Meteorological Services for Socio-Economic Development

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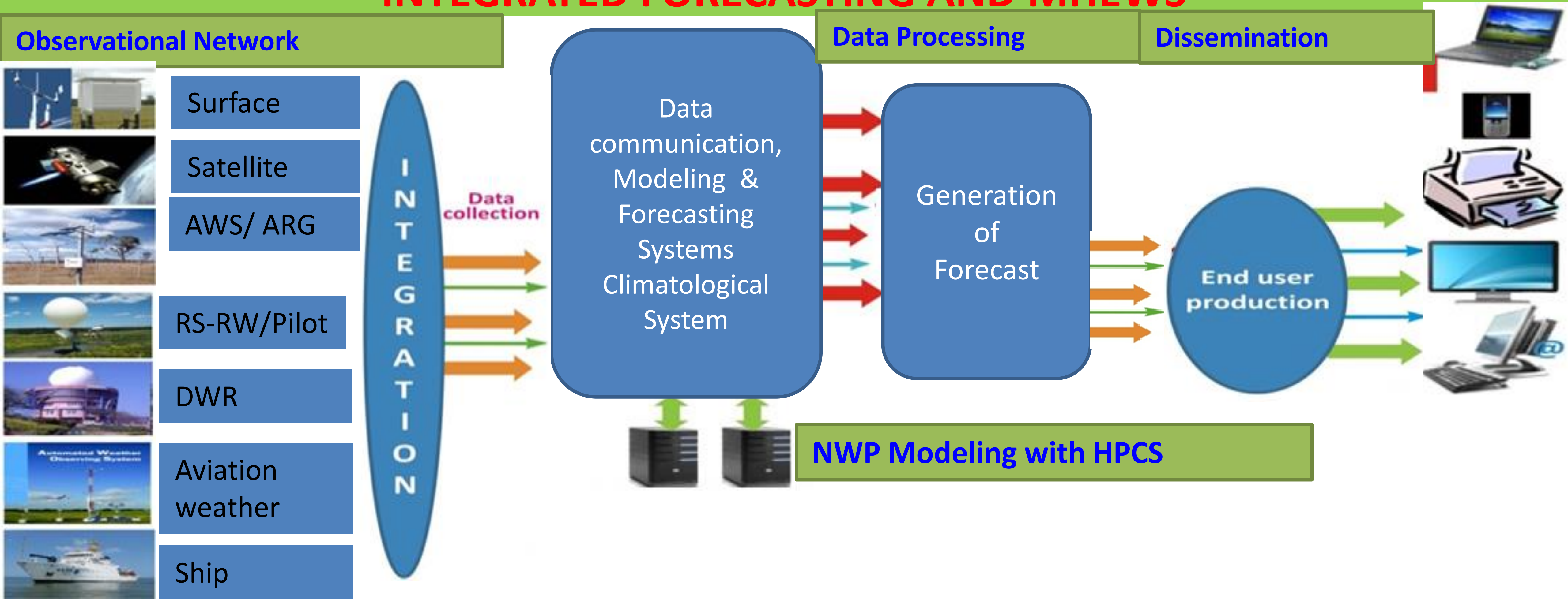
SEAMLES WEATHER AND CLIMATE FORECASTING SYSTEM

- IMD has a seamless forecasting strategy. IMD issues forecasts and warnings on different time scales and for different spatial scales:
  - Now casting- up to six hours for all types of severe weather at all districts and 1085 stations
  - Short to medium range (up to 10 days) forecasts for rainfall over cities, Blocks, districts and meteorological subdivisions
  - Extended range (up to 4 weeks) forecasts for All India, homogenous regions and meteorological sub-divisions
  - Seasonal Forecasts (one season in advance) for All India and homogenous regions and Monsoon Core Zone.

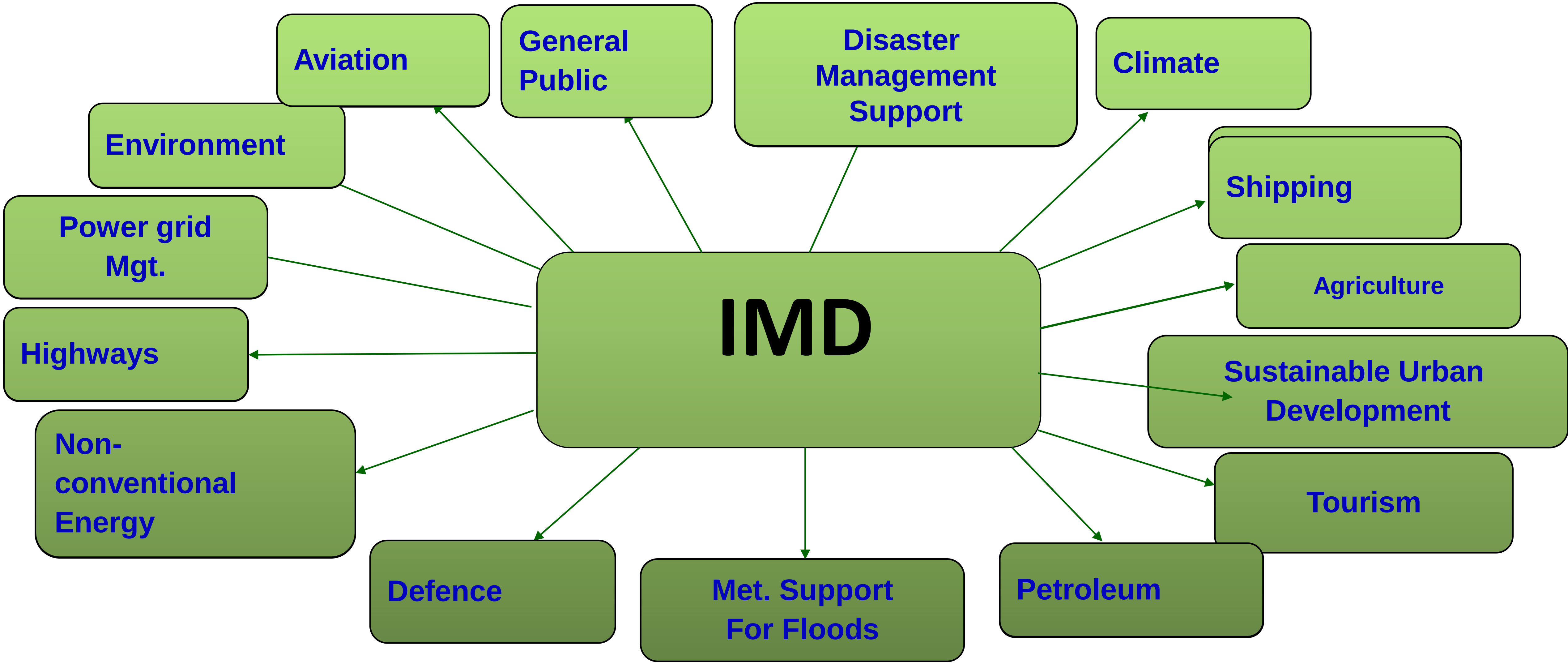
INTEGRATED FORECASTING AND MHEWS



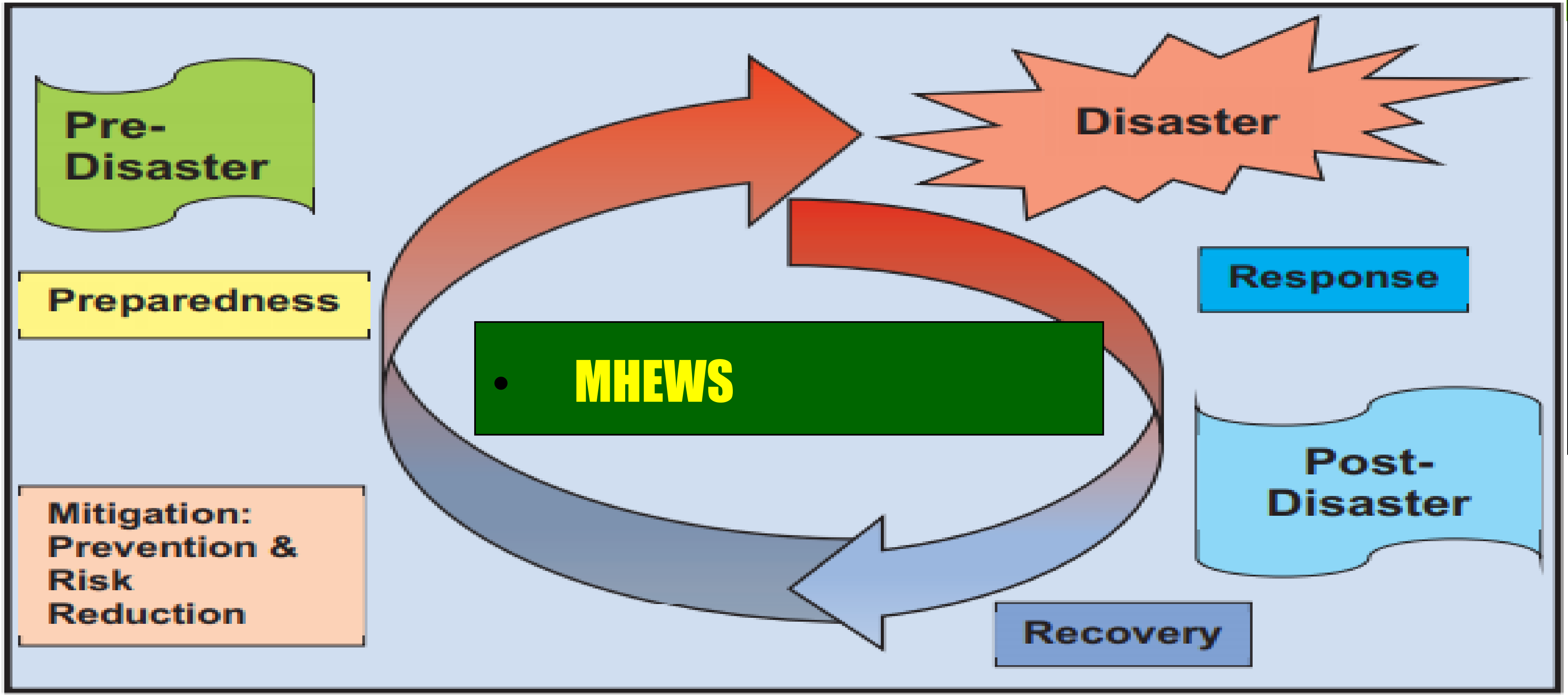
- An Array of numerical Weather Prediction (NWP) models & High performance Computing System in India for **Seamless Forecast** from a few hrs(nowcast) to short to medium range forecast (upto seven days), extended range forecast (upto 4 weeks) and seasonal forecast
- **Impact based forecast and early warning** upto five days (120 hrs) for all types of severe weather

Improvement in Economy through minimizing risk to sectors

Improvement in Economy through minimizing risk to sectors through early warning as per Demand



Disaster Risk Reduction



- **National Policy**
- **National DM Act**
- **National DM Plans**
- **National Guidelines**
- **Institutional mechanism**

- MHEWS plays a dominant role during, before and after the disasters in all phases of preparedness, prevention and risk reduction
- India is **self reliant with respect to weather and climate services** in terms of contribution to economy, development of system and infrastructure, socio-economic applications and disaster risk reduction
- In terms of forecast accuracy and service delivery, **it is at par with leading centres**
- **National Policy/plans/guidelines** are in place to enable response actions so as to reduce risk

Multihazard early warning system (MHEWS) and disaster resilience: Needs

- **MHEWS: Early warning and early action**
- **Impact based forecasting**
- **Risk knowledge**
- **Realtime risk assessment for each infrastructure vis-à-vis each natural hazard**
- **Critical infrastructure (hospitals, cyclone shelters, roads, rails, communication network, power & water supply)**
- **Ensure resilience to critical infrastructure**

Early Warning for All Initiative of UN-WMO and Role of India

Four components of an early warning system

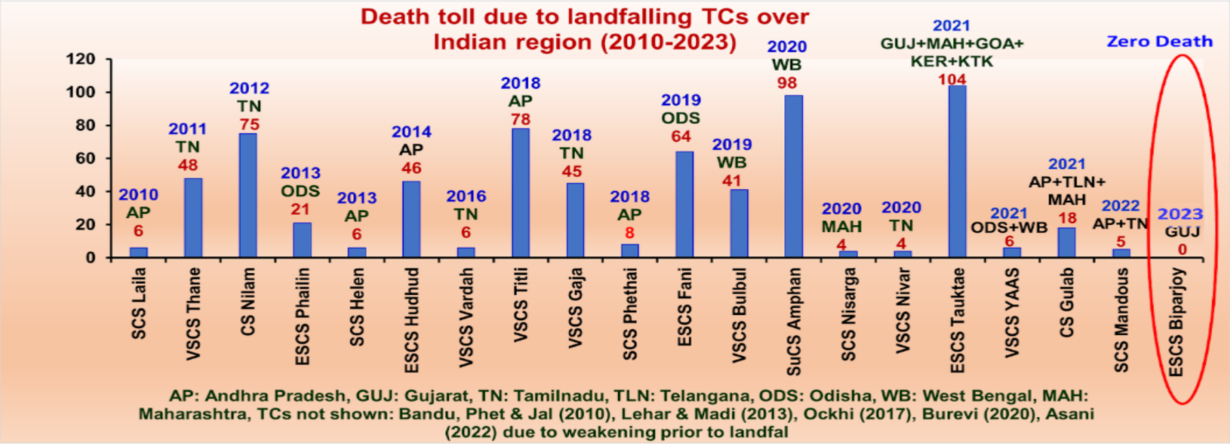
- **Improvement in Value Chain(weather Observation→Modeling→ Forecasting → Severe weather warning→Sectoral Applications) including R&D and technology intervention.**
- **An Array of numerical Weather Prediction (NWP) models & High performance Computing System in India for Seamless Forecast from a few hrs(nowcast) to short to medium range forecast (upto seven days), extended range forecast (upto 4 weeks) and seasonal forecast**
- **Impact based forecast and early warning upto five days (120 hrs) for all types of severe weather**

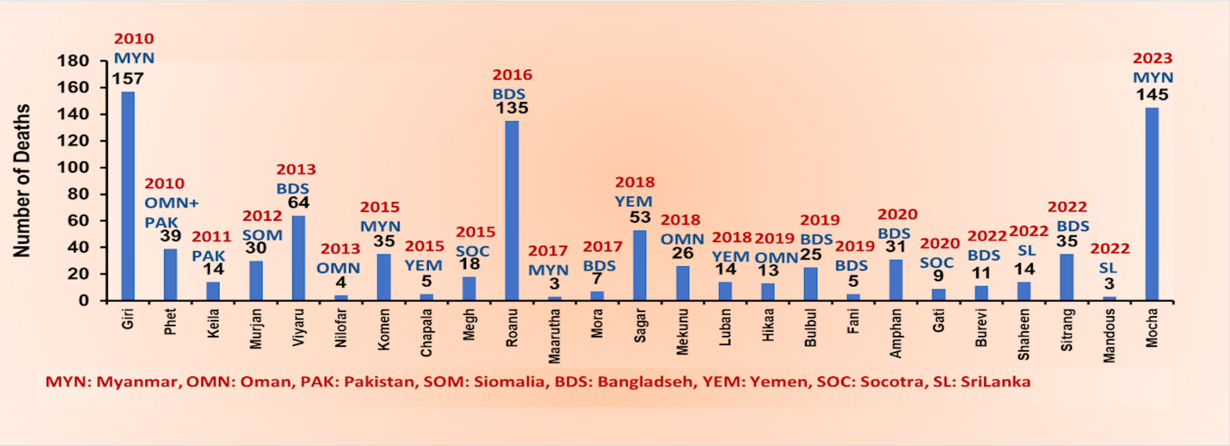
ACHIEVEMENT IN WEATHER & CLIMATE SERVICES

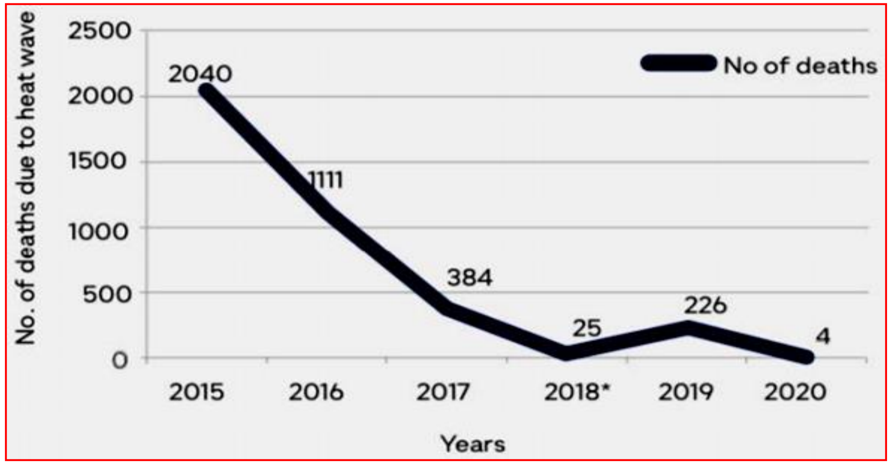
- **Introduction and expansion of seamless forecast from seasonal to nowcast**
- **Improvement in lead period of forecast from 1 day in 2006 to 3 days in 2009, 5 days in 2013 and 7 days in 2023**
- **Noticeable improvements achieved in Skills of Heavy Rainfall Forecast, lead time of warnings also increased in respect of Rainfall, heat wave, cold wave, thunderstorms, fog etc.**
- **Reduction in forecast error and improvement in forecast accuracy by about 50% in recent decade (2014-2023) compared to previous decade for all severe weather events**
- **Pin point accuracy in forecasting landfall of cyclones commencing from Phailin (2013) to Biparjoy (2023) enabled reducing deaths and government expenditure.**
- **Minimisation of loss of lives(to double digits) due to cyclones, heat/ cold waves, heavy rain.**
- **Impact based forecast was provided for all types of severe weather including cyclone, heat wave, cold wave, fog, heavy rain, thunderstorm at 739 districts and 25 capital cities.**
- **Climate information for Health, Agriculture, Water and DRR.**
- **Climate Data Service Portal developed in-house and operationalized.**
- **New strategy for LRF of southwest monsoon rainfall based on MME approach implemented in 2021.**
- **Significant improvement in climate forecast accuracy and climate services/ applications.**

Excellence in Early Warning System and DRR

- **Improved accuracy** in last 10 years. 40 % improvement in forecast skill in 2018-22 compared to 2013-17
- **Improved confidence** of disaster managers/general Public
- Enabled disaster managers and public to minimize loos of lives and properties
- **Reduction in number of deaths** due to cyclones from 10,000 in 1999 to tens/twenties in recent decades in India and similar reduction in countries in north Indian Ocean
- **Brought laurels to the country** from international community

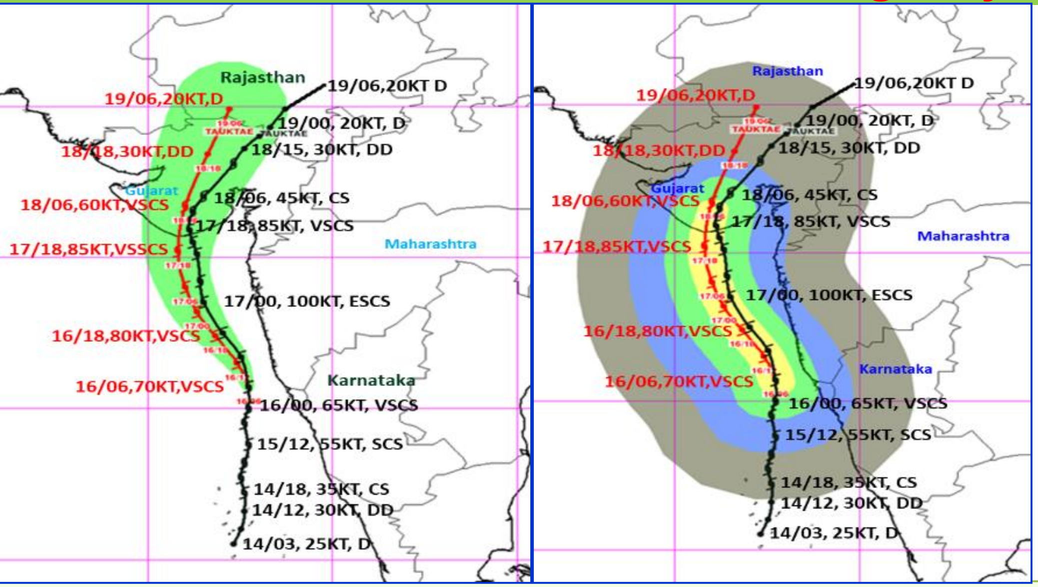






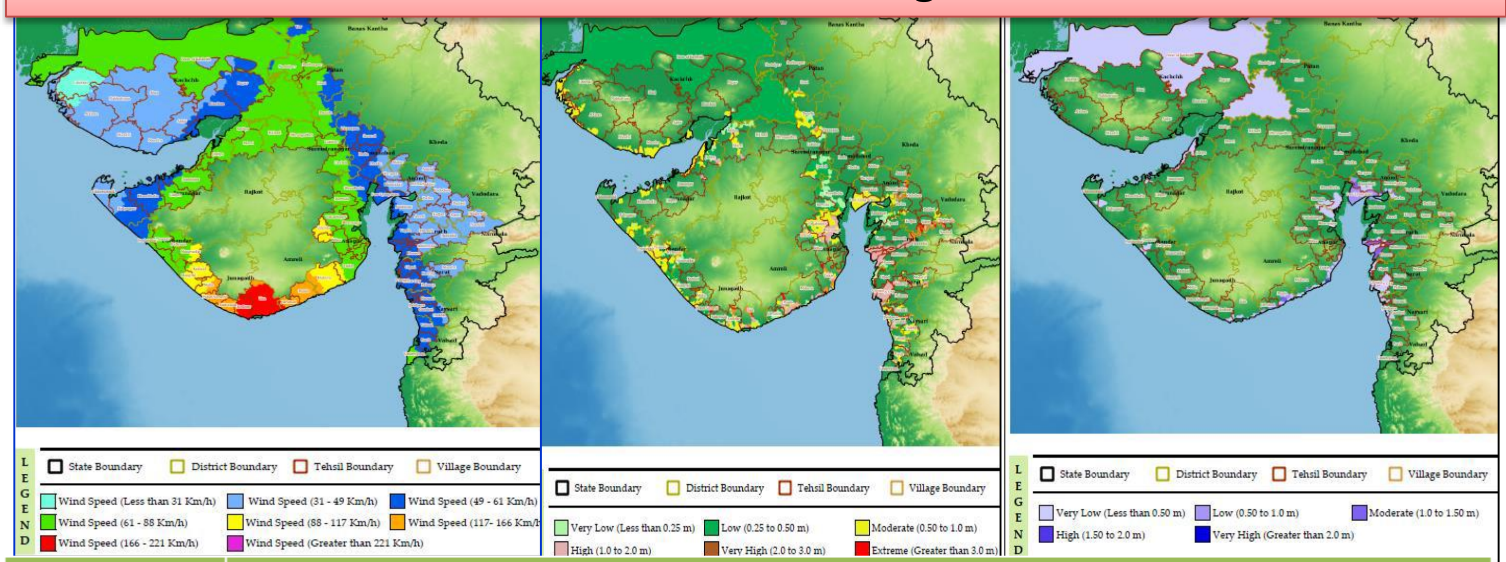
Reduction in number of deaths due to heat.
(Source: NDMA)

Dynamic impact based forecasting (IBF) of Cyclone Hazards, vulnerability and risk based warning: Cyclone Tauktae- May 2021 an example



Hazard, vulnerability and risk Analysis (Meteorological data over vulnerability and exposure data)

Flood **Wind** **Surge**



Damage Expected (Historical data)

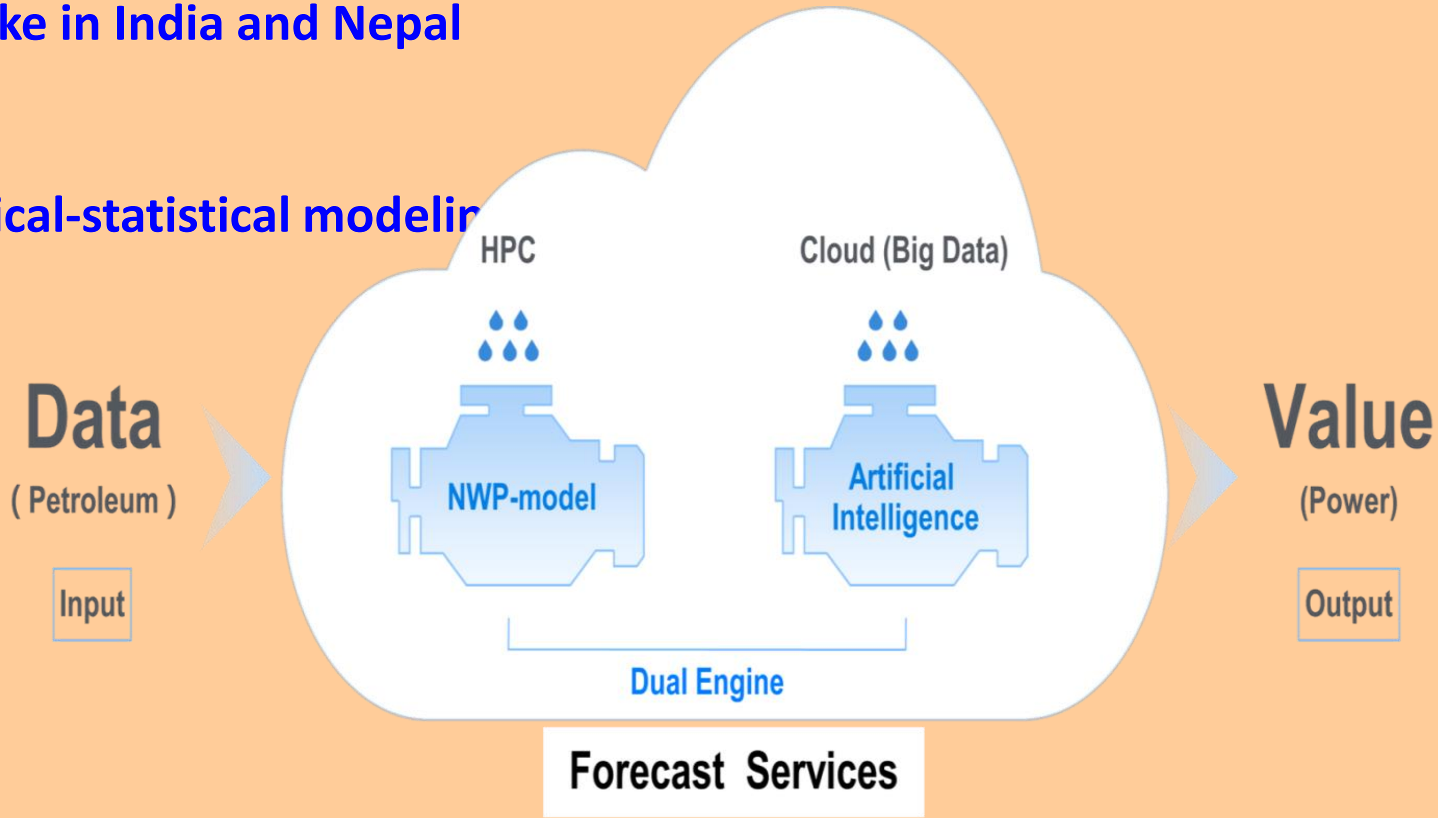
- Total destruction of thatched houses/ Extensive damage to kutcha houses/some damage to pucca houses.
- Threat from flying objects. Bending/uprooting of power/ communication poles.
- Major damage to roads. Escape routes flooding.
- Minor disruption of railways/overhead power lines/signaling systems.
- Widespread damage to salt pans/standing crops, bushy trees.
- Detachment of small boats, crafts.
- Visibility severely affected

Loss By Category	GUJARAT STATE				
Exposure Type	Exposure (INR Cr)	Wind Loss (INR Cr)	Flood Loss (INR Cr)	Surge Loss (INR Cr)	Combined Loss (INR Cr)
Agriculture	15,766.08	276,3.63	1.20	0.00	2,763.63
Building	5,48,125.92	854.70	19.42	110.71	862.06
Essential Facilities	26,647.94	16.07	2.51	9.87	19.03
Transport	3,76,787.99	15.77	1,127.47	40.83	1,128.32
Utilities	1,37,099.35	86.68	2.56	563.93	570.59

Future Needs for further improvement

- IBF is a nascent Science. It is peaking up. Huge scope to improve in collaborative approch with state/central agencies, public-private and stakeholder partnership
- Hazard, and Impact Modeling and Risk assessment

- **Scope for application of latest tech.**
  - Crowd sourcing of weather observations like in India and Nepal
  - Artificial Intelligence & machine learning
  - Digital forecasting through NWP & dynamical-statistical modelin
  - Dual engine approach
  - Digitisation of socio-economic attributes
  - Geo-spatial application
  - Last mile connectivity



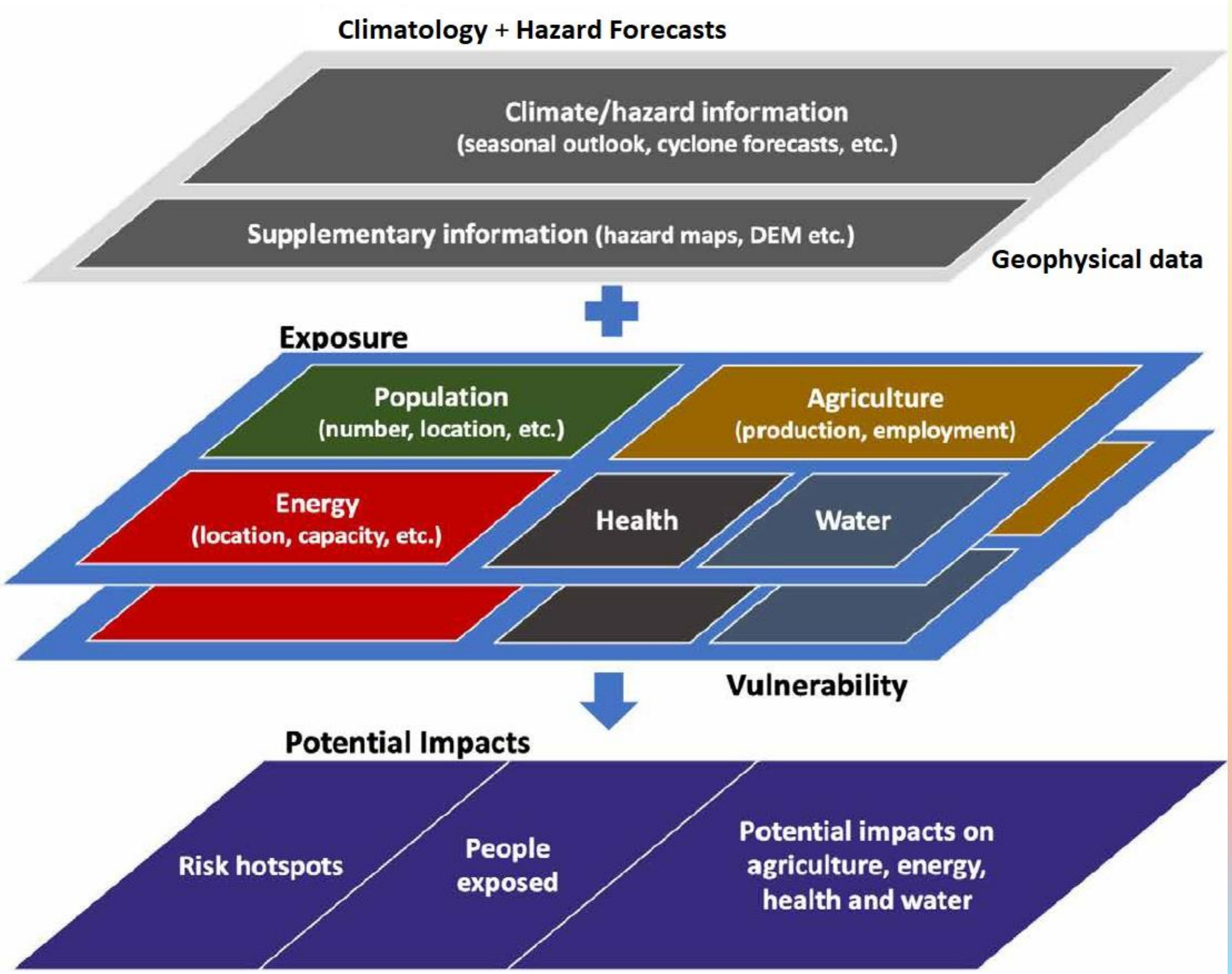
Vision - 2047

- No synoptic weather system should go undetected & unpredicted 20 days in advance, meso-scale/micro-scale weather 10 & 5 days in advance respectively.
- Development of skilful seasonal (2 weeks to 3 months) and sub-seasonal (3 months to 1 year) forecasts
- Sustainable development of weather warning services of to achieve zero death toll & zero loss to property through IBF and risk based warnings.
- Development of a weather forecasting system which can combat impact of climate change through accurate forecast, at desired spatio-temporal scales and implementation of various adaptation & mitigation measures
- India to emerge as a global leader in weather and climate forecast and services.

Strategy

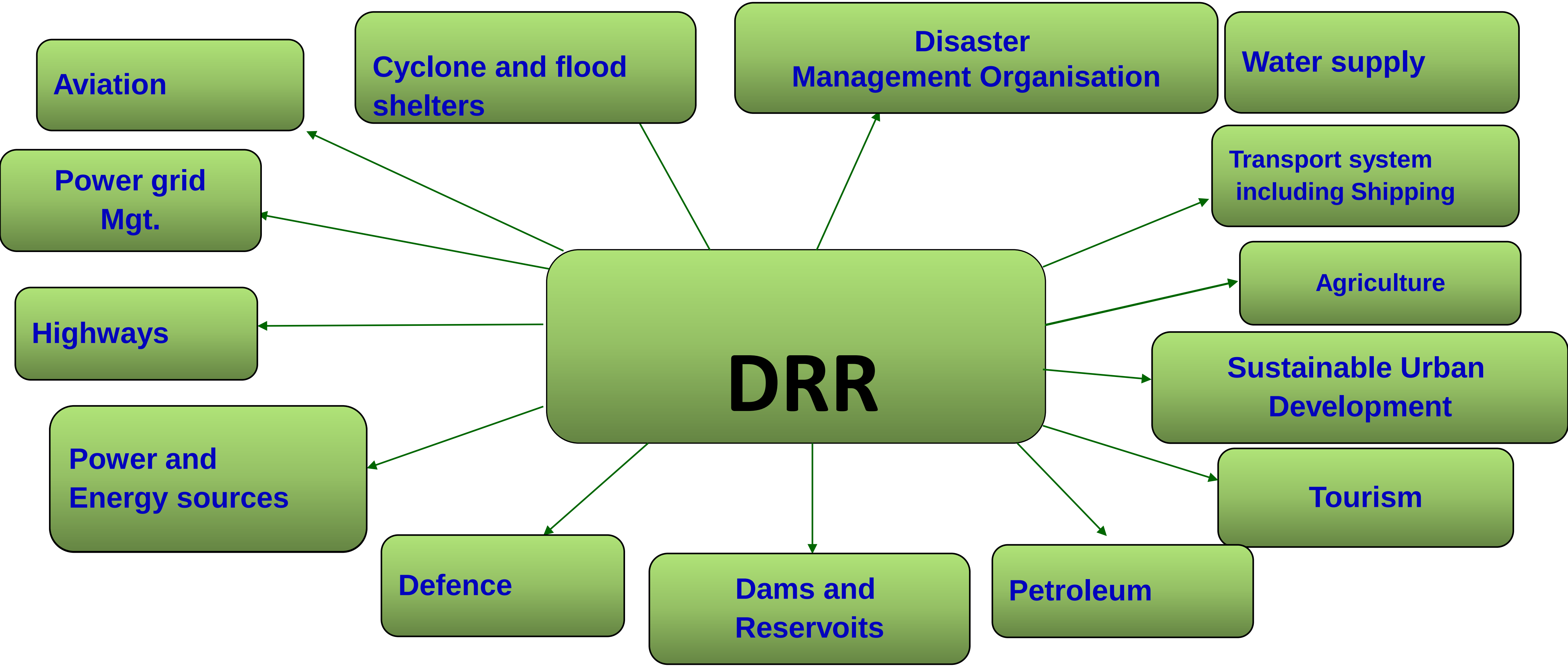
- **Improvement in observational network by 2047, so as to have AWS at each village, wind profiler & RS/RW at each block, Radar at each district, multiple scatterometer for 3-D temperature, humidity, wind profile every 25 km over BoB & AS every three hours.**
- **Development and deployment of low-cost technologies (e.g., balloons, gliders, uncrewed systems, animal-borne sensors) for collecting in situ measurements**
- **Enhancement of observations through doppler on wheels, Mesonet Probe Systems, Integrated Profiling System, instrumented tower etc.**
- **Automated prediction system using numerical, statistical and AI/ML approach.**
- **Implementation of Machine learning approach for reliable probabilistic forecasting of severe weather events, impact modelling and risk assessment at village level.**
- **Multiple research through Research Test Beds to improve understanding of severe weather hazards like flash floods, cloud bursts, lightning, tornadoe, difficult cyclones.**
- **Design climate policies with an objective to reduce the socio-economic impacts.**
- **Development of a national repository for all-hazard event and loss data, thereby improving ability to make informed decisions for resilience. Enhance mitigation studies based on future projections**
- **Enhance cooperation & collaboration among meteorologists, researchers, disaster managers, social scientists & workers. Customised sector specific risk based warnings.**

Impact Based Forecasting and Risk Based Warning for Resilient Infrastructure



- **Administrative layers (State, district, city, ward boundary & etc.)**
- **Digital Elevation Model Data**
- **Land Use Land Cover**
- **Meteorological data (Observation and Forecasts)**
- **Climatology,**
- **Infrastructure layers (Rail, Road, Buildings & etc)**
- **Demographic Data (Population, livestock & etc)**
- **Major Point of Interest (POI)- School, college, hospital, Airport, bus stand, Telcom. towers, Major industries, water resources, structures, shelters & etc.**
- **Impact Matrices for Hazards (Rainfall, Cyclone, Wind, Storm Surge, Heat/Cold Wave, Thunderstorm, Lightning**

DRR for Critical Infrastructure



- **Multi-Hazard Early Warning System (MHEWS) needs to be integrated with each and every critical infrastructure**

Needs for Regulations to ensure resilient infrastructure

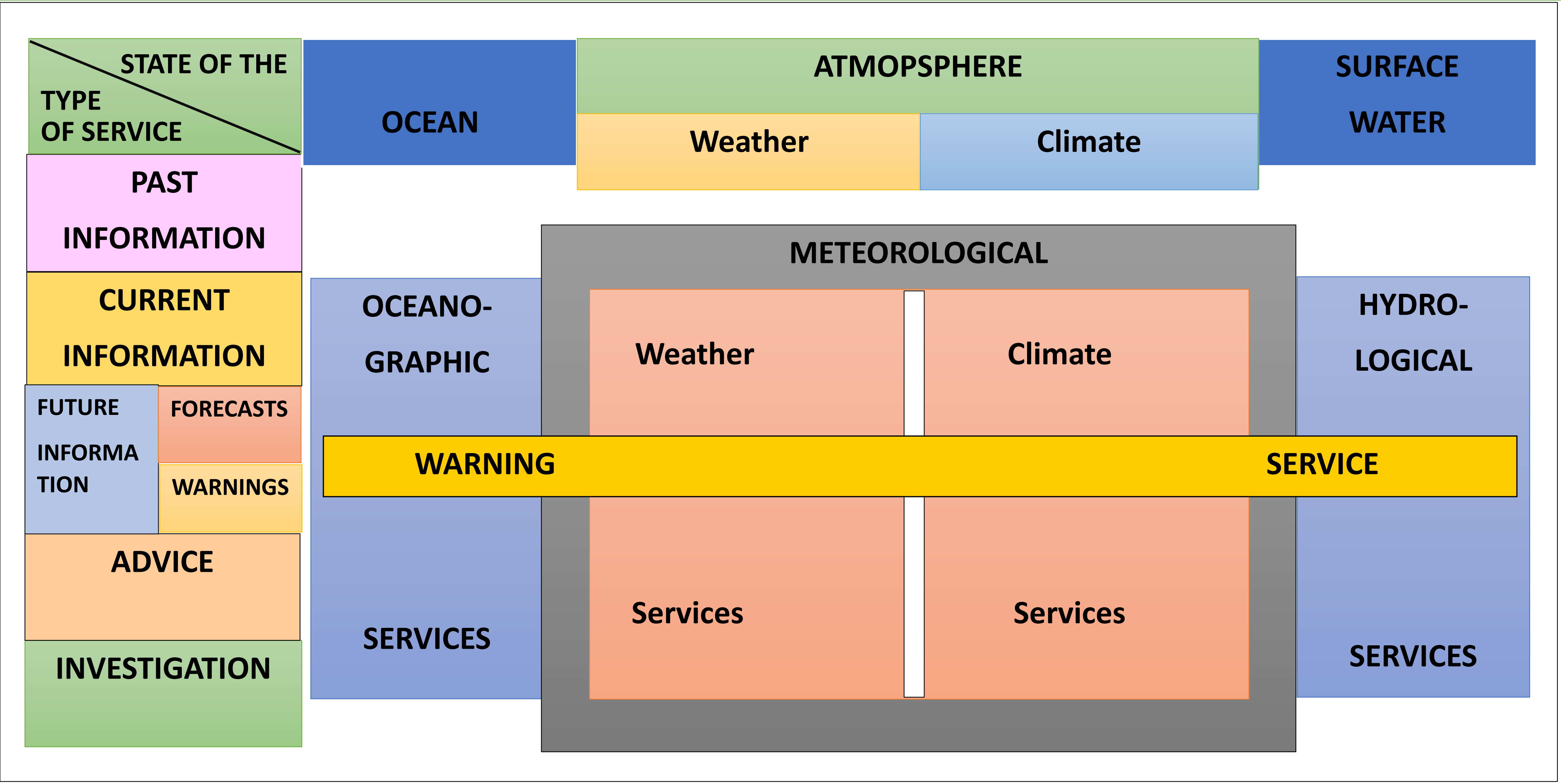
Regulations

- Standard codes like Bureau of Indian Standard codes
- Building codes of India
- Coastal zone regulations
- Hilly area regulations
- Regulations for Urban Areas
- Periodic Review of regulations
- Specific regulation for each and every infrastructure
- Standard Operation Procedure. Guidelines and Roadmap for each infratructure

Preamble: Weather Climate Services for Socio-economic Development

- **The estimates of the economic benefits of meteorological services cover a wide range of activities and much of the economy. There is incremental use of meteorological information in decision making**
- **Wide range of applications of weather, climate and water information to societal and economic development issues**
- **Changing societal needs**
- **Understanding & responding to emerging needs requires an effective dialogue between users and NMHS with effective 2 way communication**
- **Future investment by governments depends on a quantitative understanding of the impact on society and the economy**
- **Hence, the need for NMHSs to enhance their PWS (like Impact based forecast) and to develop methodologies for evaluating their socio-economic impacts and demonstrate such impacts effectively**

Impact complexities & overlapping domains



Public Information Pricing

- **Information for public good use, particularly for the basic infrastructure and for general public forecasts and warnings is provided as free**
- **Market prices can be used as a measure of the benefits to users**
- **It has applicability for those services which have private good characteristics of differential consumption and ease of exclusion**
- **It is difficult for those services with public good properties of non differential consumption and high costs of exclusion**
- **Where the characteristics of non differential consumption and excludability are combined to give mixed public and private goods, market prices may provide some measure of the benefit gained.**

Customized Service Pricing

- **In case of private good Met services, such as specialized forecasts for particular users or value added Met information, customers will purchase the services up to the volume where the benefits equals the price**
- **Prices paid by intermediaries in the communication of meteorological services is also incorporated**
- **Monopoly service charges can be imposed on particular users. For example, the NMS or a nominated private firm could be given sole rights to offer and supply specialized services (e.g. insurance) to a specific industry. In this situation, in addition to charging the marginal cost for the value added information, the monopolist include an upfront, lump-sum charge**

Understanding the behavioural response

- To make estimates of the value of Met. services by **inferring values** from the observed behavior of individuals, businesses and governments.
- **User surveys of decision-making** – especially those concerned with the use of, and responses to, meteorological information – natural experiments, and (potentially) laboratory experiments and regression methods are used.
- Collect information about the **decision-making processes** of individuals and firms, and about how they use meteorological information in these processes.
- **Sampling methods;** Mail, telephone and personal interviews may be used for samples of potential users of meteorological services.
- **Responses are sought on decision choices** whose outcomes are affected by weather and climate, what information is used in making these decision choices and, in particular, whether meteorological information is used, and if so, how is it accessed, how is it used to modify decision choices, and what decision changes are made.
- **Assessing information needs** of the users and how would they use it
- ***Natural experiments*** may be used to estimate the value of meteorological services. These are cases of clearly measured differences in the supply of meteorological services and data on observed changes in behavior between user and non-user

Methods for Estimating the Benefits

Most of the meteorological infrastructure and services are set as public goods and used by private players differentiating their investment costs.

Given that many publicly funded NMSs now impose charges for some of their services, recovering partial costs of operation, and some private sector value-adding services have emerged, the use of market prices becomes more relevant.

Need to capture direct or indirect impacts of using/not-using Met information to alter decisions to achieve better outcomes. The methods used are;

The descriptive methods:

- To find that a significant proportion of potential users (in many cases more than 50%) do not use Met. information in decision-making, and this high level of non-use is reflected in a zero willingness to pay
- Are concerned primarily with the use made of meteorological services, and only a few have provided estimates of benefits.

The prescriptive methods:

- This approach views meteorological information as a factor in the decision-making process
- The user have specific needs and act as per Met information

The contingent valuation methods:

- To estimate the benefits of public goods like Met services. Hereusers are asked to nominate the sum they would be willing to pay for a particular level of service

Methods for Estimating the Benefits

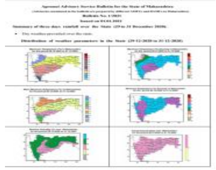
- To capture direct or indirect impacts of using/not-using Met service and, importantly, at least in principle use of information to alter decisions to achieve better outcomes.
- Most of the meteorological infrastructure and services are set as public goods and used by private players differentiating their investment costs.
- Given that many publicly funded NMSs now impose charges for some of their services, recovering partial costs of operation, and some private sector value-adding services have emerged, the use of market prices becomes more relevant. The methods used are;
- The descriptive methods:
  - To find that a significant proportion of potential users (in many cases more than 50%) do not use Met. information in decision-making, and this high level of non-use is reflected in a zero willingness to pay
  - Are concerned primarily with the use made of meteorological services, and only a few have provided estimates of benefits.
- The prescriptive methods:
  - This approach views meteorological information as a factor in the decision-making process that can be used by decision makers to reduce uncertainty. Are useful when user have specific needs and act as per Met information and operation/market reactions
- The contingent valuation methods:
  - To estimate the benefits of public goods like Met services. Here users are asked to nominate the sum they would be willing to pay for a particular level of service

Agrometeorological Advisory Services (AAS) to Farmers

Weather Forecast Model

Forecast
Rainfall, Temperature,
Wind, Humidity,
Cloud cover

Medium range Weather Forecast



Composite State Level Bulletin

Composite National Bulletin

State Met Centre

Stakeholders' Awareness

Value added forecast at district / Block level for 5 days

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

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.**

Economic Impact Assessment of AAS by MoES

- 3 (3 Rabi and 3 Kharif seasons)
- 15 Agro-climatic zones
- 4 villages in each agro-climatic zone
- 20 user farmers & 20 non-user farmers in each villages
- The major crops chosen for the study are;
    - Food grains: Wheat, Rice, Millets, Maize, Red Gram and Chickpea
    - Oilseeds: Mustard;
    - Cash crops: Cumin, Jute, Cotton and Tobacco
    - Fruit crops: Apricot, Peach and Banana
    - Vegetables: Tomato and Spinach.

Economic impact study of AAS

- **98% of surveyed farmers (**3,965 farmers across 121 districts of 11 states of India) **made modifications to at least one of nine practices based on weather advisories**
- **Average Annual Income to the surveyed farmers**

  Rs 2.43 Lakh with modification in 1 to 4 practices

  Rs 2.48 Lakh with modification in 5 to 8 practices

  Rs 3.02 Lakh in all the 9 practices

  Rs 1.98 Lakh with no modification
- **80% of farmers receiving information on high resolution weather events reported to have reduced losses.**
- **An estimated additional annual income of Rs. 12,500 per agricultural household belonging to Below Poverty Line category in rain-fed areas.**
- **Total income gain is estimated at Rs. 13,331 crore per annum in rain-fed districts.**

Source: National Centre for Applied Economic Research (NCAER), New Delhi, 2020

Economic Impact Indicators used for crops

Parameters	Indicators
Yield	Difference in yield of user and non-user farmers
Cost	❖ Difference between total cultivation cost (per acre) of user and non-user farmers ❖ Changes in cost per unit of output
Profitability	Difference in return over paid out cost (Rs/acre) of user and non-user farmers
Utility	Utility Increase in utilization by farmer for maneuvering cultural operations

Results of some studies in India

- NCMRWF-Economic impact of Agromet Advisory Service
  - Impact of AAS on Net returns (Rs/acre) is 10% to 15%
  - Impact of AAS on Yield (Q/acre) is 10% to 25%
- NCAER-Economic Benefits of the investment in Monsoon Mission:
  - Total economic benefits due to income gains of farmers and fishers =Rs 50,000 crores (approx.)
- NCAER-Impact Assessment and Economic Benefits of Weather and Marine Services:

Enhancing the impact of meteorological services

- **The meteorological services are now required to deliver services keeping in mind the possible impacts of the weather & climate phenomenon and their possible benefits**
- **Understanding exposure and vulnerability are critical for developing impact-based forecasts.**
- **Building partnerships between NMS and user communities will support the further development of impact-based forecasts that are ‘fit for purpose’ and can be used to trigger anticipatory actions to protect at-risk communities.**

Thank you