**Title**

Peering into the Heart of Thunderstorm Clouds: Insights from Cloud Radar and Spectral Polarimetry

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**Date**

2023-07-19

**Abstract**

Lightning is a natural phenomena that can be dangerous to humans. It is however challenging to study thunderstorm clouds using direct observations since it can be dangerous to fly into thunderstorm clouds. In this study, cloud radar with millimeter wavelength is used to study the properties and dynamics of thunderstorm clouds. It is based on a case of thunderstorm on 2021-06-18 from 16:10 to 17:45 UTC near Cabauw. Polarimetric radar variables are used to investigate possible hydrometeors in the clouds and look for vertical alignment of ice crystals that is expected due to electric torque. The technique of Doppler spectra analysis, which has not been used in previous studies about thunderstorms so far, is used to help understand the behaviours of different types of particles within a radar resolution volume. Due to challenges posed by Mie scattering, scattering simulations are carried out to aid the interpretation of spectral polarimetric variables. From the results, there is a high chance that supercooled liquid water and conical graupel are present in thunderstorm clouds. There is also a possibility of ice crystals arranged in chains at the cloud top. Ice crystals become vertically aligned a few seconds before lightning and return to their usual horizontal alignment afterwards. However, this phenomenon has been witnessed in only a few cases, specifically when the lightning strike is in close proximity to the radar's line of sight or when the lightning is exceptionally strong. Doppler analyses show that updrafts are found near the core of the thunderstorm cloud, while downdrafts are observed at the edges. Strong turbulence is also observed as reflected by the large Doppler spectrum width.