Impact based Forecast for Heavy rainfall: Subjective and Objective approaches

DR RAJENDRA K. JENAMANI
jenamanirk@gmail.com
Head, RSMC
National Weather Forecasting Center(NWFC)
IMD, New Delhi

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Objective

➢ **Heavy rainfall- Event , Hazard and Impact (Primary and secondary types classification)**

➢ **Towards Computing Vulnerability and Exposure**

• **Static data from various sources upto districts and sub-city scale**

• **Preparation of MH color coded Risk based Warning(Risk types and Occurrence probability)**

➢ **Four stages of Development(Threshold method, Qualitative combination method, Impact modelling method and Climate- sensitivity method)**

➢ **Real time IBF adopted by IMD in monsoon 2019-2021 at Met Sub-division wise and district scale, City based** and Skill of IBF in monsoon

➢ **Issues and Challenges**
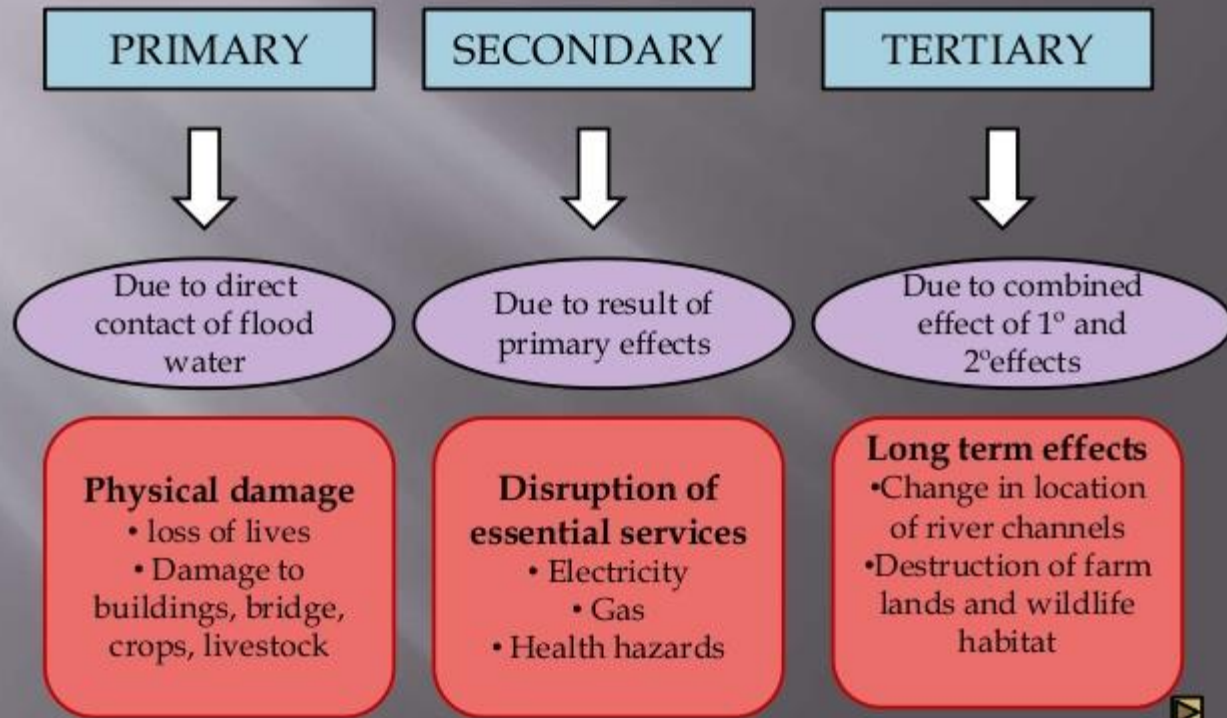
Hazards classification(Primary): Heavy rainfall

➢ **Floods:**

- **Pluvial (Surface Flood)/Flash flooding(especially Urban flooding)**

- **Costal flooding(low tide/high tide and rainfall epochs)**

- **Riverine flooding**

➢ **Land slide and Land sink**

➢ **Dam burst**

Heavy rainfall Impact classification: Hazard-Flood

Methodology

- **Threshold method:** Define a forecast threshold at which people or infrastructure in a specific location are expected to be negatively impacted, based on the vulnerability of that location/infrastructure. **Data required-**At least one historical event, or simulations, to identify magnitude of hazard impact.

- **Qualitative combination method:** In addition to threshold method, a generalized impact is developed for each severe weather type through consensus among the forecasters based on subjective assessment of potential impacts corresponding to weather warning threshold. **Daily VC**

- **Impact modeling method:** Develop a model that combines hazard magnitude with vulnerability and exposure to predict a level of impact. **Data required-**Historical hazard and impact data as well as data on the relationships between them to improve the model

- **Climate- sensitivity method:** Using a combination of socio-economic baseline data and climate data, identify areas where vulnerability is most closely correlated with forecastable climate risks. **Data required:** Baseline socioeconomic data, livelihood zones & climatology

Progress in IMD and other MoES Institutions for Heavy Rainfall-IBF and Risk based warning

➢ **Heavy rainfall- Event and Hazard Data**

➢ **Hazard, Exposure and Vulnerability for preparing color coded Impact and Risk based Warning**

➢ **Four stages of Development(Threshold method, Qualitative combination method, Impact modelling method and Climate- sensitivity method)**

Definition and Terminology

Daily Rainfall (intensity of Rainfall- 24-hours)

Descriptive Term used	Rainfall amount in mms	Rainfall in cm
Very light Rain	Trace-2.4	-
Light Rain	2.5-15.5	Upto 1cm
Moderate Rain	15.6-64.4	02-06
Heavy Rain	64.5-115.5	7-11
Very Heavy Rain	115.6-204.4	12-21
Extremely Heavy Rain	>204.4	21cm or more
Exceptionally Heavy Rain	When the amount is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm.	

Spell-Intensity of Rainfall-(1-Hour)

Intensity/Hour	Rainfall statistics of occurrences	Rain rate range
Light Spell	Upto 50th percentile	Rainfall up to 1 cm/hour
Moderate Spell	Upto 80th percentile	Rainfall up to 1-2 cm/hour
Intense Spell	90th percentile	Rainfall 2-3 cm/hour
Very Intense Spell	99.9th percentile	Rainfall 3-5 cm/hour
Extremely intense Spell	>99.99th percentile	Rainfall 5-10 cm/hour
Cloud Burst	-	Rainfall>10cm/hours

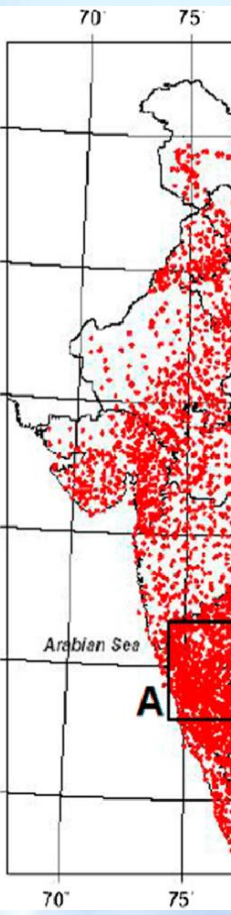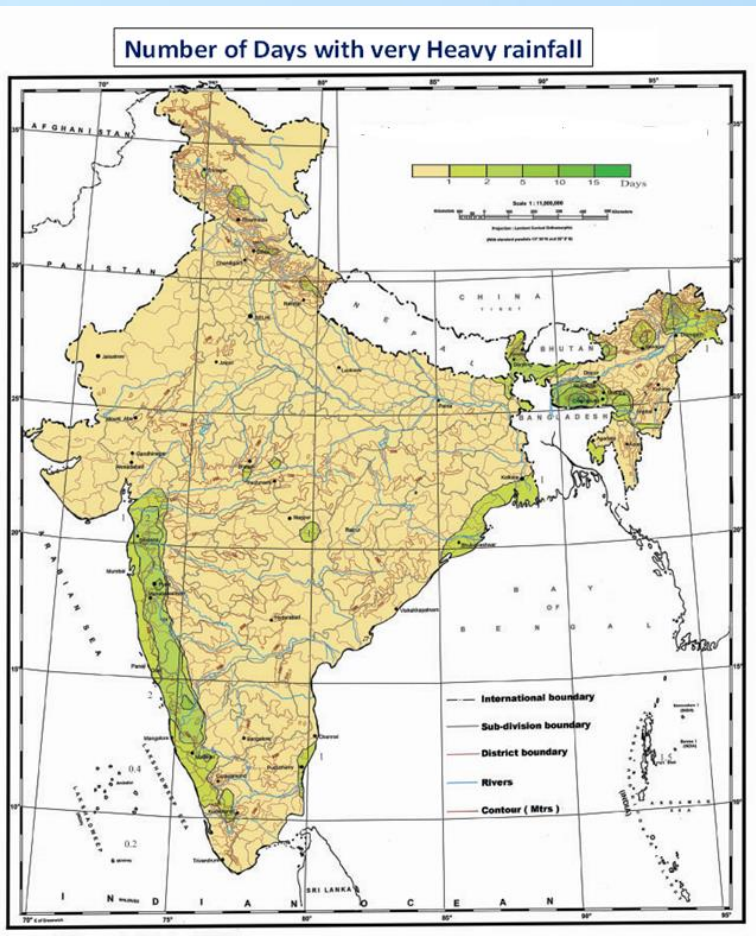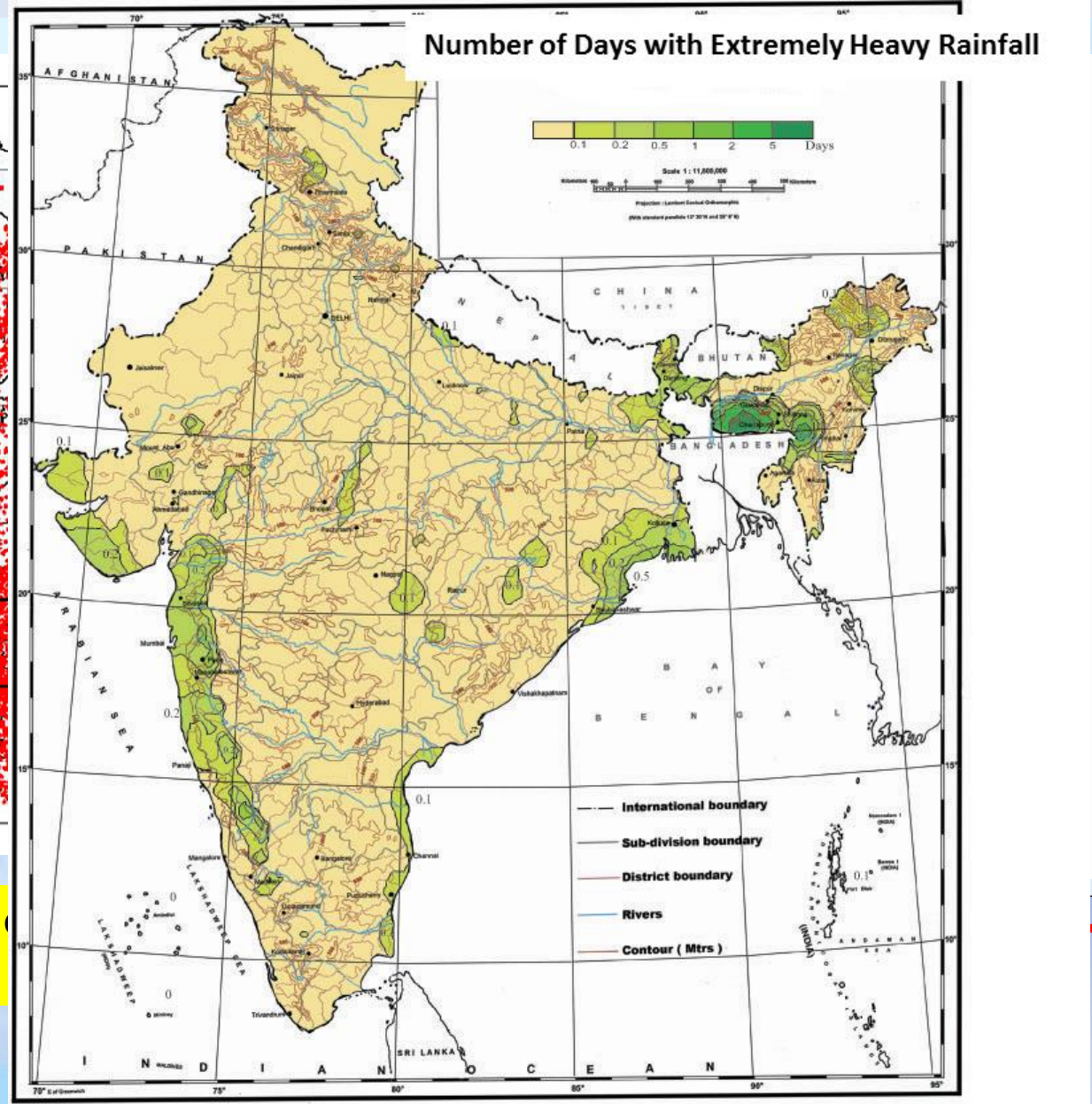## Forecasts for spatial distribution over Met-Sub-division/district

Distribution	No. of Places	Description
Isolated	one or two places	<25% of stations gets rainfall
Scattered	At a few places	(26-50)% of stations gets rainfall
Fairly Widespread	At many places	(51-75)% of stations gets rainfall
Wide spread	at most place	(76-100)% of stations gets rainfall

Probability forecasts of rainfall or weather

Term	Probability
Unlikely	probability of occurrence less than 25%
Likely	Probability of occurrence between 25 & 50%
Very likely	Probability of occurrence between 51% & 75 %
Most likely	probability of occurrence between 51% & 75 %

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Location of gauges

Number of Days with Extremely Heavy Rainfall

0.1 0.2 0.5 1 2 5 Days

Scale 1 : 11,000,000

- International boundary
- Sub-division boundary
- District boundary
- Rivers
- Contour (Mtrs)

of Himalaya and along central parts of the country.

Number of Days with very Heavy rainfall

1 2 5 10 15 Days

Scale 1 : 11,000,000

- International boundary
- Sub-division boundary
- District boundary
- Rivers
- Contour (Mtrs)

- **Frequencies are highest in ARPR, Assam, Meghalaya, SHWB and Sikkim, HP, Uttarakhand east coast, south Chhattisgarh, and West Coast of India**

INDIA METEOROLOGICAL DEPARTMENT

Cloudburst

- **Extreme amount of rainfall realized in very short period of time**
- **IMD criteria-Any Precipitation event exceeding 100mm/h**
- **Frequencies over India**
- ➢ **Highest in and around the southern rim of the Indian Himalayas especially over Uttarakhand, HP and northeastern hill states**
- ➢ **Westcoast over windward side Western Ghats Hills from Goa to Saurashtra**
- *Areas vulnerable over western Himalayas*
- ➢ At between elevation range of 1000 m and 2500 m occurred within a small geographic area of 20-30 km
- ➢ 30 cloud burst events have occurred over the southern rim of the Himalayas during 1970-2016, and around 17 cloud burst events among them occurred in Garhwal region of Uttarakhand
- ➢ **Droplet size ranges from ~4 – 6 mm with fall speed of ~10 m/s**
- **Possible causes**
- ➢ **Orographic architecture of the mountain regions**
- ➢ **Monsoonal moist laden winds at lower levels from southeast/east towards the hills, coupled with vertical shear in wind and orographic uplifting leading to intensely precipitating convective systems**

Occurrences of CB events 1969-2015 –IMD SRG/ARG data

Cloudburst Occurrences: Lack of rainfall data and observing system
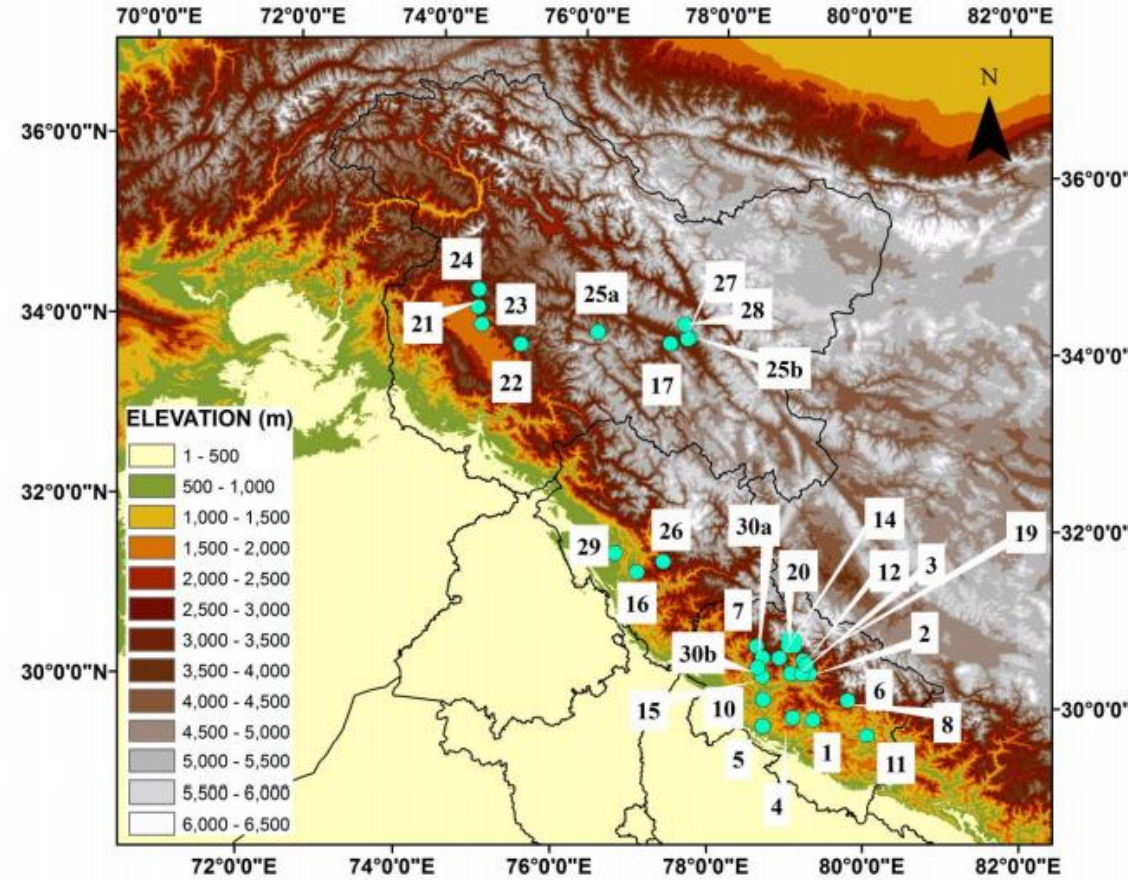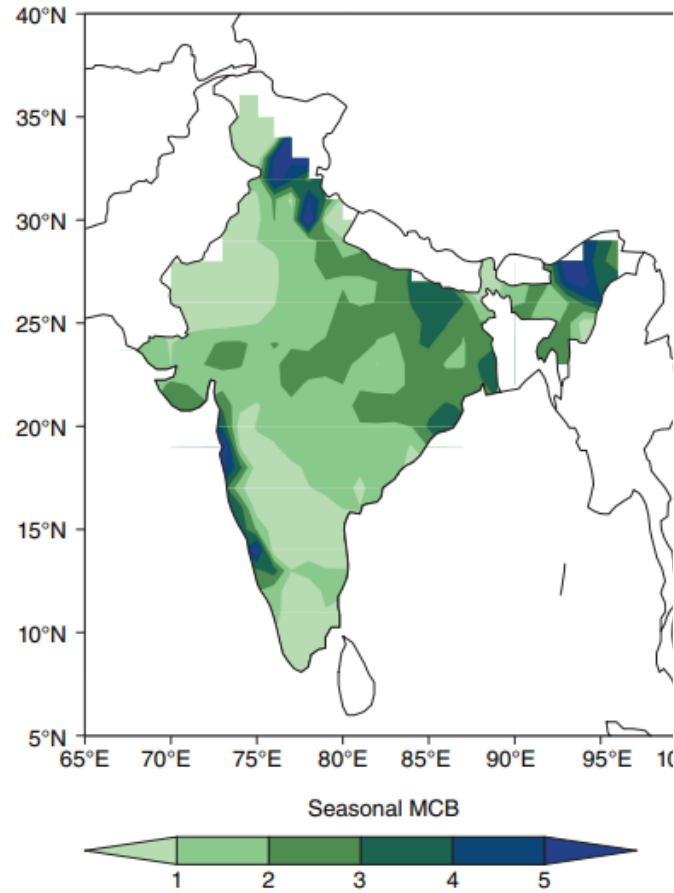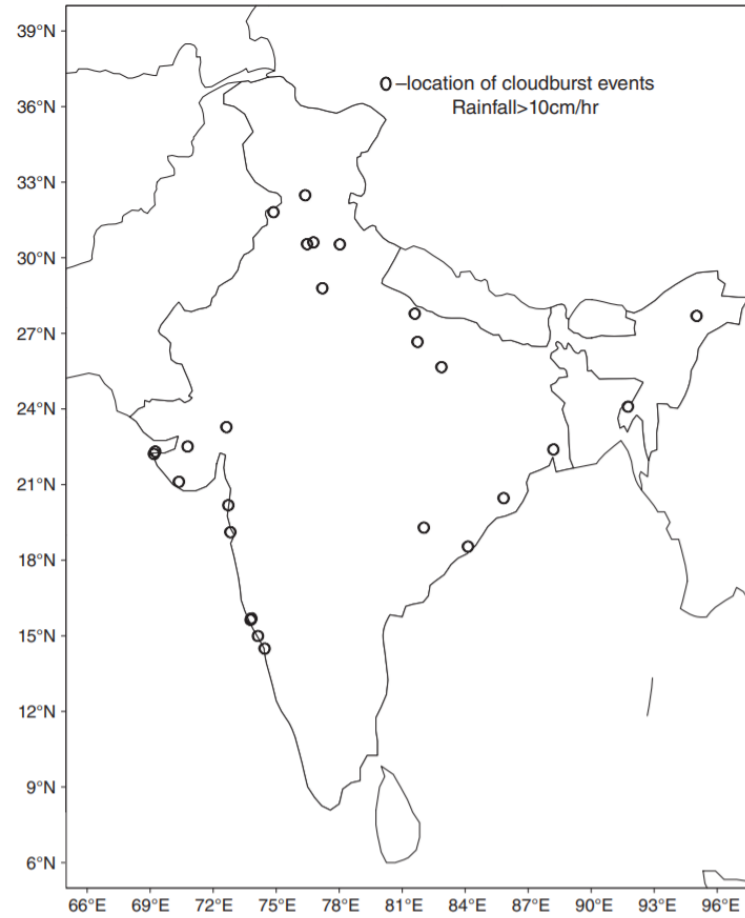
Totally 28 Cbs as per IMD criteria

Rainfall of 3-5 cm per hour in the steep slope mountainous regions of Himalayas. May cause flash flood, land slides, debris flow, flash floods with huge damages to properties and human losses, irrespective of the rainfall amount.

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Highest one- day rainfall-in-24-hours- Over India as per IMD data till

	Station	State	1-day rainfall in cm	Date of occurrence
1	Cherrapunji Obsy	Meghalaya	156.3	16-Jun-1995
2	Amini Divi	Lakshadeep	116.8	6-May-2004
3	Cherrapunji	Meghalaya	103.6	14-Jun-1876
4	Ambarnath	Maharashtra	101.0	27-Jul-2005
5	Cherrapunji	Meghalaya	99.8	12-Jul-1910
6	Mausynram	Meghalaya	99	10-Jul-1952
7	Dharampur	Gujarat		
8	Cherrapunji	Meghalaya		
9	Mawsynram	Meghalaya		
10	Tamenlong	Manipur		
11	Cherrapunji	Meghalaya		
12	Mawsynram	Meghalaya		
13	Mumbai	Maharashtra		
14	Tamenlong	Manipur		
15	Cherrapunji	Meghalaya		
16	Guna	Madhya Pradesh		
17	Cherrapunji	Meghalaya		
18	Cherrapunji	Meghalaya		

| Rainfall (cm)	Station and country	Date
World		
184.1	Cilaos, Reunion Island	15–16 March 1952
179.6	Foc Foc, Reunion Island	7–8 January 1966
166.2	Belouvc, Reunion Island	27–28 February 1964
155.2	Aurere, Reunion Island	7–8 April 1958
137.8	Muuocaicang, Nei Mouggol China	1–2 August 1977
122.8	Paishih, Taiwan	10–11 September 1963
117.5	Halaho, Taiwan	9–10 September 1963
116.8	Amini Devi, India	5–6 May 2004
115.0	Bagerio, the Philippines	14–15 July 1911
112.3	Belledenker QLD, Australia	3–4 January 1979

Major High impact rainfall event leading to flood/flash flood/land slide leading to huge lives/property losses and disruption of services in 2005-2021

- **Mumbai Unusual Extreme Rainfall event 26-27 July 2005 -94-115cm(21 cm in an hour 1430-1530IST). 400 people lost their lives**

- Leh cloud burst (1.3 cm far station recorded) on 6 August, 2010 leading to flash flood and mud slides leading to over **200 deaths**

- The Uttarakhand 14-17 June 2013 Event- (with cumulative 12-35cm over the Kedarnath area with other down side of 30-45cm and Dehradun - 60cm), devastating flash flood and series of landslides triggered **killed around 6000 people made 100,000 people stranded.**

- 30 July 2014, Malin was hit by mud flow/land slide early in the morning while residents were asleep and it was caused by a burst of heavy rainfall, and killed at least 134 people.

- Kashmiri extreme Rain event 3-7 Sept 2014- with cumulative <u>30 to 61cm in 3 to 4 days </u>with worst effect at capital town of Srinagar. Around **250 lives lost** with evacuation of 250,000 people

- Chennai 1-2 Dec 20-15 Extreme rainfall event -**(34.5 cm at Chennai Airport with 49.4cm at Tambram)**- more than 500 people were killed

- Kerala 14-16 Aug 2018 Extreme rains and Floods -25-35cm with cumulative 60-70cm by which 483 people died

- West Coast flood during different period of 1-12 Aug 2019: A Series of extreme rainfall events hit west coast of India covering Kerala, Karnataka, Maharashtra and Gujarat and caused huge losses to lives and property (around 200 people lost their lives 200 people (30-50cm per day have been reported)

- Monsoon 2020 - **Example-Extremely heavy rainfall spell over Maharashtra, Karnataka, Kerala and adjoining Tamil Nadu during 4-8 August 2020 -Kerala Munnar landslide and Kodagu landslides**

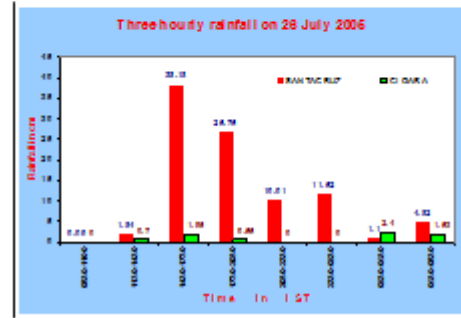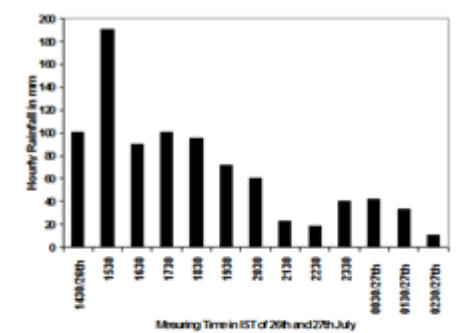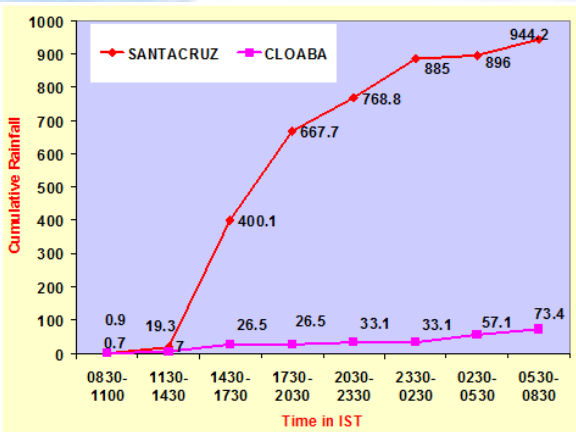- Monsoon 2021-Maharshtra flood -<u>Death toll 228, highest in Raigad with 95</u>
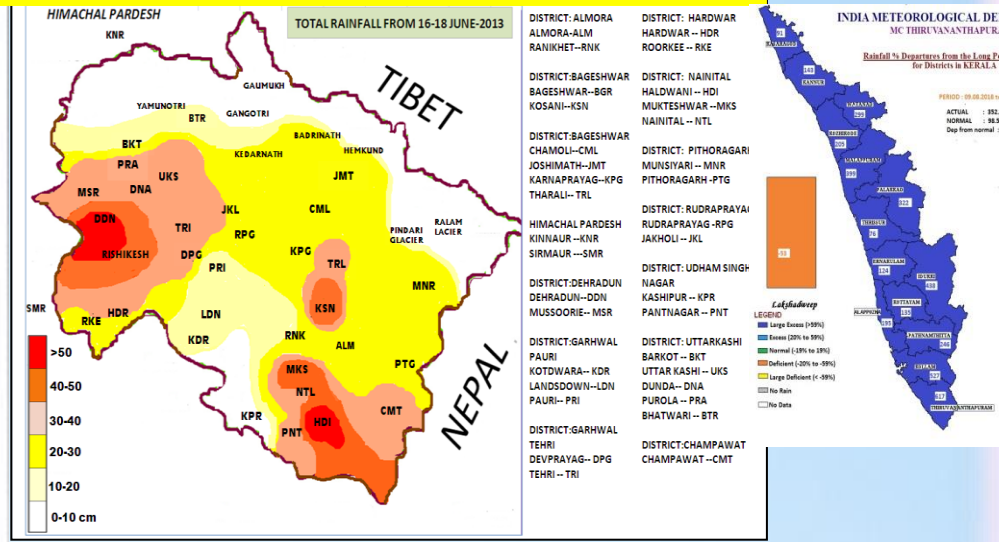
Jenamani RK, 2015, *INTORMET 2014 Chennai*

Jenamani RK, 2006, *Current Science Vol. 90, No. 10 (25 May 2006), pp. 1344-1362*

➢ **Spatially can occurred at very meso-scale at 10km by 10km with amount upto 40cm in 3-h and 20cm in an hour as was in central Mumbai**

➢ **Rainfall of 3-5 cm per hour in the steep slope mountainous regions of Himalayas. May cause flash flood, land slides, debris flow, flash floods with huge damages to properties and human losses, irrespective of the rainfall amount.**

➢ **Heavy rain for longer period like Kerala 2018 and 2019 can have huge impact**

INDIA METEOROLOGICAL DEPARTMENT

Impact

- Flash Flood and Riverine flood
- Urban Flash Flood and Flash flood over Hilly areas with steep topography
- landslides and debris flow
- Local Inundation, Road and Traffic disruption
- Agriculture
- Infrastructural Damage-Houses, roads, Airport, Hospitals, City center
- Emergency Services gets affected- Electricity, Phone/Internet and water
- Socio- economic Impact like- Human lives and health and Livestock
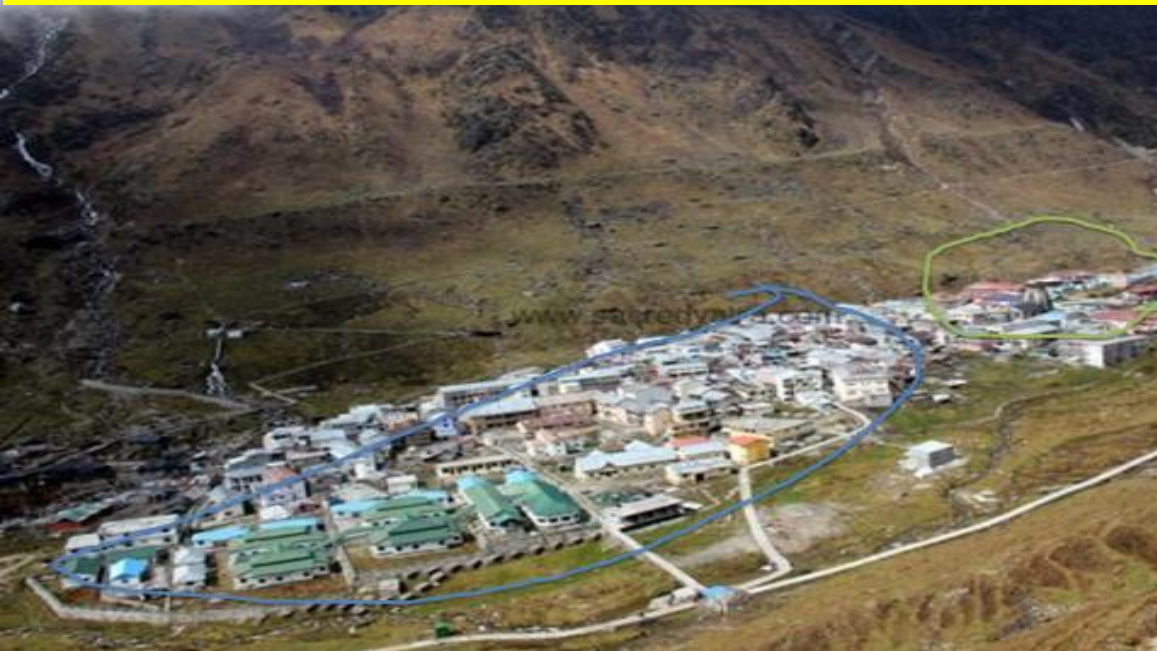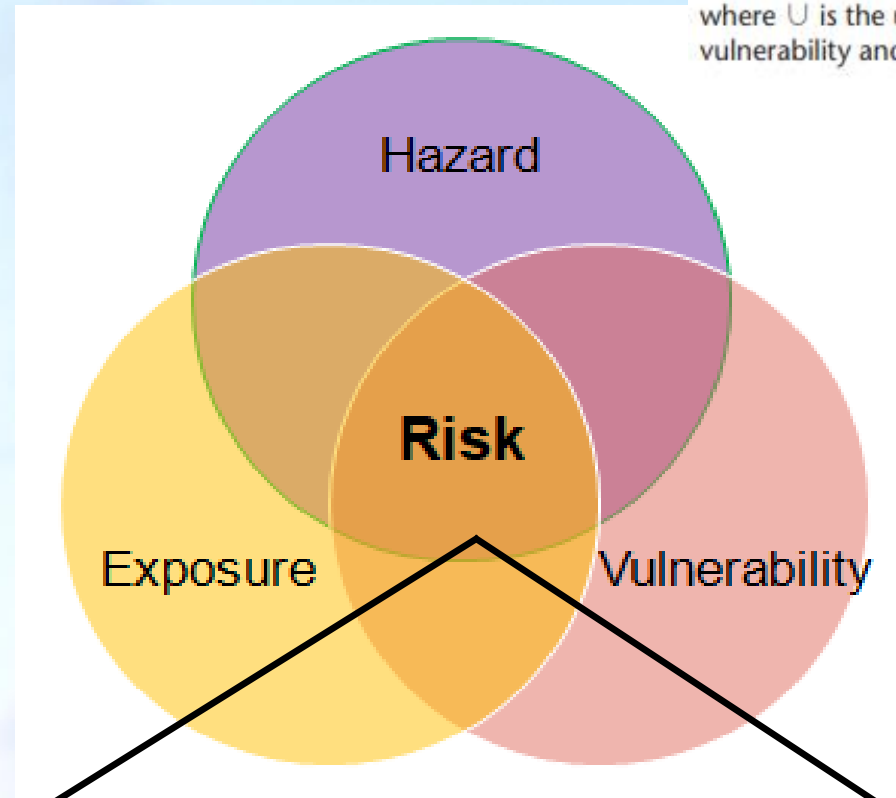
Impact of Urban Heavy rain spell/Extreme rainfall event

INDIA METEOROLOGICAL DEPARTMENT
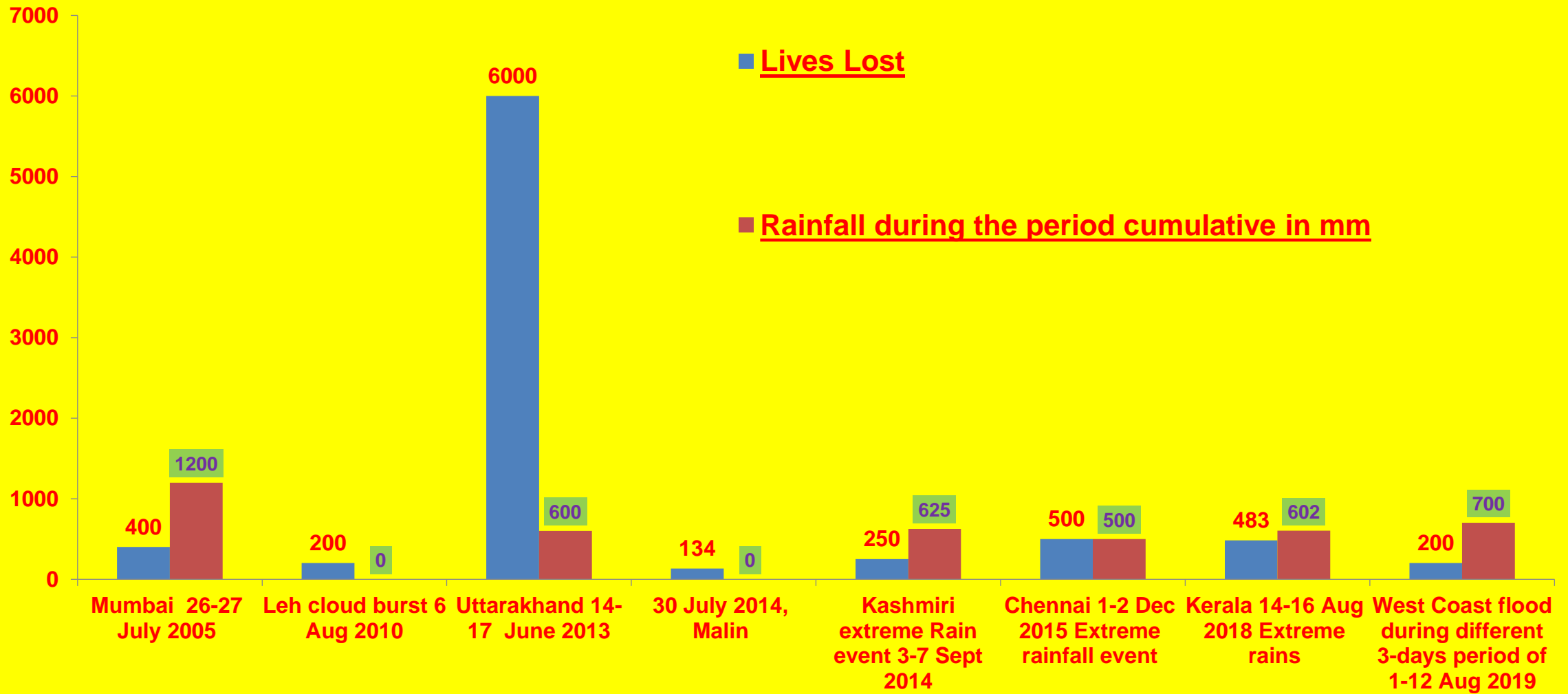
Risk Assessment

Risk may be mathematically expressed as:

$$|\text{Risk of impact } (x, t)|$$
$$\equiv |\text{hazard } (x, t)| \cup |\text{vulnerability } (x, t)| \cup |\text{exposure } (x, t)|$$

where $\cup$ is the union of the level of hydrometeorological forecast uncertainty, the degree of vulnerability and the level of exposure. Risks:

Subjective

Climatological/past impact and discuss impact with stakeholders

Objective

Impact models using vulnerability & exposure data set and meteorological information

⚠ Not secure | bmtpc.org/topics.aspx?mid=56&Mid1=178

New Initiatives : Emerging Technologies
≫ Multi-Attributes Evaluation Methodology for Emerging Housing Technologies
≫ Compendium of Prospective Emerging Technologies for Mass Housing-3rd Ed.
≫ Construction & Demolition Waste – a Ready Reckoner

E-Course on Vulnerability Atlas of India   NEW...Launch of NAVARITIH : Certificate

Home > Areas of work > Disaster mitigation and management > Hazard Maps of India

Vulnerability Atlas of India - 3rd Edition	
Hazard Maps of India	
Initiatives for Disaster Preparedness, Mitigation and Management	❖ **Earthquake Hazard Map**
Landslide Hazard Zonation Map of India	❖ **Wind Hazard Map**
Earthquake Hazard Guidelines	
Wind and Cyclone Hazard Guidelines	❖ **Flood Hazard Map**
Flood Hazard Guidelines	
Earthquake Tips	

INDIA
Flood Hazard Map

0 100 200 300 400 500 km

Total No. of Houses : 33,08,35,767*
Population : 1,21,08,54,977

Town/City
River
Area liable to Floods
( ) Probable Maximum Surge Height (m)

UTTARAKHAND
Landslide Incidence Map
(with Annual State Rainfall Normals)

0 20 40 60 80 100 km

Total No. of Houses : 33,83,410*
Population : 1,00,86,292

Town/City
Landslide
National Highway
Railway Line
State Boundary
District Boundary

Annual Rainfall Normals (mm)

12) Colour code for Warning Advisories:

The committee recommends the following colour codes for warning advisories.

WARNING (TAKE ACTION)
ALERT (BE PREPARED)
WATCH (BE UPDATED)
NO WARNING (NO ACTION)

In order to decide upon the colour to be assigned to a given weather forecast situation under the 5-day forecast scheme, we may follow the following matrix, giving thrust on the probability of occurrence of the event as well as its impact assessment.

MO : Port Blair
CR&S Pune/ CATC Bamarauli

Forecasting Circular No. 1/2018
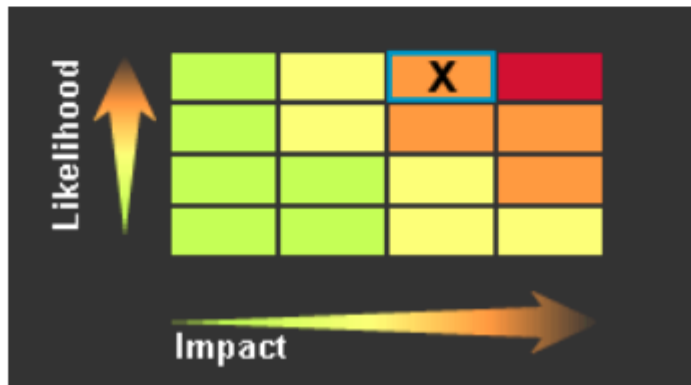
Annexure-I

Colour coding of Heavy Rainfall Warning

| Category	Colour Coding
Extremely Heavy Rainfall	Red
Scattered heavy to very heavy	Red
Isolated heavy to very heavy (consecutively for 3 days)	Red on 3rd day
Heavy to very heavy rainfall observed at least for 2 days and is expected again.	Red (on day 1)
Isolated heavy to very heavy (for consecutive 2 days)	Orange (on 2nd day)
Isolated/scattered heavy rainfall/Isolated heavy to very heavy rainfall	Yellow (on day 1)
If it is already flood situation and heavy rainfall is expected.	Orange/red
No heavy rainfall	Green

Note : This is a general guideline. Considering the location and the day and period of occurrence, the impact may be different. Hence, concerned MC/RMC may decide the colour code accordingly.

Development of an Impact based Forecast System in India through four stages

Stage-I and II (Threshold method and Qualitative combination method)

- Stage I
- Develop a generalized impact for each severe weather type through consensus among the forecasters based on subjective assessment of potential impacts corresponding to weather warning threshold
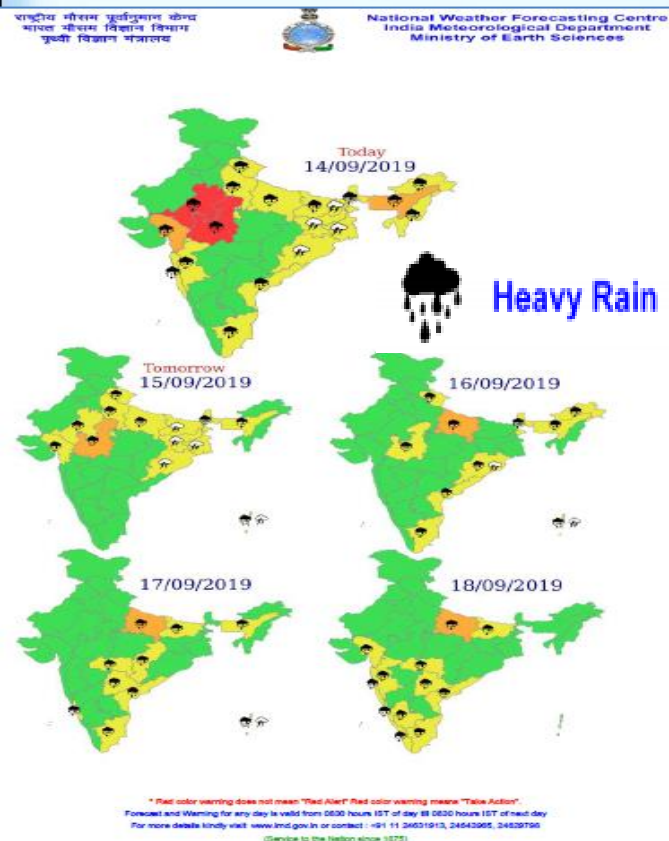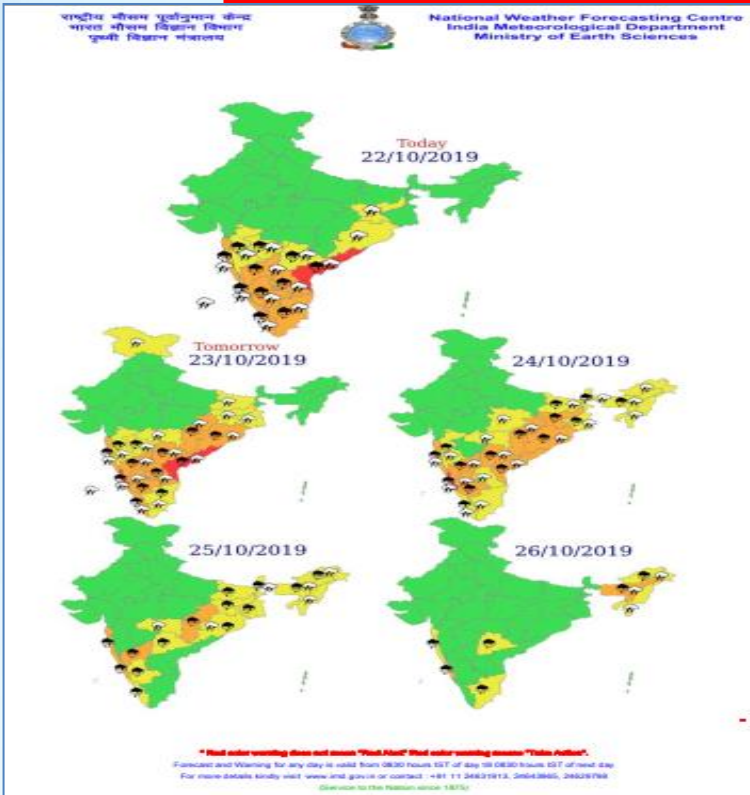

14 September (Day 1):

Heavy to very heavy rainfall with Extremely heavy falls very likely at isolated places over East Rajasthan and Meghalaya; Heavy to very heavy rainfall very likely at isolated places over West Madhya Pradesh, Assam and Gujarat Region and Heavy Rainfall at isolated places over Uttarakhand, Uttar Pradesh, Bihar, Sub-Himalayan West Bengal & Sikkim, Andaman & Nicobar Islands, Arunachal Pradesh, Nagaland, Manipur, Mizoram & Tripura, Madhya Maharashtra, Konkan & Goa, Coastal Andhra Pradesh and Tamilnadu, Puducherry & Karaikal.

- Generalised Impact information in terms of inundation, traffic jam etc for red colour warning two days in advance.
- Commenced in 2019 monsoon season

INDIA METEOROLOGICAL DEPARTMENT

Example : heavy rainfall-Monsoon 2019-Stage I and Stage II

22 October (Day 1)

Heavy to very heavy rainfall with extremely heavy falls at isolated places very likely over Coastal Andhra Pradesh & Yanam; **Heavy to very heavy rainfall** at a few places over Coastal Karnataka; at isolated places over Konkan & Goa, Rayalaseema, Interior Karnataka, Kerala & Mahe, Tamilnadu, Puducherry & Karaikal and **Heavy Rainfall** at isolated places over Madhya Maharashtra, Marathwada and Telangana.

Met. Sub-Divisions with 'Red color' warnings		Expected impact corresponding to "Red color" warning
22.10.19	Coastal Andhra Pradesh& Yanam	• Localized Flooding of roads, water logging in low lying areas and closure of underpasses.
23.10.19	Coastal Andhra Pradesh& Yanam and Coastal Karnataka	• Occasional reduction in visibility due to heavy rainfall. • Disruption of traffic flow in major cities due to water logging in roads leading to increased travel time.
24.10.19	Coastal Karnataka	• Minor damage to Kutch roads. • Possibilities of damage to vulnerable structure • Localized Mudslides.
25.10.19	Nil	• Damage to horticulture crops
26.10.19	Nil	

Stage III and IV-Monsoon 2020

➢ **IBF for 25 cities implemented in monsoon 2020 started Exposure and Vulnerability data collected for computing and assigning color code for Risk based matrix**

➢ **District-wise vulnerability also addressed**

➤IMD guidelines 2020

- **Monsoon 2020**
- ❑ **Met sub-division wise and district wise implemented for all major rainfall events**
- ❑ **In June 2020: SOP for Four stage IBF Heavy rainfall warning system implemented for 25 cities and at district levels.**
- ✓ **It is upto sub-city level at 5-days lead period (Guidance, Alert and Warning)-Mumbai , Jaipur, Bhopal, Hyderabad, Chennai, etc**
- ❑ **Products from Hazard and Impact Models- Implementation of Stage 3 and Stage 4 of IBF Heavy rainfall**
- **I-FLOWS Mumbai and C-FLOWS Chennai implemented- Dynamic model based impact wrt flood hazard covering areas and depth of inundation, types of exposure and vulnerability**
- **FFGS IMD-WMO**
- ❑ **Verification of IBF and Report preparation for Monsoon 2020**

Stage 3 and Stage 4- Adopted in monsoon 2020-What we did?

➢ **Massive socio-economic exposure and vulnerability data collection at city and district scale in progress for various weather related hazards-NWFC/MC level**

➢ **IBF of Heavy Rainfall implemented at 25 capital Cities in monsoon 2020**

• **SOP of four stage EWS was adopted**

▪ **Colour coded for Risk based matrix has been prepared using past rainfall events-vulnerability and past impact data for Mumbai, TRV, BHP and HYD**

▪ **The heavy rainfall intensity, frequencies and duration over a city has been considered for this purpose.**

▪ **Integrated with Hazard details and Impact Scenario as available from**

➢ **Chennai Flood warning system (C-FlOWS) and Mumbai Flood warning system (I-FLOWS) in full use in monsoon 2020 with time to time updates**

▪ **Feed back were shared with NCCR**

➢ **Further works in progress with NCCR, IITM, NCMRWF, WCSSP(INDO-UK Project, Sate Govt, NDMA, RIMES, Agri. Univ., CWC, GSI, Media, Municipal corporations etc**

Mega-city Integrated Flood warning System –A collaboration of stake holder-NCCR-IMD-IITM-NCRMWF-Municipal Authority –C-FLOWS and I-FLOWS for Chennai and Mumbai

South Asia Flash Flood Guidance System

Flash Flood Threat for Mumbai on 9 June 2021 – Rainfall received: 210 mm in 24 hours.

Flash Flood Threat for Odisha on 26 May 2021 – Rainfall received: 300 mm in 24 hours.

Suburban Mumbai

PFFT-06hr 2021-06-09 06:00 UTC

Threat Based Alerts
- Red – High
- Orange – Moderate
- Yellow - Low

Odisha

PFFT-06hr 2021-05-26 00:00 UTC

Threat Based Alerts
- Red – High
- Orange – Moderate
- Yellow - Low

- **30000 watersheds with 4X4 km resolution.**

- **Flash Flood Threat issued for next 6 hours.**

- **Flash Flood Risk is issued up to next 36 hours.**

System put in operations with effect from 23 October 2020.
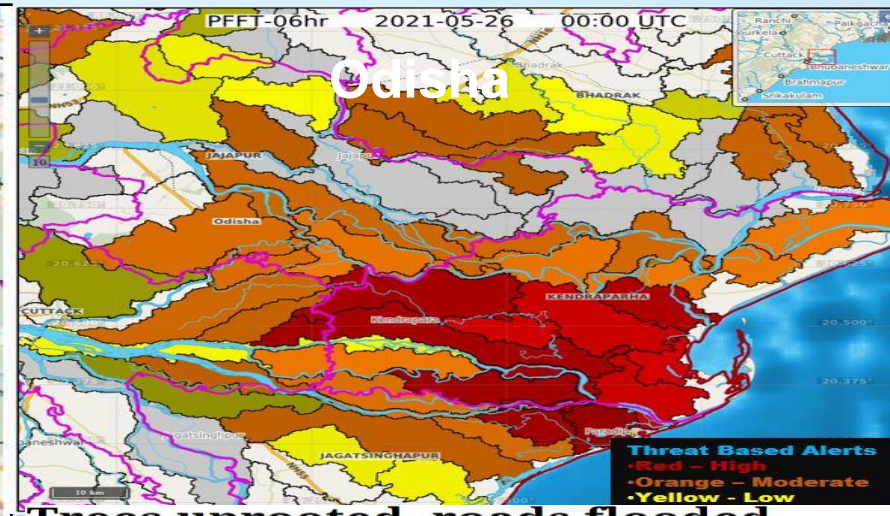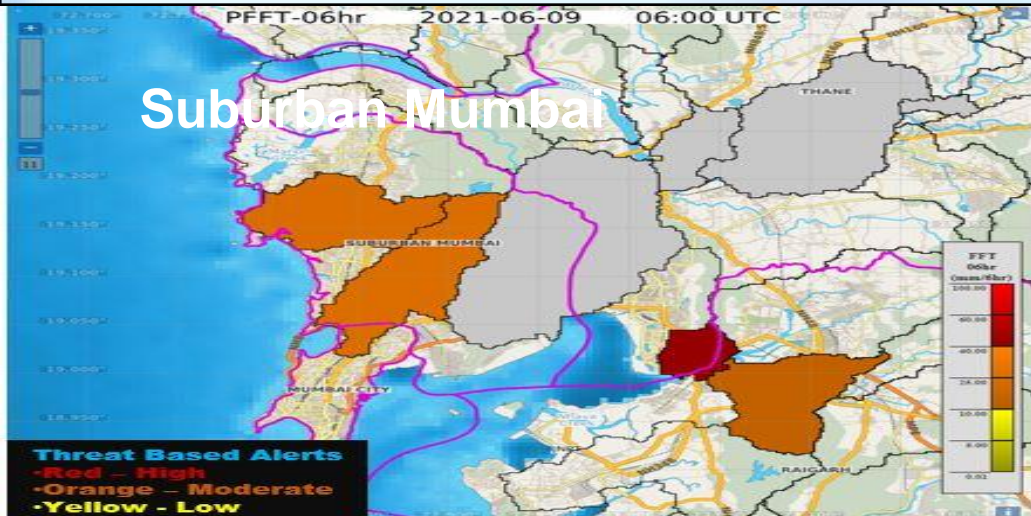
Roads waterlogged, rail services hit as heavy rain lashes Mumbai | See photos, videos

India Today Web Desk
New Delhi
June 9, 2021 UPDATED: June 9, 2021 17:46 IST

INDIA METEO

Trees uprooted, roads flooded, people living in darkness as cyclone Yaas batters Odisha

Officials are yet to assess the damages caused by the storm in the two districts but said that it appears that devastations have been less than previously feared.

Published: 26th May 2021 09:47 PM | Last Updated: 26th May 2021 11:25 PM

Sea surge enters a village in Balasore district during landfall. (Photo | EPS)

By PTI

BALASORE: Trees and electric poles were uprooted, low-lying areas inundated while kutcha houses were badly damaged as Cyclone Yaas left a trail of destruction in Odisha's coastal districts of Balasore and Bhadrak on Wednesday.

Integrated Flood Warning System (i-Flows Mumbai)

Impact Based Forecast(IBF) and warnings

WARNING DAY-1 Sunday , 05 July 2020

WARNING DAY-2 Monday , 06 July 2020

WARNING (TAKE ACTION)
ALERT(BE PREPARED)
WATCH(BE UPDATED)
NO WARNING (NO ACTION)

WARNING DAY-3 Tuesday , 07 July 2020

WARNING DAY-4 Wednesday , 08 July 2020

WARNING DAY-5 Thursday , 09 July 2020

प्रादेशिकमौसमकेंद्र, कोलाबा , मुंबई
Regional Meteorological Centre, Mumbai

Dated: 03 Aug 2020   Time of issue: 1300 hrs IST

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

| Date	03 Aug 2020	04 Aug 2020
Forecast& Warning	Heavy to very heavy rainfall at isolated places	Heavy to very heavy rainfall at a few places with extremely heavy rainfall at isolated places
Impact Expected	• Water logging/ flooding in many parts of low lying area and river banks • Localized and short term disruption to municipal services (water, electricity, etc.) • Major disruption of traffic flow. Major roads/local trains affected. • Possibility of danger to very old buildings and unmaintained structures, falling of trees etc • Closure of roads crossing low water bridges	• Widespread water logging/ flooding in most parts of low lying area and also on river banks. • Major disruption of traffic flow. Major roads/local trains and travel routes • Localized and short term disruption to municipal services (water, electricity, • Possibility of danger to very old and unmaintained structures, falling of trees etc. • Possibility of landslides in elevated hilly areas • Closure of roads crossing low water bridges
Action Suggested	• Traffic may be regulated effectively • People in the affected area may restrict their movement	• Traffic may be regulated effectively • People in the affected area may restrict their movement

COLOR CODES	
Very Low	No action
Low	Be updated
Medium	Be prepared
High	Take Action

IBF & Warning Stages

➢ **Stage -1: Heavy rainfall Watch-(3-4 days lead time daily update)**

➢ **Stage-2: Heavy rainfall Alert: (48 hours prior to the occurrence of event at 12 hourly updates)**

➢ **Stage-3: Heavy rainfall Warning (24 hours prior to the occurrence of event at 06/12-hourly updates)**

➢ **Stage-4: 12-Hours prior to occurrence event–at 3-hourly updates.**
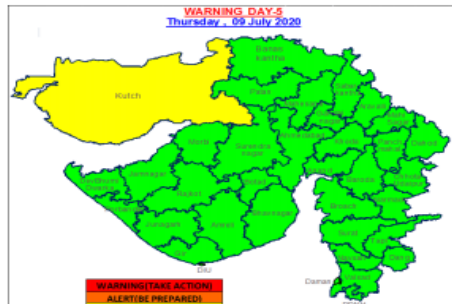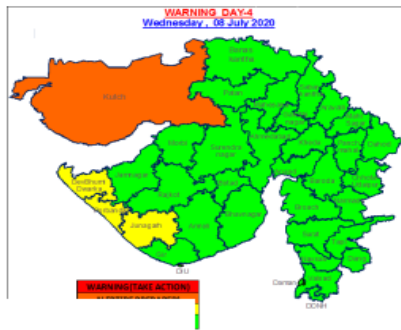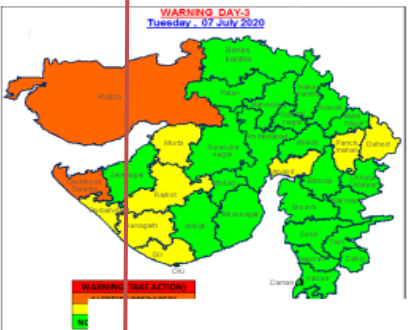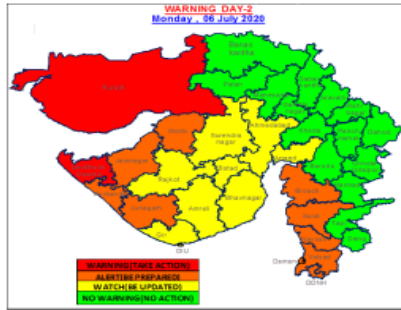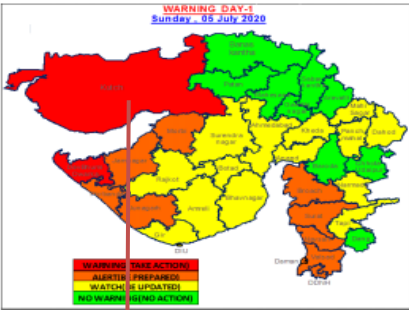
IMPACT BASED FORECAST

Expected Impact with respect to red colour warning issued for the Districts namely Devbhoomi Dwarka, Porbandar, Jamnagar, Kutch:

✓ Major damage to kuchcha roads due to inundation.
✓ Major disruption in traffic in city areas.
✓ Inundation of low lying areas leading to damage to kuchcha houses.
✓ Water logging in underpass in city areas.
✓ Sudden reduction in visibility during heavy downpour leading to road accidents.
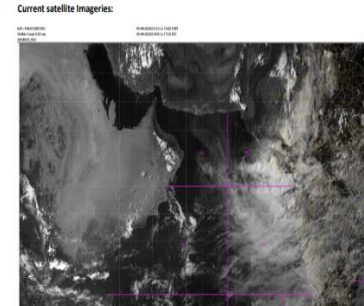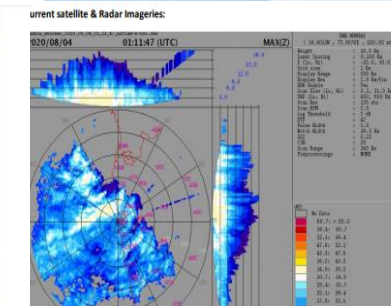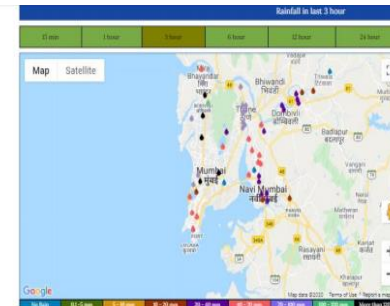
Rainfall in last 3 hour

Current satellite & Radar Imageries:

Current satellite Imageries:

Flash Flood Risk Outlook for next 24 hours: Following is flash flood risk based on the expected rainfall over the AoC as per Mesoscale model only.

Flash Flood Risk Outlook for next 24 hours:

High Risk over some areas of East Madhya Pradesh and adjoining area of Chhattisgarh, West Madhya Pradesh and adjoining areas of East Rajasthan and Gujarat sub division.

WRF FFR-24hr   2020-08-21   06:00 UTC

sh Flood Risk Outlook for t 24 hours:

h Risk over some areas of st Madhya Pradesh, East asthan and adjoining areas of st Rajasthan and Gujarat sub sion.

derate to High Risk over e areas of Konkan & Goa division.
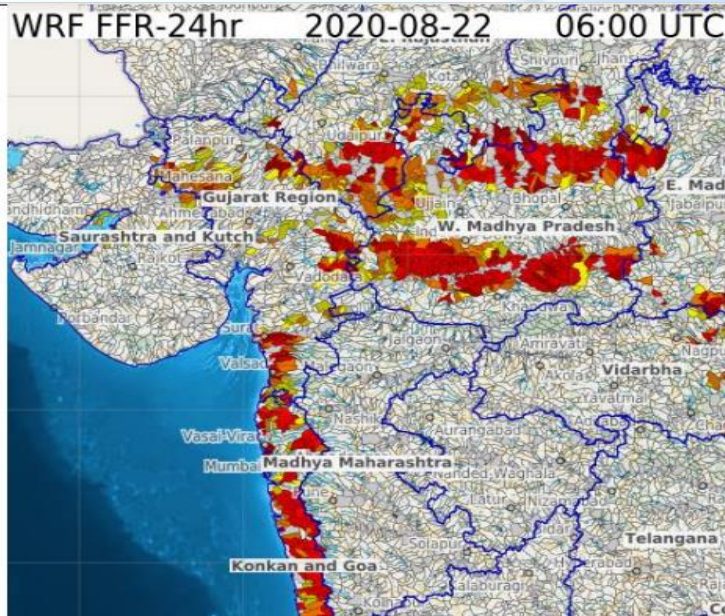
WRF FFR-24hr   2020-08-22   06:00 UTC

Flash Flood Risk Outlook for next 24 hours: Following is flash flood risk based on the expected rainfall over the AoC as per Mesoscale model only.

Flash Flood Risk Outlook for next 24 hours:

Moderate to High Risk over some areas of West Madhya Pradesh, East Rajasthan, Gujarat and adjoining areas of West Rajasthan and Saurashtra and Kutch sub division.

WRF FFR-24hr   2020-08-23   06:00 UTC

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Impact Based Forecast(IBF) and warnings

(WARNING)

WARNING DAY-1
Sunday , 05 July 2020

WARNING DAY-2
Monday , 06 July 2020

WARNING(TAKE ACTION)
ALERT(BE PREPARED)
WATCH(BE UPDATED)
NO WARNING(NO ACTION)

WARNING DAY-3
Tuesday , 07 July 2020

WARNING DAY-4
Wednesday , 08 July 2020

WARNING(TAKE ACTION)

WARNING DAY-5
Thursday , 09 July 2020

WARNING(TAKE ACTION)
ALERT(BE PREPARED)

IMPACT BASED FORECAST

Expected Impact with respect to red colour warning issued for the Districts namely
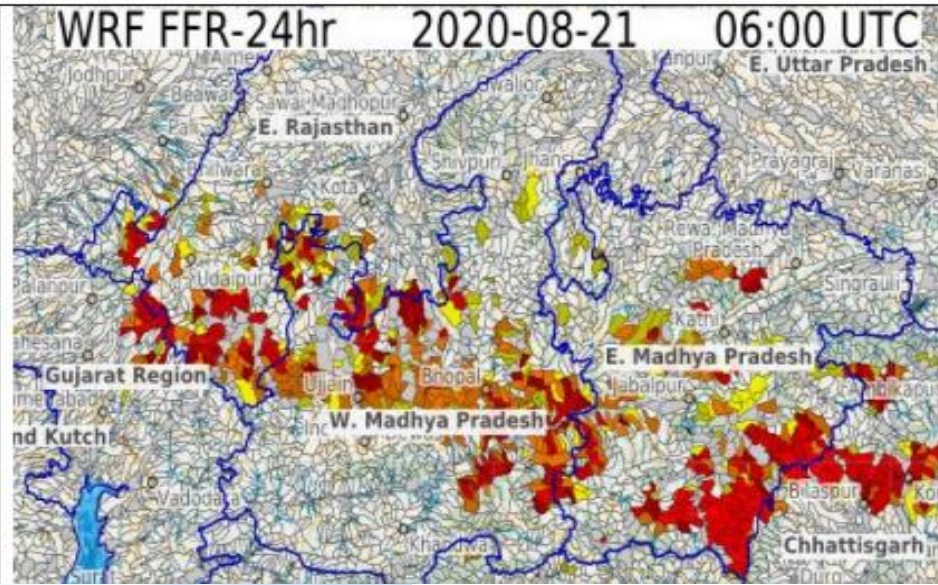
Jamnagar, Kutch:

- ✓ Major damage to kuchcha roads due to inundation.
- ✓ Major disruption in traffic in city areas.
- ✓ Inundation of low lying areas leading to damage to kuchcha houses.
- ✓ Water logging in underpass in city areas.
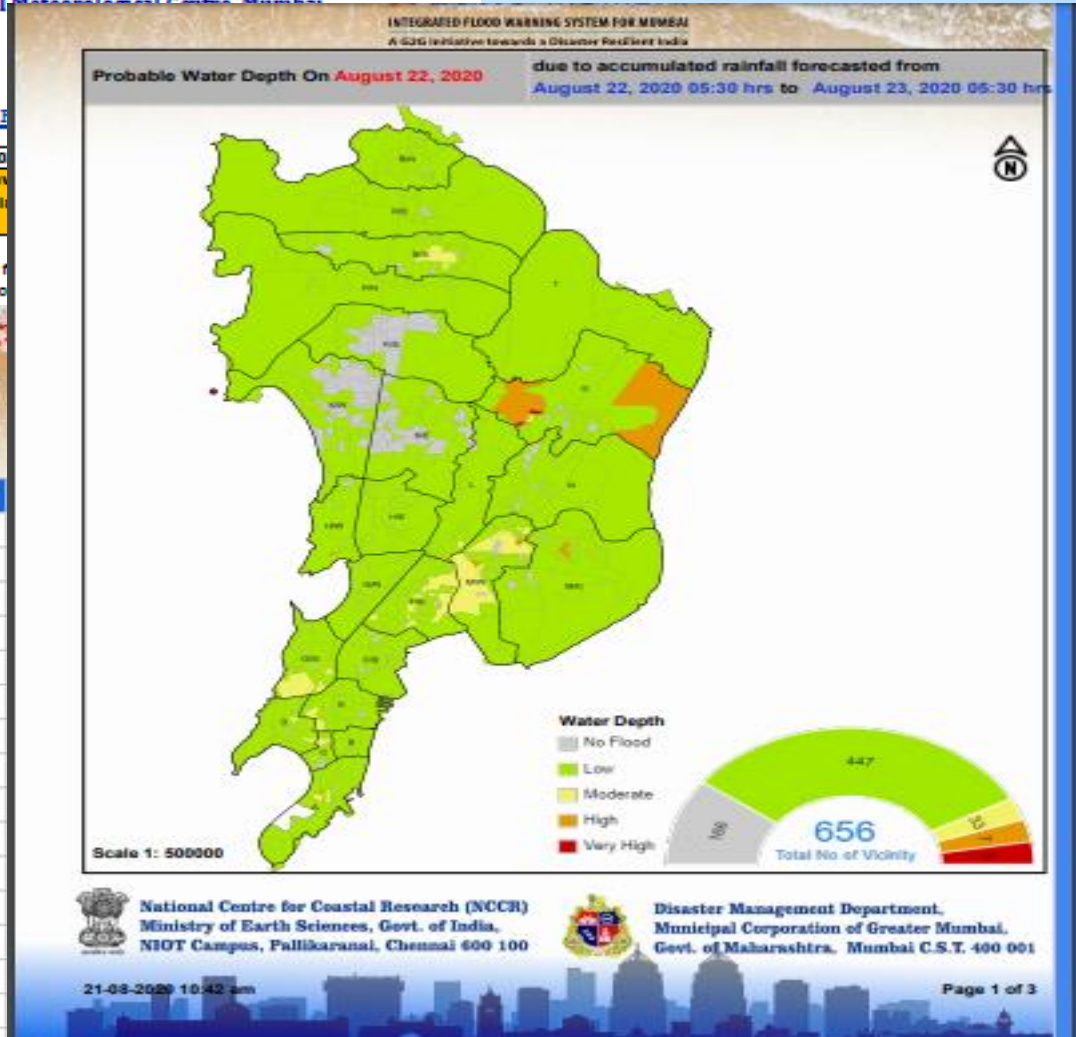- ✓ Sudden reduction in visibility during heavy downpour leading to road accide

प्रादेशिकमौसमकेंद्र, कोलाबा , मुंबई
Regional Meteorological Centre, Mumbai

Dated: 03 Aug 2020

IMPACT BASED FORECAST

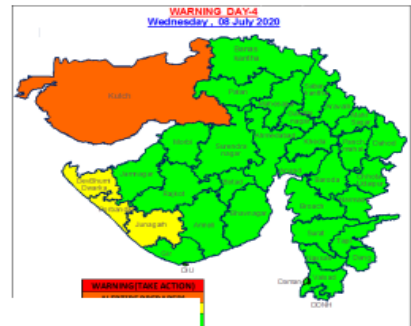| Date	03 Aug 20
Forecast& Warning	Heavy to very heav isolated pl
Impact Expected	• Water logging/ many parts of lo

Inte grated

S.No	Ward Name			
1	S			
2	S			
3	R/N			
4	M/W			
5	M/W			
6	M/E			
7	K/W			
8	K/W			
9	H/W			
10	A			
11	S			
12	R/S			
13	R/S			
14	R/S			
15	M/W			
16	M/W	Chembur	1234567890	MODERATE
17	M/W	Postal Colony (Chembur)	1234567890	MODERATE
18	M/W	Amir Baug	1234567890	MODERATE
19	M/W	Rahul Nagar	1234567890	MODERATE
20	L	Shiv Shakti Nagar (Kurla East)	1234567890	MODERATE
21	H/W	Narly Agripada (Santacruz West)	1234567890	MODERATE
22	G/S	Shanti Nagar,Lower Parel	1234567890	MODERATE
23	G/S	BDD Chawl Lower Parel	1234567890	MODERATE

INTEGRATED FLOOD WARNING SYSTEM FOR MUMBAI
A G2G initiative towards a Disaster Resilient India

Probable Water Depth On August 22, 2020

due to accumulated rainfall forecasted from
August 22, 2020 05:30 hrs to August 23, 2020 05:30 hrs

Water Depth
- No Flood
- Low
- Moderate
- High
- Very High

656
Total No of Vicinity

447

Scale 1: 500000

National Centre for Coastal Research (NCCR)
Ministry of Earth Sciences, Govt. of India,
NIOT Campus, Pallikaranai, Chennai 600 100

Disaster Management Department,
Municipal Corporation of Greater Mumbai,
Govt. of Maharashtra, Mumbai C.S.T. 400 001

21-08-2020 10:42 am

Page 1 of 3

Vatch-(3-
date)

Alert: (48
ence and

Warning
rrence &

for   to
ates.

Performance of IBF-Heavy rainfall in Monsoon 2020

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Date (Periods)	Areas of Low pressure System (LPS) formed	Moved across and dissipated	Duration of LPS	ISMR WEEKLY
4-10 Aug	Northwest Bay of Bengal (NW BOB) off Odisha-west Bengal coast as well marked low -WML	Very fast moving in the 1st half. Moved across central India and Gujarat and entered into North Arabian Sea and dissipated over Oman coast	6	+13%(FOR Week ending on 12 Aug)
9-11 Aug	Northwest and adjoining Westcentral Bay of Bengal off Odisha-north Andhra Pradesh coasts	Very fast moving and within 36-hours, it moved across Chhattisgarh to NE MP only. Its remnant moved to northwest India and caused Jaipur flood on 14 Aug 2020	2	
13-18 Aug	NW BOB off Odisha coasts-well marked low 3 days	Slow moving system Across Chhattisgarh To NEMP, but its remnant as circulation moved over to NE raj and South Punjab during 18-20 Aug caused major spell over NW India - a most peak spell in the season for NW India with NCR-Gurugram flood on 19 Aug	5	42%(for week ending on 19 Aug)
19-26 Aug	NW BOB-north Odisha-WML	Slow moving system in the 2nd half of its life. Across central India to southwest Raj and adj South Pak -caused flood over Odsiha ON 20-21 Aug, over Telengana including Wrangle and part of Hyderbad on 21 Aug, west MP –Flood over Bhopal on 22 Aug , South Raj and Gujarat-Flood on 23 and 24	7	41%(for week ending on 26 Aug)
24 Aug -2 Sept	North BOB -WML and lay over north Odisha south GWB	Slow moving system in the 1st half of its life. Moved to Pak and west Raj across north Odisha –south GWB, south Jahrkhand, north Chhattisgarh, north EMP and then central parts of WMP –Caused flood over Odisha and over MP and adj Raj-Gujarat	9	

City IBF cases

➢ **For Mumbai-   4-7 July, 14-17 July, 4-6 Aug , 21-23 Sept 202**

➢ **For Jaipur-14 Aug 2020**

➢ **For Hyderabad -13 Oct**

➢ **For Guwahati, Shilong-23 Oct**

➢ **For Delhi- 22 July**

Example-Extremely heavy rainfall spell over Maharashtra, Karnataka, Kerala and adjoining Tamil Nadu during 4-8 August 2020"

➤ Rain Event(District wise)

- **4 Aug- Mumbai (Dharavi)-38, Mumbai (Santacruz)-26; Mumbai (Colaba)-25, Hosanagar-21, Bhagamandala-19**

- **5 Aug- Palghar-46, Talasari-39, Dahanu -38, Matheran-25, Ratnagiri-22, Kalyan-17, Thane-17, Santacruz - 8, Colaba-5**

- **6 Aug- Vaibhavwadi-71(Sindhudurg); Mumbai(Colaba)-33 Mumbai(Santacruz)-15,(All Konkan).   MANANTODDY-19, VYTTIRI-18, NILAMBUR-10, KUPPADY-9, MUNNAR KSEB-8(All Kerlal) Avalanchi-58(Nilagiri-TN); Bhagamandala-49 and KOTTIGEHARA-39, (Kodagu)(all SIK)**

- **7 Aug- PEERMADE TO-26, MUNNAR KSEB-23, IDUKKI-23, MANANTODDY-21, VYTTIRI-19, MYLADUMPARA AGRI-18, KUPPADY-17, PALAKKAD-14(All Kerala) BHAGAMANDALA-40, KOTTIGEHARA-36**

Impact part of 4-8 Aug heavy rainfall levent

➤ **Mumbai- 6 Aug 2020**

▪ **local flash floods, inundation, road and traffic closures affecting severely all mode of transports including air Traffic and Airport operations, two lives were lost in Mumbai**

▪ **Mumbai (Colaba) reported the highest of 107kmph in gustiness during 1700-1715 hrs IST on 6th August –Broken windows, tree branches reported**

➤ **Munnar land slide- early hours of 7 Aug causing the death toll of 60 people under slush from this huge landslide.**

➤ **Talacauvery, Bhagamandala in Karnataka's Kodagu district Land slide on the night of 5th August-5 people missed and 40 cows 40 cows have died in the devastation,**
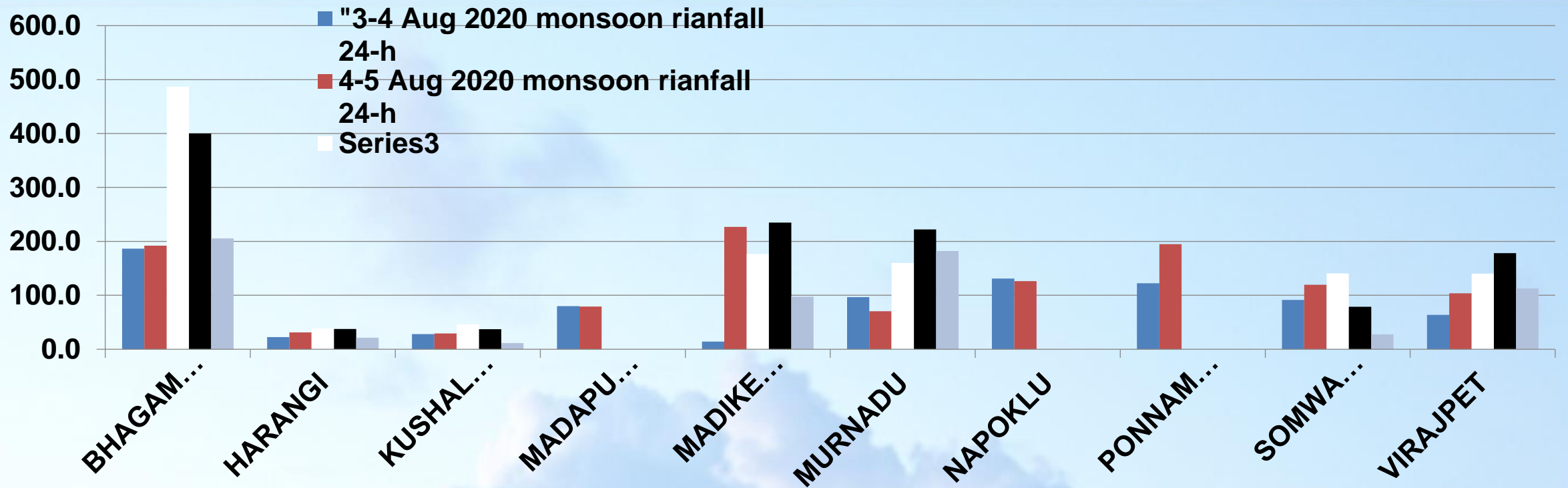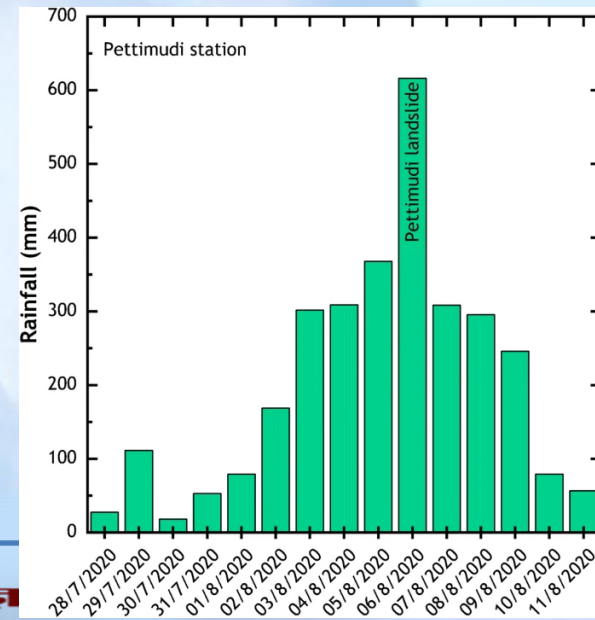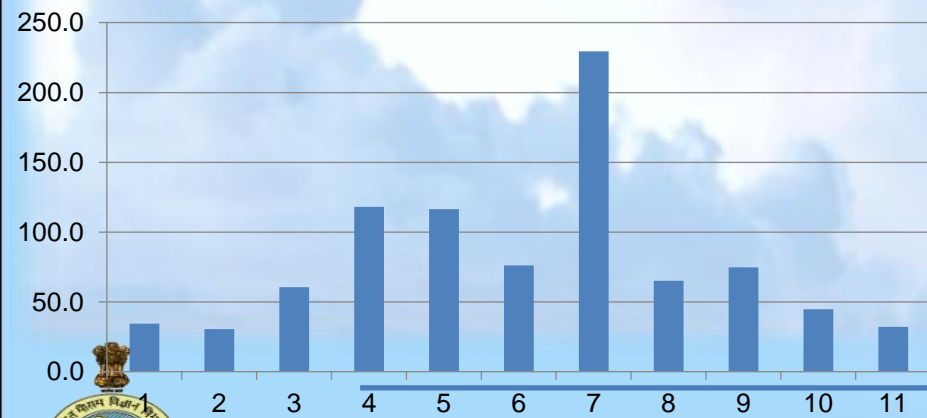
Munar and Kodagu land slide 2020

» **Future dense ARG/AWS network must be based on types of severe weather affecting district/areas most frequently called vulnerability and its impact. Urban may have a different concept as any big-city has always needed dense network for various customized information** Sir
Kindly see the trailing e-mail on the research paper reporting very high ainfall data for Munnar landslide of last 6 Aug 2020.

» It is like accurately issued current weather/METAR in aviation may have 80-90% role in the safe operation of it, timely accurate observation from a location or from an area helps and minimize disaster impact if not at in similar scale, but at least in manging more affective the impact both from high temp and rainfall events

» Satellite and RADAR or any remote based observations may have limited role to get the areas experiencing extreme weather at local scale. When we consider pockets experiencing, very high extreme temp of 45-50degC or extreme rainfall of 40-60cm in 24-h, we need surface observational field data from these locations from an optimum dense network fully functional at 24X7 . Hence density of AWS/ARG may vary as per vulnerability of district/areas and impacts e.g it may be the ideal network of ARG at each 10km for Mumbai, Kodagu and Munnar districts by looking at their rainfall variability at meso-scale, vulnerability and impacts, while for **Sohra** Cherapunji areas, we do not need much ARG as the impact is very very less in later areas.

» It is like We choose the right coastal network and preferred met instruments HWSR, that can face the severity of cyclone winds.

» **One way, in case rainfall data network, for improving observations from extreme rainfall vulnerability pockets of India, is to interact more with state and other private estate holders, who have their rainfall stations/network, like in the present case,** a tea estate company has rainfall data at Pettimudi station affected by a huge landslide on 6 Aug 2020 had 61.6cm with 300cm rainfall cumulatively got during 1-11 Aug 2020 (data provided by Pettimudi division Neymakkad Tea Estate, KDHP Ltd.) while IMD got only upto some 25 cm on that day and cumulative 88cm, very less to kind of scale the disaster area got.

Bar chart (top): monsoon rainfall comparison across stations — "3-4 Aug 2020 monsoon rianfall 24-h", "4-5 Aug 2020 monsoon rianfall 24-h", Series3. Y-axis 0.0 to 600.0. Stations: BHAGAM..., HARANGI, KUSHAL..., MADAPU..., MADIKE..., MURNADU, NAPOKLU, PONNAM..., SOMWA..., VIRAJPET

Bottom-left chart: **Munar daily rain in mm Aug 2020 monsoon** — Y-axis 0.0 to 250.0, X-axis 1–11

Bottom-right chart: Pettimudi station — Rainfall (mm), Y-axis 0 to 700, with "Pettimudi landslide" marked; X-axis dates 28/7/2020 to 11/8/2020

भारत मौसम विज्ञ...
INDIA METEOROLOGICAL DEPARTMENT

DATE of Issue of IBF	SUB-DIVISION AND DATE OF IMPACT	IMPACT & ACTION SUGGESTED
29.08.2020	Impact expected over West Madhya Pradesh & adjoining southeast Rajasthan on 29th August due to Extremely Heavy rainfall	1. Localized Flooding of roads, water logging in low lying areas and closure of underpasses mainly in urban areas of the above region. 2. Occasional reduction in visibility due to heavy rainfall. 3. Disruption of traffic in major cities due to water logging in roads leading to increased travel time. 4. Minor damage to kutcha roads. 5. Possibilities of damage to vulnerable structure. 6. Localized Mudslides. 7. Damage to horticulture and standing crops in some areas due to inundation. 8. It may lead to riverine flooding in some river catchments (for riverine flooding please visit website of center water commission (http://www.cwc.gov.in/)) 9. For specific district wise impact kindly visit IMD's sate level meteorological center websites (https://mausam.imd.gov.in/imd_latest/contents/departmentalweb.php) and national website (https://mausam.imd.gov.in/). Action Suggested • Check for traffic congestion on your route before leaving for your destination. • Follow any traffic advisories that are issued in this regard. • Avoid going to areas that face water logging problem often. • Avoid staying in vulnerable structure.

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Date	Extreme heavy rain warning and IBF	Rainfall realized	Impacts realized
19 Aug for Odsiha	• Under the influence of above systems, widespread rainfall with isolated heavy to very heavy falls very likely along with isolated **extremely heavy falls (≥ 20 cm)** over Odisha on 19th; Chhattisgarh on 19th & 20th; East Madhya Pradesh on 20th; West Madhya Pradesh on 21st & 22nd; East Rajasthan on 22nd and Gujarat State on 22nd & 23rd August, 2020.	ODISHA:- SALEPUR-30, NISCHINTAKOILI-30, NAWARANGPUR-24, MAHANGA-20, KOTPAD-19, JEYPORE-18, KOSAGUMDA-17, KHARIAR-16, PHIRINGIA-16, DHARMAGARH-16, AKHUAPADA-16, DABUGAN-15, KALAMPUR-15,	The fresh spell of rainfall has claimed two lives due to wall collapse incidents on Friday. While a woman died due to wall collapse in Kuliana area of Mayurbhanj district, another person was killed in a similar incident caused by heavy rainfall in Riamal area of Deogarh district,
20 Aug for Chhattisgarh		BHAIRAMGARH-23, DARBHA-21, LOHANDIGUDA-17, BASTANAR-17, CHHINDGARH-16, KATEKALYAN-16, BIJAPUR-12, JAGDALPUR-12,	Local flooding reported
21 and 22 West Madhya Pradesh	• Under the influence of above systems, widespread rainfall with isolated heavy to very heavy falls very likely along with isolated **extremely heavy falls (≥ 20 cm)** over Odisha on 19th; Chhattisgarh on 19th & 20th; East Madhya Pradesh on 20th; West Madhya Pradesh on 21st & 22nd; East Rajasthan on 22nd and Gujarat State on 22nd & 23rd August, 2020. • Under the influence of above systems, widespread rainfall with isolated heavy to very heavy falls very likely along with isolated **extremely heavy falls (≥ 20 cm)** over Odisha on 19th; Chhattisgarh on 19th & 20th; East Madhya Pradesh on 20th; West Madhya Pradesh on 21st & 22nd; East Rajasthan on 22nd and Gujarat State on 22nd & 23rd August, 2020.	...DORE-AWS-32, HATPIPLAYA-27, INDORE-AWS-26, GOHARGANJ-26, ...5, ASHTA-ARG-24, BADNAGAR-24, KHATEGAON-23, BADNAWAR-23, ...21, KALAPIPAL-21, BHOPAL-AWS-ARG-21, REHTI-21, DEPALPUR-20, SHUJALPUR-20, PIPARIYA-20, BARELI-20, GAUTAMPURA-20, BUDHNI-19, VIDISHA-AWS-19, HOSHANGBAD-AWS-18, UDAINAGAR-18, TONKHURD-17, SONKATCH-16, BANKHEDI-16, JAWAR-16, BAGLI-16, NUSRULGUNJ-ARG-15, NABIBAGH-15, RAISEN-AWS-15, NARSINGARH-15, 22-Aug BAJNA-27, GULANA-26, MOMAN BADODIYA-25, SARANGPUR-22, THANDLA-19, DHAR-AWS-19, SARDARPUR-18, AGAR-17, GAUTAMPURA-16, RAOTI-16, BAROD-16,	*(news clipping)* HEAVY RAIN AND FLOOD IN BHOPAL: CAR TRAPPED IN RIVER AND REMAINED TRAPPED OVERNIGHT, SDRF TEAM RESCUED – भोपा...
21 and 22 at East RAJ	• Under the influence of above systems, widespread rainfall with isolated heavy to very heavy falls very likely along with isolated **extremely heavy falls (≥ 20 cm)** over Odisha on 19th; Chhattisgarh on 19th & 20th; East Madhya Pradesh on 20th; West Madhya Pradesh on 21st & 22nd; East Rajasthan on 22nd and Gujarat State on 22nd & 23rd August, 2020.	21 Aug-LOHARIA-21, BANSWARA SR-19, BHUNGRA SR-17, SABLA SR-14, KHUSHALGARH-14 22 Aug-BHUNGRA SR-36, GHATOL-30, PIPALKHUNT SR-28, KESARPURA SR-27, ...PURA SR-26, SAJJANGARH SR-20, SAGWARA-20, LOHARIA-19, NITHUWA SR-19, ...HI-18, SABLA SR-18, BANSWARA SR-18, DUG-17, BAGIDORA SR-16, DANPUR-16, SHERGARH SR-15, KHUSHALGARH-15, ARNOD SR-15,	SE Rajasthan at Banswara District - Highest was 36cm on 22-23 Aug -Six stations extremely heavy -Due to flash flood five lives lost *(Hindi news clipping)* बाढ़ का कहर: बांसवाड़ा में 11 इंच बारिश, टापू में फंसे 6 लोग अनास नदी में कूदे, 4 बहे, एक का शव मिला, एक युवक सुरक्षित बाहर निकल...

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

31 Aug 2021: District based IBF Data status(Exposure data, Rainfall data, Impact data) and corresponding District-wise Risk Matrix preparation status (Met Sub-division Wise)

S.N.	State	No. of Districts	Exposure data collected	Impact Data/Rainfall collected	Exposure, Impact data and Rainfall data shared	Impact/Risk matrix Prepared	Separate Impact for each district	Remark
1	Andhra Pradesh	13	10		No	10	NA	Only status sheet shared
2	Gujarat	27	1		No	1	NA	Only status sheet shared
3	Haryana	22	22		22	22	For some districts	
4	Himachal Pradesh	12	12		1	1	NA	Only status sheet shared
5	Jammu & Kashmir	20	20		1	14	NA	Only status sheet shared
6	Karnataka	31	31		13	03	NA	Only status sheet shared
7	Kerala	14	14		14	14	Common impact for all districts	
8	Madhya Pradesh	52	22		No	22	NA	Only status sheet shared
9a	Maharashtra(outside Vidarbha)	36	24		No	17	NA	Only status sheet shared
9b	Vidarbha							
10	Punjab and Harahan	23	21		21	21	For some districts	
11	Rajasthan	33	33		0	0	NA	Only status sheet shared
12	Tamilnadu	40	40		0	0	NA	Only status sheet shared
13	Telangana	34	34		0	0	NA	Only status sheet shared
14	Andhra Pradesh							
15	Tripura	8	8		8	8	Common impact for all districts	

b. scheme of the cascading effects of the heavy rain event from say D10 to Day 0 and Day +10 and foot prints of three commonest: event, hazard and impact

Issues and Challenges

➢ **Heavy rainfall related Hazards has specific magnitude that unfold with a given space-time footprint and with the potential for adverse consequences**

➢ **The event footprint may vary significantly across hazards** (from D-10 to D0, D+10 issues, Also which areas to be red color impact)

➢ **Location, timing, and Intensity and duration issues**

➢ **Color coded form** as per **likelihood** and **risk of potentially damaging** event.

➢ **More spatial and Temporal impact data is the need of the hour-Free flow of data and in single system-NHP**

➢ **Hazard Models along with impact Models needs to be developed for district/states**

➢ **Proto-types DSS needs to be installed –NCCR C-FLOWS/I-FLOWS are some but will NCCR able to cater such needs?**

➢ **Outsourcing ?**

Future Plan

➢ **Land Slide product guidance products from GSI using GSI-UKMO NCUM heavy rainfall based landslide model upto 5-days with GSI**

➢ **IBF and Risk based Warning at all these 500 number of districts and 25 cities**

➢ **Integrate other systems like Flash flood guidance with Stage III (By Dec. 2021)**

❖ **Needs FFGS to have frequent updates by integrating with real time RADAR rainfall estimates to get the rainfall scenario**

❖ **FFGS to get RUC model for more frequent rainfall nowcast updates**

➢ **IBF data across all sectors-Crowd sourcing, Social Media**

➢ **Chennai and Mumbai flood warning system is in place. Performance evaluation and multi-model rainfall forecast as input to generate scenario and consensus**

➢ **Bengaluru and Kolkata flood warning system awaited**

➢ **National/Int collaboration works NDMA, Sate Govt(SATARK, T-SMART etc), WCSSP, RIMES, NCCR-IITM, NCMRWF**

➢ **Workshop: Develop display system to share information between forecasters and disaster managers (GIS Platform developed)**

➢ **Modification of Standard Operating Procedures: Evaluation of SOP with hindcast data**