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Precision Lightning Imaging with LOFAR

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We report on the improvements of our lightning imaging technique over what was reported in Hare2019, where we map lightning in 3D using timing obtained from the cross-correlation of the signals from antenna pairs in broadband VHF (30 — 80 MHZ). We use the infrastructure offered by LOFAR (LOw Frequency Array), a software radio telescope.

The infrastructure of LOFAR allows us to use a large number of simple dual-polarized dipole antennas arranged in stations of 48 antennas with a diameter of about 60m. We limit ourselves to the use of the Dutch stations only, which gives us baselines of up to 100 km. The data are sampled at 200 MHz giving 5 nanoseconds time between samples. We use LOFAR in the mode where it saves the full time-series spectra for five seconds for every antenna in the array. Upon a trigger, the data for all Dutch stations is stored for later off-line processing.

In imaging a flash our bottleneck is to handle the confusion limit. Because of the high density of sources, pulses that are detected in one time-order in the first antenna may have changed order in a second that is at an appreciable distance from the first. The pulse density where this problem surfaces depends on the imaging technique. In our new imaging method we use an approach inspired by the Kalman-filter technique. In the presentation the new technique will be explained. This allows us to obtain a larger number of located sources as compared to the approach used in Hare2019 (sometimes as much as three times as many) which allows for a more detailed analysis of small structures seen in lightning.

To show the strength of the new technique we show some images of positive and negative leader development as well as a return stroke.

Hare2019: B. Hare et al., Nature 568, 360–363 (2019).