P1B.5

COMPARISON BETWEEN TOTAL MEASURED VOLUMES OF VARIOUS TYPES OF HYDROMETEORS AND TOTAL LIGHTNING ACTIVITY DURING THE STERAO 10 JULY 1996 STORM

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1.INTRODUCTION

The relationships between lightning and microphysical and kinematic storm parameters are complex and suggest that multiple parameters have to be taken into account to characterize lightning behaviour. In general, a strong updraft in the mixed phase region is needed to produce lightning. This is the region where the non-inductive charging mechanisms are thought to generate most of the storm electrification and include graupel and ice crystals interactions in the presence of supercooled liquid water. These interactions include collisions, splintering or evaporation on the surface of particles. They depend on liquid water content, temperature, size and collision velocity of hydrometeors. To study precipitation interactions in thunderstorm mixed phase regions polarimetric radar data can be related to bulk microphysical hydrometeor types (Straka et al. 2000, Vivekanandan et al. 1999). The purpose of this paper is to compare polarimetric radar trends of hydrometeor types with total lightning activity and evaluate the method as well as the results.

Radar reflectivity, which is weighted heavily in hydrometeor classifications, depends on the 6^{th} power of the particle diameter. Thus the radar measurements are dominated by the largest particles in the resolution volume and will not resolve smaller ice crystals or droplets mixed with graupel. However these results show that bulk microphysical trends are related to lightning activity.

During the Stratospheric-Tropospheric Experiment: Radiation, Aerosols and Ozone (STERAO) experiment, which took place in Northern Colorado in the summer of 1996, polarimetric radar data from the Colorado State University (CSU)-CHILL radar were collected. Total lightning activity was recorded by the Office Nationale d'Etudes et de Recherches Aerospatiales (ONERA) 3-D lightning interferometer as well as cloud-to-ground lightning by the National Lightning Detection Network (NLDN). These data were used to study the lifecycle of a severe storm observed on 10 July 1996. This storm was also studied with gridded radar data by Lang et al (2000).

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2. METHOD

The National Center for Atmospheric Research's (NCAR) Particle Identification (PID) algorithm (Vivekanandan 1999) was used to characterize the microphysics of the storm. For particular hydrometeor types identified by the PID, the volume of the individual radar gates of individual ppi scans were computed in spherical space and then summed over the radar volume scan. Beam overlaps were identified and removed by accounting the lower half of an overlapping area of two vertically stacked gates to the radar characteristics of the lower gate and the upper half area to the upper gate area. The center time of a volume scan was addressed to the volume.

First, the time history of the total hydrometeor volume was overlaid with 1-minute total lightning activity. Next these hydrometeor volumes were normalized by the total storm volume and compared to the lightning activity. Both entities were compared to computed reflectivity volumes and fractions.

3. STERAO 10 JULY STORM

The STERAO 10 July storm developed after 21:00 UTC near the southern Wyoming-Nebraska border along the Cheyenne Ridge. The forcing mechanism associated with this storm was a north/ south oriented stationary front over central Colorado.

The storm showed electric activity for 4.5 hours between 21:52 to 2:32 UTC the next day. For the first three hours the storm had multicellular character with 2-4 cores oriented NW-SE along a confluence line. In the second part of its lifetime, from approximately 1:00 until 2:30 UTC the storm had the characteristics of a low precipitation supercell displaying short lived low and mid level rotation, a bounded weak echo and a long lived updraft. The storm lacked a well defined precipitation shaft (Dye et al 2000). The first maxima in total lightning frequency occurred around 23:17 UTC with over 50 flashes per minute. After several peaks during the transition time between multicellular and supercellular character of around 30 flashes per minute the major peak in lightning during the supercell stage of the storm reached 57 flashes per minute. The radar data shows that numerous larger and smaller peaks in lightning activity occur during new cell development and subsequent merges.

Note that this storm produced very little cloud-to-ground lightning (Lang et al, 2000; Dye et al, 2000; Defer et al, 2001). Defer et al. (2001) showed that fewer than 2% of the total flashes were cloud to ground over the lifetime of the storm. The ratio never exceeded 1:10 at any time during the life.

4. RESULTS

4.1 Comparison of total lightning activity and radar derived hydrometeor fractions

The NCAR hydrometeor PID algorithm distinguishes between 17 categories (Vivekanandan 1999 et al). Lightning is thought to be correlated to interactions between ice particles. Because of overlaps in some of the hydrometeor classifications and because of microphysical reasons, two or more particle classifications were in some cases added together.

Figure 1 shows the storm fraction of larger hail classified by the hydrometeor PID algorithm (dashed line). Note that the fractions are multiplied by a scaling factor to display them with the lightning frequency (solid line). Peaks of total lightning correlate well with the calculated hail volume fractions. Also plotted in Figure 1 is the storm fraction of the sum of small hail/graupel and small hail/graupel-rain mixture categories. For the multicellular stage a reasonably good correlation between total lightning and the fraction of the small hail/graupel categories can be found. It should be noted that until 1:00 UTC the storm had a multicellular character with 2-4 cores present at the same time. At around 1:00 UTC the storm transitioned to a low precipitation supercell with a single large core. Thus there is an overall decrease in the fraction trend.

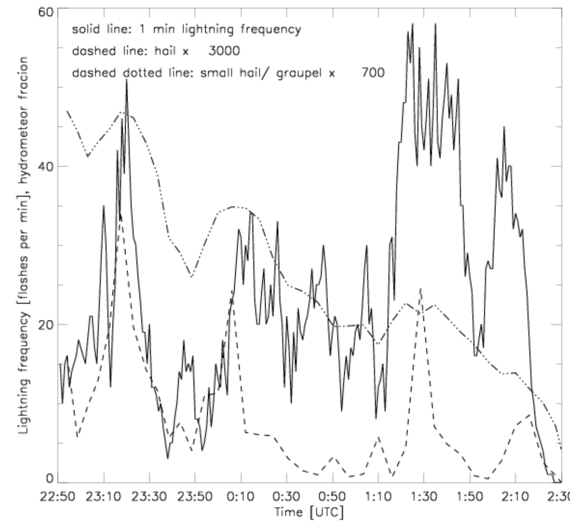

Figure 1. One minute lightning frequency (solid line) and storm fractions of larger hail multiplied by a factor of 3000 (dashed line) as well as the sum of small hail/graupel and small hail/graupel/rain mixture multiplied by a factor of 700 (dashed, dotted line).

Figure 2 shows the fraction of dry snow volume to the total storm volume. Peaks of dry snow fraction correlate well with total lightning activity. This is not true

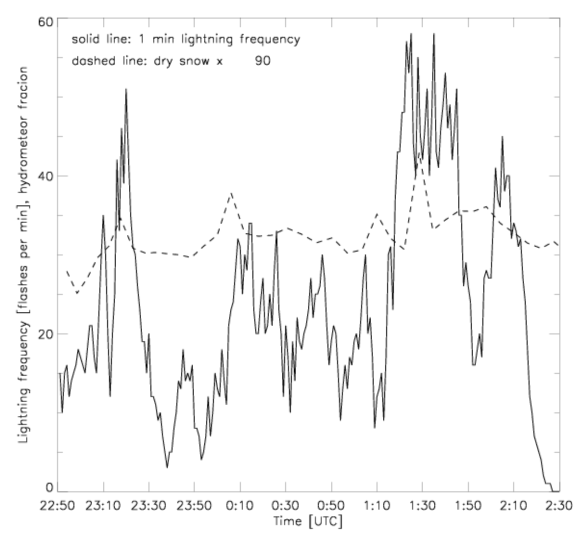

Figure 2. One minute lightning frequency (solid line) and storm fractions of dry snow multiplied by a factor of 90 (dashed line).

for the other ice categories – oriented and irregular ice crystals (not shown). Radar volumes that are classified as dry snow are generally associated with higher reflectivity compared to the other ice categories.

4.2 Comparison between total lightning activity and radar derived reflectivity fractions

As mentioned before reflectivity is heavily weighted in the hydrometeor PID algorithm. In the following, a comparison between radar volume fractions of various reflectivity intervals with the hydrometeor fractions is presented. Not surprisingly the reflectivity intervals are related to those associated with the individual hydrometeor outputs.

Figure 3 shows a comparison between radar volume fraction greater or equal 40 dBZ with the volume fraction of all precipitating ice particles. It can be seen that the reflectivity radar volume fraction trend over 40 dBZ is similar to the precipitating ice fraction derived from the PID.

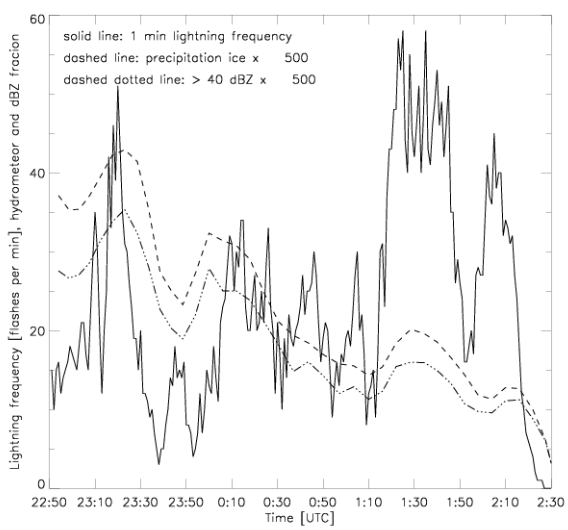

Figure 3. One minute lightning frequency (solid line) and storm fractions of precipitating ice multiplied by a factor of 500 (dashed line) as well as volumes greater or equal than 40 dBZ multiplied by a factor of 500 (dashed, dotted line).

Figure 4 shows a comparison between graupel/small hail and graupel/small hail/rain fractions with reflectivity volume fractions over 45 dBZ. Again the reflectivity fractions capture most trends that the PID fraction of precipitation sized ice particles show. The hail fraction

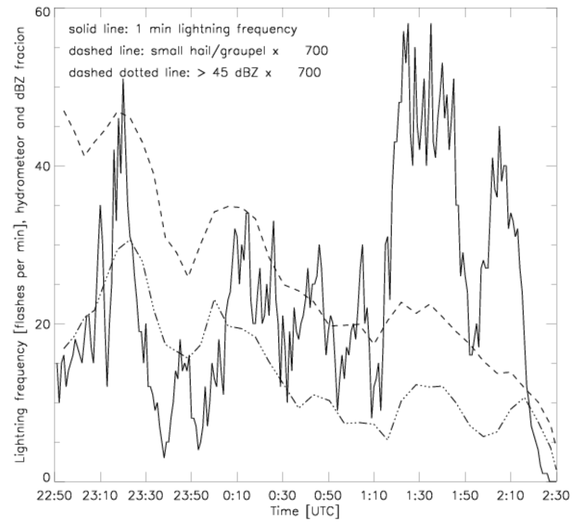

Figure 4. One minute lightning frequency (solid line) and storm fractions of the sum of small hail/graupel and small hail/graupel/rain multiplied by a factor of 700 (dashed line) as well as volumes greater or equal than 45 dBZ multiplied by a factor of 700 (dashed dotted line).

trends (Figure 1) cannot be easily reproduced by a simple radar reflectivity threshold alone.

5. CONCLUSIONS AND OUTLOOK

Bulk microphysical trends such as hail, graupel /small hail and larger ice particles show a fairly good relation to the lightning activity of the 10 July storm. This observation agrees with calculated hail volumes from gridded radar data by Lang et al 2000. Larger particles such as hail likely coincide with strong updrafts as does the increase of total lightning.

Radar volume fractions for precipitating ice and graupel/small hail are very similar to the volume of reflectivity greater than 40 dBZ and 45 dBZ respectively. In this instance radar reflectivity can be used as a representative measure of integrated electrical activity. The hail volume fraction differs significantly from radar volume fractions of reflectivity larger than higher dBZ values (e.g. 50 dBZ, 55 dBZ or 60 dBZ).

Further plans include calculating the mass of hydrometeor types which might give a better trend with lightning data, especially in terms of the ice crystals and snow categories. Also it will be investigated further how large the impact of reflectivity is on the hydrometeor PID output and whether the PID algorithm can be adjusted better to the 10 July storm. This includes a comparison with coincident microphysical measurements from aircraft.

6. ACKNOLEDGEMENTS

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