Measurement of the atmospheric electric field inside the nonthunderstorm clouds on 2012 BEXUS campaign

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Abstract. We measure an atmospheric electric field inside the nonthunderstorm clouds, because the studies of the electric charge structures inside the nonthunderstorm clouds have been few. For this purpose, a balloon with a gondola equipped with two field mills was used in balloon experiments for university students (BEXUS) organized by Europe Space Agency (ESA). From the experiment, two peaks of positive atmospheric electric filed were observed, so that simple charged spherical model is constructed. The estimated value of charges inside the cloud follows the results of Imyanitov and Chubarina (1965). In future, much more experiments should be required for the study of nonthunderstorm electricity.

Key words: Atmospheric electricity, Nonthunderstorm clouds, Field mill

1. Introduction

A study on electric charge structure in nonthunderstrom clouds has been mainly carried out by former Soviet researchers (see MacGorman and Rust, 1998). The nonthunderstorm clouds consist of stratus, stratocumulus, cirrostratus, altostratus and nimbostratus. According to Imyanitov and Chubarina (1965), the density of positive charge inside the nonthunderstorm cloud is approximately 3×10^{-10} C/m^3. Furthermore, Imyanitov et al. (1971) reported that two thirds of stratocumulus clouds (Sc) show dipole structure and that only 5% show multipole structure. The stratocumulus clouds are located at the altitude approximately from 100 m to 1800 m and its average thickness is around 500 m. In addition, 80% of stratocumulus indicated -400 to 200 V/m. However, the studies of electric charge structure in stratocumulus have been few. Therefore, a study of electric charge structure of stratocumulus is worthy to advance it.

2. Experimental purpose

European Space Agency (ESA) invites European university students to rocket and balloon campaigns called REXUS (Rocket Experiments for University Students) and BEXUS (Balloon Experiments for University Students) in their space education program. The experiments are carried out in Kiruna, Sweden since 2004

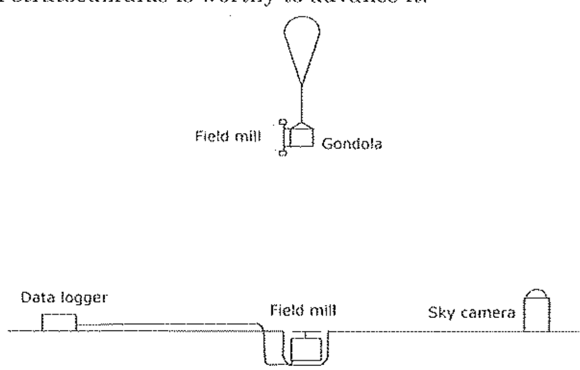

Fig. 1 Schematic diagram of experiment.

(www.esa.int/Education/Rocket_Balloon_Experiments_for_University_Students). In 2012, 14th and 15th BEXUS (Hereafter, BEXUS14 and BEXUS15) were operated. Students of Tokyo Gakugei University (TGU), Japan and Lycée Gustave Eiffel (LGE) Cachan, France who organized AMES (Atmospheric Magnetic and Electric field Sensors) Team were participated in BEXUS15.

AMES Team operated electric field measurement by using field mills. Students of TGU are in charge of a design and manufacture for a sensor, a ground-based measurement of atmospheric electric field and data analysis. On the other hand, students of LGE are mainly in charge of a design and manufacture for a balloon bus. In the case of fair weather on launched day, our purpose is to estimate ionospheric potential, while in case of cloudy weather, it is to measure the vertical profile of an electric field inside the nonthunderstorm.

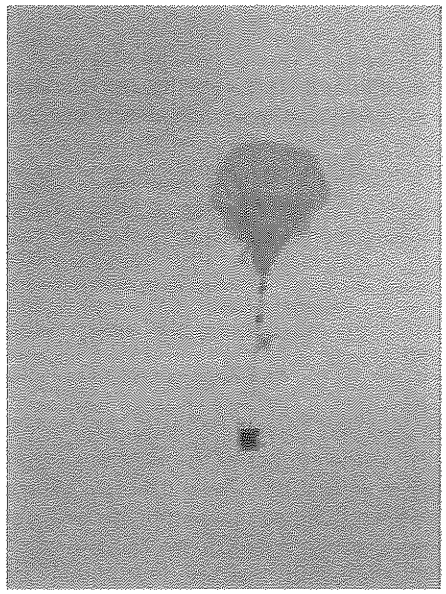

Fig. 2 Balloon in BEXUS15 just after the launch.

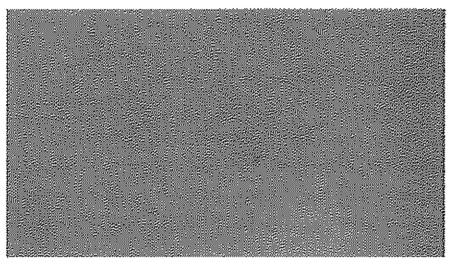

Fig. 3 Plunge into the clouds.

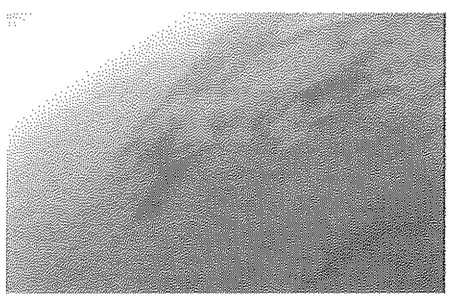

Fig. 4 Photo taken by during gondola descending. (Courtesy to D-SEND team, JAXA).

3. Observation

We use a balloon with a gondola equipped with two hand-made field mills and a data logger to measure an atmospheric electric field. Each field mill is installed vertically outside the gondola (Fig. 1). The sampling rate of field mill is 6.8 kHz. The field mill gives oscillatory signals of which the maximum amplitude is associated with the ambient electric field. To avoid transient noises, 80 % percentile of 6800 sampling points, *i. e.*, 1 second in total, is used to obtain the statistical output voltage. After this process, we finally reconstruct noiseless 1 Hz data of the output voltage.

In order to calibrate the field mill equipped on the gondola, another field mill was buried on the plane ground as a sensor surface of the field mill is set up at the ground surface, which is far enough from buildings and roads in order to keep flatly horizontal electric potential surface. For the field mill on the ground, we use a commercial field mill (EFM-100, Boltek Ltd.). Simultaneously, a cloud behavior was monitored by using the whole sky camera. Comparing between the 1 Hz gondola data and the ground-based data, we can calibrate the observed value of the atmospheric electric field on the gondola.

4. Results

BEXUS15 was done on 25 September 2012. Our measurement target became not the ionospheric potential but the electric field inside the clouds, because it was snow and then cloudy. Because of the limitation of battery volume, the electric field was measured only during ascending. In addition, we could use only the topside FM on the gondola for the analysis, because the bottom-side FM didn't work due to trouble of the propeller breaking during the launch phase. The balloon was launched at 1018UT (Fig. 2) and we estimated that the balloon plunged into the clouds at 1024UT from the video recorded on the ground (Fig. 3). The clouds were stratocumulus (Fig. 4). The balloon route and its altitude are shown in Fig. 5. The balloon was separated by a cutter for descent phase, and then landing was moderate by a parachute system. The descent speed is higher than the ascent one. Near the ground, it became approximately 8 m/s.

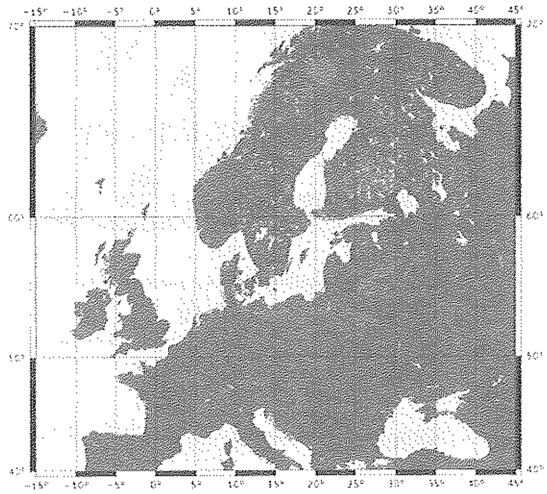

Fig. 5 (a) Location of Kiruna, Sweden.

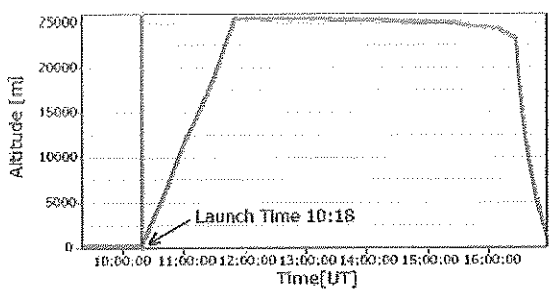

Fig. 5 (b) Altitude of the balloon.

Immediately after the launch, the electric field is slightly positive and then is enhanced positively twice (Fig. 6). After the enhancements, it becomes slight negative gradually, then it increases positively again. The relation between the temperature and balloon altitude is shown in Fig. 7. From the observed electric field, we model the charge structure inside the Sc. Although the Sc is plain-layered cloud, the time-series of AEF illustrated in Fig. 6 is shown like M-shape. Thus, we infer that the change structure is not capacitance-like parallel plate electrodes but a sphere shape. In particular, the M-shape of positive AEF may be produced by uniformly charged sphere, so that two maxima of AEF were located at the surface of the sphere. From the interval of the maxima, the radius of the sphere is estimated to be 232 m. The slight difference between the two maxima (900 V/m and 640 V/m) is expected to be originated from the different charge density between the upper and lower hemispheres of the charged region. Fitting the two maxima to the model (Fig. 7), we obtain the charge density, 3.6×10^{-11} and 6.7×10^{-11} C/m^3 in lower and upper hemisphere, respectively. Their values agree with those reported by Imyanitov and Chubarina (1965).

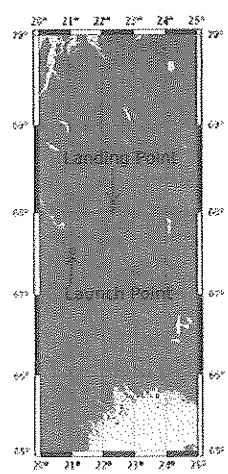

Fig. 5 (c) Trajectory of the balloon.

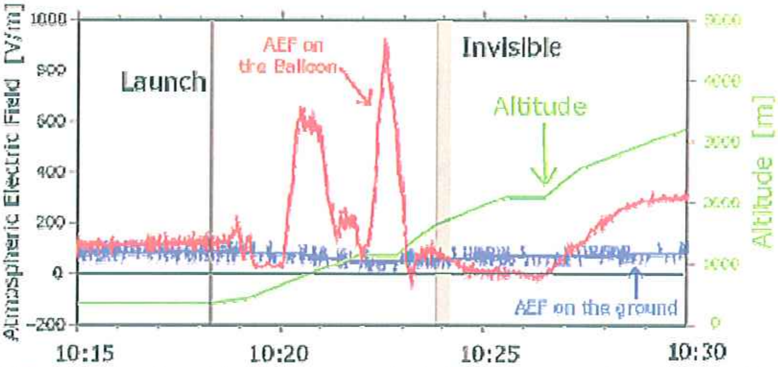

Fig. 6 Time-series the altitude, the electric field of the ground, and the balloon.

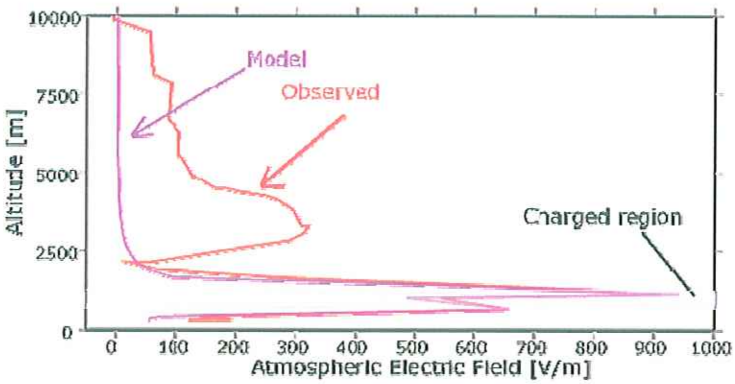

Fig. 7 Vertical profile of electric field. We note that due to time resolution of GPS record, the sampling time of AEF is one minute which is constructed by the

5. Conclusion

On this study, we measure the electric field inside the stratocumulus clouds through the student experiment campaign carried by ESA. The observed value corresponds to the previous study (Imyanitov and Chubarina, 1965; Imyanitov et al., 1971). Even in our simple model of uniformly charged sphere, the value of the charge density might be obtained. Since the studies of electrification of nonthunderstorm clouds have been rare so far, much more experiments are needed for the study of nonthunderstorm electricity.

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