Service Review

Mount Redoubt Volcanic Eruptions March - April 2009

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland

Cover Photograph: Mount Redoubt volcano in continuous eruption on March 31, 2009. Plume height is no more than 15,000 feet above sea level. The small amount of ash in the plume is creating a haze layer downwind of the volcano and dustings of fine ash are falling out of the plume. View is from the northwest.

Image Creator: Wallace, Kristi; Image courtesy of the Alaska Volcano Observatory / U.S. Geological Survey.

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January 2010

Preface

On March 22, 2009, Mount Redoubt volcano, 106 miles southwest of Anchorage, Alaska, began a series of eruptions after persisting in Orange or "Watch" status since late January 2009. Plume heights were observed at or above 60,000 feet during two of the six significant eruptions. Ashfall occurred over south central Alaska, including in Anchorage, with amounts ranging from a trace to one-half inch in depth.

The Redoubt eruptions also disrupted air traffic in the region. Hundreds of commercial flights were cancelled and cargo companies were significantly impacted. This resulted in employees being placed on unpaid leave during periods when airport operations were shut down. Anchorage is Alaska's major population center; its airport serves as a critical strategic transportation hub as the third busiest cargo airport in the world.

The impacts of the unrest at Mount Redoubt volcano continued through spring and into the summer. The threat of continuing eruptions and lahars (volcanic mud flows composed of water, ash, mud, and debris) necessitated the removal of millions of gallons of oil from Chevron's nearby Drift River Terminal. Residents, emergency management, and health officials remained on alert until Mount Redoubt volcano was downgraded to Yellow or "Advisory" status on June 30, 2009, and finally to Green or "Normal" status on September 29, 2009.

NOAA's National Weather Service (NWS) plays a central role in providing meteorological observations and analysis in addition to forecast and advisory information for volcanic ash analogous to that which is provided for most other hazards affecting the atmosphere. Volcanic ash, however, presents a unique set of challenges for NWS operations. For instance, another agency (the Department of Interior's U.S. Geological Survey, or USGS) has the lead in monitoring and warning of volcanic eruptions. The eruptions often occur with very little advanced warning, requiring very close interagency coordination as well as rapid, cohesive delivery of information to decision-makers in emergency management and air traffic.

The 2009 Mount Redoubt eruptions provided an opportune case for the NWS to examine the effectiveness of its operational products and procedures with respect to volcanic ash, and to identify lessons and best practices that may have a broader application within other NWS service areas. A multi-disciplinary team was chartered to perform this review and tasked to focus particularly on the usefulness of NWS products and services in the context of decision support

for officials in emergency management and air transportation. This report and associated recommendations are aimed at improving NWS operations and services, as well as providing useful information to our partners and users of our volcanic ash-related information and services.

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January 2010

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January 2010

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Service Review Team

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Service Review Report

1. Executive Summary

Mount Redoubt Volcano in southwest Alaska is an active volcano the National Weather Service (NWS) monitors due to its recent history of eruptions. This service review addresses the Mount Redoubt eruptions that began on March 22, 2009. The eruptions consisted of a series of explosive ash-producing events resulting in immediate action on the part of the NWS Alaska Regional Headquarters, Anchorage Weather Forecast Office (WFO), Alaska River Forecast Center, Alaska Aviation Weather Unit/Volcanic Ash Advisory Center (AAWU/VAAC), and the Anchorage Center Weather Service Unit (CWSU). Primary threats from Mount Redoubt include its proximity to a metropolitan area and surrounding communities, the potential national impact an eruption might have on the fossil fuel energy facilities in the area, and significant impacts to international airspace and sea lanes.

There were several impacts from this series of eruptions from Mount Redoubt. Two major lahars (mudflows) moved down the Drift River and partially inundated an oil terminal. Airborne ash clouds posed a hazard to aviation and caused multiple flight cancellations and reroutes. Alaska Airlines cancelled approximately 200 flights. FedEx, United Parcel Service and several other cargo airlines rerouted aircraft to Seattle. Ashfall forced Ted Stevens International Airport in Anchorage to close for 20 consecutive hours. Disruption to the aviation industry was significant for passenger travel and cargo transportation between Asia and North America. Minor ashfall impacted several communities as far downwind as Delta Junction, Alaska, 400 miles northeast of Anchorage. Elmendorf Air Force Base assets were temporarily relocated. There were also impacts to oil field operations due to the cessation of oil storage at Chevron's Drift River Oil Terminal. Cost figures for the total economic impact of this event were not available at the time of this report. However, the economic impact is estimated to be less than or equal to the cost of the impact from the 1989-1990 Mount Redoubt event (estimated at $160 million).

The Mount Redoubt Service Review Team evaluated the performance and usefulness of NWS products and services as an aide to decision making during the Mount Redoubt eruptions between March and April 2009. The team determined the WFO, AAWU/VAAC, CWSU and other partner agencies in the Alaska Interagency Operating Plan for Volcanic Ash Episodes handled this event well. The review thus focuses on areas of best practice, findings, and recommendations that could improve the performance of the NWS locally and nationally. The team identified six best practices and 15 findings and recommendations, noted in the report and summarized in Appendix B.

The top three findings from this review reflect comments by key partners:

- **Warning and Forecast Services:** Ashfall Advisories, which are zone-based, covered too large a geographical area relative to the actual threat for decision makers.
- **Communications and Technology:** Expanded use of collaborative tools such as NWSChat in the Alaska Region would be beneficial for automated product delivery and for enhancing decision support.

- **Collaboration and Coordination:** Partners expressed a need to better understand how the WFO, CWSU, and AAWU communicate with each other and formulate products.

The review team concluded that while the NWS and partner agencies responded effectively and quickly to the Mount Redoubt eruptions in spring 2009, lessons learned carry national implications.

2. Introduction

2.1 NWS Mission

As a line office of the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure that can be used by other governmental agencies, the private sector, the public, and the global community.

These services are delivered through the efforts of staff stationed at 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), 9 National Centers of the National Centers for Environmental Prediction (NCEP), 21 Center Weather Service Units, the Alaska Aviation Weather Unit, 13 Weather Service Offices, 2 Tsunami Warning Centers, 6 Regional Headquarters, and a number of other units. NWS Headquarters in Silver Spring, Maryland provides oversight, policy, and support.

2.2 Purpose of Service Review

The purpose of this document is to present findings and recommendations resulting from a service review of NWS performance during a series of eruptions at Mount Redoubt in south-central Alaska in March and April 2009. The primary focus of the team was to review the usefulness, timeliness, quality, and accuracy of NWS products and services in the context of enhanced decision making, as well as the role the NWS should play in future operations. Additionally, the team was tasked with documenting the flow of critical information to and from key decision makers in the emergency management and transportation sectors. Based on the Mount Redoubt eruptions, this report conveys findings and recommendations with national relevance. The team issued 15 recommendations based on its evaluation and findings, as well as six best practices.

2.3 Methodology

NWS formed a four-person service review team to evaluate the performance and usefulness of its products and services during a series of eruptions of Mount Redoubt between March and April 2009. Team members were chosen based on their complementary areas of

expertise. Three of the four investigators are from NWS offices; the fourth team member is from the University of Oklahoma.

The team assembled to conduct interviews in Anchorage on May 26-28, 2009. Sixteen interviews were conducted involving 30 principal individuals. The entire team either in person or over the telephone conducted interviews. The NWS arranged interviews prior to the arrival of the team in Anchorage. A staff member from the Alaska Region office accompanied the team on office visits for in-person interviews and sat in on telephone interviews. Assistance from the Alaska Region office allowed for a quick and efficient review. The presence of a regional representative during the interviews may or may not have introduced a bias. Regardless, the team concluded that any such biases were minimal, based on the diversity of the user community and the interviewees' candid feedback.

Team members conducted interviews with the following agencies and companies:

- Anchorage WFO
- Anchorage Center Weather Service Unit (CWSU)
- Anchorage Federal Aviation Administration (FAA)
- Alaska Volcano Observatory (AVO), jointly operated by the U.S. Geological Survey (USGS)
- Alaska Division of Geological and Geophysical Surveys (ADGGS)
- University of Fairbanks Geophysical Institute (UAFGI)
- Alaska Department of Environmental Conservation Division of Air Quality (DEC)
- Alaska state emergency manager office
- U.S. Air Force
- City and borough emergency managers
- Federal Express (FedEx) dispatch office
- Northwest Airlines
- Alaska Airlines
- United Parcel Service (UPS) International Operations Management office
- Washington Volcanic Ash Advisory Center (VAAC), the Anchorage International Airport
- Local media offices (KTUU, and Anchorage Daily News)

This list also includes most of the agencies in the *Alaska Interagency Operating Plan for Volcanic Ash Episodes*.[1]

[1] The agencies involved in the operating plan are: FAA; AVO, operated jointly by the USGS, ADGGS, and UAFGI; NWS; the Department of Defense (DOD); the state of Alaska, Department of Military and Veterans Affairs, Division of Homeland Security and Emergency Management (DHS&EM); the Department of Environmental Conservation Air Quality Division (DEC); and the United States Coast Guard (USCG).

The team also reviewed products and services produced by the NWS and its partners, including archived electronic communications such as NWSChat, and warning products such as advisories and Significant Meteorological advisories (SIGMET).

A semi-structured format was used for the interviews. This allowed for a certain degree of flexibility in the discussions while still ensuring that the questions remained relevant. The interview topics reflected the goal of the service review: to examine NWS actions taken and the flow of information to partners, users, and key decision makers. Interviews focused on several overarching themes:

- Timeliness, quality, accuracy, and usefulness of NWS products and services
- Effectiveness of NWS internal and external coordination and collaboration
- Quality of NWS end-to-end information dissemination
- Effectiveness of NWS preparedness activities

More specific topics examined in the interviews included:

- Flow of information, Web-based applications, communication to public and transportation sectors
- Responses by NWS partners to NWS products, services, and briefings and how well partners understood the role of the NWS
- Responses by NWS users to products and services
- Economic impacts from the actions taken by NWS partners and users based on products, services, and briefings
- Adequacy and efficacy of media coverage

Following completion of the interviews, collection of other data sources, and data analysis, and evaluation, the team discussed and agreed upon the significant findings and recommendations to improve the usefulness, accuracy, and effectiveness of the NWS products and services.

3. Summary of Events

3.1 Background

Mount Redoubt is located in the Cook Inlet Region of south-central Alaska approximately 106 miles southwest of Anchorage, Alaska's largest city (**Figure 1**). The elevation of Mount Redoubt is 10,197 feet. Equipment which includes 10 seismic stations, one pressure sensor, and three Web cameras, located on and near Mount Redoubt, seismically monitor the volcano. In addition, the volcano is monitored by airborne and satellite gas measurements, thermal imaging, two real-time Global Positioning Satellites (GPS), and several campaign stations for GPS and broadband seismicity. Visual observations through overflights and photography are used as well. It is important for the NWS to monitor the Mount Redoubt volcano because of its recent history of eruptions, proximity to a metropolitan area, potential national impact on nearby fossil fuel energy facilities, and potential serious disruption to air and marine transportation, including airports.

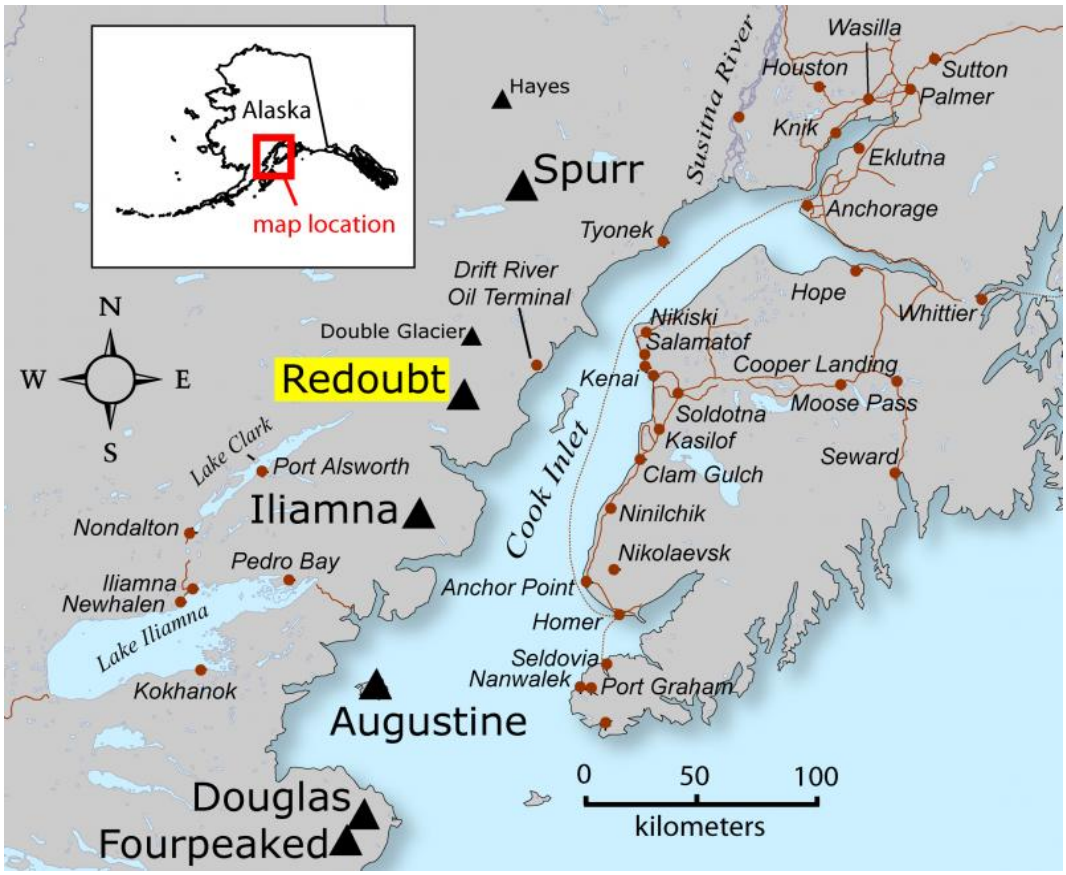

Figure 1. Map of south-central Alaska. Courtesy of Janet Schaefer, AVO/ADGGS.

3.2 Precursory Eruptive Behavior

Beginning in late July 2008, an unusually strong hydrogen sulfide (H_2S) odor was noted near the volcano, which persisted through mid-September 2008. In late September 2008, volcanic tremors began, along with steaming. A 50 m-wide hole was detected on upper Drift Glacier. During the month of October, H_2S, sulfur dioxide (SO_2), and carbon dioxide (CO_2) were all measured above background levels. On October 3, 2008, AVO sent out an Information Statement describing unrest and event possibilities. On November 5, 2008, the color code changed from GREEN to YELLOW, and the alert level changed from NORMAL to ADVISORY. The NWS uses the USGS Volcanic Activity Alert-Notification System for designations of volcano alert levels. Please see Appendix F for more information.

During the week of January 22, 2009, seismicity dramatically increased and new mudflows began to appear along the margin of the Drift Glacier and at the north base of the volcano. SO_2 levels were elevated along with seismicity. Seismic events reflecting magma displacement were occurring every hour at volcano monitoring stations. ORANGE/WATCH alert level was declared on January 25 and AVO began 24/7 staffing. AVO dropped the alert level back to YELLOW/ADVISORY on March 10, 2009, after six weeks of little change.

On March 15, 2009, at approximately 1 p.m. Alaska Daylight Time (AKDT), an explosion took place when magma neared the surface. The explosion resulted in a small ash eruption with high levels of gas. A water vapor plume was observed during an overflight. An ORANGE/ WATCH alert level was declared.

AVO returned the alert level to YELLOW/ADVISORY on March 18. On March 21, a high rate of seismicity was noted and AVO returned to ORANGE/WATCH alert level. Beginning on March 22, a series of major explosive events took place.

3.3 Eighteen Major Explosive Events:

Time	Flight Level
3/22 22:38 AKDT	FL180
3/22 23:02	FL440
3/23 00:14	FL430
3/23 01:39	FL430
3/23 04:31	FL490
3/23 19:41	FL600
3/26 08:34	FL220
3/26 09:24	FL620
3/26 23:47	FL360
3/27 00:29	FL490
3/27 08:39	FL510
3/27 17:35	FL390
3/27 19:25	FL500
3/27 23:20	FL390
3/28 01:20	FL430
3/28 13:40	FL170
3/28 15:39	FL400
3/28 19:23	FL410

On March 31, 2009, AVO noted lava dome growth. From March 30 through April 3, low-level ash and gas emissions and haze were noted across Cook Inlet. On April 4, another major explosion took place (#19).

3.4 Impacts

There were several impacts from the major eruptions of Mount Redoubt volcano. Two major lahars moved down the Drift River and partially inundated Chevron's Drift River Oil Terminal. Airborne ash clouds posed a hazard to aviation and caused multiple flight cancellations and reroutes. Alaska Airlines cancelled approximately 200 flights. FedEx, UPS and several other cargo airlines rerouted aircraft to Seattle. Ashfall forced Ted Stevens International Airport in Anchorage to close for 20 consecutive hours. Disruption to the aviation industry was significant with major economic implications. Minor ashfall affected several communities as far downwind as Delta Junction, Alaska, 400 miles northeast of Anchorage. Elmendorf Air Force Base (AFB) assets were temporarily relocated. Halt of oil storage at Drift River Oil Terminal and associated impacts upstream at production wells also resulted in significant economic impacts.

In addition to local impacts, a large volcanic event in the Anchorage area can have significant national-level impacts. Interruptions to traffic through the airport and Port of

Anchorage for more than a day, and disruptions to or destruction of the oil facilities in the area, would cause problems in the continental United States as well as with other countries that rely on these transportation hubs and resources. Sustained disruption to air traffic at the Anchorage airport alone would have a major global impact. Anchorage is one of the top five busiest air cargo hubs in the world, along with Memphis, Hong Kong, Shanghai, and Seoul. National level preparedness plans should consider potential disruption to global air cargo.

3.5 Eruptions of Redoubt in 1989-1990

Prior to the 2009 event, the last significant eruptions on Mount Redoubt took place from December 14, 1989, to April 21, 1990. The first of these eruptions took place at 9:47 a.m., December 14, 1989, after less than 24 hours of intense precursory seismicity. On December 15, 1989, three more ash rich explosions occurred. The last blast generated pyroclastic flow (a fast moving current of hot gas and rock) down the Drift Glacier. The resulting debris flow entrained ice blocks as large as 10 m in diameter and crested about 8 m above the river channel near the Drift River Oil Terminal, 35 km downstream. A Boeing 747, en route from Amsterdam, which flew into the ash cloud several hours after the eruption, experienced complete engine failure and narrowly avoided tragedy when the crew successfully restarted the engines and safely landed in Anchorage. The aircraft sustained $80 million in damages[2].

These initial explosive events were the first of 23 major explosive events between December 1989 and April 1990. The 1989-90 eruption of Redoubt seriously affected the populace, commerce, and oil production throughout the Cook Inlet region and air traffic as far away as Texas. Total estimated economic costs were $160 million, making the 1989-90 eruption the second most costly in U.S. history after Mount St. Helens in 1980. Total economic costs of the 2009 event were not available at the time of this report. However, the economic impact is estimated to be less than or equal to the cost of the impact from the 1989-1990 Mount Redoubt event. The impact on Alaskan air freight from the 2009 event alone is estimated at approximately $20 million per day for the disruption due to rerouting traffic from North America to the Far East and Southeast Asia.

[2] See http://www.avo.alaska.edu/volcanoes/volcbib.php? volcname=Redoubt
Unknown Author, 1990, Volcanic ash cloud shuts down all four engines of a Boeing 747-400, causes $80 million in damage: Aviation Week and Space Technology, v. 132, p. 93.

3.6 Summary of Products Issued

3.6.1 Volcanic Ashfall Advisories: WFO Anchorage

	Issued (UTC)	Expired (UTC)	Area (km^2)	Zone Name
1	2009-03-23 07:33	2009-03-23 23:50	45,993	Susitna Valley
2	2009-03-23 15:18	2009-03-24 00:00	95,422	Kuskokwim Valley
3	2009-03-24 04:16	2009-03-24 13:00	20,6342	Bristol Bay , Kuskokwim Valley
4	2009-03-24 04:23	2009-03-24 13:00	45,993	Susitna Valley
5	2009-03-26 17:44	2009-03-27 02:00	11,870	Western Kenai Peninsula (**Figure 2**)
6	2009-03-27 08:24	2009-03-27 23:00	57,864	Susitna Valley, Western Kenai Peninsula
7	2009-03-27 21:17	2009-03-28 12:56	95,422	Kuskokwim Valley
8	2009-03-28 05:36	2009-03-28 13:00	45,993	Susitna Valley
9	2009-03-28 13:15	2009-03-28 20:00	45,993	Susitna Valley
10	2009-03-29 00:16	2009-03-29 09:00	166,229	Matanuska Valley, Western Prince William Sound, Copper River Basin, Western Kenai Peninsula, Anchorage, Susitna Valley
11	2009-04-04 14:28	2009-04-04 19:55	11,870	Western Kenai Peninsula

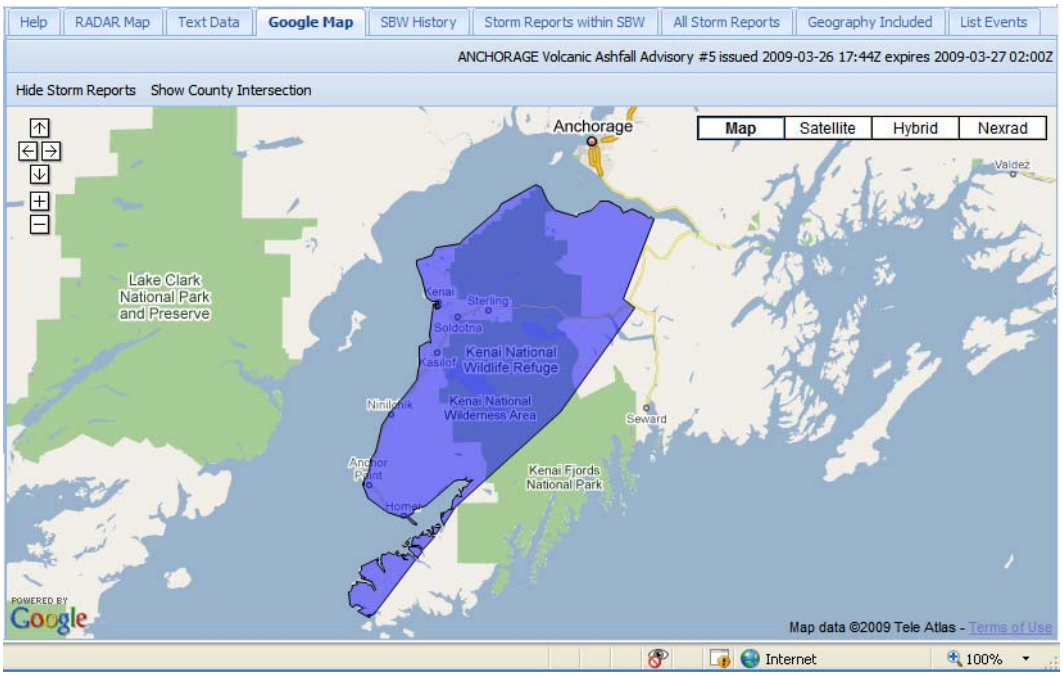

Figure 2. WFO Anchorage Ashfall Advisory No. 5 for the Western Kenai Peninsula. http://mesonet.agron.iastate.edu/vtec/#2009-O-NEW-KAFC-AF-Y-0005 (see Appendix E for additional data).

3.6.2 Summary of SIGMET Products Issued

During March and April 2009, the Alaska Aviation Weather Unit (AAWU) issued 39 SIGMETS. The team also evaluated 142 Pilot Reports (PIREPS) from the aviation community.

4.0 Socioeconomic Impacts and Related NWS Products and Services

There were several direct and indirect impacts arising from the Mount Redoubt eruptions. Two major lahars moved down the Drift River and partially inundated the Chevron oil terminal. The risk and damage inflicted on the Drift River terminal cost Chevron significantly (these data were unavailable at the time of writing). Some WFO staff expressed concern that NWS services were underutilized by those managing the Drift River terminal during this event. Like other oil terminals in the state, the Drift River site is vulnerable to natural hazards. Damage to the terminals poses a risk to the surrounding ecological and human communities. There was also a significant economic impact from halting oil storage at the Drift River Oil Terminal, which affects upstream production wells.

Airborne ash clouds posed a hazard to aviation, resulted in hundreds of cancellations, and rerouted flights in and around metropolitan Anchorage. The repercussions of human and cargo transport delays rippled through the Anchorage, Alaskan, and U.S. economies. Alaska Airlines cancelled approximately 200 flights. FedEx, UPS, and several other cargo airlines rerouted aircraft to Seattle. Ashfall caused the Ted Stevens International Airport in Anchorage to shut down all operations for 20 hours. Disruption to the aviation industry was significant with long-term and far-reaching economic implications; however, NWS clients thought these impacts were minimized thanks to timely and accurate NWS products and services. Minor ashfall affected several communities as far downwind as Delta Junction (400 miles northeast of Anchorage). Emergency managers used NWS products with varying degrees of success to prepare their communities for ashfall threats. Elmendorf AFB temporarily relocated some of its assets.

The review team did not directly assess socioeconomic impacts to local businesses and the public. Interviews with NWS partner agencies and clients indicated that the public was not greatly affected by the eruptions. The most significant impact arose from delayed air travel and degraded air quality. Increased ash in the air affected health for some residents and damaged outdoor electronics. Additionally, some members of the public apparently misinterpreted online displays of HYSPLIT airborne ash plots to be ashfall forecasts, possibly leading to less than ideal or disproportionate responses to the threat of the eruption. Tourist lodges near Mount Redoubt also noted lost revenue in NWS threat areas. NWS staff treated local concerns about loss of income on a case-by-case basis with satisfactory results. Overall, the socioeconomic impacts of the Mount Redoubt eruption were relatively minor. A larger or more prolonged eruption could have catastrophic impacts on Anchorage and the Alaskan economy, which is closely tied to its transportation sector.

5.0 Findings, Recommendations and Best Practices

A major focus of many of these findings, recommendations, and best practices applies to enhancing decision support services in the NWS.

5.1 Warning and Forecast Services

This section captures the performance of NWS field offices and evaluates the effectiveness of operational products and procedures. For this section, the team conducted a broad review of NWS products and services. The team used customer feedback as a measure of overall performance.

In general, NWS Alaska field offices performed in an exemplary manner during this event. The public advisories and aviation-related products provided critical, life saving information to the aviation community and significant public awareness information to emergency managers and the general public.

As volcanic activity increased in January 2009, WFO Anchorage increased its operational posture by implementing a one-stop-shop Web page for volcanic information from the AVO and NWS. The WFO posted its recently implemented ashfall specification table on its Web page prior to the event. In January 2009, the WFO staff reviewed and readied procedures related to ashfall product issuance. During eruptive events, the WFO staffed an extra desk to handle the additional operational workload, interagency conference calls, and public and media inquiries.

As part of every Ashfall Advisory, WFO Anchorage included forecast ashfall amounts and preparedness information as illustrated in the following example.

```
URGENT - WEATHER MESSAGE
NATIONAL WEATHER SERVICE ANCHORAGE AK
944 AM AKDT THU MAR 26 2009

“MOUNT REDOUBT HAS ERUPTED MULTIPLE TIMES THIS MORNING.THE MOST
SIGNIFICANT ERUPTION OCCURRED AROUND 924 AM WITH A PLUME RISING
UP TO 60000 FEET. ASH FROM THESE ERUPTIONS WILL TRACK TO THE
KENAI PENINSULA WITH ESTIMATED ARRIVAL OF ASH BETWEEN NOON AND
2 PM. MINOR ASHFALL IS LIKELY FROM NINILCHIK SOUTHWARD TO THE
SOUTHERN TIP OF THE KENAI PENINSULA...INCLUDING HOMER AND
COMMUNITIES ALONG KACHEMAK BAY.A TRACE TO ONE EIGHT OF AN INCH
OF ASH MAY ACCUMULATE THIS AFTERNOON.TRACE AMOUNTS OF ASH ARE
ALSO POSSIBLE FOR AREAS NORTH OF NINILCHIK.”
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For both Ashfall Advisories and SIGMETS, several users thought that ashfall hazard areas were larger than necessary. The team discovered several factors that likely contributed to customer opinion.

First, aviation users would prefer that ash SIGMETs and Volcanic Ash Advisory (VAA) statements reflect the exact outer perimeter of the ash cloud from an observational and forecast perspective. However, current observational remote sensing and dispersion model technology provide only a limited snapshot of conditions and forecast trajectory. As a result, the NWS allows for uncertainty in forecasting the areal extent of volcanic ash and therefore generally broadens the coverage beyond a simple deterministic solution. The NWS could provide both a deterministic forecast of ash cloud bounds, as well as an outer probabilistic perimeter. The team found no immediate demand for probabilistic ash cloud data from local partners; the value of this data for local partners should be further investigated. Air traffic managers also recognize the fact that any amount of airborne ash poses a potentially lethal impact to flight and that NWS warnings and advisories need to be sized to best mitigate that risk. The introduction of quantitative uncertainty for ash cloud dispersion forecasts may be helpful from a risk management perspective, but significant improvements to remote sensing techniques and improved dispersion models are needed to provide the spatial and temporal resolution desired by aviation users.

In addition to the high impact on Alaskan air freight, estimated at about $20 million per day in Anchorage, ash SIGMETs substantially impact air route traffic to and from North America and the Far East and Southeast Asia.

Second, NWS forecasts and long-fused warnings and advisories are tied to climatologically based forecast zones. In Alaska, zones vary in size from several thousand square miles to tens of thousands of square miles (**Figure 3**). Since Volcanic Ash Advisories require the use of forecast zones, it is likely that some geographical areas within the larger zones were unnecessarily included in the advisories. Use of a polygon-delineated area would more precisely reflect the hazard area.

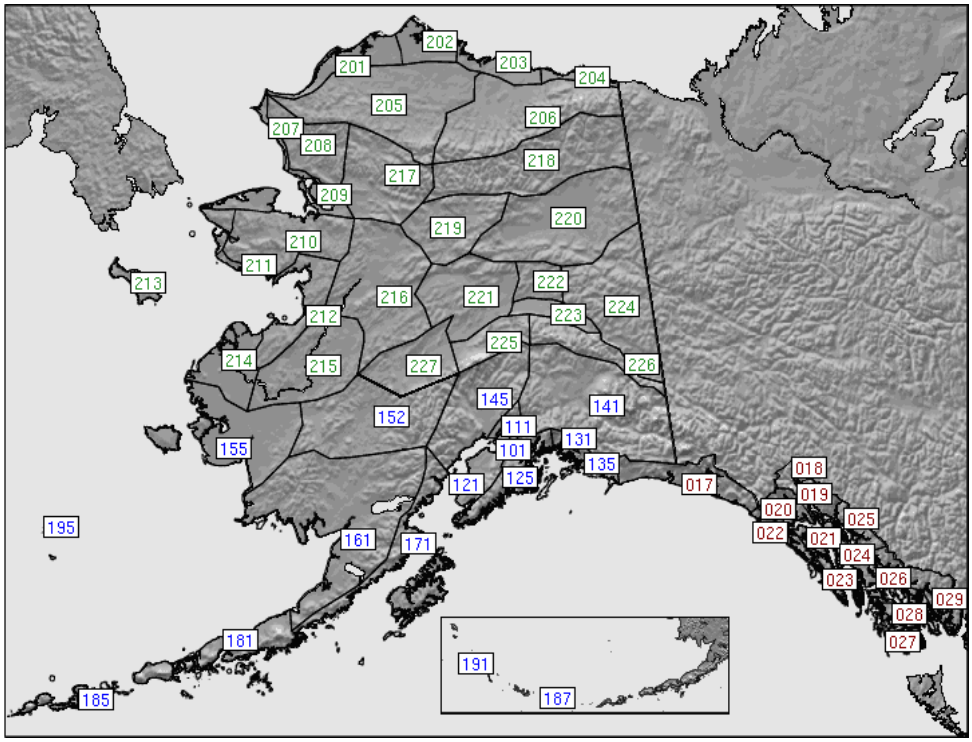

Figure 3. Map of Alaska Forecast Zones. Courtesy of WFO Anchorage. Colors designate the office responsible for those zones: Green – Fairbanks, Blue – Anchorage, Red – Juneau.

To avoid SIGMET issuance errors, a graphical user interface should be developed to handle several key product components (e.g., issuance time, product valid time) that do not always require manual intervention of the forecaster. Corrections and typographical errors create confusion and dissemination difficulties for pilots according to Air Traffic Managers at the Anchorage ARTCC.

AAWU/VAAC does not have the same capabilities as the Washington VAAC. Staff at the AAWU/VAAC need access to advanced satellite imagery to detect and track volcanic ash across their area of responsibility. In fact, the AVO has more advanced satellite information than the AAWU. Both the AVO and the Washington VAAC have access to advanced satellite information from McIDAS, MODIS, and POES satellites. (Please see Appendix C for a list of acronyms.)

Best Practice #1: WFO Anchorage conducts a volcanic ash drill training program that includes specific decision points to be successfully implemented before and during the event.

Fact: During eruptive events, WFO Anchorage augmented staffing levels to handle additional workload: taking part in coordination calls, issuing statements and advisories, and responding to public/media inquiries. NWS field offices used a shift log to document important operational issues and contacts with external partners and users.

Finding #1: Some users noted that Ashfall Advisories, which are zone-based, covered too large a geographical area relative to the actual threat.

Recommendation #1: Establish polygon-based capabilities for Ashfall Advisories that can be graphically displayed on various platforms in user-friendly geospatial formats.

Finding #2: AAWU has limited access to AVHRR satellite data. Likewise, AAWU does not have similar satellite capabilities as the Washington VAAC. AVO and Washington VAAC have access to more advanced satellite data such as McIDAS, MODIS, and POES.

Recommendation #2: Provide AAWU with identical satellite capabilities as the Washington VAAC. Allow forecasters access to non-operational systems and tools currently available, such as the Volcanic Ash Collaborative Tool (VACT), to improve forecasts and decision support. Access to advanced satellite information and use of complex enhancement curves gives users of such data a greater ability to detect airborne ash.

Fact: SIGMETs cover all types of aviation, from General Aviation and lower altitude flight levels to commercial aircraft.

Finding #3: The areal extent of certain SIGMETs related to volcanic ash and turbulence was too large to be effectively used by some users for high-altitude route planning. Several of those interviewed commented that SIGMETs were generally too large and lasted too long. Some users found it difficult to identify small SIGMET areas on established aviation graphics. Such

difficulties were encountered when the ash area was relatively small compared to the enormous domain of the graphic.

Recommendation #3a: Implement additional satellite capabilities at the AAWU to help improve temporal and spatial SIGMET accuracy.

Recommendation #3b: In addition to existing graphics, the NWS should provide SIGMETs in additional electronic and geospatial formats, including shapefiles.

Fact: At least one airline with service to Alaska used WSI Corp. SIGMETs during the volcanic events.

The CWSU should be aware that pilots may be receiving SIGMETs from other entities. Differences between NWS and WSI SIGMETs may cause confusion.

Finding #4: Both Flash Flood (FFW) and Flood (FLW) Warnings were issued for the Drift River during the event due to potential lahars.

Recommendation #4: WFOs should use FFWs exclusively for lahars given the typically rapid onset of such phenomenon.

Finding #5: NWS policy regarding Volcanic Ash is scattered throughout the Directives system.

Recommendation #5: Volcanic Ash program needs its own definitive directive.

Finding #6: The reference to UTC (i.e., "Z" time) on the HYSPLIT model output was confusing to some users.

Recommendation #6: Include Alaska Daylight Time/Alaska Standard Time and the conversion in addition to UTC on HYSPLIT and Puff model output. Given the range of potential users, from partners to the general public, features of the model should be highlighted to ensure users better understand and interpret the information.

Fact: The modeled volcanic ash cloud trajectories were not as well defined as some users would have liked.

Finding #7: Feedback from WFO, AVO, and emergency managers was mixed regarding the potential usefulness of probabilistic ash cloud forecast information.

Recommendation #7: Since probabilistic ash cloud forecasts could provide key supplemental information to help decision makers assess event-based risk, NWS Alaska Region should directly contact local emergency managers to explain the value of probabilistic ash cloud data, help to increase their understanding of these data, and learn how local emergency managers would actually use probabilistic data in specific scenarios.

5.2 Communication and Technology

Based on the responses of the interviewees, NWS offices (Alaska Region Headquarters, WFO, AAWU, and CWSU) communicated in a timely and effective manner with key partners in preparation for, and the response to, the Mount Redoubt eruption and ash event(s). The offices used a variety of methods and technologies to communicate to meet the requirements of partner agencies, the local community, and the information being shared. Primary channels of communication included the Internet, email, instant messaging via NWSChat, television, and telephone calls.

The Anchorage community and those who pass through it have a wide range of communication needs. It is challenging for NWS staff to deliver critical alert information in a concise way to this wide range of consumers. Some partners interviewed use newer social media technologies and tools such as Twitter (micro-blogging), while others still prefer traditional communication outlets, such as telephones, conference calls, and email notification. Some partners asked to receive mobile alert notification. The NWS can improve decision support in the Anchorage area by directing partners to more effective tools for data and information sharing, such as: instant messaging for automated real-time updates of NWS products and expertise (NWSChat), Real Simple Syndication (RSS) for automated Web feeds of data and product updates, and text messaging via Mobile Decision Support Services (iNWS). Improving efficiency in information delivery does not override the necessity for understanding and relating to the needs of NWS partners and the community. NWS offices must continue to provide and enhance personal communication to establish rapport with partners and learn of their concerns and impact thresholds, especially *before* high-impact events occur. This rapport creates an important foundation that helps ensure quick and accurate decision support when needed.

NWS Alaska offices extensively used instant messaging with NWSChat to aid communications, improving NWS response to Mount Redoubt eruptions. Although NWSChat conversations were primarily between NWS offices, local partners such as the FAA, benefited from this information channel and should be invited to participate more fully in the future. A dedicated multiuser chatroom was created specifically for the Mount Redoubt event. Selected log entries from these communications are included in Appendix D.

A summary of the information shared via NWSChat included:

- Change of volcano alert status: “Redoubt now in color code RED,” with links to the AVO Redoubt status Web page
- Details on eruption and ash events, such as timing, duration, altitude, and direction of ash cloud
- Notice of mudflows and lahar/pyroclastic flows in Drift River area observed via AVO cameras
- Availability of data from various imagery and information posted online via AVO Web page
- Availability of manual postings of SIGMETs, and routine and urgent PIREPs

- Location of imagery and tools that displayed ash event activity, such as local WSR-88D RADAR, USGS C-Band Doppler RADAR, GOES IR imagery, and VACT tool
- Aviation-related data, such as cancellations, diversions, and open flight paths
- Ash spotter reports posted by NWS staff
- Coordination between field offices and region headquarters regarding contacts with key partners, such as the Coast Guard and Emergency Management
- Partner conference call schedules
- Relation of ash to prevailing weather, including lightning strikes associated with eruptions
- Verification of ash between HYSPLIT models, visible satellite, PIREPs, and ashfall reports
- Tuning of the nwsbot function to auto-post specific products into the chatroom
- Details on automatic real-time posting of NWS products

The CWSU staff used NWSChat extensively to relay important specifics on the impacts of ash. Below is an example of this usage.

29 Mar 2009 22:06

"<nws-kristine.a.nelson> ANC Airport just opened 7R. There is one taxiway open. The gates are not cleared of ash, so aircraft will have to be towed from the gates to the taxiway. B747s can't land yet because their engines hang over the edges of the runway and there is a risk they may ingest ash."

Collaboration within NWSChat also made it possible to quickly identify a new and innovative concept/approach of radar to detect a debris cloud associated with a lahar. The transcript below if from a chat conversation between ANC WFO and Alaska Regional Headquarters, (ARH).

04 Apr 2009 17:33

"<nws-andrew.dixon> Preliminary analysis suggests the Kenai WSR-88D radar sampled some sort of debris cloud associated with the lahar as it descended the mountain after the eruption
<nws-carven.scott> andy...interesting. explain
<nws-andrew.dixon> I first noticed on 0.5 degree base reflectivity that there was some sort of continuous return that descended the north side of the mountain. The signature was even more pronounced when looking at 0.5 degree velocity data. I archived both reflectivity and velocity loops on AWIPS so that we don't lose them, and can analyze them later.
<nws-carven.scott> that is awesome. We need to talk to the AVO at some point Monday. That's a completely new concept.
<nws-andrew.dixon> It seems like it followed topography exactly, and velocity was highest as it dropped down the side of the mountain (as high as 20KT) and lost velocity as it spread out into the valley.
<nws-andrew.dixon> the radar beam would have been around 3,000 ft at that

radius, so it certainly makes sense to me that we would be able to see something. the weather has been so bad for previous eruptions that the weak signature was probably obscured by precip.
<nws-andrew.dixon> also, without 8bit super-res, I doubt we would have been able to see it
<nws-carven.scott> really cool. this could be whole new operational concept for a radar."

In addition to NWS staff and management, a small number of NWS partners also participated in NWSChat for Redoubt events. Registered users for the Redoubt chatroom include: NWS (53), FAA (4), AK DEC (2), Aviation (2), Academia (1), NOAA/Air Resources Lab (ARL) (1), and USAF (1). Of these NWSChat users, 16 NWS personnel posted information or queries to the chatroom during the volcanic events. Additional NWSChat users were also present in the Redoubt chatroom, benefiting from the information posted there, but did not post messages.

Best Practice #2: ARH, WFO AFC, AAWU, and CWSU used NWSChat for real-time, interactive event collaboration and information sharing. Part of the value of NWSChat is that as a social media tool it does not require "top-down" infrastructure for information flow, but rather promotes quick collaboration and response based on changing demands over time that do not require changes in configuration, staffing, or resources to accommodate this change.

Best Practice #3: NWS staff initiated personal communication and established rapport with local partners before high-impact events occurred to foster and strengthen relationships, learn partner concerns and understand agency impact thresholds.

Fact: A dedicated Redoubt chatroom was created on the NWSChat system.

Finding(s) #8: on the use of Instant Messaging (NWSChat):

- ARTCC reported they do not have the staff to participate in NWSChat but appreciated the quick information response provided by the CSWU staff who actively used NWSChat and relayed reports to them.
- AVO reported they do not have staff assigned to use NWSChat but might be interested in the NWSbot feature, which automatically posts all NWS products. Currently they have to retrieve products from the NWS manually.
- NBC outlet station KTUU and the Anchorage Daily News are not currently on NWSChat but plan to join.
- AKDEC was the only non-NWS partner to enter the redoubtchat room, although several other agencies have been granted access.
- Good collaboration was demonstrated among Alaska NWS (WFO, AAWU, CWSU, ARH) as well as Western Region Headquarters, Oakland CWSU, and NOAA ARL.

- NWSChat is a good start but communication during this event remained one-sided. (All information posted was submitted by the NWS).

Recommendation #8: Expand the use of NWSChat in the Alaska Region. Invite local media to join NWSChat. Demonstrate automated product delivery via NWSChat to key partners, specifically AVO, DHS, and EM. Determine if additional partners would benefit and, if so, provide them access.[3]

Finding #9: SIGMET plots from the Alaska AWU and Kansas City AWC are not available to users on a single Web page.

Recommendation #9: Develop a Web display of SIGMET plots that originate from the AAWU and AWC.

Fact: FedEx received direct phone support from the AAWU during Redoubt events.

[3] See section 5.3 Collaboration and Coordination for more information on the use of social media.

5.3 Collaboration and Coordination

Collaboration among the Anchorage WFO and its partner agencies generally was perceived to be efficient and effective prior to and during the Mount Redoubt eruptions. The *Alaska Interagency Operating Plan for Volcanic Ash Episodes* states explicitly:

> "Information observations indicating a volcanic eruption or the presence of volcanic ash can be incomplete and/or highly uncertain. The exchange of information between the AAWU, AVO, CWSU, ARTCC, DOD (Air Force), the NWS AWC in Kansas City, other VAACs, the WFOs, etc., is vital in determining the extent and severity of a volcanic ash event."

Indeed, interviews revealed that a great deal of collaboration and coordination goes into the exchange of information not only to determine the extent of an event, but also to communicate with all those involved in the advisory, watch, and warning process. Those interviewed were generally very pleased with the timeliness and quality of the forecast information and the special efforts made to convey forecast confidence.

- An Emergency Manager stated the "NWS effectively relayed its confidence level during calls and briefings."
- Officials from the Anchorage International Airport indicated they "received notice from NWS well before the ash hit. Service was outstanding."
- A staff member of the Anchorage Daily News noted there is "no substitute for talking to a live person during an event like this."
- FedEx reported that NWS support was "exceptional."

Formal coordination efforts, informal partnerships and relationships, and the flexibility to scale up operations in collaborative ways all contributed to the perception that NWS responded effectively. Comments such as the following reflect the good working relationships that are pivotal during an event:

- ARTCC personnel indicated the level of service and quality of products and briefings by the CWSU was outstanding and "they [CWSU] were an absolutely integral and important part of the team."
- An emergency manager noted he has "an excellent working relationship with the local NWS offices and the information flow was efficient."

Coordination efforts through a Web page and daily conference calls devoted to the eruption were pivotal information sources. The WFO spun up a coordination Web page with links to relevant agencies on the first day of the eruption, providing a "one-stop shop" for users. Interviews indicate this was especially useful to the aviation industry, which needed to determine how the WFO was responding to weather-related events around the eruption. The Web page also is mirrored within the WFO so it is available internally when the main page is down.

Best Practice #4: In conjunction with the AVO, WFO Anchorage developed a one-stop shop "Hazards and Impact" Web page for Mount Redoubt that was very useful as reported by key media, aviation, and EM partners. This coordination Web page was spun up immediately following the first major eruption. (See http://pafc.arh.noaa.gov/volcano.php).

Best Practice #5: The NWS routinely included forecast confidence levels during calls and briefings to key partners.

Best Practice #6: Daily coordination calls geared specifically toward partners (AAWU, ARTCC, AVO, CWSU, Emergency Operations Center/Emergency Management Center, and public media) were initiated and facilitated by the WFO. Interviewees who participated in the coordination calls reported the calls were essential in their ability to effectively respond to the eruption.

Fact: The WFO hosted coordination calls daily or on an as-needed basis.

Finding #10: External NWS partners, such as ARTCC and AVO, expressed a need to better understand how the WFO, CWSU, and AAWU communicate with each other and formulate products.

Recommendation #10: Cross-site orientation and site visits among partner agencies and offices within the NWS should be conducted regularly. Such site visits would have the dual benefit of clarifying roles and responsibilities during an event and enhancing understanding about NWS products and services. This type of exchange would not entail cross-training but rather understanding general concepts and knowing who does what in an office.

Fact: The WFO maintains a "phone book" of partner agency personnel in key roles as a reference. The WFO updates the "phone book" quarterly.

Fact: NWS and partners reported Mount Redoubt coordination calls were an important part of facilitating the flow of critical information and strengthening relationships.

Fact: Coordination calls were more efficient than during the 1994 and 2006 Mount Augustine Volcano eruptions.

Finding #11: NWS employees and partners who were unable to attend the regularly scheduled or ad hoc coordination calls felt at a disadvantage and expressed frustration with having to reassemble the information conveyed on the call.

Recommendation #11: The WFOs should post a podcast or similar audio file of the coordination calls on their coordination Web site.

Internal coordination among local NWS offices and partners was facilitated by close relationships between the WFO, AVO, and FAA: "We're all talking. [It's like] a three legged stool." Agencies responded to the elevated risk by scaling up operations during the Mount

Redoubt eruptions. The CWSU went to 24-hour operations and the AVO also scaled up its operations. Again, this was essential to successfully collaborating and coordinating between agencies. However, other agency personnel that the USGS brought in to assist the staff at the AVO encountered some problems. While many of them had previous experience from the Augustine eruption in 2006, they did not know the points of coordination in other offices and agencies. Specifically, they were not aware of their points of contact at the WFO. This lack of knowledge contributed to inefficiencies in interagency interactions. Understanding the roles and expertise of different people involved in the warning process is very important in terms of knowing who to call for specific information.

Finding #12: Some partners who do not already use social media and mobile information alerts requested access to this technology.

Recommendation #12a: Make individual partners aware of new tools for communicating with the NWS and assist them in implementing the technology. Implement tools for pushing data and products to subscribers in real time, such as NWSChat, Mobile Decision Support Services (iNWS), and RSS.

Recommendation #12b: The NWS should continue to pursue and evaluate the use of emerging communication and Web 2.0 technologies (e.g., Twitter) to offer new ways to interact and share weather and hazard information.

Fact: Ashfall criteria (NWS ARS 07-2002 Appendix D, Dated 2/9/09) were posted on the WFO Web page prior to the eruptive events. NWS users and partners found this reference information helpful as statements and advisories were issued.

Finding #13: Partner thresholds for response to ashfall and airborne ash vary. For example, Ted Stevens Anchorage International Airport's threshold is ash on the ground, whereas the threshold for commercial airlines and the ARTCC is ash in the air.

Recommendation #13: Determine specific partner thresholds for concern, alerting, and urgent response, and track these thresholds using a High Impact Event Catalog or similar database.

Finding #14: Currently, there are several sources of ashfall information, which are subsequently logged by multiple agencies.

Recommendation #14: Establish a single repository of ashfall reports to mesh spotter networks maintained by the AVO, WFO, DEC, and others. The WFO could place this repository on the coordination page.

The Drift River Oil Terminal is a Chevron facility used to store crude oil at the base of Mount Redoubt. The NWS reported ineffective use of the NWS Incident Meteorologist (IMET) by the Unified Command established at the site during the Mount Redoubt eruption. NWS

personnel were not informed about their roles in the Unified Command and were excluded from important meetings to which they could have made significant contributions.

Finding #15: Staff in the WFO expressed concern that NWS products and services were underutilized by Drift River Oil Terminal management during the eruption.

Recommendation #15: The NWS should have in place Memorandums of Understanding that explicitly define expectations and roles with key partners in potentially high-risk situations.

Summary

A series of major explosive events on Mount Redoubt from March 22-April 9, 2009, had significant impacts on south-central Alaska, most notably the aviation industry. Airborne ash clouds posed a major hazard to aviation and resulted in multiple flight cancellations and re-routes. Ted Stevens International Airport in Anchorage, for example, the third busiest air cargo hub in the world, was closed for 20 consecutive hours. Additionally, two major lahars impacted the Drift River drainage along the southwest flank of Mount Redoubt near Cook Inlet, the site of a large oil terminal. The lahars forced the oil terminal facility to close for several weeks. The associated impacts at the terminal and upstream at production wells had significant economic impacts. Fortunately, ashfall accumulations downwind of the volcano were relatively minor and did not pose a significant threat to life or property.

This document details findings and recommendations resulting from a week-long service review of NWS performance during the Mount Redoubt eruptive events. The service review team focused on the usefulness, timeliness, quality, and accuracy of NWS products and services in the context of enhanced decision-making. Specifically, the team examined:

- Flow of information, Web-based applications, communication to public and transportation sectors
- Responses by NWS partners to NWS products, services, briefings and how well they understood the role of the NWS
- Responses by NWS users to NWS products and services
- Economic impacts from the actions taken by NWS partners and users based on NWS products, services, and briefings, and
- The adequacy and efficacy of media coverage.

The team issued 15 recommendations based on their evaluation and findings, as well as six best practices.

Appendix A

Definitions

Best Practice—An activity or procedure that has produced outstanding results during a particular situation which could be used to improve effectiveness and/or efficiency throughout the organization in similar situations. No action is required.

Fact—A statement that describes something important learned from the assessment for which no action is necessary. Facts are not numbered but often lead to recommendations.

Finding—A statement that describes something important learned from the assessment for which an action may be necessary. Findings are numbered in ascending order and are associated with a specific recommendation or action.

Recommendation—A specific course of action, which should improve NWS operations and services, based on an associated finding. Not all recommendations may be achievable, but they are important to document. If the affected office(s) and OCWWS determine a recommendation will improve NWS operations and/or services, and it is achievable, the recommendation will likely become an action. Recommendations should be clear, specific, and measurable.

Appendix B

Best Practices, Facts, Findings, and Recommendations

Best Practice #1: WFO Anchorage conducts a volcanic ash drill training program that includes specific decision points successfully implemented before and during the event.

Best Practice #2: ARH, WFO AFC, AAWU, and CWSU used NWSChat for real-time, interactive event collaboration and information sharing. Part of the value of NWSChat is that as a social media tool it does not require "top-down" infrastructure for information flow, but rather promotes quick collaboration and response based on changing demands over time that do not require changes in configuration, staffing, or resources to accommodate this change.

Best Practice #3: NWS staff initiated personal communication and established rapport with local partners before high-impact events occurred to foster and strengthen relationships, learn partner concerns and understand agency impact thresholds.

Best Practice #4: In conjunction with the AVO, WFO Anchorage developed a one-stop shop "Hazards and Impact" Web page for Mount Redoubt that was very useful as reported by key media, aviation, and EM partners. This coordination Web page was spun up immediately following the first major eruption. (See http://pafc.arh.noaa.gov/volcano.php)

Best Practice #5: The NWS routinely included forecast confidence levels during calls and briefings to key partners.

Best Practice #6: Daily coordination calls geared specifically toward partners (AAWU, ARTCC, AVO, CWSU, Emergency Operations Center/Emergency Management Center, and public media) were initiated and facilitated by the WFO. Interviewees who participated in the coordination calls reported the calls were essential in their ability to effectively respond to the eruption.

Fact: During eruptive events, WFO Anchorage augmented staffing levels to handle additional workload: taking part in coordination calls, issuing statements and advisories, and responding to public/media inquiries. NWS field offices used a shift log to document important operational issues and contacts with external partners and users.

Fact: SIGMETs cover all types of aviation, from General Aviation and lower altitude flight levels to commercial aircraft.

Fact: At least one airline with service to Alaska used WSI Corp. SIGMETs during the volcanic

events.

Fact: The modeled volcanic ash cloud trajectories were not as well defined as some users would have liked.

Fact: A dedicated Redoubt chatroom was created on the NWSChat system.

Fact: FedEx received direct phone support from the AAWU during Redoubt events.

Fact: The WFO hosted coordination calls daily or on an as-needed basis.

Fact: The WFO maintains a "phone book" of partner agency personnel in key roles as a reference. The WFO updates the "phone book" quarterly.

Fact: NWS and partners reported Mount Redoubt coordination calls were an important part of facilitating the flow of critical information and strengthening relationships.

Fact: Coordination calls were more efficient than during the 1994 and 2006 Mount Augustine Volcano eruptions.

Fact: Ashfall criteria (NWS ARS 07-2002 Appendix D, Dated 2/9/09) were posted on the WFO Web page prior to the eruptive events. NWS users and partners found this reference information helpful as statements and advisories were issued.

Finding #1: Some users noted that Ashfall Advisories, which are zone-based, covered too large a geographical area relative to the actual threat.

Finding #2: AAWU has limited access to AVHRR satellite data. Likewise, AAWU does not have similar satellite capabilities as the Washington VAAC. AVO and Washington VAAC have access to more advanced satellite data such as McIDAS, MODIS, and POSE.

Finding #3: The areal extent of certain SIGMETs related to volcanic ash and turbulence was too large to be effectively used by some users for high-altitude route planning. Several of those interviewed commented that SIGMETs were generally too large and lasted too long. Some users found it difficult to identify small SIGMET areas on established aviation graphics. Such difficulties were encountered when the ash area was relatively small compared to the enormous domain of the graphic.

Finding #4: Both Flash Flood (FFW) and Flood (FLW) Warnings were issued for the Drift River during the event due to potential lahars.

Finding #5: NWS policy regarding Volcanic Ash is scattered throughout the Directives system.

Finding #6: The reference to UTC (i.e., "Z" time) on the HYSPLIT model output was confusing to some users.

Finding #7: Feedback from WFO, AVO, and emergency managers was mixed regarding the potential usefulness of probabilistic ash cloud forecast information.

Finding(s) #8: on the use of Instant Messaging (NWSChat):

- ARTCC reported they do not have the staff to participate in NWSChat, but appreciated the quick information response provided by the CSWU staff who actively used NWSChat and relayed reports to them.
- AVO reported they do not have staff assigned to use NWSChat but might be interested in the NWSbot feature, which automatically posts all NWS products. Currently they have to retrieve products from the NWS manually.
- NBC outlet station KTUU and the Anchorage Daily News are not currently on NWSChat but plan to join.
- AKDEC was the only non-NWS partner to enter the redoubtchat room, although several other agencies have been granted access.
- Good collaboration was demonstrated among Alaska NWS (i.e., WFO, AAWU, CWSU, ARH) as well as Western Region Headquarters, Oakland CWSU, and NOAA ARL.
- NWSChat is a good start, but communication during this event remained one-sided. (All information posted was submitted by the NWS).

Finding #9: SIGMET plots from the Alaska AWU and Kansas City AWC are not available to users on a single Web page.

Finding #10: External NWS partners, such as ARTCC and AVO, expressed a need to better understand how the WFO, CWSU, and AAWU communicate with each other and formulate products.

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Finding #13: Partner thresholds for response to ashfall and airborne ash vary. For example, Ted Stevens Anchorage International Airport's threshold is ash on the ground, whereas the threshold for commercial airlines and the ARTCC is ash in the air.

Finding #14: Currently, there are several sources of ashfall information, which are subsequently logged by multiple agencies.

Finding #15: Staff in the WFO expressed concern that NWS products and services were underutilized by Drift River Oil Terminal management during the eruption.

Recommendation #1: Establish polygon-based capabilities for Ashfall Advisories that can be graphically displayed on various platforms in user-friendly geospatial formats.

Recommendation #2: Provide AAWU with identical satellite capabilities as the Washington VAAC. Allow forecasters access to non-operational systems and tools currently available, such as the Volcanic Ash Collaborative Tool (VACT), to improve forecasts and decision support. Access to advanced satellite information and use of complex enhancement curves gives users of such data a greater ability to detect airborne ash.

Recommendation #3A: Implement additional satellite capabilities at the AAWU to help improve temporal and spatial SIGMET accuracy.

Recommendation #3B: In addition to existing graphics, the NWS should provide SIGMETs in additional electronic formats, such as shapefiles.

Recommendation #4: WFOs should use FFWs exclusively for lahars given the rapid onset of such phenomenon.

Recommendation #5: Volcanic Ash program needs its own definitive directive.

Recommendation #6: Include Alaska Daylight Time/Alaska Standard Time and the conversion in addition to UTC on HYSPLIT and Puff model output. Given the range of potential users, from partners to the general public, features of the model should be highlighted to ensure users better understand and interpret the information.

Recommendation #7: Since probabilistic ash cloud forecasts could provide key supplemental information to help decision makers assess event-based risk, NWS Alaska Region should directly contact local emergency managers to explain the value of probabilistic ash cloud data, help to increase their understanding of this data, and learn how local emergency managers would actually use probabilistic data in specific scenarios.

Recommendation #8: Expand the use of NWSChat in the Alaska Region. Invite local media to join NWSChat. Demonstrate automated product delivery via NWSChat to key partners, specifically AVO, DHS, and EM. Determine if additional partners would benefit and provide them access.

Recommendation #9: Develop a Web display of SIGMET plots that originate from the AAWU and AWC.

Recommendation #10: Cross-site orientation and site visits among partner agencies and offices within the NWS should be conducted regularly. Such site visits would have the dual benefit of clarifying roles and responsibilities during an event and enhancing understanding about NWS products and services. This type of exchange would not entail cross training, but rather understanding general concepts and knowing who does what in an office.

Recommendation #11: The WFOs should post a podcast or similar audio file of the coordination calls on their coordination Web site.

Recommendation #12a: Make individual partners aware of new tools for communicating with the NWS and assist them in implementing the technology. Implement tools for pushing data and products to subscribers in real time, such as NWSChat, Mobile Decision Support Services (iNWS), and RSS.

Recommendation #12b: The NWS should continue to pursue and evaluate the use of emerging communication and Web 2.0 technologies (e.g., Twitter) to offer new ways to interact and share weather and hazard information.

Recommendation #13: Determine specific partner thresholds for concern, alerting, and urgent response, and track these thresholds using a High Impact Event Catalog or similar database.

Recommendation #14: Establish a single repository of ashfall reports to mesh spotter networks maintained by the AVO, WFO, DEC, and others. The WFO could place this repository on the coordination page.

Recommendation #15: The NWS should have in place Memorandums of Understanding that explicitly define expectations and roles with key partners in potentially high-risk situations.

Appendix C

Acronyms

AAWU	Alaska Aviation Weather Unit
AFD	Area Forecast Discussion
AKDEC	Alaska Department of Environmental Conservation
ANC	Ted Stevens Anchorage International Airport
AP	Associated Press
ARH	Alaska Regional Headquarters
ARL	Air Resources Laboratory
ARTCC	Air Route Traffic Control Center
ASOS	Automated Surface Observing System
AVHRR	Advanced Very High Resolution Radiometer
AVO	Alaska Volcano Observatory
AWC	Aviation Weather Center
AWIPS	Advanced Weather Interactive Processing System
AWOS	Automated Weather Observing System approved by the FAA
CFS	Cubic feet per second
CWA	County Warning Area
CWSU	Center Weather Service Unit
D2D	Display 2-Dimensional
DCP	Data Collection Platform
DEC	Department of Environmental Conservation
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy

DOT	U.S. Department of Transportation
EAS	Emergency Alert System
EM	Emergency Manager
EMWIN	Emergency Managers Weather Information Network
EOC	Emergency Operations Center
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FFW	Flash Flood Warning
FLW	Flood Warning
GFE	Graphical Forecast Editor
GIS	Geographic Information Systems
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GUI	Graphical User Interface
HPC	Hydrometeorological Prediction Center
HWO	Hazardous Weather Outlook
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory Model
IMET	Incident Meteorologist
LSR	Local Storm Report
METAR	Aviation Routine Weather Report
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NAWAS	National Warning System
NCDC	National Climatic Data Center

NCEP	National Centers for Environmental Prediction
NDFD	National Digital Forecast Database
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NPW	Non-Precipitation Watch/Warning/Advisory
NWR	NOAA Weather Radio
NWS	National Weather Service
PNS	Public Information Statement
POES	Polar-orbiting Operational Environmental Satellite
POP	Probability of Precipitation
RFC	River Forecast Center
SIGMET	Significant Meteorological Information
SFP	State Forecast Product
SFT	Tabular State Forecast
SHEF	Standard Hydrometeorological Exchange Format
SPC	Storm Prediction Center
TAF	Terminal Aerodrome Forecast
URL	Universal Resource Locator
USGS	United States Geological Survey
UTC	Coordinated Universal Time (a.k.a. “Zulu” time)
VAAC	Volcanic Ash Advisory Center
VACT	Volcanic Ash Collaborative Tool
WFO	Weather Forecast Office
WRH	NWS Western Region Headquarters (Salt Lake City)
WSR-88D	Weather Surveillance Radar, 1988 Doppler

WWA	Watch, Warning, Advisory and Statement

Appendix D

Selected NWSChat Redoubt Chatroom Log Entries and List of Chatroom Users

The logs selected below were chosen as good examples of how NWS offices in Alaska are using NWSChat for real-time communication and collaboration. For reference to the full NWSChat logs, please go to https://nwschat.weather.gov/my/logs.php. This Web site requires an NWSChat user account to login.

redoubtchat log for 22 Mar 2009

22:12 <nws-kristine.a.nelson> Excerpt from last night's AVO statement: "AVO raised the aviation color code to Orange and the alert level to Watch last night at 10:09PM AKDT (March 21) based on an increase in the rate of discrete seismic events. Shallow earthquake activity under the volcano has been as high as 26 events per 10-minute period..."

redoubtchat log for 23 Mar 2009

07:42 <nwsarh-essd-Osiensky> WVAK01 PAWU 230701 WSVAK1 ANCI WS 230700 PAZA SIGMET INDIA 1 VALID 230700/231300 PANC-ANCHORAGE FIR. REDOUBT VOLCANO AT N6029 LAT W15245 LONG HAS ERUPTED. VA CLOUD INFORMATION FROM...AVO/RADAR/...VA BASES FLSFC/TOPS FL400 A FOLLOW UP VOLCANIC VA SIGMET WILL BE ISSUED AS SOON AS POSSIBLE. ERW AAWU MAR 2009
<nwsarh-essd-Osiensky> Redoubt now in color code RED .... Link: http://www.avo.alaska.edu/activity/Redoubt.php

11:53 <nws-kristine.a.nelson> Message from Dave Schneider sent on the Volcanic clouds listserver: "...Redoubt Volcano has had 4 explosive events, three of which were in the range of 40000 to 50000 feet asl. The events were at 0638, 0702, 0814 and 0939 UTC, and lasted for very roughly 10-20 minutes each. Ash has missed Anchorage and was recorded by NEXRAD radar and a new USGS C-band Doppler that was made operational just yesterday. "

15:23 <nwsarh-essd-Osiensky> AAWU, WFO AFC, CWSU - Next AK DHS&EM call will be at Noon. I will send you the dial in numbers.

redoubtchat log for 24 Mar 2009

04:53 <nwsarh-essd-Osiensky> 2009-03-23 20:29:11 <javascript:dm('div_Observation_1968');> A sixth explosive eruption occurred at 7:41PM AKDT. The National Weather Service has posted a new ashfall advisory: Mudflows are occurring in the Drift River valley and pyroclastic flows were observed in the AVO hut Webcam descending the north flank of the volcano. Link: http://pafc.arh.noaa.gov/volcano.php

10:58 <nws-kristine.a.nelson> A couple of aircraft coming into ANC or flying over tonight that

are near SIGMETed ash areas are sweating bullets and calling nearly every hour for updates. Most Airlines, including Alaska Airline have cancelled flights. Alaska Airlines continues to ask for PIREPs. They even chartered an aircraft just to send their own pilots out on an ash finding mission earlier today because they were frustrated with the lack of volash PIREPS.

redoubtchat log for 26 Mar 2009

16:47 <nws-andrew.dixon> AVO reports an eruption at Redoubt to Fl300
<nws-andrew.dixon> color code changed to Red
<Darone Jones - NWSChat Manager> what is the mean flow currently?
<nws-andrew.dixon> preliminary plume trajectory SE 10kt

17:27 <aawu-tony> A new-updated SIGMET and graphic has been issued. Graphic can be seen at: Link: http://aawu.arh.noaa.gov/aawuapps/sigmets.php

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NWSChat usernames for staff who posted information into the Redoubt chatroom during the events under this review. Other users were present, viewing communications in this chatroom, but posted no messages.

NWS/AR ANCHORAGE CWSU
nws-kristine.a.nelson
nws-christopher.waterhouse
nws-carrie.haisley

NWS/WR FREMONT CWSU
nws-zoa-MIC
nws-noel.keene
nws-marvin.percha

NWS/AR ENVIRONMENTAL AND SCIENTIFIC SERVICES DIVISION
nws-carven.scott
nwsarh-essd-Osiensky
nws-duane.carpenter

NWS/AR ALASKA AVIATION WEATHER UNIT
nws-tony.hall
nws-jeff.cotterman
nws-alberta.m.vieira

NWS/AR ANCHORAGE WFO
nws-samuel.shea
nws-andrew.dixon

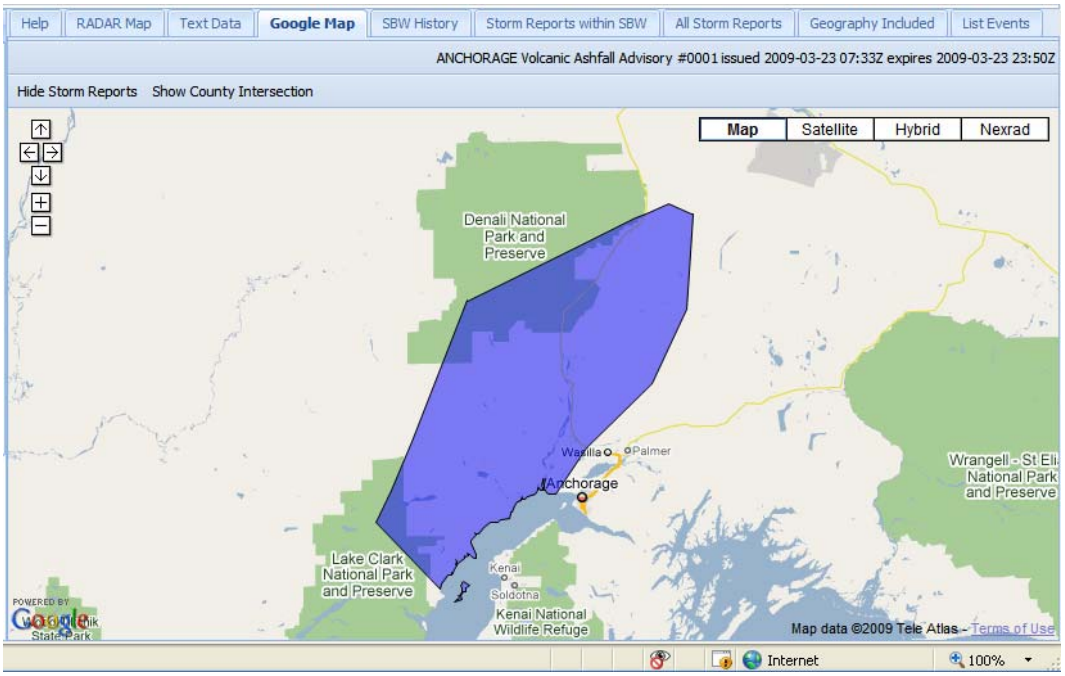
NWS/OPC OCEAN PREDICTION CENTER
nws-matt.glazewski

NWS/WR METEOROLOGICAL SERVICES DIVISION
nwswrh-jones

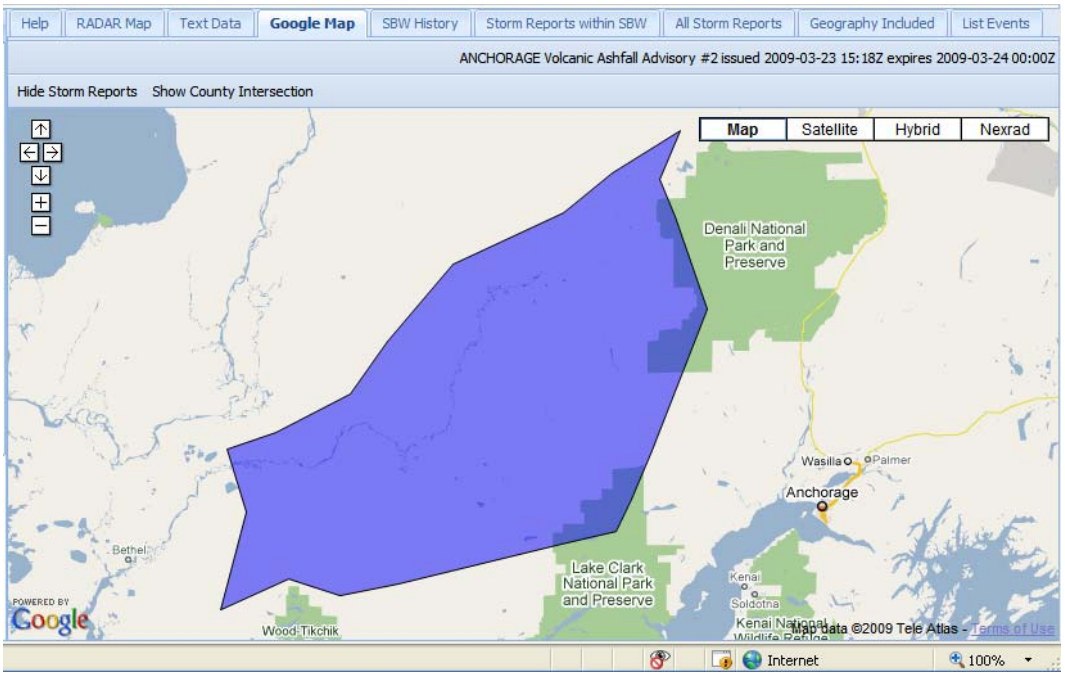
Appendix E

Ashfall Advisory Graphics

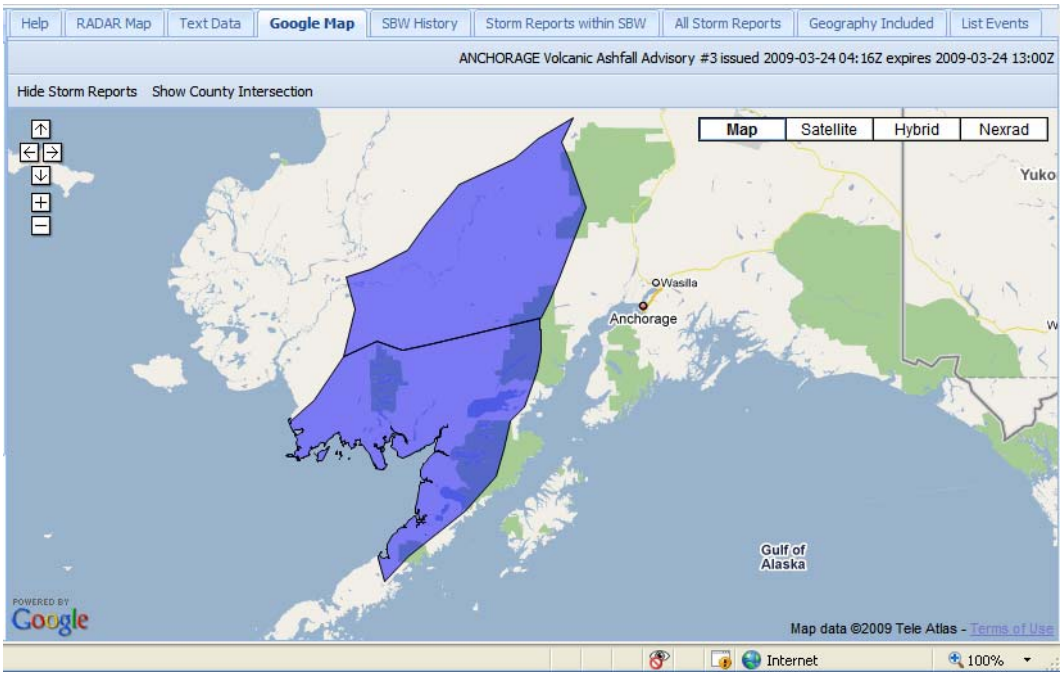
Advisory #1 Susitna Valley



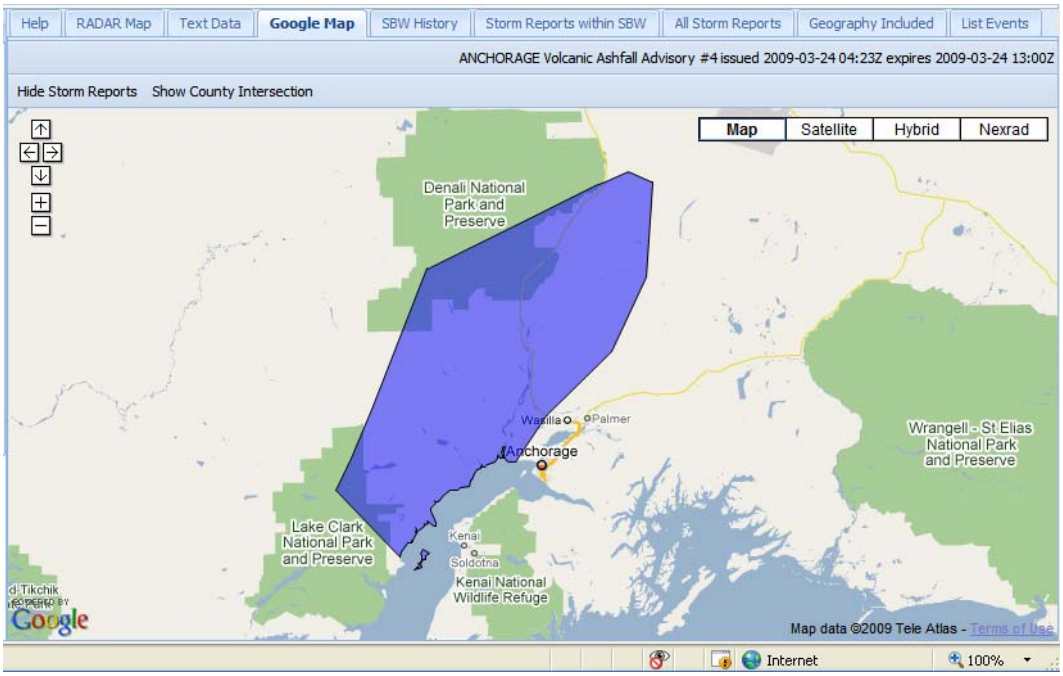
Advisory #2 Kuskokwim Valley



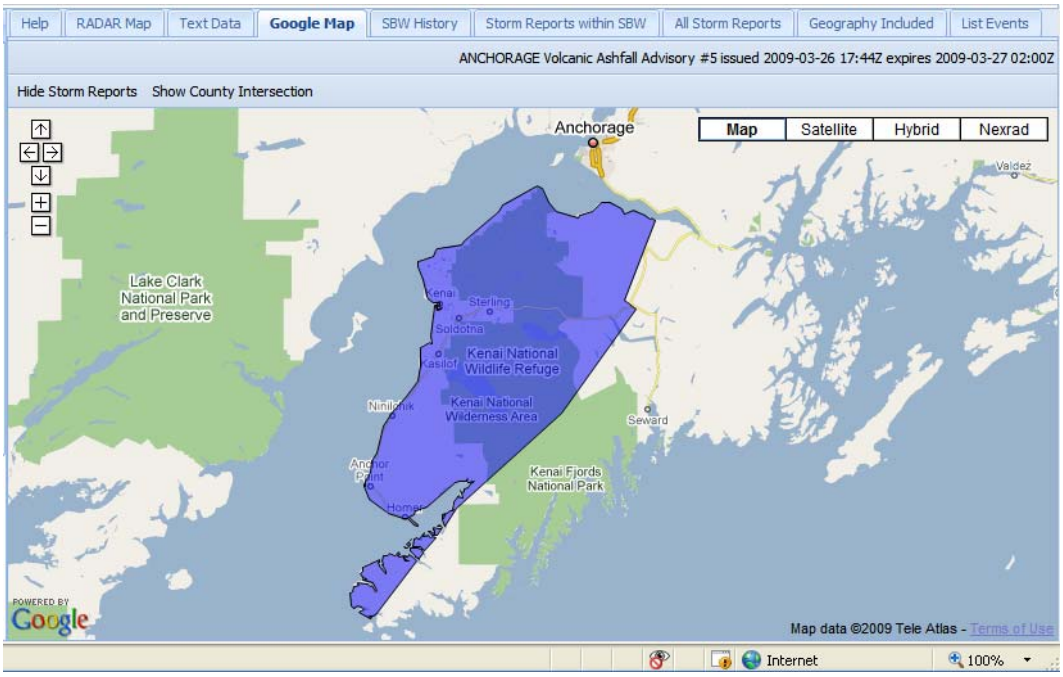
Advisory #3 Bristol Bay and Kuskokwim Valley



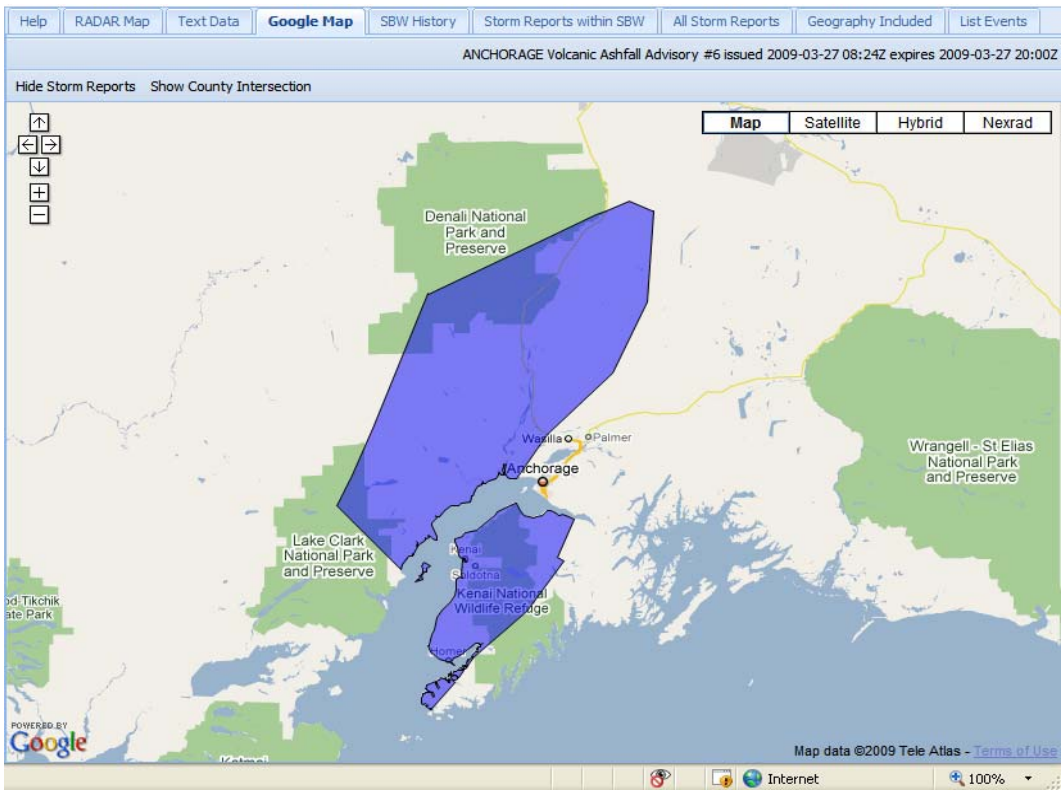
Advisory #4 Susitna Valley



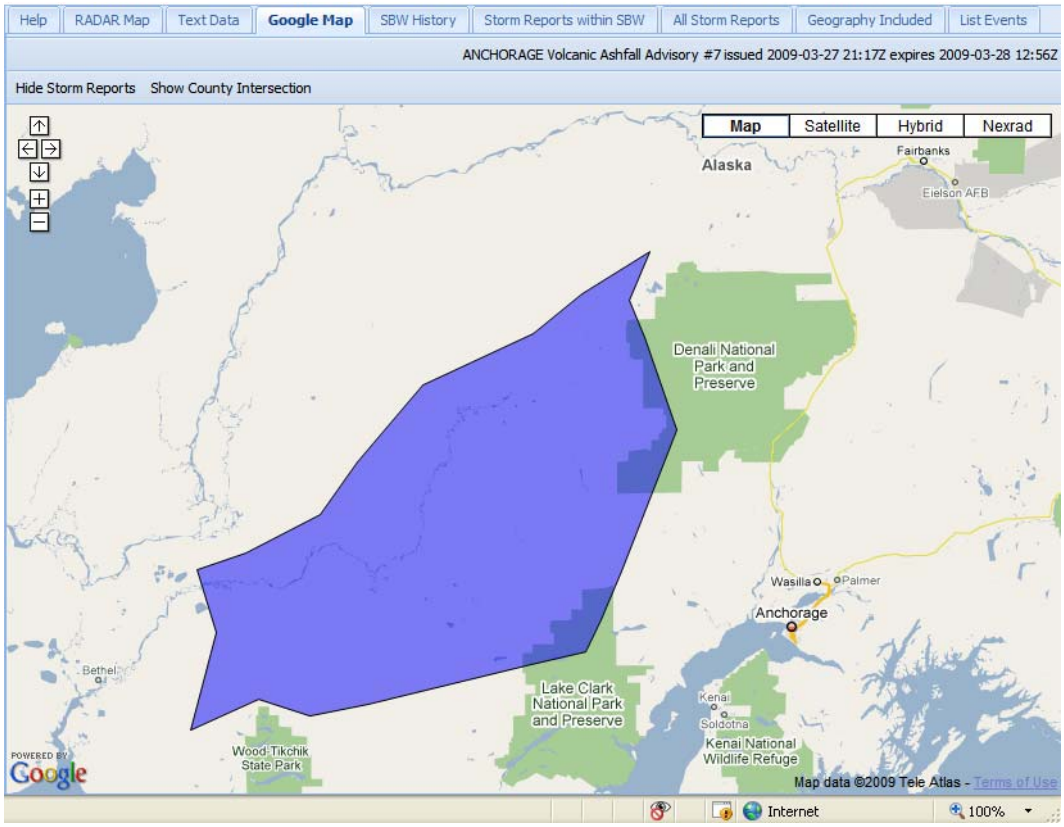
Advisory #5 Western Kenai Peninsula



Advisory #6 Susitna Valley and Western Kenai Peninsula



Advisory #7 Kuskokwim Valley



Appendix F

Volcano Alert Level/Aviation Color Code

From U.S. Department of the Interior | U.S. Geological Survey
URL: http://volcanoes.usgs.gov/activity/alertsystem/index.php

Volcano Alert Level

The four-tiered Volcano Alert Level uses the terms **Normal**, **Advisory**, **Watch**, and **Warning** (from background levels to highest threat, see Table 1). The Volcano Alert Levels are intended to inform people on the ground about a volcano's status and are issued in conjunction with the Aviation Color Code. Notifications are issued for increasing and decreasing volcanic activity and are accompanied by text detailing the nature of the unrest or eruption, potential or current hazards, and likely outcomes.

Table 1. **SUMMARY OF VOLCANO ALERT LEVELS**

NORMAL	Volcano is in typical background, non-eruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to non-eruptive background state.
ADVISORY	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
WATCH	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, **OR** eruption is underway but poses limited hazards.
WARNING	Hazardous eruption is imminent, underway, or suspected.

Aviation Color Code

The Aviation Color Code notifications are issued in conjunction with the Volcano Alert Levels. The color codes (i.e., **Green**, **Yellow**, **Orange**, **Red**), as shown in Table 2, are used to provide succinct information about volcanic-ash hazards to the aviation sector. Volcanic activity threatens safe air travel when finely pulverized, glassy, abrasive volcanic material is explosively erupted into the atmosphere and dispersed as airborne clouds in flight paths of jet aircraft. The color codes are in accord with recommended International Civil Aviation Organization procedures to help pilots, dispatchers, and air-traffic controllers who are planning or executing

flights over broad regions of the globe quickly ascertain the status of numerous volcanoes and determine if continued attention, rerouting, or extra fuel is warranted.

Table 2. **SUMMARY OF AVIATION COLOR CODES**	
GREEN	Volcano is in typical background, non-eruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to noneruptive background state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain **OR** eruption is underway with no or minor volcanic-ash emissions [ash-plume height specified, if possible].
RED	Eruption is imminent with significant emission of volcanic ash into the atmosphere likely **OR** eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible].