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USE OF SATELLITE DATA IN VOLCANO MONITORING

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The Smithsonian Institution's Scientific Event Alert Network (SEAN) gathers information about volcanic activity throughout the world. Information is quickly disseminated to scientists and government officials so that research and hazard mitigation can begin promptly, then distributed to the world scientific community via the monthly SEAN Bulletin, and excerpts of the Bulletin in the American Geophysical Union's Eos, the American Geological Institute's Geotimes, and the Bulletin of Volcanology. We encourage new initiatives in volcano monitoring that will allow us to more effectively serve the world's volcanological community.

Volcanic activity has an immediate impact on people living nearby and on aircraft flying overhead. It is crucial that eruptions be spotted quickly to allow timely evacuation of people from danger areas, rerouting of aircraft, and detailed scientific monitoring of the activity. However, many volcanoes are located in remote areas with limited communications, and it often takes many days for news of an eruption to reach the scientists and officials who must respond to it.

Satellites have the potential to provide nearly immediate detection of moderate to large eruptions anywhere in the world, and to supply valuable data about eruptions as they progress. To realize this potential, deployment and data utilization need to be improved.

NASA's TOMS instrument can detect anomalous atmospheric concentrations of SO_2, usually produced by volcanic eruptions. A tantalizing example of the potential of TOMS was provided during the April 1984 Mauna Loa eruption, when inspection of the TOMS data not only showed an extensive SO_2, plume originating from Hawaii, but also detected another zone of high SO_2 concentration over the Galapagos Islands (SEAN Bulletin v. 9, no. 3). This proved to be a previously unreported eruption of Fernandina caldera, and the prompt notification provided by TOMS was a key factor in its timely study. SO_2 concentration values generated by TOMS data help volcanologists to answer important questions about gas production in moderate to large eruptions, and have shown that the amount of SO_2 varies considerably between eruptions of similar size and ash content. SO_2 is a major parent of the H_2SO_4 droplets that comprise the bulk of the persistent volcanic stratospheric aerosols that can effect climate, and the SO_2 content of the eruption cloud seems to be a better predictor of long-term atmospheric effects than the amount of ash erupted.

Unfortunately, financial and organizational constraints currently prevent daily real-time reduction of TOMS SO_2 data, so

Pavlof Volcano, Alaska Peninsula, USA (55.42°N, 161.90°W). All times are local (= GMT - 9 hours).

At 1225 on 16 March, the pilot of Air Pacific flight S27 observed a white vapor plume rising to 6 km altitude from the volcano and drifting NW. There had been no eyewitness reports of activity at Pavlof since 15 December 1983 (see SEAN Bulletin, v. 9, no. 1). After an increase on 17-21 December, seismicity decreased to the background level of several tens of events per day and remained at that level as of 2 April.

Information Contact: Betsy Yount, U.S. Geological Survey, 4200 University Drive, Anchorage, Alaska 99508 USA; Stephen McNutt, Lamont-Doherty Geological Observatory, Palisades, New York 10964 USA.

Fernandina Caldera, Galápagos Islands (0.37°S, 91.55°W). All times are local (= GMT - 6 hours).

At 0500 on 30 March, Oswaldo Chapi and Fausto Cepeda (of the Galápagos National Park) heard noise from Fernandina Caldera, 22 km SW of their position at Tagus Cove. Glow was visible over the NW end of the caldera and a cloud was seen issuing from the same location after sunrise. The eruption was described as being smaller than the Volcán Wolf eruption of 1982 (see SEAN Bulletin v. 7, no. 8).

On 1 and 2 April, the TOMS instrument in the NIMBUS 7 polar orbiting satellite detected SO_2 produced by the eruption (figure 13). No data were available 30-31 March, and SO_2 had dropped below the detection threshold by 3 April. Strongest values on 1 April were directly over the volcano and a preliminary estimate of total SO_2 was 60,000 metric tons. No eruption cloud was evident on NOAA weather satellite imagery.

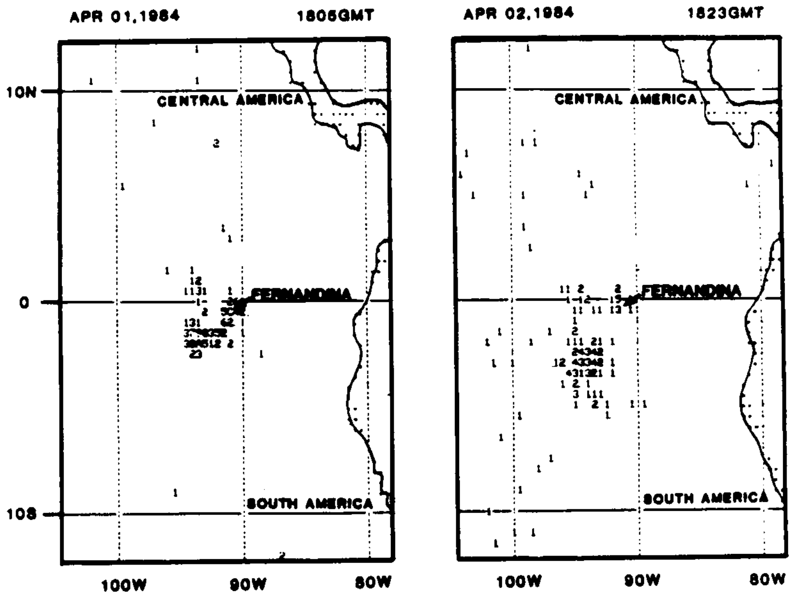

Figure 13: Preliminary SO_2 data from the TOMS instrument on the NIMBUS 7 satellite, courtesy of Arlin Krueger. All values less than 10 milliatmosphere - cm (100 ppm - meters) have been supressed. Each number or letter represents the average SO_2 value within an area 50 km across. 1 = 11-15 matm-cm = 101-150 ppm-m, 2 = 16-20 matm-cm = 151-200 ppm-m, etc.; values above 9 is followed by A, B, C, etc.

Reference 1.

Fernandina Caldera (continued)

On the afternoon of 4 April, the cruise ship Santa Cruz reported a long plume of vapor coming from the caldera, but apparently decreasing in size. They looked for glow over the volcano that night but reported none.

On 11 April Fernandina was climbed from the NW by David Day and L. Peterson, who reported an apparently inactive lava flow reaching from the western side of the caldera (near the site of the major eruption of 1968) to the lake. At 0650 the next morning, Day and Peterson heard a noise "like a large landslide" from their camp near the western caldera rim. Within 30 seconds, they reached the rim in time to see what Day described as a nuée ardente that had already moved from the vent area halfway to the lake. They left the rim and observers from Punta Espinoza, 17 km to the NE, described an eruptive cloud rising at 0655 to an estimated height of about 7 km. At 0704, Day and Peterson were overtaken by an ash rain described as "raindrops with ash" and total darkness persisted until 0720. A thickness of 3 mm of tephra accumulated during that period at their rim camp. By 0725 it was clear enough to see into the caldera. Tephra covered the new lava on the caldera floor with the exception of an area a few hundred meters across in which molten lava could be seen. Day and Peterson left the rim at 1030 and no further volcanism had been witnessed at the time of their radio report, at 1500 on 13 April, from Punta Espinoza.

This is the 6th known eruption of Fernandina since the major explosive eruption and massive caldera collapse of 1968. The last eruption was not recognized in the Galápagos, but its products are visible in an aerial photograph taken 26 March 1982. From a 900-m-long circumferential fissure on the S rim of the caldera, flows moved both inward (N) down the caldera wall and over a high topographic bench, and outward (S) where the flow ponded behind another row of circumferential vents. The eruption had not yet taken place when Tom Simkin and others passed this area on 4 December 1980.

Information Contacts: Gunther Reck, Director, Charles Darwin Research Station, Isla Santa Cruz, Galápagos Islands, Ecuador; Lucho Maldonado, Metropolitan Touring, P. O. Box 2542, Avenida Amazonas 239, Quito, Ecuador; David Day, Isla Santa Cruz, Galápagos Islands, Ecuador; Arlin Krueger, Code 963, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771 USA; Michael Matson, NOAA/NESDIS, Room 510, World Weather Bldg., Washington, DC 20233 USA.

Arenal Volcano, western Costa Rica (10.47°N, 84.73°W).

Lava extrusion continued from the vent at 1450 m altitude at the W end of the elliptical summit crater area. The lava flow that had been active in September 1983 (see SEAN Bulletin v. 8, no. 10) stopped advancing in October. During the same month, a new flow (the 43rd since nearly continuous lava production began in 1968) began to emerge, moving NW before halting at 980 m above sea level in November. Another flow (no. 44) started to advance NW in December, remaining active until February, and still another flow moved N between January and March. Extrusion of flow no. 46 started in March and it continued to travel westward late in the month. Rumblings, or sounds similar to those produced by jet aircraft, were often heard in the crater.

Information Contacts: Jorge Barquero and Erick Fernández, Programa de Investigaciones Vulcanológicas y Sismológicas, Universidad Nacional, Heredia, Costa Rica.

Reference 1. (Continued)

this valuable tool remains in only limited use. A further problem is presented by the present and future deployment of TOMS. Currently on the Nimbus 7 polar orbiter, it provides once a day global coverage, but this satellite has already suffered substantial power loss and is expected to fail within the next few years. Launch of another TOMS on a polar orbiter is, therefore, urgently needed. In the long term, however, geostationary satellites would be a better deployment for TOMS. Although polar orbiters provide global coverage, data is returned from a given location only once a day. This limits the timeliness of TOMS data, and also effectively reduces its sensitivity to volcanic SO_2. Many explosive eruptions consist of a series of brief pulses of gas and ash release lasting minutes to hours. The resulting eruption plume initially contains high concentrations of SO_2, but is quickly dispersed by winds, yielding a larger but less concentrated zone of SO_2. In the 12-hour mean interval between and explosion and data collection by a polar orbiting instrument, considerable SO_2 dispersal (and some conversion of SO_2 to other phases such as H_2SO_4) will have occurred and concentration within a given 50 x 50 km pixel will have decreased, effectively raising the eruption detection threshold. TOMS deployment on each of the major geostationary weather satellites (the successors of GOES I and II, GMS, and METEOSAT), would provide an improvement in both the timeliness and sensitivity of TOMS data.

Geostationary weather satellite data are available for virtually the entire globe, at half-hour intervals in many areas. Large eruptions such as those of El Chichon in 1982, and Alaid in 1981 were quickly spotted by NOAA scientists and the movement of their eruption clouds tracked over long distances. However, experience has shown that weather satellite data alone are generally of limited value in discovering any but the largest of previously unknown eruptions. Eruption plumes are hidden among the thousands of similar-looking weather clouds that dot the globe and further work is needed to find reliable methods of distinguishing volcanic clouds. Once an eruption is known, visible and infrared data from geostationary and polar orbiting weather satellites have been very effectively used to monitor the timing, dimensions, and altitudes of eruption clouds (see SEAN Bulletin v. 8, nos. 9-10).

TOMS and weather satellite data, therefore, complement each other. TOMS data is most useful for discovering previously unknown eruptions, and yielding a minimum volume of SO_2 produced by a given eruption. Once an eruption has been reported, weather satellite data can be used to accurately monitor its progress. To be used effectively, these data need to be analyzed jointly and in real time. Toward this end, we hope that full and timely utilization can be made of existing TOMS data, a polar orbiting TOMS can be launched in the near future, and that TOMS-type instruments can be included on future geostationary satellites.

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Una Una Volcano, Sulawesi, Indonesia (0.17°S, 121.61°E). All times are local (= GMT + 8 hours).

A powerful explosive eruption of Una Una began 18 July after at least 10 days of seismicity (see SEAN Bulletins v. 8, nos. 7-8). Since late August, no explosions have been reported by ground observers or seen on satellite imagery. Yosihiro Sawada searched all July and August images from the Japanese GMS satellite and provided table 1 (next page). Sawada notes that the data are tentative; some of the plumes may have been weather clouds. Times listed in table 1 are the beginnings of image scans, which are completed in about 25 minutes. Images are returned 14 times per day at intervals ranging from 30 minutes to 3 hours. New explosions are indicated by an arrow to the left of the time. Data shown in parentheses are for plumes that are detached from the volcano because explosive activity had (apparently) stopped. A new plume was sometimes ejected before remnants of the previous explosive pulse had dissipated; dimensions of the old plume are then listed in parentheses below data on the new activity. Coldest temperatures at the tops of plumes are shown. Ground observations of the eruption are being compiled by the Volcanological Survey of Indonesia and we hope to include that information in a future issue of the Bulletin.

Figure 4: Portions of 3 Japanese GMS geostationary weather satellite images showing the expansion of the cloud produced by the explosions of 23 July, when hot avalanches devastated Una Una island shortly after residents had been evacuated. An arrow points to the eruption plume on each image. Land areas are outlined, from Sumatra and the Malay Peninsula at left to Timor and Halmahera at right. Image scans began at 1631 (above) 1831 (above right) and 1931 (right). Images courtesy of Yosihiro Sawada.

Information Contact: Yosihiro Sawada, Seismology and Volcanology Division, Meteorological Research Institute, 1-1 Nagamine, Yatabe, Tsukuba 305 Japan.

Reference 2.

Una Una Volcano, Sulawesi, Indonesia (0.17°S, 121.61°E). All times are local (= GMT + 8 hours).

After at least 10 days of seismicity, a major explosive eruption of Una Una began 18 July. All residents of the island were evacuated before the devastating explosions of 23 July (see SEAN Bulletins v. 8, nos. 7-8). Images and a table of data (beginning 23 July) from the Japanese GMS geostationary weather satellite were shown in last month's Bulletin. A Volcanological Survey of Indonesia team monitored the eruption from near the island. Adjat Sudradjat provided the following table of their observations of explosion times and cloud heights, starting with the 23 July activity.

TABLE 4

DATE	TIME	PLUME HEIGHT (km)	DATE	TIME	PLUME HEIGHT (km)
23 July	1623	10	2-3 Aug.	1905-0200	5
25-6 July	2325-0021	7.5	4 Aug.	0915-1100	6
27 July	0400-0605	7.5	6 Aug.	1520-?	6
	1500-2010	7	7 Aug.	1100-1900	10
28 July	0002-0045	8	11 Aug.	1115-1135	8
	1630-1730	8	12 Aug.	0047-0147	9
30 July	1615-?	6	18 Aug.	1013-1240	12
1 Aug.	1834-2000	7	22 Aug.	1203-?	8
1-2 Aug.	2130-0230	6	24 Aug.	2148-2220	4
2 Aug.	0314-0600	8	25 Aug.	1847-2000	5.5
	0800-0900	8	26 Aug.	1023-1139	10

Maurice Krafft visited Una Una in mid-August. He observed and photographed the 22 August explosion (table 4 and figure 7) and pyroclastic flow deposits from previous explosions (figure 8). The entire island had been devastated except for a narrow strip of undamaged vegetation and villages along the E coast.

Figure 7: Explosion photographed from the south on 22 August by Maurice Krafft. Pyroclastic flows from this explosion continued 1/2 km beyond the SSW coast of the island and 1 km beyond the NNW coast.

Reference 3.

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