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Alaska's Pavlof Volcano Ends 11-Year Repose

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on board NASA's Aqua satellite (Figure 2, top panels); correlation with chlorophyll (NASA OC3 chlorophyll algorithm, correlation coefficient (*R*) = 0.88) and backscattering (GSM backscattering algorithm, (*R*) = 0.9; see http://oceancolor.gsfc.nasa.gov/DOCS/MSL12/MSl12_prod.html for algorithm details) are high. No noticeable trend is observed in the optical measurements below 950 meters (Figure 2, bottom panels). However, a significant elevation of subsurface backscattering at all depths is observed in November 2006 (Figure 2, middle panels), associated with the crossing of a particle-laden anticyclonic eddy observed in altimeter data (not shown). Such subsurface features, although they may have significant biogeochemical implications, cannot be resolved by ocean color observations from space; in the clearest of ocean waters, satellite measurements are limited to depths of only tens of meters.

The success of this Apex float and six other similar floats currently profiling the Pacific Ocean could lead to the design, testing, and implementation of an array of more sophisticated floats to provide critical data on biogeochemical properties, the biomass of key ecosystem variables, and temporal changes in these variables. Profiling floats could revolutionize biogeochemical modeling by providing data that satellites cannot, and for a small cost (total cost of this expandable float's components and telemetry was approximately $25,000).

Given technological advances in sensor technology, we envision the deployment of an array of floats that in addition to phytoplankton and particulate concentration, are capable of measuring parameters constraining nutrients, zooplankton, spectral radiance or irradiance, colored dissolved organic material, and oxygen. Previous biogeochemical investigations with profiling floats included measurements of beam attenuation, irradiance, and oxygen (e.g., *Bishop et al.* [2002], *Mitchell et al.* [2000], and *Riser and Johnson* [2007], respectively).

The International Ocean-Color Coordinating Group recently has assembled a scientific working group to coordinate and recommend future programs and desired protocols associated with bio-optical profiling floats (see http://www.ioccg.org/groups/argo.html). Such multifloat programs would provide data to validate satellite ocean color measurements and derived biogeochemical products. In addition, the depth-resolved, colocated physical and biogeochemical data, in conjunction with ocean color, could initialize and constrain (via assimilation and comparison) nutrient-phytoplankton-zooplankton models, which are the cornerstones of ocean ecosystem modeling.

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After an 11-year period of repose, Pavlof volcano on the Alaska Peninsula (Figure 1) began an episode of Strombolian eruption lasting 31 days, from 14 August to 13 September 2007.

The eruption began abruptly on 14 August after a minor increase in seismicity the previous day. Nearly continuous lava fountaining, explosions, and lahars caused by minor disruption of the ice and snow cover on the volcano characterized the eruption. The eruption also produced diffuse ash plumes that reached 5–6 kilometers above sea level, but the plumes were too small and did not extend high enough to affect local or regional air travel. Melting of snow and ice on the upper part of the edifice by hot debris avalanches and lava resulted in numerous lahars that entered the sea and inundated a 2×10^6 square meter area on the volcano's southern slope.

The volcano is a symmetrical, snow- and ice-mantled stratocone, 2518 meters high, located near the Izembek National Wildlife Refuge and 60 kilometers northeast of the city of Cold Bay. Pavlof, the most frequently active volcano in the Aleutian arc and one of the most active volcanoes in North America, has erupted at least 40 times since 1762. These events have been mostly moderate Strombolian eruptions (Volcanic Explosivity Index 2–3) with lava fountaining, spatter-fed lava flows, lahars, and minor ash production. The location of the vent has fluctuated between the north and south sides of the summit, and occasionally activity occurs from multiple summit vents. The location of the summit vent determines which side of the volcano is affected by lava flows and lahars.

Explosive bursts that have occurred during several historical eruptions (including those in 1906, 1950, 1973, 1975, 1980, 1981, 1983, and 1986) have produced ash plumes reaching altitudes of up to 15 kilometers and fallout up to 1 centimeter thick on nearby communities. The volcano's high frequency of eruptions, often with rapid onset, and the possibility of ash plumes entering the airspace of planes traveling North Pacific air routes (200–300 aircraft fly those routes daily, as well as regional aircraft serving local communities) make Pavlof particularly hazardous to aviation.

Pavlof has been seismically monitored since 1973, and much of the information about the volcano's eruptions since then has been interpreted from seismic data supplemented with satellite and visual observations and with intermittent field studies from 1986 to 2007. Here we provide an overview of Pavlof's most recent eruption and report observations made during visits to the volcano in August and September 2007.

Description of 2007 Activity

Throughout the summer of 2007, occasional clear views of Pavlof indicated nothing unusual. The volcano was seismically quiet in early August, and occasional small earthquakes (magnitude of 1 or less) at that time were within the range of normal background activity for Pavlof. On 14 August, the rate of small, low-frequency earthquakes increased to two to seven events per 10 minutes, whereas the day before there had been no noticeable difference in seismicity relative to background levels. The change in seismic activity prompted the Alaska Volcano Observatory (AVO) to raise the volcano alert level and color code to Advisory/Yellow on 14 August, although clear satellite views of the summit that morning indicated nothing unusual was occurring.

During the night of 14–15 August, a strong thermal anomaly was detected in advanced very high resolution radiometer (AVHRR) satellite imagery, accompanied by an increasing number of low-frequency earthquakes and tremor bursts observed on the five seismic stations that surround Pavlof. Individual discrete earthquakes and bursts of tremor lasting about 1 minute were common on 14–15 August. By midday on 15 August, AVO had received from people in the area reports of incandescent blocks on the eastern-southeastern flank of the volcano seen the night before and of a diffuse ash plume extending 3 kilometers southwest from the summit.

The change in seismicity, eyewitness reports, and a distinct thermal anomaly in the summit area left little doubt that the volcano had begun its first eruption of the 21st century. On 15 August, AVO again raised its alert level and color code, this time to Watch/Orange, where it remained until 20 September. While at this level of alert, in accordance with AVO policy, the observatory maintained 24-hour remote surveillance of the volcano.

On 16 August, seismic data from station PVV (located 8.5 kilometers south of the summit) showed clear evidence of lahar activity on the south flank of Pavlof. At least 41 lahar events occurred during the eruption, as determined from PVV seismic records. Typical events showed an increase in tremor followed roughly 11–25 minutes later by a lahar signal.

From 17 August to 13 September, long periods of volcanic tremor were punctuated with discrete, repetitive explosive events. However, as in previous Pavlof eruptions, no volcanotectonic earthquakes were recorded. As many as 14 explosions per minute were recorded in seismic data and as air waves detected by a pressure sensor located 7 kilometers northwest of the summit. The seismicity was diagnostic of quasi-continuous lava fountaining and Strombolian explosions. This activity produced a spatter-fed lava flow that descended the southeastern flank, and low-level diffuse ash bursts. AVO received several reports from residents of Sand Point, 97 kilometers east of the volcano, indicating that all of the activity was occurring on the southeastern side of the summit, and that "orange glows" and "streaks" extended from the summit down the southeastern flank. Satellite images from 15 August to early October confirmed the location of a vent just below and south of the summit and a lava flow that produced a strong and persistent thermal anomaly apparent in clear views of the volcano.

Beginning on 14 September, the seismicity changed from nearly continuous tremor to fluctuating low-level tremor and occasional explosions that decreased in magnitude and frequency over time. Seismicity continued to decline through 20 September, at which time AVO lowered its alert level and color code to Advisory/Yellow, where it remained until 5 October, when the volcano returned to its normal quiescent status and alert level and color code of Normal/Green.

Field Observations

AVO scientists visited Pavlof on 18 and 19 August and on 19 September, and they obtained thermal imagery of the eruption using a forward looking infrared (FLIR) camera. These images indicated a lava flow 565 meters long and 20–50 meters wide beginning on the upper part of the edifice 200 meters below the summit with a maximum surface temperature of 600°C. On 19 September, FLIR images indicated that the lava flow had cooled considerably, and the hottest regions were now located on the steepest (31°–34°) part of the flow, in the source area of active hot rock avalanches, but were only 120°–140°C. Also on 19 September, scientists observed a small, 5.7×10^3 square meter, triangle-shaped crater, 100–150 meters below the summit, on the upper southeastern part of the volcano; this was the vent for the 2007 eruption.

Fig. 1. Pavlof volcano in eruption, 30 August 2007. The eruption plume shown here reached an altitude of about 6 kilometers and consisted mostly of steam with minor amounts of ash, primarily in the near-vent part of the plume. After an 11-year period of repose, Pavlof experienced a minor Strombolian eruption lasting 31 days, from 14 August to 13 September. View is to the south. Photo by Christopher Waythomas, U.S. Geological Survey.

Lahars were first detected seismically on 16 August, at station PVV, indicating lahars in the channels nearby. Lahars commonly develop during Pavlof eruptions because the volcano sustains a thick cover of ice and snow throughout the year. Extensive valley-filling lahar deposits from previous eruptions are found in all major drainages that originate on the volcano. During the 2007 eruption, lahars were generated by a spatter-fed lava flow advancing over snow and ice and by hot avalanches resulting from collapsing piles of spatter and lava flow fronts.

Observations of lahars in progress on 18 and 19 August and examination of deposits on 19 September indicated that the lahars were primarily watery, hyperconcentrated flows and sediment-laden floods. The flows inundated a 2×10^6 square meter area and formed a debris fan that extended 3.6 kilometers from the base of the volcano to the coastline of Pavlof Bay. The area inundated by the lahars is a broad, low-relief debris fan that has been overrun by similar flows during previous historical eruptions. Lahars observed on 19 August traveled in 1- to 2-meter-deep, 5- to 20-meter-wide pre-existing channels across the debris fan, and they behaved as distinct flood surges with bore-like leading fronts. In several instances, the flows rose to—and occasionally over—the tops of the channel banks and formed broad, aggradational distributary flows over the debris fan surface.

The surface velocity of the channelized flows was 5–10 meters per second, as estimated from video footage. The flows appeared watery and they transported boulder-sized material along the entire length of the 10-kilometer-long flow path. As the lahar waves progressed downstream, they spread and thinned, eventually reaching Pavlof Bay. There, the waves formed a delta that added 1.3×10^5 square meters of new material to the coastline and extended it 200 meters into Pavlof Bay. The deposits produced by the lahars consist primarily of massive to stratified 1- to 2-meter-thick sequences of matrix-supported sand and fine gravel, with occasional 1- to 2-meter-thick beds of clast-supported, poorly sorted gravel.

During the period of most vigorous eruption (15 August to 13 September), the volcano produced diffuse mixed ash and steam plumes that reached as high as 5–6 kilometers. On 30 August, lightning was observed in the plume. According to pilot reports and satellite data, the ash plumes drifted mostly southeast over the North Pacific Ocean, although many plumes could not be detected in AVHRR satellite imagery using band-differencing techniques. Unlike some previous historical eruptions, AVO received no reports of ashfall on the surrounding communities; and during visits to the volcano in August and September, scientists observed only traces of ash within a few kilometers of the summit. Ash clouds that could be detected in satellite imagery did not extend more than 100 kilometers from the volcano. AVO scientists were unable, because of weather and logistics reasons, to make airborne gas measurements during the eruption, and no sulfur dioxide emissions were observed in standard Ozone Monitoring Instrument data retrievals with a detection threshold of about 10 cubic tons per day.

Hot blocks of juvenile material were collected on 19 September from a fresh avalanche deposit, 1.5 kilometers below the terminus of the lava flow. Samples were dark grey to black, were dense, and contained abundant plagioclase phenocrysts up to several millimeters in size. Analyses of these samples indicate that they are basaltic andesite in composition (53% silicon dioxide), typical of previous Pavlof eruptions.

The return period for Pavlof eruptions is 3–11 years. During the four eruptions from 1974 to 1996, there were periods of seismic and eruptive quiescence lasting 7–55 days followed by a resumption of activity. During these intervals, seismic activity was low (almost at background levels), but then it rapidly increased over periods of a few days and was followed by an eruption. However, since 5 October 2007 Pavlof has been seismically quiet and has exhibited no outward signs of unrest. In comparison with previous historical eruptions, the 2007 eruption was characteristically rapid-onset, apparently gas-poor, and of brief duration, but it lacked an explosive, ash-producing phase. The total volume of eruptive material during the 2007 event was about 10^5 cubic meters, which is similar to the eruptive volumes of many historical Pavlof eruptions. The apparently low gas production, short duration, and less explosive nature of the 2007 eruption suggest that this event may have involved residual magma from the 1996 eruption that was partially degassed and small in volume.

Photographs, images, and additional information about Pavlof and the 2007 eruption can be found on the AVO Web site at http://www.avo.alaska.edu.

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NEWS

Input Sought on Earth Surface Processes

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The U.S. National Research Council, at the request of the U.S. National Science Foundation, is conducting a study to assess (1) the state of the art of the multidisciplinary field of Earth surface processes, (2) the fundamental research questions in the future for the field, and (3) the challenges and opportunities related to answering these questions and advancing the field. The committee is addressing the task by considering research on the dynamic biological, chemical, physical, and human processes, interactions, and feedback mechanisms that affect the shape of Earth's surface across a range of spatial and temporal scales, from continental interiors to the oceans, and from polar to equatorial regions.

Because the committee cannot hear from all interested individuals during its scheduled meetings, it seeks written responses to the following questions:

1. What have been the four most significant conceptual and/or technological advances in Earth surface processes in the last 15 years?
2. What are two emergent and fundamental questions that Earth surface processes research can address?
3. What challenges (organizational, administrative, conceptual, philosophical, and so forth) exist in conducting the research needed to answer the fundamental questions identified in question 2?

Responses to these questions can be submitted at http://dels.nas.edu/besr/ESP_questionnaire.cgi. Comments received by 15 June 2008 will be considered at the committee's next meeting, 24–26 June 2008. The committee welcomes feedback through August 2008. Any written comments submitted to the committee (whether by mail, e-mail, fax, or the project's comment form) will be included in the study's public access file. The final report will be released in February 2009. The committee's membership, charge, and schedule are available at http://www8.nationalacademies.org/cp/projectview.aspx? key=48867.

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In Brief

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NASA's Phoenix spacecraft lands on Mars After a 9.5-month, 679-million-kilometer flight from Florida, NASA's Phoenix spacecraft made a soft landing in Vastitas Borealis in Mars's northern polar region on 25 May. The lander, whose camera already has returned some spectacular images, is on a 3-month mission to examine the area and dig into the soil of this site—chosen for its likelihood of having frozen water near the surface—and analyze samples. In addition to a robotic arm and robotic arm camera, the lander's instruments include a surface stereo imager; thermal and evolved-gas analyzer; microscopy, electrochemistry, and conductivity analyzer; and a meteorological station that is tracking daily weather and seasonal changes.

Peter Smith of the University of Arizona, the mission's principal investigator, said the workspace around the lander "is ideal for us because it looks very diggable. We are very happy to see just a few rocks scattered in the digging area." Phoenix is NASA's first mission to return data from either of Mars's polar regions, contributing to the agency's Mars science strategy to "follow the water." For more information, visit http://www.nasa.gov/phoenix.

Red tide Web site The U.S. National Oceanic and Atmospheric Administration has established the NOAA New England Red Tide Information Center to help people understand the significant red tides that are predicted to form there later this spring. The site (http://www.oceanservice.noaa.gov/redtide) will provide a summary of the current red tide situation and its potential harmful impacts on humans and animals and will serve as a central repository of information. The site also will have direct links to news releases, changes to relevant federal fishing regulations, links to closures of shellfish waters, and links to state agency Web sites with localized information. In addition, the site will have information about NOAA's scientific response effort as well as information from several other sources including NOAA's major response partner, the Woods Hole Oceanographic Institution (WHOI). On 24 April, WHOI scientists, using forecast models developed with NOAA funding support, predicted "that excess winter precipitation has set the stage for a harmful algal bloom similar to the historic red tide of 2005." That bloom shut down shellfish beds from the Bay of Fundy to Martha's Vineyard for several months.

China launches new weather satellite China launched its second weather forecasting satellite on 27 May. Called Fengyun 3, the new polar-orbiting satellite will monitor Earth's atmosphere, climate, oceans, and polar caps and will help scientists predict and monitor extreme weather over China, according to the Chinese Meteorological Administration. In particular, the satellite's data will be used to predict weather for the upcoming summer Olympics and will also help forecast weather while communities rebuild from the *M* 7.9 earthquake that struck central China on 12 May.

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