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Lightning and electrical activity during the Shiveluch volcano eruption on 16 November 2014

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Abstract

According to WWLLN data, a sequence of lightning discharges was detected. It occurred on the path of propagation of eruptive ash cloud formed in the result of the explosive eruption of Shiveluch volcano on 16 November 2014 in Kamchatka. Information on the cloud motion was confirmed by the measurements of atmospheric electricity, satellite observations, meteorological and seismic data. It was concluded that WWLLN resolution is enough to trace ash clouds at the stage of their fragmentation when electrification processes develop the most intensively. The undeniable advantage of WWLLN method is its efficiency and the possibility to apply in the conditions of poor visibility.

1 Introduction

Observations of atmospheric electricity variations during volcano explosive eruptions indicate the development of electrification processes of eruptive clouds which may be the result of magma (ash) fragmentation and formation of an eruptive column (James et al., 1998, 2003; Mather and Harrison, 2006), or may involve ice-ice interactions from the rapidly expanding and cooling water vapor of the volcano (McNutt and Williams, 2010). Whatever the detailed cause of volcanic ash cloud charge separation, volcano explosive eruptions are powerful sources of lightning. Thus, ash clouds, posing a threats to air transport and to the adjacent area, may be identified within seconds by a lightning location system even in conditions of poor visibility.

At present, the World Wide Lightning Location Network (WWLLN) is capable to register lightning discharges with the timing accuracy of a few microseconds (Hutchins et al., 2012a), which makes it possible to determine the location of discharges with the accuracy of a few kilometers anywhere in the world.

Eruptive cloud electrification also affects the atmospheric electric field variations which extends the complex of observation means for volcanic ash motion. During the

Shiveluch volcano eruption, a fluxmeter was used to measure atmospheric electric field variations, and WWLLN was used for locating the lightning. Moreover, to determine the beginning of the eruption, seismic data were drawn, and to observe the eruptive cloud motion, satellite images were applied. Cloud motion velocity and direction were compared with meteorological data.

2 Observation means

Data on the location of lightning discharges accompanying the eruption are available on the site http://wwlln.net. Kamchatka WWLLN site is installed in Paratunka (Fig. 1).

EF-4 fluxmeter and Vasiala wxt520 weather station are located about 120 km to the south-west from Shiveluch volcano at Kozyrevsk (KZY) seismic station of Kamchatka Branch of Geophysical Service of RAS (KB GS RAS). The closest seismic station, Baidarnaya (BDR), is located at the distance of 10 km from Shiveluch volcano crater.

Kluchi meteorological observatory of Kamchatka Department on hydrometeorology and environment control is located 48 km from Shiveluch volcano. Its data (atmospheric pressure, air temperature, humidity and height radio sounding of the atmosphere twice a day) is available on the site http://www.esrl.noaa.gov/raobs/intl/intl2000.wmo.

According to the height sounding on 16 November 2014 at 12:00 (UT), Fig. 2 illustrates temperature and wind stratification up to the height of 25 km. It had two inversions at the heights of 9–10 and 12 km where wind velocities were 17 and 11 $\mathrm{m\,s^{-1}}$, correspondingly. The height of the lower inversion corresponded to the tropopause height characteristic for the autumn-winter period in Kamchatka. For these heights, south-south western wind direction is typical (azimuth is 50 and 80°, Fig. 2b). The direction is opposite to the azimuth.

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3 Development of eruptive plume

Motion of the eruptive plume from volcano eruption is traced by lightning discharges occurring during ash cloud passage at the initial stage of its formation. The WWLLN network registered seven discharges, the time of which is shown in the Table and the location is illustrated in Fig. 1. Within the interval of 25–40 s after the beginning of the eruption, three discharges were registered near the eruption center. These discharges, may have, accompanied the rise and formation of the eruptive column. The subsequent three discharges occurred almost simultaneously in 8.4 min, supposedly, at the background of the eruptive cloud carried by wind and possibly involving ice-ice charge separation. The last discharge was registered in 17 min at the distance of 20.5 km from the eruption center.

A satellite image (Landsat 8), made 22 min after the beginning of the eruption (Fig. 3) represents the character of cloud propagation. At that time, the head part of the plume is still loaded with ash (dark area).

In 19 min after the eruption, a disturbance with the duration of 1.5 h (Fig. 4a) with two maxima exceeding the background level by $E = 90\,\mathrm{V\,m^{-1}}$ occurs in the electric field at KZY site. The behavior of meteorological parameters is calm enough which indicates fair weather conditions (Fig. 4c, d and e). It gives the ground not to refer the cause of disturbance to meteorological value variations.

If the electric field disturbance is considered as the effect of an eruptive cloud propagating at the distance of 25 km to the east of KZY site, then according to propagation time, the time difference between the eruption beginning and the time of occurrence of electric field maxima, we may estimate motion velocities of eruptive formations, which are 17 and 11 $\mathrm{m\,s^{-1}}$, correspondingly.

Agreement of the velocities of atmospheric electric structure propagation with wind velocities at definite heights indicates the fact that ash propagation might occur at two heights where temperature inversions (9–10 and 12 km) were observed.

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4 Conclusions

The Kamchatka volcano group is located near international air routes. Due to that, explosive eruptions are serious threats for communication security. To decrease the risks, effective systems for detection of eruptions are necessary. WWLLN resolution is enough to trace ash clouds at the stage of their fragmentation when electrification processes develop the most intensively. During the development of regional WWLLN segment, the observation resolution may be increased. The undeniable advantage of WWLLN method is its efficiency and the possibility to use in the conditions of poor visibility. Moreover, during the analysis not only of arrival times but also of the signal structure and its comparison with electric, acoustic and meteorological data, it is possible to obtain information on the characteristics and tendencies of development of ash cloud fragmentation process.

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References

Ewert, J. W., Holzworth, R. H., and Diefenbach, A. K.: Global Detection of explosive volcanic eruptions with the World Wide Lightning Location Network (WWLLN) and application to aviation safety (Invited), AGU Fall Meeting Abstracts, abstract #AE31A-04, p. A4, 2010.

Galle, B., Johansson, M., Rivera, C., Zhang, Y., Kihlman, M., Kern, C., Lehmann, T., Platt, U., Arellano, S., and Hidalgo, S.: Network for observation of Volcanic and Atmospheric Change (NOVAC) – A global network for volcanic gas monitoring: network layout and instrument description, J. Geophys. Res., 115, D05304, doi:10.1029/2009JD011823, 2010.

Hutchins, M. L., Holzworth R. H., Brundell J. B., and Rodger C. J.: Relative detection earthciency of the world wide lightning location network, Radio Sci., 47, RS6005, doi:10.1029/2012RS005049, 2012a.
Hutchins, M. L., Holzworth, R. H., Rodger, C. J., and Brundell J. B.: Far field power of lightning strokes as measured by the World Wide Lightning Location Network, J. Atmos. Ocean Tech., 29, 1102–1110, 2012b.
James, M. R., Lane, S. J., and Gilbert, J. S.: Volcanic plume monitoring using atmospheric electrical potential gradients, J. Geol. Soc. London, 155, 587–590, 1998.
James, M. R., Lane, S. J., and Gilbert, J. S.: Density, construction, and drag coefficient of electrostatic volcanic ash aggregates, J. Geophys. Res., 108, 2435, doi:10.1029/2002JB002011, 2003.
Lane, S. J., James, M. R., Gilbert, J. S.: Electrostatic phenomena in volcanic eruptions, Journal of Physics, Conference Series 301 012004, 1–4, 2011.
McNutt, S. R. and Williams, E. R.: Volcanic lightning: global observations and constraints on source mechanisms, B. Volcanol., 72, 1153–1167, 2010.
Mather, T. A. and Harrison, R. G.: Electrification of volcanic plumes, Serv. Geophys., 27, 387–432, doi:10.1007/s10712-006-9007-2, 2006.
Rodger, C. J., Werner, S., Brundell, J. B., Lay, E. H., Thomson, N. R., Holzworth, R. H., and Dowden, R. L.: Detection efficiency of the VLF World-Wide Lightning Location Network (WWLLN): initial case study, Ann. Geophys., 24, 3197-3214, doi:10.5194/angeo-24-3197-2006, 2006.
Thomas, R. J., McNutt, S. R., Krehbiel, P. R., Rison, W., Aulich, G., Edens, H. E., Tytgat, G., and Clark, E.: Lightning and electrical activity during the 2006 eruption of augustine volcano, in: The 2006 eruption of augustine volcano, Alaska, US Geological Survey, Chapter 25, 579–608, 2008.

Table 1. Chronology of development of eruptive plume from Shiveluch volcano eruption on 16 November 2014.

		Time	φ, N	λ, E	R, km	V, $m\,s^{-1}$
1	Arrival of a seismic wave at BDR	10:17:55.3				
2	Volcanic lightning	10:19:16.1	56.58	161.31	2.7	
3		10:19:26.7	56.67	161.38	4.5	
4		10:19:33.8	56.82	161.31	8.9	
5		10:26:22.6	56.56	161.23	10.9	
6		10:26:22.6	56.60	161.17	10.8	
7		10:26:22.6	56.64	161.13	11.9	
8		10:36:10.2	56.53	161.31	20.5	
9	Satellite image	10:40				
10	Electric field disturbances at KZY site	12:04			113.0	17.7
11		13:10			113.0	10.9

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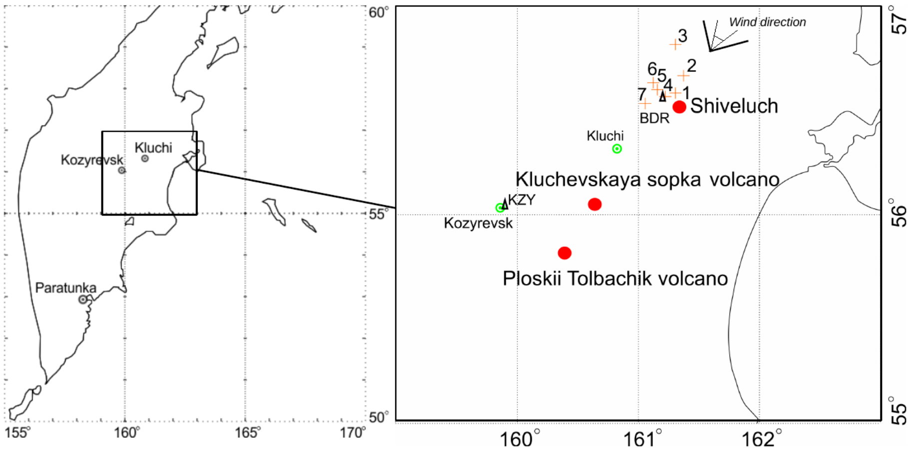

Figure 1. The northern group of Kamchatka volcanoes, observation sites and locations of lightning discharges from Shiveluch volcano on 16 November 2014.

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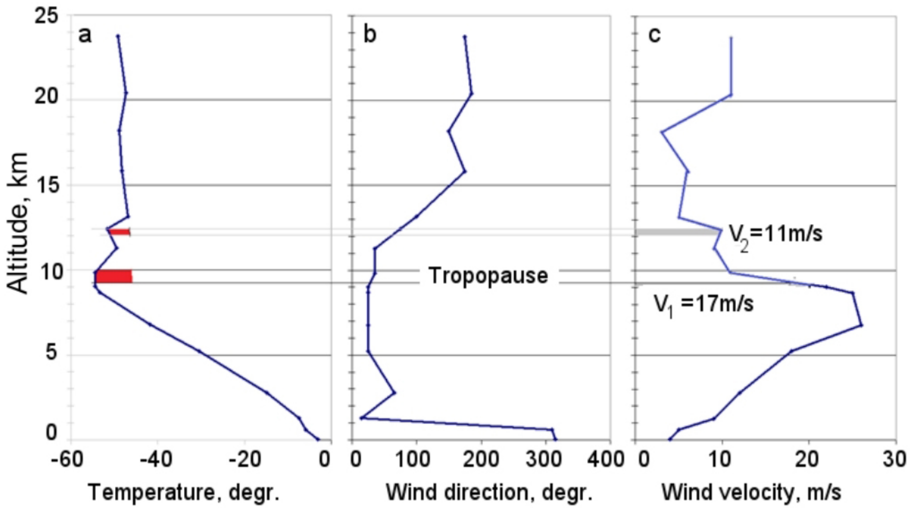

Figure 2. Stratification of temperature **(a)**, wind direction **(b)** and velocity **(c)** according to the data of Kluchi meteorological observatory at 12:00 on 16 November 2014 (UT).

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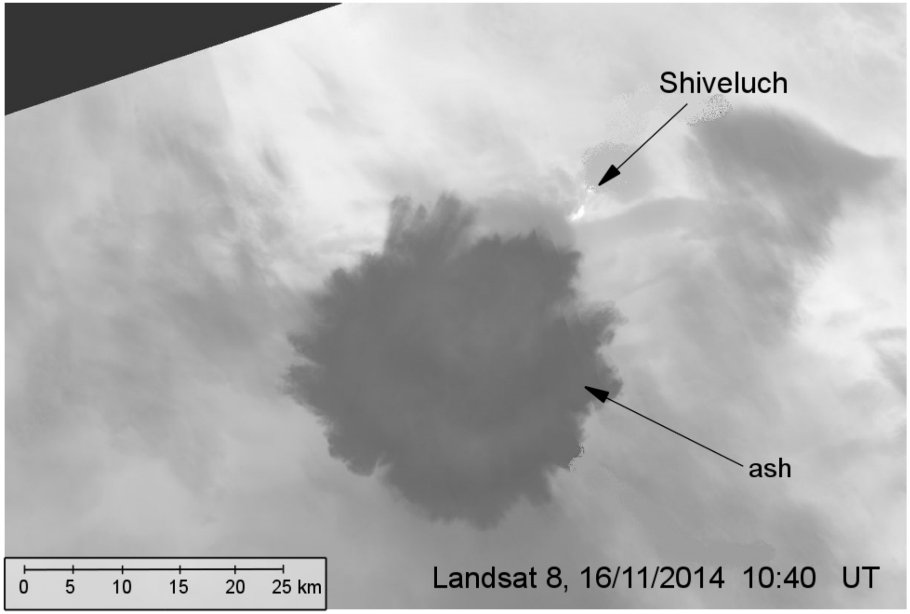

Figure 3. Satellite image (Landsat 8) of the eruptive cloud from Shiveluch volcano, made at 10:40 on 16 November 2014 (UT).

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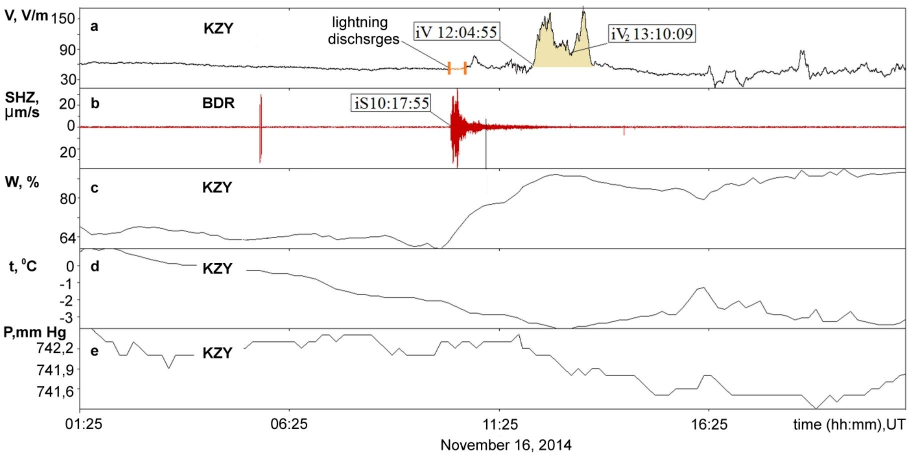

Figure 4. Electric field at KZY site **(a)**; seismic signal at BDR site accompanying the Shiveluch volcano eruption on 16 November 2014 **(b)**; meteorological parameters at KZY site (**c**, **d**, **e**).