1.3 The Incorporation of Lightning Climatologies into the Interactive Forecast Preparation System (IFPS)

Andrew I. Watson*, T.J. Turnage, Phillip E. Shafer
NOAA/National Weather Service
Tallahassee, Florida

Jessica R. Stroupe
NOAA/National Weather Service
Birmingham, Alabama

Todd P. Lericos
NOAA/National Weather Service
Spokane, Washington

and

Henry E. Fuelberg
Department of Meteorology
Florida State University
Tallahassee, Florida

1. INTRODUCTION

Much of the summertime precipitation in Florida is attributed to sea breeze induced convection. The patterns of Florida summertime sea breeze convection are further controlled by the low-level, large-scale flow. Both daily spatial and temporal patterns of convection appear to recur time and again and are influenced by the low-level wind and available moisture. This influence was first described more than 50 years ago (Byers and Rodebush 1948; Gentry and Moore 1954).

The Interactive Forecast Preparation System (IFPS) allows National Weather Service (NWS) forecasters to prepare graphical depictions of present and predicted weather. No longer does the forecaster type in text for routinely scheduled forecast products. Instead the forecaster works in a forecast database environment containing various grids of weather elements. The forecaster inherits a forecast database from the previous shift. If, in his/her opinion, the previous forecast needs no modification, it is left unchanged. If the forecast requires updating, it can be modified with editing tools, or the forecast element can be created completely from scratch. The forecaster can also populate these grids with model data or, as in this study, with data from locally developed studies or climatologies. The forecaster then edits the grids to reflect local experience and knowledge to provide "value-added" input to the forecast. A set of "smart tools" within IFPS allows the forecaster to interpolate, fill in other associated weather elements, check for consistency among the weather elements, publish the grids to a national database, generate graphical products for the internet, and produce routinely scheduled text products for public, marine, and fire weather services.

Since Florida summertime weather is controlled primarily by a recurring phenomenon, it is helpful to develop climatologies, which then can be used to depict a forecast situation. This concept is not new. Frank et al. (1967), Smith (1970), and Blanchard and López (1985) composited radar data to show that the sea breeze is influenced by low-level winds. Watson and Holle (1996), Camp et al. (1998), and Lericos et al. (2002) developed lightning climatologies for the Southeast U.S. and Florida using data from the National Lightning Detection Network (NLDN). Recently, Connell et al. (2001) produced warm season high-resolution GOES visible and infrared cloud frequency composites over northern Florida.

The close association of the Weather Forecast Office (WFO) Tallahassee with the Meteorology Department of Florida State University (FSU) has made it possible to develop these special climatologies, which can easily be incorporated into the IFPS. These include lightning, radar, and precipitation distributions, which either have been developed or currently are under development.

We are incorporating the summertime lightning distributions for various low-level flow regimes into the IFPS/Graphical Forecast Editor (GFE) as a first guess forecast for daily thunderstorm patterns. This paper describes lightning frequency based on low-level flow, the utility of using the lightning climatologies, their incorporation into the GFE, and how they can be used as a "first guess" for normal daily summertime thunderstorm activity. The lightning climatologies provide improved resolution, enabling more detailed "valued added" forecasts of the times and locations of convective storm development. Incorporating these climatological data into the IFPS/GFE provides much needed assistance to the meteorologist faced with the challenge of making detailed forecasts of summertime convection in areas of sea breeze development.

2. DATA AND METHODOLOGY

2.1 Lightning Data

In full operation since 1989, the NLDN detects and records cloud to ground (CG) lightning flashes over the continental United States and immediate coastal waters. This network, owned and operated by Vaisala Inc., provides detection data to a variety of commercial, government, educational, and public entities. The data are archived locally in the NWS WFO Tallahassee's Advanced Weather Interactive Processing System (AWIPS). Lightning data from the months of May to September 1989-2003 (15 years) were used in this study. Flash densities and lightning frequencies were constructed on a 2.5-km grid for the entire state of Florida and surrounding coastal waters.

2.2 Upper-Air Data

Rawinsonde data were used to categorize each day of the period according to the prevailing low-level flow. The mean vector wind in the 1000 to 700 hPa layer was computed each day using the 1200 UTC Tallahassee sounding. As shown in previous studies (López and Holle 1987; Camp et al. 1998; Lericos et al. 2002), the flow within this layer provides a good indication of sea breeze and thunderstorm movement during the warm season. The NWS Tallahassee County Warning Area is depicted in Fig. 1 with flow regimes identified. The flow regimes are divided into four major directions (east, south, southwest, and northwest), which are further subdivided into moderate and strong flow (Table 1). For flow regimes with wind speeds less than 5 kt, a calm flow regime also is included.

Table 1. Divisions of low-level (1000-700-hPa) mean vector wind speed.

Calm	< 5 kt
Moderate	5-10 kt
Strong	> 10 kt

2.3 IFPS and GFE

To input the lightning climatology into GFE, the lightning climatology grid positions are assigned values of latitude and longitude. A python script is then executed that opens the file, reads the data, and maps the lightning data as a grid in the GFE spatial editor, making the conversion from latitude/longitude to AWIPS world coordinates as used in GFE.

It is too time-consuming to compute the lightning grids each time they are requested in GFE. The solution was to use the saveObject and getObject python methods in GFE that allow a grid file to be saved once and accessed when required. This allows the creation of the lightning weather elements for given periods and flow regimes, which can be retrieved on demand. The forecaster can then request any lightning flow regime desired into the correct time period using a locally developed GFE procedure.

3. LIGHTNING FREQUENCIES

The concept of thunderstorm day was first identified in the literature by Alexander (1935). A thunderstorm day is defined as a 24-hour period during which thunder is heard at least once at the observation site. Watson and Holle (1996) modified the idea of thunderstorm day by relating it to lightning data. Their definition was the occurrence of one lightning flash within a grid square (2.5 x 2.5 km grid in this case) per day. Building upon the thunderstorm day concept, a frequency of occurrence, or probability of lightning within a grid square, was computed by dividing the thunderstorm day total by the number of days within the wind regime. For example, the southwest (moderate) regime contains 218 days during our 15 years of warm season data. If, for example, 90 of those 218 days recorded one lightning flash in a particular gridbox, the probability of lightning in that gridbox for this regime is 41%. This determination of frequency could be calculated on a daily or hourly basis, or in the case of probability of precipitation (POP) forecasts, for 12 hours or 6 hours.

Most precipitation in Florida during the summer is a result of thunderstorm activity. It then follows that the frequency, or probability, of lightning can be a surrogate for the probability of precipitation. If one assumes that the synoptic situation is not disturbed, and only normal summertime convective development is expected, the climatological lightning grids could be used as guidance to populate the GFE POP grids.

3.1 Daily Wind Regimes

The four moderate flow regimes and the calm flow regime for the Tallahassee NWS area are presented in Fig. 2a-d. All images are 24-hour composites. Cool colors denote lower lightning frequencies, while warm colors signify higher frequencies; orange and red begin at 15 %**.** In most of the flow regime composites, the greatest frequencies occur in the Florida peninsula, either on the east coast or the west coast depending on the flow regime. The lightning pattern is much simpler in the calm flow regime (Fig 2a), i.e., there is less wind to disturb the pattern, leaving only the influence of the land and sea. The higher lightning frequencies occur over land, while lower frequencies occur offshore over the Gulf of Mexico and Atlantic Ocean. Notice that the concave coastline produces lower lightning frequencies inland; convex coastlines produce higher frequencies.

The moderate flow regimes (Fig 2b-e and Table 1) also produce identifiable, reproducible patterns. There is a distinct difference in lightning patterns between the south (moderate) (Fig. 2b) and southwest (moderate) flow regimes (Fig. 2c). Southwest (moderate) flow generates lightning frequencies near and above 20 % along the Georgia and Florida Atlantic coast, while south (moderate) flow produces lower frequencies in that region. Conversely, in the south (moderate) flow regime, the peak in frequencies is further inland along the Georgia-Florida Atlantic coast. All moderate flow regimes produce higher frequencies in the Florida panhandle and Big Bend than in Georgia. Northwest flow (Fig. 2e) confines the highest lightning frequencies to a very narrow band along the Florida panhandle coast.

Strong flow regimes (not shown) are associated with mean vector winds greater than 10 kt (see Table 1). There is, however, no upper limit to these categories. The effect is to further disturb and blur the frequency patterns across a much larger area. During south flow (strong), lightning frequencies are quite uniform across the Florida panhandle, southwest Georgia, and southeast Alabama.

3.2 6-hourly Lightning Frequencies

Since the probability of precipitation (POP) was introduced to the public in 1966 (Roberts et al. 1967), its temporal scale has been 12 hours. The public, as well as NWS forecasters, have become accustomed to this time period. With the introduction of IFPS/GFE, and with hourly grids available for nearly every weather element, there has been an initiative in the NWS to reduce the temporal resolution of POPs from the original 12 hours, down to 6 hours or even 3 hours, to provide more detailed forecasts. At NWS Tallahassee, we produce 6-hourly POPs as well as 12-hourly POPs. We will illustrate how lightning frequencies vary over different 6 hourly intervals.

Since calm flow produces the simplest convective pattern, we will use that flow regime as an example (Fig. 3a-d) of 6-hourly frequencies. To put these images into a daily perspective, we begin with the 1200-1800 UTC period (Fig. 3a), i.e., sunrise to noon or shortly thereafter. During this period, offshore, mostly nocturnal, convection reaches its peak and begins to weaken and dissipate. Onshore, the sea breeze develops a narrow band of higher lightning frequencies along the coast. The frequencies displayed during this period are not large by any measure. Between 1800-0000 UTC (Fig. 3b), sea breeze development coupled with deep convection are at a maximum. Lightning frequencies exceed 8 % in several locations in the panhandle and down in the Florida peninsula. This begs the question: How can these frequencies be related to POPs? Climatological POPs are near 40 % in this region (see Table 2). The answer is not simple and will require further investigation. There are grid resolution questions, as well as meteorological questions such as how lightning is related to rainfall.

Table 2. Climatolgical probability of precipitation (POPs) for July 15 for regional cities. All times UTC.

	00-12	12-00	24-h
Jacksonville, FL	16	38	44
Macon, GA	18	27	36
Orlando, FL	17	49	55
Montgomery, AL	17	29	38
Tallahassee, FL	18	44	51
Tampa, FL	20	41	50

Figure 3c describes the situation between 0000-0600 UTC. Much of the coastal area (Florida Big Bend) is devoid of measurable lightning. The Florida east coast sea breeze has moved into north central Florida. Again, these frequencies are very low. Finally, between 0600-1200 UTC (Fig. 3d), the only measurable frequencies are over water, with no activity over land.

With some imagination, the reader should be able to visualize how a forecaster would use these lightning frequencies as guidance to construct POP grids that look similar, both temporally and spatially, to the lightning frequencies. We will examine this further in section 5.

3.3 Florida Peninsula

Lericos et al. (2002) introduced a somewhat novel approach to lightning climatologies. He devised his climatotogy according the location of the Atlantic ridge axis, i.e., locating the east-west ridge axis with respect to Florida rawinsonde sites (Miami, Tampa, and Jacksonville). The objective of our current study has been to complete both this peninsula study as well as the panhandle study, and provide the results to the other Florida NWS offices. Since Lericos et al. (2002) published their study, we have added 5 more years of warm season lightning data, including 2004, producing a 16-year climatology for the Florida peninsula.

An example of lightning frequency for the Florida peninsula is shown in Fig. 4. This flash pattern occurs when the ridge axis is located south of the Miami upper-air site (MFL), with all 3 Florida rawinsonde sites showing southwest flow in the 1000 to 700 hPa layer. Notice that the greatest lightning frequencies are along the Florida east coast. This is a very important forecast consideration.

Figure 5 shows the lightning activity over 6-hourly periods (0000-0600, 0600-1200, 1200-1800, and 1800-2400 UTC). Important features include nocturnal offshore convection, the lack of convection in the early morning hours over land, the beginning of sea breeze-induced convection along the west coast in the morning, and the tremendous burst of afternoon convection along the east coast.

4. GFE AND LIGHTNING CLIMATOLOGIES

The AWIPS Forecast Preparation System (AFPS) was developed at the NOAA Forecast Systems Laboratory (FSL) in Boulder, Colorado, and at the National Weather Service (NWS) Meteorological Development Laboratory (MDL) in Silver Spring, Maryland. Mathewson (1996) and LeFebvre (1996) and LeFebvre et al. (1996) first described the IFPS and GFE system.

With the cooperation of FSL, NWS WFO Tampa (reported by Watson et al. 2003) undertook ground-breaking work to make climatologies available within GFE. Problems were encountered, making the use of netCDF map projections unusable. However, using a simple Python input script written by Tim Barker, Science and Operations Officer (SOO) at WFO Boise, ID, success was finally achieved.

To use the lightning climatologies in GFE, a weather element LTG is defined and used to populate the 6-hour grids. Activity during Northwest (moderate) flow is depicted via the GFE interface in Fig. 6(a-d). On the right side of each image, one window provides the name of the regime, the number of days in the regime, and the 6-hour time period. Above the spatial editor is the lightning frequency color scale (0-30 %). The highly diurnal nature of convection and lightning again is evident, with the largest frequencies occurring between 1800-0000 UTC (Fig. 6d).

5. FORECAST EXERCISE

The following example illustrates how the lightning climatologies can be used within GFE. We assume that on a particular summer day the forecast guidance indicates that the low-level flow is northwest (moderate). We also assume that there is a relationship between lightning frequencies and POPs. Tentative investigations reveal that there is a factor of 2 difference between lightning frequencies and POPs for this flow regime. These results are shown in Fig. 7. For clarity, only the GFE spatial editor is shown. In the period between 1200-1800 UTC (Fig. 7a), there is a slight chance (20 %) of showers and thunderstorms along the coast and over the coastal waters. For comparison, summertime climatological POPs for various sites are given in Table 2.

As maximum heating occurs during 1800-0000 UTC (Fig. 7b), northwest winds obstruct and restrict the inland progress of the sea breeze confining it mainly to the coastal zone of Florida. Arbitrarily multiplying the lightning frequencies by a factor of 2 gives reasonable 30 % POPs in the Florida panhandle, 20 % POPs in Alabama and Georgia, and 40-50 % POPs down in the Florida peninsula.

It is apparent that tools could also be developed to populate POPs directly from the climatological lightning grids. The POPs can then be adjusted up or down depending on available moisture above or below normals for the particular flow regime.

6. SUMMARY AND CONCLUSIONS

The development of IFPS has produced a paradigm shift in the way the NWS makes forecasts. Converting from writing text to modifying gridded forecasts opens the door to unlimited possibilities of new products and uses. This paper demonstrates that forecasts can be made from climatologies imported into GFE.

A concentrated effort should be made to develop a national climatology database of GFE weather elements. Such a database could be incorporated as a permanent “model” database with which other guidance could be blended and compared. Climatologies are a powerful tool for the medium range forecast because they make the forecaster more aware of normal conditions for a particular time of year. They also give forecasters a good indication of how much their proposed forecast deviates from normal. It could be very desirable for NWS offices to use climatological databases as a common reference point especially in the summer season.

7. ACKNOWLEDGMENTS

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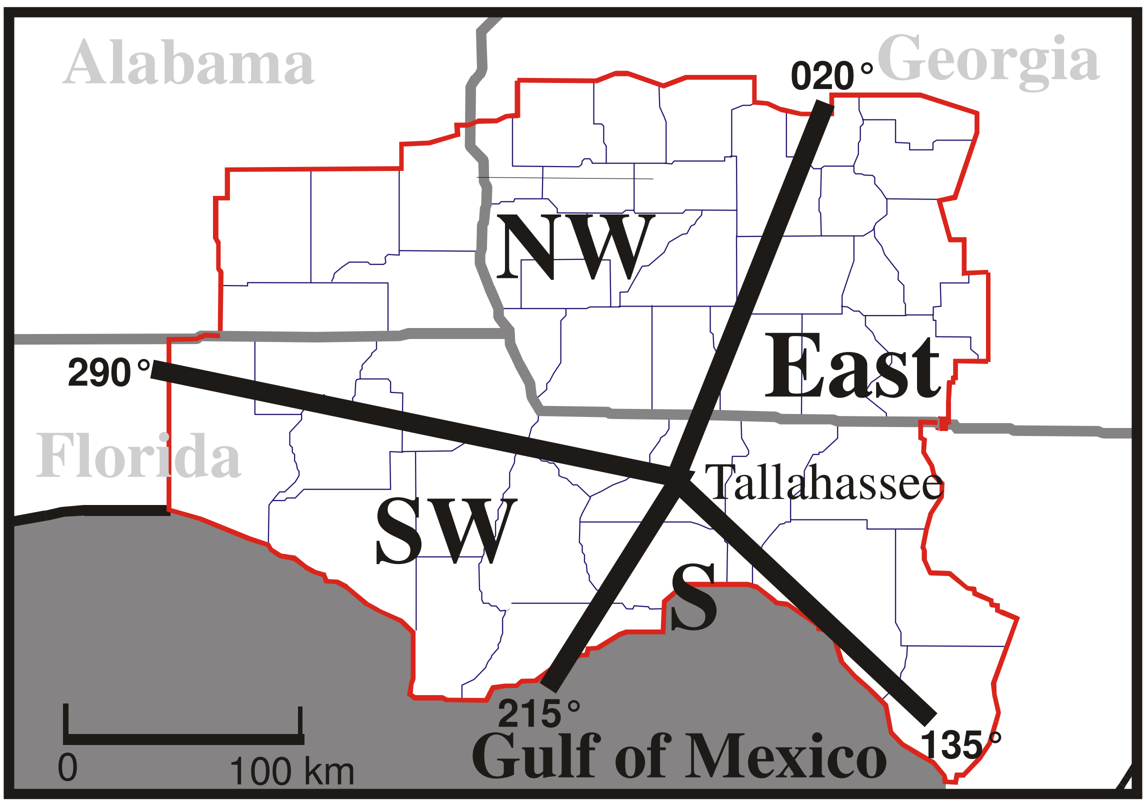


Figure 1. NWS Tallahassee County Warning Area (outlined in red) and divisions for the four principal flow directions (E, S, SW, NW). Each direction is divided into moderate and strong flow. A calm flow regime is also included for a total nine flow regimes.

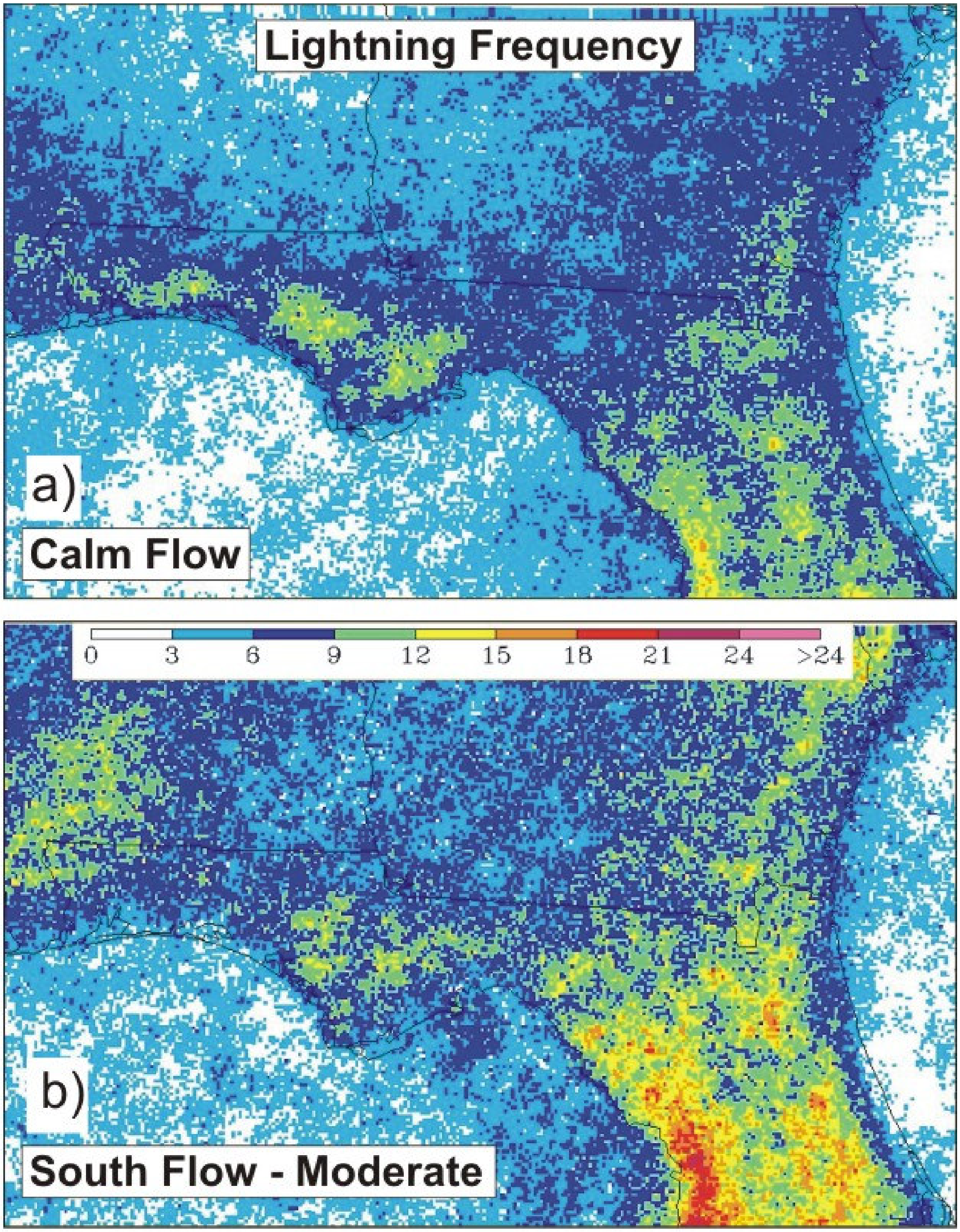
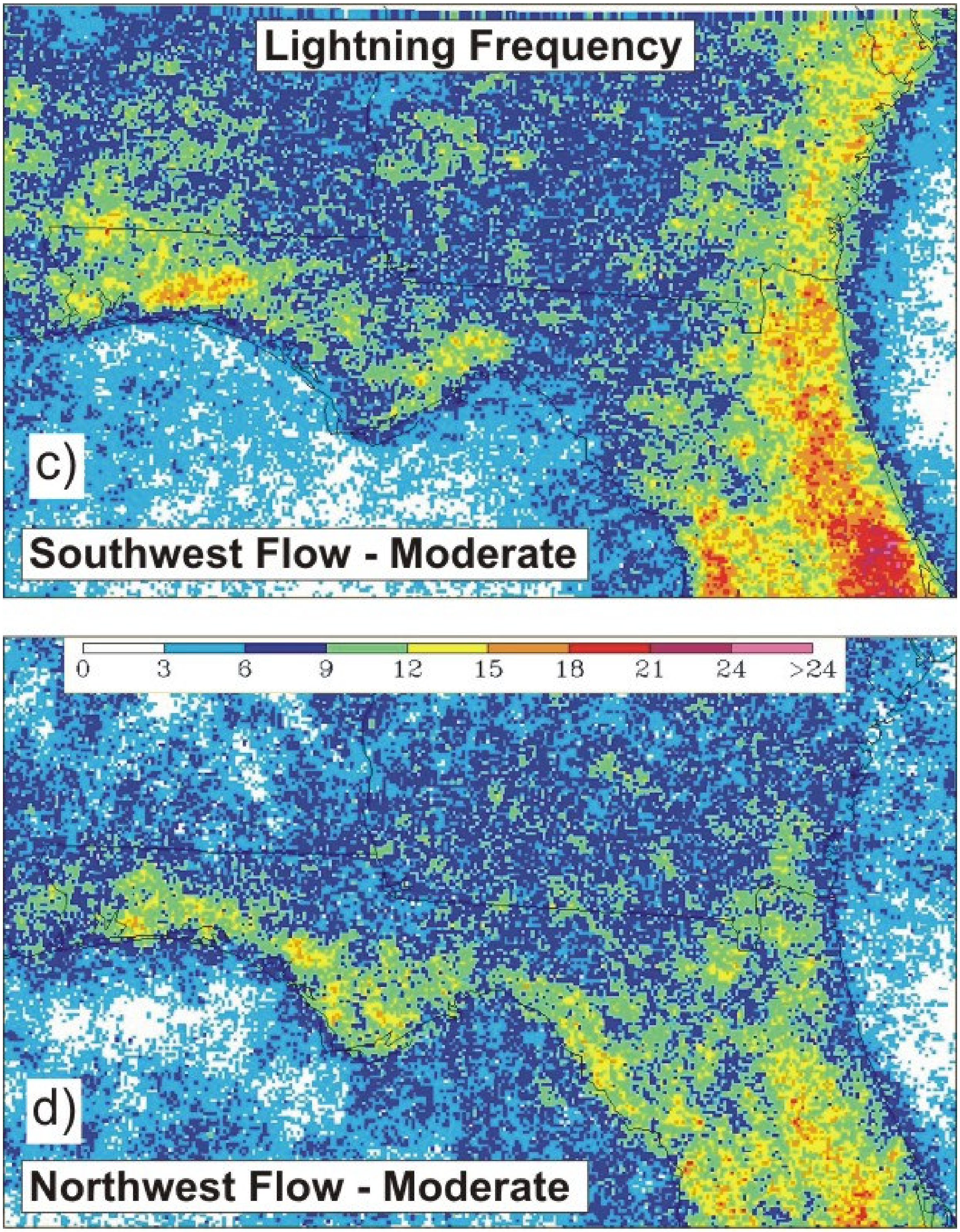


Figure 2. 24-hour lightning flash frequencies (%) for the period 1989-2003 for (a) calm flow, and the moderate (b) south, (c) southwest, (d) northwest, and (e) east wind regimes.



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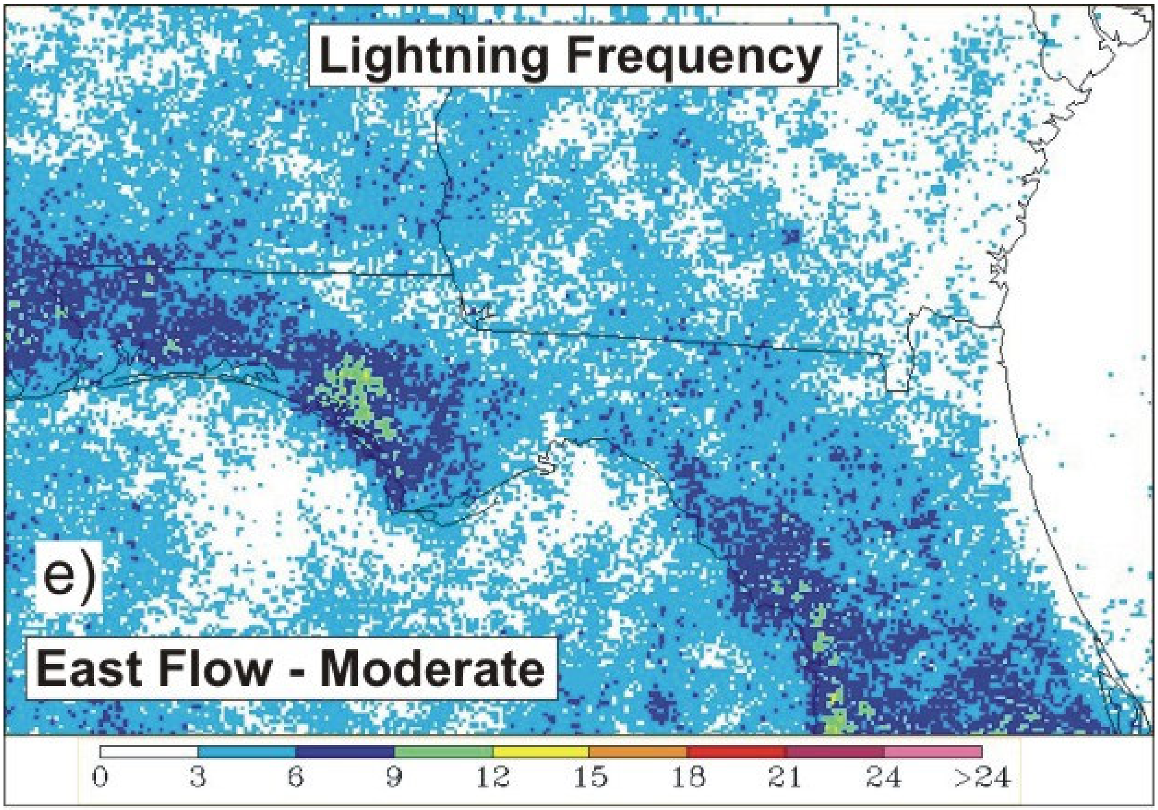

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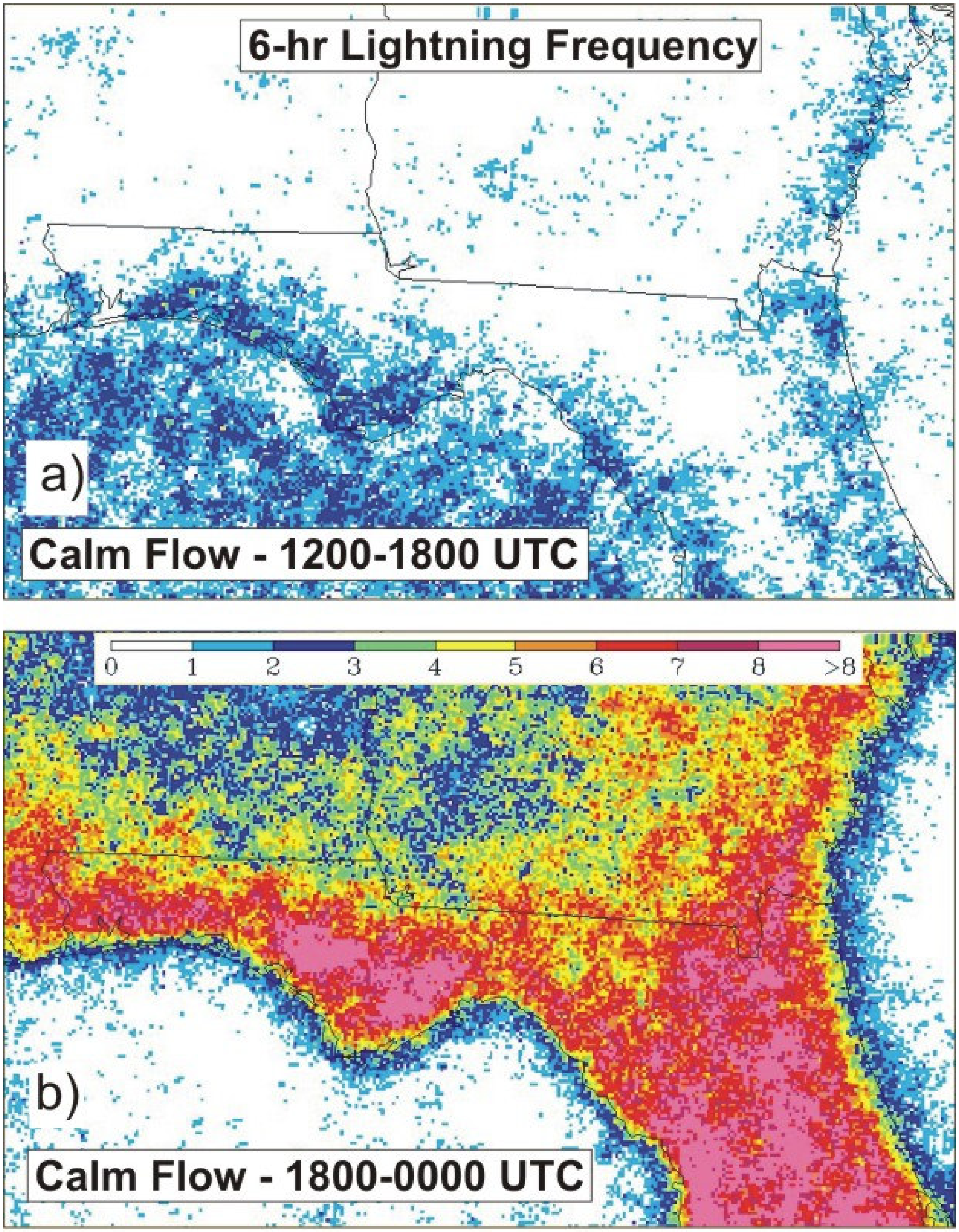
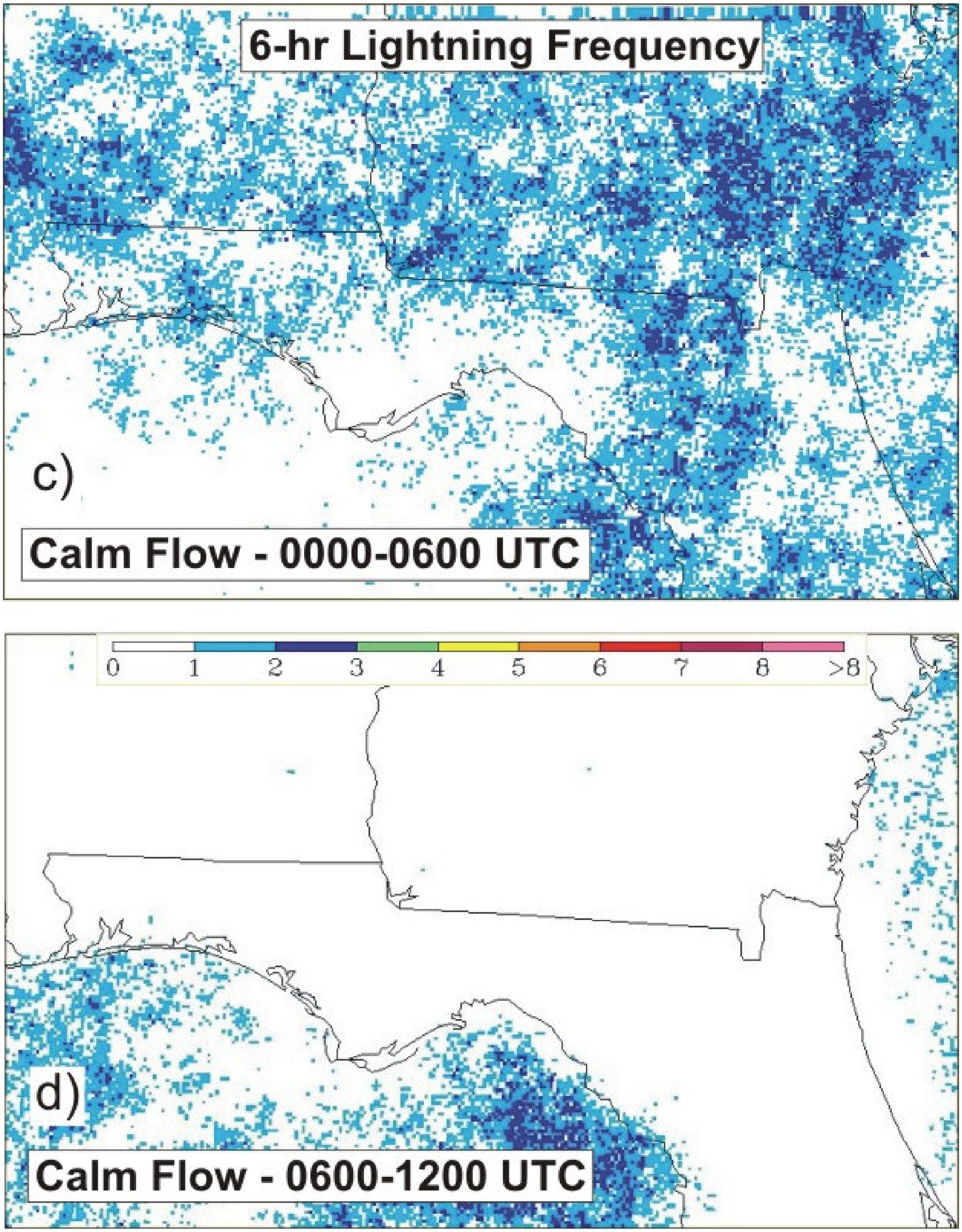


Figure 3. 6-hour lightning flash frequencies (%) for the calm flow regime for the period 1989-2003; (a) 1200-1800 UTC, (b) 1800-0000 UTC, (c) 0000-0600 UTC, and (d) 0600-1200 UTC.



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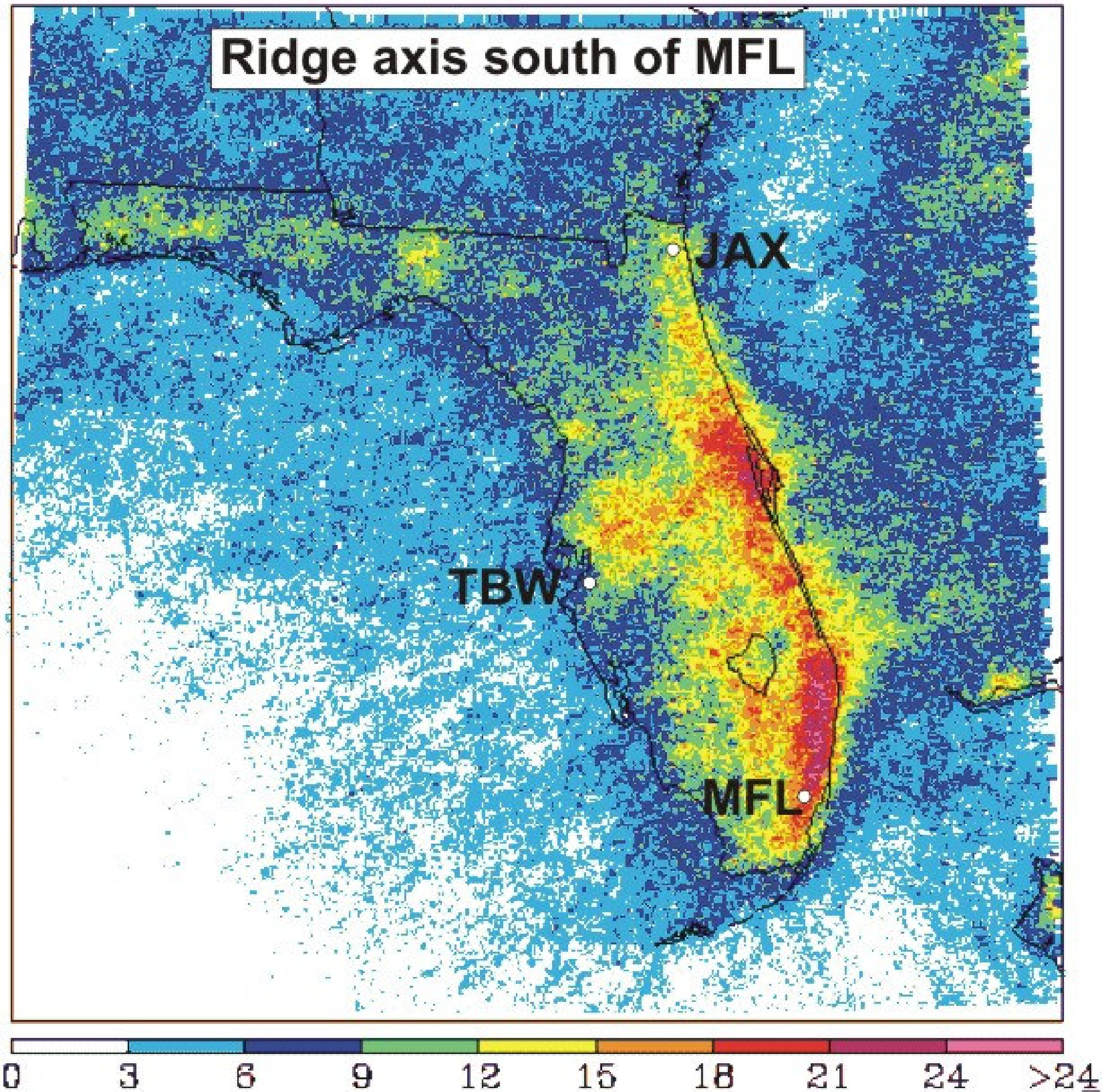


Figure 4. 24-hour lightning flash frequencies (%) for the ridge axis south of Miami (MFL), for the period 1989-2004.

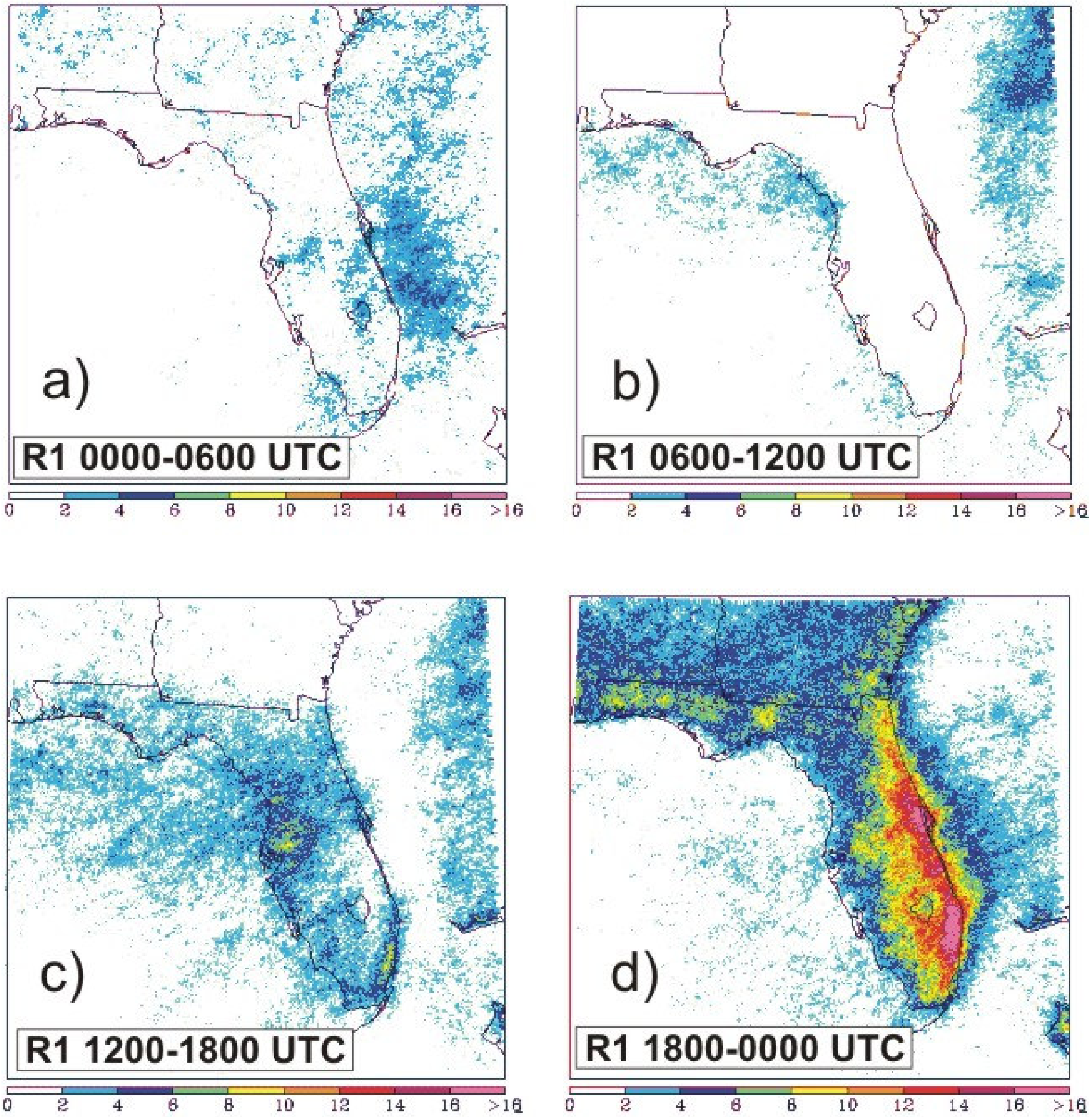


Figure 5. 6-hour lightning flash frequencies (%) for the ridge axis south of MFL, for the period 1989-2004; (a) 0000-0600 UTC, (b) 0600-1200 UTC, (c) 1200-1800, and (d) 1800-0000 UTC.

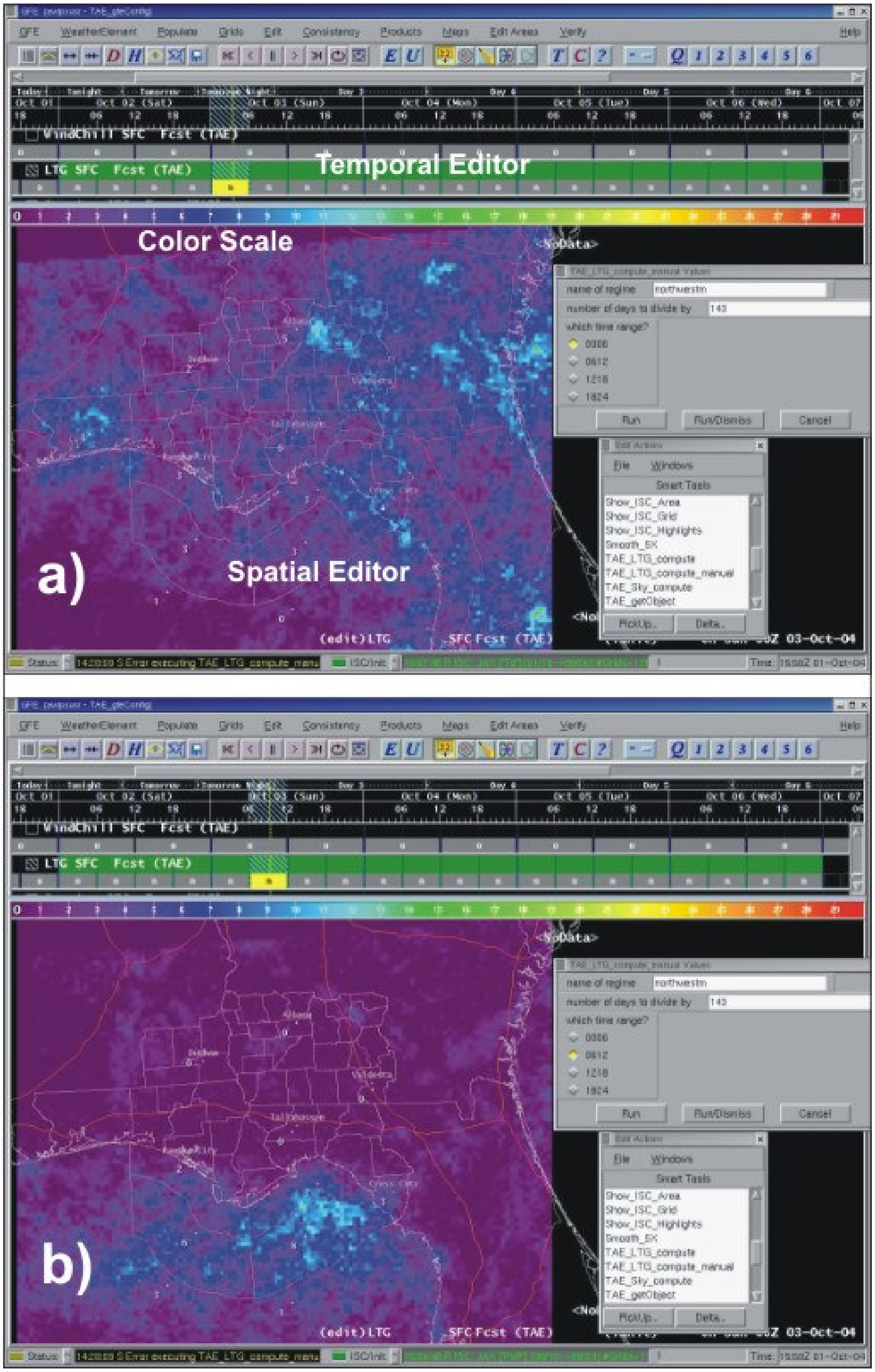
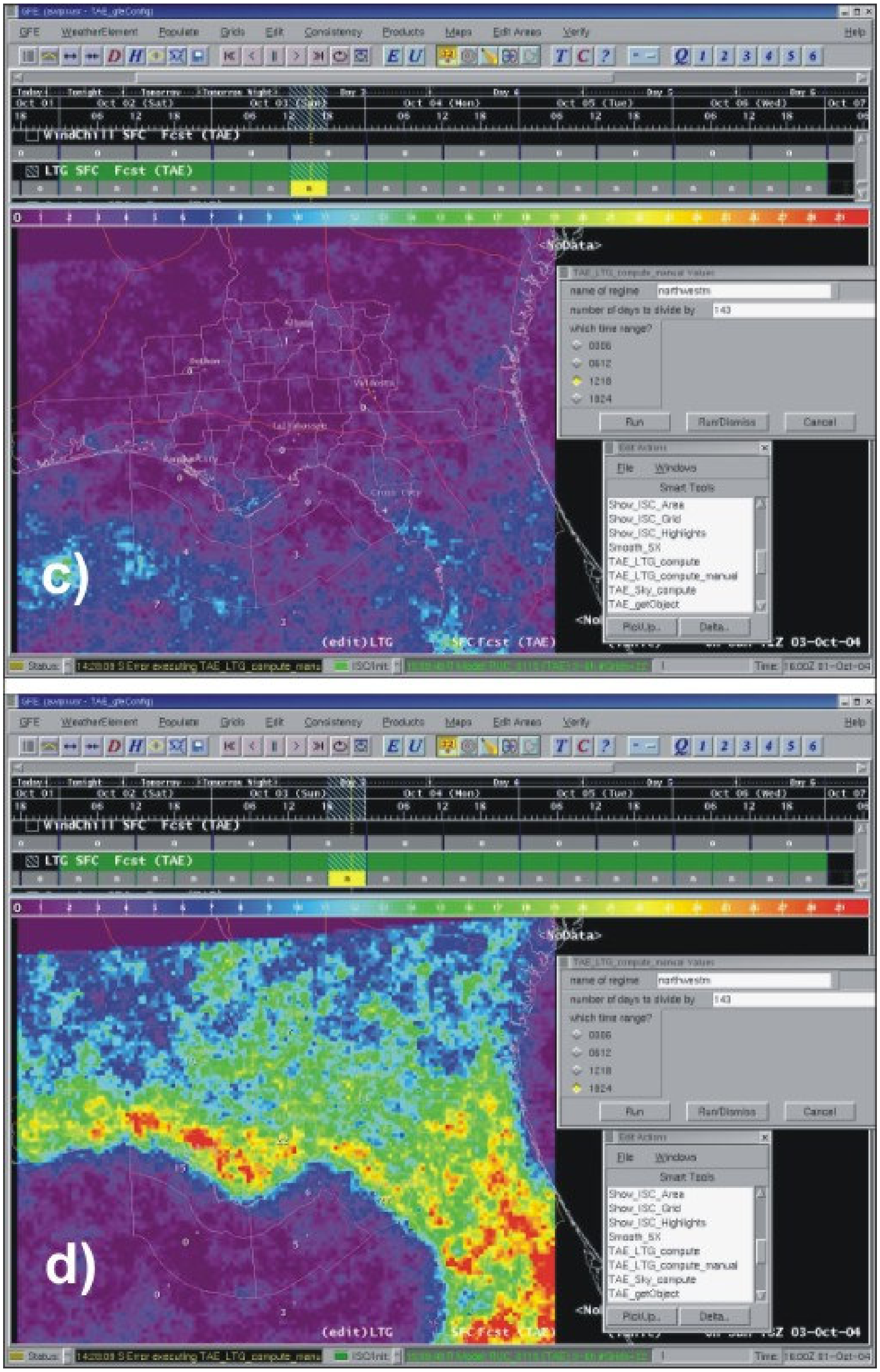


Figure 6. GFE display of 6-hour lightning flash frequencies (%) for the northwest (moderate) flow regime for the period 1989-2004; (a) 0000-0600 UTC, (b) 0600-1200 UTC, (c) 1200-1800, and (d) 1800-0000 UTC.



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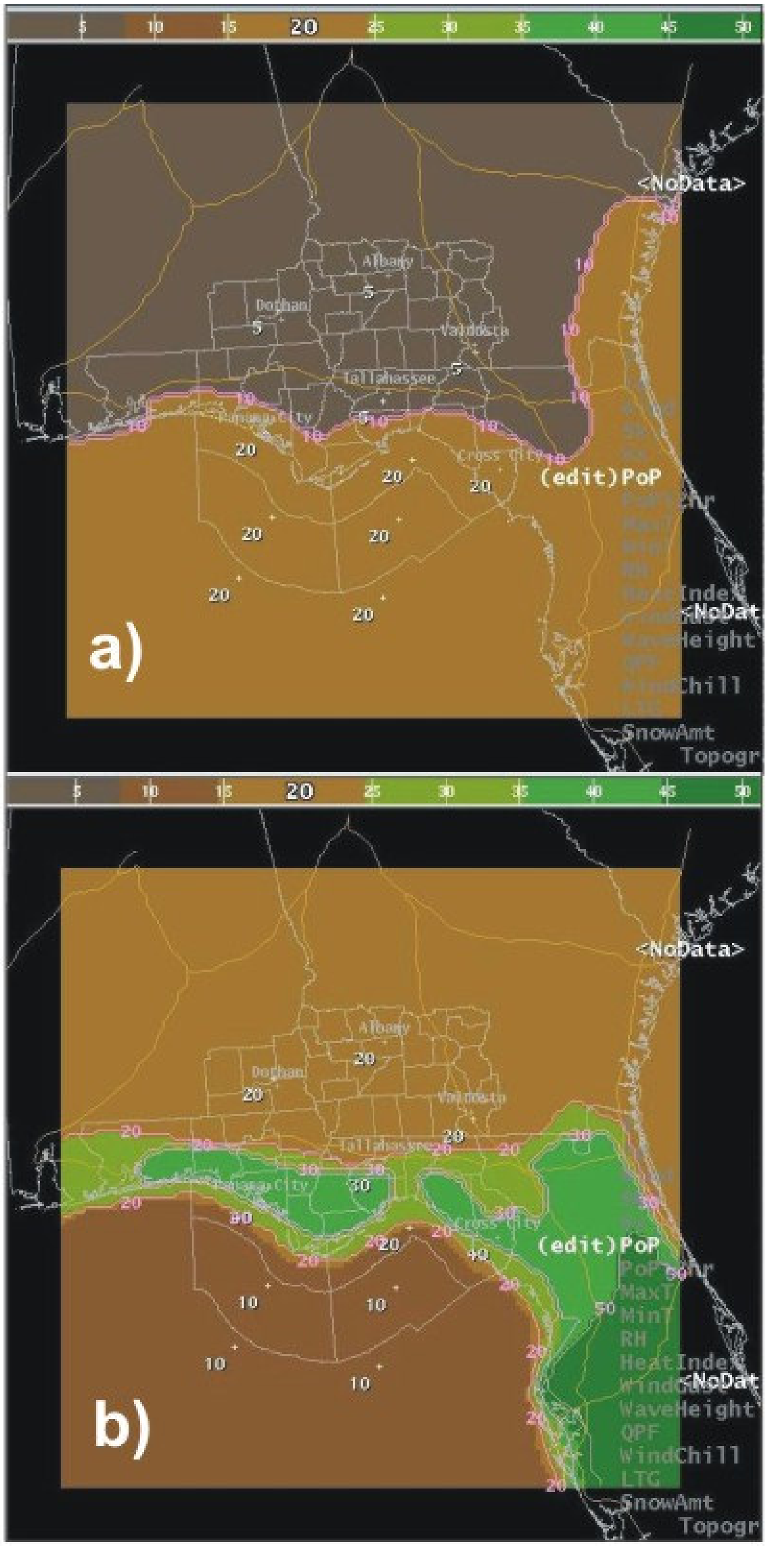

Figure 7. GFE spatial editor display of 6-hour POP (%) using the northwest (moderate) flow regime as guidance; (a) 1200-1800 UTC, and (b) 1800-0000 UTC.