

# The Japan Meteorological Agency's Volcanic Disaster Mitigation Initiatives

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## 1. Active Volcanoes in Japan

Japan is one of the most volcanic countries in the world, and has suffered many volcanic disasters in the past. In Japan, the definition of *active volcanoes* by the Japan Meteorological Agency (JMA) and the Coordinating Committee for Prediction of Volcanic Eruptions (CCPVE: private advisory body to the Director-General of the JMA that was established by the volcanic eruption prediction plan: Fuji, 2013) is widely used. According to this definition, there are 110 *active volcanoes* in Japan (see Figure 1). The definition of active volcanoes has fluctuated over the years, but in 2003 the JMA defined *active volcanoes* in Japan as "volcanoes which have erupted within 10,000 years or volcanoes with vigorous fumarolic activity" (Yamasato, 2007).

Active volcanoes range widely in the degree of activity - they exhibit from constant eruptive displays such as one sees at Sakurajima to volcanoes that are relatively quiescent over long periods. This led the CCPVE to refine the 2003 definition of active volcano (until then defined as a volcano that had erupted within 2,000 years) into three ranks—A, B, and C—depending on degree of past volcanological activity. Because this ranking is based on degree of volcanic activity in the past, it may not reflect eminence of eruption or the potential impact on society or need to respond to volcanic disasters. The CCPVE thus followed up with a project to identify volcanoes that could erupt over the next 100 years, that call for close monitoring and observation to mitigate any potential impact on society, and in 2009 they came up with a list of 47

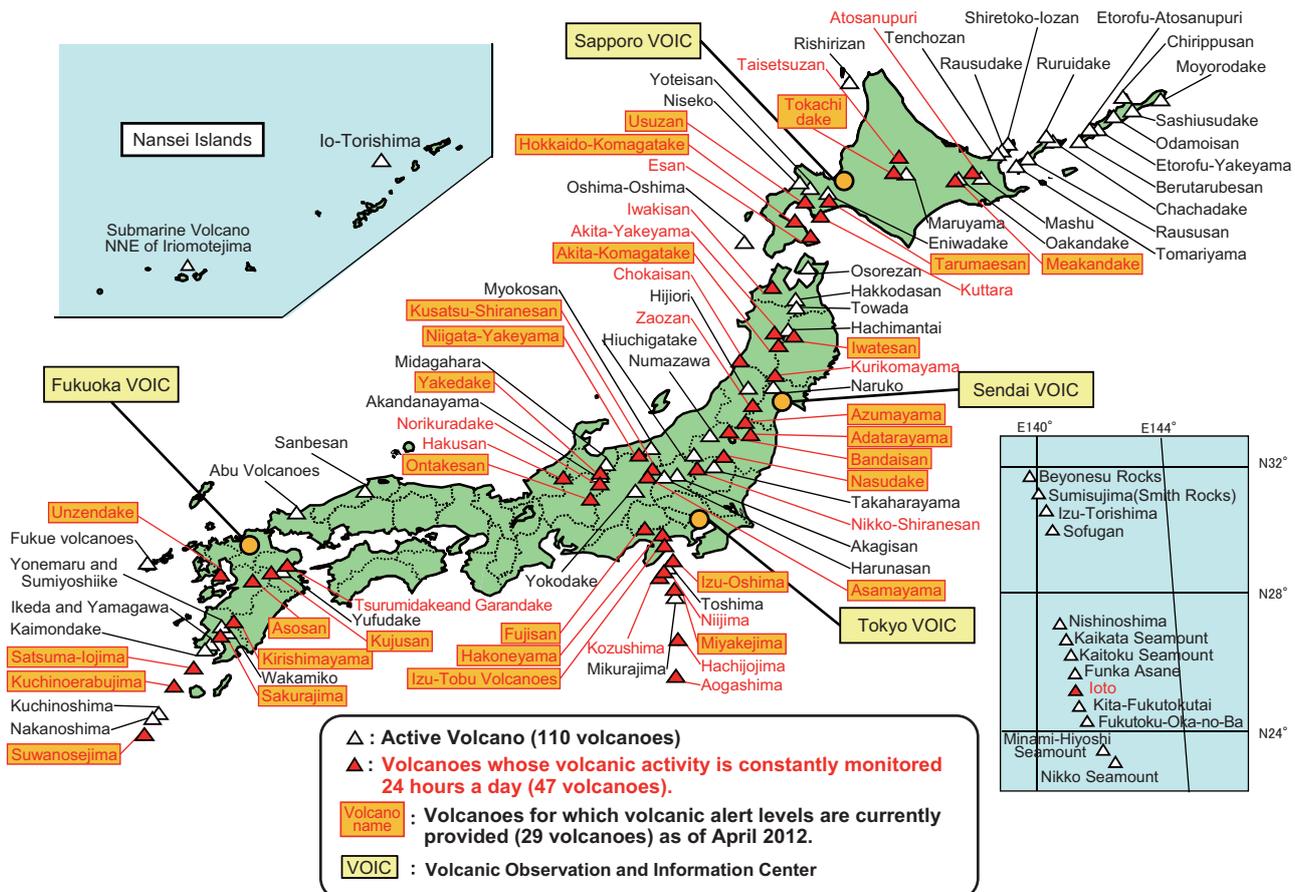


Fig. 1 Japan's active volcanoes and volcano monitoring system.

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volcanoes that met these new criteria. The JMA's constant monitoring system has been in effect to the present day, and we will describe this system in detail which is based on this same list of 47 active volcanoes. In light of the fact that the volcanoes on this watch list were selected based on different criteria than the rank system and that many of the 47 were classified as Rank C volcanoes in 2003, the JMA no longer uses the older ranking system.

## 2. Japan Meteorological Agency Responsible for Monitoring Volcanoes

In Japan, the JMA, an affiliate agency of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), is responsible for monitoring volcanic activity. Another affiliate agency of the MLIT, the Japanese Coast Guard monitors volcanoes on the seafloor and remote islands, while the Geospatial Information Authority of Japan (GSI) is in charge of monitoring crustal deformation using a nationwide crustal deformation observation network. In addition, the MLIT and prefectural erosion control departments monitor mudflows (lahars) as part of their erosion control responsibilities. Finally, universities and research institutes have their own volcanic observation networks

for research purposes, and conduct research with the goal of refining eruption prediction capabilities. This paper will be primarily concerned with the JMA's Volcanic Monitoring System.

The JMA had kept a close eye on the main active volcanoes using meteorological observatories and weather stations that are located in close proximity to the volcanoes. A mechanical seismograph was deployed at Kagoshima weather station in 1888, and this marked the beginning of constant onsite seismic observation near an active volcano. The seismograph recorded the major eruption of Sakurajima in 1914. Japan set up its first volcano observatory on Asamayama in 1911 in a team effort between the Ministry of Education's Imperial Earthquake Investigation Committee and the Nagano Weather Station.

In the 1960s, the JMA made a serious effort to implement a constant volcano observation system nationwide, and initially designated 17 active volcanoes for constant monitoring using high-sensitivity seismographs deployed at meteorological observatories and weather stations on or near the volcanoes. Other volcanoes not on this watch list were checked periodically by mobile volcano observation teams.

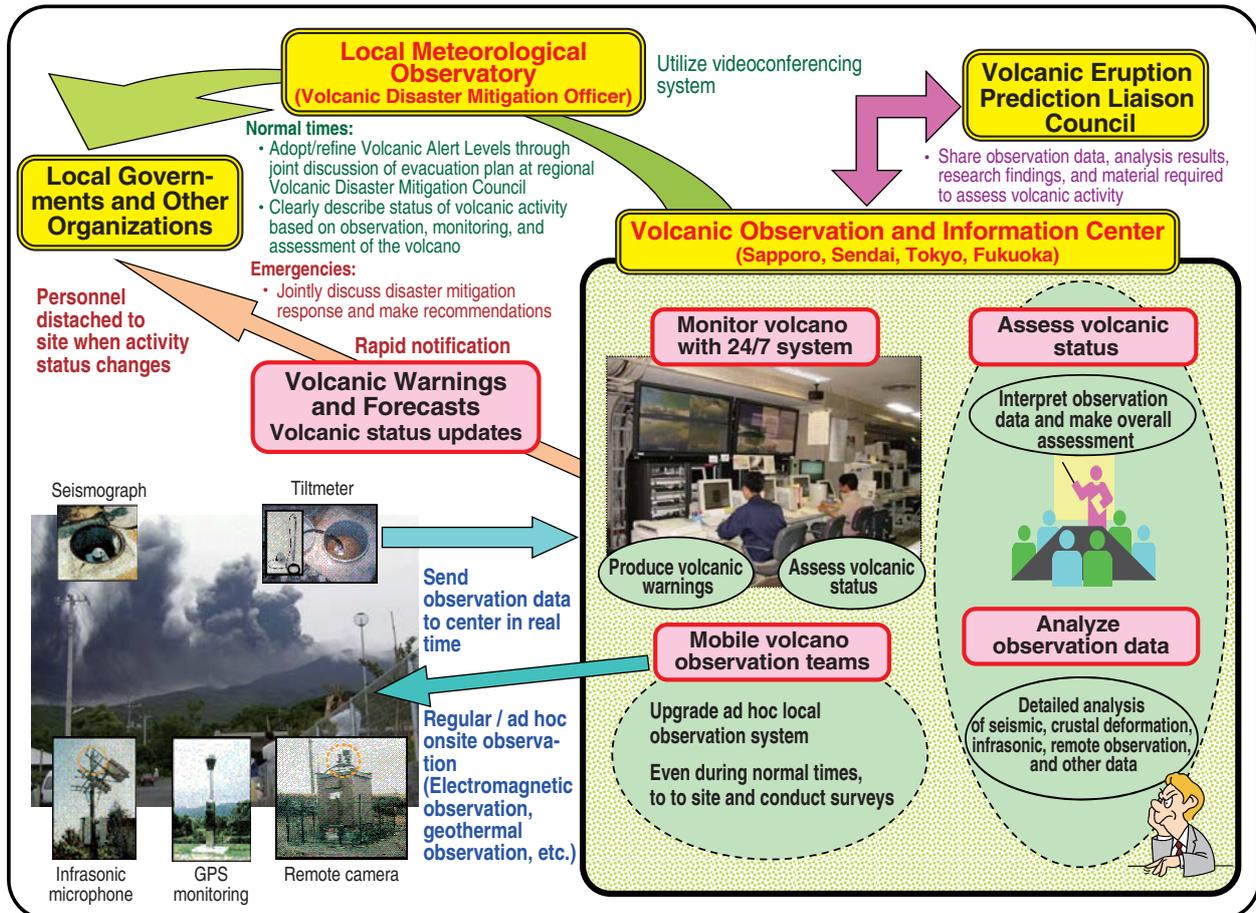


Fig. 2 JMA's volcano monitoring and warning advisories.

Beginning in 2002, a series of Volcano Observation and Information Centers (VOICs) was erected in Sapporo, Sendai, Tokyo, and Fukuoka to collect and monitor data 24 hours a day from equipment installed close to the volcanoes (Yamasato, 2005). By 2009, the 47 active volcanoes identified by the CCPVE as requiring monitoring and observation were being monitored by VOICs using borehole seismographs and tiltmeters in combination with existing equipment (**Fig. 2**).

In addition to seismic observation, GPS, and crustal deformation observation by tiltmeter, the VOICs provide a 24-hour centralized surveillance including visual monitoring by high-sensitivity cameras and camera installed on the walls of craters and infrasonic observation. More recently, we have made good progress exploiting the observational data of universities, research institutes, erosion control departments, and other relevant organizations to dramatically upgrade the monitoring system. This goes well beyond telemetry observation, for every VOIC sends mobile observation teams out to the volcanoes on a regular basis to repeatedly check geothermal temperatures, volcanic gas, GPS, geomagnetic total intensity, in order to enhance our understanding of volcanic activity. Mobile observation teams are also sent out on an ad hoc basis to improve our understanding when volcanoes act erratically or abnormally.

When volcanoes exhibit heightened or escalating unrest, staff are dispatched to the site to monitor, observe, and conduct mobile tests and measurements. Sakurajima is one of the most active volcanoes in Japan, and it is closely monitored by the Kagoshima Local Meteorological Observatory in conjunction with the Fukuoka VOIC. Resident Offices for Volcanic Disaster Mitigation have been set up at Asamayama, Izu-Oshima, Miyakejima, and Asosan. These offices pursue hazard mitigation work in collaboration with local governments, while also taking charge of the mobile observation teams.

### 3. JMA Volcanic Disaster Mitigation Information

At the same time JMA was building a constant volcano observation system during the 1960s, the agency began disseminating volcanic information to the public in 1965, and soon began providing disaster prevention information with the goal of mitigating damage and destruction caused by volcanoes.

The nature of volcanic information held by JMA has changed somewhat over the years, but beginning in December 2007 the agency began releasing volcanic warnings and forecasts in order to further mitigate volcanic disasters.

Volcanic information had a clear legal position of

importance for disaster prevention before 2007, and the basic idea of releasing volcanic warning and forecasts led to the creation of *Volcanic Alert Levels*.

Deep low-frequency earthquakes around Fujisan in 2000 boosted momentum to produce volcanic hazard maps for the area, set up a Fujisan Volcanic Hazard Map Review Committee, and other countermeasures, and the idea of Volcanic Alert Levels took hold through a series of meetings that determined JMA volcanic information could be used to trigger specific disaster prevention countermeasures at critical moments when the need arises. This approach came into focus a bit later during study sessions covering “disaster prevention countermeasures corresponding to specific volcanic information” (Fujiyama *et al.*, 2013). Essentially, the scheme works as follows. Before a volcanic anomaly occurs, relevant organizations get together and share projections based on the volcano’s past history of volcanic unrest (eruption scenario) and hazardous areas (volcanic hazard maps). They come to agreement on what criteria to use in deciding when to start evacuating people, when to prohibit people from hiking or climbing in the area, and other disaster responses. Note that these procedures are done during normal times when the volcano is quiescent. Later, if the volcano shows signs of unrests, the JMA issues a Volcanic Alert Level reflecting the current state of volcanic activity based on its 24-hour volcano surveillance system.

The Volcanic Alert Levels are divided into five stages depending on “areas that must be warned” and “responses that should be taken” for the volcano’s current state of unrest: Level 1 signifies that no particular response or action is required; Levels 2-3 indicate that, while residential areas are not threatened, the volcano is off limits for hiking or climbing; Levels 4-5 reveal that residential areas are starting to be threatened by the danger of eruptions (**Table 1**). Levels 2 and 3 are differentiated by the degree to which hiking and climbing are prohibited in hazardous areas, with the exact definitions decided in advance through consultation among local relevant organizations. Level 4 is the stage where people with special needs are evacuated and other local residents prepare to evacuate, and at Level 5, all local residents are subject to mandatory evacuation from threatened areas. Each Volcanic Alert Level is associated with specific keywords—“evacuation”, “prepare for evacuation”, “do not approach the volcano”, “do not approach the crater”, “normal” etc.—and this helps ensure response compliance of local residents, mountain climbers, sightseers, and so on.

Joint deliberations regarding of Volcanic Alert Levels for volcanoes subject to constant monitoring continue among local relevant organizations in the Volcanic

Disaster Mitigation Councils (discussed below), and “areas that must be warned” and “responses that should be taken” commensurate with the Volcanic Alert Levels are being defined in the regional disaster prevention plans of local governments for volcanoes throughout Japan. The Volcanic Alert Level scheme is gradually being implemented, and as of the end of 2012, has been put into effect for 29 volcanoes (Fig. 1).

When the Volcanic Alert Level changes (that is, the response for an area that must be warned changes), a new *volcanic warning and volcanic forecast* is issued that is commensurate with the new level. So, for example, if the level is moved up to Levels 2-3, a *near-crater warning* is issued. If the level is moved up to Levels 4-5, a *warning* is issued. At Level 1, a *volcanic forecast* is issued. If a warning is explicitly issued for an area, the local governments responsible for evacuating and preparing to evacuate people know exactly where these evacuation areas are.

Even if a volcano is not yet incorporated in the Volcanic Alert Level system, *near-crater warnings* and *warnings* will be issued, but since specific response measures have not been formulated for volcanoes outside the system and JMA warnings are tied to these response measures, there is still work to be done. Specifically, evacuation

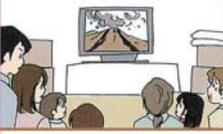
plans must be drawn up through collaboration of relevant organizations in the Volcanic Disaster Mitigation Councils (discussed below), and these volcanic districts must be successively brought into the Volcanic Alert Level system.

Volcanic warnings and forecasts are immediately transmitted to all relevant organizations and stakeholders including affected prefectures, and conveyed to local residents through municipalities, news media, and JMA’s website. In addition, warnings for submarine volcanoes are issued in the form of *near sea area warnings*.

#### 4. Collaboration Through the Volcanic Disaster Mitigation Councils

The Volcanic Alert Level framework is outlined in the Basic Plan for Disaster Prevention (the Volcano Disaster Countermeasure Volume) that was revised by the Central Disaster Management Council on December 27, 2011 and September 6, 2012. The scheme was further elaborated through linkage to evacuation plans (who, how, where, and when) drawn up through collaboration among members of Volcanic Disaster Mitigation Councils that are established in all prefectures with active volcano. The Volcanic Disaster Mitigation Councils are made up of all interested bodies and stakeholders in the prefecture including prefectural authorities, municipalities, meteorological

Table 1 Volcanic warnings / forecasts and Volcanic Alert Levels.

Abbreviated Term	Target area	Levels & Keyword		Explanation			
				Expected volcanic activity	Action to be taken by inhabitants	Action to be taken by climbers	
Warning	Residential areas	Level 5	Evacuate		Eruption that may cause serious damage in residential areas, or imminent eruption.	Evacuate from the danger zone. (Target areas and evacuation measures are determined in line with current volcanic activity.)	
		Level 4	Prepare to evacuate		Possibility or increasing possibility of eruption that may cause serious damage in residential areas.	Prepare to evacuate from alert areas. Let disabled persons evacuate. (Target areas and evacuation measures are determined in line with current volcanic activity.)	
Near-crater Warning	Non-residential areas near the crater	Level 3	Do not approach the volcano		Eruption or possibility of eruption that may severely affect places near residential areas (threat to life is possible in these areas).	Stand by, paying attention to changes in volcanic activity. Let disabled persons prepare to evacuate in line with current volcanic activity.	Refrain from entering the danger zone. (Target areas are determined in line with current volcanic activity.)
	Around the crater	Level 2	Do not approach the crater		Eruption or possibility of eruption that may affect areas near the crater (threat to life is possible in these areas).		Refrain from approaching the crater. (Target areas around the crater are determined in line with current volcanic activity.)
Forecast	Inside the crater	Level 1	Normal		Calm: Volcanic ash emissions or other related phenomena may occur in the crater (threat to life is possible in these areas).	Stay as usual.	No restrictions. (In some cases, it may be necessary to refrain from approaching the crater.)

observatories, erosion control departments, and volcanologists. Thus, the local evacuation plans (who is evacuated when and from where) are closely integrated with the Volcanic Alert Level system (Fig. 3).

JMA has stationed Volcanic Disaster Mitigation Officers, the primary in charge of volcanic disaster mitigation efforts, at most of the meteorological observatories adjacent to the 47 active volcanoes under constant surveillance that were mentioned earlier. During normal times, the Volcanic Disaster Mitigation Officers work to encourage local relevant organizations and volcanologists to organize and convene Volcanic Disaster Mitigation Councils to ensure the Volcanic Alert Level system interworks seamlessly with the local evacuation scheme if an eruption actually occurs. The officer also reconciles inconsistencies between the two schemes—areas that must receive volcanic warnings in the Volcanic Alert Level scheme and areas that must receive evacuation orders and designated off-limits in the evacuation plans—and reconcile any local problems with the Volcanic Alert Level system through joint discussions regarding the evacuation plan. Working together with local relevant organizations in the Volcanic Disaster Mitigation Councils in normal times ensures that evacuation plans integrate smoothly with the Volcanic Alert Level system. The face-to-face contact enables stakeholders to share different visions of how

disaster mitigation (share knowledge regarding specific disaster mitigation responses tailored to Volcanic Alert Levels), and is absolutely essential for cooperating with other organizations and mounting an effective evacuation plan-based response.

One specific local government initiative based on the revised Basic Plan for Disaster Prevention brought together relevant organization centered mainly around disaster management departments from Yamanashi, Shizuoka, and Kanagawa prefectures in establishing the Volcanic Disaster Mitigation Council of Fujisan on June 8, 2012. Local meteorological observatories and JMA Headquarters also participate on the Fujisan Council as a core group. In setting up the council, participants agreed to the following four conditions to ensure the Volcanic Disaster Mitigation Council would continue to serve as an substantive Evacuation Alliance System—promoting joint discussion of evacuation plans during normal time, and solid advice to evacuation sites during emergencies—in line with the Basic Plan for Disaster Prevention:

(1) Clear legal position

To eliminate differences in commitment among constituent organizations of Volcanic Disaster Mitigation Councils and to ensure adequate funding for organizations to participate in council meetings (mainly providing travel expenses to attend meetings), it is important that

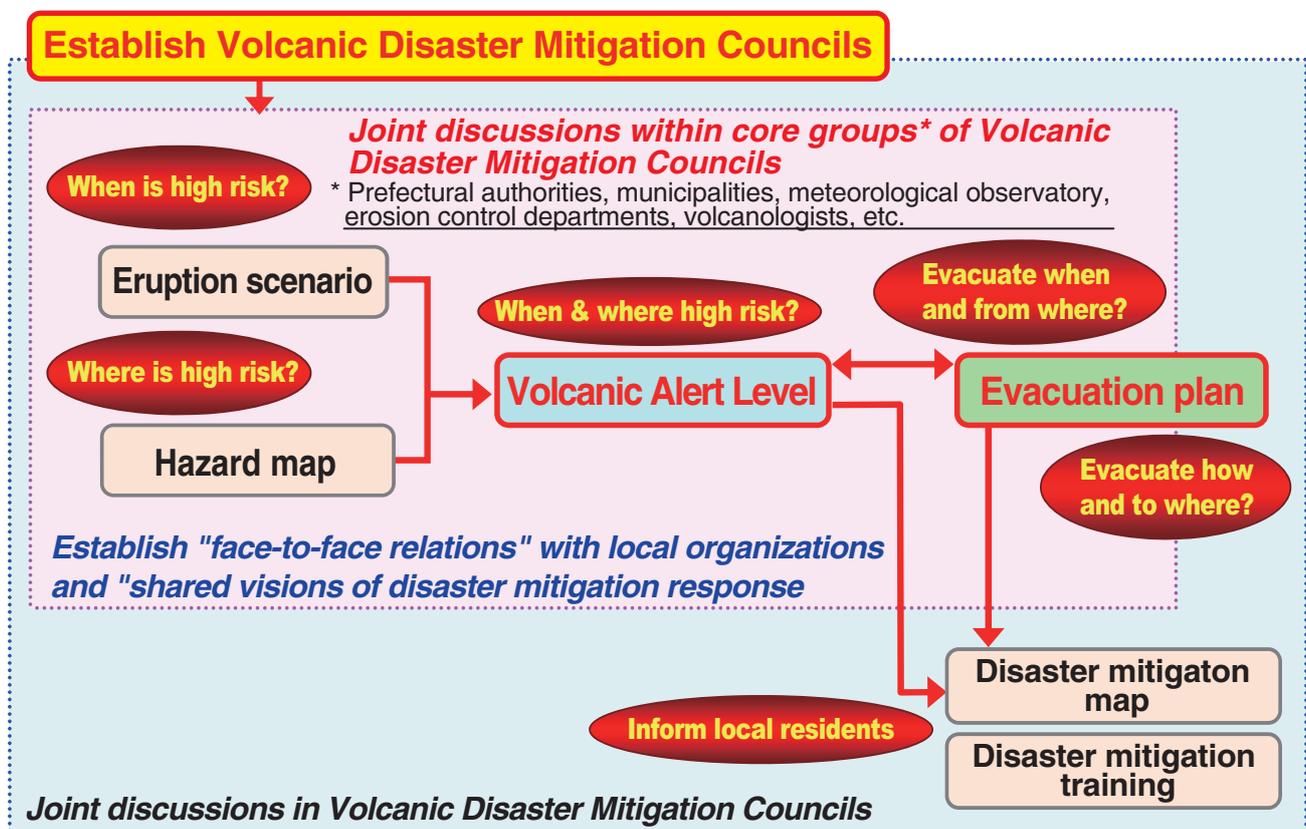


Fig. 3 Role of Volcanic Disaster Mitigation Councils based on the Basic Plan for Disaster Prevention.

councils are established based on “local disaster management plans” as defined in Article 40 of the Disaster Countermeasures Basic Act.

(2) Jurisdiction in advising target evacuation areas

To ensure proper evacuation orders based on professional consideration of volcanic risk, target evacuation areas must be defined through collaboration of constituent organizations who are members of the Volcanic Disaster Mitigation Council, and advice is given to mayors of towns and municipalities from the council. If local authorities were to make these evacuation calls on their own, there is a tendency for target evacuation areas to expand as the safety coefficient gradually increases during the process of conveying volcanic risk information to the public (warnings → hazard maps → evacuation orders), thus requiring more people to be evacuated than necessary (a phenomenon known in business administration as the bullwhip effect). Moreover, repeatedly calling for evacuation diminishes people’s trust in disaster management information, which makes it harder to get people to evacuate in the event of a real or imminent danger. Indeed, a desultory response to volcanic warnings could hinder smooth and rapid evacuation, and even increase the number of victims if warnings are not taken seriously (the so-called *cry-wolf effect*).

(3) Establish core group to conduct technical study of evacuation timing and target evacuation area

In order for Volcanic Disaster Mitigation Councils to advise mayors of evacuation timing and target evacuation areas, it is essential that the core groups most deeply involved in establishing when and what areas should be

evacuated—prefectures, municipalities, meteorological observatories, erosion control departments, professional volcanologists, and so on—can work together flexibly when required.

(4) Involvement of volcanologists

To ensure smooth technical consideration of evacuation timing and target evacuation areas, members of the Coordinating Committee for Prediction of Volcanic Eruptions and other professional volcanologists must serve as regular members (i.e., not observer status) and participate in the joint discussions.

These four conditions are essential and should be carefully considered in all of Japan’s volcanic areas in order for the Volcanic Disaster Mitigation Councils’ Evacuation Alliance System based on the Basic Plan for Disaster Prevention to work efficiently and smoothly.

**5. Other Information Besides Volcanic Warning and Forecasts**

Besides volcanic warnings and forecasts, JMA has also been issuing forecasts for the following types of volcanic phenomena since March 2008.

First, Ash Fall Forecasts are issued for eruptions exceeding a certain scale, and forecast areas likely to be affected by ash fall up to about six hours after an eruption. Assuming a plume model based on the scale of the eruption being observed, results are calculated based on JMA’s Tracer Transport Model using numerical weather prediction data and released to the public. So far, these forecasts have been issued for three volcanoes: Sakurajima,

Table 2 Various kinds of volcano-related information other than warnings and forecasts.

情報等の種類 Volcanic Information	概要及び発表の時期 Details
● 火山の状況に関する解説情報 Details of Volcanic Activity	火山性地震や微動の回数、噴火等の状況や警戒事項について、必要に応じて定期的または臨時に解説する情報。 Details of Volcanic Activity specify the number of volcanic earthquakes or tremors and the situation regarding eruptions. They are issued as often as needed.
● 火山活動解説資料 Bulletins on Volcanic Activity	地図や図表を用いて、火山活動の状況や警戒事項について、定期的または必要に応じて臨時に解説する資料。 Bulletins on Volcanic Activity specify the current status of volcanic activity. They are issued once a month or as often as needed.
● 週間火山概況 Weekly Volcanic Activity Reports	過去一週間の火山活動の状況や警戒事項を取りまとめた資料。 Weekly Volcanic Activity Reports specify the volcanic activity status for the previous week. They are issued every Friday.
● 月間火山概況 Monthly Volcanic Activity Reports	前月1ヶ月間の火山活動の状況や警戒事項を取りまとめた資料。 Monthly Volcanic Activity Reports specify the volcanic activity status for the previous month. They are issued at the beginning of each month.
● 噴火に関する火山観測報 Observation Reports on Eruption	噴火が発生したときに、発生時刻や噴煙高度等をお知らせする情報。 Observation Reports on Eruption specify event times and plume heights. They are issued as soon as eruption occurs.

Kirishimayama (Shinmoedake) and Asamayama. When Asamayama erupted in 2009, the small amount of ash-fall over western Tokyo was accurately predicted using this approach. However, current Ash Fall Forecasts only predict areas likely to experience ash fall. A more sophisticated forecast model is currently under consideration that would incorporate qualitative data based on the disaster response that should be taken.

Second, *Volcanic Gas Affected Area Outlooks* are issued when large volumes of volcanic gas are emitted that might adversely affect residential areas over a long period of time. Current forecasts clearly indicate an area subject to risk of high concentrations of volcanic gas in association with high atmospheric winds forecast two times a day as large volumes of sulfur dioxide continue to be emitted from Miyakejima.

In addition to warnings and forecasts, JMA also puts out various other types of information listed in **Table 2** either periodically or as required.

The JMA's *Details of Volcanic Activity* provide text-based information about the status of volcanic activity, that, like volcanic warnings and forecasts, are available through an online system. In addition to the regular *Bulletins on Volcanic Activity* that come out monthly with figures, charts, photos, and other detailed information, special reports are issued for volcanoes not included on the constant observation watch list when circumstances dictate. Finally, *Weekly Volcanic Activity Reports* and *Monthly Volcanic Activity Reports* are also released weekly and monthly, as indicated.

When an eruption occurs, *Observation Reports on Eruption* are released as breaking news. *Observation Reports on Eruption* deliver the minimum information

necessary as quickly as possible—the time of eruption, ash-plume height, and so on—so even in the case of volcanoes such as Sakurajima that erupt quite frequently, a report is issued within minutes of each eruption.

As part of a worldwide network for monitoring and disseminating information on atmospheric volcanic ash clouds that may endanger aviation, the JMA also puts out Airway Volcanic Ash Advisories, but we will save that for another report (Shirato, 2013).

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