



NWP Forecast System Operational & Research Activities

Rahul Saxena , NWP

**भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT**

Met Family

National Meteorological
Service Establishment

IMD
1875

Development of
NWP Techniques
especially in the
medium range

NCMRWF
1989

IITM
1960

Studies/Research in
Tropical Meteorology

Ministry of Earth Sciences was formed during 27 July 2006



Classes of Weather Forecasts

- ❖ **Nowcasting** ~ HRS
- ❖ **Short Range Forecasting (SRF)** < 3 days
- ❖ **Medium Range Forecasting (MRF)** 3-10 days
- ❖ **Extended Range Forecasting (ERF)** 10-30 days
- ❖ **Long Range Forecasting (LRF)** >30 days



NCMRWF

- Develop advanced numerical weather prediction systems

IITM

- Provide basic research in ocean- Atmosphere Climate System

IMD

- Take Met Observations and provide Current and forecast Weather Info for Weather sensitive activities



New vistas in NWP



IMD: 14 Tf , 750 processors



IITM: ADITYA 790+ Tf , 2384 computing nodes two 8-core processors

A 350 Tera Flop high performance computing system and 3 Peta Byte storage has also been installed at NCMRWF.





Operational Global Models



- NGFS (T574L64) – 10 day forecast – for 00 UTC
– 3 day forecast -12 UTC
- NCUM (25kmL70) – 10 day forecast – for 00 UTC
– 4D-Var DA
- NGEFS (T190L28; 21 members - ETR)
– 10 day ensemble forecasts
- *UM based global EPS (~33 km/L70;44 members -ETKF) undergoing trials*

Unified Model at NCMRWF

Same Model for Global/Regional/Mesoscale! – seamless model



**4 km grid
up to 36 hr forecast**

**12 km grid
up to 48 hr forecast**

**25 km global grid
up to 168 hr forecast**





INDIAN INSTITUTE OF TROPICAL METEOROLOGY

(An Autonomous Body under the Ministry of Earth Sciences, Govt. of India)

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Centre for Climate Change Research

Development of a coupled modelling system for Climate Change Studies
Assessment of Climate Change on Indian Monsoon climate;

Cloud Aerosol Interaction and Precipitation Enhancement Experiment
(CAIPEX)

System of Air Quality and Weather Forecasting And Research
(SAFAR)

WP/RASS - Project (Wind Profiler / Radio Acoustic Sounding System)



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The Migration

Up to 2007	2008-09	2010-15	2015 (from March)
<p>CYBER 2000U Origin 200</p>	<p>IBM P5 Origin 200 Altix 350</p>	<p>HPCS 14 TF</p>	<p>IITM 100 TF</p>
<p>LAM-75 km MM5-45 km QLM (TC)-40 km</p>	<p>WRF-27 / 9 km ARPS (DWR) (exp) TC-GPP, MME track & SCIP model WRF trial at RMCs</p>	<p>WRF-27/9/3 km with 3dVAR assimilation HWRF-27/9 km Polar WRF-15 km GPP, SCIP & MME for TC Nowcast Systems (WDSS-II, ARPS)</p>	<p>WRF-9/3 km with DWR assimilation HWRF-27/9/3 km Polar WRF-9 km</p>
<p>NCMRWF T80 ECMWF-2.5° (GTS)</p>	<p>MME (NCEP, ECMWF, JMA UKMO, NCMRWF)</p>	<p>GFS T-382/574 GFS T574 with GSI (3dVAR) MME global</p>	<p>GFS T574 with GSI (EnKF)</p>



Spatial and Temporal domains of Forecast

- ❑ **Nowcast for next few hours**
(Venue/ location specific)
- ❑ **Short Range for next 72 hours**
(Location/District/ State/Met Sub-division)
- ❑ **Quantitative Medium Range for next 3-7 days**
(City, District, Block)
- ❑ **Extended range for 10-15 days**
(Met Subdivision/State/ Homogeneous regions)
- ❑ **Long range for month/season**
(Homogeneous regions/country)



GFS T-574L64
(25 km)

WRF –ARW
(9, 3 kms)
Polar WRF
(15 km)
MME TC

WRF –ARW
3 Kms
Area Specific
F/C 51 Hours
(hourly)

ARPS
(9 kms)
Hourly
updates
Next 6 hours

WDSS-II
(Trigger with
every data
received)

Medium Range
(1-7 days)

Short Range
(1-3 days)

Short Range
(51 hours)

*Very short
range*
(6-24hrs)

Nowcasting
(0-2 hr)

Products Available

Analysis

(MSLP & Winds at
925,850,
700,500,300, 200
100 hPa)

Analysis

(MSLP & Winds at
925,850,700,500,300,
200 hPa)

Meteograms

For Location
specific sites in
Delhi /major
airports

Winds;
Reflectivity;
Rainfall.

Maximum
Reflectivity field
(ZMax)
(T+10,30,60,90
, 120 mins).

Forecast for 7 days

(MSLP, &
Winds at
925,850,700,500,3
00, 200, 100 hPa,
rainfall & Derived
Products)

Forecast for 3 days

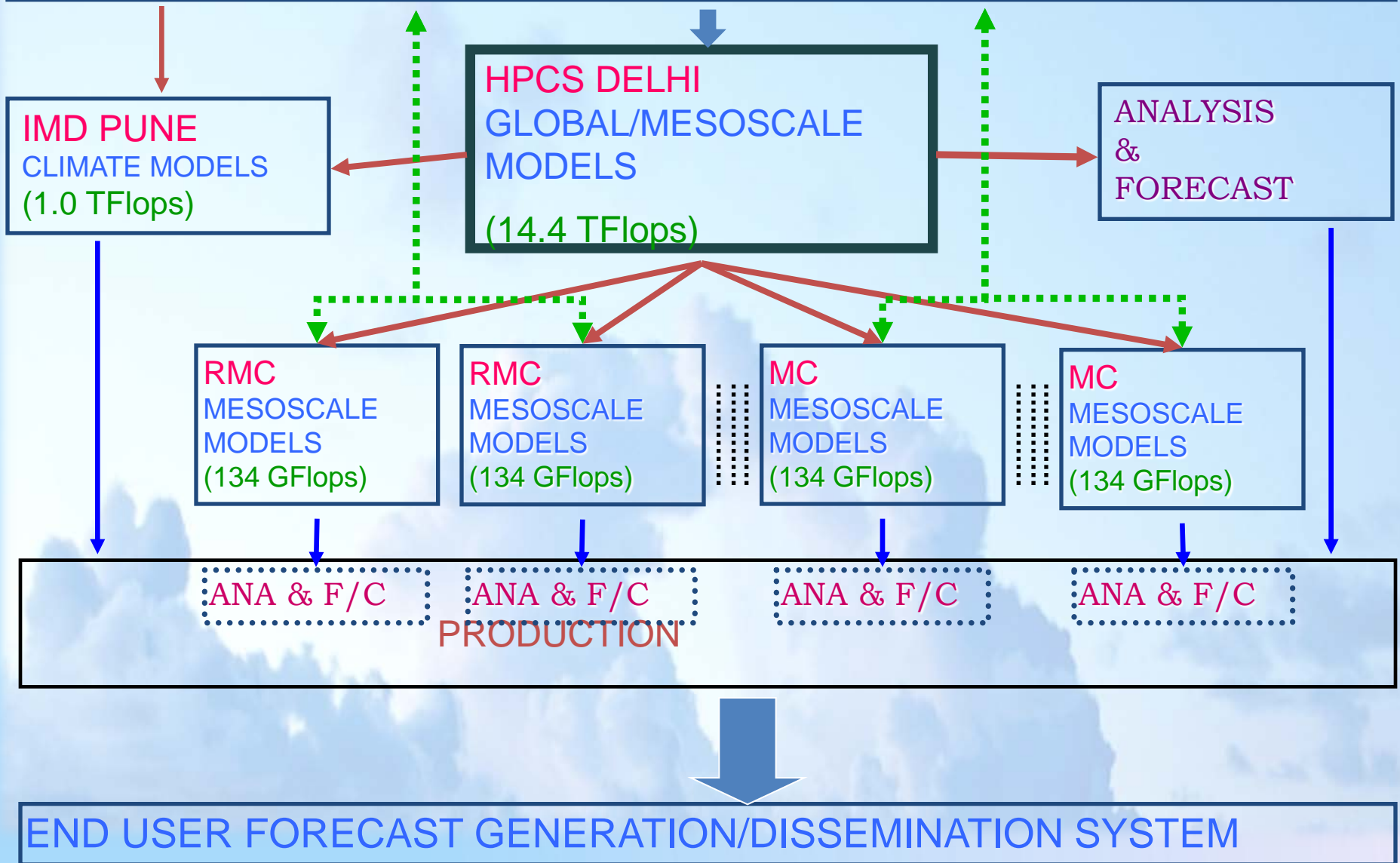
(MSLP & Winds at
925,850,700,500,300,
200 hPa, rainfall ,
Derived Products &
convective Indices

Wind spd (10m);
Rainfall;
RH;
Temperature
(DB & DP).

Location specific f/c
for 100 cities thru 9
kms



METEOROLOGICAL OBSERVATIONS



WRF and HWRF Modeling System

❖ **Migration and upgradation of WRF Forecasting System to new HPCS-Aditya at IITM, Pune**

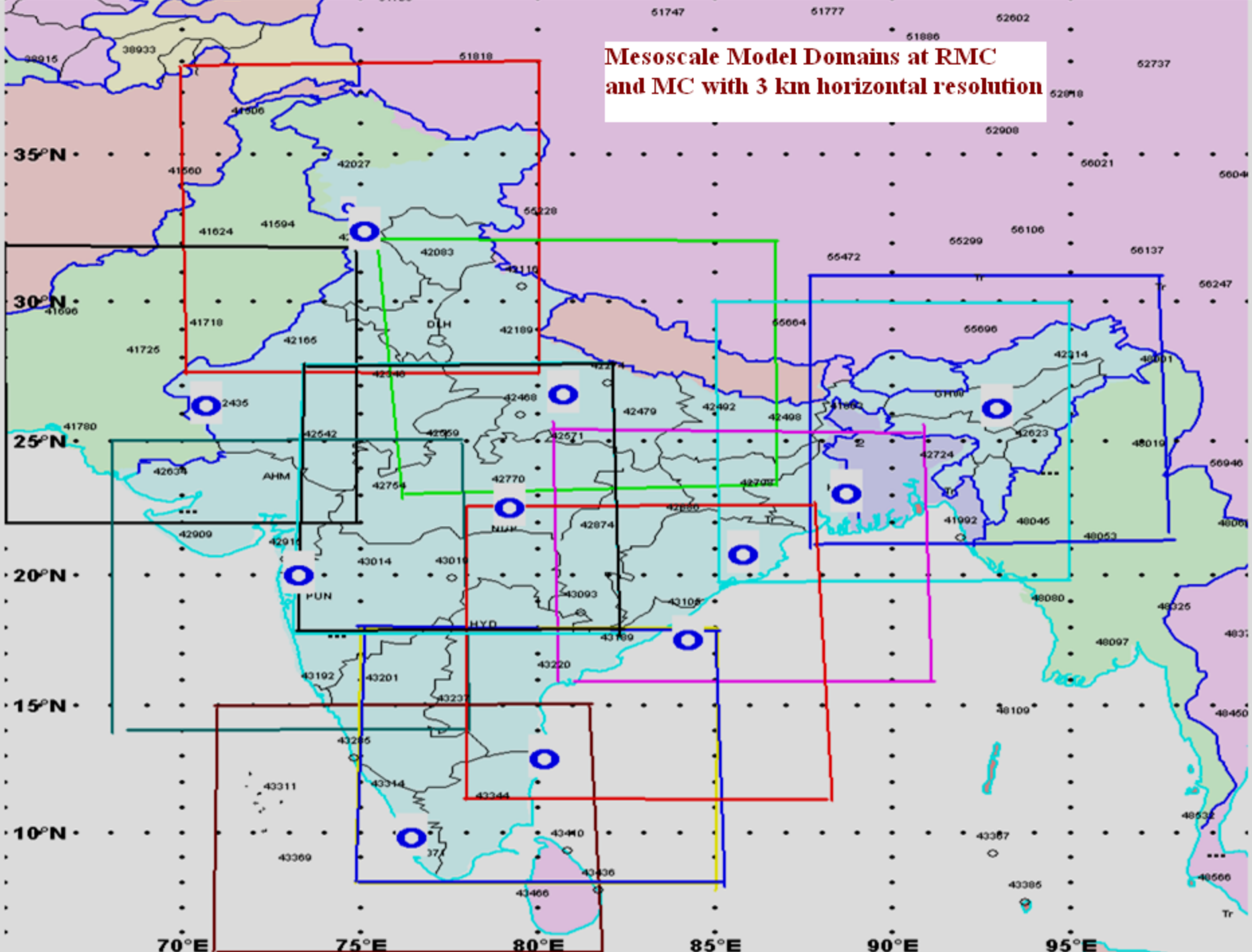
- Version (v3.6.1) upgrade of modeling system
- Increase in horizontal (9 and 3 km) and vertical resolution (45 levels up to 100 hPa)
- Successful operational forecasting of heavy rainfall events of SW Monsoon 2015 (mainly in June and July)
- Heavy rainfall episodes over Tamilnadu during NE Monsoon 2015 (November and December)

❖ **Implementation of new Triple-nest version of HWRF Model**

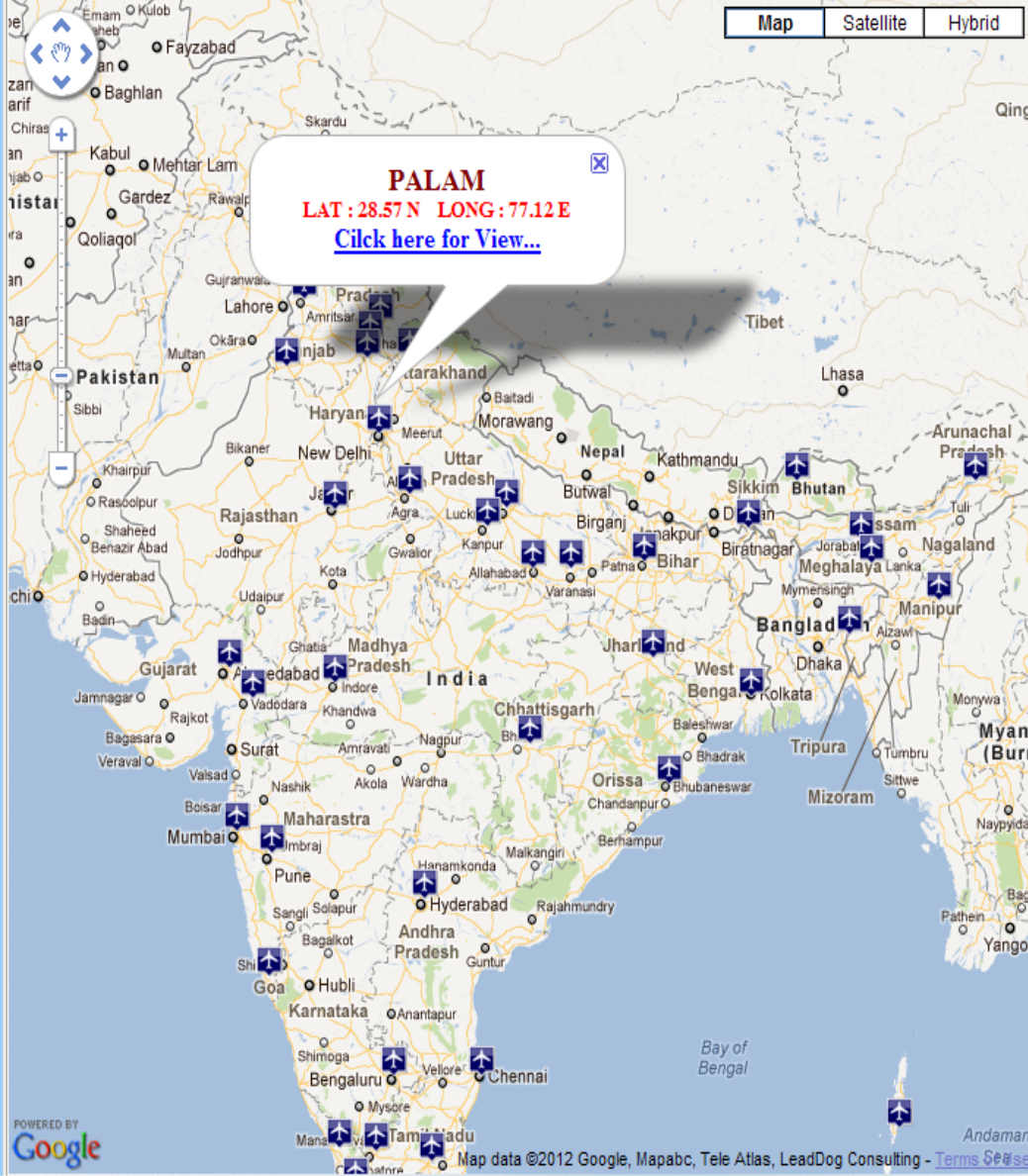
- Version (v3.6) upgrade of the model with existing GSI (3dvar) assimilation
- Resolution increase with triple nests of 27, 9 and 3 km domains
- Successful forecasting of tropical cyclones over Indian Seas during 2015 e.g. Ashobaa, Komen, Chapala and Megh with 06 hourly forecast upgrades.
- Improved forecasting of rapid intensification/ decaying of cyclones over Arabian Sea



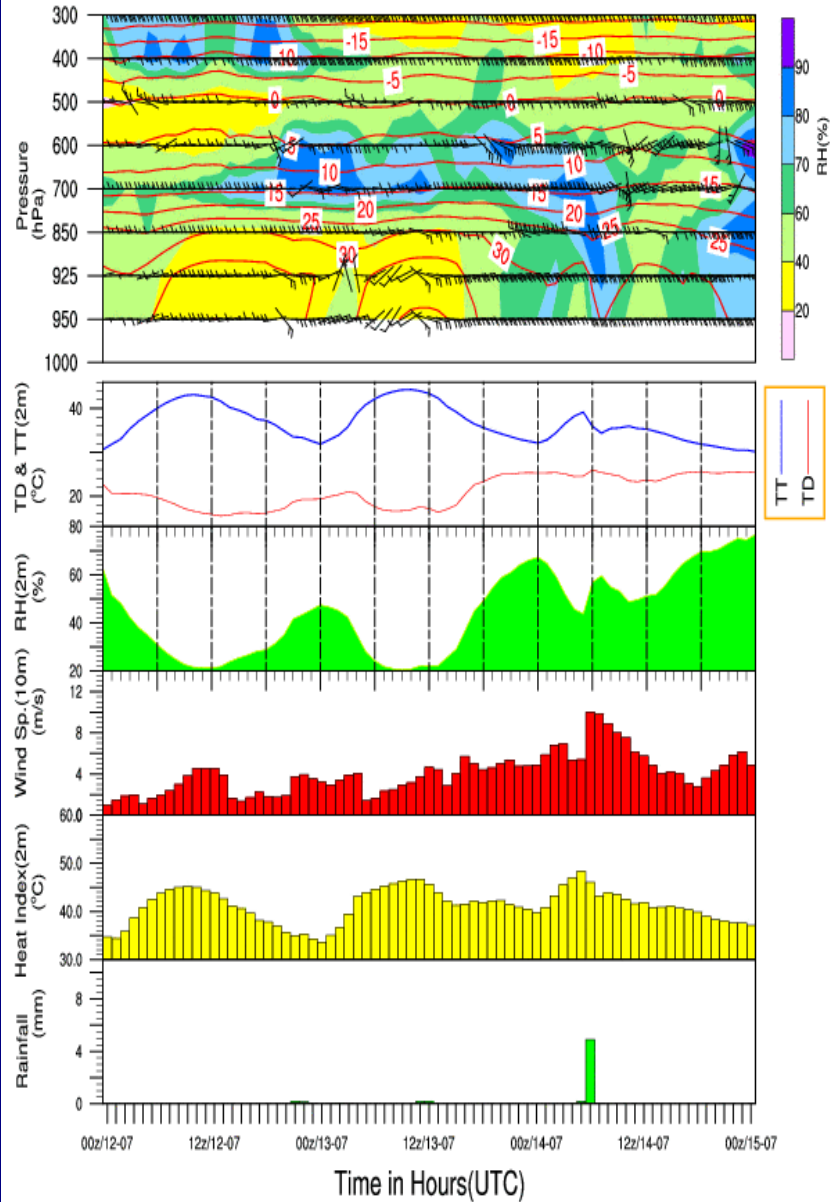
Mesoscale Model Domains at RMC and MC with 3 km horizontal resolution



WRF Location Specific Forecast for Airports 47 Locations



PALAM 00UTC/12-07-2014



GFS MODEL CONFIGURATION AT IMD

❖ In 2012, GFS T382 has been replaced by the upgraded version of the model GFS T574L64 (version *GSM 9.1.0*) (~ 25 km in horizontal over the tropics).

❖ Recently the entire **GFS** (Version 9.1.0) at T574L64 and 06 hourly cycle of **GDAS** with new Grid point Statistical Interpolation (GSI version 3.0.0) analysis scheme has been made operational in **ADITYA HPCS at IITM Pune** for day-to-day operational run

Model	Version	Horizontal Resolution	Forecast Length	Performance
GFS T574L64	GFS version 9.0.1	~25km	168 Hrs (4hr 30 min data cut-off)	10 min. for 24 hr forecast (on Aditya - 240 processors)



District level weather Forecast

❖ Considering the need of farming sector, IMD has upgraded the Agro-Meteorological Advisory Service from agro climate zone to district level. As a major step, IMD started issuing district level weather forecasts for the following meteorological parameters,

- 1) 24 hours cumulative rainfall of a day
- 2) Maximum and minimum temperature
- 3) Morning and evening relative humidity
- 4) Total cloud amount of a day
- 5) Surface wind speed and wind direction

❖ The district level forecast for the above parameters are generated daily and made available to the user





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South India
Date: 16 JUNE 2014
(MID-DAY)

Met-Sub Division	Today (16 JUNE 2014)	Tomorrow (17 JUNE 2014)	18 JUNE 2014
Coastal Andhra Pradesh	Heat wave to severe heat wave at many places	Heat wave to severe heat wave at many places	NIL
Telangana	Heat wave to severe heat wave at a few places	Heat wave to severe heat wave at a few places	NIL
Rayalaseema	NIL	NIL	NIL
Tamilnadu & Puduchery	NIL	NIL	NIL
Coastal Karnataka	NIL	NIL	NIL
North Interior Karnataka	NIL	NIL	NIL
South Interior Karnataka	NIL	NIL	NIL
Kerala	NIL	NIL	NIL
Lakshadweep	NIL	NIL	NIL

* The Warning for any day is valid from 0630 hours IST of the day till 0630 hours IST of the next day

Most Vigil (Take Action)	Be aware (Be updated)
Be prepared/updated (Keep Vigil)	No Warning

For more details kindly visit www.imd.gov.in or contact : +91 11 24631913, +91 11 24643965
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INDIA METEOROLOGICAL DEPARTMENT
NWP MODELS BASED DISTRICT LEVEL WEATHER PREDICTION
ISSUED ON: 18-06-2014
VALID TILL 08:30 IST OF THE NEXT 5 DAYS

DISTRICT : UNA STATE : HIMACHAL-PRADESH

PARAMETERS	ENSEMBLE FCST				
	DAY-1 19/06	DAY-2 20/06	DAY-3 21/06	DAY-4 22/06	DAY-5 23/06
Rainfall (mm)	3	0	0	0	7
Max Temperature (deg C)	40	40	41	42	41
Min Temperature (deg C)	27	27	28	28	28
Total cloud cover (octa)	2	0	0	0	1
Max Relative Humidity (%)	45	44	37	41	46
Min Relative Humidity (%)	21	22	19	17	19
Wind speed (kmph)	007	005	006	004	006
Wind direction (deg)	62	183	151	154	137

NOTE: -99.0 NO DATA

1

5-DAY FORECAST TABLE (77)
INDIA METEOROLOGICAL DEPARTMENT
NWP MODELS BASED BLOCK LEVEL WEATHER PREDICTION
ISSUED ON: 18- 6-2014
VALID TILL 0830 IST OF THE NEXT 5 DAYS

BLOCK : UNA DISTRICT : UNNA STATE : HIMACHAL-PRADESH

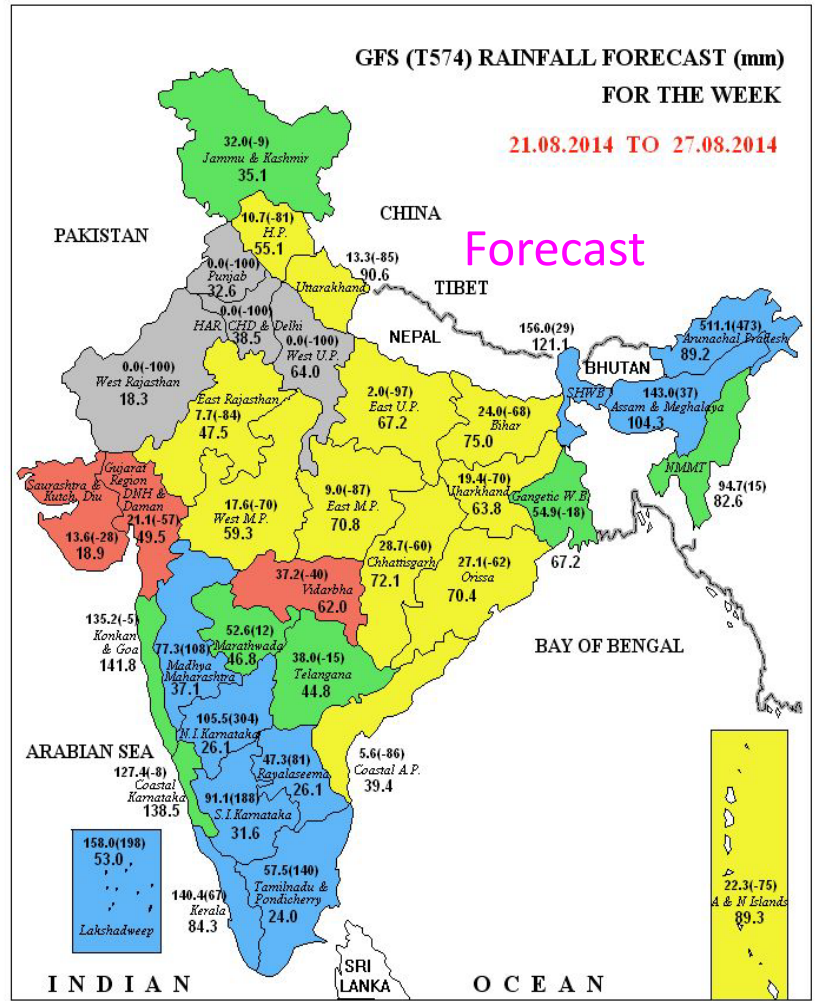
PARAMETERS	MODEL PREDICTION				
	DAY-1 19/ 6	DAY-2 20/ 6	DAY-3 21/ 6	DAY-4 22/ 6	DAY-5 23/ 6
Rainfall (mm)	8	3	0	1	10
Max Temperature (deg C)	42	42	44	46	45
Min Temperature (deg C)	28	27	32	32	31
Total cloud cover (octa)	5	3	3	3	5
Max Relative Humidity (%)	51	48	40	44	53
Min Relative Humidity (%)	21	19	18	16	16
Wind speed (kmph)	14	11	10	10	10
Wind direction (deg)	78	89	69	68	69

NOTE: -99.0 NO DATA



New Initiative: GFS 07 DAYS (WEEKLY) CUMULATIVE SUB-DIV. RAINFALL FORECAST

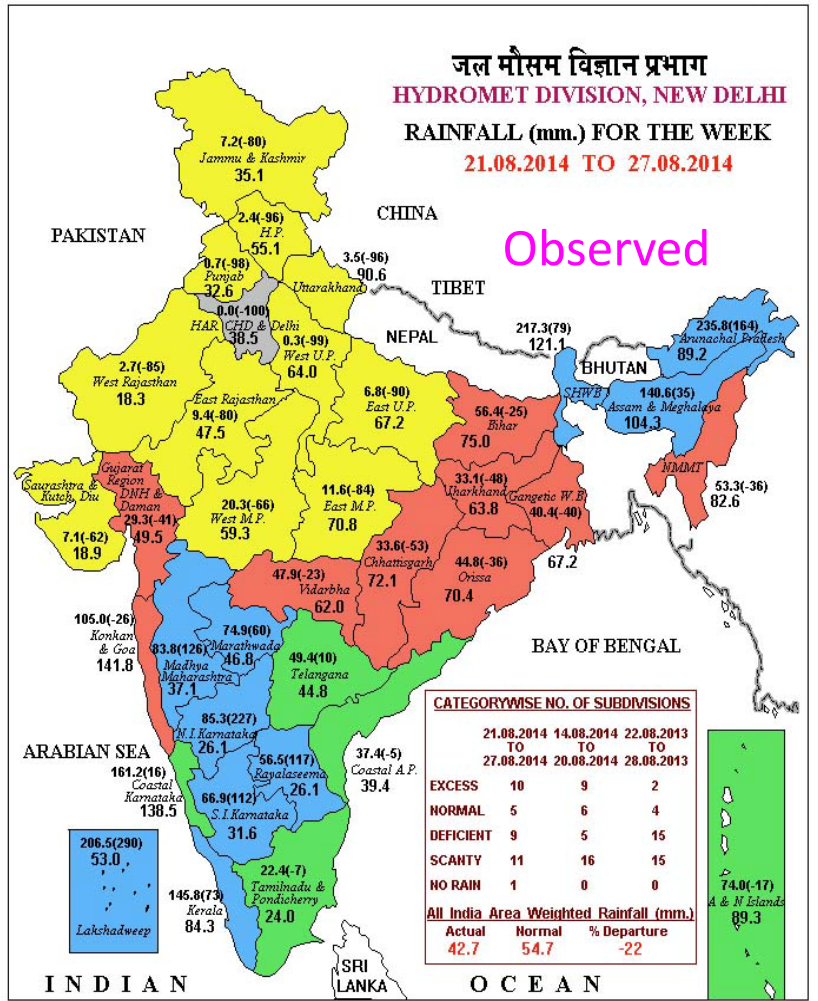
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LEGEND: [Blue] EXCESS (+20% OR MORE) [Green] NORMAL (+19% TO -19%) [Red] DEFICIENT (-20% TO -59%)
 [Yellow] SCANTY (-60% TO -99%) [Grey] NO RAIN (-100%) [White] NO DATA

NOTE: Small figures indicate weekly rainfall (mm) forecast, while bold figures indicate Normal rainfall (mm). Percentage Departures of Rainfall are shown in Brackets.

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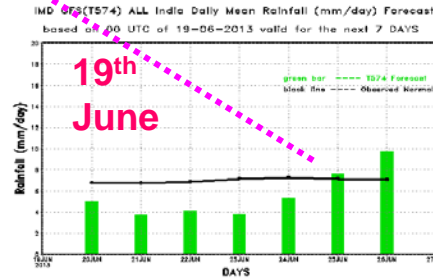
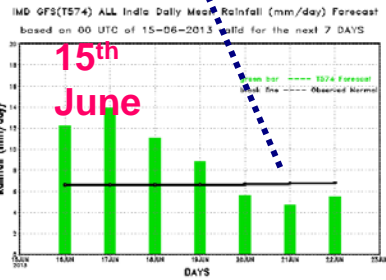
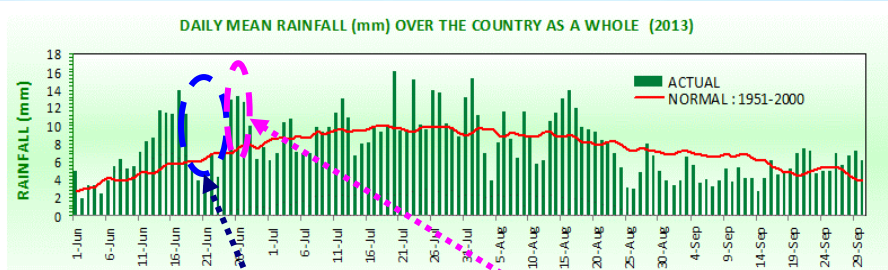


LEGEND: [Blue] EXCESS (+20% OR MORE) [Green] NORMAL (+19% TO -19%) [Red] DEFICIENT (-20% TO -59%)
 [Yellow] SCANTY (-60% TO -99%) [Grey] NO RAIN (-100%) [White] NO DATA

NOTES:
 (a) Rainfall figures are based on operational data.
 (b) Small figures indicate actual rainfall (mm.), while bold figures indicate Normal rainfall (mm). Percentage Departures of Rainfall are shown in Brackets.

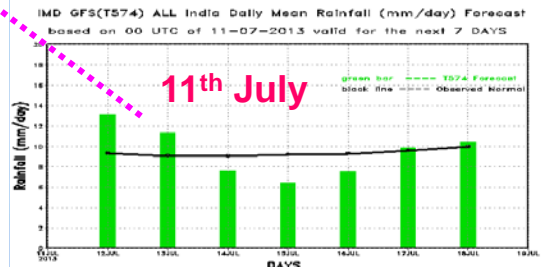
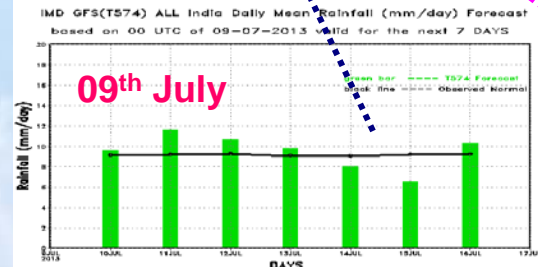
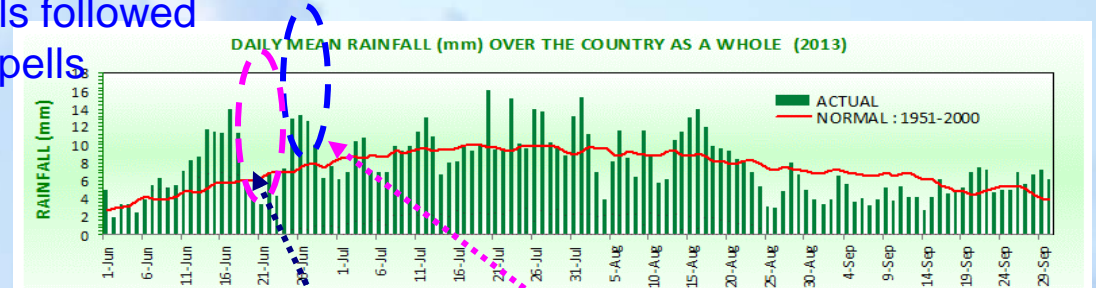
CATEGORYWISE NO. OF SUBDIVISIONS	21.08.2014 TO 27.08.2014		14.08.2014 TO 20.08.2014		22.08.2013 TO 28.08.2013	
	Actual	Normal	Actual	Normal	Actual	Normal
EXCESS	10	9	9	6	2	4
NORMAL	5	6	5	6	15	15
DEFICIENT	9	5	5	5	16	15
SCANTY	11	16	15	16	0	0
NO RAIN	1	0	0	0	0	0
All India Area Weighted Rainfall (mm.)						
Actual	42.7	54.7	42.7	54.7	42.7	54.7
Normal						
% Departure						-22

Weak and Active spells: During Monsoon 2013



Weak spells followed by Active Spells

Active spells followed by Weak Spells



Weak spells followed by Active Spells

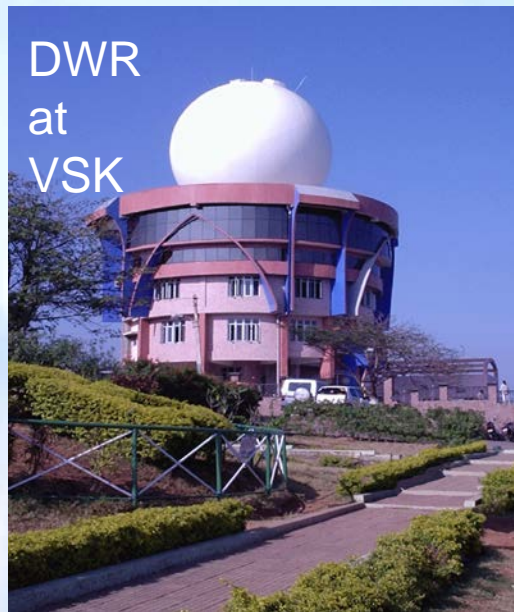
Active spells followed by Weak Spells



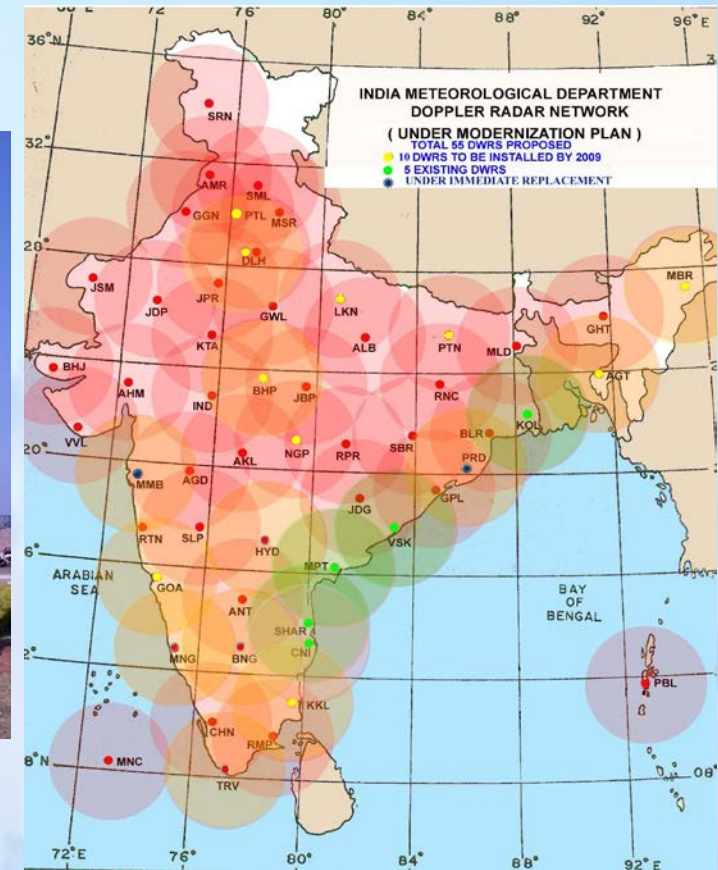
Doppler Weather Radars

... Means to Nowcasting and very short range forecasting

- Wind information
- Water content in clouds in different phases
- Digital output



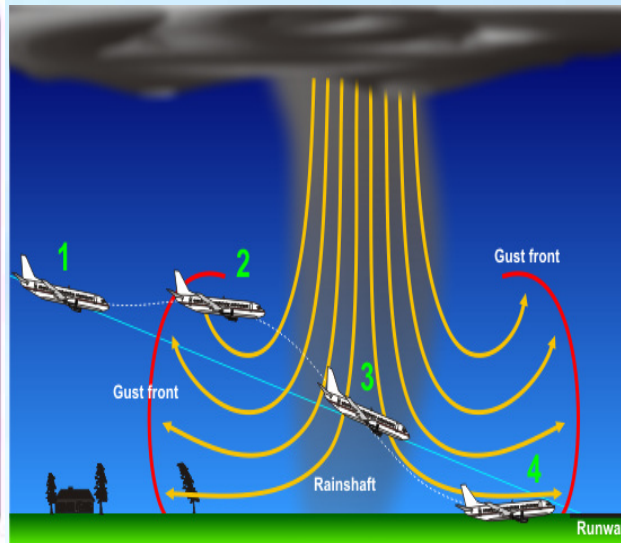
Increases forecast accuracy dramatically over the next few hours and appreciably over 24 HRS



Aviation



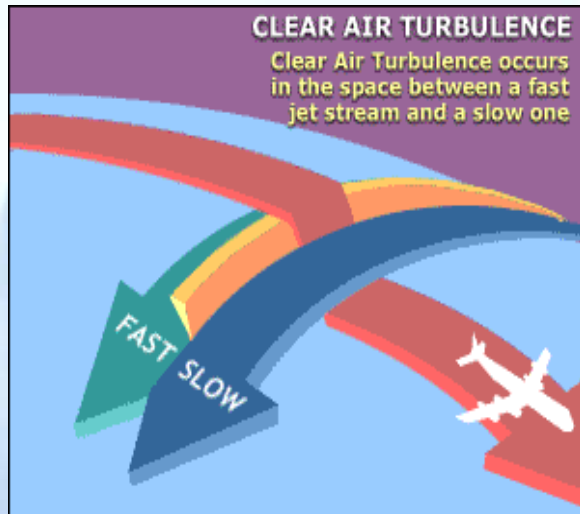
Microburst



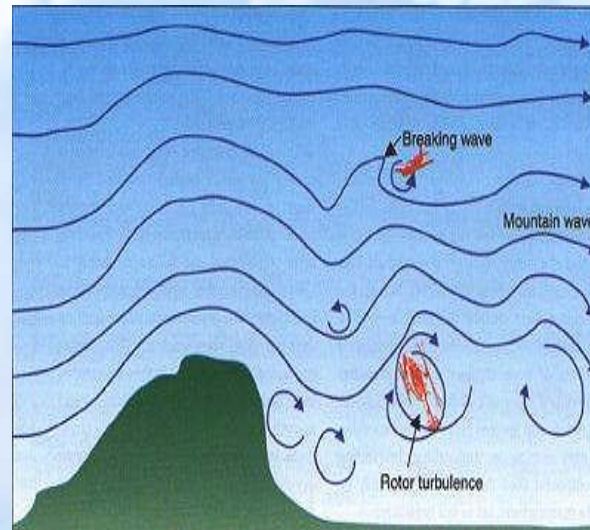
Mountainous Weather



CAT near Jet stream



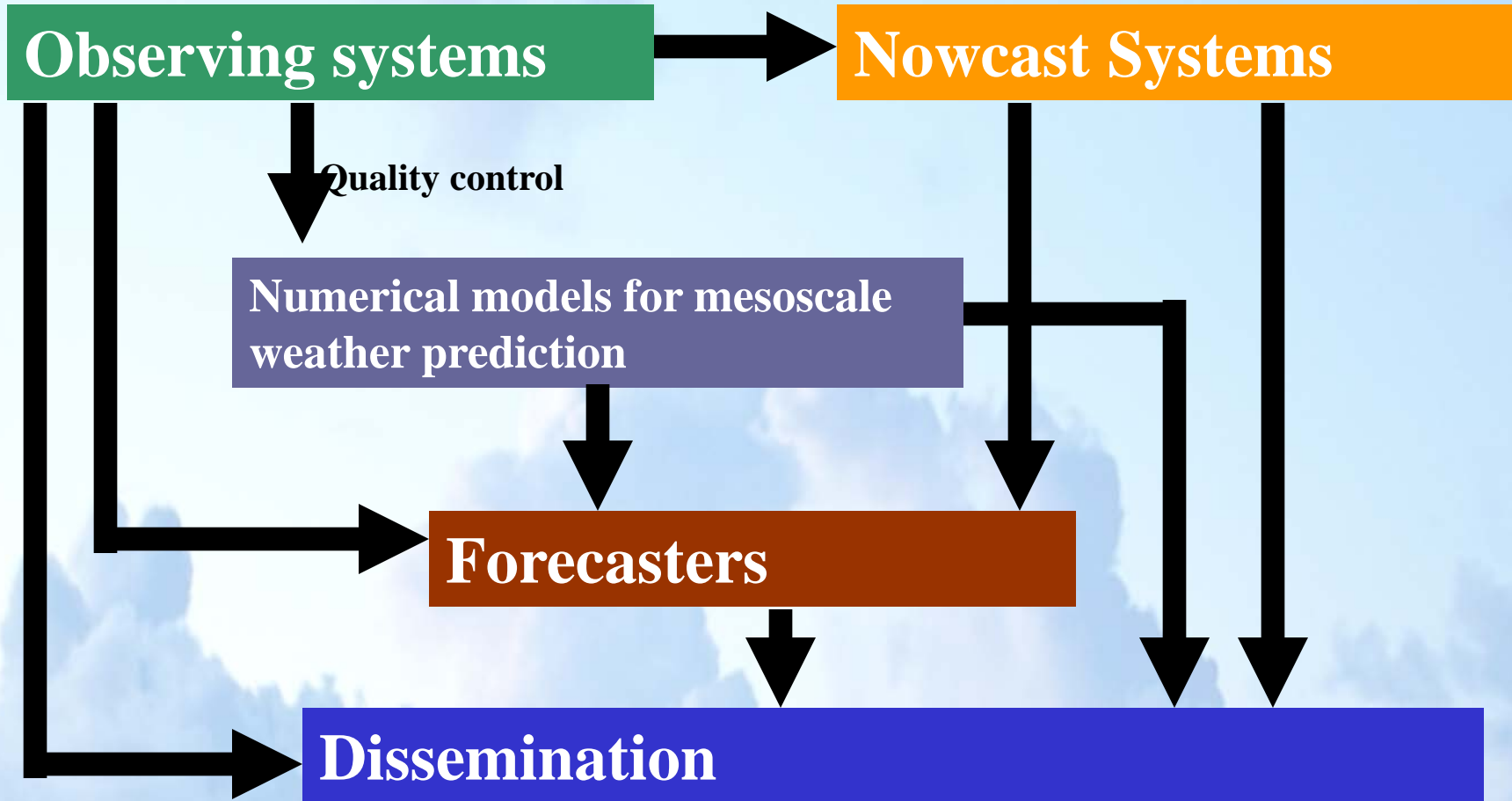
CAT near mountain barrier



Urban Flooding

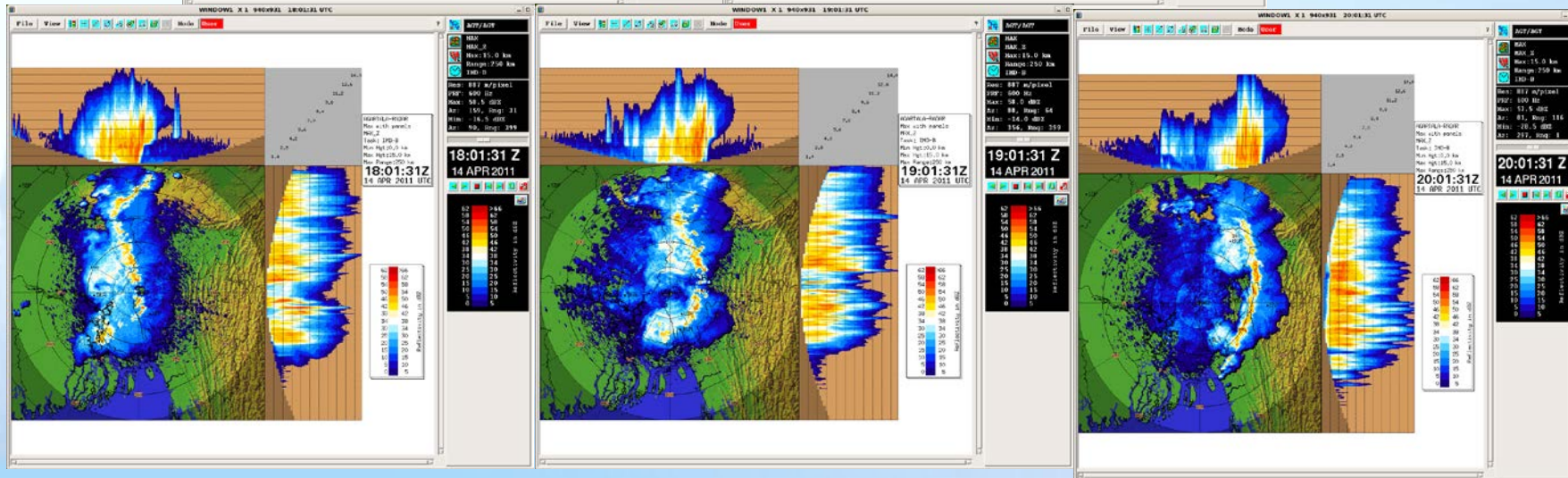
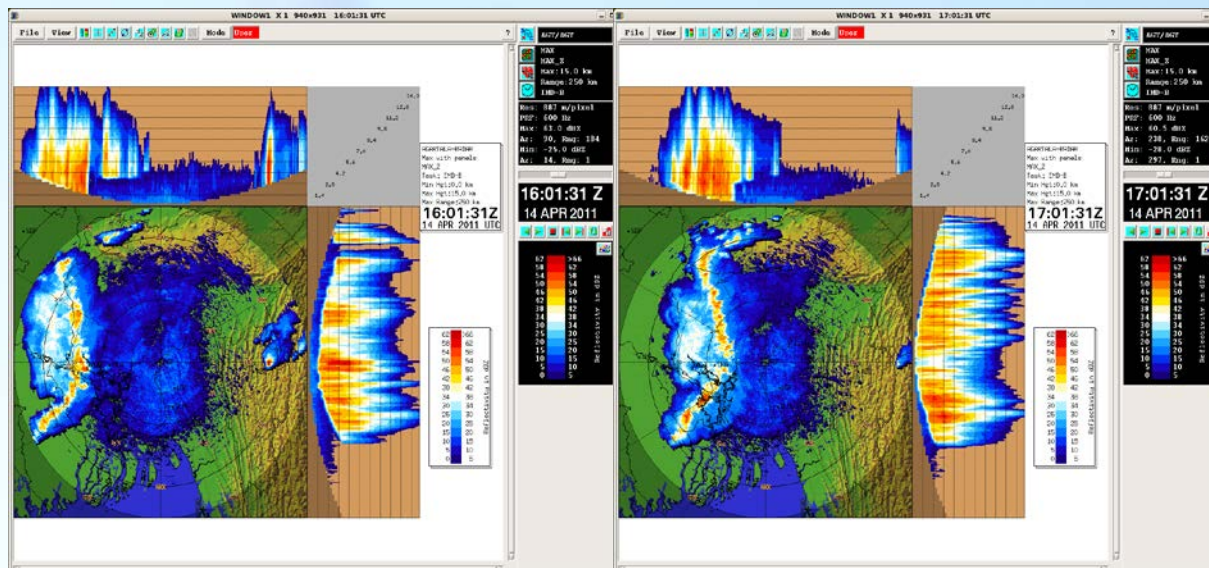


Components of Nowcasting



Propagation of severe weather as seen through DWR

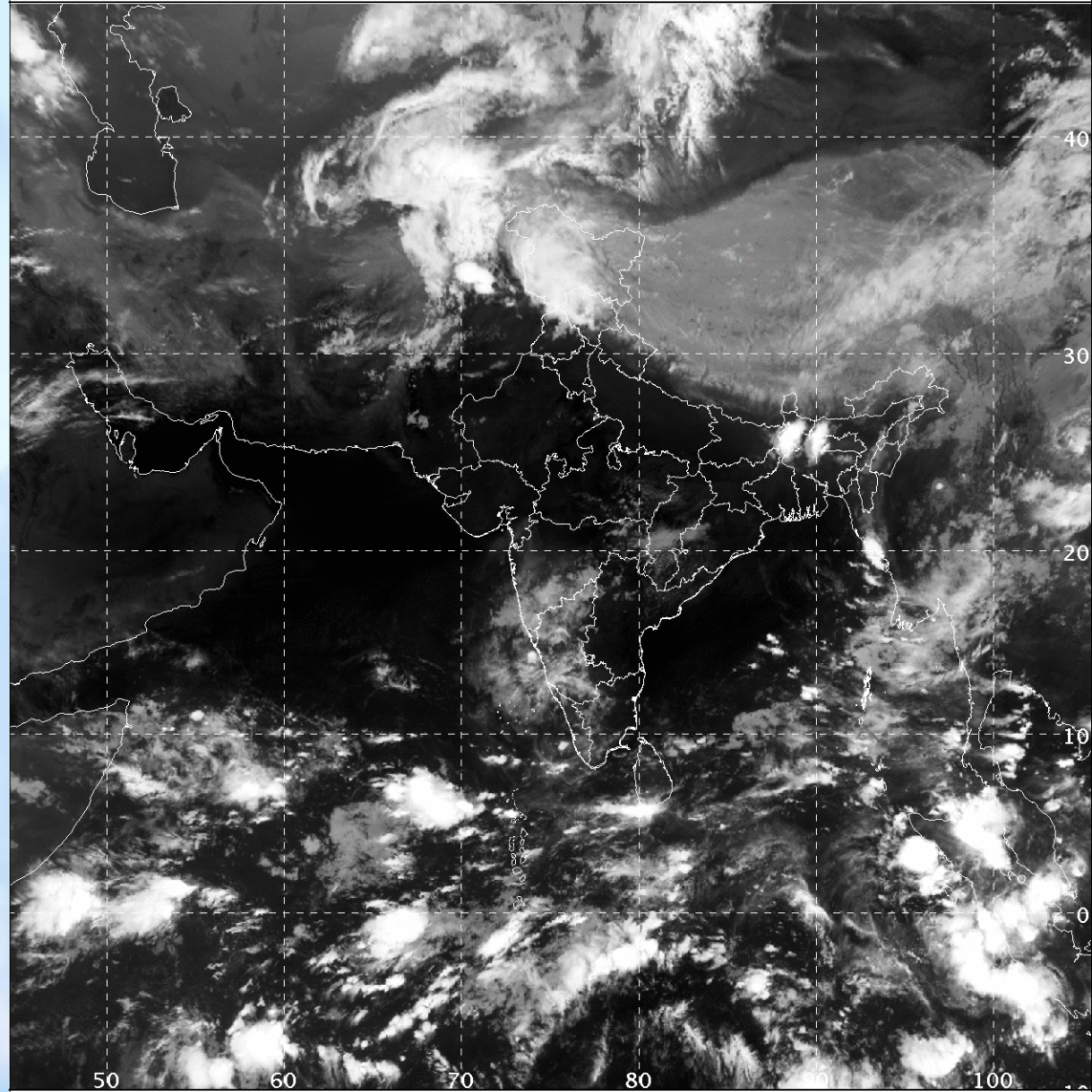
14 April 2011, 16-19 UTC



Satellite 30 May 2014

SAT :INSAT-3D IMG
IMG_TIR1 10.8 um
L1B FULL DISK FULL DISK
LINEAR Stretch: 1.0%

30-05-2014/00:00 GMT
30-05-2014/05:30 IST



IMD/Delhi



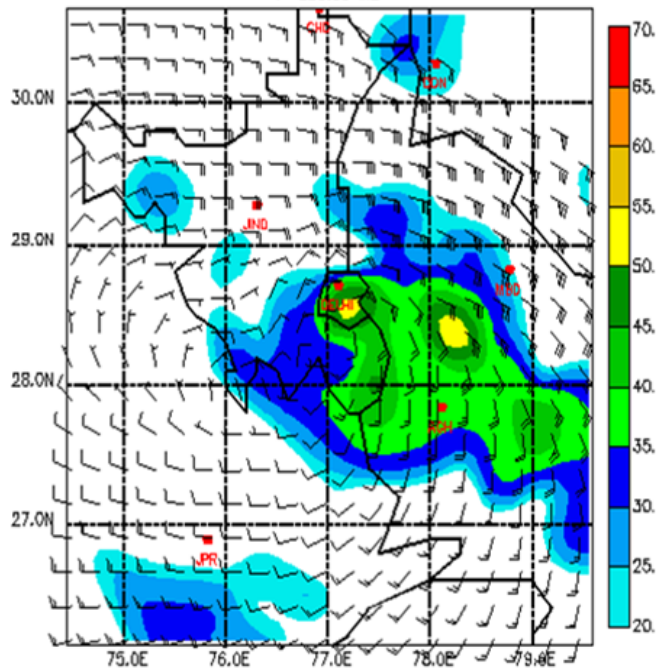
Auto Nowcast System ARPS

Valid for 0750 IST

Valid for 0810 IST

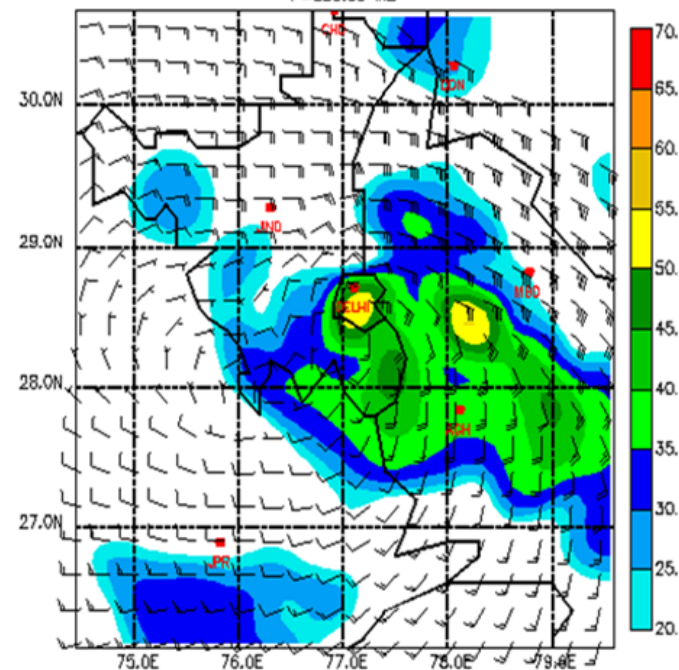
NEXT UPDATE AT 08:00 IST
IMD ARPS 850 hPa WIND(fts) & REFLECTIVITY(dBZ) FORECAST
BASED ON 06:30 IST VALID FOR NEXT THREE HOURS

02:20Z Mon 15 Aug 2011 T=94800.0 (26:20:00)
P=850.00 MB



NEXT UPDATE AT 08:00 IST
IMD ARPS 850 hPa WIND(fts) & REFLECTIVITY(dBZ) FORECAST
BASED ON 06:30 IST VALID FOR NEXT THREE HOURS

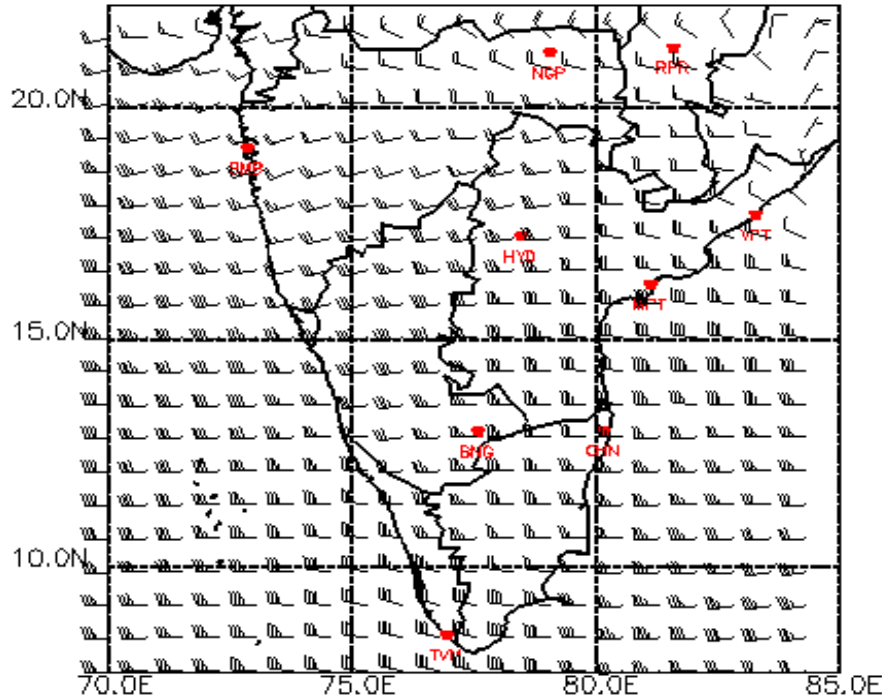
02:40Z Mon 15 Aug 2011 T=96000.0 (26:40:00)
P=850.00 MB



ARPS at 9 km
resolution with
assimilation of data
from multiple
DWRs

NEXT UPDATE AT 21:15 IST
IMD ARPS 850 hPa WIND(kts) & REFLECTIVITY(dBZ) FORECAST
BASED ON 19:30 IST VALID FOR NEXT THREE HOURS

14:00Z Sat 12 Jul 2014 T=50400.0 @ (14:00:00)
P=850.00 MB

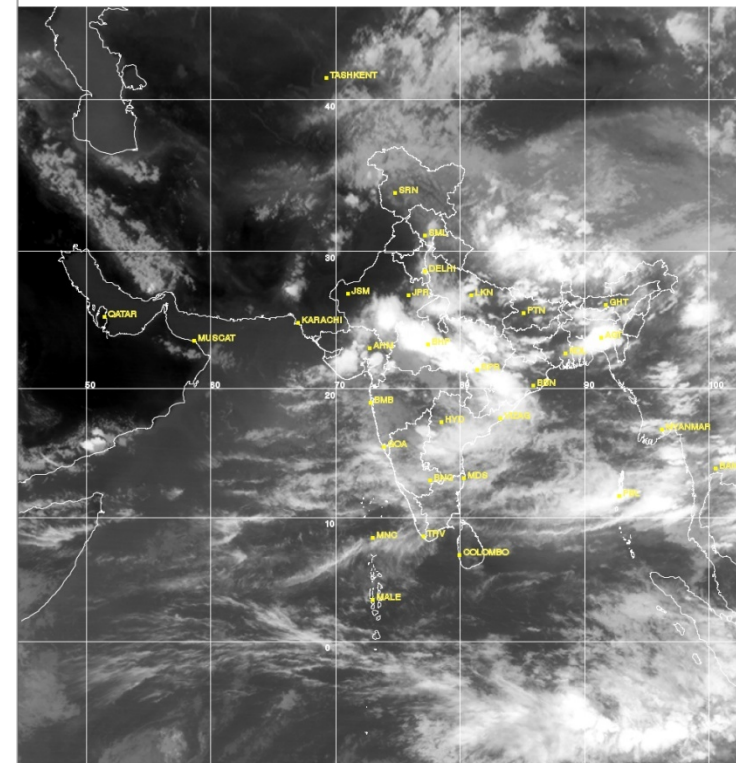


Composite Ref (dBZ, Shaded) Min=0.00 Max=0.00
U-V (m/s, Barb) Umin=-9.99 Umax=23.32 Vmin=-10.89 Vmax=4.87

NYP DIVISION, IMD, NEW DELHI

Projection : MER 12-07-2014 / 13:45Z Sat: KALPANA-1
ASI_TIR

TIR Linear Stretch 1.0%



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INDIA METEOROLOGICAL DEPARTMENT



Auto Nowcast System WDSS-II

30 minute FC

IMD WDSSII 30 min Reflectivity Forecast for Delhi and neighbourhood based on 20110815 AT 0731 hrs IST

Adopted from NSSL,USA
(based on DELHI Radar Data)

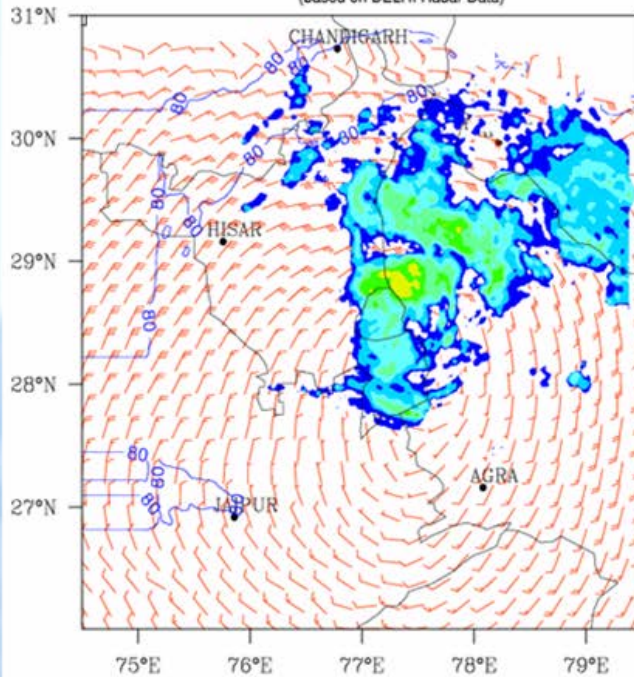


Image Superposed with Wind & RH at 850 hPa from WRF-VAR Model
Areas with Reflectivity > 30 dBZ have high probability of rainfall occurrence

60 minute FC

IMD WDSSII 60 min Reflectivity Forecast for Delhi and neighbourhood based on 20110815 AT 0701 hrs IST

Adopted from NSSL,USA
(based on DELHI Radar Data)

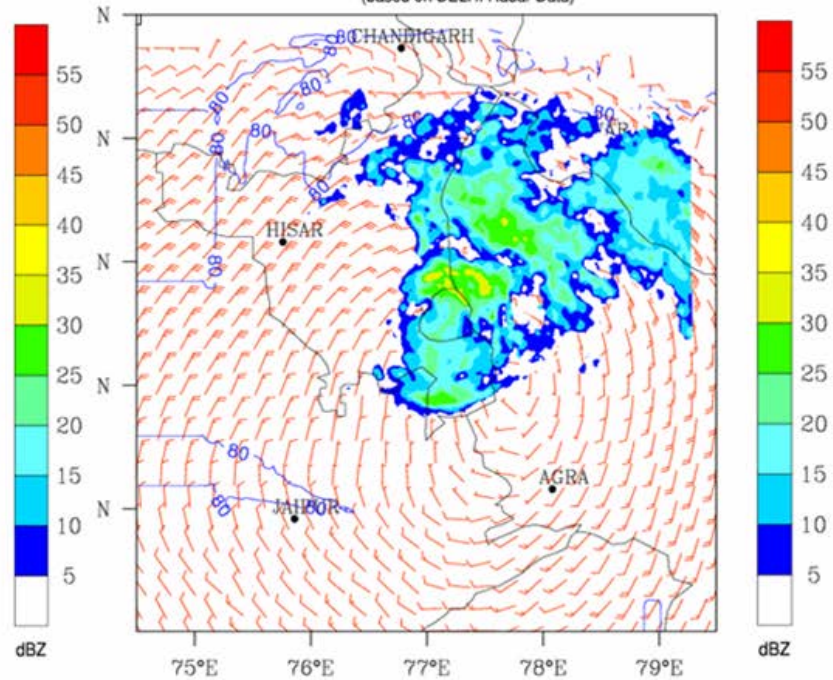
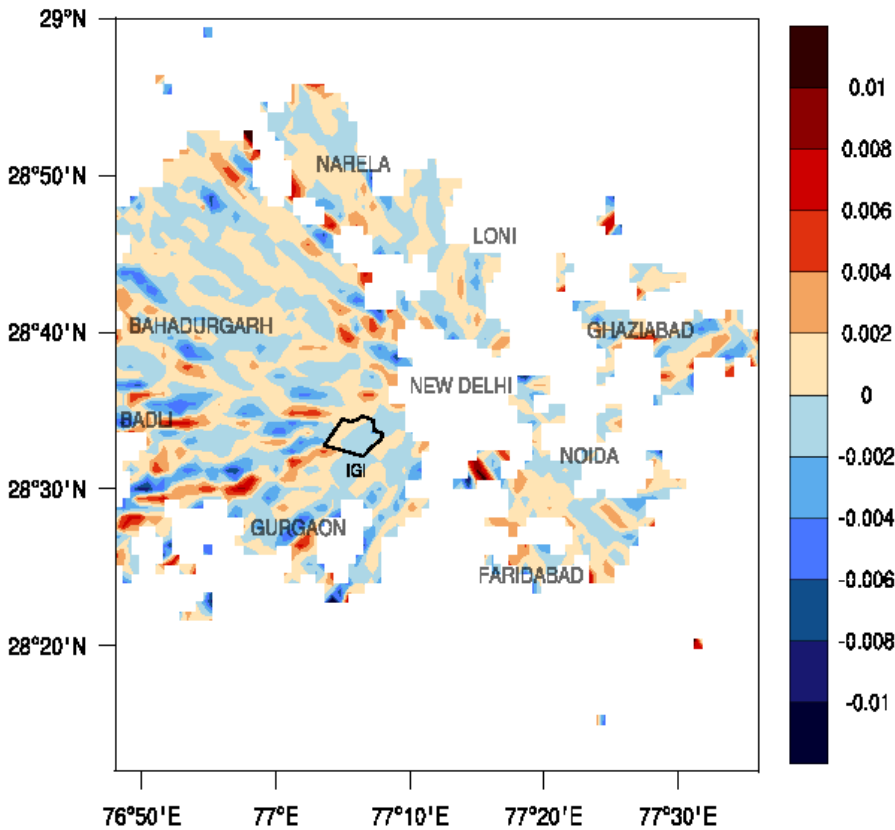


Image Superposed with Wind & RH at 850 hPa from WRF-VAR Model
Areas with Reflectivity > 30 dBZ have high probability of rainfall occurrence



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

AZIMUTH Wind Shear (per sec.) at 750m above ground
for Delhi and neighbourhood based on 20140530 AT 1532 hrs IST
Created at IMD using WDSS-II software from NSSL,USA
(based on DELHI Radar Data)



Areas with Shear $> +0.004$ (per sec) indicate high horizontal shear zones
(IGI-> Indira Gandhi International Airport)

IMD WDSSII 00 min Reflectivity Forecast for Delhi and neighbourhood based on 20140530 AT 1744 hrs IST
Adopted from NSSL,USA
(based on DELHI Radar Data)

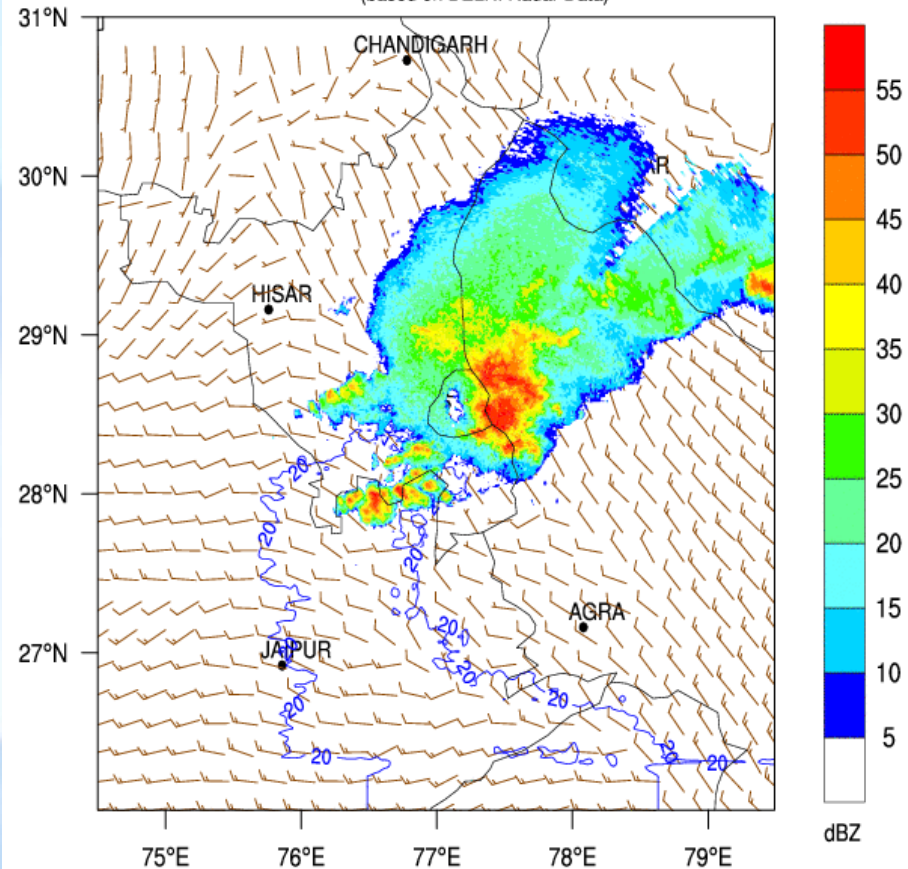
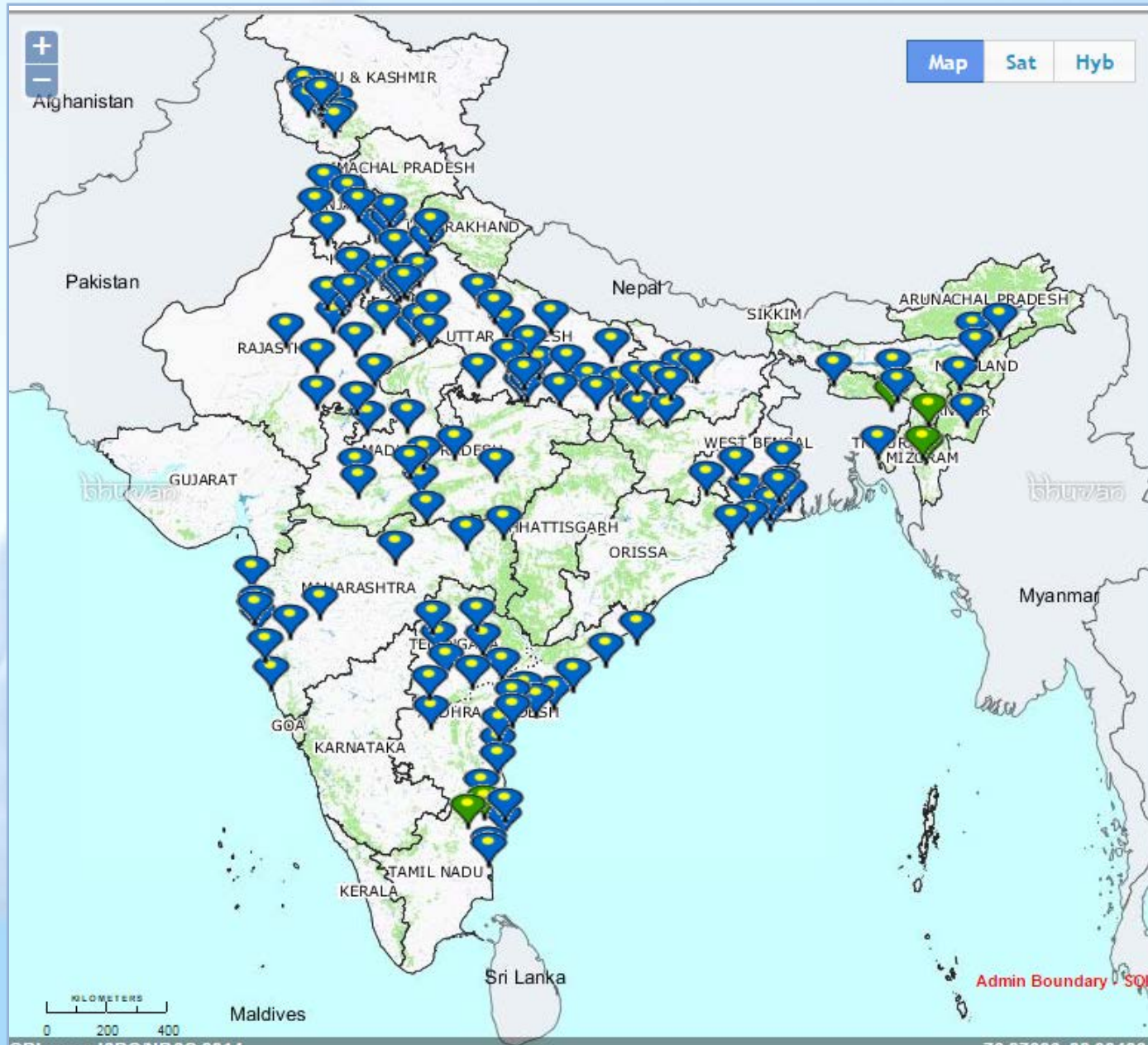


Image Superposed with Wind & RH at 850 hPa from WRF-VAR Model
Areas with Reflectivity > 30 dBZ have high probability of rainfall occurrence



Nowcast for Thunderstorm issued for 157 stations



Future Plan



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INDIA METEOROLOGICAL DEPARTMENT



Future Plan & New Activities

❖ **Nowcasting/Very Short-range Forecasting**

- WDSII using multiple RADAR with Rapid Refresh (for all radar stations) up to 3 hours
- WRF (1 km) with Rapid Update Cycle (RUC) with 3 hour interval for 24 hour forecasts

❖ **Short-range Forecasting**

- WRF Forecasting system (9 and 3 km) with its own data assimilation with DWR observations
- WRF (1 km) for regional centers (RMCs/MCs)
- HWRF upgraded coupled version (18,6 and 2 km)



Future Plan & New Activities contd....

❖ **Medium-range Forecasting**

- **Next Generation GFS (T1534/L64) with ENKF-GSI data assimilation**
- **Assimilation of latest INSAT satellite radiances along with other satellites**
- **Ensemble prediction system based on GFS modeling system (minimum 20 members)**
- ***Block level Forecast System (for 6400 + blocks) along with WRF 9 km forecasts for first three days***
- ***Parallel post-processing to handle large number of model output files and generation of several classes of products***



Future Plan & New Activities contd....

❖ **Extended Range Forecasting**

- ❖ **Operational extended range forecast system (CFS) of IITM to be implemented in IMD.**
- ❖ **Proposed to prepare MME based extended range forecast for Tmax and Tmin along with probability forecast for 4 weeks.**
- ❖ **The cyclogenesis potential for tropical cyclogenesis to be prepared based on coupled models outputs .**



Future Plan & New Activities contd....

❖ For Special Services

- Ensemble prediction system based on TIGGE data
- Dynamical-statistical Modeling for Tropical cyclone forecast
- Dynamical-statistical model for rainfall and fog
- Development of user specific products e.g. cyclogenesis probability, dry spell/wet spell, heat/cold waves, etc.
- Upgradation of SCIP model for cyclone intensity forecasting
- Working on developing dynamical-empirical hybrid model for extreme weathers like Fog and Heavy Rainfall.



THANKS



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