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PROCEEDINGS OF THE INTERNATIONAL WORKSHOP

WORLDWIDE EARLY WARNING SYSTEM OF VOLCANIC ACTIVITIES AND MITIGATION OF THE GLOBAL/REGIONAL CONSEQUENCES OF VOLCANIC ERUPTIONS

MOSCOW 2011

SECTION B. Standardized assessments of the risks related to volcanic eruptions, in particular for air traffic, Mitigation of the global/regional consequences of volcanic eruptions

MITIGATION OF RISKS OF PLANES COLLISION WITH ASH CLOUDS IN THE NORTHERN PART OF THE PACIFIC REGION.

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There are more than 800 active volcanoes on our planet now, two thirds of them are located in the northern hemisphere, and more than 200 are in the northern part of the Pacific region. Despite such a number of active volcanoes in this part of the planet, the intensity of air traffic here is the highest one.

The amount of world air transportation is constantly increasing; more and more often planes get into volcanic ash clouds. Before 1980-s such incidents were singular, in 1980- 1990-s in Alaska, USA there were 15 cases, and just during the eruption of Pinatubo volcano in Philippines in 1991 there were 18 cases of jet airplane contacts with volcanic ash. According to International Civil Aviation Organization (ICAO), for example, in 1970-1995 there were 83 such occurrences [5].

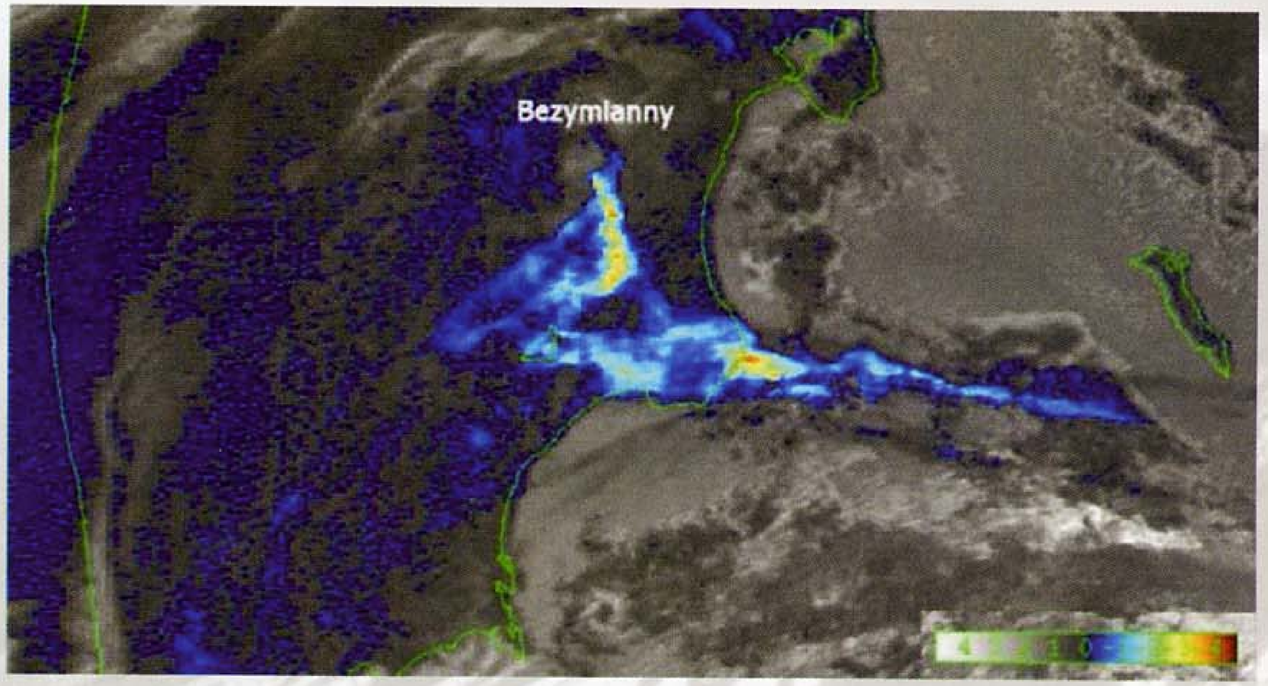

Fig. 1. The ash plume from Bezymianny volcano during the eruption on 14-15 October 2007 (image: NOAA, AVHRR (4m5), 14:19 UTC, 15 October. Data provided by AVO USGS)

The most danger to planes is posed by strong (Plinian and sub-Plinian) explosive eruptions of volcanoes during which within several hours or days up to several cubic kilometers of volcanic ashes and aerosols are discharged into atmosphere and stratosphere. Volcanic ash (particles < 2mm) is extremely abrasive as it consists of small and thin acute-angled rock and volcanic glass fragments. Because of their high specific surface ash particles can maintain electrostatic charge and absorb droplets of water and corrosive acids. Ash plumes and clouds, depending on the eruption strength and wind force and speed, can move thousands of kilometers away from the volcano for many days remaining dangerous to planes because the melting point of the finest ash particles is below the operating temperature of jet engines (Fig. 1). When a plane hits a volcanic ash or aerosol cloud it can suffer the following damage: abrasive wear of window glass and aerodynamic surfaces; clogging of ventilation and fuel systems and air pressure heads; erosion of moving parts (compressor, turbine blades); melting of trapped ash particles with their subsequent accumulation and hardening in engine area (the main cause of engine failures!); clogging and overheating of electronics etc. [2, 11].

Ash also poses threat for airfields [2, 3, 5, 8, 9, 12].

Ash falls lead to contamination of surface electronic, electro-technical, and mechanical equipment. Deposition of considerable amounts of ash can cause collapse of hangars and other structures, as well as tail tipping of parked airplanes. Wet ash can decrease braking efficiency because of reduction of undercarriage grip of the surface. Ash raised from the surface by working aircraft engines during taxiing, take-off, and landing significantly reduces visibility and affects the pilots' general condition. During sixty years ash falls which accompanied twenty volcano eruptions in seven countries of the world have caused temporary closures of about forty airports for the period that lasted from several hours to several weeks [12]. Most of these eruptions occurred after 1980. Airports of Philippines, Italy, Japan, Indonesia, Argentina, and the USA are more often than others exposed to ash falls and volcanogenic contamination. ICAO has developed a rule according to which an airfield should be completely closed if thickness of the ash layer deposited within its territory equals or exceeds 1 mm [5].

There are several hundreds of volcanoes in Kamchatka; thirty of them are active, and eruption of any of them can be dangerous to flights in the northern part of the Pacific Ocean [1-4, 7-8]. Every year 3-5 volcanoes erupt on the peninsula. Four volcanoes are in the state of almost continuous weak eruption aggravated by strong culminating explosive events: Klyuchevskoy volcano has been active for several hundreds of years; Molodoy Shiveluch volcano has been active since August 1980 when the growth of the lava dome began in the explosive crater formed during the catastrophic eruption on 12 November 1964; Bezymianny volcano has been active since 22 October 1955 from the moment of its awakening after a thousand-year silence; Karymsky volcano has been active since 1 January 1996. Besides that Avachinsky, Koryaksky, Mutnovsky, Gorely and other volcanoes become active from time to time: http://www.kscnet.ru/ivs/kvert/volcanoes/index.html. On the average, strong explosive eruptions of Kamchatka volcanoes with ashes rising to more than 8-15 km above sea level take place approximately once every eighteen months.

To mitigate the risk of planes collision with ash clouds during volcano eruptions in Kamchatka, in 1993 the KVERT (the Kamchatkan Volcanic Eruption Response Team) international project was launched which currently unites scientists from the Institute of Volcanology and Seismology (IV&S) of the Far East Branch (FEB) of the Russian Academy of Sciences (RAS), the Kamchatka Branch of the Geophysical Service (KB GS) of the Russian Academy of Sciences, and Alaska Volcano Observatory of U.S. Geological Survey (AVO USGS) [1-4, 7, 10]. In 1994 KVERT was officially registered with ICAO as the representative of Russia for notification of international air and meteorological services on volcanic danger to aviation (ICAO letter No. 29848 dated 12 October 1994).

For timely notification of aviation services on volcanic danger the KVERT scientists on the daily basis analyze data of seismic, video-visual, and satellite monitoring of volcanoes of Kamchatka and the Northern Kuril Islands. Seismic monitoring of volcanoes has been performed by KB GS RAS since 1946. The vast experience in studies of seismicity of separate volcanoes allows the scientists to predict strong explosive eruptions with sufficient confidence. Volcanists of FEB RAS IV&S has performed observation of volcanoes and have studied their activity and eruption products in detail since 1935. They have studied activity dynamics of the most active Kamchatka volcanoes and determined the cyclicity of development of some of them, which allows to make long-term and short-term forecasts of explosive eruptions of these volcanoes. In 2000-2009 within the framework of the KVERT project video cameras were installed for continuous observation of Klyuchevskoy (2000), Shiveluch (2002), Bezymianny (2003), Koryaksky (2009), and Avachinsky (2009) volcanoes. Information from these cameras is continuously communicated in real time to the Internet (http://www.emsd.iks.ru/ and http://www.kscnet.ru/ivs/kvert/index.php). Experience of comparison of seismic and visual data has allowed seismologists to establish a procedure for determination of ash discharge height based on intensity of seismic signal. Calculation error does not exceed 25% for discharges to the height of up to 6 km above sea level [6]. But the most reliable is the determination of ash discharge height by means of a radar. Analysis of satellite information on Kamchatka volcanoes has been performed by the KVERT project employees since 1998 [1]. Satellite images (NOAA, AVHRR; TERRA MODIS) are received by FEB RAS IV&S KVERT 10-16 times a day; they are processed and analyzed; besides that, current information from various satellites available in the Internet is studied daily. OMI radiometer data sent by the AURA satellite allow not only to track the movement of volcano aerosol plumes and clouds, but also to estimate their SO_2 content. In addition to prompt detection of ash plumes in the areas of active volcanoes of Kamchatka and the Northern Kuril Islands, satellite images also allow to identify thermal anomalies on volcanoes.

Continuous monitoring of growth dynamics of thermal anomaly dimensions and temperature, for example around Bezymianny volcano, has more than once enabled the KVERT volcanists to successfully predict strong explosive eruptions of this volcano, for example on 16 December 2001, 25 December 2002, 11 January 2005, 11 May 2007, 31 May 2010 etc.

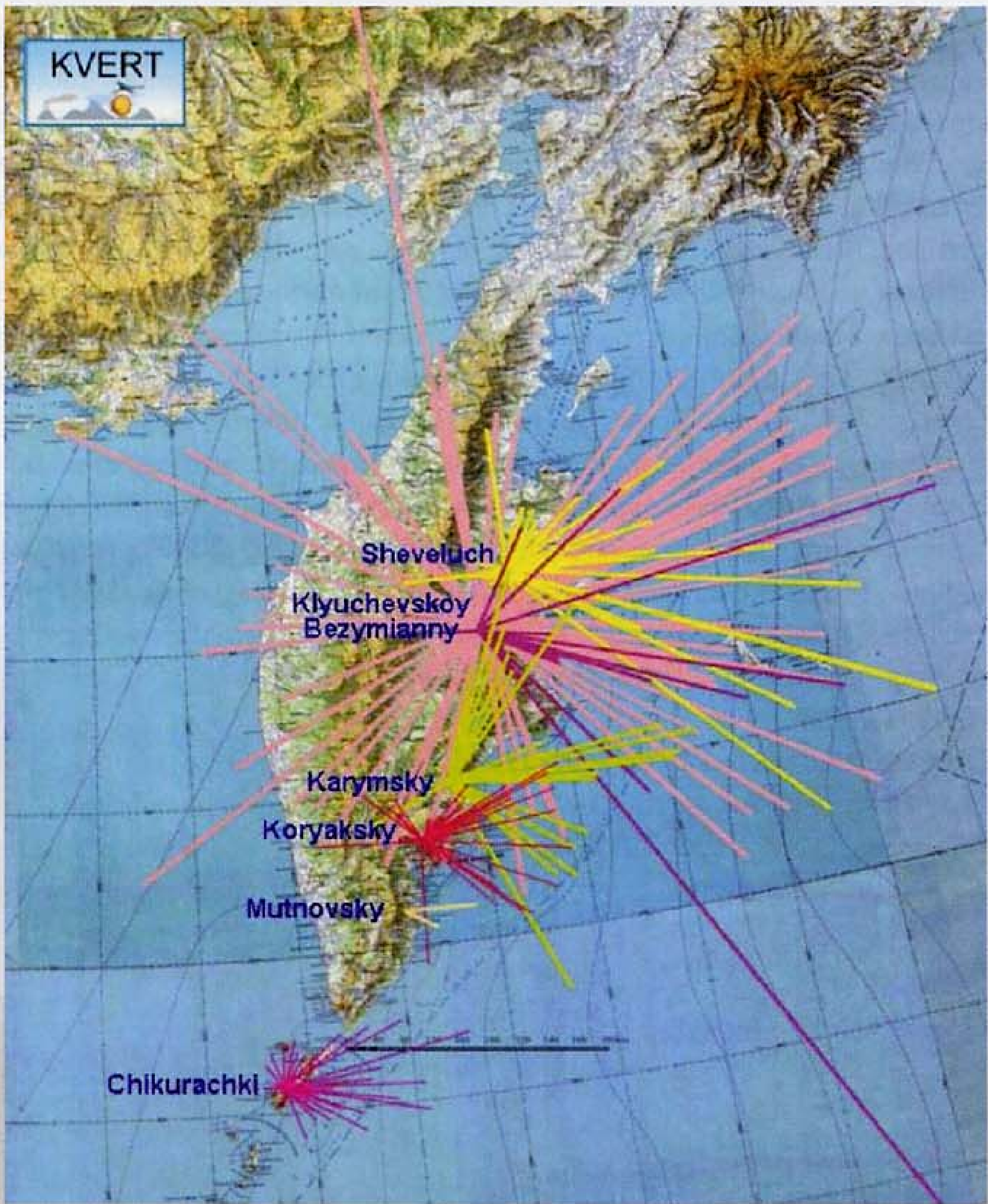

Fig. 2. Ash plumes during eruptions of volcanoes of Kamchatka and Northern Kuril Islands in 2005-2008. The diagram prepared by A. Nuzhdayev, KVERT

During eruptions ash plumes spread from volcanoes in different directions. For example according to satellite data in 2005-2008 the KVERT project employees registered more than 1,500 ash plumes during eruptions of seven volcanoes of Kamchatka and the Northern Kuril Islands (Fig. 2). Results of the strongest explosive events for each of these volcanoes are listed in Table 1.

In case of detection of an ash discharge, cloud, or plume by any type of volcano monitoring, the information by means of the automated warning system created in FEB RAS IV&S KVERT is promptly dispatched by e-mail to all interested users, first of all to Tokyo VAAC, Anchorage VAAC, Washington VAAC, Montreal VAAC, to the air companies of the Pacific region, and to EMERCOM of Russia (Fig. 3). Depending on the scale of the explosive event a KVERT Information Release can be consequently sent by e-mail and published on the websites of FEB RAS IV&S

(http://www.kscnet.ru/ivs/kvert/updates.shtml)

and AVO USGS

(http://www.avo.alaska.edu/activity/avoreport.php?view=kaminfo);

this release will include the change of the Aviation Color Code (http://www.kscnet.ru/ivs/kvert/color_eng.php)

of the volcano and the forecast of its activity for the forthcoming week. The KVERT scientists collect all available information on active volcanoes (scientific data, descriptions of eruptions from literature, tourists' observations etc.). The Catalog of Active Volcanoes of Kamchatka and the Northern Kuril Islands and KVERT Information Releases archive have been created on the FEB RAS IV&S website; there are database files of all types of volcano monitoring as well.

Table 1. The strongest explosive eruptions of volcanoes of Kamchatka and the Northern Kuril Islands in 2005-2008.

Name of the volcano	Eruptive column height (km above sea level)	Spread of ash plume (km)
Shiveluch, 2007	15	800
Klyuchevskoy, 2007	10-12	5,500
Bezymianny, 2006	13-15	1,300
Karymsky, 2006	8	300
Koryaksky, 2009	5.5	650
Mutnovsky, 2007	unknown	50
Chikurachki (Paramushir Island), 2007	5	260

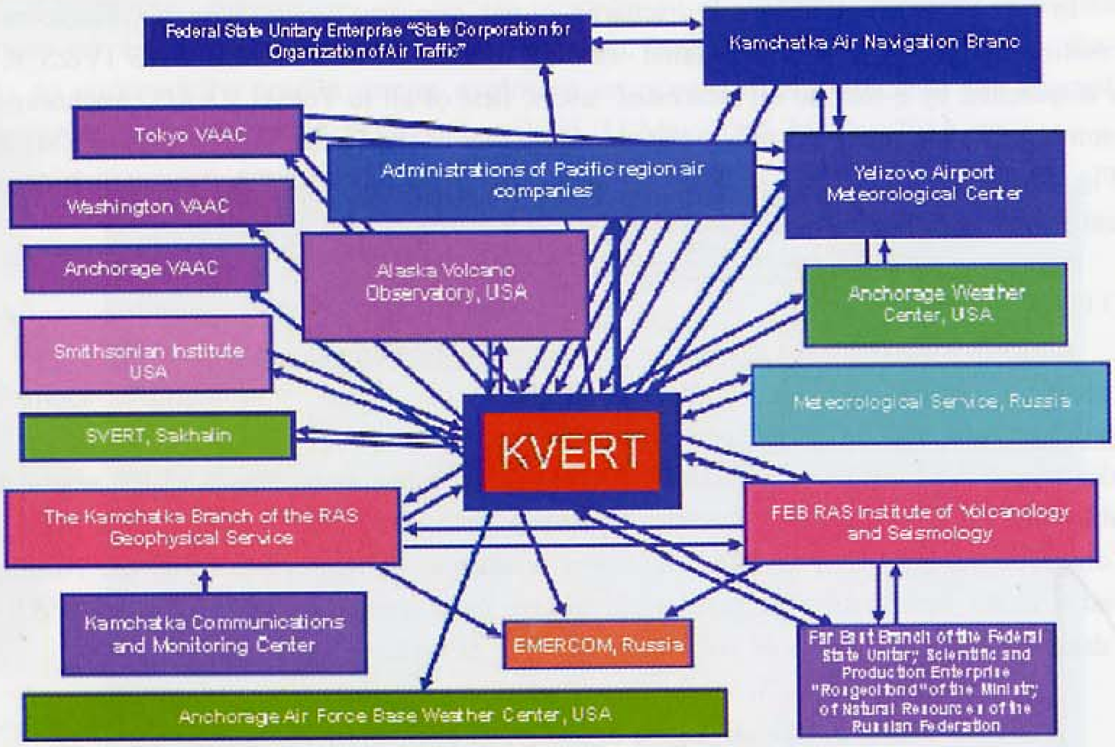

Fig. 3. Scheme of KVERT interaction with organizations of the Pacific region

Based on analysis of seismic, satellite, and visual information, as well as on volcanological experience, the KVERT scientists have more than once given early warnings to various organizations (Tokyo VAAC, Anchorage VAAC, Washington VAAC, air companies of the Pacific region, EMERCOM of Russia etc.) about preparation of volcano eruptions. For example, analysis of historical activity of Bezymianny volcano, as well as the data from its continuous monitoring made it possible for the KVERT project scientists to predict eruptions of this volcano which allowed them to promptly notify aviation services on the danger posed to planes. In 2001-2010 nine out of sixteen eruptions of this volcano were predicted (16 December 2001, 25 December 2002, 11 January 2005, 9 May 2006, 11 May 2007, 14-15 October 2007, 19 August 2008, 16 December 2009, 31 May 2010). Another example: the eruption of Bezymianny volcano on 9 May 2006 had been predicted by the KB GS RAS scientists based on seismic data two days before the event. The Aviation Color Code (ACC) was changed from ***yellow*** to the ***orange.*** Experience of studying of this volcano allowed the FEB RAS IV&S volcanists to predict the culmination of this eruption two hours prior to its beginning: ACC was changed from ***orange*** to ***red*** at 06:35 UTC on 9 May, and at 08:21 UTC on 9 May the volcano eruption began during which the ash cloud rose to 15 km above sea level. The ash plume spread for > 400 km to the east of the volcano.

For the work on mitigation of risks of planes collision with ash clouds in the northern part of the Pacific region to be successful it is necessary to ensure timely warnings about the beginning of volcano eruptions. This would be possible only with the further development of regular seismic, video, and satellite monitoring of volcanoes. Volcano monitoring requires qualified personnel, technical basis, efficient communication, and stable financing. Currently seismic stations have been installed only on ten most active volcanoes out of thirty six; video observation is performed for five volcanoes only. Satellite monitoring should be developed and improved; it is necessary to receive data from various FEB RAN IV&S satellites; software used for processing of this data should be updated. Geological and volcanological research, improvements in personnel training, and coordination of efforts of all interested partners are the prerequisites of mitigation of risks of planes collision with ash clouds.

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