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Investigation and Optimization of Parsivel Laser Raindrop Spectrum Data Transmission Process in Qinghai Province

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Abstract

In order to address the common problems such as non-standard procedures and inconsistent storage formats in the process of transmitting meteorological observation data, it is particularly important to strictly follow the current regulations for the transmission and storage of observation data. This paper discusses the transmission process of Parsivel laser raindrop spectrum data in Qinghai Province, introduces the technical principle of the Parsivel laser raindrop spectrum instrument, and summarizes the current development trends of data transmission at home and abroad. It analyzes the original transmission process, proposes optimization measures and implements them. The practical results show that the existing problems have been solved after optimization, and the support capacity of observation data for meteorological prediction and forecasting business has been improved.

Keywords

Raindrop spectrometer, transmission process, meteorological business.

1. INTRODUCTION

In recent years, the China Meteorological Administration has set a goal to "accelerate the process of intensive integration and promote the joint construction and sharing of meteorological big data resources." Starting from providing "useful data" to empower the high-quality development of Qinghais meteorological information business, and adhering to the principle of "transmitting all that should be transmitted and collecting all that can be collected," the characteristic observation data of Qinghai Province, including Parsivel (OTT Hydromet Parsivel) laser raindrop spectrometer data, has been aggregated and integrated into the Qinghai Meteorological Big Data Cloud Platform, ensuring secure sharing and efficient utilization of the data.

Currently, in-depth analysis and research on raindrop spectral data have become an indispensable key component in the field of cloud microphysics. Standardized transmission, processing, storage, and sharing of Parsivel laser raindrop spectrometer observation data facilitate easy access to distinctive observational data for various business platforms and users. This paper discusses the transmission process of Parsivel laser raindrop spectrometer data in Qinghai Province, introduces the technical principles of Parsivel laser raindrop spectrometers, and outlines current trends in data transmission both domestically and internationally. It analyzes the existing transmission process, proposes optimization measures, and implements them.

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2. PARSIVEL LASER RAINDROP SPECTROMETER TECHNICAL PRINCIPLE

Parsivel Laser Raindrop Spectrometer is a high-precision multifunctional meteorological sensor based on the principle of laser attenuation by precipitation particles. It can accurately measure various meteorological parameters of precipitation particles, including liquid, solid, and mixed states, such as diameter, velocity, distribution density, rainfall intensity, cumulative rainfall, and visibility.

The primary technology used in this instrument is laser technology, which involves emitting parallel laser beams and using an array of phototubes as receiving sensors. When precipitation particles appear in the sampling area, the instrument intelligently records the width of the precipitation particles and the time it takes for them to pass through the sampling area. Advanced algorithms are then employed to accurately calculate the size and falling speed of the precipitation particles. The key to achieving this process lies in the instruments ability to sensitively detect how much the precipitation particles obscure the laser band during their descent, including the degree and duration of obstruction, thus enabling precise measurement of the particle size and velocity. Furthermore, the instrument can use these measurement data to perform real-time, high-precision monitoring and analysis of a series of important parameters, such as precipitation type, particle number density, precipitation intensity, and cumulative precipitation amount.

In meteorological observations, the PS 32 (P arsivel32) precipitation phenomenon instrument consists of a Parsivel laser raindrop spectrometer, an electronic optical sensing component, a data acquisition unit, and a power supply unit. The electronic optical sensing component employs advanced laser technology to achieve electronic optical remote sensing, capable of directly measuring the size and speed of raindrops, and quickly calculating rainfall amounts and precipitation types. The data acquisition unit is responsible for filtering and processing real-time observational data, completing this task through an internal microcontroller and using a serial server module to transmit observational data to the Qinghai Province Raindrop Spectrometry Observation Terminal. To prevent lightning strikes, a serial isolation device is configured between the collection system, sensors, and their communication links with the serial server as an isolation measure. The power supply unit includes a power supply box, a power management unit, and dual batteries, implementing power isolation measures. These measures involve current conversion, power management, and dual battery backup, providing power to the sensors and collectors. Specifically, the power for the sensors and collectors comes from the dual battery system, which is continuously charged and discharged by the power management unit. The power management unit receives power from the power supply box, which is responsible for converting between DC and AC, effectively reducing the risk of lightning strikesThe potential damage to the components and improved safety. This design allows the Parsivel laser raindrop spectrum instrument to operate unattended continuously and without maintenance, suitable for all kinds of harsh weather conditions.

3. DOMESTIC AND INTERNATIONAL DEVELOPMENT TRENDS

Differences in meteorological data standards across industries lead to variations in the methods, formats, and quality of data sharing. This also deviates from the standard requirements for observational data set by meteorological departments, making it difficult for these data to be directly adopted in meteorological operations. As the modernization and informatization of the meteorological sector accelerate, the establishment and improvement of standards and systems have become a key focus for both national and local governments. Meteorological standardization has thus become a significant hallmark of the modernization process in meteorology.

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Since 2018, the format and transmission of meteorological observation data have gradually entered a standardized phase. For instance, in areas such as ground observation, upper-air detection, radiation measurement, acid rain monitoring, radar observation, and agricultural meteorology, the development of data formats has been completed, and pilot trials have been implemented. Through these relentless efforts, China has initially established a comprehensive, clear-structured, and uniformly standardized system for meteorological observation data formats. According to the plan, meteorological departments at all levels are accelerating the formulation and application of foundational standards and norms for data resources and information platforms in the construction of meteorological informatization. The observational data from Qinghai Provinces raindrop spectrometer has yet to achieve standardized transmission and processing. Therefore, to further enhance the utilization efficiency and value of meteorological observation data, it is urgently necessary to thoroughly investigate and optimize the transmission process based on its observational data, and develop a set of scientific and standardized standards for data transmission and storage.

4. TRANSMISSION PROCESS INVESTIGATION

In recent years, with the continuous and rapid advancement of science and technology, meteorological observation techniques have entered an unprecedented period of rapid development. Qinghai Province has achieved several significant breakthroughs in the field of meteorological observations. In particular, in the collection and application of characteristic observation data, the Parsivel laser raindrop spectrometer, as an internationally leading advanced device, has successfully established over 10 stations in Qinghai Province and put them into use. This has greatly enriched the types of meteorological observation data in Qinghai Province and provided indispensable important data for key areas such as meteorological data research, improvement of weather forecast accuracy, scientific analysis of climate change trends, and disaster prevention and mitigation.

The Parsivel Laser Raindrop Spectrometer, as a high-precision meteorological observation tool, is primarily used in the following areas of Qinghai Province: First, real-time monitoring. By instantly transmitting raindrop spectrum data, meteorological departments can quickly grasp rainfall conditions, providing crucial data support for short-term weather forecasting and disaster warnings. Second, data storage. The collected observational data are securely stored in the database at the central station for subsequent analysis and research. Finally, basic research. Researchers use this data to delve into the physical mechanisms of rainfall, enhancing their scientific understanding of the precipitation process.

Despite the achievements of the Parsivel laser raindrop spectrometer data in Qinghai Province, most of the data is currently limited to real-time monitoring and basic storage. Issues such as non-standard data transmission processes and inconsistent storage formats persist. These problems lead to slow real-time query responses and low data utilization rates, lacking in-depth analysis and comprehensive application.

4.1. Transmission process optimization and implementation

To better utilize the characteristic observation data of Qinghai Province and promote the development of meteorological research and forecasting services, it is necessary to establish and improve the data sharing mechanism. By adopting methods such as unified transmission, standardized decoding and storage, and data sharing, we aim to fully leverage resources and avoid redundant construction, thereby enhancing the effectiveness of meteorological data application.

4.1.1 Unified transmission

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First of all, in order to ensure the security, integrity and reliability of the observation data transmission and application, the characteristic observation data collection terminal needs to adapt to the network layout of the provincial meteorological information center. The specific measures are as follows:

The Raindrop Spectrum Data Collection Center station is deployed in the DMZ (De M ilitarized Zone, non-military) area. The DMZ area is a secure subnet area between the Internet and LAN for internal and external routers, and corresponding access policies are configured to enhance the security and reliability of data transmission.

For the data transmission issue between station terminals and the central station, we address key elements such as the activation and configuration of IoT cards, as well as the transmission addresses and ports after mapping to the central station. We have set up internal and external network addresses for the Yudipu Data Center station to facilitate data transmission. By adopting China Unicoms IoT technology and implementing a whitelist policy in the access control of IoT cards, only specific cards are allowed to access specific addresses. This one-to-one address access mode ensures the security and reliability of Yudipu data transmission, accurately transmitting observational data from station terminals to the central station client.

Subsequently, the integration and distribution of meteorological data were efficiently completed relying on the provincial meteorological communication system. Given that the Raindrop Spectrum Data Center station was deployed in the DMZ area, a precise one-to-one access policy was configured on the firewall device to ensure smooth communication between the provincial meteorological communication system and the central station client.

In terms of data transmission, the FTP (File Transfer Protocol) protocol is selected, and data collection strategies and rules are carefully configured within the provincial meteorological communication system to ensure that data can be accurately and efficiently collected and transmitted to the server for subsequent processing. The entire detailed process is shown in Figure 1.

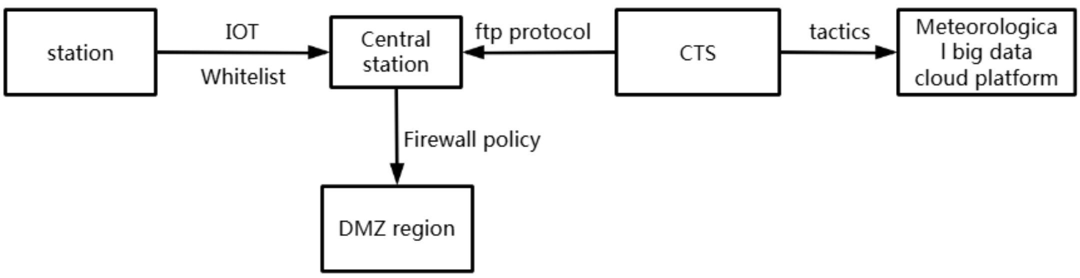

Figure 1. Data collection and distribution flow chart

4.1.2 Decoding storage

Based on the collected data, it is necessary to thoroughly analyze its format and potential application scenarios, clarifying the specific meaning of each component in the data, thereby establishing the framework of the data structure. On this basis, a detailed document titled "Parsivel Laser Raindrop Spectrometer Data Decoding Rules" should be compiled, which will elaborate on the decoding logic and standards of the data. At the same time, referring to the "Tianqing" New Data Access Standards, a raindrop spectrum data decoding program should be designed and developed, focusing on the effective decoding and processing of key elements.

In order to build a structured data storage system, the document "Parsivel Laser Raindrop Spectrometer Data Storage Structure" is formulated to clarify the structure design of the data storage table.

In the development of decoding programs, JAVA EE (Java Platform, Enterprise Edition) was chosen as the programming language, integrating advanced technologies such as the Spring B oot framework, JDBC (Java Database Connectivity), and RabbitMQ message queues to build a distributed framework. This framework is widely favored in the construction of multi-layer applications due to its flexibility, scalability, and open-source characteristics. JavaEE is a Java-based architecture built on the standard Java platform, inheriting many advantages of the standard version, such as the convenience of database access through the, JDBC API(Java Database Connectivity Application Programming Interface) implementation, which ensures "write once, run anywhere," CORBA (Common Object Request Broker Architecture) technology, and mechanisms that ensure data security for internet applications. It also fully incorporates technologies like EJB(Enterprise JavaBeans), JSP(JavaServer Pages). The JavaEE architecture design an integrated framework located in the middle layer, specifically addressing application needs that require both cost-effectiveness and high availability, reliability, and scalability.

The Spring B oo t framework serves as the foundational infrastructure for applications, with its core responsibility being to achieve pattern separation. Within the frameworks model components, it controls the business logic flow and leverages the JDBC framework to support the data access layer. On one hand, the Spring B oo t framework acts as a lightweight IoC (Inversion of Control) container, responsible for object discovery, location, instantiation, and managing dependencies between objects; on the other hand, it enhances the decoupling capabilities of the program, making the code easier to understand and maintain.

RabbitMQ message queue is specifically designed for task message processing and is an open standard at the application layer, aimed at serving message-oriented middleware. The core value of message middleware lies in decoupling components, ensuring that the sender and receiver of messages do not know about each others existence. Its server-side is developed using Erlang language and widely supports various client technologies, including Python, Java, PHP, and more. It is primarily used for message storage and forwarding in distributed systems, renowned for its excellent usability, scalability, and high availability. Its key features include message orientation, queue mechanism, routing functions (covering point-to-point communication and publish/subscribe patterns), high reliability, and security assurance. After consumers receive messages from the directory monitoring system, tasks are processed in real-time; they verify whether file content has been updated, check if the file template matches, transfer files (with rollback in case of failure), and store unstructured data.

At the same time, using asynchronous tasks (Async Task) improves the response speed and performance of the program. Asynchronous tasks allow the program to execute some time-consuming operations without blocking the main thread, so that the main thread can respond to requests from users at all levels faster and improve the user experience.

Using the aforementioned development model not only achieves a complete separation of views, controllers, and models but also independently separates the business logic layer from the data persistence layer. This way, regardless of how the frontend changes, minimal modifications are required to the model layer, and any changes to the database will not affect the frontend, significantly enhancing the reusability of the decoding program.

The main program consists of 7 packages, named config, dao, listener, model, service, util, vo, and a main program class called DataDecodeApplication. Among these, config primarily contains configuration classes, including data sources and thread pools; dao mainly handles database operations, featuring an interface for classes to implement; listener is a monitoring package, focusing on message queue listening; model represents the model layer, primarily handling data processing; service is the service layer, mainly generating log files for raindrop spectrum analysis; util includes relevant tool classes used in the program, such as data parsing tools and file handling tools.

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Define the appropriate storage structure. The data storage structure is shown below:

Table 1. Data storage structure

column name	Chinese name	data type	length	accuracy	non-empty
D_RETAIN_ID	record identification indicator	VARCHAR	200		deny
D_DATE_TIME	Data time	TIMESTAMP			deny
D_DATE_ID	Data storage materials are coded at four levels	VARCHAR	30		deny
D_IYMDHM	Time of entry into inventory	TIMESTAMP			deny
D_RYMDHM	Message reception time	TIMESTAMP			deny
D_UPDATE_TIME	Data update time	TIMESTAMP			deny
V01301	Station number (characters)	VARCHAR	100		deny
V01300	Station number (number)	NUMERIC	6	6	deny
V04001	year	NUMERIC	4	4	deny
V04002	moon	NUMERIC	2	2	deny
V04003	sun	NUMERIC	2	2	deny
V04004	time	NUMERIC	2	2	deny
V04005	component	NUMERIC	2	2	deny
V81001	Spectra data	VARCHAR	4000		deny
V81002	4680 Weather Phenomenon Code	NUMERIC	2	2	deny
V81003	precipitation intensity	NUMERIC	3	3	deny
V81004	Cumulative precipitation	NUMERIC	2	2	deny
V81005	radar reflectivity	NUMERIC	3	3	deny
V81006	Visibility in the rain	NUMERIC			deny
V81007	Precipitation kinetic flux	NUMERIC	2	2	deny
V81008	The sensor heats the current	NUMERIC	2	2	deny
V81009	service voltage	NUMERIC	1	1	deny
V81010	Status of the laser head	NUMERIC	1	1	deny
V81011	Sensor temperature	NUMERIC	1	1	deny
V_13206	Number of particles	NUMERIC	2	2	deny
V81013	Snow intensity	NUMERIC	2	2	deny
V81014	Collector number	NUMERIC	2	2	deny
V81015	sampling interval	NUMERIC	2	2	deny

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4.1.3 Data sharing

Log in to the "Tianqing" portal of Qinghai Meteorological Big Data Cloud Platform, apply for business account, register metadata, create data storage structure, and configure service interface.

Application for a business account: Submit an application to the platform to create a business account dedicated to managing and accessing Raindrop Spectrum data. This step is the basis for ensuring that data sharing can be accessed and operated on platform resources legally and securely.

Metadata registration: After successfully creating a business account, we will register the metadata of Yudrop data in detail. Metadata provides important information about the content, structure, source and context of the data, which helps users better understand and use the data.

Creation of data storage structure: Based on the previous in-depth analysis and understanding of raindrop spectrum data, a special data storage structure is created on the platform. This structure will ensure that data can be stored and managed in an efficient and orderly way, thus supporting subsequent data analysis and application.

Service Interface Configuration: Finally, a powerful service interface will be configured according to actual needs. This interface will support the rapid writing and reading of observational data information. At the same time, through a strict permission control mechanism, it ensures that only users who have been rigorously authenticated and authorized can access and use these valuable observational data

In the shared interface, historical data from observations in 2020 and 2021, as well as real-time data from current observations, has been integrated. To query this data, log into the Big Data Cloud Platform, select My Interfaces → Interface Testing Tool, choose Ground Data for the data category, and select SUFR_WEA_QH_RSD_TAB (Qinghai Raindrop Spectrum Data (A8601.0001.M001)) for the data name. Choose the service interface as needed to access the required original raindrop spectrum data. Historical data from observations from 2020 to 2022 has been integrated into the Meteorological Big Data Cloud Platform, allowing users to apply for raindrop spectrum interfaces to read the data.

5. CONCLUSION

By optimizing and implementing the Parsivel laser raindrop spectrum data transmission process, issues such as non-standard storage of characteristic observation data in Qinghai Province, inconsistent transmission formats, complex and inflexible data parsing, cleaning, and screening processes, and slow real-time queries have been resolved. This has led to the formation of a Parsivel laser raindrop spectrum dataset, promoting efficient sharing of Parsivel laser raindrop spectrometer observation data resources. As a result, various business platforms can conveniently access these unique data resources, further enhancing the support role of information technology in meteorological operations. This initiative also improves the support efficiency of informatization in Qinghais meteorological services, effectively advancing the coordinated development of meteorological information standardization.

REFERENCE DOCUMENTATION

[1] Wang Kefa, Zhang Huihui, Zhang Wei, et al. Parsivel Discrimination and treatment of abnormal data in precipitation observed by laser raindrop spectrometer [J]. Meteorological Science, 2011, 31(06): 732-736.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202504_11(4).0009

[2] Zhang Daoyuan, Qiao He, Li Yi, et al. Application research and data availability assessment of laser raindrop spectrometer in precipitation observation [J]. Meteorological Hydrology and Oceanography Instruments, 2023, 40(02):91-94.DOI:10.19441/j.cnki.issn1006-009x.2023.02.017.

[3] Qiao Wenwen, Guo Jie, Xie Lijiang. Visualization design and implementation of meteorological data transmission process [J]. Guangdong Meteorology, 2021,43(03):67-70.

[4] Yan Haiqian, Zhang Yuxin, Tian Jianbing. Design and development of laser raindrop spectrometer data application system in Qinghai Province [J]. Science and Technology of Qinghai, 2023, 30(01): 92-100.

[5] Zhang Wei, He Yao, Yang Liyuan. Research on Data Flow Optimization of Regional Automatic Weather Stations [J]. Meteorological Hydrology and Oceanography Instruments, 2020,37(01):28-30.DOI:10.19441/j.cnki.issn1006-009x.2020.01.008.

[6] Zhang Yuxin, Han Huibang, Guo Shiyu, et al. Raindrop spectrum characteristics and Z-R relationship of different precipitation cloud systems in summer on the southern slope of Qilian Mountains [J]. Research on Arid Areas, 2021,38(04):1048-1057.DOI:10.13866/j.azr.2021.04.16.

[7] Cui Qian, Jia Shijie, Fu Chao, et al. Analysis of DSG4 precipitation phenomenon instrument fault diagnosis and repair method [J]. Agricultural Disaster Research, 2022,12(12):14-16.

[8] Wang Ying, Xue Lei, Zhao Fang, et al. Progress in the standardization design and implementation of meteorological data format [J]. Progress in Meteorological Science and Technology, 2018, 8(01): 252-255.