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CLIMATOLOGY OF CLOUD-TO-GROUND LIGHTNING IN GEORGIA, USA, 1992–2003

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ABSTRACT

A 12-year climatology of lightning cloud-to-ground flash activity for Georgia revealed the existence of three primary regions of high lightning activity: the area surrounding the Atlanta Metropolitan Statistical Area, east-central Georgia along the fall line, and along the Atlantic coast. Over 8.2 million ground flashes were identified during the climatology. July was the most active lightning month and December was the least active. Annual, seasonal, and diurnal distributions of cloud-to-ground flashes were also examined. These patterns illustrated the interacting effects of land cover, topography, and convective instability in enhancing lightning activity throughout Georgia. A synoptic analysis of the ten highest lightning days during the summer and winter revealed the importance of frontal boundaries in organizing convection and high lightning activity during both seasons. The prominence of convective instability during the summer and strong dynamical forcing in the winter was also found to lead to outbreaks of high lightning activity. Copyright © 2005 Royal Meteorological Society.

KEY WORDS: lightning climatology; lightning distribution; Georgia (USA)

1. INTRODUCTION

On 19 June 1998, the US Federal Emergency Management Agency released $260 000 in funding in order to lessen the likelihood of excessive damage due to frequent lightning strikes occurring in Bartow County of northwestern Georgia (FEMA 1998). Records indicate that 582 cloud-to-ground (CG) strikes occurred within a 5-mile radius of the Bartow County jail complex during a 2-month period in 1997. While this event was excessive, CG flashes are common throughout Georgia, a state geographically situated in a region prone to lightning activity. The number of thunder events within Georgia is significant with over 70 annual events in the northeastern mountains increasing to over 100 in the far southwest (Changnon, 1988). Regionally, the southeastern United States experiences the greatest number of thunder events in the United States with Florida registering the highest event totals and casualties (Changnon, 1988; Holle *et al.*, 1995).

Evidence suggests that lightning is second only to flash floods in average annual fatalities produced by weather-related hazards (Holle *et al.*, 1995). In a study of casualties utilizing *Storm Data* for the period 1959–1994, Georgia ranked ninth highest with 410 deaths (Curran and Holle, 1997). Lightning related deaths and injuries are thought to be underreported by the National Weather Service by at least 28% and 42% respectively; therefore, actual casualties are likely considerably higher (Holle *et al.*, 1995).

Research also indicates that lightning-produced property damage (in dollars) is higher than that produced by thunderstorm winds, heat waves, and droughts in the United States, costing an estimated $332 million annually according to *Storm Data* (Holle *et al.*, 1996). In a recent investigation of insured property loss claims,

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lightning losses for Georgia were conservatively estimated at $10 million per year, which far exceeded totals recorded in *Storm Data* (Stallins, 2002).

Given the threat lightning poses to humans and the built environment in Georgia, a descriptive lightning climatology is developed in order to better discern the spatial and temporal distribution of CG flashes and their associated synoptic environments. The 12-year data set contains over 8.2 million ground flashes and builds upon previous studies that examined warm season lightning characteristics prior to the 1996 Olympic Games held in several locations within Georgia and South Carolina (Livingston *et al*., 1996; Watson and Holle, 1996). The annual spatial and temporal distribution of CG flashes and the synoptic environments associated with the ten most active warm and cool season CG flash days were examined statewide for the period 1992–2003.

The characteristics and geographical distribution of ground flashes have been investigated on a national level (Orville and Silver, 1997; Orville and Huffines, 2001; Orville *et al*., 2002). This investigation, by focusing on Georgia, examines similar ground flash characteristics and synoptic patterns on a finer resolution and scale. It is expected that the analyses utilized in this investigation will also be useful in future lightning studies of other states, regions, and countries.

2. DATA AND METHODOLOGY

Data employed for this investigation are from the National Lightning Detection Network (NLDN) for the 12-year period 1992–2003. This network consists of 106 sensors spread across the United States. Data were disseminated by *Vaisala, Inc*. The NLDN underwent a major upgrade in 1994 and 1995, increasing positional accuracy and sensitivity (Cummins *et al*., 1995). Currently, median location errors for ground flashes are approximately 500 m with 90% detection efficiency for flashes with peak currents greater than 5 kA (Cummins *et al*., 1998). Prior to 1995, median location errors were approximately 2–4 km with a detection efficiency of 70–80% (Cummins *et al*., 1995). The number of flashes reported in this study has not been corrected to include detection efficiency. However, positive ground strokes less than 10 kA recorded after 1994 have been removed. Because of the increased sensitivity of the upgraded system, research suggests that positive strokes under 10 kA in magnitude are likely cloud discharges (Cummins *et al*., 1998; Wacker and Orville, 1999a,b). For more information regarding NLDN accuracies, see Orville (1994); Cummins *et al*. (1995, 1998); Watson *et al*. (1995), and Orville and Huffines (1999). Each flash record contains time, location, polarity, magnitude, and multiplicity.

The ground flashes were spatially interpolated by kriging and were placed into 2.6×2.6 km grid cells for determining monthly and annual distributions. Kriging is a statistically based estimator of spatial variables and includes three main components: the spatial trend, local spatial autocorrelation, and stochastic variation (see Isaaks and Srivastava (1989) for a discussion of kriging). Gridding was performed using *Surfer 8* (Golden Software). A 2.6-km grid cell size was used so as to be consistent with previous Georgia lightning climatologies, to remain within or slightly coarser than the locational accuracy of the NLDN, and to allow for high spatial resolution (Livingston *et al*., 1996).

Histograms of flash data were constructed to visualize annual and monthly trends in the lightning data set. Systat's *SigmaPlot* was used for constructing the histograms. The synoptic environment present during lightning days was categorized according to records in the *Daily Weather Map Series*. This series, produced by the National Oceanic and Atmospheric Administration (NOAA), contains the 1200 UTC surface analysis for the United States. An approach similar to Dixon and Mote (2003) was used to assess the proximity of Georgia to frontal boundaries, extratropical low-pressure systems, and/or tropical systems for each lightning day in order to categorize the flashes as weakly forced, strongly forced, tropically forced, or indeterminate. Upper air analyses were not utilized for this classification.

The ten most active lightning days for the warm (June through August) and cool seasons (December through February) were extracted from the flash data set and examined with respect to the prevailing synoptic environment. Surface maps for these days were drawn from 1200 UTC surface analyses in the *Daily Weather Map* publication. Surface and upper air composites were also created, utilizing the reanalysis data set obtained from the Climate Diagnostics Center (see Kalnay *et al*. (1996) for a discussion of this data set).

3. RESULTS

3.1. Annual flash distribution

The 12-year average annual ground flash map was obtained by averaging each year's gridded distribution. Overall, the spatial distribution of the flashes resembled previous investigations that have computed flash densities for the warm season (Figure 1(a); Livingston *et al*., 1996; Watson and Holle, 1996). The highest ground flash frequencies were found along the southeastern coast of Georgia with values in isolated regions exceeding 90 flashes per 6.76 km^2 grid cell, or 13.3 flashes km^{-2} (Figure 1(a)). The location of these high frequencies coincides with the persistent warm season development of thunderstorms forced by the sea breeze convergence zone (Livingston *et al*., 1996). Another zone of high flash frequencies was evident in east-central Georgia with a subtle corridor extending southwestward (Figure 1(a)). This region of high flash frequencies corresponds spatially to the fall line or boundary between the piedmont and coastal plains (Figure 1(b)). The fall line is a region where the terrain rises northward approximately 186 m, which acts to enhance low-level atmospheric convergence and may initiate thunderstorm activity during the warm season when convective instability is high. In addition, following the development of the coastal front, an axis of dilatation often forms further inland, which can lead to the development of a Piedmont front (Businger *et al*., 1991). The Piedmont front then acts in concert with the underlying relief to focus on low-level convergence and subsequent thunderstorm development. Other regions of high flash frequencies were located to the north, east, and south of the Atlanta Metropolitan Statistical Area (MSA; Figure 1(a)). These regions of 7.4–10.4 flashes km^{-2} were possibly the result of flash augmentation due to changing land cover within and surrounding the rapidly urbanizing Atlanta MSA. Evidence suggests that urban enhancement of lightning activity surrounding urban centers occurs through dynamic forcing mechanisms initiated by urban heat island thermal properties and the topography of the built environment (Bornstein and Lin, 2000). A companion investigation focusing on the north Georgia region and Atlanta MSA is currently evaluating the effects of land cover changes in augmenting the flash distribution (Stallins *et al*., 2004).

In order to determine persistent shifts in the flash distribution during the 12-year period, a summation of the year-to-year grid differences was calculated. This trend analysis in flash frequencies illustrates the large interannual variability in ground flashes (Figures 2 and 3(a); Livingston *et al*., 1996). Annual flash counts ranged from a low of 309 089 in 1992 to 992 959 in 2003 (Figure 3(a)). However, flash counts remained fairly constant through the late 1990s, varying from approximately 600 000 to 800 000 flashes (Figure 3(a)). Persistent signals in the spatial distribution of flash trends were observed in regions surrounding the Atlanta MSA and in east-central Georgia along the fall line (Figure 2). Flash frequencies in both regions were on the order of 13 flashes km^{-2}. Changes in land cover are thought to be an important factor in the increases in flash frequencies found around Atlanta; however, further analysis is necessary in order to better discern these shifts as well as those along the fall line. Other less significant regions of flash increases occurred in southeastern and southwestern Georgia with the former likely due to interannual shifts in the coastal front (Livingston *et al*., 1996). The annual number of lightning days (i.e. a day when at least one CG flash is detected by the NLDN within Georgia) is considerably more stable than the flash counts (Figure 3(b)). Annual lightning days ranged from a low of 201 during 2000 to 250 in 1997 (Figure 3(b)). A comparison of lightning days with flash frequencies (Figures 3(a) and 3(b)) suggests that during the 1990s while lightning days remained fairly steady, flash frequencies increased. This suggests that thunderstorms developing within Georgia produce more CG flashes, especially during 2003 when 203 lightning days yielded 992 959 CG flashes, an average of 4891 flashes per lightning day. It is important to note, however, that the combined effects of natural thunderstorm variability and improvements in detection efficiency are both contributing factors in the observed flash frequency increase.

Positive polarity CG flashes also increased throughout the 12-year period (Figure 4). Positive discharges are examined separately because of (1) their ability to produce the largest currents and charge transfers; (2) their propensity to occur during the cold season in strong synoptic situations; and (3) the linkage between positive flashes and thunderclouds contaminated by smoke or pollutants (Rakov and Uman, 2003). After a sharp rise in the number of positive flashes during the mid-1990s, approximately 50 000–60 000 occurred annually in the late 1990s (Figure 4). Consistent with previous studies, approximately 6.8% of all flashes during the

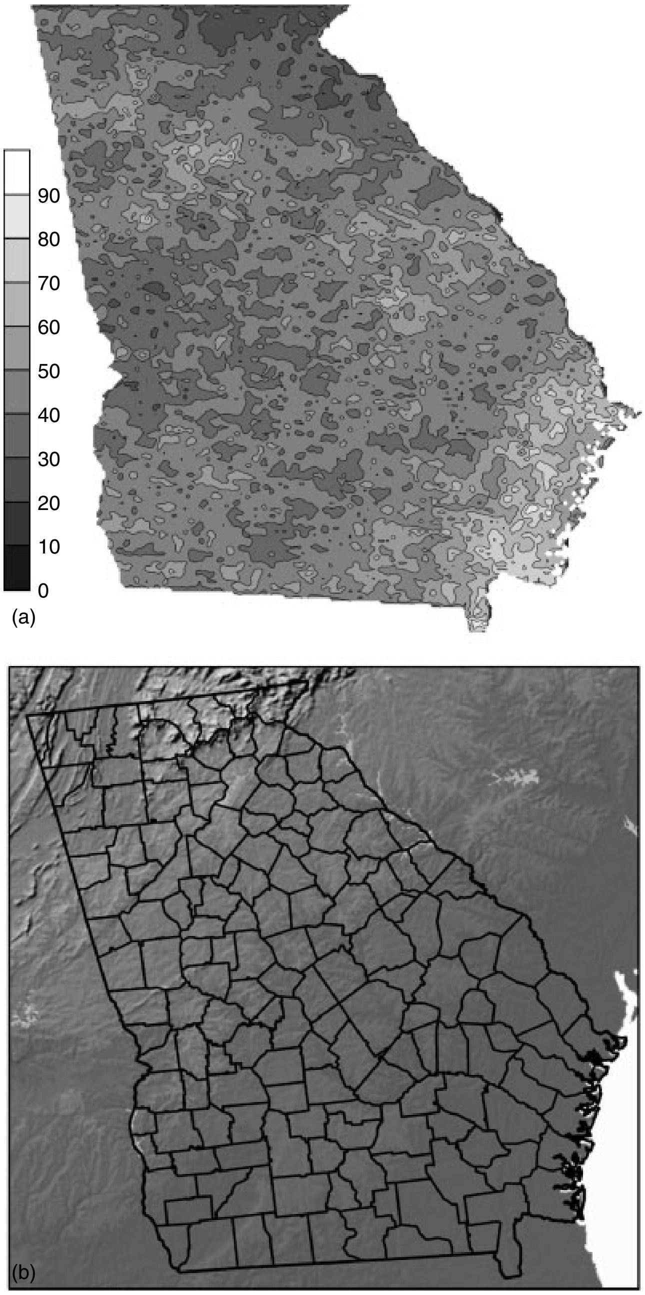

Figure 1. a) Spatial distribution of cloud-to-ground lightning activity for Georgia, 1992–2003 (per 6.76 km^2 grid cell). b) Shaded relief map of Georgia counties

12-year period were positive (Orville and Silver, 1997; Orville and Huffines, 1999). The spatial distribution of positive flashes also showed similarities with flash frequencies (Figures 1(a) and 5). The highest positive flash densities were found in southeastern Georgia. Other smaller maxima were located near the Atlanta MSA and within east-central Georgia (Figure 5). Minima in positive flashes and overall flash frequencies were observed in the northeastern portion of Georgia within the Appalachian Mountains, where previous studies have shown low incidences of thunder days (Changnon, 1988).

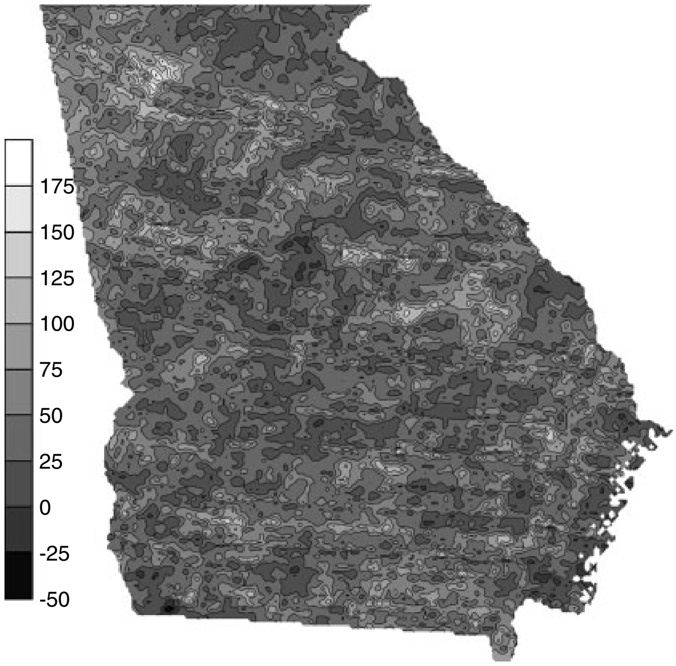

Figure 2. Spatial distribution of cloud-to-ground lightning trends for Georgia, 1992–2003 (per 6.76 km^2 grid cell)

3.2. Monthly flash distribution

Georgia experienced the greatest number of CG flashes during July when a total of 2 586 660 flashes occurred over the study period (Figure 6(a)). June and August also had high frequencies (Figure 6(a)). December is the least active month during the year with only 35 875 flashes recorded in 12 years (Figure 6(a)). The large amount of intraannual variance is illustrative of the importance of convective available potential energy in creating a thunderstorm-conducive environment within Georgia. In a year monthly lightning days also peak in July with at least one detected CG flash occurred (Figure 6(b)). This equates to over 98% of the days in July having an average of 7087 lightning flashes occurring per lightning day. June is not far behind with 330 lightning days, equaling 92% of all possible days and averaging 5219 flashes per lightning day (Figure 6(b)). The least active month was December, with only 78 lightning days equaling 21% of all possible days and averaging 460 flashes per lightning day (Figure 6(b)).

The flash percentages were reversed for positive flash frequencies (Figure 6(c)). The summer months, partly due to the very high flash counts, have the least amount of positive flashes as a percentage of the total (Figure 6(c)). For example, during July, only about 4.4% of all flashes were positive. Although a low percentage, this equates to approximately 113 787 positive flashes. During January, nearly 27% of all flashes were positive which equates to approximately 19 587 positive flashes. The significant differences in positive flash percentages between warm and cool seasons were initially identified by Orville and Songster (1987) and are further elaborated upon in Orville and Huffines (1999). The monthly distribution of positive flashes as a percentage of all activity for the 12-year period is very similar to previous findings (Orville and Huffines, 1999).

3.3. Seasonal flash distribution

There existed considerable variance in the spatial distribution of ground flashes within a particular season. During the summer (June, July, August), the three primary regions of high flash activity were evident (Figure 7(a)). These include the sea breeze corridor located in southeastern Georgia with flash counts of nearly 7.1 flashes km^{-2}, in the fall line corridor with flash counts of nearly 5.3 flashes km^{-2}, and in the area

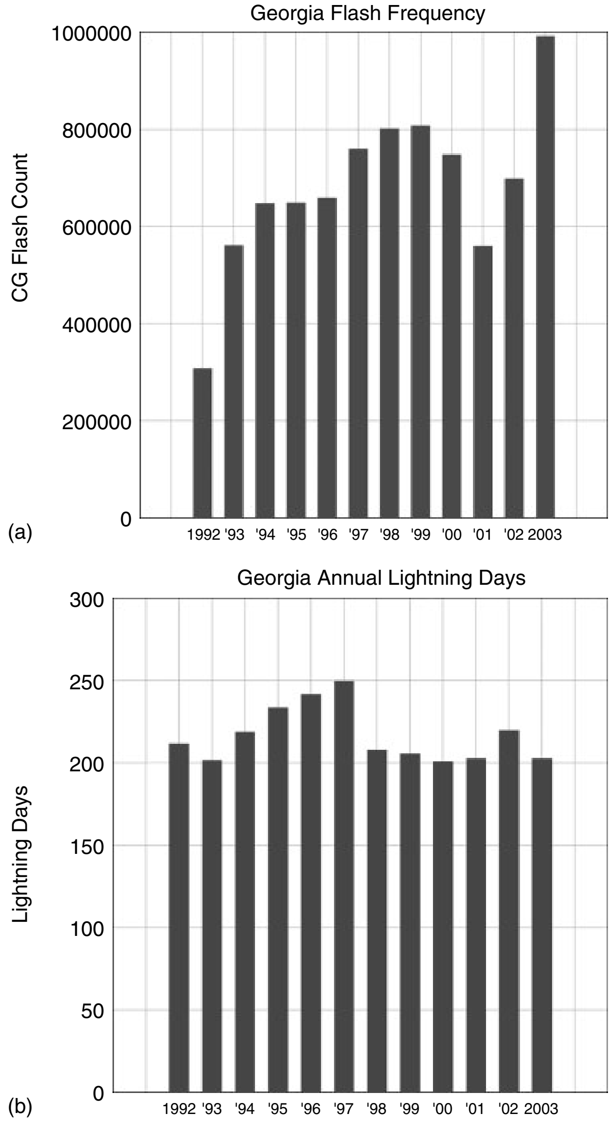

Figure 3. a) Annual cloud-to-ground lightning activity for Georgia, 1992–2003. b) Annual number of lightning days for Georgia, 1992–2003

around the Atlanta MSA with flash counts around 4.4 flashes km^{-2}. In fact, the summer flash distribution closely resembled the overall distribution (Figure 1(a)). This is expected since the majority of flashes occurred during the summer months.

A noted decrease in activity occurred during autumn (September through November; Figure 7(b)). There was still a southeastern maxima in flash activity because of the coastal front, but this activity was much weaker and was confined to a region closer to the coastline (Figure 7(b)). The relative maxima in autumn flash counts for south Georgia may be due to the increased frequency of coastal cyclogenesis and associated convection through the late autumn and winter months (Figure 7(b); Carlson, 1998). The fall line corridor and areas of increased activity surrounding the Atlanta MSA are greatly reduced during autumn, likely a result of decreases in the amount of convective instability (Figure 7(b)).

Winter (December, January, February) contained the lowest numbers of CG flashes statewide (Figures 6 and 7(c)). The three prominent regions of high flash activity (i.e. southeastern Georgia, fall line, Atlanta MSA) are

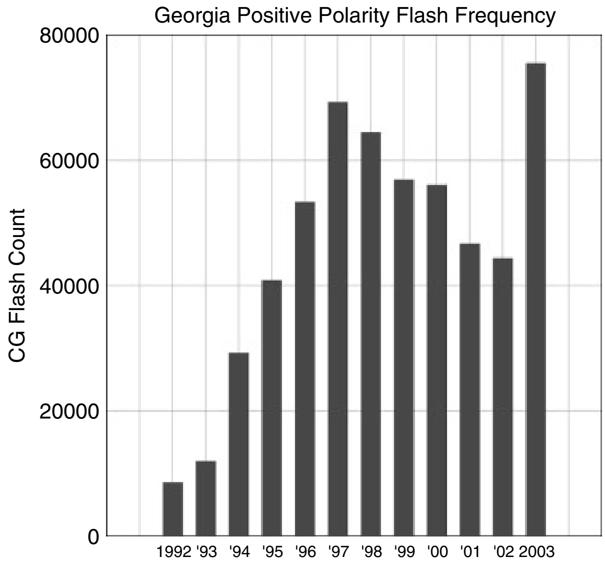

Figure 4. Annual positive polarity flash frequency for Georgia, 1992–2003

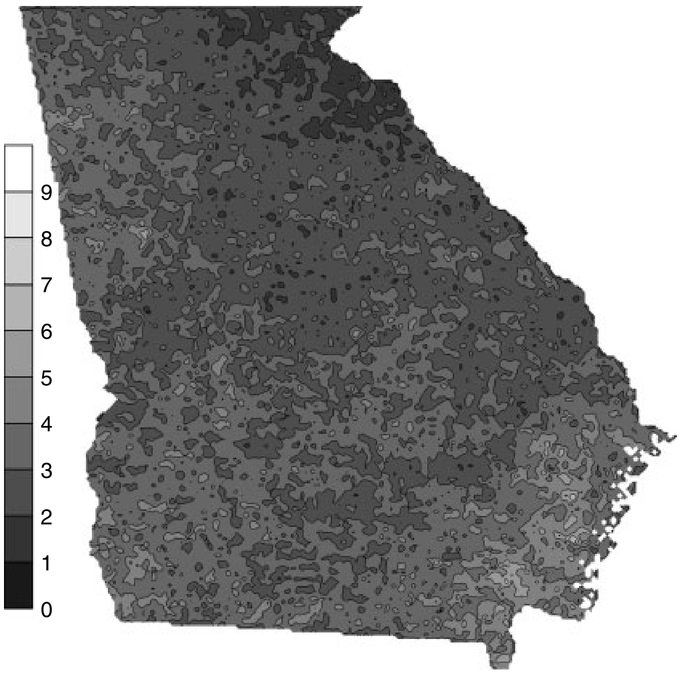

Figure 5. Spatial distribution of positive polarity cloud-to-ground lightning activity for Georgia, 1992–2003 (per 6.76 km^2 grid cell)

greatly reduced during the winter. Winter flash activity peaked in extreme southwestern and southern Georgia (Figure 7(c)). As during the autumn, transient midlatitude storms may develop along zones of baroclinity associated with the Gulf Coast, thus providing an environment conducive to thunderstorm development in southern Georgia (Carlson, 1998).

Spring (March, April, May), as a transition period to the high flash counts of summer, exhibited increased flash frequencies along the fall line and the area surrounding the Atlanta MSA (Figure 7(d)). Southeastern

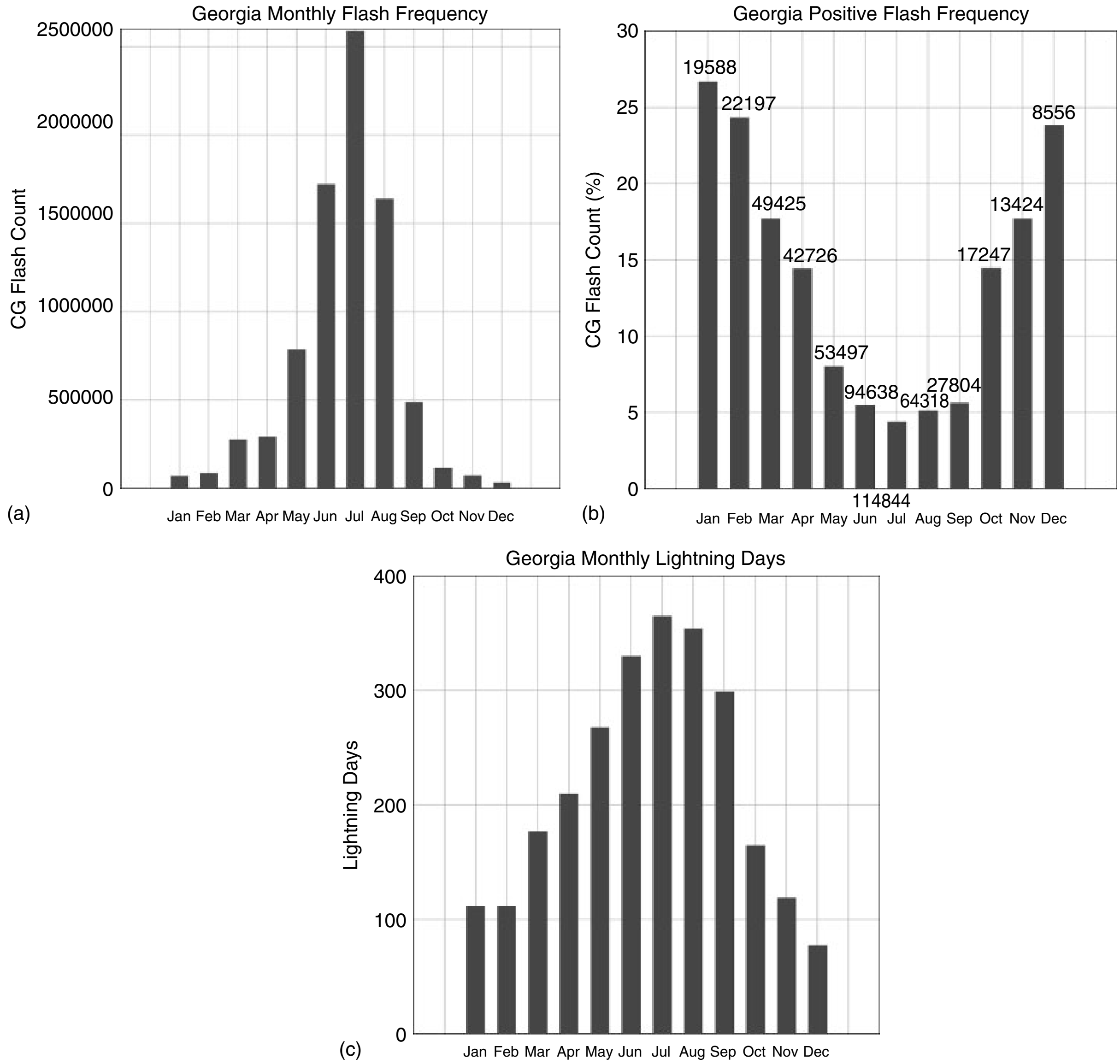

Figure 6. a) Monthly flash frequency for Georgia, 1992–2003. b) Monthly positive polarity flash frequency for Georgia (as percentage of total), 1992–2003. c) Monthly lightning days for Georgia, 1992–2003

Georgia flash counts remained low during the spring as sea-surface temperatures are slow to rise and lead to the development of the coastal front. However, it appeared that flash augmentation due to convective enhancement by land cover and topographic boundaries becomes prominent during this period (Figure 7(d)).

3.4. Diurnal flash distribution

In order to assess flash frequencies throughout the day, the entire data set was stratified and mapped according to the hour of the day. As expected, CG flash activity was much higher in the afternoon/evening than during the morning (Figure 8(a)). The three regions of enhanced lightning activity are evident, but activity in southeastern Georgia was especially pronounced with flash counts exceeding 6.6 flashes km^{-2}

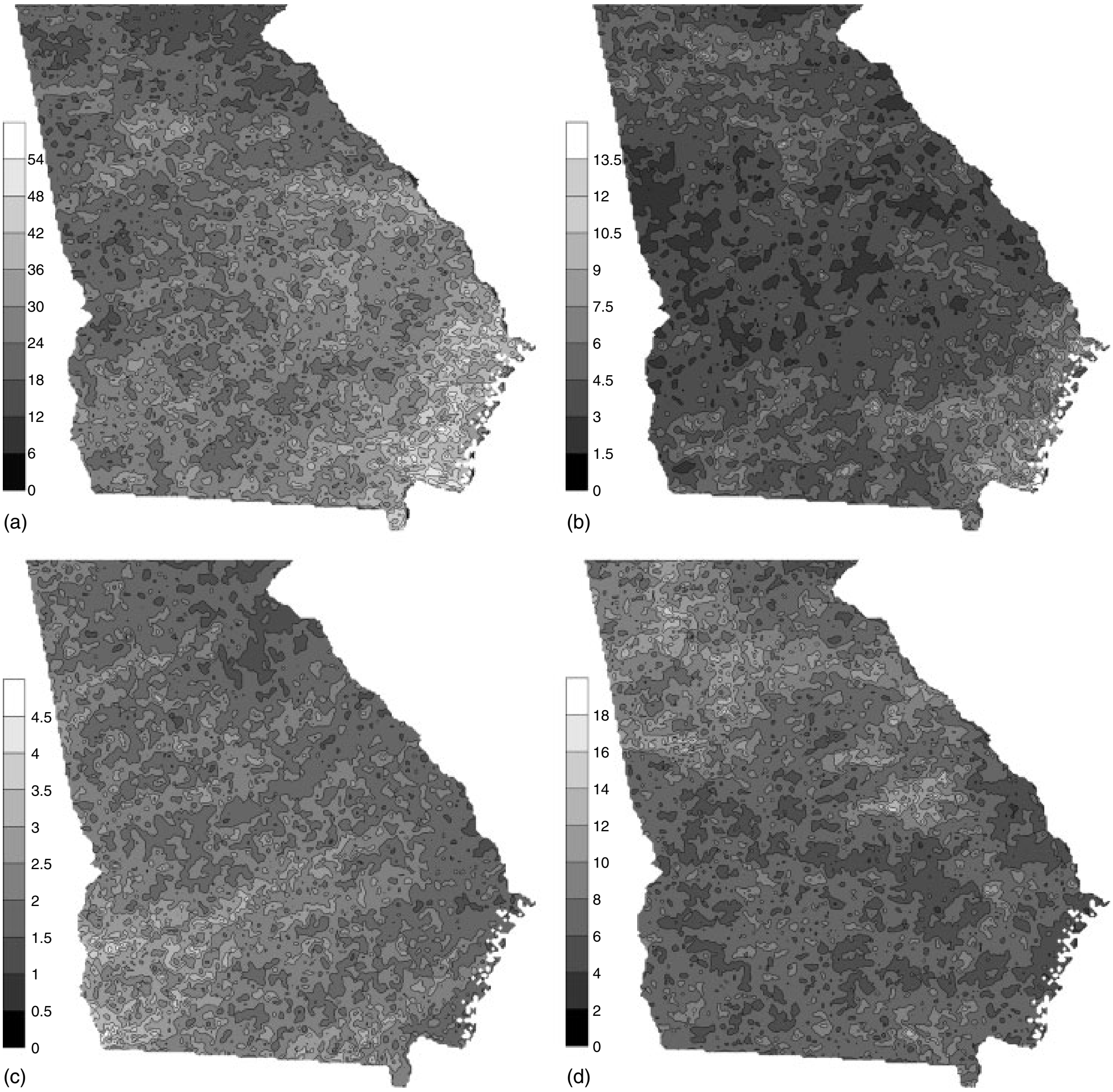

Figure 7. a) Spatial distribution of summer cloud-to-ground lightning activity for Georgia,1992–2003 (per 6.76 km^2 grid cell). b) Spatial distribution of fall cloud-to-ground lightning activity for Georgia, 1992–2003 (per 6.76 km^2 grid cell). c) Spatial distribution of winter cloud-to-ground lightning activity for Georgia, 1992–2003 (per 6.76 km^2 grid cell). d) Spatial distribution of spring cloud-to-ground lightning activity for Georgia, 1992–2003 (per 6.76 km^2 grid cell)

(Figure 8(a)). This underlines the importance of the coastal front in initiating afternoon thunderstorms in this region (Watson and Holle, 1996).

The southeastern Georgia maximum disappeared during morning hours (Figure 8(b)). Since the coastal front develops in response to differential heating between the ocean and land surface, it remains inactive in the morning hours, thereby minimizing surface convergence. However, the most prominent region of morning lightning activity surrounded the Atlanta MSA, with flash frequencies approaching 2.2 flashes km^{-2} (Figure 8(b)). Evidence suggests that convective activity induced by the Atlanta urban heat island favors early morning occurrence and may assist in creating this relative maximum (Bornstein and Lin, 2000; Dixon and Mote, 2003). Another region with pronounced morning lightning activity was along the fall line. This

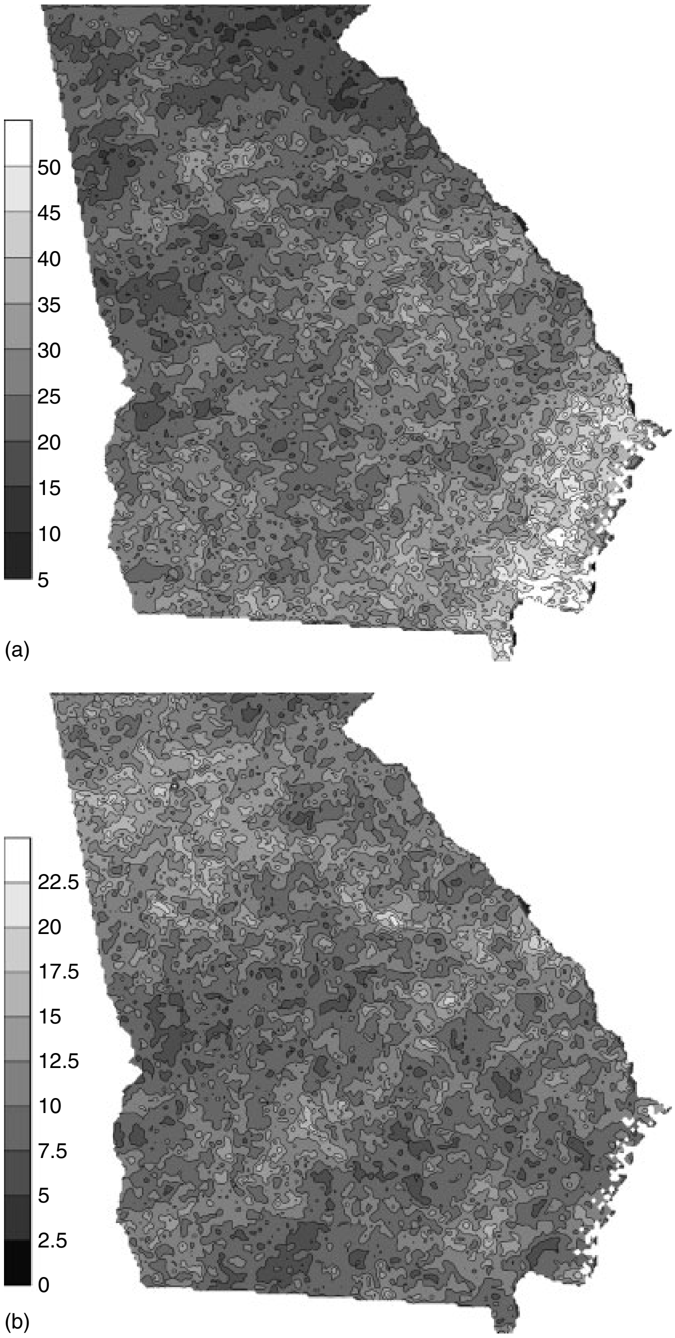

Figure 8. a) Spatial distribution of afternoon/evening (noon −11:59pm) cloud-to-ground lightning activity for Georgia, 1992–2003 (per 6.76 km^2 grid cell). b) Spatial distribution of morning (midnight −11:59am) cloud-to-ground lightning activity for Georgia, 1992–2003 (per 6.76 km^2 grid cell)

topographic break that runs from east-central to southwestern Georgia had frequencies approaching 2.2 flashes km^{-2} (Figure 8(b)). Since the coastal front is a precursor to the development of a piedmont front, it is unlikely that this zone of enhanced activity is due to the piedmont front (Businger *et al.*, 1991). However, differential heating due to terrain differences may be a factor in creating localized forcing along the fall line.

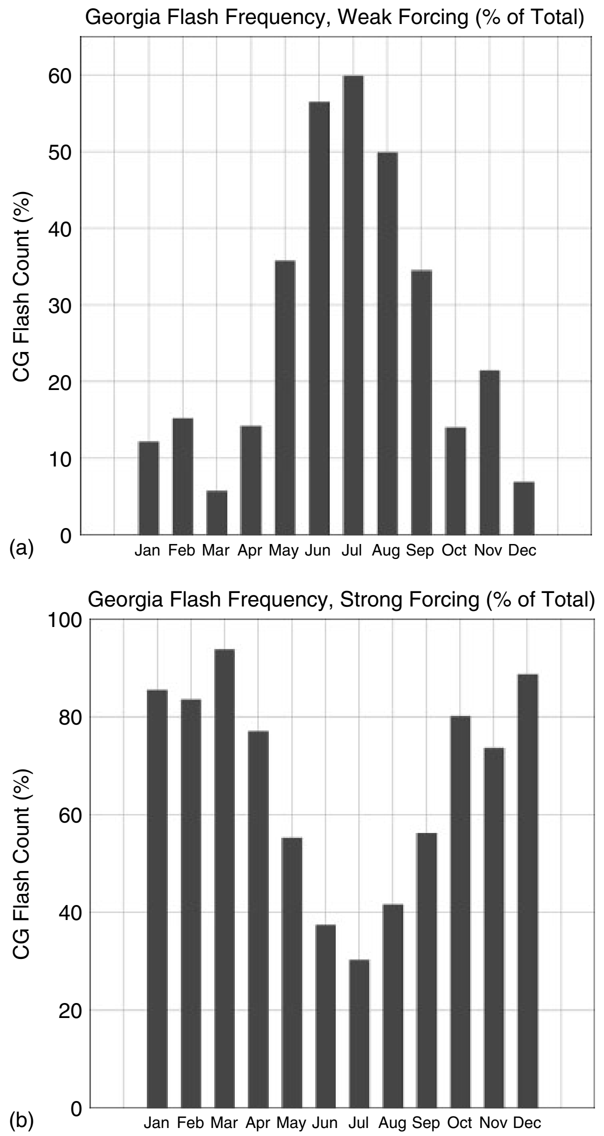

Figure 9. a) Monthly flash frequency for weak synoptic forcing events (as a percentage of total flash frequency), 1992–2003. b) Monthly flash frequency for strong synoptic forcing events (as a percentage of total flash frequency), 1992–2003

3.5. Synoptic analysis

During the summer months, a significant amount of ground flashes (>45%) occurring in Georgia were the result of weakly forced thunderstorm activity (Figure 9). This constitutes convective development distant from a frontal boundary or other organized synoptic-scale forcing and is supported by previous studies (Livingston *et al*., 1996). June and July represented the highest percentages of ground flashes associated with weakly forced synoptic environments with 56.4% and 59.8% of all flashes respectively (Figure 9(a)). During transition and cool seasons, strong synoptically forced systems produced the majority of ground flashes; March and December had the highest percentages, 93.9% and 88.8%, respectively (Figure 9(b)). The frequent midlatitude storms that track through the southeastern United States. during these months produce episodes of organized convection and squall lines (Geerts, 1998). Likewise, convective instability is typically limited during the cool season, thereby suppressing weakly forced thunderstorm development.

Table I. The ten most active summer lightning days, 1992–2003

	Date	Flash count
1	06 July 1999	44 494
2	19 August 1995	41 498
3	14 August 1999	40 348
4	27 June 1994	40 238
5	12 July 2000	40 057
6	19 July 1994	36 982
7	9 June 1994	36 396
8	18 May 2003	36 054
9	11 July 2000	35 789
10	29 June 1999	35 751

Table II. The ten most active winter lightning days, 1992–2003

	Date	Flash count
1	14 February 2000	14 872
2	24 December 2002	12 103
3	22 February 2003	10 251
4	17 February 1998	8553
5	18 January 1999	8513
6	23 January 1999	7670
7	25 January 1997	7356
8	28 February 1998	5508
9	16 February 1995	5030
10	7 January 1995	4767

July contained four of the ten highest flash count days, including the highest at 44 494 detected flashes (Table I). All the highest flash count days occurred in the warm season with the summer months containing all but one event. Although a large amount of summer ground flashes occurred in weakly forced synoptic environments, eight of the ten highest flash count days exhibited frontal boundaries in the vicinity of Georgia (Figure 10). This is likely due to mesoscale convective systems (MCSs) that have the potential to produce intense convection and high flash counts (Geerts, 1998). Evidence suggests that MCSs are approximately twice as frequent in the summer than winter in the southeast (Geerts, 1998). Summer MCSs, however, are usually smaller in size and short lived than those occurring in the winter months (Geerts, 1998). It is interesting, however, that the highest flash count day did not exhibit any synoptic-scale boundaries throughout the entire southeastern United States. (Figure 10(a)). A composite analysis of the ten highest flash count days confirmed the importance of increased instability and upper-level convective support (Figure 11). A much stronger 500-hPa height gradient was found in the Central United States with enhanced ridging over Texas. This in turn leads to northwesterly flow into the Southeast (Figure 11(a)). These conditions would likely create a favorable low to midlevel shear profile for enhancing warm advection and convective instability evident in the anomalously low-lifted indices (Figure 11(b)). Warmer than average surface temperatures also developed throughout the region (Figure 11(c)). Previous findings suggest that during active lightning days an east-to-west-oriented 500-hPa ridge develops from central Texas through Georgia (Livingston *et al.*, 1996). In this study, ridging over Texas occurred with weak troughing over the southeast (Figure 11(a)). However, greater than average instability and warm low-level temperatures were found to be consistent with earlier studies (Livingston *et al.*, 1996).

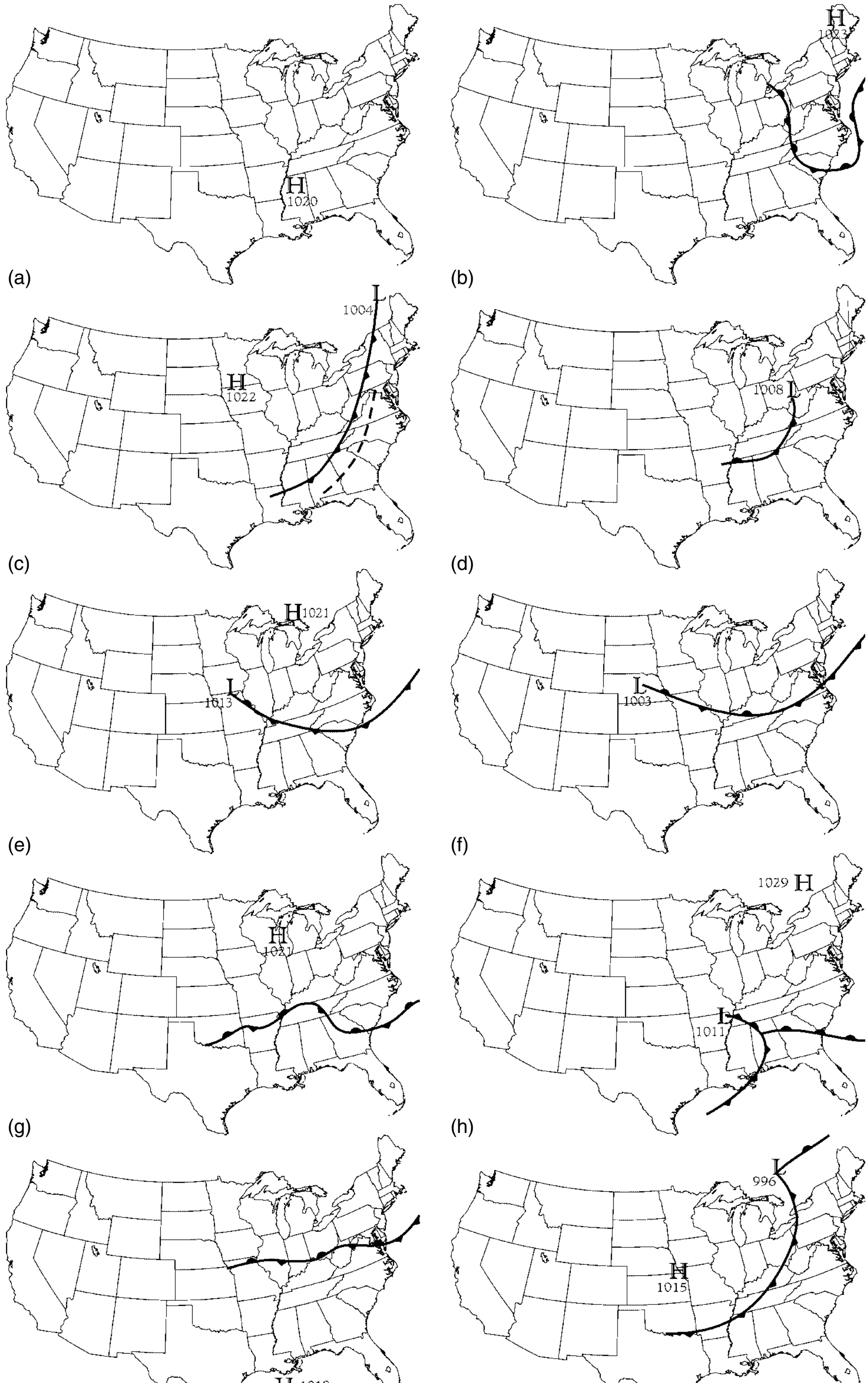

Figure 10. Relevant surface features of the ten highest summer lightning days. a) 06 July 1999, b) 19 August 1995, c) 14 August 1999, d) 27 June 2004, e) 12 July 2000, f) 19 July 1994, g) 09 June 1994, h) 18 May 2003, i) 11 July 2000, j) 29 June 1999

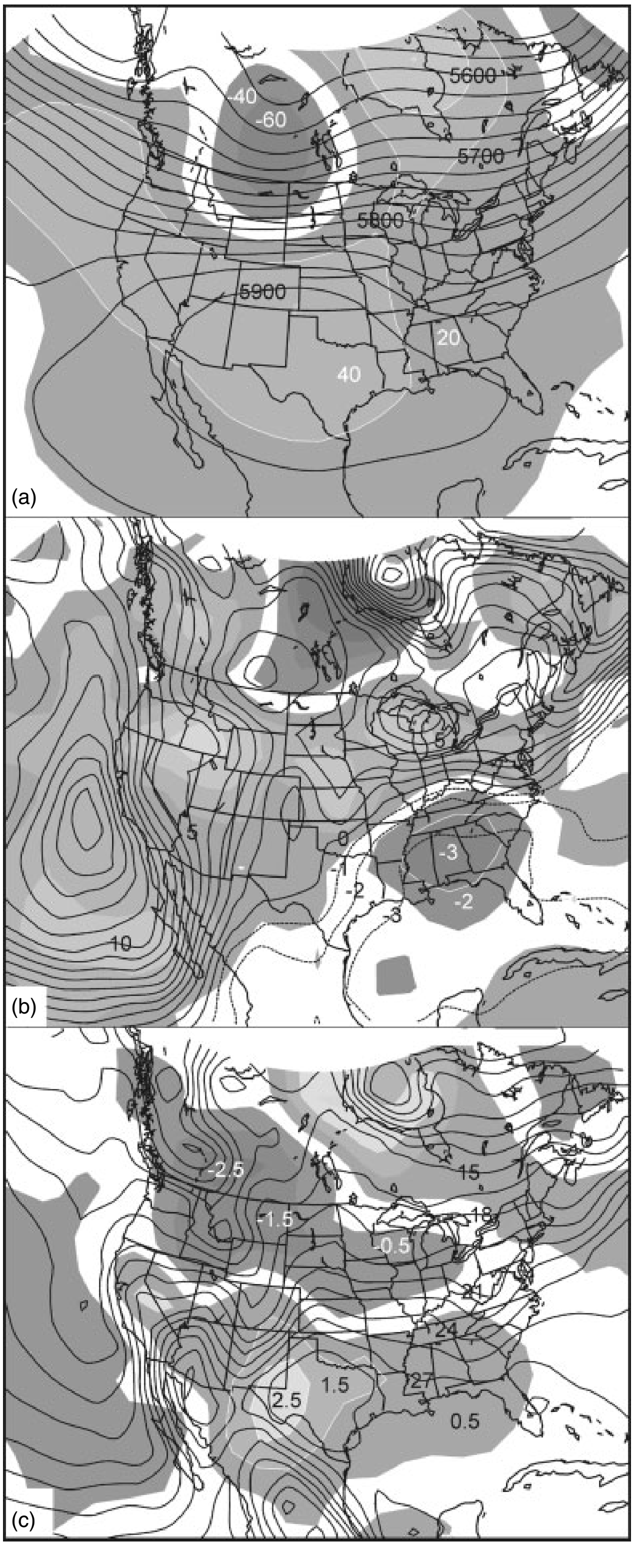

Figure 11. Composite analyses of the ten highest summer lightning days. a) 500 hPa heights and shaded anomaly (gpm), b) Lifted index and shaded anomaly (°C), c) Surface temperature and shaded anomaly (°C)

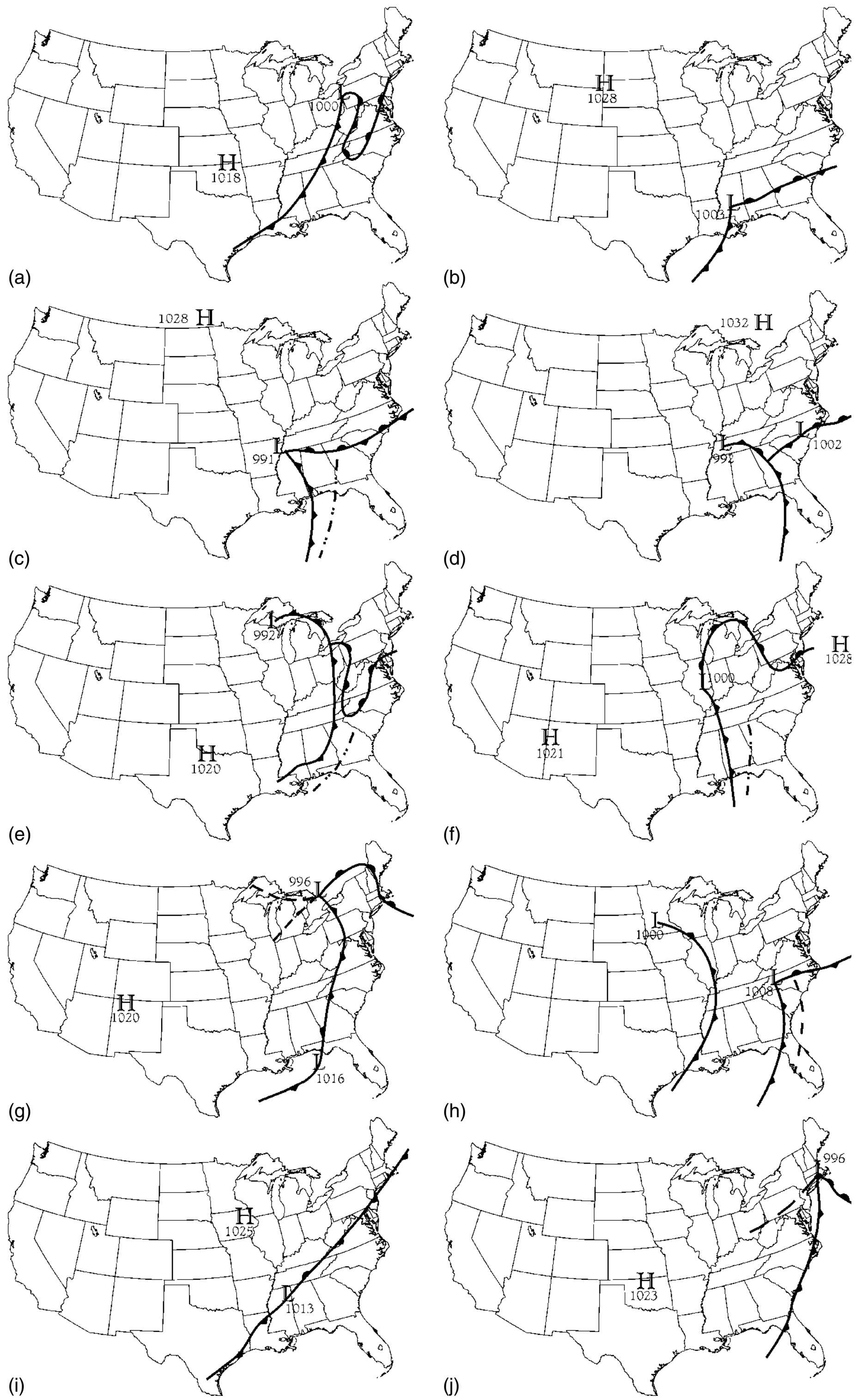

Figure 12. Relevant surface features of the ten highest winter lightning days. a) 14 February 2000, b) 24 December 2002, c) 22 February 2003, d) 17 February 1998, e) 18 January 1999, f) 23 January 1999, g) 25 January 1997, h) 28 February 1998, i) 16 February 1995, j) 07 January 1995

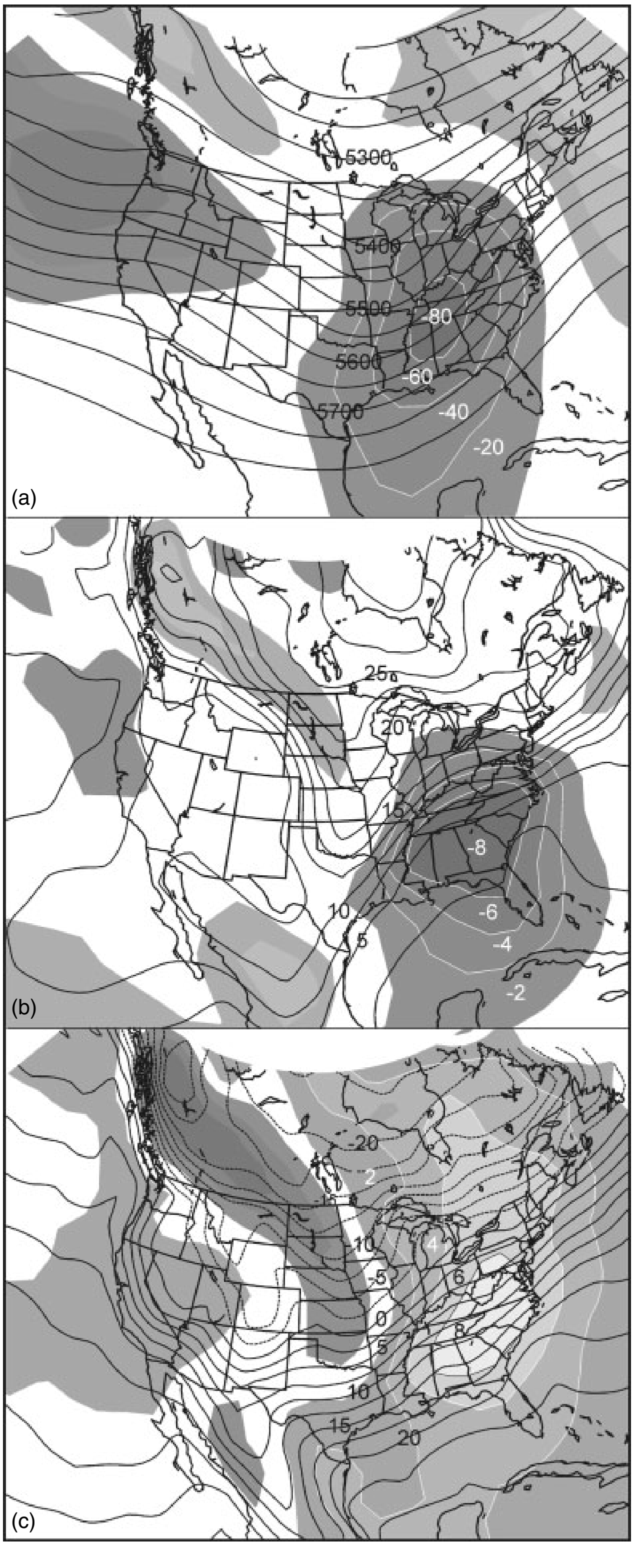

Figure 13. Composite analyses of the ten highest winter lightning days. a) 500 hPa heights and shaded anomaly (gpm), b) Lifted index and shaded anomaly (°C), c) Surface temperature and shaded anomaly (°C)

Daily winter flash counts were significantly lower than those found during the summer months (Table II). Of the ten highest winter flash count days, five occurred in February and four in January (Table II). Surface frontal boundaries were identified within the vicinity of Georgia for all ten of the highest winter lightning days with three surface maps identifying active squall lines (Figure 12). Although MCS activity is not as frequent as in the summer, MCSs are typically larger and longer lasting during the cool season in the southeast (Geerts, 1998). In the absence of significant low-level convective instability, synoptic-scale forcing appears necessary for active lightning days (Figure 13(b)). This supposition was supported in the composites of the ten highest winter lightning days, which exhibited significant 500-hPa troughing through the southeast, limited but maximized convective instability, and anomalous warm air advection into a region located in the warm sector of an approaching midlatitude storm (Figures 12 and 13). The significant synoptic-scale dynamics associated with active winter lightning days is also verified by the large proportion of flashes associated with strong synoptic forcing during the cool season (Figure 9(b)). Eight out of ten of the highest winter lightning days contained surface low-pressure centers of 1000 hPa or lower, while only one of the highest summer lightning days contained a low-pressure center of this intensity (Figures 10 and 12).

4. CONCLUSIONS

Several prominent trends can be summarized from the analysis of 12 years of CG flashes and their associated synoptic environments. These include the following.

(1) There appear to be three major regions of lightning activity in Georgia including the Atlanta MSA, the east-central region along the fall line, and coastal plains.
(2) Although lightning activity varies annually, lightning days are more stable than flash counts with evidence suggesting that more recent thunderstorm days in Georgia produce more CG flashes.
(3) The Atlanta MSA and east-central Georgia regions exhibit the greatest annual increases in lightning activity over the 12-year period.
(4) Seasonal flash distributions illustrate prominent shifts in lightning activity. Production in the three high flash density regions is suppressed during the winter, while the Atlanta MSA and east-central regions are most active in spring and summer.
(5) Synoptic boundaries were present during nearly every active lightning day regardless of the season. Organized convection (i.e. MCSs) appears important in producing the most active lightning days. However, synoptic-scale forcing is much stronger during the winter months with summer convection associated with high convective instability.

Future research will examine in more detail the distribution of lightning activity within the prominent regions identified in this analysis.

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