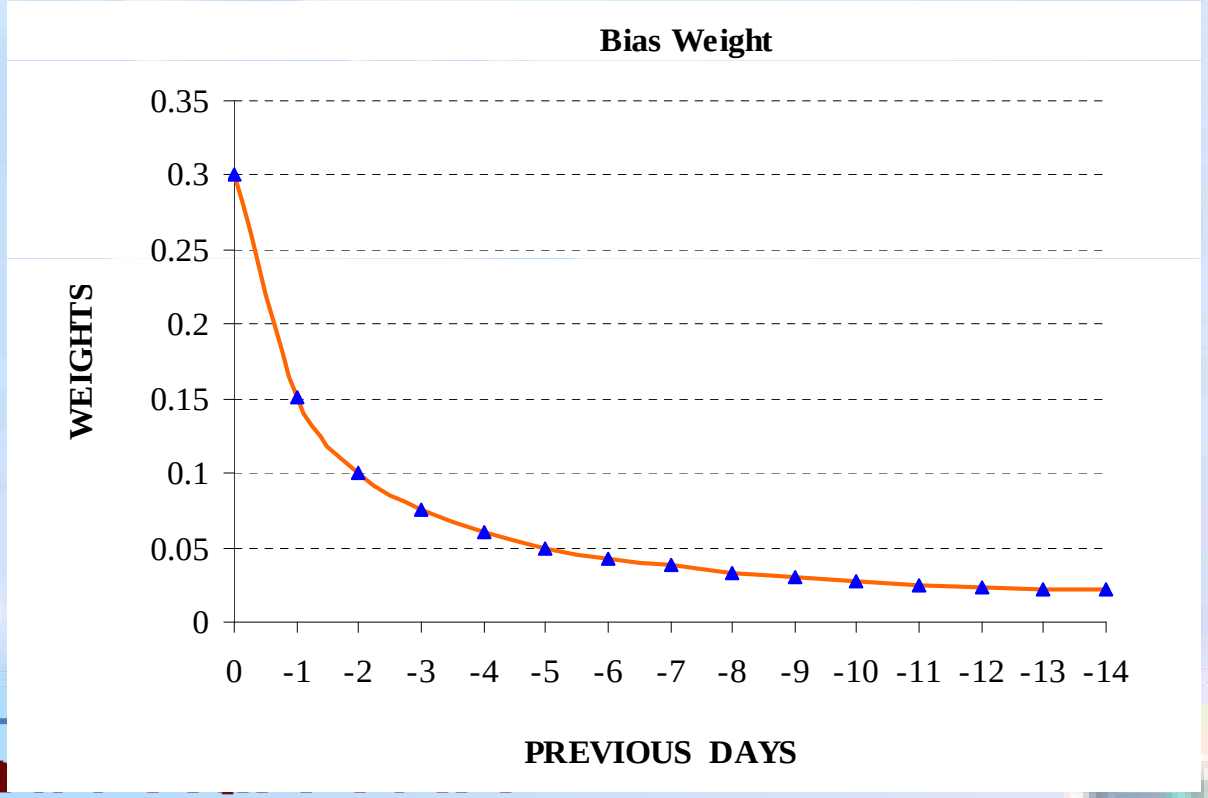
Here, $$w(i) = \frac{1}{i}$$

where i=1, 2,3, …15 days

where O=Observation;
F=Forecast,

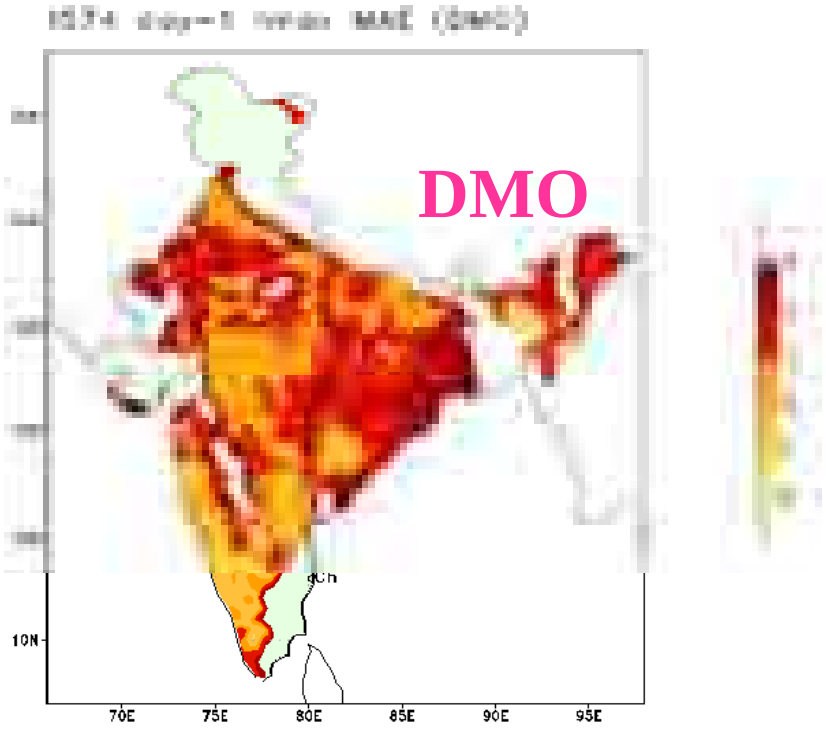
Computed from last 15 days forecasts and observations

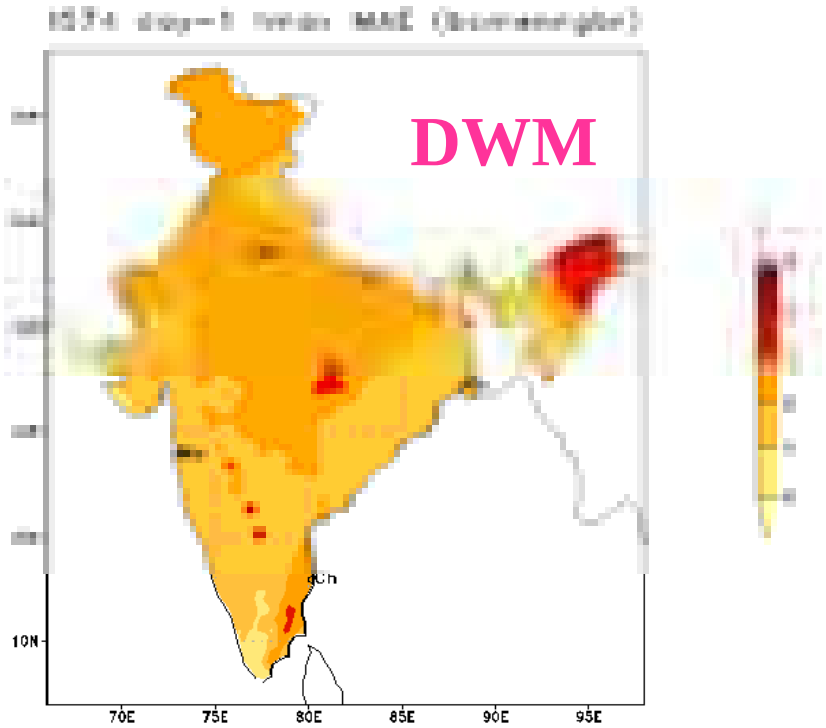
In the *Decaying Weighted Mean (DWM)* all the previous forecast errors are averaged together using an exponentially increasing weighting so that the recent data has the largest weight.

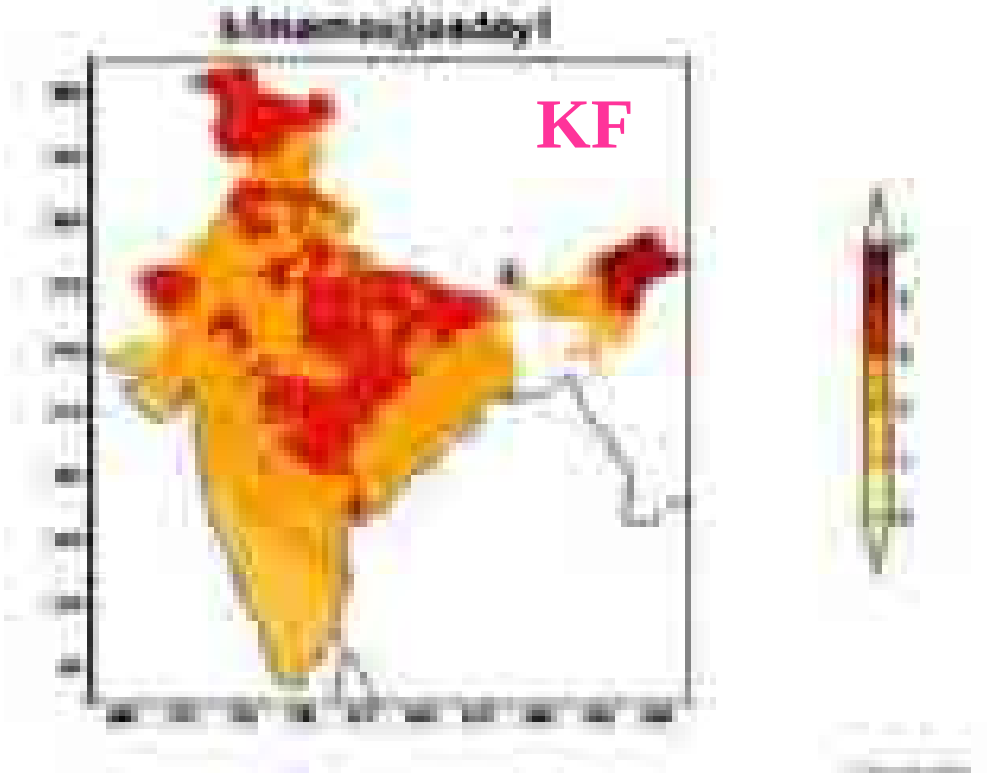


MAE in Maximum temperature (C)

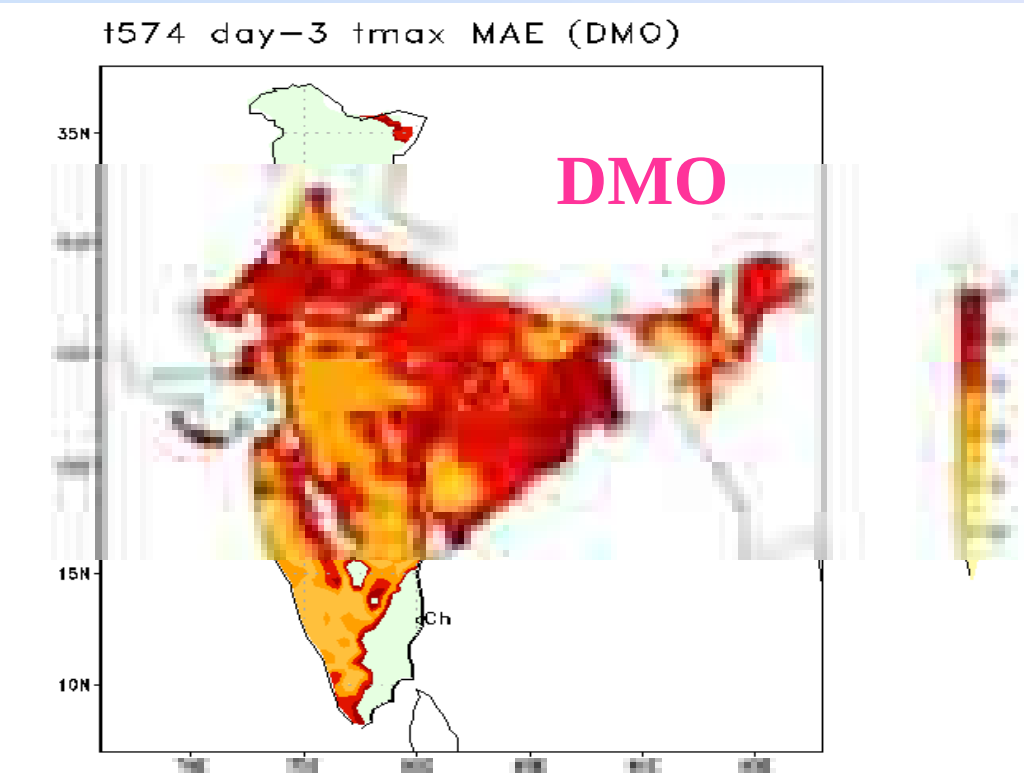
: JJAS 2015 : Day-1 Forecast

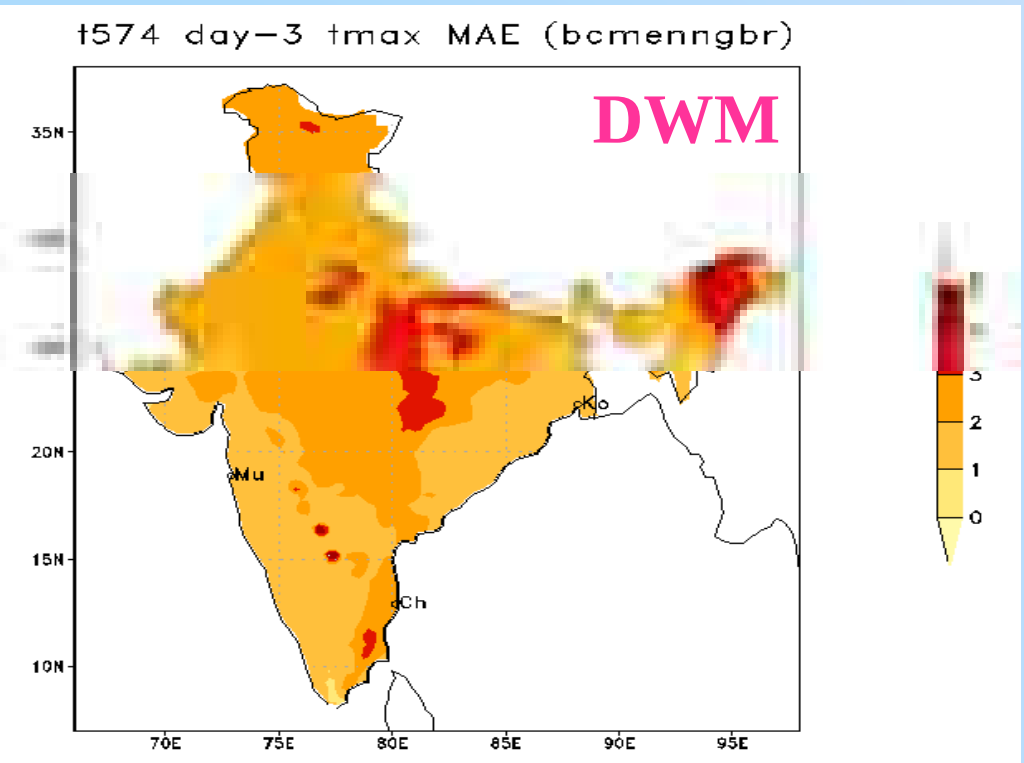


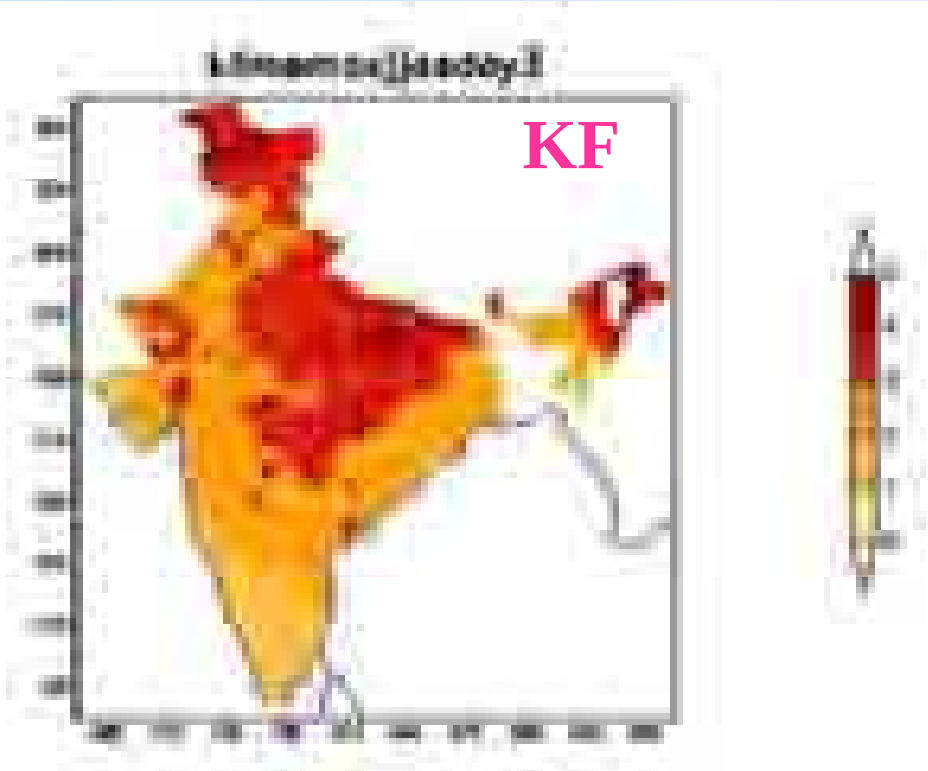




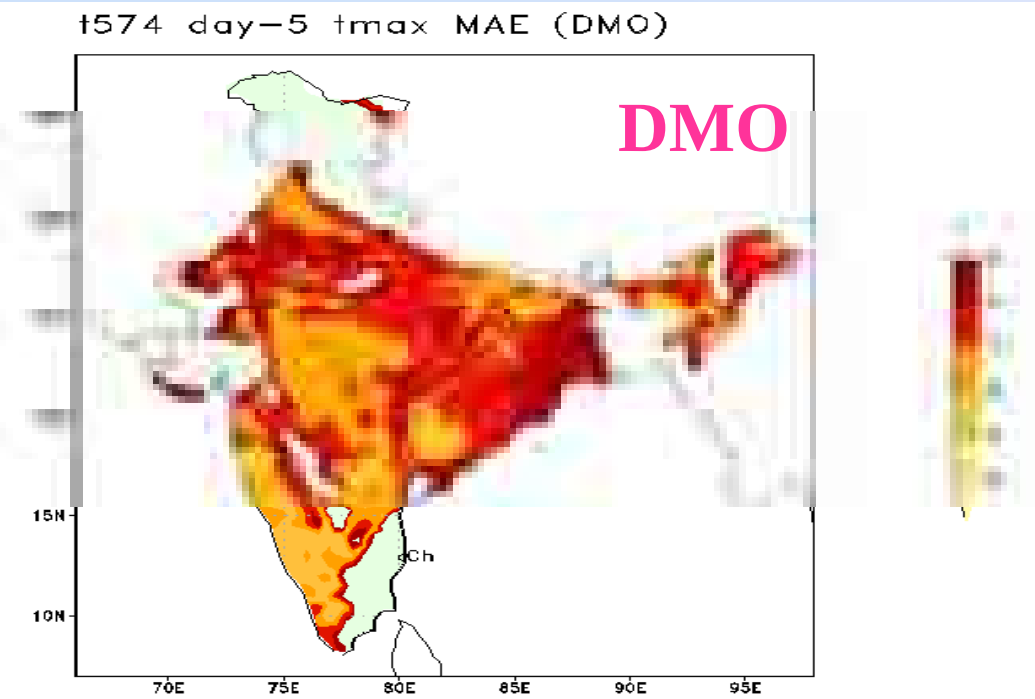
MAE in Maximum temperature (C) : JJAS 2015 : Day-3 Forecast

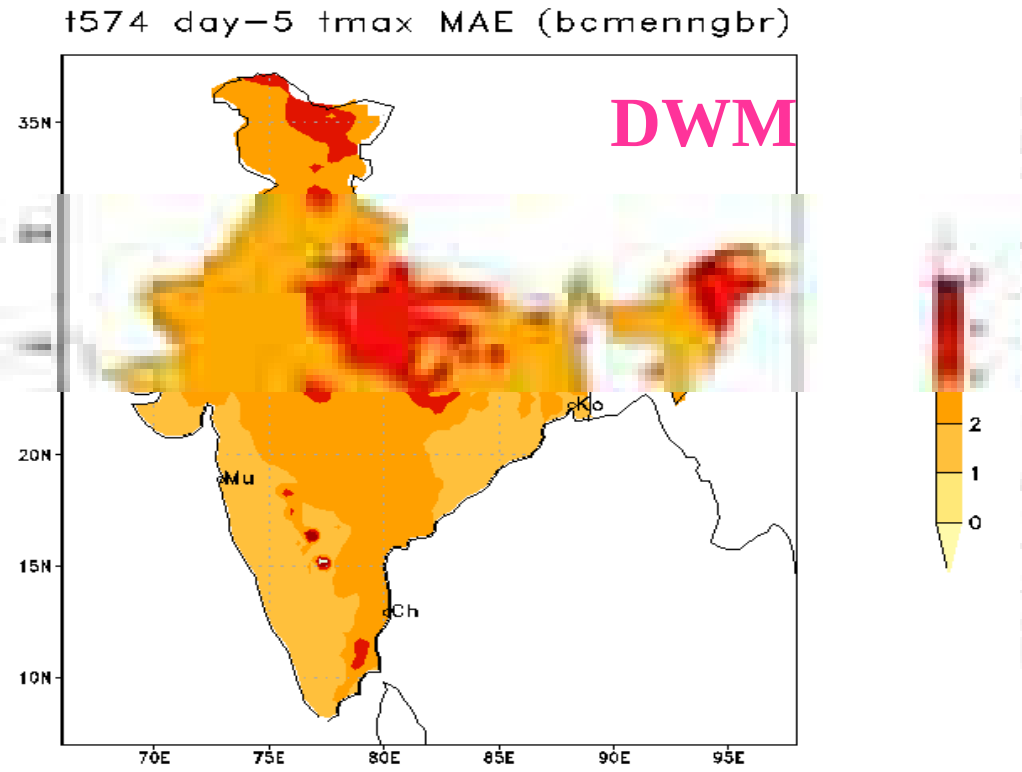


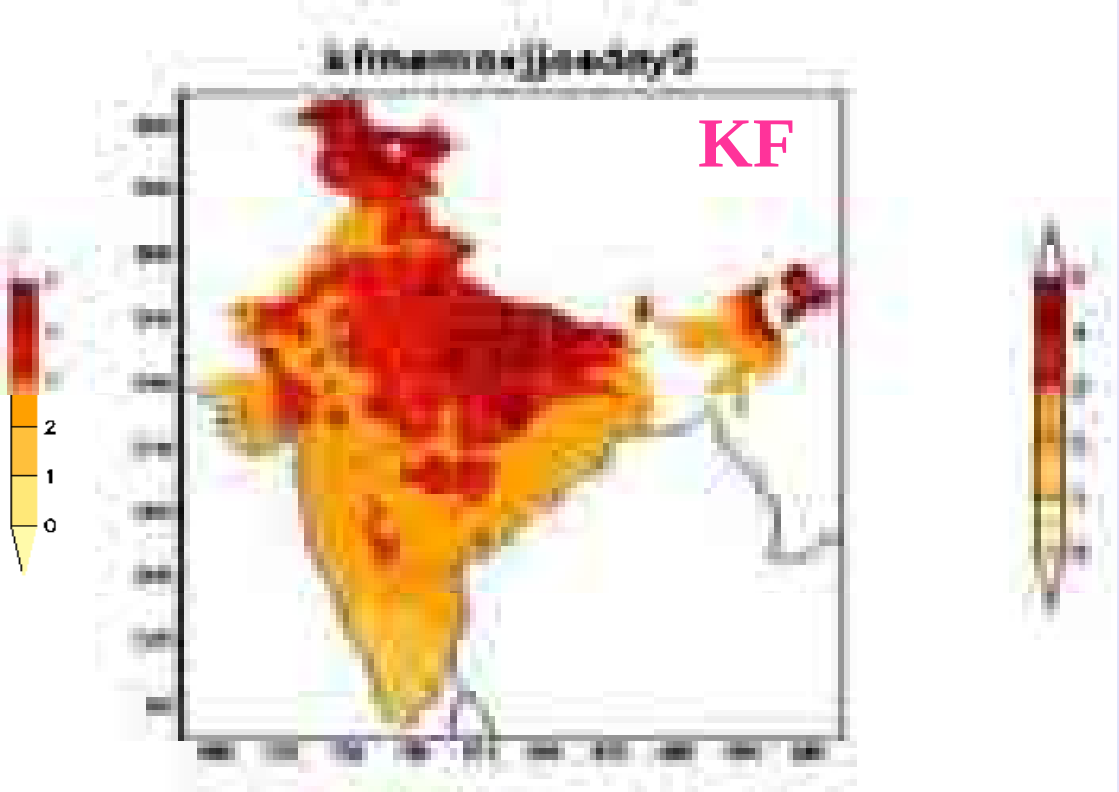


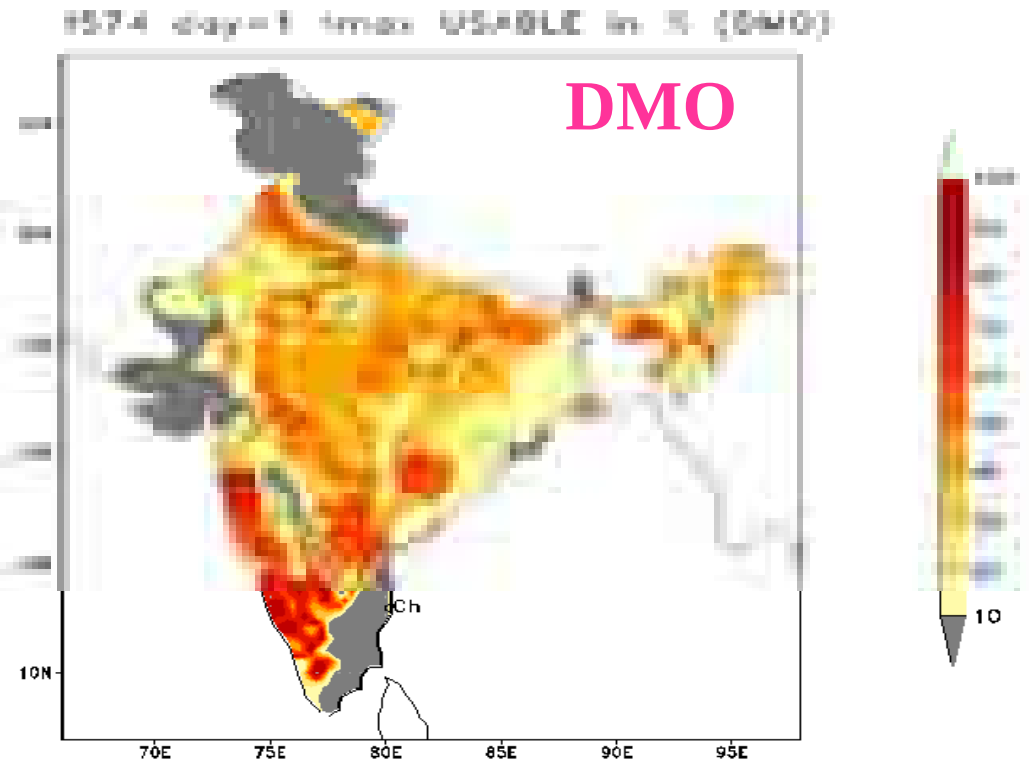


MAE in Maximum temperature (C) : JJAS 2015 : Day-5 Forecast





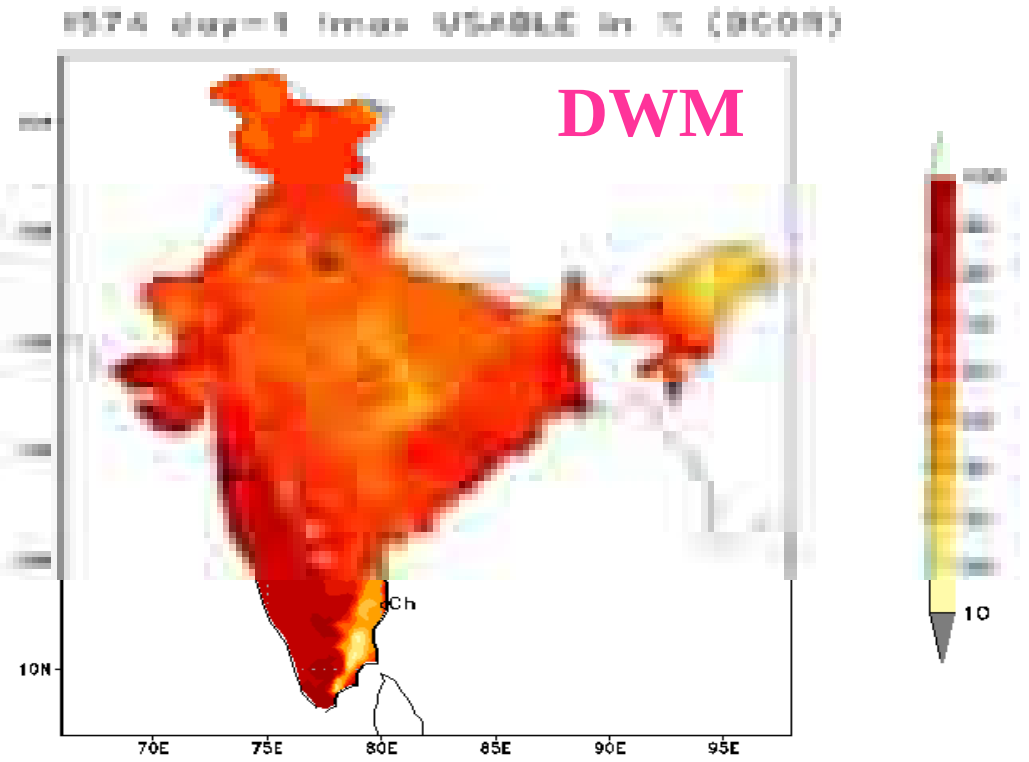


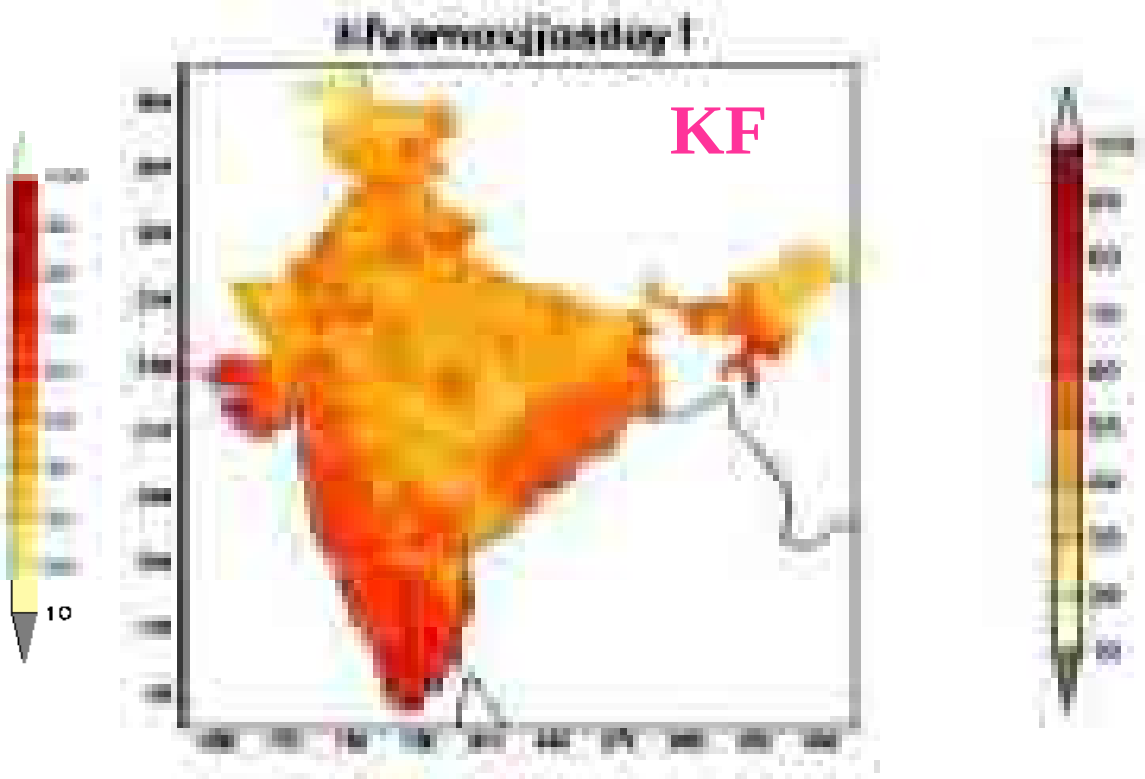


Maximum temperature (C) : JJAS 2015 :

USABLE Day-1 Forecast

(in %)

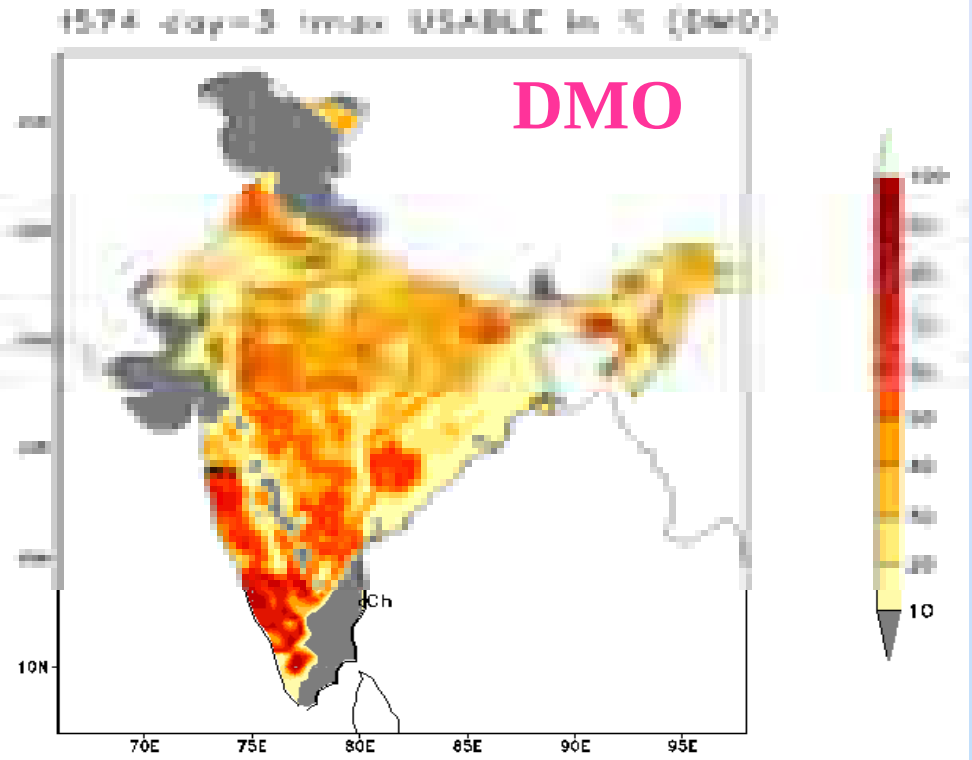


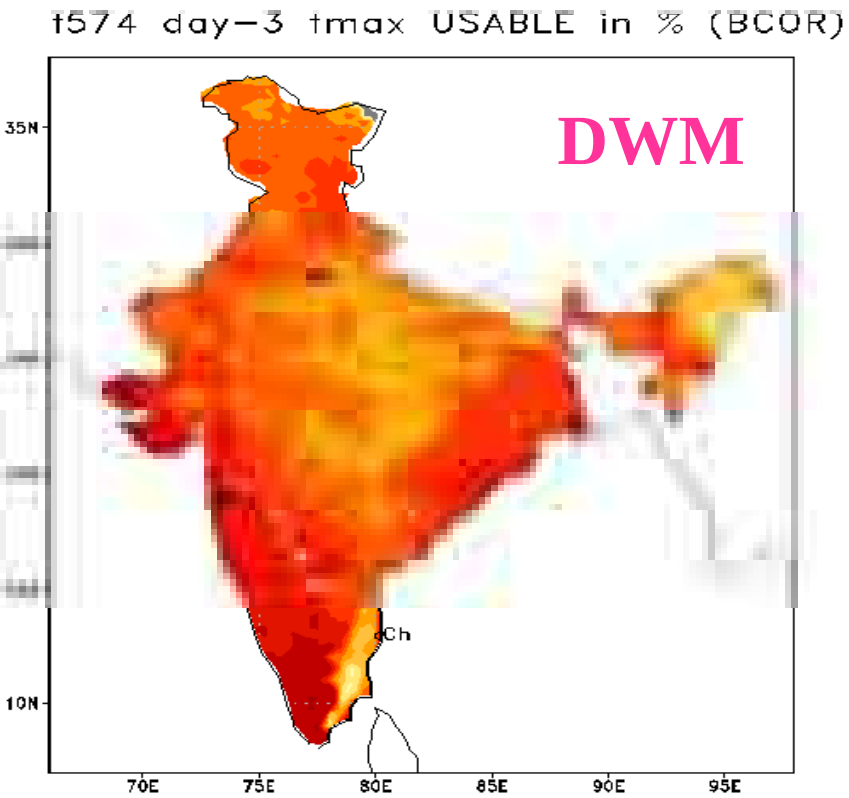


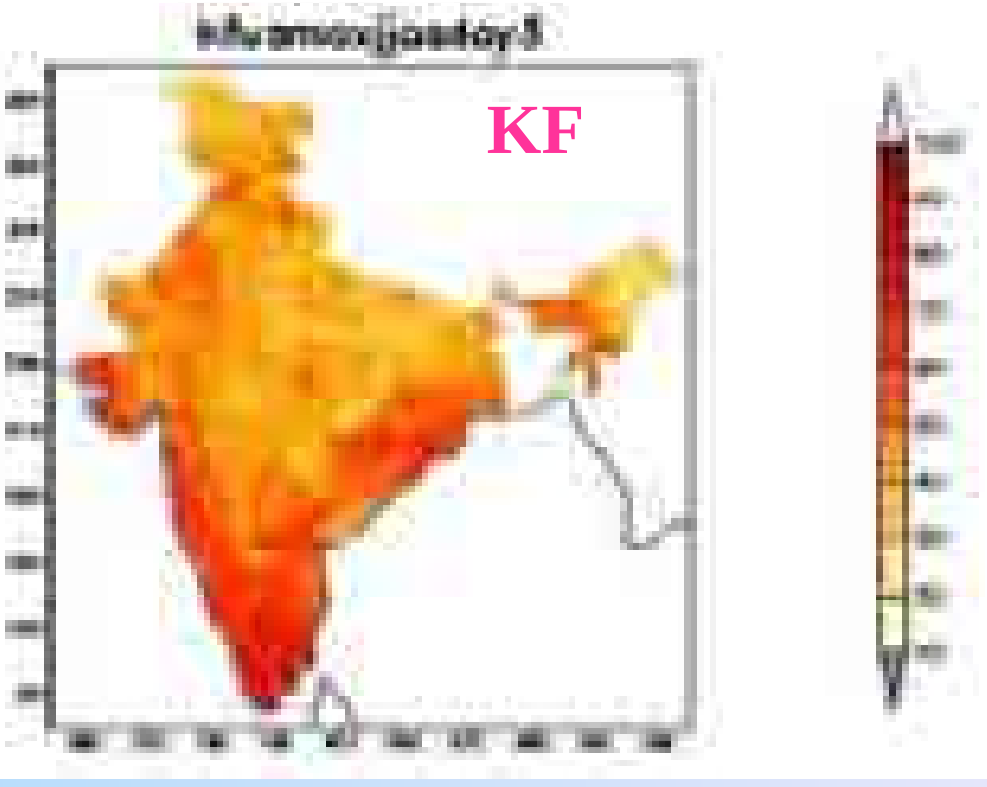
Maximum temperature (C) : JJAS 2015 :

USABLE Day-3 Forecast

(in %)



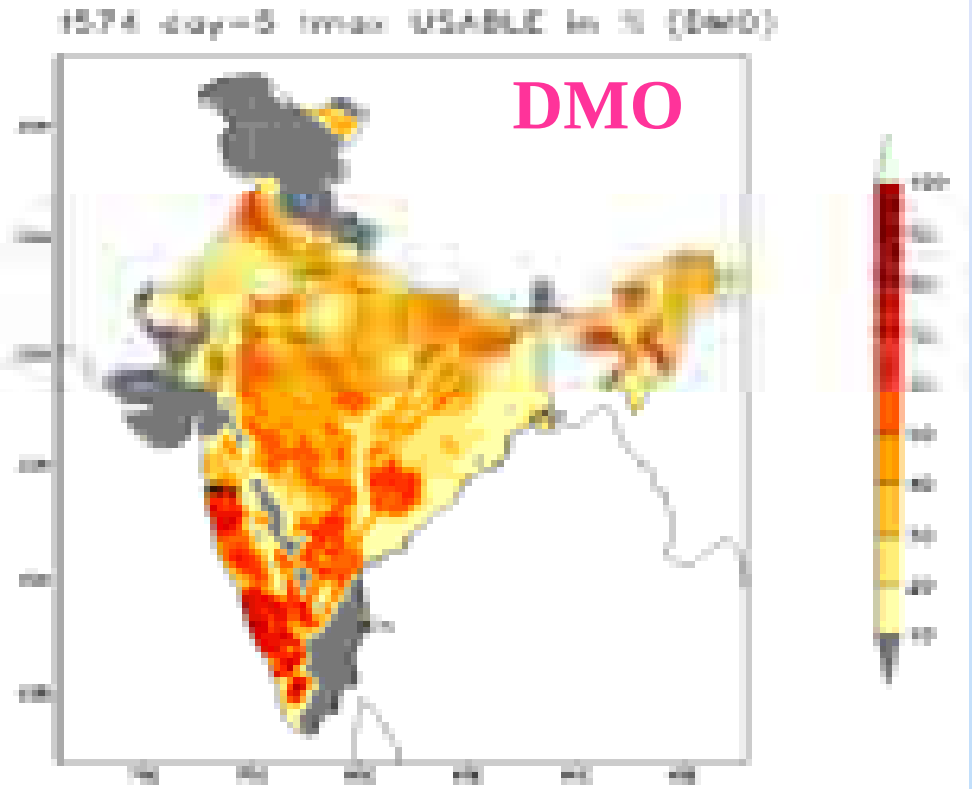


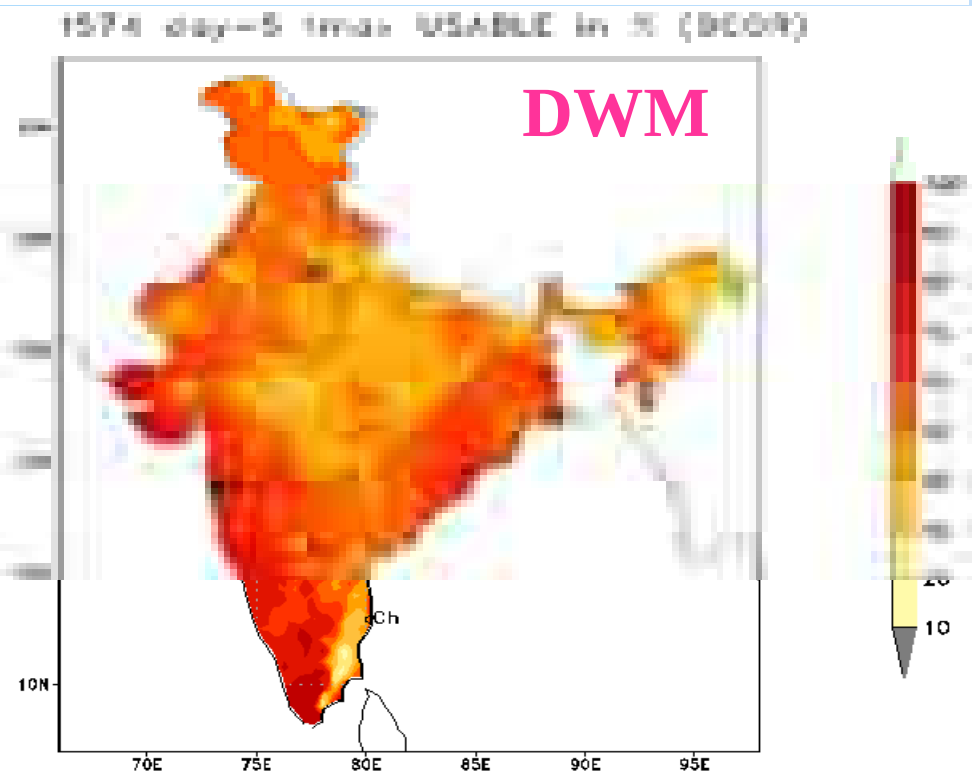


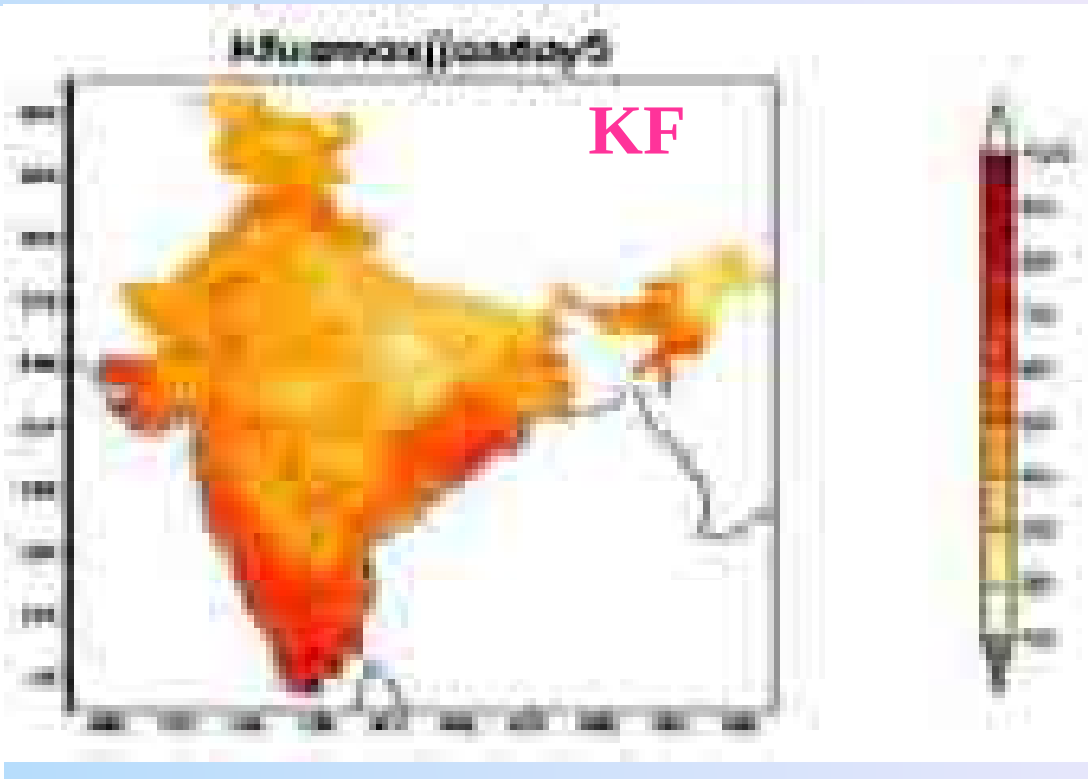
Maximum temperature (C) : JJAS 2015 :

USABLEDay-5 Forecast

(in %)



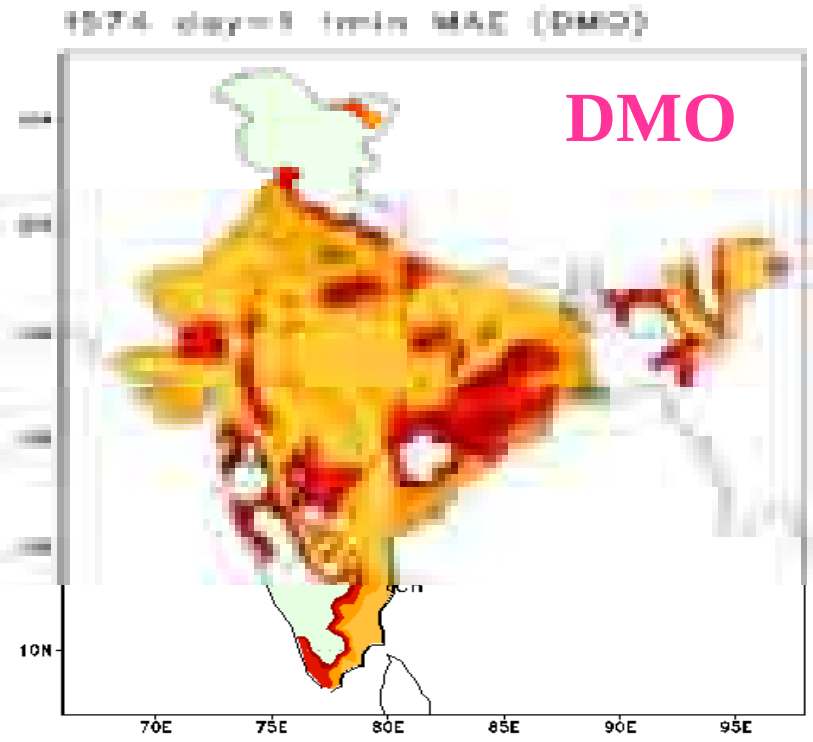


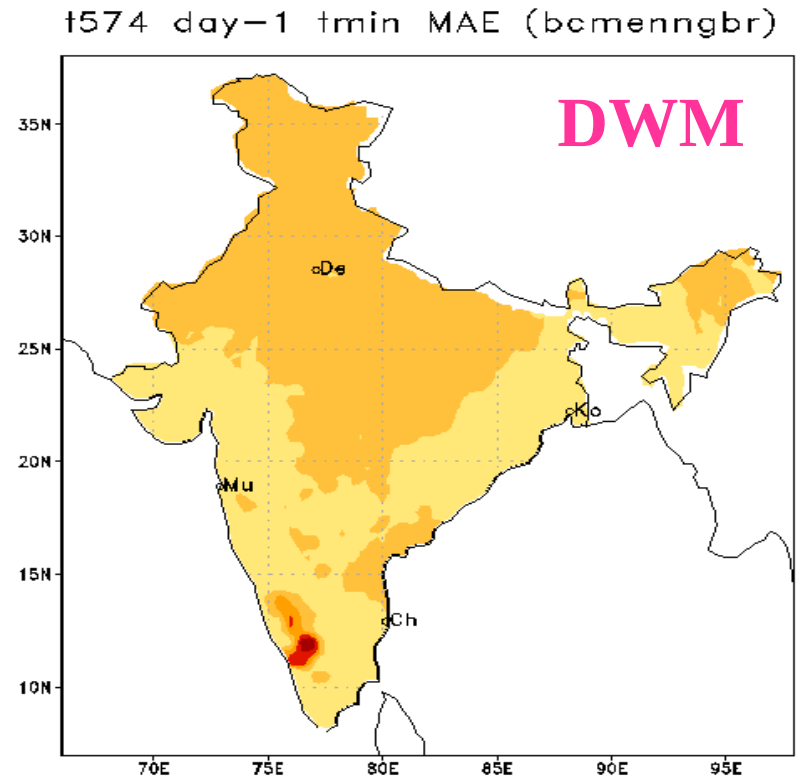


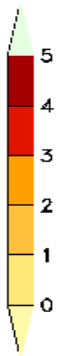
Minimum temperature

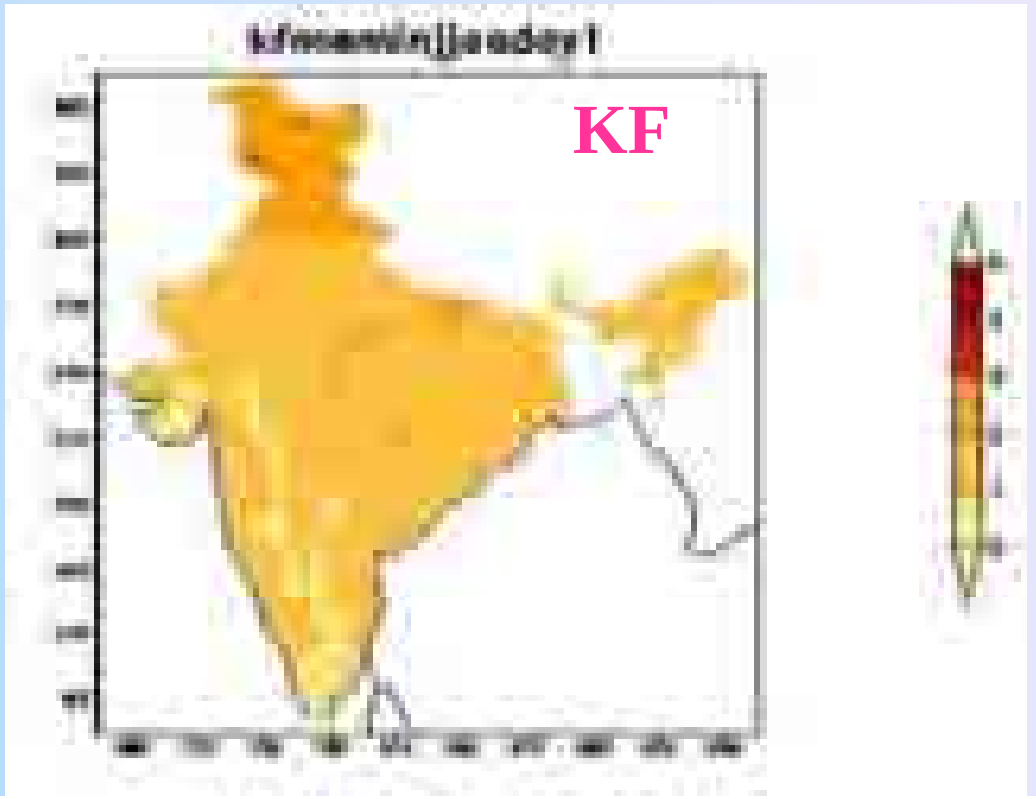
MAE in Minimum temperature (C) : JJAS 2015 :

Day-1 Forecast



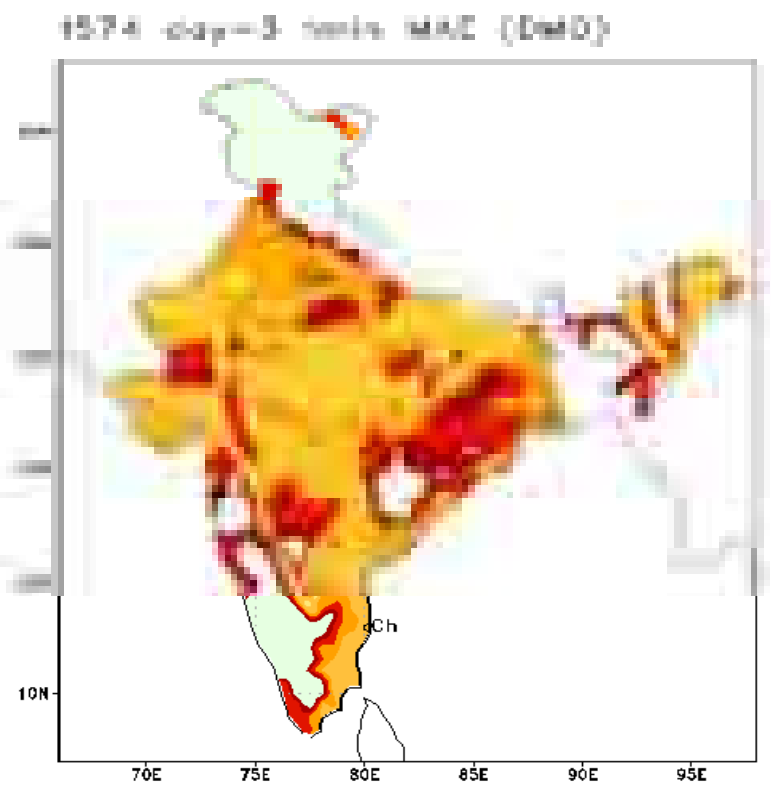


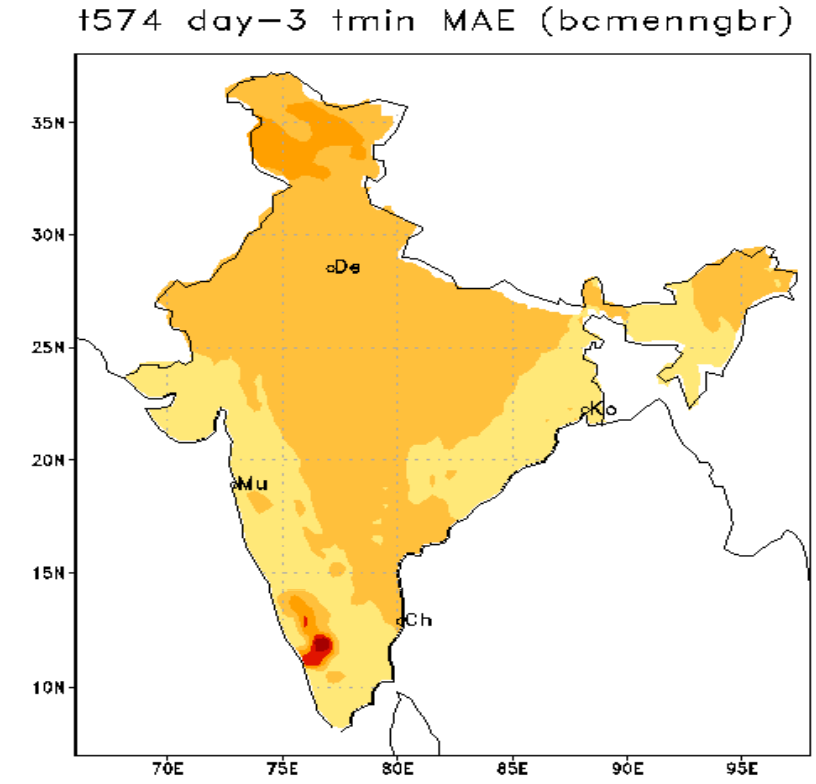




MAE in Minimum temperature (C) : JJAS 2015 :

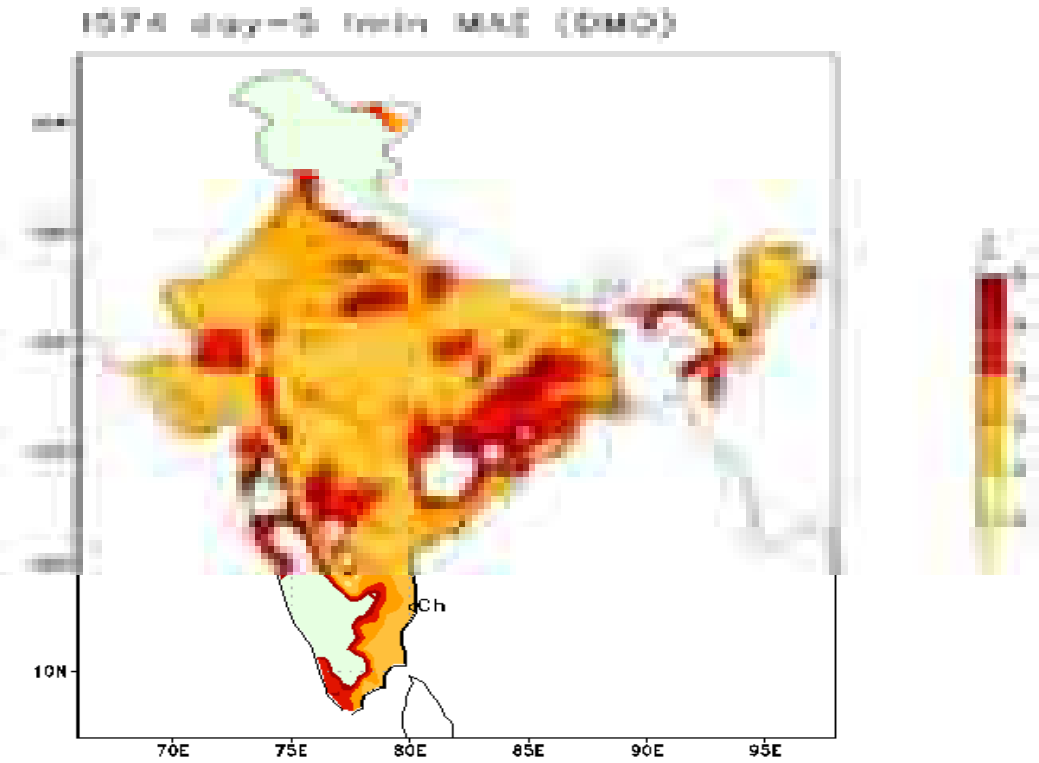
Day-3 Forecast

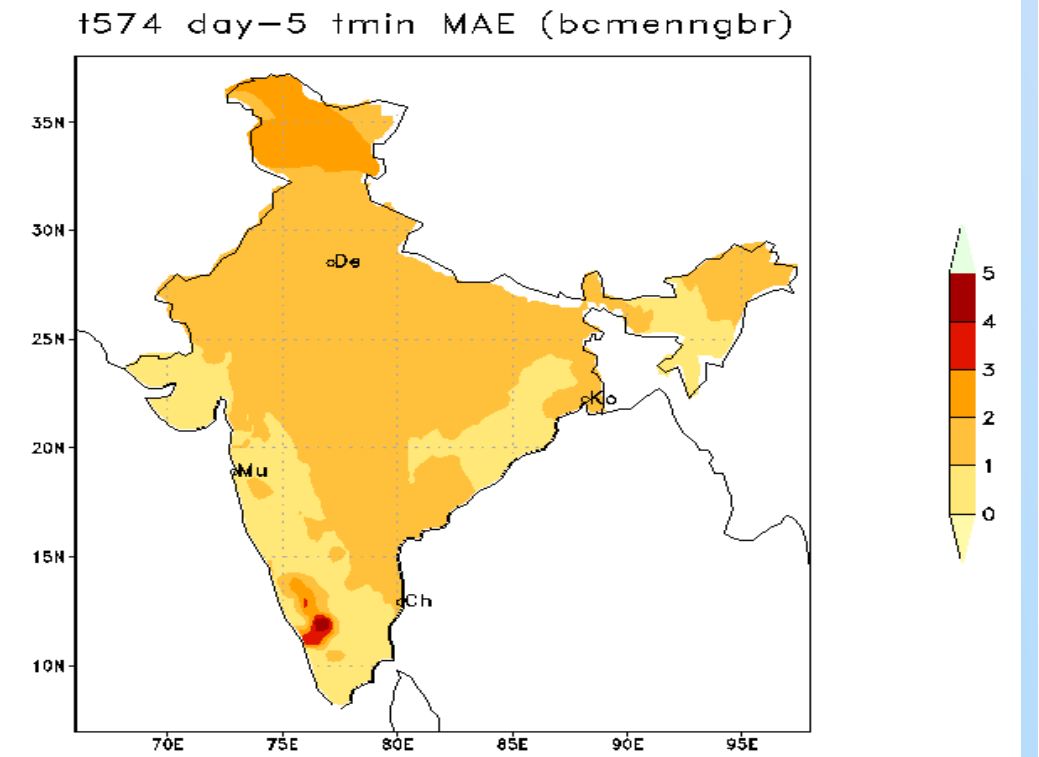


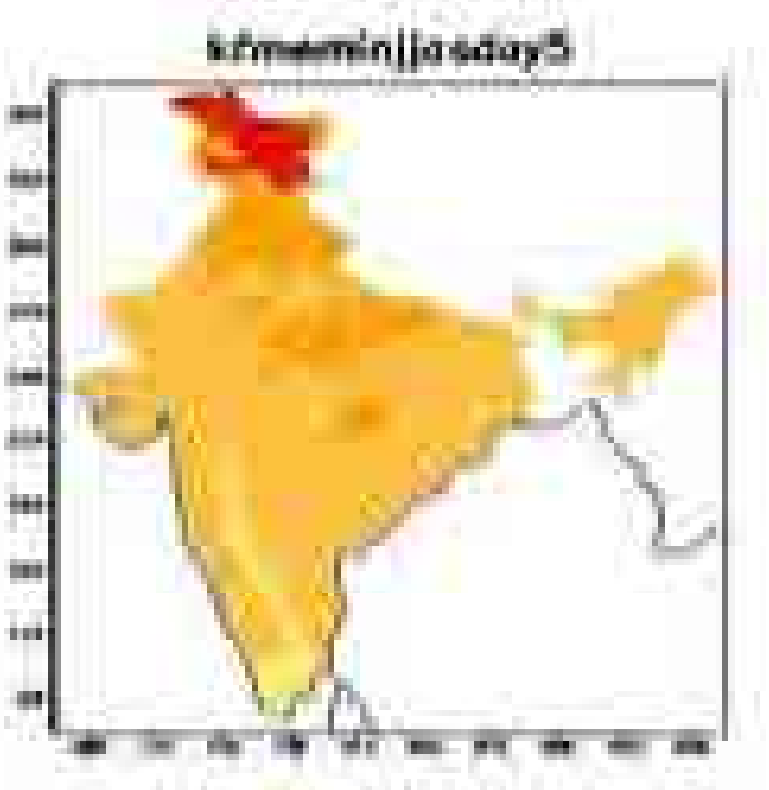


MAE in Minimum temperature (C) : JJAS 2015 :

Day-5 Forecast

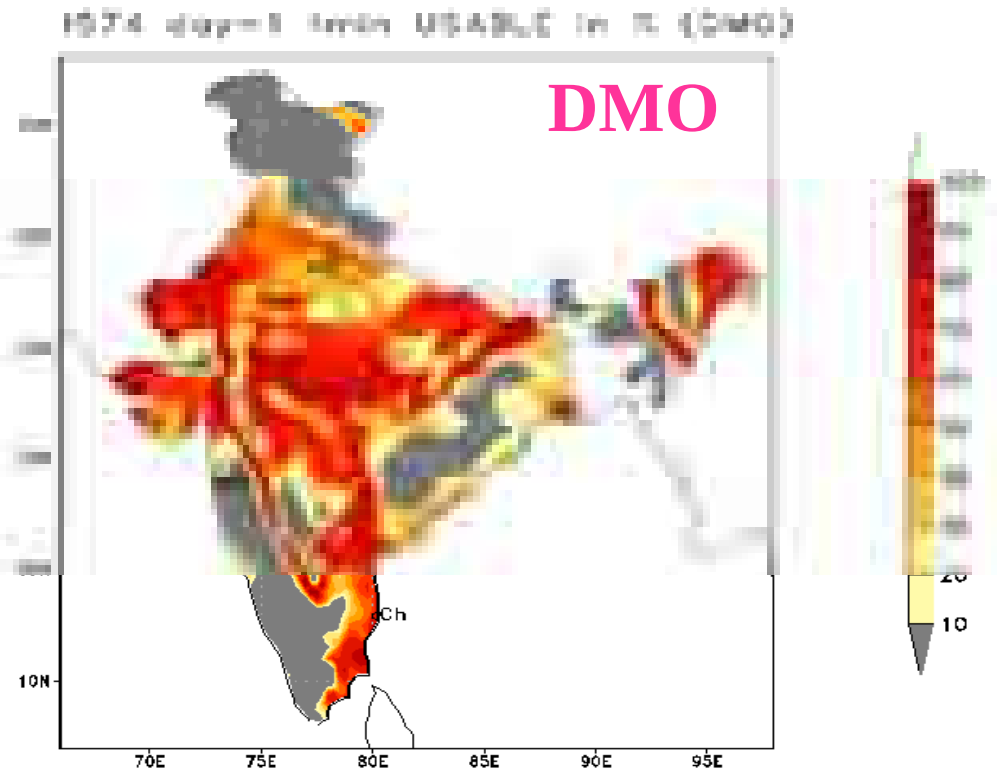


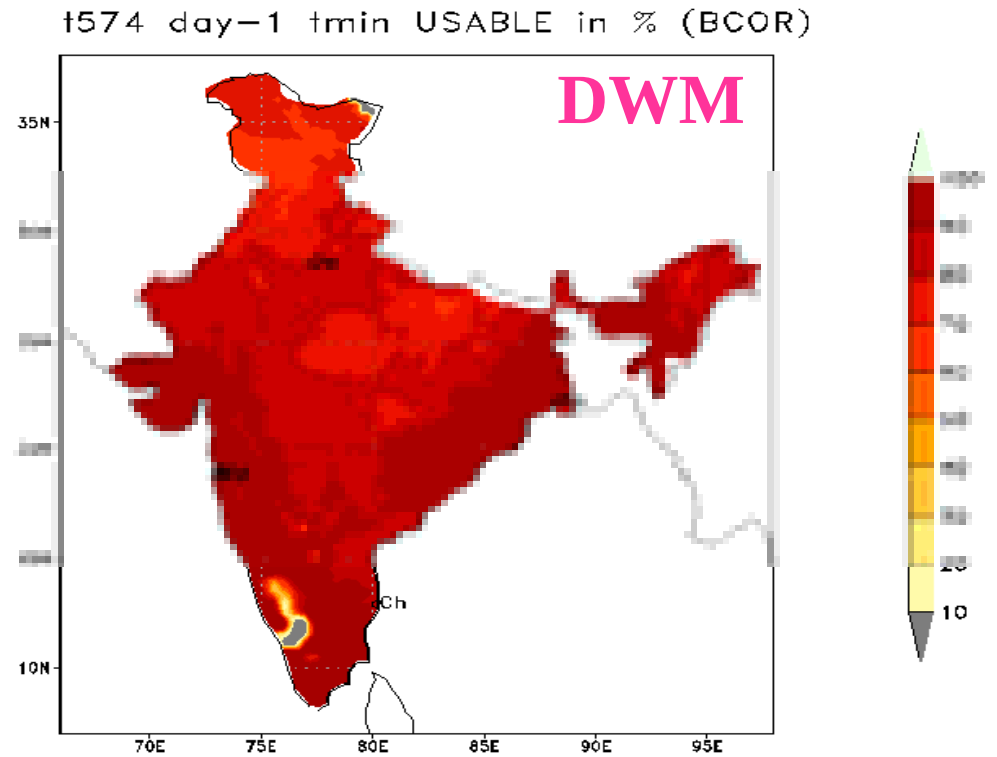


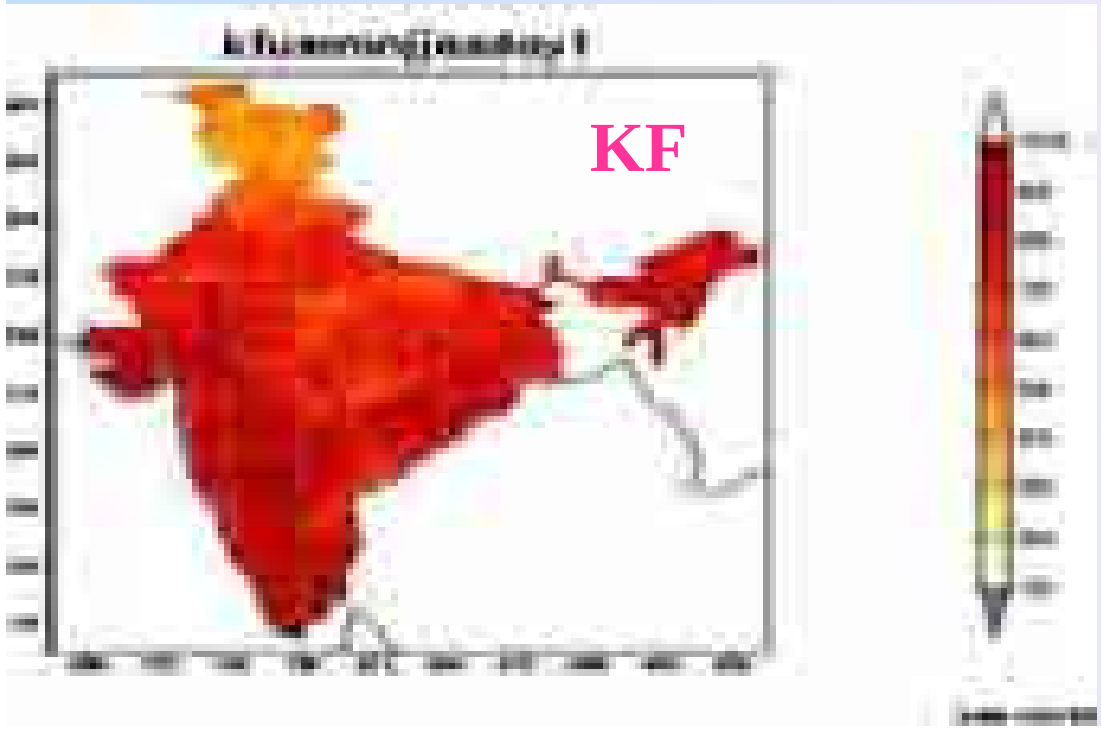


Minimum temperature (C) : JJAS 2015 :

USABLE Day-1 Forecast (in %)



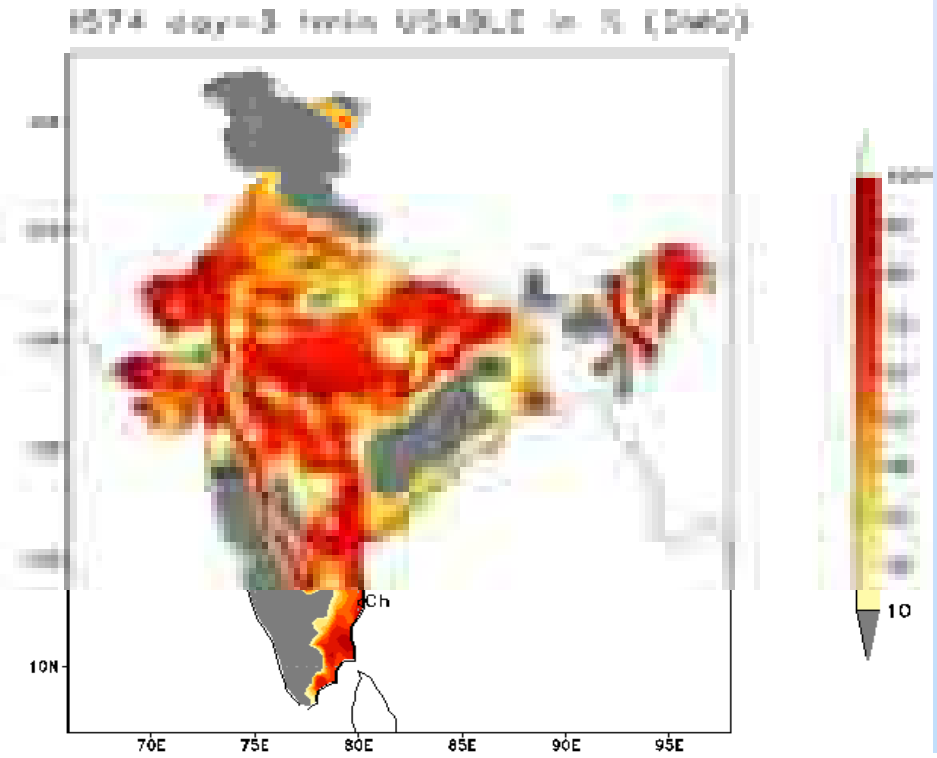


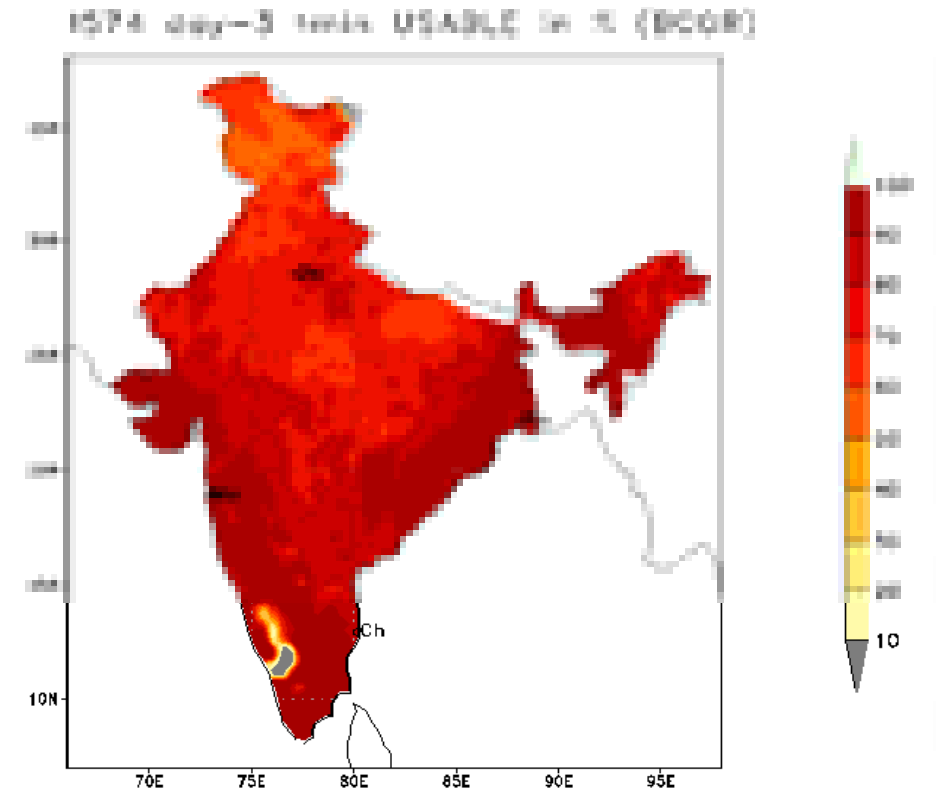


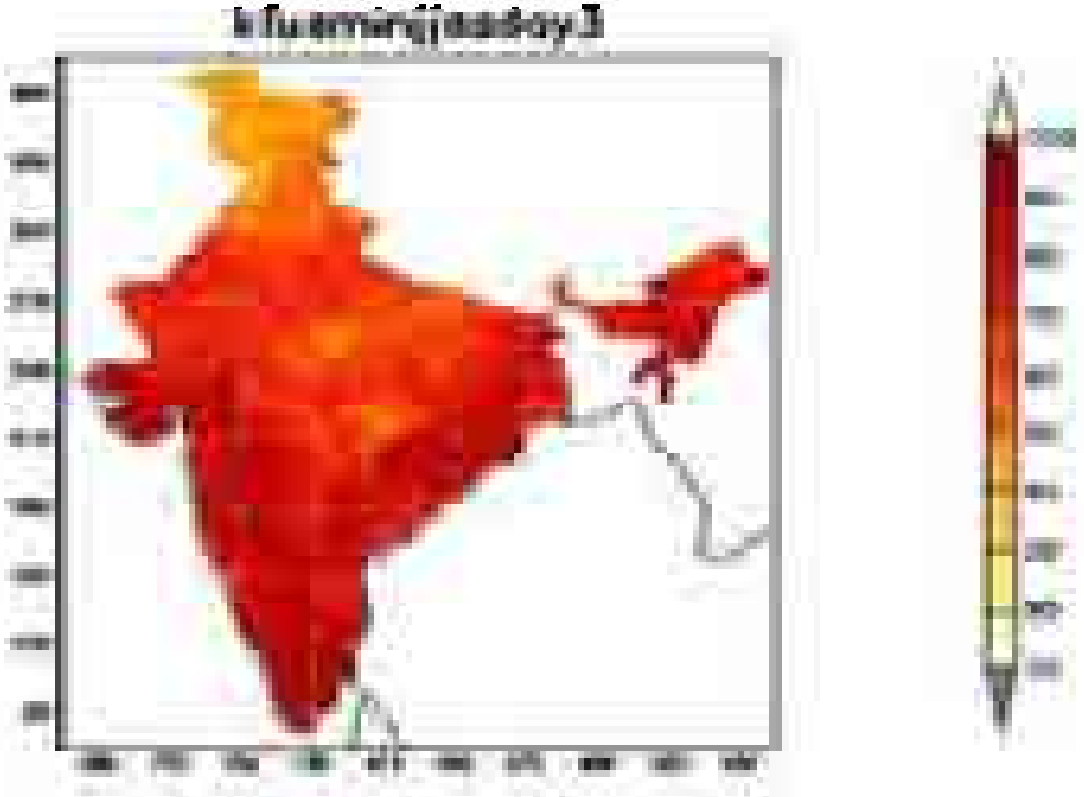
Minimum temperature (C) : JJAS 2015 :

USABLE Day-3 Forecast

(in %)





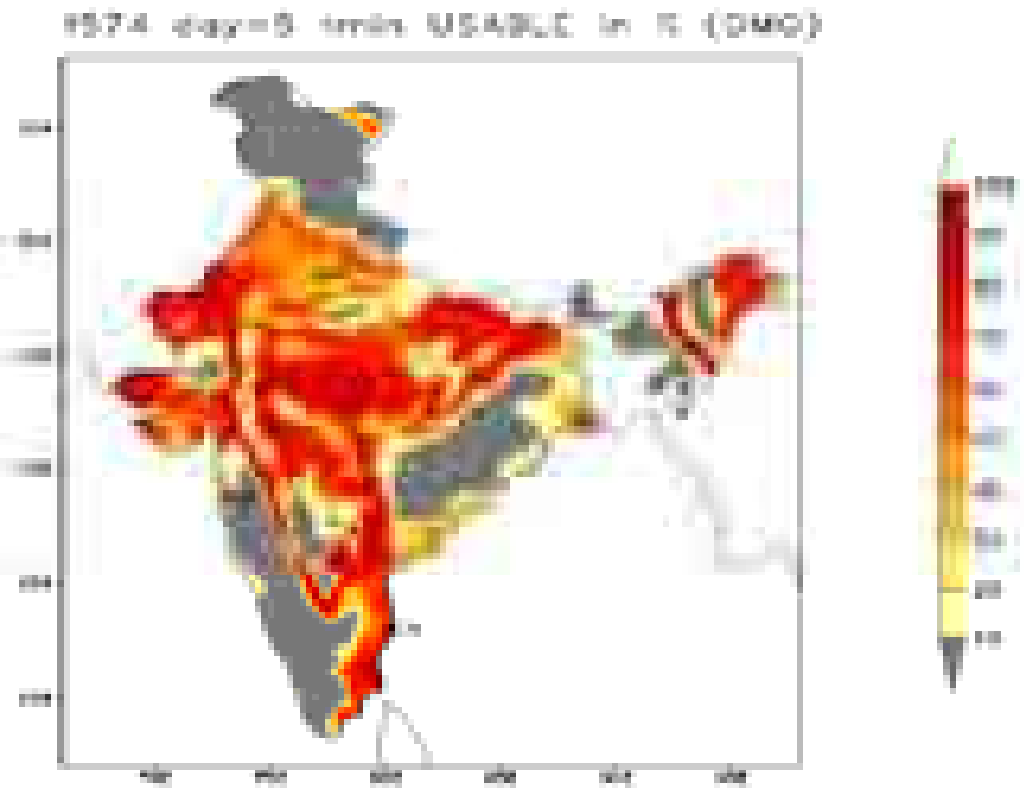


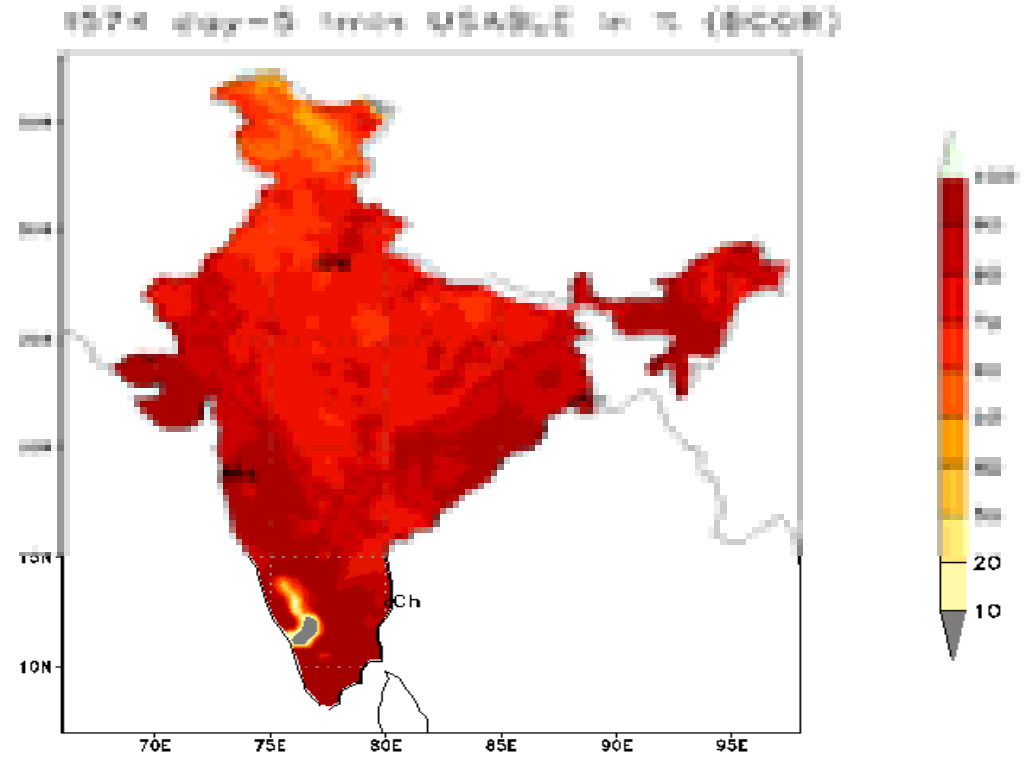
Minimum temperature (C) :

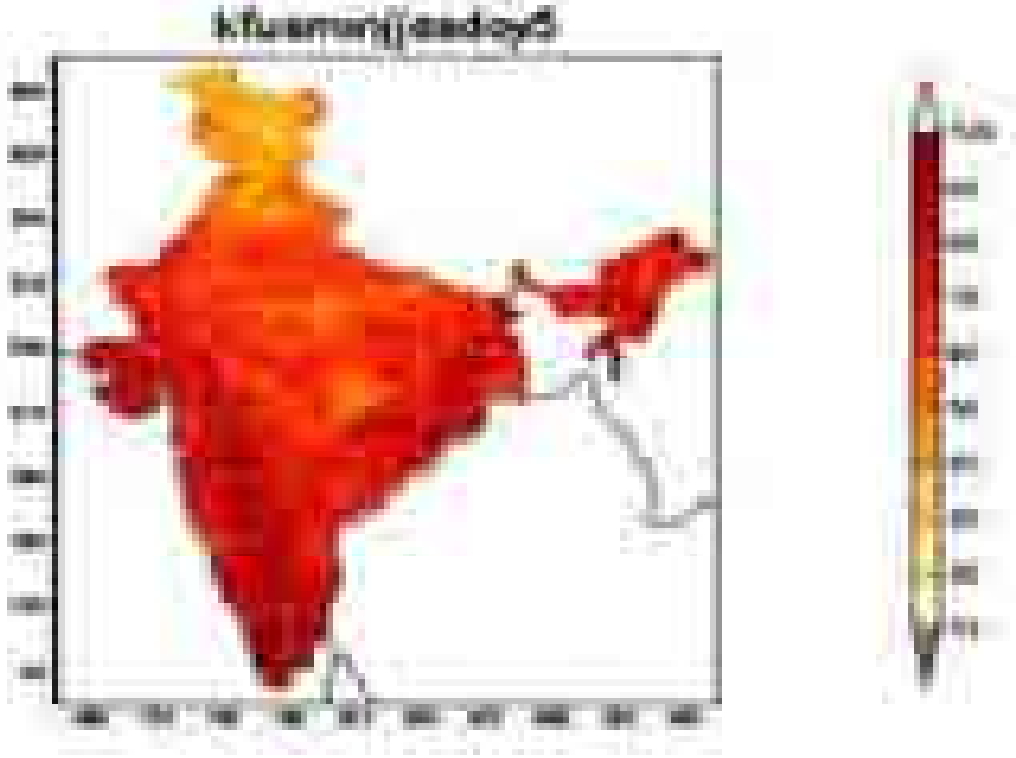
JJAS 2015 :

USABLE Day-5 Forecast

(in %)







Performance of District Level medium range quantitative Weather Forecast (DLWF)

Parameters:

- Rainfall
- Max and Min temperature
- Total cloud cover
- Surface Relative humidity
- Surface Wind

DISTRICT LEVEL FORECAST

Roy Bhowmik and Durai, 2012, JESS, 121(2), 273-285.

INDIA METEOROLOGICAL DEPARTMENT
MULTIMODEL ENSEMBLE BASED DISTRICT LEVEL WEATHER FORECAST
ISSUED ON: 13-11-2009
VALID TILL 08:30 IST OF THE NEXT 5 DAYS

DISTRICT : PUNE STATE : MAHARASHTRA

PARAMETERS	ENSEMBLE FCST				
	DAY-1 14/11	DAY-2 15/11	DAY-3 16/11	DAY-4 17/11	DAY-5 18/11
Rainfall (mm)	0	8	15	15	6
Max Temperature (deg C)	29	26	26	26	27
Min Temperature (deg C)	19	20	20	21	21
Total cloud cover (octa)	7	8	8	7	8
Max Relative Humidity (%)	98	99	98	99	99
Min Relative Humidity (%)	93	92	92	87	82
Wind speed (kmph)	004	006	006	004	002
Wind direction (deg)	90	80	110	120	90

NOTE: -99.0 ..... NO DATA

Error structure

Parameter	Modified error structure
Rainfall	if observed r/f is out by
	Diff ≤ 25% of observed- Correct
	25% of observed < Diff ≤ 50% of observed - Usable
	Diff > 50% of observed – Unusable
Temperature	for observed maximum or minimum temperature
	± 1deg c correct
	± 2 deg c usable
	>± 2 deg c incorrect
Relative humidity	± 10% correct
	+-20% usable
	>± 20% incorrect
Wind direction	± 30 deg correct
	± 40 deg usable
	>± 40deg incorrect
Wind speed	± 2 m/s correct
	-4m/s usable
	>± 4 m/s incorrect
Cloud cover	± 2 okta correct
	± 3 okta usable
	>± 3 octa incorrect

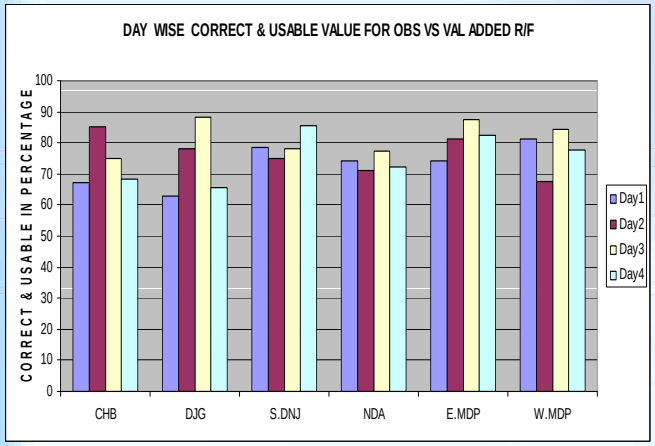
Skill Scores for verification of rainfall in Uttar Pradesh

Skill Score	Day1	Day2	Day3	Day4	Day5
Probability of Detection (POD)	0.81	1.00	0.80	0.78	0.93
False Alarm Rate (FAR)	0.13	0.13	0.29	0.07	0.07
Correct Non-occurrence (C-Non),	0.54	0.58	0.56	0.53	0.58
Critical Success Index (CSI)	0.72	0.88	0.60	0.74	0.88
Bias for Occurrence (BAIS)	0.54	0.48	0.63	0.50	0.45
Percentage correct (PC)	85	94	77	86	94
True skill score (TSS)	0.69	0.89	0.55	0.72	0.88
Heidke skill score (HSS)	0.70	0.88	0.54	0.72	0.88

East Region

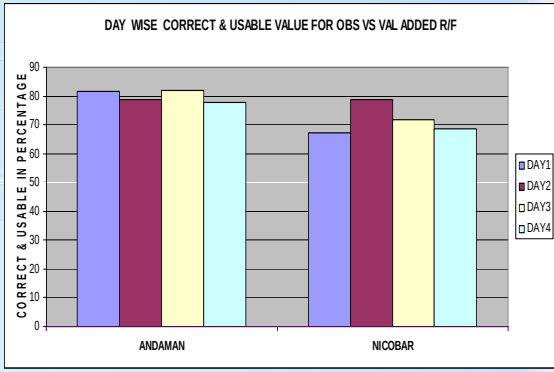
Quantitative Verification of observed and Value added rainfall forecast in Southwest monsoon 2012

West Bengal

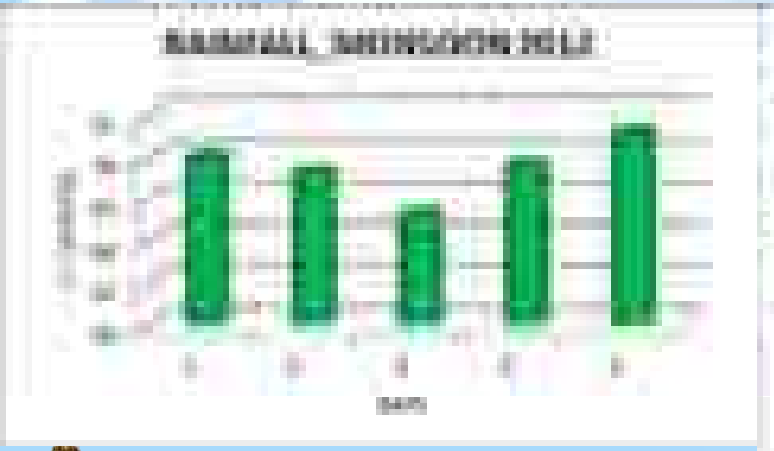


	Day1		Day2		Day3		Day4		Day5	
	C+U	NU	C+U	NU	C+U	NU	C+U	NU	C+U	NU
West Bengal	78	22	75	25	75	25	70	30		
Bihar	55	35	70	30	50	50	55	35		
Sikkim	95	5	95	5	95	5	95	5		
Jharkhand	60	40	70	30	65	35	68	32	62	38
Odisha	65	35	68	32	38	32	69	31	63	37

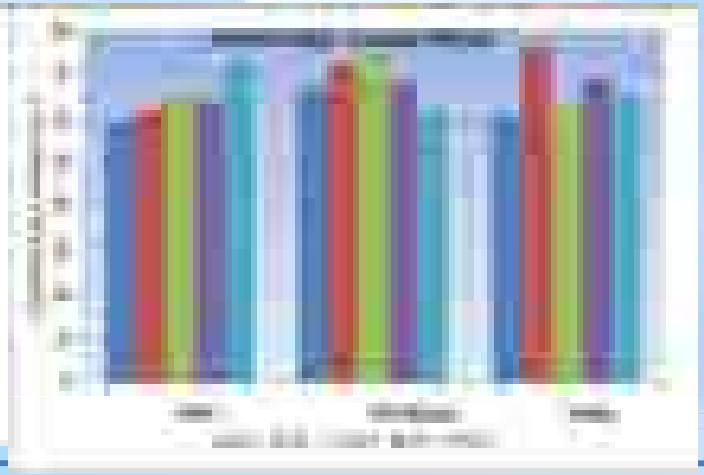
Andaman & Nicobar



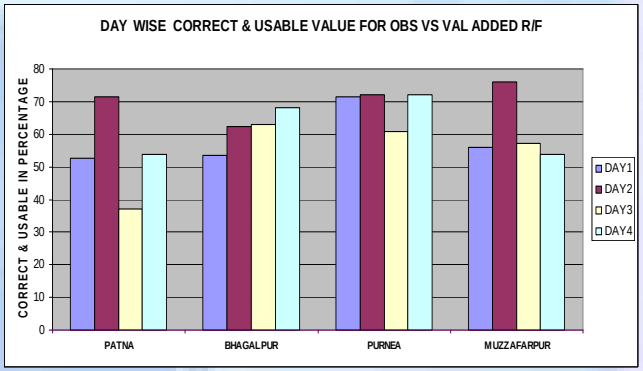
Sikkim



Jharkhand



Bihar

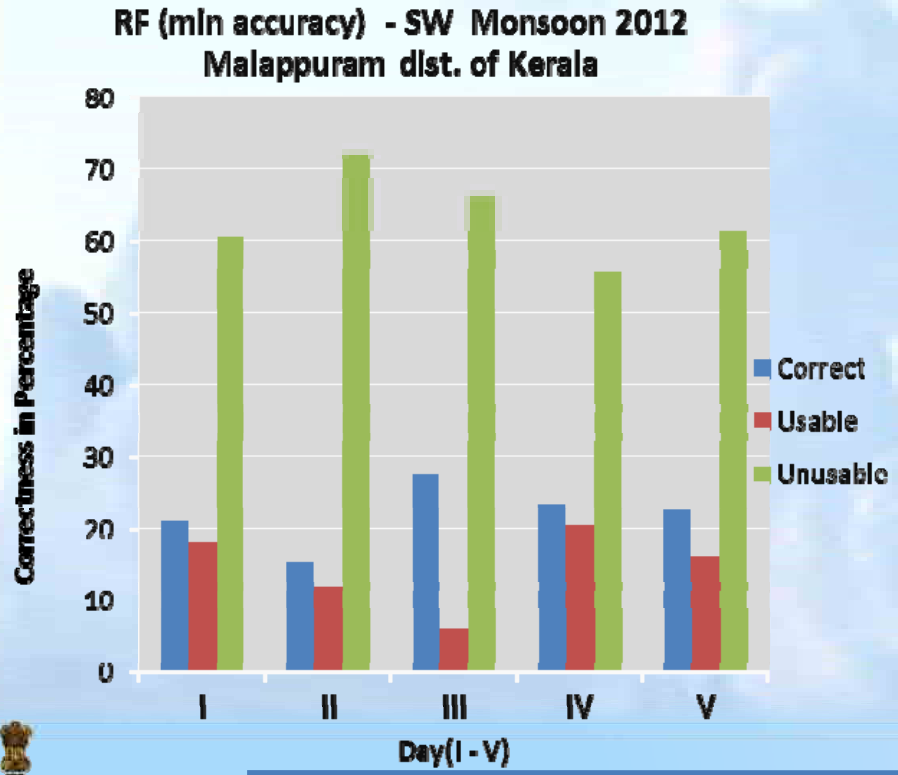


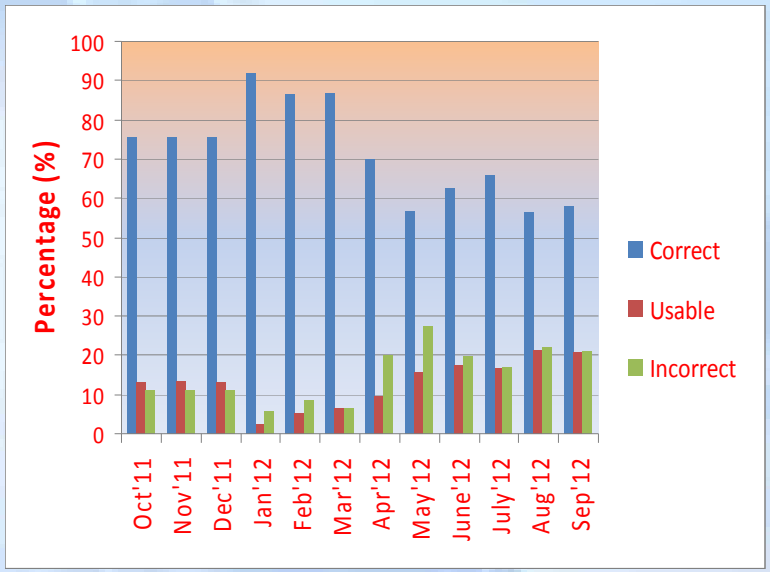
Salient Observations

- **It is observed that the performance of the model for both qualitative & quantitative forecast is very good in the region.**
- **Performance of DLWF is very good in Andaman & Nicobar Island followed by West Bengal, Sikkim, Jharkhand and Bihar.**
- **Most of the states, the forecast is found to be good even upto 5 days**
- **It is also observed that the model in few occasions failed to predict the extreme values of the meteorological parameters specially during convective activities.**

South Region

	JUNE		JULY		AUGUST		SEPT	
	C+U	NU	C+U	NU	C+U	NU	C+U	NU
Tamilnadu	75	25	80	20	75	25	78	22
AP	75	25	74	26	70	30	70	30





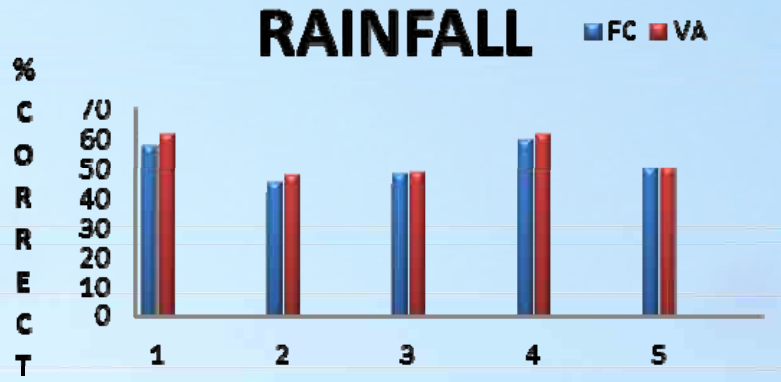
Tamilnadu

Salient Observations

- Accuracy of Forecast for Tamil Nadu during the monsoon months was 60%
- Accuracy of Forecast is variable in Kerala
- Since weather in Kerala is highly variable in space and time due to its proximity to equator and its peculiar geographic features, thorough modifications in MME output is required.
- Forecast could not capture the extreme events in the state of Karnataka.
- Forecast accuracy was very less in Andhra Pradesh during monsoon compared to other seasons.
- In this region it is noticed that the regions having high rainfall could not be captured but most of the cases in the interior where amount of rainfall is less could be captured.

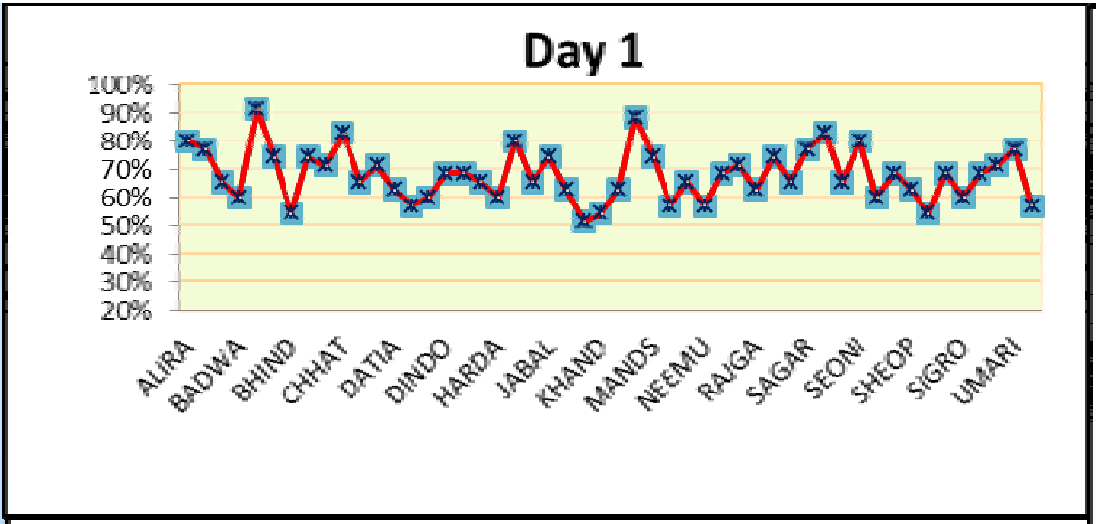
Central Region

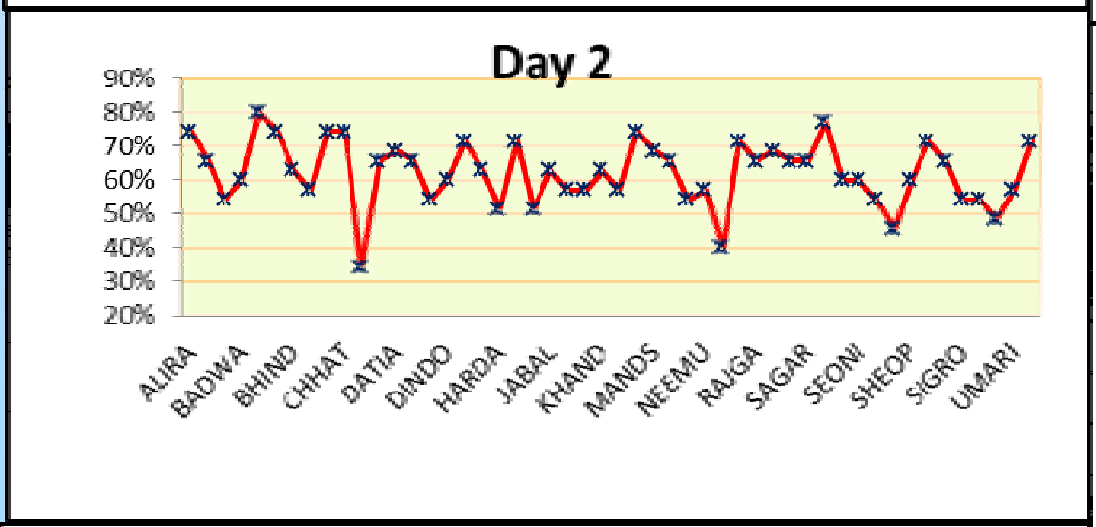
	Day 1		Day 2		Day 3		Day 4		Day 5	
	C+U	NU	C+U	NU	C+U	NU	C+U	NU	C+U	NU
Chhattisgarh	60	40	55	45	50	50	50	50	60	40
Madhya Pradesh	90	10	80	20	85	15	80	20	70	30
Nagpur	56	44	50	50	43	57	38	62	42	58

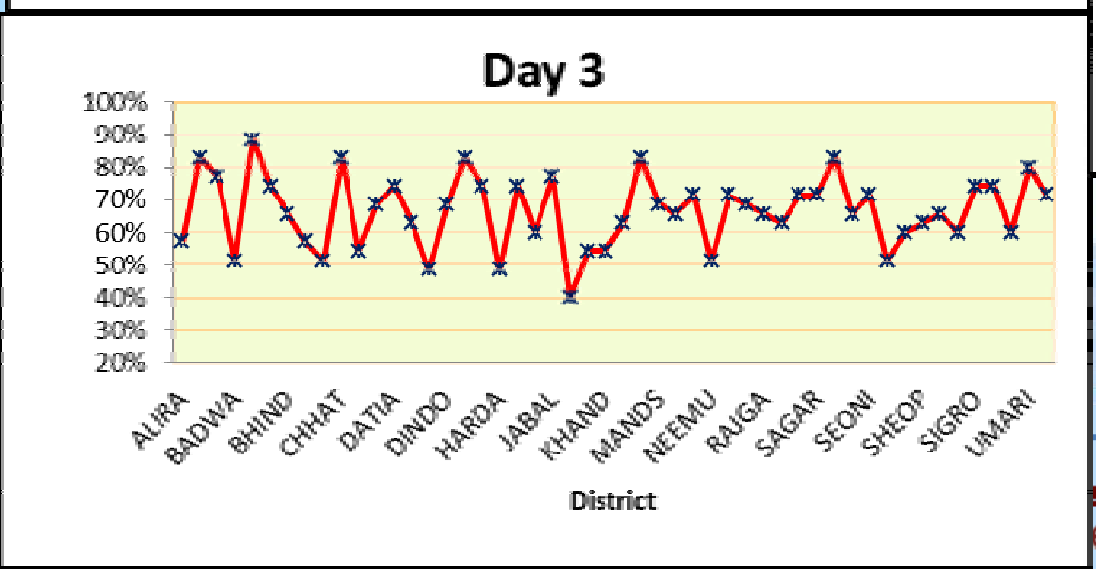


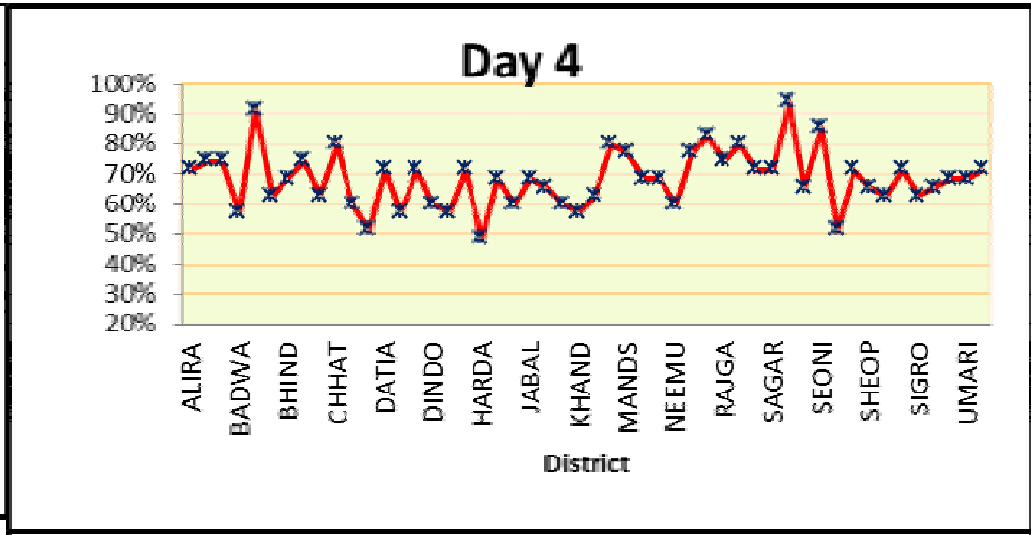
Chhattisgarh

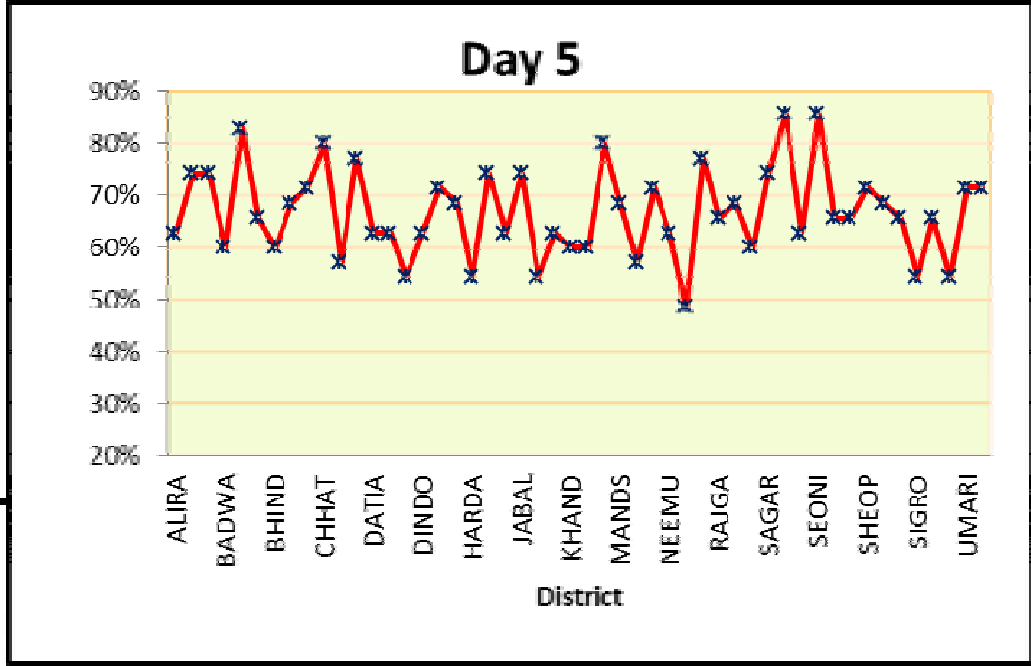
Vidharbha


Day 1
100%
90%
80%
70%
60%
50%
40%
30%
20%
ALIRA
BADWA
BHIND
CHHAT
DATIA
DINDO
HARDA
JABAL
KHAND
MANDS
NEEMU
RAJGA
SAGAR
SEONI
SHEOP
SIGRO
UMARI


Day 2
90%
80%
70%
60%
50%
40%
30%
20%
ALIRA
BADWA
BHIND
CHHAT
DATIA
DINDO
HARDA
JABAL
KHAND
MANDS
NEEMU
RAJGA
SAGAR
SEONI
SHEOP
SIGRO
UMARI


Day 3
100%
90%
80%
70%
60%
50%
40%
30%
20%
ALIRA
BADWA
BHIND
CHHAT
DATIA
DINDO
HARDA
JABAL
KHAND
MANDS
NEEMU
RAJGA
SAGAR
SEONI
SHEOP
SIGRO
UMARI
District


Day 4
100%
90%
80%
70%
60%
50%
40%
30%
20%
ALIRA
BADWA
BHIND
CHHAT
DATIA
DINDO
HARDA
JABAL
KHAND
MANDS
NEEMU
RAJGA
SAGAR
SEONI
SHEOP
SIGRO
UMARI
District


Day 5
90%
80%
70%
60%
50%
40%
30%
20%
ALIRA
BADWA
BHIND
CHHAT
DATIA
DINDO
HARDA
JABAL
KHAND
MANDS
NEEMU
RAJGA
SAGAR
SEONI
SHEOP
SIGRO
UMARI
District

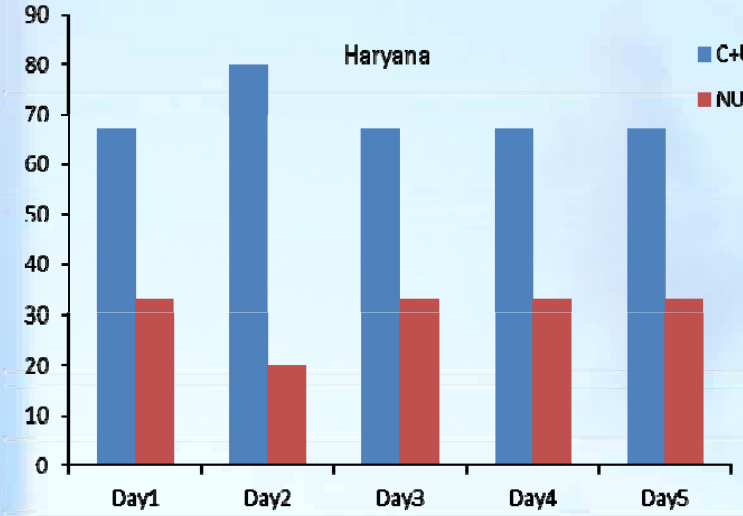

Madhya Pradesh
CAL DEPARTMENT

Salient Observations

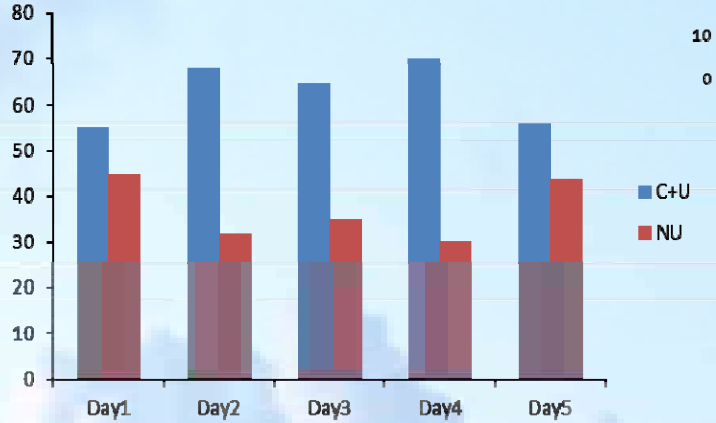
- Compared to other regions central region shows good accuracy level between observed and value added forecasted values.
- In Chhatisgarh the Qualitative Value Added f/c for Rainfall for the monsoon season is upto 82% correct compare to77 % for Model f/c.
- In Vidharbha the amount of rainfall usable is found to be more for all the stations.
- Compared to the other two states in the region Madhya Pradesh showed a greater accuracy in predicting the actual value added rainfall. It is noticed that in all the district the accuracy level is more than 60% on all the five days.

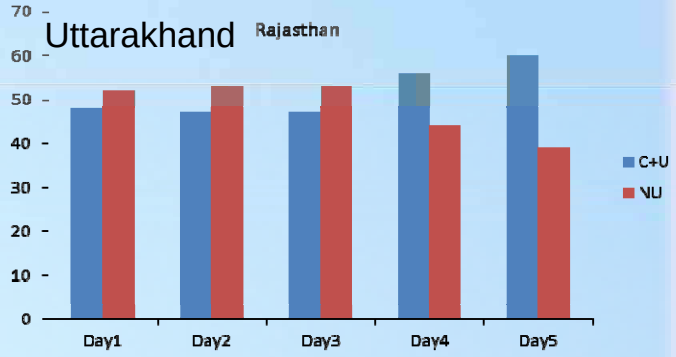
North Region

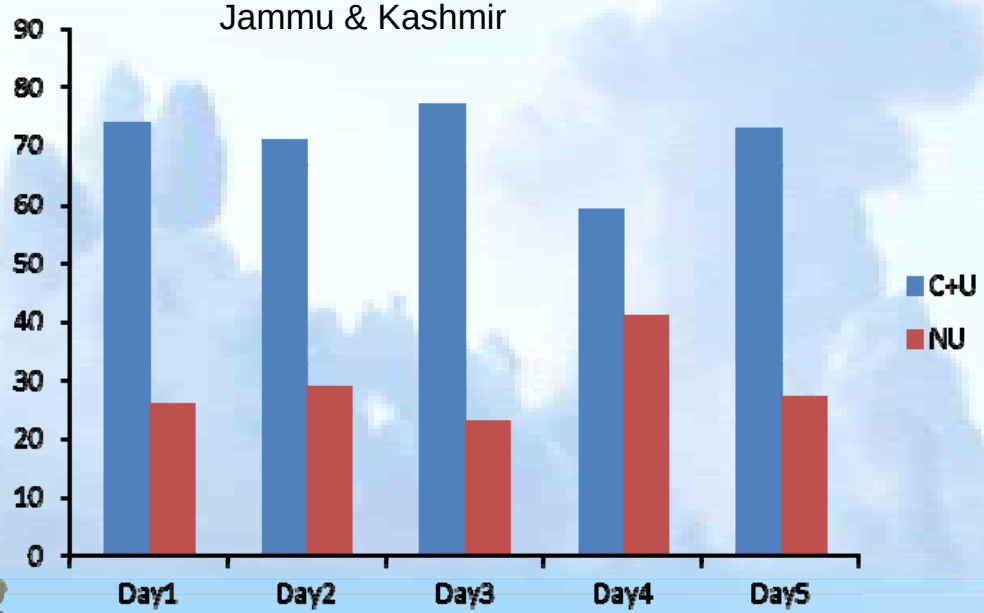
State	Day1		Day2		Day3		Day4		Day5	
	C+U	NU	C+U	NU	C+U	NU	C+U	NU	C+U	NU
New Delhi	46	54	43	57	37	63	38	62	30	70
Rajasthan	48	52	47	53	47	53	56	44	60	39
Punjab	60	40	50	50	65	0	67	33	66	34
Shimla	90	10	95	0	90	10	75	25	0	0
Haryana	67	34	80	20	67	33	67	33	67	33
Dehradun	54	45	68	32	65	35	70	30	56	54
JK	74	26	71	29	77	23	59	41	73	27

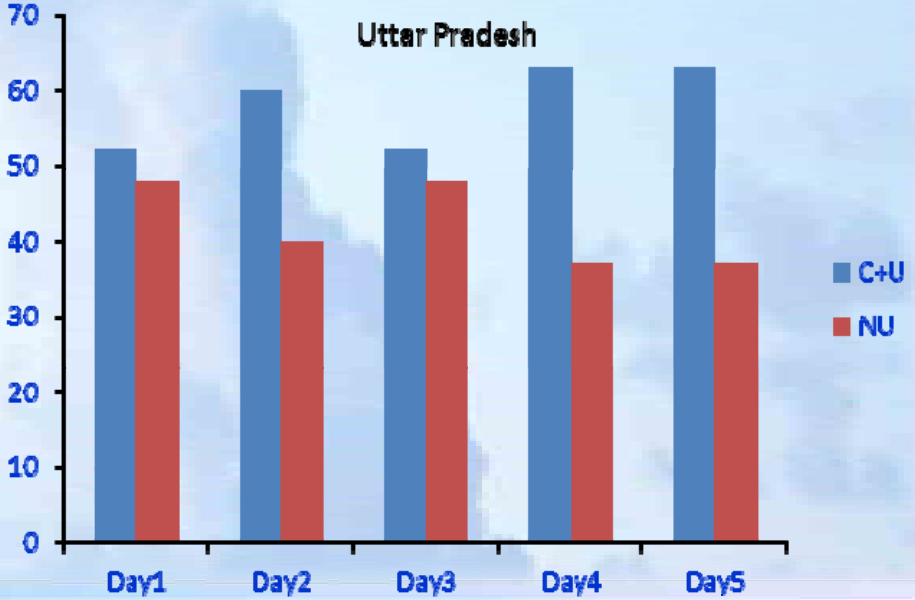

Haryana
C+U
NU
90
80
70
60
50
40
30
20
10
0
Day1
Day2
Day3
Day4
Day5

Rahasthan


80
70
60
50
40
30
20
10
0
Day1
Day2
Day3
Day4
Day5
C+U
NU


Uttarakhand
Rajasthan
70
60
50
40
30
20
10
0
Day1
Day2
Day3
Day4
Day5
C+U
NU


Jammu & Kashmir
90
80
70
60
50
40
30
20
10
0
Day1
Day2
Day3
Day4
Day5
C+U
NU

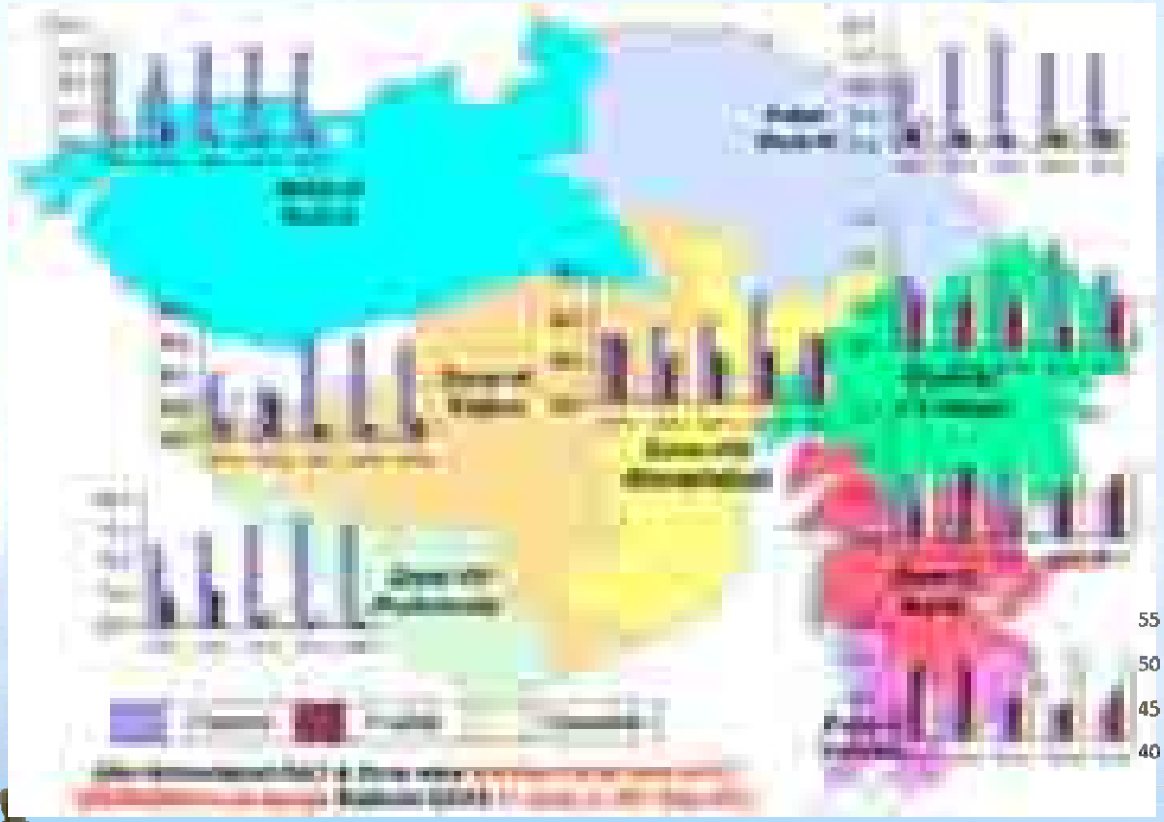

Uttar Pradesh
70
60
50
40
30
20
10
0
Day1
Day2
Day3
Day4
Day5
C+U
NU

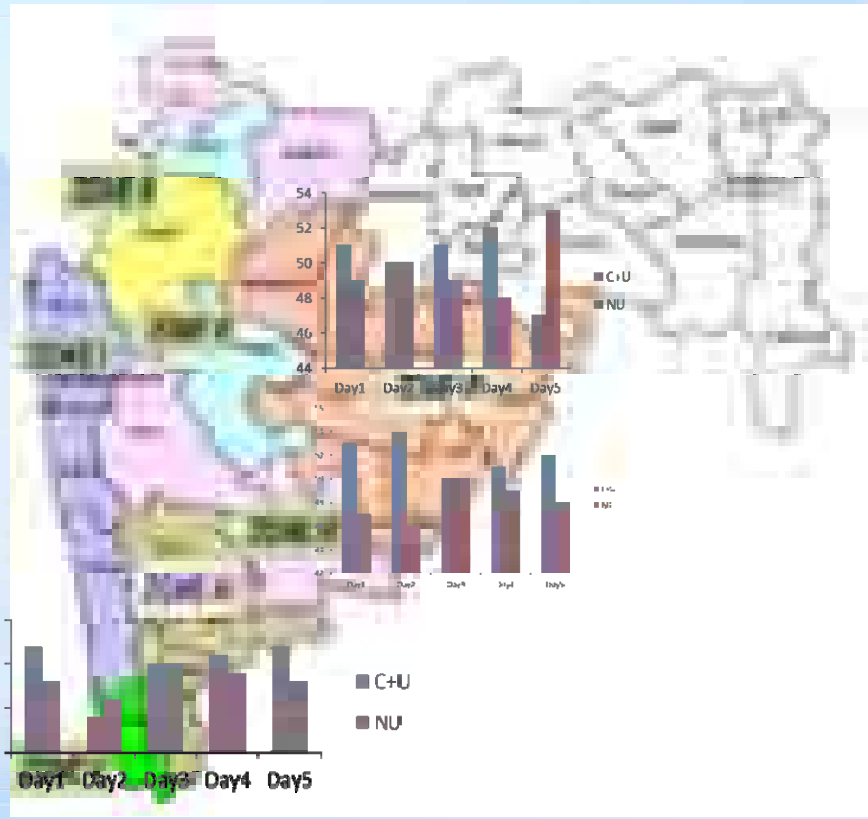
Salient Observations

- Himachal Pradesh shows a good accuracy between the observed and value added forecasted values in the northen region. Though being a hilly region the accuracy level was very good.
- All the others in the North region showed a accuracy level of more than 50% for all the five days.
- The other parameters in the region also showed good accuracy level in other seasons especially in winter season (Tmin).

West Region

	Day1		Day2		Day3		Day4		Day5	
	C+U	NU	C+U	NU	C+U	NU	C+U	NU	C+U	NU
Mumbai	55	45	54	46	50	50	51	49	52	48
Gujarat	80	20	70	30	60	40	60	40	60	40





Western Region

- In West region, the regions where the rainfall is less the accuracy of forecast level is more compared to the regions where there is high rainfall occurring.
- In Gujarat all the regions showed accuracy of more than 50% in all days except the high rainfall zone.
- In Maharashtra the Marathwada and Madhya Maharashtra region showed greater accuracy as compared to the coastal region on all five days.

CONCLUSION

- Qualitatively the model forecast for rainfall is able to predict correctly in all the regions of the country. Quantitatively the accuracy level of the observed value varied drastically from the regions of low, moderate and high rainfall intensity.
- The accuracy of value added forecast for other parameters Temperature, Relative Humidity , Cloud, Wind speed and direction in the regions showed good results during the monsoon period
- The value added forecast verification in all the other seasons also showed good results.
- Though the MME model could predict the true values in Hill regions in the North but in other regions having some hilly areas the same could not come true in respect of temperature

Bottle Necks

1. Lack of trained manpower: Many of the personnel are not informed of the various methods of doing value addition to the Multimodel Ensemble forecast.
2. Insufficient Observatory network : At present IMD is having around 559 Surface observatories, 675 AWS, 127 Agro AWS observatories and 856 ARGs but still there are around 253 unrepresented districts in the country.

Initiatives at SMRC

- **Research programme and activities are based on the following broad thematic areas like-**

  (i) Monsoon

  (ii) Severe Thunderstorm,

  (iii) Tropical Cyclone and

  (iv) Climate Change

- **Long Term Programmes**

  (i) SAARC STORM Programme

  (ii) Monsoon Initiative Programme

SAARC STORM Programme (2009-2015) (Severe Thunderstorm Observation and Regional Modelling)

Observation: Collecting intense field observations for better understanding of atmospheric processes during different stages of convective developments like features of genesis, structure and life cycle of localized severe thunderstorm

- **Modelling:** Study Impact of these intense observations in improving prediction of mesoscale convection over the region and validate available models with the data to beIing collected during the Pilot Field Experiment.

SAARC STORM Programme (2009-2015)

Progress

- **Phase-I (2009-14: Bangladesh, Bhutan, eastern India and Nepal)**
- **Phase-II (2012-14:Afghanistan, northwest India and Pakistan)**
- **Phase-III (2013-14:S Peninsula of India, Sri Lanka & Maldives).**

Activities during 2009-2015:

- **Six Pilot Field Experiments have been conducted during 15 April – 31 May of 2009-2014 jointly over Phase-I countries**
- **Three Pilot Field Experiments been conducted during 1 May-15 June of 2012-2014 jointly over Phase-II countries.**

Two Pilot Field Experiments have been conducted during March - June of 2013-14 over Phase-III Countries.

SAARC STORM Programme (2009-2015)

- **As a part of the SAARC STORM Programme, a Memorandum of Understanding (MoU) between SMRC and Indian Space Research Organization (ISRO) was signed.**

- **Under this MoU 50 Automatic Weather Stations (AWS), 4 GPS sounding stations and 01 (one) Doppler Weather Radar (DWR) are scheduled to be installed in the data sparse regions of Bangladesh, Bhutan and Nepal.**

- **Installation of 10 (Ten) AWSs over Bhutan has completed during May-June 2014 by ISRO Scientists in coordination with SMRC.**

- **Installation of 01 (One) GPS Sonde in Bhutan is progressing.**

- **SMRC has been coordinating with ISRO and Ministry of External Affairs (MoEA), India to install 24 AWSs & 1 GPS Sonde in Bangladesh and 16 AWSs, 2 GPS Sonde & 1 Doppler Radar in Nepal**

Monsoon Initiative Programme

- To sensitize the stake holders on SAARC Monsoon Initiative Programme
- Sharing of experience and best practices, understanding of issues related to use of monsoon forecast information by the stakeholders and preparedness for monsoon 2014
- To review existing capabilities and requirements of stakeholders in relation to monsoon forecast
- To convert challenges into opportunities to improve monsoon forecast

SAARC Monsoon Initiative Programme

- Training/ Seminar for capacity building
- Research
- Meeting of SAARC Working Group on Monsoon (SWGM)
- Meeting of National Working Groups on Monsoon (NWGM)

- No. of Trainings Conducted:8
- No. of Manpower Trained: 194
- No. of Seminars/workshops conducted: 24
- No. of participants in seminar: 728
- No. of Research Report Published:52
- No. of Research Papers published: 62
- No. of Newsletter published: 38

Challenges

- Pre-processing for improving initial analysis: Assimilation of new observations like INSAT radiance, DWR, radiometer
- Post-processing: Model bias removal and calibration
- Improving parameterization of land surface process, Cumulus Convection, Cloud with Indian condition

Work Plan: Block Level Forecast

- Taking the benefits of the dense observations from different sources, such as Doppler weather Radar, wind profiler, radiometer etc, being made available from the modernization programme phase I and II, and high resolution GFS (12 km in horizontal), it is now possible to start assimilation of WRF 3 km (domain covering for each RMC)
- GEFS at 12 km resolution for block level forecast
- Development of neural network technique to generate bias free block level 3 days forecasts from WRF outputs

Work Plan: Nowcast and Metropoliton city forecast

- WRF at 3 km and 1 km at RMCs/MCs
- Rapid Updates of model (WRF) run: Three hourly cycle at H/Q
- GIS and DWR based Nowcast and mesoacle forecast system for major cities/airports of India

Work Plan: Hurricane Model

- To Increase Forecast Lead time to 5 days
- NOAA HWRF
  - > Ocean Component
  - > Land Surface data
  - > Airborne data
- Goal: 20% improvement of F/C Skill for track prediction

  Improving forecasts of intensity, landfall rainfall and surface wind fields

New Activities at IMD

> *Bias corrected products*
> *HWRF Coupling*
> *Experimental Block level F/c*

Conclusions

- **Meso-scale Data Assimilation**
  - > Common data base for SAARC region
  - > Centrally Processed
  - > Rapid Updates
  - > DWR, INSAT 3D
- **Assimilation of Land-surface Process**
  - > In-situ Observations
  - > Satellite Observation

THANKS