Lightning Evolution and Thunderstorm Dynamics for the 21 July 1998 EULINOX Supercell Storm

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Introduction

During the 1998 field campaign EULINOX extensive measurements within and around thunderstorms were carried out mainly in southern Germany. As the primary goal was to determine more exactly the production and transport of nitrogen oxides produced by lightning phenomena, the measurements included aircraft measurements of chemical constituents (Cb anvil penetrations as well as lower–level flights), DLR's polarimetric C–band Doppler radar observations and lightning detection using the ONERA's VHF interferometer (ITF). The EULINOX project was finished at the end of 1999, and the preliminary analysis presented here is focused on the cloud physics of the 21 July 1998 supercell storm concerning lightning evolution as measured with radar and ITF. A supercell had formed after a cell splitting over the Alpine foreland in the late afternoon of 21 July 1998 and soon developed typical characteristics such as a persistent single updraft and a pronounced weak echo region with a significant echo overhang. This cell moved east over one of the ITF stations and passed approximately 20 km S of DLR's radar site at Oberpfaffenhofen.

VHF Interferometer Data

The ITF system (Solomon et al., 1999) has been designed to detect VHF sources of lightning events at a frequency of 114 MHz. It is especially suited to observe intracloud (IC) flashes but can also detect negative cloud–to–ground (CG) flashes quite well. However, 3D reconstruction of individual discharges is limited to an elevation interval from 8° to 42°. In the following we will discuss: i) volume data, i. e. VHF sources averaged over 3 min in time and a 1 km^3 grid in space, and ii) point data which reveal the 3D structure of each flash by giving the 3D location of each VHF signal within an individual flash.

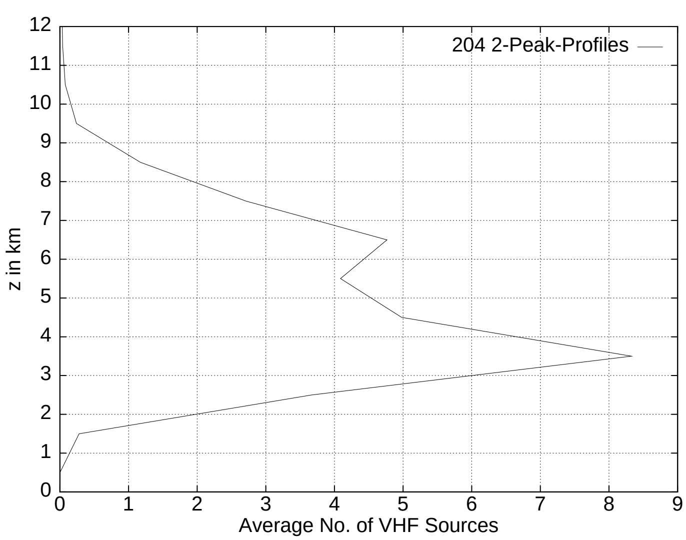

Figure 1: Mean vertical profile of VHF sources between 17:00–20:00 UTC. To reveal the second peak at 6.5 km only profiles containing two distinct peaks were averaged. The lower peak at 3.5 km is present in all profiles, however.

The volume data were analyzed in order to derive mean profiles of VHF activity within the supercell storm. Due to the elevation limitation, only data from that region where vertical profiles were available from at least 3 km to 9 km AGL were used. Averaging the vertical columns at each horizontal gridpoint revealed a maximum of VHF activity at about 3.5–4.5 km AGL. Some individual vertical VHF columns had two peaks, however. These were averaged separately, and the result is given in Fig. 1. Aside from the low–level maximum, now a secondary maximum at 6.5–7.5 km can be seen. This is due to dominant IC activity, but lower than expected. Similar profiles have been reported by Solomon et al. (1999), just as the temperature levels found for these peaks, 0°C and -15°C, respectively. Few signals are located below 2.5 km in Fig. 1 due to the 8° elevation criterion during EULINOX.

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Radar and VHF Interferometer Point Data

The polarization diversity Doppler radar at DLR was used to determine the life cycle of the storm and the microphysical composition of the hydrometeors. Höller et al. (1994) developed an algorithm which uses the polarimetric quantities Z, ZDR, and LDR to discriminate between individual hydrometeor types.

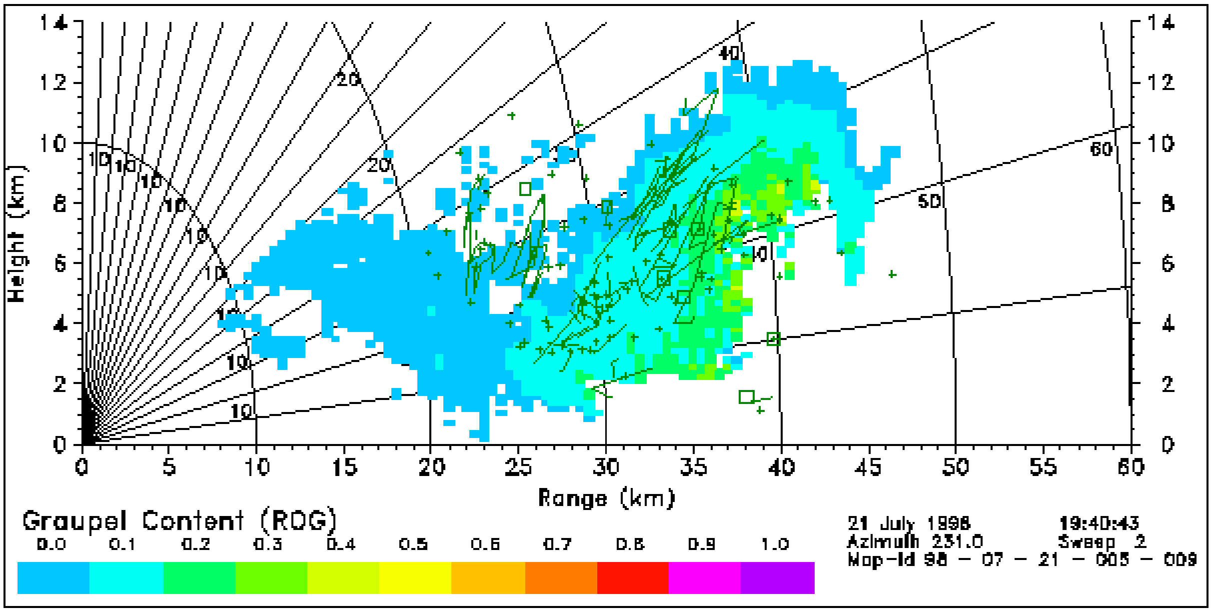

Figure 2: Graupel content in g m^{-3} computed from an RHI scan at 231° through the storm. Nearby VHF lightning signals plotted as line segments and crosses are highly correlated with the graupel region.

As shown in Fig. 2, VHF signals from flashes (line segments and crosses) near the depicted RHI scan at 17:40 UTC agree well with the area in which graupel is found within the storm. A weaker correlation exists between the VHF sources and the snow content. In addition, most flashes are located on the left flank downshear of the main updraft and the reflectivity maximum. Similar results have been described by Carey & Rutledge (1998). Interestingly, these authors also observed an unusually high IC / CG ratio just as was the case for the EULINOX storm.

Conclusions

By means of C–band radar and VHF interferometry the life cycle of a supercell storm was investigated to clarify the lightning initiation processes. Our study confirms the strong influence of graupel particles for the charge separation and the downshear displacement of lightning activity due to updraft tilting and advection of charged hydrometeors off the storms core region. Further studies will help to identify the causes for the high IC / CG ratio in the storm which might be due to the small separation of only 3 km between the freezing level and the -15°C–level corresponding to the altitudes of highest number of VHF sources. Gaining more insight in these effects will aid in developing improved lightning parameterizations for mesoscale and global models.

References

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