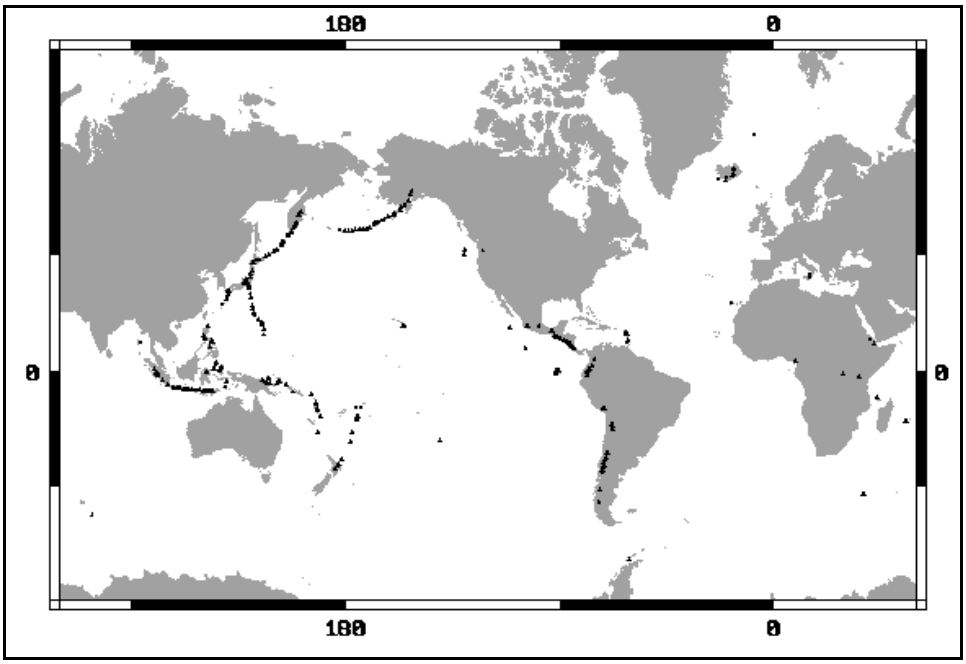
Chapter 10

SERVICE AREA: Volcanic Ash and Other Airborne Hazardous Materials

1. Problem Description Volcanic ash is pulverized rock. It is composed largely of siliceous materials with a melting temperature below the operating temperature of a jet engine at cruise altitude. Volcanic ash in the atmosphere is usually accompanied by gaseous solutions of sulphur dioxide and chlorine. The combination of the pulverized rock and acidic gases can significantly affect the performance of jet engines at cruise altitudes. Ash clouds are often invisible, particularly at night.

To put this problem in perspective, the ash from the Mount Pinatubo eruption in 1991 circled the globe within a matter of days and affected a multitude of air traffic routes. Consequently, aircraft that traversed this thin layer of ash required more maintenance. Globally, during the period of 1980 through 1996 there were 167 volcanic eruptions that produced an ash plume of great concern to civil aviation[14].



Locations of volcanoes known to have erupted since 1964. Data courtesy of the Smithsonian Institution Global Volcanism Program.

Within the United States, a particular area of concern is along the Aleutian Islands and the Alaskan Peninsula. The density of active volcanoes in this area, lying as it does adjacent to the heavily-traveled North Pacific Air Traffic Routes, makes the ash threat especially acute. The generally westerly flow of winds in the region means that ash can be transported easily into airspace over the Canadian and U.S. Pacific Northwest regions. Ash from volcanoes on the Kamchatka Peninsula of Russia also poses a threat because it tends to drift into the heavily traveled North Pacific airways, which are within U.S. Flight Information Regions.

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[14] *Manual on Volcanic Ash, Radioactive Debris, and Toxic Chemical "Clouds"*, International Civil Aviation Organization, Final Draft of First Edition, January 1997.

Volcanic Ash poses a danger to civil aviation in several ways by:

- fusing to compressor and turbine blades, leading to complete engine failure,
- abrading cockpit windows,
- abrading airframe and flight surfaces, thereby lessening aircraft performance,
- clogging the pitot-static system, producing inaccurate airspeed and altitude inputs to the navigation system,
- damaging the air conditioning and equipment cooling systems, and
- contaminating aircraft avionics and fuel.

Volcanic ash can be present at any altitude and is a threat to all categories of aviation. Of greatest concern are those eruptions where ash is ejected to operational flight altitudes in remote regions of the globe. These areas are difficult to monitor. However, ash at any level can pose a risk to all types of aircraft operations.

A similar hazard to aviation can exist when accidental releases of radioactive materials or toxic chemicals into the atmosphere occur during an industrial or transport accident. Although these substances are perhaps not as acutely hazardous as volcanic ash in the short-term, the long-term, serious consequences to humans must not be taken lightly. Toxic gases ingested into the air handling system of the aircraft could affect not only passengers but also the crew's ability to control the aircraft. The accident at Chernobyl in April 1986 produced a radioactive cloud which was reported to have reached altitudes of 2 miles. A natural gas leak in Chemery, France in 1989 lead to the diversion of aircraft from a nearby airport. The International Civil Aviation Organization (ICAO) is greatly concerned about the possible short term and long term effects that both radioactive and toxic gas clouds could have on the aircraft and passengers which traversed through them.[15]

Additionally, blowing dust and smoke from forest fires can cover large areas and pose a hazard for aircraft flying at low and mid-altitudes and taking off and landing at affected airports.

2. Objectives The overall goal of the Volcanic Ash and Other Airborne Hazardous Materials Service Area is to eliminate encounters with ash or any other airborne hazardous material that could impair the safety of aircrews and passengers in flight and damage to the aircraft. This goal can be accomplished by improving the ability to detect, track, and forecast hazardous clouds and to provide adequate warnings to the aviation community on the present and future location of the cloud. In order to reach this goal and to provide a means to quantitatively measure the progress, the National Aviation Weather Program establishes these objectives:

- prevention of accidental encounters with hazardous clouds,

[15] *ICAO, op. cit.*

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- reduction of air traffic delays, diversions, or evasive actions when hazardous clouds are present, and
- development of a single, worldwide standard for exchange of information on airborne hazardous materials.

3. Operational Decision Makers The range of decision makers described in Chapter 2 applies in the case of volcanic ash and other airborne hazardous materials.

4. Current Operations Concept

4.1 Preflight Operations. During the preflight phase, a pilot obtains weather-related information either via local briefings from service providers or via the Direct User Access Terminal System (DUATS) from a computer terminal. Notice of the presence, horizontal and vertical extent, and expected trajectory of volcanic ash and other hazardous clouds is contained in SIGMETs and NOTAMs.

When a KLM 747 encountered an ash cloud over Anchorage, Alaska in 1989 the ash caused a flame out on all four engines. The aircraft managed to make an emergency landing at Anchorage, but damage to the aircraft exceeded $80 million.

A special notice, called an ASHTAM, is used to warn of volcanic ash clouds. Because volcanoes frequently, but not always, exhibit signs of impending eruptions for days or even months prior to the actual explosion, ASHTAMs can contain status reports of eruption potential for those volcanoes that are being actively monitored throughout the world. Unfortunately, not all active volcanoes are monitored and volcanoes do sometimes erupt with little or no precursory behavior.

If a pilot receives warning of a hazardous cloud prior to takeoff, he or she should plan appropriate avoidance routes and review proper procedures for escape maneuvers in case the aircraft enters a cloud inadvertently. The latter is especially important because

- cloud motion forecasts can sometimes underestimate forward motions and dispersion, and
- hazardous clouds are often difficult to identify from a distance during daylight and almost impossible to identify at night.

Because volcanic ash clouds cross international and Flight Information Region (FIR) boundaries, ICAO, under its International Airways Volcano Watch program, has recommended the establishment of a network of Volcanic Ash Advisory Centers (VAACs) throughout the world. The VAACs monitor for volcanic ash, activate numerical trajectory/dispersion models to forecast movements, and issue advisory information. The VAACs provide expert advice to the Meteorological Watch Offices (MWO) which provide meteorological services for a FIR or control areas, issuing SIGMETS and warnings based on observations and forecasts. For the release of radioactive materials or toxic chemicals, the

World Meteorological Organization (WMO) has designated a number of Regional Specialized Meteorological Centers (RSMC) to provide trajectory forecasts. Additionally, both the Environmental Protection Agency and the Nuclear Regulatory Commission are involved during chemical/toxic spills and radioactive incidents.

4.2 Terminal Operations. Ash which affects the terminal area is reported in surface observations, which provide a means to accurately assess the hazard to aircraft. Normally, ample warning can be provided to all aircraft types concerning the operating conditions at both the airport and the airspace in the terminal area. An eruption that produces a significant amount of ash can cover nearby airports, forcing them to close. In sparsely settled areas, such as the Alaskan coast, this can mean that inbound flights may have to divert considerable distances to find suitable landing sites. Delays and diversions caused by airport closures ripple throughout the National Airspace System. Incoming ash can also force military installations to evacuate tactical aircraft to alternative locations in order to maintain combat readiness status.

One of the greatest dangers from volcanic ash fallout is that braking conditions on runways deteriorate very rapidly. A coating of less than ¼ inch of ash has been reported to make runways unusable due to slippery conditions. Airport ground equipment can be rendered virtually inoperative by a coating of ash. In addition, ash removal from runways can take a very long time, especially if the ash gets wet.

Toxic chemicals or radioactive gases released into the atmosphere are most likely to contaminate airspace from the surface to 2,000 feet. Aircraft operating en route and during descent or ascent could be exposed to toxic chemicals or radioactive gases unnecessarily, unless alternative arrival or departure routes were available. The hazardous gases could also rapidly and severely degrade the ability of airport personnel to conduct normal operations.

4.3 En Route Operations. In order to maximize the likelihood of avoiding an ash cloud or any other airborne hazardous material while en route, pilots must take advantage of all available transmitted information, via either voice transmission or message transmission from area control centers. Pilots, especially those operating in remote areas, should familiarize themselves with the locations of active volcanoes along their route.

Pilots flying in areas of known or suspected volcanic activity should be aware of some of the danger signs: a smell of sulfur, appearance of fine dust particles, static discharges on windows, and so on. Because thin ash clouds are often difficult to observe during daylight hours and impossible to see at night, these signs may be the first indication that the aircraft is entering a cloud and the pilot should begin escape maneuvers.

If an aircraft does encounter volcanic ash, the pilot must understand the options available and make tactical decisions in a timely manner. During an eruption, controller workload will increase considerably due to the need to alert other aircraft of the airborne hazardous material and the need to reroute en route aircraft around the contaminated airspace. Similarly, if a radioactive or toxic chemical cloud was detected at middle or high flight levels, controllers would be required to alert aircraft of the hazard and take appropriate actions to reroute aircraft.

5. Needed Service Improvements The number of reported encounters with volcanic ash indicates a need for significant improvement in the detection, tracking, and notification process of ash clouds. Ideally, decision makers, which includes pilots, dispatchers, and air traffic controllers, require more timely and accurate information on the ash cloud as it traverses various flight levels.

Although the aviation industry's experience with other hazardous gas clouds is much more limited, it is likely that any improvements driven by the volcanic ash problem will be equally beneficial in dealing with other substances.

5.1 Production of Information. Analyses and forecasts of volcanic ash trajectory and dispersion need to meet specific standards of accuracy for geographical location and extent, as well as for duration, especially at flight levels above 25,000 feet. As we learn more about the dynamics of volcanic ash, we are also learning that information is also required not only at middle flight levels but also from the surface to the top of the terminal airspace. These forecasts need to include not only the projected trajectory of the ash cloud over space and time but also the flight levels that are affected. In addition, there is a need to understand the composition and density of the cloud. As forecast precision improves, pilots, dispatchers, and ATC providers can make avoidance plans with greater confidence. This improved precision will require higher resolution input data and finer-scale modeling tools.

Although volcanoes and hazardous material spills and explosions are not meteorological phenomena, once ash and chemicals become airborne, they are spread by local meteorological conditions. Forecasting the spread of an ash or toxic cloud requires not only knowledge of atmospheric conditions but also accurate knowledge of the initial content, concentration, and height of the plume. Observational tools and techniques must be refined and developed to improve capabilities for establishing plume parameters at their source and as they spread in order to enhance the accuracy and reliability of forecasts.

5.2 Product Generation and Delivery. Information providers must be able to transmit volcanic ash products to ATC service providers, airline operations centers, traffic managers and, ultimately, directly to flight decks in a readily understandable graphical format. These improvements will require both continued product development and the identification of necessary communications paths and frequencies.

6. Volcanic Ash and Other Airborne Hazardous Materials Initiatives On pages 10-6 and 10-7 are the initiatives which have been identified for this service area.

Number	Volcanic Ash and Other Airborne Hazardous Materials Initiatives	Relative Ranking*	Cooperating Organizations
1	Develop and implement analysis products for volcanic ash and other hazardous airborne materials which are applicable for use by ATC providers, airline operations centers, and pilots in flight planning, strategic decision-making, and tactical avoidance.	★★★★	NOAA(NWS, NESDIS & OAR/ARL) Industry**, FAA, NASA
2	Develop and implement ground-to-air Flight Information Service capabilities to readily disseminate volcanic ash and other airborne hazardous material initial warning products within 30 minutes of occurrence and updates within 15 minutes of product generation.	★★★	FAA, NASA, DoD, Industry
3	Improve current ground-based communications systems to readily disseminate volcanic ash and other airborne hazardous material initial warning products within 30 minutes of occurrence and updates within 15 minutes of product generation.	★★★	FAA, NASA
4	Develop and implement a multifunctional color cockpit display which includes volcanic ash clouds, hazardous airborne material clouds along with terrain, and traffic hazards.	★★★	NASA, Industry
5	Improve the resolution and accuracy in time and space of trajectory forecasts (up to 1 hour) of volcanic ash clouds and other airborne hazardous material in affected airspace for tactical avoidance.	★★	NOAA(NWS & OAR/ARL), EPA DoD
6	Improve the resolution and accuracy in time and space of trajectory forecasts (1 hour or greater) of volcanic ash clouds and other airborne hazardous material in affected airspace for strategic avoidance.	★★	NOAA(NWS & OAR/ARL), EPA, DoD
7	Improve the detection of volcanic eruptions (e.g., using satellite-based techniques) as well as the resolution and accuracy of observations of volcanic ash clouds and other airborne hazardous materials.	★★	USGS, NOAA/ NESDIS, NASA

8	Establish a quantitative ICAO standard for describing the composition of volcanic ash clouds and other airborne hazardous materials in terms of proportion of gas, acid content, particle sizes, and density.	★	***
9	Develop aircraft-mounted forward-looking technologies for detecting volcanic ash clouds.	★	***

Volcanic Ash and Other Airborne Hazardous Materials Initiatives

* The relative rankings assigned to the initiatives are based on a qualitatively calculated benefit/cost ratio. It's possible that a high-benefit initiative which is costly to implement may rank lower than a medium-or low-benefit initiative which is medium or low in cost to implement. All these initiatives are considered to have a positive benefit to aviation; however, when benefits and costs are considered, some rank relatively higher than others. Details can be provided upon request. Four stars (★★★★) is the highest ranking.

** The term ""Industry" in this context refers to private organizations (e.g., airlines, manufacturers, associations) which may represent both users and providers of weather information.

*** Although the Joint Action Group felt these are worthwhile and beneficial initiatives, the cooperating organizations are yet to be determined.