3D imaging of winter lightning and winter lightning charge structure

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Previous studies reported that lightning discharges during winter on the border of Sea of Japan have quite different features from lightning discharges during summer, such as high occurrence rate of upward lightning, positive cloud-to-ground (CG), and bipolar flashes, and large charge transfer to the ground via return strokes and continuing current [Rakov and Uman 2003]. One of explanations of these distinct winter thunderstorm features is related to the low charge structure during winter and large horizontal extension of charge regions contributing to lightning discharges. Understanding of charge structure during winter is very useful for feasibility study of tactical lightning avoidance product for airport operation. We have been conducting lightning observation campaign during winter and summer thunderstorm seasons with a use of weather radars and Broadband Observation network for Lightning and Thunderstorm (BOLT), which is a 3D lightning mapper, in order to examine lightning charge structure during winter and summer and discuss the explanation shown above. BOLT is a LF sensor network to locate both intra-cloud (IC) and CG flashes in 3D. The BOLT in this observation campaign consisted of eleven BOLT sensors. The BOLT system is almost the same as the BOLT system in Yoshida et al. [2014]. Electromagnetic radiations associated with lightning discharges were detected by the antennas of BOLT sensors.
We succeeded in locating lightning discharges, including IC discharges, negative and positive cloud-to-ground (CG) discharges, and upward lightning discharges. Charge structures contributing to lightning discharges estimated by BOLT were quite lower than summer lightning. We compare distributions of the BOLT source altitudes and BOLT temperature, which is the temperature corresponding to BOLT source altitudes. BOLT source altitude distributions peaked at 1.7 km for winter lightning and at 7.4 km for summer lightning. BOLT temperature distributions of winter and summer lighting had similar distribution, peaking at -6 ºC for winter and -9 ºC for summer, indicating that non-inductive charging mechanism had an important role on electrification within winter thunderstorms as well as summer thunderstorms. Furthermore, we compare histograms of horizontal extension of each flash during winter and summer, indicating that horizontal extent of winter lighting had significant larger distribution compared to that of lightning discharges during summer. These results support that the explanations associated with distinct winter lightning characteristics.
Moreover, we performed detail analyses of 39 winter flashes shows that ratios of positive CG, bipolar, and upward flashes to total CG flashes were quite higher than summer thunderstorms. Our analysis with previous observations indicate that hybrid flashes are more frequent during winter than summer.

References

1. V. A. Rakov, and M. A. Uman, Winter lightning in Japan, in Lightning: Physics and Effects, chap. 8, pp. 308–320, Cambridge Univ. Press, Cambridge, U. K., 2003
2. S. Yoshida, Wu, T. Ushio, K. Kusunoki, and Y. Nakamura, "Initial results of LF sensor network for lightning observation and characteristics of lightning emission in LF band", *J. Geophys. Res. Atmos.*, **119**, 12,034–12,051, doi:10.1002/2014JD022065, 2014.