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STRUCTURE AND CHARACTERISTICS OF PRECIPITATION SYSTEMS OBSERVED BY TRMM

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1. INTRODUCTION

Multi-sensor measurements from the suite of instruments on the Tropical Rainfall Measuring Mission (TRMM) satellite are providing useful information to investigate convective structures within varied convective regimes. Recent studies by Boccippio et al. (2000) and Nesbitt et al. (2000) have shown high correlations between lightning flash rates and microwave brightness temperatures, supporting the linkage between deep convection, convective mass (precipitation ice) flux, and lightning activity. Goodman et al. (2000) examined six supercells observed during a TRMM overpass in the later stages of the 3 May central Oklahoma tornado outbreak. They found the storms, each having reflectivity cores of 40 dBZ extending to a height in excess of 10 km, were dominated by in-cloud (IC) lightning, with periods of little or no cloud-to-ground (CG) lightning activity.

The goal of the present study is to begin a more comprehensive examination of the spectrum of storm types and their attributes worldwide, and as a function of season, location, and convective regime using the observed lightning, microwave scattering, and reflectivity signatures. A global, multi-year data set (1998-2000) is being assembled to further our understanding of convective processes in different climatological regimes. This paper reports on the initial examination of this data set.

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2. METHODOLOGY

TRMM provides total lightning (in-cloud plus cloud-to-ground) from the Lightning Imaging Sensor (LIS), passive microwave ice scattering from the TRMM Microwave Imager (TMI), and radar reflectivity profile information from the 14 GHz Precipitation Radar (PR). These sensor data are being cataloged for precipitation features observed by TRMM since its launch in November 1997 (Nesbitt et al., 2000). The precipitation features are defined by their surface rainfall or ice scattering signatures, with horizontal scales ~100-10,000 km^2. Additionally, convective scale (~100 km^2) storms are defined by the lightning data. Over the U.S. the national cloud-to-ground lightning observations (NLDN, Cummins et al., 1998) are used to also determine the ratio of in-cloud to cloud-to-ground lightning, where it is hypothesized these ratios are related to the vertical profile of reflectivity and concentration of precipitation-sized ice.

3. RESULTS

Figure 1 shows the global distribution of high flash rate storms January 1998-August 1999. The southeast U.S. has by far the greatest concentration of the highest flash rate storms (>30 flashes per min). Other extra-tropical (20-30 deg N and S) regions with these most intense storms are southeast South America, near the coast of South Africa, the Himalayas, and southeast Australia. Some of the intense storms occur unexpectedly over the open ocean, and these will be the subjects of more detailed future study.

Figure 2 shows the minimum 37-GHz polarization-corrected temperature (PCT), an indicator of strong scattering from precipitation-sized ice. We note the greatest similarities between the ice scattering and highest flash rates occur in the extra-tropics. However, we note there are significant ice scattering signatures in northwestern Australia (Darwin area), central Africa, and Colombia not associated with the highest flash rates.

Table 1 is the result of a more detailed examination of the Nesbitt et al. (2000) TRMM (PR, TMI) database, U. S. only for all of 1999, and the associated LIS and NLDN flash rates. The table orders the storms by total flash rate. The top ten flash rates are from those storms observed in the TRMM orbits which produced the lowest 85 GHz or 37 GHz PCT in the 1999 sample of U.S. precipitation features.

This initial analysis shows the most electrically active 3 May Oklahoma tornado outbreak supercell (Stroud storm) examined by Goodman et al., 2000 is not even in the top ten of the highest flash rate storms of 1999, nor does the 3 May storm possess the lowest 85/37 GHz PCTs for the same year. Interestingly, all of the top-ranked intense electrical storms occur in the spring. The top ten flash rates in the table are from those storms observed in the orbits that produced the lowest TMI brightness temperatures, and thus may not necessarily represent the highest flash rate storms in the U.S during the year. One of the difficulties in examining these data in their present form is their classification as precipitation features, not as individual storms. Some of these extreme storms, such as the top-ranked N. Texas squall line of 17 May, are not isolated supercells, but may be multi-cellular complexes or even larger mesoscale convective systems.

The second ranked south Texas supercell does indeed seem to be a giant electrical storm, having an IC flash rate of 303 min^{-1} and IC:CG ratio of 61:1 during the overpass. Figure 3 shows a PR vertical cross-section of this storm, which produced 2.75” hail and straight-line wind damage. The storm has a tilted 40 dBZ PR reflectivity core extending to nearly 15 km altitude, and 50 dBZ echo extending above 11 km. At an earlier time, the NEXRAD-estimated storm top reached 19 km.

4. SUMMARY AND CONCLUSIONS

This study presents an initial examination of the global and regional characteristics of storms under a variety of convective regimes. The giant electrical storms sampled by TRMM are most common in the extra-tropics, specifically in the southeastern U.S. during the spring season. This study also provides a larger context for the 3 May 1999 TRMM observations of tornadic supercells, heretofore having produced the highest documented flash rates during TRMM’s 3-yr of on-orbit operations.

The TRMM precipitation feature database developed by Nesbitt et al. (2000) has been expanded (S. Nesbitt, 2001, personal communication); from this database, those orbits containing the lowest 85 GHz and/or 37 GHz polarization corrected brightness temperatures were identified. Lightning clusters in the United States (where NLDN data is available) were identified using LIS data for 16 such orbits from 1999. The 3 May 1999 multi-cellular Stroud storm ranks 11th by total flash rate in this sample. Storms with the greater flash rates tend to also have lower brightness temperatures at both 85 GHz and 37 GHz. The ratios of IC to CG lightning in the 3 May storm is indeed unusually large, but not unique among storms with extreme flash rates. Some other storms with higher brightness temperatures and lower flash rates than those listed in Table 1 are also noted to have large ratios of intracloud to cloud-to-ground lightning.

5. REFERENCES

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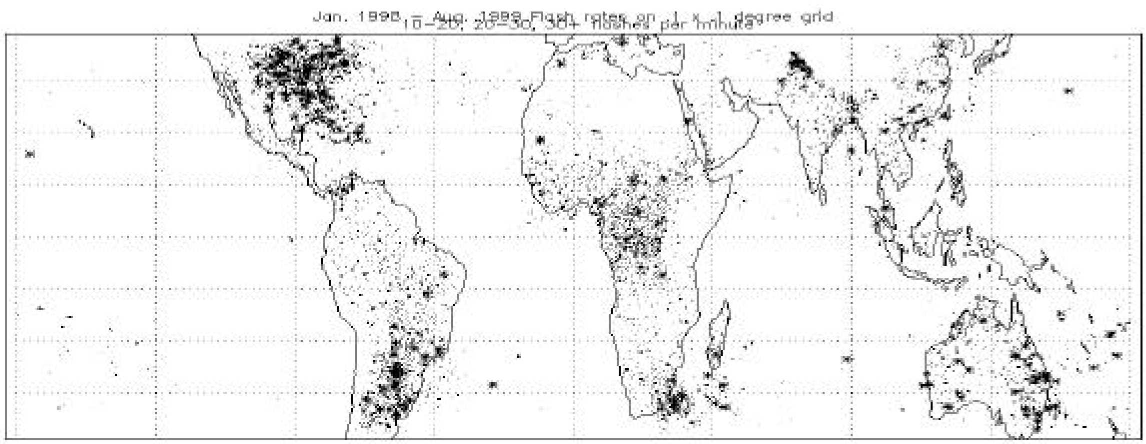

Fig. 1. Distribution of high flash rate storms January 1998-August 1999. LIS flash rate per min in 0.1 x 0.1 deg grid. Flash Scale: dot, 10-20/min; small star, 20-30/min; large star, >30/min.

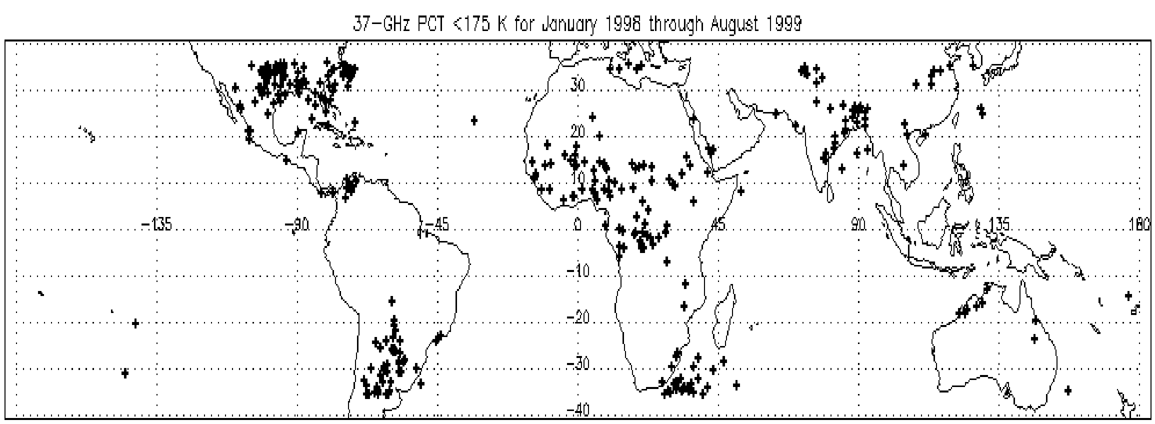

Fig. 2. Distribution of minimum TMI 37 GHz PCT<175K storms January 1998-August 1999.

Description	Time Date	Orbit	Min 85	Min 37	IC min^{-1}	CG min^{-1}	IC:CG
Part of N. TX squall line	2226 17 May	8453	60	95	524	85.5	6
S. TX isolated cell	0338 11 May	8346	55	119	303	5.0	61
Part of N. TX squall line	2049 17 May	8452	60	130	204	7.0	29
Part of N. TX squall line	2226 17 May	8453	57	135	173	18.5	9
SW OK multicell	0236 25 June	9055	64	142	165	17.0	10
Big Bend (Mex) multicell	0651 25 April	8096	64	125	156	21.0	7
Arkansas multicell	2226 17 May	8453	52	130	152	20.0	8
Part of N. TX squall line	2049 17 May	8452	65	135	161	8.0	20
NW Gulf squall line	0338 11 May	8346	60	137	125	31.0	4
SE TX multicell	2214 3 April	7759	63	140	145	9.5	15
Central OK Outbreak(Stroud)	**0403 4 May**	**8236**	**66**	**136**	**149**	**5.0**	**30**

Table 1. Flash rates and minimum polarization corrected brightness temperatures for extreme ice scattering events in the United States during 1999. Storms are sorted in descending order by total flash rate.

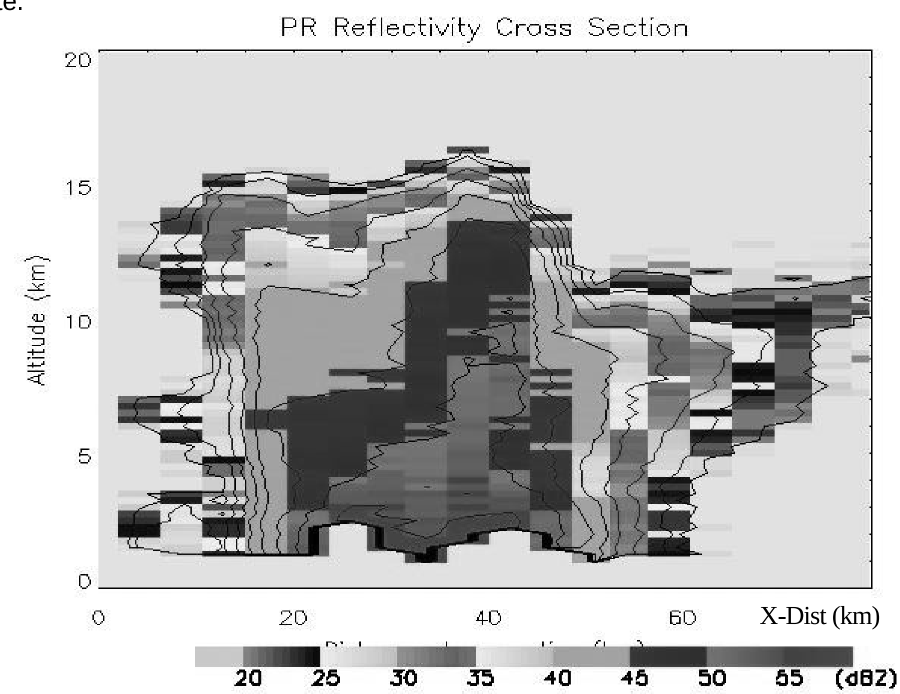

Fig. 3. PR cross-section through the south Texas supercell, TRMM orbit 8346, at 0338 UTC on 11 May 1999. Reflectivity contour interval every 5 dBZ.