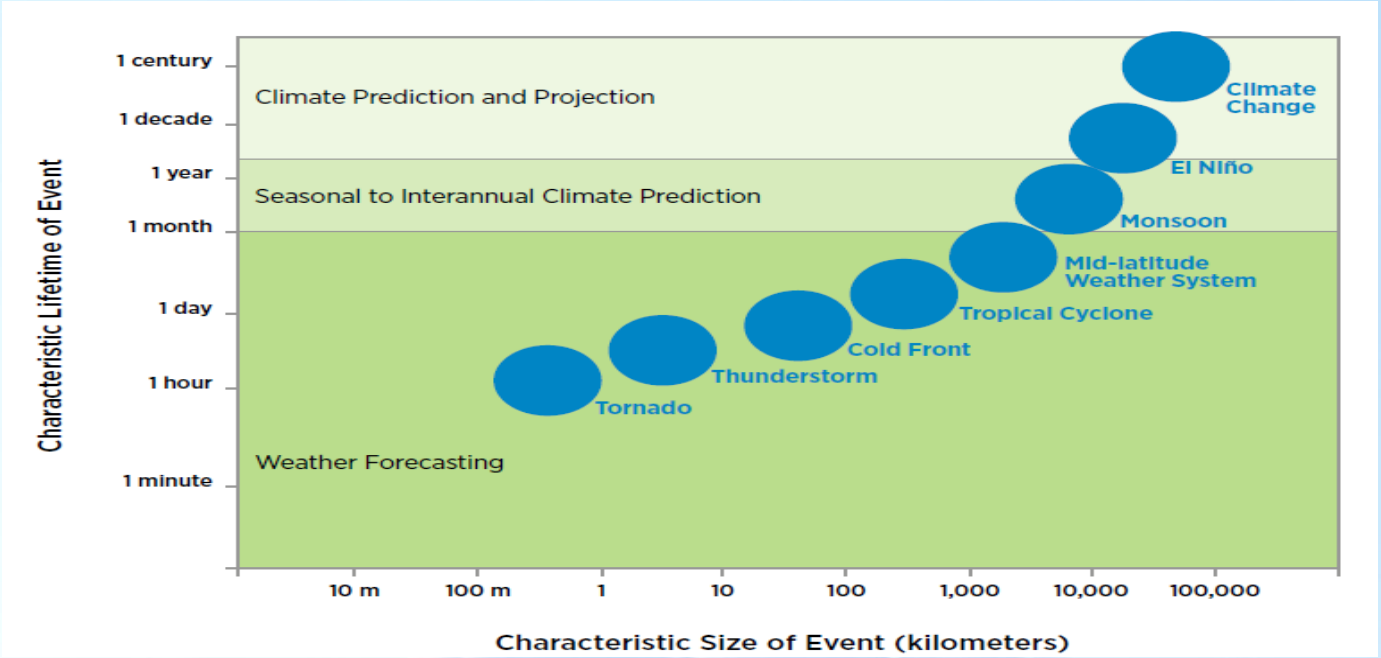
INTEGRATING MULTI-HAZARD EARLY WARNING SYSTEMS AND IMPACT ASSESSMENT TOOLS

K J Ramesh
India Meteorological Department
New Delhi

Inputs of climate information services to various stages of the climate resilient framework



An operational framework for managing climate and disaster risk

PILLAR 2

Risk Reduction

Avoided creation of new risks and reduced risks in society through greater disaster and climate risk consideration in policy and investment

PILLAR 3

Preparedness

Improved capacity to manage crises through developing forecasting, early warning and contingency plans.

PILLAR 4

Financial Protection

Increased financial resilience of governments, private sector and households through financial protection strategies

PILLAR 5

Resilient Reconstruction

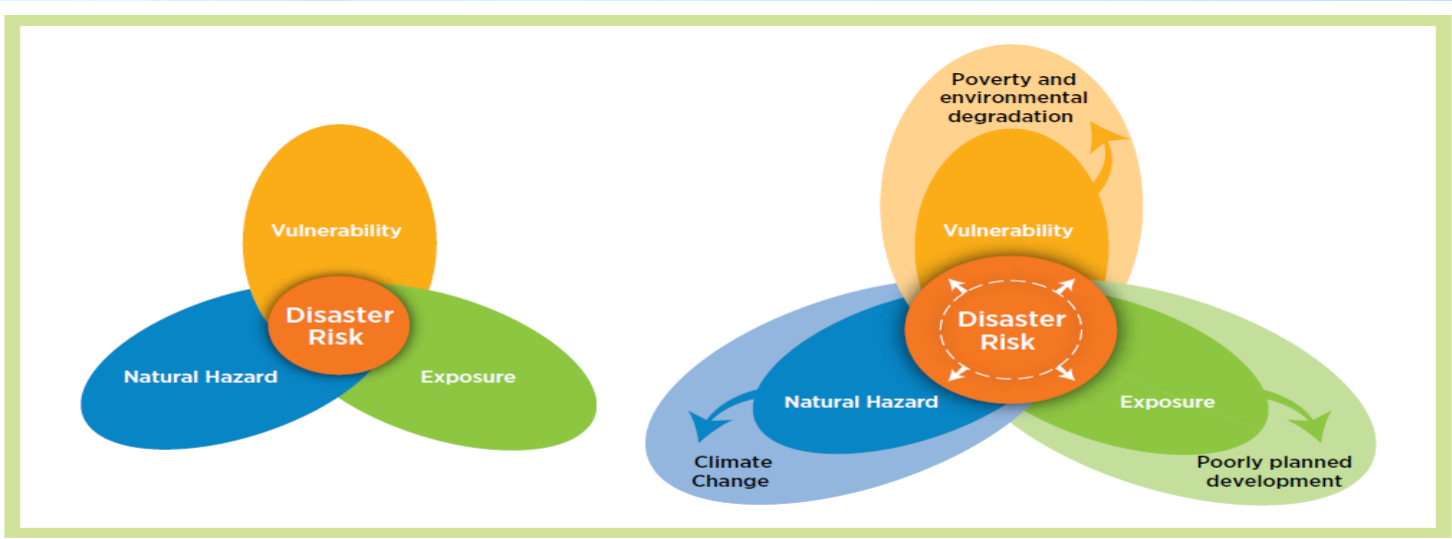
Quicker, more resilient recovery through support for reconstruction planning

PILLAR 1

Risk identification

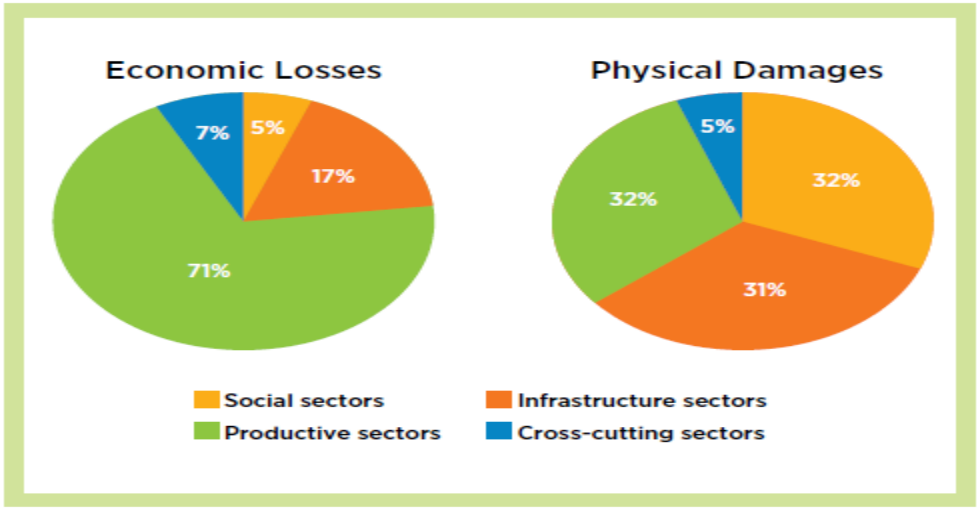
Improved identification and understanding of disaster and climate risks through building capacity for assessments and analysis

Disaster and Climate Risk



Disaster risk is determined by the occurrence of a natural hazard (e.g., a cyclone), which may impact exposed populations and assets (e.g., houses located in the cyclone path). Vulnerability is the characteristic of the population or asset making it particularly susceptible to damaging effects (e.g., fragility of housing construction). Poorly planned development, poverty, environmental degradation and climate change are all drivers that can increase the magnitude of this interaction, leading to larger disasters.

Total loss and damage from hydro-meteorological disasters, by affected sector (1972–2013)



Major science themes/applications/services of the organisation

- **Prediction of land, atmospheric and Oceanic states at different scales to provide weather and climate services in different spatial and temporal range**
  - **Nowcasting (up to 6 hours)**
  - **Short range (1-2 days)**
  - **Medium range (few days – week)**
  - **Extended Range (2 weeks)**
  - **Seasonal (Few months, e.g. Jun-Sep Monsoon)**
  - **Climate Scales**

  Spatial range : Location, Block, District, Meteorological Sub-division, River catchment, State and Homogeneous regions

Weather Forecast and Warning

- All India weather Inference - Updated 4 times a Day
- All India Weather Forecast -Updated 4 times a Day
- All India Weather Warning - Updated 4 times a Day
- Nowcast warning –Updated every 3 Hours
- FOG Forecast – Location specific during winters
- Regional Weather Forecast
- Regional Weather Warning
- Bay Bulletin: Sea Area Bulletin, Coastal Area Bulletin
- Pre Cyclone Watch, Cyclone Alert, Cyclone Warning
  Post Landfall outlook
- Port Warning

5 Days Rainfall Forecast:

S.No.	MET-SUBDIVISION	28 Aug	29 Aug	30 Aug	31 Aug	01 Sept
1.	Jammu & Kashmir	ISOL	ISOL	ISOL	ISOL	ISOL
2.	Himachal Pradesh	ISOL	ISOL	SCT	SCT	SCT
3.	Uttarakhand	FWS	FWS	FWS	FWS	FWS
4.	Punjab	SCT	ISOL	ISOL	ISOL	ISOL
5.	Haryana, Chandigarh & Delhi	FWS	FWS	ISOL	SCT	ISOL
6.	West Uttar Pradesh	FWS	FWS	SCT	FWS	FWS
7.	East Uttar Pradesh	FWS	FWS	FWS	FWS	FWS
8.	West Rajasthan	ISOL	ISOL	DRY	DRY	DRY
9.	East Rajasthan	FWS	FWS	SCT	SCT	SCT

Outlook for subsequent 2 days (from 0830 hrs IST of 2nd Sept 2018 to 0830 hrs IST of 04th Sept, 2018):

- Fairly widespread rainfall activity likely over Uttar Pradesh.
- Isolated to scattered rainfall activity in the rest of the region.

SPATIAL DISTRIBUTION (% of stations reporting)

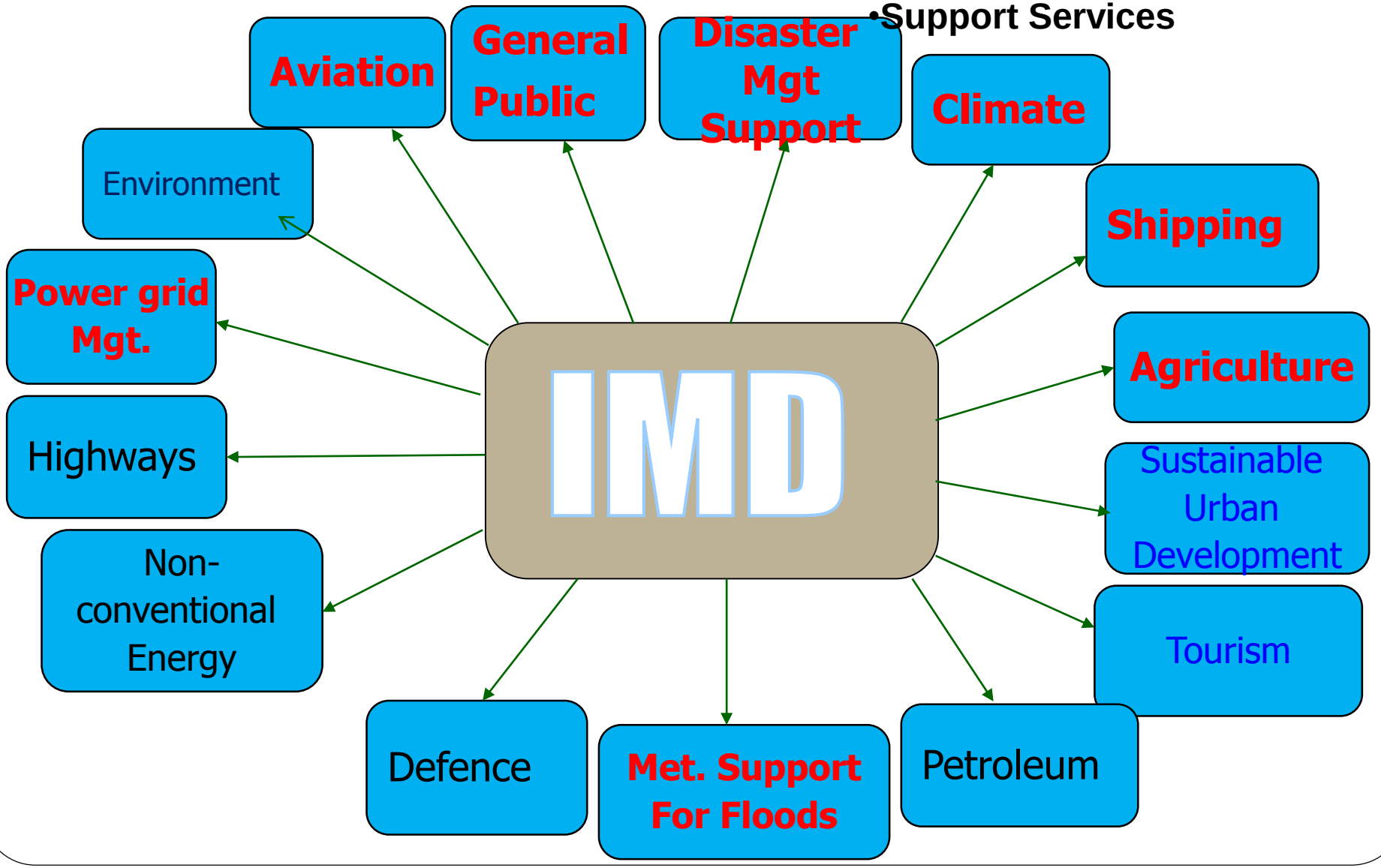
% Stations	Category
76-100	Widespread(WS/Most Places)
51-75	Fairly Widespread(FWS/Many Places)
26-50	Scattered(SCT/ A Few Places)
1-25	Isolated(ISOL)

Probabilistic Forecast

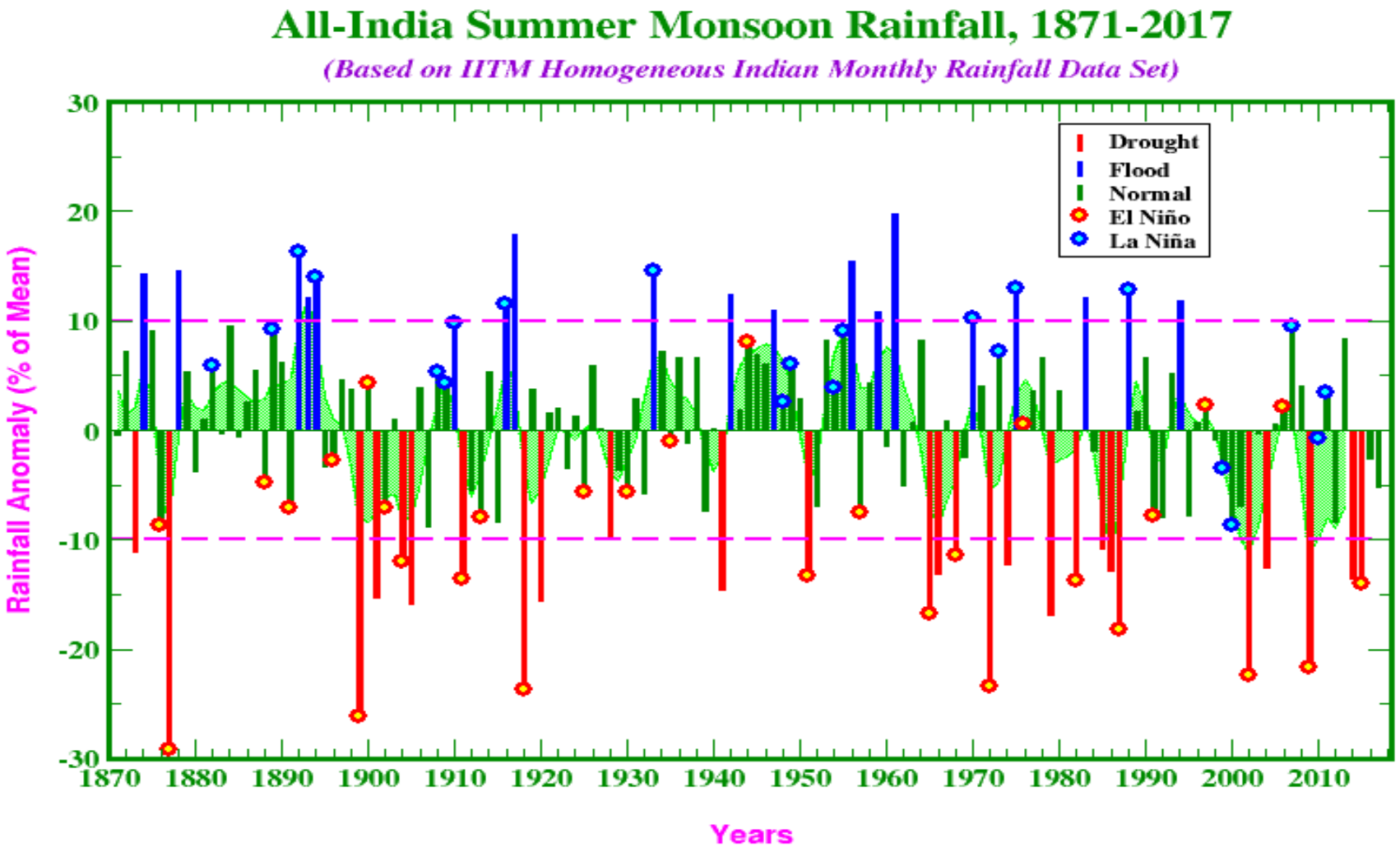
Terms	Probability of Occurrence (%)
Unlikely	<25
Likely	25 - 50
Very Likely	50 – 75
Most Likely	>75

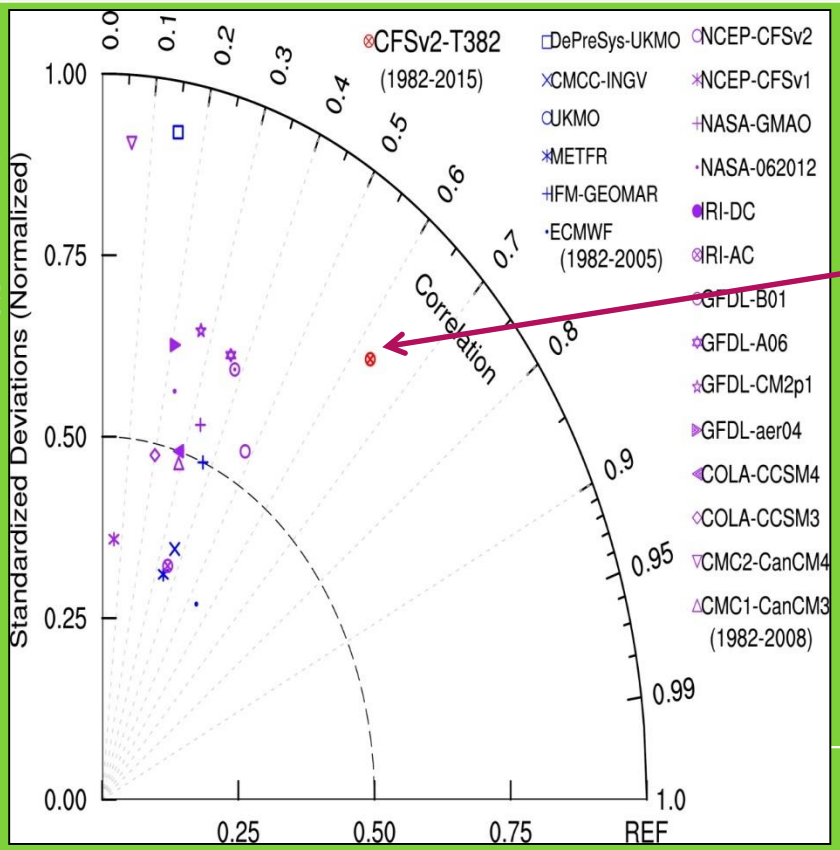
Major services of IMD

- Core Services
- Accelerated efforts to improve services
- Support Services



All India Summer Monsoon Rainfall Departure (1901-2017)

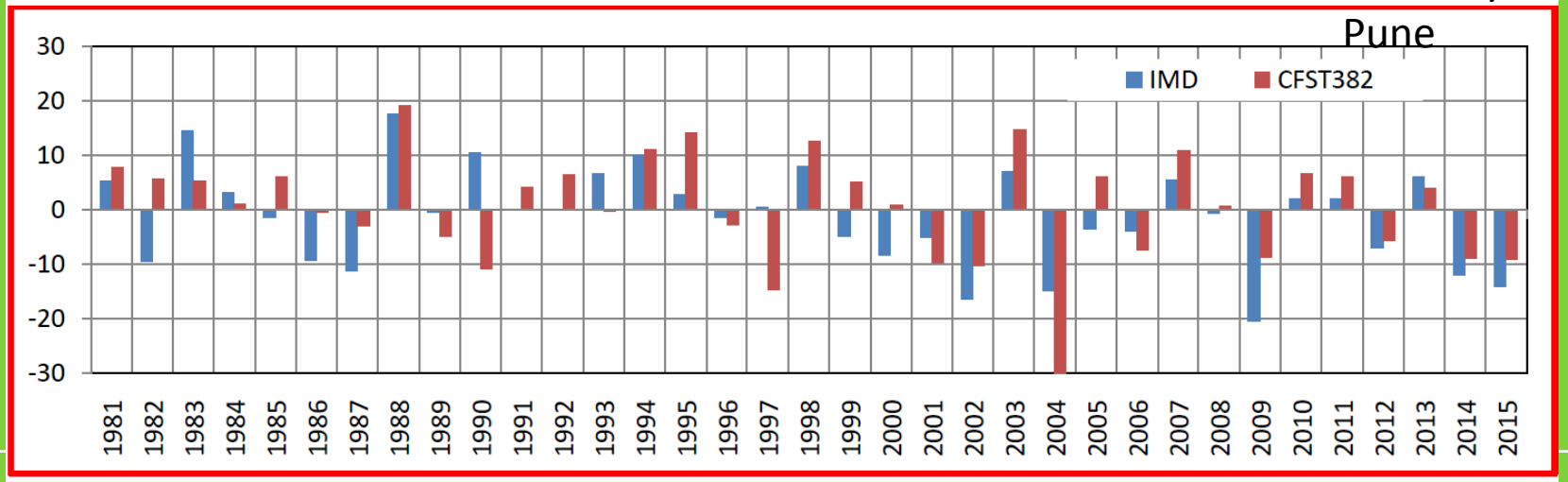




Monsoon Mission Model Performance (Prediction Skill as well as inter-annual variance) is better than other models for Indian Monsoon.

Performance of Monsoon Mission Dynamical Model for Seasonal Monsoon Prediction.

Courtesy: IITM Pune



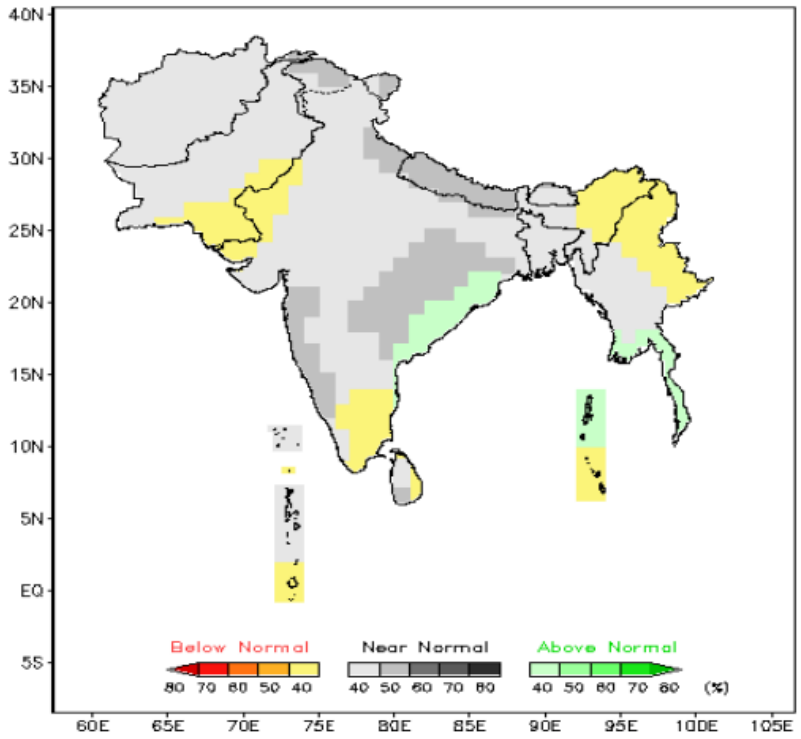
South Asian Climate Outlook Forum (SASCOF): Beginning & Objectives

- In a meeting convened by WMO, the Directors General of the National Meteorological and Hydrological Services (NMHSs) in South Asia and Permanent Representatives (PRs) of the respective countries with WMO, at the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, on 6 August 2009, the PRs of south Asian nations with the WMO had unanimously agreed to establish a South Asian Climate Outlook Forum (SASCOF), to be implemented from 2010 onwards. The main objectives of SASCOF are the following.
- *To review the progress made in understanding and long range prediction of summer monsoon both regionally and globally;*
- *To make available detailed information on climate variability in South Asia for dissemination along with the seasonal outlook;*
- *To provide a platform for the stakeholders of SASCOF to share and exchange experience and knowledge on summer monsoon and its prediction;*
- *To initiate capacity building/human resource development activities for the South Asian region, particularly in seasonal prediction;*
- *To build collaboration and partnerships among the members of SASCOF for mutual benefit;*
- *To identify needs of user sectors through a dialog among different groups.*

SASCOF meetings so far

- This is one of the important LRF activities of the center. RCC, Pune has been providing technical support and taking lead role in the preparation and issuance of consensus forecast during all these forum meetings.SASCO is co-sponsored by WMO and coordinated by IMD, currently under the demonstration phase for a WMO RCC for South Asia and IITM at Pune.

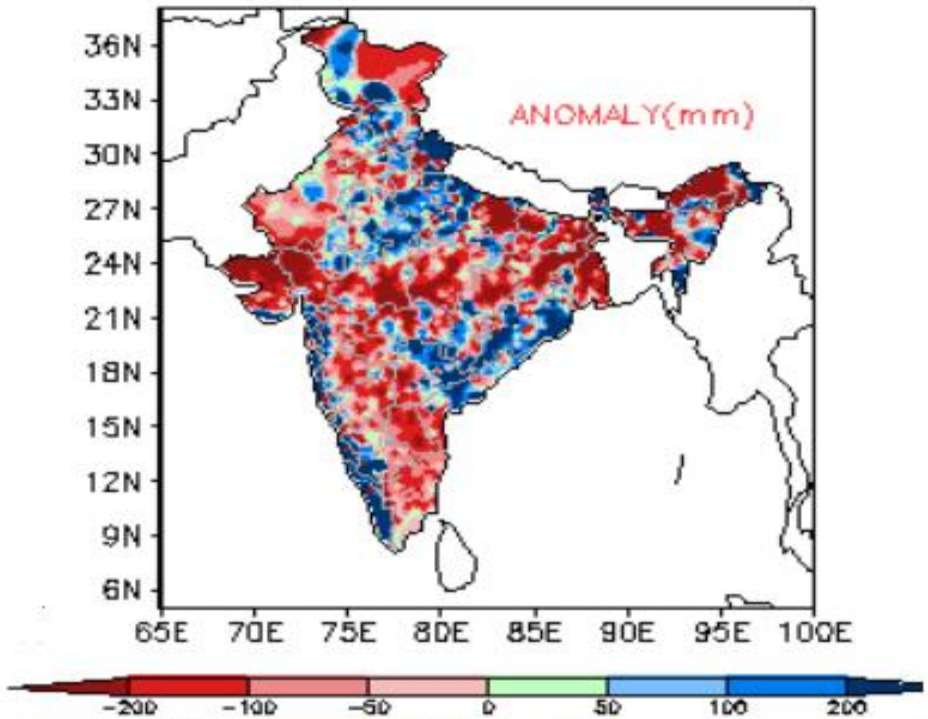
- The first three (during 2010-2012) and fifth (during 2014) meetings of SASCOF were held in Pune, India.
- fourth session (in 2013) of the SASCOF was held at Kathmandu, Nepal
- sixth session (in 2015) was held at Dhaka, Bangladesh.
- Seventh session (2016), SASCOF for SW monsoon was held in Colombo, Sri Lanka
- 8th Session will be held in Thimpu, Bhutan (last week of April)
- After six sessions of SASCOF conducted each year during the period 2010-2015, first SASCOF that was focused on the NE monsoon season (October to December), was held in Chennai, India during 14-15 Oct 2015.
- Last year, looking into requirements of the member countries of the region, consensus forecasts were also prepared for the NDJ and DJF seasons through e-mail discussions. and
- SASCOF for NE monsoon during 2016 was held during Oct., 2016 in Nay Pyi Taw, Myanmar.
- SASCOF-10 for SW Monsoon during 2017 was held in Thimpu, Bhutan
- SASCOF-11 for NE monsoon during 2017 was held in Sept., 2017 in Male, Maldives
- SASCOF-12 for SW Monsoon during April 2018 was held in Pune, India



Probability of the most likely category for the 2018 Southwest Monsoon Rainfall

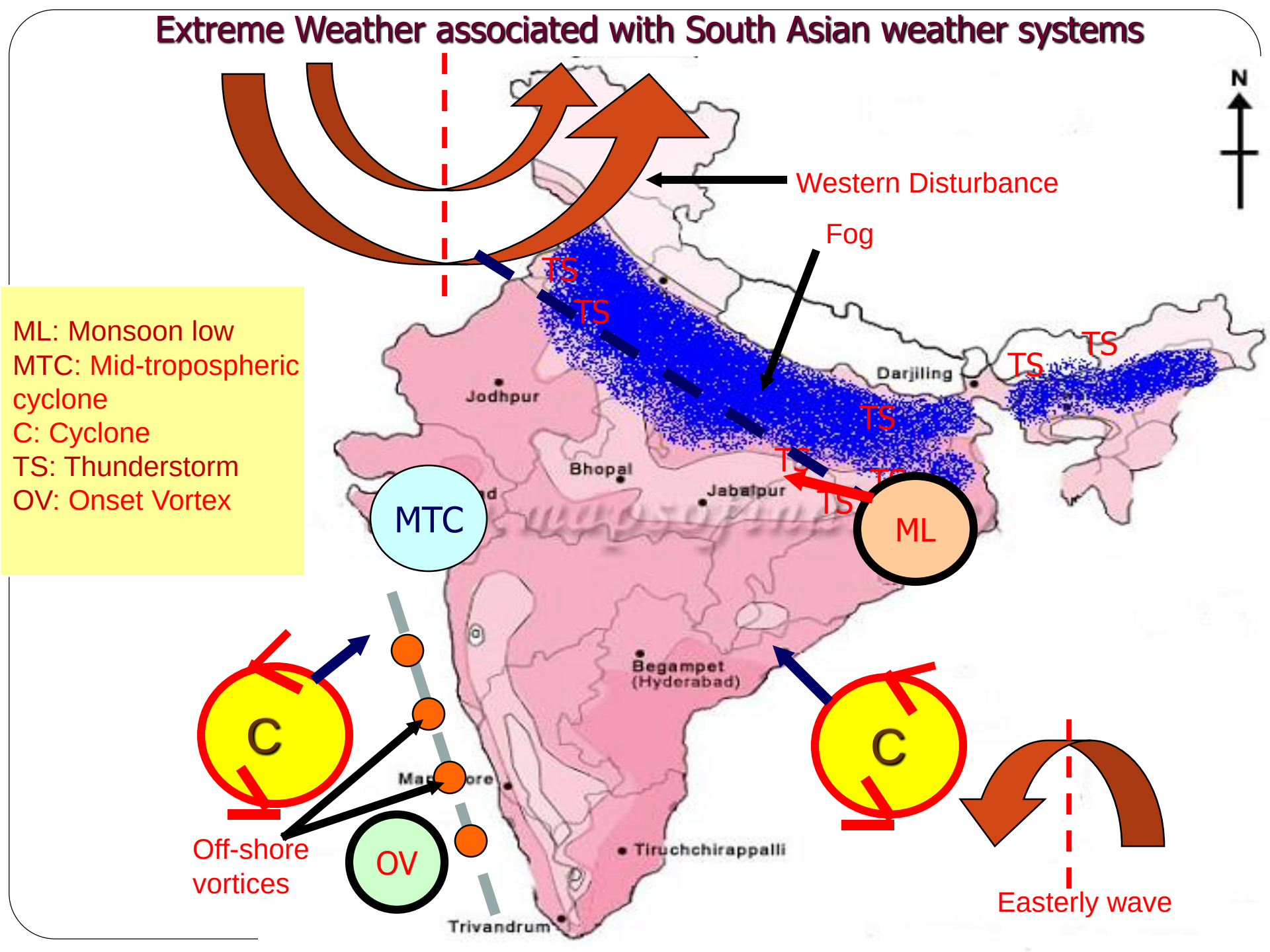
SASCOF-12 Forecast
Issued on 18th April 2018

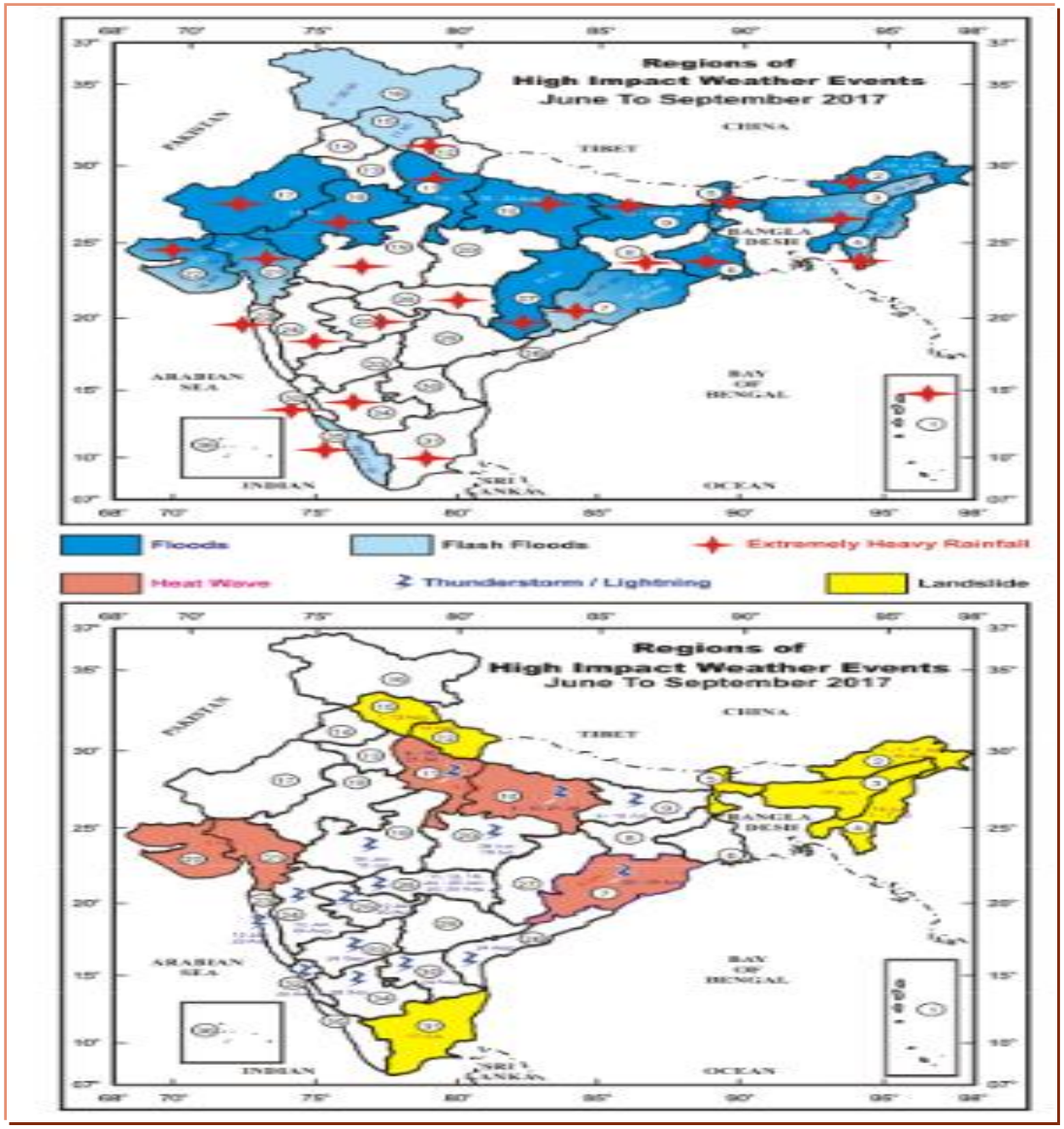
Seasonal Rainfall Anomaly
1st June – 14th Sept. 2018



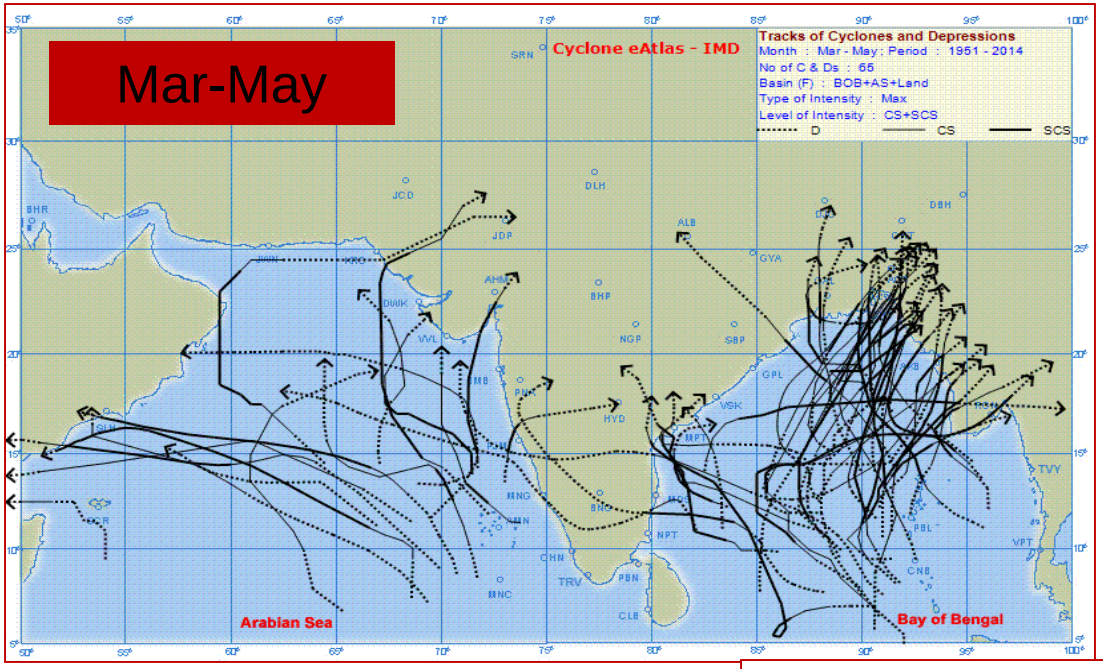
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

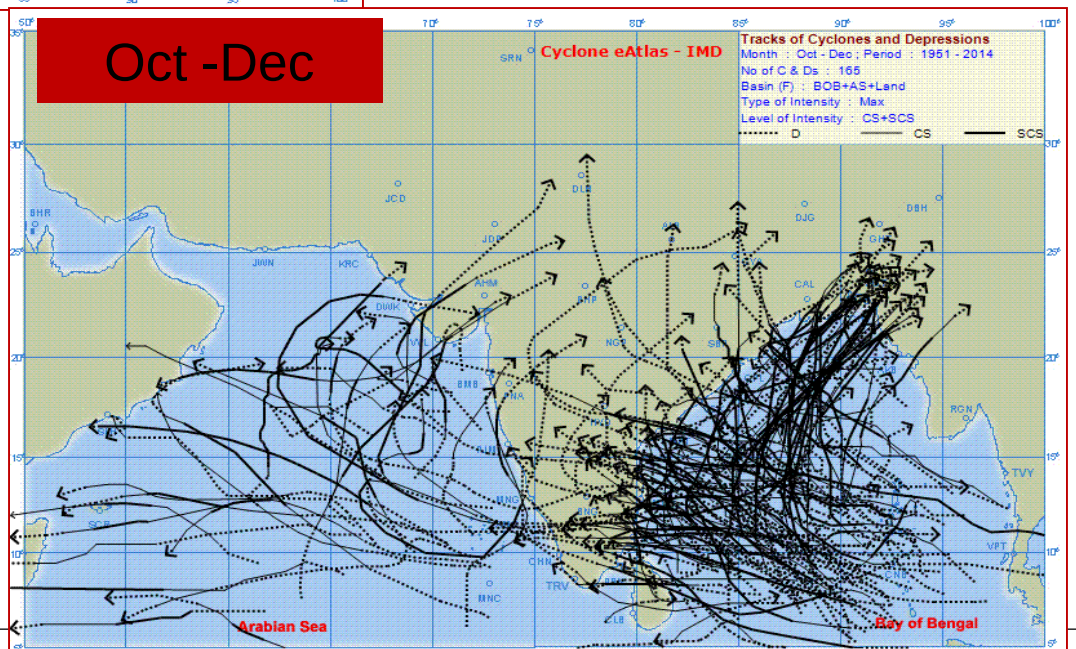
Extreme Weather associated with South Asian weather systems



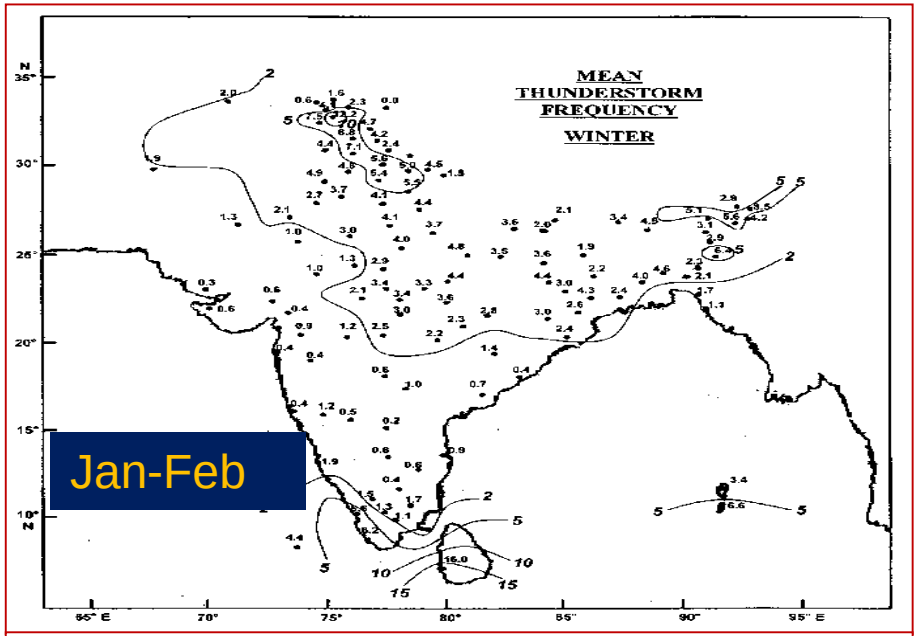

Regions of
High Impact Weather Events
June To September 2017
PAKISTAN
CHINA
TIBET
BANGLA DESH
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
SRI LANKA
Floods
Flash Floods
Extremely Heavy Rainfall
Heat Wave
Thunderstorm / Lightning
Landslide
Regions of
High Impact Weather Events
June To September 2017
PAKISTAN
CHINA
TIBET
BANGLA DESH
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
SRI LANKA

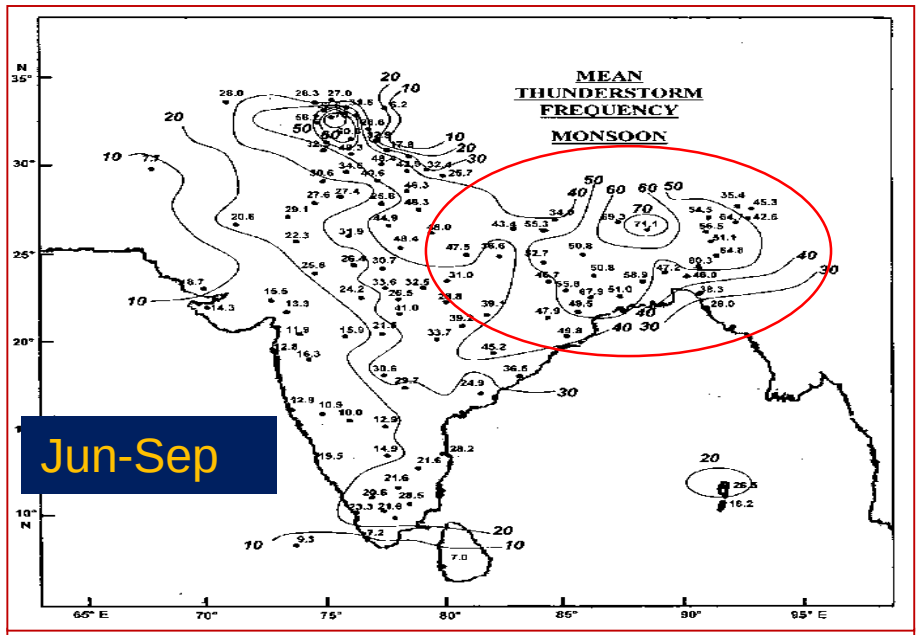
Pre-monsoon (MAM) and Post monsoon Tropical Cyclone (OND); 1951-2014

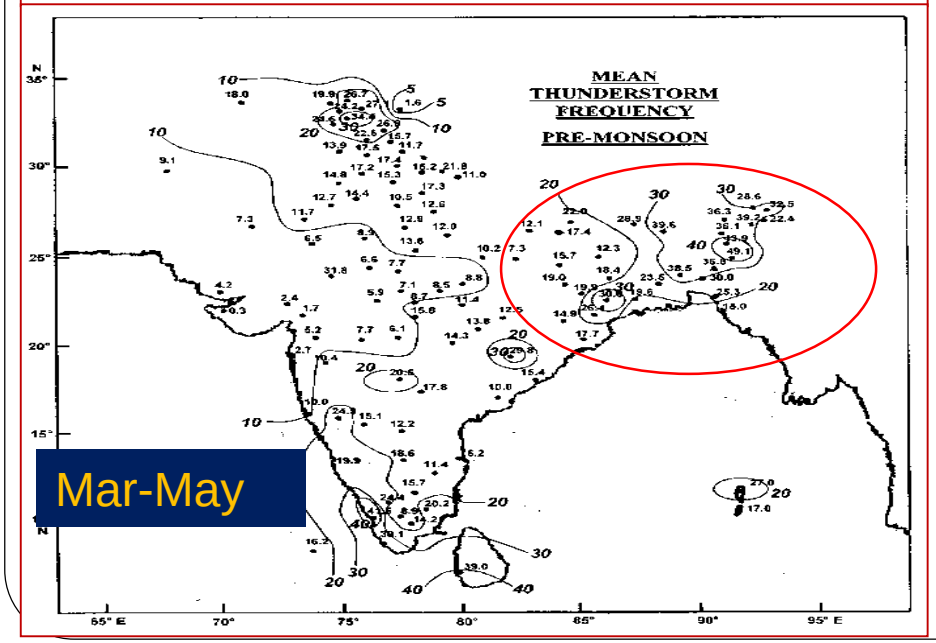


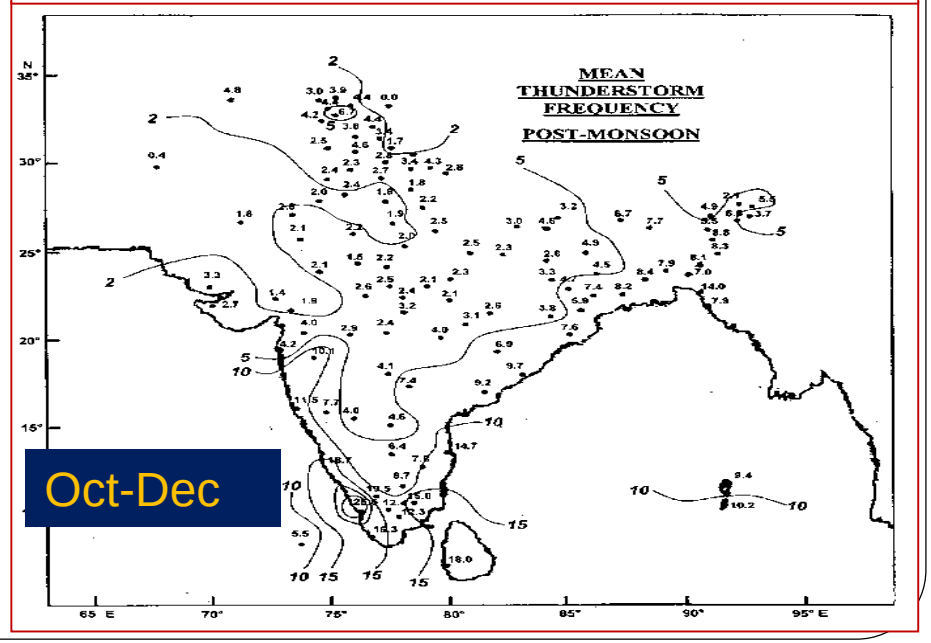


Thunderstorms









Numerical Weather Prediction (NWP) Modeling: Backbone for Forecasting and Warning Services

Models in 2018

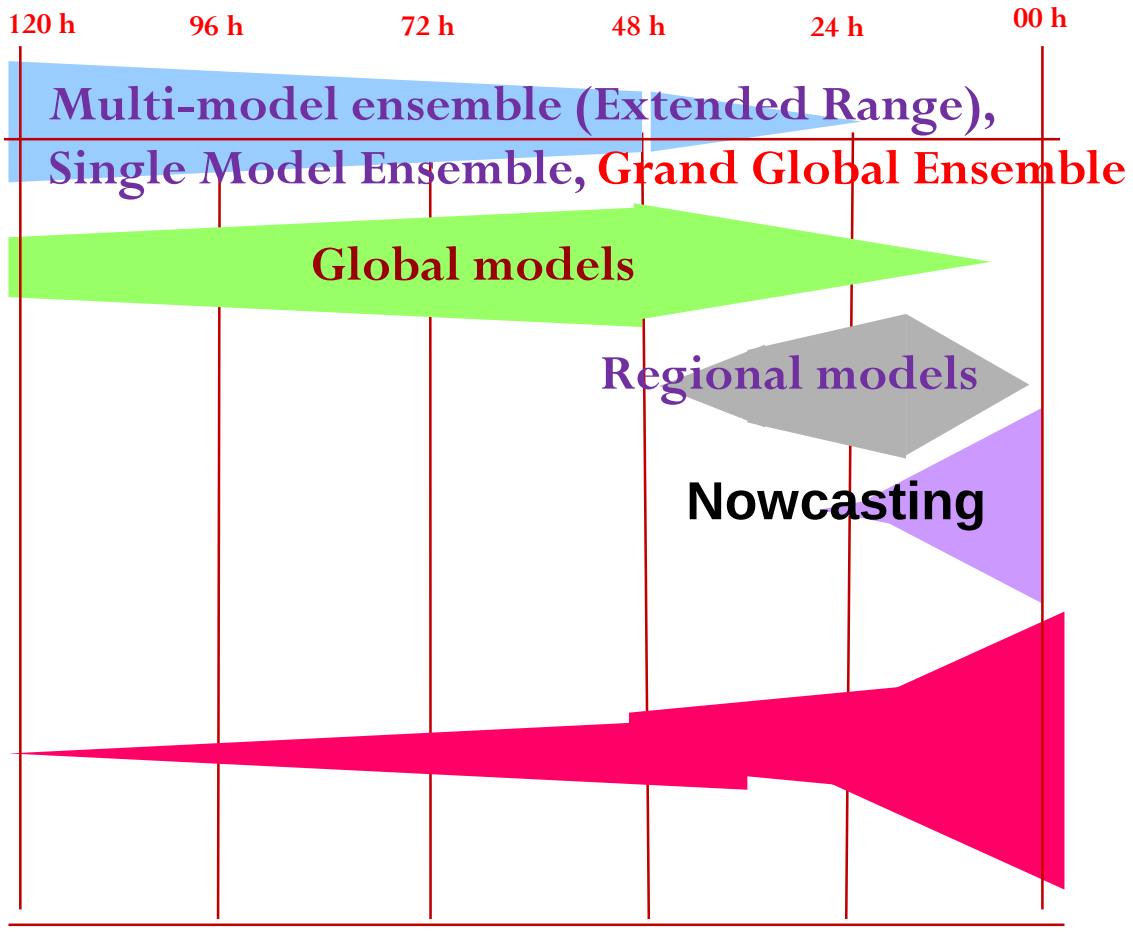
Ensemble Prediction Systems
GEFS (12km), UMEPS(9Km)

Global Models
GFS(T1534), Unified Model

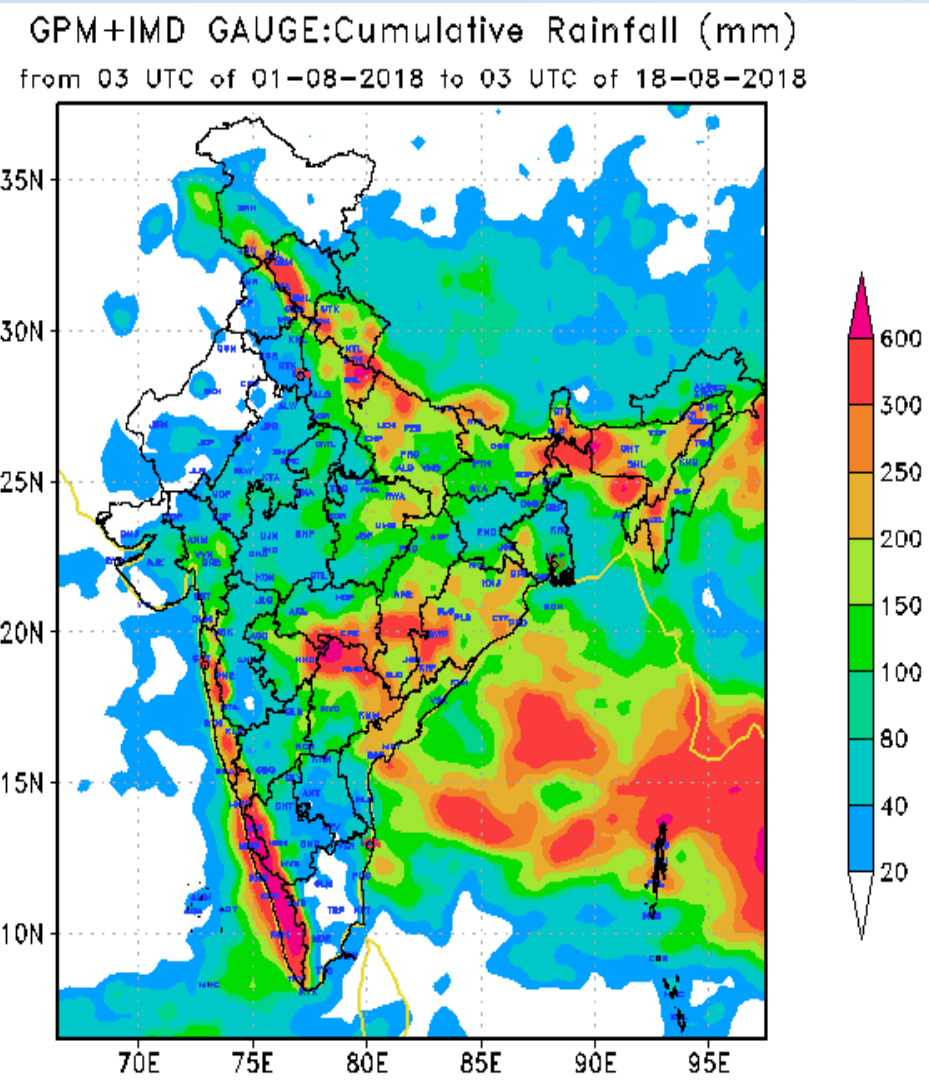
Regional Models
WRF, HWRF

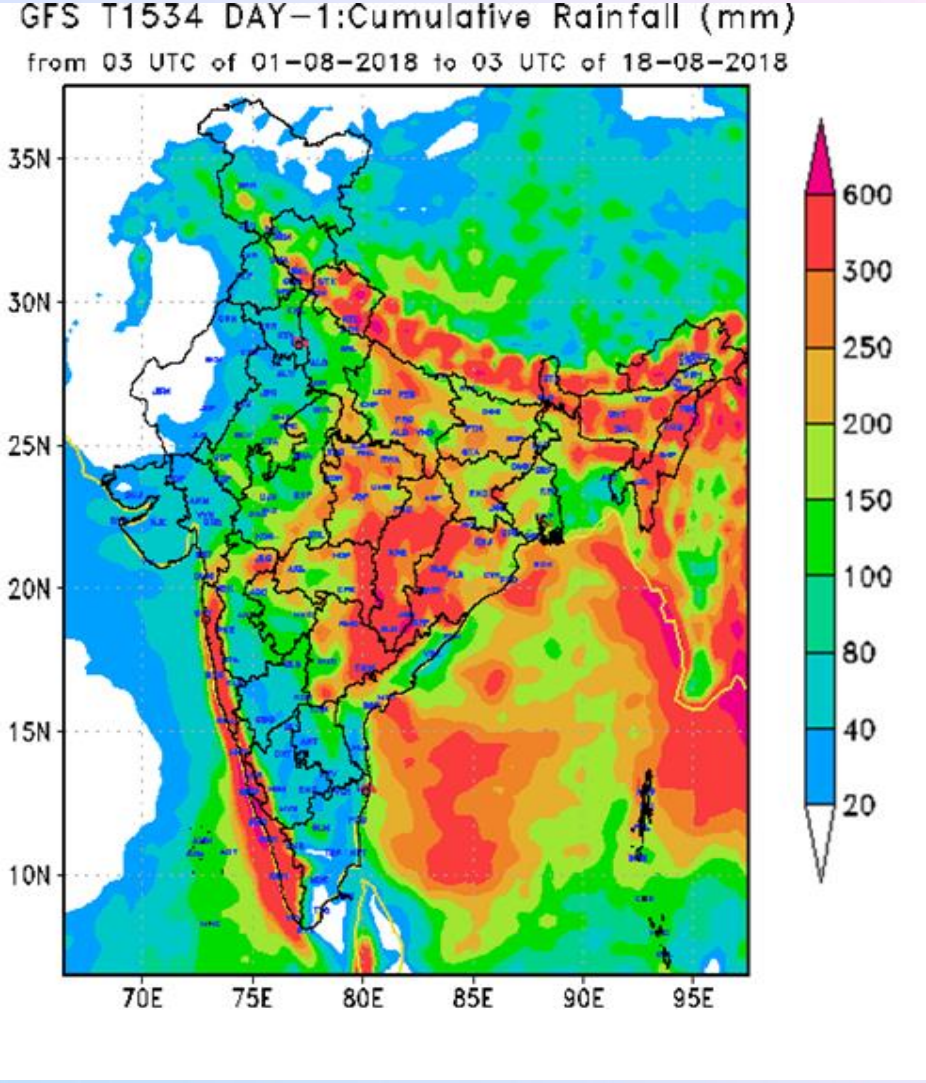
Nowcasting Tools
(WDSSII, ARPS Model)

Warnings Activities

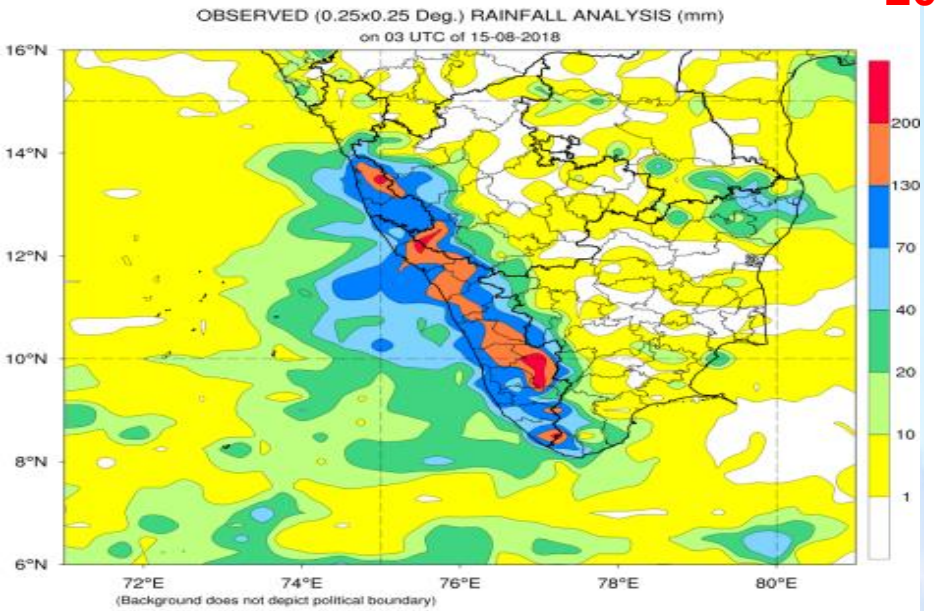


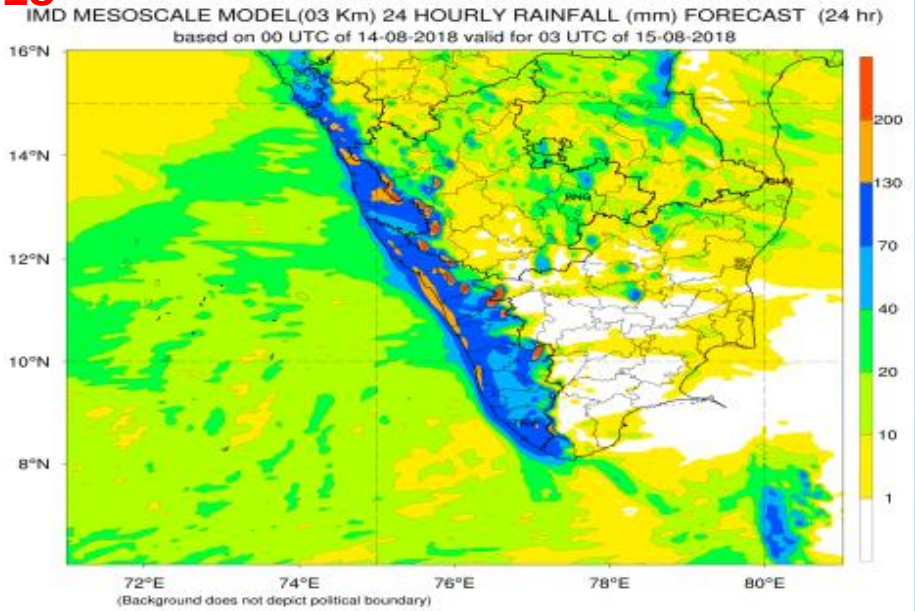
❖By 2019:1-3 km Regional multi-model prediction system, ocean-atmosphere-land surface coupled severe weather pred. systems, Parametric models and Expert systems – severe weather Warning up to 5-7 days, Forecast outlook up to 10-15 days.

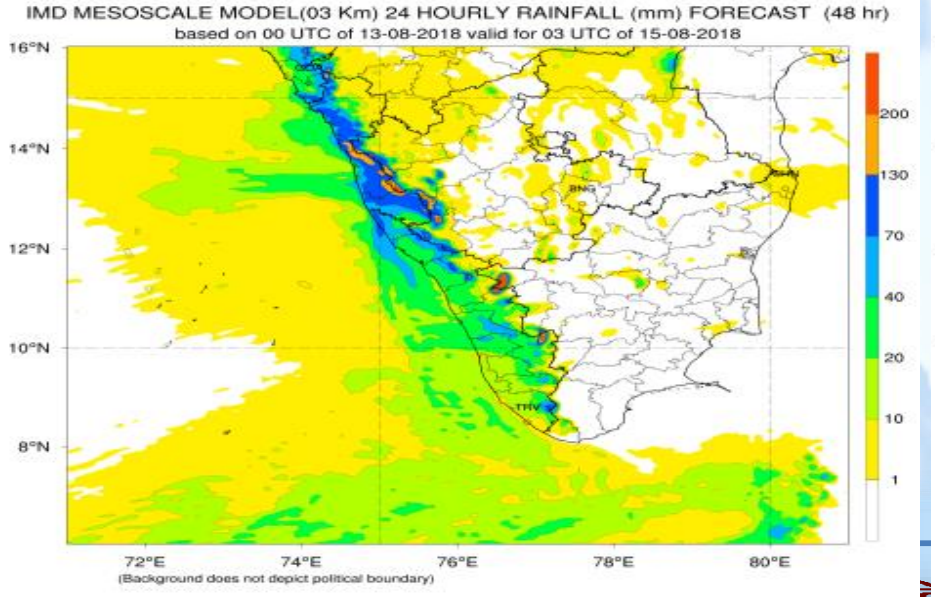

GPM+IMD GAUGE:Cumulative Rainfall (mm)
from 03 UTC of 01-08-2018 to 03 UTC of 18-08-2018
35N
30N
25N
20N
15N
10N
70E
75E
80E
85E
90E
95E
600
300
250
200
150
100
80
40
20

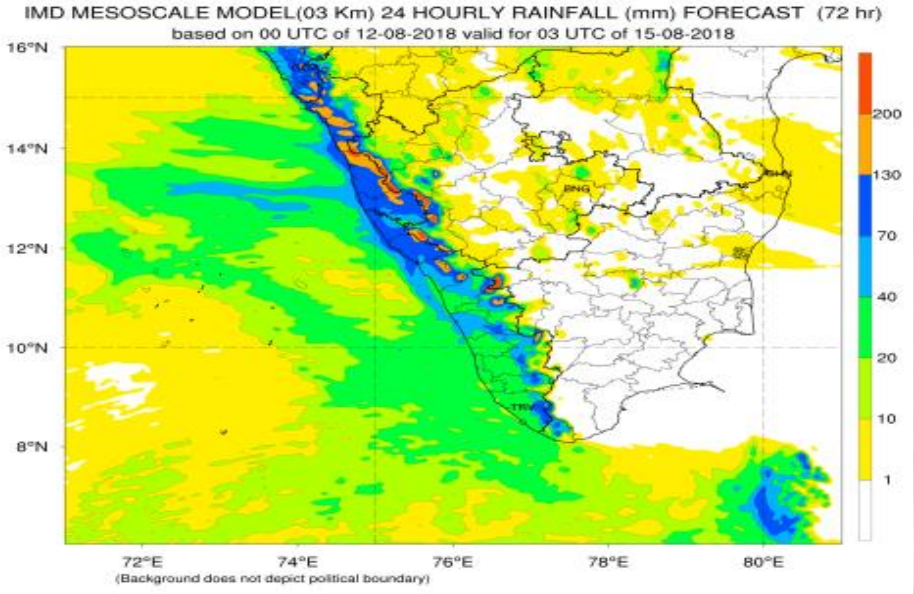

GFS T1534 DAY-1:Cumulative Rainfall (mm)
from 03 UTC of 01-08-2018 to 03 UTC of 18-08-2018
35N
30N
25N
20N
15N
10N
70E
75E
80E
85E
90E
95E
600
300
250
200
150
100
80
40
20

WRF (3 km) Forecast & IMD observed Rainfall Analysis at 03 UTC 15-08-2018









OPERATIONAL ERF IMPLEMENTED IN IMD

- Extended Range Forecast – Coupled Atmospheric-Ocean General Circulation Models (CFSv2) at different resolutions CFSv2_T382, CFSv2_T126, GFSbc_T382, GFSbc_T126 (with 16 members) implemented in IMD in December 2016.

- The hindcast (2003-2017) and forecast is run once in a week (every Wednesday initial condition) for 32 days period and the forecast for mean and anomaly is prepared for 4 weeks on every Thursday. (TMAX, TMIN, RAIN, WIND, MJO, etc)

The operational products are prepared for use in India and abroad.

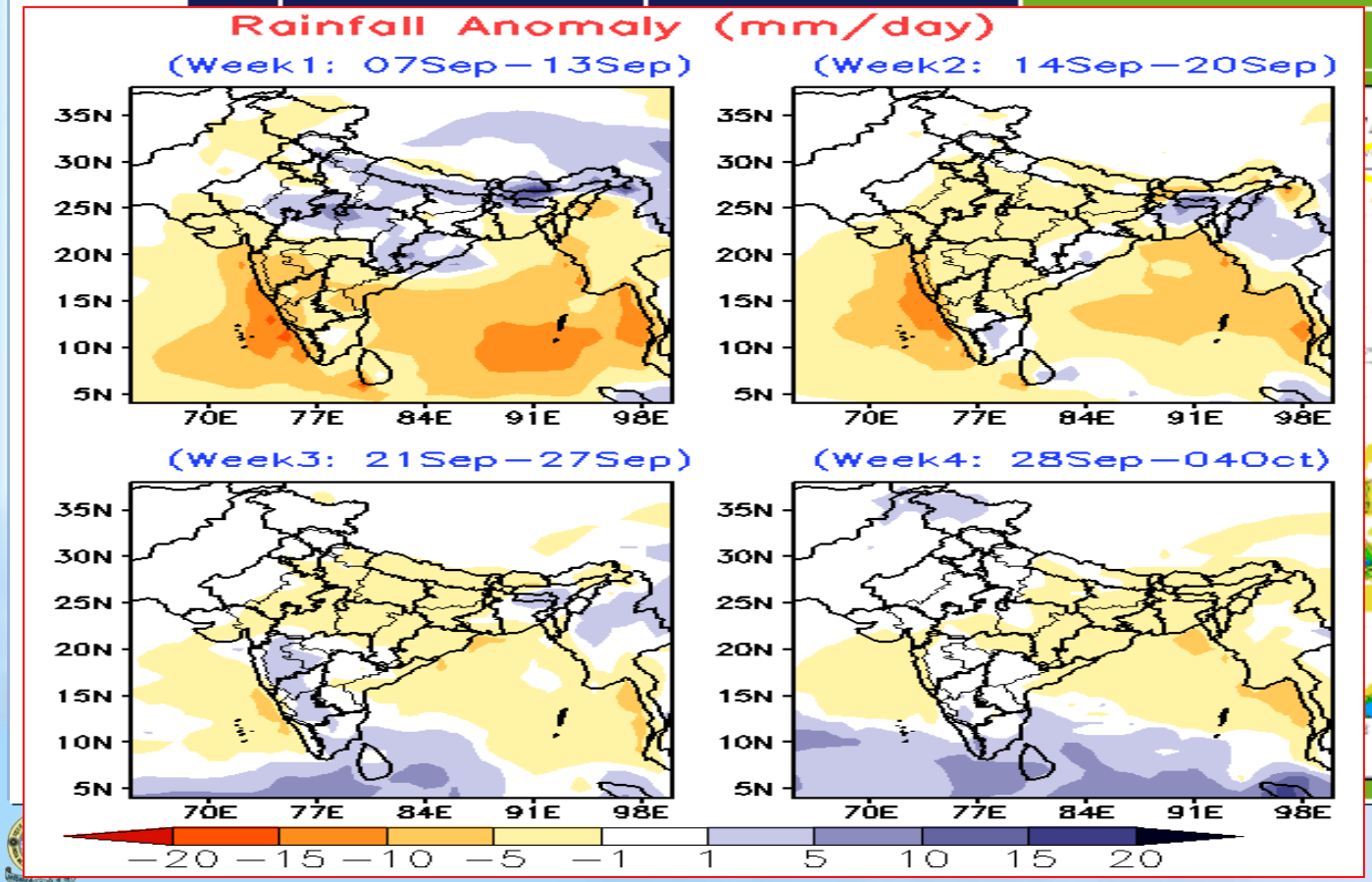
❖The customised products in the form of met subdivision level forecast for two weeks are used for Agro advisory purpose.

❖The products are also prepared for QATAR and adjoining country Bhutan

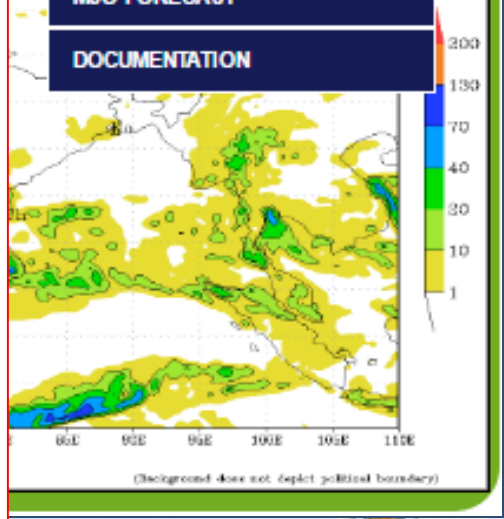
Extended Range forecast products available in IMD

NUMERICAL WEATHER PREDICTION DIVISION

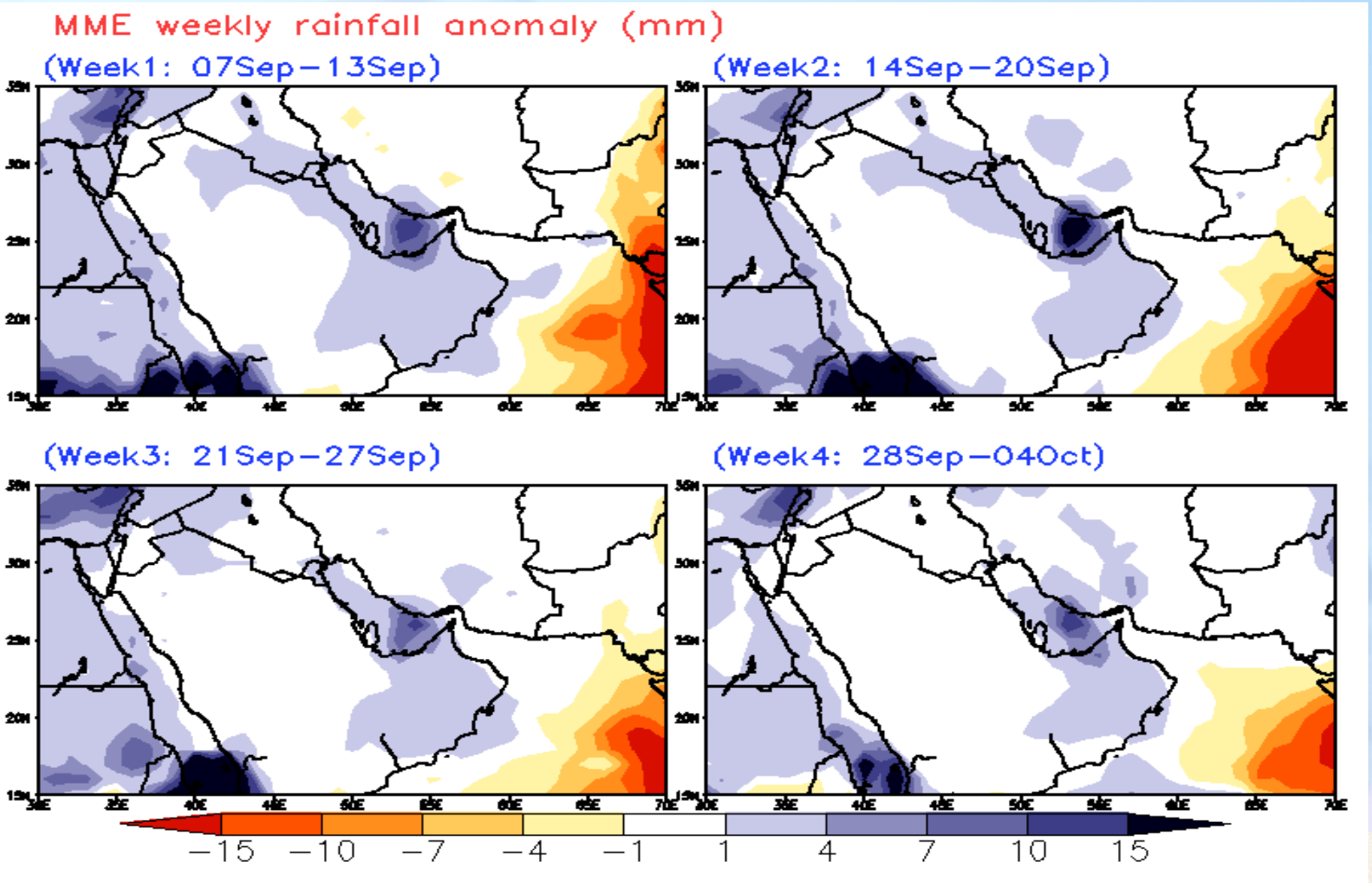
HOME | SHORT RANGE FORECAST >> | MEDIUM RANGE FORECAST >> | EXTENDED RANGE FORECAST >> | SEASONAL FORECAST >>



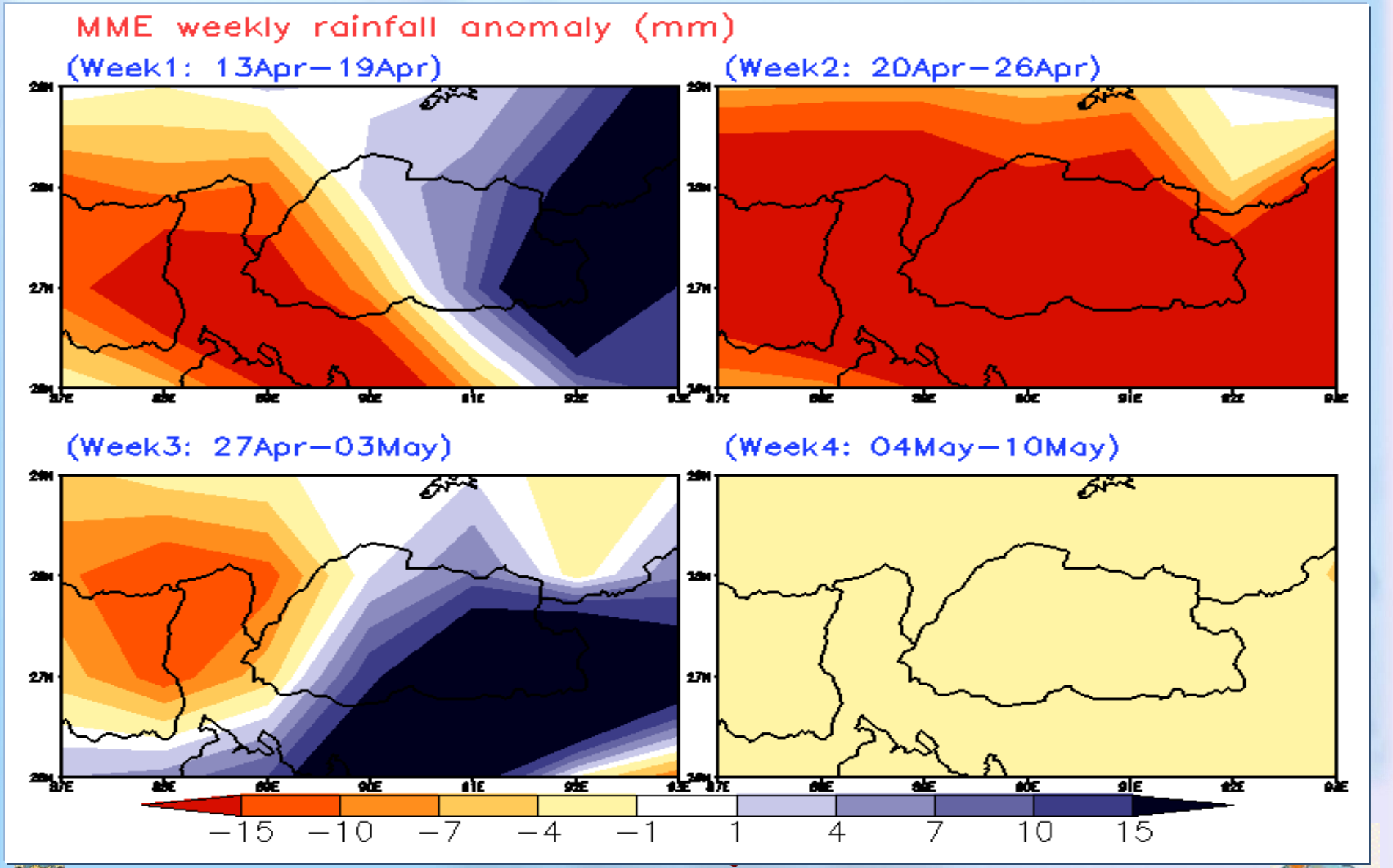
- COUPLED MODEL BULLETIN
- ANIMATION PRODUCTS
- 04 WEEK PRODUCTS
- WEEK WISE PRODUCTS
- MJO FORECAST
- DOCUMENTATION



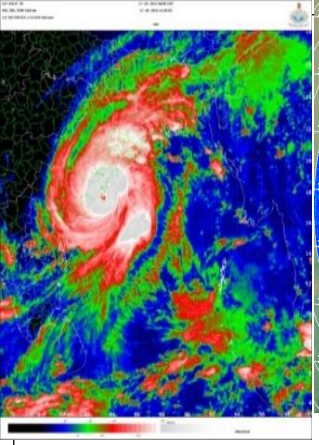
Forecast products for QATAR

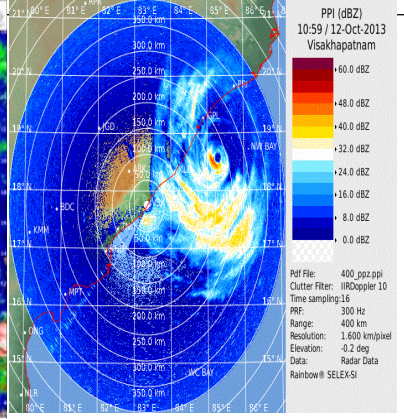


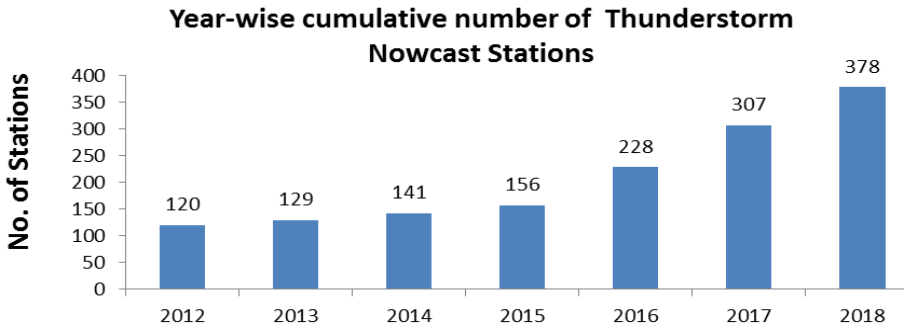
Forecast products for Bhutan



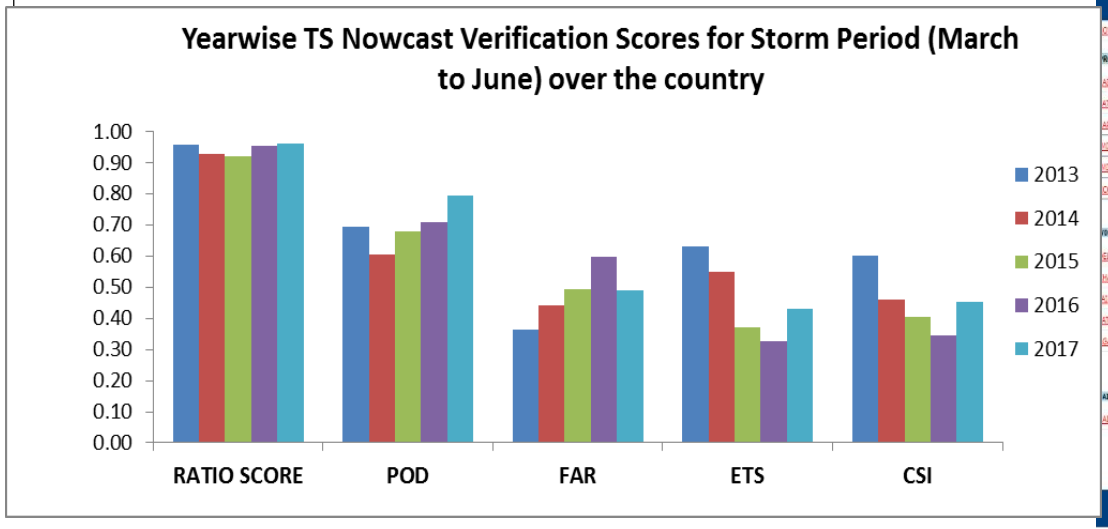
Operational Nowcasting

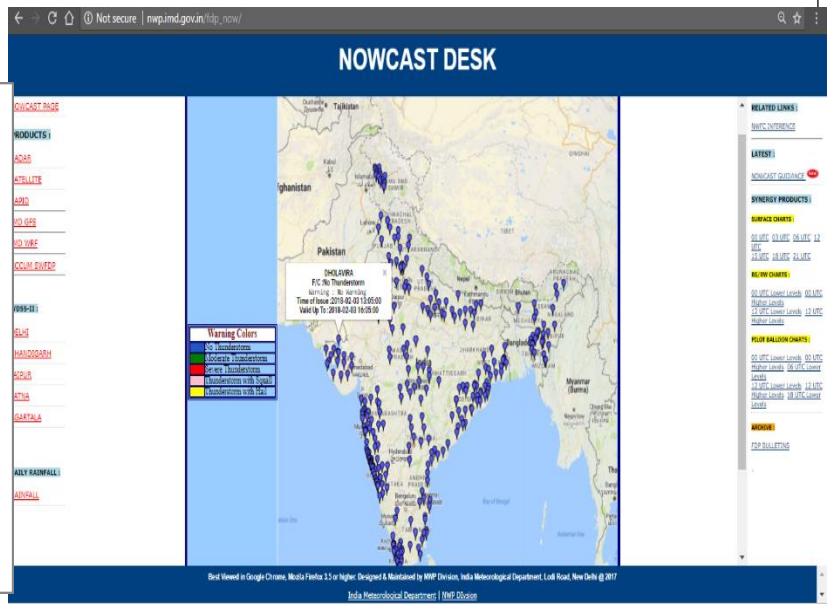




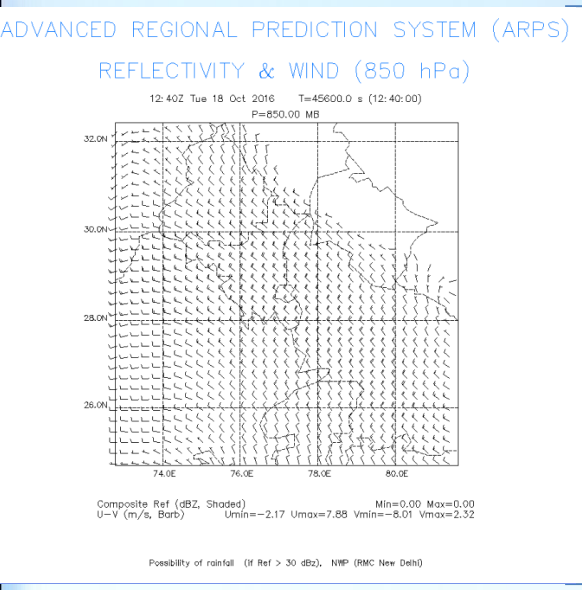


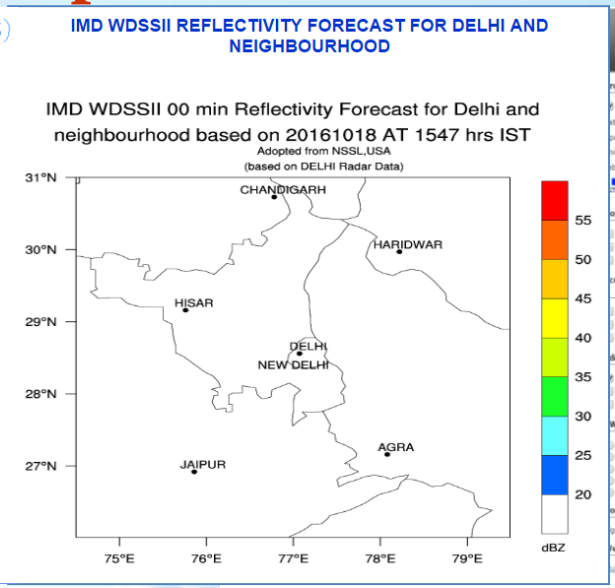
- 378 stations covered so far in by March 2018
- Nowcasting for district level since 2017
- Nowcast Page is updated by Meteorological Centres
- Nowcast bulletins by SMS issued for severe weather for district level and transmitted through SMS and e-mail
- Target: location specific nowcast for 660 stations by 2019

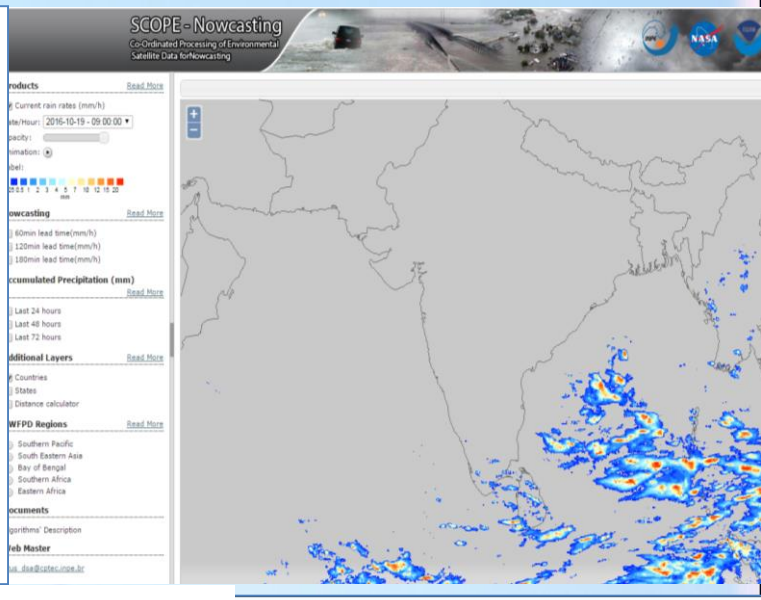




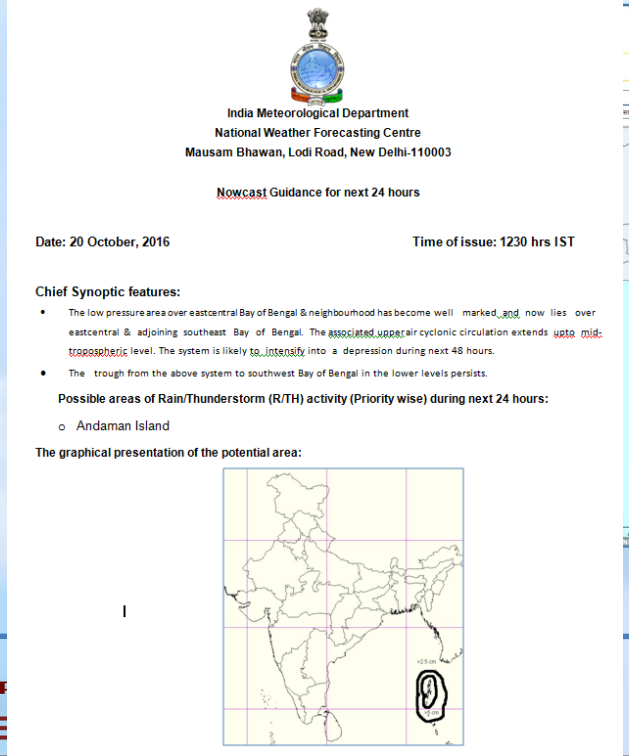
Guidance products and Nowcast Services







- Nowcast Guidance Bulletin from 5 October 2016.
- Based on Nowcast Guidance Bulletin, MC/RMC will issue round the clock Nowcast Bulletin
- Pan India nowcast being issued for severe weather like heavy rain/snow, thunderstorm etc



India Meteorological Department
National Weather Forecasting Centre
Mausam Bhawan, Lodi Road, New Delhi-110003

Nowcast Guidance for next 24 hours

Date: 20 October, 2016 **Time of issue: 1230 hrs IST**

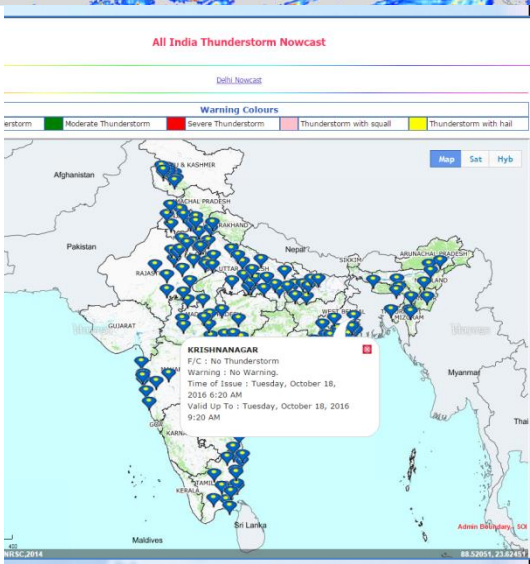
Chief Synoptic features:

- The low pressure area over eastcentral Bay of Bengal & neighbourhood has become well marked and now lies over eastcentral & adjoining southeast Bay of Bengal. The associated upper air cyclonic circulation extends upto mid-tropospheric level. The system is likely to intensify into a depression during next 48 hours.
- The trough from the above system to southwest Bay of Bengal in the lower levels persists.

Possible areas of Rain/Thunderstorm (R/TH) activity (Priority wise) during next 24 hours:

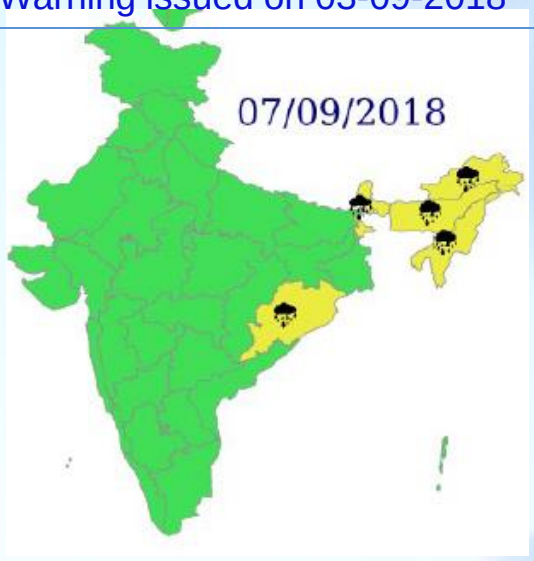
- Andaman Island

The graphical presentation of the potential area:



Deep Depression (07 September)

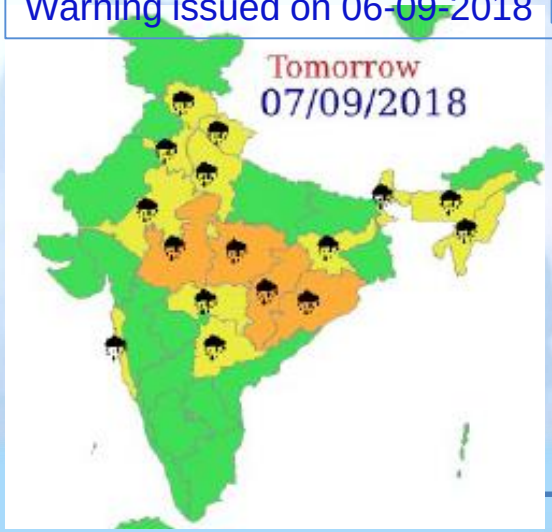
Warning issued on 03-09-2018



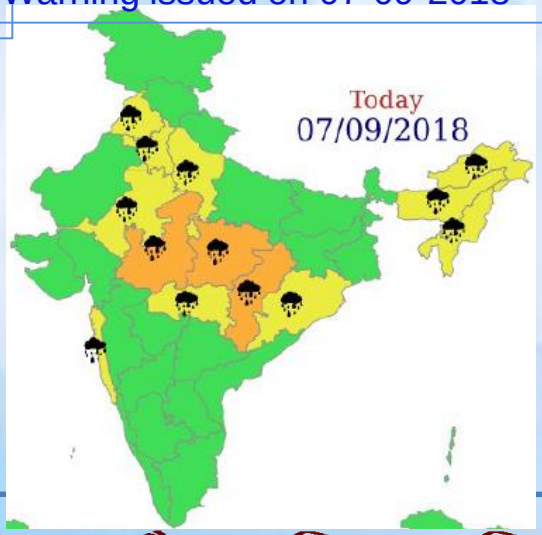
Warning issued on 04-09-2018

Warning issued on 05-09-2018

Warning issued on 06-09-2018



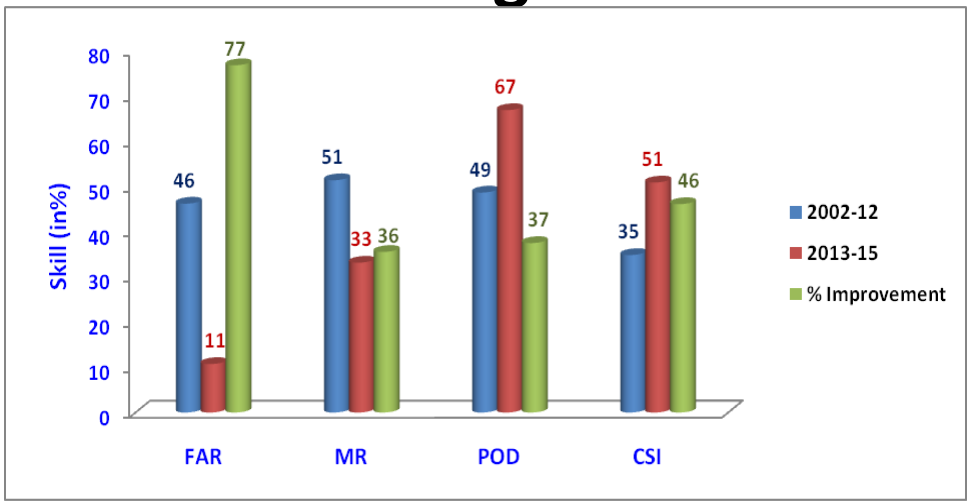
Warning issued on 07-09-2018



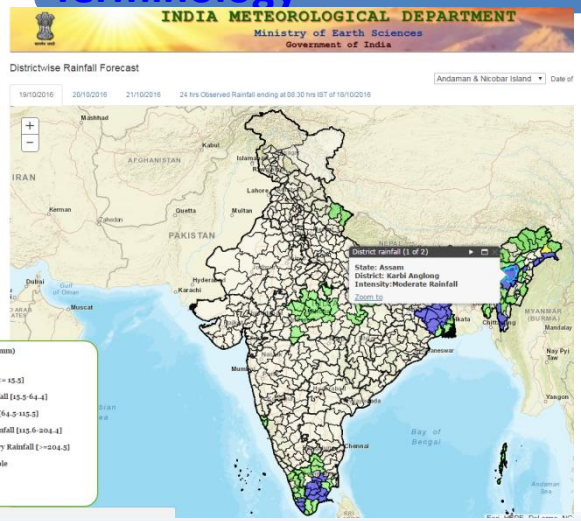
Severe Weather Forecast &Warnings skills

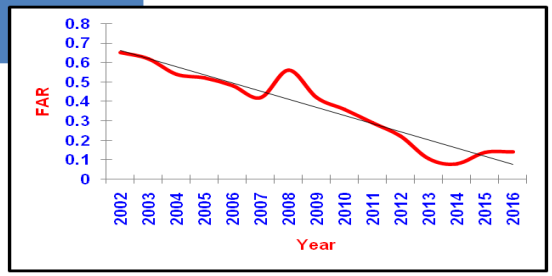
Noticeable improvements achieved in Skills of Heavy Rainfall Forecast (**False Alarm Rate reduced from 46% to 11% & Probability of Detection increased from 49% to 67% from 2002-12 to 2013-15**)

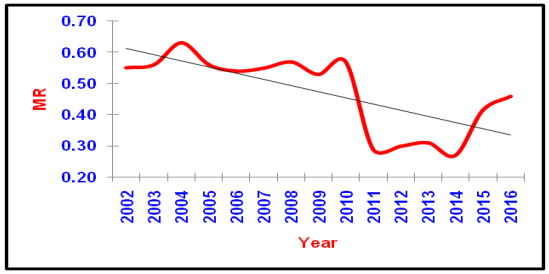
Lead time of warnings increased from 3 to 5 days in respect of Rainfall, heat wave, cold wave .

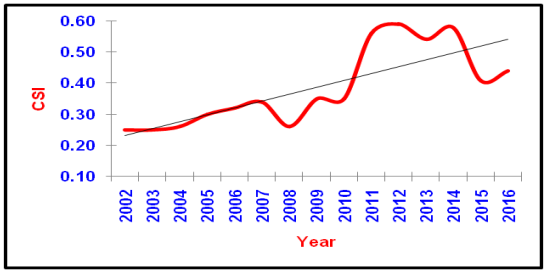


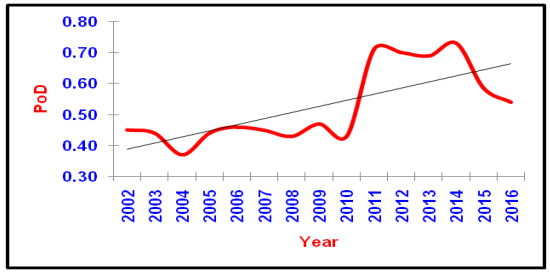
Introduced new **Forecast bulletin Terminology**









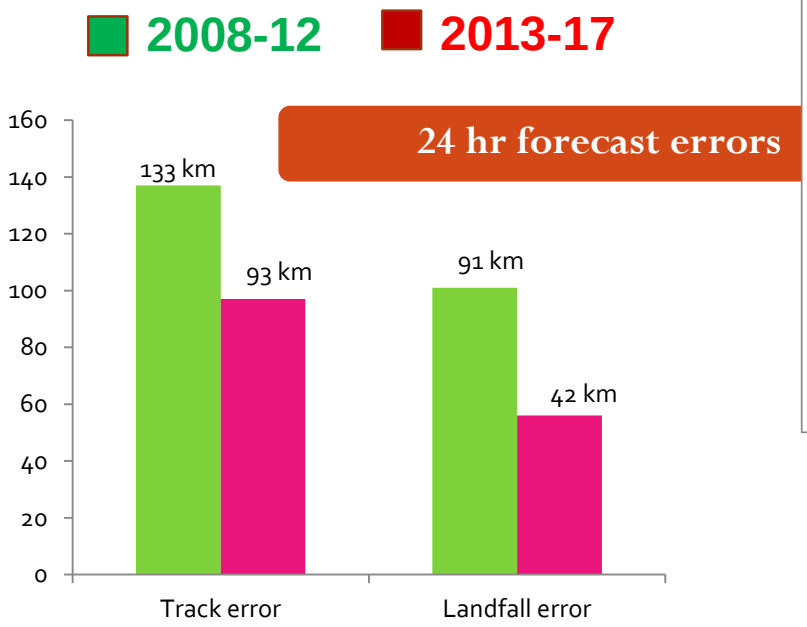


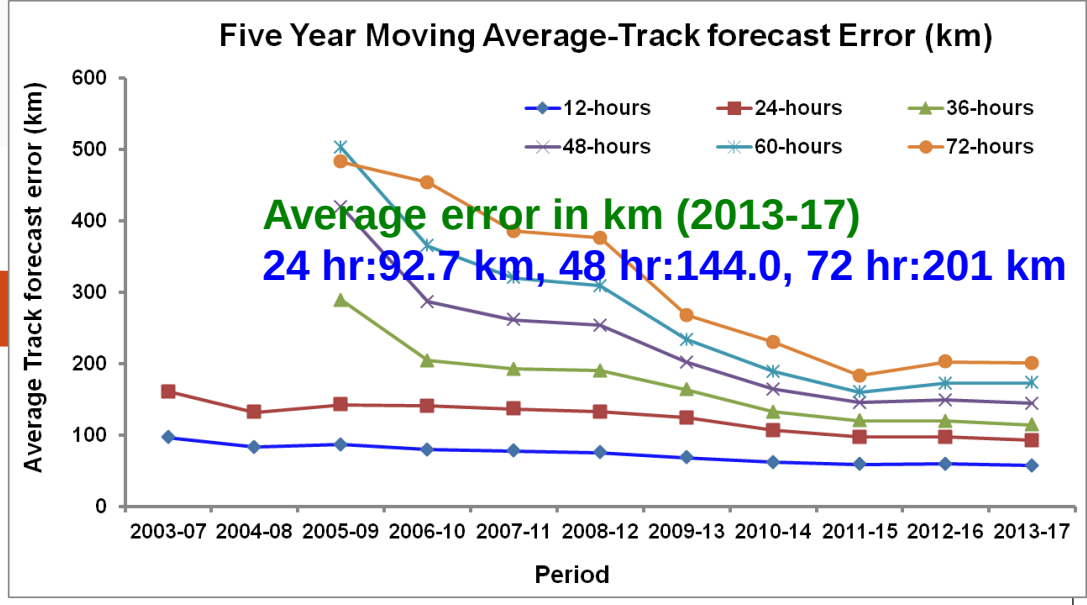
Target for 2019 : Improvement of accuracy and skill by 20% up to 7 days

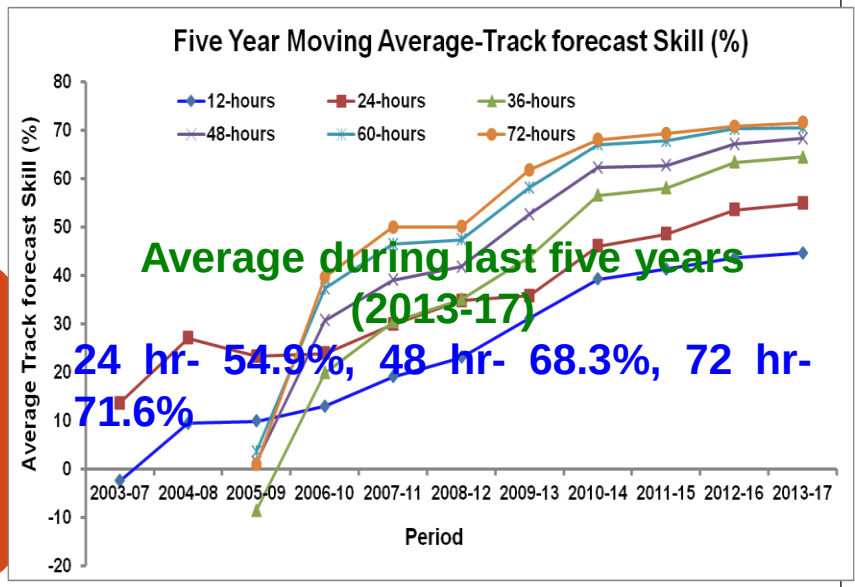
Home Page of RSMC Website

- IMD has launched a website exclusively for RSMC, New Delhi.
- The data, forecast and products will be available to all the countries of the region through this website.

Cyclone Forecast: Achievements







Genesis forecast with lead period for systems developing near coast

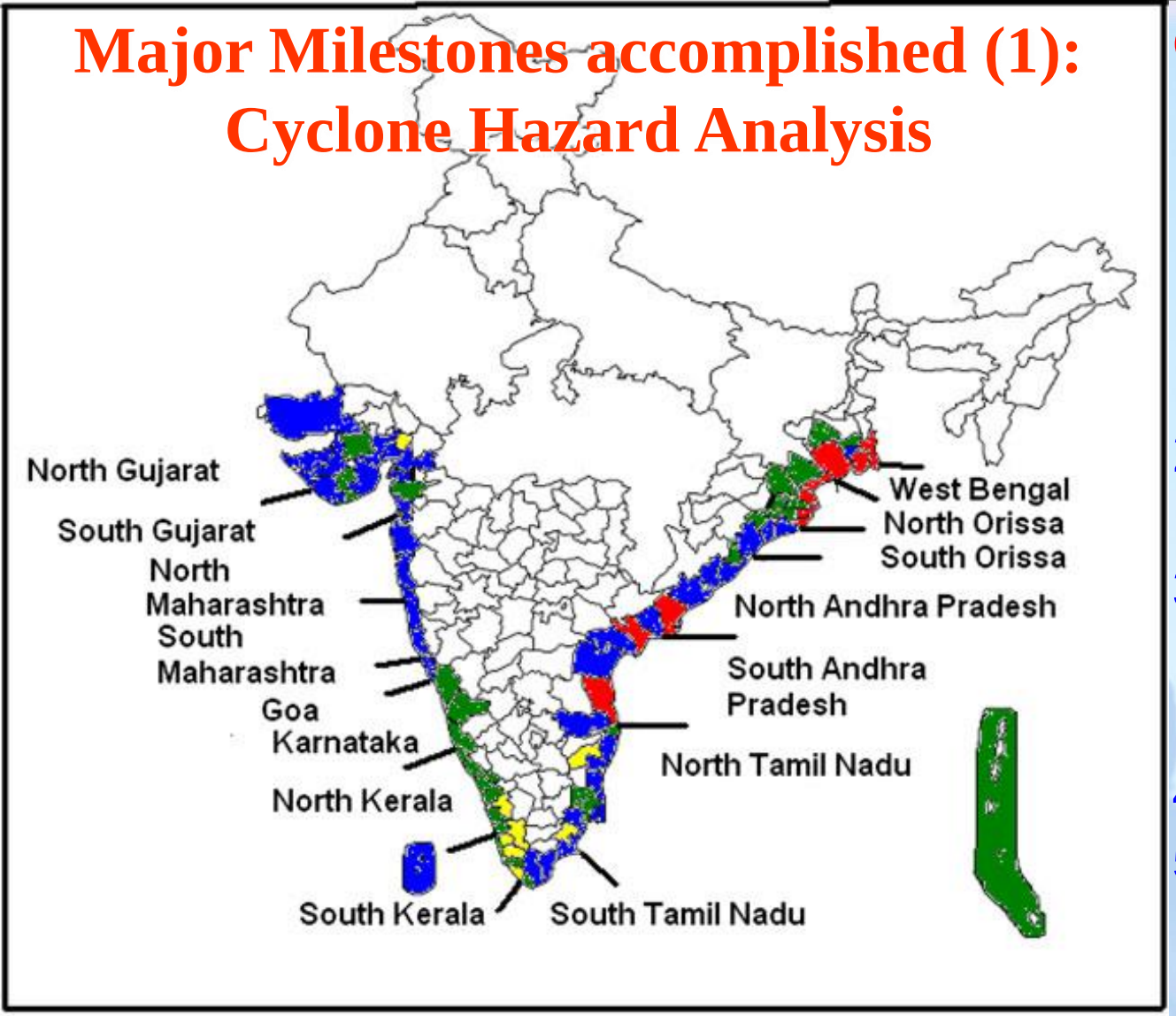
Intensity forecast, specially rapid intensification and weakening

Heavy rainfall warning -Location specific and river catchment wise

Target for 2024 : Reduction in error and Improvement of skill by 20% up to 7 days

Target for 2024 : Dynamical Impact based Forecast and Warning

Major Milestones accomplished (1): Cyclone Hazard Analysis



Cyclone hazard prone districts of India based on

1. Frequency of total cyclones,
2. Total severe cyclones,
3. Actual/estimated maximum wind strength,
4. PMSS
5. PMP

TYPES OF POTENTIAL DAMAGES ACCOMPANYING TROPICAL CYCLONES

CYCLONE

LOCAL TIDES

LOCAL COASTAL CONFIGURATION

STORM SURGE

- FLOODING OF COASTAL AREAS
- EROSION OF BEACHES
- LOSS OF SOIL FERTILITY FROM SALINE INTRUSIONS

WIND

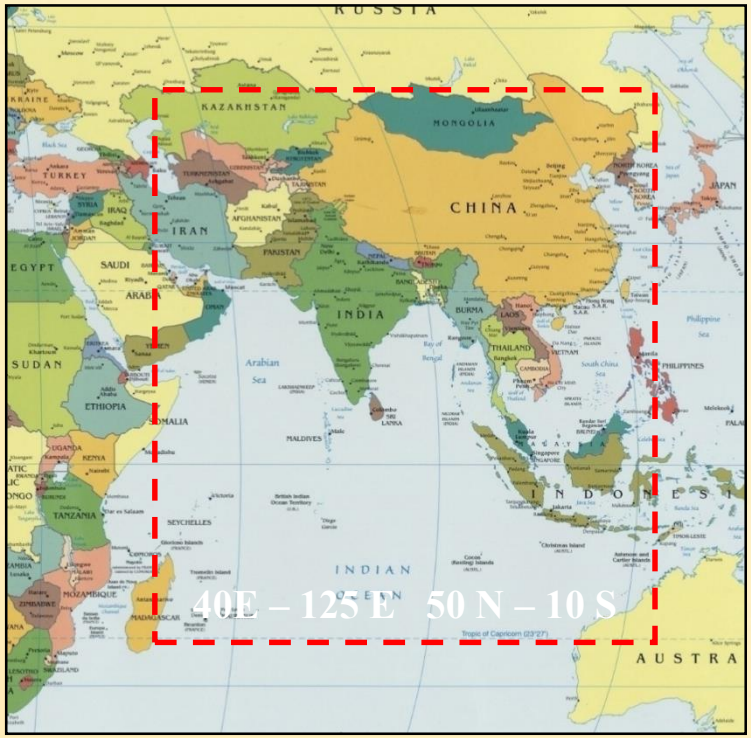
- DAMAGE TO STRUCTURES
- LOSS OF POWER/COMMUNICATION
- INJURIES & LOSS OF LIFE
- DESTRUCTION OF CROPS, VEGETATION, LIVE-STOCK

RAIN

- CONTAMINATION OF WATER SUPPLY SYSTEM
- LAND SUBSIDENCE
- FLOODING OF INLAND AREA

SWFDP – Bay of Bengal

Focus: Coastal communities and activities



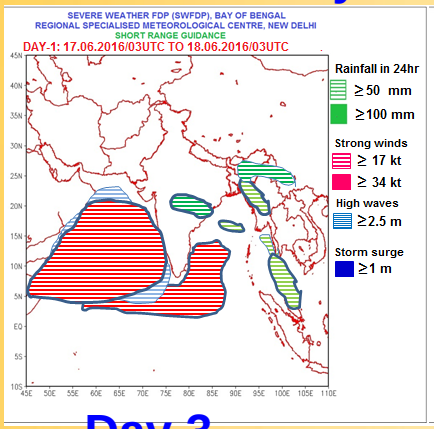
- Bangladesh
- India
- Maldives
- Myanmar
- Sri Lanka
- Thailand
- Bhutan (later)
- Nepal (later)
- Afghanistan (later)
- Pakistan (later)

Severe Weather from TCs, severe thunderstorms and monsoon:
Heavy precipitation, Strong winds
Large waves / swell, Storm Surge

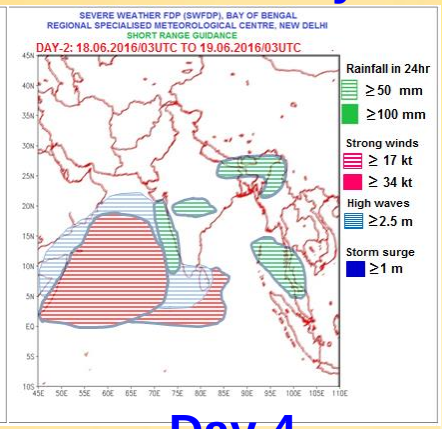
Improved severe weather forecasting , warning services to disaster management (PWS) and other sectoral applications

Severe Weather Forecast Demonstration Project

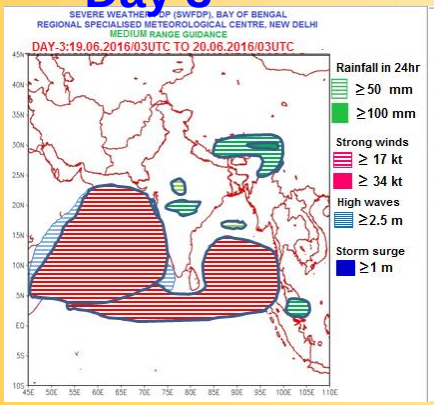
Day 1



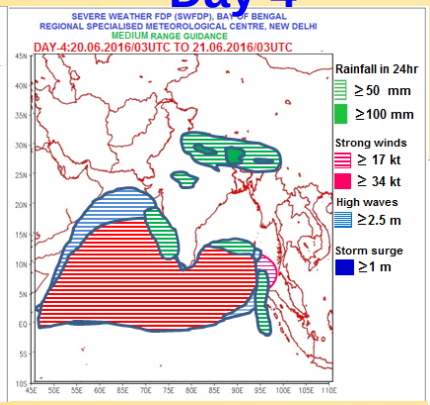
Day 2



Day 3

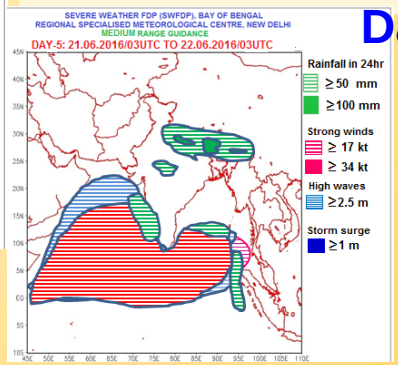


Day 4

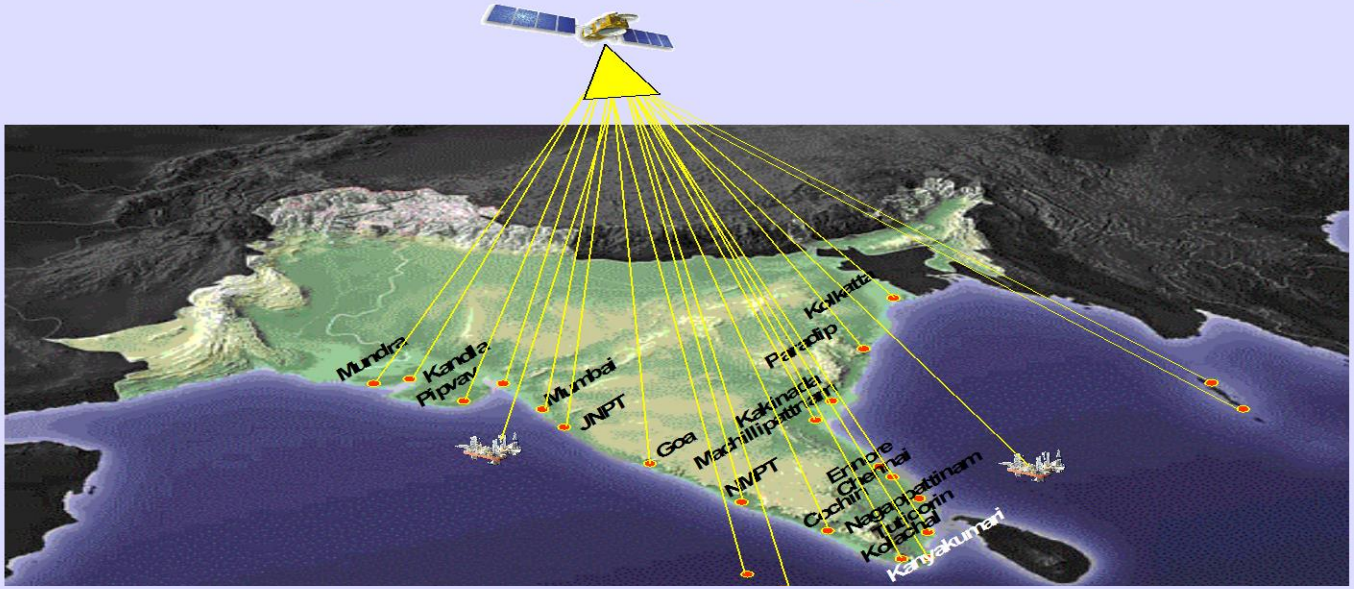


- Three tier cascading system (global, regional and national partners)
- Project will commence in pilot mode in 2 May 2016 for cyclone, heavy rain, wind and wave with RSMC, New Delhi as Regional Centre
- Global model products from NCEP, ECMWF, UKMO, JMA will be available for this domain

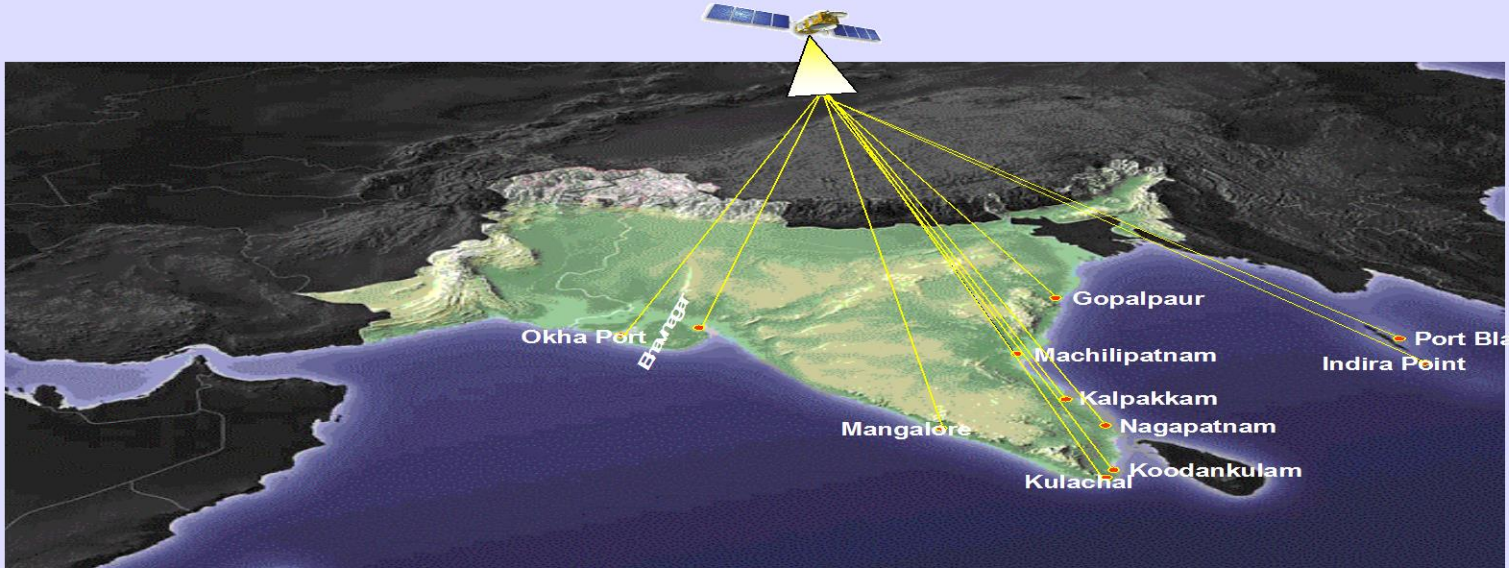
Day 5



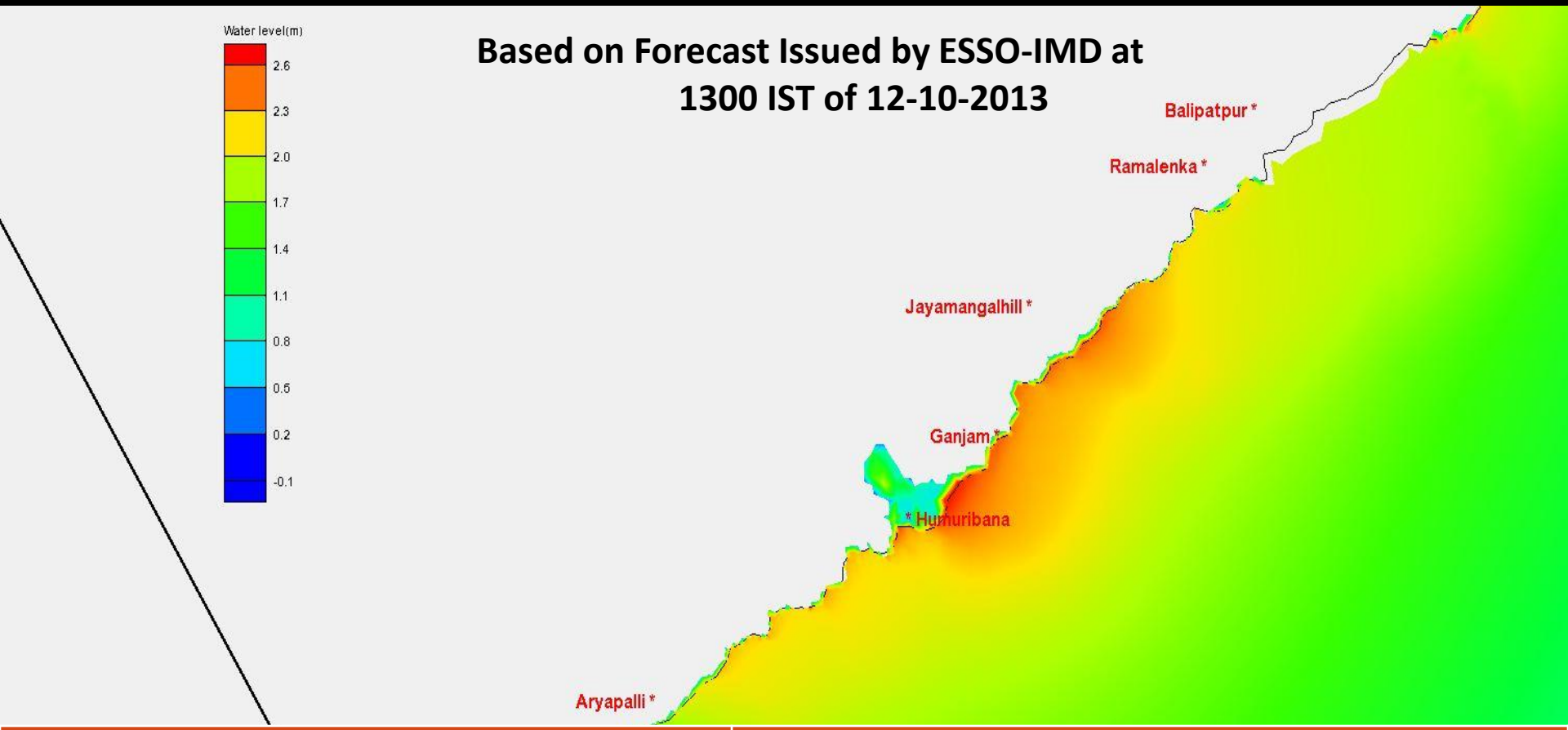
Sea Level Monitoring Stations



HF Radar-based Monitoring of Surface Current and Wave

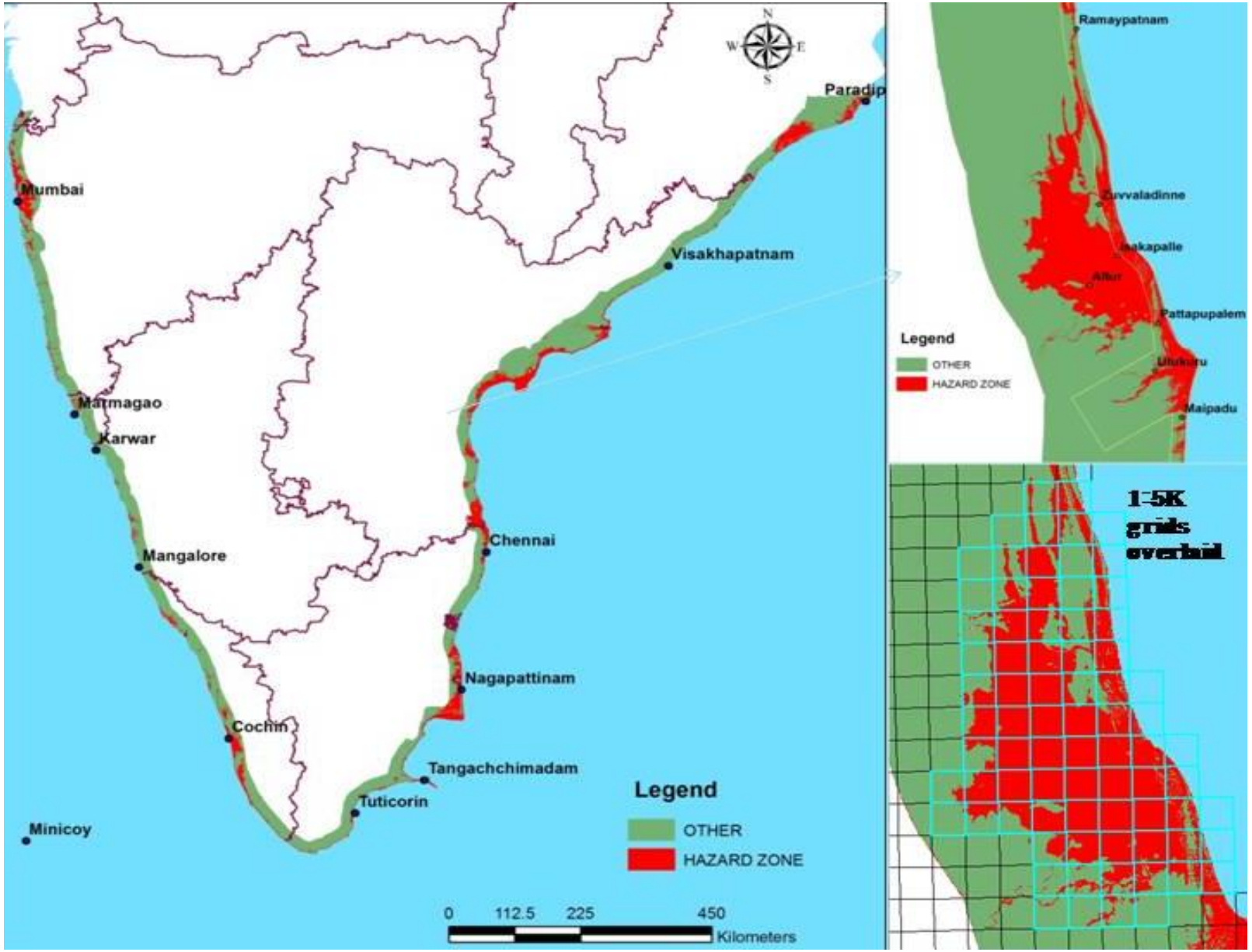


Storm Surge Modeling –Phailin Cyclone



EXPECTED TIDE AT PARADEEP	-0.3M DURING LANDFALL
EXPECTED WIND SPEED	210 - 220 KMPH
MAX EXPECTED SURGE	2.6 M AT GANJAM, ORISSA
MAX EXPECTED INUNDATION EXTENT	3 KM THROUGH RIVER NEAR GANJAM, ORISSA

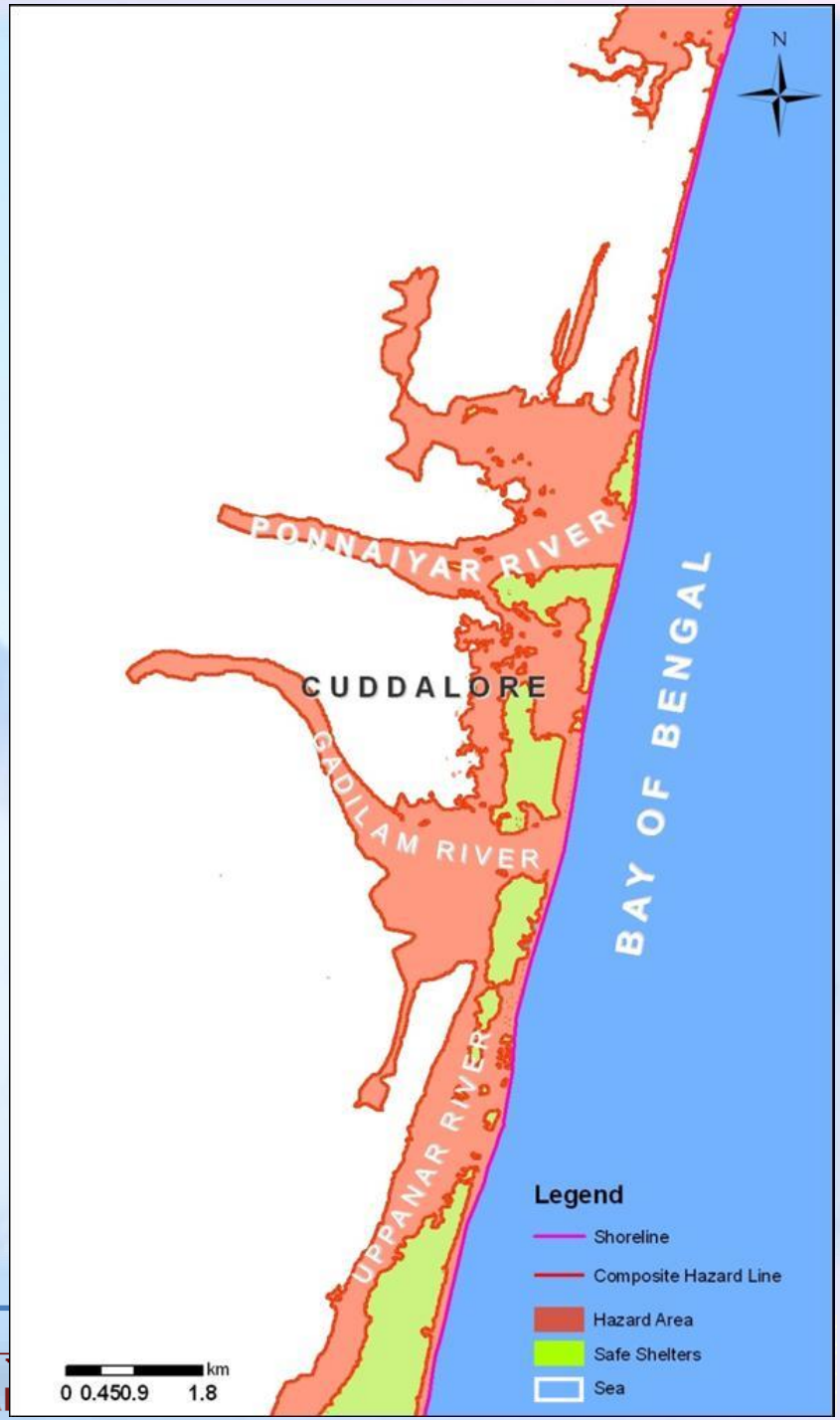
Multi-Hazard Vulnerability



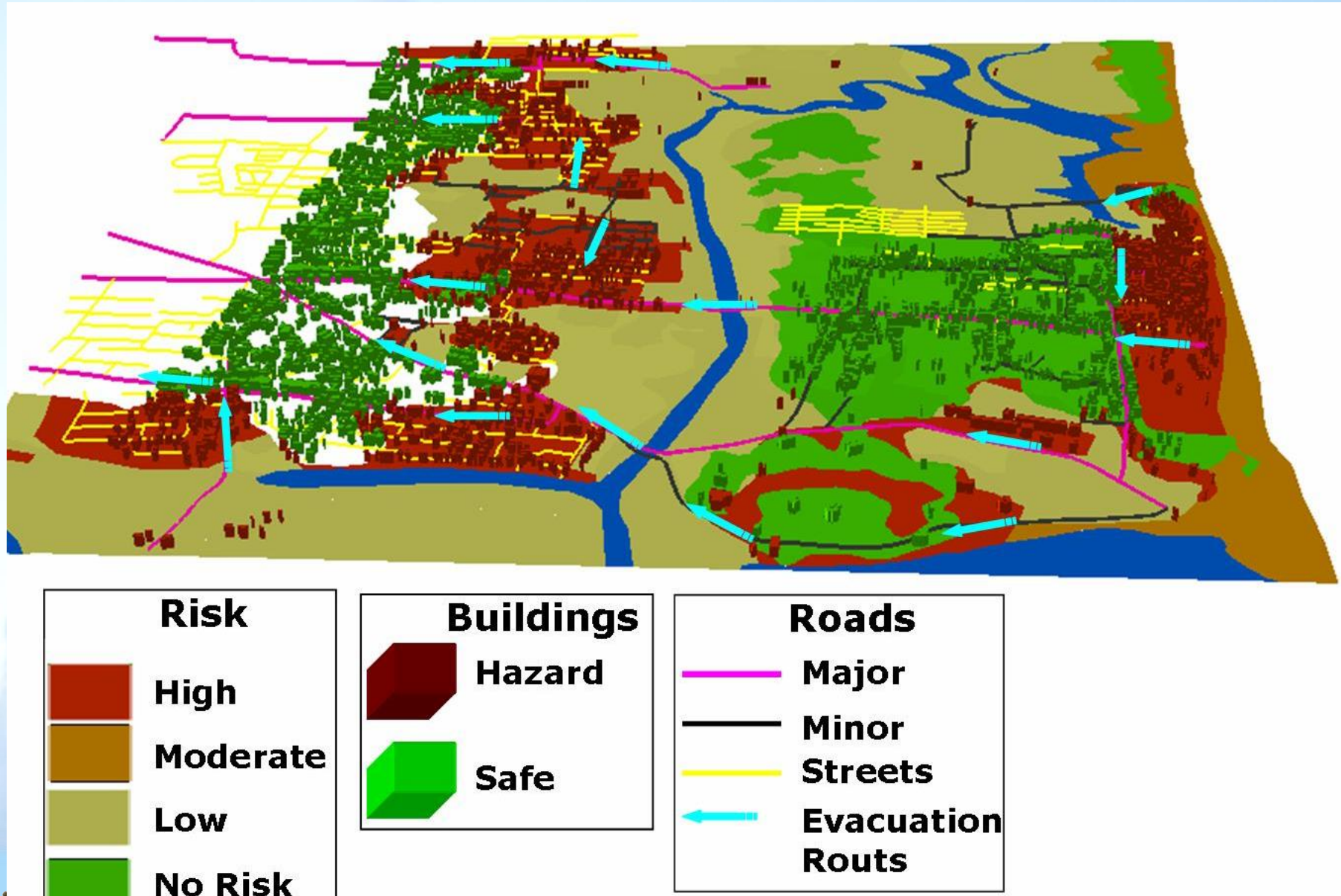
Case Study

Composite Multi-hazard line and future shoreline overlaid on DEM

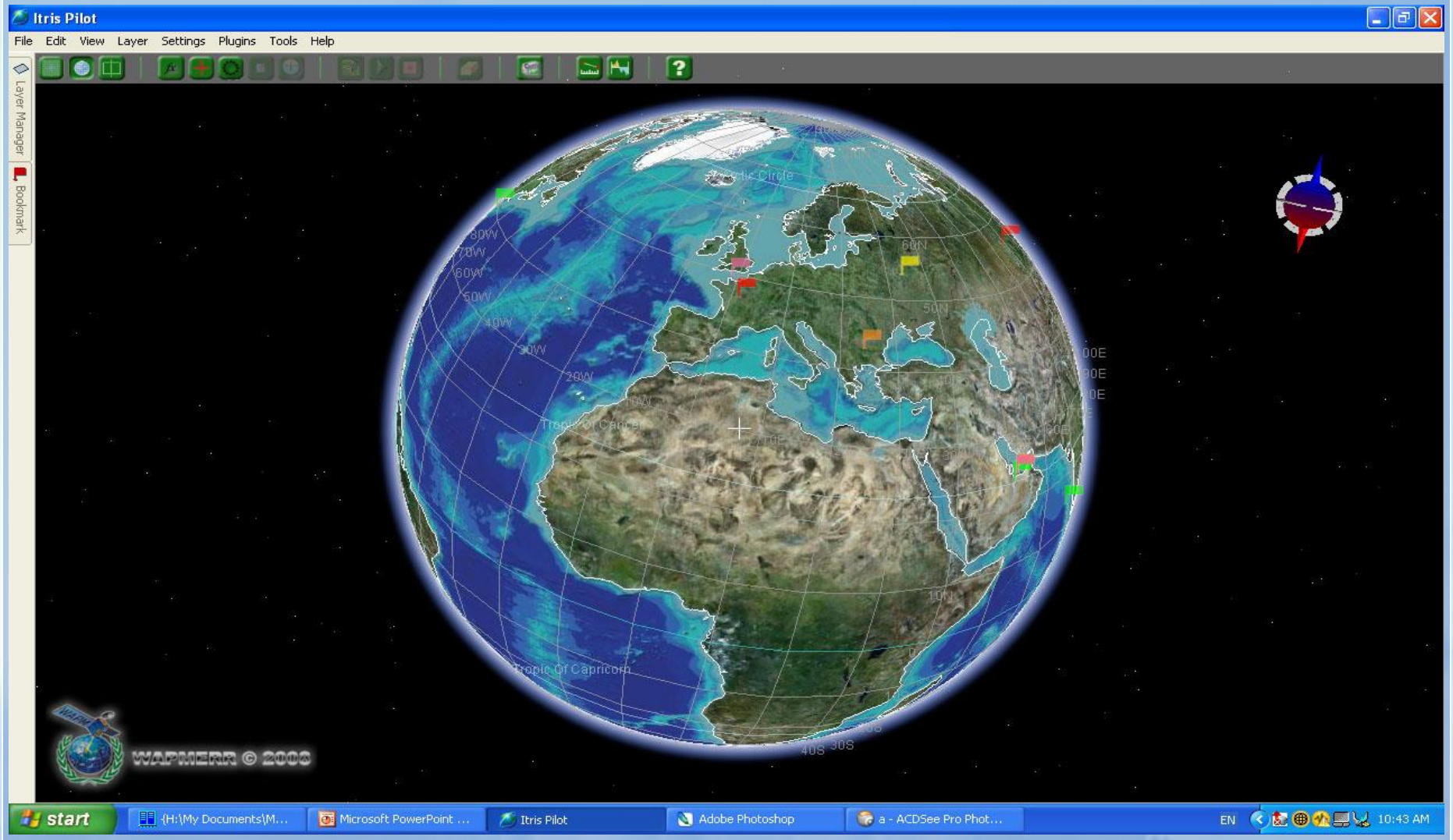
Building polygons are in hazard area (pink) and non-hazard area (green) are overlaid



Risk Mapping and Disaster Management



3D GIS



Main window shows 3D model of the Earth surface.
The cities having 3D building models are marked by colored flags.

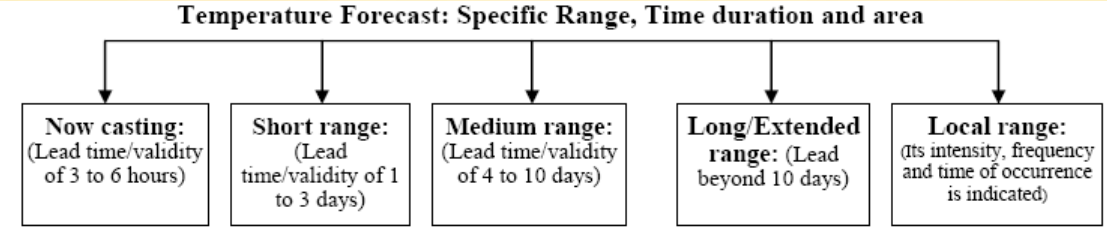
Allows to select any area of the Earth surface and zoom in on this area up to the highest resolution 60 cm (if a certain satellite imagery of the highest resolution is available)

Manipulation with realistic 3D models and textures of real buildings.
Inclusion of real object images (peoples, items, signs) in a 3D model.
The building brief (address, telephone, owner) appears in the pop-up information box.

The example of design a photographically exact 3D model. These real buildings are the buildings for public worship in Nagapattinam (India).

Heat action plan

- Heat action plan is extended to seven cities across Central India.
- Letter written by HMoES to all chief Secretaries for preparing Heat Action Plan
- Daily Bulletin on Heat Wave issued during April to June
- Indian Medical association and power sector among other were provided forecast



3.3 Identification of Color Signals for Heat Alert[3]:

Red Alert (Severe Condition)	Extreme Heat Alert for the Day	Normal Maximum Temp increase 6° C to more
Orange Alert (Moderate Condition)	Heat Alert Day	Normal Maximum Temp increase 4° C to 5° C
Yellow Alert (Heat-wave Warning)	Hot Day	Nearby Normal Maximum Temp.
White (Normal)	Normal Day	Below Normal Maximum Temp.

[3] Ahmadabad Heat Action Plan 2015

Heat Wave defined in India

Heat wave considered when actual Max. temp. is 40°C or more for plains and 30°C or more for Hilly regions

a) Based on Departure from Normal

Heat Wave: Departure 4.5^{O}C to 6.4^{O}C

Severe Heat Wave: Departure >6.4^{O}C

b) Based on Actual Maximum Temperature

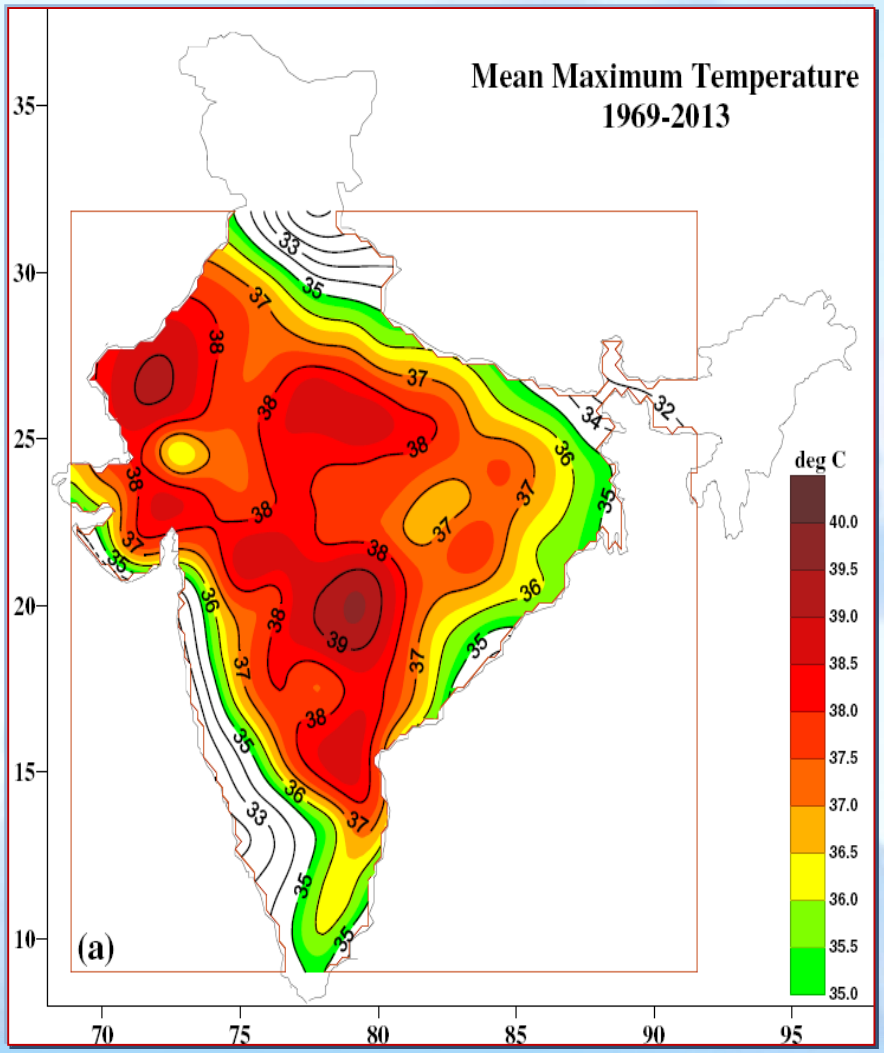
Heat Wave: Maximum Temperature ≥ 45^{O}C

Severe Heat Wave: Maximum Temperature ≥47^{O}C

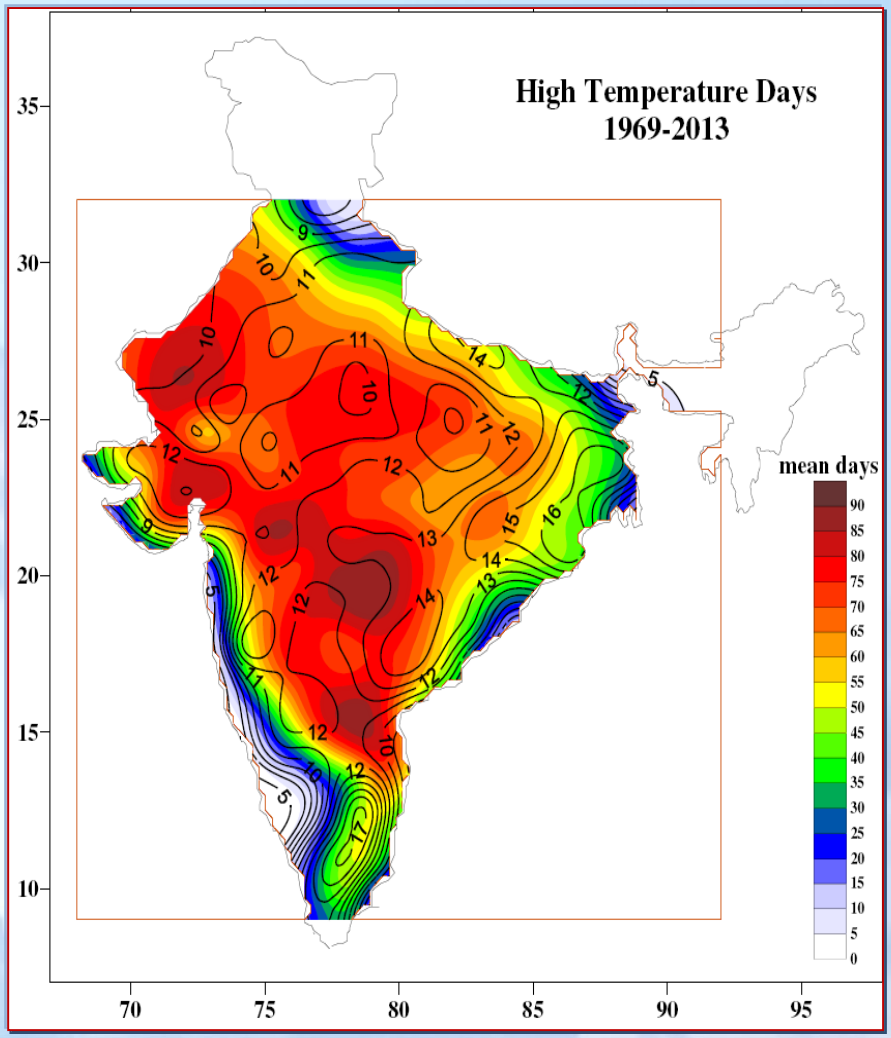
c) Criteria for describing Heat Wave for coastal stations

When Max Temp departure from normal is 4.5^{O}C or more, provided actual maximum temperature is 37^{O}C or more.

Long-term climatological summer (March-June) mean Tmax

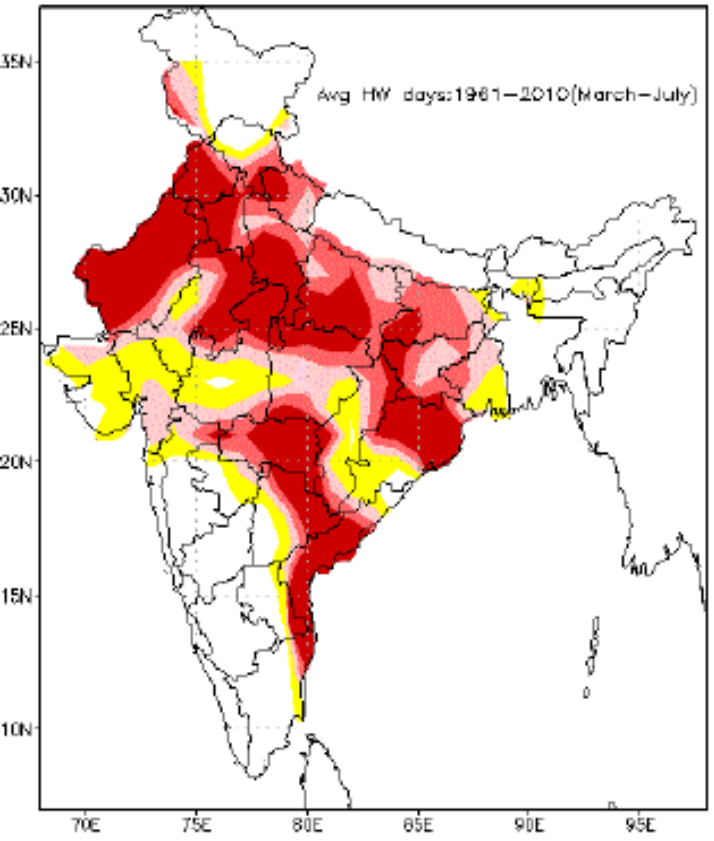


Climatological mean number of days of summer (March–June) high (Tmax>37°C) days

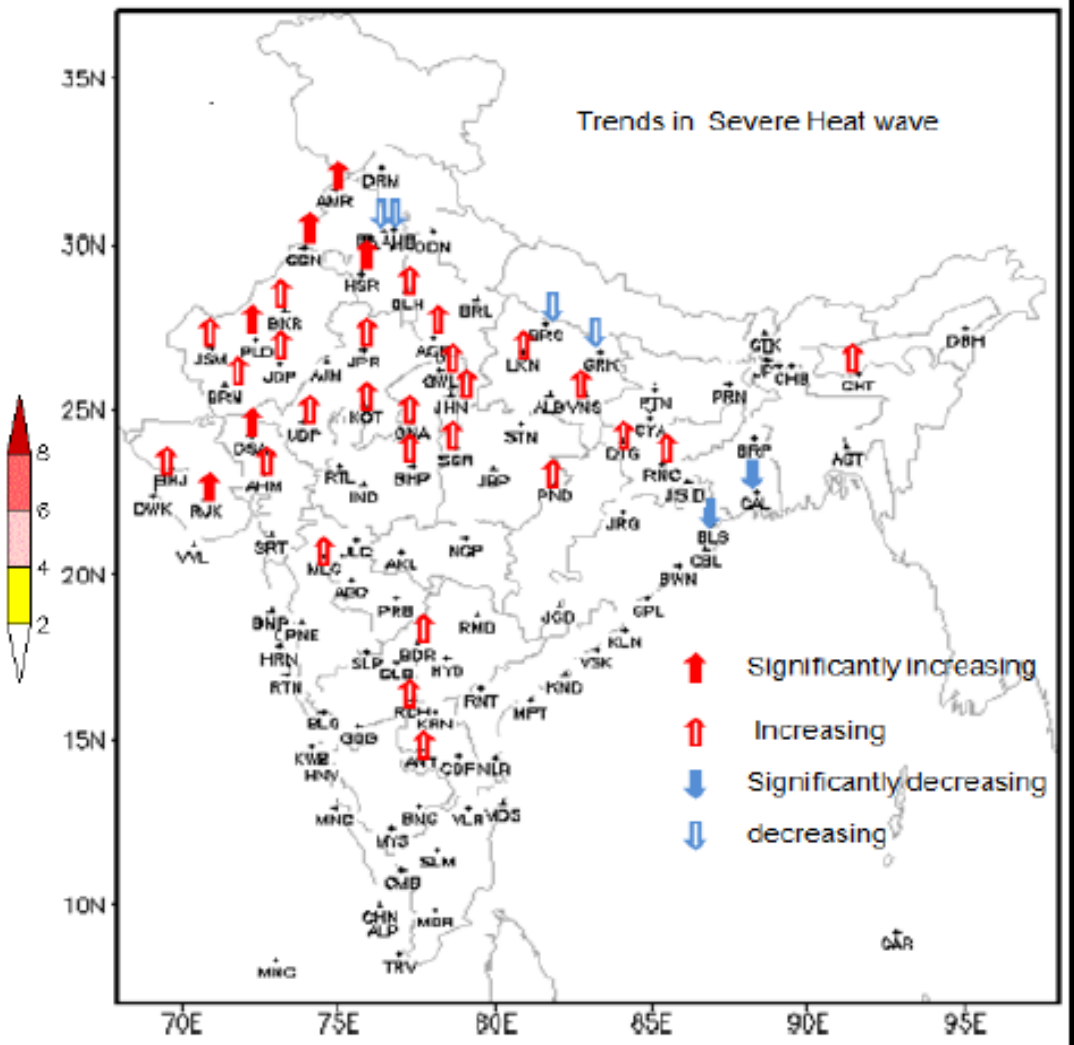


Jaswal et al. (2015), *J. Earth Syst. Sci*

Heat waves over India

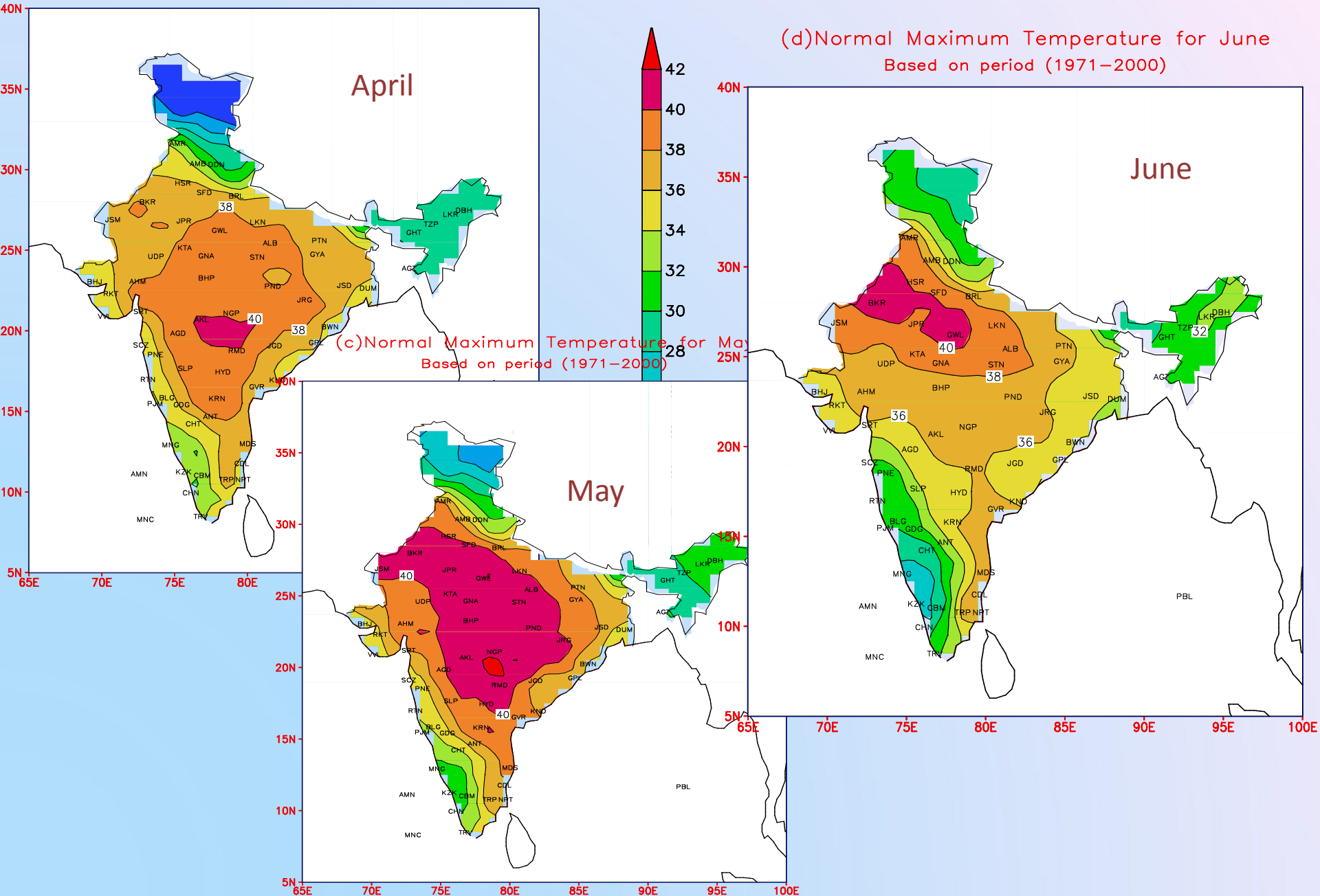


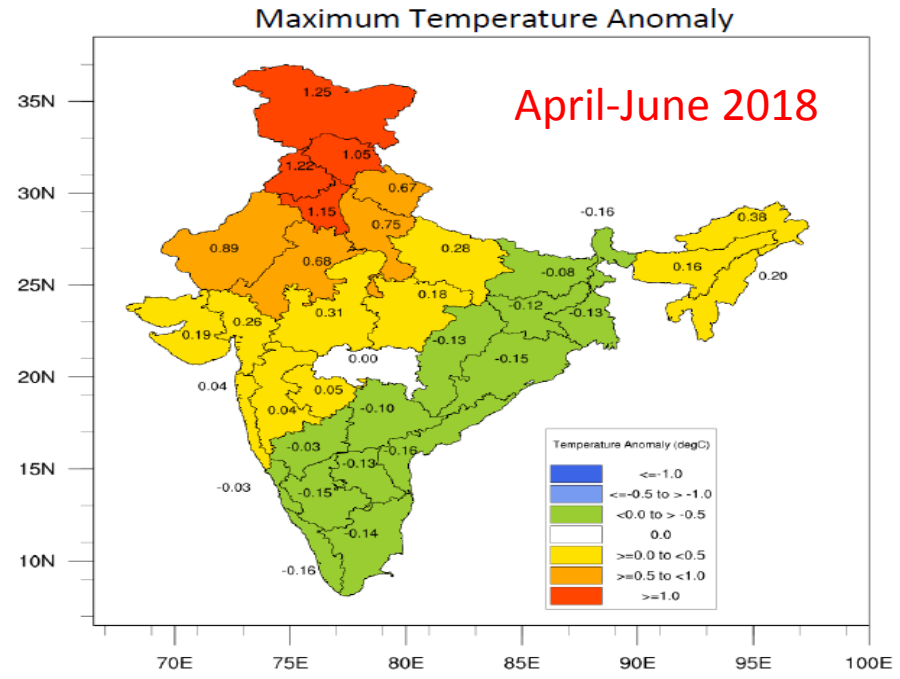
Average Frequency of Heat Wave Days

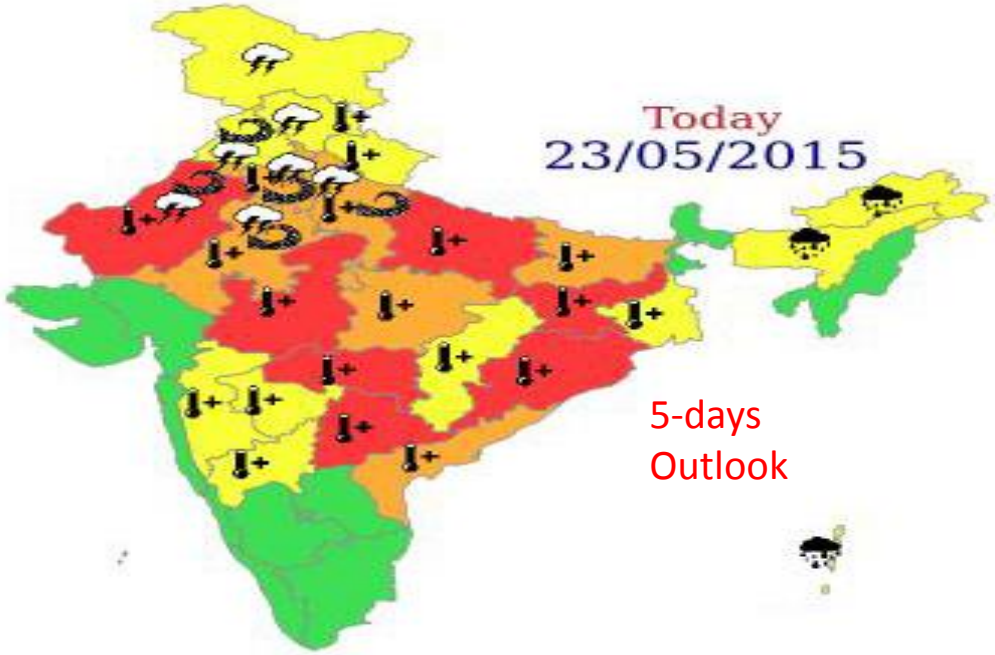


Trends in severe heat waves over India

Main Period of Heat Waves: April - June

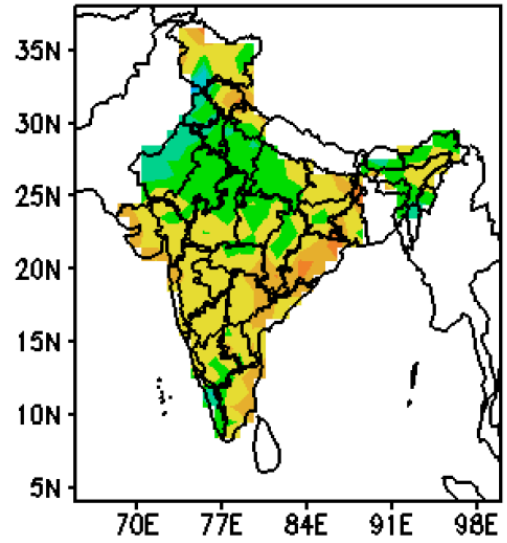




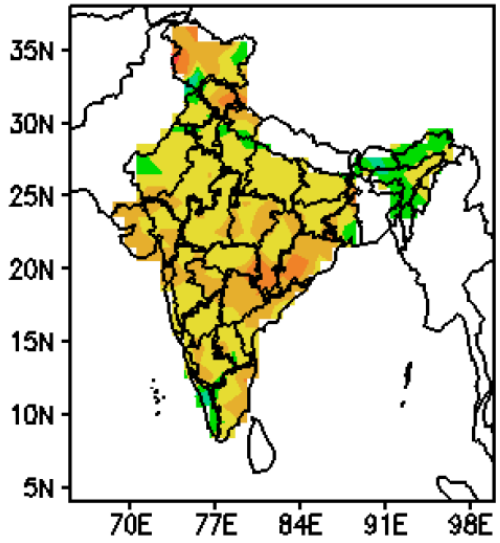


Most Vigil (Take Action)	Be aware (Be updated)
Be prepared/updated (Keep Vigil)	No Warning

(Week1: 20Apr–26Apr)



(Week2: 27Apr–03May)



Impact Based Forecasts as Per Thresholds Provided By The Users

10 CITIES IN 2016

	≤ 41 deg. Selsius
	41.1 to 43 Celcius
	43.1 to 44.9 Celcius
	> or eq. 45 deg Celcius

DATE		Forecast in colour code	May-16	ACTUAL in
	FC	COLOUR CODE	ACT	COLOUR CODE
01	42		43.1	
02	41		43.3	
03	42		42.1	
04	42		42.5	
05	40		39.6	
06	41		40.0	
07	41		39.9	
08	41		40.6	
09	43		42.4	
10	43		42.7	
11	42		43.0	
12	44		43.5	
13	44		44.0	
14	44		44.6	
15	44		44.0	
16	44		44.3	
17	45		43.5	
18	46		45.0	
19	47		46.9	
20	46		48.0	
21	43		44.6	
22	43		44.0	
23	43		42.6	
24	42		43.0	
25	41		41.9	
26	42		41.5	
27	41		41.4	
28	42		41.5	
29	41		40.8	
30	41		41.3	
31	41		41.5	

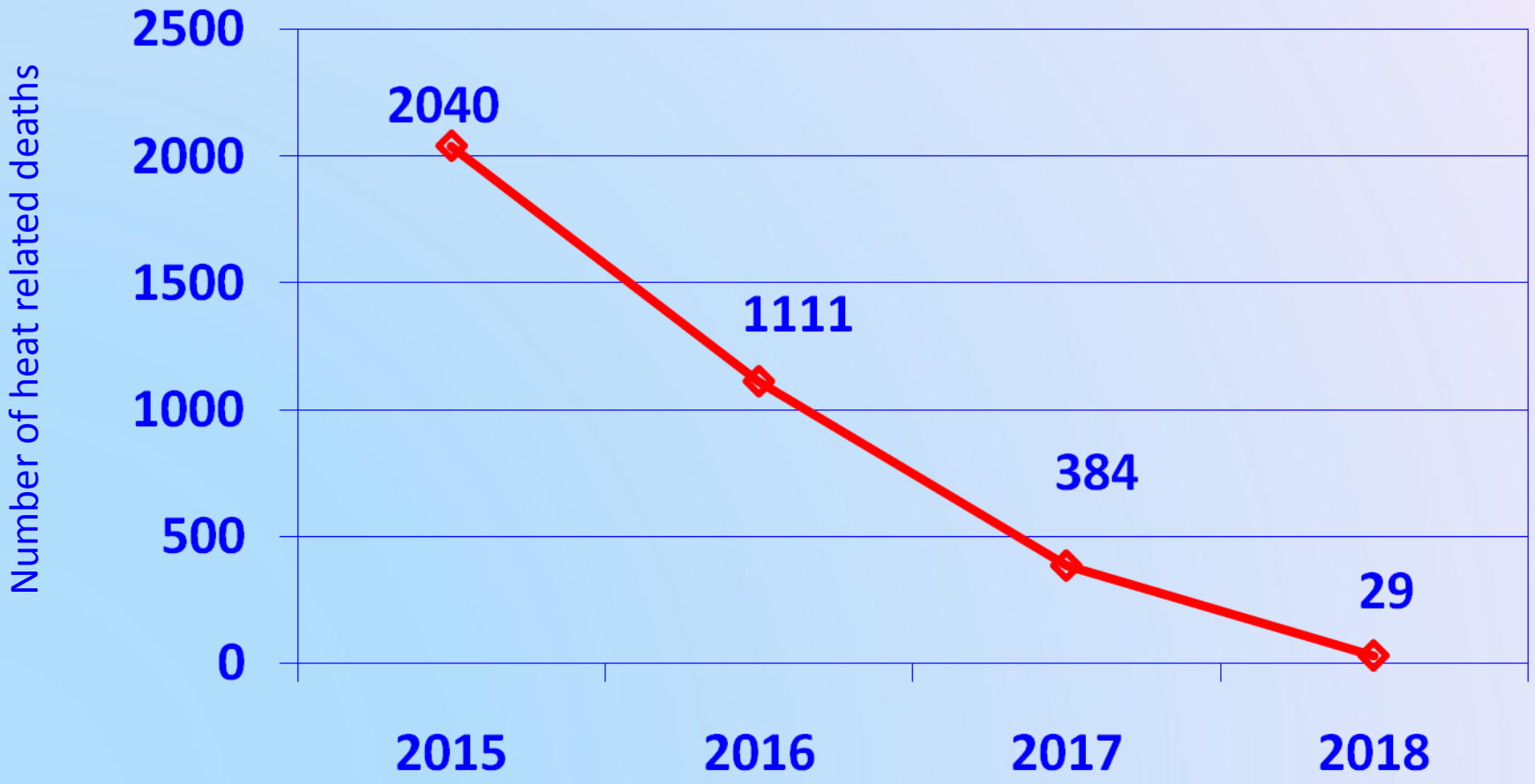
Example: T.Max for Andhra

(Forecast for 11.3.2018 to 13.3.2018) Dated 10/03/2018

Districts	Total Mandals	Observed AWS Data 10.03.2018				Forecast for Next 24hr (Valid from 08.30am 11.03.2018 to08.30am of 12.03.2018)				Forecast for Next 48hr(Valid from 08.30am 12.03.2018 to08.30am of 13.03.2018)			
		Very Hot	Hot	Warm	Slightly Warm	Very Hot	Hot	Warm	Slightly Warm	Very Hot	Hot	Warm	Slightly Warm
Srikakulam	38	0	7	26	5	0	0	0	38	0	0	28	10
Vizianagaram	34	0	4	26	4	0	0	0	34	0	0	0	34
Visakhapatnam	43	0	4	27	12	0	0	0	43	0	0	0	43
East Godavari	64	0	14	40	10	0	0	0	64	0	0	0	64
West Godavari	48	0	8	37	3	0	0	0	48	0	0	0	48
Krishna	50	0	7	34	9	0	0	2	48	0	0	0	50
Guntur	57	0	5	18	34	0	0	16	41	0	0	5	52
Prakasam	56	0	0	0	56	0	0	10	46	0	0	9	47
Nellore	46	0	2	14	30	0	0	9	37	0	0	1	45
Chittoor	66	0	0	0	66	0	0	34	32	0	0	8	58
Kadapa	51	0	0	3	48	0	0	5	46	0	0	0	51
Anantapuramu	63	0	0	0	63	0	0	0	63	0	0	0	63
Kurnool	54	0	0	6	48	0	0	0	54	0	0	0	54
	670	0	51	231	388	0	0	76	594	0	0	51	619
* Based on Observed AWS data						* Based on WRF Model Simulations and using Temperature and Humidity Combination							

Heat-Health service of IMD has resulted in Significant reduction in number of deaths due to heat.

(Source: NDMA)



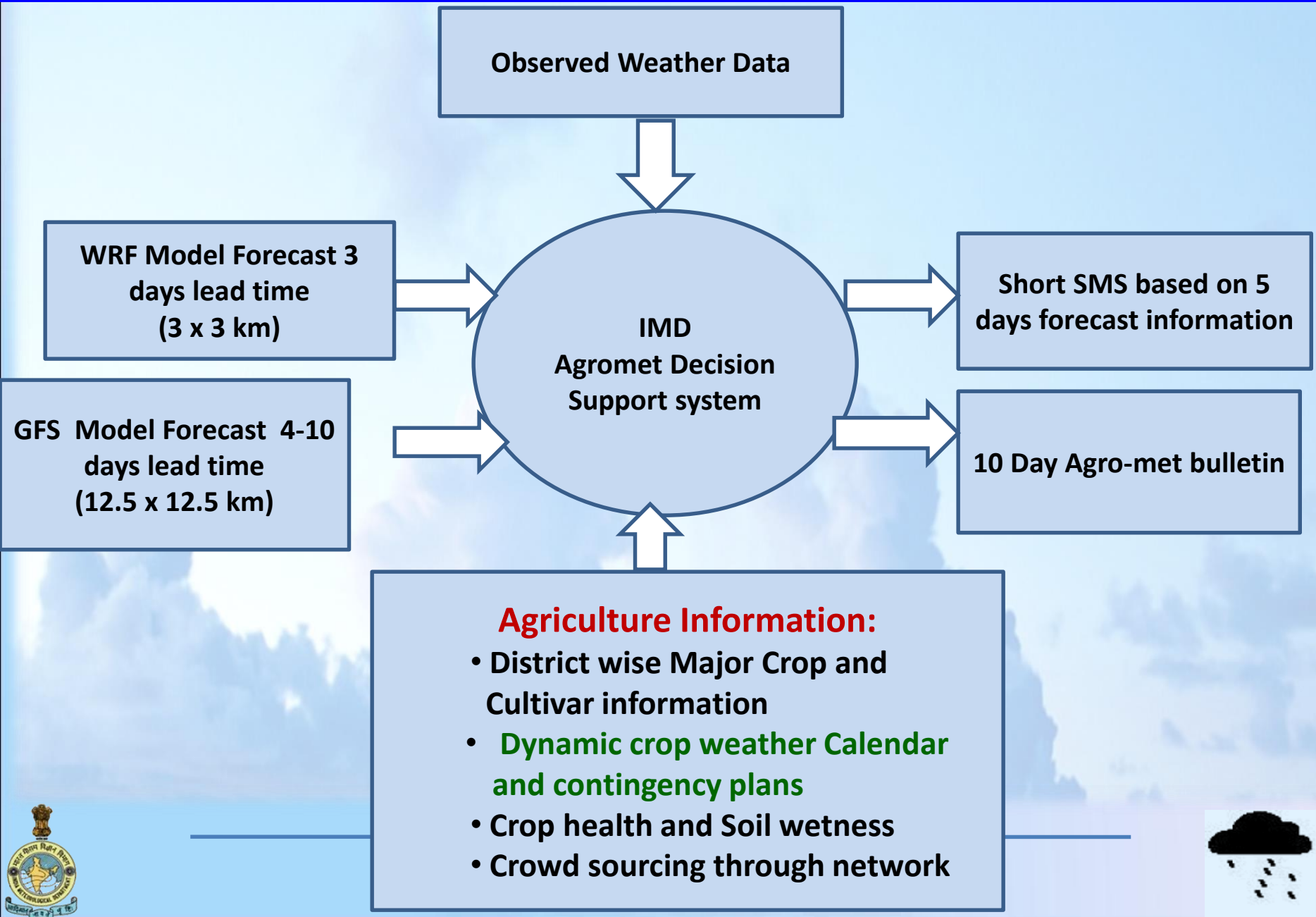
"JSW- The Times of India 8th Earth Care Awards 2018" in the category of "Leadership in Urban Climate Action" was jointly awarded to IMD, IIPH, Gandhinagar and Ahmedabad Municipal Corporation for Ahmedabad Heat Action Plan

The Awards was given away by the Hon'ble Union Minister of Science & Technology, Earth Sciences, Environment, Forest and Climate Change Dr. Harsh Vardhan Ji in New Delhi on 17 April 2018.

Weather based farm management advisory

- Crop & Variety Selection
- Sowing & Harvesting Dates
- Intercultural operations
- Irrigation Management
- Fertilizer Application
- Plant Protection from Pest/Disease
- Post harvest management
- Livestock Management (Shelter, Health, Nutrition)

Automation of Advisory System (Agromet-DSS)



AGROMET-DSS

Weather Information

- Observation
- Forecast
- Verification

Crop Information

- Crops, cultivars, sowing data
- Stage and stage of crops
- Dynamic crop Weather calendar and Contingency Plan

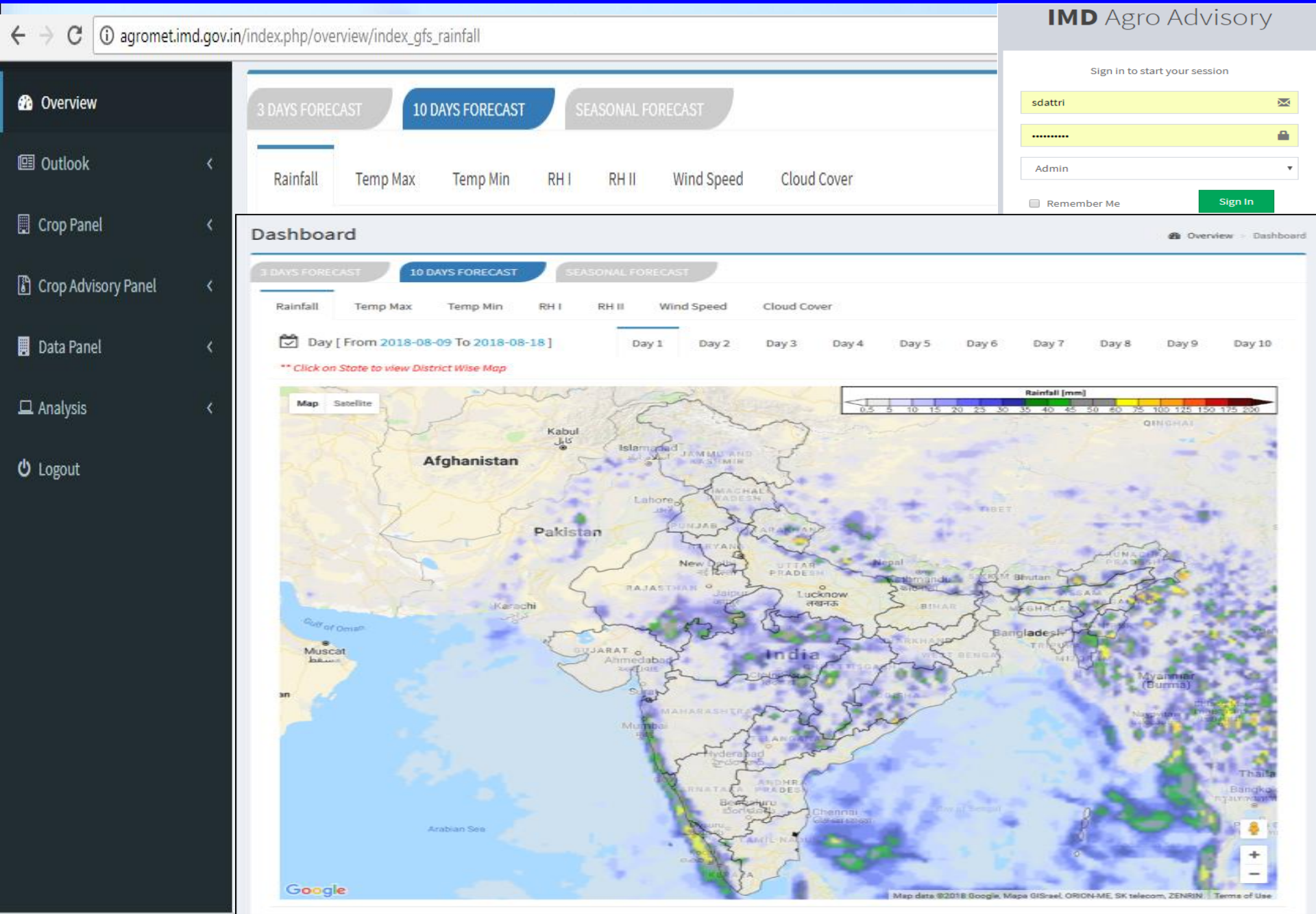
Agromet Advisory

- Broad advisory from Agromet-DSS
- Advisory for Irrigated and Rainfed agriculture.
- Vetting of advisory by Expert Panel

Dissemination

- Multi-mode dissemination to stakeholders

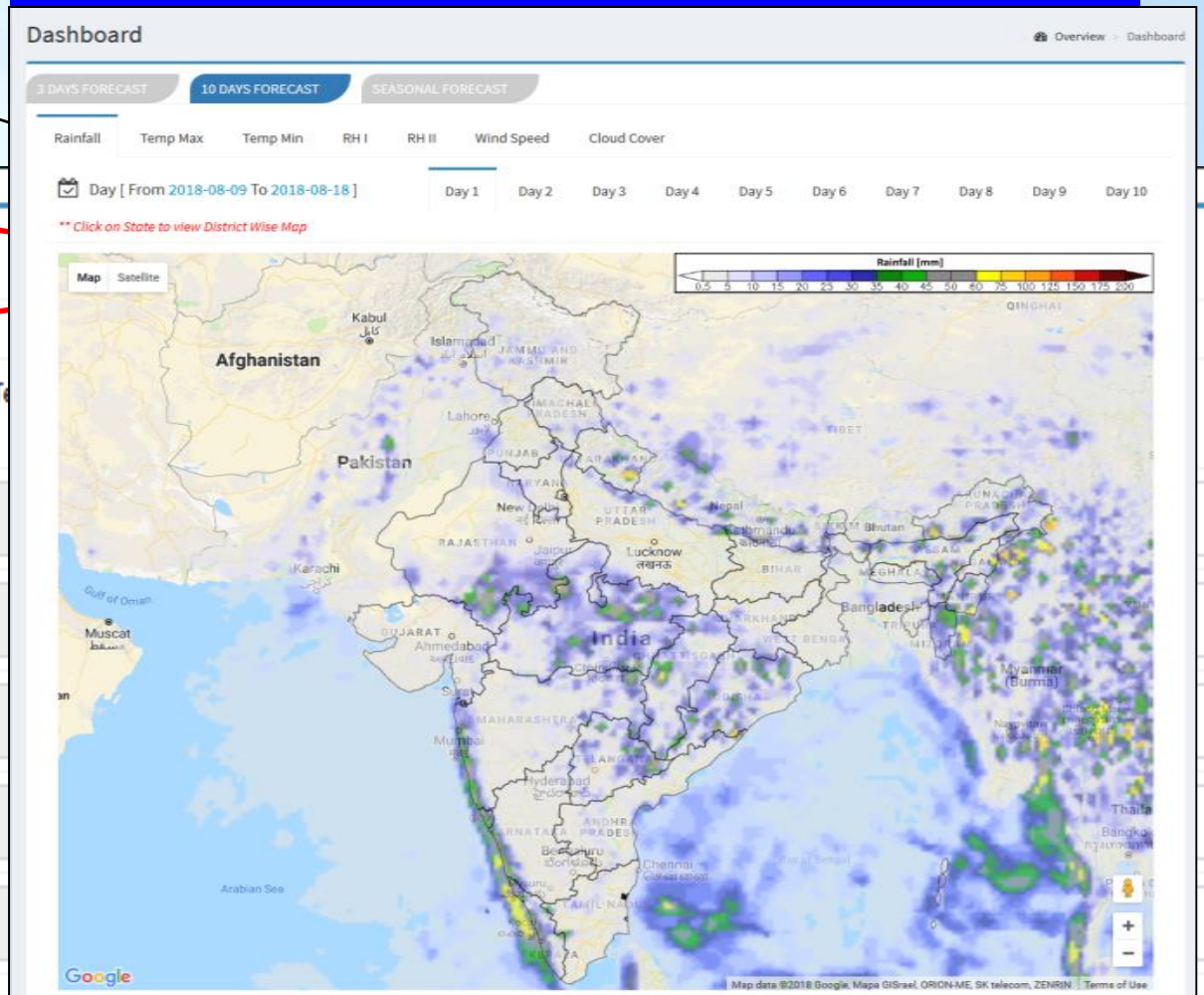
agromet.imd.gov.in



District Level Model Forecast and Value Addition

Value Addition of ANANTPUR (Andhra Pradesh)

Date(yyyy-mm-dd)	Rainfall-(mm)		Temp Max(°C)		Te
2018-09-13	20	20	36.6	36.6	
2018-09-14	5	5	35.9	35.9	
2018-09-15	1	1	35.7	35.7	
2018-09-16	9	9	36.2	36.2	
2018-09-17	62	62	35.6	35.6	



Agromet DSS - Crop Weather Calendar

View Crop Calendar

Crop Panel > View Cro

Select State Madhya Pradesh

Select District Jabalpur

Crop Name Paddy-Kranti

Show

Stage Name	*Stage Start*	*Stage End*	*Ideal Conditions*		*Crop Activity*		
NURSERY	20-Jun	4-Jul	**Parameter**	**Max** / **Min**	**Activity Name**	**Activity Start**	**Activity End**
			Rainfall	77 / 70			
			Temperature Max	0 / 0			
			Temperature Min	41 / 31			
			Relative Humidity	30 / 23			

AGROMET-DSS MENU

Overview: Display of observed weather parameters on India map for 1-10 days

Outlook: District and Block level forecast and value addition

Crop Panel: Crop List, growth stages, crop calendar, rainfed and irrigated crop information

Crop Advisory Panel: Crop custom advisory

Data Panel: Information of receiver groups (e-mail group)

Analysis: Forecast analysis in graphical form & skill score

Logout

Dynamic Crop Calendar & District level contingency action for rain-fed agriculture (CRIDA)

- Advisories are prepared separately for rainfed and irrigated areas/crops in a district.
- Timing of Onset rain based sowing date for rainfed crops for each of the 660 districts in India.
- Crop calendar (CRIDA) dynamically linked with progress on sowing time to define crop cycle.
- Weather forecasts for 10 days- rain spell (3-day quantitative and 4-10 days outlook) – Updated and Verified on-line on Daily basis at MC level
- Contingency Actions in Advisories- Based on the rainfall scenario - need for supplementary or micro irrigation in dry land/ rainfed areas; re-sowing of short duration varieties etc.
- Early season/Mid-season/End season Deficiency of rainfall-linked with Contingency plans

Economic Impact Assessment Of AAS

Survey conducted by National Council of Applied Economic Research (NCAER) in 2015.

- 95% of farmers experienced improved accuracy & reliability
- Incremental profit assessed to be 25% of net income.
- 24% farmers have access to AAS
- Annual Economic Profit on 4-principal crops (wheat, paddy, sugarcane and cotton), assesed as Rs. 38,463 crs in 2010 which raised to Rs. 42,000 crs in 2015.
- Service has the potential of generating net economic benefit up to Rs. 3.3 lakh crores on the 22-principal crops when AAS is utilized by All farming households in the country

District level Agro-meteorological Services during monsoon season

Preparation of value added medium range forecast at district level

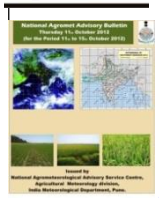
T1534

Tuesday Friday

Parameters

Rainfall, Wind speed and direction, Maximum temperature, Relative humidity, Minimum temperature, Cloud cover

NWP products



From Composite State Level Bulletin, Agrimet Division, IMD preparing National AAS bulletin

State Met Centre (SAMC) Issuing State Level Composite Bulletin

Conducting State Level Meeting

Value addition

Issuing District Level Bulletin In all total 636 bulletins in 14 languages &uploading in the website of Agrimet Division (http://imdagrimet.gov.in)

Agromet Field Units (AMFUs)

Conducting Farmer Awareness Programme

Dissemination of Agromet Advisory through Multi-Channel

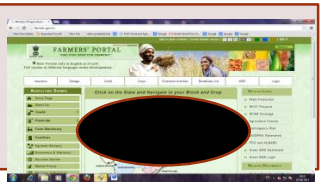
Kisan Sanchar

Reliance Foundation

FFCO KISAN SANCHAR LTD.

Mahindra Samriddhi

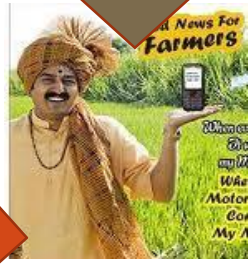
handygo



Organised different training programmes

Established feedback mechanism

Agromet Advisory



40.0 million farmers Receiving SMS

Also Brochures for Awareness were completed for 14 languages

Economic benefits from savings in farm inputs. Increased farm productivity

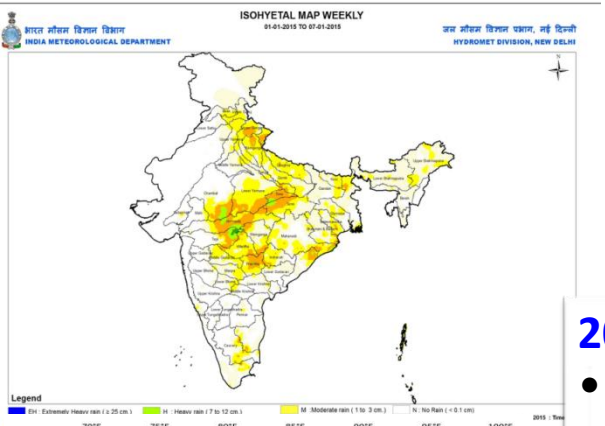
HYDROLOGICAL SERVICES

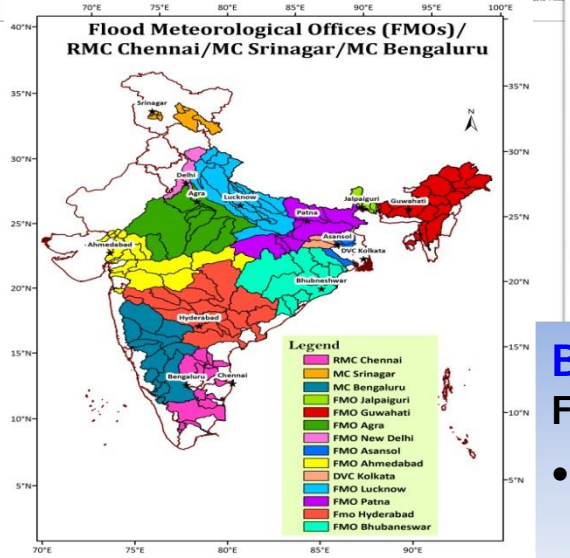
- **2016 : Pre**paration of Rainfall Statistics; daily, weekly& monthly. Commended by the President of India.
- Provides real-time rainfall information by means of GIS based rainfall products.

2006

- Conventional Quantitative precipitation forecast (QPF) to CWC for flood forecast purposes for 125 river basins

The district-wise and river basin-wise rainfall statistics is helpful to farmers for their agricultural activities and flood forecast/ water management.





2016

- Quantitative precipitation forecast (QPF) to CWC for flood forecast purposes increased from 125 to 146 river sub-basins.
- QPF increased from 5 day to 7 days from flood season 2015.
- Sub catchment wise QPF from NWP models- GFS for 7days in addition to WRF, MME for 3 days
- QPF for 4 new catchments Jhelum, Pennar, Torsa, Sankosh which involves 12 sub catchments.

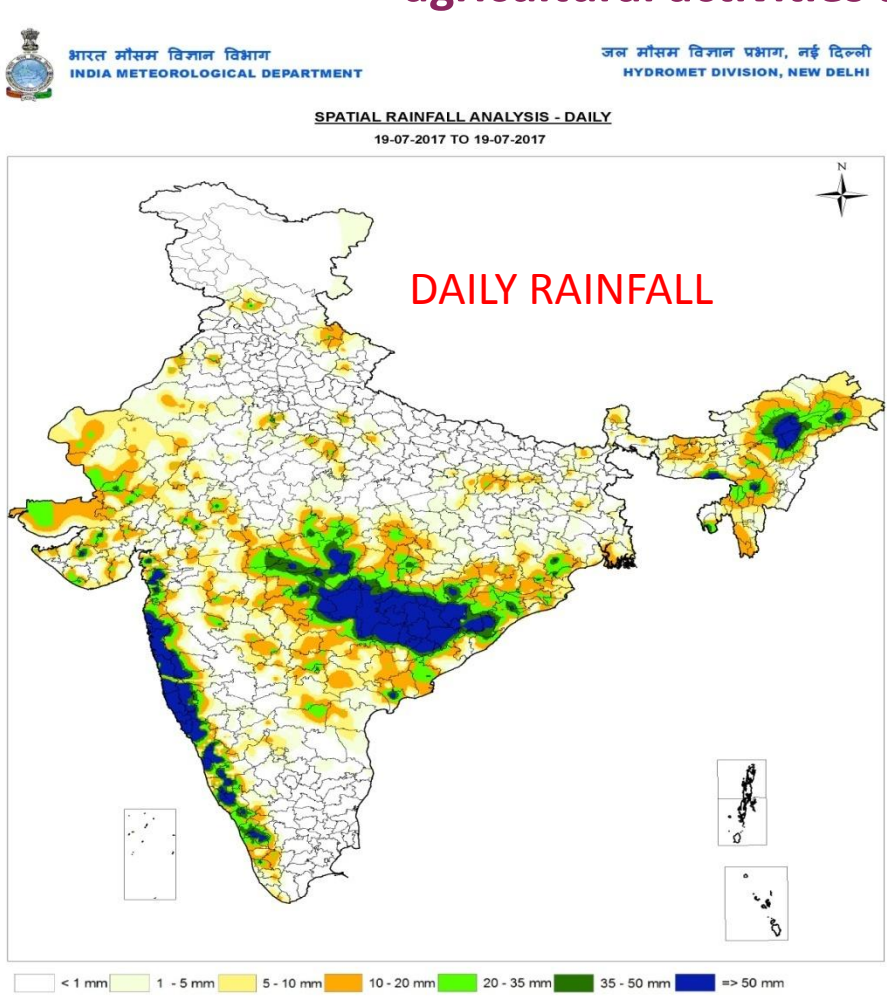
By 2019 : Develop a State-of-the-Art **Hydrological Information System and Flood Warning** Support for all the Major River Basins of the Country.

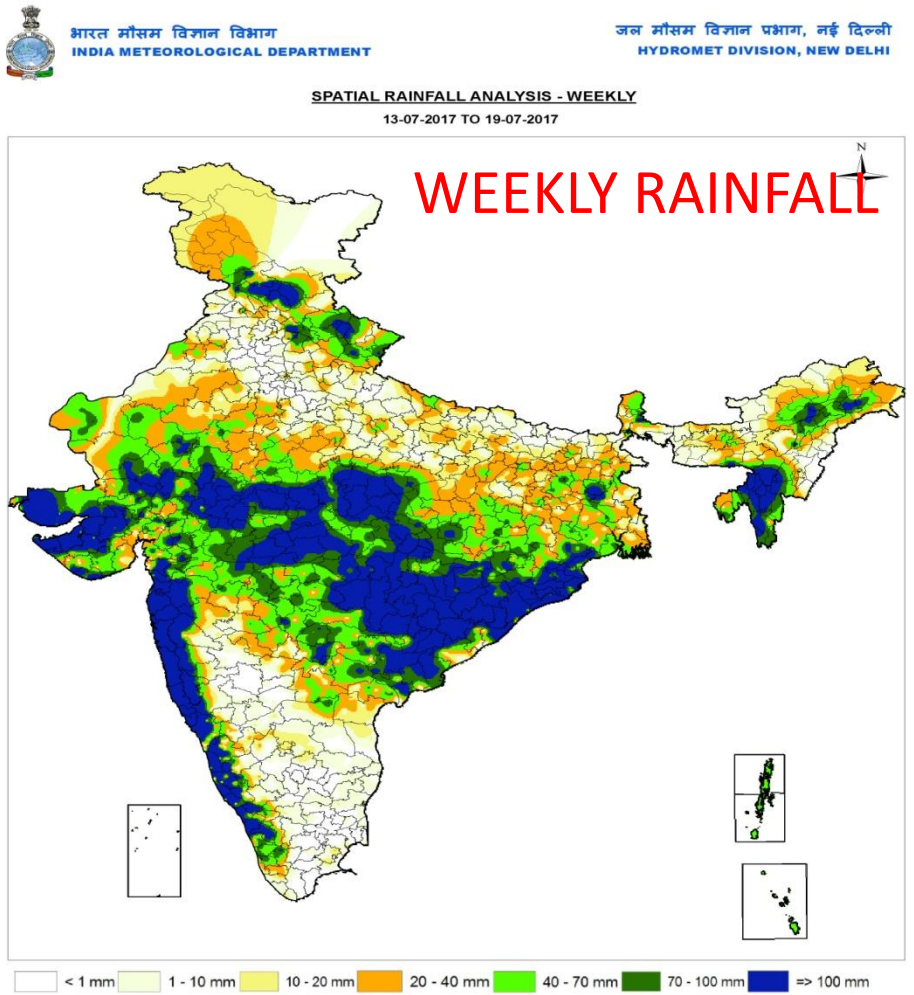
- Monitor the three dimensional variability of **regional hydrological cycle** and assess its expected changes and impacts in the future.

HYDROLOGICAL SERVICES

- **Pre**paration of Rainfall Statistics; daily, weekly& monthly. Commended by the President of India.
- Provides real-time rainfall information by means of GIS based rainfall products.

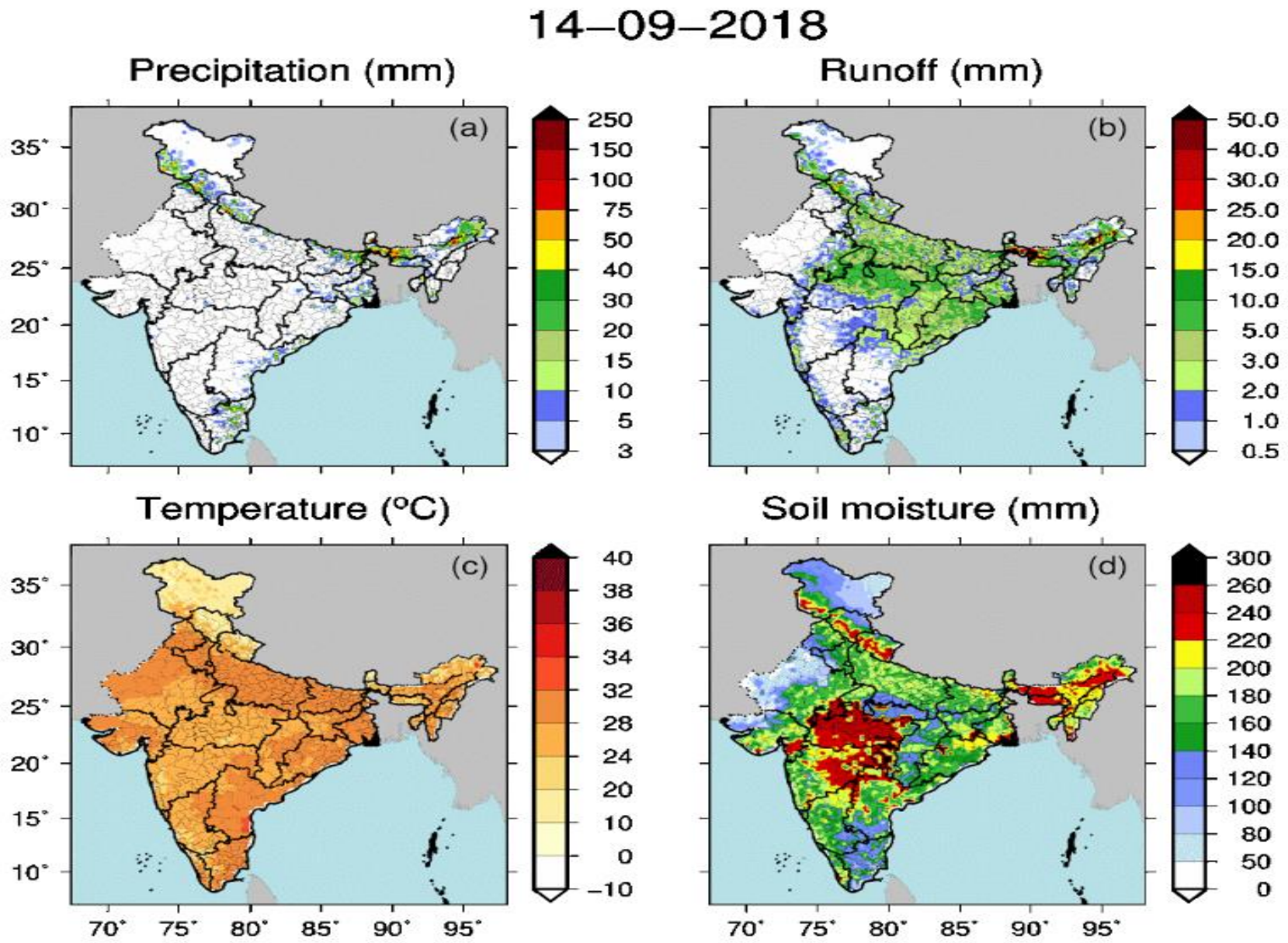
District-wise and river basin-wise rainfall statistics is helpful to farmers for their agricultural activities and water management



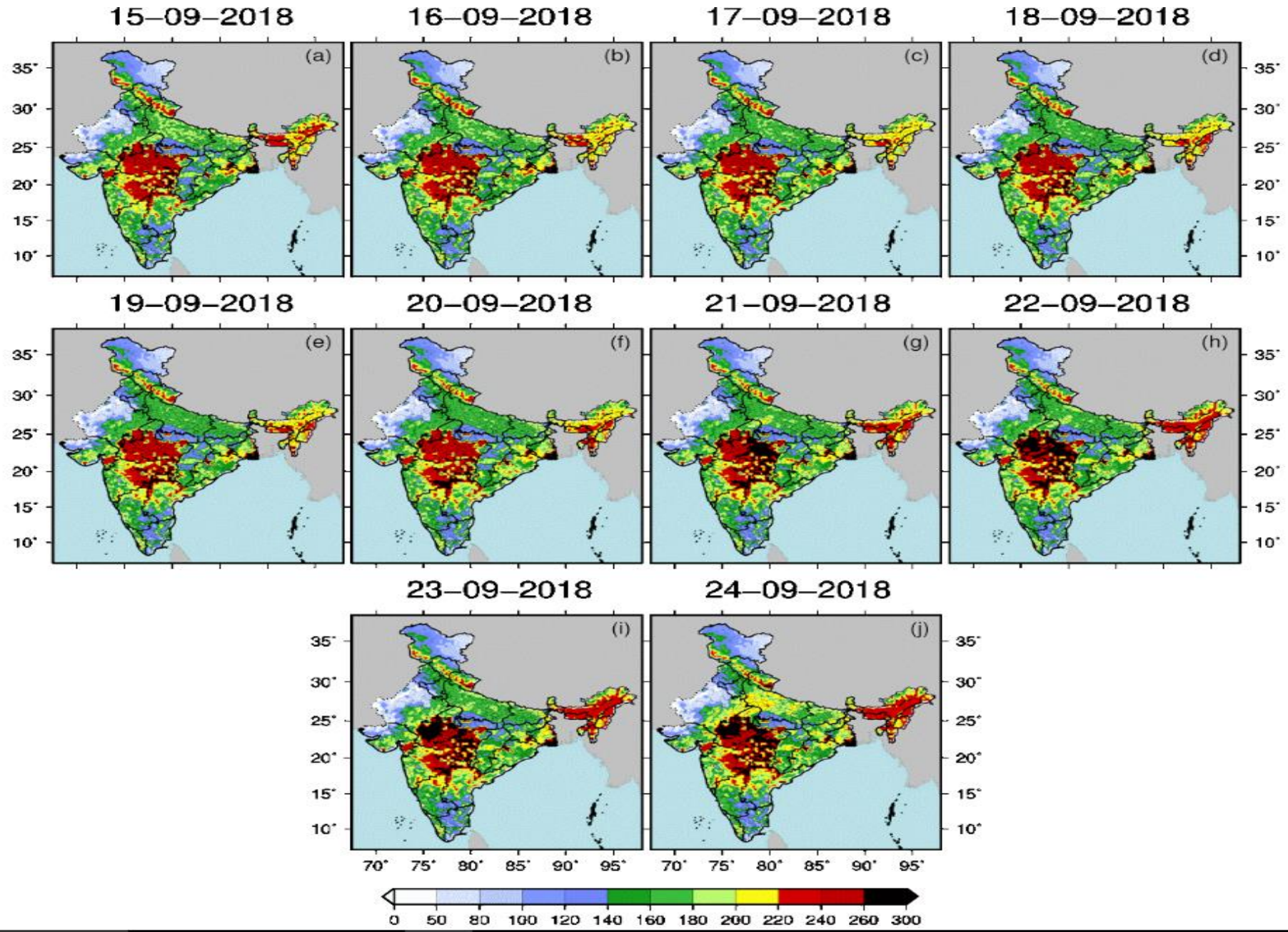


Analyzed Soil Hydrology Products

(Based on Variable Infiltration Capacity (VIC) Model: Joint Efforts of IIT Gandhinagar and IMD)



10-Day Simulated Soil Moisture (12km scale)



River Basin Scale Hydrological Response Assessment for Flood Warning
(Based on Soil and Water Assessment Tool(SWAT): Joint Efforts of IIT Delhi and IMD)

Flood Forecast for River Basins based on IMD Rainfall Forecast

Home | GFS Hydrology | WRF Hydrology | Rainfall

Home Tab: Click on desired river basin (avoid clicking label)
A window opens to 'GFS Hydrology' tab showing

- the river basin with subbasin on the left map panel
- CWC - IMD FMO subbasins on the top right map panel
- Chart, table and description on the bottom right panel for subbasin average daily rainfall and stream flow

Stream flow forecast at sub basin level for river basins

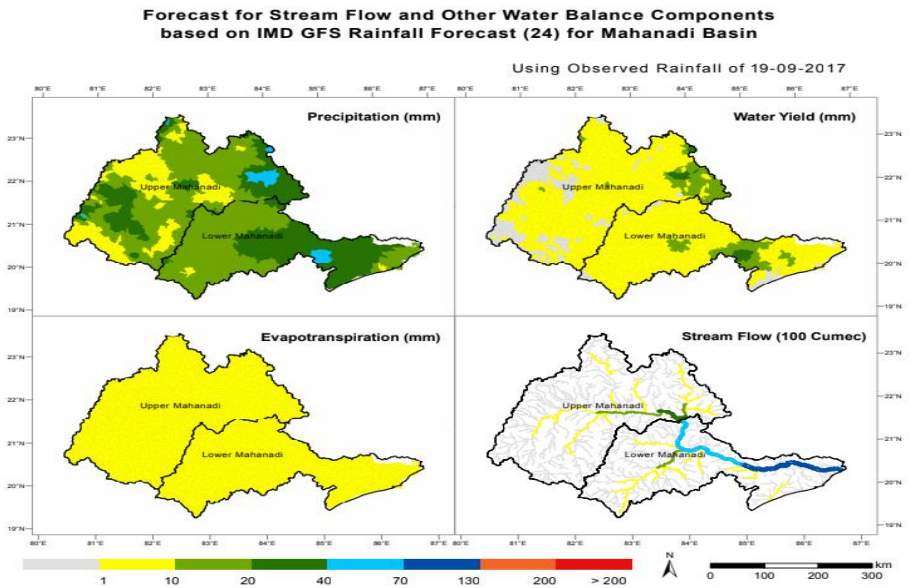
SWAT hydrological model (https://swat.tamu.edu/) is used to simulate the stream flow. Hydrological modelling has been carried out for the entire river basin. Calibrated and validated model is currently run at daily time step to produce stream flow forecast.
Input data used example:

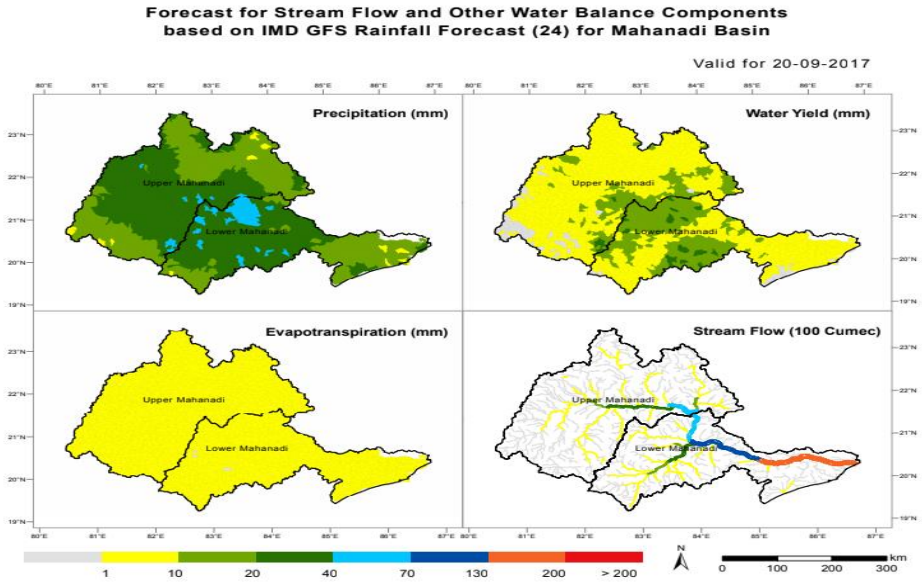
- Digital Elevation Model: DEM SRTM – 30m resolution
- Landuse (NRSA 2007-08)
- Soil – NBSSLUP/FAO
- Reservoir characteristics and operation rules (Major and medium projects)
- Current management/operation practices, existing irrigation as per crop demand. (Note: Current crop management practices include irrigation sources from Surface and Ground water).
- Weather
  - Current day : GPM (IMD) gridded rainfall, temperature at 25km resolution
  - Forecast : IMD WRF (9 km grid) – 3 days forecast and IMD GFS (25 km grid) - 6 days forecast

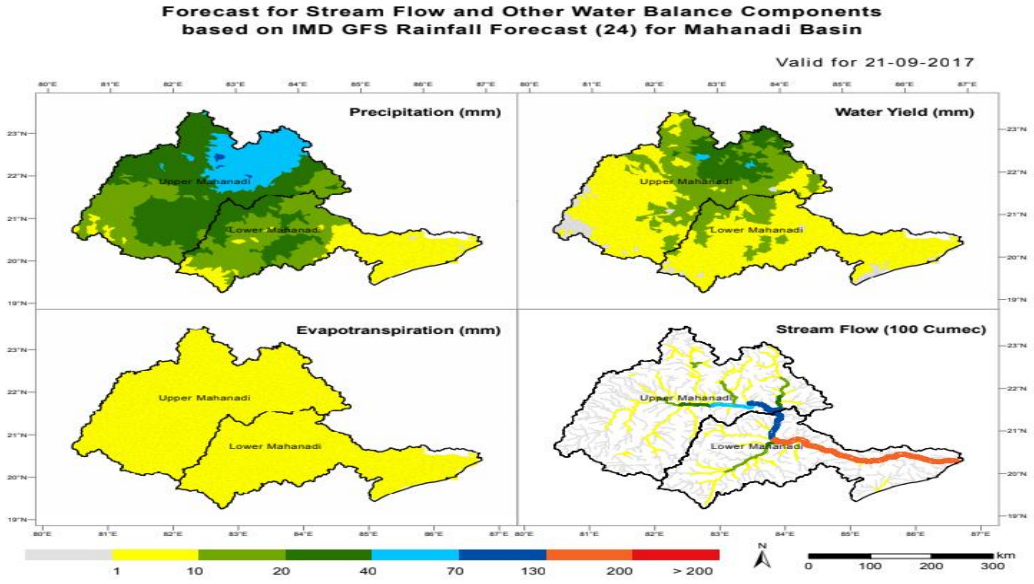
- **SWAT operates on a daily time step at basin scale and has been modified as per Indian Conditions.**
- **SWAT uses a two-level disaggregation scheme; a preliminary sub-basin identification is carried out based on topographic criteria, followed by further discretization using land use and soil type considerations.**
- **Areas with the same soil type and land use form a Hydrologic Response Unit (HRU), a basic computational unit assumed to be homogeneous in hydrologic response to land cover change.**

SWAT Products –Mahanadi Basin

- SWAT hydrological model run parameters on Mahanadi basin calibrated using measured discharges.
- 3 days (observed, 2 days forecast using IMDGFS rainfall forecast)







South Asia – Regional Flash Flood Guidance System (SAsiaFFGS)

Ministry of Earth Sciences

Under

Global Initiative Project for Flash Floods with MoU between various organisations like UN-WMO, HRC, USAID/ OFDA, NOAA and regional NMHS (IMD).

Implemented

By

भारत मौसम विज्ञान विभाग

India Meteorological Department

WORLD METEOROLOGICAL ORGANIZATION

HYDROLOGIC RESEARCH CENTER
A Non-Profit Research Corporation, Established 1993

Introduction to SAsiaFFG Implementation Background

The South Asia Flash Flood Guidance System

- The primary mission of the South Asia (SAsiaFFG) System is to provide real-time informational guidance products pertaining to the imminence of potential small-scale flash flooding throughout the region of application.

- Ingests real-time satellite and gauge precipitation data on an hourly basis and, on the basis of available spatial databases, produces flash-flood-occurrence diagnostic indices over small basins in the region of interest.

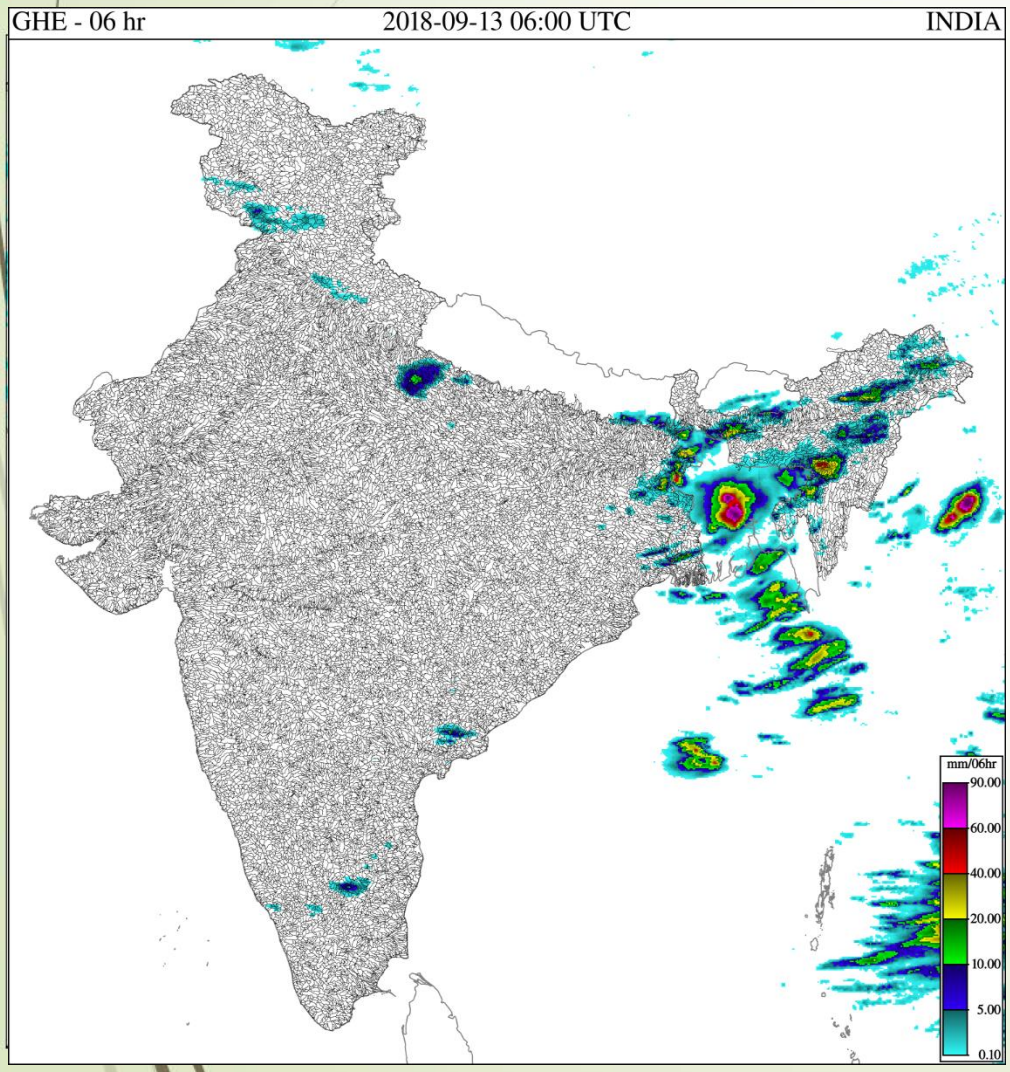
- The diagnostic flash flood guidance index may then be used with nowcasts or forecast rainfall volumes of the appropriate durations to identify the likelihood of flash flooding at the outlet of specific small catchments.

- SAsiaFFG is not a predictive system in itself, rather it is a diagnostic system for flash floods that the forecaster can use with forecasts or nowcasts of precipitation to produce forecasts and ultimately warnings for flash floods.

FFGS Satellite Precipitation: GHE

Remotely-sensed precipitation estimates provide good spatial coverage and detail.

In situ observations (rain gauges) provide “ground truth” but often have sparse coverage.

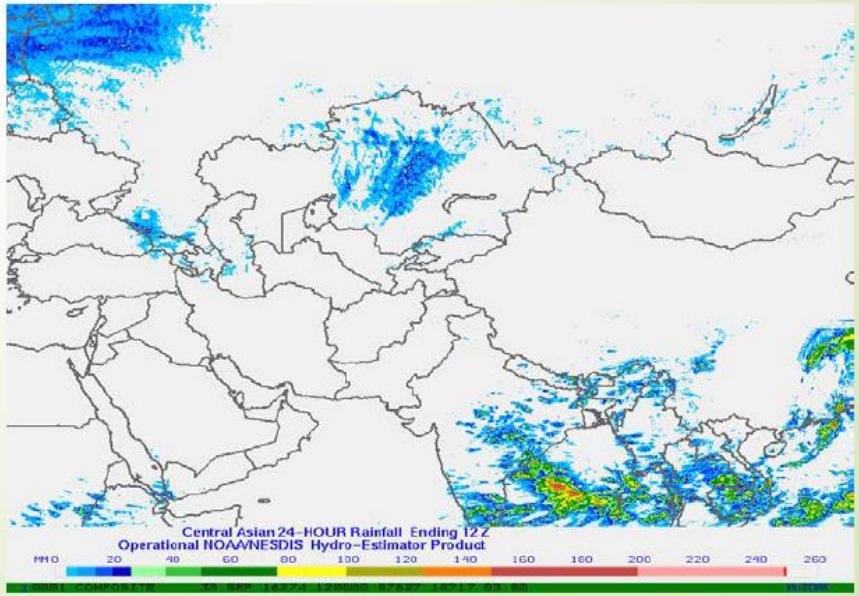


Global Hydro-Estimator (GHE):

Rainfall rate based on Cloud Top Brightness Temperature (Infrared (IR) based).

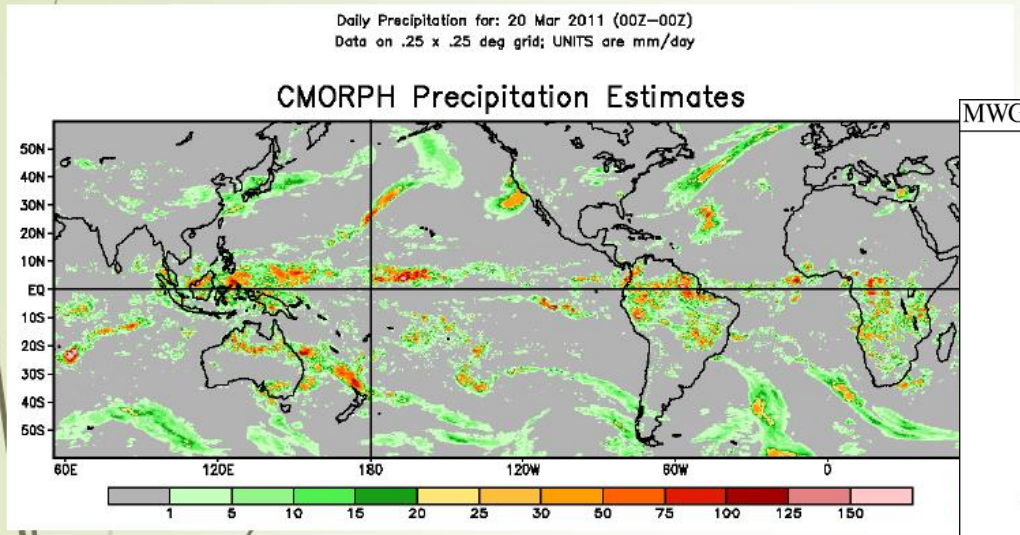
This is an indirect measurement.

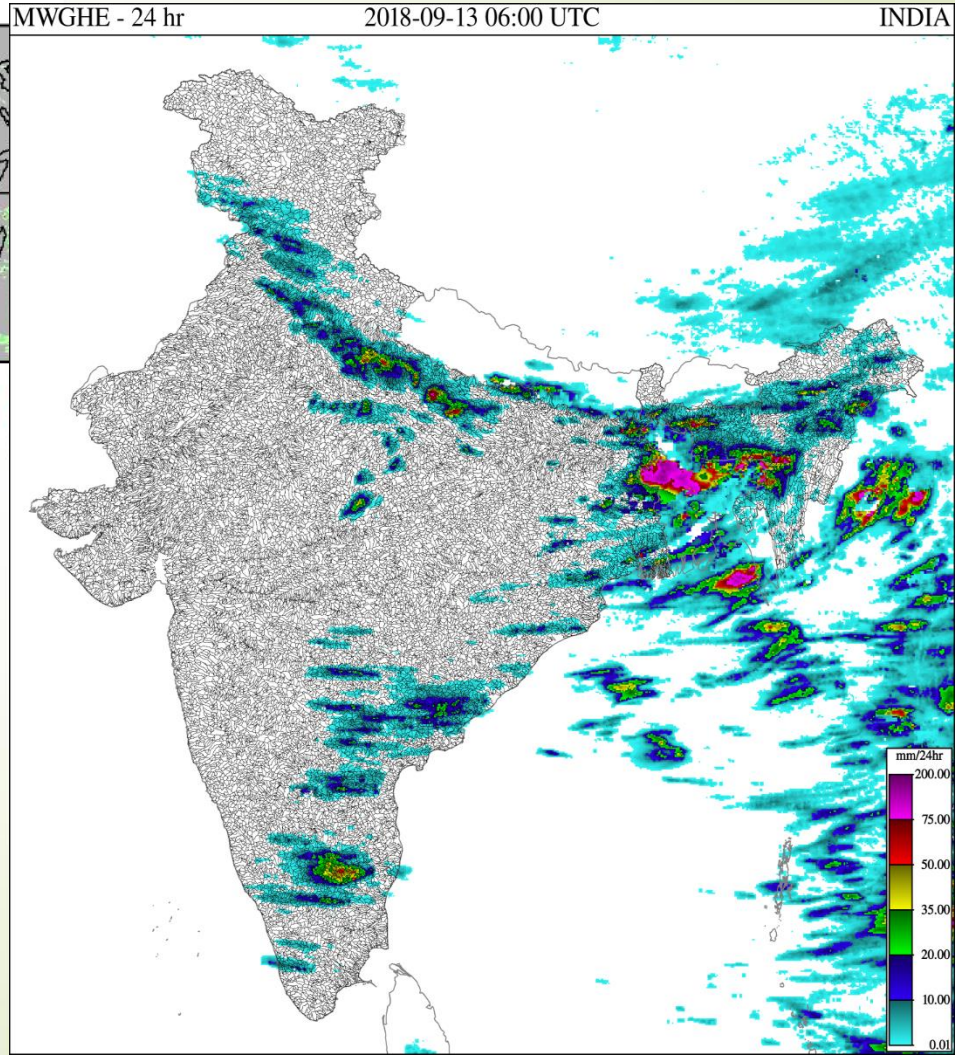
- ~ 4km resolution
- ** Short latency ** (< ½ hour)



FFGS Satellite Precipitation: MWGHE

HRC effort to combine IR-based GHE rainfall with MW-based CMORPH rainfall.



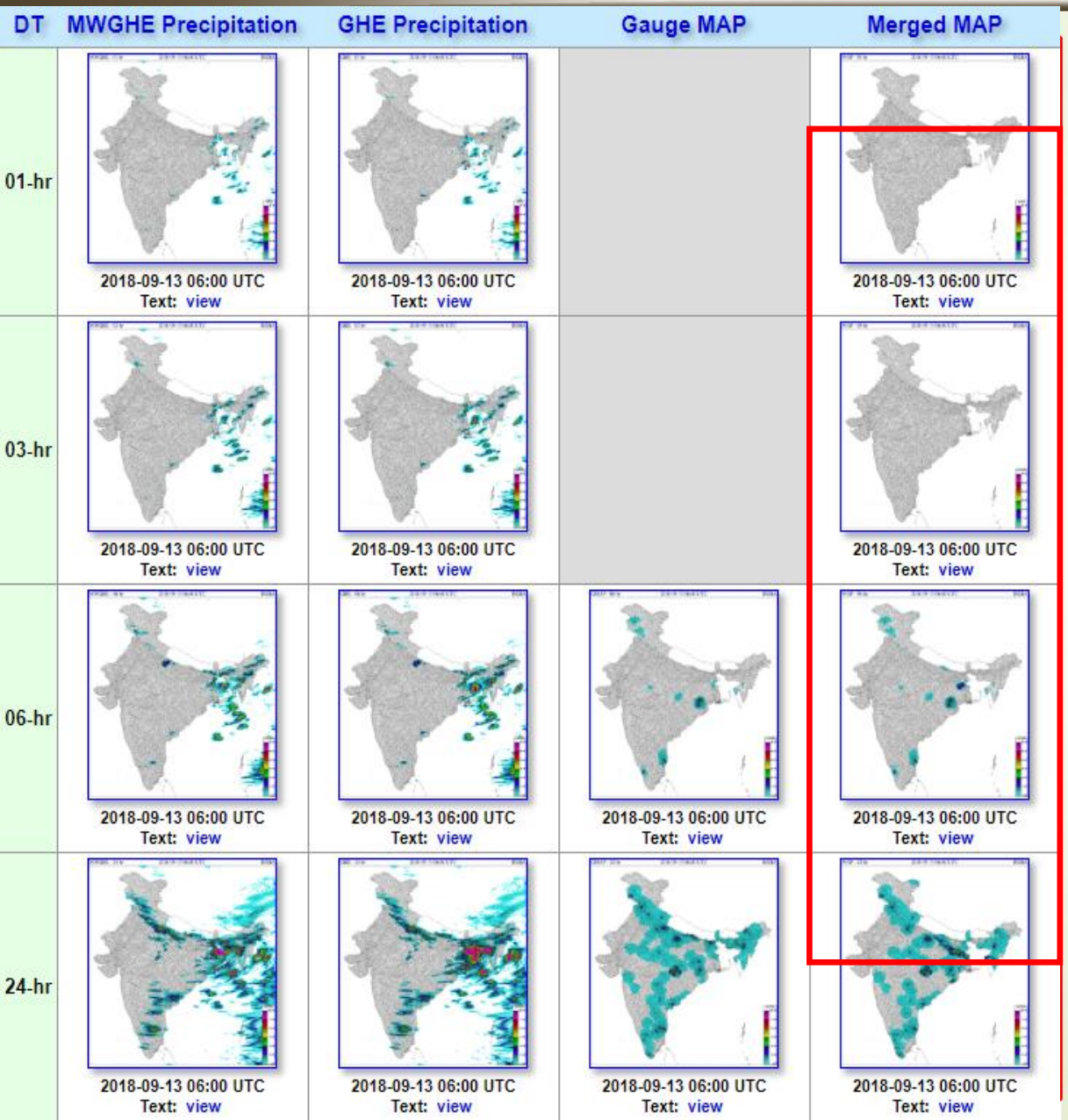


CMORPH is based on microwave scattering from hydrometeors.

This is still an indirect measurement.

- ~ 8km resolution
- 18-26 hour latency in operations

Merged MAP Product



Merged MAP is the *best estimate* of Mean Areal Precipitation over each small watershed. 1-, 3-, 6-, and 24-hour accumulations.

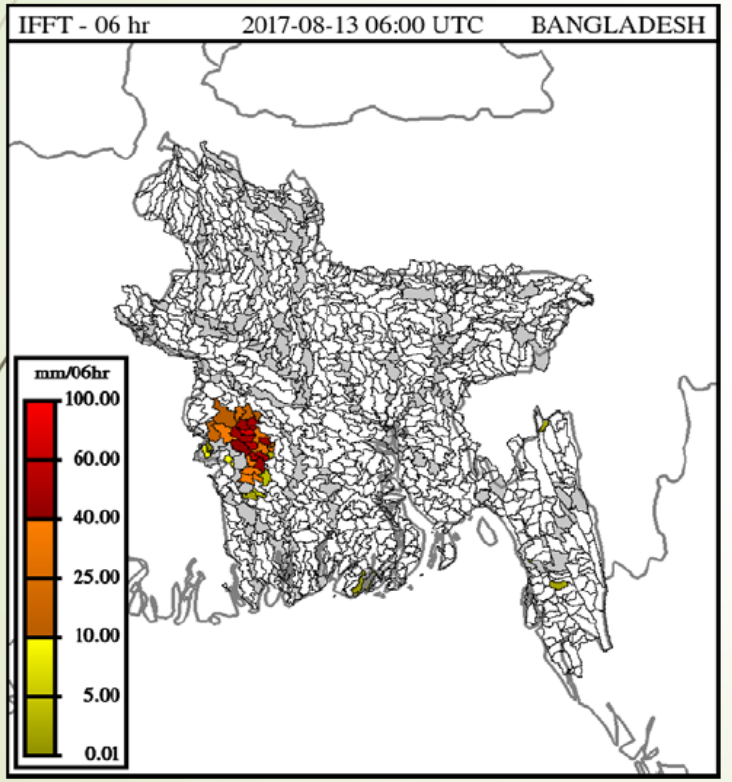
- Satellite
- Real-time gauges
- Radar (if available)

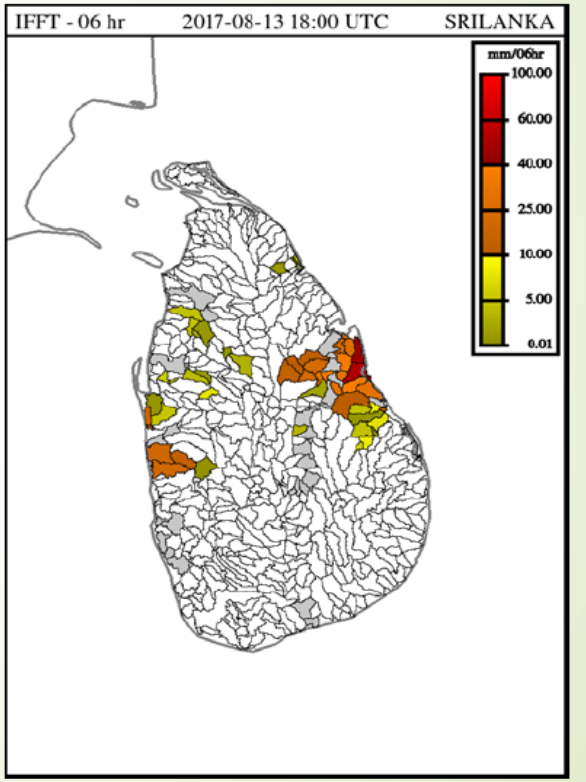
* Includes bias adjustment

FFT: Flash Flood Threat

Potential for flash flooding is increased when ***PRECIPITATION > FFG***.

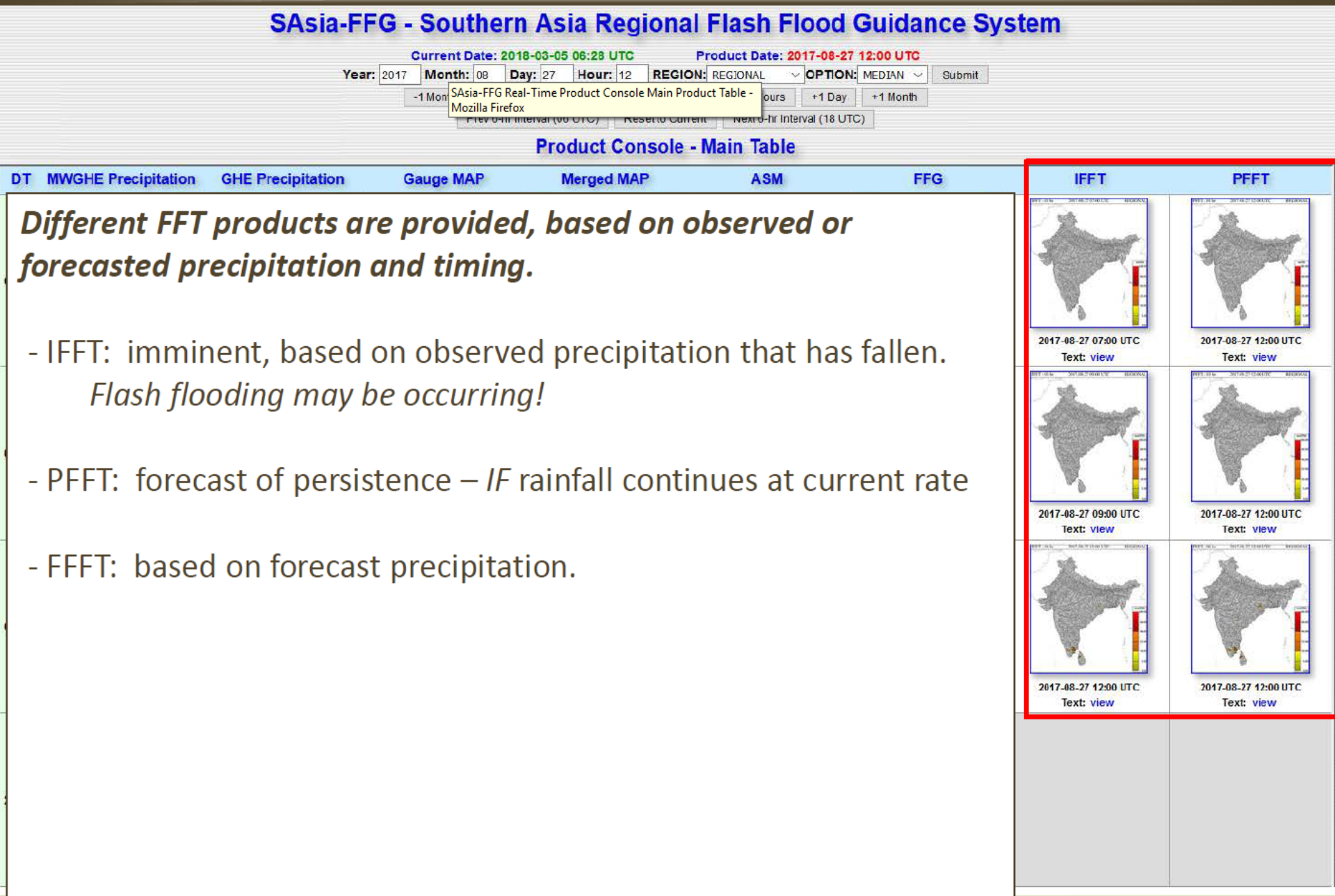
Flash Flood Threat, FFT, defined: ***FFT = MAP - FFG***





FFT provides indication of regions of potential concern.
Color bar provides magnitude of FFT.

FFGS Products: FFTs



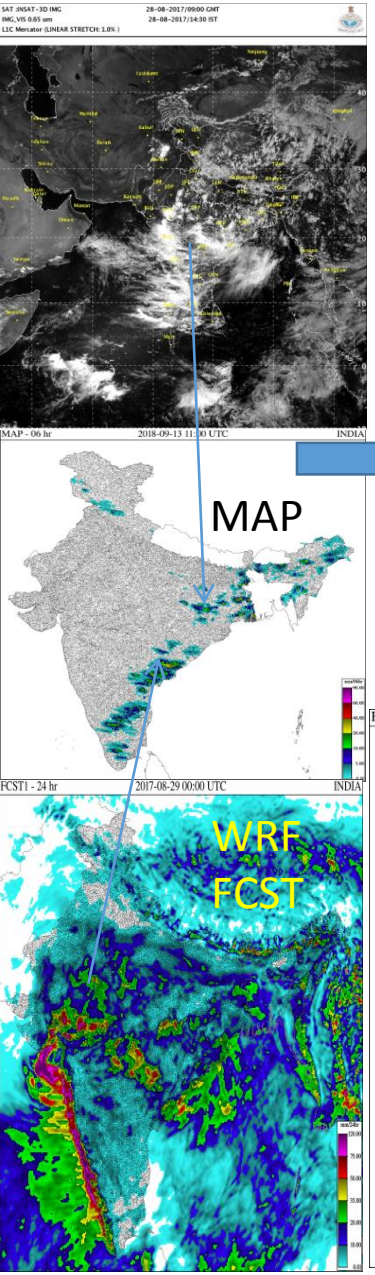
Different FFT products are provided, based on observed or forecasted precipitation and timing.

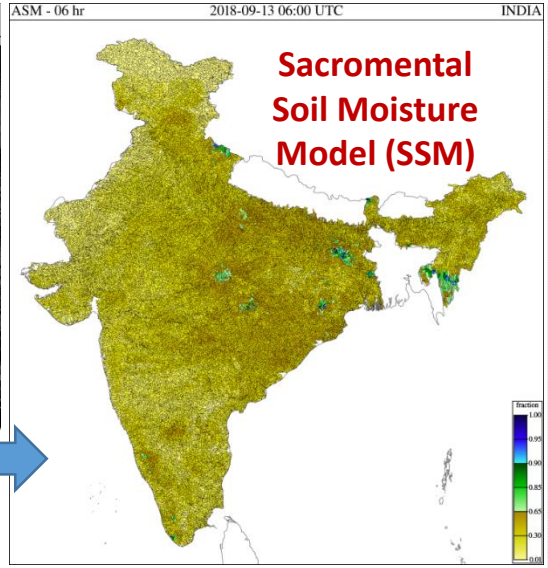
- IFFT: imminent, based on observed precipitation that has fallen.
  Flash flooding may be occurring!

- PFFT: forecast of persistence – *IF* rainfall continues at current rate

- FFFT: based on forecast precipitation.

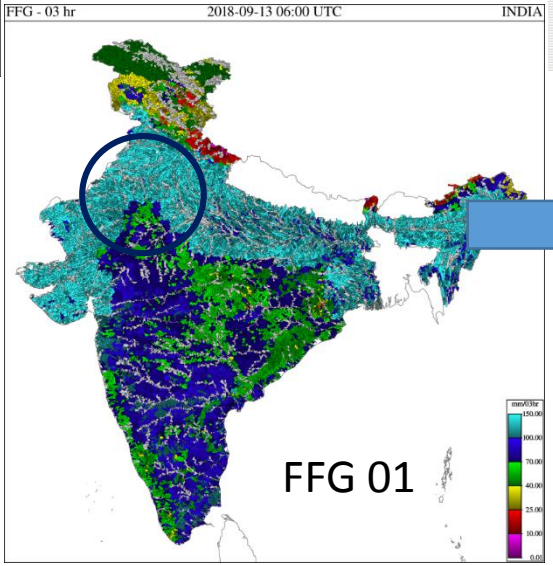
MAPSERVER Visualises multiple outputs/ forecasts of the micro level catchment areas at the same time which identifies flash flood prone zones.

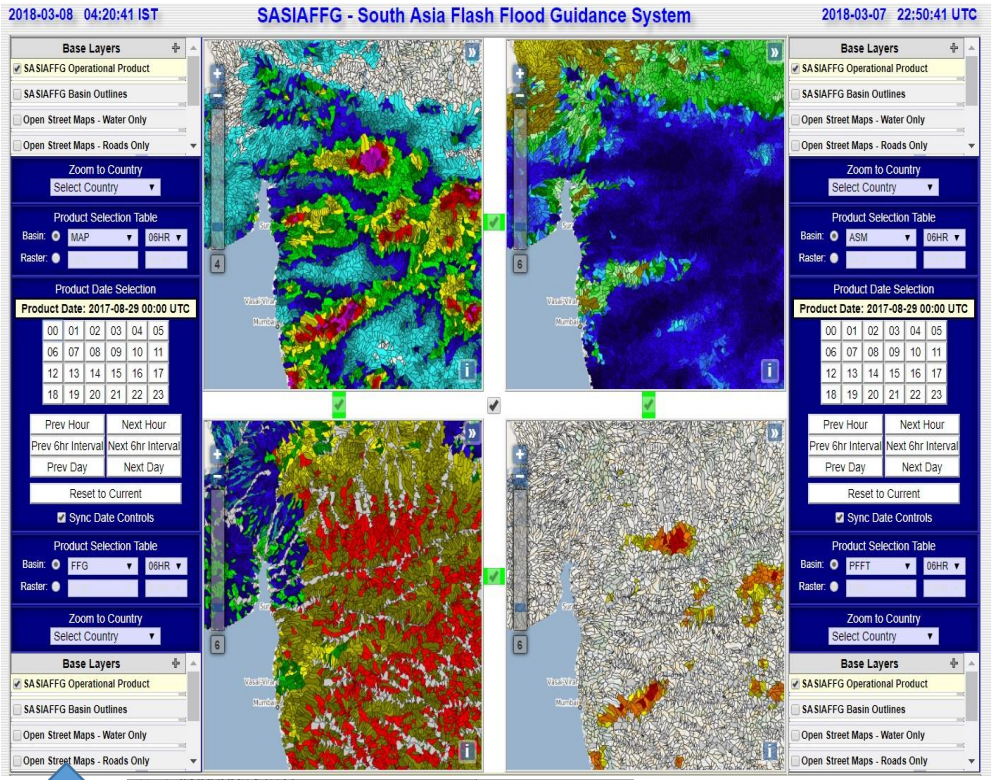


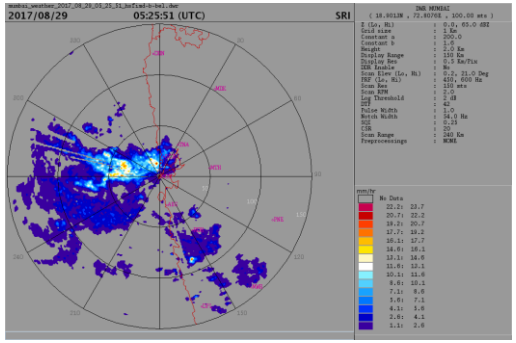


Low FFG Values

High Risk of Flash Flood Potential







Verified by Mumbai Radar Data

146 Sub Basin s

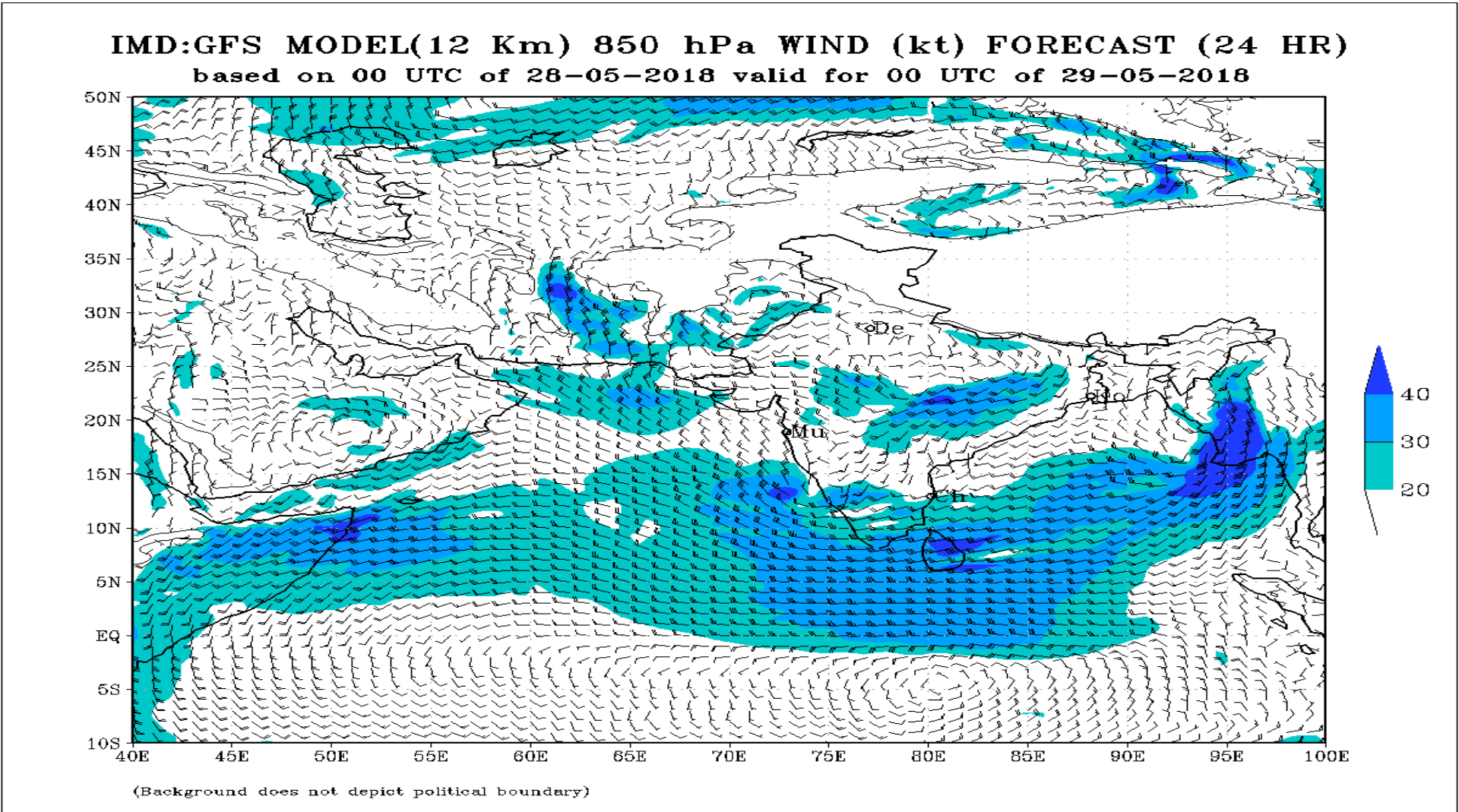
28780 Micro watersheds

FF Case Study: Mangalore on 29th May 18

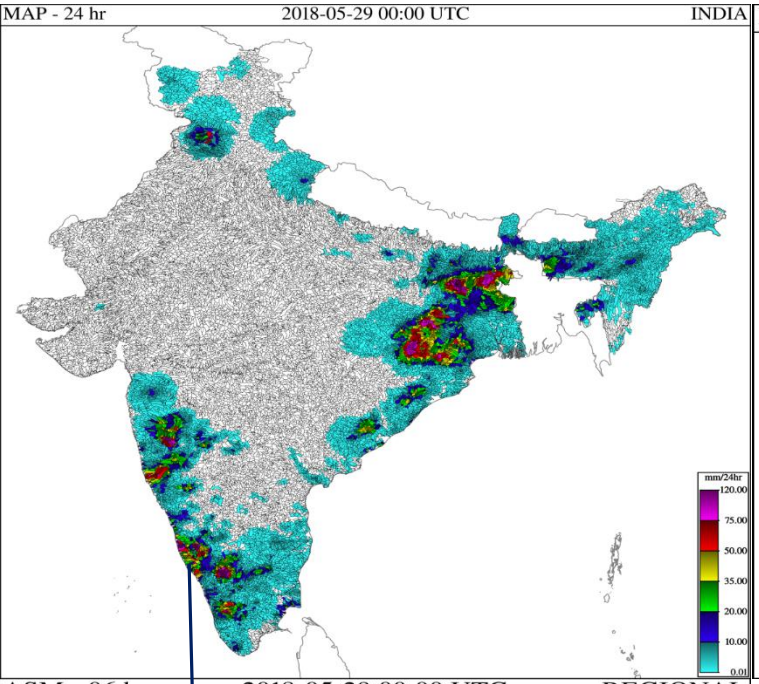
SYNOPTIC CONDITIONS

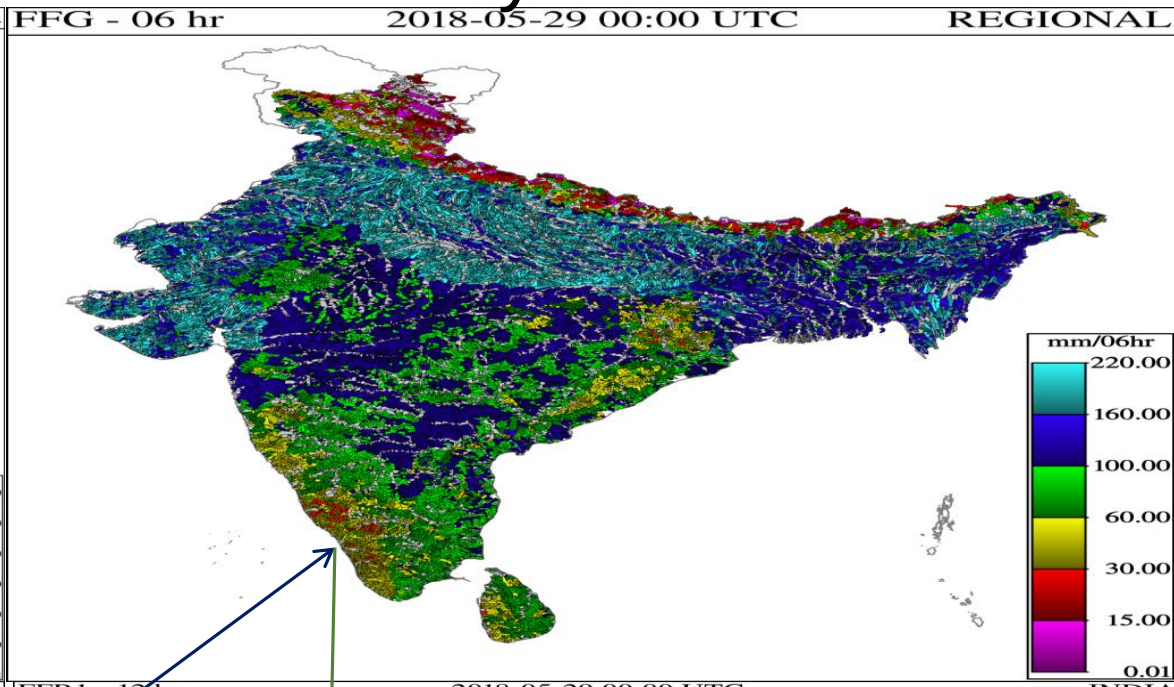
The well marked low pressure area lay over southeast Arabian sea and adjoining east central Arabian Sea off north Kerala Karnataka coasts.

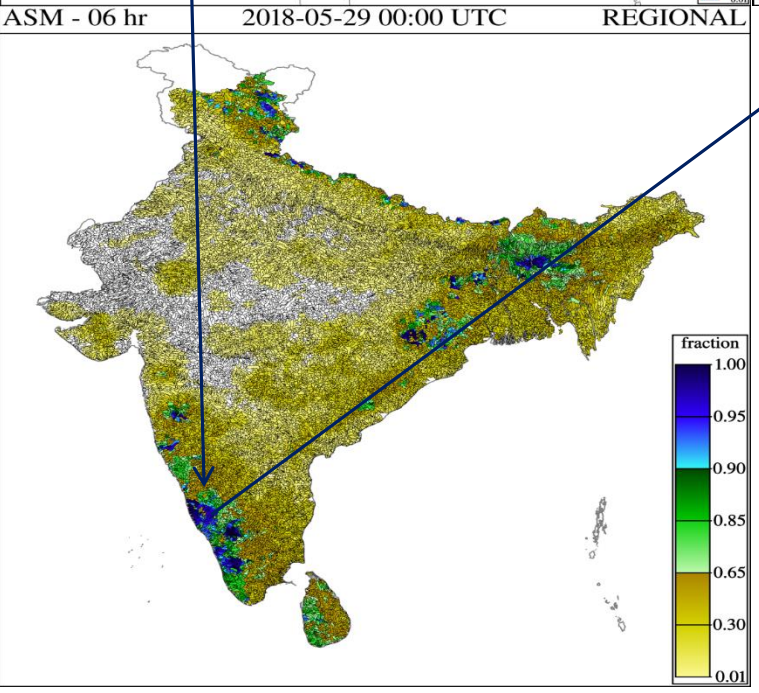
Associated cyclonic circulation extends up to 7.6 km above mean sea level.

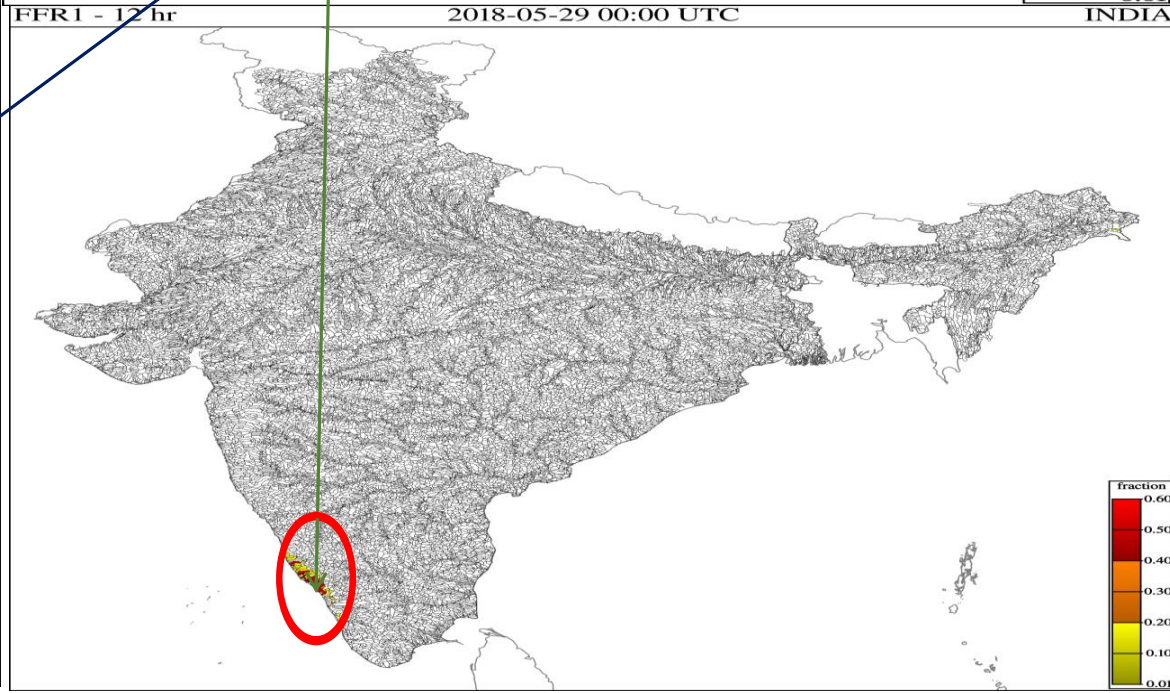


Flash Flood Risk 29th May – 00UTC









Rainfall Observation on 30th May'18

DISTRICT: DAKSHINA KANNADA	26	27	28	29	30
BANTWAL					
BELTHANGADI					
DHARMASTHALA	42.2	2.6	58.2	38.2	37.6
MANGALURU	57	11.4	44.4	49.6	285
MANGALURU AP OBSY	38.2	12.5	18.7	26.4	283.8
MANI	45.4	0.4	26.8	2.2	48.2
MUDUBIDRE	40.2	4.2	40.2	17.4	212.4
MULKI	14.2	16.4	21.5	78.4	
PANAMBUR OBSY	47.4	23.4	38.3	37.5	333.8
PUTTUR HMS	63	1	38	4	214
SUBRAMANYA	32.2	4.4	66.6	13.6	75.8
SULYA	124	2.4	80.8	13	122.2
SULYA ARG					
UPPINANGADI					
VITLA ARG					
DISTRICT: UDUPI					
BRAHMAVAR AWS					
KARKALA	31.4	1.2	30.8	85.8	131.4
KOLLUR	0	0	25	4.4	
KOTA	6.4	0	68	58.4	90.8
KUNDAPUR	2	1.4	20.8	27	29.4
SIDDAPURA	0	0	24.8	2.2	36.6
SIDDAPURA ARG					
UDUPI	6.5	0.1	58.6	49.5	160.8

Mangaluru: Heavy downpour leaves city in a shambles

Stanley Pinto | TNN | Updated: May 29, 2018, 14:55 IST

A- A+

Many low lying areas in the city witnessed artificial flooding.

MANGALURU: Torrential rains that lashed that the city on Tuesday morning inundated most of the low lying areas in the city. The rains which started at 9am left the city in a shambles with the steady drizzle turning to a downpour by mid-afternoon. Many low lying areas in the city witnessed artificial flooding and water entered many compounds – making it difficult for residents to venture out or come in.

Major areas that saw inundation were Kodialguthu, Kottara Chowki, PVS, Kadri Kambala, Panjimogeru, Adyar, Yekkuru and other areas. Most of the roads in the city were ankle deep water due to either drains being full or lack of drains.

MANGALURU

South west monsoon: Heavy rains lash Mangaluru, schools to be closed tomorrow

Anil Kumar Sastry

MANGALURU, MAY 29, 2018 14:34 IST
UPDATED: MAY 29, 2018 16:32 IST

Mangalore Rain: The south-west monsoon had hit the Karnataka coast earlier than usual. Mangalore and areas around it have been receiving heavy rains since Monday night. Although there was a sigh of relief for the locals during the early hours of Tuesday, there has been unabated rainfall since 9:30 am, according to a report by The Hindu. Various low-lying areas including Kottara Chowki and Ballal Bagh experienced waterlogging on Day 1 of the season.

One Air India, one SpiceJet and one Air India Express was diverted from Karnataka's Mangalore airport due to rain and poor visibility. Air traffic control (ATC) says 'it will improve soon'. Rescue operations are underway in Mangalore's Panambur as streets got water-logged following pre-monsoon rains.

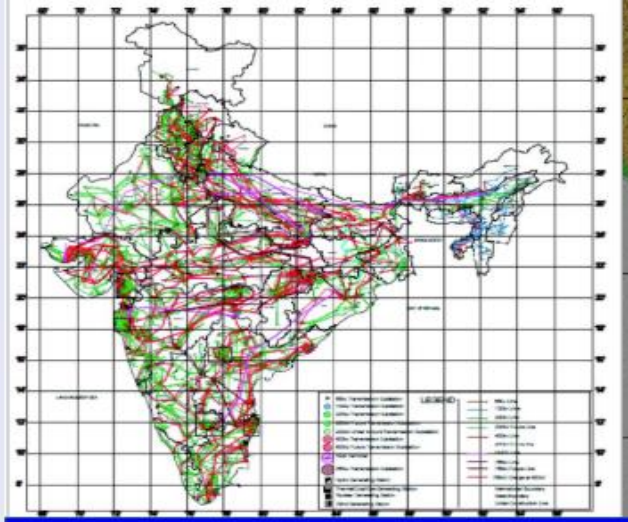
The Mangaluru Central Railway Station and the adjacent Railway Mail Service office were completely inundated with rainwater and overflowing sewage

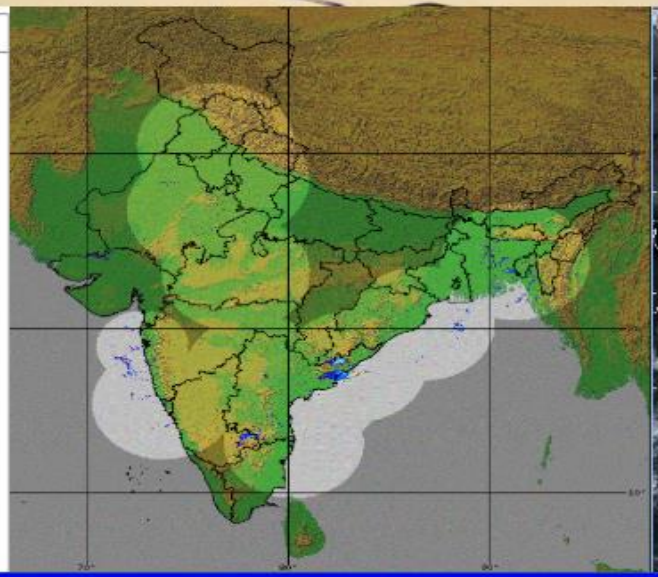
11:52:03

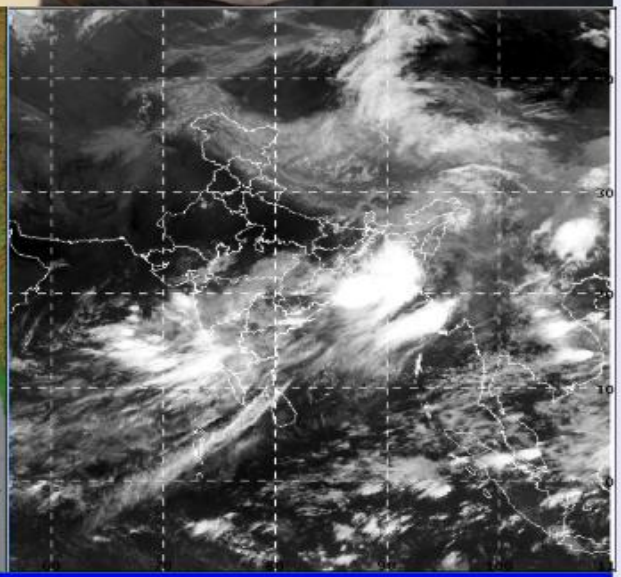
Sunday, September 16, 2018

WEATHER PORTAL FOR POWER SECTOR

ALL INDIA POWER MAP







POWER SYSTEM OPERATION CORPORATION LIMITED
B-9 (1st FLOOR), QUTAB INSTITUTIONAL AREA, KATWARIA SARAI, NEW DELHI 110016.

Important Topics

- Important Terminology
- Weather Forecast and Warning
- Meteogram
- Radar Images
- Satellite Image
- RAPID
- METAR
- Experience so far

- Weather Portal For Power Sector
  http://amssdelhi.gov.in/NRLDC/index.html

Important Terminology

Important Meteorological terminologies have been described

Example:-

Rainfall Category

% Stations	Category
76-100	Widespread (Most Places)
51-75	Fairly Widespread (FWS/Many Places)
26-50	Scattered (SCT/A Few Places
1-25	Isolated (ISOL)

Cyclone Intensity	Damage expected to Power /Communication lines
Deep depression (52-62 km/hr)	Nil
Cyclone Storm (63-67 Km/hr)	Minor
Severe Cyclone Storm (88-117 Km /hr)	Minor
Very Severe Cyclonic Storm (118-221 Km/hr)	Large scale disruption of Power lines
Super cyclone (222 Km/Hr and Above)	Total disruption of Power lines

Heat Wave : Heat wave is considered if maximum temperature of a station reaches at least 40°C or more for Plains, 37°C or more for coastal stations and at least 30°C or more for Hilly regions. Following criteria are used to declare heat wave:

Based on Departure from Normal

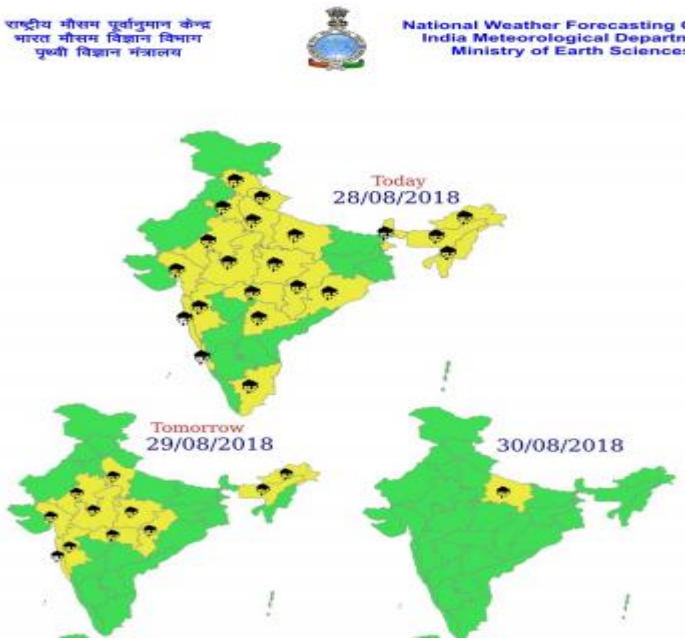
- Heat Wave: Departure from normal is 4.5°C to 6.4°C
- Severe Heat Wave: Departure from normal is >6.4°C

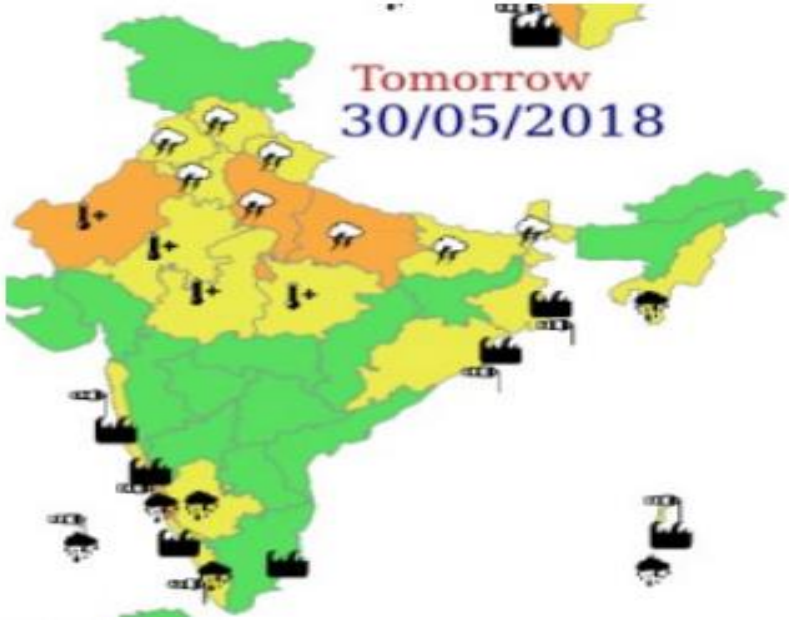
Based on Actual Maximum Temperature (for plains only)

- Heat Wave: When actual maximum temperature ≥ 45°C
- Severe Heat Wave: When actual maximum temperature ≥47°C

To declare heat wave, the above criteria should be met at least in 2 stations in a Meteorological sub-division for at least two consecutive days and it will be declared on the second day.

Weather Warnings





WARNING

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

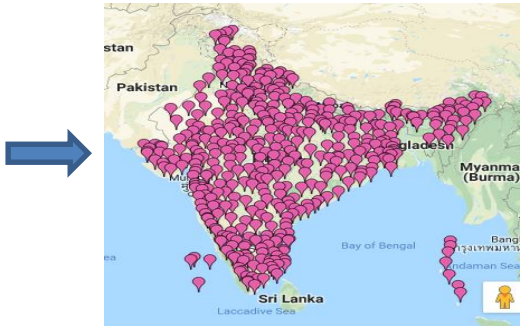
Probabilistic Forecast

Terms	Probability of Occurrence (%)
Unlikely	< 25
Likely	25 - 50
Very Likely	50 - 75
Most Likely	> 75

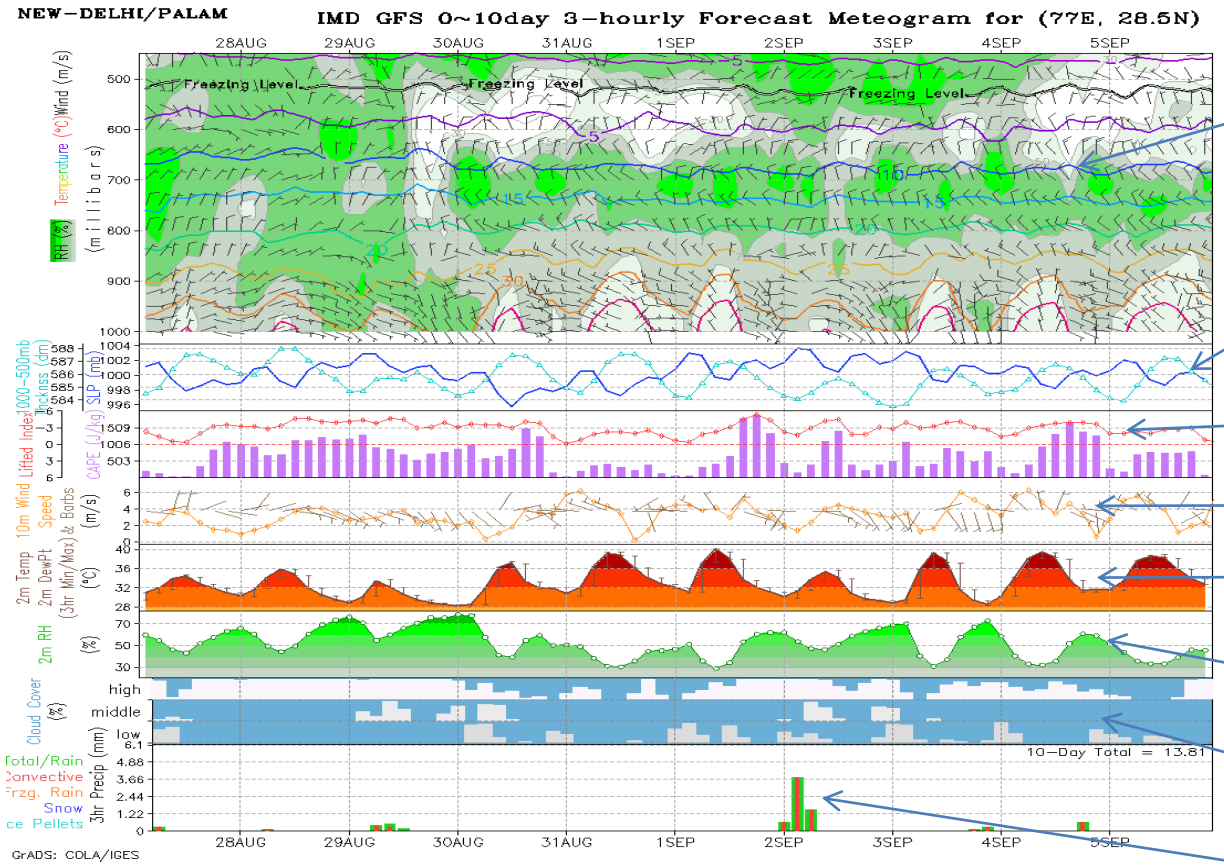
Heavy Rain
Heavy Snow
Thunderstorm
Dust Storm
Strong Winds
Visibility
Cyclone
Squall/ Hail
Frost
Cold Wave
Heat Wave
Sea State

Meteogram

- Reference document discusses Meteogram
  - Meteogram is a plot of various Meteorological Variables
    - Rainfall,Cloud cover,Temperature ,Humidity ,Wind Speed, Indices of Thunderstorm, Sea level pressure
    - Three hourly forecast for 10 days.
    - Updated twice daily
    - Available for 450 locations in India



Typical Meteogram Plot



Relative Humidity

Mean Sea Level Pressure

Thunderstorm Indices

Wind Speed & direction

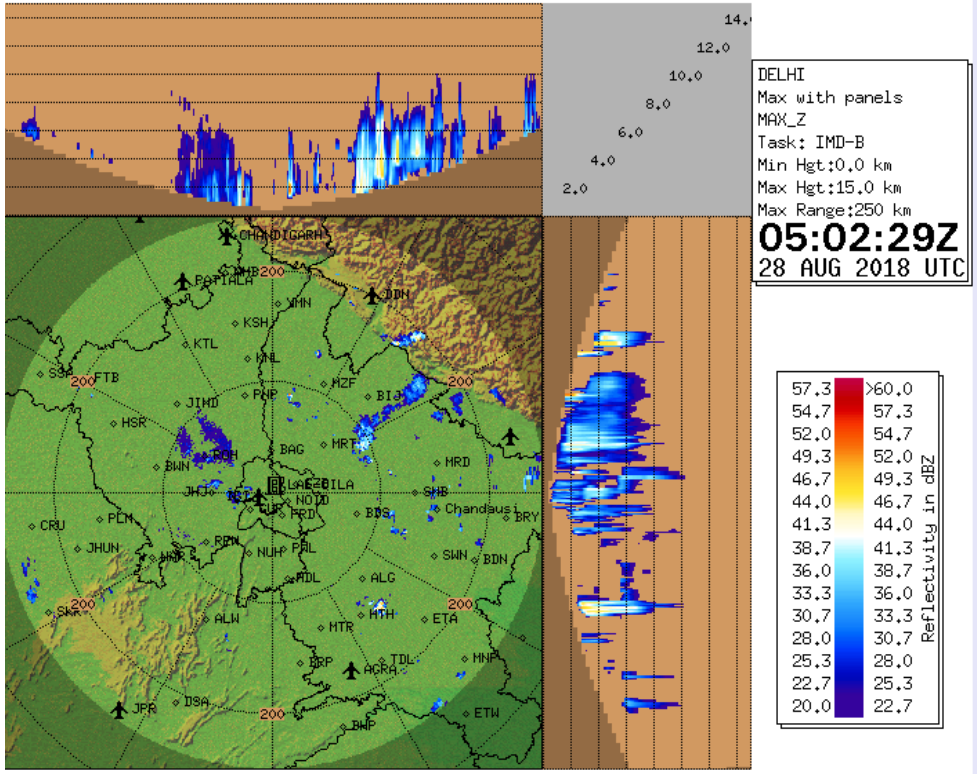
Temperature

Relative Humidity at 2 Meter

Clouds

Rains

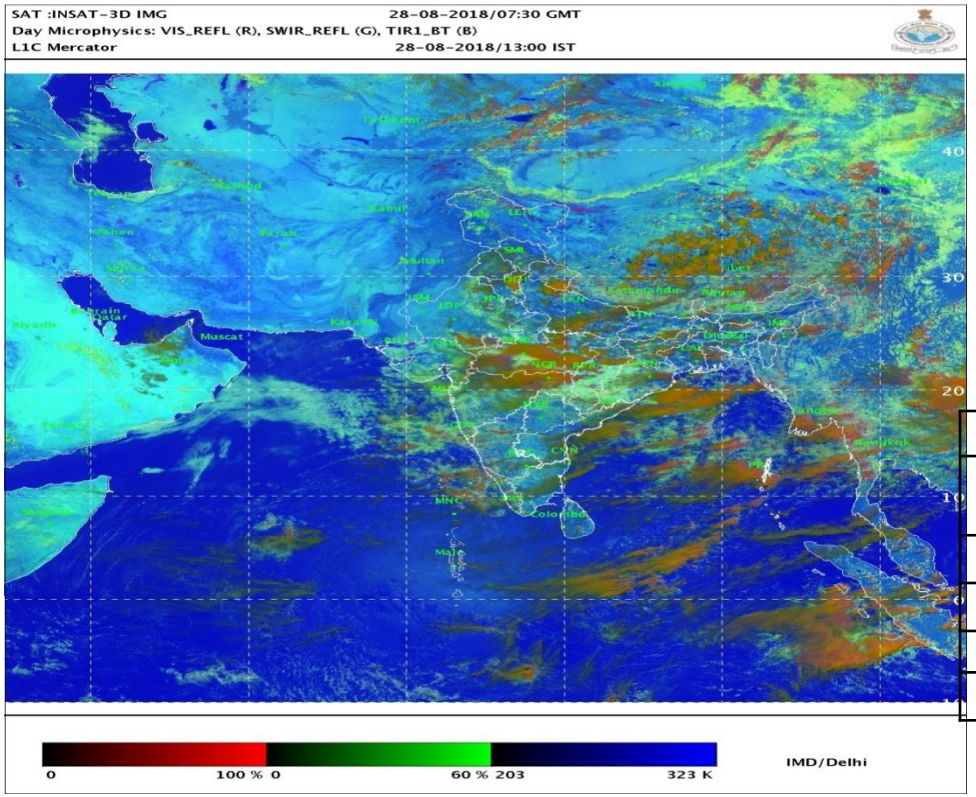
Radar Images



Reference document explains the details of various Radar Products:
Plan Position Indicator (Max (Z)), Surface Rainfall intensity (mm/hr), Plan Position indicator
(Mean velocity (m/s) , Precipitation Accumulation (mm)

- Radar Image Uses in System operation :
  - Identifying distance and height of Clouds (Kms)
  - Movement of clouds /Thunderstorm/Rains
  - Location of Rainfall and its intensity in mm/h
    - {Assessment of the impact and advance control measures required to maintain the Grid Security}
  - Total Rainfall in mm in the last 24 hours (mm)
    - Assessment of demand in next 24 hours
  - Wind speed and direction at the Location of Radar (knots)
    - load reduction due to factors, like, switching off of distribution lines to prevent collateral damage/distribution network outage

Satellite Image

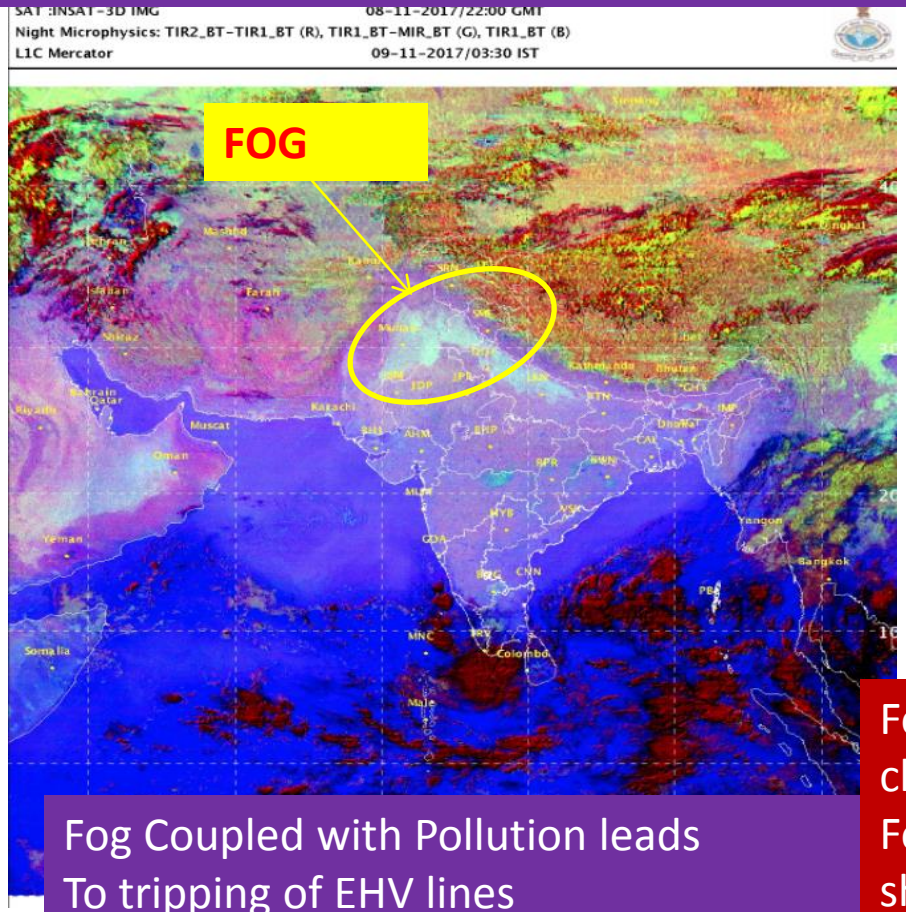


Satellite makes measurement indirectly by sensing electromagnetic radiations coming from the surface below INSAT 3D is being used to monitor the Weather . Image is updated every 30 minutes.

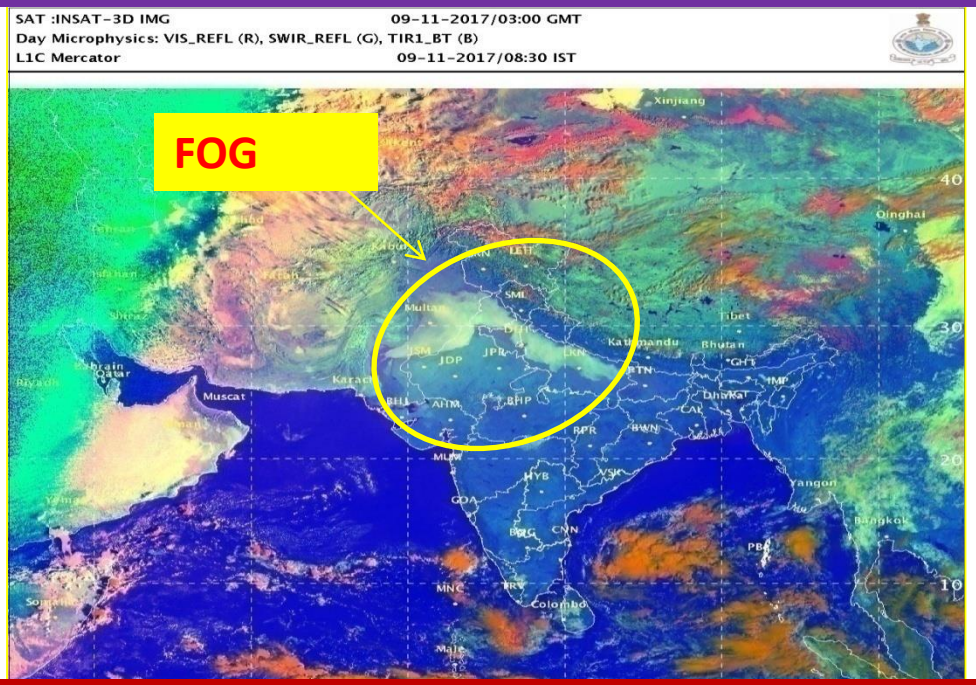
The weather document explains different types of satellite Image with their colour coding for monitoring of Fog, Cloud Cover, sand, dust, snow, cyclone etc.

FOG	
LOW CLOUDS (Nearest to Satellite)	
MID LEVEL ORGAPHIC CLOUD	
(DEVELOPED CLOUD)	
SNOW	
SAND /DUST	

FOG Monitoring using Satellite Images

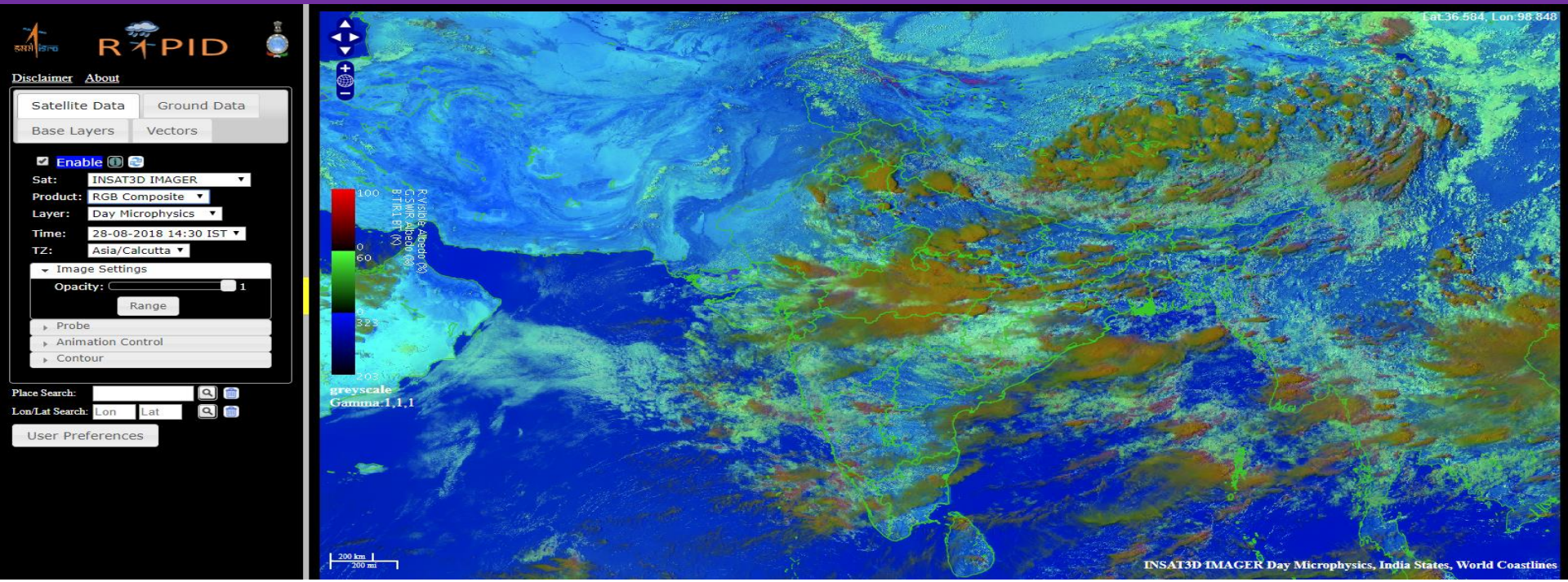


Fog Coupled with Pollution leads
To tripping of EHV lines



Fog will have a sharp/smooth boundary ,while low clouds will have disbursed boundary. In animation Fog will remain stationary while low clouds will show some movement.

RAPID
(Real time Analysis of Products & Information Dissemination)



RAPID-Real time Analysis of Products & Information Dissemination is a web based quick visualization and analysis tool for satellite data on a real time basis. . Using RAPID one can interact like actual satellite workstation and may zoom to any actual resolution.

METAR

A METAR weather report is predominantly used by pilots in fulfilment of a part of a pre-flight weather briefing, and by meteorologists, who use aggregated METAR information to assist in weather forecasting. METAR is the scheduled observation taken at the end of each hour/half hour (important Airports).

A typical METAR contains data for the

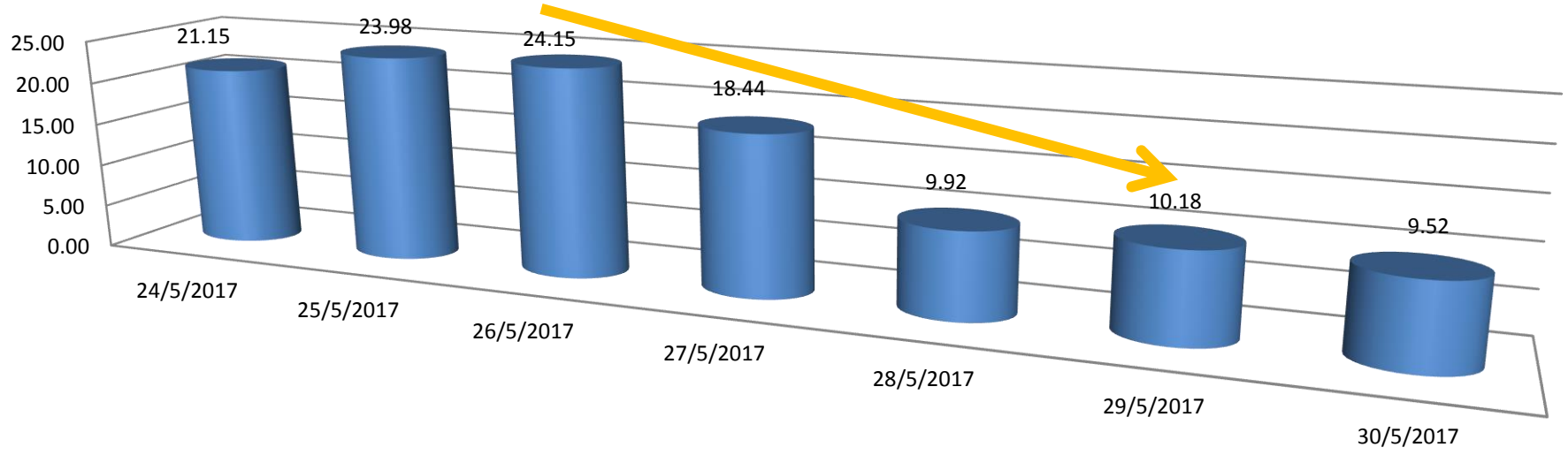
- temperature,
- dew point,
- wind direction and speed,
- precipitation,
- cloud cover and heights,
- visibility and
- barometric pressure.

The visibility at an Airport can provide a good idea about status of FOG/SMOG.

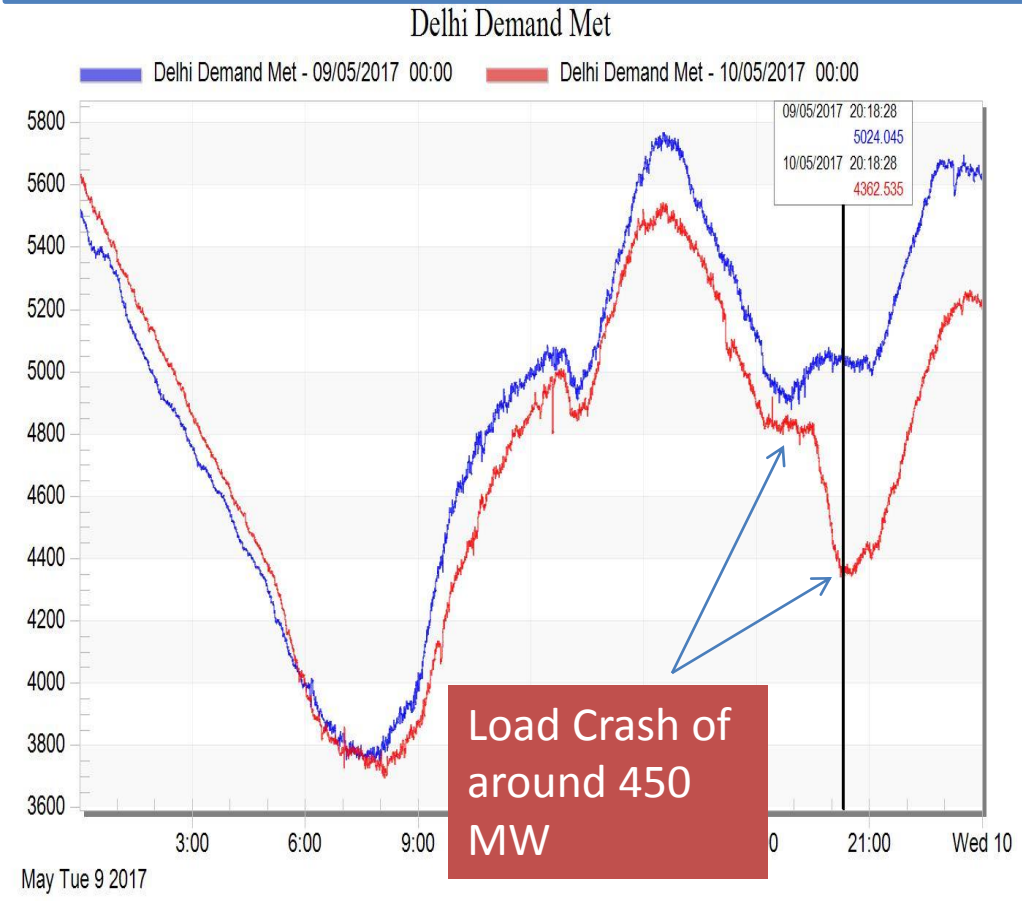
Benefit achieved by Uttar Pradesh

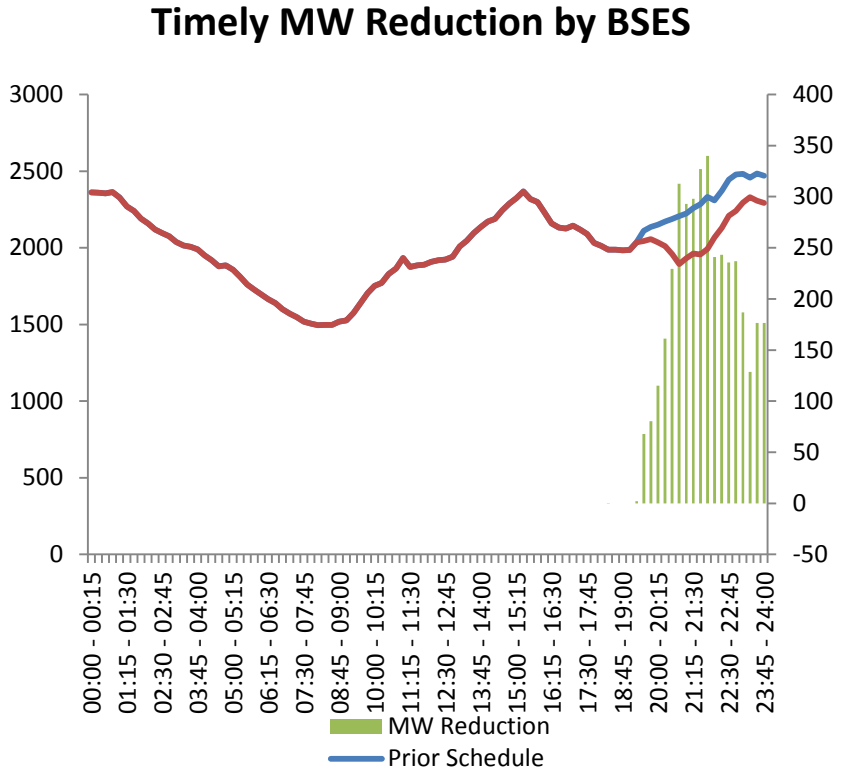
- Meteogram, wind and rain forecast for 27/28/29-05-2017 helped in better load assessment of UP control area by U.P. State Load Despatch Centre.
- As anticipated, UP demand went down from 19000 MW to 17000 MW due to change in weather conditions.
- Accordingly, STOA & purchase from Power Exchange of the order of 2000 MW was reduced. i.e Backing down of approximately 13 MU of costly thermal generation .

Total Power Exchange & Bilateral



Benefit achieved by BSES

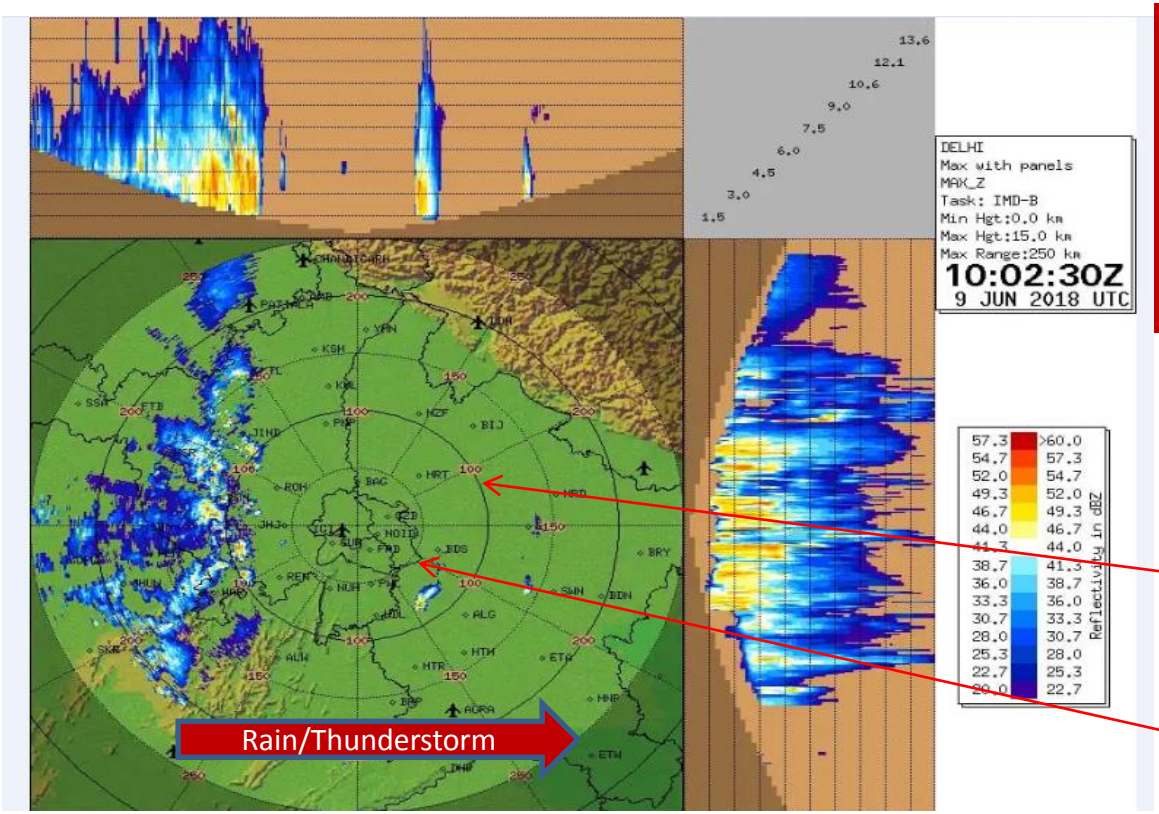




Savings by BSES

S.no.	Date	Savings (Mus)
1	10/05/2017	0.24
2	31/05/2017	0.48
3	20/06/2017	1.49
4	30/08/2017	1.43
5	31/08/2017	1.26
6	22/09/2017	2.19
7	23/09/2017	1.87
	Total	8.96

Radar Image for Rain/Thunderstorm Monitoring



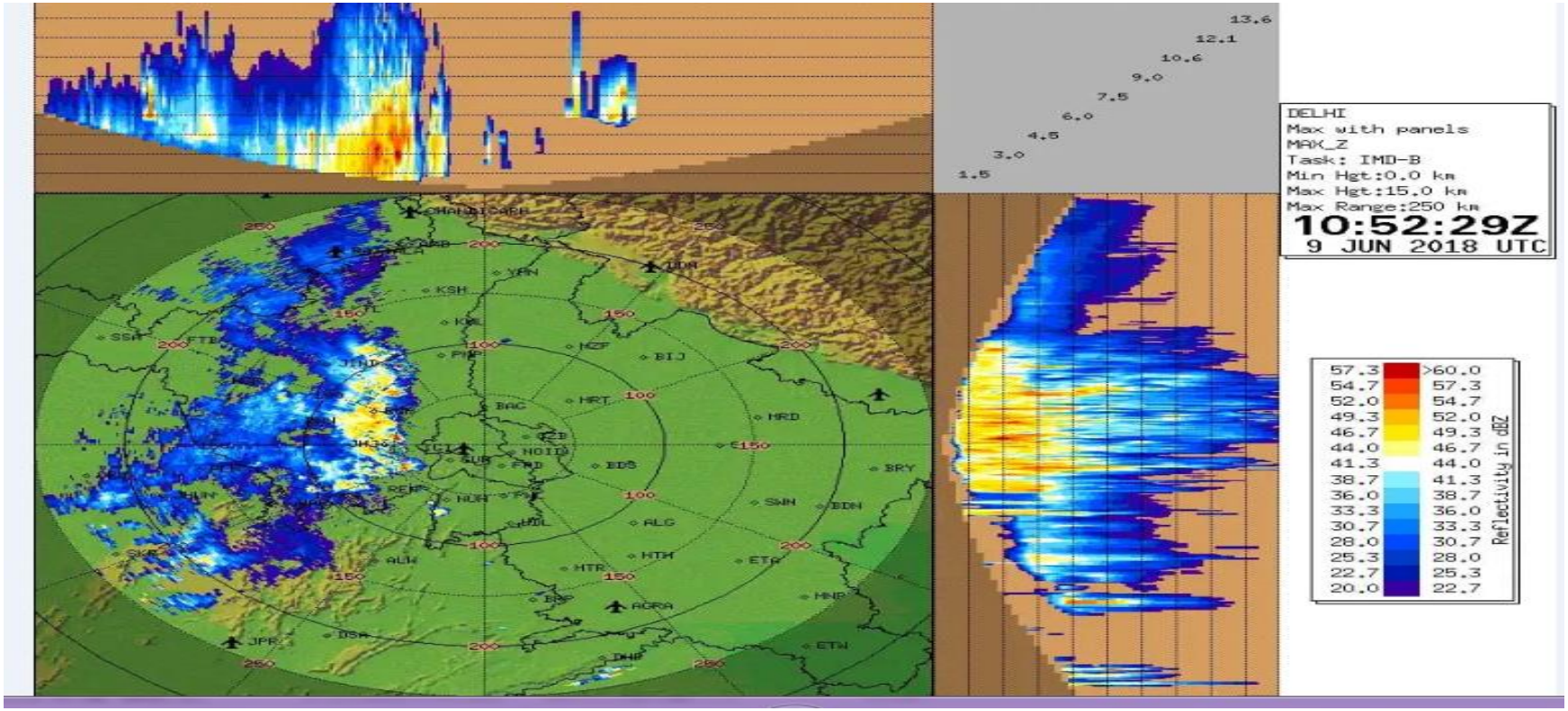
Thunderstorms:

- **A likely phenomena during summers**
- **Leads to Load Crash**
- **Excursion in Voltage and Frequency**

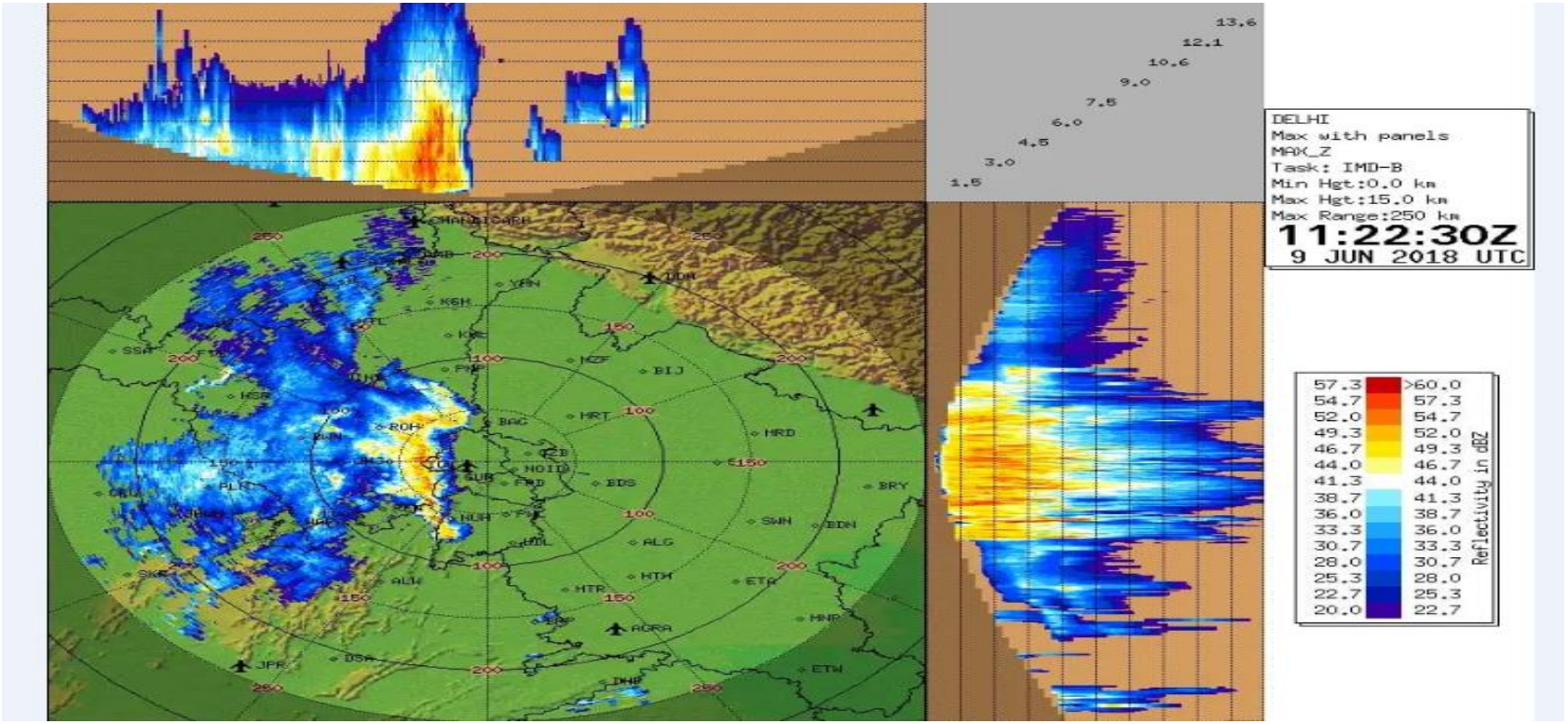
100 km Boundary

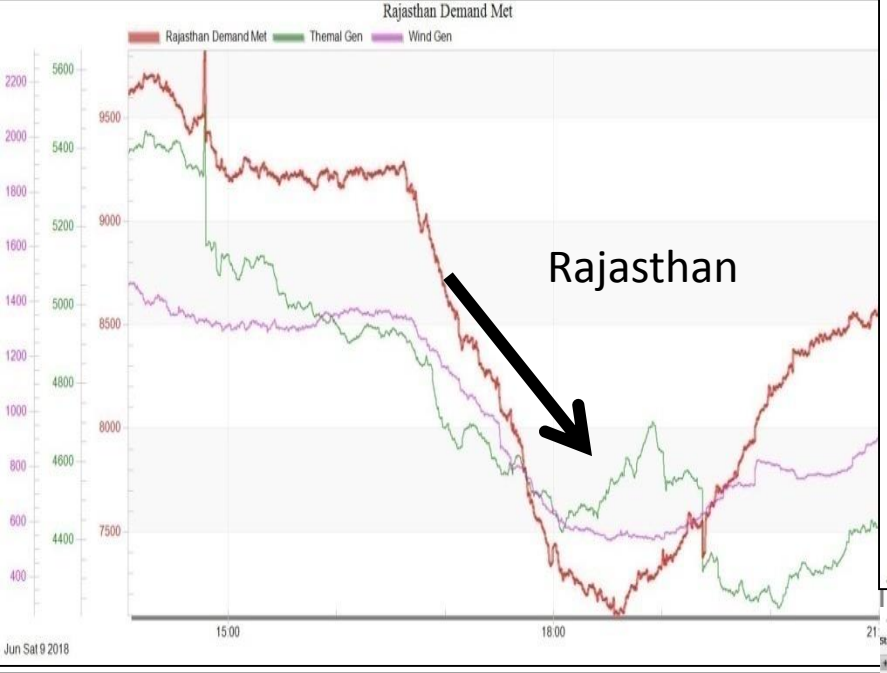
50 km Boundary

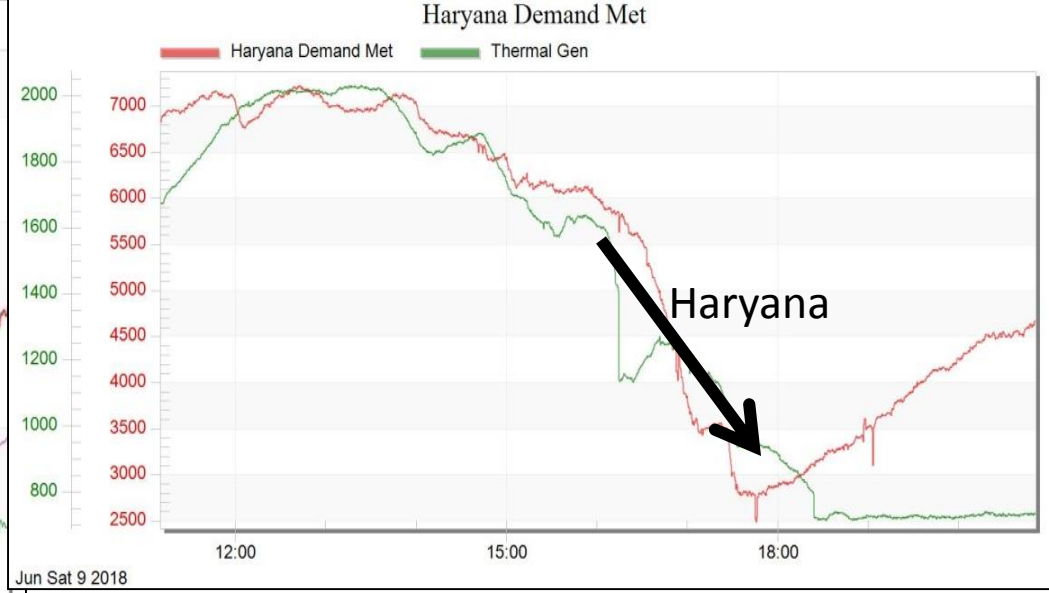
Radar Image for Rain/Thunderstorm Monitoring

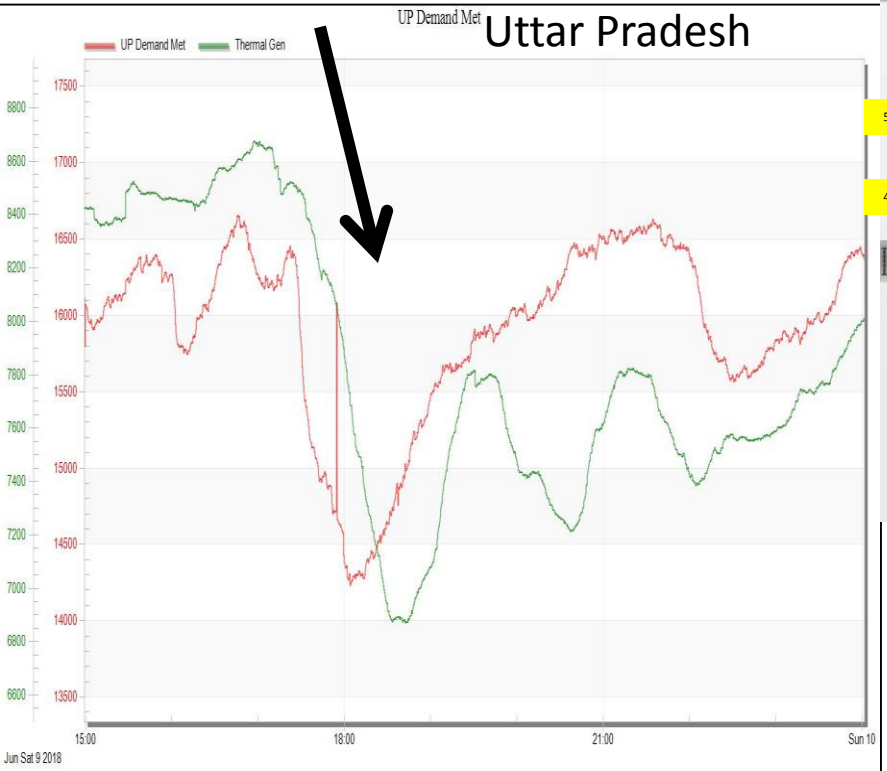


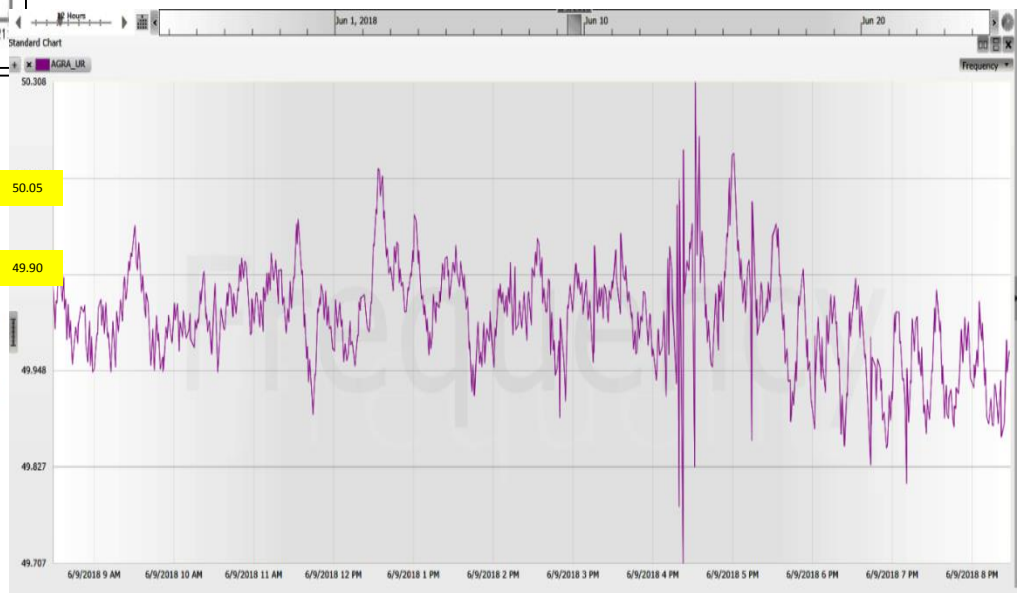
Radar Image for Rain/Thunderstorm Monitoring











- Near Real time Radar image helped in Timely Reduction of Generation in State Control area/ISGS Generation, RRAS (Reserves Regulation Ancillary Services) Regulation leading to better Load Generation balance in the Grid

Activities Critical for Coastal Areas

- Observing Systems for Atmospheric and Oceanic Science & Services – multi-scale networks over **Land** (**Doppler Weather Radars; Automatic Weather Stations/Rain Gauges; High Wind Speed Recorders etc**.), **Sea** (**moored and drifting buoys, Argo Floats, ADCP and Current Moorings etc.**), in-situ airborne & ship borne platforms and **Satellite Based systems** (**INSAT, Kalpana, OCEANSAT, Megha Tropique, NOAA, EUMETSAT** etc.) for real time data transmission and reception
- 24X7 system of severe weather surveillance and forecasting (continuously scaling up) - **Cyclones; Tsunami and Storm Surges; all other severe weather systems**; River basin scale meteorological support for river flood warning system
- Continuously monitoring the pattern of sea level changes all along the Indian coastline with established 26 tide gauges.
- Vulnerability of the Coastal Zones – [3-Dimensional Geographical Information System (3D GIS) maps for the entire coastal stretch; mosaic with other available topographic and thematic high resolution maps at 1:100000; 1:25000; 1:5000 scale; shoreline change maps at 1:25000 scale] for effective emergency response, risk reduction, sustainable shoreline management and natural resource management
- Climate services information products viz. **spatial monthly scale anomalies of rainfall and temperature; minimum/maximum temperature; standardized Precipitation Index** (SPI) etc. along with severe weather events.

Future Plans for Coastal Areas

- Building multi-scale & multi-sensor networks for Long-term measurements of various environmental/terrestrial/marine/bio-geochemical/GHGs variables at large/regional/local/eco-system scales to **capture vital signatures of the earth system response to climate variability and change**
- Comprehensive multi-institutional Program for **Changing Water Cycle**; **thermal expansion of Bay of Bengal and Arabian Sea**; **Sea Level Changes & coastal zone impacts**; **Engineering and Technical Solutions for Structural Safety of Coastal Investments**
- Build Earth System Model (ESM) to treat comprehensively the coupling of various sub-systems (ocean-atmosphere; land-atmosphere; cryosphere-atmosphere; biogeo-chemical cycles over ocean and land; aerosols-GHGs-clouds-precipitation etc.) to improve our predictions of **weather, climate, hazards, air quality and Environment**
- Expanding services in support of four key climate-sensitive sectors, including **agriculture, water, health, Energy and climate and disaster risk management** for rendering customized services for societal, environmental or economic benefits
- Accelerating initiatives **related to Capacity Building – for regular induction of skilled and specialized manpower**

Activities to be augmented to the Multi-Hazard Early Warning Systems

- **Observational and Prediction Systems**
  - Hourly and 3-Hourly Telemetered Data (Land, Ocean and Space based observational systems)
  - Need for seamless data sharing /exchange of information amongst agencies
  - Build local scale severe weather forecast systems
- **Quantification of Impact**
  - Impact assessments to include likely spatial impacts on ground based on severe weather forecasts
- **Customization of Early warning system products**
  - Development of Decision Support Systems(DSS) for sectoral customization of Early warning system products
  - Need for developing decision making tools for effective response strategies at district and sub-district level

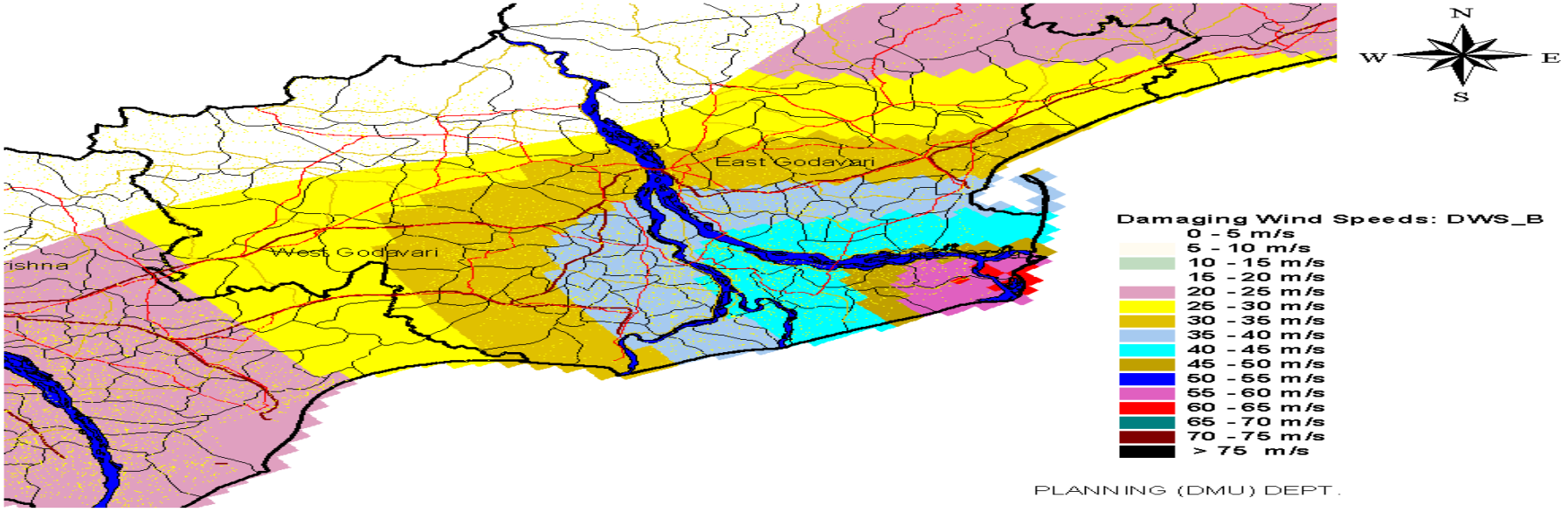
Local Scale Multi-Hazard Assessment Tools Development

- Adaptation of appropriate district scale models for storm surge/tsunami waves along coastal River/Delta systems [To generate storm surge/Tsunami inundation Maps]
- Development of appropriate regional scale models for Wind Damage Assessment, Heavy Precipitation and spatial inundation scenarios in coastal urban areas, Coastal SEZs/EPZs/Oil and Gas Installations and catchment scale coastal river hydrological models[To generate Wind Hazard Maps]
- Integrate the above information in to a multi-hazard risk management and decision making tool for district level multi-hazard response planning

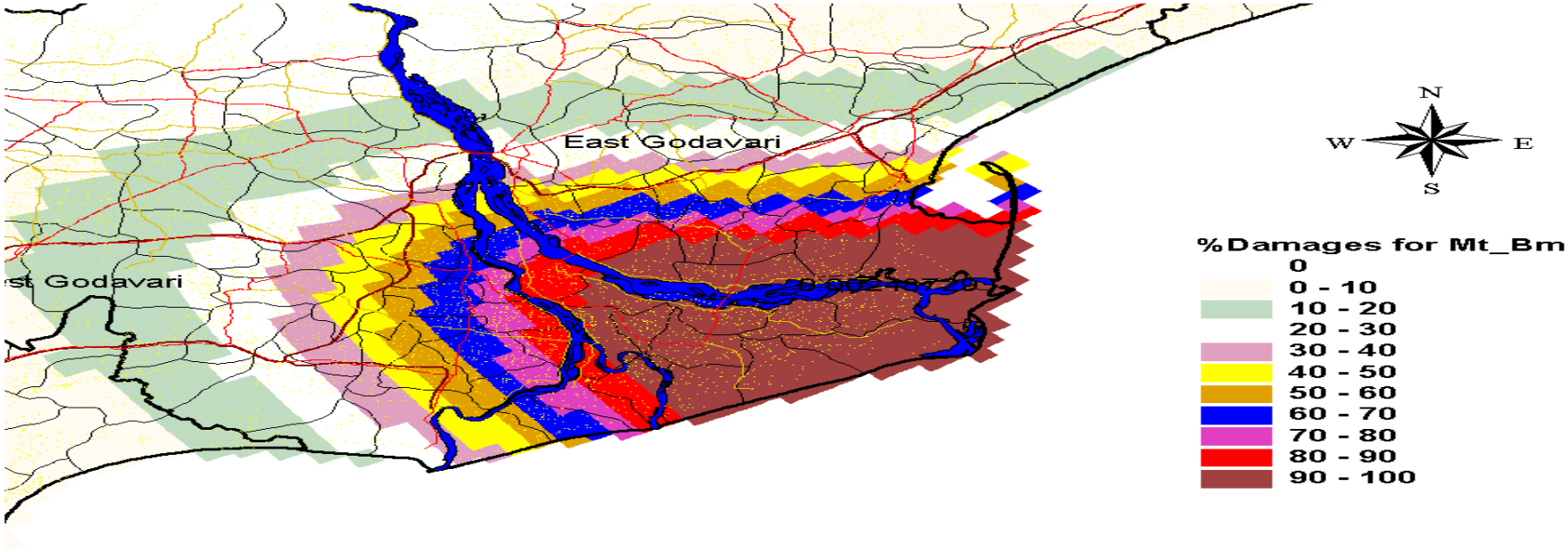
Quantified Information

- Population to be affected
- Densely populated villages
- Areas under threat
- Threat to Crops
- Damage to Structures
- Rail and Road network in the affected areas
- Vulnerable points
- Cyclone shelters

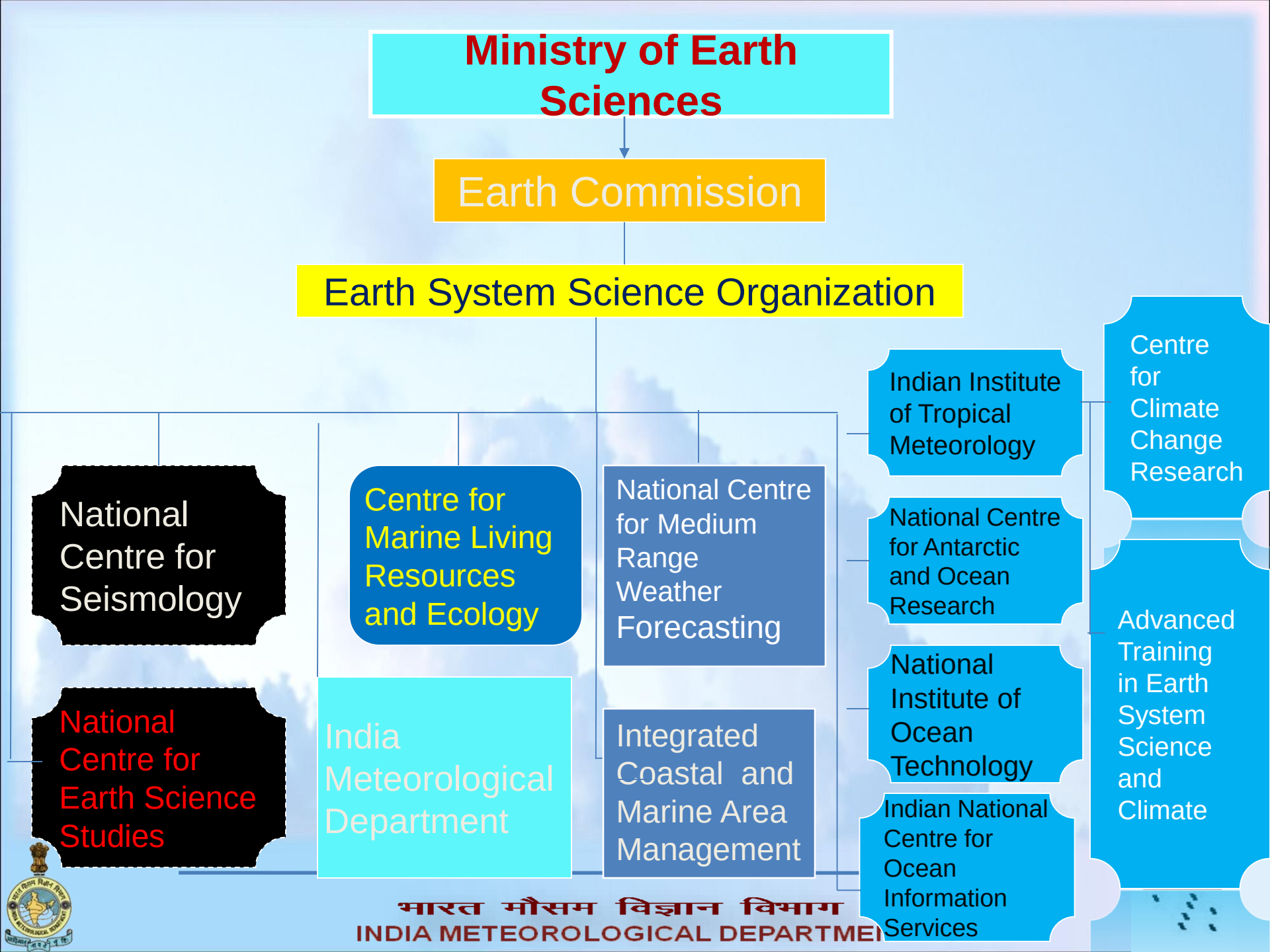
DAMAGING WIND SPEEDS -NOV.1996 CYCLONE



WIND HAZARD MAP- DAMAGE TO TILED HOUSES



Thanks


Ministry of Earth Sciences
Earth Commission
Earth System Science Organization
National Centre for Seismology
National Centre for Earth Science Studies
Centre for Marine Living Resources and Ecology
India Meteorological Department
National Centre for Medium Range Weather Forecasting
Integrated Coastal and Marine Area Management
Indian Institute of Tropical Meteorology
National Centre for Antarctic and Ocean Research
National Institute of Ocean Technology
Indian National Centre for Ocean Information Services
Centre for Climate Change Research
Advanced Training in Earth System Science and Climate
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMEI

Agencies dealing with various Hazards within the Ministry of Earth Sciences, Government of India

HYDRO-METEOROLOGICAL HAZARDS – IMD, INCOIS

Tropical Cyclones, Local Severe Storms, Winter Systems.
[Support for Floods, Drought Snow Avalanches]
Climate change impacts on severe weather events (IITM and IMD)

GEOLOGICAL HAZARDS

Earthquakes & Tsunamis (NCS and INCOIS)
[Support for Rain Induced Landslides/Mudslides (IMD; NCESS)]

ENVIRONMENTAL IMPACTS

-Air pollution & Haze, FOG, Smog (IMD)
-Coastal Zone Management (NCCR)
-Coastal Erosion (NCCR; NCESS)
-Eco-system monitoring/ modeling (IITM and IMD)