Experimental Lightning Advisories and Warnings
for Point Locations in East Central Florida

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1. Introduction and Background

Lightning kills or injures more people in Florida on an average annual basis than any other weather phenomenon (Hagemeyer and Carney, 1996). It frequently poses a threat to outdoor activities where afternoon storms can develop quickly and convection is often enhanced by the collision of sea breeze and outflow boundaries. According to Huffines and Orville (1999), Peninsular Florida experiences the highest annual frequency of cloud-to-ground (CG) lightning strikes, as well as the associated number of thunderstorm days, in the country. In particular, during the summer months the prevalence of deep convective lightning storms across East Central Florida (ECFL) highlights the need for advancing short-term, high-resolution lightning forecasts and warnings to help reduce casualties.

Since 1997, National Weather Service (NWS) forecasters at the Weather Forecast Office (WFO) in Melbourne (MLB), Florida, have issued Excessive Lightning Alerts (ELAs) for thunderstorms expected to achieve an average of twelve (12) CG strikes per minute, over a period of several minutes, occurring within ECFL (Sharp 2005). Issuing ELAs has proven to be somewhat helpful to people in downstream locations. Yet, it more directly addresses concerns for those who are well away from adequate shelter or concerns for increased property damage having greater opportunity to occur during peak CG periods of excessive lightning. To improve overall lightning services by addressing the problems of onset and cessation, MLB forecasters have sought to emulate lightning operations modeled after that of the United States Air Force (USAF) 45th Weather Squadron (45WS). The 45WS issues lightning watches and warnings for specific users at specific locations. Namely, these are the Cape Canaveral Air Force Station, Kennedy Space Center, Patrick Air Force Base, and Melbourne International Airport. This is all done in support of sensitive aviation and spaceflight operations. In a paper by

Weems et al. (2001), the authors acknowledged the difficulty in forecasting the initial CG strike with sufficient lead time. Consequently, the 45WS produces watches and warnings (in phases), accounting for any form of lightning (e.g., in-cloud, cloud-to-cloud, cloud-to-air, cloud-to-ground, etc.).

During June and July 2009, WFO MLB conducted a two month experiment to test similar capabilities for issuing CG lightning advisories and warnings for pre-determined point locations in ECFL. This paper will describe the methodology used by forecasters and will reveal examples of experimental text products which were produced. A case study will also be presented to illustrate the utility of the forecast process and to highlight potential benefits for specific users such as emergency managers during incident support situations, major airports in support of sensitive ground operations, or the general public relative to the concentrated amassing of people outdoors (e.g., life guards overseeing the safety of beach-goers at crowded beaches).

2. Product Description

Accurate short-term forecasts of CG lightning strikes have important safety implications for people engrossed in outdoor activities, especially during the summer convective season in Florida. Advanced notification is critical to allow sufficient time to find safe shelter before the onset of lightning. The challenges facing forecasters include producing accurate, timely, and articulate products with favorable lead-times, while simultaneously limiting false alarms. Striking such a balance aims to raise user response, while concurrently limiting the desensitization of user awareness.

During the summer of 2009, WFO MLB issued experimental lightning advisories (Figure 1) and warnings for point locations within MLB's County Warning Area (CWA). For this study, the Melbourne International Airport (KMLB) and Orlando International Airport (KMCO) were selected as the coastal and inland points of

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interest respectively. An advisory (phase 1) meant that CG lightning was expected to occur within five nautical miles of the point of interest. A warning (phase 2) signified the imminent likelihood of a CG strike within five nautical miles of the point of interest or that it was occurring. These products were produced with a desired 30-minute (10-minute) advisory (warning) lead-time. A buffer area having a radius of five nautical miles about the interest point was used to account for inherent uncertainties when attempting to locate forecast CG strikes, thereby improving safety. In practice, both the lead-time length and radius of the buffer area can be defined according to user demands.

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BULLETIN
PHASE ONE LIGHTNING ADVISORY
National Weather Service Melbourne FL
1600 UTC Tue Jul 07 2009

THE NATIONAL WEATHER SERVICE IN MELBOURNE HAS ISSUED A

* PHASE ONE LIGHTNING ADVISORY FOR...
  AREAS WITHIN A 5NM RADIUS OF...

* ORLANDO INTERNATIONAL AIRPORT

* FROM 1600 UTC TO 1745 UTC.

A PHASE ONE LIGHTNING ADVISORY MEANS THAT CLOUD TO GROUND LIGHTNING
STRIKES ARE EXPECTED TO DEVELOP WITHIN THE INDICATED AREA. GROUND
PERSONNEL SHOUND BE ON GUARD FOR LIGHTNING ACTIVITY DEVELOPING SOON
AND TAKE PRECAUTIONS AS NECESSARY AND AS DIRECTED. THE SAFEST PLACE
TO BE DURING A LIGHTNING STORM IS INDOORS IN A SUBSTANTIAL STRUCTURE
AWAY FROM WINDOWS.

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Fig 1. An example of the (experimental) Lightning Advisory product.

3. Forecast Process

Until *"forecaster-over-the-loop"* type automation can be matured, the forecast process requires a dedicated meteorologist and manual methods. That is, during the project a dedicated meteorologist continually monitored WSR-88D radar data via the Advanced Weather Interactive Processing System (AWIPS) workstation during prime convective hours between 1700 to 2100 UTC (e.g., 1200 to 1600 LST). The forecaster analyzed satellite and WSR-88D time-lapse data to assess lightning storms within the CWA, with active monitoring for convective initiation and the presence and movement of sea/lake breeze and outflow boundaries. Unique AWIPS software procedures were developed that allowed the forecaster to efficiently assess the CG lightning threat posed by developing storms near KMLB and KMCO (Figure 2). These AWIPS procedures offered interrogation of such radar products as Enhanced Echo Tops and Vertically Integrated Liquid (VIL), which were used to evaluate the storm's growth rate and lightning potential (Figure 3). Complementary analysis tools such as the

System for Convection Analysis and Nowcasting (SCAN) and the Four-Dimensional Stormcell Investigator (FSI) further helped ascertain convective trends conducive to electrification near KMLB and KMCO. Considerable effort was committed to evaluating higher reflectivity ($\geq$ 35 dBZ) within the mixed phase layer aloft (0 to -20 deg C). In conjunction with the detailed radar-based analyses, the Lightning Detection and Ranging (LDAR) network (Figure 4) surrounding the Kennedy Space Center was instrumental in tracking the initiation and evolution of total lightning signals aloft within growing cells, and at times offered valuable minutes to lead-times. With a reasonable likelihood for CG onset relative to KMLB and KMCO, experimental lightning advisories and/or warnings were generated. Although they were not disseminated externally, they were time stamped and locally archived for operational validation and subsequent verification.
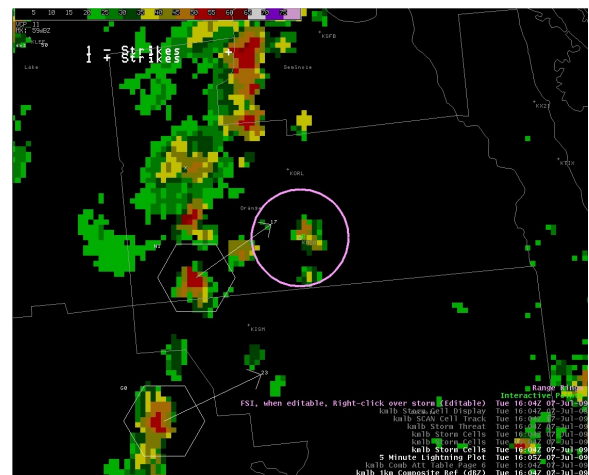

Fig 2. A developing thunderstorm approaches Orlando International Airport (KMCO). The forecaster monitored the radar on an AWIPS workstation in order to determine when the storm was capable of producing lightning within the circle surrounding KMCO.

4. Verification

Each advisory or warning was logged in a spreadsheet for verification purposes. Following each forecast session, the forecaster re-plotted and re-evaluated all CG strikes on an AWIPS workstation to ascertain whether any strikes actually occurred within the advisory/warning radii, and if so, at what time. Whenever one or more lightning strikes occurred within the prescribed radii during an advisory/warning period, the event was documented with a positive verification score (Figure 5). If no CG strikes occurred during the

advisory/warning period, the event was deemed a false alarm. Conversely, if one or more lightning strikes occurred before (after) a product was issued (expired), the event was logged as a missed event. Finally, the difference between the time of the first CG strike and the beginning of the advisory period was recorded as the lead-time for the product. Collectively, this data was used to calculate the Probability of Detection (POD), False Alarm Ratio (FAR), Critical Success Index (CSI), and average lead-time statistics for the lightning advisory and warning products.
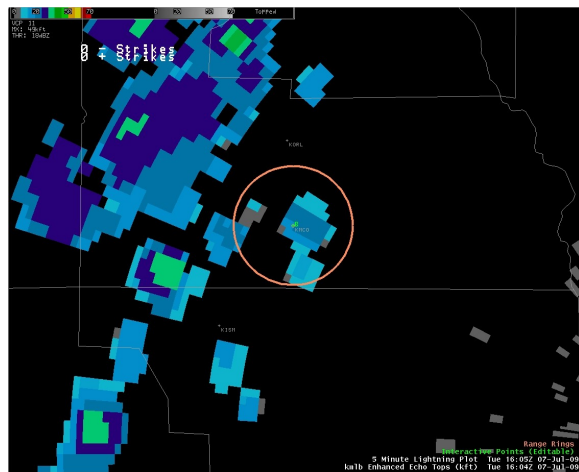

Fig 3. An enhanced echo tops (EET) display of the storm approaching KMCO in Fig. 2. This product indicated the developing thunderstorm had cloud tops of 35 Kft, and a loop of the display showed the storm's positive vertical growth and growth rate.
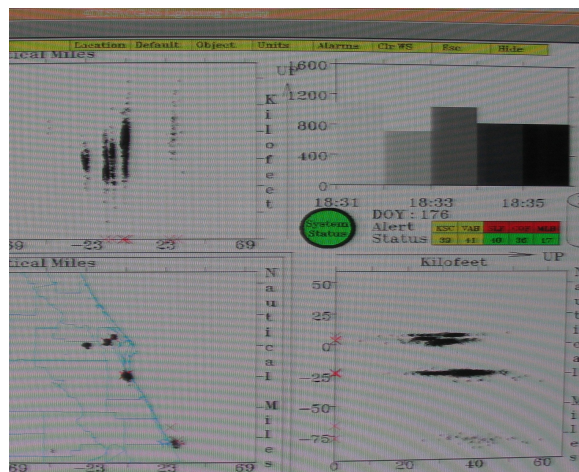

Fig 4. Lightning Detection and Ranging (LDAR) as displayed at NWS Melbourne. Total lightning data such as LDAR data was used extensively to assist forecasters in making lightning advisory and warning decisions.
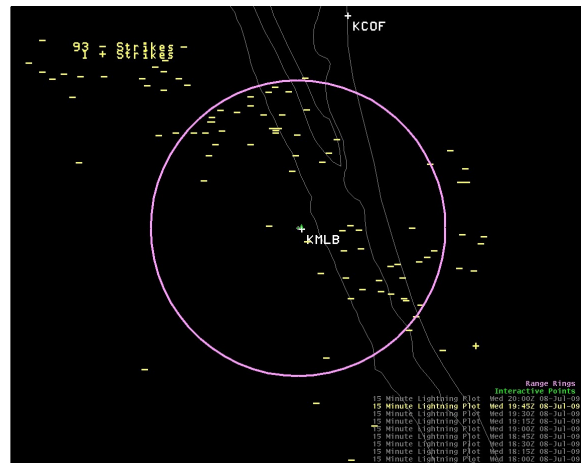

Fig 5. CG lightning strikes around Melbourne International Airport (KMLB) are plotted on an AWIPS workstation to verify the advisory/warning issued by the forecaster. The purple ring represents a five nautical mile radius surrounding the airport.

5. Results

Over the course of the project, a total of sixty six (66) advisories and warnings were issued and verified for KMLB and KMCO (Table 1). Overall, forecasters were able to achieve a 32-minute lead-time for advisories and a 14-minute lead-time for warnings, both of which exceeded the goals set prior to the project (Figure 6). Statistical analysis revealed a POD of 75.0% (89.7%) for advisories (warnings) and an FAR of 48.3% (29.7%) for advisories (warnings). More so, an independent examination of KMCO and KMLB results uncovered some interesting characteristics. In particular, the POD (92.3%), FAR (20.0%), and CSI (0.75) for KMCO warnings were significantly better than the same statistics for KMLB warnings (87.5%, 36.4%, and 0.58, respectively). These results suggest that predicting CG lightning strikes for ECFL coastal locations poses greater challenges and require further investigation.

	KMCO		KMLB	
	Advisory	**Warn**	**Advisory**	**Warn**
POD	66.7%	92.3%	81.8%	87.5%
FAR	50.0%	20.0%	47.1%	36.4%
CSI	0.400	0.750	0.474	0.583
Lead Time (min)	28:20	16:07	34:27	13:24

Table 1. Probability of Detection (POD), False Alarm Ratio (FAR), Critical Success Index (CSI), and average lead time statistics for Orlando (KMCO) and Melbourne (KMLB) International Airport.
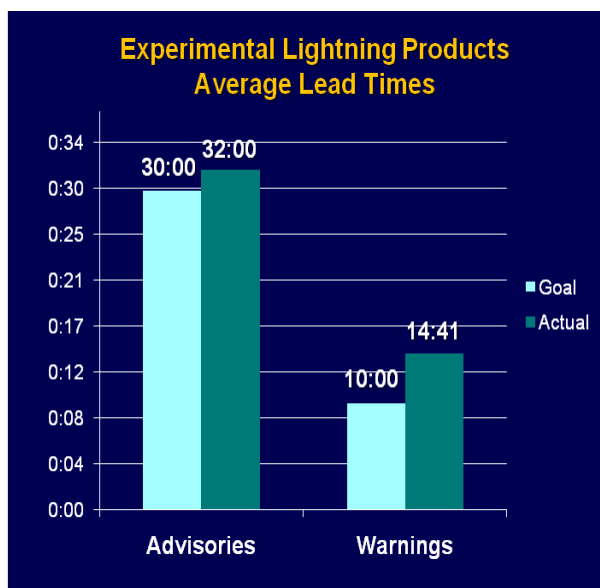
Fig 6. The average lead times achieved for CG lightning advisories and warnings over the two month period. The lead times for both advisories and warnings exceeded the goals set at the beginning of the project.

The statistics clearly indicate that forecasters exhibited skill in producing CG lightning advisories and warnings. Furthermore, the overall average lead-time for advisories and warnings exceeded the target lead-times, which suggests that NWS forecasters can successfully provide advanced notification of CG lightning strikes to point locations of interest. It is interesting to note that the FAR for advisories was noticeably higher than for warnings, most likely because of the greater desired lead-time. In order to achieve a 30-minute lead-time, forecasters had to accept the inherent challenge and thus issue an advisory prior to realizing a high degree of confidence that a CG strike would occur. Since the target lead-time for warnings was 10-minutes, the FAR was naturally lower because forecasters did not have to issue the product as far in advance of the potential lightning event and therefore confidence was greater.

At this time, the resources required to continually monitor the radar through manual interrogation techniques, and to issue subsequent advisories/warnings for developing lightning threats, render this process practical only for specific, predetermined point locations. Because of the prevalence of deep convection across ECFL during the warm season, it would be impossible to produce these products on a daily basis for all places at all times (e.g., the entire CWA). To do that would likely require an alternative approach

(perhaps with color graphics and dynamically probabilistic). Therefore, if incorporated into WFO operations in the near-term, the advisory/warning products would primarily be textual and utilized for specific decision-support roles to assist emergency management operations whenever incidents (e.g., response to disasters) occur or other significant populations at risk, such as high-density outdoor gatherings. Further experimentation is needed in order to develop an efficient methodology for discontinuing advisories/warnings when the forecaster determines the CG lightning threat is no longer present. Discontinuing the products at the correct time is also extremely important since the final strikes of a lightning storm tend to be just as deadly as initial strikes (Holle et al. 1993).

6. Summary

During the summer of 2009, WFO MLB forecasters tested the capability of issuing CG lightning advisories and warnings for point locations in ECFL. The experiment revealed that lightning advisories and warnings can be issued with a considerable degree of success and favorable lead-times by WFOs. Demonstrating skill for advanced warnings of CG lightning strikes for specific locations has important safety and preparedness implications. Ultimately, the results could lead to the incorporation of lightning advisories and warnings into WFO (MLB) operations to provide decision-support for emergency management officials and to help protect high-density gatherings of people at outdoor events.

7. Acknowledgments

8. References

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