3D Observations of Cloud-to-cloud lightning flashes accompanied by K-change using VHF broadband digital interferometer

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Cloud-to-cloud (CC) lightning flashes have been less documented than cloud-to-ground (CG) flashes because of the difficulty of securing photographic records of in-cloud channels. Historically, ground-based electric field measurements have been primary means for studying cloud discharges. VHF-UHF lightning mapping systems have made it possible to obtain images of in-cloud channels. Lightning Research Group of Osaka University (LRG-OU) has been developing the VHF broadband digital interferometer (DITF) since 1995. The ultra-wide detection frequency makes it possible that the images of lightning channels are visualized with a high accuracy. We have operated the VHF broadband DITF in Fukui, the coastal area of the Sea of Japan during winter thunderstorm period and in Darwin, Australia during the monsoon season and so forth. Its time and special resolutions have been improved recently. We realized the new findings in thunderclouds detected by the VHF broadband DITF during the '06-'07 field campaign in Darwin.

As a result, the CC event visualized by the VHF broadband DITF can be summarized as follows. In the early stage, negative breakdowns developed with comparable propagating velocities to stepped leaders in the case of CG flashes. In the late stage positive breakdown initiates from near the arrival point of the preceding negative breakdown accompanied by J-change. When the positive leader reaches near the initiation point of preceding the negative breakdowns, the negative recoil streamer progresses through the same channel in the opposite direction accompanied by K-change. Then another positive leader initiates from near the arrival point of the preceding negative breakdowns accompanied by J-change again. When the positive leader reaches near the initiation point of preceding the negative breakdowns, the negative recoil streamer progresses through the same channel in the opposite direction accompanied by K-change again. Therefore the CC flash includes breakdowns that progresses through the same channel time and time again.

From three-dimensional VHF observations, it is found that in the several CCs subsequent breakdowns progressed through the same channel that preceding breakdowns progress had progressed corresponding to multiple CG flash. It is considered that the subsequent breakdowns are negative recoil streamers accompanied by K-change.