VOLCANIC ASH AND AVIATION SAFETY:
Proceedings of the First International Symposium
on Volcanic Ash and Aviation Safety
U.S. GEOLOGICAL SURVEY BULLETIN 2047

THE AERONAUTICAL VOLCANIC ASH PROBLEM

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ABSTRACT

The International Civil Aviation Organization (ICAO) requires warnings and flight-planning information about one of the most potentially hazardous but non-meteorological aeronautical phenomena that exists, volcanic ash. This paper discusses the provision of required information based on the experiences gained from eruptions of Mount St. Helens and Redoubt Volcano in the United States. The frequency and duration of these eruptions, as well as the lack of guidelines about ash concentrations and their affect on aircraft, have made it difficult to meet the requirements for supporting safe and efficient aeronautical operations with available information messages. While progress has been achieved with warnings and flight-planning data, efficient dissemination has not been achieved for graphical representations of ash clouds. Meeting aeronautical information requirements for this non-meteorological phenomenon requires cooperation, research, and development among people in various disciplines to attain safe and efficient operations.

INTRODUCTION

The experience gained in providing meteorological information on volcanic ash clouds to those in aeronautical operations has resulted in adjusting some procedures to accommodate requirements. This paper briefly discusses the requirements and challenges and how support will be improved, primarily through communications, in the near future.

During the past decade, a number of aircraft have encountered volcanic ash clouds while in flight. Three incidents involved loss of engine power and posed potential disaster for passengers and crew; these encounters caused extensive damage to the aircraft. Fortunately, such incidents have been rare, and disaster has been averted because of good crews and equipment. These incidents have, however, instilled a healthy awareness of and respect for the problem of volcanic ash.

The relative infrequency of large volcanic eruptions and the inability to predict the onset of eruptions in an aeronautically timely manner increases the potential danger faced by crews and operators. In spite of the non-meteorological nature of volcanic eruptions and ash, the responsibility rests with meteorologists for: (1) the issuance of alphanumeric significant meteorological (SIGMET) information to warn of the hazard, and (2) the inclusion of ash-cloud information in abbreviated, plain-language, area forecasts and on significant weather charts used for flight planning.

Satellite images, radar data, aircraft reports, and cooperation and information coordination with volcanologists are all essential for early detection of eruptions and for tracking ash clouds. However, there are considerable limitations inherent in the system that provides SIGMET information. Two limitations are: (1) forecasting the onset of eruption with the timeliness required for aeronautical operations—this goal will certainly elude meteorologists, and (2) determining the concentration of erupted ash particles and (or) gases that may or may not affect aircraft. Hopefully, studies that address these limitations will also provide guidance as to when ash concentrations are sufficiently low so that the ash no longer threatens aircraft.

Wind data in the form of particle-trajectory and dispersion-model forecasts for flight planning are essentially the only aspect of the volcanic eruption and ash problem that adheres to meteorological prediction principles (Murray and others, this volume; Stunder and Heffter, this volume). This means that meteorologists need help in providing the best ash-cloud-warning service for the aeronautical community.

The experience in the United States for issuing ash cloud warnings and SIGMET's began with the eruption of Mount St. Helens in 1980. The St. Helens experience differed considerably from the more than 25 eruptions at Redoubt Volcano, which is 177 km southwest of Anchorage, Alaska, and to which meteorologists responded beginning in December 1989. Mount St. Helens eruptions were longer in duration and less frequent that those of Redoubt Volcano. Initially, each Redoubt eruption lasted several hours, and subsequent eruptions, some consisting primarily of steam, lasted less than 30 minutes (Brantley, 1990).

ALPHANUMERIC INFORMATION REQUIREMENTS

The international requirements for reports, warnings, and forecasts about volcanic ash are contained in the ICAO publication entitled "Meteorological Service for International Air Navigation, Annex 3," (ICAO, 1992)—this publication is hereinafter referred to as "ICAO Annex 3." United States domestic and international procedures and policies meeting these requirements are detailed in National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS) operations manuals. Within the United States, additional measures are taken both from a warning and flight-planning point of view. For warnings, NWS meteorologists assigned to air route traffic control centers (ARTCC) provide center weather advisories (CWA's) as a quick response to new or quickly changing conditions that may not be detailed in SIGMET's prepared by meteorological watch offices (MWO's). For flight planning, trajectory information (see Recent Developments section in this paper) is provided to aeronautical and meteorological facilities in accordance with existing agreements. Currently, this information is distributed on a limited basis, but extensive distribution of flight-planning information through meteorological graphics communications systems within the United States and internationally are planned and are nearing fruition. This will result in extensive distribution of this information to the aeronautical community and to information providers.

REPORTS

Recommended practices concerning observations and reports of volcanic activity by meteorological stations are described in the ICAO Annex 3 (chap. 4, p. 20): "The occurrence of pre-eruption volcanic activity, volcanic eruptions, and volcanic ash clouds should be reported without delay to the associated air traffic services unit, aeronautical information services unit, and meteorological watch office. The report should be made in the form of a volcanic activity report [VAR—see Fox, this volume] comprising the following information in the order indicated:

a. Message type: volcanic activity report,
b. Station identifier: location indicator or name of station,
c. Date and time of message,
d. Location of volcano and name if known,
e. Concise description of event, including, as appropriate, level of intensity of volcanic activity, occurrence of an eruption and its date and time and the existence of a volcanic ash cloud in the area together with direction of ash cloud movement and height."

The standard concerning aircraft observations and reports that is cited in ICAO Annex 3 (chap. 5, p. 24) is that "special observations shall be made by all aircraft whenever...

c. Volcanic ash is observed or encountered,...
e. Pre-eruption volcanic activity or a volcanic eruption is observed."

Note—Pre-eruption volcanic activity, as used in both contexts cited above, means unusual and (or) increasing volcanic activity that could presage a volcanic eruption.

The ICAO standard for the contents of special air reports of pre-eruption volcanic activity, a volcanic eruption, or volcanic ash cloud and their order in the volcanic activity report (VAR) (Fox, this volume) is:

- Aircraft identification,
- Position,
- Time,
- Flight level or altitude,
- Volcanic activity observed,
- Air temperature,
- Wind, and
- Supplementary information.

SIGMET INFORMATION

SIGMET's are aeronautical meteorological warnings, and they are issued in alphanumeric form. The ICAO Annex 3 (chap. 7, p. 34–36) standard on the issuance of SIGMET information includes the occurrence and (or) expected occurrence of volcanic ash cloud at subsonic, transonic, and supersonic cruising levels. The recommended issuance of "SIGMET messages concerning volcanic ash cloud... expected to affect a flight-information region (FIR) should be issued at least 12 hours before the commencement of the period of validity and should be updated at least every 6 hours."

This requirement combined the short-term requirement for hazardous SIGMET information and the longer term requirement for flight-planning data. However, at the ICAO communications-meteorology-operations divisions and the World Meteorological Organization (WMO) commission on aeronautical meteorology meeting (September 1990, held in Montreal, Canada), several states that have had experience with volcanic activity SIGMET's indicated that permitting the period of validity of SIGMET's for volcanic ash to be extended up to 12 hours, in their opinion, was quite impossible given current volcanic-activity-observing techniques, especially concerning ash particle size and density.

Even though the requirement does state "up to 12 hours," local user requirements during the Redoubt Volcano eruptions led to SIGMET updates as often as every 2 hours. This implied a dichotomy of purpose for the SIGMET (i.e., updates every 2 hours and the requirement for an outlook for up to 12 hours).

A few initial Redoubt Volcano eruptions in December 1989 and January 1990 lasted up to several hours; subsequent eruptions lasted usually less than 30 minutes (Brantley, 1990). With the frequency and duration of Redoubt Volcano eruptions, the MWO issuing SIGMET's would not have been able to comply with the spirit of the long-term requirement at the volcano or for flight-information regions (FIR's) affected downstream by the ash cloud.

Another significant aspect of SIGMET's being valid essentially from 12 to 24 hours is that the area encompassing volcanic ash could be very large. Situations did occur at Redoubt Volcano whereby ash was spread at high levels far to the southeast and at low levels to the north and northwest. In this case, the area was already quite large. However, consider the area that would be covered by ash with the wind directions indicated above and with a speed of 100 knots at high levels and 25 knots at low levels for a period of 12 to 24 hours. A SIGMET encompassing such as ash cloud would be meteorologically supportable but operationally difficult to implement. Even the 4-hour-valid-period SIGMET's issued for the initial Redoubt Volcano ash clouds resulted in large areas that unnecessarily restricted air traffic—this is a considerable impact at or near high-density routes and aerodromes, such as Anchorage International Airport.

Ash dispersion can quickly become complicated and can cover extensive areas with ash that is emanating only from the source. However, rapidly transported ash at high levels that falls into lower levels with different wind directions essentially results in multiple, albeit less concentrated, sources and an extremely complicated ash-cloud pattern.

SIGMET DISSEMINATION

SIGMET's are disseminated over teletypewriter or computer networks in alphanumeric, abbreviated, plain language. ICAO Annex 3 (p. 36) recommends that "SIGMET messages should be disseminated to meteorological watch offices,... and to other meteorological offices, in accordance with regional air navigation agreement."

GRAPHICS REQUIREMENTS

The requirements for graphical information (i.e., charts for flight documentation) reside in ICAO Annex 3, chapter 9, and is entitled "Service for Operators and Flight Crew Members." Flight documentation, usually in the form of charts, is provided "to operators and flight crew members for:

a. Pre-flight planning by operators,
b. Use by flight crew members before departure,
c. Aircraft in flight."

For pre-flight planning purposes by the operator, the ICAO recommendation for significant en-route weather information is that the information should normally be supplied as soon as available, but not later than 3 hours before departure.

Prior to the ICAO/WMO meeting in 1990, different ways to portray volcanic ash on significant weather charts were tried in the United States for the Redoubt Volcano eruptions. However, the inclusion of ash clouds on significant weather forecast charts caused concern among aeronautical operators. One of the early Redoubt eruptions occurred before the significant weather chart was disseminated, and the projected ash cloud area was determined by trajectory information. This area was enclosed by a scalloped line and identified with a plain-language note. Unfortunately, the area enclosed was larger than it might have been under those meteorological conditions, and it caused some anguish among users. It should be noted, however, that large areas can be expected under certain meteorological conditions.

Experience with these charts showed that:

1. Inclusion of ash clouds on significant weather forecast charts is consistently possible only if the volcano erupts shortly before or during the preparation of a chart and, of course, if the meteorologist is notified in time,
2. Providing long-term (up to 12 hours and beyond) volcanic ash information by outlining the ash cloud on significant weather charts, while possible, may be confusing and may be a disservice to the aeronautical user when the area delineated is significantly larger than it might be or if the chart is prepared for an eruption that turns out to be mostly steam (hence, posing little or no hazard), and
3. The lead time that must exist so that the charts are available to the operator, in addition to the time required to prepare the chart, makes it an extremely difficult task to include the information as precisely as desirable.

The Redoubt Volcano experience led the United States to suggest at the September 1990 ICAO/WMO meeting that the best way to inform flight planners about volcanic ash was to include a statement such as "see potential SIGMET's for volcanic ash" near the volcano on the significant weather chart—this statement would be included on all significant weather charts until the volcano becomes inactive again. Discussions pointed out that longer term, precise information on the occurrence and location of volcanic ash cannot be adequately depicted on significant weather charts. The reason for this is that these charts should be in the users' hands some 9 hours before the valid time—this time corresponds approximately to the midpoint of the flight. Also, these charts are prepared up to 6 hours before being disseminated. The net result is that a volcanic eruption and ash cloud may have occurred at any time during a period of 15 hours and may not be depicted on the significant weather chart that the air crew receives. It was agreed at the meeting that an ash

cloud could not be included reliably for short-term eruptions because of timing and dissemination requirements.

The participants at the ICAO/WMO meeting in 1990 felt that WMO should be requested to develop, in consultation with ICAO, appropriate symbology to represent the volcanic ash phenomenon on significant weather charts--this resulted in the recommendation that WMO, in consultation with ICAO, develop appropriate symbology to represent the occurrence of volcanic eruptions on world-area forecast system significant weather charts. Subsequently, it was agreed that symbology would be added to the significant weather chart at the location of the volcano and that adequate information would be added to the legend of the chart, including a statement advising concerned air crews to inquire about SIGMET's in an area where a volcanic eruption or ash contamination is suspected.

RECENT DEVELOPMENTS

Since the First International Symposium on Volcanic Ash and Aviation Safety in 1991, graphic information has been developed. The volcanic ash forecast transport and dispersion (VAFTAD) model, developed by National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory, is a three-dimensional, time-dependent depiction of the volcanic ash cloud (Stunder and Heffter, this volume). Eruption input includes volcano name and location, eruption time, and ash-cloud-top height. The model assumes a given particle-size distribution throughout the initial ash cloud. Ash is advected horizontally and vertically as it falls through the atmosphere, using either the Washington World Area Forecast Center global wind and temperature computer model data or a U.S. regional model.

This graphic information, produced automatically and shortly after notification of an eruption, will be disseminated internationally in addition to significant weather charts on ICAO world-area forecast system satellite broadcasts. Broadcasts operated by the United States are expected to begin in late 1993 or early 1994 over the Americas and in late 1994 over the Pacific Ocean—astern Asia area. In the United States, the graphic will be disseminated on meteorological computer and graphic-disseminationsystems.

SUMMARY

Problems faced by meteorologists and operators concerning: (1) when and where an eruption may occur, (2) the timely notification of an eruption in the aeronautical sense, and (3) what concentrations of volcanic ash threaten life and property, contribute to the difficulty in providing useful volcanic ash information. However, improved dissemination of information will significantly assist in planning for efficient flight and will contribute to safe operations.

REFERENCES CITED

Brantley, S.R., ed., 1990, The eruption of Redoubt Volcano, Alaska, December 14, 1989–August 31, 1990: U.S. Geological Survey Circular 1061, 33 p.

International Civil Aviation Organization (ICAO), 1992, Meteorological Service for International Air Navigation, Annex 3 (11th ed.): International Civil Aviation Organization.