The Impacts on Air Traffic of Volcanic Ash from the Okmok and Kasatochi Eruptions During the Summer of 2008

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During the summer of 2008, two major volcanoes, Okmok and Kasatochi, erupted in the Aleutian Islands. Volcanic ash and SO_2 from these eruptions dispersed through the atmosphere which created the potential for major problems for air traffic en route near the ash dispersions. To verify any impacts on aviation from the eruptions, synoptic weather patterns were analyzed to estimate the altitude of the ash cloud as it dispersed after each eruption. Volcanic ash advisories (VAAs) issued by the Washington Volcanic Ash Advisory Center (VAAC) were also assessed, and information from the Aviation Safety Reporting System (ASRS) database and the United States Geological Survey (USGS) was investigated to identify the number of direct impacts and to examine the efficiency of in-flight communications to pilots regarding direct volcanic ash encounters.

I. Introduction

Aircraft in flight routes over the Aleutian Islands are periodically faced with the threat of encountering volcanic ash from any of the major active volcanoes on those islands. Air traffic which may be hundreds or more miles away from the eruption may be affected depending on the amount of ash in the atmosphere and the rate of its dispersion.[4] An ash encounter may result in a wide range of impacts, including windscreen scouring, catastrophic engine damage, and the loss of the aircraft, crew and passengers. Volcanic ash poses a serious concern to the aviation industry not only due to the direct economic impact incurred from aircraft system damage or catastrophic losses, but also due to significant direct and indirect costs incurred by the airlines and passengers due to the need to reroute, delay, or even cancel flights as safety measures. Although no aircraft have crashed due to an encounter with volcanic ash, there have been several major, close calls involving total engine failure and significant loss of altitude.[5] By understanding the impacts of the Okmok and Kasatochi eruptions, the aviation industry may better prepare for future threatening volcanic eruptions.

II. Case Studies

During the summer of 2008, two major volcanoes erupted in the Aleutian Islands sending ash and SO_2 throughout the atmosphere and over much of western North America. Okmok (Figure 1) erupted on 12 July 2008, and Kasatochi (Figure 2) erupted on 7 August 2008. Figure 1 shows the dispersion of SO_2 which is indicative of the dispersion of volcanic ash from Okmok over the northwestern United States five days after the volcano's initial eruption.[2] This dispersion displays a zonal flow pattern due to the prevailing westerly winds.

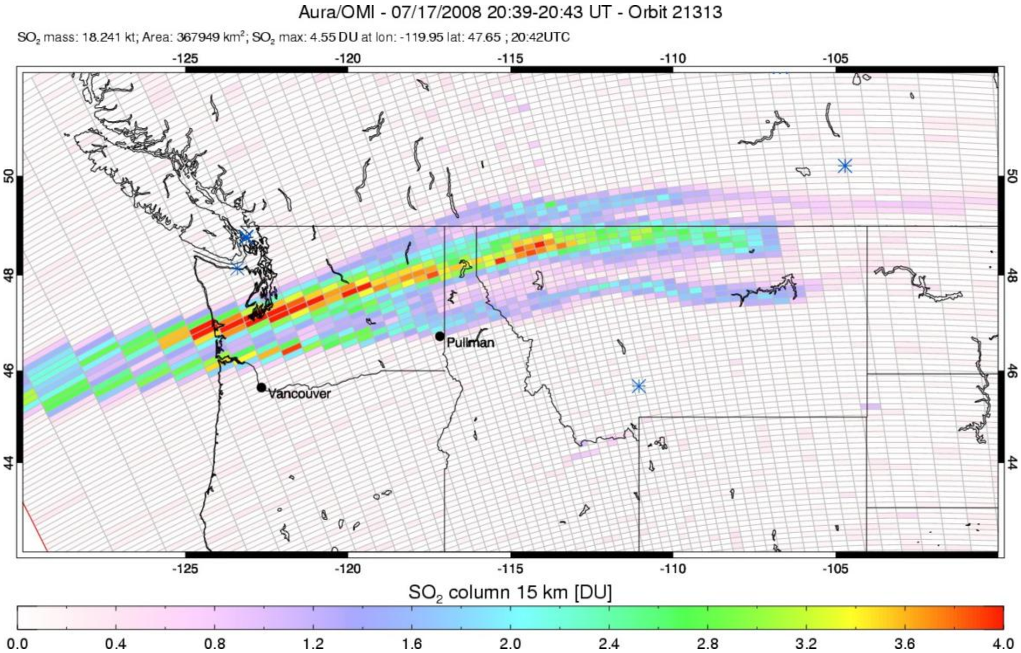

Figure 1. SO_2 as detected by Aura/OMI in the northwestern United States five days after the initial eruption of Okmok.

Figure 2, below, shows the dispersion of SO_2 which is indicative of the dispersion of volcanic ash from Kasatochi only four days after it initially erupted.[2] The ash dispersion for the Kasatochi eruption, unlike that of the Okmok eruption, features an intricate flow pattern covering a much larger area over a range of altitudes associated with a rather complex synoptic pattern.

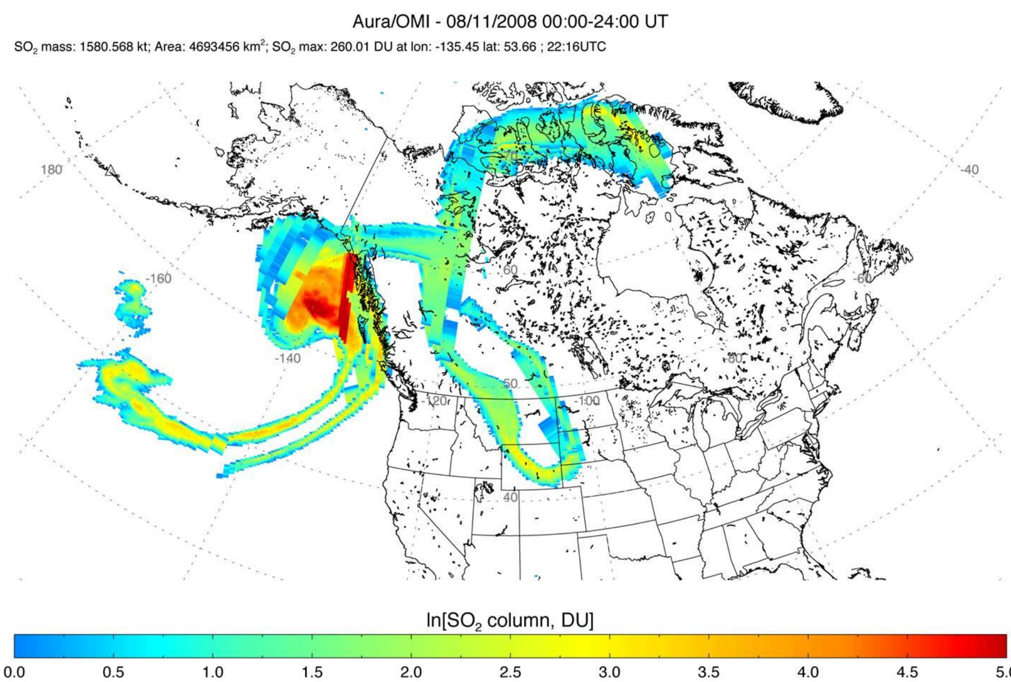

Figure 2. SO_2 as detected by Aura/OMI in North America four days after the initial eruption of Kasatochi.

It is important to assess the impacts on aviation so valuable information may be obtained and used to develop better warning systems to mitigate these impacts. Indirect impacts involve air traffic that may have had to be rerouted, delayed, or cancelled. These impacts can cause major air traffic backups and problems for the air traffic management services in the U.S. and Canada. Volcanic ash can cause an enormous amount of damage to aircraft and danger to passengers.[5] There are no definitive studies as to the effects of volcanic sulfate gas on the exposure to aircraft, but it can cause respiratory problems for crew and passengers. Therefore, ash encounters with aircraft must be avoided.

III. Methods

In this study, the synoptic weather patterns were analyzed at various levels to determine at which altitude most of the SO_2 dispersion of each eruption occurred. Next, advisories issued by the Washington Volcanic Ash Advisory Center (VAAC) which pertained to the geographic regions and altitudes of the SO_2 dispersion associated with the Okmok and Kasatochi eruptions were examined. Finally, information was obtained about direct or indirect impacts from pilot reports.

A. Analyzing Synoptic Weather Patterns

Figures 1 and 2 represent the SO_2 dispersion columns as recorded by Aura/OMI satellite images. Since the images are generated through measurement of column SO_2 in the atmosphere, it is difficult to discern at which altitude the majority of the volcanic ash dispersions for each eruption occurred. To determine these altitudes, the synoptic weather patterns at various pressure levels were analyzed. Wind vectors at the surface and at pressure levels of 850mb, 700mb, 500mb, 300mb, and 200mb were examined. The synoptic meteorological conditions suggest winds which most closely fit the flow of SO_2 dispersion for each volcanic eruption and provide an estimate of the level at which most of the ash dispersion may have occurred.

B. Assessing and Comparing Volcanic Ash Advisories as Issued by the Volcanic Ash Advisory Centers

The Volcanic Ash Advisory Centers (VAACs) monitor specific regional areas of responsibility and issue advisories about volcanic ash hazards specific to those regions. The next step of the study was to identify the VAAC which issued advisories pertaining to the geographic regions of Figures 1 and 2. The archived advisories were obtained from the VAAC's database and the altitudes and locations which were noted in the advisories were compared with those altitudes which were ascertained by analyzing the synoptic weather patterns.

C. Investigating Reported Impacts on Aviation

A number of studies have already been done to better understand the circumstances surrounding these eruptions and their impacts. Reports about aviation impacts from the volcanic ash as stated from pilots were also examined. These studies and reports were acquired from the United States Geological Survey (USGS) and the NASA Ames Research Center's Aviation Safety Reporting System (ASRS) database.

IV. Results

Archived synoptic weather maps support the pattern of ash dispersion observed from the Okmok and Kasatochi eruptions as depicted in Figures 1 and 2. NCEP/NCAR reanalysis data from the NOAA Earth Science Research Laboratory were used to generate plots of geopotential height at various pressure levels in the atmosphere corresponding to the two time periods associated with Figures 1 and 2. Plots with height lines most closely matching the flow of the ash dispersion in the Aura/OMI satellite images were selected. This information was used to determine the pressure level at which the volcanic ash had likely reached and was being dispersed. It can be seen in Figure 3 that at 300mb the wind patterns affecting the volcanic cloud over the Pacific Ocean were primarily zonal (west to east) becoming weakly anti-cyclonic at the coast and then flattening out and resuming their zonal flow over the continent. Figure 4 conforms much more to the complex dispersion pattern for Kasatochi that was depicted in Figure 2.

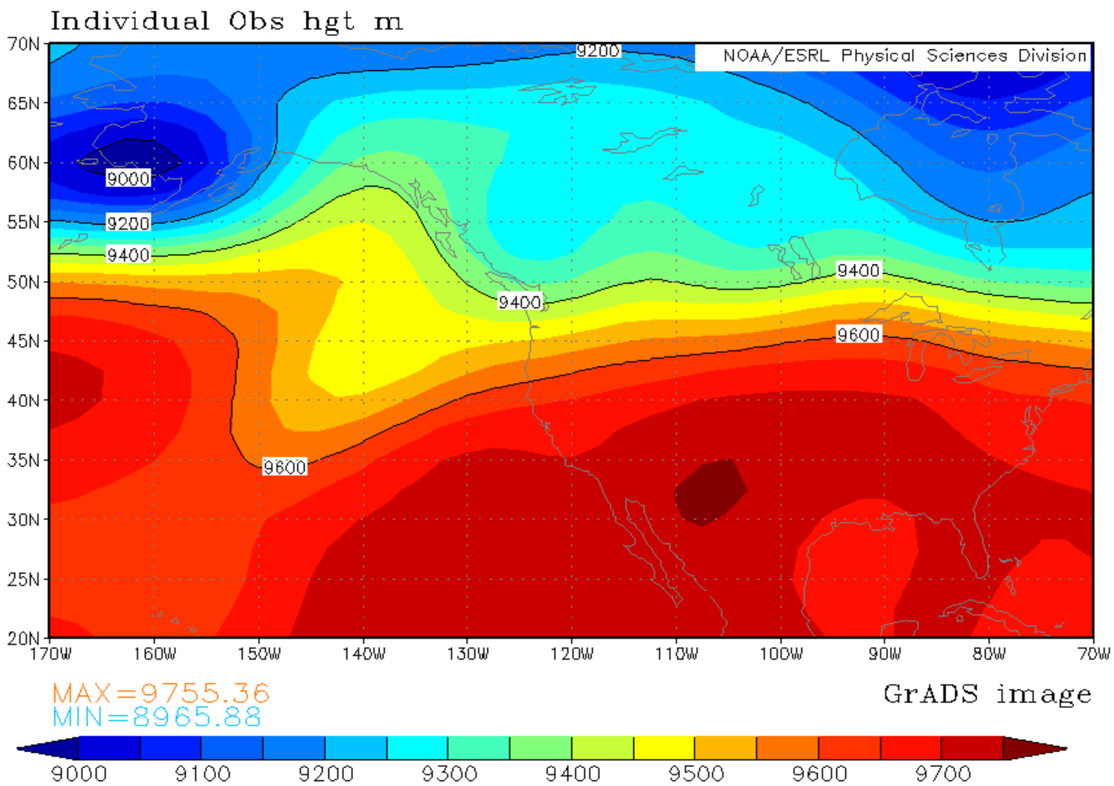

Figure 3. Plot of geopotential height at 300mb (www.arl.noaa.gov).

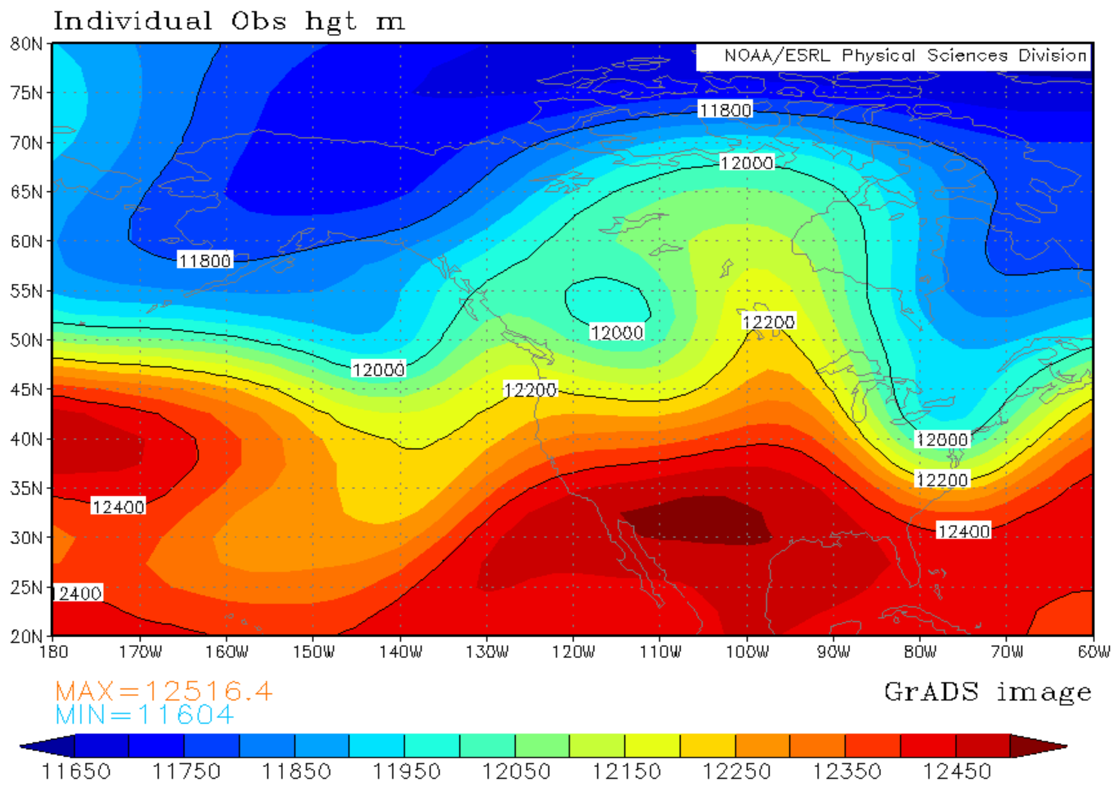

Figure 4. Plot of geopotential height at 200mb.

The data from the Washington VAAC displays volcanic ash advisories that correspond to the SO_2 dispersion images from Aura/OMI shown earlier. Advisories could not be obtained for the exact dates and times represented in those figures, but figure 5 displays a representative advisory for the volcanic ash from the Okmok eruption. This advisory was issued on 18 July 2008 for the northwestern United States and part of Canada. Figure 6 displays a representative advisory for the volcanic ash dispersion from the Kasatochi eruption. The advisory was issued on 10 August 2008 and covered a much larger geographic region due to the complex flow pattern of the ash dispersion, as depicted in Figure 2. Figure 6 also shows that ash was below FL400 (40,000ft or 12km).

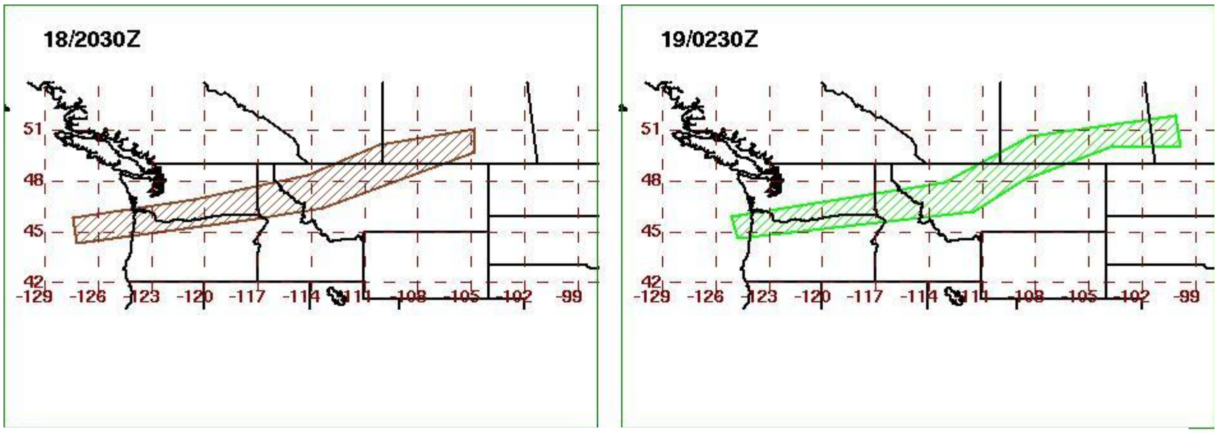

Figure 5. Volcanic ash advisory issued by the Washington VAAC on 18 July 2008 for Okmok eruption (http://www.ssd.noaa.gov/VAAC/archive.html).

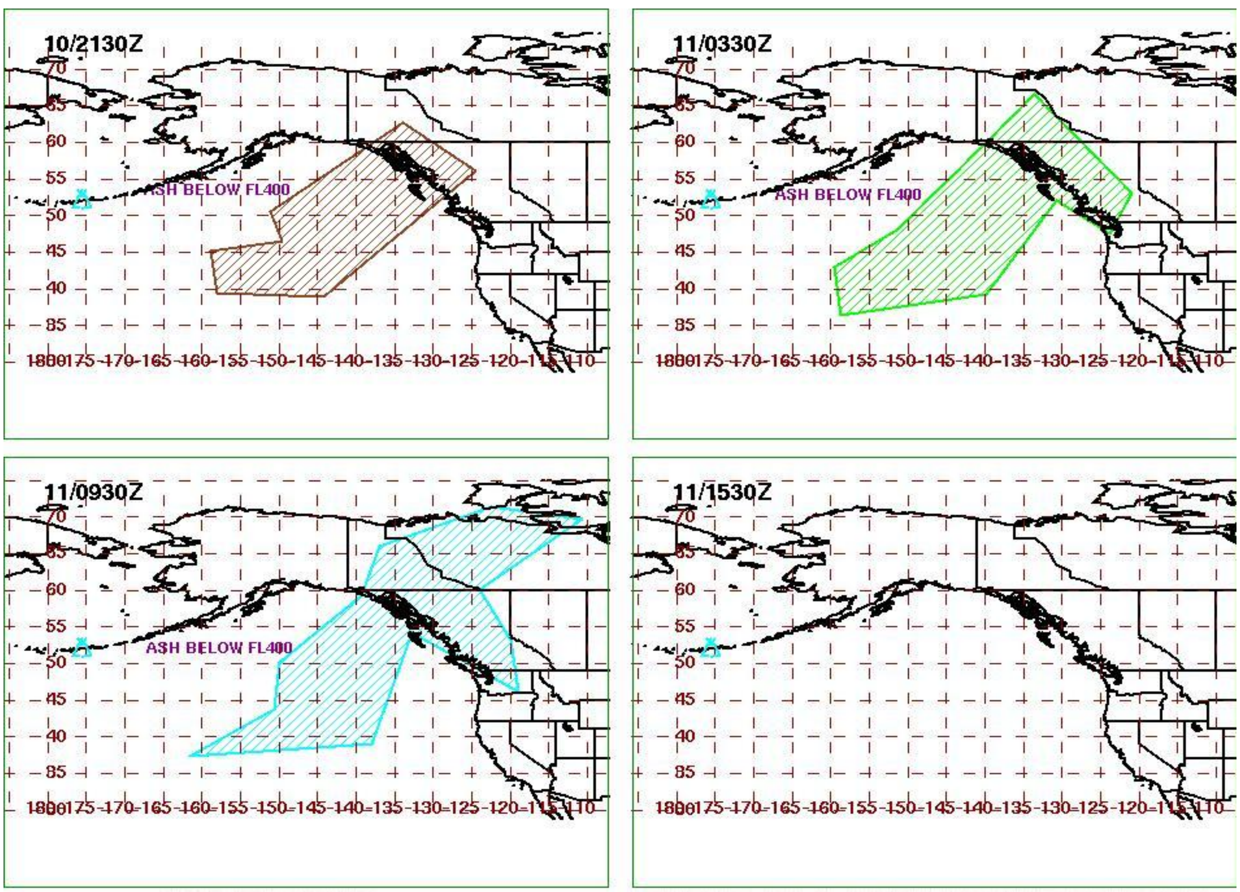

Figure 6. Volcanic ash advisory issued by the Washington VAAC on 10 August 2008 for Kasatochi eruption

The volcanic ash dispersion from the Okmok eruption resulted in a non-damaging aircraft encounter which occurred near Kodiak Island on 15 July 2008. The pilot report indicated that neither pilot smelled anything unusual or noticed any change in aircraft performance.[1] On 11 August 2008, however, a 757 aircraft encountered an ash cloud over the Yukon from the Kasatochi eruption. The crew reported smelling sulfur and seeing a yellow and brown haze, but there were no reported changes in aircraft performance.[3]

Finally, an ash cloud from Kasatochi was detected over the Gulf of Alaska on 10 August 2008. Flights were cancelled from Anchorage to Seattle, Portland, San Francisco, Denver, Los Angeles, and Vancouver. Over 6,000 passengers were stranded due to these cancellations.[3]

V. Conclusion

Figure 3 shows that ash following the Okmok eruption was likely at a pressure level of 300 mb. Based on the geopotential height plots, 300 mb is the only plotted pressure level at which the atmospheric flow hooked anticyclonically over northern Idaho, as suggested by Figure 1. Furthermore, Figure 4 reveals that ash following the Kasatochi eruption had reached an altitude of 200 mb. The plot of geopotential height at 200 mb suggests a southwesterly flow due west of Oregon, which is supported by Figure 2 as it displays ash dispersion following a similar pattern. Figure 6 helps to confirm the height determined in Figure 4 because it shows the ash as being below FL400, and Figure 4 shows flow at 200mb which is approximately the same altitude.

The volcanic ash advisories from the Washington D.C. VAAC took advantage of the information provided in Figures 1-4. Figures 1 and 2 display regions where there are elevated levels of column SO_2 in the atmosphere, which is an indicator of volcanic ash. The regional Volcanic Ash Advisory Centers used this information to issue advisories by outlining the geographic region over which the ash was covering. Figures 3 and 4 helped to indicate the flow pattern of the ash cloud, which also helped in the issuing of the advisories.

Due to the dispersion of volcanic ash clouds from both of these eruptions, many flights were cancelled and thousands of travelers were stranded. Numerous flights were required to reroute, and the pilots of the aircraft who encountered the volcanic ash from the Okmok and Kasatochi eruptions were required to make important decisions and reroute in-flight. This indicates that measures should be taken to improve forecasting and communication in regard to volcanic ash dispersion.

Future research should be undertaken to conduct similar studies on Mt. Redoubt which began a series of eruptions on 22 March 2009. These eruptions produced an ash plume reaching 60,000 ft above mean sea level. The analysis of synoptic meteorological conditions undertaken in this study should be repeated. In addition, the Iterative Spectral Fitting (ISF) algorithm, developed by Arlin Krueger and others, may be implemented to determine SO_2 plume altitudes.[6] These should be compared to CALIPSO lidar retrievals for validation. All of this information should then be compared to the related VAAC advisories and any pilot reports that may be available.

References

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