Annexure -I

Multi-Hazard Early Warning Decision Support System (MHEW-DSS): A Digital Transformation in Forecasting and Disaster Risk Reduction

Introduction

The India Meteorological Department (IMD) is the nodal agency for providing weather forecasting and early warning services across India for various weather-related hazards. Earlier, IMD relied on semi-manual systems that were slow and less accurate. To overcome these issues, IMD designed and built a new digital system using open-source technology and in-house expertise. With this development India is no longer dependent on costly foreign systems.

The MHEW DSS works in real time and uses advanced tools like Geographic Information System (GIS) maps. This allows forecasters to quickly collect, analyze, and share weather information in an easy-to-understand way. However, before the introduction of the DSS, forecasting processes were largely manual, fragmented, and dependent on multiple standalone systems. These legacy systems lacked automation, interoperability, and timely dissemination, resulting in inefficiencies, limited lead time, and inconsistent communication among users. Recognizing the need for modernization, IMD undertook a major initiative to re-engineer its forecasting workflow through digital transformation. The Multi-Hazard Early Warning Decision Support System (DSS) was conceived to integrate all aspects of weather forecasting and hazard warning from observation to dissemination within a single, automated, and interoperable platform. The initiative reflects IMD's vision of a "Weather Ready and Climate Smart Nation" and embodies the philosophy of "Har Har Mausam, Har Ghar Mausam", ensuring that every household, sector, and region has access to timely and actionable weather information. The DSS aims to overcome critical gaps in earlier systems, such as fragmented data sources, slow communication channels, limited automation, and underutilization of radar and satellite datasets. By addressing these challenges, IMD has established a state-of-the-art, real-time, and impact-oriented forecasting framework that serves diverse stakeholders, from farmers and disaster managers to transport, power, and health sectors.

Objectives

The primary objective of the DSS is to build an integrated and indigenous system capable of delivering accurate, real-time, and impact-based multi-hazard forecasts across India. The system is designed to empower forecasters, decision-makers, and communities through improved information flow and timely early warnings. Specific objectives include the integration of multi-source atmospheric and oceanic data, automation of forecasting workflows, and generation of consensus-based forecasts from multiple model outputs. The DSS also aims to enable impact-based forecasting and risk-based warnings by the forecaster in IMD that translate technical meteorological data into actionable information for users. It provides localized forecasts up to ten days in advance, covering 1.5 lakh pincodes, 5700 blocks, and over six lakh villages through IMD's digital platform (Mausamgram https://mausamgram.imd.gov.in/). Furthermore, it emphasizes scalability, open-source adaptability, and replicability across various sectors such as agriculture, transport, marine, energy, and tourism. The objective of the DSS was to enable forecasters to develop judicial weather warnings and forecasts. On the other hand a DSS is also developed general DSS to take their decision in their day today activities especially during weather hazardous situation to minimize the loss of life and properties and to optimize the socio-economic activities.

Strategy Adopted

The DSS development strategy centered around comprehensive process re-engineering of the entire forecasting and warning generation workflow. This involved automation, data integration, high-performance computing, and geospatial visualization to improve both efficiency and accuracy. The system integrates data from Radars, Automatic Weather Stations, satellite platforms, and ocean buoys to capture real-time atmospheric and oceanic conditions. Numerical Weather Prediction (NWP) models run by IMD are combined through a multi-model ensemble approach, allowing forecasters to identify the most accurate guidance for each scenario. The Weather Analysis and Forecast Enabling System (WAFES) serves as the analytical backbone of DSS. From analog mode of forecasting to digital forecasting system. It automatically generates diagnostic charts, dynamic weather products, and visualizations that aid expert consensus forecasting. A key feature of the DSS is its transition from conventional forecasting to impact-based forecasting (IBF) and risk-based warning systems. The DSS not only predicts the weather but also evaluates its implications on health, agriculture, energy, transport, and infrastructure. Color-coded warnings green, yellow, orange, and red convey varying levels of risk, making the forecasts actionable for disaster managers and local authorities. Multi-hazard interoperability has been achieved through a single GIS-enabled platform that unifies warnings related to cyclones, heavy rainfall, floods, heatwaves, and marine hazards. The WebGIS-based DSS allows visual comparison and integration of multiple data layers, ensuring consistent, non-redundant, and user-oriented forecast dissemination.

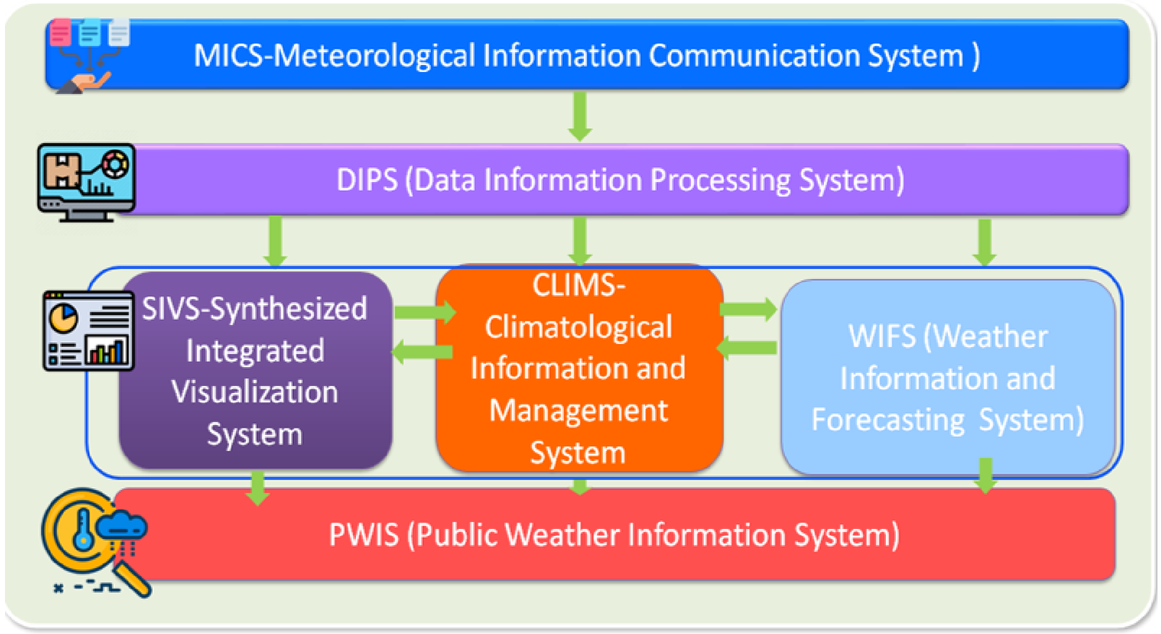

Figure 1: Components of Weather analysis and forecast enabling system (WAFES)

WAFES consist of five components namely

1. Meteorological Information Communication system (MICS)
2. Data information System (DIPS)
3. Synthesized Integrated visualization system (SIVS)
4. Public Weather Information system (PWIS)

While the MICS collecting data, accumulating them in a centralized platform, the DIPS scrutinizes data, applies the quality control and pre process the data before the analysis.
There is a large variation in the type of data commencing from manual observatories to that from Automatic weather Stations/Automatic Rain Gauge/Satellite/Radar among others. Also the time of collection of data also varies with different types of data. The DIPS processes all these heterogenous data and converts into a single format compatible with DSS. The developed DSS has got the capability to integrate HD5, netcdf, ASCII, BUFR, TIFF.
The process data are synthesized in an integrated visualization platform to visualize different layers of information like pressure, wind temperature, rainfall etc based on observation and models. It also help in comparing, comprehending and analyzing the various weather parameters, weather system, weather structure, genesis, evolution dissemination and its impact. To facilitate the decision making CIPS is utilized along with the CIMS and MICS. It helps in comparing the real time data with historical data assessing the extreme condition of observation data and forecast and hence the hazard and vulnerability potential. Weather information and forecast system enables comparing, comprehending and analyzing various data from numerical weather prediction models about seven in numbers and run twice a day based on 00 utc and 12 utc.

The DSS compares the NWP models output at the initial state of ocean and atmosphere with an actual observations hence find out the best performing model also the multi model average as selected by the forecaster, necessary bias correction thus can be made in the model forecast by comparing with initial observation and calculation the consensus average value from multi model ensemble technique. Further the DSS helps in calculating the extremity on hazard expected (eg Heavy rainfall, very heavy rainfall, extremely heavy rainfall) along with likelihood of occurrence of hazard (low, moderate, high)probability of occurrence of heavy rainfall in a given district.
Further DSS assess the impact of extreme weather predicted based on the likely hood of occurrence and severity of hazard in scale 1 to 16. It assigns the color code Green, yellow, orange and red corresponds to low intensity and low probability, to hazard with high intensity and high probability.

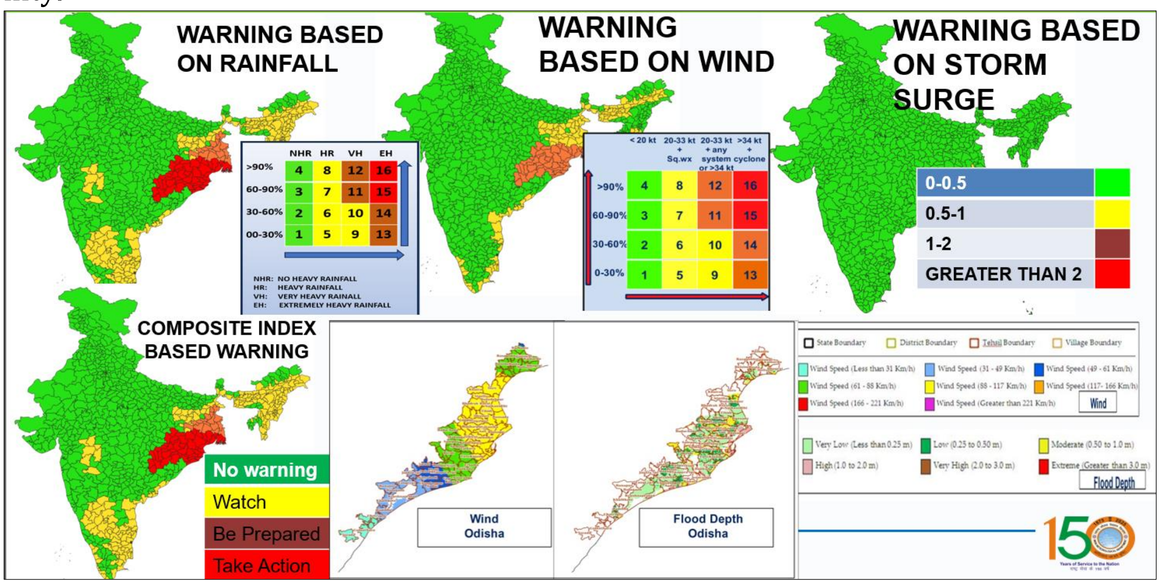

Figure 2 Multi-hazard interoperability : An example of Color Coded Warning For Cyclone Dana Based On 0830 IST of 23/10/2024 for 24/10/2024

The IBF thus generated has further attributed in terms of socio-economic parameters like impact on house, roads, bridges, culverts, various utilities like school, hospitals, shelters, infrastructure like power, electric poles, telecom etc and expected action to be taken thereof. These exercise are carried out for each severe weather parameters in a multi hazard scenario and the highest weightage is given to the most severe and most likely hazard.
Once the product are generated these are pushed to front end of DSS meant for general public, stakeholders. The first guess of IBF from DSS is generated at 10:30 IST based on observation of 5:30 IST to 8:30 IST which help the forecaster to add values and finalize the forecast through exchange of knowledge, experience and expertise in interpreting meteorological observation and model guidance through a video conferencing system.

Technology adopted

TO carry out the above mentioned task the system architecture integrates a geospatial data workflow combining PostgreSQL/PostGIS, Python-based automation, and web mapping interfaces for efficient data management and visualization. Geospatial datasets from multiple sources are processed and integrated in Python using libraries such as Pandas, GeoPandas, GDAL, NumPy, and PSYCOPG2, enabling automated data cleaning, conversion to CSV/GeoJSON, and database maintenance. The processed data are stored in a PostgreSQL geospatial database and published through GeoServer for web-based mapping services. On the front end, interactive visualization and user access are provided via Leaflet, JavaScript, HTML5, and PHP, allowing users to view, query, and analyze geospatial information in real time. This integrated backend–frontend framework ensures automation, scalability, and seamless dissemination of dynamic spatial data for decision support and forecasting applications.The DSS has various automatic dissemination methds like sms,emails, whatsapp, graphical buleetin including common alterting protocol which gives alerts directly to the affected common public.

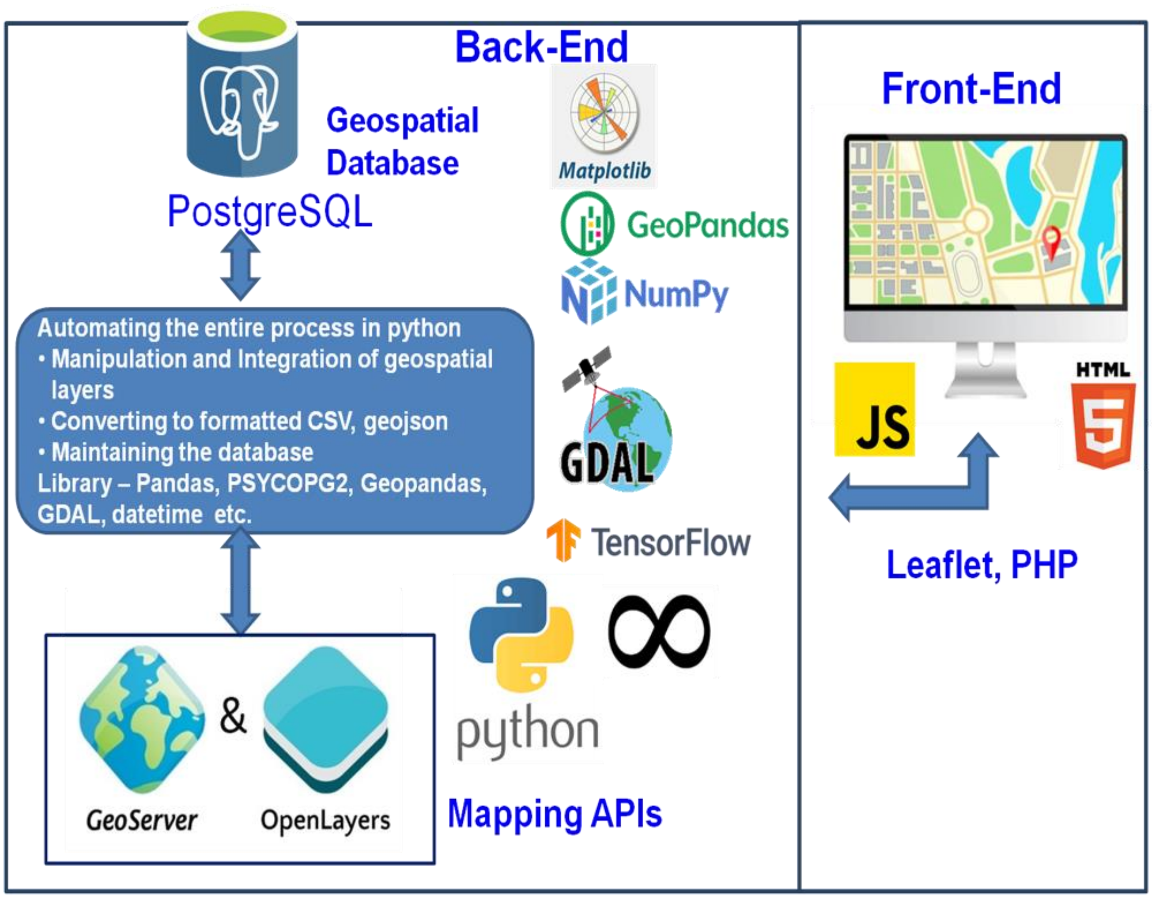

Figure 3 Technologies used in development of MHEWS-DSS

Achievements and outcome

The implementation of the DSS has resulted in measurable improvements in the efficiency, accuracy, and scope of weather forecasting in India. More than ninety percent of data collection, quality control, and integration processes have been automated, allowing seamless data ingestion from multiple sources. The forecast preparation time has been reduced by approximately three hours, while the forecast lead time has increased from five to seven days. Integration of real-time observational data with NWP guidance has enhanced accuracy by fifteen to twenty percent. Prior to DSS, different IMD divisions operated independently, producing uncoordinated forecasts for various phenomena. The new system consolidates all forecasting modules within a single interoperable framework, ensuring synergy among outputs, consistency in warning messages, and improved confidence among users.

Sectoral services have expanded significantly through DSS including

- Agriculture,
- Transport sector (customized weather modules have been developed for Indian Railways and National Highways, providing route-specific forecasts)
- Marine sector benefits from three-hourly ship route forecasts for up to five days, covering wind, wave, and visibility parameters.
- Urban
- Power
- Hydrology
- Tourism
- Health
- Aviation

These applications further demonstrate the scalability of DSS. Dissemination and outreach have expanded exponentially. During extreme weather events, over sixty-nine million targeted alerts have been issued. The DSS has also earned national and international recognition

Conclusions

The Multi-Hazard Early Warning Decision Support System has significantly strengthened India's disaster preparedness, operational efficiency, and institutional capability. Multi-hazard interoperability ensures faster, coordinated decision-making among disaster management agencies, thereby reducing casualties, infrastructure losses, and economic disruption. The system's adoption has led to tangible socio-economic benefits, including improved agricultural resilience, better energy planning, safer transportation, and enhanced public health preparedness during extreme events such as heatwaves. By integrating forecast dissemination with local

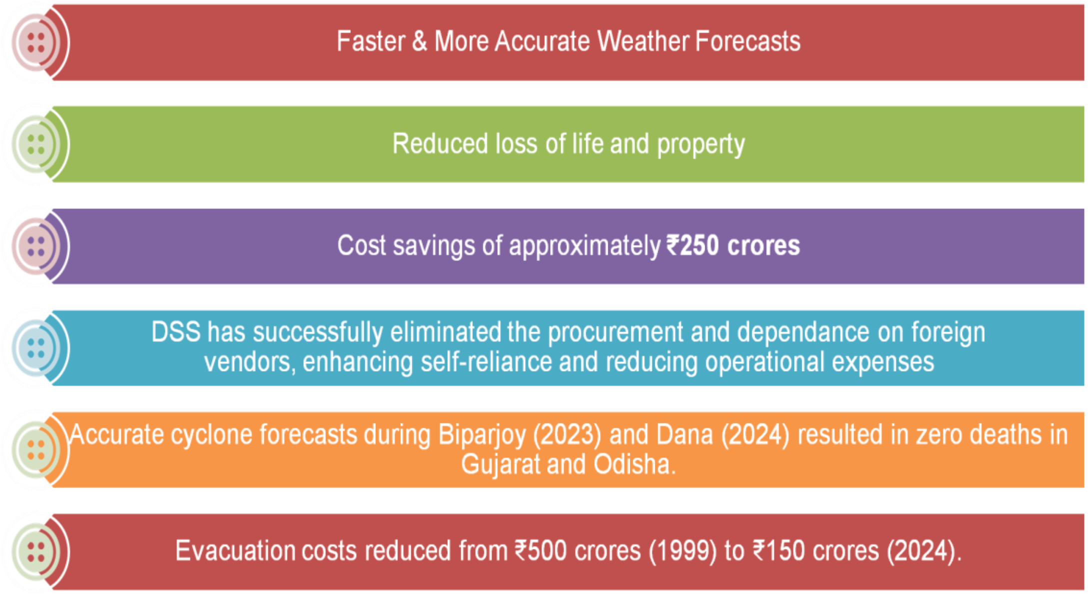

Figure 4 Major impact of DSS

governance structures, the DSS empowers panchayats, farmers, and communities to make timely, informed decisions. This democratization of weather information fosters community-level resilience and aligns with national goals of sustainable and inclusive development. The DSS represents a transformative milestone in India's meteorological history. It embodies the convergence of scientific innovation, digital governance, and public service. By modernizing forecasting through automation, interoperability, and impact-based analysis, IMD has positioned India as a global leader in multi-hazard early warning systems and disaster resilience. The DSS demonstrates the integrated role of technology, science, and governance protecting lives, livelihoods, and ecosystems in a changing climate.

The various public modules of the Multi-Hazard Early Warning Decision Support System are readily accessible at https://imdgeospatial.imd.gov.in/.

Figure 5: Geospatial Services web page

Stakeholders & Key Beneficiaries

The MHEW-DSS benefits multiple categories:

- Government: National and State Disaster Management Authorities, ministries (Agriculture, Power, Urban and Rural, Health, Marine, Surface transport, Aviation etc.
- Citizens: Farmers, fishermen, rural and urban populations.
- Businesses & industries: Aviation, transport, energy, marine, and agriculture sectors.
- Regional partners: South and south East Asian and Middle East countries under IMD's Regional Specialized Meteorological Centre mandate.
- Thus, the DSS acts as both a national public good and a regional support system.

Key Benefits / Value Creation

Benefits are multi-dimensional:

- Government: Approx ₹250 crore cost savings, better disaster preparedness.
- Citizens: life-saving early warnings (Zero loss of life due to cyclone Biparjoy (2023) and Dana (2024), better service delivery.
- Business & economy: Power sector savings of ₹500 crore annually; reduced losses in agriculture, fisheries, marine, onshore and offshore industries, surface transport, Indian Railways, aviation and agriculture etc.
- Economy: Estimated economic benefit of ₹13,331 crore annually across rain-fed districts.
- Environment: Reduced disaster impacts and improved climate resilience.

Award and Recognition:

List of Awards:

1. Government of India , Department of Administrative Reforms and Public Grievances presented National Award for e-Governance 2025 (Silver) for Multi Hazard Early Warning Decision Support System

2. IMD DG Dr Mruntyujay Mohapatra awarded with the prestigious UNDRR award "THE SASAKAWA AWRD" for disaster risk reduction 2025.

3. The India Meteorological Department (IMD) has won the Award of Excellence at the Digital Transformation Summit 2026. This prestigious honor recognizes IMD's 'Multi-Hazard Early Warning Decision Support System' for its innovation and excellence in public service delivery."