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3D Lightning Radio Imaging with Multi-Site VHF Interferometry

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Lightning is a powerful broadband radio emitter. Low frequency emissions (below approximately 100 kHz) are produced mainly by powerful lightning processes, such as cloud-to-ground strokes, and can be measured from hundreds to many thousands of km distant from the lightning itself. These signals form the basis for many lightning detection and geolocation networks. But some lightning processes also emit strongly at much higher frequencies, to at least several hundred MHz, and these processes are much smaller in spatial scale. This enables fast detailed imaging of lightning channel and flash development through interferometric imaging of the VHF radio emissions, a concept that has been developed and implemented by numerous research groups.

We have developed a new multi-site, long-baseline VHF interferometer that is capable of 3D lightning imaging through coherent interferometric processing of the long baseline signals. The system is composed of a 3-antenna short (50 meter) baseline main site and two single-antenna sites that form two orthogonal 5 km baselines with the main site. All signals are recorded with 1-200 MHz bandwidth. There are challenges in processing the long baseline data due to the wide ±17 microsecond range of possible time shifts, and also merging short- and long-baseline data into single 3D solutions for VHF source locations, and we will describe some approaches for handling these that have proven effective with our measurements. We will focus on and present results from different processes in cloud-to-ground and in-cloud lightning flashes. While this is a processing-intensive and data-intensive 3D lightning imaging technique, the improvements it brings in spatial resolution and the number of located points compared to other 3D techniques, such as LF interferometry or lightning mapping arrays, provide valuable new insight into the spatial structure and temporal development of lightning flashes.