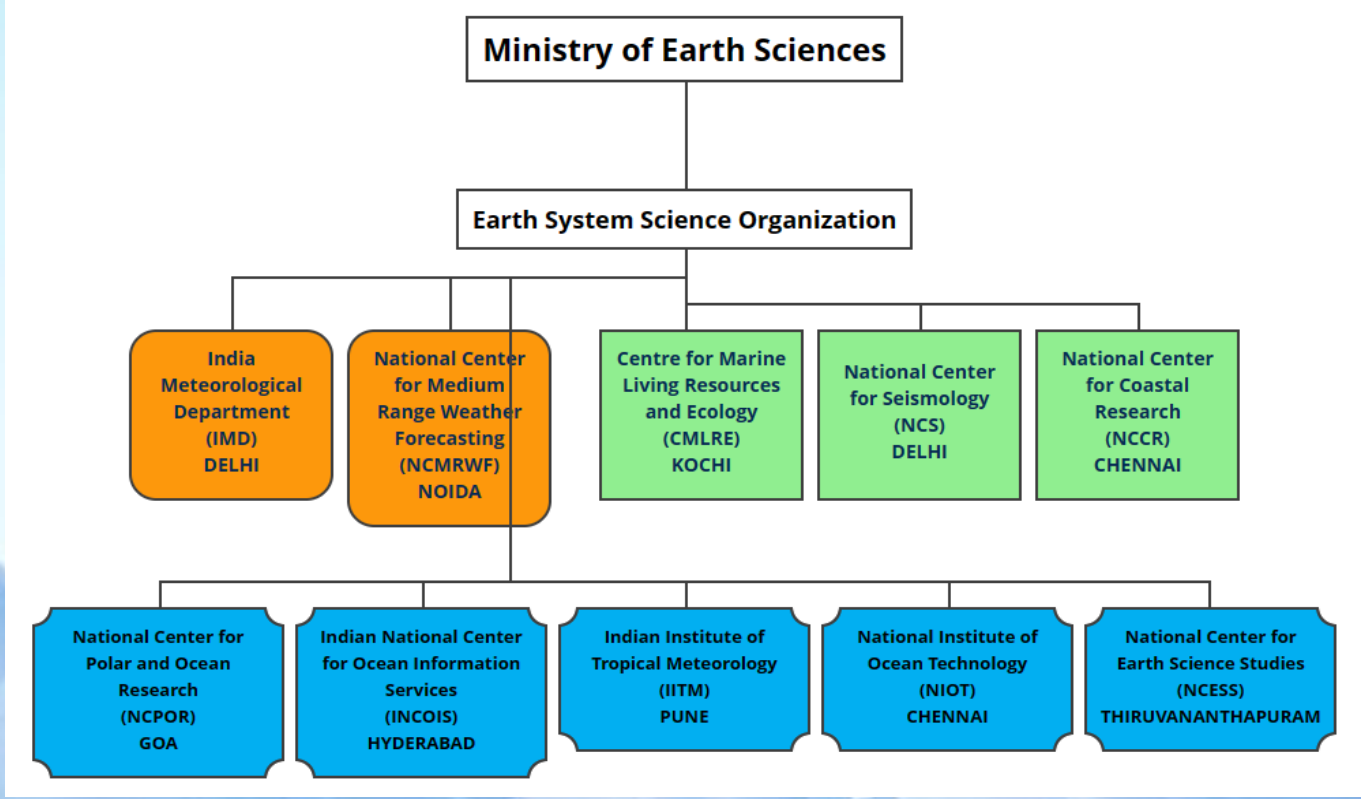
Fourth Leadership and Management Programme for Senior Management of National Meteorological and Hydrological Services (NMHSs), Singapore, from 4 to 8 September 2023

India Meteorological Department (IMD): Organization Structure, Achievements and Challenges

D. Sivananda Pai

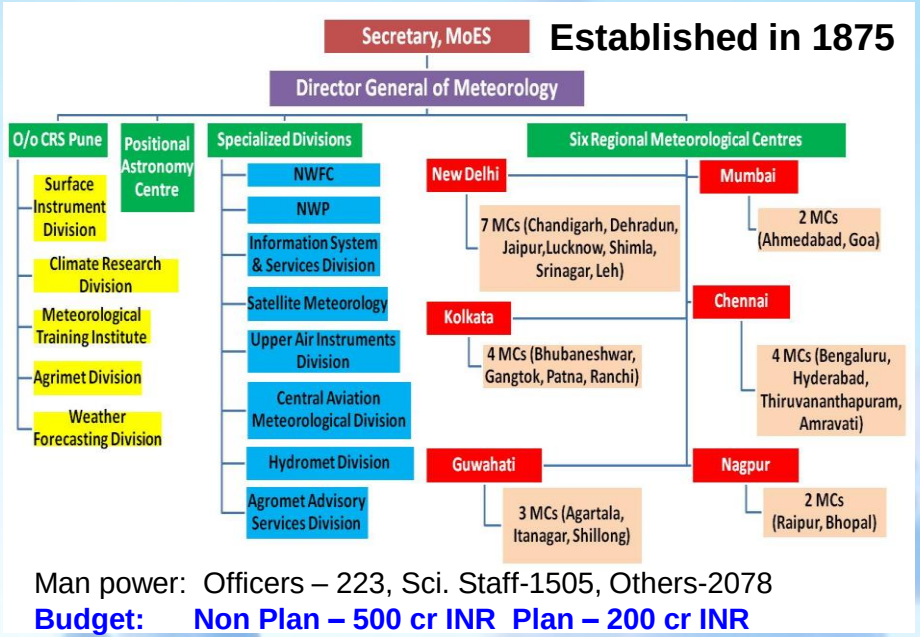
India Meteorological Department
Ministry of Earth Sciences
Government of India

Organization Set up of Ministry of Earth Sciences (MoES)



2 Subordinate offices,
3 Attached offices and
5 Autonomous bodies

ORGANIZATIONAL STRUCTURE OF IMD



Man power: Officers – 223, Sci. Staff-1505, Others-2078

Budget: Non Plan – 500 cr INR Plan – 200 cr INR

WMO recognized Centers

- **RSMC for Tropical Cyclones and Severe weather**
- **RSMC for Flash flood guidance**
- **Regional Climate Centre (RCC), Pune for South Asia**
- **Regional Meteorological Training Centre**
- **GPC for Long Range Forecasting**

Mandates

- To take meteorological observations and to provide current and forecast meteorological information for optimum operation of weather-sensitive activities like agriculture, irrigation, shipping, aviation, offshore oil explorations, etc.
- To warn against severe weather phenomena like tropical cyclones, norwesters, dust storms, heavy rains and snow, cold and heat waves, etc., which cause destruction of life and property.
- To provide meteorological statistics required for agriculture, water resource management, industries, oil exploration and other nation-building activities.
- To conduct and promote research in meteorology and allied disciplines.

Our Vision

To provide efficient Weather and Climate Services for the safety of life and property and to contribute towards the National development.

Various Socio-economic Sectors to Which Services are Provided

Monsoon


Aviation


Agriculture


Shipping


Hydrology

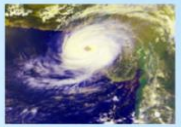

Transport


Power & Energy


Tourism


Health


Sports


Cyclone


Disaster Management


Flood


Defence


Pilgrimage


Mountaineering

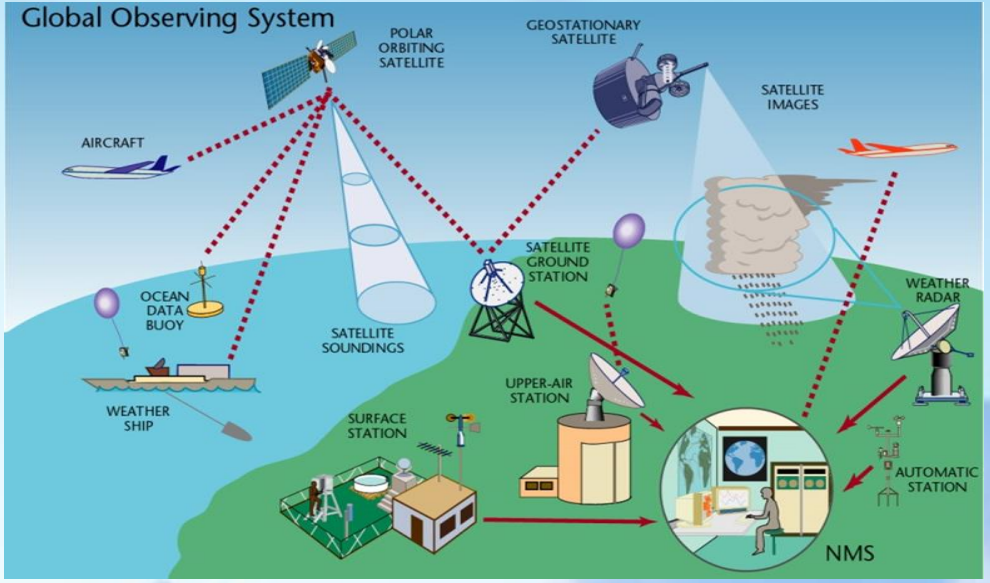

Fog


Fisheries

Climatology

Urban Development

Detection, Observation and Monitoring of Weather and Climate: Observational System



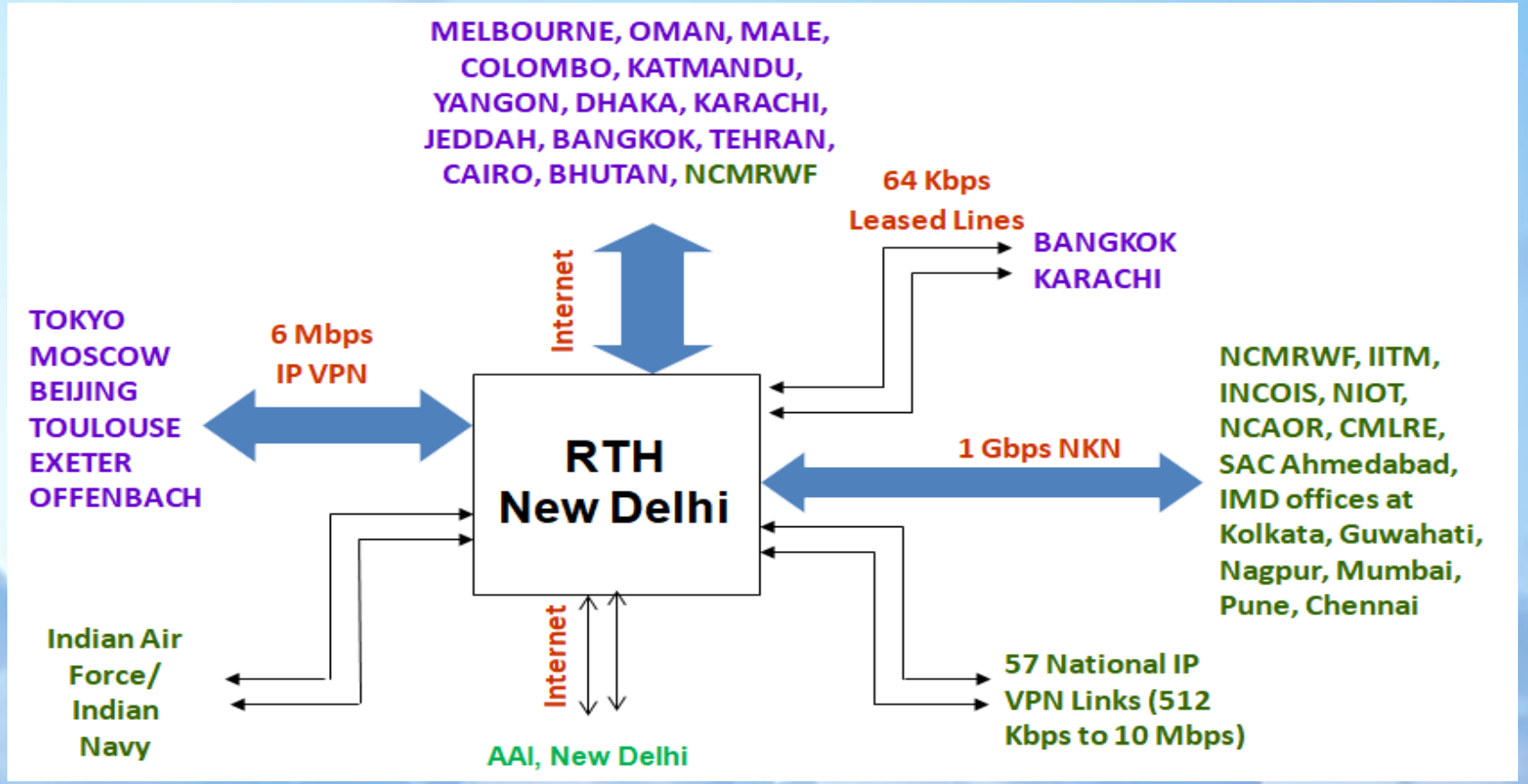
Name of the Instrument	2023	Till (2025-26)
Doppler Weather Radar (DWR)	37	63
Automatic Weather Stations (AWS)	1008	1287
Automatic Rain Gauge (ARG)	1382	1624
High Wind Speed Recorders	35	75
Agro-AWS	200	530
Automatic Snow Gauge	0	59
Radio Sonde - Upper Air Observation Stations	56	56
GPS based PB stations	23	62
RVR systems at Airports	137	182
Digital Current Weather Systems at Airports	107	125
Aviation Weather Observing Systems (AWOS)	0	18
Heliport Weather Observing Systems (HAWOS)	6	10
Microwave Radiometers	0	5
Wind Profilers	0	9
Rainfall Monitoring Stations	5896	7000

Components

- Surface observations
- Upper-air observations
- Marine observations
- Aircraft-based observations
- Satellite observations
- Weather Radar observations

- Surface observatories: 206 (Departmental) +320 (non-departmental)
- Skyradiometer (12) Glaciological observatories (37)
- Evaporation stations (222) Radiation (45) Ozone stations (10)
- International Voluntary Observing Fleet: (203)
- Aeronautical (71)
- Agro-meteorological (223) Agro-AWS(200)
- Buoys: 20 Satellites - INSAT-3D, 3DR

Information and Communication Technology



Seamless Operational Forecasting Based on Dynamical Modeling Systems

Nowcast (Forecast up-to next 12 hours) to Short Range (Forecast up-to next 3 days): Regional Models

- High resolution Rapid Refresh (HRRR-2km, hourly update) – for 12 hrs for all severe weather
- Electric – WRF (E-WRF-3km, twice a day update) - for 6 hrs

- Weather Research and Forecasting (WRF-3km, updated four times a day) - for 3 days
- Regional Unified model (NCUMR ~4km, updated twice a day) - for 3 days
- NEPS-Regional (12 member, 4km, once a day update) – for 3 days
- Weather Research and Forecasting (WRF-400m, updated once in a day) - For Delhi Air pollution– for a day

Medium Range Models (Forecast up-to next 10 days) :
Global Atmospheric Models and Regional/ Global Ensemble Models

- IMD-Global Forecast System (~12 km) - Updated 4 times a day
- NCUM-G (~12 km) - updated twice a day
- Global Ensemble Forecast System (21 member~12 km) –twice a day update
- NEPS-Global (22 member~12km, twice a day update)

Extended Range Models (Forecast up-to next 28 days) : Atmosphere-Ocean Coupled Models -

- Climate Forecast System (CFS) Extended Range (~38 km); 16 ensemble members; Updated twice a week
- NCMRWF modelling system (60~km); 16 ensemble members; Updated twice a week

Seasonal Forecast Models (Forecast for Monthly and Seasonal average) : Atmosphere-Ocean Coupled Models -

- Climate Forecast System (CFS) Extended Range (~38 km); 20 ensemble members for 9 months – Updated Monthly

Cyclone Forecast Models

- Hurricane WRF (HWRF) –HYCOM ocean coupled Model Triple nest (2x6x18km)

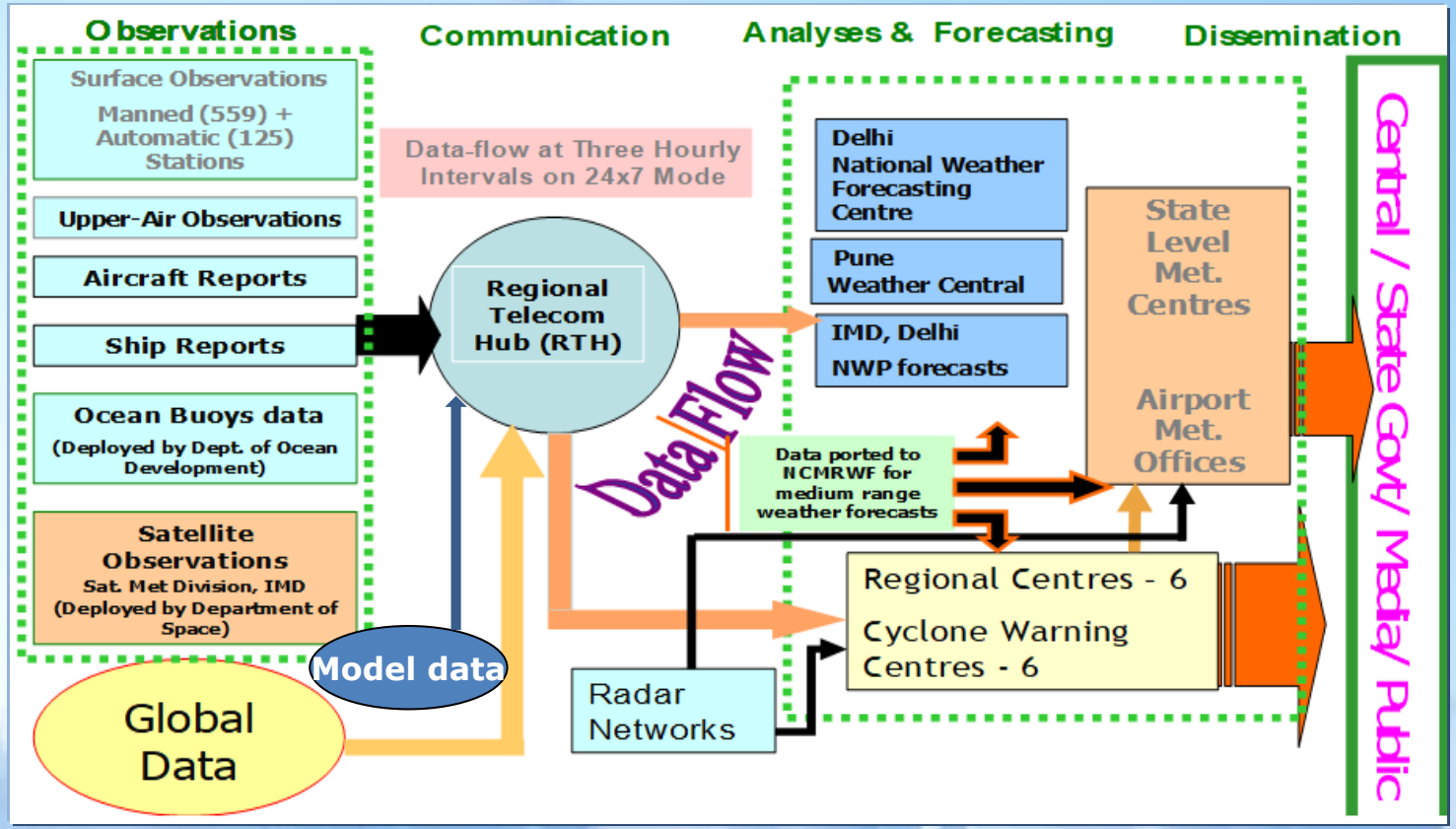
Supported by global observations and High Performance Computers (~10 petaFLOPS)

Warning Dissemination system

- **Telephone, Tele-fax, Mobile Phones (SMS) through IMD severe weather network, Agromet Network, INCOIS network.**
- **VHF/HFRT/Police Wireless, Aeronautical Fixed Terminal Network**
- **Global telecommunication system (GTS) :**
- **NAVTEX , Internet (e-mail), ftp**
- **Mass Media: : Radio/TV, News Paper network (AM, FM, Community Radio, Private TV) : Prasar Bharati and private broadcasters, Websites, Dedicated websites and web pages, Social media, Weekly and daily Weather Video**

- Social Media and Mobile Apps
- IMD Apps: Mausam/ Meghdoot/DAMIN/RAIN ALARM, UMANG
- Social Media: Facebook, Twitter, Instagram, BLOG
- Twitter: https://twitter.com/Indiametdept
- Facebook::https://www.facebook.com/India.Meteorological.Department/
- Blog: https://imdweather1875.wordpress.com/
- Instagram:https://www.instagram.com/mausam_nwfc
- Youtube:https://www.youtube.com/channel/UC_qxTReoq07UVARm87CuyQw
- IMD APIs

Frame Work for the Early Warning System

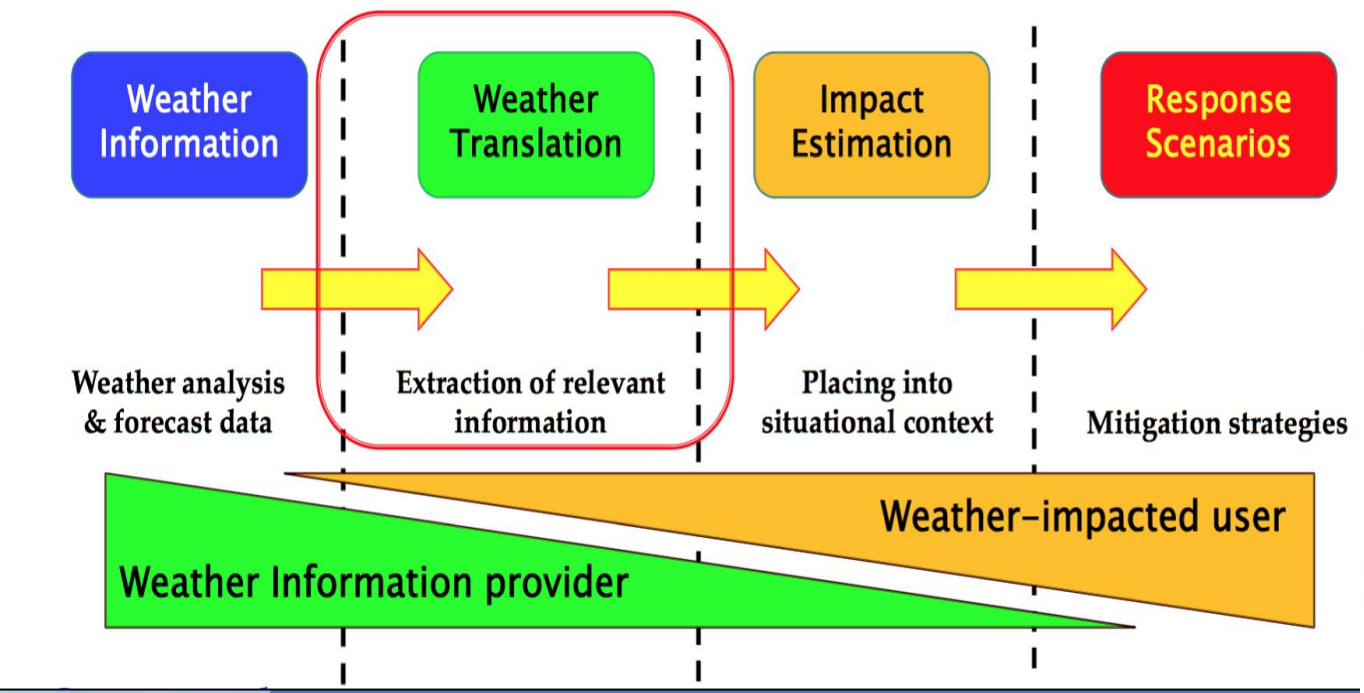


Warning Dissemination Systems

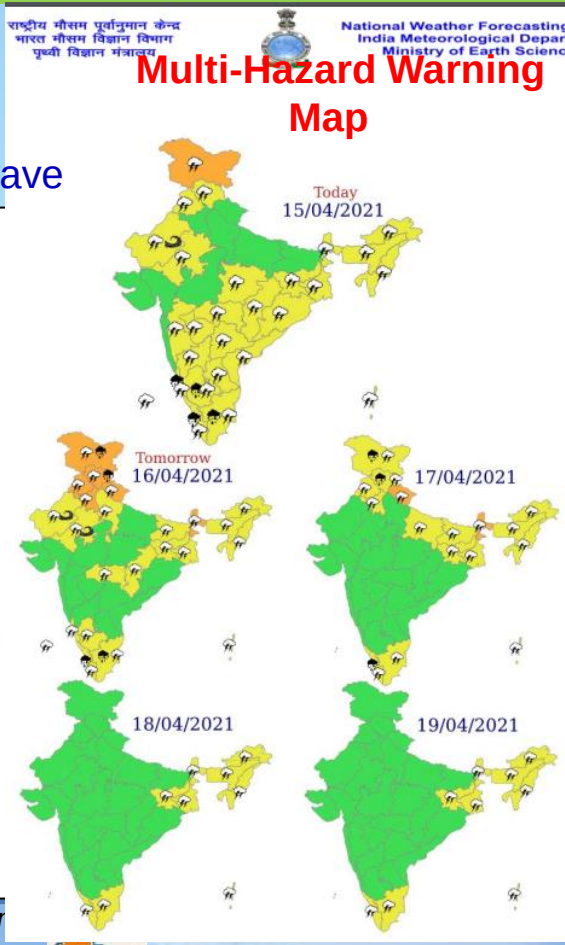
Radio/TV, News Paper, Public Website, Mobile Apps , Facebook , Twitter, Instagram, BLOG, Youtube, Telephone, Tele-fax, Mobile Phones , VHF/HFRT/Police Wireless, Aeronautical Fixed Terminal Network,GTS, NAVTEX , Internet (e-mail), Weekly and daily Weather Video

Impact-based Forecasting in India

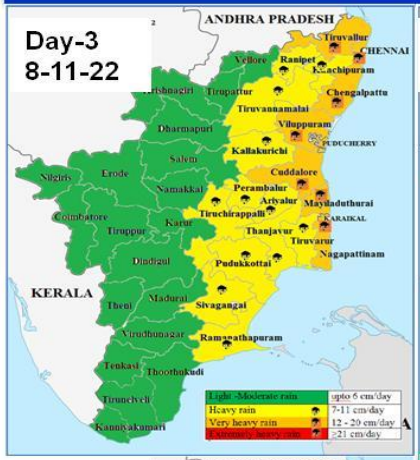
- Relevant information from weather forecast is extracted and placed into situation context to produce impact estimations;
- With potential impact information, response scenarios are set-up
- Targeted Hazards: Cyclone, Heavy rain/flood, Thunderstorm, Heat/cold wave

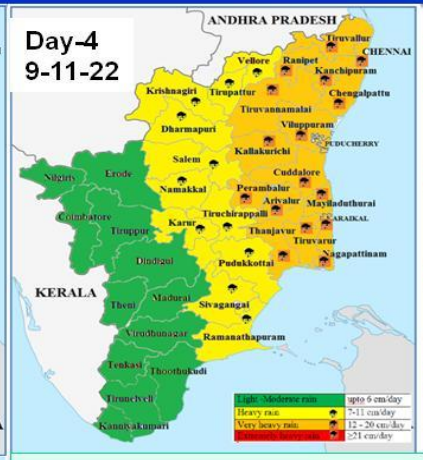


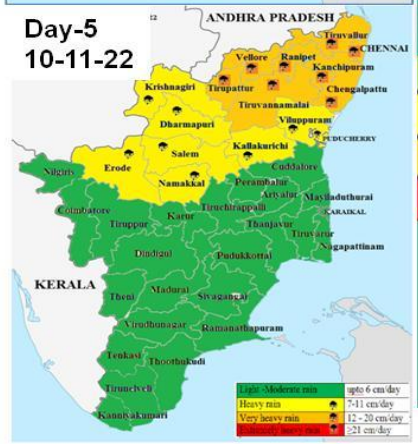
Source: Baode Chen and Xu Tang (2014) Translating weather forecasts into impact-relevant information



Impact Based Forecast – District Level Heavy Rainfall







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.**

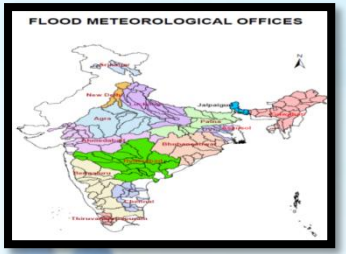
Impact	Action
Very Low	No action
Low	Be updated
Medium	Be prepared
High	Take Action

Impact based district level Heavy rainfall warning for Tamil Nadu, Puducherry and adjoining South Coastal Andhra Pradesh: Severe Cyclonic Mandous (6-10 Dec 2022)

- ✓ Major damage to kutcha & pucca roads
- ✓ Flooding of escape routes
- ✓ Inundation/localized flooding in low lying areas due to heavy rains
- ✓ Poor visibility leading to disruption of traffic due to heavy rains

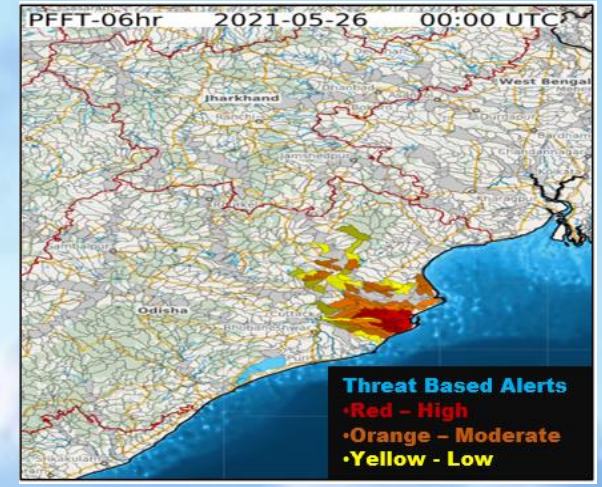
Hydromet Services of IMD for Flood Forecasting

Riverine Flood Forecasting (Quantitative Precipitation Forecast)



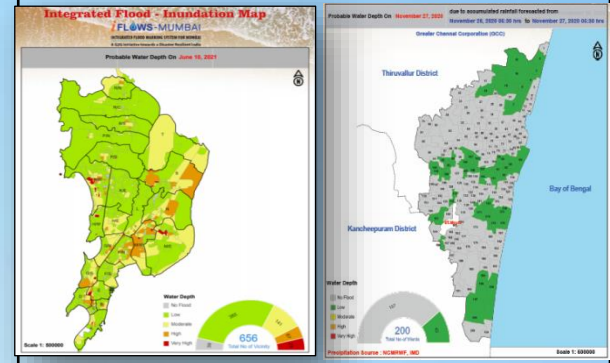
- **Hydromet services through 15 Flood Met. Offices for 153 river sub basins.**
- **Sub-basin-wise Quantitative Precipitation Forecast: and Heavy rainfall warnings upto 5 days**

South Asia Flash Flood Guidance System (SAsiaFFGS)



- **First of its kind in South Asia (Bangladesh, Bhutan, India, Nepal, Sri Lanka).**
- **High resolution (4X4 km) and 30000 watersheds over Indian region.**
- **Capable of issuing flash flood Threat and risk for next 6 and 24 hours respectively.**

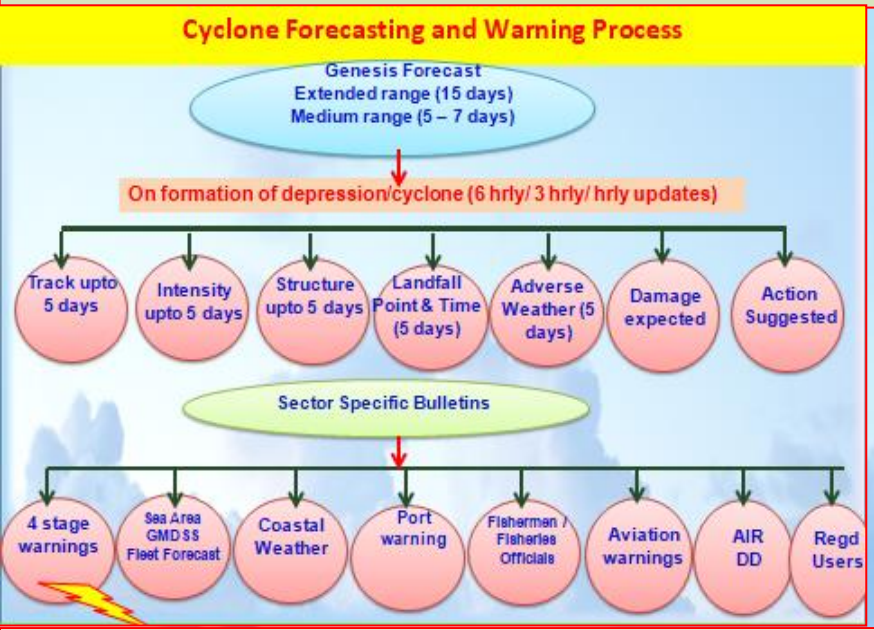
City Specific Flood Forecast (Integrated Flood Warning System)

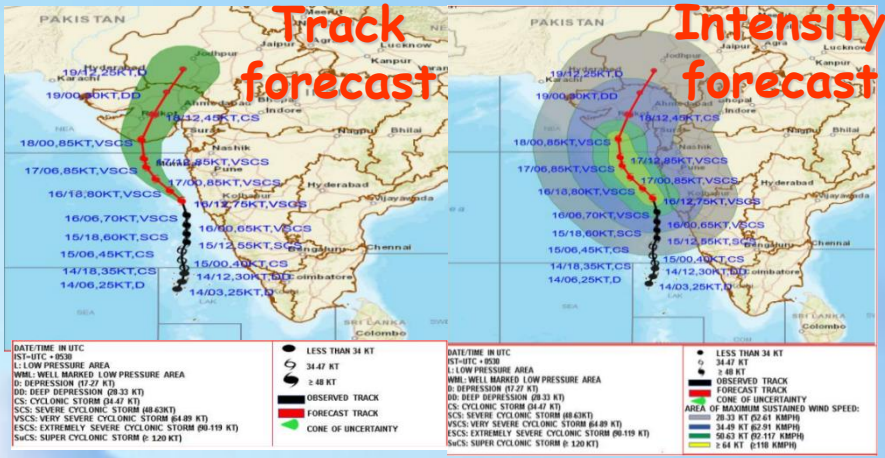


Code	Water Depth (feet)
	No flood
	3-4
	4-5
	5-6
	>6

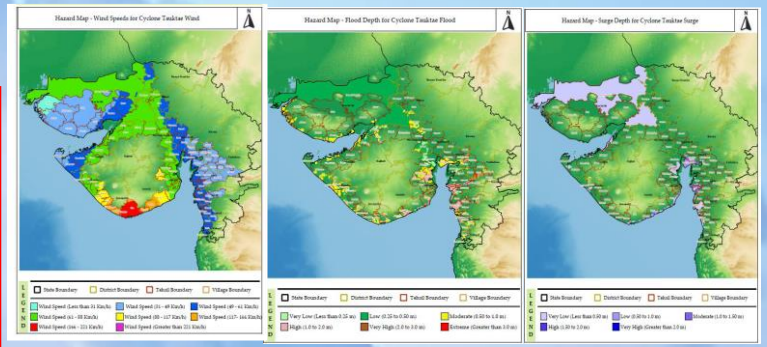
- **Implemented at Mumbai and Chennai Cities.**
- **Ward-wise probable water depth/inundation.**

Cyclone Monitoring and Forecasting Process of IMD





Impact based forecast of cyclone



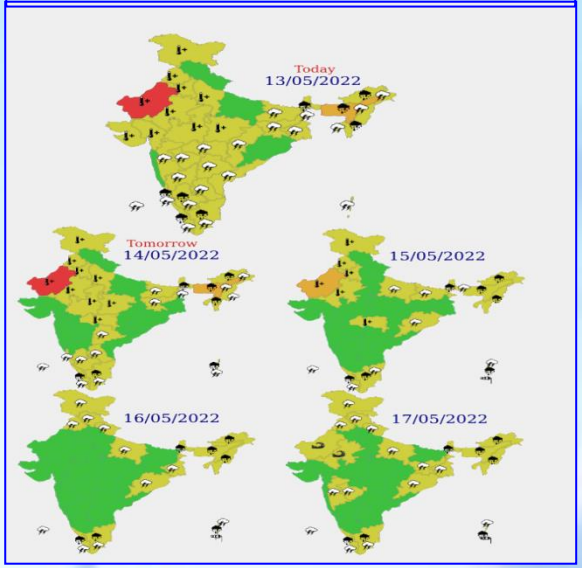
- **Pre-cyclone watch (Yellow)** –72 hours in advance.
- **Cyclone Alert (Orange)**- 48 hrs in advance.
- **Cyclone warning (Red)** – Issued at least 24 hrs in advance indicating latest position of Tropical Cyclone, intensity, time and point of landfall, storm surge height, type of damages expected and actions suggested.
- **Post-Landfall Outlook**- Issued about 12 hrs before landfall & till cyclone force winds prevail; District Collectors of interior districts besides the coastal areas are also informed.

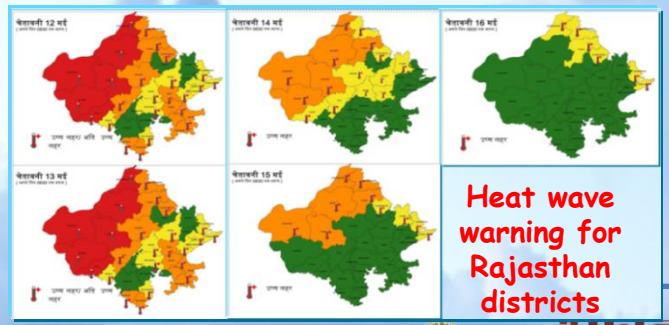
विभाग
EPARTMENT

Heat Wave warning

- Seasonal and extended range (upto two weeks) outlook
- District level heat/cold wave warning (upto five days)
- Heat action plan with different states and cities
- Daily bulletins two times (0830 & 1600 hours IST)
- Warnings issued to different users (through **e-mail, CAP, whatsApp, facebook, twitter, press release etc.)** like, MHA, NDMA, SDMA, CS of states, DC/DM of different districts of states, health department, Indian Railway, Road transport, Media etc.

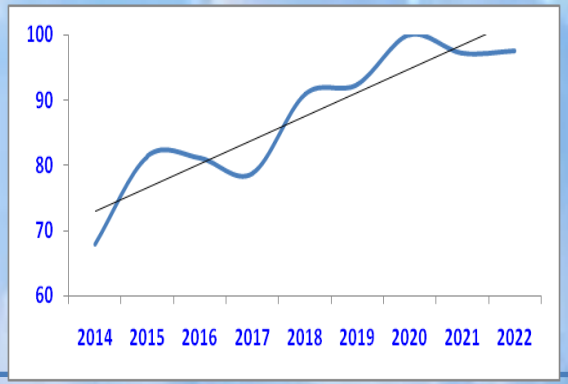
Impact based Heat Wave warning for next 5 days (Example)



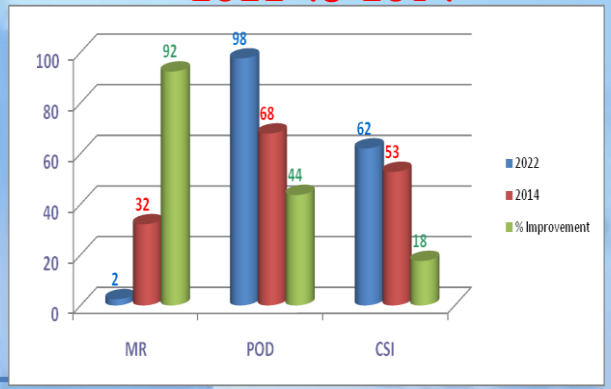


Heat wave warning for Rajasthan districts

Heat Wave warning Skill : Probability of Detection (PoD)



Heat wave warning skill 2022 vs 2014



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Urban Meteorological Services

Setting up High Density Meso-network and high resolution Modeling framework for major cities for Early Weather and Air pollution Monitoring/Forecast

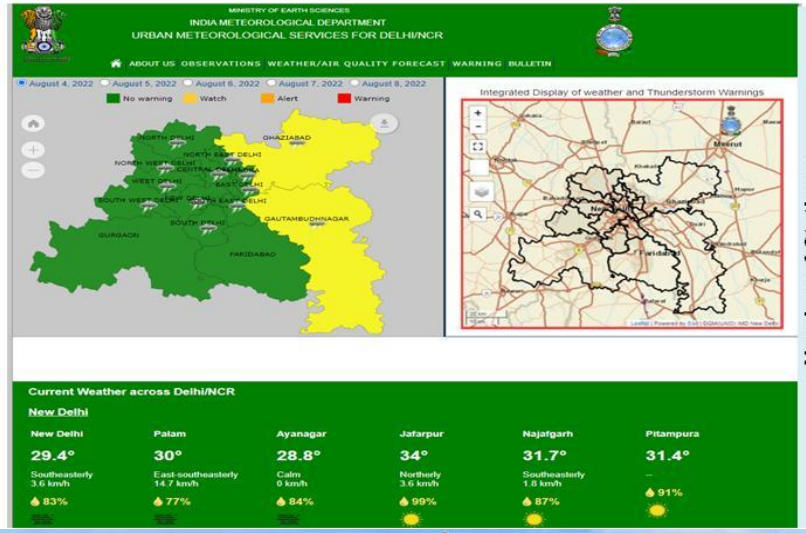
1) Current Weather Observations
2) Current Air quality Observations
3) Radar, Lightning and Satellite data
4) Weather warning of District/stations
5) Nowcasting (District/stations)
6) Daily Bulletin

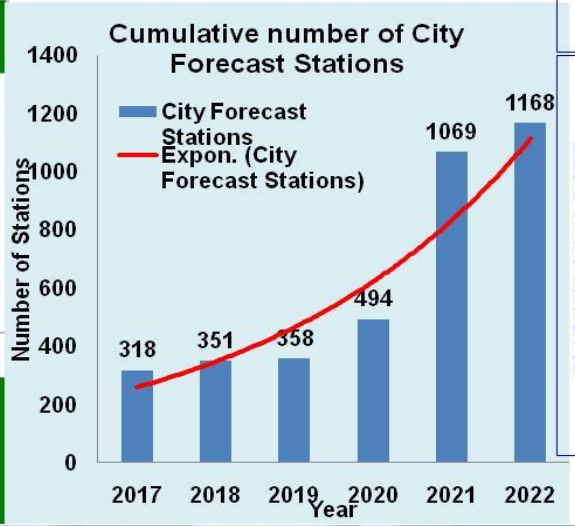
Augmentation:

Commissioning of 5X-Band DWRs and 200AWS/ ARGs in major cities for development of Urban Meteorological Services

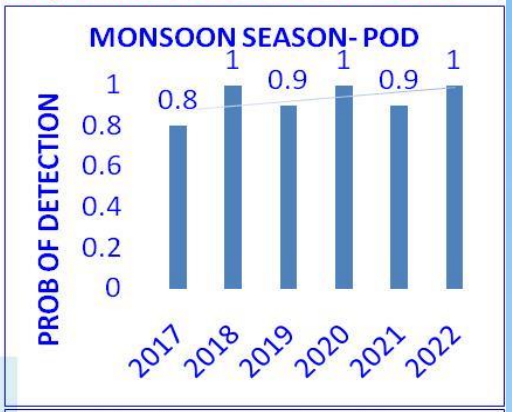
Future Plan:

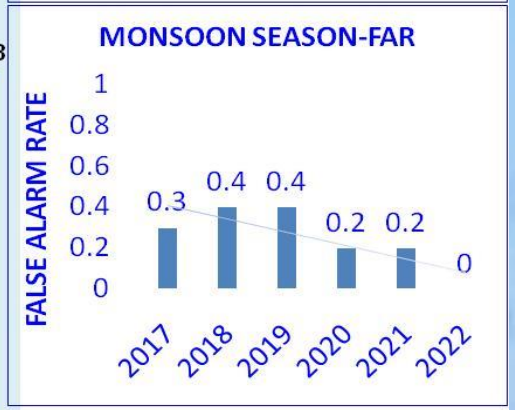
More than 100 Smart Cities



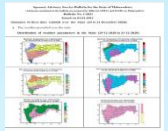


City forecast skill over Delhi





Agrometeorological Advisory Services (AAS) to Farmers



Composite State Level Bulletin

Composite National Bulletin

Biweekly (Tuesday & Friday) Weather based Farm Advisory for all districts and ~3100 blocks in English & Regional languages

Weather Forecast Model

Medium range Weather Forecast

Forecast

Rainfall, Temperature, Wind, Humidity, Cloud cover

State Met Centre

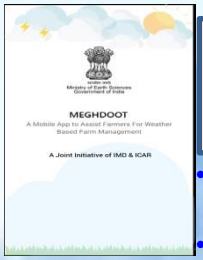
Stakeholders' Awareness

Value added forecast at district / Block level for 5 days

Agromet Field Units/ District Agromet Units

Special Weather Advisory during extreme events

Multi-Channel Dissemination

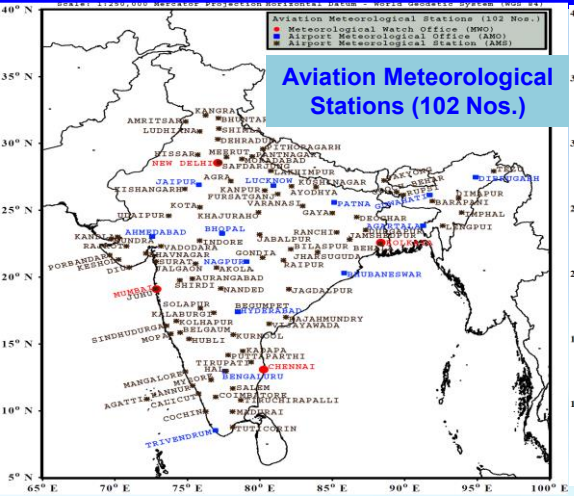


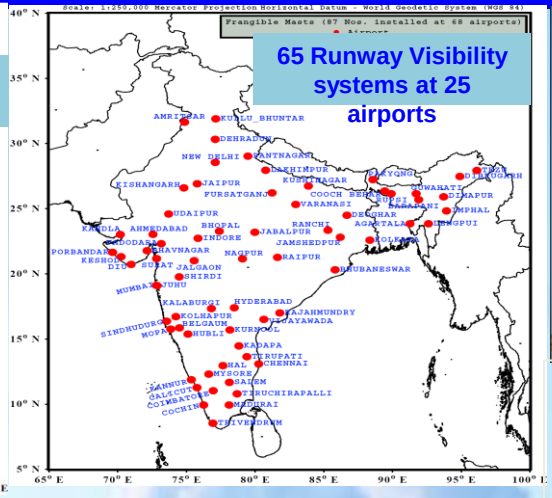
Radio, TV, Press, KVKs, State Extension mechanism, Public-Private Partners (IKSL & Reliance Foundation), Mobile text message, Mobile Apps, Social media

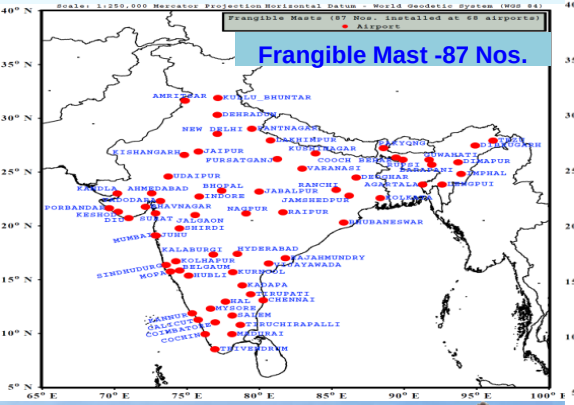
- Farmer Awareness Program (FAP)
- Training programmes
- Dynamic & End of Season Feedback mechanism

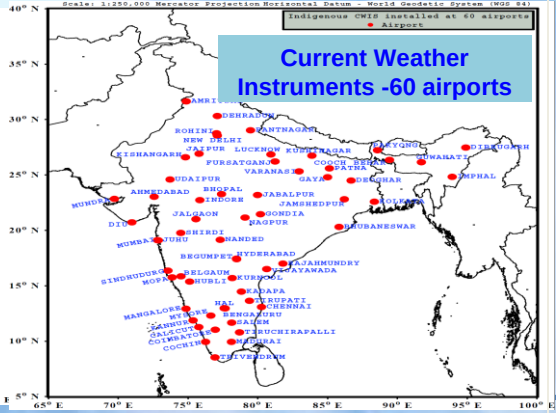
- Economic benefits from savings in farm inputs.
- Increased farm productivity and food security.

Aviation Meteorological Services









Future Plans

- 10Heliport-Aviation Weather Observing System
- Automated Weather Observing Systems (AWOS) in 18 major airports
- Digital Current Weather Instrument System (DCWIS) on frangible Mast: Overall, 96 DCWIS will be installed at 74 Airports. As on date, 87 frangible masts have been installed at 67 airports
- RVR systems:As on date, IMD has installed RVR systems at 32 airports
- Wind Profilers: 7 Wind Profilers at NE India airports.

Climate Services Provided by IMD

IMD is the nodal Government agency responsible for providing operational weather and climate services required for the country. IMD provides the following Climate Services through the Office of Climate Research and Services (CR&S), Pune.

- **Climate Monitoring and Analysis**
  - Monitoring or rainfall and temperature, Climate Diagnostic Bulletins - monthly, seasonal, & annual , Annual Climate statement of the country, Monsoon Reports, ENSO & IOD
- **Climate Prediction**
  - Seasonal and Extended Range forecasts, MJO, MISO, ENSO, IOD etc,
  - ENSO & IOD Monthly bulletin
- **Climate Data Management**
  - Climate Data Centre: Online data reception, quality check, archival, data rescue, Gridded data, Climatology data products
- **Climate Applications**
  - Agriculture Sector: drought monitoring based on Aridity anomaly and SPI maps, Agromet Advisory Services
  - Water Sector: Rainfall products at different spatial scales like district, subdivision, state, country, river basins, and temporal scale like daily/ weekly/ monthly etc.
  - Health sector: Heat action plan, heat index maps and identifying meteorological windows for diseases
- **Climate Research & Training**
  - Research in climate variability, climate change, climate prediciton etc.
  - WMO RMTC – Training and capacity building in general meteorology, climate science, climate services for participants from IMD and other national and international agencies.

Achievements

- Overall improvement in the Early Warning System for extreme weather and climate events
- Improved Observational Network (Surface, Upper Air, Remote Sensing, Oceanic)
- Implementation of Seamless Forecasting System based on dynamical models (Nowcast, short ,medium , extended and seasonal forecasts)
- Use of Multi model forecasting method for generating operational forecasts
- Weather forecast is issued for 721 districts and 6818 blocks, city forecast for 1184 stations, and nowcast for the 721 districts and 1166 stations.
- Introduced location specific Impact based forecast
- Tailor made warnings and advisories for various weather and climate sensitive sectors like water, health, environment, transport, energy, agriculture, disaster management etc.
- Use of latest technology for dissemination of weather and climate information – CAP, Mobile applications, social platforms (like twitter, face book, whatsapp, instagram, yutube etc.), website, email, print and electronic media etc.

Achievements

- Significant improvement in the forecast accuracy of various extreme weather events like cyclones, heavy rainfall, heat and cold waves, lightening, floods etc. leading to significant reduction in the loss of life and property.
- Improvement in the skill of monsoon rainfall forecasting at various time and spatial scales
- Services to international community as WMO recognized Centers such as RSMC for Tropical Cyclones and Severe weather, RSMC for Flash flood guidance, Regional Climate Centre (RCC), Pune for South Asia, Regional Meteorological Training Centre, and GPC for Long Range Forecasting
- Implemented E-office, an electronic way of file processing was launched across all offices of IMD on 01.01.2021
- Replaced all Mercury Barometers with Digital Barometers in accordance with the UNEP Minamata convention (as mercury is hazardous to human health)
- In house development of Climate Data Service Portal for data services
- Provides flash flood guidance for >30,000 watersheds in India and South Asian countries of Nepal, Bhutan, Bangladesh and Sri Lanka on a daily basis.
- Actively supports various activities of WMO

Future Plans

- Use of latest technologies in all components of early warning system.
- Expansion of AWS and ARG station networks so as to have at least one AWS in each Block and one Agro-AWS in each District of India.
- Development of Urban Meteorological Services through commissioning of X-Band (50 KM) DWRs and AWS/ARGs in major urban centres.
- Conventional mercury and alcohol type sensors in Stevenson's screen will be replaced by electronic sensors for observations, preparation of synop messages and auto transmission to end users with a concept of Smart Observatory.
- Implement observation network based on data renting policy wherever possible.
- Major upgradation of Meteorological facilities at all airports through commissioning of State-of-art Integrated Aviation Weather Observing Systems (AWOS), Heliport Weather Observing & Transmitting System (HAWOS), Microwave Radiometers, Doppler LIDARs, Wind Profilers etc. to support Aeronautical MET Services.

Future Plans

- Implementation of National Framework for Climate Services
- Development of New RAPID online visualisation & Analysis tool after integration of All satellite products, RADAR Data, NWP data and Synoptic data with mobile compatibility.
- Development of web based analysis tools for weather forecasting.
- In house development of tools for robust decision support system (DSS) for various sectors.
- Use of AI/ ML for weather and climate forecasting.
- Automatic generation of Bulletins including text, graphics
- Automatic generation of audio, video warnings
- Automatic dissemination system for respective users.
- Multiple reliable dissemination means including multilingual audio, video, audio-visual (2D, 3D, 4D), text, graphics, text-cum graphics through email, fax, alarm, website in GIS enabled platform, API, Mobile App, RSS feed, social media, OGC web services etc.
- Cyber Security Management Tool for IMD like SIEM and SOC to prevent cyber attacks.

Challenges

- Regular modernization/ up gradation of services in terms of man power, infrastructure, capacity building and government funding - Sustainability of met services
- The demand for sector specific weather and climate forecast information is growing rapidly. However, this need engagement with other stakeholders in a multi-sector enterprise that will serve better the society and will better use available resources.
- Prediction of extreme events is already a challenge. With increasing trends in the frequency and intensity of extreme events associated with the warming climate, and exacerbation of its impact due to changes in the land use land cover, increasing populations etc., the problem is becoming more challenging.
- Need for newer technology for improving observation network, HPCS for higher resolution models and the dissemination of warnings and advisories to large number of last mile users in time (which is very costly affair)
- NMSs have technical skills often unfamiliar to users. (Lack of continuous interaction with users)
- Legal responsibility issues often unclear when weather/climate information is disseminated
- Entry of private companies/ additional players in the met. Services. (diverging information emerging from multiple sources creates confusion among the users and impact the credibility of met services).


भारत मौसम विज्ञान विभाग
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Thank you