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USING A PERSONAL COMPUTER TO OBTAIN PREDICTED PLUME TRAJECTORIES DURING THE 1989–90 ERUPTION OF REDOUBT VOLCANO, ALASKA

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ABSTRACT

The Alaska Volcano Observatory (AVO) and the Anchorage Weather Service Forecast Office (WSFO) obtain predicted plume trajectories daily for Redoubt Volcano, Alaska. A model developed by the National Oceanic and Atmospheric Administration (NOAA) Air Resource Laboratory calculates predicted plume trajectories. The model, running on NOAA's NAS/9000 mainframe computer in Suitland, Md., uses forecast wind fields obtained from the NOAA National Meteorological Center. The model uses measured and forecast winds to predict the path of a weightless particle released at various pressure-altitudes above a specified location. The paths indicate the general direction and speed that ash from an eruption at that location will travel.

In response to the 1989–90 Redoubt eruption, we programmed an IBM-XT-style personal computer to automatically dial the NAS/9000 mainframe computer and obtain the predicted trajectories. Twice daily, after the predicted wind fields are updated, AVO and WSFO can easily collect and plot the trajectories predicted for the next 72 hours. Thus, the trajectories are immediately available in the event an eruption should occur. The predicted trajectories are plotted on a map of Alaska, showing the predicted location of the ash plume at 3-hour intervals for different altitudes between 5,000 and 53,000 ft. The plots are easily telefaxed to interested parties. The program has been modified to enable the user to obtain predicted plume trajectories for other U.S. volcanoes.

INTRODUCTION

Volcanic ash ejected into the atmosphere can cause severe problems to airplanes and to municipal and industrial facilities, as well as to people on the ground downwind from the volcano. Knowing where ash will travel is vital to mitigating its effects. If notified in time, people in the path of the ashfall can take precautionary measures as complex as shutting down portions of a power facility or as simple as canceling a dinner date. Conversely, in areas unlikely to be affected by ashfall, industry can avoid wasting resources in preparation for ash that is not traveling in their direction. In this report, we describe a method to routinely acquire predicted wind speeds and directions (trajectories) at various pressure-altitudes and to plot and display the data in a simple, easy-to-distribute format. The predicted plume trajectories currently provide the only method that predicts, before an eruption, where ash will be blown (as opposed to tracking already-erupted ash). AVO and WSFO took advantage of this capability and informed other agencies daily as to where ash from Redoubt would go if the volcano were to erupt. In the event of an eruption, the predicted plume trajectory, having been plotted earlier, is ready for immediate use, thereby saving valuable time.

During the Redoubt eruption, plots were especially useful to the aviation industry. They were sent daily to Anchorage International Airport authorities, who then distributed them to the airlines, many of which required their flight crews to use them in flight planning (Casadevall, in press).

DESCRIPTION OF PREDICTED PLUME TRAJECTORIES

A computer model, developed by NOAA's Air Resource Laboratory (ARL), provides predicted plume trajectories based on forecast wind fields. The wind fields are calculated twice daily by the National Weather Service (NWS) from observations taken at 00:00 and 12:00 Greenwich Mean Time (GMT) (Heffter and others, 1990). Using the latitude and longitude of the volcano and the time of the hypothetical eruption, the model predicts the locations of dimensionless, weightless particles at 3-hour increments after they are released into the atmosphere at various pressure-altitudes above the volcano. The model ignores effects from gravity and dispersion. Unlike volcanic ash, the model's ideal particles never fall to Earth, but remain at the pressure-altitude at which they were released forever.

The model accepts times for hypothetical eruptions up to 48 hours into the future in 3-hour increments. AVO can always have the latest predicted trajectories by obtaining the predicted trajectories from the NOAA computer twice daily after the latest weather observations are processed. Owing to the time required to process weather observations and calculate the predicted wind fields, the latest predictions are typically available about 3 hours after the actual measurements, at 03:00 and 15:00 GMT (or 18:00 and 06:00 AST).

OBTAINING PREDICTED PLUME TRAJECTORIES

Predicted plume trajectory plots were first used to predict trajectories of volcanic ash during the 1980 emptions of Mount St. Helens, Washington (Miller and others, 1981; Smith, 1980). At that time, the technique to acquire trajectories was time consuming, requiring the full attention of a person for an hour or more (E. Brown, oral cornrnun., 1991). As the level of activity at Mount St. Helens declined, the U.S. Geological Survey discontinued obtaining plume trajectory data.

In 1988, NOAA signed a memorandum of understanding with the Federal Aviation Administration (FAA) to provide the FAA with predicted plume trajectories (Heffter and others, 1990). During the 1989–90 eruptions of Redoubt Volcano, NOAA provided trajectory information to the FAA within 1 hour of NOAA's notification of the eruption and typically within 3 hours of the actual eruption (Heffter and others, 1990). Because an ash plume can move hundreds of kilometers during a 3-hour delay, AVO and the Anchorage WSFO felt that they needed trajectory information more quickly in order to issue timely warnings. Ideally, the trajectory information would be available before an eruption. This would allow AVO and WSFO to concentrate on the myriad other tasks involved in monitoring an eruption (data analysis, notifying interested agencies, answering media inquiries, etc.) and would avoid using personnel or phone and computer resources during an eruption to obtain the information. It would also allow AVO to include the information in daily updates sent to various public agencies and other users, including the aviation community, that could be affected by ashfall. Finally, it enabled AVO and WSFO to have the information ready for immediate distribution should an eruption occur.

In order to acquire the plume trajectories daily, even when there was little chance of an eruption, the process had to be simplified, or, as was the case with Mount St. Helens, it would fall into disuse. We were able to do this by using computer hardware and software unavailable in 1980. The necessary equipment consists of an IBM XT (or compatible) personal computer, a 1,200-baud Hayes-compatible modem, a printer, the software package PROCOMM Plus (for communication with the NOAA computer), and Geograf Utilities (for the screen and printer graphics drivers). Users initiate the program with a few keystrokes and are prompted to answer a few questions. Then the program dials the NOAA NAS/9000 computer in Suitland, Md., runs the plume trajectory program for various hypothetical eruption times and pressure-altitudes, logs the data on the XT, and finally produces plots of the paths of the predicted plume trajectories on the user's printer. The entire process takes less than 20 minutes.

PLOTS OF PROJECTED PLUME TRAJECTORIES

Following the format of Smith (1980), trajectories at different pressure-altitudes for a single hypothetical eruption time are plotted as a map on a single 8%-by-11-inch sheet. The map shows the paths traveled by ideal particles released above the volcano at different pressure-altitudes at the hypothetical eruption time indicated on the plot (figs. 1 and 2). Symbols along the paths indicate positions of the particles at 3-hour time intervals. Stronger winds will blow the particles faster along their paths, and the symbols will be spaced correspondingly farther apart than for light winds. By plotting

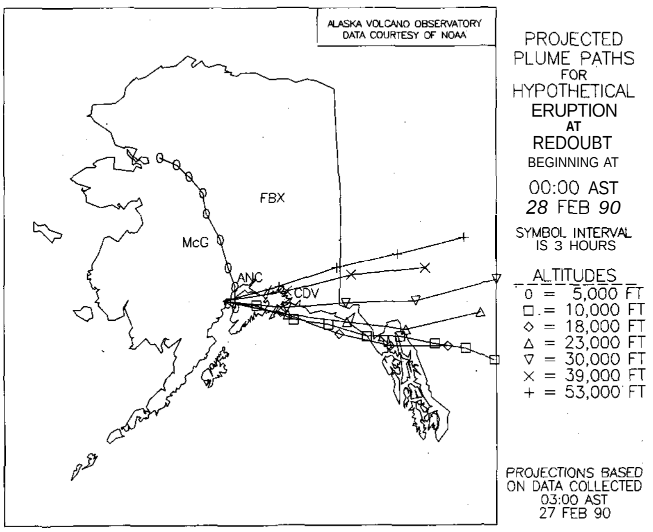

Figure 1. Example of predicted plume trajectories plotted over the State of Alaska for a hypothetical eruption beginning at 00:00 Alaska Standard Time (AST), February 28, 1990. Cordova (CDV), McGrath (McG), Fairbanks (FBX), and Anchorage (ANC) are approximately located. Trajectories for ideal particles released at various pressure-altitudes above Redoubt Volcano are plotted. The location of the symbols on the trajectory paths indicate the positions of the ideal particles at 3-hour intervals after eruption time.

all trajectories on a single map, the user can quickly visualize where the ash is likely to go without paging back and forth between seven plots of trajectories at individual altitudes. The data are plotted on maps of two different scales. One covers Alaska (fig. 1), and the second covers Cook Inlet and surrounding areas (fig. 2).

USE OF PREDICTED PLUME TRAJECTORIES

Users of the projected plume trajectories must understand that the trajectories give only a general indication of where ash will travel. The accuracy of the trajectories is limited by the accuracy of the predicted winds and the model's assumption of a weightless, dimensionless particle. For instance, the plots always show a travel path extending for 24 or more hours for an ideal particle. Users need to be informed that, although they may lie in the path of the ideal particle as indicated by the plot, gravity will likely cause the actual, non-ideal ash to settle before it reaches them.

The model also does not consider the effect of dispersion of the ash as it travels along the trajectory. Users should not be fooled into thinking that they will not be affected by ash simply because they are not located directly on the line predicted by the model. Until current research (Sparks and others, this volume; Stunder and Heffter, this volume; Tanaka, this volume) is incorporated into the model, we suggest qualitatively defining the area that may be affected by ash as an arc of ±30° along the trajectory as it travels away from the volcano. This would also allow for inaccuracies in the predicted trajectory.

For small to moderate size eruptions, such as those at Redoubt, the major factor in the path's accuracy is the accuracy of the predicted winds. Rather than focusing attention on one plot at a given altitude, users should look through the suite of plots for each day to develop an idea of the stability of the weather system. Stable systems will generally have all trajectories for all altitudes, except perhaps 5,000 ft, traveling in about the same direction. The effects of the 5,000-ft trajectory are usually ignored both because the erupting vents at most volcanoes are usually above 5,000 ft in altitude and because they usually eject ash into higher altitudes where the winds are generally stronger. For stable systems, where the winds above 10,000 ft blow in the same general direction throughout the day, we feel the accuracy of the predicted winds to be quite good. Such was the case for the February 24, 1990, eruption of Redoubt (fig. 3). On days when the winds change or even reverse direction, it may be difficult to predict with any certainty where ash will travel (fig. 4). It is best to err on the side of caution during such times. Heffter and others (1990) provide a more detailed analysis of the accuracies of the trajectories.

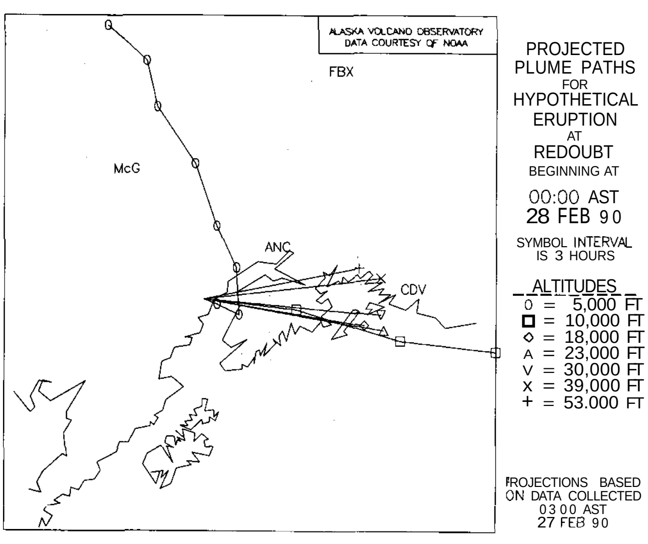

Figure 2. Example of predicted plume trajectories in figure 1 plotted over a map of Cook Inlet and surrounding areas for a hypothetical eruption beginning at 00:00 Alaska Standard Time (AST), February 28, 1990. Cordova (CDV), McGrath (McG), Fairbanks (FBX) and Anchorage (ANC) are approximately located.

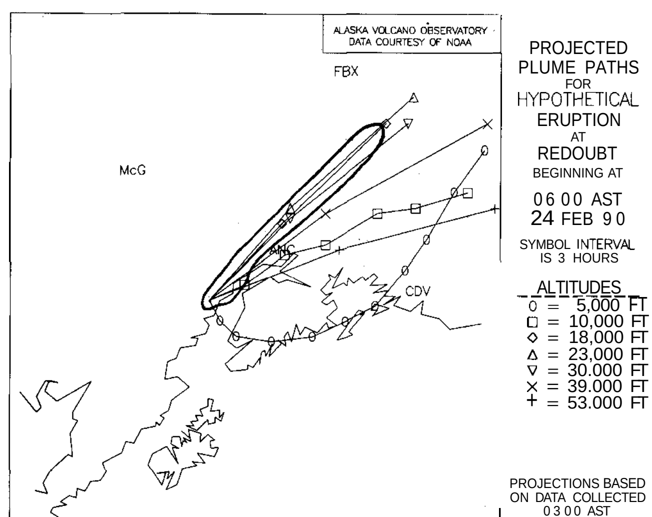

Figure 3. Predicted plume trajectories for the February 24, 1990, eruption of Redoubt Volcano with the actual ground deposition (heavy line) outlined (from Scott and McGimsey, in press). Because the eruption plume reached an altitude of only 28,000 ft (Brantley, 1990), the winds at 39,000 and 53,000 ft did not affect ash deposition. Note that the spacing between symbols for the winds at 18,000, 23,000, and 30,000 ft are more than twice that for winds at 5,000 and 10,000 ft—this indicates that the wind speed at higher altitudes is more than twice that at lower altitudes. For this reason, the pattern of ground deposition was influenced predominantly by the winds at 18,000, 23,000, and 30,000 ft. Cordova (CDV), McGrath (McG), Fairbanks (FBX) and Anchorage (ANC) are approximately located.

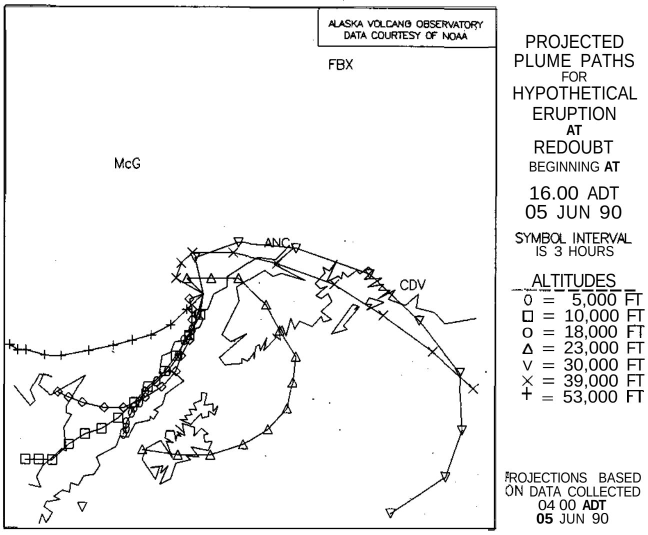

Figure 4. Plot showing the difficulty in determining where ash will travel when wind directions are expected to change. The 23,000- and 30,000-ft altitudes show the ash first going north and then curling to the southeast. The winds at 10,000- and 18,000-ft altitudes move the ash south as it falls through those altitudes. Note also that the spacing between symbols is significantly less than that in figure 3, indicating that the winds are much milder than on February 24,1990. With this pattern of plume trajectories, it is not possible to say much more than the ash is likely stay in the Cook Inlet area (because of the low wind speed) and could affect any or all of the area. Cordova (CDV), McGrath (McG), Fairbanks (FBX) and Anchorage (ANC) are approximately located.

Major eruptions (such as the June 15, 1991, eruption of Mt. Pinatubo, Philippines, or those with strong horizontal wind components, such as the May 18, 1980, blast of Mount St. Helens) are special cases. They can disperse large quantities of ash in any or all directions for many kilometers before prevailing winds control the path traveled by the ash (Self and Walker, this volume).

CONCLUSIONS

Projected plume trajectories are an important tool for mitigating hazards associated with ashfall resulting from volcanic eruptions. This is the only currently used method that predicts plume paths before an eruption. By simplifying the procedure to obtain plume-trajectory data, we enabled AVO and WSFO to obtain trajectory plots on a routine basis. AVO included the trajectory information in its daily updates that were sent to various governmental agencies and businesses (including Anchorage International Airport, where authorities distributed them to all 26 carriers located there) (Casadevall, in press). In the event of an eruption, projected plume paths were ready for immediate distribution. Thus, AVO and WSFO were able to make full use of predicted plume trajectories, both before and after eruptions.

We recommend that the ARL model be improved to include the effects of dispersion and gravity on volcanic ash. Such improvements would greatly enhance the effectiveness of plume trajectories without adding to the operational cost of acquiring them.

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