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

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Abstract

~~According to~~ Based onWWLLN SPELL OUT ACRONYM ON FIRST USAGEdata, a sequence of lightning discharges was detected. It occurred on the path of propagation of an eruptive ash cloud formed ~~in the result of~~ by the explosive eruption of Shiveluch volcano on 16 November 2014 in Kamchatka. 5 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~~ sufficient 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 THE DETECTION EFFICIENCY OF THE WWLLN FOR TOTAL LIGHTNING IS QUITE SMALL and the possibility to apply in the conditions of poor 10 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 15 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~~ aviation and to the adjacent area, may be identified within seconds by 20 a lightning location system even in conditions of poor visibility.

At present, the World Wide Lightning Location Network (WWLLN) is capable of registering lightning discharges with a 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 GIVE REFERENCE FOR THIS NUMBER 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 WHERE? 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~~ used, and to observe the eruptive cloud motion, satellite images were applied. Cloud motion velocity and direction were 5 compared with meteorological data.

2 Observational ~~means~~ methods

Data on the location of lightning discharges accompanying the eruption are available on the site http://wwlln.net. The Kamchatka WWLLN site is ~~installed~~ located in Paratunka (Fig. 1). An EF-4 fluxmeter and a Vasiala wxt520 weather station are located about 120 km to the 10 south-west from Shiveluch volcano at the Kozyrevsk (KZY) seismic station operated by the Kamchatka Branch of Geophysical Service of RAS (KB GS RAS). The closest seismic station, Baidarnaya (BDR), NOT SHOWN IN FIGURE 1 is located at a distance of 10 km from Shiveluch volcano crater. Kluchi meteorological observatory maintained by the Kamchatka Department of 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~~ thermodynamic sounding on 16 November 2014 at 12:00 (UT), Fig. 2 illustrates temperature and wind stratification up to a height of 25 km. It showed two inversions at the heights of 9–10 and 12 km where wind velocities were 17 and 11 m s−1 20 , ~~correspondingly~~ respectively. The height of the lower inversion corresponds to the tropopause height ~~characteristic~~ typical 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 actual wind direction is opposite to the azimuth. |

3 Development of eruptive plume

Motion of the eruptive plume from the volcano eruption is traced by lightning discharges occurring during ash cloud passage at the initial stage of its formation. The WWLLN network registered a total of seven discharges, the times for which are shown in the Table and 5 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- 10 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 Vm−1 DO YOU MEAN THE BACKGROUND (FAIR WEATHER) LEVEL IS 90 v/m? occurs in the electric field at the KZY site. The behavior of meteorological parameters is calm enough which indicates fair weather conditions (Fig. 4c, d and e). ~~It~~ This gives justification ~~the ground~~ not to attribute ~~refer~~ the cause of disturbance to other meteorological effects ~~value variations.~~

If the electric field disturbance is considered as the effect of an eruption cloud propagating at ~~the~~ a distance of 25 km to the east of the KZY site, then according to propagation time, the time difference between the eruption ~~beginning~~ onset and the time of occurrence of electric field maxima, we may estimate motion velocities of eruptive charge formations, which are 17 and 11 m s−1 , respectively ~~correspondingly~~.

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

4 Conclusions

The Kamchatka volcano group is located near international air routes. ~~Due to that~~, As a result, explosive eruptions are serious threats for communication security WHY IS ONLY THIS PROBLEM CITED?. To decrease the risks, effective systems for detection of eruptions are necessary. The WWLLN resolution is ~~enough~~ sufficient to trace ash clouds at the stage of their fragmentation when electrification processes develop the most intensively. During the development of the regional WWLLN segment WHAT IS MEANT BY THIS?, the observation resolution may be increased. The undeniable advantage of the WWLLN method is its efficiency AGAIN, THE EFFICIENCY IS NOT LARGE 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 the ash cloud fragmentation process. DO YOU HAVE THAT IN THIS CASE? SEE MY GENERAL COMMENTS.

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References

ONE THAT SHOULD BE ADDED TO EXISTING REFERENCES:

Williams, E.R. and S.R. McNutt, Total water contents in volcanic eruption clouds and implications for electrification and lightning, Chapter 6 in *Recent Progress in Lightning Physics* (ed., C. Pontikis), 81-93, Research Signpost Publishing, Kerala, India, 2005.