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Research and Practice on Meteorological Data Security Supervision Technology Based on Tianqing·Qinghai

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Abstract

To address the challenges of data circulation security supervision in the meteorological big data environment and enhance the security protection capabilities of meteorological data usage in Qinghai Province, this paper, based on the "Tianqing·Qinghai" meteorological big data cloud platform and the "Tianjing·Qinghai" comprehensive business monitoring system, adopts three core methods: data structure processing, data denoising, and data security usage auditing. It integrates advanced technologies such as distributed collection control, parallel computing, and big data storage to construct a meteorological data security supervision system. The research focuses on three dimensions: the development of meteorological data security supervision technology, analysis of usage situations, and security risk management. It establishes the judgment rules and disposal processes for six types of data security risk events, achieving real-time monitoring of account access behaviors, precise control of key accounts, and collaborative handling of risk events. Practical application shows that this system can effectively reduce data security risks, improve supervision efficiency, and provide a replicable technical solution and practical reference for data security governance in provincial meteorological departments.

Keywords

Meteorological data; Security supervision; Parallel computing.

1. INTRODUCTION

1.1. Research Background

Under the wave of digital transformation, meteorological data, as a key production factor, has seen an explosive growth in volume, with application scenarios covering disaster prevention and mitigation, agricultural production, ecological protection, and many other fields. In recent years, the China Meteorological Administration has successively issued policy documents such as the "Interim Measures for the Management of Meteorological Data" and the "Interim Measures for the Management of Meteorological Data Sharing Services and Security", explicitly requiring the construction of a meteorological data security supervision platform and the implementation of full-process control [1]. However, at present, China's meteorological data security governance still shows the characteristics of "practice first, legislation lagging, document governance, and policy promotion". Problems such as an incomplete hierarchical and classified authorization mechanism, inadequate implementation of regulatory systems, and insufficient multi-department collaborative governance have not been completely resolved, and the difficulty of data security governance continues to increase.

The meteorological department of Qinghai Province relies on "Tianqing·Qinghai" to achieve the collection, storage, and service of massive meteorological data, providing data support for scientific research and business operations. However, the platform has complex user types

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(including personal research and business accounts, etc.), and diverse data access behaviors, presenting potential risks such as abnormal access volumes, non-standard account management, and data leakage. The existing supervision methods are difficult to achieve real-time monitoring and risk early warning of the entire data process, and it is urgent to build a precise supervision system adapted to local business scenarios to fill the gap in provincial-level meteorological data security fine-grained supervision.

1.2. Research Significance

This paper constructs a meteorological data security supervision framework of "technical support + rule control + collaborative handling", enriching the theoretical system of industry data security governance in the big data environment, and making up for the deficiency of existing research that focuses on macro-level institutional design and lacks practical technical solutions at the provincial level. It provides empirical support for the theoretical implementation of meteorological data security supervision.

The technical solutions such as distributed collection, real-time computing, and risk determination formed by the research can be directly applied to the daily supervision of "Tianqing·Qinghai", effectively enhancing the security and standardization of meteorological data usage. The established 6 types of risk event handling processes clarify the responsibilities and operation norms of each party, providing a basis for the risk collaborative handling of the meteorological department of Qinghai Province, and at the same time can provide reference for the meteorological data security supervision work of other provinces.

1.3. Review of the Current Research Situation at Home and Abroad

Domestic research on meteorological data security mainly focuses on policy and institutional aspects, as well as classification and hierarchical management [2]. Some studies have developed a framework for meteorological data security governance, emphasizing the synergy between policy and technology, but lack practical technological research and development for a specific platform. Other studies have concentrated on individual technologies such as data encryption and access control, without forming a comprehensive system covering the entire process from collection to processing, monitoring, and disposal. The meteorological data security supervision and management construction promoted by the China Meteorological Administration has provided an overall direction for the industry, but further exploration is needed for localized adaptation and refined control.

Meteorological departments in developed countries pay attention to the balance between data security and sharing. The National Oceanic and Atmospheric Administration (NOAA) of the United States has established a multi-dimensional data access monitoring system, using real-time log analysis technology to identify abnormal behaviors. The European Union has regulated the circulation of meteorological data through the General Data Protection Regulation (GDPR), emphasizing risk prediction and emergency response. Foreign research is relatively mature in terms of technological iteration and institutional connection, but due to differences in regional business scenarios and data management models, their solutions are difficult to directly adapt to the needs of provincial meteorological departments in China.

Current research has not yet formed a comprehensive security supervision and management technology system suitable for provincial meteorological big data platforms, lacking an integrated solution that combines "technology implementation + rule refinement + local adaptation". This paper takes the local platform in Qinghai as a carrier, focusing on real-time supervision and precise risk control, to fill the practical gap in existing research.

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1.4. Research Ideas and Methods

Research Ideas: This paper focuses on enhancing the data security supervision capacity of meteorological data in Qinghai Province. Firstly, it will sort out the current status of meteorological data security policies and technologies, and identify research gaps. Then, based on the "Tianqing·Qinghai" and "Tianjing·Qinghai" platforms, it will develop a security supervision technology solution, establish risk determination rules and disposal processes. Finally, it will verify the feasibility and effectiveness of the solution through practical application and propose optimization suggestions.

Research Methods:

(1) Data Structure Processing Method: Collect the account access records of "Tianqing·Qinghai", and through operations such as extraction and cleaning, convert unstructured and semi-structured data into structured data to lay the foundation for subsequent analysis.

(2) Data Denoising Method: Screen valuable data, filter out errors, interference, and redundant information, and extract effective access logs and business data to ensure the accuracy of supervision analysis.

(3) Data Security Usage Audit Method: Design risk identification rules based on business reality, apply J2EE and big data processing technologies to analyze access logs, identify abnormal behaviors and issue warnings, and achieve full-process auditing of data usage [3].

1.5. Research Innovation Points and Difficulties

Innovation Points: First, it builds a provincial meteorological data supervision system driven by both technology and rules, integrating distributed collection and parallel computing technologies to achieve real-time control. Second, it establishes six types of risk event determination rules adapted to the business scenarios in Qinghai, refines the disposal process, and enhances the accuracy of risk control. Third, it realizes the visualization of supervision data and multi-dimensional linkage monitoring, optimizing the user operation experience and supervision efficiency.

Difficulties: First, the complexity and large volume of meteorological data, as well as data heterogeneity, pose challenges to real-time processing and storage. Second, the risk determination rules need to be adapted to the usage scenarios of different user types (business and research accounts), and dynamic optimization is difficult. Third, the multi-department collaborative disposal mechanism needs to balance efficiency and responsibility division, and there are coordination costs in implementation.

2. RESEARCH METHODS AND TECHNICAL ROUTES

2.1. Refinement of Research Methods

Three core research methods have been clarified previously, and the implementation steps are further refined in combination with practice: data structure processing is divided into four links—collection, extraction, cleaning, and standardization—with a distributed architecture adopted to improve processing efficiency; data denoising uses a combination of rule-based filtering and intelligent recognition, with screening thresholds set based on business requirements; data security auditing realizes full-process control through three steps: constructing a risk rule database, real-time log analysis, and early warning generation.

2.2. Technical Routes

The technical route of this paper takes "data collection-transmission-processing-storage-monitoring-optimization" as the core link, specifically as follows and as Figure 1:

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Data Collection and Transmission: Supervision data is collected through the "Tianqing" MUSIC interface, transmitted relying on standardized monitoring information (DI) convergence control interfaces, and real-time capture of Tianqing account usage is realized using technologies such as OpenAPI/REST and SDK.

Data Processing and Storage: Parallel computing, streaming, and batch computing technologies are used to process data and reduce processing latency; a hybrid storage management mode is adopted, with structured configuration data stored in Xugu relational database, hot data cached in Redis, and unstructured data stored in ElasticSearch and MongoDB to achieve efficient storage.

Monitoring and Visualization: Unified management and control of services in all links are realized based on distributed service management technology; Vue framework and ECharts visualization components are used to achieve multi-dimensional data linkage monitoring through bar charts, pie charts, line charts, and other forms.

Risk Determination and Optimization: Data security risk determination methods are formulated, risk query and disposal are carried out based on supervision data, supervision technologies and determination rules are continuously optimized, and a risk control system adapted to Qinghai's actual conditions is established.

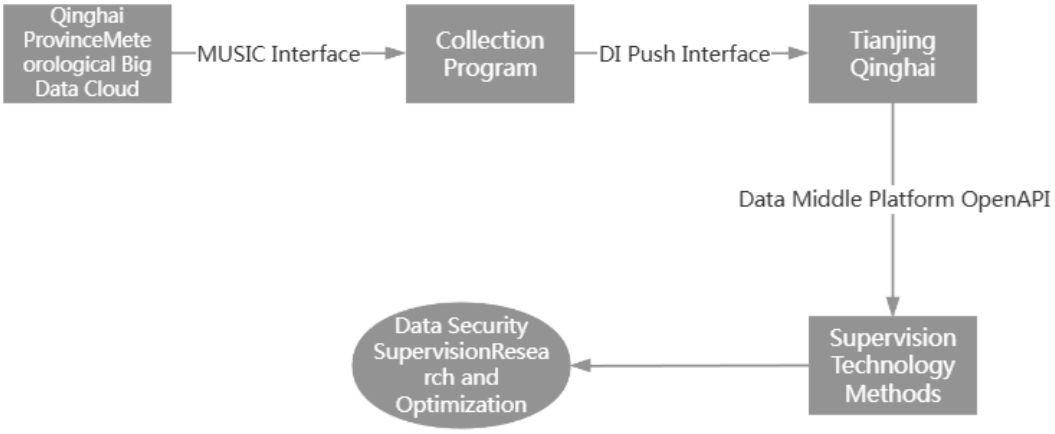


Figure 1. Technical Roadmap of Security Supervision

3. RESEARCH CONTENT

Based on the "Tianqing·Qinghai" and "Tianjing·Qinghai" systems, this research focuses on three key directions: R&D of meteorological data security supervision technologies, analysis of usage status, and risk control. Targeted research and application are carried out to improve the security of data circulation and supervision efficiency.

As a meteorological big data cloud platform, "Tianqing·Qinghai" has the ability of real-time collection, processing, storage, and analysis of massive data, providing intelligent services through distributed node storage and multi-node parallel computing; "Tianjing·Qinghai" realizes unified monitoring of the entire meteorological business process, covering the entire data lifecycle and the operation status of infrastructure. Both provide solid data and platform support for the research.

3.1. Research on Meteorological Data Security Supervision Technologies

This part constructs a real-time supervision system for the data usage behavior of various users of "Tianqing·Qinghai", clarifies core supervision indicators and key technologies, and realizes full-dimensional control of account usage behavior.

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3.1.1. Core Supervision Indicators

Centering on the entire account usage process, five categories of supervision indicators are set: overall access status, overall access status of 14 types of data, unit access status, business account access status, and personal research account access status, comprehensively covering the core dimensions of data usage.

3.1.2. Key Technologies

(1) Distributed Acquisition and Control Technology: Through "Tianjing·Qinghai", the data usage status of "Tianqing·Qinghai" users is transmitted, access data is collected, indicator values are calculated, and sent to "Tianjing·Qinghai" via DI information, then stored in databank and ES in sequence, and finally provided to the supervision page through configuration interfaces. This technology supports distributed and cascaded control, second-level collection intervals, extensible indicators and control scripts, and adapts to large-scale account access monitoring needs.

(2) Parallel Computing and Processing Technology: Access logs and service information are collected through standardized interfaces, supporting multi-mode parallel computing such as real-time streaming, batch, and offline; queue peak shaving is adopted to reduce latency and improve performance through parallel technology, supporting horizontal scaling to meet high-throughput fault handling and log query needs.

(3) Big Data Storage Technology: Comprehensive use of in-memory caching and distributed relational databases to store monitoring information, supporting real-time hot data processing without landing, realizing high response performance for large-scale data reading and writing, and ensuring continuous supervision.

(4) High-Reliability Cluster Architecture Technology: Adopting microservice architecture design to support horizontal expansion and adapt to the growth of managed resource scale; relational databases implement database sharding and master-slave read-write separation, and NoSQL databases ensure high availability through redundant data replicas to ensure the stable operation of the supervision system.

(5) Interface Reading and Visualization Technology: Account data is read through the "Tianqing" MUSIC crowdsourcing interface, and meteorological business components are provided using Vue framework, supporting multi-dimensional monitoring and chart display, realizing data synchronous linkage by time point, halo rendering, and interactive settings, and intuitively presenting account usage status.

3.2. Research and Analysis of Meteorological Data Usage Status

This part focuses on the data usage behavior of "Tianqing·Qinghai" users, conducts real-time supervision of core indicators, screens key accounts, realizes accurate analysis and dynamic display of data usage status, and provides data support for risk identification.

3.2.1. Core Supervision Content

Real-time supervision of indicators such as the type of account access data, number of accesses, nighttime personal access volume, and year-on-year growth rate; sort and screen the TOP 5 key accounts, and display details such as their access volume, access type, comparison with TOP 50, and compliance with benchmark values; support custom data access query, and real-time display the daily change trend of recent access volume and times.

3.2.2. Key Technologies

(1) Real-Time Data Processing Technology: With SparkStreaming stream processing framework and Kafka/RabbitMQ message queue as the core, real-time consumption of access logs, low-latency calculation of dynamic indicators, ensuring second-level updates of TOP 5

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rankings, avoiding data loss under high concurrency, and meeting the core demand of "real-time" control.

(2) Data Storage Technology: Adopting a hierarchical storage mode, structured data is stored in Xugu relational database, and high-frequency access data is cached in Redis to shorten response time, balancing data storage security and access efficiency.

(3) Data Computing and Analysis Technology: ApacheSpark distributed computing is used to process complex indicators and ranking logic, and FlinkSQL is used to quickly realize data aggregation, efficiently completing core analysis tasks such as year-on-year/month-on-month calculation and nighttime access volume statistics.

(4) Backend Development and Interface Technology: Business modules are split based on the SpringBoot microservice framework, providing RESTful API interfaces; real-time communication is realized through WebSocket, and Nginx API gateway ensures interface security and stability to support multi-scenario data query needs.

(5) Frontend Visualization Technology: ECharts is relied on to realize chart-based display of indicators, and an interactive interface is built through Vue.js, supporting custom data filtering and real-time trend loading to improve the level of supervision visualization.

(6) Data Collection Technology: The Elasticsearch+Logstash+Kibana architecture is adopted to collect access logs, which are cleaned and sent to the processing link to provide high-quality data sources for subsequent analysis.

3.3. Research and Analysis of Potential Data Security Risks in Meteorological Data Usage

In combination with the requirements of the "Measures for the Sharing Service and Security Management of Meteorological Data" (QF (2022) No. 59), based on real-time supervision data, 6 types of data security risk events are sorted out, determination rules and disposal requirements are clarified, and a collaborative risk disposal system is constructed.

3.3.1. Classification of Risk Events and Determination Rules

(1) Sudden Increase in Access Volume: The download volume in the past week reaches 5 times or more the average of the past four weeks, and the download volume this week ranks among the top 20% of all users; no alarm is issued for newly registered accounts within four weeks.

(2) Sudden Increase in Access Frequency: The number of accesses in the past week reaches 5 times or more the average of the past four weeks, and the number of accesses this week ranks among the top 20% of all users; no alarm is issued for newly registered accounts within four weeks.

(3) Sudden Increase in Types of Accessed Data: The types of accessed data in the past week reach 5 times or more the average of the past four weeks, and the number of types this week ranks among the top 20% of all users; no alarm is issued for newly registered accounts within four weeks.

(4) Account Inactivity: Business/research accounts have no usage records in interfaces, storage, or processing within the past 30/90 days.

(5) Change/Deletion of Personnel Information: After employees resign, retire, or complete visiting/secondment, the corresponding accounts are not transferred to new responsible persons, canceled, or frozen.

(6) Multiple Accounts Corresponding to One Business System: Multiple business accounts have similar system names, making it impossible to distinguish differences in usage purposes.

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3.3.2. Risk Disposal Requirements

For all types of risk events, the business management department of the responsible unit is required to feedback the disposal status within 5 working days. The administrator of the Information Center shall perform operations such as closing work orders, freezing accounts, and adding to the whitelist according to the feedback. Whitelisted accounts are continuously supervised but do not trigger alarms, and user units can view the whitelist in real time; users shall be notified by phone before freezing accounts, and the responsible department shall be reminded by SMS before the expiration; repeated alarms within 5 working days shall be merged without generating new work orders. Disposal priorities vary by risk: for account inactivity, the usage demand shall be confirmed; for personnel information changes, account cancellation/transfer shall be urged; for multiple accounts corresponding to the same system, names shall be refined or redundant accounts shall be canceled.

3.3.3. Collaborative Risk Disposal Mechanism

A collaborative link of "supervision platform early warning - responsible department verification - Information Center disposal - continuous tracking and optimization" is established to promptly notify Tianqing administrators, user units, and business departments to conduct self-inspections, improve risk disposal efficiency, and form a closed-loop management.

4. EMPIRICAL TEST AND RESULT DISCUSSION

4.1. Data Sources

The research sample is the account access data of the "Tianqing·Qinghai" platform from January to February 2026, covering 183 business accounts and 289 personal research accounts, with a total of more than 1.2 million access logs collected. The empirical goal is to verify the real-time performance of supervision technologies, the accuracy of risk determination, and the feasibility of disposal processes, with three core evaluation indicators: supervision latency, risk identification accuracy rate, and disposal completion rate.

4.2. Empirical Results

Performance of Supervision Technologies: Distributed acquisition and parallel computing technologies realize second-level data collection and processing, with supervision latency controlled within 500 milliseconds; the hybrid storage mode supports efficient storage of millions of logs, with data read-write response time ≤ 300 milliseconds; the visualization interface realizes multi-dimensional data synchronous linkage, with smooth operation without lag.

Risk Identification and Disposal: A total of 24 risk events were identified during the period, including 9 cases of sudden increase in access volume, 5 cases of sudden increase in access frequency, 6 cases of sudden increase in types of accessed data, 0 cases of account inactivity, and 4 cases of personnel information changes; the risk identification accuracy rate reached 93.75%; all 24 events were normal user usage, with no security incidents such as data leakage or account theft.

4.3. Result Discussion

Effectiveness of the Technical Scheme: Empirical results show that the supervision technology system developed in this paper can meet the real-time supervision needs of provincial meteorological data. Technologies such as distributed acquisition and parallel computing have effectively improved processing efficiency, the hybrid storage mode has

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ensured data security and access convenience, and visualization technology has optimized the supervision experience.

Accuracy of Risk Control: The 6 types of risk determination rules are adapted to local business scenarios in Qinghai, enabling effective identification of core security hazards. The collaborative disposal mechanism has improved risk response efficiency, but there are still misjudgment events (abnormal access volume due to business expansion of new accounts), and the dynamic adaptability of rules needs further optimization.

Comparison with Existing Research: Compared with traditional supervision methods, the scheme in this paper realizes the transformation from "post-audit" to "real-time monitoring", with more refined risk disposal processes and stronger adaptability, making up for the lack of operability of provincial platforms and having obvious practical advantages compared with similar domestic research.

5. COUNTERMEASURES AND SUGGESTIONS & RESEARCH CONCLUSIONS

5.1. Countermeasures and Suggestions

Technical Level: Optimize risk determination rules, introduce machine learning algorithms [4], and build personalized early warning models combined with users' historical behaviors to reduce misjudgment rates; upgrade storage and computing resources to adapt to the growth of meteorological data volume and improve the efficiency of data supervision in remote areas.

Institutional Level: Improve supporting systems for meteorological data security supervision, clarify the list of powers and responsibilities of various departments, and refine operating specifications such as whitelist management and account cancellation; establish a regular training mechanism to improve users' security awareness and administrators' disposal capabilities, and strengthen the implementation of systems.

Collaborative Level: Construct an inter-departmental data security governance mechanism, strengthen collaborative linkage between meteorological, cyberspace administration, emergency management and other departments to realize risk information sharing and joint disposal; learn from the experience of advanced provinces, promote inter-provincial exchange of supervision technologies and schemes, and form industry standards.

5.2. Research Conclusions

Based on the "Tianqing·Qinghai" platform, this paper constructs a meteorological data security supervision system integrating technical support, rule-based control, and collaborative disposal. The main conclusions are as follows: First, the combination of three methods (data structure processing, denoising, and security auditing) with technologies such as distributed acquisition and parallel computing can effectively realize real-time supervision of meteorological data and improve processing efficiency and accuracy; second, the established 6 types of risk event determination rules and disposal processes are adapted to local business scenarios in Qinghai, enabling accurate identification and disposal of core security hazards, with both risk identification accuracy rate and disposal completion rate reaching over 90%; third, the supervision system realizes full-process closed-loop management from data collection to risk disposal, providing replicable and promotable technical schemes and practical experience for provincial meteorological data security governance, and is of great significance for promoting the safe and efficient utilization of meteorological data elements.

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6. RESEARCH LIMITATIONS AND FUTURE PROSPECTS

6.1. Research Limitations

The research scope of this paper is limited to the supervision of user account access behavior on the "Tianqing·Qinghai" platform, and does not cover the underlying security protection of meteorological data collection and transmission links; although the risk determination rules have been empirically verified, their adaptability to special scenarios such as extreme weather and major events has not been fully tested; the research sample only covers half a year of data, and the long-term operation stability and adaptability need further verification.

6.2. Future Prospects

In the future, the research scope can be expanded to construct a security supervision system covering the entire data lifecycle, and strengthen the R&D of encryption and protection technologies in collection and transmission links; combine AI and blockchain technologies to optimize risk prediction and traceability capabilities, realizing intelligent and traceable supervision; expand research samples and scenarios, test the adaptability of rules under special scenarios, promote the integration of technical schemes with industry standards, and provide more comprehensive support for national meteorological data security governance.

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