# Charge distributions for cloud-to-ground flashes with horizontally long leaders

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Ground-based electric field measurements and optical observations have been conducted traditionally for studying cloud-to-ground (CG) flashes. Recently, VHF-UHF lightning mapping systems have made it possible to obtain images of in-cloud lightning channels. Some CG flashes with long lightning channels that extend more than horizontally have been reported. This type of the lightning discharges is often observed more frequently in winter thunderstorm season than in summer season. They are sometimes observed in summer lightning. However, it is not understood why the leaders do not progress to the ground directly. It is considered that there are causal associations between the leader progressions and the charge distributions near the lightning channels.

It is known that VHF impulses are mainly radiated from the tip of negative breakdowns like at the negative stepped leader. From this aspect it is noticed that the VHF impulse source location during leader developing phase is equivalent to the imaging of the leader progression. Lightning Research Group of Osaka University (LRG-OU) has been developing the VHF broadband digital interferometer (DITF) that leads us to visualize the lightning channels by localizing the VHF radiation sources since 1995. The ultra-wide detection frequency makes it possible that the images of lightning channels are visualized with a high accuracy.

We succeeded in visualizing CG flashes with the long horizontal negative leaders in three-dimension by the VHF broadband DITFs during the 2006-2007 field campaign in Darwin, Australia. For the purpose of revealing the relationship between the leader progressions and the charge distributions in thunderclouds, we use the VHF broadband DITF and the Bureau of Meteorology Research Centre C-band dual polarization weather radar data to estimate charge distributions in thunderclouds.

As a result, the followings are concluded. In the CG flashes, the negative breakdowns occur in near the boundary regions of the graupel and upper snow layer. The horizontally long negative leaders progress in the snow layer where is considered to be the positive charge region. It is also found that the negative leaders progress along the valleys in the snow layer like 'slide'. When the negative leaders reach the end of the snow layer, the negative leaders change its direction of the progression horizontal into downward. In other words, the negative leaders change its direction when the leaders reach the regions where positive charge does not exist. In four CGs having long negative leaders parallel to the ground, the similar features are identified.