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Science and Society

In March 2013, the Kamchatkan Volcanic Eruption Response Team (KVERT) celebrated the 20th anniversary of its activity. This team, which was created by the joint efforts of Russian and American scientists, analyzes on a daily basis the data supplied by the complex (seismic, video, visual, and satellite) monitoring system of volcanoes of Kamchatka and the Northern Kuril Islands to notify airline companies and all interested organizations about potential hazards.

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Volcanoes and Their Hazard to Aviation

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Volcanism is a diverse and hazardous natural phenomenon. Strong and catastrophic eruptions and accompanying events (explosions with ash emissions up to 35 km above sea level, pyroclastic flows, and tsunamis) can do irreparable damage to the population, as has been recorded more than once by historians and modern scientists. For example, the eruption of Mount Vesuvius in 79 A.D. led to the burial and destruction of the cities of Pompeii, Herculaneum, and Stabiae; the eruption of Krakatau in 1883 caused tsunamis that killed more than 20000 people. Our planet has more than 800 active volcanoes, two-thirds of which are in the Northern Hemisphere, the most populated part of the planet. Eruptions largely take place in the Pacific Rim, where regular flights take place. The global air traffic capacity is constantly growing, and airplanes increasingly often find themselves in volcanic ash clouds. Until the 1980s, such incidents were rare; in the 1980s–1990s, 15 incidents happened in Alaska (United States); and the eruption of Mount Pinatubo (Philippines) in 1991 resulted in 18 encounters of airplanes with ash clouds. From 1935 through 2000, about 100 such episodes took place [5]. We still remember the events related to the eruption of Eyjafjallajökull (Iceland) in 2010, when many European airlines suffered losses owing to the sustained closures of airports.

Volcanic ash is extremely hazardous to modern aviation [3, 5, 7, 10, 12, 14, 15, 18]. Depending on wind force and speed, ash plumes and clouds can travel several thousand kilometers, remaining hazardous to airplanes for many days, because the melting temperature of fine ash particles is lower than the working temperature of jets under cruising performance. Ash consists of fine and thin sharp-edged rock fragments and volcanic glass; owing to the high specific surface, its particles can confine the electrical charge and absorb condensed moisture and corrosive acids. If an airplane finds itself in such clouds, the following damage can occur [10, 12, 14, 15, 17]:

- abrasion of windowpanes and aerodynamic surfaces;
- obstruction of the ventilation and fuel systems and the pitot–static tube;
- erosion of moving parts (compressor and turbine blades);
- melting of captured ash particles with their subsequent accumulation and hardening near the engine (the main cause of engine shutdown);
- clogging of spray nozzles and cooling radiators; and
- obstruction and overheating of electronic equipment.

Let us give an example. On May 18, 1980, at an altitude of 10700 m, between the cities of Pasco and Spokane, a DC-9-30 airplane, flying from San Francisco to Calgary, for 4 min was in an ash cloud that had formed several hours after the beginning of the catastrophic eruption of Mount St. Helens (United States). As a result, the airplane's windshield and compressor blades in the engines suffered abrasion and oil in the oil tubes turned out to be contaminated [8, 10]. This became the first serious warning about the danger of complex ash contamination, able to cause damage to or destruction of an airplane's vitally important systems (air-purifying, electronic, and navigational equipment) and jet turbines.

On December 15, 1989, a Boeing 747, flying from Amsterdam with 231 passengers and 13 crewmembers on board, began drifting down for land approach in Anchorage, Alaska. At an altitude of 7500 m, at a distance of 240 km from Redoubt Volcano, it found itself in an ash cloud (the emission had occurred 90 min before). While the plane was grabbing for altitude to leave the cloud, volcanic ash particles that had got into the engines melted, and the caked mass formed

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Potential hazard to aviation from the Kamchatka and Northern Kuril Islands eruptions in 1993–2013

Volcanoes	Eruptions	Eruption date (UTC)
Shiveluch	7 strong	1993–2013; paroxysmal events: 22.04.1993; 19.05.2001; 09.05.2004; 28.02.2005; 22.09.2005; 29.03.2007; 27.10.2010
Klyuchevskoi	11	15.03.1993–02.10.1994; 02–04.1995; 01–09.1997; 02–09.1998; 05–12.1999; 22.03.2003–03.03.2004; 10.01–03.04.2005; 15.02–26.07.2007; 16.10.2008–29.01.2009; 18.09.2009–01.10.2010; 01.09.2012–15.01.2013
Bezymyannyi	26	1993–2013; paroxysmal events: 20–23.10.1993; 05.10.1995; 09.05.1997; 05.12.1997; 24.02.1999; 13.03.2000; 01.11.2000; 06.08.2001; 16.12.2001; 25.12.2002; 26.07.2003; 13.01.2004; 18.06.2004; 11.01.2005; 30.11.2005; 09.05.2006; 24.12.2006; 11.05.2007; 14–15.10.2007; 05.11.2007; 19.08.2008; 16–17.12.2009; 31.05.2010; 13.04.2011; 08.03.2012; 01.09.2012
Tolbachik	1	27.11.2012–2013
Kizimen	1	09.12.2010–2013
Karymskii	2 strong	1996–2013; strong events: 02.01.1996; 13–14.05.2006
Avachinskii	1	05.10.2001
Koryakskii	1	20.12.2008–26.08.2009
Gorelyi	Activation	07.2010–2013
Mutnovskii	4	17.03.2000; 29.06.2000; 17.04.2007; 03.07.2013
Alaid	1	06.10–12.12.2012
Ebeko	3	1998; 07.2005; 29.01–09.04.2009
Chikurachki	6	25.01–01.05.2002; 17.04–16.06.2003; 10.03–07.04.2005; 04.03–07.04.2007; 19.08–20.10.2007; 29.07–15.08.2008

a glassy "shirt" on the turbine blades. Owing to this, the four engines stopped and the plane was in free-fall for 8 min. Only at 2000 m from the earth did the pilots managed to start, first, one and, then, a second engine. The plane landed safely 38 min after the beginning of the mishap [8]. Sixty kilograms of volcanic ash was removed from each turbine; the engines and the navigational and electrical systems were replaced. The company's losses amounted to about $80 million [14].

Ash is also hazardous to airports: ash showers contaminate electronic and electrical land equipment, and large ash sediments can cause wreckage to hangars and other buildings and upturn parked planes onto their tails [10, 14, 18]. Over the past 60 years, ash showers, which accompanied about 20 eruptions in seven countries, have led to the temporary closures of 40 airports for periods from two hours to several weeks [18]. The majority of these eruptions happened after 1980. Airports in the Philippines, Italy, Japan, Indonesia, Argentina, and the Unites States are exposed to ash showers and volcanic pollutants more often than airports in other countries. The International Civil Aviation Organization (ICAO) has elaborated the following rule: an airport should be closed completely if the thickness of the ash layer on its territory is 1 mm or more [10].

Kamchatka hosts 30 active and potentially active volcanoes, and the eruption of any of them can be hazardous to air flights in the northern part of the Pacific [1, 3, 6, 12, 13, 15]. Explosive eruptions of four to eight volcanoes annually take place on the peninsula. Four volcanoes are in a state of almost uninterrupted mild or moderate eruption, which are the background of paroxysmal explosive events: Klyuchevskaya Sopka has been active for several hundred years; Young Shiveluch, since August 1980, when a lava dome began to grow in the explosive crater formed during the catastrophic eruption of November 12, 1964; Bezymyannyi, since October 22, 1955, the moment when it awakened after millenarian dormancy; and Karymskii, since January 2, 1996, the beginning of a new active phase. In 2003–2013, 66 violent explosive eruptions took place, in which ash clouds rose up to 8–15 km above sea level and ash plumes extended up to 5000 km from the volcanoes, constituting direct and potential threats to air traffic (see table). Shiveluch saw 12 such events; Bezymyannyi, 26; and Klyuchevskoi, 8. In addition, explosive eruptions of other active volcanoes of Kamchatka are observed from time to time. For example, Kizimen has been erupting since December 9, 2010; the fissure eruption in the Tolbachik Dale, named after the 50th anniversary of the Institute of Volcanology and Seismology of the RAS Far East Branch, since November 27, 2012; and Koryakskii erupted from December 20, 2008, through August 26, 2009. Other volcanoes may become active at any

Fig. 1. Explosive eruption of Bezymyannyi Volcano (May 9, 2006) with ash emission to 15 km above sea level.

moment: short explosive eruptions of Avachinskaya Sopka (October 5, 2001), Mutnovskii (April 17, 2007; July 3, 2013), Gorelyi (July 2010–2013), and other volcanoes were observable. Great explosive eruptions of Kamchatka volcanoes, during which ashes rise to 8–15 km above sea level and higher, occur approximately once every year and a half (Fig. 1) [3]. This is highly hazardous to local and international airlines flying quite close to the peninsula (Fig. 2). More than 30000 passengers and cargoes totaling several million dollars are daily carried by the busy air routes from Asia to North America and Europe and back [14, 15].

In view of the necessity to discover quickly increased activity of volcanoes in the northwestern part of the Pacific and to warn air companies in a timely manner about the beginning of eruptions, on the basis of the Institute of Volcanic Geology and Geochemistry, RAS Far East Branch, in collaboration with the Kamchatka Branch of the RAS Geophysical Survey (http://www.emsd.ru) and the Alaska Volcano Observatory of the US Geological Survey (AVO USGS, http://www.avo.alaska.edu), as well as owing to the collective efforts of the USGS and the Geophysical Institute of the University of Alaska in Fairbanks, the Kamchatkan Volcanic Eruption Response Team (KVERT) was created in March 1993 [1, 3, 6, 8, 13], which in 1994 was formally registered in the International Civil Aviation Organization (ICAO) as Russia's representative on notifying aviation and meteorological services of the world about volcanic hazards [8]. To estimate the hazardous level of Kamchatka volcano eruptions to aviation, KVERT began to use color codes developed by AVO USGS in 1989. Since 2009, KVERT has been using the ICAO-recommended Aviation Color Codes (http://www.kscnet.ru/ivs/kvert/color_eng.php) [2]. After the unification of the Institute of Volcanic Geology and Geochemistry, RAS Far East Branch, and the Institute of Volcanology, RAS Far East Branch, in 2004, KVERT has worked within the Institute of Volcanology and Seismology, RAS Far East Branch (http://www.kscnet.ru/ivs/kvert), keeping all its responsibilities relative to airlines in the Pacific Rim [1, 3, 15]. At present, the Institute of Volcanology and Seismology, RAS Far East Branch, functions as a volcano observatory of Russia to provide information about volcanic activity in the Far East to the international air transport user aeronautical service.

KVERT's goal is to decrease the risk of airplanes flying into ash clouds in the northern part of the Pacific Rim by recording in a timely manner an increase in volcanic activity, recognizing and tracing volcanic ash clouds, and warning the airline flight administration about the hazards. KVERT associates constantly analyze the monitoring data on Kamchatka active volcanoes, including seismic data, performed by the Kamchatka Branch of the RAS Geophysical Survey; video–visual monitoring (Institute of Volcanology and Seismology, RAS Far East Branch, and the Kamchatka Branch of the RAS Geophysical Survey); and satellite monitoring (Institute of Volcanology and Seismology, RAS Far East Branch, and AVO USGS), as well as other information from various sources, such as associates of scientific stations, EMERCOM, and

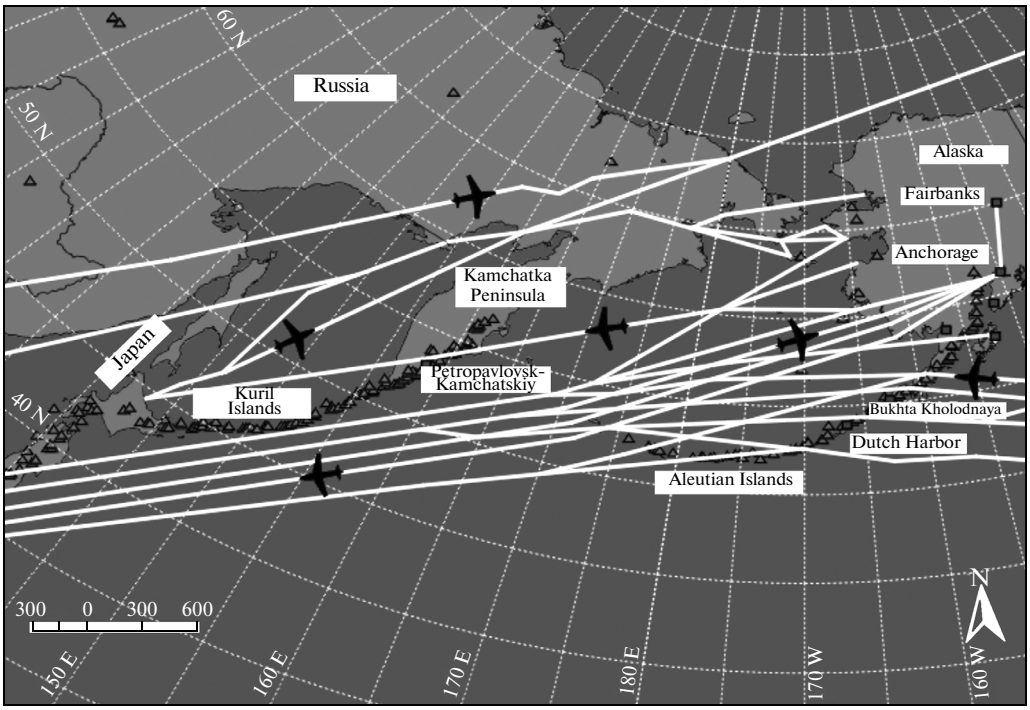

Fig. 2. International air routes in the northwestern part of the Pacific Rim.

meteorological stations, as well as from pilots, tourists, and alpinists.

The most reliable data about the beginning and development of eruptions are *visual observations,* which, unfortunately, depend on weather conditions. Observations over the northern group of volcanoes are performed by associates of the Institute of Volcanology and Seismology, the Levinson-Lessing Kamchatkan Volcanological Station, and the seismological stations at Klyuchi and Kozyrevsk. These data are communicated to the Institute of Volcanology and Seismology (Petropavlovsk-Kamchatskiy) by telephone, radio, or e-mail. Avachinskii, Koryakskii, Gorelyi, and Mutnovskii volcanoes are monitored by associates of the Institute of Volcanology and Seismology and the Kamchatka Branch of the RAS Geophysical Survey directly from Petropavlovsk-Kamchatskiy. Associates of the Institute of Volcanology and Seismology collect field data about Karymskii Volcano from April through January. In addition, visual information about these and other active volcanoes comes to KVERT from the pilots of local and international airlines, meteorologists, tourists, alpinists, and local lore specialists. In 2000–2012, the Institute of Volcanology and Seismology and the Kamchatka Branch of the RAS Geophysical Survey installed video cameras to monitor Klyuchevskoi, Shiveluch, Bezymyannyi, Kizimen, Avachinskii, Koryakskii, Gorelyi, Mutnovskii, and Tolbachik volcanoes, information about which is continuously communicated to the Internet (http://www.kscnet.ru/ivs/kvert) in real time. Owing to infrared video cameras, it is possible to monitor active volcanoes at night as well.

In 1997, KVERT began *satellite monitoring* of active Kamchatka volcanoes within its agreement with AVO. From 1998 through May 2013, twice a day, KVERT received updates from AVO about the state of Kamchatka volcanoes whose color code was "other than Green," the information being based on the results of processing all satellite data available [1, 3, 16]. To monitor volcanic activity, scientists use data from the NOAA (National Oceanic and Atmospheric Administration) satellites with Advanced Very High Resolution Radiometers (AVHRR), Geostationary Operational Environmental Satellites (GOES), Geostationary Meteorological Satellites (GMS), *Terra* and *Aqua* with Moderate Resolution Imaging Spectroradiometers (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometers (ASTER), and other orbiters [1–3, 10, 14, 16]. Satellite images make it possible to detect thermal anomalies near volcanoes, indicating an increase in volcanic activity, and ash clouds and plumes hazardous to aviation [2, 3, 11, 14, 16, 17]. For example, satellites helped trace the ash cloud from the eruption of Bezymyannyi Volcano on October 5, 1995, over a distance of 5000 km: from the volcano to Unalashka (the Aleutian Islands). The close collaboration of KVERT and AVO in using satellite information has helped decrease hazards to aviation in this region: 15 flights have been cancelled because of eruptions [3]. At present, data from the NOAA satellites are posted on the website

http://www.saa.noaa.gov and are available to any user. KVERT also works with this information. Since 2002, KVERT scientists have been processing and analyzing various satellite data practically in real time to sense ash plumes and thermal anomalies on the active volcanoes of Kamchatka and the Northern Kuril Islands. Since September 2002, KVERT has been collaborating with the Russian Federal Geological Foundation (Rosgeolfond). In 2007–2009, it collaborated with the Planeta Far East Research Center. Since 2010, it has been collaborating with the Kamchatka Hydrometeorology and Environmental Monitoring Department, and since 2011, with the RAS Space Research Institute and the Planeta Far East Research Center.

In 1997, V.Yu. Kir'yanov (KVERT) and S.B. Felitsyn (RAS Institute of Precambrian Geology and Geochronology) performed an experiment on melting ash particles to assess their impact on airplane engines [7]. The authors established that the melting temperature of all ashes studied was in the range of 1200 to 1400°C, while the temperature that caused changes in ash particle morphology (670–800°C) was, on average, 500°C lower than the melting temperature and close to the turbine blade surface temperature [7, 17]. At such temperatures, the particles begin to fuse and weld to the blades. The size of ash particles is a more important characteristic than their composition. From this point of view, the most hazardous to international and local aviation are explosive eruptions of Bezymyannyi, Shiveluch, Karymskii, Ebeko, Gorelyi, and Klyuchevskoi volcanoes. The ash plumes during their eruptions rise to 8–15 km above sea level, spread for several hundred kilometers, and can remain in the atmosphere for several days.

In 1998, information about KVERT's activity was first posted on the Internet; a catalogue was compiled, containing data about 30 active Kamchatka volcanoes with specified coordinates, heights, and eruption dates. In 2003, a catalogue of active volcanoes of Kamchatka and the Northern Kuril Islands, assessing the hazard of each of them to aviation, was posted on the KVERT website on the server of the Institute of Volcanology and Seismology, RAS Far East Branch (http://www.kscnet.ru/ivs/kvert/volcanoes/index.php).

In 2000, in accordance with KVERT recommendations, the Kamchatka Branch of the RAS Geophysical Survey created an Internet page updated daily with data about the seismic and visual monitoring of Kamchatka volcanoes (http://www.emsd.ru/~ssl/monitoring/main.htm) [8]. This information and video–visual and satellite monitoring data, as well as information from other sources (AVO, Internet, field volcanologists, and observations of meteorologists, pilots, and tourists), allow KVERT associates to assess volcanic hazards adequately and to warn stakeholders of their emergence immediately. An information list on KVERT operations was published in English in October 2002 (http://www.avo.alaska.edu/pdfs/usgsfs064-02.pdf) and in Russian in April 2003 (http://geopubs.wr.usgs.gov/fact/fs064-02/fs064-02russian.pdf) [6, 13].

In February 2003, the Third Moscow International Innovation and Investment Show awarded KVERT a gold medal for its activity on the program Flight Safety under Volcanic Eruptions.

On April 19–25, 2003, in Petropavlovsk-Kamchatskiy, KVERT associates organized the international conference "Monitoring Volcanic Activity of the Kamchatka and North Kuril Region: Past, Present, and Future." The conference was timed to coincide with the tenth anniversary of the foundation of KVERT and was dedicated to the establishment of SVERT—the Sakhalin team for aviation safety in the Kuril Islands region. During the conference, Chikurachki Volcano on the island of Paramushir (Northern Kuril Islands) started to erupt; the eruption continued from April 18 to June 25. One of the decisions at the conference was to charge KVERT with the responsibility to ensure aviation safety in the area of the Shumshu, Paramushir, and Atlasov islands.

Since May 9, 2003, KVERT information releases have been called *Volcanic Activity of the KNK Region*. Since July 11, 2003, KVERT Information Releases, submitted in English to the Kamchatka aviation services, have been accompanied by Russian translations. *The Kamchatka and Northern Kuril Volcano Hazard Prognosis for Aviation* began to be published in Russian on the Internet (http://www.kscnet.ru/ivs/kvert/progn/). October 1–4, 2003, the international conference "Volcanic Data Representation Meeting on the Issues of Their Impact on International Air Routes" was held in Petropavlovsk-Kamchatskiy with the participation of ICAO representatives. The conference appreciated KVERT's activity.

From May 9, 2004 (from the moment of the strong eruption of Shiveluch Volcano), KVERT began its close collaboration with the Tokyo Volcanic Ash Advisory Center (VAAC), whose area of responsibility included Kamchatka and the Kuril Islands. At present, KVERT and Tokyo VAAC exchange information about Kamchatka eruptions, and KVERT sends operational, daily, and weekly reports on the activity of the volcanoes to its colleagues. Since January 2005, the KVERT website has been publishing weekly updates (http://www.kscnet.ru/ivs/kvert/updates/).

For 12 years, AVO has been an intermediary between KVERT and airline companies of the Pacific Rim, communicating information about volcanic eruptions in Kamchatka and the Northern Kuril Islands. Since May 6, 2005, all the KVERT reports and releases about the state and hazards of volcanoes of Kamchatka and the Northern Kuril Islands have been sent to the aviation, meteorological, and scien-

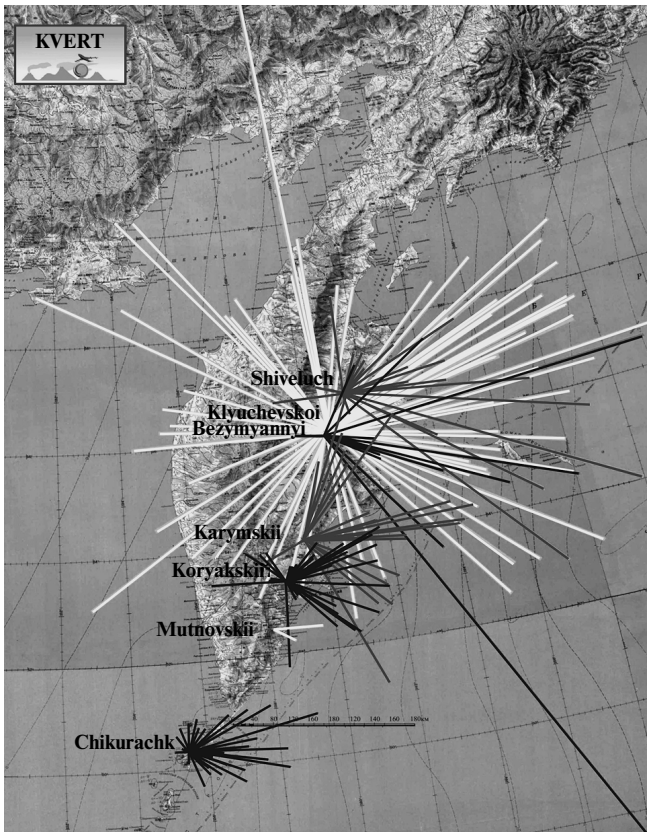

Fig. 3. Diagram of ash plume propagations during the Kamchatka and Northern Kuril Islands eruptions in 2005–2008.

tific organizations of the Pacific Rim (more than 300 users) without AVO mediation.

In 2008, the full English version of the KVERT website was published on the Internet [1]. The team was the first to register the beginning of the eruption of Koryakskii Volcano (December 20, 2008, 52 years after the previous one), 25 km away from Petropavlovsk-Kamchatskiy and Elizovo, and rapidly warned the aviation organizations of the Pacific Rim about it (see table).

Since 2010, ICAO-developed information reports in the VONA (Volcano Observatory Notice for Aviation) format have been issued. An automated system of e-mailing operational KVERT reports and posting them simultaneously on the website (http://www.kscent.ru/ivs/kvert/oper/archives.php) has been created. Satellite data analysis has made it possible to construct a diagram of the spread of ash plumes that appeared under explosive eruptions of the Kamchatka volcanoes in 2005–2008 (Fig. 3) [9].

In 2011, the website was upgraded: now all VONA/KVERT releases are automatically e-mailed to all users simultaneously and are posted on the website and in the KVERT database (http://www.kscnet.ru/ivs/kvert/van). We continue cataloguing the active volcanoes of Kamchatka and the Northern Kuril Islands, one of its components being the assessment of the hazard of each volcano to local and international aviation (http://www.kscnet.ru/ivs/kvert/volcanoes/index_eng.php). On August 22–23, 2012, KVERT associates participated in the ICAO-organized international conference "Meeting of the Volcanic Ash Exercise Steering Group for the Far Eastern Part of the European Region ICAO," aimed at coordinating the actions of the aviation services of Russia's Far East under a KVERT-announced hazard associated with strong volcanic eruptions (ash rising to more than 10 km above sea level) (http://www.paris.icao.int/documents_eanpg/files.php?subcategory_id=205).

In January 2013, a drill was conducted on the interaction between aviation services of Russia's Far East under notification of the hazard of ash plume spread during the eruption of Karymskii Volcano. Recommendations for improvement of the interaction between the aviation services have been published in the Internet on the ICAO website (http://www.paris.icao). Jointly with associates of the RAS Space Research Institute; the Computing Center, RAS Far East Branch; and DTs NITs Planeta, we created the information service called Kamchatka and Kuril Volcano Activity Remote Monitoring [4].The sensing of an ash plume near a certain active volcano and registration of the preparation for or the beginning of strong explosive eruptions point to the real hazard to air flights in a given region; this is why a VONA report about a plume (with data on its sizes and localization) or about the activation of a volcano is operationally sent to the Internet (http://www.kscnet.ru/ivs/kvert/van/ index.php?type=1) and is e-mailed simultaneously to all stakeholders. In the first place, such information comes to the Meteorological Center of Elizovo airport; the Kamchatka Aerial Navigation Branch of the State ATM Corporation; Tokyo VAAC; Anchorage VAAC; Washington VAAC; Montreal VAAC; Darwin VAAC; Pacific Rim airline companies; AVO USGS; the Kamchatka, Sakhalin, and Khabarovsk EMERCOM Departments of Russia; local mass media; and so on (Fig. 4). To specify the level of hazard to aviation from each active volcano of Kamchatka, KVERT scientists use ICAO-recommended aviation color codes.

In addition to the rapid response to volcanic eruptions accompanied by ash emissions, to assess the situation near a volcano of Kamchatka or the Kuril Islands, it is very important to forecast its activity and hazard to aviation for the immediate future (days and weeks). The multifaceted analysis of published information about the activity of volcanoes (descriptions of eruptions, their products, substance composition, and activity dynamics) and data received by KVERT over its 20-year daily monitoring of volcanic activity makes it possible to assess reliably the hazard level of each volcano

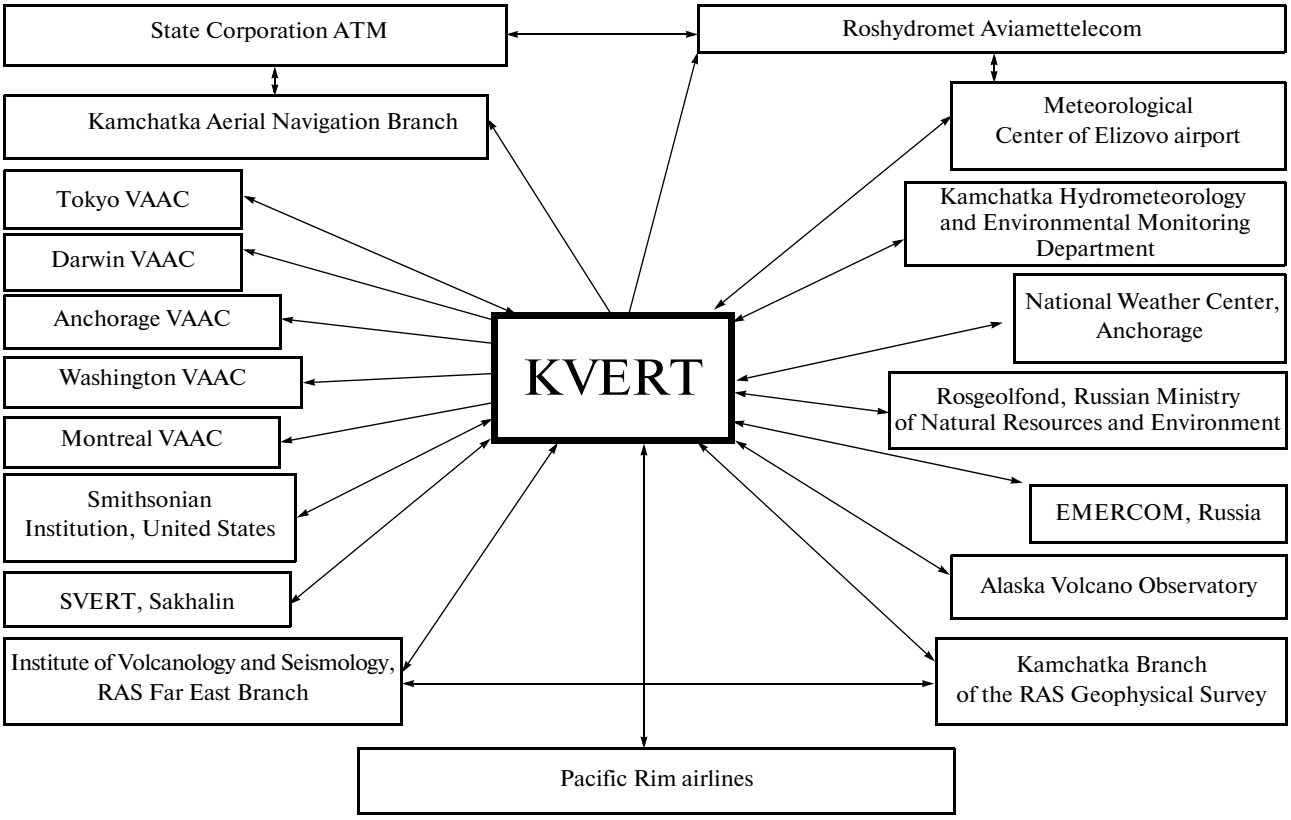

Fig. 4. Scheme of KVERT's interaction with the Pacific Rim organizations.

for aviation and the peninsula's population. For example, the following information was learned [2, p. 19]:

> At the initial stages, explosive eruptions of Klyuchevskoi Volcano are, as a rule, hazardous only to local airlines, because ash plumes spread predominantly at altitudes of up to 6–7 km above sea level for the first several dozens kilometers from the volcano. Closer to the end of the eruptions, we always observe an increase in the volcano's explosive activity, the ash plumes rising up to 8–10 km above sea level and spreading to a distance of up to 5000 km from the volcano. During such periods, the hazard to international air traffic becomes real.

Let us give another example. The more than ten-year satellite monitoring of Bezymyannyi Volcano has made it possible to understand the prerequisites of its explosive eruption, based on the linear dependence of the amount of juvenile substance coming to the earth's surface on the size and temperature of the thermal anomaly at the moment of its satellite imaging [2, 11, 16]. Owing to observations of the changes in the temperature and size of the thermal anomaly near Bezymyannyi Volcano in 2001–2012, ten eruptions of this volcano were predicted (December 16, 2001; December 25, 2002; January 11, 2005; May 9, 2006; May 11, 2007; October 14–15, 2007; August 19, 2008; May 31, 2010; March 8, 2012; and September 1, 2012). "The real-time implementation of forecasts was the Internet publication of KVERT Information Releases, containing the Orange or Red color codes and the warning about the coming strong eruptions before their beginning" [2, p. 20].

Depending on the activity of the Kamchatka and Northern Kuril Islands volcanoes, KVERT annually issued 60–80 weekly and special VONA/KVERT Releases (70 per year, on average). In addition, as and when necessary, the team e-mailed operational information about the activity of volcanoes to the users; for example, 100 times in 1993 (starting from April), 175 times in 2006, and 420 times in 2007. Rapid and reliable notification allowed pilots to avoid encounters with ash clouds.

The KVERT website on the server of the Institute of Volcanology and Seismology, RAS Far East Branch, hosts the following data archives:

• from 2002, data on the visual and satellite monitoring of volcanoes of Kamchatka and the Northern Kuril Islands (http://www.kscnet.ru/kvert/index_eng.php);

• from 2003, weekly information about forecasts on the volcanoes' hazard to aviation in Russian (http://www.kscnet.ru/ivs/kvert/progn/);

• from 2005, weekly KVERT Information Releases about the state of volcanoes and the forecast of their activity for the following week in English (http://www.kscnet.ru/ivs/kvert/van/index.php?type=3);

• from 2010, VONA/KVERT Operative Reports on ash emissions and ash plumes in English (http://www.kscnet.ru/ivs/kvert/van/index.php?type=5);

• from 2011, data about changes in aviation color codes in ICAO-format VONA/KVERT Releases in English (http://www.kscnet.ru/ivs/kvert/van/index.php?type=1); and

• from 2011, VONA/Daily Reports about the state of volcanoes whose color code is other than Green for the previous day in English (http://www.kscnet.ru/ivs/kvert/van/index.php?type=2).

Colleagues from AVO and KVERT jointly published nine works describing volcanic activity in Alaska, the Aleutian Islands, Kamchatka, and the Kuril Islands in 1998–2008 (for example, http://pubs.usgs.gov/of/2005/1310). Over the past 20 years, KVERT associates have published more than 90 scientific papers concerning volcanoes and aviation safety in the northwestern part of the Pacific Rim. In addition, in 2009–2012, they made presentations about KVERT's activities at 24 international and domestic conferences that discussed the hazard of explosive eruptions to aviation and mitigation methods.

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The earth continues to develop, and volcanic eruptions continue to happen; hence, assessing volcanic hazards to aviation remains topical. The number of air flights in the Pacific Rim continues to increase; accordingly, the probability of damage to airplanes and even death to passengers owing to encounters with ash clouds increases. The role of volcanological observatories in mitigating the hazard to air traffic in areas of high volcanic activity is becoming increasingly obvious. It is necessary to improve observations of the volcanoes of Kamchatka and the Kuril Islands, to spread the network of seismic stations and video systems, to enhance satellite monitoring and data analysis, and to increase the efficiency of notification about volcanic hazards to air services.

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