

## **USGS ALERT-LEVEL SYSTEM FOR COMMUNICATING THE STATUS OF ACTIVITY AT U.S. VOLCANOES**

### Background

Volcano monitoring in the United States is conducted by five volcano observatories operated by the USGS Volcano Hazards Program and affiliated partners. Under the Stafford Act (Public Law 93-288), the USGS has the Federal responsibility to issue timely and effective warnings of potential volcanic disasters to the affected populace and civil authorities. As part of this responsibility, the volcano observatories issue frequent public statements about the status of activity at U.S. volcanoes.

This document describes a common alert-level system for characterizing the level of hazardous activity at volcanoes that has been developed by the USGS Volcano Hazards Program to replace three separate systems currently used by the different observatories. The system is a means to communicate the status of a volcano in a clear, direct form to non-volcanologists and to prompt people and organizations potentially at risk to seek further information or decide upon mitigation measures. The system employs a set of general terms (Advisory, Watch, Warning) used by the National Weather Service for hazardous meteorological phenomena and thus familiar to emergency-management authorities. As part of the system, color codes (described in a later section) are used to provide information about volcanic-ash hazards to the aviation sector.

A system for communicating the status of volcanic activity must account for the up-and-down nature of activity during many volcanic crises and the diverse types of hazardous phenomena that can be produced. During unrest, volcanoes exhibit a wide range in precursory styles and durations, and episodes of unrest commonly do not culminate with eruptions. Periods of increasing and decreasing unrest may occur before or after an individual eruptive episode, or before it becomes clear that no eruption is forthcoming. Volcanoes operate on individual time scales, some progressing to eruption very quickly (days to weeks), others taking months to a year or more. Volcanic eruptions can vary in style, from relatively mild events that produce small lava flows to extremely explosive events, and in size, from erupted volumes of  $0.001 \text{ km}^3$  to (rarely)  $>100 \text{ km}^3$ . Generally, an eruption involves episodes of eruptive activity separated by non-eruptive intervals of hours to months. The duration of a single eruptive episode usually ranges from a few minutes to tens of hours, whereas an entire eruption can last for a day to decades.

The USGS notifies the appropriate Federal and State emergency management agencies of notable unrest and eruptive activity, and those agencies then start a branching process of information dissemination to other state agencies, counties, cities, and adjacent states, as appropriate. USGS volcanic-activity notices and accompanying information also are made available directly to the public through the internet and to local news media. Some eruptions, such as those producing only lava flows or mudflows, may affect only ground-based communities, whereas eruptions producing ash clouds may affect only the aviation sector. Explosive eruptions that occur at volcanoes with nearby communities or that are large enough to produce significant ash fall on more distant populated areas will involve both ground and aviation risks.

For aviation hazards, USGS reports of volcanic activity are part of an integrated worldwide warning system that follows procedures sanctioned by the International Civil Aviation Organization (ICAO) and that in the United States involves the FAA and NOAA. Under ICAO procedures, volcano observatories notify the aviation sector about precursory activity and eruptions using a four-level color code initially developed in 1990 by the USGS for Alaskan volcanism (see later section).

## Description of Volcanic-Alert Levels

The USGS ranks the level of activity at a U.S. volcano using the terms **Normal**, **Advisory**, **Watch**, and **Warning** (Table 1). These alert levels reflect conditions at the volcano and the expected or ongoing hazardous volcanic phenomena. Assigning an alert level depends upon monitoring data and interpretation of changing phenomena. Alert levels are not always followed sequentially and escalate or de-escalate depending on volcanic behavior. USGS volcanic-activity notices are accompanied by explanatory text to give fuller explanation of the observed phenomena and to clarify hazard implications to affected groups. Updates that describe the ongoing activity are issued on a regular basis, at increasing frequency at higher alert levels.

Volcanic events are different enough that it is not possible to predetermine a detailed set of geophysical and geochemical criteria for each level that would be applicable universally. The alert-level definitions are guidelines for scientists to use to gauge the level of hazardous activity and for public officials and the public to consider when deciding what actions they need to take. Note that **Watch** is used for both heightened precursory unrest and minor eruptive activity because both states bear close watching but do not have immediate, major hazardous effects. Because the size, style, and reach of eruptions can vary substantially, a higher level (**Warning**) is needed to highlight very hazardous eruptive activity.

### **Normal:** *Typical background activity of a volcano in a non-eruptive state*

This level applies to inactive, non-erupting volcanoes, with allowance for periods of increased steaming, seismic events, deformation, thermal anomalies, or detectable levels of degassing as long as such activity is within the range of typical non-eruptive phenomena seen at a volcano during its monitoring history or at similar types of volcanoes. Strictly speaking, **Normal** is not an “alert” level *per se*, inasmuch as no concern or warning of potentially hazardous activity is implied. In some cases, unrest initially considered anomalous – for example, increased steaming at Mt. Baker in 1975 – eventually may be viewed as normal background activity. At volcanoes that appear to be quiet and inactive but are not monitored with any ground-based sensors, the absence of unrest cannot be confirmed; accordingly, **Normal** is not assigned to such volcanoes, and the alert level is left unspecified.

### **Advisory:** *Elevated unrest above known background activity*

This level is declared when a volcano is exhibiting signs of elevated unrest above known background levels. Progression toward eruption is by no means certain. After a change from a higher level, **Advisory** means that volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.

### **Watch:** *Heightened/escalating unrest with potential for eruptive activity OR a minor eruption underway that poses limited hazards*

This level is declared for two situations: (1) when a volcano is exhibiting heightened or escalating unrest with potential for eruptive activity (timeframe variable) or (2) when a minor eruption is underway with limited hazardous impact. When changing from **Advisory**, this level implies increased potential for an eruption (not necessarily imminent). When changing from **Warning**, this level signifies that the volcano is still showing signs of heightened activity that may lead to renewed highly hazardous activity or that the volcano has settled into minor eruptive activity with limited hazards.

**Warning:** *Major or highly hazardous eruption underway or imminent*

This level is declared by the USGS when a major or highly hazardous eruption appears to be imminent or is confirmed or suspected<sup>1</sup> to be underway. Accompanying information will indicate in as much detail as possible the eruption's time of onset, duration, size, intensity or explosivity, and impact on the landscape and atmosphere. When the major eruptive period ends or settles into milder, less hazardous activity, the level is downgraded.

<sup>1</sup> Because of the remoteness of some volcanoes or because of poor weather conditions, some eruptions may not be confirmed visually or on satellite images, but ground-based monitoring data may strongly suggest that eruptive activity is occurring; in such cases, the accompanying information will say that a "suspected" rather than a "confirmed" eruption is underway.

**Information Statement:** *Notable event at a volcano, not necessarily eruptive*

Phenomena such as prominent steam plumes, small avalanches and rock falls, minor mudflows, changes in appearance of a lake in a volcanic crater, and minor seismic activity may occur while a volcano is at a **Normal** level. Most such events are short-lived and lack recognizable precursors and do not necessarily suggest volcanic unrest or major flank instability that would warrant a crisis response. However, owing to public and media inquiries that often result from a notable event, the USGS along with other involved agencies will attempt to verify the nature and extent of the event and issue explanations in the form of an **Information Statement**. An **Information Statement** also may be issued periodically to provide commentary about a significant event or change occurring within higher alert levels.

<b>SUMMARY OF VOLCANIC-ALERT LEVELS</b>	
<b>NORMAL</b>	<p><b>Typical background activity of a volcano in a non-eruptive state</b>  <i>After a change from a higher level:</i>            Volcanic activity considered to have ceased, and volcano reverted to its normal, non-eruptive state.</p>
<b>ADVISORY</b>	<p><b>Elevated unrest above known background activity</b>  <i>After a change from a higher level:</i>            Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.</p>
<b>WATCH</b>	<p><b>Heightened/escalating unrest with increased potential for eruptive activity (timeframe variable) <u>OR</u> a minor eruption underway that poses limited hazards</b></p>
<b>WARNING</b>	<p><b>Highly hazardous eruption underway or imminent</b></p>

## Aviation Color Codes

Eruptions threaten aviation safety when plumes of finely pulverized, glassy, abrasive rock particles (“ash”) are explosively erupted and disperse as airborne clouds in flight paths of jet aircraft. Numerous instances of aircraft flying into volcanic-ash clouds have demonstrated both the economic costs and life-threatening potential of this hazard. The accepted mitigation strategy is to avoid encounters of aircraft with ash clouds, which requires that pilots, dispatchers, and air-traffic controllers quickly learn of occurrences of explosive eruptions and the whereabouts of airborne ash clouds globally.

For the aviation sector, in accord with recommended ICAO procedures, the USGS issues color-coded alert levels – **Green, Yellow, Orange, and Red** – focused on ash hazards (Table 2). Color codes are especially suitable for the aviation sector because pilots, dispatchers, and air-traffic controllers planning or executing flights over broad regions of the globe quickly need to ascertain the status of numerous volcanoes and determine if continued attention, re-routing, or extra fuel is warranted. As with the **Watch** term, **Orange** is used for both heightened precursory unrest and minor eruptive activity, and there are two levels (**Orange** and **Red**) to cover the range of eruption size and impact

All Volcano Advisories, Watches, and Warnings will include the “Aviation Color Code,” clearly identified as such to differentiate it from other hazard statements. In most cases, the term and aviation-specific color code will move together (e.g., **Normal** and **Green**; **Advisory** and **Yellow**; **Watch** and **Orange**; **Warning** and **Red**). However, there may be occasions when activity at a volcano poses a hazard to the aviation sector that is significantly lower than hazards posed to ground-based communities. In those cases, the aviation color code will be lower than what is normally associated with the activity term. An example is a large lava flow heading towards a town (Volcano **Warning** in effect) that is unlikely to produce any ash in flight routes or near an airport (Aviation Color Code **Orange**). Conversely, an ash plume that does not yield significant ash fall onto ground communities but does drift into air routes might warrant a Volcano **Watch** and Aviation Color Code **Red**. To preclude the impression that the aviation color codes and the general terms always are at the same level, color codes are summarized in a separate table (Table 2).

<b>GREEN</b>	<b>Volcano is in normal, non-eruptive state.</b> <i>or, after a change from a higher level:</i> <b>Volcanic activity considered to have ceased, and volcano reverted to its normal, non-eruptive state.</b>
<b>YELLOW</b>	<b>Volcano is exhibiting signs of elevated unrest above known background levels.</b> <i>or, after a change from higher level:</i> <b>Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.</b>
<b>ORANGE</b>	<b>Volcano is exhibiting heightened unrest with increased likelihood of eruption.</b> <i>or,</i> <b>Volcanic eruption is underway with no or minor ash emission</b> <i>[specify ash-plume height if possible].</i>
<b>RED</b>	<b>Eruption is forecast to be imminent with significant emission of ash into the atmosphere likely.</b> <i>or,</i> <b>Eruption is underway with significant emission of ash into the atmosphere</b> <i>[specify ash-plume height if possible].</i>