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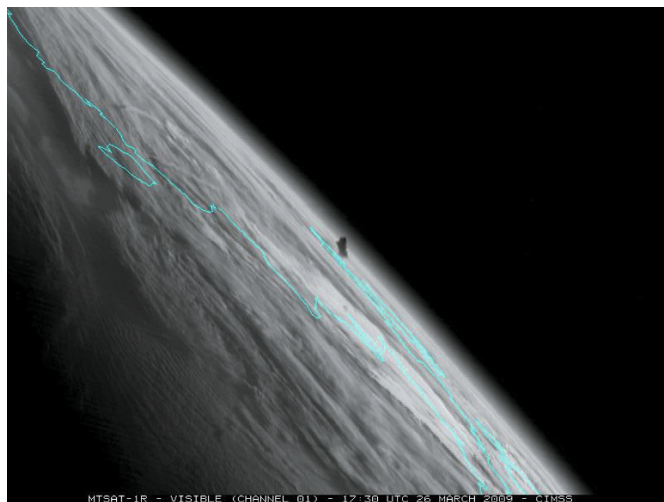
## Preface

Prior to satellites and other spaceborne sensors, volcanoes in the North Pacific were not on the mental map of most volcanologists. They were far away and shrouded in clouds. We couldn't see them. There were the almost mythological eruptions of Katmai in 1912 on the American side and Bezymianny in 1956 and Tolbachik in 1975–1976 on the Russian side; few had a detailed understanding of what was happening in this part of the world.

Satellites changed this. Some of the change is specific to the region and other aspects apply to volcanism worldwide. The scale of this region was never really seen and certainly never adequately mapped before there were satellites. Also, as is the case with the volcanoes of Venus, much of the area is shrouded in clouds. Seeing through the persistent cloud cover, radar satellites permitted development of digital elevation models and the first-



Jonathan Dehn and Kenneson Dean in the Volcano Monitoring Room where satellite data are analyzed at the University of Alaska Geophysical Institute. Ken and Jon are members of the Science Team at the Alaska Volcano Observatory, University of Alaska Fairbanks (photograph by Debbie Dean).



A view of Earth from MTSAT at a height of 3,800 km (geostationary orbit). A plume (center) from the eruption of Redoubt Volcano, 2009 can be seen extending well into the atmosphere. Image is from the U.S. National Weather Service, processed by the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin Madison.

order interpretation of major events, such as caldera formation and edifice collapse.

Likewise, and this applies globally, the true extent of great eruptions was never seen before there was satellite remote sensing. They are simply too big to see: eruption columns rising quickly to 30 km altitude and then spreading laterally hundreds of kilometers before fully coupling with wind patterns. Nor was it known that increased heat flux can also be observed from space at many volcanic vents prior to explosive eruptions, and often are precursor signals to impending activity. This new perspective has stimulated advances in understanding plume dynamics, ash and gas dispersal, and lava flow. Along with this have come several new kinds of measurements: spatial changes in surface temperature relating to eruptions in the infrared, the ash and SO<sub>2</sub> content of volcanic clouds in the infrared and ultraviolet, the movement and impact of these clouds, and spatially continuous surface deformation in the microwave through InSAR techniques. Remote-sensing, seismic, and deformation data together provide a more holistic picture of subsurface, surface, and airborne volcanic processes and the monitoring of activity.

Scientists at the University of Alaska's Geophysical Institute developed a reception, analysis, and information distribution system using satellite data as part of the newly formed Alaska Volcano Observatory in December 1989. At that time,

Redoubt Volcano was erupting. There were a lot of hurdles to clear to make satellite-based analyses practical. Few thought these data would be that useful, at least in an eruption response setting. Problems included: timely data access; timely coverage; timely processing of data; detection, location, and measurements; distribution of data products; and data volume (see Chapter 7 for a more detailed description of satellite data reception and analysis in a response setting).

Scientists at UAF had been experimenting with real-time access to Landsat and AVHRR data for the analysis of active surface processes for several years in the 1980s and had developed a working relationship with the NOAA Tracking Station near Fairbanks (Dean *et al.*, 1990; George *et al.*, 1992, Chapter 1). Therefore, data access did not appear to be a problem for the AVO project (early 1989–1990). However, timely access to data became a problem in that it took hours (initially) to acquire and process the data. This was critical because the speed of ash clouds can be over 45 km/h, while jet aircraft fly at 900 km/h. Therefore, by the time AVO detected and located an ash cloud it had moved hundreds of kilometers. The time required for data access is now down to minutes after the data are received by the station.

Fortunately, satellites provide timely coverage of volcanoes. Polar-orbiting satellite data were received almost hourly based on tracking several



Antennas for receiving satellite data on the roof of the Geophysical Institute, University of Alaska Fairbanks (photograph by Debbie Dean).

satellites and overlapping coverage. However, there is a period of several hours after midnight when no data were received. In the mid-1990s, data from geostationary satellites were added to the data pool thereby increasing observations to 15 minutes (at best) 24 hours per day. However, the spatial resolution of geostationary data is several kilometers per pixel compared with one kilometer at nadir for polar-orbiting data.

Another problem was detection; it was relatively simple to detect cold opaque plumes, but difficult to detect ash clouds at the time. Prata (1989, Chapter 5) had developed ash detection techniques but these were not incorporated into AVO until after 1993. Also, it was not easy to identify the location of any detected feature because the images had no geographic reference, and there were no measurable scales to determine the hazardous nature of the cloud or plume. After analysis, the high-quality images were sent as quickly as possible to the rest of AVO, by fax. Faxed images were low quality and often difficult to interpret.

A final problem was data volume. We were tracking two satellites, each with morning and evening passes, each with three orbits over Alaska daily. A swath of data was about 140 MB in volume; this required 1,680 MB of storage per day. Personal computer disk storage was typically less than 50 MB during this period.

Most of these issues were resolved over the next few years as technology advanced and UAF purchased an AVHRR receiving station in 1993. During the past 20 years our understanding of plumes, ash clouds, and thermal anomalies in terms of detection and their significance has improved significantly.

After more than 20 years of collecting data, the UAF system has developed one of the largest archives of satellite data devoted to volcanic eruptions. As part of the AVO project, students, staff, and faculty participated in the analysis and warning of hazardous conditions. To educate students on the use of these data for volcanic eruptions, a course was developed: "Remote Sensing of Volcanic Eruptions". The large satellite data archive, high frequency of volcanic activity in the North Pacific region, participation in the AVO project, and the course became the impetus for this book.

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