Electrical Conductivity and Chemical Composition of Snow Collected in Niigata Prefecture, Japan

Akira Takahashi, Shin-ich Fujita and Gaku Sakata
Central Research Institute of Electric Power Industry
1646 Abiko, Abiko-shi, Chiba 270-1194 Japan, *ataka@criepi.denken.or.jp*

***Abstract*— In December 2005, a large-scale power outage occurred in the Kaetsu area of Niigata Prefecture, Japan, during an unprecedented severe snowstorm event. The accretion of wet and seasalt-rich snow on the insulators of power transmission lines was considered to be one of the main causes of the power outage. In this study, to investigate the formation mechanism of seasalt-rich snow, field observations for snow and aerosol were conducted in the Kaetsu area from January to February 2008. It was found that the electrical conductivity (EC) of snow was 100µS/cm or less for most observation periods. However, at the beginning and end of January and the end of February 2008, relatively large EC values were obtained under strong wind conditions when a developing low-pressure passed over the Sea of Japan side. Particularly at the end of February, EC of snow exceeded 600µS/cm, which was the maximum throughout the entire observation period. In this case, the contribution ratio of seasalt components in snow to EC was estimated to be 90% or more.**

I. Introduction

Strong cold air masses had flowed intermittently to Japan during the period from December 2005 to January 2006. Therefore, the area along the Sea of Japan experienced a record snowfall; the maximum record for December was updated in various places. Because of those unprecedented severe snowstorms, a large-scale power outage occurred in the Kaetsu area of Niigata Prefecture in December 2005 [1], [2]. Some 650,000 households were blacked out, some for a maximum of 31 hours.

It was reported that one of the main causes of the power outage was the accretion of wet and seasalt-rich snow on the insulators of transmission lines. Many of the electrical flashovers on insulator strings occurred approximately 20-30km from the seacoast. No power outage caused by the accretion of seasalt-rich snow on the insulators in such an inland area had ever been reported [3], [4].

It is necessary to clarify the mechanism of the accretion of snow on the insulators in this area, and it is also important to examine the formation mechanism of seasalt-rich snow. To obtain information in order to solve those problems, the Central Research Institute of Electric Power Industry conducted field observations for snow and atmospheric aerosol in the Kaetsu area, from January to February 2008. In this paper, the results of this field observation are reported.

II. Field Observation

The field observation site of the Central Research Institute of Electric Power Industry was established in the Kaetsu area adjacent to the location where ground faults due to the accretion of seasalt-rich snow on the insulators occurred in December 2005 (Fig. 1). In this field site, an ultrasonic anemometer (Vaisala WMT510) was installed at the top of a 10m mast for the measurement of the wind velocity and wind direction. The temperature and humidity were measured using a weather transmitter (Vaisala WXT510) installed 1.5m from the ground. The amount of precipitation was observed using a tipping-bucket-type rain gauge (Metic RR-5) installed on the ground.

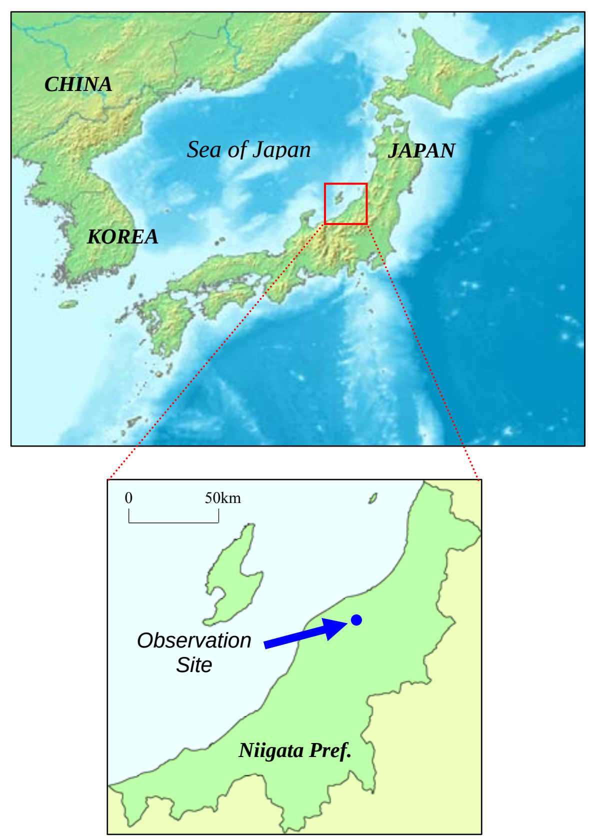

Fig. 1. Location of the field observation site in Kaetsu area of Niigata prefecture.

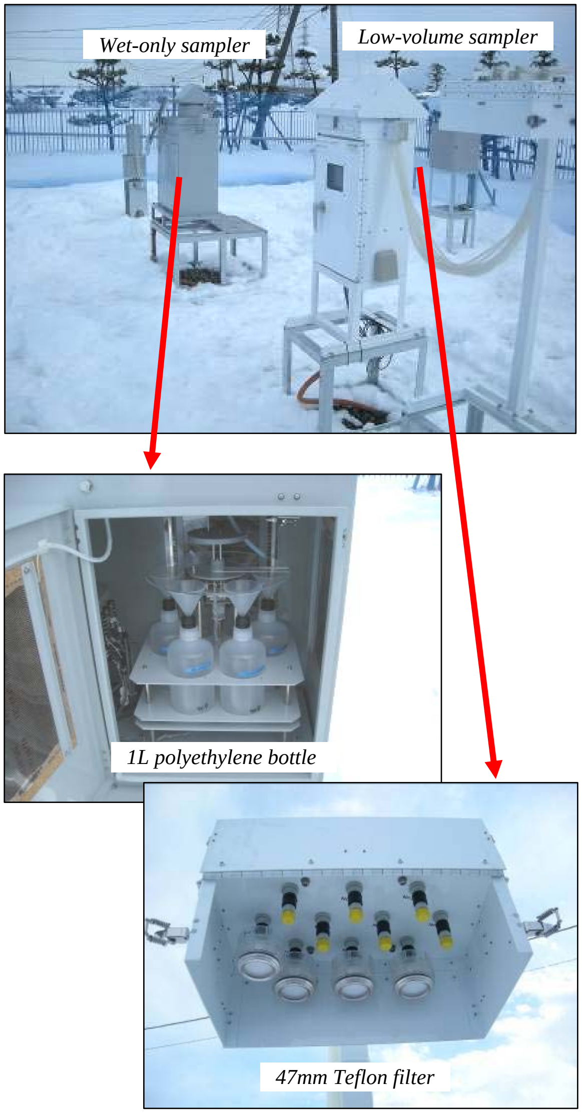

Fig. 2. Wet-only sampler for collecting snow samples and Low-volume sampler for collecting atmospheric aerosol samples

The wet-only sampler (Metic) was used for the collection of snow samples (Fig. 2). This sampler was equipped with a precipitation sensor and the lid of the collection funnel opened only when snow or rain was detected. In addition, six 1L polyethylene bottles were loaded into this sampler and sequential sampling were enabled by rotating the nozzle connected to the polyethylene bottles. In this observation, the sampling interval of snow was set at 6 hours. Atmospheric aerosol samples were collected using a ten-line low-volume sampler (Tokyo Dylec GS-10N) installed on the ground in the site (Fig. 2). Ten 47mm Teflon filters (Pall Zeflour) were loaded into this sampler, and aerosol samples were sequentially collected on those filters every 6 hours in addition to snow sampling.

All collected samples of snow and the Teflon filters were shipped to the analytical laboratory of the Central Research Institute of Electric Power Industry in Chiba Prefecture. The Teflon filter was extracted by ultrasonic vibration in distilled-deionized water. The electrical conductivity (EC) of snow samples was determined using an EC electrode (DKK-TOA CM-40S). The concentrations of Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Mg^{2+} Ca^{2+} and NH_4^+ in the snow samples and in the filter extract were determined by ion chromatography (Dionex DX-520).

III. Results and Discussion

Fig. 3 shows the temporal variation of the observed EC and Na^+ concentration in snow and Na^+ concentration in atmosphere from January to February 2008. In addition, the observed wind velocity, wind direction, and amount of precipitation are also shown in the lower column of Fig. 3. Each dot in the plot shows the value for each parameter every 6 hours as stated above.

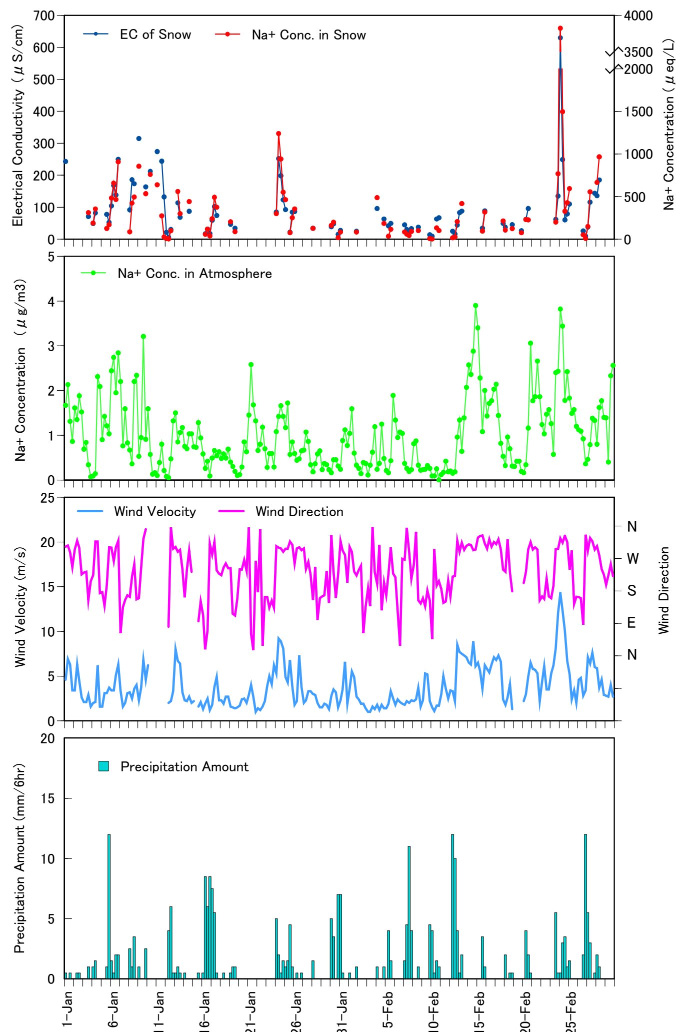

Fig. 3. Observation results of electrical conductivity and Na^+ concentration in snow, Na^+ concentration in atmosphere, wind velocity, wind direction, and precipitation amount at the Kaetsu area of Niigata prefecture during period from January to February 2008.

In most of the observation periods, EC values of snow were mostly less than 100μS/cm, but relatively large values exceeding 100μS/cm were observed at the beginning and end of January and the end of February. At the end of February, a value of more than 600μS/cm was observed, which was the maximum during all periods. However, the increase to such a large value was temporary, and EC decreased to a normal value promptly after reaching the maximum. The marked increases in EC at the beginning of January and the end of February were observed under the condition of strong wind accompanying the passage of a well developed low-pressure along the Sea of Japan side.

As is evident from Fig. 3, the temporal variation of EC of snow was in good agreement with that of the Na^+ concentration in snow. This suggests that EC of snow is controlled significantly by a change in the concentration of seasalt components in snow. To verify this hypothesis, the quantitative contribution of the seasalt components to EC of snow was evaluated on the basis of observed results of the chemical compositions of snow. Fig. 4 shows the relative contribution ratios of seasalt components and non-seasalt components on EC of snow collected in February, which were estimated from the theoretical equivalent conductivity of each chemical component in snow [5].

It is obvious from Fig. 4 that most of the period from the beginning of February to the middle of February when EC of snow was below 100μS/cm, the contribution of the seasalt components to EC did not greatly exceed 50%. On the other hand, at the end of February, when the maximum value of EC was observed, the contribution ratio of seasalt components reached more than 90%. These results indicate that the large increase in EC of snow collected in this area at the end of February was caused by an extreme increase in the concentration of seasalt components in snow.

As shown in Fig. 3, the daily and day to day variations of Na^+ concentration in atmosphere were greater than those of snow. When the maximum concentration of Na^+ in snow was observed at the end of February, the maximum value was observed also in the Na^+ concentration in atmosphere. Other than that period, however, the times of the occurrence of peaks in the Na^+ concentration in snow and those in atmospheric aerosol did not correspond. The above results suggest that the Na^+ concentration in snow was not strongly affected by the Na^+ concentration in atmosphere. Therefore, below-cloud scavenging is not considered to be a dominant process of seasalt loading to snow in the studied area.

While relatively large EC value was observed at the end of February, no wet snow accretion on insulator strings were occurred around the field observation site. It was because the precipitation was small and the ambient temperature was low for snow to accrete on insulators.

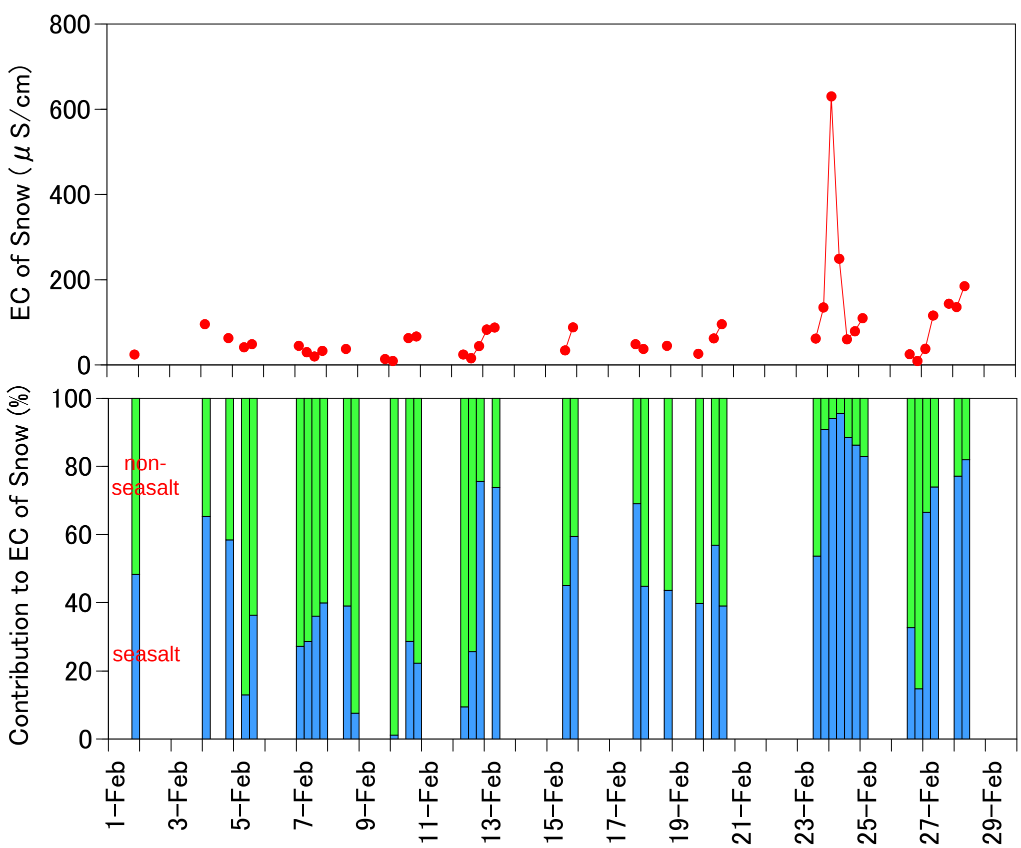

Fig. 4. Observed electrical conductivity of snow and estimated contribution ratios of seasalt (blue bar) and non-seasalt (green bar) components on electrical conductivity in February 2008.

IV. Conclusions

For most of the field observation period from January to February 2008, EC values of snow were generally below 100µS/cm, although a value exceeding 600µS/cm was temporarily observed in the Kaetsu area of Niigata prefecture.

The temporal variation of EC of snow agreed well with that of Na^+ concentration in snow. In addition, the estimated contribution ratio of seasalt components to EC increased with increasing observed EC value. Therefore, we suggest that EC of snow is largely influenced by a change in the concentration of seasalt components in snow. The temporal variation of Na^+ concentration in snow and that in atmosphere did not correspond. These results suggest the possibility that below-cloud scavenging is not a major process of seasalt loading to snow.

V. Acknowledgements

The authors would like to acknowledge to the Federation of Electric Power Companies of Japan and the Tohoku Electric Power Co. Inc. for their support and cooperation on this research.

VI. References

[1] T. Onodera, H. Inukai and T. Odashima, "Overview of power outage in the Niigata Kaetsu Area caused by a snowstorm", IWAIS XII, 2007.

[2] G. Sakata, H. Homma, "Overview of blackout in Niigata and study on property of wet snow packed with sea-salt on insulator strings", 2009 World Congress on Insulators, Arresters & Bushings, 2009

[3] N. Sugawara and K. Hosono, "Insulation properties of long rod and line post insulators for 33 kV transmission line in we-snow storm on January 2004", IWAIS XI, 2005.

[4] S. Fikke, T. Ohnstad, T. Teslstad, H. Först and L. Rolfsen, "Effect of long range airborne pollution on outdoor insulation", NORD-ID '94, Paper 1.6, 1994.

[5] *Technical Manual for Wet Deposition Monitoring in East Asia,* Acid Deposition Monitoring Network in East Asia, Mar.2000.