ISSN 0252-1075
Contribution from IITM
Technical Report No. 12
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Technical Report on Design and Development of a Disdrometer Data Portal (DDP)

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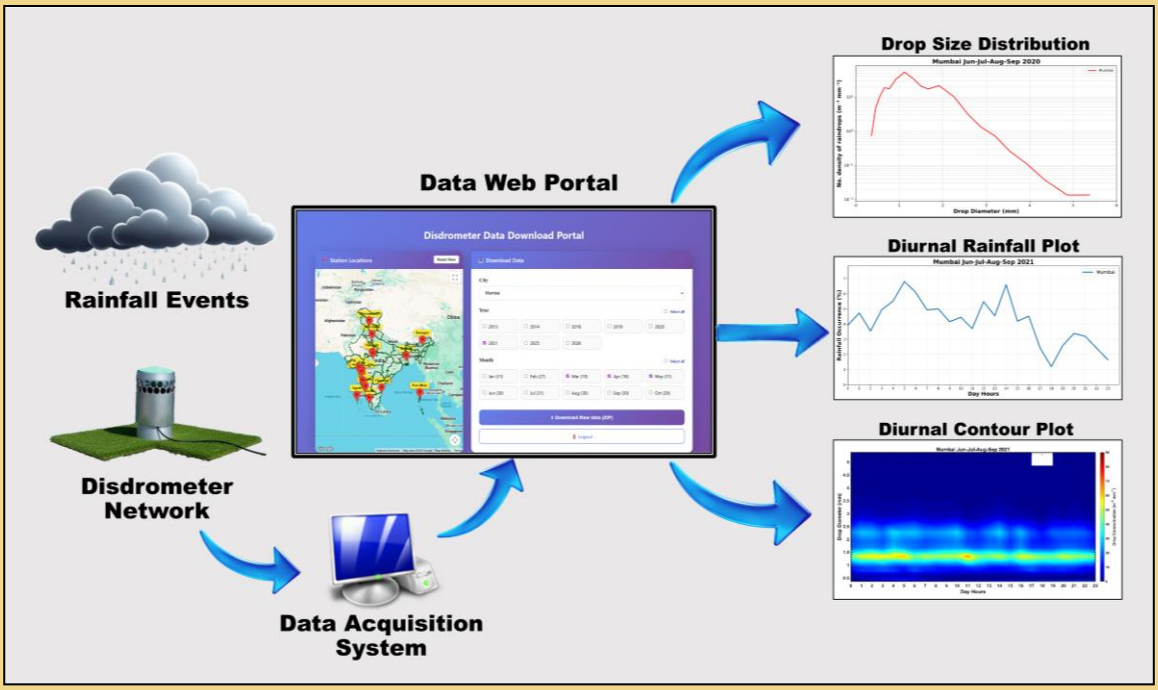

Atmospheric Research Testbed (ART)
Indian Institute of Tropical Meteorology (IITM)
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PUNE, INDIA
http://www.tropmet.res.in/

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DOCUMENT CONTROL SHEET

Ministry of Earth Sciences (MoES)
Indian Institute of Tropical Meteorology (IITM)

ESSO Document Number
ESSO/IITM/ART/TR/02(2026)/209

Title of the Report
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2. Dr. Gargi Rakshit, Scientist D, India Meteorological Department (IMD), New Delhi.

Type of Document
Technical Report

Number of pages and figures
28, 13

Number of references
16

Keywords
Disdrometer Data Portal (DDP), Disdrometer Network, Raindrop Size Distribution (DSD), Precipitation Microphysics, Rainfall Intensity, Data Visualization, Role-Based Access Control, Geospatial Visualization

Security classification
Open

Distribution
Unrestricted

Date of Publication
June 2026

Contents

ABSTRACT

Disdrometer observations constitute a fundamental component of precipitation microphysics research, hydrometeorological studies, and weather monitoring activities. High temporal resolution measurements of raindrop size distribution, rainfall intensity, and accumulated rainfall obtained from disdrometers are extensively used for understanding rainfall processes, validating radar-based precipitation estimates, improving numerical weather prediction models, and studying cloud precipitation. With the establishment and expansion of the IITM Disdrometer Network across diverse climatic regions of India, a substantial volume of high-frequency observational data is being generated on a continuous basis.

The effective utilization of these datasets requires a centralized, secure, and standardized mechanism for data access, management, and analysis. In the absence of such a system, data retrieval becomes fragmented, time-consuming, and dependent on manual interventions, which can lead to inconsistencies, data redundancy, and limited reproducibility of analyses. To address these challenges, an Disdrometer Data Portal (DDP) has been designed and developed at the ART-HACPL, Indian Institute of Tropical Meteorology (IITM).

This technical report documents the complete design, development, implementation, and operational capabilities of the DDP. The DDP provides authenticated access to raw disdrometer datasets through an intuitive web-based interface, allowing users to select observation stations, years, and months of interest. In addition to raw data download, the system supports geospatial visualization of disdrometer locations using a Google Map based interface. Advanced administrative functionalities include rainfall intensity-based filtering, seasonal aggregation of data, automated generation of processed datasets in spreadsheet format, and standardized scientific visualization products such as Drop Size Distribution plots, diurnal rainfall percentage plots, and diurnal contour plots.

The DDP significantly enhances operational efficiency, data accessibility, and reproducibility of scientific analyses for scientists at IITM. Furthermore, the modular and scalable architecture of the system provides a robust foundation for future expansion toward real-time data ingestion, advanced analytics, and broader dissemination.

Keywords: *Disdrometer Data Portal (DDP), Disdrometer Network, Raindrop Size Distribution (DSD), Precipitation Microphysics, Rainfall Intensity, Data Visualization, Role-Based Access Control, Geospatial Visualization*

PURPOSE AND SUMMARY

The primary purpose of developing the DDP is to streamline, standardize, and modernize access to disdrometer datasets generated under the IITM Disdrometer Network. Prior to the development of this DDP, data access and dissemination were largely dependent on manual file transfers, decentralized storage practices, and ad hoc data requests. Such approaches, while functional for limited datasets, become inefficient and error-prone as the volume and diversity of observations increase.

The DDP has been conceived as a centralized platform that integrates data discovery, structured data staging, role-based access control, automated processing, and scientific visualization within a single unified framework. By providing a web-based interface, the system eliminates the need for manual intervention in routine data access tasks and ensures consistent handling of observational datasets across users.

The DDP supports two distinct categories of users: **General Users** and **Administrative Users**. General users, including scientists and students, are provided with controlled access to raw disdrometer data and station location visualization. Administrative users are granted extended privileges for data filtering, seasonal aggregation, generation of processed datasets, and automated scientific plot generation. This segregation of access ensures both data security and operational flexibility.

The developed DDP provides an integrated operational framework that supports routine scientific analysis and internal data sharing within IITM. The formalization of data access and processing procedures improves consistency, traceability, and reproducibility of results, and enables the system to evolve in response to future institutional and research requirements.

1. INTRODUCTION

Disdrometers are specialized meteorological instruments designed to measure the size and fall velocity of individual hydrometeors, particularly raindrops. Impact-type disdrometers, such as those manufactured by Distromet, operate by converting the mechanical momentum of each impacting raindrop into an electrical signal, from which the raindrop diameter and drop size distribution (DSD) are derived (Distromet, 2024). These high temporal resolution measurements form the basis for precipitation microphysical analysis and allow indirect assessment of dominant rainfall processes, such as drop growth through coalescence, breakup, and evaporation, through statistical interpretation of the observed size and velocity spectra. Disdrometer-derived parameters are extensively used in studies related to rainfall variability, cloud precipitation interactions, validation of radar reflectivity rainfall relationships, and characterization of precipitation structure during extreme rainfall events.

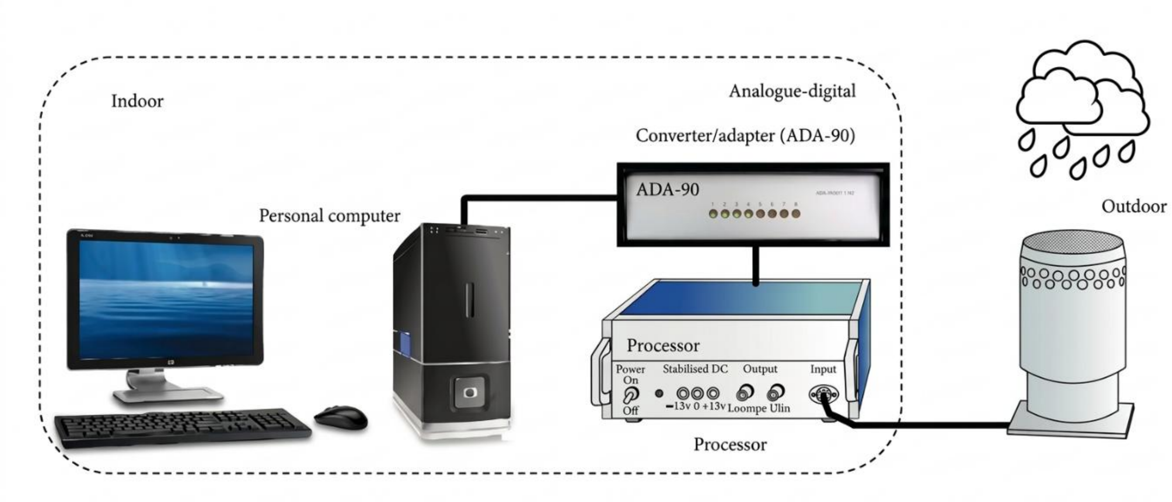

Figure 1: Block Diagram of Disdrometer System

Table 1: Technical Specification

Parameter	Value
Sensor type	Impact based
Drop Size Range	0.3–5.3 mm
Drop classes	20 size classes for drop diameter
Drop Velocity	Based on drop size and derived from impact energy
Output products	DSD, rainfall rate and rainfall accumulation
Rain rate	Up to 200 mm/h
Sampling area	50 cm²

The ART-HACPL group of Indian Institute of Tropical Meteorology (IITM) has established a network of disdrometers across multiple geographical locations in India, encompassing coastal regions, orographic stations, plains, and urban environments. This network enables systematic monitoring of precipitation characteristics under diverse meteorological conditions. With continuous operation and high temporal resolution, the network generates a large volume of observational data on a daily basis.

As the scale of data generation has increased, the need for an efficient and standardized data management system has become increasingly evident. Traditional approaches based on decentralized storage and manual data sharing are inadequate for handling large, multi-year datasets and supporting multiple users simultaneously. These approaches often result in duplication of effort, delays in data access, and challenges in maintaining data integrity.

The development of the DDP represents a strategic initiative to address these challenges. By centralizing data access and integrating processing and visualization tools, the DDP enables users to efficiently retrieve, analyze, and interpret disdrometer observations. This report provides a detailed description of the DDP, covering its objectives, system architecture, methodologies, operational capabilities, and future scope.

It is important to note that the IITM DDP has been developed exclusively as an internal institutional tool for use within the IITM intranet. The DDP is purpose-built to manage the specific data formats, network structure, and research workflows of the IITM Disdrometer Network, and is not intended for comparison or integration with publicly accessible national or international data platforms. Its design priorities role-based access, automated scientific visualization, and seasonal aggregation are tailored specifically to the operational and scientific requirements of IITM.

2. SYSTEM OVERVIEW

The DDP is a web-based application designed to provide secure and controlled access to disdrometer datasets and associated analytical tools. The system has been developed primarily for internal use at IITM, with provisions for extending access to authorized external users if required in the future. The DDP architecture emphasizes modularity, scalability, and ease of use, ensuring that it can accommodate increasing data volumes and evolving user requirements.

The DDP integrates multiple functional components, including user authentication, available data discovery, structured data staging, automated processing, and visualization. These components work together to deliver a seamless user experience while maintaining data security and operational efficiency.

2.1 Objectives of the DDP

The key objectives of the DDP are as follows:

- To provide a centralized platform for accessing disdrometer datasets generated under the IITM Disdrometer Network.
- To enable intuitive selection of observation stations and temporal ranges through a web-based interface.
- To support geospatial visualization of disdrometer locations using a map based interface.
- To automate routine data handling tasks, including file staging, compression, and cleanup.
- To provide advanced data processing and visualization capabilities for authorized administrative users.
- To enhance reproducibility, traceability, and efficiency of scientific analyses.

2.2 User Roles and Access Levels

The DDP implements a role-based access control mechanism to ensure secure and controlled access to disdrometer datasets and associated functionalities. Access to the DDP is restricted to authorized users and is available only within the IITM internal network (intranet).

Users can access the DDP through a standard web browser by navigating to the internal server address:

https://10.2.2.26/

Upon accessing the DDP, users are presented with a **secure login interface** requiring valid credentials. The login page serves as the entry point to the system and ensures that only authenticated users can proceed to data selection and processing modules. Based on successful authentication, users are assigned appropriate access privileges corresponding to their designated role. A representative screenshot of the login interface is shown in the figure below.

Login credentials for authorized access to the DDP may be provided upon request, subject to approval by the Project Director / Project In-charge.

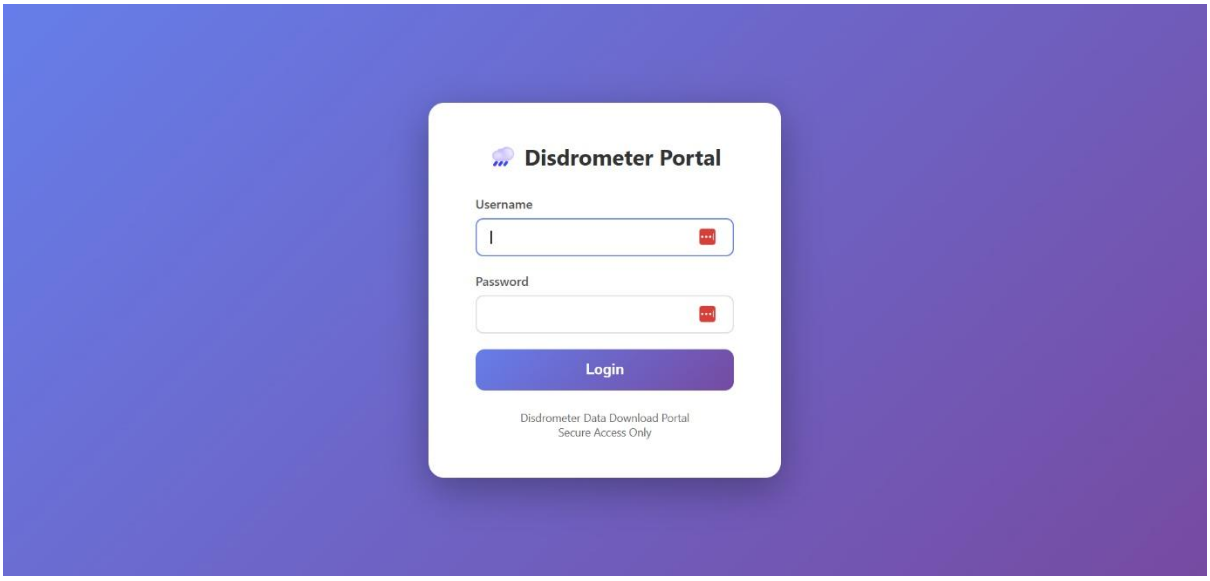

Figure 2: Login interface of the DDP showing secure user authentication.

Following authentication, the DDP provides access to functionalities according to one of the two defined user categories: **General Users** and **Administrative Users**.

General Users are provided with access to core data retrieval and visualization functionalities of the DDP. These users can select cities, years, and months of interest through the DDP interface and download raw disdrometer data in compressed formats for further offline analysis. In addition to data download, General Users can visualize the geographical locations of disdrometer stations using an interactive Google Map based interface. This feature enables intuitive spatial exploration of the disdrometer network and allows users to identify and select observation stations directly from the map. The combination of form-based selection and map-based visualization improves usability and supports region-focused data analysis.

Administrative Users are granted extended privileges beyond those available to General Users. In addition to accessing raw data and station visualization, Administrative Users can generate processed datasets in spreadsheet format, apply rainfall intensity-based filtering, perform seasonal aggregation of data for selected years, and generate standardized scientific plots. These plots include Drop Size Distribution, diurnal rainfall percentage, and diurnal contour visualizations.

Administrative Users also have access to previously generated outputs, enabling verification, quality control, and consistency checks across analyses.

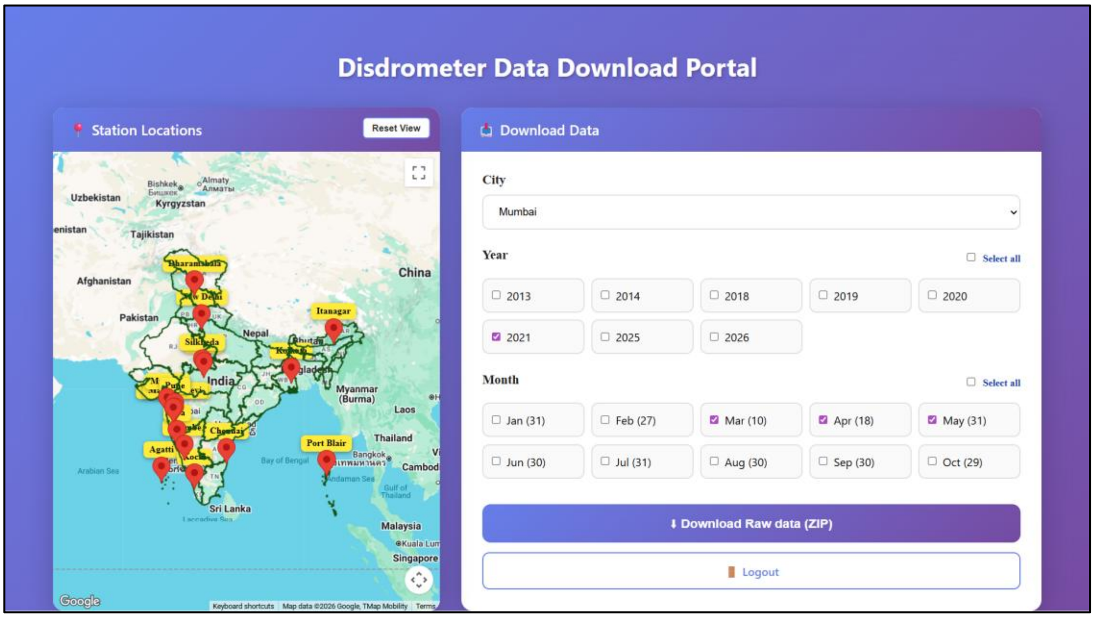

Figure 3: Dashboard screen for the General User for data download

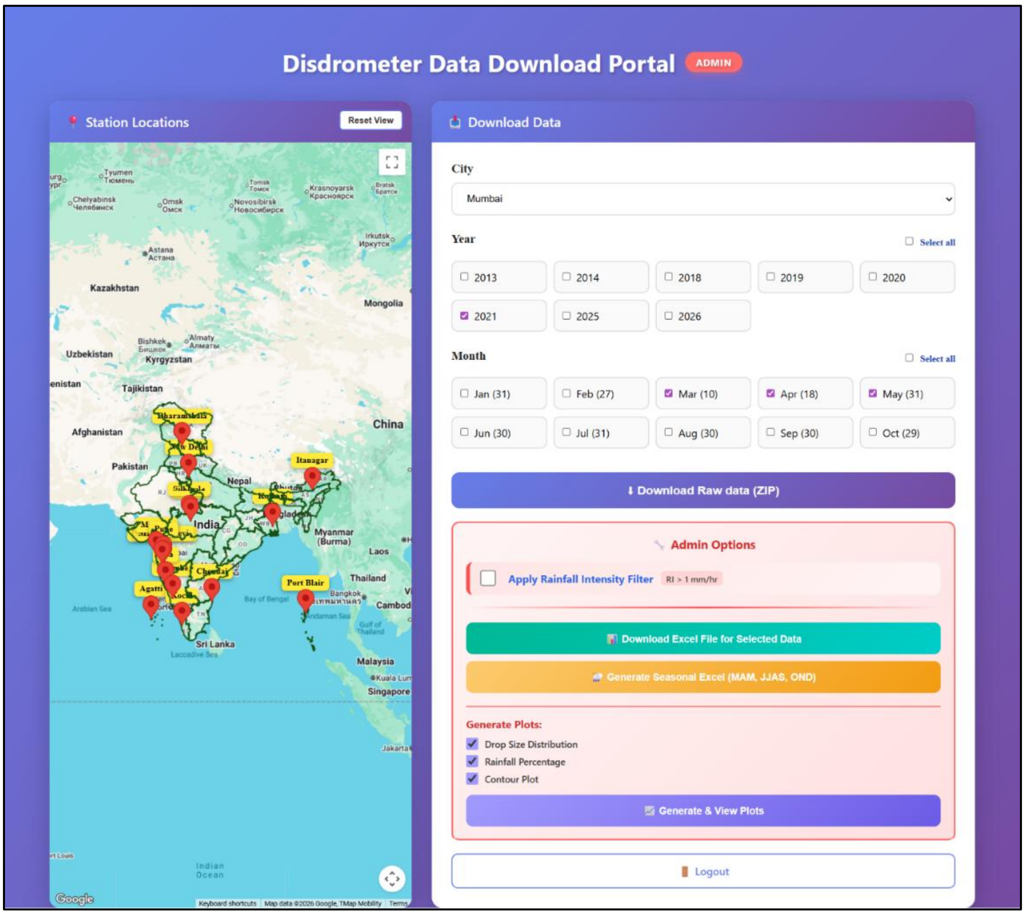

Figure 4: login screen of the Admin User Data DDP

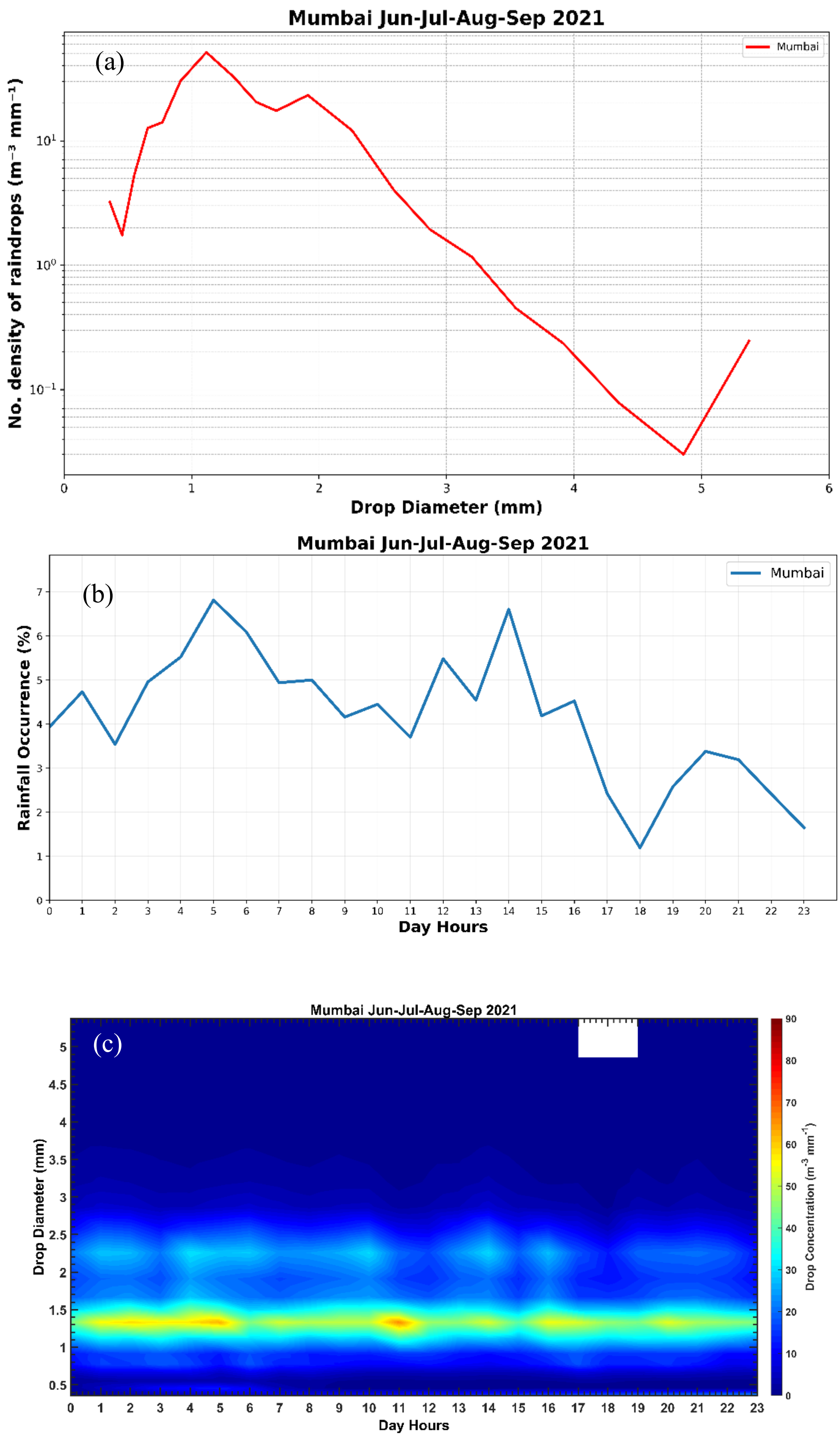

Figure 5: Generated Plots of Selected City Year and Months

2.3 Overall Workflow of the DDP

The typical workflow of the DDP begins with user authentication, followed by selection of observation parameters such as city, year, and month. Based on the selected criteria, the system identifies the relevant data files and stages them into a temporary workspace. For general users, the staged data are compressed and made available for download. For administrative users, additional processing steps such as filtering, aggregation, and plot generation may be applied before delivering the outputs.

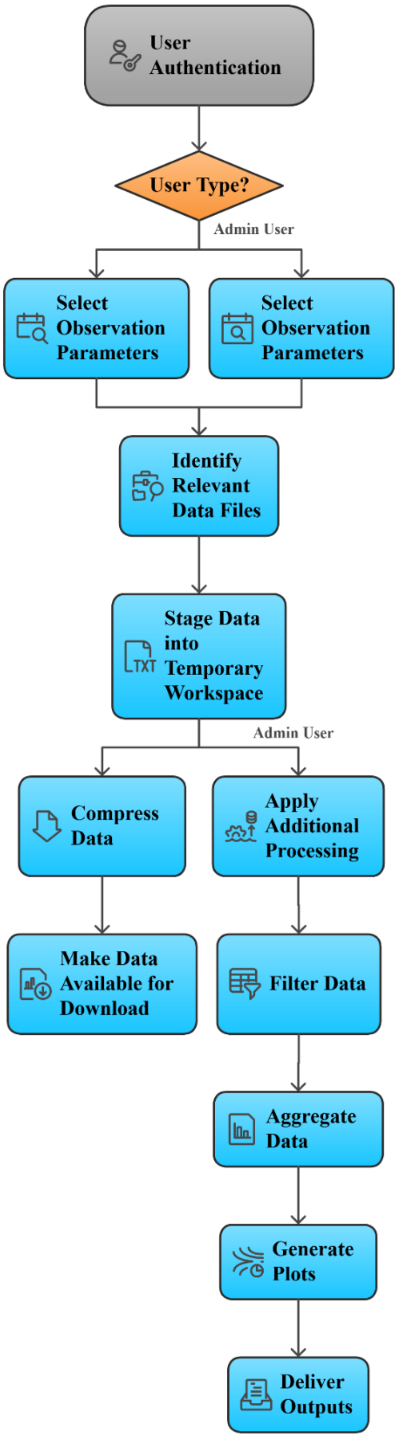

Figure 6: Overall Workflow of the DDP

3. METHODOLOGY

The DDP has been developed following a structured and modular methodology that emphasizes reliability, scalability, reproducibility, and ease of maintenance. The overall design philosophy is centered on separating user interaction, data management, processing logic, and visualization into distinct functional layers. This approach ensures that individual components of the system can be modified or enhanced without affecting the overall stability of the DDP.

The methodology adopted for the development of the DDP encompasses software architecture design, selection of appropriate technologies, organization of raw data, implementation of role-based access control, automated data staging, application of filtering and aggregation algorithms, and generation of scientifically standardized visualization products. Each of these aspects is described in detail in the following subsections.

3.1 Software Architecture

The software architecture of the DDP follows a modular, service-oriented design. The DDP is implemented as a web-based application with a clear separation between frontend presentation, backend logic, and data management layers. This architecture facilitates scalability, simplifies debugging, and enables efficient future expansion.

At a high level, the system architecture consists of the following components:

- **User Interface Layer:**
  Responsible for presenting web pages to users, capturing user inputs, and displaying results such as download links, maps, and generated plots.
- **Application Logic Layer:**
  Handles request processing, authentication, authorization, data staging, and orchestration of processing workflows.
- **Data Management Layer:**
  Manages access to raw disdrometer data, temporary working directories, processed outputs, and cleanup operations.
- **Visualization and Analysis Layer:**
  Generates scientific plots and processed datasets based on user-selected parameters and administrative controls.

This layered architecture ensures that user-facing components remain decoupled from data processing routines, thereby improving system robustness and maintainability.

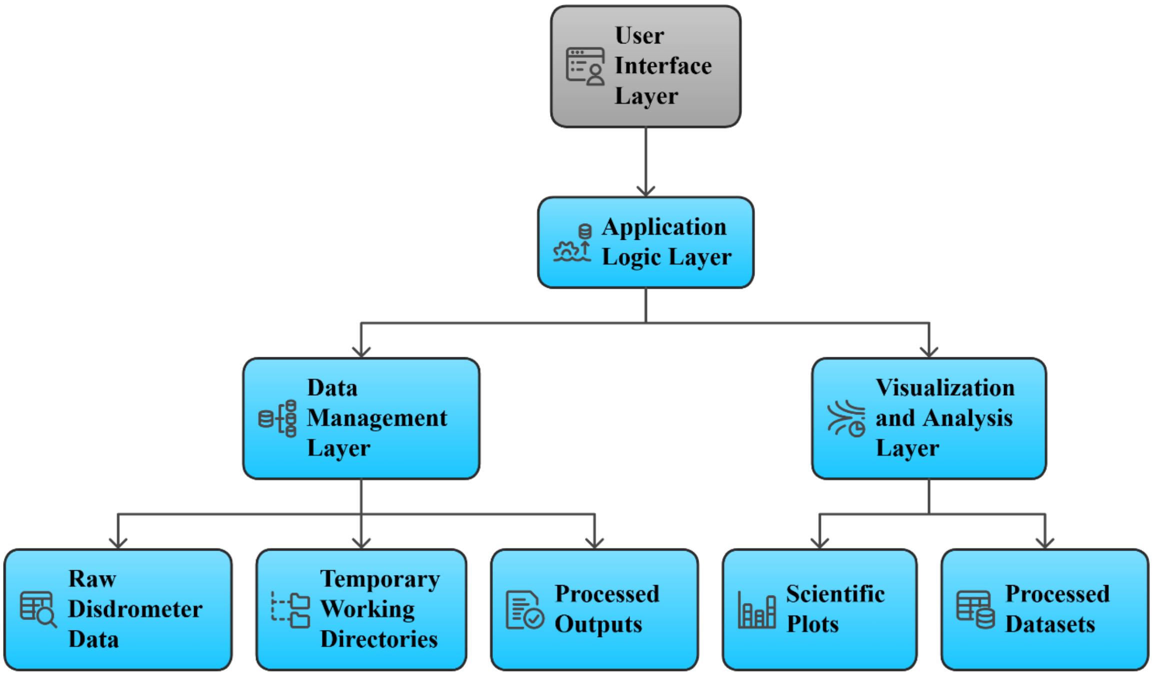

Figure 7: High-level layered system architecture of the DDP illustrating the interaction between the user interface, application logic, data management, and visualization and analysis components.

3.2 Technology Stack

The DDP has been developed using a combination of open-source, widely adopted software technologies to ensure long-term sustainability, ease of maintenance, and seamless deployment within the existing IITM computing and networking environment. The technology stack primarily comprises Python-based backend services, implemented using the Flask web framework, and a browser-based frontend developed using HTML, CSS, and JavaScript. The selection of these technologies was guided by considerations such as reliability, flexibility, minimal dependency on proprietary software, and compatibility with institutional infrastructure.

Component	Technology
Backend Framework	Python 3.12.9 + Flask 3.1.2
Frontend Technologies	HTML5, CSS3, JavaScript
Data Processing & Plotting	Pandas, Matplotlib
Deployment Environment	WSGI / Gunicorn / Waitress
Mapping Framework	Google Maps JavaScript API
Data Format Support	JSON, ZIP, XLSX

The DDP architecture follows a server–client model, wherein backend services running on an internal server handle user authentication, data management, processing workflows, and file delivery, while the frontend provides an interactive user interface for data selection, visualization, and user interaction through standard web browsers within the IITM intranet. The major components of the technology stack and their roles within the system are described in the following sections.

3.2.1 Backend Framework

The backend of the DDP is implemented using Flask, a lightweight Python-based web framework. Flask has been selected due to its modular design, minimal overhead, and suitability for developing secure internal web applications.

The Flask framework is responsible for:

- Handling incoming HTTP requests from users
- Managing URL routing and request dispatching
- Implementing user authentication and session management
- Enforcing role-based access control for general and administrative users
- Orchestrating data staging, filtering, and processing workflows
- Serving processed outputs such as ZIP archives, Excel files, and plot images

The backend logic is organized into modular Python scripts, each responsible for a specific functional domain, such as authentication, data discovery, data copying, processing, and visualization. This modular structure enhances maintainability and allows individual components to be updated independently without affecting the entire system.

3.2.2 Frontend Technologies

The frontend of the DDP is developed using standard web technologies, namely HTML, CSS, and JavaScript. These technologies provide a simple yet effective mechanism for building interactive user interfaces accessible through standard web browsers within the IITM intranet.

The frontend layer supports:

- User login and authentication interfaces
- Form-based selection of city, year, and month
- Dynamic enabling and disabling of options based on data availability
- Submission of user requests to the backend services
- Display of status messages, alerts, and download links
- Visualization of generated plots for administrative users

Cascading Style Sheets (CSS) are used to maintain a clean and consistent layout across pages, while JavaScript is employed to handle dynamic user interactions and asynchronous communication with backend services. This separation between presentation and logic ensures that user interface enhancements can be implemented without modifying backend processing routines.

3.2.3 Geospatial Visualization

To provide spatial context to disdrometer observations, the DDP integrates a Google Map based visualization module. This module displays the geographical locations of disdrometer stations as markers on an interactive map.

The geospatial visualization component allows users to:

- View the spatial distribution of the IITM disdrometer network
- Identify station locations visually
- Select stations directly from the map interface for data retrieval
- Associate geographic context with selected datasets

The map-based interface improves usability, particularly for users conducting regional or comparative studies, and reduces reliance on textual station lists alone.

3.2.4 Data Processing Libraries

Disdrometer data processing within the DDP is performed using standard Python scientific computing libraries. These libraries are used for reading raw disdrometer data files, filtering observations based on rainfall intensity thresholds, aggregating data seasonally, and computing statistical quantities required for visualization.

The data processing routines are designed to operate on staged copies of raw data, ensuring that original datasets remain unaltered. By leveraging well-established scientific libraries, the DDP ensures numerical reliability and consistency with commonly accepted data analysis practices in atmospheric sciences.

3.2.5 Visualization and Plotting Tools

The DDP incorporates automated generation of scientific plots using Python-based plotting libraries and external visualization utilities where required. These tools are used to generate publication-quality plots such as:

- Drop Size Distribution (DSD) plots
- Diurnal rainfall percentage plots
- Diurnal contour plots

Plot generation routines follow standardized methodologies and produce high-resolution graphical outputs suitable for inclusion in technical reports and presentations. For certain specialized visualizations, external executable utilities are invoked from the backend to ensure consistency with established plotting formats already in use within the research group.

3.2.6 Deployment and Internal Network Operation

The DDP is deployed within the IITM internal network (intranet) and is not exposed to the public internet. This deployment strategy ensures data security and compliance with institutional access policies.

The application is executed using a dedicated server runner script (run_server.py), which launches the Flask application through a production-grade WSGI server. This setup allows the DDP to:

- Handle multiple simultaneous user requests
- Operate continuously on internal servers
- Restrict access to authorized users within the IITM network

Configuration parameters such as server port, directory paths, and cleanup intervals are maintained in centralized configuration files, enabling easy reconfiguration and consistent deployment across environments.

3.2.7 Advantages of the Selected Technology Stack

The use of open-source and widely supported technologies offers several advantages:

- Seamless integration with existing IITM infrastructure
- Reduced dependency on proprietary software
- Ease of maintenance and future upgrades
- Flexibility to incorporate new analytical and visualization modules
- Long-term sustainability of the system

Overall, the selected technology stack provides a robust and scalable foundation for the DDP, ensuring reliable operation and adaptability to evolving scientific and operational requirements.

3.3 Data Organization and File Structure

Raw disdrometer data generated under the IITM Disdrometer Network are stored in a structured directory hierarchy based on observation station and year of measurement. This organization ensures systematic storage of large volumes of data and simplifies automated discovery and retrieval.

Each station directory contains year-wise subdirectories, within which daily or event-based data files are stored. File naming conventions encode essential metadata such as observation date and station identifier, enabling automated parsing by the DDP.

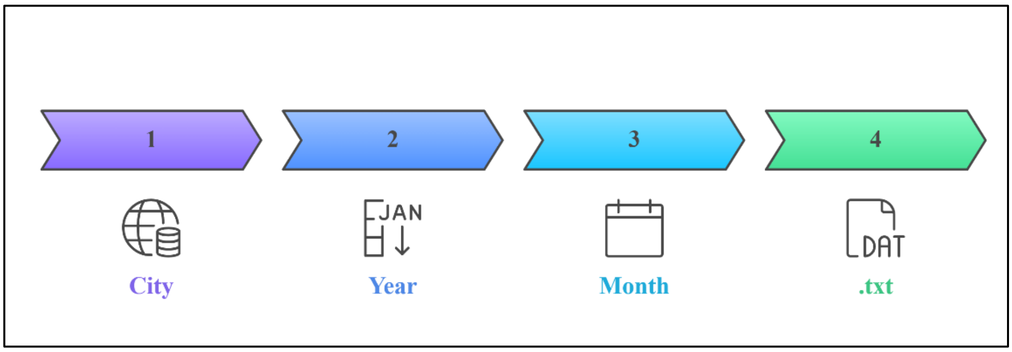

Figure 8: Folder Structure in Data Storage

Within the DDP workflow, raw data are never modified directly. Instead, copies of the required files are staged into a temporary workspace when a user submits a data request. This approach preserves the integrity of the original datasets while allowing flexible processing and filtering operations on the staged copies.

3.4 Data Discovery and Availability Mapping

An important feature of the DDP is its ability to dynamically identify and present available data to users. Upon selection of a station, the system scans the corresponding raw data directories to determine the years and months for which data are available.

This availability mapping enables the DDP to populate year and month selection options dynamically, preventing users from requesting data that do not exist. In addition, the system can compute metadata such as the number of available observation days within a selected month, providing users with contextual information about data completeness.

The dynamic discovery mechanism significantly improves user experience and reduces unnecessary processing requests.

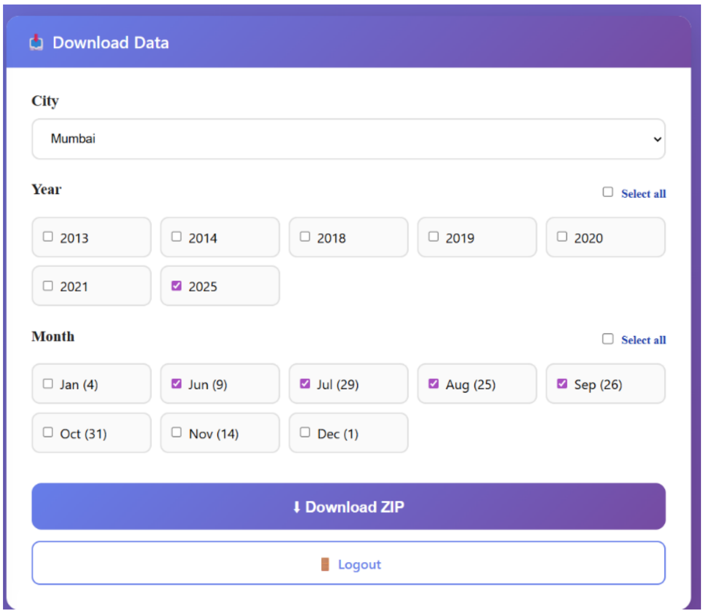

Figure 9: Data Discovery and Availability Mapping

3.5 Authentication and Role-Based Access Control

User authentication is a core component of the DDP methodology. Access to the system is restricted to authorized users through a secure login mechanism. Upon successful authentication, a user session is established and maintained throughout the interaction with the DDP.

Role-based access control is implemented to differentiate between **General Users** and **Administrative Users**. Based on the assigned role, users are presented with different interface elements and functionalities. General users are limited to raw data access and station visualization, while administrative users are granted access to advanced processing and visualization tools.

This role-based design ensures data security, prevents unauthorized operations, and maintains operational discipline within the system.

3.6 Data Staging and Temporary Workspace Management

When a user submits a data request, the DDP creates a temporary workspace dedicated to that request. Relevant raw data files are copied into this workspace based on the selected station, year, and month criteria.

For general users, the staged data are compressed into a single archive file and made available for download. For administrative users, the staged data may undergo additional processing steps before final outputs are generated.

To optimize storage usage and maintain system performance, the DDP incorporates automated cleanup routines. Temporary workspaces and generated archives are automatically removed after a predefined time interval, ensuring that obsolete data do not accumulate on the server.

3.7 Rainfall Intensity (RI) Filtering

Rainfall intensity-based filtering is an important analytical feature available to administrative users. This capability allows users to apply a predefined rainfall intensity threshold to disdrometer observations, retaining only those measurements that exceed the specified threshold.

RI filtering is particularly useful for excluding noise-dominated observations and focusing analysis on significant rainfall events. The filtering operation is applied during the data staging phase, ensuring that subsequent processing and visualization routines operate only on the filtered dataset.

This functionality supports targeted microphysical analysis and improves the interpretability of generated plots and statistics.

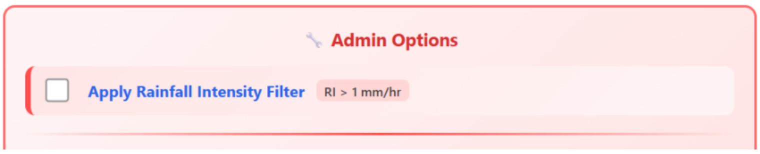

Figure 10: Data Filtering option

3.7.1 Mathematical Formulations for RI Filtering, DSD Computation, and Diurnal Analysis

The key data processing operations within the DDP are based on the following formulations, consistent with the DISDRODATA software conventions of the Distromet RD-80 disdrometer (Distromet, 2024).

Rainfall Intensity (RI): RI is computed directly from the raw drop count data across all 20 size classes using the relation:

$$\boldsymbol{RI = \frac{\pi}{6} \cdot \frac{3.6}{10^3} \cdot \frac{1}{F \cdot t} \cdot \sum_{i=1}^{20} (n_i \cdot D_i^3)} \qquad \text{---------------------- (1)}$$

where n_i is the number of drops measured in size class i during time interval t (s), D_i is the mean drop diameter of class i (mm), and F = 0.005 m² is the effective sensing area of the RD-80 sensor. The portal provides a user-configurable RI threshold, adjustable between 0.1 and 1 mm/hr, to selectively retain only those time steps corresponding to meaningful rainfall events and exclude noise-dominated observations.

Drop Size Distribution (DSD): The number density of drops per unit volume for each size class is computed as:

$$\boldsymbol{N(D_i) = \frac{n_i}{F \cdot t \cdot v(D_i) \cdot \Delta D_i}} \qquad \text{---------------------- (2)}$$

where $v(D_i)$ is the terminal fall velocity of drops of diameter D_i (m/s) and ΔD_i is the diameter interval of size class i (mm), both of which are instrument-defined constants for the 20 size classes of the RD-80 (Distromet, 2024). The mean DSD for a selected period is obtained by averaging $N(D_i)$ across all valid time steps T:

$$\boldsymbol{\bar{N}(D_i) = \frac{1}{T} \cdot \sum N(D_i)} \qquad \text{---------------------- (3)}$$

Diurnal Analysis: Hourly rainfall contributions are normalized by the total accumulated rainfall over the selected period to obtain the percentage occurrence for each hour h:

$$\boldsymbol{P(h) = \left[\frac{R(h)}{\sum_h R(h)}\right] \times 100} \qquad \text{---------------------- (4)}$$

where R(h) is the rainfall accumulation during hour h (mm). This normalization enables consistent inter-station and inter-seasonal comparison of diurnal rainfall patterns.

3.8 Seasonal Filtering and Aggregation

In addition to RI-based filtering, the DDP supports seasonal aggregation of disdrometer data. Administrative users can group observations into predefined climatological seasons, such as pre-monsoon, monsoon, and post-monsoon periods.

Seasonal aggregation enables comparative analysis of precipitation characteristics across different seasons and years. The aggregated datasets can be exported in spreadsheet format, facilitating further analysis using external tools.

The implementation of seasonal filtering within the DDP ensures consistency in the definition of seasons and eliminates manual errors associated with ad hoc data grouping.

Figure 11: Generate Seasonal Spreadsheet Option

3.9 Data Quality Considerations

While a comprehensive automated quality control pipeline is planned as a future enhancement, the DDP incorporates dedicated safeguards addressing the key aspects of data quality assurance as outlined below.

i. Instrument Errors and File Integrity Raw disdrometer files are stored in protected directories and are never modified by any user operation. All processing is performed exclusively on staged copies within isolated temporary workspaces, thereby protecting the integrity of original measurements against instrument read errors or file corruption.

ii. Noise Handling The portal provides a user-configurable rainfall intensity (RI) threshold, adjustable between RI ≥ 0.1 mm/hr to RI ≥ 1 mm/hr, allowing users to selectively exclude spurious low-intensity signals arising from instrument noise, insects, or debris, which are well-documented sources of measurement uncertainty in impact-type disdrometers (Distromet, 2024). This flexibility enables targeted noise rejection suited to different observational and climatic contexts.

iii. Missing Data The data housed within the DDP database is pre-filtered and quality-screened prior to insertion into the portal repository. Absence of data for a particular period therefore indicates either that observations were not acquired during that interval, or that the raw data did not meet the required quality standards during the pre-insertion screening stage and were consequently excluded. The dynamic data availability mapping mechanism reflects this by presenting only those months and years for which validated data files are confirmed to exist, preventing requests against missing, incomplete, or below-standard records.

iv. Consistency Checks Consistency of processed outputs is maintained through standardized processing routines applied uniformly across all selected datasets, reducing the risk of user-induced analytical inconsistencies. Advanced quality control measures, including automated fall velocity consistency checks, flagging of anomalous drop spectra, and inter-sensor cross-validation across network stations, are identified as priority enhancements under the future scope of the DDP.

3.10 Scientific Plot Generation

One of the key strengths of the DDP is its ability to automatically generate standardized scientific plots. These plots are produced using well-established methodologies and are intended to support routine analysis and reporting.

Figure 12: Plot Generation Option

3.10.1 Drop Size Distribution (DSD)

Drop Size Distribution plots represent the concentration of raindrops as a function of drop diameter. These plots provide insights into the microphysical characteristics of rainfall and are widely used in precipitation research.

Within the DDP, DSD plots are generated by averaging drop concentration measurements across selected time periods and size bins. The resulting plots are produced on logarithmic scales to capture the wide dynamic range of drop concentrations. The automated generation of DSD plots ensures consistency across analyses and reduces manual processing effort.

3.10.2 Diurnal Rainfall Percentage

Diurnal rainfall percentage plots illustrate the temporal distribution of rainfall occurrence over a 24-hour period. These plots are useful for identifying preferred rainfall hours and understanding diurnal variability in precipitation.

The DDP computes hourly rainfall contributions and normalizes them by the total rainfall amount to obtain percentage values. The resulting plots provide a clear representation of rainfall occurrence patterns and can be directly used for comparative analysis across stations and seasons.

3.10.3 Diurnal Contour Plot

Diurnal contour plots depict the joint variation of raindrop size distribution and time of day. These plots offer a comprehensive view of how drop size characteristics evolve diurnally.

The DDP generates contour plots by computing hourly mean drop size distributions and visualizing them as two-dimensional contour fields. This visualization technique enables identification of systematic temporal patterns and supports advanced microphysical analysis.

3.11 Google Map Based Station Visualization

The DDP integrates a Google Map based visualization module to display the geographical locations of disdrometer stations. Each station is represented by a marker on the map, providing users with an intuitive overview of the spatial distribution of the network.

Users can select stations directly from the map interface, which automatically updates the data selection parameters. This geospatial interaction enhances usability and supports spatially oriented analysis of precipitation observations.

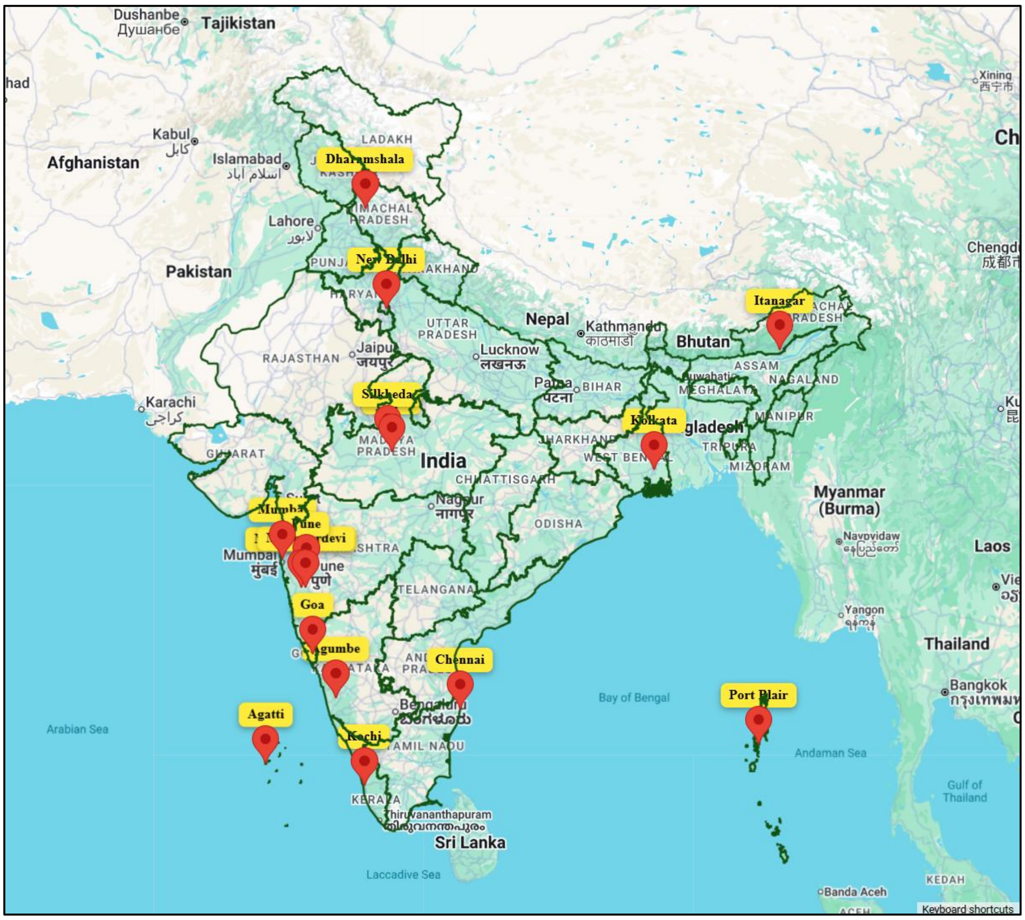

Figure 13: Interactive Google Map Based Station Visualization and Selection

4. DDP CAPABILITIES AND OUTPUTS

The DDP has been designed to support a wide range of user requirements, from routine raw data access to advanced data processing and visualization. The DDP consolidates multiple operational capabilities within a single web-based framework, thereby eliminating the need for separate tools or manual workflows. The capabilities of the system are closely aligned with the needs of scientists, researchers, and students working with disdrometer data.

One of the primary capabilities of the DDP is the provision of structured raw data downloads. Users can select observation stations, years, and months of interest through the DDP interface, after which the system automatically stages the relevant data files into a temporary workspace. These files are then compressed into a single archive and made available for download. This approach significantly reduces the time and effort required to locate and retrieve large numbers of data files manually.

In addition to raw data access, the DDP supports geospatial visualization of disdrometer stations. The integrated Google Map based interface provides a clear overview of the spatial distribution of observation sites. Users can interact with the map to identify station locations and select them directly for data retrieval. This spatial context is particularly useful for users working on regional or comparative studies.

For administrative users, the DDP offers an extended set of capabilities focused on data processing and analysis. These include the generation of processed datasets in spreadsheet format, application of rainfall intensity–based filters, seasonal aggregation of data, and automated generation of scientific plots. The availability of these capabilities within the same platform streamlines the analysis workflow and reduces dependence on external scripts or manual processing.

The DDP also maintains a record of recently generated outputs, allowing administrative users to review and verify results. This feature supports quality control and ensures consistency across repeated analyses.

Overall, the capabilities of the DDP are designed to support efficient data handling, promote standardized analysis practices, and enhance the scientific utility of disdrometer observations at IITM.

4.1 Raw Data Download

Raw disdrometer data constitute the foundational input for all subsequent analyses. The DDP provides a structured and user-friendly mechanism for accessing these datasets. Users can select the desired station, year, and month through the DDP interface, after which the system automatically identifies and stages the corresponding data files.

The staged files are compressed into a single archive to facilitate efficient transfer and download. This approach ensures that users receive a complete and organized dataset corresponding to their selection criteria, without the need to manually navigate complex directory structures. The raw data download capability is available to both general and administrative users.

4.2 Processed Data Outputs

Administrative users are provided with the capability to generate processed datasets in spreadsheet format. These processed outputs may include combined datasets spanning multiple months or seasons, as well as summary statistics derived from the raw observations.

The spreadsheet outputs are designed to be compatible with commonly used data analysis tools, enabling users to perform further analysis without additional data preparation. By automating the generation of processed datasets, the DDP reduces manual effort and minimizes the potential for errors.

4.3 Visualization Outputs

Visualization plays a critical role in interpreting disdrometer observations. The DDP generates a range of standardized plots that are widely used in precipitation microphysics research. These plots are produced in high-resolution formats suitable for inclusion in technical reports and presentations.

The automated generation of visualization outputs ensures consistency in plot formatting and methodology across different analyses. Users can rely on the DDP to produce reproducible and scientifically meaningful visualizations without requiring in-depth knowledge of plotting scripts.

5. SECURITY, DEPLOYMENT, AND MAINTENANCE

Security, reliability, and maintainability are key considerations in the design and operation of the DDP. The system has been deployed within the IITM intranet environment to ensure controlled access and compliance with institutional data management policies.

User authentication mechanisms restrict access to authorized personnel only. Role-based access control further ensures that advanced processing capabilities are available only to designated administrative users. This layered security approach protects the integrity of the data and prevents unauthorized operations.

The DDP has been designed to operate reliably under routine usage conditions. Automated background tasks manage temporary data storage by periodically removing outdated files and directories. This cleanup mechanism prevents uncontrolled growth of storage usage and helps maintain system performance over time.

Maintenance of the DDP is facilitated by its modular architecture. Individual components can be updated or replaced without affecting the overall functionality of the system. This design approach simplifies troubleshooting and supports long-term sustainability of the DDP.

5.1 Deployment Environment

The DDP is deployed on dedicated server infrastructure within the IITM intranet. The deployment environment has been configured to support continuous operation, secure access, and efficient handling of user requests. Server configuration parameters, such as port assignments and directory paths, are managed through centralized configuration files to ensure consistency across deployments.

5.2 Data Security and Integrity

Data security and integrity are maintained through a combination of access controls and operational safeguards. Raw disdrometer data are stored in protected directories and are never modified directly by user operations. All processing and filtering operations are performed on copies of the data staged in temporary workspaces.

This approach ensures that the original datasets remain intact and can be reused for future analyses. Role-based access control, described in Section 3.5, further ensures that administrative functionalities are restricted to authorized users only.

User activity on the DDP is recorded through server-side log files maintained by the application. These logs capture login events, data selection parameters (station, year, and month), processing operations initiated, and file download activity. The log records support operational auditing, performance monitoring, and troubleshooting of system issues.

Routine backups of the raw disdrometer data repository are performed on the IITM institutional server infrastructure in accordance with institutional data backup policies. This backup strategy ensures recovery capability in the event of hardware failure or accidental data loss, and complements the operational safeguard of never modifying original data files during DDP operations.

5.3 Maintenance and Operational Monitoring

Routine maintenance activities for the DDP include monitoring system performance, verifying data availability, and applying software updates as required. Log files generated by the system provide a record of user activity and processing operations, which can be used for troubleshooting and auditing purposes.

The modular design of the DDP allows new features or enhancements to be integrated with minimal disruption to existing operations. This flexibility is particularly important for accommodating evolving research requirements and expanding the scope of the disdrometer network.

6. SUMMARY AND CONCLUSION

The DDP represents a significant advancement in the management and utilization of disdrometer observations at the Indian Institute of Tropical Meteorology. By providing a centralized, secure, and user-friendly platform for data access and analysis, the DDP addresses many of the limitations associated with traditional, manual data handling approaches.

The integration of raw data access, geospatial visualization, automated processing, and standardized scientific visualization within a single system enhances operational efficiency and promotes reproducibility of analyses. The role-based access control mechanism ensures data security while providing flexibility for advanced analytical workflows.

Overall, the DDP serves as a robust operational tool that supports ongoing research, internal collaboration, and student training activities at IITM. Its modular and scalable architecture provides a strong foundation for future enhancements and long-term sustainability.

7. FUTURE SCOPE

While the DDP currently addresses key operational requirements for centralized data access, processing, and visualization, several avenues for future enhancement have been identified to further improve its scientific and operational capabilities. One potential direction is the integration of real-time or near-real-time data ingestion, enabling users to access disdrometer observations shortly after acquisition. Such a capability would support event-based monitoring and rapid analysis during significant rainfall events.

Additional future developments may include the provision of application programming interfaces (APIs) for programmatic data access, allowing automated retrieval of datasets for large-scale analyses and model integration. Integration of the DDP with other meteorological datasets, such as weather radar, satellite-based precipitation products, and reanalysis datasets, would enable multi-source comparative studies and enhance the interpretability of disdrometer observations.

The analytical capabilities of the DDP can also be extended through the incorporation of advanced data-driven techniques, including machine learning based methods for pattern recognition, classification of rainfall regimes, and identification of extreme precipitation events. In this context, the adoption of agent-based or agentic artificial intelligence frameworks presents a promising opportunity for automated and intelligent analysis workflows.

Agentic AI approaches can be employed to autonomously coordinate multi-city data comparison tasks, wherein software agents dynamically select stations, time periods, and analysis methods based on predefined scientific objectives. Such agents can automate comparative analyses of raindrop size distributions, diurnal rainfall characteristics, and seasonal variability across multiple locations, reducing manual intervention and ensuring methodological consistency. The integration of agentic AI can further support intelligent decision-making in selecting appropriate filters, visualization types, and comparative metrics based on data availability and quality.

Expanding the scope of visualization and analysis modules, along with extending controlled access to a broader user community under defined data-sharing policies, will further enhance the scientific utility and operational value of the DDP. Collectively, these enhancements will position the DDP as a scalable and intelligent platform capable of supporting advanced precipitation research and operational monitoring activities at IITM.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Director, Indian Institute of Tropical Meteorology (IITM), Pune, for providing the institutional support and facilities necessary for the development of the DDP. The authors also acknowledge the support of the ART–HACPL & ART-CI laboratories for facilitating disdrometer network operations and data management activities. Technical support received from collaborators and contributors involved in software development and system deployment is also sincerely acknowledged.

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