VERIFICATION OF EARTH NETWORK'S DANGEROUS THUNDERSTORM ALERTS AND NATIONAL WEATHER SERVICE WARNINGS

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ABSTRACT

Earth Networks Incorporated (ENI) has expressed the potential for their Dangerous Thunderstorm Alerts (DTAs) to increase lead time by an additional nine minutes over current National Weather Service (NWS) tornado warnings while maintaining a similar probability of detection (POD) and false alarm ratio (FAR). These automated, storm-based alerts combine lightning-based storm tracking with total lightning flash rate thresholds to designate regions with an increased potential for severe and hazardous weather. ENI produces alert polygons at three different levels: (1) basic thunderstorm, (2) significant thunderstorm, and (3) dangerous thunderstorm. Verification statistics (POD, FAR and lead time) were calculated for ENI's level 3 DTAs and NWS severe thunderstorm and tornado warnings are calculated for a year of data, March 2013 through Feb 2014. A more in depth case study was done for 20 May 2013. The goal of this comparison is to evaluate how well DTAs perform relative to NWS warnings and if use within operational meteorology will improve warnings.

1. INTRODUCTION

Total lightning is defined as the combination of both in-cloud and cloud-to-ground flashes. Several studies support that increases in total lightning activity often precede severe weather events due to increasing storm electrification coinciding with increasing updraft strength (e.g., Williams et al. 1999; MacGorman et al. 2008; Schultz et al. 2009). Thus, tracking surges in total lightning can be useful in forecasting severe weather events (e.g., Schultz et al. 2009).

Earth Networks Incorporated (ENI) is a private company that has developed a Total Lightning Network (ENTLN). This network monitors total lightning and uses proprietary algorithms for storm identification and tracking, that allows total lightning flash rates of thunderstorms to be used to predict and track severe weather as it is happening (Heckman and Liu 2012).

ENI also produces thunderstorm alerts using ENTLN data across the continental United States (CONUS). These alerts, concentrated in a polygon, mark an area that ENTLN has forecasted to be in danger of severe weather (Fig. 1). The alert area is determined by storm tracking and lightning flash rate algorithms that monitor when the flash rate of a storm has breached a certain threshold (Heckman and Liu

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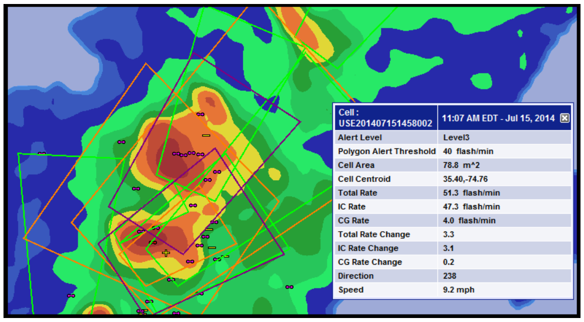
2012). There are three levels of the alerts, each with a higher requisite threshold. The highest level (Level 3) alerts are known as Dangerous Thunderstorm Alerts (DTAs). DTAs are produced every minute and are publicly updated every 15 minutes as long as a storm's lightning flash rate remains above the predetermined threshold for severe weather (Earth Networks, 2013). ENI claims a nine minute greater lead time for their DTAs over National Weather Service (NWS) tornado warnings (Murphy 2013) with an equivalent probability of detection (POD) and false alarm ratio (FAR).



Cell : USE201407151458002	11:07 AM EDT - Jul 15, 2014
Alert Level	Level3
Polygon Alert Threshold	40 flash/min
Cell Area	78.8 m^2
Cell Centroid	35.40,-74.76
Total Rate	51.3 flash/min
IC Rate	47.3 flash/min
CG Rate	4.0 flash/min
Total Rate Change	3.3
IC Rate Change	3.1
CG Rate Change	0.2
Direction	238
Speed	9.2 mph

Fig. 1. Example of ENI thunderstorm alerts.

The goal of this study is to examine how well ENI's DTAs perform when tracking severe weather and whether they would be a valuable product for NWS forecasters to use in the warning decision process. To perform this analysis, verification statistics of both the DTAs and NWS warnings were examined from March 2013 through February 2014. Additionally, the 20 May 2013 severe weather outbreak was also evaluated in greater detail for comparison. NWS Storm Events Database was used to acquire recorded observations of severe weather (i.e., thunderstorm wind over 25.93 m/s (58 mph), hail greater than 2.54 cm (1 in), and tornadoes). Verification of the DTAs and NWS warnings follows the methodology of the NWS for storm-based warnings (i.e., since 2007). Results for the DTAs and NWS warnings were then compared to each other to evaluate how well each performed.

Methods and data used in this study are explained in Section 2. The results obtained from these methods are presented in Section 3. A discussion on the results is found in Section 4. Finally the conclusion, present in Section 5, summarizes the project and its findings.

2. DATA AND METHODS

2.1 Data

Data for this project was acquired from ENI (thunderstorm alerts), the NWS Interactive Product Database (NWS storm warnings), and the NWS StormDat program (storm reports). The data examined included ENI alerts, NWS storm data (for hail, thunderstorm wind, and tornadoes), and NWS storm warnings (severe and tornado). Data for the alerts contains the level, issuance and expiration time, the lightning threshold observed, and a set of latitudes and longitudes that outline the issued alert polygon.

Storm reports from 2013 through June 2014 were obtained for this study in the form of data files. These files included the type of event (i.e., tornado, thunderstorm wind or hail), begin and end times, time zone where the event occurred, wind speed, hail size, tornado size and strength, and a start and end latitude and longitude where the event occurred.

NWS storm warnings for March 2013 through February 2014 were also obtained. These files contain the type of warning (severe thunderstorm or tornado), the weather forecasting office it came from, an issuance and expiration date and time, and an array of latitudes and longitudes that outline the warning polygon area.

2.2 Methods

The verification process for both NWS warnings and ENI's alerts followed NWS storm verification techniques. Specifically, POD and FAR were calculated using the following equations:

$$\mathrm{POD} = \frac{A}{A+C} \tag{1}$$

$$\mathrm{FAR} = \frac{B}{A+B} \tag{2}$$

The variables A, B, and C were found by using a contingency table as shown in Table 1.

Table 1**.** Sample contingency table that was used to calculate POD and FAR.

	Report: Yes	**Report: No**
Warning: Yes	A	B
Warning: No	C	X

For POD, A is the number of reports that fall within a warning polygon. For FAR, A is the number of warnings verified by a report. B is the number of false alarms (i.e., unverified warnings): when there was a storm warning/alert with no storm report. C is the number of misses (i.e., un-warned storm reports): when there was an occurrence of severe weather, but no warning/alert (NWS 2011). Severe criteria included thunderstorm wind over 25.93 m/s (58 mph), hail greater than 2.54 cm (1 in) and tornadoes to verify a warning or alert. This project treats reports with paths as a hit if any or part of the path falls within the alert or warning.

In order calculate A, B and C, two Python programs were created to compare NWS warnings and ENI thunderstorm alerts to Storm Data reports for a case study on 20 May 2013. The same programs were then used to verify a full years worth of data (from March 2013 through February 2014). Unlike the case study, for the yearly analysis only the level 3 DTAs were analyzed along with the NWS warnings. After calculating the three variables A, B, and C, the POD and FAR for both NWS warnings and alerts were calculated.

Lead times for NWS warnings (tornado and severe thunderstorm) and the ENI alerts were also calculated. A warning or alert had to be verified before a lead time was calculated. For ENI alerts, all three report types (thunderstorm wind, hail and tornadoes) could verify the alert. For NWS tornado warnings, only tornado reports could verify the warning and for NWS severe thunderstorm warnings, both severe wind and hail could verify the warning. After an alert or warning was verified, a lead time was calculated by finding the difference between the warning/alert start time and the start time of the first report.

3. RESULTS

3.*1 Case Study: 20 May 2013*

Thunderstorm Alerts and NWS warnings from 20 May 2013 were evaluated across the CONUS. This was the last day of a three day severe weather outbreak, including the Moore, OK EF5 tornado that caused 24 fatalities. A total of 40 tornadoes occurred that day plus hundreds of severe wind and hail reports (NWS 2014). All three levels of ENI thunderstorm alerts for this day were evaluated with a focus on level 3 (DTAs) as well as NWS warnings.

Figure 2 shows a reflectivity image of the EF5 Moore tornado report (pink path) along with the DTAs (pink polygons) and NWS tornado warnings (red polygons) that were valid at 20:13 UTC. As evident in the images, all of the DTA polygons include part of the tornado report as do both of the NWS tornado warnings. However, the amount of area the DTAs cover is much larger than the NWS tornado warnings.

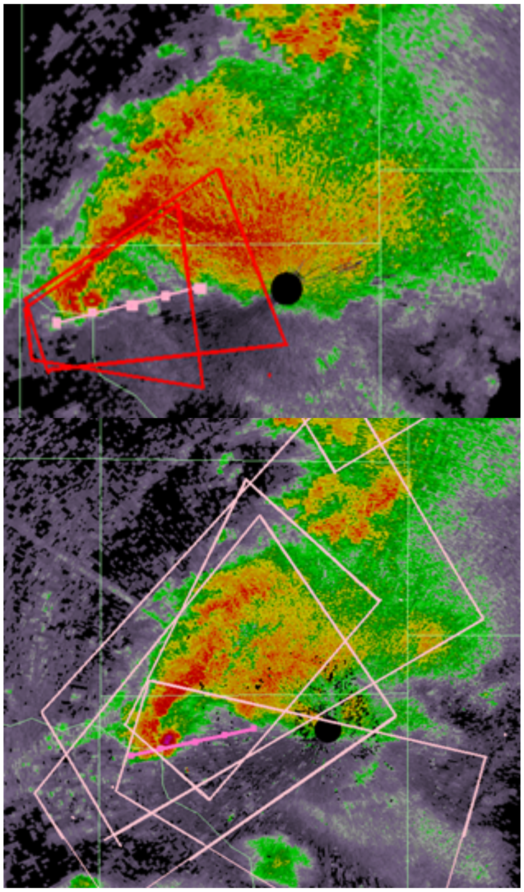


Fig. 2. Example image of NWS tornado warnings (top) and DTAs (bottom) with the EF5 Moore tornado report (pink dotted line) at 20:13 UTC

Table 2. Lead times for NWS severe thunderstorm and tornado warnings and the three levels of ENI thunderstorm alerts.

Type of Warning/Alert	Lead Time (minutes)
Severe Thunderstorm	16. 8
Tornado	14.3
Level 1	16.1
Level 2	17.2
Level 3 (DTAs)	18.5

Across the CONUS on 20 May, lead time for the ENI thunderstorm alerts increased with increasing level of DTA (Table 2). Additionally, all three levels of ENI thunderstorm alerts had longer lead times than NWS tornado warnings. However, only levels 2 and 3 of the ENI thunderstorm alerts had longer lead time than NWS severe thunderstorm warnings. The DTAs performed the best out of the three ENI thunderstorm alert levels with a 4.2 minute greater lead time than NWS tornado warnings and a 1.7 minute greater lead time than NWS severe thunderstorm warnings.

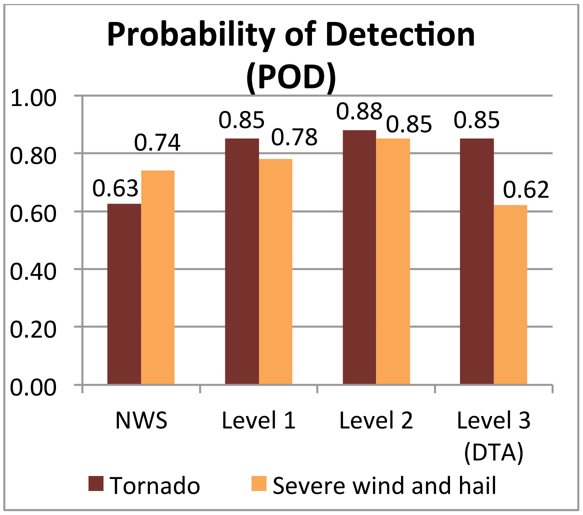


Fig. 3. Probability of detection (POD) for NWS warnings and three levels of ENI thunderstorm alerts.

The POD was calculated for the three levels of ENI alerts and NWS warnings for tornado and severe wind and hail reports (Fig. 3). All three levels of ENI thunderstorm alerts had a greater POD for tornado reports than NWS warnings for 20 May across CONUS. Levels 1 and 2 of ENI alerts also had a greater POD for severe wind and hail reports than NWS. Level 3 DTAs POD for severe wind and hail was 0.12 less than NWS. Overall, the DTAs POD performed better than NWS tornado reports, but not as well as severe thunderstorm wind and hail reports.

The FAR was also calculated for ENI thunderstorm alerts and NWS warnings. Figure 4 shows the results that were found.

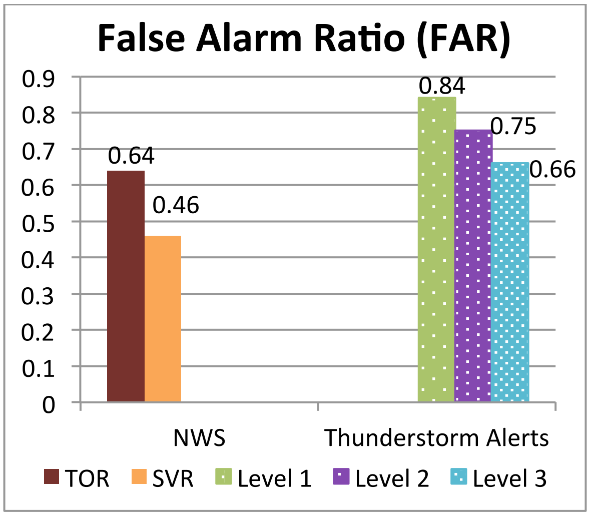


Figure 4. False alarm ratio (FAR) for NWS warnings and ENI thunderstorm alerts.

All levels of the ENI thunderstorm alerts had a higher FAR than both NWS tornado and severe thunderstorm warnings. The level 3 DTAs had only a 0.02 difference with NWS tornado warnings. The general trend was that FAR decreases for ENI thunderstorm alerts with an increase in thunderstorm alert level.

3.2 Results for a full year

In addition to the individual case study of 20 May 2013, verification statistics of DTAs and NWS warnings were calculated for a whole year (March 2013 – February 2014). Instead of analyzing all three levels of ENI thunderstorm alerts, only the level 3 DTAs were included. The same verification methods were used as described before.

Monthly lead times for NWS tornado/severe and level 3 DTAs were calculated (Table 4).

Table 3. Average monthly lead times for NWS tornado and severe thunderstorm warnings and DTAs.

Average Monthly Lead Times (minutes)

Month	NWS Tornado Warnings	NWS Severe Warnings	DTA
March	12.1	14.9	10.9
April	11.9	14.6	13.2
May	11.4	15.4	15.4
June	9.8	15.3	15.2
July	12.2	14.4	15.0
August	11.7	14.9	15.8
September	12.7	14.7	14.8
October	13.2	13.5	15.0

November	9.1	16.2	11.6
December	7.4	15.7	13.4
January	7.5	16.1	10.8
February	9.4	15.9	15.5
Average:	10.7	15.1	13.9

Average lead times for the whole year (bottom row) show that DTAs performed 3.2 min better than NWS tornado warnings. However, the DTAs had an annual lead time that was 1.2 min behind that of NWS severe warnings. Lead times for the DTAs were the greatest from May through August which are also the months with the most DTA warning polygons.

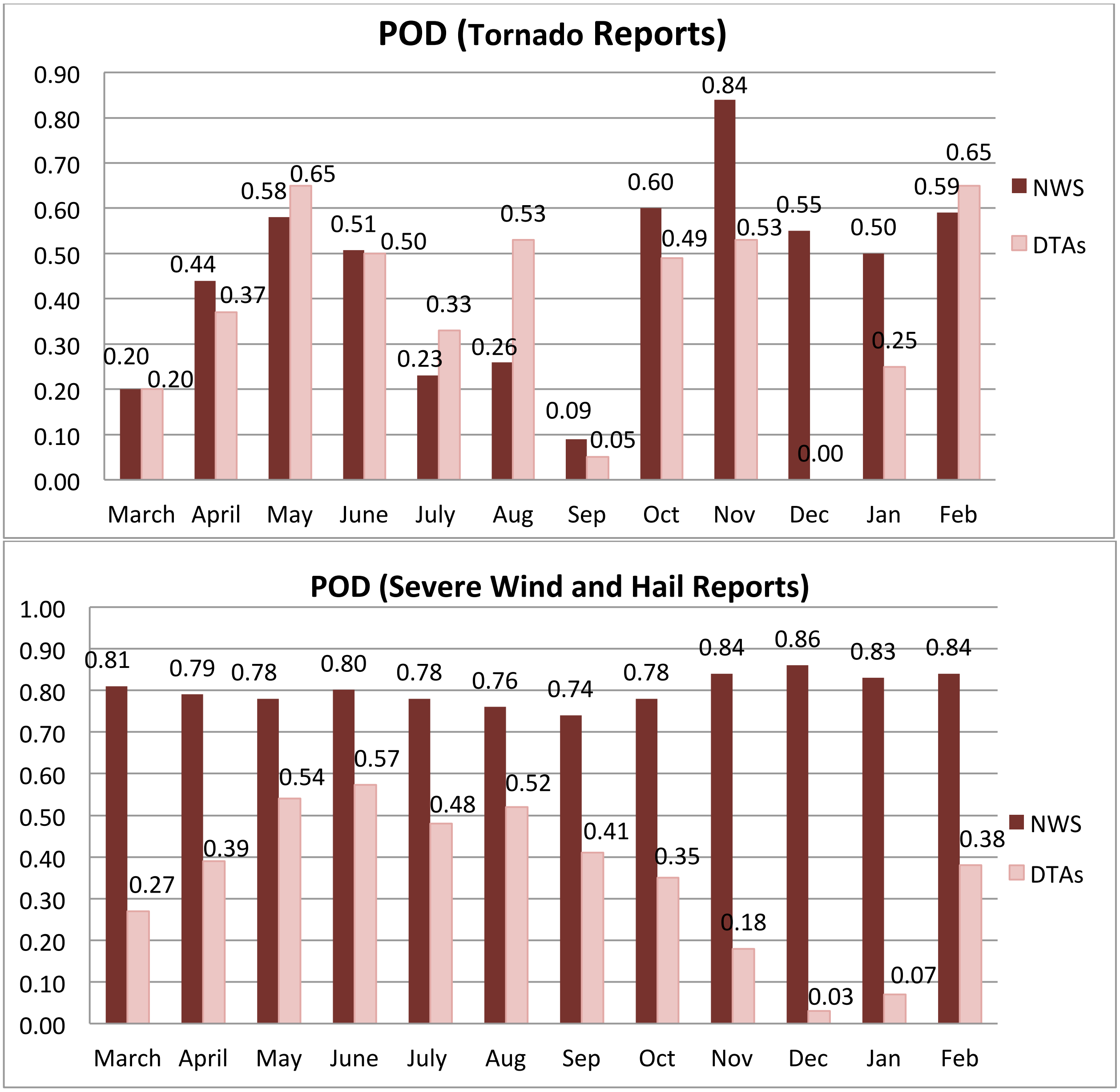


Fig. 5. Probability of detection (POD) for (a) tornado reports and (b) severe wind and hail reports, separated by month.

Monthly POD of the DTAs showed similar results to the NWS for tornado reports only (Fig. 5a). However, DTAs had a significantly lower POD than NWS when looking at severe wind and hail reports. The DTAs also showed an interesting trend in that some of their best months for their POD (for both tornadoes and severe wind and hail) fell between April and August. This is especially evident when looking at the POD for severe wind and hail events. A clear peak in June can be seen in the DTAs as evident in Figure 4. But, the opposite appears to be true for the NWS. NWS had their best months for both tornado and severe wind and hail POD from October through February.

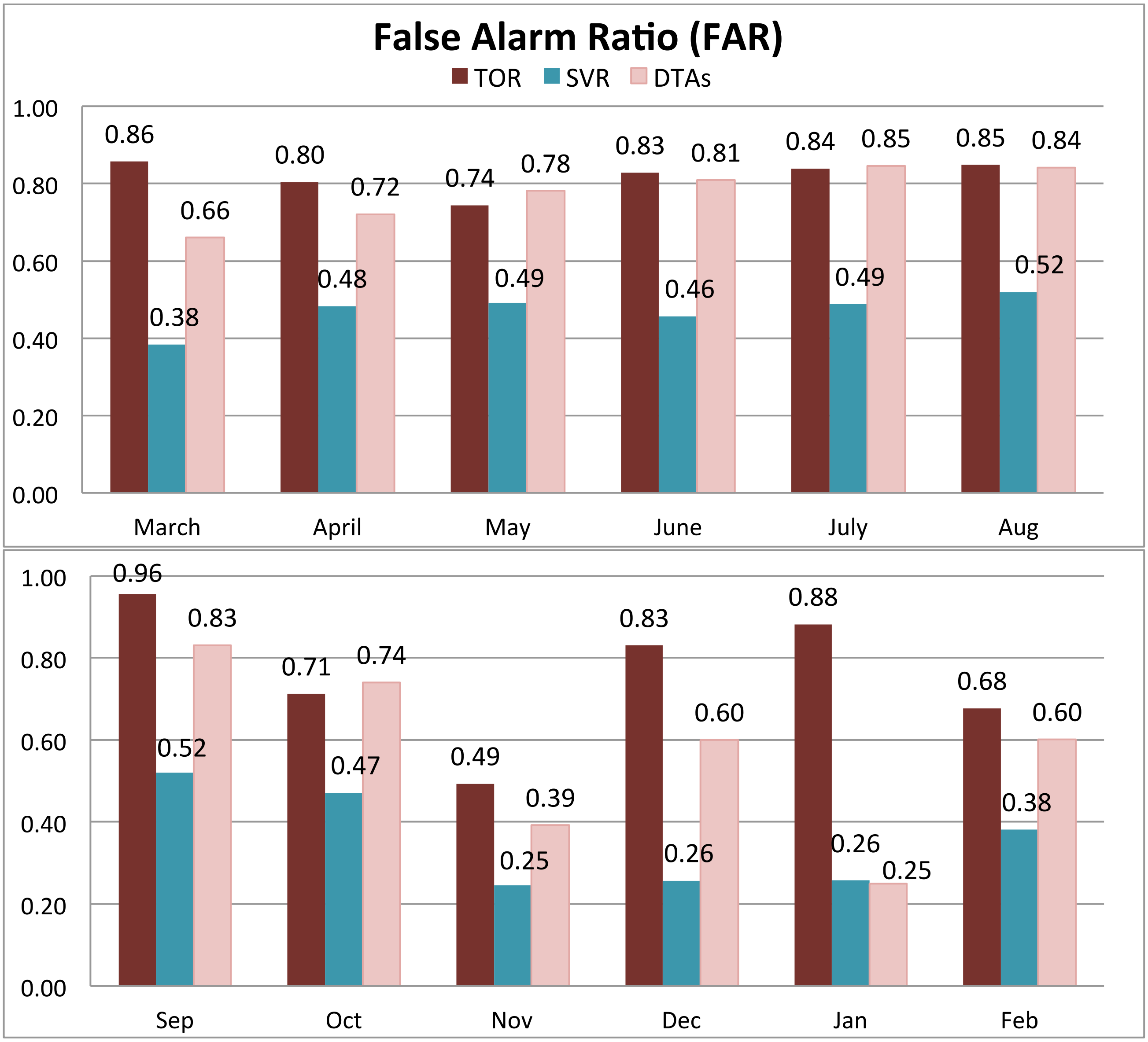


Fig. 6. False alarm ratio (FAR) for NWS tornado and severe thunderstorm warnings and DTAs, separated by month.

After calculating the monthly FAR for the year (Fig. 6), it was found that the DTAs had, on average, slightly less false alarms throughout the year than NWS tornado warnings, but they did not perform nearly as well as NWS severe thunderstorm warnings.

DTAs had their best FARs from November 2013 through February 2014. These months also had the fewest DTAs. DTAs had their worst FARs from June 2013 through September 2013, which includes some of the months with the most DTAs (e.g., June, July, and August).

4. DISCUSSION

DTAs performed comparably in the 20 May 2013 case study and in the results for a full year when it came to the POD. Their FAR, however, did prove to be on the higher side when compared to NWS severe thunderstorm warnings. When looking at the DTAs next to NWS warnings (Fig. 2), it is obvious that DTAs consistently had a higher number of warning polygons released at one time. This is because a new DTA polygon is released every 15 minutes, but they do not expire for 45 minutes, leading to a buildup of multiple warning polygons at a single time. More warning polygons gives the DTAs a better chance of verifying via storm report (thus increasing the POD), but also increases the chances of having a warning polygon without a storm report (thus increasing the FAR). The warned area is also much greater in this situation. The months from April through August in Figures 4 and 5 on average had the highest number of DTAs, therefore had a higher POD, yet also showed a very high FAR.

An interesting trend that is also evident in the annual results (Figs. 4 and 5) is that the POD of the DTAs was, on average, best from April through August. These months are during the convective season so there were more alerts/warnings and storm reports. The case study for the 20 May 2013 severe weather outbreak also showed promising results for the DTAs in terms of tornado reports. Once again, this was a very convective event and contained a significant amount of total lightning activity (NWS, 2014). In terms of the severe wind and hail reports, however, the DTAs did not do as well.

Since severe weather events during the months from April through August are mostly convective events, it is expected that these months will contain the most lightning activity (Heckman and Liu 2012). Since DTA's are generated from total lightning activity in storms, it can be expected that more DTAs will be issued with more total lightning activity, thus increasing the chances of a DTA polygon covering an observed event during these months. This explains why DTAs would have a higher POD and also higher FAR at this time of year. It is also important to note that while the DTAs have their best POD during these convective months, their FAR is also at its highest.

When the lead times for NWS warnings and DTAs were calculated, it is important to note that all three report types would verify a DTA. This is different when calculating lead times for NWS as only a tornado report could verify a tornado warning and only a severe wind or hail report could verify a severe thunderstorm warning. This makes a DTA easier to verify and could be a factor into the higher lead times found in this study.

Based on this study, it is plausible for the NWS to use DTAs as another tool in the warning decision process, but because of a high FAR, DTAs cannot be used by themselves.

5. CONCLUSION

The change in lightning activity in storms is a very important factor to keep in mind when issuing storm warnings as they have been supported by many previous studies to precede severe weather events (e.g., Williams et al. 1999; MacGorman et al. 2008; Schultz et al. 2009). DTAs are generated by ENI based off total lightning activity and can be a useful tool for forecasters by providing data and times when total lightning activity reaches certain thresholds.

DTAs had their highest lead times during the first half of the year in this study (Table 4), specifically from March through October. DTAs performed 3.2 minutes faster than NWS tornado warnings, but were 1.2 minutes slower than NWS severe thunderstorm warnings. Note, the DTAs are verified via all storm reports which may be a reason for higher lead times because alerts do not focus on a specific threat.

This study found that DTAs performed best in terms of POD during the months with the most convective activity, and therefore, the most total lightning activity. The more lightning activity detected, the more DTA polygons will be active at a certain time. Numerous DTAs meant more area was warned which lead to more verified alerts when a storm report was reported. However, when there were no reports, a large area was warned. This led to the convective season not only having a high POD, but also a high FAR.

As with all other forecasting aids, DTAs alone cannot be used to forecast severe weather. But, use of them in conjunction with other forecasting tools during convective severe weather outbreaks could help improve forecasting of the events or situational awareness.

6. ACKNOWLEDGMENTS

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