P2.1

USING FLOW REGIME LIGHTNING AND SOUNDING CLIMATOLOGIES TO INITIALIZE GRIDDED LIGHTNING THREAT FORECASTS FOR EAST CENTRAL FLORIDA

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1. INTRODUCTION

The forecasters at the National Weather Service in Melbourne, FL (NWS MLB) produce a cloud-to-ground (CG) lightning threat index map for their county warning area (CWA) that is posted to the URL

http://www.srh.weather.gov/mlb/ghwo/lightning.shtml.

The lightning threat index map is issued for the 24-hour period beginning at 1200 UTC (0800 AM EDT) each day at a grid resolution of 5 x 5 km. The map from 3 July 2004 is shown in Figure 1 as an example.

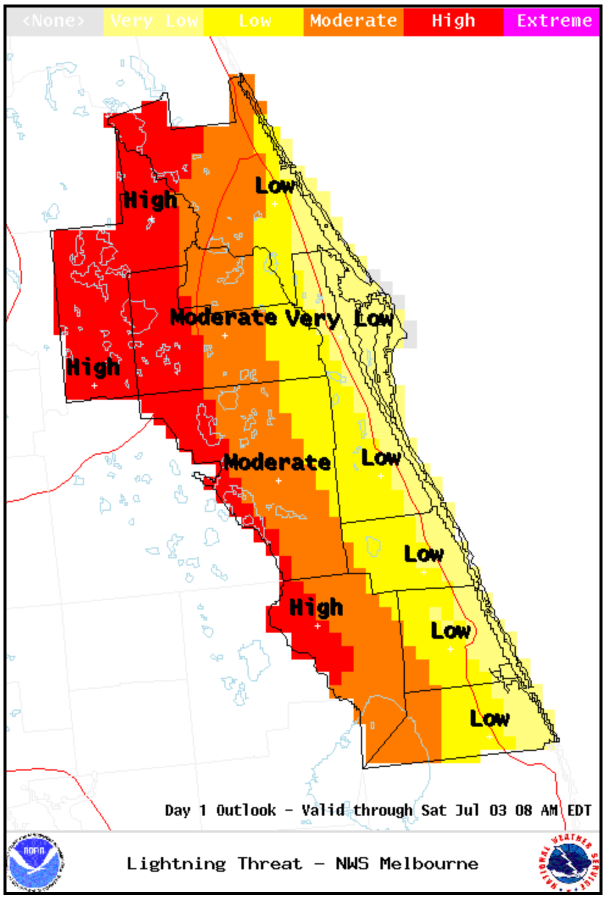

Figure 1. An example of the lightning threat index map issued daily by NWS MLB. The color legend for each threat level is shown at the top of the image.

Florida is the lightning capitol of the United States. More deaths are caused by lightning in the state than any other weather phenomenon (Figure 2). Given the hazardous nature of lightning in east-central Florida, especially during the warm season months of May–September, these maps help users factor the threat of CG lightning, relative to their geographic location, into their daily plans (Sharp 2005).

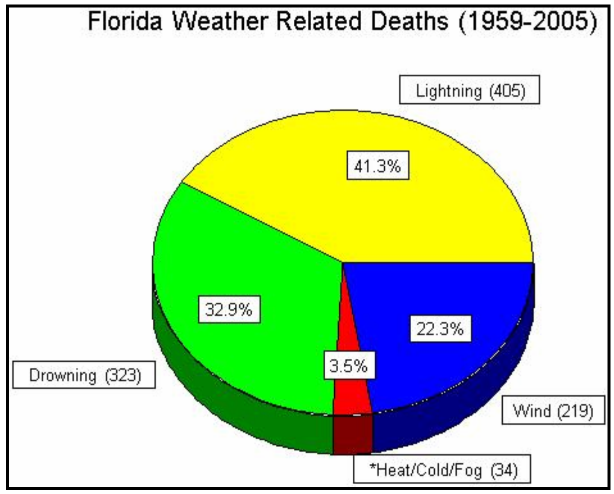

Figure 2. This pie chart shows the percentage of deaths caused by weather phenomena in Florida in the 47-year period 1959–2005.

The maps are color-coded in five levels from Very Low to Extreme, with threat level definitions based on two parameters:

- The likelihood of CG lightning occurrence and
- The expected amount of CG activity.

On a day in which thunderstorms are expected, there are typically two or more threat levels depicted spatially across the CWA, as seen in Figure 1. The locations of relative lightning threat maxima and minima often depend on the position and orientation of the low-level ridge axis, forecast propagation and interaction of sea-breeze/lake-breeze/outflow boundaries, expected evolution of moisture and stability fields, and other factors that can influence the spatial distribution of thunderstorms over the CWA.

The NWS MLB forecasters prepare the maps using the Advanced Weather Interactive Processing System (AWIPS) Graphical Forecast Editor (GFE). They first create a first-guess map using the spatial lightning density and frequency climatologies described in Lambert et al. (2006), which are based on the large-

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scale flow regime (Lericos et al., 2002) over the Florida Peninsula. They then determine the final spatial distribution of the threat levels for the day by refining this map through a subjective analysis of all parameters related to thunderstorm formation.

To assist in this refinement when creating the final map, NWS MLB requested that the Applied Meteorology Unit (AMU) (Bauman et al. 2004) create climatological soundings for each flow regime at Miami (MFL), Tampa (TBW), Jacksonville (JAX), and Cape Canaveral Air Force Station (XMR), Florida. The forecasters will compare the observed and forecast soundings to the climatological soundings and refine the lightning threat areas based on the differences between them (Short 2006). This approach of using both the spatial and sounding climatologies will help increase forecaster efficiency in creating the map, improve consistency between forecasters, and enable the MLB forecasters to focus on other mesoscale details of the forecast.

2. BACKGROUND

Several studies have taken place whose results have direct relevance to this work. The framework of this task was built upon these results.

2.1 Previous Related Work

Lericos et al. (2002) identified major synoptic-scale flow regimes over the Florida peninsula and found a strong relationship between the regimes and the distribution of CG lightning over Florida. The flow regimes were determined from the MFL, TBW, and JAX soundings and the lightning distributions were determined using gridded CG lightning data from the National Lightning Detection Network (NLDN) (Cummins et al. 1998). Lambert and Wheeler (2005) used these flow regimes as predictors of CG lightning over Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS). The flow regimes were shown to have a large influence on the probability of lightning occurrence in the local KSC/CCAFS area.

Flash densities and frequencies of occurrence for each flow regime in the years 1989-2002 were created on a 2.5 x 2.5 km grid by Stroupe (2003). Figure 3 shows the distribution of daily (24 hour) lightning occurrence frequency for southwesterly to westerly flow over the peninsula, calculated by dividing the number of days with lightning occurrence by the number of flow regime days. Note the clear distinction of high values along the east coast and lower values along the west coast. This is due to the influence of the larger scale flow pattern on the inland propagation and interaction of peninsular-Florida's two sea breezes: the east coast sea breeze from the Atlantic Ocean, and the west coast sea breeze from the Gulf of Mexico. In this case, the west coast sea breeze will propagate across the state while the east coast sea breeze propagates very little, setting up a zone of convergence along the east coast.

Lambert et al. (2006) built on the results of Lericos et al. (2002) and Stroupe (2003) by creating two types of gridded climatologies based on flow regime: CG lightning densities and frequencies of occurrence. The images in Figure 4a-b are the climatologies for the flow regime in which the low-level ridge extending eastward from the Atlantic Ocean anticyclone is south of TBW and north of MFL. The goal for creating the two climatologies was to combine them to create a first-guess climatological lightning threat index map (Figure 5) for each flow regime. The forecasters at NWS MLB now use these first-guess maps to begin creating the lightning threat index map for the day instead of starting from a blank map, as they had done previously.

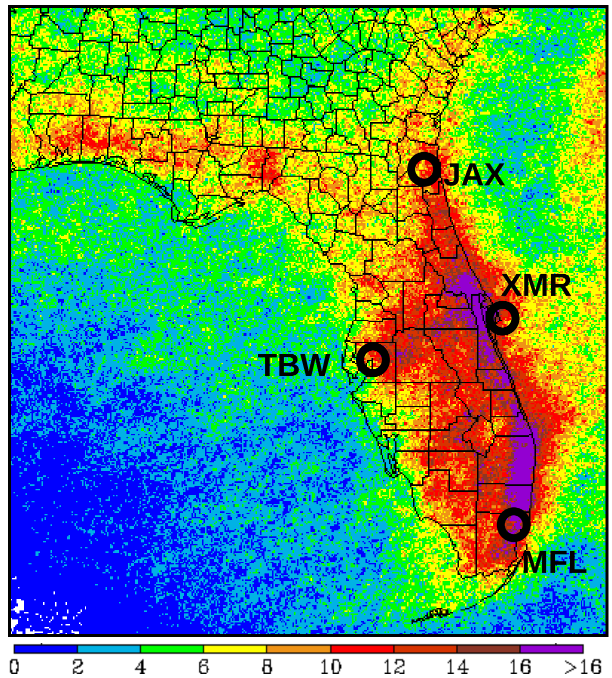

Figure 3. The distribution of daily CG frequencies of occurrence (percent) over Florida for southwest flow in the years 1989-2002 (Stroupe 2003). The locations of the soundings used in this study are indicated by the black circles.

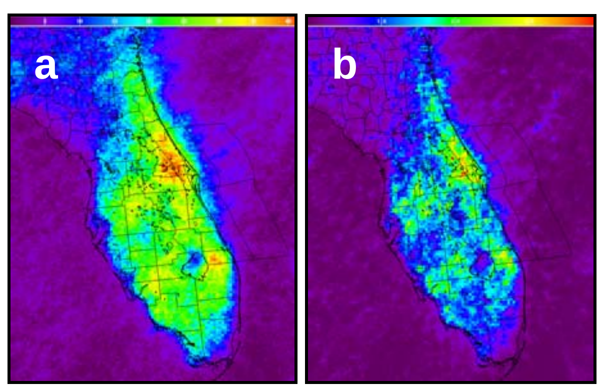

Figure 4. The climatologies of a) CG frequency of occurrence and b) CG density with the ridge axis between Miami and Tampa in the years 1989-2004.

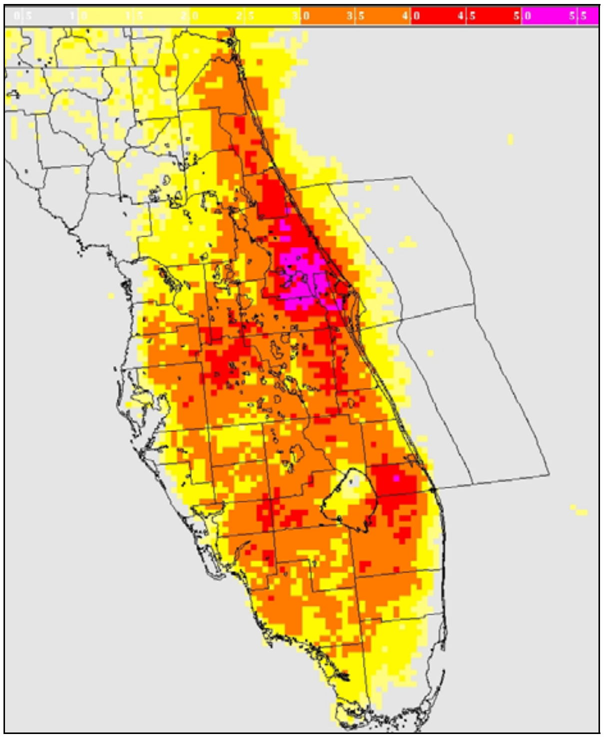

Figure 5. The first-guess lightning threat index map based on the climatological CG density and frequencies in Figure 3.

2.2 Current Work

As a follow-on to the creation of the flow regime climatologies and first-guess lightning threat index map (Lambert et al., 2006), the forecasters at NWS MLB requested flow regime-based climatological vertical profiles of temperature, dew point, and wind for the morning soundings at MFL, TBW, JAX, and XMR. After they establish the flow regime for the day through an analysis of observations, the forecasters can overlay the observed soundings on their corresponding climatological soundings to determine differences in moisture, stability, shear, and other parameters that could enhance or inhibit thunderstorm formation.

3. DATA

The two data-types needed for this task were the MFL, TBW, JAX, and XMR morning soundings and the dates of each flow regime occurrence. The period of record (POR) for the data was the warm seasons (May-September) in the years 1989-2004.

The JAX, TBW and MFL 1200 UTC soundings were used to create the climatological soundings because they are used to determine the daily flow regime. They are also more likely to capture the large scale low-level flow than the 0000 UTC soundings. The latter soundings could observe winds that have been contaminated by afternoon thunderstorms. The NWS MLB forecasters also requested climatological soundings for XMR since it is the only sounding location in their CWA. Due to 45 WS operational requirements, the morning sounding at XMR is released at the asynoptic time of 1000 UTC. This time was used because is the closest regularly scheduled XMR sounding to 1200 UTC.

The flow regime dates were the same as those used in Lambert et al. (2006). Those dates were provided by personnel at the NWS office in Tallahassee, FL and Florida State University (FSU). The flow regime, definitions, and the number of days in each are shown in Table 1. If the low-level wind directions at the three stations on a particular day did not fit the definitions of the first seven flow regimes in Table 1, it was grouped into the "Other" category. If one or more sounding was missing, a flow regime could not be calculated and the day was grouped into the "Missing" category.

Table 1. This table contains the flow regime names, their definitions, and the number of days each occurred during the POR.

Names	*Definitions*	*# Days*
SE-2	Ridge north of Florida	225
SW-1	Ridge south of Florida	271
SE-1	Ridge btwn TBW and JAX	312
SW-2	Ridge btwn TBW and MFL	242
PAN	Ridge over Panhandle	111
NW	Peninsular NW flow	94
NE	Peninsular NE flow	172
Other	Undefined Regime	828
Missing	Missing sounding	193

4. DATA PROCESSING

The soundings included data at 12 mandatory levels from the surface to 100 mb: 1000 mb, 925 mb, 850 mb, 700 mb, 500 mb, 400 mb, 300 mb, 250 mb, 200 mb, and 150 mb. These levels provide an average vertical resolution of approximately 5000 ft (1525 m), from the surface to 55 000 ft (16.8 km). The soundings also included significant level data to describe notable variations in temperature, dew point, wind speed, or wind direction between the mandatory levels.

4.1 Vertical Interpolation

The number and pressure of the significant levels varied by day and location. In order to create consistent levels for the mathematical averaging, and to produce climatological profiles with sufficient vertical resolution to depict important features, the levels in all of the soundings were interpolated to a resolution of 25 mb. The interpolated soundings had an average vertical resolution of approximately 1500 ft (460 m).

4.2 Compositing

After the soundings were interpolated to 25-mb intervals, they were stratified by station and flow regime. Composite soundings were produced for each station and each flow regime by averaging temperature, water vapor mixing ratio, and the u- and v-wind components. Water vapor mixing ratio was calculated from the dew point at each level in the interpolated soundings. After averaging the mixing ratios, an average dew point was computed from the average mixing ratio. This procedure was followed because water vapor mixing ratio is the thermodynamic variable of interest and the relationship between dew point and water vapor mixing ratio is non-linear. The average wind speeds and directions were computed from the u- and v-wind components.

5. SOUNDING DISPLAY

The National version of the Skew-T Hodograph Analysis and Research Program (NSHARP; Hart and Korotky 1991) is a software package designed to ingest, analyze, and display sounding data. The NWS MLB forecasters requested that the AMU format the composite soundings for ingest, analysis and display by their NSHARP system.

Figure 6 shows the NSHARP display of the XMR composite sounding for the SE-1 flow regime. In addition to the “Parcel Data” and “Thermodynamic Data” shown on the right-hand-side of Figure 6, the NSHARP analysis package provides several optional graphical and text displays, as indicated by the eight-button panel under the RAOB panel. The “NEXT PAGE” button brings up detailed analyses of low level stability, storm relative motion, the mean wind in several layers, environmental shear, convective initiation, storm type, severe potential, precipitation type and a hodograph analysis. The NSHARP software also provides an ability to edit temperature and dew point profiles graphically, with an instant update to stability parameters and thermodynamic variables.

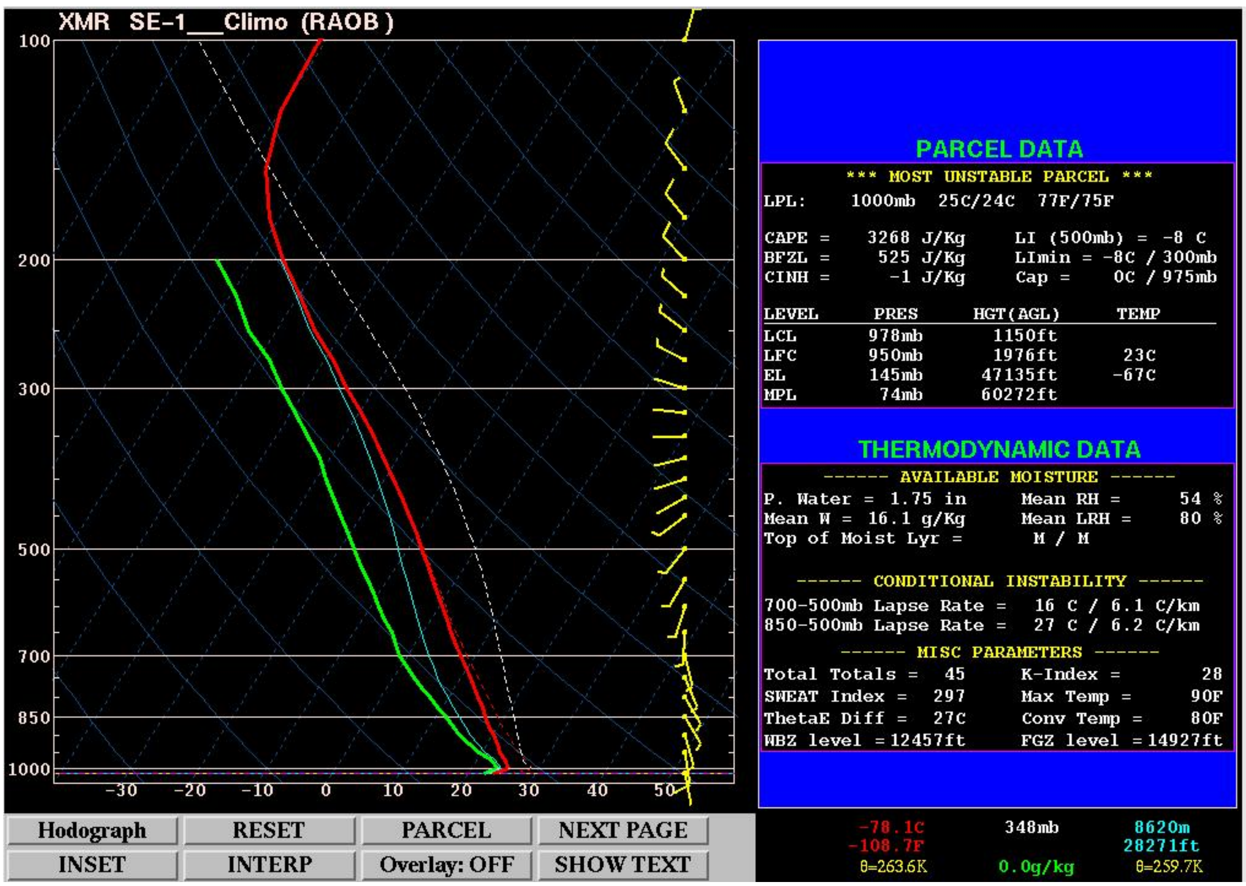

Figure 6. An NSHARP display of the climatological sounding from XMR for the SE-1 flow regime. The temperature profile versus pressure is depicted by the red line, dew point by the green line, and wet-bulb temperature by the blue line. The dashed white line shows the temperature profile of a saturated parcel rising moist adiabatically from 950 mb to 100 mb. The average wind speed and direction profile is shown by the yellow wind barbs on the right-hand-side. The panel on the right-hand-side shows stability parameters and other thermodynamic variables computed from the sounding.

6. CASE STUDY

The sounding climatologies were delivered to NWS MLB forecasters at the beginning of the 2006 warm season, and were used with success in several instances. Their usefulness in one particular case, on 13 July 2006, will be shown as a demonstration.

On this particular day, the low-level ridge axis extending westward from a high over the Atlantic Ocean was north of JAX, representing the SE-2 regime (Table 1) and resulting in general southeasterly flow over the peninsula. Figure 7 shows the spatial distribution of the climatological lightning probability for this flow regime. Lightning occurrence tends to be concentrated on the west coast, with a maximum just north of Tampa Bay. The forecasters began by using this climatology as a background map to create the lightning threat index map for the day.

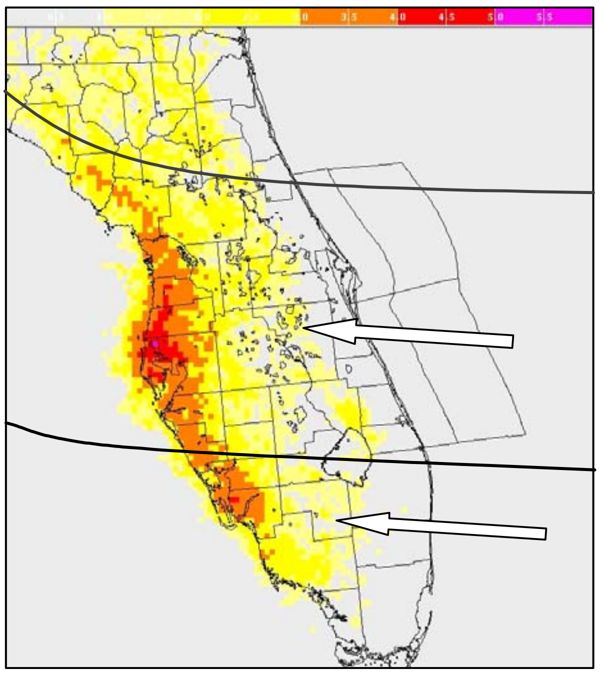

Figure 7. The 1800-2400 UTC climatological lightning probability for the SE-2 flow regime. The scale at the top indicates lower values for grey and light yellow, increasing to the right into the orange, red, and pink. The black lines represent isobars that define the ridge to the north, and the white arrows show the general flow over the peninsula.

The climatological soundings for XMR and TBW are overlaid on the observed 1200 UTC soundings (purple lines) for those locations in Figure 8a and b, respectively. The climatological thermodynamic and wind profiles are similar for both stations. Note the low-level southeasterly flow indicative of the SE-2 regime. The average low-level wind direction at all stations on this day varied between 110–130° with the ridge axis north of JAX.

The XMR sounding was clearly drier than climatology on this day, indicated by the dry layer between 800–450 mb. The temperature profile was similar to climatology, and just slightly warmer in the 750–400 mb layer. Table 2 shows the sounding moisture parameter precipitable water (PW), and stability parameters K-Index (KI) and Total Totals (TT) for the observed and climatological soundings. They show not only that it was drier at XMR, it was also more stable. The conditions at TBW were just the opposite. Except for a very shallow layer near 700 mb, the observed sounding was more moist than climatology. The observed temperature contour was only slightly warmer than climatology. The parameters in Table 2 bear out that this sounding was both more moist and more unstable than climatology.

Based on the spatial distribution of the lightning probabilities for this flow regime and the differences between the observed and climatological soundings, the forecasters created the lightning threat index map shown in Figure 9a. Even though map bears a strong resemblance to the climatological first-guess map in Figure 7, it was the comparison between the observed and climatological soundings that helped the forecasters create the final map. This forecast was verified with the NLDN data shown in Figure 9b.

Table 2. This table compares the sounding parameters PW, KI, and TT between the observed XMR and TBW 1200 UTC soundings on 13 July 2006 and their corresponding climatological soundings for the SE-2 regime.

Sounding Parameter	***XMR***		***TBW***	
	Obs	**Climo**	**Obs**	**Climo**
PW	1.65 in	1.81 in	1.98 in	1.73 in
KI	6	28	32	27
TT	42	44	44	43

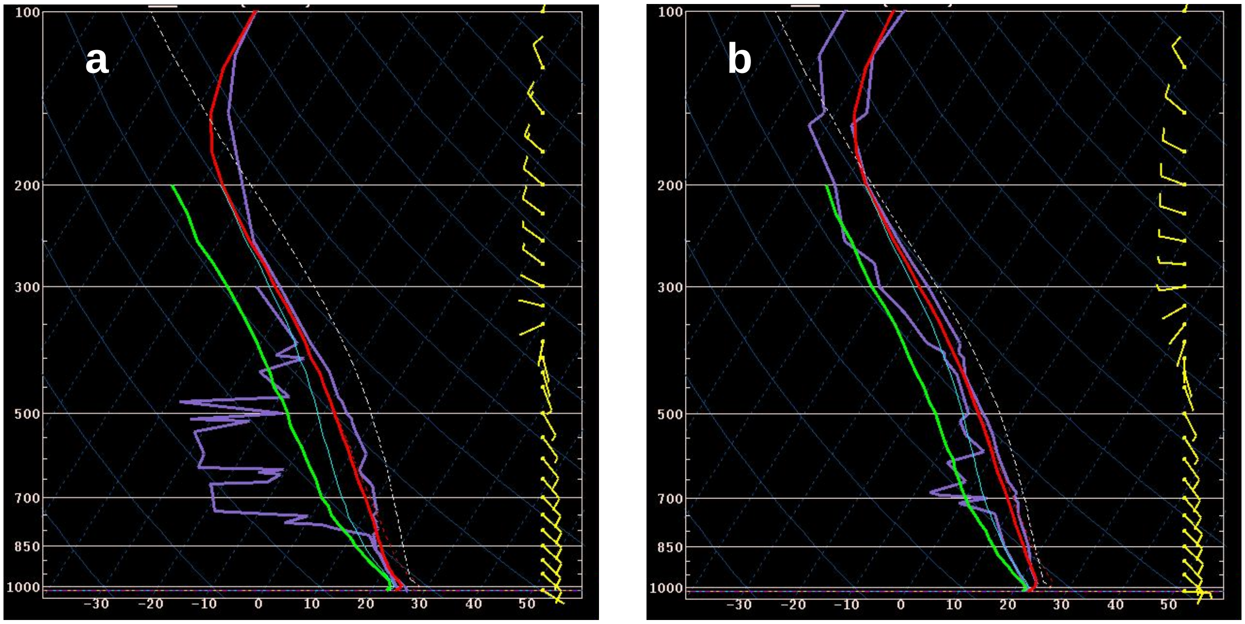

Figure 8. The climatological soundings overlaid on the 1200 UTC soundings on 13 July 2006 for a) XMR and b) TBW. The colors for the climatological soundings are the same as in Figure 6, the observed sounding temperature and dew point temperature profiles are in purple. The climatological wind profile is on the right.

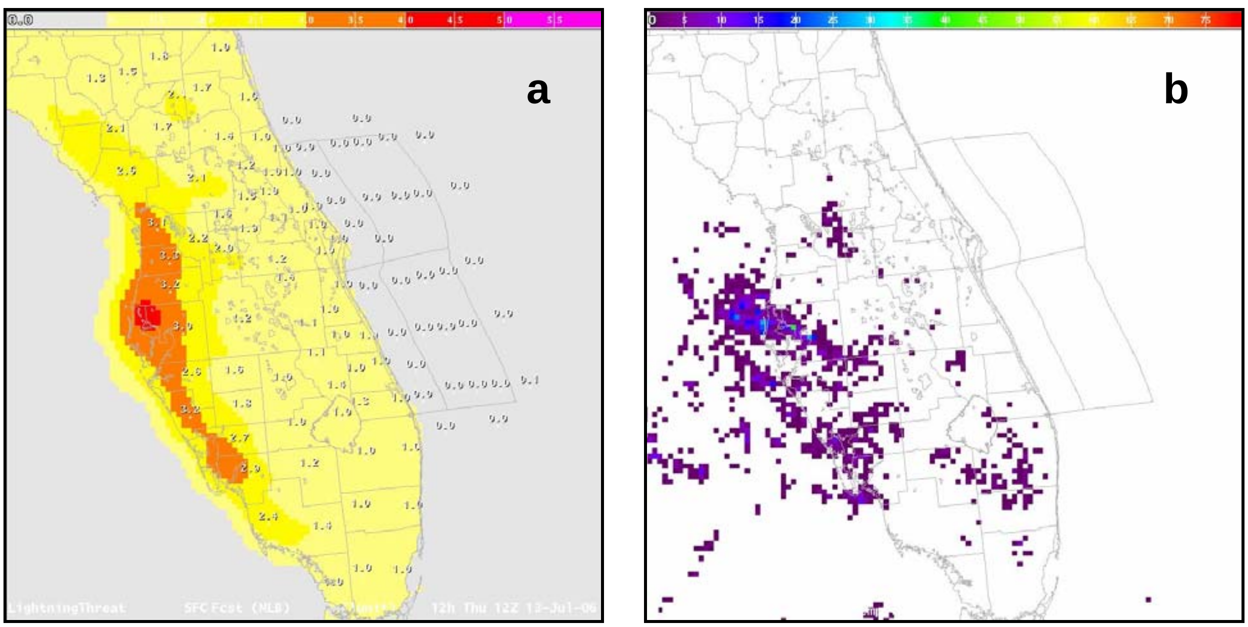

Figure 9. a) The lightning threat index forecast map and b) 5 km gridded lightning density observations from NLDN on 13 July 2006 (# strikes / 5 km^2 / 24 hours).

7. SUMMARY

Climatologies of CG lightning frequency and density based on flow regime were created by the AMU in Phase I of this work (Lambert et al. 2006) and used by NWS MLB forecasters to create a first guess climatological lightning threat index map. An example is shown in Figure 7. The forecasters modify this first guess map based on a subjective analysis of the observed and forecast parameters that affect thunderstorm formation.

The goal of the work described herein was to create climatological soundings based on flow regime as another tool the forecasters can use to adjust the first-guess map (Short 2006). The climatological vertical profiles of temperature, dew point, wind speed and direction were generated for each flow regime from daily morning soundings at JAX, TBW, MFL and XMR during the warm season, from a 16 year database spanning 1989-2004. Daily flow regime classifications, based on research at FSU, were the same as used in Phase I.

The resulting climatological soundings were formatted for analysis and display by NSHARP and were delivered to NWS MLB in June 2006 where they are now being used operationally to assist in creating the daily lightning threat index map.

While the NWS MLB creates these maps only for their CWA (see Figure 1), the 13 July case demonstrates the utility of the soundings. Had individuals planning outdoor activities in the Tampa area had access to a map like this, it would have at least made them think about changing their plans. More information about the lightning threat index map and how it is created, as well as the flow regimes and the resulting lightning climatologies, can be found at the URL:

www.srh.noaa.gov/mlb/amu_mlb/LTG/ltgclimothreat.htm

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