



Wx Early Warning System and Hydromet Support for Flood Forecasting

Dr. Ashok Kumar Das

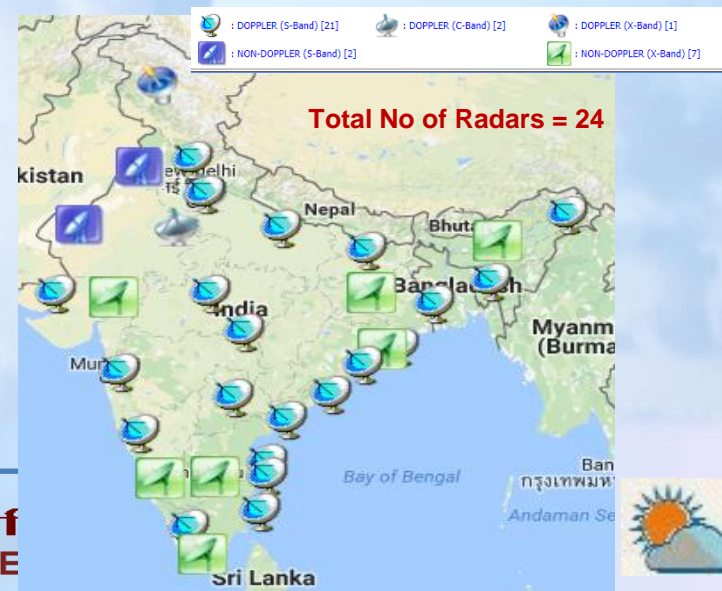
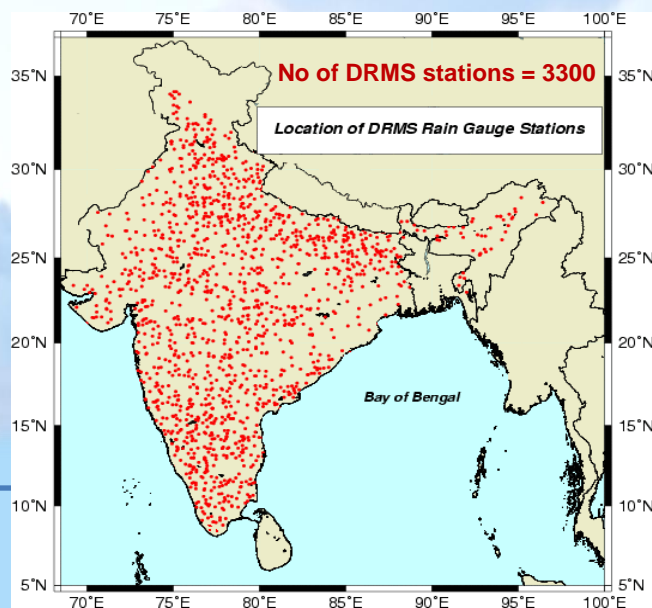
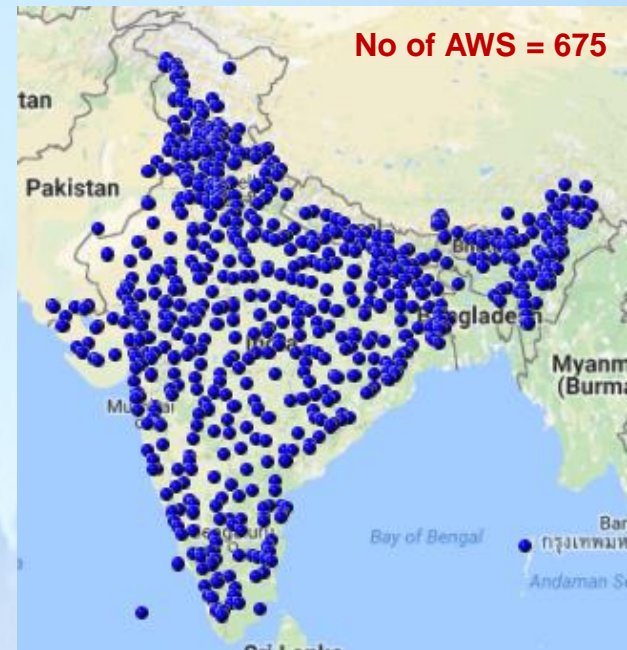
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**भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT**



Weather Monitoring Services



Major Services to different Sectors



Cyclone Warning

- Strong Winds
- Heavy Rainfall
- Storm Surge
- Coastal Inundation



Flood Meteorological Warning

- Categorical QPF
- Aerial averaging of rainfall



Hydrological Management

- Design storm values for Hydrological Projects



Agro Meteorological Advisory

- Crop Management Advisories
- Pest & Disease Advisories
- District Level Meteorological Forecast



Fisheries Warning

- Adverse weather
- Sea state

(Coastal)



Navigational Advisory

- Adverse Weather
- Sea State

(High Seas)



Major Services to different Sectors (Contd.)



Aviation Meteorological Forecast

- Route & Terminal Aerodrome forecast
- Weather hazards warning
- Flight Planning information



Heavy Rainfall & Fog Forecast

- Safety of culverts & bridges
- Driver's visibility



Environmental Monitoring

- Environmental clearances for industries etc
- Aerosol, Acid rain, Ozone, Atmospheric radiation



Mountain Meteorological Forecast

- Cloud burst
- Snow & Avalanche



Storm Surge Warning

- Storm Surge
- Astronomical tide
- Coastal bathymetry effects

Major Services to different Sectors (cont..)



Meteorological Services for Defense

- Troop & logistic movements
- Upper air observations



Meteorological Services to Mountaineers

- Warning for hazardous weather en-route



Meteorological Services to Antarctic Expeditions

- Comprehensive weather services



Meteorological Services for Spacecraft Launching

- Identification of favorable time window for launching



Meteorological Services for Pilgrimage

- Amarnath Yatra, Kumbha mela etc



Positional Astronomy

- Astronomical ephemeris
- Indian calendar & Rashtriya Panchang
- Eclipses & Astronomical phenomena



Spatial and Temporal domains of Forecast

- **Nowcasting for next 3-6 hours (city~227)**
(Venue/ location specific)
- **Short Range for next 1-3 days (city~324)**
(Location /District /State /Met Sub-division)
- **Medium Range for next 3-10 days (Districts)**
- **Extended range for 4 weeks**
(Met Subdivision/State/ Homogeneous regions)
- **Long range for month/season**
(Homogeneous regions/country)



NWP modelling Capabilities

- GFS-T1534L64 with 4-D Hybrid En-Var Data Assimilation
 - 12 km resolution and 6 hour interval for 10 days
 - twice daily at 00 and 12 UTC
 - delayed by 6 hours
- WRF with 3D Var assimilation using multiple radar observations
 - 9 km forecast for 3 days and 3 hour interval
 - twice daily at 00 and 12 UTC
 - delayed by 6 and half hours
- WRF at 3 km resolution generate hourly forecasts for 2 days
 - twice daily at 00 and 12 UTC
 - delayed by 10 hours
- Global Ensemble forecasting system (GEFS) T1534
 - 12 km resolution with 6 hourly interval
 - twice daily at 00 and 12 UTC
- Multi-Model Ensemble forecasts (3 global Models: JMA, NCEP, IMD)
 - 25 km resolution for rainfall
 - Once daily at 00 UTC
 - Delayed by 6 hours
- Extended Range Forecast run for 32 days
 - Updated every Thursday day





NUMERICAL WEATHER PREDICTION DIVISION

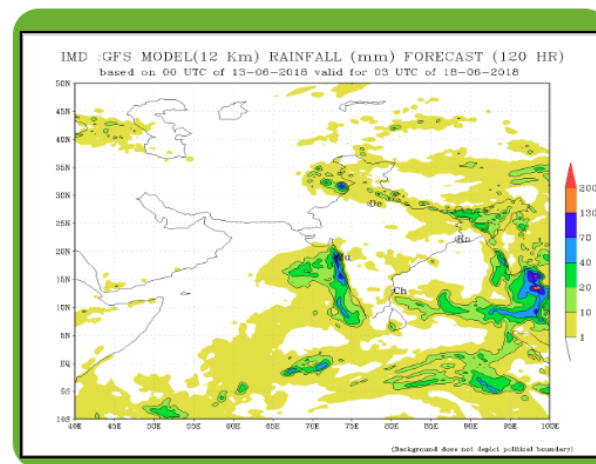
HOME	SHORT RANGE FORECAST >>	MEDIUM RANGE FORECAST >>	EXTENDED RANGE FORECAST >>	SEASONAL FORECAST >>
	WRF(09 KM) >			
	WRF(03 KM) >			
	WRF HYSPLIT >			
	WRF POLAR >			
	HWRP			

[GFS T1534 HEAT WAVE PRODUCTS](#) ^{NEW}

[HOT DAY, HEAT WAVE & SEVERE HEAT WAVE](#) ^{NEW}

[EXTENDED RANGE FORECAST VERIFICATION REPORT-2017](#) ^{NEW}

[HEAT WAVE WARNING OVER INDIA :IMPLEMENTATION REPORT 2017](#) ^{NEW}



NUMERICAL WEATHER PREDICTION DIVISION

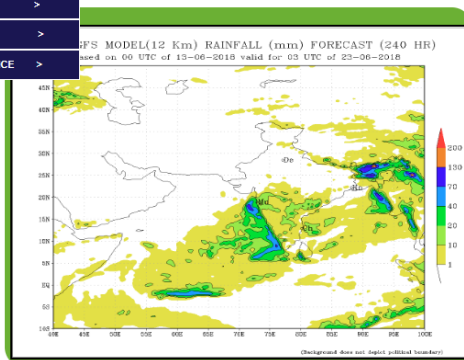
HOME	SHORT RANGE FORECAST >>	MEDIUM RANGE FORECAST >>	EXTENDED RANGE FORECAST >>	SEASONAL FORECAST >>
		GFS(T-1534) >		
		GEFS(T-1534) >		
		CYCLONE GUIDANCE >		

NEW ...

[EXTENDED RANGE FORECAST VERIFICATION REPORT-2017](#) ^{NEW}

[HEAT WAVE WARNING OVER INDIA :IMPLEMENTATION REPORT 2017](#) ^{NEW}

[GFS FOG/POLLUTION PRODUCTS](#)



NUMERICAL WEATHER PREDICTION DIVISION

HOME	SHORT RANGE FORECAST >>	MEDIUM RANGE FORECAST >>	EXTENDED RANGE FORECAST >>	SEASONAL FORECAST >>
			MME(CF Sv2/GF Sbc) >	

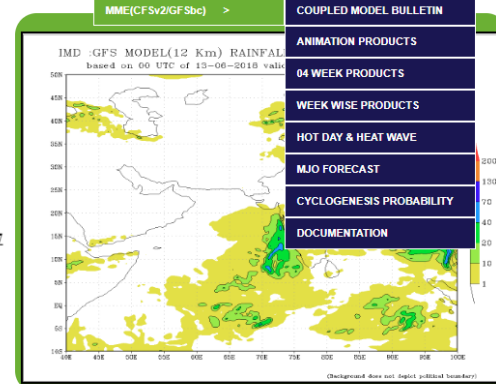
NEW ...

[GFS T1534 HEAT WAVE PRODUCTS](#) ^{NEW}

[HOT DAY, HEAT WAVE & SEVERE HEAT WAVE](#) ^{NEW}

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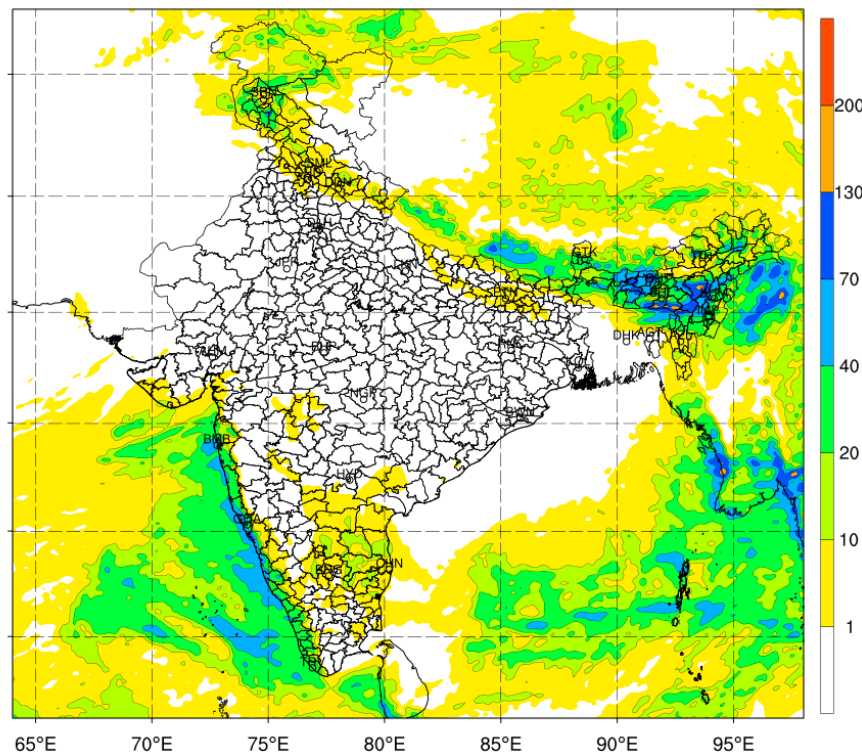


- COUPLED MODEL BULLETIN
- ANIMATION PRODUCTS
- 04 WEEK PRODUCTS
- WEEK WISE PRODUCTS
- HOT DAY & HEAT WAVE
- MJO FORECAST
- CYCLOGENESIS PROBABILITY
- DOCUMENTATION

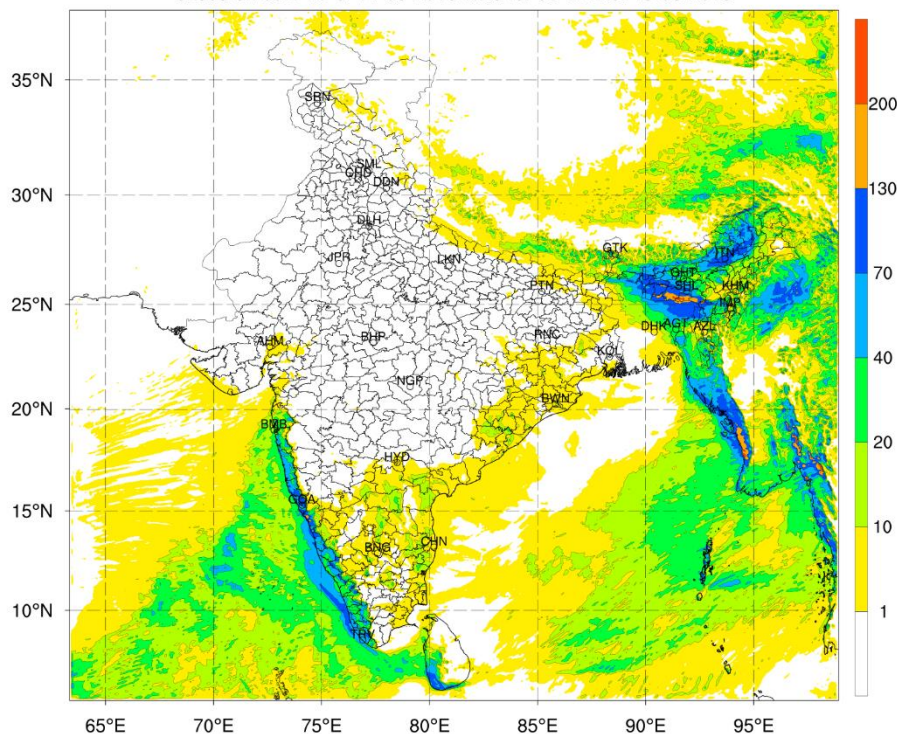


WRF model products

IMD NEW DELHI WRF (09 Km) RAINFALL (mm) FORECAST (48 hr)
based on 00 UTC of 14-06-2018 valid for 03 UTC of 16-06-2018

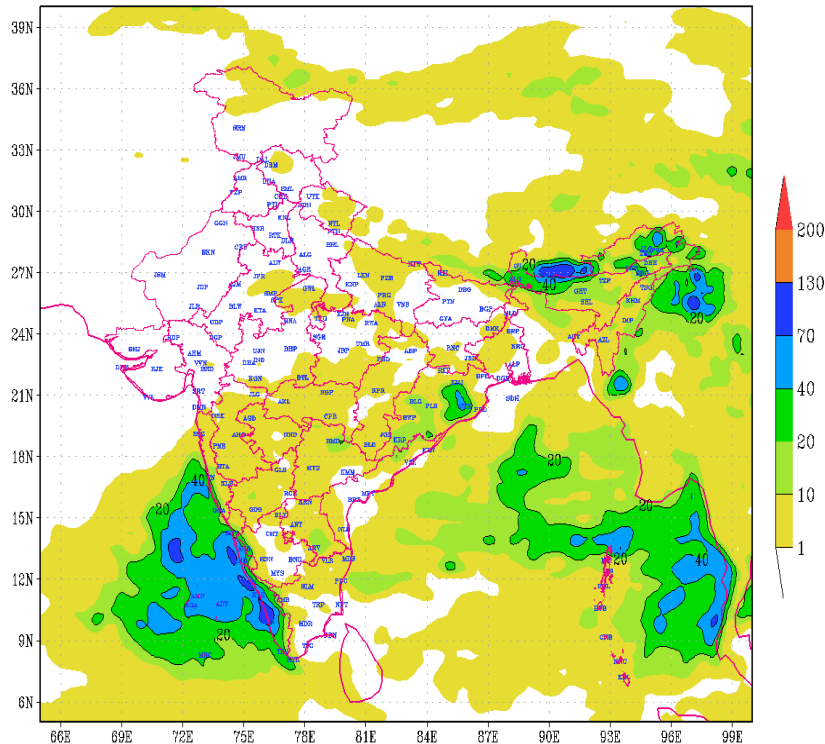


IMD MESOSCALE MODEL(03 Km) 24 HOURLY RAINFALL (mm) FORECAST (24 hr)
based on 00 UTC of 14-06-2018 valid for 03 UTC of 15-06-2018



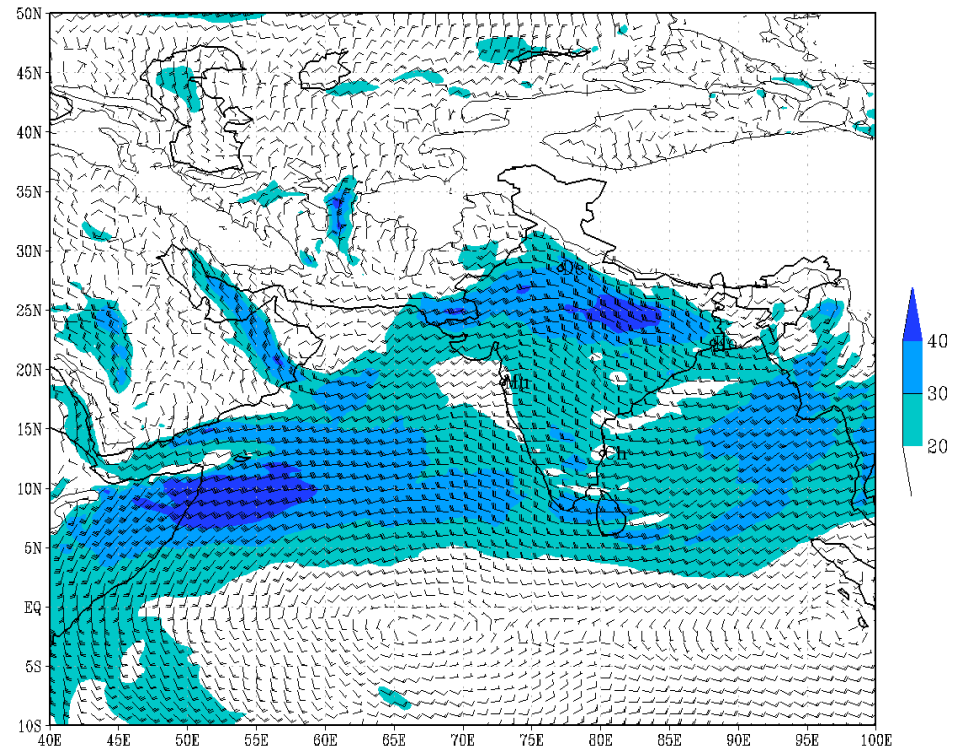
GFS model products

IMD :GFS MODEL(12 Km) RAINFALL (mm) FORECAST (168 HR)
based on 00 UTC of 14-06-2018 valid for 03 UTC of 21-06-2018



(Background does not depict political boundary)

IMD:GFS MODEL(12 Km) 850 hPa WIND (kt) FORECAST (00 HR)
based on 00 UTC of 14-06-2018 valid for 00 UTC of 14-06-2018

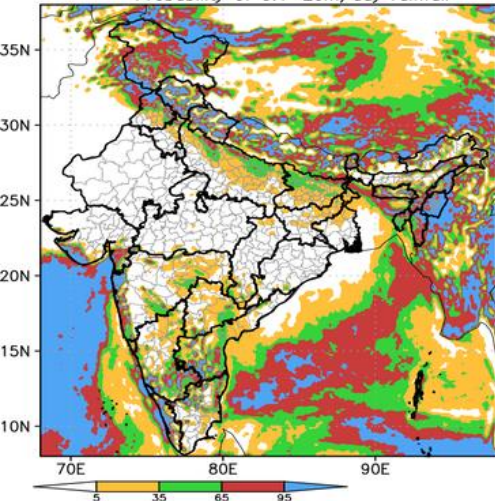


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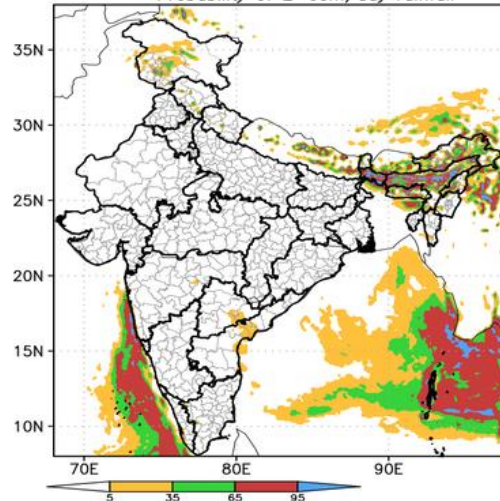


GEFS model products

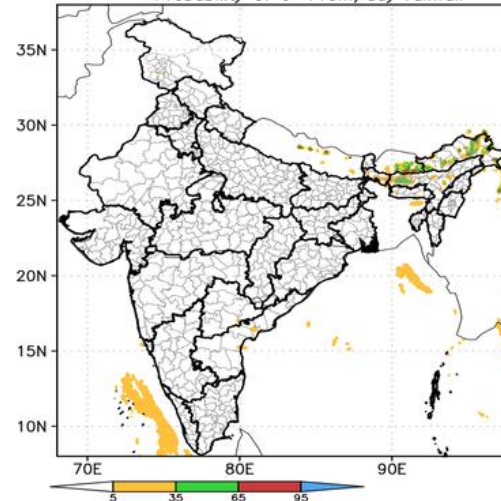
GEFS SL T1534 Probabilistic Quantitative Precipitation
IC:2018061400 Day-2 Forecast Valid for 00Z16JUN2018
Probability of 0.1–2cm/day rainfall



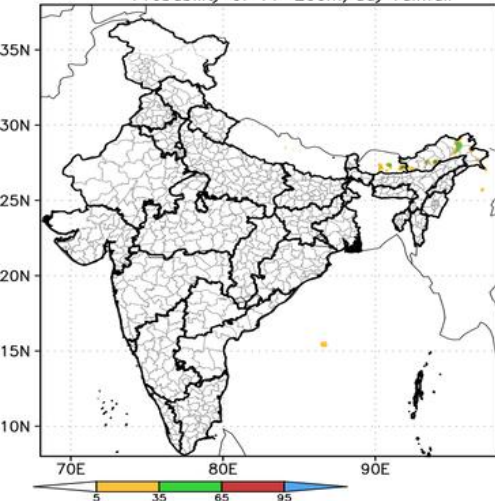
GEFS SL T1534 Probabilistic Quantitative Precipitation
IC:2018061400 Day-2 Forecast Valid for 00Z16JUN2018
Probability of 2–6cm/day rainfall



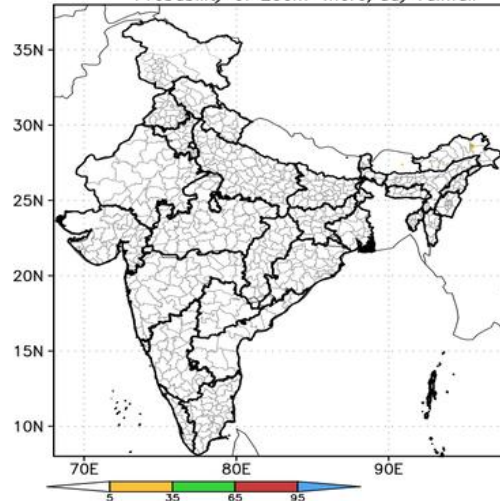
GEFS SL T1534 Probabilistic Quantitative Precipitation
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Probability of 6–11cm/day rainfall



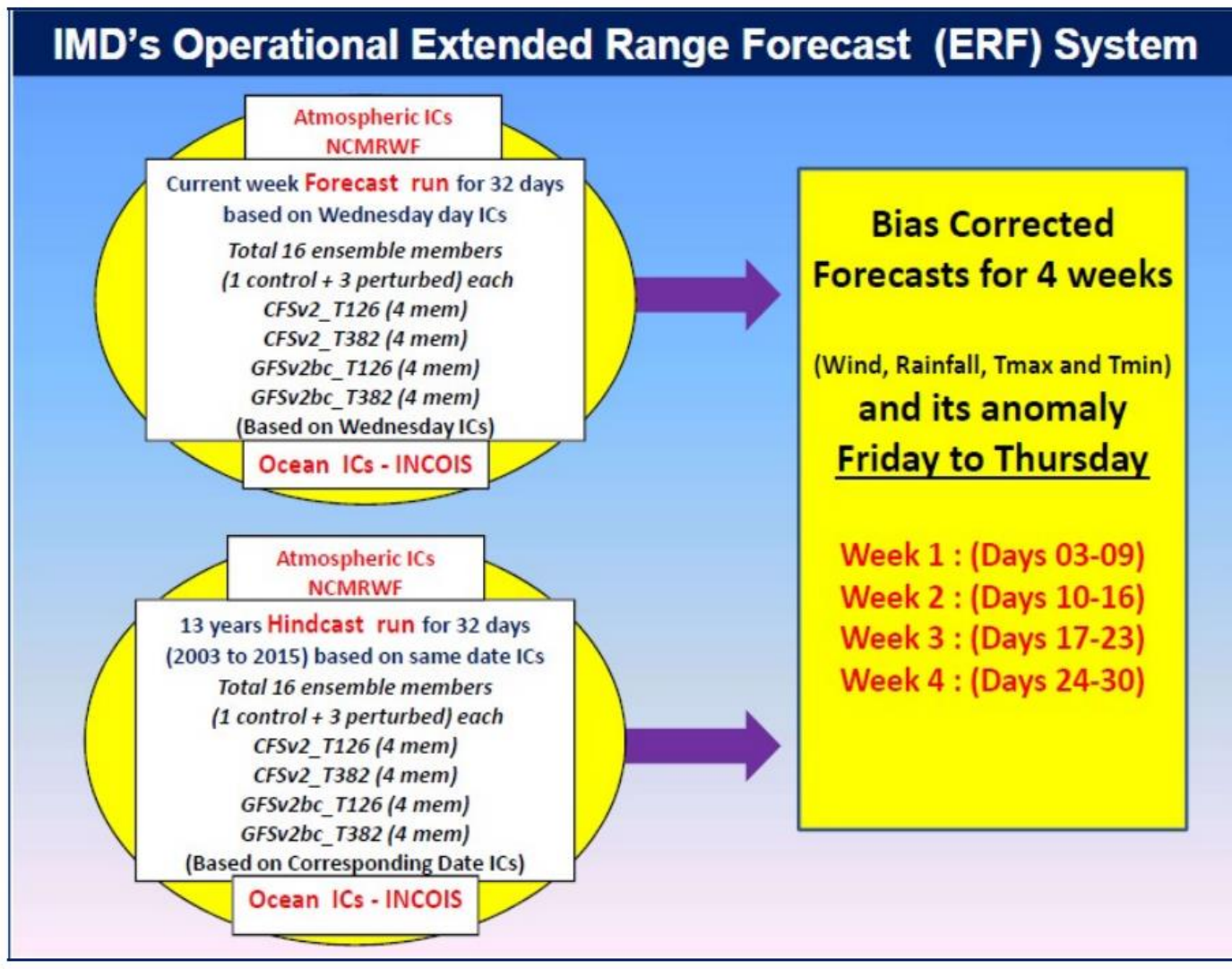
GEFS SL T1534 Probabilistic Quantitative Precipitation
IC:2018061400 Day-2 Forecast Valid for 00Z16JUN2018
Probability of 11–20cm/day rainfall



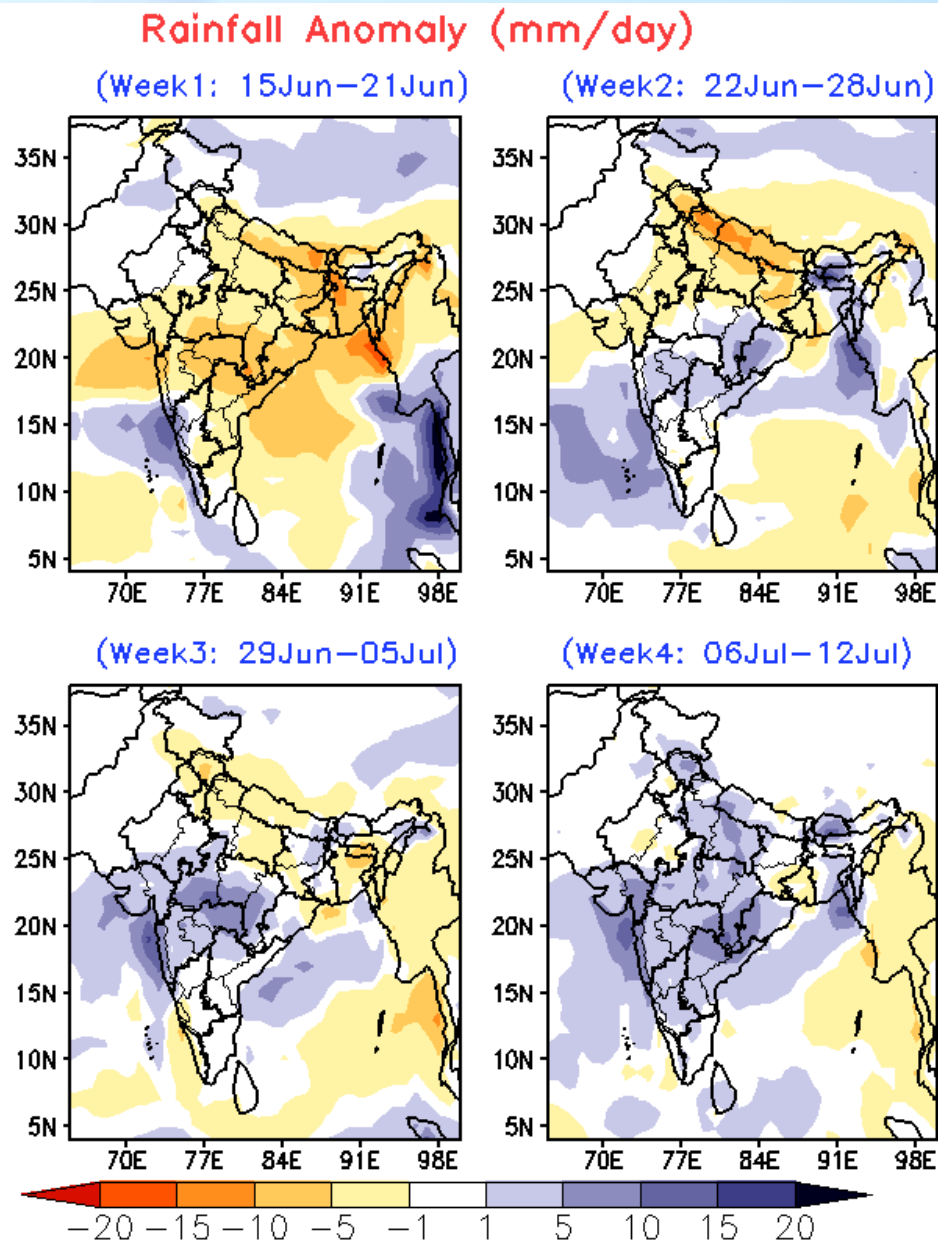
GEFS SL T1534 Probabilistic Quantitative Precipitation
IC:2018061400 Day-2 Forecast Valid for 00Z16JUN2018
Probability of 20cm–more/day rainfall



ERPS model

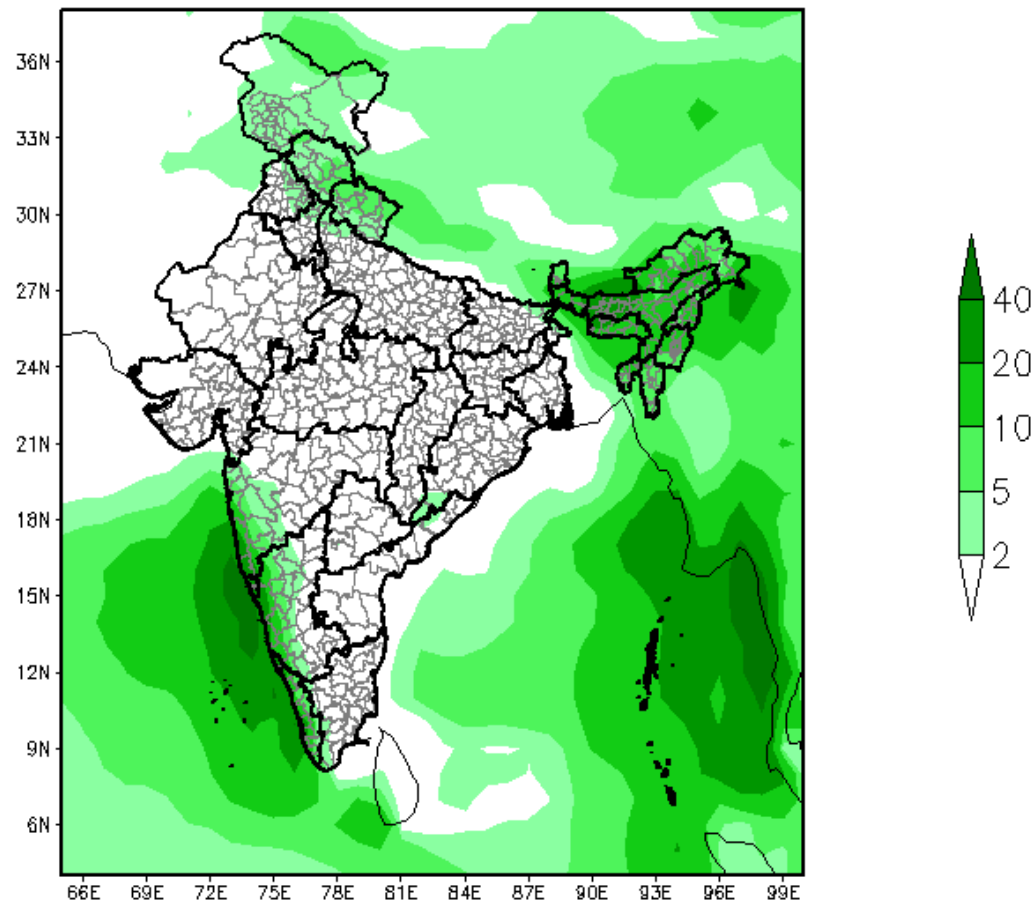


ERPS model products



ERPS model products

MME Weekly Rainfall (mm/day)
(Week1: 15Jun–21Jun)

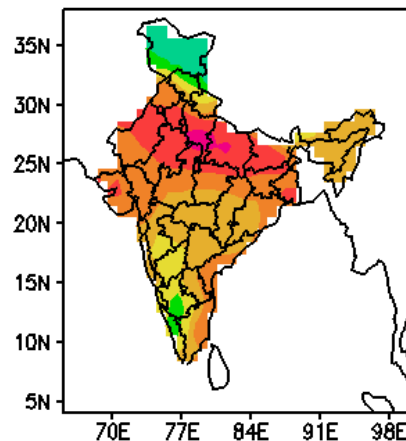
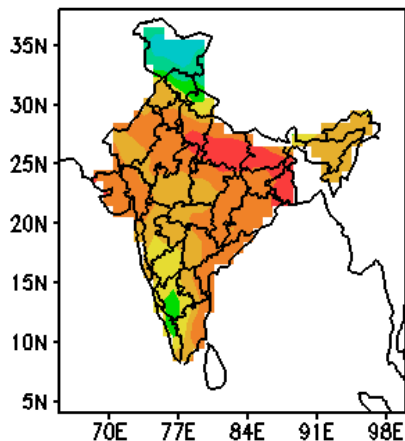


ERPS model products

MME Bias Corrected Actual Tmin (Deg C)

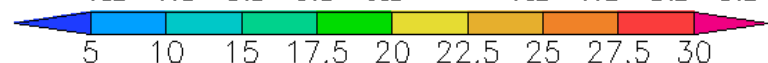
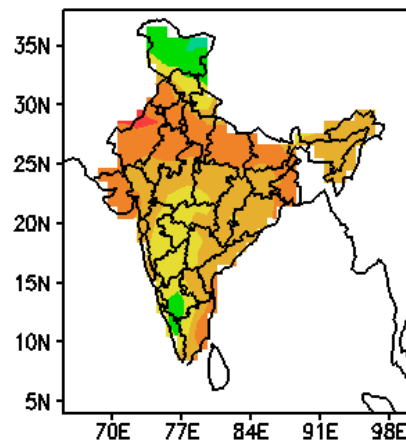
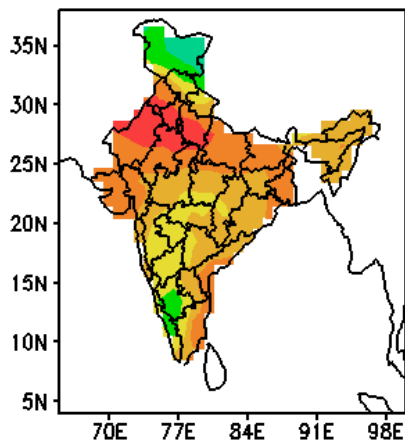
(Week1: 15Jun-21Jun)

(Week2: 22Jun-28Jun)



(Week3: 29Jun-05Jul)

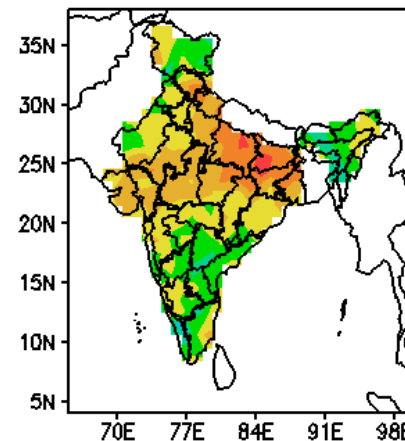
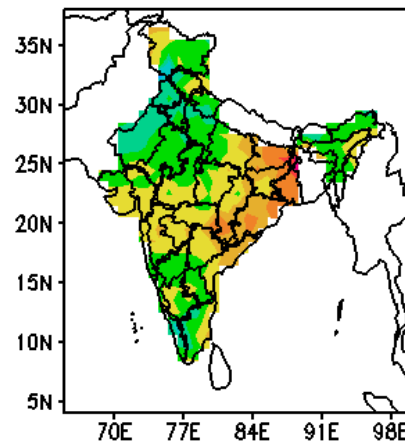
(Week4: 06Jul-12Jul)



MME Bias Corrected Tmax Anomaly (Deg C)

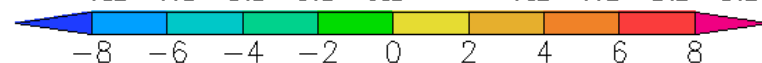
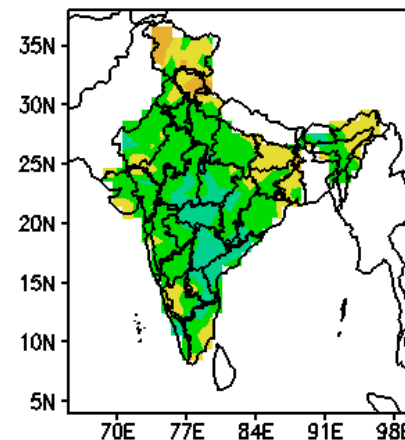
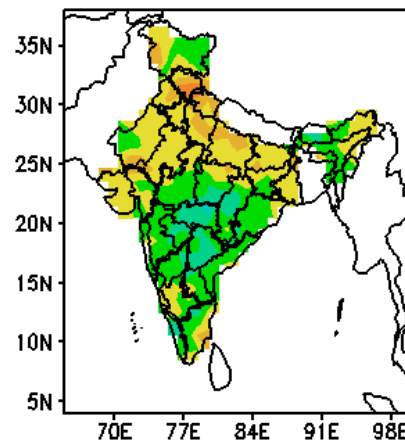
(Week1: 15Jun-21Jun)

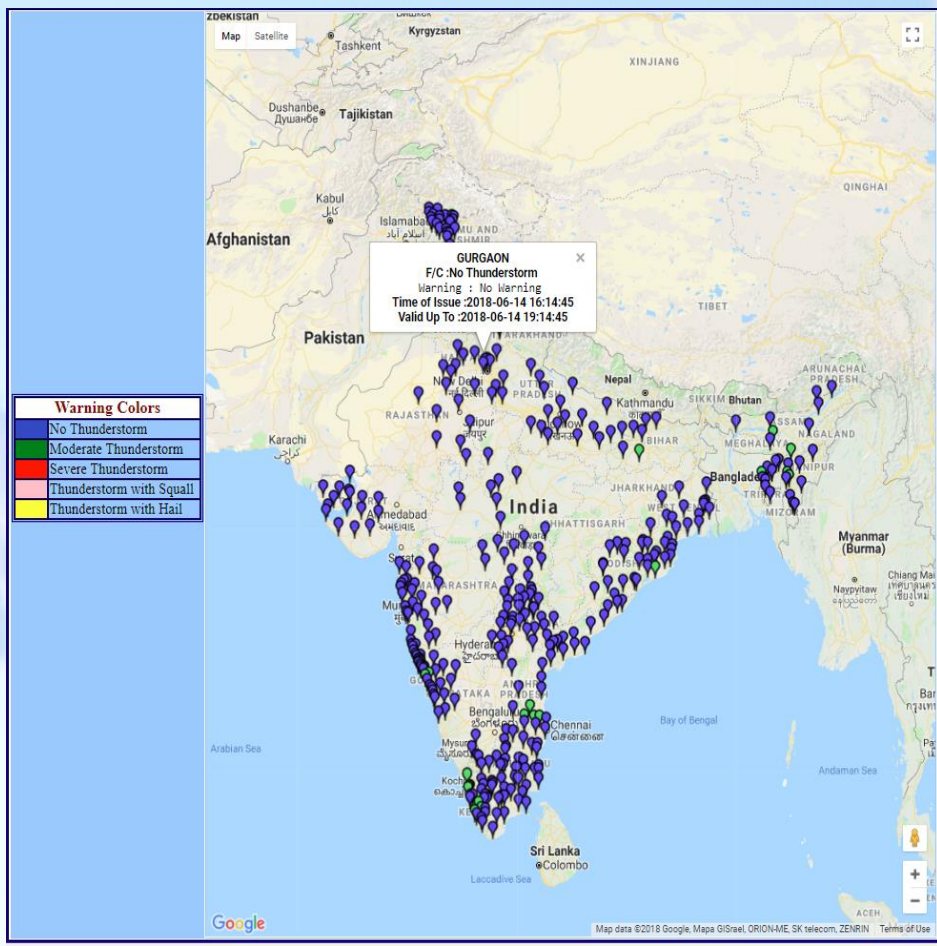
(Week2: 22Jun-28Jun)



(Week3: 29Jun-05Jul)

(Week4: 06Jul-12Jul)





City Forecast

www.imd.gov.in/pages/city_weather_main.php

Apps | who seminar at Sing | rapid | CWC AFF (Beta) | Index of /pub/merge | Index of /pub/merge | PDFill PDF Tools | G | FREE PDF Tools to M | USGS HydroSHEDS | Index of /realtime/ | Index of /realtime/ | International Dam Se | District-wise

Thursday, 14 June 2018 05:55 PM IST

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Weather Information

- All India Weather Inference
- All India Weather Forecast
- All India Weather Warnings
- Weekly Weather Report
- Extended Range Outlook
- Marine Weather Bulletins
- Heat Wave
- Nowcast Warnings
- T-Phi Grams (3D Sounder)
- City Weather
- Nowcast Desk

Specialized Forecasts

- Tourism Forecast
- Highway Forecast
- Mountain Weather Bulletin
- Mata Vaishno Devi Yatra

Rainfall Information

- Monsoon
- Cyclone

Departmental Sites

- MOES Sites

Visitors since 1st June 2018

010-40006- web directory

City Weather

Search : Go

[Statewise List of station](#)

Local Weather Report and Forecast For: Jhansi Dated : Jun 14, 2018

Past 24 Hours Weather Data

Maximum Temp(°C) (Recorded on 13/06/18)	42.1
Departure from Normal(°C)	1
Minimum Temp (°C) (Recorded on 14/06/18)	32.1
Departure from Normal(°C)	4
24 Hours Rainfall (mm) (Recorded from 0830 hrs IST of yesterday to 0830 hrs IST of today)	NIL
R.H. at 0830 hrs (%)	60
R.H. at 1730 hrs (%) (Recorded on 13/06/18)	38
Today's Sunset (IST)	19:07
Tomorrow's Sunrise (IST)	05:25
Moonset (IST)	20:45
Moonrise (IST)	06:50

7 Day's Forecast

Date	Min Temp	Max Temp	Weather
14-Jun	31.0	41.0	Mainly Clear sky
15-Jun	30.0	40.0	Mainly Clear sky
16-Jun	30.0	40.0	Mainly Clear sky
17-Jun	31.0	40.0	Mainly Clear sky
18-Jun	32.0	40.0	Mainly Clear sky
19-Jun	32.0	41.0	Mainly Clear sky
20-Jun	32.0	42.0	Partly cloudy sky



Hydromet- services



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT



LANDMARK: BACKGROUND OF HYDROMET DIVISION

- **1890- The Rainfall Resolution of India**
which made India Meteorological Department as controlling authority for all rainfall measuring agencies.
- **1949 - A special hydrometeorological unit was established at Alipore, Kolkata to provide operational met service to Damoder Valley Corporation.**
- **1963 – Storm Analysis Unit was established as per Khosala Committee's recommendations**
- **1971 - The Hydromet Division is formally established to cater increasing demands of value added information to rainfall data as per users' specific needs.**



SERVICES RENDERED BY HYDROMET DIVISION

Hydro met Division is providing the services in the field of

- **Hydro met Support (QPF) for Flood Forecasting**
- **Rainfall Monitoring**
- **Hydro met Design**



Hydro met Forecasting (QPF) for Flood Forecasting



NATURE OF FLOODS IN INDIA

- ❖ Maximum floods Occur in S-W MONSOON season.
- ❖ Flood is an ANNUAL FEATURE of major rivers.
- ❖ According to the estimate of the **National Commission on Flood**, the area prone to floods in the country was of the order of 40 million hectares, out of which it is considered that 80%, i.e., 32 million hectares could be provided with reasonable degree of protection.
- ❖ On an average 75000 SQ. KMS of area & 33 million population faces **FLOOD WRATH** every year.



Flood Prone areas in India

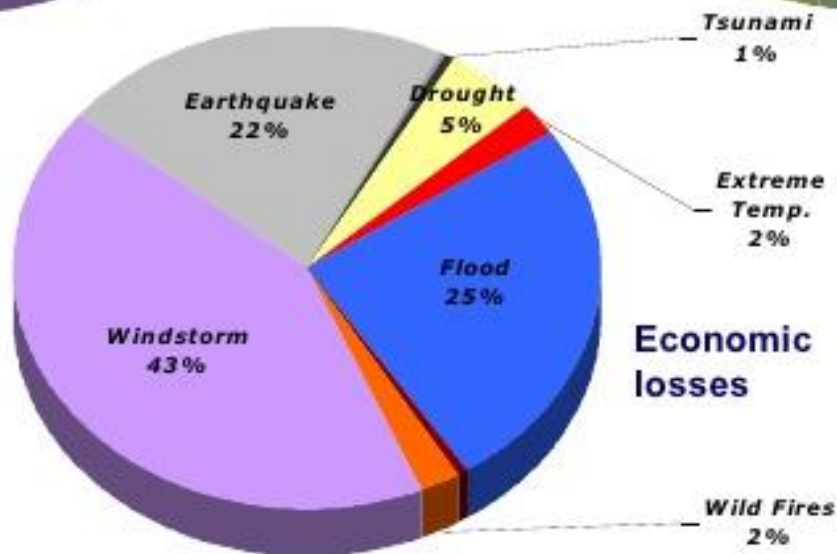
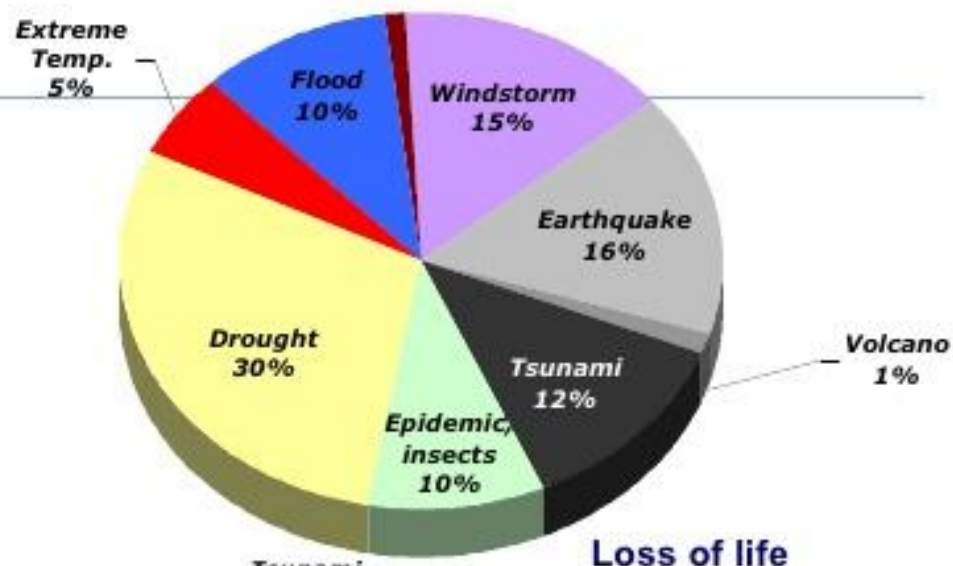
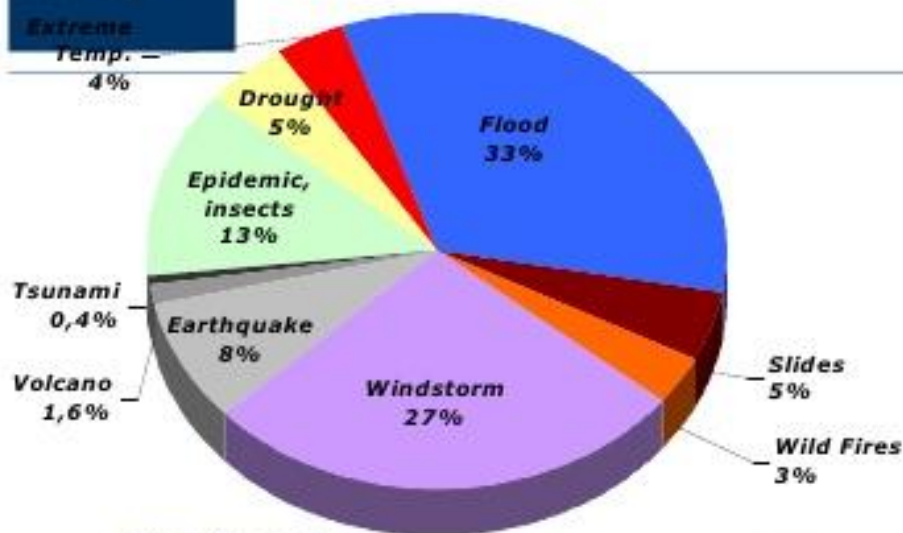
~ 40 million Ha
(RBA,1980)

- ✓ Major Flood Prone States: Assam, Bihar, West Bengal, UP,
- ✓ Odisha & Andhra Pradesh
- ✓ Major Flood Prone Basins: Ganga, Brahmaputra & Mahanadi





Global Distribution of Disasters Caused by Natural Hazards and their Impacts (1980-2007)



Source: EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium

90% of events, 70% of casualties and 75% of economic losses are related to hydro-meteorological hazards.

EXPERTS OPINION

Though total immunity from floods is not feasible, the losses particularly of lives and movable property can be minimized by

- ❖ **Structural Measures**
- ❖ **Non Structural Measures**

Structural

**Construction of Dams,
Embankments etc**

Costly

**Saves both movable and
immovable property**

Non Structural

**Flood Warnings
Flood plain zoning
etc**

Relatively less costly

Saves only movable property.



ORGANISATIONS DEALING FLOODS

- ❖ FLOOD CONTROL DEPARTMENTS OF STATES
- ❖ CENTRAL WATER COMMISSION
- ❖ INDIA METEOROLOGICAL DEPTT.
- ❖ NATIONAL DISASTER MANAGEMENT AUTHORITY
- ❖ STATE DISASTER MANAGEMENT AUTHORITY
- ❖ GANGA FLOOD CONTROL COMMISSION
- ❖ BRAHMAPUTRA BOARD
- ❖ MINISTRY OF AGRICULTURE
- ❖ STATE CRISES MANAGEMENT GROUPS



CAUSES OF FLOODS

I. METEOROLOGICAL FACTORS

- (a). HEAVY RAINFALL
- (b). CYCLONES, THUNDERSTORMS, CLOUD BURSTS
- (c). SUDDEN MELTING OF SNOW / ICE
- (d). STORM SURGES

II. GEOGRAPHICAL FACTORS

- (a). EARTH QUAKES
- (b). LAND SLIDES ETC
- (C). GLACIAL OUT BURST

III. MAN MADE FACTORS

- a). FAILURE OF DAMS AND OTHER CONTROL WORKS LIKE RESERVOIRS
- b). ENCROACHMENT IN FLOOD PLAIN AREAS

IV. OTHER FACTORS (LOCAL SCALE)

- (a). DEBRIS FLOW
- (b). BACK WATER
- (c). CHANGE IN RIVER COURSE

However majority of floods occur due to Heavy rains in short period. Hence accurate QPF is a prime factor of reasonable Flood forecasting and warning.



CAUSES OF FLOOD

A **glacial lake outburst** flood is a type of outburst flood occurring when water dammed by a glacier or a moraine is released.



CAUSES OF FLOOD

ENCROACHMENT IN FLOOD PLAIN AREAS



CAUSES OF FLOOD

AVALANCHES: A huge mass of snow, ice, and rocks falling rapidly down a mountainside.

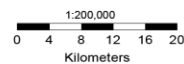
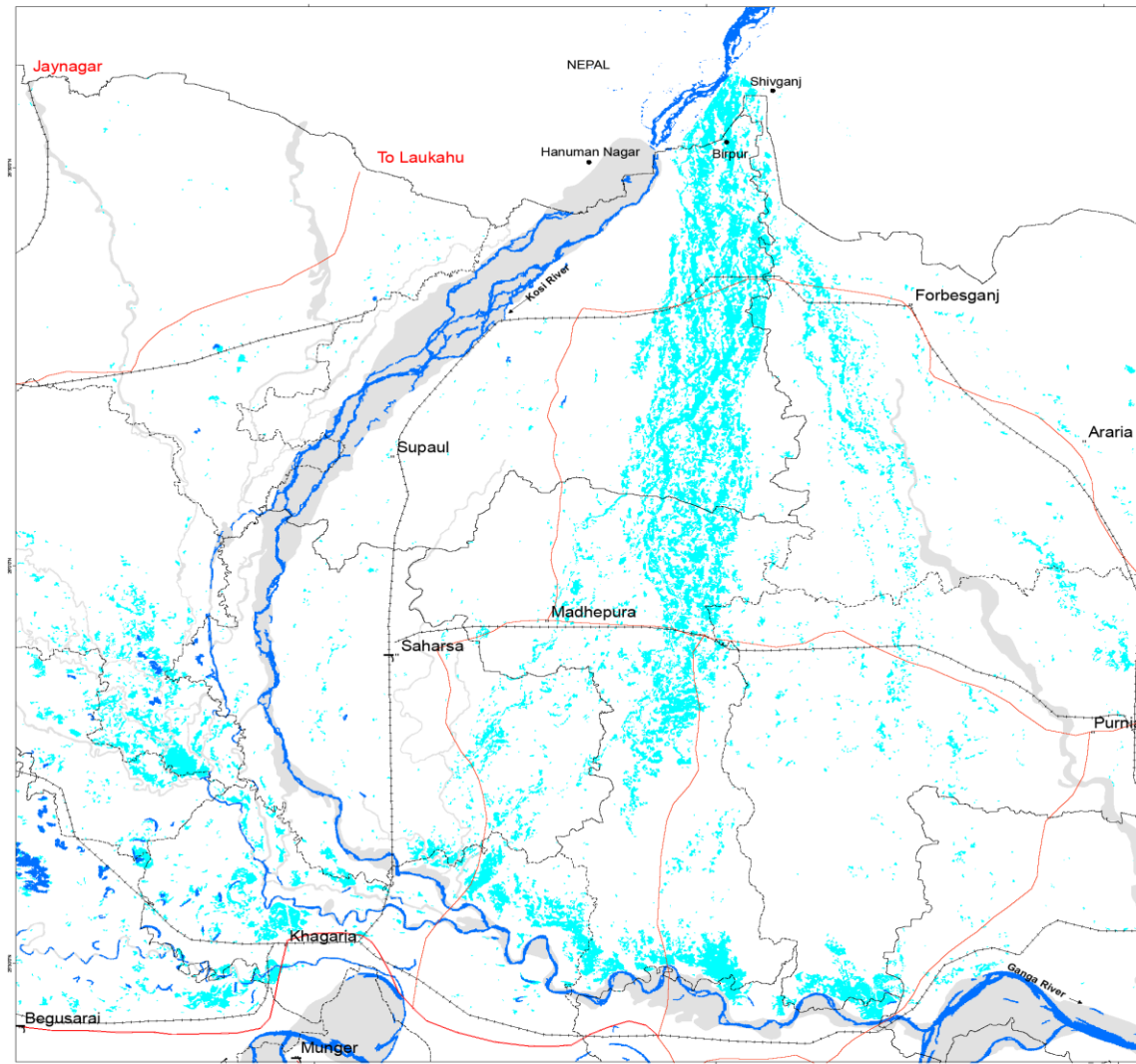


LANDSLIDES:
The sliding down of a mass of earth or rock from a mountain.



CAUSES OF FLOOD

Based on the analysis of IRS-P6 data of 23-August-2008 & Radarsat data of 22-August-2008



μ

Decision Support Centre (DSC)
RS & GIS Applications Area
National Remote Sensing Agency
Dept. of Space, Govt. of India
HYDERABAD- 500 037
E-Mail: flood@nrsa.gov.in
nrsa



HIGH LEVEL COMMITTEES CONSTITUTED TO STUDY PROBLEM OF FLOODS

- ❖ POLICY STATEMENT- 1954
- ❖ HIGH LEVEL COMMITTEE ON FLOODS-1957
- ❖ POLICY STATEMENT- 1958
- ❖ MINISTERIAL COMMITTEE ON FLOOD CONTROL- 1964
- ❖ MINISTERIAL COMMITTEE ON FLOODS & FLOOD RELIEF- 1972



Flood Forecasting

MINISTERIAL COMMITTEE ON FLOODS & FLOOD RELIEF-1972 RECOMMENDED THAT

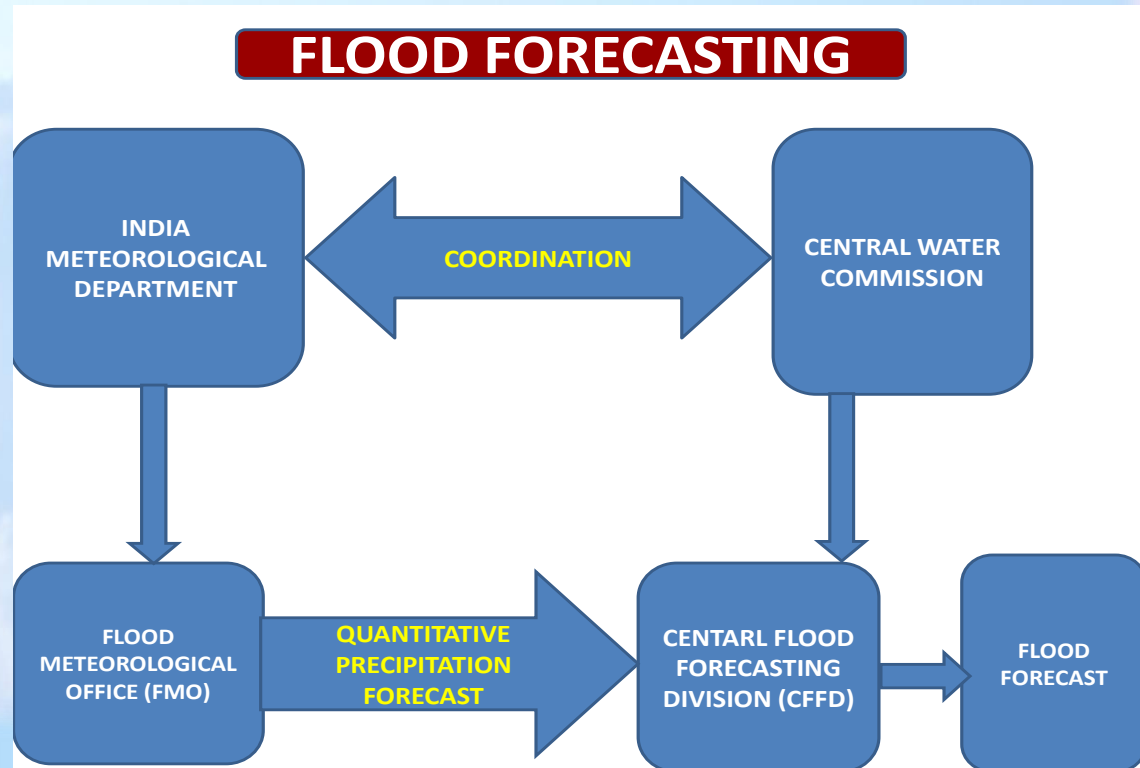
- ❖ Flood Forecasting Centres should be established in all flood prone basins.
- ❖ Flood Meteorological Offices should be established by India Meteorological Department to work in close co-operation with Flood Forecasting Centres

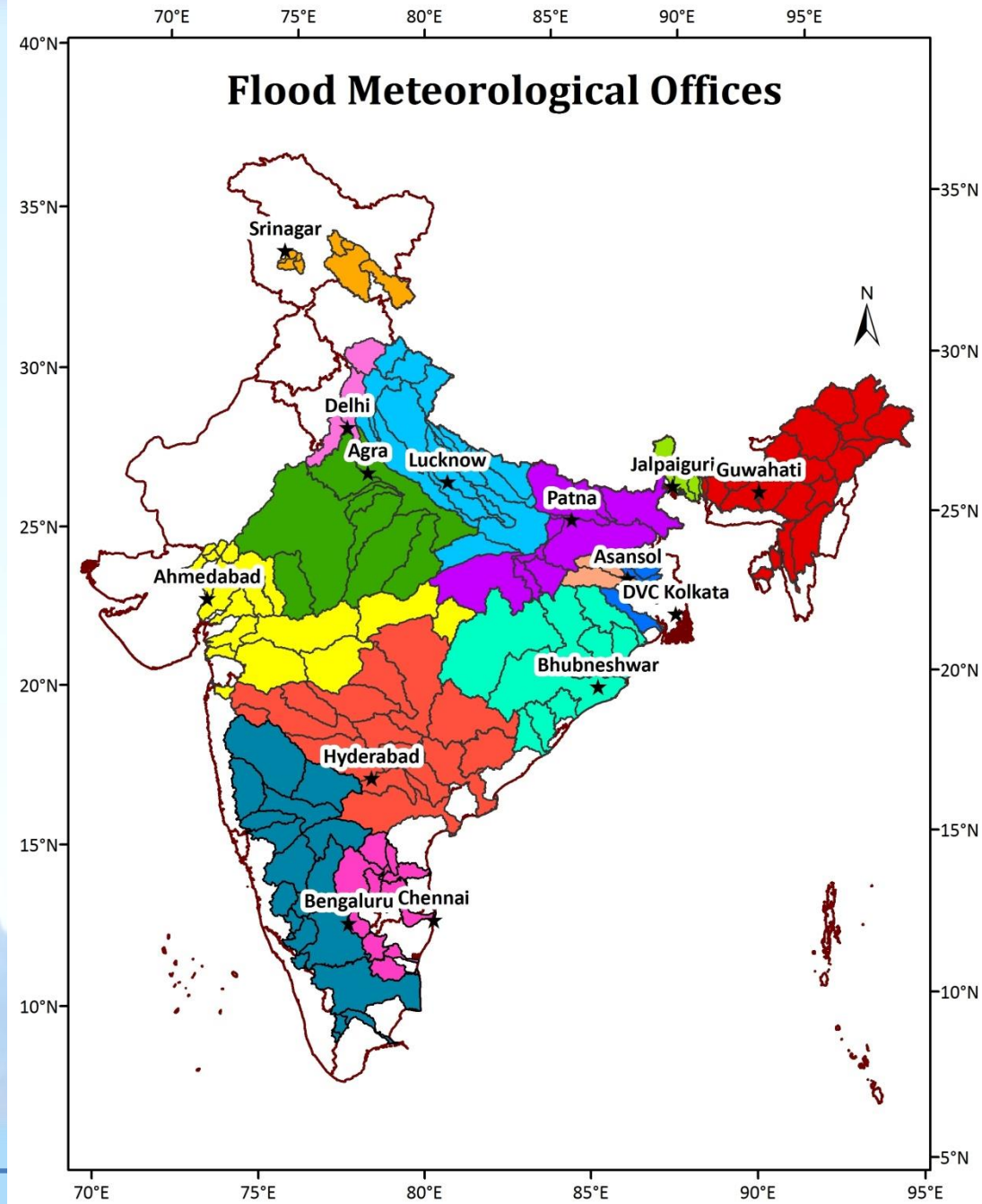
In India Flood Forecasting activity is the joint responsibility of

- India Meteorological Department
- Central Water Commission.

IMD provides Hydromet Input through their Flood Forecasting Offices(FMOs).

In hydromet input, Quantitative Precipitation Forecast (QPF) is the main input which is used in rainfall runoff models by CWC.





Sl. No.	FMOs	Date of Estt.	River Basins
1	Agra	29-Mar-85	Banganga, Chambal, Betwa, Ken, Yamuna
2	Ahmedabad	Jan-74	Narmada, Tapi, Daman-Ganga, Sabarmati, Banas, Mahi
3	Asansol	Mar-80	Ajoy, Mayurakshi, Kangsabati
4	Bhubaneswar	11-Jan-74	Subarnarekha, Baitarni, Burhabalang, Vamsadhara, Brahmani, Mahanadi, Rushikulya
5	Guwahati	Aug-75	Brahmaputra, Barak, Dehung, Lohit, Buridihing, Subansiri, Dhansiri (N,S), Jiabharali, Kapili, Manas/ Beki, Sankosh
6	Hyderabad	Apr-77	Godavari, Krishna
7	Jalpaiguri	24-Jul-74	Teesta, Jaldhaka, Raidak
8	Lucknow	Sep-74	Ghaghra, Rapti, Ramganga, Gomti, Sai, Sahibi, Chhatang, Bhagirathi, Alaknanda, Ganga
9	New Delhi	15-Jun-74	Yamuna, Sahibi
10	Patna	Dec-73	Kosi, Mahananda, Adhwara, Bagmati, Gandak, Punpun, Sone, Kanhar, North Koel
11	MC Srinagar	Jun-15	Jhelum, Dah, Nimmo, Khalsi
12	RMC Chennai	Jun-16	Pennar, Vellar
13	MC Bengaluru	Jun-16	Krishna, Cauvery, Tungabhadra, Vaigai
14	DVC	1949	Barakar, Damodar, Lower Valley



Collection of rainfall data

Selection of stations

- ❖ Rainfall data are collected from IMD surface observatories, FMO network and other IMD observatories as well as other organisation observatories.
- ❖ It may be ensured that rainfall data received from the network maintained by other agencies confirm to IMD Standards.
- ❖ The rainfall data of state raingauge should also be collected for the stations lying the river basins from concerned FFD.
- ❖ AWS/ARGs data, within the area of basin/sub-basin, may be used after scrutiny/validation of data and rainfall data from those stations.

Collection of rainfall data

Frequency of collection

- ❖ FMOs receive rainfall data from hydromet observatories recorded at 0830 hrs. IST as a routine.
- ❖ In case of expectation of heavy to very heavy rainfall, FMOs in consultation with RMCs may examine the possibility of obtaining rainfall data at more frequent intervals, for instance, once in six hours.



Collection of rainfall data

Mode of communication

- ❖ The rainfall data may be collected by landline telephone, Fax, mobile phone, e-mail, internet, websites etc.
- ❖ When the normal mode of communications fail, efforts should be made for transmission of rainfall data through alternate channels including seeking help of the local police authorities and state government officials for use of their channels of communication in extreme cases.
- ❖ During the failure of internet services which is generally mode of communication for exchange of all information and data, other means of communication may be pre-decided and used with co-ordination with CWC.



Period of Watch of Flood Met. Offices

- ❖ The flood season may vary depending upon location of basin and onset/withdrawal of S-W monsoon.
 - Brahmaputra Basin from 1st May to 31st October
 - All other basins upto Krishna basin from 1st June to 31st October and
 - Basins south of Krishna basin (Pennar, Cauvery and southern rivers) from 1st June to 31st December.



Weather Charts

Synoptic Charts:

FMOs co-located with Met. Centres should use the weather charts prepared by them. FMOs which are not co-located with MCs should consult/obtain from the respective RMC/MC, the real time weather charts prepared by them.

Rainfall analysis charts:

Rainfall analysis charts should be prepared for basins and sub-basins. Normally rainfall analysis charts may be prepared daily or more frequently if situation so demands.



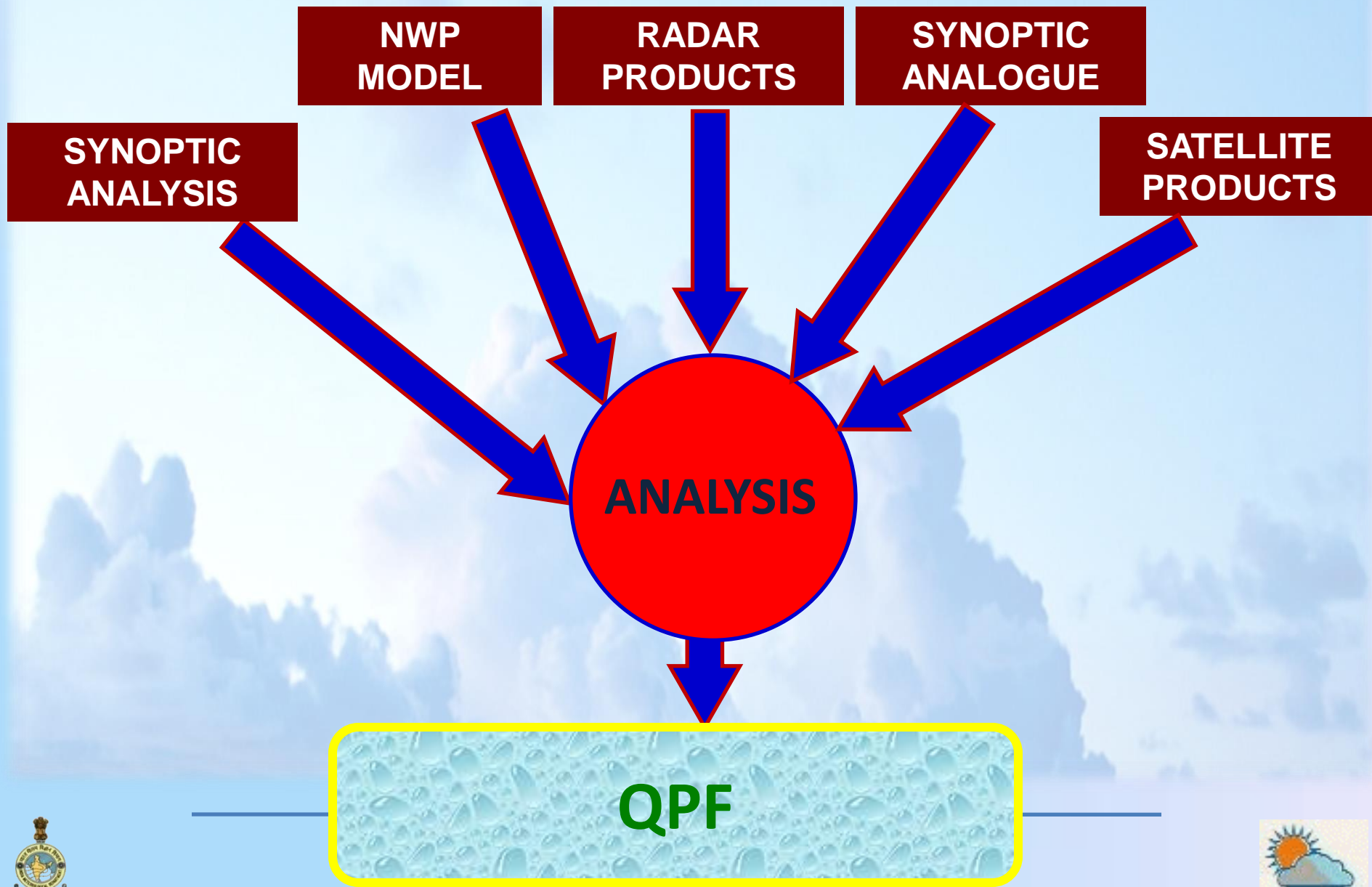
Early Warning System for Floods

Flood Forecasting - Role of IMD

- Observation and Collection of meteorological Data
- Transmission of data to forecast centers
- Analysis of data and formulation of forecast (Quantitative Precipitation Forecasts) & issue of heavy rainfall warnings
- Dissemination of forecasts/warnings to Flood Forecast Centres of CWC



Inputs for issuing of QPF



Information to be supplied to concerned FFD.

- ❖ **All FMOs for issue of 'Hydromet Bulletin' which contains**
 - **synoptic situation(over the jurisdiction area),**
 - **Sub-basin wise spatial and Intensity distribution of Rainfall with Categorical QPF (0, 0.1-10, 11-25, 26-50, 51-100, >100mm) for day 1 to day 3.**
 - **Heavy Rainfall Warnings(HRW) and Outlook for consequent 4 days.**
 - **Significant Rainfall (≥ 5 cm).**
 - **Realized basin average rainfall at 0830 hrs IST.**
- ❖ **If any significant development of weather takes place after issue of hydromet bulletin, it needs to be communicated to concerned FFD by e-mail/fax/telephone etc.**
- ❖ **DURING FLOOD SEASON, FMOs send QPF Bulletin (9.30AM) and HYDROMET BULLETINS (12.30PM) to CFFD**



Information to be supplied to concerned FFD.

- ❖ Advance rainfall warning may be given so that concerned FFD is in a position to issue 'Flood Alert'(In the case of Depression / Cyclonic storms, likely direction of movement may form the basis of such warnings).
- ❖ The daily weather summaries and other such meteorological information as required by concerned FFD may be supplied.
- ❖ In case concerned FFD desires, rainfall analysis map may be supplied.



QPF during non flood season

- During the period of 'Flood Alert' for specified basins as notified by concerned FFD.
- During the weather situations where there is expectation of significant rainfall leading to floods in a particular basin/sub-basin.
- If heavy rainfall is expected during non-flood season or in the event of formation of Cyclone, concerned FMO need not to wait for any demand from concerned FFD to issue QPF/HM Bulletins.



QPF VERIFICATION REPORT

Verification of QPF:

Following different skill scores are to be computed from 6X6 Contingency table;

- ❖ Percentage Correct Forecast (PC)
- ❖ Heidke Skill Score (HSS)
- ❖ Critical Success Index (CSI)

Observed range (mm)	Forecast range (mm)						Total
	0	1-10	11-25	26-50	51-100	>100	
0	a	b	c	d	e	f	A
1-10	g	h	i	j	k	l	B
11-25	m	n	o	p	q	r	C
26-50	s	t	u	v	w	x	D
51-100	y	z	aa	ab	ac	ad	E
>100	ae	af	ag	ah	ai	aj	F
Total	G	H	I	J	K	L	T

$$PC = \frac{a+h+o+v+ac+aj}{T} \times 100$$

$$CSI = \frac{a}{A+G-a} + \frac{h}{B+H-h} + \frac{o}{C+I-o} + \frac{v}{D+J-v} + \frac{ac}{E+K-ac} + \frac{aj}{F+L-aj}$$

$$HSS = \frac{\frac{T(a+h+o+v+ac+aj) - (AG+BH+CI+DJ+EK+FL)}{T}}{\frac{T+T - (AG+BH+CI+DJ+EK+FL)}{T}}$$



QPF VERIFICATION REPORT

The POD, FAR, MR, C-NON, CSI, BIAS, PC, TSS and HSS for each category is to be computed by reducing the 6X6 contingency table into 2X2 contingency table for occurrence / non occurrence (YES/NO). The computing procedure for various skill scores tests are as follows over sub basins.

Observed	Forecast	
	Yes	No
Yes	A	B
No	C	D

$$\text{Probability of Detection (POD)} = \frac{A}{A+B}$$

$$\text{False Alarm Rate (FAR)} = \frac{C}{C+A}$$

$$\text{Missing Rate (MR)} = \frac{B}{B+A}$$

$$\text{Correct Non-Occurrence (C-NON)} = \frac{D}{C+D}$$

$$\text{Critical Success Index (CSI)} = \text{Threat Score} = \frac{A}{A+B+C}$$

$$\text{Bias for occurrence (BIAS)} = \frac{A+C}{A+B}$$

$$\text{Percentage Correct (PC)} = \frac{A+D}{A+B+C+D} \times 100 = \text{Hit Rate} \times 100$$

$$\text{True Skill Score (TSS)} = \frac{A}{A+B} + \frac{D}{C+D} - 1$$

$$\text{Heidke skill score (HSS)} = 2 \left\{ \frac{AD-BC}{B^2+C^2+2AD+(B+C)(A+D)} \right\}$$

The final skill score will be the average of these.

For best/perfect forecast, POD=1, FAR=0, MR=0



FMOs activities during non flood season

FMOs also perform following functions during non flood season :

- ☐ **Preparation of synoptic cum statistical analogue model for QPF for each sub basin for their area of jurisdiction. It is to be updated after five years**
- ☐ **Preparation of hydrometeorology of river basins**
- ☐ **FMO stations are being inspected by Zonal Instrument Maintenance Centre (ZIMC) every year for accurate and efficient reception of rainfall data on real time basis**



QUANTITATIVE PRECIPITATION FORECAST

WHAT IS QUANTITATIVE PRECIPITATION FORECAST (QPF)?

QPF IS THE EXPECTED AMOUNT OF RAINFALL ACCUMULATED OVER A SPECIFIED TIME PERIOD OVER SPECIFIED AREA.

**There are two approaches for its computation
1) Synoptic Analogue and 2) Dynamical.**



Development of Techniques for QPF - basin wise

- ❖ It is essential to have synoptic-cum-statistical analogue models for each basin under the jurisdiction of a FMO. On the basis of availability of longer data sets, FMOs should prepare such analogues for the basins.
- ❖ Existing analogue, if prepared more than five years back should be updated.



FMO AGRA

Frequency of Occurrence of Aerial Rainfall more than 10 mm for various synoptic situations and different locations over LOWER YAMUNA BASIN

Year 1998-2006

System	11-25	26-50	51-100	>100	Total	11-25	26-50	51-100	>100	Total	11-25	26-50	51-100	>100	Total	11-25	26-50	51-100	>100	Total	11-25	26-50	51-100	>100	Total	Grand
	Sub-basin A					Sub-basin B					Sub-basin C					Sub-basin D					Sub-basin E					Total
S11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S12	1	0	0	0	1	1	0	1	0	2	0	1	0	0	1	1	1	1	0	3	1	1	0	0	2	9
S13	0	1	0	0	1	3	1	0	0	4	0	0	0	0	0	2	3	1	0	6	4	0	0	0	4	15
S14	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Total	1	2	0	0	3	4	1	1	0	6	1	1	0	0	2	3	4	2	0	9	5	1	0	0	6	26
S21	0	0	0	0	0	2	0	0	0	2	4	2	1	0	7	2	4	2	0	8	4	2	0	0	6	23
S22	0	0	0	0	0	3	3	0	0	6	2	1	0	0	3	5	0	0	0	5	9	3	1	0	13	27
S23	2	0	0	0	2	8	0	1	0	9	2	0	0	0	2	11	6	0	0	17	2	0	1	0	3	33
S24	9	7	0	0	16	6	0	0	0	6	4	1	2	0	7	3	1	0	0	4	3	2	0	0	5	38
Total	11	7	0	0	18	19	3	1	0	23	12	4	3	0	19	21	11	2	0	34	18	7	2	0	27	121
S31	3	0	0	0	3	2	0	0	0	2	3	1	1	0	5	8	0	0	0	8	19	3	0	0	22	40
S32	0	0	0	0	0	2	1	0	0	3	2	0	0	0	2	5	0	0	0	5	11	0	0	0	11	21
S33	3	3	0	0	6	11	1	0	0	12	3	1	0	0	4	7	6	0	0	13	1	0	0	0	1	36
S34	16	4	1	0	21	8	1	1	0	10	21	7	0	0	28	12	4	0	0	16	13	2	0	0	15	90
Total	22	7	1	0	30	23	3	1	0	27	29	9	1	0	39	32	10	0	0	42	44	5	0	0	49	187
S41	0	0	0	0	0	0	0	0	0	0	7	0	0	0	7	5	4	0	0	9	22	8	2	0	32	48
S42	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	1	0	0	0	1	9	0	0	0	9	12
S43	0	0	0	0	0	7	4	1	0	12	2	0	0	0	2	15	3	0	0	19	4	0	0	0	4	37
S44	25	6	2	0	33	9	5	1	0	15	18	4	0	0	22	11	0	2	0	13	1	0	0	0	1	84
Other	6	2	0	0	8	3	3	0	0	6	5	1	2	0	8	5	1	0	0	6	7	4	0	0	11	39
Total	31	8	2	0	41	20	12	2	0	34	32	6	2	0	40	37	8	2	1	48	43	12	2	0	57	220
G.Total	65	24	3	0	92	66	19	5	0	90	74	20	6	0	100	93	33	6	1	133	110	25	4	0	139	554

Legend: Sij

i: Intesity Classification of System

j: Location Classification of System

i=1

Depression/Deep
Depression/Cyclone

i=2

Well Marked Low/Low

i=3

Upper Air Cyclonic Circulation

i=4

Monsoon Trough

j=1

East U.P.

j=2

East M.P. & adj. areas

j=3

West M.P.

j=4

West M.P. and adj. Rajasthan

Sub basin wise Dynamical Model Rainfall

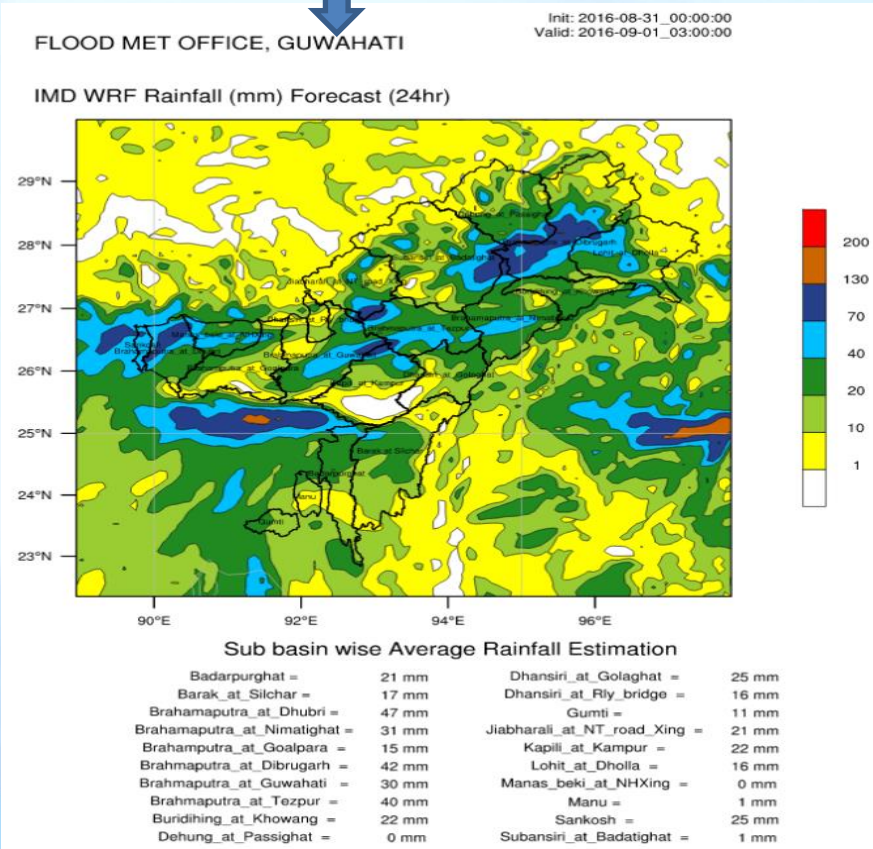
**WRF(ARW) (9km x 9km) (00utc & 12 utc),
Multi-Model Ensemble (0.25 deg x 0.25
deg) (00utc) and GFS (T-1534)
(12kmX12km) (00utc) sub-basin wise
rainfall forecast are being uploaded on
IMD's website in real-time**



Sub basin wise Dynamical Model Rainfall

OUTPUT PRODUCTS
OF MME

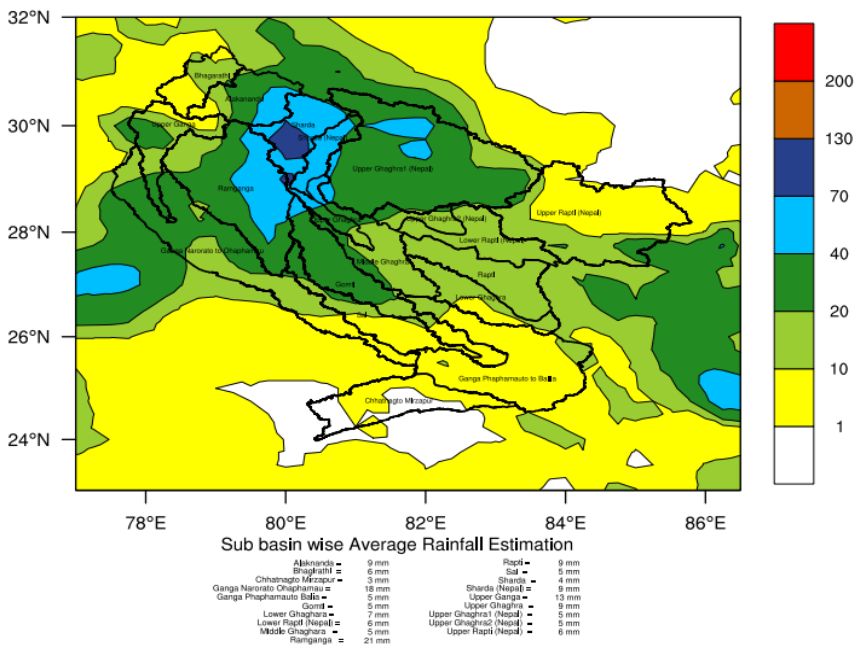
OUTPUT
PRODUCTS OF
WRF



FLOOD MET OFFICE LUCKNOW

IMD MME Rainfall(mm) Forecast (24hr)

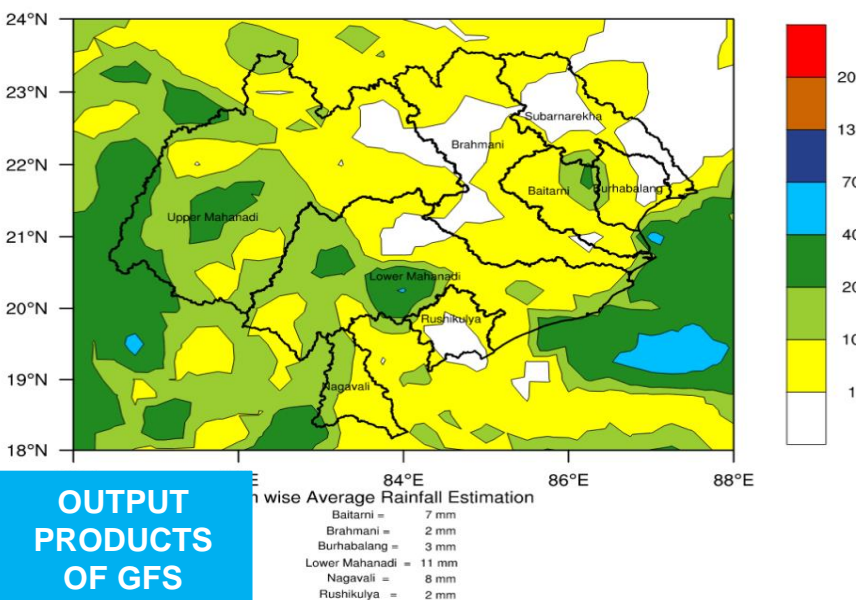
DAY2 FCST VALID FOR 26062015 TILL 08:30 IST



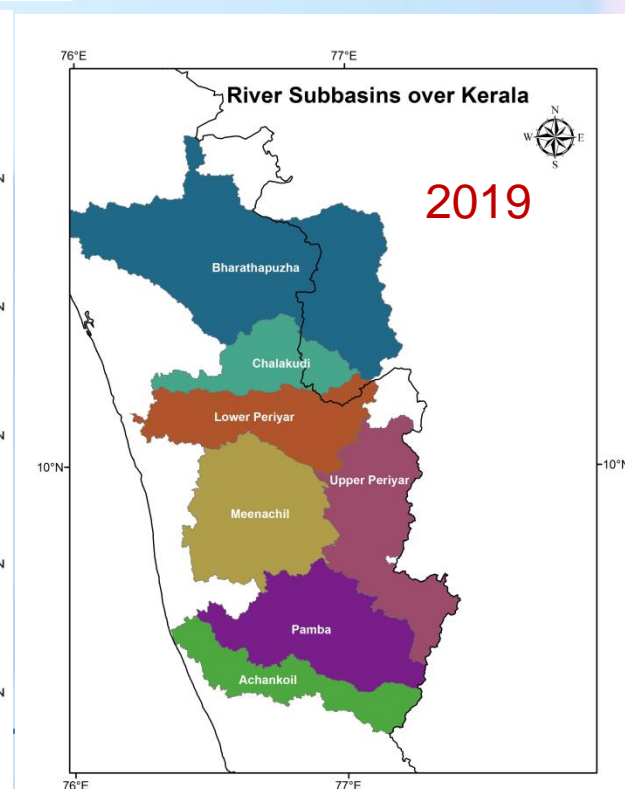
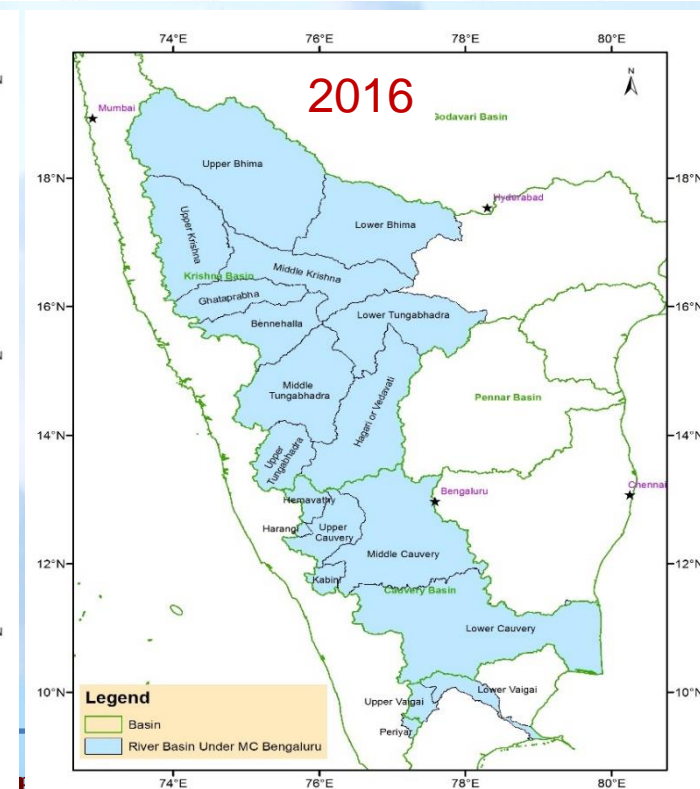
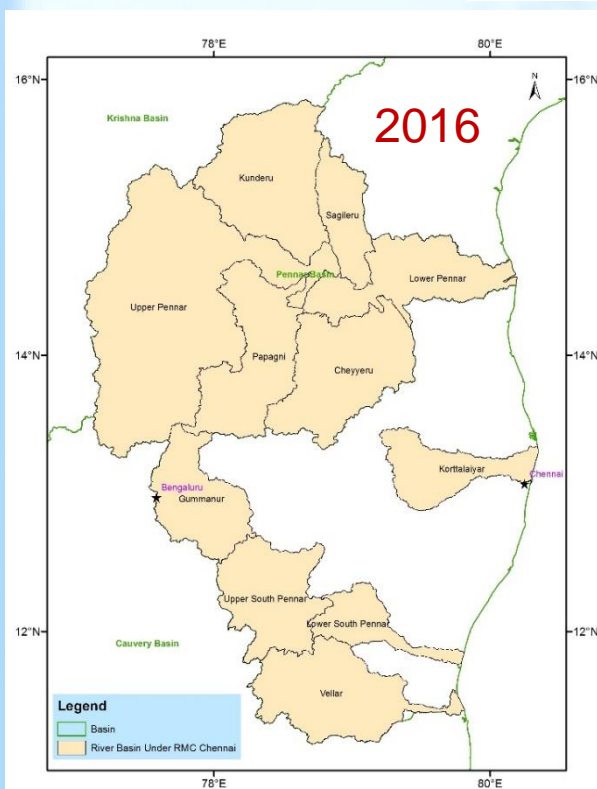
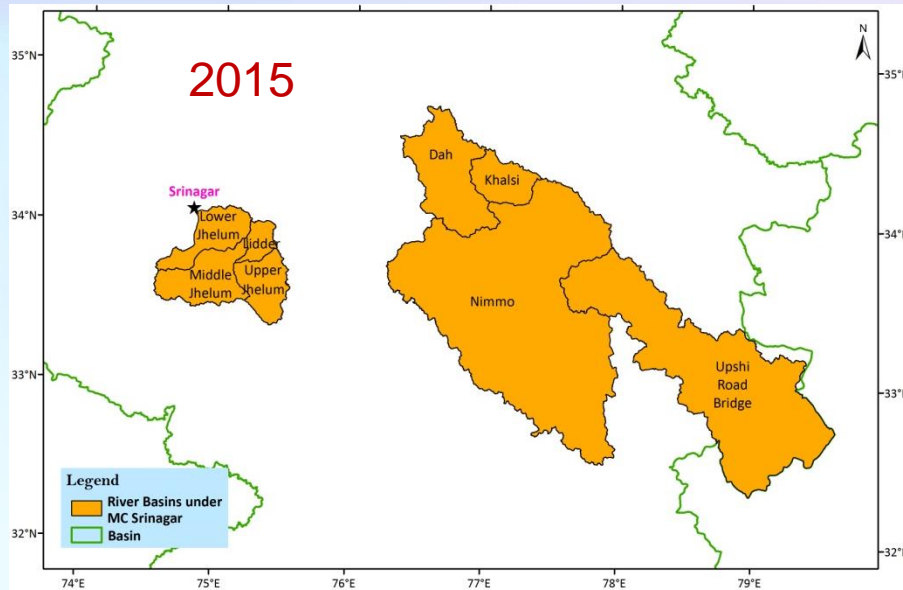
FLOOD MET OFFICE BHUBANESWAR

IMD GFS Rainfall(mm) Forecast (24hr)

Day 1 FCST valid for: 01.09.2016 TILL 08:30 IST

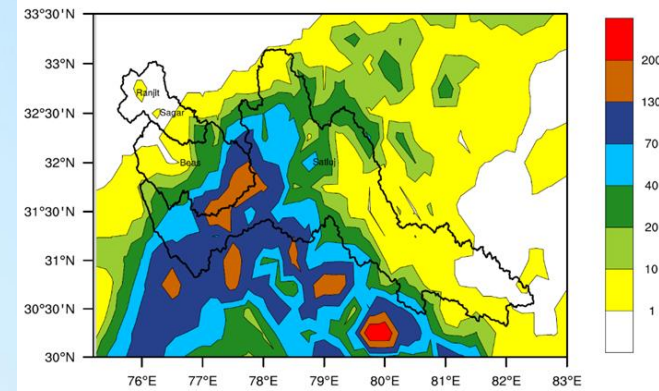
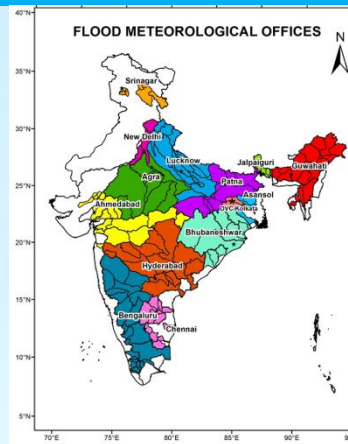


OUTPUT
PRODUCTS
OF GFS

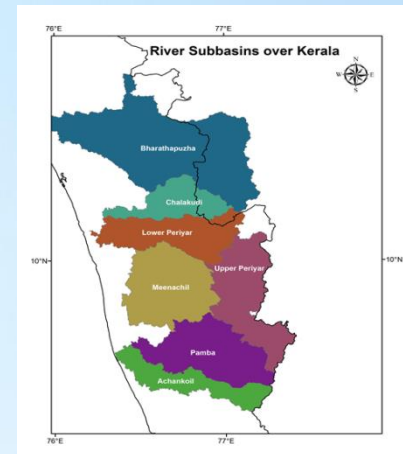
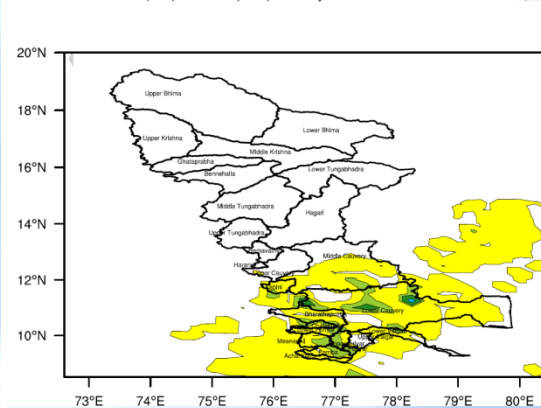


Hydromet Support for Flood Forecasting

- ❑ NWP model based Sub basin wise QPF (WRF and GFS) is extended for
 - i. Kerala River basin
 - ii. Ranjit Sagar dam catchment area
- ❑ Daily monitoring of Flood Situation & QPF issued by IMD provided to Central Agencies
- ❑ MoU between TERI and IMD for joint activity 'Development of Flood Warning System for Guwahati' and "Jorhat".
- ❑ NWP Model data (WRF & GFS) are provided operationally to CWC for their flood forecasting model



IMD GFS Rainfall(mm) Forecast (96hr) Day 4 FCST valid for: 09.03.2019 TILL 08:00



Real Time Monitoring of Flood Forecasting Activities

FMO Patna			Flood Level		Quantitative Precipitation Forecast (QPF)									
S. No.	Basin	Sub-Basin	Severe Flood	Extreme Flood	Day-1 26-50mm	Day-1 51-100mm	Day-2 26-50mm	Day-2 51-100mm	Day-3 26-50mm	Day-3 51-100mm	Day-3 51-100mm	Day-3 51-100mm	Day-3 51-100mm	Day-3 51-100mm
1	Ganga	Kosi/Mahananda												
2		Bagmati Adhwara												
3		Gandak												
4		Sone												
5		Upper Sone												
6		Kanhar												
7		North Koel												
8		Zone VI												
FMO Asansol														
S. No.	Basin	Sub-Basin												
1	Kangsabati	Kangsabati												
2	Ajoy	Ajoy												
3	Mayurakshi	Mayurakshi												
FMO New Delhi														
S. No.	Basin	Sub-Basin												
1	Yamuna	Yamuna upto Hathnikund												
2		Yamuna upto Mathura												
3	Sahibi	Sahibi												
FMO Agra														
S. No.	Basin	Sub-Basin												
1	Banganga	Gambhir												
2	Chambal	Upper Chambal												
3		Lower Chambal												
4		Sind												
5		Kumhari												
6	Betwa	Betwa												



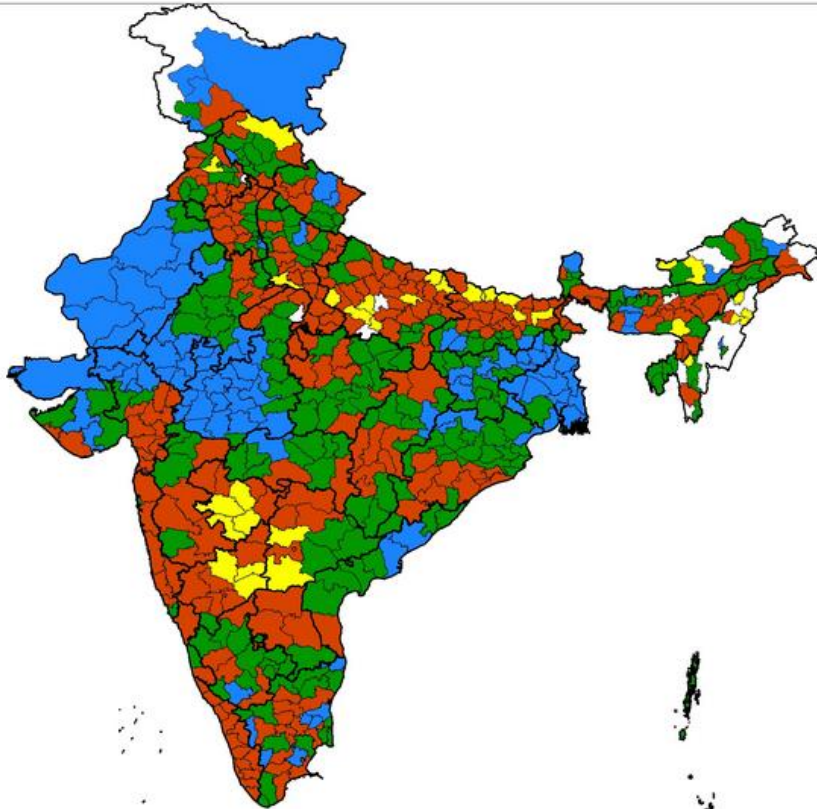
CRIS (CUSTOMISED RAINFALL INFORMATION SYSTEM)

THE SYSTEM CRIS WHICH WAS MADE OPERATIONAL ON 15TH JANUARY, 2015 ON IMD WEBSITE PROVIDES REAL-TIME RAINFALL INFORMATION BY MEANS OF GIS BASED RAINFALL PRODUCTS FOR ANY PLACE IN INDIA.

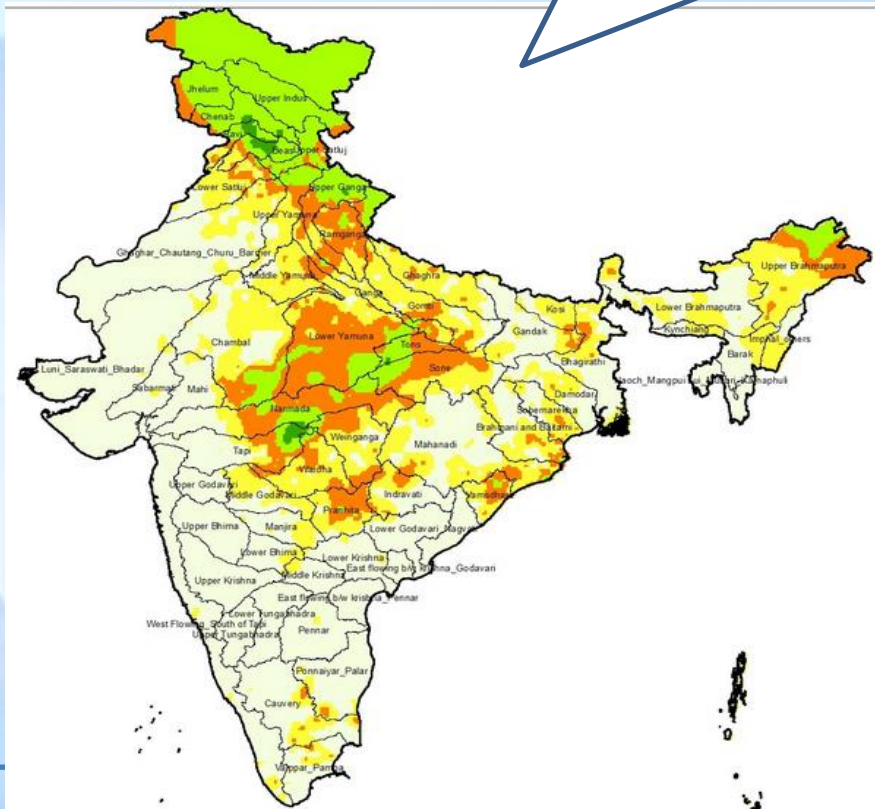


CUSTOMISED RAINFALL INFORMATION SYSTEM

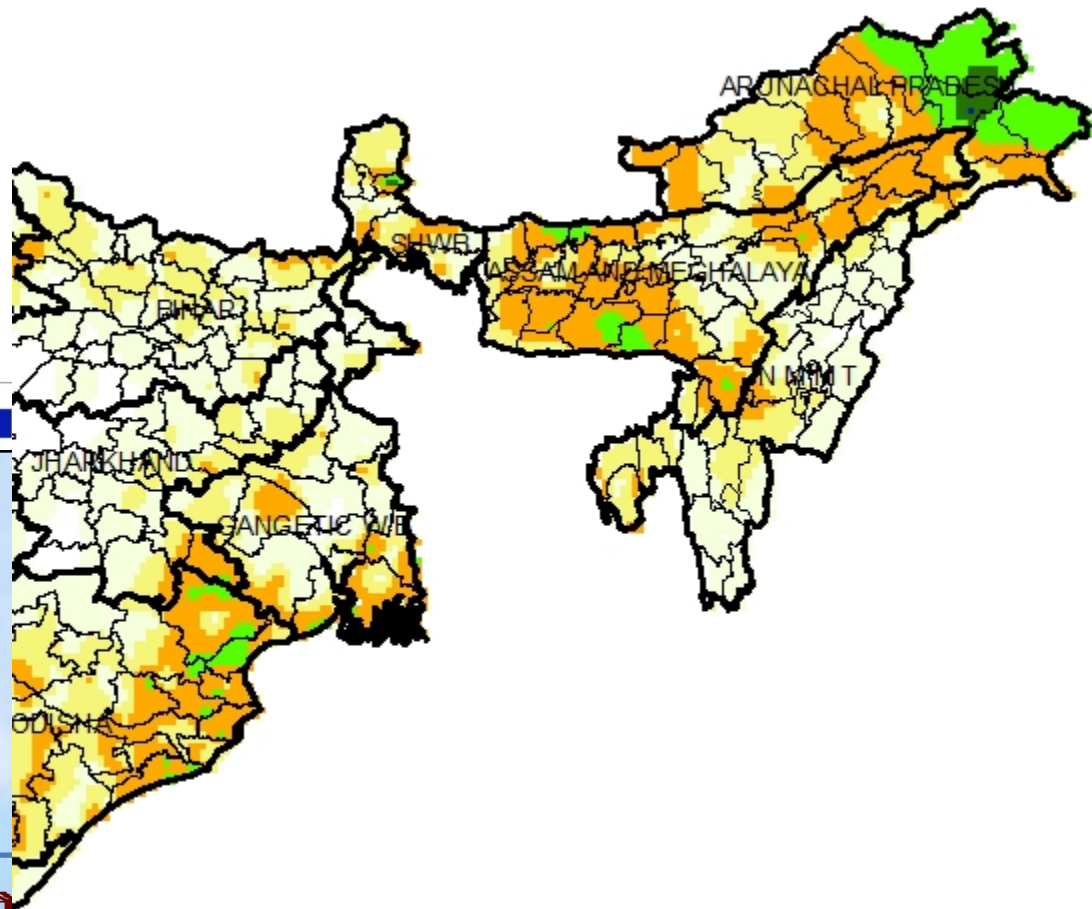
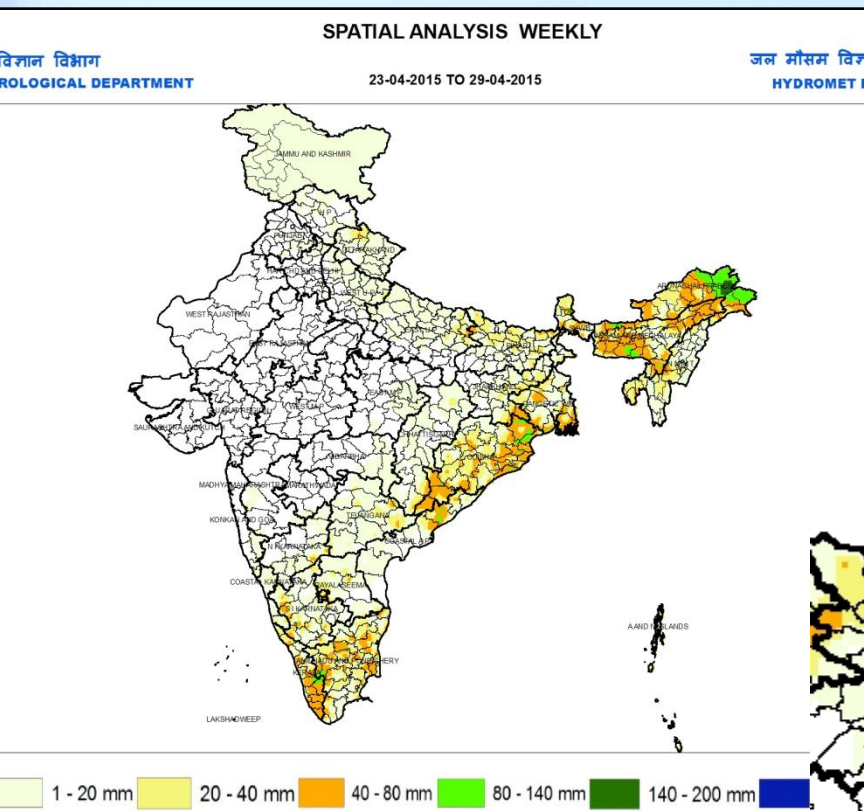
THE DISTRICT-WISE RAINFALL STATISTICS IS HELPFUL TO FARMERS FOR THEIR AGRICULTURAL ACTIVITIES.



RIVER BASIN-WISE SPATIAL ANALYSIS OF OBSERVED RAINFALL IS USEFUL FOR FLOOD FORECASTING AND WATER RESOURCE MANAGEMENT

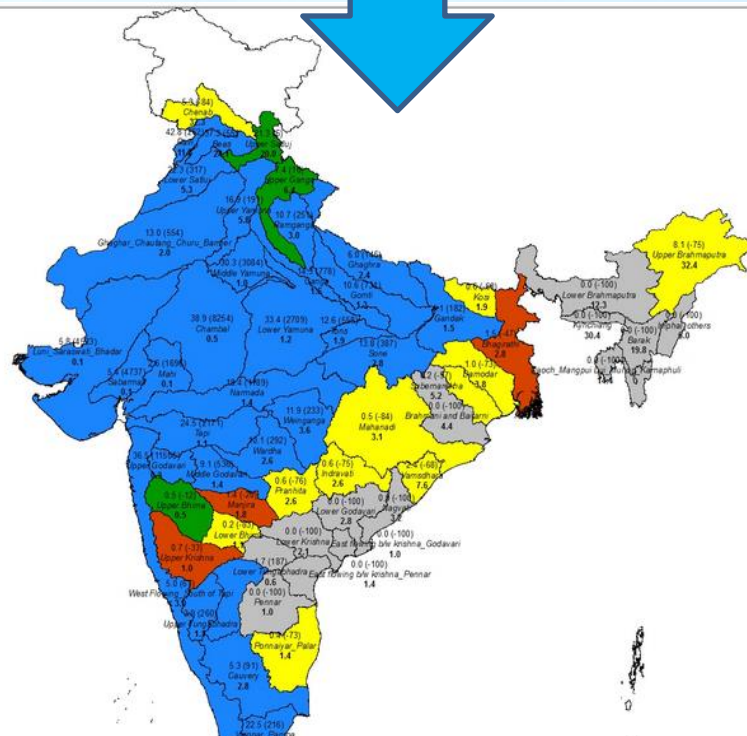


SPATIAL DISTRIBUTION



Products on CRIS (River Basin wise information)

Computation of River basin wise rainfall statistics(actual, normal & % dep.) which is useful for flood forecasting and Water Resources management



Legend :

Excess [20% or more] Normal [-19% to 19%] Deficient [-59% to -20%] Scanty [-99% to -60%] No Rain [-100%] NO DATA

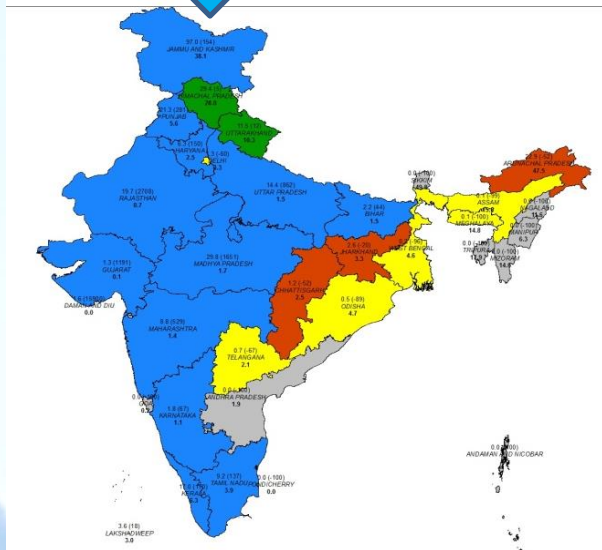
NOTES :

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT



Products on CRIS

State-wise Rainfall map



Customized Rainfall Information System (CRIS)

Hydromet Division

India Meteorological Department

Ministry Of Earth Sciences

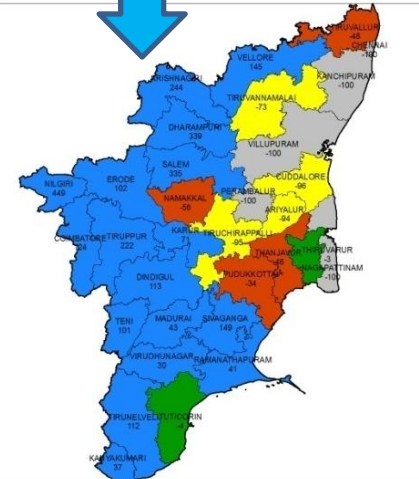
New Delhi-110 003

STATE WISE RAINFALL MAP

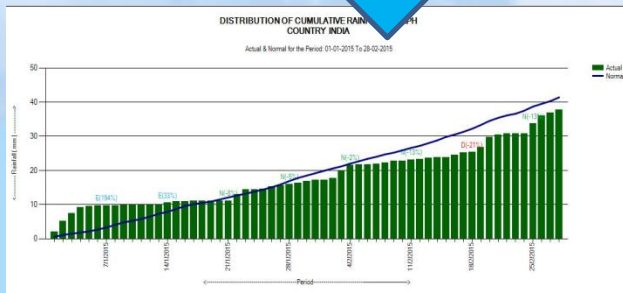
Select State --Select--

- Select--
- ANDAMAN & NICOBAR
- ANDHRA PRADESH
- ARUNACHAL PRADESH
- ASSAM
- BIHAR
- CHANDIGARH
- CHHATTISGARH
- DADAR & NAGAR HAVELI
- DAMAN & DIU
- DELHI
- GOA
- GUJARAT
- HARYANA
- HIMACHAL PRADESH
- JAMMU AND KASHMIR
- JHARKHAND
- KARNATAKA
- KERALA
- LAKSHADWEEP

District wise rainfall map for a State (Available for all states)



Cumulative Rainfall distribution. Useful for real time rainfall information



मौसम विज्ञान विभाग
METEOROLOGICAL DEPARTMENT

Legend :

Excess [20% or more] Normal [-19% to 19%] Deficient [-59% to -20%] Scanty [-99% to -60%] No Rain [-100%] NO DATA

NOTES :

Products on CRIS

WEEK-BY-WEEK DEPARTURES OF RAINFALL FROM NORMAL HELP VARIOUS STAKE HOLDERS (LIKE GOVT. AGENCIES, FLOOD AND DROUGHT MITIGATING AGENCIES, INSURANCE AGENCIES ETC.) FOR ESTIMATING DROUGHT AND FLOOD CONDITIONS IN THE COUNTRY.

Customized Rainfall Information System (CRIS)
Cumulative Rainfall Real Time Station Data (ARG/AWS) Dated: 04-03-2015 and Time:03:00 UTC



India Meteorological Department
Hydromet Division, New Delhi

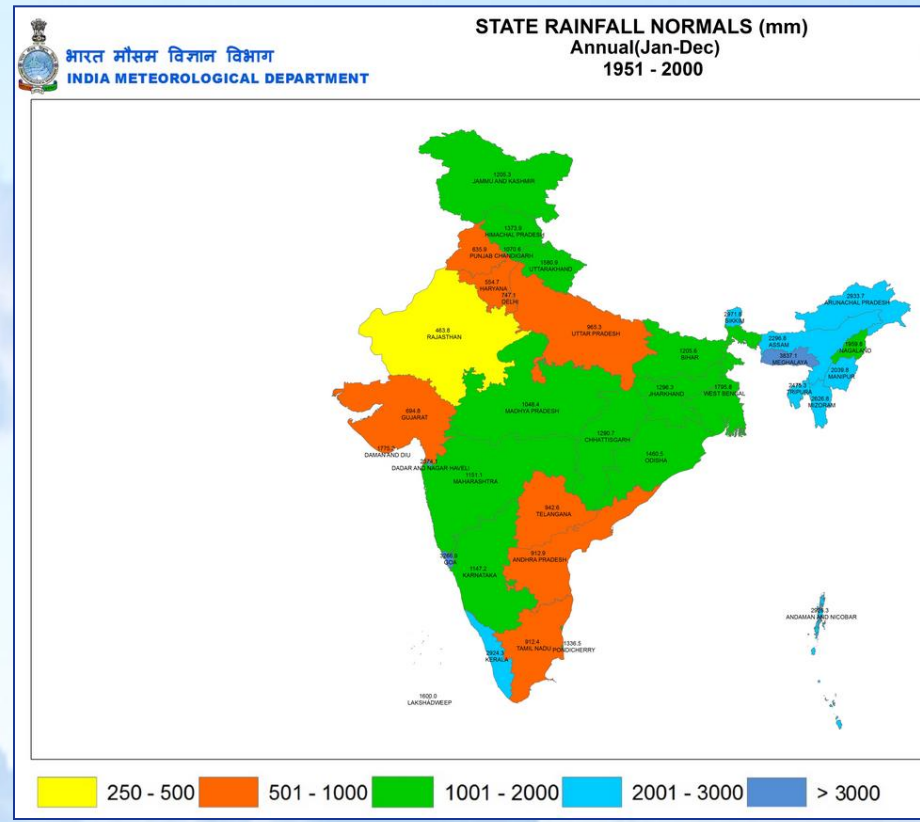
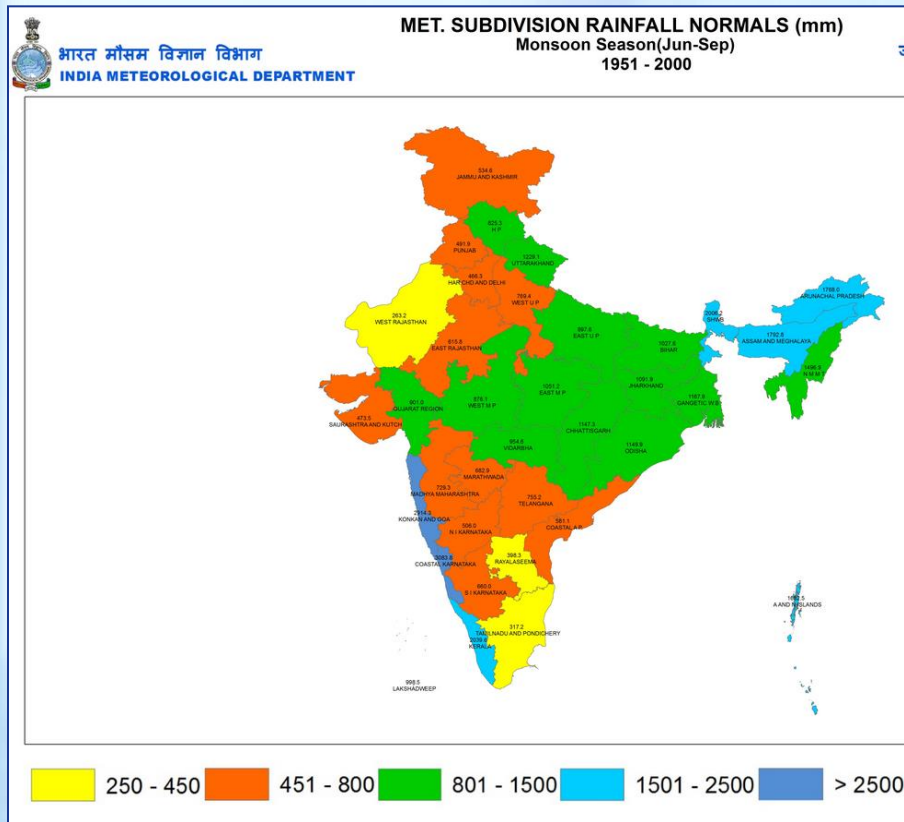
SUBDIVISION - WEEK BY WEEK DEPARTURES
Period :01-01-2015 To 25-02-2015

S NO.	MET SUBDIVISION	Week End 7-1-2015	Week End 14-1-2015	Week End 21-1-2015	Week End 28-1-2015	Week End 4-2-2015	Week End 11-2-2015	Week End 18-2-2015	Week End 25-2-2015
1	N M M T	221	9	-47	-100	-100	-100	-44	3
2	VIDARSHA	909	-100	-100	-100	-100	49	-21	-72
3	WEST MADHYA PRADESH	1314	-99	-99	392	-94	187	-66	-100
4	RAYALASEEMA	92	-100	-99	-100	-100	-100	-100	-100
5	TAMILNADU & PONDICHERY	72	-99	-100	-43	-97	-94	-98	-100
6	BIHAR	350	-100	-99	-32	-81	-100	-75	-64
7	MARATHWADA	1302	-100	-100	-100	-100	55	-100	-100
8	N. I. KARNATAKA	479	-100	-100	-100	-100	-100	-100	-100
9	S. I. KARNATAKA	382	-100	-62	-100	-100	-100	-99	-86
10	ASSAM & MEGHALAYA	172	-67	-80	-100	-85	-100	-66	-64
11	GANGETIC WEST BENGAL	268	-95	-100	-100	-97	-100	6	-49
12	JHARKHAND	213	-100	-100	-75	-31	-99	-70	-75
13	SHIBI & SIKKIM	151	-69	-100	-100	-78	-100	-22	-39
14	EAST MADHYA PRADESH	564	-100	-100	71	-17	64	-11	-97
15	CHHATTISGARH	736	-100	-100	-100	-85	-80	-83	-92
16	SAURASHTRA & KUTCH	-67	-100	11608	7478	-100	-100	-100	-100
17	COASTAL ANDHRA PRADESH	-39	-100	-98	-100	-87	-100	-91	-98
18	ARUNACHAL PRADESH	3	-88	-100	-97	-36	-94	-62	-80
19	TELANGANA	998	-100	-100	-100	-100	-100	-100	-100
20	LAKSHADWEEP	-100	-70	-100	-90	-99	-100	-100	-100
21	COASTAL KARNATAKA	377	-100	-100	-100	-100	-100	549	266
22	A & N ISLAND	-75	106	1147	-97	-98	-92	-87	-26
23	KONKAN & GOA	1563	-100	-100	-100	-100	-100	-100	-100
24	EAST RAJASTHAN	-83	-99	706	933	-100	-92	-100	-95
25	PUNJAB	-73	9	43	14	20	-100	-67	93
26	UTTARAKHAND	243	-66	-75	-36	3	-100	-63	9
27	WEST RAJASTHAN	-68	-91	192	38	-38	-100	-100	-94
28	HAR. CHD & DELHI	-2	-65	-12	29	-38	-100	-100	-62
29	HIMACHAL PRADESH	-32	-42	6	19	21	-97	-32	139
30	GUJARAT REGION	52	-100	13179	1107	-100	-100	-100	-100
31	JAMMU AND KASHMIR	-97	-77	-35	-36	92	-63	-17	119
32	MADHYA MAHARASHTRA	213	-100	-100	300	-100	510	-100	-100
33	EAST UTTAR PRADESH	541	-100	-98	101	-60	-73	-100	-100
34	WEST UTTAR PRADESH	317	-70	6	100	-89	-80	-100	-97
35	KERALA	-37	-66	-72	-95	-83	-96	-28	-88
36	ODISHA	456	-100	-100	-100	-99	-65	-61	-91

Plotting of Hourly cumulative (daily) AWS/ARG rainfall data on Pan India. Useful for real time rainfall information

RAINFALL NORMAL MAPS

SEASONAL & ANNUAL NORMAL RAINFALL (1951-2000) MAPS OF STATE, MET SUB DIVISION AND RIVER BASINS





INDIA METEOROLOGICAL DEPARTMENT

Ministry of Earth Sciences
Government of India



Friday, 22 July 2016
10:14 PM IST

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Visitors since 1st June 2016

80 mm, Anantapur 29.6/21.7/0.10 mm, Cuddappah 30.4/24.0/11.00 mm, Kakinada 32.0/26.9/15.10 mm, Kalingapatnam 31.8/27.7/NIL, Kurnool 29.5/23.7/2.70 mm, Machilipatnam 31.7/27.9/NIL,

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