Development of a IT-based Volcanic Disasters Response System

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In Baekdu Mountain (located in Korea), earthquakes, which are resumed volcanic activity, have been observed occurring about 10 to 15 times every month since 2002. In order to respond to it quickly, an IT-based volcanic disaster response system should be developed. This paper aims to development of a IT-based volcanic disaster response system. This response system should have maximized compatibility and scalability based on international standards of design. For effectively supporting user's decisions, a damage prediction model based on spatial information should be provided. In this system, we are mainly proving simulation results of volcanic disaster preparedness system. Adopting the scenarios of volcanic activity-induced damage based on volcanic eruption categories and information has firstly performed the simulation. As a result of the simulation are demonstrated in a form of GIS Viewer, table and chart. According to the results and disaster preparedness management standard, associated disaster correspondence processes are also provided in the decision making. More thematic maps on GIS Viewer and analysis results would be used to intuitively and comprehensively understand the simulation results in this system. It is expected that the program developed through this study will offer the potential to reduce casualties during volcanic eruption as well as, to minimize the damage in the fields of industry, the environment, and transportation.

Key Words: *Volcanic Disaster, Response System, Decision-support System*

1. Introduction

The Baekdu Mountain in Korea was the site of a big volcanic explosion in 969, an event that had a wide-spread impact(more than by 1000 km) the East sea in Korea or Hokkaido in Japan. Since 2002, volcanic earthquakes(which indicate resuming volcanic activity) have been observed 10 to 15 times each month (Fig 1).

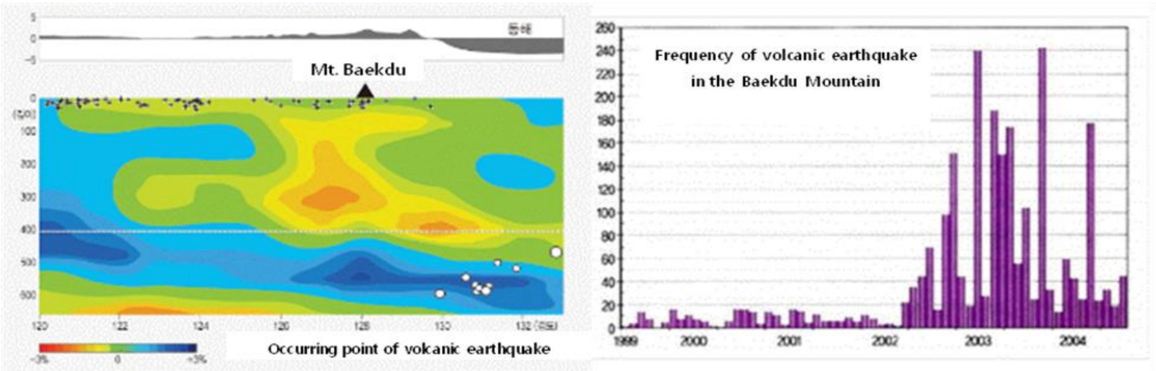


Fig. 1 Location of magma and frequency of volcanic earthquake on Baekdu Mountain

Small-scale volcanic eruptions do not cause much damage. However, if a volcanic eruption as big as the past huge explosion on Mount Baekdu occurs again, it will have larger political, social, and economic impact. Therefore, there is a need to develop an integrated volcano disaster response system in order to minimize any potential volcano damage. This study aims to provide development strategies and design of system. The system compiles diverse volcanic disaster damage prediction simulation technologies based on spatial information, and presents management standards and response manuals to enable responses by region and type of damage. Also, we provide the pilot system to support decision-making for disaster-prevention specialists.

The research flow chart is shown in Fig 2 below. First, in order to develop the volcanic disaster response system, the National Emergency Management disaster prevention system and a related system (Earthquake Disaster Response System) were studied and analyzed; these systems will later become the volcanic disaster response system's operating structure. The work processes were defined based on the results of this analysis and a volcanic disaster response architecture was defined. After studying and constructing the necessary DB, a pilot system was developed

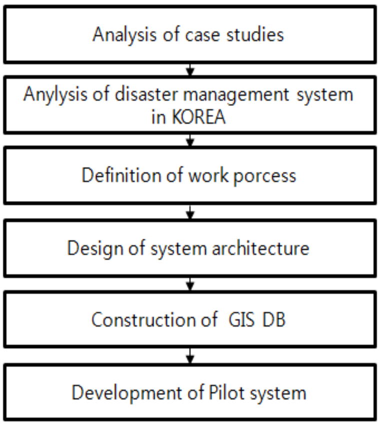


Fig. 2 Flow chart of research

Disasters that occur during a general volcanic eruption are caused by direct damage such as pyroclastic flows, volcanic mudflows, and volcanic floods, and by indirect damage due to volcanic ash. It is expected that the China and North Korean regions in the vicinity of Mt. Baekdu will be affected by direct damage and that indirect damage due to volcanic ash and the like will occur in South Korea. A damage prediction simulation studies or case studies have been provided to help construct response systems related to Mt. Baekdu eruptions, either outside or inside ROK. Kim (2011), through simulations of Mt. Baekdu volcanic eruptions, predicted that volcanic lava would flow downhill toward China and that the volcanic ash would spread across the North Korean region toward Ulleungdo within nine hours. Mt. Baekdu volcanic eruption simulations at the National Disaster Management Institute show that the volcanic ash would cover Ulleungdo within eight hours after the eruption and reach the Japanese Islands in 12 hours, causing severe damage such as paralysis of air transportation in Northeast Asia (Fig 3 and Fig 4) (National Disaster Management Institute report, 2011).

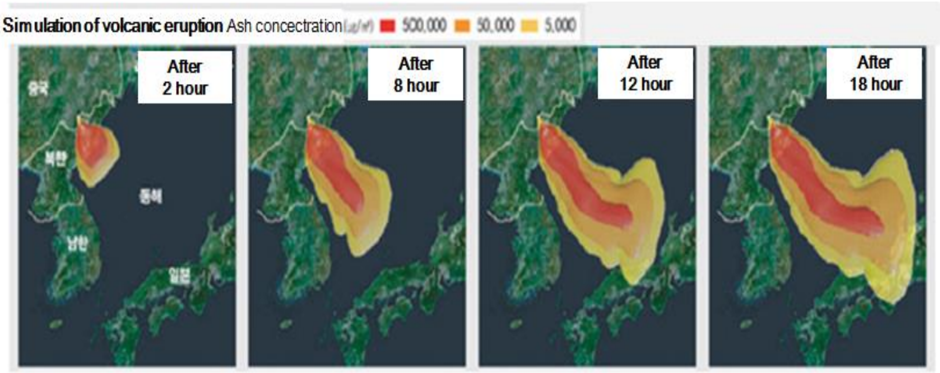


Fig. 3 Simulation of volcanic eruption in Mt. Baekdu(National Disaster Management Institute report, 2011)

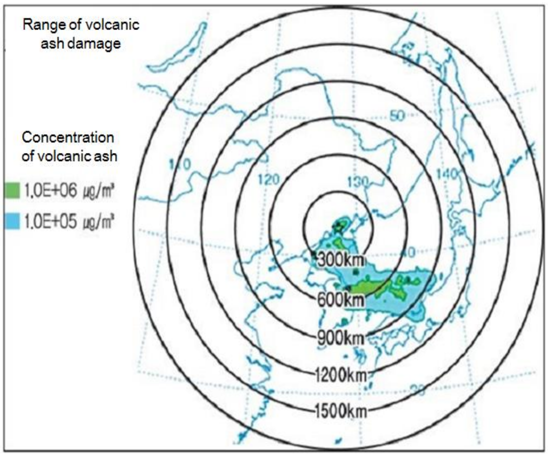


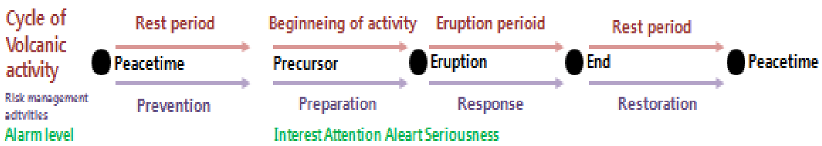
Fig. 4 Range of volcanic ash damage(National Disaster Management Institute report, 2011)

Yun et al. (2012) proposed the Mt. Baekdu volcano monitoring observational equipment and operating standards and presented an implementation plan for an optimal observational system. They also announced the implementation of a sensing network, tiltmeter, magnetometer, and sulfur oxide (SO_2) monitoring observation network as short-term observation plans, and pushed for the development of crustal fluctuation detection through the construction of a GPS observation network and a GIS-based on-site information, analysis, and evaluation system as part of mid-range and long-term observational plans. Kim and Park (2012) proposed a plan for integrating volcanic disaster damage prediction and damage reduction technology into a volcanic damage response system. They suggested to prepare a damage prediction and volcanic damage map in accordance with volcanic damage scenarios for prevention and response, and also proposed a volcanic damage map based on the volcanic observation information provided by the Meteorological Agency during precursors of eruptions and volcanic eruptions.

After reviewing and analyzing these preliminary research studies, we determined that previous researches sufficiently demonstrated the necessity for a disaster prevention decision-making system for volcanic disasters by executing volcanic disaster damage prediction simulations based on research using experimental GIS and fragmentary scenarios. We came to the conclusion that there is a necessity for an integrated response system that can comprehensively perform and monitor disaster prediction simulations, preliminary responses, and recovery to prevent volcanic disasters.

2. Design of response system for volcanic disasters

The volcanic disaster response system usually performs prevention tasks through volcanic activity monitoring based on connections with related agencies, as shown in Fig. 5, and it must perform preparation tasks through scenario-based predictions of volcanic damage at the start of the volcanic activity that is typically a precursor to a volcanic eruption. During the subsequent volcanic eruption, direct response measures such as rapid and accurate disaster response predictions must be performed through real-time volcanic disaster damage predictions, and the system must be able to support final aggregate confirmation and recovery tasks for damage situations that arise in the recovery period after the eruption.



	Level			
When	Peacetime	Precursor	Eruption	End
Who	·NEMS operator ·System operator	·NEMS operator ·Related organization operator ·System operator	·NEMS operator ·Related organization operator ·System operator	·NEMS operator ·Related organization operator ·System operator
What	Prevention task	Praparation task	Response task	Restoration task
How	▪Volcano monitoring ▪System maintenance	▪Damage prediction of volcanic disaster based on scenarios ▪Prior prepatation	▪Realtime damage prediction of volcanic disaster ▪Damage Conformation ▪Damage minimization	▪Volcanno monitoring for additional eruption ▪Damage Conformation ▪Prompt retoration
Why	Sctientific evidence and relevant laws			

Fig. 5 Definition of support work for volcanic disaster response

When the first precursor events occur and are detected through continual monitoring of volcanic activity, a decision-maker chooses and employs the scenario that is most similar to the present situation, selected from the specific processes for volcanic disaster response and based on a scenario-based simulation results database, as shown in Fig 6. The decision-maker then computes the most accurate damage prediction results through a real-time simulation when the eruption is imminent or during the start of the emergency. With the results inferred through the third simulation, the disaster situation must be expressed virtually through a 2D/3D GIS system. Subsequently, the damage estimate information is extracted from the disaster prediction and disaster estimate database and is compiled and analyzed for use in disaster relief response by field and region. Finally, the decision-maker establishes and implements a comprehensive response strategy based on the situation response database.

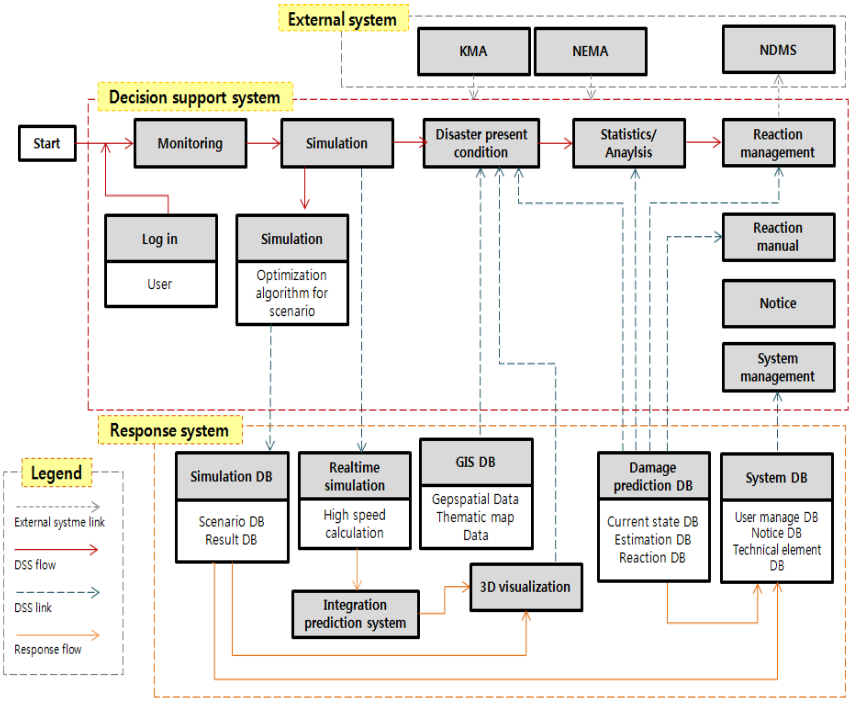


Fig. 6 Work process of volcanic disaster response system

The volcanic disaster response system architecture is derived, as shown in Fig 7, based on analysis of the task processes. Externally, it is linked with relevant agencies such as the Meteorological Agency and National Emergency Management Agency; internally, it is composed of a comprehensive damage prediction module, decision-making support module, GIS visualization module, and damage prediction DB

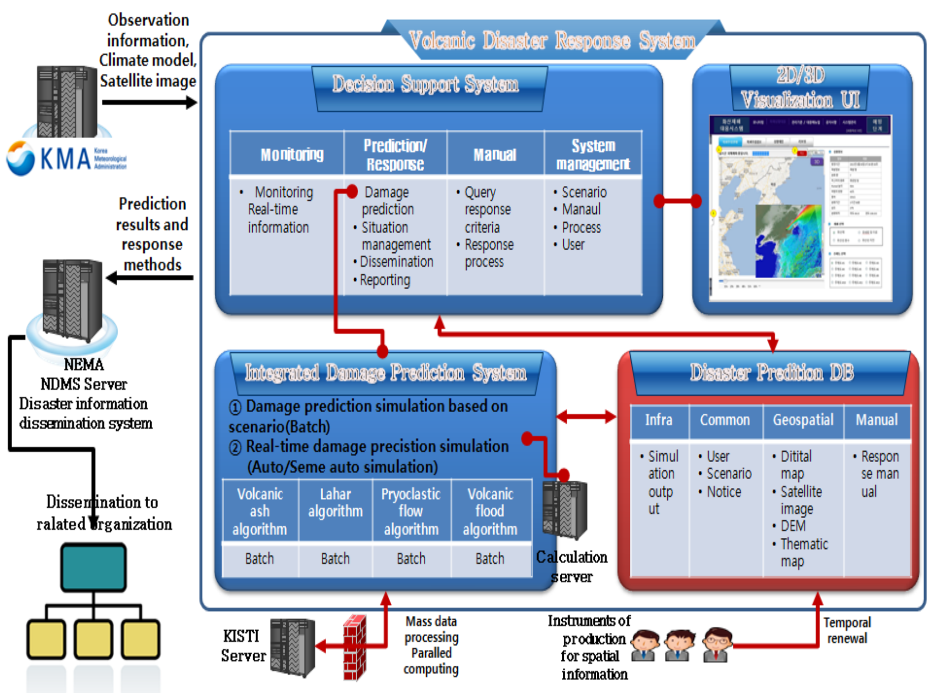


Fig. 7 Architecture of volcanic disaster response system

In Fig 7, the integrated disaster prediction system is combined in a scenario with a volcanic ash damage prediction model program. Here, the volcanic ash damage prediction model program must be integrated with the program based on volcanic ash prediction research. In order to combine physical disaster prediction programs into an integrated prediction system, each prediction program is integrated separately and the system is then constructed. The volcanic ash prediction system can be linked with the internet or other networks as well as being placed into an internal prevention system as an integrated program.

Simulation modules that can predict damages such as volcanic ash, volcanic flow, and volcanic floods are loaded into the comprehensive damage prediction module, which is a real-time operation and scenario-based operation. In the visualization UI model, the simulation results can be shown based on the 2D or 3D GIS map and even a 4D environment. In the decision-making support module, the damage situation response support tasks must be performed based on management standards and response plans together with the integrated damage prediction results and damage items, and the results for each damage situation and response plan must be transferred to the managers at the relevant agencies through the National Emergency Management Agency's situation dissemination system. The damage prediction DB comprehensively manages the GIS DB, scenario DB, statistical DB, management standard, and situational response manuals. This enables these components to be maintained and managed with the most recent DB.

The system menu is designed based on the system architecture and work process analysis results. The structure of the main menu was composed of five sections: monitor, disaster prediction, notifications, management standards/response manuals, and systems. The lower-level menus are as shown in Fig. 8.

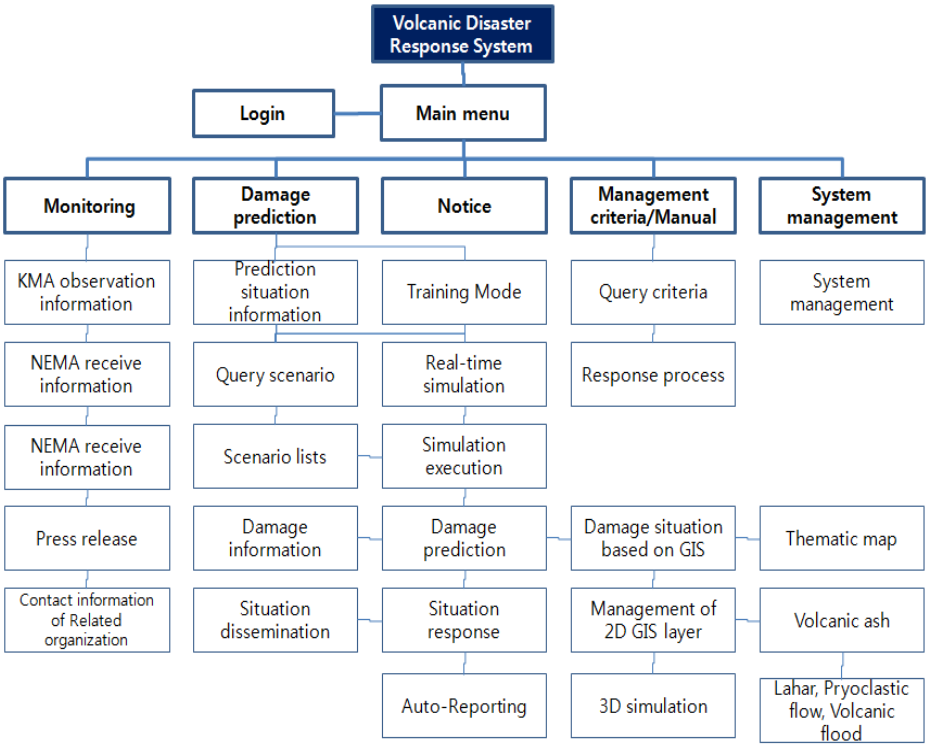


Fig. 8 Configuration of system menu

3. Volcano disaster-related GIS database

The spatial range for the construction of a basic GIS DB needed in the system was set through consultation with volcanologists, as shown in Fig 10, by dividing areas into Region 2 (100 km × 100 km centered around Mt. Baekdu), in which direct damage from factors such as volcanic flows, pyroclastic flows, and so on arise, and Region 1 (1,600 km × 1,600 km centered around Mt. Baekdu), in which indirect damage from factors such as volcanic ash arise. For some materials, depending on need, the effects of these materials were compiled globally.

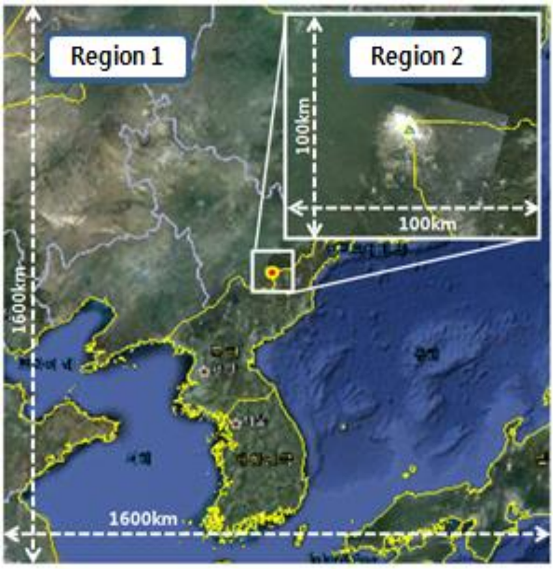


Fig. 10 Study area

The GIS database for system is such that, based on the materials detected, the appropriate resolution can be achieved for various regions, as shown in Table 1. A satellite image map, digital elevation models, digital map, land coverage map, water system map, land relief map, azimuthal projection map, and residential density map were created, enabling their use as simulation input data and system service maps.

Table 1 Basic GIS DB for system

Region	Covered Area	Data	Rectangle Size
Region 1	North Korea Area	Satellite Image(0.5m), DEM(10m), Digital map(1/5,000−1/25,000), Land cover map(Medium class lev-el), Watershed map(1/25,000), Gradient map(20m), Azimuth map(20m), Residential density map(1/25,000)	1,600km×1,600km (Center: Mt. Baekdu)
	South Korea Area	Satellite Image(0.5m), DEM(1m−5m), Digital map(1/1,000−1/5,000), Land cover map(small class level), Watershed map(1/5,000), Gradient map(5m), Azimuth map(5m), Residential density map(1/5,000), 3D-model(Seoul and 6 major metropolitan cities)	
	Part of Japan & China	Satellite Image(15m), DEM(90m), Land cover map(Large class level), Watershed map(1/100,000), Gradient map(90m), Azi-muth map(90m), Residential density map(1/100,000)	
Region 2	Mt. Baekdu	Satellite Image(0.5m), DEM(10m), Land cover map(small class level), Displacement change map(50m), Temperature change map(50m), Digital map(1/5,000), Watershed map(1/5,000), Gradient map(10m), Azimuth map(10m), Residential density map(1/5,000)	100km×100km (Center: Mt. Baekdu)

4. Development of a pilot system

A volcanic disaster response pilot system is developed by defining work processes, establishing a basic GIS DB, proposed system design. Spring MVC, Spring iBatis, and PostgreSQL are used as development environments and are built with the standard framework architecture (Ver 2.5) in order to prepare an electronic government framework base

In the monitoring screen shown in Fig 11, the Mt. Baekdu region satellite images (e.g., National Meteorological Satellite Center) linked with the National Meteorological Center, meteorological models, and volcano disaster occurrence are expressed, and volcanic disaster situation monitoring (such as for volcanic earthquake occurrences) is enabled through linkages with an earthquake disaster response system.

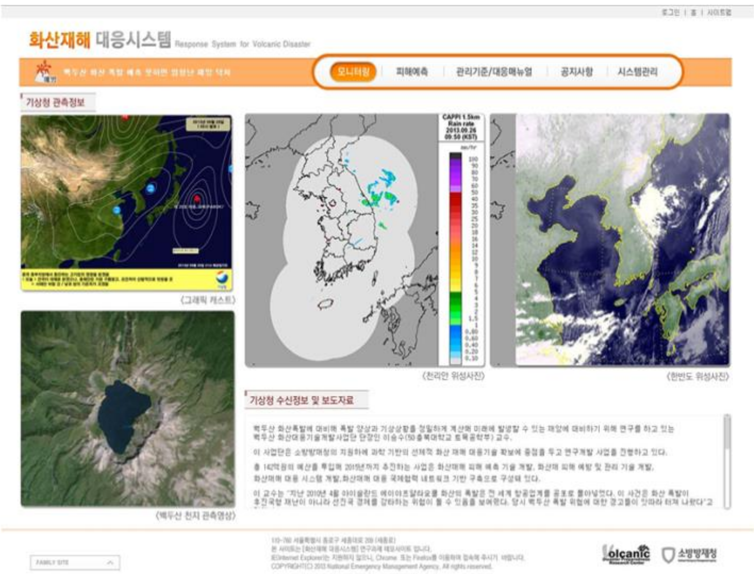


Fig. 11 Volcanic disaster response pilot system(monitoring UI)

The damage prediction module can derive results about the extent of damage with time and regional damage levels, as shown in Fig 12.

Furthermore, the results of the damage prediction, illustrated enable statistical calculations for each damage area/region such that the relevant agencies and each local government can query the relevant parts. This system also allows for measurement of the amount of damage incurred and accumulated amount of damage per hour. Finally, the system was built to allow transmission of information (such as predicted damage situations and response manuals) to the relevant agencies and local governments. Then, if the relevant agencies and local government predict damage situations and calculate the amount and extent of damage, rapid responses and measurements are enabled (Fig 13).

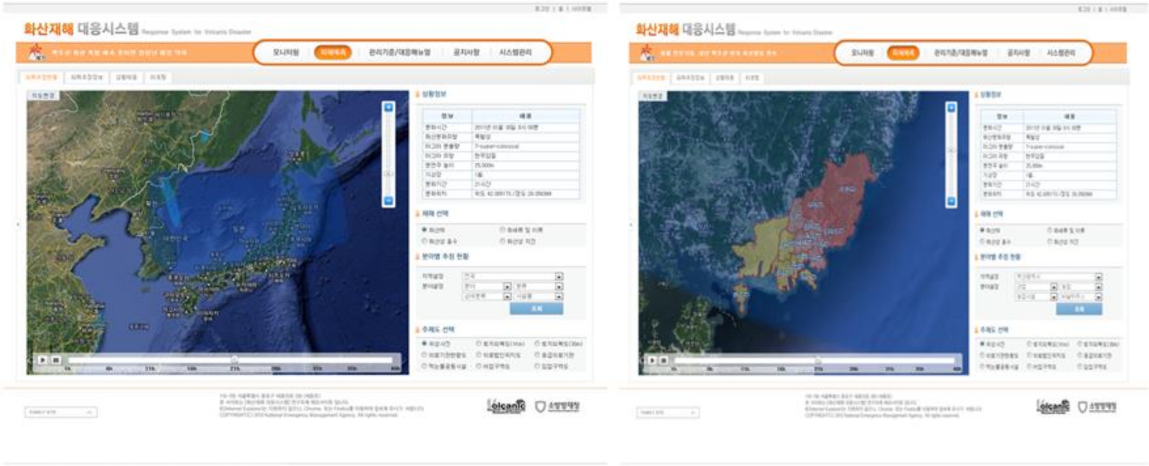


Fig. 12 Volcanic disaster response pilot system(result of volcanic ash diffusion simulation)

Fig. 13 Volcanic disaster response pilot system(damage amount of volcanic ash simulation and response manual)

The pilot system developed in this study does not implement all of the functions that have been designed, since the pilot system is developed to prioritize the implementation of the necessary major functions. As a result, the development of additional functions will be necessary in the future. There is a need to expand the spatial scope to the entire earth and not just East Asia in order to utilize this system as a global system. Furthermore, the system must be enhanced such that it can support decision-makers to prepare for a variety of possibilities by calculating and comparing a variety of results using different models simultaneously, rather than simply using just one type of modeling as at present.

4. Result

This research presented a volcanic disaster response system development plan based on spatial information that allows rapid response to the risk of an imminent volcanic disaster at Mt. Baekdu and described the development of a pilot system. We studied in detail the related preceding research in detail and analyzed the NMDA disaster prevention system and other relevant systems (i.e., earthquake disaster response systems) into which this system would be loaded. Then, we derived a pilot system by defining the work processes and system designs. This system requires additional verification, particularly through additional revision and supplementation tests, and will become a disaster response system similar to the existing earthquake disaster response system within the response and recovery field of the National Disaster Management System (NDMS).

As seen in the large number of existing volcanic disaster simulations, volcanic disasters occur in an instant and cause massive human and physical damage across vast areas. The volcano disaster response system developed through this research was constructed based on spatial information, thus enabling it to be used to monitor a diverse array of processes (e.g., from volcanic disaster monitoring to occurrence predictions). This is a rare quality in disaster systems globally; therefore, it is expected that this system will be of great use in volcanic disaster response tasks and will minimize damage due to volcanic disasters in areas adjacent to Korea, including Mt. Baekdu. We believe that it will be possible to export this system to other countries in which volcanic disasters occur, such as Central and South American countries and Indonesia.

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