AMeDAS: Supporting Mitigation and Minimization of Weather-related Disasters

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The Automated Meteorological Data Acquisition System (AMeDAS) is a meteorological observation system comprising approximately 1,300 stations scattered throughout Japan. It is operated by the Japan Meteorological Agency (JMA) to gather weather data such as amounts of precipitation, wind direction and speed, air temperature, sunshine duration, and depth of ground snow. Quality-assured and statistically processed observational data are used for issuing weather warnings and advisories as well as weather forecasting at JMA, and disseminated throughout Japan via JMA's Automated Data Editing and Switching System (ADESS), while some of this data is also provided to Asian and other countries via the same route. Having secured a commission from JMA for a system upgrade at the AMeDAS Center in FY2015, Fujitsu is currently engaged in system development. This paper describes some of the initiatives involved in the system upgrade. They are performed from the perspective of operational continuity in the case of portable data collection platform (DCP) precipitation recorders, which allow observation work to quickly recover from the impact of typhoons and earthquakes. One initiative enhances work efficiency by automatically detecting abnormal data fragments. This paper also presents accounts of the maintenance system which we at Fujitsu offer to ensure stable, round-the-clock operation of the system, involving our systems engineers in charge, relevant product departments, as well as support and sales teams.

1. Introduction

In Japan, before the Japan Meteorological Agency (JMA) introduced the Automated Meteorological Data Acquisition System (AMeDAS) in 1974, weather observation was manually conducted, and the data collection had its limits. Today, the AMeDAS makes it possible to measure the amounts of precipitation at 17 km intervals, and wind direction/speed, air temperature, and sunshine duration at 21 km intervals. As the system evolves, dedicated observational equipment and networks are developed, and the observation is progressively automated and unmanned, thereby enhancing the data-collection efficiency. Furthermore, a dual-base system was introduced in 2007. With a base installed in eastern and western Japan, it ensures operational continuity in the event of natural disasters and other calamities where one base becomes incapacitated.

In 2015, the AMeDAS underwent a system upgrade, adopting the latest data processing technology for higher efficiency and reliability.[1] Having been successful in securing the commission from JMA, Fujitsu is now undertaking the system delivery. In this paper, we describe the basic AMeDAS configurations, and explain major improvements made to the system.

2. Basic configurations

The AMeDAS comprises approximately 1,300 stations distributed throughout Japan, and gathers weather data such as amounts of precipitation, wind direction and speed, air temperature, sunshine duration, solar irradiance, depth of ground snow, humidity, and atmospheric pressure (**Figure 1**). The collected data are converged into the AMeDAS Center System (hereafter, the Center System) for quality verification and statistical processing.

The Center System is an important social information system that requires round-the-clock operation. Therefore, it must be highly reliable and durable. To realize this, the East Center System and West Center

System form a parallel configuration to process data simultaneously. The post-process observational data are used by JMA for providing the nation with everyday weather information, and issuing weather forecasts as well as varying degrees of weather warnings and advisories. The data are also distributed to governmental

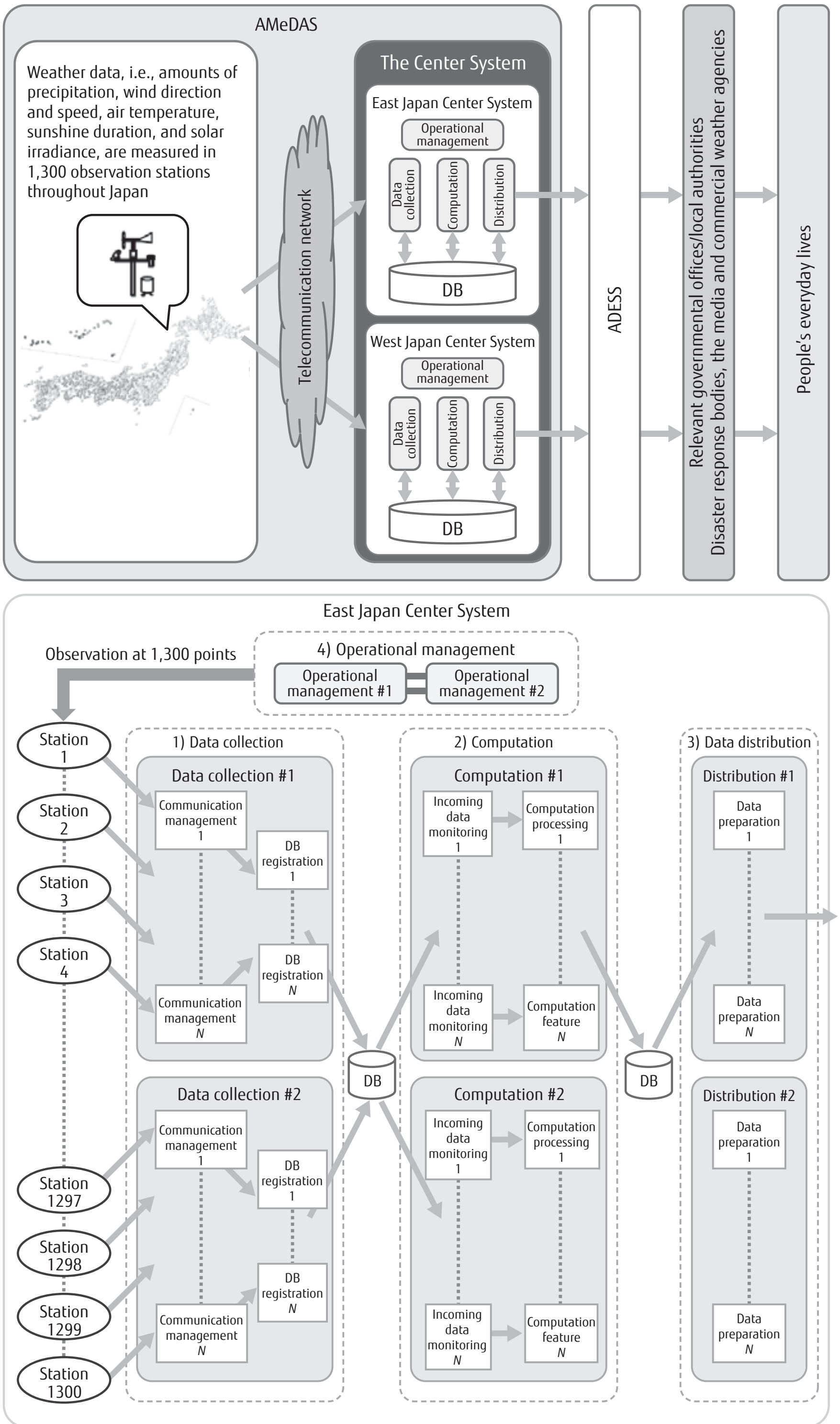

Figure 1
Overview of the Center System.

offices, the media and commercial weather agencies via JMA's dedicated Automated Data Editing and Switching System (ADESS).

The Center System has the following four main functions.

1) Data collection

Connected to stations throughout the country, it receives real-time observational data and stores them in a database (DB).

2) Computation

It processes the observational data thus collected through statistical computation. The system also verifies the data quality.

3) Data distribution

After computation of the data, the system stylizes the data into certain formats and distributes them to external users.

4) Operational management

The system monitors all servers throughout the country. It also monitors and centrally manages the performance of all stations in the country.

Fujitsu collaborated with JMA to develop these functions. We will explain each of their features in the following sections.

3. Data collection

In order to connect to all stations in the country and gather observational data at the minimum interval of every minute, it is crucial to minimize missing data, and to enable quick recovery of the lost segments. In this section, we will explain the data collection feature in terms of its mechanism to prevent impaired data, and how operational continuity is enhanced.

1) Mechanism to prevent missing data

The observational data generated at stations are transmitted to the Center System in real time through a telecommunication network for the AMeDAS. **Figure 2** shows the relationship between the station and this feature of the Center System.

This feature normally takes a redundant configuration with two pieces of equipment in order to prevent the data collection from being suspended due to a hardware malfunction or network errors. Upon startup, stations attempt to connect to Data collection

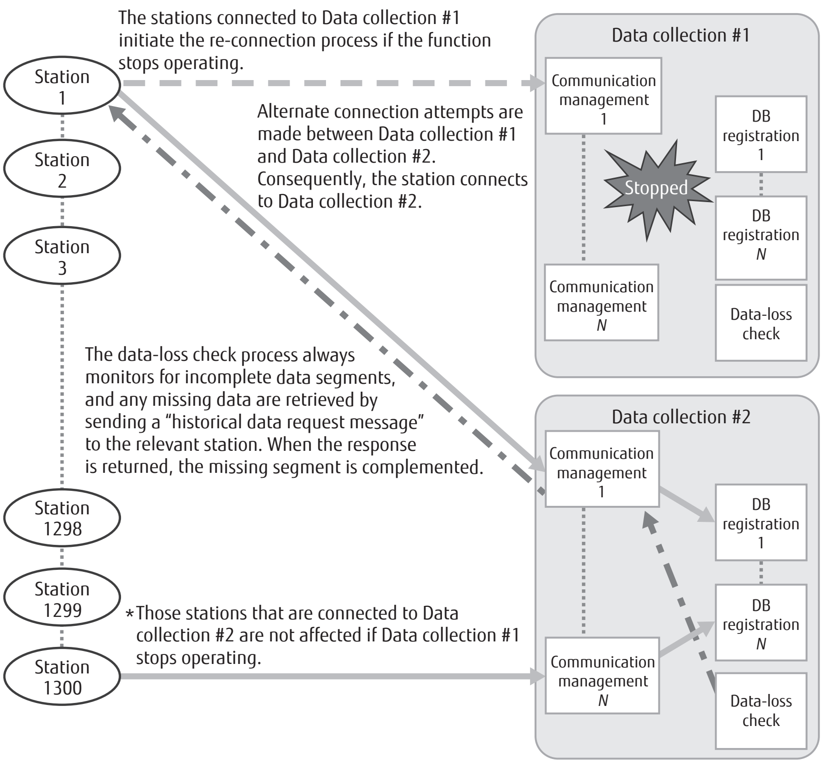

Figure 2
Coordination of station and data collection feature.

#1. Where the connection fails, it tries to connect to Data collection #2. If the second attempt also fails, the station will revert to Data collection #1 to establish a connection. Meanwhile, the pieces of equipment stand by to accept connection requests from stations through the ports assigned to each station. Priority is given to the latest connection request to ascertain that a connection will be established even if earlier requests resulted in a mismatch due to a network error. This mechanism enables automatic rerouting to the second data collection device upon a failure of the first device, thereby ensuring continued data transmission and collection.

The AMeDAS is also equipped with a system to prevent missing data without having delivery confirmation. More specifically, there is a process to verify observational data for missing segments (data-loss check process) that is independent of the data transmission management process. Every time data is received, the data-loss check process verifies the continuity of the data, and it sends a "historical data request message" to the station in question for a resending of the data when a portion of it is missing. This mechanism enables automatic recovery of the missing portion of observational data.

2) Improvement of observational continuity

If natural disasters such as earthquakes, tsunami, and typhoons cause damage to the stations, the observational data necessary for protecting the disaster-stricken areas will become inaccessible. The data collection feature of the Center System is made compatible with the data format for the portable data collection platform (DCP) precipitation recorders to facilitate early recovery of the observational work.

The portable DCP precipitation recorder is powered by photovoltaic (PV) fuel cells, and transmits data via a satellite network, making it easy to be installed even in a demanding environment such as a disaster zone. **Figure 3** describes the data communication method between the Center System and portable DCP precipitation recorders.

The satellite telecommunication networks are inferior to the networks that use dedicated lines in terms of the transmission quality. It was anticipated that, if the same communication method as the permanent observation stations is adopted, it may result in a high incidence of data resending, and the line may become overworked. Therefore, we have decided that the data-loss check is not applied to this data transmission, and instead a 20-minute volume of the latest data is received at 10-minute intervals. In this method, the 10-minute lag time ensures that the same observational data are transmitted twice to cover any missing segments.

The portable DCP precipitation recorder was deployed successfully following the major earthquakes that devastated Kumamoto Prefecture in 2016, and it enabled precipitation observations to be resumed the day after the event.

4. Computation

The computation feature is responsible for

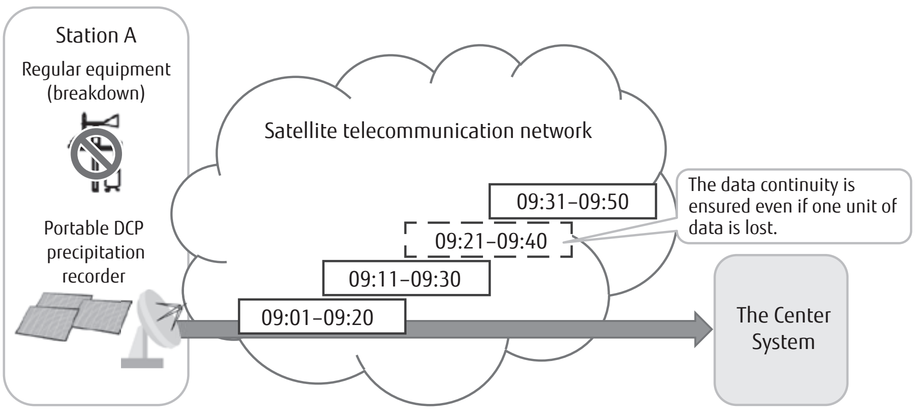

Figure 3
Overview of portable DCP precipitation recorder.

obtaining data from the DB, processing them by nearly 1.35 million different calculations and checking the data quality and probability. The challenge in these tasks is to ensure efficiency in performing the computation for this vast number of items quickly. This section describes the work conducted to realize the expected level of efficiency, and explains the method of calculating meteorological data, as well as the quality verification system.

1) Realization of efficiency in computational processing

A unit of observational data that is collected at 1-minute intervals consists of six segments of data obtained every 10 seconds. Each segment includes a total of 10 factors, such as the amount of precipitation, wind direction and speed, and air temperature. The precipitation data are used to obtain the cumulative volume of rainfall during the past 1 minute, 1 hour, 24 hours, and so on. In a similar manner, the wind direction and speed, the air temperature, and other factors, and so on are processed. The overall computational items amount to 173 in total. Multiplying this figure by the number of observational stations, the number of per-minute computational items becomes approximately 1.35 million (1,300 stations multiplied by 173 items, and again by 6 values) (**Figure 4**).

The computation feature must be able to complete these 1.35 million items within one minute before the subsequent data set is collected. The feature meets this performance requirement by adopting mechanisms designed to minimize the stand-by time and thus enhance the efficiency of data processing. There are two mechanisms as described below.

- Non-synchronization between two processes

The timing of data transmission from the stations is not regular, and depends on the progress of data processing at the stations, and the network traffic. In order to ensure that the computation commences as soon as the data are received, it is necessary to monitor the observational DB frequently for the available data. This necessitates accessing the DB, which increases the inevitable waiting time for input/output (I/O) responses. In addressing this issue, two independent processes were prepared: data collection monitoring to monitor the storage of observational data, and computational processing for executing the computation. Applying a queue management method to an asynchronous communication between these two processes, the waiting time for I/O responses is reduced.

- Reduction of DB access

While the computation feature utilizes history data up to the latest 24 hours, as in a 24-hour cumulative precipitation calculation, a significant amount of waiting time for I/O responses would be generated if these data were loaded entirely from the DB. To reduce this waiting time, access to the DB is reduced by storing the data for the latest 24 hours on, and loaded from, shared memory. This enhances the data-processing efficiency.

The system described above realized more than a 10-fold performance improvement compared with the Center System of the previous generation in terms of processing speed, and it is now capable of computing approximately 1.35 million items within one minute.

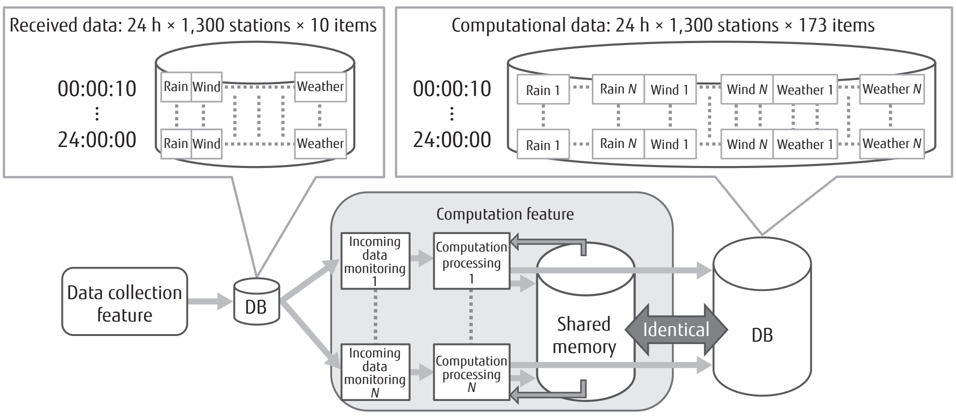

Figure 4
Overview of the computation feature.

2) Meteorological calculations

For a long time, weather conditions were identified through observations conducted manually by JMA staff. In recent years, however, automated weather observation has been gaining wider recognition, and it involves the use of a device known as a visibility meter[2)] in view of the trend toward automation and efficiency enhancement. The visibility meter comprises a projector and detector. The former sends a laser beam, which travels through the atmosphere and scatters before reaching the detector. The visibility meter combines measurements from the detector with other meteorological data to generate weather observational data (e.g., rain, snow, sleet, etc.), and transmits them to the Center System.

The meteorological calculation feature uses this information, and modifies the output by referencing other data such as air temperature and humidity, to obtain the weather types. For example, the visibility meter sends data to indicate sleet. The meteorological calculation feature looks up the temperature and humidity, and if it is warm and humid, the system modifies the information from the visibility meter and identifies the weather as rain, while the opposite condition means the system modifies the information to snow.

The meteorological calculation makes it possible to accurately record changes in the weather during the course of a day.

3) Quality verification system

Sometimes, it happens that an observational device at stations suffers a malfunction and sends data with abnormal values like, for example, an air temperature of −50°C. These irregular data are extracted by the automatic quality control (AQC) system, which in turn flags the data for use restriction or warning, depending on the extent of the irregularity. As examples, five cases of irregularity responses are described below.

- If more than *x* minutes of sunshine were recorded in the latest 10 minutes, but more than *y* mm of rainfall were also reported during the same period, then the solar irradiation value is tagged with a property description “credibility possibly questionable.”
- If more than *x* minutes of precipitation were recorded, but the humidity is below *y* %, then the humidity value is tagged with a property description “credibility possibly questionable.”
- If solar irradiation is recorded after sunset or before sunrise (the sunset/sunrise times are calculated based on the geographical coordinates and calendar), then the solar irradiation value is tagged with a property description “credibility highly questionable.”
- If a wind speed of more than *x* m/s is recorded, but the wind direction remains unchanged for more than *y* minutes, then the wind direction value is tagged with a property description “credibility highly questionable.”
- If a wind speed of 0 m/s is recorded, but the wind direction changes more than *x* degrees continuously for more than *y* minutes, then the wind speed value is tagged with a property description “credibility highly questionable.”

When the irregularity cases as described above are detected by the AQC, agents responsible for the station, such as a local meteorological observatory, will be notified. The agent then follows a prescribed task flow to inspect and adjust the observational device and modify the observational data from the Center System interface, to improve the data quality.

A new feature has been added that automatically detects irregular changes in the observation values (**Figure 5**). It compares the expected value derived from the value of a certain past period, to which the least squares method has been applied, against the calculation result. And if the difference is greater than the threshold, the value is tagged with the “irregular value” label, meaning that it requires a discussion. Subsequently, responsible staff members are notified.

The threshold value used in the judgment may be configured by months or by geographical boundaries, to reflect seasonal/regional differences. The introduction of the irregular value made it possible to automatically detect suspicious irregular data, which the AQC could not identify previously. Ultimately, this provides support so that staff are prompted to verify the irregular values.

5. Operation management

In order to ascertain reliable, round-the-clock operation of the AMeDAS, there must be a system that displays the operational statuses of the Center System and all observational stations in an efficient manner.

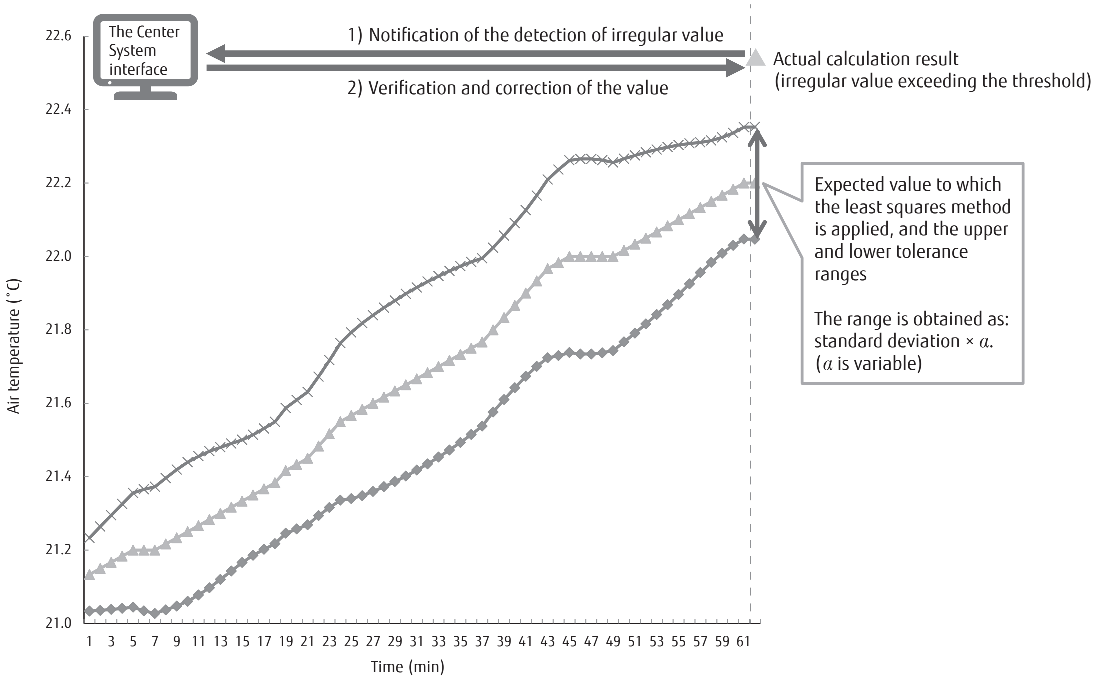

Figure 5
Example of atmospheric temperature irregular value.

It must enable prompt detection of, and response to, any irregularities. To realize such a system, the Center System employs FUJITSU Software Systemwalker Centric Manager, a piece of integrated management middleware for the operational management. This facilitates centralized monitoring of the servers, network devices, and observational stations throughout the country. If a problem is detected, it sends out an alert. Status monitoring and alerts are illustrated in **Figure 6**.

Basically, the alert is signaled by an alarm sound and warning indicator to call for the attention of the on-site JMA staff. An e-mailing option is incorporated for critical alerts. This e-mail-based alert is sent not only to the JMA staff responsible for AMeDAS operation, but also to system operation support (Fujitsu) to facilitate quick initial responses.

The alarm sound and warning indicator as well as e-mail-notification are configured with flexibility by means of the action definition feature of the Systemwalker Centric Manager. For example, it is possible to set different alarm sounds and/or warning indication colors according to the level of criticality, and different e-mail addresses for certain types of messages. This feature gives a degree of flexibility to the monitoring, and enables necessary responses to be made promptly in the case of an emergency.

6. Emergency support

Apart from these various features of the AMeDAS system, emergency support is another crucial feature (**Figure 7**). The AMeDAS must operate throughout the year, and deliver meteorological data to the nation accurately without delay. To ensure that the AMeDAS serves this important mission, Fujitsu has developed a group-wide support system.

The Technical Account Manager (TAM) is a service platform division of Fujitsu FSAS Inc., and it responds to emergency calls at any time, day or night. It receives automated e-mail-alerts in an emergency, and initiates troubleshooting immediately. When an emergency response is required, TAM contacts the systems engineers (SEs) responsible for AMeDAS operation using an emergency contact list to coordinate responses. The SEs carry dedicated mobile phones with them for responding to the emergency calls. Furthermore, they communicate with JMA staff and the staff of the manufacturing division for the relevant products, such as middleware, platform software, etc. They then work to

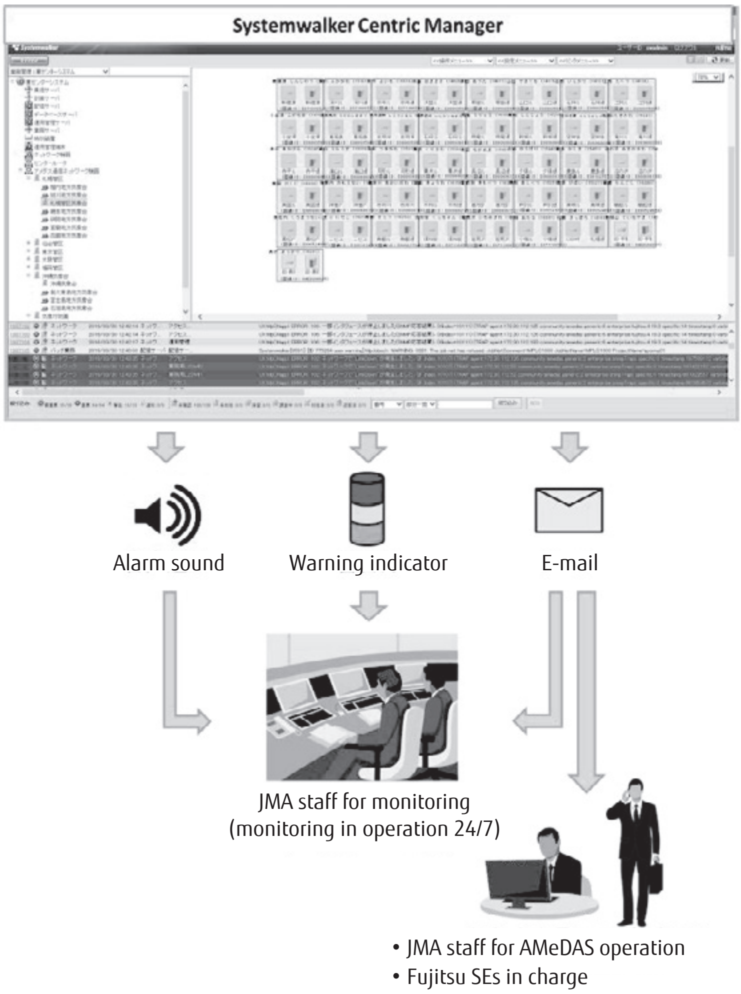

Figure 6
Overview of status monitoring and alert system.

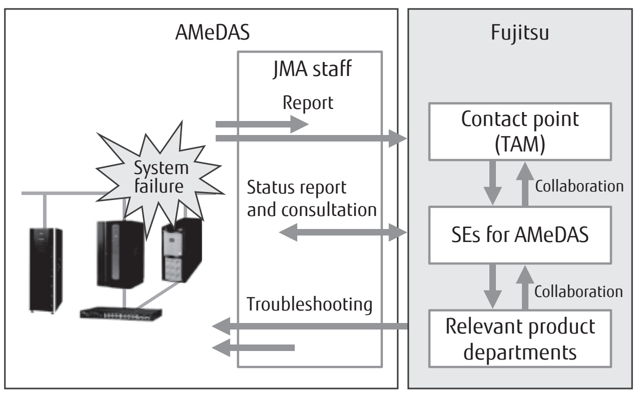

Figure 7
Overview of emergency support.

isolate the cause, followed by identifying and executing countermeasures. There are regular opportunities to exchange information among the SEs, manufacturing divisions, and sales team. Sharing accident case data and other information deriving from different systems helps to prevent errors and problems from occurring.

As described above, there are many people, from JMA staff throughout Japan to the operational support SEs, the maintenance support team, manufacturing division, and sales staff, who form part of AMeDAS collaborative support so that the system operates stably every day.

7. Conclusion

This paper gave accounts of AMeDAS features and described aspects of some improvements. It also outlined the emergency support system. The AMeDAS is an important social information system that helps to make people's lives convenient and safe by collecting and distributing meteorological observational data. We will continue our dedicated efforts to ensure reliable operation of the system, which is given the highest priority, and pursue further improvements so that more accurate observational data can be provided faster in the future.

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