Geophysical Research Abstracts
Vol. 17, EGU2015-6997-1, 2015
EGU General Assembly 2015

Probing atmospheric electric fields in thunderstorms through radio emission from cosmic-ray induced air showers

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Energetic cosmic rays impinging on the atmosphere create a particle avalanche called extensive air shower. In the leading plasma of this shower electric currents are induced that generate the emission of radio waves which have been detected with LOFAR, an array of a large number of simple antennas primarily developed for radio-astronomy observations.

Events have been collected under fair-weather conditions as well as under atmospheric conditions where thunderstorms occur. Of the 196 radio pulses detected under fair weather conditions, the intensity as well as the polarization can be reproduced rather accurately for 192 event with the standard model [1] using a superposition of a geomagnetically-induced transverse current and charge excess contributions. This indicates that the emission process is well understood.

For most of the events measured under thunderstorm conditions as well as the 4 fair weather events we observe large differences in intensity and polarization pattern from the fair weather model. We observe for these events that it is not possible to get a good fit of the measured intensity pattern. For the same events the dominant polarization direction differs from the orientation observed in the fair-weather condition.

We show that this difference is a consequence of atmospheric electric fields. We also show that the effects of atmospheric electric fields are understood, and that from the cosmic-ray radio footprint the atmospheric electric field can be deduced. Therefore, measuring radio emission from cosmic ray extensive air showers during thunderstorm conditions provides a new tool to probe the atmospheric electric fields present in thunderclouds.

[1] P. Schellart et al., arXiv:1406.1355 [astro-ph.HE].